GridPix detectors are micro Time Projection Chambers (μTPCs) with a pixel chip as readout anode. It measured a 3D position of single electrons created by ionizing particles (Fig. 1, left). The TimePix chip was developed at CERN and is based on the Medipix2 design. It has 256×256 square pixels with a 55 μm pitch. Each individual element of the pixelmatrix is connected to a preamplifier, discriminator and digital counter integrated on the chip. The digital counter can either be used to measure the drift time in Time to Threshold (ToT) or the time over Threshold (ToT) of the signal.

Simultaneously, which allows doing a correction on the time to threshold. µσ of 22 ns [4]. For comparison the drift velocity in Argon/Isobutane (80:20) is 50 m/ns.

The simulated spectrum for electrons with zero drift distance has an average delay of about 25 ns with a sigma of 22 ns [4]. For comparison the drift velocity in Argon/Isobutane (80:20) is 50 m/ns. The time to threshold resolution is dominated by time walk effects. Figure 3 shows the Time over Threshold spectrum without correction as measured with Gossipo3 (right).

Time Walk Correction

The time to threshold resolution is dominated by time walk effects. Figure 3 (left) shows that the simulated spectrum for electrons with zero drift distance has an average delay of about 25 ns with a sigma of 22 ns [4]. For comparison the drift velocity in Argon/Isobutane (80:20) is 50 m/ns. The next generation TimePix (currently under development) is capable of measuring both TtoT and ToT simultaneously, which allows doing a correction on the time to threshold.

Gossipo3 is a single pixel prototype chip with a 560 MHz oscillator developed by Nikhef and Bonn University to test the most important structures for doing high resolution time measurements. It is able to measure both TtoT and TtT simultaneously. Gossipo3 is used to verify the simulated resolution after time walk correction. The Time to Threshold (ToT) spectrum without correction is shown by Fig. 2 (left). The ToT spectrum without correction, the error reduces by a factor 3. The simulated ToT spectrum with correction (left), with correction (right). The error reduces by a factor 3.

Fig. 4: Time to threshold spectrum measured by Gossipo3 without correction (left), time to threshold spectrum with correction as measured by Gossipo3 (right). The error reduces by a factor 7.

False Hit Identification

GridPix beam telescope (Fig. 6) measurement performed in the SPS beam at CERN gave insight into time walk at different amplification fields, the measured times for different amplification fields is shown by Fig. 7 (left). Time walk is the dominant error in time measurements with small signals with TimePix. Small signals occur either when the charge in the avalanche is small or low amplification fields or when a large avalanche of an adjacent pixel induces a signal on the incident pixel at high amplification fields (∼124 kV/cm), giving rise to false hits (Fig. 7 right).

Fig. 5: Left: a SEM image of a 8 μm thick SiRN layer on top of a pixel. Right: gain as function of the grid voltage for different Fe-55 conversion events rates.

Gossipo3 is a single pixel prototype chip with a 560 MHz oscillator developed by Nikhef and Bonn University to test the most important structures for doing high resolution time measurements. It is able to measure both TtoT and TtT simultaneously. Gossipo3 is used to verify the simulated resolution after time walk correction. The Time to Threshold (ToT) spectrum without correction is shown by Fig. 2 (left). The ToT spectrum without correction, the error reduces by a factor 3. The difference with the simulated error reduction can be explained by less electronic noise, e.g. 70 electrons in simulations to 25 electrons in Gossipo3. In addition Gossipo3 failed to record small signals.

Fig. 3: Simulated TtoT spectrum without correction (left), with correction (right). The error reduces by a factor 3.

Since the bare TimePix chip is not able to measure single electrons, a grid is placed on 50 μm thick aluminum with holes etched in it. Between the grid and the chip the electric field (∼103 V/cm) is large enough to create avalanches, to generate enough charge to be measured by the chip. A SiRN protection layer is deposited on the pixels to avoid damage from discharges. The individual ionisation electrons are focused into the grid-holes. The electron drift time is measured by an internal counter started by an external trigger to obtain an absolute time measurement.

Fig. 2: Time to threshold as function of time over threshold, as measured with Gossipo3 (right).

References


SiRN Protection layer

A Silicon Nitride (SiRN) protection layer (Fig. 5, left) quenches lethal discharges, resulting in a limited charge on each pixel. The SiRN layer should be slightly conductive in order to avoid charge up effects. The resistance of the SiRN layer is measured by observing the gain reduction as function of the grid voltage for different Fe-55 conversion event rates [4]. From Fig. 5 (right) the resistance of the SiRN layer is calculated to be ∼1010 Ω cm.

Fig. 5: Left: a SEM image of a 8 μm thick SiRN layer on top of a pixel. Right: gain as function of the grid voltage for different event rates.

GridPix for Proton Therapy

In external beam radiotherapy it is of crucial importance that most of the energy of the incident particle is absorbed in the tumour. The energy absorbed in the tumour is a function of the proton energy. Densities along the proton path might be calculated with X-ray CT information. The combination of this information and proton beam transmission data is under study. Fig. 9 represents a setup with two GridPix detectors that are used to reconstruct 3D tracks of the passing protons and a calorimeter that measures the final energy of the passing protons. Because of the low mass, GridPix detectors hardly influence the proton path. The first GridPix detector will serve as a beam monitor during irradiation.

Fig. 9: Proton therapy setup, the Phantom is simulating a human body, two GridPixes are used for tracking, a calorimeter measures the energy for calibration.