The T2K TPC: beam test and particle identification method

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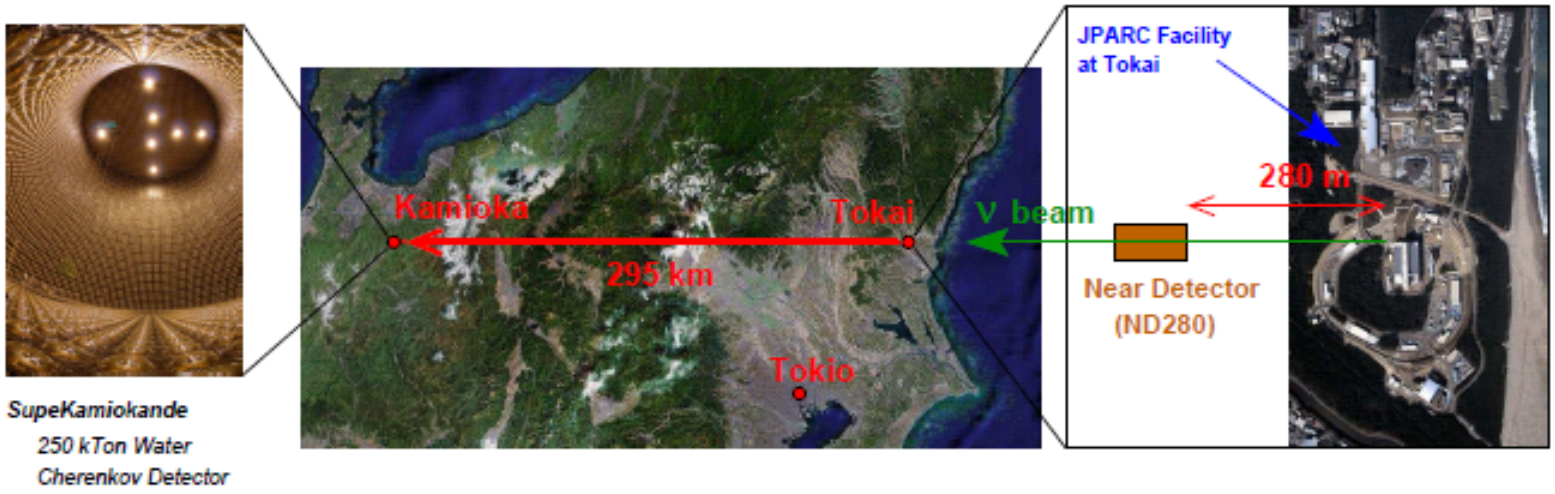
Summary

- The T2K experiment
- The Near Detector and the TPCs
- The MicroMegas
- The TPC Module 0
- The Particle Identification in the TPC
- Results of the beam test

The T2K experiment



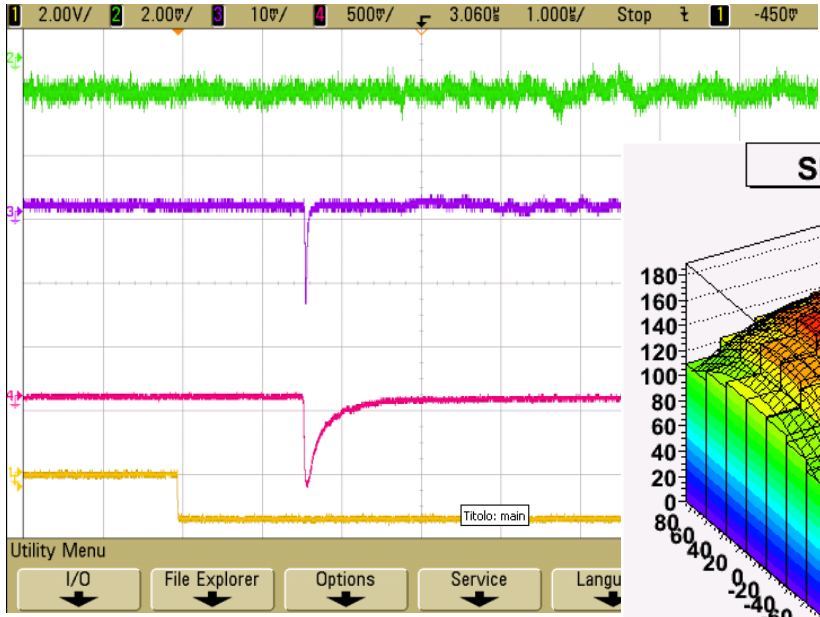
- Long Baseline Neutrino oscillation experiment
  - The neutrino beam started in April 2009
  - The data taking with all the ND280 facility installed will start in December 2009
- 30 GeV proton accelerator will be used to produce a ν_μ beam that will be send from Tokai to SuperKamiokande
  - **L = 295 Km**
  - Mean neutrino energy **E_ν = 0.7 GeV** (where the maximum of the oscillation is expected)
- **ν_e appearance** → First measure of θ_{13}
- **ν_μ disappearance** → Precise measurement of θ_{23} and Δm^2_{23}

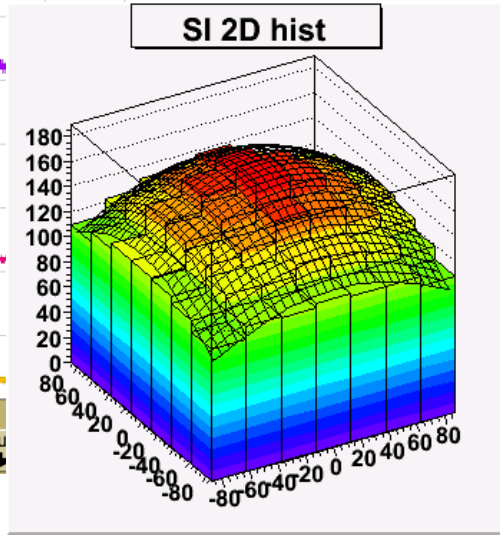
First T2K neutrino beam

- The T2K neutrino beam is in the commissioning phase
- On April 23rd the proton beam has been extracted and sent to the target → The first T2K neutrinos has been produced!

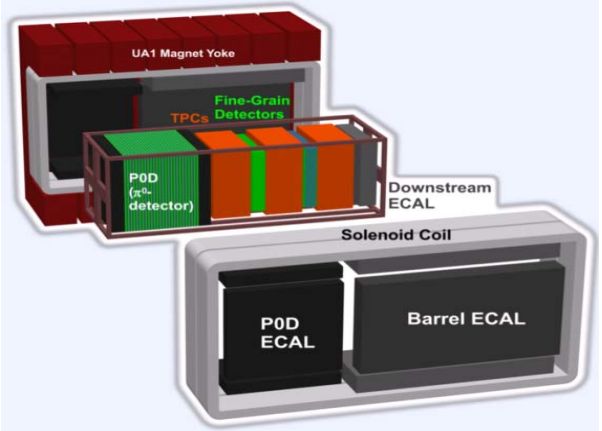
$$p + N \rightarrow \pi^+ \rightarrow \mu^+ + \nu_\mu$$

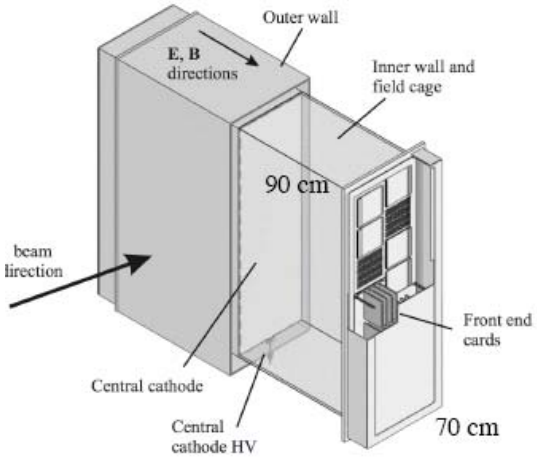
- Muons produced with neutrinos have been detected in the Muon Monitor
- Many neutrinos to detect in the next months/years!
- Many physics to do…





The Near Detector and the TPC





- Near Detector complex at **280 meters** from the neutrino beam production point
- Several detectors inside the UA1 magnet (with a field of **0.2 T**)
  - Characterize neutrino beam (before the oscillations)
  - Measure ν_e contamination in the beam
  - 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 perform electron/muon separation

Readout plane

Signal Amplification:

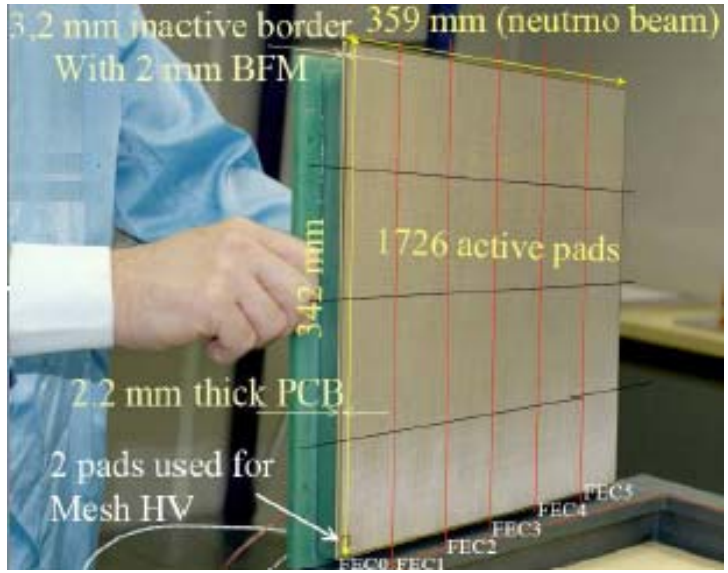
•12 large (35x36 cm²) bulk-MICROMEGAS on each endplate → 72 modules in 3 TPCs

•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



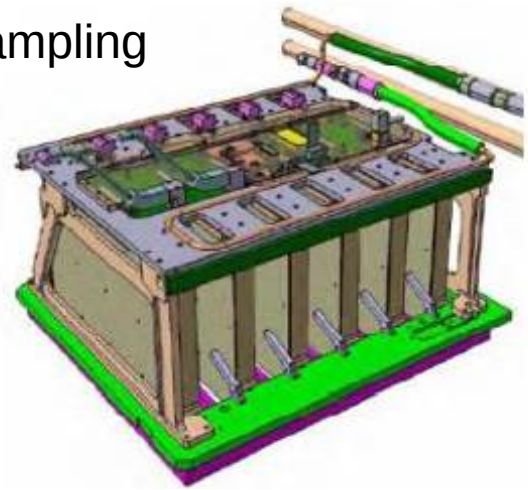
Readout electronic:

• ASIC AFTER (72 channels) with programmable gain, sampling time…

• 6 FEC + 1 FEM on each module

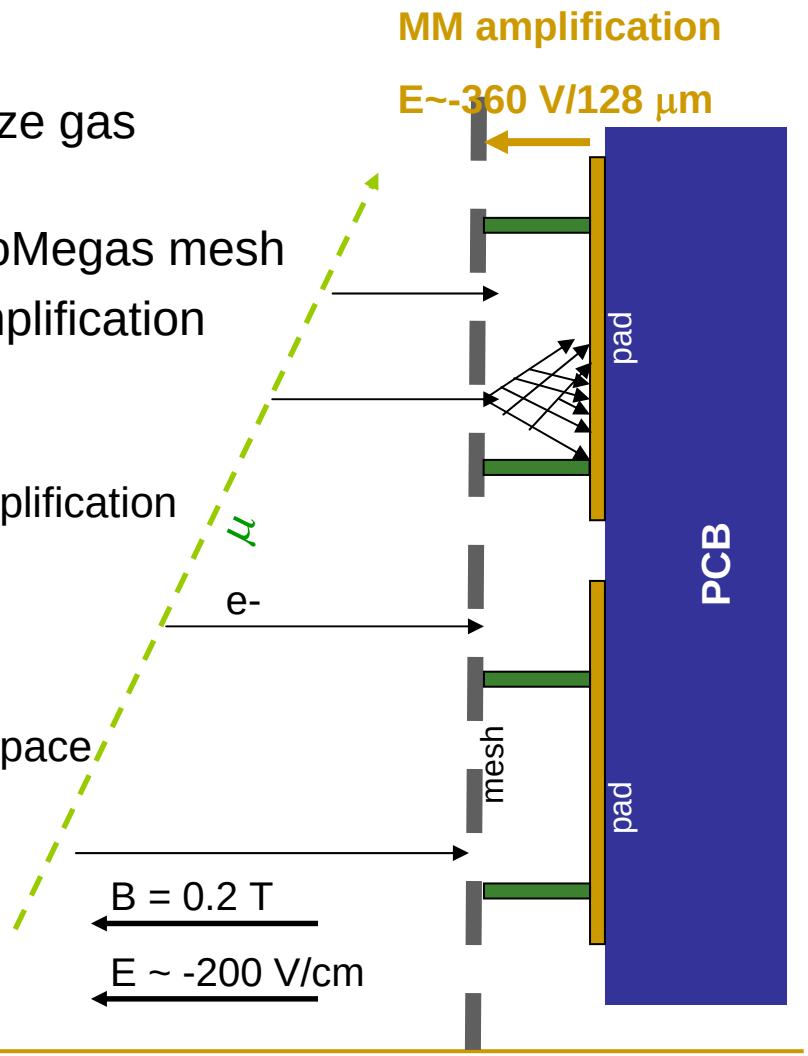
Front-End Card (FEC)

Front-End Mezzanine (FEM)



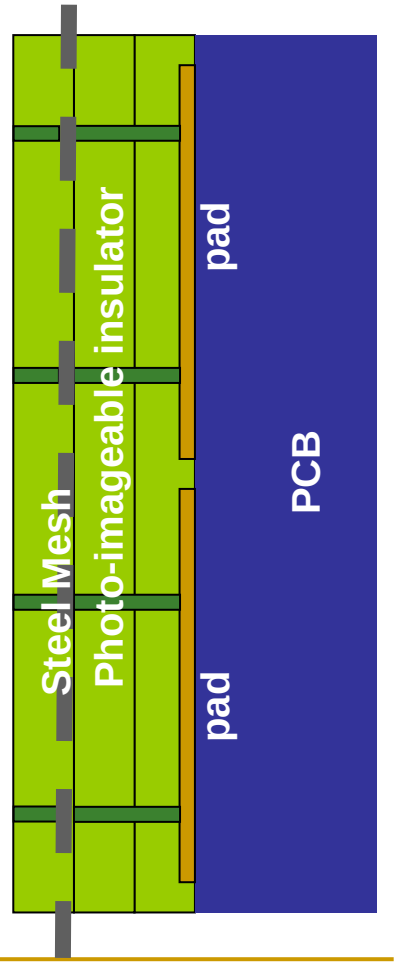
The MicroMegas principles

- Charged particles crossing the TPC ionize gas molecules
- The produced electrons drift to the MicroMegas mesh
- Once on the mesh the e^- enter in the amplification region where avalanches are generated
  - **Gain ~ 10^3 - 10^4**
  - **~ 100% collection efficiency** (if drift/amplification field is high enough)
  - Small gap → short rise time
- Ions flow back to the mesh
  - Only few ions permil go back to the drift space
  - Avoids space charge effects



The Bulk MicroMegas

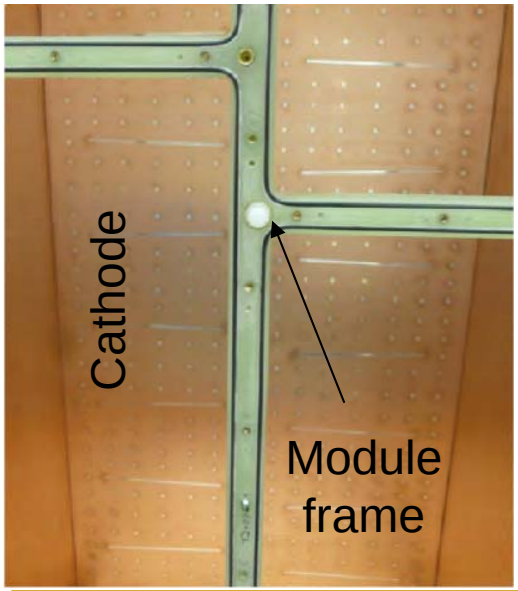
- The Bulk MicroMegas is a technology developed at CERN/Saclay
- Sandwich of:
  - 3 photo-imageable insulator layer (Pyralux) of 64 μm each
  - 1 steel mesh with a width of 2.4 mm and 2 layers (x,y) of 19 μm wires
- The sandwich is laminated on the PCB, exposed to UV, cleaned-heat-dried 2-3 times and then after a global QC test it's 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

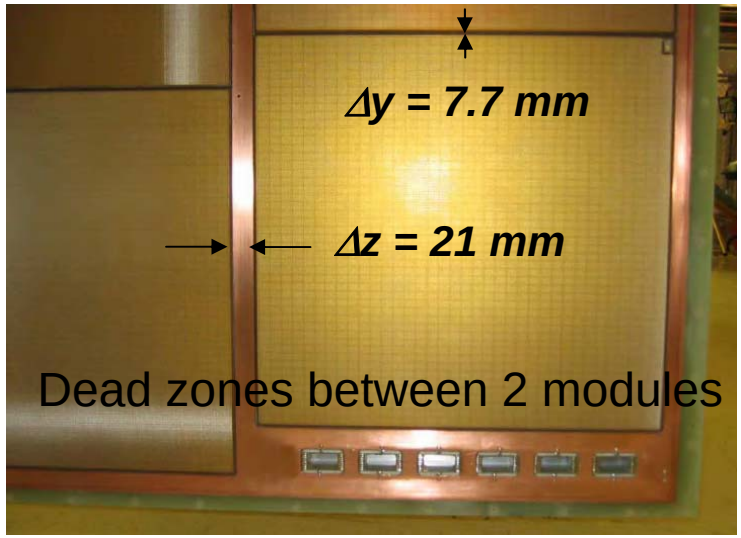


The TPC Module 0 @ TRIUMF

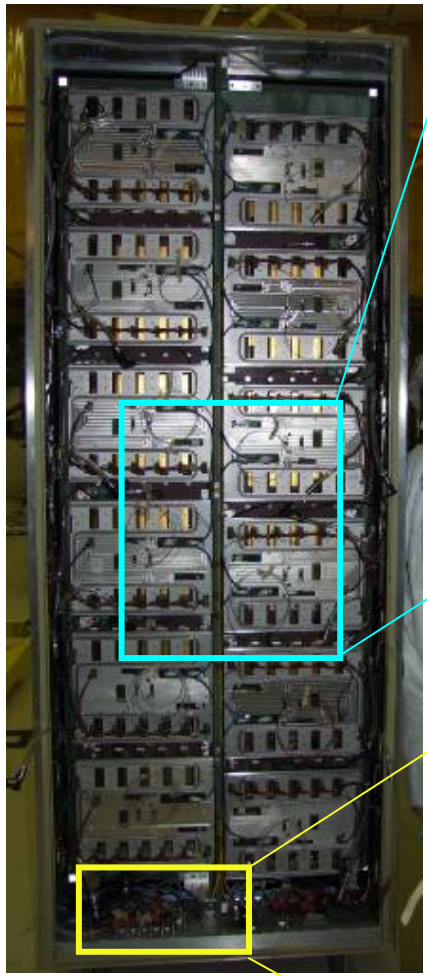
TPC Module 0 @ TRIUMF

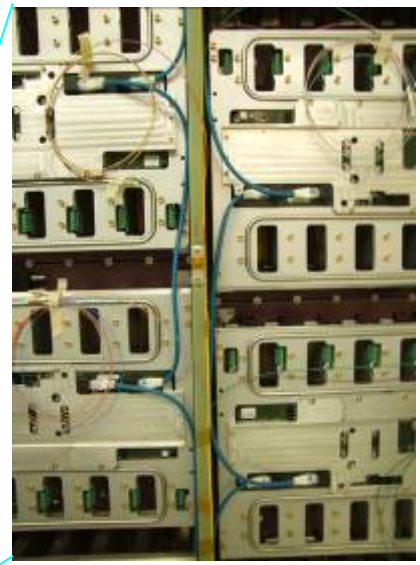
Internal face





Installation of the electronic on the TPC

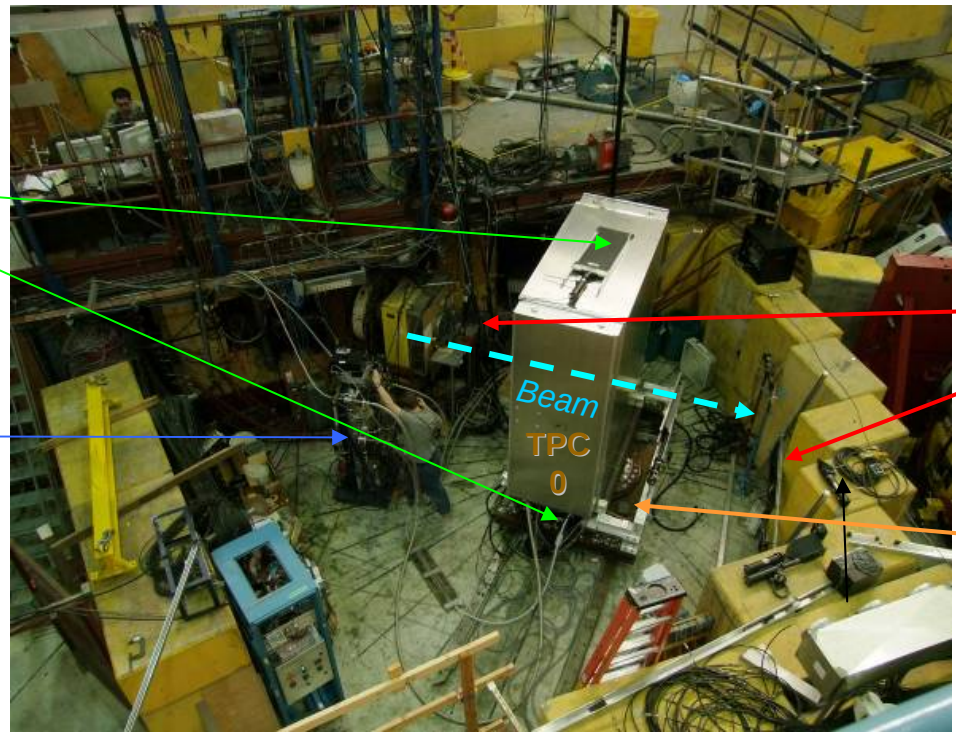




Module 0 is now completely equipped with 24 MicroMegas and all the Front-End electronic

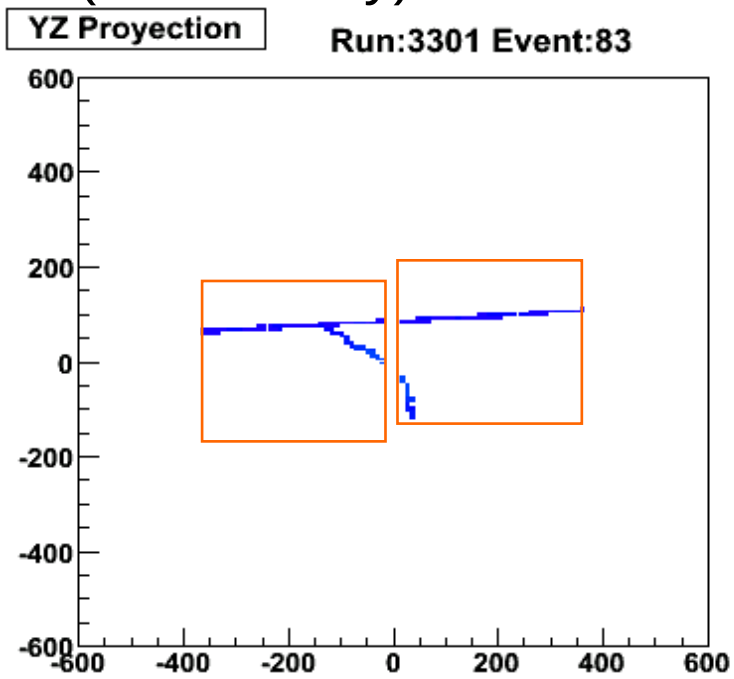
Beam test with Module 0

- Starting from September the Mod 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 module

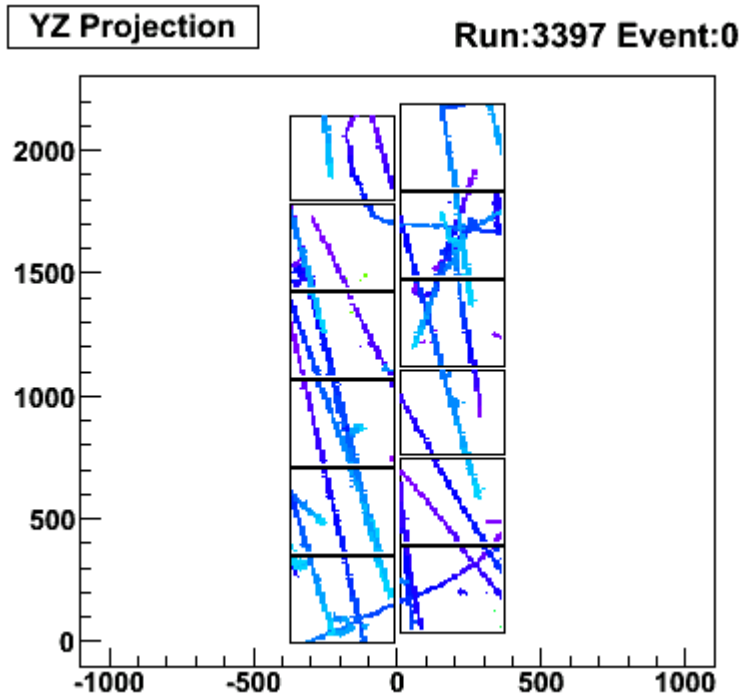


Some tracks from module 0 tests

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



- Cosmic on the full endplate



Particle Identification in the TPC

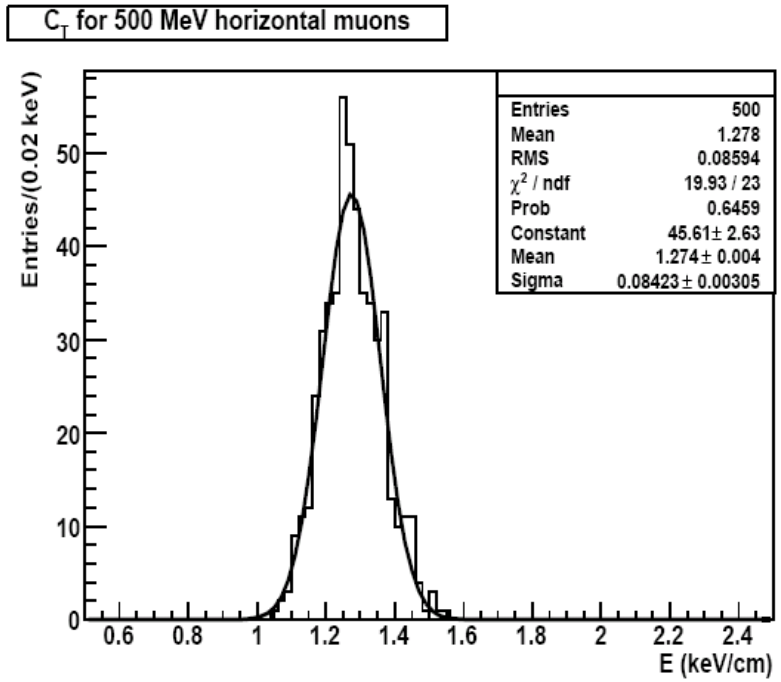
The Particle Identification in the TPC

- The TPCs are able to recognize different particles using measurements of the energy loss in the gas
  - The main purpose of this measurement is to distinguish electrons from muons → Measure the ν_e contamination in the beam, one of the main backgrounds to the measurement of θ_{13} via ν_e appearance
- We developed a method to perform the PID using MC simulation
- We tested this method using the beam test of the TPC Module 0
- The PID is based on the measurement of the truncated mean of the track crossing the TPC

PID with MC simulation

- For each reconstructed track that crosses all the TPC we have 72 measurements of energy (36 in each MM module)
- We measure the truncated mean of the charge for each track, selecting the 70% of the clusters with less charge (to reject Landau tails)
- We also need to parameterize corrections for the track angle and for the number of samples

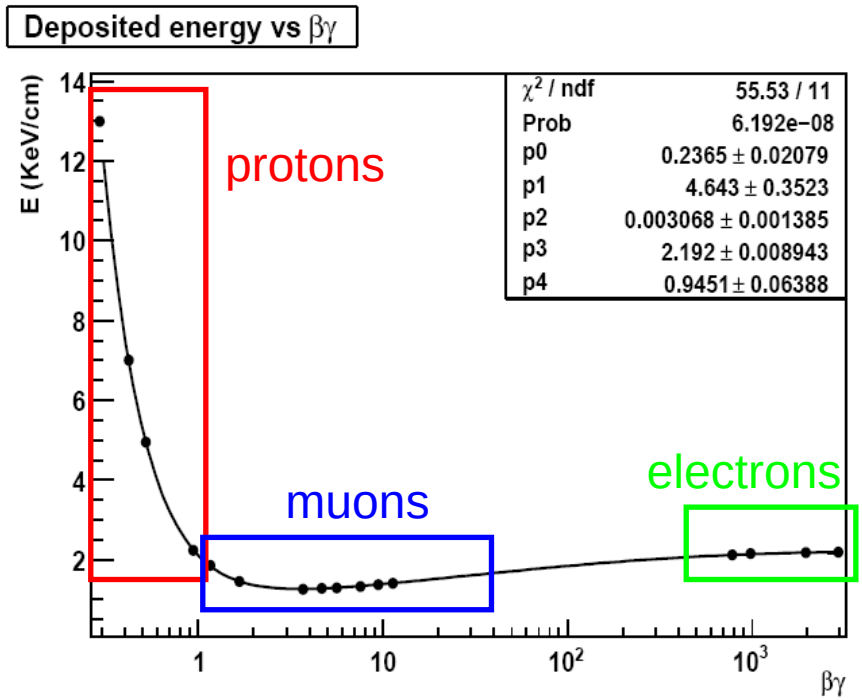
MC simulation



- Gaussian distribution
- Resolution (σ/Mean) ~6.6%

Parameterization of the expected energy loss curve

- The energy loss in the gas is a function of only $\beta\gamma$
- Producing samples of different particles (electrons, muons, protons) we parameterized the expected curve of the energy loss



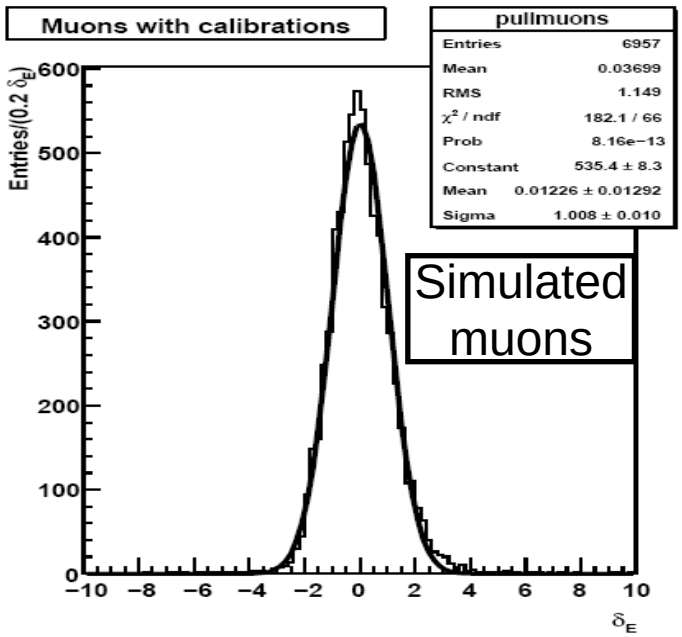
- Knowing the parameterization for each track:
  - Measure the momentum P
  - Measure the trun mean C_T
  - Compare C_T with C_E for a particle of momentum P and mass M_i (i= e, μ, π, p, K)

Simulation of neutrino interactions

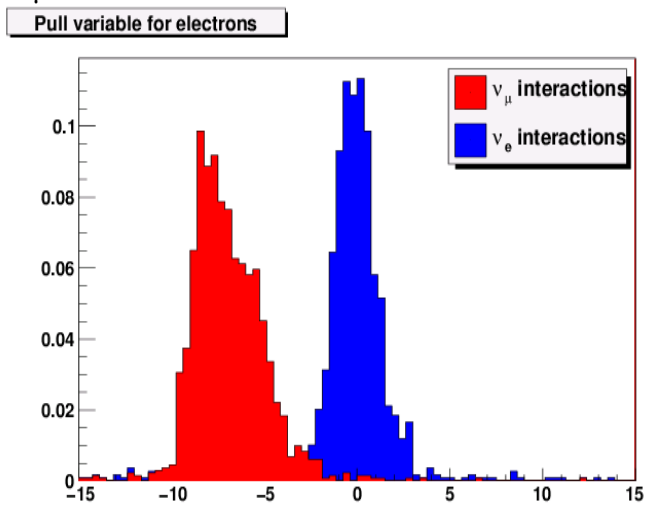
- To quantify the PID we define a pull variable

$$P^j(i) = \frac{C_T(i) - C_E^j(i)}{\sigma_E^j(i)} \qquad j = e, \mu, \pi, p, K$$

- The distribution of the pull for a given particle in the right hypothesis is a gaussian centered in 0 with width 1



Looking at the pull in the electron hypothesis we can distinguish ν_e/ν_μ interactions



Results of the Beam Test

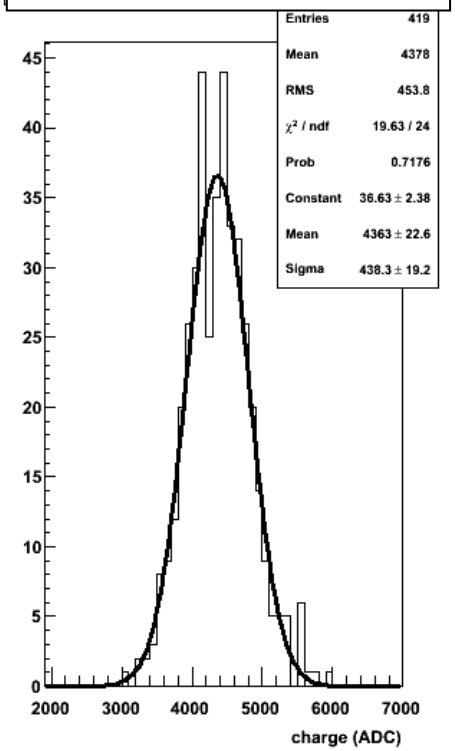
Purpose of these studies

- 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
- We took data with different momenta (from 100 MeV/c to 350 MeV/c)
- For each reconstructed track we measured the truncated mean
- The TOF allowed to select samples of different particles independently from the TPC response

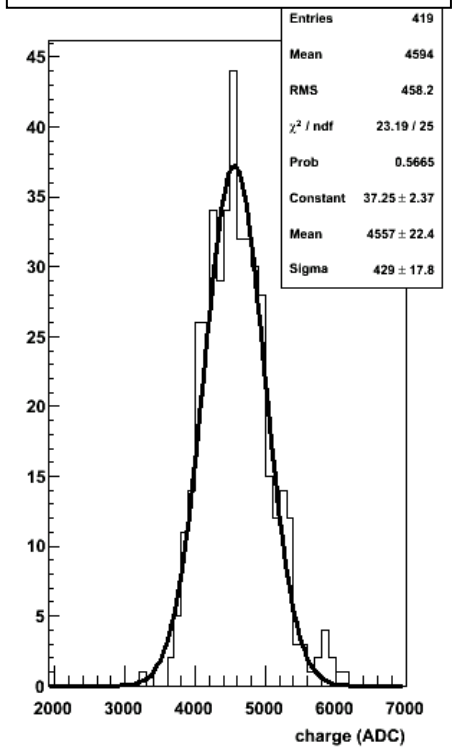
Energy resolution in the MicroMegas

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

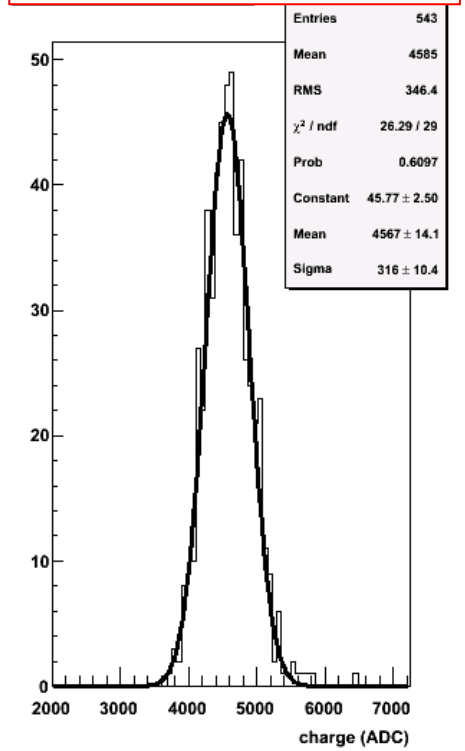
Res 1st MM = 10.0%



Res 2nd MM = 9.4%



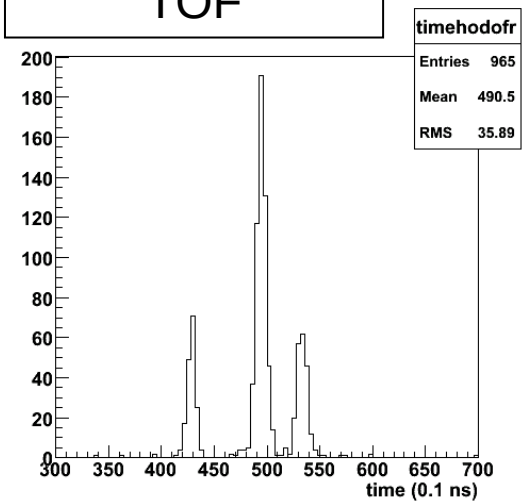
Res all TPC = 6.9%



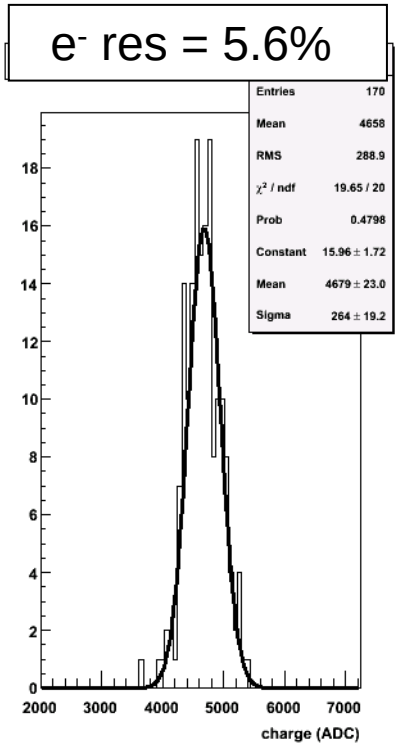
Resolution for different particles

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

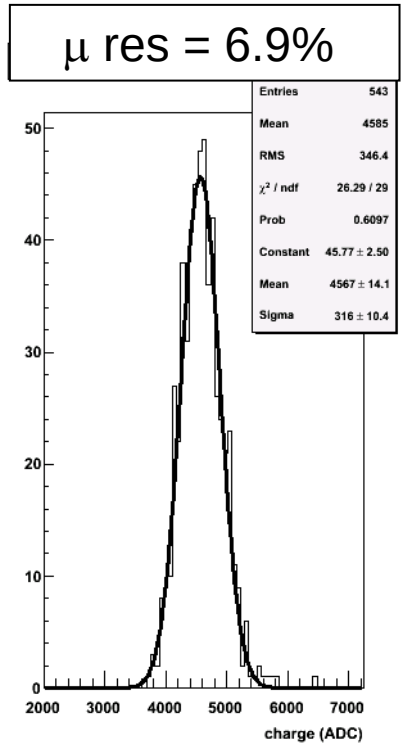
TOF



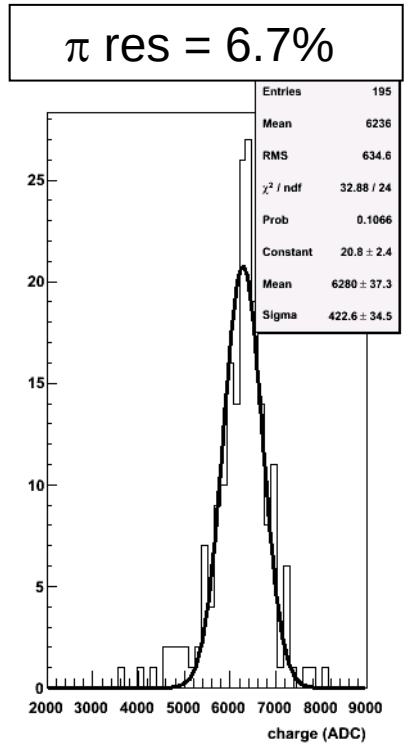
e^- res = 5.6%



μ res = 6.9%



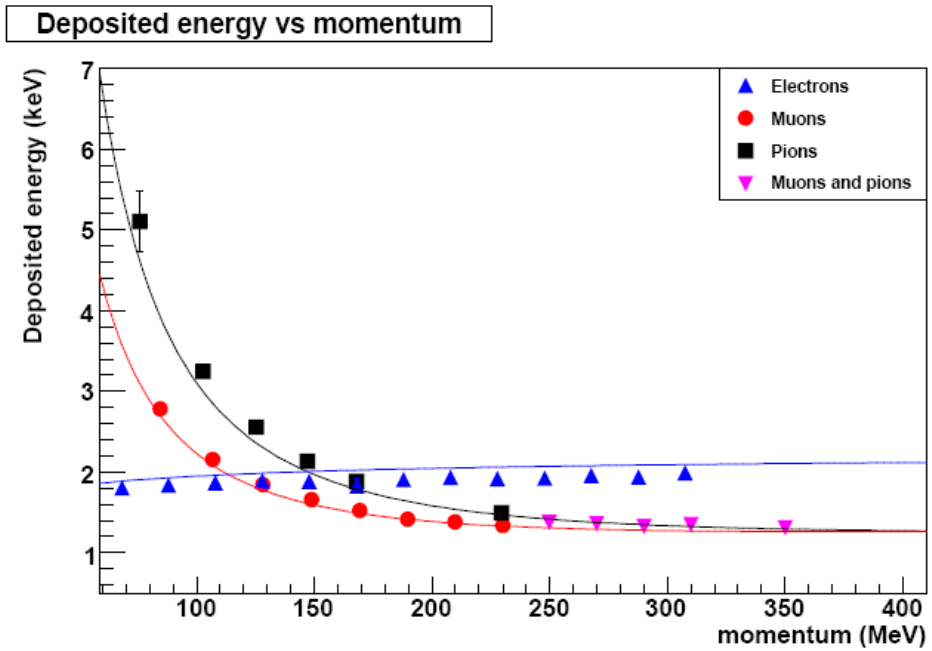
π res = 6.7%



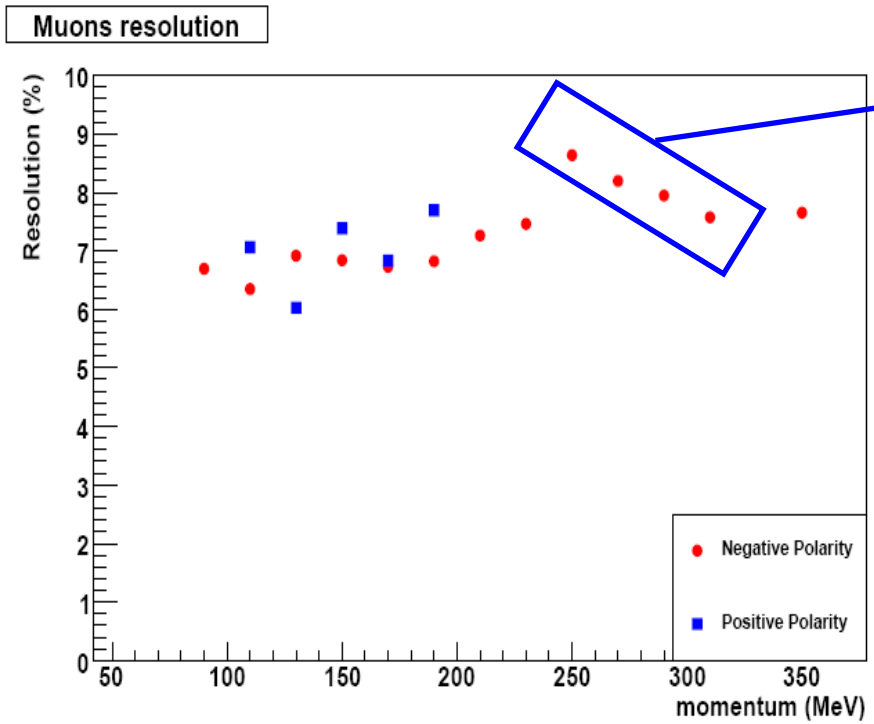
- At 150 MeV/c we can clearly see 3 different peaks

Energy loss vs momentum

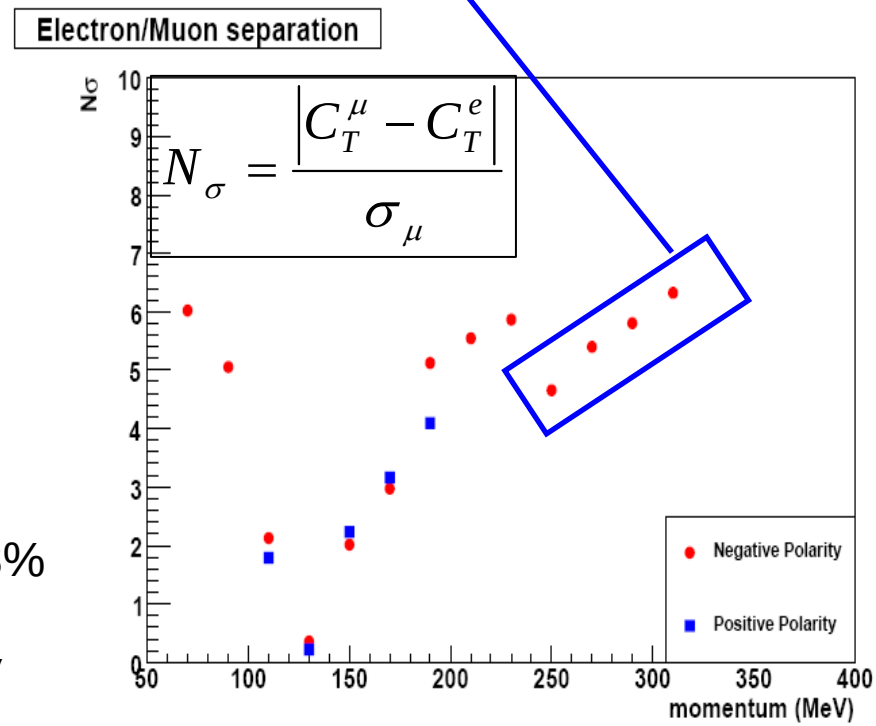
- Selecting particle with the TOF we computed the CT
- Compared the obtained curve for μ, π and e with the expected one from the MC studies →good agreement



e/μ separation



The TOF cannot distinguish muons from pions



- 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
  - The Module 0 is ready, fully equipped and is taking data in a beam test
  - The Module1 will be ready and equipped at the end of May
  - Module 0 and Module 1 will be installed at Tokai in August/September
  - The Module 2 will be ready during the summer and will be installed at Tokai in October
  - T2K will start the data taking in December 2009
- We developed methods to perform the PID in the TPC and we tested them with the data taken in the beam test
  - Energy resolution for muons better than 8%
  - e/μ separation better than 5σ
  - This will allow to measure the ν_e contamination in the T2K beam

Back up slides

History of tests