Implementation and first results for ProtoDune SP

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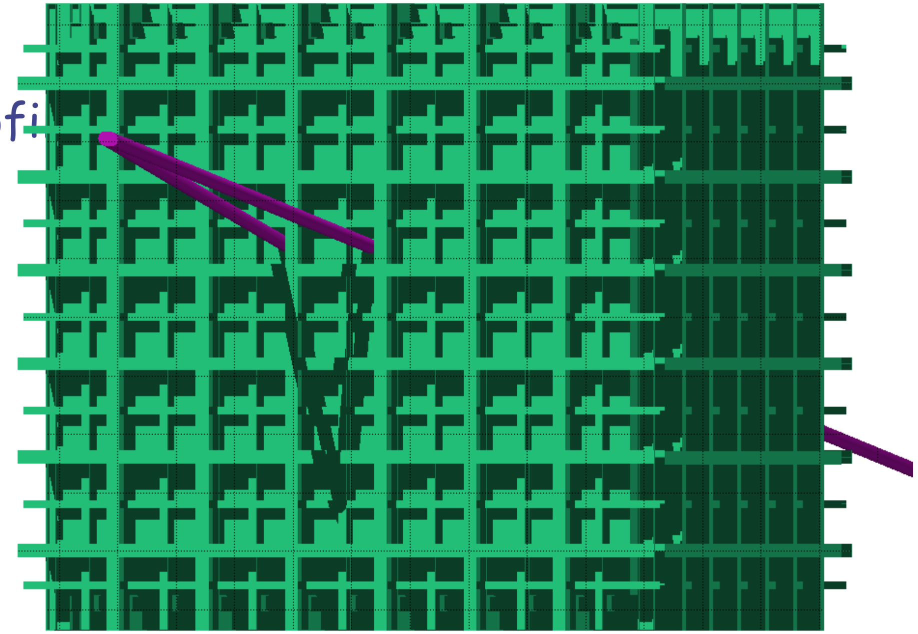
The ProtoDUNE warm cryostat – FLUKA model

- Dimensions: 11.404 x10.756x11.404 m3 (WxHxL)
- IPE beam profiles: small and large
  - 304 L – Stainless steel (8000kg/m3)
- 0.8 m space between the closest profi
- 1.6 m between large profiles
- Internal space (insulation limit):

8.548x7.9x8.548 m3



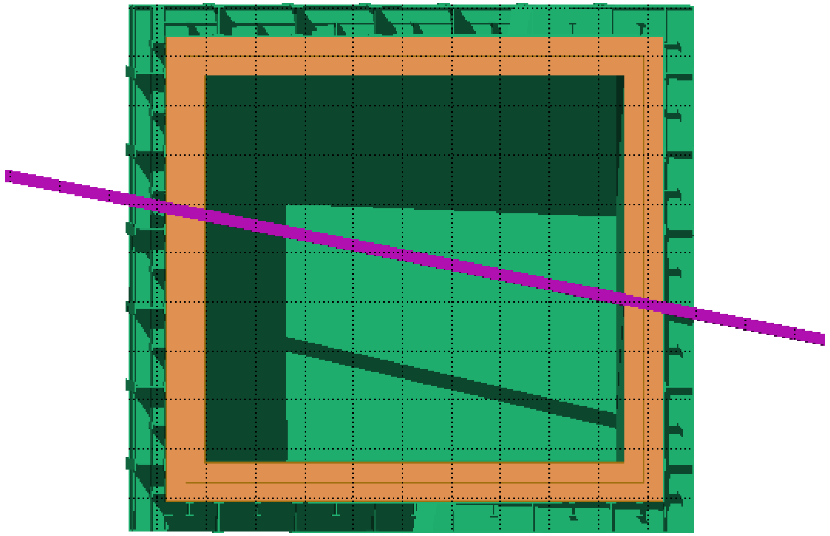
Ref. drawing: CENDUNCR0017 (2016/02/17)

The ProtoDUNE – BEAMS

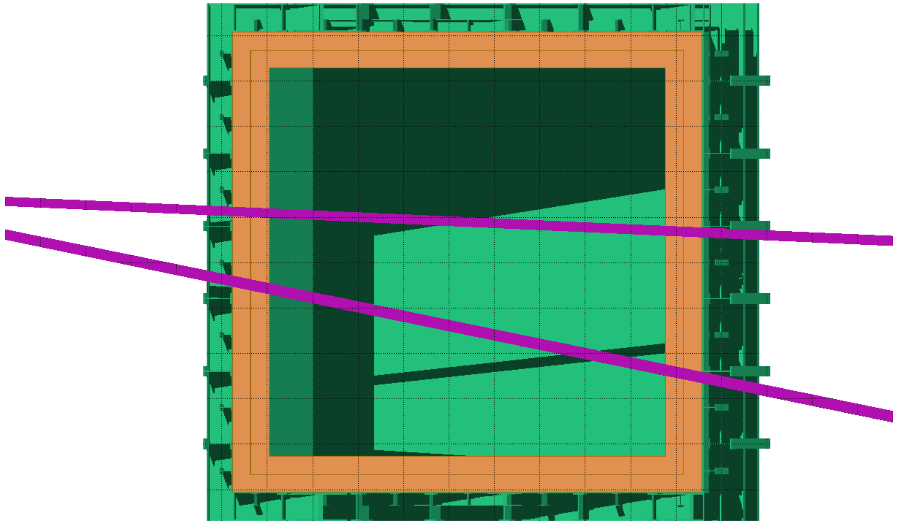
BEAM 1
BEAM 2

Vertical angle:
11. 342 deg.

- BEAM 1: horizontal ly: 2.604 deg.
- BEAM 2: horizontal ly : 11.844 deg.



Vertical cross section
Y-Z



Horizontal cross section
X-Z

Ref. drawing: PARTICLES BEAMS/
ST0743852_03

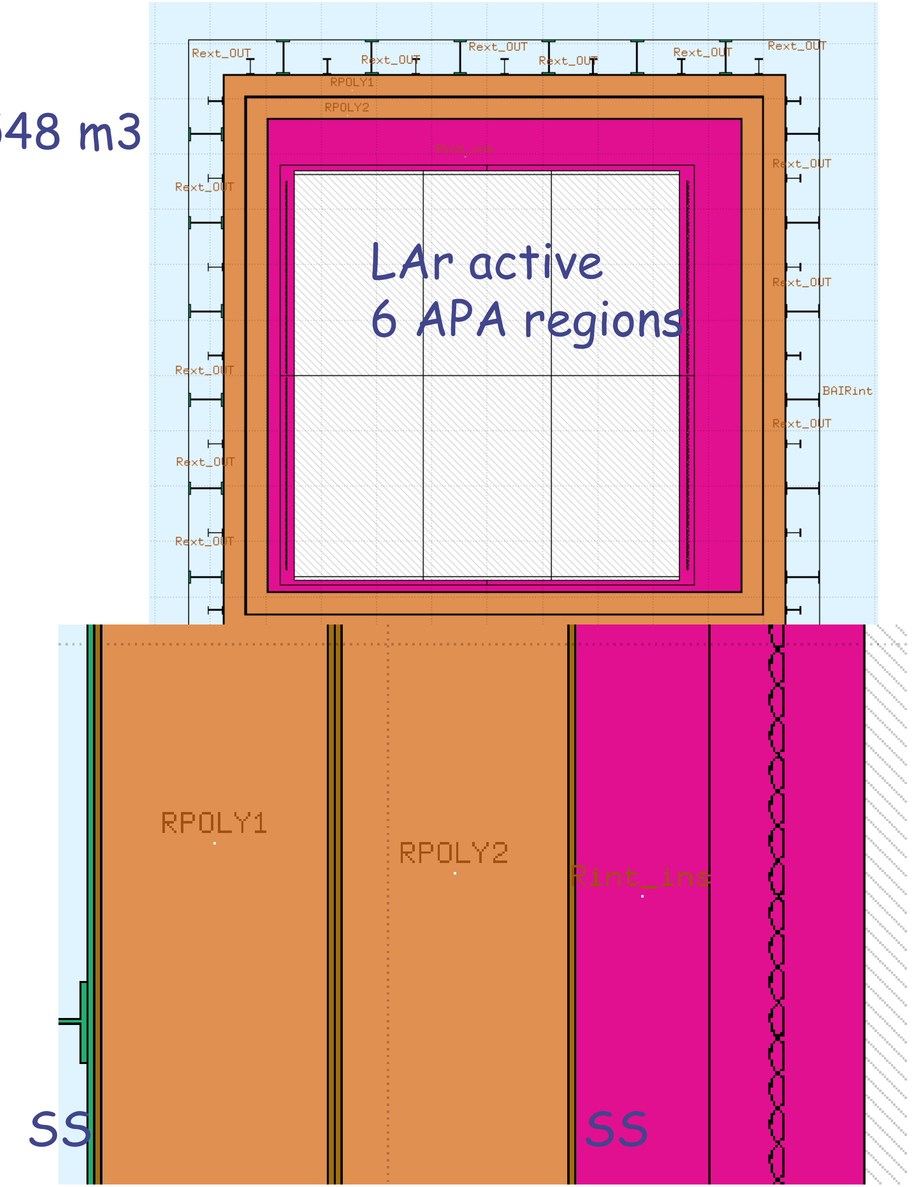
The ProtoDUNE detector - internal structure

- Active LAr : 7.2 mx5.9mx7m (WxHxL)
- LAr volume (active and inactive region) 8.548x7.9x8.548 m3
- APAs + Cathode + field cage are inside
- Modular internal structure- can be expanded

INSULATION (0.8 m)

- From internal part (Ar)

- 1.2 mm thick SS membrane (8000 kg/m3)
- 1.2 cm plywood layer (700 kg/m3)
- 37.54 cm of polyurethane foam (90 kg/m3)
- 2 layers of plywood, 2.4 cm in total
- Secondary SS membrane 0.2mm
- 37.54 cm of polyurethane foam
- 1.2 cm of plywood
- External SS membrane – 1cm thick



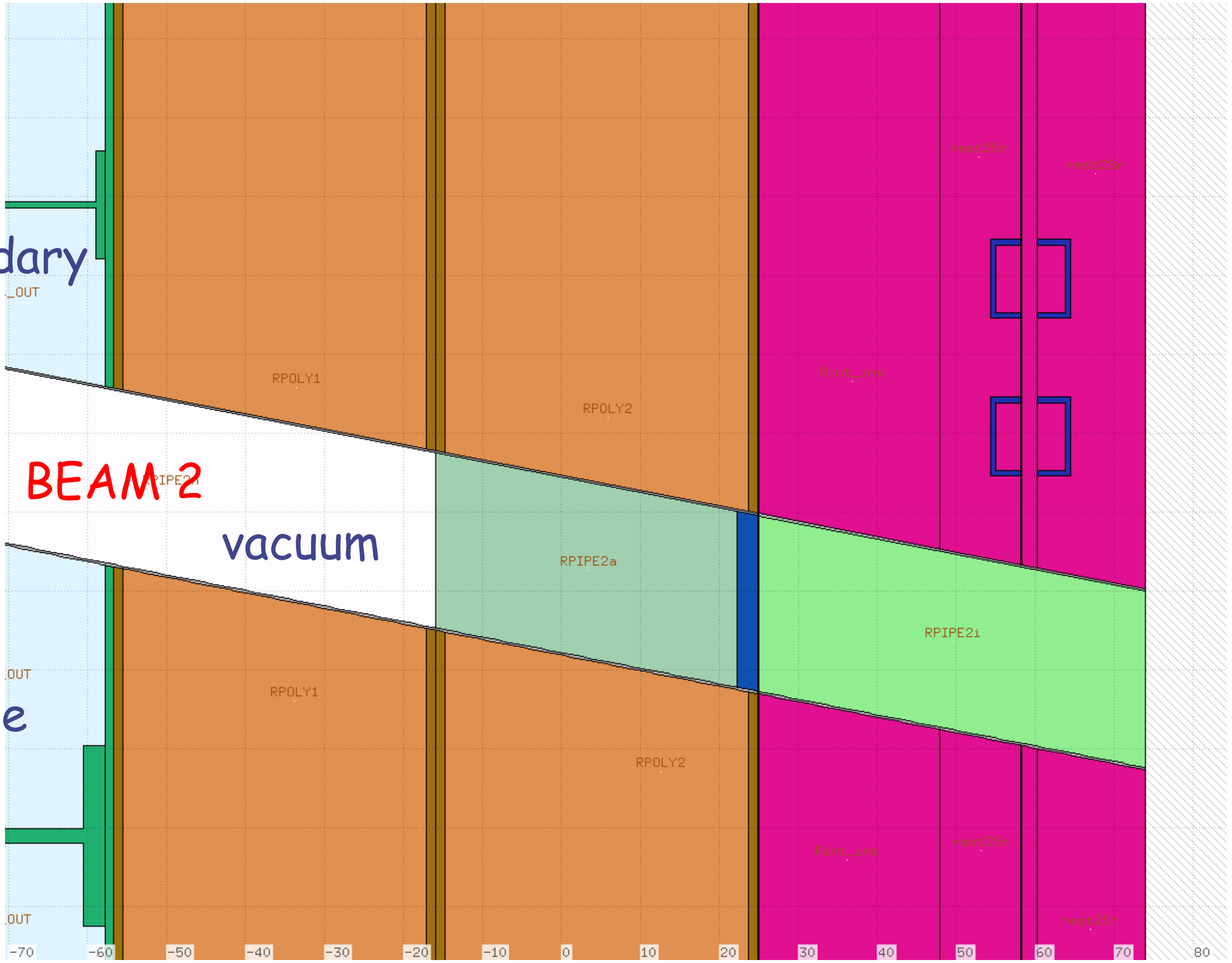
The ProtoDUNE beam penetration

Beam penetration (BEAM 2)
- G10 - 0.5 mm
- Nomex – 25 mm (48 kg/m3)
- G10 - 0.5 mm
- low density material up to secondary plywood layer

Entrance window:
- 0.2 mm Al

Internal plug: up to active Lar, N_2

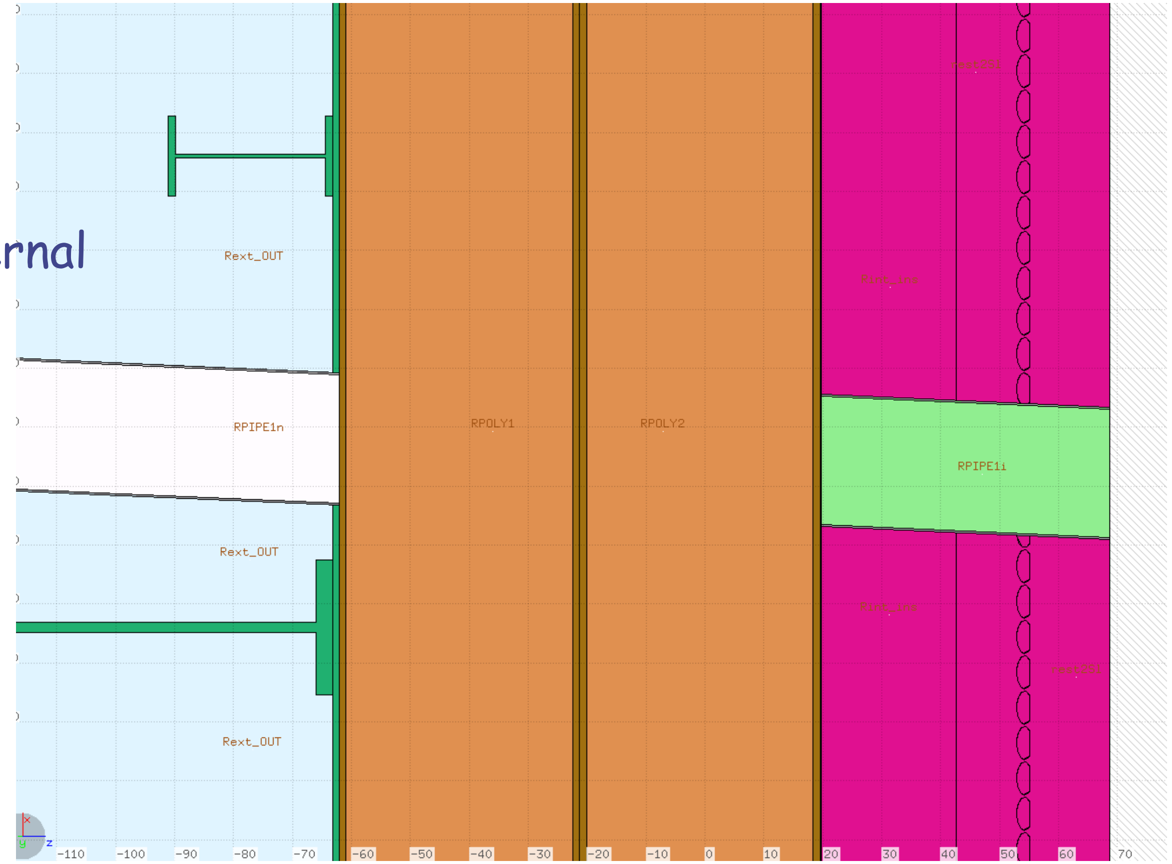
Pipe internal and external diameters:
- 21.9 and 22.5 cm
- 3 mm of Al or G10 pipe structure



Beam 1

BEAM 1

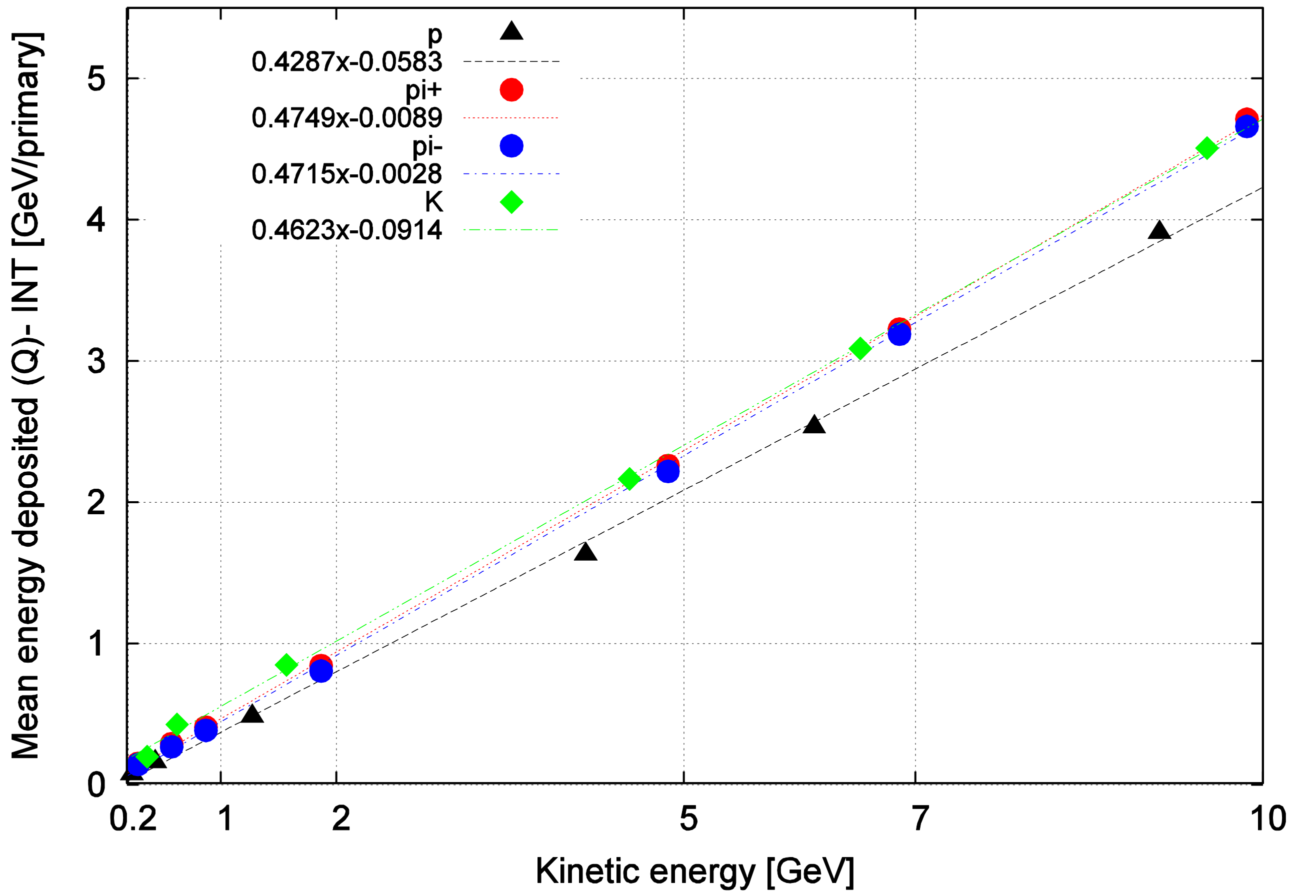
- Penetration only through the external SS membrane,
 plug inside LAr



Preliminary studies of the energy deposited in the LAr detector (ongoing)

- EM and hadronic components of the total deposited energy for protons, pions, kaons
- Energy deposited with recombination (quenching) correction as a function of particle momentum
- Energy deposited density (2D maps)
- Drift time cut above 3 ms
- Full simulation, no reconstruction. Quantities are “true” deposited or deposited and quenched energy

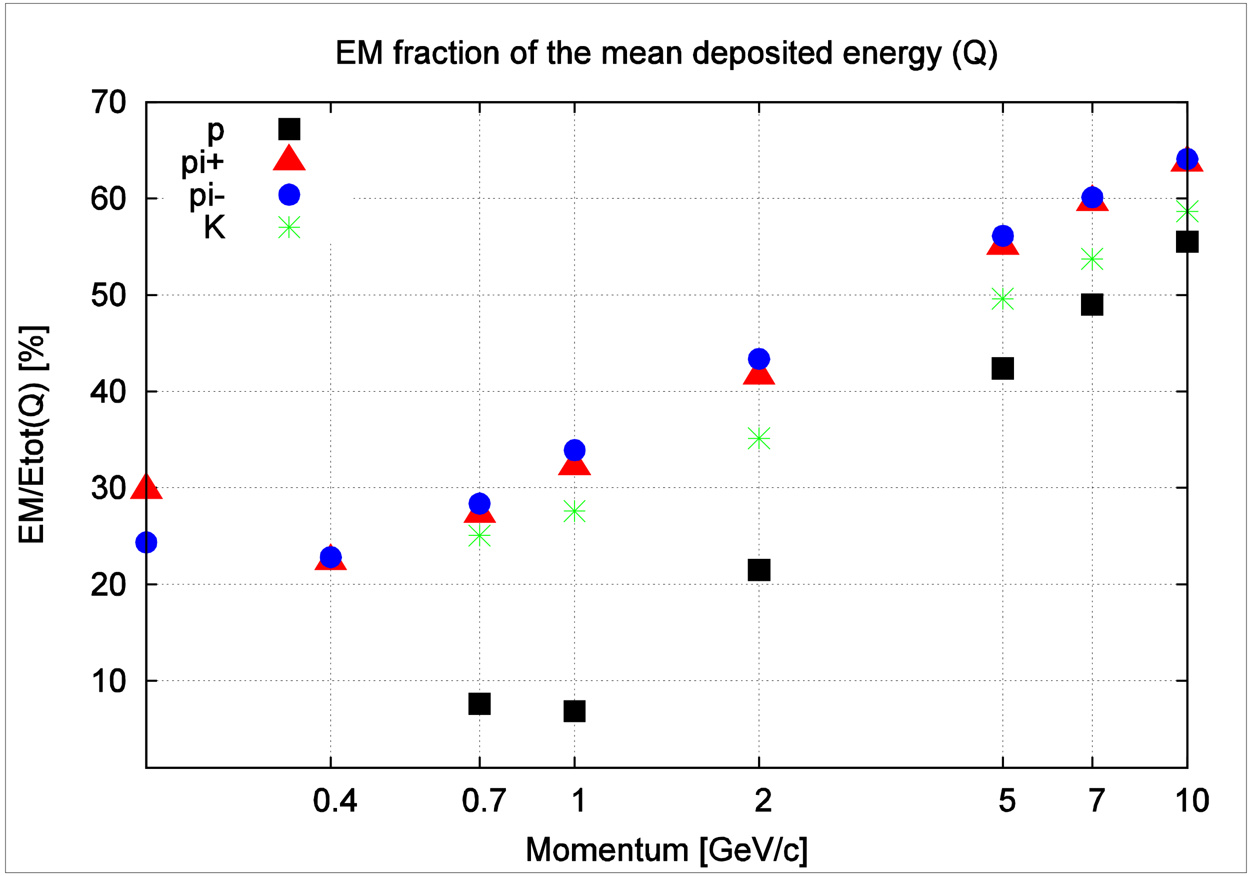
Mean energy deposited in the active LAr detector (quenched)



Interacting particles only
Quenching according to Icarus

Hints of non-linearity,
No hint of non-containment.

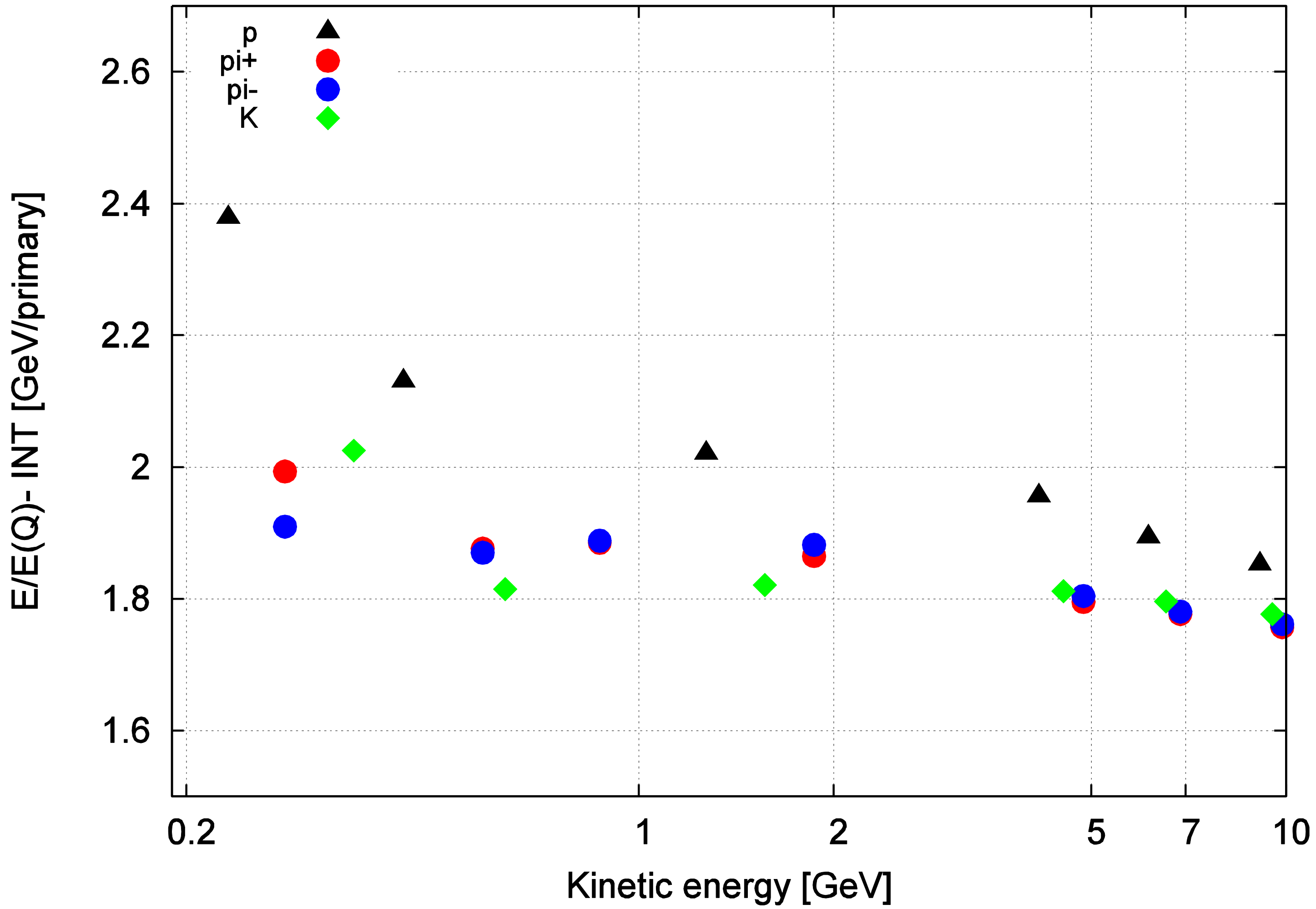
EM component



Fraction of the total energy deposited, quenched, in the active LAr that goes into EM component

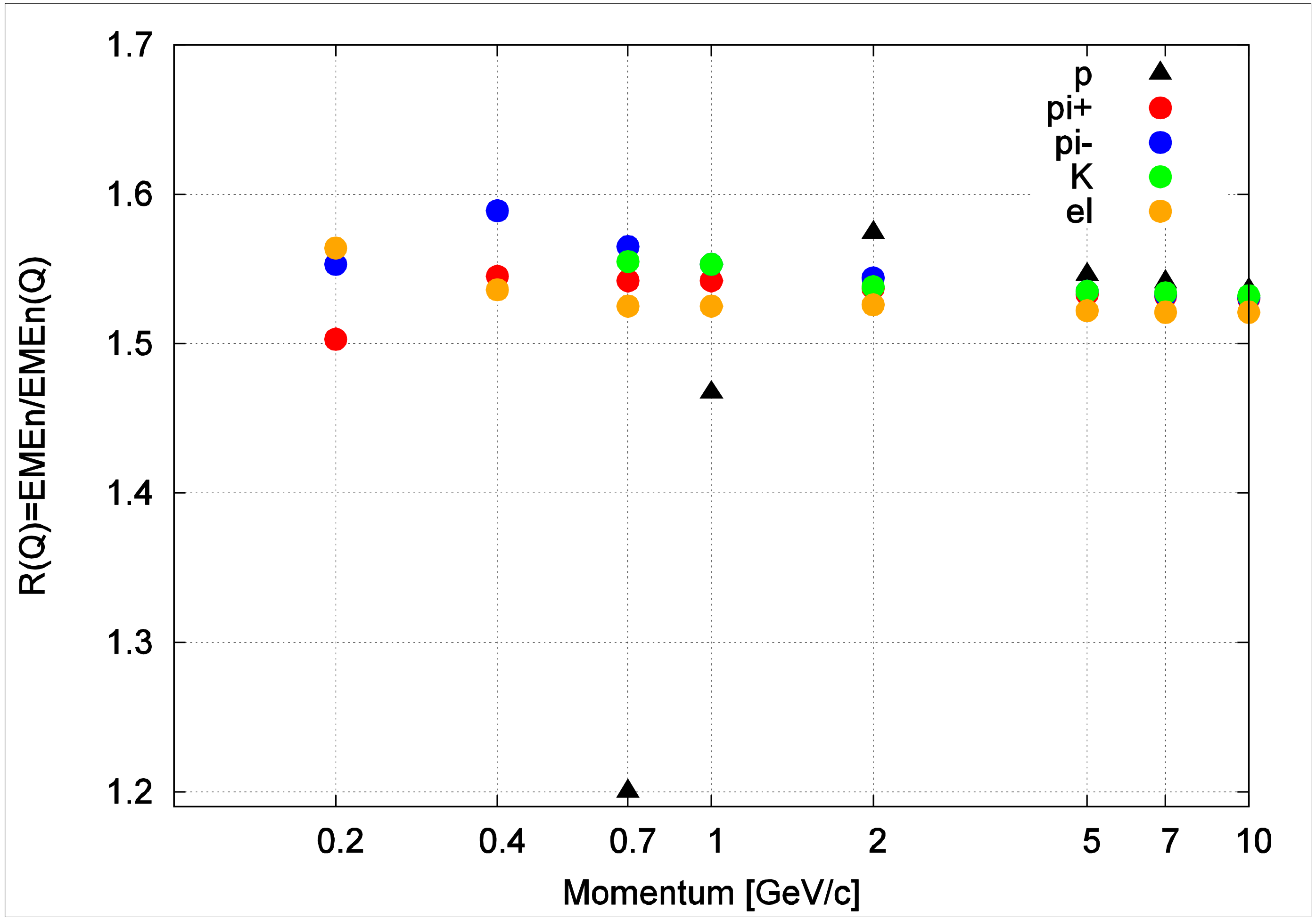
Differences among projectiles

--- Quenching correction ---



Total energy to quenched total energy ratio
Interacting particles

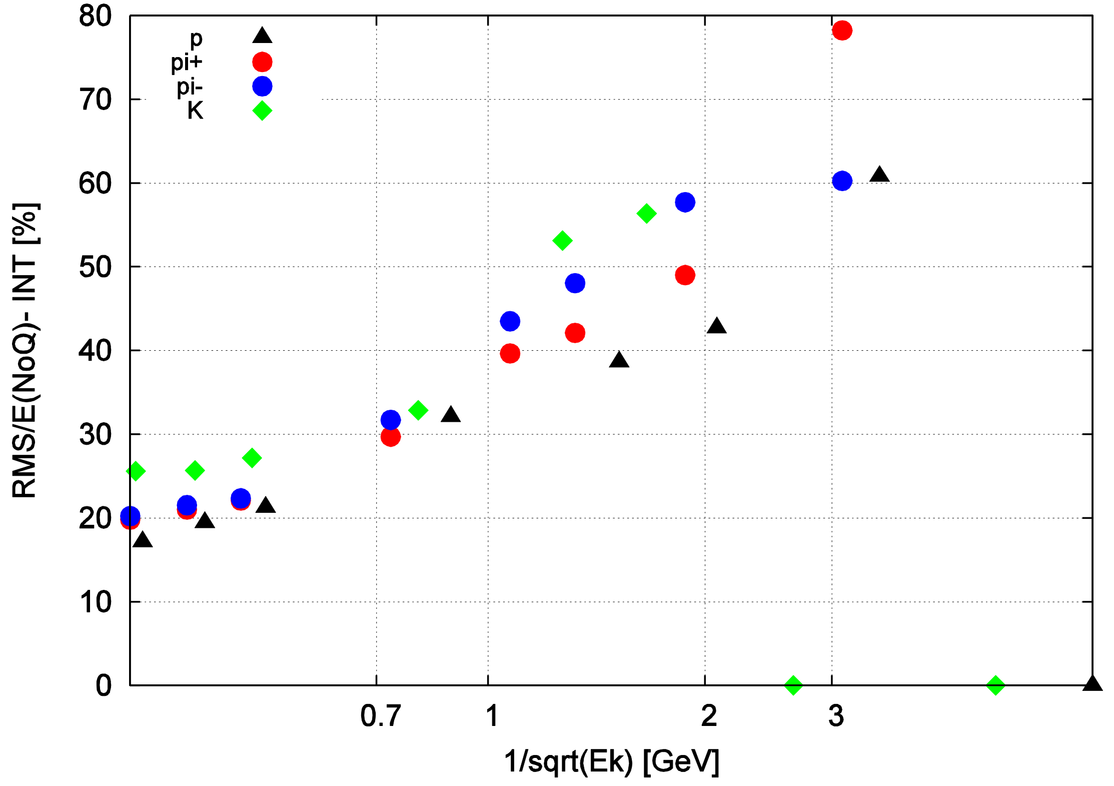
--- Quenching correction for the EM component

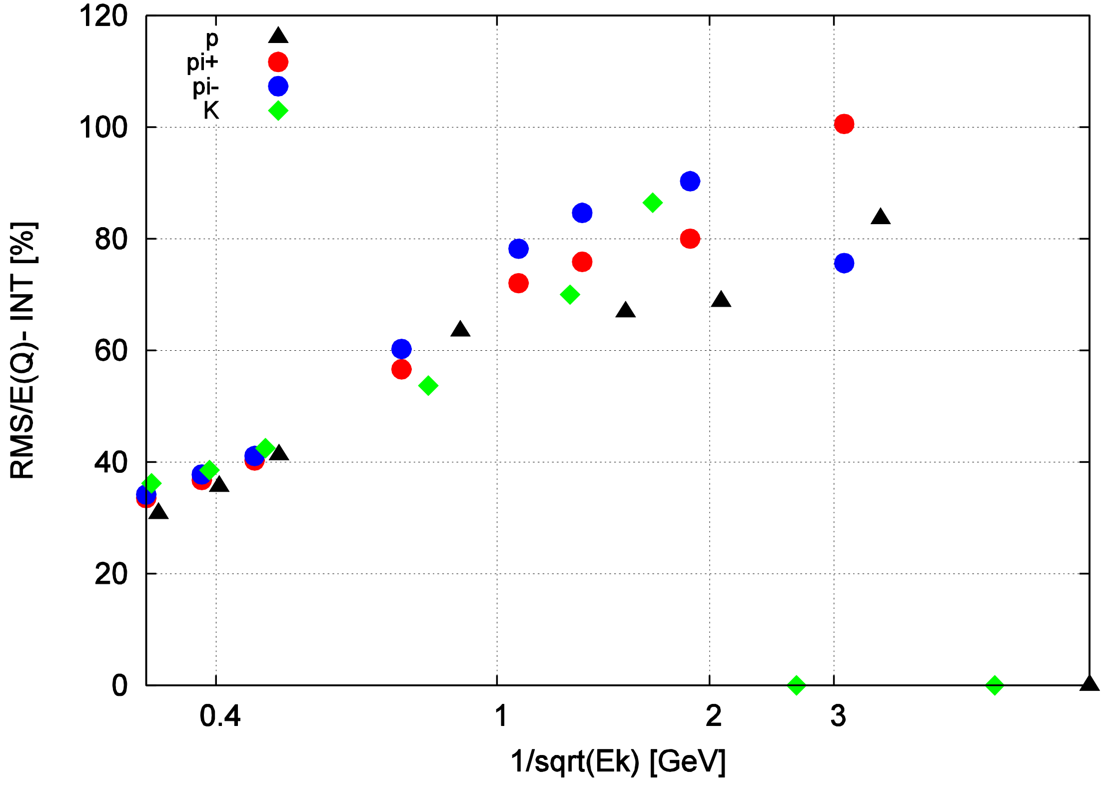


EM energy to Quenched EM energy ratio

Resolution

Rms (%) of energy deposition. Left : no quenching, right: with quenching

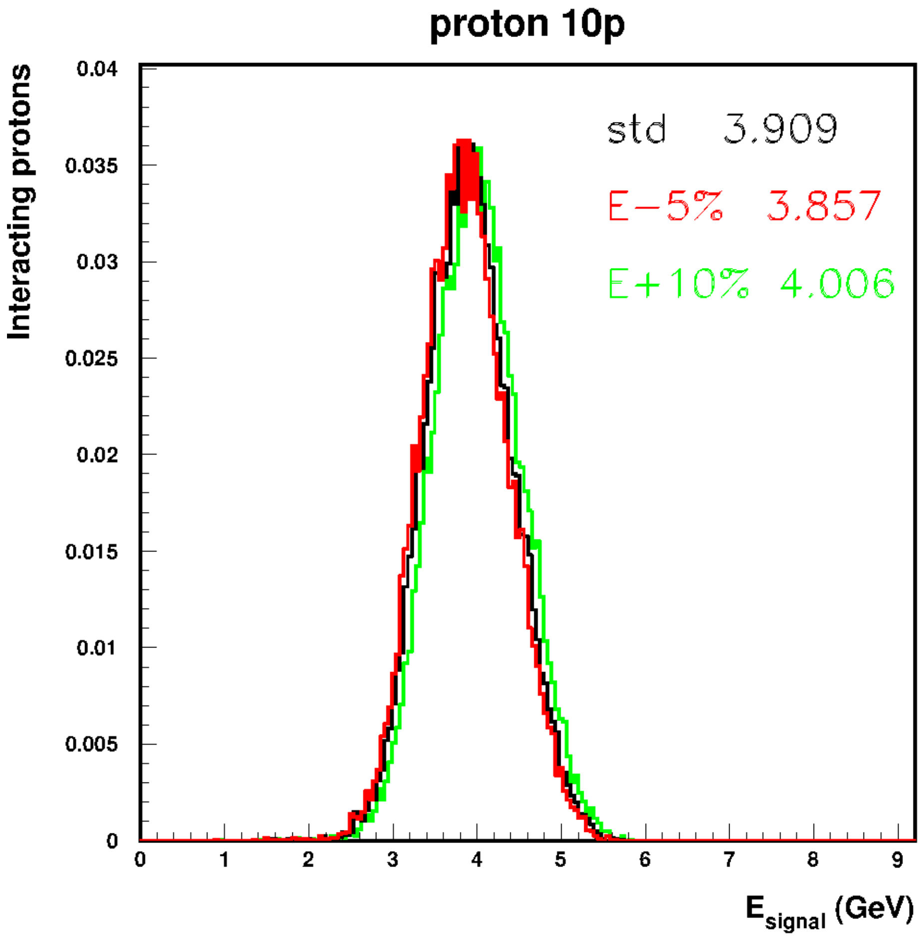


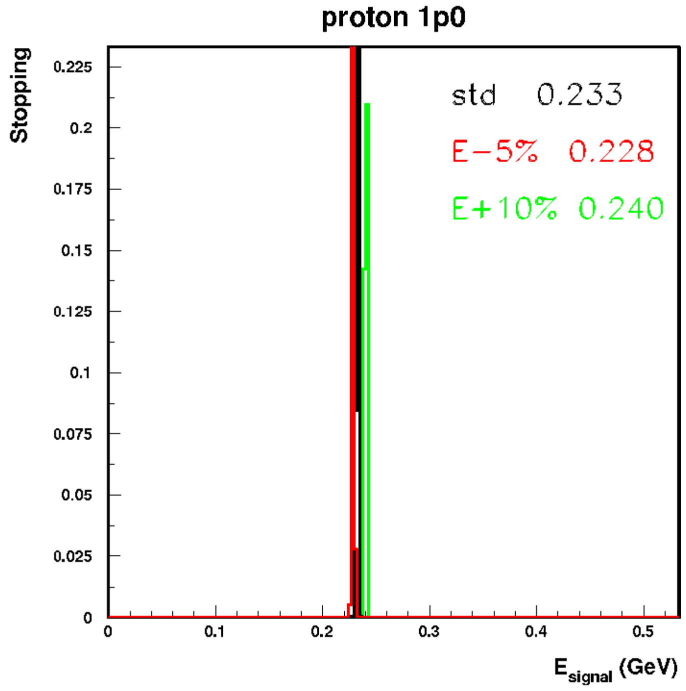


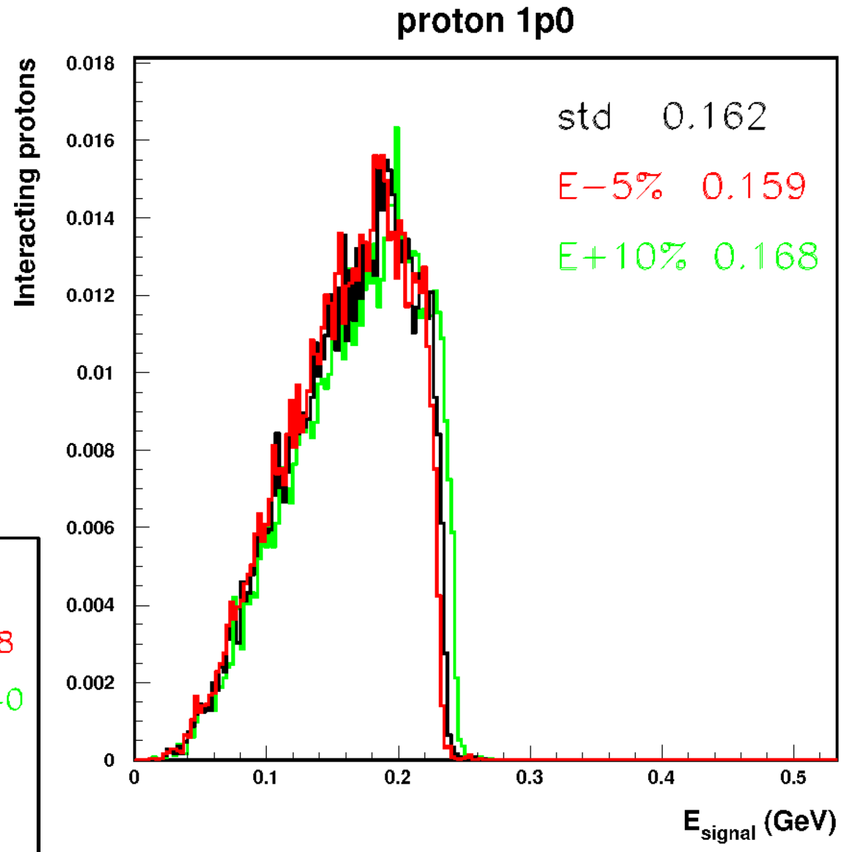
Quenching MUST be corrected back, also will need differenr EM-had calibrations, as expected

Effect of E-field variations on quenching

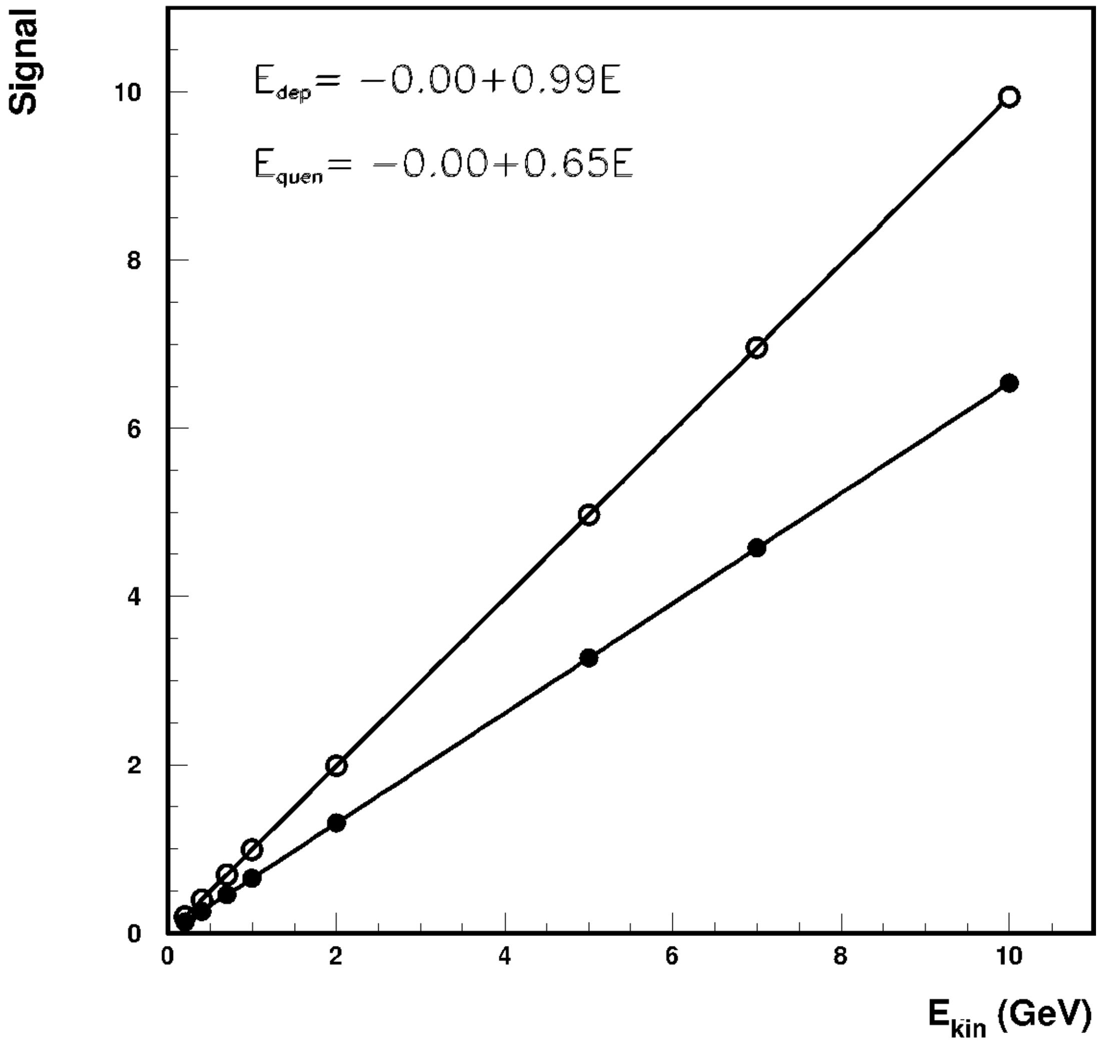
- Assuming Birks law with $k_B \div 1/E_{drift}$

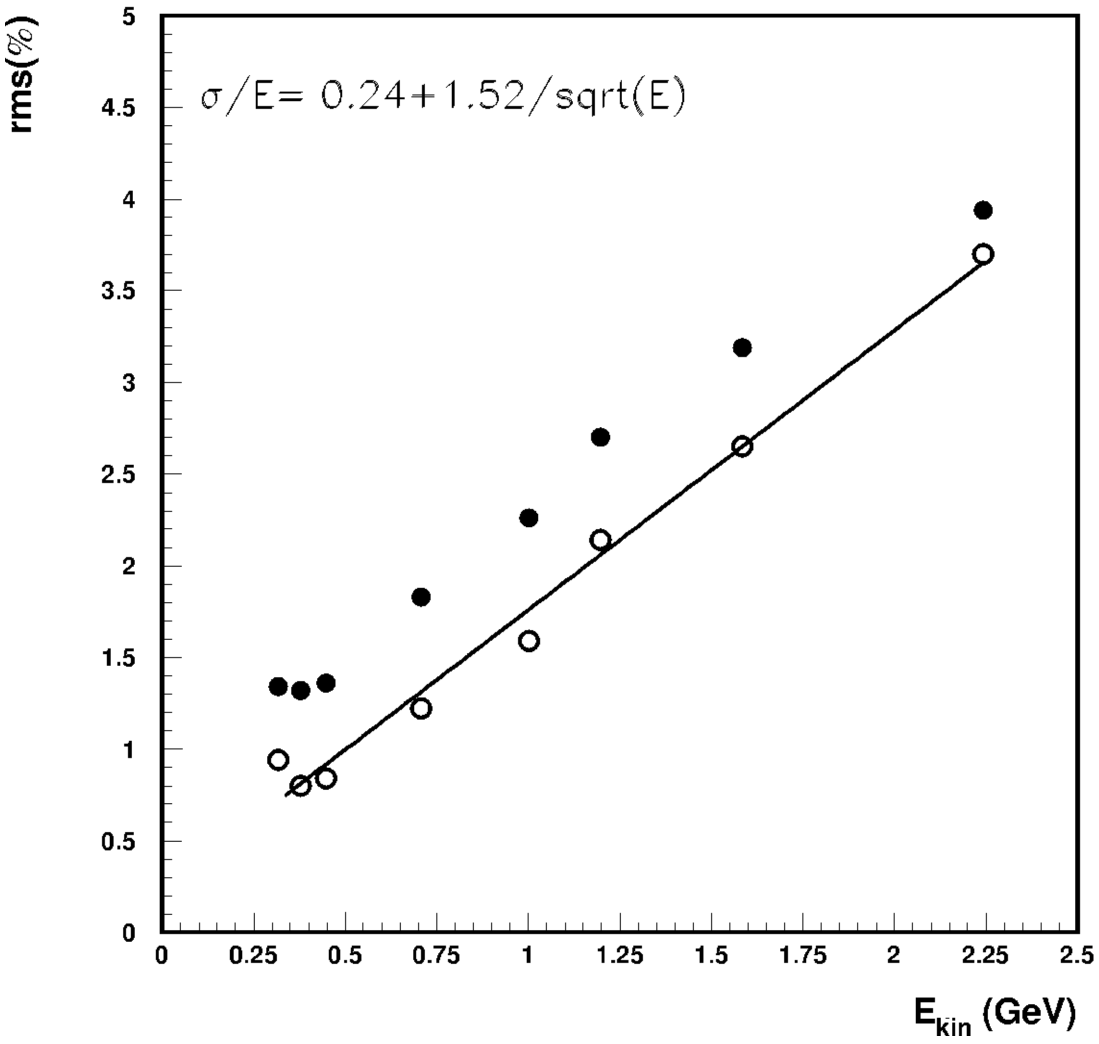




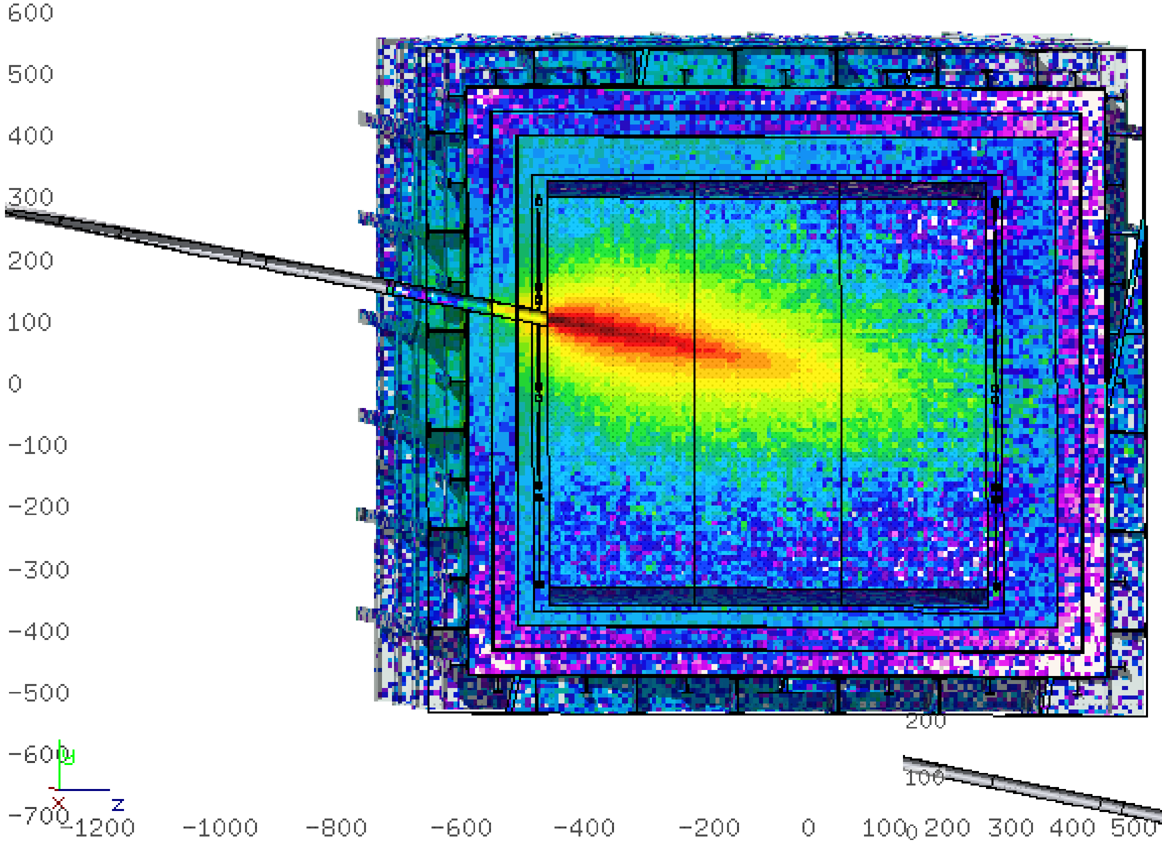


Electron beam

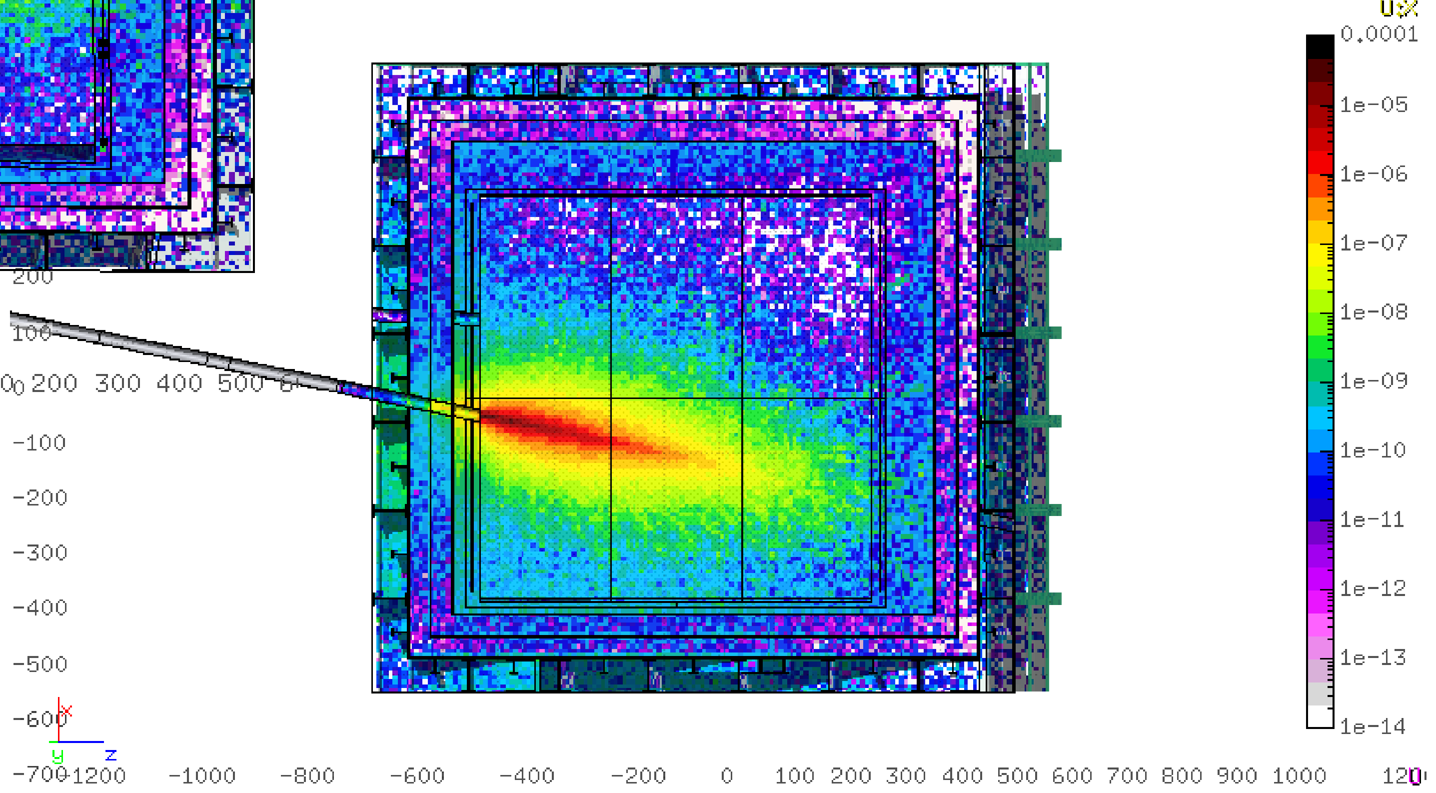




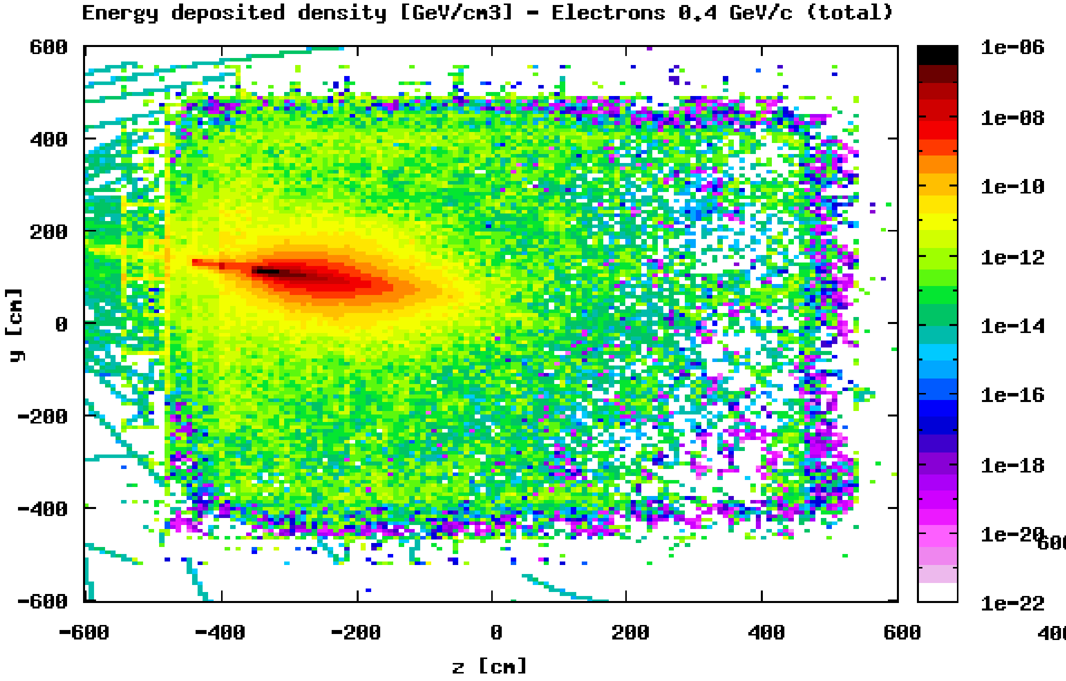
Energy deposition maps



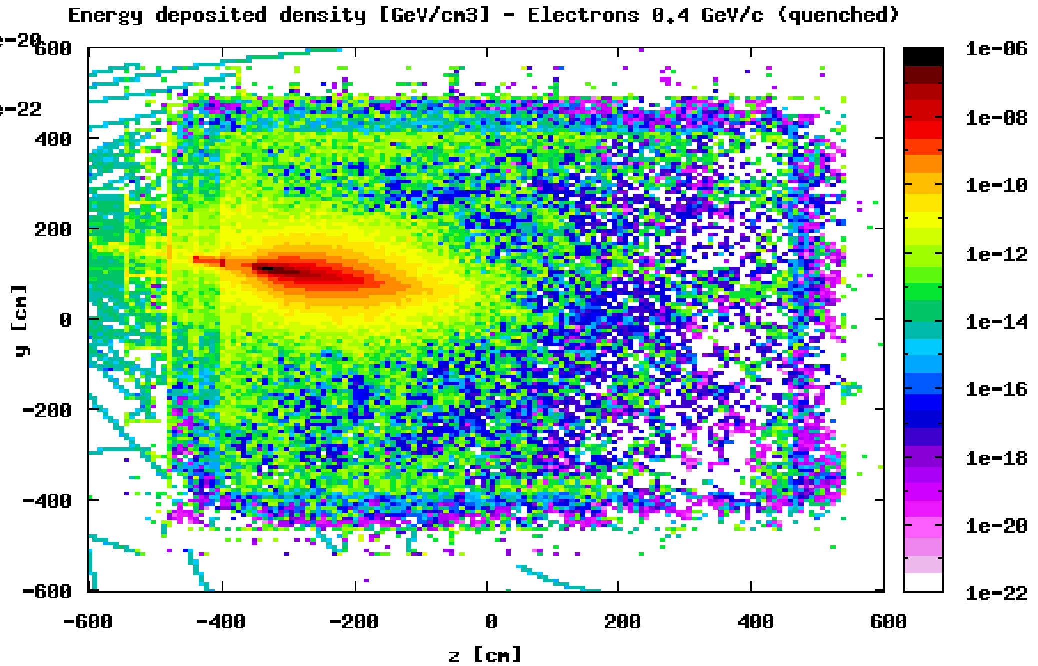
5 GeV/c protons , side and top views
Deposited en, GeV/cm^3, averaged over thousands of primaries



Energy deposited density - electrons



0.4 GeV/c electrons,
Deposited en, and quenched signal
GeV/cm^3, averaged over
thousands of primaries
➔ Small hits everywhere



Thoughts on requirements:

From proposal requirement table:

- Protons from 0.7 GeV/c
- Pions+- from 0.2 GeV/c
- Electrons from 0.2 GeV/c
- Kaons+ from 1 GeV/c

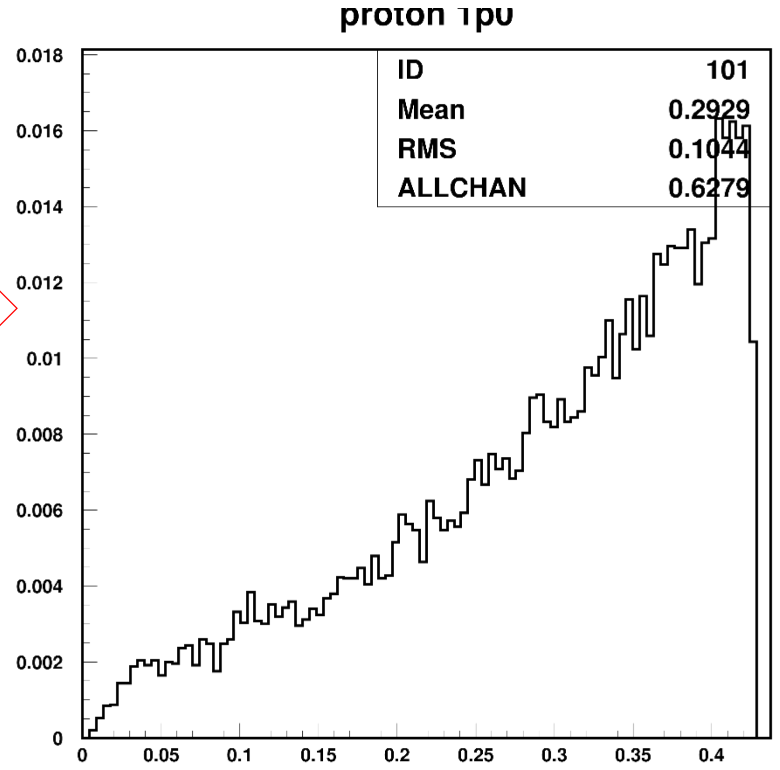
Do we really need these low energies? And can we get them?

In the following a few ideas, also based on full FLUKA simulations in the full ProtoDUNE detector geometry

Protons: was 0.7 GeV/c

- We need interacting and stopping particles.
- For stopping, the "initial "energy has small meaning
- At 1 GeV/c, still 35% of protons do stop. (only 5 per mill at 2 GeV/c) AND, 1 GeV/c the protons interact at all energies, from max down to "zero" :

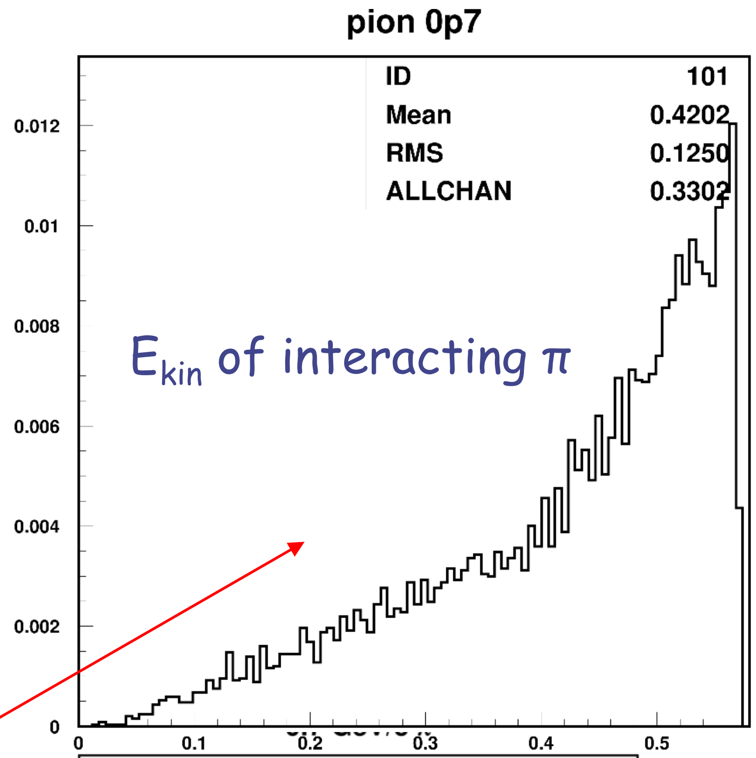
Kinetic energy of protons at the point of interaction in PD active LAr
Original momentum is 1GeV/c

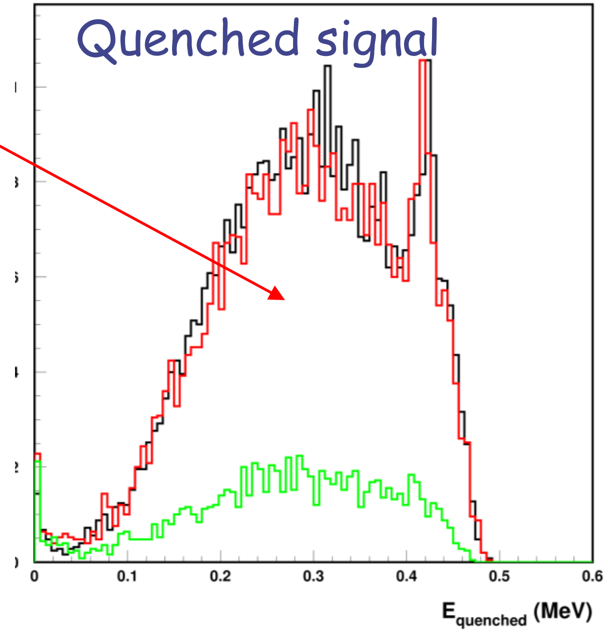


NO NEED to go below 1 GeV/c?

Pions: was 0.2 GeV/c

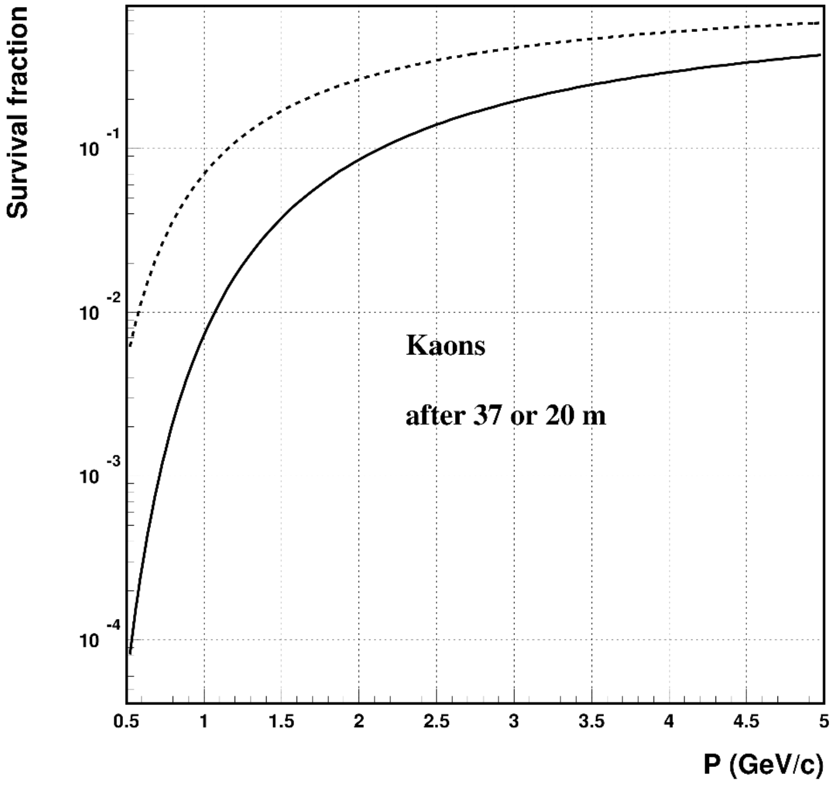
- Need interactions, decay, decay-at-rest (for quenching meas.)
- Pions decay along the beamline
- For a 37m beam line, at 0.2 GeV/c only 4% of the π reach the detector
- The fraction of (stopping π)/(from target π) is 2% at p=0.2, 1.3% at p=0.7. (To be selected from many more interacting π)
- As for protons, there are still interactions all the way from Emax to zero.
- ➔ consider having pions above p≈0.7GeV/c as first priority ?

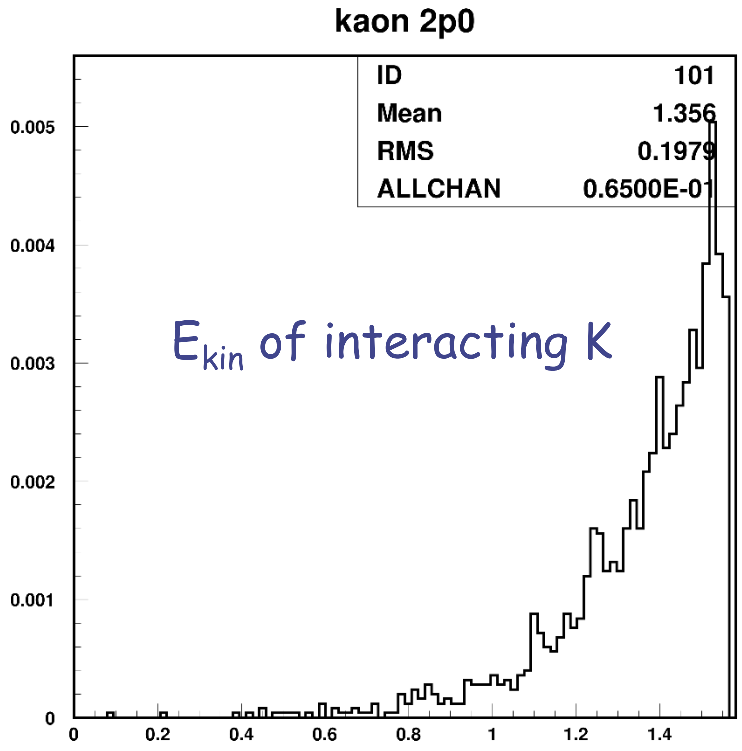




Kaons: was 1GeV

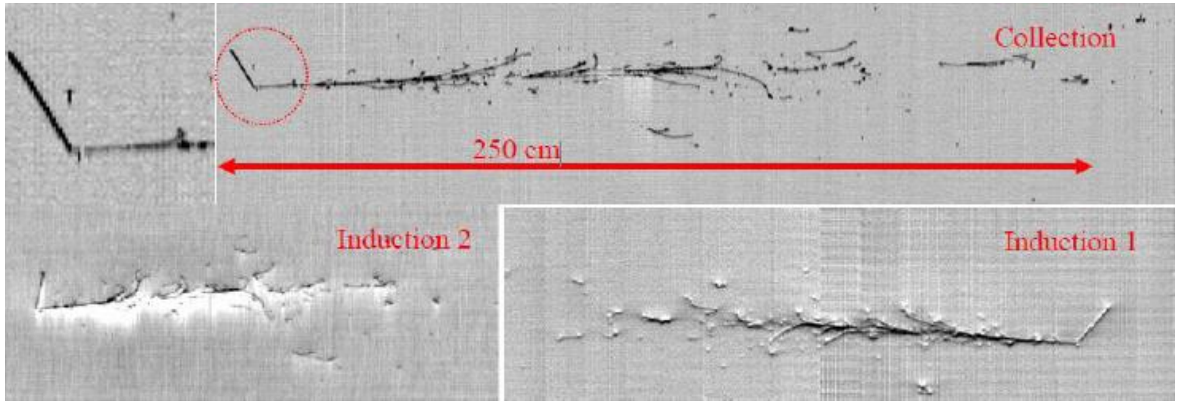
- And one would like to have.. But...no hope below 2 ≈GeV/c or more
- There will be no decay at rest
- And only "high"energy interactions





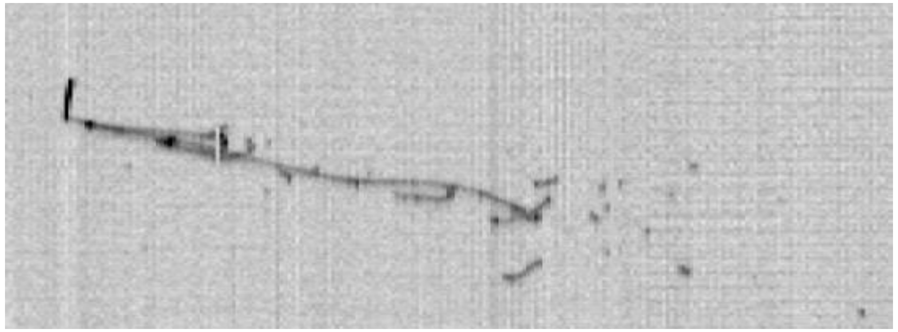
Electrons: was 0.2 GeV/c

- At low energy, topology is different from standard shower
- Would like to check ID and reco



Icarus T600 2.1 GeV electron

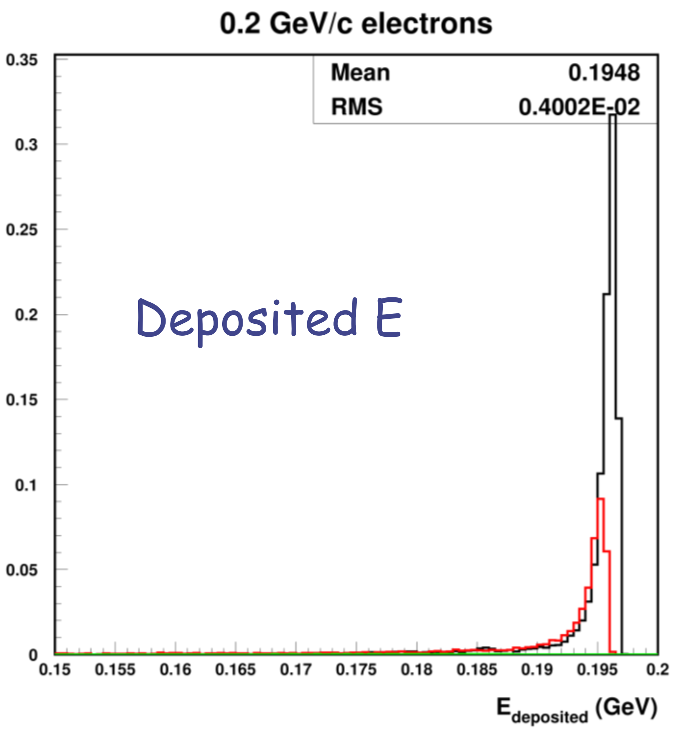
Real data, atm nu events , from SPSC presentation



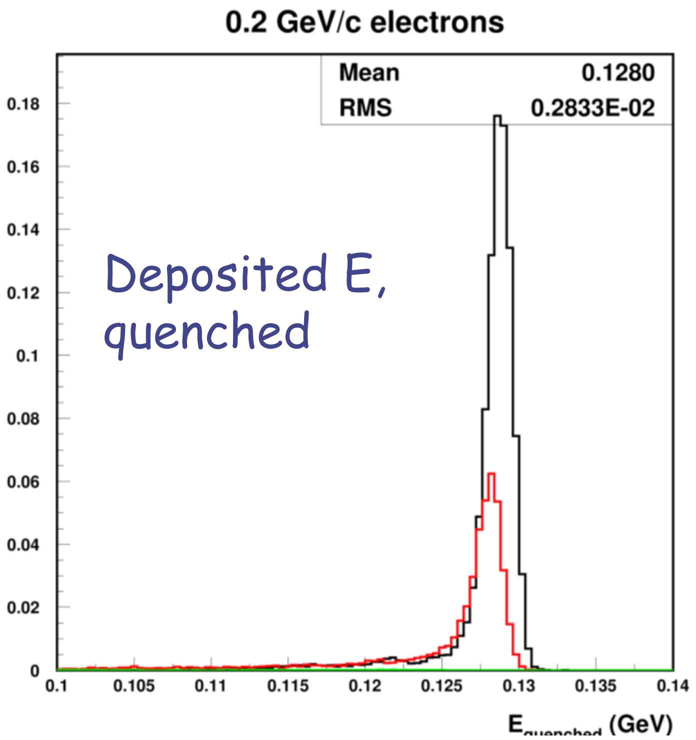
Icarus T600 0.2 GeV electron

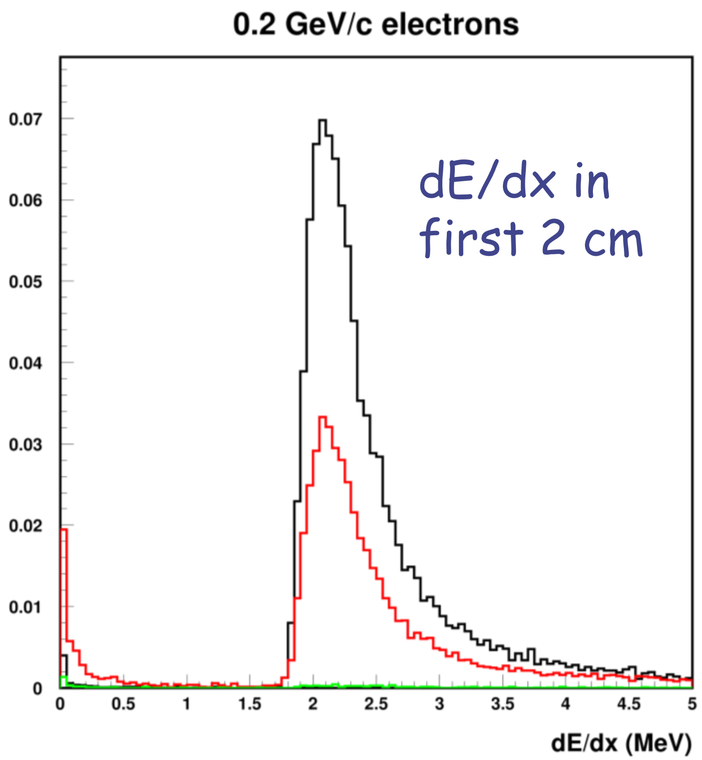
- main argument to keep low material budget

Low energy electrons



Signal from 0.2 GeV/c electrons
Black line: no materials in the beam line, only the beam window ➔ fine

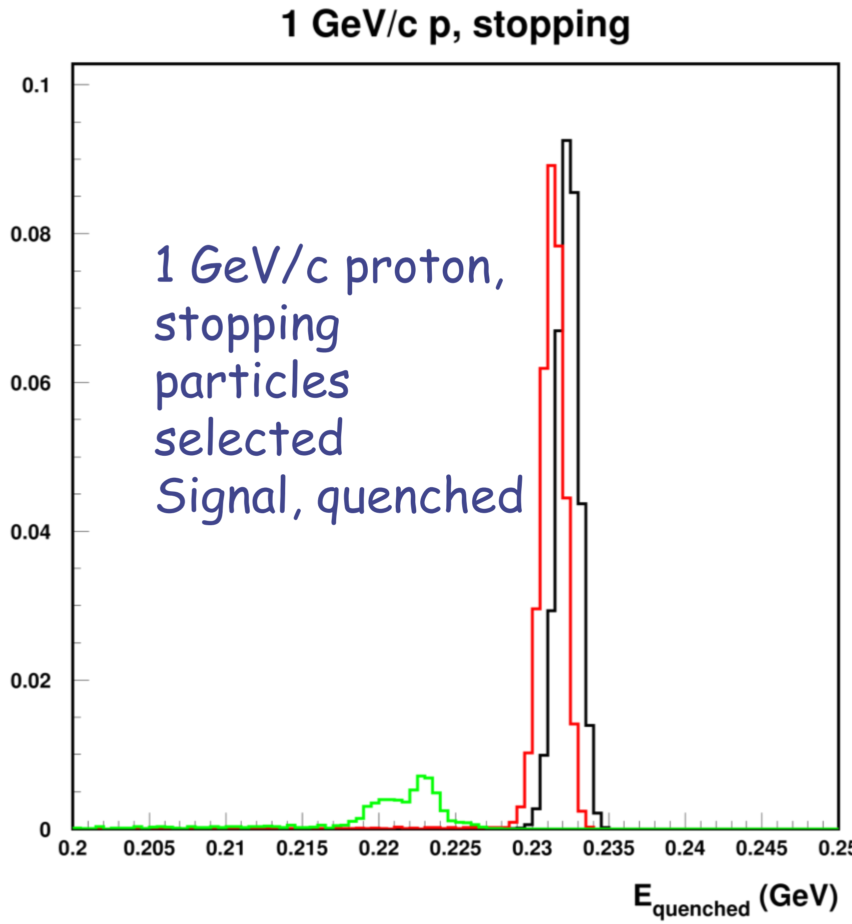




Other colors: different materials in the beam line..
Red: with spectrometer
Green: with spectrometer and tof

can spoil or destroy the signal

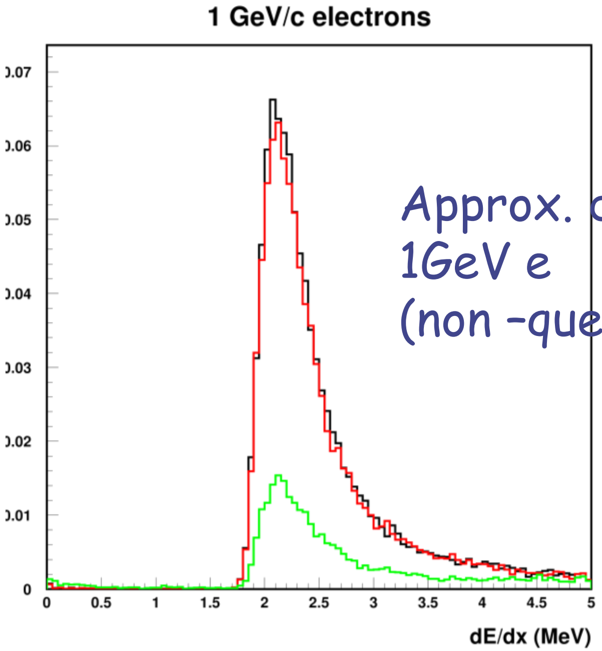
A couple of other examples



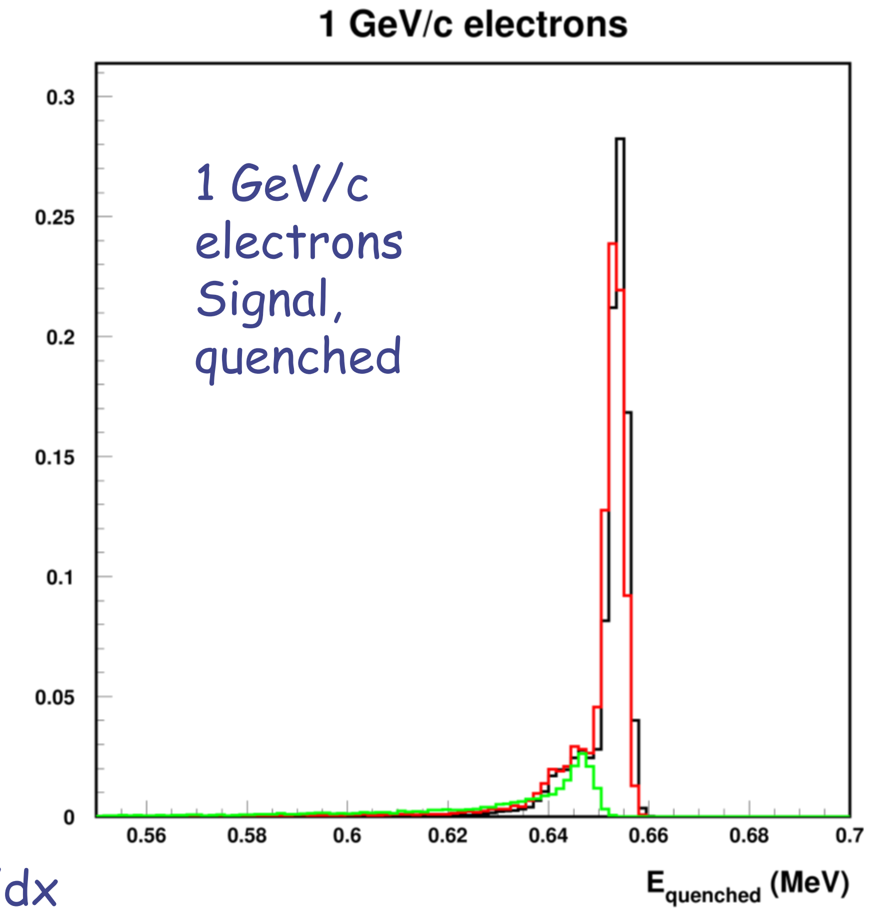
1 GeV/c proton, stopping particles selected
Signal, quenched

As before, black is the condition with beam window only

Red and green have materials before



Approx. dE/dx 1GeV e (non –quenched)



1 GeV/c electrons
Signal, quenched

Conclusion

- ProtoDUNE full FLUKA simulation ready
- For the moment, derive basic quantities from MC without reconstruction
- Useful to understand general features, and for the optimization of the beamline