



Marshall Space Flight Center



IXPE

Imaging
X-Ray
Polarimetry
Explorer

IXPE RELATED GEANT4 SIMULATION

Fei Xie

IAPS/INAF

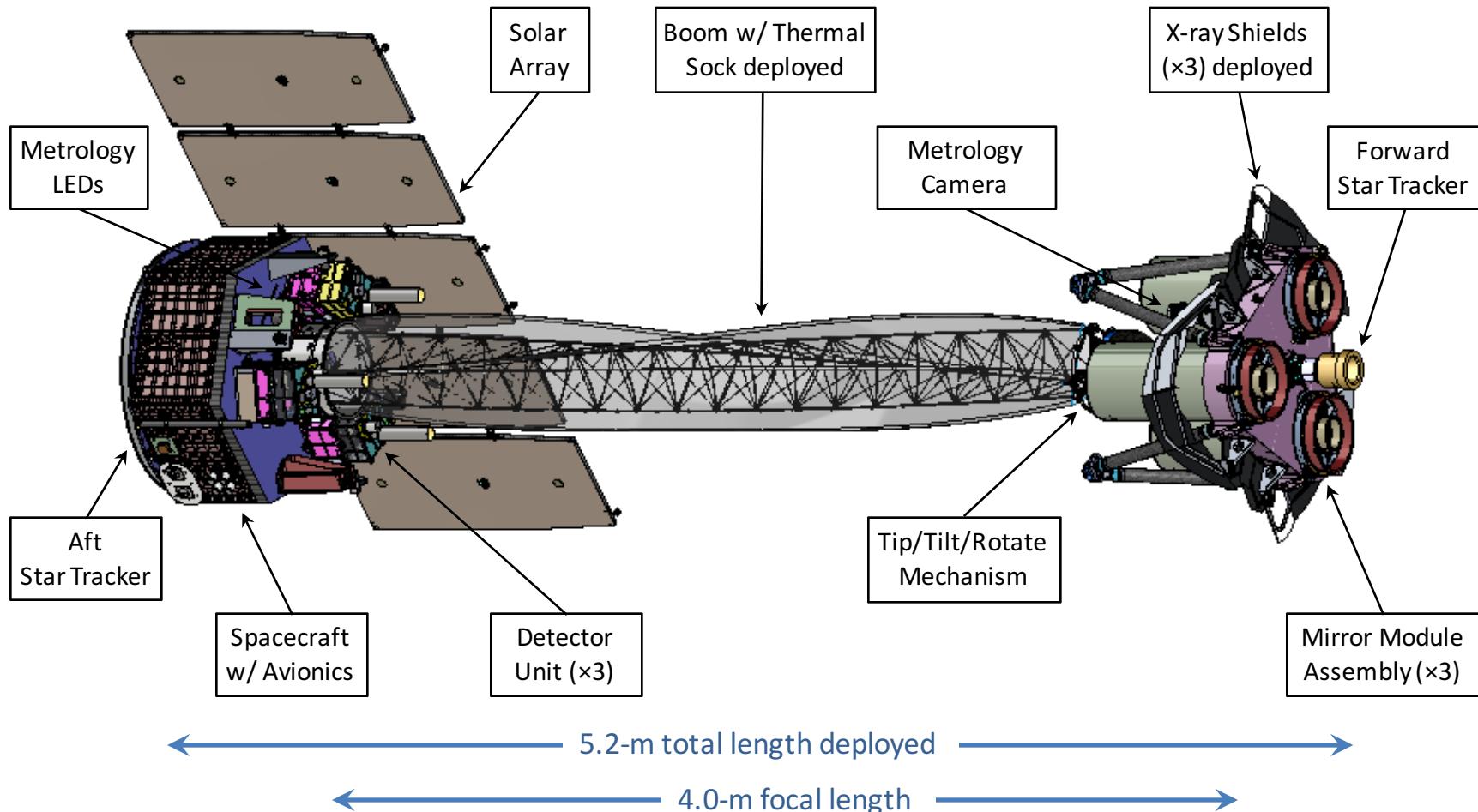
On behalf of the IXPE team

IMAGING X-RAY POLARIMETRY EXPLORER

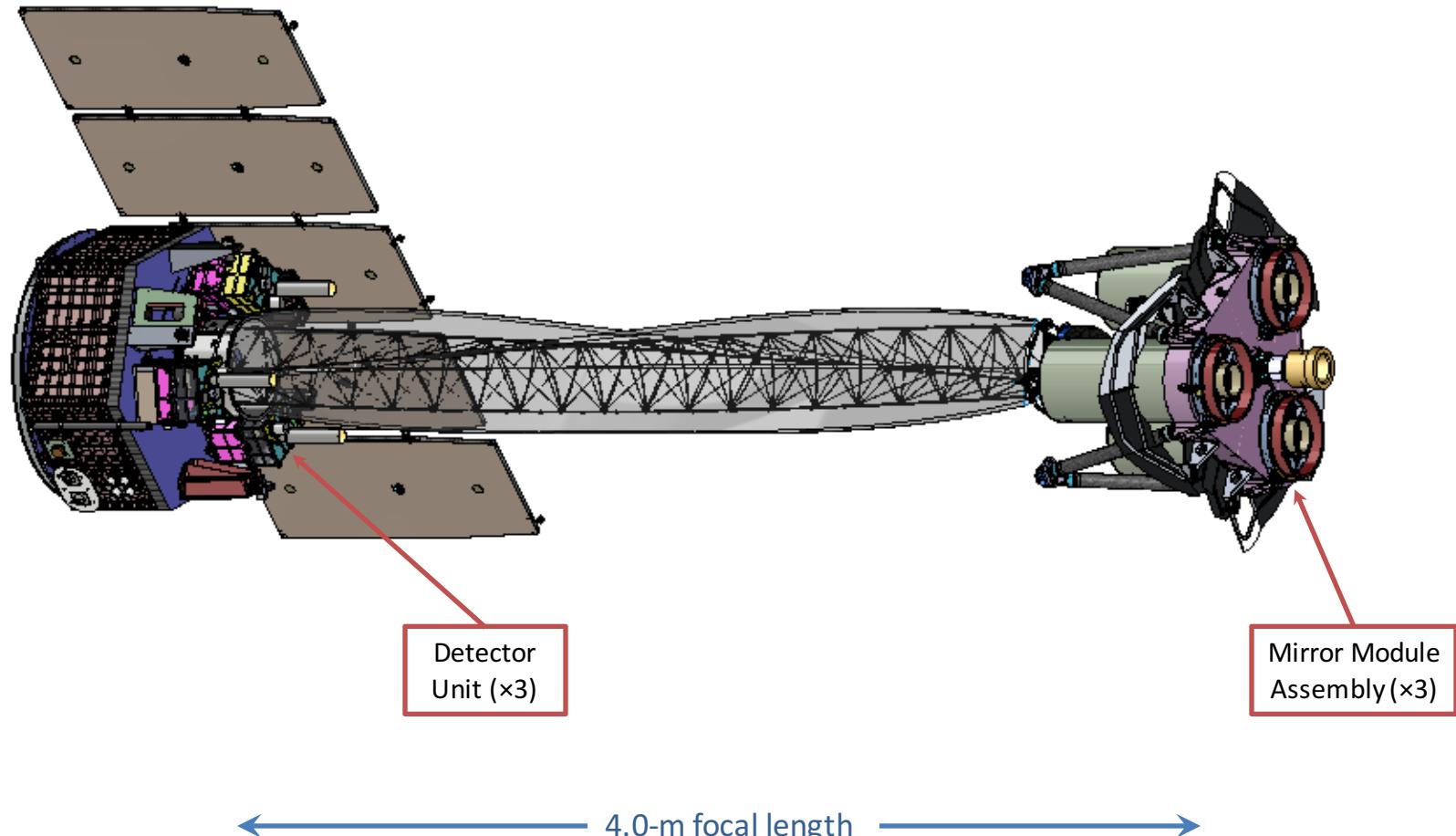
■ Next small mission by NASA

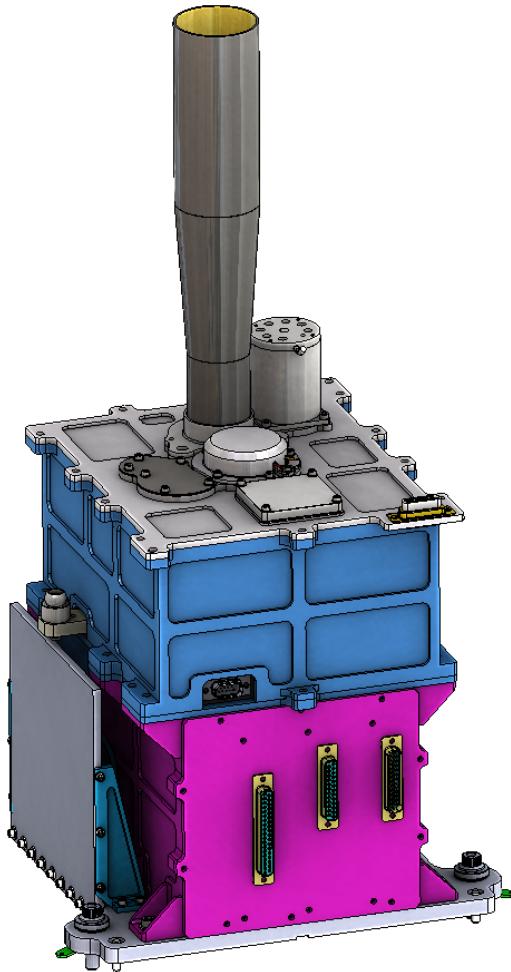
- Low Earth circular orbit satellite
 - Altitude: 620 km
 - Inclination: 0.73°
 - SpaceX Falcon 9
- Launch ready by April 2021
- 2 year baseline operation

IXPE OBSERVATORY

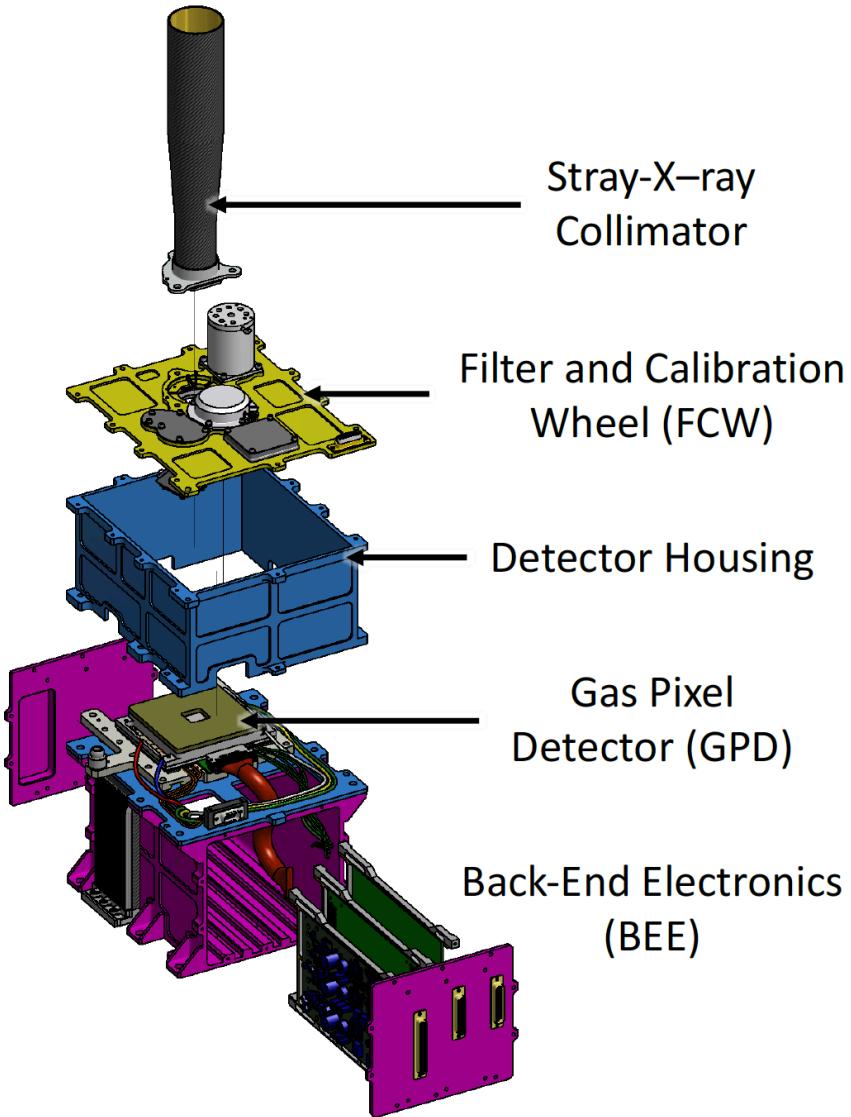
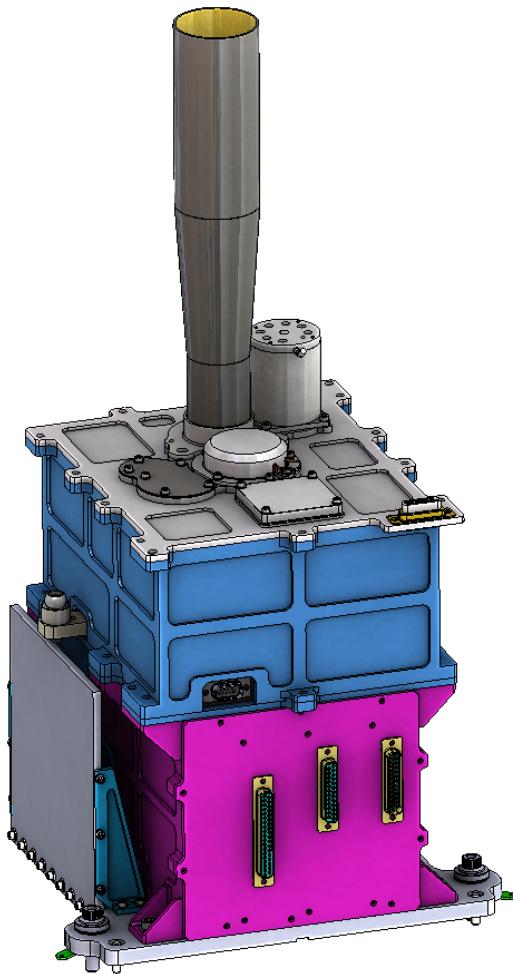


IXPE OBSERVATORY

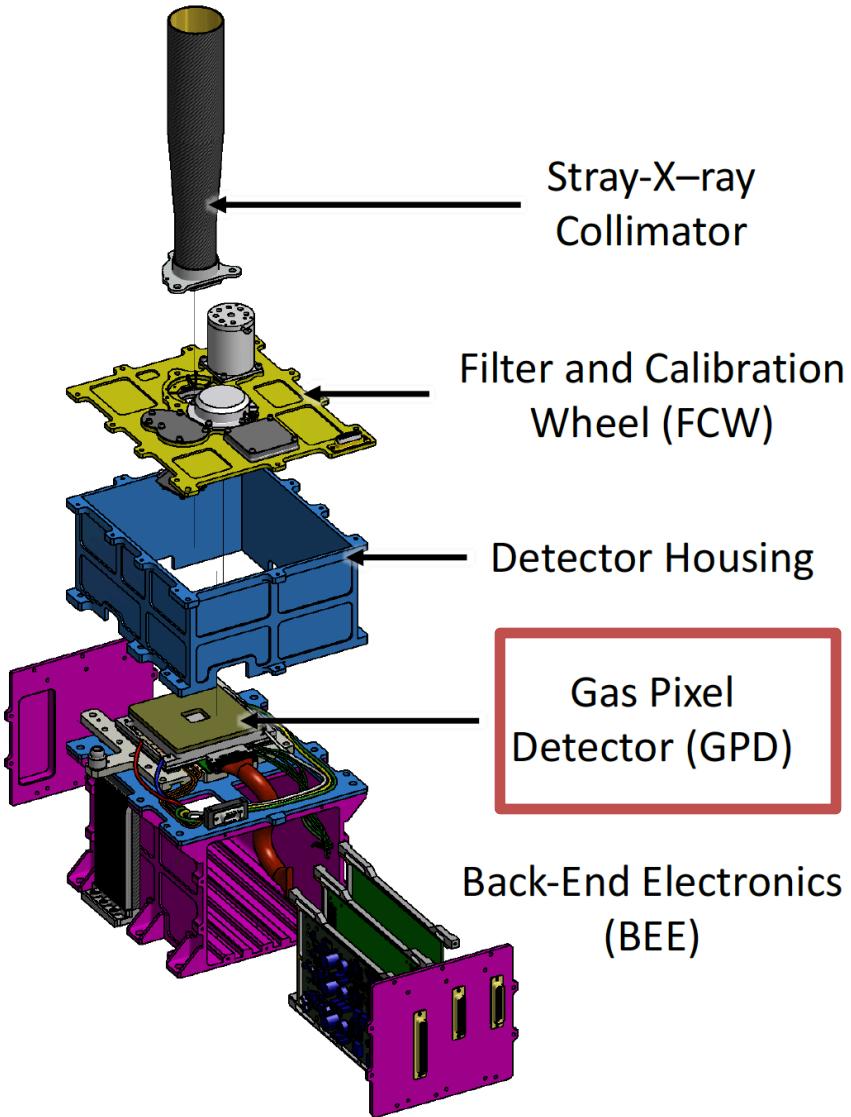
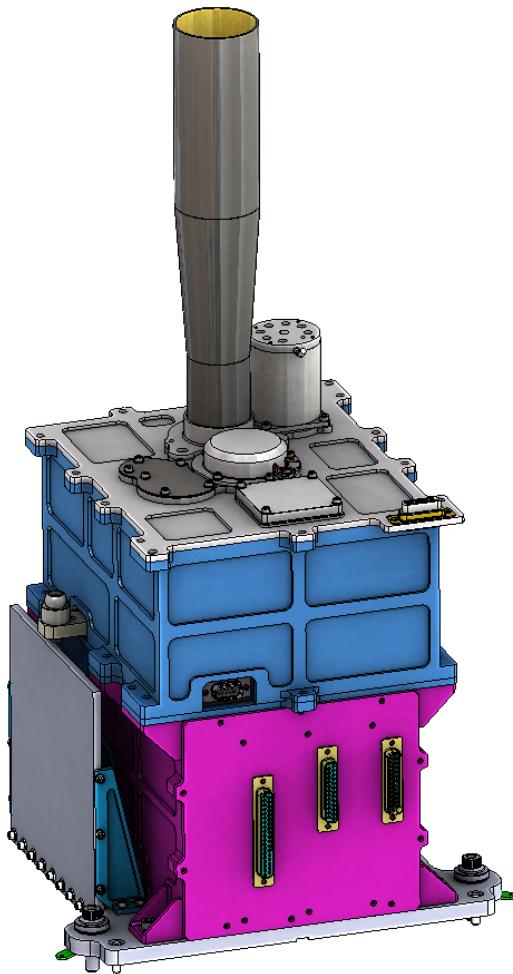




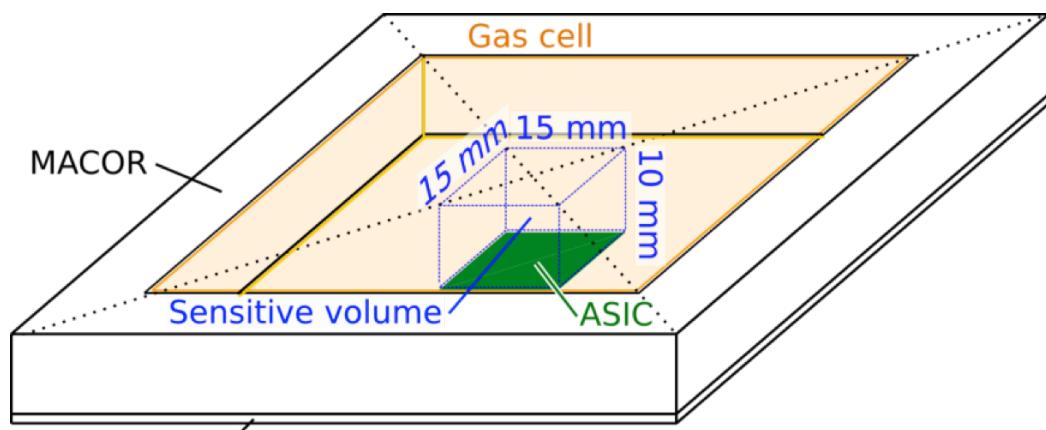
DU: DETECTOR UNIT



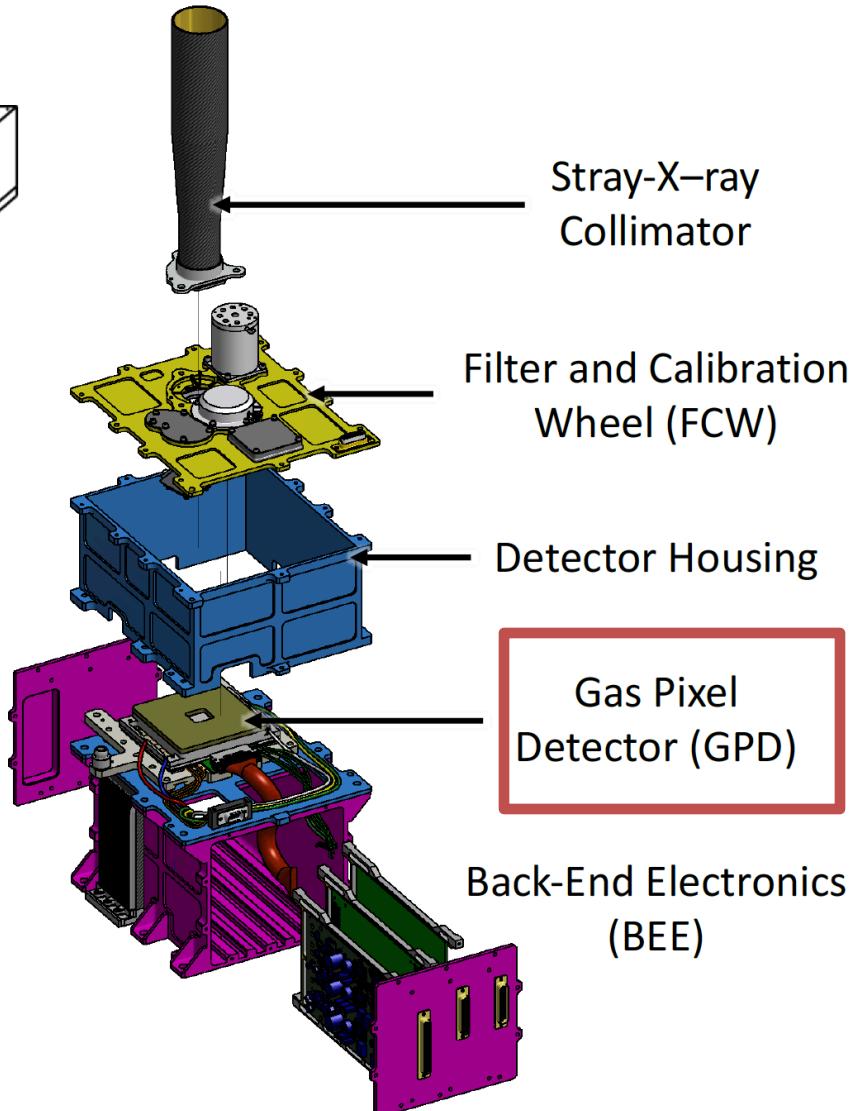
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DETECTOR UNIT

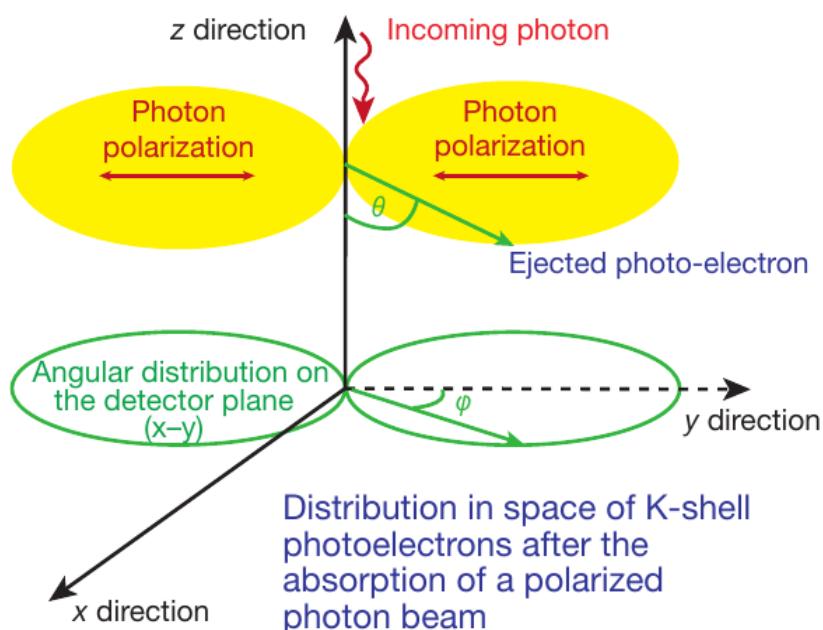


GAS:DME (Dimethyl Ether, C₂H₆O)
 Filling area: 60 x 60 x 10 mm
 Sensitive area: 15 x 15 x 10 mm
 Energy range: 2-8 keV



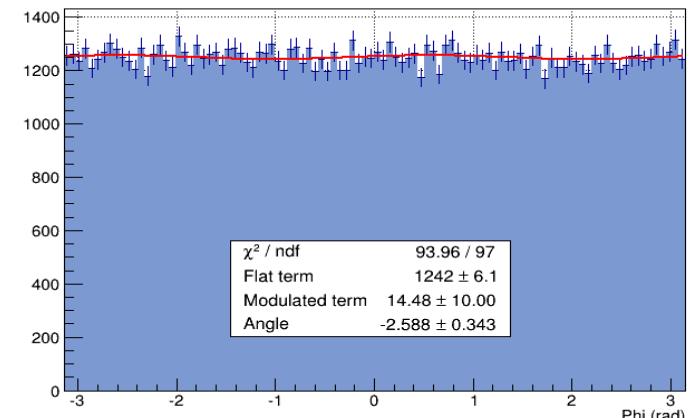
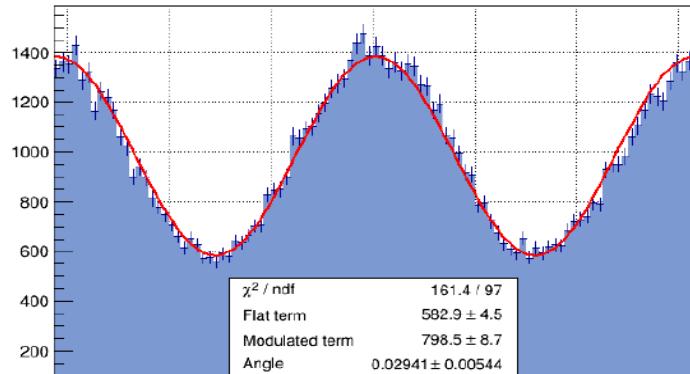
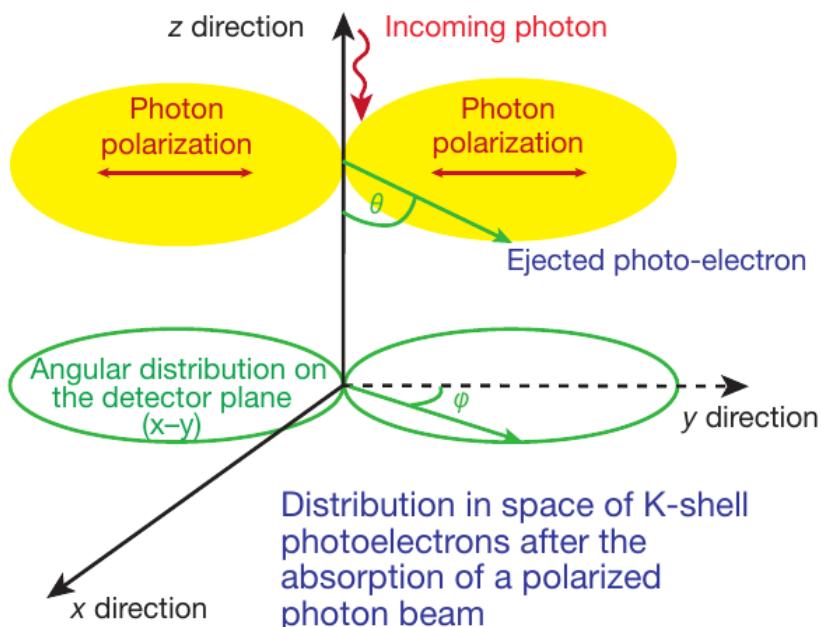
The photoelectric effect

$$\frac{\partial\sigma}{\partial\Omega} = r_0^2 \frac{Z^5}{137^4} \left(\frac{mc^2}{h\nu}\right)^{7/2} \frac{4\sqrt{2}\sin^2(\theta)\cos^2(\varphi)}{(1 - \beta\cos(\theta))^4}$$

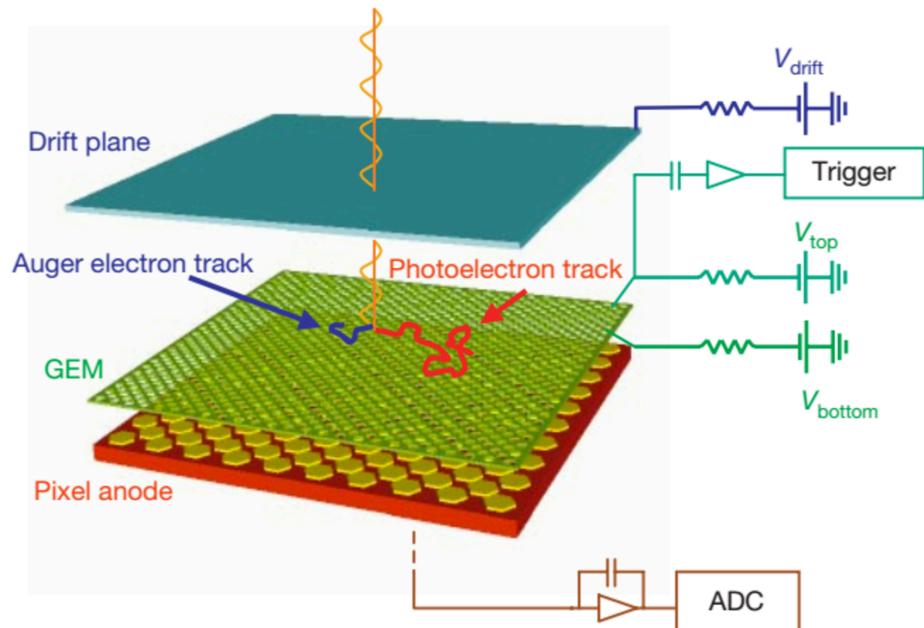


The photoelectric effect

$$\frac{\partial\sigma}{\partial\Omega} = r_0^2 \frac{Z^5}{137^4} \left(\frac{mc^2}{h\nu}\right)^{7/2} \frac{4\sqrt{2}\sin^2(\theta)\cos^2(\varphi)}{(1 - \beta\cos(\theta))^4}$$



MULTIPLIER AND READOUT



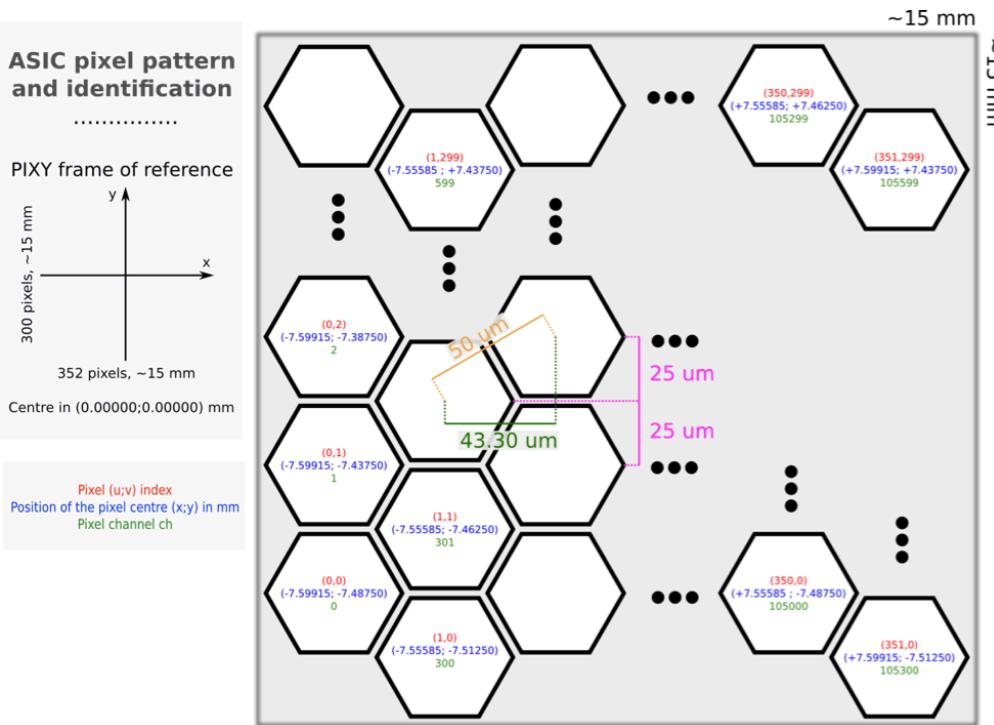
Costa et al. 2001

❖ GPD-Proportional counter :

- Photon absorbed
- Photoelectron emitted
- Lose energy by ionization
- Drifted by E-field
- Charge amplified by GEM¹
- Charge collected on ASIC
 - 1.5 x 1.5 cm
 - 352 x 300 pixels
 - Pixel pitch: 50 μm
- Direction reconstruction
- Modulation curve

¹Gas Electron Multiplier

MULTIPLIER AND READOUT

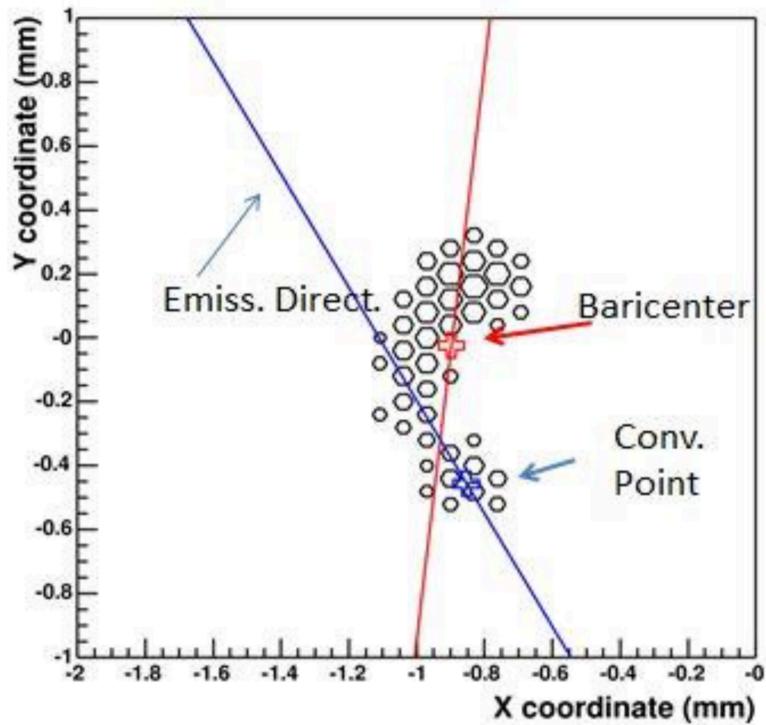


❖ GPD-Proportional counter :

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- **Charge collected on ASIC**
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MULTIPLIER AND READOUT



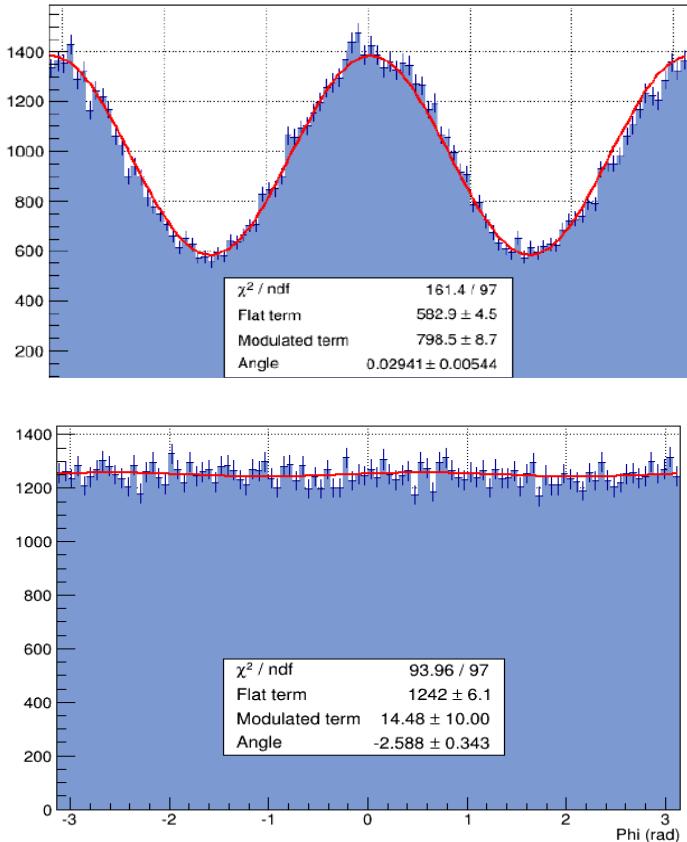
The energy loss increases with decreasing kinetic energy

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MULTIPLIER AND READOUT



Amplitude → polarization degree
 Phase → polarization angle

❖ GPD-Proportional counter :

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- Photoelectron emitted
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- **Modulation curve**

¹Gas Electron Multiplier

■ Start from simple geometric model

- Only one GPD
- Cross check with lab data

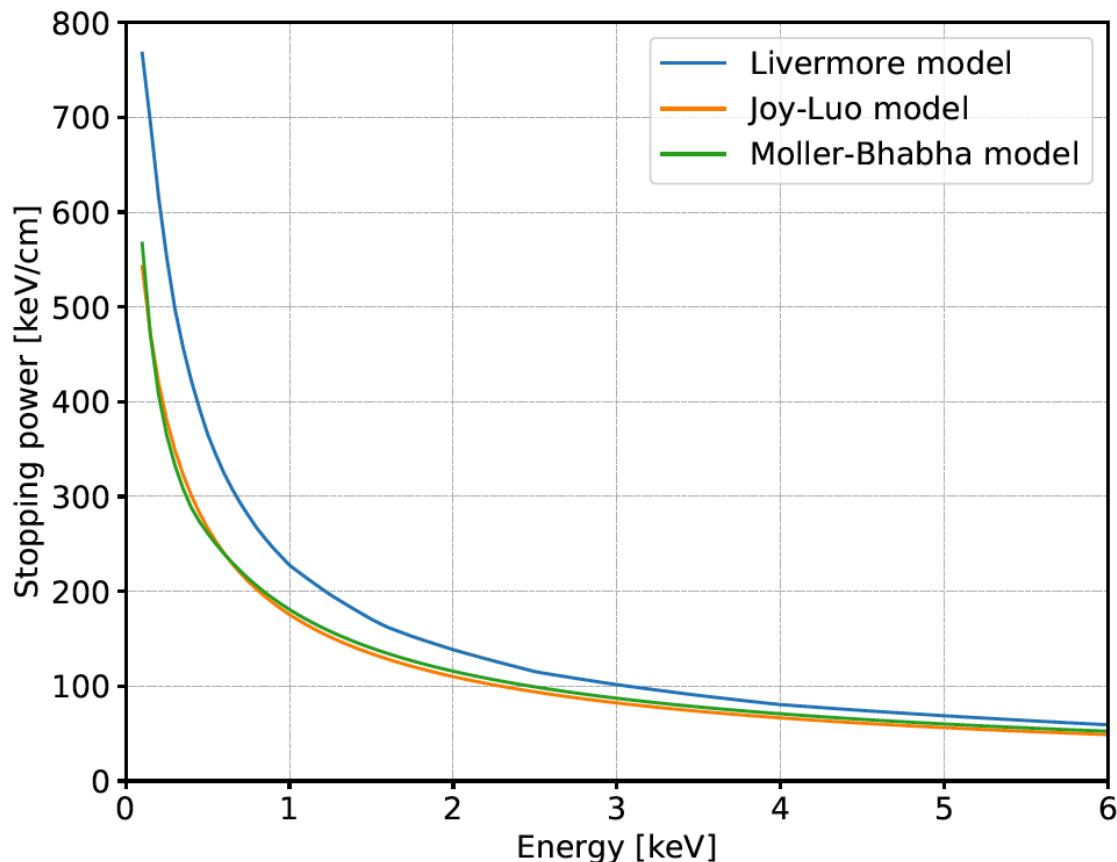
■ G4EmLivermorePolarizedPhysics

- For Gamma photoelectric effect:
 - **NO:** G4LivermorePolarizedPhotoElectricModel
 - **YES:** G4LivermorePolarizedPhotoElectricGDModel (G.O.Depaola, 2006)
 - Optimized for measuring linearly polarized X-rays in the energy range of few keV
 - Properly taking into account the direction of the photo-electron

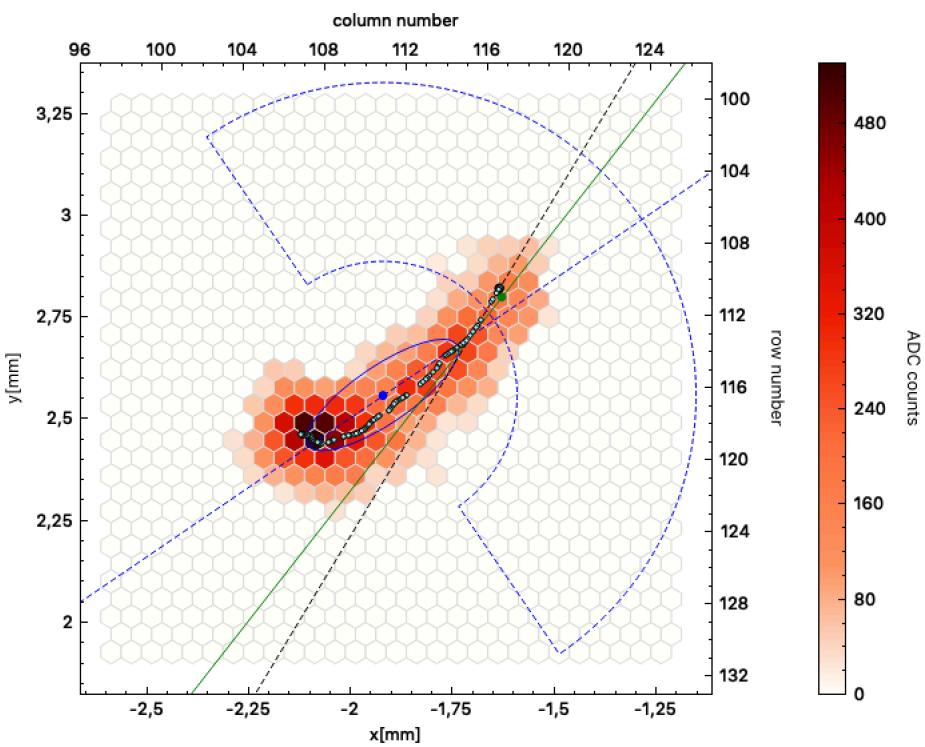
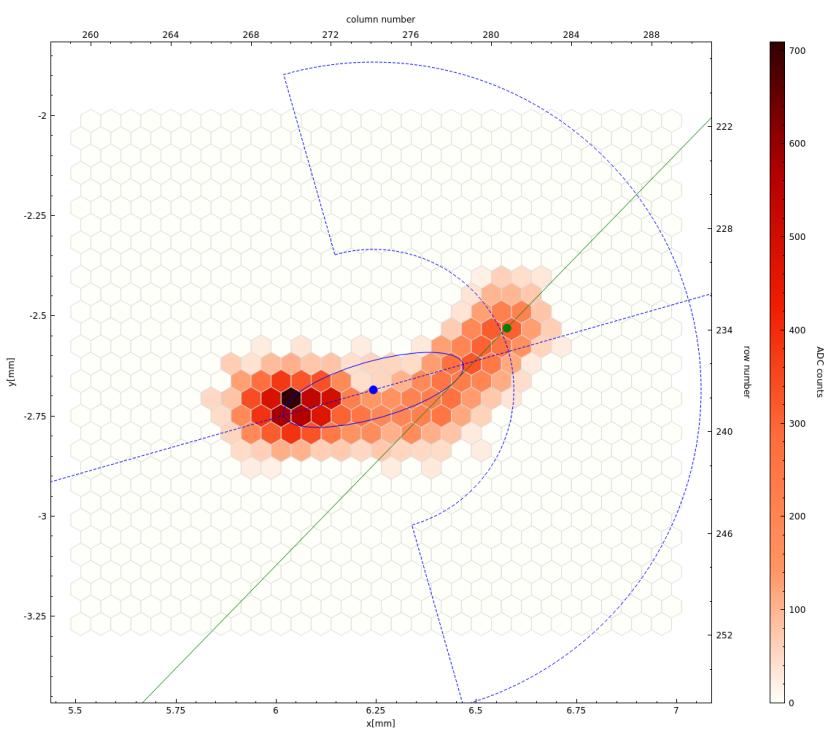
■ G4EmLivermorePolarizedPhysics

- For electron ionization
 - NO: G4LivermoreIonisationModel
 - YES: G4MollerBhabhaModel (V. Grichine, 2011)
 - Modification on mean excitation energy for the gas

■ G4EmLivermorePolarizedPhysics

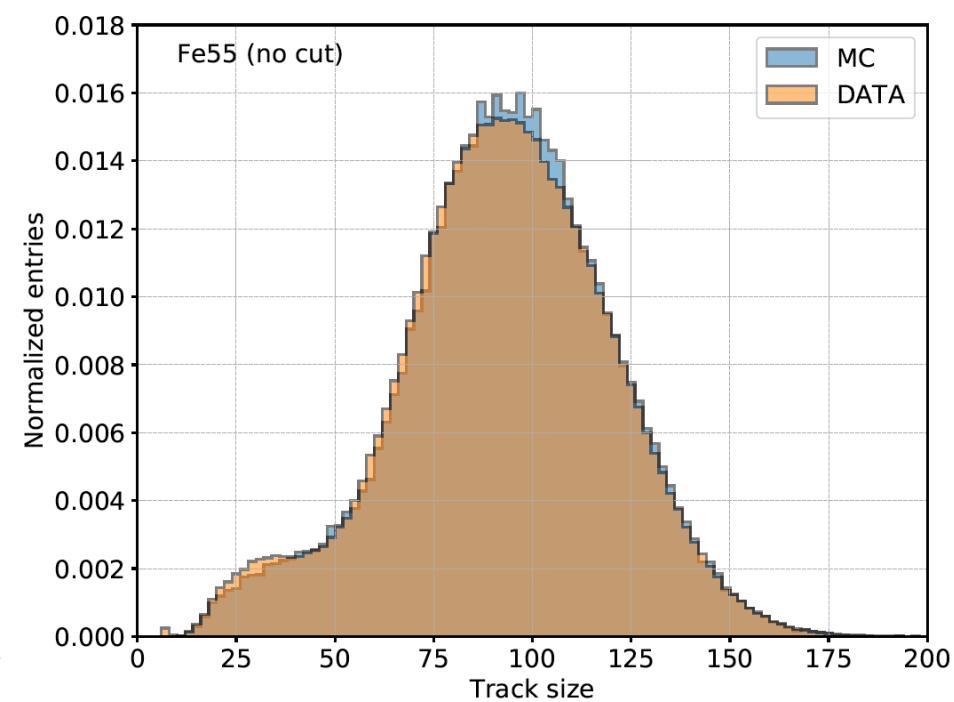
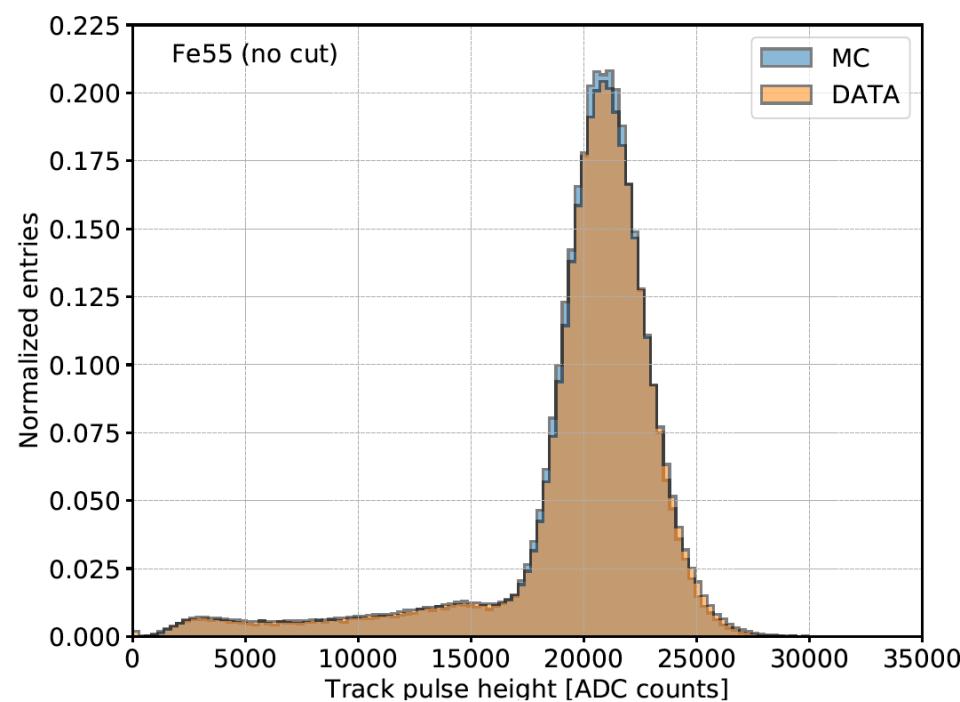


VALIDATION ON SIMULATOR

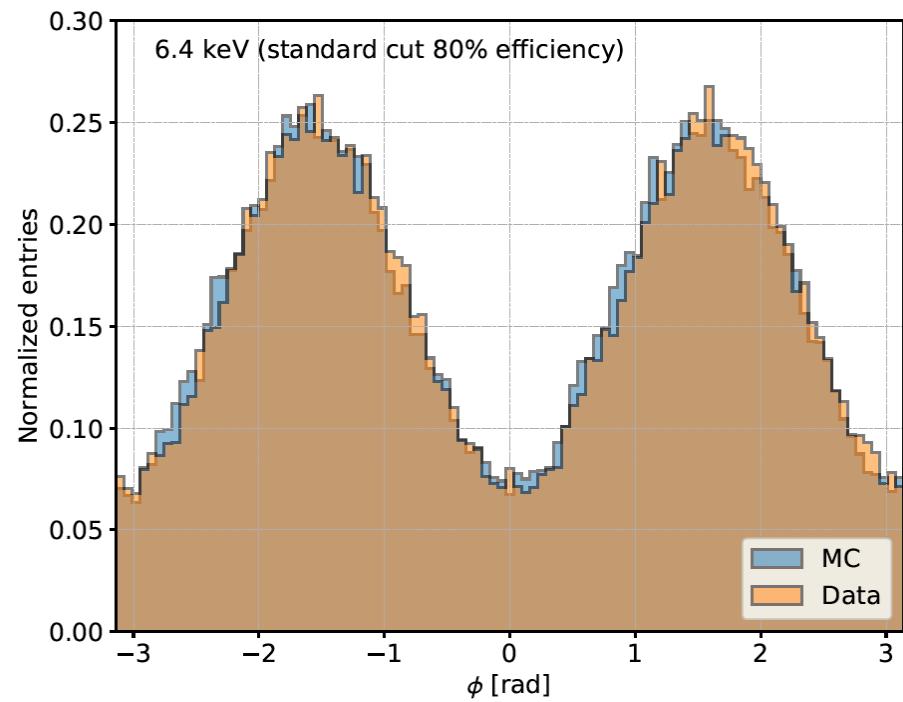
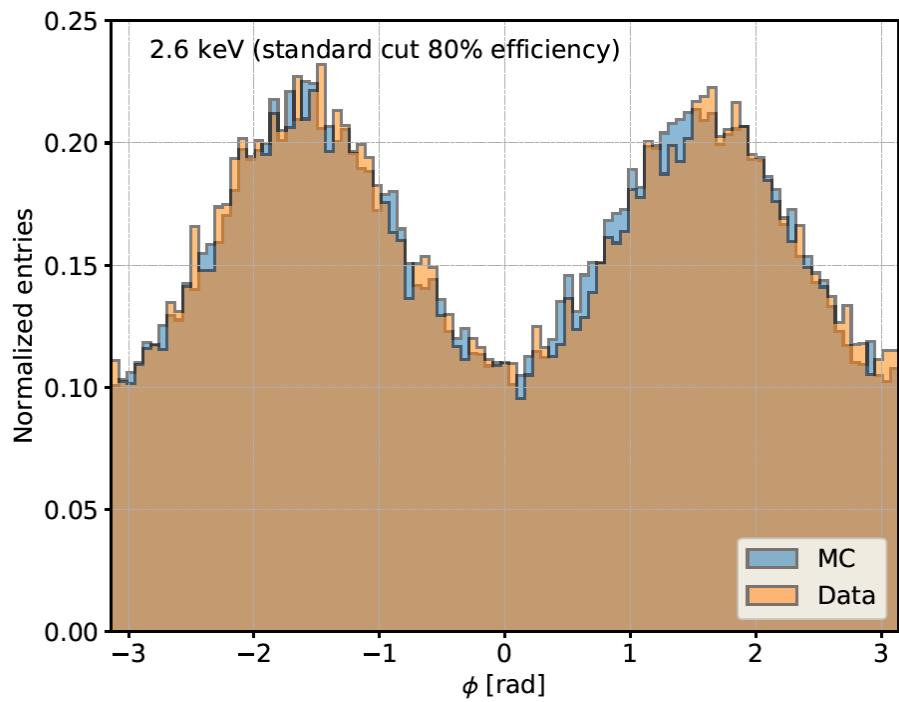


Fe55@5.9keV

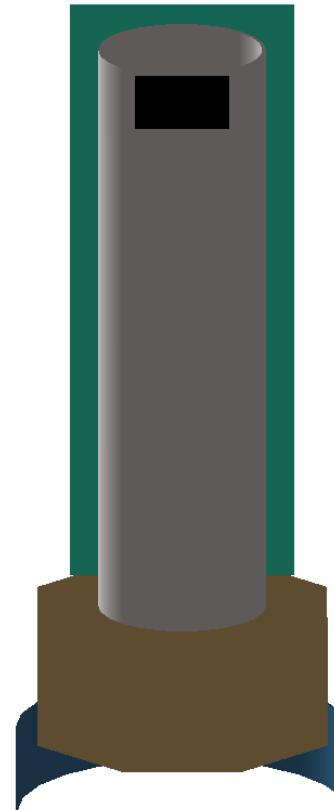
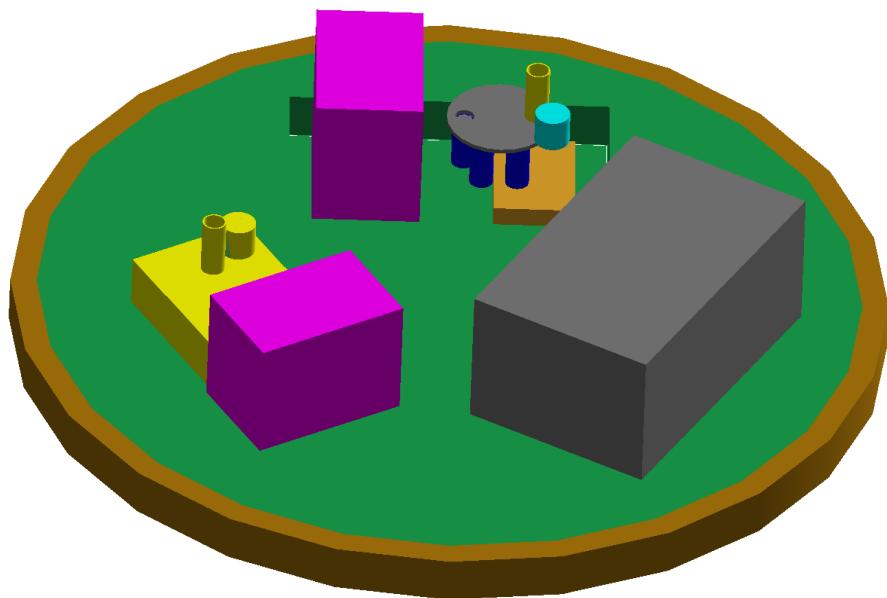
VALIDATION ON SIMULATOR



VALIDATION ON SIMULATOR



BACKGROUND SIMULATION

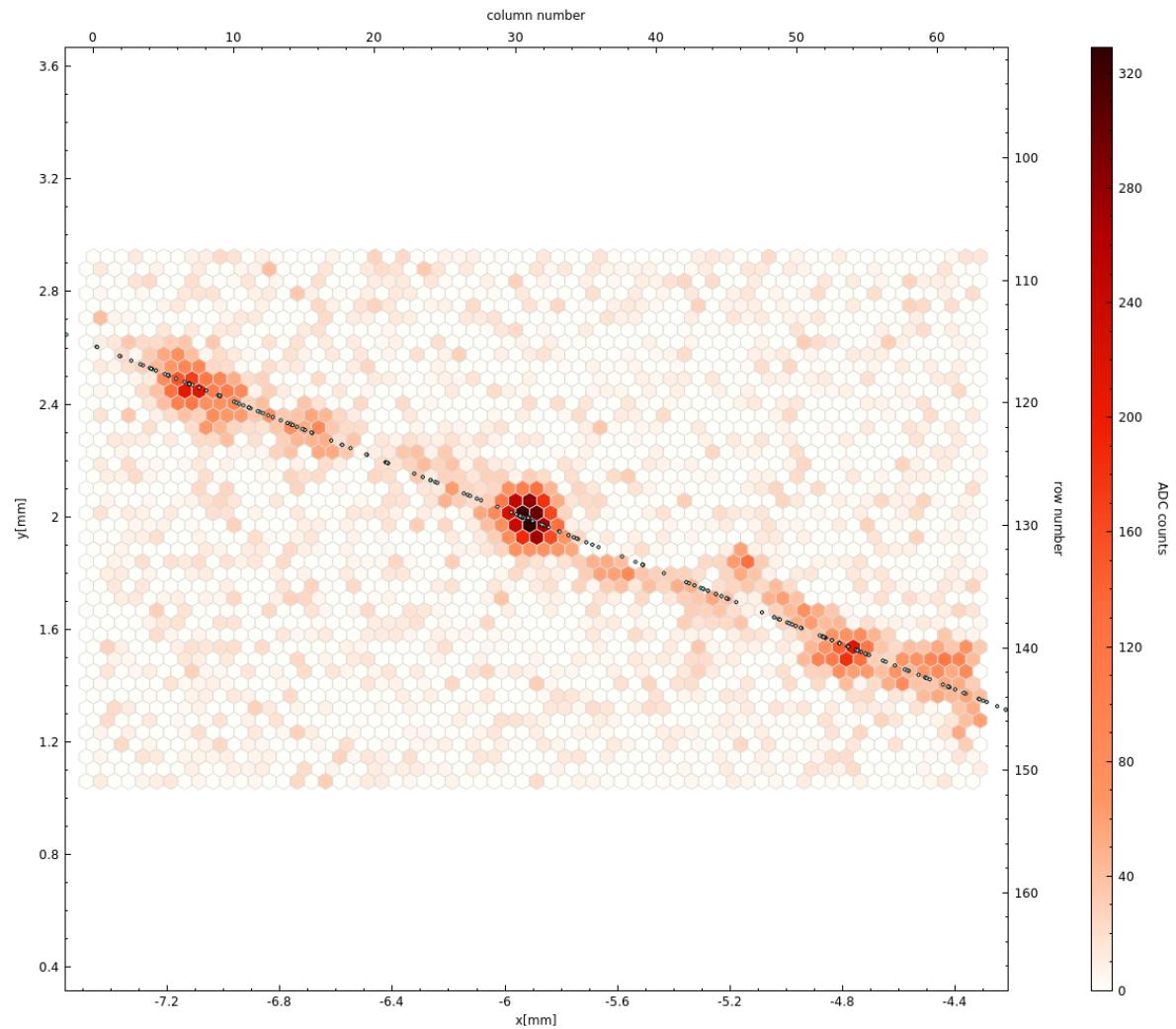


BACKGROUND SIMULATION

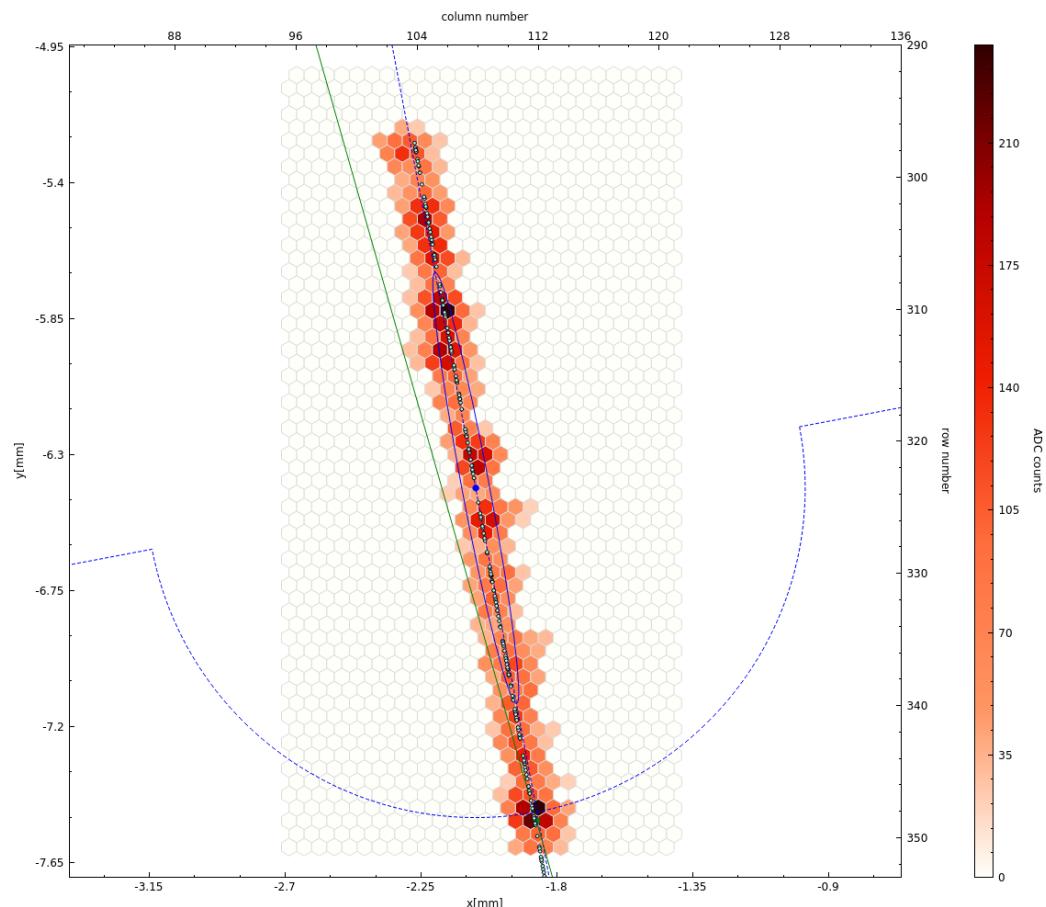
- **Shielding physics list**
 - Hadronic physics
 - Decay physics
 - Electromagnetic physics
 - `ixpeEMphysicsList`

- **Apply different cuts in different regions**

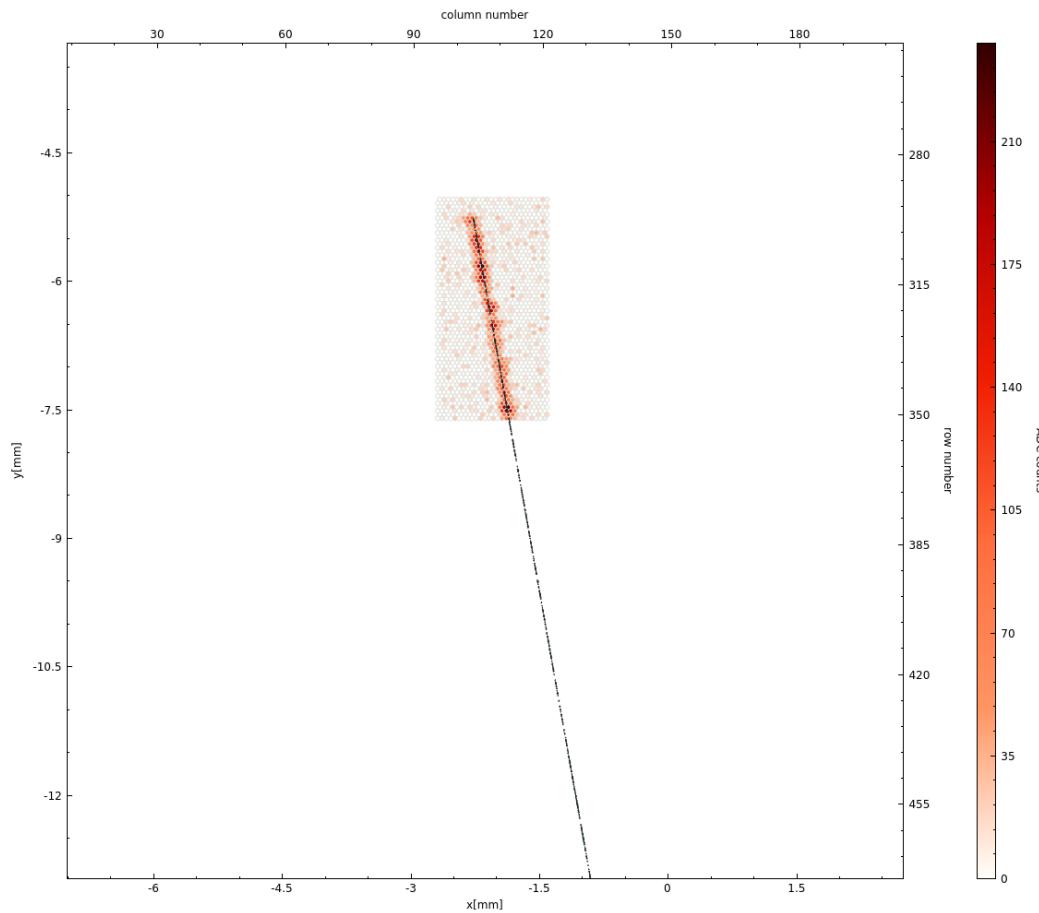
SIMULATED DATA OF PRIMARY PROTON



SIMULATED DATA OF PRIMARY PROTON



SIMULATED DATA OF PRIMARY PROTON



■ Background requirement:

- 0.04 count/cm²/s per DU
- For the faintest and extended source

■ Background rejection method

- Energy
- Track size
- Charge density
- Border
- Skewness
- ...



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Thank you!