Collaboration Meeting
March 12-14, 2024

The T2K TPC upgrade

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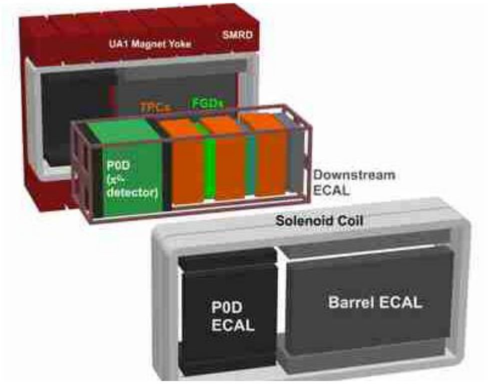
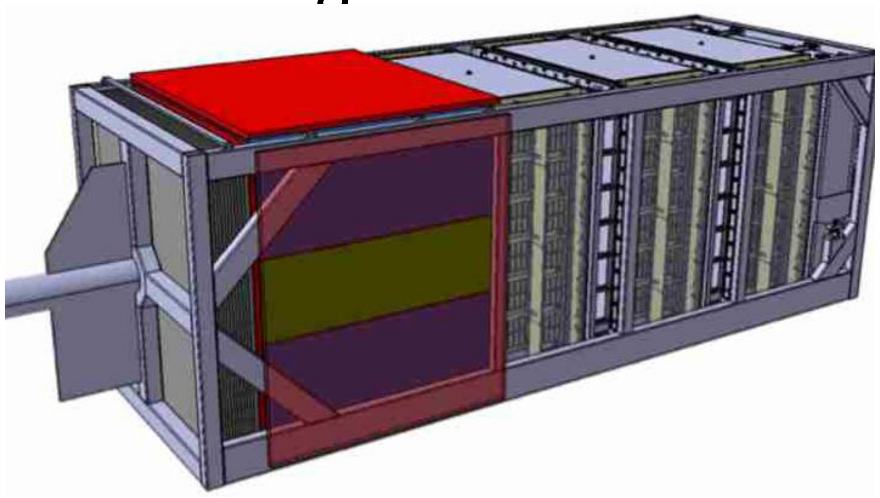
Thanks to Thorsten Lux and David Henaff to whom I stole slides

And also Tristan Daret, Shivam Joshi, Samira Hassani, Jean-François Laporte…

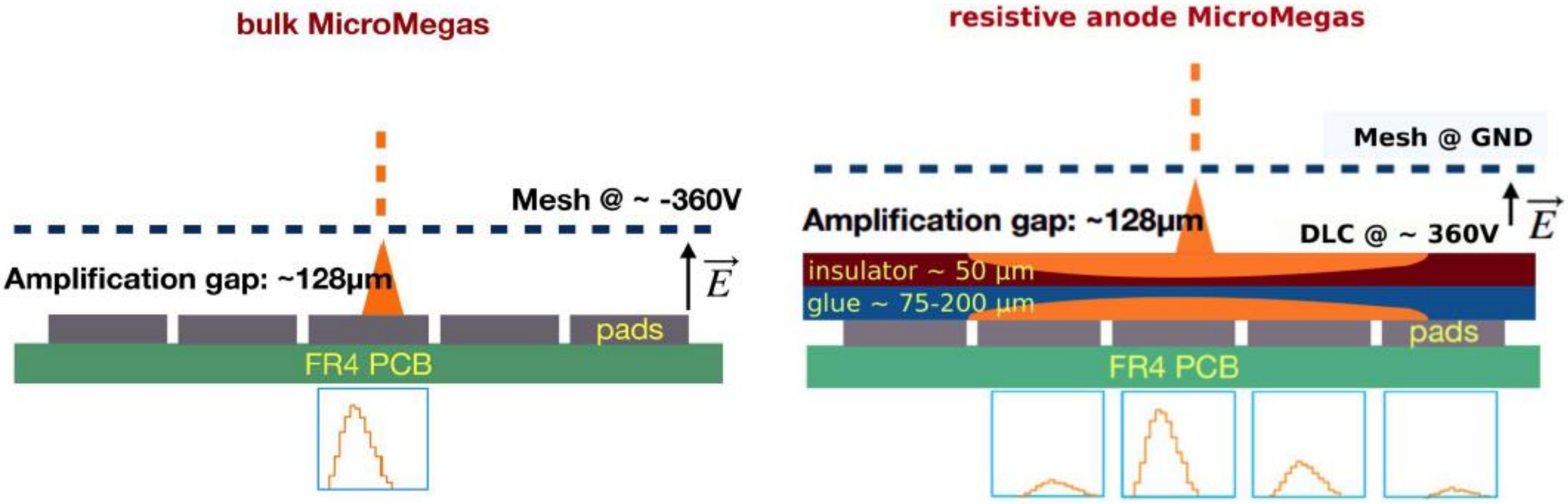
Introduction

- T2K (Tokai to Kamioka) is a long baseline νe-$\nu\mu$ oscillation experiment in Japan. ND280 is the near detector at 280m from the target, used to monitor the beam composition and intensity.
- The tracking is carried out by large TPCs (Proposal by Dean Karlen and Marco Zito).
- Upgrade in progress by adding 2 more 'High Angle TPCs' to the 3 vertical ones on each side of an instrumented target





- These TPCs were very much inspired by LCTPC R&D, both for the field cage and for the Micromegas TPCs. Standard readout for the first 3, and resistive readout for charge sharing for the last 2.



- The requirement differs from ILC's : more relaxed space resolution (several 100 microns), and dE/dx e-µ separation rather than K-π

A lot was learnt in the last decade

Beam test at DESY in 2015 (LCTPC, 2 DLC modules)

Cosmic-ray test at Saclay in 2017 (T2K)

Beam test at CERN in August 2018 (T2K)

Beam test at DESY in November 2018 (LCTPC)

Cosmic-ray test in Saclay since January 2019 (LCTPC/FCC)

Beam test at DESY in June 2019 (T2K)

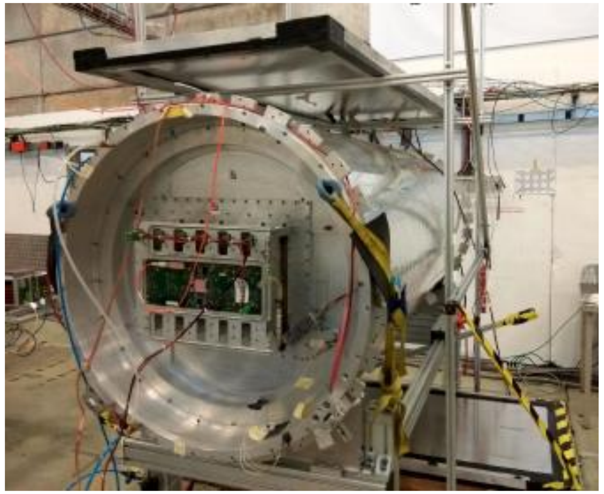
Cosmic test at CERN since December 2019 (T2K)

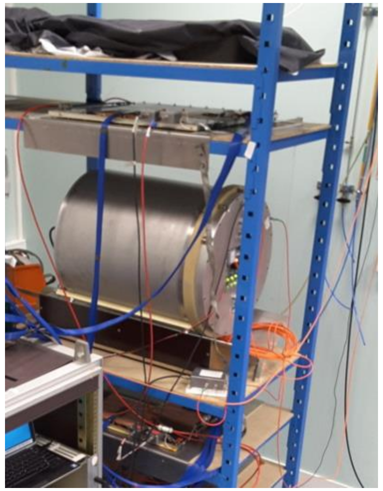
Cosmic tests in Saclay in 2020 (T2K)

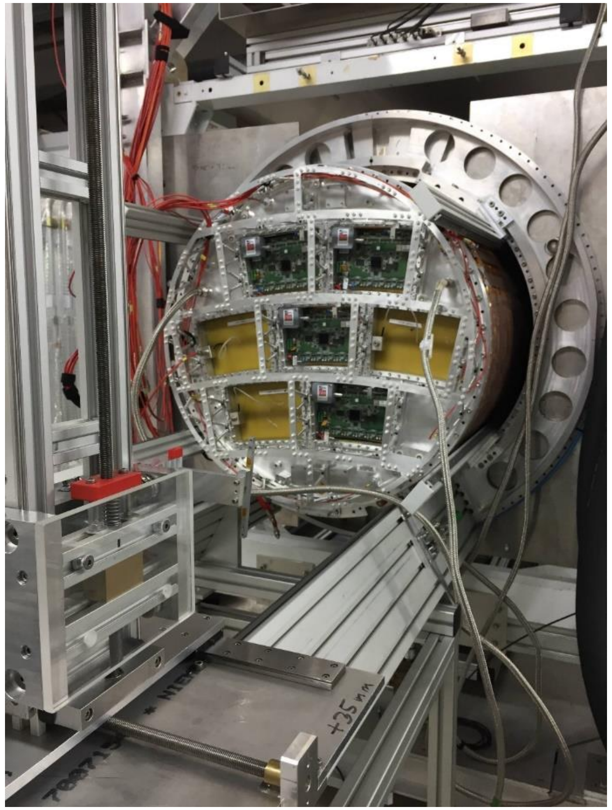
Beam test a DESY in June 2021

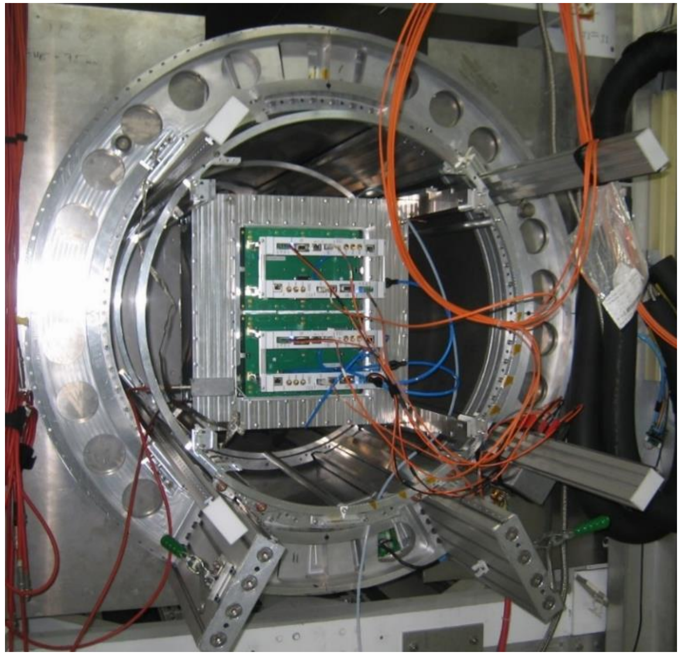
Cosmic test at CERN in 2022

Systematic characterization of ~40 T2K modules, X-ray test bench, CERN 2022-2024

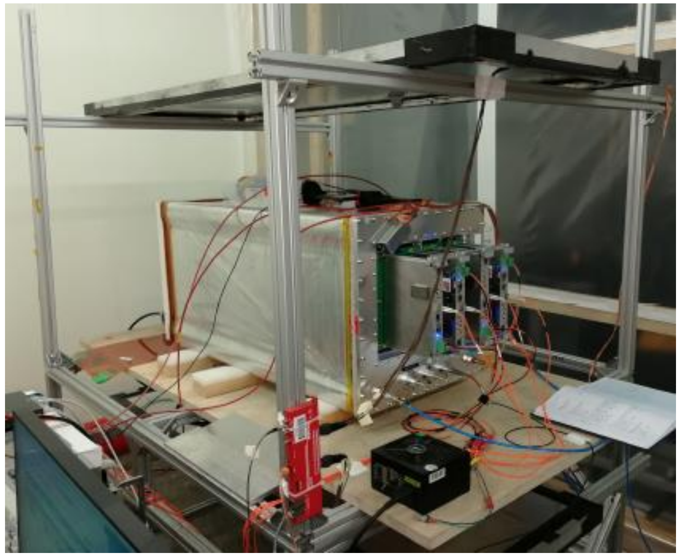








5 TPC of 15, 58, 60, 100 and 150 cm length with 1000 to 2000 channels
All with DLC charge spreading

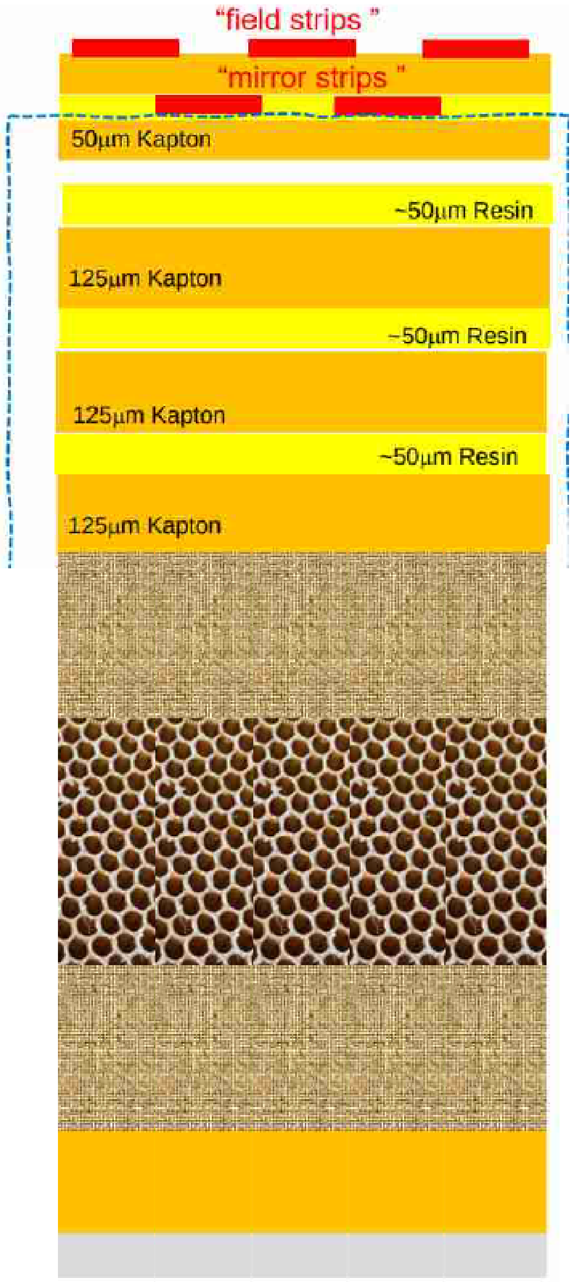


Overal conclusion : extremely reliable and stable operation

Design of the Field Cage

Largely based on the LC-TPC design

Material	Thickness
Strips on Kapton foil	Cu 17um / Kapton 50um / Cu 17um
Coverlay	Glue 150um / Kapton 425um
Aramid Fiber Fabric (Twaron)	2mm
Aramide HoneyComb	35mm
Aramid Fiber Fabric (Twaron)	2mm
Kapton foil	125um
Aluminium foil	50um



Note that the first half cage realized exhibited current leakage, preventing a normal operation. This problem arised from an antistatic spray. Extra insulation was added.

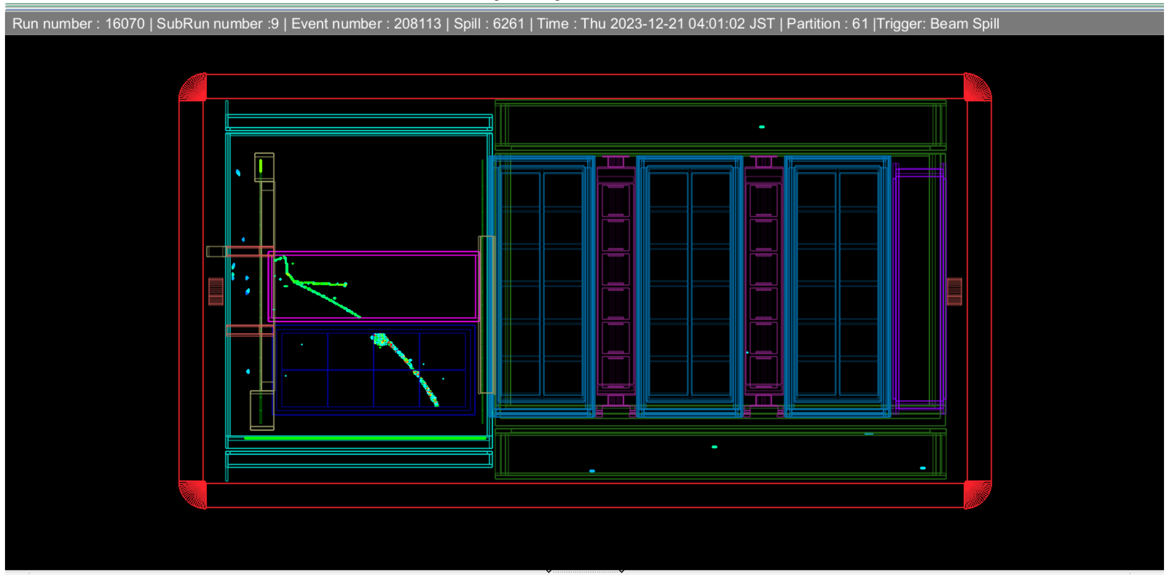
HA-TPC Installation

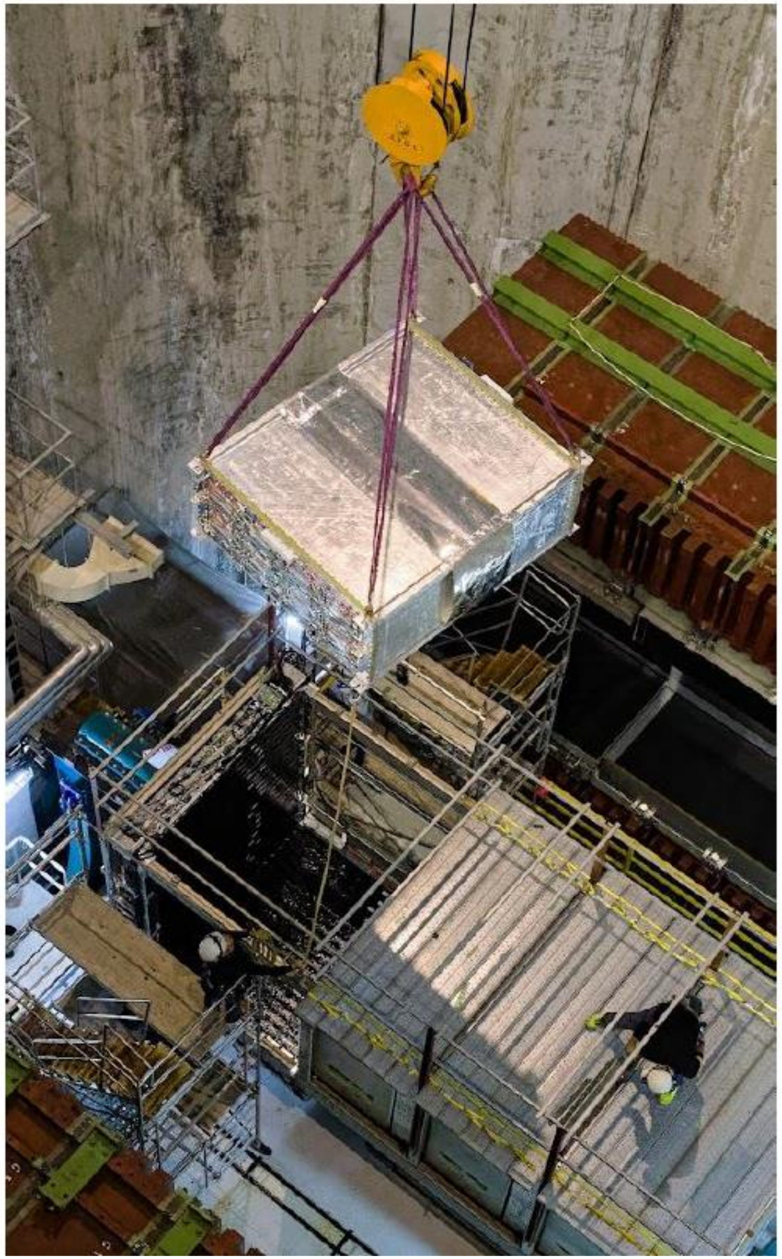
Bottom TPC delivered at JPARC on August 25. It was shipped by plane. Re-tested in surface building. Installed in the UA1 magnet on September 7th.

Commissioned September-October 2023. Cosmics and debugging.

Data taking February 5 to March 6. Stable operation.

One of the first event displays :



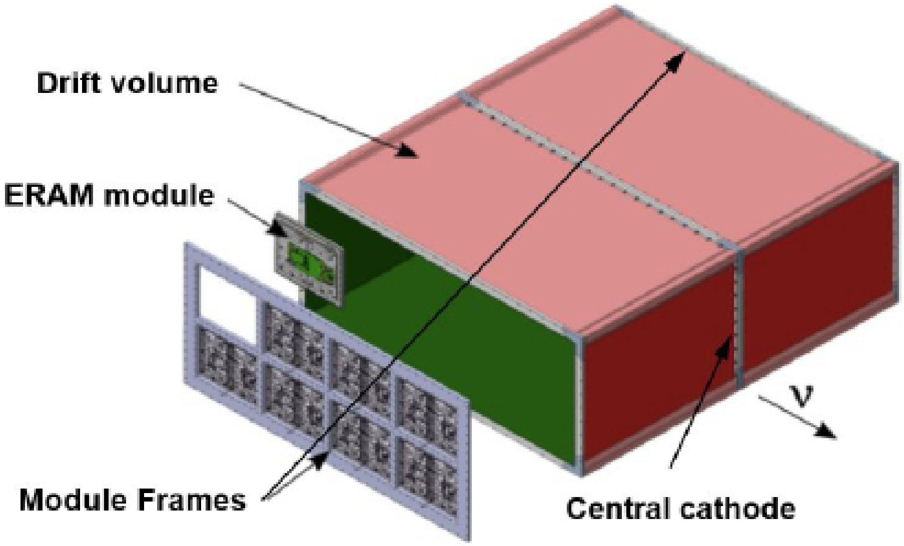


Charge Sharing

See talk by Shivam Joshi at Collaboration meeting 2023

Particle Identification by dE/dx

Slides by Tristan Daret



Particle identification

In a TPC, the particle identification (PID) is obtained via the energy loss dE/dx, which is characteristic of each kind of particle

Our resistive MicroMegas (ERAM) modules are divided into pads and each of them records a local estimation of dE/dx

Energy loss

dE/dx is the energy lost (dE) by a particle per unit length (dx), by ionization and excitation, and depends on the material crossed

Since dE/dx depends on the momentum via βγ=p/m, the PID depends on the momentum measurement as well

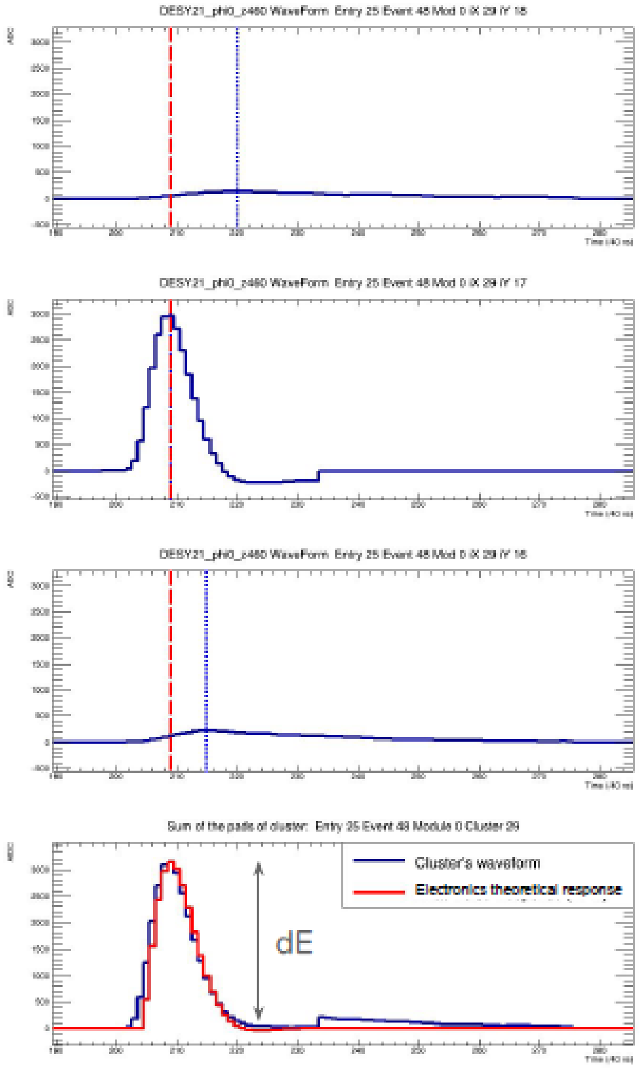
$$\left\langle -\frac{dE}{dx} \right\rangle = Kz^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 W_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2} \right]$$

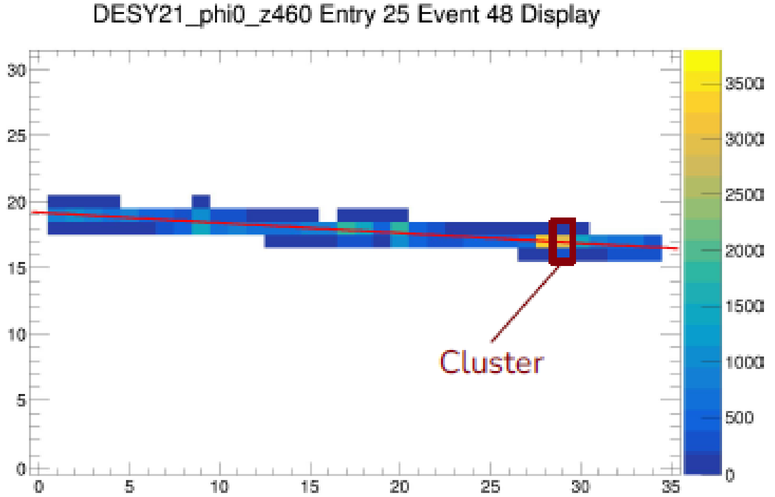
$$W_{\max} = \frac{2m_e c^2 \beta^2 \gamma^2}{1 + 2\gamma m_e/M + (m_e/M)^2}$$

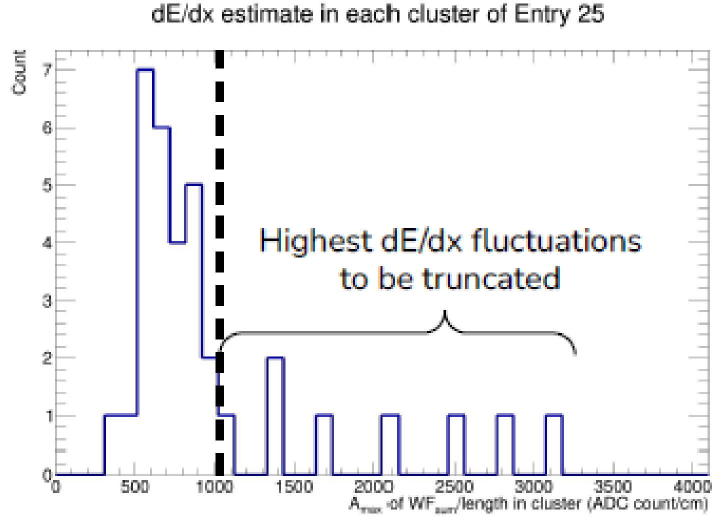
Relativistic Bethe-Bloch equation of dE/dx

Must adapt to the case with charge sharing of resistive Micromegas (ERAM)

1^{st} method: "sum of waveforms" in a cluster WF_{sum}







1. Clusterize the pads into slices and sum the waveforms in each slice to get dE

2. Get the track length in each cluster to get dx

3. Truncate the clusters with the highest dE/dx (top 30%) to get rid of fluctuations

just like for vertical TPCs!

4. Get the mean over remaining estimates dE/dx

2^{nd} method: model-assisted “Crossed Pads” (XP)

Complete modelization of the detector’s response, depending on:

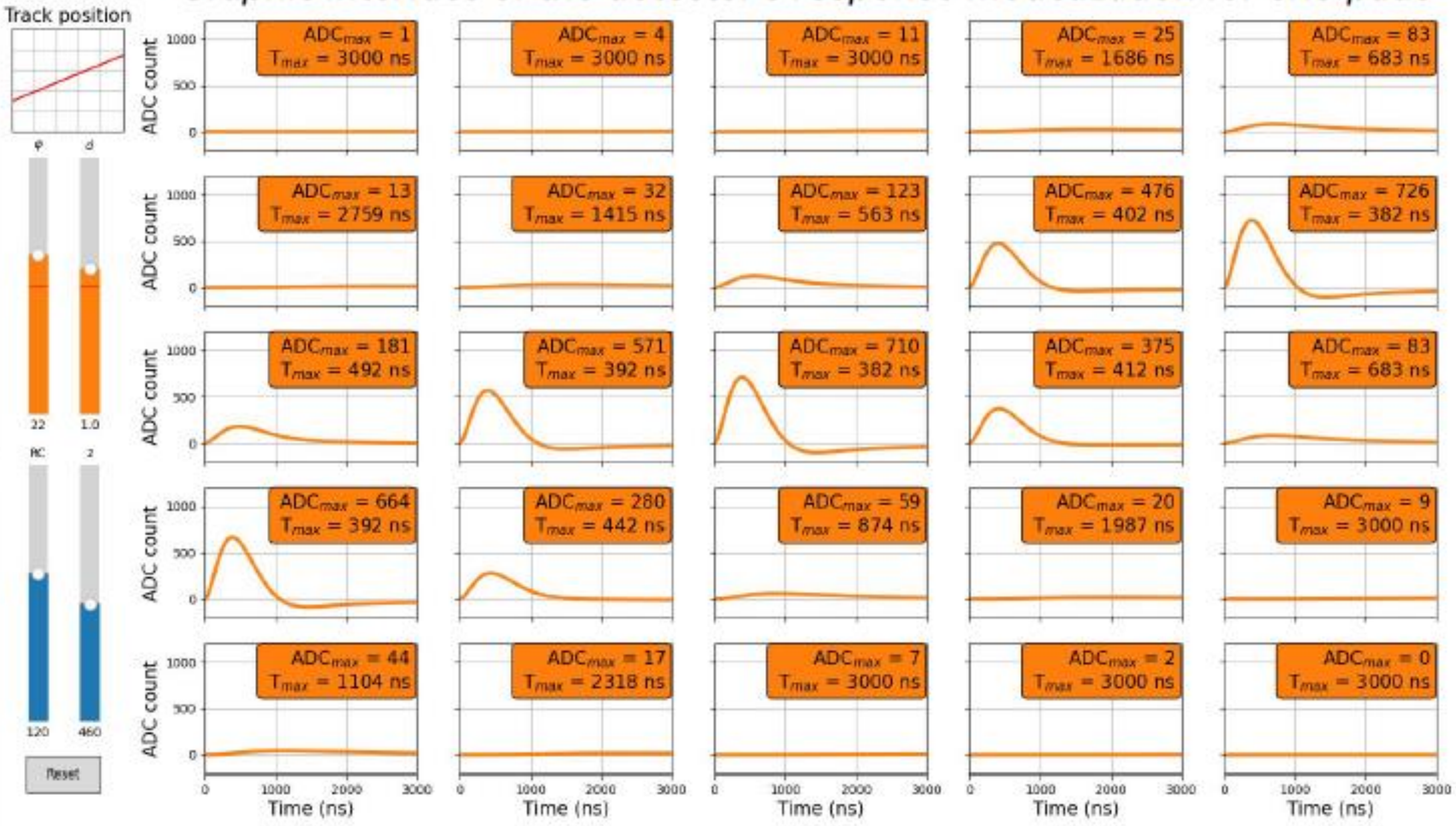
1. Track angle φ
2. Distance of the track to the pad center (i.e. impact parameter) d
3. Drift distance
4. Diffusion coefficient of the pad 1/RC

For crossed pads, the real charge deposited Q_{anode} is reconstructed using the track length, A_{max} and the data needed by the model

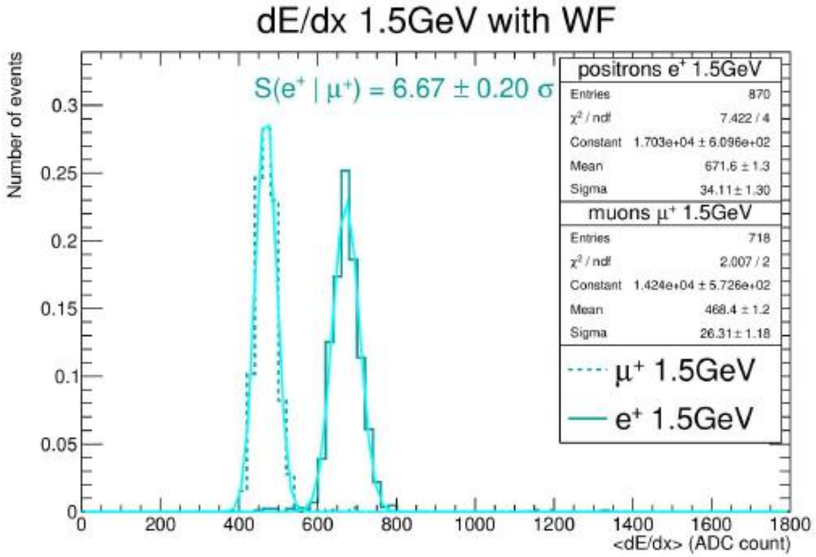
The usual truncation is applied afterwards

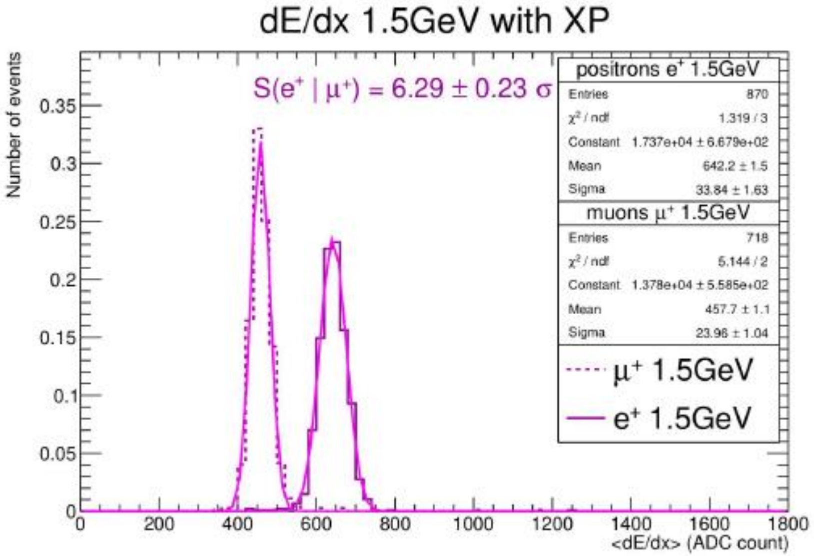
➢ No need for clusters anymore

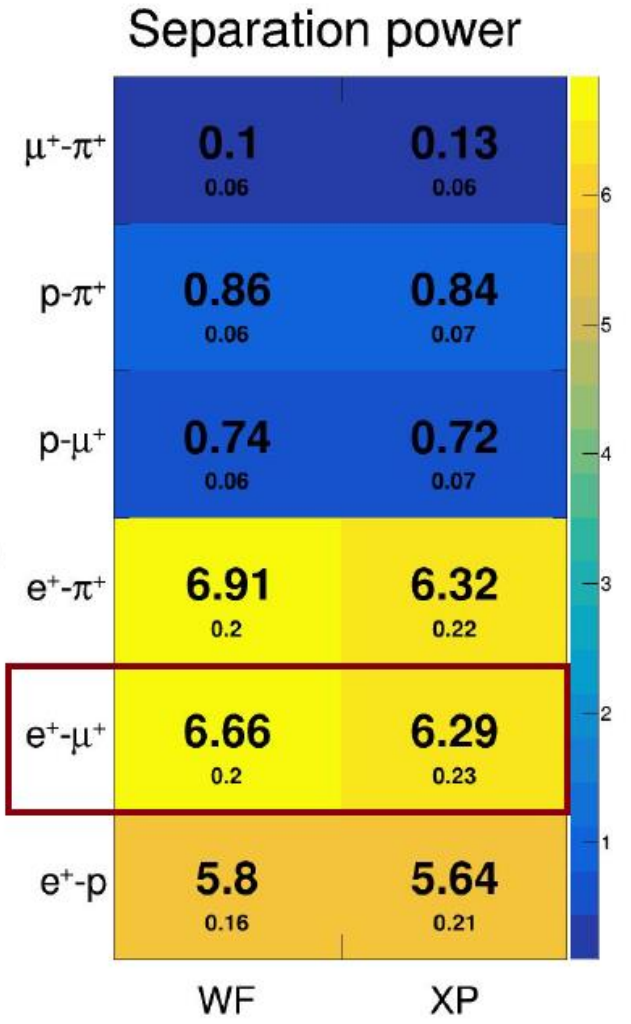
Graphic interface of the detector’s response modelization for 5x5 pads



Separation power with 4 detectors (1.5 GeV @ CERN)







- μ^+ & e^+ split by more than 6σ
- Tracks will not fully cross 4 detectors so the effective separation power will be lower

$$S(e^+,\mu^+) = \frac{|\mu_{e^+} - \mu_{\mu^+}|}{\sqrt{\left(\sigma_{e^+}^2 + \sigma_{\mu^+}^2\right)/2}}$$