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Performance of the track reconstruction framework Corryvreckan with regard to the usage in proton therapy

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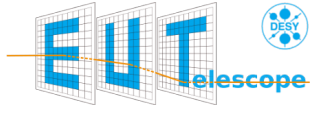
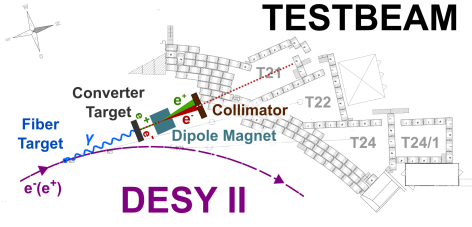
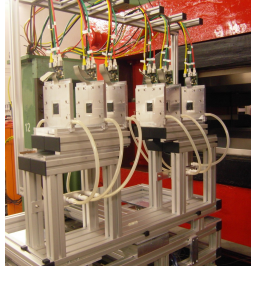
Physik
E-IV



DESY Testbeam

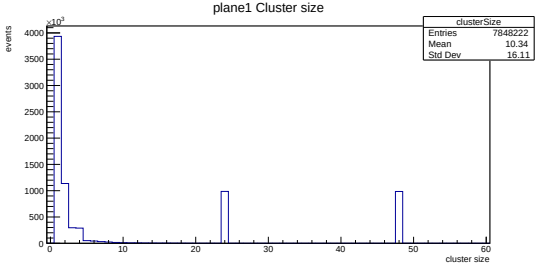
- DESY Testbeam setup:
  - 5 GeV electron beam
  - Telescope: 6 ×Mimosa26
- Analysis of testbeam data of June 2020 Batch 3
  - DUT's: 2 ×RD53a (middle), 1 ×FEI4 (reference)
- New reconstruction software Corryvreckan will replace EUTelescope
  - Less external dependencies
  - Easy to use modular structure
- Comparison of reconstruction steps of Corryvreckan and EUTelescope

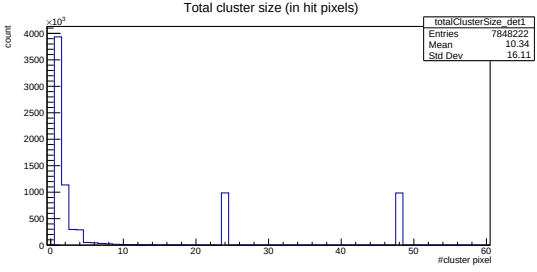




Corryvreckan and EUTelescope: Clustering

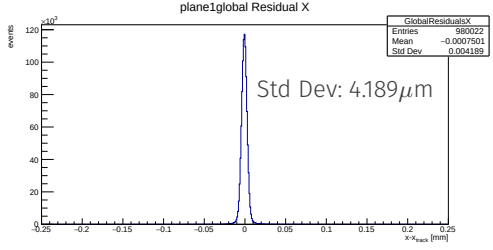
- First reconstruction step: Clustering of pixel hits
- Both frameworks calculate charge-weighted cluster center
- Result: Identical cluster sizes

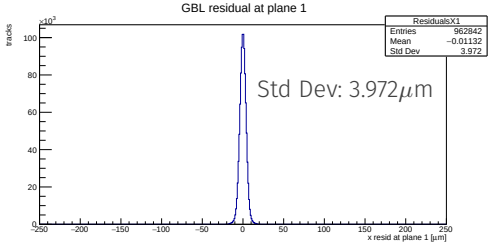


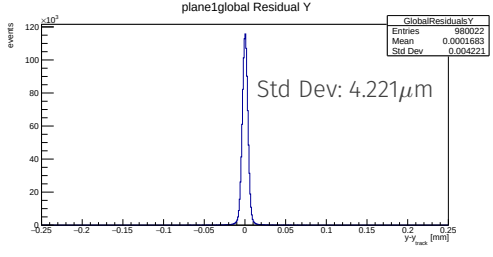


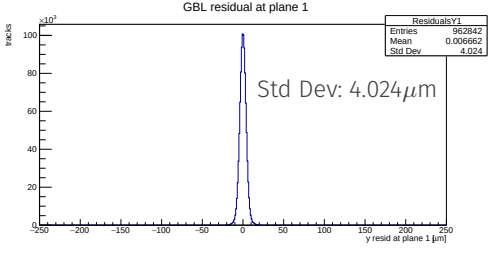
Corryvreckan and EUTelescope: Residuals

- Mean and standard deviation sufficiently small and comparable



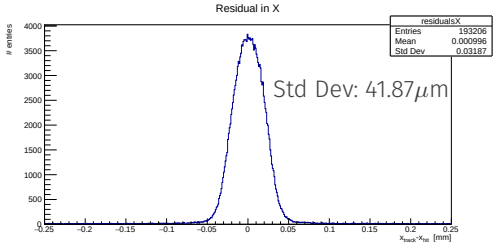


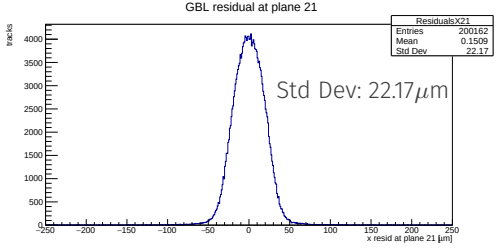


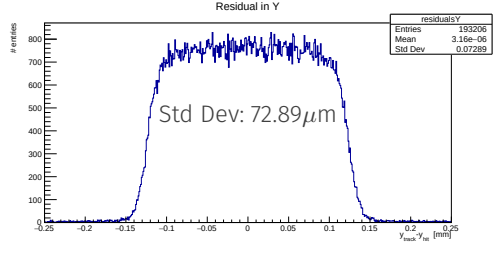


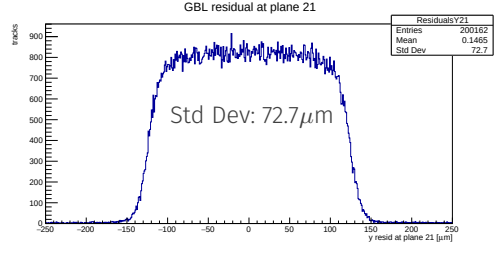
Residuals DUT

- Comparison of calculated residuals of an FEI4 sensor



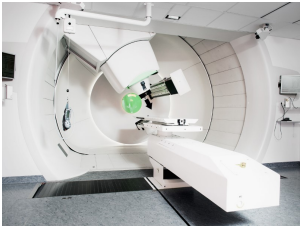


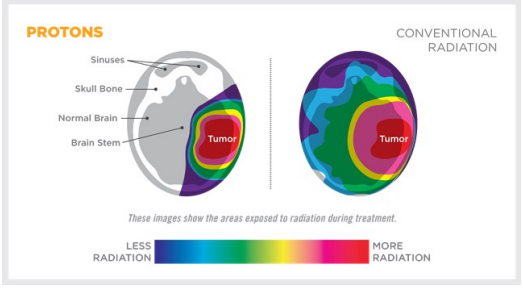


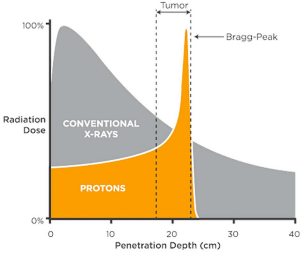


Track reconstruction in proton therapy

- Proton therapy uses the energy deposition of protons to irradiate tumors
  - Advantage: Less damage for healthy tissue due to different energy deposition

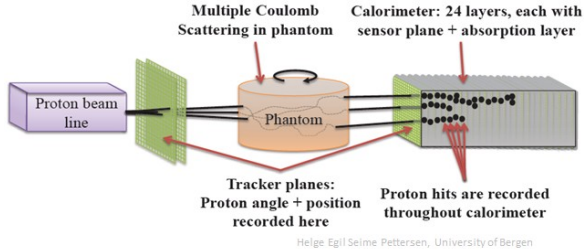




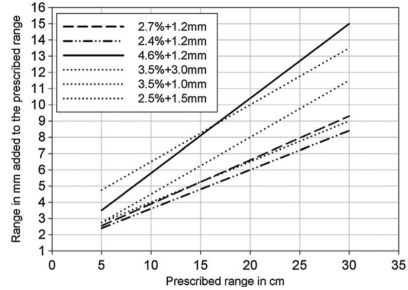


Proton computed tomography

- CT scan necessary for irradiation plan
- Using X-ray CT scans causes uncertainties for the irradiation plan
  - Prescribed range increases with travel distance
- Track reconstruction can help in creating proton computed tomography scans
- Can Corryvreckan reconstruct low energy proton beams with high track density?

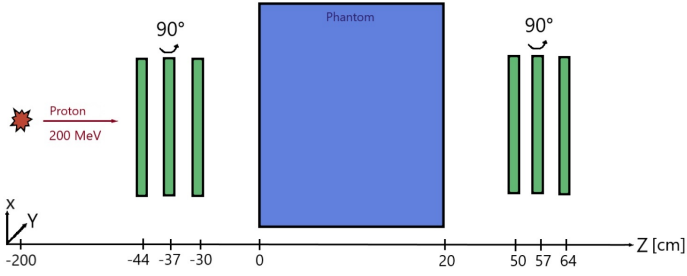


[Harald Paganetti 2012 Phys. Med. Biol. 57 R99]



Performance test: Energy

- Telescope setup: 6 $\times$IBL planar sensors
- Middle sensor of triplets is rotated by 90° to increase resolution in horizontal direction
- Protons events are simulated with the Allpix^2 framework



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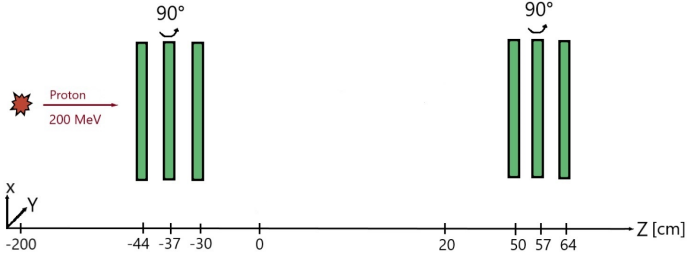
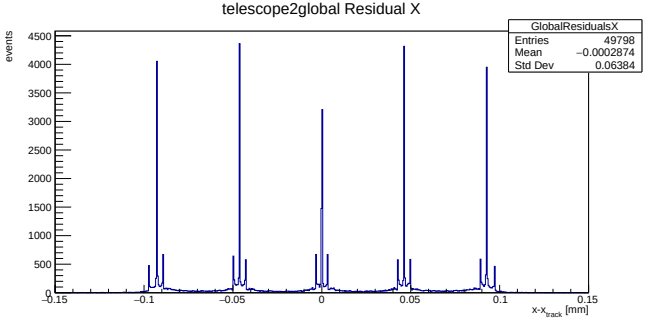
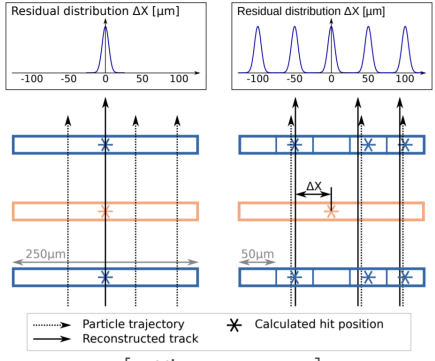


High energies

- 50000 protons with 100 GeV simulated
- 5 peak structure due to different spatial resolutions of the sensors
- Optimal alignment causes precise peaks

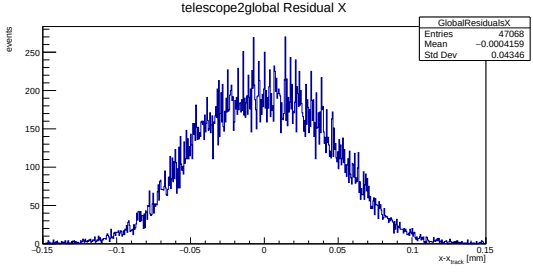


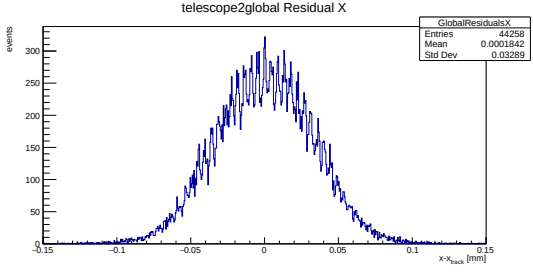


[arXiv:1603.07776]

750 MeV and 500 MeV Residuals

- Stronger scattering for lower energies ⟶ peak structure vanishes

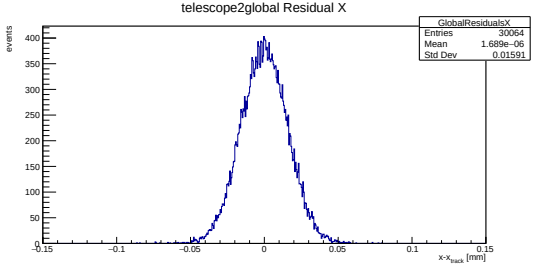


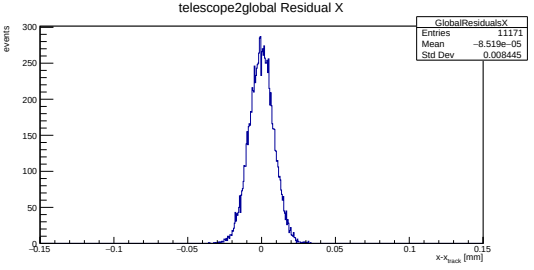


- Many low energy protons don’t deposit energy in all planes anymore ⟶ Less tracks

250 MeV and 150 MeV Residuals

- Significant amount of particles do not traverse all planes

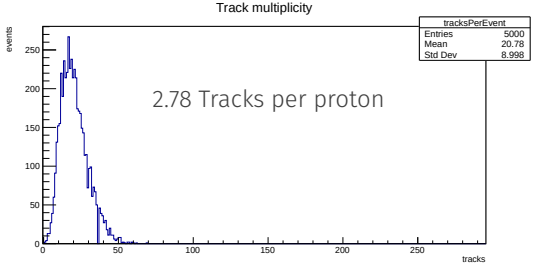


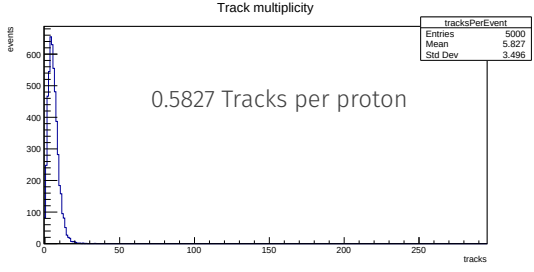


- Smaller statistics can be countered by taking more data

Performance test: Track density

- Tracking module connects every cluster of the first and the last plane within allowed timestamps
- More particles per event lead to higher amount of tracks with false cluster combinations
- Stronger cuts result in less false and true tracks $\longrightarrow$ Unknown ratio





Track multiplicity for 10 protons (250 MeV) per entry for weak and strong cuts.

Results and Outlook

- Corryvreckan produces comparable results
- Low energy particles cause problems in track reconstruction due to stronger scattering
  - More particles get deflected
  - Standard deviation of residuals decreases

Outlook:

- Implementing machine learning algorithms for track finding
- Track density: Determine ratio of true and false tracks

The measurements leading to these results have been partly performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF)