FROM MESONS TO **TOMOGRAPHY**

Mesons are particles built of matter and antimatter. They arise in a result of interaction between cosmic radiation and atom nuclei in the atmosphere. The matter and the antimatter inside mesons almost immediately annihilate and a meson disintegrates into lighter particles or turns into energy in the form of light. **The research of the mechanism of creation and decay of mesons has been the field of my scientific activity for almost twenty years,** that is since my first visit to the Juelich Research Centre in Germany at the time of writing my Master's thesis. The initial goal of my visit was to develop a method for testing a new particle detector, which was to be constructed of a large scintillating plate surrounded by a „matrix" of photomultiplier tubes, i.e. devices transforming light pulses generated by particles passing through a scintillator into electric pulses. However, it turned out, that such a detector was already being tested by Magnus Wolke, a Master's student from Münster (presently a leader of a 200-person group of a team studying the degree of conservation of different kinds of symmetry in nature by analysis of meson decay).

Having been acquainted with the potential of laboratories at the research centre **I found an equally interesting field of scientific activity and decided to study the properties of scintillating strips in view of using them to measure the speed of particles,** which were to be registered in an experiment we were preparing. **The detector** I was testing **was designed to produce a signal to trigger the measuring of time of a flying particle,** while a pulse from the Magnus detector was to stop this time measuring. These detectors (indicated in Fig.1 as *START* and *STOP*) were a part of a larger detection system, which we used for over ten years to study the structure of mesons, to search for a new kind of nuclear matter (so-called mesic nucei) and matter composed solely from strong interaction quanta (i.e. gluons), as well as to study many other fascinating phenomena. The four large orange blocks shown in Fig.1 represent dipole magnets – a fragment of the accelerator ring in which protons, travelling at a speed close to that of light, collide with hydrogen nuclei (injected into the ring in the form of microscopic droplets) and create mesons.

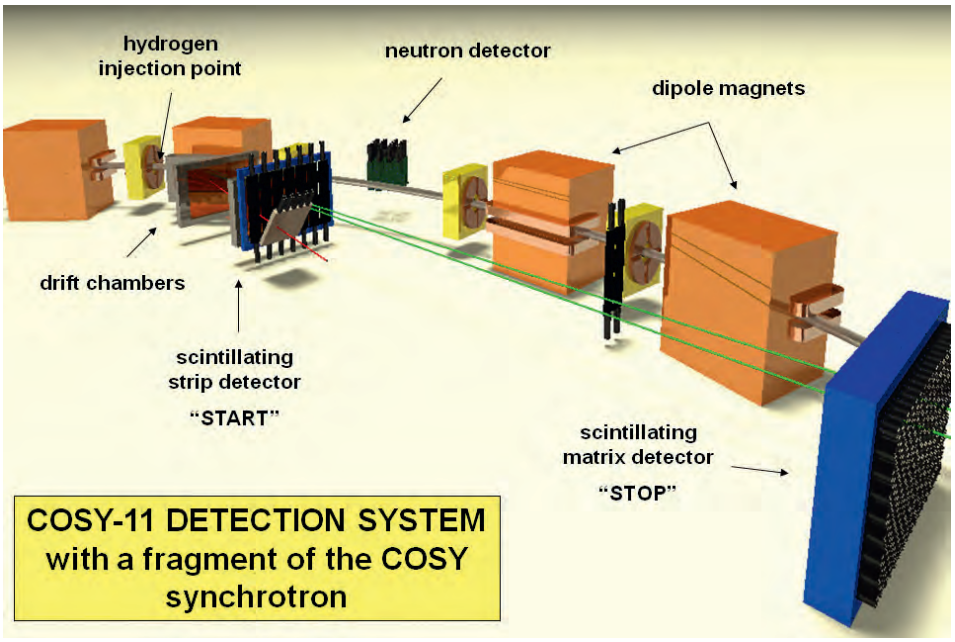

Fig. 1. This illustration presents a part of the COSY synchrotron with COSY-11 detection system. The COSY-11 detection system was designed and built to a large extent at the Institute of Physics of the Jagiellonian University. The COSY proton synchrotron is installed at the research center in Juelich nearby Aachen (Germany).

The COSY synchrotron is one of many laboratories at the Juelich Research Centre, which is presently the largest interdisciplinary research centre in Europe. Nuclear medicine is one of the disciplines studied there. During a "doors open day" at the Centre I visited the medical institute with my children, where – as it turned out – human brain studies were performed using both Nuclear Magnetic Resonance (NMR) and Positon Emission Tomography (PET). **For many years I was interested in the functioning of the brain at a popular science level,** reading books on this issue just for the pleasure of it. At that time, it crossed my mind that it would be good to have my brain tomographed.

During the visit I found out that **the Centre was searching for volunteers needed for**

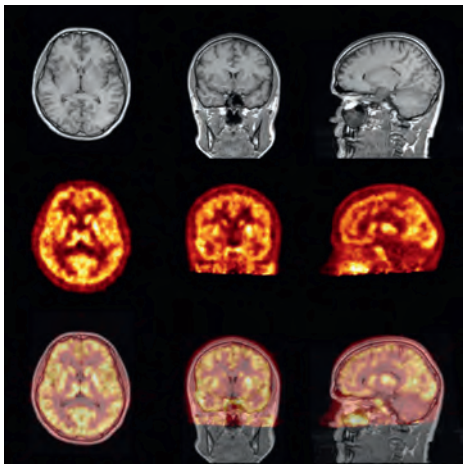

Fig. 2. Illustration of adenosine A1 receptors density distribution in my brain on Dec 5th, 2002. Three cross sections are shown: transverse (left column), coronal (middle column) and sagittal (right column). The brighter the hue the greater the concentration. The top row presents NMR images, the middle row – PET imaging and the bottom row – a superposition of both images.

research aimed at gaining a better understanding of central nervous system disorders; thus I was listed as a volunteer. After a month or so I received an e-mail requesting for my permission to take a tomographic image. This was required for a comparison with brain images of people with impaired movement due to the Parkinson disease. The subject of this research was the distribution of A1 adenosine receptors. The research called for some sacrifice – a day earlier I had to stop drinking coffee as adenosine molecules are similar to caffeine particles, which allegedly block adenosine receptors in the brain. Moreover, a pharmaceutical agent needed for a PET scan is injected intravenously, what for some generally unclear reasons I have a holy terror of. After some 90 minutes of PET scanning I was taken to another room, where a NMR image of my brain was taken. After all this scanning I received a souvenir – the image shown in Fig. 2. **PET tomography allows to obtain the density distribution of a radio-labelled drug metabolized by the patient at a resolution of a few millimetres, while the NMR method allows a much more precise determination of the shape of the human organs.** Therefore, with a combination of both methods a physician is able to determine where, when and at which concentration a given substance accumulates in the organism. The possibilities offered by this laboratory impressed me a lot. It is worth mentioning that since 2008 this institute operates one of four tomographs that is capable to generate a PET and a NMR image at the same time and, since 2009, they run also a world-wide unique device: dual PET/NMR tomograph with magnetic field three times greater than fields used so far.

Perhaps that was the time when it dawned on me that the detectors of the type we used for COSY synchrotron experiments could be advantageous in tomography. After all, positon and electron in the patient's body create for a short while a system called a „positonium", which (being composed, just like mesons, from matter and antimatter) almost immediately annihilates turning into radiation quanta. These quanta fly out of a patient toward detectors and a tomographic image is reconstructed on the basis of their flight direction. Anyway, it was at that time, i.e. during my post-doctoral fellowship at the Juelich Research Centre (2001-2003), that **I managed to develop a general outline of the strip tomograph and the matrix tomograph** (the concept of the latter is shown in Fig. 3). I was then under the wrong impression that both those methods – NMR and PET – were already routine tools in hospitals. However, upon returning to Krakow in 2004, at a time when my wife had an accident and stayed unconscious in a hospital, it occurred that it was impossible to diagnose her with tomographic imaging. At that time hospitals in Krakow had only one NMR device and no PET at all.

Then I began in earnest to work on both concepts, which **I sincerely believe will allow to construct a PET tomograph at a much lower cost, using polymer scintillators instead of very expensive inorganic crystals.** The area of this research seemed very interesting to me and offered a large potential of research translating into real effects in our daily life. I also believed that the issue can be interesting to the others, especially to young researchers. At first, in order to acquaint some young people better with this field, we initiated a practical at the Student Physics Laboratory running demonstrations illustrating PET tomograph operations on the example of a linear model. I believe students liked this practical as they are happy to perform it and often present it at an annually-organized poster session. Fig. 4 presents a general concept of a PET tomograph using polymer scintillator strips. The location of the gamma quantum hit (a key factor to reconstruct the image) in relation to the scintillator centre (Δl) is determined on the basis of the time difference measured at the strip ends, while the place of annihilation along the gamma quanta flight line (Δx) is determined from the time difference between gamma quanta hits on both modules.

After my discussion with Gabriela Konopka-Cupiał, Ph.D. Eng., and Maciej Czarnik, in spring 2009, I was once again able to continue the development of my ideas. Thanks to the very effective actions undertaken by CITTRU (Centre for Innovation, Technology Transfer and University Development), patent applications could be worked on faster and due to the formulation of rational arguments in support of new solutions I was in a position to convince myself that the chance for an effective realisation of these solutions was at hand.

That was the beginning – **now at the Institute of Physics we are constructing a two-module prototype of the strip tomograph.** Provided the tests of this miniature device prove the assumptions for the design and given that the operation principles of the tomograph were correct, the next stage would be optimisation and construction of a second device of real, practical size. Once the proof of concept is there, we can hopefully prepare such a new PET instrument for patients.

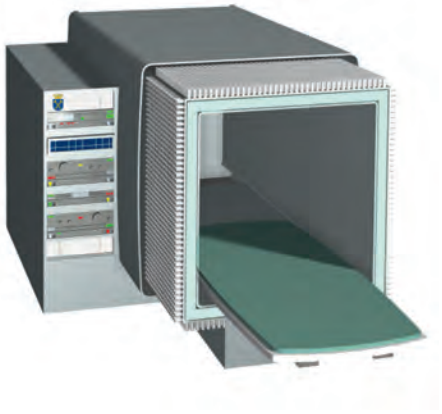

Fig 3. 3D model of the matrix PET tomograph invented at the Jagiellonian University.

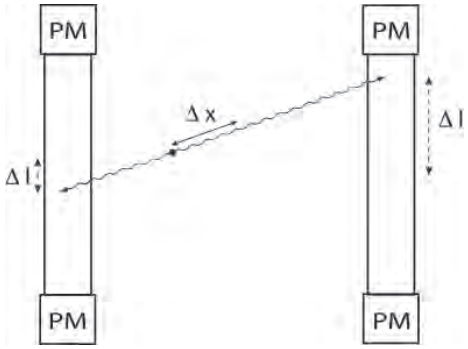

Fig 4. A scheme of a two-module strip PET tomograph. The dot marks the place of annihilation of a positon with an electron. PM indicates photomultiplier units.

CONTACT

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