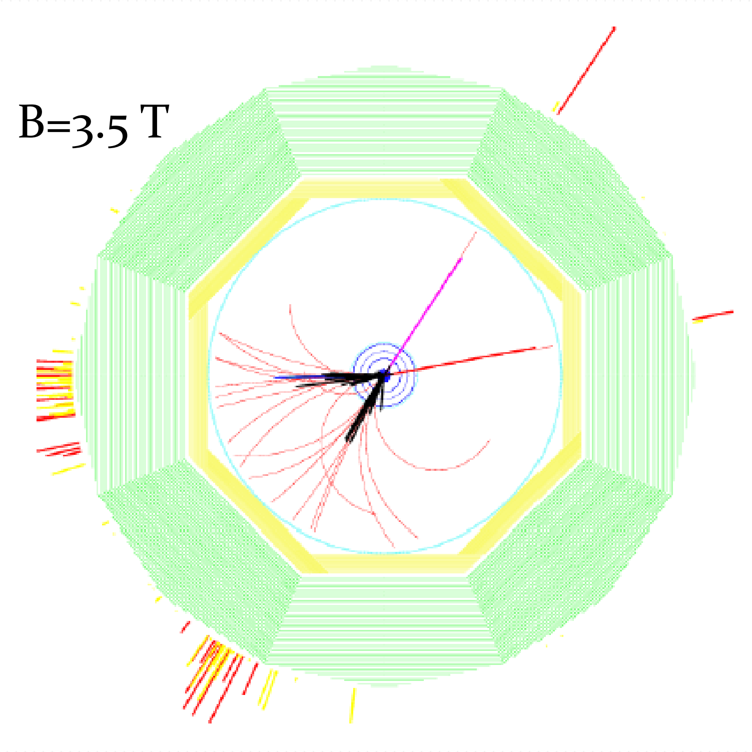
# A TPC for the Linear Collider

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



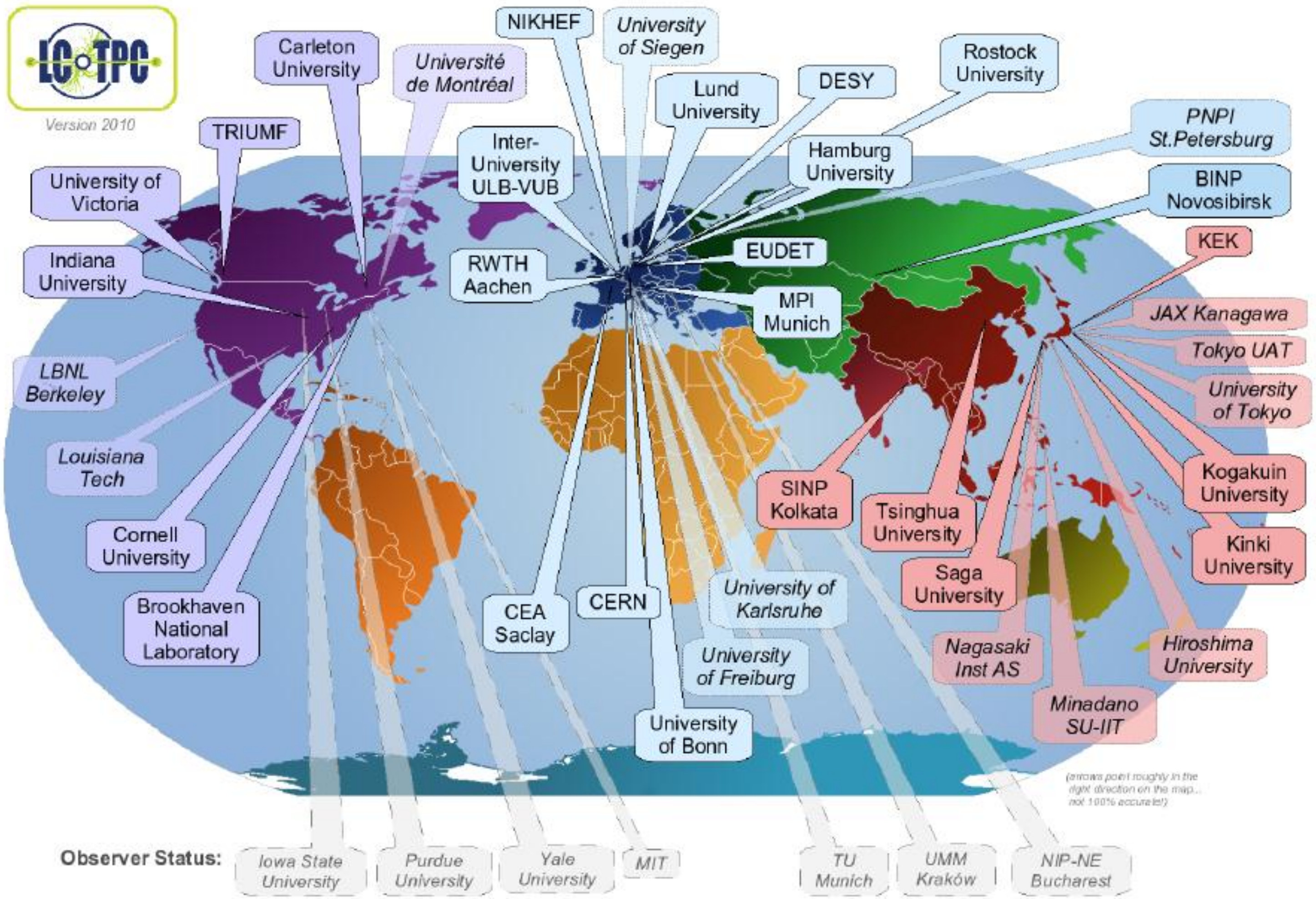

Benchmark process: e+e- -> HZ, Z->μμ

**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° in the barrel region, <25% X° in the endcap region

# All the R&D is gathered in LCTPC

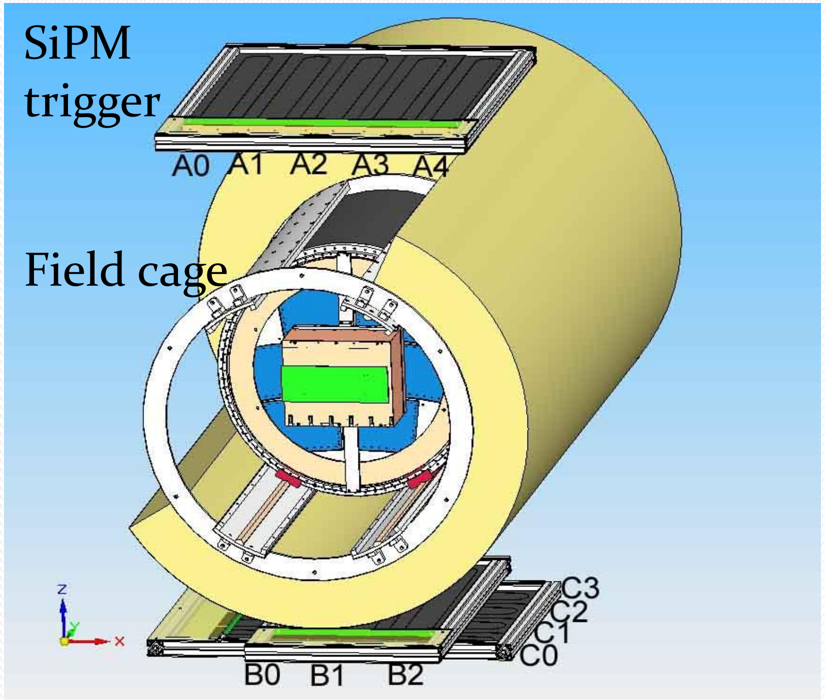


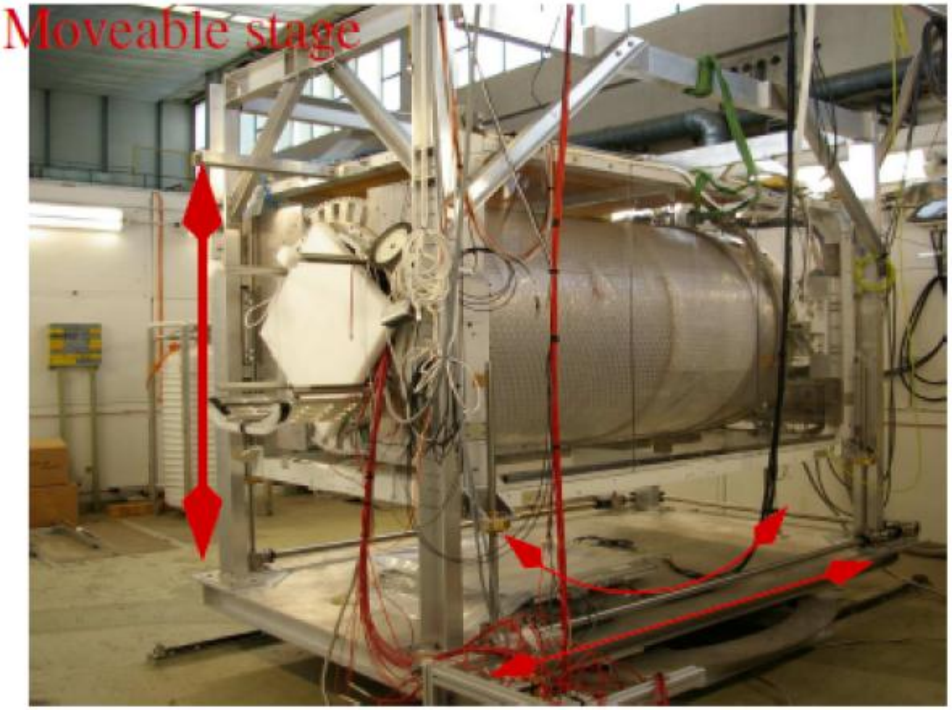

38(*) member + 7 observer institutes from 12 countries

(*) 25 signed the MOA

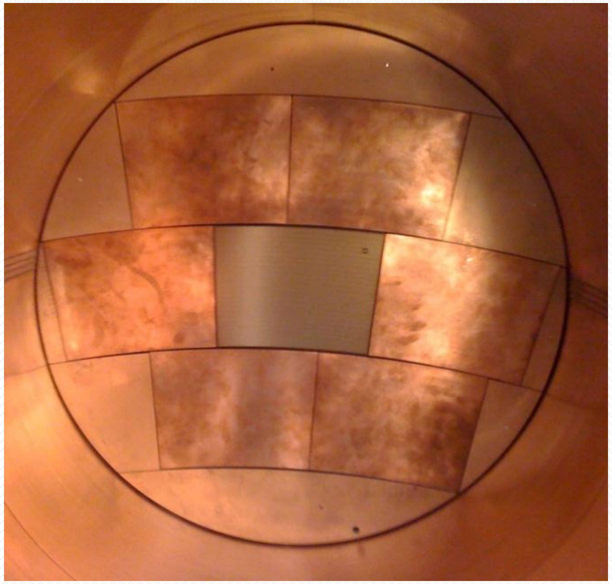
# The EUDET test setup at DESY

- The EUDET (FP6) setup at DESY is operational since 2008
- Being upgraded within AIDA (FP7): autonomous magnet with internal He compressors



# 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')

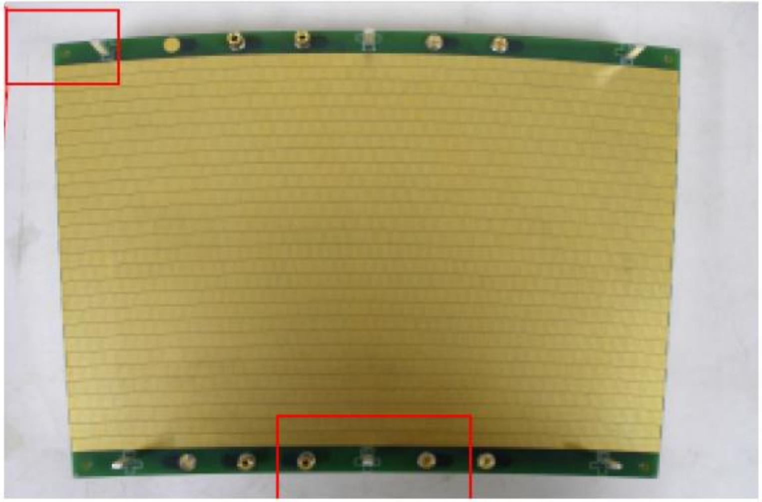
# Advantages of MPGDs

## TPC with MPGDs

- Small pitch of gas amplification regions (i.e. holes)
  => improves spatial resolution, reduction of *E*×*B*-effects
- No preference in direction (as with wires)
  => all 2 dim. readout geometries can be used
- No ion tail => very fast signal (O(10 ns))
  => good timing and double track resolution
- Direct $e^-$-collection on pads
  => small transverse width
  => good double track resolution
- Ion back drift can be reduced significantly
  => continuous readout is possible
- Discharges probability can be reduced by using resistive electrodes or specific voltage setting
- Lower mechanical tension, MPGDs don't have to be stretched
  => lower material budget in end plates

Performance may be further enhanced by highly pixelized readout.

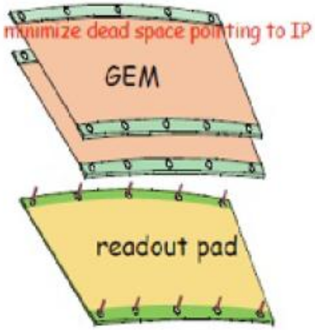
# Double GEM Modules

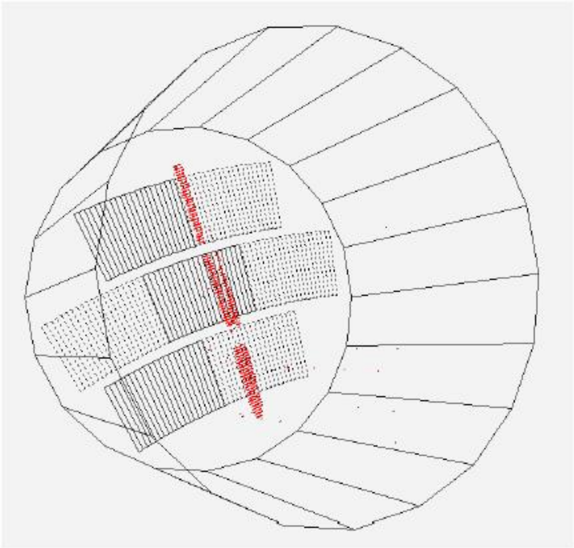


<u>GEM Module</u>

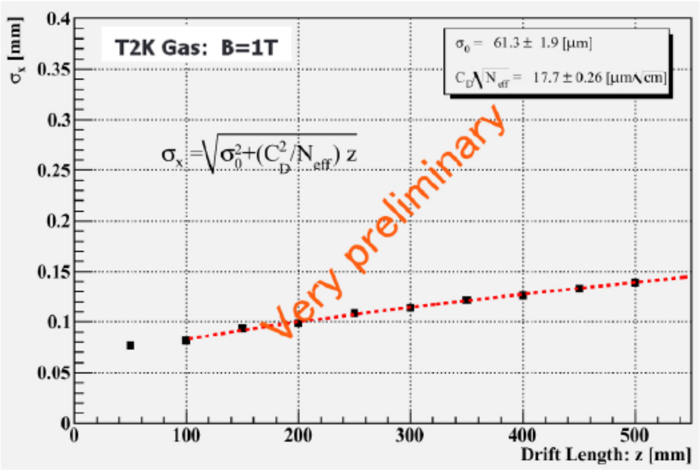
1.2×5.4 $mm^2$ pads - staggered
28 pad rows (176-192 pads/row)
5152 pads per module

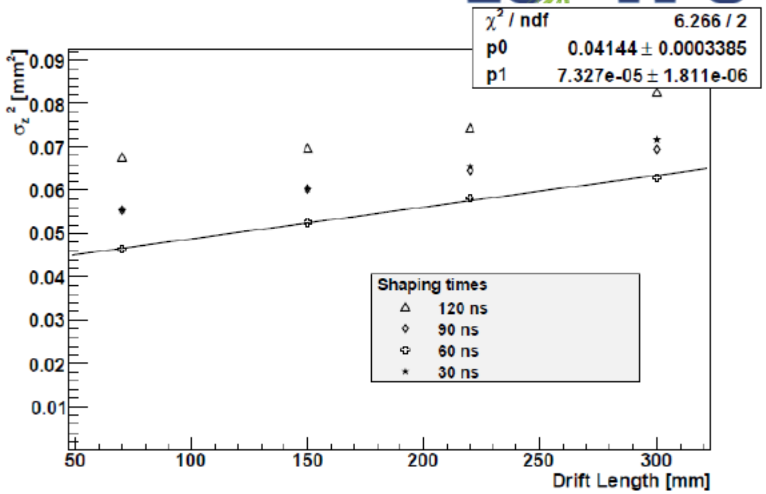
2 LCP-GEMs, 100 μm thick



# Performance of Double GEMs



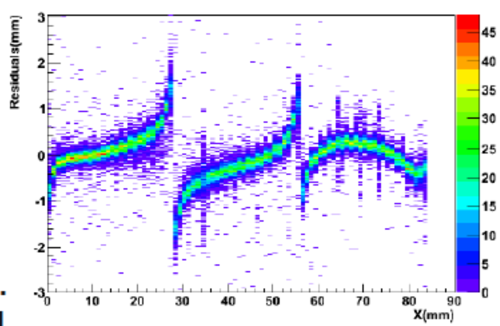

Resolution parametrized as $\sigma = \sqrt{\sigma_0^2 + D_t^2/N_{eff} \cdot z}$

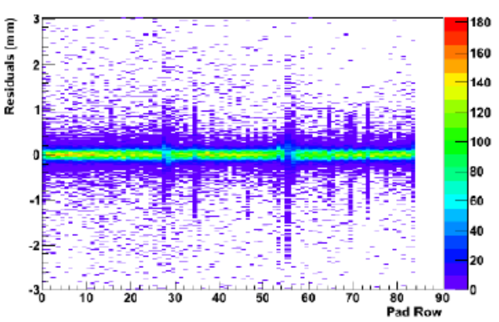
$\rightarrow \sigma_0 = 61.3 \pm 1.9\ \mu m$

Field distortions due to frame observed.

Effect corrected in analysis.

New modules are designed.



# Triple GEM Module

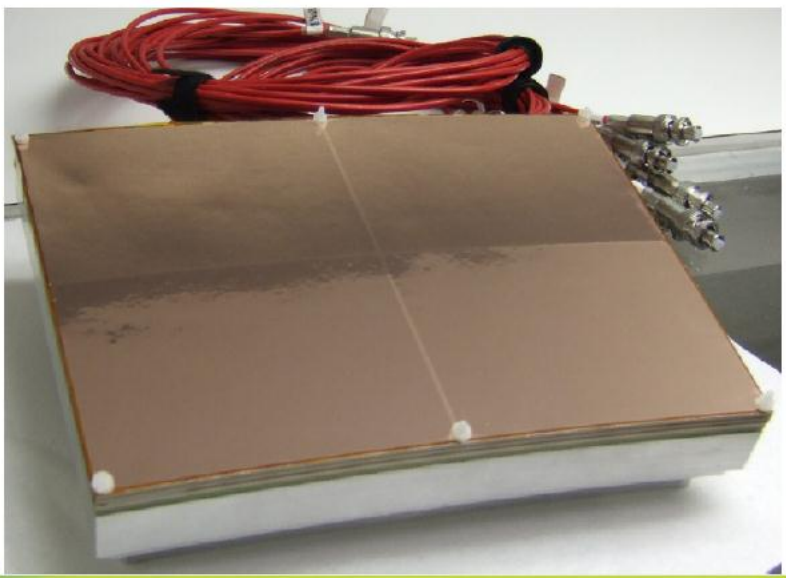
3 standard CERN GEMs mounted on thin ceramic structure (bar size ~1 mm) to reduce dead space.

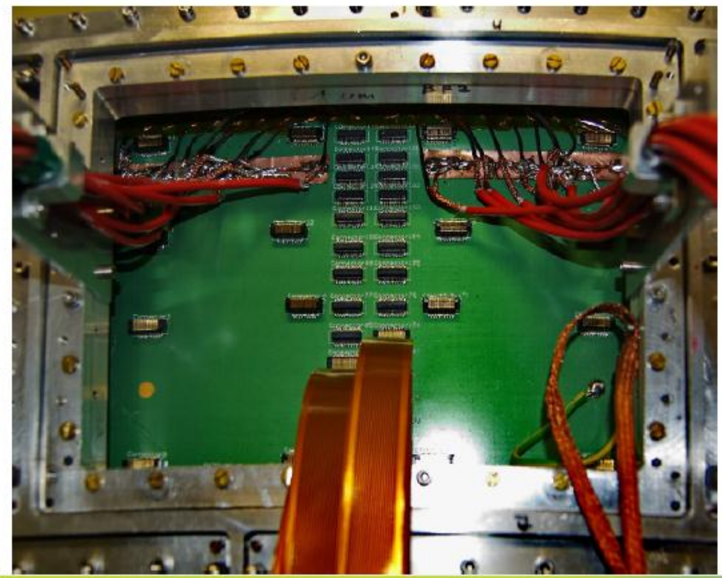
GEM is segmented into 4 parts to reduce energy stored in one sector.

1000 small pads ($1.26 \times 5.85\ mm^2$)

First version tested last year: Detector could be operated in test beam, but a few shortcomings were identified.

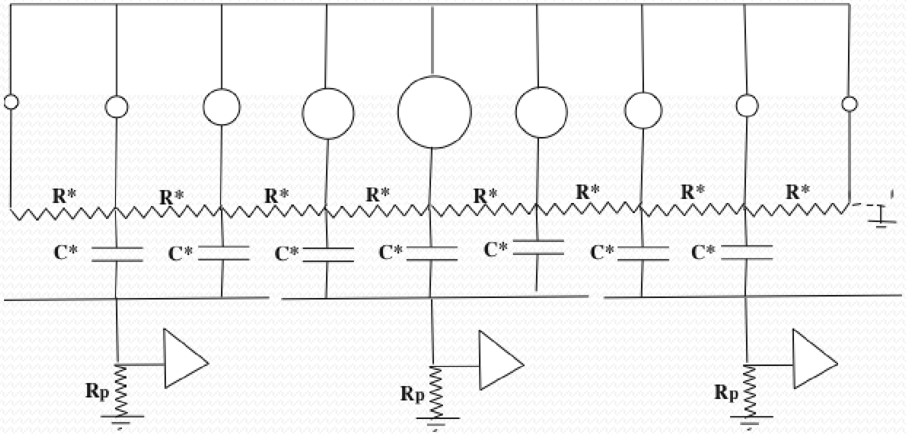
Second version is being built with ~5000 pads.

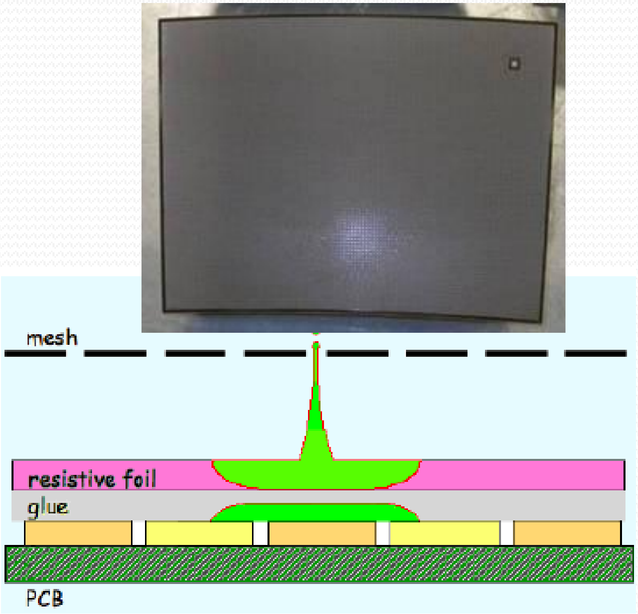




# Charge spreading by resistive foil

Resistive coating on top of an insulator: Continuous RC network which spreads the charge: improves position sensitivity



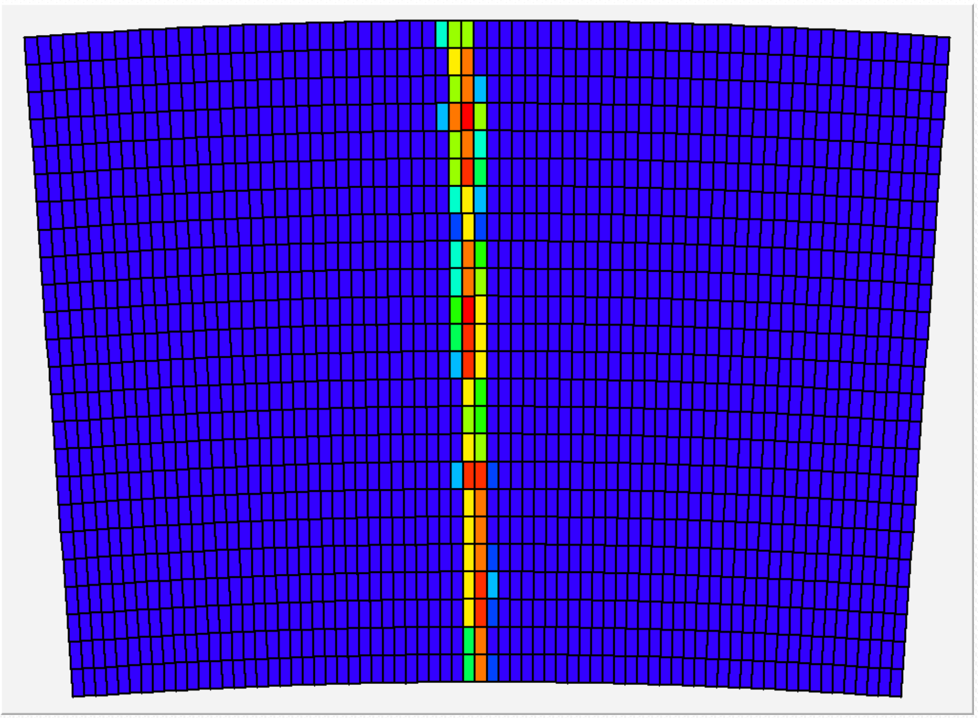




M. Dixit, A. Rankin, NIM A 566 (2006) 28

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

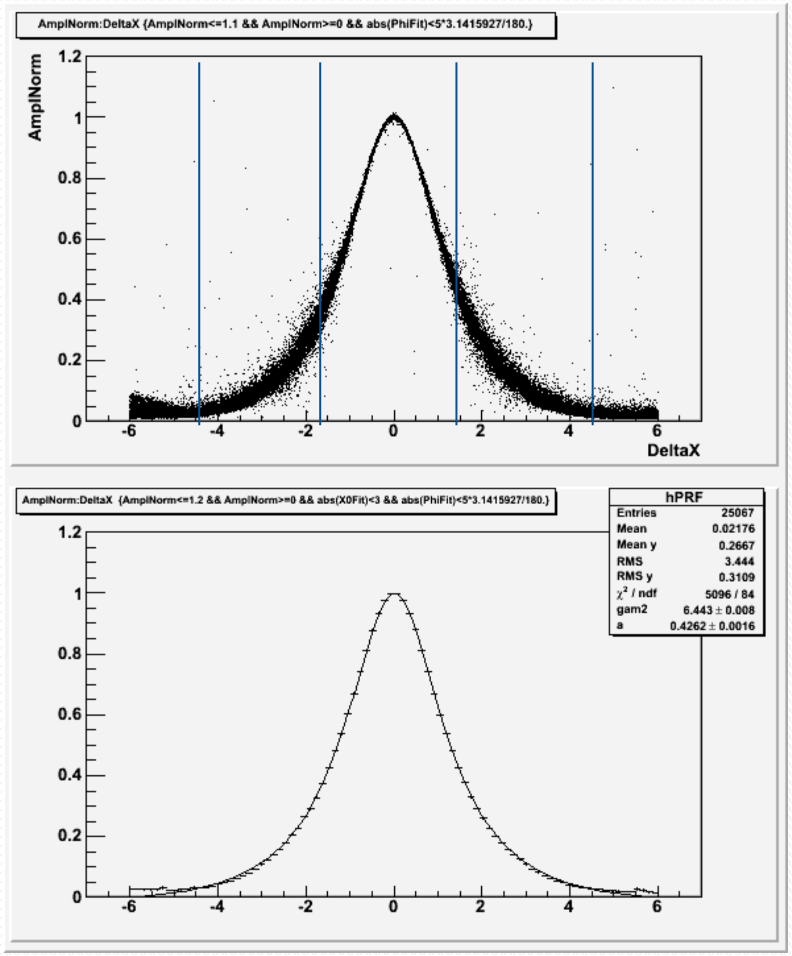
# Pad response

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



24 rows x 72 columns of 3 x 6.8 mm² pads

Z=20cm, 200 ns shaping




x(pad) – x(track) (mm)

# Uniformity (B=1T data)

MEAN RESIDUAL vs ROW number

Z-independent distortions

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

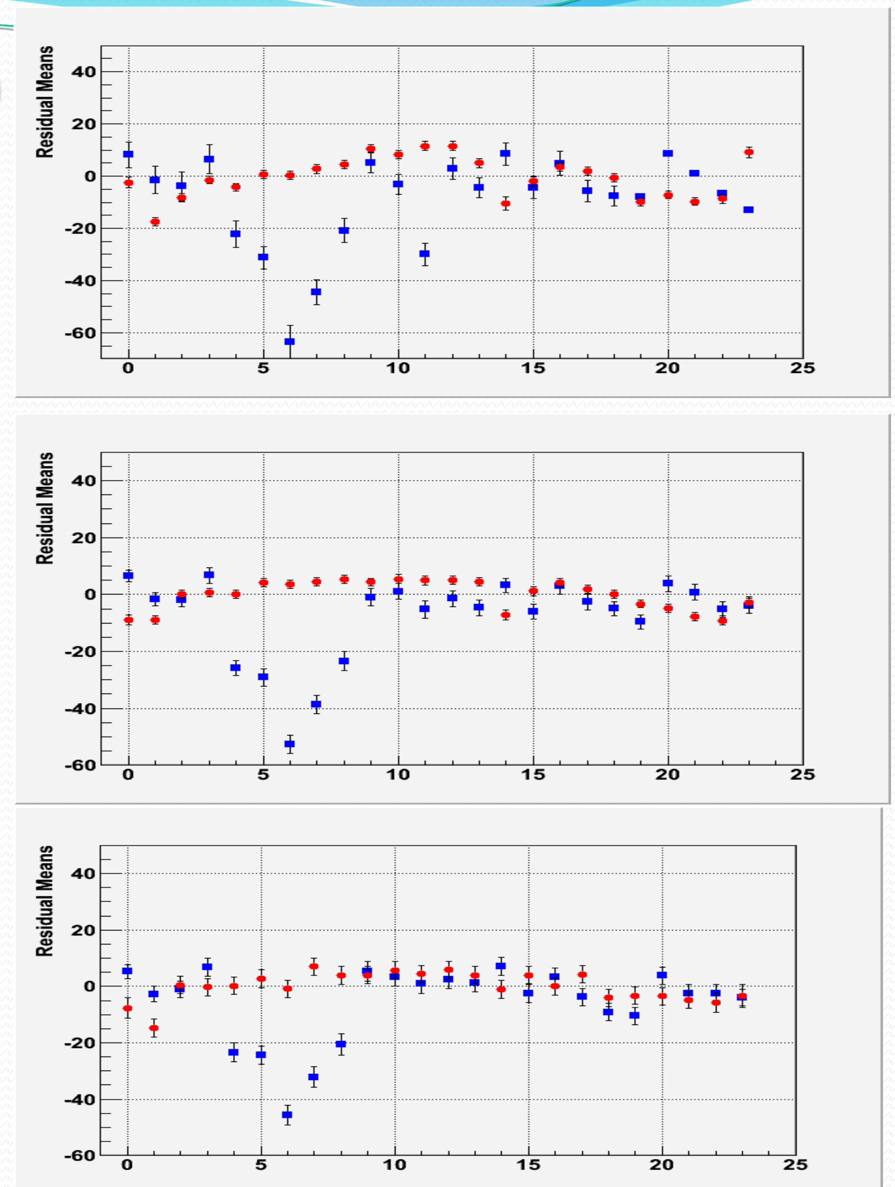
Rms 7 microns for CLK film (red points)

-> select CLK

Z=5cm

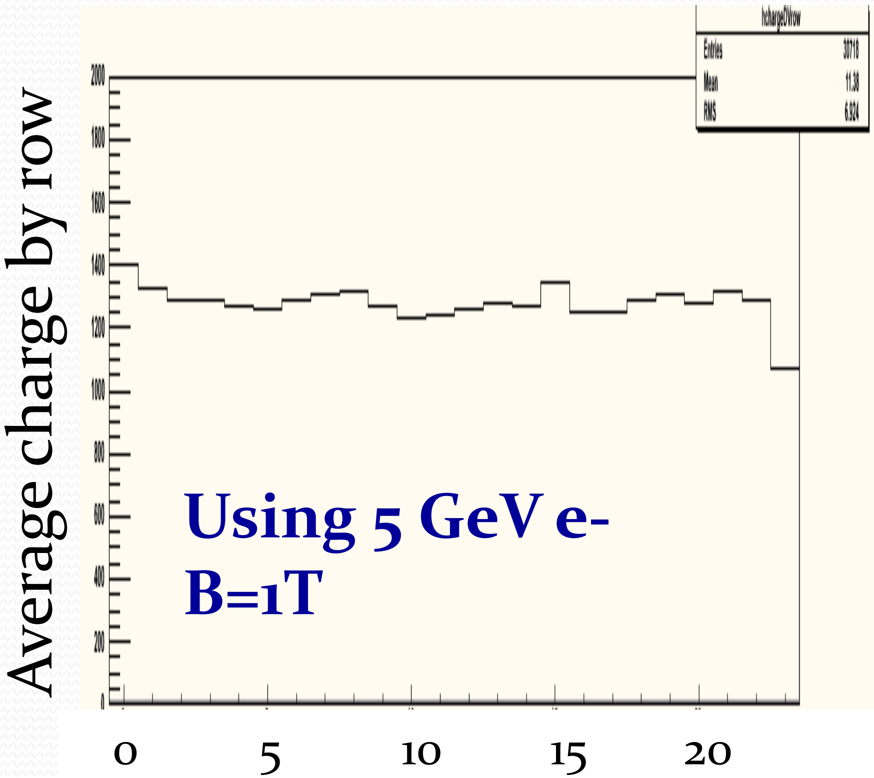
Z=35cm

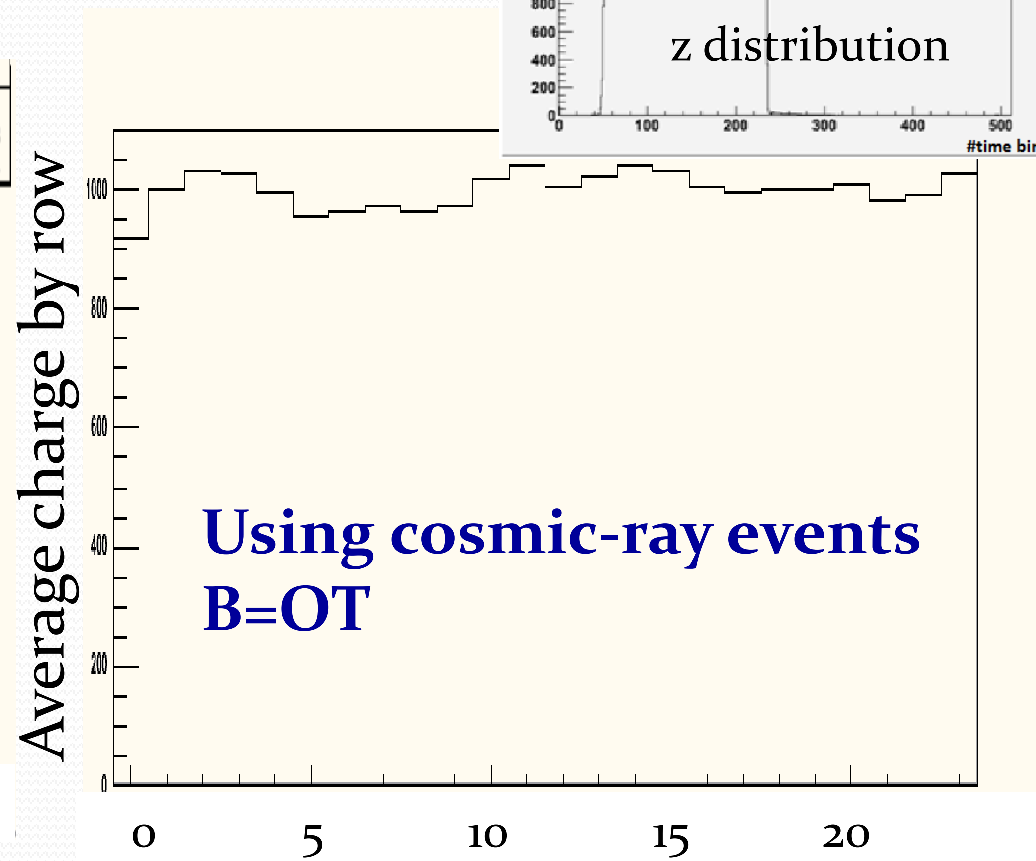
Z=50cm

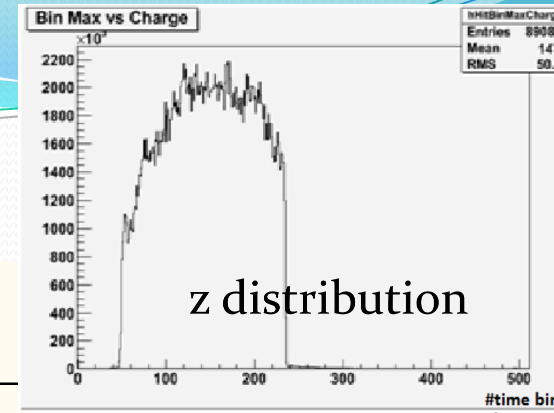



Row number

# Uniformity




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

# Data analysis results (B = 0T & 1T)
## Carbon-loaded kapton resistive foil

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

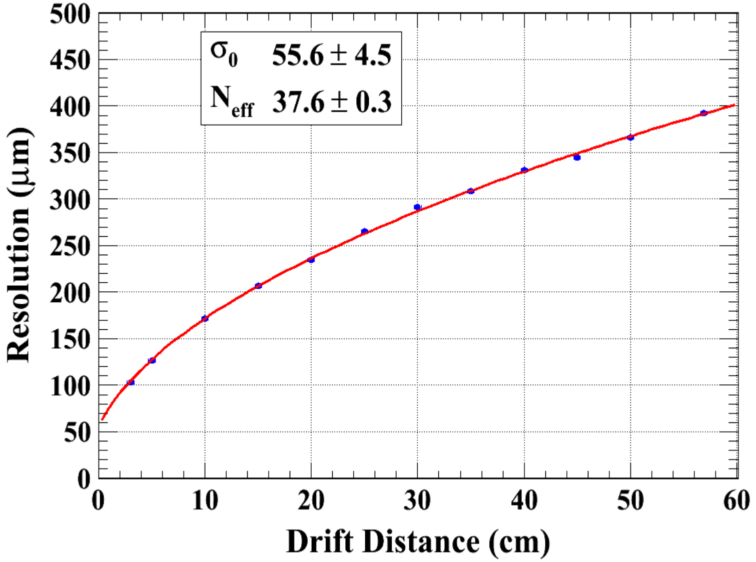
$$\sigma = \sqrt{\sigma_0{}^2 + \frac{C_d^2 \cdot z}{N_{eff}}}$$

$\sigma_0$ : the resolution at Z=0

$N_{eff}$ : the effective number of electrons

$C_d$ : diffusion constant

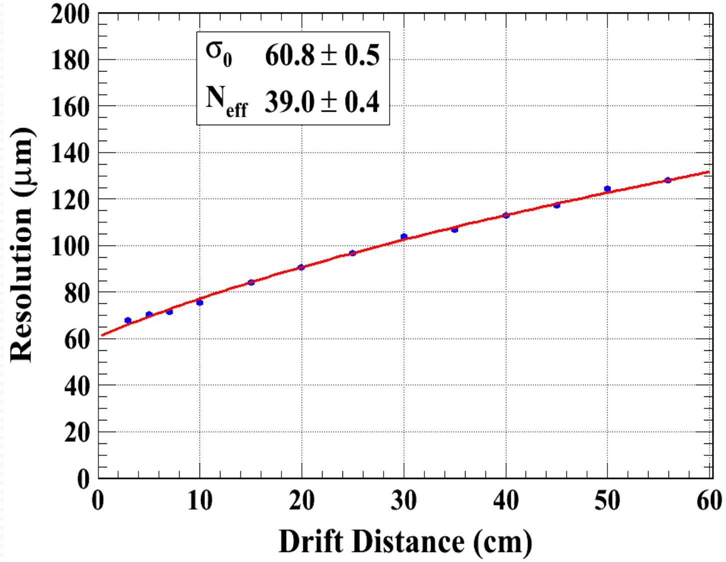
B=0 T $C_d$ = 315.1 μm/√cm (Magboltz)




**Module 4**

[ $\chi^2$ : 10.6
Ndf: 10 ]

B=1 T $C_d$ = 94.2 μm/√cm (Magboltz)




**Module 3**

[ $\chi^2$ : 29.1
Ndf: 11 ]

# $N_{eff}$ 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)
- $\sigma_0$= 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.

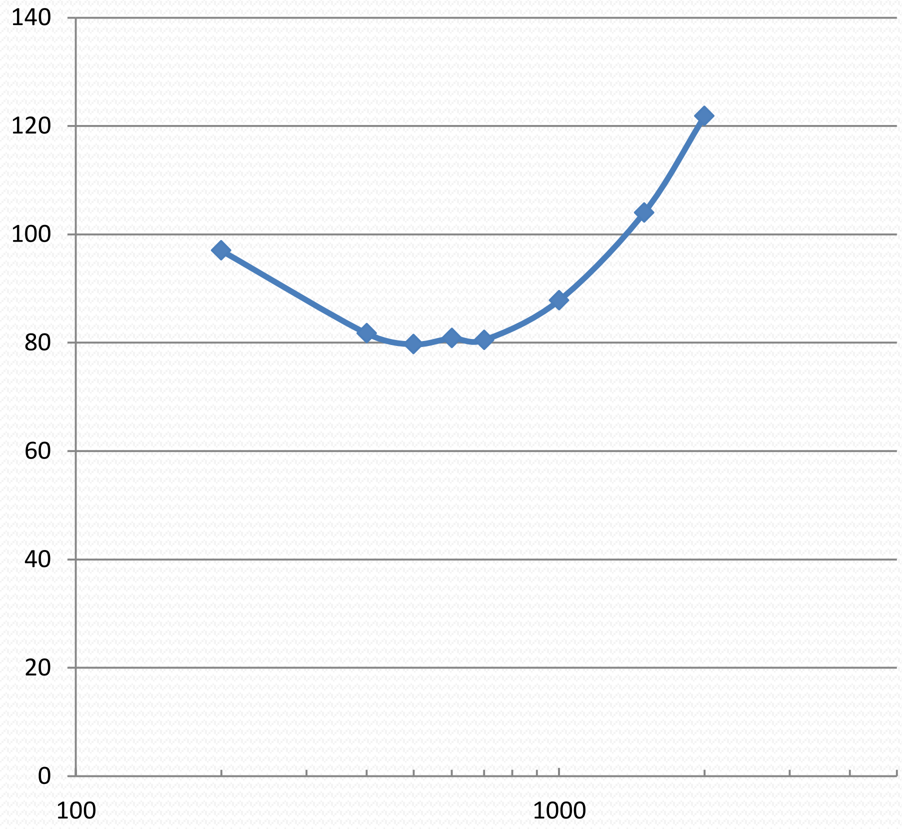
Thus $N_{eff}$ has to be between 23.5 (for exponential gain fluctuations) and 47.1 if there are no gain fluctuations.

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

# Dependence of resolution with peaking time

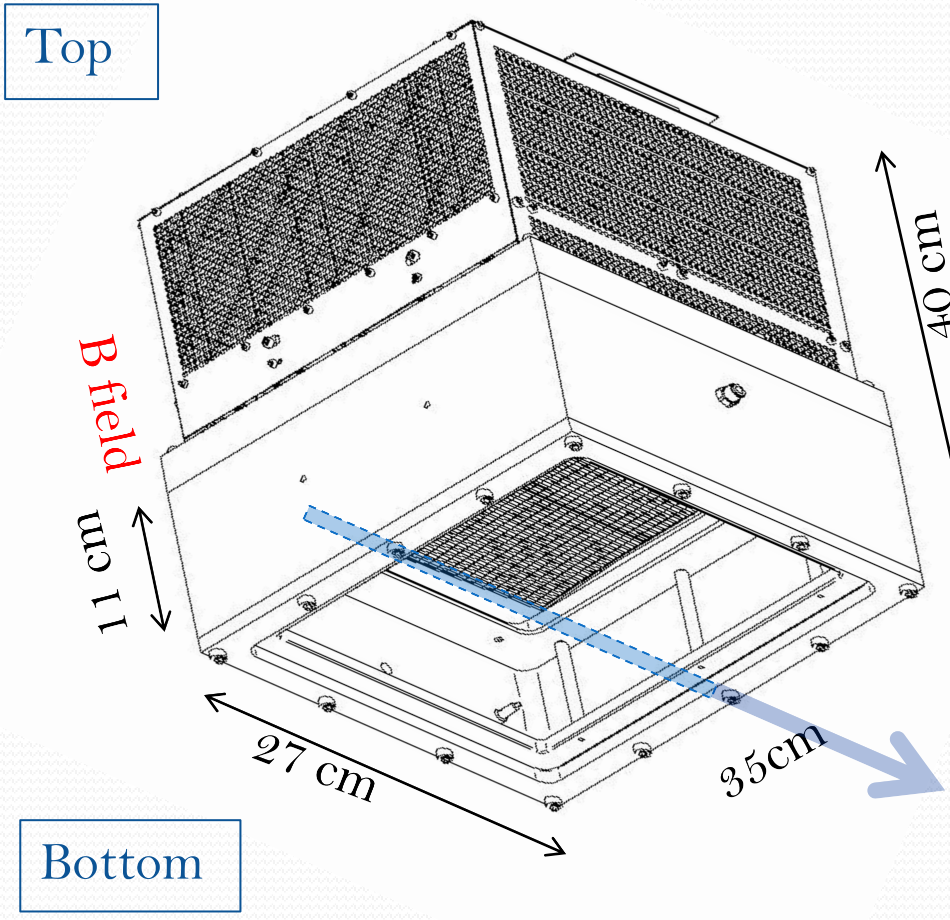
Z=5cm

CLK 5 MΩ/sq

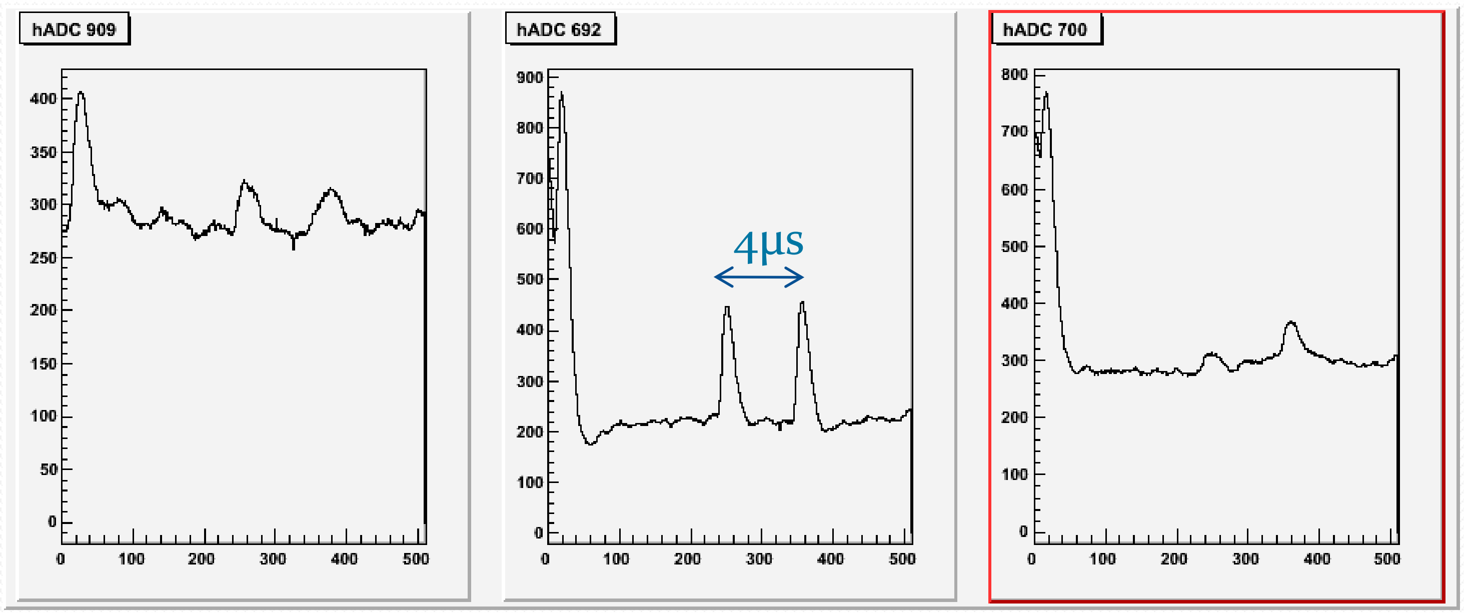



Optimum resolution for 500 ns peaking time -> try to lower resistivity to lower this peaking time (faster charge spreading)

# Test in a high intensity π beam



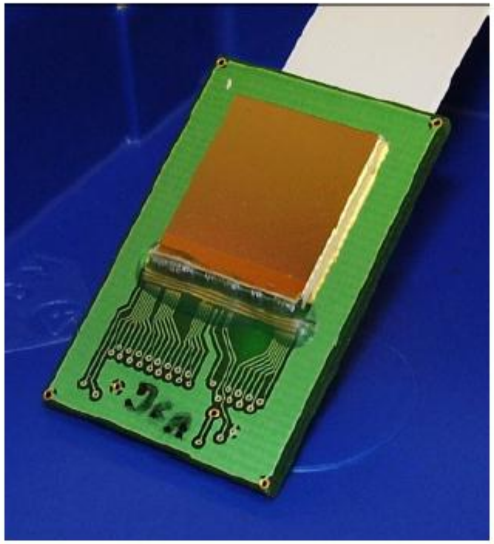
- Test at CERN (July 2010) at 180 kHz (5 x 2 $cm^2$ beam) showed no charging up and stable operation
- Peaking time of 200 ns is enough to obtain the best resolution -> 300 ns suffice to distinguish 2 tracks on the same pad

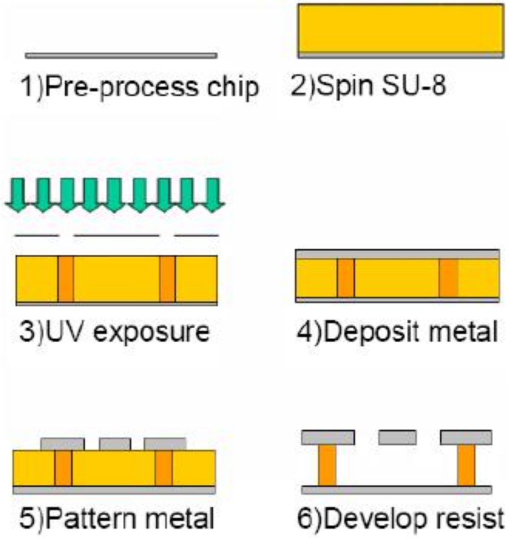


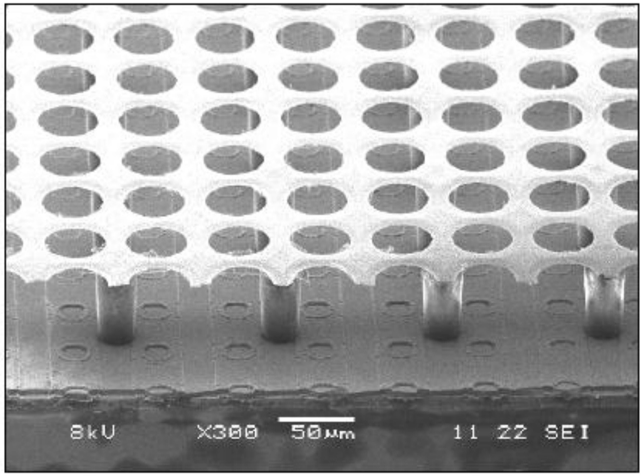

Time (in 40 ns bins)

# Highly Pixelized Readout

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





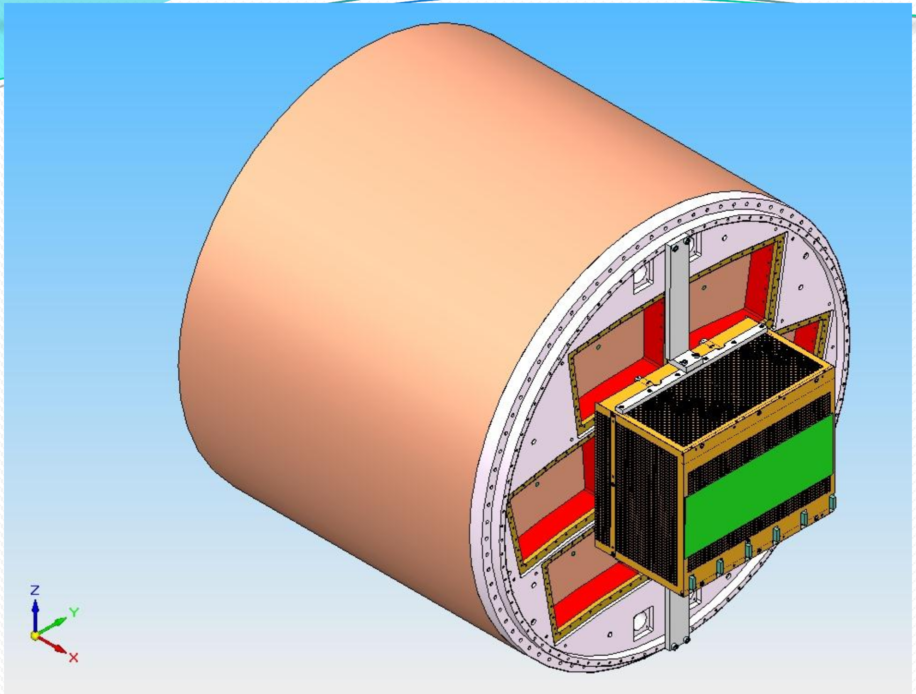

Timepix derived from Medipix-2

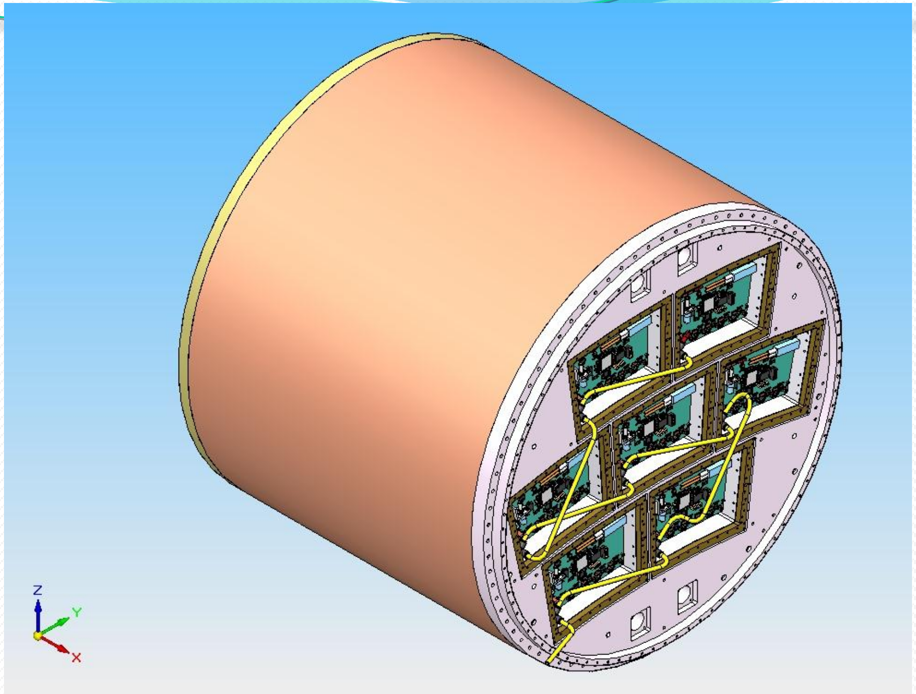
256 × 256 pixels of size 55 × 55 µm²

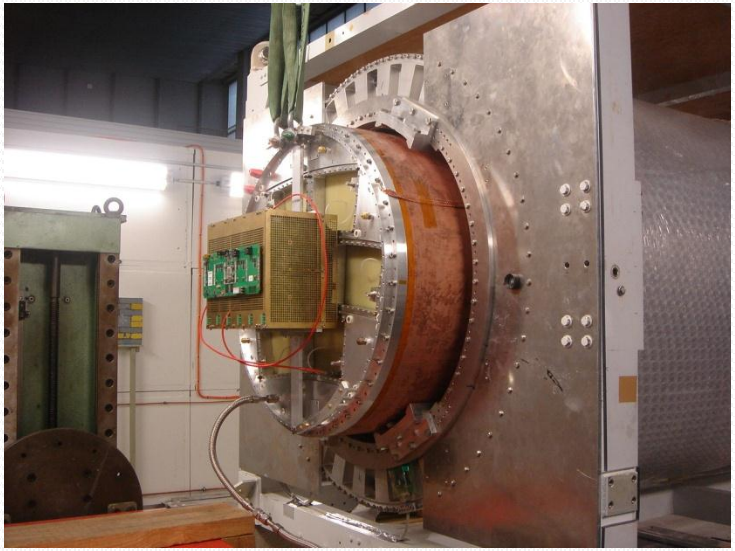
Each pixel can be set to:

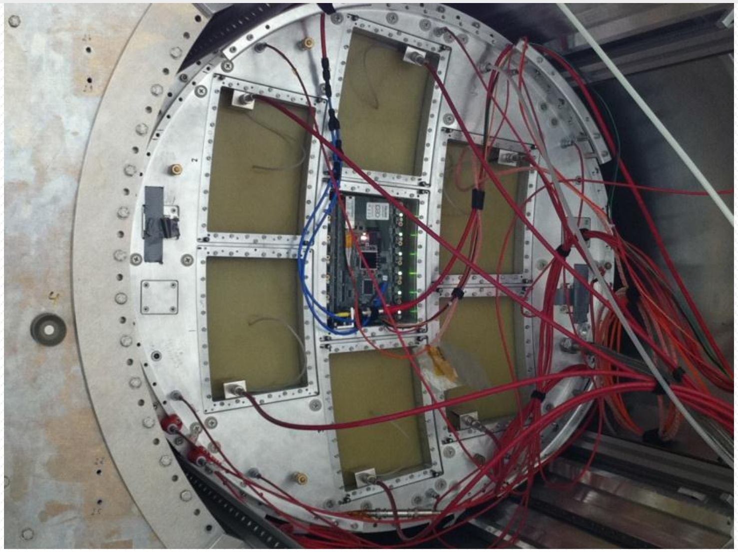
- TOT ≈ integrated charge
- Time between hit and shutter end

# 7 module project – Micromegas electronic integration





# Integration and cooling

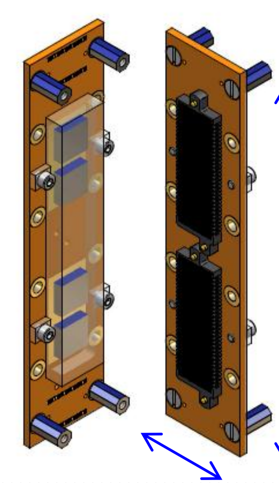
- New detector : new routing to adapt to new connectors, lower anode resistivity (3 MΩ/sq), new res. foil grounding on the edge of the PCB.
- New 300 points flat connectors
- New front end: keep naked AFTER chips and remove double diodes (count on resistive foil to protect against sparks)
- New Front End Mezzanine (FEMI)
- New backend ready 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

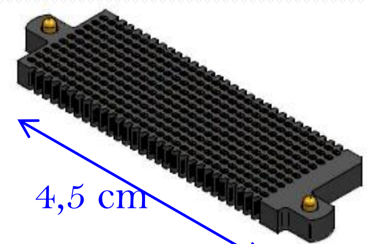
- Remove packaging and protection diodes
- Wire –bond AFTER chips
- Use 2 × 300 pins connector
- Use tiniest resistors (1 mm × 0.5 mm) from O to 10Ω

FEC





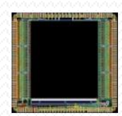






Chip



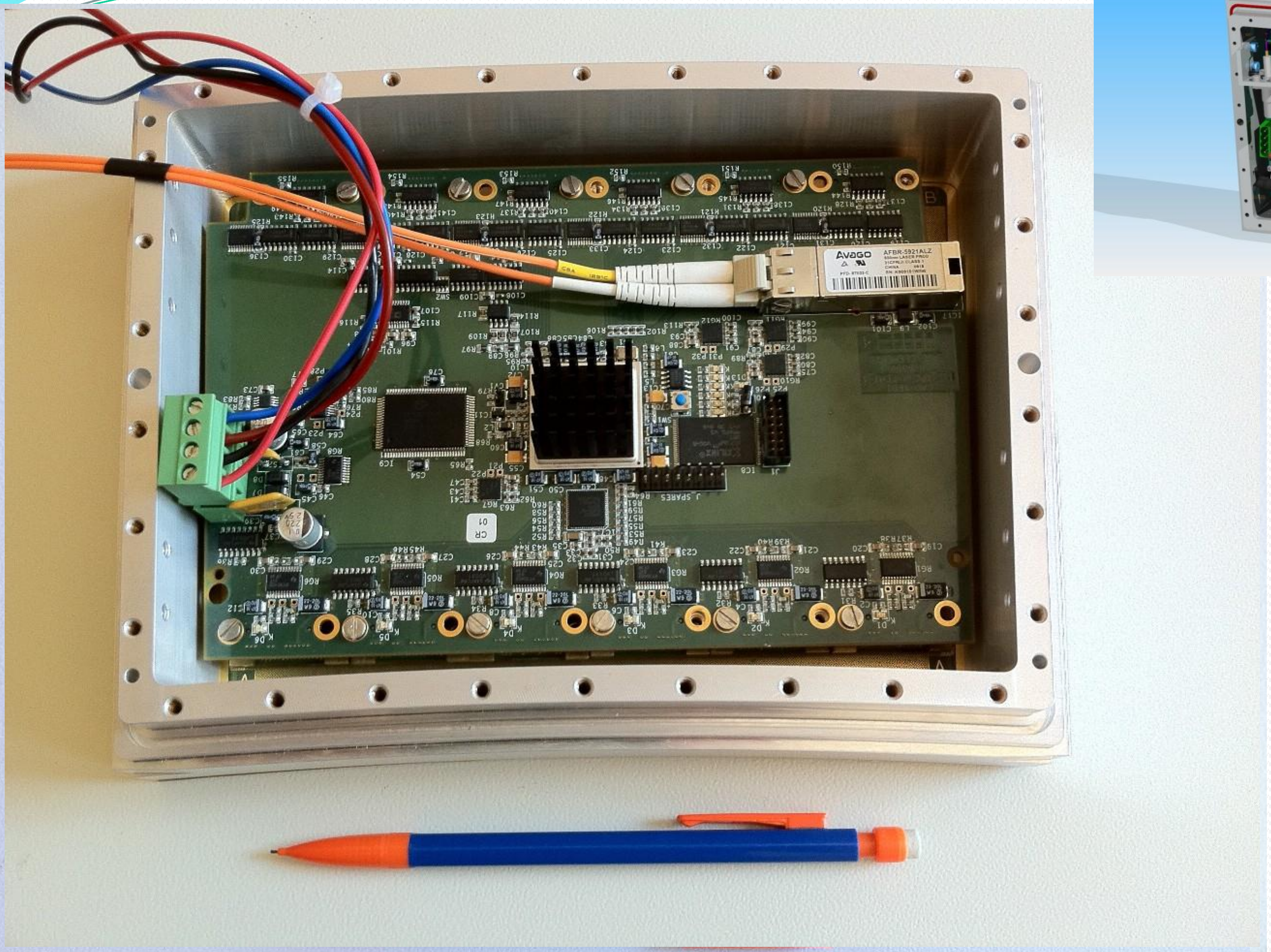


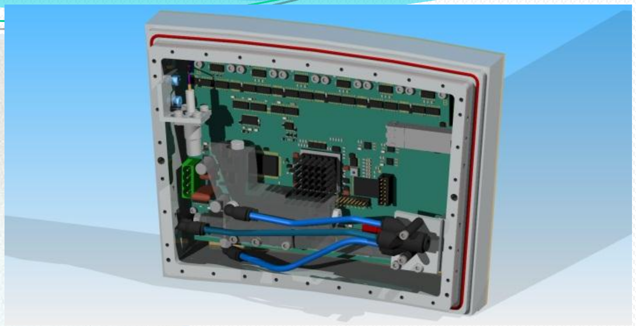


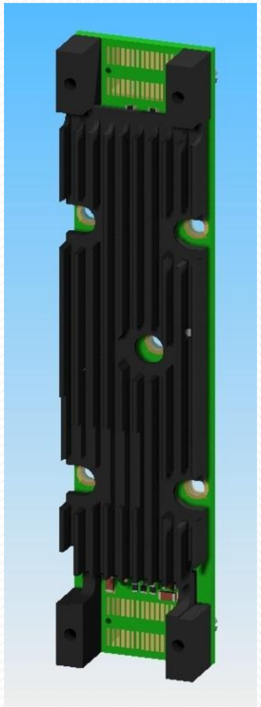
after 2 weeks of operation: no ASIC lost:

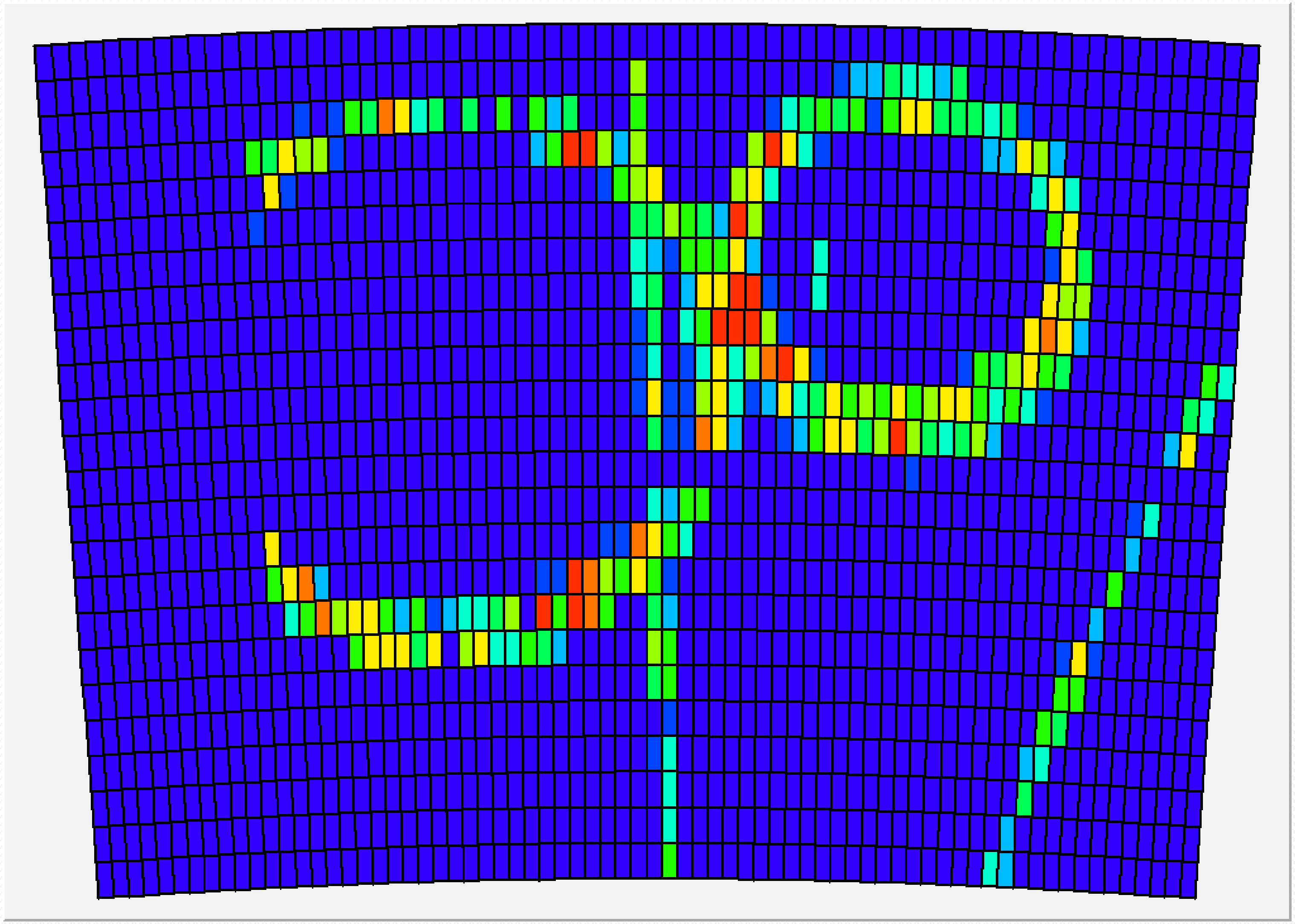
**The resistive foil protects against sparks**

# First prototype of the electronics

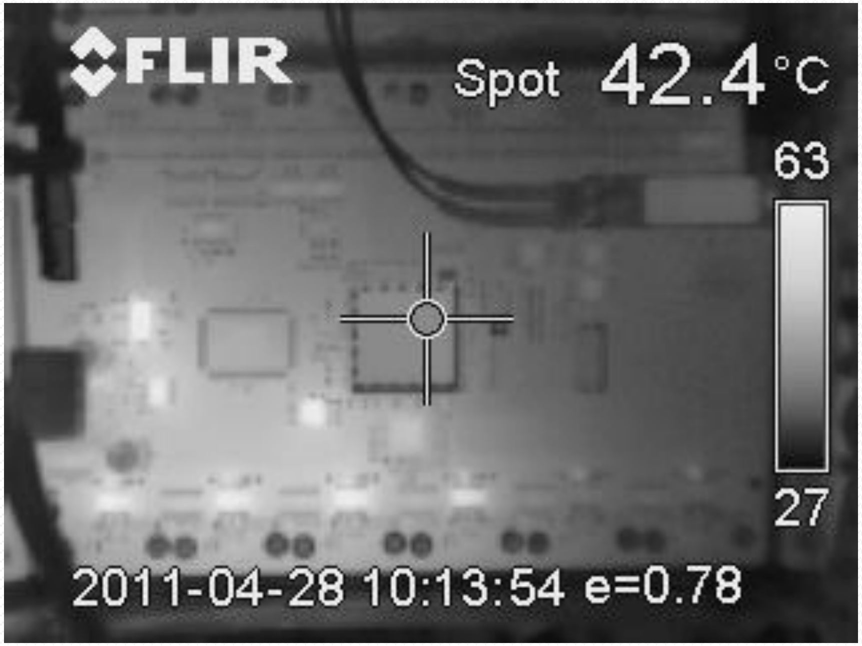


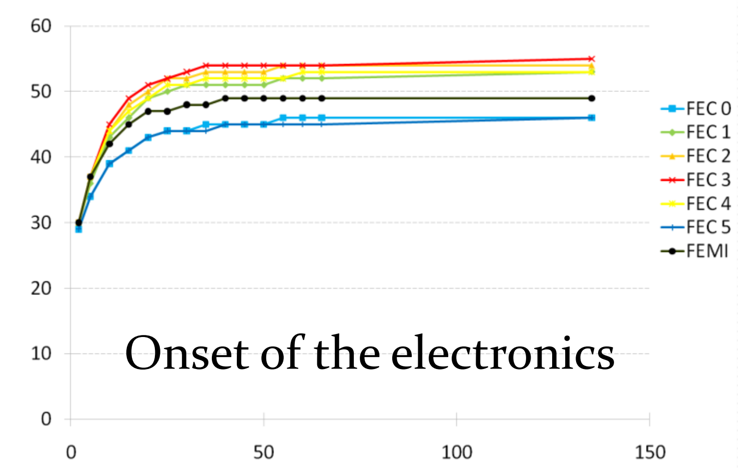


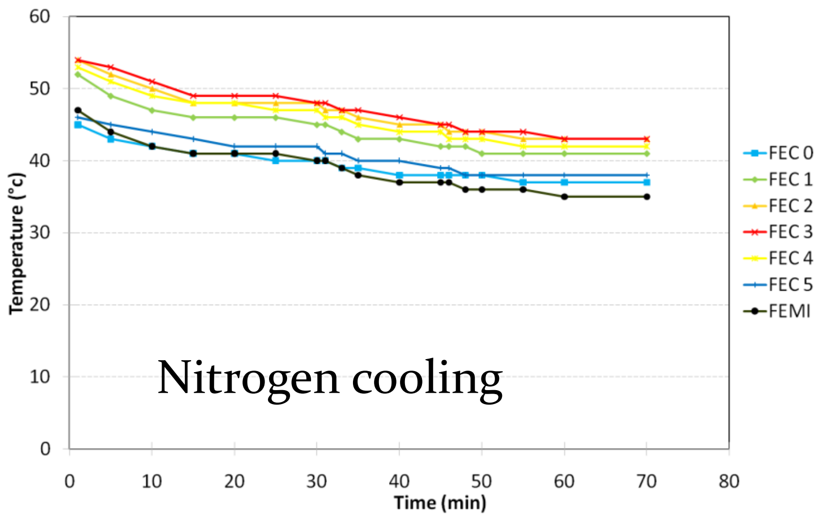




- Thermal studies. IR camera shows hot spots (regulators, ADC). T-probes on every component.
- 2-phase $CO_2$ cooling under study (KEK, Nikhef)



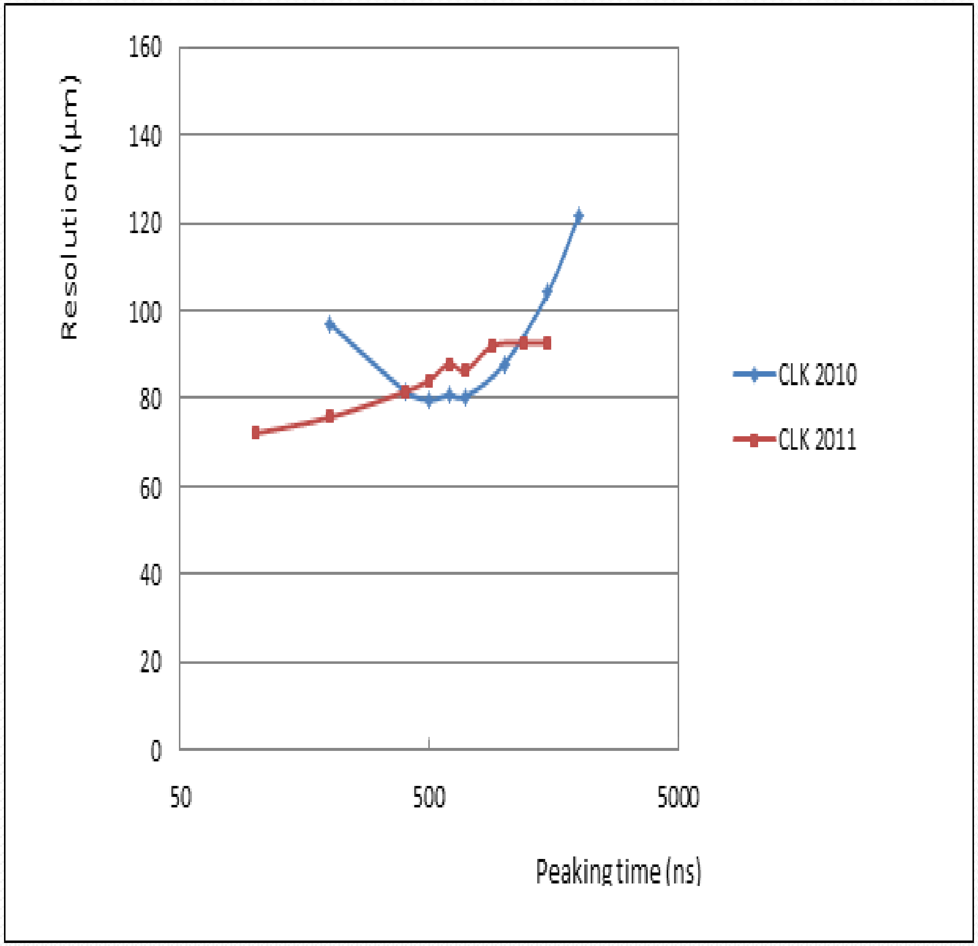



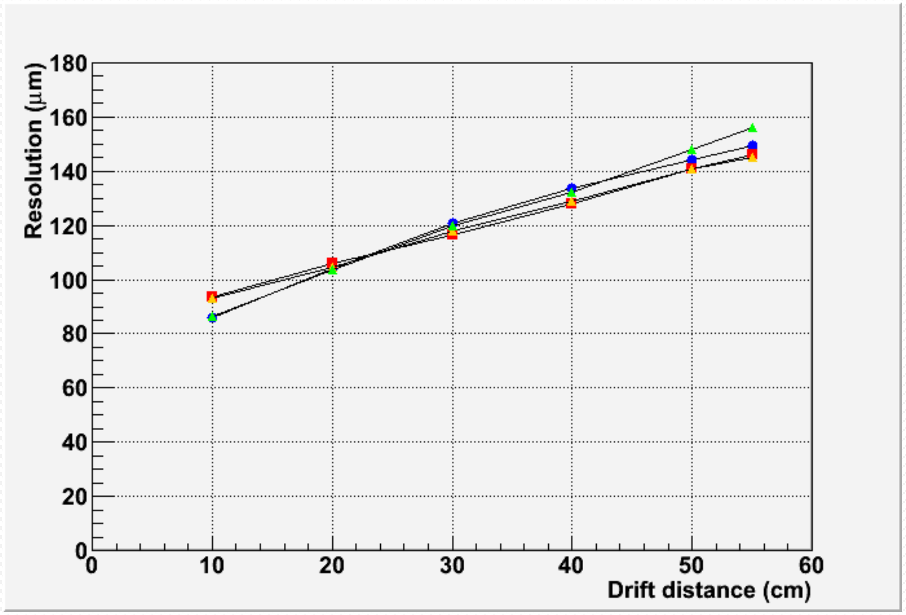
# Preliminary results : resolution (B=1T data)

- Tends to confirm previous measurements

(excluding lines with ASICs in bad contact).

- Optimum resolution now obtained for peaking time below 200 ns




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

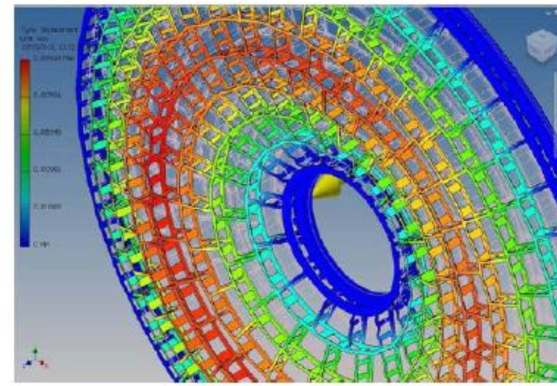
Deflection of 220 μm for overpressure of 2.1 mbar

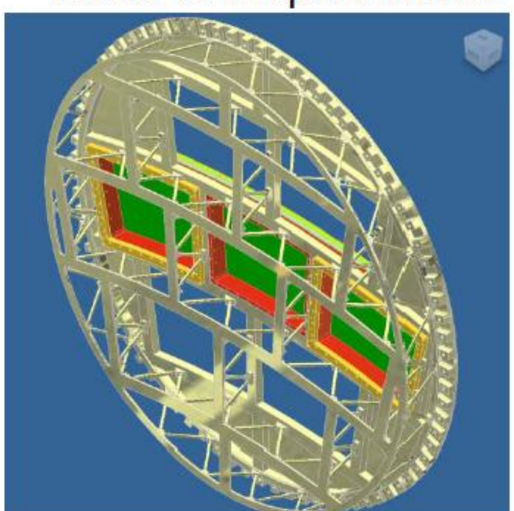
Several materials and designs have been studied

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

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

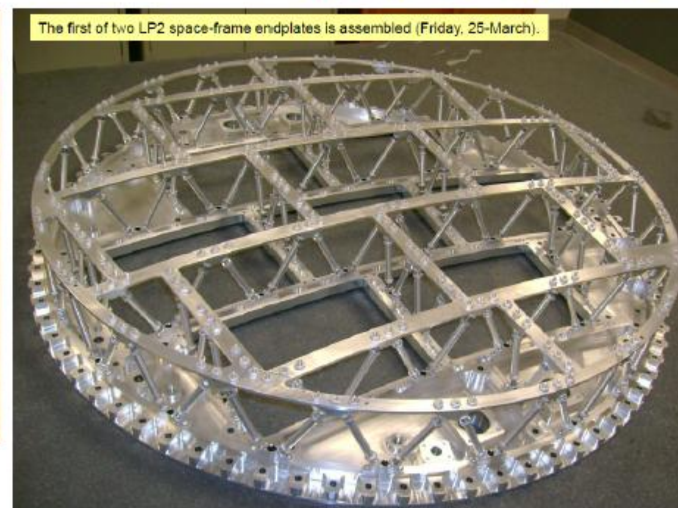
Preliminary measurements of deflection are very close to requirements





strut space-frame

test structure



# Ion disk and gating

# 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
  - 6 different power regions for power cycling
  - High level filtering (baseline subtraction, spike removal)

# CONCLUSIONS

- MPGDs have been shown to fulfill the requirements for the readout of a TPC for the LC.
- Integration  work (electronics and cooling) is going on, and practical production issues are addressed for the pad readout.
- Pixel readout needs more development to gain in reliability and operability in large surfaces.