UNIVERSITÄT BONN

Gas Det Bonn

# Development of a GridPix X-ray polarimeter

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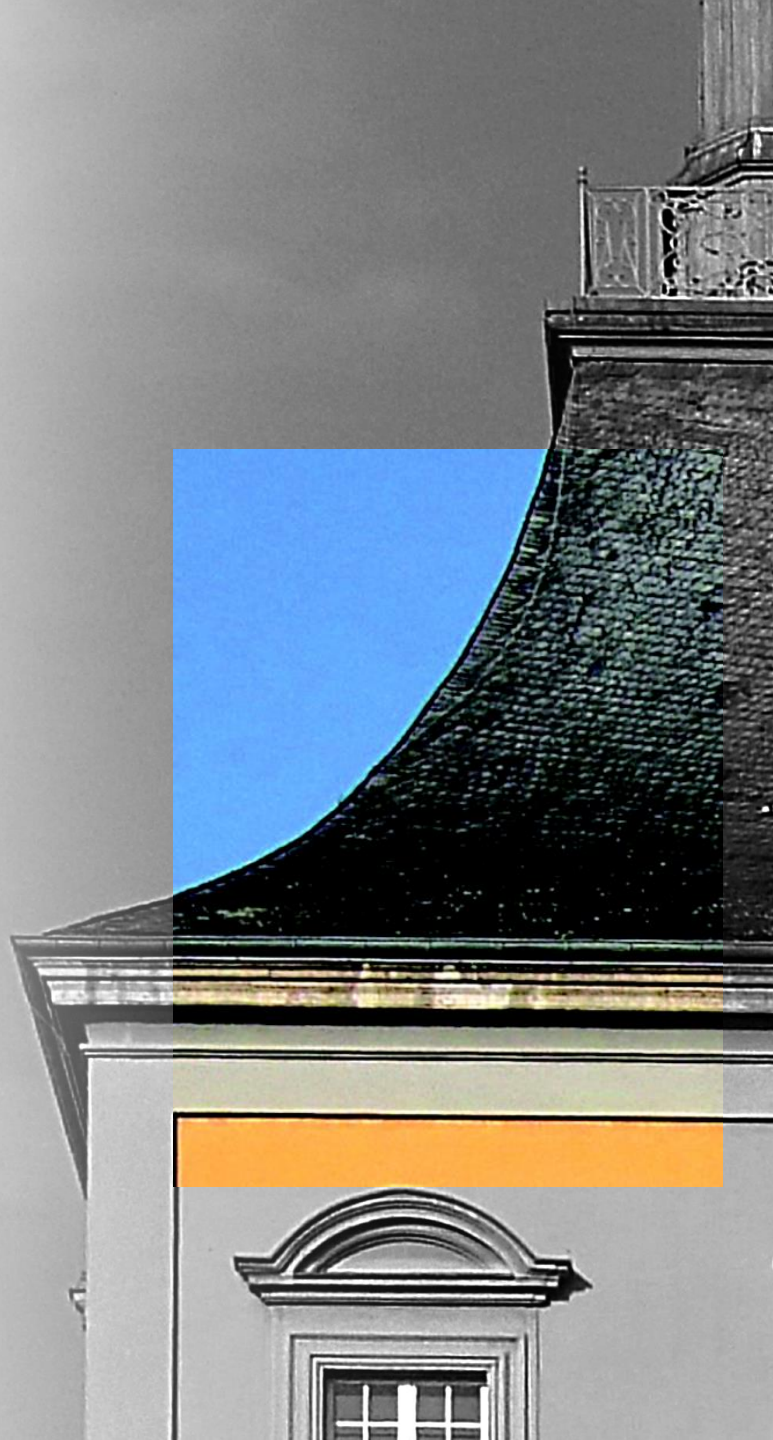
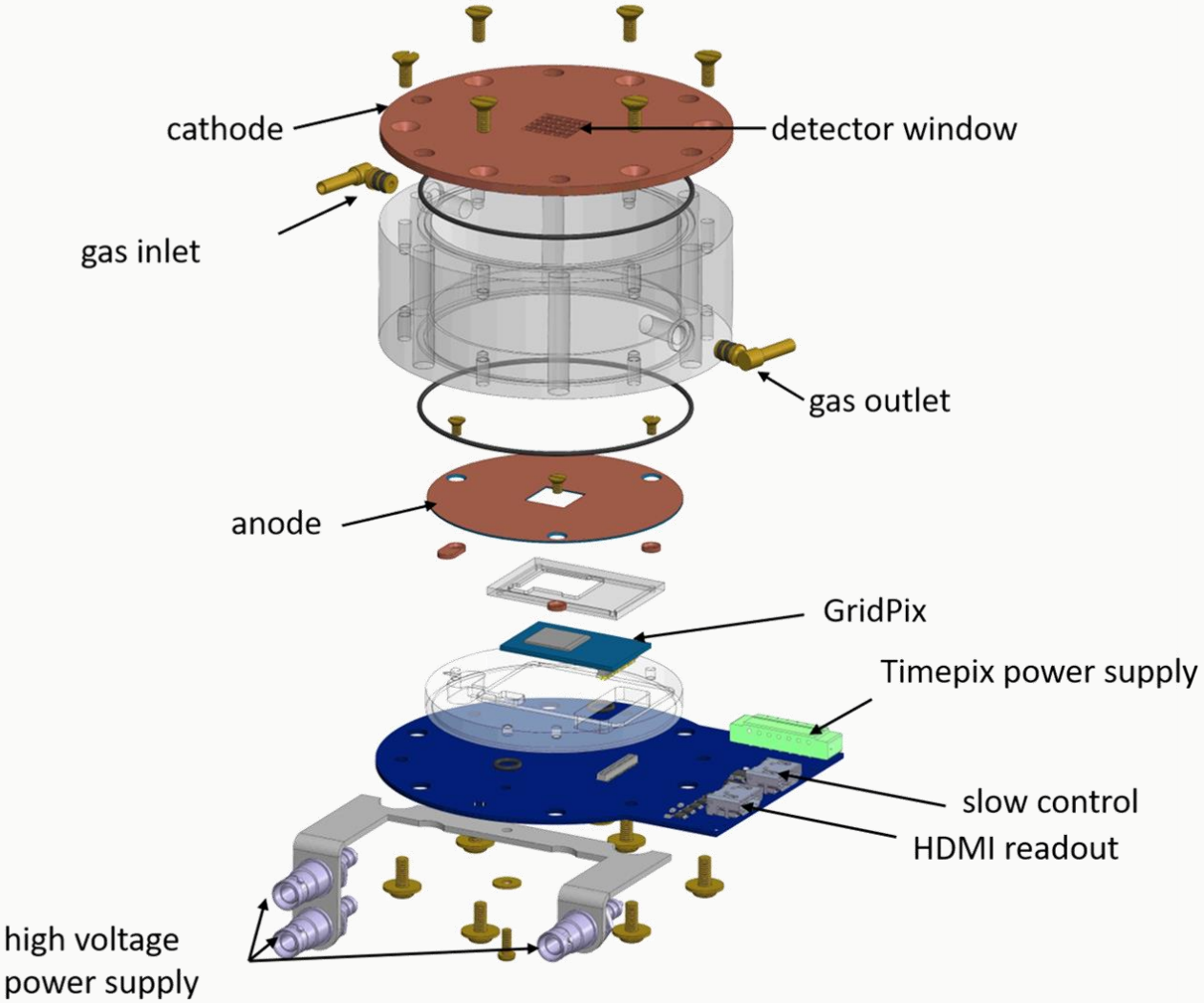
TIPP 2021

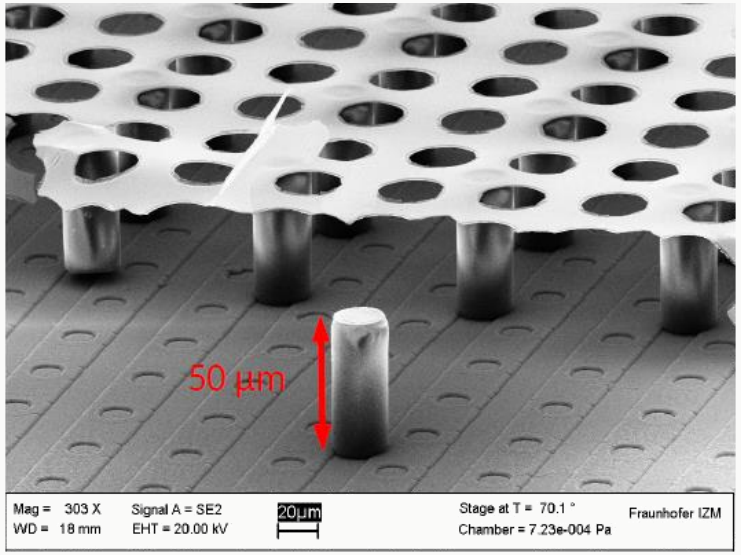
GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung



# GRIDPIX DETECTOR




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

256 x 256 pixels (each 55 µm x 55 µm)

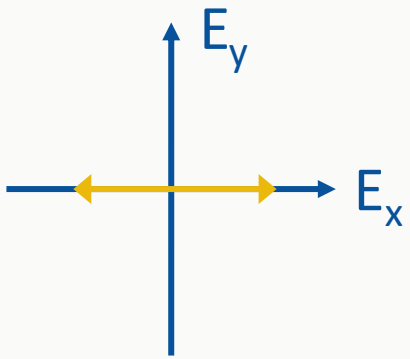
Single electron detection possible

# X-RAY POLARIZATION BASICS

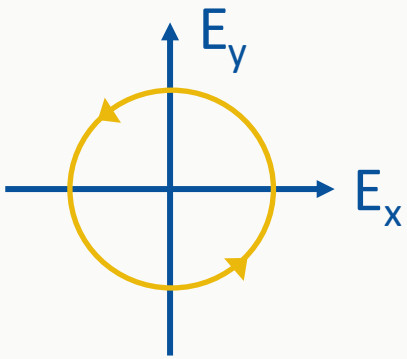
## Electric field vector:

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

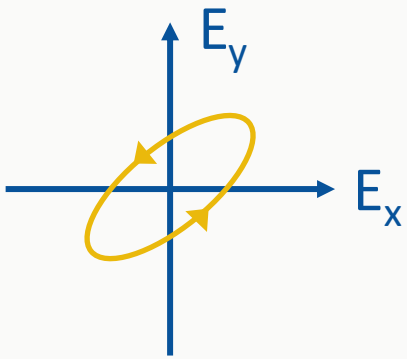
## Linear polarization:



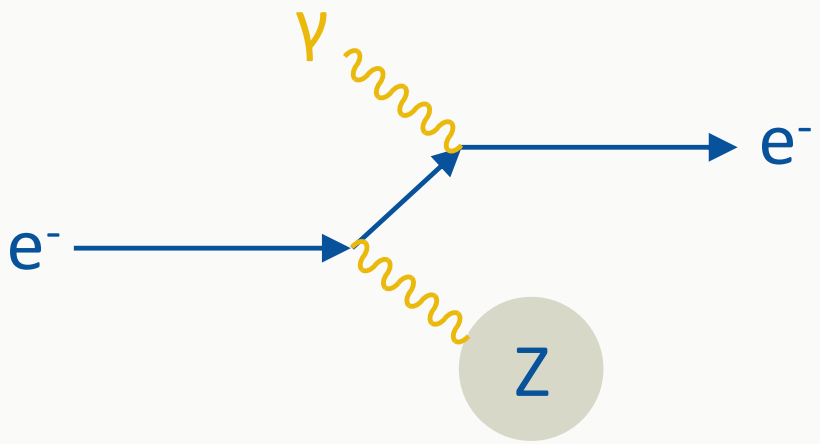

## Circular polarization:




## Elliptical polarization:

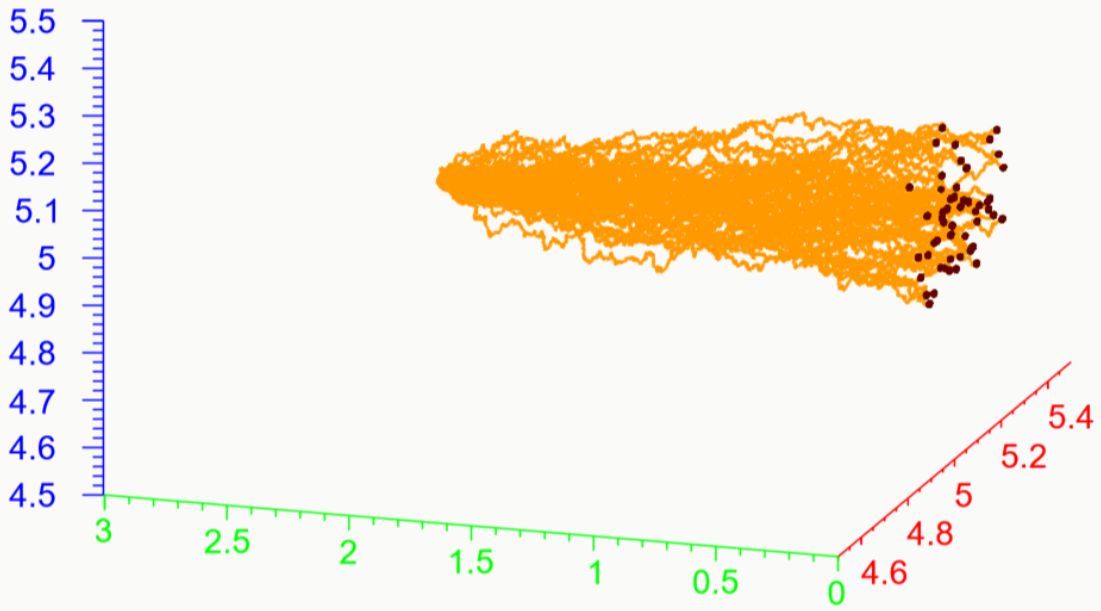


# X-RAY POLARIMETRY IN GASEOUS DETECTORS



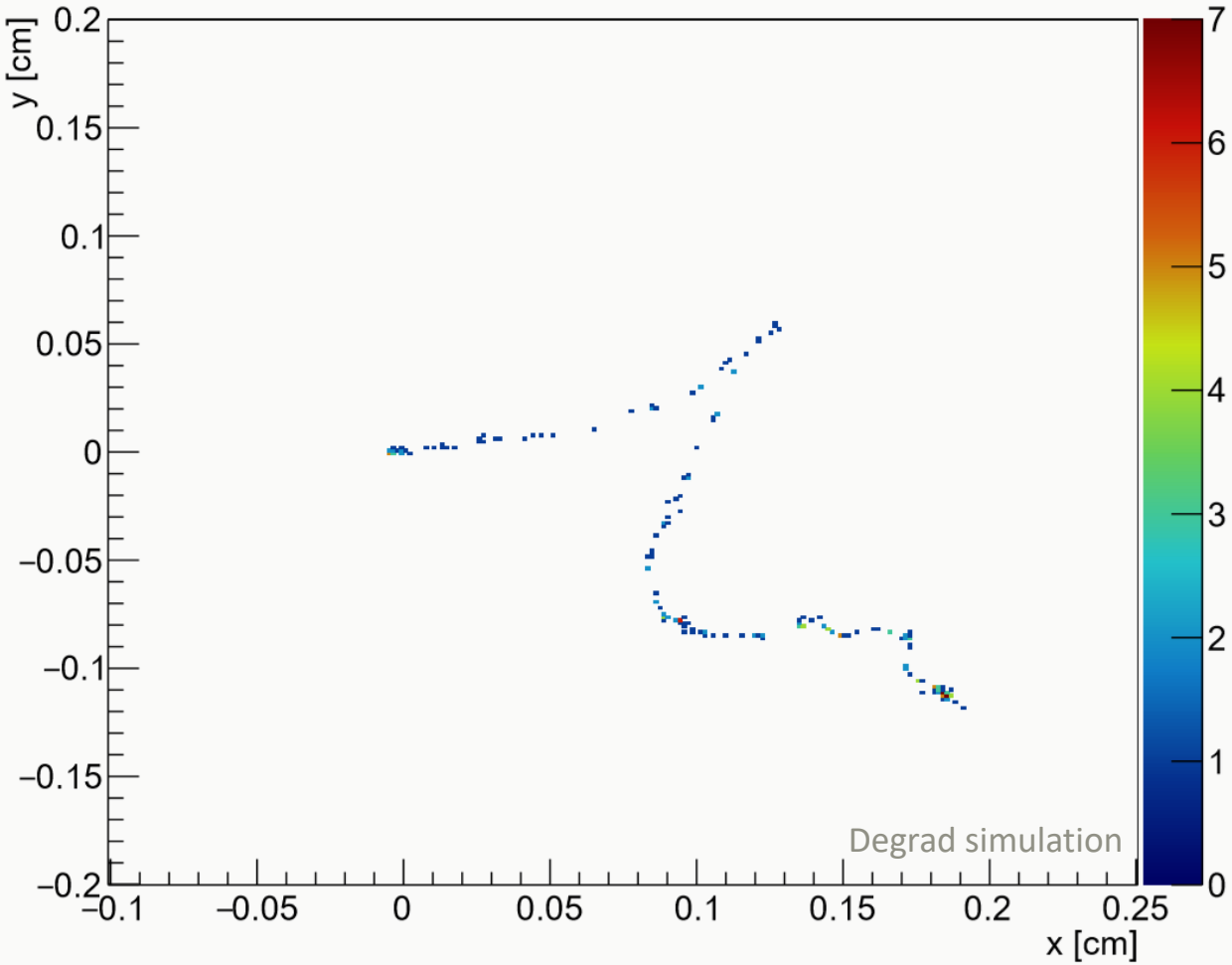

- Photon interacts with the gas via photo effect
- Direction of the photoelectron is correlated with E-field direction ($\cos^2$-distribution)

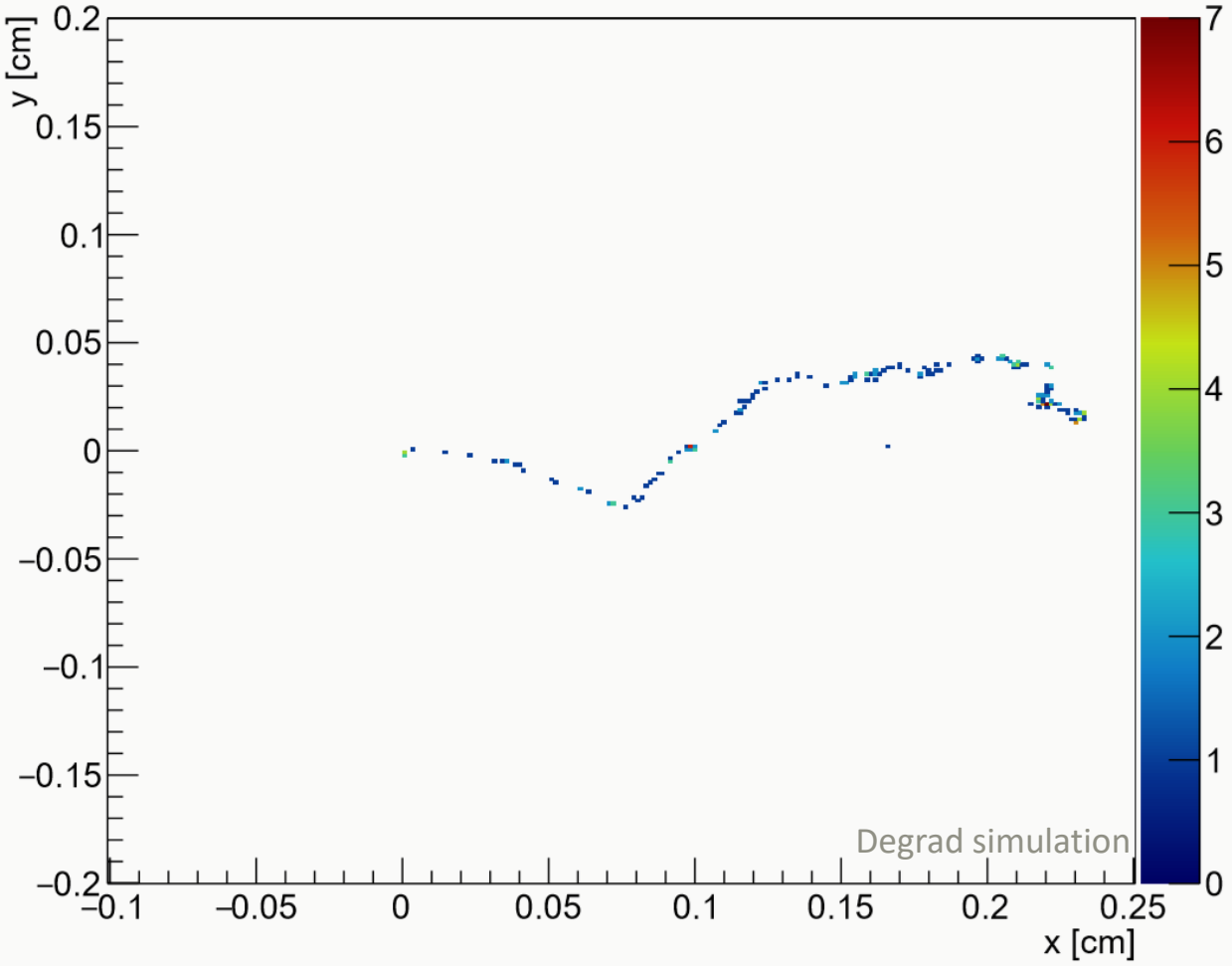
# X-RAY POLARIMETRY IN GASEOUS DETECTORS



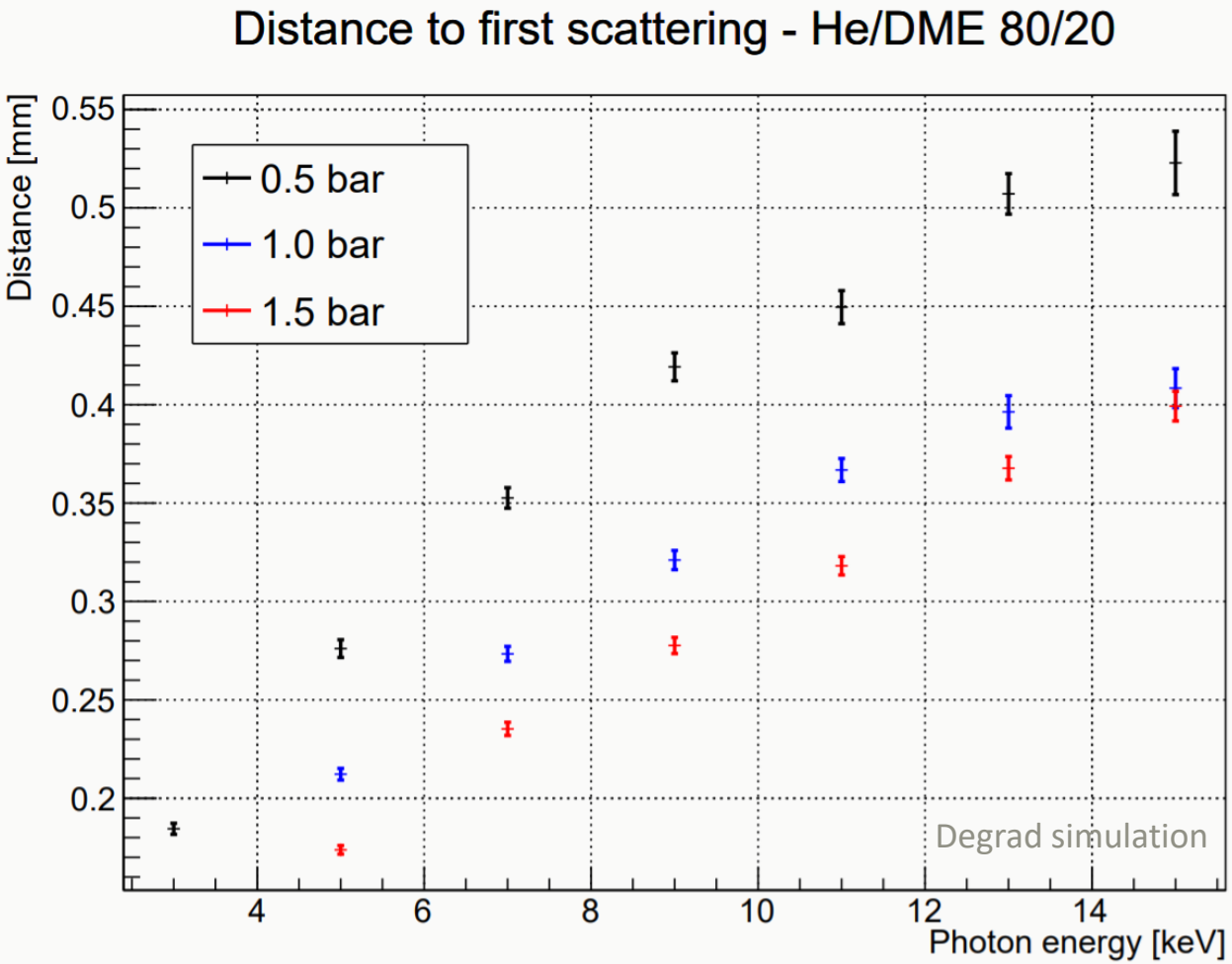

- Photon interacts with the gas via photo effect
- Direction of the photoelectron is correlated with E-field direction ($\cos^2$-distribution)
- Photoelectron further ionizes the gas
- Electrons und ions are separated by an electric field
- Diffusion of electrons during drift towards the readout
- Amplification of electrons and collection of the avalanches

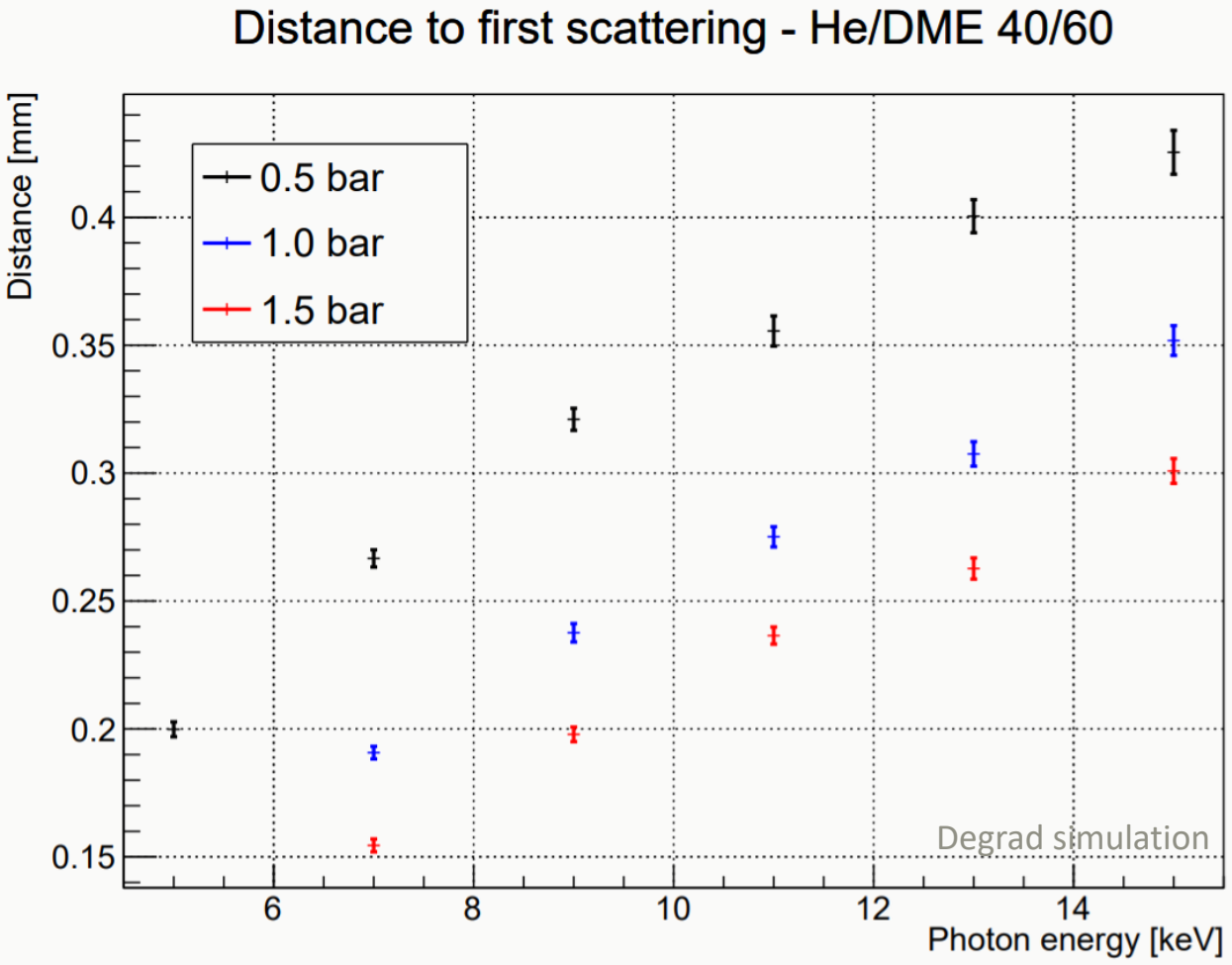
# X-RAY POLARIMETRY IN GASEOUS DETECTORS



# PHOTOELECTRON TRACKS



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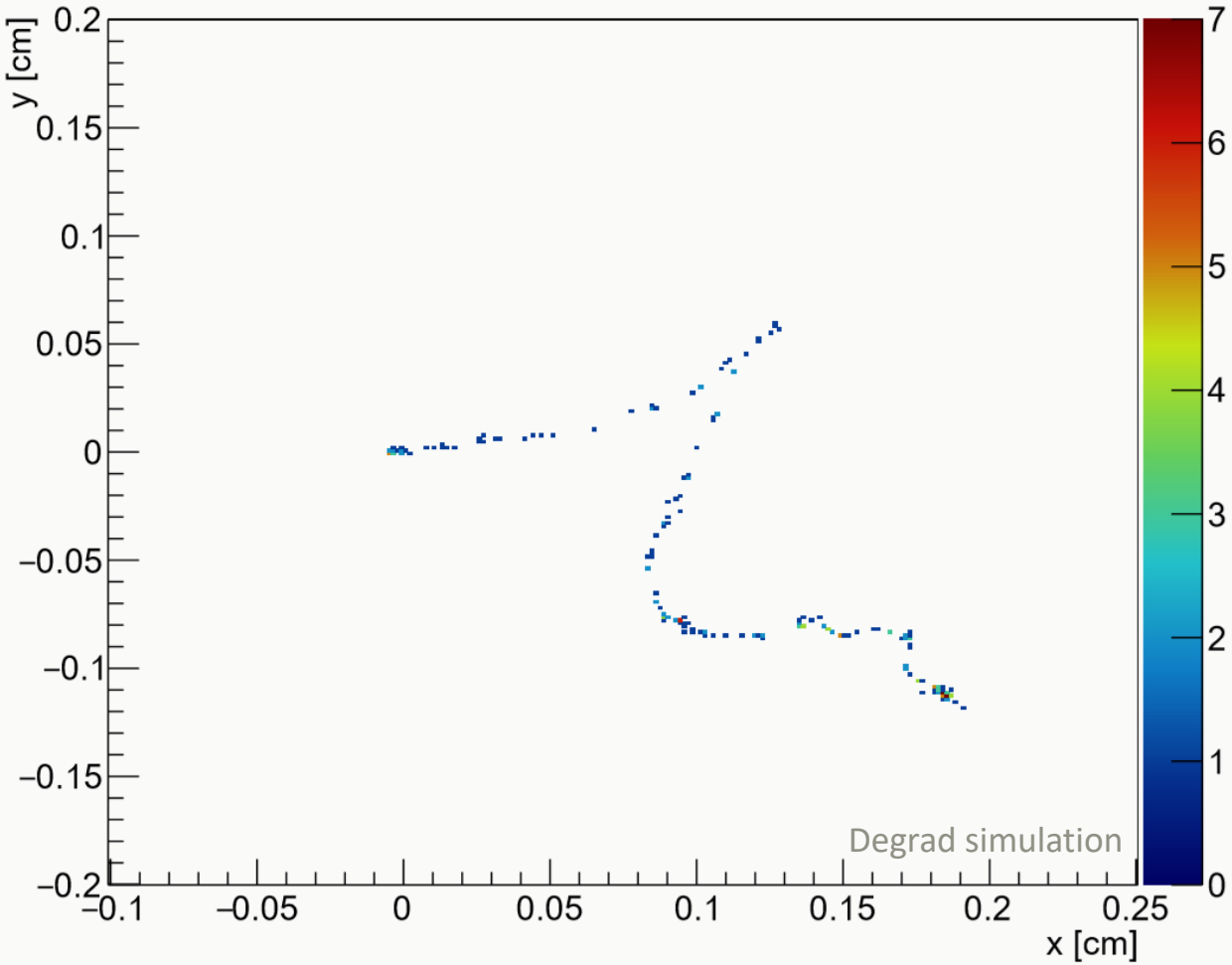
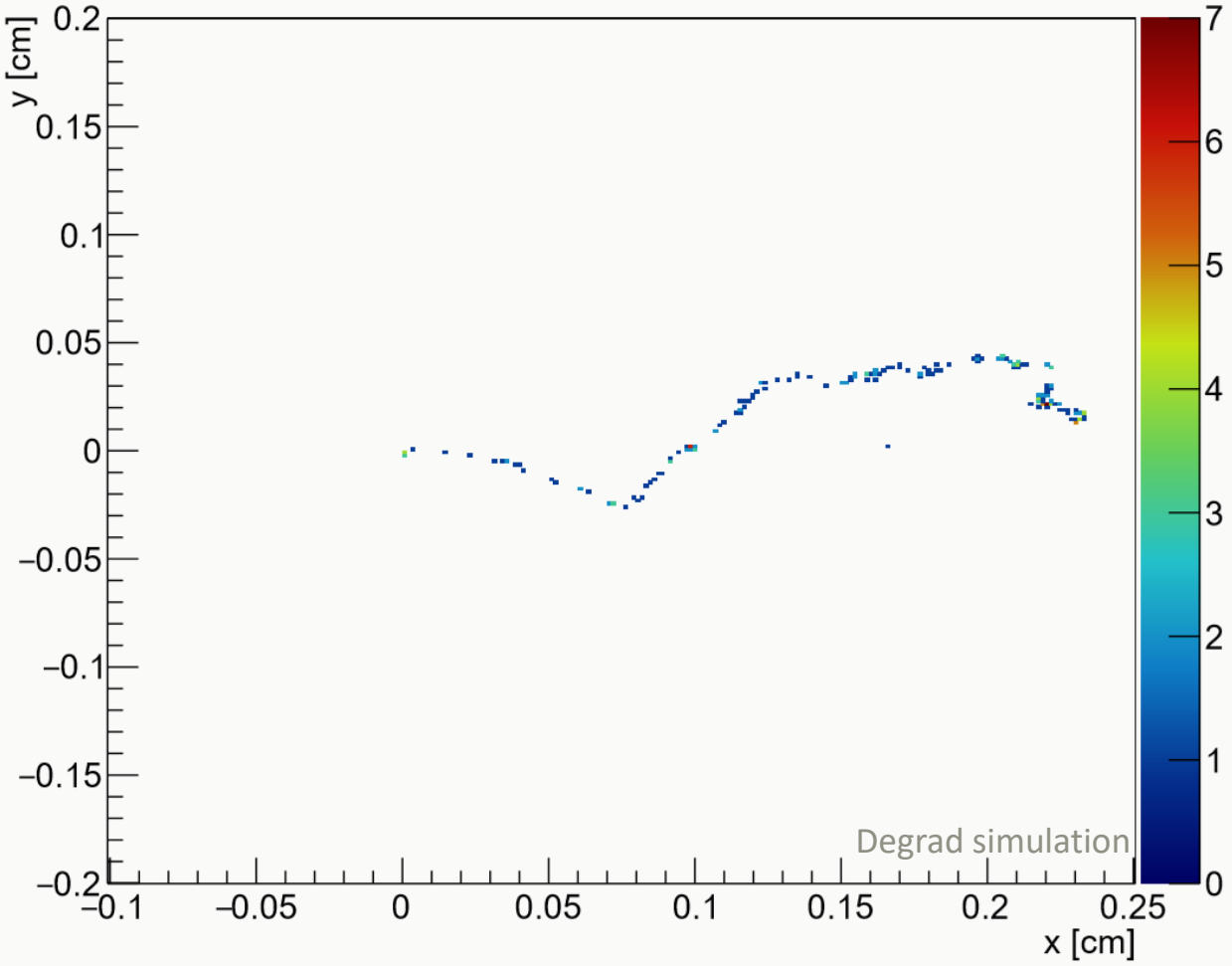
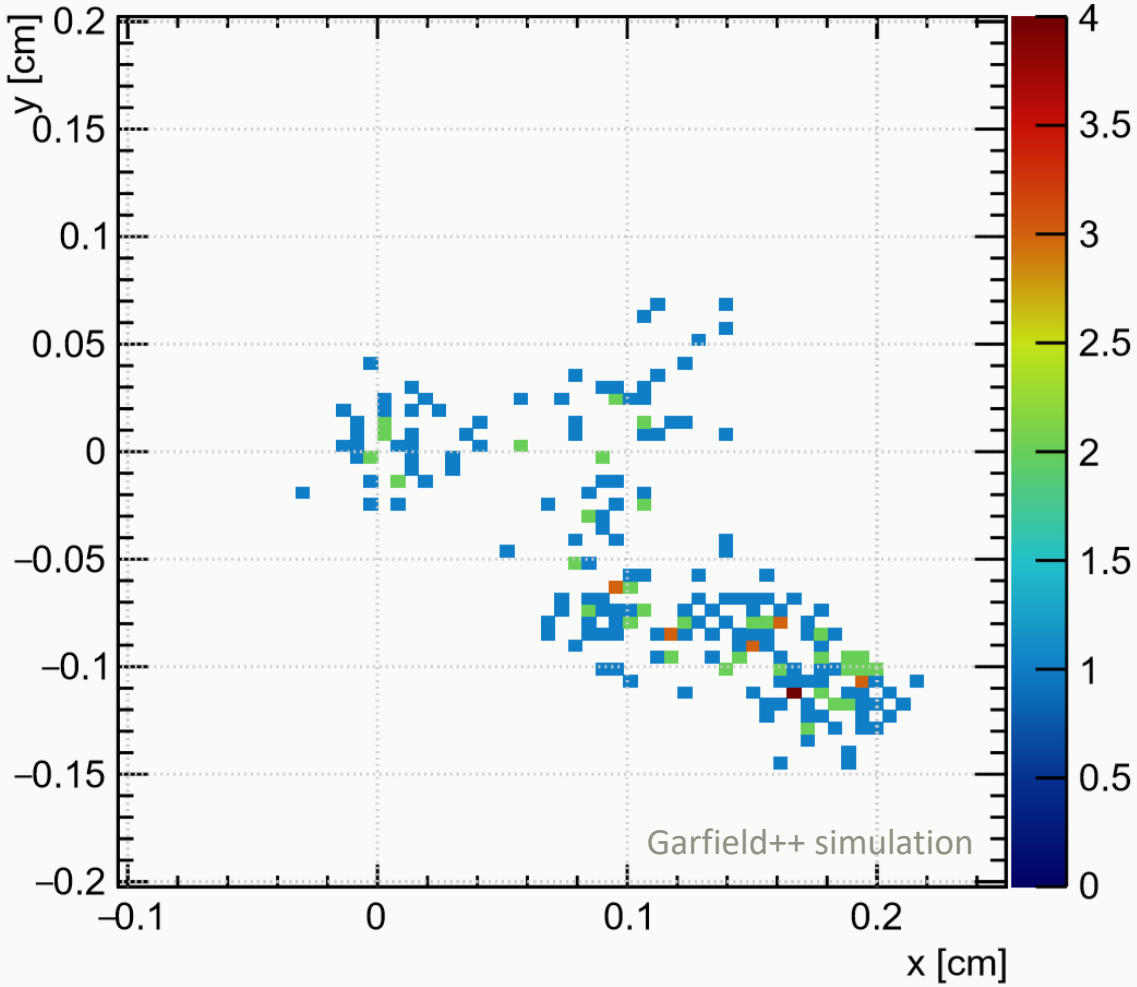
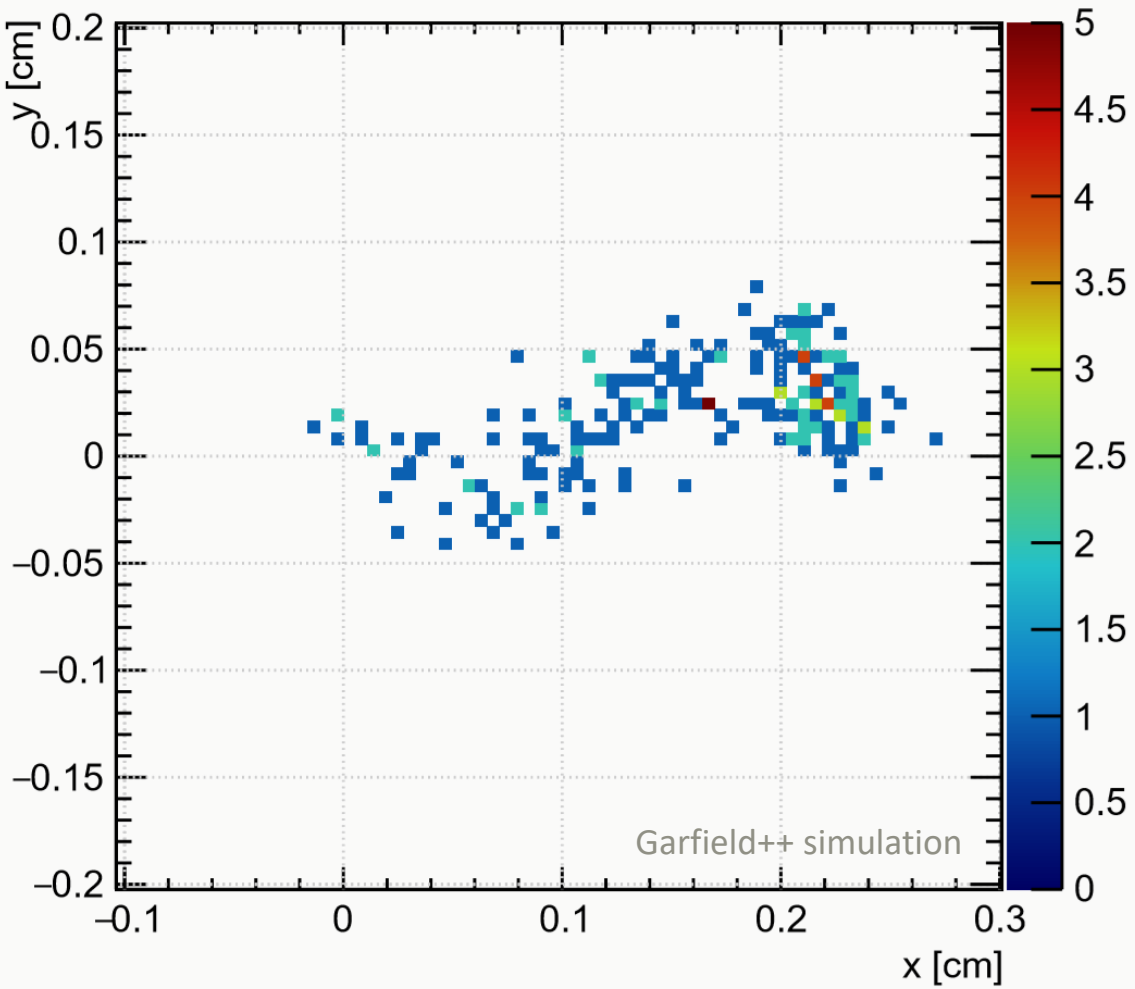


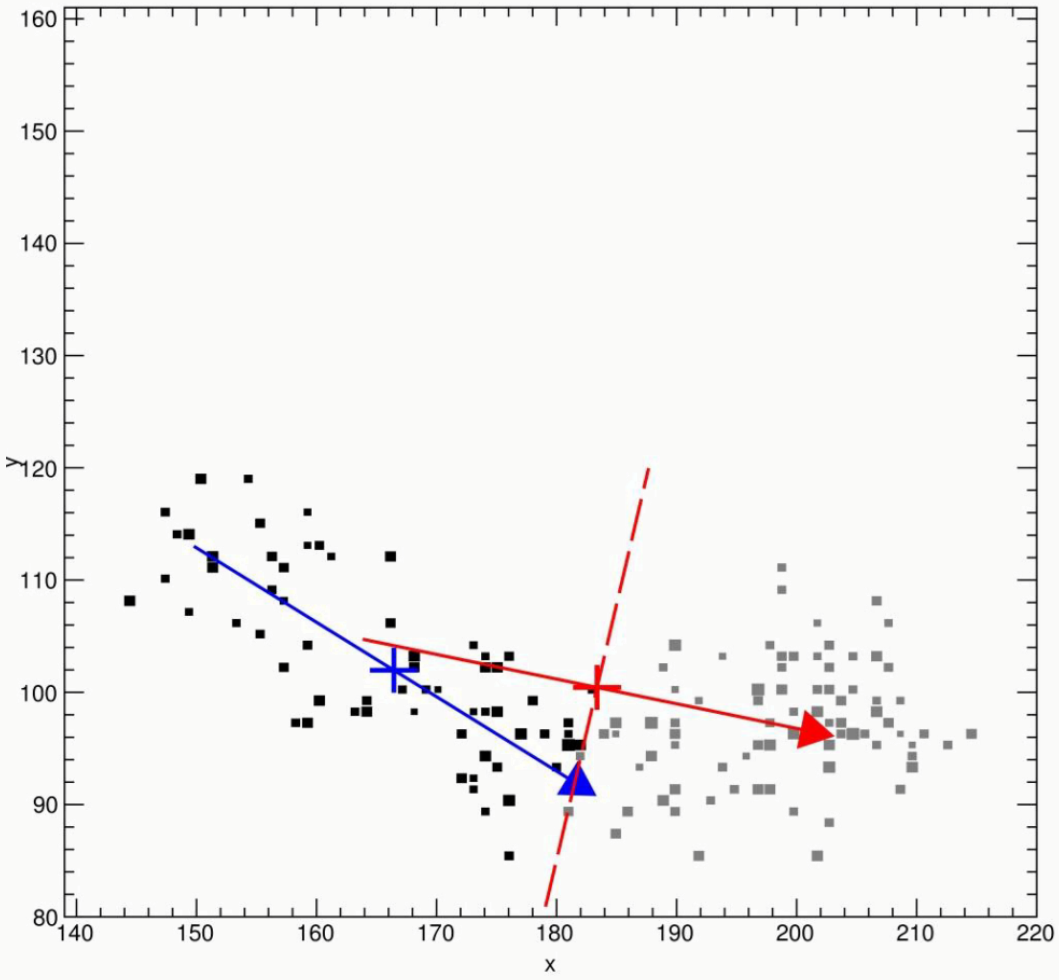
# X-RAY POLARIMETRY IN GASEOUS DETECTORS



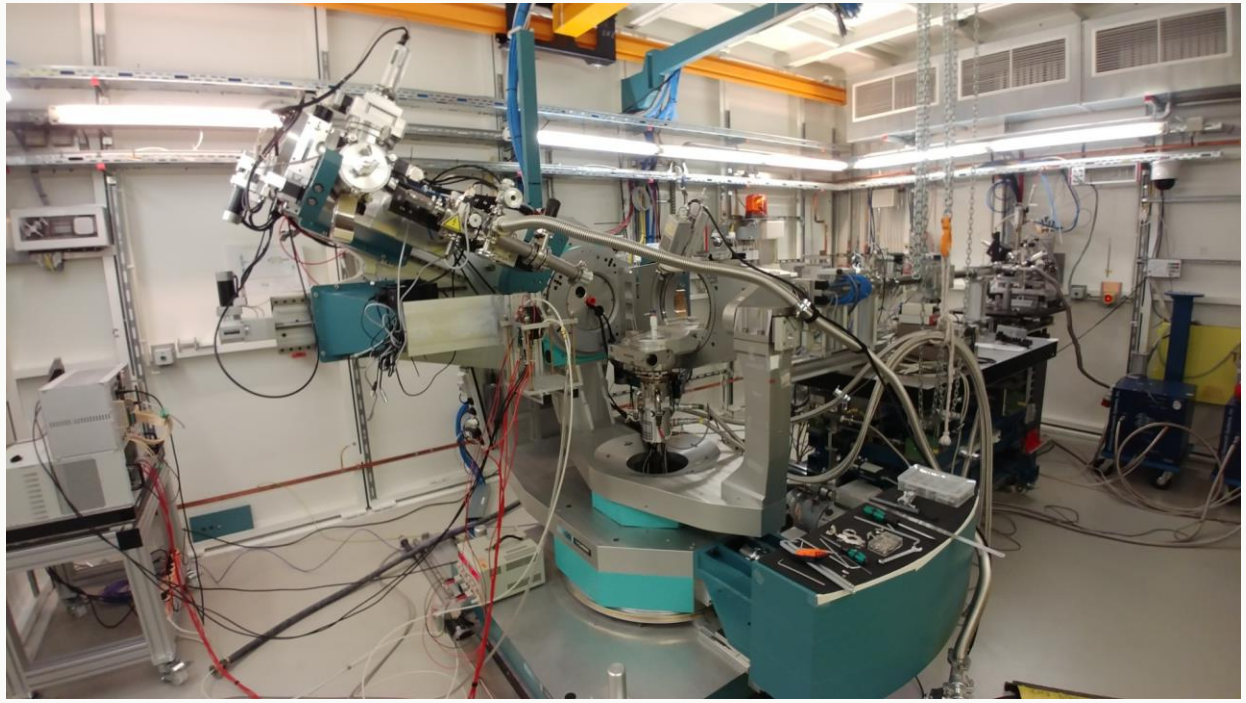
# RECONTRUCTION

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 ($cos^2$)

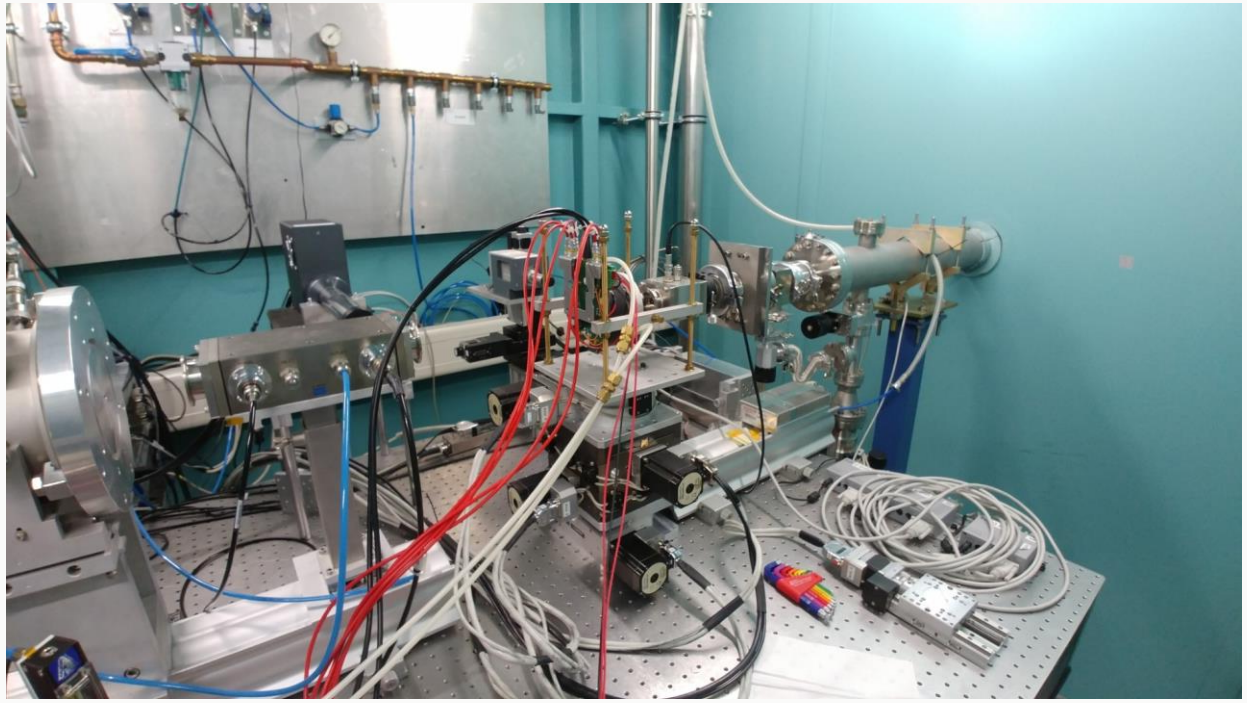


# TESTBEAMS

## PETRAIII – P09

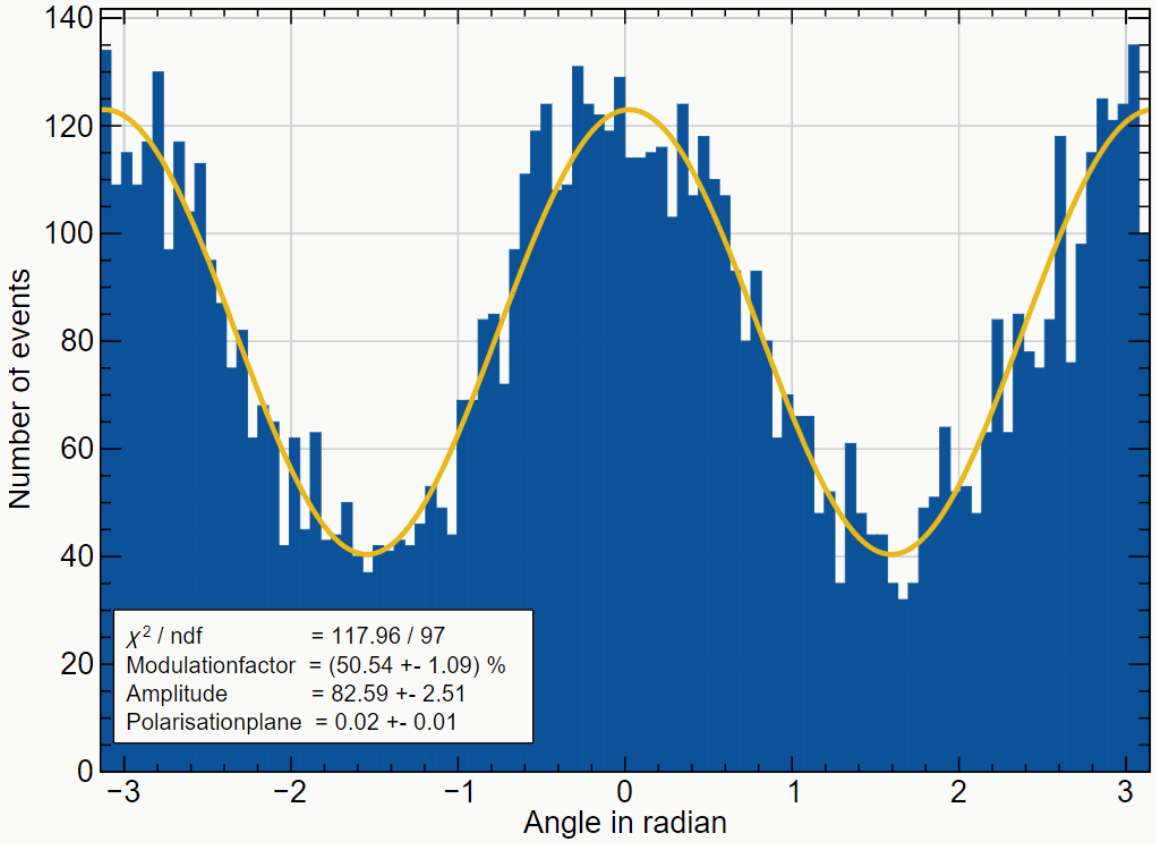


## KARA – INE beamline

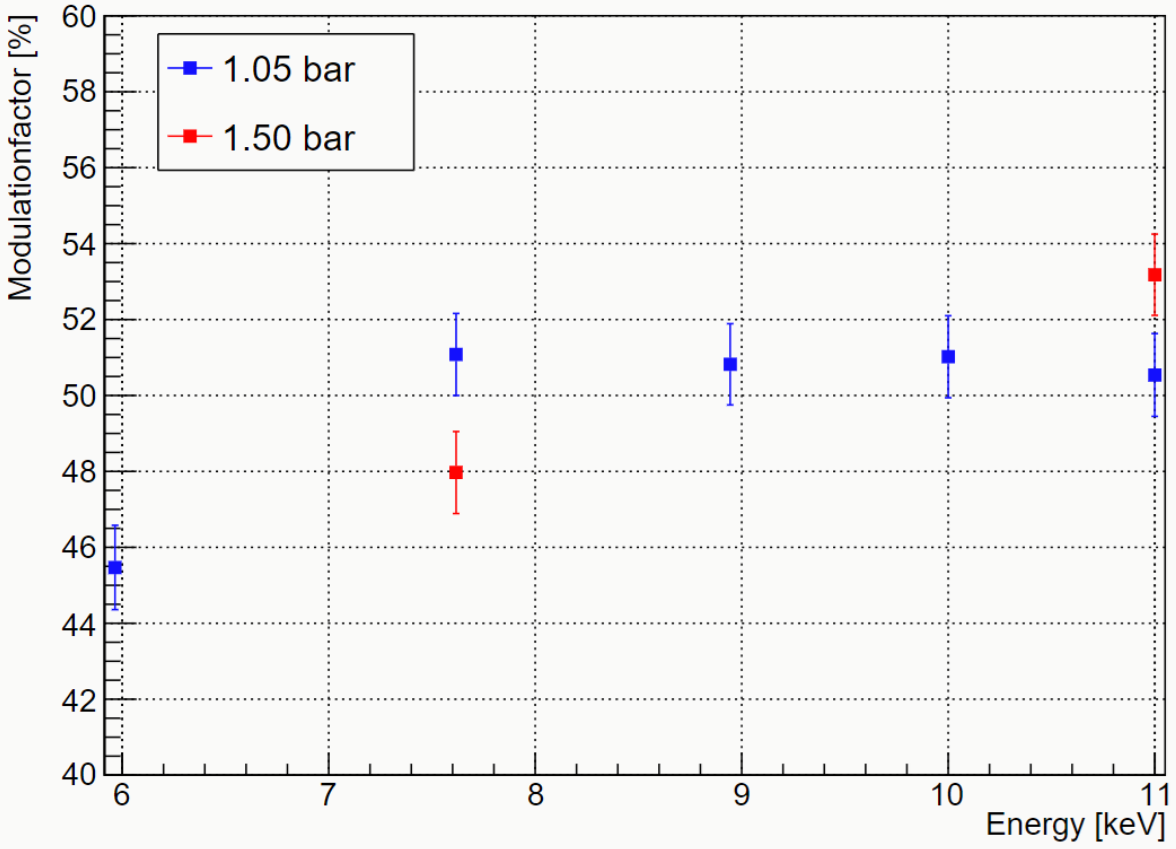


# PRELIMINARY RESULTS – HE/DME

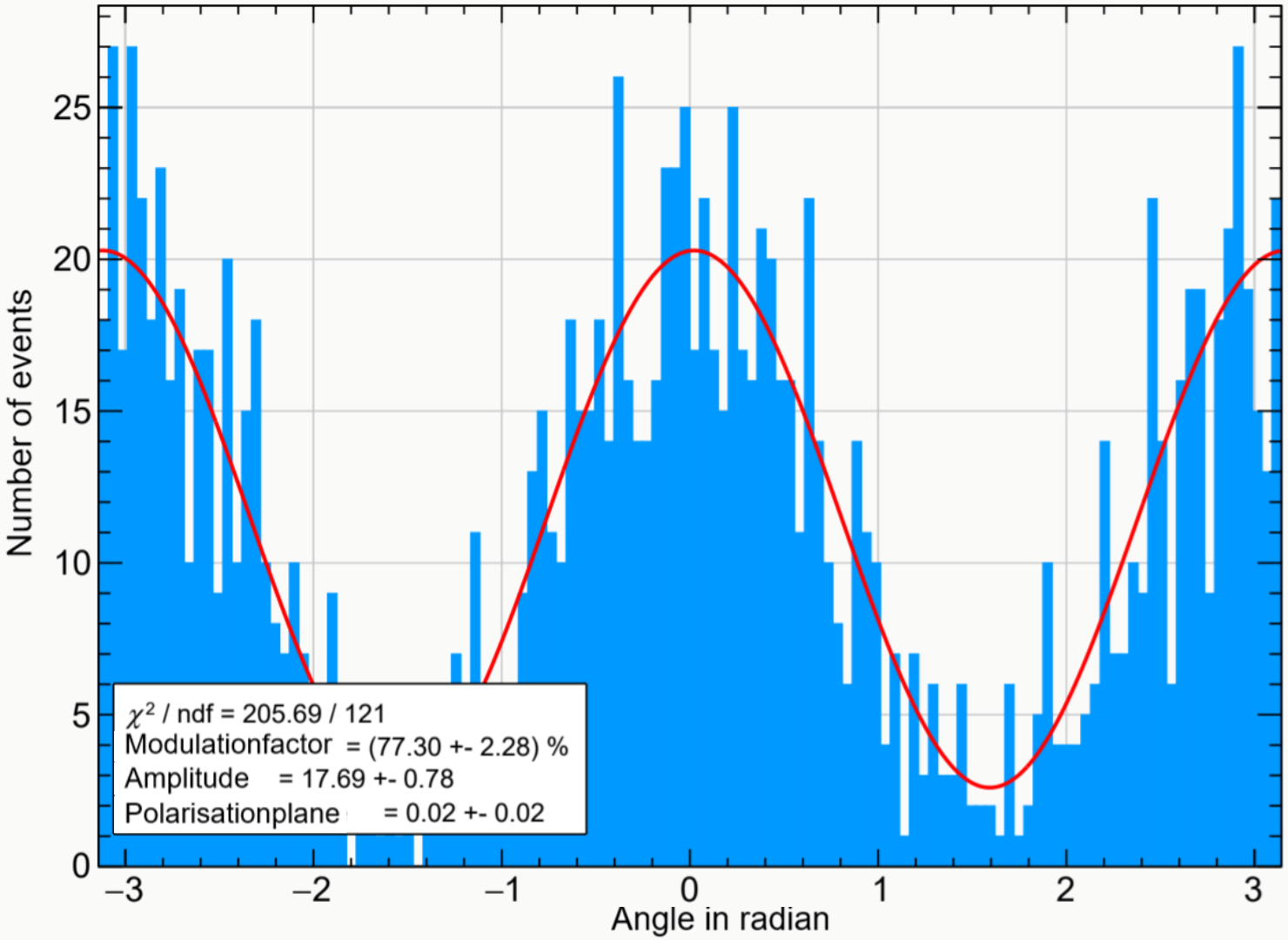
11.0 keV – 1.50 bar




He/DME 80/20



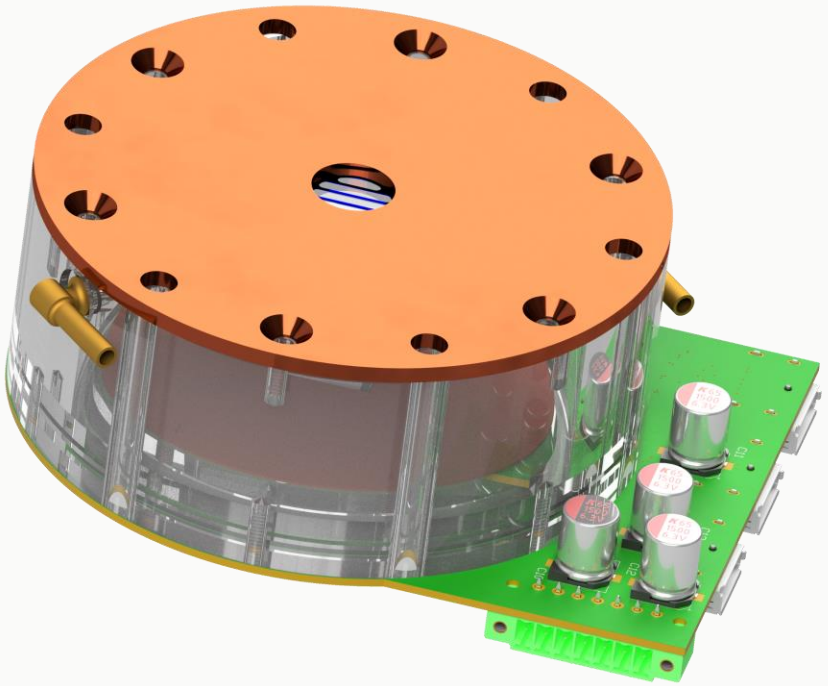
# PRELIMINARY RESULTS

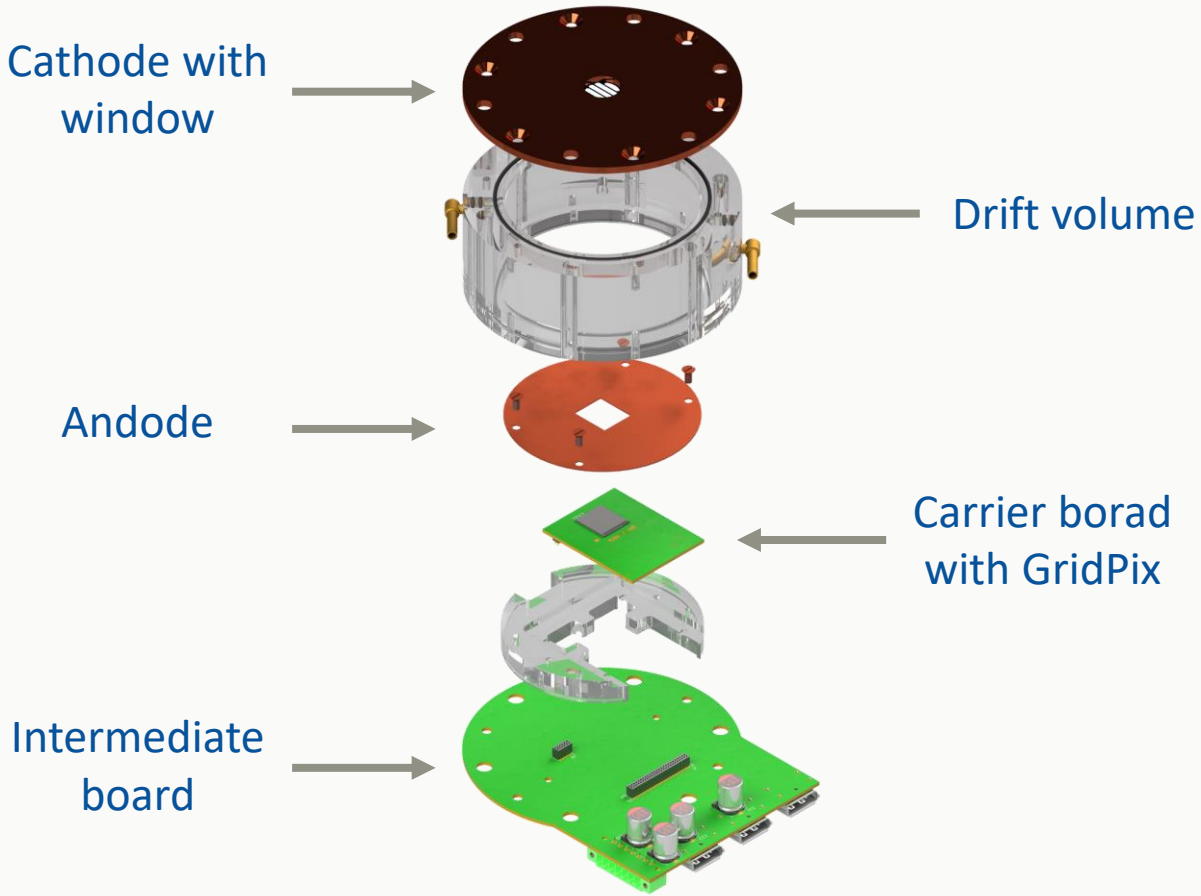


# TIMEPIX3

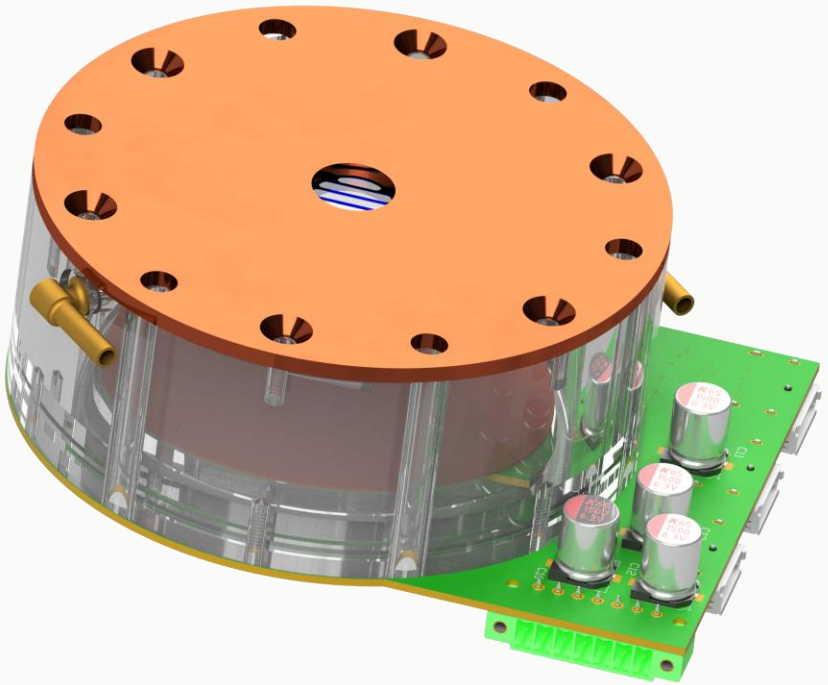
| | |
|---|---|
| Developed by | Medipix Collaboration |
| Pixel size | (55 x 55) µm |
| Pixel matrix | 256 x 256 |
| Time of Arrival (ToA) | 14 + 4 Bits (1.56 ns) |
| Time over Threshold (ToT) | 10 Bits |
| Modes | **ToT & ToA** /<br>Hit Counter & iToT /<br>Only ToA |
| Readout | **Data driven** /<br>Sequential |

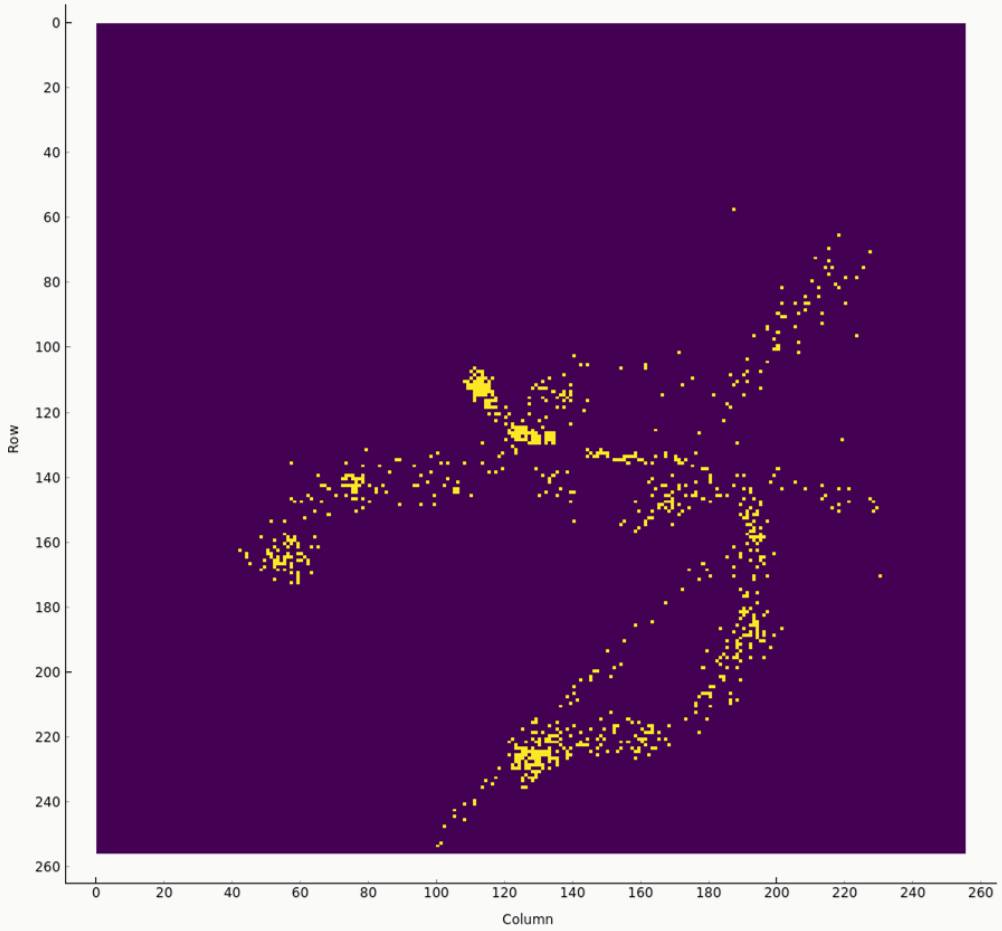
# TIMEPIX3 GRIDPIX DETECTOR



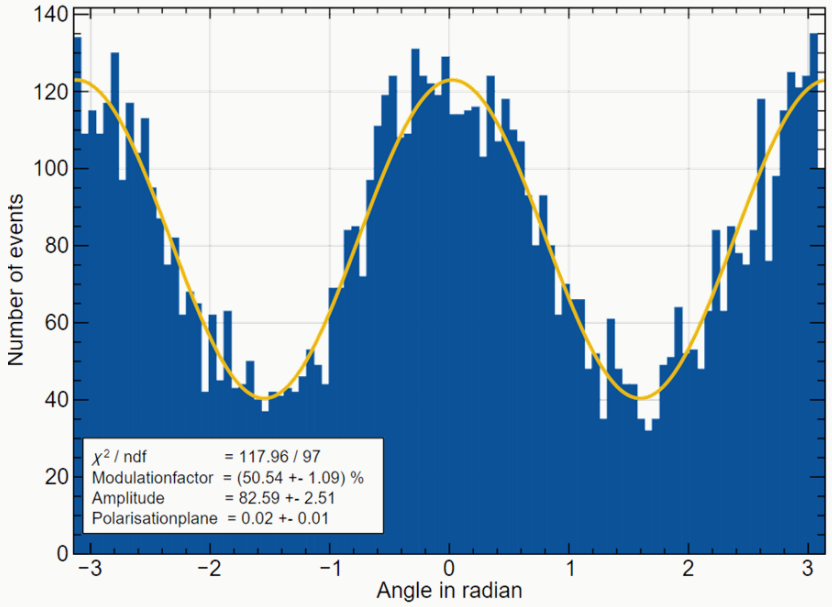


# TIMEPIX3 GRIDPIX DETECTOR





# SUMMARY

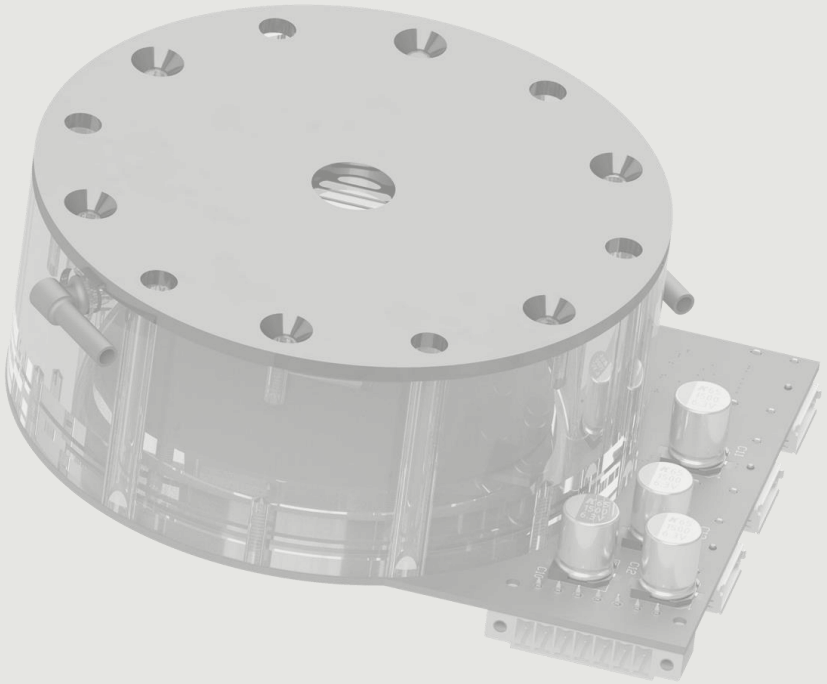



- Timepix based detector operated and tested in testbeams
- Achieved modulation factors of up to 78 %
- Improvements for detector and analysis in the future
- Timepix3 based detector in preparation

# Thank you for your attention

Markus Gruber

gruber@physik.uni-bonn.de



# BACKUP

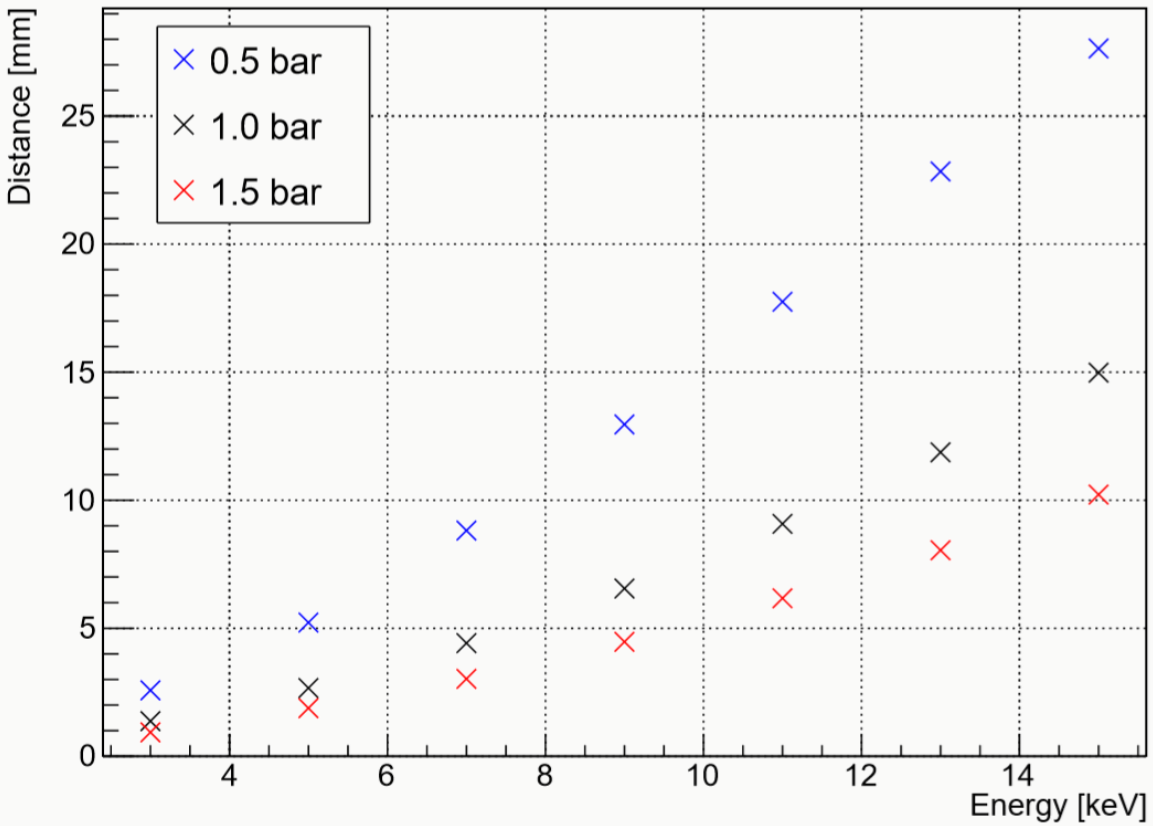
# WHY X-RAY POLARIMETRY

- 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

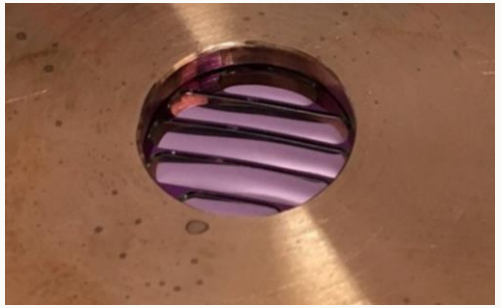
Wishlist:

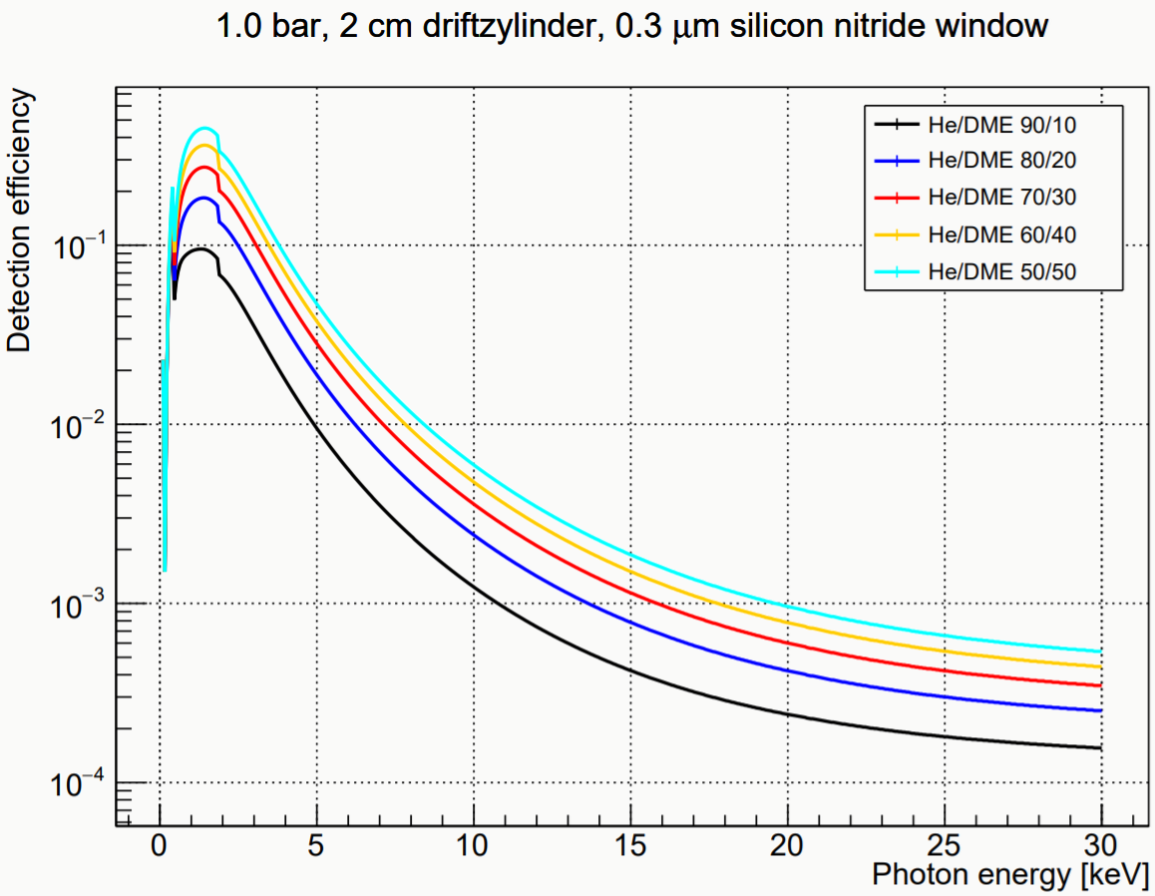
- Good photon detection efficiency
- Long photoelectron tracks
- Low multiple scattering
- Low diffusion
- Reasonable gas gain

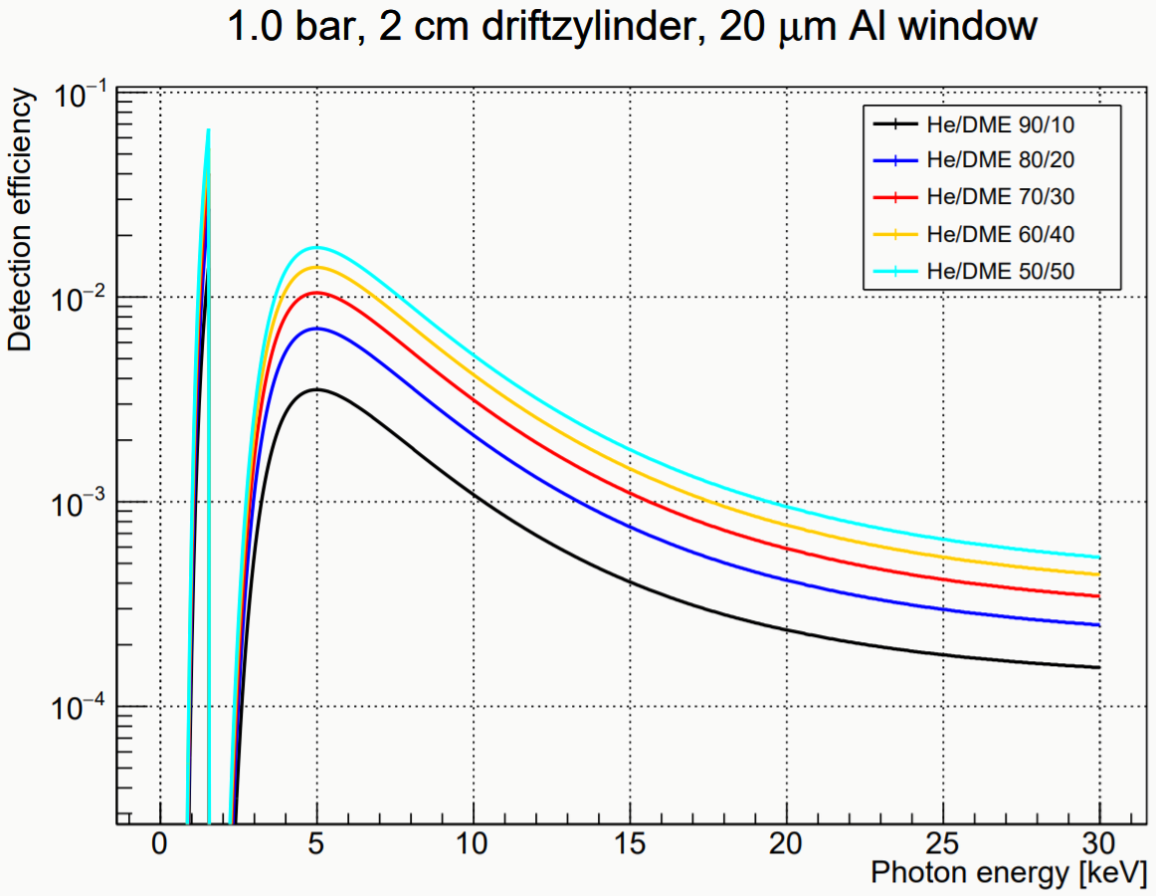



Transverse diffusion: $256\ \mu m/\sqrt{cm}$ @ 0.5 bar
$177\ \mu m/\sqrt{cm}$ @ 1.0 bar
$146\ \mu m/\sqrt{cm}$ @ 1.5 bar

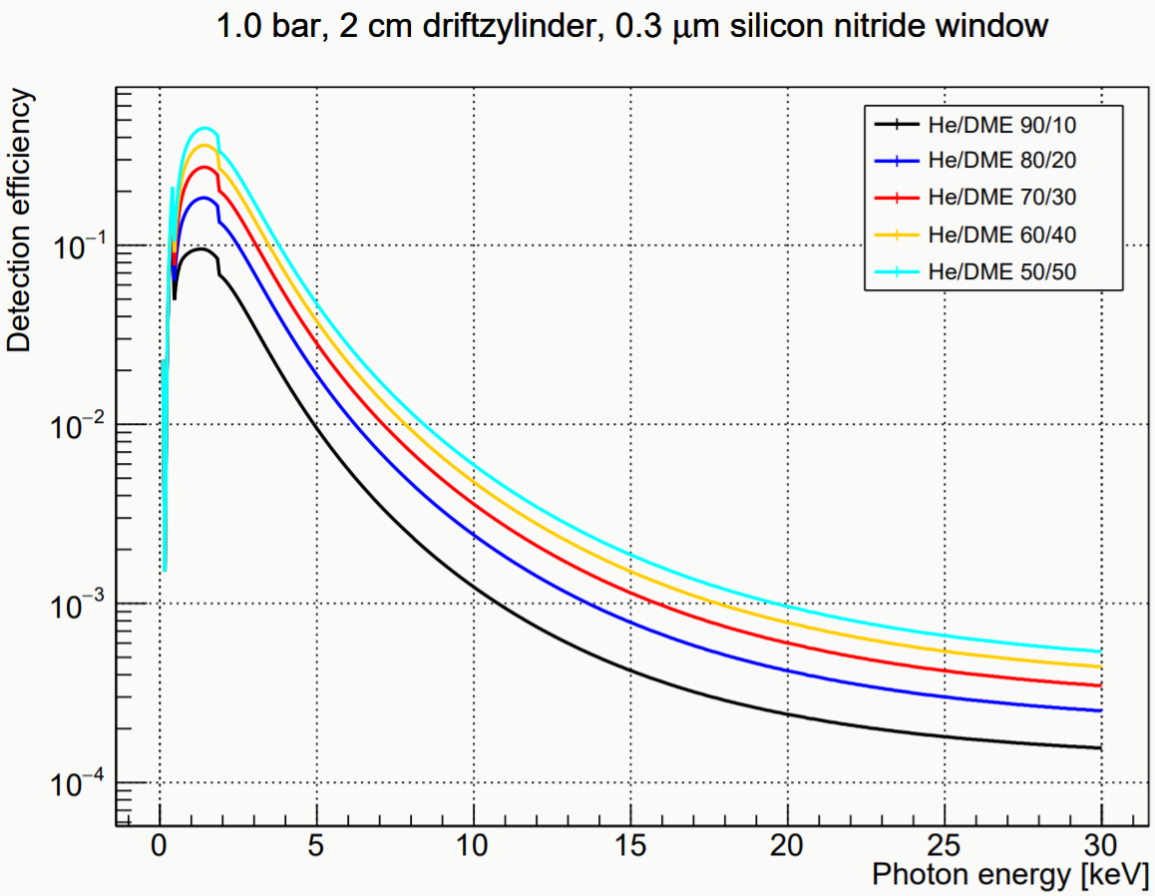
# ABSORPTION OF PHOTONS - WINDOW

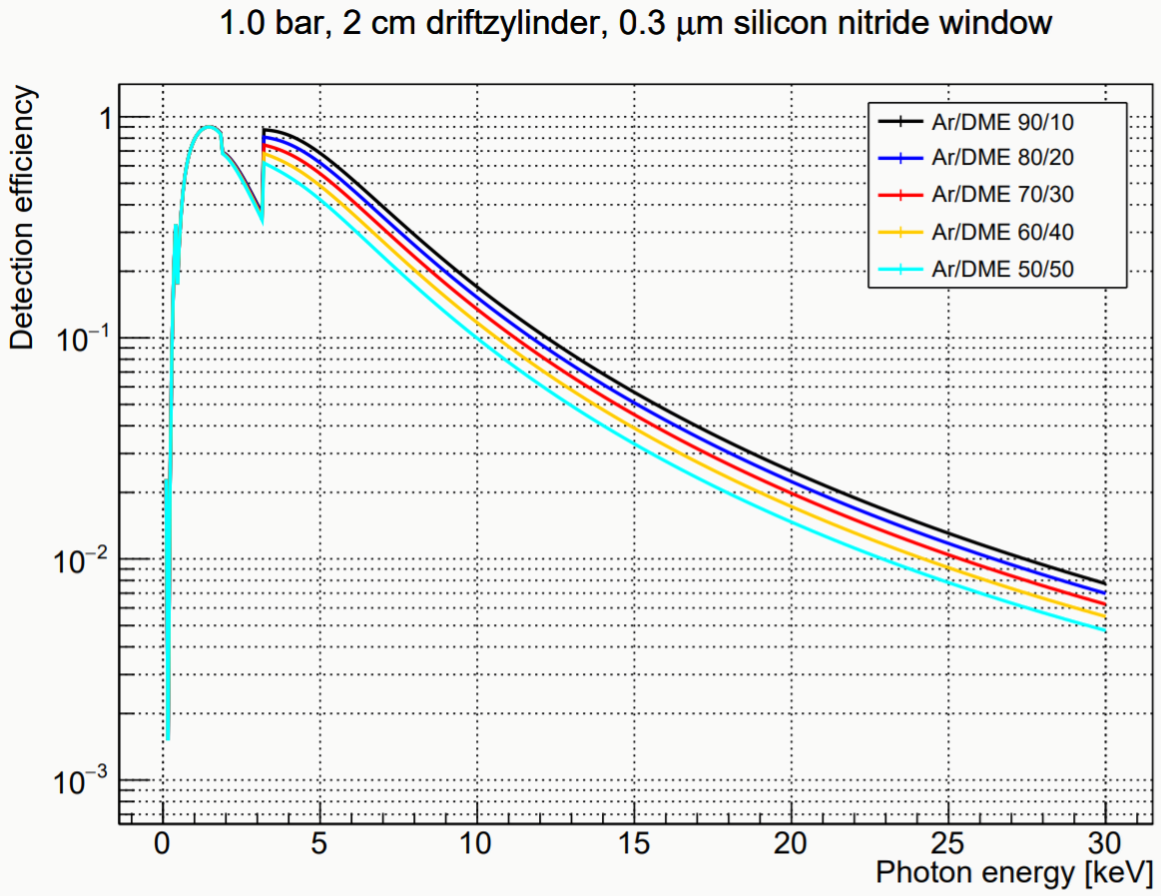




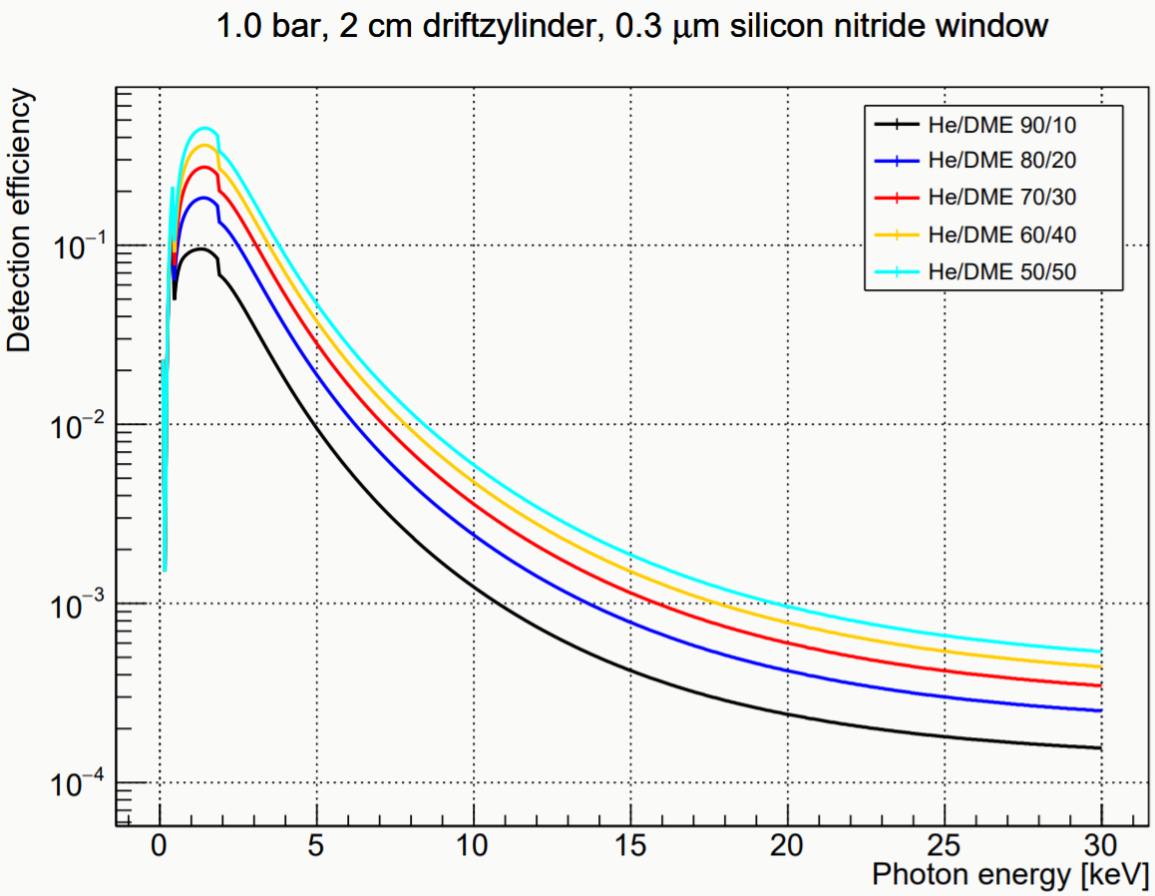



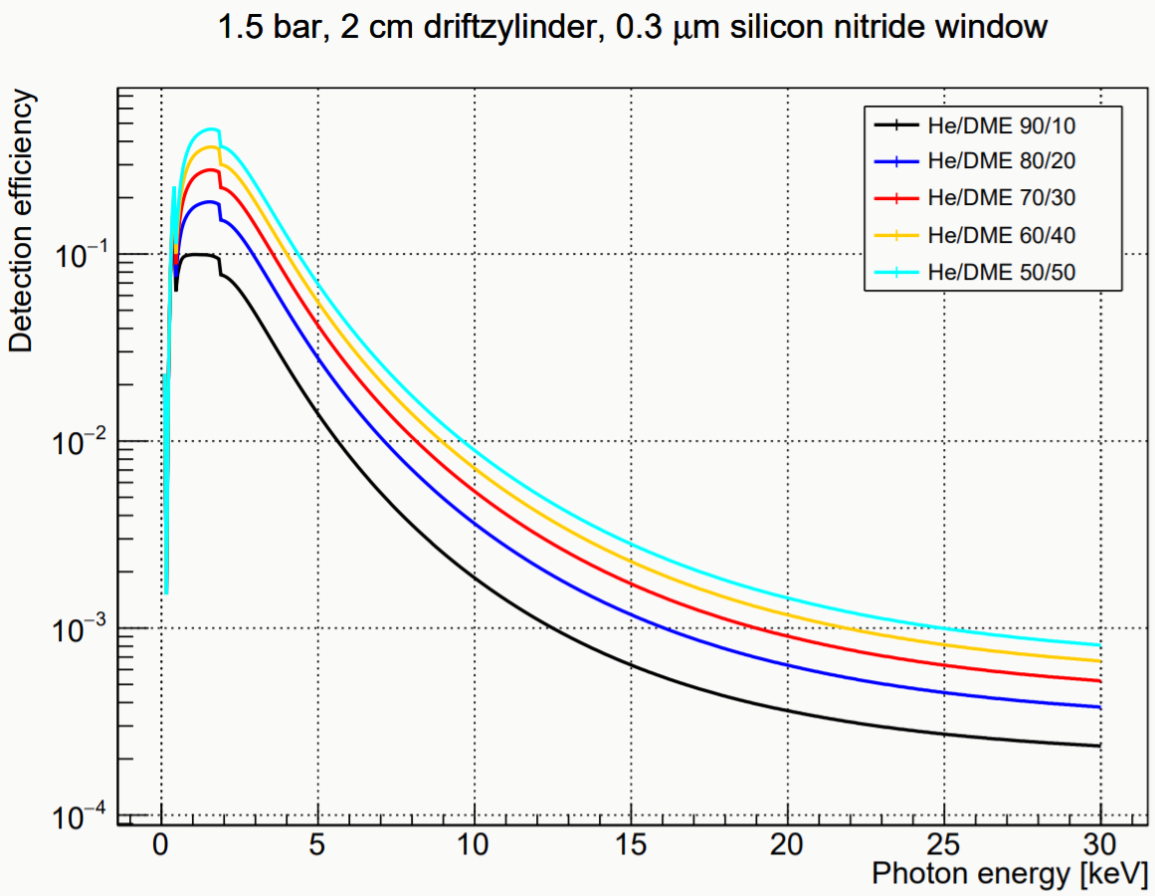
# ABSORPTION OF PHOTONS - GAS



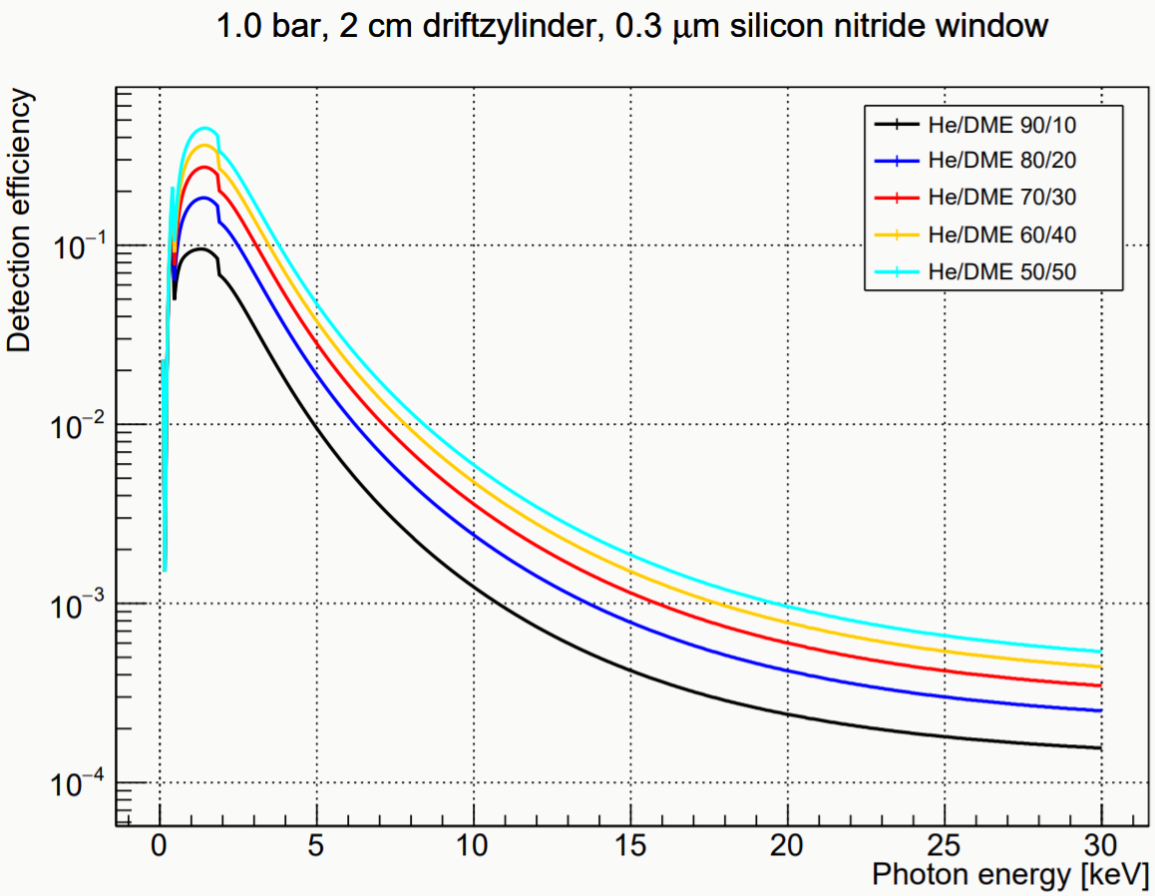



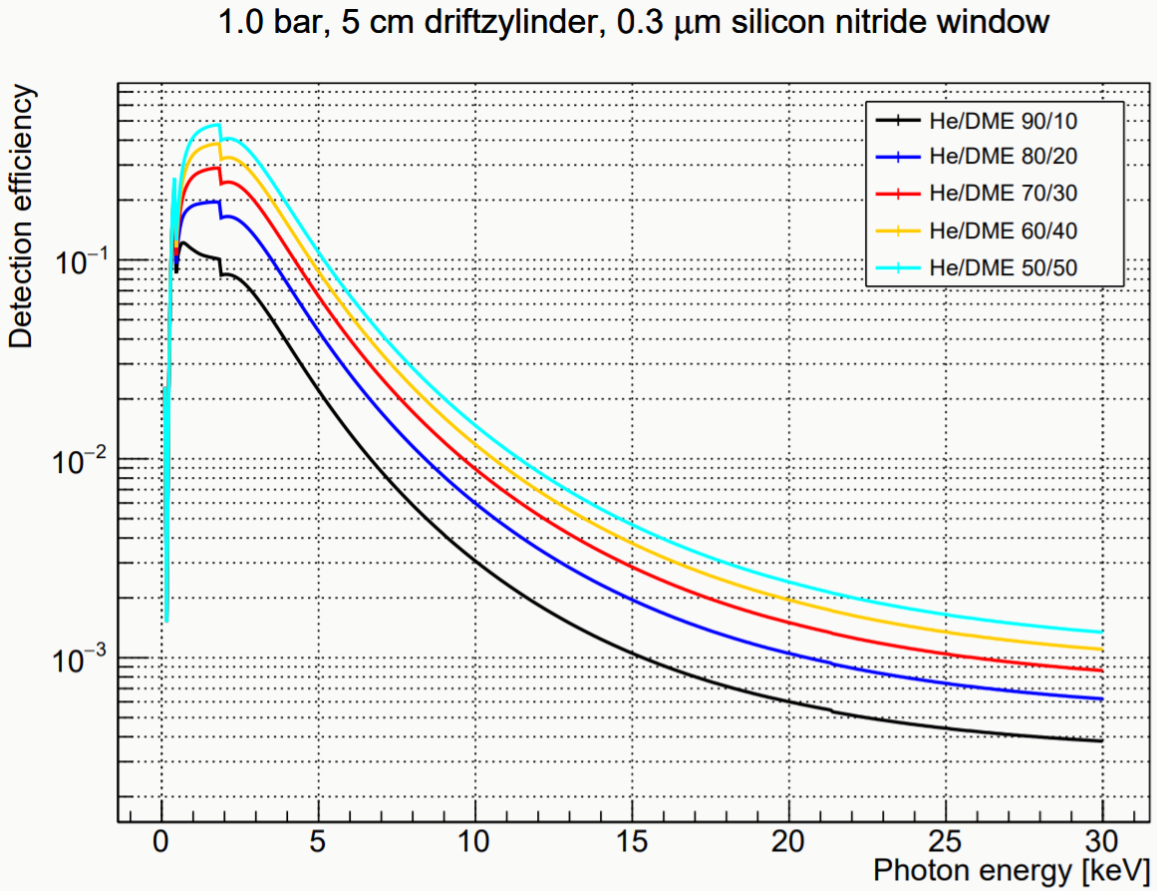
# ABSORPTION OF PHOTONS - PRESSURE



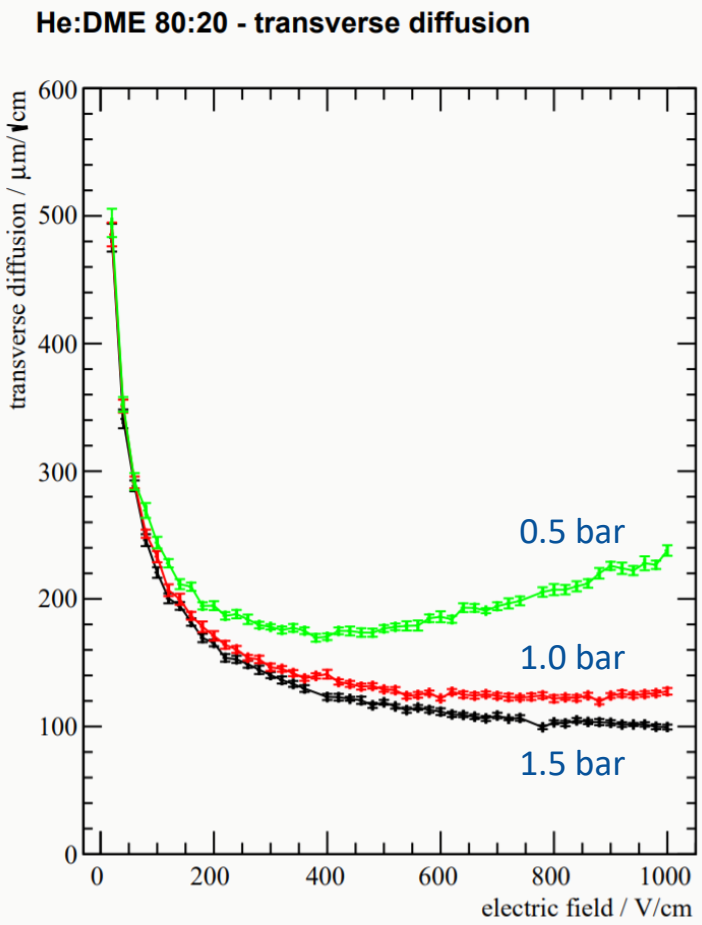



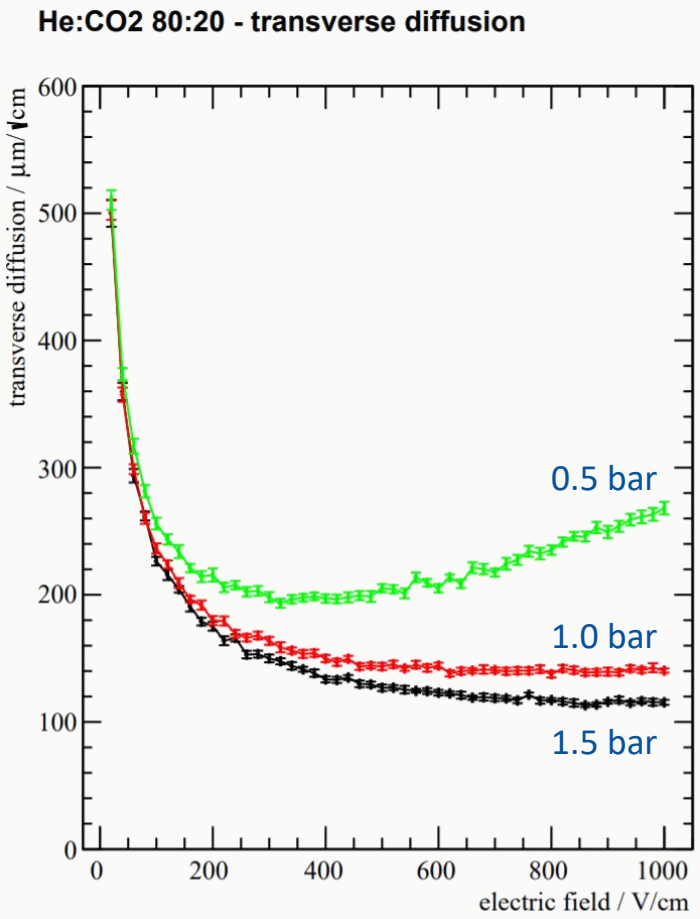
# ABSORPTION OF PHOTONS - DRIFTLENGTH

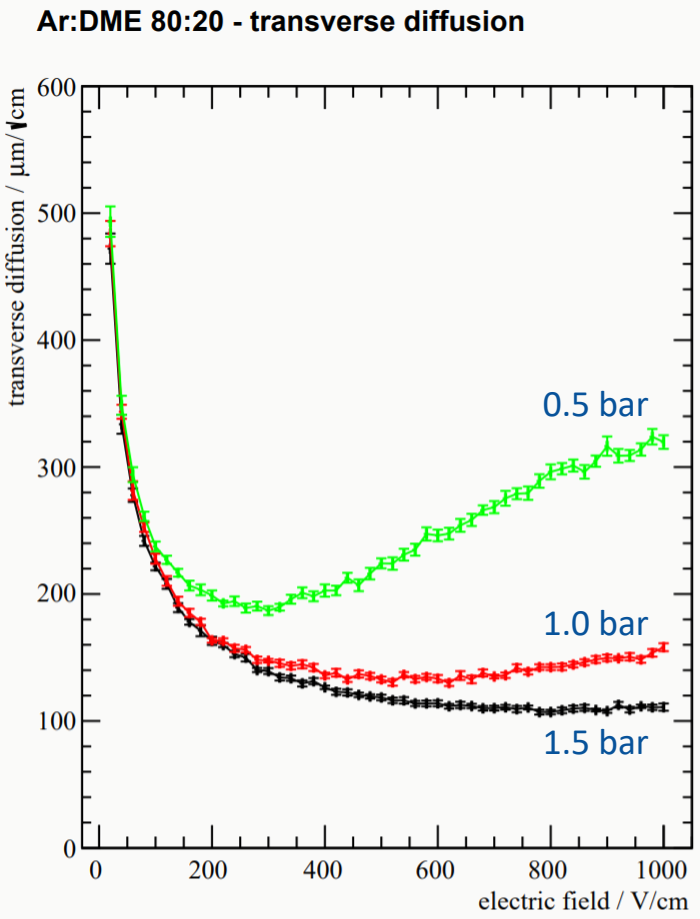


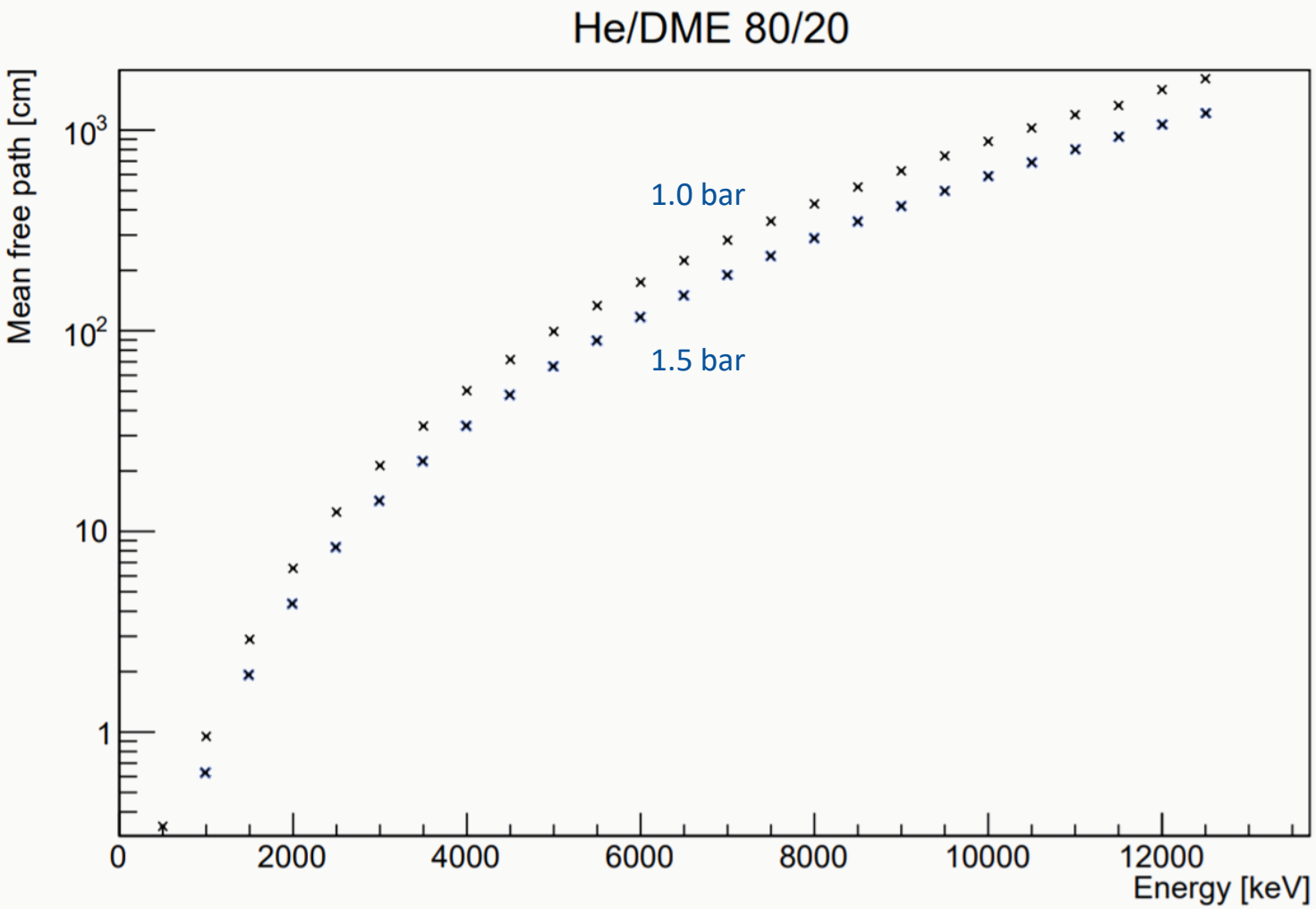
# DIFFUSION


He:DME 80:20 - transverse diffusion
transverse diffusion / µm/√cm
electric field / V/cm
0.5 bar
1.0 bar
1.5 bar

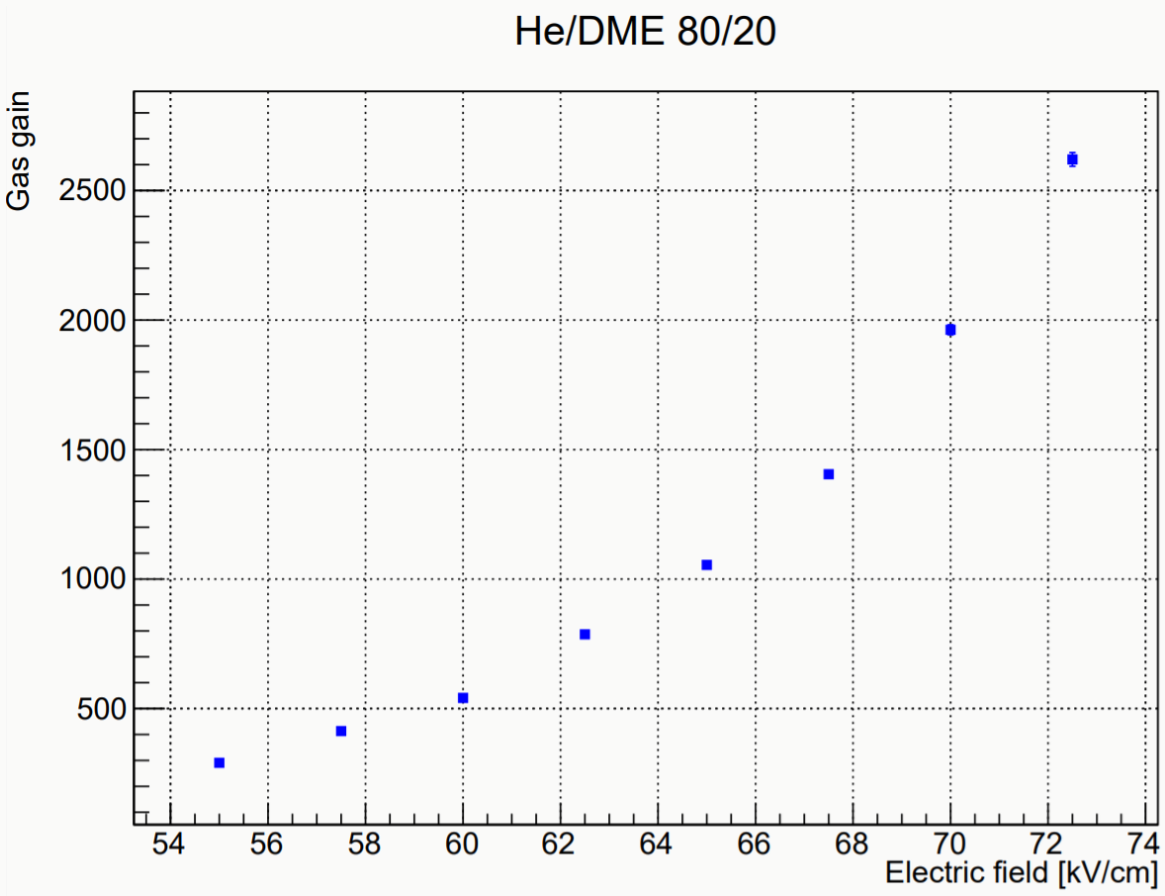

He:CO2 80:20 - transverse diffusion
transverse diffusion / µm/√cm
electric field / V/cm
0.5 bar
1.0 bar
1.5 bar

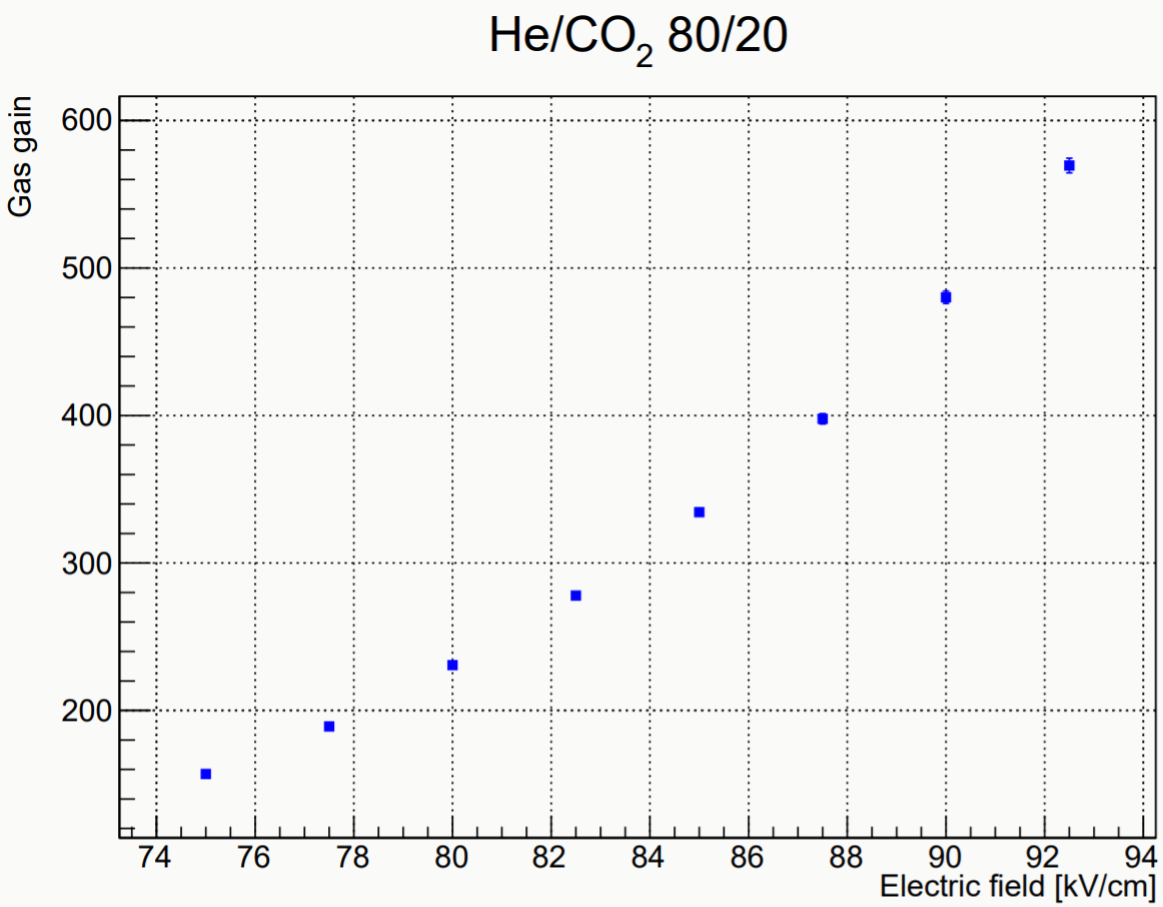

Ar:DME 80:20 - transverse diffusion
transverse diffusion / µm/√cm
electric field / V/cm
0.5 bar
1.0 bar
1.5 bar

# DIFFUSION – DRIFT LENGTH

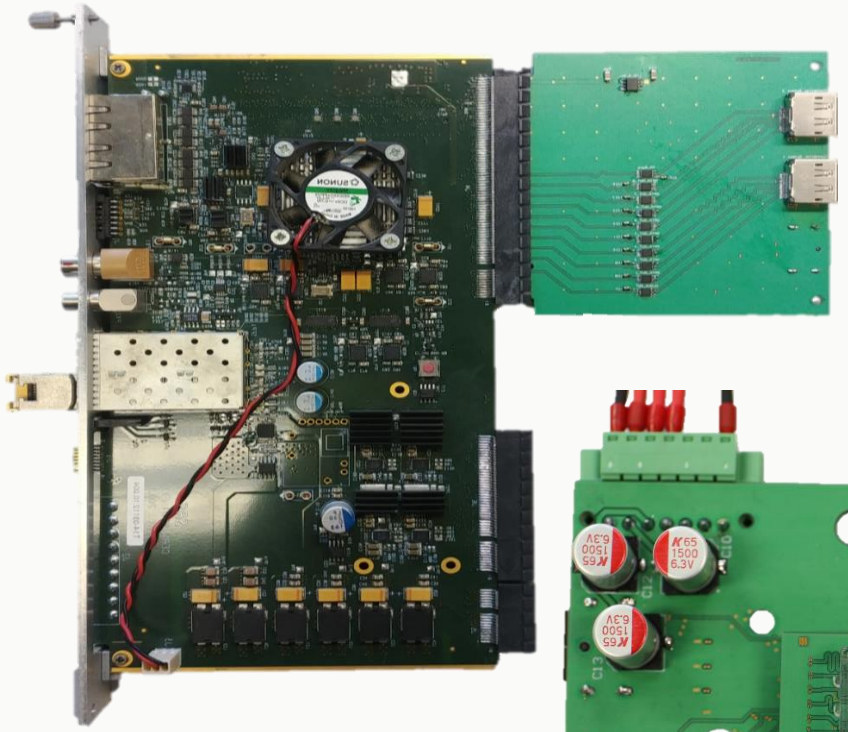


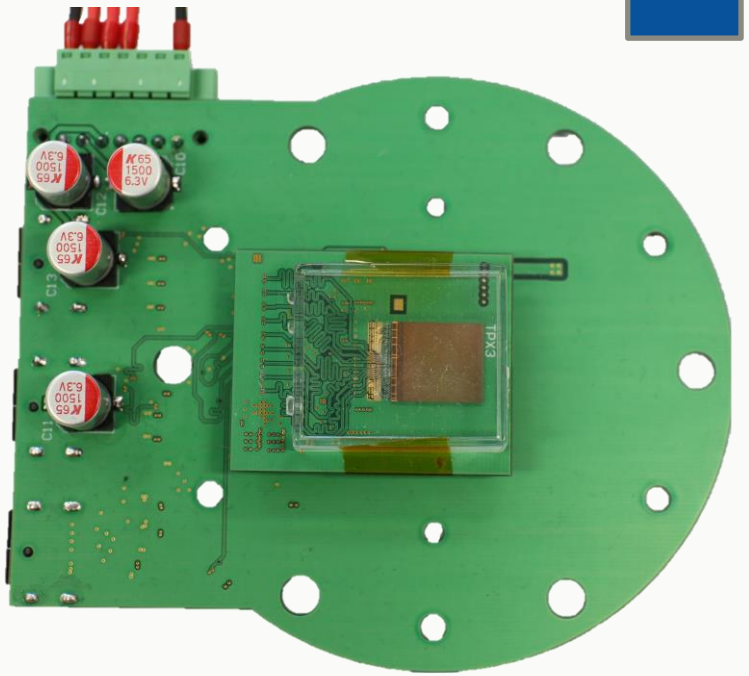
# AMPLIFICATION



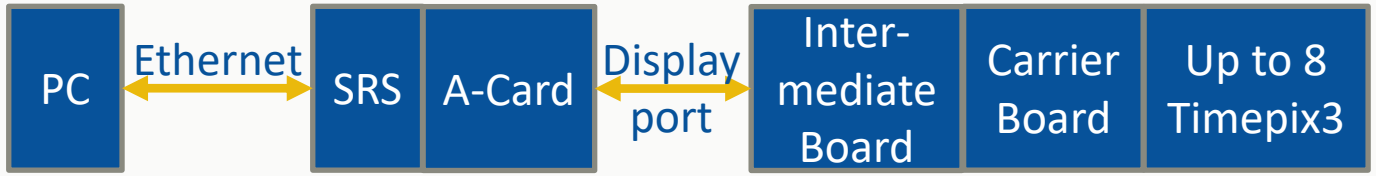



# TIMEPIX3 READOUT





- 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

# SETUP