High Precision Measurements of Track-segments of Ionising Particles with GridPix Detectors

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Detector R&D

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Concept: TPC

Gaseous Time Projection Chambers:

- Charged particles ionise the gas
- Electrons drift to electrode (X,Y)
- Drift time $\times$ drift velocity gives (Z)
- Fit through all (X,Y,Z) reconstructs track segment
- Usually: huge (meters)
Concept: TPC

Gaseous Time Projection Chambers:

- Charged particles ionise the gas
- Electrons drift to electrode (X,Y)
- Drift time $\times$ drift velocity gives (Z)
- Fit through all (X,Y,Z) reconstructs track segment
- Usually: huge (meters) in the past!
- GridPix detectors can be 1000 times smaller!
### Concept: GridPix TPC

- Driftgap is meters-millimeters
- TimePix chip, $256 \times 256$ pixels
- $55 \, \mu m$ pitch
- Pixel: 10 ns time resolution

- The crucial part: the grid
- Electrons drift through the grid
- In between the grid and the chip, the field is large (100 kV/cm)
- Multiplication takes place, signal is measured by pixel measures individual electrons!
GridPix

- Right: SEM picture from the chip with a grid

Some example measurements:
- Sr-90 decay in B field (right), $\pi$-cathode interaction (left)

1.4 cm
My Work: GridPix Performance Studies

- Analysis: resolution, efficiency
- Tested: 3 GridPixes (1 mm gas layer) in the SPS accelerator at CERN, tilted 45°
- Analysis is ongoing; some results are shown in the next slides
Track Position Resolution is function of:

- ionisation number $\sim 5 \text{ mm}^{-1}$
- electron diffusion $\sim 2 \times 10^{-2} \frac{\text{mm}}{\sqrt{\text{mm}}}$
- clock cycle $\times$ drift velocity $\sim 0.01 \text{ mm}$
- timewalk $\times$ drift velocity $\sim 0.13 \text{ mm}$
- pixel pitch $\sim 5.5 \times 10^{-2} \text{ mm}$

Diffusion and drift velocity; function of the Electric field.
Timewalk; function of the charge on pixel

Resolutions can be adjusted by:
- chip specs (see next talk, F. Zappon)
- gas choice: CO$_2$/DME (50:50)
Track Position Resolution

Position Resolution for a GridPix (1 mm gas layer)

Data: resolution measured by itself

From FWHM: $\sigma = 10 \text{ um}$

Data: resolution measured from reference

After extrap. correction $\sigma = 10 \text{ um}$
Track Position Resolution

Position Resolution for a GridPix (1 mm gas layer)

Simulated resolution agrees with measurements

Data: resolution measured by itself

From FWHM: \( \sigma = 10 \text{ um} \)

Data: resolution measured from reference

After extrap. correction \( \sigma = 10 \text{ um} \)
The number of ionisations is poisson distributed
The probability of 0 electrons is the inefficiency
From below the detection efficiency is estimated
>98%
Conclusion:

- The position resolution agrees with simulations
- The efficiency is as expected from simulations

Outlook:

- The DAQ readout frequency is improved by factor 30
- New beam tests are planned for this spring
- A laser setup is being finished to investigate gas properties
- A step to mass production is taken (8” wafers) because of high demands
GridPix is being investigated for usage in dual phase dark matter experiments (right); see poster P07.13 (Rolf Schön)

GridPix in proton therapy (bottom); data taken @ KVI Groningen, analysis ongoing.
Acknowledgements

- Bonn University: Y. Bilevych
- KVI Groningen
Backup Slides (discharges)
Backup Slides (timewalk)
Backup Slides (gas)

Drift velocity vs E
Gas: CO$_2$ 50%, DME 50%, T=900 K, p=0.98692 atm

Diffusion coefficients vs E
Gas: CO$_2$ 50%, DME 50%, T=900 K, p=0.98692 atm

Along Z
Along XY