Antimatter reveals cancer

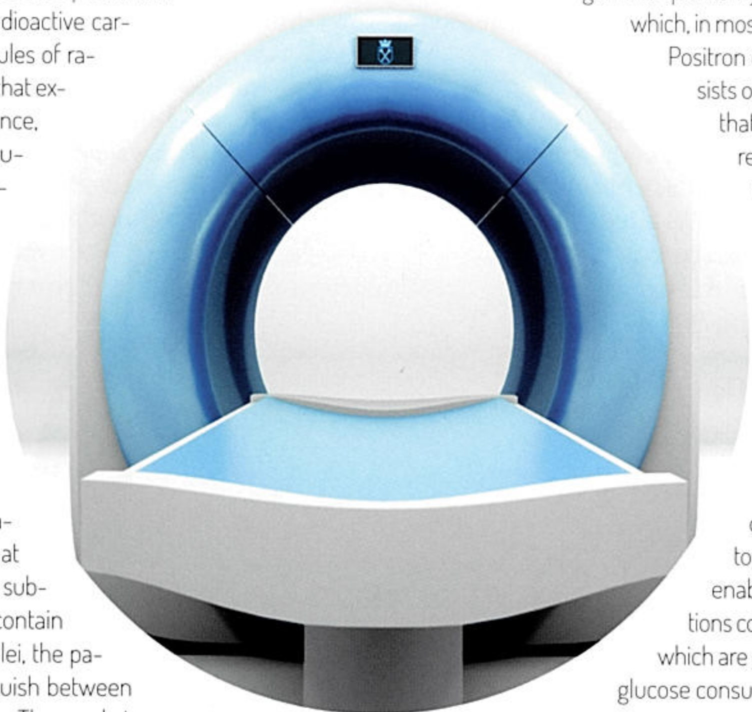
A new technology of gamma quanta detection, which may significantly lower the costs of medical diagnostics and enable the imaging of the whole human body during a single scan, is currently being developed at the Department of Nuclear Physics of the Jagiellonian University.

The body of every living organism contains atoms with radioactive nuclei. They have practically the same chemical properties as stable atoms, which means that both types of atoms are used similarly in the metabolic processes of living organisms. For example, we ingest radioactive potassium ^{40}K with food; we inhale radioactive carbon dioxide $^{14}CO_2$ or molecules of radioactive water vapor $^{3}H_2O$ that exist in the air. As a consequence, atoms with radioactive nuclei (e.g., ^{40}K, ^{14}C, or ^{3}H) constitute a part of our bodies and every second an average of eight thousand instances of radioactive decay of atomic nuclei occurs in our bodies.

Tracking the flight of gamma quanta

Positron emission tomography is based on the fact that after the administration of a substance whose molecules contain atoms with radioactive nuclei, the patient's body cannot distinguish between stable and radioactive atoms. These substances are selected to be processed as strongly as possible in the tissues that are to be diagnosed. The most commonly used substance is glucose, in which one of the atoms is radioactive fluorine ^{18}F.

As a result of radioactive transformation, the nuclei of fluorine ^{18}F transform into nuclei of oxygen ^{18}O. The consequence of this metamorphosis is the emission of nuclear radiation in the form of a positron (anti-electron) and a neutrino (a neutral subatomic particle). Practically nothing interacts with the neutrino while it "escapes" from the body, but the anti-electron slows down as a result of interacting with electrons, and finally, after losing velocity as an antimatter particle, it annihilates the encountered electron at a distance of approx. one millimeter from the location where the nuclear transformation took place. The annihilation usually results in the creation of two gamma quanta flying in opposite directions, which, in most cases, leave the organism. Positron emission tomography consists of recording gamma quanta that fly out of the human body, reconstructing their trajectories and recreating an image of the annihilation locations. The distribution of annihilation spots corresponds to the map of dissemination of the fluorine ^{18}F in the organism, which in turn represents an image of the intensity of metabolism of the glucose administered to the patient. Such an image enables us to identify the locations containing cancerous tissues, which are characterized by increased glucose consumption.



↑ Visualization of the tomography

New tomograph

Imaging of metabolic processes is particularly useful for early detection of cancer and cancer metastases as it allows for the detection of changes in tissues before morphological modifications occur that may only be captured with use of other imaging methods. Currently, inorganic crystals are used as radiation detectors. This is a very expensive technology. A PET tomograph costs over ten million Polish zloty, which is why there are only about ten such devices in Poland at the moment.

The Department of Nuclear Physics of the Jagiellonian University is working on a **breakthrough technology of gamma quanta detection**. The innovative aspect of the developed solution is the use of organic materials for radiation detection, as well as the method of reconstructing the spot of gamma quanta reaction, based mainly on measuring the timing of the recorded signals. The tomograph will consist of polymer strips, which will be optically connected to a device that transforms light impulses into electrical ones. The technique developed will enable the size of the diagnostic chamber to increase without a significant increase in the production costs, which will allow for the imaging of the whole human body at the same time.

The method developed is an example of **transferring innovative methods** of radiation detection used in fundamental studies in nuclear physics and molecular physics to the field of medical applications. The invention was awarded a gold medal at the 58th World Exhibition of Innovation, Research and New Technologies (Brussels Innova 2009). A small-scale prototype is currently under construction with which new electronic modules and new methods of the reconstruction of signals and images developed by the Department of Nuclear Physics at the Jagiellonian University in the last two years will be tested. If the tests are successful, the construction of a prototype of a size enabling the imaging of human body that is planned for 2014 will begin. ■

Annihilation is the process in which a subatomic particle, colliding with its antiparticle, transforms into energy in the form of gamma quanta or other new particles.
Gamma quanta are particles of nuclear radiation similar to light photons, but millions of times stronger.

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