Particle tracking and radiation field characterization with Timepix3 in ATLAS

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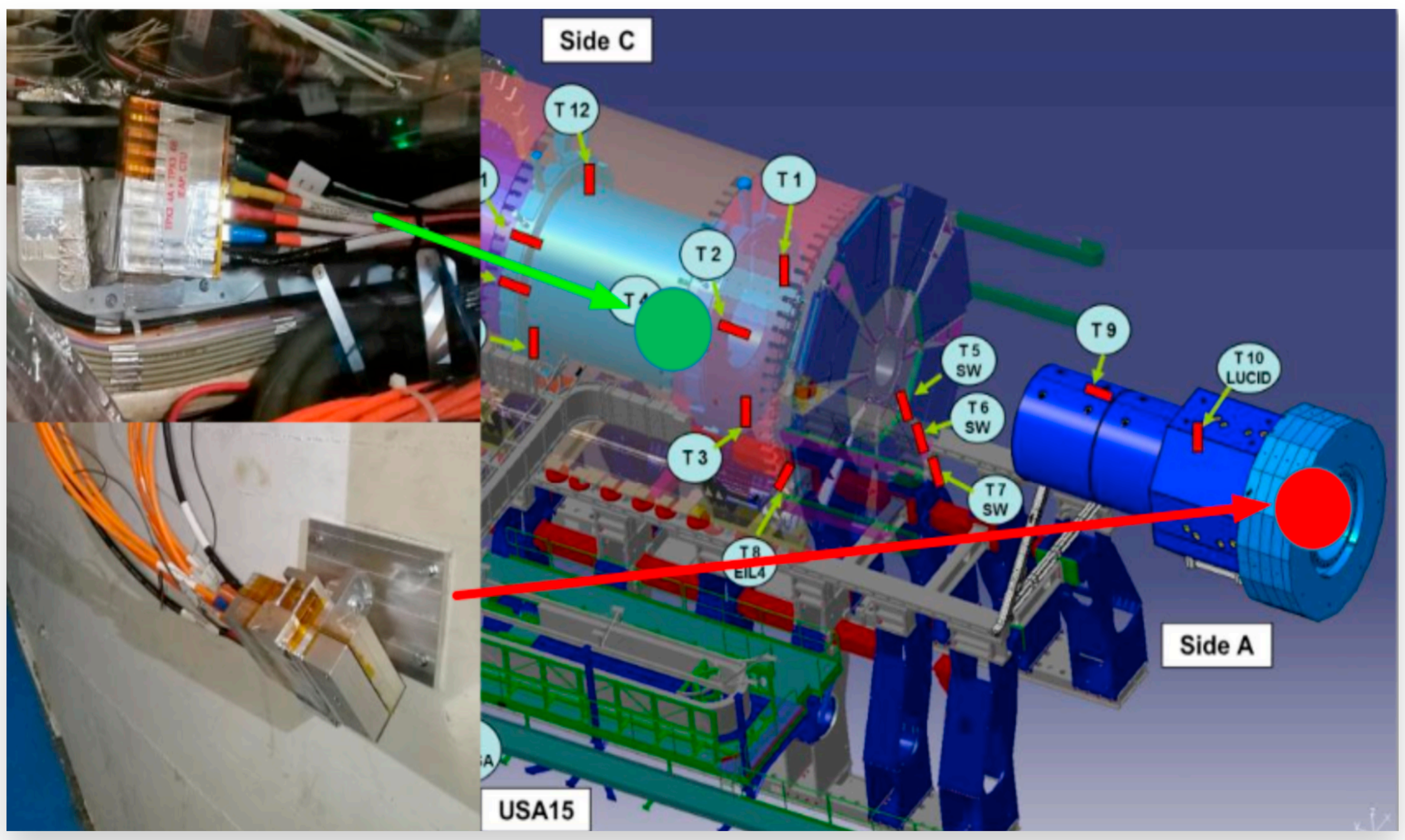
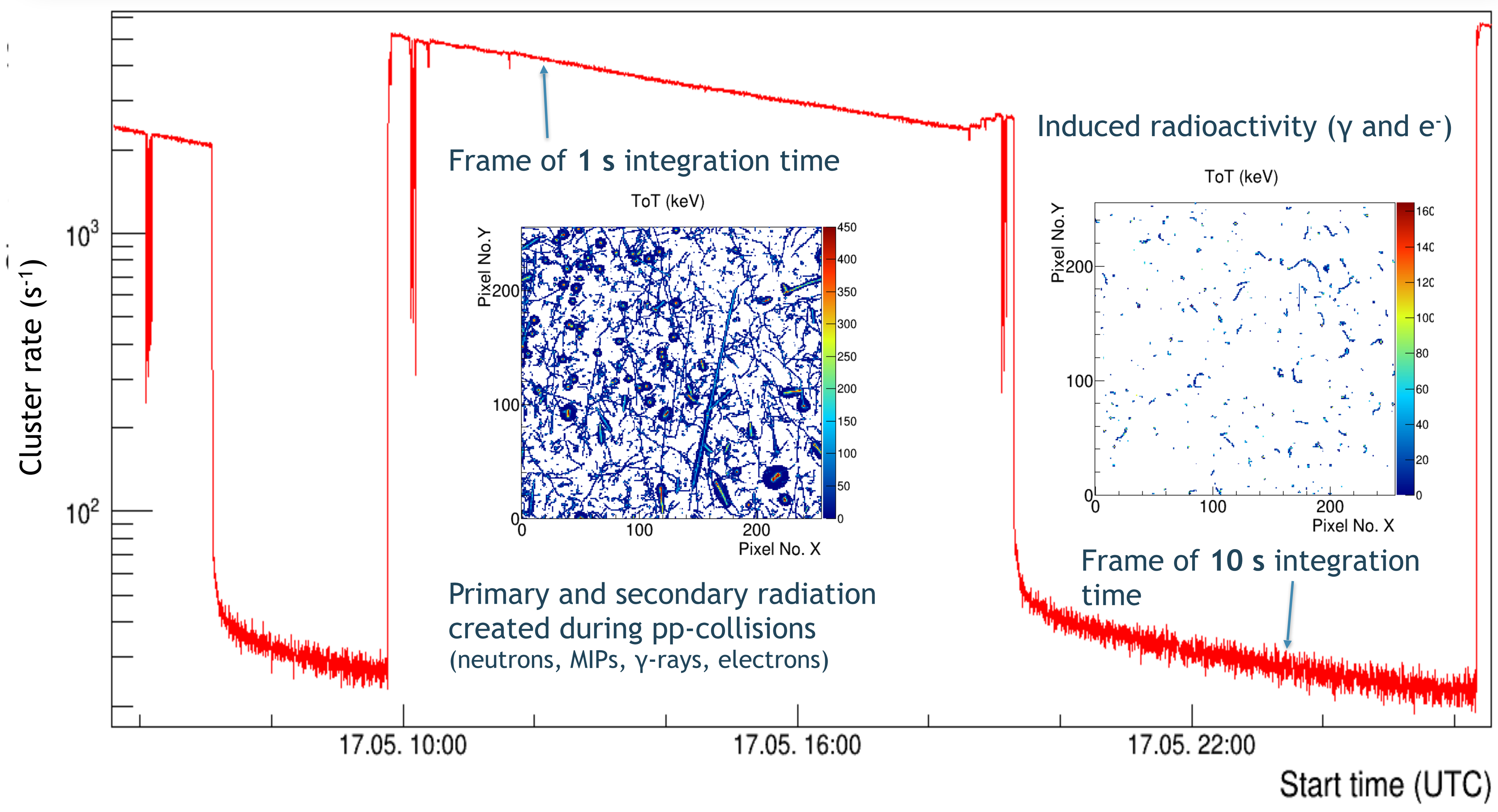
Context

- The ATLAS experiment at the LHC features a unique and complex radiation environment (neutrons, minimum ionizing particles, gammas, electrons), affecting detector operation and performance.
- These mixed radiation fields and their detrimental effects are predicted using Monte Carlo simulations during the design phase of the experiment and its upgrades. Once the experiment has started, it is important to benchmark simulations with measurements.
- In addition to standard types of radiation monitors, a network of Timepix and Timepix3 detectors was installed in ATLAS to characterize the radiation field between 2015 and 2018.
- Each detector allows the discrimination of different particle types and their contribution to the measured total ionizing dose (TID). This is done by analysis of the pixel clusters left by interactions in silicon sensors. It is also possible to measure the incident angles and stopping power of MIPs. Timepix3 offers the possibility to distinguish radiation field particles present during and in-between bunch crossings.



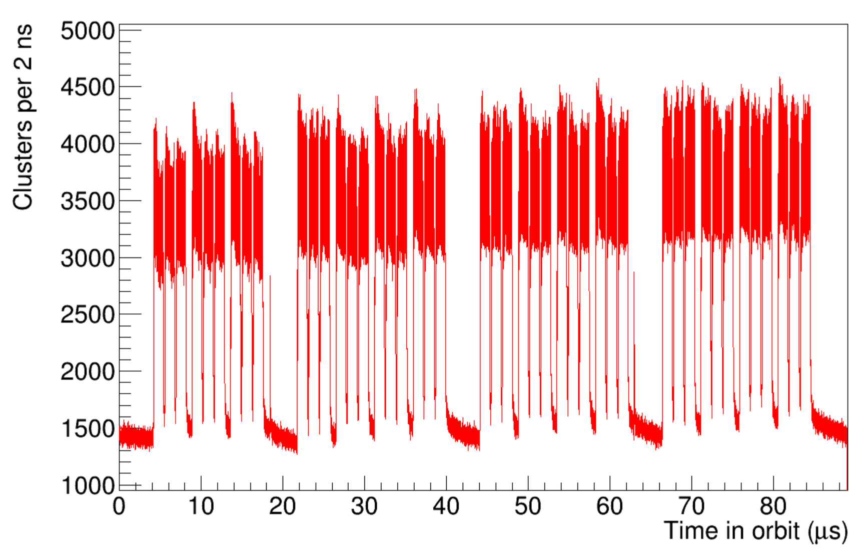
Schema of the ATLAS cavern with placement of individual Timepix3 devices

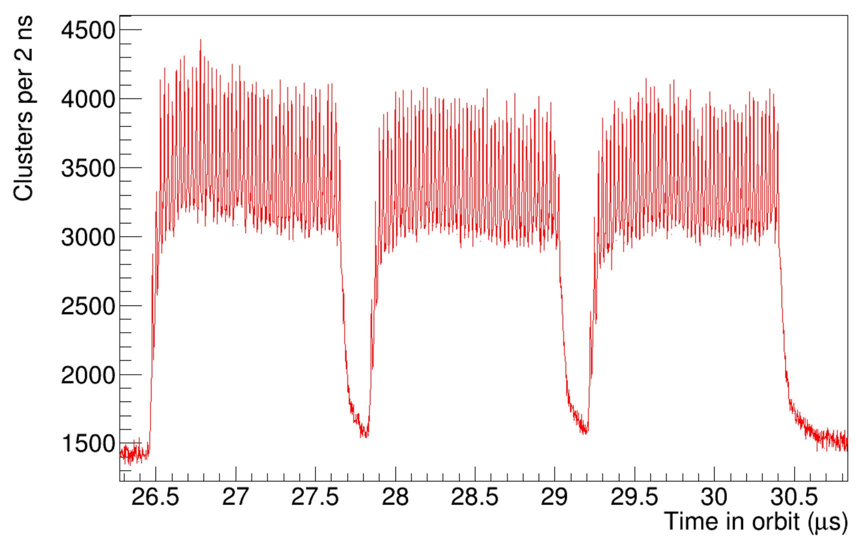
Measurement of radiation levels in ATLAS during and after collision periods

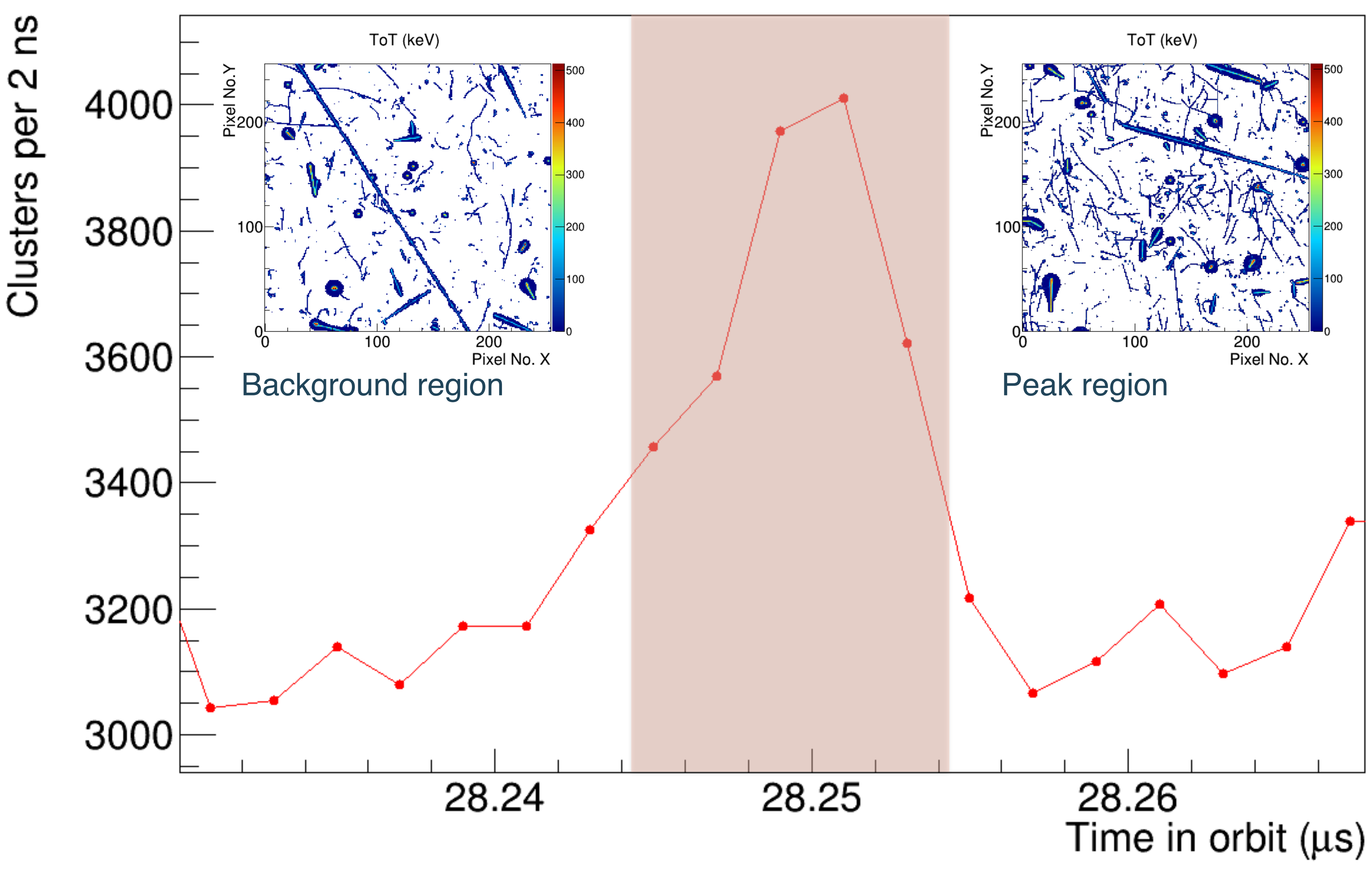


Timepix3 allows continuous measurement of the particle flux rate. Each pixel has a 1.56 ns timestamping precision.

Synchronization with orbit clock and bunch crossing ID

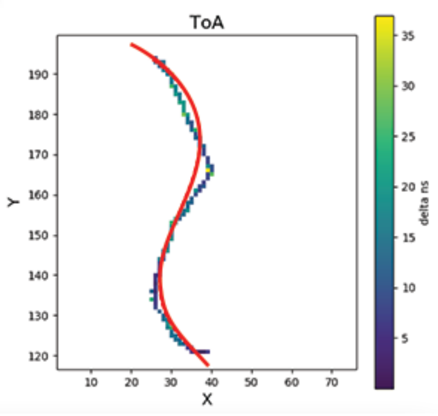


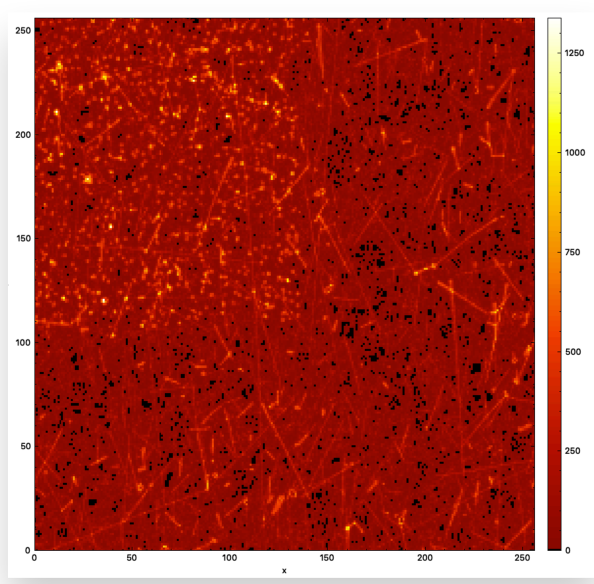




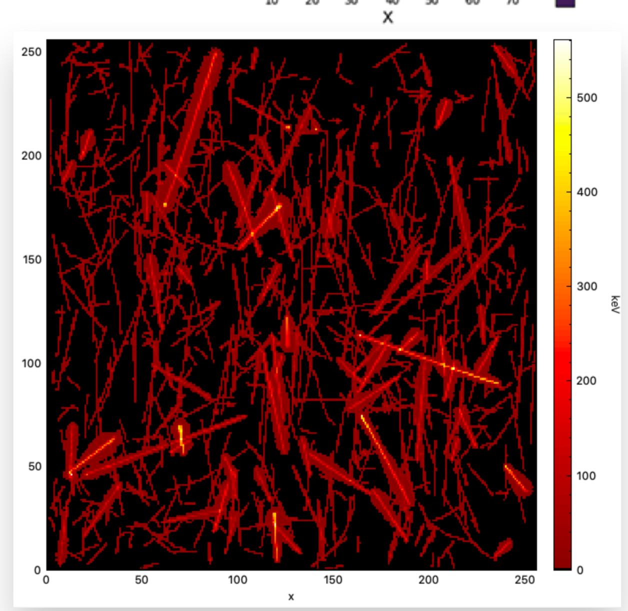
Measuring the fluence and directions of minimum ionizing particles (MIPs)

- Directional analysis of the MIP flux is possible due to the straight path of these particles in the pixelated sensor
- Polynomial fitting was used to filter out the non-straight tracks by describing the winding of a cluster
- Angles of individual clusters are computed
  - ϕ is [0°,360°] angle viewed from top of sensor
  - Θ is [0°,90°] angle the particle traversed through the sensor (0° is perpendicular to the sensor)



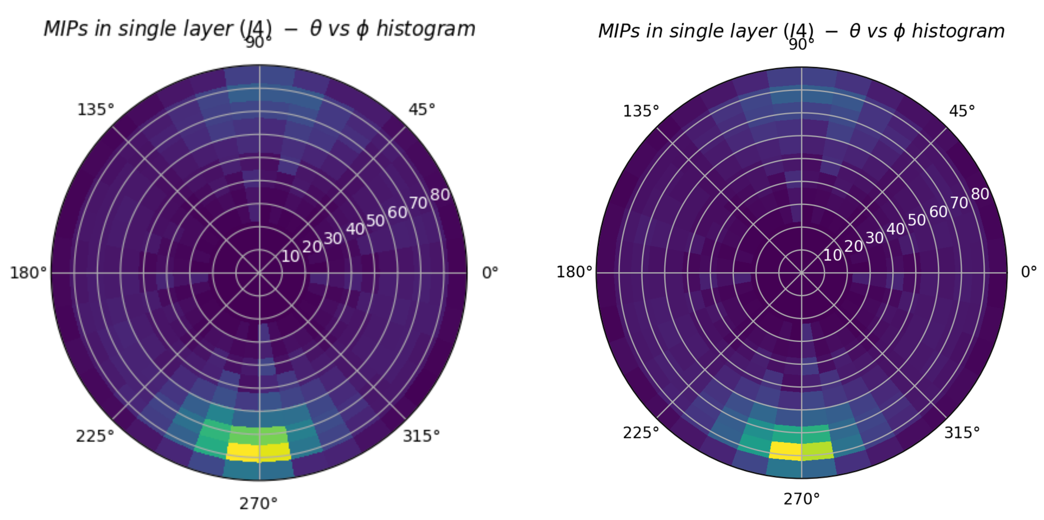


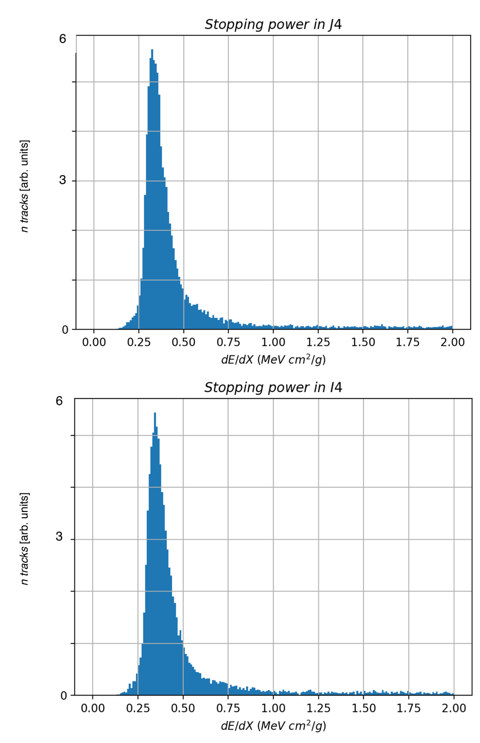
Raw 10s of data measurement inside ATLAS
(top left corner was covered by neutron convertor)



10s frame with MIPs and straight heavy tracks that both can be used to determine the angular distribution of the flux

- Distribution of directions of incoming particles was projected
- Stopping power was calculated





Conclusion

- The timestamping precision of Timepix3 allows the analysis of radiation field components during and in-between LHC bunch crossings.
- The Timepix3 chip allows the measurement of MIP directions and dE/dX (with a single sensor layer). Data-driven readout and simultaneous ToA and ToT information of Timepix3 will improve the capabilities of particle discrimination.
- Timepix3 is considered for ATLAS-Run3 operation.

References

[1] P. Burian, P. Broulím, B. Bergmann *et al.*, “Timepix3 detector network at ATLAS experiment”, *J. Instrum.*, vol. 13, no. 11, p. C11024, November 2018

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