

T2K ND280 Upgrade

Thorsten Lux

On behalf of the T2K Collaboration

The Tokai-to-Kamioka (T2K) experiment

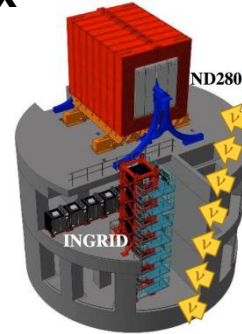
Far detector

Super Kamiokande



Near detector

complex



J-Parc

Neutrino Beam



Mt. Ikeno-Yama
1360 m

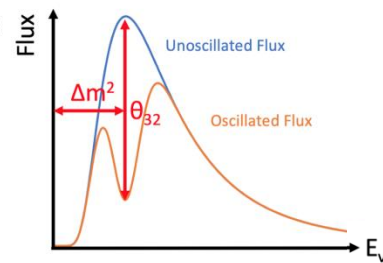
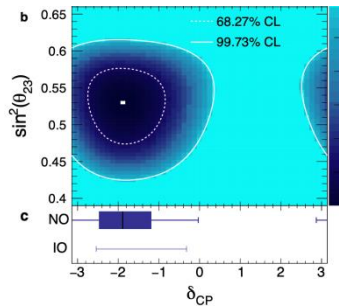
water equiv. \updownarrow 1700 m

Neutrino beam

295 km

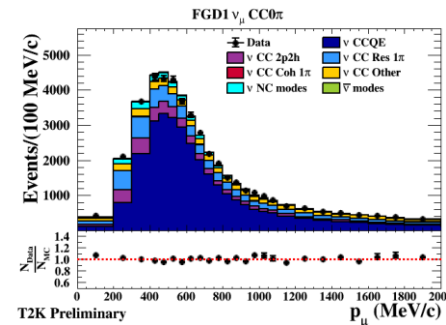
@SK

Measure oscillated
beam



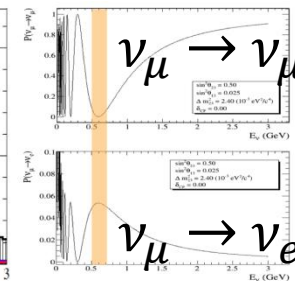
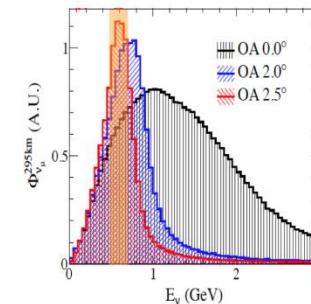
@ND280

Characterize beam and
 ν interactions



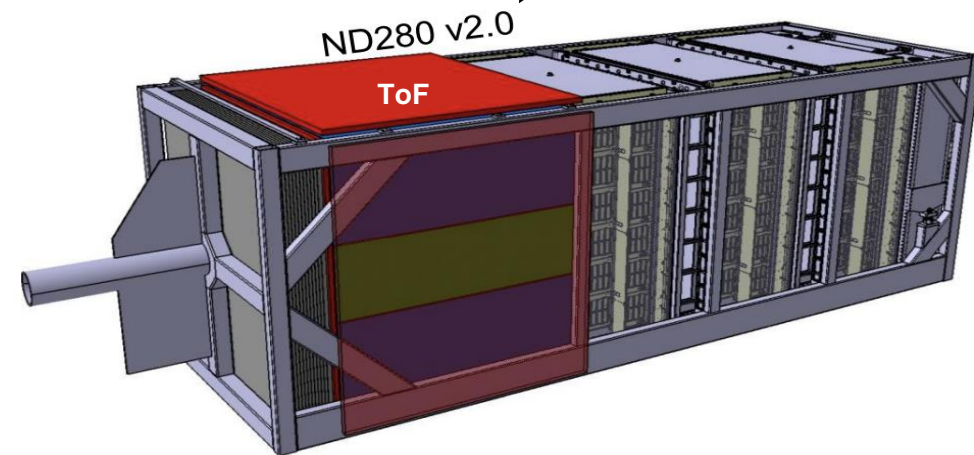
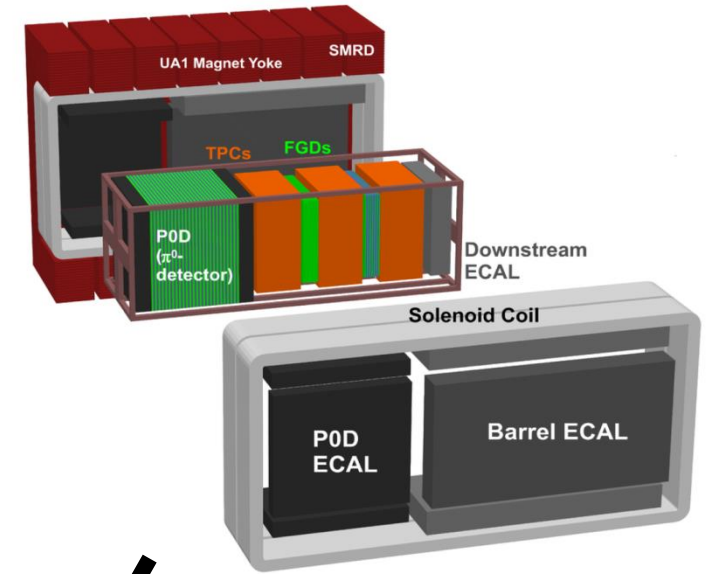
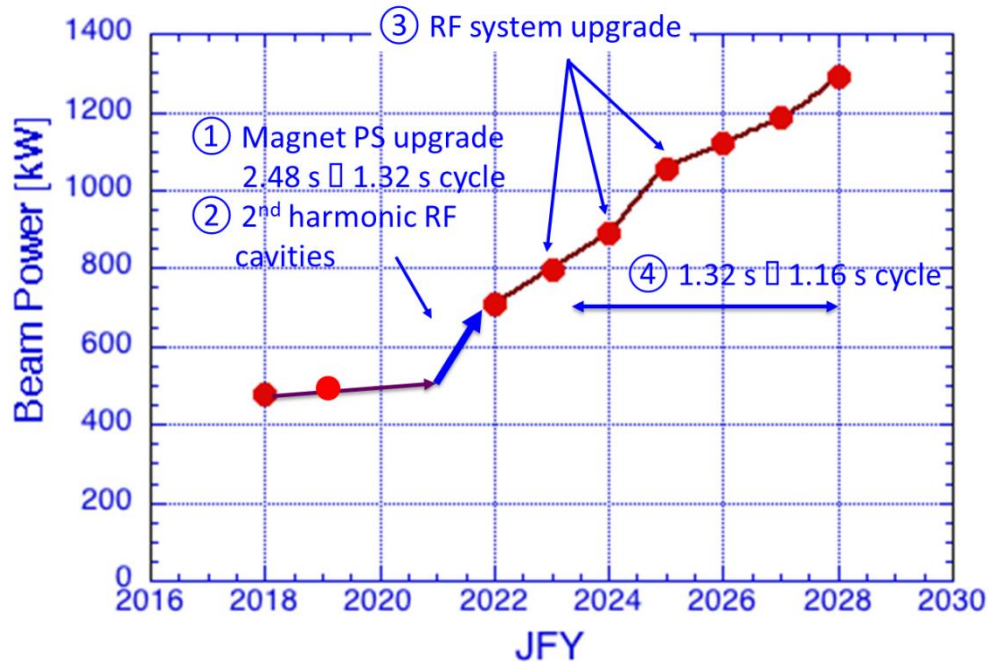
@J-PARC

Create Neutrino's
off-axis beam ν_μ or $\bar{\nu}_\mu$



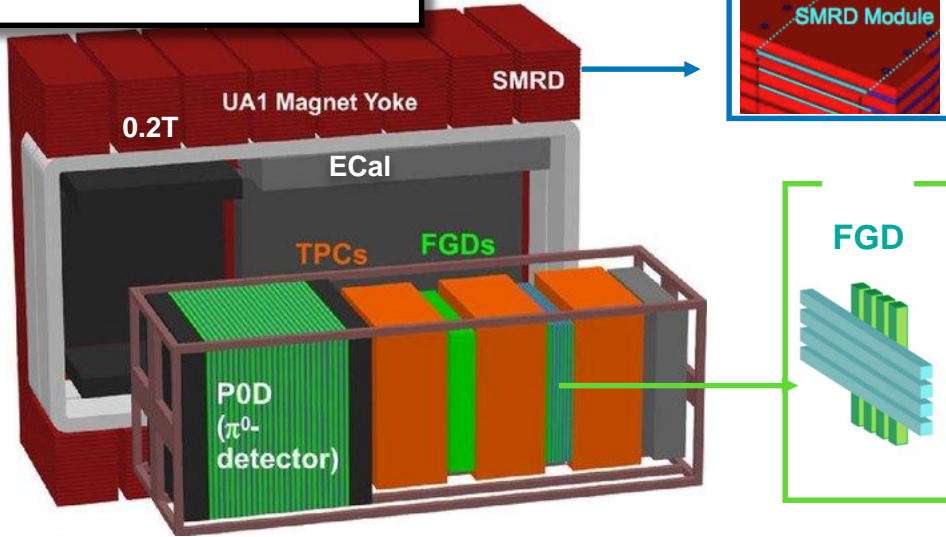
T2K-II (2022-2026)

- New subdetectors for ND280
- beam power upgrade: 0.5 MW \rightarrow 1.1 MW (\rightarrow 1.3 MW HyperK)
- statistics: 3E21 POT (2018) \rightarrow 12E21 POT (2026)
- aim: systematics from 5-6% to 4%
- Aim for CPV observation in optimal scenario at 3σ



The current ND280 detector

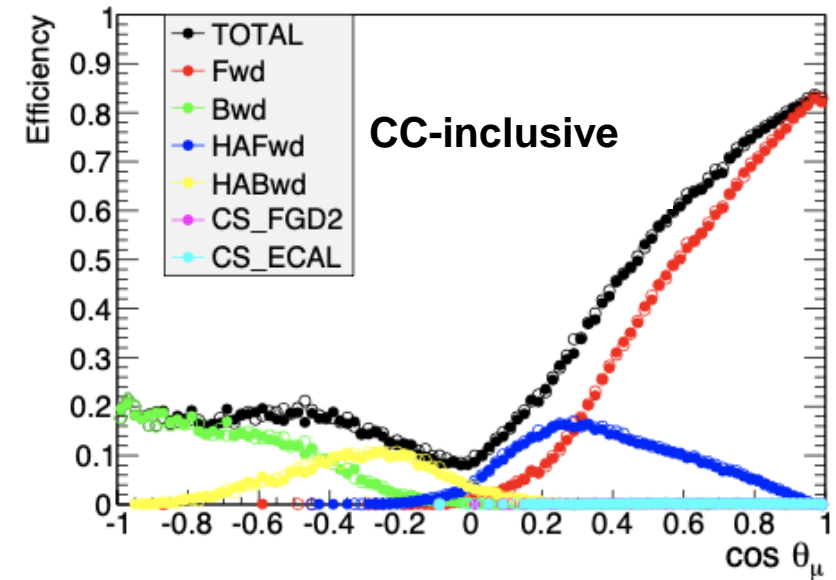
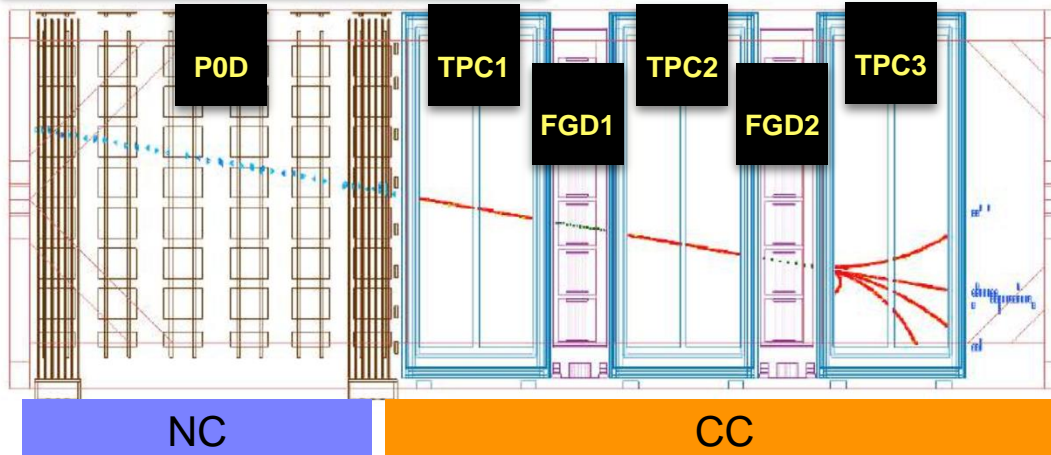
Current ND280 sketch



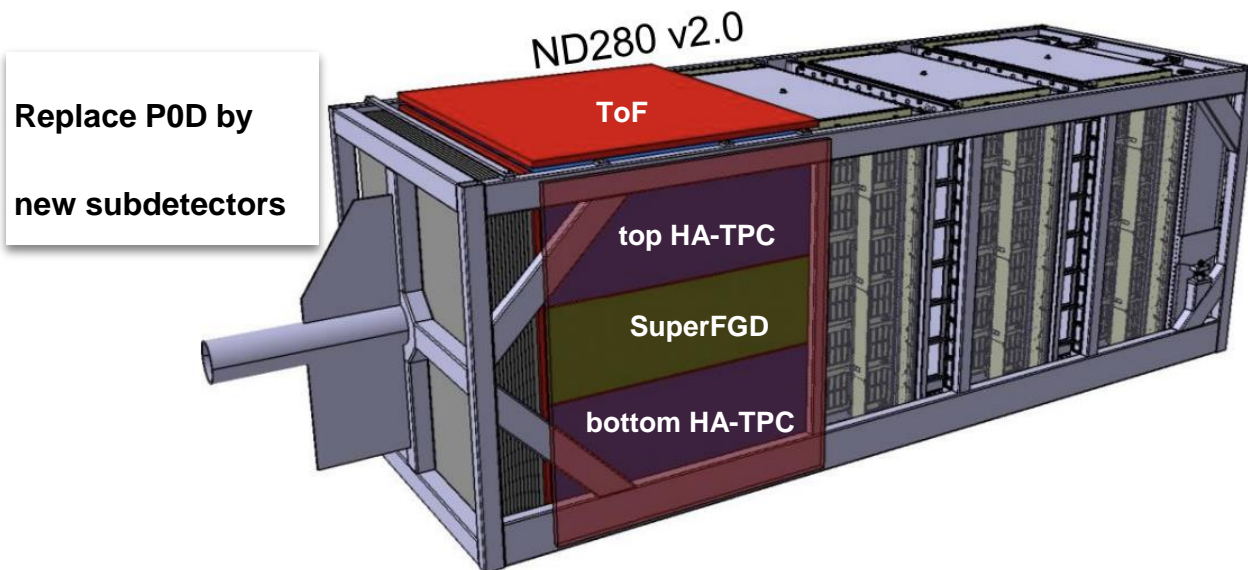
Current limitations

- ✦ Tracks w/o TPCs (high angle).
- ✦ Tracks w/o TPCs (low momentum).
- ✦ Limited timing information => no direction information
- ✦ No neutron info
- ✦ Poor electron/photon separation
- ✦ High detection threshold

Event display of basket elements

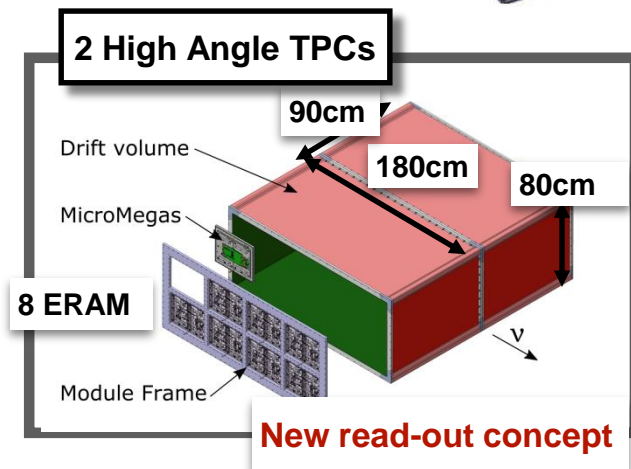


The upgraded ND280 detector

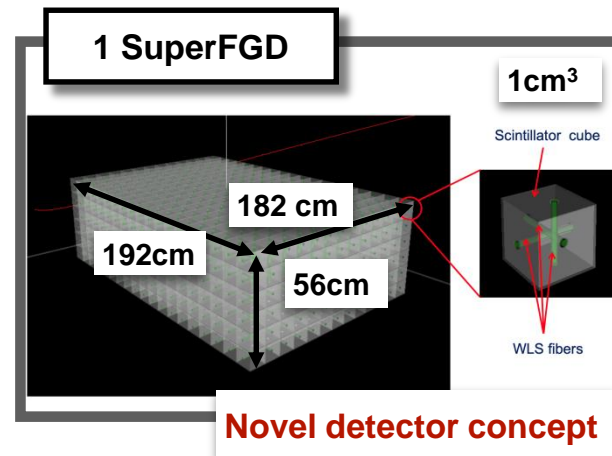


Milestones

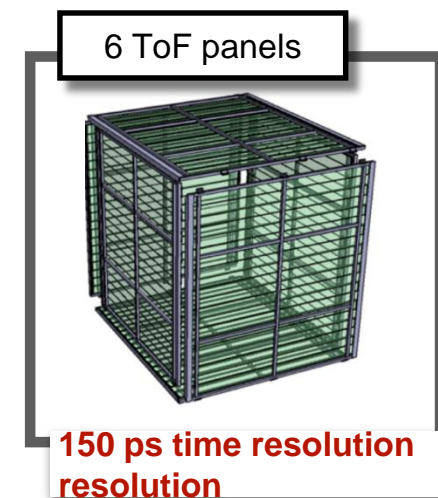
- ✦ 2018 → TDR [arXiv:1901.03750](https://arxiv.org/abs/1901.03750)
- ✦ 2021/22 final modules
- ✦ 2022 installation



NIM A 957 163286 (2020)



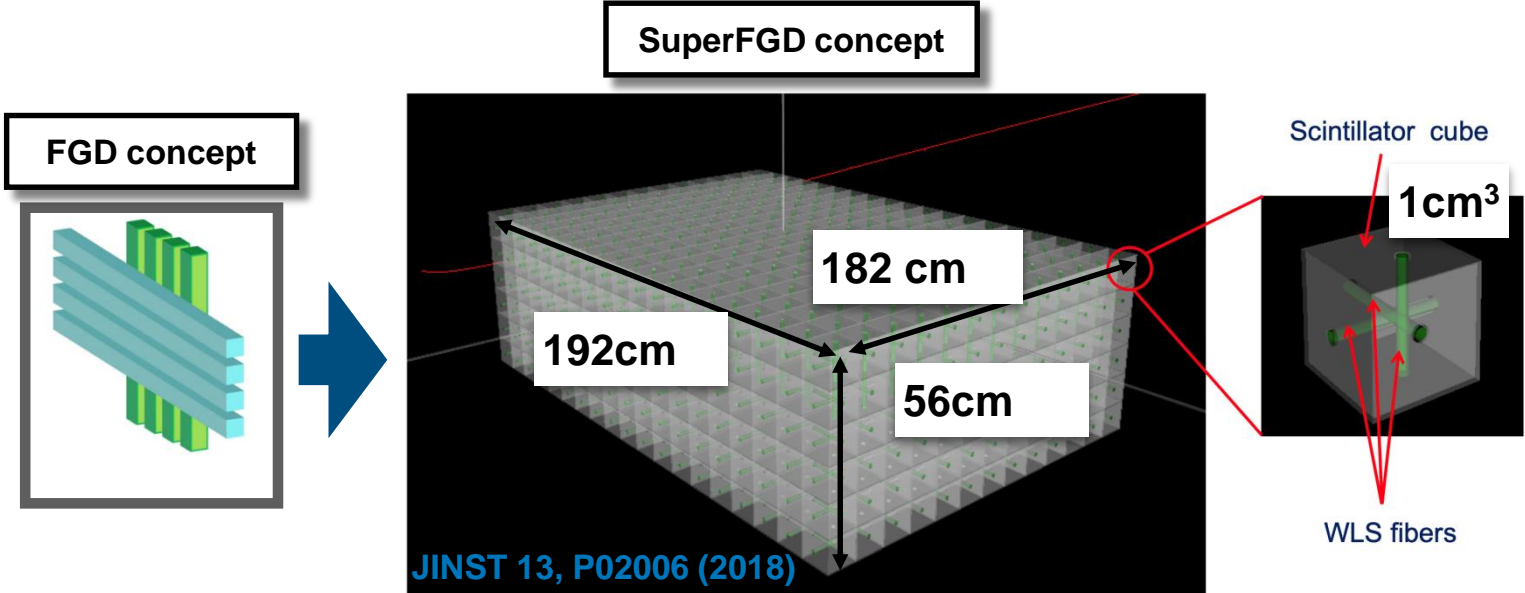
JINST 13, P02006 (2018)
JINST 15 P12003 (2020)



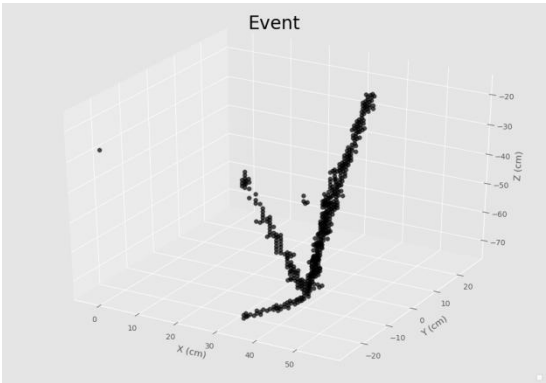
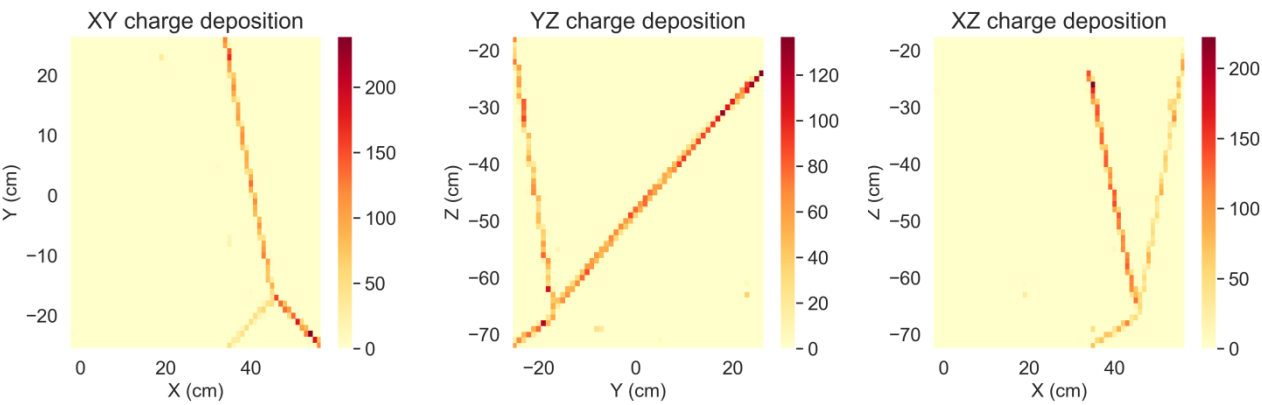
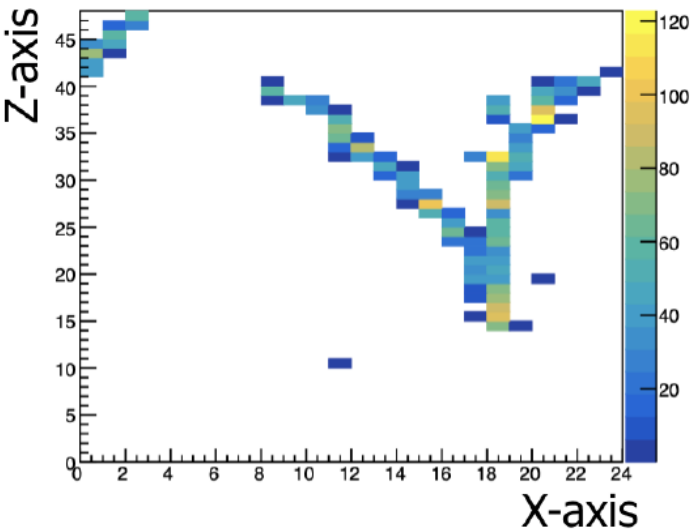
JPS Conf. Proc. 27, 011005 (2019)

A new scintillator tracker concept (SuperFGD)

To improve the granularity the new active target will be a novel 3D tracking technology

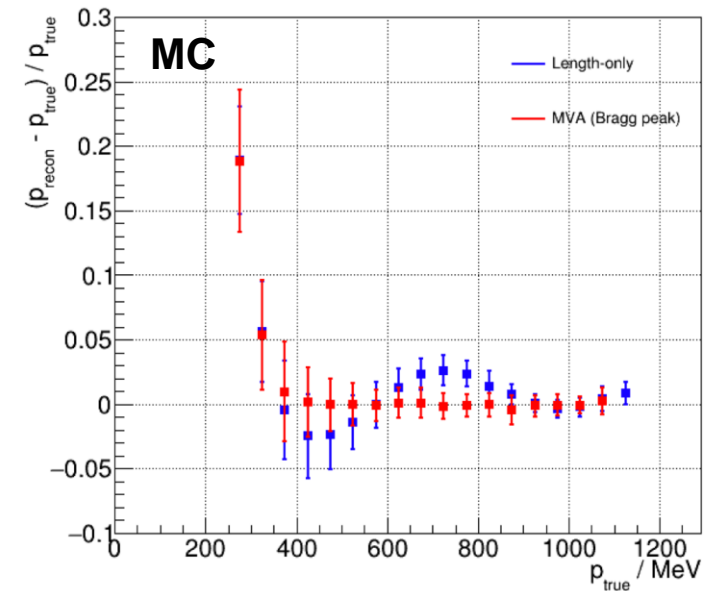
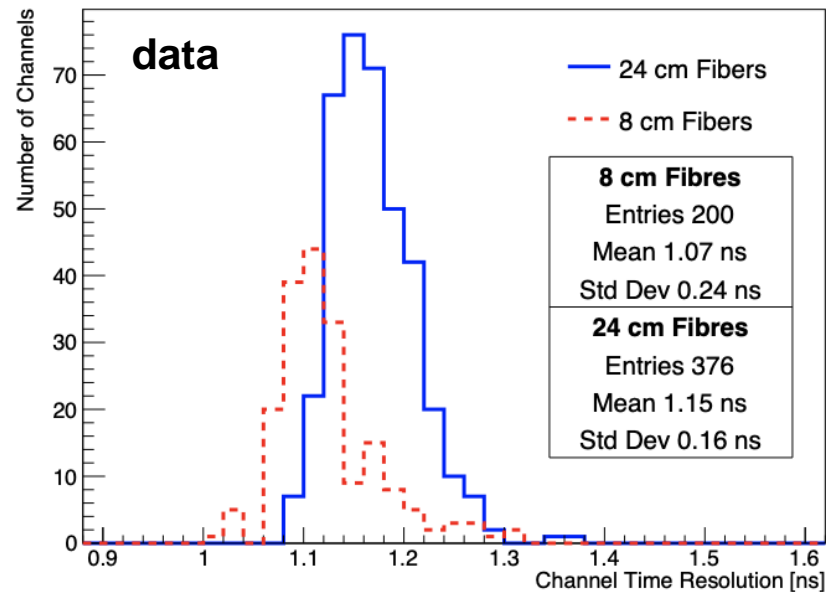
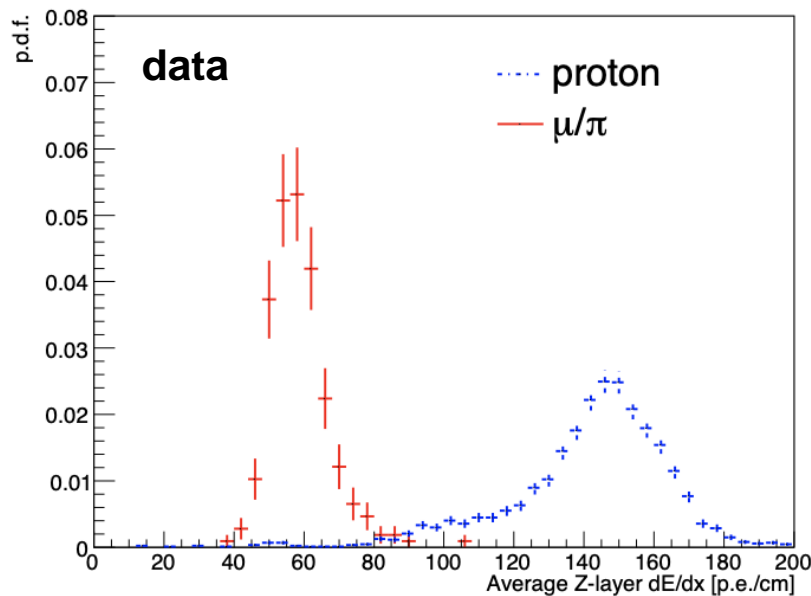
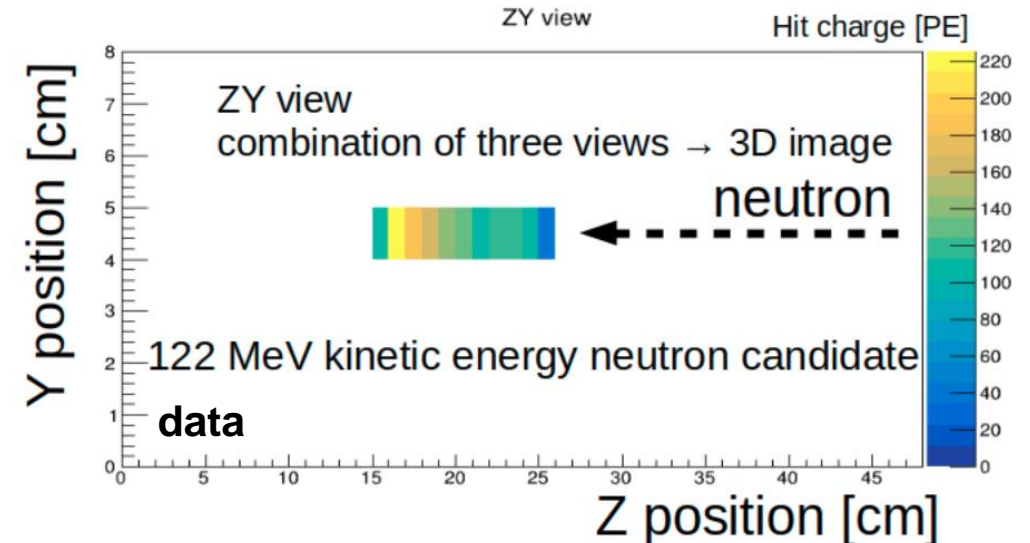


Testbeam event



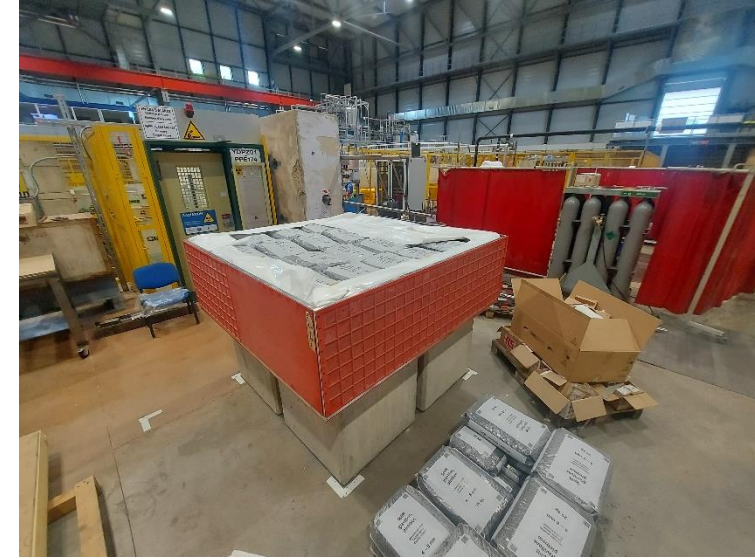
SuperFGD Testbeam and MC Performance

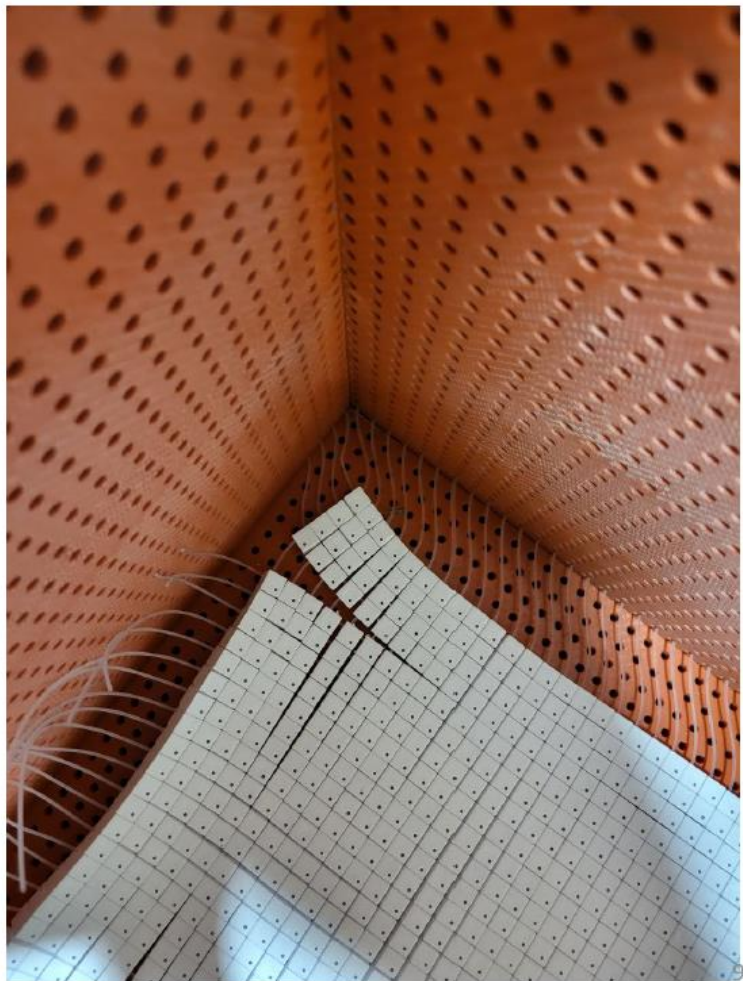
- Various prototypes were exposed to testbeams at CERN (charged particles) and Los Alamos (neutrons)
- Charged particle analysis indicates good dE/dx and timing (published Dec. 2020, **2020 JINST 15 P12003**)
- Neutron data analysis ongoing
- Used to tune MC
- Promising results for stopping particles



SuperFGD Status

- Cubes were successfully shipped to J-PARC in June
- Assembly structure arrived in September at J-PARC
- All box panels arrived at CERN in August
- Quality control including 3.5 t load test performed successfully at CERN
- Box arrived at J-PARC 24th of October 2022
- Cube layer assembly in box started and is progressing very well
- This stage expected to be completed by 21st of November
- Foam necessary to close box expected to arrive mid of December



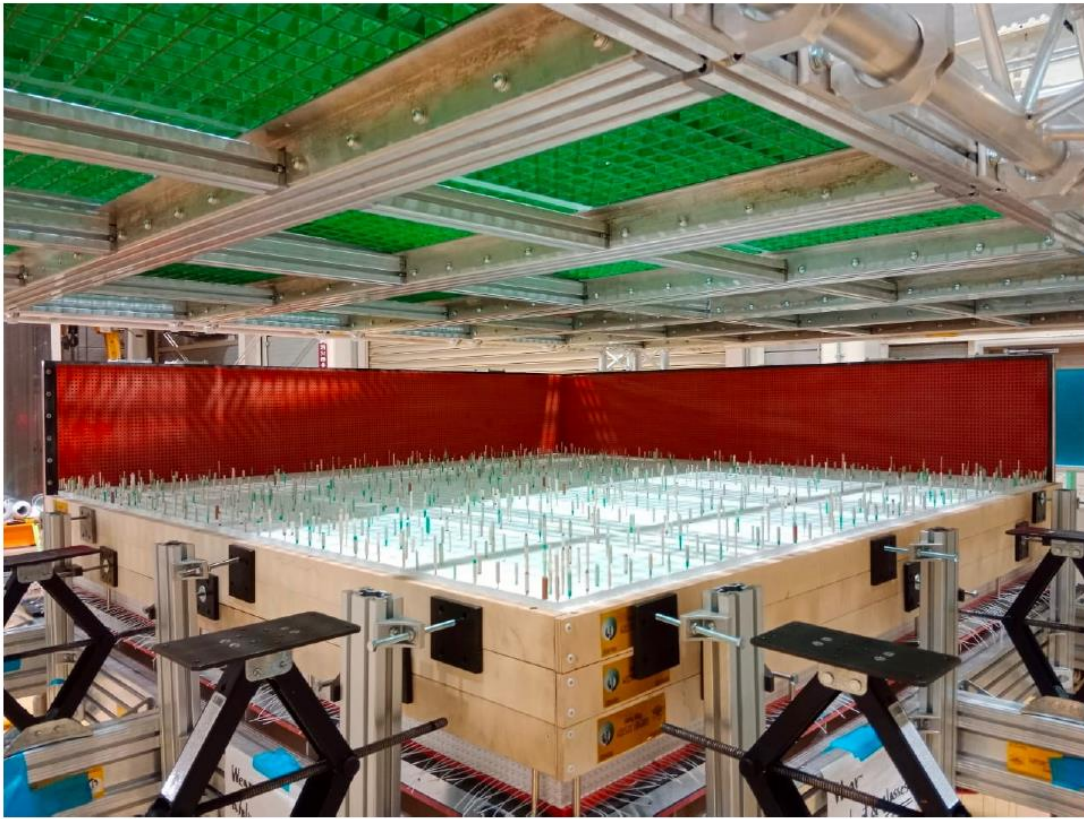


Starting with aligning the first layer in the corner

Vertical spikes to keep alignment everywhere



Still with fishing lines



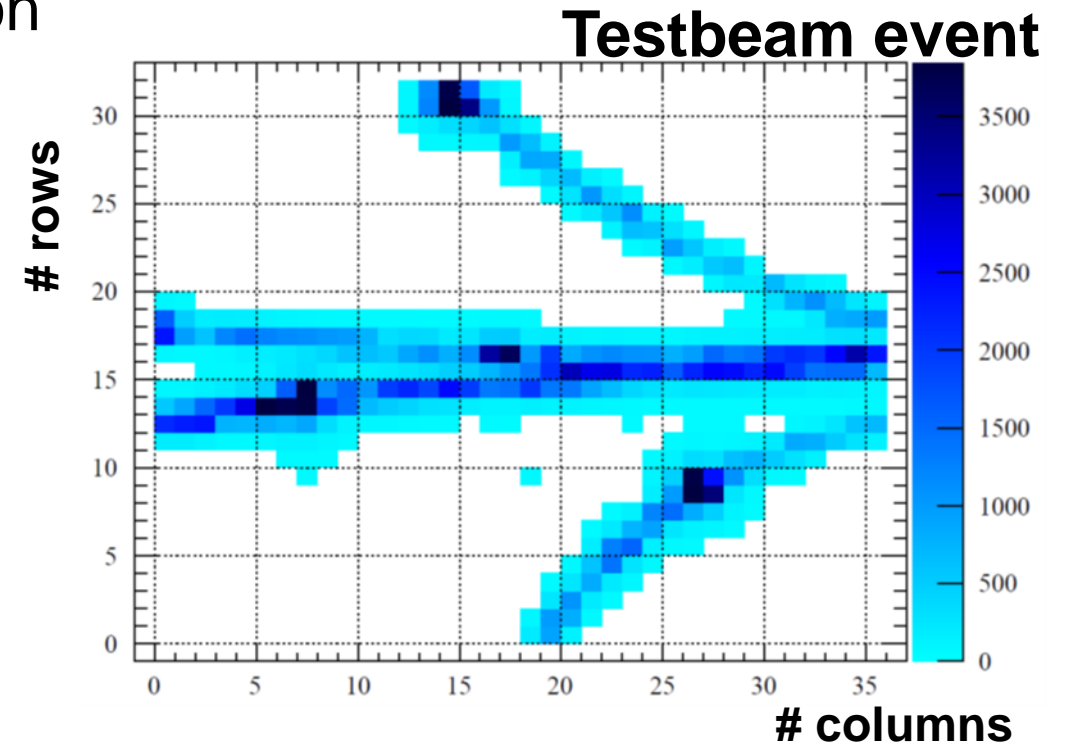
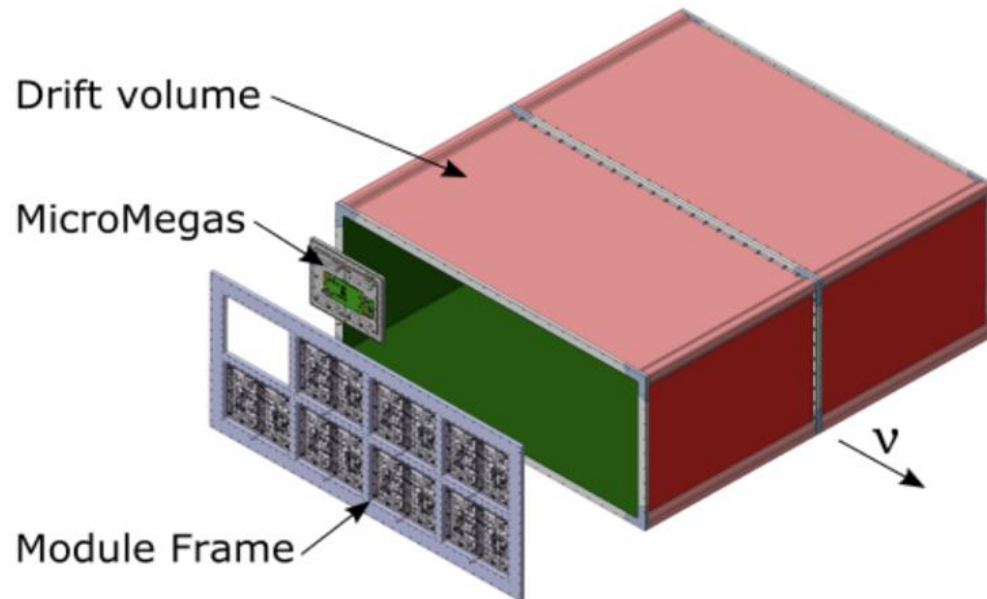
Status 1st of November:
23 layers were assembled

International team currently at J-PARC
working on the assembly



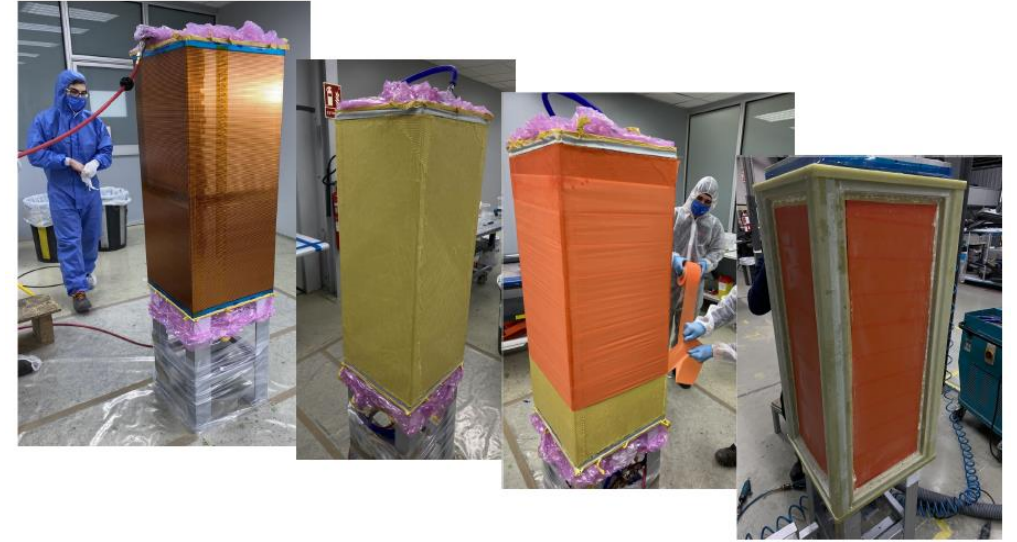
High Angle-TPCs

- 2 new TPCs consisting of 4 field cage halves being produced
- Dimensions: 1865x2000x820 mm³
- Composite materials for field cage
- Readout by 8 resistive Micromegas (ERAM) per side (novel technology)
- 1152 readout channels with 10.09x11.18 mm² pads per ERAM
- T2K gas (95 Ar, 3 CF₄, 2 iC₄H₁₀)
- Providing tracking and particle identification



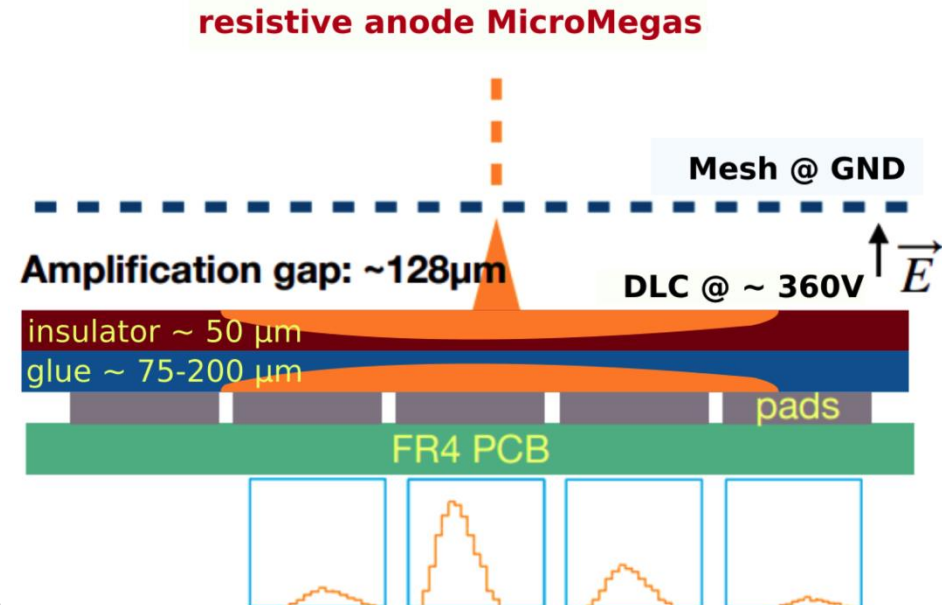
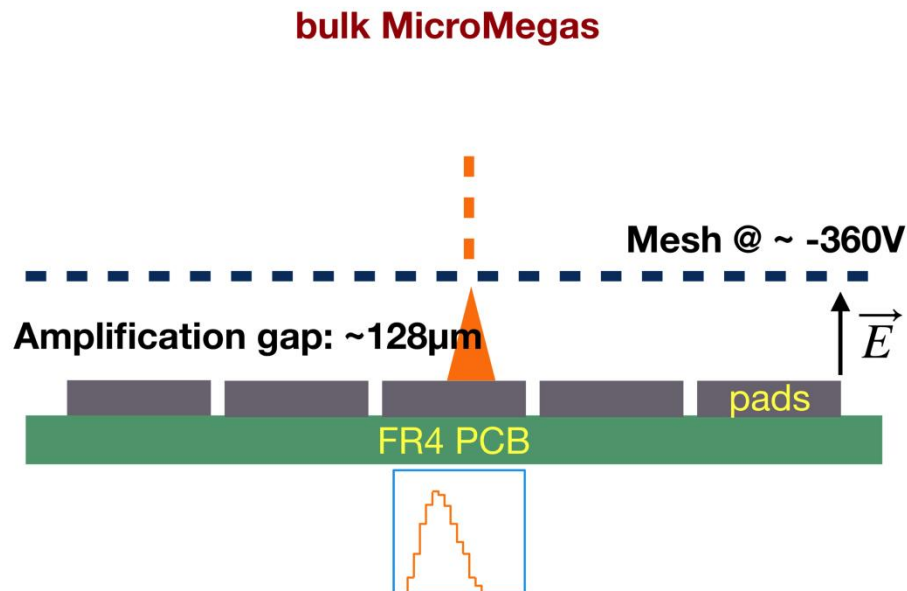
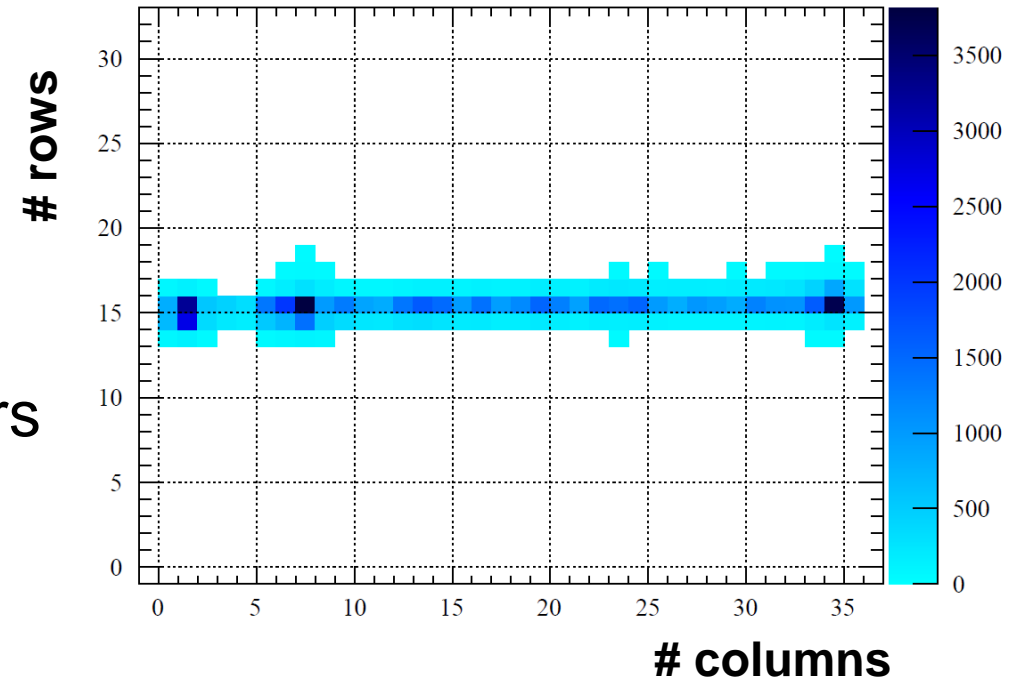
HA-TPC Field Cage

- TPC consists of 2 halves and separate cathode
- Production based on layers wrapped around mould
- 2 full length prototypes for 1 MM + several mock-ups were produced and tested
- Successfully tested:
 - Metrology
 - HV stability in air and argon up to 35 kV
 - Gas tightness



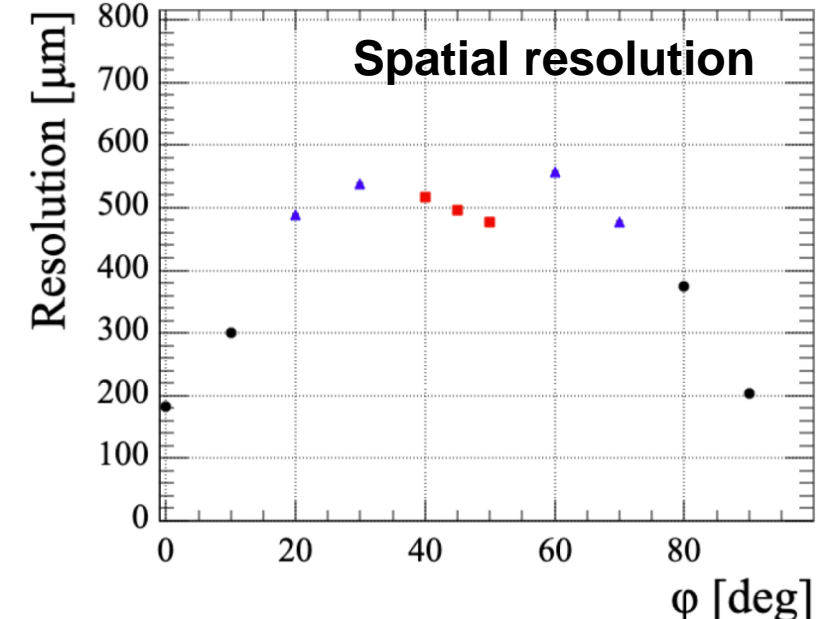
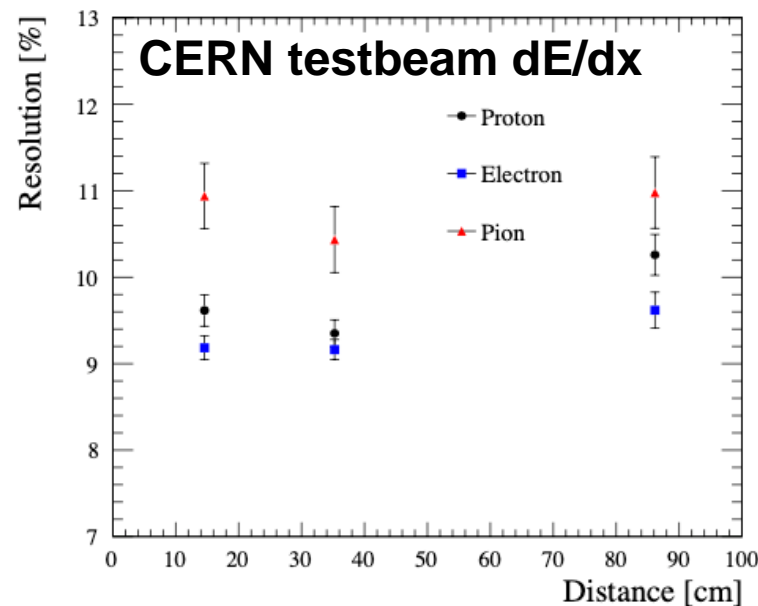
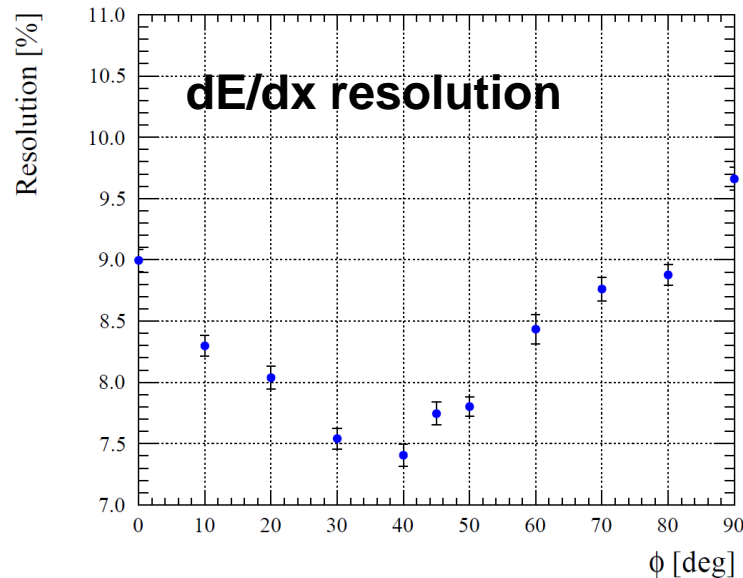
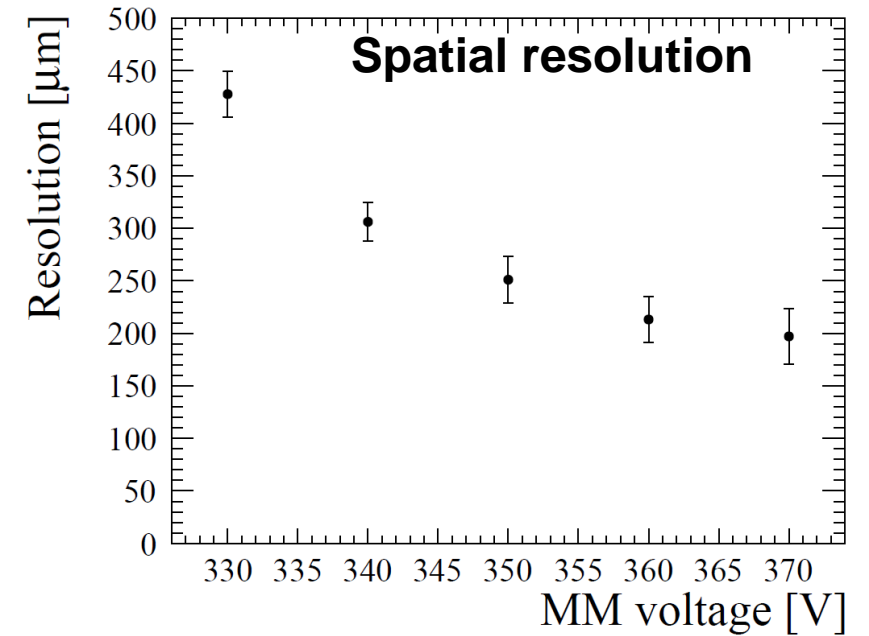
HA-TPC ERAM Modules

- Novel resistive MM readout
- Charge over several pads => better point resolution
- 32 ERAM modules needed + 8 spares
- Various prototypes with different RC parameters produced and tested
- Pre-production of 8 modules ongoing at CERN MPGD workshop



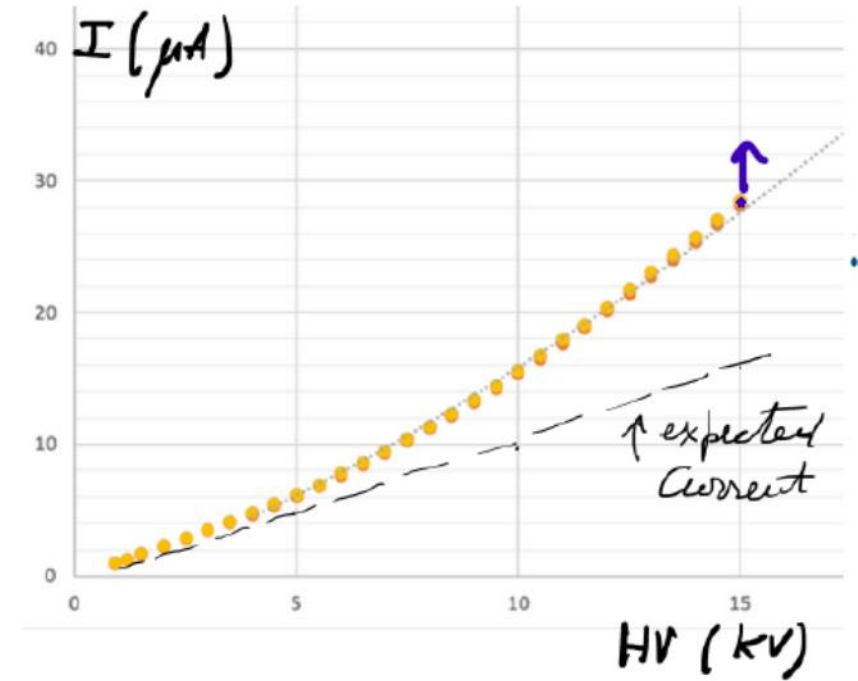
HA-TPC ERAM Results

- Very good dE/dx and point resolution performance
- For all angles better than 600 μm (using different reconstruction algorithms)
- For first 15 cm values below 300 μm
- dE/dx resolution below 10% for final detector



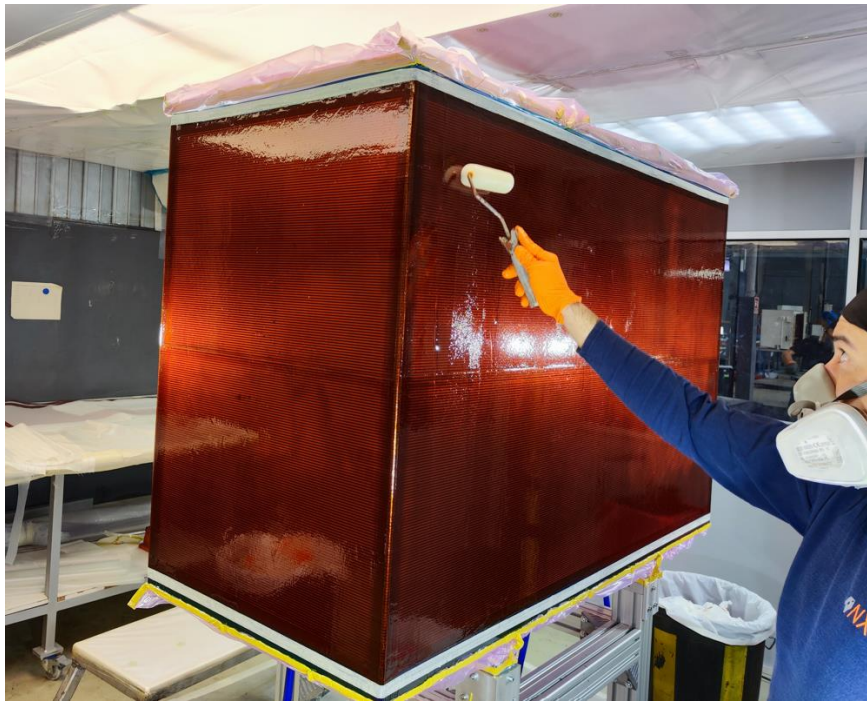
HA-TPC Status

- Production of final field cages (FC) started beginning of 2022
- Unusual problems with FC0 observed
- Identical production procedure as very successful prototype
- Investigation of the problem and developing improved quality control took several months
- Production of FC1 started in October and progress very well until now



Strip alignment



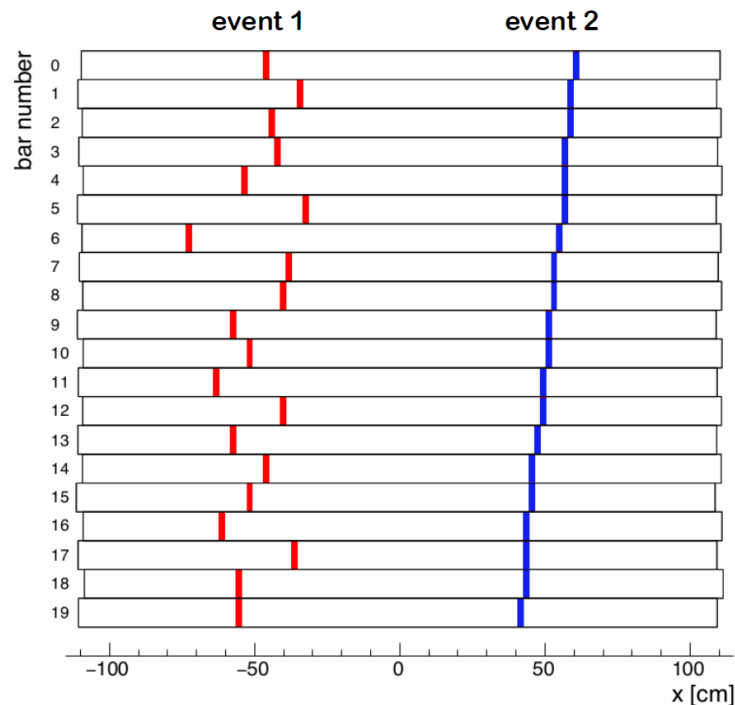


Kapton layer gluing

Drying
the
chamber
in
autoclave
after
Kapton
glueing

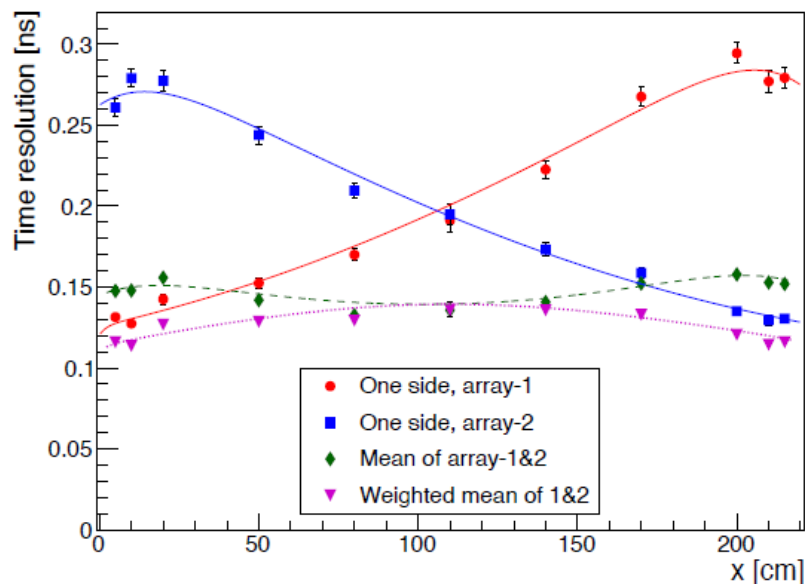
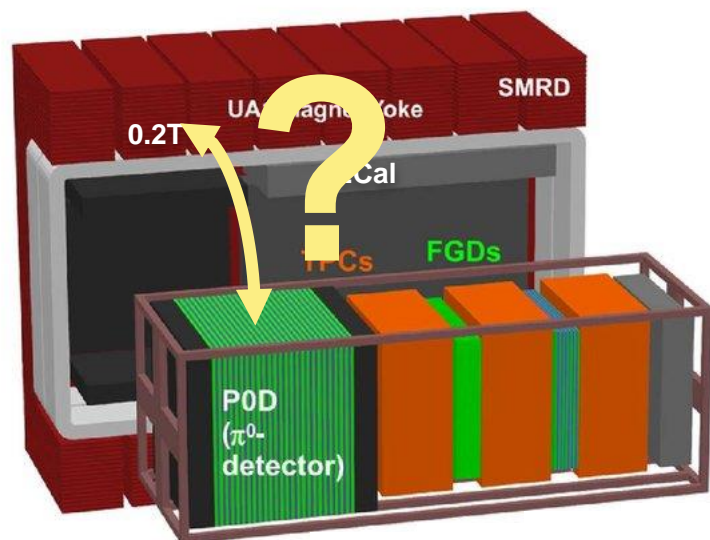


Placing 1st Twaron layer



TOF

- 6 modules (2.3x2.5 m²) mounted each with 20 bars
- Double sided readout with 12 SiPMs per side
- Tested in several testbeams
- Excellent time resolution of 150 ps achieved
- Currently quality control of all modules using cosmics
- Important to determine direction of particles
- Ready for shipment to J-PARC



- Ongoing until summer 2023: SFGD assembly and commissioning at J-PARC
- Spring 2023: neutrino beam with existing ND280
- Installation of new detectors:
 - July 2023: bottom HA-TPC
 - August/September: SuperFGD
 - November 2023: top HA-TPC
 - December 2023: last TOF panels
- Depending on neutrino beam availability the installation of top HA-TPC might be postponed

Significant number of secondments will be needed!

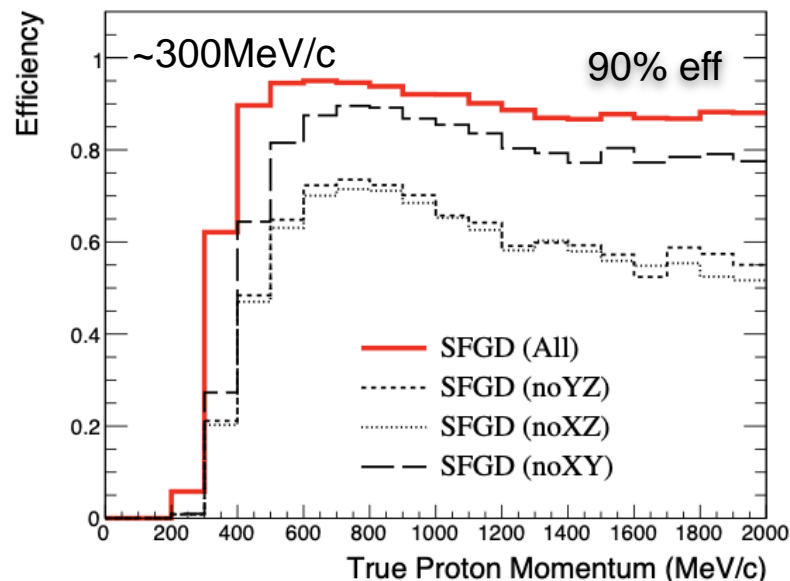
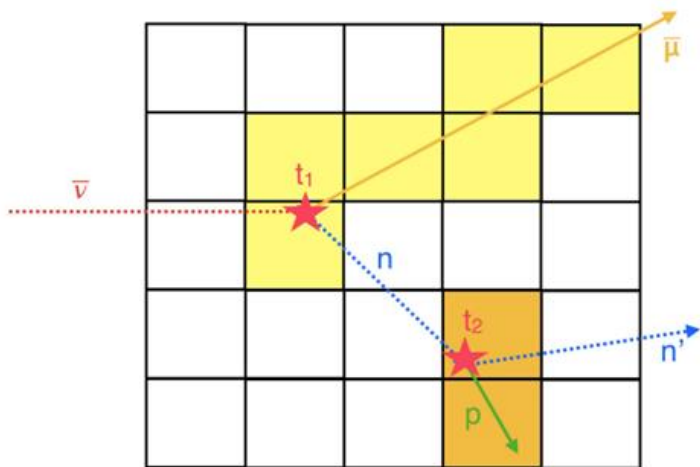
- ND280 Upgrade project progressing well
- In 2023 the new subdetectors will be installed
- Will require significant amount secondments
- Status of deliverables and milestones:
 - Deliverable: TDR => done
 - Milestones: Prototypes and their testing => done
 - Final deliverable: Article about new subdetectors => after installation

Backup

Physics Impact

- Ugraded ND280 covering similar phase space coverage as SuperKamiokande
- Significant lower energy threshold
- Neutron detection capability

Much better constraint on beam and better cross section measurements!



Current ND280 threshold: ~500MeV/c

