

# High Angle TPCs for T2K ND280 Upgrade

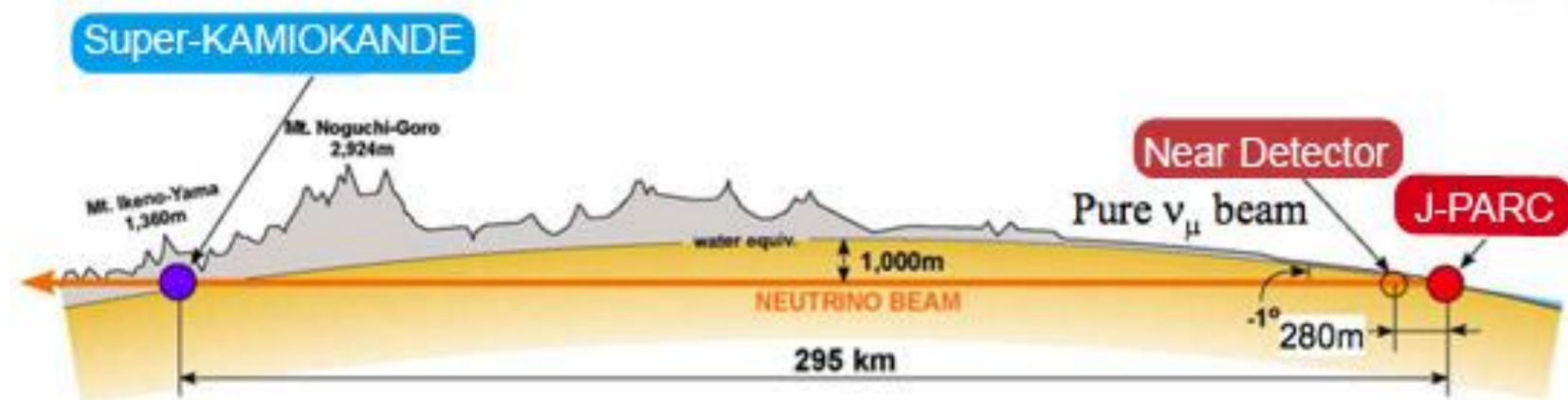
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## INTRODUCTION

The T2K (Tokai to Kamioka) experiment is a long-baseline neutrino experiment in Japan, to study the phenomenon neutrino oscillation. A beam of muon neutrinos (or anti-neutrinos) is produced at Japan Proton Accelerator Research Complex in Japan.

- The near detector complex at J-PARC including ND280 detector, characterizes the neutrino beam before oscillation and provide a baseline measurement.
- This beam is directed over a baseline of 295 km to the water cherenkov detector Super-Kamiokande.



### GOALS

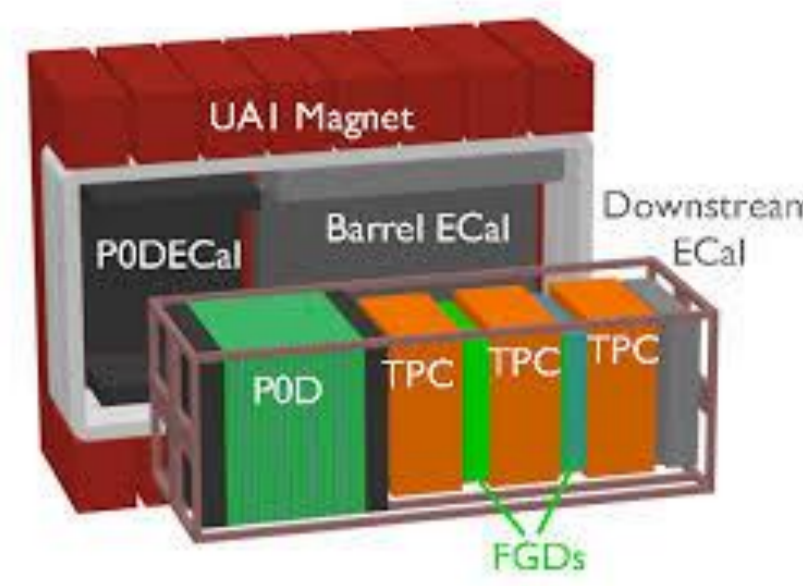
1. Observation of  $\bar{\nu}_e$  or  $\nu_e$  appearance to determine  $\sin^2\theta_{13}$  and  $\delta_{CP}$
2. Precise measurement of  $\sin^2\theta_{23}$  and  $\Delta m_{32}^2$  through  $\nu_\mu$  or  $\bar{\nu}_\mu$  disappearance

## ND280

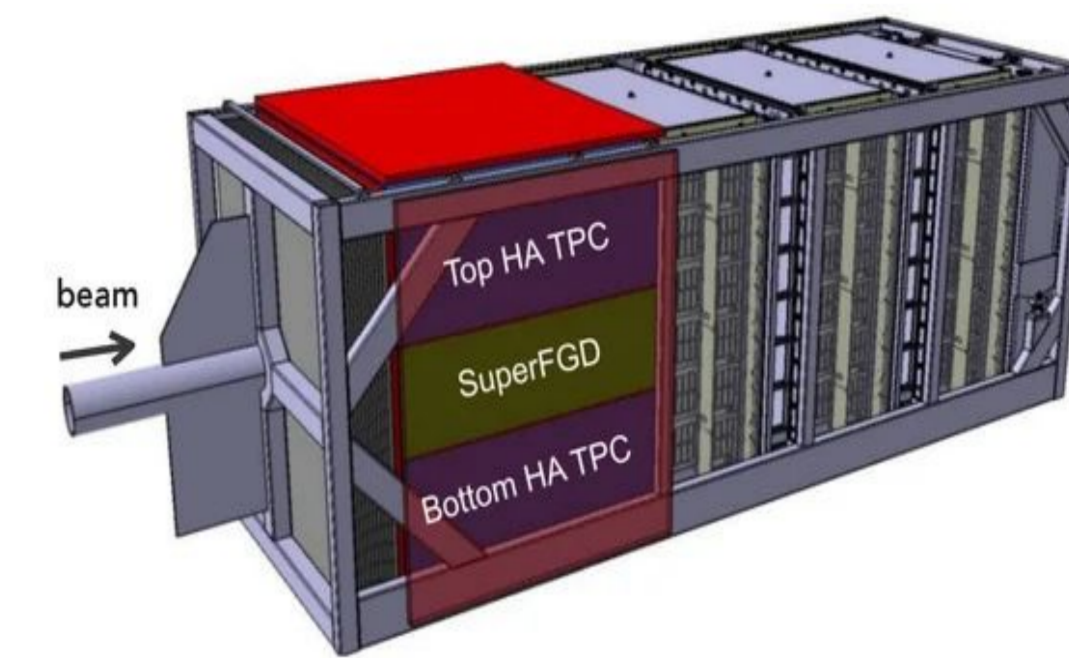
The ND280 detector[1] is located 2.5° away from the beam axis (at same angle as far detector), which reduce the systematic uncertainties providing finer constraints on CP-violating parameter.

- Positioned inside a **0.2 T magnet**. It comprised a  $\pi^0$  detector, 3 Time Projection Chambers (TPC) and two Fine Grained Detectors (FGD).
- Measure neutrino flux and cross-section interactions with the nucleus to accurately predict the expected flux at Super-Kamiokande for oscillation analysis.
- ND280 is upgraded with 2 **High-Angle TPCs**, a Super-Fine Grained Detector (SFGD) & 6 Time of Flight (ToF) planes.
- The upgrade increased the target mass within ND280 basket and it also ensure **4π acceptance** of charged particles.

### ND280



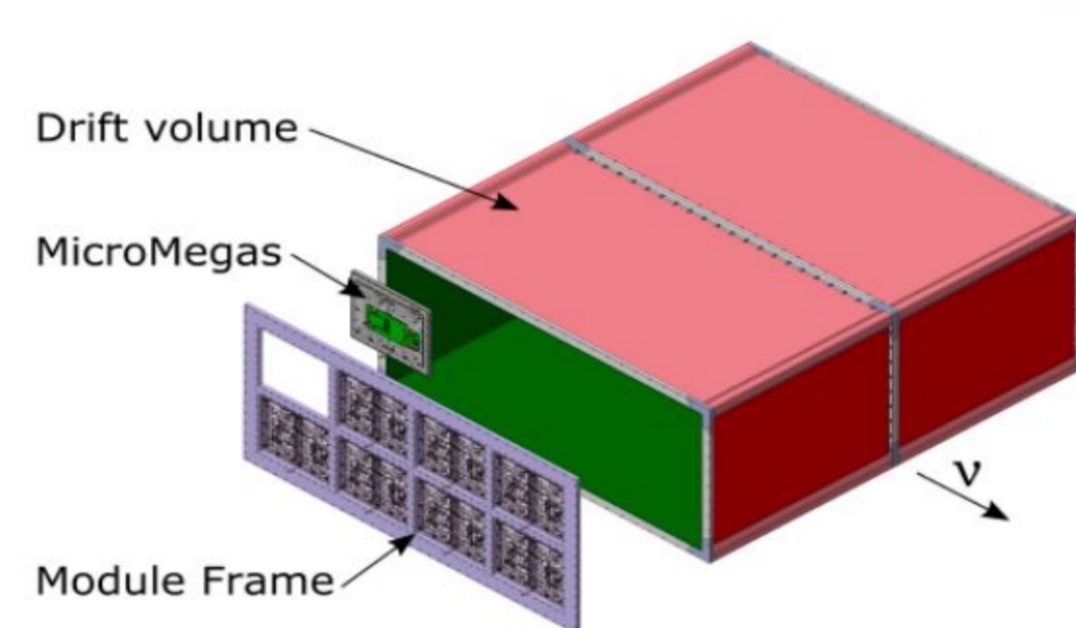
### ND280 Upgrade



## HIGH-ANGLE TIME PROJECTION CHAMBER

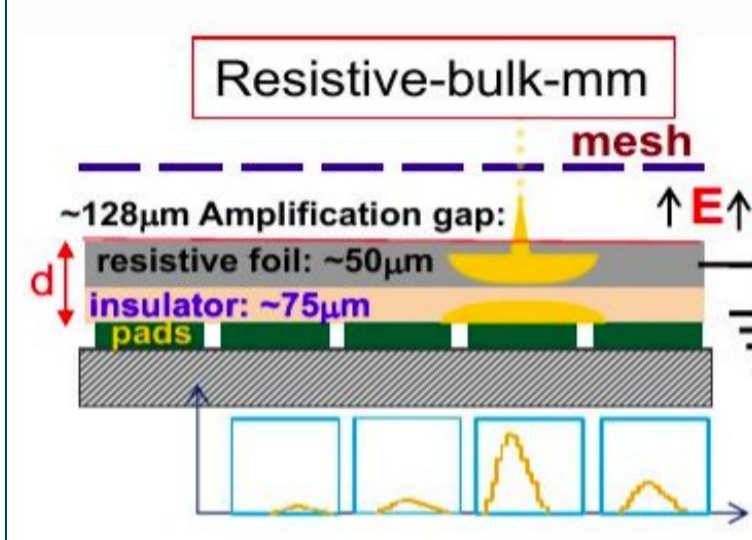
Two HA-TPCs measure the charged particles exiting the new active target SFGD. TPCs provide crucial information for event reconstruction & analysis;

1. Track reconstruction in 3D
2. Charge and Momentum measurement
3. Particle Identification by combining dE/dx with momentum measurement



Parameter	Value
Overall x × y × z (m)	2.0 × 0.8 × 1.8
Drift distance (cm)	90
Magnetic Field (T)	0.2
Electric field (V/cm)	275
Gas Ar-CF <sub>4</sub> -iC <sub>4</sub> H <sub>10</sub> (%)	95 - 3 - 2
Drift Velocity cm/μs	7.8
Transverse diffusion (μm/√cm)	265
Micromegas gain	1000
Micromegas dim. x-y (mm)	340 × 410
Pad z × y (mm)	10 × 11
N pads	36864
el. noise (ENC)	800
S/N	100
Sampling frequency (MHz)	25
N time samples	511

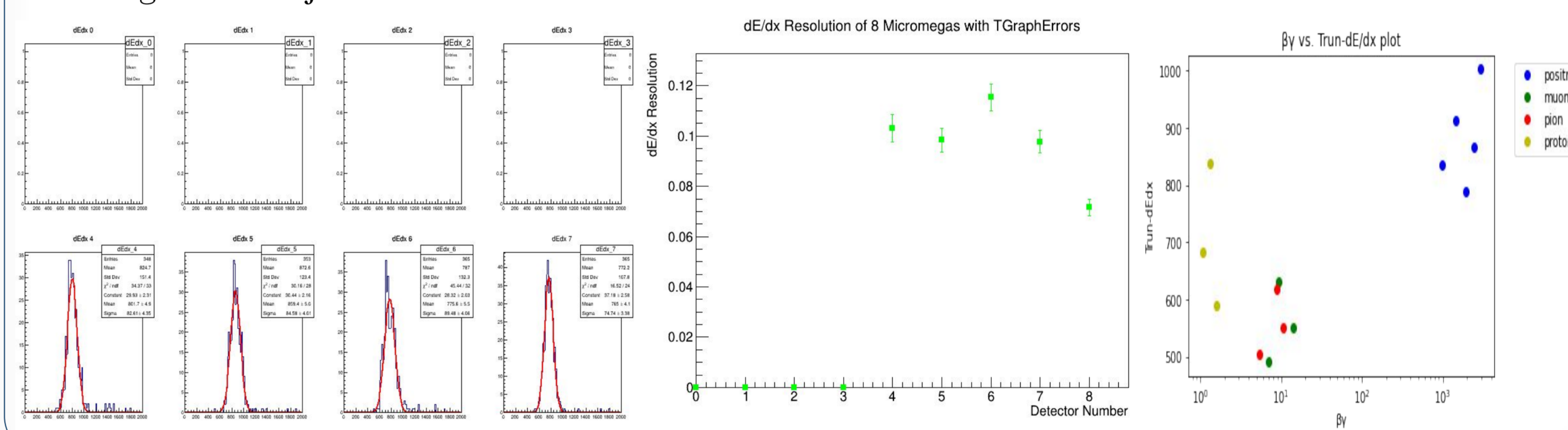
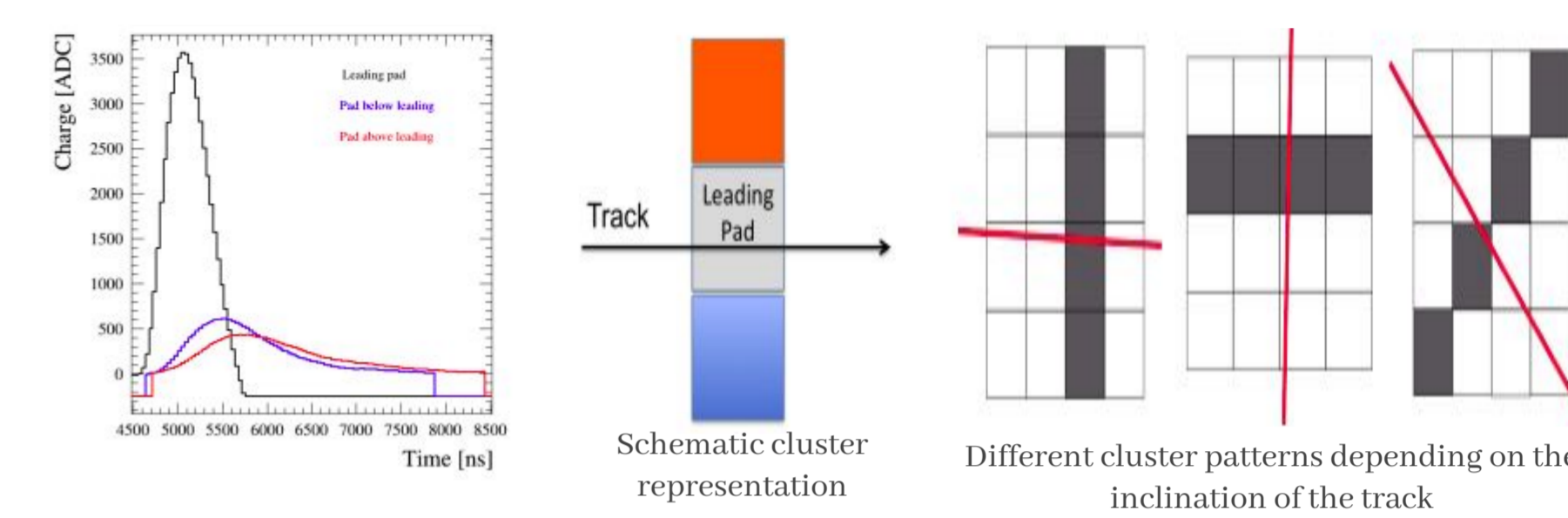
- Field cage with 2 drift volumes with a common central cathode and closed by anode with 8 readout modules
- Encapsulated Resistive Anode Micromegas(ERAM)[2] with new resistive bulk technique is used in readouts



## ENERGY RESOLUTION

Preliminary studies of dE/dx performed with the collected data from CERN Test Beam of HA-TPC in September 2022. The dE/dx study was done with the truncated mean method.

- Pads in each column were grouped together into clusters
- Charge in the clusters is sorted in increasing order
- The 30% clusters with the highest charge were rejected

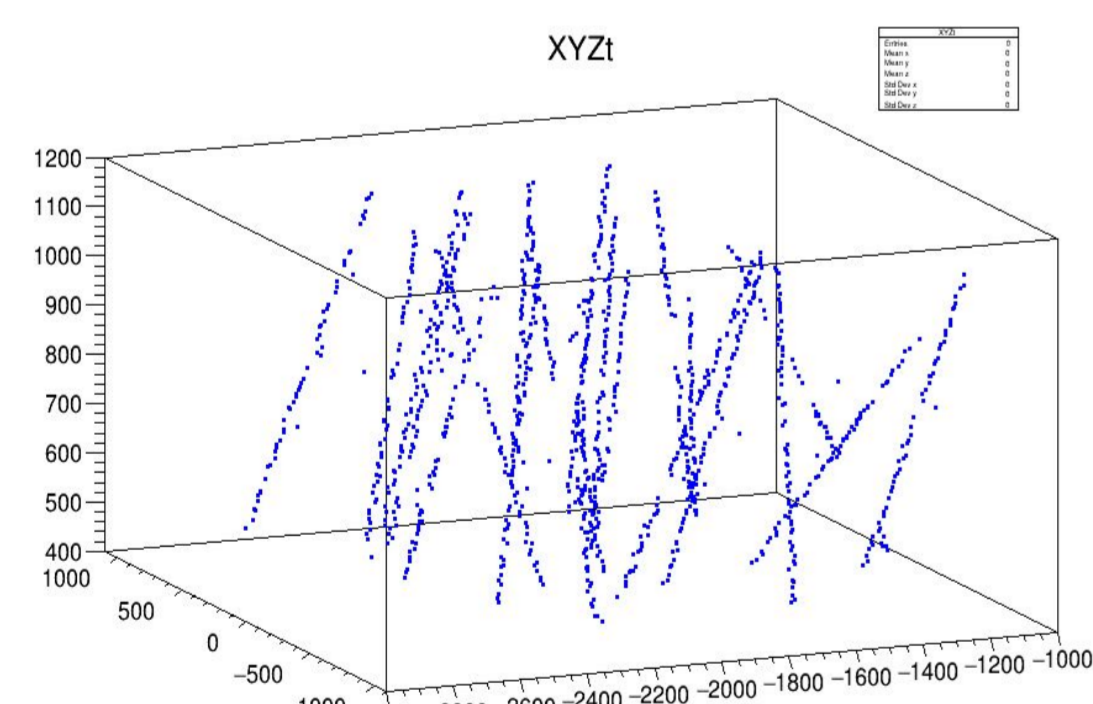
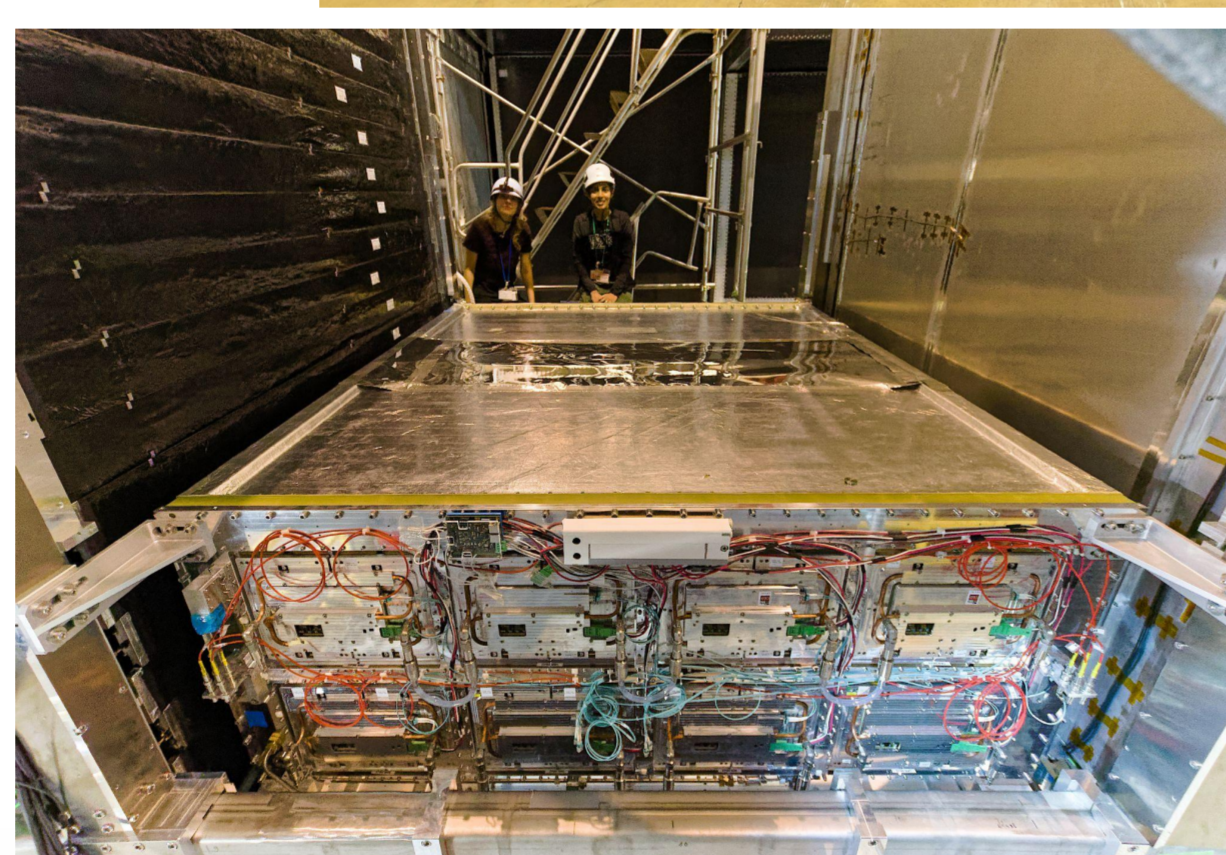


## INSTALLATION & COMMISSIONING OF HA-TPC

After a series of quality control tests in J-PARC, one of the HA-TPC was installed in the ND280 basket on 08 September 2023.

### Commissioning with ToF

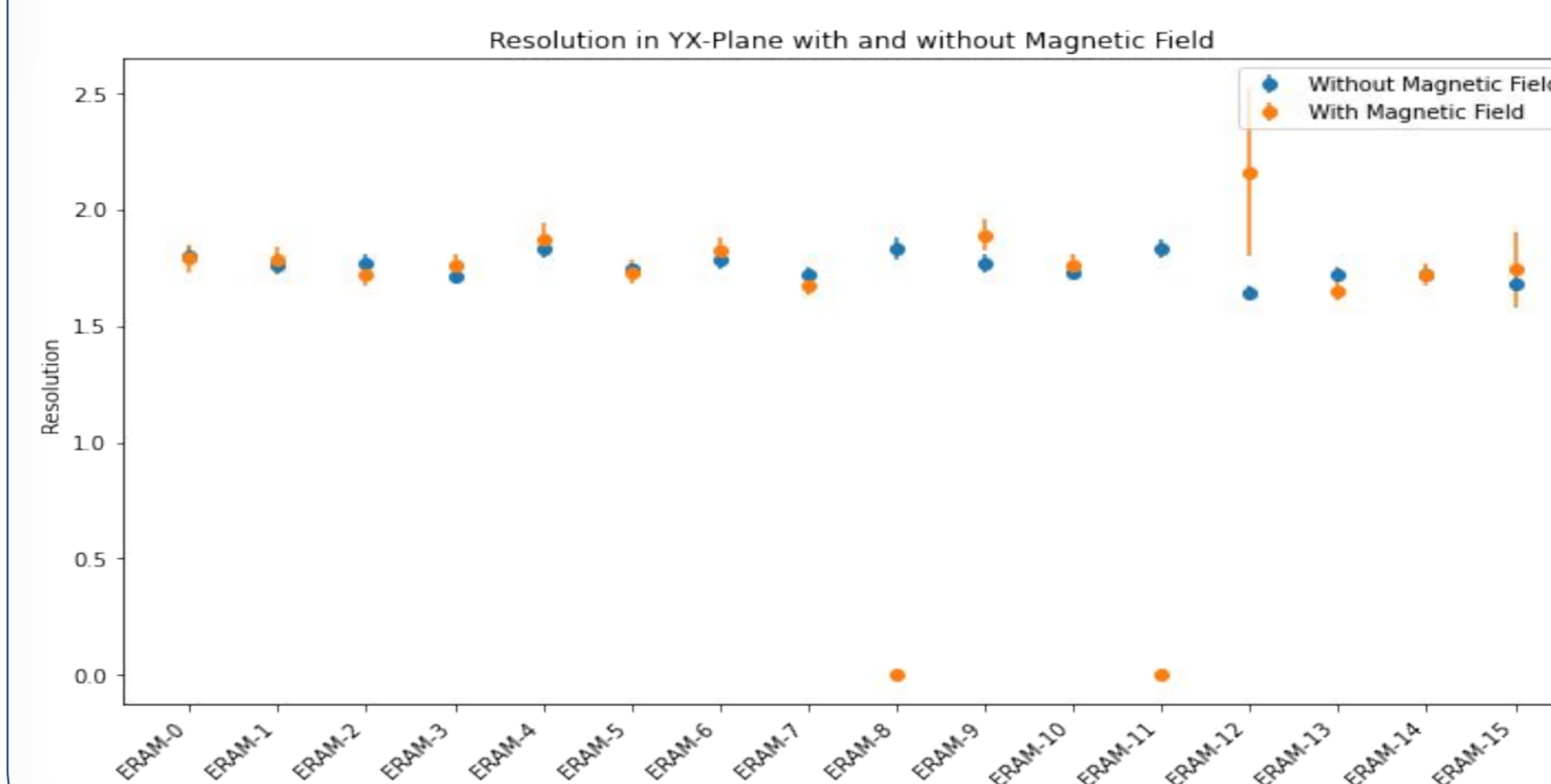
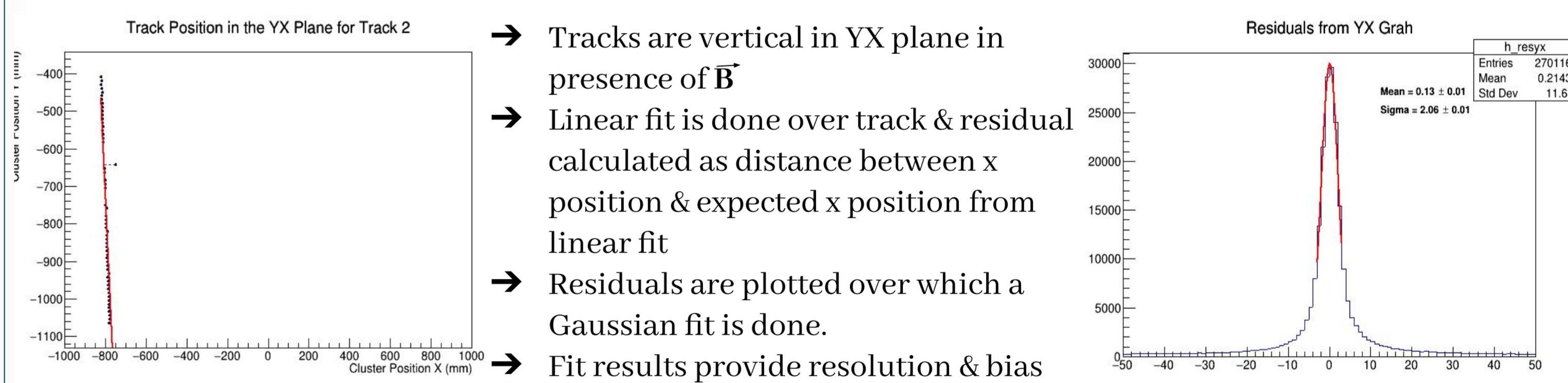
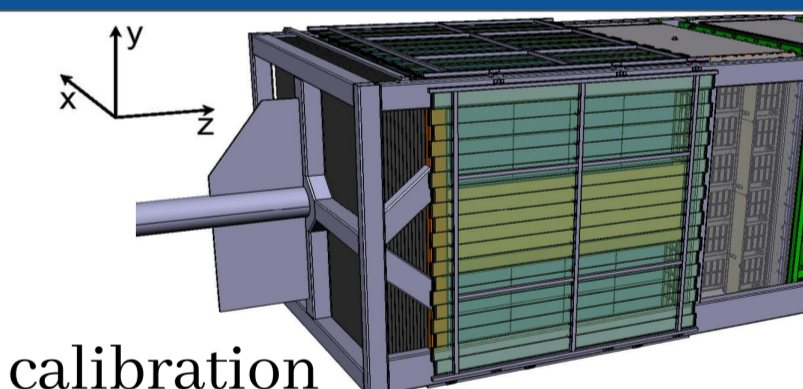
- Presence of 4 ToF panels (top, bottom, up & down)
- Coincidence between 2 planes of ToF
- Stable data taking for a few hours



## SPATIAL RESOLUTION ALONG X-DIRECTION

For TPC the x-direction refers to direction along which the  $\vec{E}$  is applied, causing ionised electrons to drift from central cathode to the anode. Spatial resolution in this direction is critical for several reasons;

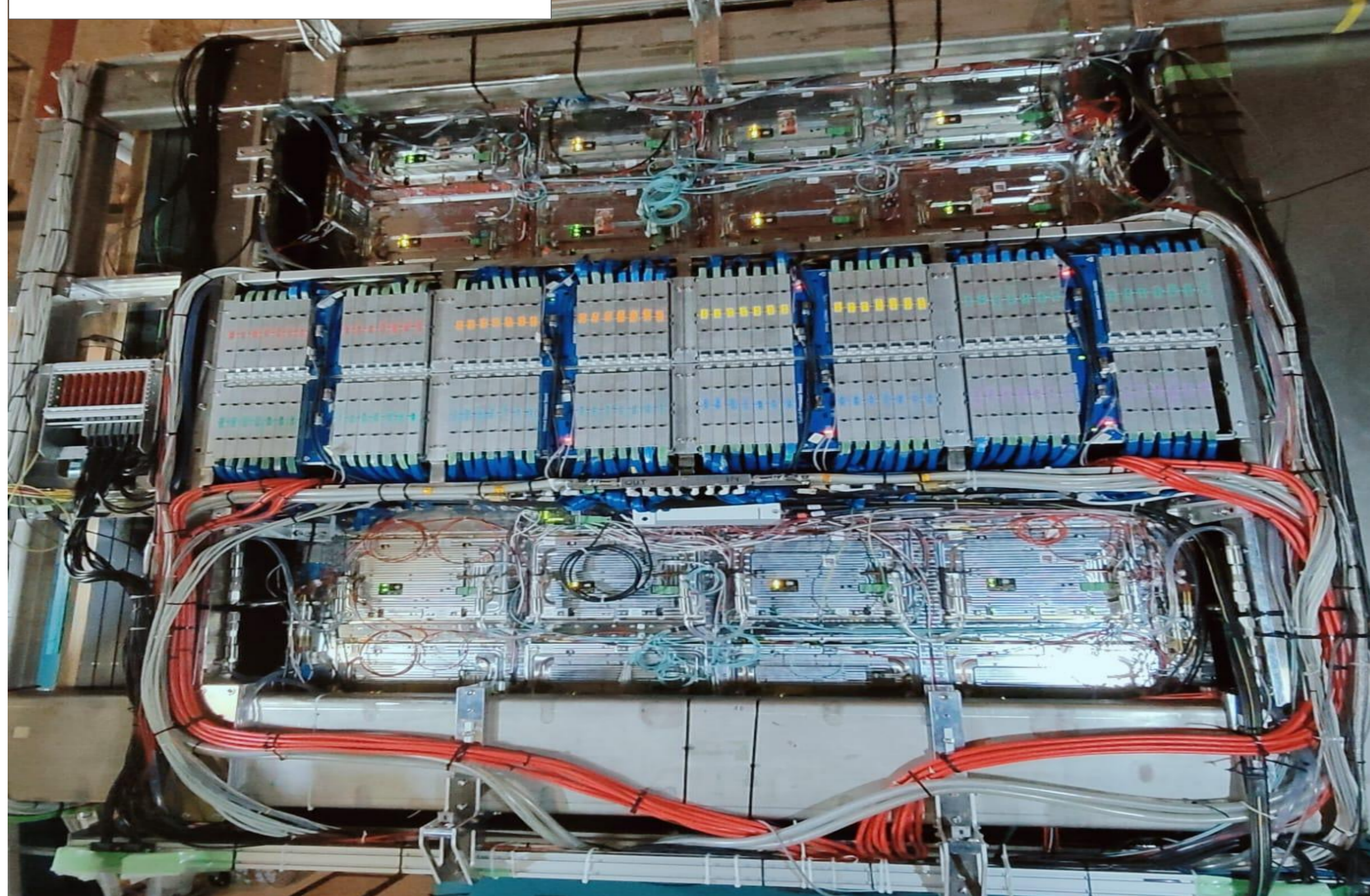
- Precise drift time measurement: distance to time conversion & drift velocity calibration
- Track reconstruction & identification: track clarity & vertex precision
- Improved momentum & energy measurements
- Systematic uncertainty reduction: field uniformity calibration



### Next Steps

- Study of the x-resolution for each pad of ERAMs
- Check for the  $\vec{E}$  distortions
- Get more precise time measurement

## UPGRADED ND280



## REFERENCES

- [1] K. Abe et al. T2K ND280 Upgrade - Technical Design Report. 2019
- [2] D. Attié et al. "Performances of a resistive Micromegas module for the Time Projection Chambers of the T2K Near Detector upgrade". Nucl. Instrum. Meth. A 957 (2020), p. 163286

## ACKNOWLEDGEMENT

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