

# Detection efficiency simulations of the ATLAS-TPX detector

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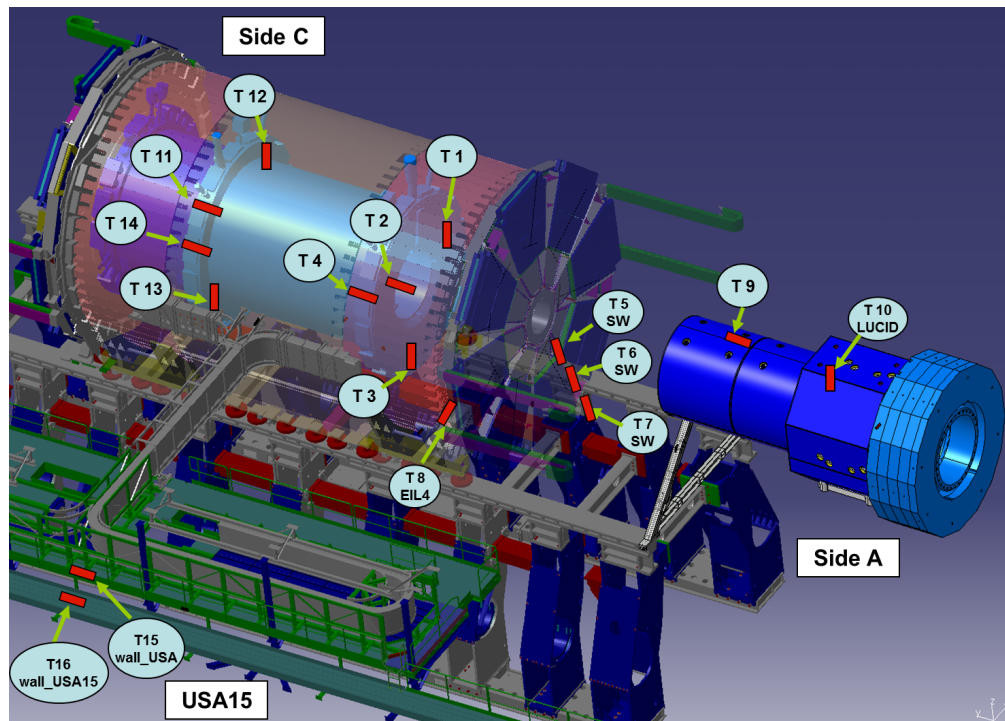
August 18<sup>th</sup> 2021, 2<sup>nd</sup> Allpix Squared User Workshop

# Overview

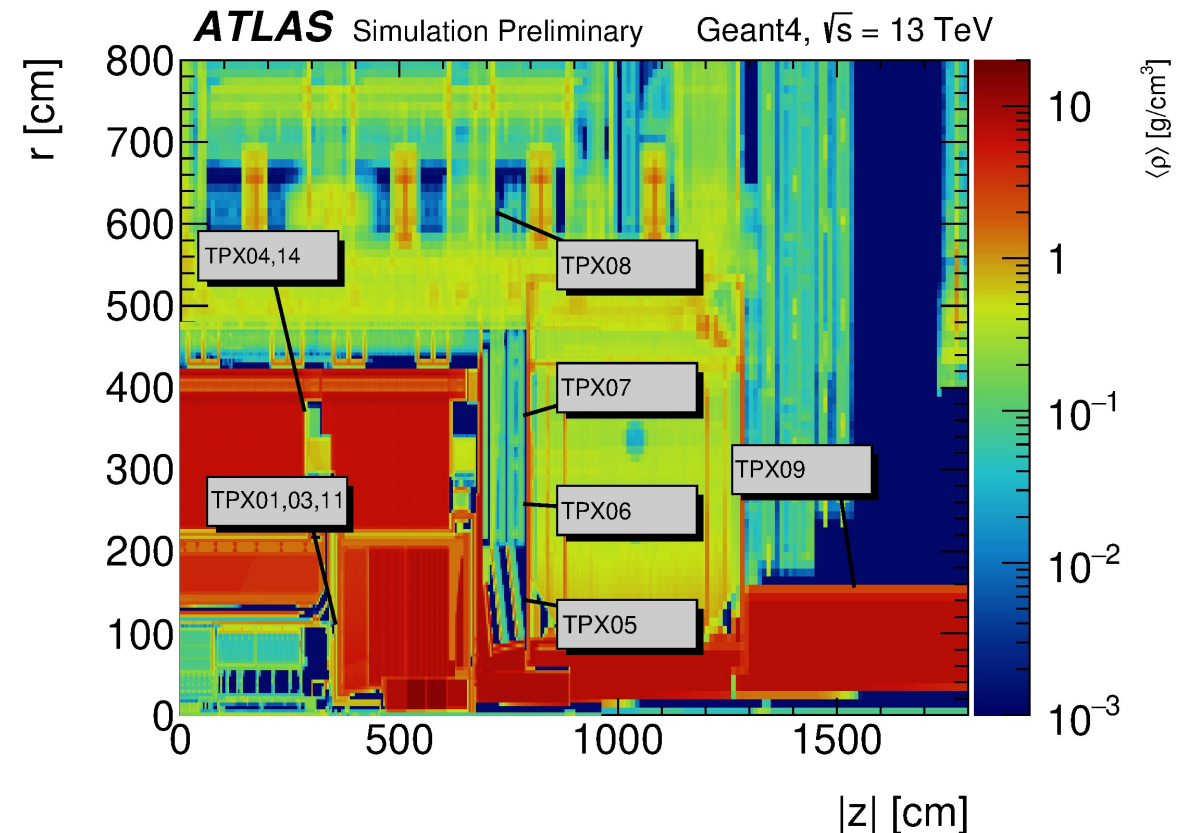
- Motivations
- The ATLAS-TPX detector
- Detection efficiency studies
- Application of results

# Motivation

- Use Timepix detectors to benchmark radiation field simulations in ATLAS
- Detection efficiency studies are needed to measure charged particle fluences



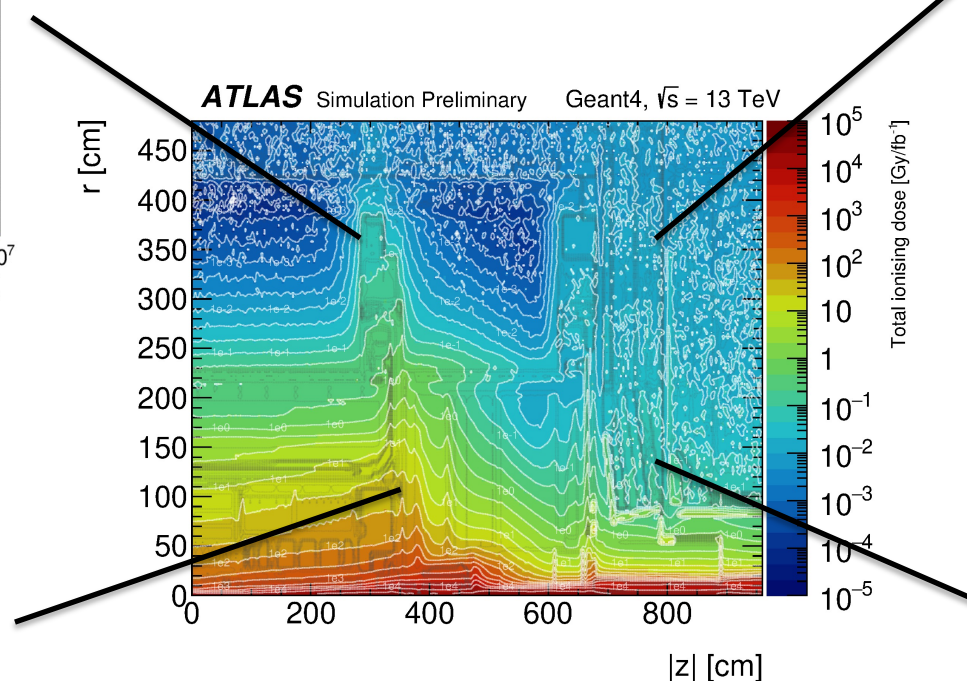
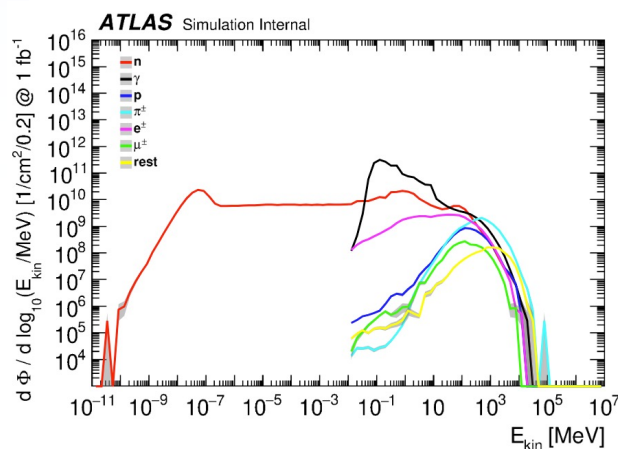
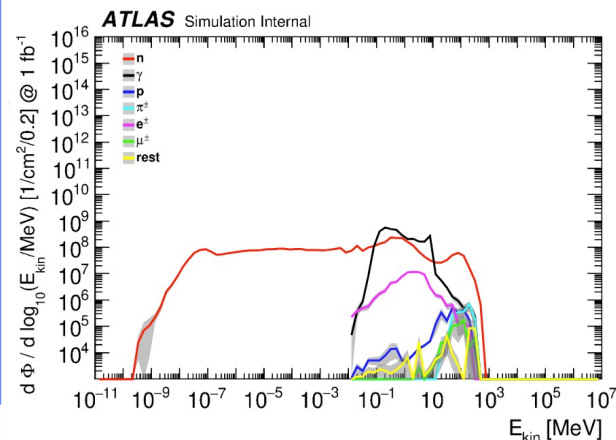
Position of Timepix radiation detectors in ATLAS



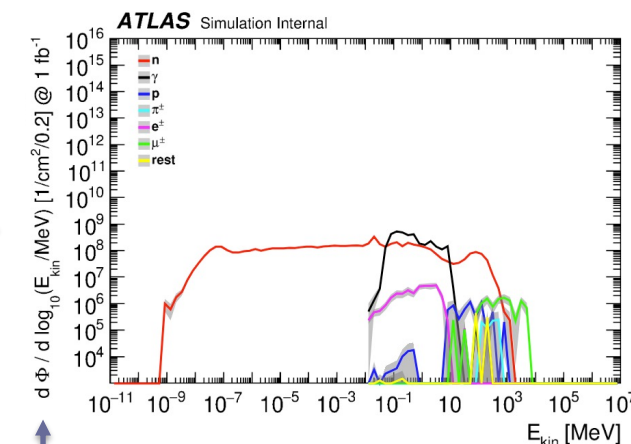
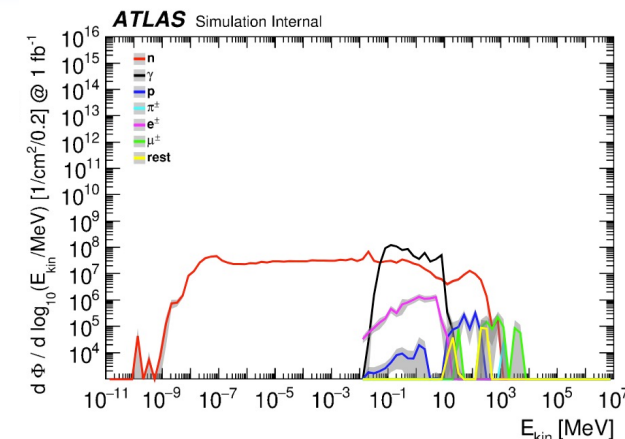
Geant4 model of the ATLAS experiment: average material density in cylindrical coordinate system. Timepix detector locations are shown on top.

# Radiation field in ATLAS

## Particle spectra at different locations in ATLAS



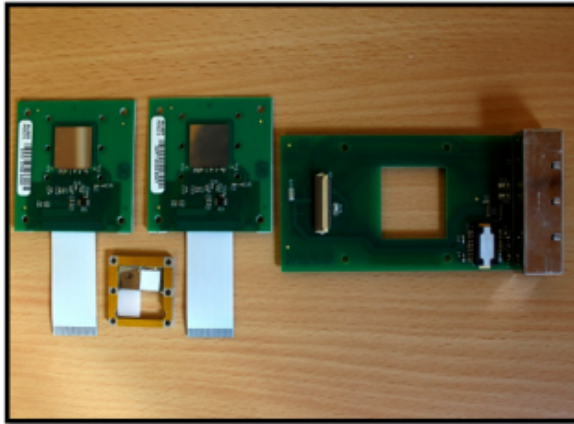
Map of total-ionizing dose in ATLAS  
(simulated with Geant4)



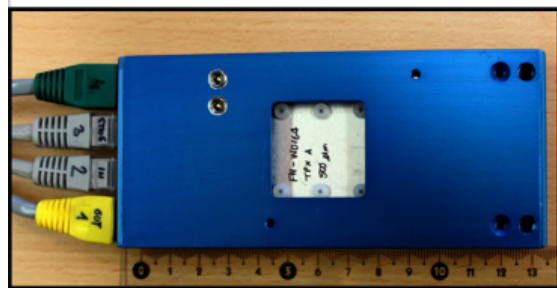


# The ATLAS-TPX detector (1/3)

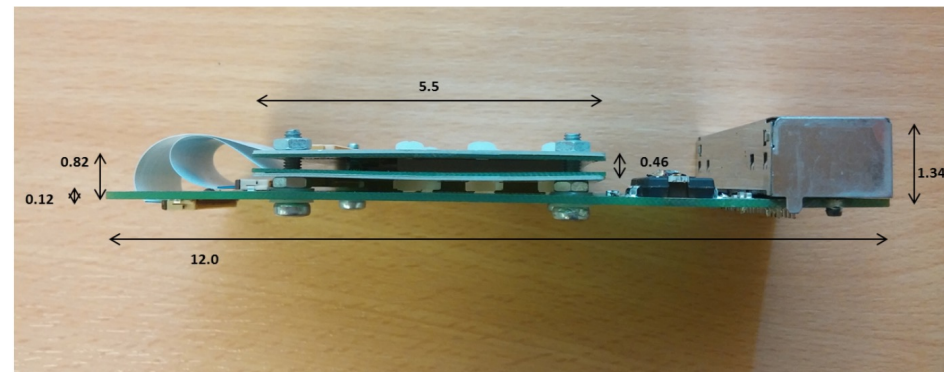
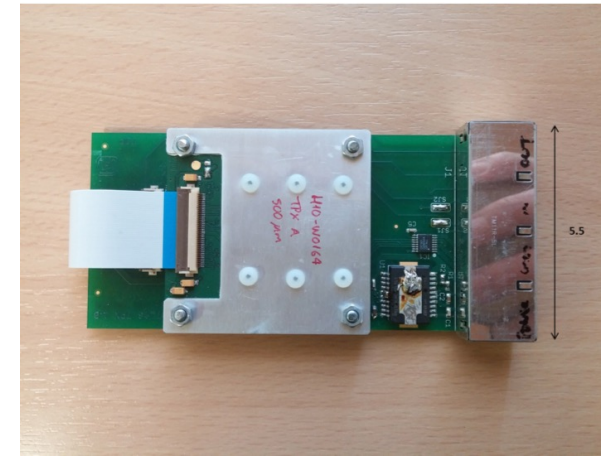
- ATLAS-TPX: two Timepix chips facing each other with neutron converters in between
- Silicon sensors: 300  $\mu\text{m}$  and 500  $\mu\text{m}$



Main components: two Timepix detectors, neutron converters, mother board



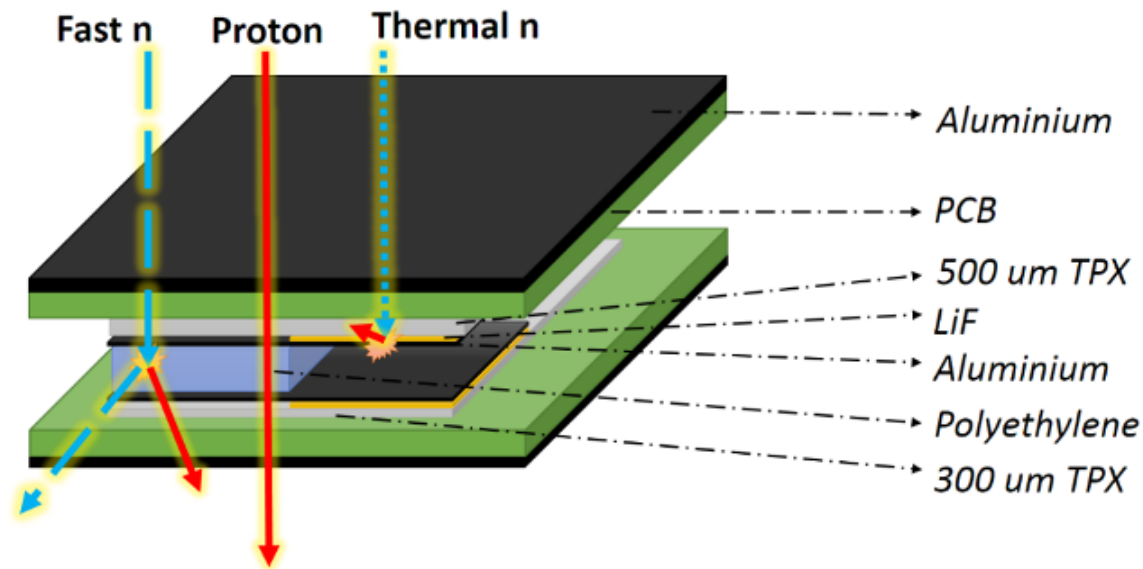
Detector in its Al casing with ethernet connections



Dimensions of the assembled detector

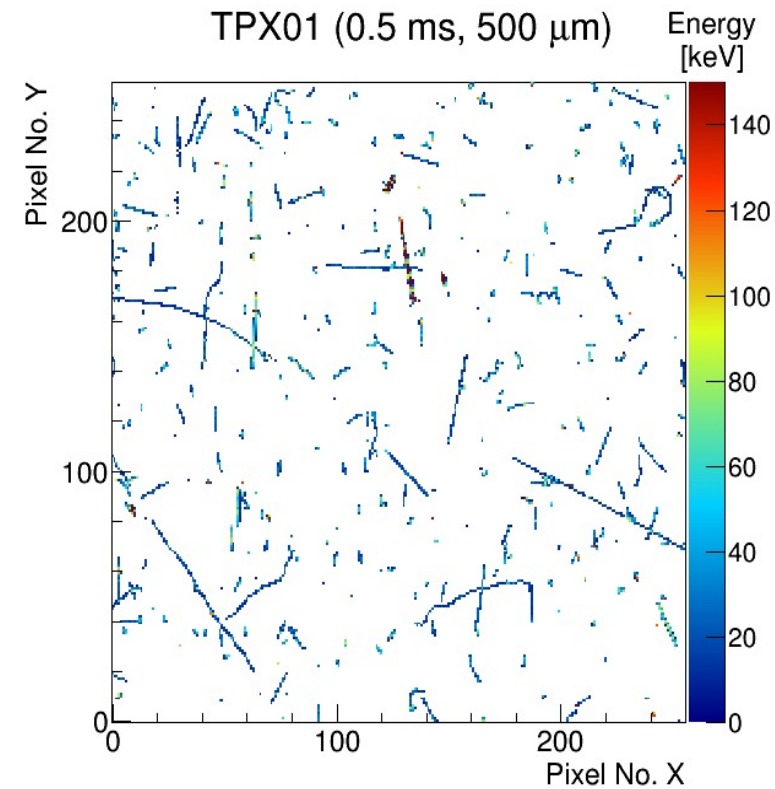
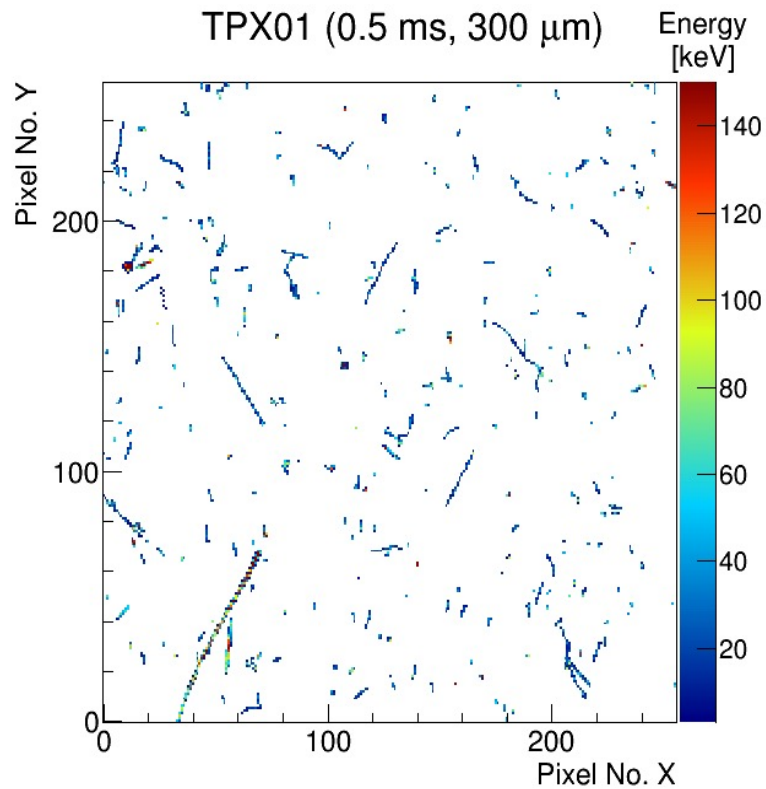
# The ATLAS-TPX detector (2/3)

- Measurable values: ionizing dose, thermal & fast neutron fluence, **charged particle fluence**
- Timepix in ToT mode with per-pixel X-ray energy calibration
- Use of coincidence between the 2 Timepix detectors and pattern recognition algorithms



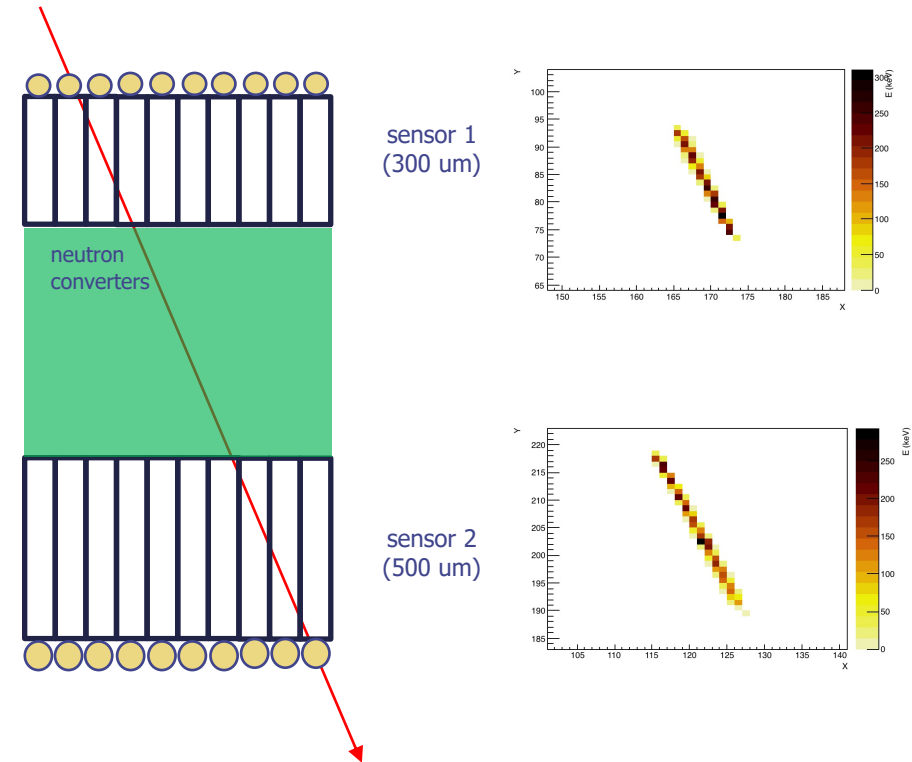
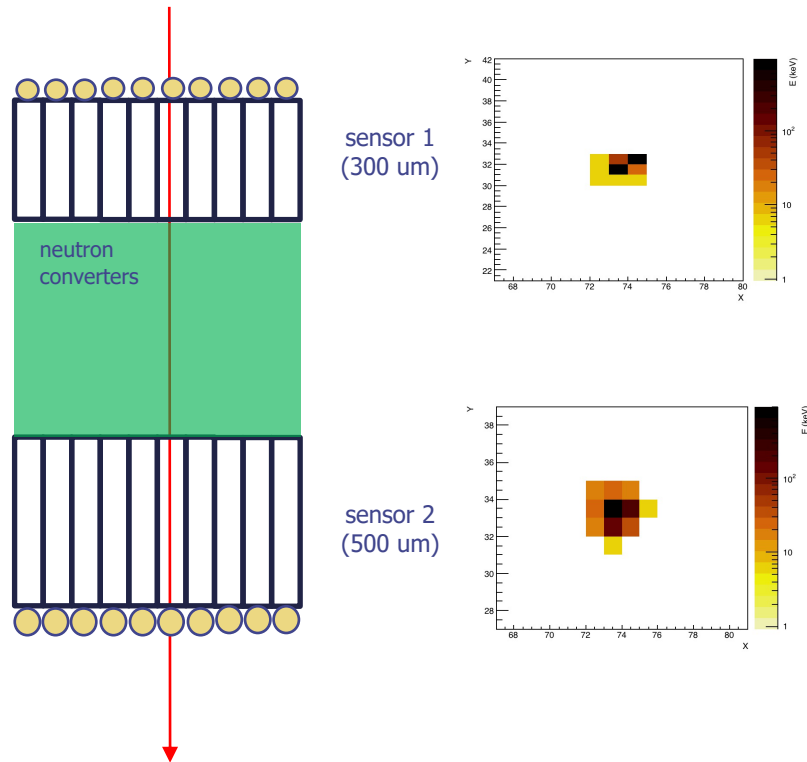
# The ATLAS-TPX detector (3/3)

- Example of measured data with an ATLAS-TPX detector



# Measuring charged particle fluence (1/2)

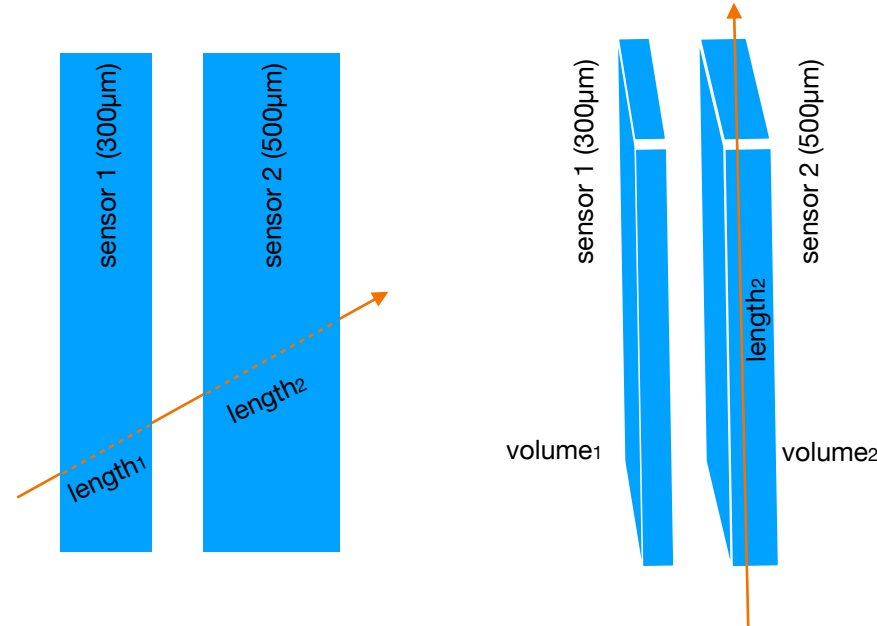
- Step 1: select charged particle events with pattern recognition and coincidence





# Measuring charged particle fluence (2/2)

- Step 2: convert cluster rate to fluence
- Each cluster count is normalized with the corresponding effective area



$$A_{eff} = \frac{Volume_1 + Volume_2}{length_1 + length_2}$$

# Need for detection efficiency study

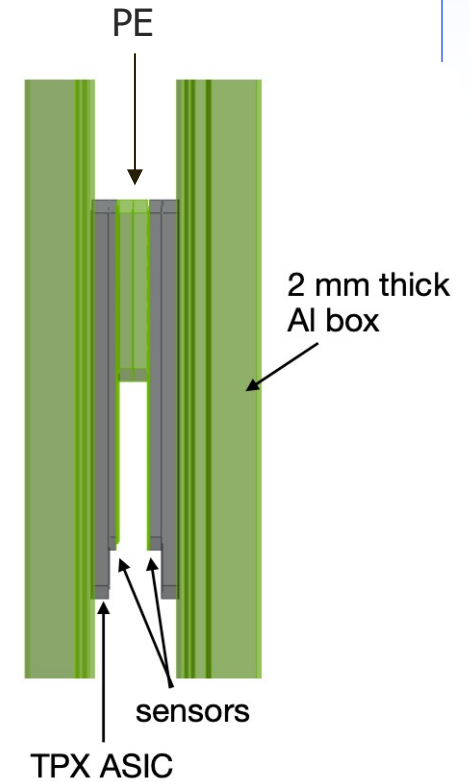
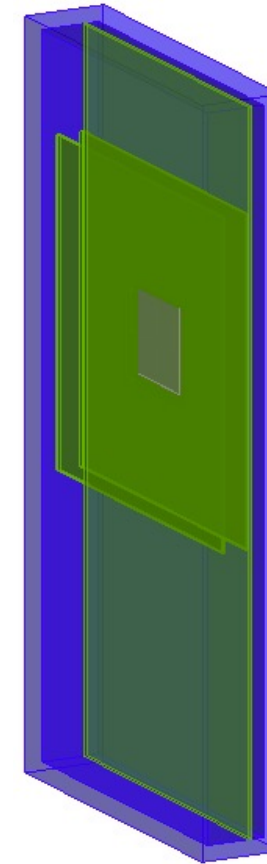
- The reconstructed fluence is affected by:
  - Delta-rays
  - Compton/pair-production interactions (background due to  $\gamma$ -rays)
  - Cluster overlapping
  - Cluster mis-identification
  - Particle absorption in the detector casing
  - Rejection of low energy electrons by pattern recognition algorithms
- When benchmarking predictions of fluences in ATLAS, the detection efficiency must be determined
- **This is where Allpix2 were used**

# Simulation overview

- The detection efficiency was determined for:
  - main particle types present in ATLAS that contribute to the measurement
    - Charged particles (signal):  $e^-$ ,  $p^+$ ,  $\mu^-$ ,  $\pi^-$
    - $\gamma$ -rays (background)
  - Different energies
  - Isotropic fields
- Detection efficiency = reconstructed fluence / emitted fluence

# Detector model

- Use of two models based on 'timepix.conf' with additional layers:
  - Neutron converters :
    - LiF ( $6\text{ }\mu\text{m}$ )
    - PE ( $1200\text{ }\mu\text{m}$ )
  - PCBs: Si ( $300\text{ }\mu\text{m}$ ) + Al support ( $300\text{ }\mu\text{m}$ )
  - Mother board: Si ( $640\text{ }\mu\text{m}$ )
- Detector casing (2mm) added as a passive 'box' in the detector .conf file
  - Empty window in front of sensor included as a 2<sup>nd</sup> box filled with air



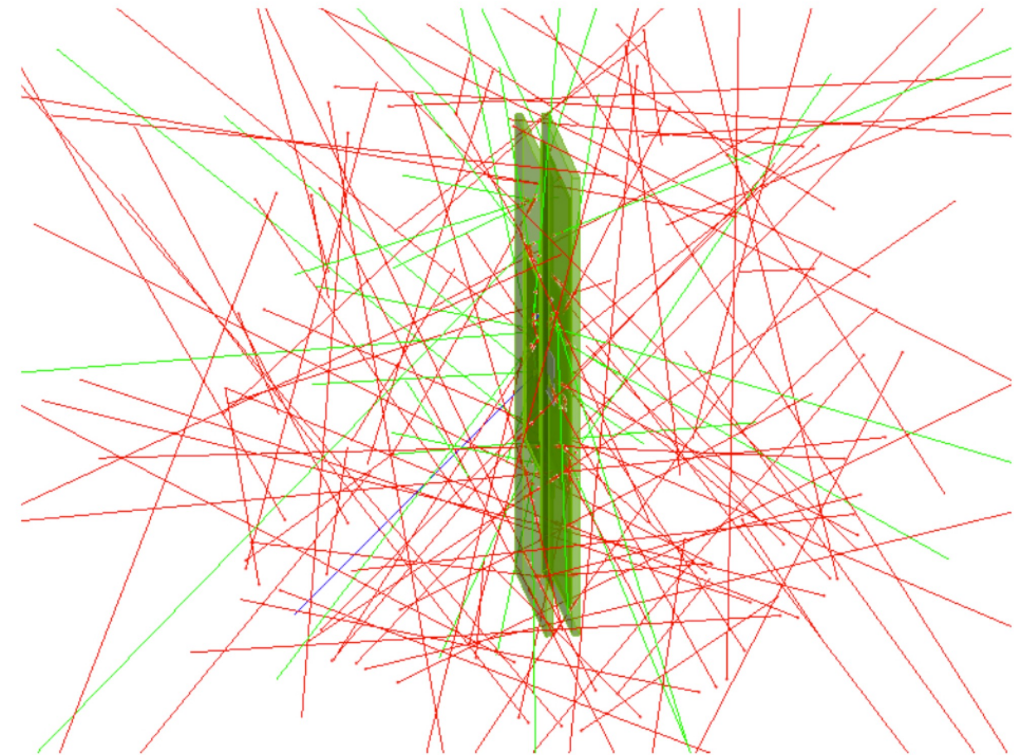


# Particle source

- Isotropic fields can be obtained with a sphere source and cosine emission angle
- Radius = 10 cm
- 100 particles per event to avoid cluster overlapping
- $10^7$  events for each particle type at e energy

```
[DepositionGeant4]
log_level = "ERROR"
physics_list = FTFP_BERT_EMY
charge_creation_energy = 3.64eV
number_of_particles = 100
particle_type = "pi-"
source_energy = 1GeV
##----- SPHERE -----#
source_type = "sphere"
sphere_radius = 10cm
source_position = 0 0 0
```

Cosine emission angle is the default if 'sphere\_focus\_point' is not used



# Detector modules

```
[ElectricFieldReader]
log_level = "WARNING"
model = "linear"
bias_voltage = -150V
depletion_voltage = -50V

[ProjectionPropagation]
log_level = "WARNING"
temperature = 293K
output_plots = false

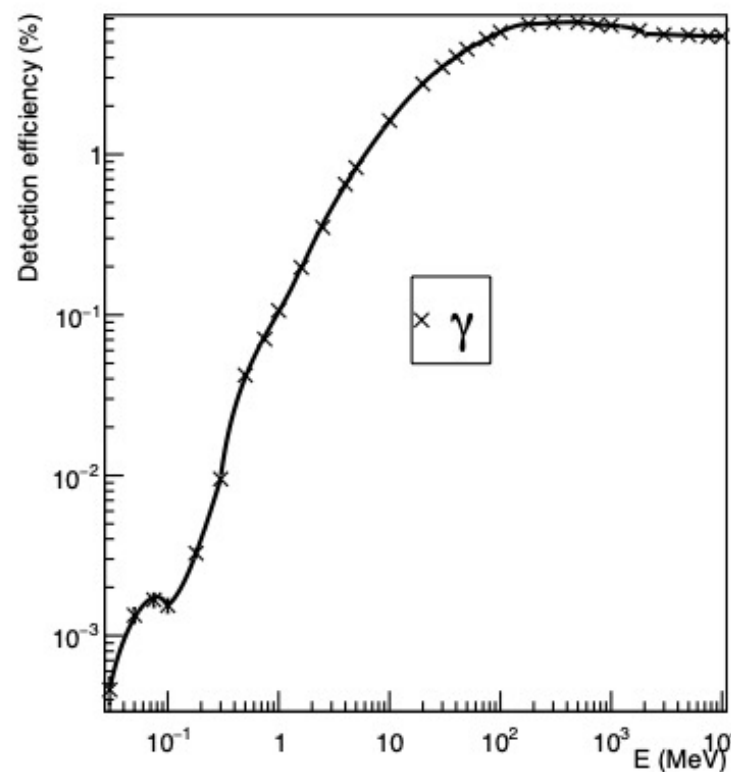
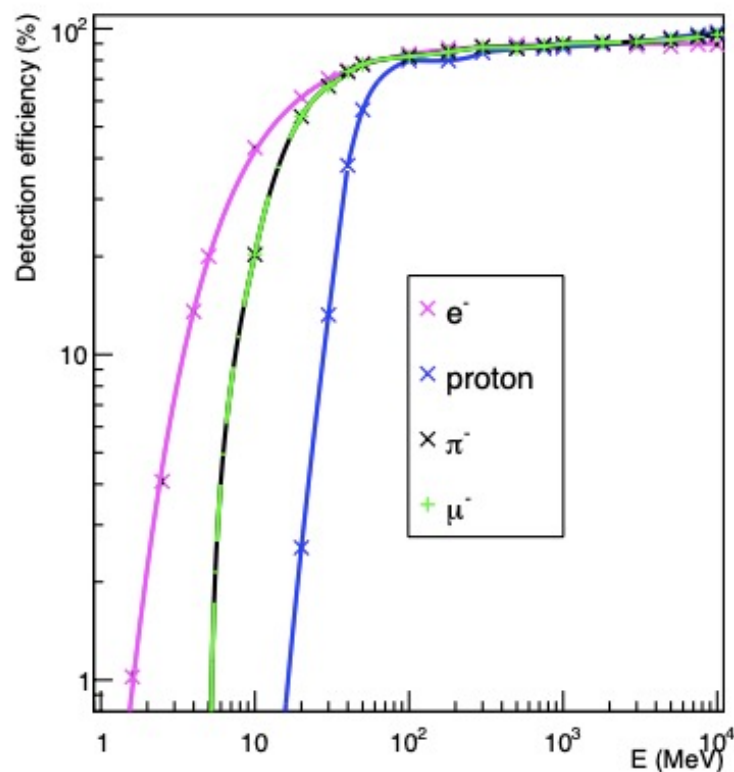
[SimpleTransfer]
log_level = "WARNING"
max_depth_distance = 5um

[DefaultDigitizer]
log_level = "WARNING"
threshold = 3e # in keV if gain is 0.00364
threshold_smearing = 0e
gain = 0.00364
adc_smearing = 0
```

# Writer module

- I wrote a dedicated 'writer' module to get output in the same format than measured data
- It writes a single ROOT file with:
  - A TTree with a list of clusters. Each cluster/leaf has:
    - Some basic info: cluster size, cluster energy, list of pixel hits/ToT, frame number, etc...
    - Layer in which the cluster was detected
    - Cluster type according to pattern recognition algorithms
    - the MCParticleID corresponding to the cluster and primary/secondary information
  - A TDirectory with ground truth info about particle fluences

# Detection efficiencies

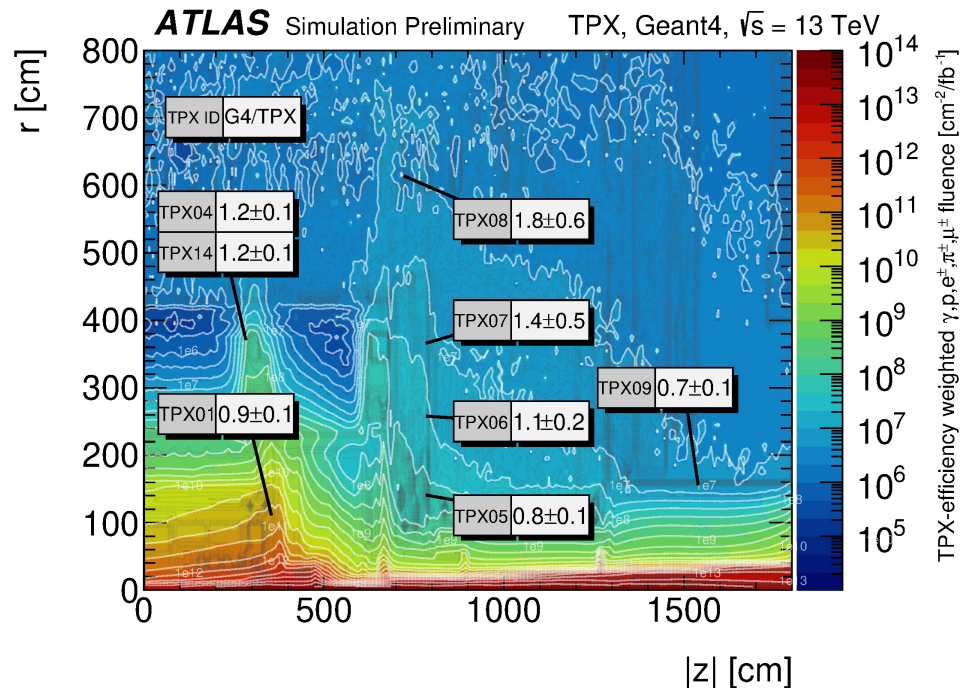


Detection efficiency for charged particles (signal) and photons (background). Each point represents an Allpix2 simulation run.



# Application of results

- Comparison of charged particle fluences between ATLAS-TPX measurements and Geant4 predictions in ATLAS



Map of Geant4-simulated charged particle fluences (G4) normalized to an integrated luminosity of  $1 \text{ fb}^{-1}$  and comparison with Timepix measurement at different locations in the ATLAS cavern for Run 2 (proton-proton collisions at  $\sqrt{s} = 13 \text{ TeV}$ ). The map is efficiency weighted, includes the gamma background, and is normalized to the effective exclusive fluences.

Convolution of Geant4-simulated fluence and Allpix2-simulated detection efficiency

$$\frac{G4}{TPX} = \frac{SIMU_{charged} + SIMU_{\gamma}}{MEAS}$$

ATLAS-TPX measurement

Thank you for your attention

And thank you Allpix2 !

