T2K Test Bench results on uniformity and reproducibility of Micromegas production

A. Ferrero*

for TRIUMF, University of British Columbia, University of Victoria, IRFU-CEA/Saclay, RWTH Aachen University, INFN Italy, Barcelona University, Valencia University and University of Geneve*

RD51 Collaboration Meeting, October 14 2008

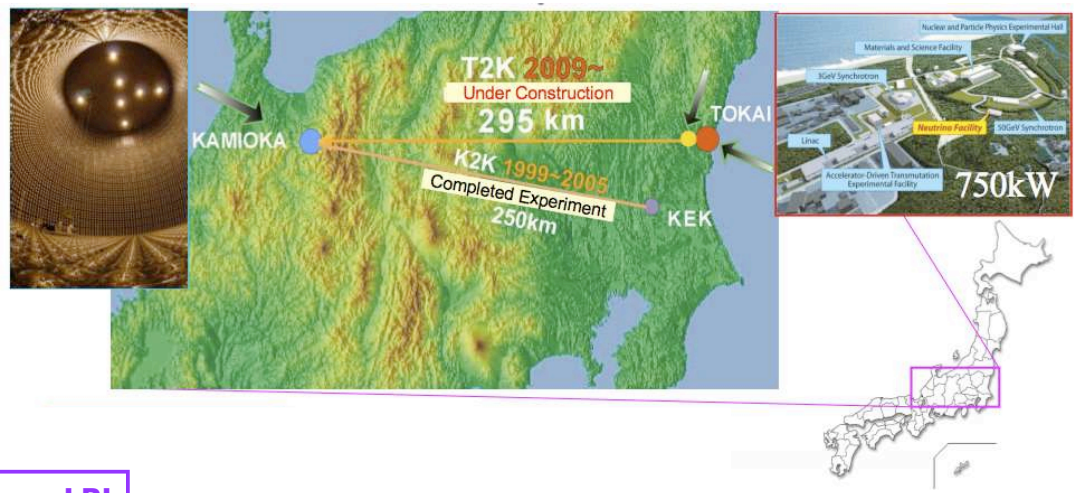
The T2K experiment and ND280 detector

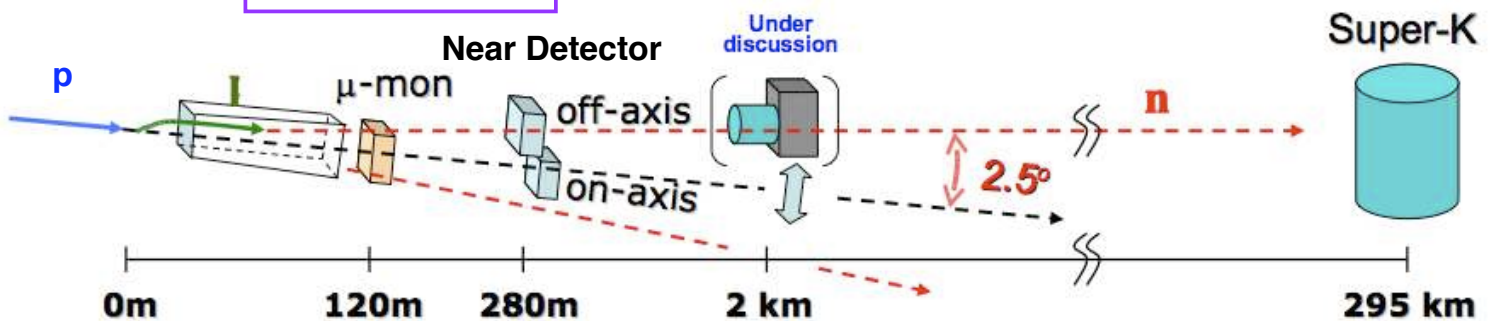
- MEASURE ν_μ DISAPPEARANCE
  more accurate determination of the "atmospheric" parameters θ_{23} and Δm_{23}
  $\delta(\sin^2 2\theta_{23}) \approx 0.01$
  $\delta(\Delta m^2_{23}) \approx 3 \times 10^{-5}$ eV

  c.f. : $\delta(\sin^2 2\theta_{23}) \approx 0.04$
  $\delta(\Delta m^2_{23}) \approx 2 - 3 \times 10^{-4}$ eV^2 — SK, K2K, MINOS

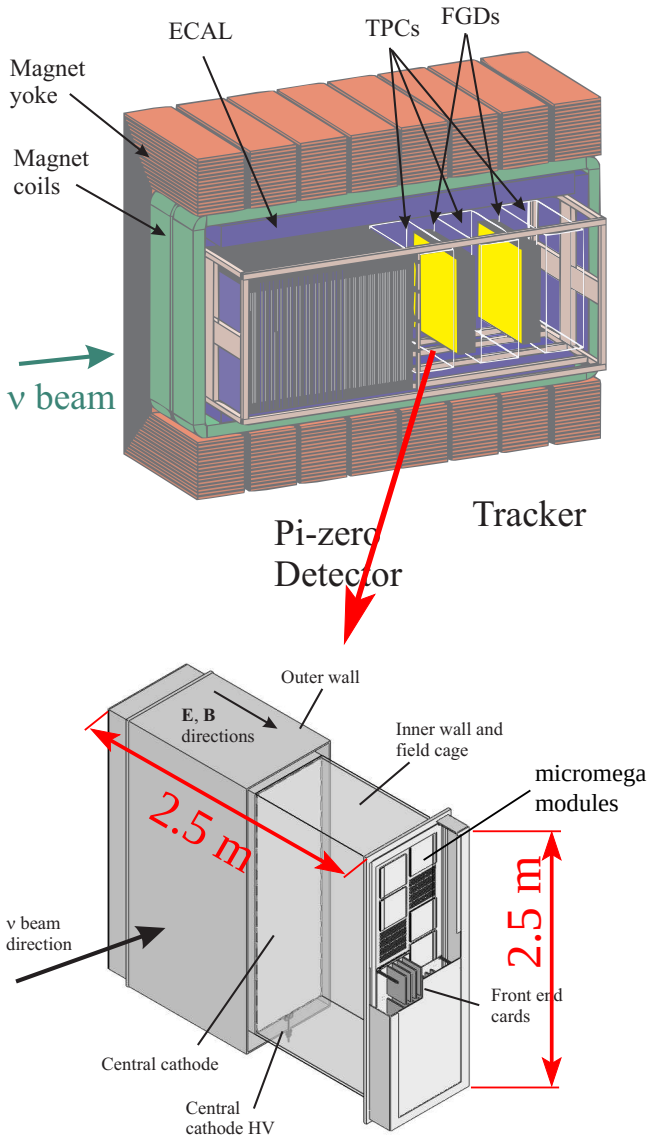
- SEARCH FOR $\nu_\mu \rightarrow \nu_e$ APPEARANCE
  measurement of θ_{13} with a better sensitivity
  $\sin^2 2\theta_{13} \sim 0.008$ (90%CL)

  c.f.: $\sin^2 2\theta_{13} < 0.14$ (90%CL) — CHOOZ + atm + LBL solar + KamLAND



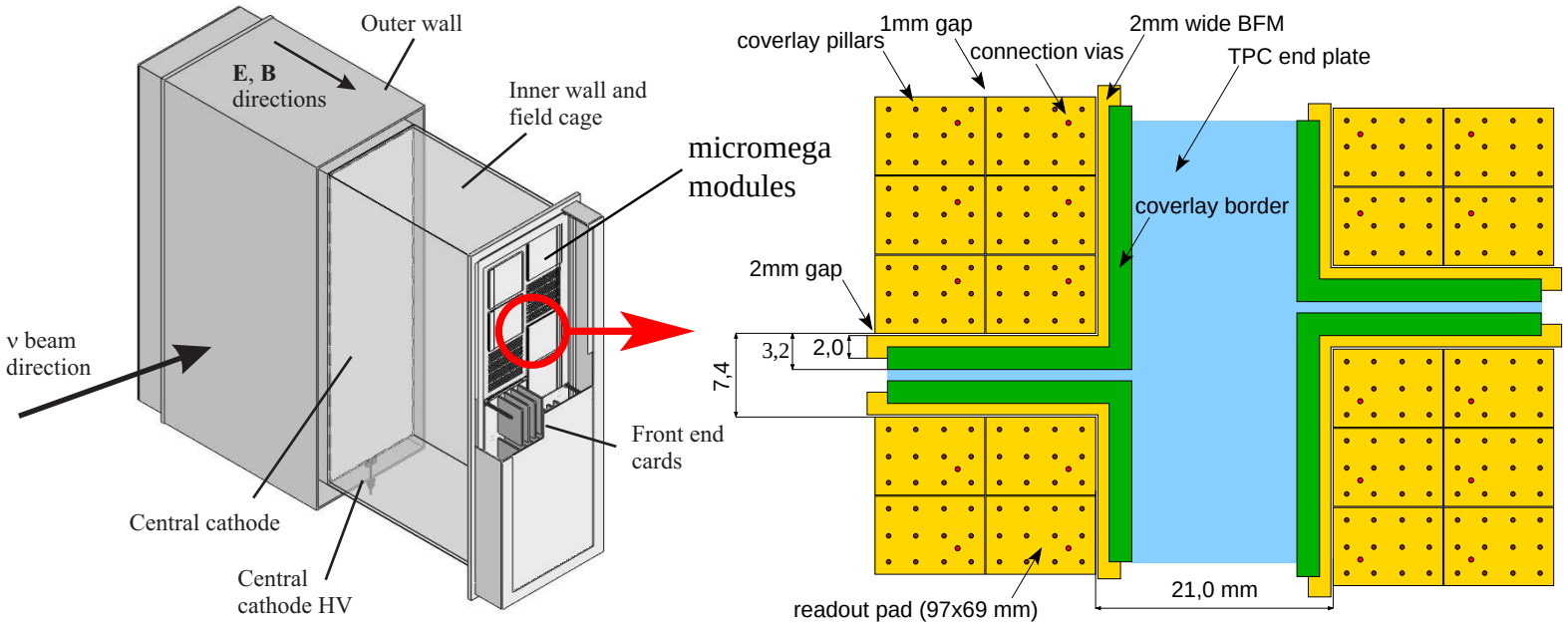


The ND280 detector



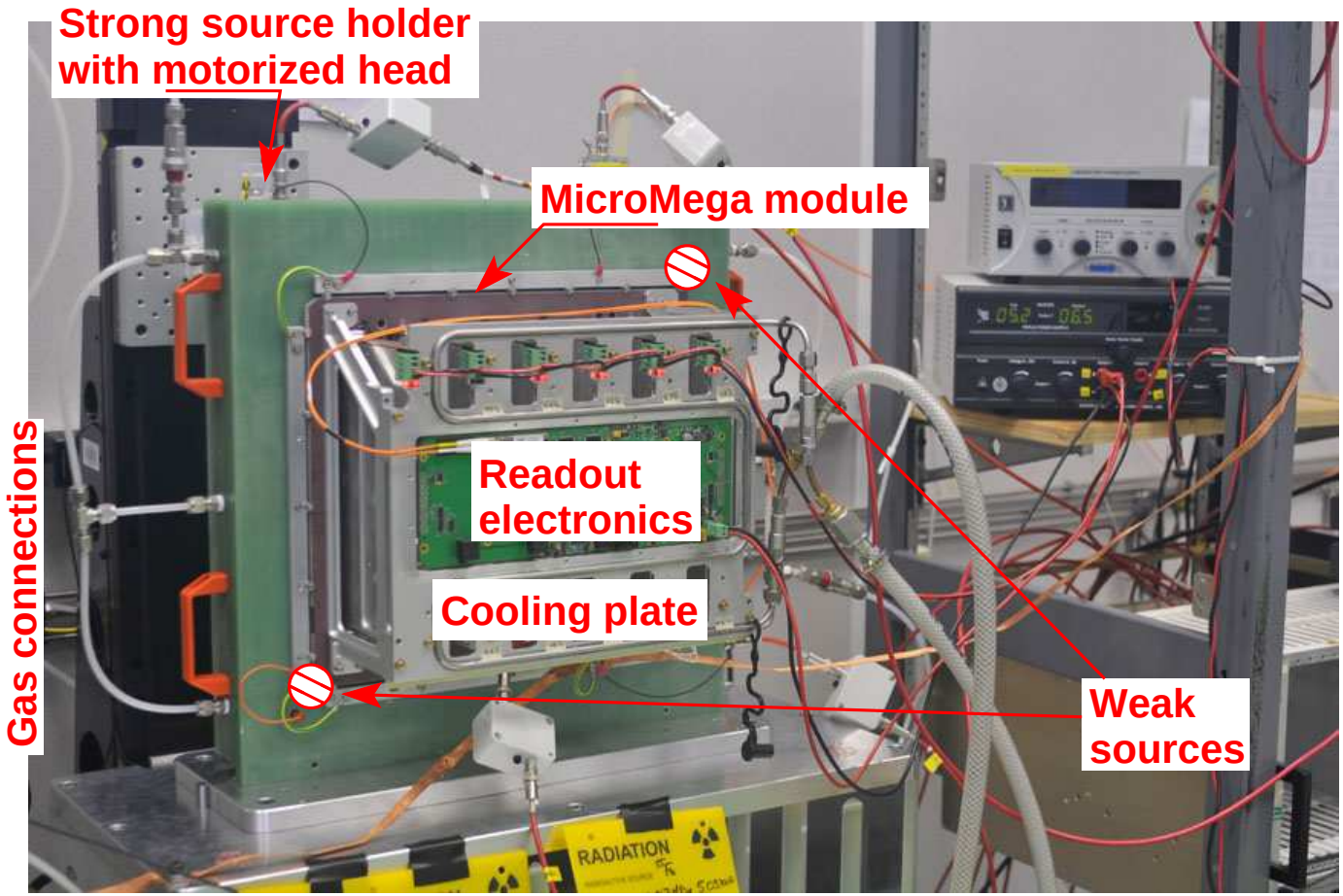
- ND280 characterizes the neutrino beam from J-Parc to SuperKamiokande (SK)
  - Energy spectrum
  - Cross-section$\times$flux measurement
  - Nuclear effects in neutrino interactions
  - Fraction of ν_e in the neutrino beam
  - Study background processes for the ν_μ/ν_e oscillations measurement at SK
- Particle tracking with TPC detectors
  - Very low material density
  - Excellent particle identification via dE/dx
  - Momentum determination through deflection in a transversal 0.2T magnetic field
  - $\sim$1.2m long drift volume filled with Ar:CF_4:iC_4H_{10} (95:3:2) - E=200 V/cm

Bulk Micromegas for TPC readout



- First large-size TPC with MPGD readout
- 35×36 cm^2 bulk micromegas covering a surface of about 1.0×2.5 m^2
  - Highly reduced geometrical dead zones
  - Uniform response over the full active surface
  - Readout based on AFTER ASICs
  - 72 modules in total for 3 TPCs, 120k readout channels
- Momentum resolution must be $< 10\%$ at 1 GeV/c $\rightarrow$ 9.7×6.9 cm^2 pads
- Energy resolution needs to be $< 10\%$ for a 3σ e/μ separation ($0.5 - 1$ GeV) $\rightarrow$ pad-by-pad signal calibration
- Each module has to be validated and characterized before installation $\rightarrow$ dedicated test bench at CERN

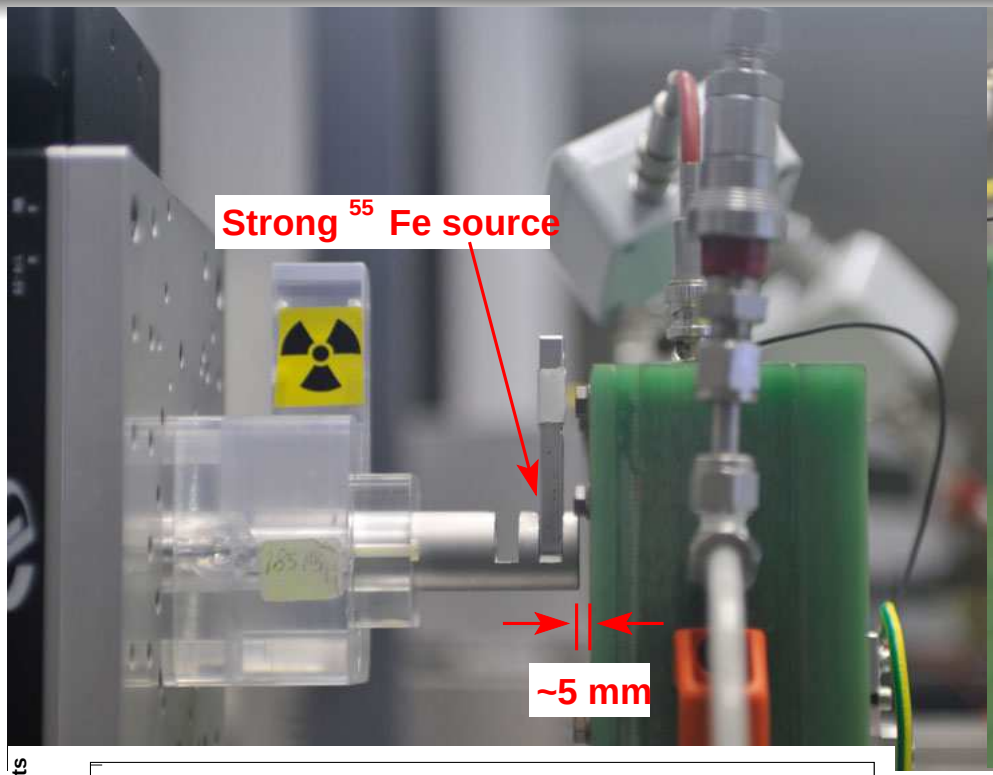
Main goal: determine the quality, the signal amplitude mapping and the energy resolution of a given bulk micromegas module

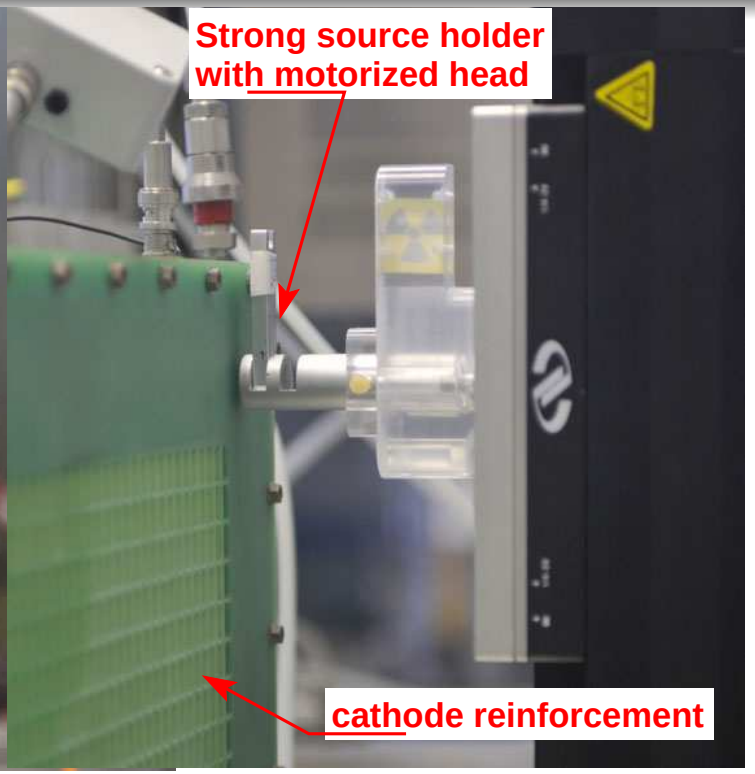


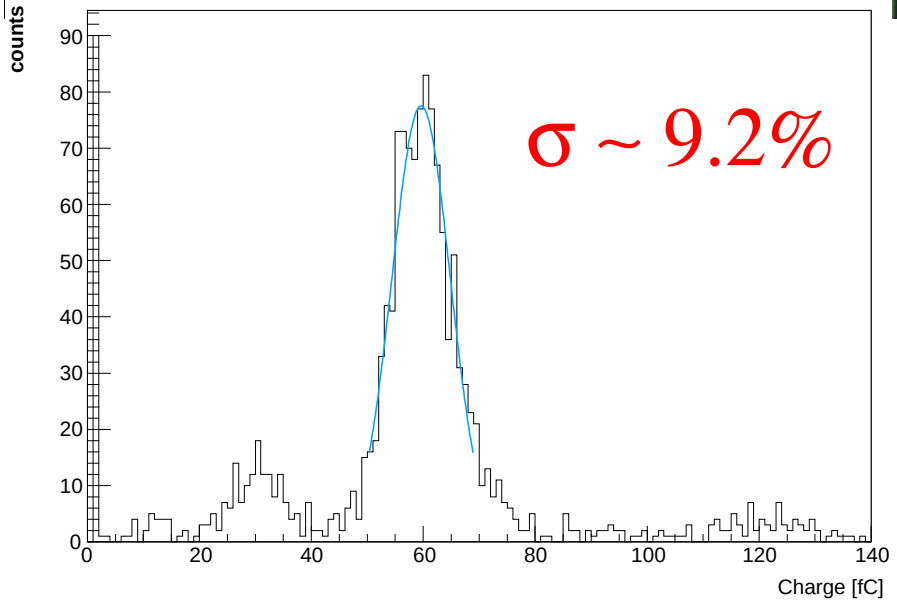
The detectors are characterized by scanning the active surface with a strong ^{55}Fe source (5.9 keV photons)

The modules are mounted in a gas-tight box providing a 4 cm thick drift volume

Strong source





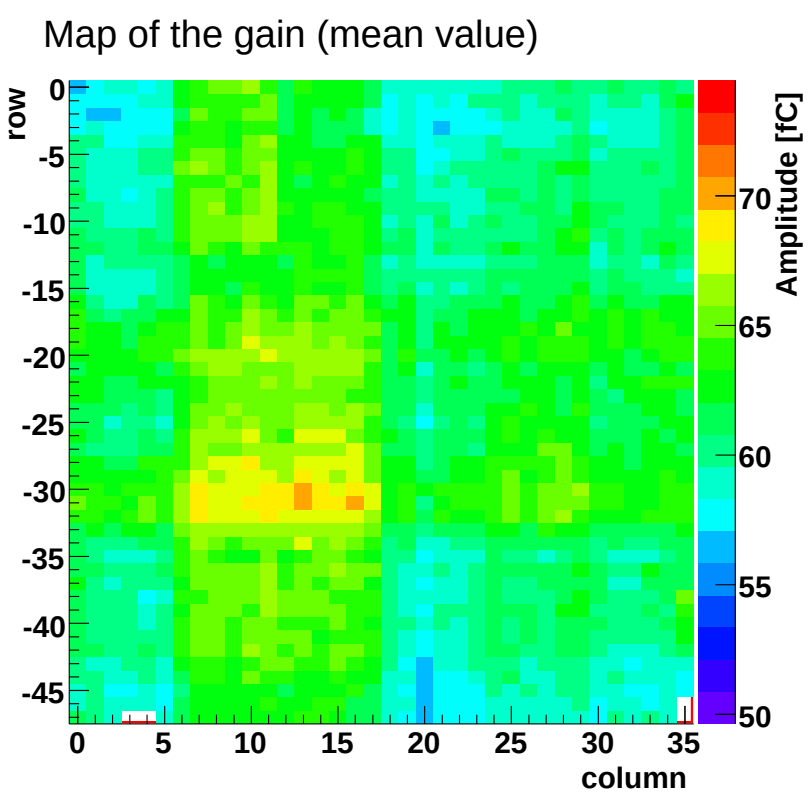


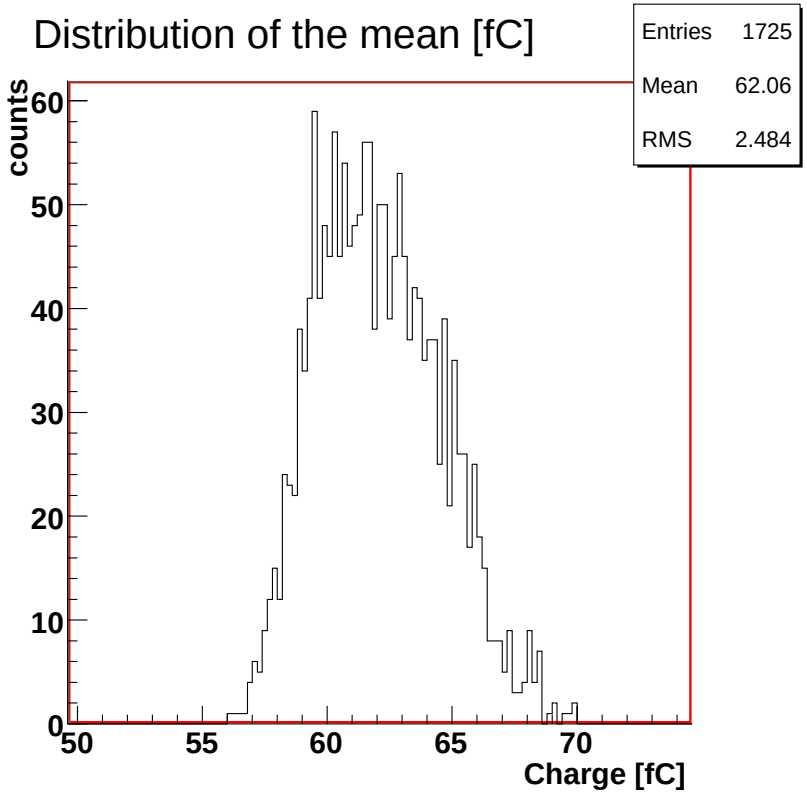
← typical single-pad amplitude spectrum from 5.9 keV photons

- Mean value: gain
- Peak width: energy resolution

One module can be completely scanned in ∼ 6 hours

Pad-by-pad distribution of mean signal amplitudes



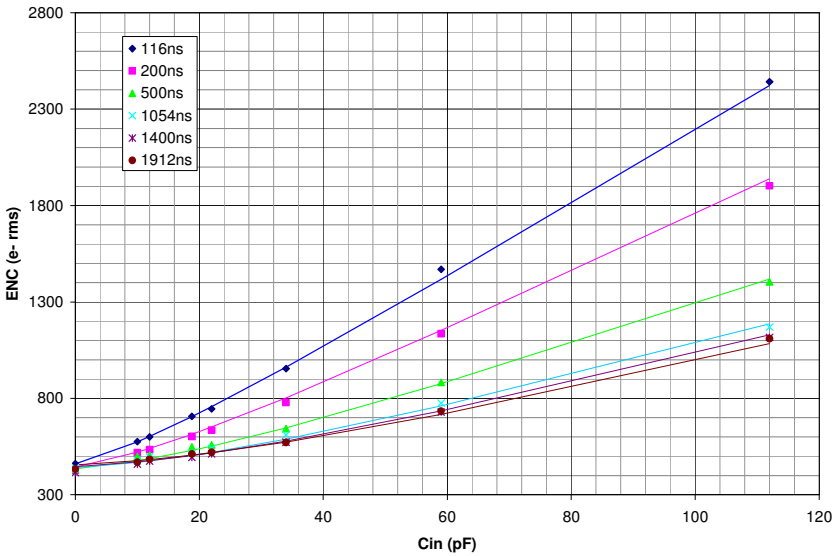


- Measurements performed at the nominal mesh voltage of -350V
- Each bin in the 2D map represents one pad (36 $\times$ 48 matrix)
- Signal amplitude dispersion: $\sim$4% RMS

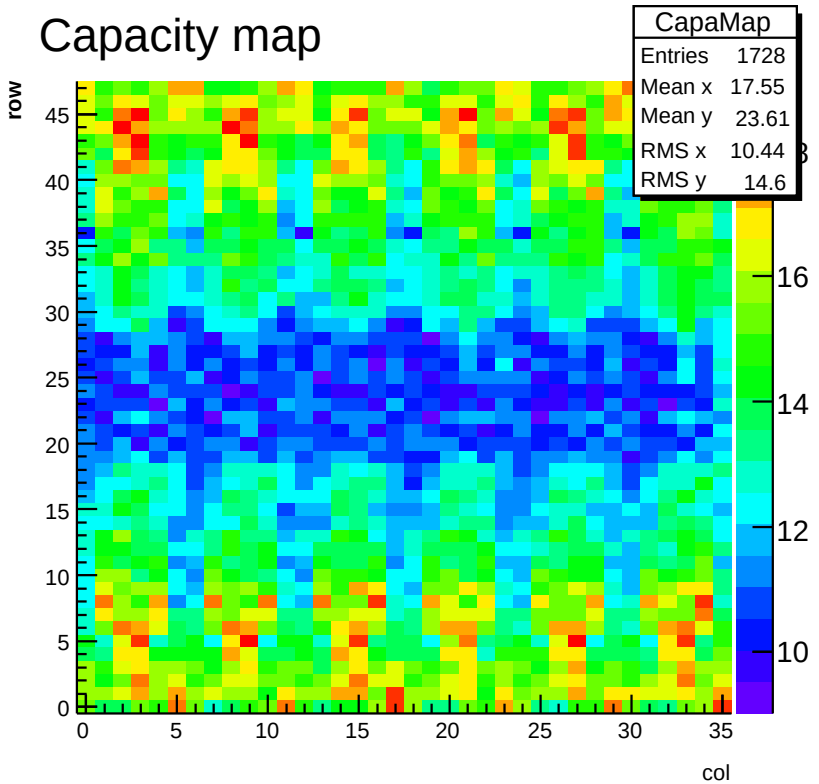
Capacitance correction

The dispersion of signal amplitudes can be reduced by taking into account the pad-by-pad parasitic capacitance

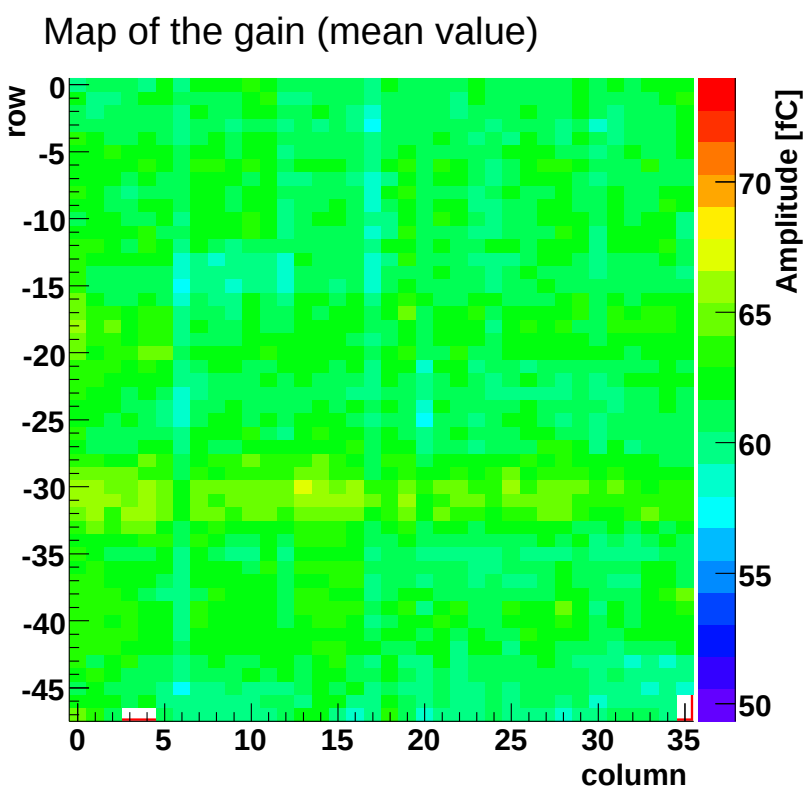
Typical noise vs. input capacitance curve for the final readout electronics

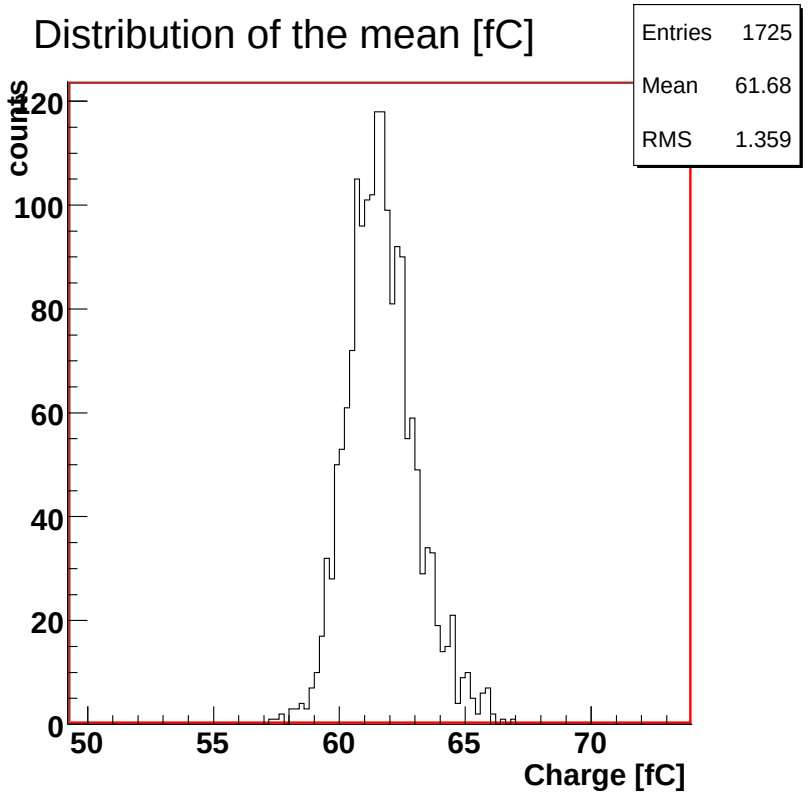


Capacitance map measured from the pad-by-pad noise with grounded mesh



Pad-by-pad distribution of mean signal amplitudes - corrected



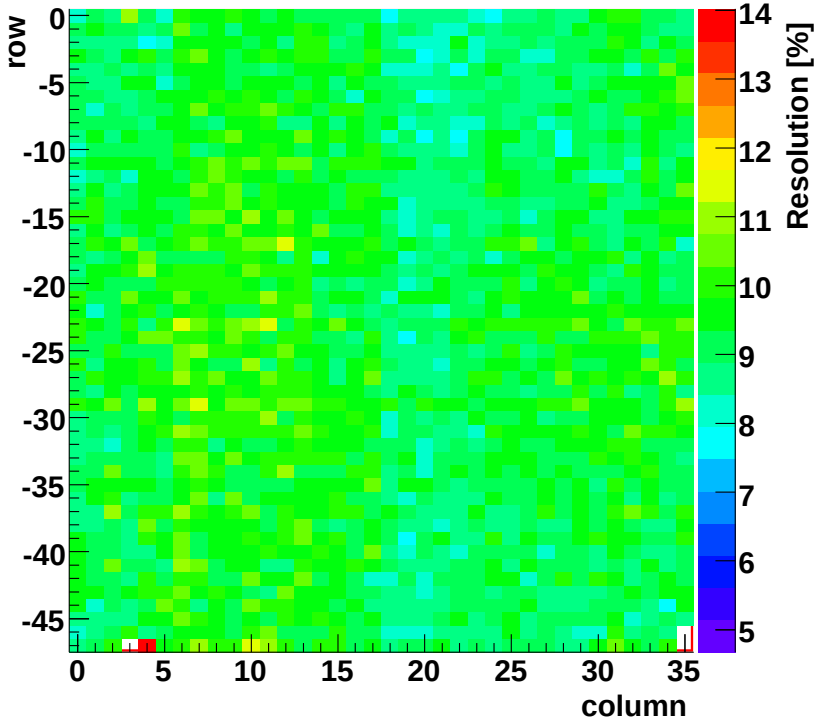


- The uniformity greatly improves after taking into account parasitic capacitances
- Corrected signal amplitude dispersion: ∼2% RMS
- Uniform response also at the edges of the active surface
- No further corrections for temperature and atmospheric pressure have been applied to the data

Energy resolution

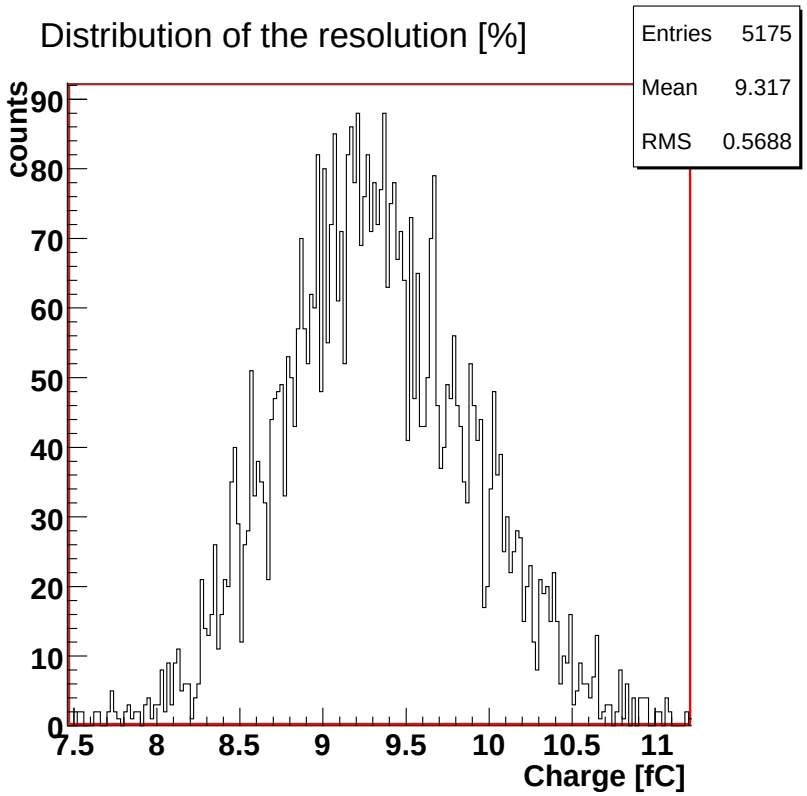
Resolution map

Map of the resolution (sigma)



Resolution (mean∼9.3%)

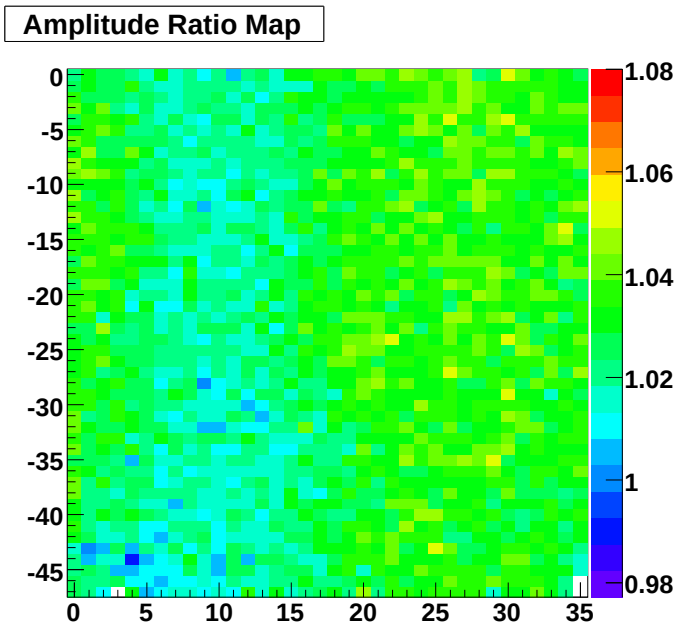
Distribution of the resolution [%]

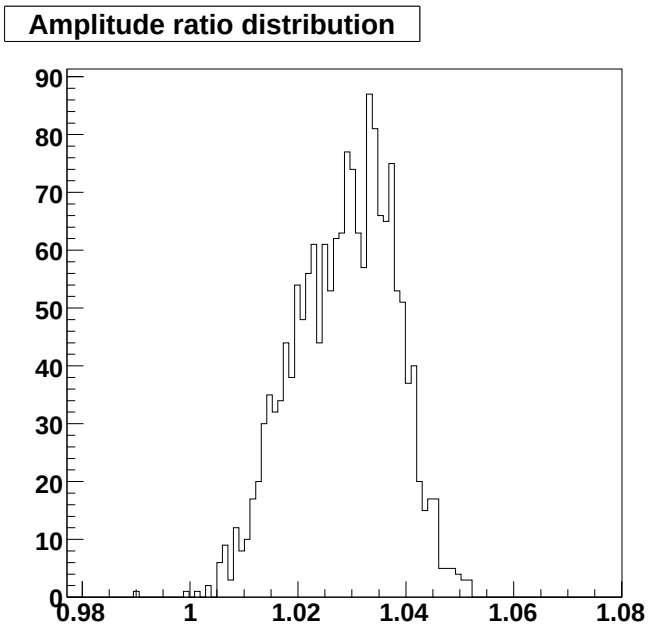


No sign of performance degradation at the edges of the active surface

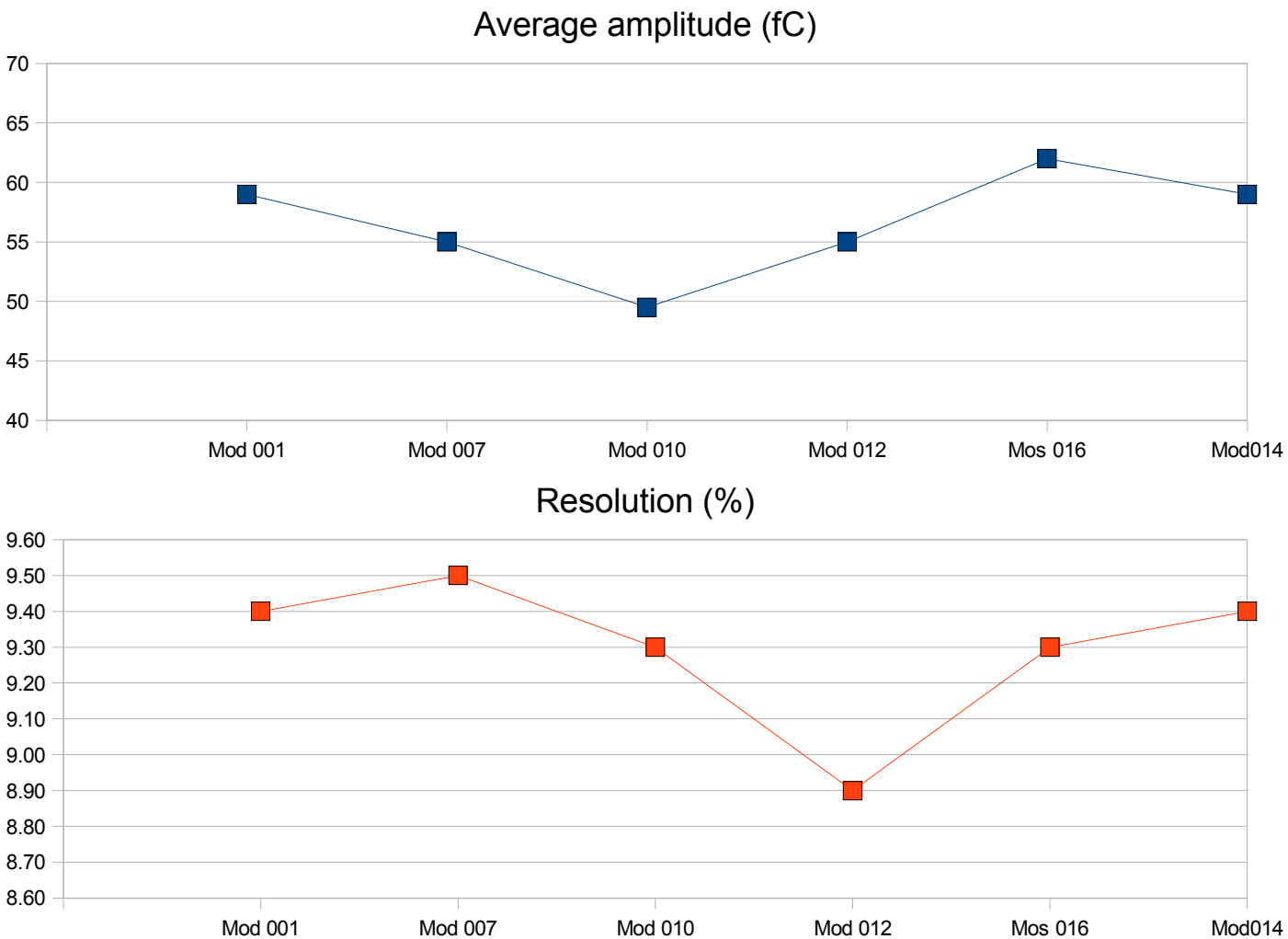
Result reproducibility

- For each module, two independent full scans are done to check stability
- Comparison is made by computing the pad-by-pad ratio of measured amplitudes for the two runs (see plots)
- The RMS of the ratio distribution is typically $< 1\%$
- The mean value shows variations of few %, mostly due to re-adjustment of mesh HV between scans





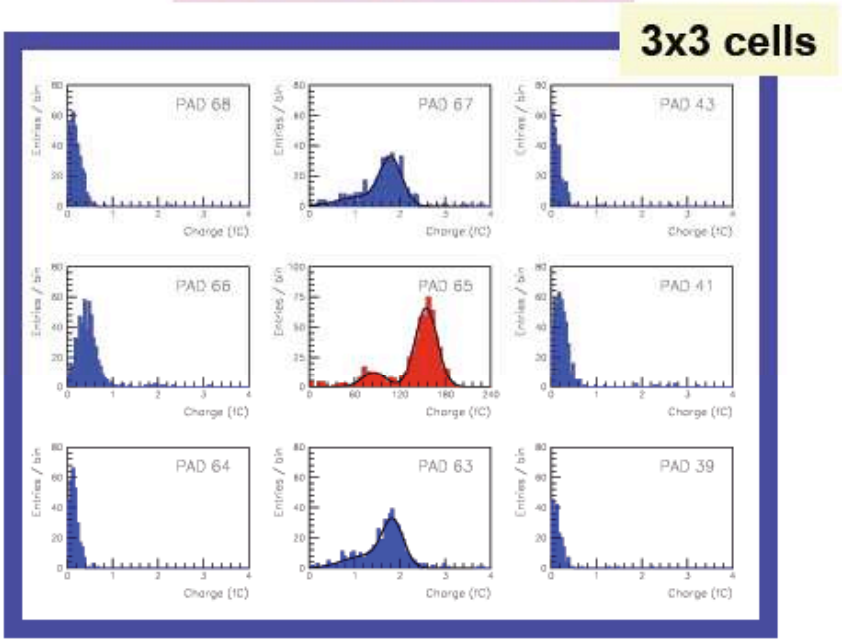
Current status of MM calibration



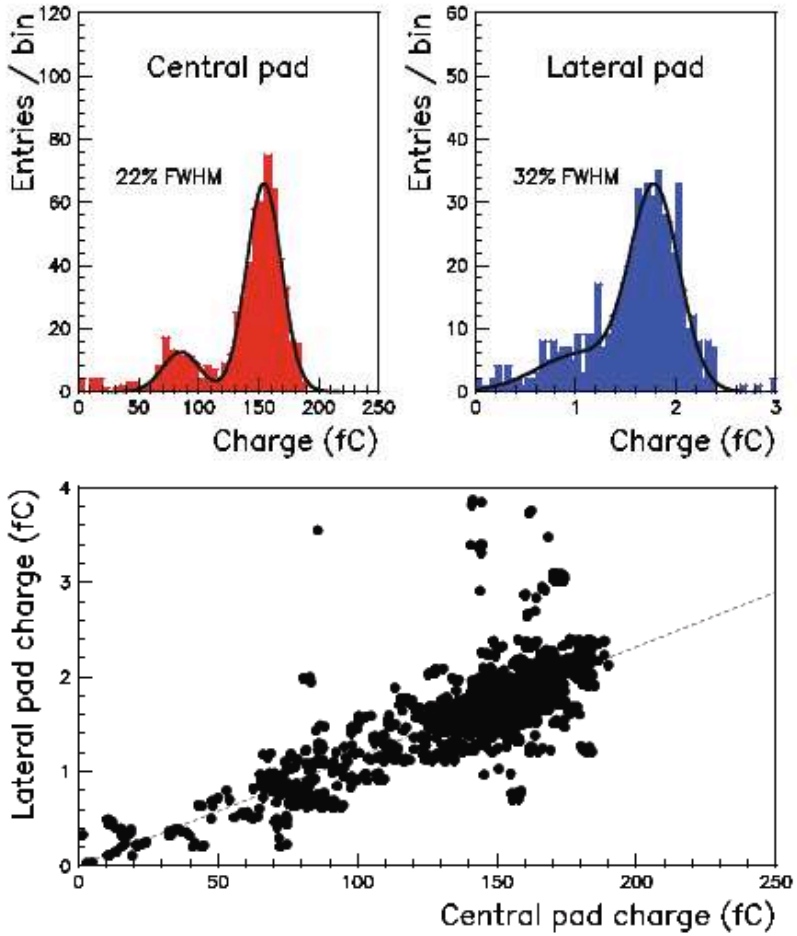
- Six mass production modules tested so far
- Good agreement of measured gain and resolution between modules
- Excellent quality: no local defects or “dead” pads observed so far

Signal cross-talk

^{55}Fe signal contained in 1 pad



~1.2% observed cross-talk effect
⇒ 2.5 pF parasitic capacitor



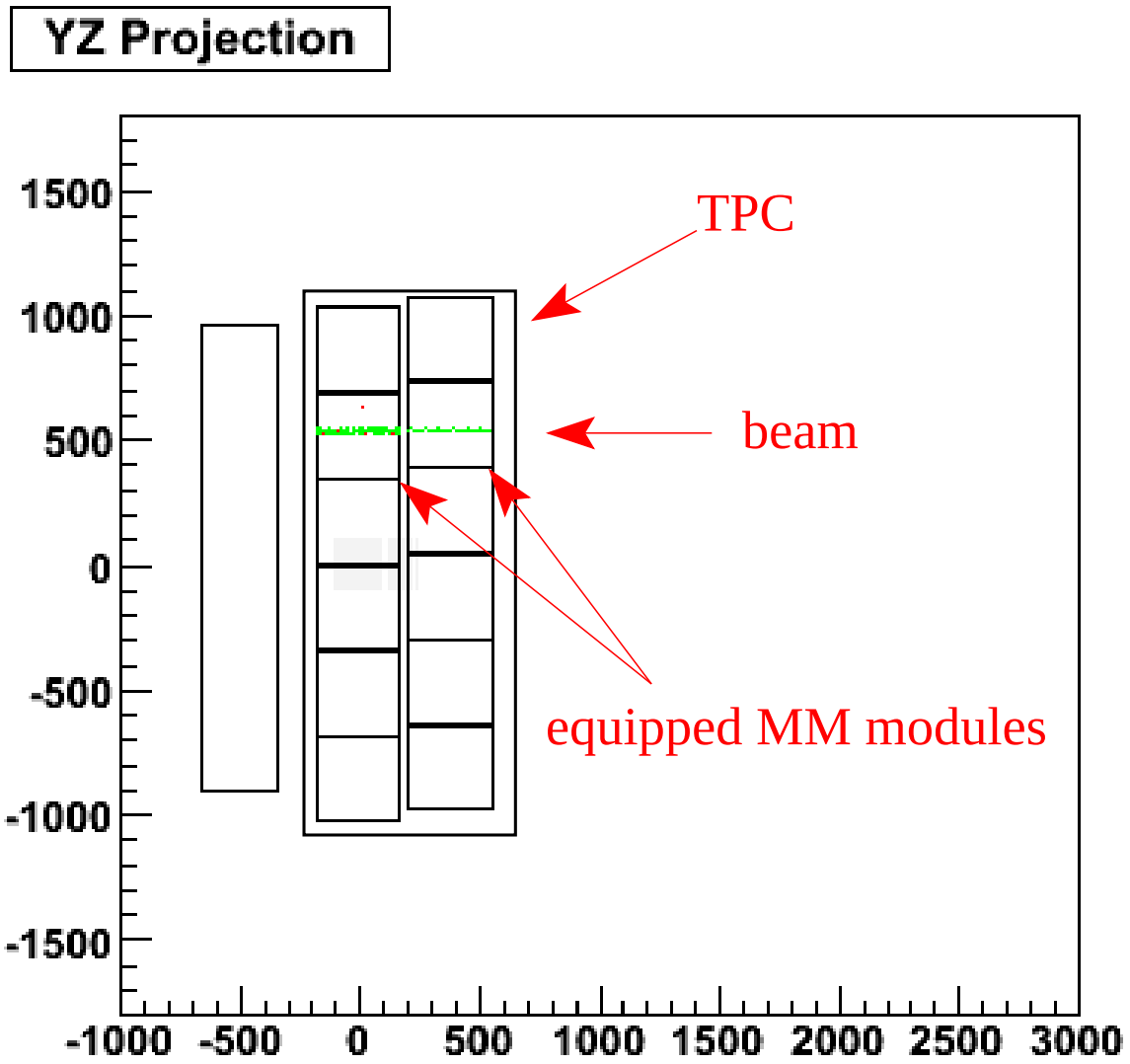
Values mesured with an intermediate MM PCB version.
Final PCB improves the figure to $< 1\%$

Conclusions and outlook

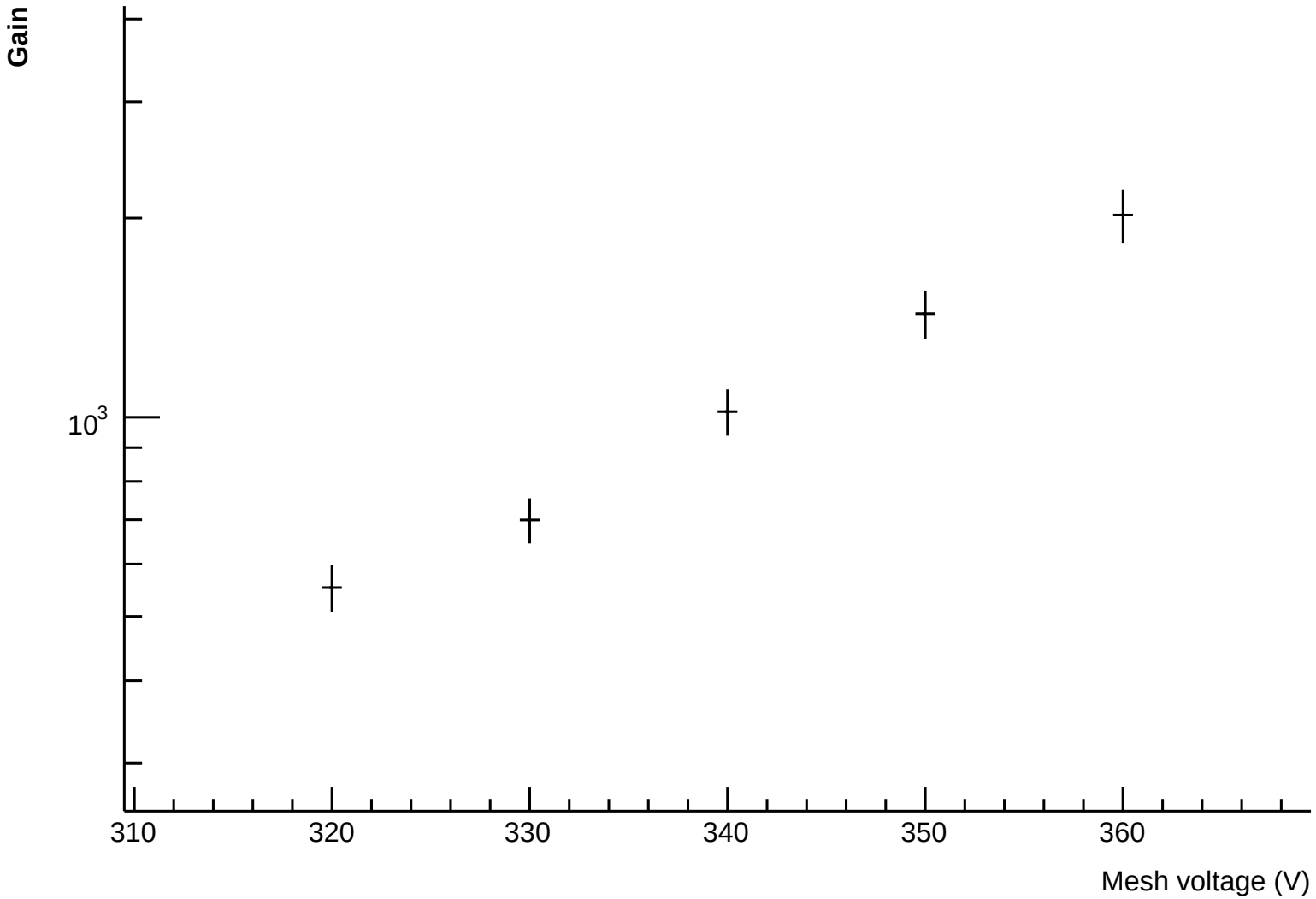
- The production and test of Bulk Micromegas detectors for the ND280 TPCs is ongoing - 72 modules need to be validated and installed by summer 2009 (+ some spares)
- A dedicated test bench has been set-up at CERN, imploying an ^{55}Fe source with motorized holder that allows precise scans in semi-automated mode
- 6 modules of the final production already characterized
  - Gain uniformity over the detector surface is very satisfactory
  - Energy resolution is also uniform (including outer edges) and basically similar for all modules
- One ND280 TPC detector, equipped with two MM modules, has been tested at Triumf in September 2008
  - Nominal voltage and gas mixture
  - Tracks already seen in TPC! (see next slide)
  - Very low spark rate obesrved ($\sim$ 1 every 10 hours)

First tracks in ND280 TPC

Data collected at TRIUMF with an 150 MeV beam (pions+electrons+muons)

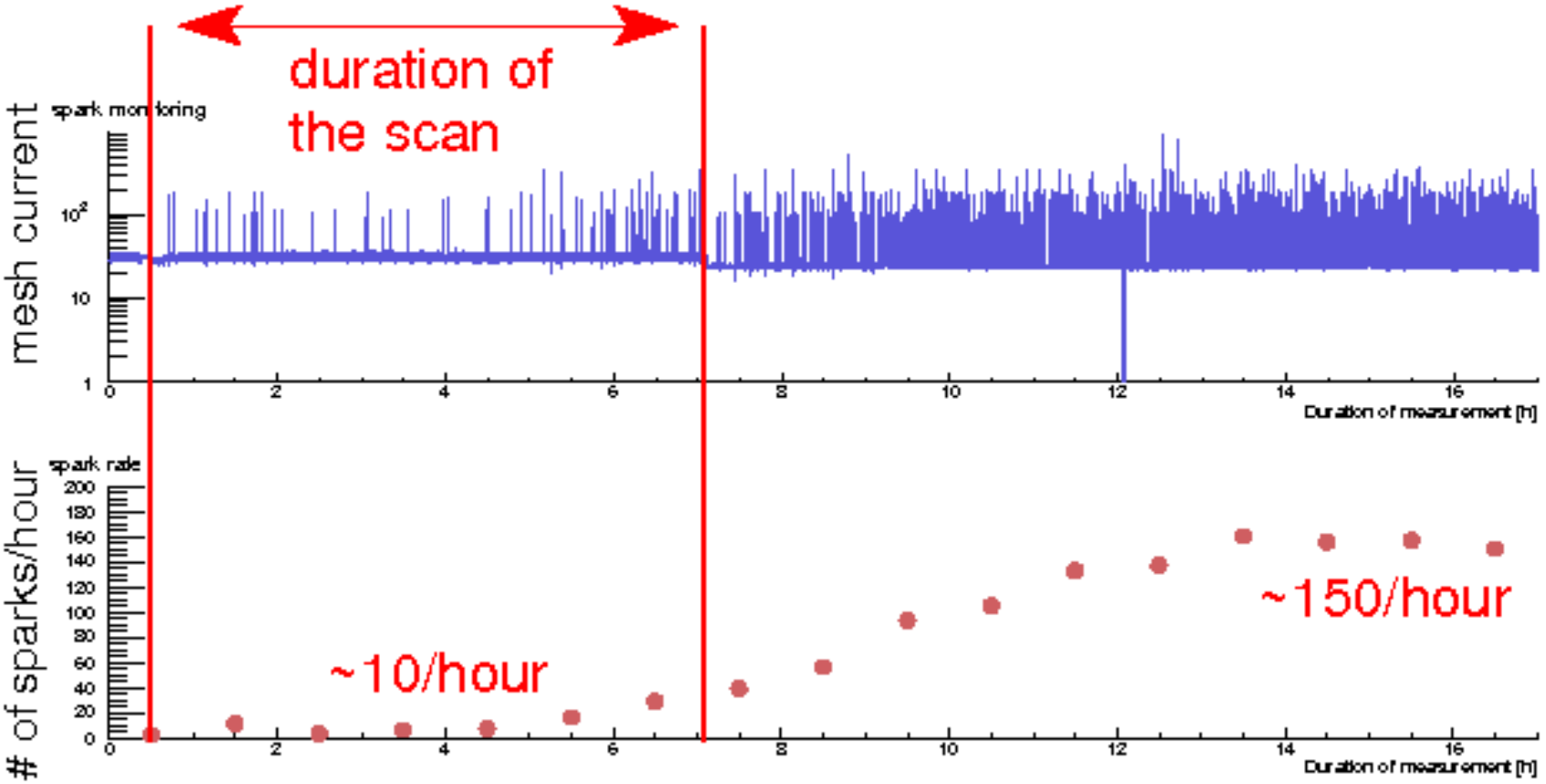


MM014, gain vs. mesh voltage



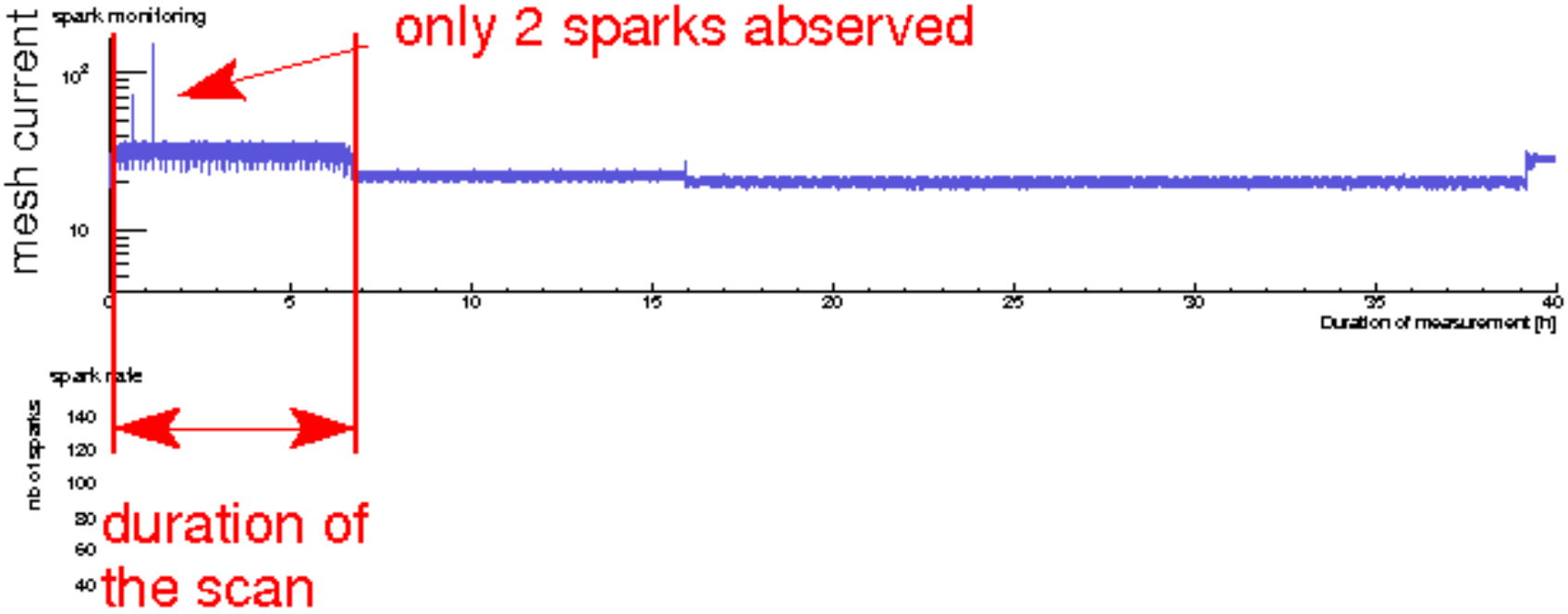
Spark rate during module tests

The typical picture:



Spark rate during module tests (2)

Measurement with an “alternative” drift box:



- Anomalous spark rate is only peculiar to a particular drift box
- The effect is under investigation and not yet understood
- There is not indication that the anomalous sparking reduces the quality of the data taken during detector tests
- Rates of the order of 1 every 10 hours have been assesed with other test boxes as well as in the final environment (ND280 TPC)