Detector model and reconstruction systematics constrains with ProtoDUNE

Laura Zambelli

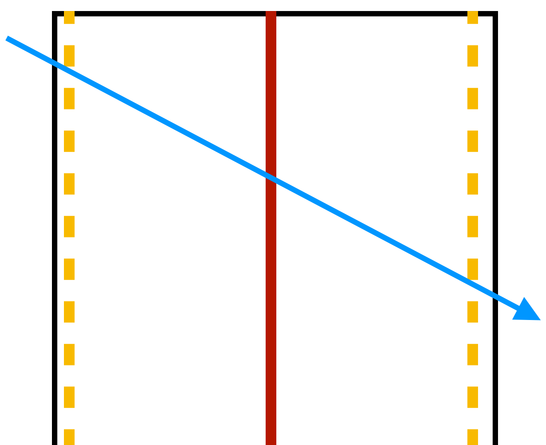
March 27th 2024, DUNE-IN2P3 meeting

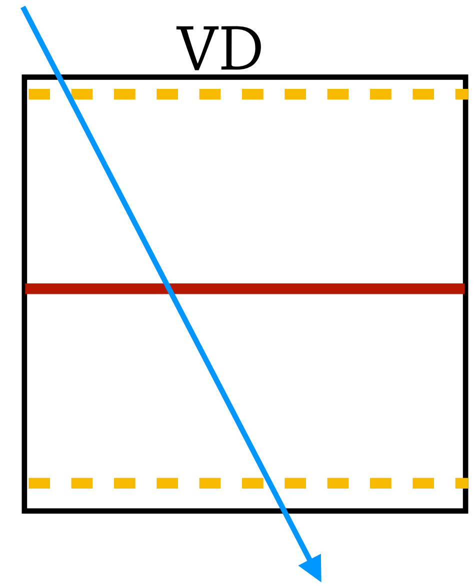
Cosmic Samples

Useful cosmic track topologies to study the detector boundaries and field distortions
-> With just the charge system, the correct timing of the tracks can be retrieve if the tracks crosses at least one instrumented plane

HD

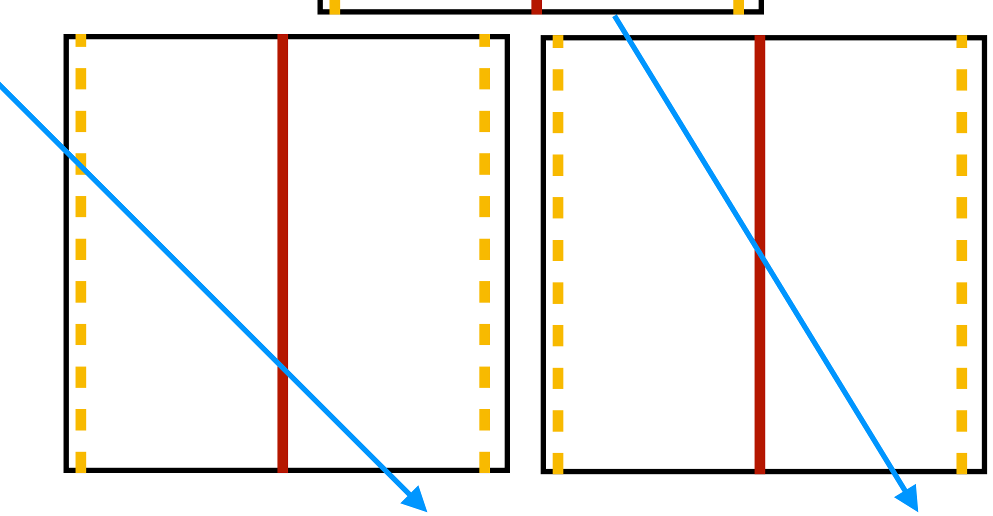
VD

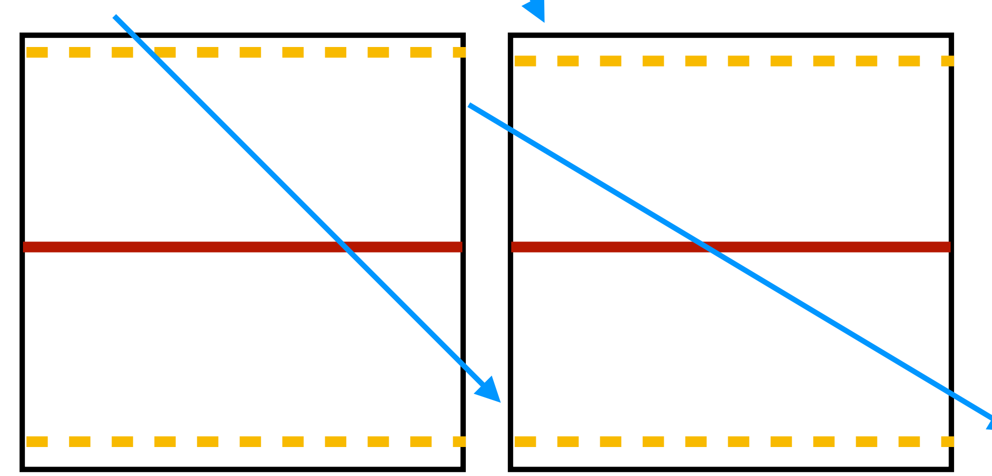




Anode-cathode-anode

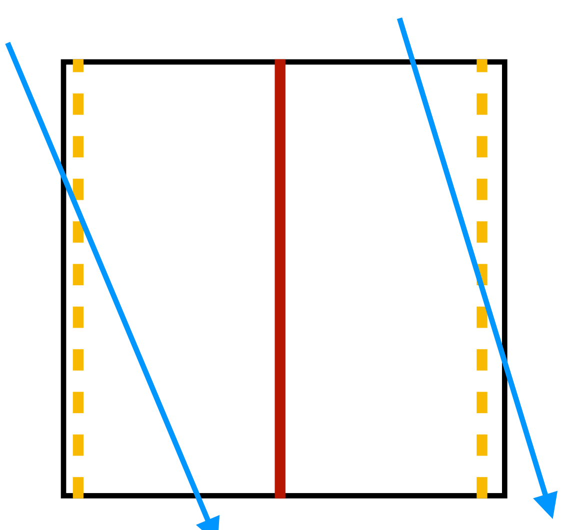
-> Golden topology, as it provides 3 crossing planes
-> Easier to have in protoDUNE-VD

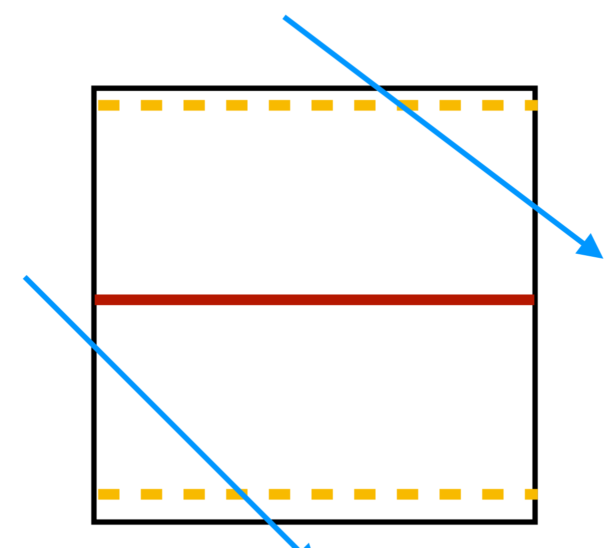




Cathode-crossers

-> Allow to study the field distortion around the cathode, where the effect is stronger

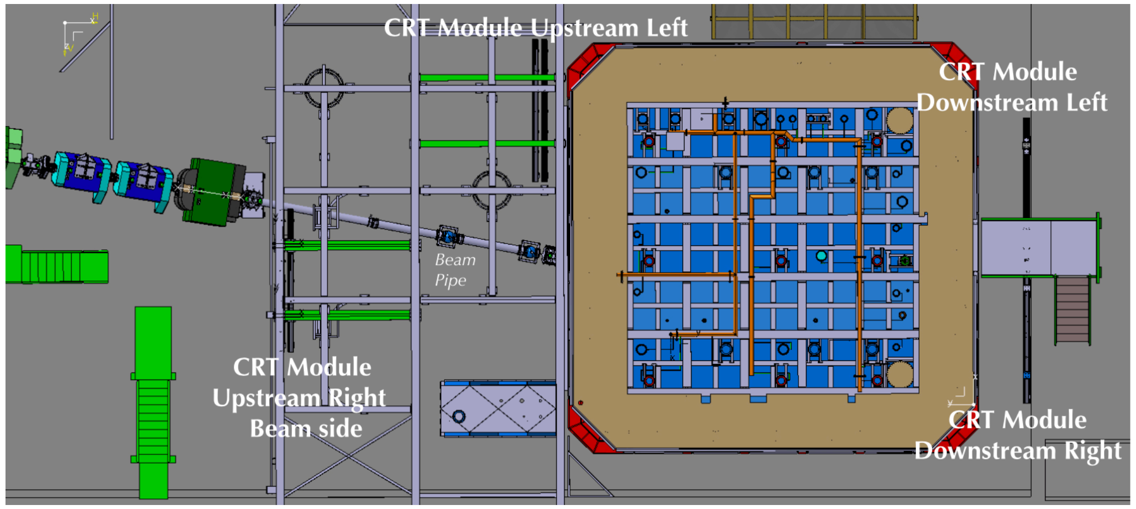




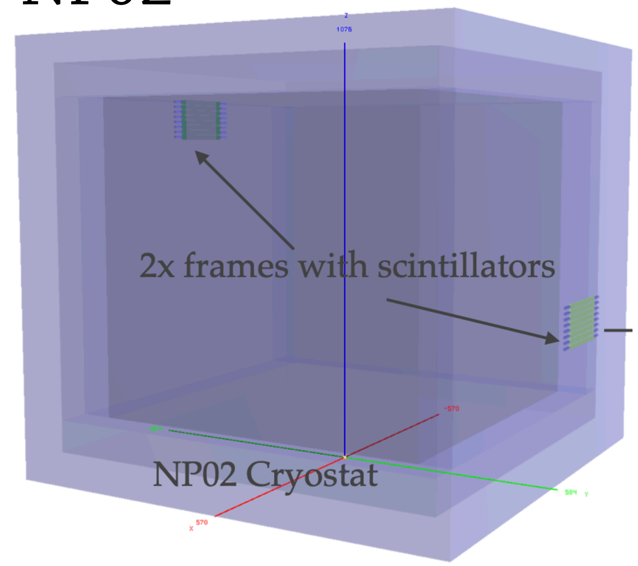
Anode-crossers
-> Study the field distortion around the anode, calibrate the charge-light delays

Other samples

NP04



NP02



CRT-trigger tracks

-> The external CRT system provides a track entry and exit point into the active volume

-> Comparison of CRT-tracks reconstruction vs expected trajectories is also useful to probe the space-charge effect

Laser System

-> A laser is shoot inside the active volume at an energy such that the argon in ionized

-> Many directions can be explored (and recorded by the DAQ), providing a clean probe to the field distortions

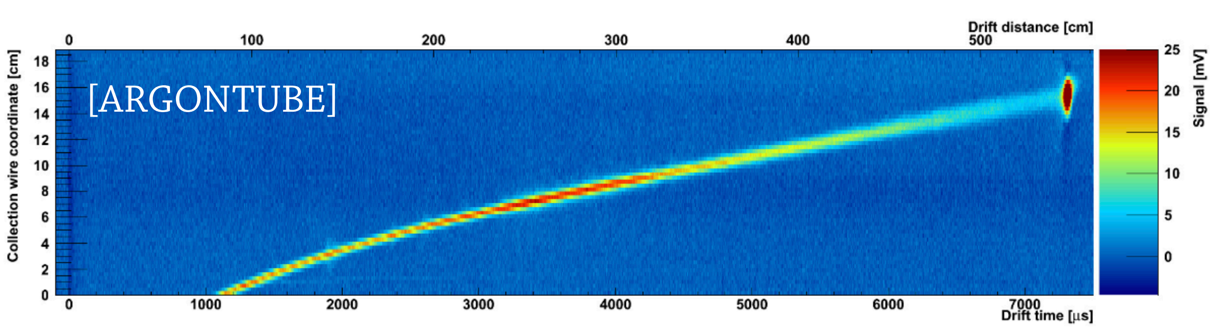
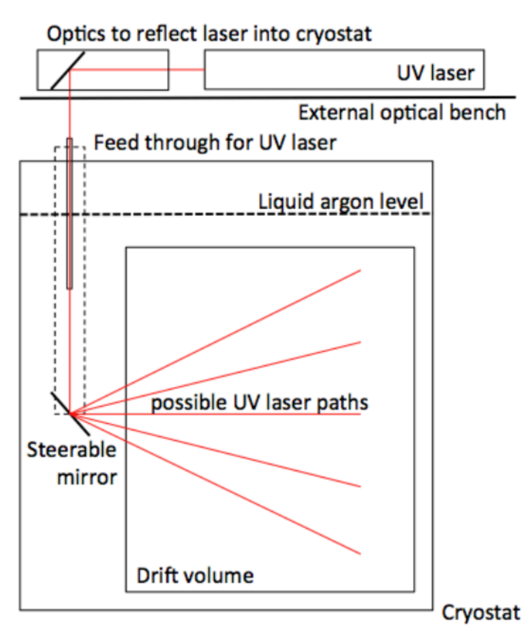


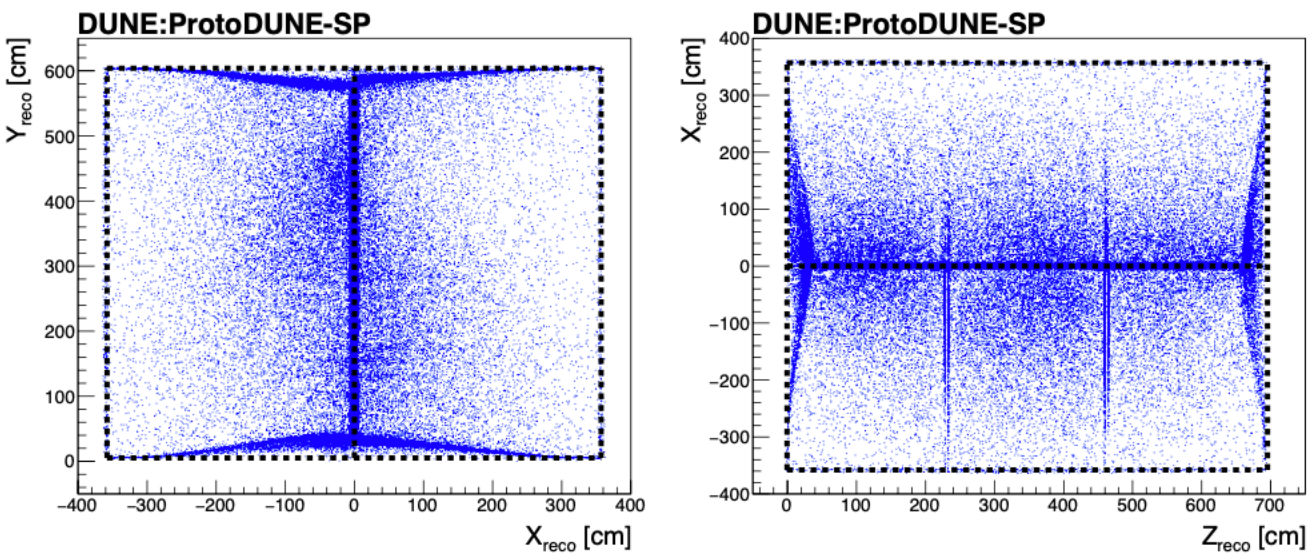
Figure 4. Ionization tracks caused by UV laser beam in a 5 m long drift liquid argon TPC. 100 tracks superimposed. Reproduced with permission from [25].

[MICROBOONE]

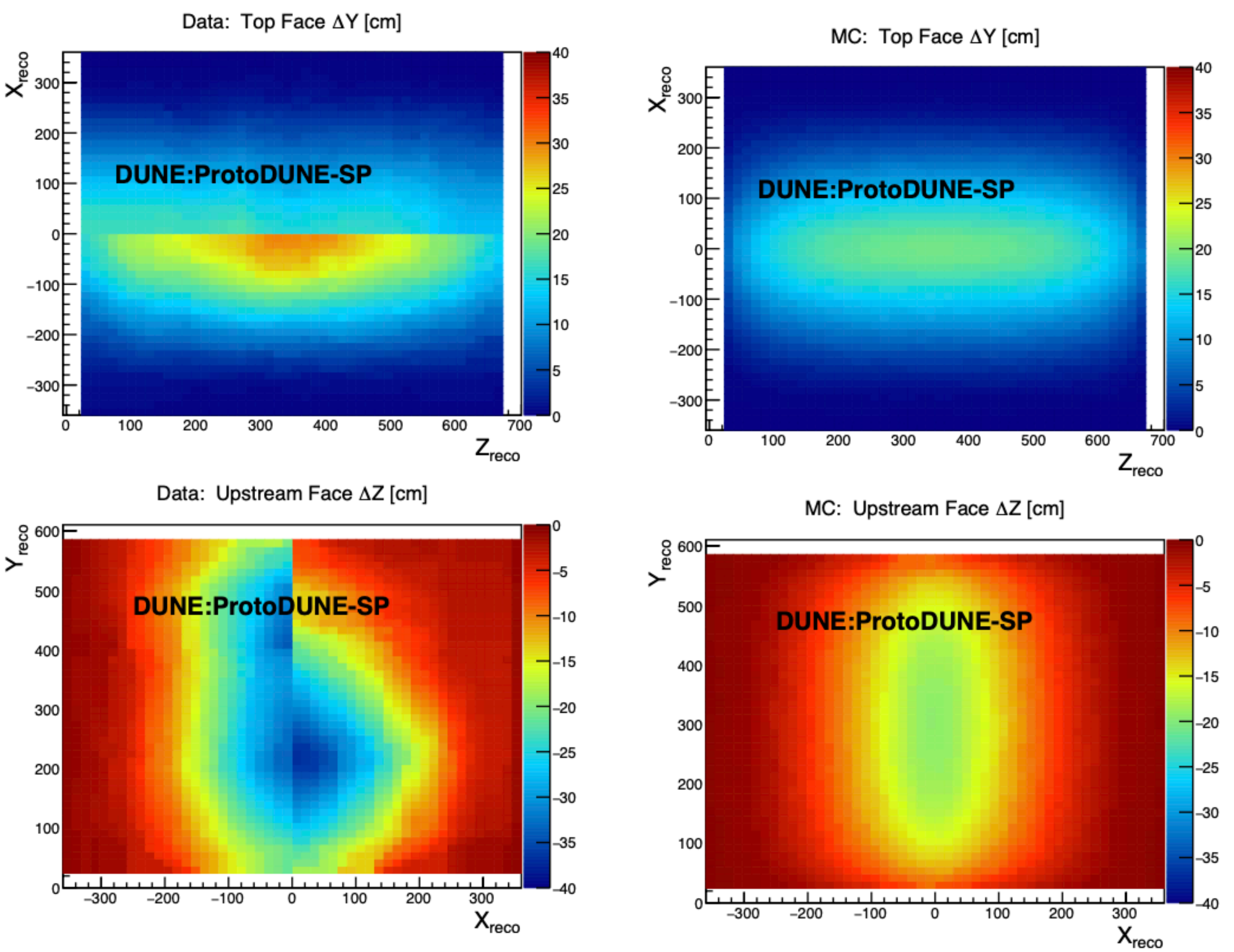


Space-Charge Effects

-> These samples allows to probe the distortions due to the space-charge effects



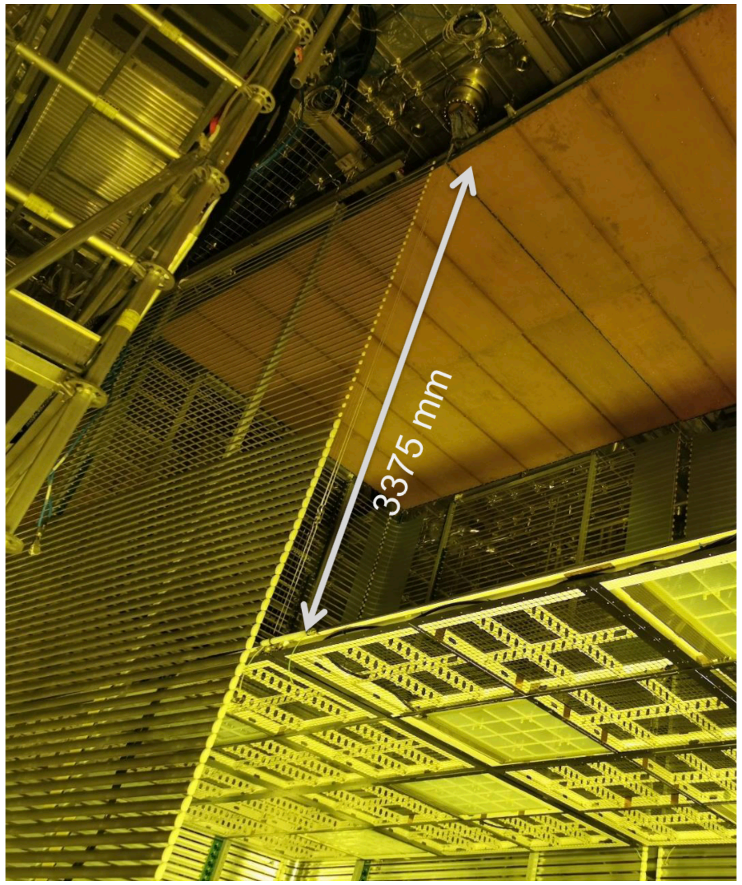
Tracks endpoints is a 1st candle to make sure the detector is symmetric, and the different element position

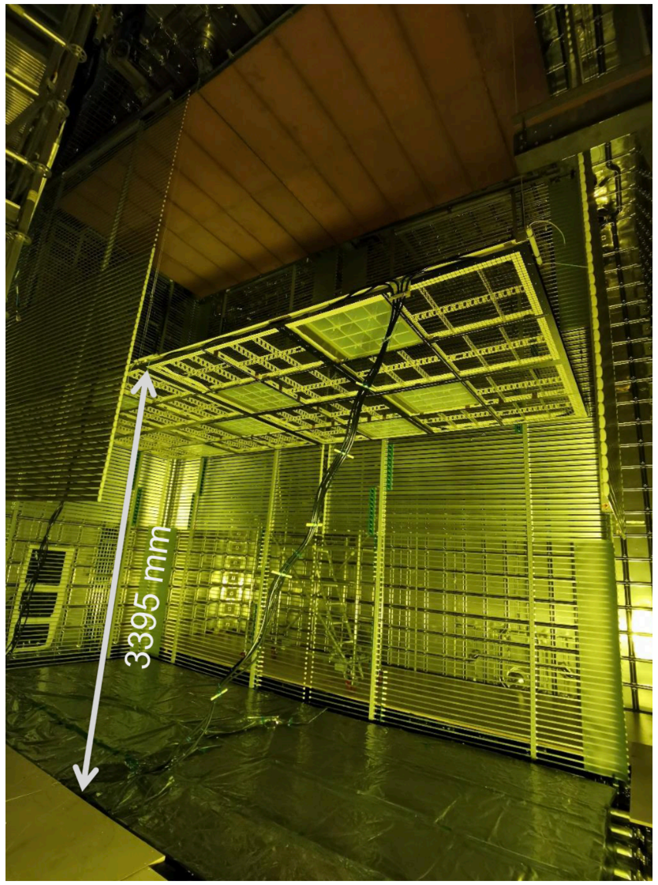


Experience from ProtoDUNE-SP showed that simulations did not reproduce the data correcly
-> Flow of LAr to be taken into account

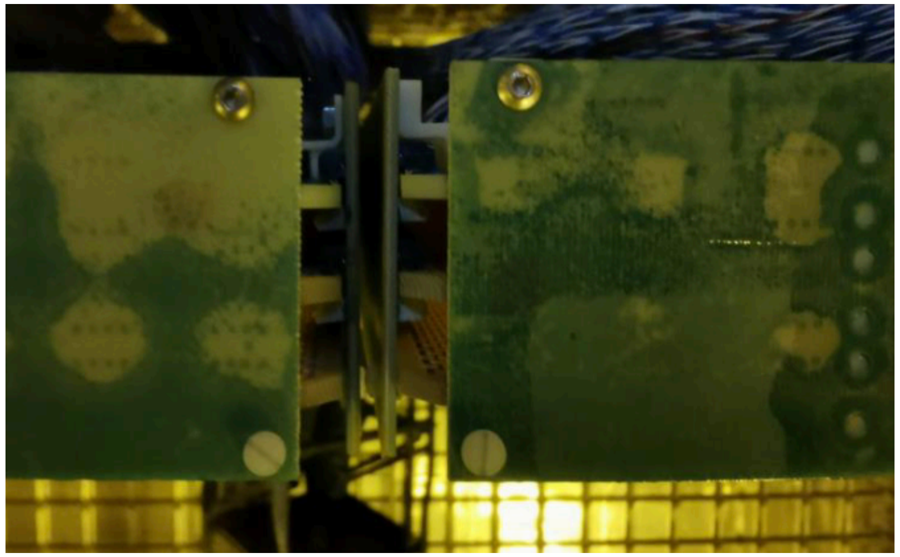
Matthew Siden's slides on protoDUNE-II SCE predictions

Detector geometry





In ProtoDUNE-VD, the drift distance should be the same for top & bottom volumes, since cable elongation & cathode buoyancy at cold have been taken into account
-> To be check
-> TopCRP+Cathode can be vertically moved



Un-instrumented area between two CRPs are under study with COMSOL simulations (Yoann)
-> to be checked with data

Energy scale and resolution

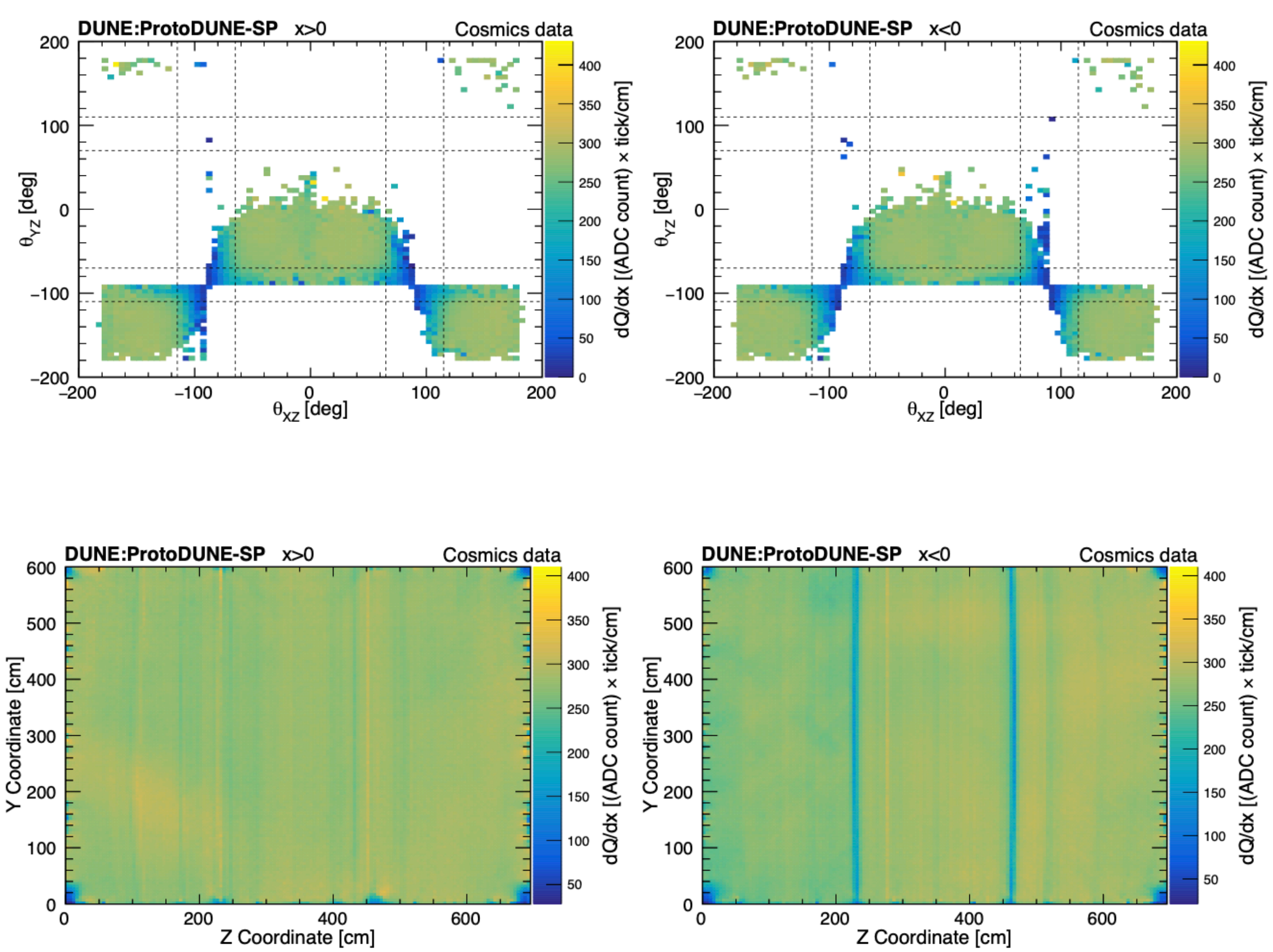
The expected charge deposition of muons is very well known

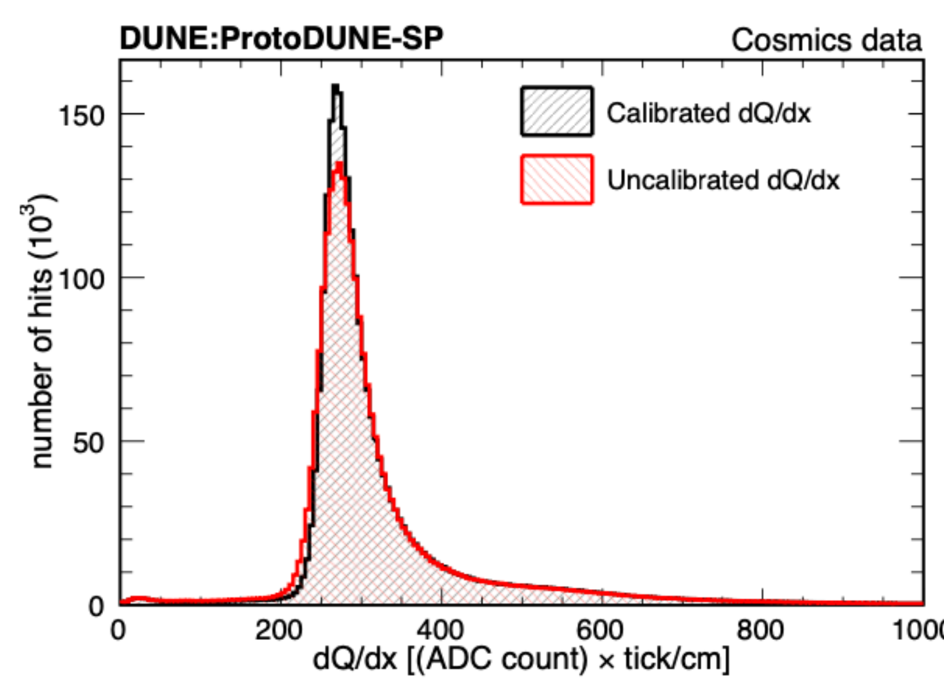
From the data, the measured dQ/dx can be degraded from many sources:

- Electronic gain: can be monitored frequently (at least for bottom electronics)
- SCE: established with cosmics samples + CRT + laser systems, and dQ/dx corrected
- Impurities: Can be corrected if the track is properly t_0-ed
- Diffusion, transparency, topology, … : can be studied with data sufficient statistics ; and with dedicated simulation (e.g. Joshua's work)

-> In protoDUNE-SP, dQ/dx correction factors was computed along x and (YZ) planes.

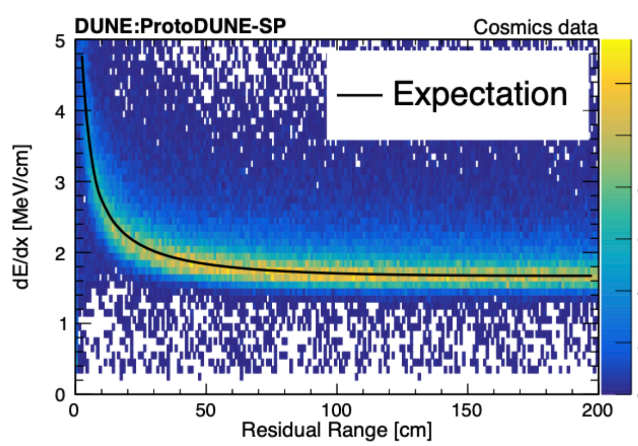
-> The overall calibrated dQ/dx distribution of MIP muons is sharper



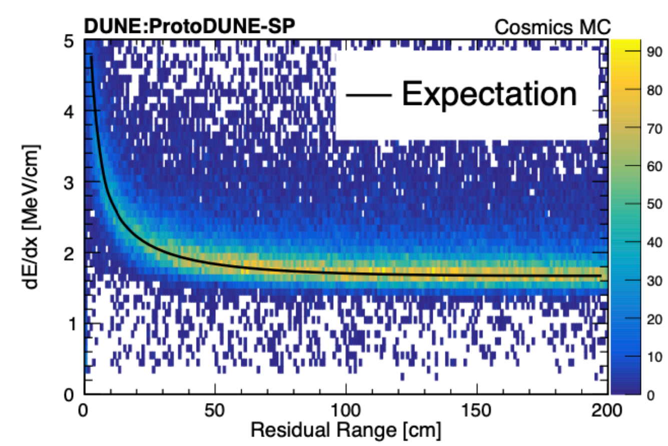


Energy scale and resolution

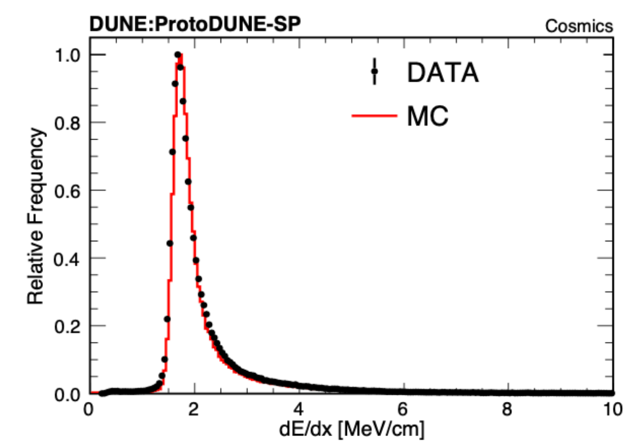
The expected charge deposition of stopping muons is also very well known!
Once the calibration factors are known from data (and better, understood), stopping muons samples can used to provide an energy scale and resolution measurement



(a) Data



(b) MC

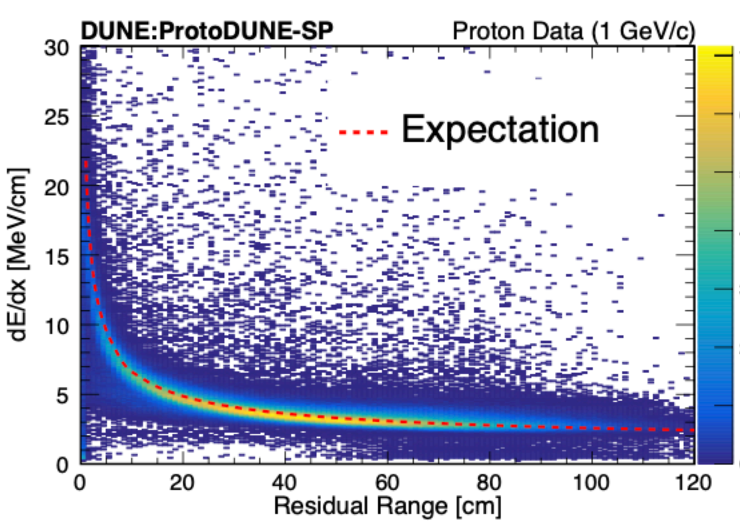


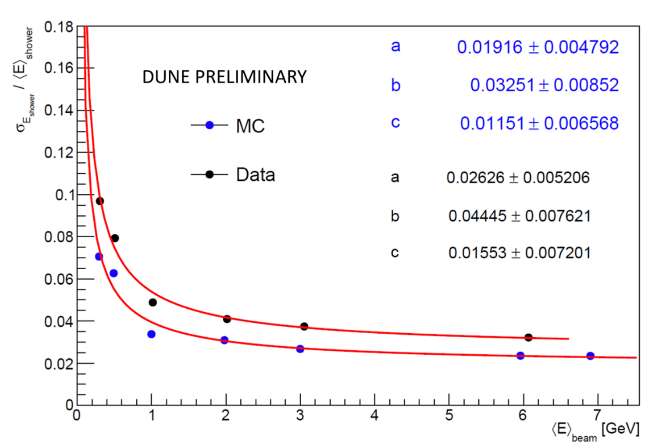
(c) dE/dx comparison

The other method, is to use the beam data :

-> For protoDUNE-HD we should have an energy scan at negative polarity

-> Hope to have the same for protoDUNE-VD next year



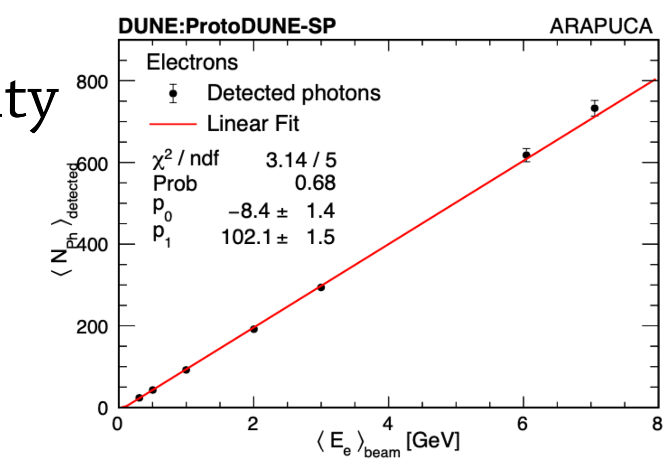


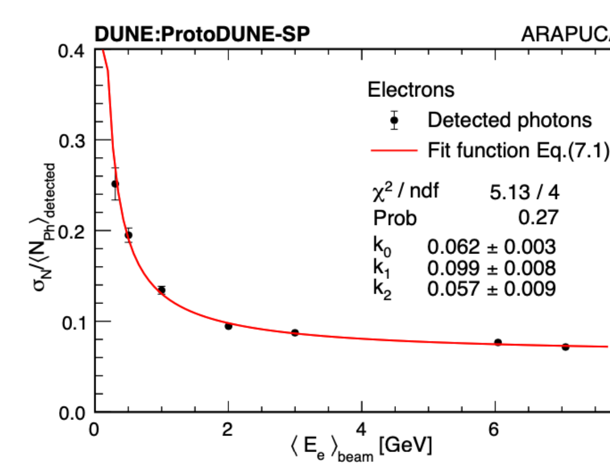
: Measured positron energy resolution across the beam momentum settings of the test beam. The ons are fitted to the equation: $\frac{\sigma_E}{E} = \sqrt{a^2 + (b/\sqrt{<E>})^2 + (c/<E>)^2}$.

[R. Diurba proceeding]

Same analysis done for the light system ->

To be done : combined charge and light!





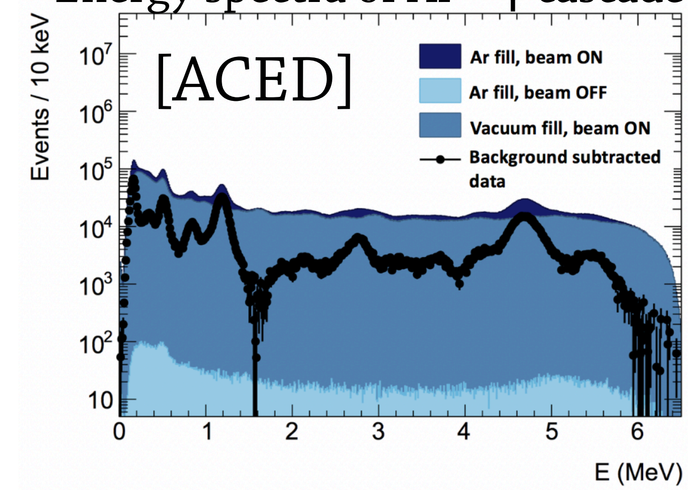
Energy scale and resolution

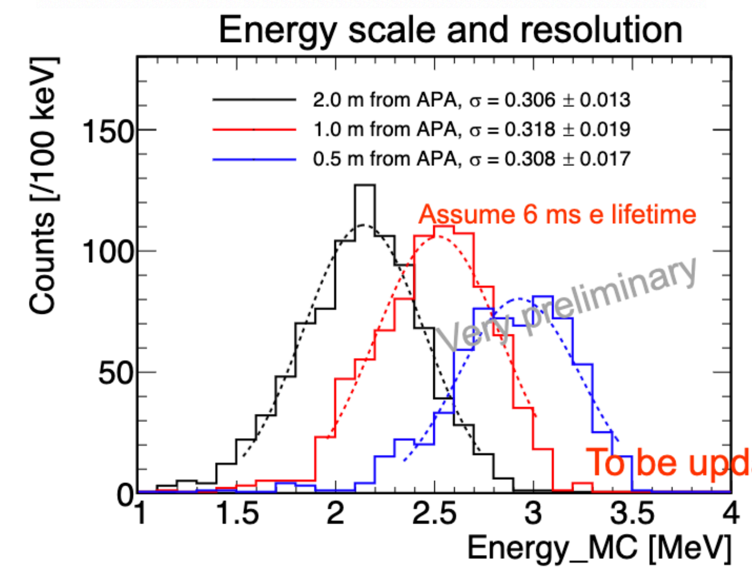
Low energy :

- Reconstruction of Ar^{39} spectrum (and other isotopes…) : Emile's work

- In the protoDUNEs, Pulsed Neutron source system will be installed
->Inject 57 keV neutrons (elastic scattering length of ~30m) in the detector from the outside
-> Once slow down, neutrons are captured by Ar^{40}
-> Ar^{41} deexcitation emits a 6.1 MeV γ cascade, with mostly 167 keV, 1.2 MeV and 4.7 MeV gammas
-> Will be tested in the next VD-Coldbox run!

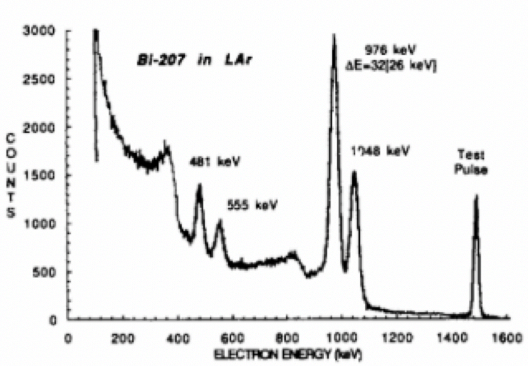
Energy spectra of Ar^{41} γ cascade





MC Studies

- Bi^{207} sources



Pulse height spectrum of the Bismuth source in LAr,at E=10.9 kV/cm. The 976 keV electron peak is visible with a total energy resolution of 32 keV (fwhm).

-> ~1 MeV peak from electronic capture
In ProtoDUNE-HD two sources have been installed (near the anode and near the cathode)
In ProtoDUNE-VD, a mini TPC with a Bi source will be installed outside of the active volume