T2K / TPC detector

Workshop IRFU MPGD

Saclay, December 6, 2011

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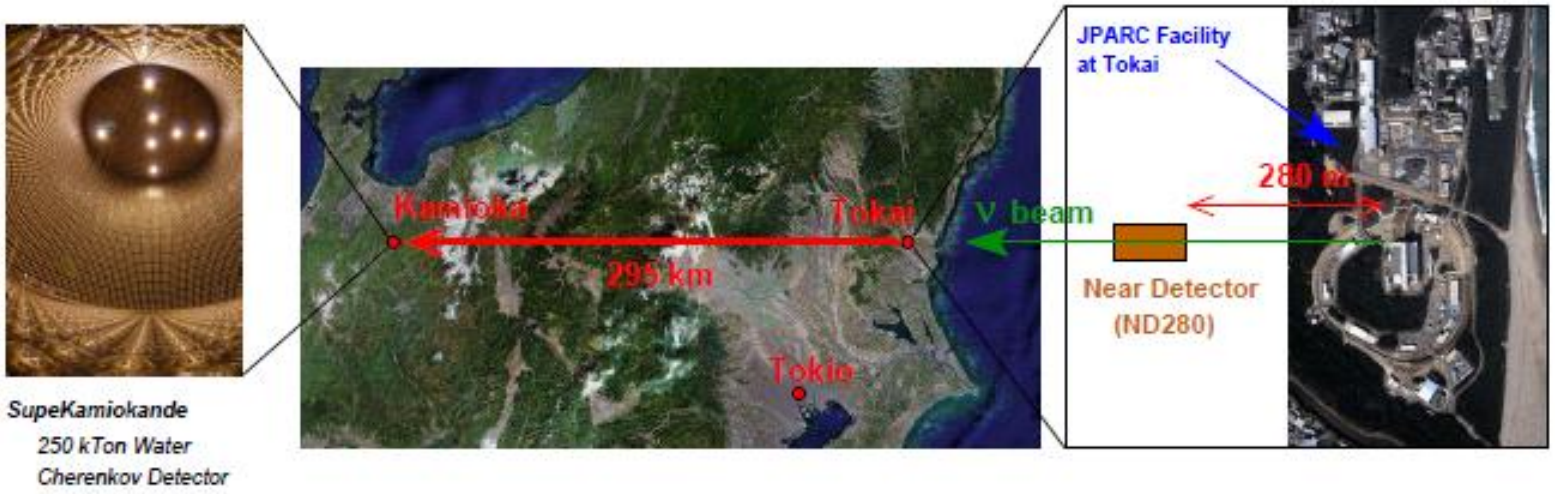
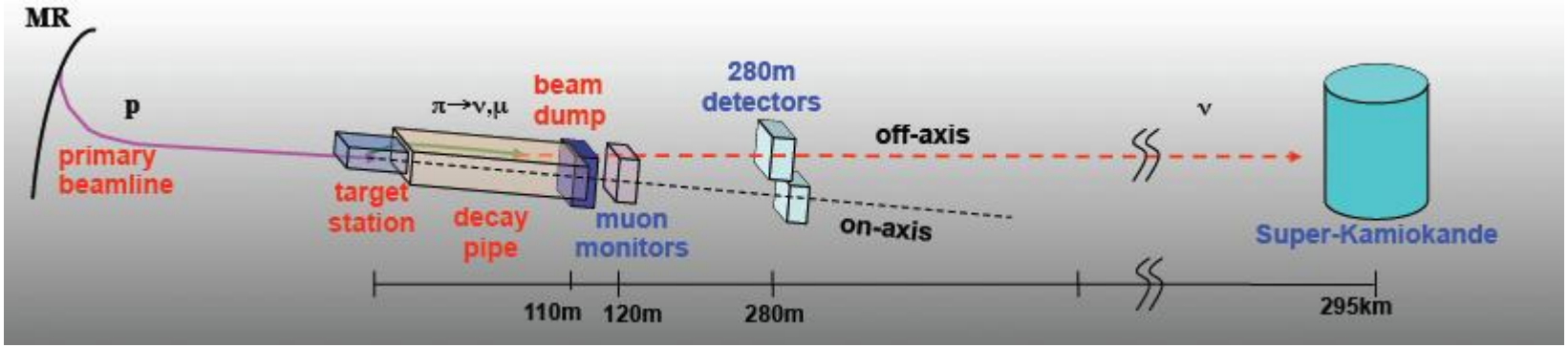
CEA, IRFU, SPP, Saclay

The T2K experiment



- Long Baseline Neutrino oscillation experiment.
- 30 GeV proton accelerator used to produce a ν_μ beam sent from Tokai to SuperKamiokande.
  - Baseline **L = 295 Km**
  - Peak neutrino energy **E_ν ~ 0.6 GeV**
- **ν_e appearance** → First measurement of θ_{13}
- **ν_μ disappearance** → Precise measurement of θ_{23} and Δm^2_{32}

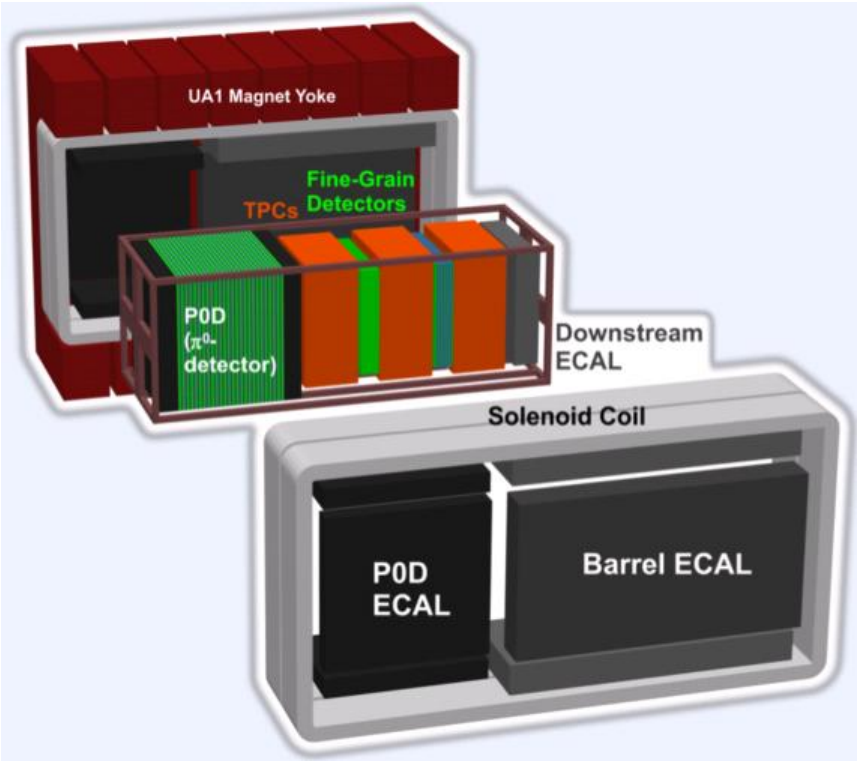
ND280 in T2K experimental setup



- Off - Axis Near Detector ND280 at **280 meters** from the neutrino beam production target.

- Characterize the neutrino beam before oscillation:
  - Measure ν_μ energy spectrum.
  - Measure ν_e intrinsic contamination in the beam.
  - Measure cross-section of background process to oscillation signal (NC π^0).

The Near Detector ND280

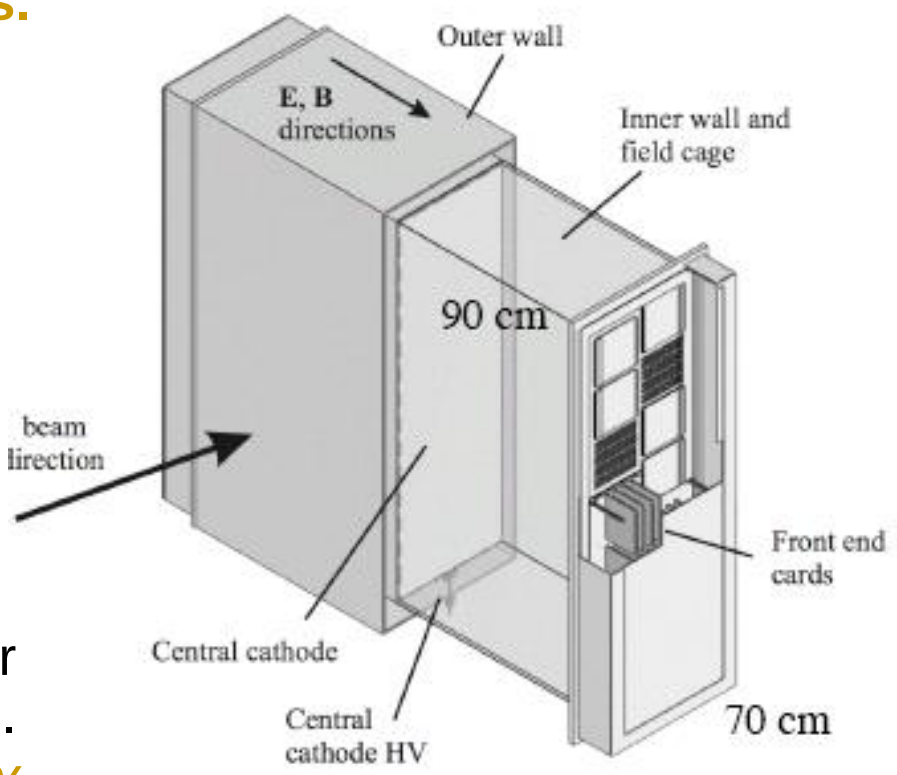


- Several detectors inside a magnet (with a field of **0.188 T**)
  - 2 FGDs: active target (1 t each) for the tracker, scintillator based (plus water in FGD 2),
  - 3 TPCs: tracking and PID,
  - P0D: scintillator bars interleaved with lead and brass sheets and water bags (π^0),
  - ECAL: scintillator planes with radiator (EM showers).
  - SMRD: scintillator planes in magnet yoke (high angle muons).

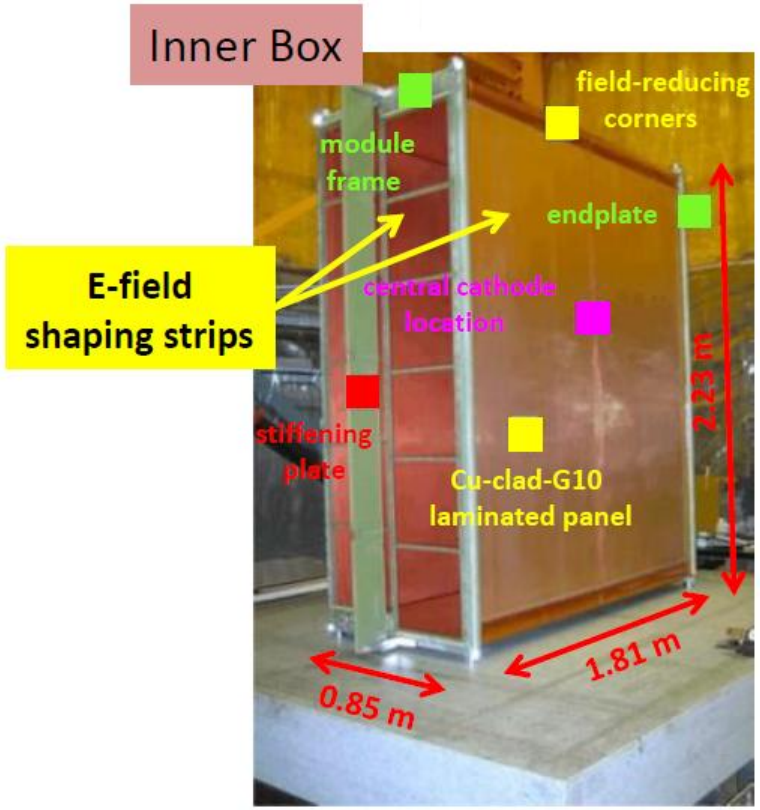
The Time Projection Chambers

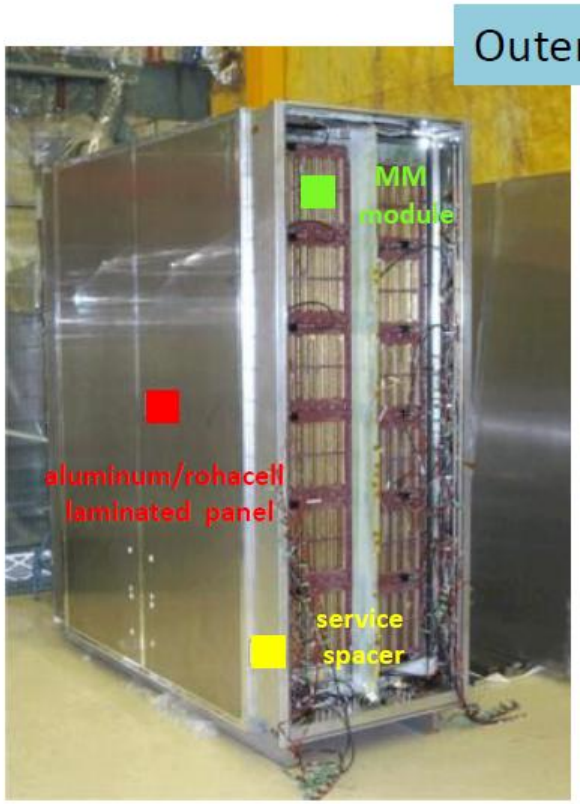
- **3 large TPCs with central cathodes.**
- Tracking length: **72 cm** (per TPC).
- Long drift distance: **90 cm** (x2).
- Active height: **200 cm**.
- Total active area: **~9m²**.

- Requirements:
  - **$\delta p_t/p_t$ < 10% @ 1GeV** to reconstruct neutrino energy spectrum.
  - Absolute momentum scale smaller than **2%** (for Δm^2_{32} measurement).
  - **dE/dx resolution better than 10%** to separate electrons from muons.



Mechanical structure

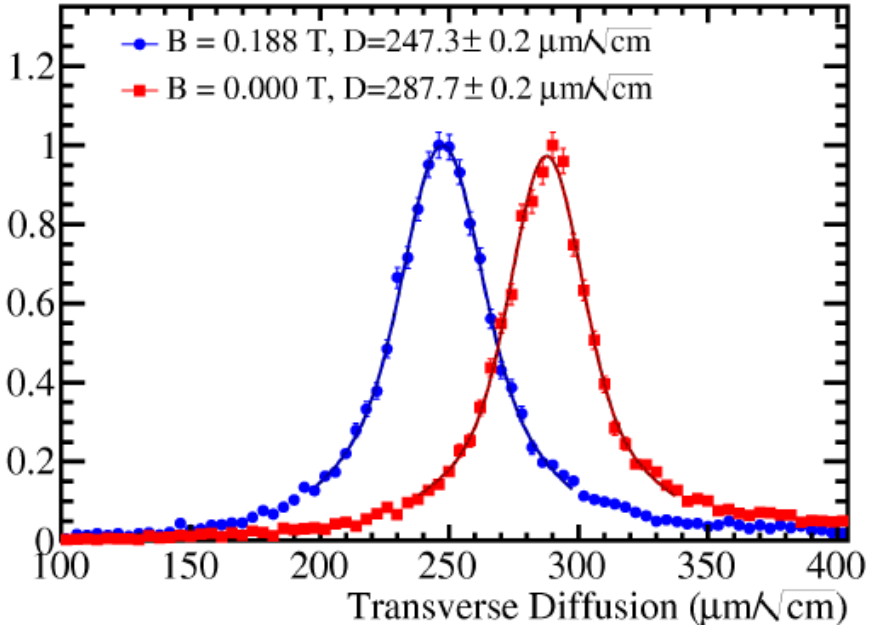


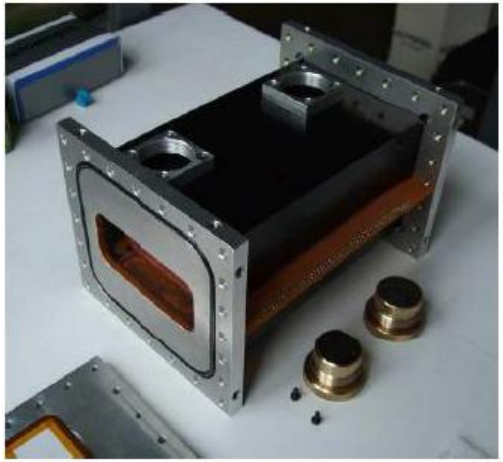


- E-field shaped by copper strips
  - Cathode flatness: **0.1 mm**.
  - Module plane planarity: **0.2 mm**.
- Service spacer (cooling, HV connections, electronics, temperature probes, ...).

Gas

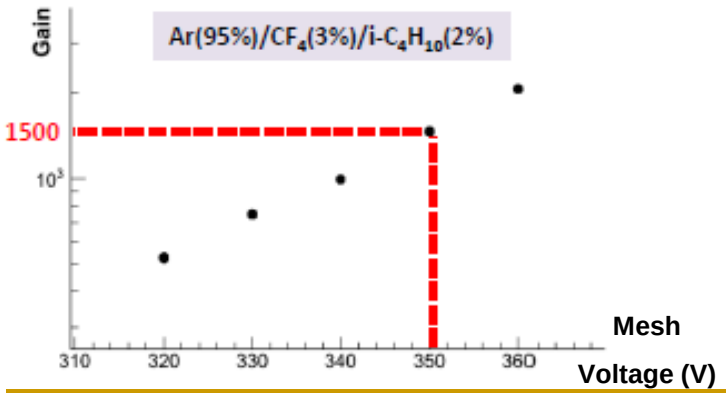
- Gas mixture in the inner drift volume:
  95:3:2 Argon:Freon:Isobutane.
- Gas properties:
  - Low transverse diffusion:
    250 µm/√cm .
  - Large drift velocity: **7.5 cm/µs**.
  - Few impurities : **O_2 < 2 ppm**.
- Two small TPCs monitor the supply and return gas (gain, drift velocity, …).
- Outer volume filled with **CO_2**.

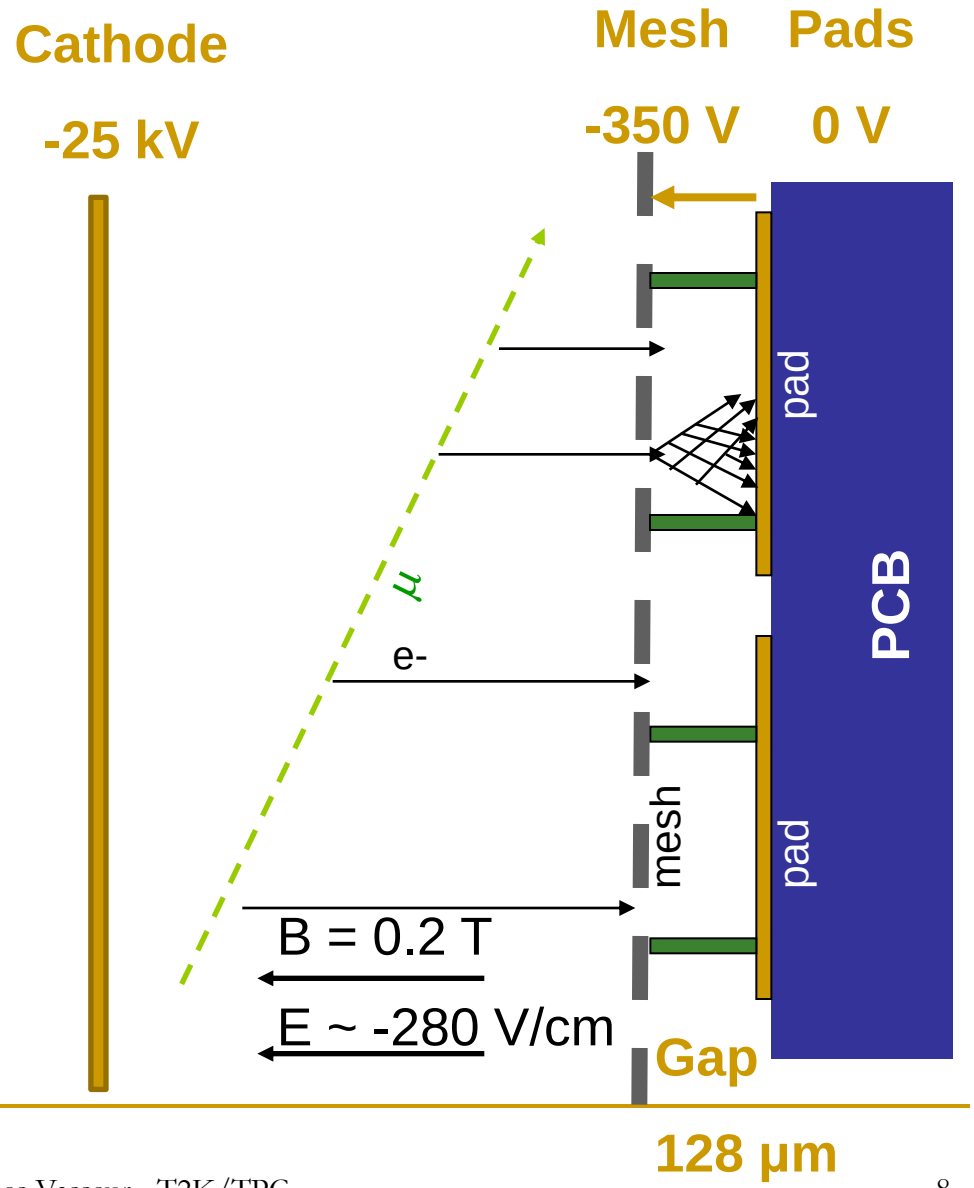




Micromegas detectors

- Ionization of the gas by charged particles crossing the TPC.
- Electrons drift to the Micromegas mesh.
- Avalanches generated in the amplification region.
  - **Gain ~ 1500**





Micromegas module

- Bulk-Micromegas technology
  - *Nucl. Instrum. Meth. A560, 405 (2006)*

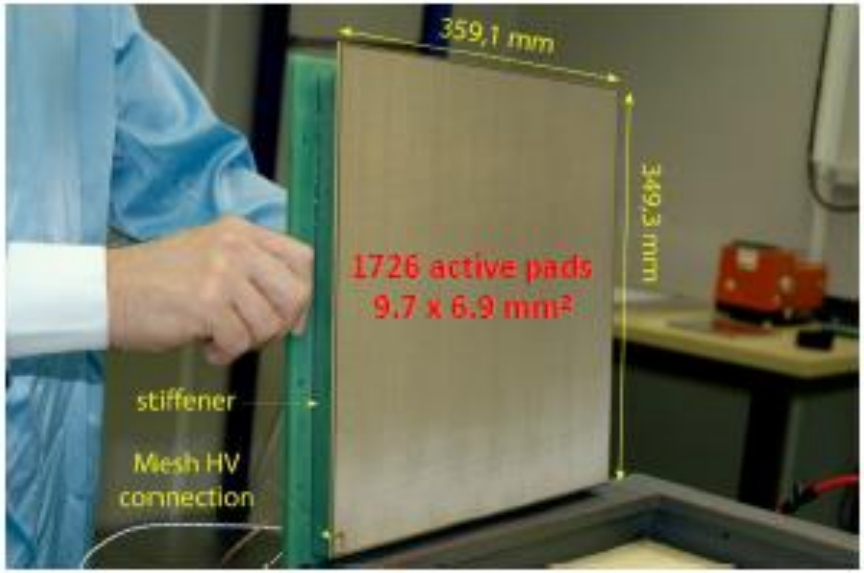
- 12 modules on each endplate

→ 72 modules in 3 TPCs

- Each module (35 x 36 cm²) has 1726 active pads (6.9 x 9.7 mm)

- Total of ~120 000 channels

- MM modules were produced at **CERN/TS-DEM-PMT**



Readout electronic

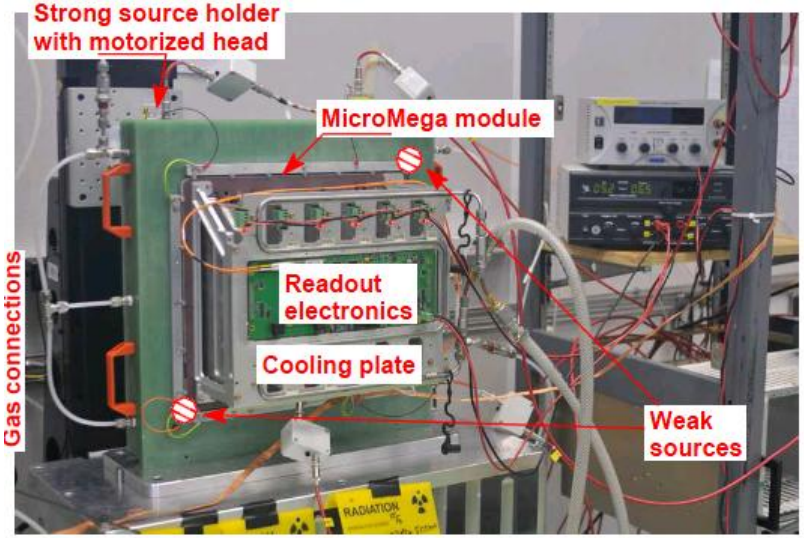
- FEE based on asic AFTER (72 channels) with programmable:
  - maximum charge (120 - 600 fC): 120 fC
  - peaking time (100 – 2000 ns): 200 ns
  - sampling frequency (up to 100 MHz) : 25 MHz
- 6 FEC + 1 FEM on each module.
- Data from 72 modules sent by optic fibers to 18 DCC and then to DAQ.

Front-End Card (FEC)

Front-End Mezzanine (FEM)

Micromegas tests at CERN

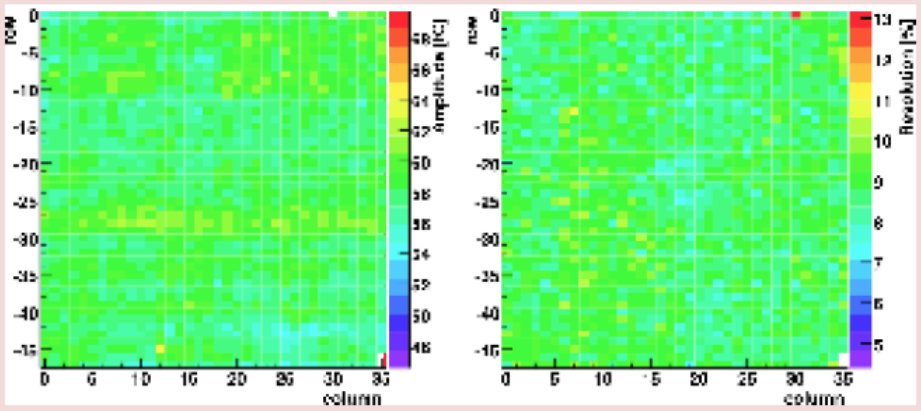
- Characterization of each module with a ^{55}Fe source emitting 5.9 keV photons.
- Results within a module:
  - Energy resolution: 6% dispersion
  - Gain uniformity: 3% dispersion



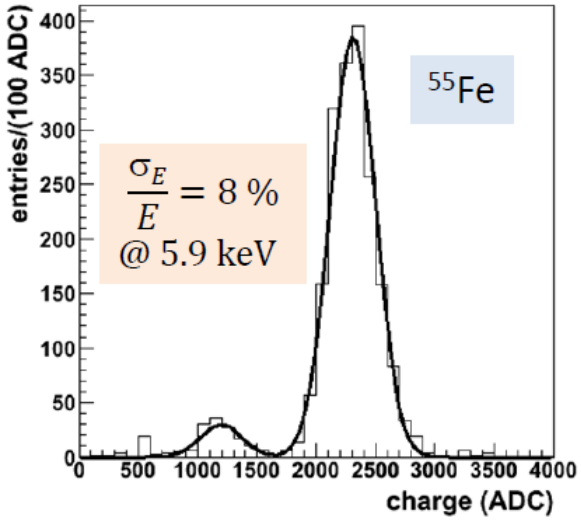
^{55}Fe

Charge collection uniformity

Resolution uniformity

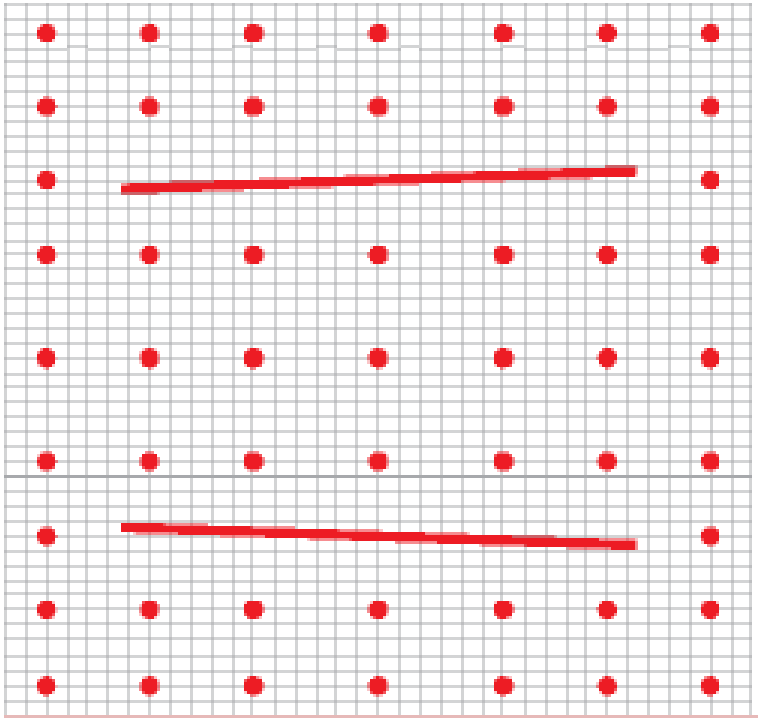


$Ar:CF_4:IC_4H_{10}$ (95:3:2)



Laser calibration system

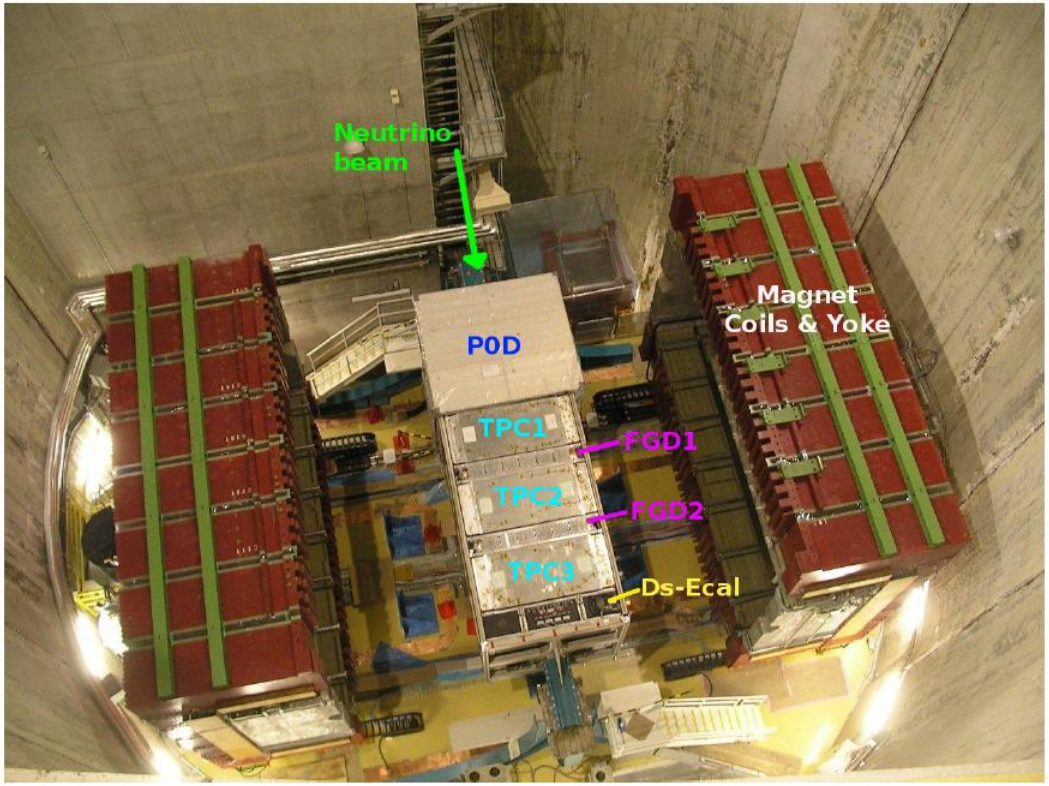
- UV laser:
  - 266 nm UV light.
  - Brought through a set of optical fibers.
  - Target pattern: aluminum discs and strips glued on cathode.



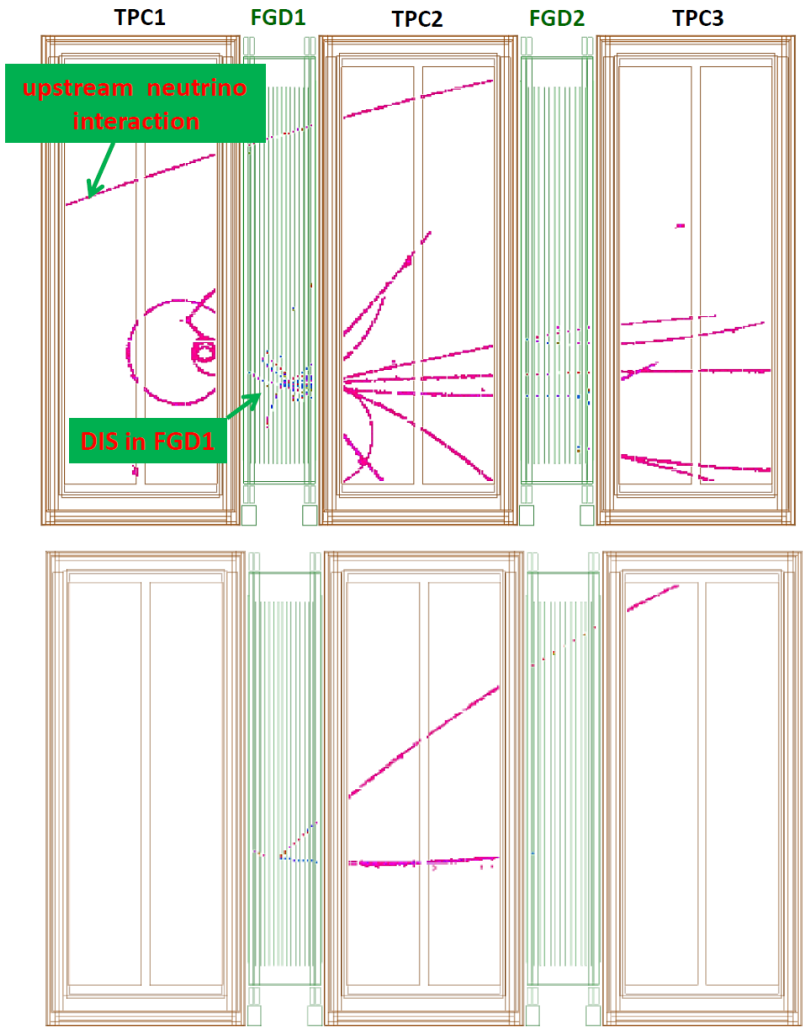
- Study of:
  - E- and B-field distortions
  - Gain variations
  - Drift velocity

Milestones

- 2007-2009: production and construction phase in Canada and Europe.
- 2008-2009: assembling of the TPCs and tests with beam at TRIUMF.
- Oct 2009 – Jan 2010: commissioning of the 3 TPCs at J-PARC
- Jan 2010 – Jun 2010: first T2K physics run.
- Nov 2010 – Mar 2011: second T2K physics run.



Event displays



- Deep inelastic scattering candidate with an additional through going track.

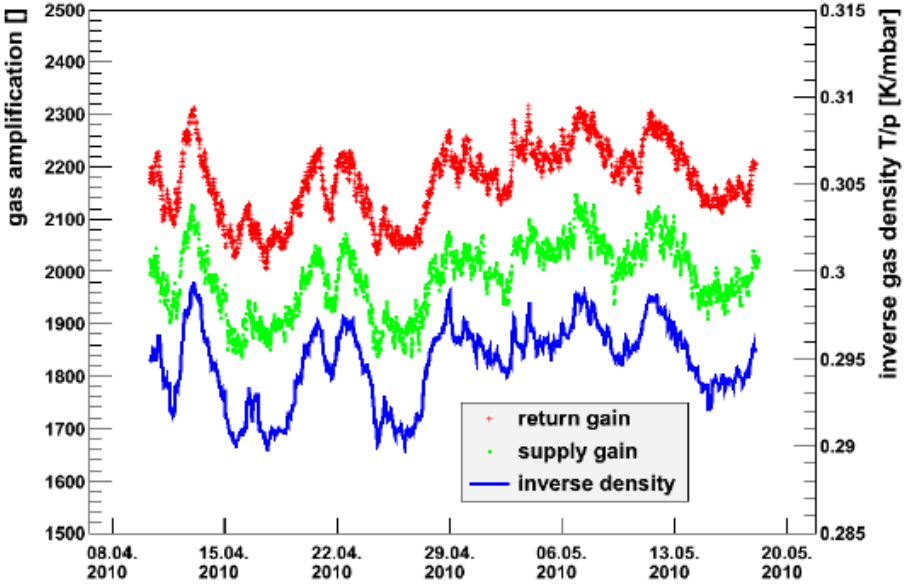
- Charged current quasi-elastic neutrino interaction candidate.

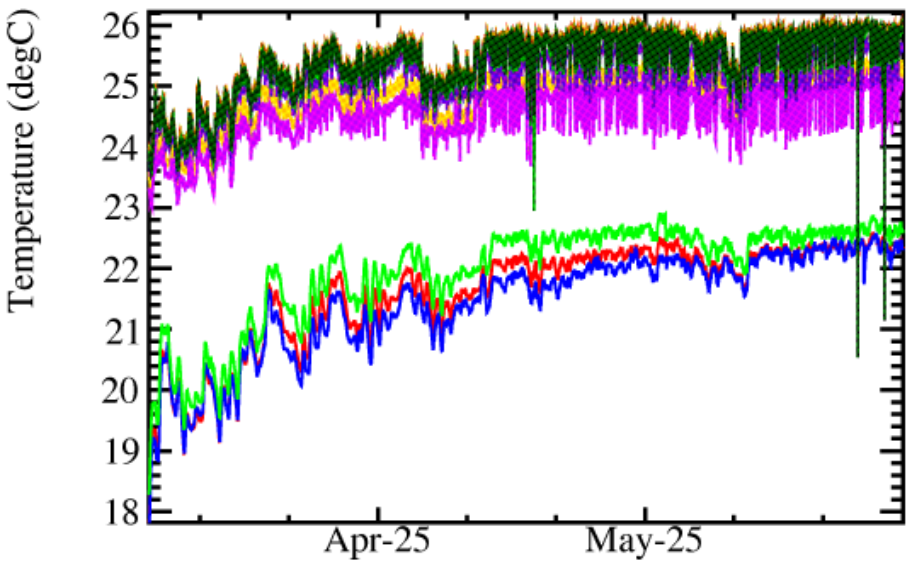
Operation

- Nearly 100% live fraction during beam time.
- Spark rate per module < 0.1/h (at 350 V).
- FEE LV consumption: 2.8 kW.
- Rate of TPC data to DAQ: < 2MB/s (at 20 Hz).
- Monitoring many quantities: gain, gas density, gas quality, drift velocity, temperatures, voltages and currents.

Gain stability

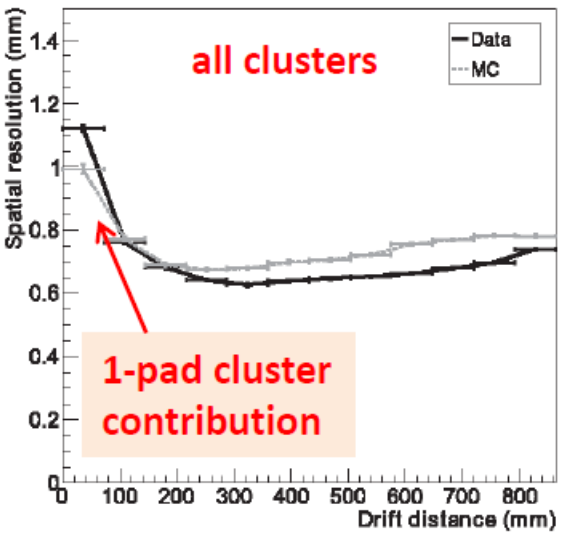
- Gain variations mainly due to temperature and pressure changes.
- Gain stability within 1% after T and P corrections.

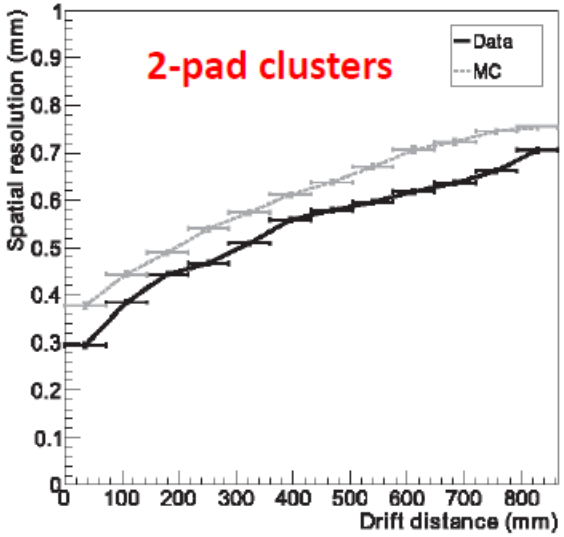


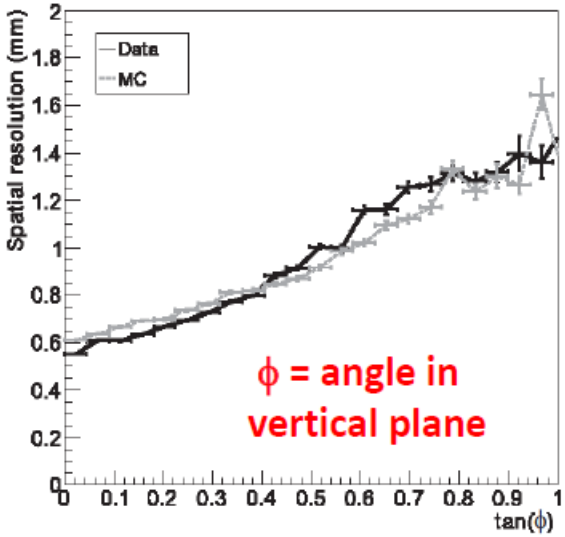


Spatial resolution

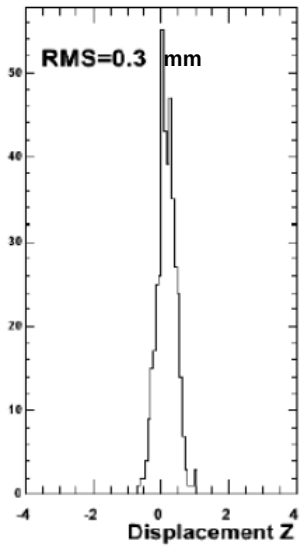
- Clusters formed from neighboring pads within a column (horizontal tracks) or a row (vertical tracks).
- Spatial resolution estimated by comparing coordinates from global track fit with single cluster fit.
- Spatial resolution of 600 μm for horizontal tracks.

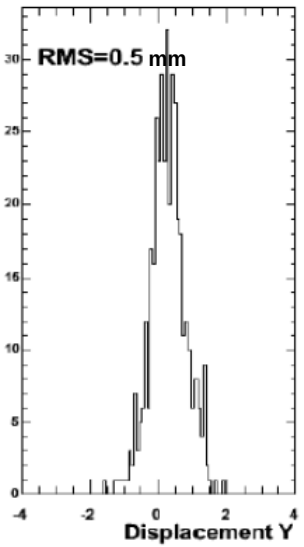


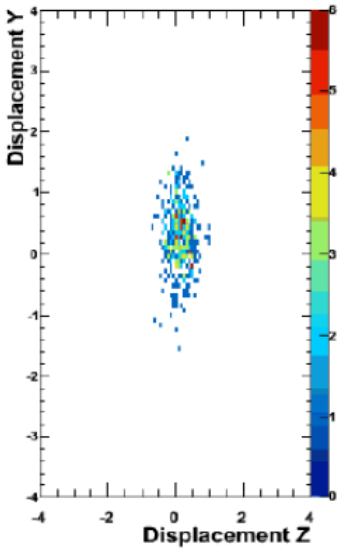




Field distortions from laser data

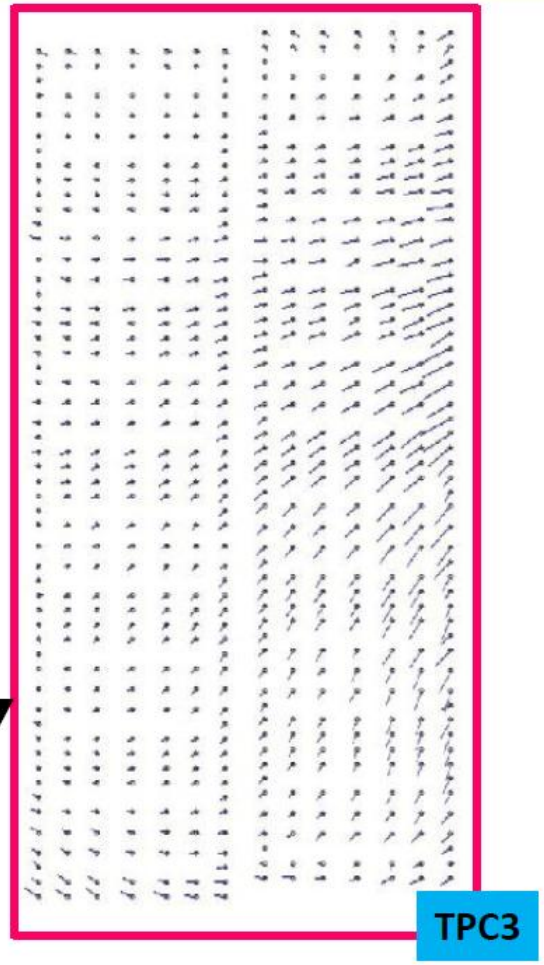






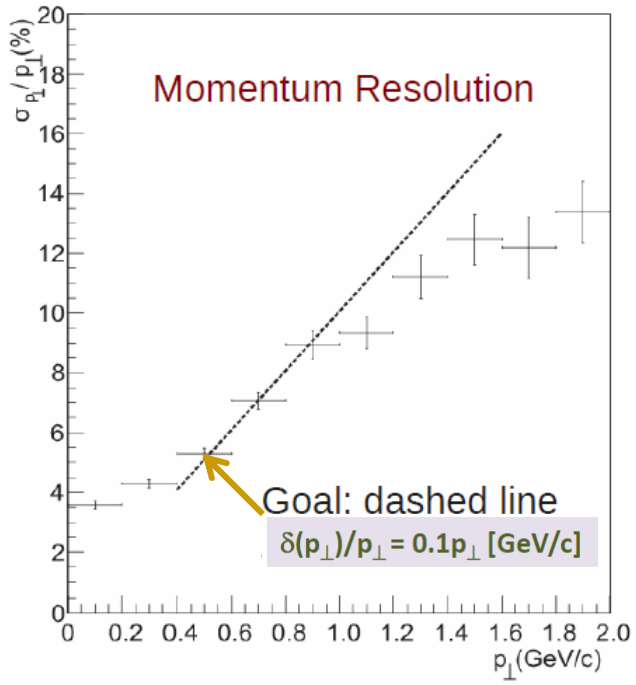
- E-field distortions from observed offsets w.r.t. survey:
  - RMS values smaller than point resolution.
- B-field from comparing measurements with and without magnetic field:
  - Offset typically less than 1 mm, reaching 5 mm at maximum.

Displacement of target images when magnet is turned on (×10)

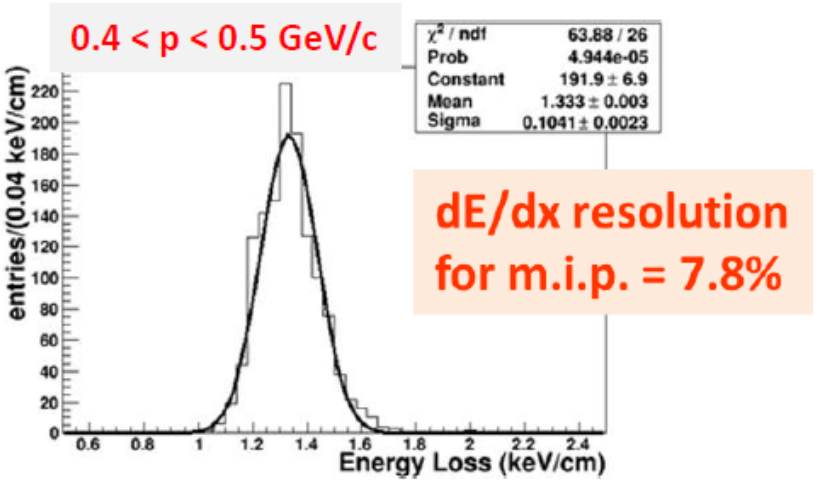


Momentum resolution and PID

- Measured spatial resolution is sufficient to reach required momentum resolution (from MC study).



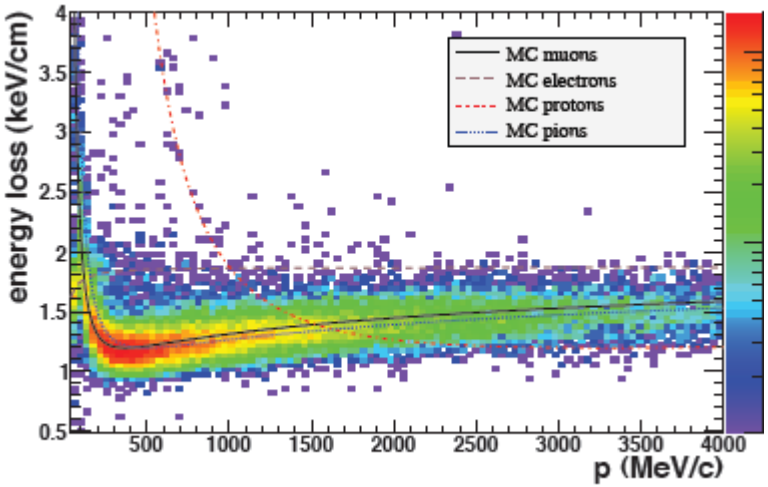
- Measured resolution on dE/dx on data meets requirement.
- Truncated mean method.



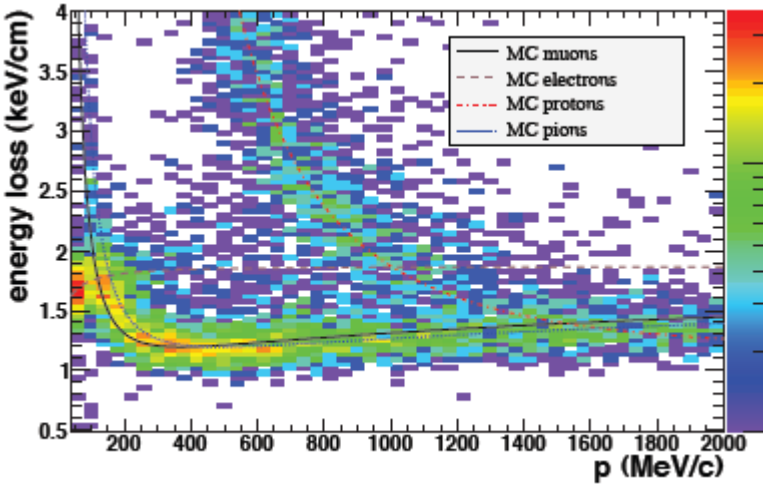
Tracks in beam data

- The TPC, measures:
  - Sign of charge
  - Momentum
  - Energy loss

Negatively charged tracks

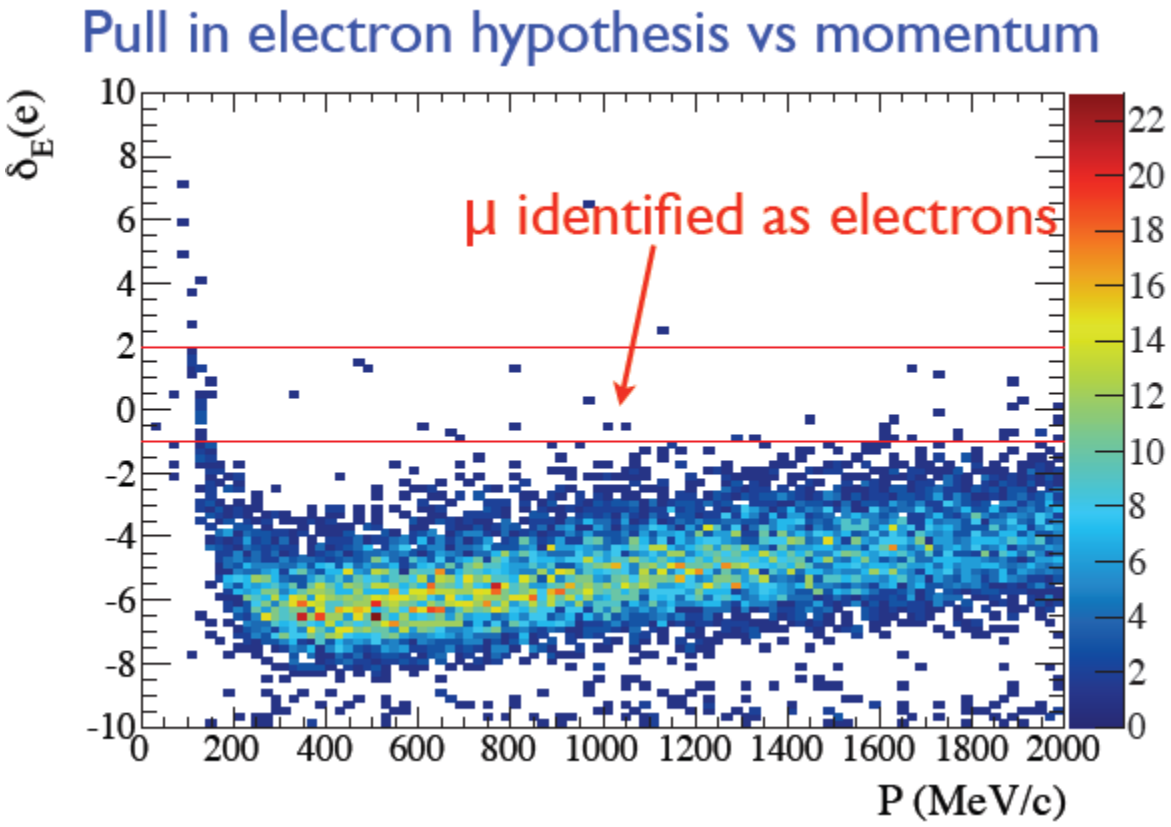


Positively charged tracks



Muon misidentification

- To measure the ν_e beam component, need to select electrons and reject muons.
- Control sample of sand muons crossing the 3 TPCs.
- Misidentification probability of the order of few per thousand.



Current hardware situation

- The T2K data taking was stopped by the earthquake on March 11, 2011.
- For the TPC, the gas system, cooling, FEE, BEE, HV for cathodes and micromegas modules were all powered up successfully at the end of May 2011.
- After re-alignment, the accelerator will be recommissioned in December 2011.
- Start of new physics run in January 2012.

Conclusions

- The three T2K ND280 TPCs have been operating successfully during the first two physics run from January 2010 to March 2011.
- They will be ready for the next T2K physics run foreseen for January 2012.
- They are contributing in an essential way to T2K physics results.
  - See Edoardo Mazzucato's talk.
- More information on the TPCs can be found in our publication.
  - *Nucl. Instrum. Meth. A637, 25 (2011)*.