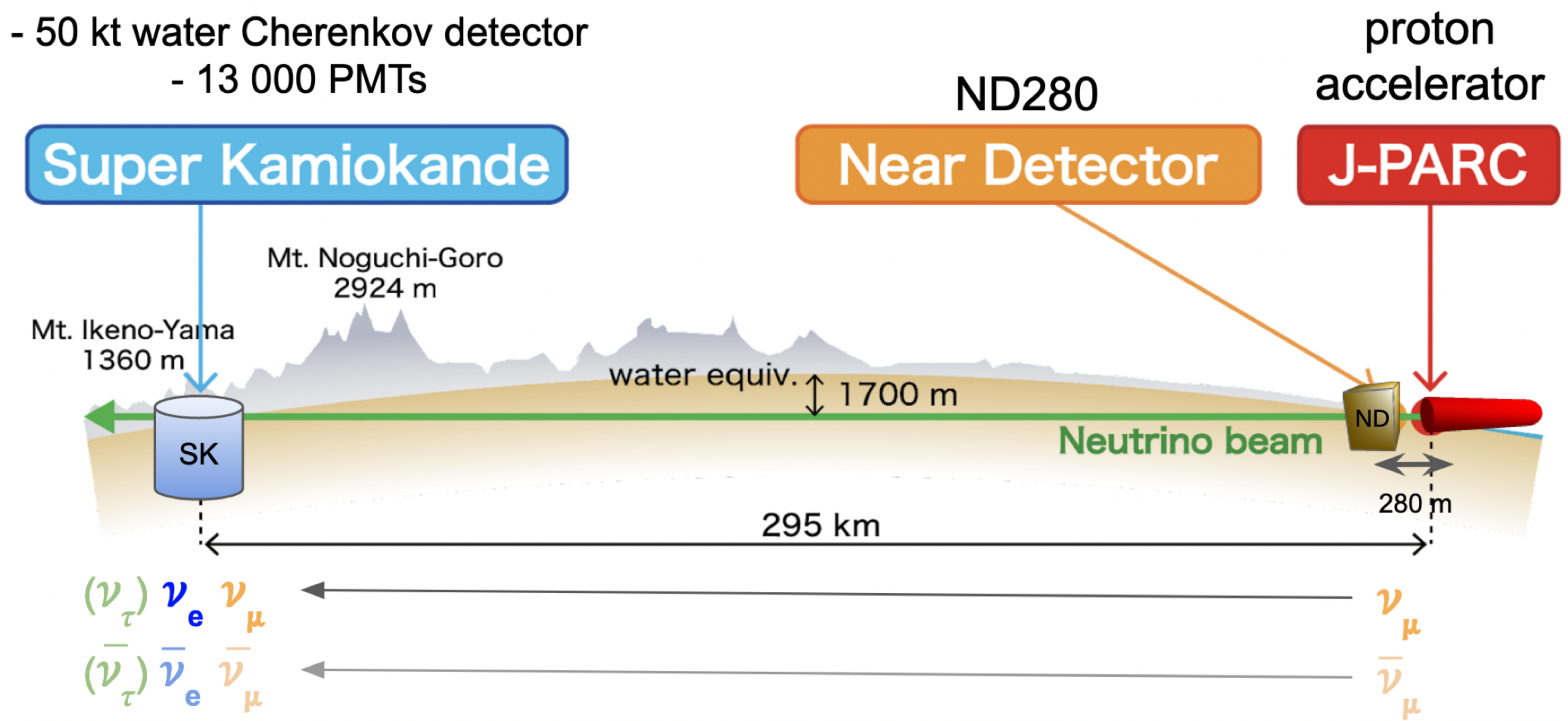
# The T2K experiment and the upgrade of its near detector ND280

Anaëlle Chalumeau*, Ulysse Virginet**
On behalf of the LPNHE neutrino group

## From Tokai to Kamioka: the T2K experiment




- T2K: long baseline neutrino oscillation experiment located in Japan
- $\nu_\mu$ or $\bar{\nu}_\mu$ beam produced at J-PARC accelerator
- Near detector ND280: characterizes (anti) neutrino flux and cross-section before neutrino oscillations
- Far detector Super-Kamiokande (SK): detects $\nu_\mu$ ($\bar{\nu}_\mu$) and $\nu_e$ ($\bar{\nu}_e$) charged current interactions through Cherenkov effect
- Off-axis techniques: ND280 and SK at 2.5° from beam for a narrower band beam peaked at 0.6 GeV

## The contributions of the LPNHE group

- **Design**, **production** and **tests** of ND280 Upgrade HA-TPC front end electronics, see Fig.1
- The HA-TPC data acquisition system based on MIDAS
- The HA-TPC simulation and reconstruction (track fitting) software: the use of **new resistive MicroMegas technology** requires adapting the full software chain
- Analysis of HA-TPC prototypes: test-beam data at CERN in 2018 [1] and at DESY in 2019 [2] and 2021 [4]
- Track reconstruction **new methods** in the HA-TPCs (log Q method, machine learning)

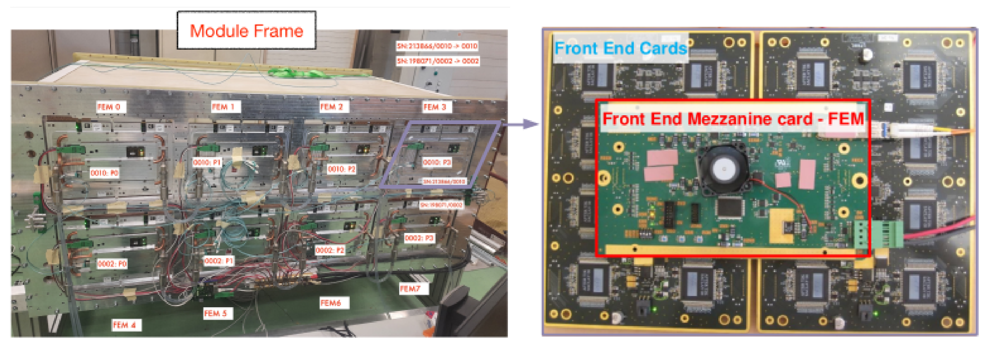
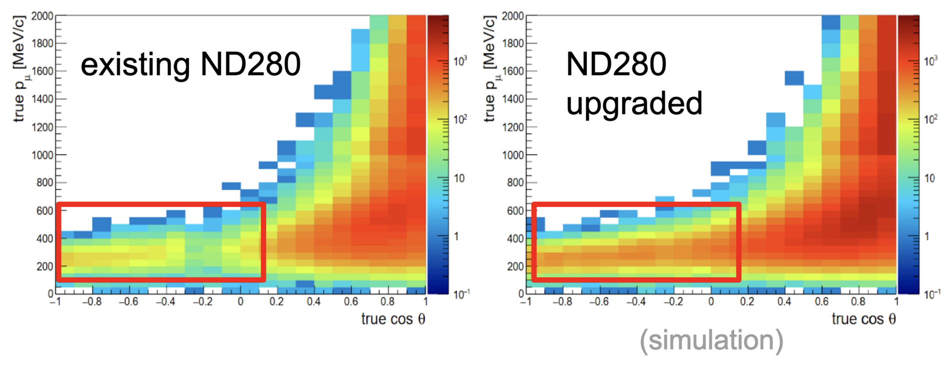



*Figure 1. HA-TPC field cage equipped with 8 ERAMs (left), each readout by 2 Front-End Cards (FEC) and 1 Front-End Mezzanine (FEM) (right)*

## The upgrade of the Near Detector ND280

Reasons for the upgrade:

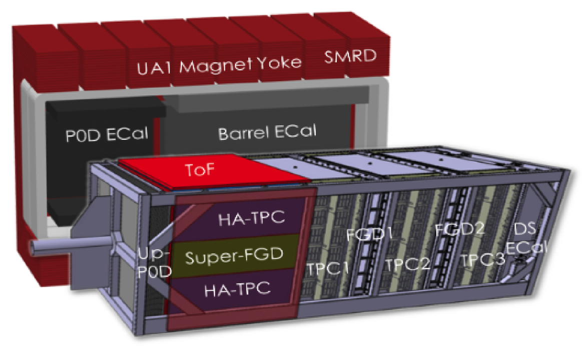



1. Increase angular acceptance (limited phase-space coverage of the current ND280)
2. Reduce systematic uncertainties via better measurements of neutrino interactions [3]

The upgraded detector:

- 1 Fine Grained Detector (SuperFGD) placed between
- 2 **High-Angle Time Projection Chambers** (HA-TPC) instrumented with resistive MicroMegas

→ ongoing comissionning in Tokai!




## The Encapsulated Resistive Anode Micromegas (ERAM) technology

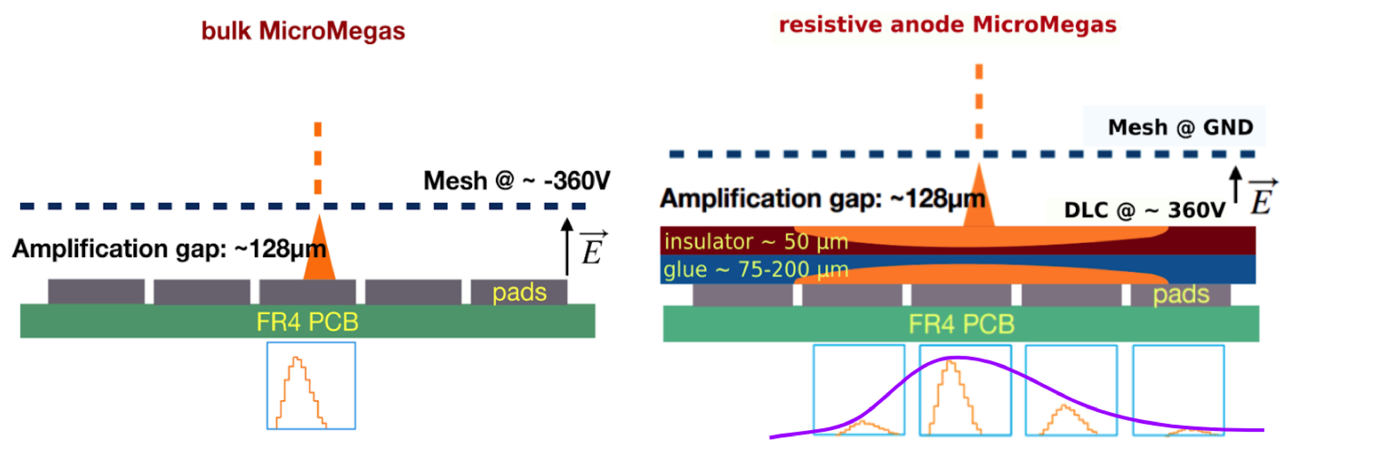



*Figure 2. Previous bulk micromegas (left) and new encapsulated resistive anode micromegas technology (right)*

Charge deposited spread on adjacent pads with Gaussian behavior:

→ Larger $e^-$ avalanche + time information
→ Improved spatial resolution: **200 µm for horizontal tracks** [4] (vs 600 µm with bulk MicroMegas)

## HA-TPC installation and first tracks

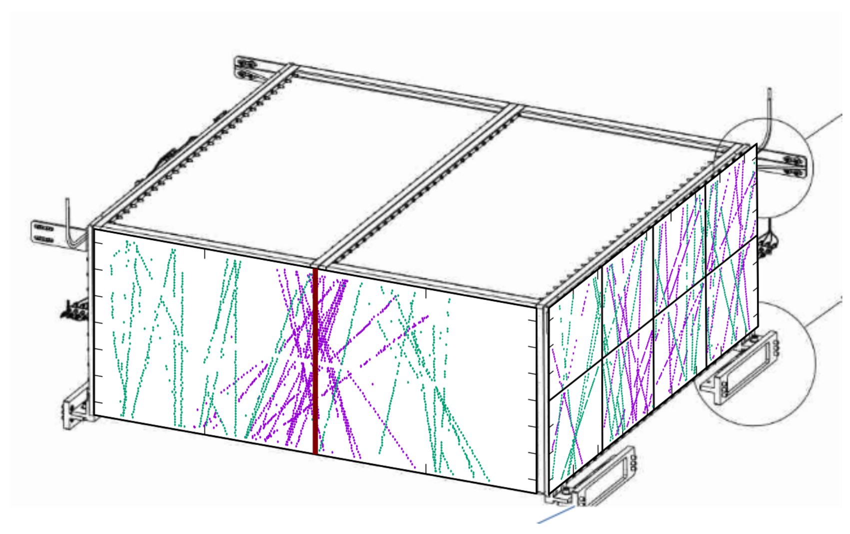


*Figure 3. First cosmics tracks observed at J-PARC (October 2023)*

*Figure 4. Bottom HA-TPC and SuperFGD inside ND280 (October 2023)*

## The High-Angle TPC Reconstruction Software

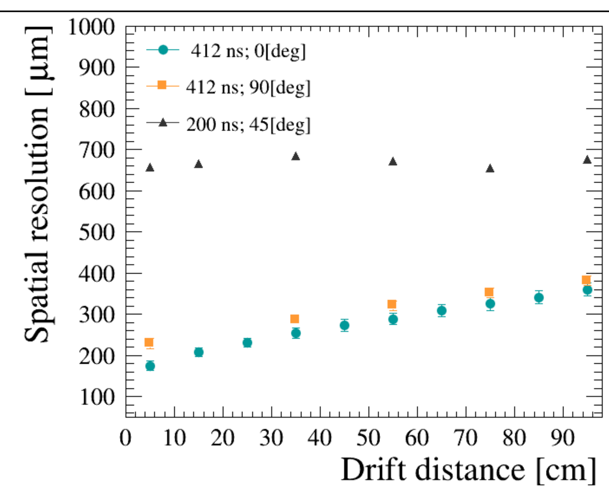



*Figure 5. Spatial resolution as a function of drift distance*

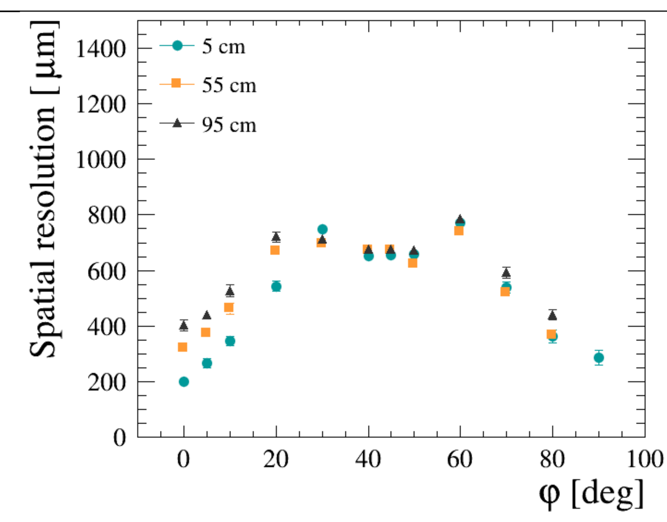



*Figure 6. Spatial resolution as a function of track angle*

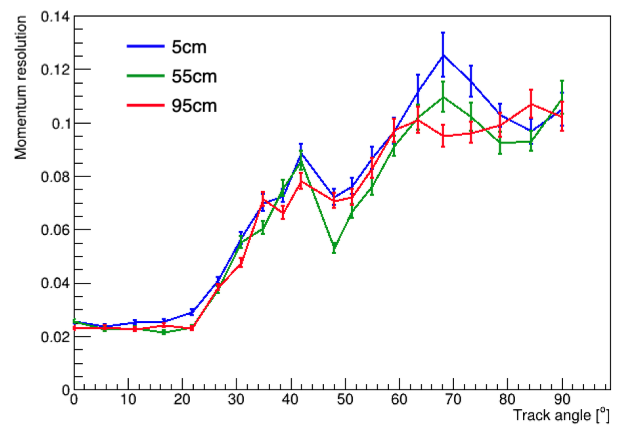



*Figure 7. Momentum resolution as a function of the track angle for 800 MeV.c$^{-1}$ $\mu^-$*

- HA-TPC prototype exposed to the DESY test beam 2021 showed a spatial resolution **better than 800 µm** for all the track topologies
- The Geant4 simulations results obtained showed a momentum resolution **better than 3%** for horizontal tracks and **of the order of 10%** for vertical tracks because of their shorter length

## Neural networks for HA-TPC track reconstruction

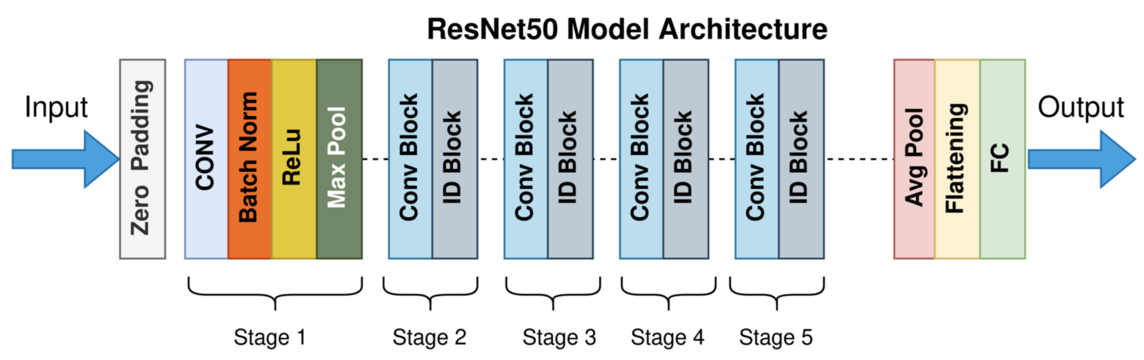



*Figure 8. Standard architecture using convolution operation widely used for image recognition, fed with HA-TPC images of deposited charge (MC simu)*

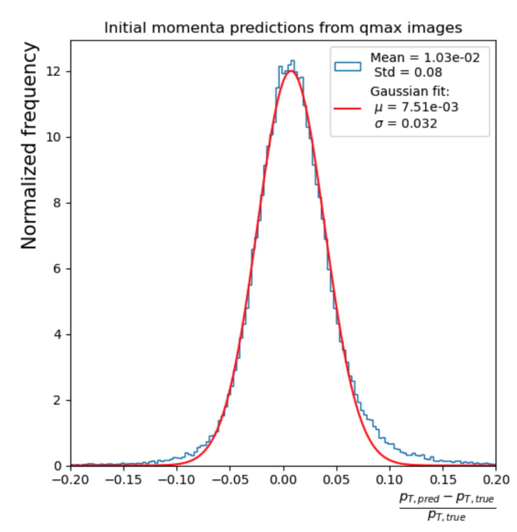



*Figure 9.* ***3% momentum resolution*** *for 0.2-2 GeV muons at 45°(vs 6.5% with current algorithms)*

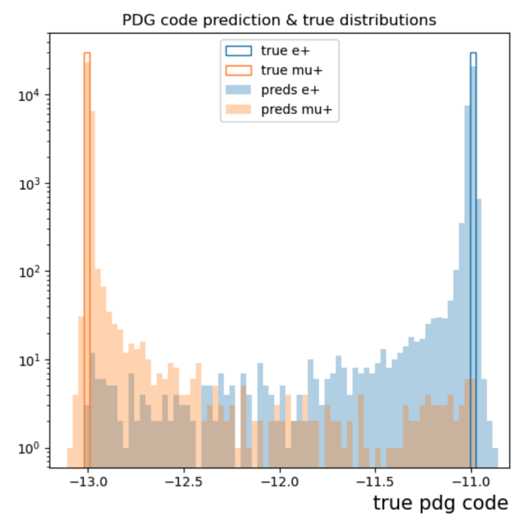



*Figure 10.* ***PID*** *between muons and electrons: PDG code predictions*

## References

[1] 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*, 957:163286, 2020.

[2] D. Attié et al. Characterization of resistive Micromegas detectors for the upgrade of the T2K Near Detector Time Projection Chambers. *Nucl. Instrum. Meth. A*, 1025:166109, 2022.

[3] S. Dolan et al. Sensitivity of the upgraded T2K Near Detector to constrain neutrino and antineutrino interactions with no mesons in the final state by exploiting nucleon-lepton correlations. *Phys. Rev. D*, 105(3):032010, 2022.

[4] U. Yevarouskaya et al. Analysis of test beam data taken with a prototype of tpc with resistive micromegas for the t2k near detector upgrade. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 1052:168248, 2023.

* anaelle.chalumeau@lpnhe.in2p3.fr, ** ulysse.virginet@lpnhe.in2p3.fr