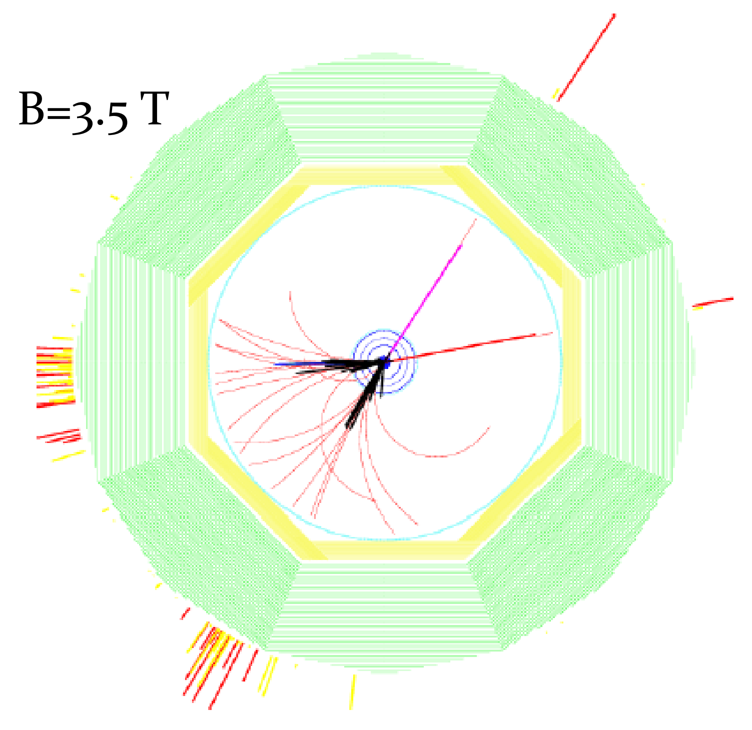
A TPC for the Linear Collider

P. Colas
on behalf of LCTPC

2 detector concepts : ILD and SiD

Both based on the ‘particle flow’ paradigm

- SiD: all-silicon
- ILD: TPC for the central tracking



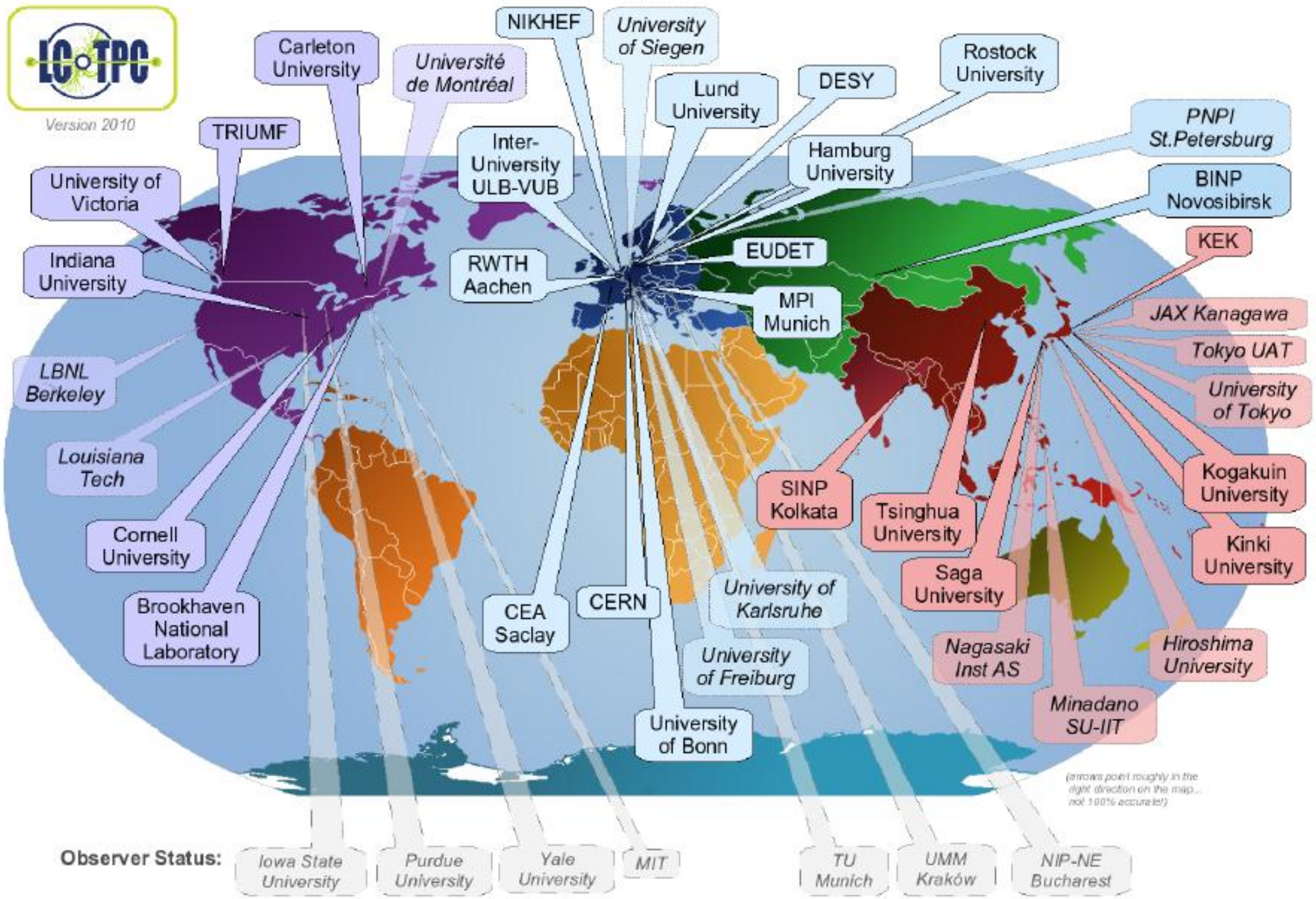
Benchmark process: e+e- -> HZ, Z->μμ

Requirements:
Momentum resolution
$\delta(1/p_T)$ <2.10^{-5} GeV/c with vertex constraint
$\delta(1/p_T)$ <9.10^{-5} GeV/c TPC only
(200 points with 100 μ resolution in Rϕ)

2-track separation: 2 mm in Rϕ and 6 mm in z in a high density background

Material budget: <5% X_0 in the barrel region, <25% X_0 in the endcap region

All the R&D is gathered in LCTPC



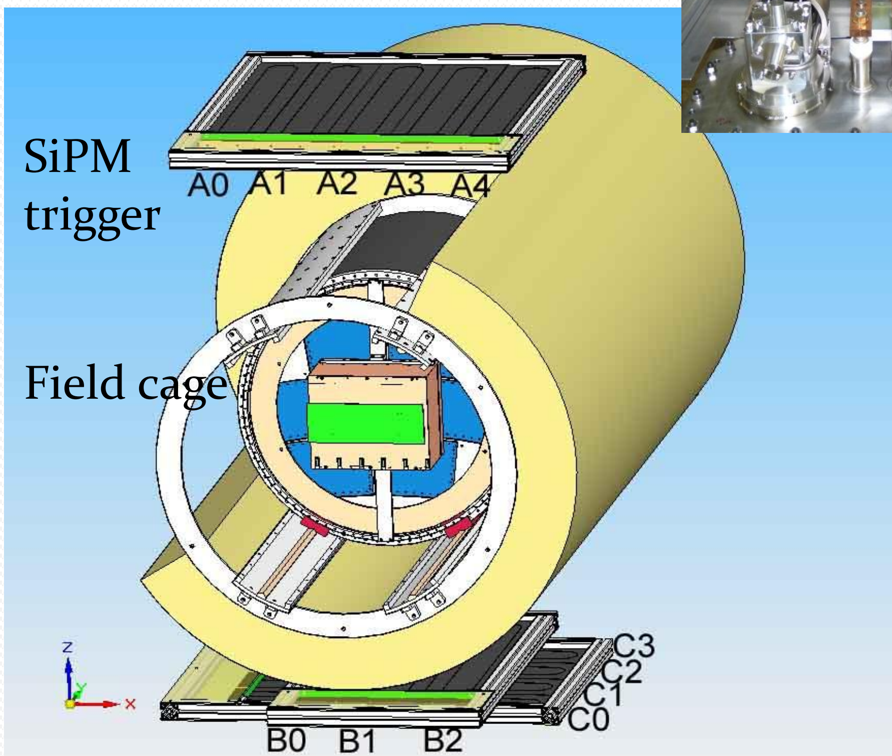
38(*) member + 7 observer institutes from 12 countries

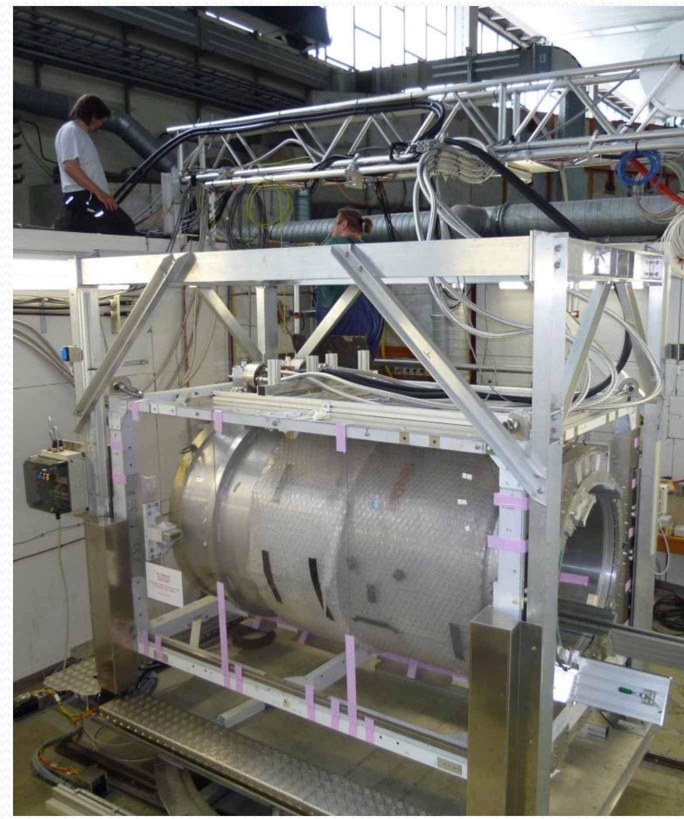
(*) 25 signed the MOA

www.lctpc.org

The EUDET test setup at DESY

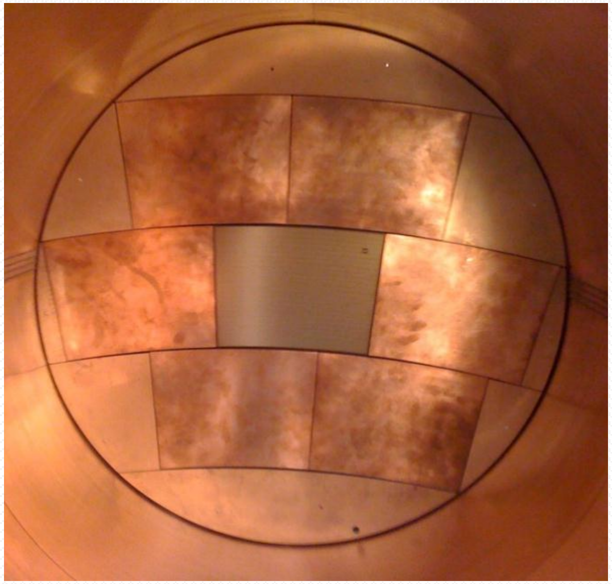
- The EUDET (FP6) setup at DESY is operational since 2008
- Just upgraded within AIDA (FP7): autonomous magnet with 2 cryo-coolers





Beam tests at DESY : 5 technologies

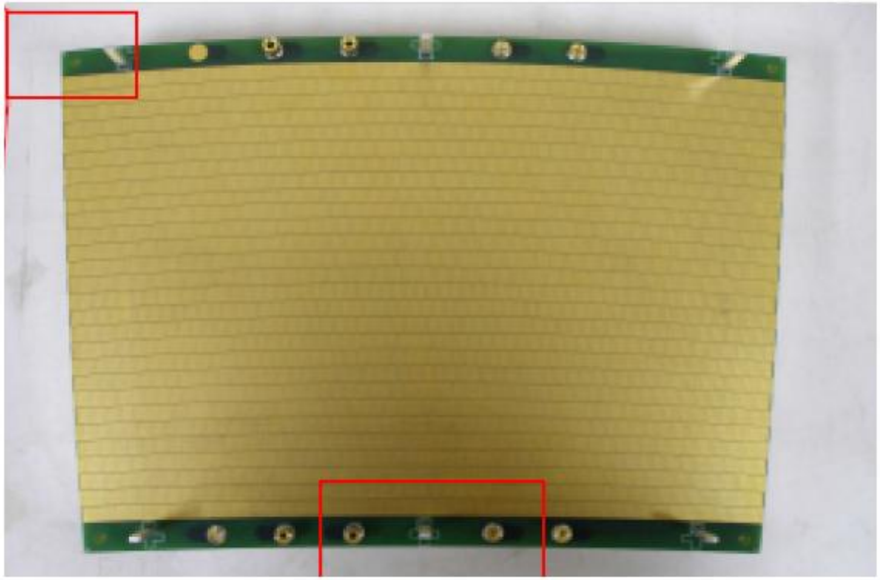
- Laser-etched Double GEMs 100 μ thick (‘Asian GEMs’)
- Micromegas with charge dispersion by resistive anode
- GEM + pixel readout
- InGrid (integrated Micromegas grid with pixel readout)
- Wet-etched triple GEMs (‘European GEMs’)

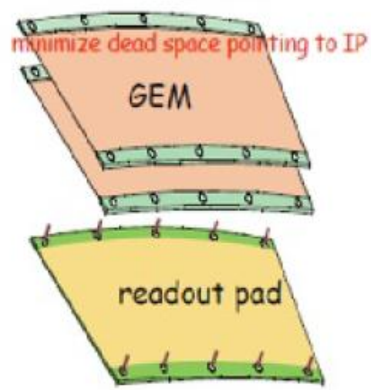


Advantages of MPGDs over wires

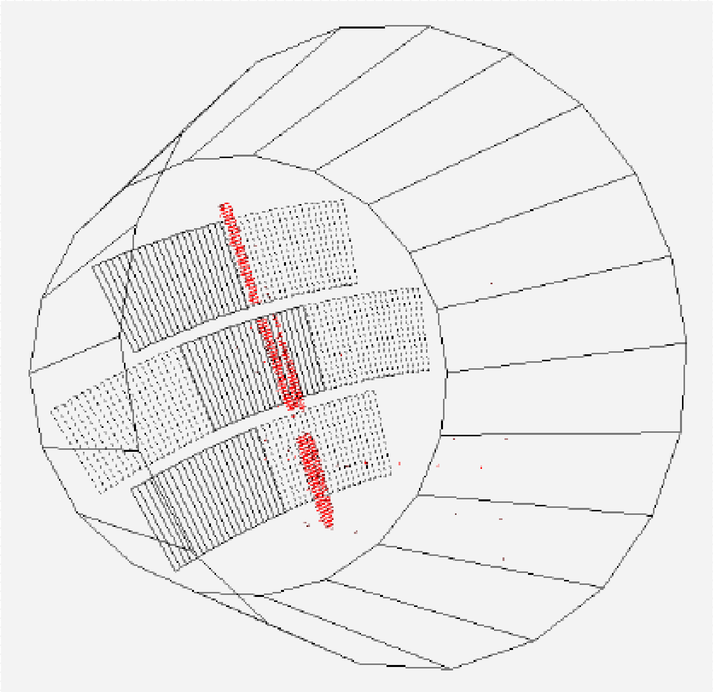
- Reduction of ExB effect (improves spatial resolution)
- Less mechanical tension
- Less ageing than wires
- Fast signal O(few ten ns), fast and efficient ion collection
- Natural or tunable suppression of ion backflow
- Discharge probability and consequences can be mastered (use of resistive coatings, several step amplification, segmentation)

Double GEM Modules (Asian GEMs)

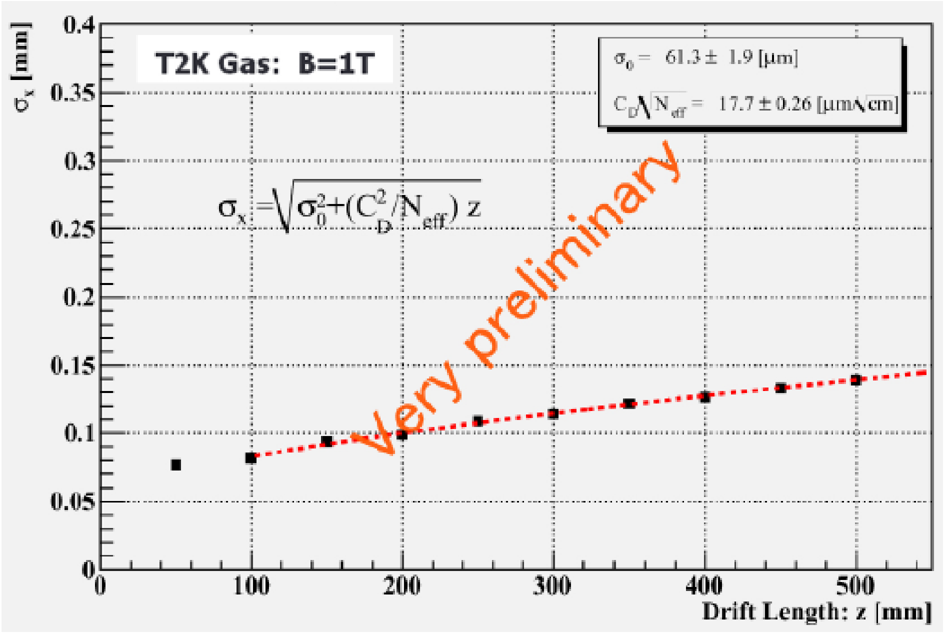




Laser-etched Liquid Crystal Polymer
100 µm thick, by SciEnergy, Japan
28 staggered rows of 176-192 pads
1.2 x 5.4 mm^2

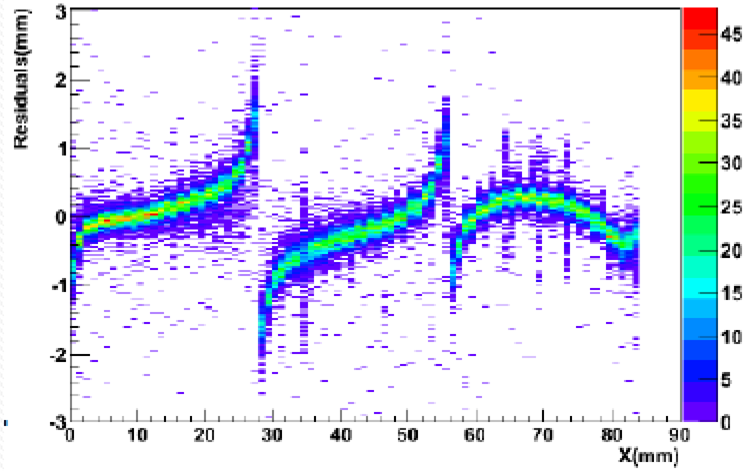


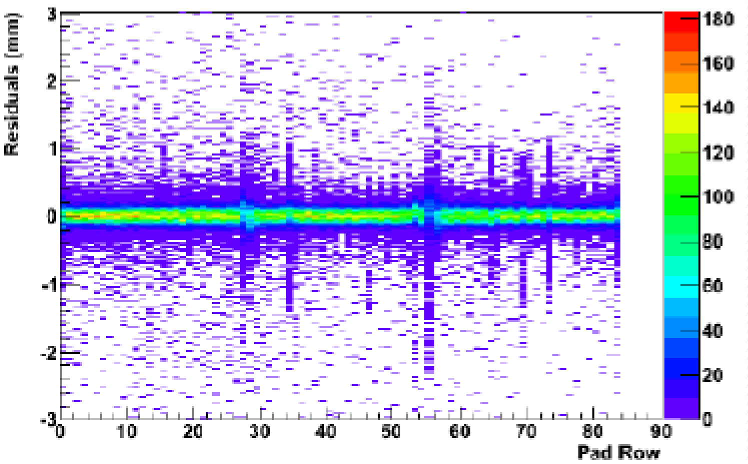
Performance of Double GEMs



rϕ resolution at zero drift: 60 microns
Behavior consistent with expectation from diffusion.

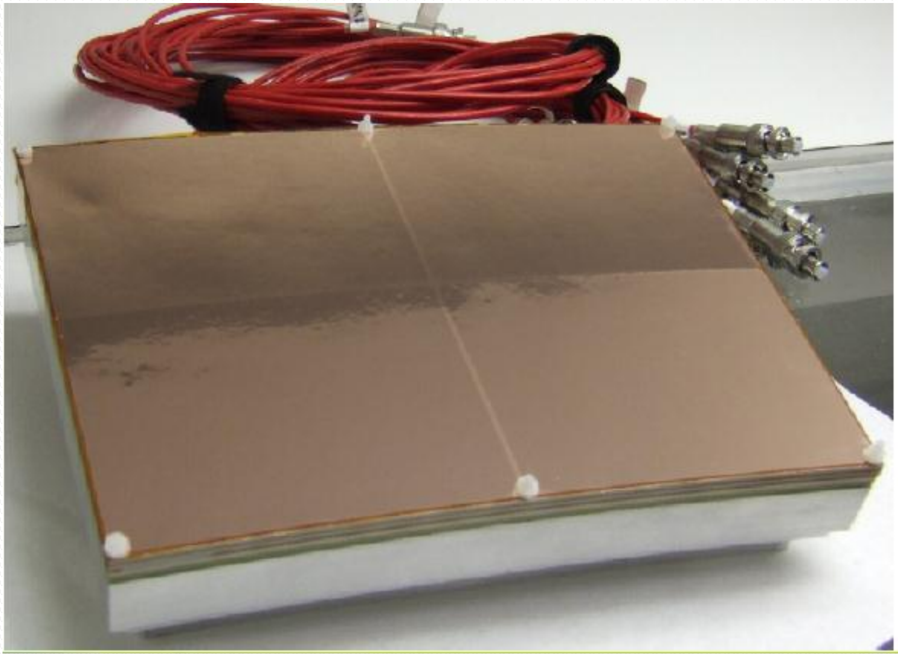
Distortions due to HV setting on the frame : corrected offline

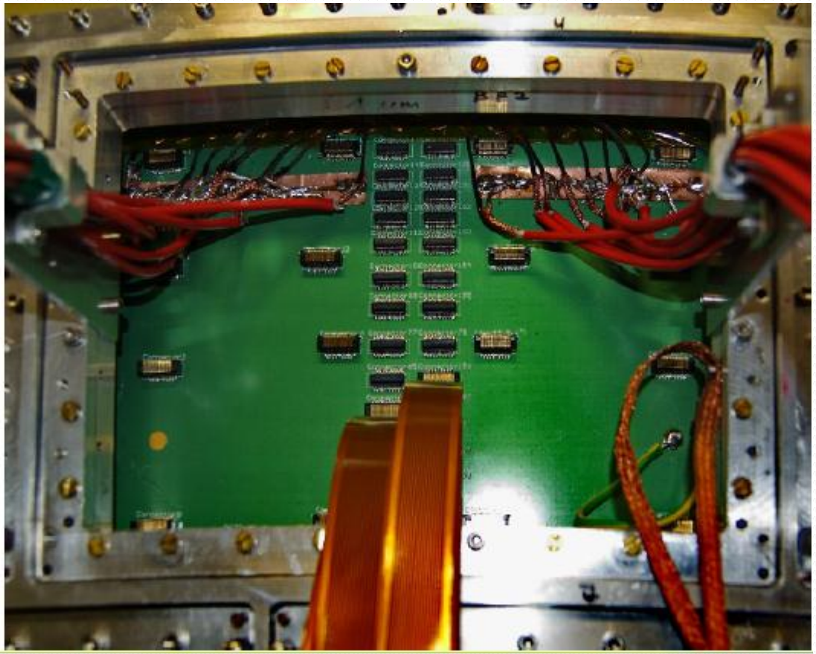




Tripple GEM Module ('European GEMs ')

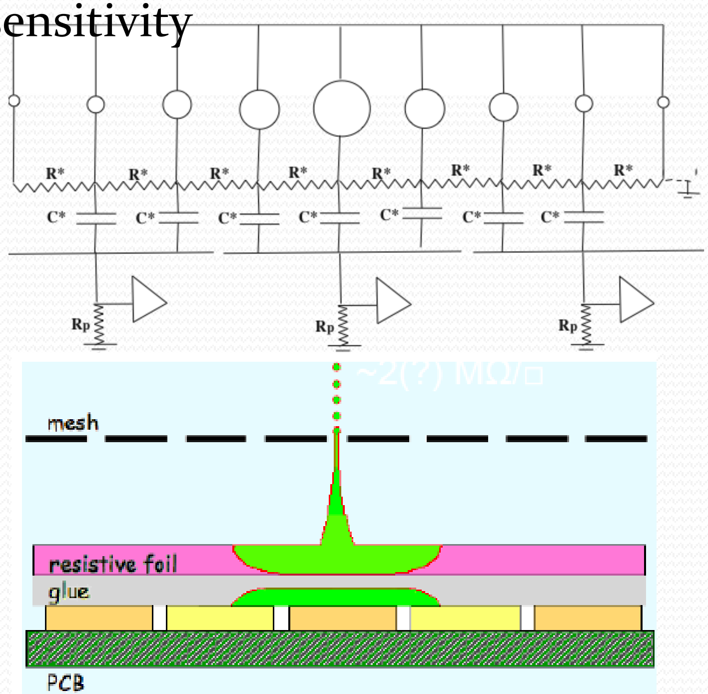
3 standard CERN GEMs mounted on a light ceramic frame (1 mm) and segmented in 4 to reduce stored energy.
Partially equipped (1000 pads, 1.26 x 5.85 mm^2)
5000 pad version being built





Charge spreading by resistive foil

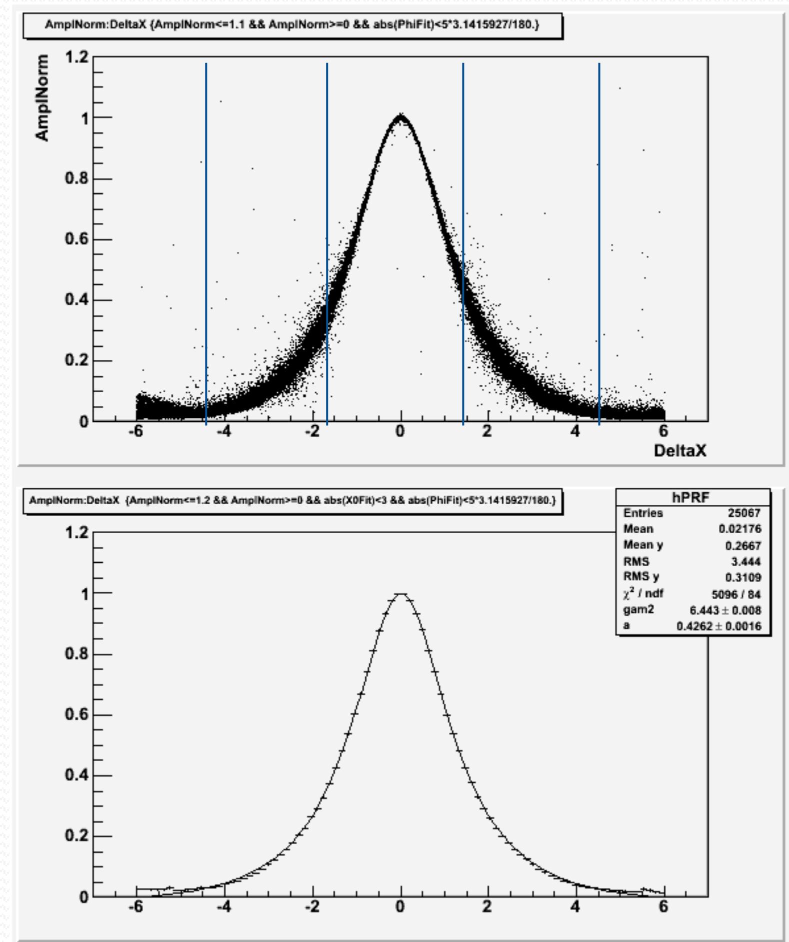
Resistive coating on top of an insulator: Continuous RC network which spreads the charge from σ(avalanche)~15μ to mm: matching pad width improves position sensitivity



M. Dixit, A. Rankin, NIM A 566 (2006) 28

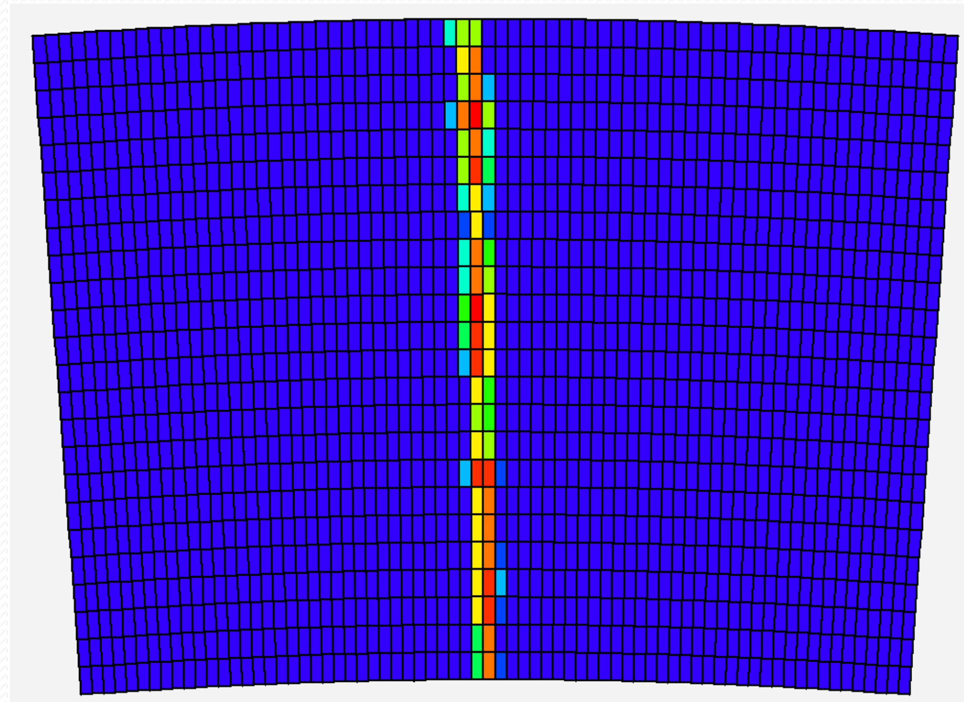
PAD RESPONSE: Relative fraction of 'charge' seen by the pad, vs x(pad)-x(track)

Z=20cm, 200 ns shaping



x(pad) – x(track) (mm)

Micromegas Modules with resistive coating



24 rows x 72 columns of 3 x 6.8 mm² pads

Various resistive coatings have been tried: Carbon-loaded Kapton (CLK), 3 and 5 Mohm/square, resistive ink.

Uniformity (B=1T data)

MEAN RESIDUAL vs ROW number

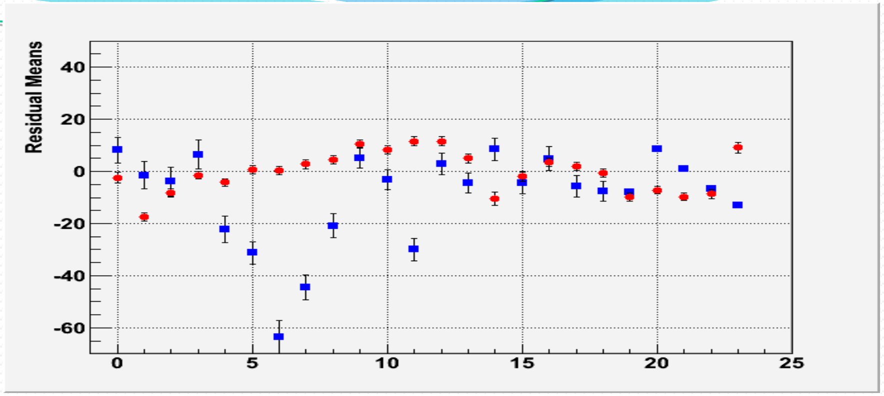
Z-independent distortions

Distortions up to 50 microns for resistive ink (blue points)

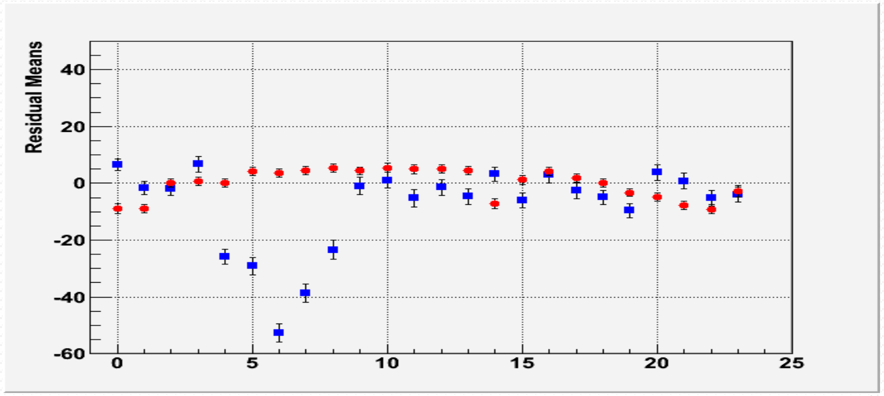
Rms 7 microns for CLK film (red points)

-> select CLK

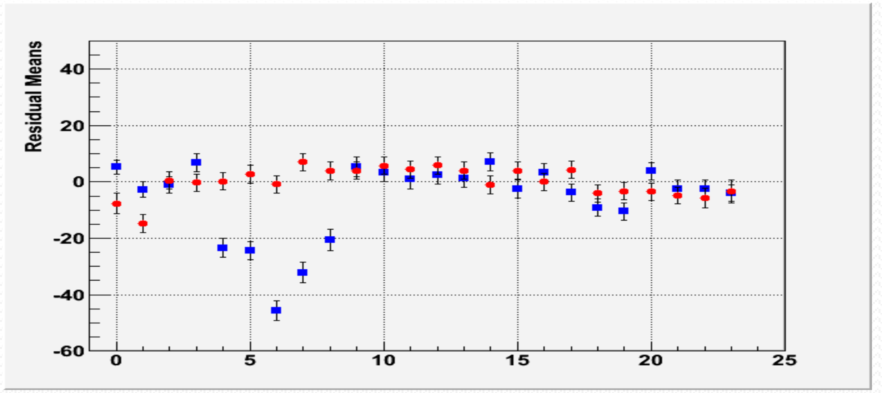
Z=5cm



Z=35cm



Z=50cm



Row number

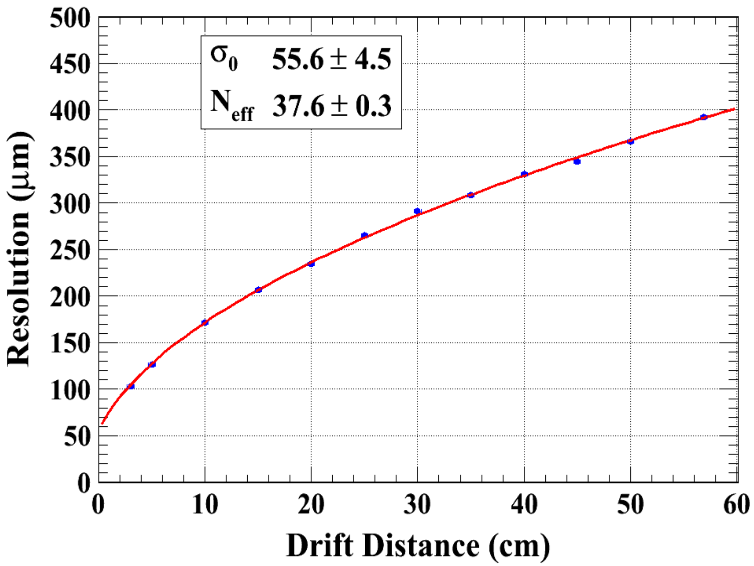
Micromegas results (B = 0T & 1T)
Carbon-loaded kapton resistive foil

Gas: Ar/CF4/Iso 95/3/2

$$\sigma = \sqrt{\sigma_0{}^2 + \frac{C_d^2 \cdot z}{N_{eff}}}$$

σ_0 : the resolution at Z=0
N_{eff} : the effective number of electrons
C_d : diffusion constant

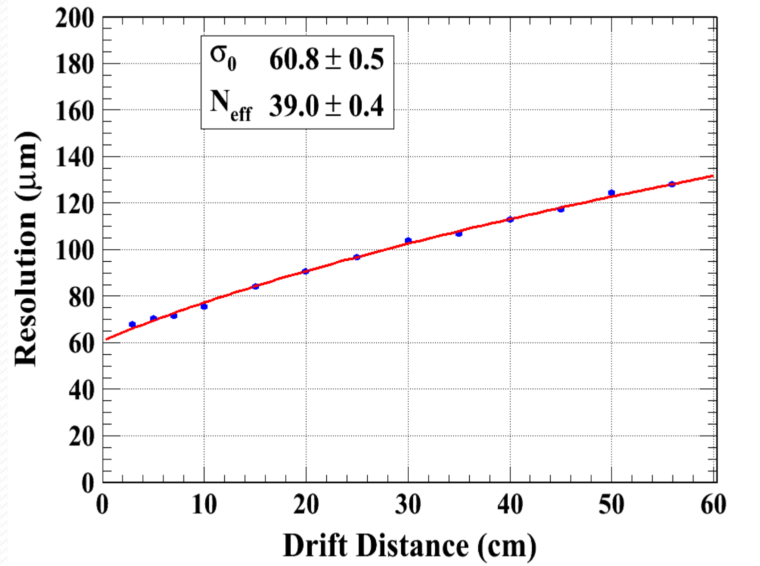
B=0 T C_d = 315.1 μm/√cm (Magboltz)



Module 4

χ² : 10.6
Ndf: 10

B=1 T C_d = 94.2 μm/√cm (Magboltz)



Module 3

χ² : 29.1
Ndf: 11

Micromegas results (B = 0T & 1T)
Carbon-loaded kapton resistive foil

Gas: Ar/CF4/Iso 95/3/2

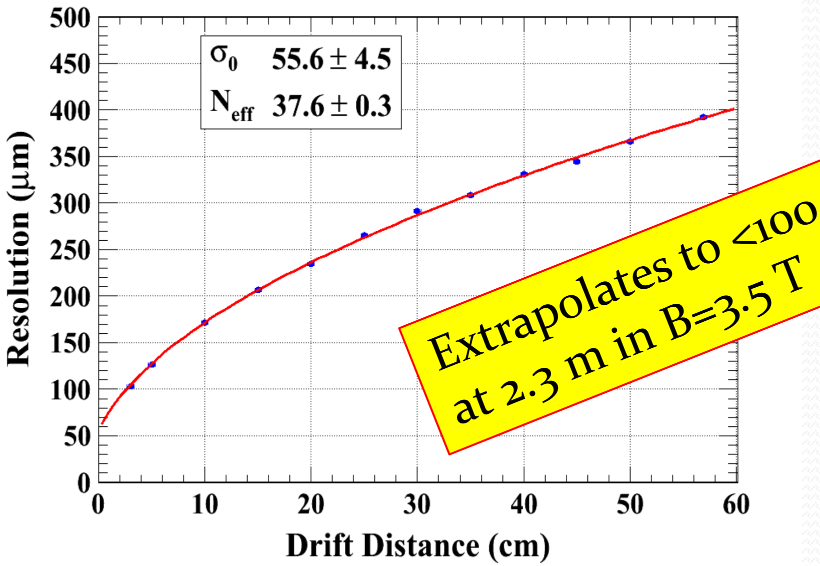
$$\boxed{\sigma = \sqrt{\sigma_0{}^2 + \frac{C_d^2 \cdot z}{N_{eff}}}}$$

σ_0 : the resolution at Z=0

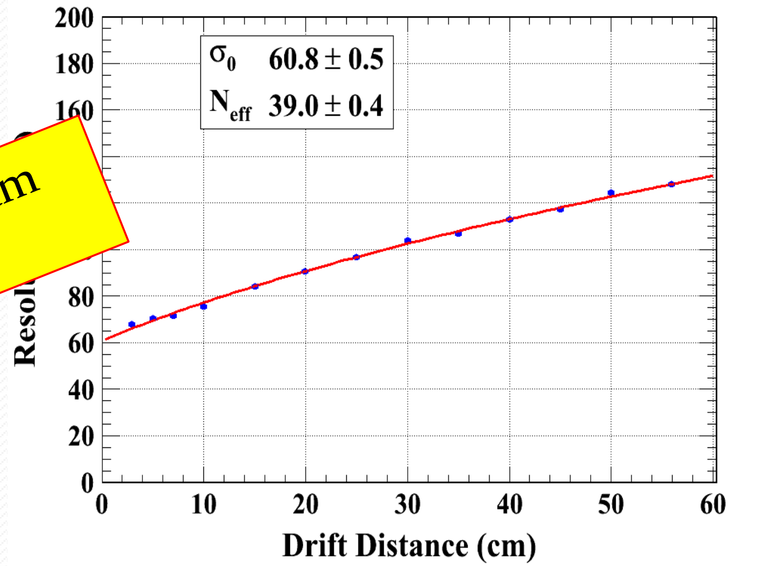
N_{eff} : the effective number of electrons

C_d : diffusion constant

B=0 T C_d = 315.1 μm/√cm (Magboltz)



B=1 T C_d = 94.2 μm/√cm (Magboltz)



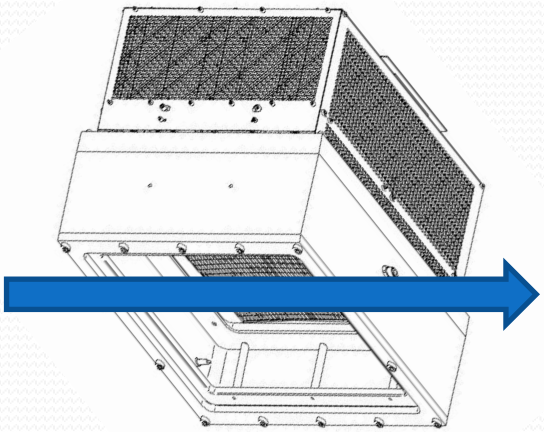
Module 4

χ^2 : 10.6
Ndf: 10

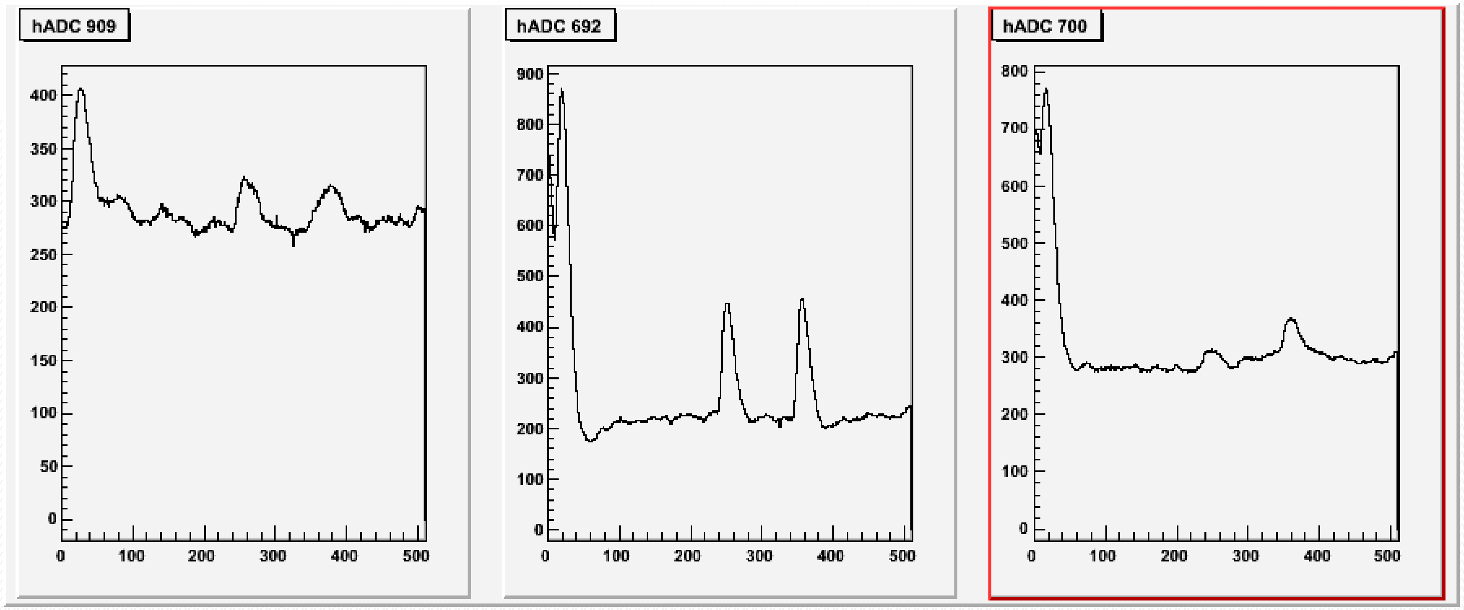
Module 3

χ^2 : 29.1
Ndf: 11

Test in a high intensity π beam

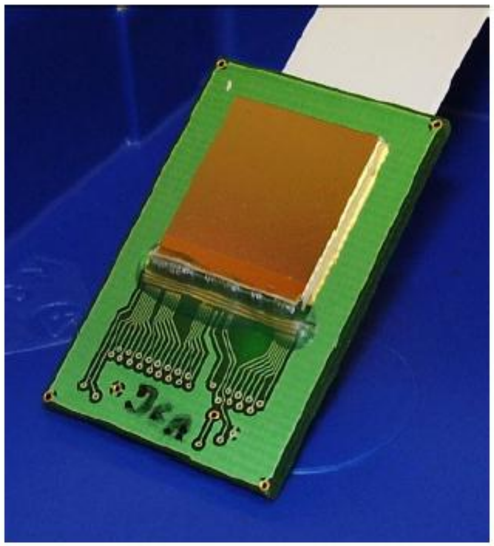


Test at CERN (July 2010) at 180 kHz (5 x 2 cm² beam) showed no charging up and stable operation

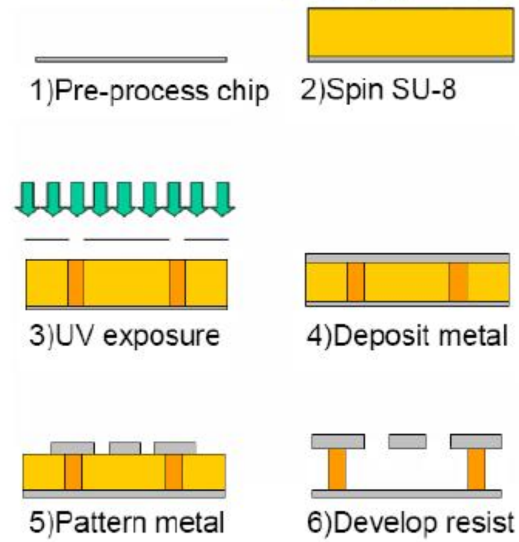


Highly Pixelized Readout

Bump bond pads for Si-pixel detectors serve as charge collection pads.



See T. Krautscheid's talk, this session

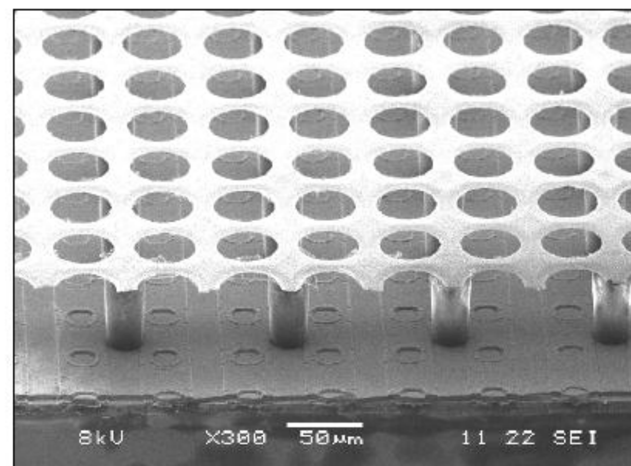


Timepix derived from Medipix-2

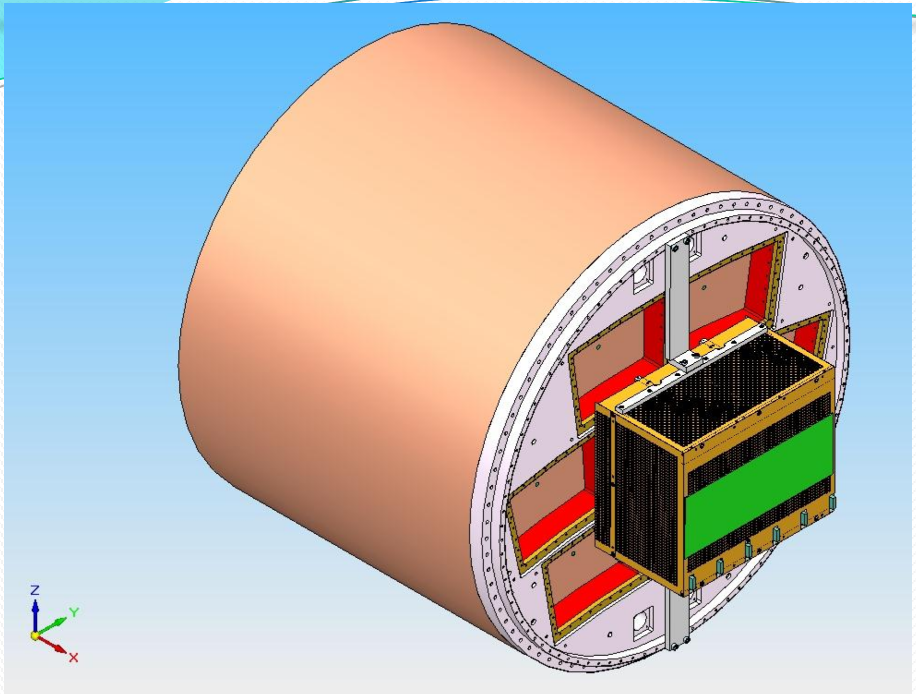
256 × 256 pixels of size 55 × 55 μm²

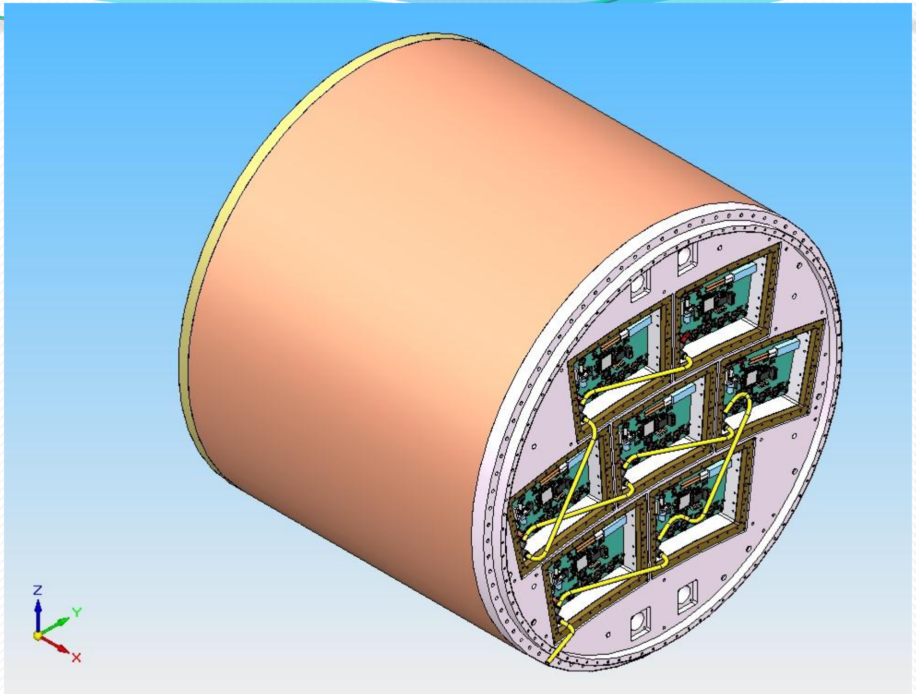
Each pixel can be set to:

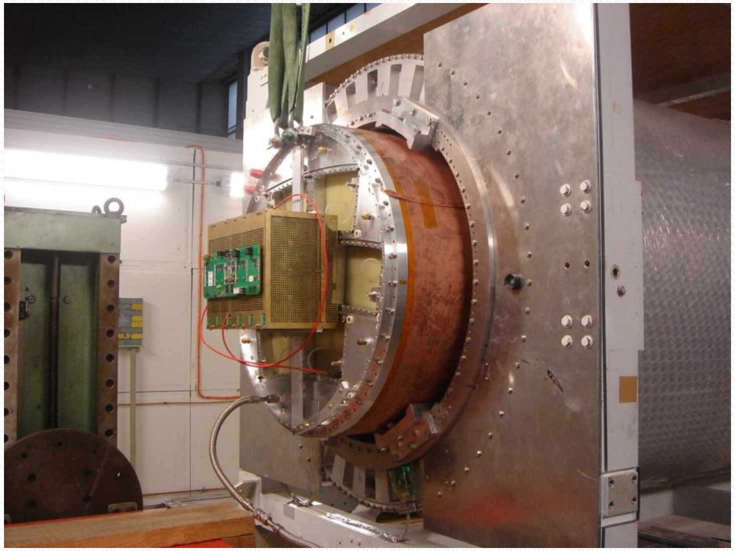
- TOT ≈ integrated charge
- Time between hit and shutter end

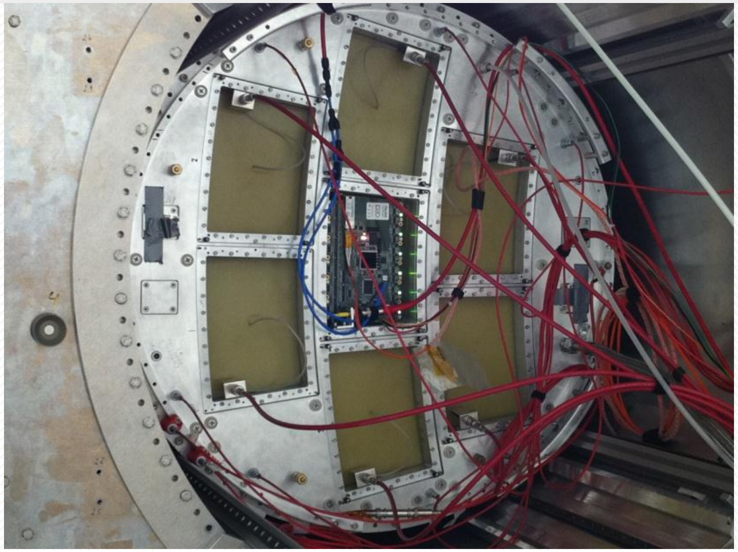


7 module project – Micromegas electronic integration









Integration of the T2K electronics

- New detector : new routing to adapt to new connectors, lower anode resistivity (3 MΩ/sq), new res. foil grounding on the edge of the PCB.
- New 300 points flat connectors (zero extraction force)
- New front end: keep naked AFTER chips and remove double diodes (count on resistive foil to protect against sparks)
- New Front End Mezzanine (FEMI)
- New back-end for up to 12 modules
- New DAQ, 7-module ready and more compact format
- New trigger discriminator and logic (FPGA).

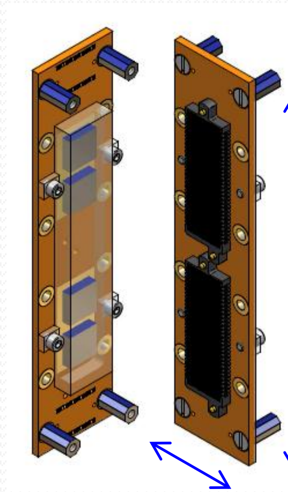
Integrated electronics for 7-module project

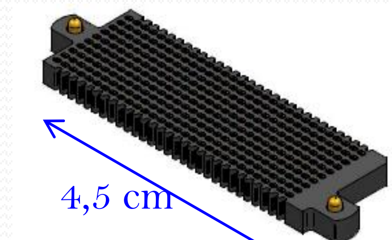
- Remove packaging and protection diodes
- Wire –bond AFTER chips
- Use 2 × 300 pins connector

FEC

25 cm

14 cm

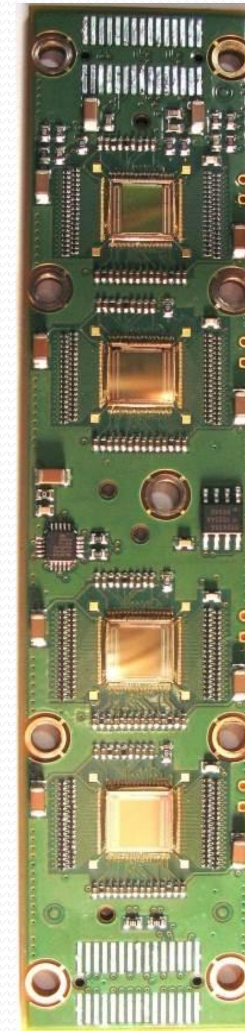




4,5 cm

12,5 cm

2,8 cm

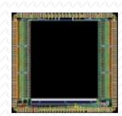


3,5 cm

Chip

3,5 cm

0,78 cm

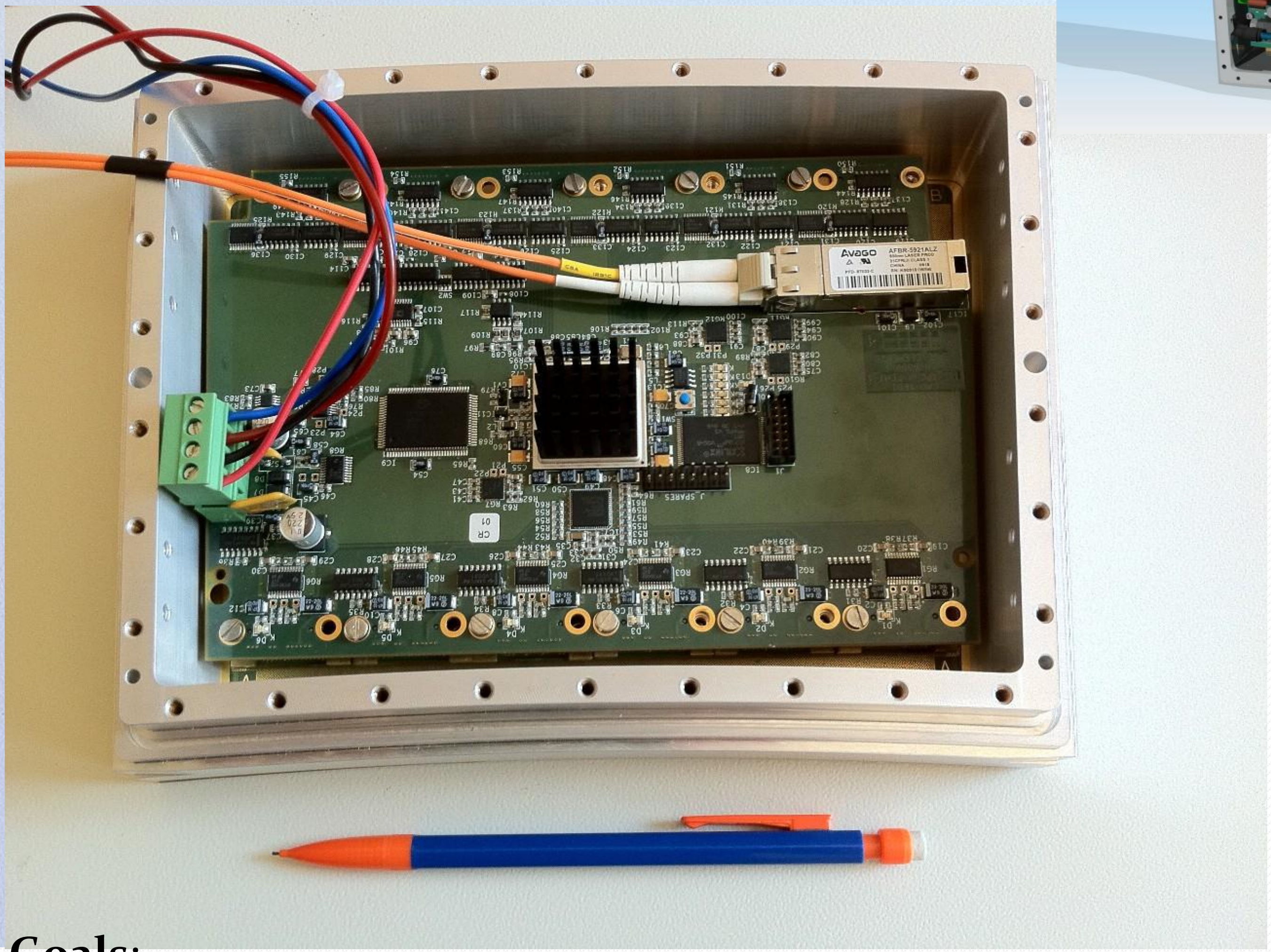


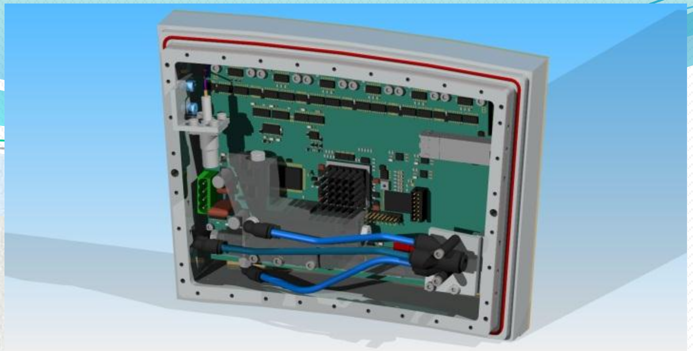
0,74 cm

after 2 weeks of operation: no ASIC lost:

The resistive foil protects against sparks

The goal of < 25% Xo is attained



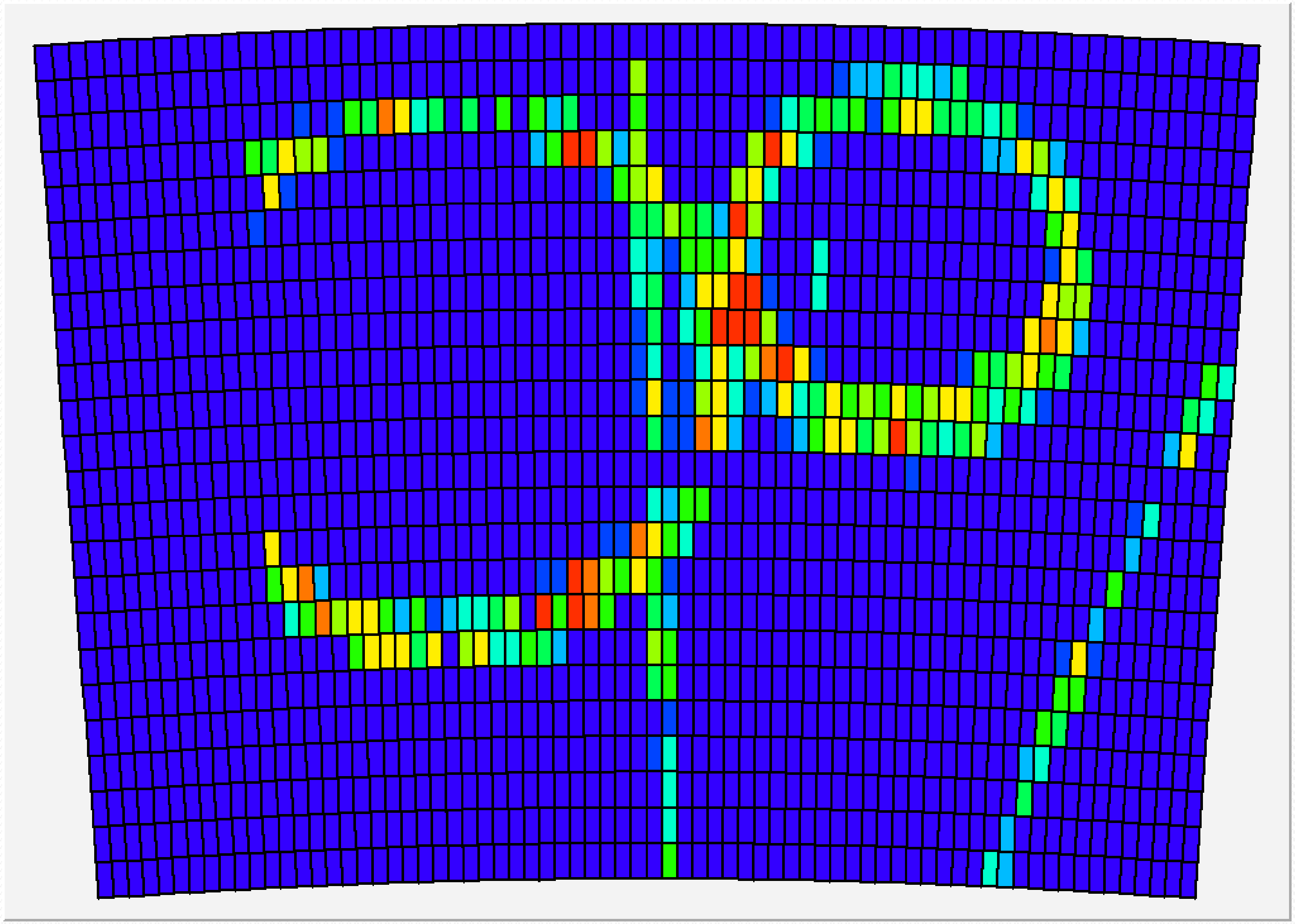


radiator

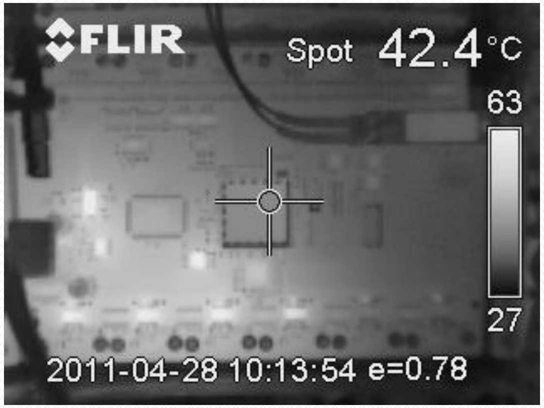
Goals:

-test of full integration

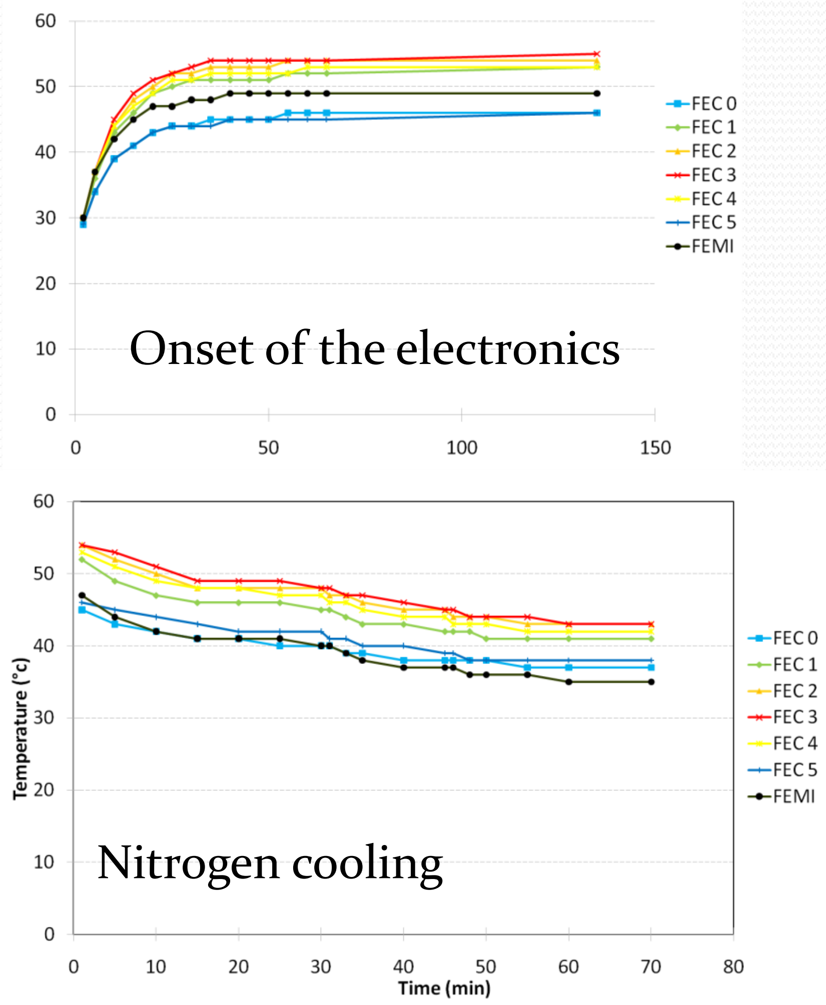
-test of quasi industrial production, with characterization and qality procedures



- **Thermal studies**. IR camera shows hot spots (regulators, ADC). T-probes on every component.

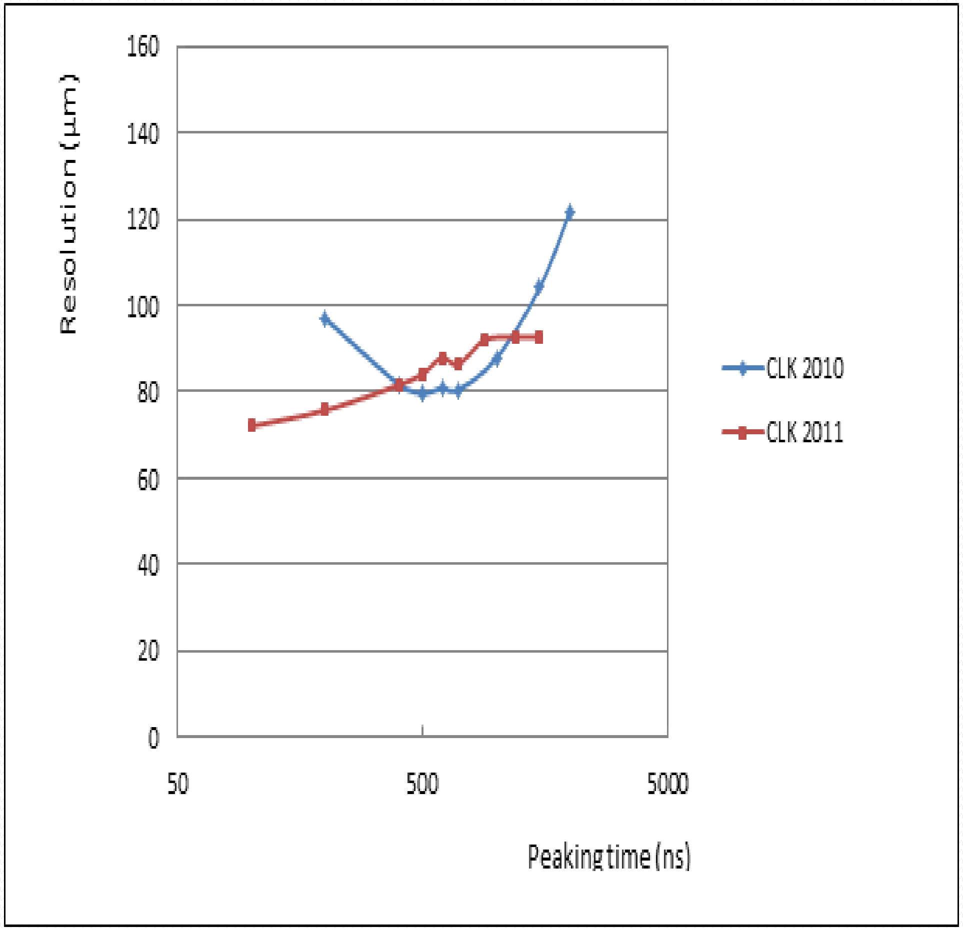


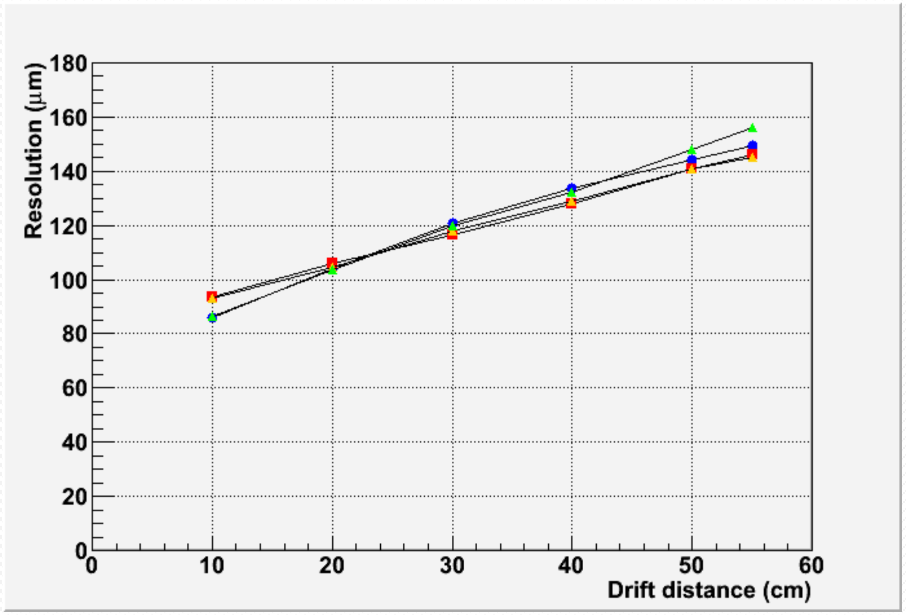
2-phase CO_2 cooling under study (KEK, Nikhef)



Preliminary results (May 2011) : resolution (B=1T data)

- Confirms previous measurements (excl. rows with ASICs in bad contact).
- Optimum resolution now obtained for peaking time below 200 ns : good for 2-track separation





Resolution vs z for various peaking times.

New End Plate

Material budget requirement for final end plate: 8% X_0

→ Finite Element Analysis of final end plate

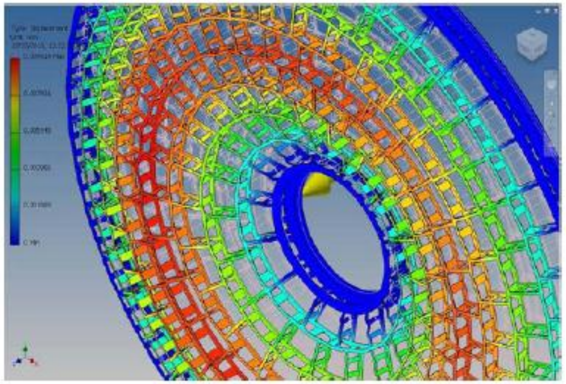
Deflection of 220 μm for overpressure of 2.1 mbar

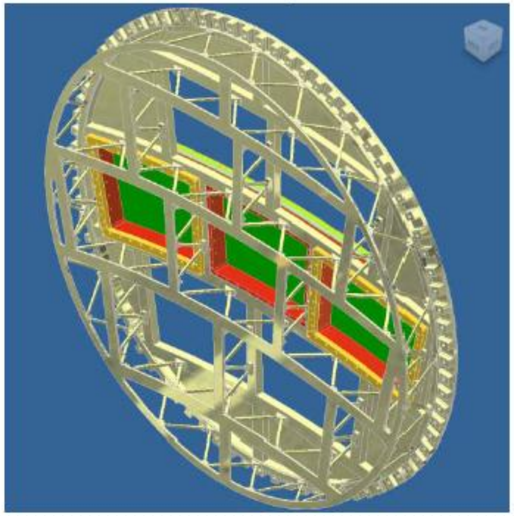
Several materials and designs have been studied

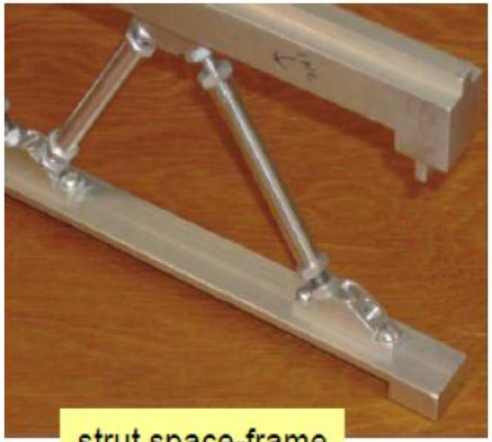
Strut space-frame design provides greatest strength-to-material.

Second end plate for LP designed and built (8.8 kg)

Preliminary measurements of deflection are very close to requirements

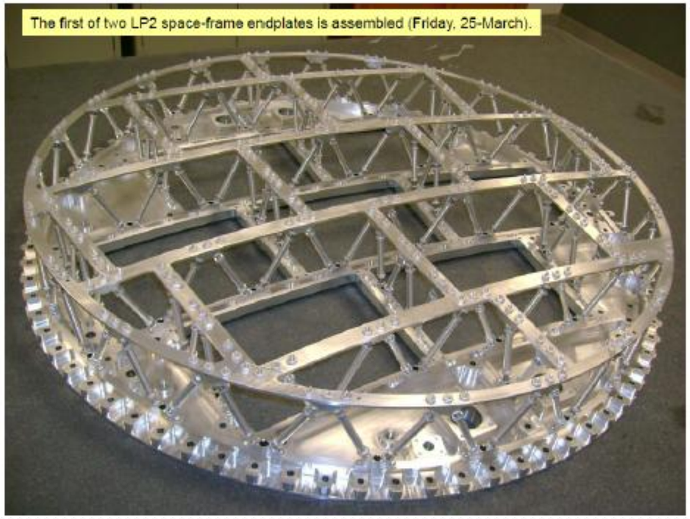






strut space-frame

test structure



Ion disk and gating

- During 1 ms every 200 ms, bunch crossings produce ionization in the gas: positive ions drift very slowly to the cathode. Ions produced in the avalanches near the anode drift all the way back to the cathode, resulting in a slowly moving ion sheet.
- Background evts have been simulated and charge density and resulting electric field estimated. Preliminary results :

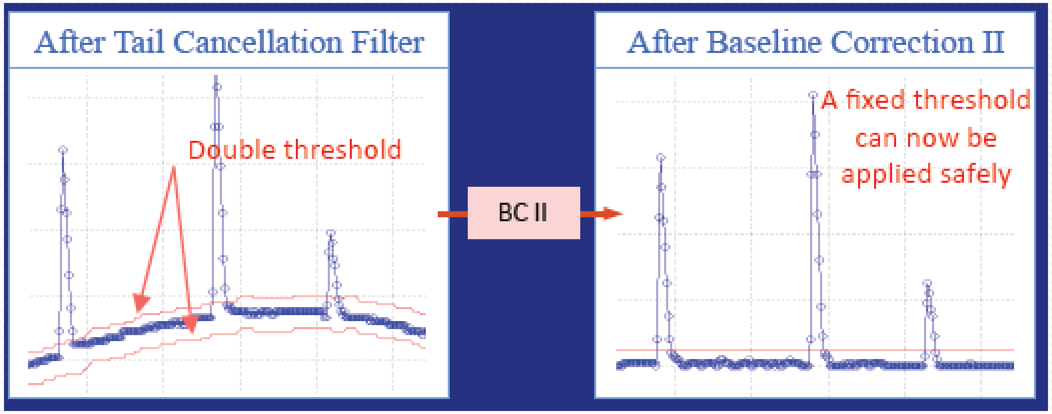
  Primary ionization gives up to 8.5 μm distortions (can be tolerated)

  ‘ion sheet’ effect results in 60 μ distortions (not acceptable)

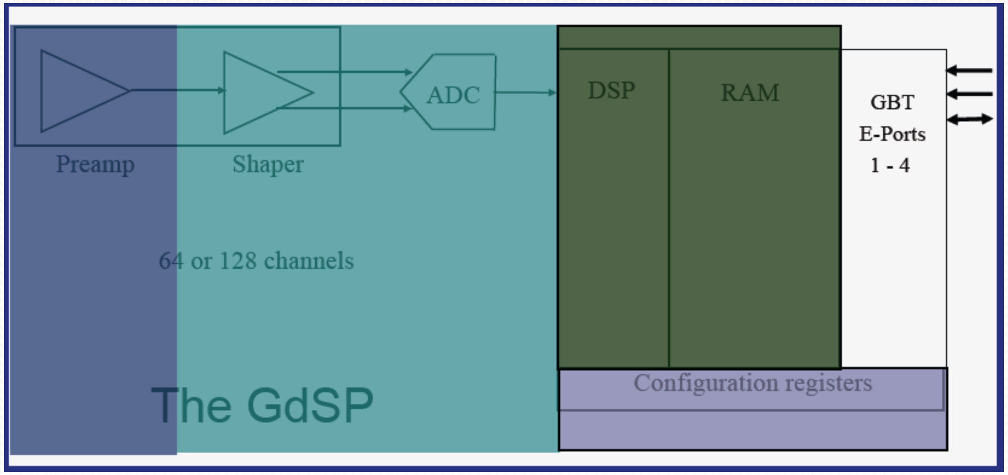
  With a gating grid near the anode, this can be reduced to a negligible amount.
- -> gating is necessary between train crossings

Preparation for future electronics

- Design and optimization work in progress for a new chip GdSP, evolution from SALTRO16:
  - 64 or 128 channels
  - 130 nm technology
  - Very low noise
  - Integrated ADC
  - Low power consumption (all-inclusive 7-8 mW/ch)
  - 6 different power regions for power cycling
  - High level filtering (baseline subtraction, spike removal)

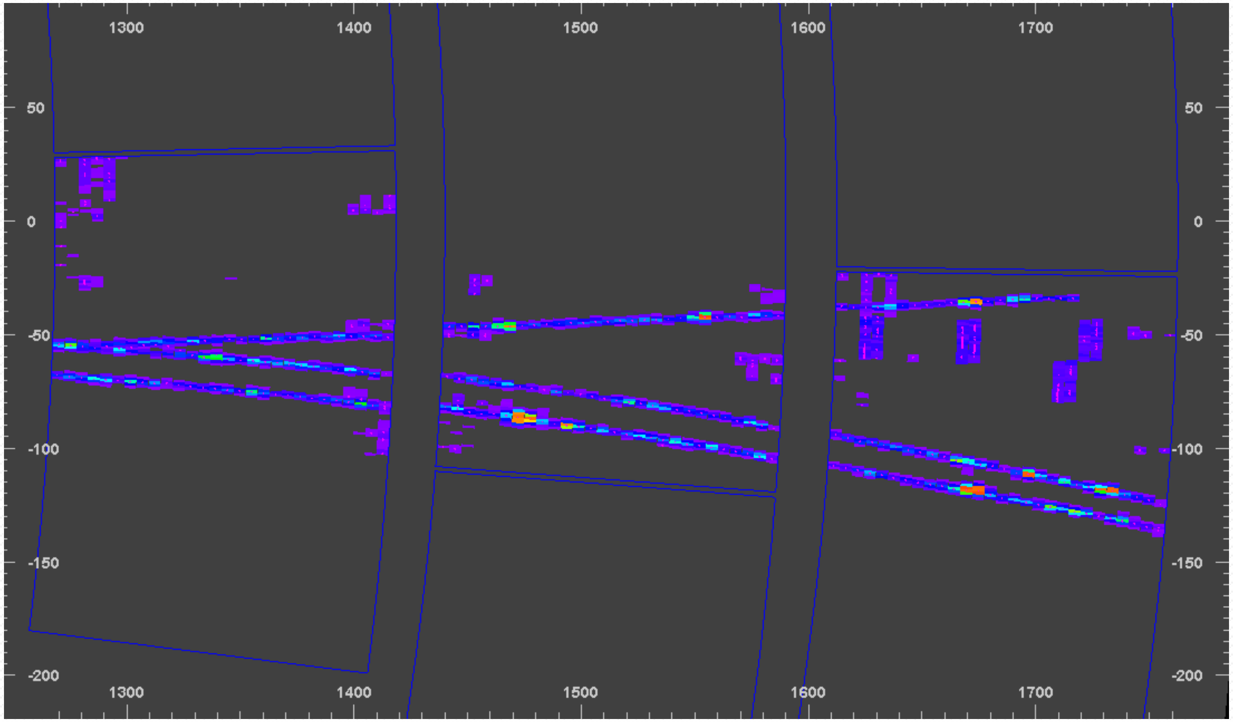


Gaseous detector Signal Processor, P. Aspell *et al.*



Software : track reconstruction and fitting

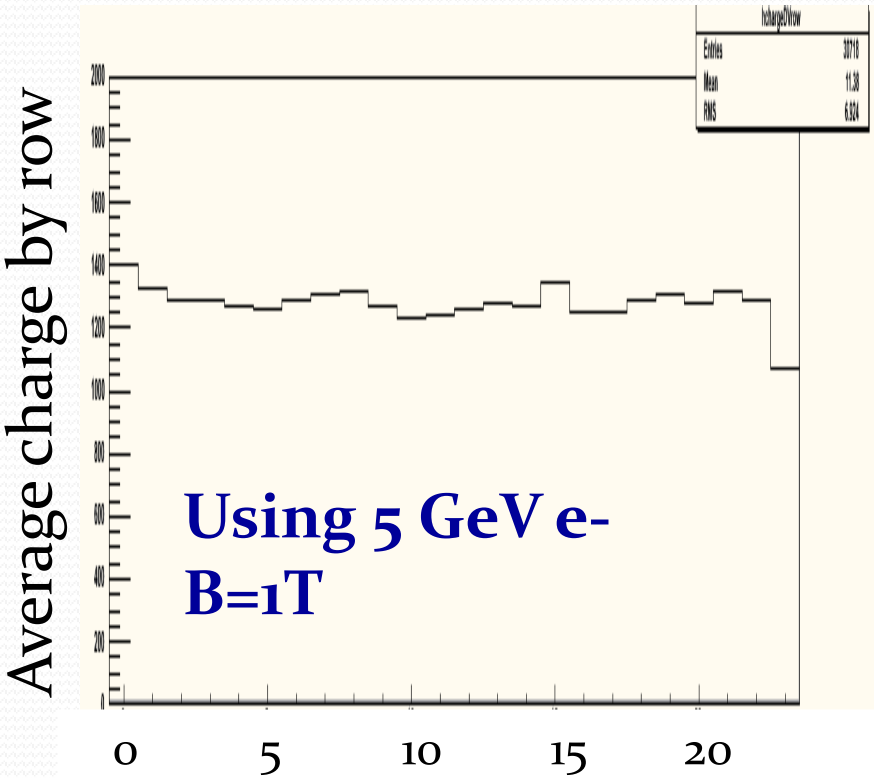
- Going from various programs for track reconstruction to one (Marlin TPC) within LC framework
  - Can serve for all beam test prototypes and for ILD simulation data
  - Allow multi-module alignment
  - Kalman filter track finding and fitting

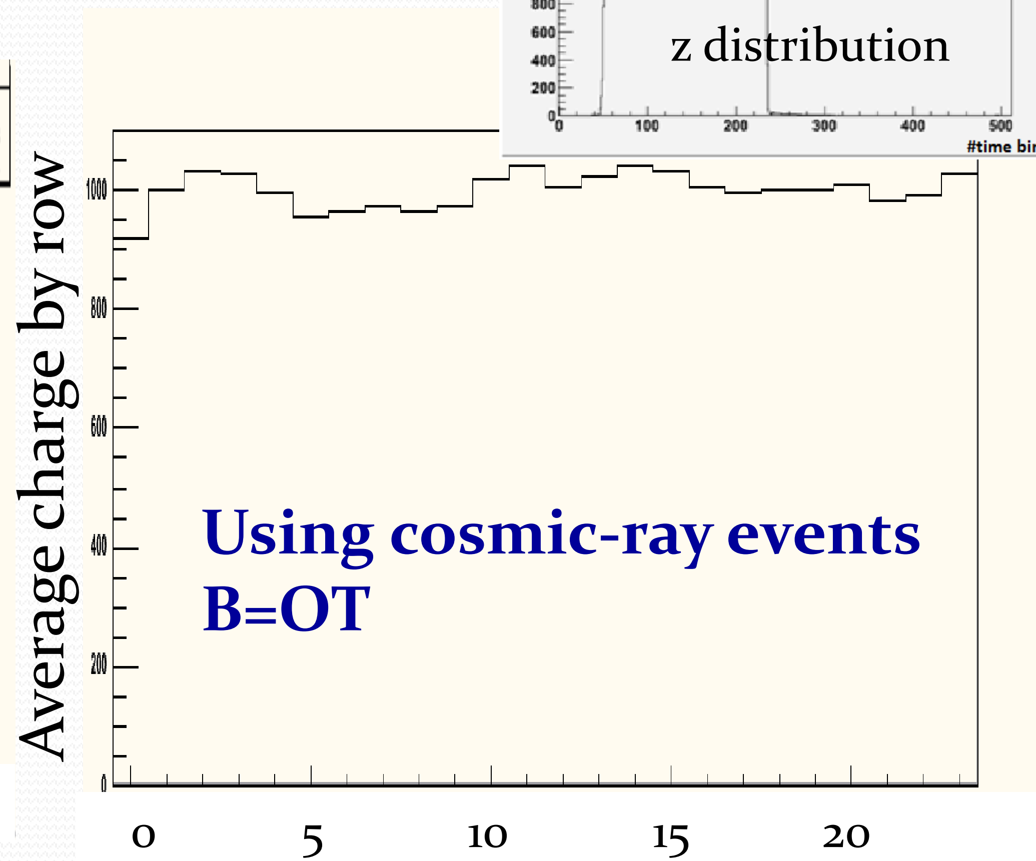


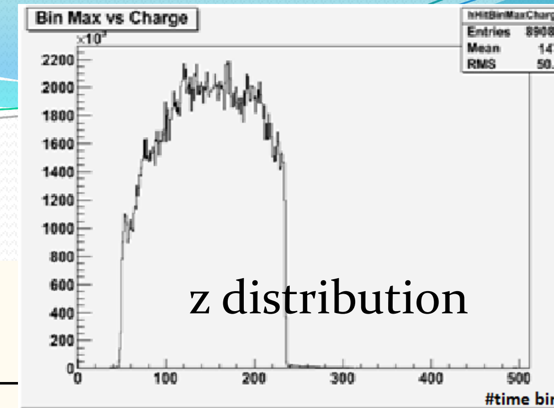
CONCLUSIONS

- MPGDs have been shown to fulfill the requirements for the readout of a TPC for the LC.
- Pixel readout needs more development to gain in reliability and operability in large surfaces.
- Integration work (electronics and cooling) is going on, and practical production issues are addressed for the pad readout.
- All aspects/limitations are being addressed to be included in the 'Detector Baseline Document'

Uniformity







Excellent uniformity up to the edge of the module, thanks to the 'bulk' technology.

N_{eff} measurement with Micromegas

Averaging B=0T and B=1T data, modules 4, 5 and 3 (excluding ink module):

- N_{eff} = 38.0±0.2(stat) (systematics difficult to assess)
- σ_0= 59 ± 3 μm

$$N_{eff} = \frac{1}{<1/N>} \frac{<G>^2}{<G^2>}$$

D. Arogancia et al., NIM A 602 (2009) 403

Note that 1/<1/N> = 47.1 from Heed for 5 Gev electrons on 6.84mm long pads.

Thus N_{eff} has to be between 23.5 (for exponential gain fluctuations) and 47.1 if there are no gain fluctuations.

1/<1/N> = 34.9 for 5.4 mm pads (GEM case).