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Proton Track Reconstruction Inside a Digital Tracking Calorimeter for Proton CT

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Background
Proton CT is a prototype imaging modality for the reconstruction of the Proton Stopping Power inside a patient for more accurate calculations of the dose distributions in proton therapy treatment dose planplanning systems. A prototype proton CT system, called the Digital Tracking Calorimeter (DTC) is currectly under development where aluminum energy absorbers are sandwiched between ˜40 MAPS-based pixel sensor layers.

The following measurements need to be performed in the DTC:

- The initial proton vector incident on the front face of the detector
- The stopping depth of each proton in the detector

These measurements necessarily require performing track identification and reconstruction inside the DTC. The track reconstruction will also allow disentangling a large number of protons thus contributing to increased rate capabilities of the DTC.

Methods

Methods
A DTC detector has been modeled using the GATE 7.2 Monte Carlo framework. A design having 3.5 mm aluminum absorbers has been suggested based on range accuracy requirements: The detector is modeled based on previous experience with track identification and reconstruction in similar prototypes, such as with the ALICE-FoCal experiment. A water phantom of variable thickness is used for degrading a 230 MeV proton beam to different energies.

Upon degradation by a water phantom, a proton beam of a up to a few thousands particles in a 100 cm² area and a mean energy of ˜200 MeV is incident on the detector. In this regime, the proton tracks are heavily influenced by multiple Coulomb scattering. Each primary proton is tracked through the detector using a track-following approach, with a search cone depending on the expected scattering. A high quality tracking algorithm improves the detector characteristics in terms of contributing to increased rate capabilities, i.e. a higher incident beam intensity. The tracking quality is evaluated at various incident proton densities [protons / cm²] by the fraction of tracks with correct endpoints. Quantitative evaluation is based on a comparison between the correctly identified and reconstructed proton tracks using the current algorithm and the true proton tracks from Monte Carlo simulations.

Results and conclusion
Preliminary results indicate that at 10 protons / cm² about 80% of the tracks are correctly identified and reconstructed, the remaining 20% are either "close misreconstructions"or protons that undergo large angle scatter and thus are are wrongly identified.

Primary authors: PETTERSEN, Helge Egil Seime (University of Bergen (NO)); MERIC, Ilker (Western Norway University of Applied Sciences (NO)); Dr ODLAND, Odd Harald (Haukeland University Hospital); Mr SØLIE, Jarle Rambo (Western Norway University of Applied Sciences); ROHRICH, Dieter (Department of Physics & Technology-University of Bergen)

Presenter: PETTERSEN, Helge Egil Seime (University of Bergen (NO))

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