IFAE Institute for High Energy Physics

EXCELENCIA SEVERO OCHOA

BIST Barcelona Institute of Science and Technology

T2K ND280 Upgrade

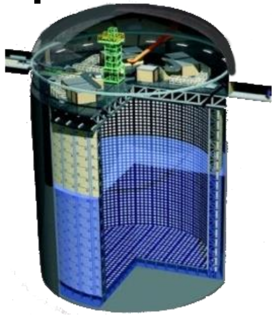
Thorsten Lux

On behalf of the T2K Collaboration

The Tokai-to-Kamioka (T2K) experiment

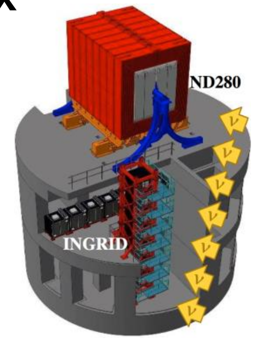
Far detector

Super Kamiokande



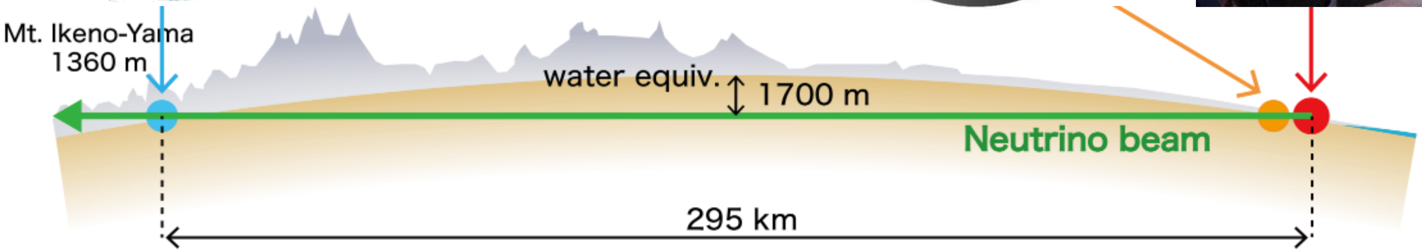
Near detector

complex



J-Parc

Neutrino Beam



@SK

Measure oscillated beam

←

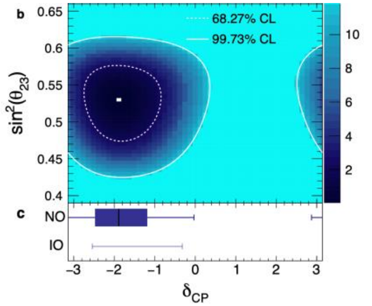
@ND280

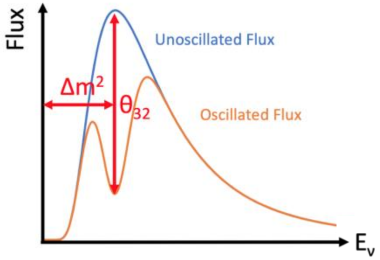
Characterize beam and ν interactions

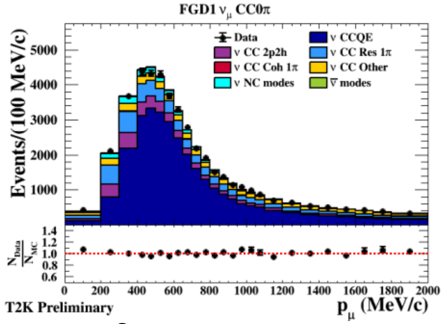
←

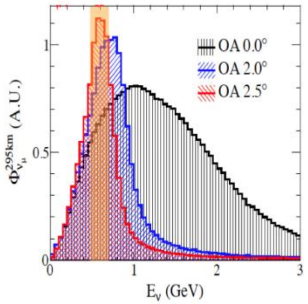
@J-PARC

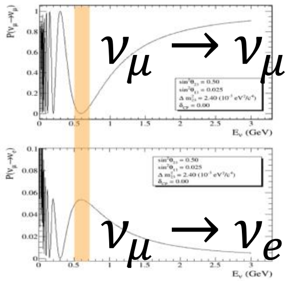
Create Neutrino's off-axis beam ν_μ or $\bar{\nu}_\mu$





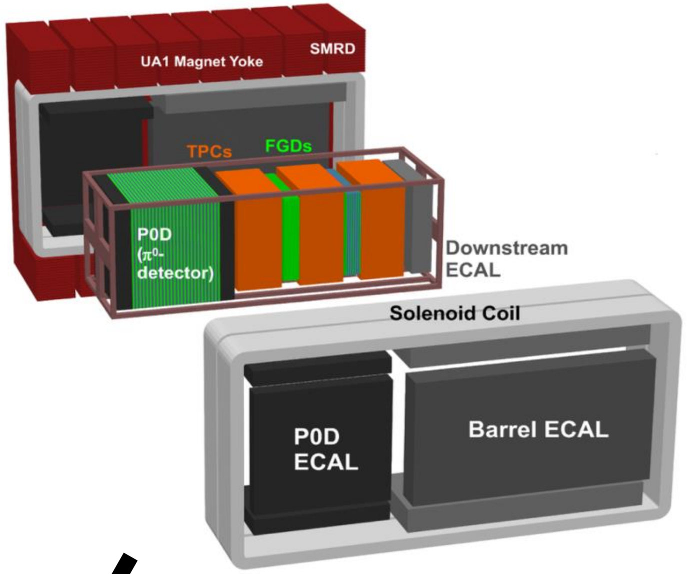


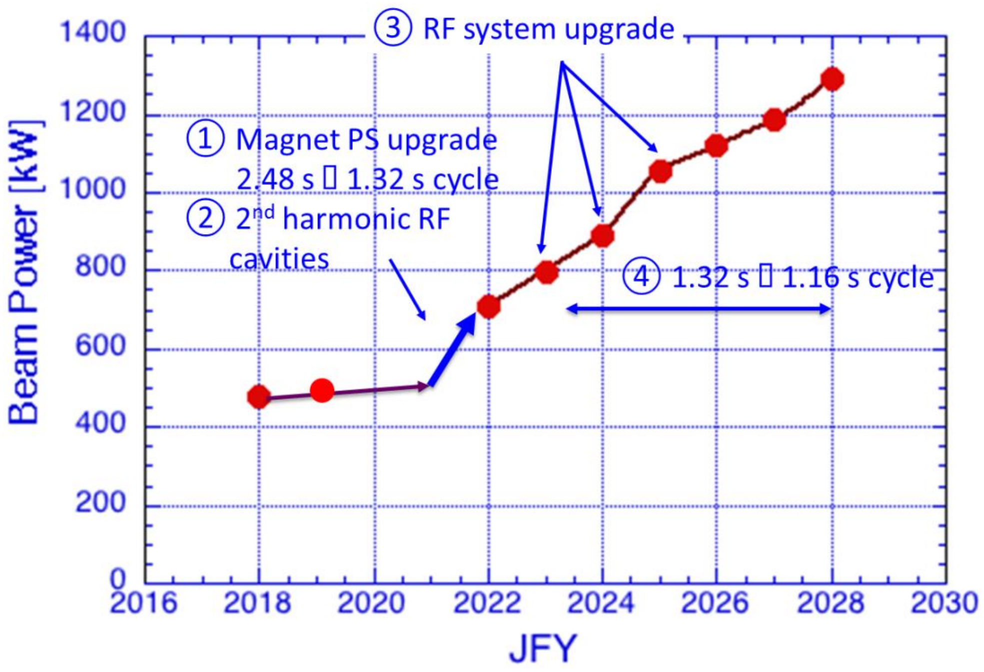


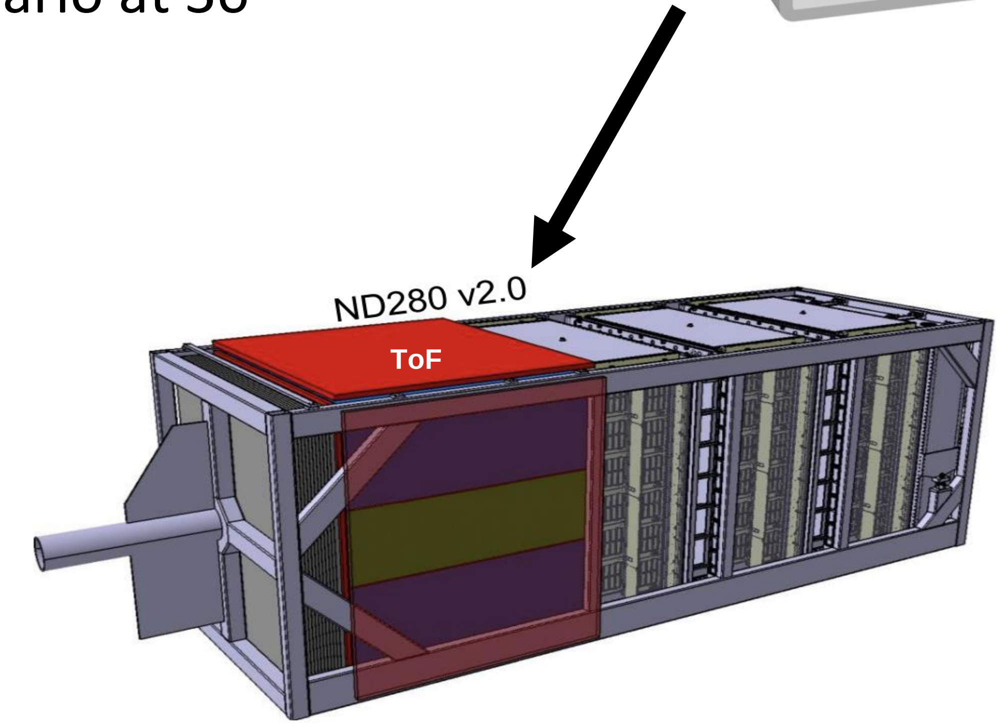


T2K-II (2022-2026)

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

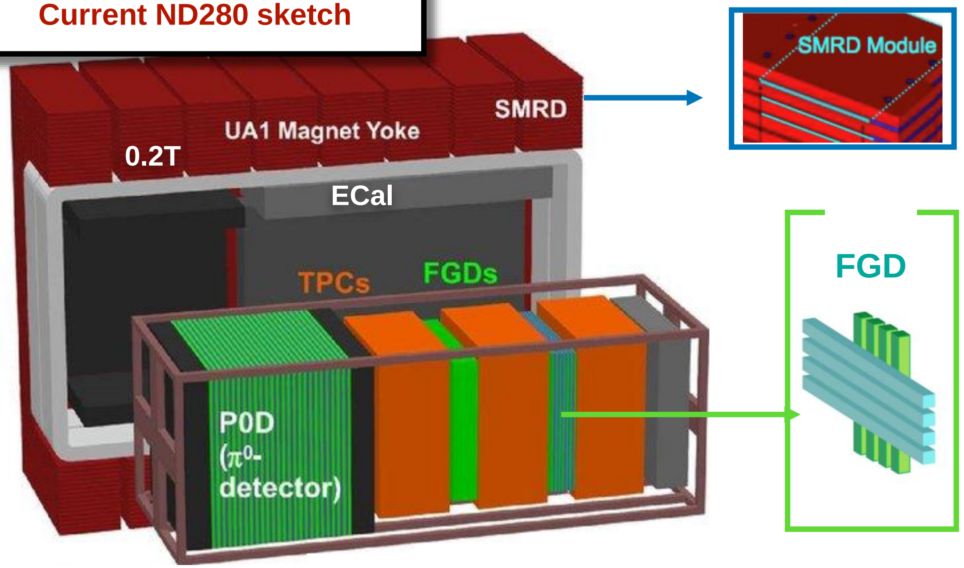






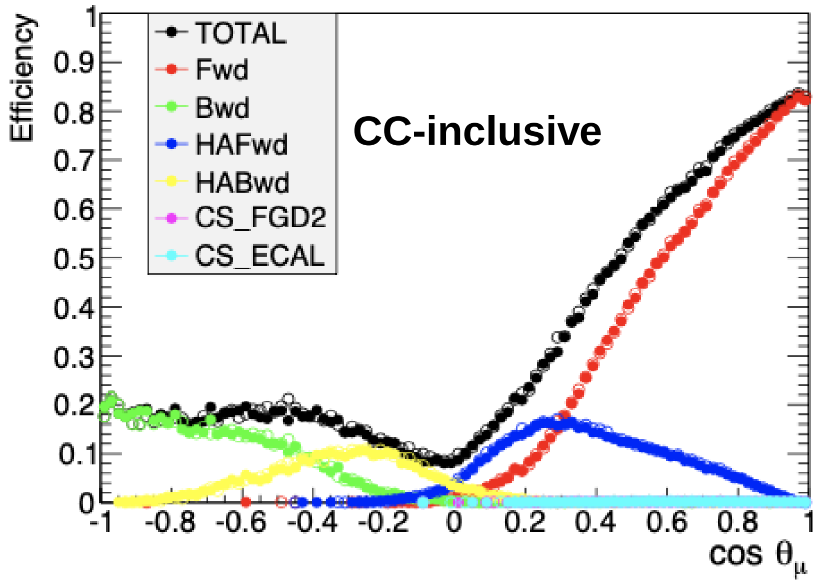
The current ND280 detector

Current ND280 sketch

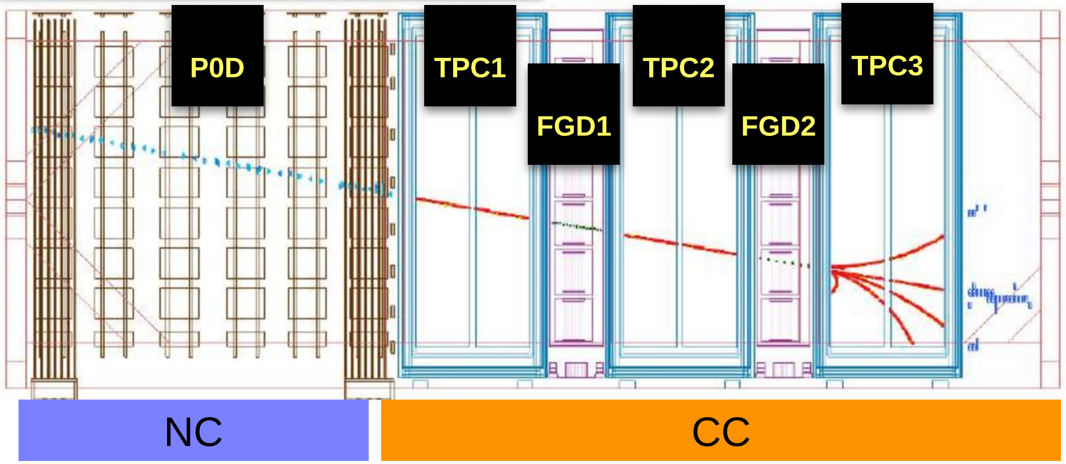


Current limitations

- 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



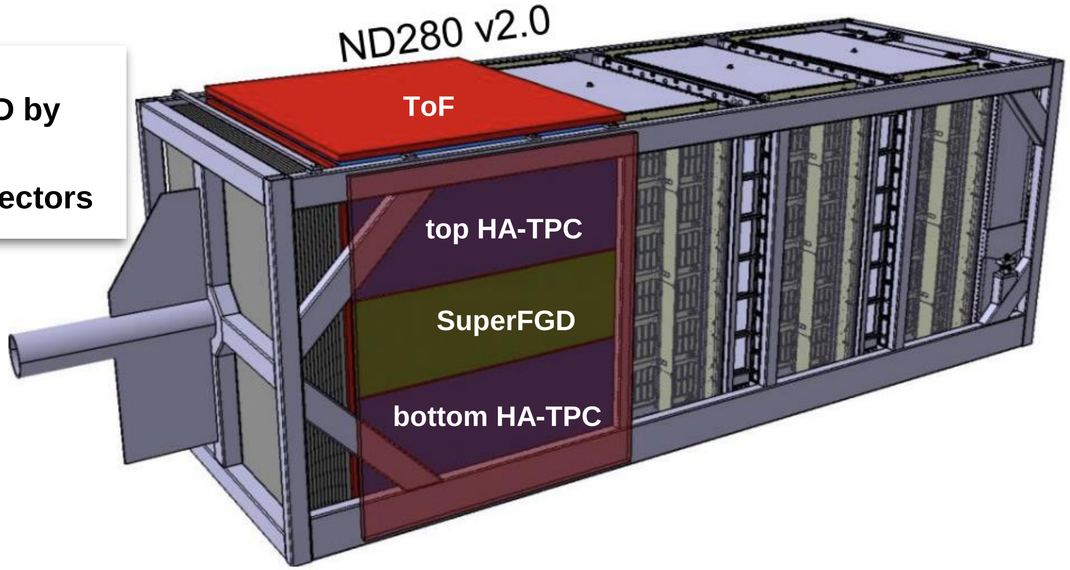
Event display of basket elements



The upgraded ND280 detector

Replace P0D by

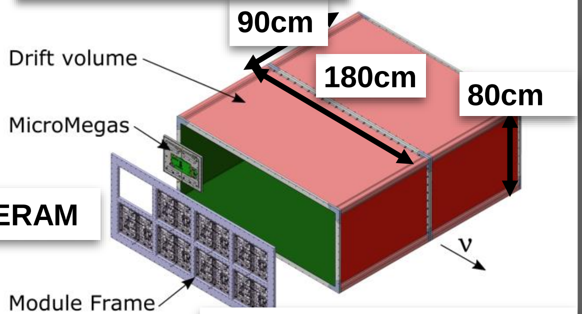
new subdetectors



Milestones

- ✦ 2018 → TDR arXiv:1901.03750
- ✦ 2021/22 final modules
- ✦ 2022 installation

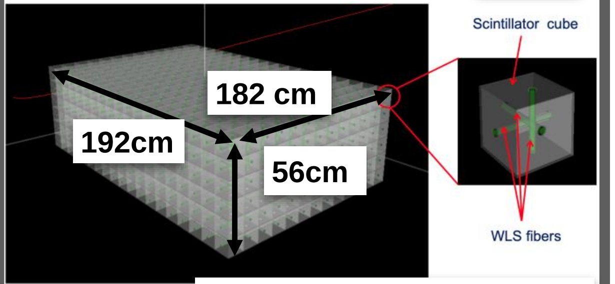
2 High Angle TPCs



New read-out concept

NIM A 957 163286 (2020)

1 SuperFGD



Novel detector concept

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

6 ToF panels

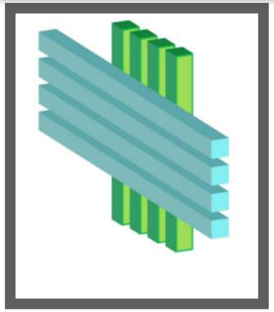
150 ps time resolution resolution

JPS Conf. Proc. 27, 011005 (2019)

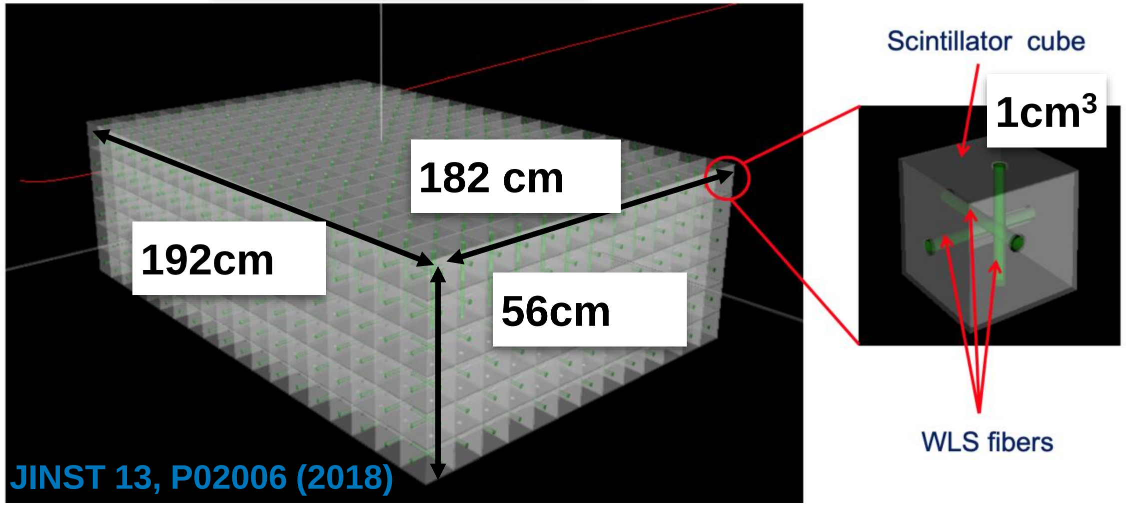
A new scintillator tracker concept (SuperFGD)

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

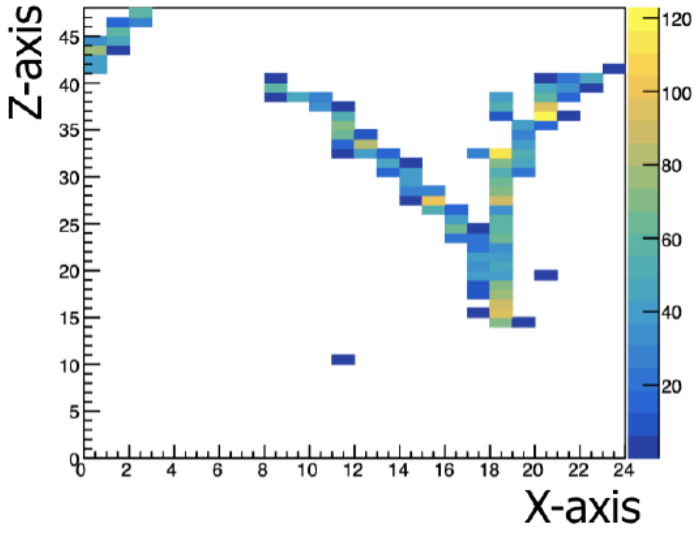
FGD concept

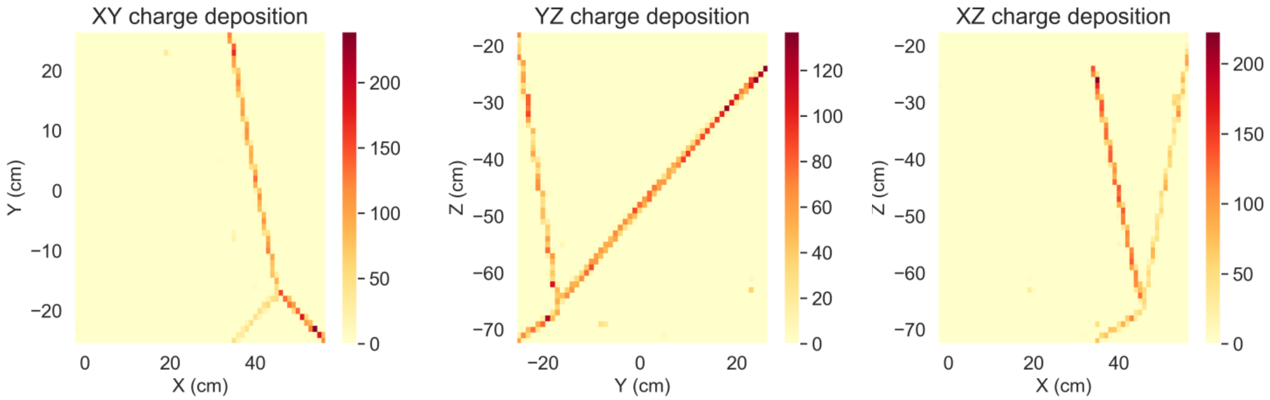


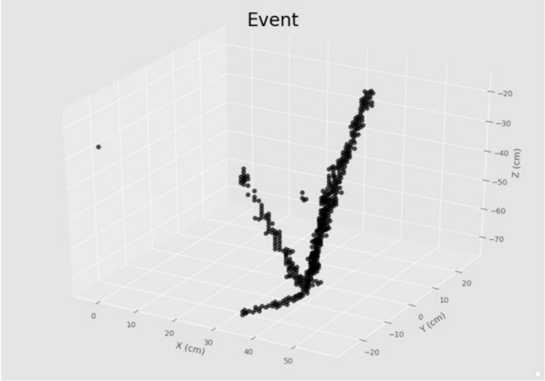
SuperFGD concept



Testbeam event

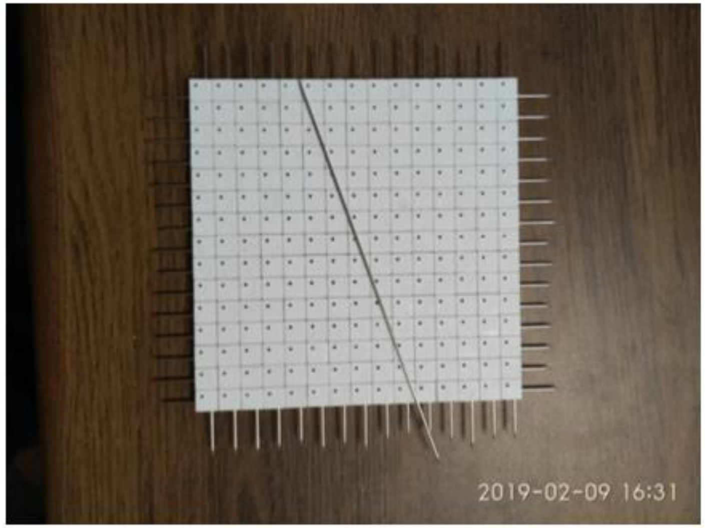


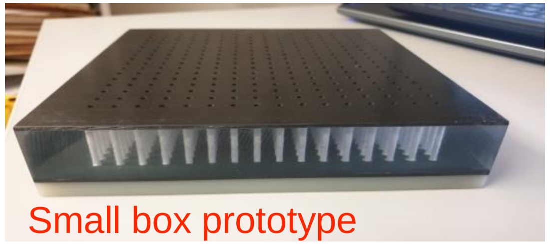


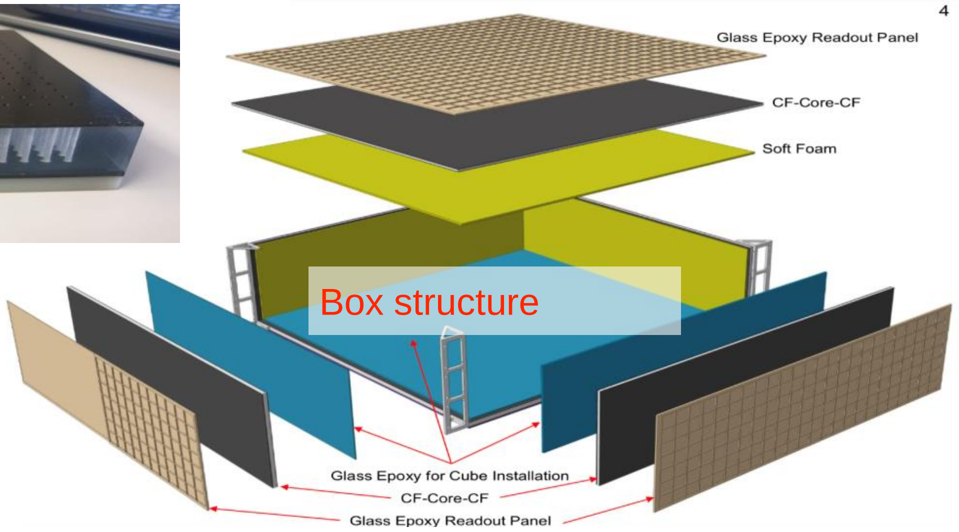


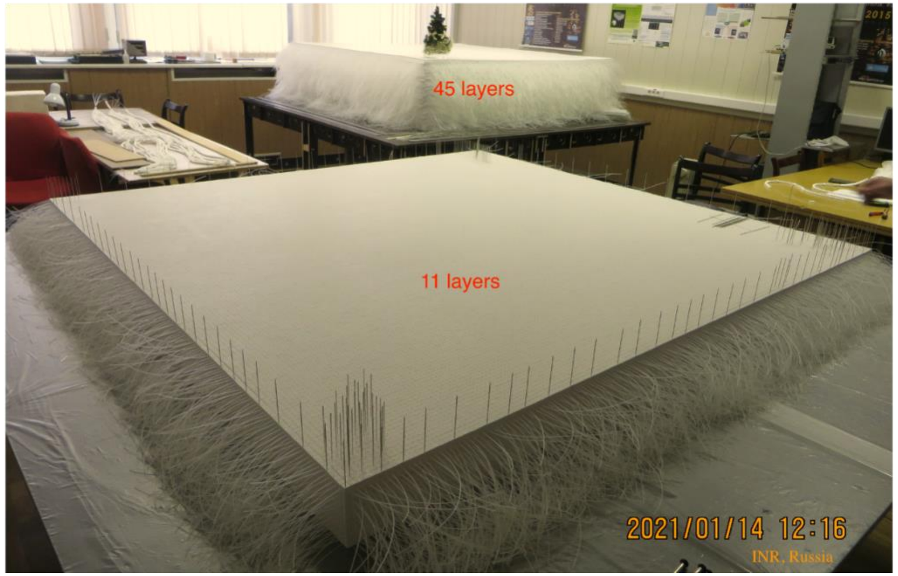
Scintillator cubes and Box design

- Production of all cubes (~2.1 millions) finished.
- All cubes and holes underwent quality control
- 56 layers + 1 spare (182x192 cubes) assembled
- Design of the box finished and validated with prototypes
- Box: 120k precise holes, has to withstand weight of 2 tonnes and earthquakes
- Production to be started soon



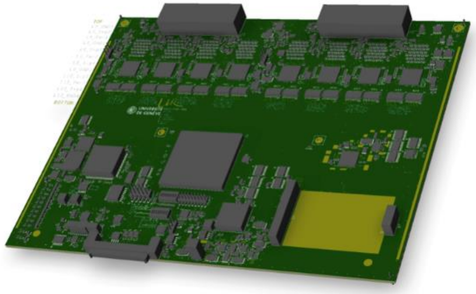

Small box prototype

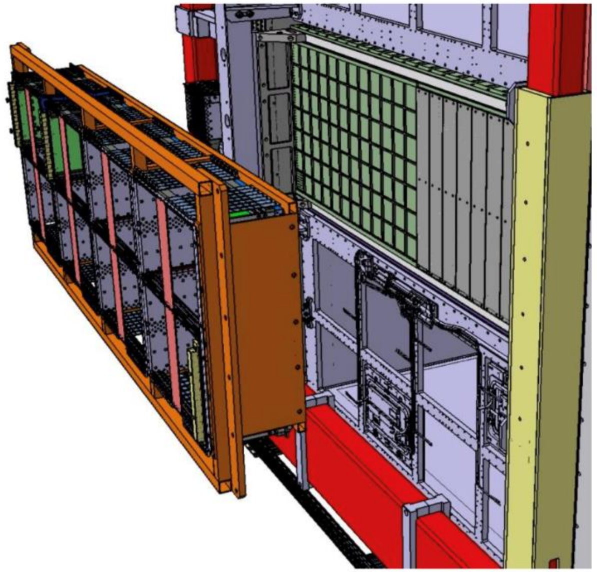


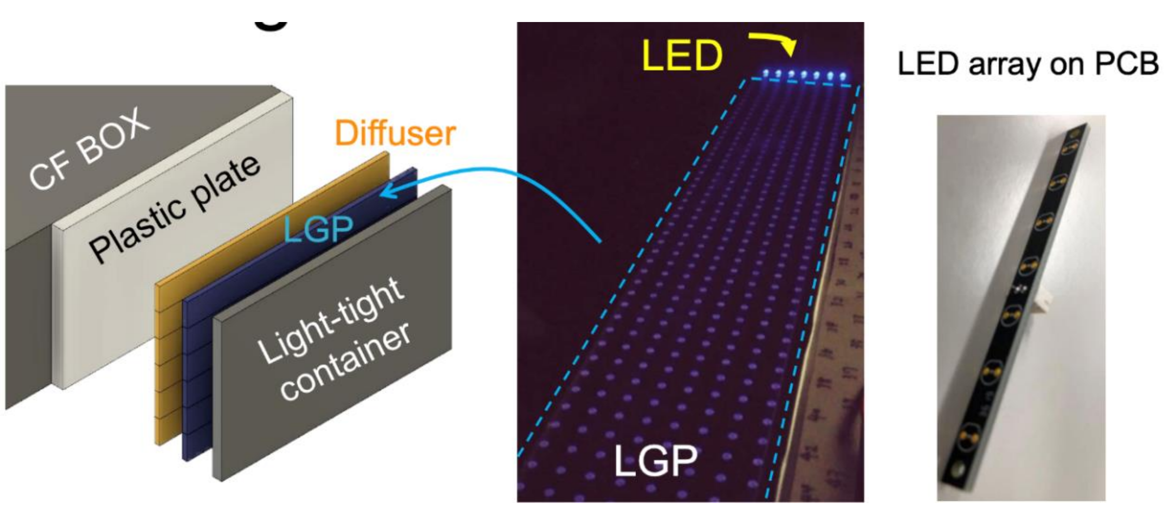


MPPC/Electronics/Calibration

- Approx. 60k MPPC will readout the fibers
- Design of electronics based on the CITIROC chip is being finished
- Excellent timing information: 2.5 ns binning
- Integrated calibration system will allow to calibrate all MPPCs regularly

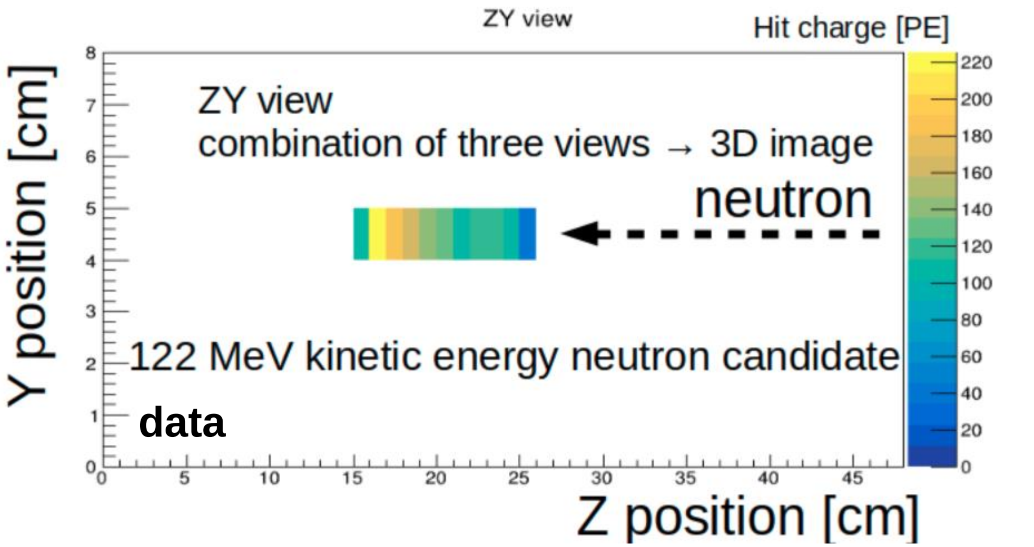


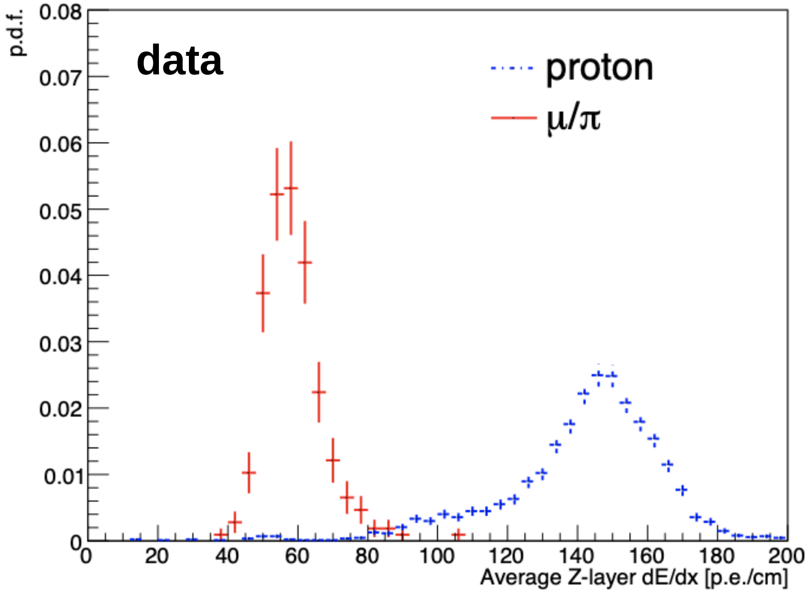


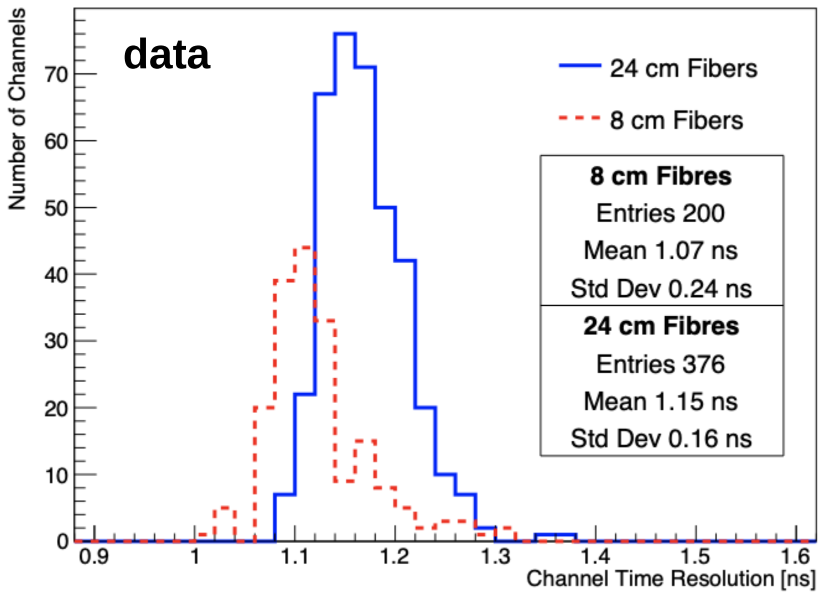


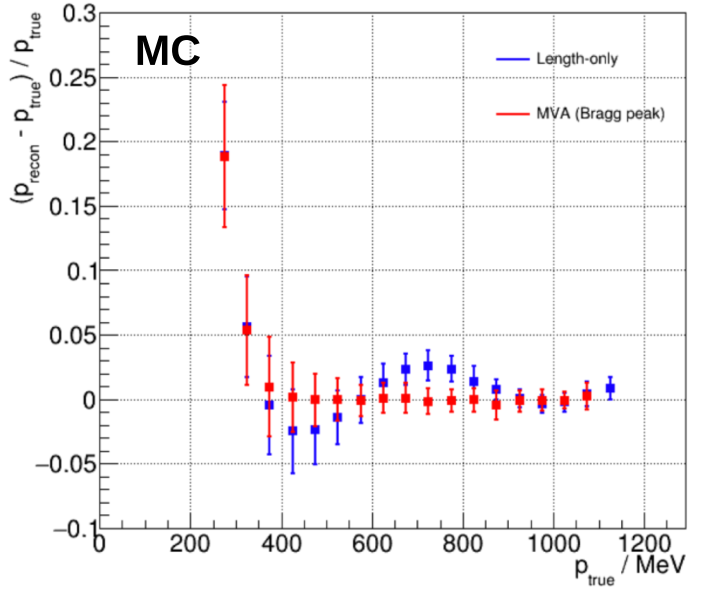
SuperFGD Testbeam and MC Performance

- 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



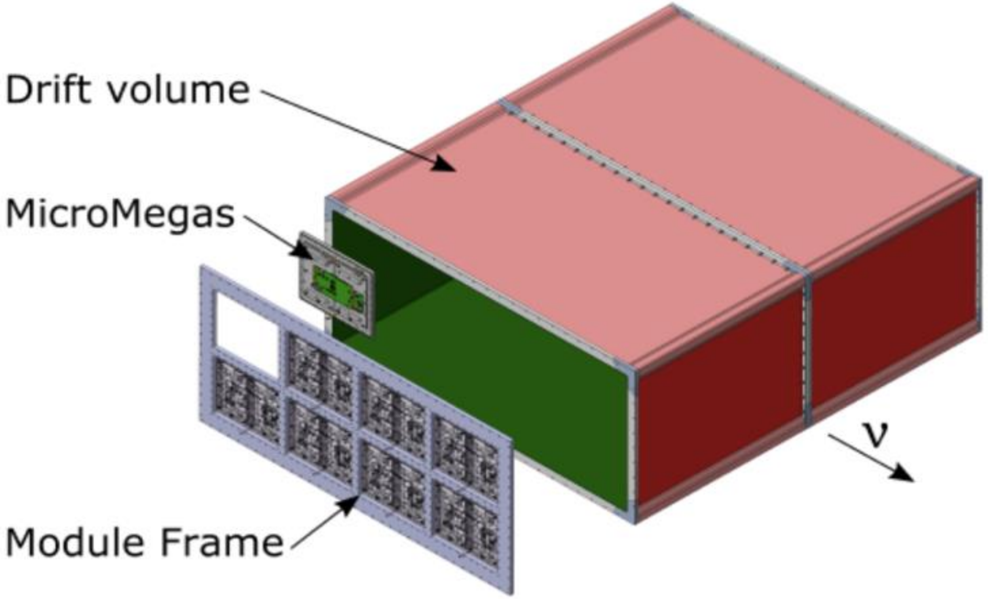




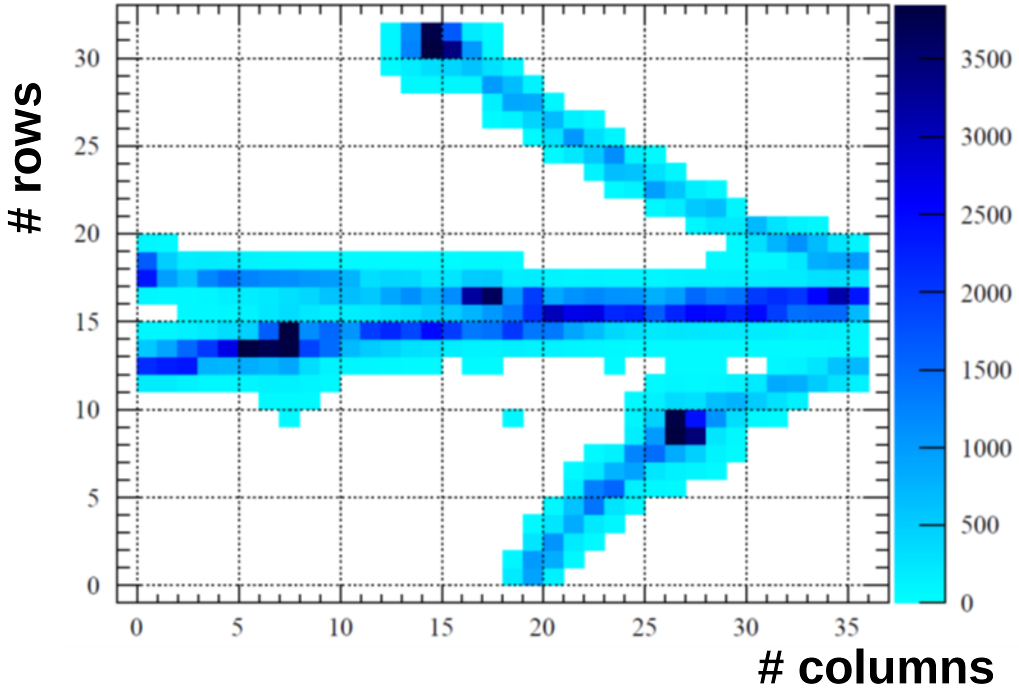


High Angle-TPCs

- 2 new TPCs 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

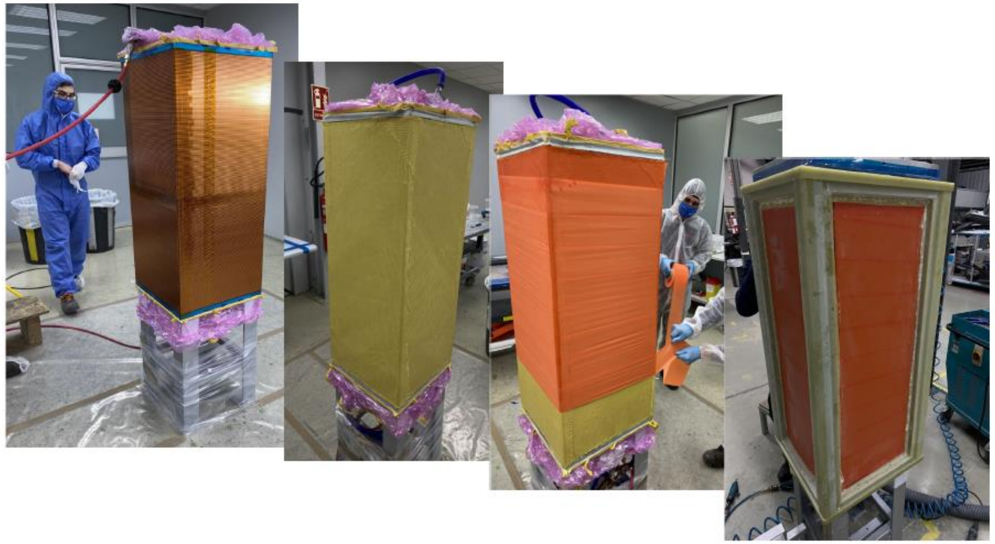


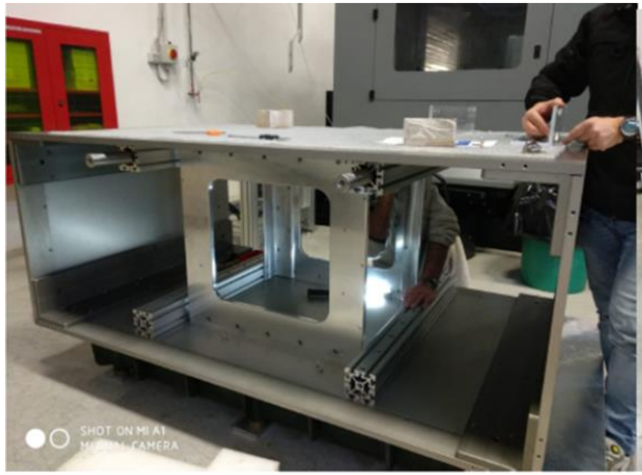
Testbeam event

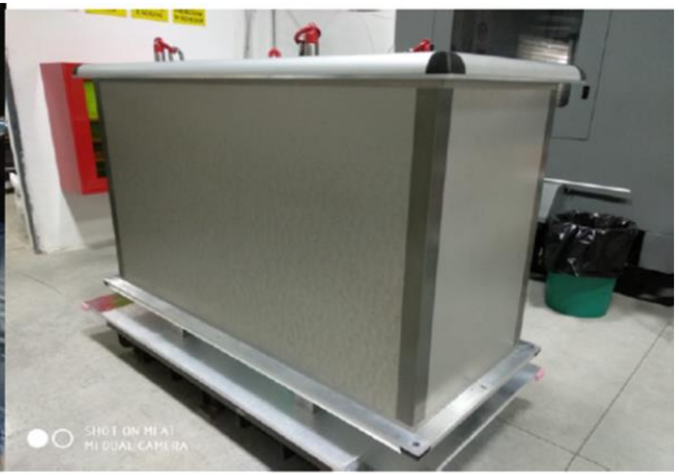


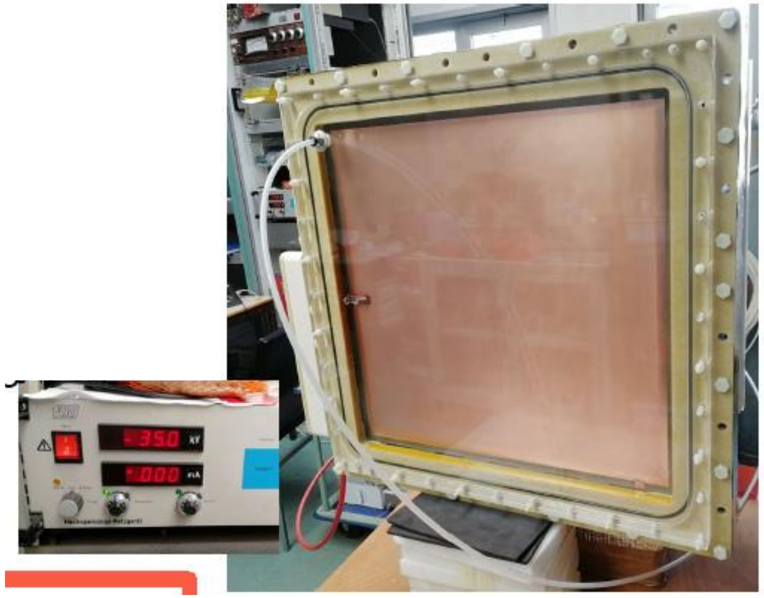
HA-TPC Field Cage

- 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



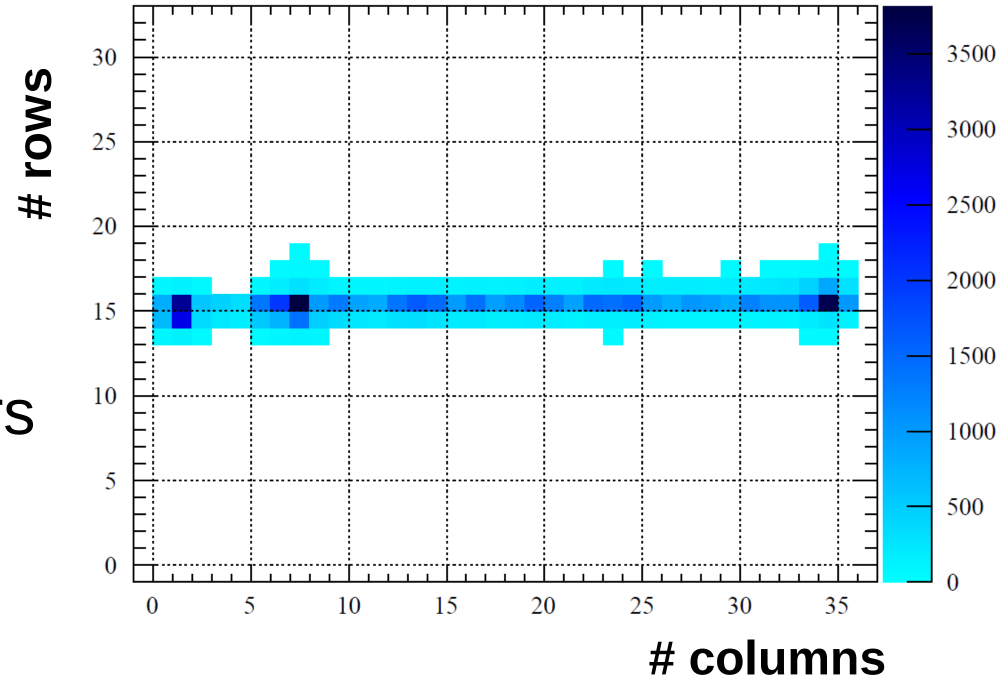


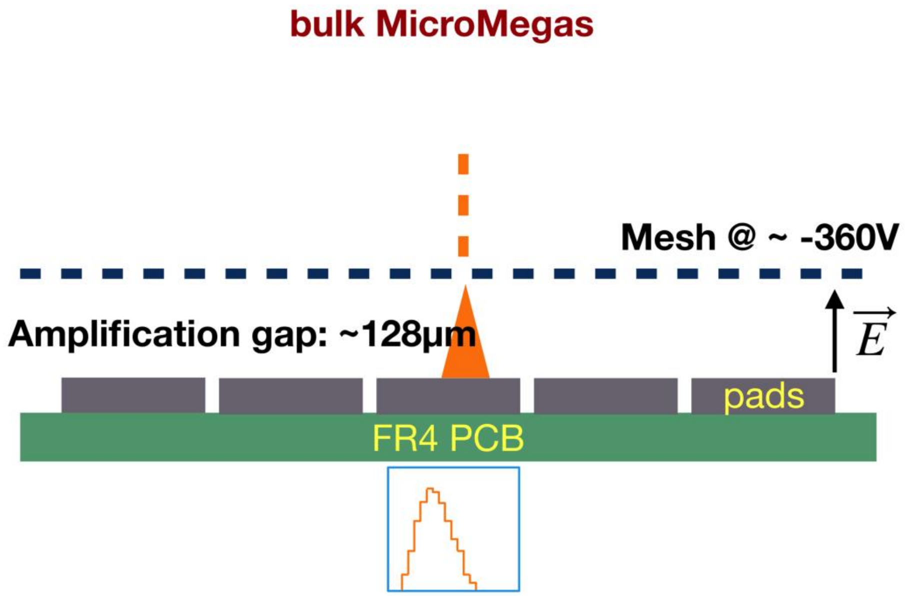


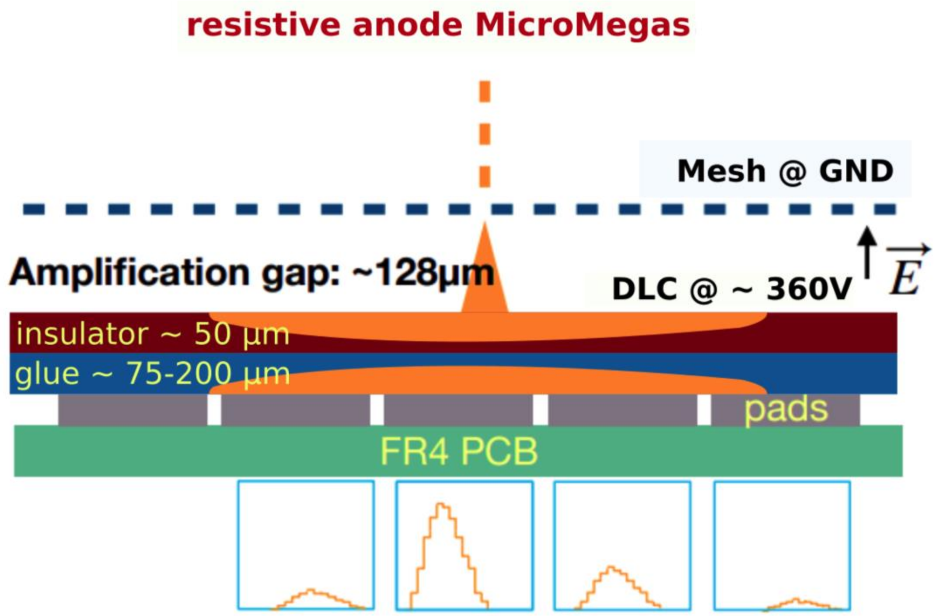


HA-TPC ERAM Modules

- 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

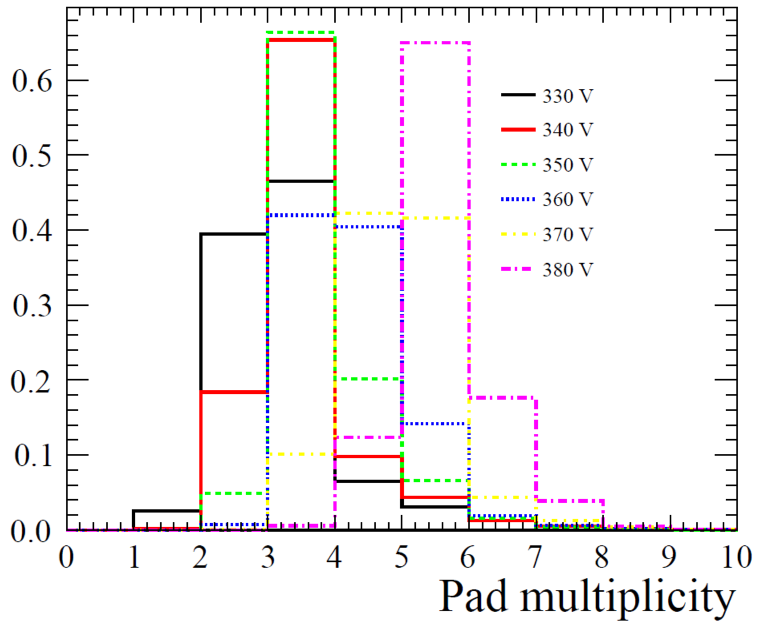


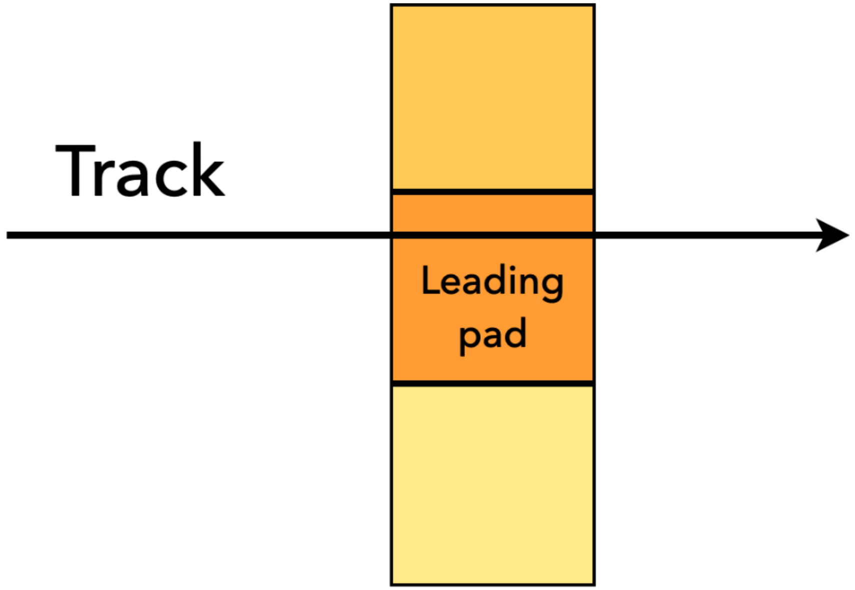


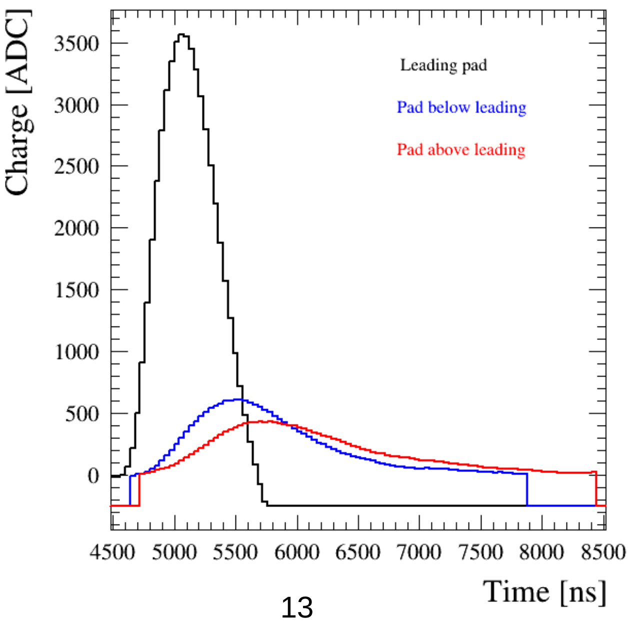


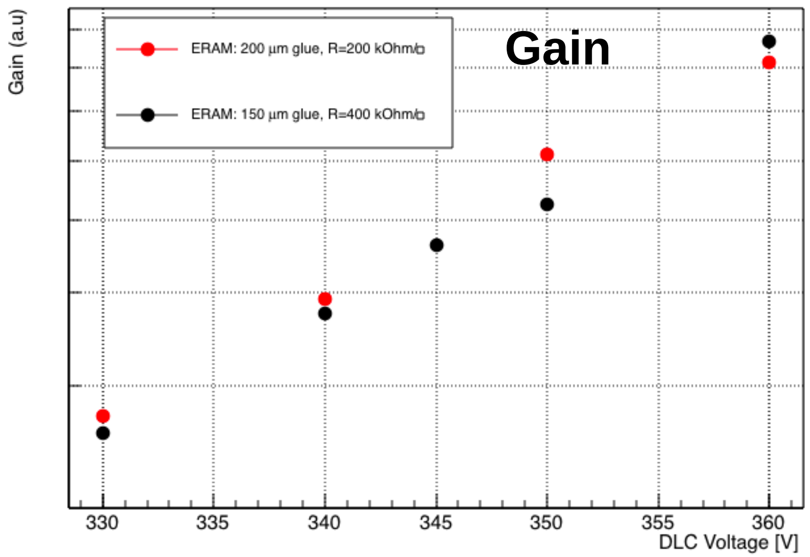
HA-TPC ERAM Results

- Prototypes tested in testbeams (DESY/CERN) and with cosmics (Saclay)
- Excellent understanding of performance of this new technology
- New reconstruction algorithms developed based on testbeam data



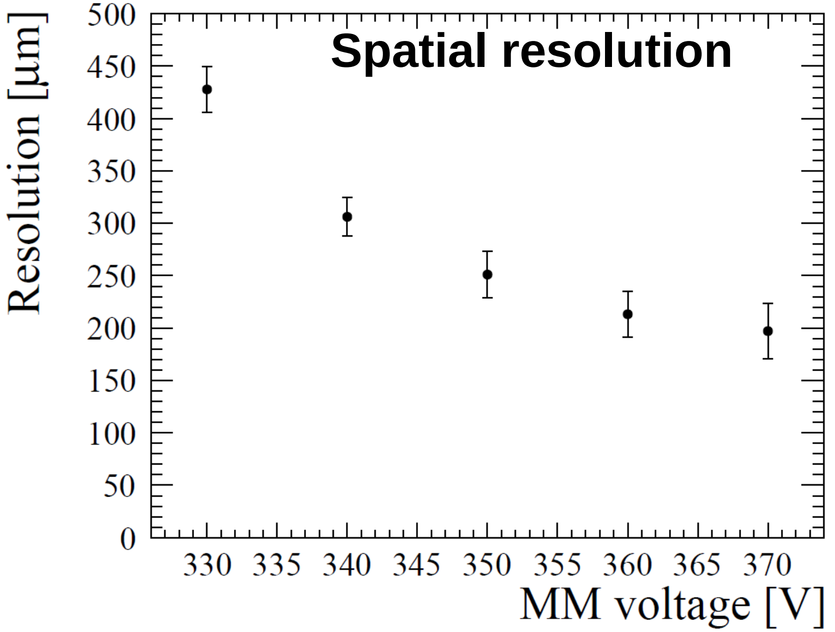


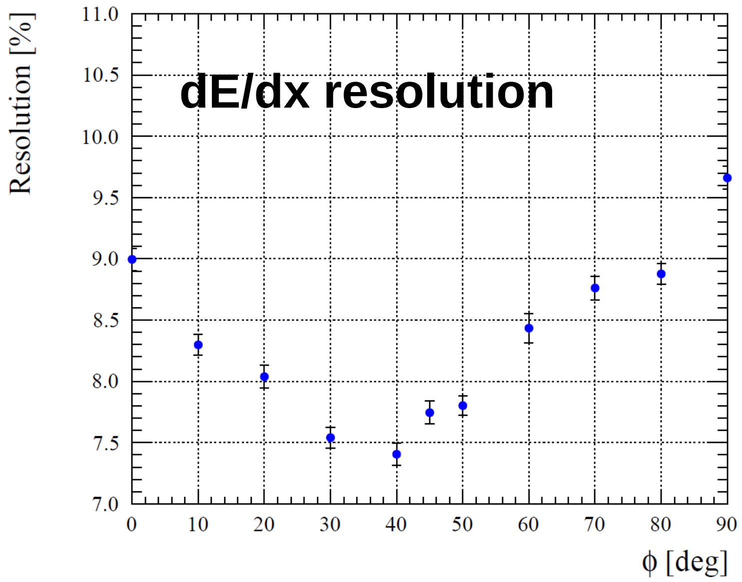


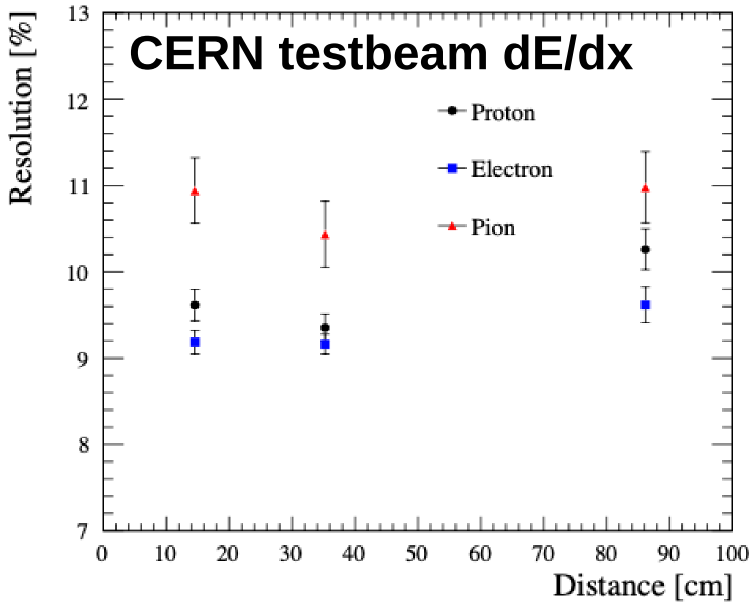


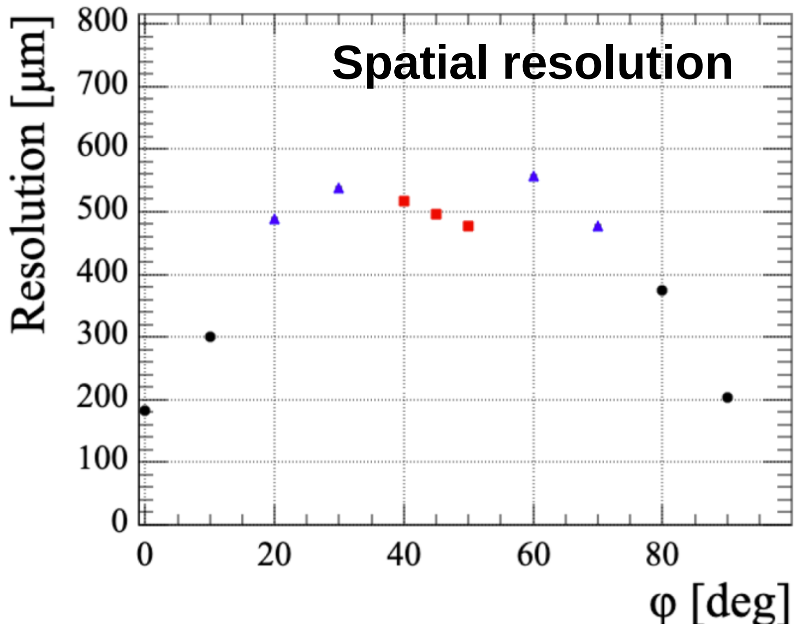
HA-TPC ERAM Results

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

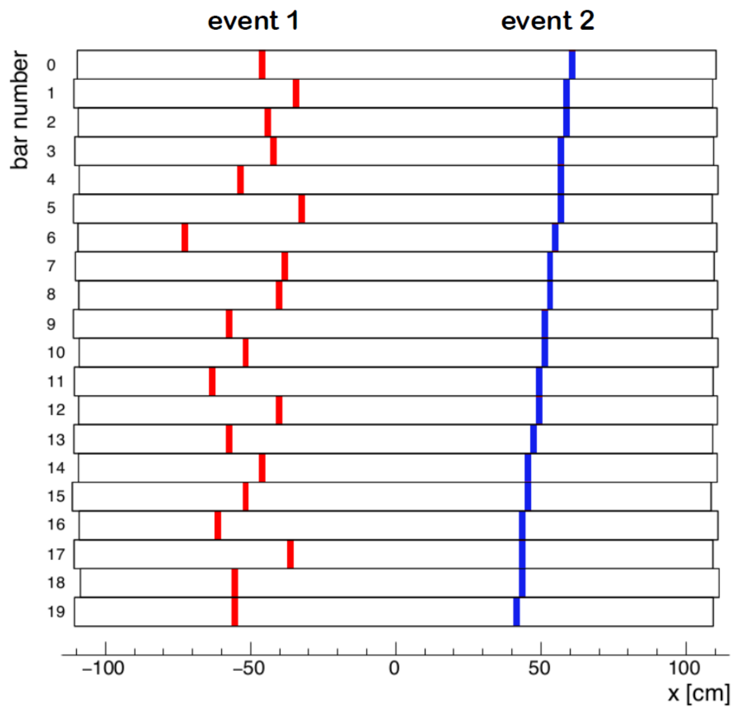




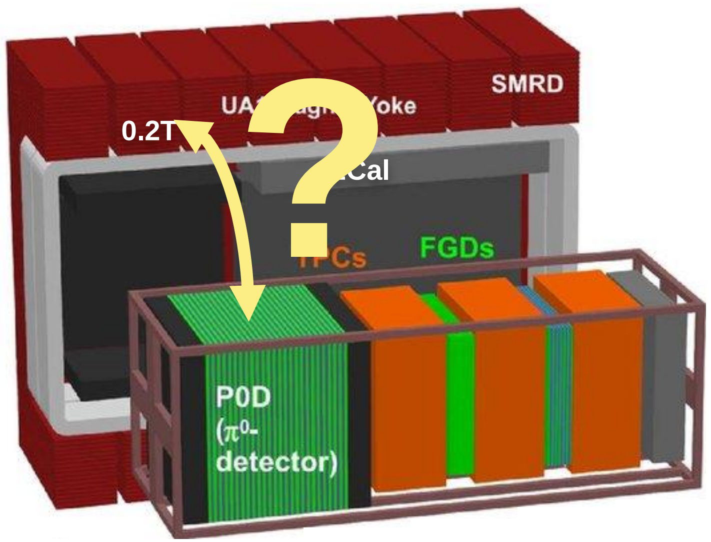


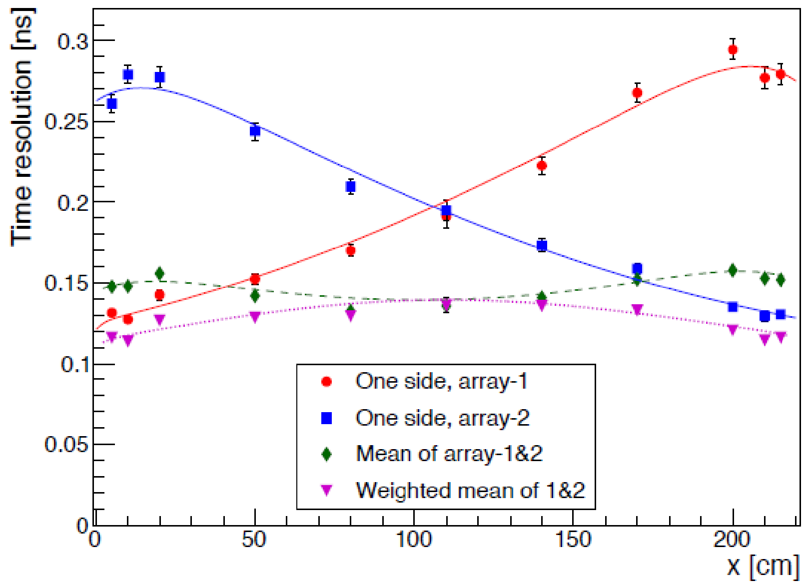


TOF



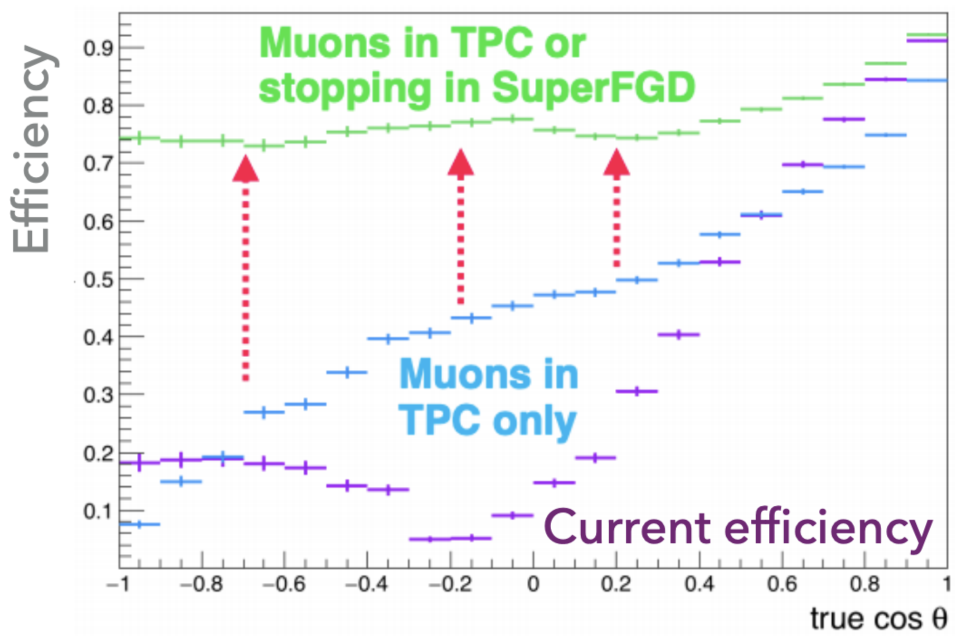
- 6 modules (2.3x2.5 m2) mounted each with 20 bars
- Double sided readout with 12 SiPMs per side
- Tested in several testbeams
- Excellent time resolution of 150 ps achieved
- Currently quality control of all modules using cosmics
- Important to determine direction of particles



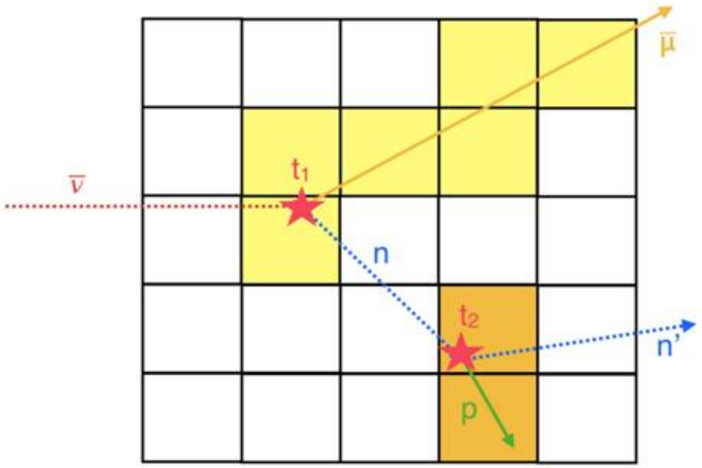


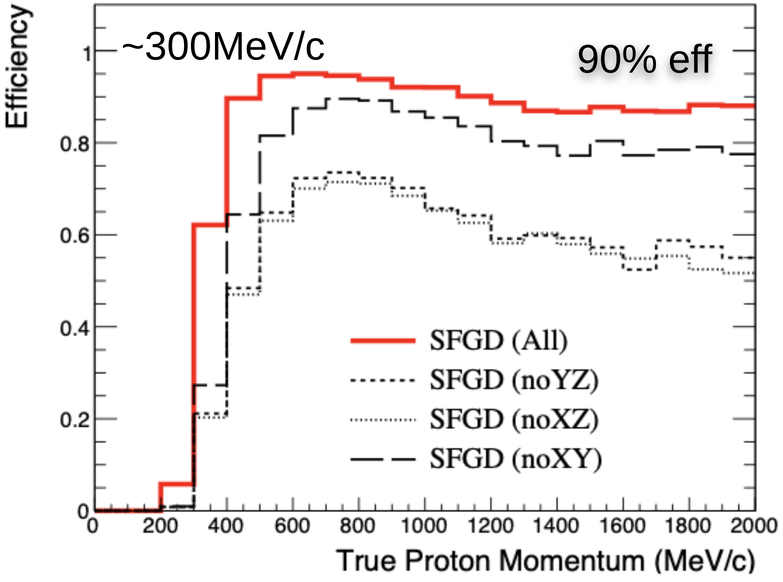
Physics Impact

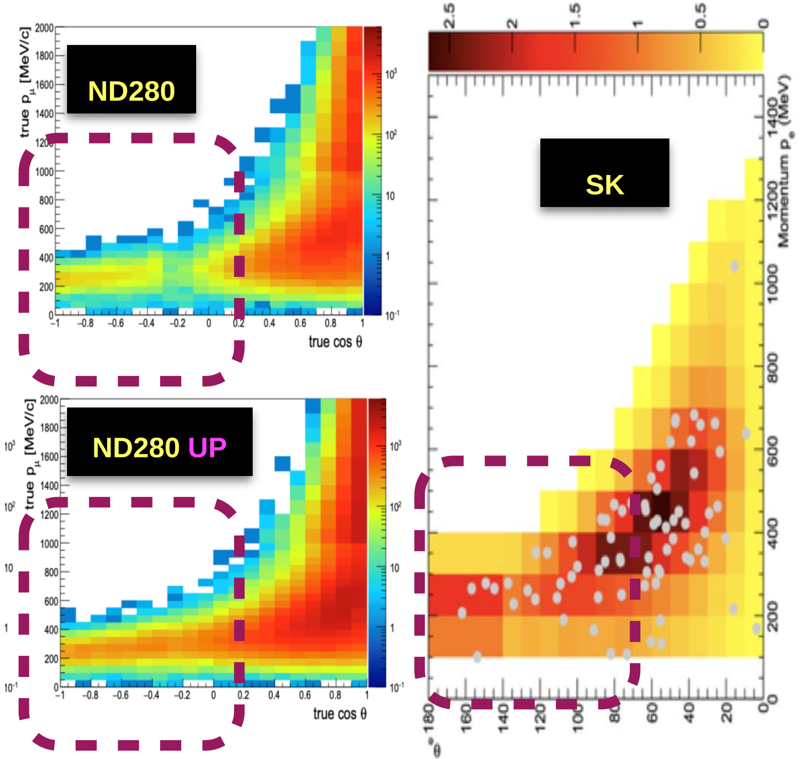
- Ugraded ND280 covering similar phase space coverage as SuperKamiokande
- Significant lower energy threshold
- Neutron detection capability



Much better constraint on beam and better cross section measurements!



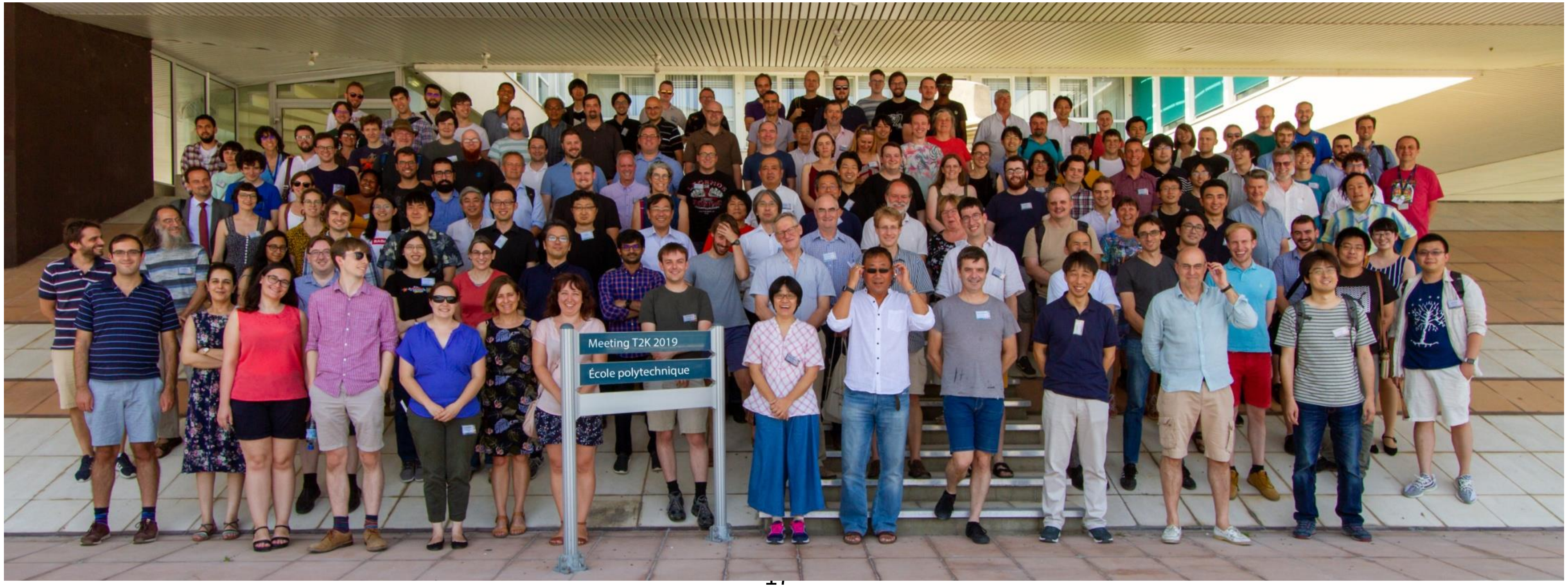




Current ND280 threshold: ~500MeV/c

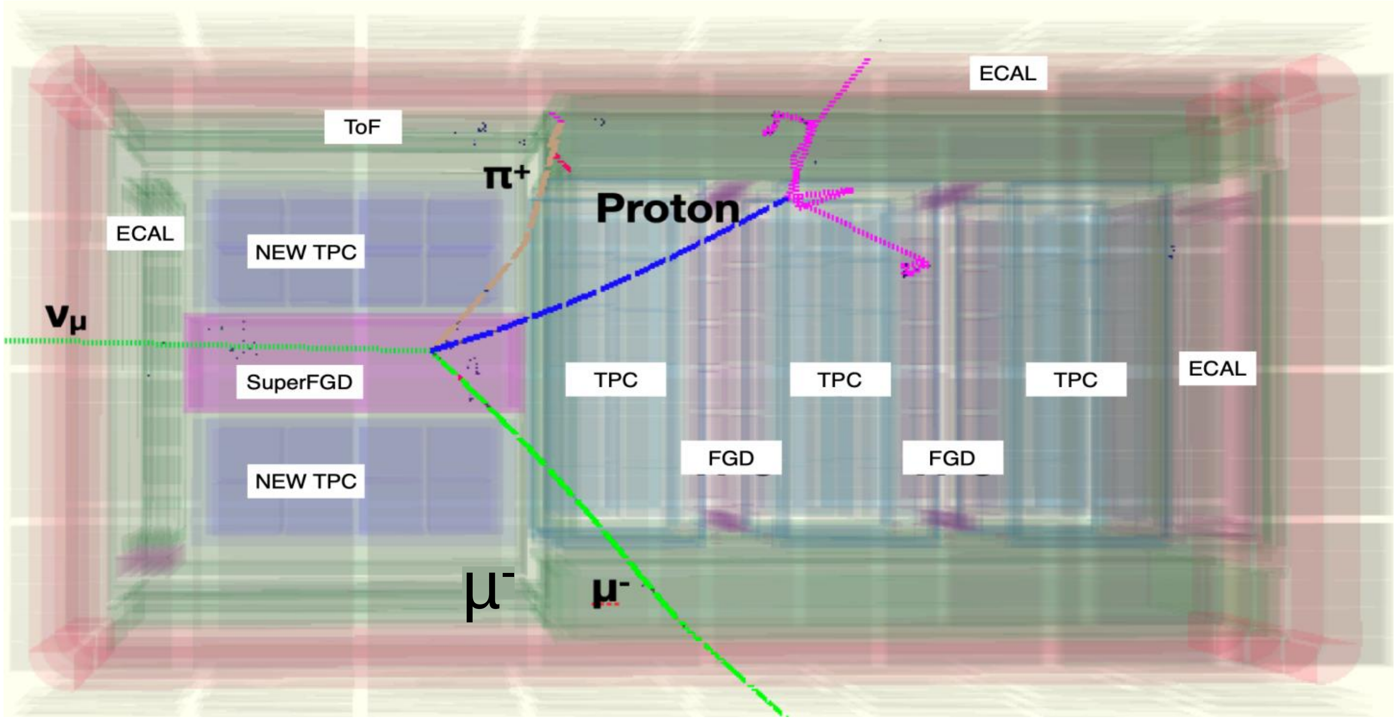
Summary

- Upgrade of ND280 will be crucial to reduce systematic uncertainties
- Important not only for T2K but also HK/DUNE
- Novel technologies will be used
- All new detector technologies were tested in intensive testbeam campaigns
- Construction of new subdetectors progressing
- T2K collaboration looking forward for the data from the upgraded ND280 in 2023



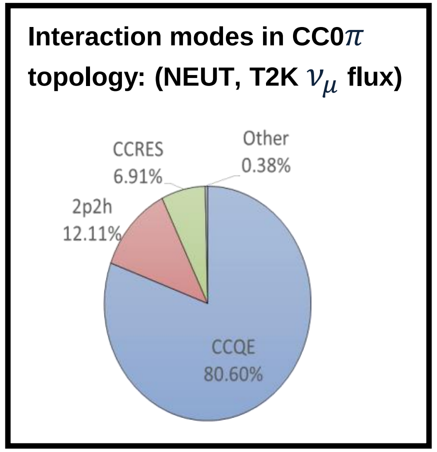
Related Talks and Posters

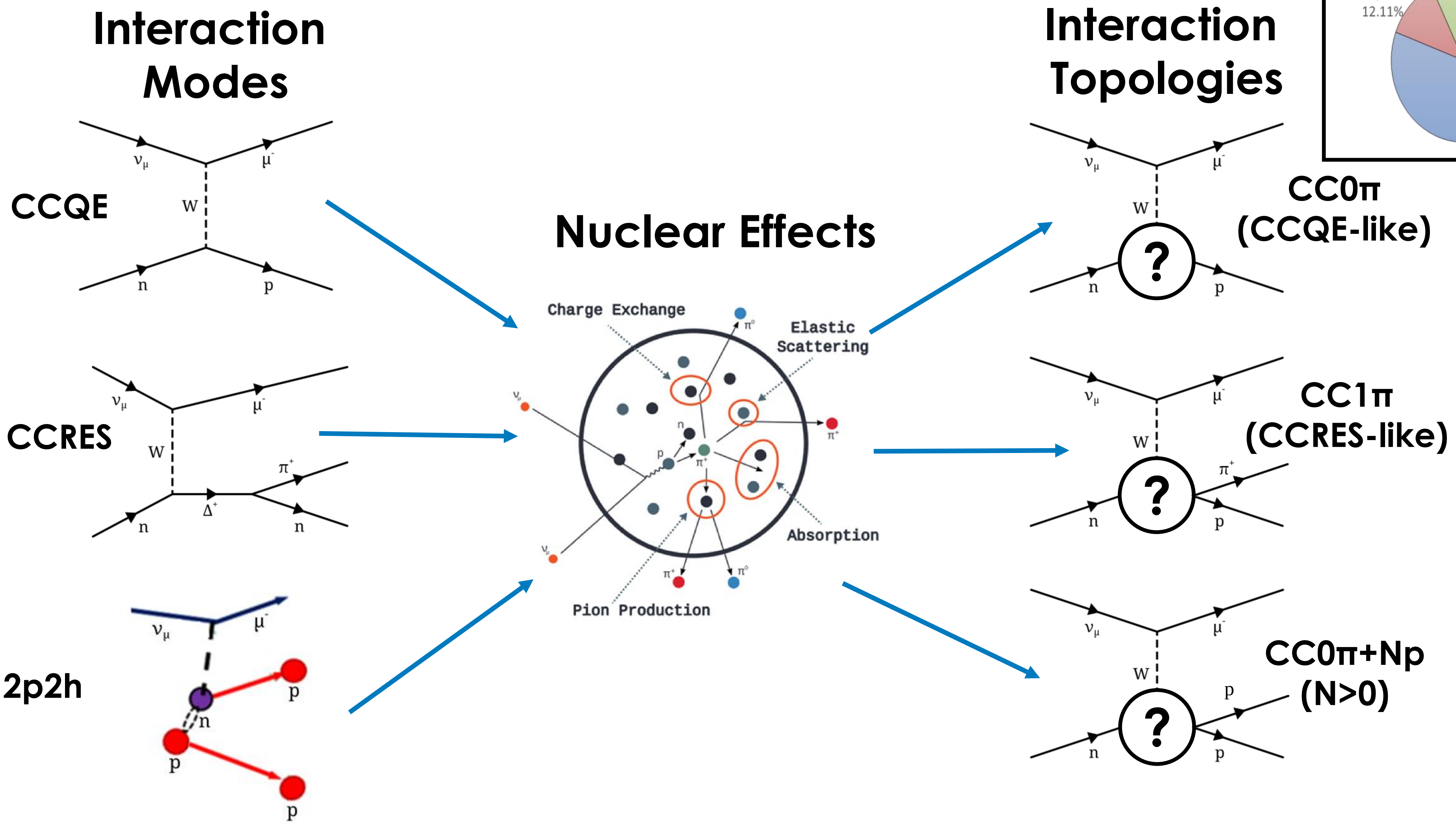
- Talk:
  - "Scintillator cubes for 3D neutrino detector SuperFGD" by Sergei Fedotov
- Posters:
  - "The SuperFGD prototype PID beam tests”
  - “Development of the in-situ Calibration System using LEDs and Light Guide Plates for the SuperFGD”



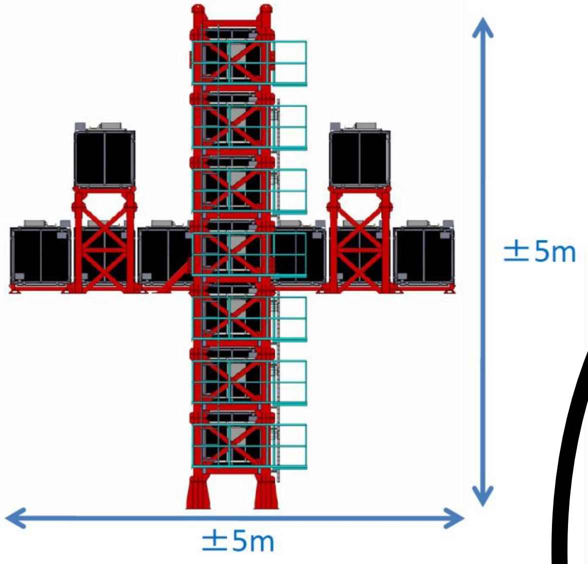
Backup Slides

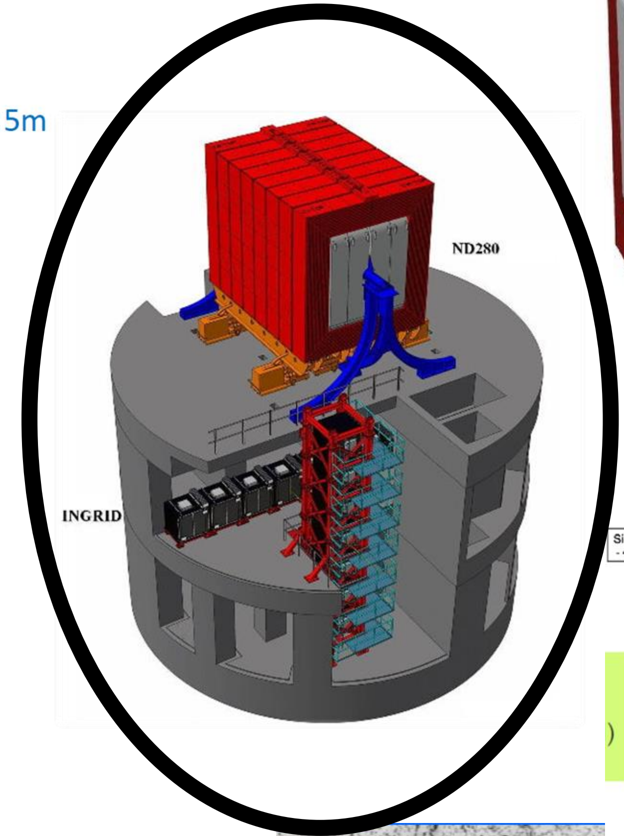
Physics Processes vs Event Topologies

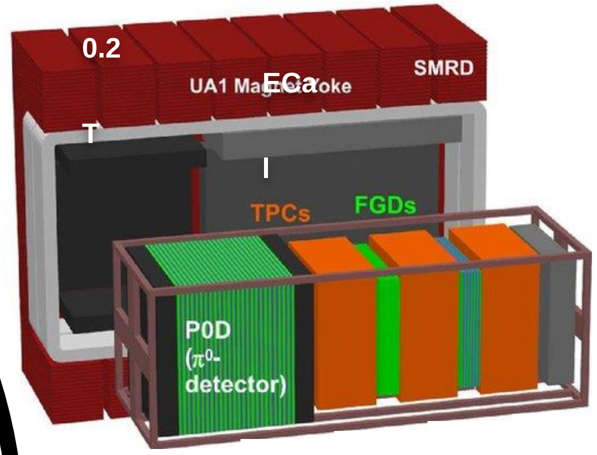




Several Near Detectors





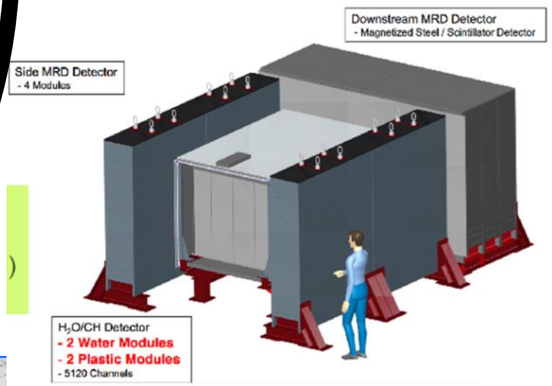


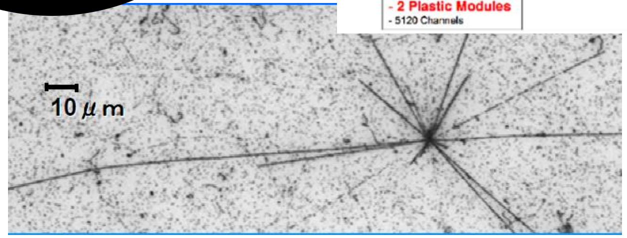
ND280:

- Off-axis
- Magnetized
- Cross-sections

INGRID:

- On-axis
- Monitoring beam direction and flux





Others:

- WAGASCI
- NINJA