First results from the Timepix4 telescope

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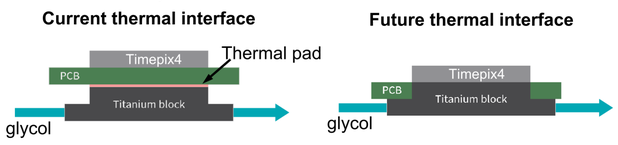
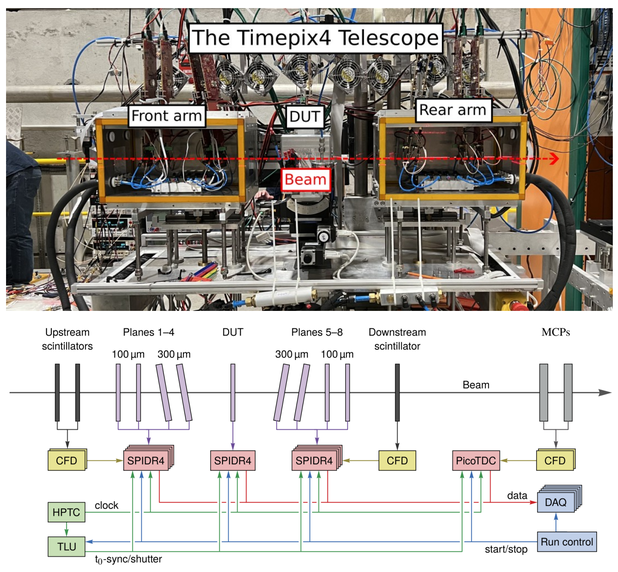
The Timepix4 telescope

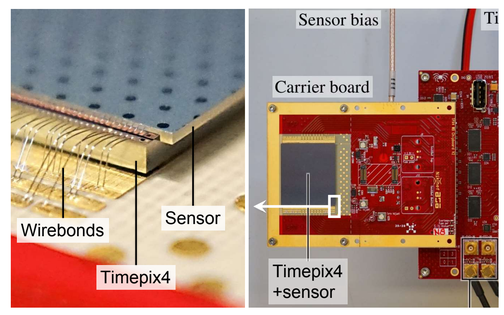
- Two arm beam telescope with eight planes with n^+-on-p planar silicon sensors on Timepix4v2 ASICs
  - 4 x 300 µm sensors for spatial resolution (angled)
  - 4 x 100 µm sensors for time resolution (perpendicular)
  - Sensor upgrades are anticipated (LGAD, 3D, ...)
- Time reference system with two MCP-PMTs to study telescope timing and obtain better track time precision
- Assemblies cooled using glycol at 20 °C
- Operated at SPS H8 beamline at CERN (180 GeV/c mixed hadrons)





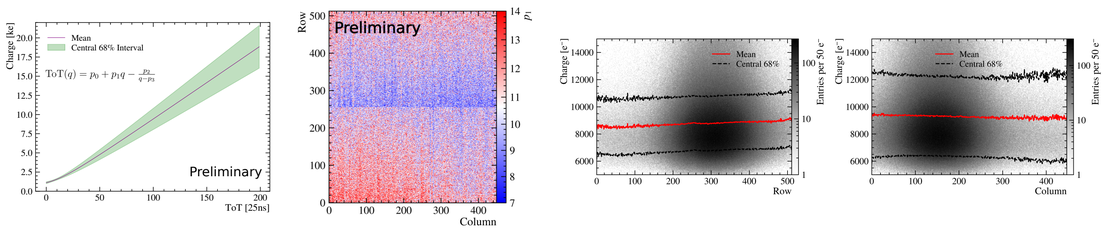
Timepix4 ASIC

- Developed by CERN, Nikhef and IFAE [1]
- 448 × 512 pixels, 55 µm × 55 µm pitch
- Simultaneous measurement of Time of Arrival (ToA) and Time over Threshold (ToT)
- ToA-bin size: 25 ns/128 = 195 ps [2]
- Max readout bandwidth 163.84 Gbit/s



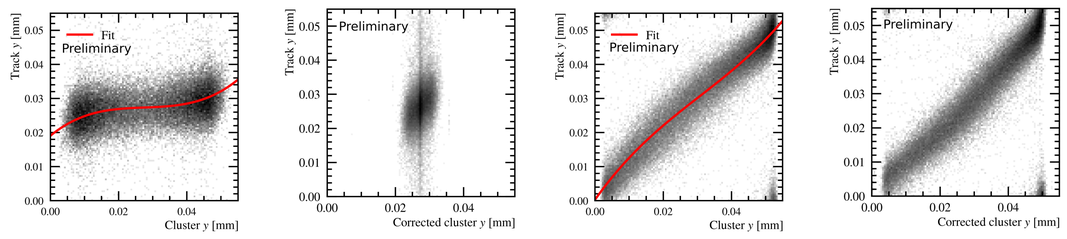
Charge calibration

- Pixel-to-pixel ToT variations due to differences in discharge current
- ToT nonlinear near threshold
- Use per-pixel calibration to convert from ToT to deposited charge



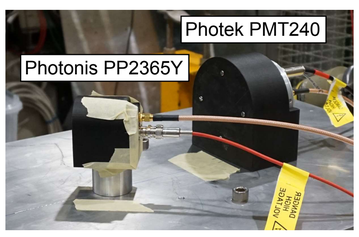
η-corrections

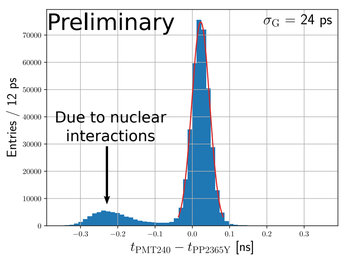
- Charge sharing non-linear at perpendicular incidence
- Charge weighted cluster position does not reproduce track position
- Apply correction per plane for clusters with width 2

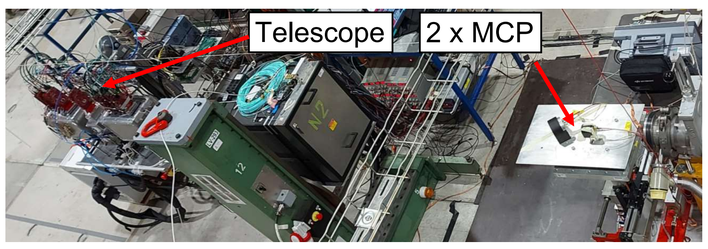


Time reference system

- Two MCP-PMTs provide precise time reference for tracks and studies of the telescope timing performance
- Combined MCP-PMT resolution: **12** ps
- Placed far downstream to not hinder other groups in same beam area (large material contribution)



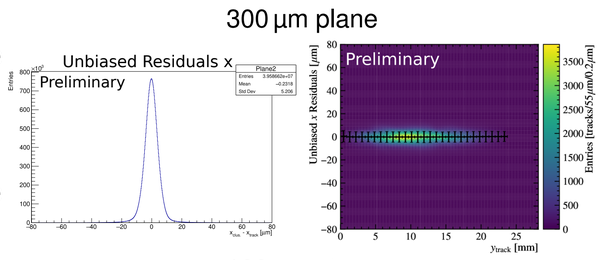




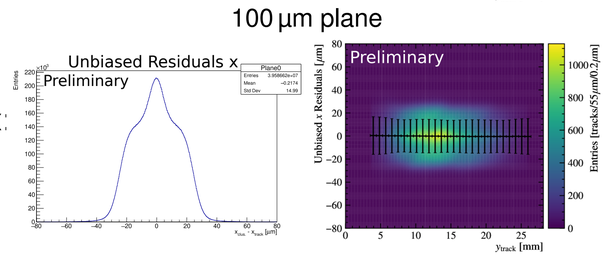
Spatial resolution

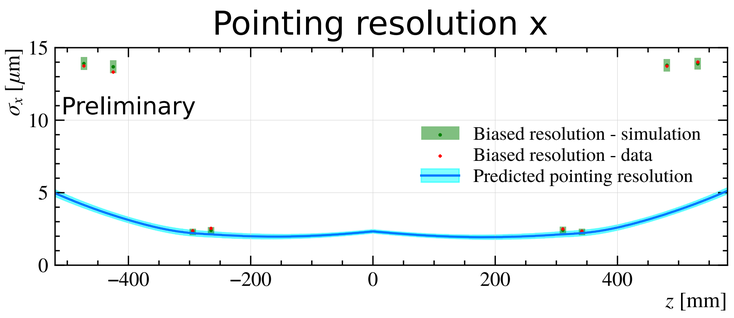
- Four innermost planes rotated by 9 ° around x and y to enhance charge sharing between pixels
- Alignment using Millipede algorithm [3]
- Compare biased residuals in data and simulation and minimize difference in widths to find intrinsic sensor resolutions:
  - 300 µm planes: **x**: **(3.3 ± 0.3)** µm, **y**: **(3.5 ± 0.3)** µm
  - 100 µm planes: **x**: **(14.4 ± 0.5)** µm, **y**: **(14.3 ± 0.5)** µm
- Use simulation to predict pointing resolution at DUT position: **x**: **(2.32 ± 0.12)** µm, **y**: **(2.38 ± 0.12)** µm
- Milling PCBs would improve pointing resolution to 2.0 µm

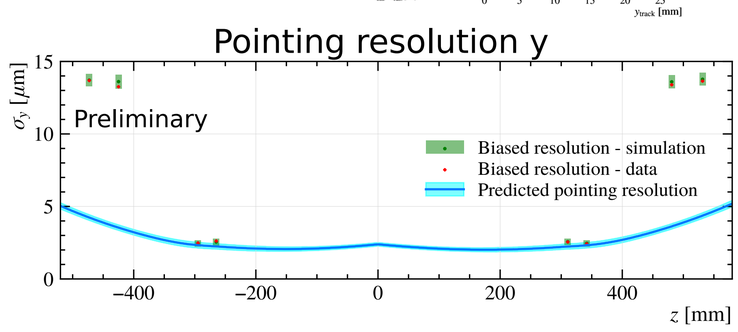
300 µm plane



100 µm plane







Time resolution

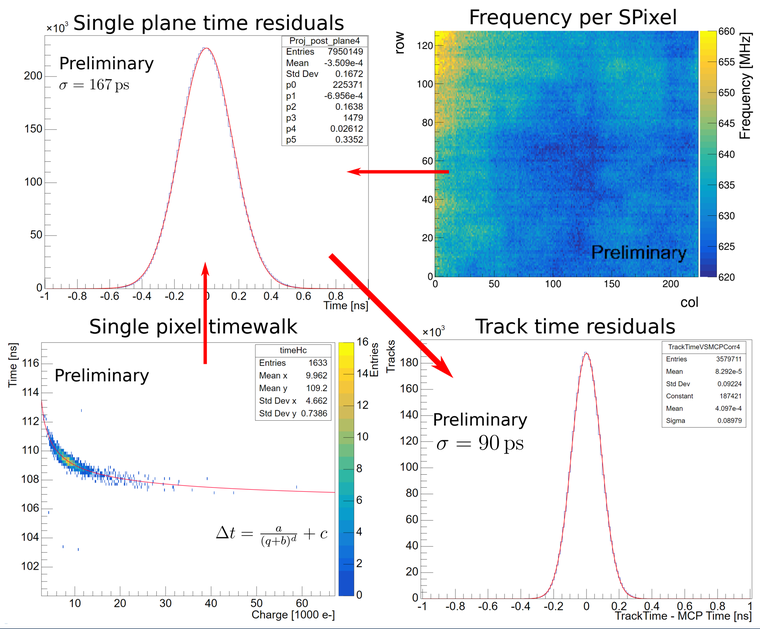
- Four outermost planes at perpendicular incidence to maximize charge per pixel
- Large signals cross threshold earlier than smaller ones

→ Per-pixel timewalk corrections

- ToA measurment with 640 MHz voltage controlled oscillator (VCO) (one per superpixel)
- Variations in VCO frequency

→ Per-superpixel VCO corrections

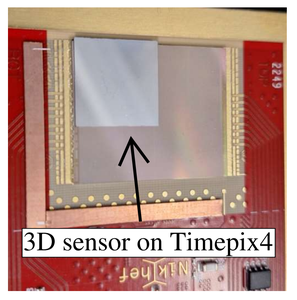
- Single plane resolution after timewalk + VCO corrections: **170** ps
- Track time with 4 x 100 µm orthogonal planes: **90** ps

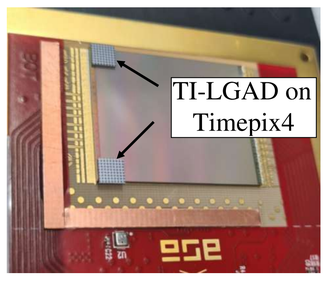


Outlook

- Mill PCBs to reduce material and improve pointing resolution
- Ready to move on to faster sensor technologies for telescope planes
- Move focus from telescope to DUT studies

→ Recent data taking in early May 2024 with iLGAD, TI-LGAD and 3D sensors as DUTs





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References

[1] X. Llopart *et al.*, JINST **17** (2022) C01044. [2] K. Heijhoff *et al.*, JINST **17** (2022) P07006. [3] V. Blobel *et al.*, CPC **182** (2011) 1760.