International PhD Studies in Nuclear Physics and Innovative Technologies

Paweł Moskal

Kraków, 24.09.2014

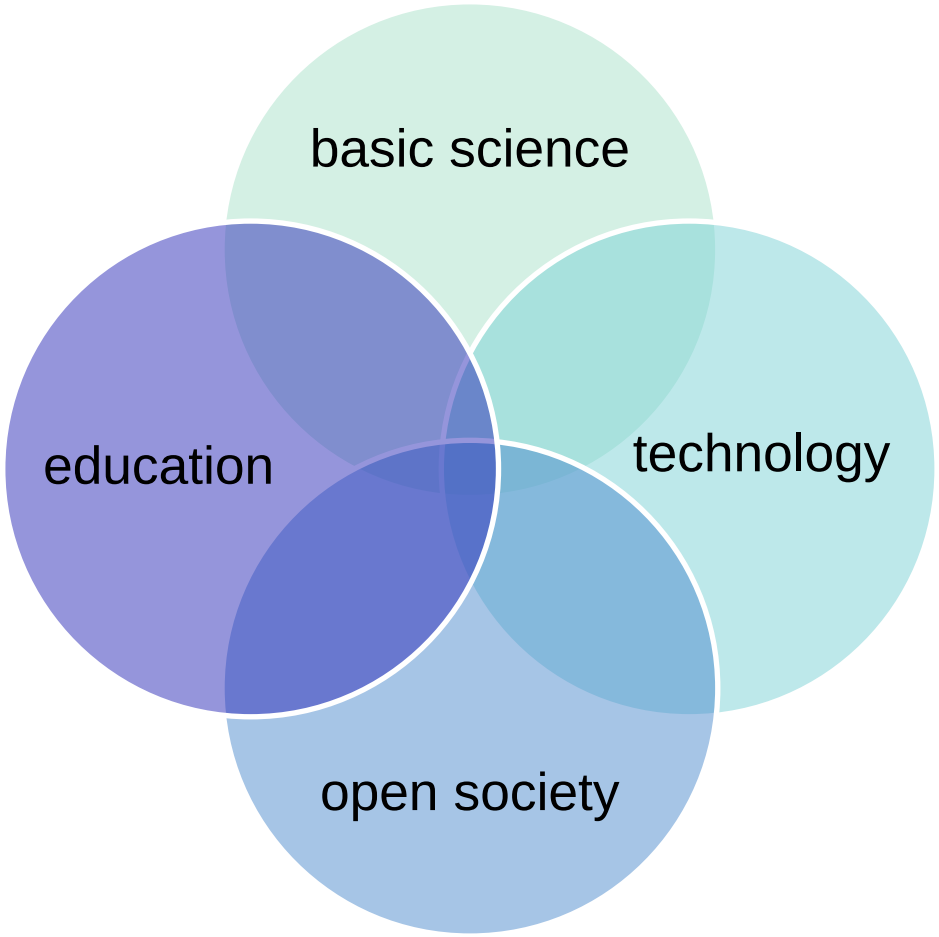
INNOWACYJNA GOSPODARKA
NARODOWA STRATEGIA SPÓJNOŚCI

UNIWERSYTET JAGIELLOŃSKI W KRAKOWIE

FNP
Fundacja na rzecz Nauki Polskiej

UNIA EUROPEJSKA
EUROPEJSKI FUNDUSZ ROZWOJU REGIONALNEGO

INTERNATIONAL PHD PROJECTS IN APPLIED NUCLEAR PHYSICS AND INNOVATIVE TECHNOLOGIES
This project is supported by the Foundation for Polish Science – MPD program, co-financed by the European Union within the European Regional Development Fund



It is a continuation of Maria Curie's endeavor. Expressed in her words: ***"It is easy to understand how important for me is the conviction that our discovery is a blessing for humanity not only by its scientific importance but also because it permits the reduction of human suffering and treatment of a terrible disease. This is indeed a great reward for the years of our enormous effort"***. And she also appealed that ***"Therapy should be permanently backed up by scientific research without which no progress is possible"***

R.F. Mould, The British Journal of Radiology, **71**, 1229 (1998)

Research Institutes (20)	Universities (28)
National Center for Nuclear Studies, Warsaw, Poland	Autonomous University of Barcelona, Spain
Atomic Energy Commission, Saclay, France	Bochum University, Germany
German Cancer Research Center, Heidelberg, Germany	Bonn University, Germany
Grand Accelerateur National d'Ions Lourds, France	Catholic University Leuven, Belgium
GSI Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany	Fordham University, New York, USA
Institut Pluridisciplinaire Hubert Curien, IN2P3/CNRS, France	J.W. Goethe University of Frankfurt, Germany
Laboratorie de Physique Corpuluscaire, Caen, France	Jagiellonian University, Poland
Laboratory of Instrumentation and Experimental Particles Physics, Coimbra, Portugal	Justus-Liebieg University, Giessen, Germany
Max-Plank-Institute for Nuclear Physics, Heidelberg, Germany	Kyushu Institute of Technology, Japan
National Institute of Nuclear Physics, Catania, Italy	Kyushu University, Japan
National Institute of Nuclear Physics, Florence, Italy	Lund University, Sweden
National Institute of Nuclear Physics, LNF Frascati, Italy	Nara Women's University, Nara, Japan
National Institute of Nuclear Physics, Milano, Italy	Northwestern University, Evanston, Illinois, USA
National Institute of Nuclear Physics, Rome, Italy	Roma-Tre University, Italy
Nuclear Physics Institute Polish Academy of Sciences, Cracow, Poland	Technical University, Dresden, Germany
Nuclear Physics Institute, Research Center Jülich, Germany	Université de Strasbourg, Strasbourg, France
Paul Scherrer Institute, Switzerland	University "La Sapienza", Rome, Italy
Research Institute for Particle and Nuclear Physics, Budapest, Hungary	University of Ferrara, Italy
Swiss Federal Institute of Technology, Zürich, Switzerland	University of Florence, Italy
The Svedberg Laboratory, Uppsala, Sweden	University of Georgia, Athens, USA
	University of Groningen, The Netherlands
	University of Ioannina, Ioannina, Greece
	University of Lisbon, Portugal
	University of Technology, Munich, Germany
	University of Trento, Italy
	University of Vienna, Austria
	Uppsala University, Sweden
	Wuppertal University, Germany

- **200 candidates from 5 continents and 40 countries:** Algierii, Bangladeszu, Belgii, Bułgarii, Burkina Faso, Chin, Egiptu, Etiopii, Francji, Niemiec, Ghany, Indii, Indonezji, Iranu, Iraku, Jordanii, Kenii, Malezji, Nepalu, Nowej Zelandii, Nigerii, Norwegii, Strefy Gazy, Pakistanu, Polski, Rosji, Arabii Saudyjskiej, Południowej Afryki, Hiszpanii, Sri Lanki, Sudanu, Szwecji, Syrii, Tadżykistanu, Tanzanii, Ukrainy, USA, Zjednoczonych Emiratów Arabskich, Wietnamu i Włoch.

- ***91.5% of candidates are from abroad***

Name (Master Institution)	PhD Supervisors
Jan Gajewski (AGH Cracow)	Prof. Paweł Olko, Prof. Oliver Jaekel, Prof. Anonty Lomax
Grzegorz Wyszyński (Jagiellonian University)	Prof. K. Bodek, Prof. Klaus Kirch, Dr. Bernhard Lauss, Dr. Gilles Quemener
Ghanshyam Khatri (Royal Institute of Technology, Sweden)	Prof. S. Kistryn, Prof. N.Nayestanaki, Prof. G. Orlandini, Prof. A. Sa Fonseca
Kacper Topolnicki (Jagiellonian University)	Prof. Jacek Golak, Prof. U-G. Meissner, Prof. Kenshi Sagara, Prof. H. Kamada
Sushil Sharma (University of Delhi, India)	Prof. B. Kamys, Doc. F.Goldenbaum, Prof. K-H. Kampert
Magdalena Skurzok (Jagiellonian University)	Prof. Paweł Moskal, Prof. James Ritman, Prof. Q. Haider, Prof. S. Hirenzaki
Jinesh Sebastian (Cochin University, India)	Dr hab. Z. Sosin, Dr hab. A. Wieloch, Dr Christelle Stodel, Dr Antoine Drouart
Krzysztof Pelczar (Jagiellonian University)	Prof. Marcin Wójcik, Prof. M. Lindner, Dr. Stefan Schoenert

Name (Master Institution)	PhD Supervisors
Sedigheh Jowzaee (University of Guilan, Iran)	Prof. Jerzy Smyrski, Prof. Mauro Savrie, Prof. James Ritman
Izabela Pytko (Jagiellonian University)	Prof. W. Wiślicki, Prof. F. Ceradini, Dr. Fabio Bossi, Prof. R. Escribano, Prof. Mavda Velasco
Grzegorz Korcyl (Jagiellonian University)	Prof. Piotr Salabura, Prof. W. Kuhn, Prof. M. Traxler
Sebastian Kupny (Nuclear Physics Institute, Cracow)	Dr hab. Janusz Brzychczyk, Prof. W. Trautmann, Prof. Angelo Pagano
Antoni Marcinek	Prof. R. Płaneta, Prof. M. Gaździcki, Prof. Zoltan Fodor
Andrzej Pyszniak (UMCS, Lublin)	Prof. Z. Rudy, Prof. Hans Stroeher, Doc. Andrzej Kupść, Prof. Johan Bijnens
Yasir Ali (Machester University, UK)	Prof. Z. Majka, Prof. Peter Senger, Prof. Fouad Rami
Tomasz Twaróg (Jagiellonian University)	Dr. hab. T. Kozik, Prof. R. Bougault, Prof. G. Poggi

Original application was for 24 projects

Funds for 16 projects were granted

+ Iryna Ozeriańska (JU/FZ-Juelich)
+ Łukasz Kapłon (Doctus scholarship)
+ Tomasz Bednarski (Doctus scholarship)
+ Szymon Niedźwiecki (Doctus scholarship)
+ Neha Sharma (JU/PET)
+ …

one of the achievements
of MPD is that we feel challanged to provide
these PhD students as good conditions as FNP does.

Supervisors:

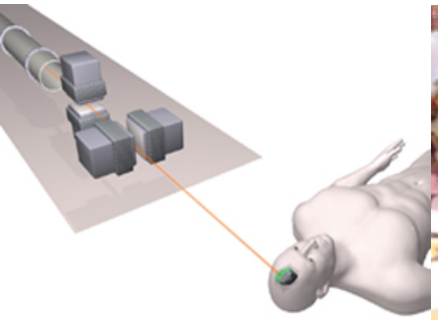
1 x NCBR (INNOTECH); 5 x HARMONIA; 5 x OPUS …

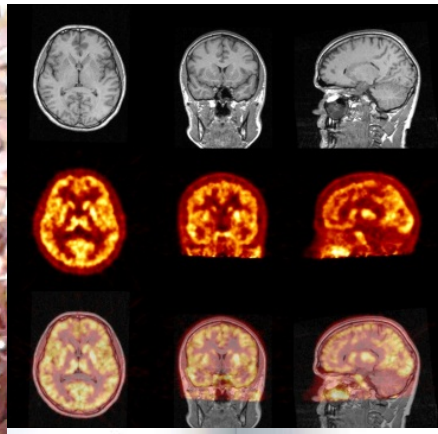
PhD students and Postdocs:

2 x PRELUDIUM

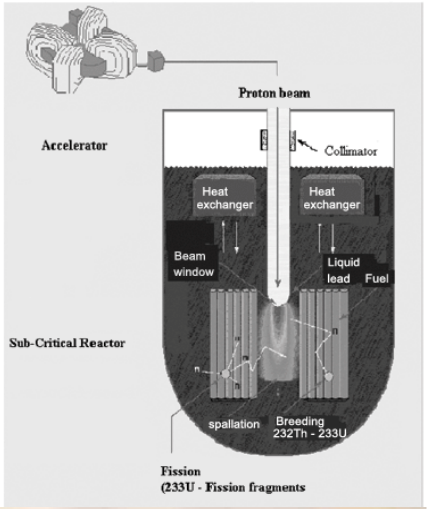
1 x FUGA (1st place in the ranking list)

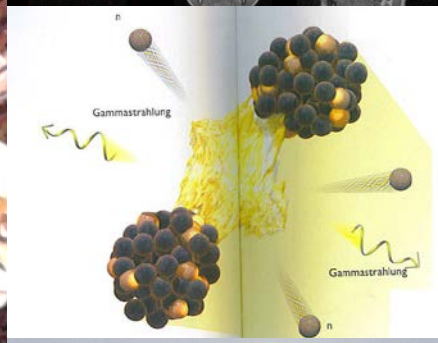
International PhD Studies in Nuclear Physics and InnovativeTechnologies



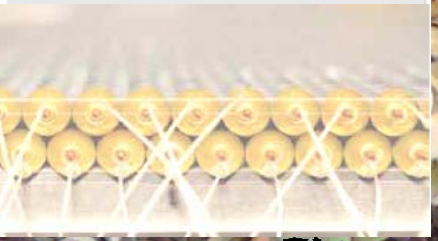


Medical applications of nuclear physics:
Innovations in medical imaging
and radiotherapy





Nuclear energy research:
fission, fusion
and spallation processes



New materials and technologies
in radiation detection

High performance data processing:
Pattern recognitions and
optoelectronics based real-time
signal processing

140 publications (Nature, PRL, PL, PRC, EPJ, JPG, NIM,…
Bio-Algorithms…,Nucl. Med. Rev., Radiotheraphy & Oncology,
11 International patent applications
15 minutes / 140 ~= 6 seconds / article

1) New kind of matter (**Phys. Rev. Lett. 2014**)
-- Discovery of the Dibaryon (six quark state)
-- Search for the mesic nuclei

2) Confirmation of the primary nuclear fusion in the Sun
(**Nature 2014**)

3) Developement of the utterly new method for PET
-- studies of morphology and symmetries
2 International Patents granted in 2014 and
10 International patent applications submitted in 2014

4) **Perspectives**

(an example of future research based on the project achievements)

MATTER

Meson

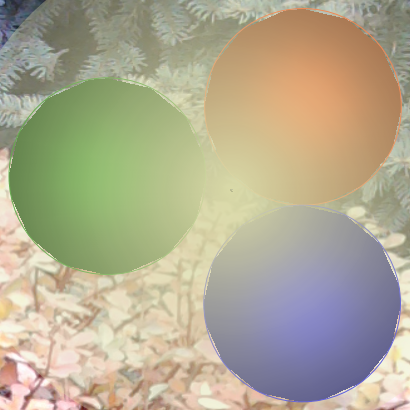
Baryon

1947 Powell in Cracow
1950 Powell <-- Nobel Prize
1960 Quark Model

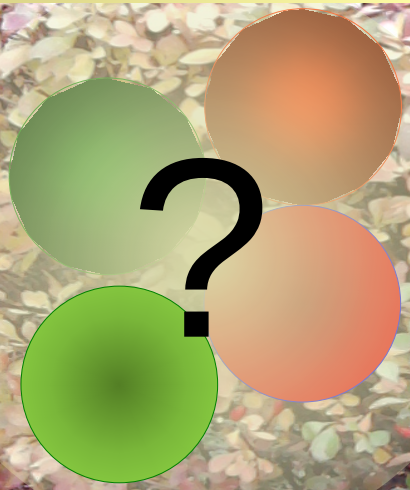
MATTER

Meson

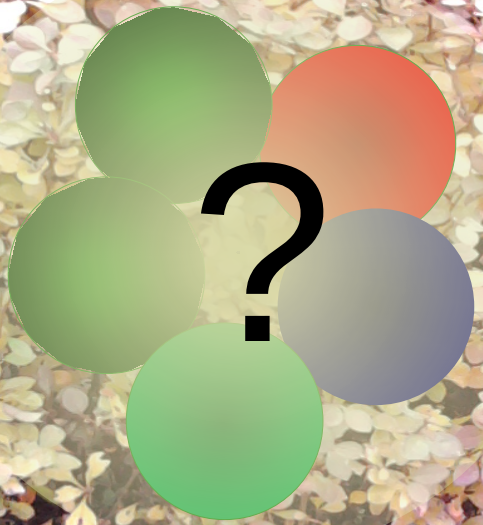
Baryon



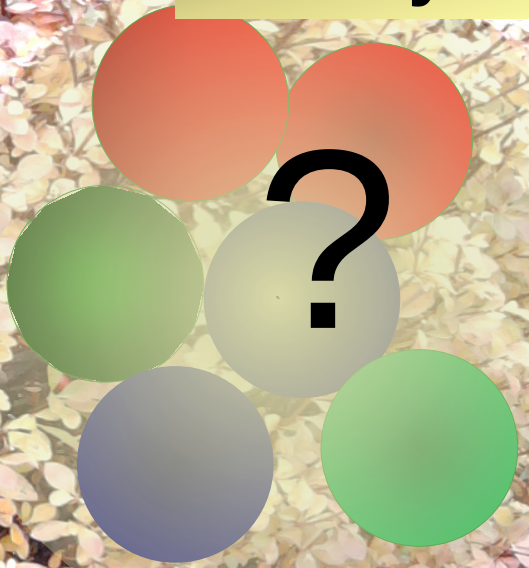
Tetraquark



Pentaquark



Dibaryon

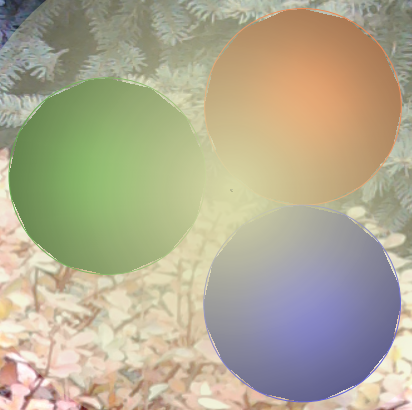


~60 years
no confimration

MATTER

Meson

Baryon



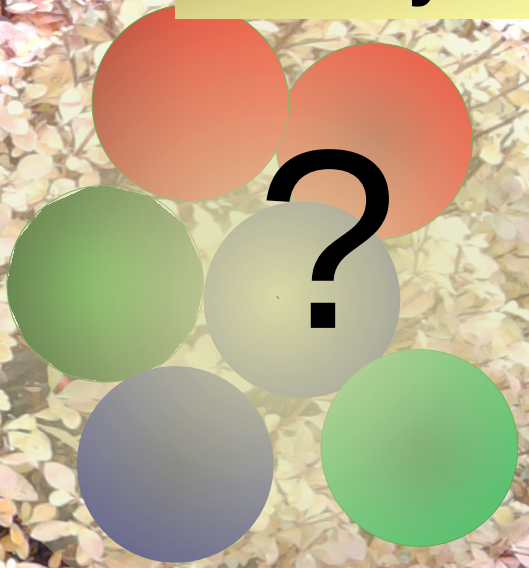
Tetraquark

Pentaquark

Dibaryon

Z(4430)

?



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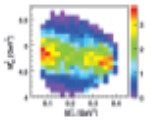
Belle 2008; LHCb 2014

NEWSPAPER



Dalitz plot of the d-π^0 versus the π^0-π^0 invariant mass squared for the $pd \to dn^0\pi^0\pi^0 +$ (spectator proton) interaction, from an experiment by the WASA-at-COSY Collaboration. The experimental results point to the existence of a new, unconventional $I = 0$, $J^P = 3^+$ resonance in the two-baryon system. [P. Adlarson *et al.*, Phys. Rev. Lett. **106**, 242302 (2011)]

PHYSICAL REVIEW LETTERS™

Contents

Articles published – 17 June 2011

VOLUME 106, NUMBER 24 17 June 2011

(Continued Inside)

Selected for a Viewpoint in *Physics*. Please visit http://physics.aps.org/. By suggesting a few manuscripts each week, we hope to promote reading across fields. Please see our Announcement Phys. Rev. Lett. 98, 010001 (2007).

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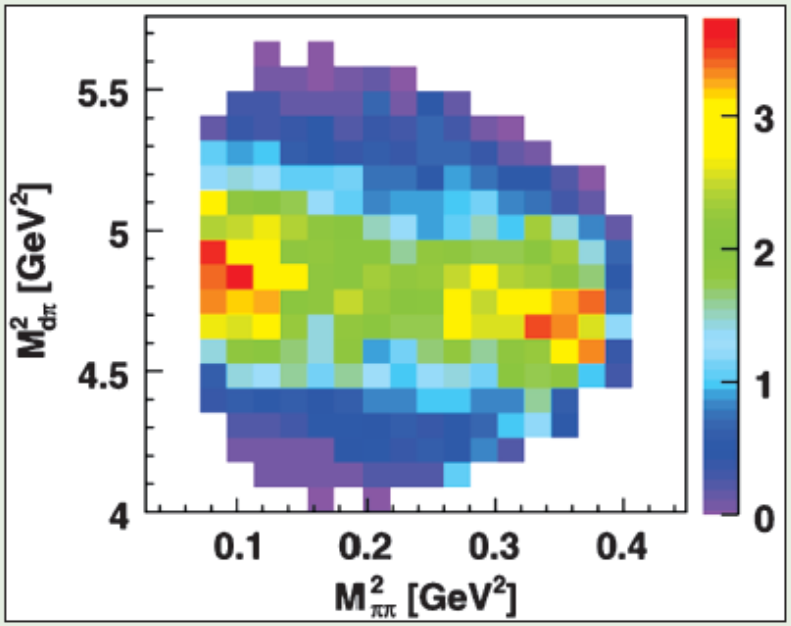
PHYSICAL REVIEW LETTERS

Articles published week ending 17 JUNE 2011

PRL 106 (24), 240401–249901, 17 June 2011 (240 total pages)



24

Published by
American Physical Society

APS physics

Volume 106, Number 24

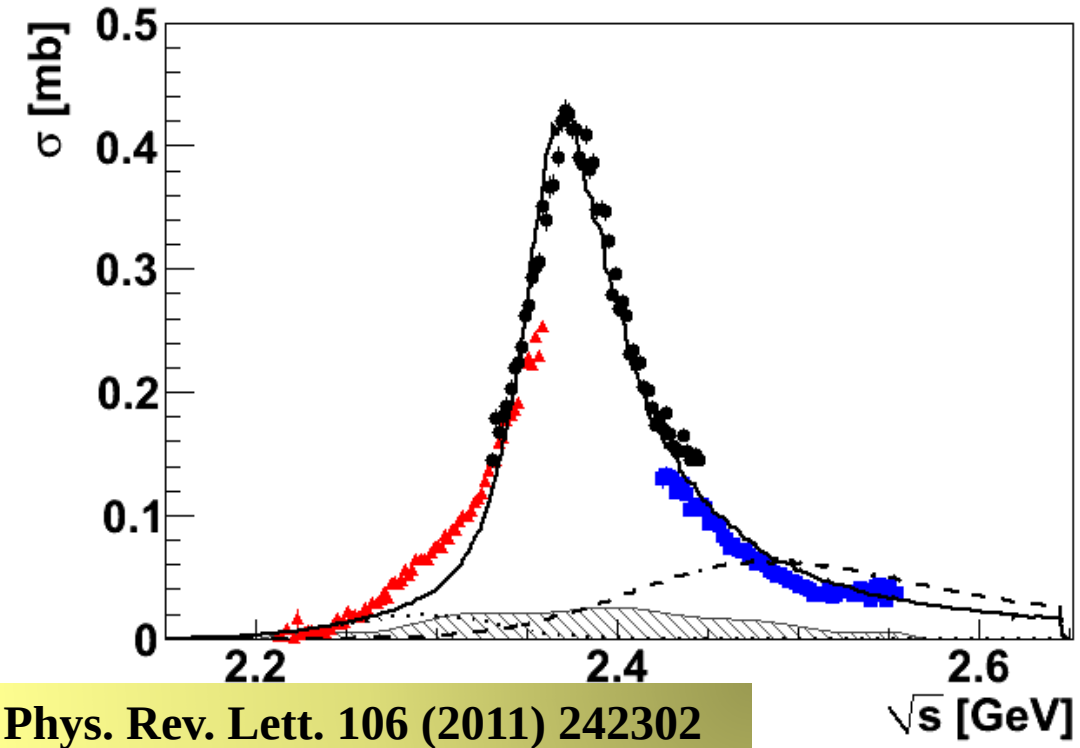
…chen aus sechs Quarks gefunden. Die Entdeckung könnte ein altes Rätsel lösen.

…immer wieder Hinweise auf die Existenz von Tetra- und Pentaquarks gab. Der exotische Quarkzustand, der am ringförmigen Teilchenbeschleuniger Cosy jetzt möglicherweise gesichtet wurde, soll sogar aus sechs Quarks bestehen.

Als recht unwahrscheinlich gilt unter Experten derweil, dass die Resonanz auf eine statistische Schwankung oder einen Messfehler zurückzuführen ist, wie das bei dem vermeintlichen Teilchenfund im April am Tevatron höchstwahrscheinlich

Double pionic fusion - a new resonance?

Cross section for $pn \rightarrow d\pi^0\pi^0$

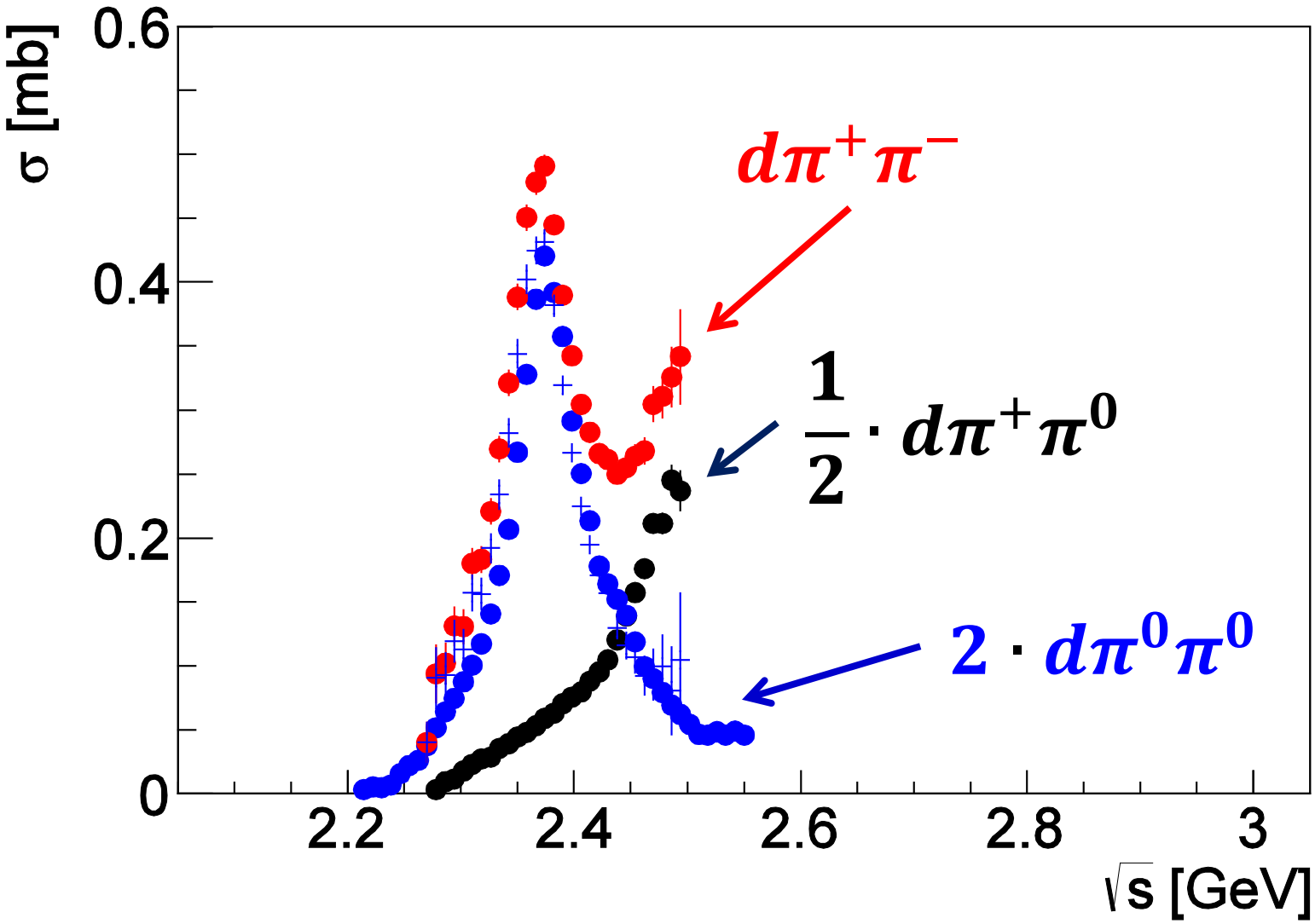


Phys. Rev. Lett. 106 (2011) 242302

The decay modes of the dibaryon

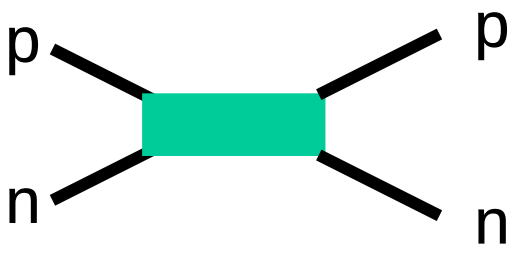
Channel	Publications
d $\pi^0\pi^0$	P. Adlarson et. al Phys. Rev. Lett. 106 (2011) 242302 P. Adlarson et. al Phys. Lett. B721 (2013) 229-236
d $\pi^+\pi^-$	P. Adlarson et. al Phys. Lett. B721 (2013) 229-236
pp$\pi^0\pi^-$	P. Adlarson et. al Phys. Rev. C 88, 055208
np$\pi^0\pi^0$	arXiv:1409.2659
np	P. Adlarson et al. Phys. Rev. Lett. **112**, 202301, (2014) P. Adlarson et al. Phys. Rev. C **90**, 035204 , (2014)
^{3}He $\pi\pi$	M. Bashkanov et. al Phys.Lett. B637 (2006) 223-228 arXiv:1408.5744
^{4}He $\pi\pi$	P. Adlarson et. al. Phys.Rev. C86 (2012) 032201

Total cross section $pN \rightarrow d\pi\pi$

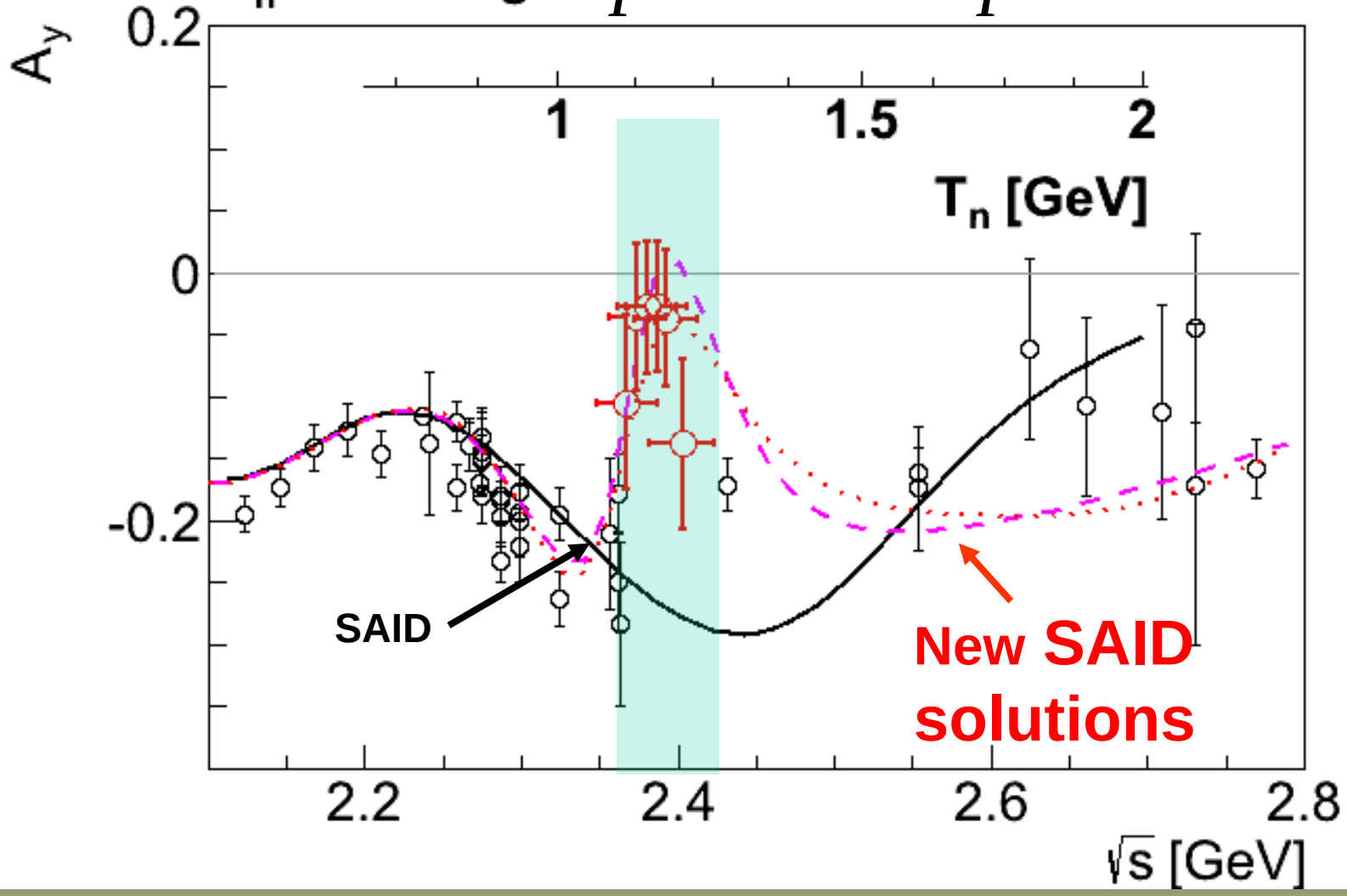


WASA-at-COSY: Phys. Lett. B721 (2013) 229

A_y energy dependence at 83°



$\vec{n}p \rightarrow d^* \rightarrow pn$

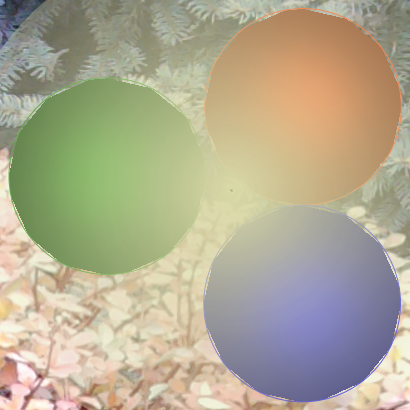


WASA-at-COSY: Phys. Rev. Lett. 112 (2014) 202301

MATTER

Meson

Baryon

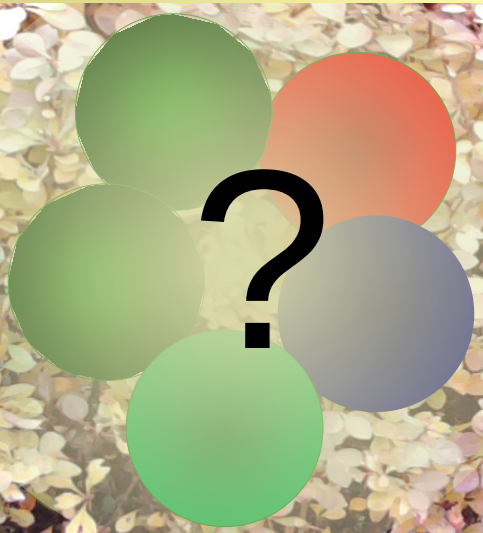


Tetraquark

Pentaquark

Dibaryon

Z(4430)



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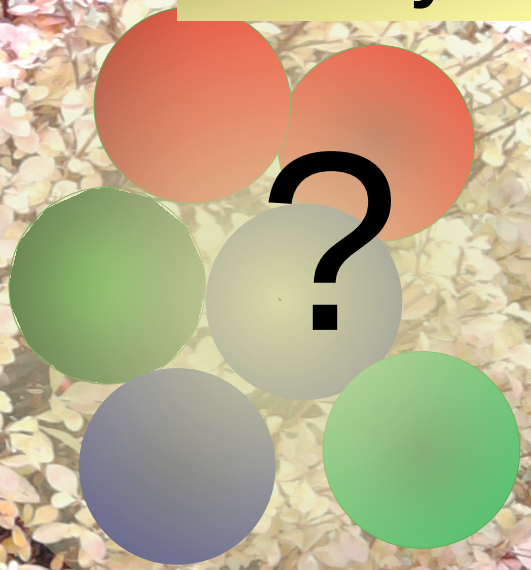

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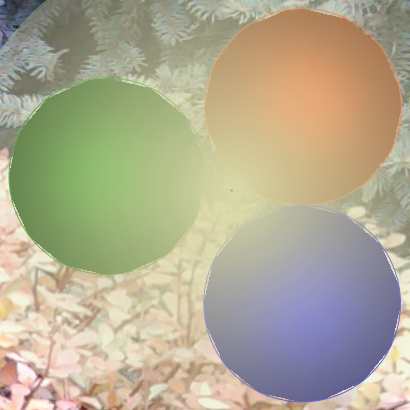
Belle 2008; LHCb 2014

MATTER

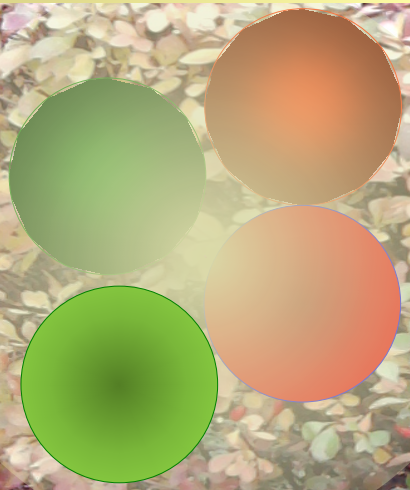
Meson

Baryon



Tetraquark

Dibaryon



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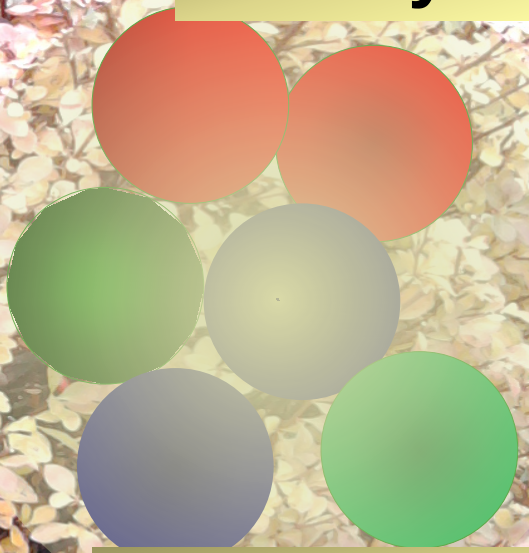


Belle 2008; LHCb 2014

WASA-at-COSY

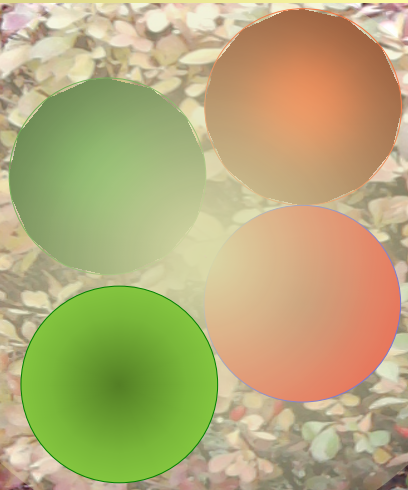
MATTER

Meson

Baryon

Dibaryon

Tetraquark



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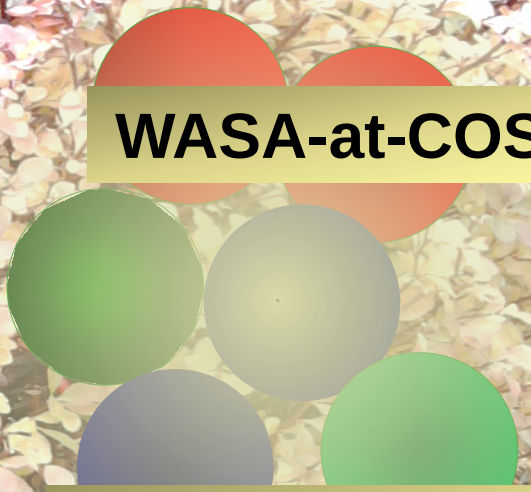
WASA-at-COSY



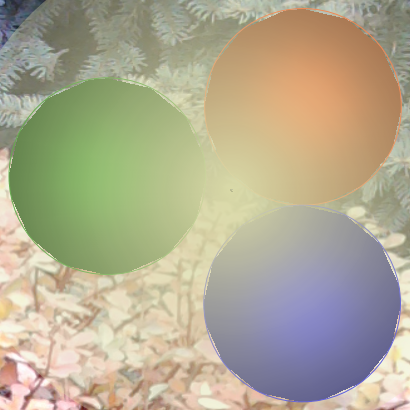
BELLE 2008; LHCb 2014

Heinz Clement, Cracow 2014

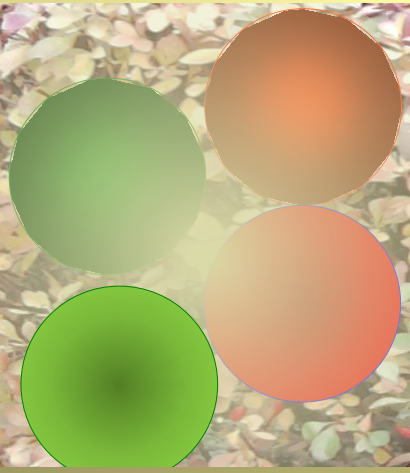
MATTER

Meson

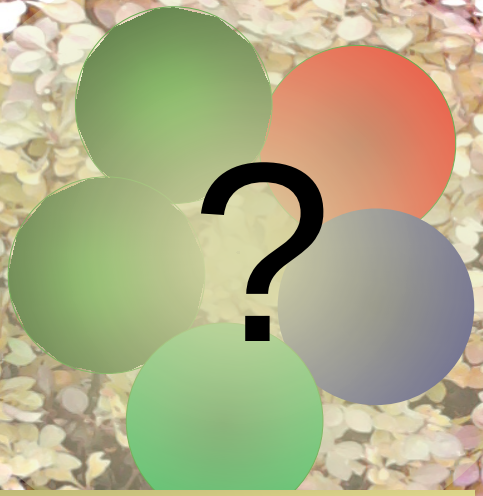
Baryon



Tetraquark



Dibaryon



Belle 2008: Phys. Rev. Lett. 100 (2008) 142001
LHCb 2014: Phys. Rev. Lett. 112 (2014) 222002

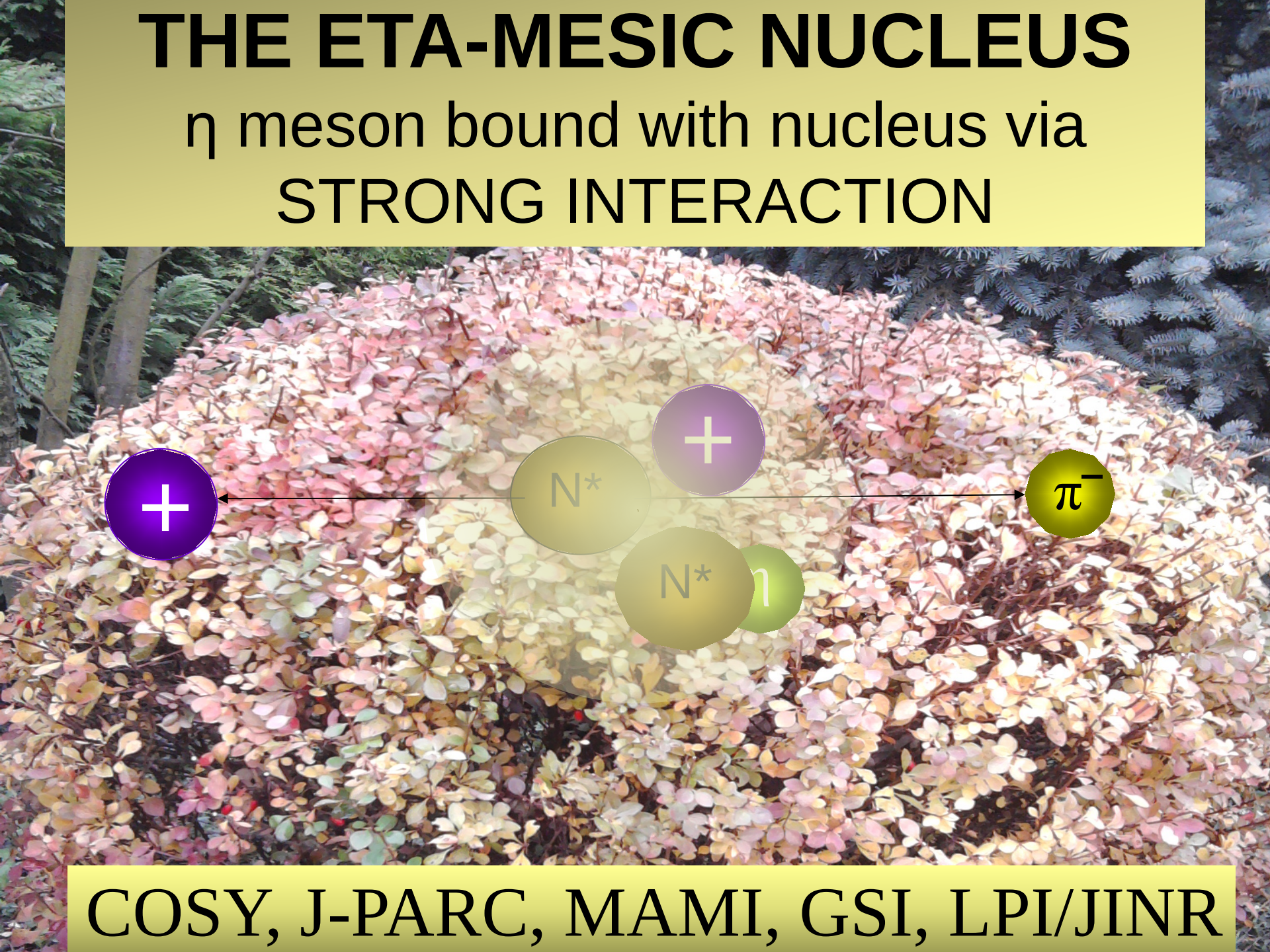
WASA-at-COSY
Phys. Rev. Lett.
112 (2014) 202311

2014

EXCITING YEAR
FOR THE HADRON PHYSICS

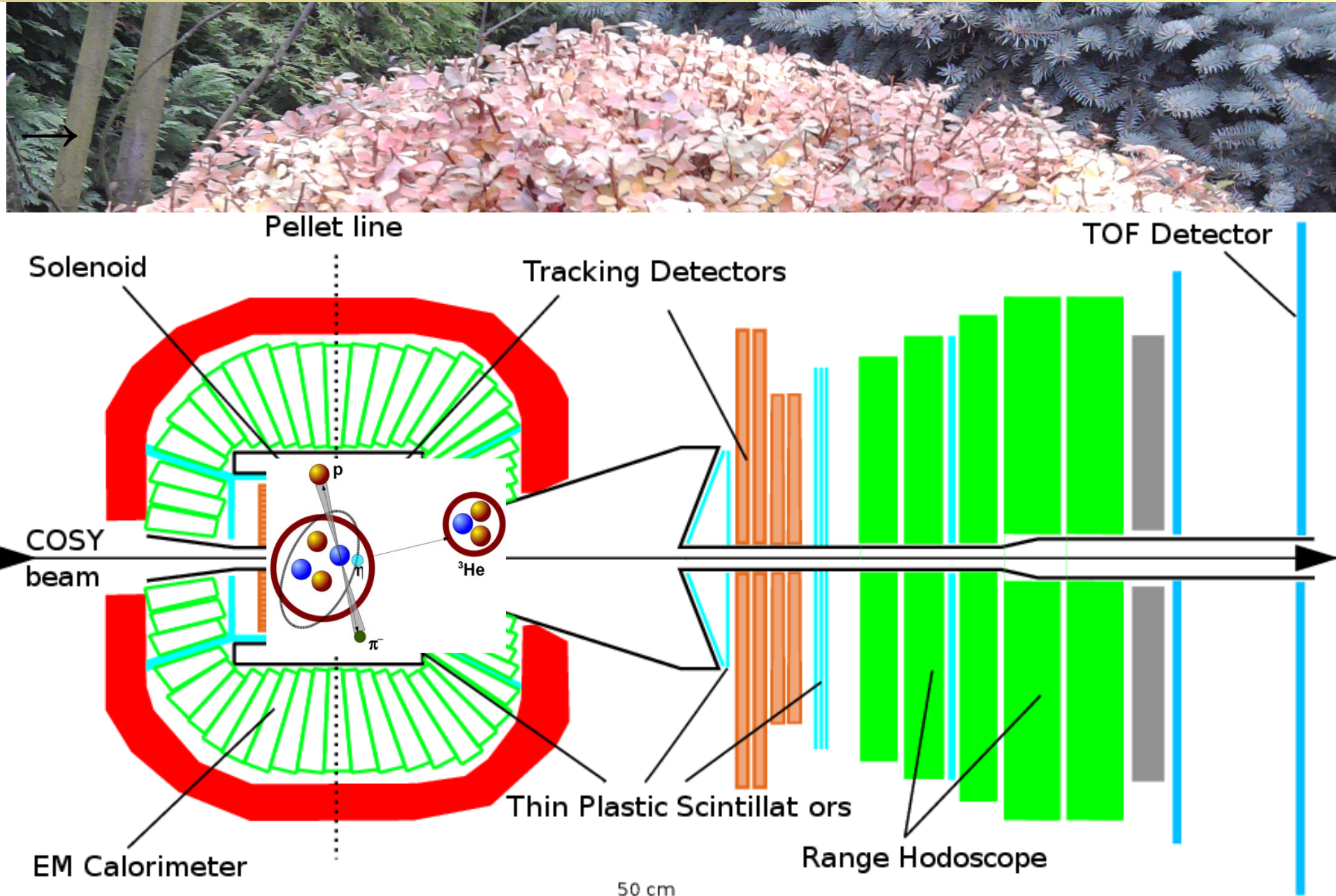
THE ETA-MESIC NUCLEUS

η meson bound with nucleus via STRONG INTERACTION



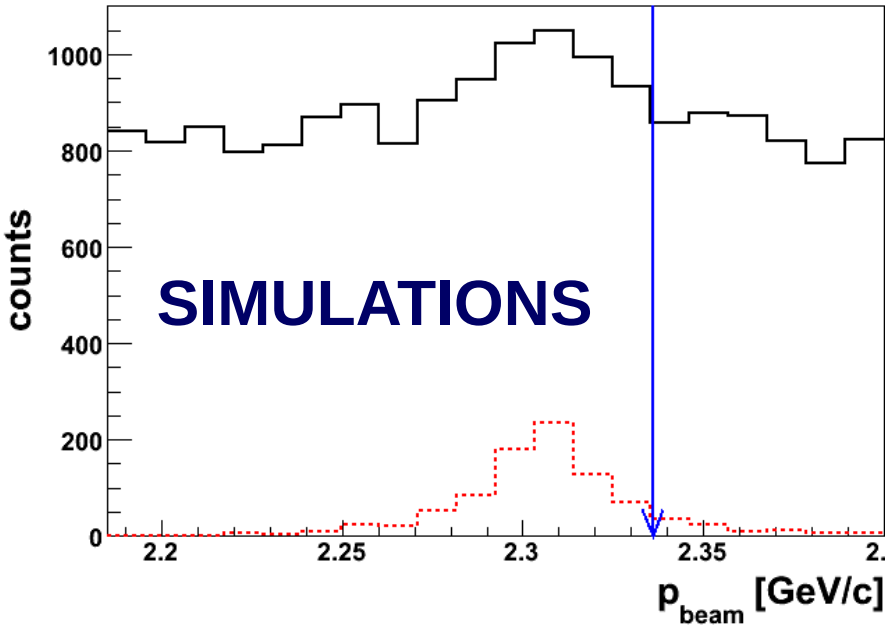
COSY, J-PARC, MAMI, GSI, LPI/JINR

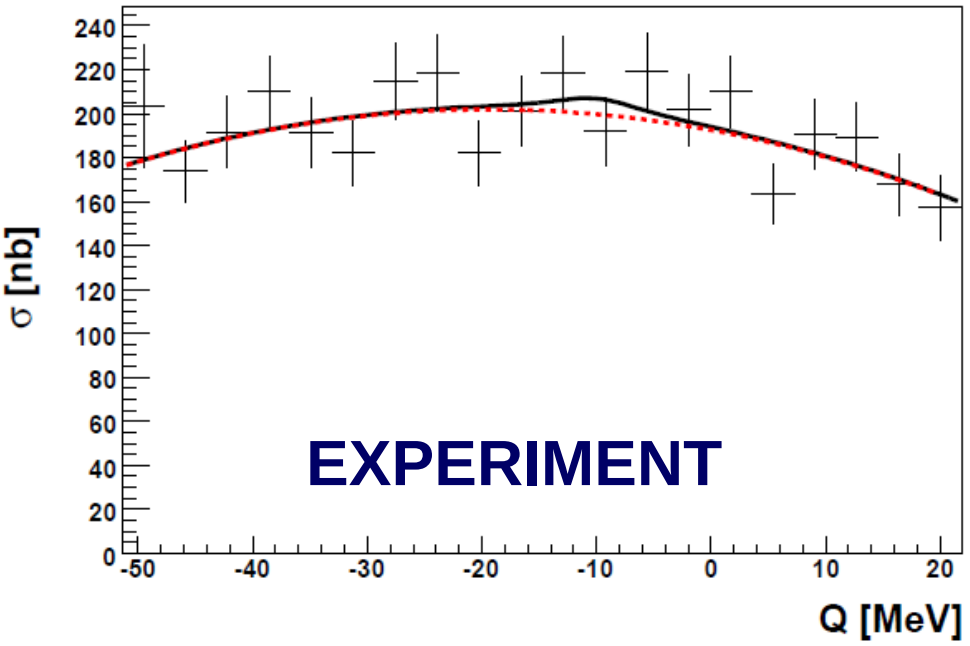
WASA-at-COSY


Pellet line
Solenoid
Tracking Detectors
TOF Detector
COSY
beam
p
η
³He
π⁻
Thin Plastic Scintillat ors
EM Calorimeter
Range Hodoscope
50 cm

$$d+d \rightarrow (^4He\text{-}n)_{bound} \rightarrow {}^3He + p + \pi^-$$

$$d+d \rightarrow {}^3He + p + \pi^-$$





Upper limit of about 25 nb

WASA-at-COSY: Phys. Rev. C87(2013) 035204

140 publications (Nature, PRL, PL, PRC, EPJ, JPG, NIM,…
Bio-Algorithms…,Nucl. Med. Rev., Radiotheraphy & Oncology,
11 International patent applications
15 minutes / 140 ~= 6 seconds / article

1) New kind of matter (**Phys. Rev. Lett. 2014**)
-- Discovery of the Dibaryon (six quark state)
-- Search for the mesic nuclei

2) Confirmation of the primary nuclear fusion in the Sun
(**Nature 2014**)

3) Developement of the utterly new method for PET
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(an example of future research based on the project achievements)

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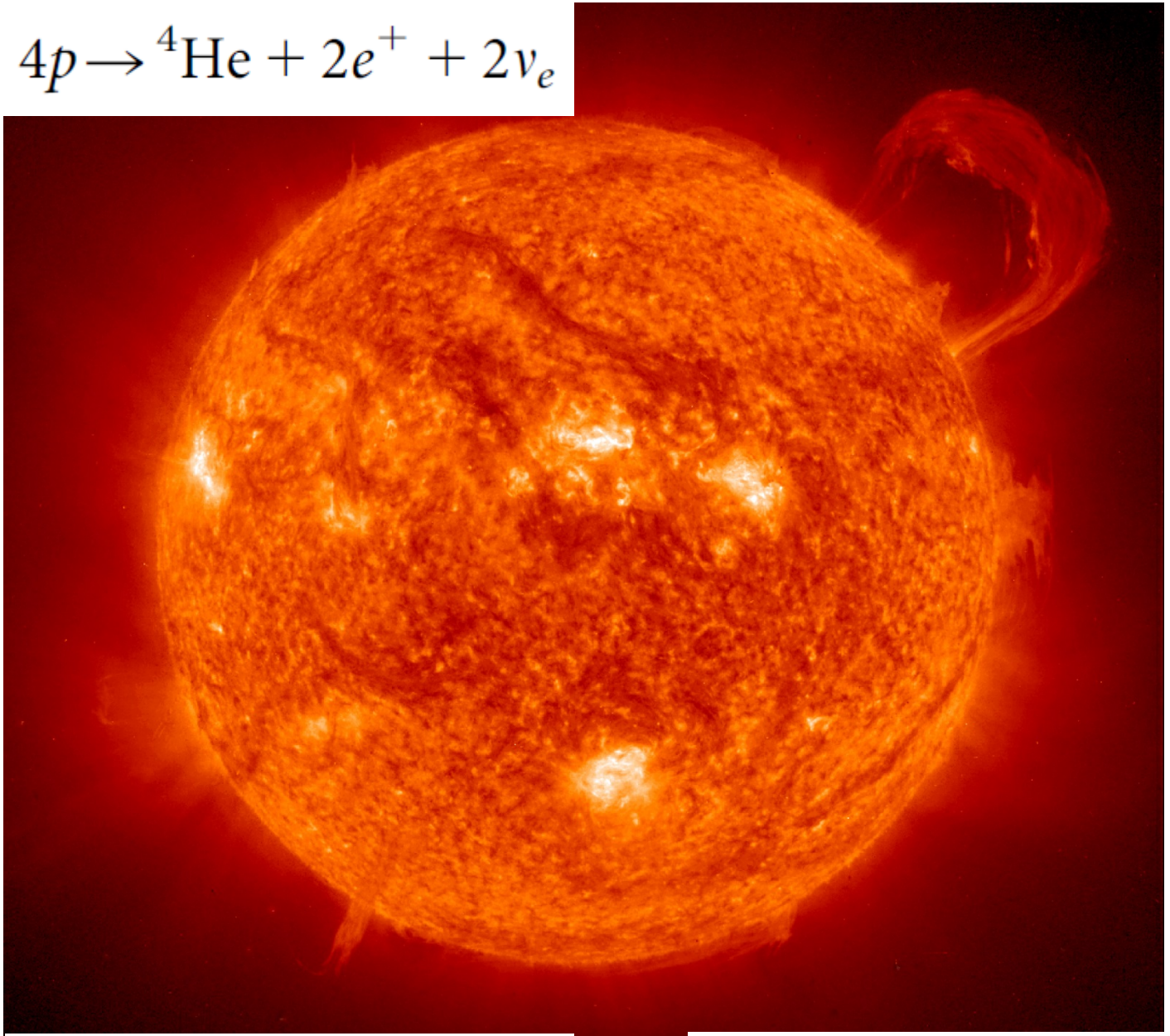
$$4p \rightarrow {}^{4}\mathrm{He} + 2e^{+} + 2\nu_e$$



$$p + p \rightarrow {}^{2}\mathrm{H} + e^{+} + \nu_e$$

$$\nu_x + e \rightarrow \nu_x + e$$

solarsystem.nasa.gov

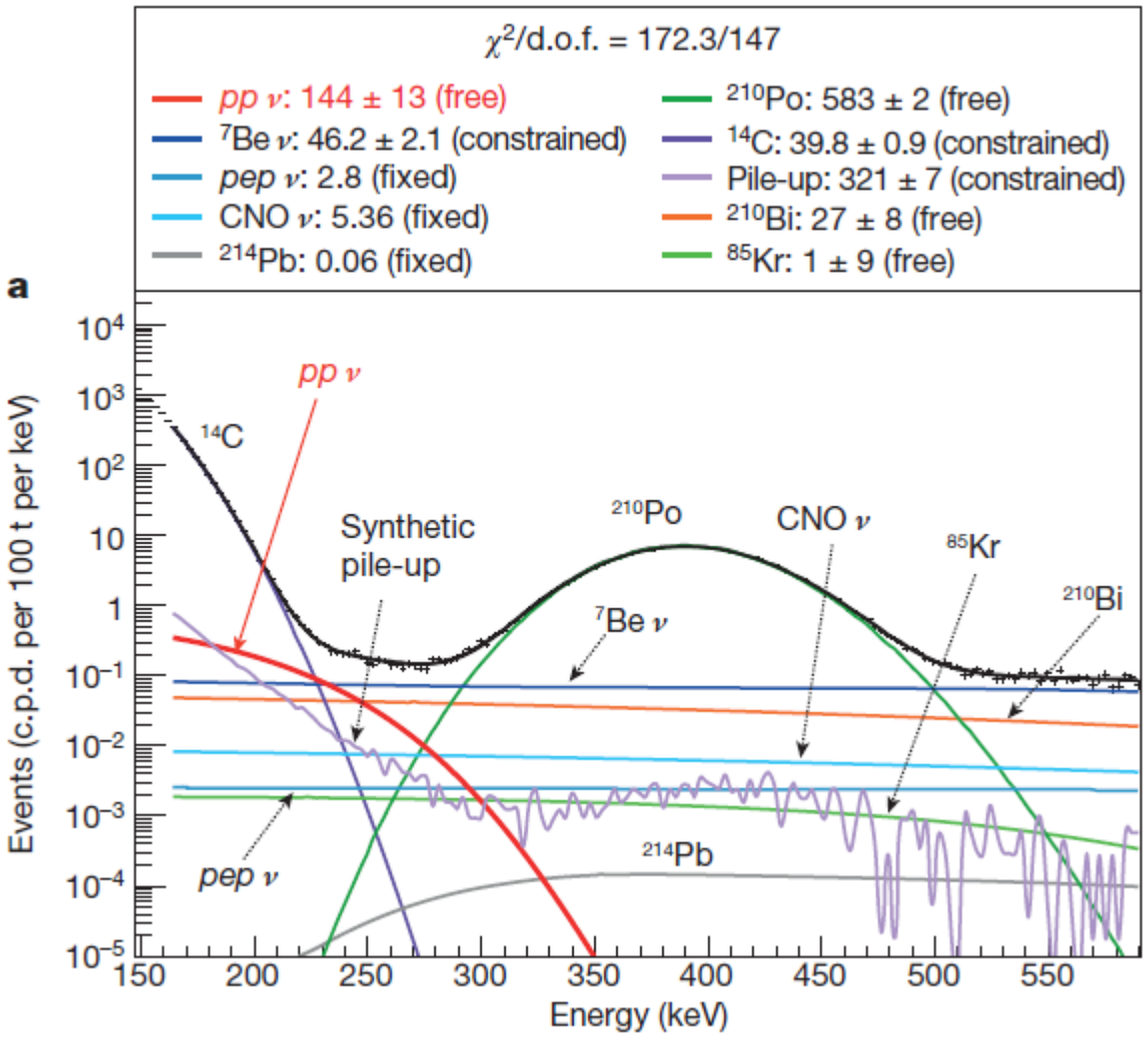
ARTICLE

doi:10.1038/nature13702

Neutri
proton he Sun

Borexino Collaboratio

In the core of the Su
primary reaction is
pp neutrinos consti
that follow. Althou
Sun's energy and c
eluded direct detec
the power of the Su



We have known for 75 y
from the fusion of light n
is transformed into heliu
reactions releasing 26.73
ized as

gen into helium. The
ino. These so-called
tted in the reactions
nuclear origin of the
usion have hitherto
about 99 per cent of
s.

no flux is $(6.6 \pm 0.7) \times$
rediction of the standard
$)^{10}$ cm^{-2} s^{-1}).
us with a direct glimpse at
n shining and strongly re-
ne entirety of the Sun's en-
fer the total energy radiated
by the Sun, 3.84×10^{33} erg s^{-1}. However, because photons produced in
the Sun's core take a very long time (at least a hundred thousand years;

The cycle begins with the fusion of two protons into a deuteron, which

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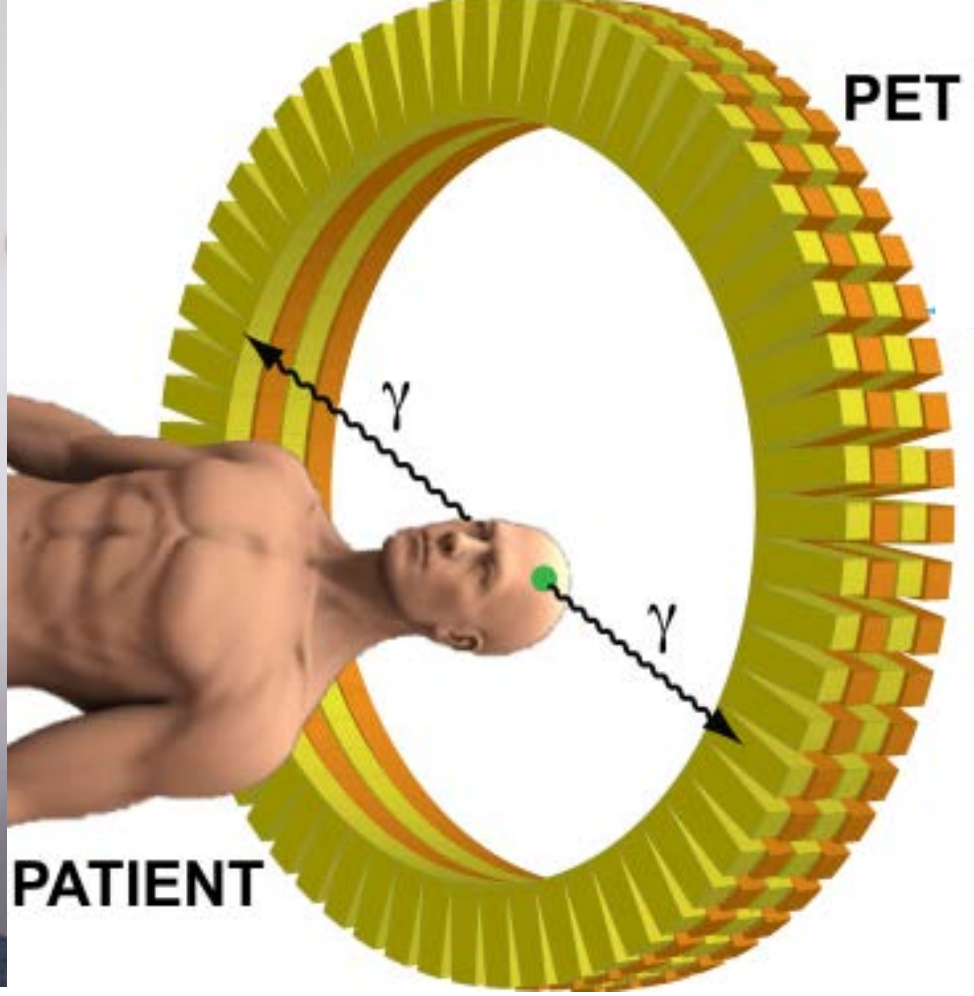
Radioactive suger
emitting antimatter

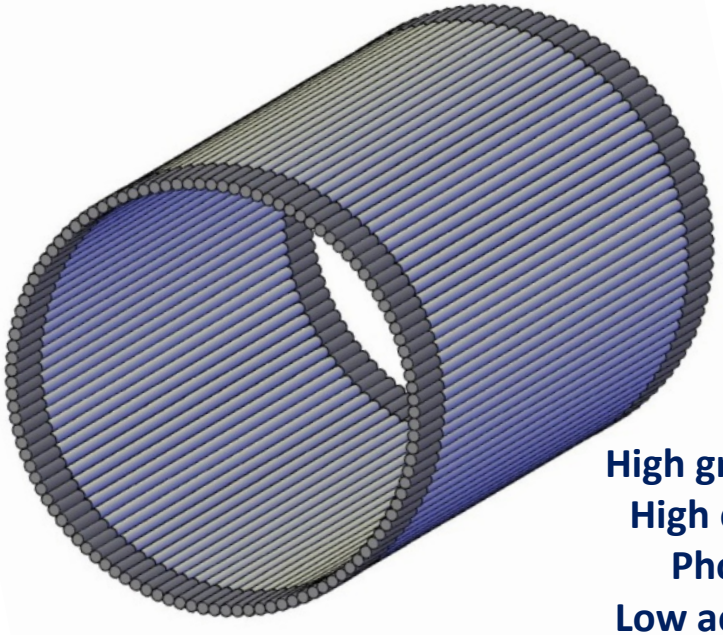


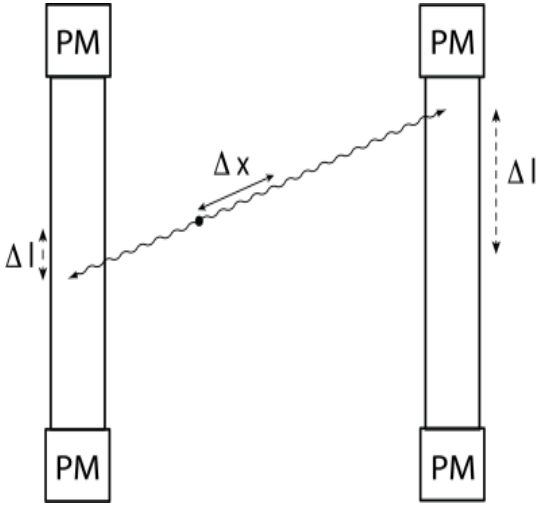
200 000 000

gamma quanta per second

Fluoro–deoxy-glucose
(F-18 FDG)

J-PET





new paradigm

Crystal	→	Polymer
Energy	→	Timing
High granularity	→	Low granularity
High efficiency	→	Low efficiency
Photoeffect	→	Compton scattering
Low acceptance	→	High acceptance
Analog electronics	→	Digital sampling in voltage domain
Triggering	→	Triggerless DAQ
.....	→	Opportunity for simultaneous PET and CT
.....	→	Opportunity for simultaneous PET and MRI
	→	less expensive
	→	Opportunity for morthometric imaging

So far:
sigma(TOF) = 100ps ;
Sampling in voltage domain
with precision of 21ps (sigma)
for 10 Euro per sample;
Triggerless DAQ;

J-PET: Nucl. Instr. & Meth. A764 (2014) 317
J-PET: Nucl. Instr. & Meth. A764 (2014) 186
J-PET: Radiotheraphy and Oncology 110 (2014) S69
Patent WO2011008119 (2014)
Patent WO2011008118 (2014)
10 International patent applications (2014)

Utterly new concept
Experts do not accept it !

KAPITAŁ LUDZKI
NARODOWA STRATEGIA SPÓJNOŚCI

Projekt współfinansowany przez Unię Europejską
w ramach Programu Operacyjnego Kapitał Ludzki

UNIA EUROPEJSKA
EUROPEJSKI
FUNDUSZ SPOŁECZNY

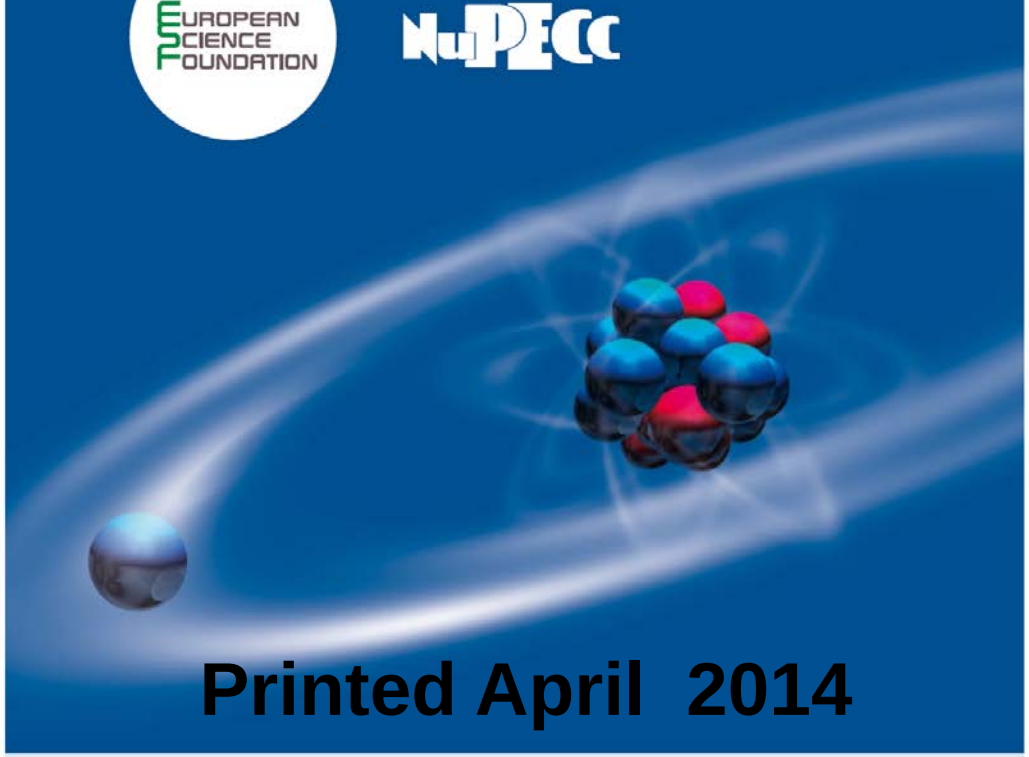
numer umowy: Umowa nr CITTRU/061023/01/10/2009
płatne ze środków: budżetu projektu Kompas innowacji (PSP:S/FS0/0023)
jednostka organizacyjna: CITTRU

Warszawa, dnia 17 listopada 2009 roku.

Recenzja wniosku patentowego nr 9534/09

„Urządzenie matrycowe i sposób do wyznaczania miejsca i czasu reakcji kwantów gamma oraz zastosowanie urządzenia do wyznaczania miejsca i czasu reakcji kwantów gamma w emisyjnej tomografii pozytonowej"

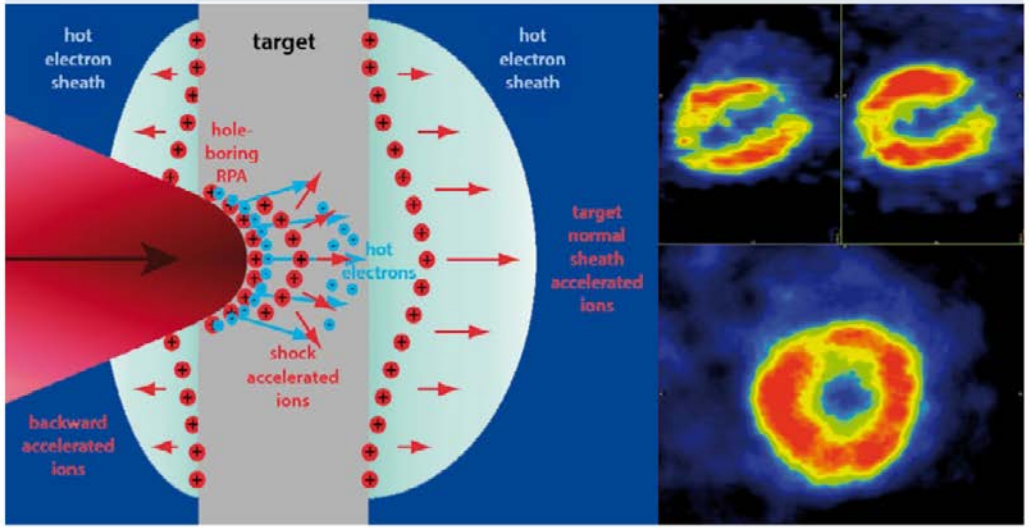
Kierując się obecnym stanem wiedzy, zarówno z zakresu dostępnych technologii, jaki i podstaw fizyki uważam, że proponowane rozwiązanie nie nadaje się do zastosowania w praktyce. Przedłożony wniosek przedstawia ogólną definicję tomografii pozytonowo emisyjnej, natomiast w dalszym jego części proponuje rozwiązania, które świadczą o niezrozumieniu zasady działania układu detekcyjnego będącego fizyczną podstawą dyskutowanej metody obrazowania, czyli detekcji kwantów anihilacji gamma o energii 511 keV.



Printed April 2014

Nuclear Physics European Collaboration Committee (NuPECC)

Nuclear Physics for Medicine



INSTYTUT FOTONOWY COMPANY

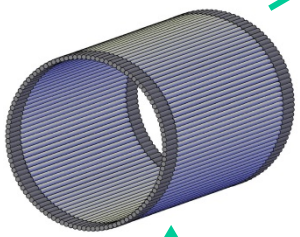
ELECTRONICS

P. Salabura, T. Kozik, M. Pałka, P. Strzempek

Nowoczesna Elektronika COMPANY

DAQ TRIGGERLESS

G. Korcyl, M. Kajetanowicz



SIMULATIONS

P. Kowalski, W. Wiślicki (Świerk Computing Centre)

D. Kamińska, O. Rundel

Analysis framework

W.Krzemień, T. Gruntowski, A.Gruntowski

SYNTHESIS OF SCINTILLATORS

Ł. Kapłon, A. Wieczorek, A. Kochanowski, M. Molenda, A. Danel (AU)

EXPERIMENTS, CALIBRATIONS

D. Alfs, T. Bednarski, E. Czerwinski, J. Smyrski, E. Kubicz, Sz. Niedźwiecki, I. Pytko, M.Skurzok, M. Silarski, M. Zieliński

TIME and HIT-POSITION RECONSRUCTION

L. Raczyński, N. Sharma, N.Zoń

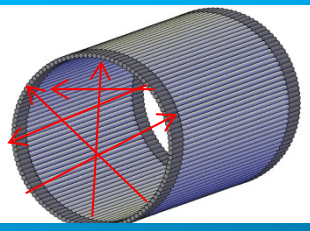


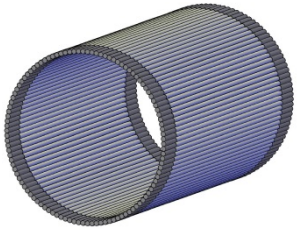
IMAGE RECONSTRUCTION

P. Białas, J. Kowal, Z. Rudy, A. Słomski, A. Strzelecki

IMAGE VISUALISATION

SILVERMEDIA IT COMPANY

ANALOG DIGITAL

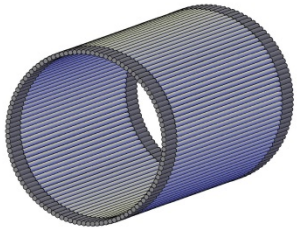


FFE
Sampling
in voltage domain

FFE
Sampling in domain
of fraction of amplitude

Readout
electronics

New idea… BREAK THROUGH

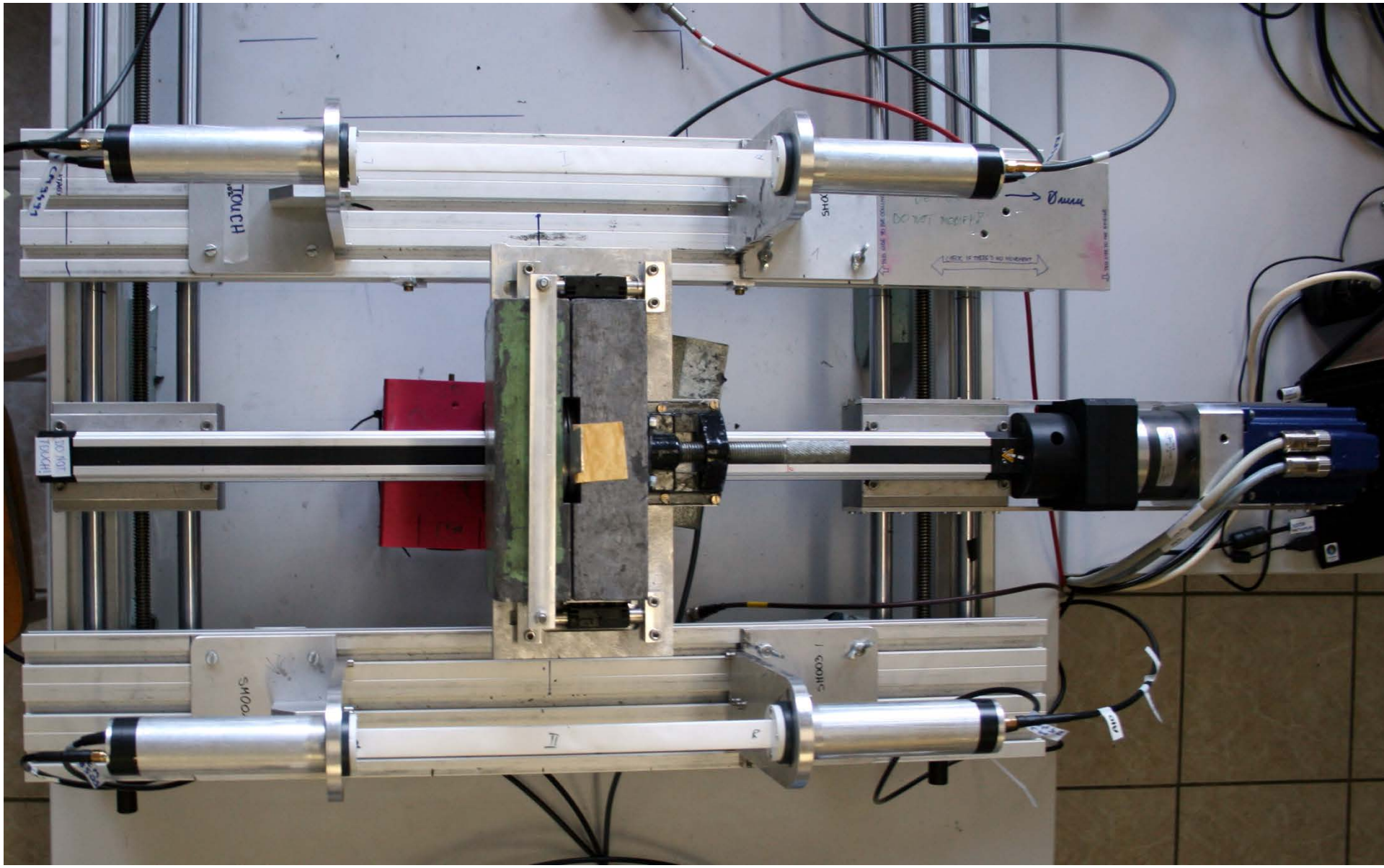


ONLY DIGITAL

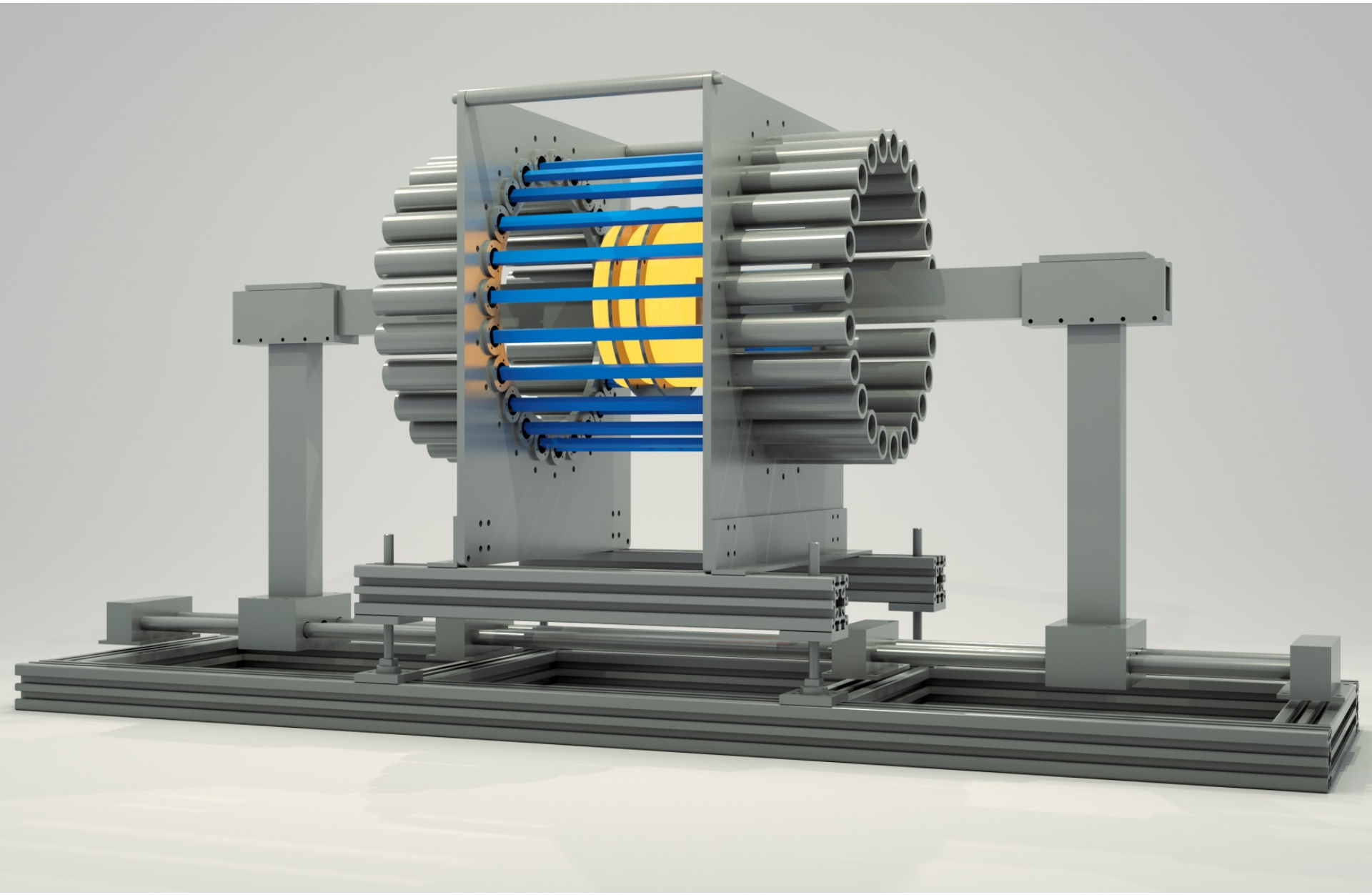
FFE sampling & Readout electronics

PCT/EP2014/068367

precision of 21ps (sigma) for 10 Euro per sample



J-PET: Nucl. Instr. & Meth. A764 (2014) 317
J-PET: Nucl. Instr. & Meth. A764 (2014) 186



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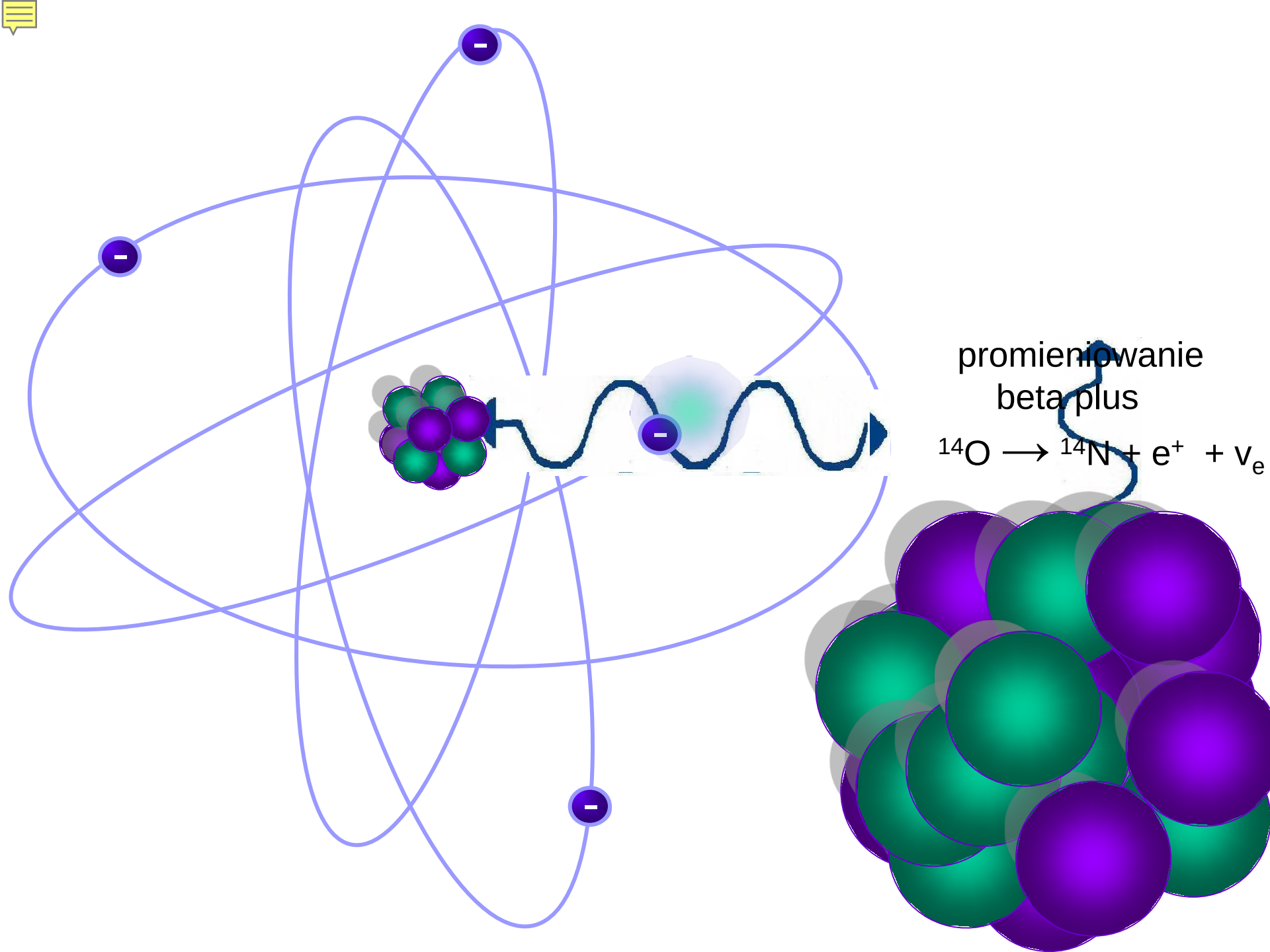
simultaneous PET-CT scan: **PCT/EP2014/068363**
and
simultaneous PET-MRI scan: **PCT/EP2014/068373**

petct_animation41_loop.mp4

Z³o¿enie_PET_MRI.avi

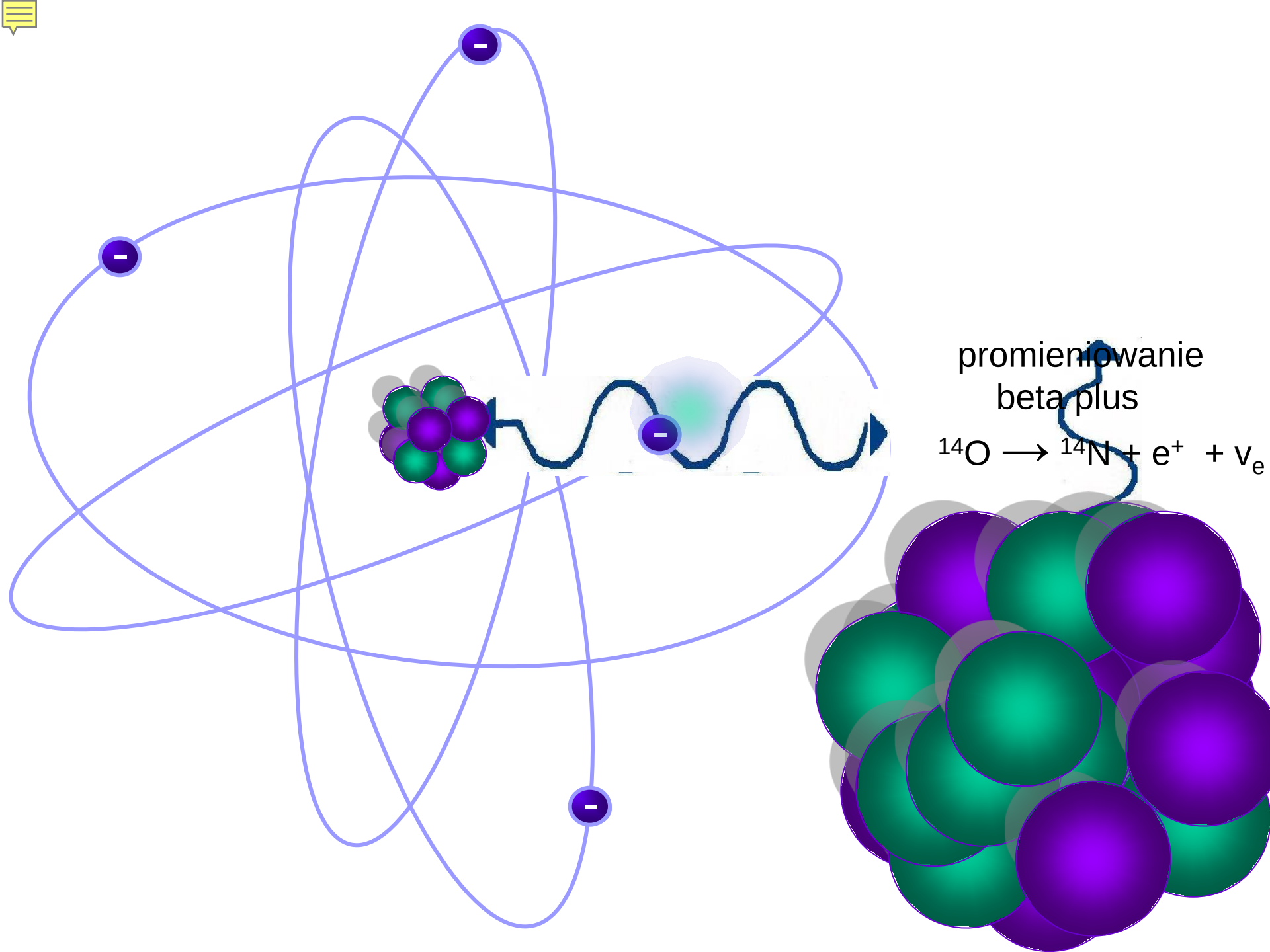
promieniowanie
beta plus

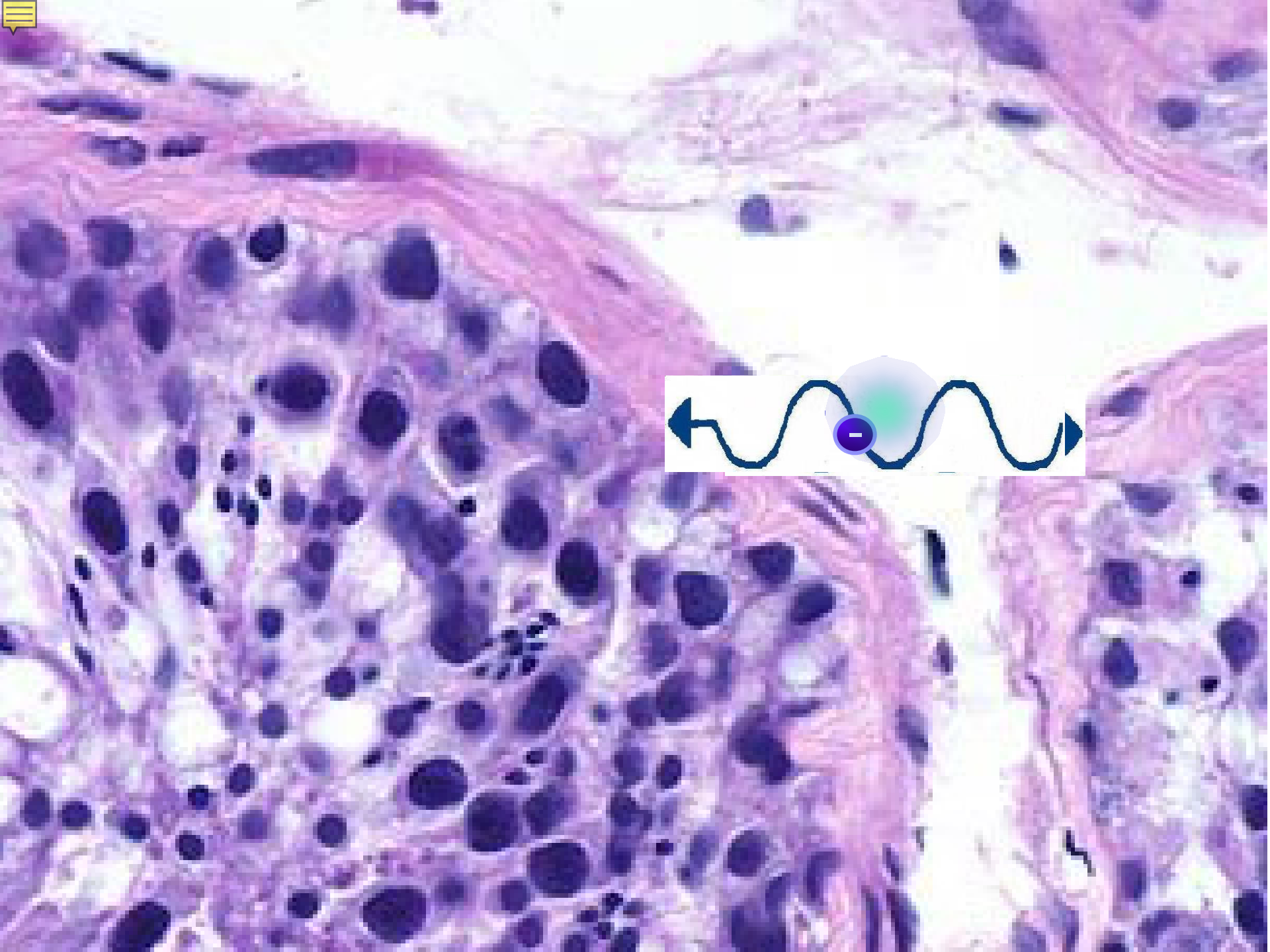
$^{14}O \longrightarrow {}^{14}N + e^{+} + \nu_e$

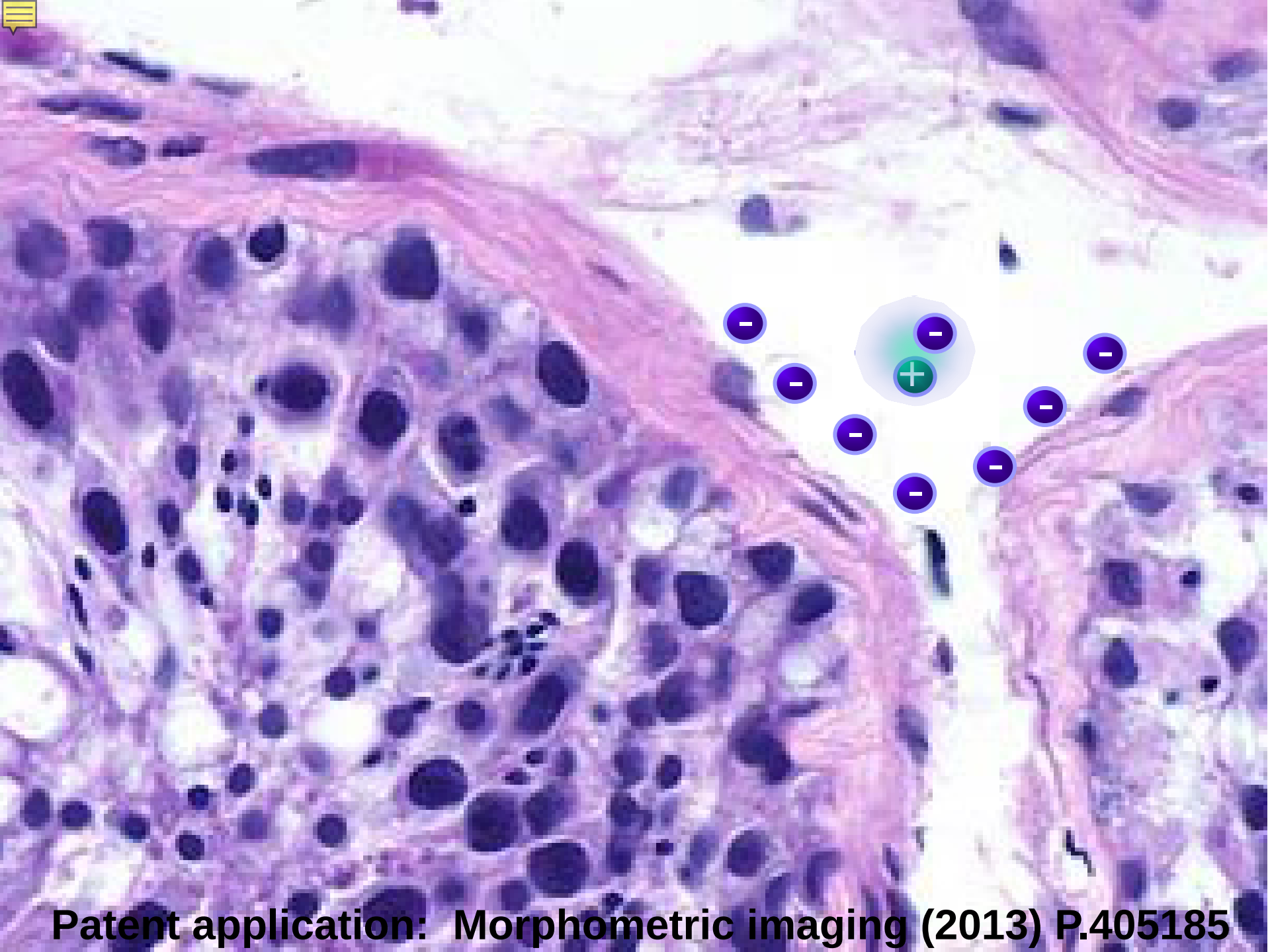


promieniowanie
beta plus

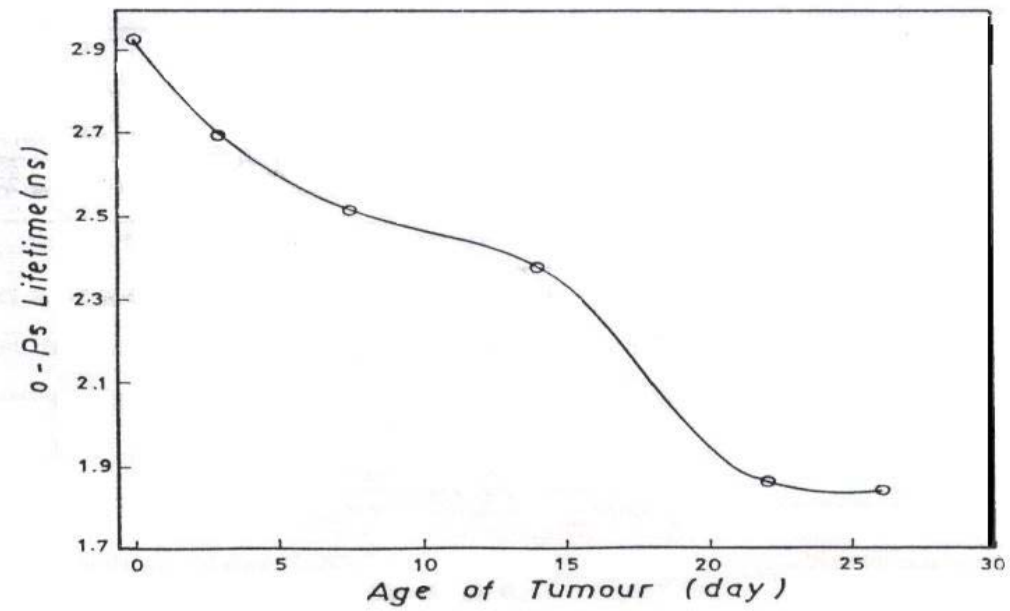
$^{14}O \longrightarrow {}^{14}N + e^{+} + \nu_e$





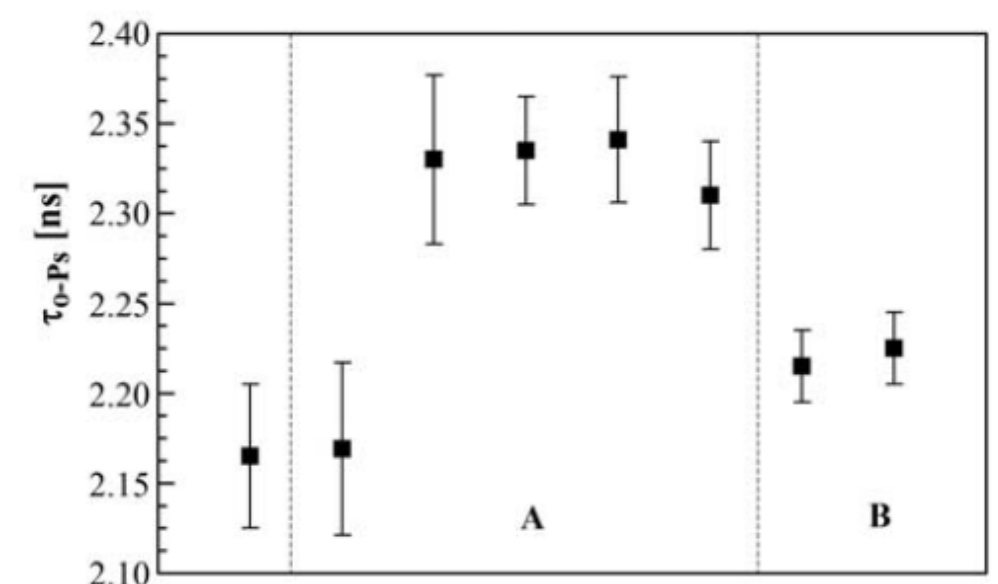


Patent application: Morphometric imaging (2013) P.405185

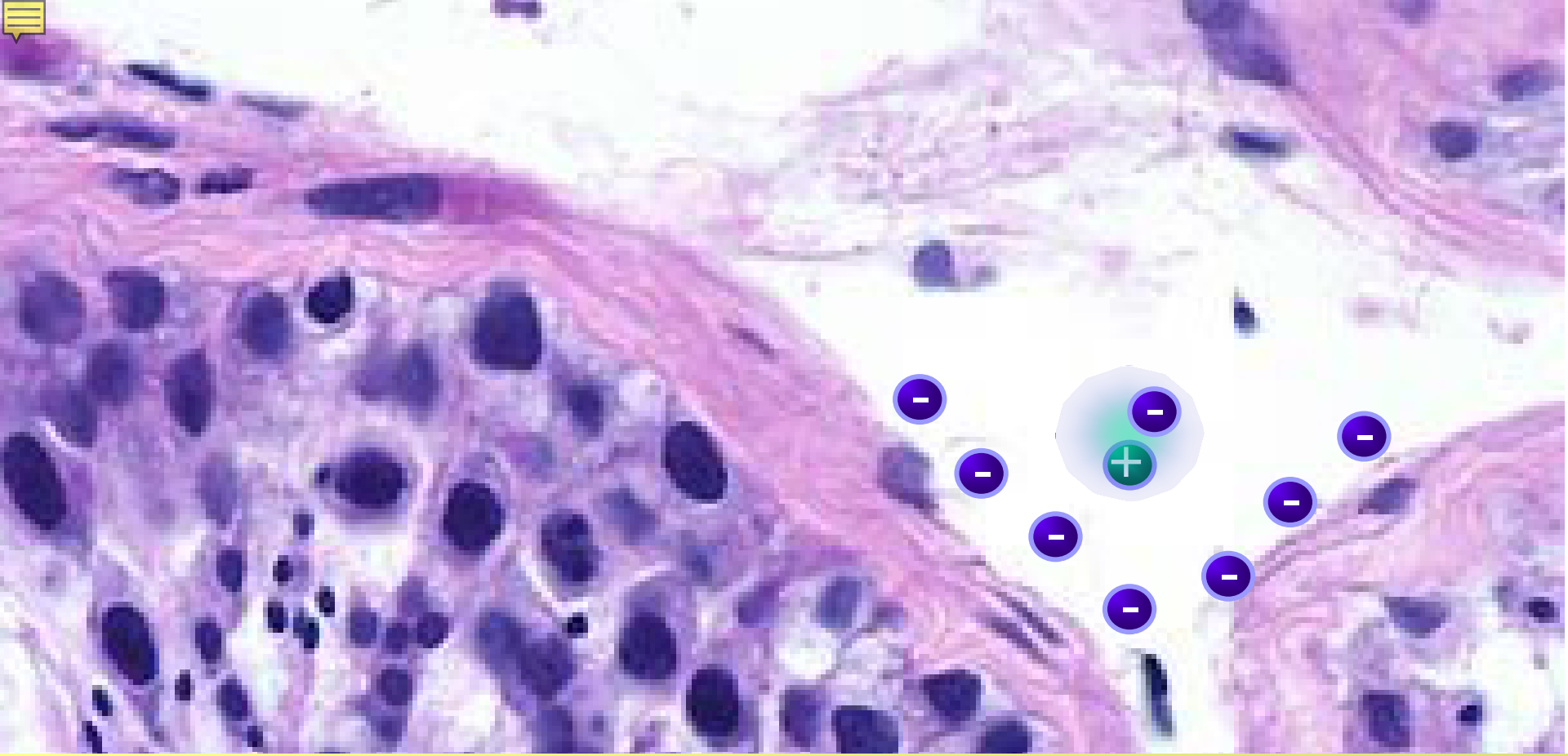


The age of mice's tumour with o-Ps lifetime

A.H. Al-Mashhadani et al., Iraqi J. Sci. 42C, 60 (2001) 3.



R. Pietrzak et al., NUKLEONIKA 58 (2013) 199



$$N(\Delta t) = N_o P_{ps} \tfrac{3}{4} e^{-\Delta t/\tau o\text{-}Ps} + N_0 \tfrac{1}{4} P_{ps} e^{-\Delta t/\tau p\text{-}Ps} + N_0 (1\text{-}P_{ps}) e^{-\Delta t/\tau b}$$

$$(\tau_{o\text{-}Ps} \cdot P_{poz})^{-1} \qquad W = SUV / (\tau_{o\text{-}Ps} \cdot P_{poz})$$

Patent application:
Morphometric imaging PCT/EP2014/068374 (2013)

Heavy Ion Laboratory in Warsaw
NCBR (^{44}Sc)

National Hadron Therapy Center in Cracow

Świerk Computing Centre

Workshop on basics of data analysis using ROOT:
an object-oriented framework written in C++

General tele-symposium in the framework of the International PhD Studies in Applied Nuclear Physics and Innovative Technologies

„In **ancient Greece** the **symposium** (Greek συμπόσιον *symposion*, from συμπίνειν *sympinein*, "to drink together") was a drinking party”

Few highlights presented were:

-- Fantastic group of PhD students and Postdocs…

-- Discovery of new kind of matter in the form of dibaryon…

-- First evidence for the neutrinos from the primary fusion

-- J-PET project … 100ps .. Unique posiblities for PET/CT, PET/MRI; new concept for the morphometric imaging ….
This concept and detector opens us possibilities for bio and medical physics research and also for the research at the frontier of basic physic for studies of discrete symmetries as e.g. time reversal symmetry ….

I am more than excited with this future posibilities, I am almost ionized when anticipating the future reserach opened by our present achievements within this project….☺

ALL THIS IS POSSIBLE TO VERY LARGE EXTENT DUE THE SUPPORT FROM FNP…


THANK YOU
FOR YOUR ATTENTION