the T2K near detector TPC (10 years later)

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outlook

- Detector concept and requirement
- R&D activity
- Brief description of subsystems
- Life and achievements
- Lessons learned

Requirements and TPC motivations

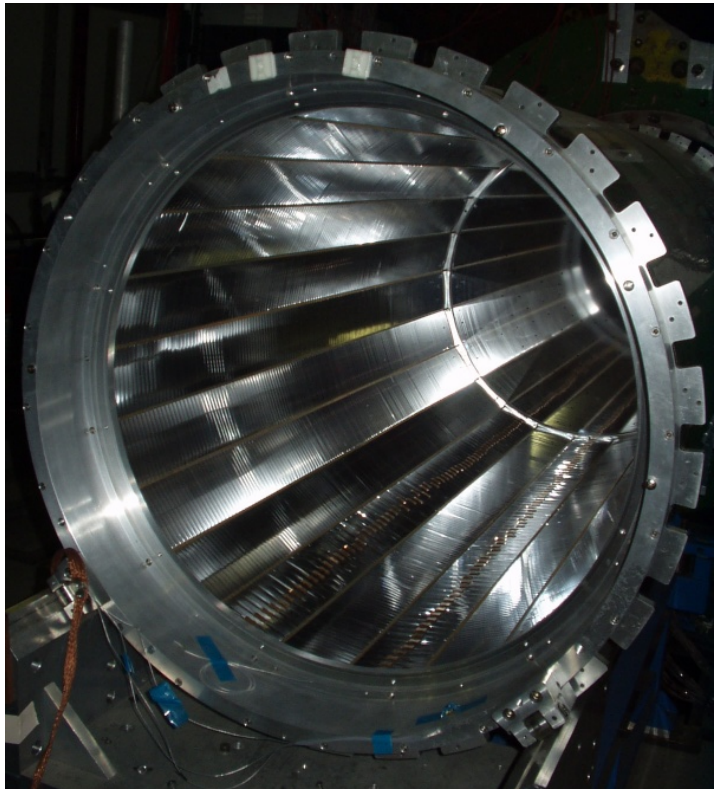
From a slide ~ 11 years ago

Resolution: σ ~ 500μm	Any decent tracker could do
Particle ID: e/μ/p	TPC !
Avg momentum < 1GeV/c	As-light-as-possible: TPC
Mild magnetic field	Low diffusion gas
Low track density	Few tracks per event → no need for small pads
Broad angle range for e and μ, + very large angle p	Dependency of σ from track angle → MPGD amplification → Squared (or almost) pads

R&D

- Optimize pad size & shape to the specific case
- Test gas mixture to find the most appropriate for low-diffusion in mild (0.2T) magnetic field
- Need large (~1.5m^2) pad planes
  - maximum size of GEM and MM ~30cm
  - Study modularity (dead space, mechanical constraints, etc)
- Study performance of prototypes of realistic size

Test-bed



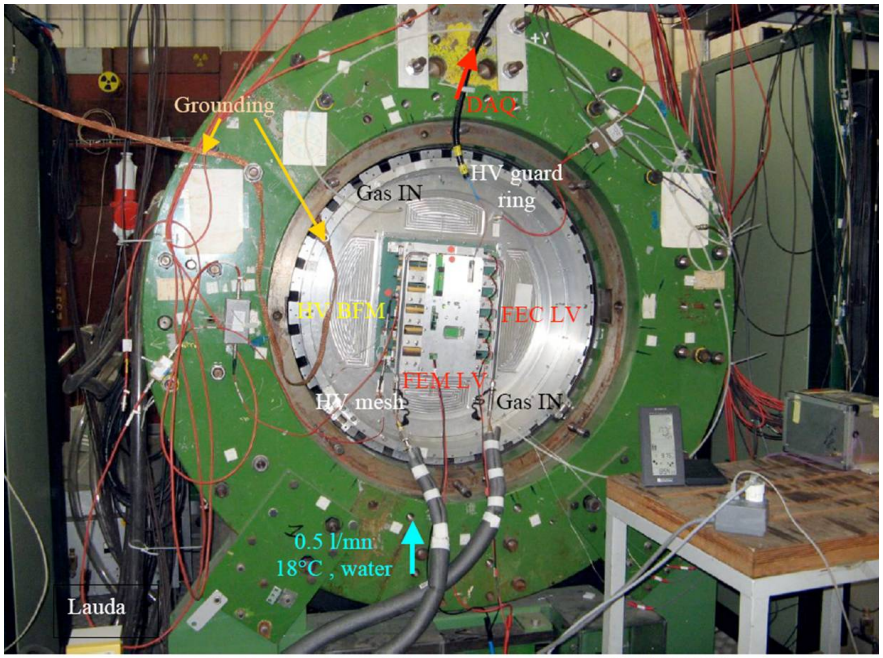
Field cage:

- used in the HARP experiment
- “sweet field” region: ~ 150 cm long, ~ 80 cm diameter
- excellent uniformity: less than 1% field (E and B) distortion

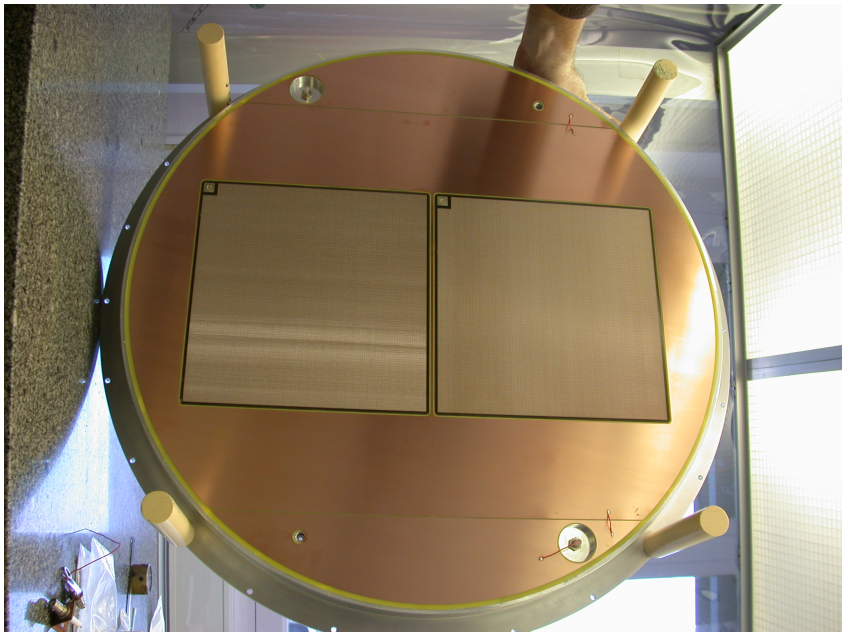
Field-cage: up to 35 kV

Magnet: up to 0.7 T

R&D prototypes

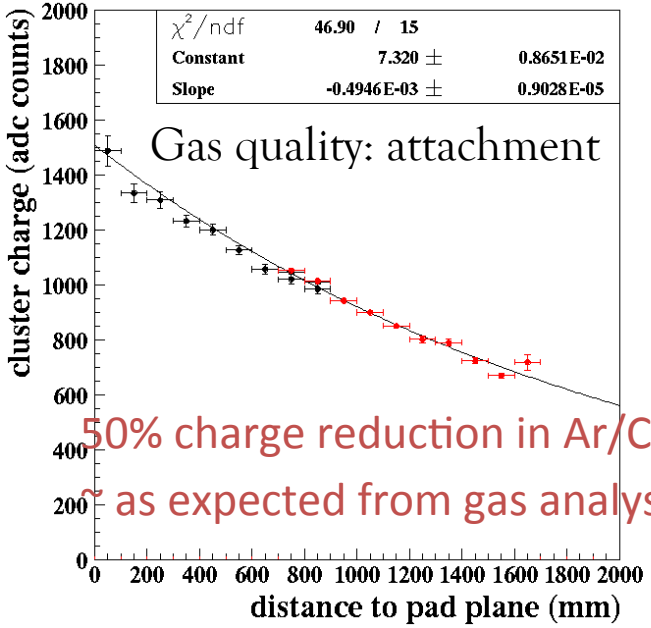


Hardware setup in T9A experimental zone (09/19/2007)



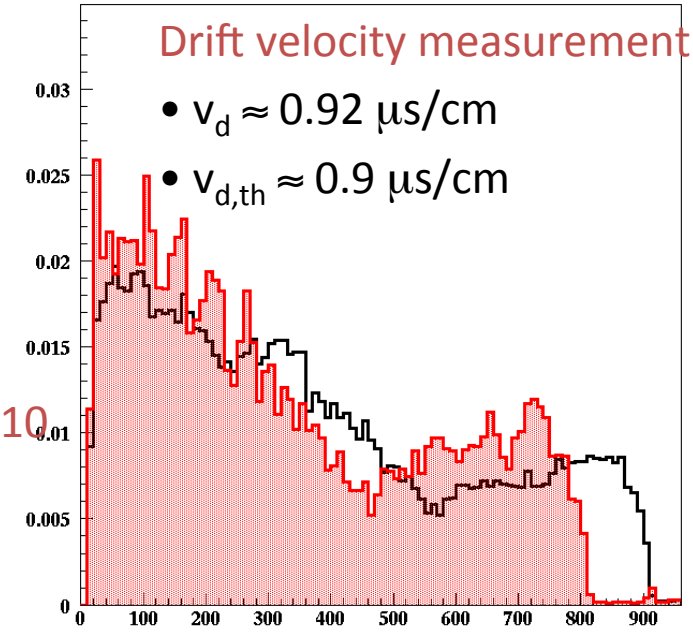
- GEM and MM end-plates developed by late 2005 and tested early 2006
- Several gas mixtures (Ar + CO_2, CH_4 and iCH_4)

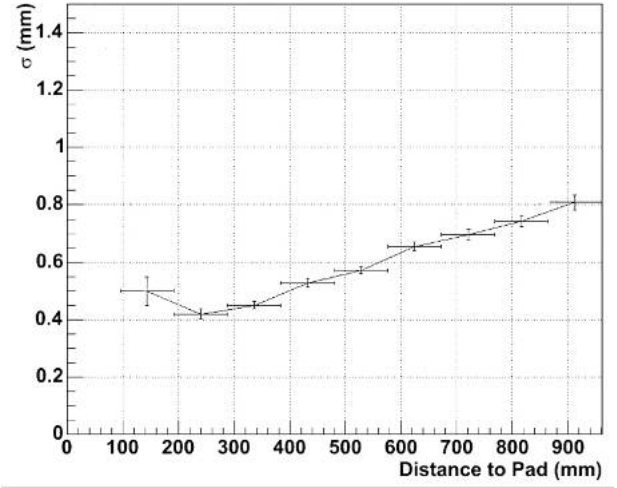
Prototypes: initial performances



50% charge reduction in Ar/CO2 90/10

~ as expected from gas analysis

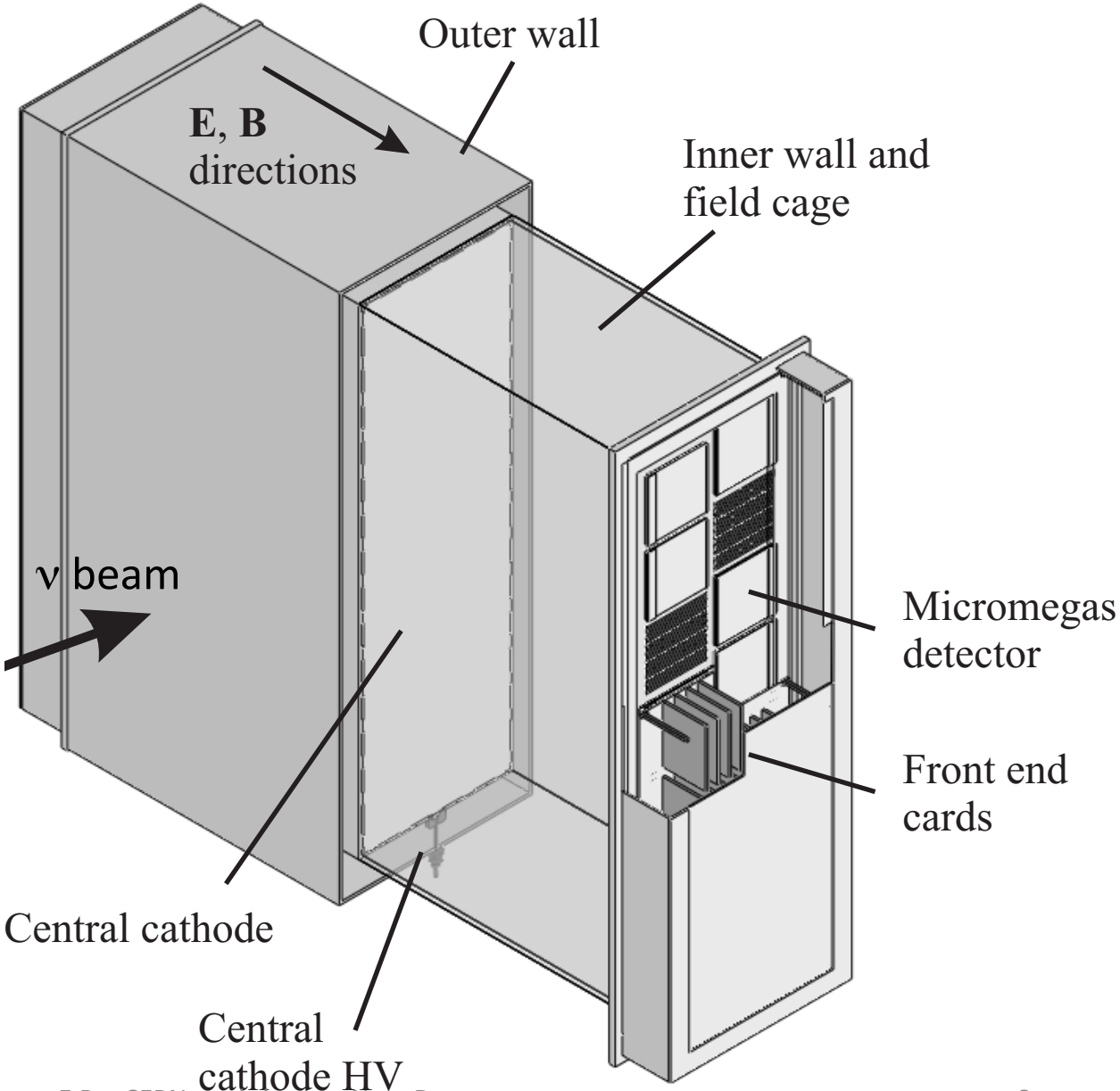




- first indications from the test beam
  - resolution within specs
  - ability to measure typical working parameters

ND280 TPC module

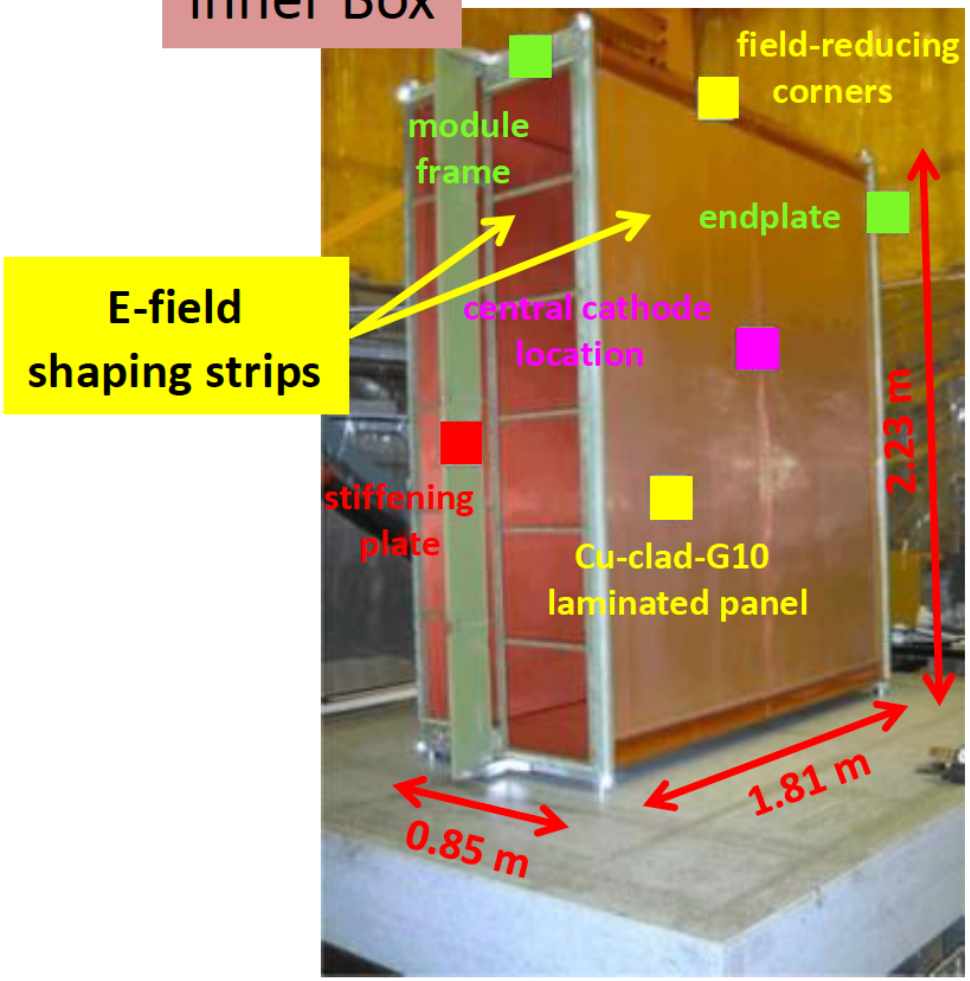
- Outer volume (*2.5 x 2.5 m2 in the plane perpendicular to the neutrino beam direction, and 0.9*m along the beam direction
- Active volume *1.8 x 2.2 x0.7 m3*
- Gas mixture: *Ar,iC_4H_{10},CF_4 (95/2/3)*
- The central cathode is set at moderately high potential (close to 25 kV).
- The outer box is separated from the inner box by a gap of 6.8 cm on the sides and top and 11.8 cm on the bottom.
- Pad plane made by tiles of MM readout modules

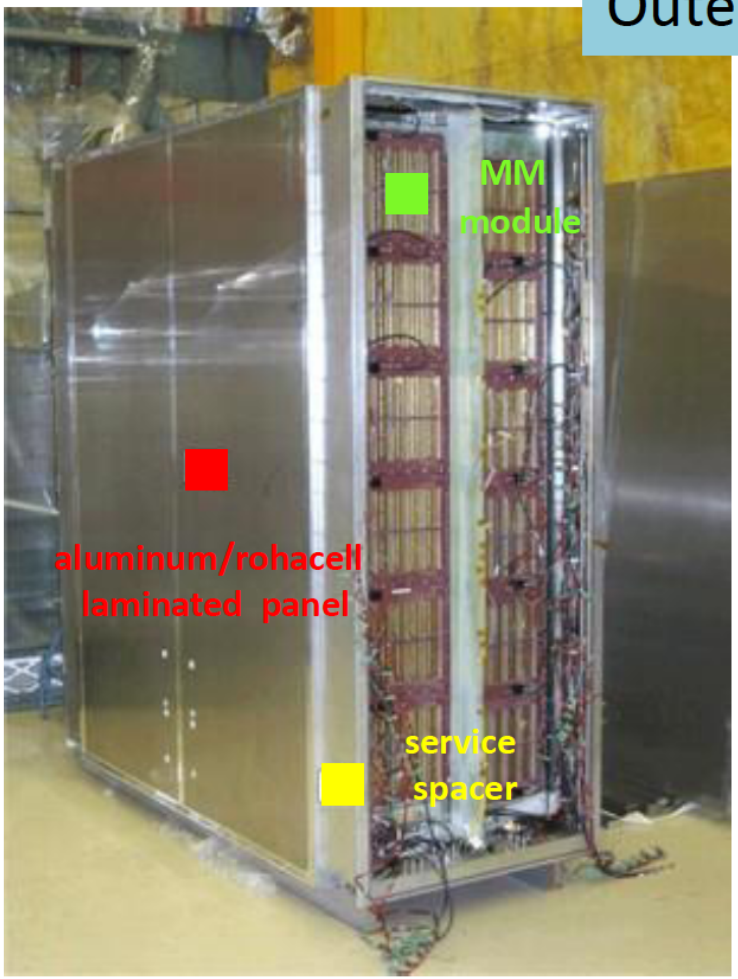


Field cage

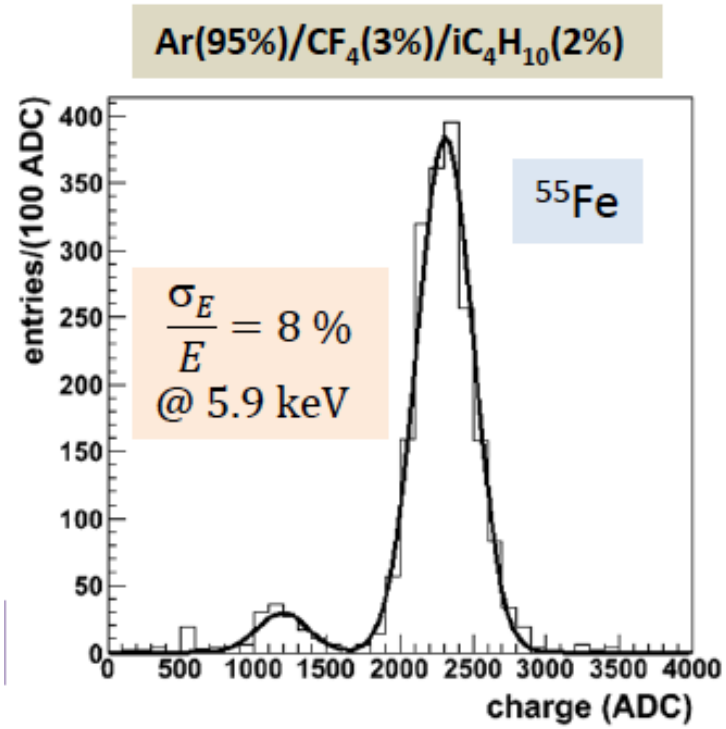
Inner Box

Outer Box





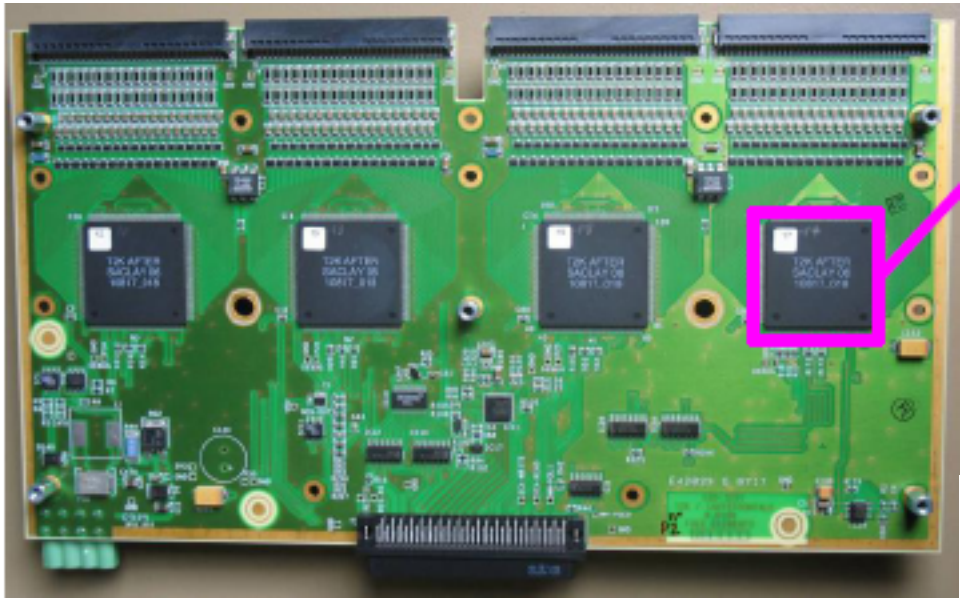
Amplification



- 359.1 x 349.3 mm2
- 1726 active pads.
- 9.8 x 7.0 mm2
- 128 μm amplification gap.
- 72 modules for 3 TPC´s.

- TPC Gas: Ar(95%) CF_4(3%) iC_4H_{10} (2%)
- Gain: 1500 @ 27.4 kV/cm
- Drift Velocity : 7.8 cm/μs
- Drift field: 279 V/m

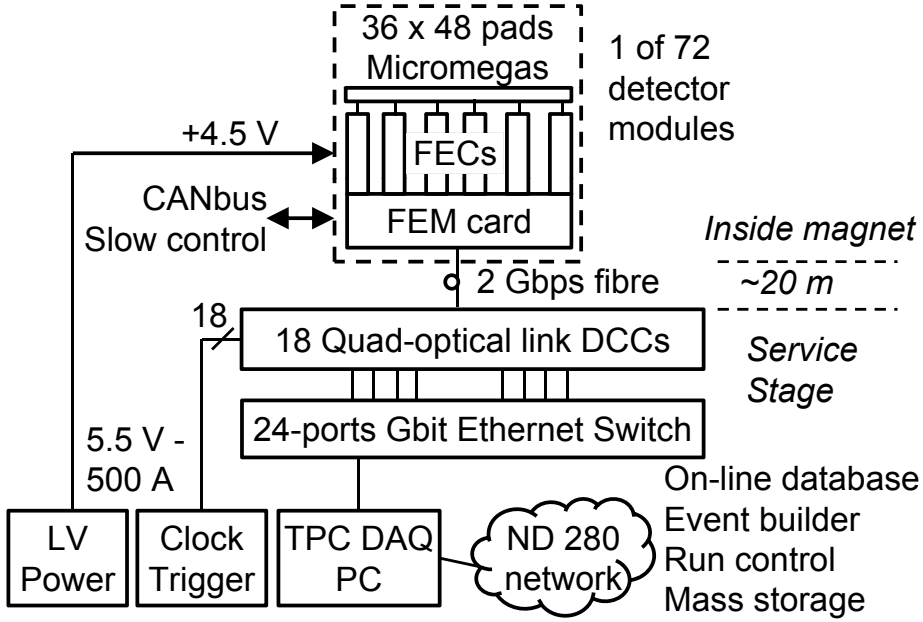
FE electronics



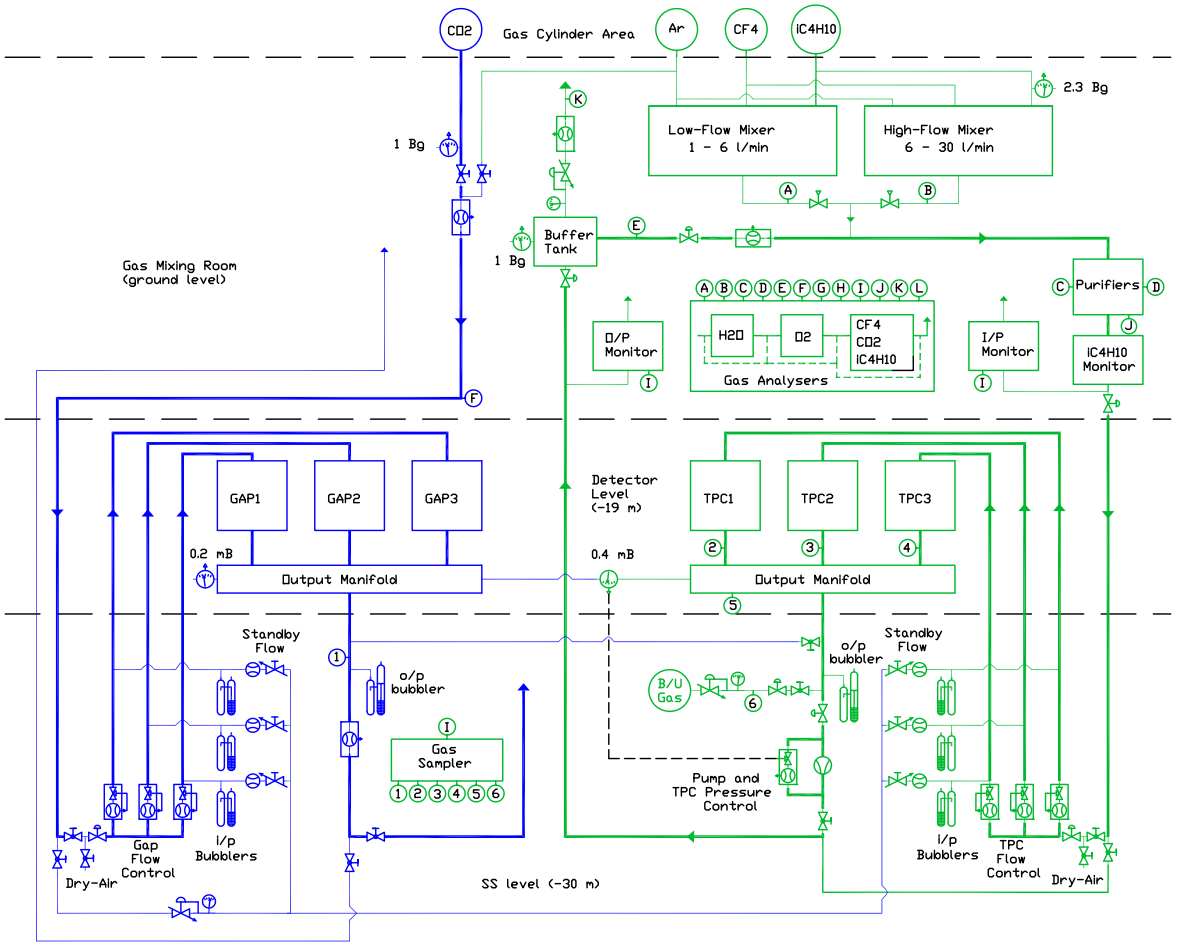
- 1 MM = 1 FEM + 6 FECs = (24 AFTERS)
- FEM : data collector, 0 suppression, slowcontrol…
- Data Concentrator Card (DCC) reads 4 FEM´s.

18 DCC´s based on xlink demonstrator card.

- 124416 channels / 3 TPC
- Front End Electronics based on ASIC chip:
- 72 channels x 511 analog memory cells.
- programable gain: 1.8 - 4.1 mV/fC
- peaking time : 0.1- 2 μs (0.2 μs).
- sampling frequency up to 100 MHz (25Mhz)



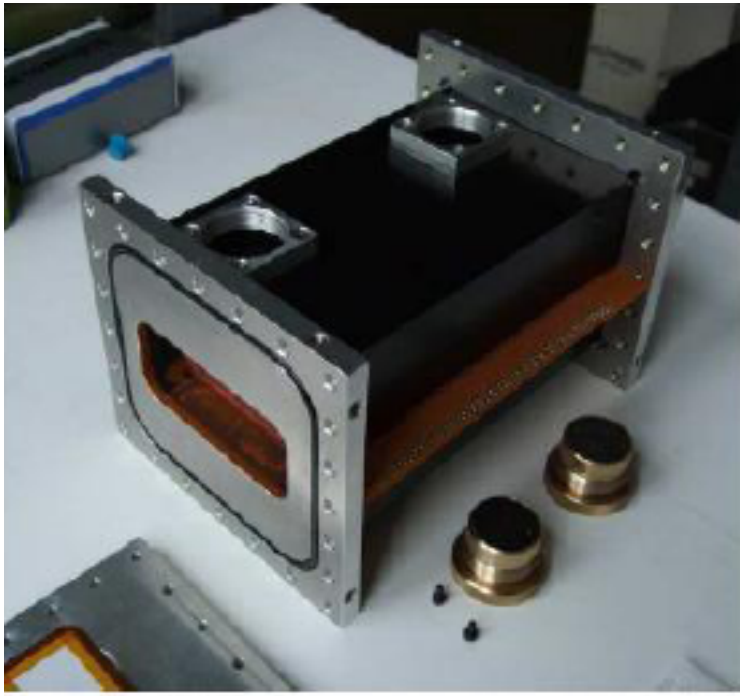
Gas system

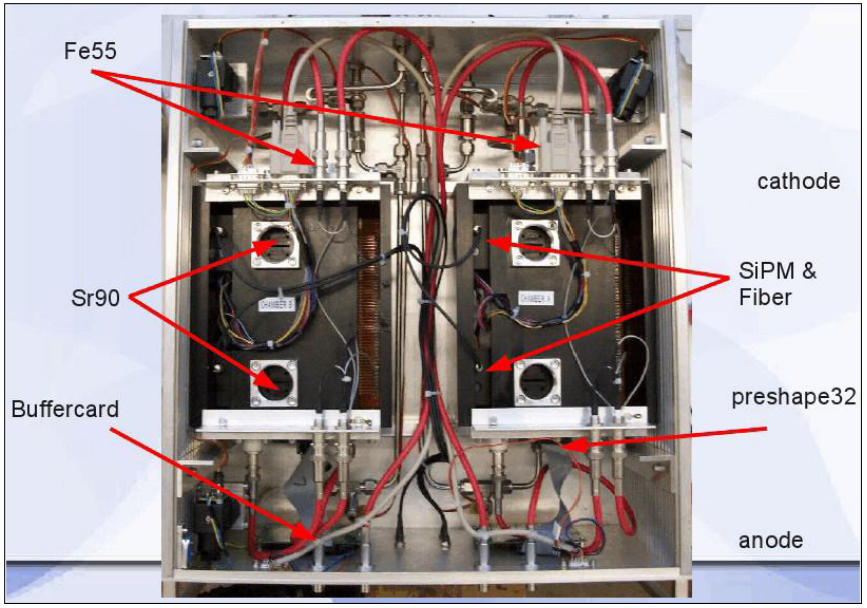


- Very stable operation:
- H_20 (<5ppm) 0_2 (<2ppm) and $C0_2$ (20ppm-120ppm) at the exhaust pipe.
- Ar (95.001±0.001%), CF_4 (2.9999±0.0008%) and iC_4H_{10}. (2.0000±0.0007%)
- Gap differential pressure 0.4+-0.03 mbar
- 22.2 L/min for the 3 gaps. (~5 volume exchanges every 1.5 days).
- 30.0 L/min for the 3 volumes (~5 volume exchanges every day).

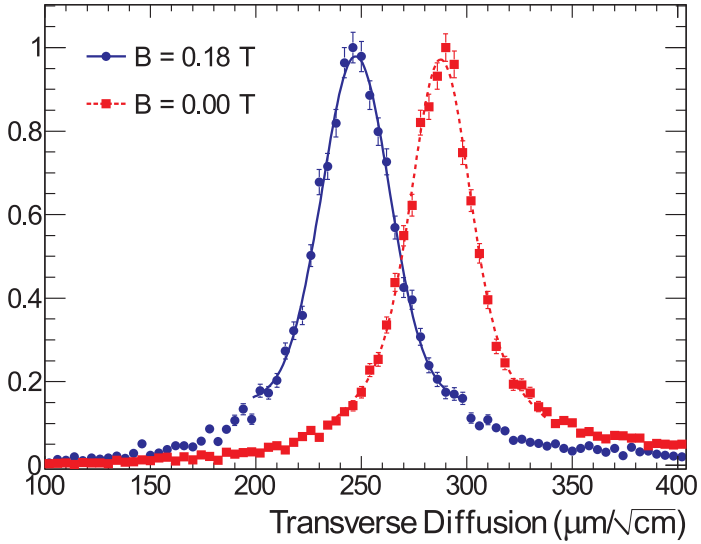
Gas monitoring chambers

- Two chambers inserted in the gas system (sample input and output gas from the big TPC volumes).
- 2 ^{90}Sr sources at different distances to monitor drift velocity. T0 from scintillating fibers. Online monitor every 30 minutes.
- 1 ^{55}Fe source to monitor gas amplification variations.

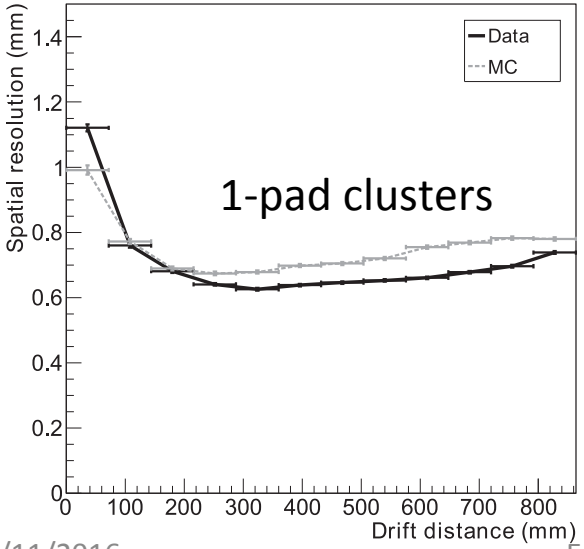


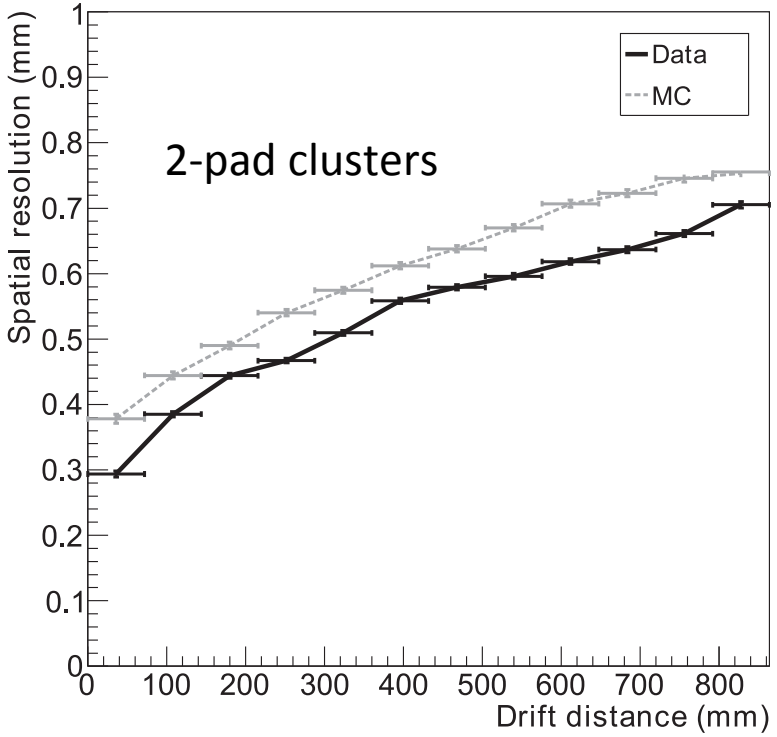


Performance

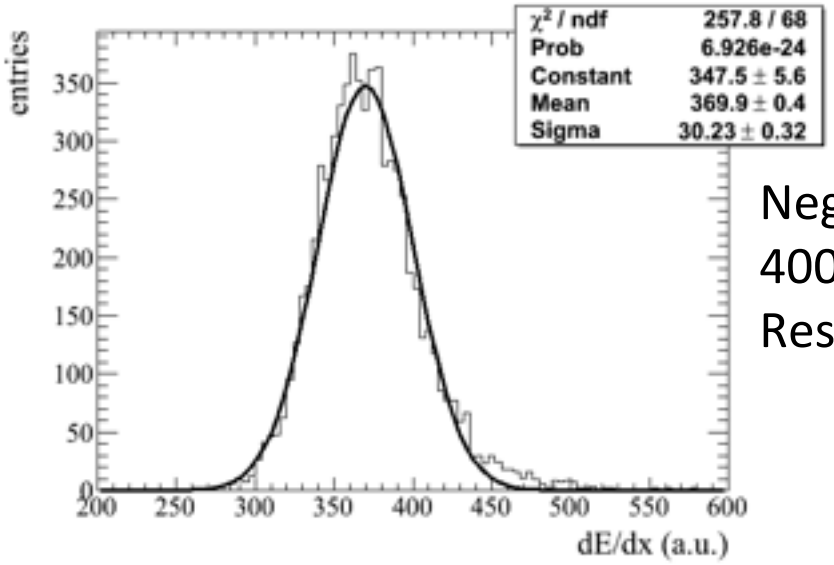


Likelihood fit: takes into account (and fits) transverse diffusion



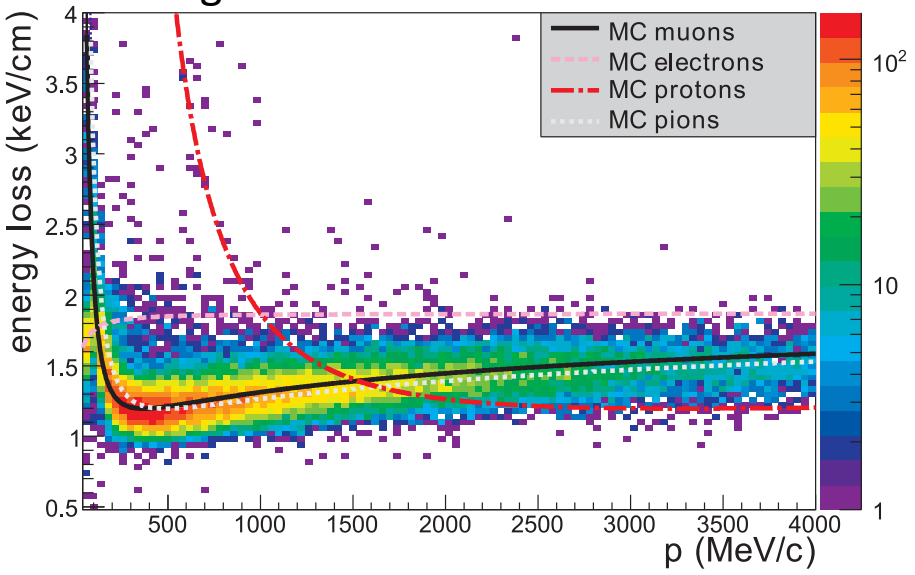


Performance

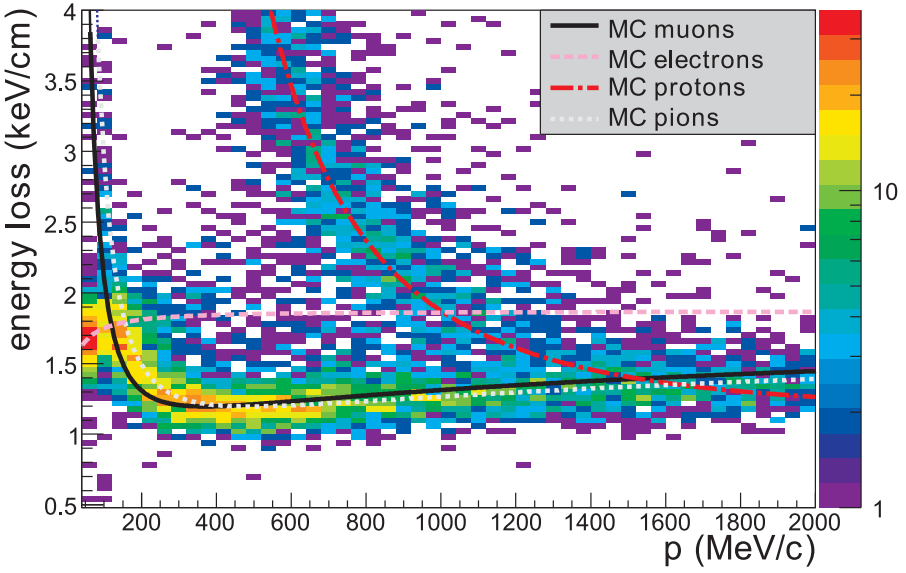


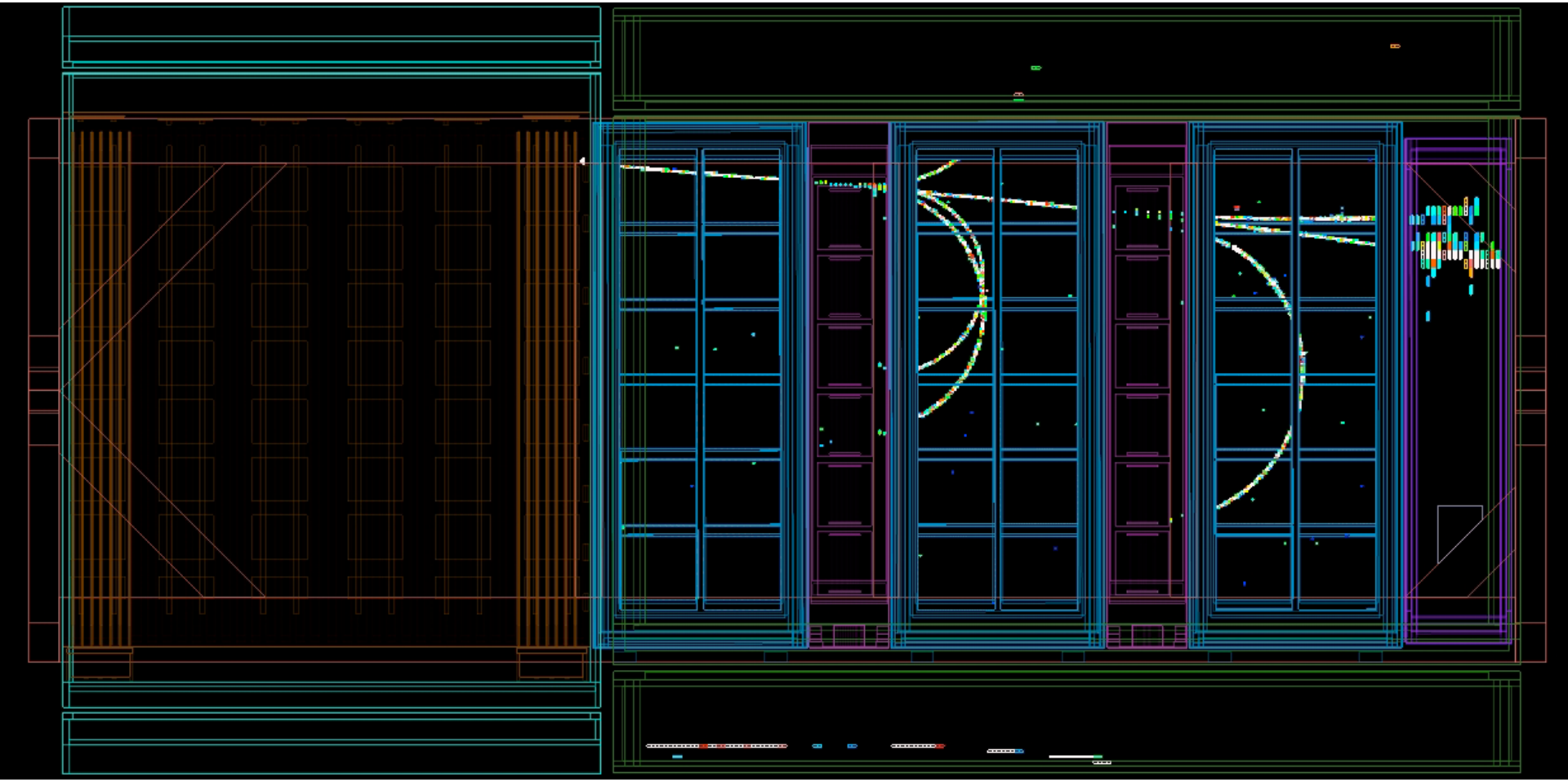
Negative tracks
400 MeV/c < p < 500 MeV/c
Resolution: better than 8%

Negative tracks



Positive tracks





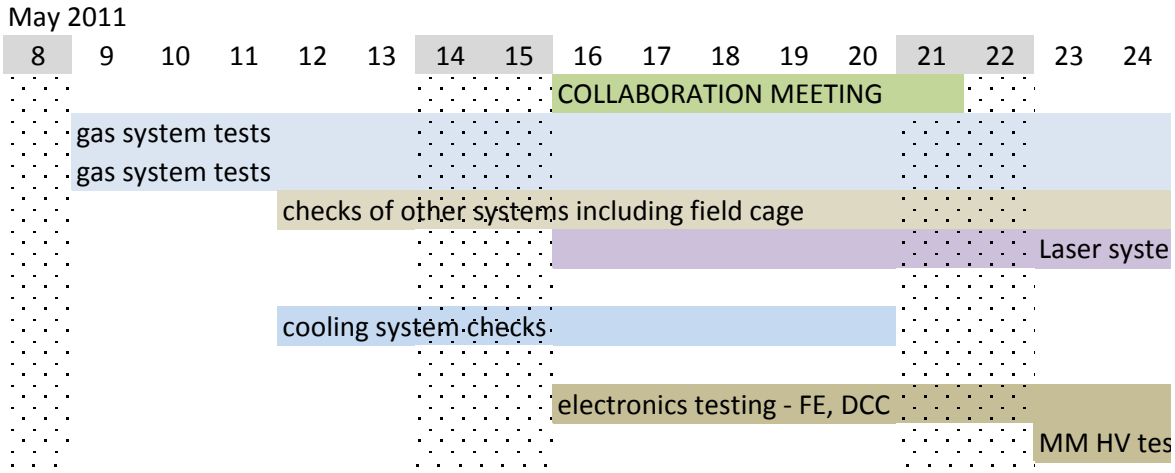
Operation record

- Very stable operation during 7 years
  - expected operational lifetime > 10 years
- Few hardware faults
  - no failures of MM (72 of them) or FEC
  - replaced a few FEMs
  - few ASICs off (<0.2% dead channels)
  - disconnected 1 PhotoMOS (1/12 MM)
- DCCs upgraded
  - with more recent model of Virtex demonstration boards

Robustness: earthquake survival ...

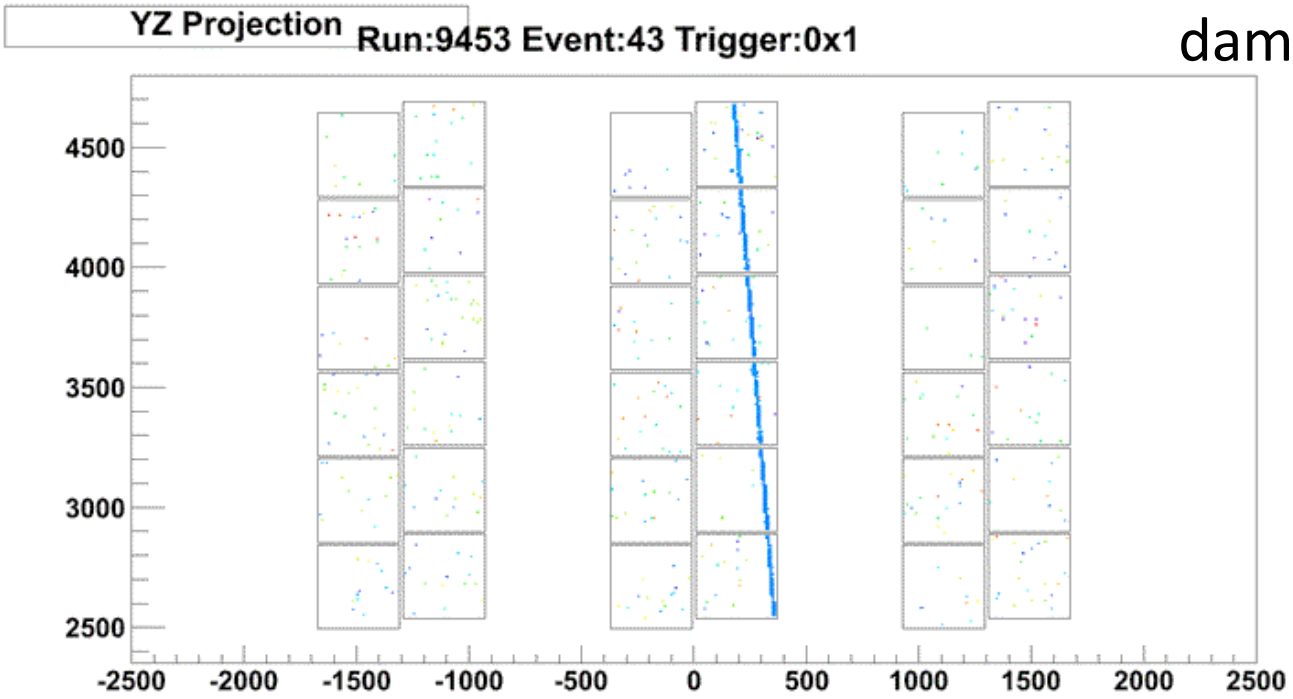
- 11/03/2011 Tohoku earthquake. M9 at epicenter, M7.5 in Tokai
- Electrical power to ND280 goes off immediately (TPC has no backup). Safety Ar supply remains active in the inner volumes, outer volume flow stops.
- Air conditioning in the pit stops → very high humidity (beyond dew point)
- No access allowed to the lab during several weeks

… and fast recovery



~ 2 months later the TPC was switched back on

Assessment (to our surprise): no damage!



Initial motivations and requirements

- All elements proved very stable and robust
- The T2K TPC has been fully successful w.r.t. the main requirements:
  - ✓Momentum resolution better than 10% for 1 GeV muons. Good point resolution to balance the very low magnetic field.
  - ✓Energy scale known at the 2% level. Achieved by an excellent control of magnetic and electric field distortions
  - ✓dE/dx resolution better than 10% to allow a 3 sigma separation of electrons and muons for momenta > 200MeV/c

Lessons learned

- Resolution: pad charge sharing limitations
  - resistive readout planes not realistic 10 years ago
- Complexity
  - Dual-layer field-cage designed for never-used HV values → acceptance lost (dead space and material in walls)
    - 200 MeV/c cutoff for muons
    - large-angle protons undetected most of the time
  - gas system for dual-volume field-cage
    - involved manpower and issues with long-term maintenance
- Track length, dE/dx resolution
  - it is OK for 3 σ separation of e/μ
  - increase track length, if possible
- dynamic range with heavily ionizing tracks
- delicate relative alignment of the MM modules
  - → larger modules now possible

conclusions

- more than 10 years have passed since the original idea of a TPC tracker for ν-oscillation in 2004
- The detector has been in stable operation since 2009
- Overall a very positive experience
- Changing needs of the experiment shows shortcomings in the present TPC configuration
- Future evolution will provide new occasions for R&D
- The original idea of a TPC in the near detector of a ν-oscillation experiment is here to stay