TPC for the near detector of the T2K experiment

Workshop FJPPL'09

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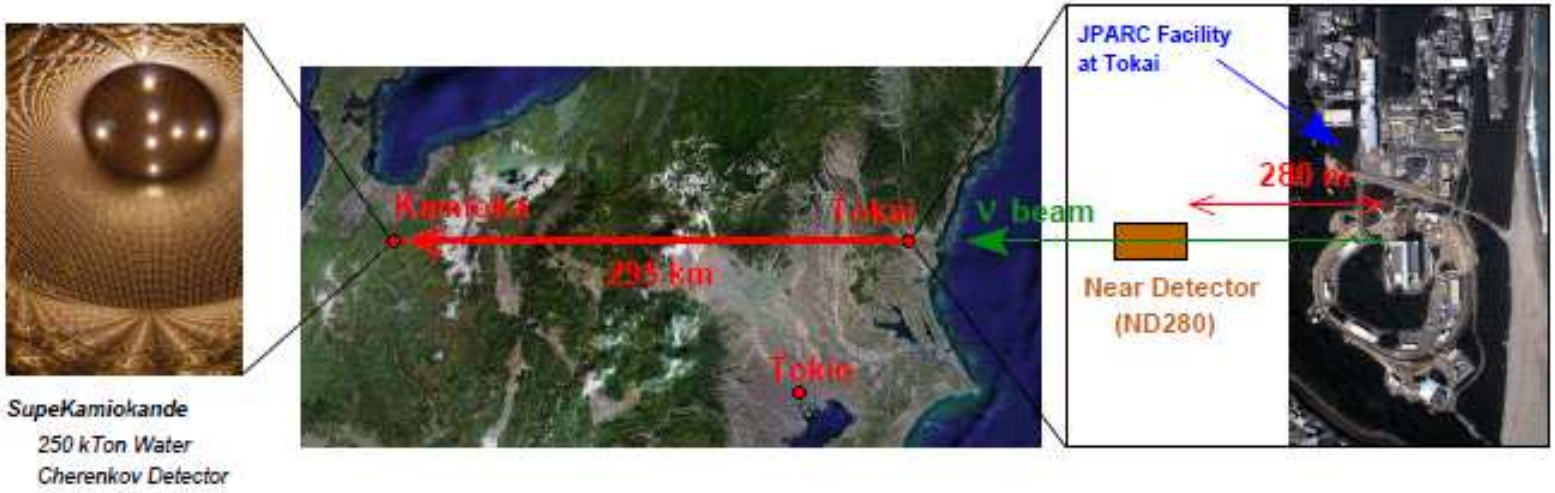
Outline

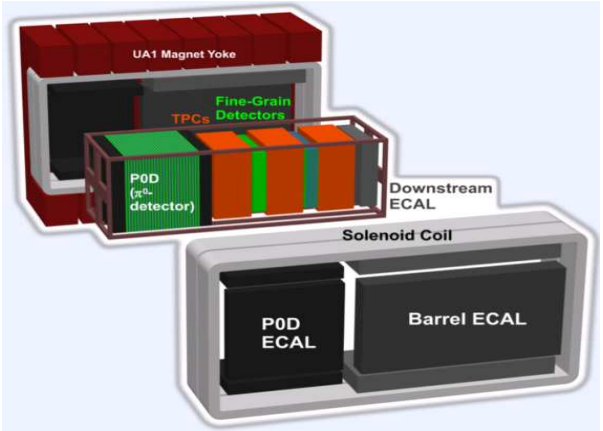
- T2K experiment and ND280
- Presentation of the TPC
- Production status
- Results of the beam test

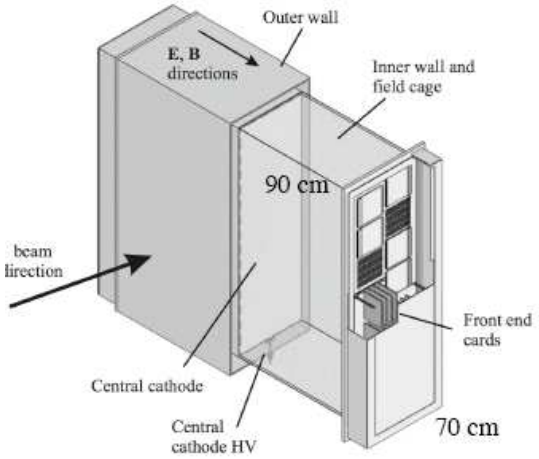
The T2K experiment



- Long Baseline Neutrino oscillation experiment
- 30 GeV proton accelerator used to produce a ν_μ beam that will be send from Tokai to SuperKamiokande
  - The neutrino beam started in April 2009
  - **L = 295 Km**
  - Mean neutrino energy **E_ν = 0.7 GeV**
- **ν_e appearance** → First measurement of θ_{13}
- **ν_μ disappearance** → Precise measurement of θ_{23} and Δm^2_{23}

The Near Detector and the TPCs



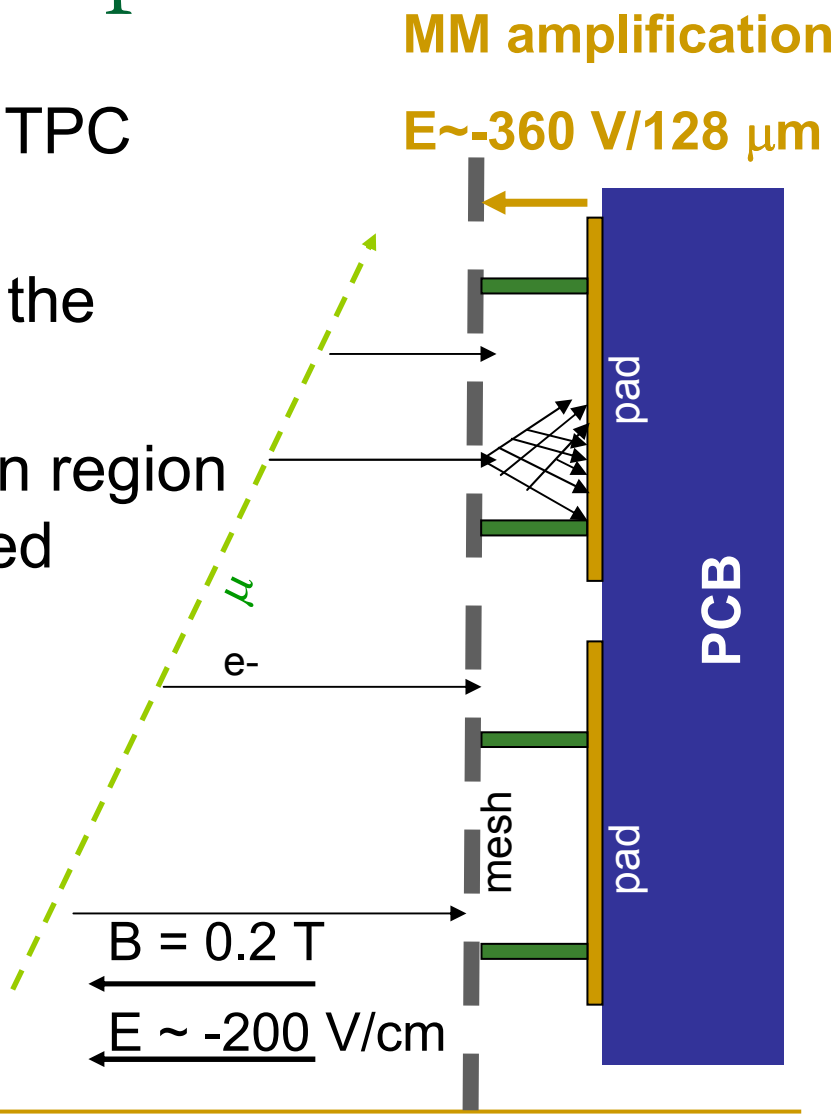


- Near Detector at **280 meters** from the neutrino beam production point
- Several detectors inside a magnet (with a field of **0.2 T**)
  - Characterize neutrino beam (before oscillation)
  - Measure ν_e contamination
  - Study background process to oscillation signal

- **3 large TPCs**
- Long drift distance (**90 cm**)
- Total active area ~9m^2
- Requirements:
  - **$\delta p/p < 10\%$ @ 1GeV** to reconstruct neutrino energy spectrum
  - **dE/dx resolution better than 10%** to separate electron/muon

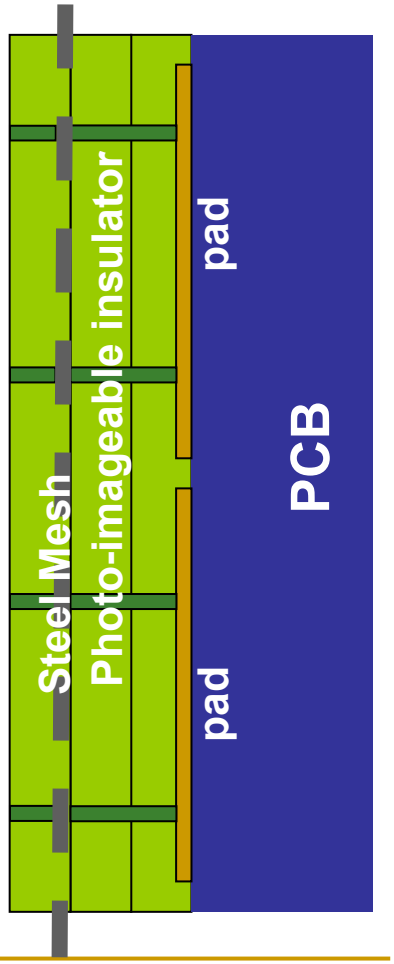
The MicroMegas principles

- Charged particles crossing the TPC ionize gas molecules
- The produced electrons drift to the MicroMegas mesh
- Electrons enter the amplification region where avalanches are generated
  - **Gain ~ 10^3 - 10^4**
  - **~ 100% collection efficiency**
  - Small gap → short rise time
- Ions flow back to the mesh
  - Only few ions per mil go back
  - Avoids space charge effects



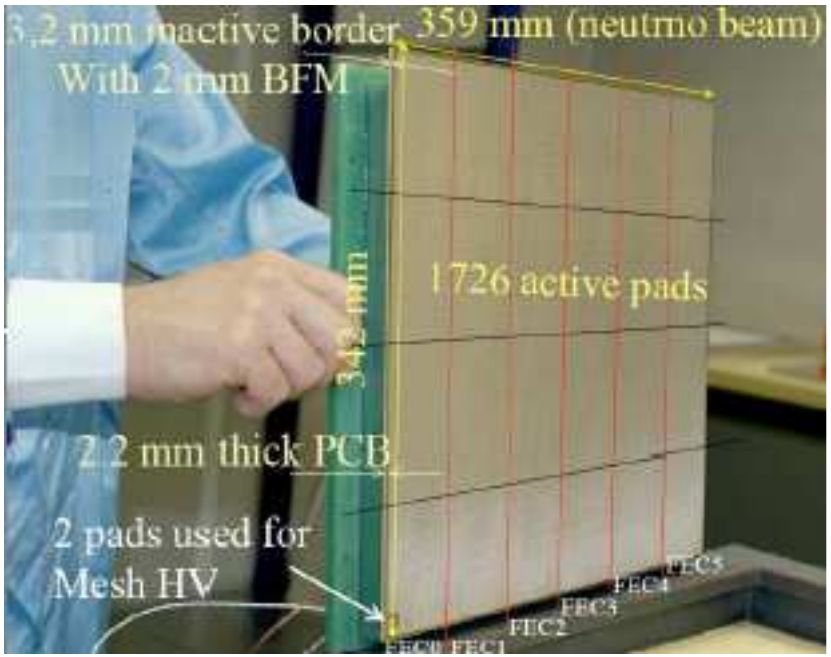
The Bulk MicroMegas

- Technology developed at CERN/Saclay
- Sandwich of:
  - 3 photo-imageable insulator layer of 64 μm each
  - 1 steel mesh with a width of 2.4 mm and 2 layers (x,y) of 19 μm wires
  - The sandwich is laminated on the PCB, exposed to UV, cleaned-heat-dried 2-3 times and then cut to the final dimensions
  - Total thickness **19.5 mm**
- Advantages:
  - Steel mesh → **Robustness**
  - **Large area** can be produced
  - **Less dead zones** on the edge
  - Better **gain uniformity** in the corners



MicroMegas module

• 12 large bulk-MICROMEGAS (35x36 cm²) on each endplate
→ 72 modules in 3 TPCs
• Each module has 1726 active pads (6.9x9.7 mm)
• Pads are arranged in 36 columns and 48 rows
• Total of ~120 000 channels
• MM are produced **CERN/TS-DEM-PMT** and are tested and validated in a test bench at CERN

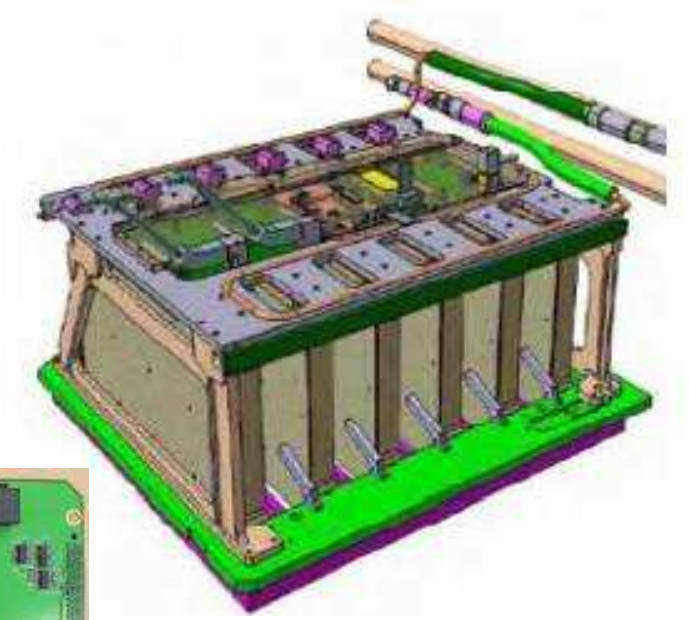


Readout electronic

- ASIC AFTER (72 channels) with programmable gain, sampling time…
- 6 FEC + 1 FEM on each module

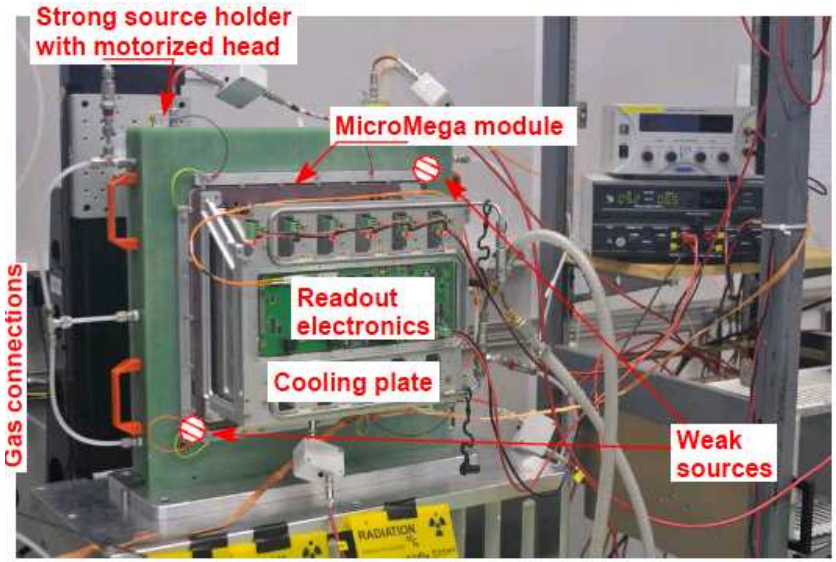
Front-End Card (FEC)

Front-End Mezzanine (FEM)



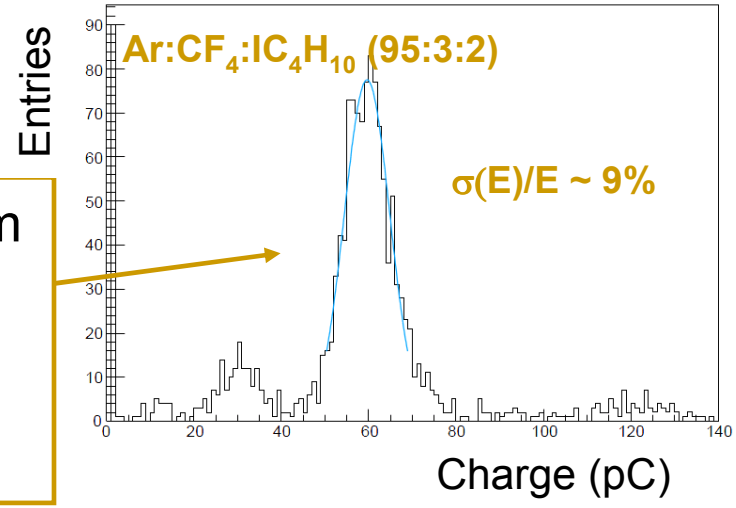
The T2K MicroMegas Test Bench

- Characterization of each detector with a complete scanning of the active area with a ^{55}Fe source emitting 5.9 keV photons
- Purpose:
  - Find **faulty pads**
  - Determine **energy resolution**
  - Measure gain as a function of mesh voltage
  - Measure pad per pad **gain uniformity**



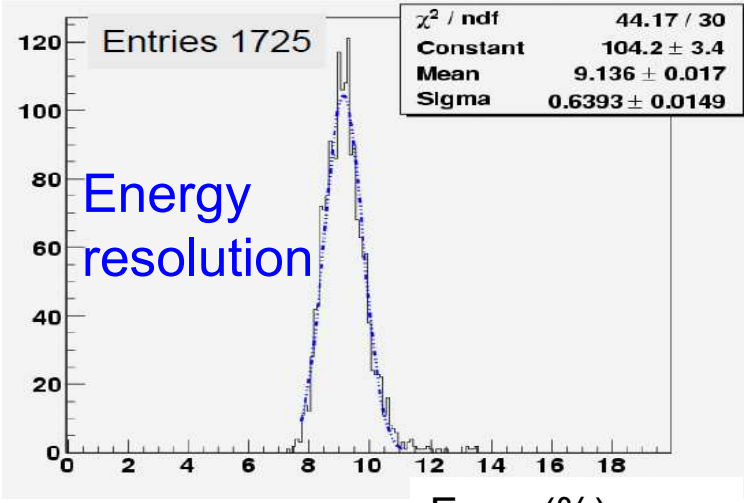
Single pad amplitude spectrum for 5.9 keV photons

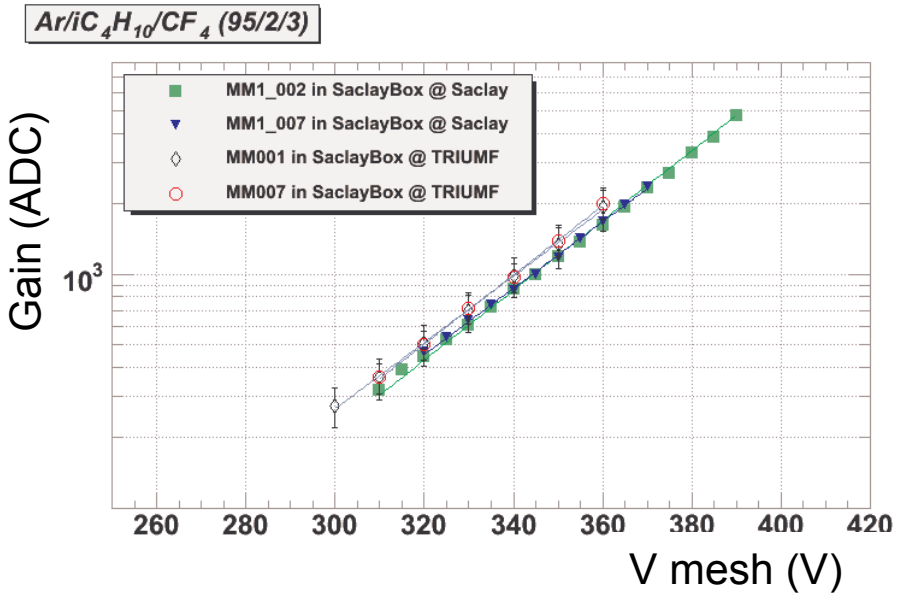
- Mean → Gain
- Sigma → Energy Resolution

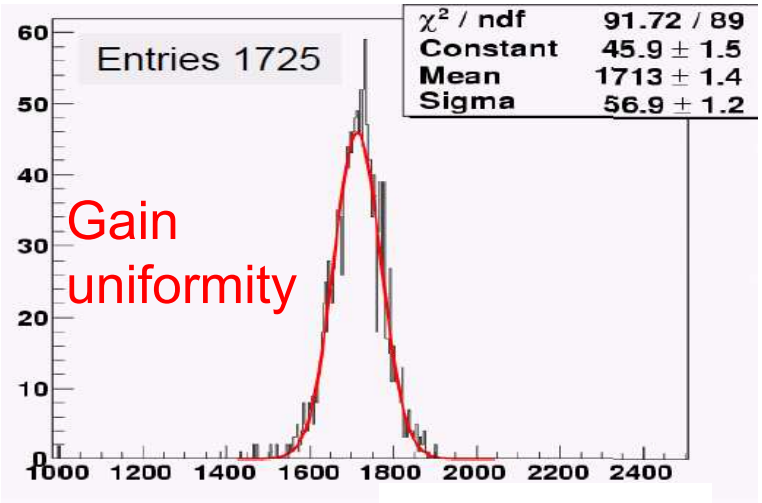


The MicroMegas modules calibration

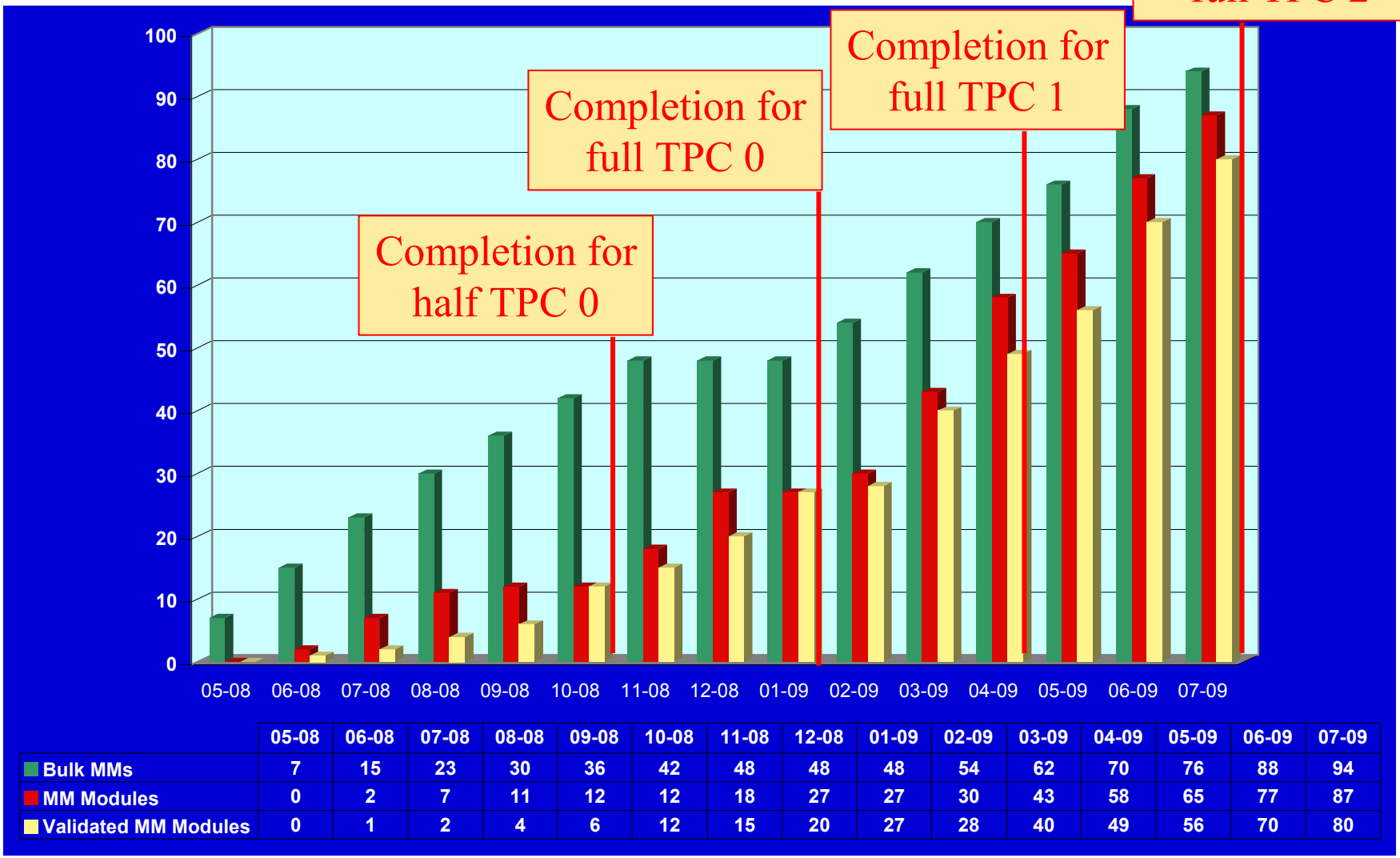
- Results for a typical module:
  - Good energy resolution: 9% with a 6% dispersion
  - Good gain uniformity: dispersion ~3%
- Similar gain curve for all modules







Production status

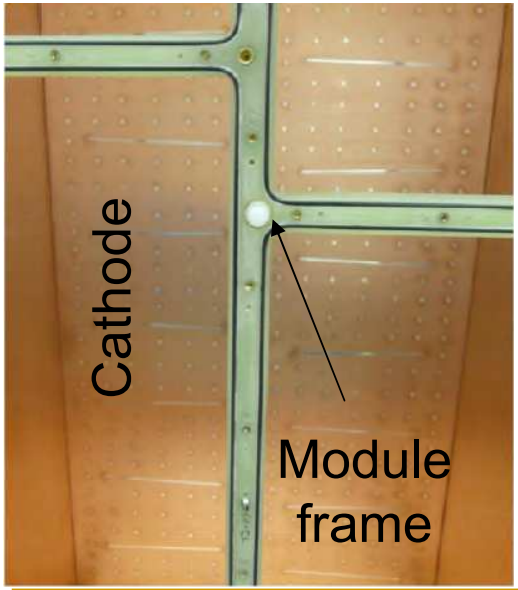


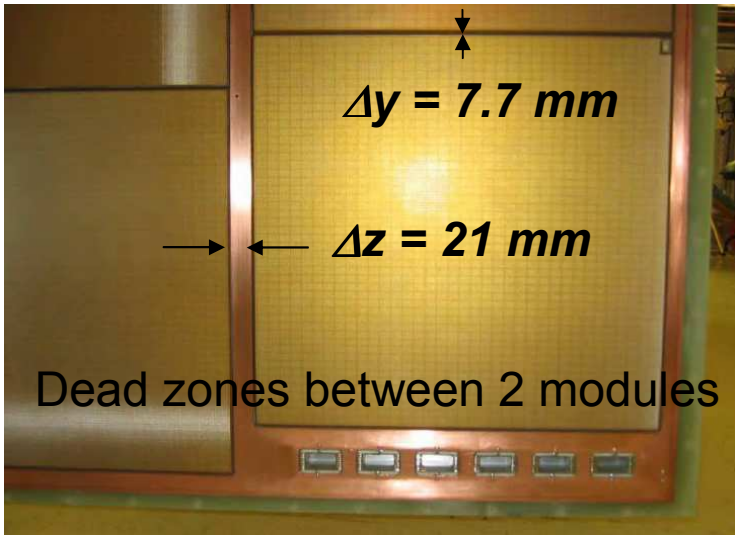
	05-08	06-08	07-08	08-08	09-08	10-08	11-08	12-08	01-09	02-09	03-09	04-09	05-09	06-09	07-09
Bulk MMs	7	15	23	30	36	42	48	48	48	54	62	70	76	88	94
MM Modules	0	2	7	11	12	12	18	27	27	30	43	58	65	77	87
Validated MM Modules	0	1	2	4	6	12	15	20	27	28	40	49	56	70	80

TPC construction

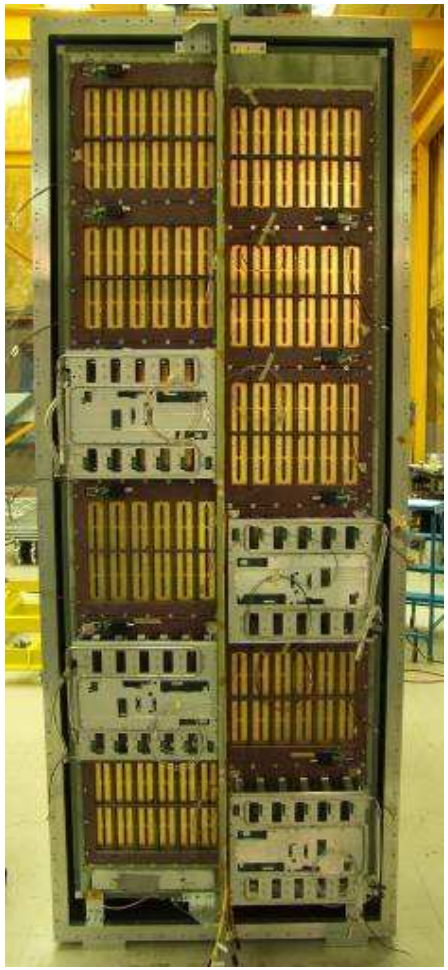
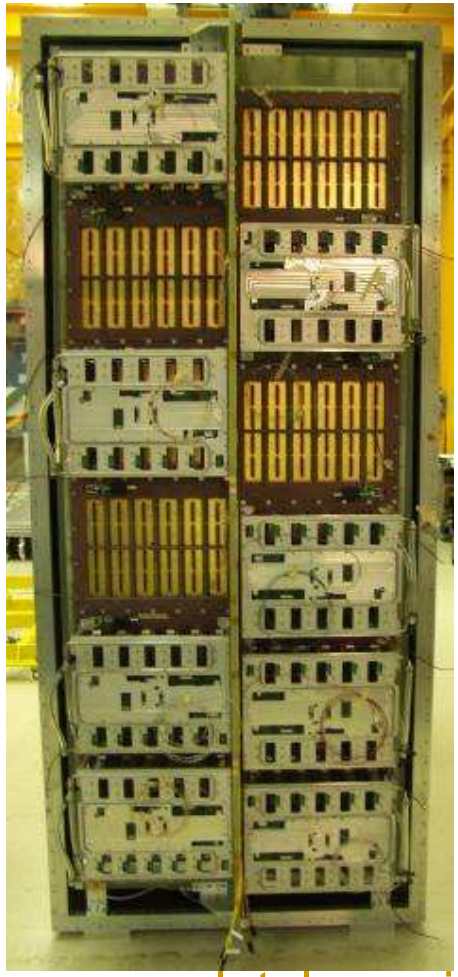
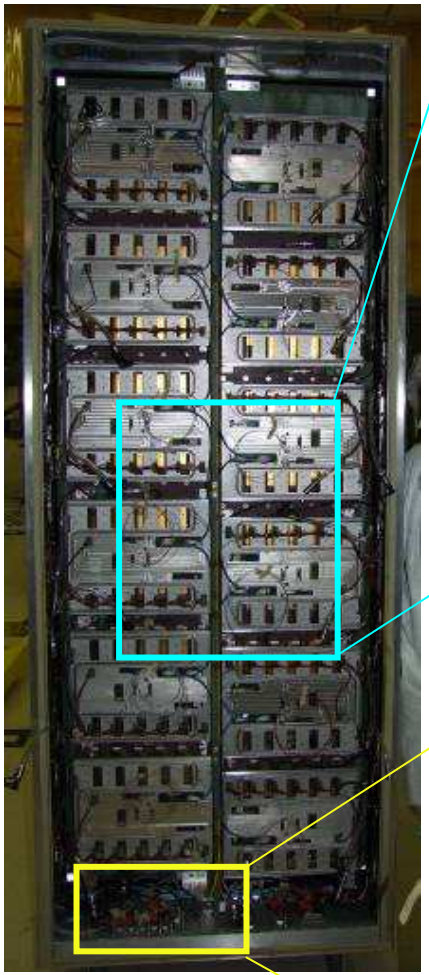
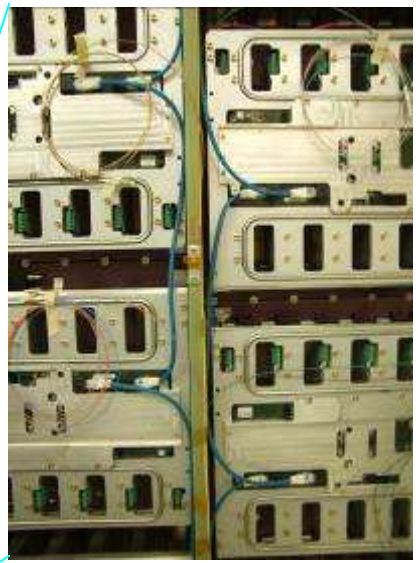
- Performed at TRIUMF

Internal face



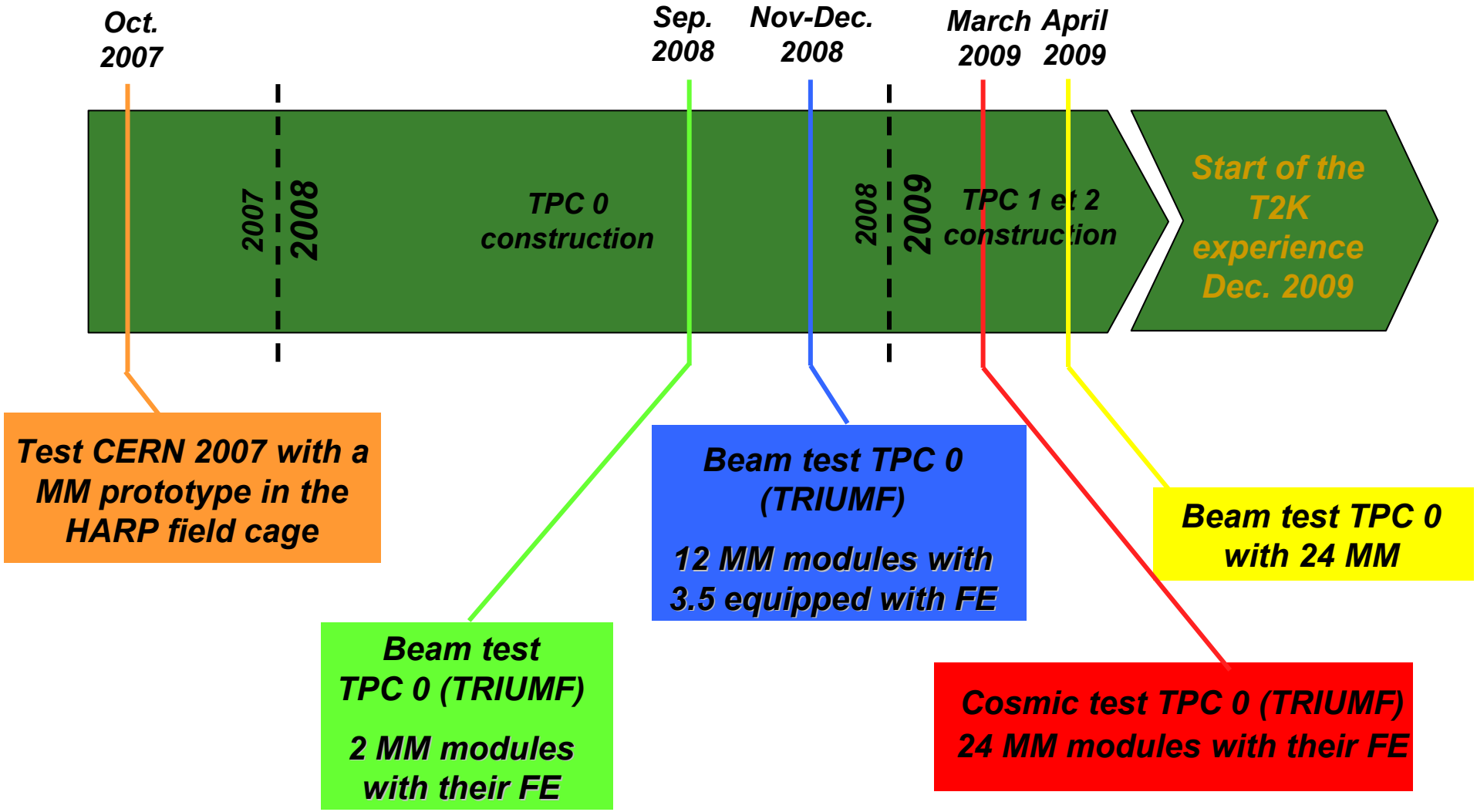


Installation of the electronic on the TPC

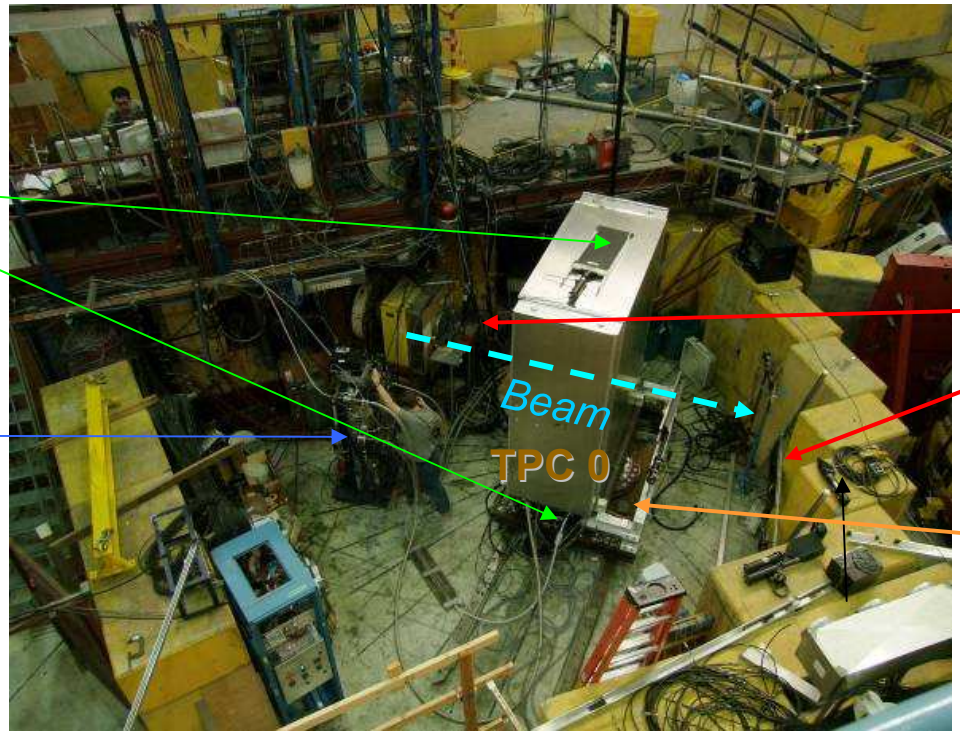

TPC 0 is now completely equipped with 24 MicroMegas modules and all the Front-End electronic

History of tests



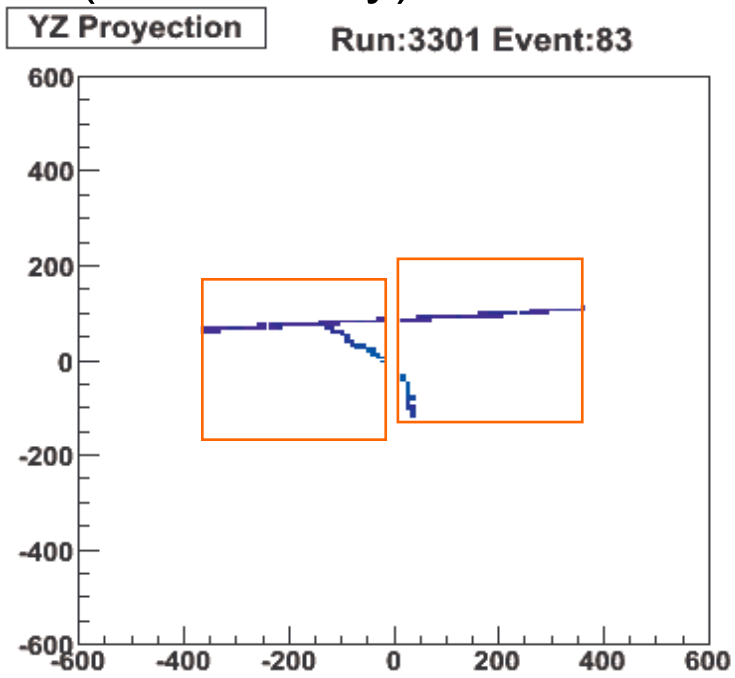
Beam test with TPC 0

- Starting from September 2008 the TPC 0 has been installed in the M11 beam line at TRIUMF
- The beam provides e, μ, π with a momentum up to 400 MeV/c
- A Time of flight system provides e, μ, π tagging
- Each track crosses 2 MicroMegas modules

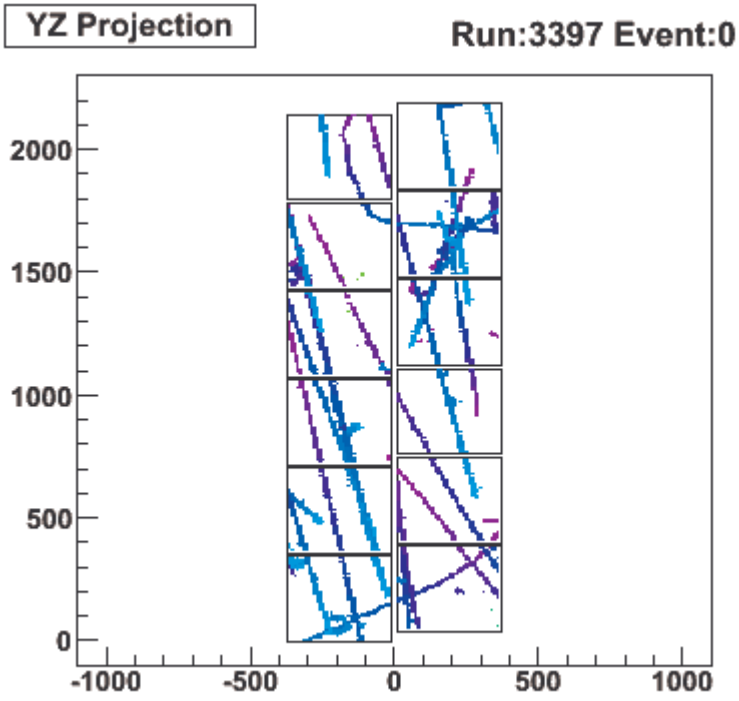


Some tracks from TPC 0 tests

- Beam track on 2 MM modules (with a δ ray)



- Cosmic on the full endplate



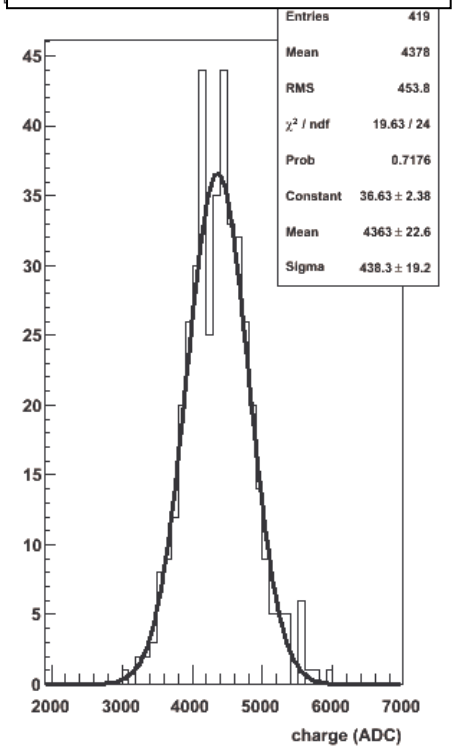
Purpose of the beam test studies

- The beam test have been used to check the capabilities of the T2K TPC
- In particular we used the beam test data to:
  - Study the energy resolution of the TPC
  - Test the PID method
- Data were taken with different momenta (from 100 MeV/c to 350 MeV/c)
- The TOF allowed to select samples of different particles independently from the TPC response

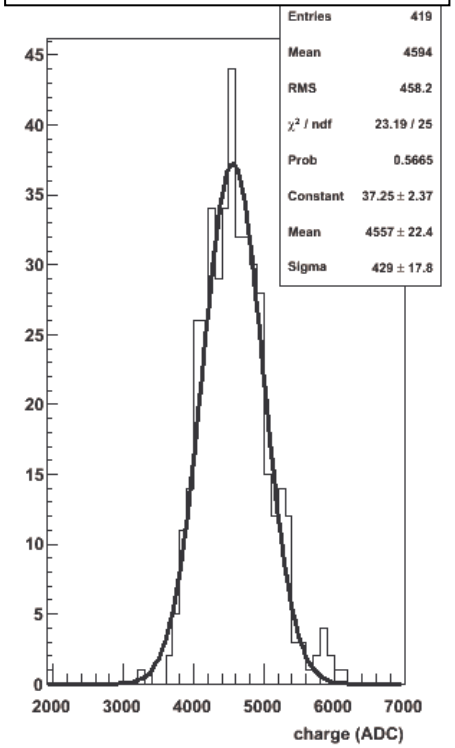
Energy resolution in the MicroMegas

- Muons, p = 150 MeV/c, energy resolution in the 2 MM modules

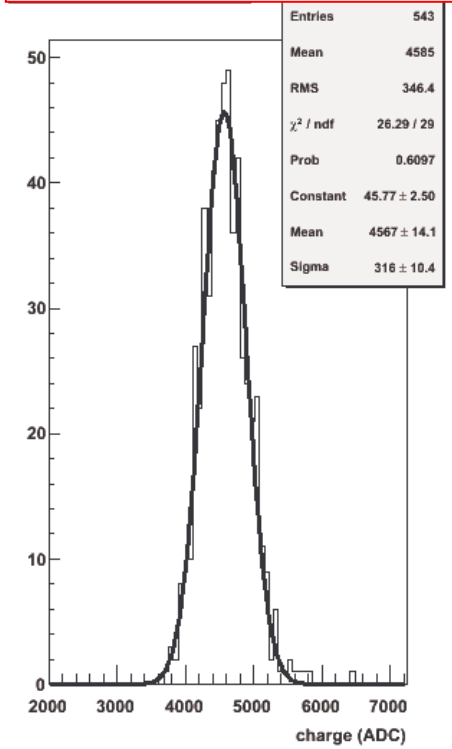
Res 1st MM = 10.0%



Res 2nd MM = 9.4%

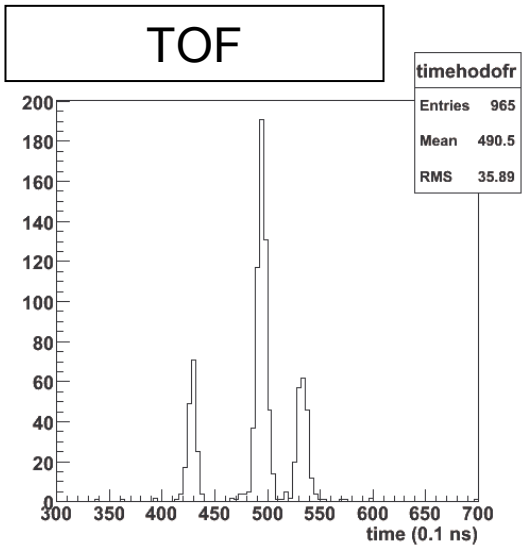


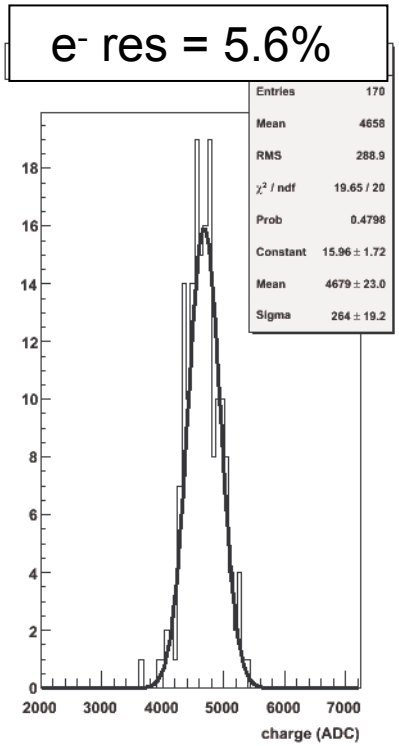
Res all TPC = 6.9%

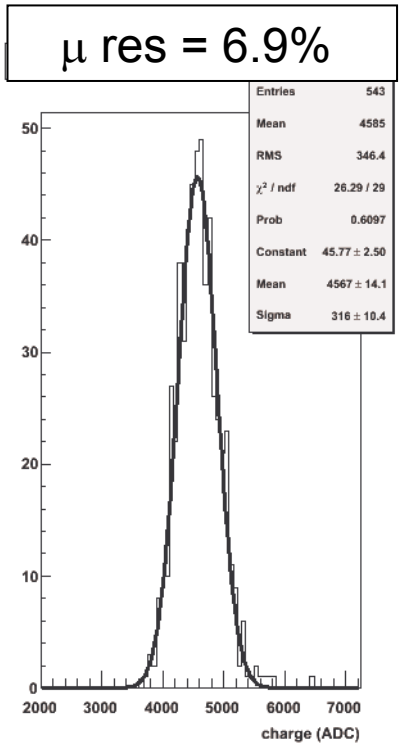


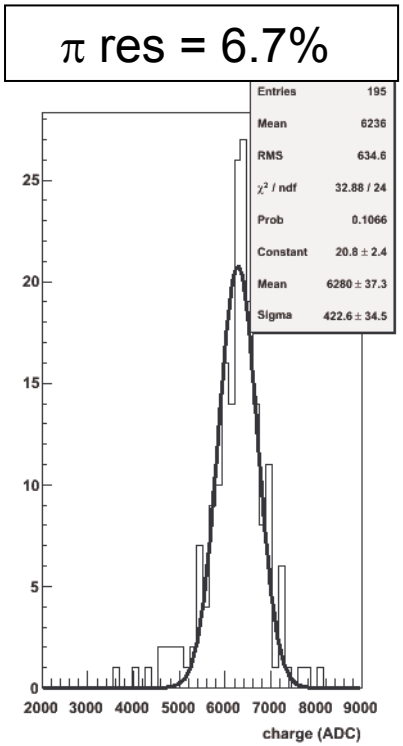
Resolution for different particles

- With the TOF system we selected samples of electrons, muons and pions for a given momentum
- TPC horizontal, p = 150 MeV/c





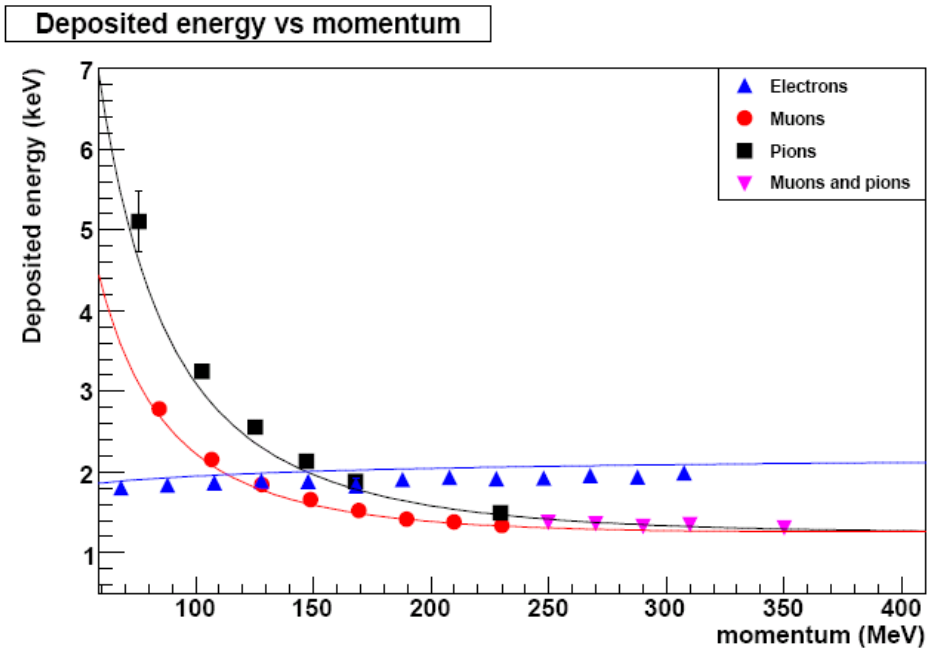




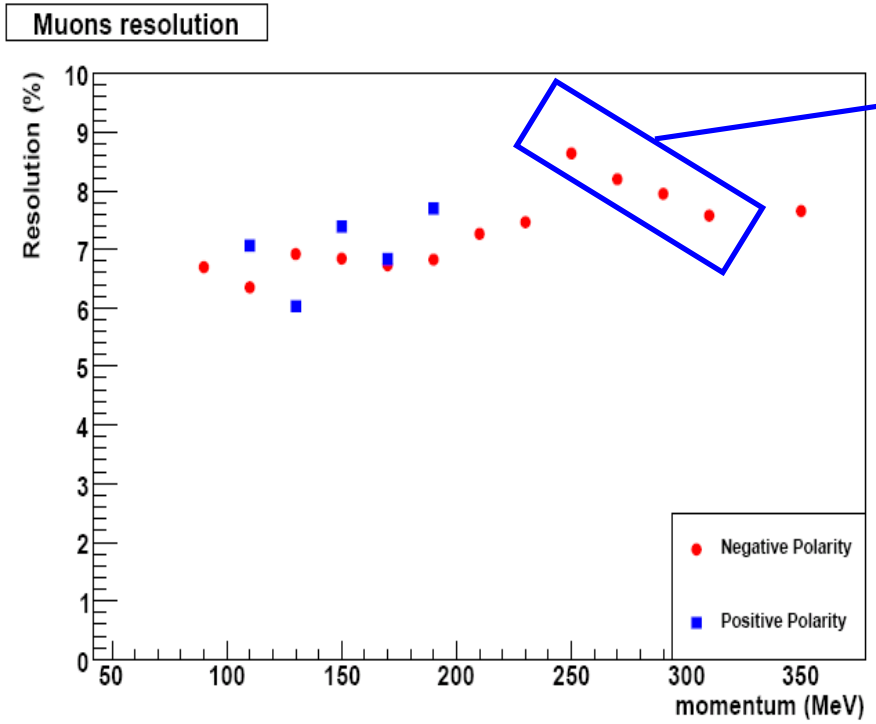
- At 150 MeV/c we can clearly see 3 different peaks

Energy loss vs momentum

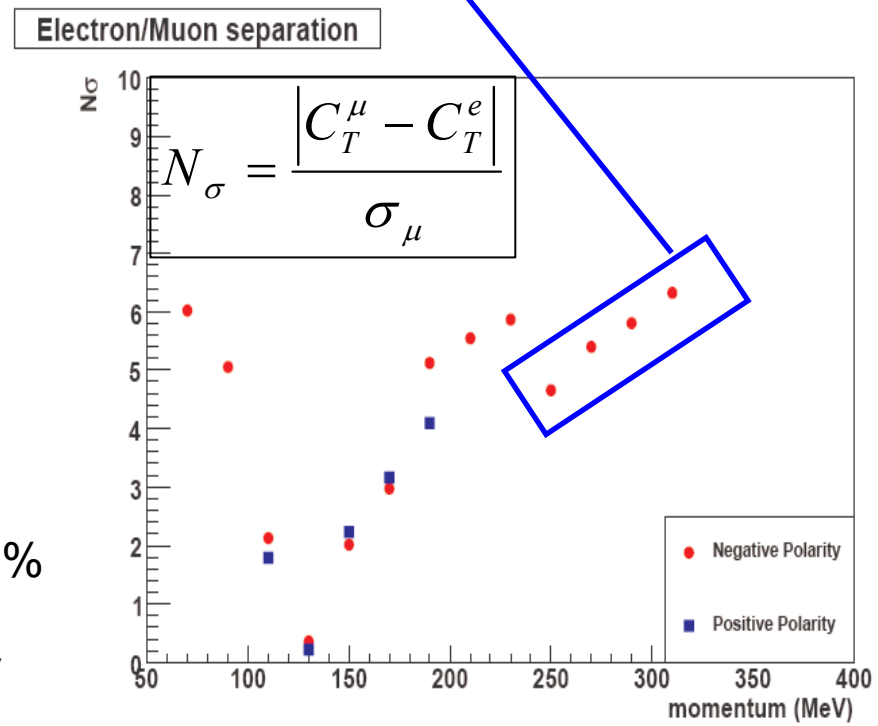
- Selecting particle with the TOF
- Compared the obtained curve for μ, π and e with the expected one from the MC studies →good agreement



e/μ separation



The TOF cannot distinguish muons from pions



$$N_\sigma = \frac{\left|C_T^\mu - C_T^e\right|}{\sigma_\mu}$$

- Resolution for muons better than 8%
- Separation larger than 5σ if the momentum is larger than 200 MeV

Conclusions

- The T2K TPCs are under construction at TRIUMF
  - TPC 0 is ready, fully equipped and has been tested in a beam test
  - TPC 1 will be ready and equipped in June
  - TPC 0 and 1 will be installed at Tokai in July/August
  - TPC 2 will be ready in October and will be installed at Tokai in December
  - The 3 TPCs will be ready for data taking in December 2009

- The TPC performance was tested with the data taken in the beam test
  - Energy resolution for muons better than 8%
  - e/μ separation better than 5σ