Development of a GridPix X-ray polarimeter

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GRIDPIX DETECTOR

Combination of Timepix-ASIC and integrated gas amplification stage (InGrid)

256 x 256 pixels (each 55 µm x 55 µm)

Single electron detection possible
Electric field vector:

$$\vec{E}(z, t) = \epsilon_x e_x \cdot \cos(kz - \omega t) + \epsilon_y e_y \cdot \cos(kz - \omega t + \phi)$$

Linear polarization:  Circular polarization:  Elliptical polarization:
Photon interacts with the gas via photo effect

Direction of the photoelectron is correlated with E-field direction ($\cos^2$-distribution)
Photon interacts with the gas via photo effect

Direction of the photoelectron is correlated with E-field direction (cos²-distribution)

Photoelectron further ionizes the gas

Electrons und ions are separated by an electric field

Diffusion of electrons during drift towards the readout

Amplification of electrons and collection of the avalanches
X-RAY POLARIMETRY IN GASEOUS DETECTORS
PHOTOELECTRON TRACKS

Distance to first scattering - He/DME 80/20

Distance to first scattering - He/DME 40/60

Degrad simulation

Photon energy [keV]
X-RAY POLARIMETRY IN GASEOUS DETECTORS

Degrad simulation

Degrad simulation
X-RAY POLARIMETRY IN GASEOUS DETECTORS

Garfield++ simulation

Garfield++ simulation
1. Get linear fit (including pixel charge)
2. Get skewness of charge distribution
3. Split at center of charge
4. Linear fit of first part
5. Fit of angular distribution ($\cos^2$)
PRELIMINARY RESULTS – HE/DME

11.0 keV – 1.50 bar

He/DME 80/20

\begin{itemize}
\item \( \chi^2 / \text{ndf} = 117.99 / 97 \)
\item \( \text{Modulation factor} = (50.54 \pm 1.09) \% \)
\item \( \text{Amplitude} = 82.59 \pm 2.51 \)
\item \( \text{Polarisation plane} = 0.02 \pm 0.01 \)
\end{itemize}
PRELIMINARY RESULTS

\[ \chi^2 / \text{ndf} = 205.69 / 121 \]

- Modulation factor: \((77.30 \pm 2.28\%)\)
- Amplitude: \(17.69 \pm 0.78\)
- Polarisation plane: \(0.02 \pm 0.02\)
**TIMEPIX3**

<table>
<thead>
<tr>
<th>Developed by</th>
<th>Medipix Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel size</td>
<td>(55 x 55) µm</td>
</tr>
<tr>
<td>Pixel matrix</td>
<td>256 x 256</td>
</tr>
<tr>
<td>Time of Arrival (ToA)</td>
<td>14 + 4 Bits (1.56 ns)</td>
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<tr>
<td>Time over Threshold (ToT)</td>
<td>10 Bits</td>
</tr>
<tr>
<td>Modes</td>
<td>ToT &amp; ToA /</td>
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<tr>
<td></td>
<td>Hit Counter &amp; iTot /</td>
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<tr>
<td></td>
<td>Only ToA</td>
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<tr>
<td>Readout</td>
<td>Data driven /</td>
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<tr>
<td></td>
<td>Sequential</td>
</tr>
</tbody>
</table>
TIMEPIX3 GRIDPIX DETECTOR

- Cathode with window
- Andode
- Drift volume
- Carrier board with GridPix
- Intermediate board
TIMEPIX3 GRIDPIX DETECTOR
SUMMARY

- Timepix based detector operated and tested in testbeams
- Achieved modulation factors of up to 78%
- Improvements for detector and analysis in the future
- Timepix3 based detector in preparation
Thank you for your attention
WHY X-RAY POLARIMETRY

- Material science:
  - Investigation of magnetic properties of several samples (single crystals, thin films, powders)
  - Probe changes of magnetic properties as function of pressure
- Astronomy:
  - Study of the magnetic field configuration in magnetars
  - Study of X-Ray emission mechanism and geometry of AGNs and pulsars
GAS CHOICE

Wishlist:

- Good photon detection efficiency
- Long photoelectron tracks
- Low multiple scattering
- Low diffusion
- Reasonable gas gain

Transverse diffusion:
- $256 \, \mu m/\sqrt{cm} @ 0.5 \, bar$
- $177 \, \mu m/\sqrt{cm} @ 1.0 \, bar$
- $146 \, \mu m/\sqrt{cm} @ 1.5 \, bar$
1.0 bar, 2 cm driftzylinder, 0.3 μm silicon nitride window

1.0 bar, 2 cm driftzylinder, 20 μm Al window
ABSORPTION OF PHOTONS - GAS
ABSORPTION OF PHOTONS - PRESSURE

1.0 bar, 2 cm driftzylinder, 0.3 μm silicon nitride window

1.5 bar, 2 cm driftzylinder, 0.3 μm silicon nitride window
ABSORPTION OF PHOTONS - DRIFTLENGTH

1.0 bar, 2 cm drift cylinder, 0.3 μm silicon nitride window

1.0 bar, 5 cm drift cylinder, 0.3 μm silicon nitride window
DIFFUSION – DRIFT LENGTH

He/DME 80/20

Mean free path [cm]

Energy [keV]

1.0 bar

1.5 bar
TIMEPIX3 READOUT

- Data driven Timepix3 readout
- Same Hardware concept as for Timepix readout:
  - Python software based on basil framework
  - Modular approach
  - Hitrate: 85 Mhits/s (One Timepix3)
    max. 15 Mhits/s with SRS