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Development of a High-rate HV-CMOS Sensor for Real-time Monitoring of a Medical Ion-beam

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Radiotherapy is an important method in treatment of tumors. The most commonly used radiotherapy is X-ray and gamma radiation. More recently, irradiation with heavy ionized particles –such as protons and carbon ions –have been introduced clinically. The source of these particles is a particle accelerator. In contrast to X-ray and gamma radiation, ions and protons deposit energy close to the end of their path, in a small tissue volume (Bragg-peak). By adjusting the beam direction and particle energy, it can be achieved that the largest portion of energy is delivered to the tumor and the healthy tissue in front and behind is less affected.

The present beam monitors are made of gas-filled ionization and multi-wire projection chambers (MWPC) that provide dose, position, and spot size information. We are developing a replacement detector system based on HV-CMOS technology. This technology promises to not only match the current beam monitoring system, but also significantly improve some key parameters: better spatial resolution, smaller integration time, 2-dimensional depiction of the beam spot and operational in a wider beam parameter range. However, the biggest advantage of a solid-state detector over MWPCs is the magnetic field tolerance. A simultaneous operation of magnetic resonance imaging and ion- irradiation allows for aiming at moving tumors deep inside the human body while sparing sensitive organs, like lung, colon or heart.

HV-CMOS is the right choice of technology, since standard monolithic active pixel sensors (MAPS) are not radiation tolerant enough to survive months or even years of continuous in-beam operation, while hybrid detectors exceed the material budget and are inhomogeneous affecting the beam (bumps). We have designed three pixel chips: HitPix1, a small test chip with in-pixel hit-counting electronics. HitPix2 is larger and with improved frontend for highest rates. HitPixInt integrates the deposited charge. All share a frame based read-out and the ability to calculate the projection of the beam profile on-chip. The sensors have been successfully tested at the Heidelberg Ion-Beam Therapy Center (HIT) in a medical beam and in the magnetic field of an MRI-machine. The next step is the construction of a multi-chip detector demonstrator.

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