# 1st Symposium on Theranostics

Saturday 09 October 2021 - Monday 11 October 2021

Theranostics Center / on-line

# Book of Abstracts

Scientific conference 1st Symposium on Theranostics will take place on 9 – 11 October 2021 at the newly established "Theranostics Center" in Kopernika 40 St. in Kraków, Poland. The conference will bring together physicists and medical specialists devoted to the development of medical diagnostic and treatment methods. The main purpose of the 1st Symposium on Theranostics is to exchange knowledge and experience from various institutions in the field of applied and fundamental nuclear physics, biology, biotechnology, chemistry, materials science, medical imaging, radiotherapy and healthcare.

# Contents

**Prof. Zbigniew Rudy Memorial Session** / **64**

## Zbyszek

**Corresponding Author:** ufkamys@cyf-kr.edu.pl

**Prof. Zbigniew Rudy Memorial Session** / **65**

## Presentations of Zbigniew Rudy J-PET prize

**Corresponding Author:** beatrix.hiesmayr@univie.ac.at

**Saturday Morning Session** / **72**

## Perspectives for Total-Body PET in Poland

**Author:** Paweł Moskal[1]

[1] *Jagiellonian University*

**Corresponding Author:** ufmoskal@gmail.com

The lecture will concern perspectives for Total-Body PET in Poland.

**Saturday Morning Session** / **73**

## Extracellular vesicles – their potential in theranostics

**Author:** Ewa Stępień[1]

[1] *Jagiellonian University*

**Corresponding Author:** e.stepien@uj.edu.pl

The lecture will concern extracellular vesicles – their potential in theranostics.

**Saturday Morning Session** / **17**

## History of radiotherapy in Poland. A brief outline of the problem

**Author:** Ryszard Witold Gryglewski[1]

[1] *Jagiellonian University Collegium Medicum*

**Corresponding Author:** ryszard.gryglewski@uj.edu.pl

The radiotherapy in Poland has its long and rich history and following lecture is focused on exploring its rudiments from late 1890s until first decades after Second World War. Main centres of radiology and radiotherapy with names of physicians pioneering in that field are shortly described. How the possibilities and needs of the emerging radiotherapy were perceived in the medical community? How plans and goals for the future were articulated? And how has the prospect of research and therapeutic opportunities changed over the years? These questions are only an invitation to a wider discussion. It should be remembered, that past and tradition of radiotherapy in Poland are far more extended and that is why this presentation should be seen only as a general introduction to its history.

**Saturday Noon Session / 23**

## Nano-theranostics: harnessing nanoscale functionality for next-generation theranostic technologies

**Authors:** Zdenka Kuncic[1]; Yaser Gholami[2]; Richard Maschmeyer[2]; Hushan Yuan[3]; Moses Wilks[3]; Marc Normandin[3]; Lee Josephson[3]; Georges El Fakhri[3]

[1] *University of Sydney, Australia*

[2] *University of Sydney*

[3] *Harvard Medical School, Massachusetts General Hospital*

**Corresponding Author:** zdenka.kuncic@sydney.edu.au

**Abstract**

Nanoscale geometric confinement changes the properties of materials. The most immediate effect is an enhancement in the surface area to volume ratio, which results in faster surface chemistry reaction rates, a property exploited in various nanomedicine approaches. Arguably more interesting, however, are changes in physical properties, including optical, electrical and magnetic properties. In this talk, I will focus on how the superparamagnetic properties of iron oxide nanoparticles can be harnessed to enhance imaging with PET-MRI and to enable novel image-guided, tumour-targeting nanotheranostic strategies. Super-Paramagnetic Iron Oxide Nanoparticles (SPIONs), which enhance MRI image contrast, were labelled with a PET isotope (Zr-89) to demonstrate their use in PET-MRI [1]. Moreover, it was found that the SPIONs localise the emitted positrons sufficiently to improve PET image resolution in PET-MRI [2]. Such SPIONs were also labelled with a range of clinical therapeutic (Y-90) and theranostic (Lu-177, Cu-64/67) radioisotopes, thus demonstrating their potential for cancer nano-theranostics leveraging clinical imaging technologies.

**References**

[1] Y. Gholami et al. A radio-nano-platform for T1/T2 dual-mode PET-MR imaging. Int. J. Nanomed. 15, 1253 (2020) doi.org/10.2147/IJN.S241971

[2] Y. Gholami et al. Positron annihilation localization by nanoscale magnetization. Sci. Rep. 10, 20262 (2020) doi.org/10.1038/s41598-020-76980-9

[3] Y. Gholami et al. A chelate-free nano-platform for incorporation of diagnostic and therapeutic isotopes. Int. J. Nanomed. 15, 31 (2020) doi.org/10.2147/IJN.S227931

**Saturday Noon Session / 6**

## Whole gamma imaging: PET combined with Compton imaging

**Author:** Taiga Yamaya[1]

[1] *National Institutes for Quantum and Radiological Science and Technology (QST)*

**Corresponding Author:** yamaya.taiga@qst.go.jp

Whole gamma imaging (WGI) is a novel concept of combined PET with Compton imaging. An additional detector ring, which is used as the scatterer, is inserted in a conventional PET ring so that single gamma rays can be detected by the Compton imaging method. In addition to a conventional PET mode, Compton imaging (single-gamma mode) is possible. Further large impact can be expected for triple gamma emitters such as 44Sc (about 4 h half-life), that emits a positron and a 1157 keV gamma ray almost at the same time (triple-gamma mode). In principle, only a few decays would be enough to localize the source position by calculating intersection points of a 511 keV line-of-response with a 1157 keV Compton cone. We developed a prototype of the WGI system [1][2]. All interaction events were recorded as list-mode data, and event selection such as coincidence detection was done in software. We measured a 137Cs point source in the single-gamma mode and a 22Na point source with convention-al coincidence detection. The 22Na point source was also used to demonstrate the triple gamma mode as it emits a 1275 keV gamma ray after a positron decay. In the single-gamma mode, spatial resolution for the 137Cs point source obtained by 3D list-mode OSEM was 4.4 mm FWHM (8 cm off-center) - 13.1 mm FWHM (center). Spatial resolution values for the 22Na point source, obtained by the absorber-absorber coincidence and the scatterer-scatterer coincidence, were almost the same (below 2 mm). In the triple gamma mode, where only simple backprojection was applied and no image reconstruction algorithm was applied, spatial resolution for the 22Na point source was 4.8 mm FWHM (8 cm off-center) - 5.7 mm FWHM (center). WGI with 44Sc can be also used to measure positronium lifetime [3], which may enable a new field of “quantum PET (Q-PET)”. One possible application of Q-PET is hypoxia imaging of tumor patients [4].

References
[1] E. Yoshida, H. Tashima, K. Nagatsu, et al., “Whole gamma imaging: a new concept of PET combined with Compton imaging,” Phys. Med. Biol., 65, 125013, 2020.
[2] H. Tashima, E. Yoshida, H. Wakizaka, et al., “3D Compton image reconstruction method for whole gamma imaging,” Phys. Med. Biol., 65, 225038, 2020.
[3] P. Moskal, B. Jasińska, E.Ł. Stępień, et al., “Positronium in medicine and biology,” Nat. Rev. Phys. 1, 527-529, 2019.
[4] K. Shibuya, H. Saito, F. Nishikido, et al., “Oxygen sensing ability of positronium atom for tumor hypoxia imaging,” Commun. Phys. 3, 173, 2020.

**Saturday Noon Session / 70**

## Ps in solutions - could be of help for PET and detection of carcinogens?

**Author:** Sergey Stepanov[1]

**Co-authors:** Liliya Zemskaya ; Mariya Ivanova ; Vsevolod Byakov ; Olga Ilyukhina ; Petr Stepanov ; Anatoly Fenin

[1] *NRC ”Kurchatov Institute” - Institute for Theoretical and Experimental Physics*

**Corresponding Author:** stepanov@itep.ru

stepanov@itep.ru

It is known that the concentration of the dissolved oxygen in malignant tumors is much lower than in healthy tissues. Therefore, cancer cells permanently live in conditions of oxygen starvation. On the other hand, dissolved oxygen efficiently shortens the lifetime of the ortho-Ps atom. It takes place because, firstly, oxygen may oxidize Ps (taking away an electron from it and converting Ps into a “free” positron). Secondly, since the O2 molecule is paramagnetic, it is able to induce the process of ortho-to-para Ps spin conversion. Both of these effects reduce the Ps lifetime in liquids. This means that the lifetime of the Ps in healthy tissues will be shorter than in malignant ones. This relationship between the ortho-Ps lifetime and the concentration of the dissolved O2 can be used to develop a new, additional method for detecting tumors using modern positron emission tomographs [1, 2].

It is recognized that one of the main causes of cancer is chemical carcinogens. Physicochemical methods for determining the carcinogenic activity of substances are based on the fact that most of carcinogens are, in particular, effective electron scavengers. However, it is known that track electrons, generated by ionizing slowing down of the fast positrons when they pass through a medium, are the main precursors of the positronium atom (Ps). We have shown that the complete inhibition of the Ps formation in a cellular milieu by the test chemical compound can serve as an indication of its carcinogenic properties.

This approach is similar to what was done by G. Bakale using nanosecond pulsed radiolysis setup in 80's. The advantages of the positron approach over the Bakale's method are reduced to simplicity, speed and economic benefit.

The simplest model is proposed for interpretation of the carried out experiments on Ps inhibition, oxidation and ortho-para conversion.

[1] S.V. Stepanov, V.M. Byakov, P.S. Stepanov "Positronium in Biosystems and Medicine: A New Approach to Tumor Diagnostics Based on Correlation between Oxygenation of Tissues and Lifetime of the Positronium Atom" Physics of Wave Phenomena, V. 29(2), 174-179 (2021) DOI: 10.3103/S1541308X21020138
[2] P.S. Stepanov, F.A. Selim, S.V. Stepanov, A.V. Bokov, O.V. Ilyukhina, G. Duplatre, V.M. Byakov "Interaction of positronium with dissolved oxygen in liquids", Physical Chemistry Chemical Physics, V. 22, 5123-5131 (2020) doi.org/10.1039/C9CP06105C
[3] Vsevolod M. Byakov, Sergey V. Stepanov "Detection of carcinogenic and anticancerogenic properties of chemicals by means of the positron annihilation lifetime spectroscopy". RENSIT, 12(1):115-128 (2020); DOI: 10.17725/rensit.2020.12.115

**Saturday Noon Session / 8**

# Oxygen sensing ability of positronium

**Author:** Kengo Shibuya[1]

[1] *University of Tokyo, Japan*

**Corresponding Author:** shibuken@youshi.c.u-tokyo.ac.jp

Positronium (Ps) is an exotic atom consisting of a positron and an electron, and around 10<SUP>11</SUP> Ps atoms form in the human body during a PET scan. We have discussed little Ps in PET because its formation does not change the spatial information obtained by PET; Most Ps annihilates into back-to-back gamma-ray photons. However, Ps can provide other unique information due to the delay of the gamma-ray emission as long as its lifetime. The lifetime varies according to the chemical and physical environment for Ps. For example, the lower dissolved oxygen concentration (pO<SUB>2</SUB>), the longer a Ps atom survives in solutions. This is because of the unpaired electrons in the O<SUB>2</SUB> molecule that enhance Ps annihilation via the electron exchange interaction. Knowing pO<SUB>2</SUB> distribution is important for cancer patients because hypoxic cells are often resistant to radiotherapy as well as chemotherapy.

Moskal *et al.* named the new concept of PET as "Ps imaging [1]," and they also found that the Ps lifetime differs between healthy and cancer cells [2]. The difference may come from a combination of several chemical and physical conditions, but how each factor changes the Ps lifetime is a challenging matter to be understood. Some efforts have revealed how O<SUB>2</SUB> molecules reduce Ps lifetime. Stepanov [3] found a positive correlation between the pO<SUB>2</SUB> and Ps annihilation rate (the inverse of the lifetime) in water. Furthermore, we found good linearity between them by accumulating 50 times larger number of counts, as shown in Fig. 1 [4]. This line is namely calibration line for Ps as an oxygen sensor, and this result indicates a possibility of Ps as a hypoxia biomarker candidate. In other words, during a PET scan, 10<SUP>11</SUP> nanosized sensors for O<SUB>2</SUB> are spontaneously created in vivo, and it is worth trying to read the indicator for improving cancer treatments.

**Fig. 1** pO<SUB>2</SUB> vs Ps decay rate: squares (Lee [5]), triangles (Stepanov [3]), and circles (Shibuya [4]). (see at *https://www.nature.com/articles/s42005-020-00440-z/figures/3*)

**References**
[1] P. Moskal, *et al.*, *Nature Rev. Phys.*, **1**, 527–9 (2019).
[2] P. Moskal, *et al.*, *bioRxiv* (2021). (doi: 10.1101/2021.08.05.455285)
[3] P. S. Stepanov, *et al.*, *Phys. Chem. Chem. Phys.* **22**, 5123 (2020).
[4] K. Shibuya, *et al.*, *Commun. Phys.*, **3**, 173 (2020).
[5] J. Lee, *et al.*, *J. Chem. Phys.* **44**. 2506 (1966).

**Saturday Noon Session** / **1**

## How quantum entanglement can help in theranostics?

**Author:** Beatrix Hiesmayr[1]

**Co-author:** J-PET collaboration

[1] *University of Vienna*

**Corresponding Author:** beatrix.hiesmayr@univie.ac.at

Quantum entanglement is a phenomenon that shows the every working at small scales which differs strongly from the laws governing our daily world. Reading out this quantum information has the potential to reveal unknown processes and connections and on the long term to provide doctors with quantum indicators. This contribution focuses on the entanglement of two and three gammas emitted from positronium atoms, which is a frequent process in human beings undergoing e.g. a PET-scan (PET=Positron Emission Tomography). Theory predicts these two or three photon events to be entangled, more precisely in very special types of entanglement [1,2]. With the cutting-edge technology developed by the J-PET collaboration at the Jagiellonian University the detection of entanglement at this high energy scales is -for the first time- in reach [3]. This talk will give an overview over the progress made. Particularly, novel software developments [4] are needed to tackle this involved problem.

[1] B.C. Hiesmayr and P. Moskal, Sci Rep 9, 8166 (2019).
[2] B.C. Hiesmayr and P. Moskal, Sci Rep 7, 15349 (2017).
[3] P. Moskal, N. Krawczyk, B. C. Hiesmayr, M. Bała, C. Curceanu, E. Czerwinski, K. Dulski, A. Gajos, M. Gorgol, R. Del Grande, B. Jasinska, K. Kacprzak, L. Kapłon, D. Kisielewska, K. Klimaszewski, G. Korcyl, P. Kowalski, T. Kozik, W. Krzemien, E. Kubicz, M. Mohammed, Sz. Niedźwiecki, M. Pałka, M. Pawlik-Niedźwiecka, L. Raczynski, J. Raj, Z. Rudy, S. Sharma, M. Silarski, Shivani, R. Y. Shopa, M. Skurzok, W. Wislicki, B. Zgardzinska, Eur. Phys. J. C 78, 970 (2018).
[4] W. Krzemień, A. Gajos, K. Kacprzak, K. Rakoczy and G. Korcyl, SoftwareX 11, 100487 (2020).

**Saturday Noon Session** / **46**

## First three-photon positronium image obtained with the J-PET scanner: towards multi-photon imaging

**Author:** Aleksander Gajos[1]

[1] *Jagellonian University, Kraków, Poland*

**Corresponding Author:** aleksander.gajos@uj.edu.pl

**First three-photon positronium image obtained with the J-PET scanner: towards multi-photon imaging**

Aleksander Gajos
on behalf of the J-PET Collaboration
Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University,
S. Łojasiewicza 11, 30-348, Kraków, Poland
e-mail: aleksander.gajos@uj.edu.pl

Positronium atoms, i.e. bound states of electron and positron, produced by up to 40% of positrons in conventional Positron Emission Tomography (PET) scans, are presently not utilized for imaging. However, their annihilations may carry essential information complementary to the functional imaging of PET [1].

The recently proposed technique of multi-photon imaging with the Jagiellonian Positron Emission Tomography (J-PET) scanner [2] aims at spatially-resolved determination of positronum properties in the examined volume. To date, use of two-photon positronium annihilations to obtain a positronium lifetime image was demonstrated [2]. Another conceivable modality comprises obtaining an image as a map of the ratio of two-photon to three-photon annihilations of positronium, for which spatial reconstruction of three-photon annihilations of the positronium trilet state is required.

The talk will discuss the capability of the J-PET scanner to record, identify and reconstruct three-photon positronium annihilations. Methodolgy and results of the first test of three-photon imaging with J-PET [3] will be presented, including the first image of an object of extensive dimensions obtained solely using ortho-positronium annihilations into three photons. Performance of this imaging method will be discussed and compared to that of conventional two-photon imaging with the same setup.

**References:**

[1] P. Moskal, B. Jasińska, E. Ł. Stępień and S. D. Bass, „Positronium in medicine and biology", Nat. Rev. Phys., vol. 1, pp. 527-529, 2019, doi: 10.1038/s42254-019-0078-7.

[2] P. Moskal, et al., „Positronium imaging with the novel multi-photon PET scanner", Science Advances, to be published.

[3] Moskal et al., „Testing CPT symmetry in ortho-positronium decays with positronium annihilation tomography", Nat. Commun., vol. 12, pp. 5658, 2021, doi:10.1038/s41467-021-25905-9.

**Saturday Afternoon Session / 4**

# Cyclotron production of theranostic pair 43/44Sc - 47Sc on calcium targets

**Authors:** Rafał Walczak[1]; Aleksander Bilewicz[1]; Jarosław Choiński[2]; Anna Stolarz[3]; Agnieszka Majkowska-Pilip[4]; Marek Pruszyński[5]

[1] *Institute of Nuclear Chemistry and Technology*

[2] *Heavy Ion Laboratory, University of Warsaw*

[3] *Warsaw Uniwersity*

[4] *Institute of Nuclear Chemistry and Technology, Dorodna 16, 03-195 Warsaw, Poland*

[5] *Institute of Nuclear Chemistry and Techology*

**Corresponding Author:** r.walczak.ichtj@gmail.com

The 43Sc (T1/2 = 3.89 h) and 44Sc (T1/2 = 3.92 h) are an ideal β+ emitter in PET diagnosis. Both radionuclides can be used as an alternative to 68Ga, because 43/44Sc has a longer half-life and forms theranostic pair with β- emitter 47Sc, which is important in planning radionuclide therapy. However in comparison with 44Sc, 43Sc has half-life and beta plus radiation similar to 44Sc, moreover, gamma-ray energy emission and intensity is much lower (372 keV, 23%) than in the case of 44Sc (1157 keV,

99%) what is not negligible for the patient and medical personnel. On the other hand 47Sc as low energy β- emitter is an attractive candidate for radioimmunotherapy. In our work, we propose a new way for cyclotron production of 43Sc in 42Ca(d,n)43Sc nuclear reaction and 47Sc by proton irradiation of 48Ca target in 48Ca(p,2n)47Sc and 48Ca(p,d)47Ca⟶47Sc reaction.

In the present work, we used enriched 42CaCO3, 44CaCO3 and 48CaCO3 targets (Isoflex, Russia). To manufacture the targets enriched 42CaCO3, 44CaCO3 and 48CaCO3 powder was pressed with graphite powder ( 10-25%), mounted to a water-cooled target holder and irradiated with a beam of proton or deuteron at different energies. The activity of the samples was measured with high-resolution γ-ray spectrometry. CaCO3 targets were dissolved in 1 M HCl and a microfiltration process after alkalization of target material solution was used to separate 43/44Sc from calcium target materials and for production of 47Sc generator. The obtained by deuteron irradiation of 42Ca radionuclide of 43Sc and 44Ca radionuclide of 44Sc were radionuclidaly pure. In the case of proton irradiation of 48Ca obtained product contained a mixture of radionuclides 47Sc, 48Sc, and 47Ca which is a 47Sc mother radionuclide. After irradiation with 60 MeV proton beam followed by chemical separation of the Ca isotopes and waiting for the maximum growth of 47Sc by 5,6 days, 44 MBq/μAh of 47Sc can be eluted from the generator with no other contaminating scandium activity. After separation solution of 43/44/47Sc was loaded on cation exchange Dowex 50 resin for purification and change of environment.

The proposed methods allow obtaining high activity of 43Sc, 44Sc and 47Sc. Scandium isotopes were separated from the targets with the efficiency of more than 90% and eluted in the volume of 0.5 ml. The level of Ca2+ in 43/44Sc and 47Sc fractions is less than 3 μg/ml. The recovery of the calcium target is nearly quantitative making the proposed production process economically feasible.

Scandium radionuclides, separated by our method, have sufficient quality for labeling of the biologically active molecules, which has been confirmed by labeling bioconjugates of Trastuzumab, anti-HER2 nanobody and DOTA-TATE. For DTPA-Trastuzumab, DTPA-nanobody and DOTA-TATE efficiency of labeling was 99% and for DOTA-nanobody 60% (t=50°C).

This work was carried out as a part of the projects nr. IAEA-RC-23299-RO

**Saturday Afternoon Session / 12**

# In vitro and in vivo studies of iron oxide nanoparticles toxicity with theranostic potential

**Authors:** Joanna Chwiej[1]; Natalia Janik-Olchawa[1]; Agnieszka Drozdz[1]; Katarzyna Matusiak[1]; Karolina Planeta[1]; Damian Ryszawy[2]; Maciej Pudelek[2]; Aleksandra Wajda[1]; Maciej Sitarz[1]; Christophe Sandt[3]; Ferenc Borondics[3]; Daniel Horak[4]; Michal Babic[4]; Magdalena Wytrwal-Sarna[1]; Marta Gajewska[1]; Angelika Kmita[1]; Zuzanna Setkowicz[2]

[1] *AGH University of Science and Technology*

[2] *Jagiellonian University*

[3] *SOLEIL*

[4] *Czech Academy of Sciences*

**Corresponding Author:** joanna.chwiej@fis.agh.edu.pl

Among the new materials exhibiting theranostic potential are undoubtedly magnetic iron oxide nanoparticles (IONPs) [1]. Due to their size, they can interact at the cellular and molecular level of biological systems. In turn, their unique magnetic properties mean that they can be used as contrast agents in MRI and as carriers for targeted drug transport, allowing for simultaneous monitoring of pharmaceutical distribution. IONPs can also induce local hyperthermia in response to an external magnetic field and thus selectively destroy cancer cells [2-5].
Extensive efforts are now underway to design IONPs with the desired physicochemical properties. However, in order to translate these theranostic nanomaterials (NMs) into clinical practice, the research aiming at determination of the biocompatibility of IONPs and the safety of their use in humans are necessary. The toxicity studies of NMs are mainly carried out *in vitro* on cell lines and cultures.

*In vitro* experiments provide mechanistic information on the toxicity of NMs and, in particular, on their genotoxicity, cytotoxicity, the possibility of causing oxidative stress or the development of inflammatory processes in cells. They are, therefore, a very important step in the complex process of enhancing NMs biocompatibility and their biomedical potential [6]. However, their results cannot be directly translated into *in vivo* models, which are still crucial and mandatory before the first human studies [7-8].
The talk will present the results of own research demonstrating how the use of instrumental techniques, including the methods of atomic and molecular spectroscopy, can support the characterization of the properties of IONPs and the assessment of their toxicity and therapeutic potential *in vitro* and *in vivo* [9-12].
References:
[1] Zhu L, Zhou Z, Mao H, Yang L (2017) Nanomedicine (Lond) 12:73-87. [2] Corot C, Robert P, Idée JM, Port M (2006) Adv Drug Deliv Rev 58:1471-1504. [3] Pankhurst QA, Connolly J, Jones SK, Dobson J (2003) J Phys D Appl Phys 36:167-181. [4] Dobson J (2006) Drug Dev Res 67:55-60. [5] Sun C, Lee JS, Zhang M (2008) Adv Drug Deliv Rev 60:1252-1265. [6] Dhawan A and Sharma V (2010) Anal Bioanal Chem 398:589-605. [7] Steger-Hartmann T and Raschke M (2020) Curr Opin Toxicol 23-24: 6-10. [8] Nayak R, Meerovich I, Dash AK (2019) AAPS PharmSciTech 20:160. [9] Matusiak K, Skoczen A, Setkowicz Z, Kubala-Kukus A, Stabrawa I, Ciarach M, Janeczko K, Jung A, Chwiej J (2017) Nanotoxicology 11:1225-1236. [10] Skoczen A, Matusiak K, Setkowicz Z, Kubala-Kukus A, Stabrawa I, Ciarach M, Janeczko K, Chwiej J (2018) Chem Res Toxicol 31:876-884. [11] Janik-Olchawa N, Drozdz A, Ryszawy D, Pudełek M, Planeta K, Setkowicz Z, Sniegocki M, Zadło A, Ostachowicz B, Chwiej J (2020) Sci Rep 10:15447. [12] Drozdz A, Matusiak K, Setkowicz Z, Ciarach M, Janeczko K, Sandt C, Borondics F, Horak D, Babic M, Chwiej J (2020) Spectrochim Acta A Mol Biomol Spectrosc 236:118355.

**Saturday Afternoon Session** / **59**

## Theranostics in particle therapy

**Author:** Antoni Rucinski[1]

[1] *Instytut Fizyki Jądrowej PAN*

**Corresponding Author:** antoni.rucinski@ifj.edu.pl

Particle therapies with protons, helium or carbon ions are emerging treatments enabling precise targeting of pathological cancer tissues due to inverted depth-dose distribution (Bragg peak) offering improved dose conformity with respect to conventional radiotherapy by X-rays. In addition to their dosimetric advantages, protons and heavier ions penetrating patient tissue undergo scattering and nuclear interactions and produce secondary radiation of different type, i.e., radioactive isotopes, ions, photons, and neutrons at varying energies. The secondary radiation induced by primary ions, which is not present in conventional X-ray therapy, can be detected and used to image therapeutic dose in the patient and gain information about patient anatomy simultaneously with the radiation therapy. I will review the ongoing research and development of imaging methods based on secondary radiation induced by particle beams, focusing on the underlying potential of particle therapy to be considered as theranostic approach to radiation therapy.

**Saturday Afternoon Session** / **48**

## Characterization and research on a large axial field of view PET in Bern

**Author:** Kuangyu Shi[1]

[1] *Dept. Nuclear Medicine, University of Bern*

**Corresponding Author:** kuangyu.shi@dbmr.unibe.ch

Recent advances in the large axial field of view (LAFOV) PET revolutionize PET imaging to meet several clinical demands. This talk will characterize the performance of a LAFOV PET (Siemens Biograph Vision Quadra) installed in Bern. On the other side, the increased complexity makes the exploration of the potential of the new instrument more challenging. This talk will share some developments of artificial intelligence (AI) in LAFOV PET in Bern from the perspectives of imaging optimization. It will also discuss the potentials and challenges during the development of AI technology.

**Saturday Afternoon Session** / **71**

## Total-Body PET Kinetic Modeling and Parametric Imaging with EXPLORER

**Author:** Guobao Wang[1]

[1] *University of California Davis*

**Corresponding Author:** gbwang@ucdavis.edu

Department of Radiology, University of California Health, Sacramento CA 95817, USA

The uEXPLORER total-body PET system provides a very high level of detection sensitivity and simultaneous coverage of the entire body for dynamic imaging. This brings several potential benefits for tracer kinetic modeling and parametric imaging, including more reliable estimation of tracer kinetics for clinical use, noninvasive derivation of blood input function, and total-body parametric imaging of micro kinetic parameters. Along with its attractive properties, total-body kinetic modeling also brings significant challenges, such as the large scale of total-body dynamic PET data and the need for organ and tissue appropriate input functions and kinetic models. In this talk, I will discuss the potential benefits, technical challenges, and examples of ongoing research applications of total-body kinetic modeling and parametric imaging.

**Saturday Evening Session** / **50**

## Unparalleled and Revolutionary Impact of PET Imaging on Research and Day to Day Practice of Medicine

**Author:** Abass Alavi[1]

[1] *University of Pennsylvania*

**Corresponding Author:** abass.alavi@pennmedicine.upenn.edu

The lecture will concern unparalleled and revolutionary impact of PET imaging on research and day to day practice of medicine.

**Sunday Morning Session** / **18**

## Positron annihilation as a process to observe of the pathogenic tissue modification.

**Author:** Bożena Jasińska[1]

[1] *Institute of Physics, Maria Curie Sklodowska University*

**Corresponding Author:** bozena.jasinska@poczta.umcs.lublin.pl

Two the most known techniques based on positron-electron annihilation are PET (Positron Emission Tomography) and PALS (Positron Annihilation Lifetime Spectroscopy).
PET is a diagnostic method enabling imaging of the metabolism of chosen substances in the living organism. Metabolism rate depends on many factors, one of them is cancer growth in some region of body.
Other technique, commonly used in material sciences, PALS, allows following precisely kind of processes leading to positron annihilation, including creation and decaying the positronium (bound state of positron-electron) states. It is known that o-Ps lifetime value reflects size of the free spaces in which it is trapped. Then one can expect it can be used to investigate tissue modification during some kind of diseases. Additionally, intensity of this component allows to follow charge activity of some processes, including cell apoptosis or radical creation.
Preliminary investigation performed on real healthy and altered human tissues using PALS clearly indicates that it is possible to distinguish between healthy and diseased tissues and between different kinds of lesions of the some organ using techniques based on positron annihilation. So, it is justified to include the new imaging method based on positronium properties in PET diagnosis.

**Sunday Morning Session / 30**

## Solid-liquid structure model for Ps-based oncological nanodiagnostics

**Author:** Bożena Zgardzińska[1]

[1] *Institute of Physics, Maria Curie-Sklodowska University*

**Corresponding Author:** bozena.zgardzinska@poczta.umcs.lublin.pl

Solid-liquid structure model for Ps-based oncological nanodiagnostics

B. Zgardzińska*
for the J-PET collaboration

*email: bozena.zgardzinska@mail.umcs.pl

Institute of Physics, Maria Curie-Sklodowska University, Pl. Marii Curie-Skłodowskiej 1, 20-031 Lublin, Poland

For an aging society, the socio-economic consequences of neoplastic diseases justify research towards developing effective oncological diagnostics. An opportunity for the development of highly sensitive nanodiagnostics is the combination of two technique based on the same annihilation process, the Positron Emission Tomography (PET) and the Positron Annihilation Lifetime Spectroscopy (PALS). While the first imaging technique uses annihilation quanta, the second has been used for decades to determine the structure of materials at nanometer level and based on the hydrogen-like unstable positronium atom (Ps=e^-+e^+).
The biological material still belongs to the group of complex systems that have been poorly investigated using the PALS technique. Due to large morphological and physiological diversity of tissue, different origin of cells, metabolism and functionality, there are a number of factors that affect and disrupt the process of Ps creation and annihilation. On the other hand, the neoplastic processes lead to tissue dysfunction and are associated with changes in both the structure and metabolism of the tissues building the organ.
As a simplification of complex biological system we proposed to adopt a solid-liquid structure model. As a consequence of such approach we could distinguish two types of volumes in which Ps annihilates: the nano-bubbles in the liquid phase of the sample (body fluid, mainly water), and the nanovolumes in rigid structure, similar to the solid phase of the sample.
The samples taken from healthy and neoplastic tissues of the human uterus and liver were investigated using PALS technique. The analysis was performed using the solid-liquid structure model. The INTI plot mapping was used to determine the type and degree of neoplastic lesions. The total water content (free and physiosorbed) of healthy and altered tissue was estimated. The possible influence of chemical composition (radicals and O2 concentration) as well as the chemotherapy treatment was discussed.

The observations and the above listed results may be used to develop additional functionality of new generation PET scanners in the field of non-invasive diagnostics accompanying imaging.

**Sunday Morning Session** / **47**

## X-ray detectors for exotic atoms and other types of applications

**Author:** Catalina Curceanu[1]

[1] *lnf-infn*

**Corresponding Author:** catalina.curceanu@lnf.infn.it

I shall discuss various X ray detector systems used in exotic atoms experiments, starting with the Silicon Drift Detectors used in kaonic atoms measurements at Frascati within the SIDDHARTA-2 experiment. I shall then present the VOXES system, based on HAPG crystals, able to perform extreme precision X ray measurements. The VOXES system can be used both for fundamental science and for societal applications; in this context I shall present some of this ongoing applications at LNF-INFN.

**Sunday Morning Session** / **51**

## Test targets for J-PET experiments with medicine and physics

**Author:** Marek Gorgol[1]

[1] *Maria Curie-Sklodowska University, Institute of Physics, Department of Material Physics, Pl. M. Curie-Sklodowskiej 1, 20-031 Lublin, Poland*

**Corresponding Author:** marek.gorgol@mail.umcs.pl

J-PET, as a total body PET device, gives an opportunity to perform additional investigations in medicine, that couldn't be performed with the use of standard PET detectors. It can be also used as new research device for physics. However, these both aspects are very challenging because many difficulties and artifacts that requires explanation and overcoming. Therefore, various chambers and targets need to be used at particular stages of testing and development. The overview of chambers dedicated for J-PET will be presented with the emphasis of various problems encountered during the research, as well as the solution of each one. The future plans for creating the chambers required for the further stages of research will be also discussed.

**Sunday Morning Session** / **29**

## Polystyrene-based plastic scintillators for theranostics applications

**Author:** Łukasz Kapłon[1]

**Co-author:** Gabriel Moskal [1]

[1] *Jagiellonian University*

**Corresponding Author:** lukasz.kaplon@uj.edu.pl

Łukasz Kapłon on behalf of the J-PET Collaboration.

Plastic scintillators are used in many applications connected with medical devices, for example in time-of-flight positron emission tomography [1], long-axial field of view positron emission tomography scanners [2] and in plastic scintillation dosimetry [3]. Scintillators absorb ionizing radiation and convert its energy into visible light via fluorescence. Purpose of this research is to find optimal fluorescent dyes combination dissolved in polystyrene matrix. Polymer scintillators were synthesized from styrene monomer in bulk radical polymerization [4].

In this research one the best fluorescent compound emitting ultraviolet light is combined with a few fluorescent dyes shifting scintillators emission to blue and green light spectrum [5]. Emission maxima of manufactured polystyrene scintillators are close to maximum quantum efficiency of light detectors used in plastic scintillation detectors. Light output of scintillators as a measure of gamma radiation conversion into blue and green light will be presented. High light output and matching emission spectra of scintillator with quantum efficiency of light detector is needed to obtain good signal-to-noise ratio in scintillation detectors [6].

Green-emitting plastic scintillators have several advantages over blue-emitting scintillators in plastic scintillation dosimetry application. Firstly, green light is less attenuated by polystyrene matrix and yellow compounds resulting from radiation damage. Secondly, the longer the wavelength of scintillators light, the smaller portion of Cerenkov light is emitted in this green bandwidth in plastic dosimeter and subtraction of this stem signal is easier. Thirdly, green light around 500 nm is the least attenuated in plastic optical fibers usually glued to plastic scintillators forming scintillation dosimeter.

References
[1] S. Niedźwiecki et al., Acta Phys. Pol. B, 48 (2017) 1567-1576
[2] P. Moskal, E. Stępień, PET Clin, 15 (2020) 439-452
[3] L. Beaulieu, S. Beddar, Phys. Med. Biol., 61 (2016) R305-R343
[4] Ł. Kapłon et al., Bio-Algorithms and Med-Systems, 10 (2014) 27-31
[5] Ł. Kapłon, Acta Phys. Pol. B, 51 (2020) 225-230
[6] A. Wieczorek et al., PLoS ONE, 12 (2017) e0186728 1-16

This work was supported by grant for the early stage of research financing from Centre for Technology Transfer CITTRU from the Jagiellonian University in 2021; the National Science Centre of Poland through grant OPUS No. 2019/35/B/ST2/03562 and the Jagiellonian University under project No. CRP/0641.221.2020.

**Sunday Noon Session** / **45**

## Innovative Positron Emission Tomography for a Beam Range Monitoring in Proton Radiotherapy

**Authors:** Jakub Baran[1]; on behalf of the J-PET collaboration[None]

[1] *IFJ PAN*

**Corresponding Author:** jakubbaran92@gmail.com

Improving the precision and conformity of proton treatment delivery by application of proton beam range monitoring remains to be one of the greatest challenges of the proton radiation therapy[1]. One of the most commonly investigated approaches is to measure proton beam range by means of detection of annihilation gammas produced in patient during irradiation. A new, modular, easy-configurable plastic scintillator based J-PET technology[2,3] is being developed at the Jagiellonian University, Poland offering the possibility to address the proton beam range monitoring by means of positon emission tomography (PET) imaging[4].

We developed a workflow to perform Monte Carlo simulations (GATE)[5] of proton therapy treatment of patients including β+ activity production, coincidence events detection and PET image reconstruction (CASToR)[6] just after the irradiation. Six different J-PET based scanner setup configurations (single-layer, multi-layer, cylindrical, dual-head) were designed and investigated. We compared efficiency, number of registered coincidences (true and scattered) and reconstructed activity images distribution for different geometrical setup configurations. The expected activity reconstructed using J-PET scanner was compared to the actual β+ activity distribution produced in the patient.

Our results show that all investigated J-PET setup configurations are feasible to acquire and reconstruct the β+ activity produced during patient irradiation with a proton beam. The efficiency of the configurations ranges from 0.06% (single layer dual-head) to 0.52% (triple layer barrel). The reconstructed PET images were compared to ground truth production activity distribution revealing good agreement, which will be further improved by optimization of the reconstruction and image post-processing protocols. Experimental validation of the simulations will be performed on phantoms and in the clinical-like conditions in order to fully evaluate the J-PET detector capabilities.

[1] Knopf, AC, and Lomax, A., "In vivo proton range verification: a review." Physics in Medicine & Biology 58.15 (2013): R131.
[2] Moskal, P., et al. "Positronium in medicine and biology." Nature Reviews Physics 1.9 (2019): 527-529.
[3] Moskal, P., et al. "Simulating NEMA characteristics of the modular total-body J-PET scanner—an economic total-body PET from plastic scintillators." Physics in Medicine & Biology 66.17 (2021): 175015.
[4] Baran, J., et al. "Studies of J-PET detector to monitor range uncertainty in proton therapy." 2019 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC). IEEE.
[5] Grevillot, L., et al. "GATE-RTion: a GATE/Geant4 release for clinical applications in scanned ion beam therapy." Medical Physics 47.8 (2020): 3675-3681.
[6] Merlin, T., et al. "CASToR: a generic data organization and processing code framework for multi-modal and multi-dimensional tomographic reconstruction." Physics in Medicine & Biology 63.18 (2018): 185005.

**Sunday Noon Session / 3**

# 103Pd/103mRh in-vivo generator for Auger electron targeted therapy

**Author:** Nasrin Abbasi Gharibkandi[1]

**Co-authors:** Aleksander Bilewicz [2]; Joanna Gierałtowska [2]

[1] *Institute of Nuclear Chemistry and Technology*

[2] *Institute of Nuclear Chemistry and Technology*

**Corresponding Author:** n.abbasi@ichtj.waw.pl

In recent years the application of Auger emitters for cancer targeted therapy has got great attention. Current clinically useful systemic radiation therapies are mainly based on β- radiation emitters. However, the tissue range of low energy β- particles is about several hundred cells length that is not optimal for treatment of small-size tumors [1]. Tissue range of α particles is only around several cells length (40 – 100 μm), what in combination with their high linear energy transfer (LET≈100keV/μm) results in high radiocytotoxicity. However, this therapeutic approach cannot be used widely due to the low availability of α-emitters [2]. Auger electrons are similar to high-LET particles, like α particles, and can induce considerable cell damage. Furthermore, compared to α and β- radiation, Auger emitters remain of low toxicity while travelling in blood or bone marrow but become highly efficient when incorporated into DNA of target cells. Hence, Auger radiotherapy is considered a promising field for targeting small tumors such as metastases [3]. Since most of the energy released by Auger electrons is deposited in close proximity from the decay site, the successful use of Auger emitters in therapy requires their precise delivery to a sensitive organelles in the cells [4]. We propose new idea to deliver the Auger emitter 103mRh to the cell nucleus by using an in-vivo 103Pd/103mRh generator conjugate. Synthesized trastuzumab or inhibitor of PSMA radiobiocojugates labeled with

103Pd (t1/2 = 16.99 d) will transport the radionuclide to the cytoplasm in the perinuclear area. As a result of nuclear decay, 103mRh (t1/2=56 min) will be released and in the form of 103Rh_aq^(3+) will penetrate the nuclear membrane and bind to the DNA inducing cytotoxic effect. In the first step, we synthesized Au nanoparticles, which were covered with a layer of metallic Pd. Next, using PEG linker, we attached monoclonal trastuzumab to the core-shell nanoparticles. The preliminary studies of cytotoxicity of non-radioactive Au@Pd nanoparticles and Au@Pd-trastuzumab bioconjugates were performed.

References
[1] Y.-m. Song, X.-r. Zheng, and X.-q. Yao, "Study on the interactions of ruthenium (III), rhodium (III) and palladium (II) ions with DNA," Transition metal chemistry, vol. 31, pp. 616-620, 2006.
[2] C. Parker, V. Lewington, N. Shore, C. Kratochwil, M. Levy, O. Lindén, et al., "Targeted alpha therapy, an emerging class of cancer agents: a review," JAMA oncology, vol. 4, pp. 1765-1772, 2018.
[3] A. I. Kassis, "The amazing world of auger electrons," International journal of radiation biology, vol. 80, pp. 789-803, 2004.
[4] S. Aghevlian, A. J. Boyle, and R. M. Reilly, "Radioimmunotherapy of cancer with high linear energy transfer (LET) radiation delivered by radionuclides emitting α-particles or Auger electrons," Advanced drug delivery reviews, vol. 109, pp. 102-118, 2017.

**Sunday Noon Session / 26**

## 3D printed lightweight and modular lithium-ion Uninterruptible Power Booster for medical devices.

**Authors:** Gabriel Moskal[1]; Marcin Molenda[2]

[1] *Department of Chemical Technology, Faculty of Chemistry of the Jagiellonian University, Kraków, Poland;Total-Body Jagiellonian-PET Laboratory, Jagiellonian University, Kraków, Poland*

[2] *Department of Chemical Technology, Faculty of Chemistry of the Jagiellonian University, Kraków, Poland*

**Corresponding Author:** gabriel.moskal@doctoral.uj.edu.pl

Advanced devices for diagnostics and medical therapy require a constant and stable power source. The disadvantage of commonly used uninterruptible power supply (UPS) is the heavy weight[1], centralization and the need to use specially prepared rooms and dedicated electrical installations. The aim of the presented research is to prepare a safe, economic and modular Uninterruptible Power Booster (UPB). A UPB can increase the insufficient power output of the mains supply, guaranteeing power for the pre-planned time. Low price and modularity are possible due to the use of 3D printing and Li-ion cells, which will allow the construction of UPB installed in the immediate vicinity of the protected device. Among available technologies of chemical energy storage, Li-ion cells are characterized by high gravimetric and volumetric energy density[1]. Currently, liquid electrolytes(LE) are used in Li-ion cells, which have good ionic conductivity, but are flammable, toxic and sensitive to lithium dendrite overgrowth, which may lead to an internal short circuit and damage to a given module. For safety reasons, a much better solution than LE would be solid electrolytes(SE), which would not be flammable and hazardous to the environment. Due to the fact that SE constitute a barrier to lithium dendrites, they can extend the working time of li-ion cells[2]. Currently, there is no known material that would fit well as a SE for li-ion cells. There are several materials under development, but they are not ready for industrial applications[3,4].This presentation concerns the research conducted on SE, synthesized with the use of cheap, environmentally safe materials. For this purpose, syntheses of materials based on silicon glass and polysaccharides were performed. Methods of syntheses and the results for measuring the ionic conductivity of the tested electrolytes and an example UPB for J-PET mobile tomograph will be presented[5,6]. The use of this solution with stationary devices will allow to reduce electricity costs by loading the energy storage using a less expensive night tariff, and then using the collected energy during the day, and also to install the device in a room without access to a UPS system.

[1]S. Anuphappharadorn Et al., Energy Procedia,56(2014)352-358
[2]J. Xie, Y. Lu, Nature Communications,11(2020)2499
[3]F. Zheng Et al., Journal of Power Source,389(2018)198-213
[4]A. Manthiram Et al., Nature Reviews Materials,2(2017)16103
[5]P. Moskal, E. Stępień,PET Clinics,15(2020)439-452
[6]P. Moskal et al., Nature Reviews Physics,1(2019)527-529

**Sunday Noon Session** / **21**

# Metabolic and positronium imaging sensitivity of the total body J-PET tomographs

**Author:** Szymon Parzych[1]

[1] *Faculty of Physics, Astronomy and Applied Computer Science Jagiellonian University, 30-348 Kraków, Poland*

**Corresponding Author:** szymon.parzych@student.uj.edu.pl

On behalf of the J-PET Collaboration

A new and popular trend in the field of medical imaging, especially in the positron emission tomography, is the construction of scanners with a whole human body coverage. Such total body PET tomographs prove to be much more efficient and accurate with respect to the clinically available PET systems [1]. One of the groups, which is currently developing a total body scanner, is the Jagiellonian PET Collaboration (J-PET) [2]. In contrast to the standard crystal-based detectors, it utilizes axially arranged plastic scintillators.

During conventional PET imaging the information taken into reconstruction comes from the two, back-to-back annihilation photons. Standard metabolic imaging enables the diagnosis of the uptake of radiopharmaceuticals in cells [3]. Nevertheless, in almost 40% of cases positrons annihilations occur through the creation of a metastable positronium atom. Properties of such atoms like formation probability and mean lifetime turn out to have a dependence on the inner structure of tissues. It was proven that they can be used as an additional diagnostic indicator. The recently proposed positronium mean lifetime imaging method enables study of these characteristics [3-7].

In the framework of this work a simulation-based study of the sensitivity to the conventional and positronium imaging was conducted on the total body tomographs designed with the J-PET technology. For that a dedicated Toy Monte-Carlo model working in the event-by-event basis has been developed and validated. The research was conducted basing on the "NEMA Standards Publication NU 2-2018" [8]. Moreover, a comparison with the traditional short axial field of view PET system was performed.

References:
[1] S. R. Cherry et al., Total-Body PET: Maximizing Sensitivity to Create New Opportunities for Clinical Research and Patient Care, J. Nucl. Med., vol. 59, no. 1, pp. 3-12, Jan 2018
[2] P. Moskal et al., Simulating NEMA characteristics of the modular total-body J-PET scanner – an economic total-body PET from plastic scintillators, Phys Med Biol., vol. 66, no. 17, Sept 2021
[3] P. Moskal, E. Ł. Stepien, Prospects and Clinical Perspectives of Total-Body PET Imaging Using Plastic Scintillators, PET Clin., vol. 15, no. 4, pp. 439-452, Oct 2020
[4] P. Moskal, Positronium Imaging, 2019 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2019, pp. 1-3
[5] P. Moskal et al., Performance assessment of the 2 γpositronium imaging with the total-body PET scanners, EJNMMI Phys., 7:44, June 2020
[6] P. Moskal et al., Positronium in medicine and biology, Nat Rev Phys, vol. 1, pp. 527–529, Sept 2019
[7] P. Moskal et al., Feasibility study of the positronium imaging with the J-PET tomograph, Phys Med Biol., vol. 64, no. 5, Mar 2019
[8] NEMA Standards Publication NU 2-2018, National Electrical Manufacturers Association, 2018

**Poster Session** - Board: 6 / **22**

# A simulation study to compare performance of analog and digital silicon photomultiplier tube by LTspice package

**Author:** Keyvan Tayefi Ardebili[None]

**Corresponding Author:** keyvantayefi1994@gmail.com

Detectors play a fundamental role in understanding physical phenomena and improved our understanding. The rapid development in this area of science has been increased interest to enhance the performance of detectors to achieve precise results. Photomultiplier tube (PMT) known as one of the main parts of the detectors which are constructed in the shape of a vacuum tube and can detect light photons emitted by scintillators and amplify the intensity of light up to 100 times. Alongside the advantages of PMT, it has weaknesses such as being sensitive to a magnetic field which prevents their use in magnetic resonance imaging (MRI), low gain, and less coverage of scintillators. These weaknesses caused to development of an alternative type of element called silicon photomultipliers (SiPM). SiPMs are the latest generation of photomultipliers, which due to their low operating voltage, are currently used by many groups in a variety of fields, including high-energy physics calorimetry, solid-state physics, and nuclear medicine. SiPMs consist of independent pixels that are connected parallel to each other. It has a rectangular sensitive cross-section where each pixel consists of a series connection of an avalanche photodiode (APD) in Geiger mode and a quenching resistor. Thanks to this geometrical design, SiPM are able to provide larger sensitive areas in comparison to PMTs. In this study, we made a comparison of analog and digital SiPM as the most popular and recent type of photomultipliers via LTspice simulation package. The obtained results can provide a general perspective for each type for further utilization.

References:
[1] S. Yamamoto, et al., Med. Phys., vol. 39, 2012, pp. 6900-6907.
[2] B.K. Lubsandorzhiev, Nucl. Inst. Meth. in Phys. Res. Sec. A, vol. 567, 2006, pp. 236-238
[3] S. Gundacker, A. Heering, Phys. Med. Biol. vol. 65, 2020, pp. 101-108.
[4] F. Acerbia, S. Gundacker, Nucl. Inst. Meth. in Phys. Res. Sec. A, vol. 926, 2006, pp. 16-35.
[5] I. Bokati, V. Korotaev, et al., Phot. Mat. A, vol. 11367, 2020, pp. 78-83.
[6] P. Lecoq, S. Gundacker, Eue. Phys, J, vol. 136, 2021, pp. 213-221.

**Poster Session** - Board: 3 / **16**

## CPT symmetry test in positronium annihilations with the J-PET detector

**Author:** Neha Chug[1]

[1] *Jagiellonian University*

**Corresponding Author:** neha.chug@doctoral.uj.edu.pl

Discrete symmetry under the combined transformation of charge, parity, and time reversal (CPT) can be tested in the decays of positronium atom, the lightest bound system built of charged leptons. Jagiellonian Positron Emission Tomograph (J-PET) device constructed from plastic scintillators, detects the photons originating from electron positron annihilation. This feature enables J-PET to study CPT symmetry in the three photon annihilations of the triplet state of positronium. Signs of violation of the CPT symmetry can be sought as a non-vanishing expectation value of an angular correlation operator that is odd under CPT transformation. Technique to estimate the spin of ortho-positronium and momenta of annihilation photons for single recorded ortho-positronium event allows J-PET to measure the expectation value of CPT symmetry odd angular correlation operator. J-PET measures a broad range of kinematical configurations of ortho-positronium annihilation to three photons and is the first experiment to determine the full range of the CPT-odd angular correlation. The presentation will include the methods of performing the CPT symmetry test using an angular correlation operator which involves the spin and momenta of photons originating from o-Ps$\rightarrow 3\gamma$ decay using extensive size positronium production and annihilation chambers with the J-PET detector.

**Poster Session** - Board: 19 / **56**

## Convolutional neural networks in classification of multi-photon coincidences in J-PET scanner

**Author:** Paweł Konieczka[1]

[1] *NCBJ*

**Corresponding Author:** pawel.konieczka@ncbj.gov.pl

Paweł Konieczka, on behalf of the J-PET collaboration

Convolutional Neural Networks are excellent at analyzing images by learning abstract representations. CNN has been an overwhelming strategy in computer vision tasks and has achieved expert-level performances in various fields. There has been a surge of interest in the potential of CNN among radiology researchers and several studies have already been published in areas such as classification [1] and image reconstruction [2].

First general methodology to transform a non-image data into an image for CNN architectures has been presented in [3]. Nevertheless, this method cannot be applied to large data sets, where number of features is very small, because of computational complexity of PCA. The introduction of scheme of non-image data transformation into 2-dimensional matrices will be proposed [4].

The goal of this poster is to present results of multi-photon coincidences classification in J-PET scanner using CNNs. Bayesian optimization of two convolutional network architectures (DeepInsight [3], YOLOv1 [5]) will be presented.

References:

[1] Yasaka, Koichiro, et al. Deep learning with convolutional neural network for differentiation of liver masses at dynamic contrast-enhanced CT: a preliminary study. Radiology, 2018, 286.3: 887-896.

[2] Liu, Fang, et al. Deep learning MR imaging–based attenuation correction for PET/MR imaging. Radiology, 2018, 286.2: 676-684.

[3] Sharma, Alok, et al. DeepInsight: A methodology to transform a non-image data to an image for convolution neural network architecture. Scientific reports, 2019, 9.1: 1-7.

[4] Raczyński, Lech, Introduction of non-image PET data transformation to image-form approach for classification using Convolutional Neural Networks. 1st Symposium on Theranostics, 2021.

[5] Redmon, Joseph, et al. You only look once: Unified, real-time object detection. In: Proceedings of the IEEE conference on computer vision and pattern recognition. 2016. p. 779-788.

E-mail: pawel.konieczka@ncbj.gov.pl

**Poster Session** - Board: 2 / **14**

## The in vitro study of the toxicity and therapeutic effects of iron oxide nanoparticles with different core size

**Author:** Natalia Janik-Olchawa[1]

**Co-authors:** Agnieszka Drozdz [1]; Damian Ryszawy [2]; Maciej Pudełek [2]; Karolina Płaneta [1]; Zuzanna Setkowicz [3]; Aleksandra Wajda [4]; Maciej Sitarz [4]; Magdalena Wytrwał-Sarna [5]; Marta Gajewska [5]; Joanna Chwiej [1]

[1] *Faculty of Physics and Applied Computer Science, AGH University of Science and Technology*

[2] *Faculty of Biochemistry Biophysics and Biotechnology, Jagiellonian University*

[3] *Institute of Zoology and Biomedical Research, Jagiellonian University*

[4] *Faculty of Materials Science and Ceramics, AGH University of Science and Technology*

[5] *Academic Centre for Materials and Nanotechnology, AGH University of Science and Technology*

**Corresponding Author:** natalia.janik-olchawa@fis.agh.edu.pl

Nanotechnology is a combination of science, engineering and technology in a nanoscale. This revolutionary technics is used in many fields of science and life [1,2]. Advances in nanotechnology resulted in the development of theranostic nanoparticles constituting the diagnostic and therapeutic agent in a single particles [3]. Such features are possessed, among others, by magnetite nanoparticles which serving as the contrast agents for MRI can be used in medical diagnostics. In turn, their interaction with the external magnetic field cause that they can be used as drug carries or agents for the local hyperthermia.
To introduce iron oxide nanoparticles (IONPs) into clinical practice their biocompatibility and potential mechanisms of toxicity are to be determined. The main objective of our study was the analysis of therapeutic potential and potential toxicities of IONPs based on different cellular models. The impact of PEG-coated magnetite NPs with three different core diameters (5, 10 and 30 nm), determined by TEM, on the normal and cancer cell lines was examined. The cytotoxicity of nanomaterials was assessed by MTT assay and trypan blue staining. Cell motility, intracellular ROS production and actin cytoskeleton rearrangements were also studied. For this purpose, fluorescence microscopy and time-lapse videomicroscopy were used. Moreover, the anomalies in the distribution and structure of biomolecules induced in cells by IONPs were examined and for this purpose Raman microspectroscopy was applied.
The obtained results showed changes in cell life parameters which depended on the IONPs core diameter, cell line, exposure time and dose. What is more, the fluorescence microscopy with TIRF module showed changes in cytoskeleton organization and cell morphology for some cell lines after the treatment with IONPs.

References:
[1] Dadfar SM, Roemhild K, Drude NI, von Stillfried S, Knüchel R, Kiessling F, Lammers T. Iron oxide nanoparticles: Diagnostic, therapeutic and theranostic applications. Adv Drug Deliv Rev. 2019. 138:302-325.
[2] Suciu M, Ionescu CM, Ciorita A, Tripon SC, Nica D, Al-Salami H, Barbu-Tudoran L. Applications of superparamagnetic iron oxide nanoparticles in drug and therapeutic delivery, and biotechnological advancements. Beilstein J Nanotechnol. 2020. 11:1092-1109.
[3] Revia RA, Zhang M. Magnetite nanoparticles for cancer diagnosis, treatment, and treatment monitoring: recent advances. Mater Today (Kidlington). 2016. 19(3):157-168.

**Poster Session** - Board: 1 / **10**

## Impact of PRRT with the use of 90Y/177LuDOTA-TATE to change of SUVs obtained in 68Ga-DOTA-TATE PET/CT in patients with neuroendocrine tumors – does the use of a theroanostic pair of radiopharmaceuticals may affect the estimation of survival after PRRT?

**Author:** Marta Opalińska[1]

**Co-authors:** Anna Sowa-Staszczak [2]; Adrian Kania-Kuc [3]; Ibraheem Al Maraih [3]; Alicja Hubalewska-Dydejczyk [2]

[1] *University Hospital in Krakow*

[2] *B. Chair and Department of Endocrinology, Jagiellonian University Medical College, Kraków, Poland*

[3] *Nuclear Medicine Department, University Hospital, Krakow, POLAND*

**Corresponding Author:** mkal@vp.pl

Impact of PRRT with the use of 90Y/177LuDOTA-TATE to change of SUVs obtained in 68Ga-DOTA-TATE PET/CT in patients with neuroendocrine tumors – does the use of a theroanostic pair of radiopharmaceuticals may affect the estimation of survival after PRRT?

Introduction
Peptide receptor radionuclide therapy (PRRT) is an effective therapeutic option for metastatic neuroendocrine tumor (NET) therapy in case of good somatostatin receptor expression in tumors tissue. Despite significant progress in management of NETs, searching for novel predictive and prognostic factors is crucial. The high heterogeneity of the somatostatin receptors density in different NET metastatic lesions and inside single tumours probably influence an clinical outcome. Some up-to-date studies indicate that the response to PRRT assessed on the basis of imaging of somatostatin receptors may be a potentially useful tool for prediction of overall PRRT effect.

Aim
Assessment of corrected SUV max change in metastatic NET lesions associated with PRRT counted in [68Ga]Ga-DOTA-TATE PET/CT and its potential impact on long-term treatment outcomes.

Materials and Methods
Among all patients treated with PRRT using 177Lu or 177Lu/90YDOTA-TATE in 2017-2019 due to dissemination of G1 and G2 classifications neuroendocrine neoplasm, 13 patients who had 68Ga-DOTATATE PET/CT performed no longer than 6 months before and 6 months after PRRT. For all measurable metastatic lesions corrected SUVmax (taking into account individual for each patients SUV max of reference organs normal liver or spleen), mean value of SUV max in both PET/CTs (before and after PRRT) was calculated. Those results were correlated with clinical outcome of the disease assessed during follow-up one on the basis of other imaging studies as positive (stabilization (SD) or regression (PR)) or negative (progression (PD).

Results
The mean follow-up was 8.9months. PD was found in patients, PR or SD in 10 patients. Among patients with regression, a decrease in the mean value of corrected SUVmax in comparison to the baseline study of 277.12% was observed. Among patients with SD, a mean of corrected SUVmax in comparison to the baseline study decreased by 180.80%. Decrease in the mean value of corrected SUVmax in comparison to the baseline study in patients with regression and stabilization taken together was in average 209.85% Increased values were observed among progressive patients, where change of corrected SUVmax was in average 6.11%.

Conclusion
A decrease in the value of corrected SUVmax in metastatic lesions obtained from routine PET/CT tests with 68Ga-DOTA-TATE may indicate a lower risk of neuroendocrine tumor progression within a 9 months from the end of PRRT and may constitute an additional independent parameter helping to estimate the risk of progression in this group of patients.

**Poster Session** - Board: 10 / **31**

## Classification of heavy metal contaminated samples based on micro-CT images using machine learning algorithms

**Author:** Dominik Panek[1]

**Co-authors:** Bartosz Leszczyński [2]; Dorota Wojtysiak [3]; Ewa Stępień [2]

[1] *M. Smoluchowski Institute of Physics, Jagiellonian University*

[2] *M. Smoluchowski Institute of Physics, Jagiellonian University*

[3] *Department of Animal Genetics, Breeding and Ethology, Faculty of Animal Sciences, University of Agriculture in Kraków*

**Corresponding Author:** dominik.panek@doctoral.uj.edu.pl

Being able to predict whether a sample is contaminated with any toxic substances or not is crucial, especially when it comes to health, and this is where machine learning algorithms are essential [1-

2]. In our research the emphasis was put on the ability to classify samples contaminated with two types of heavy metals: zinc (Zn), cadmium (Cd), and the mixture of these two elements (Zn+Cd), based on the micro-computed tomography (micro-CT) images. Contaminated samples, which were operculum, were coming from the Carassius Gibelio fish. Prior to the micro-CT scan fish were bred in the environment containing a concentration of 4 mg/ml of water of each element. Additionally, a control group, with no exposure to any heavy metal was cultured.
After micro-CT scans, images were reconstructed in order to get information, which would help algorithms learn about the dataset, and finally, which would be able to classify samples into proper groups. The key features of the reconstructed images were: grayscale maximum value in a given group, masses of the samples, mean grayscale values, and area under the grayscale histograms.
Applied machine learning models included: logistic regression, SVM (Supporting Vector Machine), decision trees, and KNN (K-nearest neighbors, with different numbers of neighbors k = 1, 2, 3, ..., 10). Results left us no doubt that most of the applied machine learning models are very good when it comes to classification. The best results were achieved for the simplest logistic regression, where the overall accuracy was 90%, a second-best algorithm was KNN with an accuracy of 71% for k = 1 and 86% for k = 4, next were decision trees with an accuracy of 70% and SVM with an overall accuracy of 50%.

References
[1] Heavy metals in suspended matters during a tidal cycle in the turbidity maximum around the Yangtze Estuary, Huaijing Zhang et al., Acta Oceanologica Sinica 34, 36–45(2015).
[2] Toxicity, mechanism and health effects of some heavy metals, Monisha Jaishankar, Interdiscip Toxicol. 2014 Jun; 7(2): 60–72.

**Poster Session** - Board: 11 / **32**

# A new model for spheroid growth

**Author:** Monika Szczepanek[1]

**Co-authors:** Kamil Dulski [2]; Ewa Stępień [1]; Paweł Moskal [2]

[1] *Department of Medical Physics, M. Smoluchowski Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland, Total-Body Jagiellonian-PET Laboratory, Jagiellonian University, Poland*

[2] *Department of Experimental Particle Physics and Applications, M. Smoluchowski Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland, Total-Body Jagiellonian-PET Laboratory, Jagiellonian University, Poland*

**Corresponding Author:** monika.szczepanek@uj.edu.pl

Spheroids are a model commonly used in research into new cancer treatments and therapies. They mimic the structure, microenvironment and cells signaling present in solid tumors [1]. The following features can be recalled, that makes spheroids a perfect model for investigations into cancer treatment, like their layered composition, forced by the availability of nutrients, the growth kinetics and the expression pattern of some genes similar in spheroids and tumors [2,3]. In particular, three types of cells in the spheroid, as well as in tumors, can be distinguished, which maintain their layered architecture: dead cells inside the spheroid (necrotic zone); living, non-proliferating cells in the middle (quiescent zone); and living and proliferating cells in the outer layer of the spheroid [4,5]. We propose a new spheroid growth model which reveals the growth dynamics of three spheroid zones. The model assumes different probabilities of the cell transition from proliferating to non-proliferating cells and from non-proliferating to necrotic ones. This biological process goes only in one direction. We present a theoretical model based on simulations and experimental data. By the presented model, it is possible to assess proliferative and non proliferating cells, which may be helpful in an experiment planning, when particular fraction of proliferating cells are needed. In addition, the simulation data allow not only to confirm the prediction from the model used, but also to check how cells in a given state are distributed inside the spheroids. In particular, the model allows an additional estimation of the fraction of dead cells indirectly, only from the growth curve. Therefore, the presented model can potentially provide more information than the standard approach in such studies of the growth dynamics of tumors – the Gompertz curve.

**References:**
[1] A. S. Nunes et al., Biotechnol. Bioeng. 116, (2019).
[2] E.Ł. Stępień et al., Acta Phys. Pol. B 51, (2020).
[3] E. Axpe et al., PLoS One 9, (2014).
[4] M. Szczepanek, Acta Phys. Pol. B 51, (2020).
[5] H. Karimi et al, Micron 137, (2020).
**Acknowledgments:**
This work was supported by the Foundation for Polish Science through the TEAM POIR.04.04.00-00-4204/17 Programme and the SciMat Priority Research Area budget under the Strategic Programme Excellence Initiative at the Jagiellonian University through grant No. U1U/P05/NW/03.23.

**Poster Session** - Board: 12 / **38**

## Spectrometric study of biomolecular differences of β-cell EVs subpopulations from hyperglycemic conditions

**Authors:** Magdalena Marzec[1]; Carina Rząca[2]; Agnieszka Kamińska[3]; Ewa Stępień[1]

[1] *Jagiellonian University*

[2] *Zakład fizyki medycznej WFAIS UJ*

[3] *Uniwersytet Jagielloński*

**Corresponding Author:** magda.skalska@uj.edu.pl

Extracellular vesicles (EVs) are a spherical shape structures surrounded by a protein-lipid membrane. EVs are important in the detection of various diseases, such as cardiovascular disease or cancer, and may have a high therapeutic potential [1]. The molecular composition and size of EVs membranes vary depending on the source cells, the current stage of development and environmental conditions. Their basic classification distinguishes three subpopulations: exosomes derived from endosomes (50–150 nm), microbubbles budding in the cell membrane (100–1000 nm) and apoptotic bodies (100–5000 nm). Specific features of these EVs subgroups have been proposed, but there are still no standardized markers to distinguish these populations [2].
In the work, we propose the use of secondary ion mass spectrometry with a time-of-flight analyzer (ToF-SIMS) to assess the differences in the molecular composition of EV subpopulations: exosomes, ectosomes and a mixture of both populations. EVs, derived from pancreatic β-cells grown under hyperglycemia conditions (HC), were purified by Low-Vacuum Filtration and concentrated by ultracentrifugation. ToF-SIMS, as a highly sensitive qualitative technique, made it possible to perform a comparative analysis of the tested samples. During the analysis, significant differences in the intensities of the characteristic peaks of amino acids and individual lipid groups were revealed. The demonstrated changes concern EV subpopulations and their mixture obtained from glycerin conditions. It can be assumed that various EV subpopulations derived from pancreatic β-cell cultures are characterized by a changed molecular composition related to biogenesis of the discussed structures. The external environment has a significant impact on the protein-lipid EV membrane composition.
Keywords: extracellular vesicles; β-cell; ToF-SIMS; hyperglycemia; lipidomic;
[1] E. Stępień, E. Stankiewicz, J. Zalewski, J. Godlewski, K. Zmudka, and I. Wybrańska, "Number of microparticles generated during acute myocardial infarction and stable angina correlates with platelet activation.," Arch. Med. Res., vol. 43, no. 1, pp. 31–35, Jan. 2012, doi: 10.1016/j.arcmed.2012.01.006.
[2] E. Ł. Stępień, A. Kamińska, M. Surman, D. Karbowska, A. Wróbel, and M. Przybyło, "Fourier-Transform InfraRed (FT-IR) spectroscopy to show alterations in molecular composition of EV subpopulations from melanoma cell lines in different malignancy," Biochemistry and biophysics reports, vol. 25. Department of Medical Physics, Marian Smoluchowski Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, 30-348, Kraków, Poland., p. 100888, 2021, doi: 10.1016/j.bbrep.2020.100888.
This work was supported by the National Science Center (NCN), grant OPUS 17 to prof. E. Stępień (No. 2019/33/B/NZ3/01004) and the SciMat Priority Research Area budget under the Strategic Program Excellence Initiative at the Jagiellonian University.

**Poster Session** - Board: 13 / **40**

# ATR-FTIR spectroscopy of extracellular vesicles derived from endothelial cells cultured in hyperglycemic conditions

**Author:** Carina Rząca[1]

**Co-authors:** Andrzej Wróbel [2]; Ewa Stępień [1]

[1] *Jagiellonian University*

[2] *Uniwersytet Jagielloński*

**Corresponding Author:** carina.rzaca@doctoral.uj.edu.pl

carina.rzaca@doctoral.uj.edu.pl

Nowadays extracellular vesicles (EVs) are being actively researched. EVs are involved with several biological processes including cell signalling, transfer specific cargo (lipids, proteins, and nucleic acids) and biomarkers of disease. EVs can be divided according to their size and way of arising into exosomes (diameter from 30 nm to 100 nm) and ectosomes (diameter from 100 nm to 1000 nm) [1,2,3].

The Attenuated Total Reflectance Fourier Transform Infrared spectroscopy (ATR-FTIR) method is based on the characteristic absorption of infrared radiation at specific wavelengths by functional groups like N–H, C=O, CH2, CH3, and PO2. An IR spectrum carries specific information on the sample's molecular composition and structure [6,7,8]. The aim of this study is investigation endothelial EVs cargo modifications in hyperglycemic conditions.

In this experiment we used cells, exosomes and ectosomes derived from telomerase-immortalized human microvascular endothelium cell line (TIME) cultured in normoglycemic and hyperglycemic conditions. The parameters were determined to characterize the chemical state of the lipids and proteins of the EVs: saturated to unsaturated fat ratio, acyl chain length, protein phosphorylation and lipid to protein ratio [2,6]. In addition, the percentage contribution of the following secondary protein structures was calculated based on the analysis of the second derivative of the spectra in the Amide I band range: side chain, inter β-sheet, β-sheet, random coil, α-helix and β-turn [2].

FTIR results showed that exosomes, ectosomes and cells differ in content of protein and lipid components. Moreover, obtained results revealed differences in the molecular composition and secondary structures of proteins from EV subpopulations derived from hyperglycemic endothelial cells. Statistically significant differences were found between ectosomes from normoglycemia and hyperglycemia conditions for the values of almost all calculated parameters. Summarizing, ectosomes can be considered as diabetes biomarkers. ATR-FTIR analyses may be useful in identifying new biomarkers of diabetes and its complications.

References
1. Stępień EŁ et al. Arch. Med. Res. 2012;43: 31-35.
2. Stępień EŁ et al. Biochem Biophys Rep. 2021;25:100888.
3. Roman M et al. Nanomedicine. 2019;17:137-149.
4. Stępień EŁ et. al. Theranostics. 2018;8:3874-3890.
5. Alexandru N et al. Biochem Biophys Res Commun. 2016;472:1-10.
6. Ricciardi V et al. Appl. Sci. 2020;10:2974.
7. Dogan A et al. Genomics 2013, 14:386
8. Kumar S et al. Chem. Soc. Rev., 2016, 45, 1879.

Acknowledgments
This study was supported by the Polish NCN grant OPUS 17 to prof. E. Stępień (2019/33/B/NZ3/01004) and the SciMat Priority Research Area budget under the Strategic Programme Excellence Initiative at the UJ.

**Poster Session** - Board: 14 / **41**

# The Present and the future of Breast Cancer diagnosis

**Authors:** Shivani .[1]; Elżbieta Luczyńska[2]; Sylwia Heinze[3]; Paweł Moskal[4]

[1] *Jagiellonian University*

[2] *Medical College of Rzeszow University, Cracow, Poland*

[3] *Department of Radiology, Center of Oncology Cracow Branch, Cracow, Poland*

[4] *Department of Experimental Particle Physics and Applications, M. Smoluchowski Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland, Total-Body Jagiellonian-PET Laboratory, Jagiellonian University, Poland*

**Corresponding Author:** shivani.shivani@doctoral.uj.edu.pl

The purpose of the presented investigation is to compare the sensitivity, specificity, PPV, and NPV for standard mammography, spectral mammography, ultrasound, and magnetic resource imaging (MRI), which are the commercially available imaging modalities for breast cancer. The aim of our investigation is to design, construct and establish the performance characteristics of the Jagiellonian Positron Emission Mammography (J-PEM), for the detection and diagnosis of cancer. Its construction is based on a novel idea of PET tomography based on plastic scintillators [1,2] and wavelength shifters (WLS) [7,8] and a new concept of positronium imaging [3,4,5]. This study characterizes the performance of a newly developed J-PEM scanner prototype. The prototype system consists of a single module of plastic scintillators, built from two layers of the plastic scintillator (6x24x500 mm) and one layer of the wavelength shifters (3x10x100 mm) [6,7] placed orthogonally between them. Each scintillator bar is attached at both ends to Silicon Photomultipliers for the signal readout. This 3D system is based on the novel idea of applying plastic scintillators to detect annihilation photons and improving spatial resolution by utilization of wavelength shifters (WLS). J-PEM can be an effective system for the detection and diagnosis of breast cancer in its early stage by improving sensitivity and specificity and it can be achieved by the combined use of plastic scintillators, which have superior timing properties, with the WLS. In addition, this device will be developed in view of the classification of malignancy based on the possibility of positronium mean lifetime imaging.

**References**:
[1] P. Moskal, Sz. Niedźwiecki, et al., "Test of a single module of the J-PET scanner based on plastic scintillators," Nucl. Instr. Meth. A 764, 317 (2014).
[2] P. Moskal, O. Rundel, et al., "Time resolution of the plastic scintillator strips with matrix photomultiplier readout for J-PET tomograph," Phys. Med. Biol. 61, 2025 (2016).
[3] P. Moskal, D. Kisielewska, et al., "Feasibility study of the positronium imaging with the J-PET tomograph," Phys. Med. Biol. 64, 055017 (2019).
[4] P. Moskal, B. Jasińska, et al., "Positronium in medicine and biology," Nature Reviews Physics 1, 527-529 (2019).
[5] P. Moskal, D. Kisielewska, et al., "Performance assessment of the 2gamma positronium imaging with the total-body PET scanners, "EJNMMI Physics. 7:44 (2020).
[6] J. Smyrski, P. Moskal, et al., "Application of WLS strips for position determination in Strip PET tomograph based on plastic scintillator, "BioAlgorithms and Med-Systems 10, 59 (2014).
[7] J. Smyrski, et al., "Measurement of gamma quantum interaction point in plastic scintillator with WLS strips," Nuclear Inst. and Methods in Physics Research A 851, 39-42, (2017).

**Poster Session** - Board: 15 / **44**

## Cyclotron produced gallium-68 chloride [68Ga]GaCl3 as an alternative to 68Ge/68Ga generators

**Authors:** Jakub Boratyński[1]; Michał Jagodziński[2]; Zbigniew Rogulski[2]

[1] *Univeristy of Warsaw*

[2] *University of Warsaw*

**Corresponding Authors:** j.boratynski@voxel.pl, mj.jagodzinski@uw.edu.pl

**Jakub Boratyński 1,2, Michał Jagodziński 1,2 and Zbigniew Rogulski 2**

*1 Centrum Produkcji Radiofarmaceutyków VOXEL S.A, ul. Wrocławska 1-3, 30-006 Kraków,*
*2 Wydział Chemii, Centrum Nauk Biologiczno-Chemicznych, Uniwersytet Warszawski, ul. Żwirki i Wigury 101, 02-089 Warszawa*

**E-mail: j.boratynski@voxel.pl**

The 68Ga isotope is usually eluted from the 68Ge/68Ga generator and is therefore readily available in PET (Nuclear Medicine) laboratories which do not have a cyclotron in place. The characteristics of the 68Ga isotope that this possesses make it a desirable radionuclide for PET diagnostics and the first widely available PET radioactive metal ion for routine use worldwide. With the help of a chelator, it can be easily attached to a biologically active molecules, which makes it suitable for conjugation with various biomolecules using bifunctional chelators and various macromolecules. Additionally, the selection of the chelator enables one compound to be radiolabelled with different radiometals. Thanks to this, it is possible to widely use (PET, SPECT, MRI, multimodal PET/SPECT/CT and therapy) of the compound only through the exchange of the radiometal with minimal changes in biological behavior. This facilitates patient-centered care, from diagnosis to molecular imaging to treatment, e.g. possible combination with 177Lu or 90Y isotopes as a theranostic pair.
Due to serious disadvantages of 68Ge/68Ga generators, such as a very high purchase cost, short expiry date of the generator, low activity of the obtained isotope, low availability on the market and the need to keep a break between successive elutions, the number of PET studies with the use of 68Ga based radiopharmaceuticals do not meet the market demand [1], hence recently attempts have been made to obtain this valuable isotope using medical cyclotrons by irradiating of liquid (solution of 68Zn salts) [2] or solid target made of metallic 68Zn [3][4].
The paper presents the method of obtaining [68Ga]GaCl3 via a solid target technology in a medical cyclotron at the VOXEL Radiopharmaceuticals Production Center in Kraków, in quality compliant with the requirements of the European Pharmacopoeia and Good Manufacturing Practice (GMP). This method leads to obtain much greater activities, allowing for the subsequent distribution of the 68Ga isotope. The above method may be an attractive alternative to 68Ge/68Ga generators and in the future, by increasing the availability of the 68Ga isotope, may contribute to changing the cancer diagnosis strategy.

[1] K. Kumar, Cancer Biotherapy And Radiopharmaceuticals, 35, 3 (2020).
[2] F. Alves, V.H.P. Alves, S.J. Do Carmo, A.C. Neves,M. Silva, A.J. Abrunhosa, Modern Physics Letters A, 32, 17, (2017).
[3] M. Lin, G.J. Waligorski and C.G. Lepera, Applied Radiation and Isotopes, 133, 1–3 (2018).
[4] A.H. Alnahwi, S. Tremblay, S. Ait-Mohand, J.F. Beaudoin, B. Guéri, Applied Radiation and Isotopes, 156, 109014, (2020).

**Poster Session** - Board: 16 / **49**

## Free radicals influence on the positronium lifetime in melanocytes and melanomas cell cultures

**Author:** Ewelina Kubicz[1]

**Co-authors:** Julia Nizioł ; Paweł Moskal [2]; Ewa Stępień [1]

[1] *Jagiellonian University*

[2] *Department of Experimental Particle Physics and Applications, M. Smoluchowski Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland c Total-Body Jagiellonian-PET Laboratory, Jagiellonian University, Poland*

**Corresponding Author:** ewelina.kubicz@uj.edu.pl

Positronium, a bound state of positron and electron has been proposed as a novel biomarker for examining cancer cells [1]. This atom is copiously created in cells during Positron Emission Tomography (PET) imaging [2-3].Our pre-clinical studies have shown significant differences in the lifetime of positronium between normal and neoplastic cells and tissues [4-5]. Due to the conversion process concentrations of free radicals, especially reactive oxygen species (ROS) have a significant influence

on the properties of positronium, such as its lifetime and production intensity in the tissue [6-7]. We investigated the role of antioxidants, such as vitamin C and epigallocatechin gallate (EGCG), on the values of the newly proposed biomarker.
Studies were conducted on in vitro cell culture of normal human cell: melanocyte HEMa-LP cell line and two cell lines of melanoma: WM115 (primary melanoma) and WM266-4 (metastatic melanoma) as an example of cancer cells with different degree of malignancy. Cells were exposed to vitamin C in various concentrations (100, 1000 μM) and EGCG (10, 100 μM). Positronium lifetime was determined by means of Positron Annihilation Lifetime Spectroscopy and Na-22 isotope was used as a source of positrons.
Obtained results showed differences in positronium lifetime, between normal and cancer cell in relation to their malignancy. Resulting o-Ps lifetime in HEMa-LP, WM115, and WM266-4 cells was equal to 1.91(02)ns, 1.95(03)ns, 1.99(01)ns, respectively in control; 1.93(02)ns, 1.96(01)ns, 1.98(01)ns in 1000 μM concentration of vitamin C and 1.91(02)ns, 1.93(01)ns, 1.89(02)ns in 100μM concentration of EGCG. No significant differences were observed in measured solutions without the cells, resulting in o-Ps lifetime of 1.91(02)ns, 1.88(01)ns in vit. C and EGCG solution, respectively.
Outcome of our experiment confirmed the validity of employing positronium as an indicator, which may have a direct impact on better and more accurate diagnostics. The Jagiellonian Positron Emission Tomography scanner can be applied for simultaneous PET and positronium imaging [8-12].

References:
[1] Moskal, P. et al., Patent No: US 9851456; PL 227658; PCT/EP2014/068374.
[2] Moskal, P.et al., Nat. Rev. Phys. 1, 527–529 (2019).
[3] Moskal, P. 2019 IEEE Nucl. Scien. Sympo. and Medical Imaging Conference Proceedings, NSS/MIC 2019, doi:10.1109/NSS/MIC42101.2019.9059856 (2020).
[4] Moskal, P. et al., Developing a Novel Positronium Biomarker for Cardiac Myxoma Imaging, bioRxiv
[5] Kubicz, E. AIP Conf. Proc. 2182, 050004 (2019).
[6] Stepanov, P. S. et al., Phys. Chem. Chem. Phys. 22, 5123–5131 (2020).
[7] Shibuya, K. et al. Commun. Phys. 3, 173 (2020).
[8] Moskal, P. et al. Phys. Med. Biol. 61, 2025–2047 (2016).
[9] Gajos, A. et al. Adv. High Energy Phys. ID 8271280 (2018).
[10] Moskal, P. et al. Phys. Med. Biol. 64, 055017 (2019).
[11] Moskal, P. et al. EJNMMI Phys. 7, 44 (2020).
[12] Moskal, P. & Stępień, E. PET Clin. 15, 439–452 (2020).

**Poster Session** - Board: 17 / **54**

## Physicochemical characteristic of poly(amidoamine) dendrimers are their application in controlled drug delivery systems

**Author:** Magdalena Szota[1]

**Co-authors:** Katarzyna Reczyńska-Kolman [2]; Elżbieta Pamuła [2]; Olga Michel [3]; Julita Kulbacka [3]; Barbara Jachimska [4]

[1] *Jerzy Haber Institute of Catalysis and Surface Chemistry Polish Academy of Sciences*

[2] *Department of Biomaterials and Composites, Faculty of Materials Science and Ceramics, AGH-University of Science and Technology*

[3] *Department of Molecular and Cellular Biology, Wroclaw Medical University, Wroclaw, Poland*

[4] *Jerzy Haber Institute of Catalysis and Surface Chemistry, PAS, Niezapominajek 8, 30-239 Krakow, Poland*

**Corresponding Author:** magdalena.szota@ikifp.edu.pl

Poly(amidoamine) (PAMAM) dendrimers are monodisperse synthetic polymers with nanosize ranging from 1-14nm. Dendrimer synthesis can be precisely controlled in size, shape, molecular mass, composition, and reactivity [1,2]. The study's main aim was to investigate the correlation between the physicochemical properties of the carrier and the active substance and the efficiency of the

PAMAM-5FU complex formation. Experimental studies show that analysis of physicochemical properties of both PAMAM dendrimers and 5-fluorouracil play a significant role in the formation of high-efficiency PAMAM-5FU complex. The ligand binding's effectiveness to the dendrimers' structure is strictly dependent on the complex formation conditions: molar ratio, ionic strength, pH, and dendrimer generation. The fact that drug molecules bind most effectively under alkaline conditions when the dendrimer is close to the isoelectric point indicates the significant influence of the ligand charge, which occurs in a deprotonated form. Studies have confirmed the system's ability to attach approximately 20 5FU molecules per dendrimer molecule for the fourth generation dendrimer and about 25 molecules for the sixth generation dendrimer. Comparing these values with the nominal number of amine groups present in the dendrimer structure, a system efficiency of 16% for G4PAMAM and 5% for G6PAMAM dendrimers was obtained.
The decrease in the zeta potential of the PAMAM-5FU systems compared to the dendrimer itself indicates a change in the carrier's surface charge by drug immobilization. In addition, it may reveal the presence of ligand molecules on the PAMAM surface. H1 NMR spectra indicate the presence of drug molecules both inside the structure and on its surface. The research confirms the possibility of immobilizing the active agent in two ways and thus indicates the unique properties of the structure of dendrimers.
We demonstrated that both G4PAMAM and G6PAMAM present no toxicity towards normal cells. Furthermore, the observed activity of 5-FU/PAMAM complexes in four cancer cell lines, resulting in decreasing of a fluorouracil IC50 dose by up to 30%. Considering that most of the traditionally administered 5-FU is decomposed to inactive metabolites before reaching its target, drug conjugation with dendrimers seems to be a promising approach that increases drug toxicity and stability, ultimately leading to overcoming of transportation-related drug resistance.

Acknowledgments: This work was partially supported by project NCN OPUS 2016/23/B/02788,
References
1. Jachimska B. Physicochemical characterization of PAMAM dendrimer as a multifunctional nanocarriers, Nanoparticles in Pharmacotherapy. ; 2019. doi:10.1016/b978-0-12-816504-1.00003-
2. Rae JM, Jachimska B. Analysis of dendrimer-protein interactions and their implications on potential applications of dendrimers in nanomedicine. Nanoscale. 2021;13(4):2703-2713. doi:10.1039/d0nr07607d

**Poster Session** - Board: 18 / **34**

## Fast scanning of spent nuclear fuel dry storage casks using cosmic ray muons: Monte Carlo simulation study.

**Author:** Anzori Georgadze[1]

[1] *Kiev Institute for Nuclear Research*

**Corresponding Author:** a.sh.georgadze@gmail.com

Stable development of fission-based nuclear energy facilities requires the safe management of spent nuclear fuel. The growing number spent nuclear fuel in dry storage casks in intermediate storage sites around the world require efficient tools for non-destructive routine verifications of safe storage of spent fuel assemblies. Using a cosmic ray muon for screening of spent nuclear fuel in dry storage casks appears to be the most suitable solution for non-destructive verifications of fuel casks for safeguard purposes. Fast scanning of a fully or partially loaded dry storage casks is evaluated using Monte - Carlo simulation with Geant4 package and muons produced using CRY event generator. The point of closest approach (POCA) algorithms is used for reconstruction of muon interactions with dry storage casks. A Kolmogorov–Smirnov test was used to classify generated data samples for fully loaded casks and samples with one fuel assemble missing in dry storage casks. We use the Receiver Operating Characteristic (ROC) technique to characterize tradeoff between detection and false alarm rates. For one-hour measurement time detection rate can be achieved ~96%. The developed method of statistical analysis of reconstructed POCA points allows detecting dry storage casks with one fuel assemblies missing in a relatively short time of ~1 hour without full image reconstruction. The results of modelling demonstrate that the scattered muon tomography allows to perform efficient non-destructive scanning of dry storage casks for nuclear nonproliferation purposes.

**Poster Session** - Board: 20 / **57**

## Simulations of absorption in the brain of gamma quanta from positronium atoms

**Author:** Agata Jędruszczak[None]

**Corresponding Author:** agatajedruszczak1999@gmail.com

Agata Jędruszczak for the J-PET collaboration
agatajedruszczak1999@gmail.com
Jagiellonian University in Kraków; Faculty of Physics, Astronomy and Applied Computer Science, Profesora Stanisława Łojasiewicza 11, 30-348 Kraków

The poster shows the results of the research on the absorption in the brain of gamma quanta from positronium atoms created during the PET imaging.
Positronium imaging [1] is a new imaging method that allows to determine not only the location of the tumor, but also the degree of its malignancy [2]. It is the multi-photon imaging, which uses not only 2$\gamma$, but also 3$\gamma$ annihilations. Amount of detected photons from decay into 2$\gamma$ or 3$\gamma$ give information about tissue structure. Moreover, the 3$\gamma$/2$\gamma$ ratio allows the description of neoplastic changes [3]. The brain in these studies is approximated by a sphere with water. Monte Carlo simulations of positron decays and photon absorption in the brain and skull were performed. The simulation results were compared with theoretical calculations. The results of the percent events for which none of photons scattered in the head are as follows: 26.10 ± 0.05 % for para-positronium and 8.40 ± 0.03 % for ortho-positronium (absorption in the brain), 20.84 ± 0.05 % for para-positronium, 5.46 ± 0.02 % for ortho-positronium (absorption in the brain and in skull). The values of the ratio from the simulation are: 0.322 ± 0.002 for absorption in the brain and 0.262 ± 0.002 for absorption in the brain and skull. The dependence of absorption probability of photons in the head on the location of positronium atom decay in the brain is determined.
The poster will present the above-mentioned results and plots obtained in the simulations. The methods by which the simulation results were obtained will also be presented.
References
[1] P. Moskal et al., "Positronium imaging with the novel multi-photon PET scanner", Science Advances (in press)
[2] P. Moskal, D. Kisielewska, C. Curceanu et al., "Feasibility study of the positronium imaging with the J-PET tomograph",Phys. Med. Biol. 64:055017 (2019)
[3] B. Jasińska, P. Moskal, "A New PET Diagnostic Indicator Based on the Ratio of 3$\gamma$/2$\gamma$ Positron Annihilation",Acta Phys. Pol. B,48:1577-1582 (2017).

**Poster Session** - Board: 21 / **58**

## The development of a method for determining ortho-Positronium mean lifetime in extracellular vesicles using Positron Annihilation Lifetime Spectroscopy

**Author:** Julia Niziol[1]

**Co-authors:** Ewelina Kubicz [2]; Ewa Stępień [3]; Paweł Moskal [4]

[1] *Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland*

[2] *Jagiellonian University*

[3] *aM. Smoluchowski Institute of Physics, Jagiellonian University*

[4] *Department of Experimental Particle Physics and Applications, M. Smoluchowski Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland, Total-Body Jagiellonian-PET Laboratory, Jagiellonian University, Poland*

**Corresponding Author:** julia.niziol@student.uj.edu.pl

Positron annihilation lifetime spectroscopy (PALS) has been used less extensively in studies with biological material, although its use in interrogating free volume, voids and defects in polymers is well

established. There exist a number of results, e. g. by E. Kubicz and the J-PET group [1], showing the correlation between cell structure and the PALS parameters, such as mean ortho-Positronium (o-Ps) lifetime and intensity. This technique has also been demonstrated to have utility as an in situ molecular probe in self-assembled biomimetic systems for which it is highly sensitive to conformational, structural and microenvironmental transformations [2].

Extracellular vesicles (EVs) are defined as bilayer cell membrane fragments released into the extracellular space by various types of cells. EVs play dual role throughout the body, due to their involvement in both physiological and pathological conditions [3]. Growing interest in these spherical structures emerges from their involvement in cell-to-cell communication, tumour progression and their possible application as biomarkers or drug delivery systems [4].

Applying PALS to study EVs required set-up modifications (chamber design) and calibrations, in order to adjust the system for studies of liquid samples in temperature controlled conditions. For that purpose, the system was equipped with the Lauda LOOP L100 thermostat. Temperature of investigated samples was estimated from calibration data obtained through extensive thermal testing.
Two EV samples derived from normal pancreatic beta-cell cultures suspended in PBS solution were examined: (1) from culture under normoglycemic and (2) hyperglycemic conditions. EV concentrations in the samples were determined using qNano technique and its values were respectively: (1) $9 \times 10^{10}$ and (2) $6,9 \times 10^{10}$ particles/mL.

Preliminary results demonstrate strong correlation between mean o-Ps lifetime and EV concentration in the sample. Studied concentrations of EVs were too low, therefore it was mainly the PBS solution that was contributing to the resulting o-Ps lifetime value, and not the EVs itself.
Obtained result opens perspective for further research, when applying higher EVs to PBS ratio. Such experiments were performed e. g. by P. Sane et al. [5] and demonstrated that observing changes in o-Ps lifetime, corresponding to phase transitions of membrane lipids in vesicles (multilamellar DPPC), is feasible with PALS technique.

References:
[1] Kubicz, E., Doctoral Thesis, Jagiellonian University (2020).
[2] Fong, C. et al., Physical chemistry chemical physics : PCCP vol. 17,27: 17527-40 (2015).
[3] Stępień, E. et al., Expert opinion on therapeutic targets vol. 16,7: 677-88 (2012).
[4] Surman, M. et al., Current pharmaceutical design vol. 25,2: 132-154 (2019).
[5] Sane, P. et al., The journal of physical chemistry. B vol. 113,7: 1810-2 (2009).

**Poster Session** - Board: 22 / **61**

## BSA as a biologically active nanocarriers – computational studies

**Author:** Kamil Rakowski [1]

**Co-author:** Barbara Jachimska [2]

[1] *Jerzy Haber Instiute of Catalysis and Surface Chemistry Polish Academy of Sciences*

[2] *Jerzy Haber Institute of Catalysis and Surface Chemistry Polish Academy of Sciences*

**Corresponding Author:** kamil.rakowski@ikifp.edu.pl

Human albumin (HSA) is the main plasma protein that ensures the maintenance of proper osmotic blood pressure and is also involved in the transport of metabolites to cells. It exhibits high solubility at pH = 7.4 and the ability to bind molecules, making it possible to use it as a transporter of drugs such as 5-fluorouracil (5-FU). 5-FU is a drug that causes the incorporation of fluoronucleotides in place of nucleotides that inhibit the thymidylate synthesis of the nucleic acid enzyme. 5-Fluorouracil is used to treat a number of cancers. The biggest problem is its susceptibility to dihydropyrimidine dehydrogenase (DPD), which metabolizes 5FU to the form of dihydrofluorouracil (DHFU) and destroys its therapeutic activity. The crystallographic model of bovine albumin (BSA), which is an equivalent of human albumin (HSA), was selected for the research. Before the docking process, the model was prepared in the Gromacs program. The object was simulated until the conformational changes stabilized, which was monitored via the RMSD function. Finally, the thus obtained BSA

model was used for interaction with 5-FU. Before the docking process, the drug was prepared in the Avogadro program. Hydrogens corresponding to a protonation state of pH = 7.4 were added to the drug molecule and minimized in the MMFF94 field using a Conjugate Gradient. The standard protocol of random docking on the whole protein volume was used, the MGLTools tool was used, docked using the rigid Autodock Vin methods. The lowest energy complex was simulated with MD, the drug-free control and the protein/ligand complex were simulated for another 100ns under the same conditions. In the conducted research, the ligand was randomly docked in the entire BSA volume. The results unique for the protein were visualized, and the complex with the most favorable energy was simulated using molecular dynamics methods. BSA has been shown to bind 5-FU at a similar position as HSA in the IB domain. Moreover, it has been established by computational methods that the binding of 5-FU at the center of the protein (IIIA and IIA domains) may be the most common and energetically most beneficial for BSA. Docking at the center with the lowest Gibbs free energy was investigated in detail. Hydrophobic domains inside the ligand-binding pocket have been shown to influence the organization of solvent molecules and the formation of water clusters. The formed clusters constitute the main mechanism that stabilizes the drug inside the canal, which may show promise for its controlled release at elevated temperatures. During the simulation, 5-FU moves into the cavity between domains IIIA and IIA. The binding of 5-FU may affect the mobility of adjacent BSA domains, in particular the IB domain, which is one of the most important pockets for binding substances with therapeutic potential. The presence of the ligand between domains IIIA and IIA resulting in the appearance of strong local chain fluctuations (110-118AA, IB domain).

**Poster Session** - Board: 23 / **68**

## Assessment of the influence of the Beta parameter in the reconstruction of Q.Clear.

**Authors:** Konrad Skórkiewicz[1]; Anna Sowa-Staszczak[2]; Kazimierz Łątka[3]; Alicja Hubalewska-Dydejczyk[None]

[1] *Jagiellonian Univeristy*
[2] *CM UJ*
[3] *UJ*

**Corresponding Author:** konrad.skrk@gmail.com

Molecular PET / CT imaging is used for the diagnosis of patients with neuroendocrine tumors with the use of radiolabelled somatostatin analogues. Iterative image reconstruction techniques are used to obtain the image.Unfortunately, as a result of the significant impact of the so-called “Partial Volume Effect” in minor changes in pathological radiopharmaceutical uptake, the results of the quantitative assessment are underestimated. In PET images, it affects the assessment of the diagnostic test results as a false negative result. The selection of appropriate Q.Clear reconstruction parameters in the PET / CT MI DR system can reduce the impact of this phenomenon. In order to perform the appropriate analysis, measurements has been made using the NEMA IEC PET Body Phantom, in which the hot spheres have been filled concentration 10:1 of 68Ga isotope. The raw data was reconstructed using a Q.Clear reconstruction for a Beta parameter in the range 150-1000, in steps of 50. The analysis showed a clear decrease in the maximum values and mean SUVs with higher values of the Beta parameter for the smallest spheres.

**Poster Session** - Board: 24 / **69**

## Myocardial perfusion scintigraphy - criteria of SPECT/CT protocol selection.

**Authors:** Adrian Kania-Kuc[1]; Marta Opalińska[1]; Ibraheem Al Maraih[2]; Anna Sowa-Staszczak[3]; Alicja Hubalewska-Dydejczyk[3]

[1] *Nuclear Medicine Unit, Department of Endocrinology Department of Endocrinology, Oncological Endocrinology and Nuclear Medicine, University Hospital, Kraków, Poland*

[2] *Nuclear Medicine Department, University Hospital, Krakow, POLAND*

[3] *Chair and Department of Endocrinology, Jagiellonian University Medical College, Kraków, Poland*

**Corresponding Author:** adrian.kania7@gmail.com

**Key words:**
myocardial perfusion, nuclear medicine, SPECT/CT, image quality

**Background:**
Myocardial perfusion imaging with 99mTc-MIBI by SPECT/CT plays a major role in the diagnosis of coronary artery disease (CAD) as a non-invasive test to assess perfusion in cardiomyocytes. The exam allows to assess the severity of the disease, the effectiveness of the therapy, and has a prognostic value. One disadvantage of this imaging method is the relatively long SPECT acquisition time. The possible solution to this problem is shortening of the examination time by improving the quality of imaging and changing the acquisition parameters. The use of SPECT/CT with cadmium-zinc telluride (CZT) technology may improve scanning parameters including reduction of acquisition time, however maintenance of high-quality imaging is required.

**Aim:**
The aim of the study was to check the possibility of implementation of a new myocardial perfusion imaging protocol with reduced acquisition time.

**Material and methods:**
We compared two protocols of myocardial perfusion SPECT/CT with 99mTc-sestamibi using different acquisition and reconstruction parameters. Two scans for one patient was done firstly as an 8 minutes protocol, the second was shortened to 6 minutes. The acquisition was performed on a CZT camera one after the other. Then CT scan for attenuation correction was performed according to the standard SPECT/CT procedure. The analysis was performed on planar perfusion reconstruction of the SPECT myocardium. The volume of the greatest distribution of radionuclides in the heart was selected semi-automatically on the obtained coronary images. For both protocols, three measurements were performed at the same locations and similar volumes in each measurement, calculating the number of counts, mean, standard deviation (SD) and volume. The measured volumes gradually increased in the measurements. The SD standardized to the volume of 1 ml was considered an important parameter of the differentiation capacity of regions with a lower uptake of 99mTc-sestamibi in cardiomyocytes. All images were assessed by two nuclear medicine specialists in order to confirm the quality of the imaging.

**Results:**
Performed examination of one patient with confirmed myocardial ischemia indicated a 10.48% decrease in SD/ml and 23.62% decrease in the number of counts of the measured volume. The amount of decrease in SD/ml significantly reduced the possibility of diagnosis of small ischemia regions in 6 minutes protocol in comparison with 8 minutes protocol.

**Conclusion:**
On the basis of comparative analysis performed by nuclear medicine specialists, the 8-minute protocol was selected as the standard SPECT/CT myocardial perfusion procedure due to better image quality and greater resolution for small ischemic area of myocardium.

**Poster Session** - Board: 4 / **19**

## The use of x-ray volume imaging system for verification of the positioning accuracy during stereotactic radiotherapy of the head and lungs

**Authors:** Anna Czubowicz[1]; Andrzej Chmiel[2]; Katarzyna Matusiak[1]

[1] *AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Krakow*

[2] *Department of Radiotherapy for Children and Adults of the University Children's Hospital of Krakow, ul. Wielicka 265, 30-663 Krakow*

**Corresponding Author:** katarzyna.matusiak@fis.agh.edu.pl

The aim of this study was to analyzed the differences between the reconstruction of the patient's anatomy in the therapeutic area, performed with the use of the X-ray Volume Imaging system (XVI) of the Elekta system, and the actual patient positioning. The results obtained from the cone beam tomography (CBCT) performed twice (before and after irradiation) were compared with the reference images from computed tomography (CT) obtained during the treatment planning.

The comparison was made for two groups: 20 patients irradiated in the head area and 45 patients irradiated in the lung area. The results were analyzed in three steps. The first was the analysis of data using the Student's t-test for one sample. It consisted in assessing whether the mean values of the isocenter shift implemented in relation to the isocentre planned in the direction of X, Y, Z for the studied patients are statistically significantly different from 0. Then the data were analyzed using the Student's t-test for paired samples. It was done to check whether the mean values of the isocenter shift realized in relation to the isocentre planned in the X, Y, Z directions for the studied patients before irradiation are statistically significantly different from the mean values of the shift for the studied patients after irradiation. The third stage of the analysis of the results originating from the XVI system was the calculation of population systematic and random errors in order to calculate the CTV-PTV margins according to the van Herk method. The practical part of this work was carried out in cooperation with the Department of Radiotherapy for Children and Adults of the University Children's Hospital in Krakow.

Analysis of obtained data confirmed the high precision of radiotherapeutics procedures performed at the Department of Radiotherapy for Children and Adults, University Children's Hospital in Krakow. Moreover, the effectiveness of XVI system in set-up margins reduction was confirmed.

**Poster Session** - Board: 5 / **20**

## Event Identification in Compton Camera Imaging via Machine Learning for Proton Therapy Monitoring

**Author:** Majid Kazemi Kozani[1]

**Co-authors:** Andrzej Magiera [1]; Aleksandra Wrońska [1]; Jonas Kasper [2]

[1] *Marian Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland*

[2] *Physics Institute 3B, RWTH Aachen University, Aachen, Germany*

**Corresponding Author:** majid.kazemi.kozani@doctoral.uj.edu.pl

One of the most important challenges in hadron therapy is the development of online monitoring techniques. Monitoring systems based on the detection of secondary radiation such as prompt gamma (PG) emission produced during treatment are promising approaches for this purpose [1,2]. The SiFi-CC, a Compton camera based on stacks of heavy scintillating fibers and SiPMs, is being developed for PG imaging [3,4]. A machine learning approach based on TMVA [5] to recognize Compton events is proposed for the classification of pseudo-data generated by the Geant4 simulation for a 180 MeV spot-scanning proton beam impinging on a PMMA phantom. To reconstruct a Compton event, a minimum of two interactions is required. Therefore, the proposed method first builds a learning set of the events filtered with interactions that yielded at least one interaction in each of two modules of the SiFi-CC. The data set is used to train the boosted decision tree (BDT) model using nine features including the position and deposited energy of interactions in the scatterer and the absorber, and the cosine of internal scattering angles term. A 10-fold cross-validation of the BDT model shows a great increase in the signal to background ratio. A software based on the LM-MLEM algorithm [6,7] was applied for the reconstruction of the PG distribution. Very good agreement between the reconstructed distal edge position and that of simulated Compton events was obtained. Moreover, it was shown that the precision of a few millimeters in distal edge position determination is feasible.

References:
[1] C.H. Min, et al., Nucl. Instrum. Methods Phys. Res. A. vol. 580, 2007, pp. 562–565.
[2] L. Kelleter, et al., Phys. Med., vol. 34, 2017, pp. 7-17.

[3] J. Kasper, et al., Phys. Med., vol. 76, Jul. 2020, pp. 317-325.
[4] A. Wrońska, et al., Acta. Phys. Pol. B, vol. 51, 2020, pp. 17-25.
[5] A. Hoecker, et al., Rep. no. CERN-OPEN-2007-007.
[6] S. J. Wilderman, et al., IEEE Nucl. Sci. Symp. Med. Imaging Conf. Rec., vol. 3, 1998, pp. 1716-1720.
[7] S. J. Wilderman, et al., IEEE Trans. Nucl. Sci., vol. 48, 2016, pp. 111-116.

**Poster Session** - Board: 7 / **25**

# Positronium biomarker in 3D melanoma spheroid model, a novel probe for cancer diagnosis

**Author:** Hanieh Karimi[1]

**Co-authors:** Paweł Moskal [2]; Ewa Stępień [3]

[1] *Department of Medical Physics, M. Smoluchowski Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland, Total-Body Jagiellonian-PET Laboratory, Jagiellonian University, Poland*

[2] *Department of Experimental Particle Physics and Applications, M. Smoluchowski Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland c Total-Body Jagiellonian-PET Laboratory, Jagiellonian University, Poland*

[3] *Department of Medical Physics, M. Smoluchowski Institute of Physics, Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Kraków, Poland*

**Corresponding Author:** karimihanieh1@gmail.com

Spheroids are three-dimensional cancer cell models able to mimic important properties of real tumors such as physical structure, physiological characteristics, and gene expression patterns. In this research, the lifetime of Positronium has been evaluated in spheroids formed from human melanoma cell lines, WM266-4 and WM115. In the first step, spheroids were formed from WM266-4 and WM115 melanoma cell lines, using the hanging drop method and the size, rate of proliferation and viability of spheroids were evaluated precisely by optical, fluorescent Microscopy and micro-CT [1].
After precise determination of spheroid characteristics, we created spheroids in 5D microplates for measuring positronium lifetime by PALS spectroscopy. The lifetime of positronium is environmentally dependent and it provides information about the size of intra-molecular spaces in cells, thus it is related to the tissue morpholo-gy. To determine the positronium lifetime, the spheroids were inserted into an Aluminium chamber and irradi-ated with positrons emitted from 22Na radionuclide. The photons resulting from the annihilation of positrons inside the spheroids were measured by the dedicated detector build from BaF2 scintillators and digitizing acqui-sition system. We observe differences in the lifetime of positronium depending on the degree of malignancy of the melanoma cells. WM266-4 showed a higher velocity in division than WM115 which got 1.5 and 2.74-fold more cells after the 4th and 8th day while WM115 demonstrated 1.4 and 1.7-fold more cells after 4th and 8th days, respectively. The Lifetime of o-Ps in WM266-4 spheroids was 1.87 ns and 1.86 ns in 4th and 8th day after cul-turing while in WM115 spheroids, the o-Ps lifetime was 1.90 ns and 1.87 ns in 4th and 8th day, respectively. In conclusion, both cell lines showed a reduction in an o-Ps lifetime during the time. This decrease in lifetime indicates the reduction in molecular mobility because of the high concentration of cells in spheroids which are growing during the time. We can also consider this difference in an o-Ps lifetime for malignancy diversity. The results will be reported in the context of its application of positronium as a biomarker for the in-vivo assess-ment of the degree of cancer malignancy with the total-body PET scanners [2].
Keywords: Spheroids, melanoma, Hypoxia, Positron imaging
Acknowledgments
This work was supported by the Foundation for Polish Science (FNP) through grant TEAM/2017-4/39 program, and DSC grant, nom. N17/MNS/000023.
References
1. Karimi, Hanieh, et al. “X-ray microtomography as a new approach for imaging and analysis of tumor spheroids.” Micron 137 (2020): 102917.
2. Moskal, Paweł, and Ł. Stępień, Ewa. “Prospects and clinical perspectives of total-body PET imaging using plastic scintillators.” PET clinics 15.4 (2020): 439-452.

**Poster Session** - Board: 8 / **27**

# Optimization and enhancement of CNR in MRI using core/shell contrast agent

**Author:** David MacDonald[None]

**Co-authors:** Barbara Blasiak ; Boguslaw Tomanek [1]

[1] *Main Supervisor*

**Corresponding Author:** dmlmacdona@gmail.com

Title:
Optimization and enhancement of CNR in MRI using core/shell contrast agent

D. MacDonald [1], B. Blasiak [1] [2], B. Tomanek [1] [2] [3]

Presenting author:
David MacDonald
dmlmacdona@gmail.com

Magnetic resonance imaging (MRI) provides the best soft contrast tissue among diagnostic imaging modalities such as CT, PET or X-ray. The contrast provided by MRI is based on the proton density and on interactions of protons with the surrounding molecules of tissues causing so called T_1 and T_2 relaxations. MRI techniques utilize these processes for contrast manipulation by producing T_1 or T_2 weighted MR images. While MRI contrast may be provided solely by tissues themselves due to differences in their relaxation times, contrast agents shortening T_1 and T_2 further improve detection of small pathologies such as early stages breast or brain cancers. Recently T_1/T_2 core shell contrast agents have been developed with an expectation that the contrast to noise ratio (CNR) would be greater than when compared to T_2 contrast agent. To prove this, firstly we calculated optimal parameters in commonly used Spin Echo and IR TrueFISP pulse sequences that provide the greatest CNR for known T_1 and T_2 relaxation times for an animal model of breast cancer. The results show that the CNR of a tumor for a T_1/T_2 core shell contrast agent is greater than that of just a T_2 contrast agent for both the Spin Echo and IR TrueFISP pulse sequences. To demonstrate the potential of our core/shell contrast agent in vivo MRI we imaged mice with breast tumors after intravenous injection of 0.25 mL of non-targeted core shell contrast agent NaDyF4 (20 nm)/NaGdF4 (~ 0.5 nm). Then to further increase the CNR, we subtracted a T_1 weighted image with T_2 weighted image. Post-injection results show that the best CNR comes from the T_1 weighted image subtracted by the T_2 weighted image, and the CNR for the T_1 weighted image is greater than the CNR for the T_2 weighted image.

[1] Instytut Fizyki Jadrowej Polish Academy of Science, Waleregо Eljasza Radzikowskiego 152, 31-342 Kraków, Poland
[2] University of Alberta, 116 St & 85 Ave, Edmonton, AB T6G 2R3, Canada
[3] University of Calgary, 2500 University Dr NW, Calgary, AB T2N 1N4, Canada

**Poster Session** - Board: 9 / **28**

# Comparison of SP3 and S-Trap LC-MS/MS approaches in proteomic analysis of ectosomes derived from thyroid cancer and normal thyroid follicular cells

**Author:** Magdalena Surman[1]

**Co-authors:** Magdalena Wilczak [1]; Karolina Chudaszek [2]; Urszula Jankowska [3]; Sylwia Kędracka-Krok [2]; Ewa Stępień [4]; Małgorzata Przybyło [1]

[1] *Jagiellonian University in Krakow, Faculty of Biology, Institute of Zoology and Biomedical Research*

[2] *Jagiellonian University in Krakow, Faculty of Biochemistry, Biophysics and Biotechnology, Department of Physical Biochemistry*

[3] *Jagiellonian University in Krakow, Molopolskie Centre of Biotechnology*

[4] *Jagiellonian University in Krakow, Faculty of Physics, Astronomy and Applied Computer Science, Department of Medical Physics*

**Corresponding Author:** magdalena.surman@uj.edu.pl

The small size of ectosomes makes their isolation and obtaining the appropriate protein yield for liquid chromatography-tandem mass spectrometry (LC-MS/MS) proteomic analyzes a considerable methodological challenge. Especially isolation of ectosomes from limited amount of body fluids of cancer patients means that a much smaller amount of protein is available for LC-MS/MS. The SP3 (solid-phase-enhanced sample preparation) method used by us so far [1] works when it is possible to obtain the appropriate amount of ectosomal protein as a result of scaling cell cultures. The aim of this research was to develop a method of sample preparation for LC-MS/MS based of S-Trap microcolumn technique that would give the same quality results despite using less protein.

Two cell lines were used in these research: anaplastic thyroid carcinoma (8305C) and normal thyroid follicular (Nthy-ori 3-1) cells. Ectosomes were isolated from conditioned media concentrated by low-vacuum filtration by differential centrifugation, and prepared for LC-MS/MS using SP3 or S-Trap techniques. Then LC-MS/MS was used to analyze the protein content of the ectosome proteome. Next, Gene Ontology (GO) analysis was performed using UniProt Database to classify identified proteins according to the biological processes, molecular functions and their cellular origin.

Using the SP3 method we identified 410 proteins in 8305C ectosomes and 558 proteins in Nthy-ori 3-1 ectosomes. S-Trap technique increased the numbers of identified proteins to 915 in 8305C ectosomes and to 804 proteins in Nthy-ori 3-1 ectosomes. For 8305C and Nthy-ori 3-1 ectosomes, 304 and 357 proteins were identified by both protocols , respectively. Alongside the proteins identified regardless of chosen sample preparation method (SP3 or S-Trap) provided significant number of protein that were not identified by the other one. According to GO the most abundant groups of proteins for both types of ectosomes were those connected with cytosolic or membrane origin. In 8305C ectosomes, several cancer-associated proteins were found, which suggests their possible role in cancer promotion.

Acknowledgements: The research was funded by the BioS Priority Research Area under the program "Excellence Initiative –Research University" at the Jagiellonian University in Krakow (U1U/P03/DO/13.17).

[1] Surman et al., , Int J Mol Sci. 2020, 21(8): 2934.

**Monday Morning Session** / **74**

## New technologies for Total Body PET imaging

**Author:** Stefaan Vandenberghe[None]

**Corresponding Author:** stefaan.vandenberghe@ugent.be

The lecture will concern new technologies for Total Body PET imaging.

**Monday Morning Session** / **2**

## List-mode TOF MLEM reconstruction for the total-body J-PET with a realistic system response matrix

**Author:** Roman Shopa[1]

[1] *National Centre for Nuclear Research, Poland*

**Corresponding Author:** roman.shopa@ncbj.gov.pl

We modify the time-of-flight maximum likelihood expectation maximisation (TOF MLEM) image reconstruction algorithm by an updated model for the system response matrix (SRM) of the total-body Jagiellonian PET (J-PET) scanners, which modular multi-layer geometry complicates SRM estimation and requires more computational power to calculate correction factors [1].
The elongated plastic scintillators of the J-PET, which use Compton scattering for the detection of positron-electron annihilation photons, imply the smooth dependence of SRM on the obliqueness angle $\theta$. We thus represent it as a set of functions unique for each bin and acquired by a log-polynomial fit of the Monte Carlo simulated emissions of $\gamma$-photons on 2D transverse planes with different $\theta$.
By utilising the GATE software [2], a NEMA IEC phantom [3] was simulated in a 140-cm long 24-module J-PET, comprised of 2 detector layers (inner radius 393 mm) and a layer of wavelength shifters [4]. The data collected from a 500-s long scan was post-smeared according to the assessed temporal (191 ps) and axial (5 mm) resolution. Only true coincidences were considered.
The updated SRM was employed for the list-mode TOF MLEM reconstruction. For the predefined NEMA IEC attenuation map, two versions of attenuation correction were applied: a conventional (integration over bins) and a simplified on-the-fly recalculation for each measurement, which improves performance and is less sensitive to boundary effects.
Compared to the reference list-mode TOF MLEM from the CASToR framework [5], a substantial improvement in the image quality and mean squared error with respect to ground truth were observed. The simplified attenuation correction proved to be a reliable alternative, producing outcomes similar or better than the conventional approach.
To summarise, the proposed analytical SRM model for the total-body J-PET proved to be superior to the reference method employed for crystal-based scanners. The modified TOF MLEM and attenuation correction do not require high computational power and can be extended to account for the non-collinearity, positron range and other factors.

[1] P. Moskal et al., "Simulating NEMA characteristics of the modular total-body J-PET scanner—an economic total-body PET from plastic scintillators," Phys. Med. Biol., vol. 66, no. 17, pp. 175015, Sep. 2021.
[2] S. Jan et al., "GATE: a simulation toolkit for PET and SPECT," Phys. Med. Biol., vol. 49, no. 19, pp. 4543-4561, Oct. 2004.
[3] Performance Measurements of Positron Emission Tomographs, NEMA NU 2-2012, 2013.
[4] J. Smyrski et al., "Measurement of gamma quantum interaction point in plastic scintillator with WLS strips," Nucl. Instrum. Methods Phys. Res. A, vol. 851, pp. 39-42, Apr. 2017.
[5] T. Merlin et al., "CASToR: a generic data organization and processing code framework for multi-modal and multi-dimensional tomographic reconstruction," Phys. Med. Biol., vol. 63, no. 18, pp. 185005, Sep. 2018.

**Monday Morning Session / 42**

## Micro-CT journey - from bones to personalized medicine

**Authors:** Bartosz Leszczyński[1]; Andrzej Wróbel[1]; Greetje Vande Velde[2]; Witold Jamróz[3]; Ewa Stępień[1]

[1] *M. Smoluchowski Institute of Physics, Jagiellonian University*

[2] *Department of Imaging and Pathology, KU Leuven, University of Leuven*

[3] *Department of Pharmaceutical Technology and Biopharmaceutics, Jagiellonian University Medical College*

**Corresponding Author:** bartosz.leszczynski@uj.edu.pl

X-ray microtomography (micro-CT) is a well establised nondestructive 3D method for small sample internal structure imaging. For over 20 years, micro-CT is known as a golden standard in bone microarchitecture analysis, as an alternative to histological sectioning method for preclinical research [1, 2]. Micro-CT surpasses histological analysis because it provides 3D information with several micron sampling.

In recent years, micro-CT has been succesfully used in micro-angiography research. For this purpose it needs addition of contrast agents either by staining the sample for ex-vivo scanning or using perfusion in small animal in-vivo micro-CT [3, 4]. Staining methods enhance imaging contrast globally by diffusion process in examined tissue, particullary in areas with high affinity to a specific contrasting solutions. Recent research proofs the potential of this metod in imaging of 3D cell cultures called spheroids [5]. The injected contrast agent works more locally. It can enhance image contrast of blood vessels, heart, kidneys and urinary bladder.

From the other hand micro-CT is an indispensable tool in material science including drug design for a personalized medicine. This work shows how micro-CT can help in design and quality control of individualy 3D printed tablets [6, 7].

References

[1] Leszczyński, et al. (2014). Three dimensional visualisation and morphometry of bone samples studied in microcomputed tomography (micro-CT). Folia morphologica, 73(4), 422–428. https://doi.org/10.5603/FM.201
[2]Pilutin, A., et al. (2021). Morphology and serum and bone tissue calcium and magnesium concentrations in the bones of male rats chronically treated with letrozole, a nonsteroidal cytochrome P450 aromatase inhibitor. Connective tissue research, 62(4), 454–463. https://doi.org/10.1080/03008207.2020.1771329
[3]Leszczyński, et al.(2018). Visualization and Quantitative 3D Analysis of Intraocular Melanoma and Its Vascularization in a Hamster Eye. International journal of molecular sciences, 19(2), 332. https://doi.org/10.3390/ijms19020332
[4] Tielemans, B., et al. (2020). From Mouse to Man and Back: Closing the Correlation Gap between Imaging and Histopathology for Lung Diseases. Diagnostics, 10(9), 636. https://doi.org/10.3390/diagnostics10090636
[5] Karimi, H., et al.(2020). X-ray microtomography as a new approach for imaging and analysis of tumor spheroids. Micron, 137, 102917. https://doi.org/10.1016/j.micron.2020.102917
[6] Jamróz, W., et al. (2020). Speed it up, slow it down…An issue of bicalutamide release from 3D printed tablets. European journal of pharmaceutical sciences : official journal of the European Federation for Pharmaceutical Sciences, 143, 105169. https://doi.org/10.1016/j.ejps.2019.105169
[7] Jamróz W., et al.(2020). Multivariate Design of 3D Printed Immediate-Release Tablets with Liquid Crystal-Forming Drug-Itraconazole. Materials, 13(21), 4961. https://doi.org/10.3390/ma13214961

**Monday Morning Session / 15**

# Introduction of non-image PET data transformation to image-form for classification using Convolutional Neural Networks

**Author:** Lech Raczyński[1]

[1] *Department of Complex Systems, National Centre for Nuclear Research*

**Corresponding Author:** lech.raczynski@ncbj.gov.pl

Recently, Convolutional Neural Networks (CNNs) [1] have achieved state-of-the-art performance in many areas including medical sciences, and are the method of choice commonly used for data recognition or classification. CNNs have proven to work most efficiently on 2-dimensional data that are in form of images.

In case of Positron Emission Tomography (PET) [2,3] studies, CNN may be applied directly to the reconstructed distribution of radioactive tracer injected to the patient's body, as for example a pattern recognition tool. Nonetheless, much PET data still exists in non-image format and therefore opens challenging research questions on whether they can be effectively trained using CNN. Examples of such tasks are estimation of time-of-flight from signals registered in scintillators [4] or classification of coincidence events acquired by PET scanner [5].

The goal of this presentation is the introduction of scheme of non-image data transformation into 2-dimensional matrices, as a preparation stage for classification based on CNNs. The first work to apply CNN on different kinds of non-image datasets, e.g., gene expression or text information, was proposed in [6]. Here, we will focus mainly on the problem of processing of vectors with small number of features in comparison to the number of pixels in the output images. As an example, a

discussion of application of the proposed methodology to classification of PET coincidence events will provided [7].

**References**

[1] Lecun Y, Bengio Y and Hinton G. Deep learning, *Nature* vol. 521, pp. 436, 2015.

[2] Humm J L, Rosenfeld A, Del Guerra A. From PET detectors to PET scanners, *European J. of Nucl. Med. & Mol. Imag.* vol. 30, pp. 1574, 2003.

[3] Bailey D L. *Positron Emission Tomography: Basic Sciences*, Springer-Verlag, New York, 2005.

[4] Berg E and Cherry S R. Using convolutional neural networks to estimate time-of-flight from PET detector waveforms, *Phys. Med. Biol.*, vol. 63, pp. 02LT01, 2018.

[5] Bielecki J. Application of the machine learning methods to the multi-photon event classification in the J-PET scanner, *Msc thesis, Warsaw University of Technology*, 2019.

[6] Sharma A, Vans E, Shigemizu D, Boroevich K A and Tsunoda T. Deepinsight: A methodology transform a non-image data to an image for convolution neural network architecture. *Scientific Report*s vol. 9, pp. 11399, 2019.

[7] Konieczka P. Convolutional Neural Networks in classification of multi-photon coincidences in J-PET scanner, *1st Symposium on Theranostics*, 9-11 October 2021.

**Monday Morning Session / 60**

## Theranostic and Monte Carlo simulation

**Author:** David Sarrut[1]

[1] *CNRS*

**Corresponding Author:** david.sarrut@creatis.insa-lyon.fr

We will describe our experiences regarding dosimetry in radionuclide therapy (Lu177 and SIRT) performed at our institution. Dose estimation from post and per-treatment SPECT images is performed via dose-rate computation with Monte-Carlo simulation (Gate/Geant4). We will also describe current investigations of deep learning to speed up Monte Carlo simulations.

**Monday Noon Session / 11**

## PRRT as a tool for treatment of severe hypoglycemia in patients with primary inoperable insulinoma

**Author:** Marta Opalińska[1]

**Co-authors:** Anna Sowa-Staszczak [2]; Ibraheem Al Maraih [1]; Aleksandra Gilis-Januszewska [2]; Alicja Hubalewska-Dydejczyk [2]

[1] *Nuclear Medicine Unit, Department of Endocrinology Department of Endocrinology, Oncological Endocrinology and Nuclear Medicine, University Hospital, Kraków, Poland*

[2] *Chair and Department of Endocrinology, Jagiellonian University Medical College, Kraków, Poland*

**Corresponding Author:** mkal@vp.pl

PRRT as a tool for treatment of severe hypoglycemia in patients with primary inoperable insulinoma

Introduction
Severe hypoglycaemia in a course of inoperable insulinoma may be life-threating and it is not always well controlled even by high doses of diazoxide, which in some cases cause a significant toxicity. Nowadays, other forms of effective therapy are not available - use of protein kinase inhibitors (everolimus, sunitynib) sometimes bring satisfactory effect but is often associated with the risk of serious side effects. Use of Peptide receptor radionuclide therapy (PRRT) in patients with good expression of somatostatnin receptor, characterized by relatively low toxicity, is potentially valuable treatment option.

Aim
Evaluation the PRRT effect on insulin levels in patients with primary inoperable insulinoma.

Materials and methods
3 patients (female with metastatic insulinoma, male with primary inoperable pancreatic tumor, female with MEN1 syndrome and hepatic metastases) were treated with PRRT (90Y/177Lu DOTATATE or 90YDOTA-TATE in the dose 7.4GBq /m2) due to severe hypoglycemia poorly controlled by diazoxide in course of primary inoperable insulinoma.

Results
In all patients PRRT had no complications. Patient 1 baseline fasting glucose concentration increased to 5.9mmol/L from 2.4mmol/L after PRRT. In patient 2 fasting glucose level 2.30mmol/L[3.30 - 5.60] increased after PRRT to value 7.0mmol/L[3.30 - 5.60] while baseline insulin level initially 31.15uU/mL [2.6 - 24.9] dropped to 15.44uU/mL[2.6 - 24.9]. In patients 3, baseline fasting glucose level 2.5mmol/L[3.30 - 5.60] increased after PRRT to value 7.9mmol/l[3.30 - 5.60], and insulin dropped from 57.96uU/mL[2.6 - 24.9] to 6.32 uU/mL[2.6 - 24.9]. 2 patients after PRRT had their dizaoxide dose reduced and 1 discontinued.

Conclusion
PRTT was effective in reduction of serum insulin levels and diazoxide dose in patients with severe hypoglycaemia in the course of primary inoperable insulinoma.

**Monday Noon Session / 13**

## Radioactive arsenic (III) compounds as potential theranostic radiopharmaceuticals

**Author:** Monika Łyczko[1]

**Co-authors:** Krzysztof Lyczko [1]; Agnieszka Majkowska-Pilip [1]; Aleksander Bilewicz [1]

[1] *Institute of Nuclear Chemistry and Technology*

**Corresponding Author:** m.lyczko@ichtj.waw.pl

Arsenic compounds have been known and used in medicine for centuries. Arsenic (III) in the form of simple inorganic compounds easily oxidizes, which makes its administration in the human body difficult. As2O3 is now used in the successful treatment of acute promyelocytic leukemia.
The high affinity of arsenic to sulfur atoms and creating strong bonds with sulfur-containing compounds provides a wide range of applications of arsenic compounds in medicine.
The application of arsenic compounds enables the use of a wide range of radioactive arsenic isotopes in nuclear medicine, both in diagnostics and therapy. Arsenic has four isotopes - β+ emitters (70/71/72/74As) and three β- emitters (74/76/77As), which can be obtained in a reactor or in an accelerator. The half-lives of As radioisotopes are in the range from 53 minutes to 18 days. 72As can be also obtained from the 72Se/72As generator [1,2], which would facilitate the synthesis of radiopharmaceuticals in the hospital. Arsenic is also an interesting candidate for use in the innovative β + γ diagnostic technique, which allows increasing the precision of the examination with the use of a lower dose of the radioisotope for the patient [3].
For the synthesis of arsenic complexes on a weight scale the ligands containing thiol groups were used. The synthesis was carried out in a nitrogen atmosphere under reflux, and chloroform was used

as a solvent. The four arsenic (III) compounds with dithiol ligands were obtained. The compounds were examined by X-ray diffraction and their mass was determined by ESI Q-TOF-MS. The results of both studies confirmed the expected structure of the tested compounds, which allowed to determine the retention time of the peaks on HPLC chromatograms. Also, the UV-Vis spectra of the tested complexes were measured. Toxicity studies of arsenic compounds on NB4 acute promyelocytic leukemia cells were performed using the MTS test. All compounds as well as As2O3 induced cytotoxicity in a time and dose-dependent manner.
The established synthesis conditions on a weight scale allowed for the syntheses with the use of the radioactive 76As isotope, which were examined by TLC and HPLC methods. Radioactive complexes were formed with high efficiency within 0.5 h of synthesis and were relatively stable in human serum.

Funding: This work was supported by the IAEA Research Contract No: 23299

[1] E. Chajduk, K. Doner, H. Polkowska-Motrenko, A. Bilewicz, "Novel radiochemical separation of arsenic from selenium for 72Se/72As generator", Appl. Rad. Isot., vol. 70 pp. 819–822, 2012.
[2] M. Jennewein, A. Schmidt, A. F. Novgorodov, S. M. Qaim, F. Rösch, "A no-carrier-added 72Se/72As radionuclide generator based on distillation". Radiochim. Acta, vol. 92, pp. 245-249, 2004.
[3] M. Sitarz, J.P. Cussonneau, T. Matulewicz, F. Haddad. "Radionuclide candidates for β+γ coincidence PET: An overview". Appl Radiat Isot. vol.155, 108898, 2020.

**Monday Noon Session / 7**

## Novel and fast method of gene mutation identification using Surface Enhanced Raman Spectroscopy (SERS)

**Author:** Jan Krajczewski[1]

**Co-authors:** Andrzej Kudelski [1]; Agata Kowalczyk [1]; Anna Nowicka [1]; Janusz Weyher [2]; Igor Dzięcielewski [3]; Stanisław Góźdź [4]; Małgorzata Chłopek [4]; Artur Kowalik [4]

[1] *Faculty of Chemistry, University of Warsaw*
[2] *Institute of High Pressure, Polish Academy of Science*
[3] *Institure of High Pressure, Polish Academy of Science*
[4] *Holy Cross Cancer Center*

**Corresponding Author:** jankra89@gmail.com

An early and accurate diagnosis of specific DNA mutations has a decisive role for effective treatment. Especially, when an immediate decision on treatment most needs to be made, the rapid and precise confirmation of clinical findings is vital. Herein, we show a new strategy for the gene mutation (BRAF c.1799T>A; p. V600E) identification using highly SERS-active and reproducible SERS substrate (photo-etched GaN covered with a thin layer of sputtered gold) and surface enhanced Raman scattering (SERS) spectroscopy. The detection is based on the conformation change (gauche → trans) of the alkanethiol linker modifying the capture DNA during the hybridization process. The value of the intensity ratio of the ν(C–S) bands of the trans and gauche conformer higher than 1.0 indicated the presence of mutation. The demonstrated new DNA SERS (bio)sensor is characterized by the low detection limit at the level of pg/μL, wide analytical range from 6.75 pg/μL to 67.5 ng/μL and high selectivity. The proposed bioactive platforms, based on nanostructured GaN substrates modified with thiolated ssDNA (single stranded DNA) can be successfully used in the analysis of clinical samples.

**Monday Noon Session / 9**

## 193m,195mPt-based nanobioconjugates for combined „chemo-Auger" theranostics of hepatocellular carcinoma (HCC) and HER2+ breast cancer.

**Author:** Kamil Wawrowicz[1]

**Co-authors:** Agnieszka Majkowska-Pilip [1]; Marzena Szwed [2]; Aleksander Bilewicz [1]

[1] *Institute of Nuclear Chemistry and Technology, Dorodna 16, 03-195 Warsaw, Poland*

[2] *Faculty of Biology and Environmental Protection, University of Lodz, Pomorska 141/143 St,90-236 Lodz, Poland*

**Corresponding Author:** k.wawrowicz@ichtj.waw.pl

Despite the broad development of medicine for cancer treatment, current therapeutic approaches are not efficient at dealing with aggressive and therapy-resistant neoplasms such as breast cancer or hepatocellular carcinoma. In these tumors, one of the most difficult steps of the therapy process is metastases treatment due to the spread of small size tumors. Targeted therapy with most efficient Auger electrons emitters – 193mPt (30 A.E. per decay) and 195mPt (36 A.E. per decay) - is one of the most promising concept for this approach. Moreover, 195mPt can be easily imaged via SPECT as a result of emission suitable for imaging photons with energy ~98.90 keV. Platinum-based radiopharmaceuticals, due to their relevant characteristics, are encouraging candidates for realizing "chemo-Auger" therapy which should be significantly more effective than typical Auger therapy. Chemotoxicity of platinum can be promoted in highly oxidative environment which occurs in most of hepatic cells and in some of breast/ovarian cancer cells. Biological effectiveness studies of platinum-induced chemotoxicity were realized with two types of nanocarriers – 30 nm core-shell (Au@Pt) and ultra-small 2 nm platinum (PtNPs) nanoparticles, used in forms of HER2+ targeted bioconjugates with Trastuzumab, as well as only polymer-stabilized conjugates for HCC. Research for non-radioactive (bio)conjugates chemotoxicity included evaluation for 2D and 3D in vitro tumor spheroid models. Moreover, one of the main parts was aimed at determining the mechanism of chemotoxicity. There are two different concepts of platinum biological activity. In order to identify the factors responsible for cytotoxic effects, nuclei isolation and oxidative stress markers determination were performed. Obtained results confirmed, that for chemotoxicity of platinum-based nanomaterials, highly oxidative environment is a crucial parameter. Due to presence of naturally occurring increased H2O2 concentration in HCC cells cytoplasm, in this cancer cells significant cytotoxicity was observed at similar level for both - Au@Pt and PtNPs conjugates (~50% at 72h post treatment). Furthermore, our results strongly indicates, that in HER2 overexpressed breast/ovarian cancer cells the oxidative potential is insufficient for inducing cytotoxic effects of platinum. After widely conducted chemical and biological research for non-radioactive conjugates, evaluation with radioactive 193m,195mPt will be performed. Due to very limited availability of high specific activity Pt radionuclides, during subsequent part of research, various direct and indirect ways for high specific activities production will be under investigation.
This research was funded by National Science Centre (NCN), grant number UMO-2019/35/B/ST4/01433 (OPUS)". The contribution of PhD student Kamil Wawrowicz was realized within Project No. POWR.03.02.00-00-I009/17-00 (Operational Project Knowledge Education Development 2014–2020 co-financed by European Social Fund).

**Monday Noon Session / 62**

## Quercetin loaded mesoporous silica nanoparticles to contrast gram positive and gram negative bacteria infections

**Author:** Cristina Carucci[1]

**Co-authors:** Giulia Sechi [2]; Marco Piludu [3]; Maura Monduzzi [2]; Andrea Salis [2]

[1] *University of Cagliari*

[2] *Department of Chemical and Geological Sciences, University of Cagliari-CSGI and CNBS, Cittadella Universitaria, S.S. 554 bivio Sestu, 09042-Monserrato (CA), Italy*

[3] *Department of Biomedical Sciences, University of Cagliari, Cittadella Universitaria, S.S. 554 bivio Sestu, 09042-Monserrato (CA), Italy*

**Corresponding Author:** cristina.carucci@unica.it

Nowadays antibiotic resistance is defined by the World Health Organization (WHO) as one of the biggest treat for human health. [1] In the absence of substantial new antibiotic discovery, drug delivery systems (DDS) can be used to transport and release a biologically active compound at the needed site. [2-3] Among several nanocarriers used for drug delivery, mesoporous silica nanoparticles (MSNs) present several advantages. For example, they present an high surface area (up to 1000 m2/g) and they can be easily functionalized with chemical groups which allow to increase, delay, and localize drug release at cell targets. [3] To date, to increase MSNs biocompatibility and increase their stability polymer coated nanoparticles are under study. [4-5]
In this work, MSNs were functionalized separately with two amine groups, triethylenetetramine (TETA) and 3-aminopropyltriethoxysilane (APTES) to give MSN-TETA and MSN-NH2 prior poly-L-lysine (PLL) modification. After functionalization, the flavonoid quercetin was loaded into MSNs. Structure and function were determined by a wide range of techniques such as TEM, SAXS, TGA, FTIR, N2-adsorption/desorption isotherms, DLS and ELS. Drug release was assayed at different conditions (pH and drug loadings) giving release values within the range of drug concentration (2-10 μg/mL) in plasma after an oral administration dose of 200-500 mg of quercetin. Preliminary microbiological assays were also performed indicating a better efficacy of the DDS against Gram positive bacteria.

References
[1] S. Hernando-Amado, T.M. Coque, F. Baquero, Nat Microbiol, 2019, 4, 1432–1442
[2] M. Vallet-Regí, D, Lonzano, B. Gonzalez et al. Advanced Healthcare Materials, 2020, 9, 2000310
[3] RR. Castillo, M. Vallet-Regí, Int J Nanomedicine, 2021;16:4409-4430
[4] G.G. Abdo, M.M. Zagho, A.Khalil, Emergent Materials, 2020, 3, 407–425.
[5] K. Kuldeep,K.Deepak.,A. Rosling, J. Rosenholm,Applied Science, 2020, 10, 1, 289

**Monday Afternoon Session / 39**

# Targeted nanoparticles for cancer detection in animal models.

**Author:** Barbara Błasiak[1]

**Co-authors:** Frank C. J. M. van Veggel [2]; Armita Dash [2]; John Matyas [3]; Dragana Ponjevic [3]; Garnette Sutherland [4]; Boguslaw Tomanek [5]

[1] *Polish Academy of Sciences, Institute of Nuclear Physics; Department of Clinical Neurosciences, University of Calgary*

[2] *Department of Chemistry, University of Victoria,*

[3] *Faculty of Veterinary Medicine, University of Calgary*

[4] *Department of Clinical Neurosciences, University of Calgary*

[5] *Polish Academy of Sciences, Institute of Nuclear Physics; Department of Clinical Neurosciences, University of Calgary; University of Alberta, Department of Oncology*

**Corresponding Author:** barbara.blasiak@ifj.edu.pl

Magnetic Resonance Imaging (MRI) has been used for early cancer detection, as it provides high spatial resolution and soft tissue contrast. Yet its specificity is low. Standard contrast enhanced MRI is based on tumors vasculature (i.e. Gd-based) and it does not provide sufficiently high specificity for tumor diagnosis and thus targeted contrast agents providing T2 contrast have been applied to provide information on tumor specificity[1,2].
Therefore, we have developed core/shell NaDyF4/NaGdF4 nanoparticles changing both T1 and T2 relaxation times of surrounding water molecules. The NPs were conjugated with tumor specific antibodies and proteins. The relaxation times (T1 and T2) of the nanoparticles with various core/shell sizes and concentrations were measured at 9.4T and 3T to find the optimum T1/T2 ratio for maximum contrast. T1- and T2-weighted images using core/shell nanoparticles of the animal models of brain, breast and prostate cancer were collected. Mouse models of cancer were used at 9.4T. We imaged 6 weeks nude mice with the tumor before the injection of the targeted and non-targeted contrast agents and in different time after injection (10 min after,1h, 2h and 24h). The core/shell based NPs provided improved tumor contrast when the T1 and T2-weighted MR pulse sequences were applied. The results show that the developed NPs may improve the efficacy of MRI in cancer detection.
References:

1. Blasiak B, Tomanek B, et al Detection of T2 changes in an early mouse brain tumor. Mag Res Imag 2010, 28:784-9.
2. Tomanek B, Iqbal U, Blasiak B, at al. Evaluation of Brain Tumor Vessels Specific Contrast Agents for Glioblastoma Imaging. Neuro-Oncology, 2012, 14(1):53-63.

**Monday Afternoon Session / 5**

## Uncovering the diagnostic power of exosomes for prosthetic joint failure

**Authors:** Ana Ribeiro[1]; José Mauro Granjeiro Granjeiro[2]; Maria Helena Fernandes[3]; Maria José Oliveira[4]; Sónia Melo[4]; Wanderson Souza[5]

[1] *International Iberian Nanotechnology Laboratory*

[2] *Dental School, Fluminense Federal University, Niterói, Brazil*

[3] *Faculty of Dental Medicine, University of Porto, Porto, Portugal*

[4] *Institute for Research and Innovation in Health, University of Porto, Portugal, Porto, Portugal*

[5] *Directory of Life Sciences Applied Metrology, National Institute of Metrology Quality and Technology, Rio de Janeiro, Brazil*

**Corresponding Author:** ana.ribeiro@inl.int

The effect of debris exposure on the osteoimmunological crosstalk is poorly understood. For the first time, we report that titanium dioxide nanoparticles (TiO2 NPs), similar in size and composition to wear debris associated with prosthetic implants, altered bone exosomes biogenesis and cargo. Using mass spectrometry analysis, we identified urokinase-type plasminogen activator (uPA), specifically enriched in exosomes derived from bone cells pre-incubated with TiO2 NPs. Besides uPA contribution to the generation of inflammatory signals, uPA was also previously reported in patients with aseptic loosening of total hip prosthesis. Functional tests with isolated bone derived exosomes confirmed the activation of human macrophages with consequent secretion of inflammatory cytokines that may contribute to particle induced osteolysis and implant loosening. These findings, indicate that the osteoimmunological communication trough exosomes was disturbed by TiO2 NPs and that uPA may be proposed as a biomarker to early diagnose nanoparticle induced osteolysis, avoiding or delaying a revision surgery, thereby decreasing disease burden and improving patient health.

**Monday Afternoon Session / 53**

## β-lactoglobulin as a platform for designing biologically active carriers – experimental and computational studies

**Authors:** Paulina Komorek[None]; Sylwia Świątek[1]; Gregor Turner[2]; Barbara Jachimska[1]

[1] *Jerzy Haber Institute of Catalysis and Surface Chemistry, PAS, Niezapominajek 8, 30-239 Krakow, Poland*

[2] *Department of Chemical and Process Engineering, University of Strathclyde, James Weir building, 75 Montrose Street, Glasgow, G1 1XJ, United Kingdom*

**Corresponding Author:** paulina.komorek@ikifp.edu.pl

β-lactoglobulin (LGB) is known as one of the most interesting transport proteins. In particular, it can serve as a carrier for hydrophobic molecules, through the binding of potential ligands at the active site located in the β-barrel [1]. According to previous studies, the binding of ligands to LGB is strongly dependent on the pH of the solution due to the conformational changes of LGB known as the Tanford transition [2]. In the presented study, the interactions and binding behavior of anesthetic tetracaine (TET) to LGB were investigated under varying environmental conditions (pH, ionic

strength, concentration, LGB-TET complex molar ratio). The Laser Doppler Velocimetry (LDV), the UV-Vis spectroscopy, and the Circular Dichroism (CD) were utilized to determine the physicochemical properties of LGB and LGB-TET complex in a sodium chloride solution. Electrophoretic mobility measurements showed that the zeta potential of the LGB became more positive upon interactions with TET due to electrostatic forces of the amino group present in the TET structure. The finding suggested the formation of LGB-TET complexes and the binding of ligand molecules on the protein surface. Based on UV-vis spectra the binding constant (K-UV) of the LGB-TET complex was calculated, while CD spectra showed that interactions with the ligand did not change the secondary structure of LGB molecules. Quartz Crystal Microbalance with Dissipation Monitoring (QCM-D) measurements presented that the molar ratio of LGB to TET is equal to 1:13 confirming the binding of TET not only to β-barrel but also on the LGB surface. What is more, QCM-D performed under varying environmental conditions allowed determining the optimized conditions for LGB-TET complex formation. Implementation of molecular docking enabled estimation of the binding position of the TET. The method suggested that interactions between the protein and ligand were possible with the most likely binding site with the hydrophobic cavity located in β-barrel [3].

**References:**

1. G. Kontopidis, C. Holt, L. Sawyer. Invited Review: β-Lactoglobulin: Binding Properties, Structure, and Function. Journal of Dairy Science 2004, 87(4), 785-796
2. B. Y. Qin, M. C. Bewley, L. K. Creamer, H. M. Baker, E. N. Baker, G. B. Jameson. Structural basis of the Tanford transition of bovine beta-lactoglobulin. Biochemistry 1998, 37(40), 14014-14023
3. S. Świątek, P. Komorek, G. Turner, B. Jachimska. β-Lactoglobulin as a potential carrier for bioactive molecules. Bioelectrochemistry 2019, 126, 137-145

**Acknowledgments:**

This work was partially supported by project NCN OPUS 2016/23/B/ST5/02788 and InterDokMed POWR.03.02.00-00-I013/16.

**Monday Afternoon Session / 33**

## Positronium Imaging with the J-PET detector for the medical purposes

**Author:** Kamil Dulski[1]

[1] *Jagiellonian University*

**Corresponding Author:** kamil.dulski@gmail.com

Positronium Imaging [1-4] is a branch of Positron Emission Tomography (PET) which focuses on the spatial and structural correlation probed by positronium (positron-electron atom) formation in the test sample or in the tissues of patient. It is possible due to the (main) influence of the size of the free volumes (nm scale) on the mean lifetime of the long-lived positronium state - ortho-positronium (total spin number S = 1) [1-6]. Moreover, the position of positronium decay can be reconstructed based on its decay products – high-energy photons [1-8]. Therefore, by using additional marker of the positronium formation the lifetimes and the positions of a single decays of positronia can be collected during a scan. The positronium images consist of an estimate of the mean positronium lifetime in each image voxel. Such marker that can be used to estimate the formation of the positronium is an additional photon associated with the creation of a positron which forms positronium with an electron from the tested sample [1-4]. Due to the additional contrast that can differentiate healthy cells from neoplastic cells from the mean lifetime of the positronium, the potential of PET to detect neoplastic lesions may be increased, where the possibilities of determining the degree of malignancy from positronium imaging are also discussed [1-4]. The first demonstration of positronium imaging was performed on the J-PET detector [1], which is based on an innovative technology that benefits from the excellent timing capabilities of plastic scintillators (resolution ≈ 100 ps) as well as a relatively large axial field-of-view (FOV ≈ 0.5 m) [3, 5-8]. Fundamentals of positronium imaging and results from the imaging of the phantom consisting of heart tumor tissues (Cardiac Myxoma) and normal pericardial tissues by the J-PET detector will be shown. These are also the first images obtained by positronium imaging, and the J-PET detector is the first device capable of collecting such images.

References:

[1] P. Moskal, K. Dulski et al., Science Advances 2021 (in press)
[2] P. Moskal ... K. Dulski et al., EJNMMI Phys. 7 (2020) 44

[3] P. Moskal and E.Ł. Stępień, PET Clin. 15 (2020) 439
[4] P. Moskal et al., Nature Rev. Phys. 1 (2019) 527
[5] K. Dulski et al., NIM A 1008 (2021) 165452
[6] K. Dulski et al., Hyperfine Interact. 239 (2018) 40
[7] P. Moskal ... K. Dulski et al., IEEE Trans. Instrum. Meas. 70 (2021) 2000810
[8] S. Niedźwiecki ... K. Dulski et al., Acta Phys. Pol. B 48 (2017) 1567
Acknowledgment:
This work was supported by the Foundation for Polish Science (FNP) through grant TEAM/2017-4/39, nom. N17/MNS/000023 and the DigiWorld (Total-Body Jagiellonian-PET Laboratory) and the SciMat (PSP: U1U/P05/NW/03.23) Priority Research Area as part of the Excellence Initiative program at the Jagiellonian University.

**Monday Afternoon Session** / **52**

## Total-Body PET: System Design and Applications

**Author:** Suleman Surti[1]

[1] *University of Pennsylvania*

**Corresponding Author:** surti@pennmedicine.upenn.edu

The current generation of commercial PET scanners has excellent performance and diagnostic image quality, but the system sensitivity and dynamic imaging capability are limited by the scanner's axial length. In recent years there has been an interest in developing whole-body PET scanners with much longer AFOV that not only increase the system sensitivity but can also image the whole-body of a patient without bed translation. Currently there are at least two commercial scanners offering at least 1 m long axial field-of-view (AFOV). An important outcome of very high sensitivity is the potential to significantly reduce routine clinical scan times which can be beneficial in reducing patient motion artifacts and increase patient throughput. Alternately, the injected dose can be reduced that is beneficial in areas such as pediatric imaging and serial imaging of patients for monitoring response to therapy. Whole-body imaging with large axial coverage will allow one to perform dynamic imaging for pharmacokinetic studies over multiple organs. In this presentation we will present the design concepts underlying the development of long AFOV systems (two commercial and one research), followed by a few example studies illustrating the imaging capabilities and clinical/research potential of such systems. Finally, new design concepts that aim to reduce the cost of these system will be introduced

**66**

## Award ceremony for the best posters

**67**

## Closing of the conference

**Authors:** Paweł Moskal[1]; Ewa Stępień[1]

[1] *Jagiellonian University*

**Corresponding Authors:** ufmoskal@gmail.com, e.stepien@uj.edu.pl