# T 92: Detectors 8 (semiconductors)

Time: Thursday 16:00–17:45 Location: Geb. 30.23: 2/1

T 92.1 Thu 16:00 Geb. 30.23: 2/1

**A double arm spectrometer for the measurement of energy loss in silicon sensors** — •Laura Bees, Tamasi Kar, and André Schöning — Physikalisches Institut, Ruprecht Karl University, Heidelberg

The aim of the double arm spectrometer is to precisely measure the energy loss of low energy electrons $< 50$MeV in silicon sensors with a resolution of $\ll 1\%$. It is designed such that a charged particle is deflected in two 180° turns in strong magnetic fields with opposite polarity. The detector arms, which each comprise two thin (monolithic) pixel layers, detect the particle's position and direction before entering and after leaving the magnetic field. Located between the two spectrometer arms is the position sensitive device under test (DUT). The energy loss in the DUT can be deduced from the particle's momentum difference measured between the first and second arm. In the talk, results obtained from a Geant4 simulation are presented. Of particular interest is the maximum achievable energy loss resolution and the study of systematic uncertainties from magnetic stray fields and misalignment.

The double arm spectrometer will serve as a high precision instrument to calibrate the energy loss in tracking detectors and for measuring the energy resolution in $\frac{dE}{dx}$ measurements. It can also be used for studying the energy resolution of converted photons in the Mu3e-Gamma experiment, which has been proposed to search for the lepton flavor violating decay $\mu^+ \to e^+ + \gamma(e^+e^-)$ and employs an active silicon converter.

T 92.2 Thu 16:15 Geb. 30.23: 2/1

**Non-linear Response of Silicon Photomultipliers** — •Lukas Brinkmann — University of Hamburg, 22761, Luruper Chaussee 149, Hamburg, Germany

In this talk, a method and novel setup are presented that study the non-linear response of SiPMs under different conditions.

The response function of the SiPM to increasing light intensity was measured. From this response function both the on-set of non-linearity can be determined as well as a correction that expands the dynamic range. An essential part of the correction is that it only depends on the measured SiPM response and does not require a linear light source.

The response function shows no dependence on operating voltage and minor dependence on the temporal distribution of light. For the given Hamamatsu SiPM investigated (S14160-1315PS, pixel pitch 15 $\mu$m, number of pixels 7296), the on-set of linearity was found to be at 15% of the total number of pixels fired, highlighting the limited dynamic range. With the correction function deviation from linearity by 5% occurs once the measured charge is equal to approximately 80% of the total number of pixels having fired.

The method and setup can be used to reliably measure the response function of the studied SiPM and increase the dynamic range by a factor of five.

T 92.3 Thu 16:30 Geb. 30.23: 2/1

**Ultrafast timestamping of charged particles using a digital SiPM** — •Stephan Lachnit[1,2], Inge Diehl[1], Finn Feindt[1], Erika Garutti[2], Karsten Hansen[1], Frauke Poblotzki[1], Daniil Rastorguev[1,3], Simon Spannagel[1], Tomas Vanat[1], and Gianpiero Vignola[1,4] — [1]DESY, Hamburg, Germany — [2]Universität Hamburg, Germany — [3]Bergische Universität Wuppertal, Germany — [4]Universität Bonn, Germany

Silicon Photo-Multipliers (SiPMs) have emerged as crucial semiconductor detectors in the realm of single-photon detection and timing. Traditionally analog devices, SiPMs are now evolving with the integration of digital readout techniques akin to monolithic active pixel sensors. This brings forth new possibilities such as full hitmap readout, pixel masking, and on-chip timestamping. In the context of High Energy Physics, the ultrafast $\mathcal{O}(10\,\text{ps})$ timestamping capabilities of digital SiPMs position them as compelling contenders for 4D tracking applications. However, this requires evaluating the performance of SiPMs in charge particle detection.

At DESY, a digital SiPM has been developed using LFoundry's 150 nm CMOS process. In this contribution, the analysis of data from a testbeam at DESY-II using 4 GeV electrons is shown. A time resolution of $(46 \pm 5)$ ps for the direct detection of electrons at the center of the Single-Photon Avalanche Diode (SPAD) cells has been measured. Variations in response times were observed at the periphery of the SPAD cells.

T 92.4 Thu 16:45 Geb. 30.23: 2/1

**Characterisation and Performance of a Digital SiPM in an 150 nm CMOS Imaging Technology** — •Gianpiero Vignola[1,2], Inge Diehl[1], Karsten Hansen[1], Tomas Vanat[1], Finn Feindt[1], Daniil Rastorguev[1,3], Simon Spannagel[1], and Stephan Lachnit[1,4] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]University of Bonn, Germany — [3]University of Wuppertal, Germany — [4]University of Hamburg, Germany

Silicon Photomultipliers are arrays of Single Photon Avalanche Diodes (SPADs) and represent the most widely used technology in the field of solid state single photon detection nowadays. They are extensively employed in high-energy physics, medical and various commercial applications. Commercial CMOS processes have recently implemented SPADs in process design kits, allowing a low-cost implementation of monolithic SiPMs with customised electronics. Digital SiPMs allow for reduced readout system complexity, because digitization and processing are done on chip. Furthermore, it is possible to implement new features such as single pixel masking and full hit map readout. These features make dSiPMs an attractive technology for applications like optical fibre readout, calorimetry and 4D-tracking of charged particles.

A prototype digital SiPM was developed by DESY using LFoundry 150 nm CMOS imaging technology. In this contribution, the design and functionality of the dSiPM will be presented together with the results of the characterisations performed. Particular attention will be paid to spatial and temporal resolution in MIP detection.

T 92.5 Thu 17:00 Geb. 30.23: 2/1

**Active Transverse Energy Filter Development for KATRIN** — •Kevin Gauda, Sonja Schneidewind, Kyrill Blümer, Christian Gönner, Volker Hannen, Hans-Werner Ortjohann, Sebastian Wein, and Christian Weinheimer for the KATRIN-Collaboration — University of Münster, Institute of Nuclear Physics

The KATRIN experiment aims to measure the neutrino mass via tritium $\beta$-decay spectroscopy. An upper limit of $0.8\,\text{eV/c}^2$ (90% C.L.) was published in 2022 (Nat. Phys. 18, 160-166 (2022)). Despite implementation of efficient countermeasures, we still observe an elevated experimental background (150 mcps instead of 10 mcps), which needs to be reduced to reach the targeted sensitivity of $0.2\,\text{eV/c}^2$. Radioactive decays in the stainless steel vessel of the main spectrometer produce highly-excited Rydberg or autoionizing atomic states in the volume. These release low-energetic electrons, which are energetically indistinguishable from $\beta$-electrons at the detector. Their angular distribution, however, is significantly sharper. The "active Transverse Energy Filter" (aTEF) concept was invented to reduce this background by discrimination of electrons in a large magnetic field based on their pitch angle (EPJ-C 82, 922 (2022)).

This talk will introduce the "Si-aTEF" as a concept based on Si-PIN diodes. The fabrication process, prototype performance, and measures against leakage current from surface damage will be presented. The implementation of the Si-aTEF in KATRIN – success supposed – and the expected sensitivity improvement will be shown. This work is supported by BMBF under contract number 05A23PMA.

T 92.6 Thu 17:15 Geb. 30.23: 2/1

**Determination of the impurity density profile of a large-volume germanium detector** — •Felix Hagemann[1], Iris Abt[1], Arthur Butorev[2], David Hervas Aguilar[1], Johanna Lührs[1], Julia Penner[1], and Oliver Schulz[1] — [1]Max-Planck-Institut für Physik, Garching — [2]Technische Universität München

Over the past four years, a novel experimental setup has been built, commissioned and operated at the Max-Planck-Institute for Physics in Munich to characterize the bulk of germanium detectors via Compton scattering. In this fully automated setup, a detector is irradiated with a collimated beam of 661.66 keV gammas from a $^{137}$Cs source. A part of these gammas Compton scatter in the germanium detector and are detected by pixelated cameras placed nearby, allowing to reconstruct their interaction point in the detector.

Compton imaging the undepleted volume when operated below its depletion voltage gives access to the real impurity density profile of the detector. The obtained impurity density profile is reproduced independently using capacitance measurements. The results shows that only impurity density profiles with a radial dependence can realistically capture the observations.

T 92.7 Thu 17:30 Geb. 30.23: 2/1

**A HV-CMOS sensor based beam monitoring system for therapeutic ion beams** — •Bogdan Topko[1], Matthias Balzer[2], Alexander Dierlamm[1,2], Felix Ehrler[2], Ulrich Husemann[1], Pietro Marchesi[1], Ivan Perić[2], and Hui Zhang[2] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Institute for Data Processing and Electronics (IPE), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Therapeutic ion beams for cancer treatment have significant benefits over photon irradiation. The Bragg peak of ion energy deposition and accurate control of the beam position and size via the beam delivery system enable the largest amount of energy to be deposited into the tumor with the least amount of damage to healthy tissue. In this approach the beam monitoring system is needed to deliver doses to the tumor in an efficient and safe manner. The presented studies are focused on the development of a beam monitoring system based on HV-CMOS sensors. The beam position, shape and fluence should be provided by the system in real time. The system should be tolerant to the magnetic fields and vibrations for the MRI-guided ion beam therapy application. The HV-CMOS HitPix sensor family with counting electronics and frame based readout has been developed at the ASIC and Detector Lab (IPE, KIT) to fulfill these requirements. Recent results of ion beam measurements and a beam monitor demonstrator are presented.