MidTerm Revision

Imaging Cosmic And Rare Underground Signals

INTENSE Meeting

24th of June 2022

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A little bit about myself…

- I was born in Sabadell, Spain
- I studied Physics in Barcelona and then moved to Madrid to do the Master Degree
- I completed my master's thesis at CIEMAT: "*Analysis of light detection with ProtoDUNE dual-phase liquid argon experiment at CERN*"

Where am I currently?

- I joined the ICARUS Neutrino Group based in Padova on January 2021
- The first part of the PhD position, has been intended to the calibration of the ICARUS detector during its commissioning phase at FNAL

Courses

- Multimessenger Astroparticle Physics by A. De Angelis "*Neutrinos as Multimessenger particles*" March 2021
- Neutrino Physics by R. Brugnera, M. Lattanzi and S. Dusini "*Where are we with sterile neutrinos?*" June 2021
- Statistical Data Analysis by T. Dorigo, D. Bastieri and L. Stanco *"Statistical status on sterile neutrinos" July 2021*
- Standard Model & Flavour Physics by G. Simi and M. Tosi *"Test of lepton universality in beauty-quark decays" September 2021*
- *EU funding: opportunities for Research and Innovation and proposal writing by M. Schisani June 2022*

Workshops

- XIX International Workshop on Neutrino Telescopes held online during 18-26th February 2021, organized by INFN Padova
- Calibration Workshop: Ntuples Tutorial held remotely on 27th Sept–1st Oct 2021, organized by SBN Collaboration
- International Workshop on Cosmic-Ray Muography held in Ghent, Belgium during 24-26th November 2021, organized by Ghent University as part of the European Project INTENSE-Rise
- Workshop "Summer Students at Fermilab and other US Laboratories", will be held in Pisa during 18-21st July 2022, as part of the INTENSE training

Actively involved in the Analysis ICARUS working groups where I periodically report the status of my progress

Summer Schools

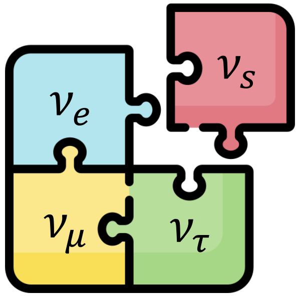
Done

- *Neutrino Summer Lecture Series held online during June/July 2021 and organized by Fermilab*
- *Fermilab 2021 Summer Student School at INFN Laboratori Nazionali di Frascati, online attendance during 2-4th August 2021*
- *FNAL C++ Software School held remotely during August/September 2021*
- *INFN School Of Underground Physics: Theory & Experiment, at LNGS, Gran Sasso during 20-24th June 2022*

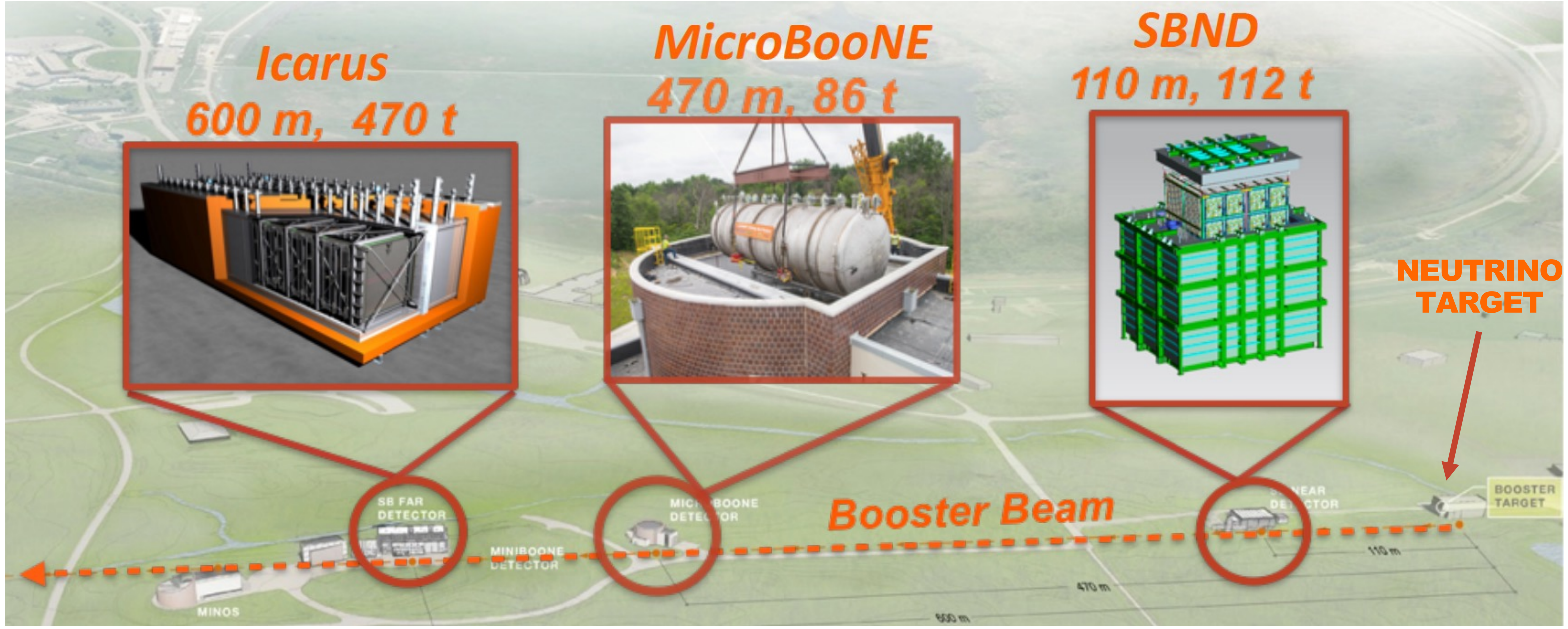
Coming soon …

- *Tri-Institute Summer School on Elementary Particles, at TRIUMF, Vancouver during 4-15th July 2022*
- *50th SLAC Summer School, at SLAC National Accelerator Laboratory, California during 8-19th August 2022*

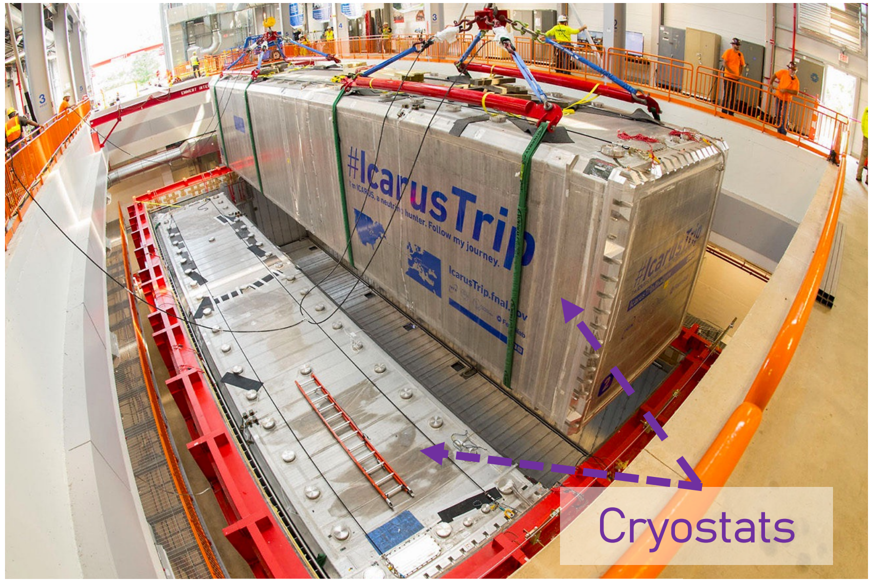
ICARUS in Short-Baseline Neutrino Program

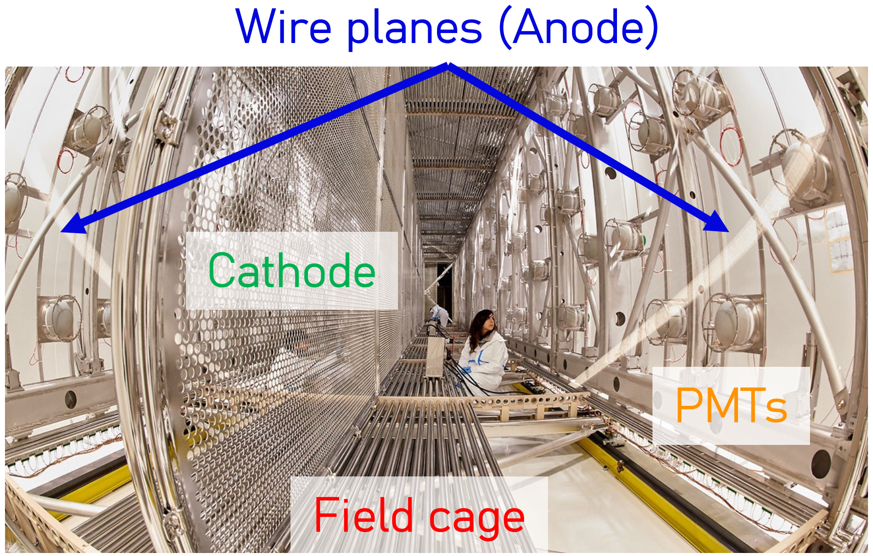


- Several anomalies have been observed in neutrino oscillations experiments
- Some of them can be explained by introducing an additional sterile neutrino state (ν_s)
- ICARUS, being the Far Detector of SBN Program, is aiming to definitely solve the "sterile neutrino puzzle" collecting high statistics of neutrino interactions from the Booster Neutrino Beam (BNB)



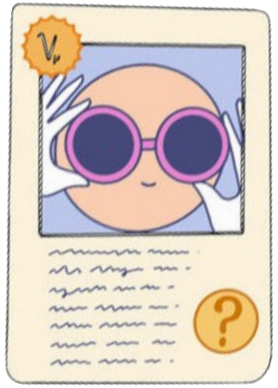
ICARUS detector





- ICARUS-T600 LAr Time Projection Chamber (TPC) is a high precision detector perfect for neutrino physics
- The detector is composed of 2 identical cryostats, each one hosting 2 TPCs, with a common central cathode (maximum drift length of 1.5 m). It is filled with 470t of Liquid Argon (LAr) and equipped with almost 54k readout wires
- The detector provides:
  1. detailed images of the interaction events inside LAr thanks to its ultra purity and 3D-geometrical mm precision over 340 m^2
  2. Precise local deposited energy measurement used for particle identification and calorimetric event reconstruction
  3. Fine measurement of the abundant scintillation light produced by charged particles in the LAr

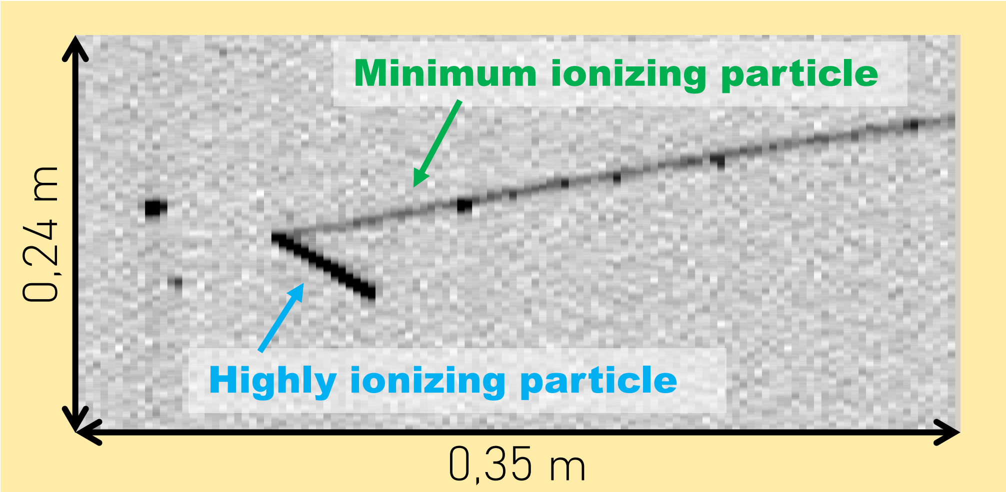
Research

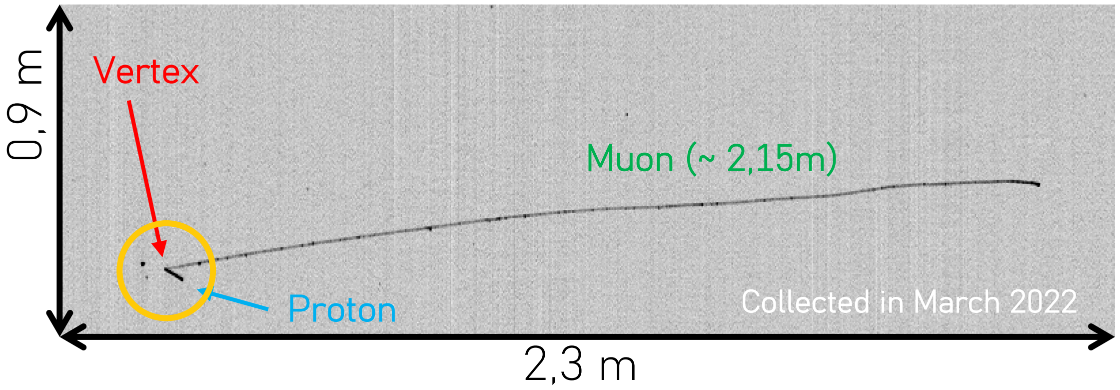


- Our initial main goal is to optimize the detector response and event reconstruction in order to perform a high-quality analysis of fully contained quasi elastic $\nu_\mu CC$ events

Visual Study of neutrino events

- It allows to select $\nu_\mu CC$ fully contained events. This sample will be used as standard candles to verify and improve the performance of our reconstruction algorithms





Towards an optimal performance …

Study on containment conditions

The study of cosmic muons crossing the detector allows to measure our precision when reconstructing the entry and exit points of the tracks. It also helps setting up confinement conditions to recognize contained events

Cathode Planarity studies

The evaluation of cathode planarity is essential to identify possible variations of the electric field, that could affect track reconstruction

Equalization of the TPC wire response

A precise measurement of deposited energy along the tracks (dE/dx) is mandatory for particle identification. This requires a global calibration to convert recorded signal into deposited energy and a final equalization of the TPC wire response

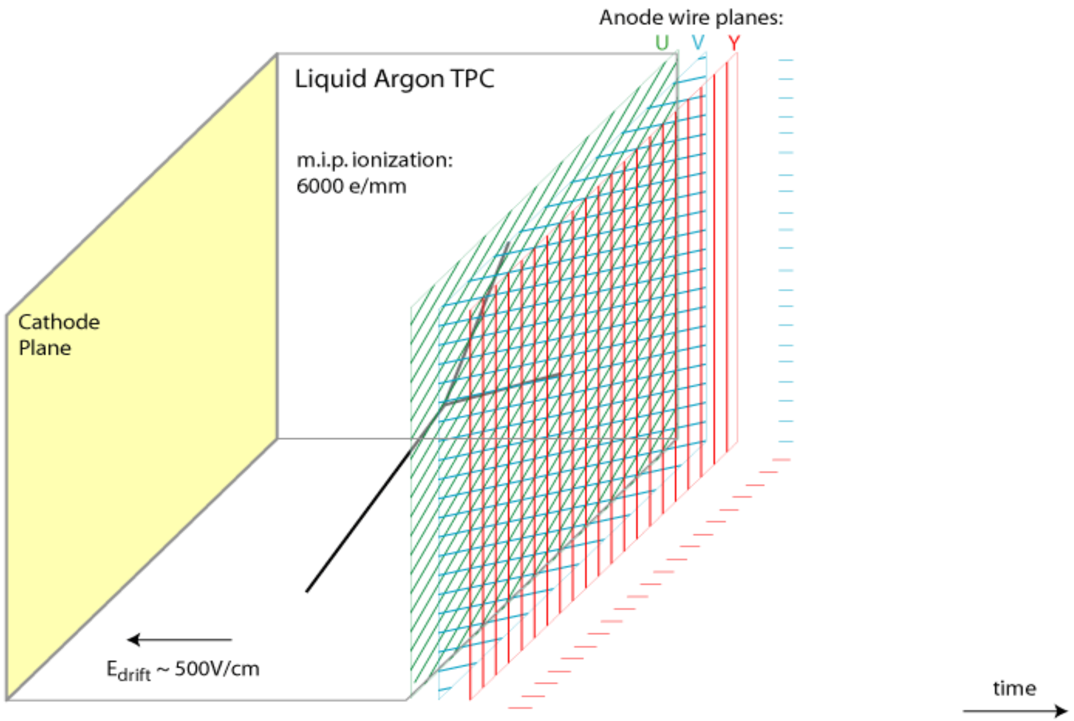
Outlook

- We would like to start tackling reconstruction problems to devise possible mitigation strategies in view of an efficient identification and analysis of the neutrino interactions

THANK YOU !

BACKUP SLIDES

LAr TPC Working Principle



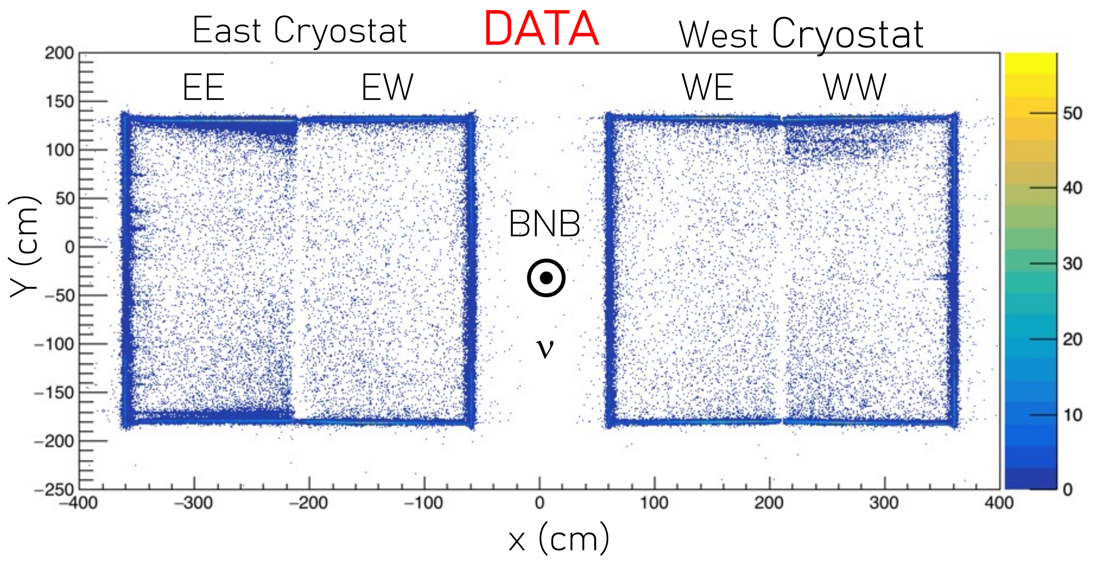
- When a neutrino interacts with liquid argon it produces charged particles that deposit their energy, creating ionization electrons and scintillation light

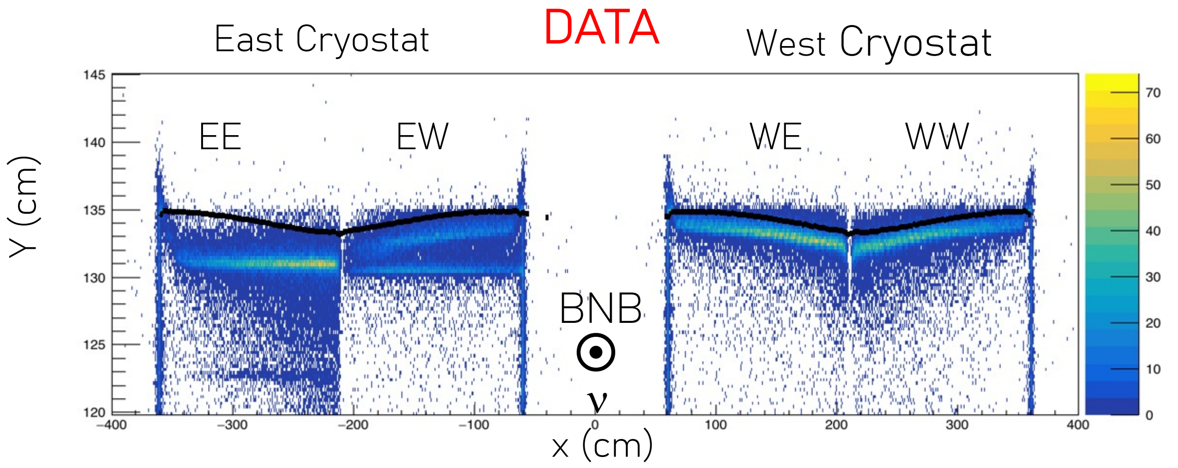
- The scintillation light propagates inside the detector until it is collected by the PMTs behind the wires. We use this light to recognize when an interaction has occurred

- The ionization electrons are collected in the wire planes, thanks to the electric field. We combine the collected signals to obtain a complete 3D reconstruction of the event

Study on containment conditions

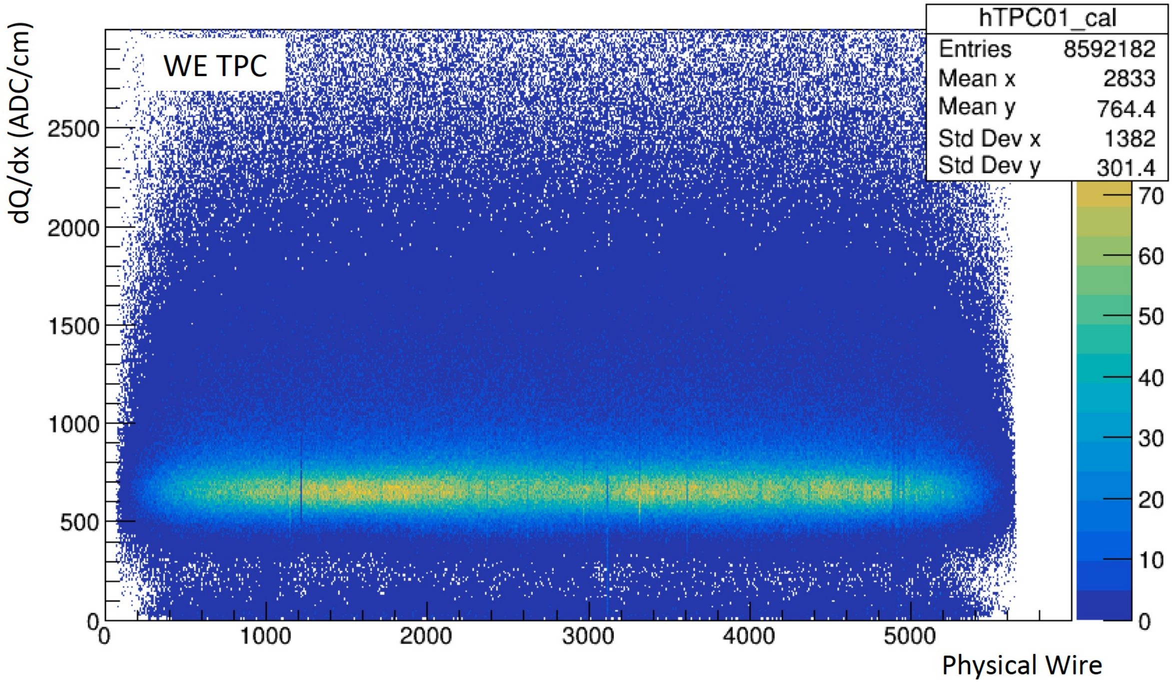
- Our main goal is to optimize the detector response in order to perform a high-quality analysis for neutrino events
- At the moment, we are interested in $\nu_\mu CC$ contained events, which guarantees us that all calorimetric variables can be fully reconstructed. Hence, we need to quantify how well we can reconstruct the entry and exit points of the events
- We studied a sample of cathode crossing cosmic muons, taking advantage of the fact that we know precisely their starting and ending positions
- Despite removing all tracks tagged as stopping particles, we found many of them starting or ending in the middle of the detector
- We realised that due to Space Charge Effects (SCE) and possible reconstruction effects we were wrongly modeling the borders of the detector
- 5-10% of the points are reconstructed more than 5cm away from the borders, depending on the TPC





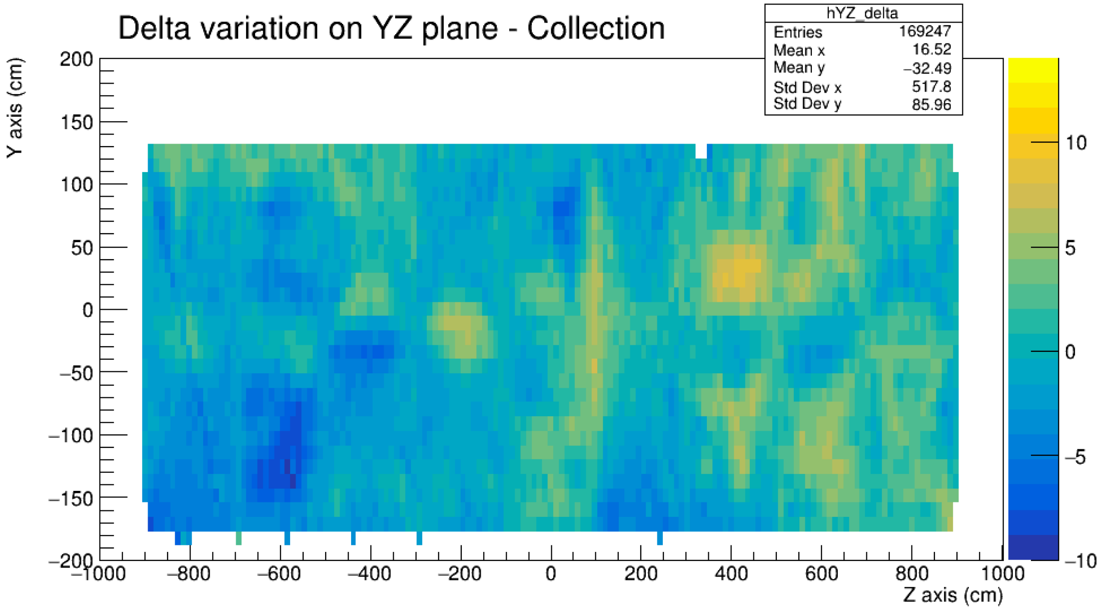
Equalization of the TPC wire response

- The aim of the TPC Calibration is to identify a global calibration constant used to convert the recorded signals into deposited energy
- The basic idea is to equalize the distribution of the deposited charge along the track (dQ/dx) for each wire to a common value
- To account for signal attenuation due to the electronegative impurities we need to correct dQ/dx as a function of the electron lifetime
- The dQ/dx distribution for each channel is fitted with a Landau convoluted with a Gaussian to extract the most probable value



- The dispersion of the MPV distribution for all the wires drastically reduces from $\sim 4\%$ before calibration to $< 1\%$ after the calibration
- We were also able to use the method to spot malfunctioning channels, that will be considered for further analysis
- There are still some discrepancies between TPCs and Data vs MC that need to be better understood

Cathode planarity studies



- In order to determine the absolute position of the track along the drift coordinate, we need to measure the absolute time t_0 at which the particle is crossing the detector
- For out of time tracks, we need to know the exact cathode crossing point since its absolute position is found by connecting the two segments of the track in both adjacent TPCs
- Local deviations from planarity in the central cathode could affect the uniformity of the electric field causing a poorly reconstructed drift time. In this study we tested the cathode planarity by exploiting cathode crossing cosmic muons
- The method relies on the difference between the maximum drift times of the tracks in the two adjacent chambers to estimate the cathode distortion at the crossing point between the TPC
- We observed variations corresponding to an absolute cathode displacement of almost $2\ cm$
- We found some geometrical considerations of the detector which are not yet implemented in the MC. Such as the finite dimension of the cathode or the splitting of the wires of the first Induction plane, which are causing some distortions during the track reconstruction, specially merging of cathode crossing tracks

Visual Study of neutrino events

- We are currently selecting fully contained $\nu_\mu CC$ events to study their properties and tune our algorithms
- The previous studies are fundamental elements to obtain an efficient and detailed reconstruction of ν events
- Events are visually studied, identifying the neutrino vertex and the end of the muon
- The distribution of neutrino interactions is homogeneous in the YZ plane, and we mainly see muons ~ 2 m long