Performance of the first T2K-TPC

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On behalf T2K/TPC group:

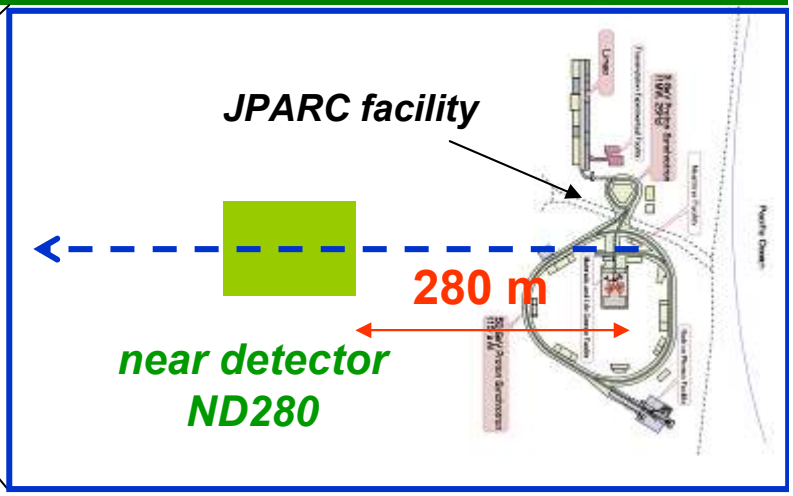
Canada	University of British Columbia,
	University of Victoria,
	TRIUMF
France	IRFU-CEA Saclay,
	LPNHE Paris-VI-VII universities
Germany	RWTH Aachen University
Italy	INFN/Bari
Spain	UAB/IFAE University of Barcelona
	University of Valencia
Switzerland	CERN/TS-DEM-PMT,
	DPNC/University of Geneva

Outline

- Introduction
- T2K-TPC
- Readout endplate
- TPC test and performance
- Conclusion

The T2K experiment

Super-Kamiokande Cerenkov detector

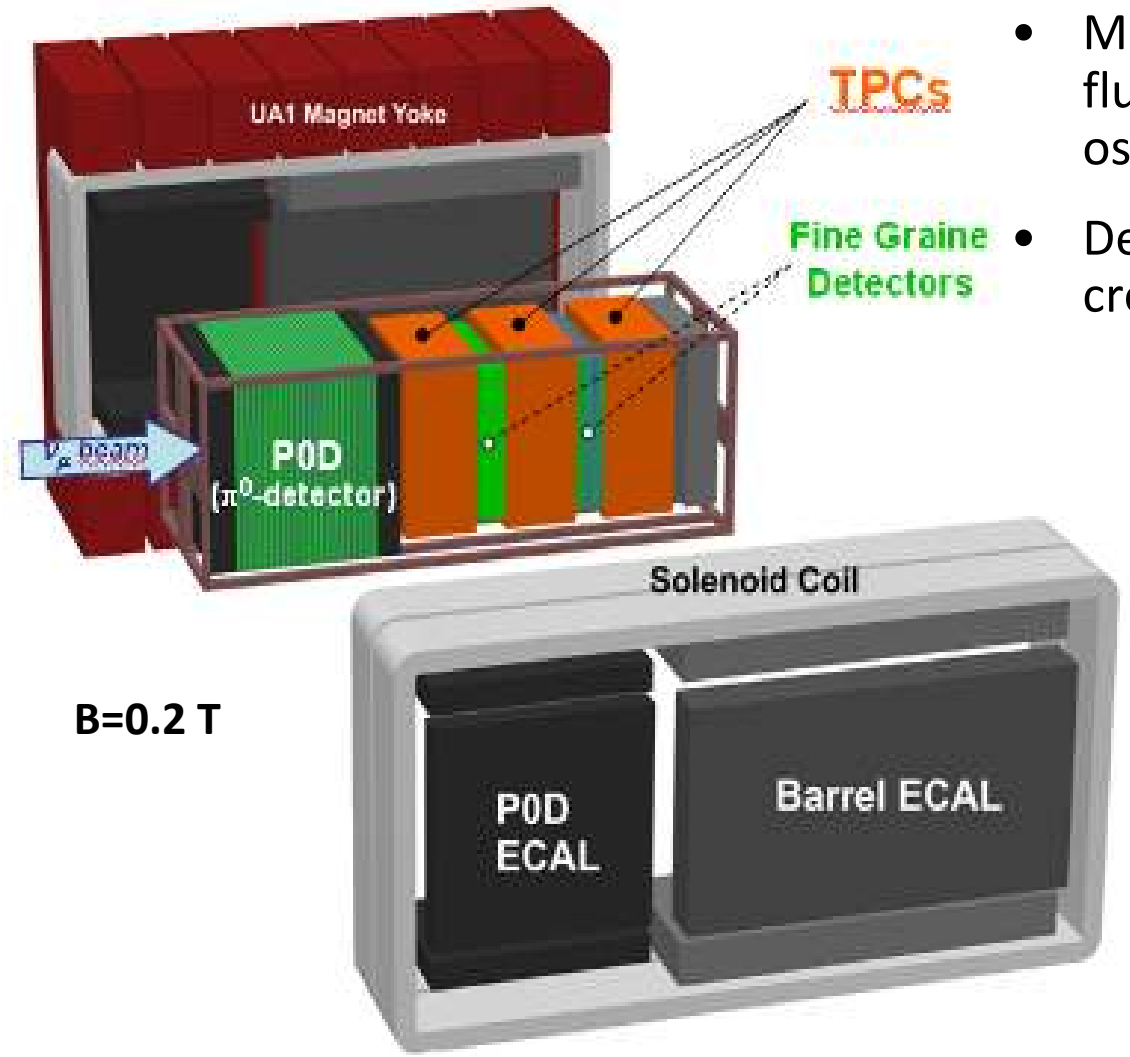


A long baseline neutrino oscillation experiment

- Intense ν_μ beam with 650 MeV/c energy mean for neutrino oscillation study
- Main goals
  - Direct search for $\nu_\mu \rightarrow \nu_e$ **appearance** (θ_{13})
    - $\sin^2 2\theta_{13} < 7.10^{-3}$ (90% CL) expected for T2K (***5.10²¹ POT***)
  - ν_μ **disappearance** → to improve "atmospheric" oscillation parameters measurement

$$\delta\left(\sin^2 2\theta_{23}\right) \approx 0.01 \qquad \delta\left(\Delta m^2{}_{23}\right) \approx 3.10^{-5}\, eV$$

The near detector ND280



B=0.2 T

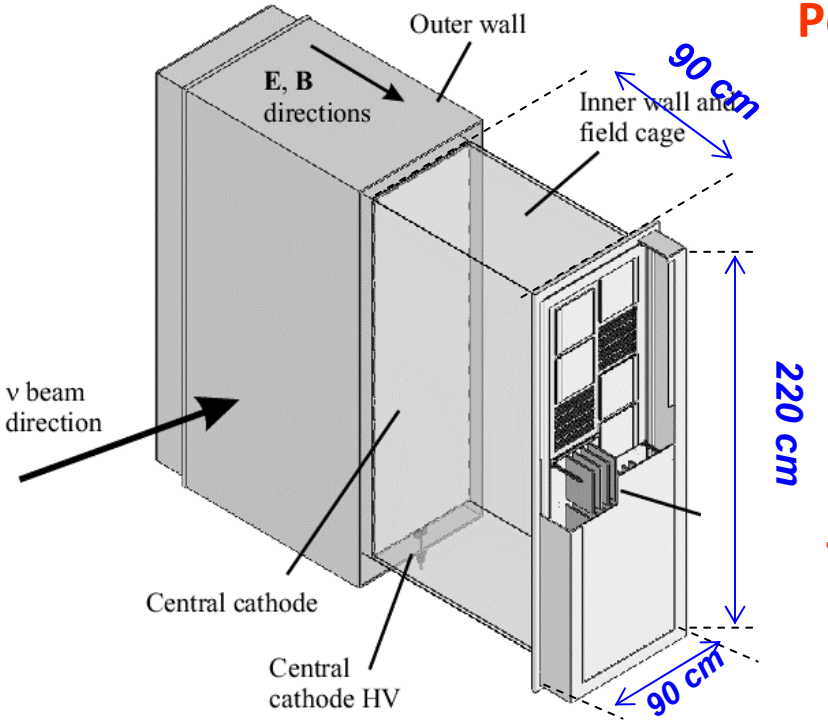
A magnetized detector to:

- Measure energy spectrum and fluxes for ν_μ and ν_e prior to oscillation
- Determination of ν interaction cross-section

TPCs:

- Measure charge and momentum of charged particles
- Particle identification to distinguish e, μ, π and p
- Excellent pattern recognition

T2K/TPC outline



Performance requirements:

- **dE/dx resolution < 10 %** to perform e/μ separation
- Momentum measurement with resolution **δp/p < 10% @ p ≈ 1GeV/c**
  - High segmentation
  - Good spatial resolution

TPC readout design:

- Sampling length ~ 70 cm
- Pad size ~ 70 mm²
- **MICROMEGAS** as amplification device

Gas choice:

- $Ar/iC_4H_{10}/CF_4$ (95/2/3)
  - Fast gas mixture $v_d \approx$ 7.8 cm/μs @ 280 V/cm → *to avoid electron attachment*
  - Low transverse diffusion $C_T \approx$ 270 μm/√cm @ 0.2 T → *good spatial resolution*

TPC field cage

Momentum bias to be controlled better than 2%:

- Track distortion to be understood within ~ 100 µm, requires:
  - Small electric field distortion (<10^{-4} level)
  - Careful consideration on field cage design and mechanicals (it's not a simply box !!!)
  - Mechanical tolerance for machining and assembly ~100 µm
  - Design takes care about deflection due to over pressure <1mBar

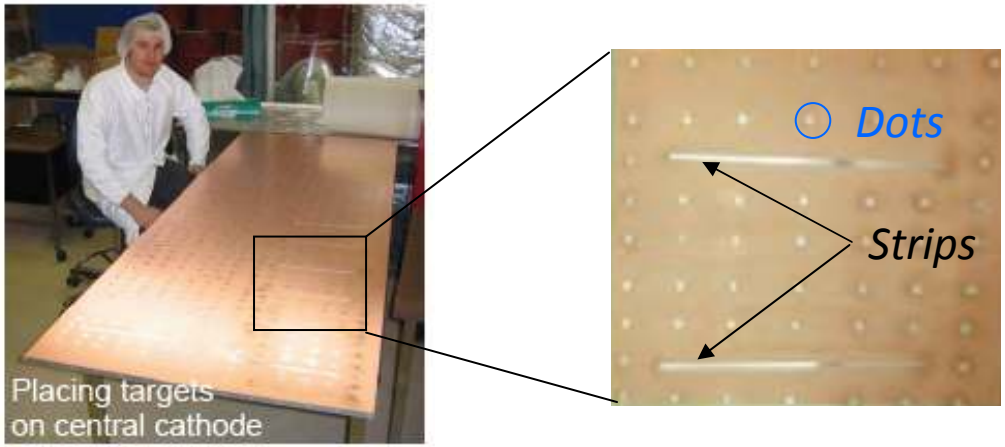
Field cage strip cut

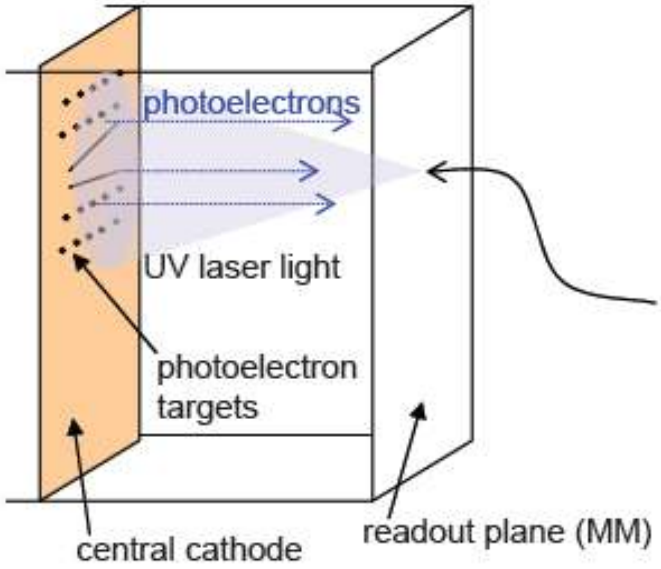
connects strips on adjacent panels

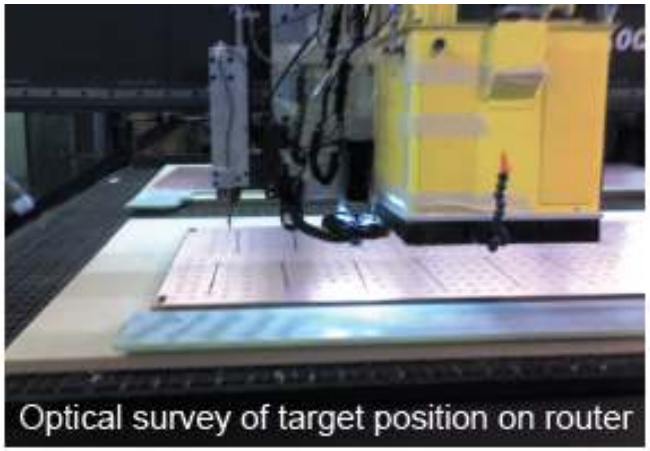
Inner box assembly

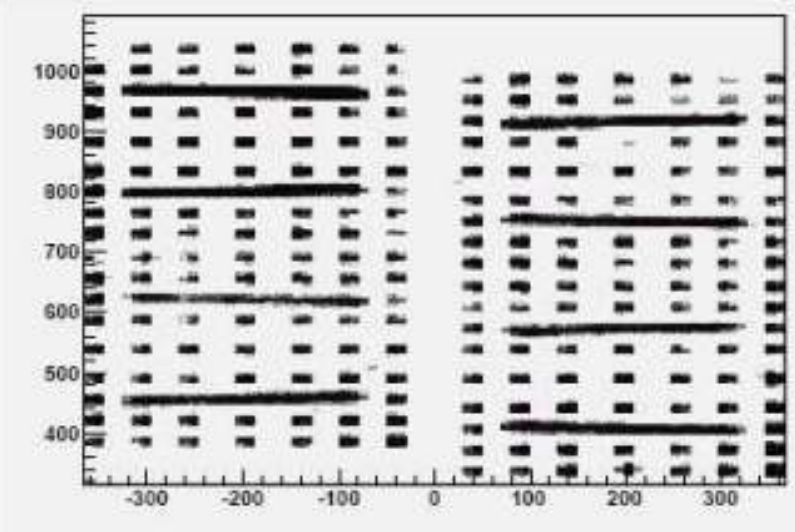
Laser calibration system

- Al targets on the central cathode illuminated by UV laser light:
  - **Field distortion calibration** (in situ)
  - Electron drift velocity (V_d)









Bulk-MICROMEGAS (T2K design)

Bulk-MICROMEGAS characteristics:

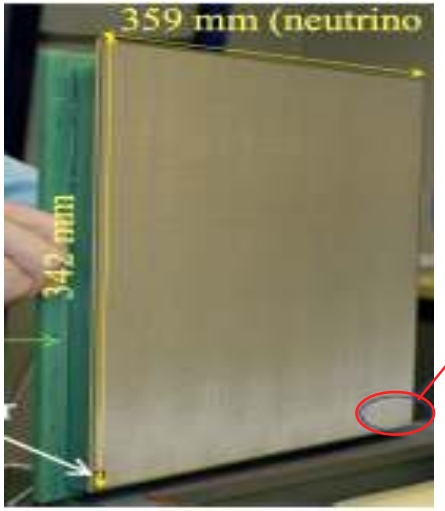
- all-in-one detector → *anode + mesh*:
  - Simple design, robust and cheap
  - Massive production
  - Good uniformity
  - Minimized blind areas (edges, corners)
- Saclay design and production by CERN/TS-DEM-PMT

T2K bulk-MM:

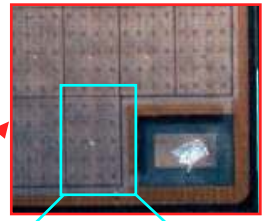
- 128 µm amplification gap
- Large surface **34x36 cm²**
- **1726** active pads (6.9 x 9.7 mm²)
- 48 rows, 36 columns of pads
- 12 MICROMEGAS detectors per plan
- **72** MM for 3 TPCs
- Total equivalent surface about **9 m²**

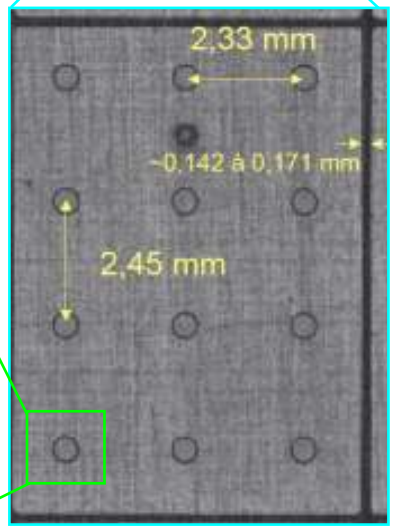
→ **First large size MPGD based TPCs**

T2K bulk-MM

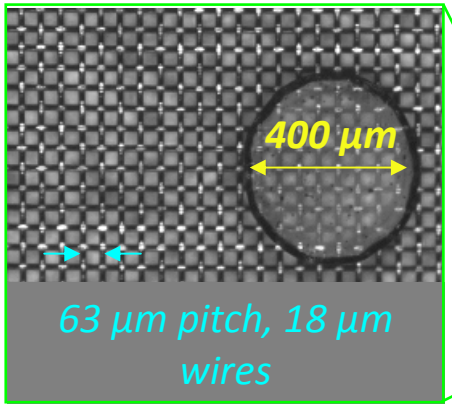


HV mesh via





Pad details

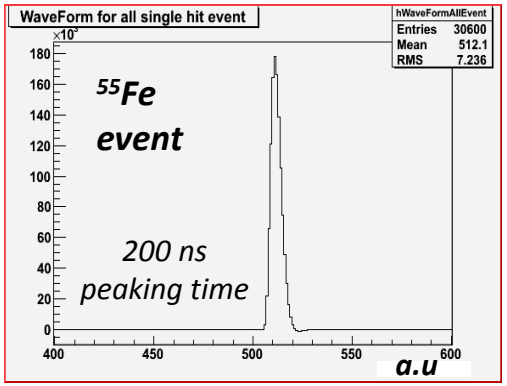


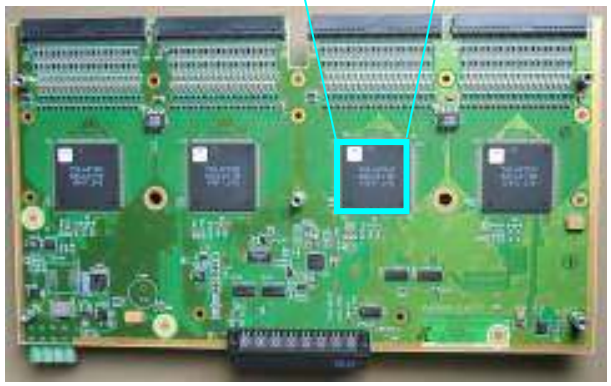
Mesh, pillar zoom

Front-end electronics

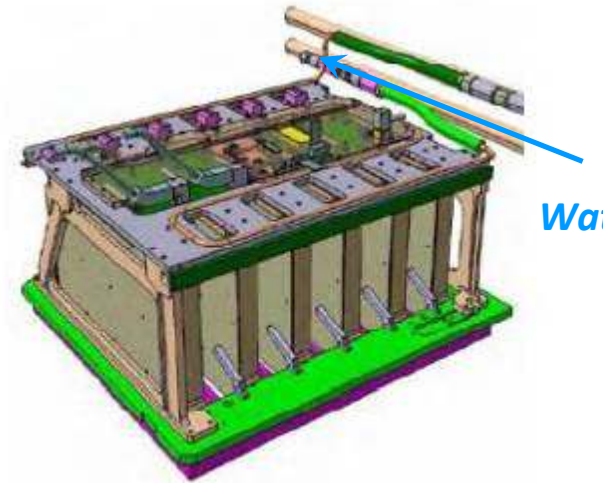
124 272 pads to readout:

- AFTER chip based electronics
  - 72 channels x 511 analog memory cells
  - 72-to-1 data concentration
  - Charge range (120 -> 600 fC) adjustable
  - Programmable peaking-time (100 ns -> 2 µs, 16 values)
  - M.I.P. / noise ratio : 100
  - Power consumption per channel : 7 mW
- 6 FECs per MM module + 1 FEM

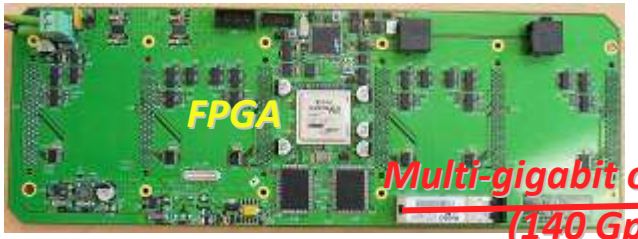




Front-End Card (FEC)



Water @ 18°C

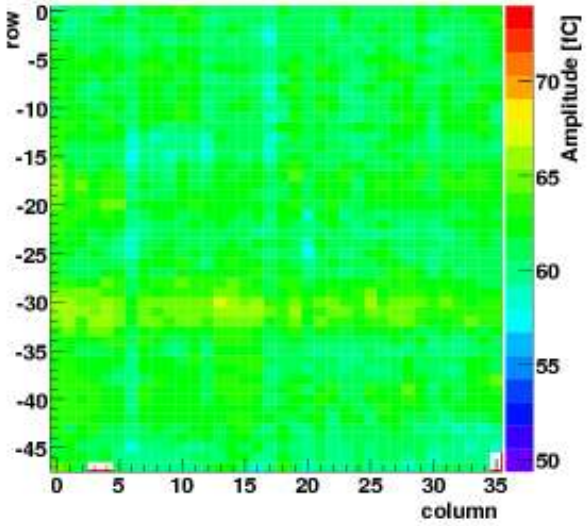


Front-End Mezzanine Card (FEM)

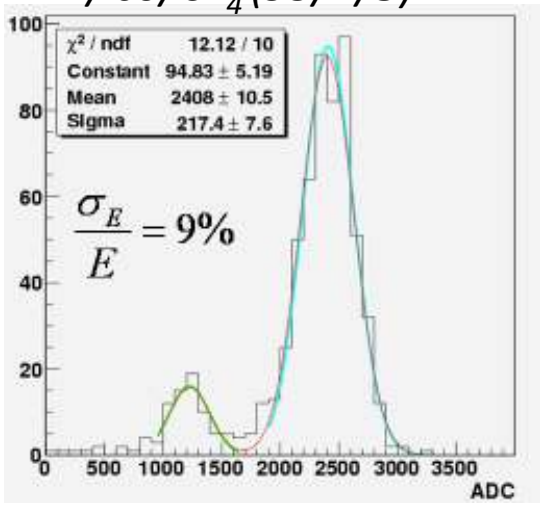
MICROMEGAS test and calibration

(X, Y) ^{55}Fe scanning:

Response uniformity

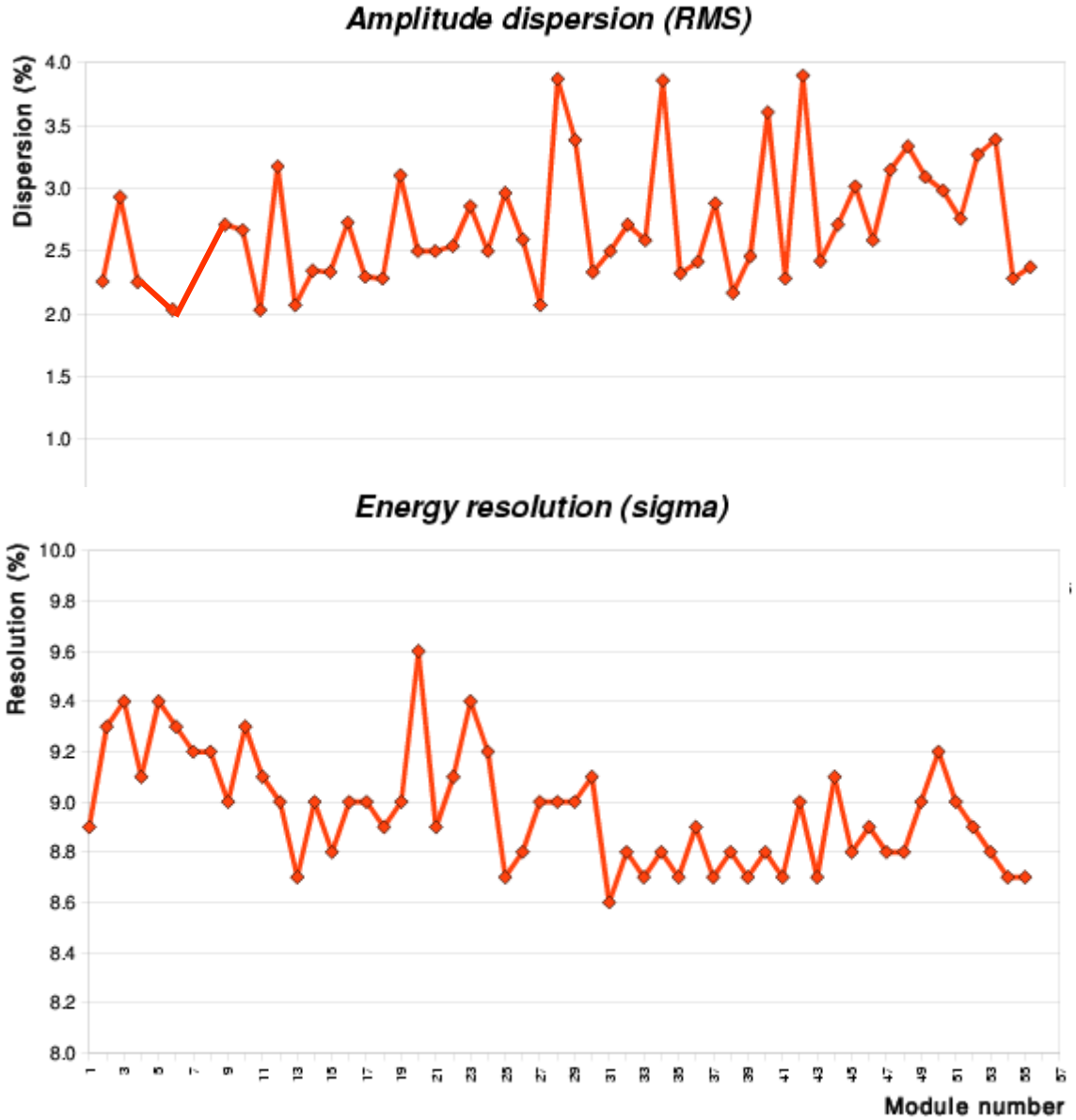


Ar/iso/CF_4 (95/2/3)



- Quality control check
  - Faulty pads
  - Edge effect
- Characterization and calibration pad per pad
  - Energy resolution measurement @ 5.9 keV
  - Gas gain as function of V_{mesh}
  - Gain and resolution uniformity @ nominal gain (G~1500, V_{mesh}=-350 V)

MM production summary



Status:

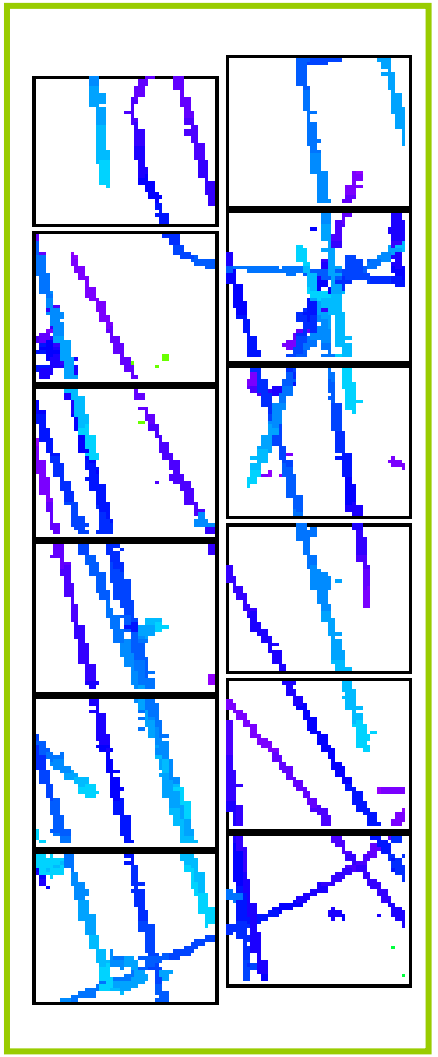
- ~75% of production completed → 61 MM tested
- 3 rejected modules (35nA current, broken, low gain on 100 pads)
- ~10 faulty pads

Performance:

- **Good gas gain uniformity** → dispersion ≈ 3% over all MM surface
- **No edge effect**
- **Good energy resolution** @5.9 keV → ~ 9 % (σ_E/E)
- Sparking rate: 0.1 h^{-1} and per MM @ V_{mesh} = -350 V

Readout endplate

First T2K-TPC module completed, tested and ready to be sent to Japan



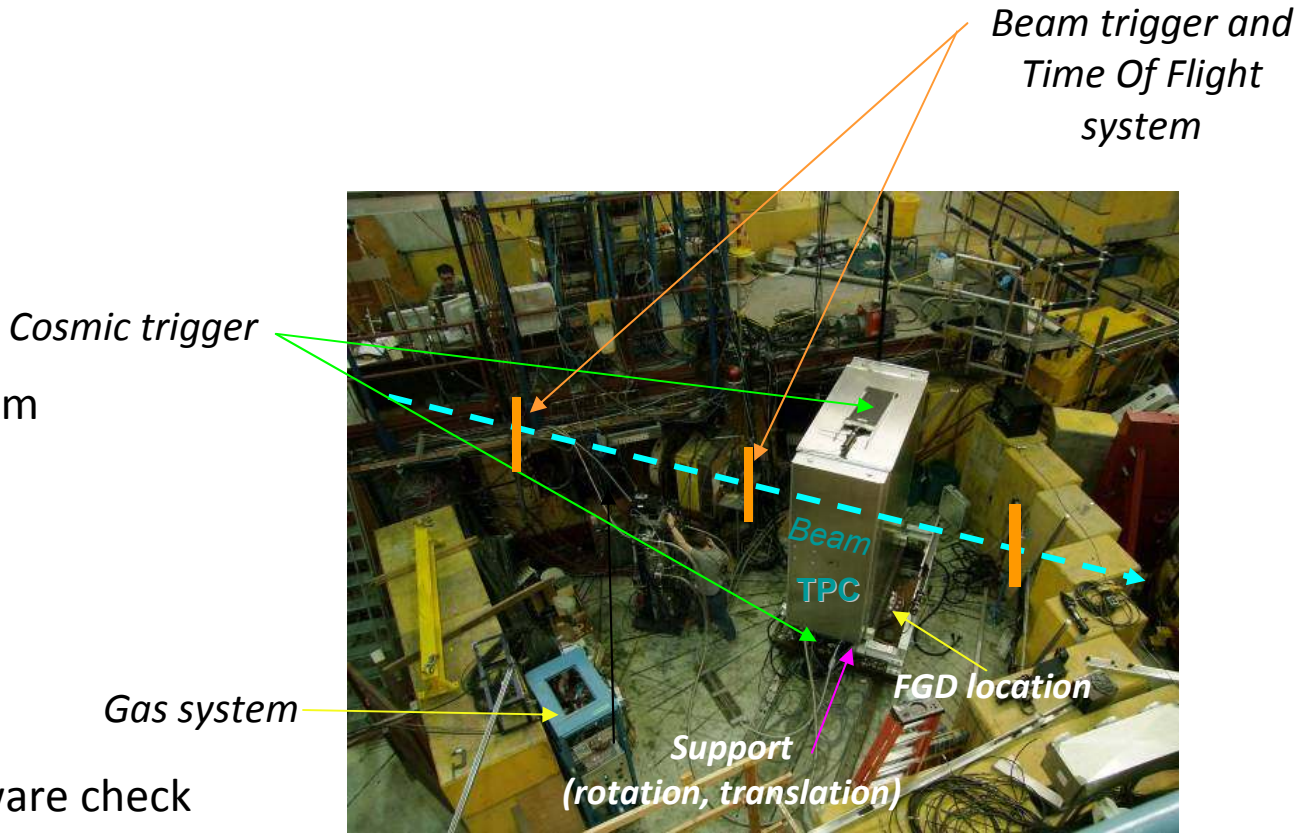
Tests @ TRIUMF

M11 area (TRIUMF, Vancouver):

- Beam test : e, p, π and μ up to 450 MeV/c
- Cosmic ray test

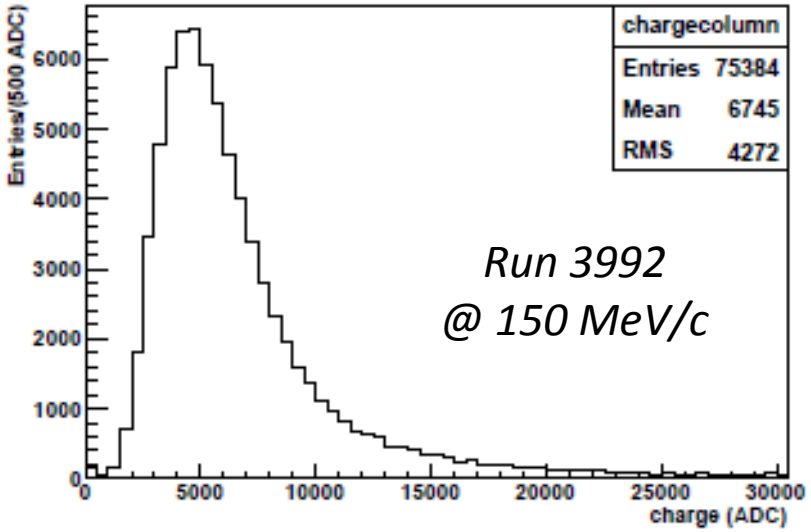
- Complete system test
  - HV system
  - Gas
  - Electronics
  - Cooling
  - Slow control
  - Laser calibration system
  - TPC box
    - *O_2 level < 5 ppm*
    - *H_20 level < 15 ppm*

- First test TPC+FGD
  - Track reconstruction
  - Input for ND280 software check

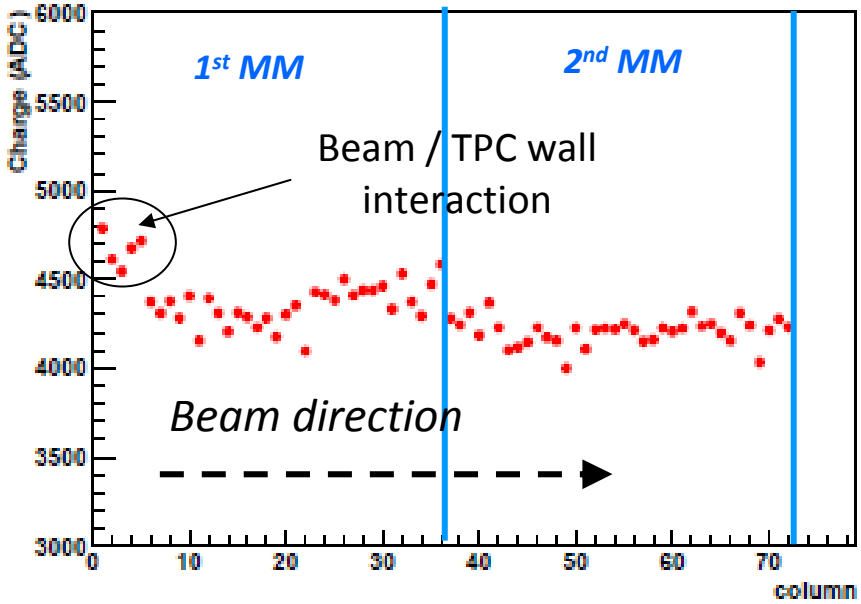


Charge measurement

Cluster charge distribution



MPV from Landau fit VS pad column

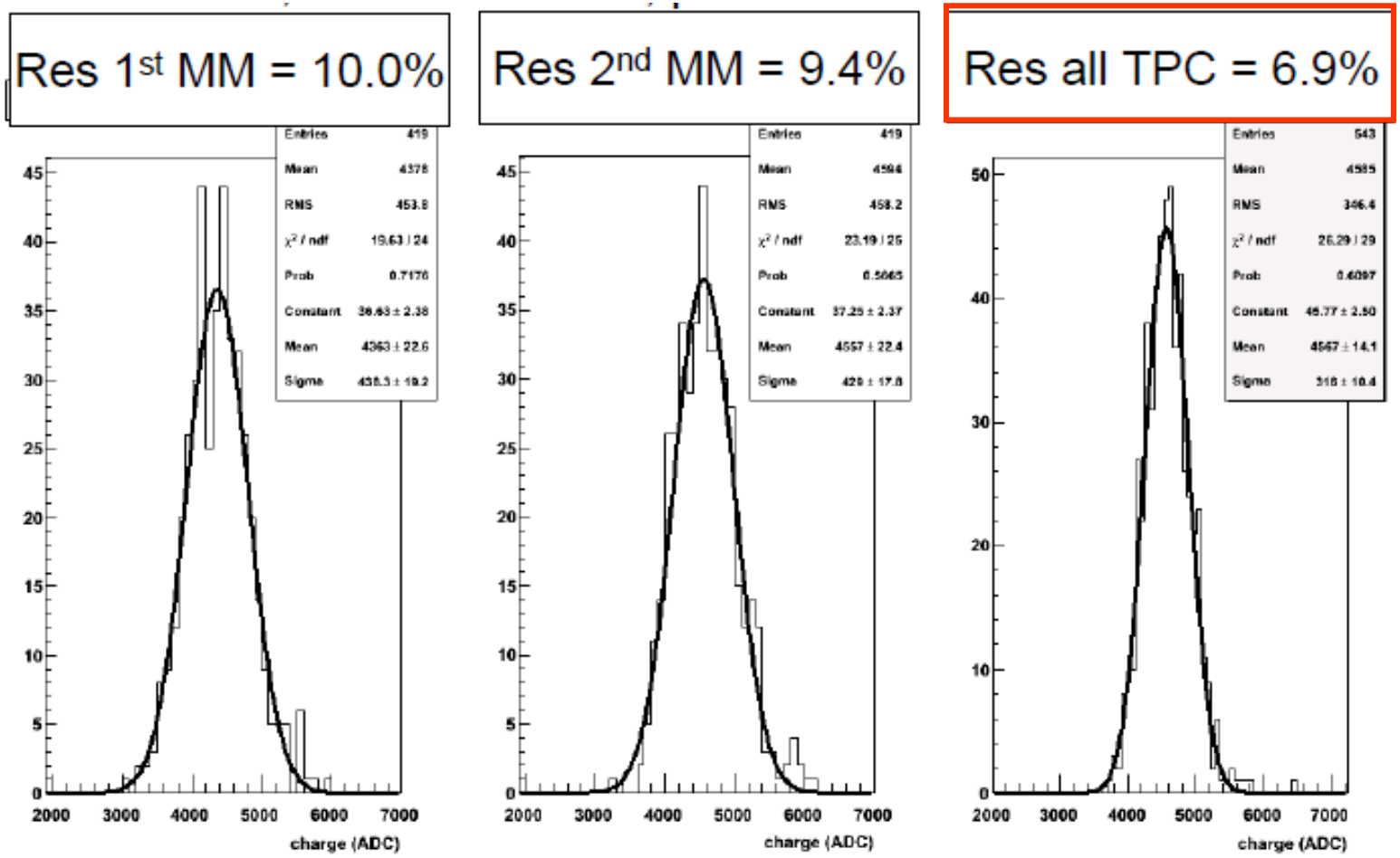


- Clustering method:
  - Time and space correlation by column
  - Typical number of pads per cluster: 2 or 3 pads
- dE/dx method:
  - 72 clusters
  - Truncated mean computed track by track
  - Truncated fraction of 70%

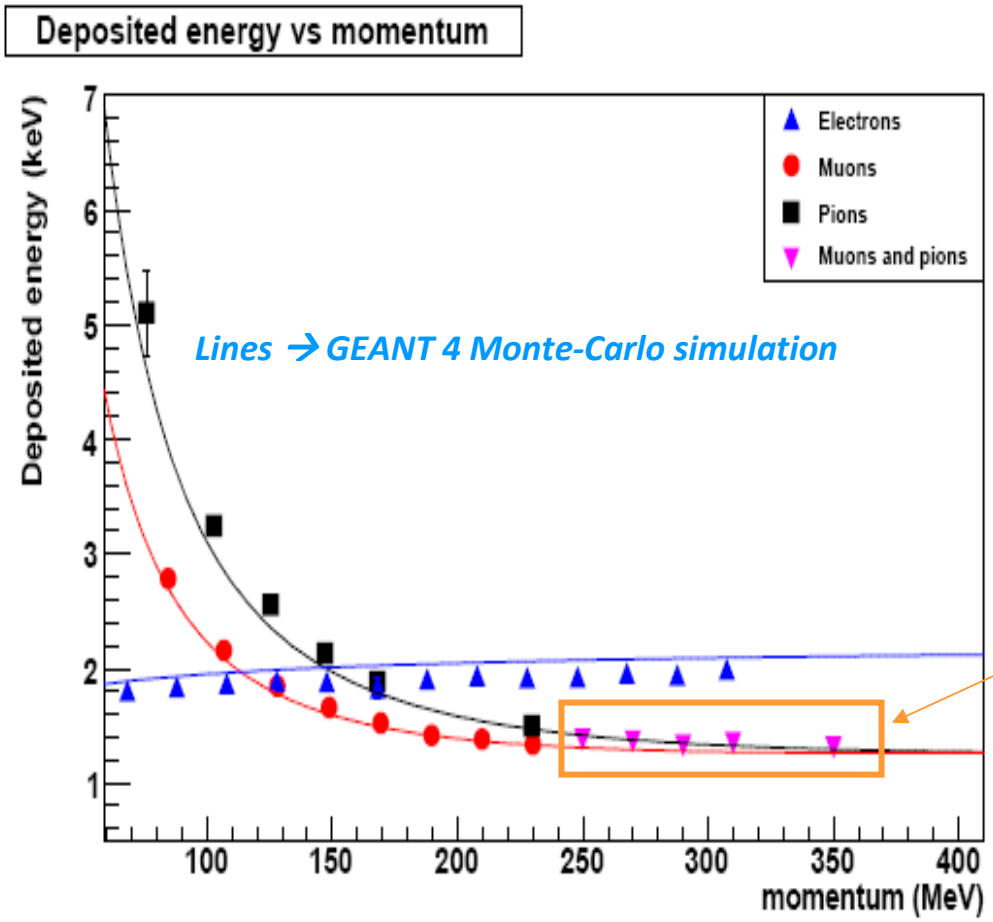
dE/dx resolution

- dE/dX resolution ~7% for μ @ 150 MeV/c and V_{MM} = -350 V extracted from truncated mean (truncated fraction used: 70% over 72 samples)

2 MM

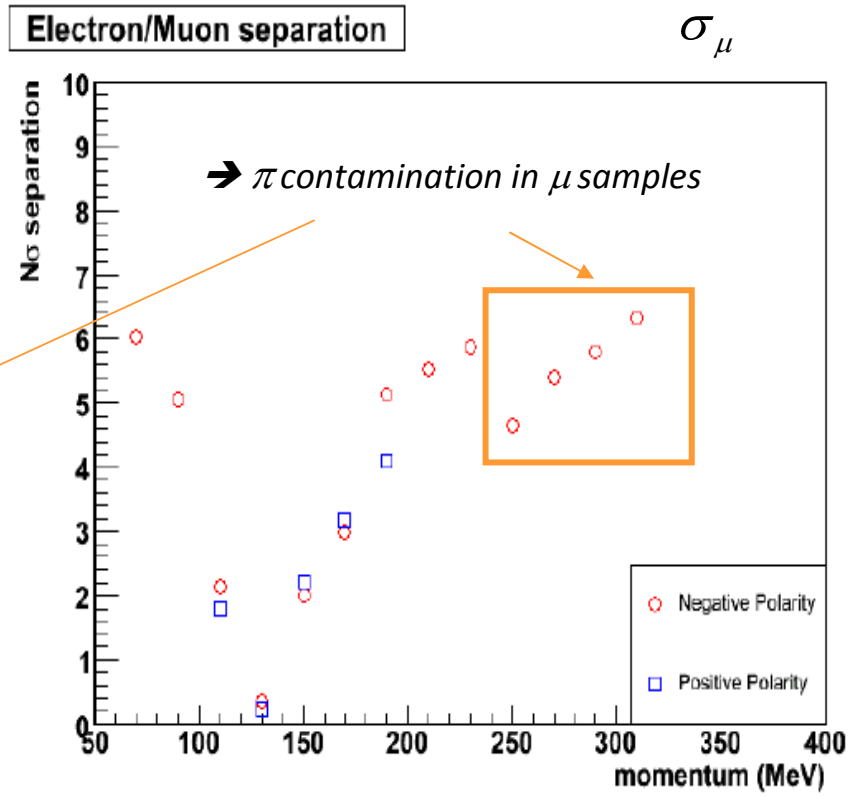


e/μ separation capability



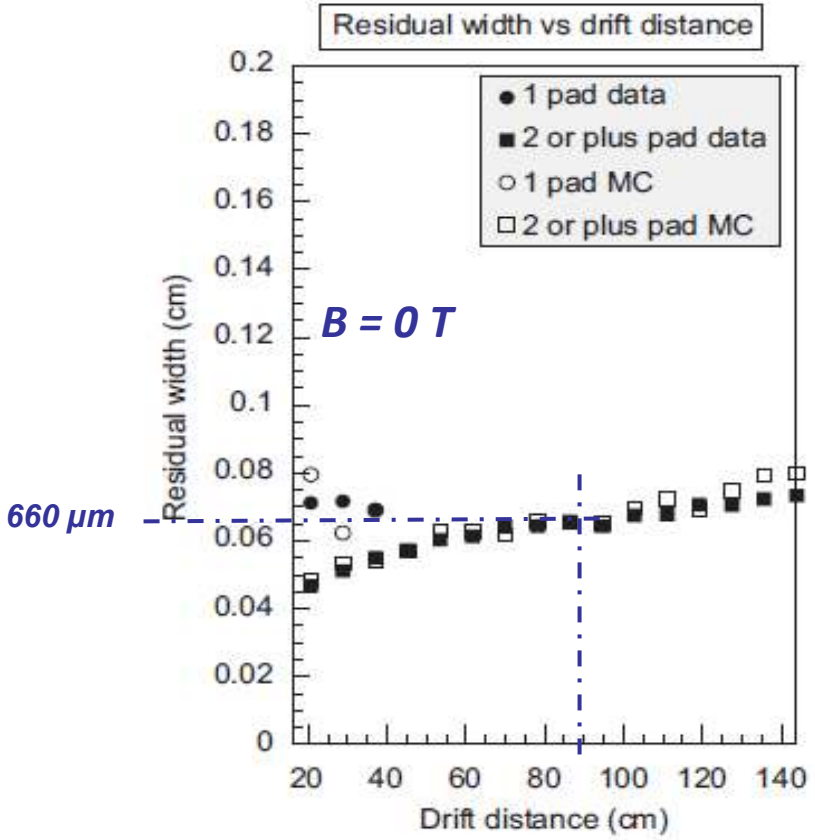
- e/μ separation > 5 σ for particle momentum > 200 MeV/c

$$N\sigma = \frac{\left|CT_\mu - CT_e\right|}{\sigma_\mu}$$



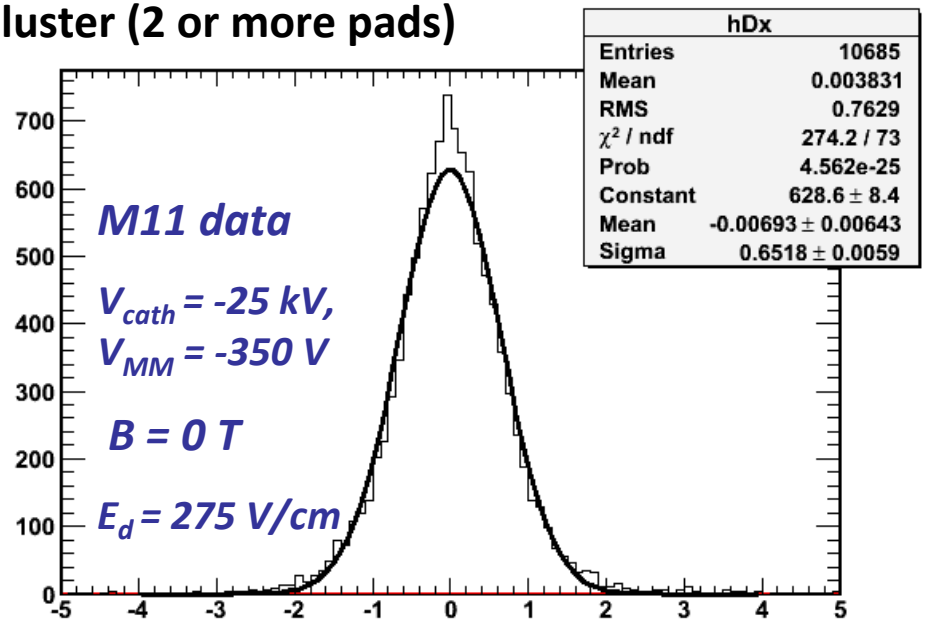
Spatial resolution from M11 data

HARP Test (T2K MM prototypes):



First TPC @ M11 (TRIUMF):

Residual distribution
Cluster (2 or more pads)



- Spatial resolution 650 µm measured @ 76 cm drift distance
  - Compatible with previous results obtained with prototypes
  - Sufficient to meet momentum resolution goals

Future schedule

- Maintain m11 data analysis effort (distortion fine analysis)
- 2nd TPC is completed and is ready for mounting FEE
  - this week
- Beam test for 2nd TPC
  - this month
- 3rd TPC construction and assembly is ongoing
- Installation of the two first TPCs at the ND280 site
  - begin this summer
- Commissioning phase for the two first TPCs
  - in fall 2009
- Installation of the 3rd TPC at the ND280 site
  - Dec. 2009
- Start neutrino data taking, ➔ Dec. 2009 / Jan. 2010

Conclusion

- The T2K TPCs are the first large TPCs dedicated to HEP experiment using MPGD as amplification device
- Production and validation of bulk-MICROMEGAS are almost completed (61/80 done in one year)
- Excellent uniformity and good energy resolution for bulk-MICROMEGAS modules
- First TPC module successfully tested
- Performance goals met (7% dE/dx resolution and ~650 µm spatial resolution were measured at TRIUMF facility)
- Full system successfully tested

Much work ahead for our group to bring the 3 TPCs into full operation in Japan by the end of the year

Irfu

cea

saclay

Thank you !!!

Any questions ?

Bulk-MICROMEGAS process back-up

(1) Base material

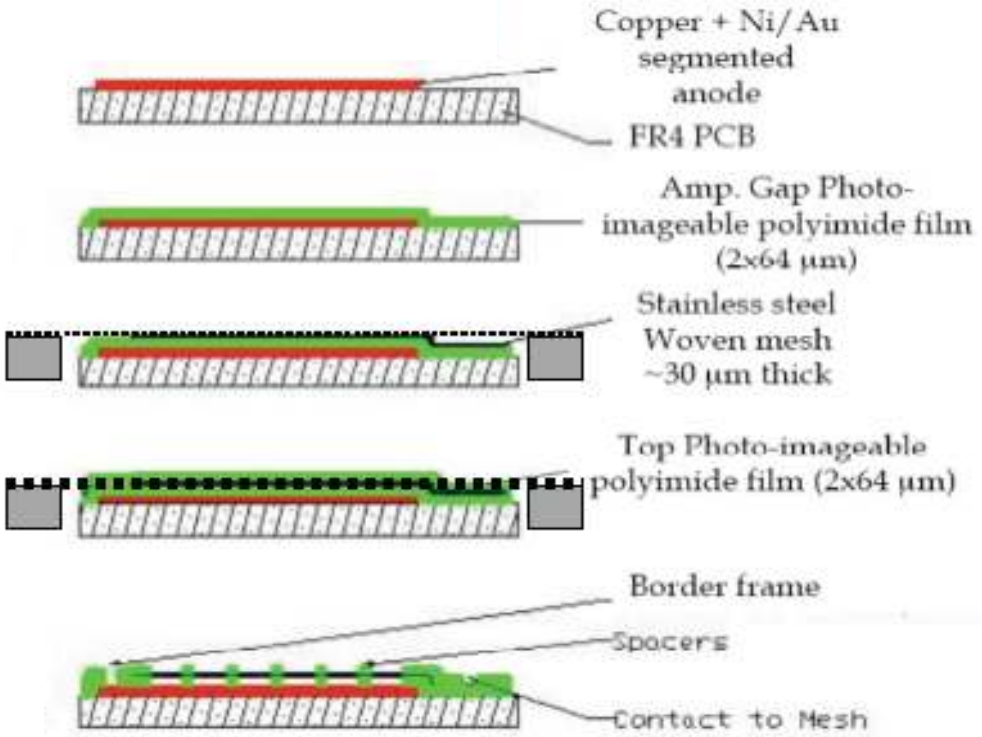
(2) Lamination of Vacrel

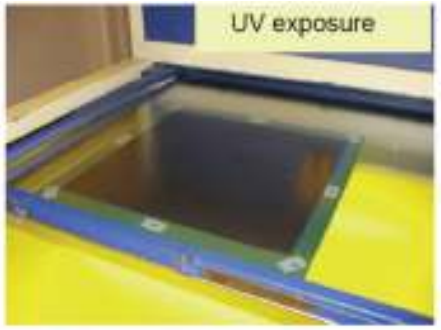
(3) Positioning of Mesh

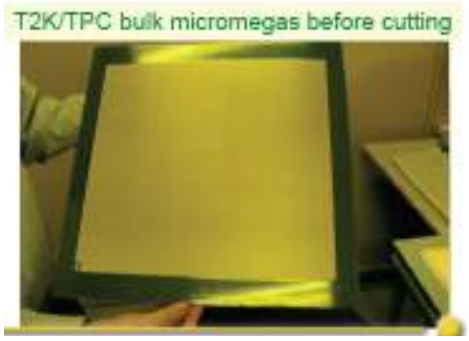
(4) Encapsulation of Mesh

(5) UV exposure

(6) Development of contacts and spacer

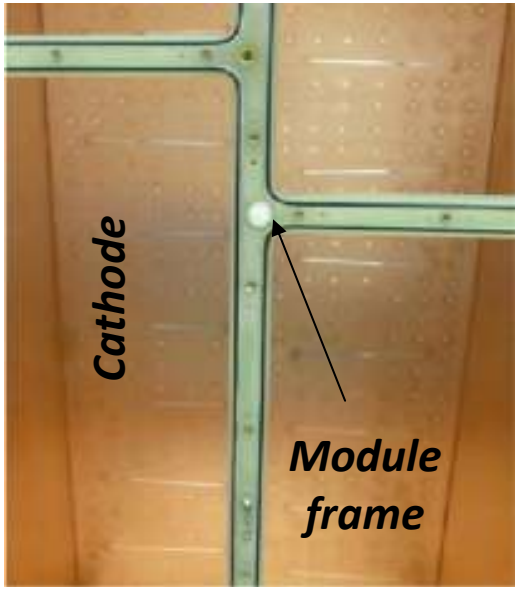


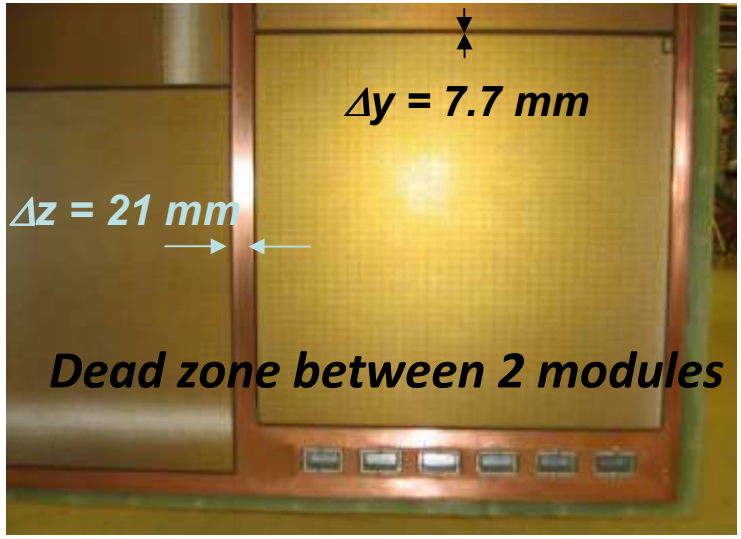




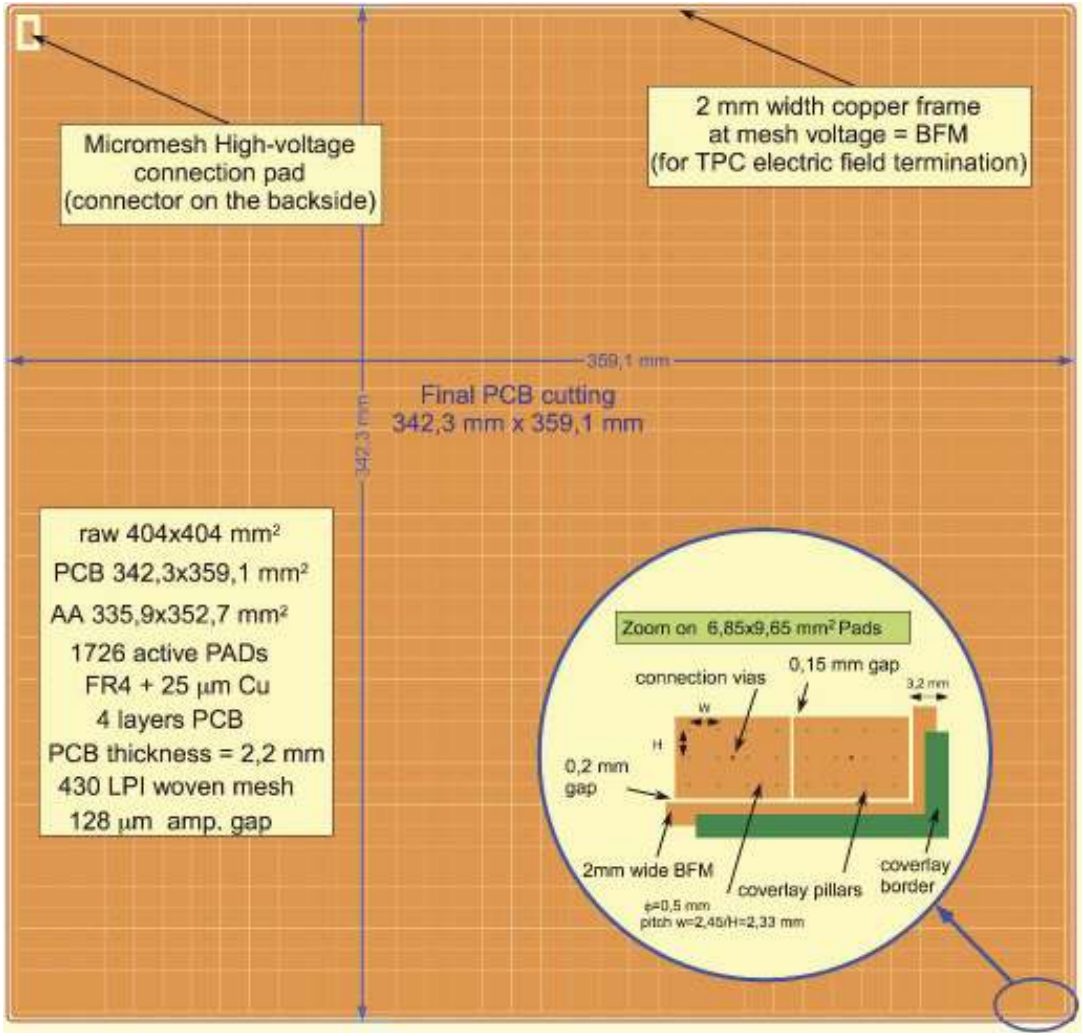
TPC module 0 (TRIUMF) back-up

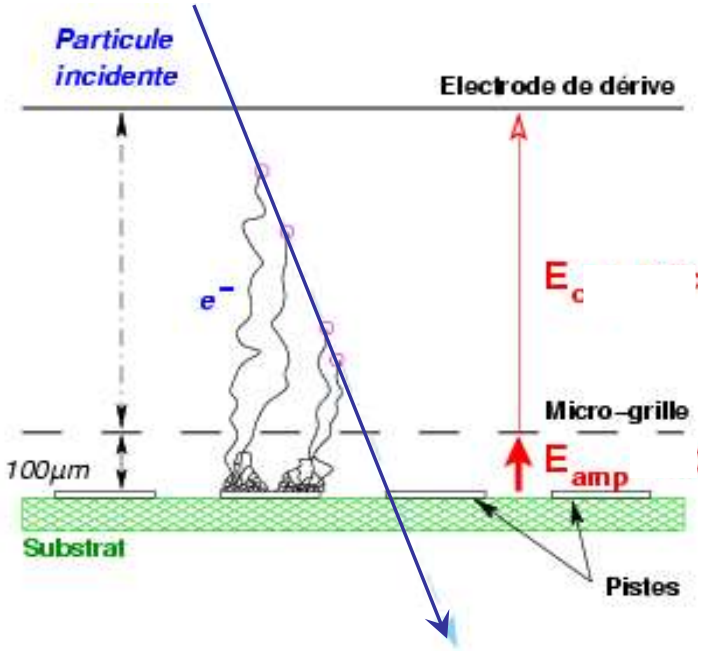
Field cage strips



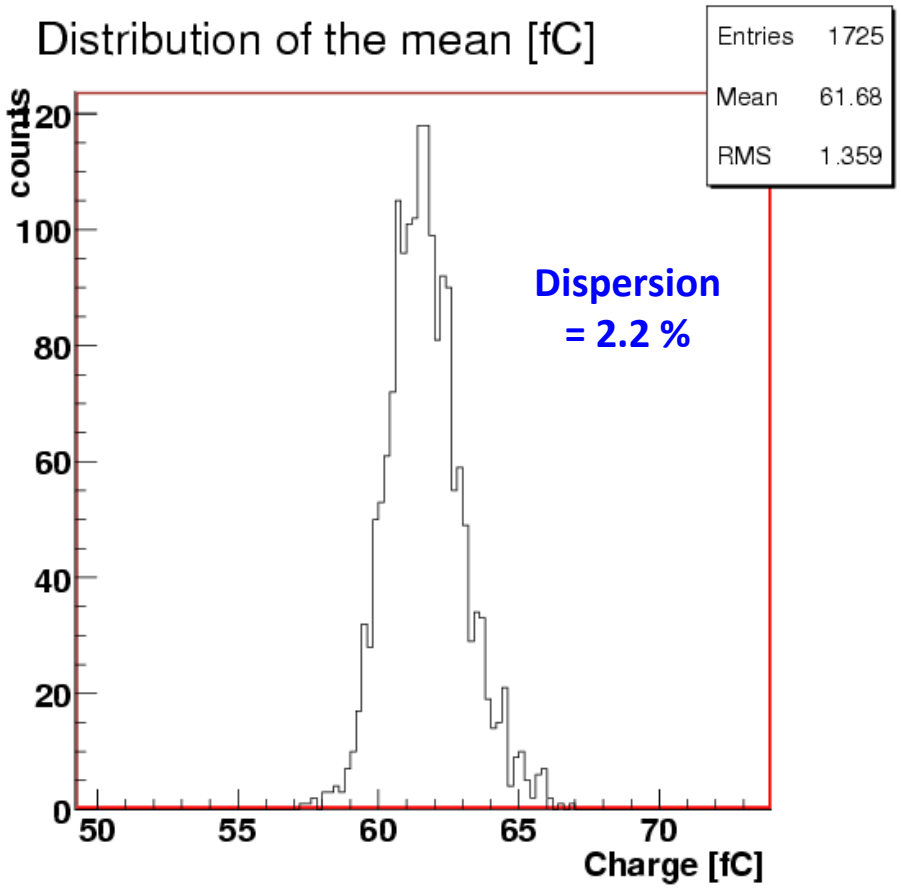


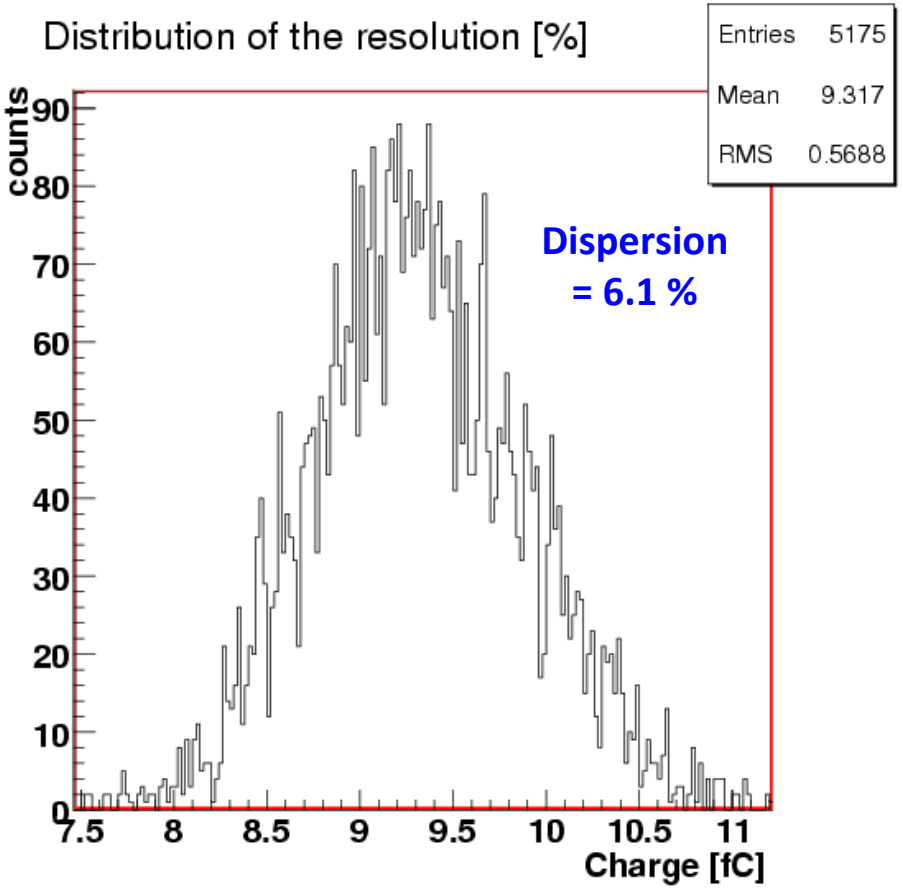
Bulk-MICROMEGAS back-up





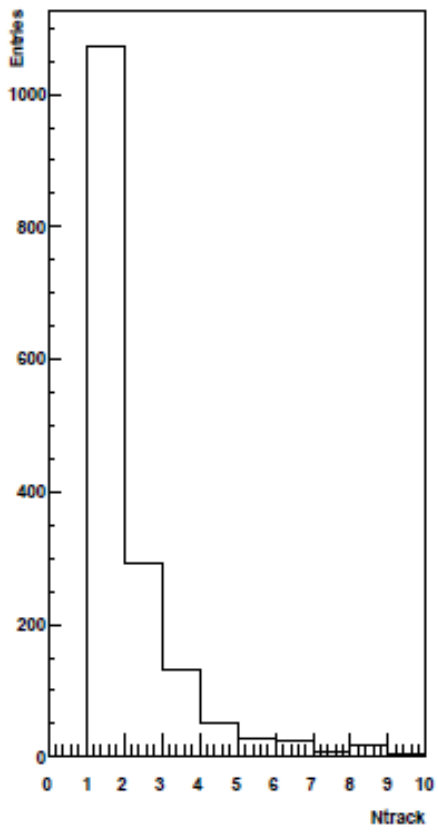
Gain & resol dispersion back-up



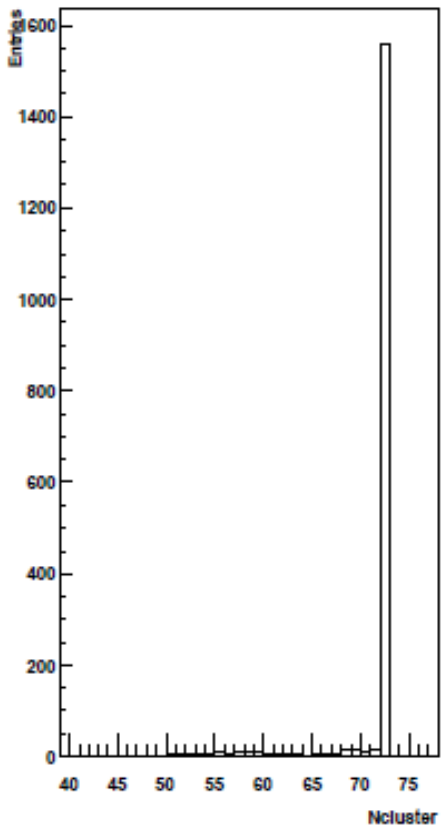


Back-up

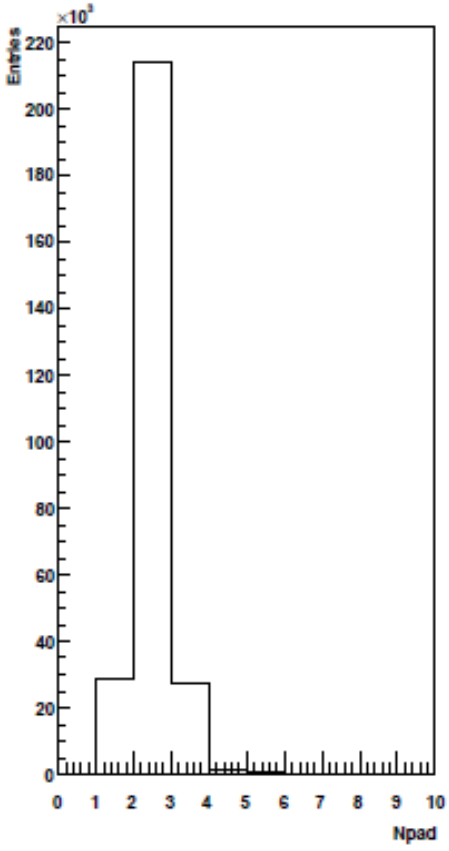
Number of reconstructed tracks



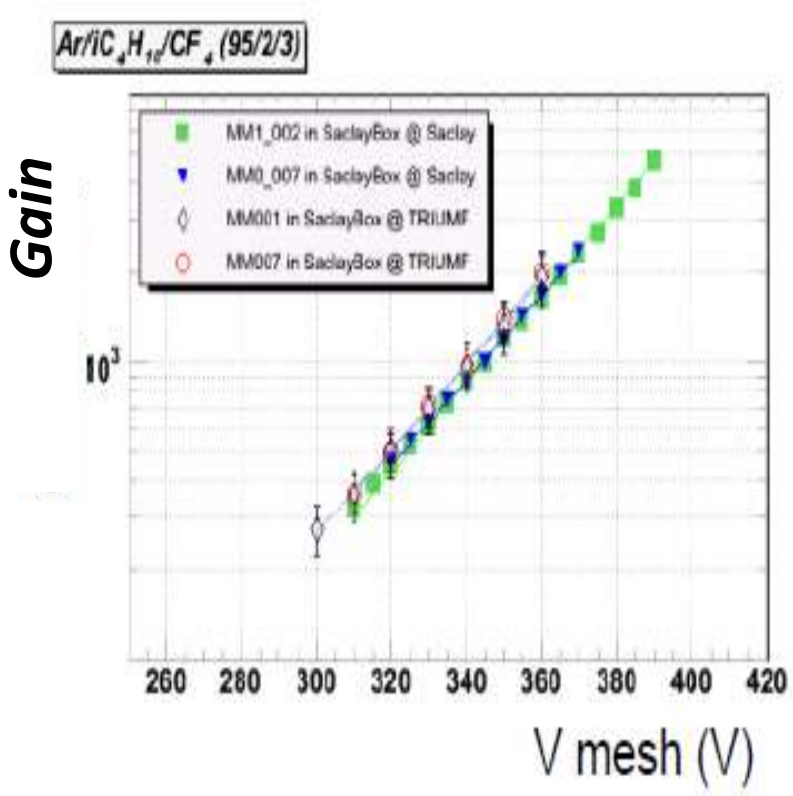
number of cluster per track

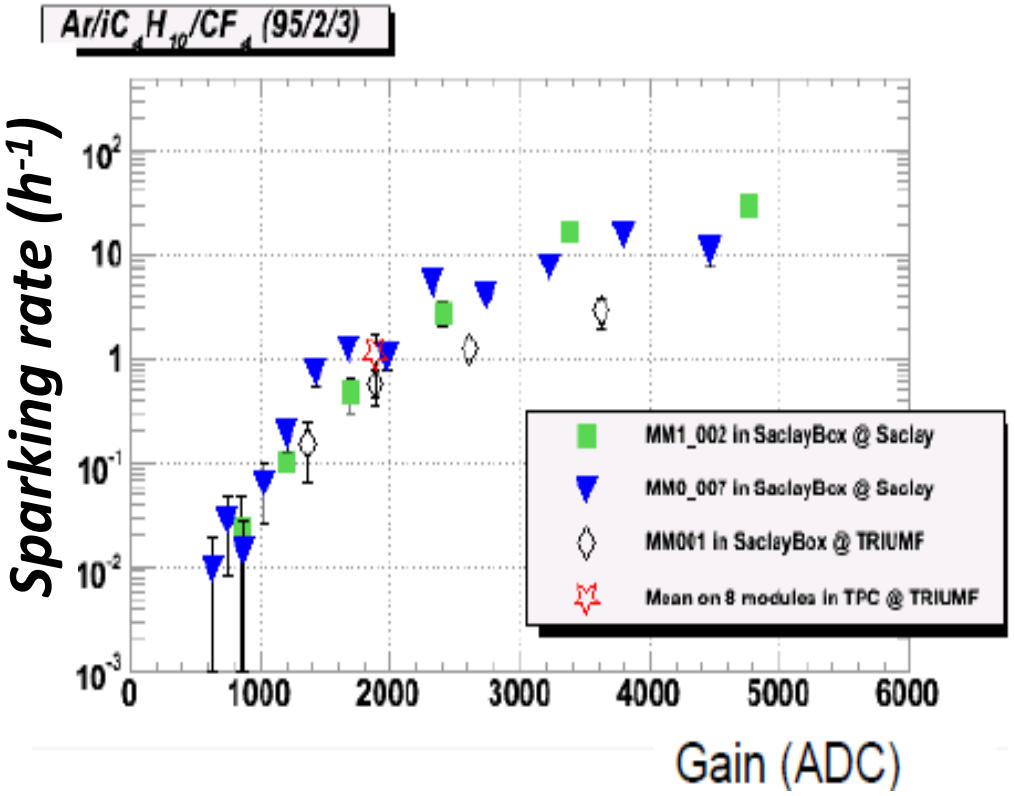


number of pad per cluster

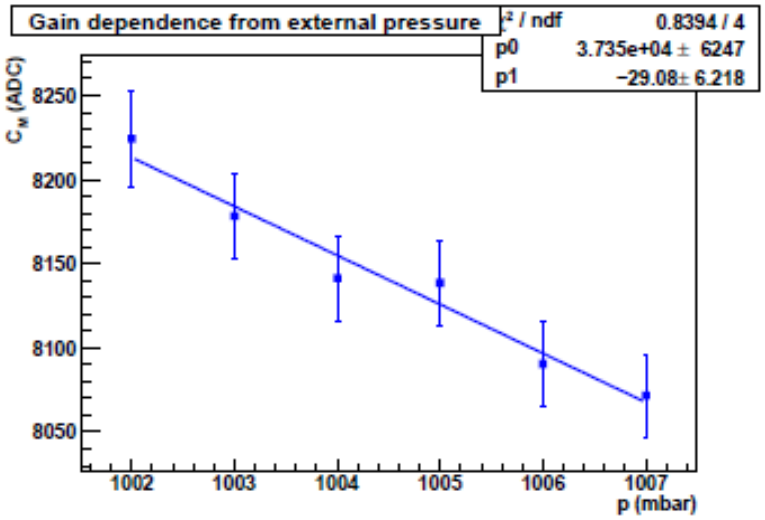


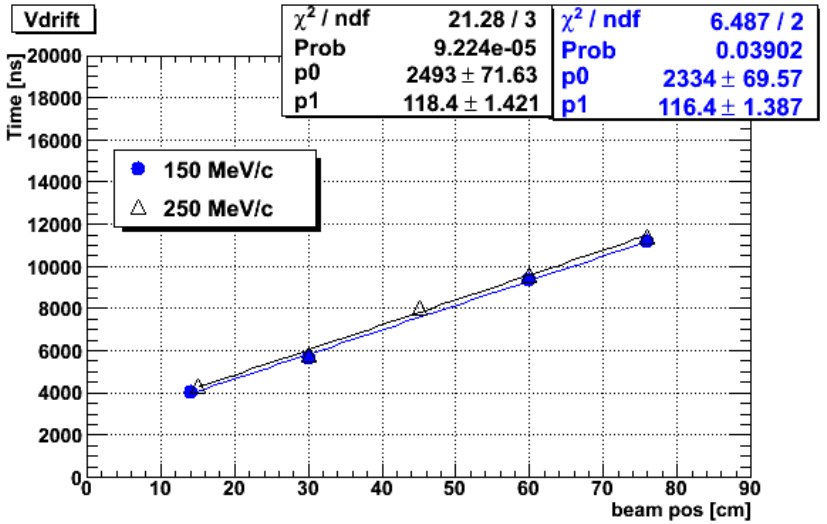
Gain and sparking rate



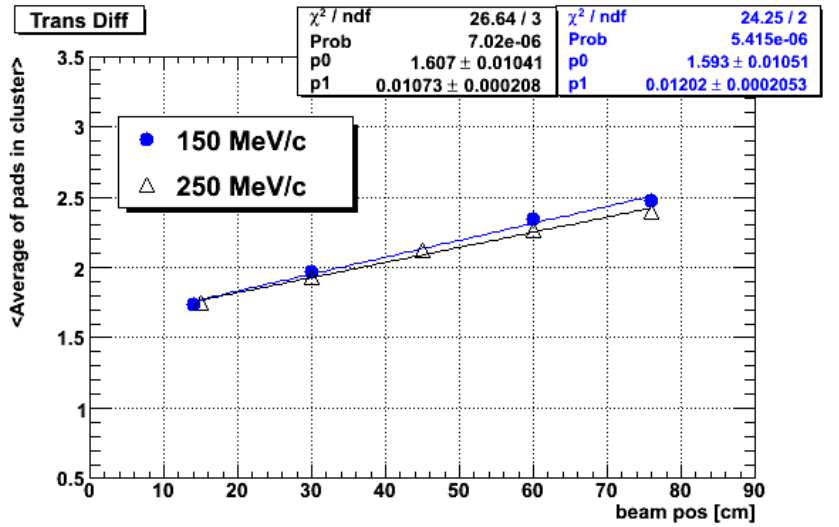


Gaseous mixture back-up

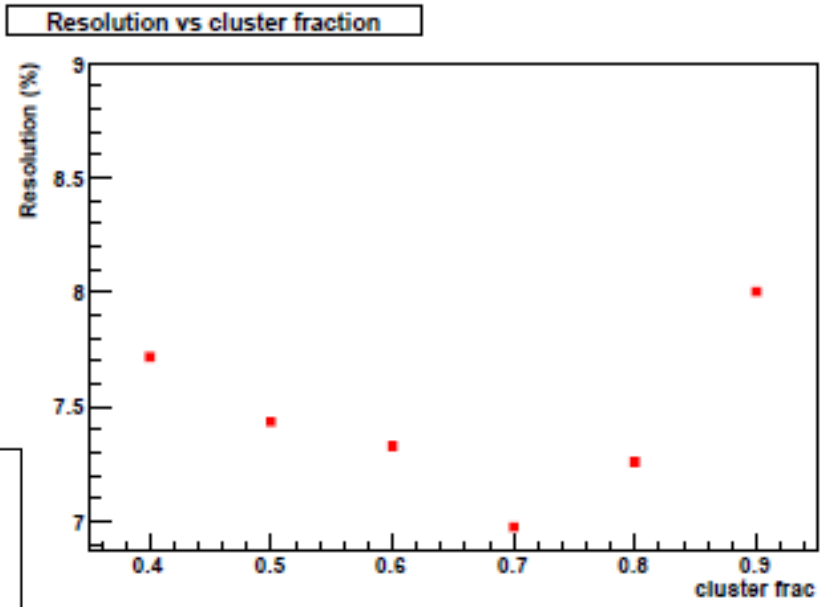


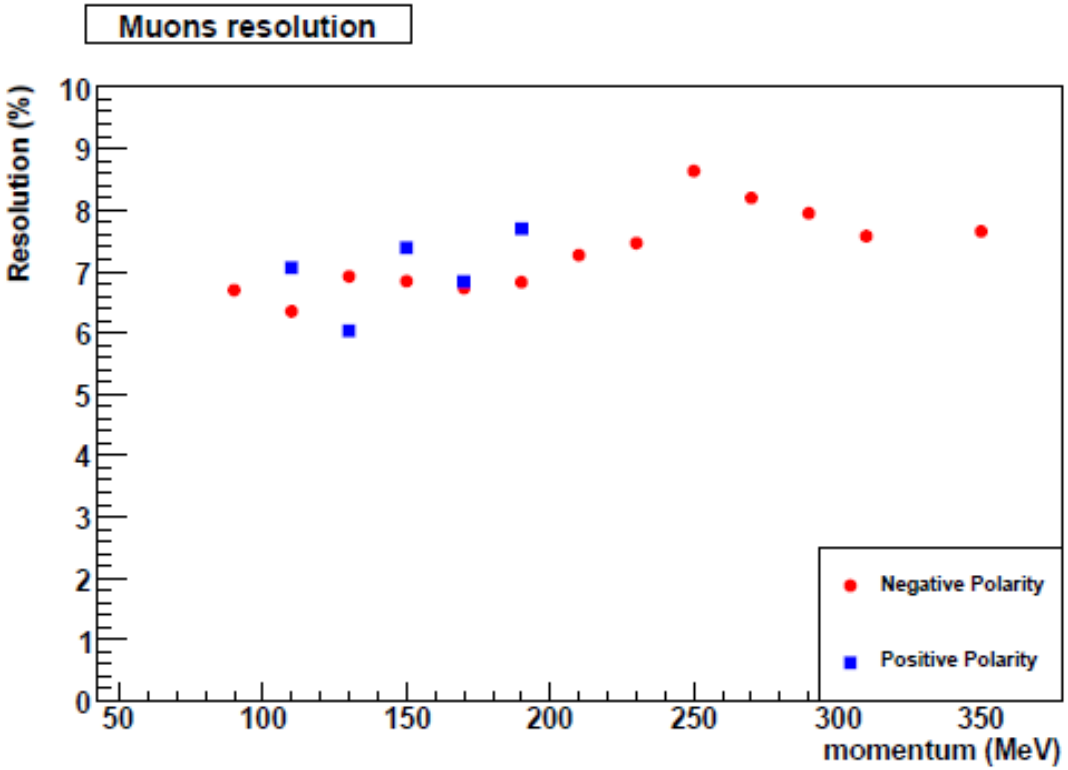


- O_2 level < 5 ppm
- H_20 level < 15 ppm



dE/dx resolution back-up

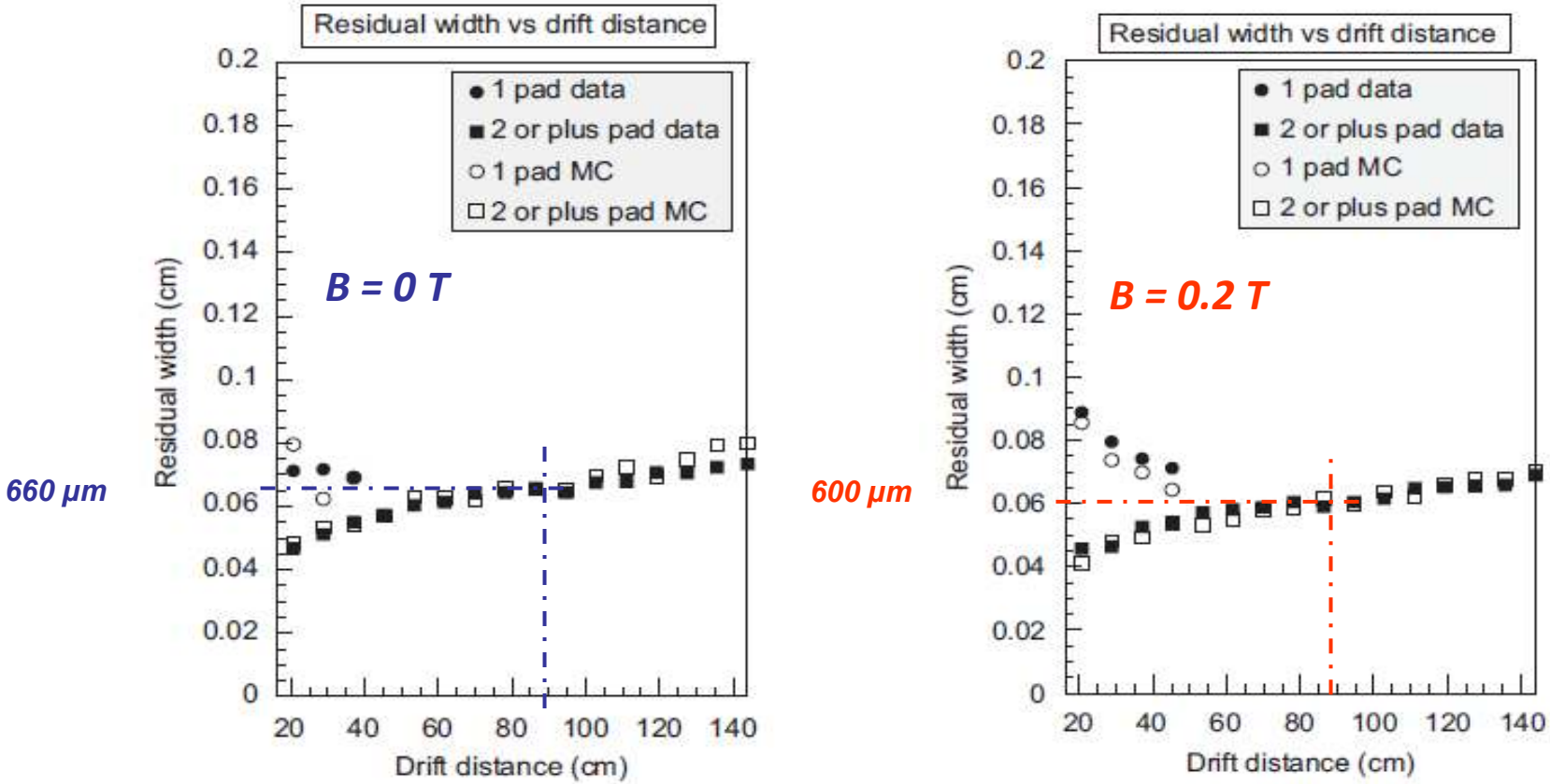


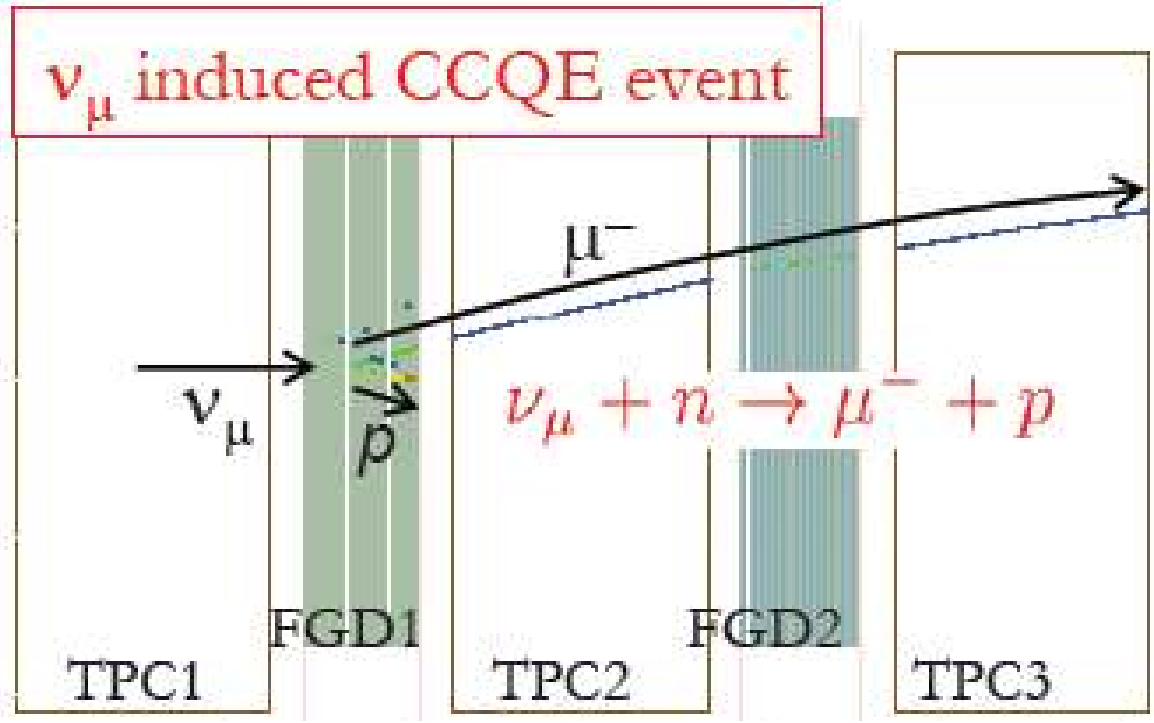


Spatial resolution (HARP test)

- Cosmic test @ CERN (Sept. 2007):
  - T2K MICROMEGAS module prototypes in the HARP field cage

➔ **Spatial resolution < 600 µm achievable for drift distance < 90 cm T2K gas choice**



S. Anvar, et al.,NIM A (2009), Vol 602, Issue 2, 21 April 2009, p 415-420

CCQE event back-up