Dual phase detectors

Dorota Stefan CERN/NCBJ
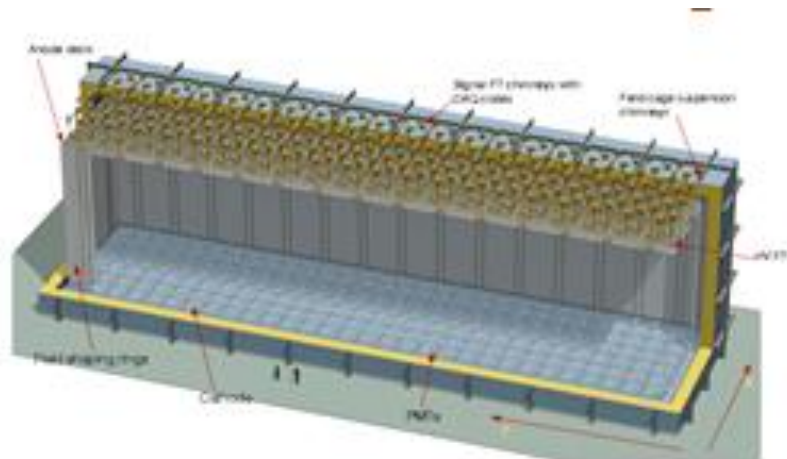
Planned dual phase detectors

WA105: prototype 1 x 1 x 3 m³

Will collect cosmic muons this Fall.
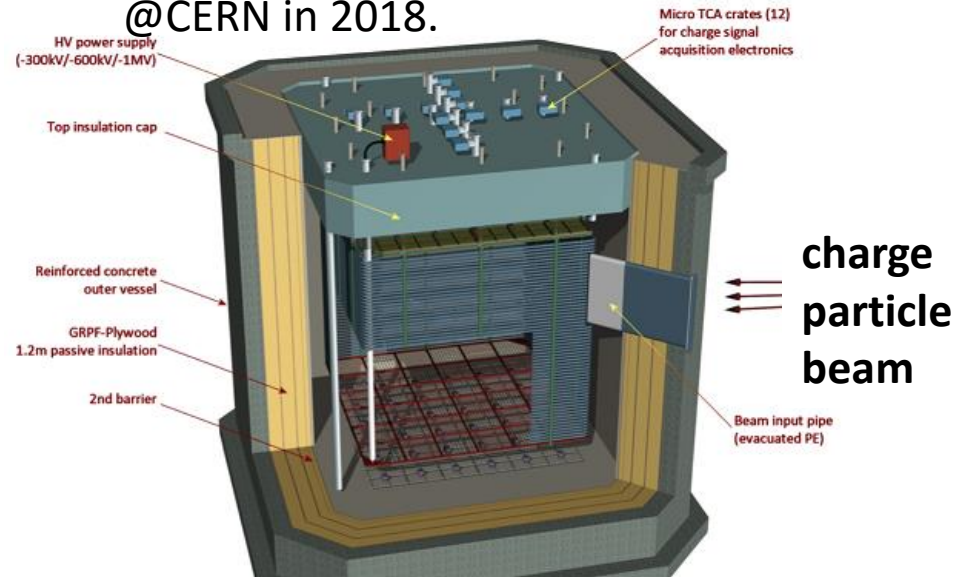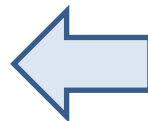

Photo from Sebastian Murphy, ETHZ

ProtoDUNE dual phase

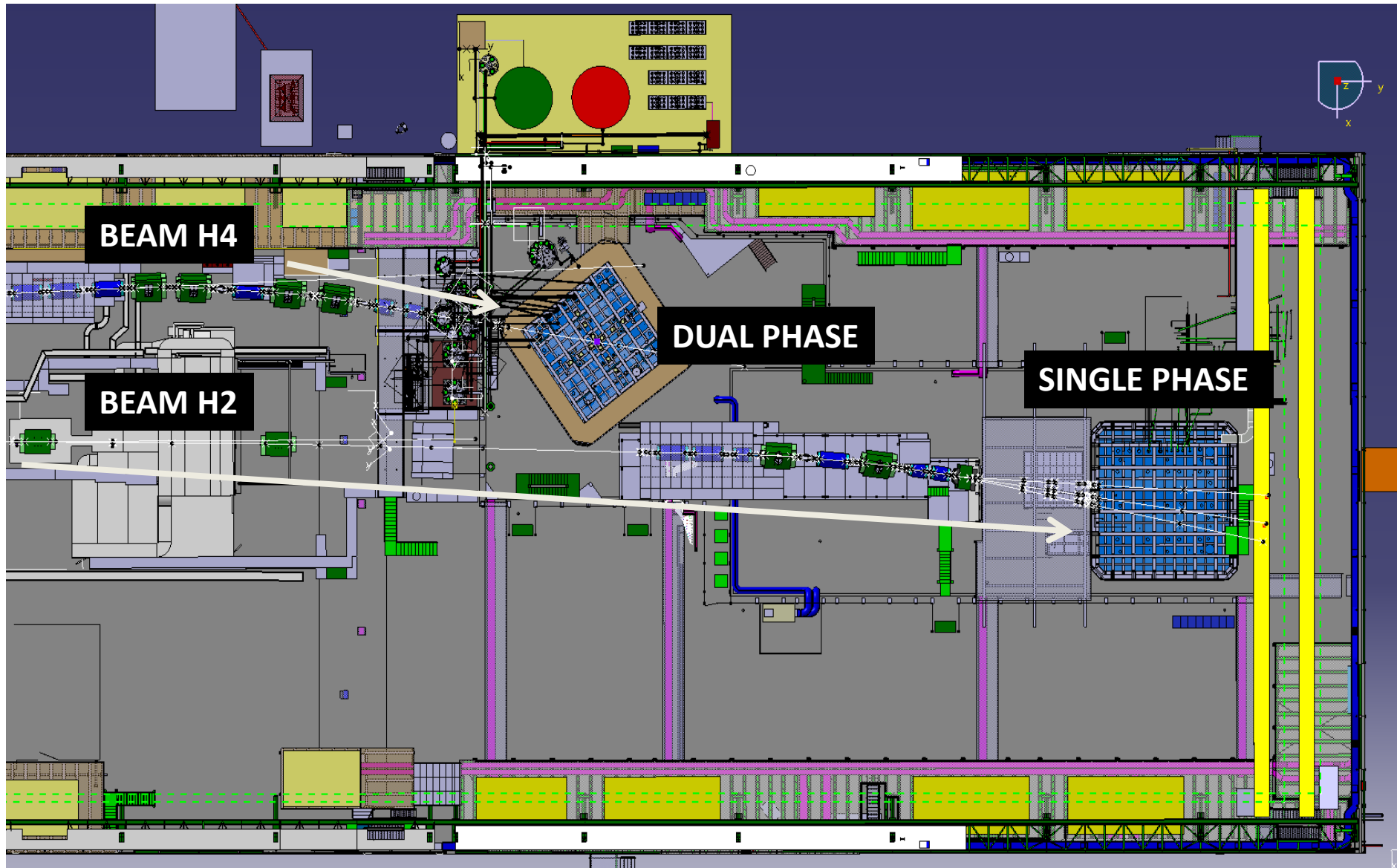Will be operating on the test beam @CERN in 2018.
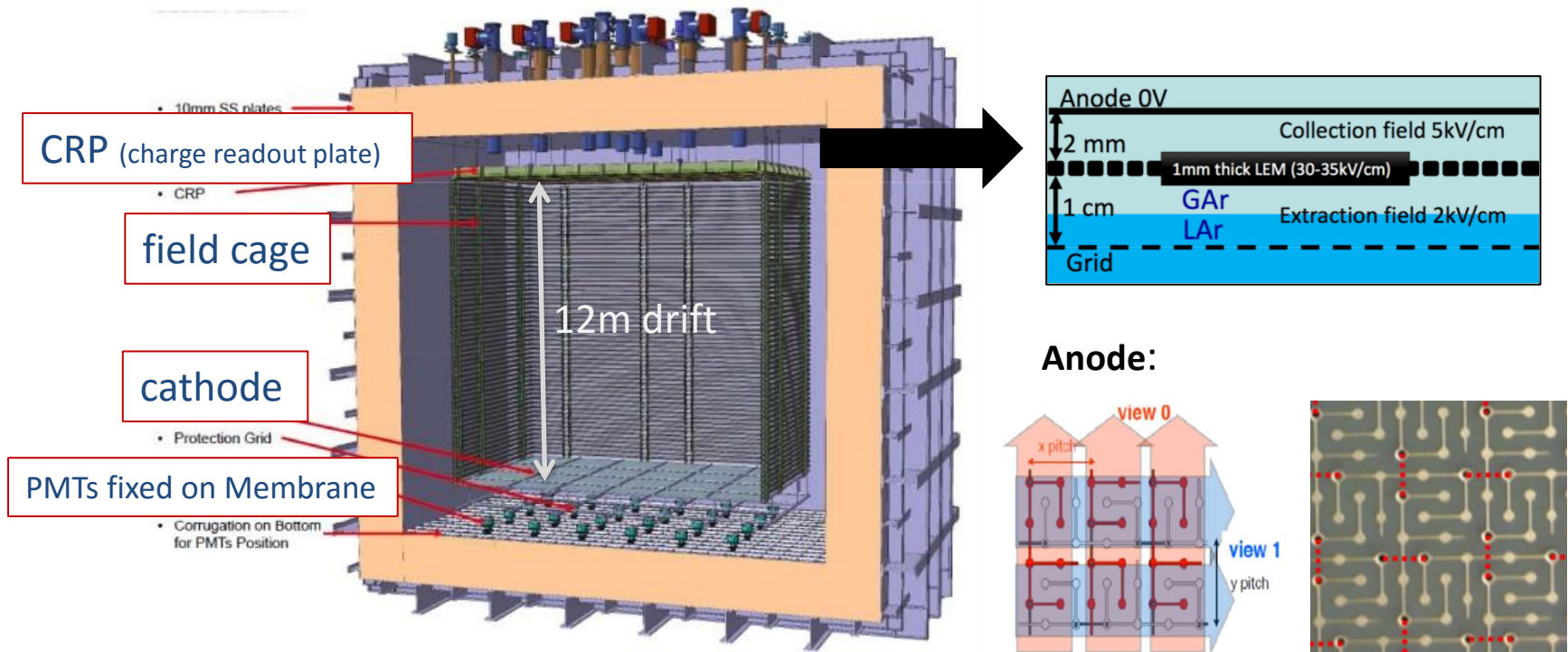

charge particle beam

Far Detector:
- 12 x 12 x 60 m³
- The charge readout over 12x 60 m² is accomplished with independent 3 x 3 m² modules.

EHN1 at CERN in 2018

BEAM H4

BEAM H2

DUAL PHASE

SINGLE PHASE

Dual phase technology

CRP (charge readout plate)

field cage

12m drift

cathode

PMTs fixed on Membrane

Anode:

- 10mm SS plates
- CRP
- Protection Grid
- Corrugation on Bottom for PMTs Position

Anode 0V

2 mm — Collection field 5kV/cm

1mm thick LEM (30-35kV/cm)

1 cm — GAr / LAr — Extraction field 2kV/cm

Grid
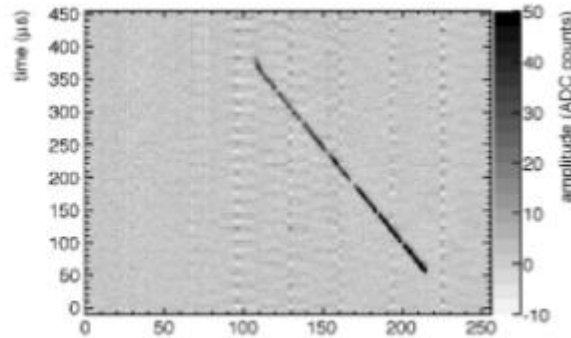
view 0

x pitch

view 1

y pitch

- Readout of ionization charge:
  - ionization electrons extracted into Ar gas phase,
  - charge amplification via large electron multipliers (LEM),
  - CRM readout: 2 views in *collection* mode.

- Single, 12m long vertical drift.

- Scintillation light collected by PMTs located below the cathode.

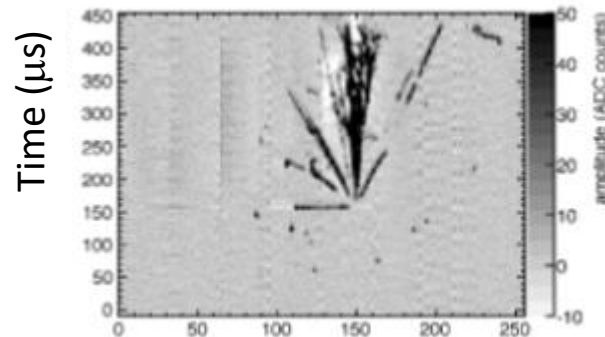# Example of collected data by dual phase prototype in Zurich
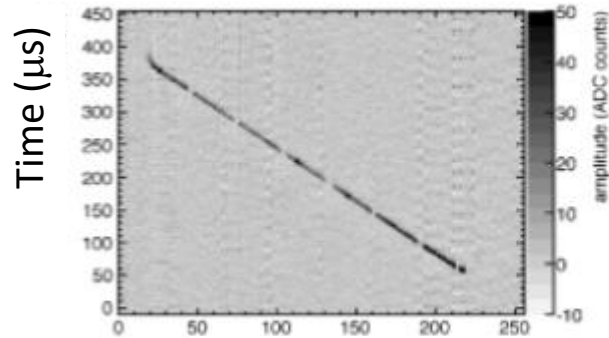
cosmic muon track
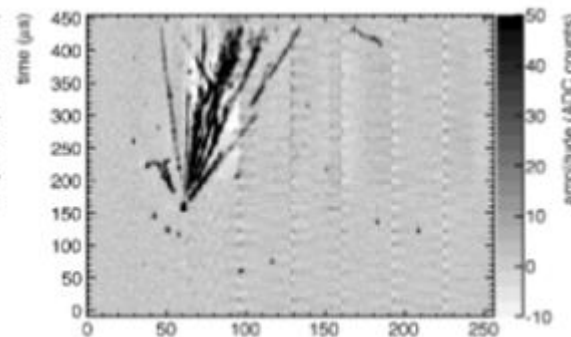
hadronic shower

Data collected by 200 liter prototype in Zurich,
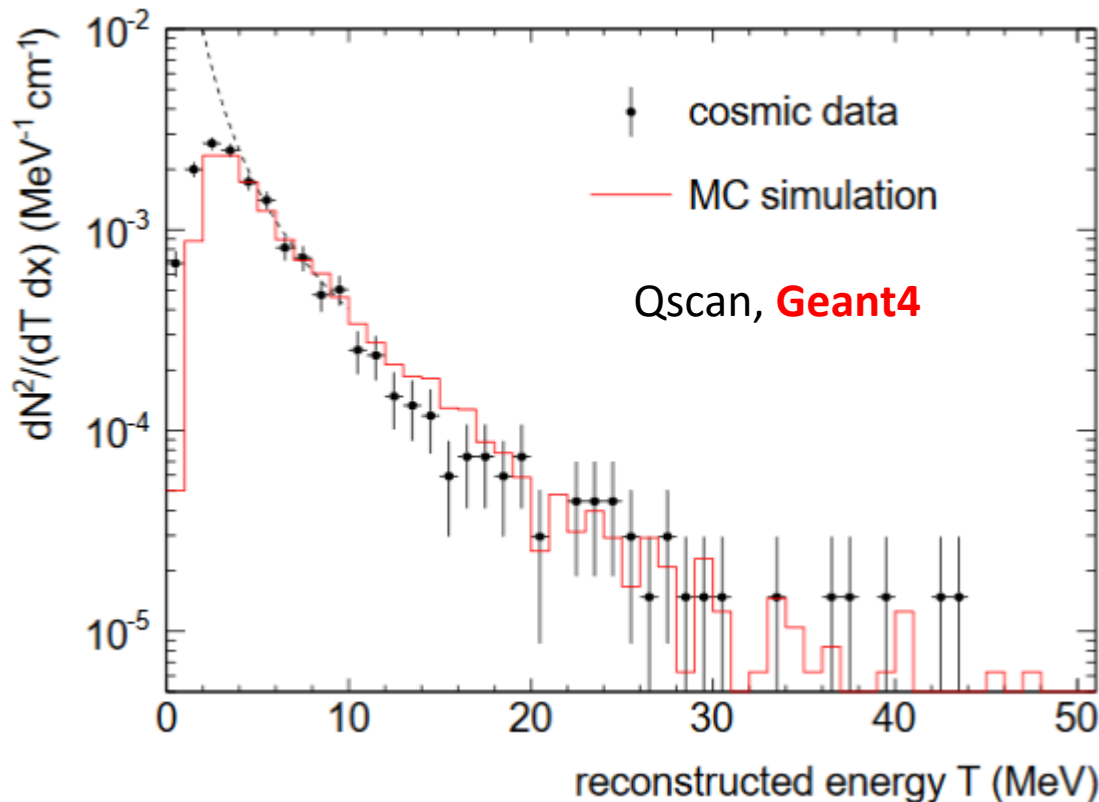arXiv: 1301.4817

Spatial reconstruction
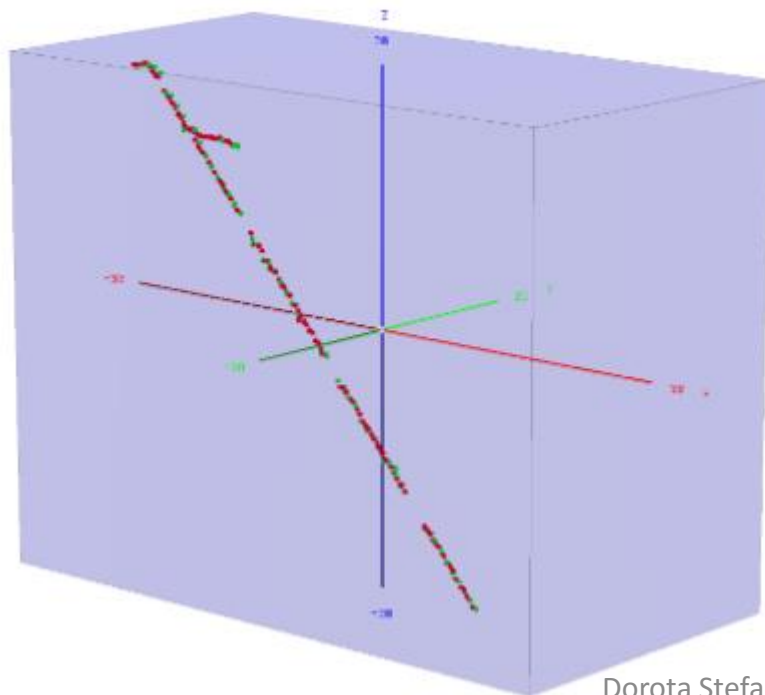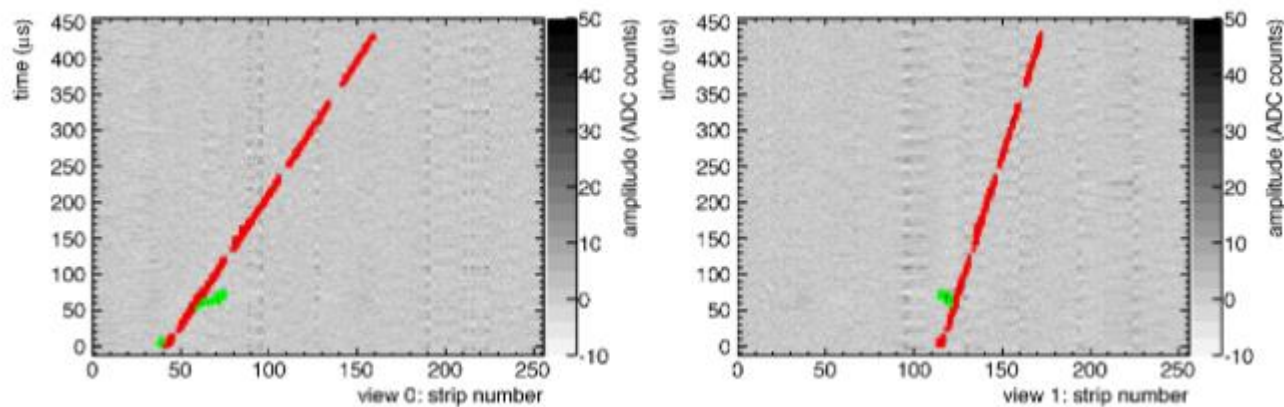
- Simple reconstruction: hit by hit match at the same electron drift.

- Two collections allow easy use of charge information in spatial reconstruction.

arXiv: 1301.4817

Calorimetric reconstruction

Number of reconstructed δ-rays, normalized by the μ track length

- Qscan has been interfaced with **Geant4**.

- Muons with a uniform distribution between 1 and 10 GeV/c and with the angular distribution of the observed cosmic rays.

- **Reconstructed energy of δ-rays above 3MeV agrees well with data**.

arXiv: 1301.4817

LArSoft dual phase implementation

- Independent TPC units with 12 m drift and readout area of 3 x 3 m^2 each.

- X-axis points in the direction of the electron drift, y-axis is along vertical, z-axis in the neutrino beam direction.
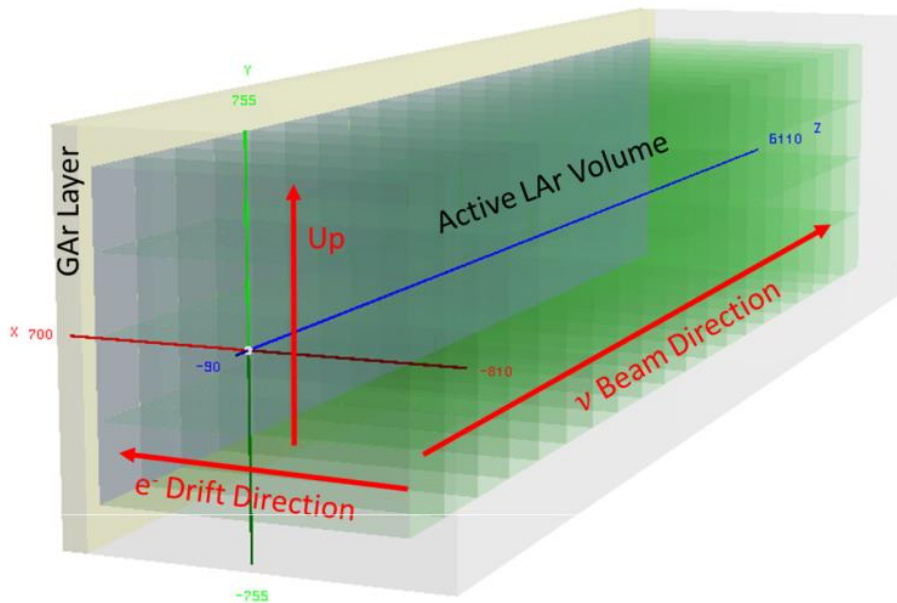
10kt DP TPC implementation in LArSoft by Vyacheslav Galymov
→ LArSoft Coordination meeting

1st Vplane
(assigned geo::kU in larsoft)
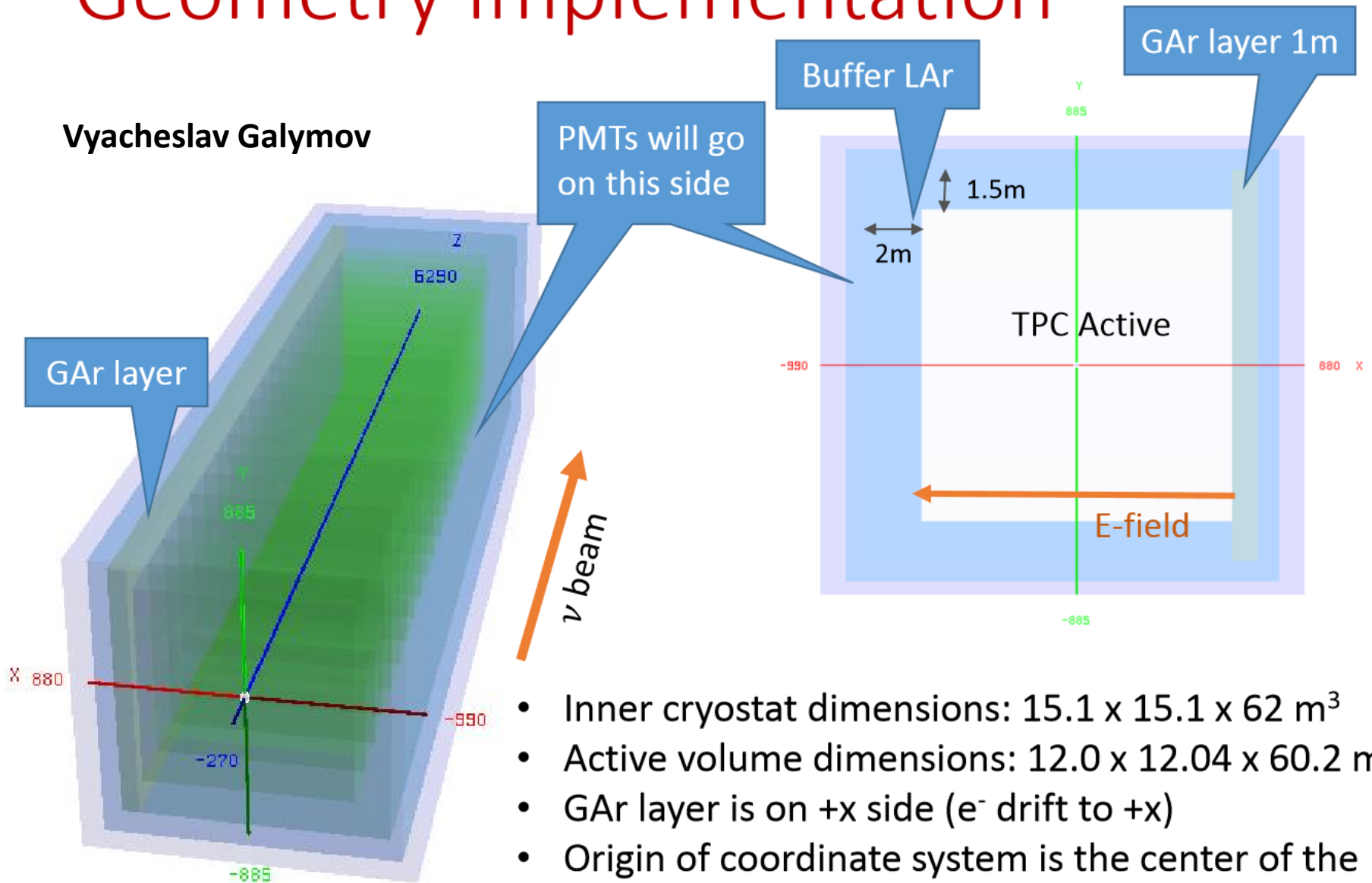
2nd Zplane
(assigned geo::kV in larsoft)
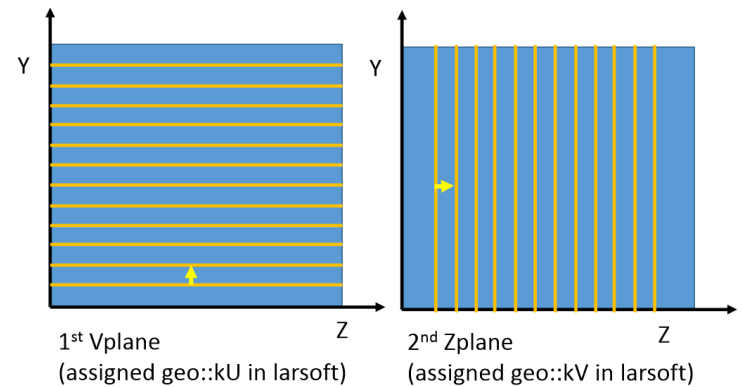
charge readout in LArSoft defined as wire planes

For DP we have two views → two wire planes (in collection mode)

Geometry Implementation

Vyacheslav Galymov
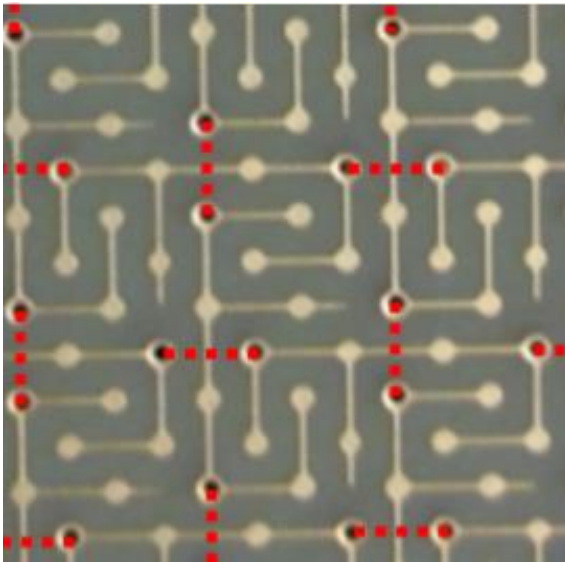

- Inner cryostat dimensions: 15.1 x 15.1 x 62 m^3
- Active volume dimensions: 12.0 x 12.04 x 60.2 m^3
- GAr layer is on +x side (e$^-$ drift to +x)
- Origin of coordinate system is the center of the TPC active volume at the upstream end
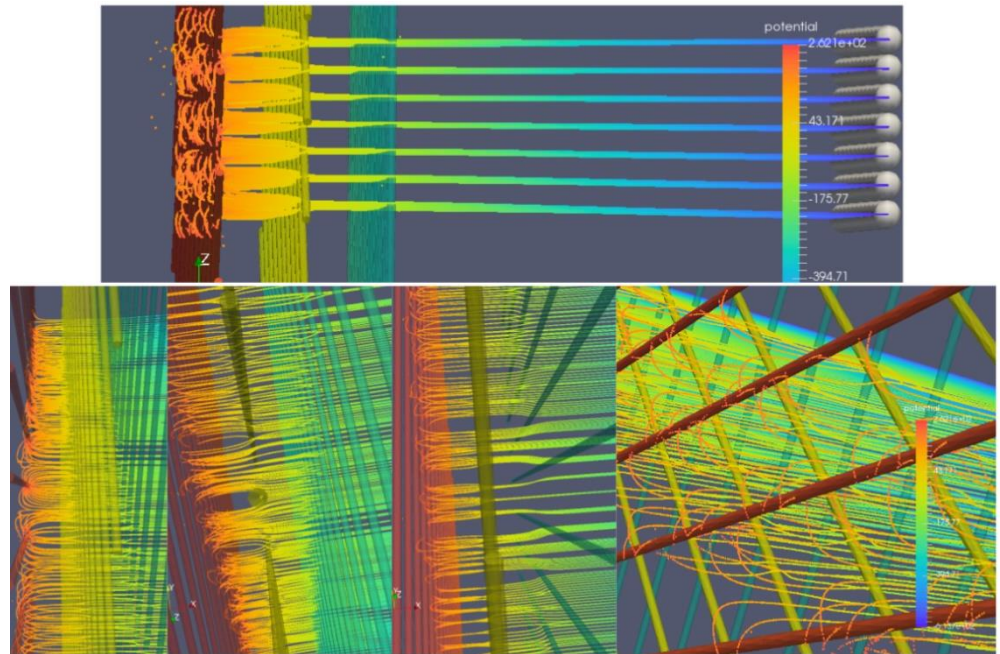
Signal simulation in LArSoft

- Needed realistic simulation of 3D field and detector response (keep in mind extraction grid, LEM and gas layers on the ionization electrons way from LAr).

- Similar work done by Brett Viren for single-phase, contact Brett for hints on tools such as BEM++, ParaView and LARF and integration with LArSoft.

Drift path visualizations in SP detector

Dual phase readout

Pictures were taken from Brett Viren's presentation:
https://indico.fnal.gov/getFile.py/access?contribId=79&sessionId=20&resId=0&materialId=slides&confId=10613

The standard hit reconstruction implemented in LArSoft incudes:

1. Deconvolution of the E-filed and electronics response +filtering and noise removal.

2. Hit finding and fitting with assumption of Gaussian shape of ionization pulses.

adopted from SP to work with DP
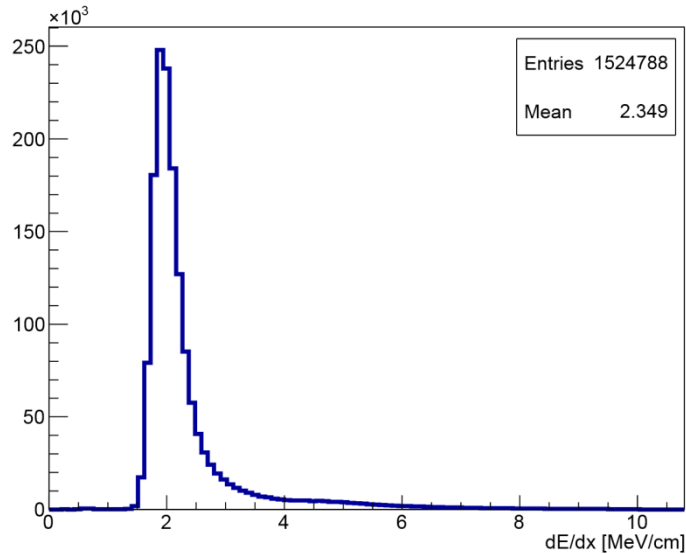

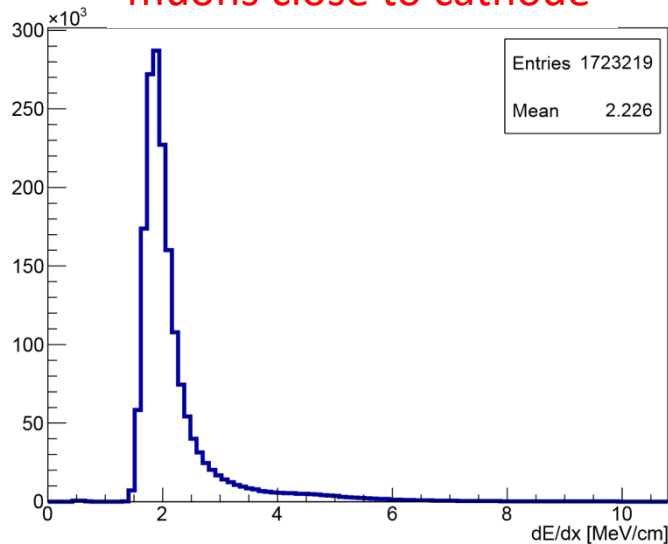Filter function

Impulse response from DP electronics
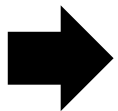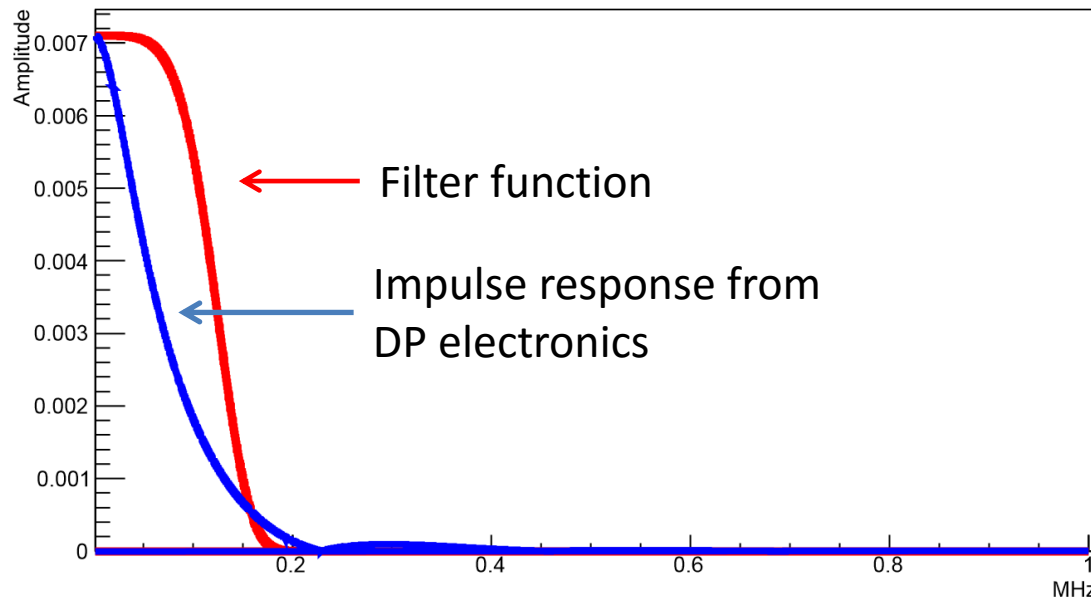
➡ …**but in dual phase we do not need to do deconvolution if fitting function includes field response and electronics signal shaping; there are no bipolar induction-like signals.**
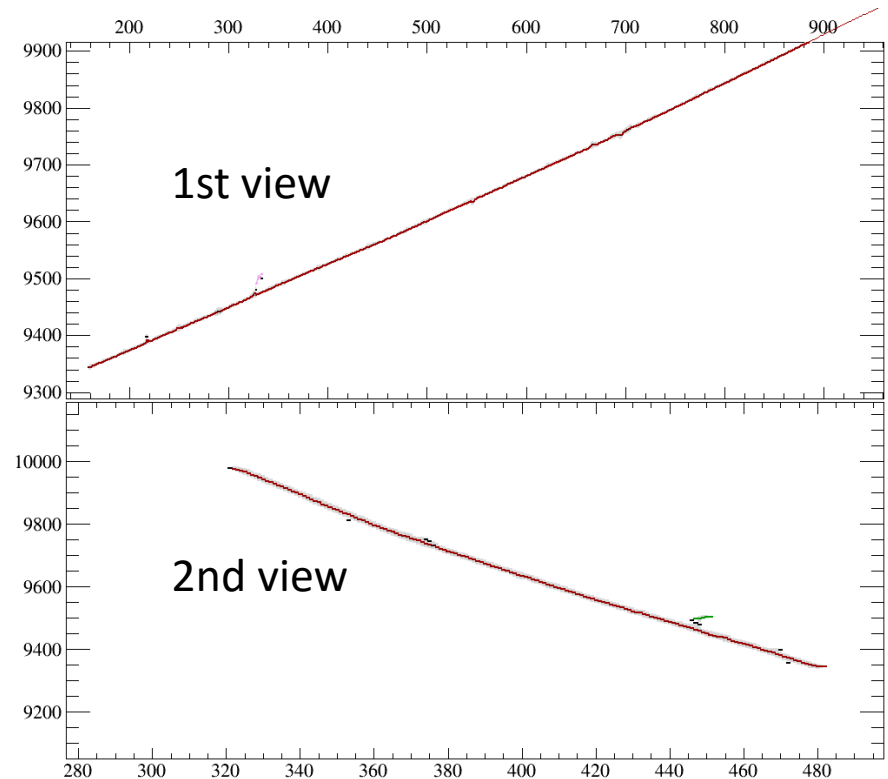
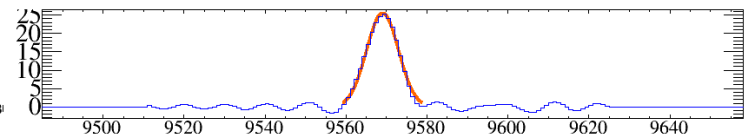# Output from reconstruction - examples

muons close to CRM

muons close to cathode

gaushit→ linecluster →
ProjectionMatchingAlgorithm

1st view

2nd view

Output from reconstruction - examples

proton @ 2 GeV/c

drift samples

channel number

drift samples

channel number

Stopping muons + decay products

Michel electron
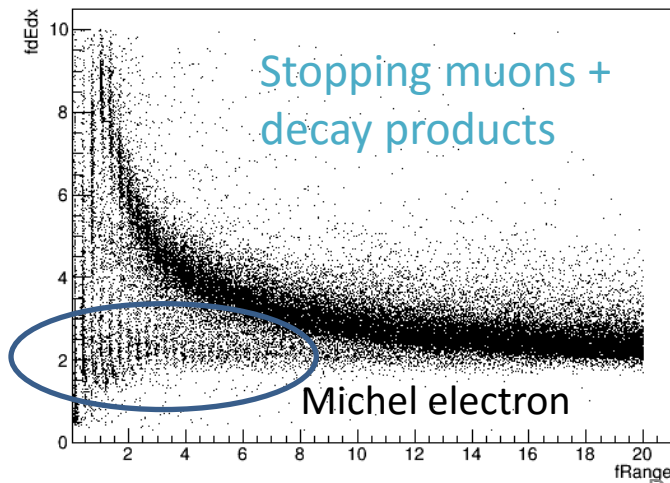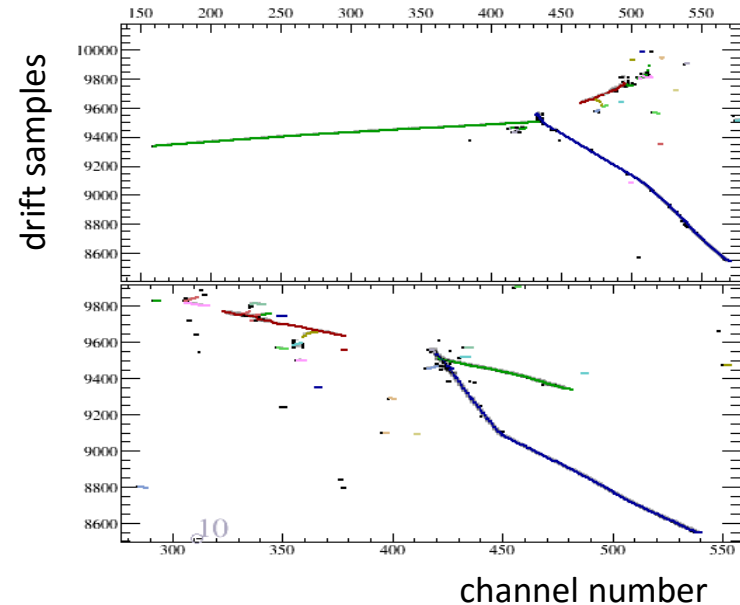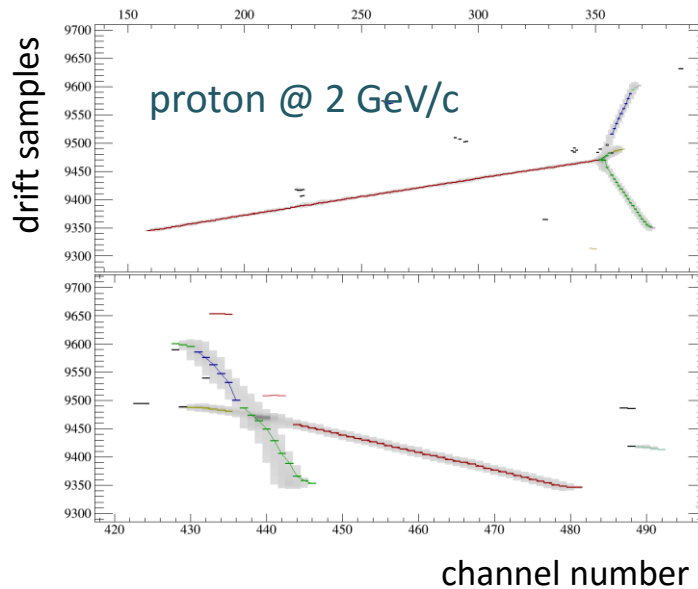
- Images above: color shows association of tracks between views:
  reconstruction of more complicated topologies seems to work correctly.

- One of the current reconstruction effort is to identify precisely the point of muon decay (important for calibration studies in protoDUNEs).

Reconstruction for far detector DUNE dual phase

- Basic checks of spatial and calorimetric reconstruction for DP FD has been performed in LArSoft.

- First MC production has been done (pion 2GeV/c and sample of neutrinos). Aaron Higuera starts making reconstruction efficiency evaluation. Those need to be understood to find where SP algorithms need to be tuned/modified.

- **Following improvemenets should be considered**:

  - Change the fitting procedure, e.g. make fitting using raw (not deconvoluted) signal.

  - Make realistic simulation of the detector response.

  - Noise should be added to the simulation.

  - Some minor tuning of higher level reconstruction algorithms may be expected to get best results on DP signals.

  - Other reconstruction chains/algorithms should be tested e.g. *pandora, CNN,* and *trajcluster.*

  - Implementation of the flat readout planes (now they are modeled as a two thin *wire planes* 0.3 mm thick, with proper E field between planes).

Summary

- Dual phase prototypes at CERN: 1 x 1 x 3 this Fall, protoDUNE in 2018.

- Far Detector implementation exists in LArSoft, first simulation, reconstruction and analysis have been started.

- Current implentation of Far Detector requires lots of improvements.

- ProtoDUNE geometry is not implemented in LArSoft. Potential work towards this direction should be discussed with Dario Autiero and Takuya Hasegawa on the Technical Board meeting of WA105 Collaboration.

- Available reconstruction for both protoDUNEs (single and dual phase) would provide valuable set of data to understand performance of both technologies.