A Large TPC Prototype for an ILC Detector

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On behalf of the LCTPC Collaboration

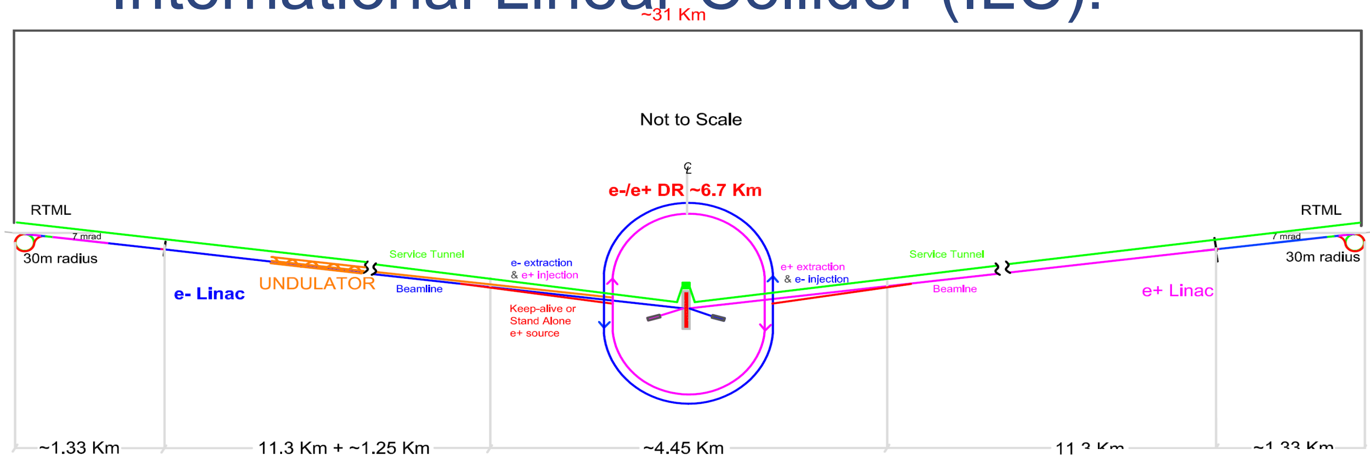
Overview

- Introduction
  - Linear Colliders, Detectors
- The Large Prototype TPC
- Beam test setup in Desy
- 3 detector technologies
  - Test-beam results
- Laser Calibration setup
- Conclusions and future plans

Future e^+e^- Linear Colliders

A future e^+e^- linear collider will be needed to study in details the LHC discoveries

- International Linear Collider (ILC):

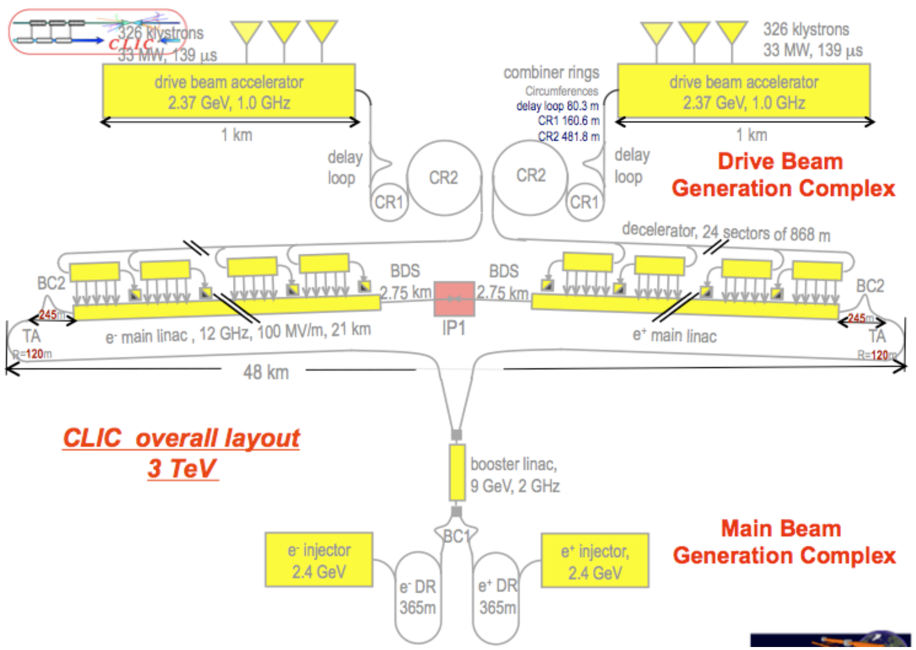


Schematic Layout of the 500 GeV Machine

- E_{CM}=0.5 - 1.0 TeV
- L=2x10^{34} cm^{-2} s^{-1}
- Expect EDR phase ends 2012, constr. starts > 2015

- Compact Linear Collider (CLiC):
  - Higher energy (3TeV)
  - Compact
  - Technology not available before 2015

  => ILC remains the baseline



ILD detector for the ILC

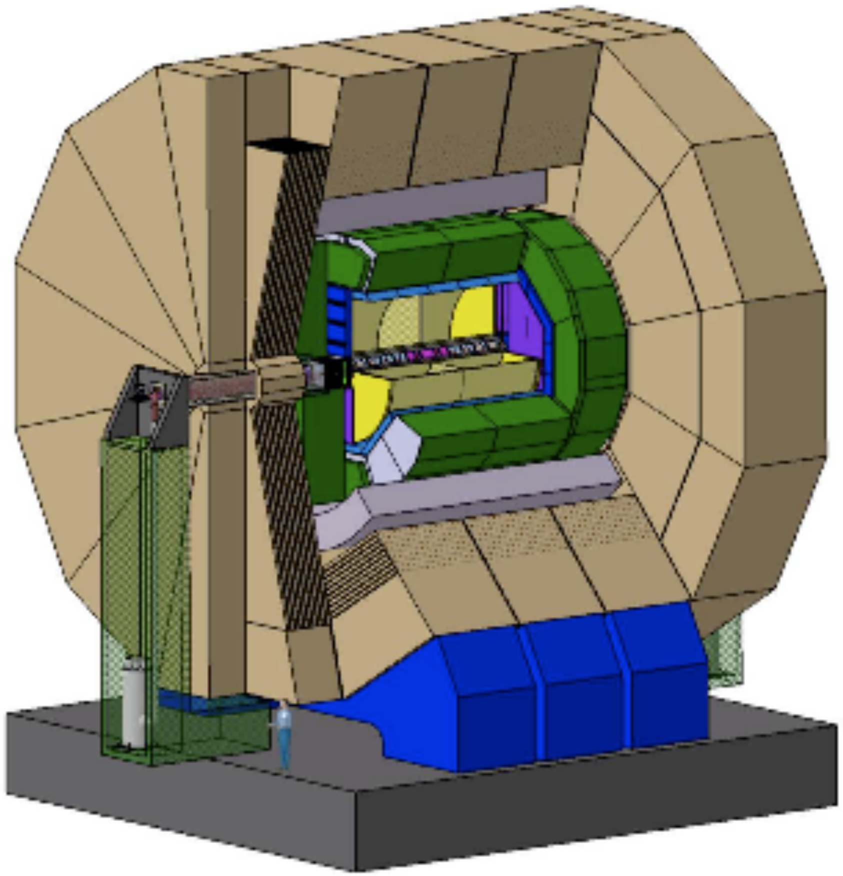
- Concept based on particle flow

  -> large tracker and high granularity calorimeters inside high (3.5T) magnetic field:

  - **Si vertex detector**
  - **Large TPC (L=4.3m, Ø=3.6m)**
    - 200 hits/track
    - δ1/pt ~ 9 10^{-5} /GeV/c
    - σ (rφ) < 100 µm
    - Rad length: $0.04X_0$-$0.15X_0$
    - dE/dx resol ~ 5%
  - **Si envelope (in- and outside)**
    - Precise calo impact
  - **Calo**

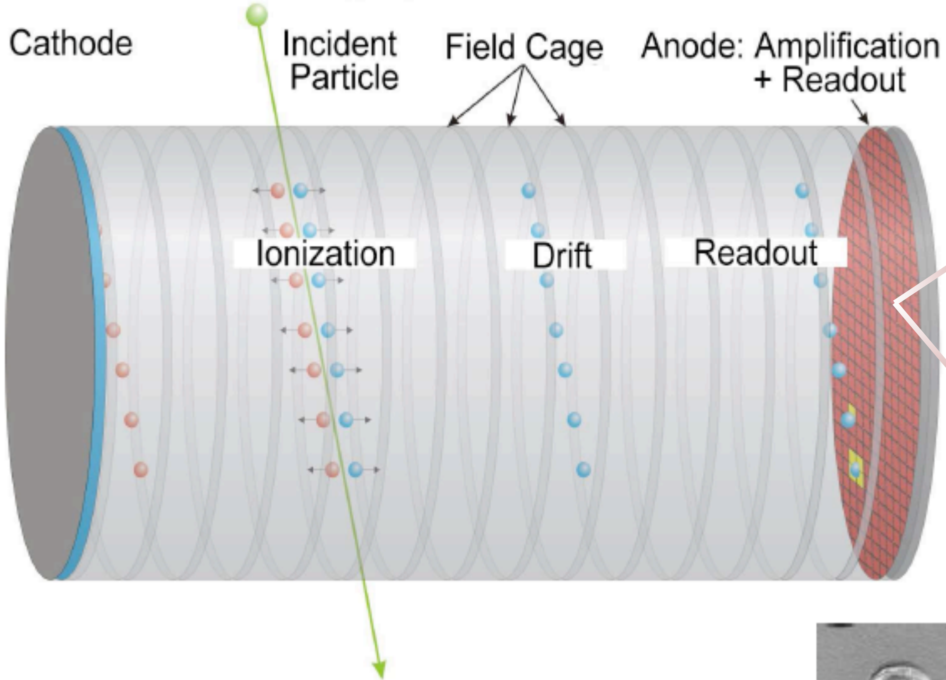
$$\sigma_{E_{\rm em}}/E_{\rm em} \simeq 15\%/\sqrt{E({\rm GeV})} \oplus 1\%$$

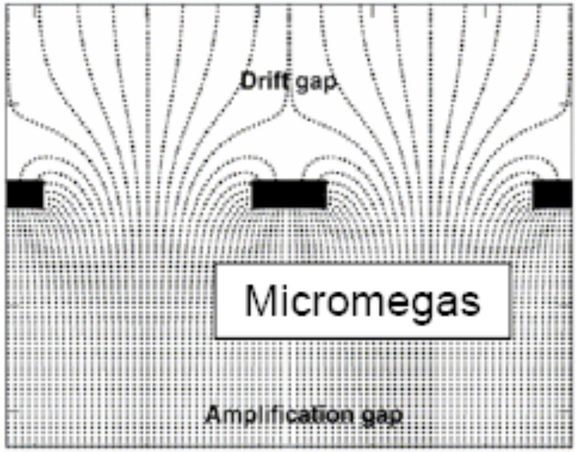
$$\sigma_{E_{\rm jet}}/E_{\rm jet} \simeq 30\%/\sqrt{E({\rm GeV})}$$



TPC with MPGD

- Micro Pattern Gas Detector (MPGD) instead of MWPC for the electron amplification stage: Not limited by the ExB effects

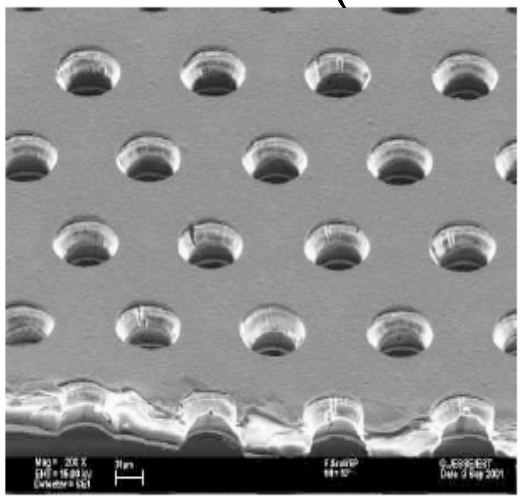


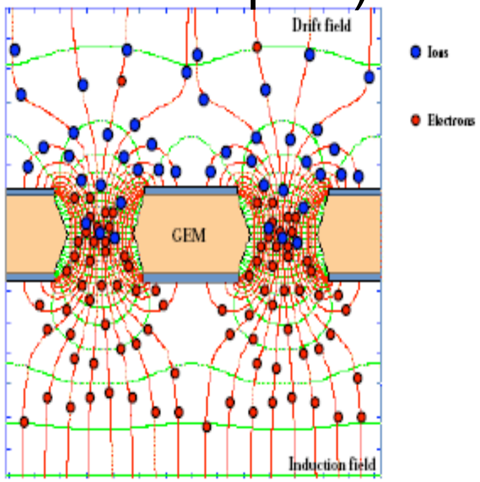


MICROMEGAS

OR

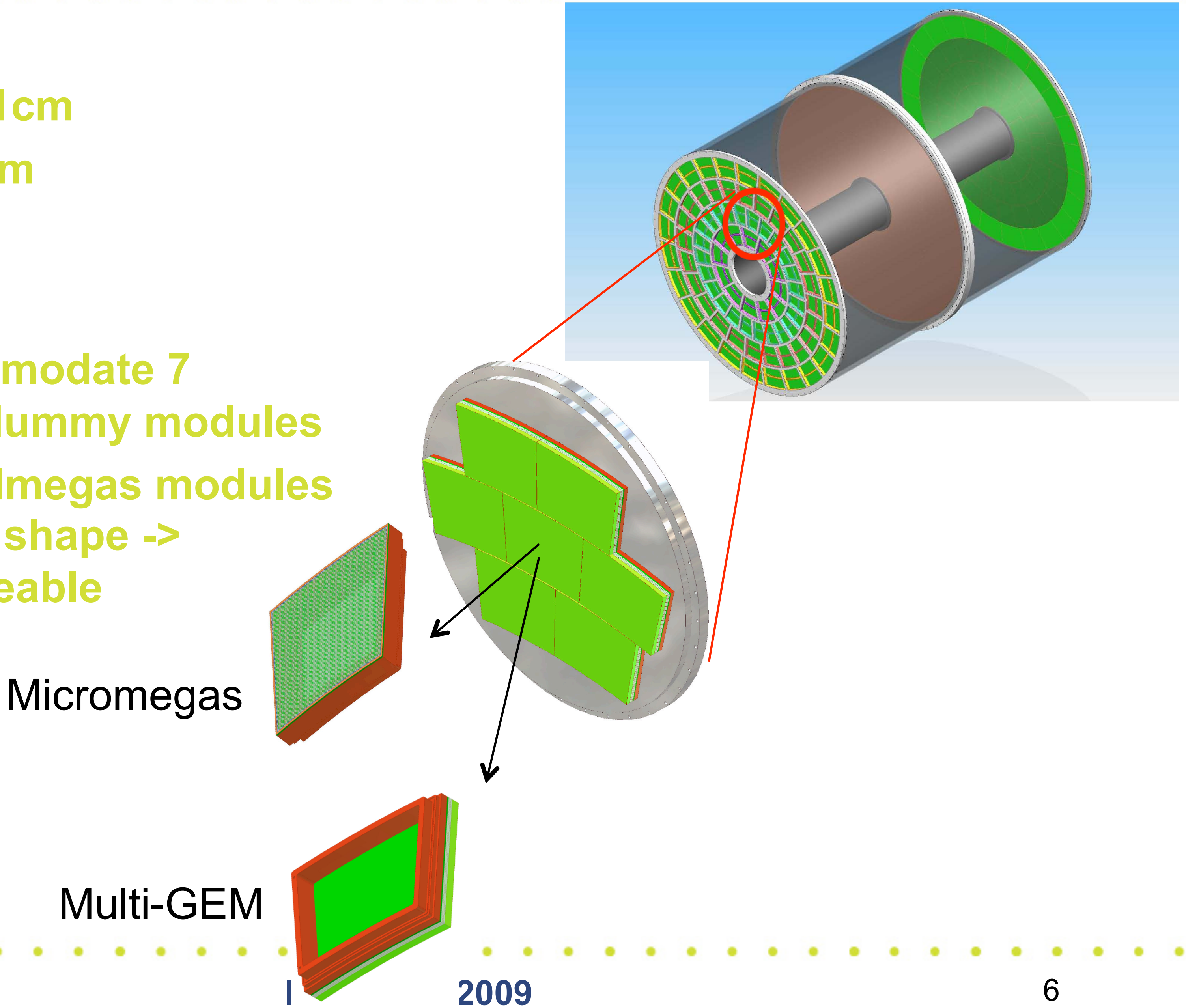
GEM (Gas ElectronMultiplier)



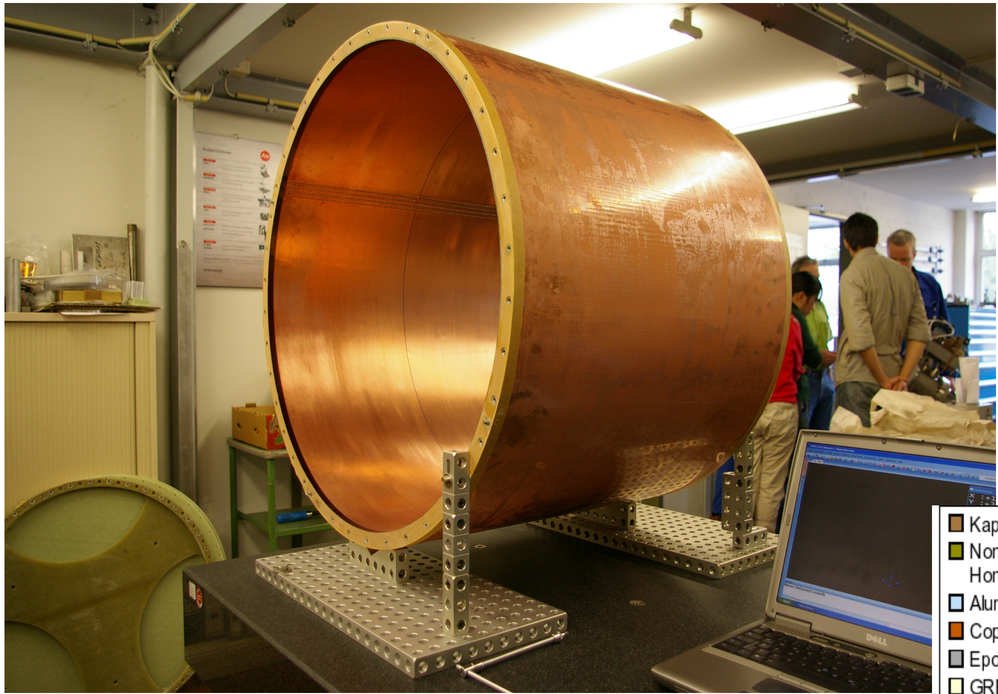


Large Prototype TPC (LPTPC)

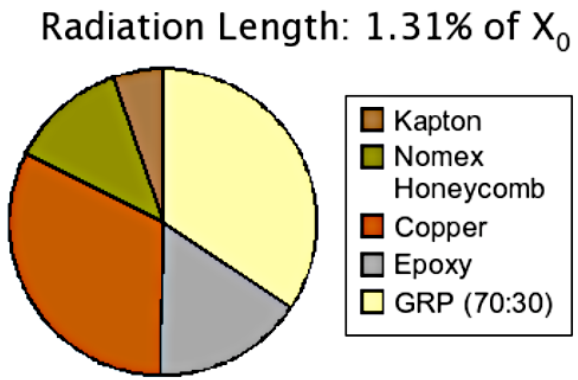
- Dimensions:
  - **Length = 61cm**
  - **Diam = 77cm**
- Endplate :
  - **Aluminium**
  - **Can accommodate 7 detectors/dummy modules**
  - **GEM and Mmegas modules have same shape -> interchangeable**

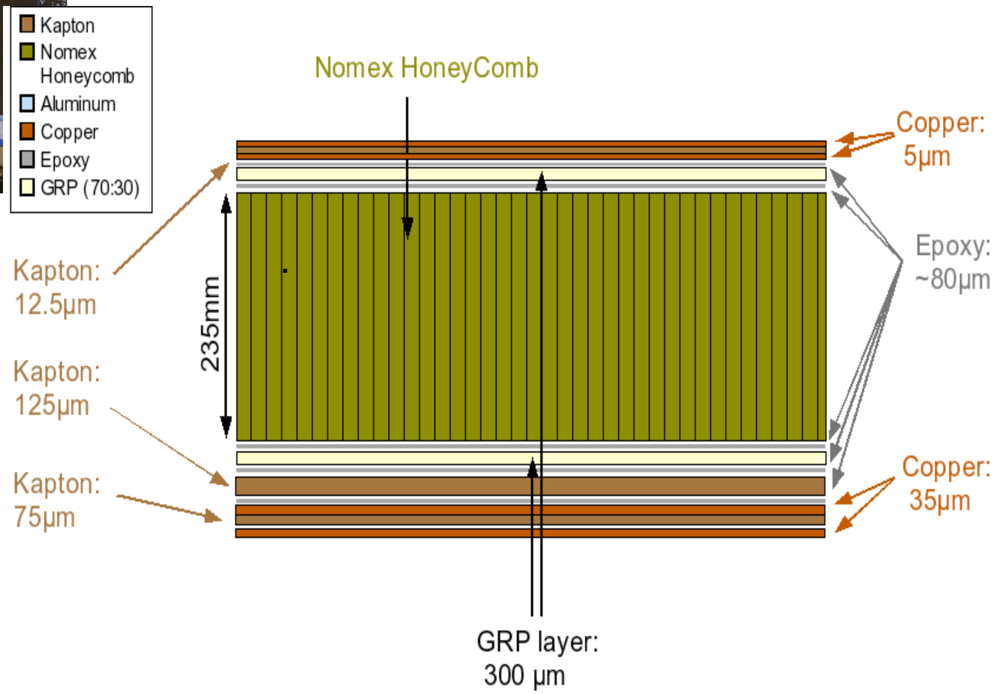


The field cage

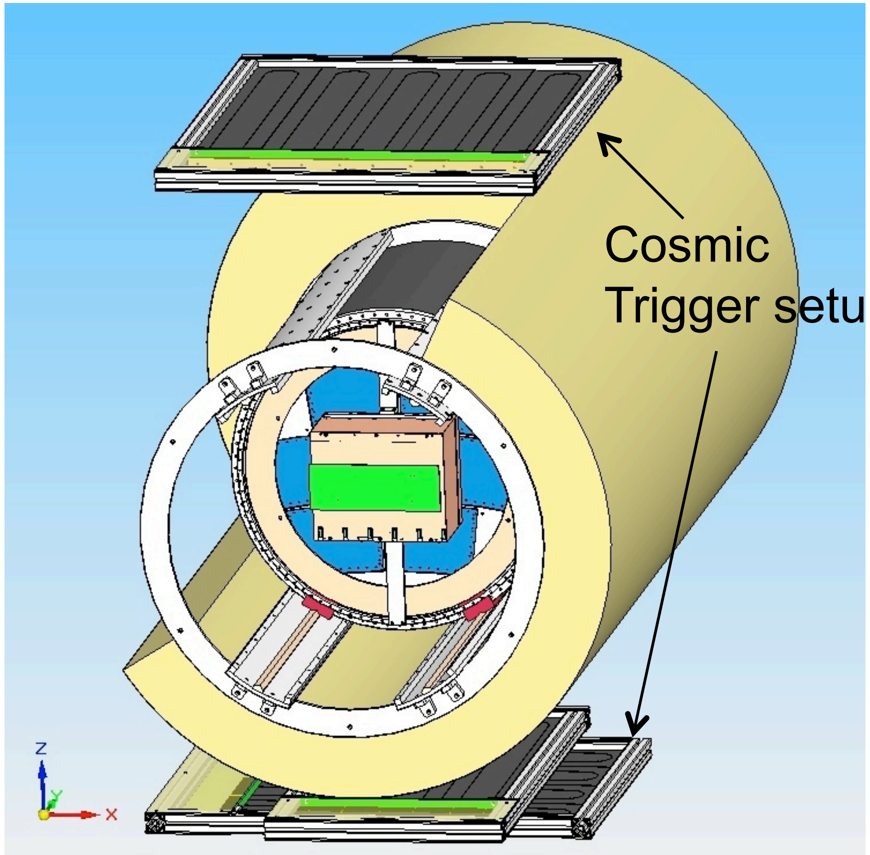


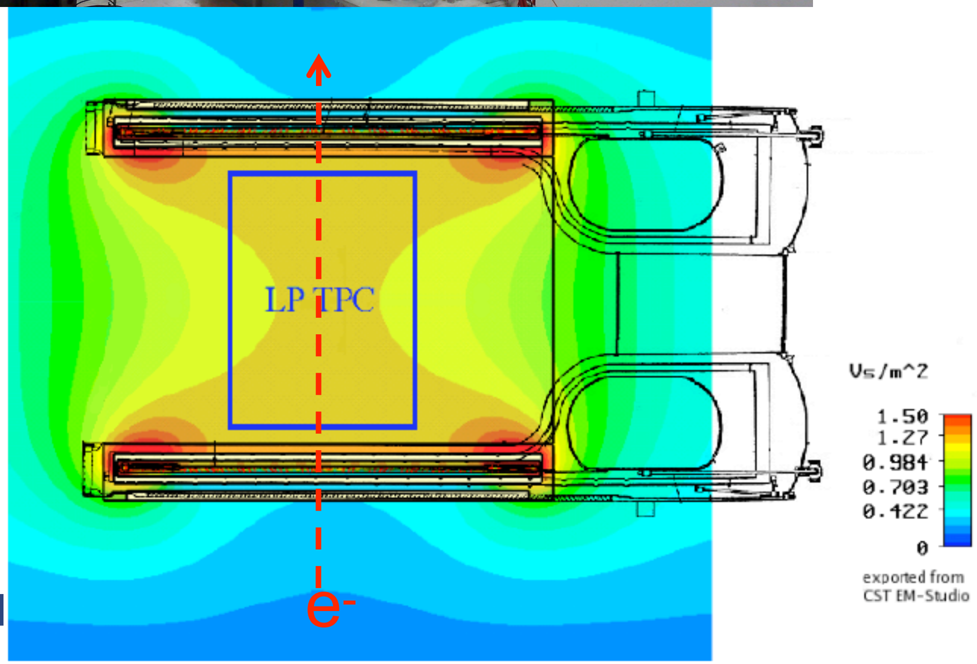
HV : up to 20kV





DESY set-up

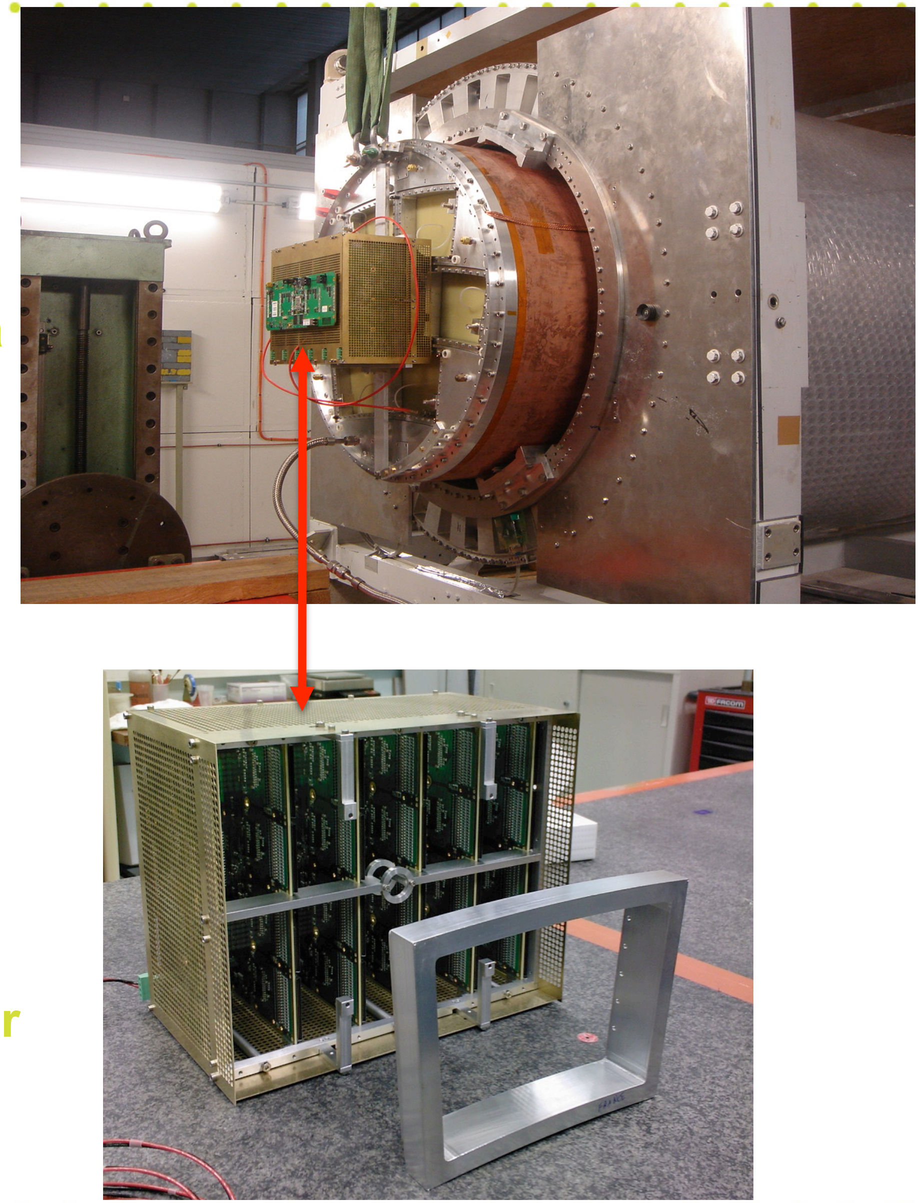




- LPTPC is only half of the LCTPC
- Slided in a superconductor solenoid of up to 1.5 T
- $1 < p < 6$ GeV/c e^-

LPTPC equipped with MICROMEGAS

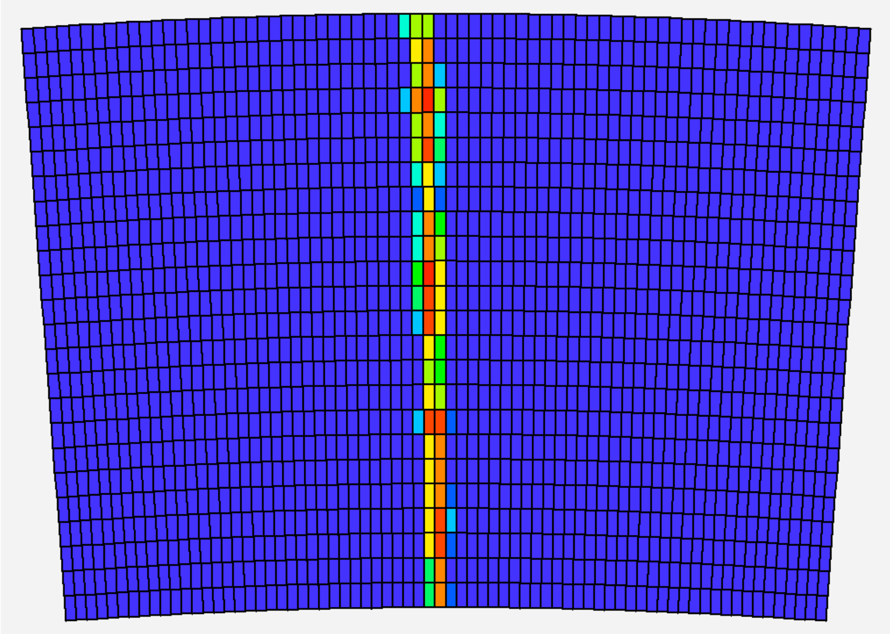
- 3 bulk mMEGAS module tested
  - Regular anodes
  - Resistive anodes (carbon loaded kapton)with a resistivity ~ 5-6 MΩ/□
  - Resistive anodes (resistive ink) with a resistivity ~ 1-2 MΩ/□
- 1726 (24x72) pads of ~3x7 mm²

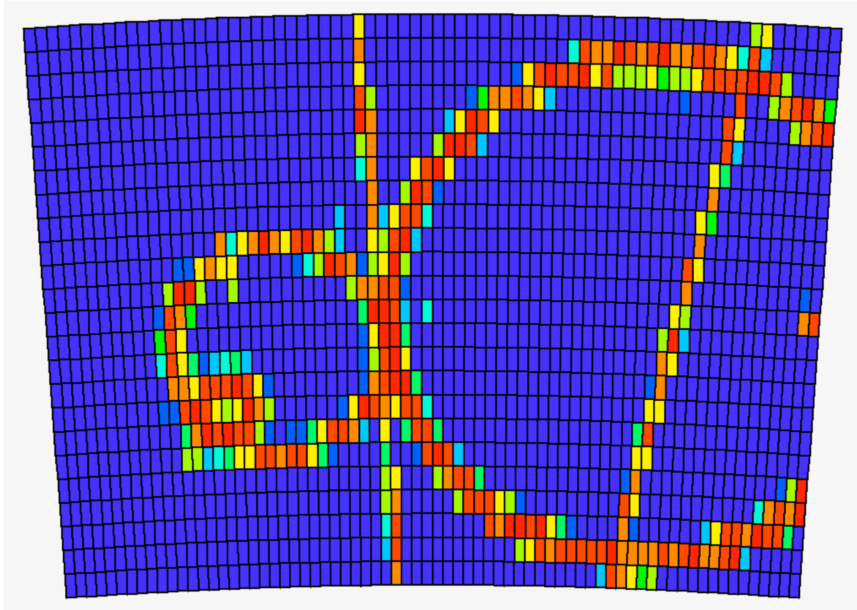


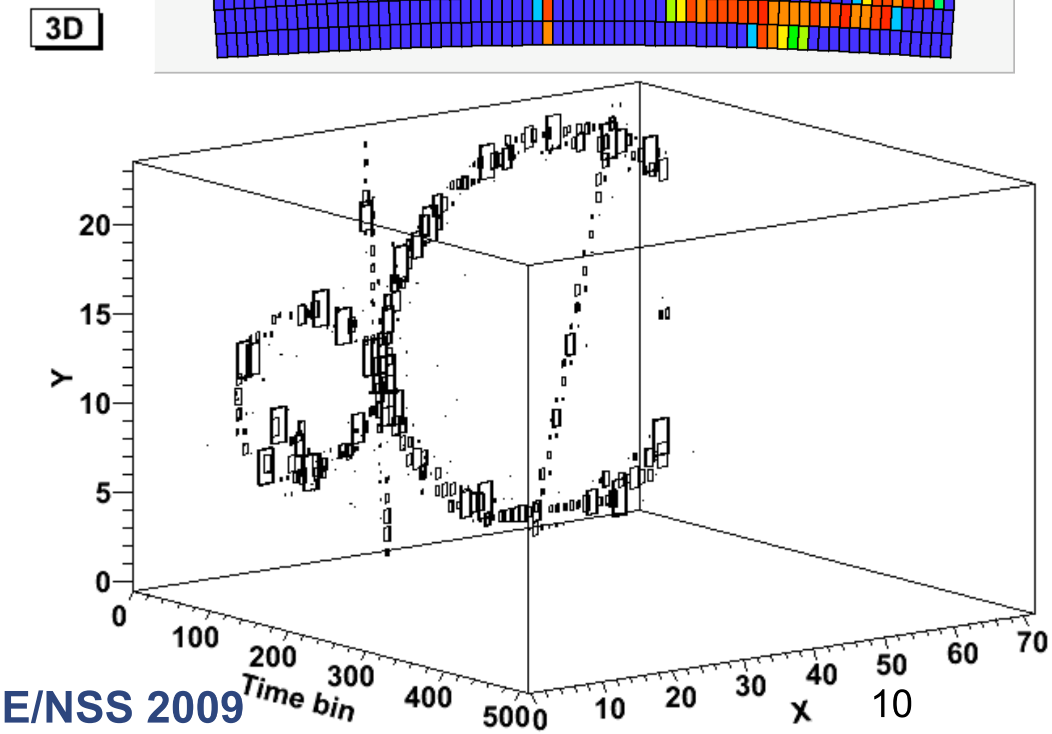
- AFTER-based electronics (72 ch./chip):
  - low-noise (700 e-) pre-amplifier-shaper
  - 100 ns to 2 μs tunable peaking time
  - full wave sampling by SCA

Some events

B=1T, T2K gas: $Ar/CF_4/iso\text{-}C_4H_{10}$ (95:5:3)



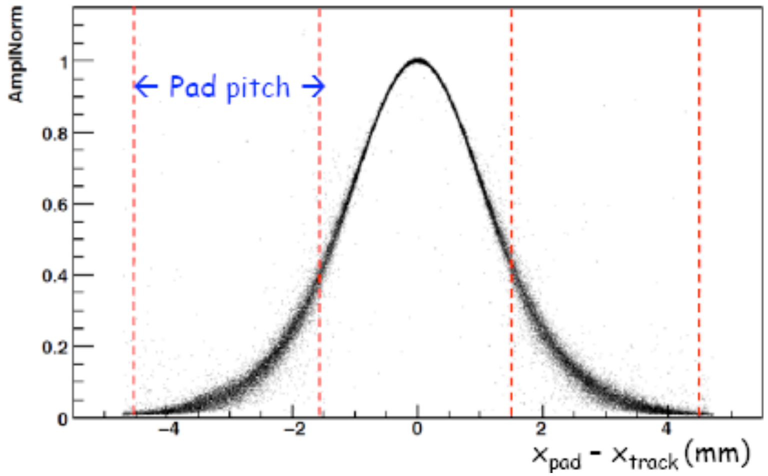




MICROMEGAS RESULTS

5 GeV e⁻, B=1T

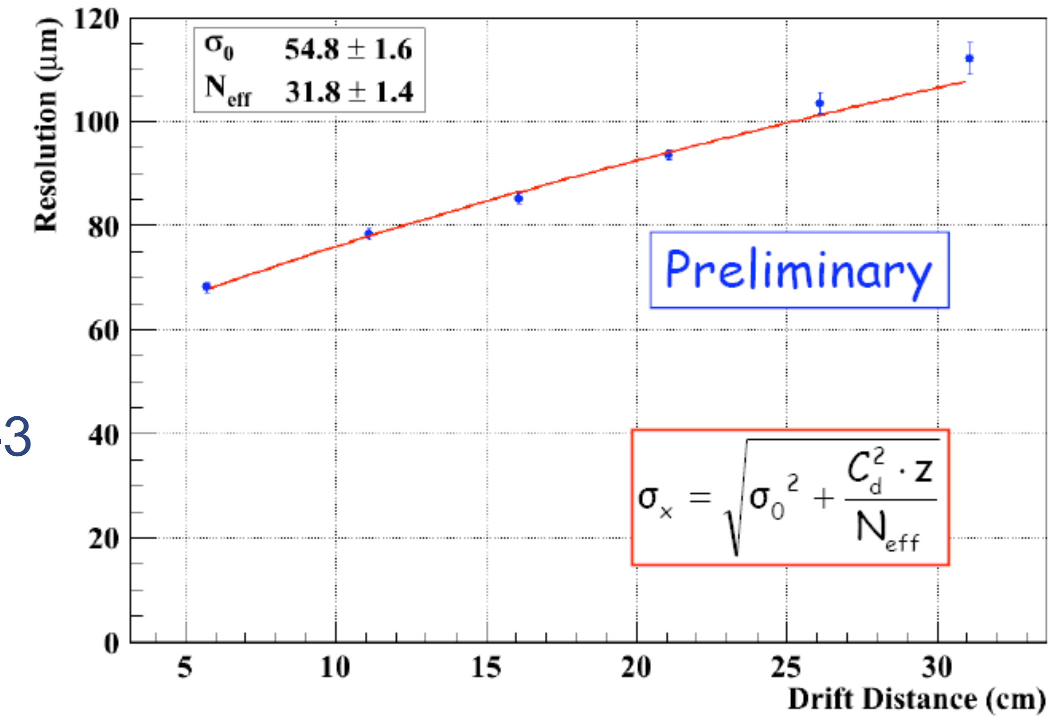
- Pad response:
- Fraction of row charge on a pad vs. $x_{pad} - x_{track}$ normalized to central pad charge



- Clear charge spreading over 2-3 pads

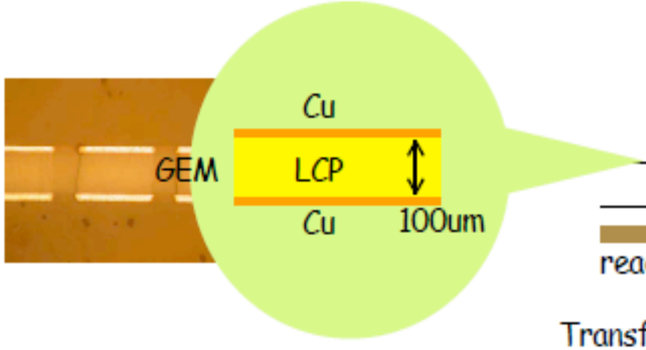
(500 ns shaping)

- Spatial Resolution:
- At z=0, σ_0=54.8±1.6μm (~ wpad/55)
- Effective number of electrons N_{eff}=31.8±1.4 consistent with expectation



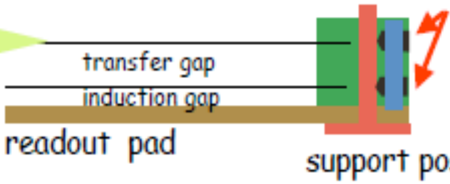
Double GEM structure

GEMs



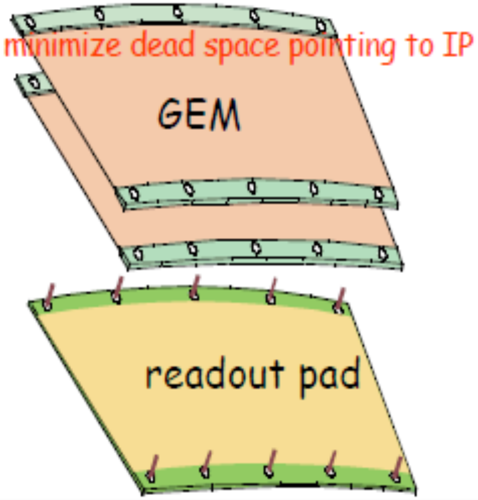
Can we stretch GEM ?

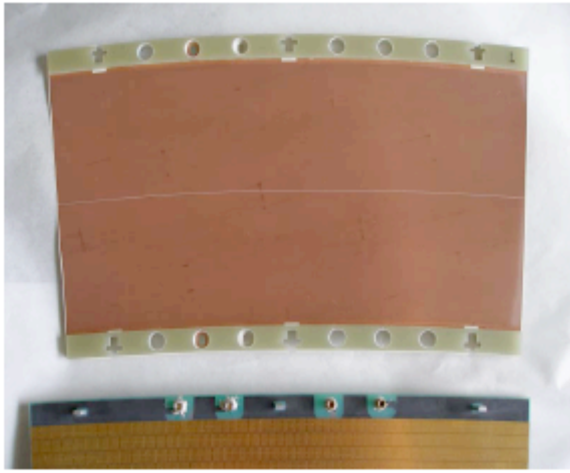
mounting(stretch) mechanism



Transfer gap ~ 4mm : enlarge signal distribution
(+2mm) width > 0.3* pad pitch

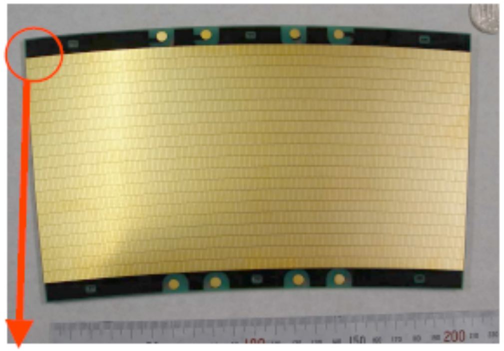
frame : top & bottom frame.
no side frame

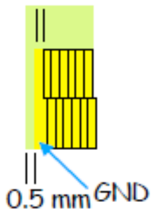




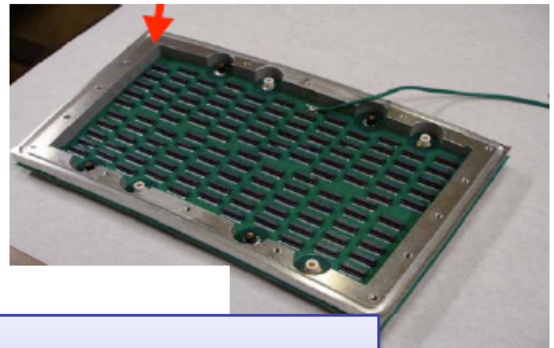
28 pad raws (176/192 pads/raw)
~1.2(w) x 5.4(h) mm^2
staggered every each layer

Total 5,152 ch/module



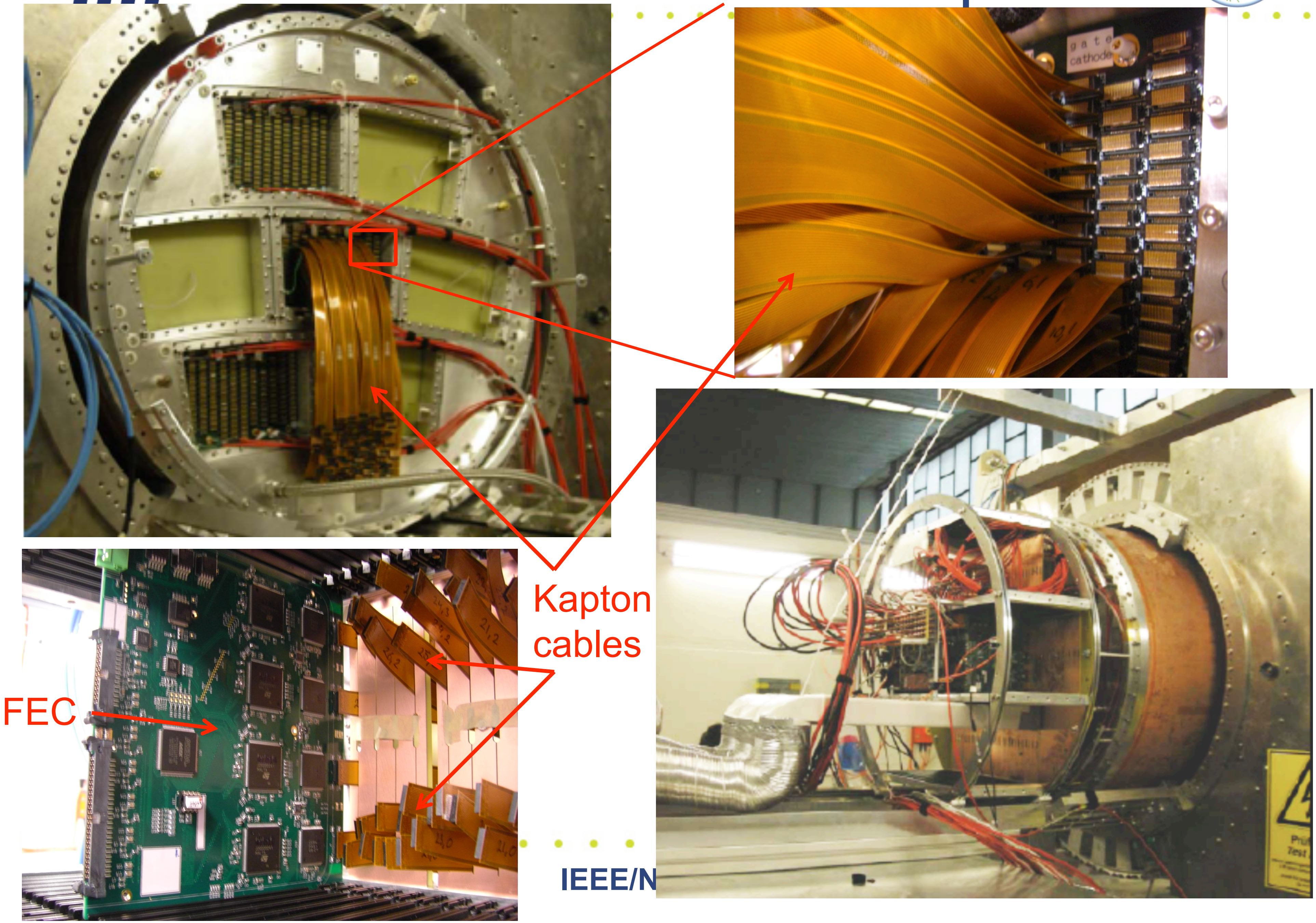


6 layers PCB
one GND layer

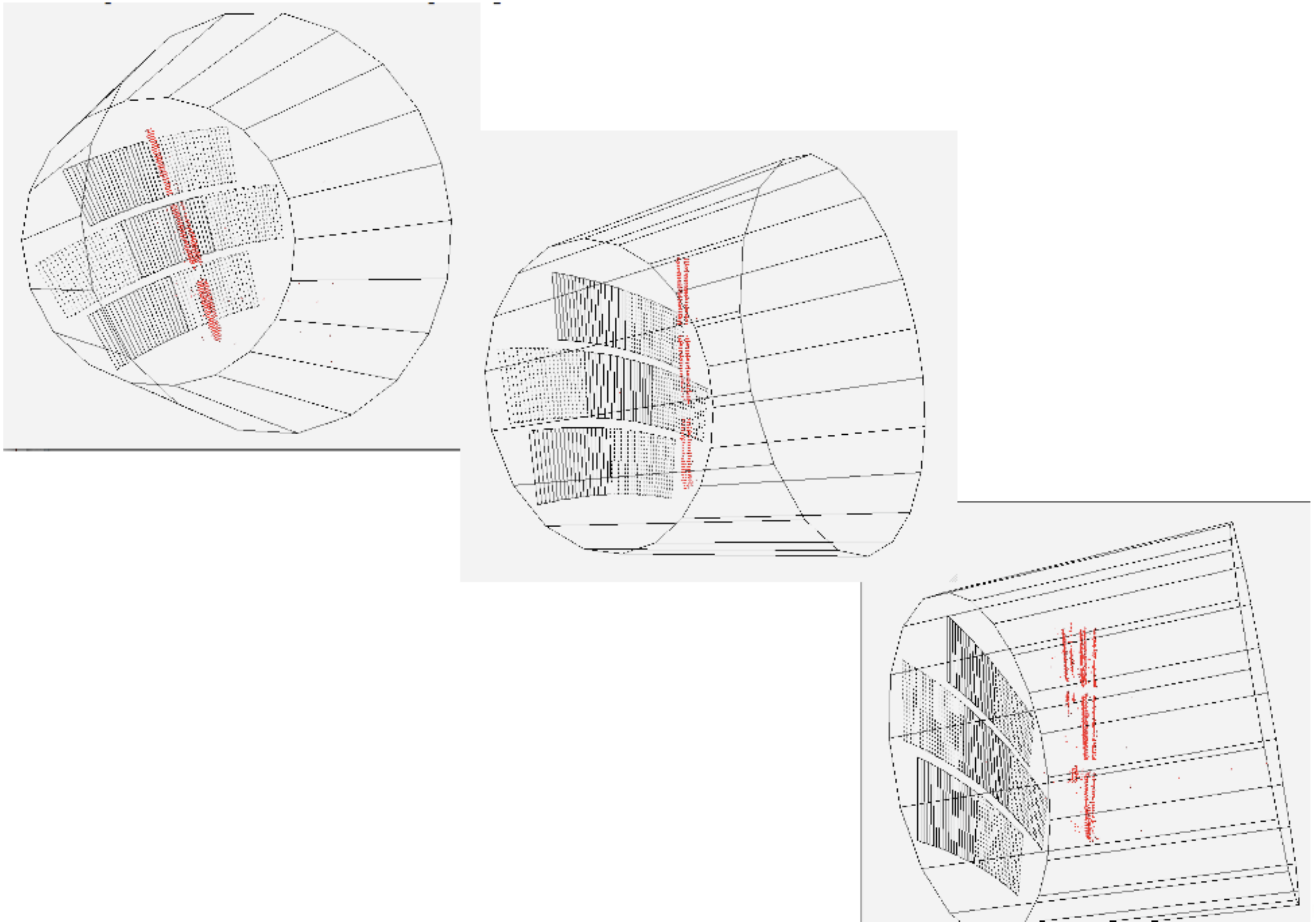


• ALTRO (ALICE) Electronics
+ new PCA16 preamp. (tunable gain, peak. and decay time, polarity,…)

Double GEM set-up



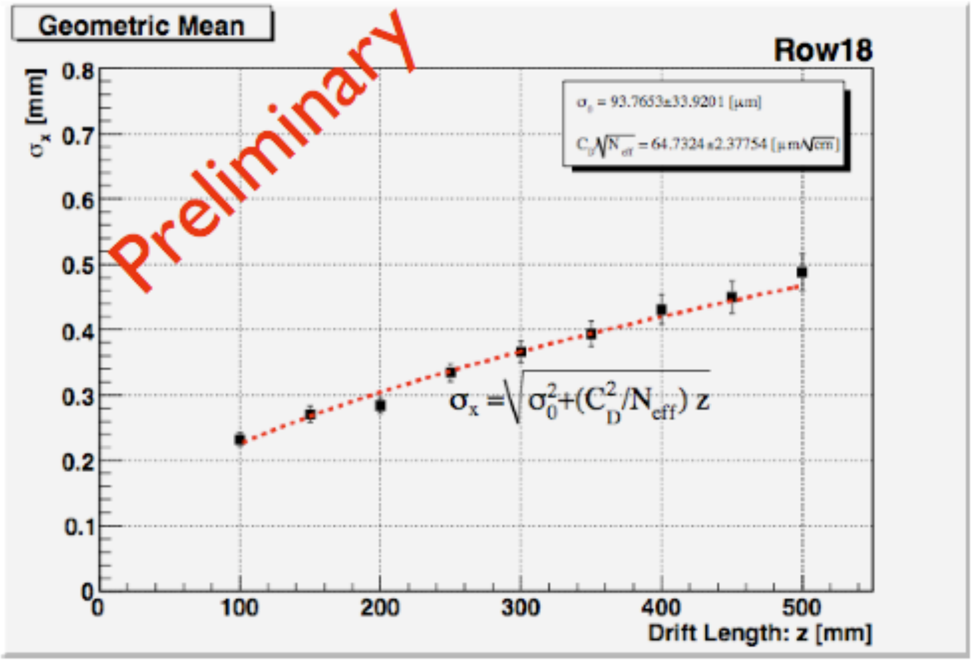
Some Double GEM Events

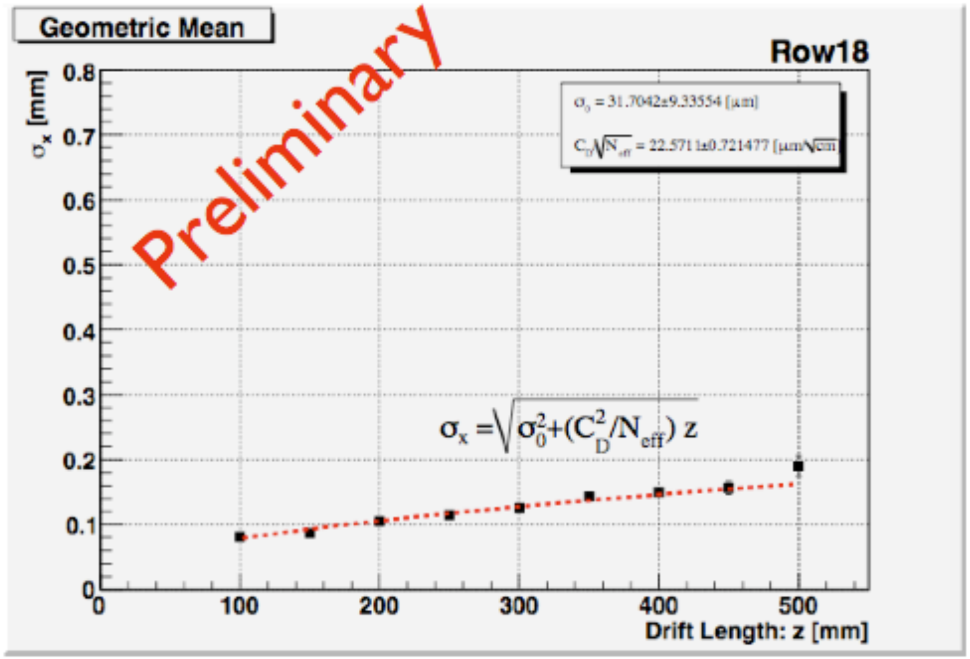


Double GEM Resolution

At z = 0, σ 0 = 93.8 ± 33.9 μm

At z = 0, σ 0 = 31.7 ± 9.3 μm





B=0T

B=0T

$$\begin{cases} C_D = 303 \pm 1 [\mu/\sqrt{cm}] \\ \frac{C_D}{\sqrt{N_{eff}}} = 65 \pm 2 [\mu m/\sqrt{cm}] \end{cases}$$

Garfield

$$C_D = 311.8[\mu m / \sqrt{cm}]$$

$$\longrightarrow N_{eff} \sim 22 \pm 1$$

Result of MP-TPC
Neff = 21±2

B=1T

B=1T

$$\begin{cases} C_D = 101.6 \pm 0.4 [\mu/\sqrt{cm}] \\ \frac{C_D}{\sqrt{N_{eff}}} = 22.6 \pm 0.7 [\mu m/\sqrt{cm}] \end{cases}$$

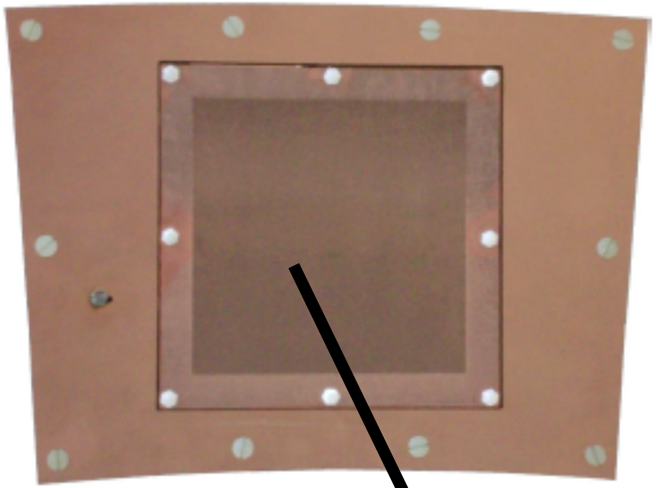
Garfield

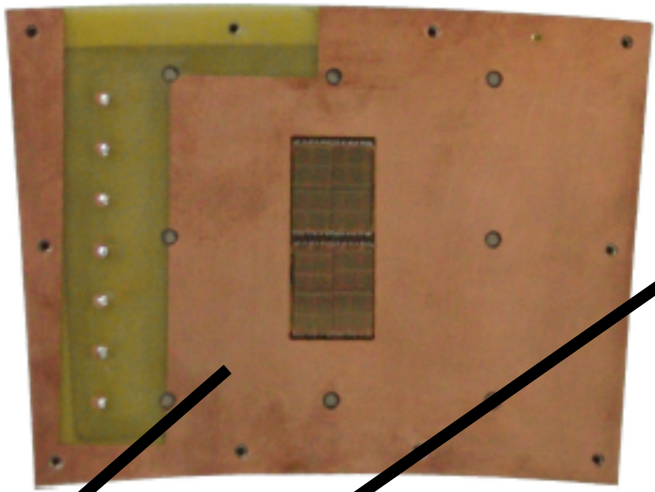
$$C_D = 95.4[\mu m / \sqrt{cm}]$$

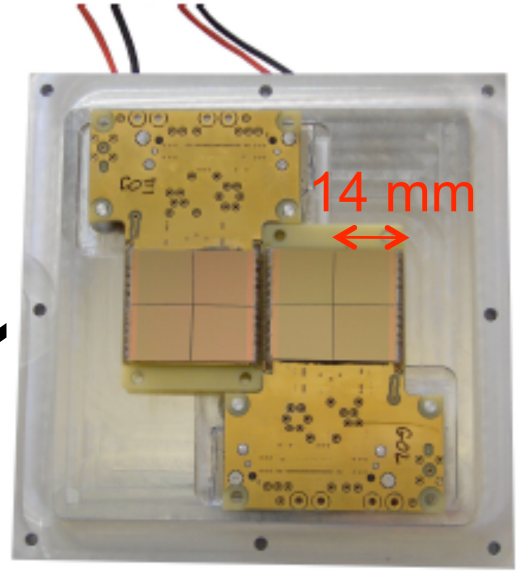
$$\longrightarrow N_{eff} \sim 20 \pm 1$$

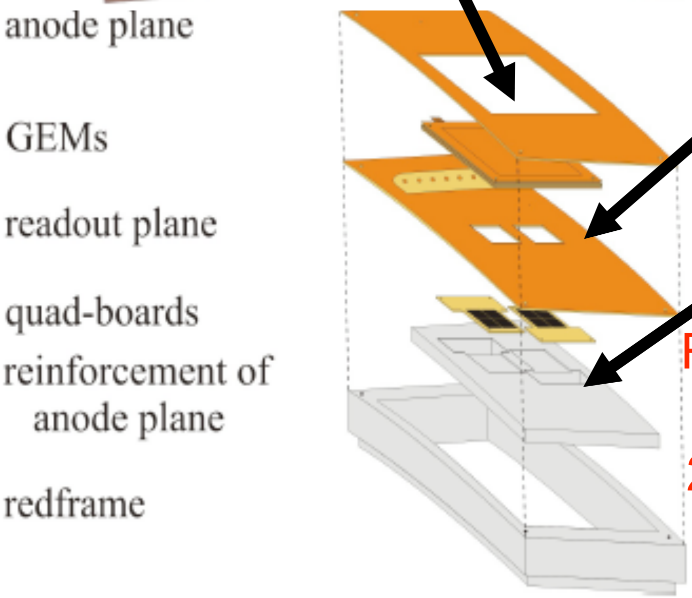
3-GEM Structure & TimePix

3-GEM + CMOS pixel readout

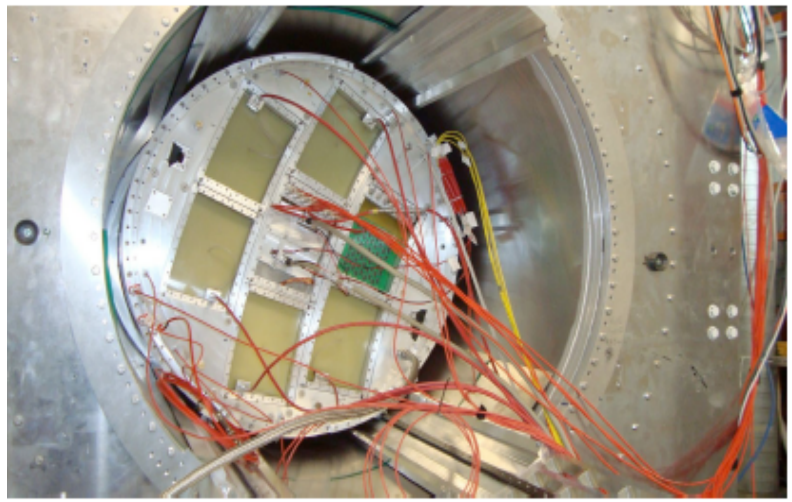






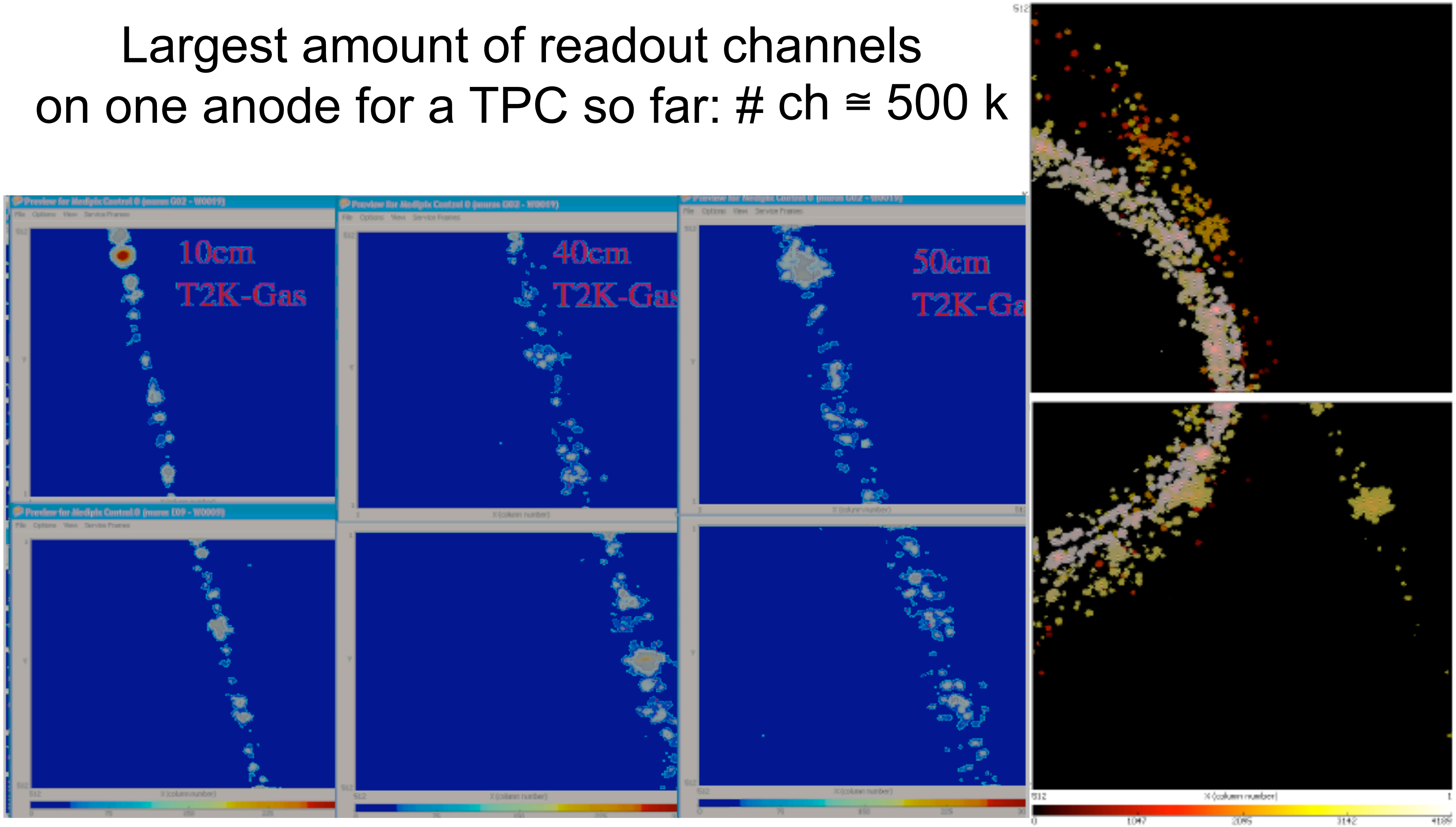


Readout:2 quadboards
4 TimePixChips each
256x256ch each chips

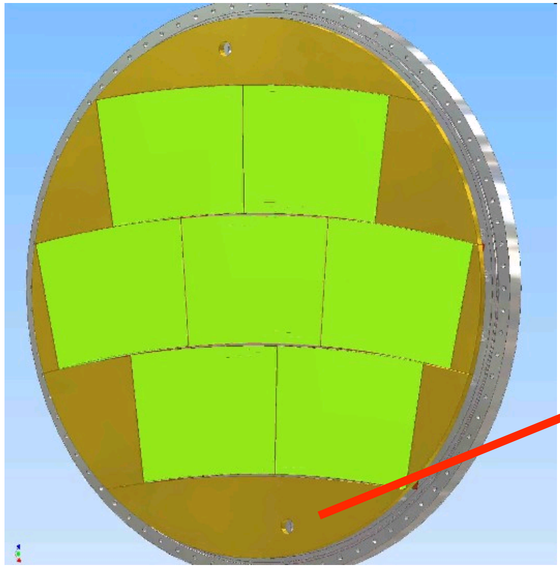


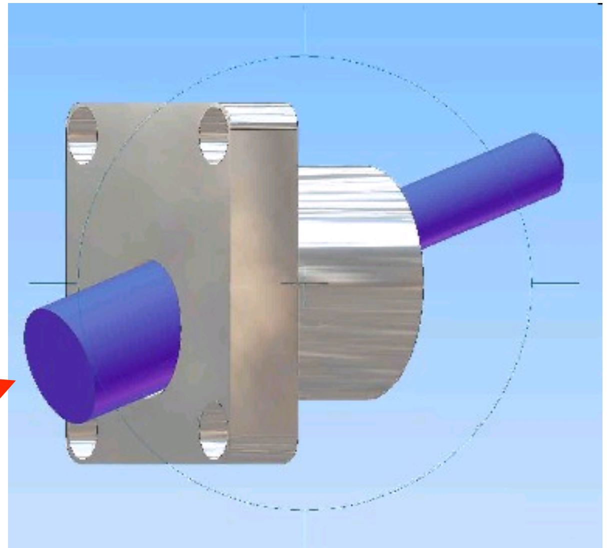
3-GEM Structure & TimePix

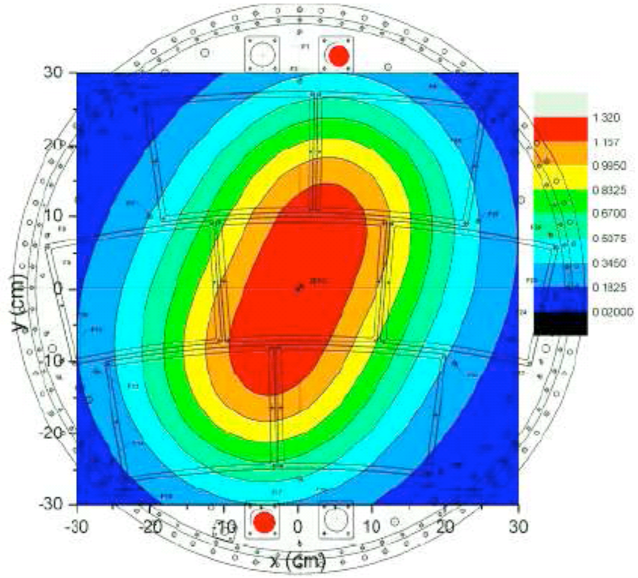
Largest amount of readout channels
on one anode for a TPC so far: # ch ≅ 500 k

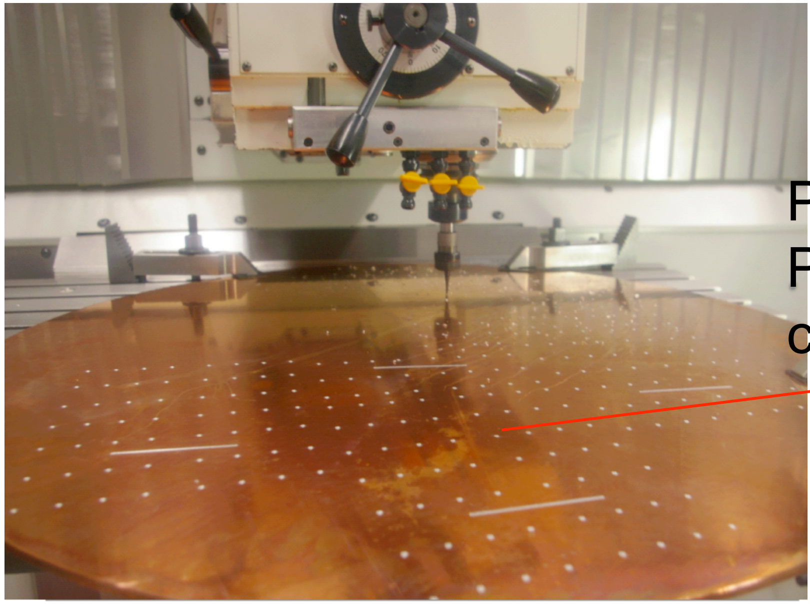


Laser Calibration Setup

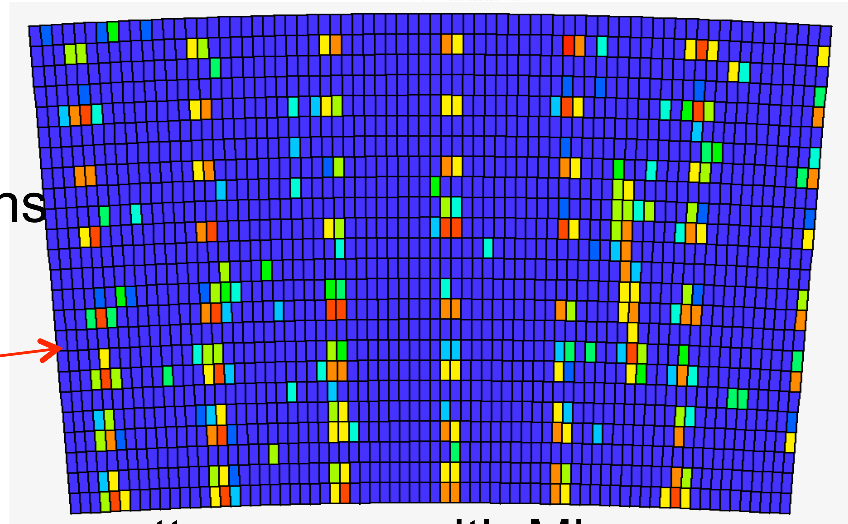








Photoelectrons
Produced at
cathode



=> pattern seen with Micromegas

Conclusions and plans

- A large prototype TPC has been built which allowed to address
  - Assembling
  - Commissioning
- LPTPC tested with several MPGD and electronics technologies
  - MICROMEGAS, GEM
  - AFTER, ALTRO, CMOS Pixel
- Several beam tests have been performed with 5GeV e^- & B=1T
- The analyses of all these data are ongoing and preliminary results look promising
- Future plans:
  - Combined test with MICROMEGAS and Si Envelope (Nov 2009)
  - Large scale test with 7 modules (~10 k channels) and more integrated electronics (spring 2010)

Acknowledgments

EUDET Detector R&D towards the International Linear Collider

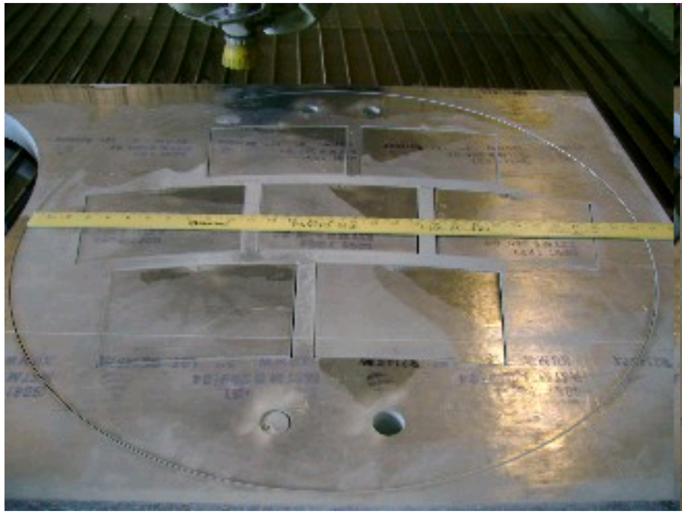
NSF

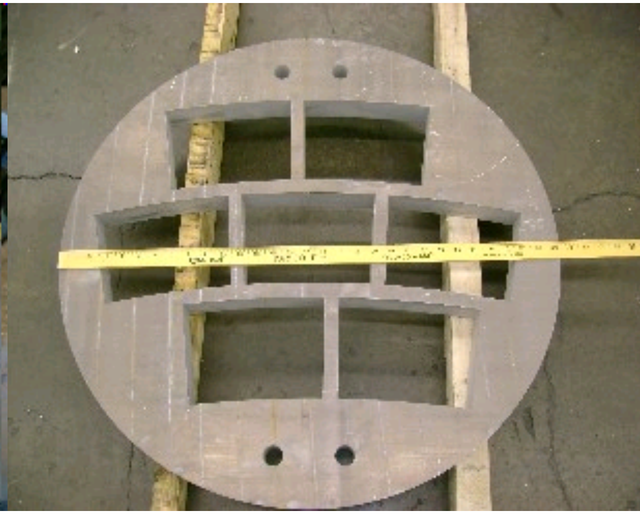
Back-up slides

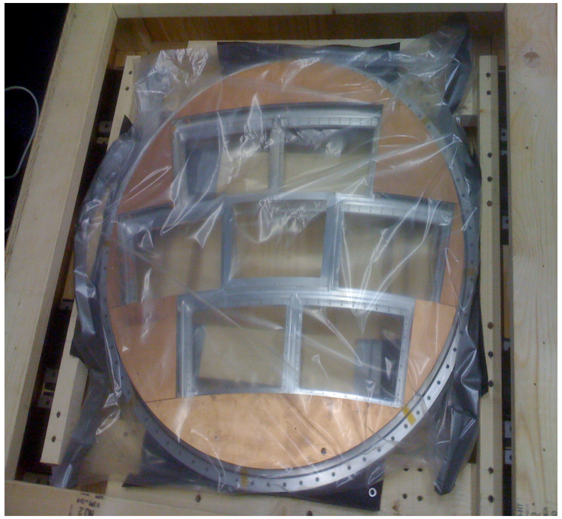
TPC Performance

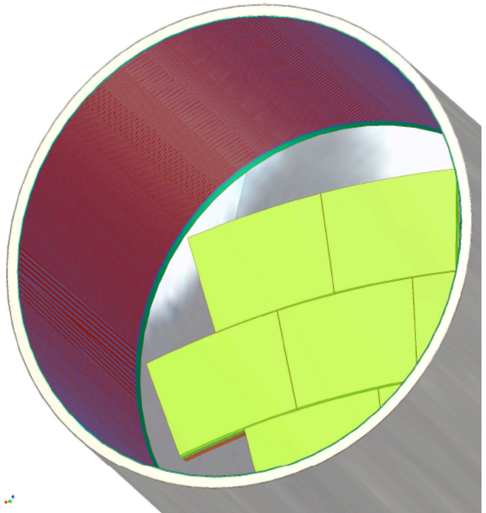
Size	$\phi = 3.6$m, L $= 4.3$m outside dimensions
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 9 \times 10^{-5}$/GeV/c TPC only ($\times$ 0.4 if IP incl.)
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 2 \times 10^{-5}$/GeV/c (SET+TPC+SIT+VTX)
Solid angle coverage	Up to $\cos\theta \simeq 0.98$ (10 pad rows)
TPC material budget	$\sim 0.04X_0$ to outer fieldcage in r
	$\sim 0.15X_0$ for readout endcaps in z
Number of pads/timebuckets	$\sim 1{\times}10^6/1000$ per endcap
Pad size/no.padrows	$\sim$ 1mm$\times$4–6mm/$\sim$200 (standard readout)
$\sigma_{\rm point}$ in $r\phi$	$< 100\mu$m (average over $L_{sensitive}$, modulo track ϕ angle)
$\sigma_{\rm point}$ in rz	~ 0.5 mm (modulo track θ angle)
2-hit resolution in $r\phi$	~ 2 mm (modulo track angles)
2-hit resolution in rz	~ 6 mm (modulo track angles)
dE/dx resolution	~ 5 %
Performance	$> 97\%$ efficiency for TPC only ($p_t > 1$GeV/c), and
	$> 99\%$ all tracking ($p_t > 1$GeV/c) [82]
Background robustness	Full efficiency with 1% occupancy,
	simulated for example in Fig. 4.3-4(right)
Background safety factor	Chamber will be prepared for 10 $\times$ worse backgrounds
	at the linear collider start-up

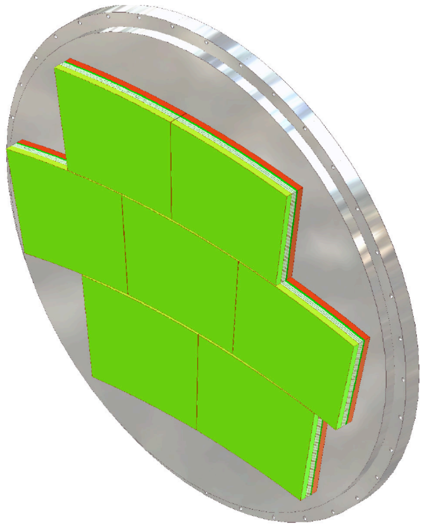
LP-TPC Endplate



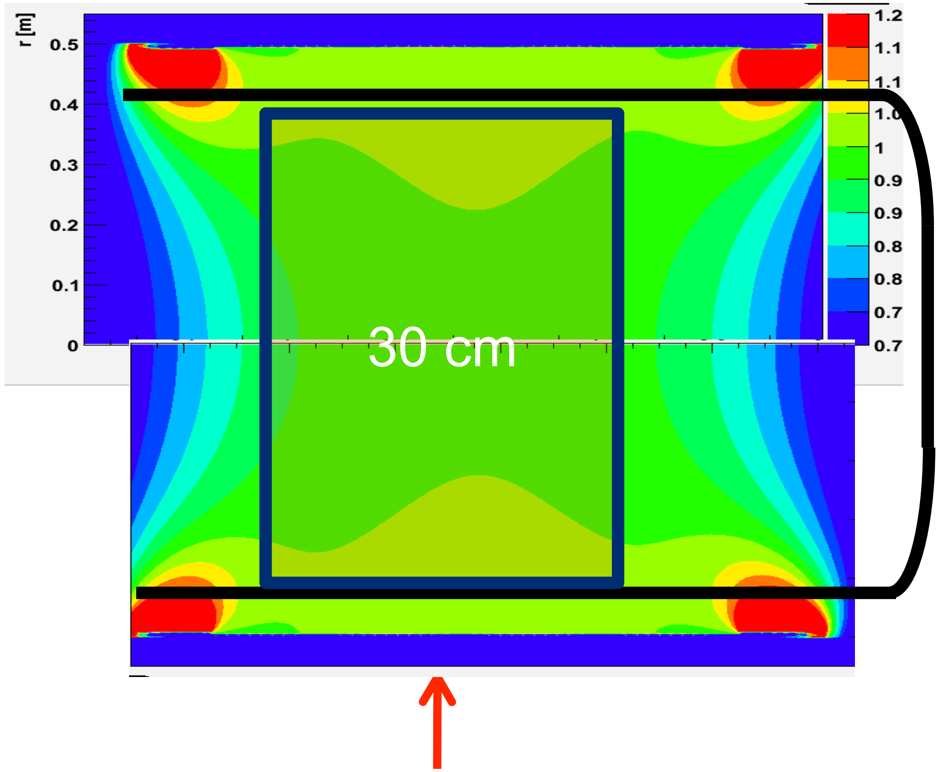




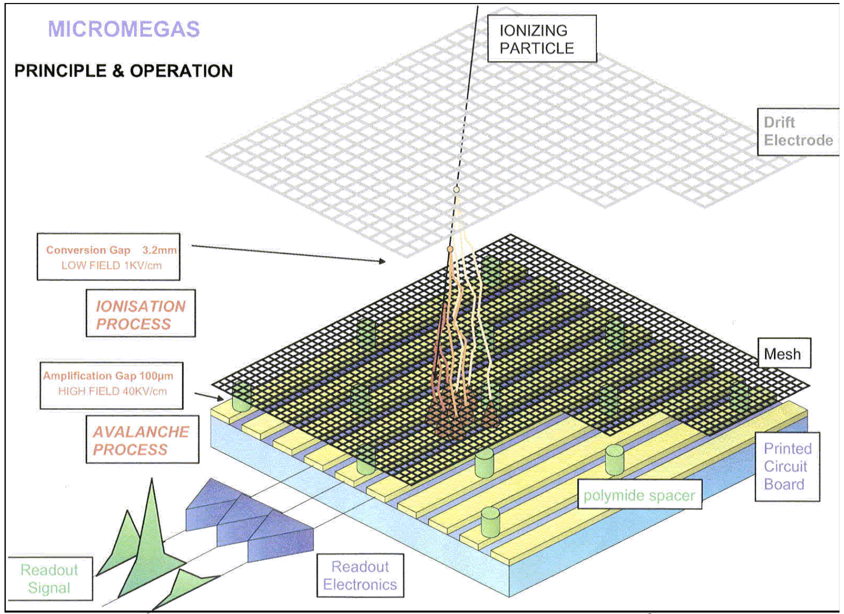


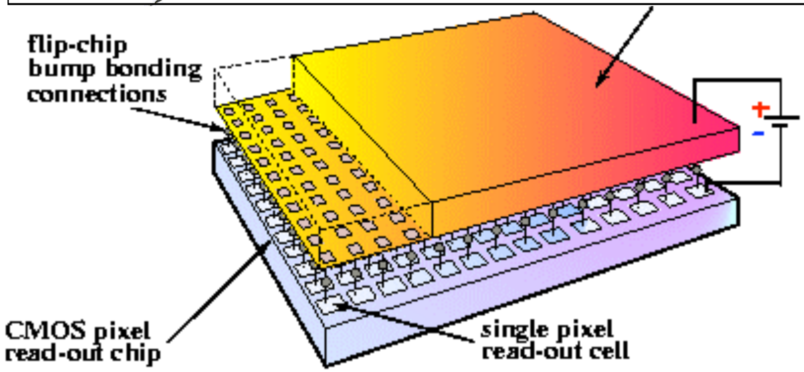


B field



TimePix





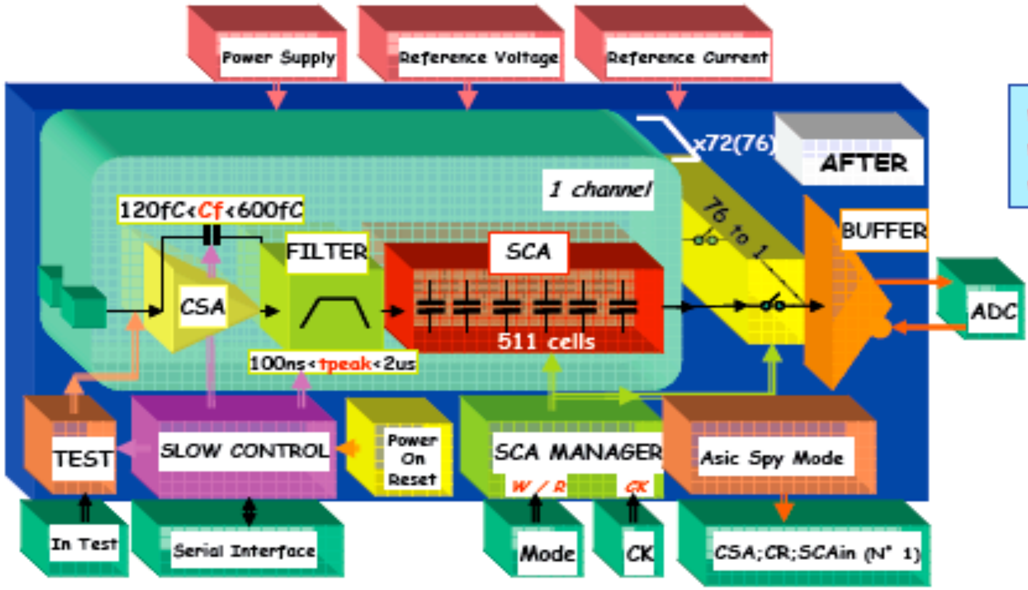
High field created by Gas Gain Grids
Most popular: GEM and Micromegas

Use 'naked' CMOS pixel readout chip as anode

J. Timmermans
NIKHEF

Readout Electronics: AFTER

AFTER Main Features



- No zero suppress.
- No auto triggering.
- No selective readout.

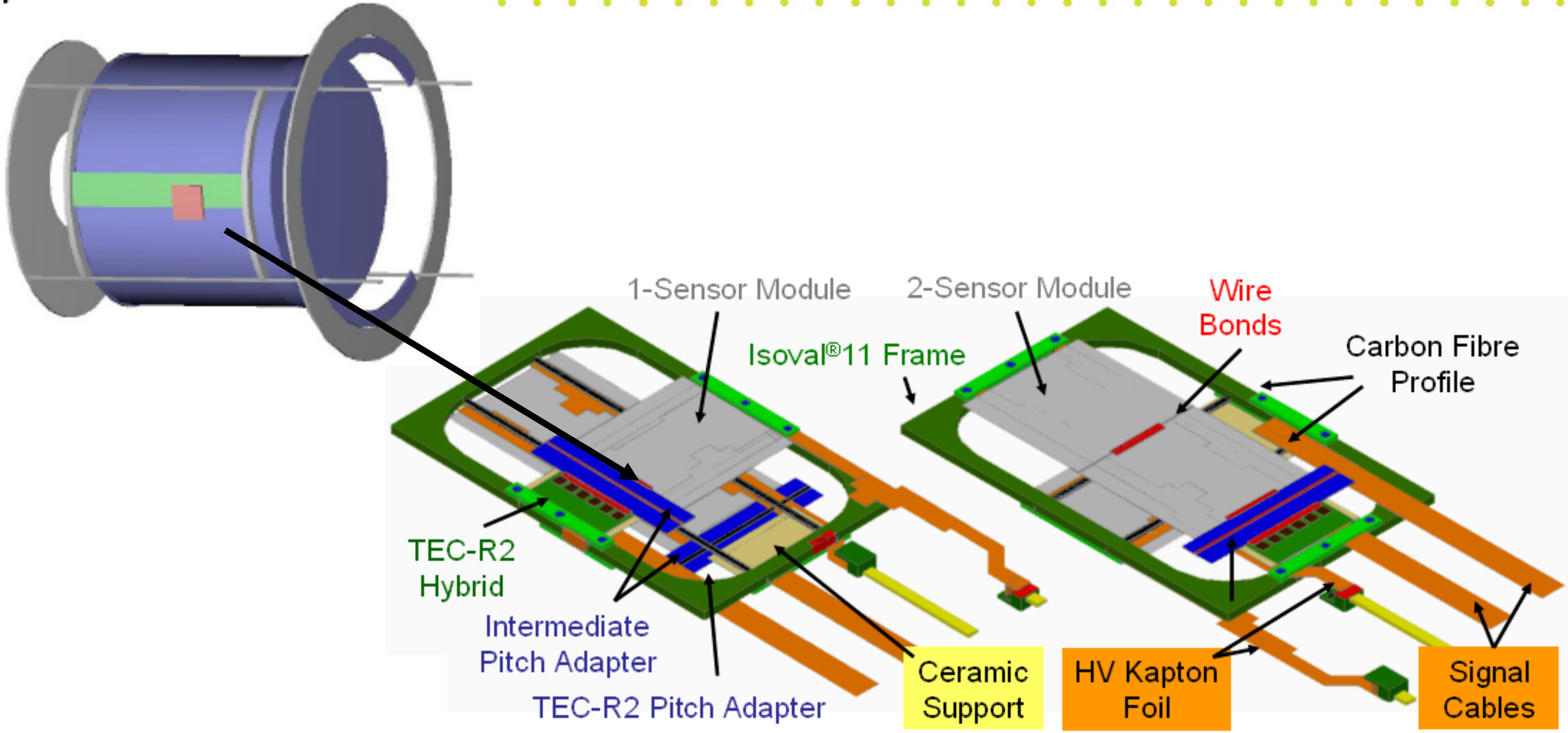
Main features:

- **Input Current Polarity:** positive **or** negative
- **72** Analog Channels
- **4** Gains: 120fC, 240fC, 360fC & 600fC
- **16** Peaking Time values: (100ns to 2µs)
- **511 analog memory cells / Channel:** Fwrite: 1MHz-50MHz; Fread: 20MHz

- **Slow Control**
- **Power on reset**
- **Test mode:** calibration or test **[channel/channel]** functional **[72 channels in one step]**
- **Spy mode on channel 1:** CSA, CR or filter out

LCTPC meeting Oct. 10, 2007 E. DELAGNES 4

Si Envelope



1-Sensor Module
2-Sensor Module
Wire Bonds
Carbon Fibre Profile
Isoval®11 Frame
TEC-R2 Hybrid
Intermediate Pitch Adapter
TEC-R2 Pitch Adapter
Ceramic Support
HV Kapton Foil
Signal Cables