# A Large TPC Prototype at DESY

**Klaus Dehmelt**

**DESY**

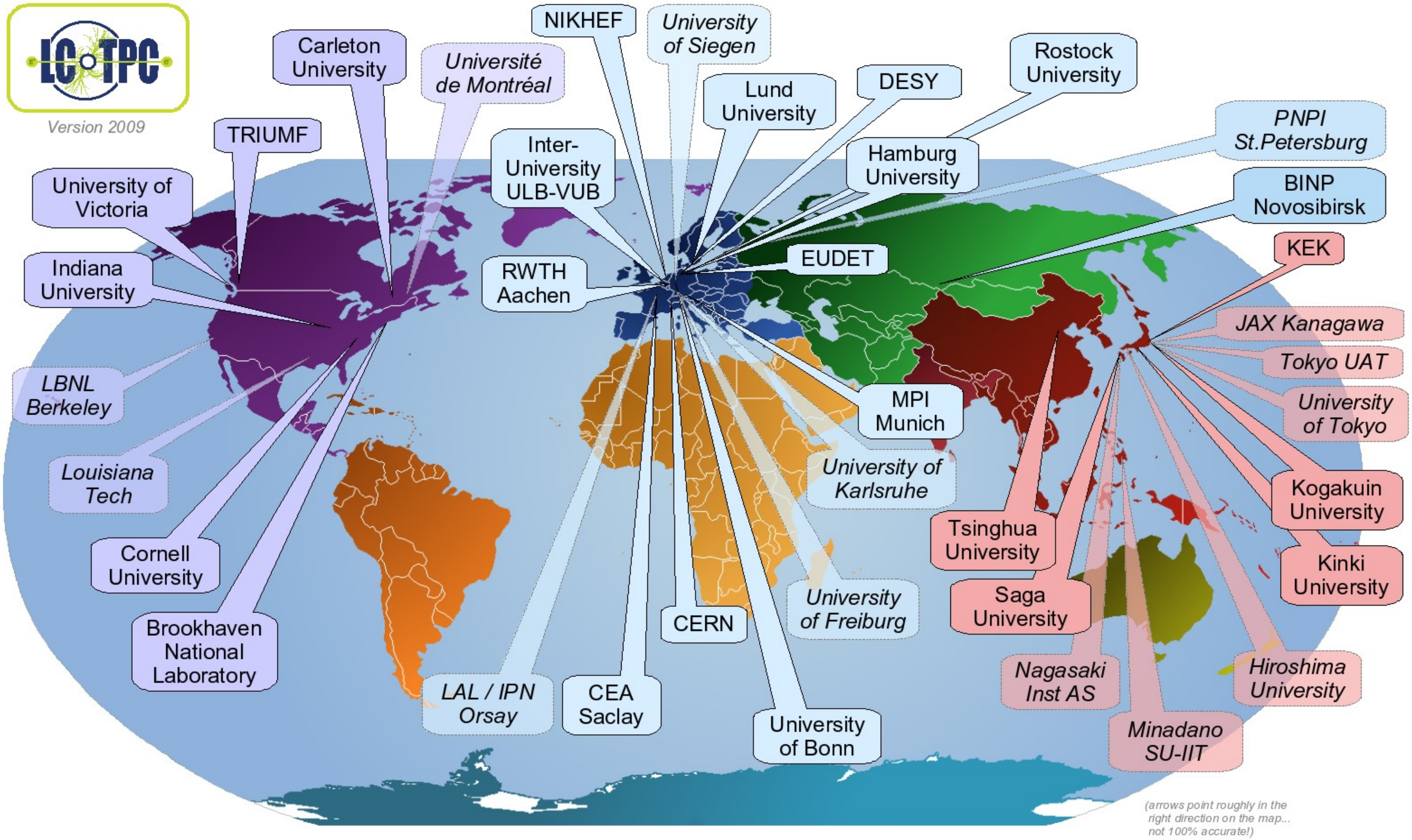
**On behalf of the LCTPC Collaboration**

***ALCPG09***

**Albuquerque, New Mexico, USA**

**Sept 30, 2009**

# LCTPC Collaboration



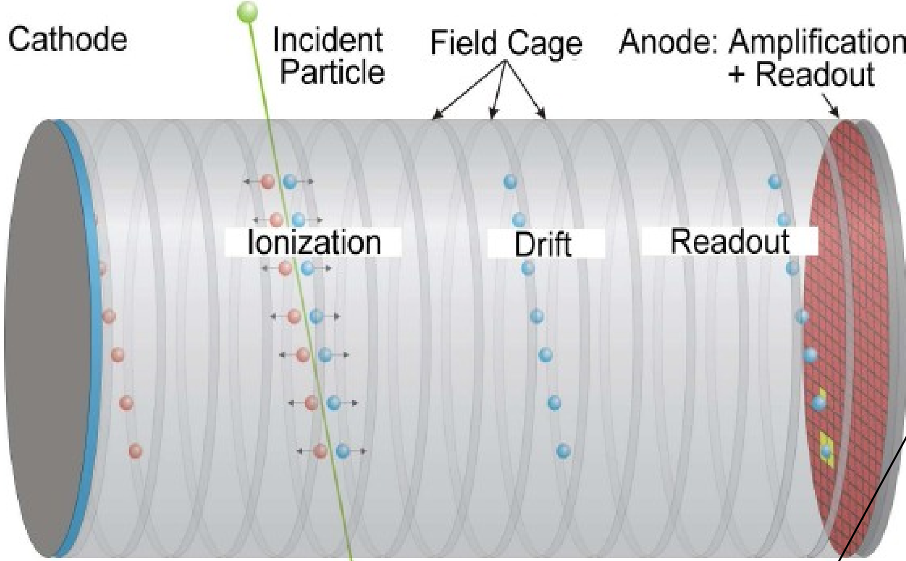
# LCTPC Collaboration

- Performance goals and design parameters for a TPC with standard electronics at the ILC detector

| | |
|---|---|
| Size | $\phi = 3.6$m, L = 4.3m 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 | $\sim 1\times10^6$/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 $\phi$ angle) |
| $\sigma_{\rm point}$ in $rz$ | $\sim$ 0.5 mm (modulo track $\theta$ angle) |
| 2-hit resolution in $r\phi$ | $\sim$ 2 mm (modulo track angles) |
| 2-hit resolution in $rz$ | $\sim$ 6 mm (modulo track angles) |
| dE/dx resolution | $\sim$ 5 % |
| Performance | > 97% efficiency for TPC only ($p_t$ > 1GeV/c), and |
| | > 99% all tracking ($p_t$ > 1GeV/c) |
| Background robustness | Full efficiency with 1% occupancy |
| Background safety factor | Chamber will be prepared for 10 $\times$ worse backgrounds at the linear collider start-up |

with MPGD

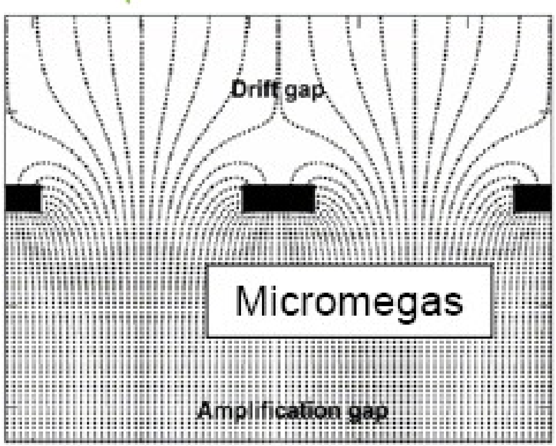
# TPC with MPGD



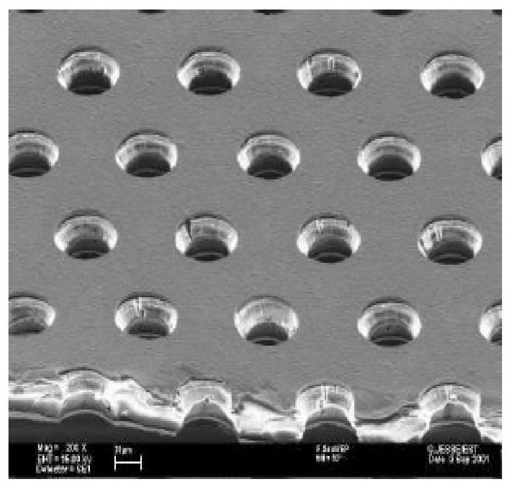

**MicroPatternGasDetector**

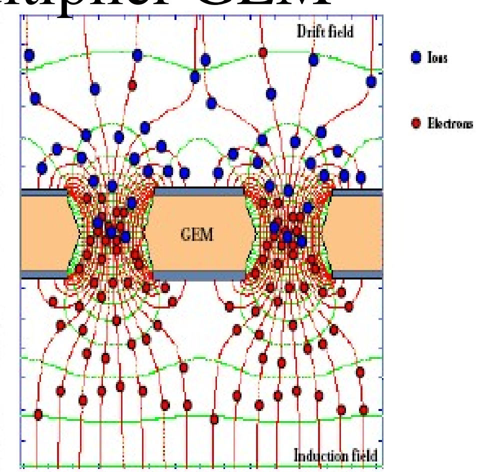
**MPGD**

not limited by **E** x **B** effects

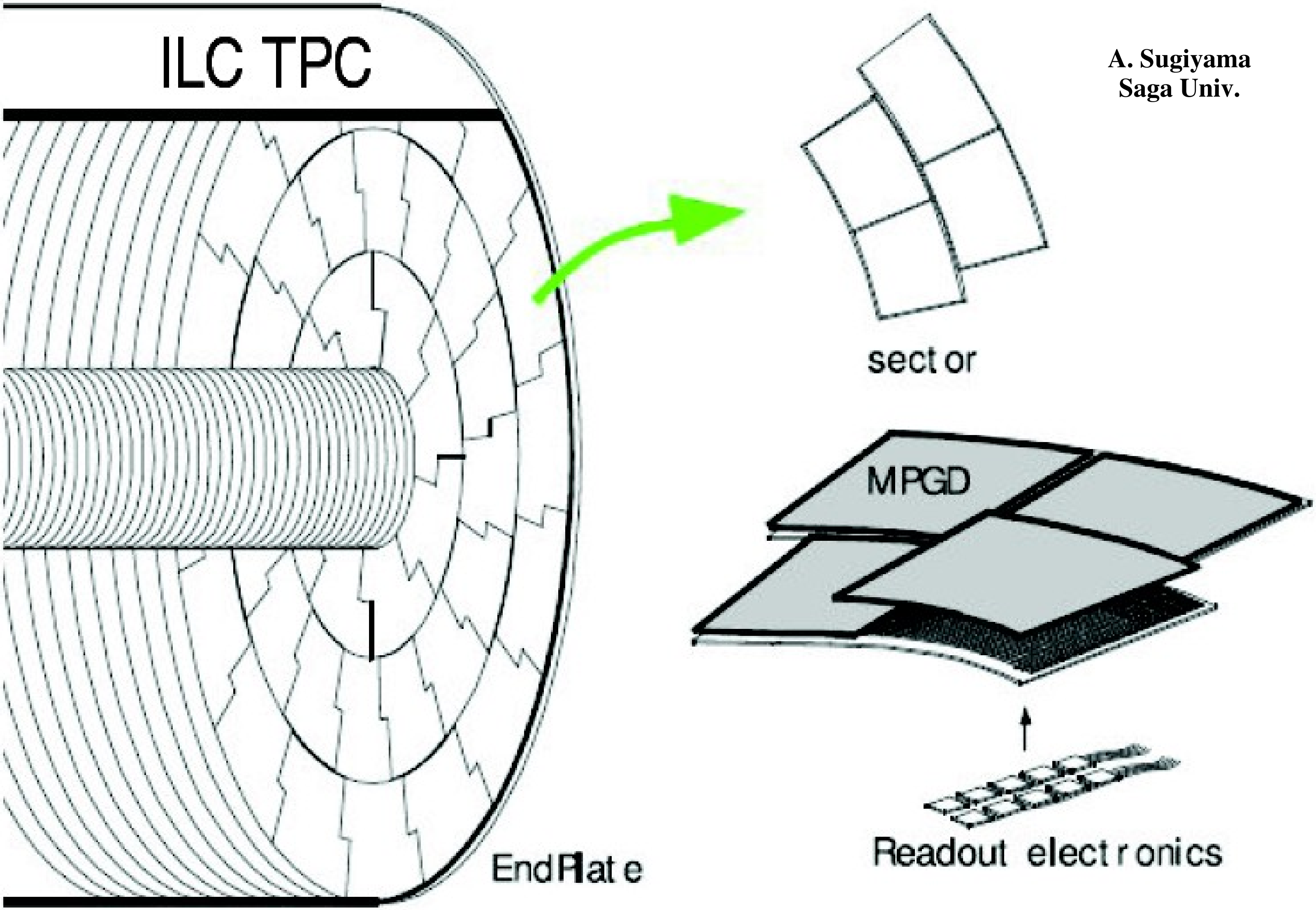



Gas Electron Multiplier GEM



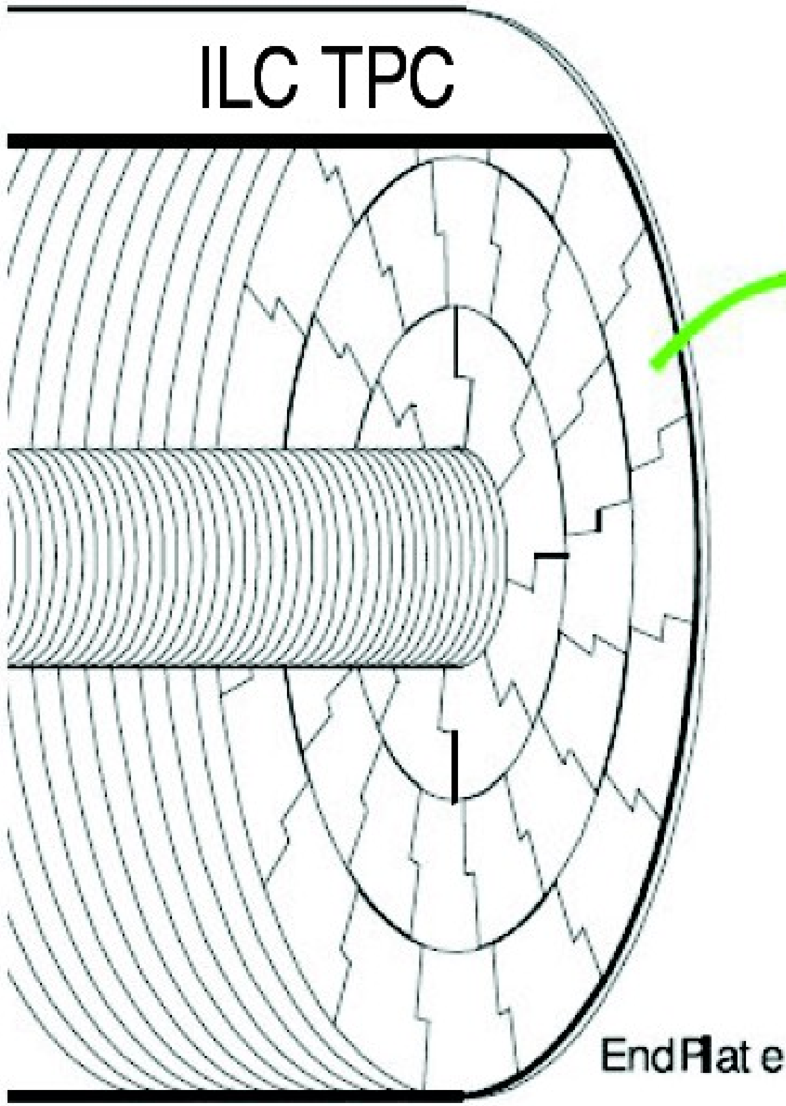


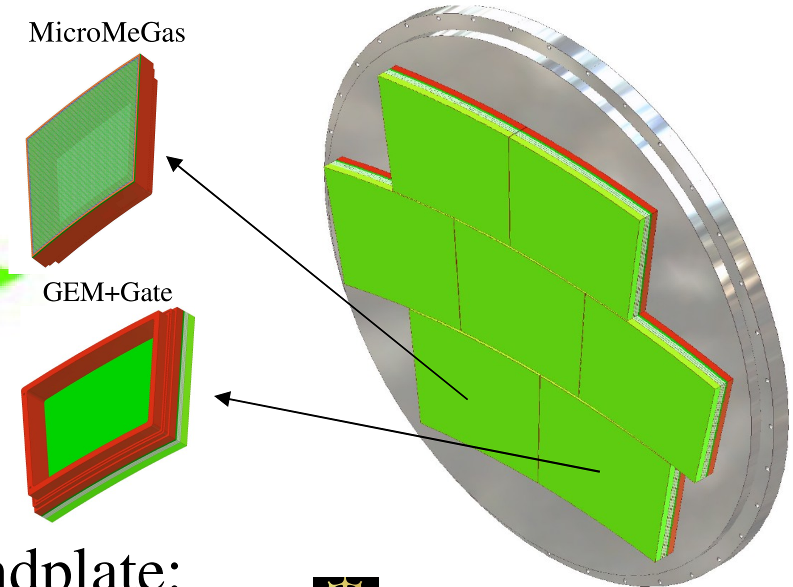
# TPC with MPGD




A. Sugiyama
Saga Univ.

# TPC with MPGD



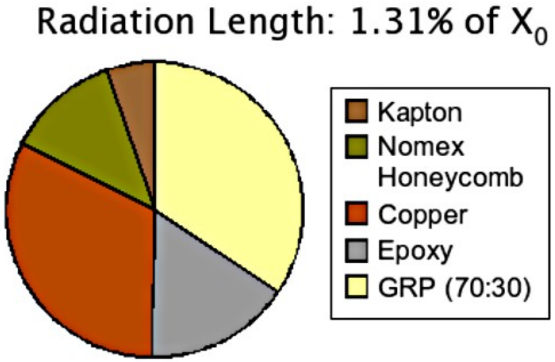



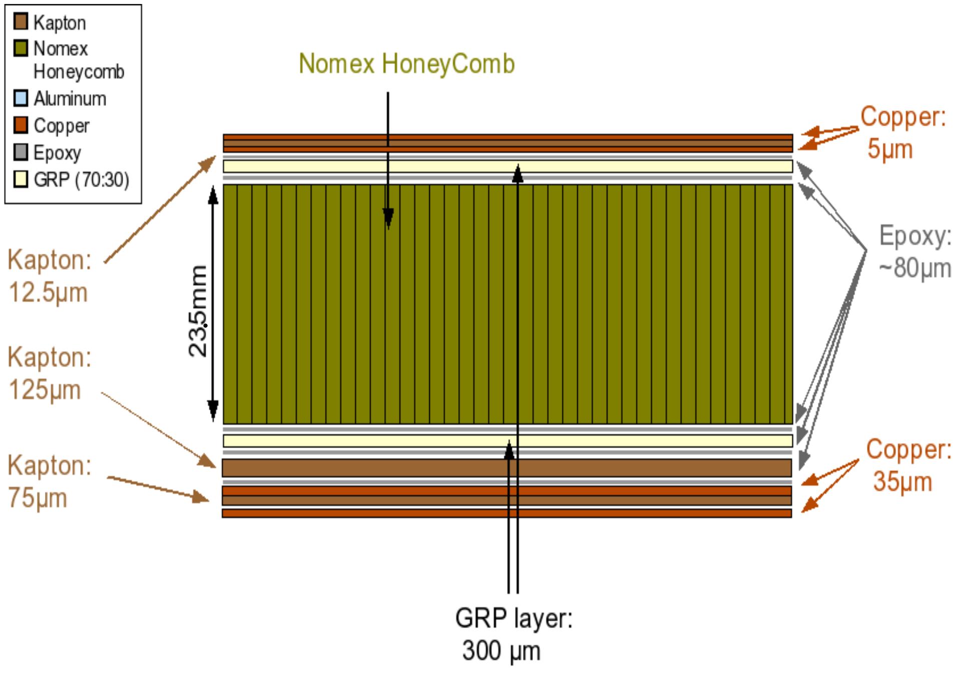

D. Peterson, Cornell

<u>Endplate</u>:

- Aluminum
- Accommodates seven detector/ dummy modules
- $d = d_{outer,FC} = 770$ mm
- Modules have same shape → interchangeable

# LP-TPC Field Cage (FC)



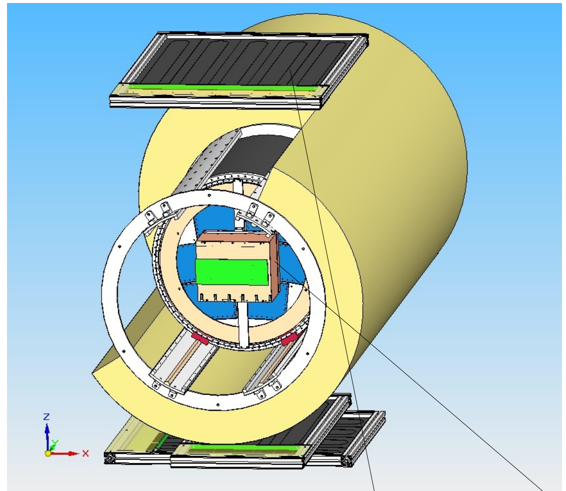




Diameter: Inner 720 mm, Outer 770 mm
Wall thickness 25 mm
Length 610 mm
HV to be applied: up to 20 kV

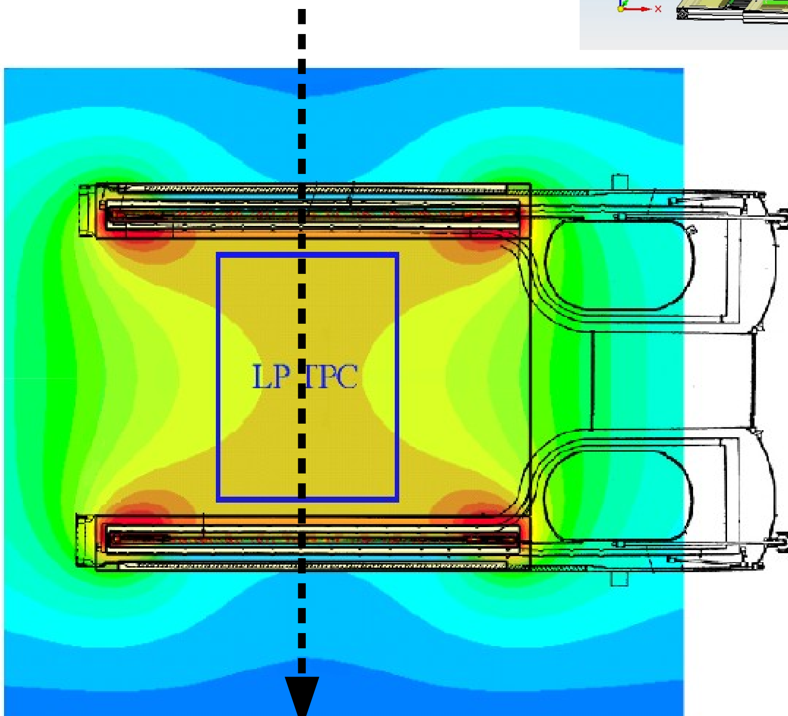
# DESY Setup

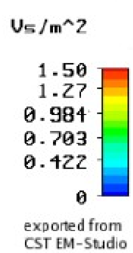
*PCMAG:* superconducting magnet, up to 1.25 T

- *e*⁻ test beam @DESY (1GeV/c<p<6GeV/c)

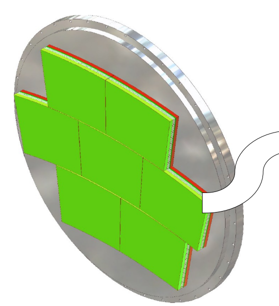


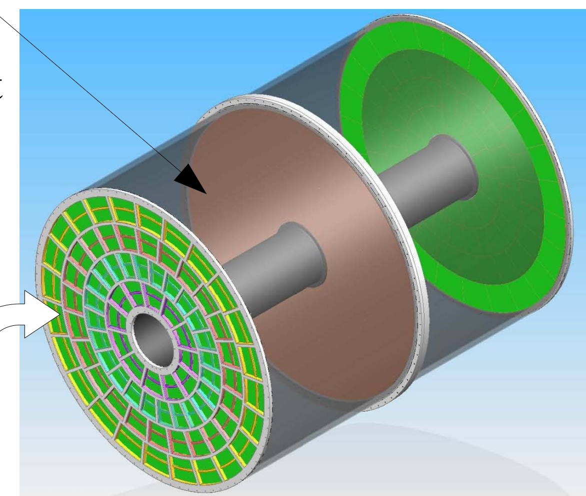
Cosmic Trigger Setup



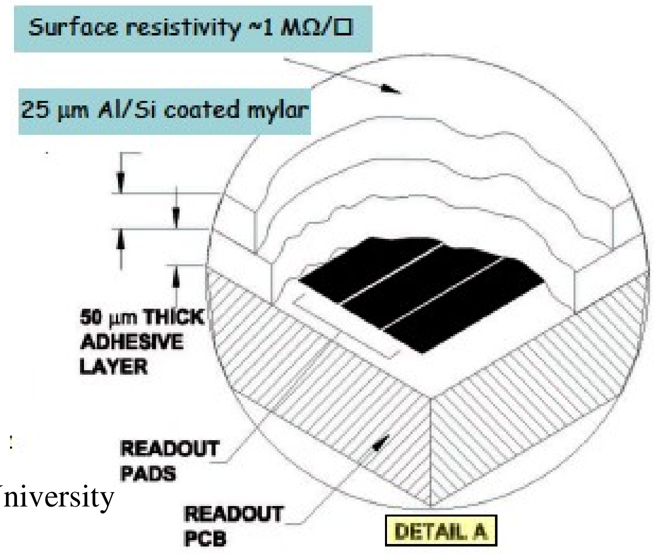

LP as half part of a TPC





# MicroMeGaS Structure

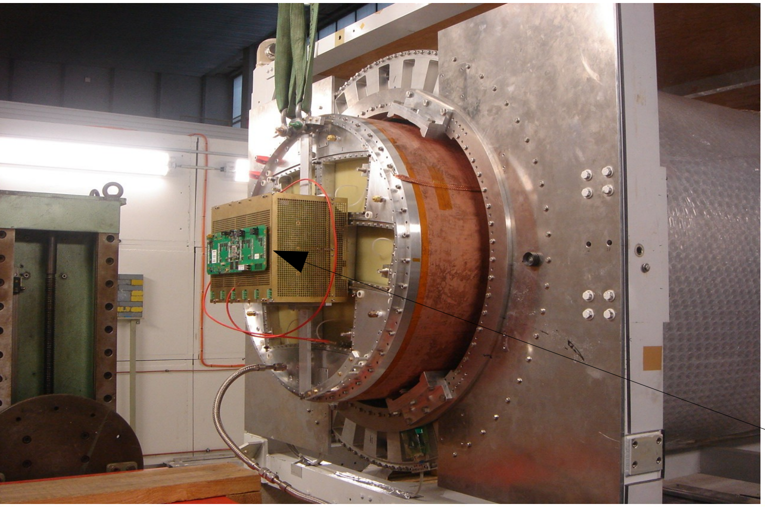
‘Bulk Micromegas’ panels, without resistive foil and with resistive carbon-loaded kapton, have been produced at CERN (Rui de Oliveira)

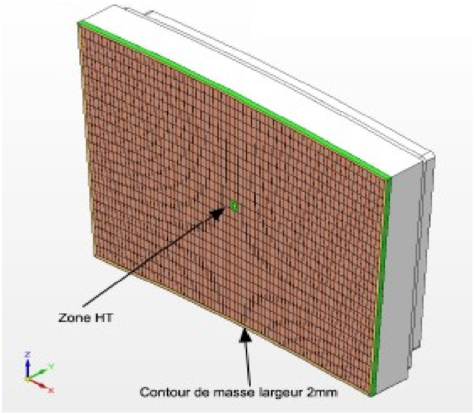



P. Colas, CEA Saclay
M.S.Dixit, Carleton University

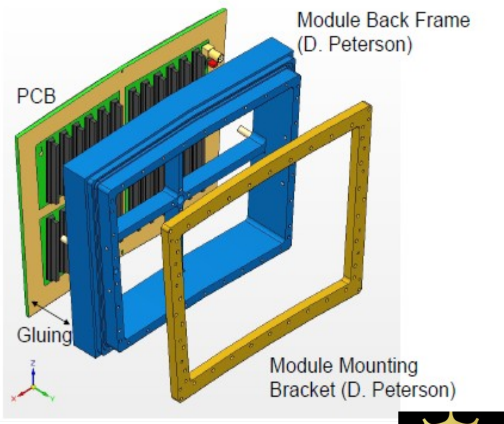
MicroMeGaS for LP:

**24 rows x 72 pads**
**Av. Pad size: 3.2 x 7mm²**






Detector side




Readout electronics: AFTER (T2K TPC)

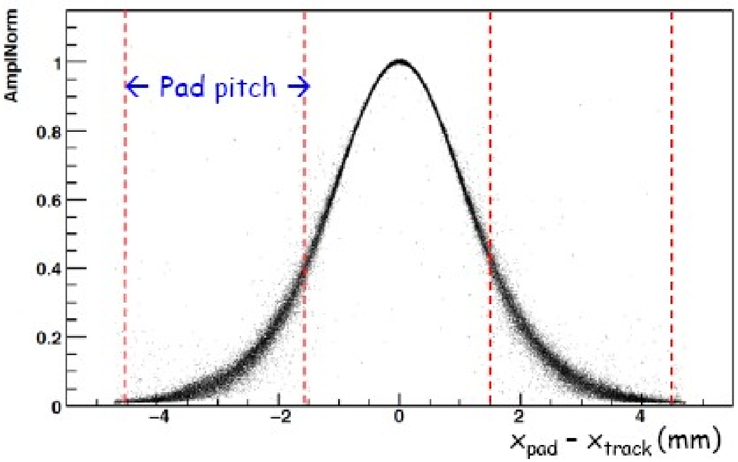
# MicroMeGaS Structure



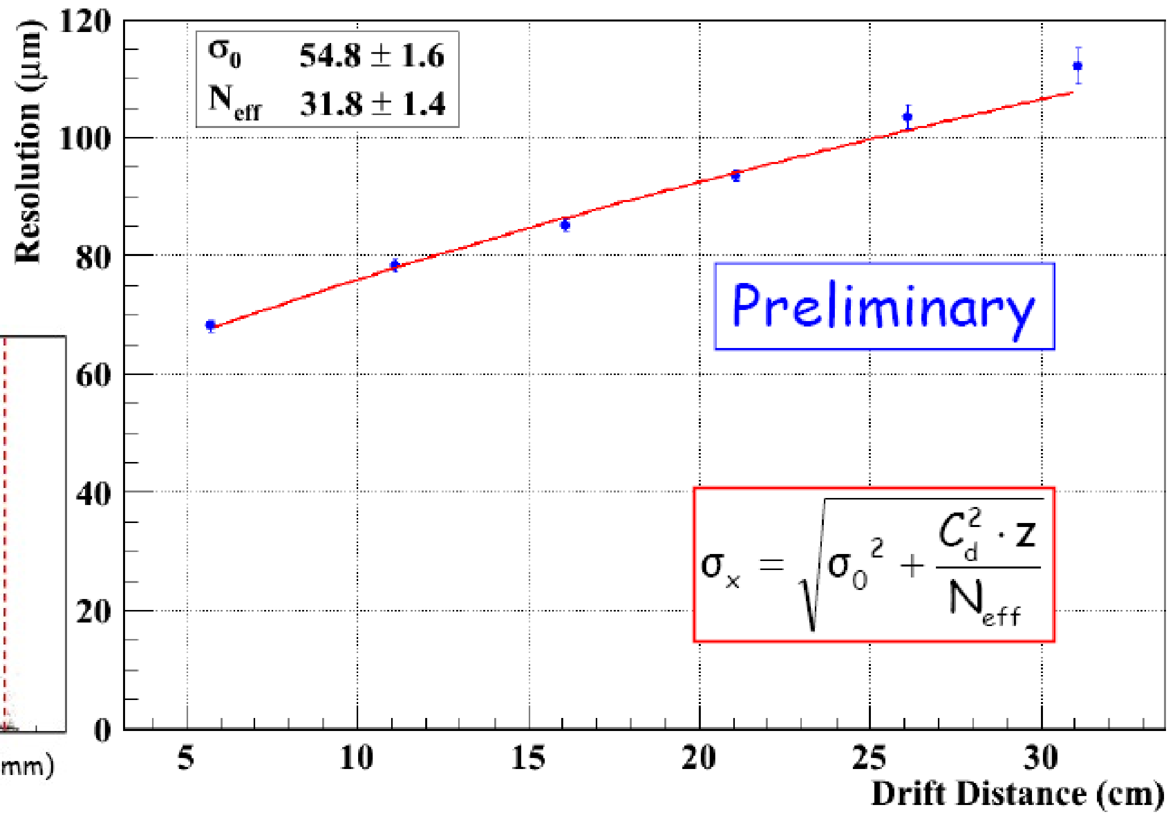
## Electrons (5 GeV), Magnetic field (B=1T)

- Fraction of the row charge on a pad vs $x_{pad} - x_{track}$ (normalized to central pad charge)

→Clearly shows charge spreading over 2-3 pads (data with 500 ns shaping)



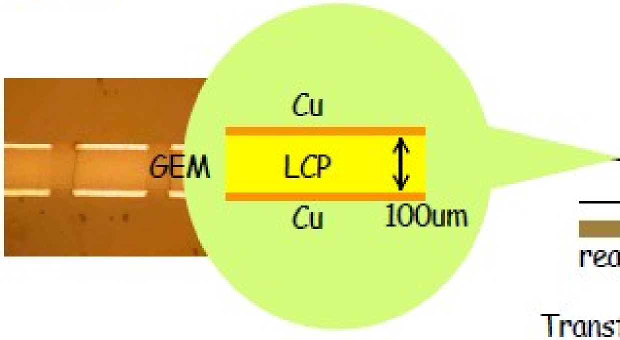

- Resolution at z=0: $\sigma_0$ = 54.8±1.6 μm with 2.7-3.2 mm pads ($w_{pad}$/55)
- Effective number of electrons: $N_{eff}$ = 31.8±1.4 consistent with expectations



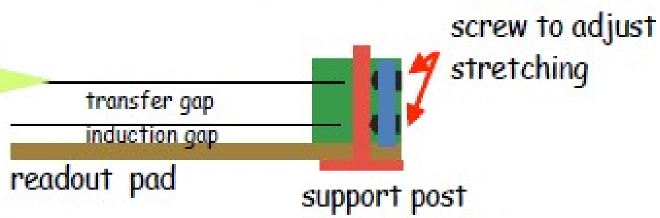

P. Colas, CEA Saclay

# Double GEM Structure

**GEMs**

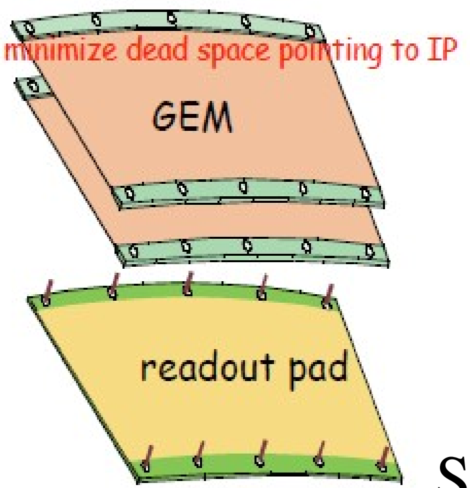


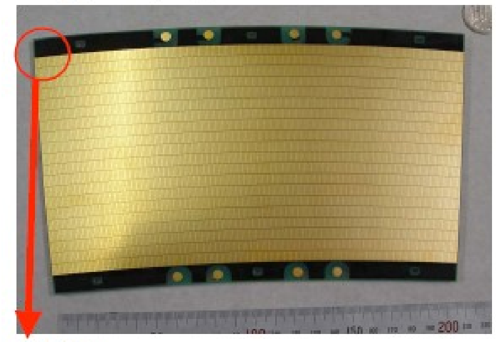

mounting(stretch) mechanism




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

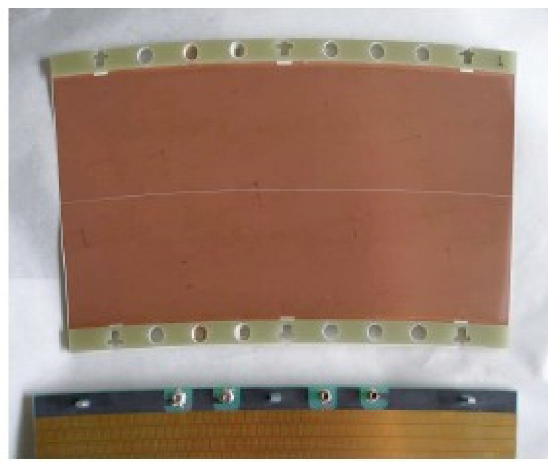
frame : top & bottom frame.
no side frame

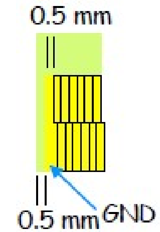


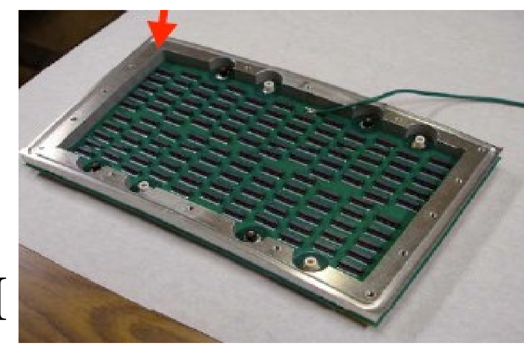
28 pad raws (176/192 pads/raw)
~1.2(w) x 5.4(h) $mm^2$
staggered every each layer

Total 5,152 ch/module





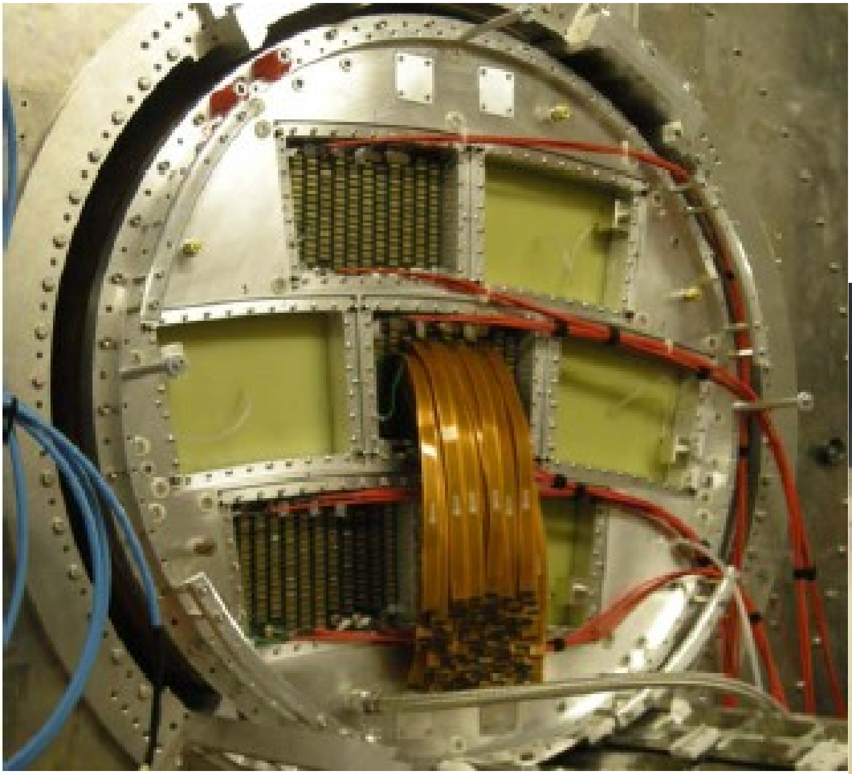

6 layers PCB
one GND layer



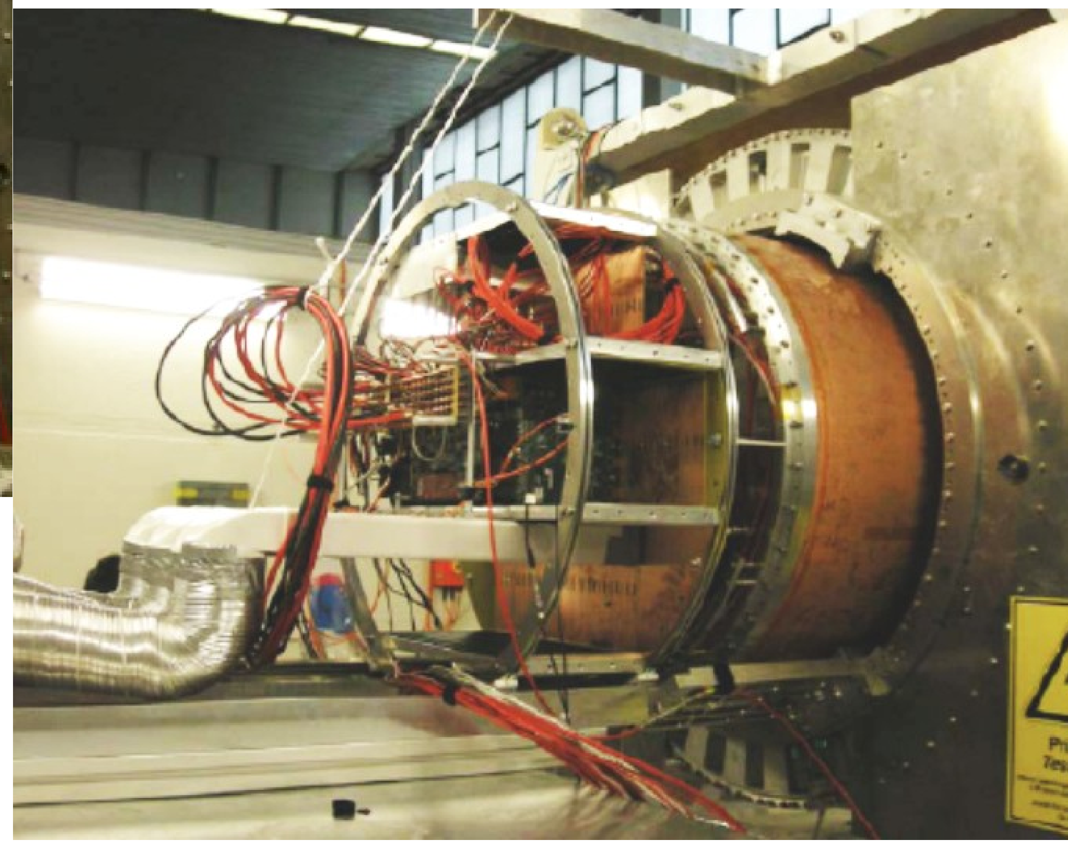
Setup planned w/ gating GEM

A. Sugiyama, Saga Univ.

# Double GEM Structure



About 3200 channels readout electronics



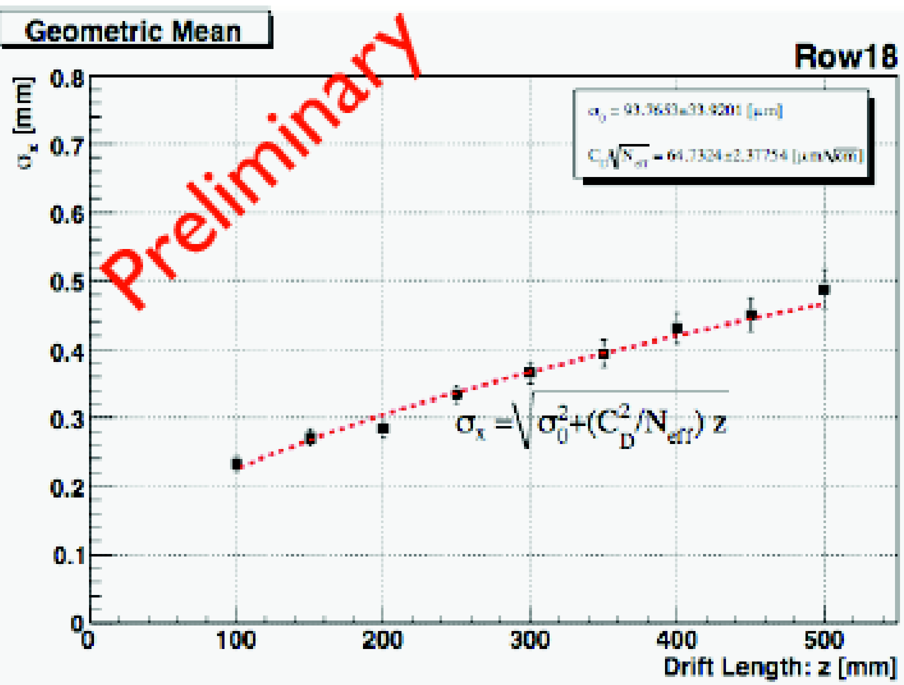
Readout electronics:
Based on ALTRO (ALICE TPC)
L. Joensson, LUND University

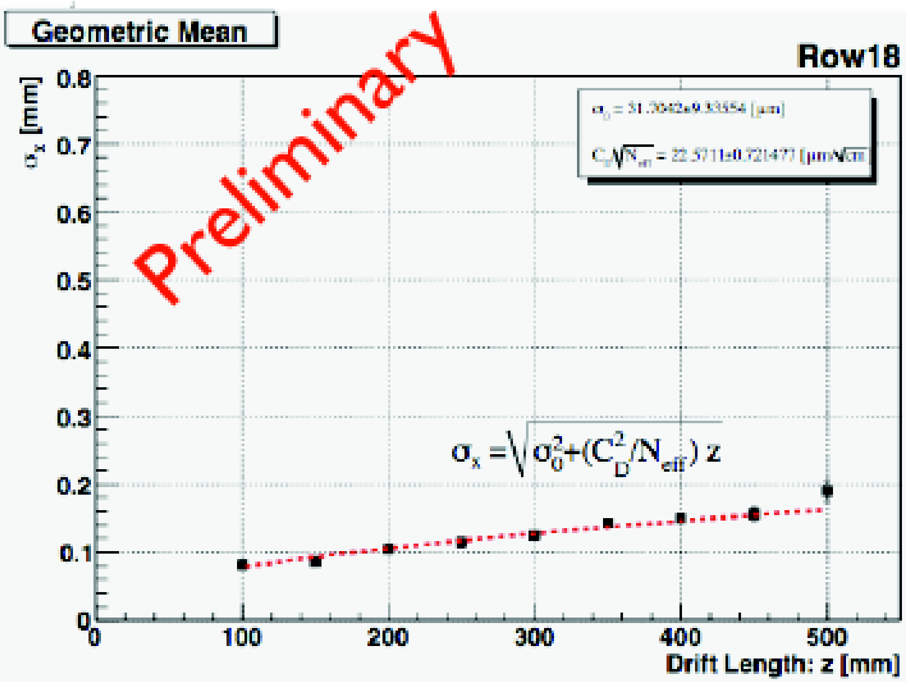
# Double GEM Structure



## Resolution as a function of drift distance

R. Yonanime, KEK




**B=0T**

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

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

Garfield

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

Result of MP-TPC
Neff = 21±2

**B=1T**

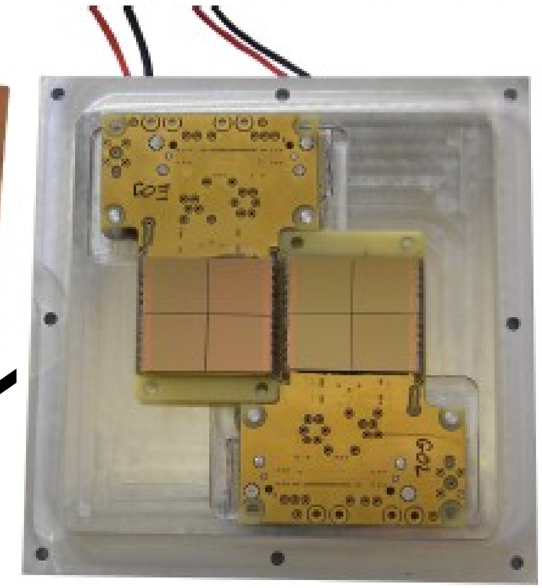
$$\begin{cases} C_D = 101.6 \pm 0.4 [\mu/\sqrt{cm}] \\ \dfrac{C_D}{\sqrt{N_{eff}}} = 22.6 \pm 0.7 [\mu m/\sqrt{cm}] \end{cases}$$

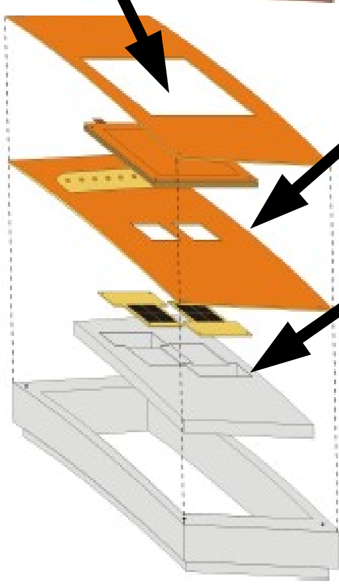
$$\longrightarrow N_{eff} \sim 20 \pm 1$$

Garfield

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

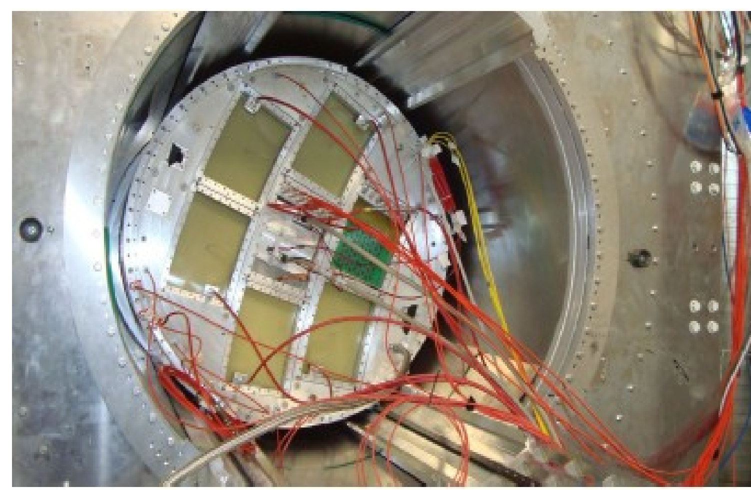
# 3-GEM Structure & TimePix






Readout:
2 quadboards
(4 TimePix
Chips each)

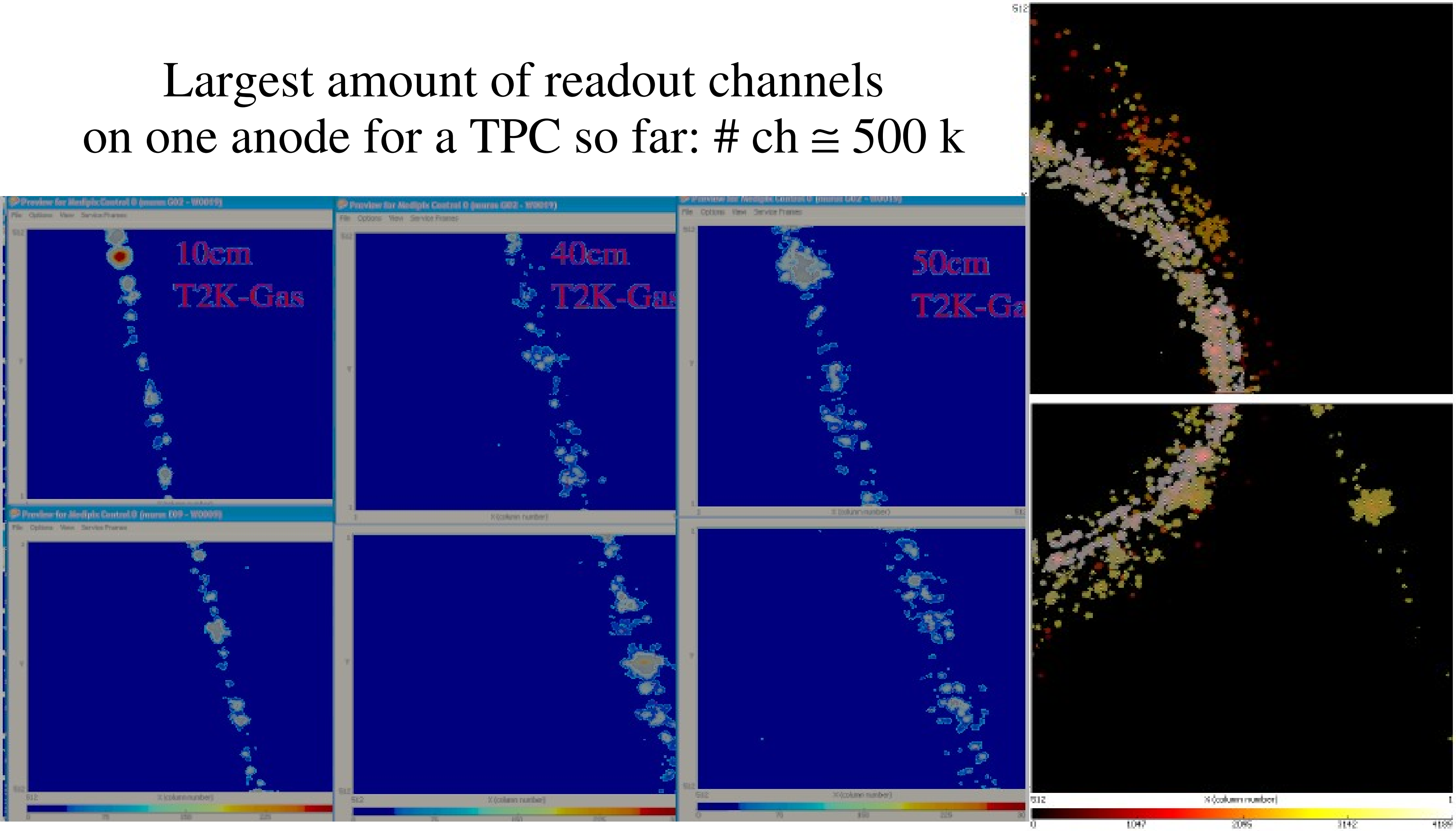
J. Kaminski, Univ. of Bonn



# 3-GEM Structure & TimePix

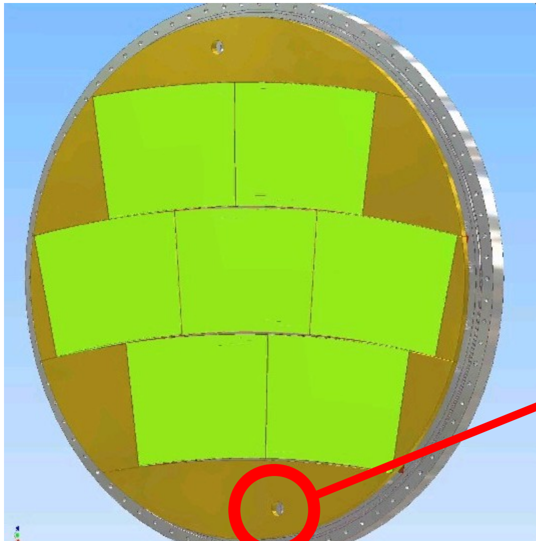


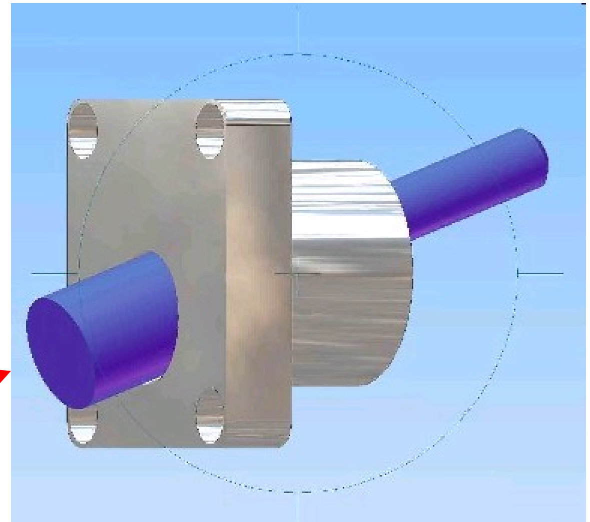
Largest amount of readout channels
on one anode for a TPC so far: # ch ≅ 500 k

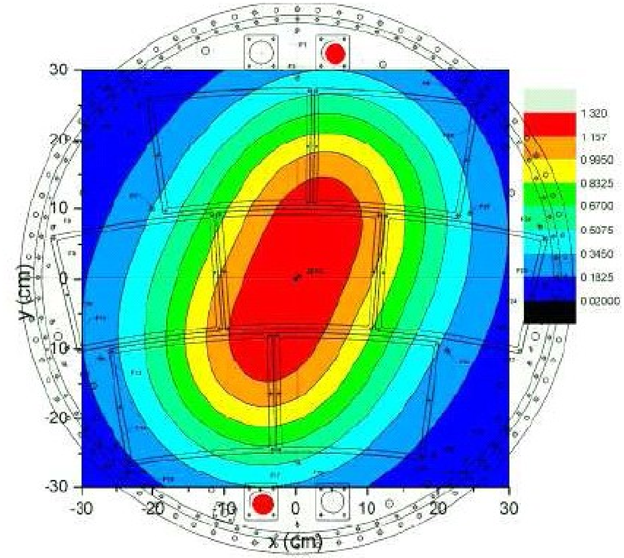



J. Kaminiski, Univ. of Bonn

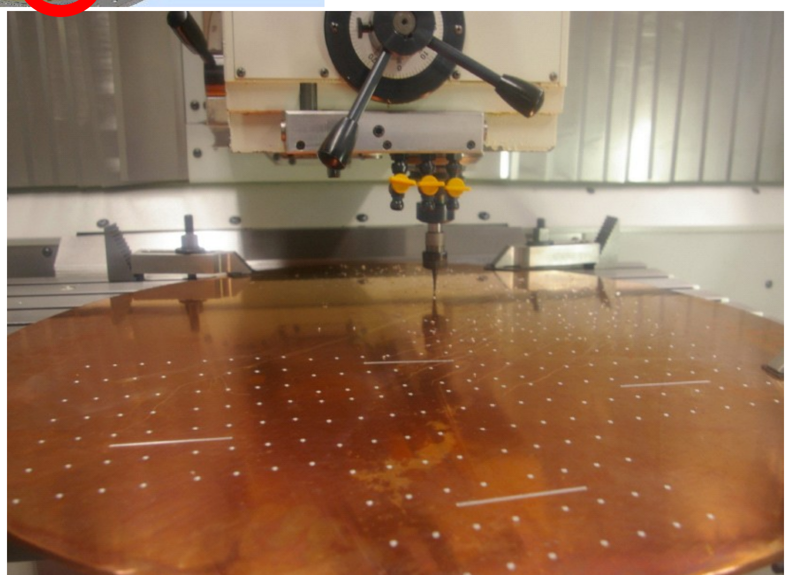
# Laser Calibration Setup



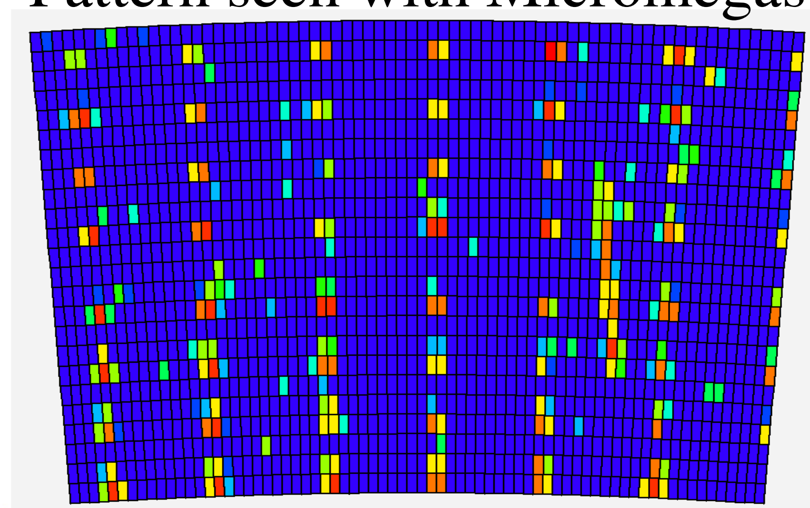




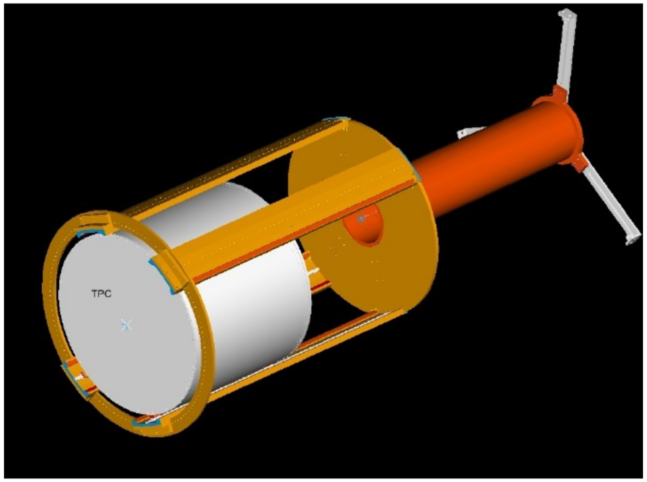

P. Conley
Victoria Univ.

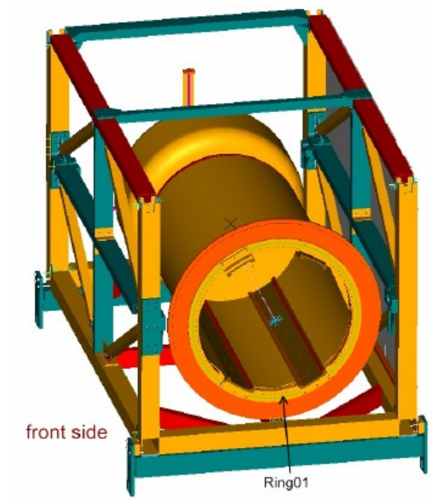


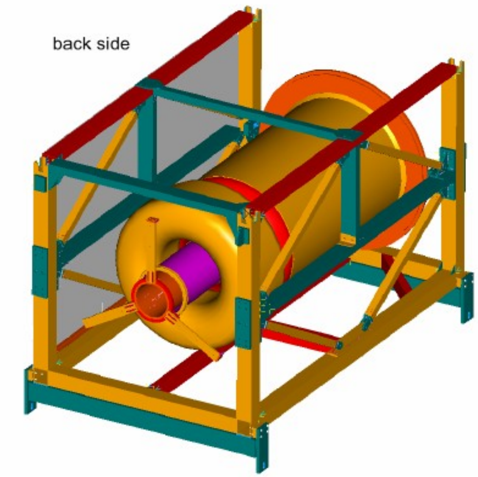
Pattern seen with Micromegas

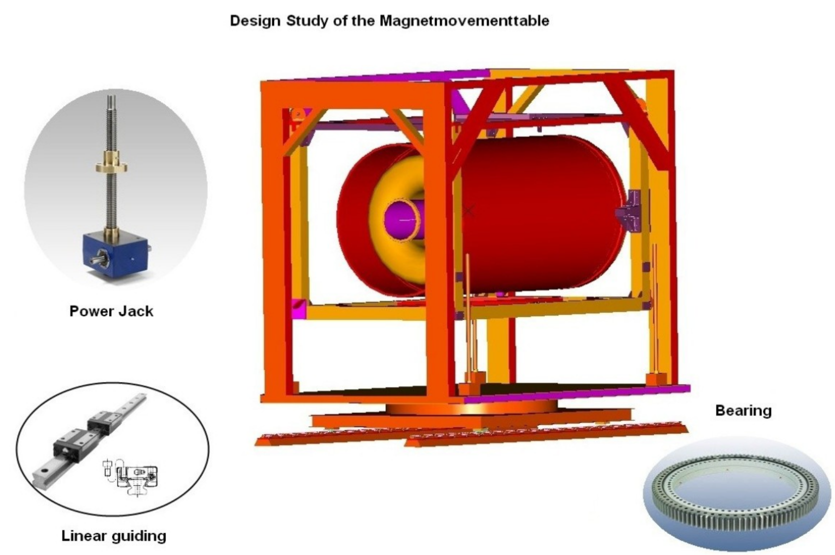


# LP Mechanics



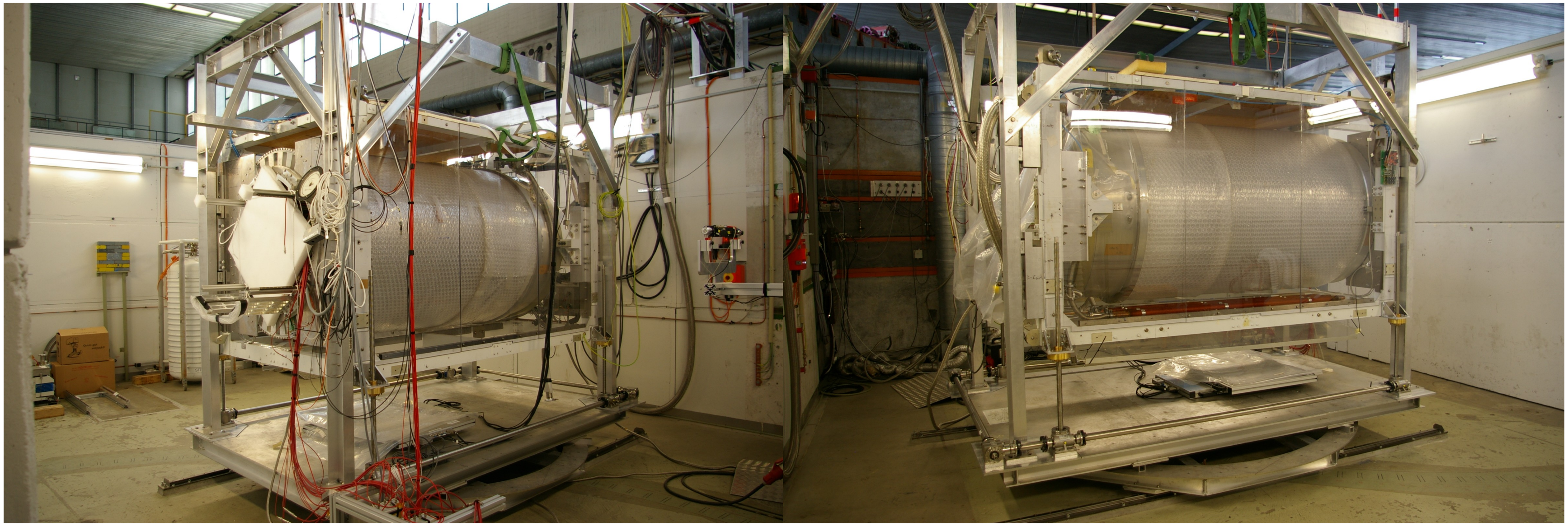




Support structures:

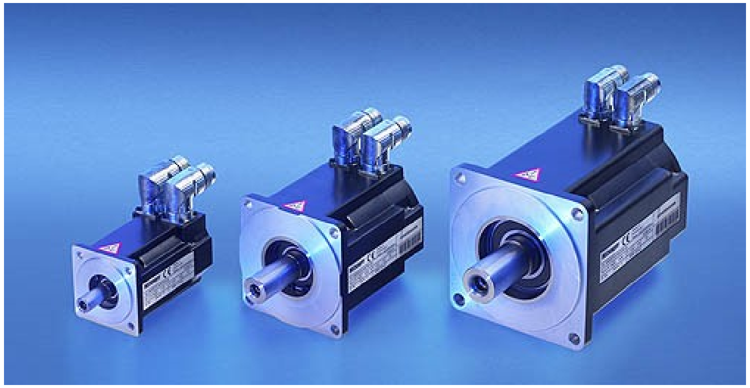
- TPC
- PCMAG

F. Hegner, V. Prahl, R. Volkenborn, DESY

# LP Mechanics



## Actuation and Control



# Standard CERN-GEM

10 x 10 $cm^2$
CERN GEM:

Flatness study

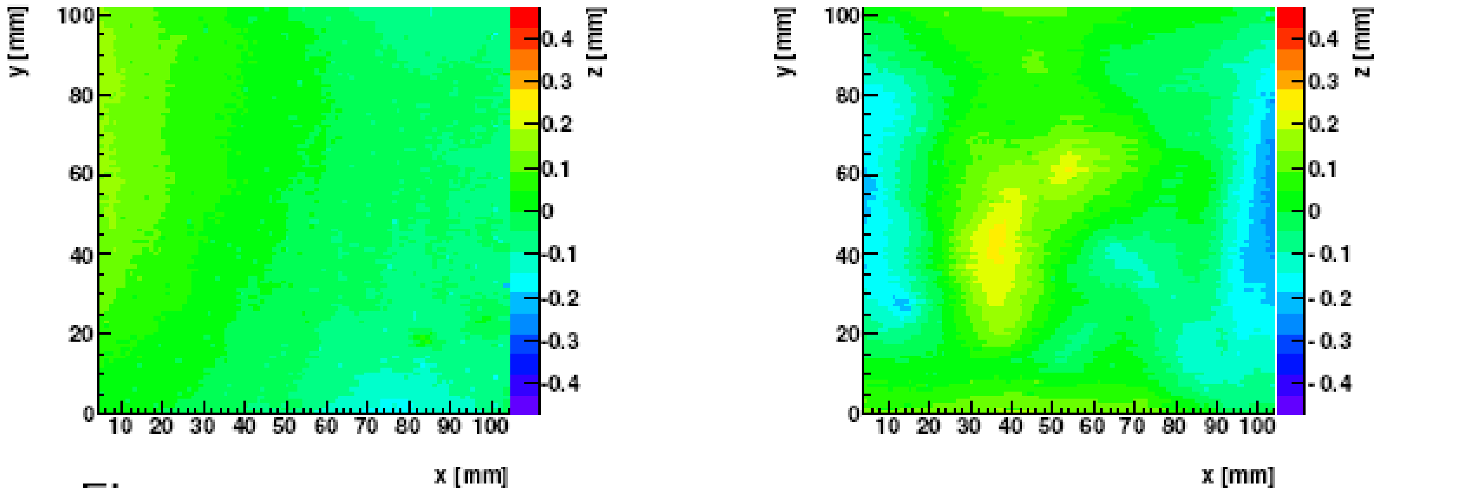



Figure: GEM 7 (Δz: 355 $\mu$m) - GEM 17 (Δz: 509 $\mu$m) - GRP frames

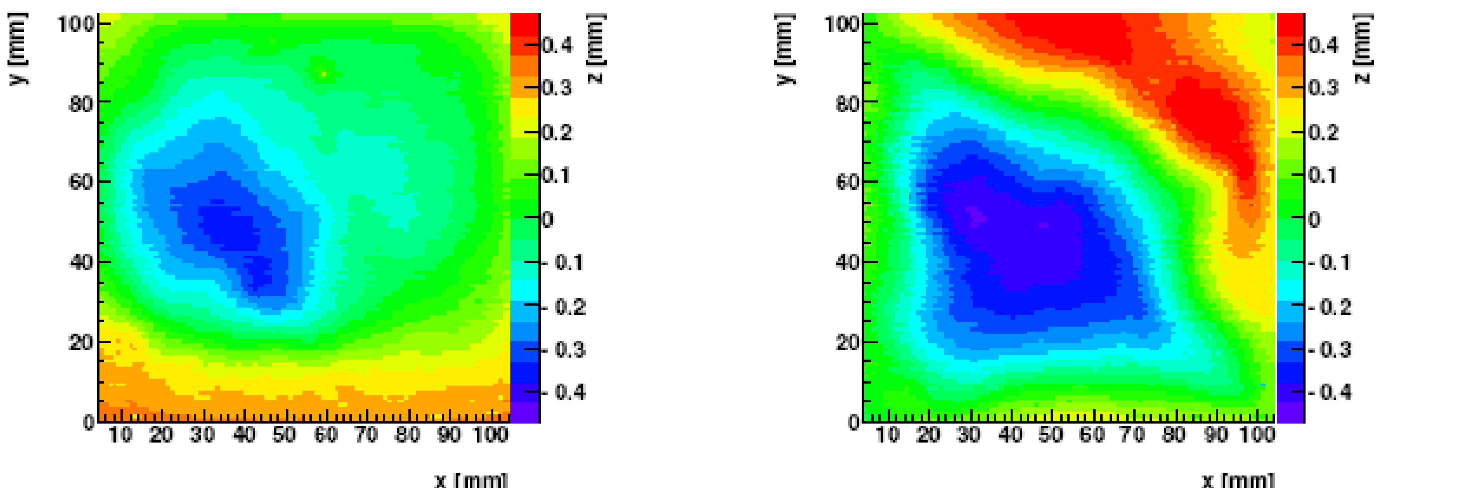


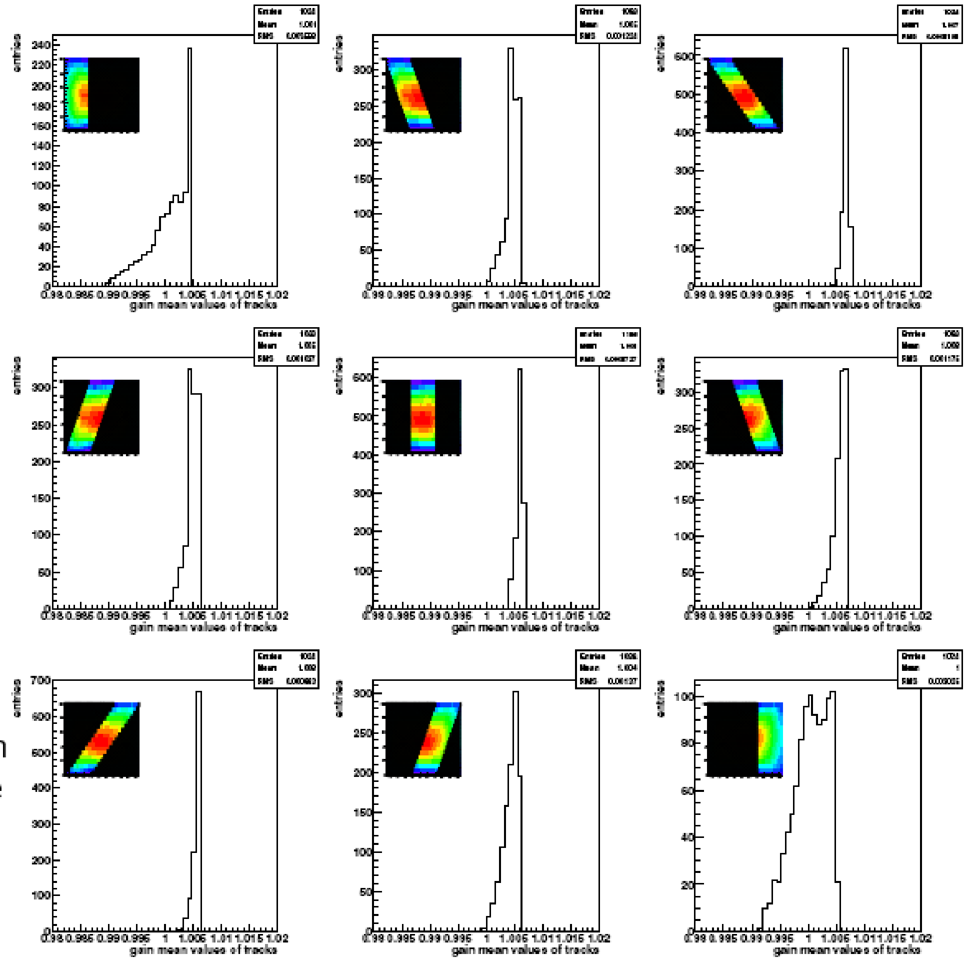

Figure: GEM 18 (Δz: 733 $\mu$m) - GEM 26 (Δz: 922 $\mu$m) - GRP frames

L. Hallermann, DESY

# Standard CERN-GEM

| region | mean value | RMS |
|---|---|---|
| left-left | 1.001 | 0.36 % |
| left-mid | 1.005 | 0.12 % |
| left-right | 1.007 | 0.05 % |
| mid-left | 1.005 | 0.10 % |
| mid-mid | 1.006 | 0.06 % |
| mid-right | 1.006 | 0.12 % |
| right-left | 1.006 | 0.07 % |
| right-mid | 1.004 | 0.14 % |
| right-right | 1.000 | 0.30 % |

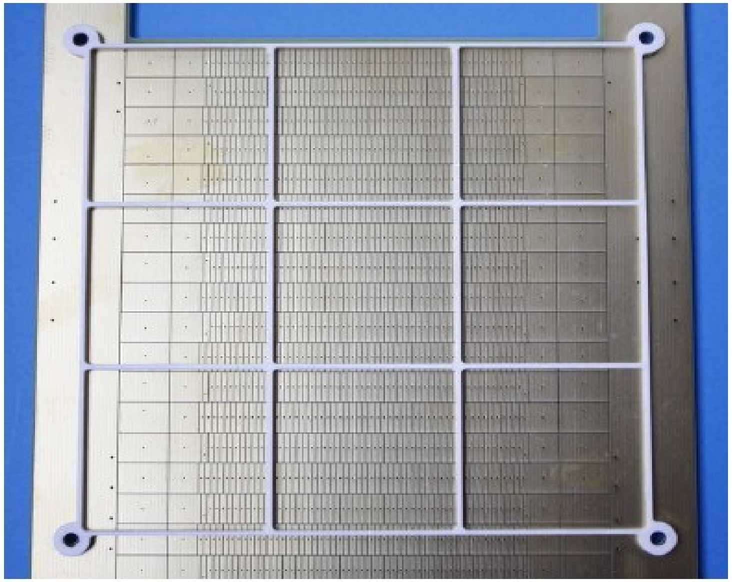
Table: Mean values and root mean squares of averaged track gains in different regions. The RMS represents the fluctuation of the effective gain corresponding to tracks within one region.

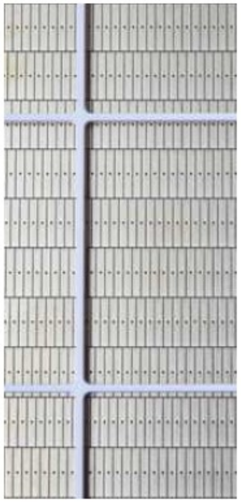


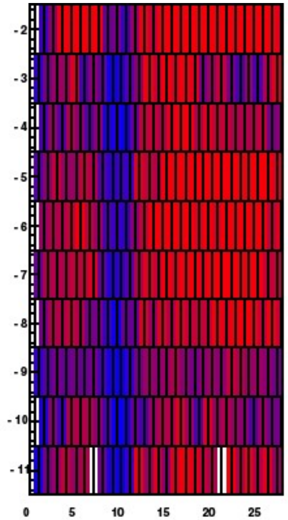

L. Hallermann, DESY

# Standard CERN-GEM

- triple grid GEM
- sensitive volume $10 \times 10 \times 66\,\text{cm}^3$
- pad size: $1,27 \times 7\,\text{mm}^2$
- 12 rows, 48 pads
- cosmics
- 95% Argon, 5% $CH_4$
- magnetic field up to 4 T





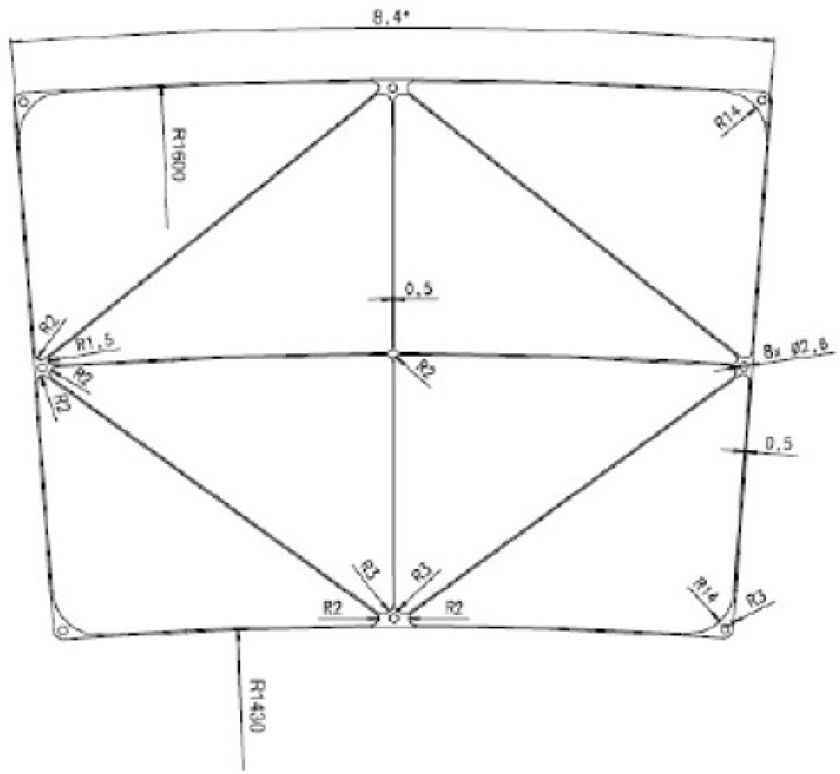



L. Hallermann, DESY

# LP DESY-GEM Module

Design studies started

- Complete area coverage for LP module
- Standard CERN GEM:
  d = 70 µm
  p = 140 µm
  50 µm thick Kapton, each side covered with 5 µm Cu
- Ceramic frame
- Readout pads:
  (1.1 / 1.25) x (5.6 / 5.8) $mm^2$
  28 rows
- Gating GEM / wires optional



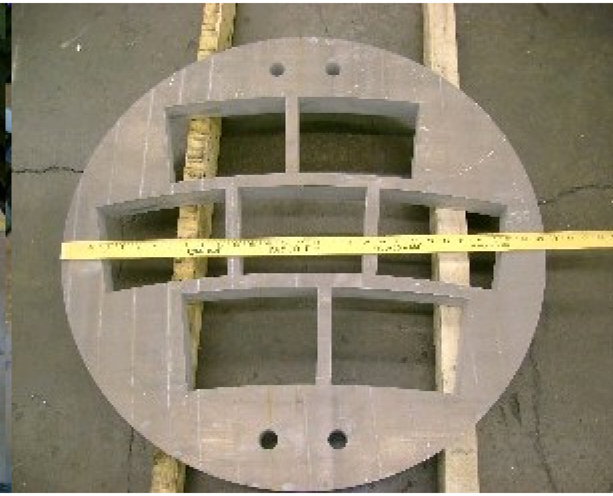

S. Caiazzo, DESY

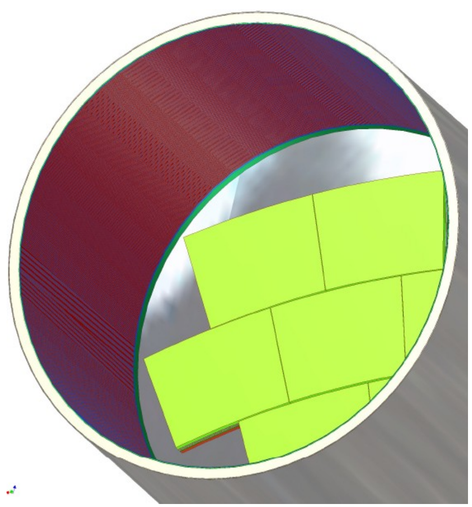
# Summary & Outlook

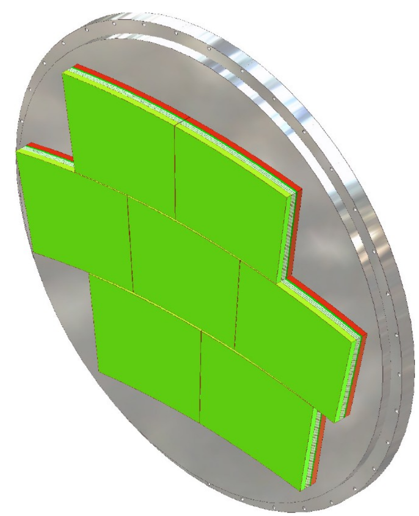
- A Large Prototype of a TPC has been built and is being assembled/tested/commissioned by the LCTPC collaboration
- Two MPGD technologies (with three electronics techniques) are being tested
- Infrastructure for Large Prototype has been constructed
- $e^-$ test beam (DESY) in conjunction with PCMAG (*1T* magnet)
- Preliminary results are looking very promising
- Further test beam campaigns in the next year:
  - Backplane integrated 10,000 channel readout system, based on ALTRO electronics
  - Seven Micromegas modules with AFTER electronics attached to the modules
  - DESY GEM w/ ceramic grid

Backup Slides

# LP-TPC Endplate

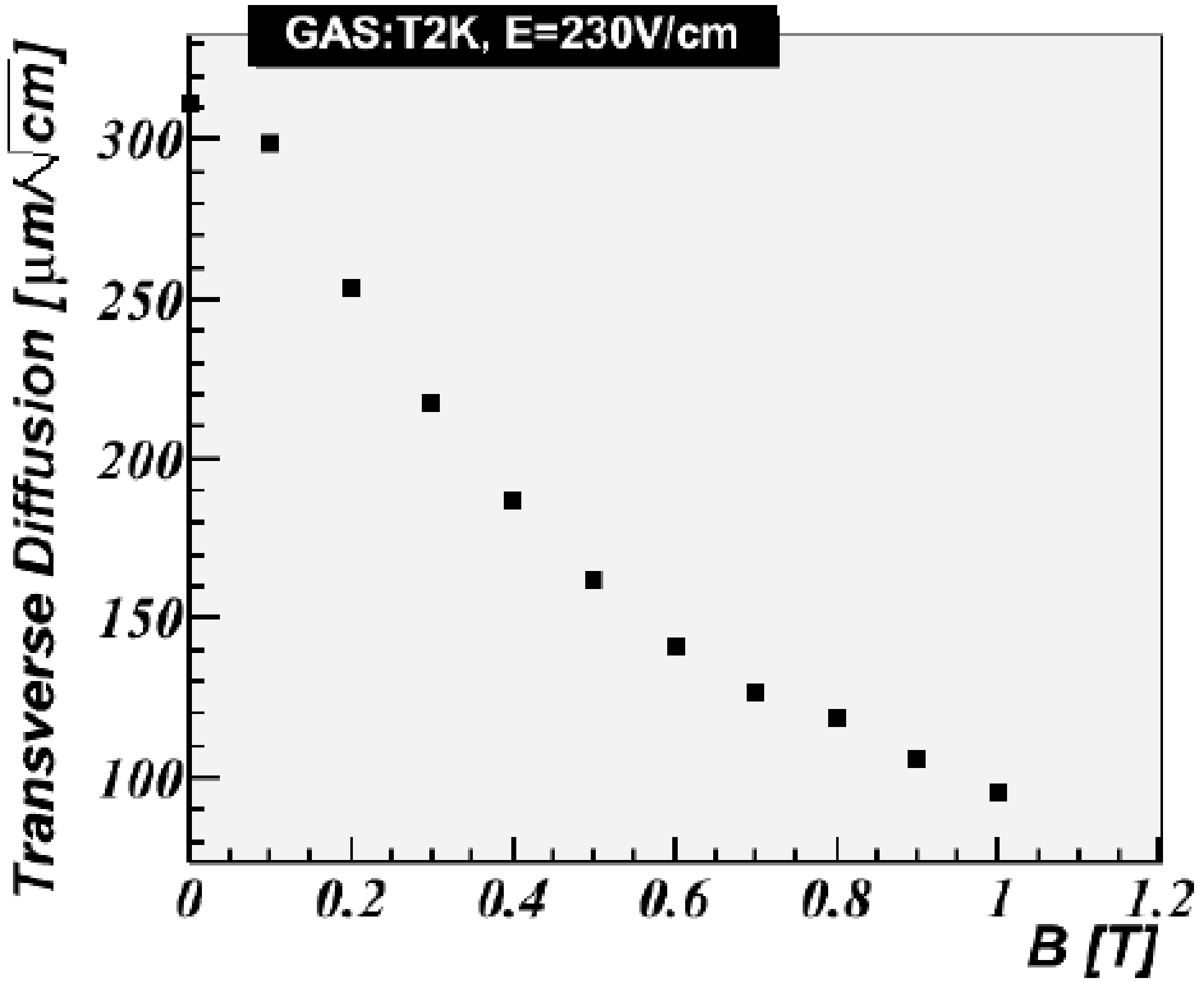




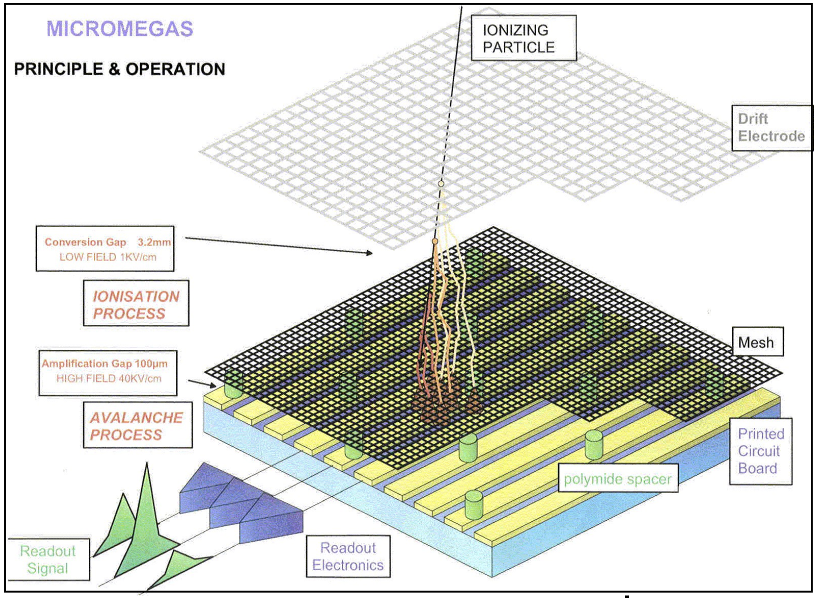


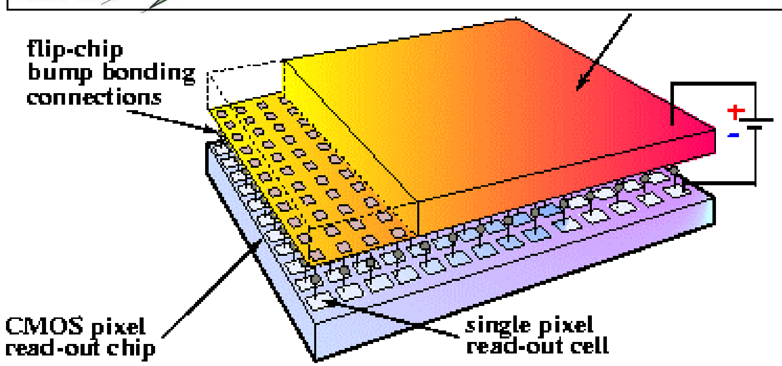
D. Peterson, Cornell

# Charge Spreading



# 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

*Three-fold readout electronics*:

- ALICE based:
  new PCA16 amplifier chip + ALTRO chip (EUDET & LCTPC)

- T2K based:
  AFTER electronics for T2K TPC (CEA Saclay)

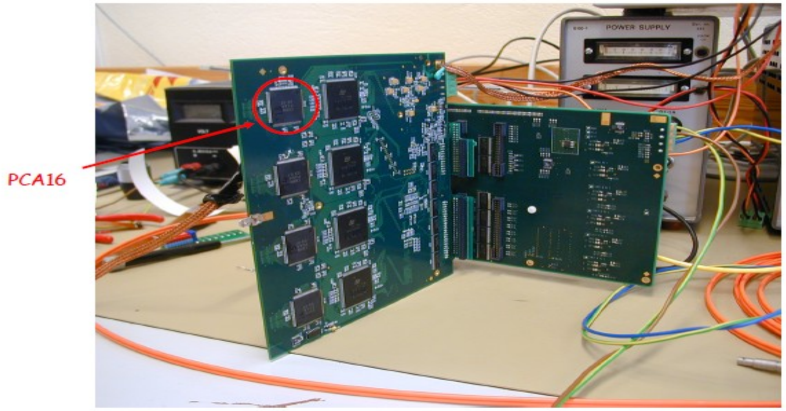
- TDC based:
  ASDQ chip + TDC (EUDET & Uni Rostock)

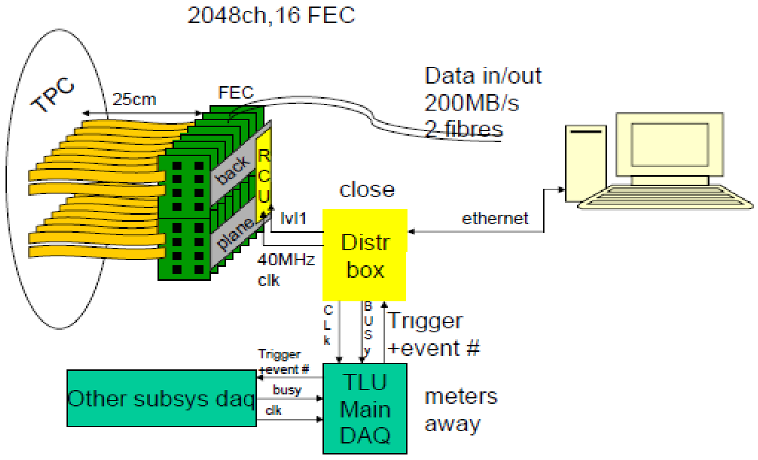
**AFTER electronics for MicroMeGAS (resistive anode readout)**
**ALTRO and TDC based electronics will be hooked to the GEM detector modules (connector compatibility)**

# PCA16:

1.5 V supply; power consumption <8 mW/channel
16 channel charge amplifier + anti-aliasing filter
Fully differential output amplifier
Programmable features
signal polarity
Power down mode (wake-up time = 1 ms)
Peaking time (30 – 120 ns)
Gain in 4 steps (12 – 27 mV/fC)
Preamp out mode (bypass shaper or not)
Tunable time constant of the preamplifier
Basically pin-compatible with PASA

The test set up with a fully equipped front end board

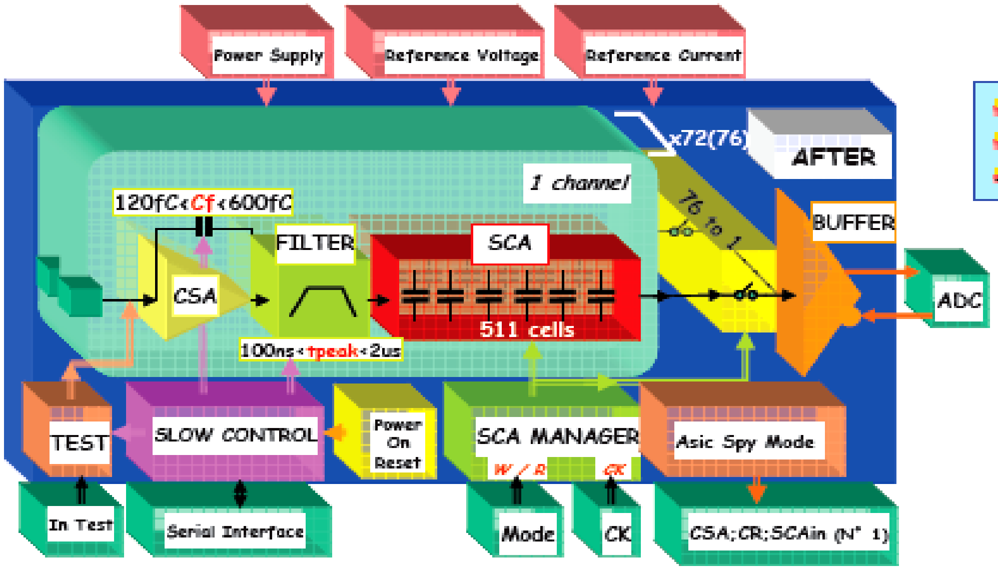


# Readout Electronics: AFTER

## AFTER Main Features

dapnia
cea
saclay




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

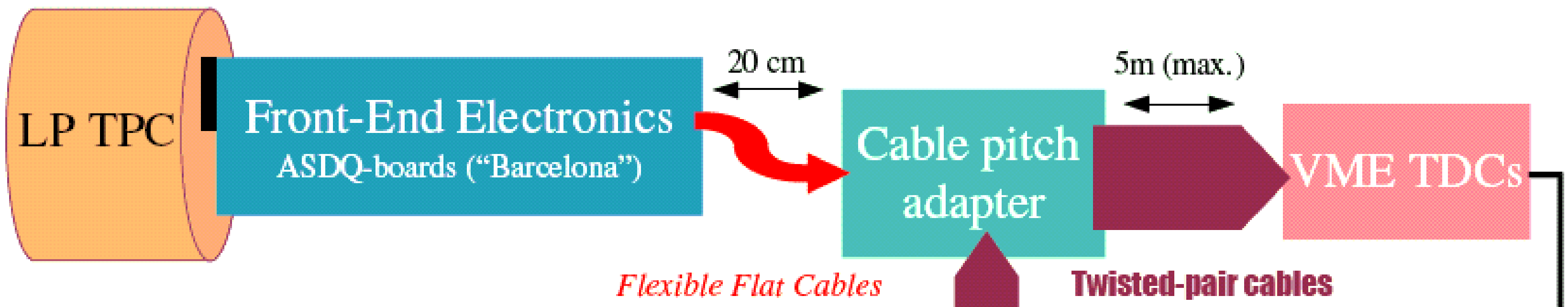
**Main features:**

- **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

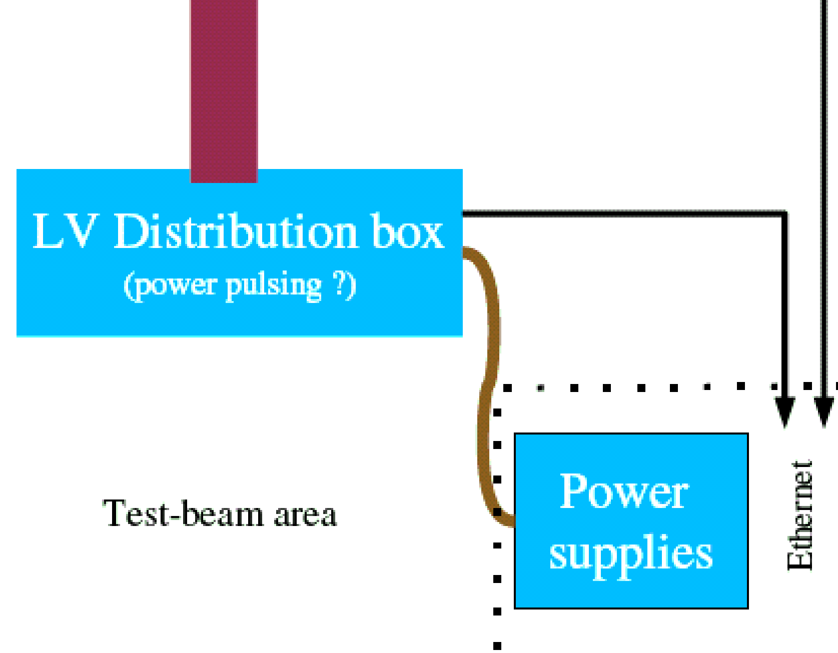
*LCTPC meeting Oct. 10, 2007* *E. DELAGNES* 4

# Readout Electronics: TDC

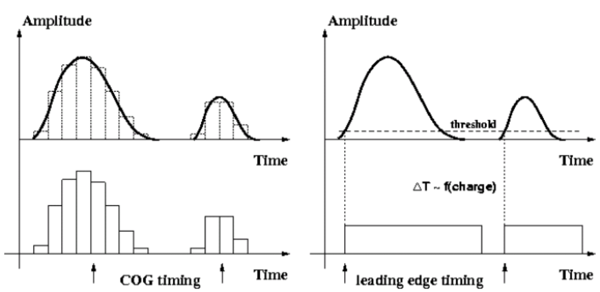



32 channels
Board size: 30 mm x 100mm*

Boards will be installed directly onto the endplate.



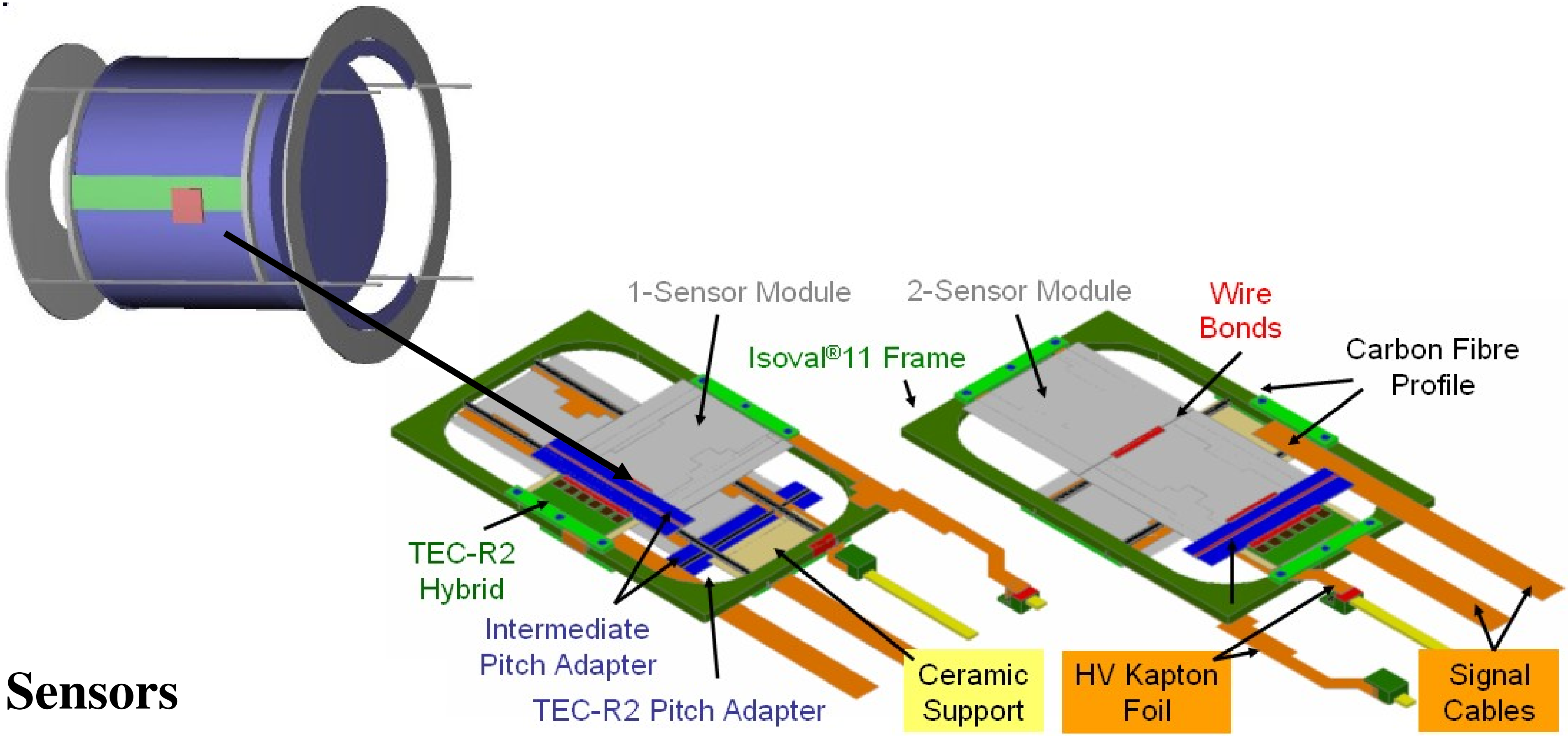

**TPC signal processing with Time-to-Digit Converter**




- **The time of arrival is derived using the leading edge discriminator.**
- **The charge of the input signal is encoded into the width of output digital pulse.**

A. Kaukher, Univ. Rostock

# Si Envelope




## Sensors

- first setup: only 768 channels can be read out
  - ➘ the readout sensitive area is reduced to 38.4 x 38.4 $mm^2$ (only the intersecting readout area of the two modules on top of each other is interesting)