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Micropattern based TPC for the T2K tracking system

On behalf of the T2K TPC group

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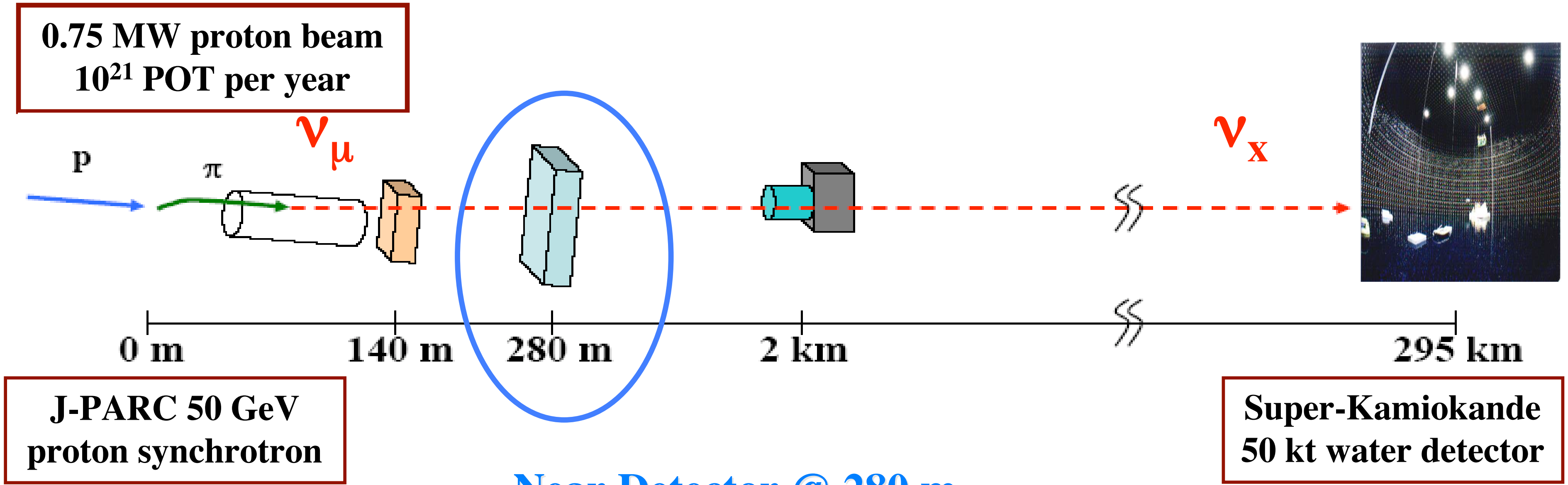
DSM/Dapnia, CEA/Saclay, and LPNHE, Paris-VI-VII, France
RWTH Aachen University, Germany
INFN, Sezione di Bari, Italy
Valencia University and Universitat Autonoma de Barcelona, Institut de Fisica d'Altes Energies, Spain
DPNC, Section de Physique, University of Geneva , Switzerland

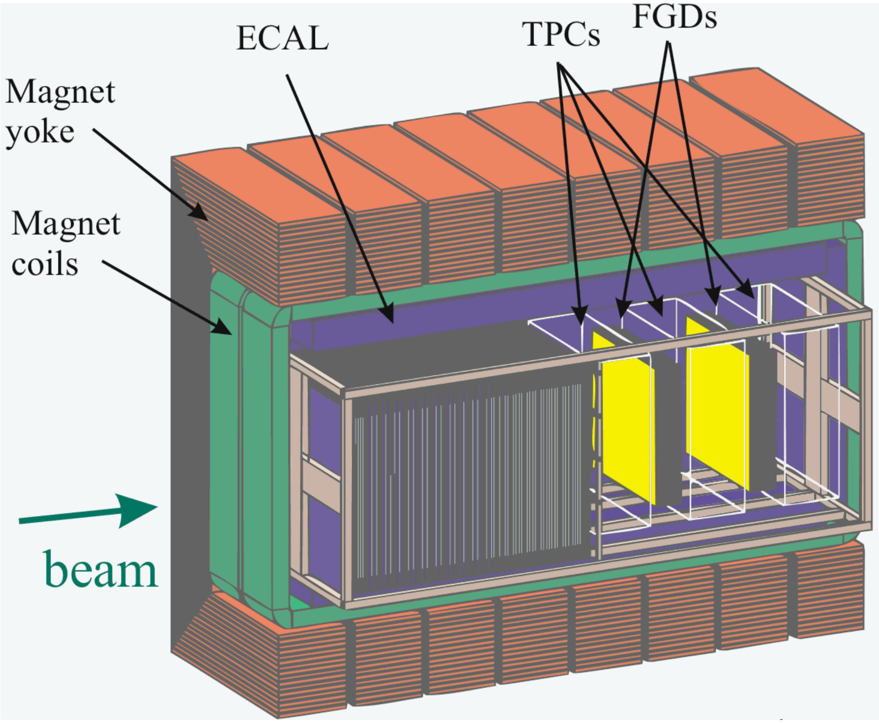
T2K Goals and Setup



Near Detector @ 280 m
(off-axis)

- **Measurement of ν_e appearance: discovery of non zero θ_{13} down to $\sin^2 2\theta_{13}$ ~0.01**
- Measurement of ν_μ disappearance: improve accuracy for $\sin^2 2\theta_{23}$ and Δm^2_{23} (down to ~1% and ~2% respectively)

The Near Detector



Measure neutrino beam properties and neutrino interaction cross sections

- Measure ν_μ beam prior to oscillation
- Measure intrinsic ν_e contamination
- Study NC π^0 production
- Study non QE ν cross-section

TPC performances

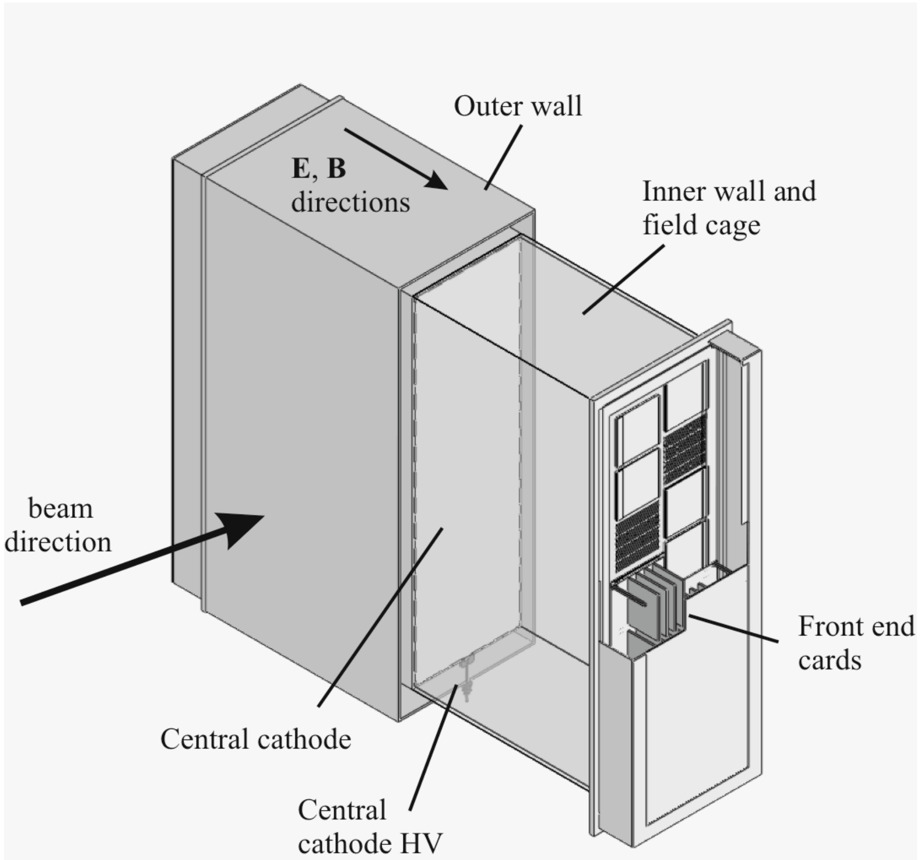
- 10% momentum resolution at 1 GeV/c
- 10% dE/dx resolution for e/μ identification

- UA1 magnet provides 0.2 T B field
- Inner volume: $3.5 \times 3.6 \times 7.0$ m^3
- Front optimized for π^0 from NC
- Rear optimized for CC studies
- Surrounded by ECAL and muon detector

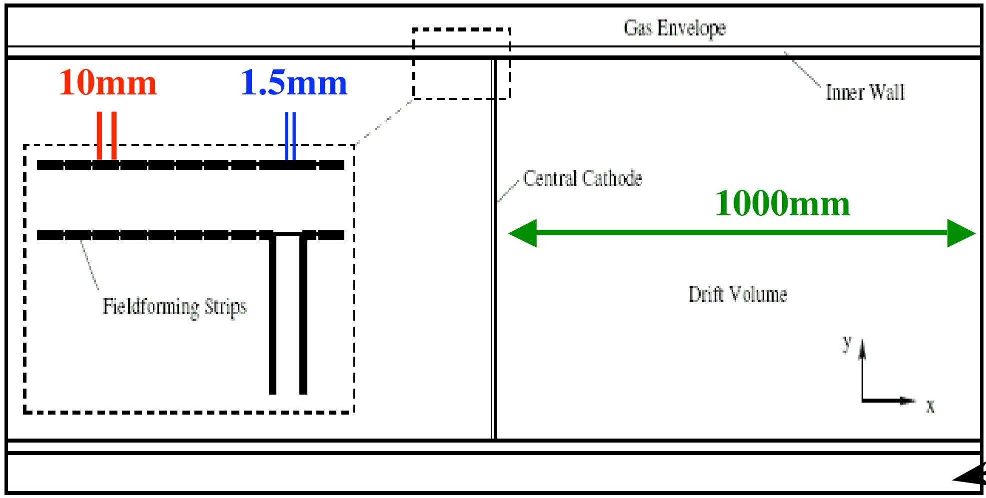
TPC Design

- Instrumented with bulk Micromegas
  - 12 modules / endplate
  - 1726 pads / module
  - 9.7 x 6.9 mm^2 pads
- 2.5 m x 2.5 m x 0.90 m (outer)
  2.0 m x 2.3 m x 0.76 m (inner)
  → max. lever arm: 72 cm
  → drift distance up to 100 cm
- B = 0.2 T
- E_{drift} ~ 200 V/cm
- V_{drift} ~ 8 cm/μs
- Gas: Ar - CF_4 - iC_4H_{10} 95-3-2 (%)

~ 120k channels



TPC Field Cage



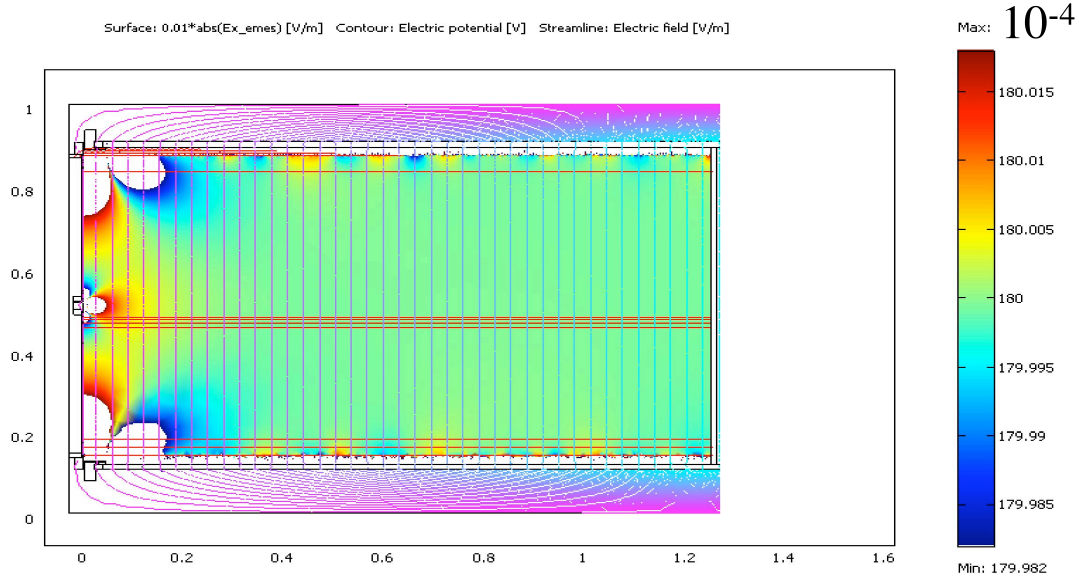
CO_2

- Double structure with inner and outer box.
- Envelope filled with CO_2
- 10 mm wide strips with 1.5 mm gap on both sides of the inner box
- Ground on outer box

Field cage developed and to be constructed at Triumf

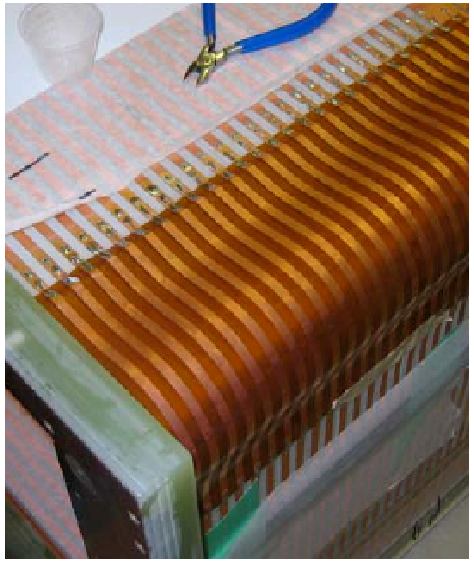
Drift field distortions studied with COMSOL Multiphysics.

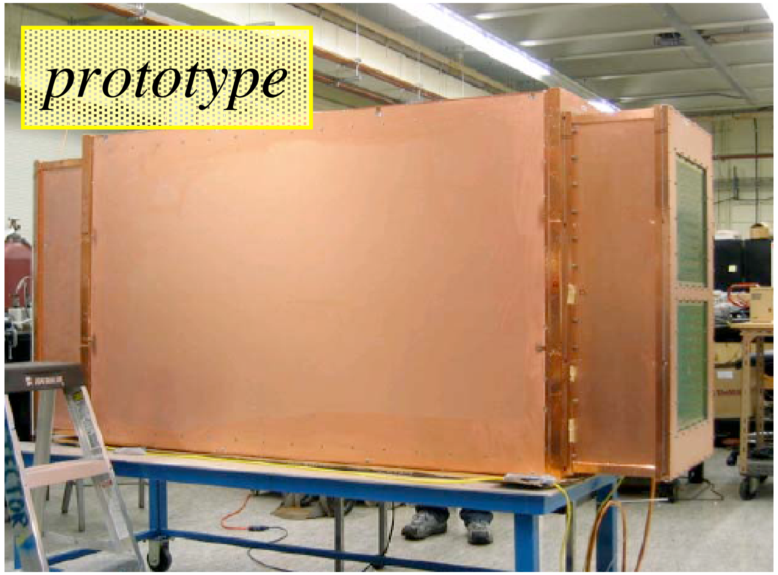
Displacement < 100 μm



TPC Field Cage

Special care is taken about the rectangular shape of the TPC.





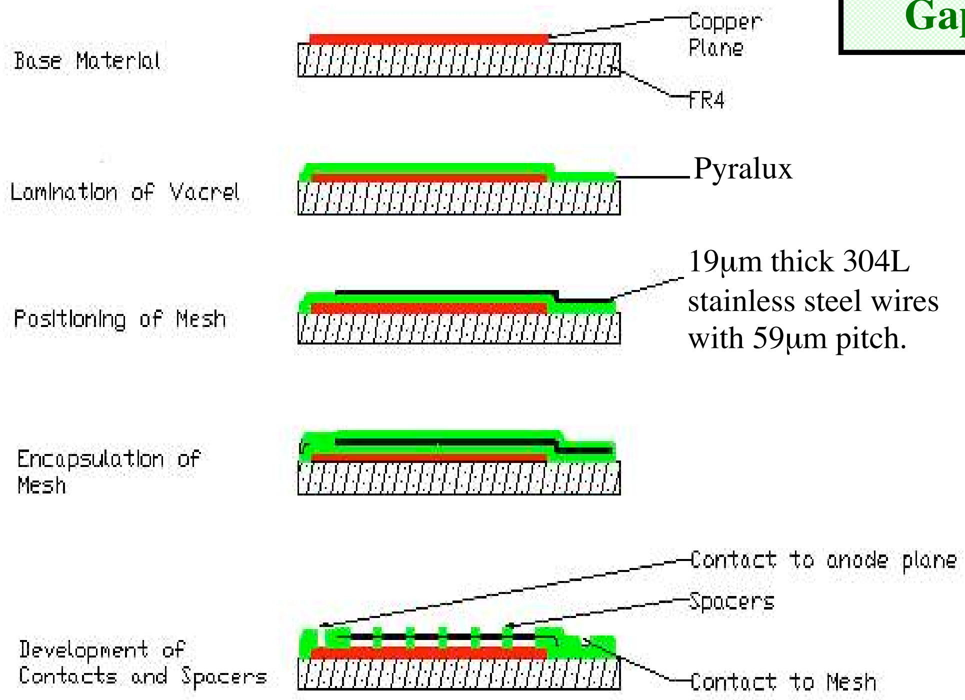
◆ Built at Triumf and operated at University of Victoria

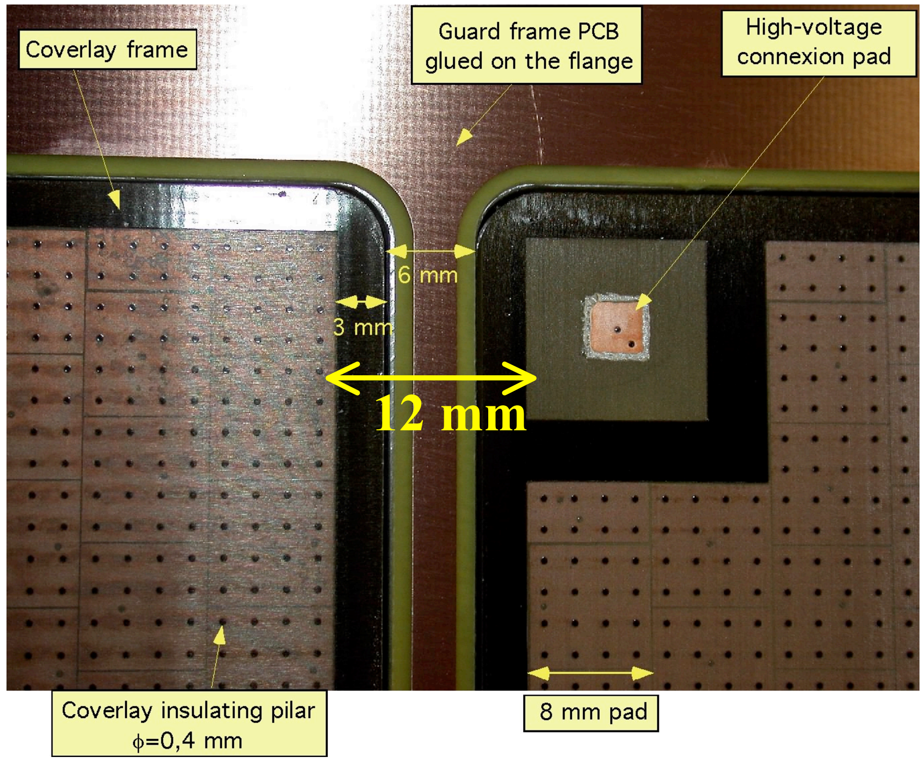
◆ Aluminium strips on the cathode are targets for the laser calibration system

Bulk Micromegas

Easy process, suitable for mass production. Robust.
Dead zones on the edges of the module are minimized.
Gap fixed by spacers thickness → good uniformity

Bulk production process

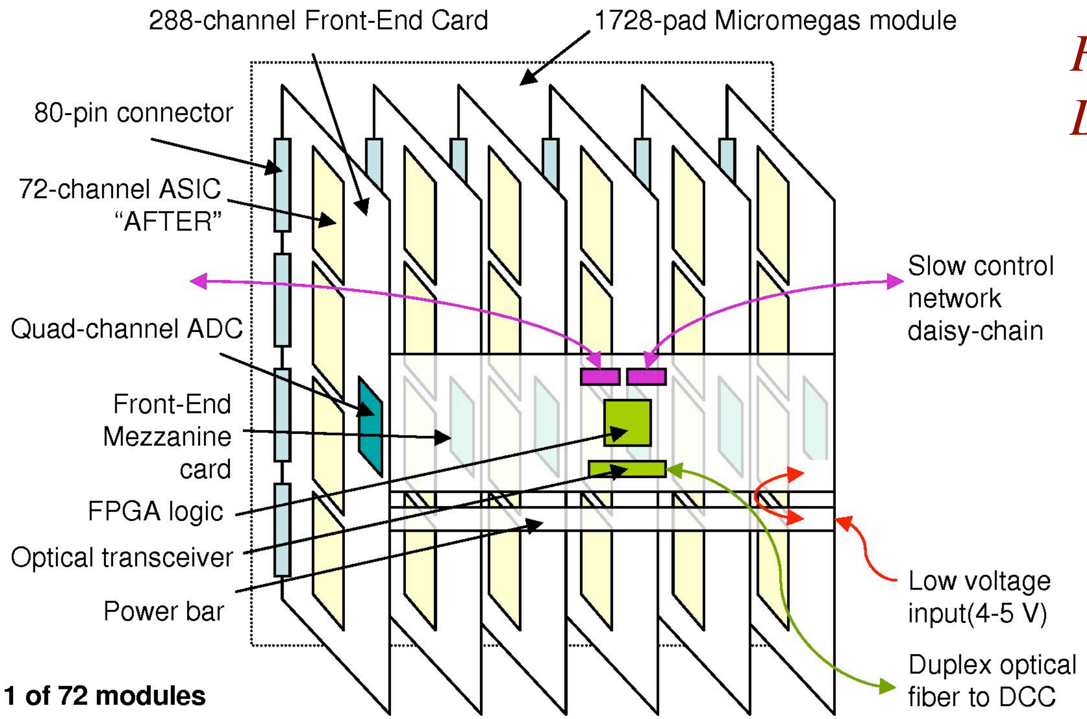




Pad size of the first bulk that was produced

Developed at CERN & CEA Saclay
To be built at CERN/TS-DEM-PMT

Readout Electronic



FEC and FEM from CEA Saclay
DCC from LPNHE Paris-VI-VII

Module size: 36x34 cm^2
Pad size: 6.9 x 9.7 mm^2

Micromegas Module

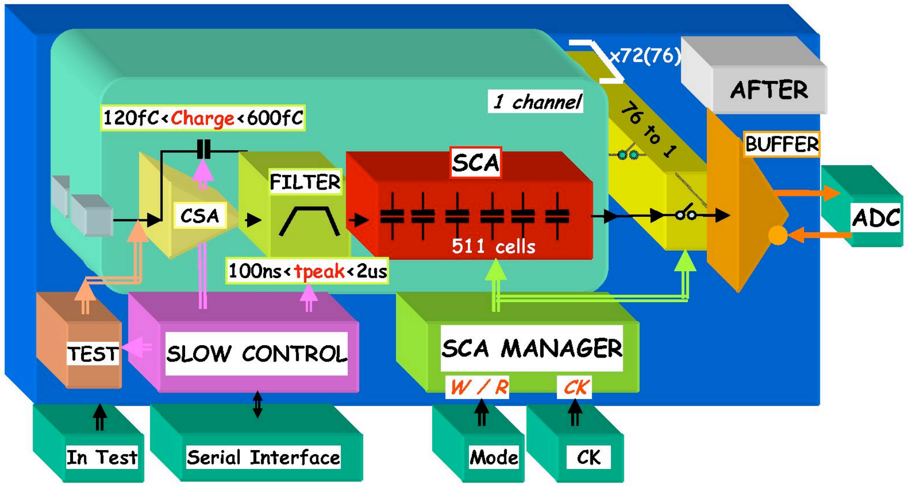
- 6 Front-End Card (FEC)
  - 4 ASIC per FEC
  - 72 channels per ASIC
- 1 Front-End Mezzanine Card

- 1 data concentrator card per readout plane (= 12 mezzanine cards)
- 1 merger PC per 3 TPC (data reduction, formatting)
- ND280 DAQ

ASIC Characteristics

Number of channels	***72***
Number of time bins	***511***
Dynamic Range/Gains	*120fC to 600fC (4 values) on 12 bits*
Max Range/Noise with detector (Requirements)	*1000 (750 e- rms noise for 120fC range)*
I.N.L	*< 1.5%*
Power Consumption	*7mW / channel*
Sampling Frequency	***1MhHz to 50MHz***
Readout Frequency	*20 – 25MHz*
Shaping: ***Unipolar; Semi-Gaussian;*** **16 peak times:** ***100ns to 2µs***	
Signal Polarity	*Negative(TPC) or Positive*
Calibration Mode	*1 common external cap.*
Test Mode	*1 cap. for each channel*

Technology: ***AMS CMOS 0.35µm***
Area: ***7546µm x 7139 µm***
Package: ***LQFP 160 pins***
Number of transistors: ***400,000***

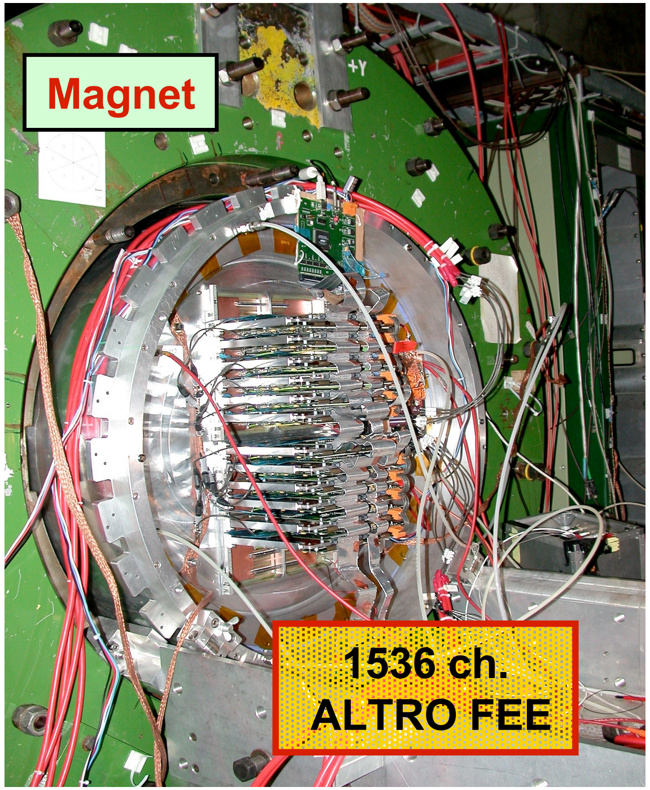


Designed and build at CEA Saclay

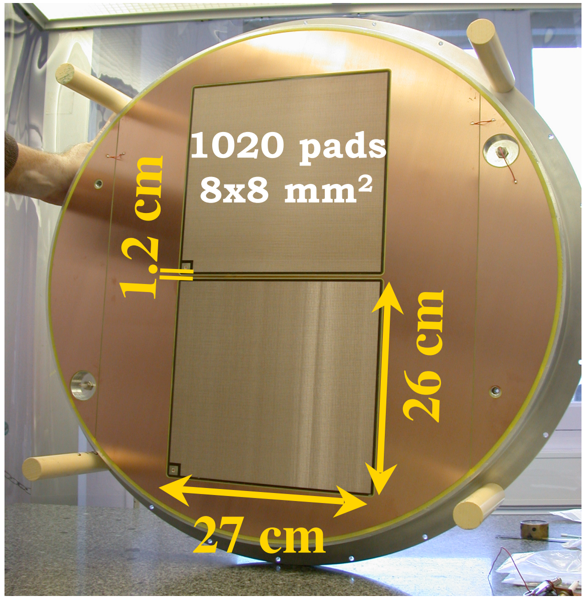
AFTER: ASIC For TPC Electronic Readout

dapnia
cea
saclay

Test of Bulk Micromegas

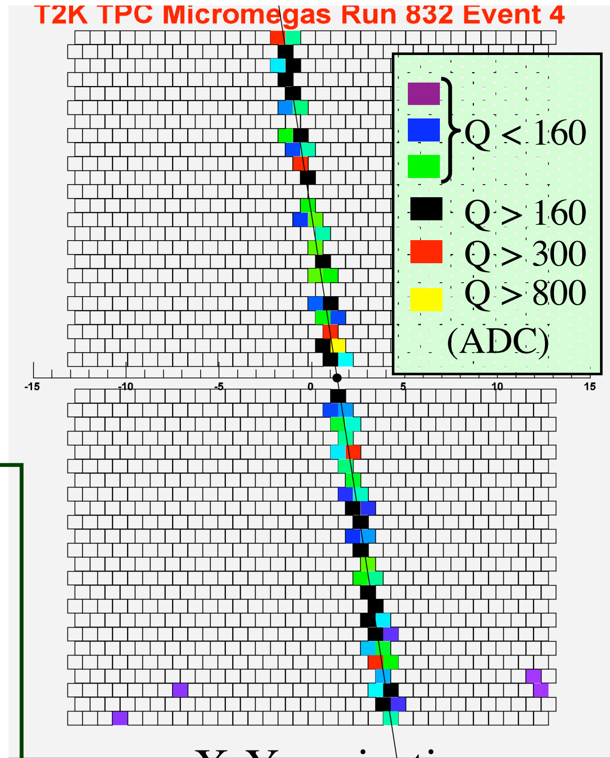


Ex-HARP field cage instrumented with 12 ALTRO Front-End Cards



First version of bulk Micromegas tested at CERN in Oct. 2005 with cosmic tracks

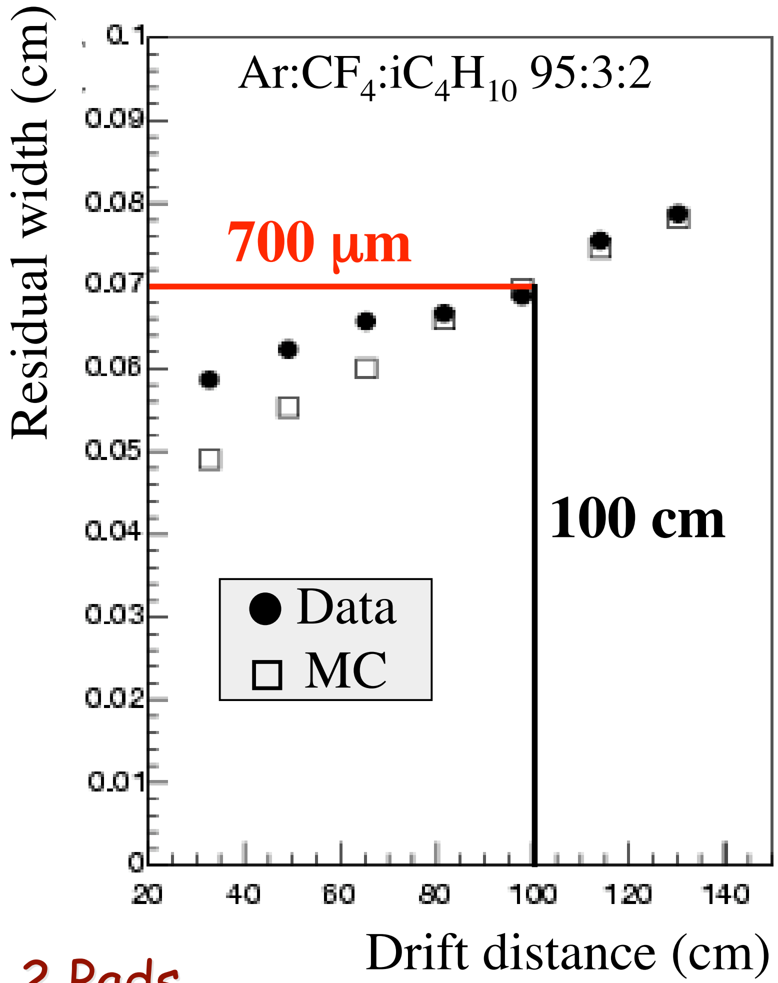
Event recorded at B = 0.2T in Ar (95%) iC_4H_{10} (2%) CF_4 (3%)



X-Y projection

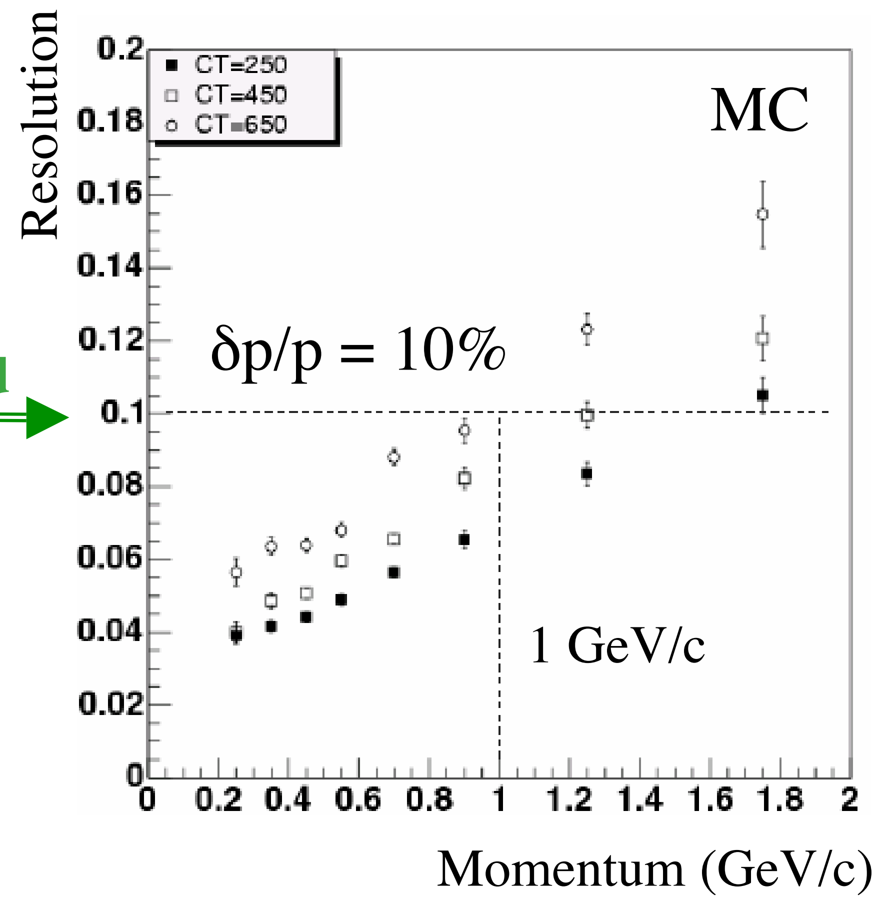
J. Bouchez et al., Nucl. Instr. And Meth. A 574 (2007) 425

TPC Performances

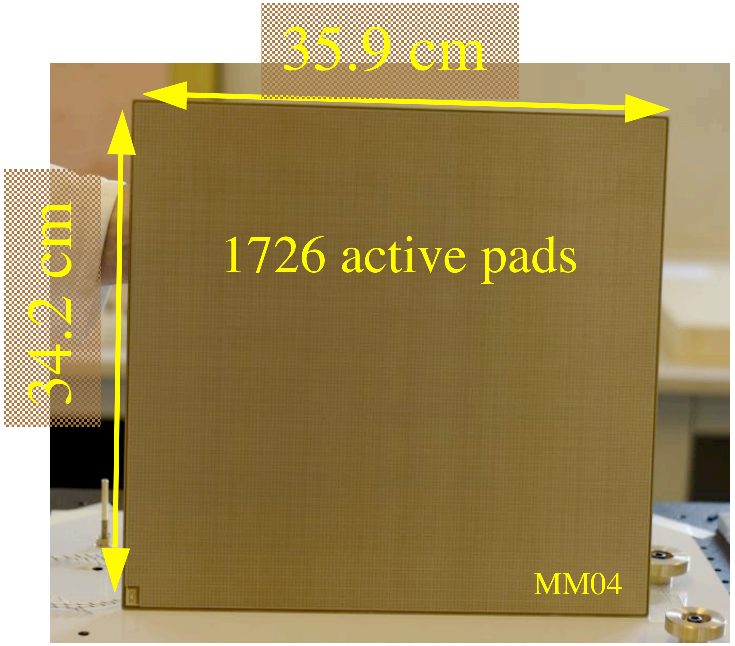


2 Pads

Expected



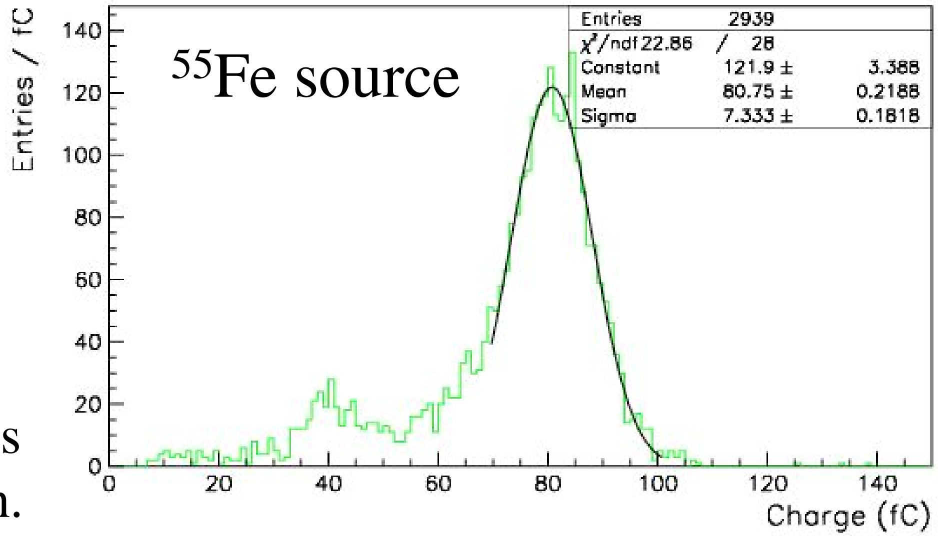
Latest Test Results



Ar(95%) / iC_4H_{10}(2%) / CF_4(3%)
ASIC: t_p = 200 ns and f_s = 20MHz
V_{mesh} = 370 V (gain ~ 2200)
E_{drift} = 200 V/cm

MM07

Energy resolution (σ) 9% @ 5.9 keV



Modules with final design.
A new manufacturing technique improves the gain uniformity and energy resolution.

Test in Sept. 2007 at CERN with final readout modules and electronics

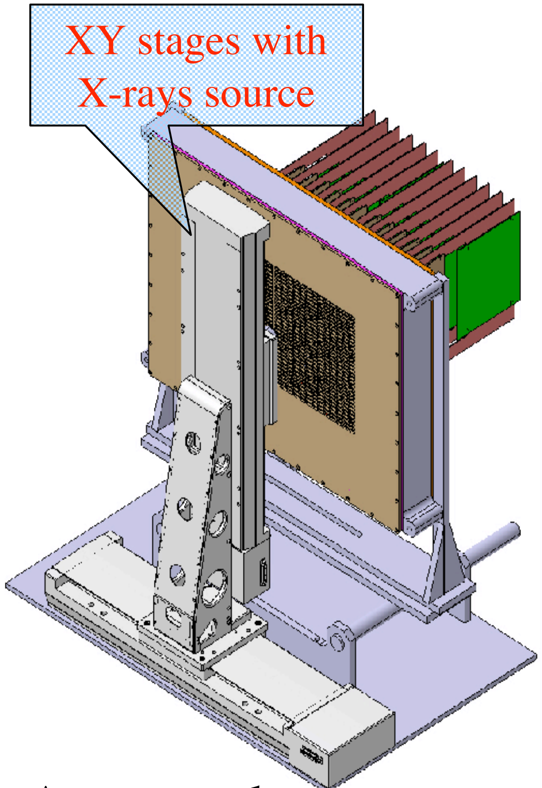
Milestones

2007	Construction of a full size TPC prototype
Sept. 2007	Test of MM modules with T2K's electronic at CERN
Early 2008	Tests with TPC prototype and electronics at TRIUMF
2007 - 2009	Construction of TPCs and MM modules
Early 2009	Full system tests at TRIUMF
Summer 2009	Shipping to JPARC
Fall 2009	Commissioning

T2K Data Taking: Fall 2009

Backup

Micromegas Test Bench



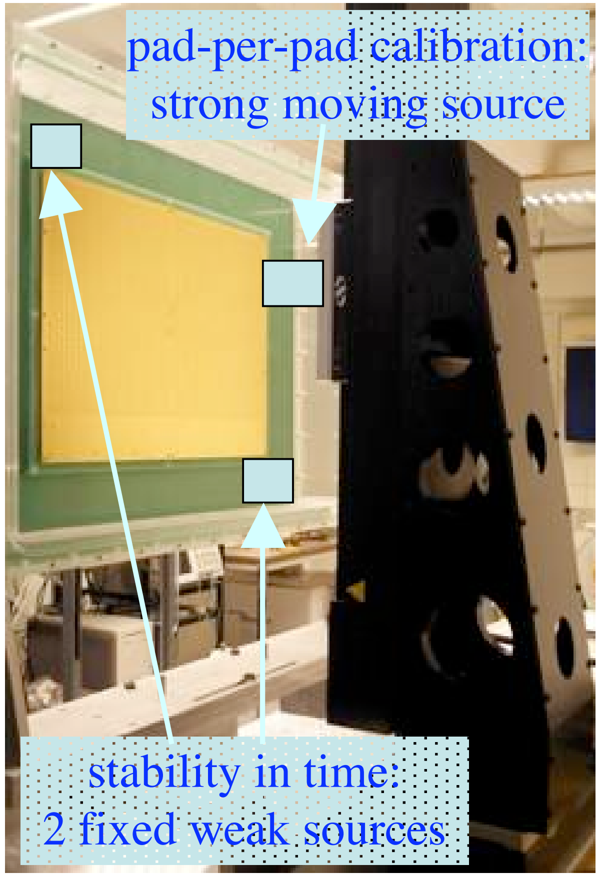
Automated movement
in x and y

Goal

- Absolute energy calibration
- Relative pad-per-pad fluctuations
- Time stability of the gain

Setup

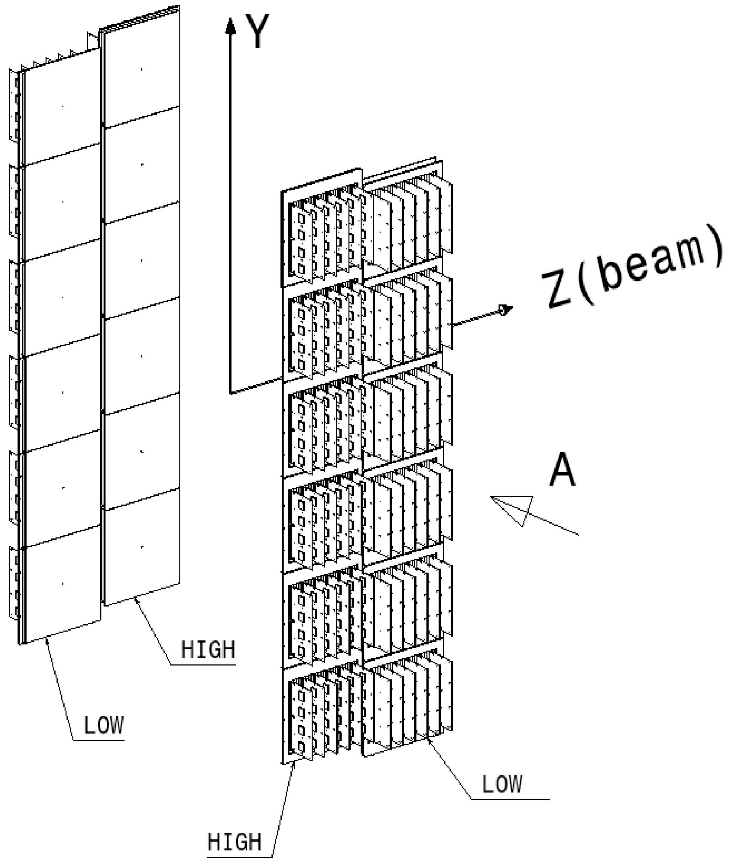
- Small drift chamber (20.5l)
  61.6 x 44.4 x 7.5 cm^3 (4cm drift)
- P and T monitoring
- G10 grid:
  - ensure flatness of cathode for drift field uniformity
  - HV protection



Modules held vertically,
like in the TPC

Developed at Université de Genève, DAQ system from IFAE

Readout



3 TPCs
2 planes per TPC
12 modules per plane
6 FECs per module
(4 ASIC per FEC)
288 pads per FEC
124 416 pads in total

Module size: 36x34 cm^2
Pad size: 6.9 x 9.7 mm^2

T2K's TPC group

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