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From single photon counting to tracking detectors

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Recent advances in semiconductor technology allow constructing highly efficient and low noise pixel detectors of ionizing radiation. Steadily improving performance of front end electronics enables fast digital signal processing in each pixel which enables to register more complete information about each detected quantum (energy, time, number of particles). All these features improve and extend the applicability of pixel technology in different fields.
In most imaging application the pixel detectors are operated in single particle counting mode. In this mode the signal generated by the particle is compared with a certain preselected energy threshold to remove noise and, if higher, it is counted in a digital counter. Such approach provides low noise, energy discrimination and absolutely linear image accumulation. Resulting images have extremely high dynamic range and virtually unlimited contrast which plays an important role in imaging of low contrast objects such as soft tissue structures.
Pixel detectors can be operated also in the so called tracking mode with reduced exposure time having only few particle traces in each frame. The shapes of such traces are characteristic for different particle types. Some pixel detector such as Timepix can measure also the arrival time or energy deposited by the particle in each pixel. Analyzing the shapes of the recorded traces it is possible to collect more information about the passing radiation. For instance it is possible to suppress undesired background caused by particles with differently shaped traces, to improve spatial resolution or to create full energy spectra in each pixel. Using coincident techniques based on time stamping it is possible to derive also other radiation properties such as polarization of X-rays, identification of secondary particles and nuclear reaction or decay products.
Radiation imaging methods can be based or enhanced by particle tracking principles. A few examples will be given such as fully spectroscopic X-ray transmission imaging, neutron and proton radiography with very high spatial resolution and imaging based on ion scattering.
A brief view into the future of pixel detectors and their applications including also spectroscopy, tracking and dosimetry will be given too. Special attention will be paid to the problem of detector segmentation in context of the charge sharing effect.
This work is carried out in frame of the Medipix Collaboration.

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