A Large TPC Prototype at the DESY II Test Beam

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DESY

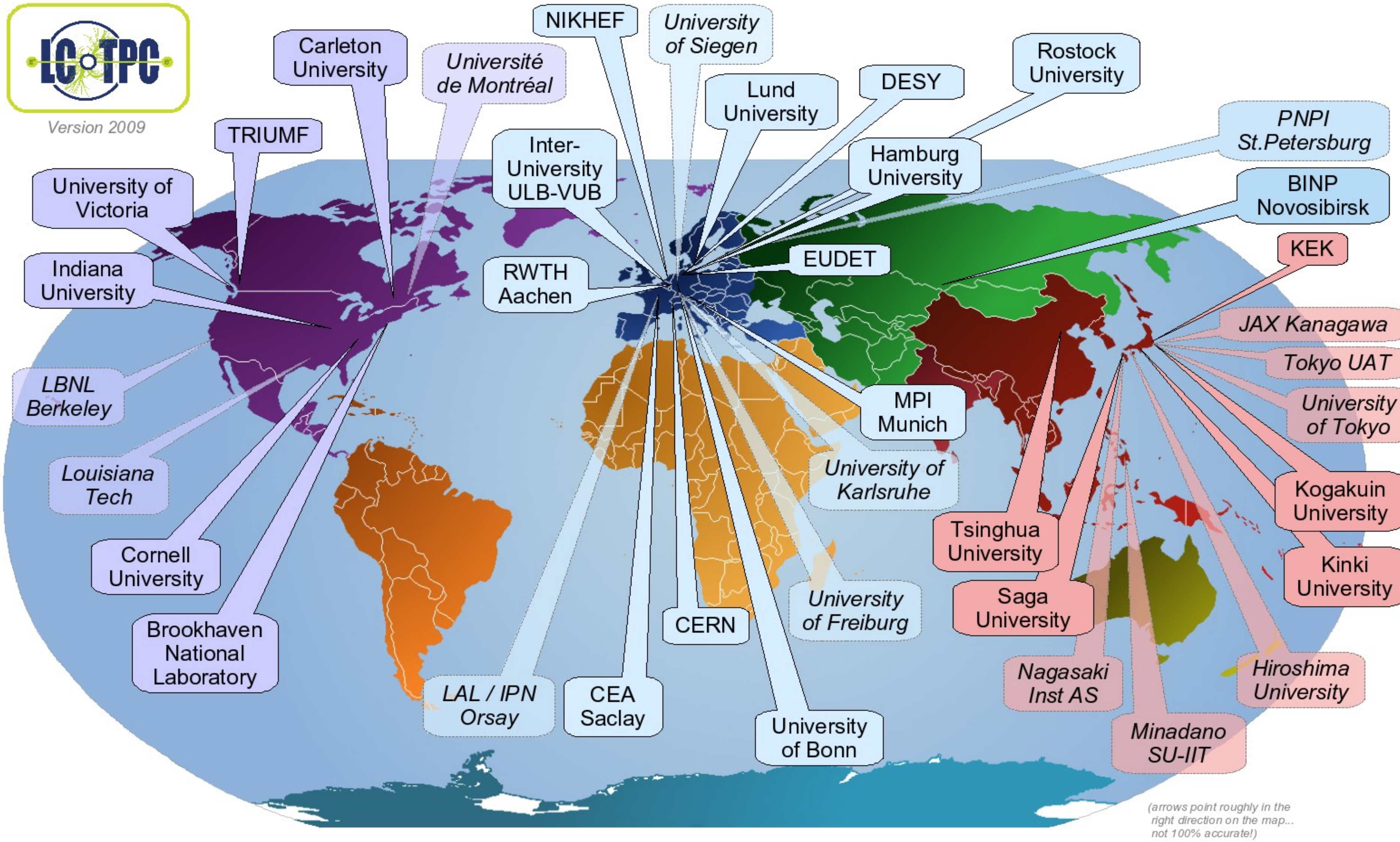
On behalf of Klaus Dehmelt and the LCTPC Collaboration

Physics at the Terascale

Hamburg, Germany

November 12, 2009

LCTPC Collaboration



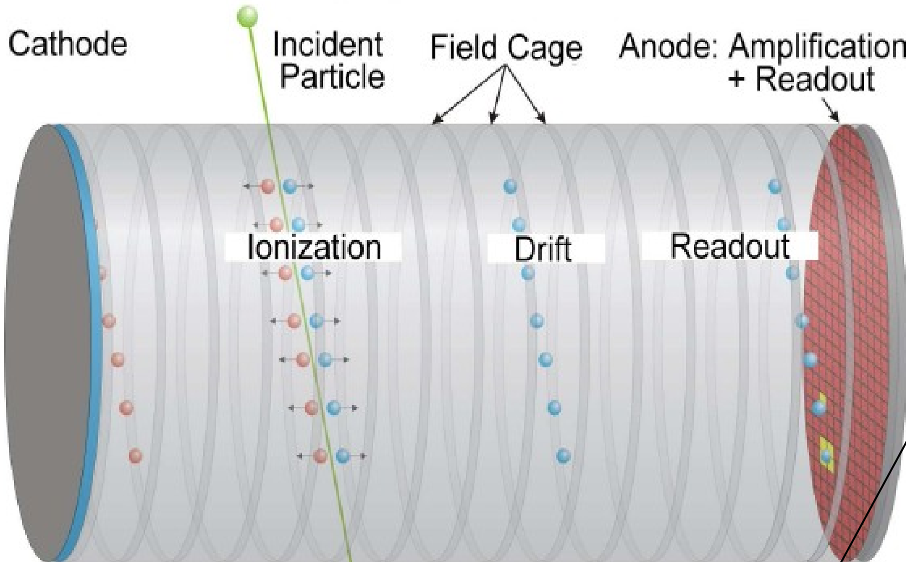
LCTPC Collaboration

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

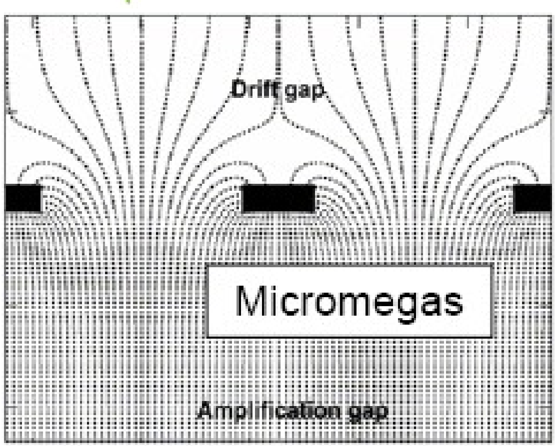
Size	$\phi = 3.6$m, L = 4.3m outside dimensions
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 9 \times 10^{-5}$/GeV/c TPC only ($\times$ 0.4 if IP incl.)
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 2 \times 10^{-5}$/GeV/c (SET+TPC+SIT+VTX)
Solid angle coverage	Up to $\cos\theta \simeq 0.98$ (10 pad 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)
σ_{point} in $r\phi$	$< 100\mu$m (average over $L_{sensitive}$, modulo track ϕ angle)
σ_{point} in rz	$\sim$ 0.5 mm (modulo track θ 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

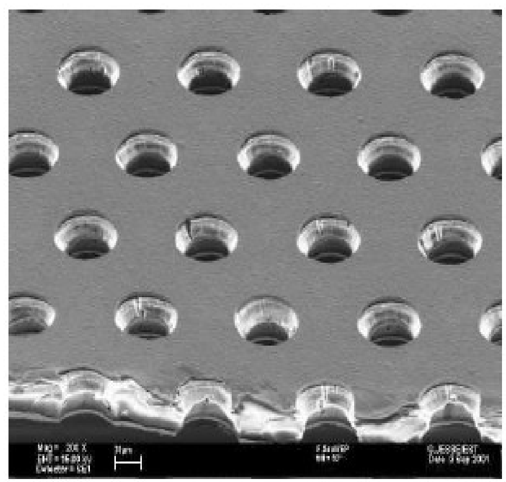
TPC with MPGD

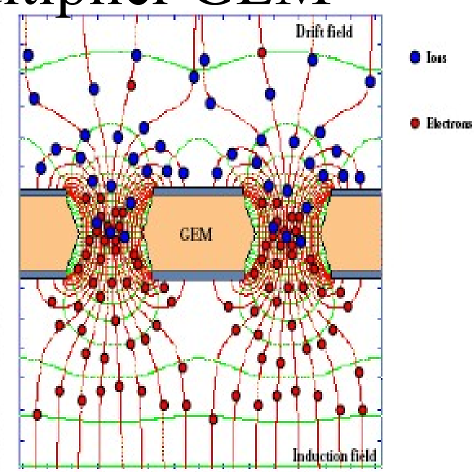


MicroPatternGasDetector
MPGD
not limited by **E** x **B** effects

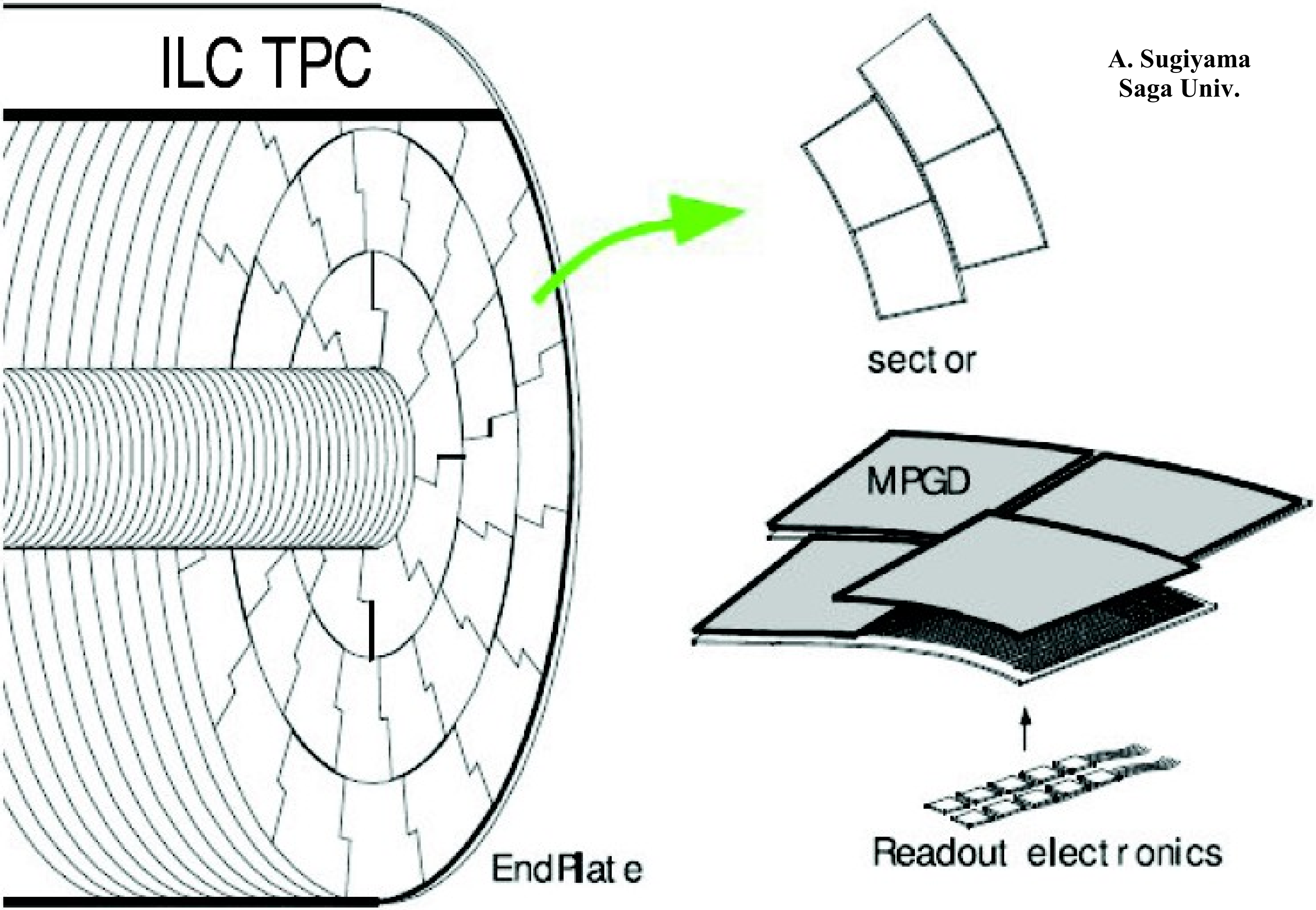


Gas Electron Multiplier GEM



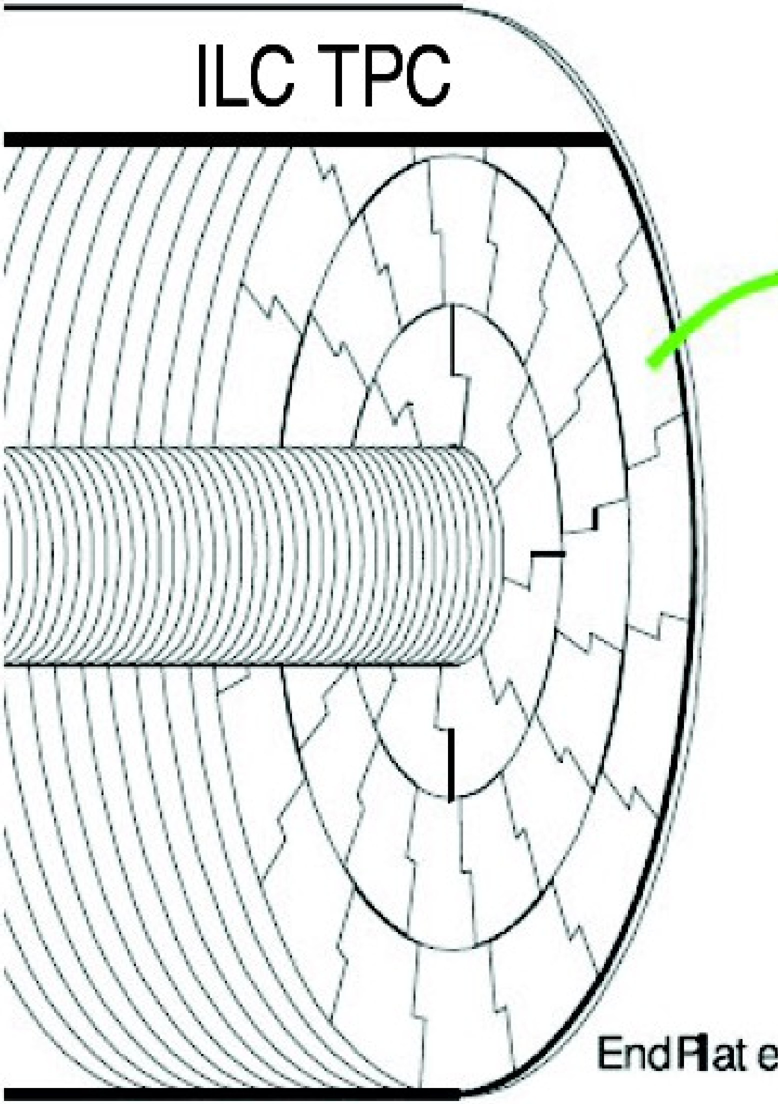


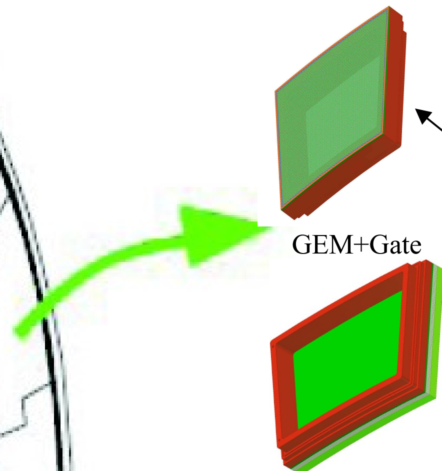
TPC with MPGD

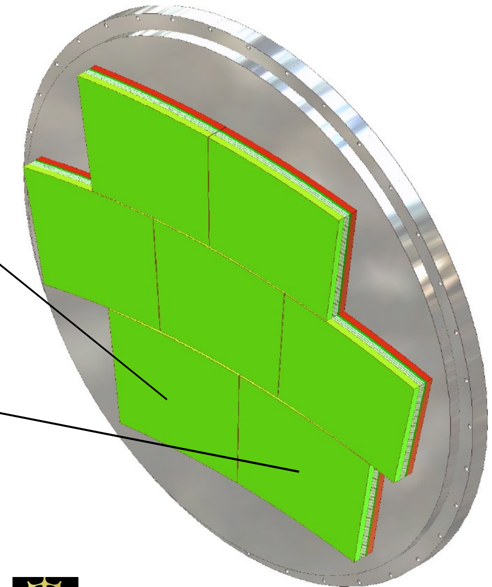


A. Sugiyama
Saga Univ.

TPC with MPGD





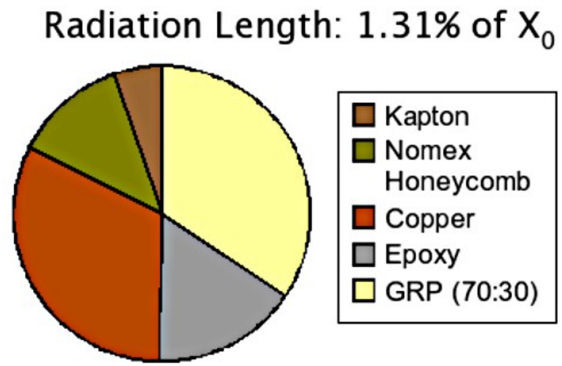


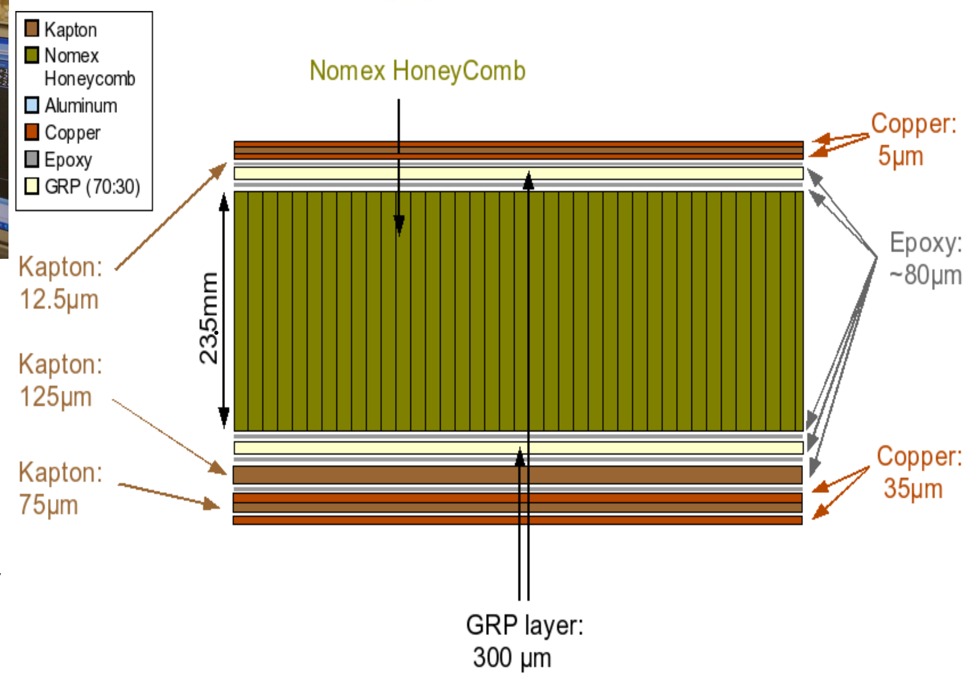
Endplate:

D. Peterson, Cornell

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

LP-TPC Field Cage (FC)

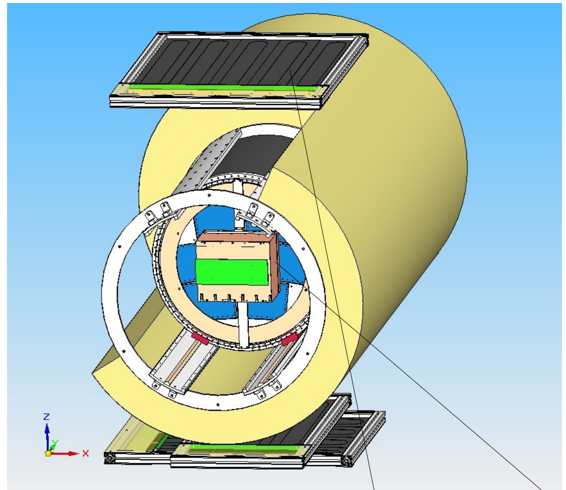




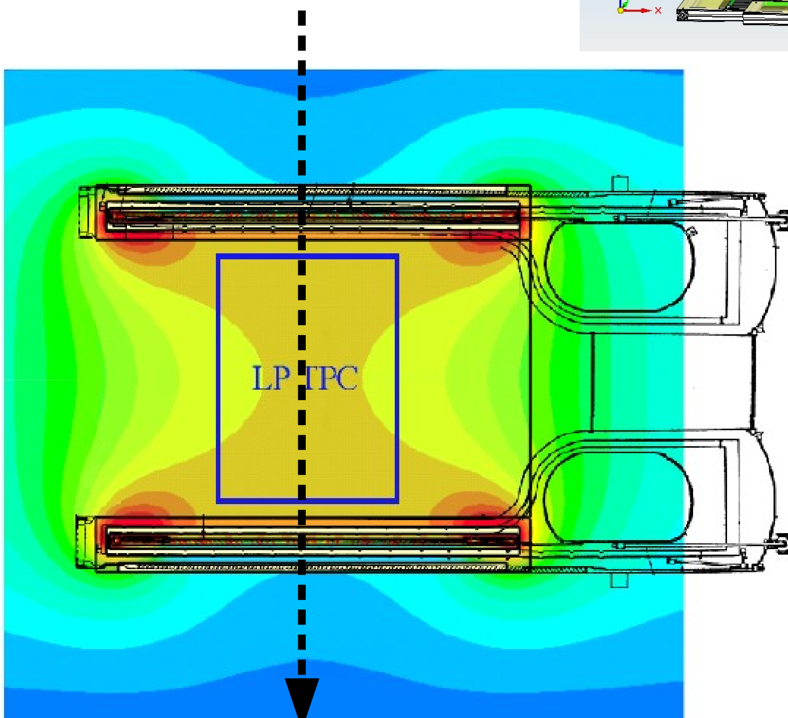
Diameter: Inner 720 mm,
Outer 770 mm
Wall thickness 25 mm
Length 610 mm
HV to be applied: up to 20 kV

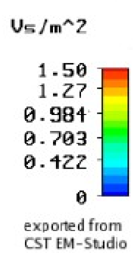
DESY Setup

- *PCMAG:* superconducting magnet, up to 1.25 T
- e^- test beam @DESY (1GeV/c<p<6GeV/c)

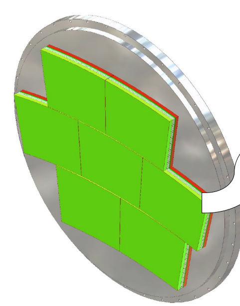


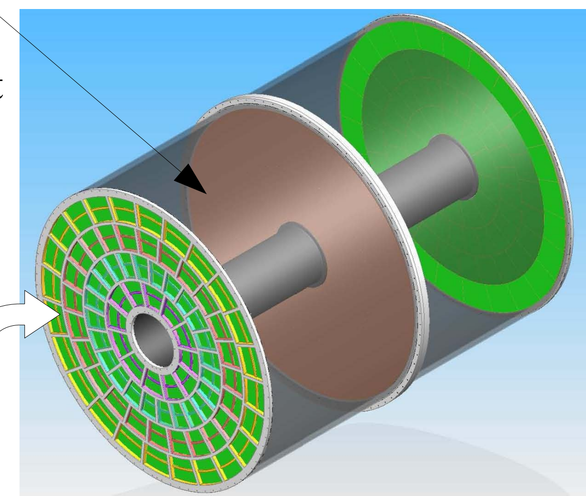
Cosmic Trigger Setup



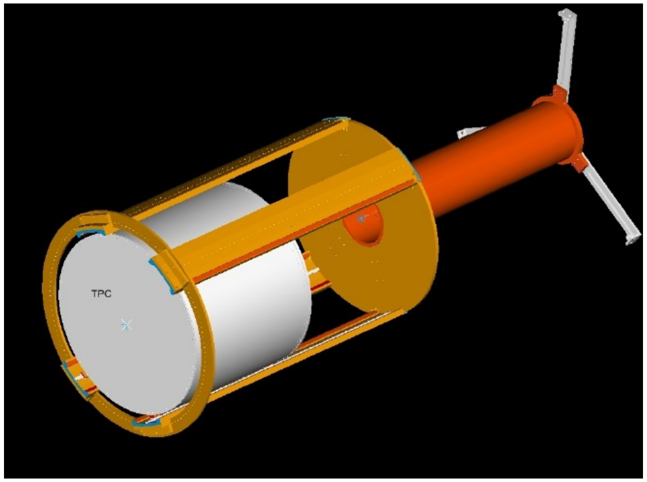


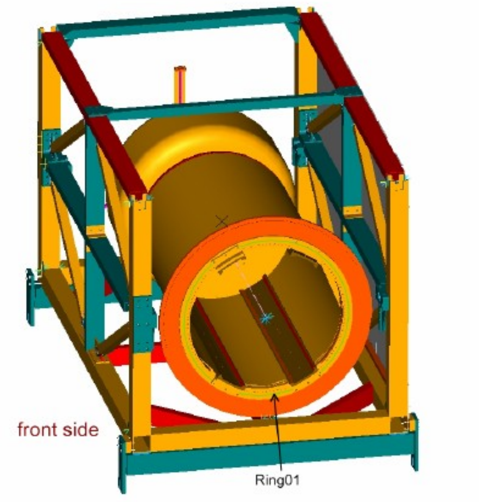
LP as half part of a TPC

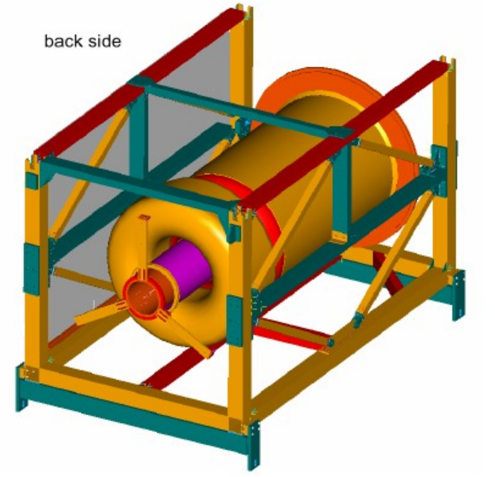




LP Mechanics



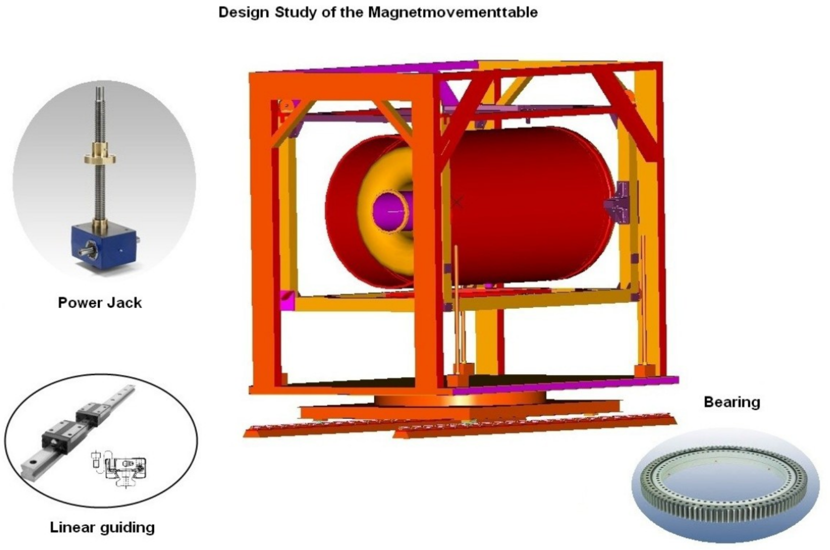




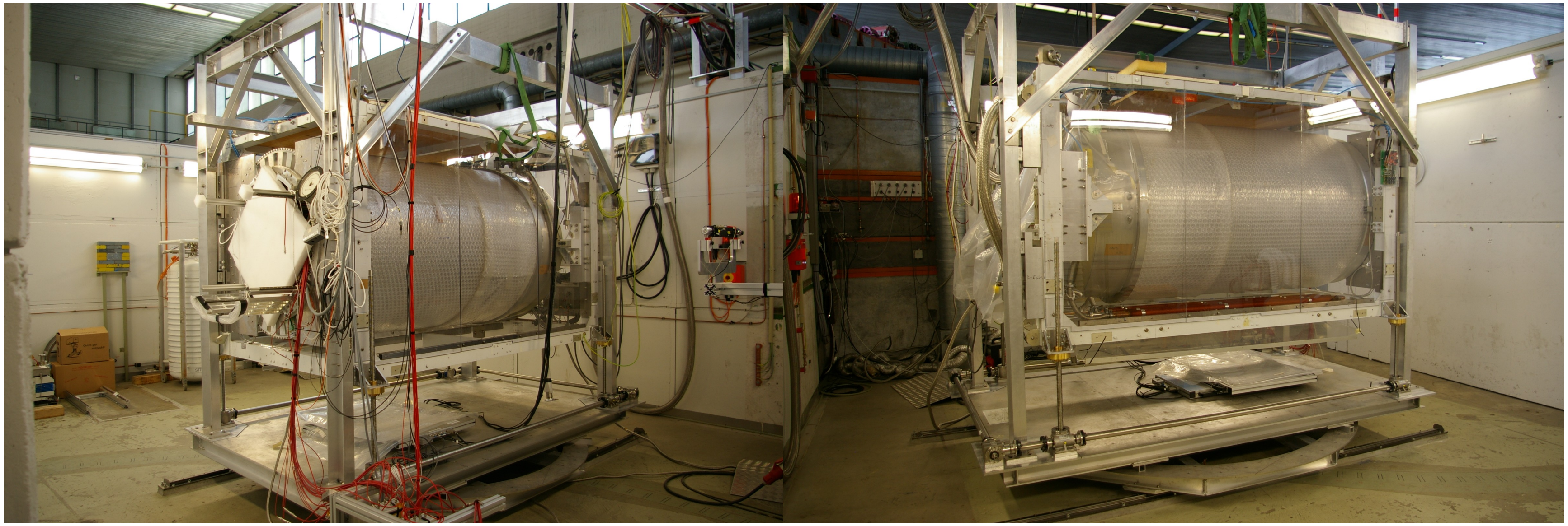
Support structures:

- TPC
- PCMAG

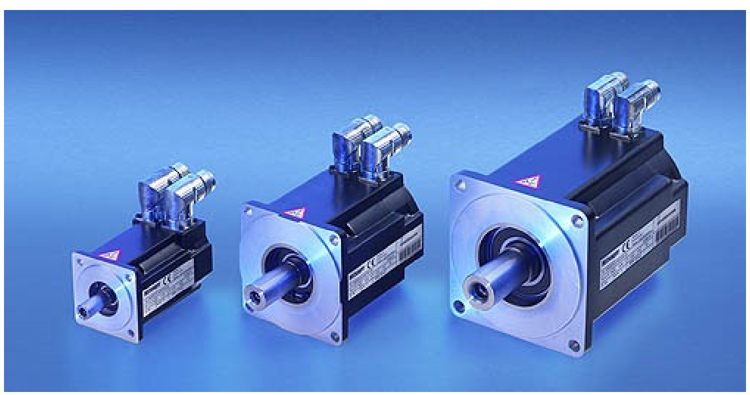
F. Hegner, V. Prahl, R. Volkenborn, DESY



LP Mechanics

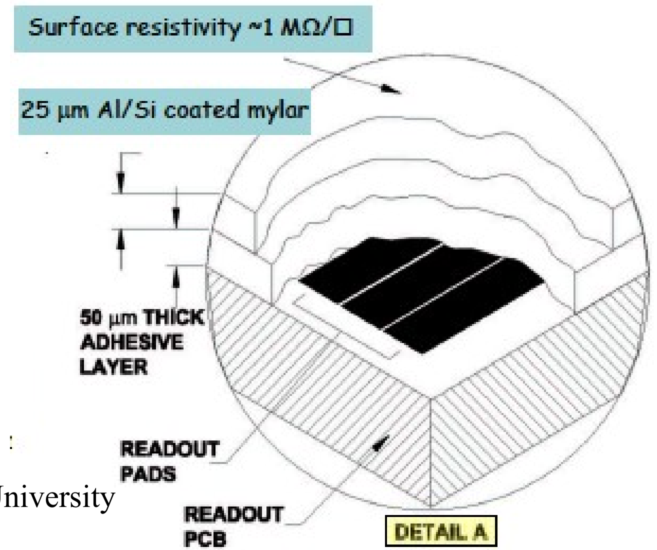


Actuation and Control



MicroMeGaS Structure

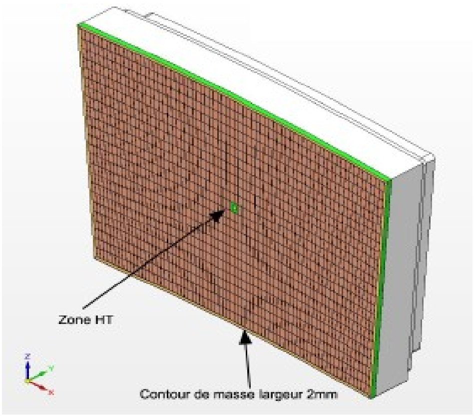
‘Bulk Micromegas’ panels, without resistive foil and with resistive carbon-loaded kapton, have been produced at CERN (Rui de Oliveira)



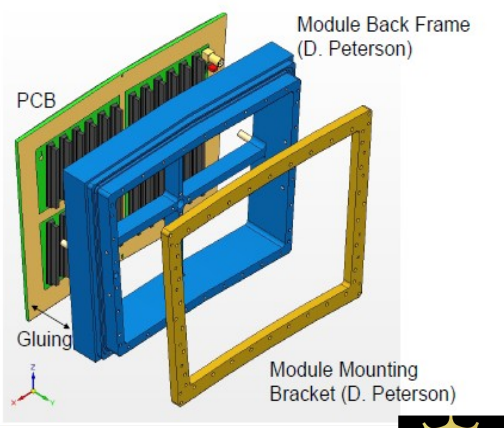
MicroMeGaS for LP:

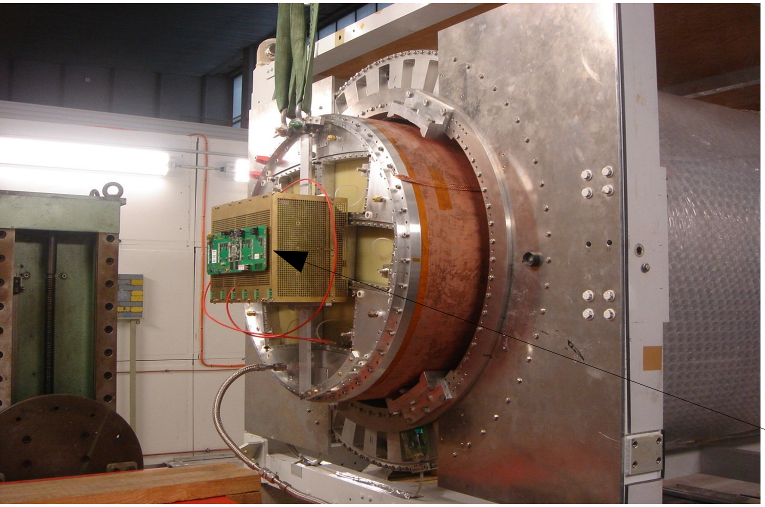
24 rows x 72 pads
Av. Pad size: 3.2 x 7mm²

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



Detector side





Readout electronics: AFTER (T2K TPC)

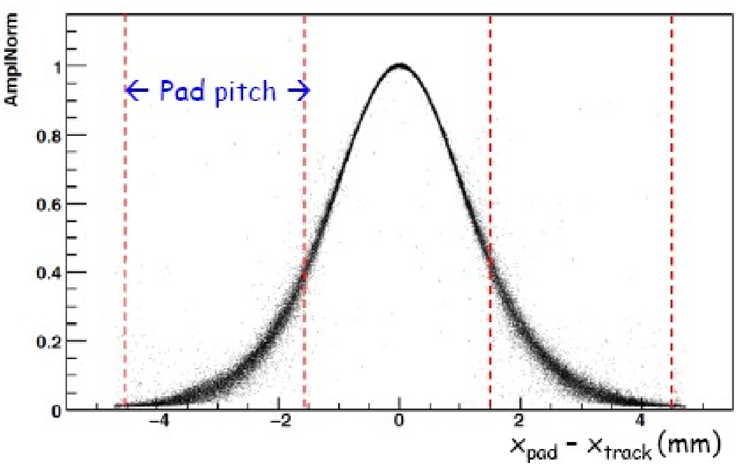
MicroMeGaS Structure

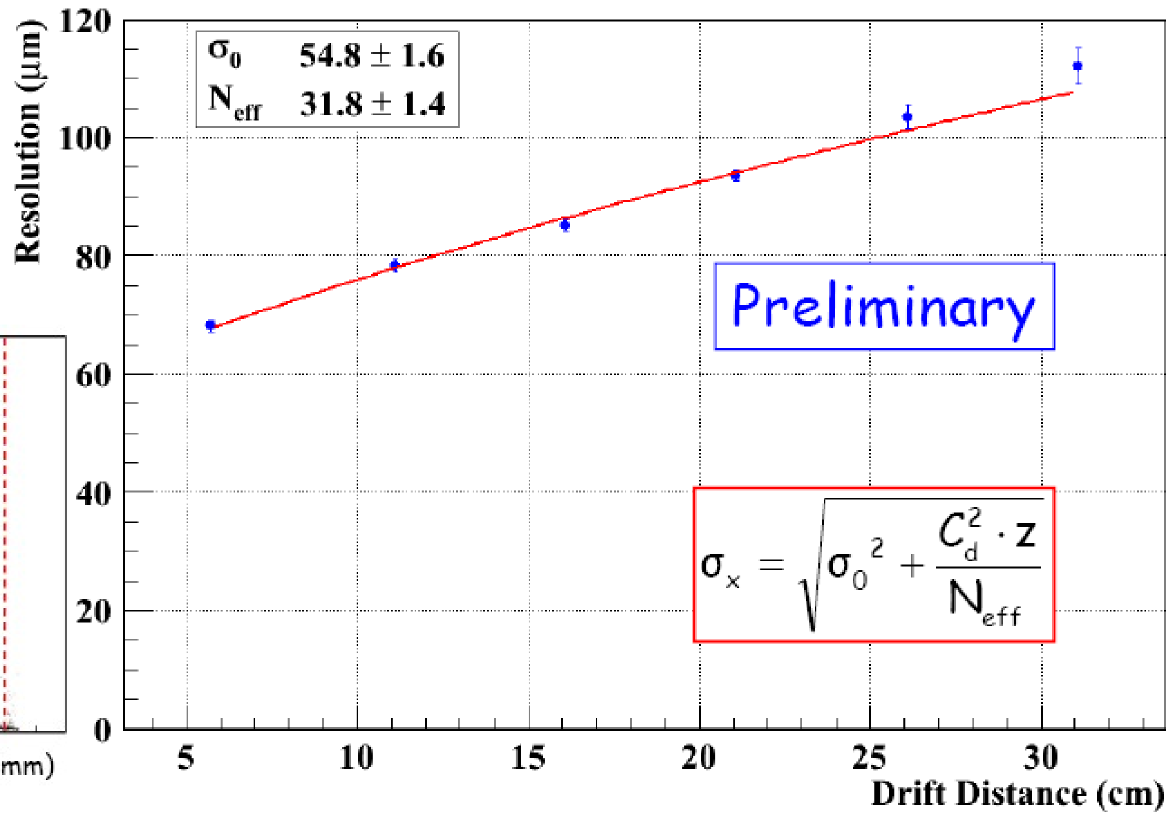
Electrons (5 GeV), Magnetic field (B=1T)

- Resolution at z=0: σ_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

- 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)



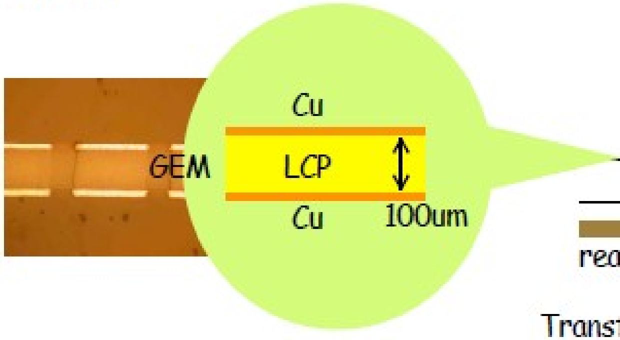


Double GEM Structure

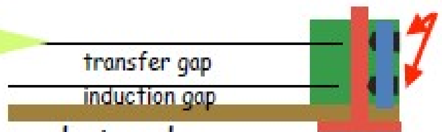
28 pad raws (176/192 pads/raw)
~1.2(w) x 5.4(h) mm^2
staggered every each layer

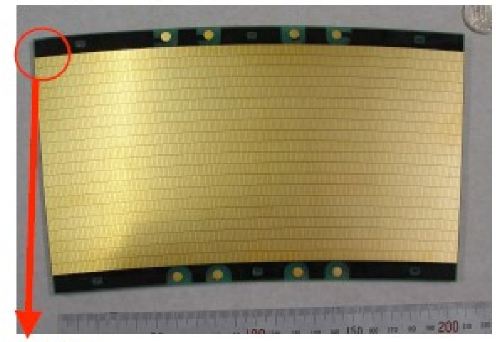
Total 5,152 ch/module

GEMs



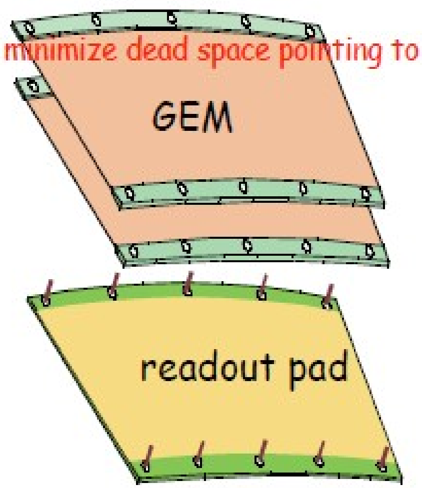
mounting(stretch) mechanism

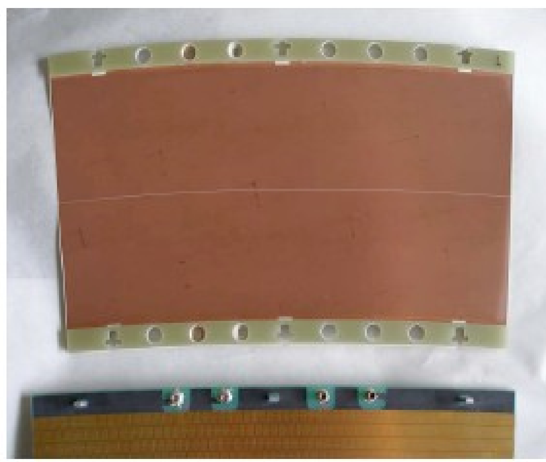




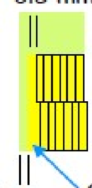
Transfer gap ~ 4mm (+2mm) : enlarge signal distribution width > 0.3* pad pitch

frame : top & bottom frame.
no side frame



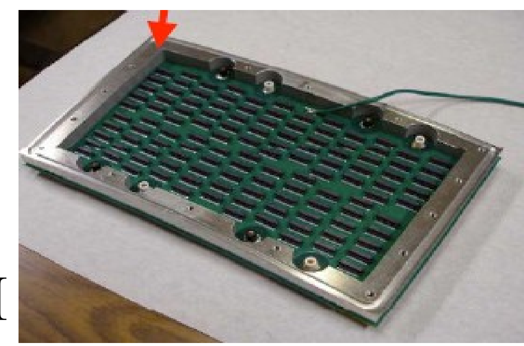


0.5 mm



0.5 mm

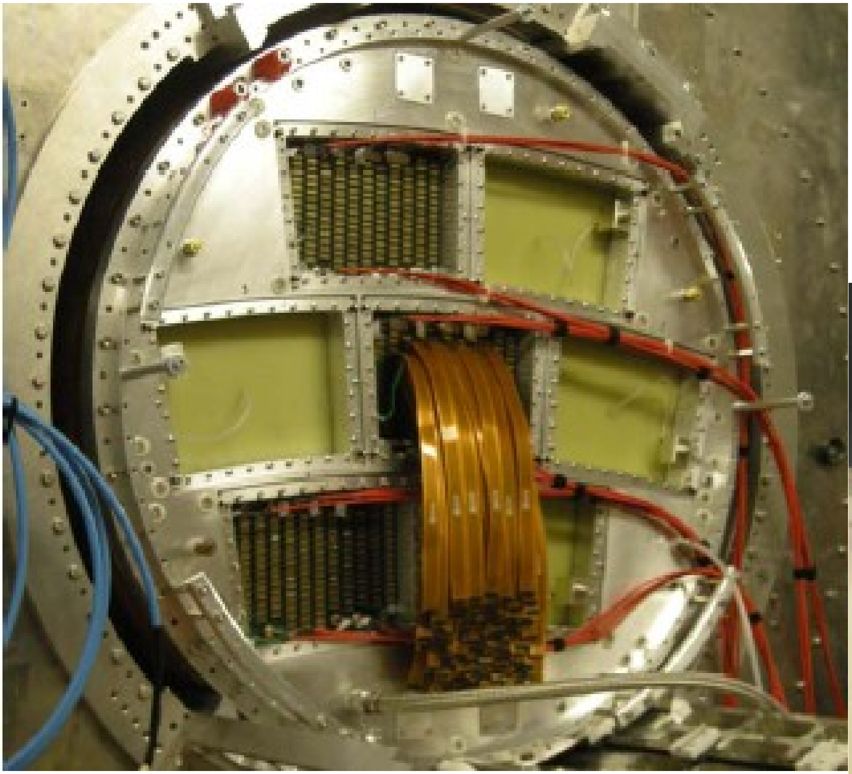
6 layers PCB
one GND layer



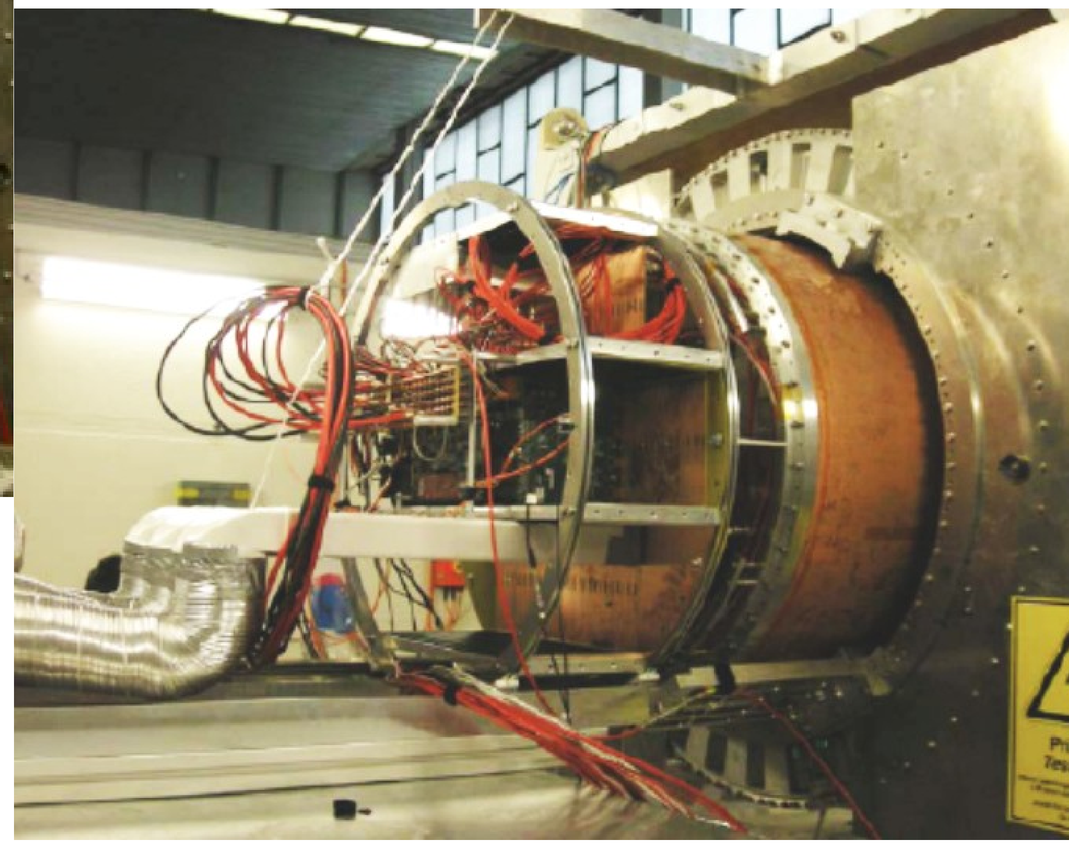
Setup planned w/ gating GEM

A. Sugiyama, Saga Univ.

Double GEM Structure



About 3200 channels readout electronics

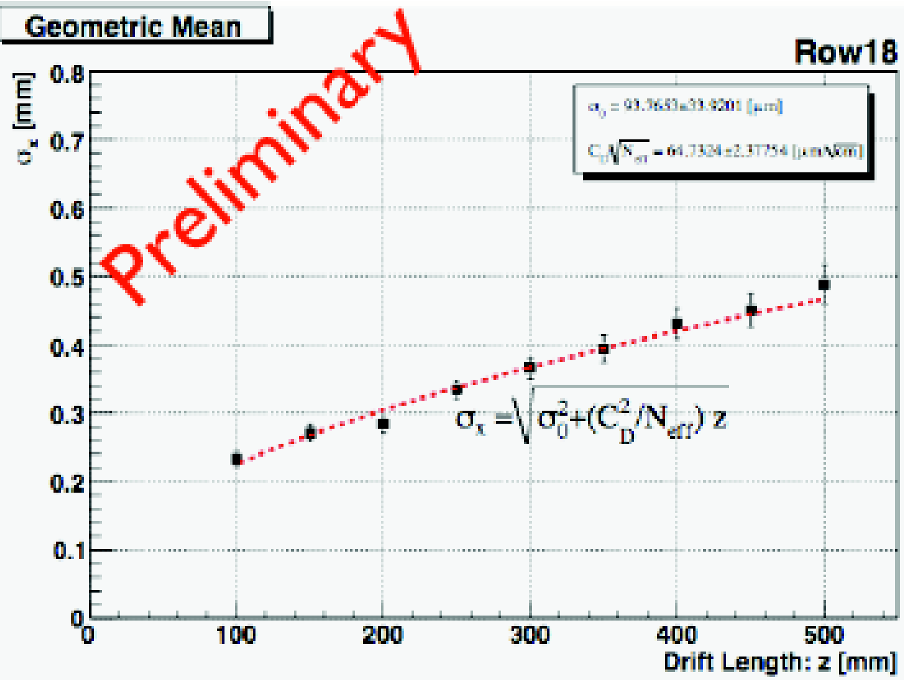


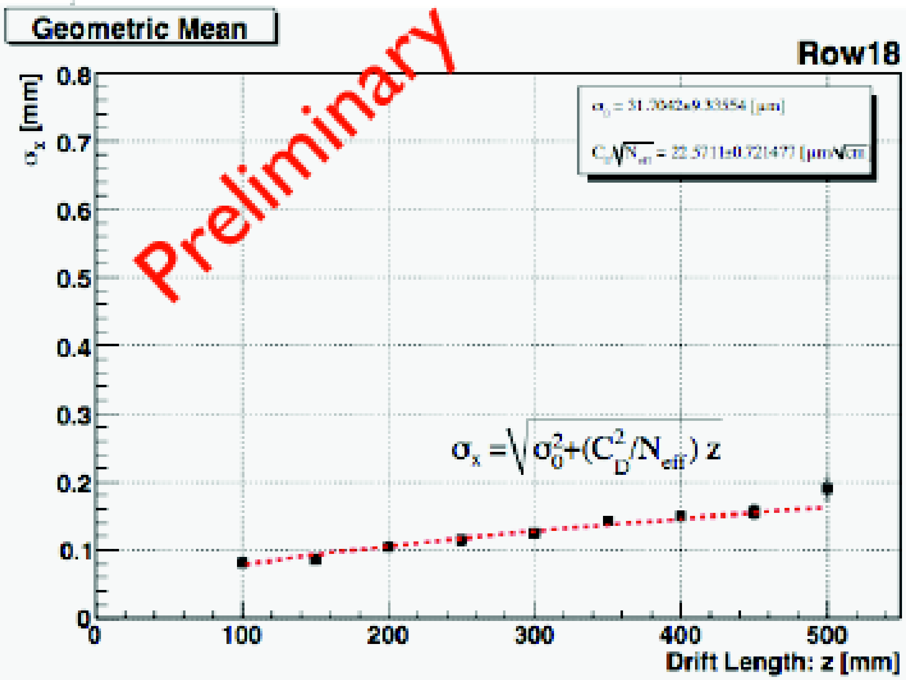
Readout electronics:
Based on ALTRO (ALICE TPC)
L. Joensson, LUND University

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

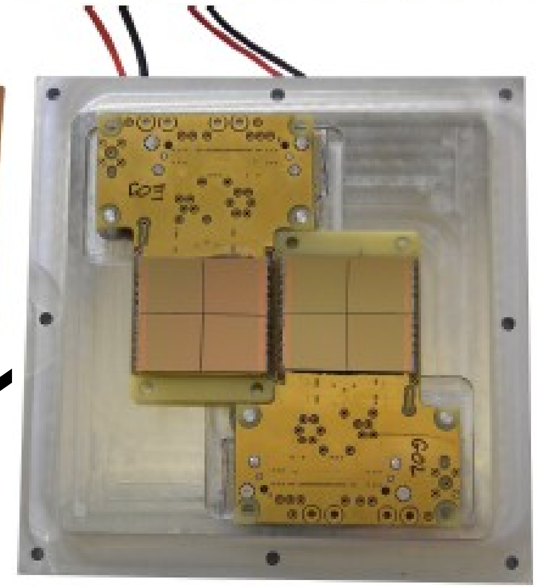
$$\begin{cases} C_D = 101.6 \pm 0.4 [\mu/\sqrt{cm}] \\ \dfrac{C_D}{\sqrt{N_{eff}}} = 22.6 \pm 0.7 [\mu m/\sqrt{cm}] \end{cases}$$

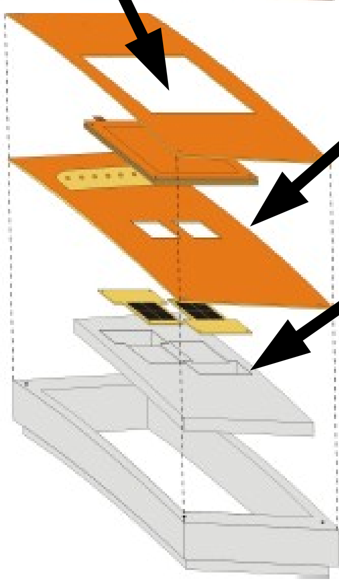
$$\longrightarrow N_{eff} \sim 20 \pm 1$$

Garfield

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

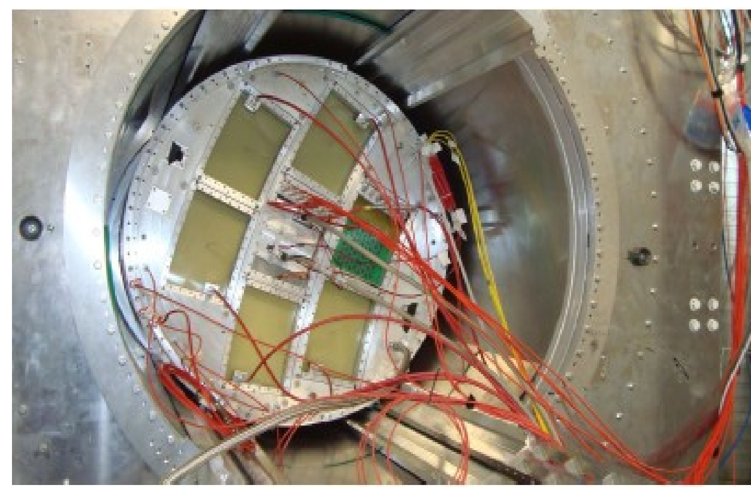
3-GEM Structure & TimePix





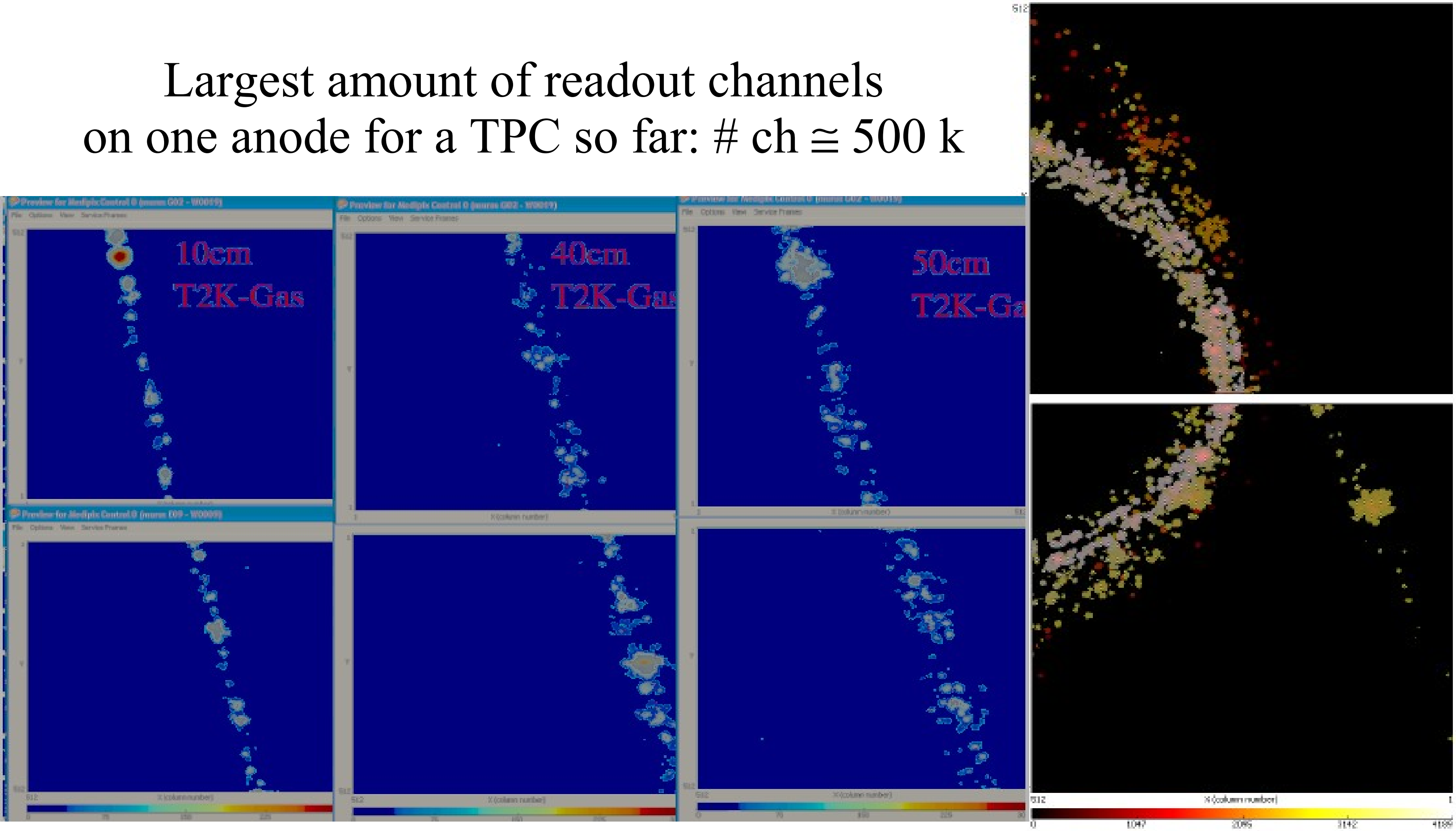
Readout:
2 quadboards
(4 TimePix
Chips each)

J. Kaminski, Univ. of Bonn



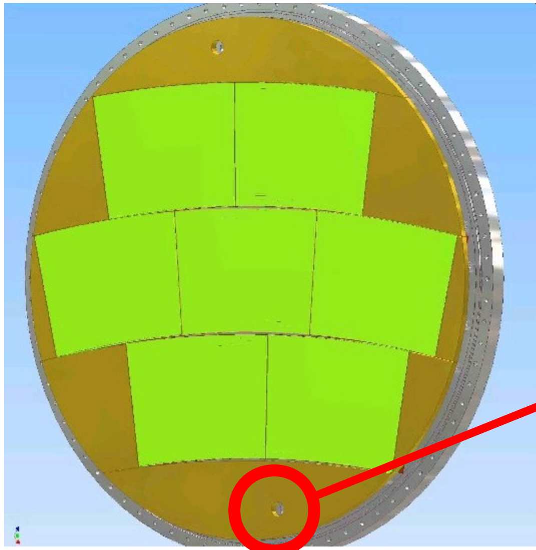
3-GEM Structure & TimePix

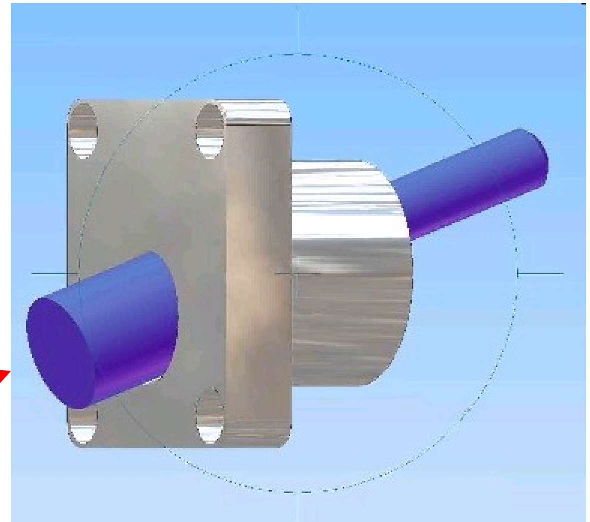
Largest amount of readout channels
on one anode for a TPC so far: # ch ≅ 500 k

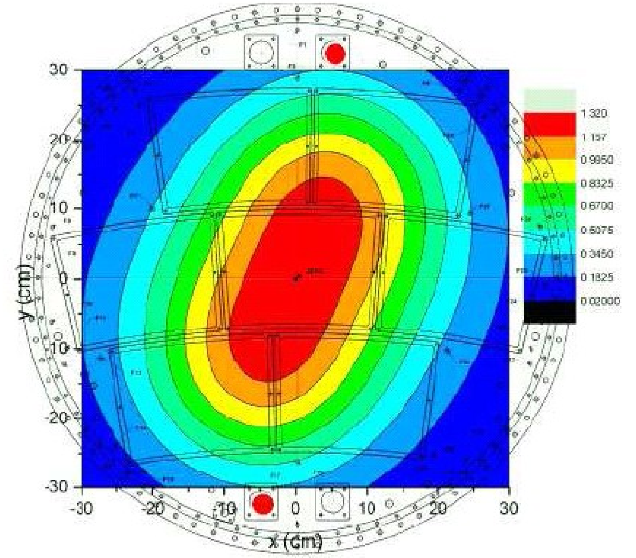


J. Kaminiski, Univ. of Bonn

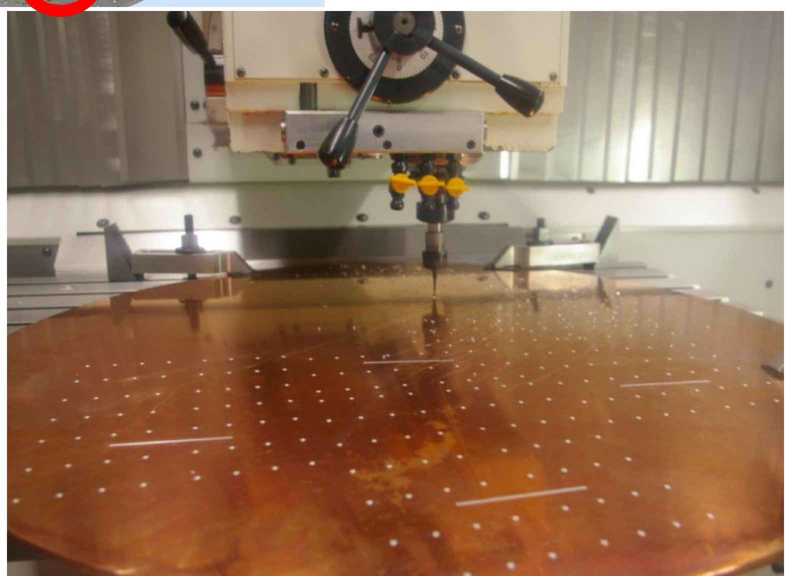
Laser Calibration Setup



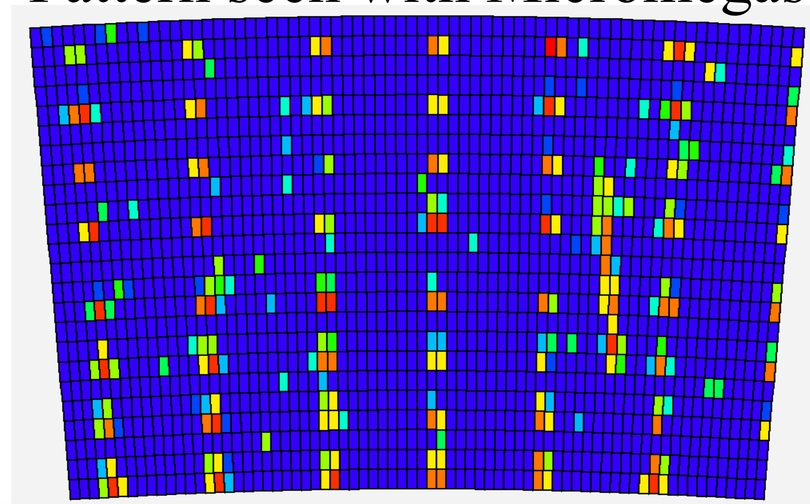




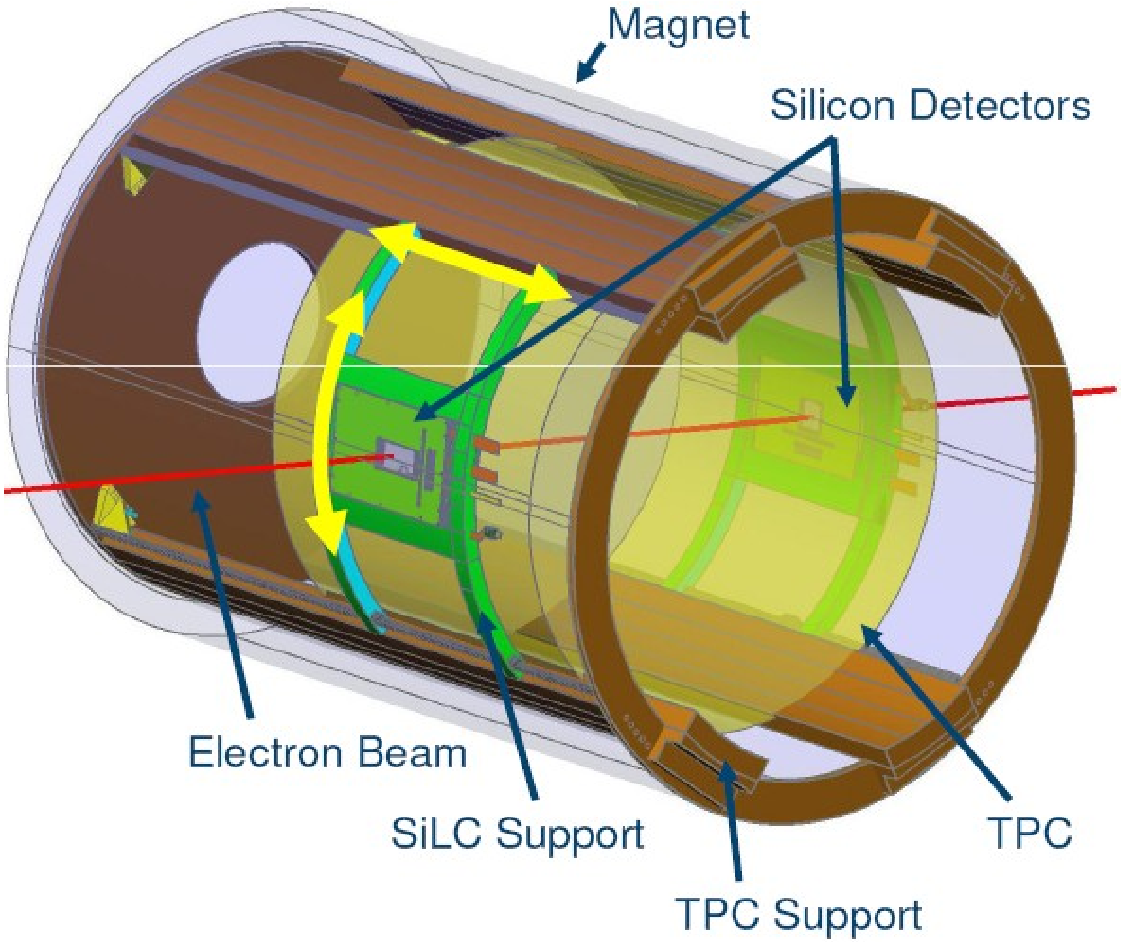
P. Conley
Victoria Univ.

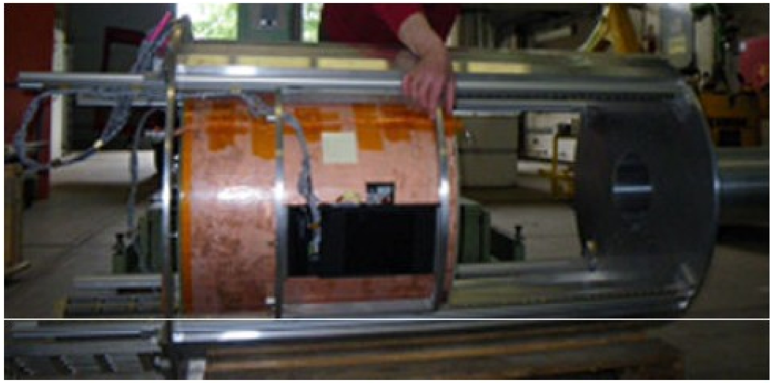


Pattern seen with Micromegas



Si Envelope


Magnet
Silicon Detectors
Electron Beam
SiLC Support
TPC
TPC Support



Standard CERN-GEM

10 x 10 cm^2 CERN GEM:

Flatness study

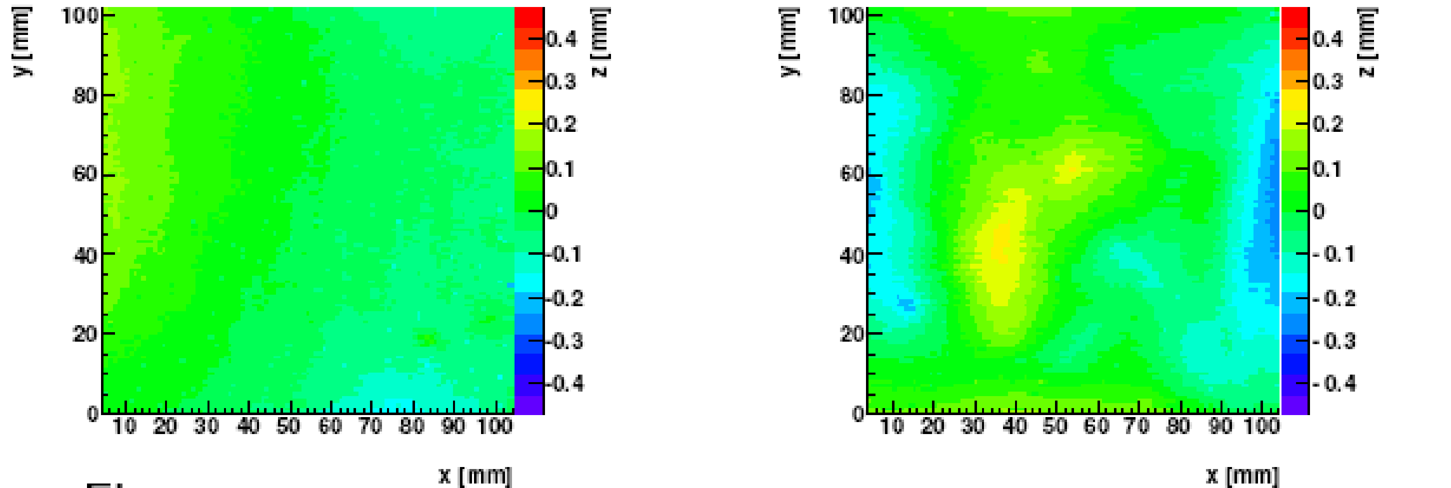


Figure: GEM 7 (Δz: 355 μm) - GEM 17 (Δz: 509 μm) - GRP frames

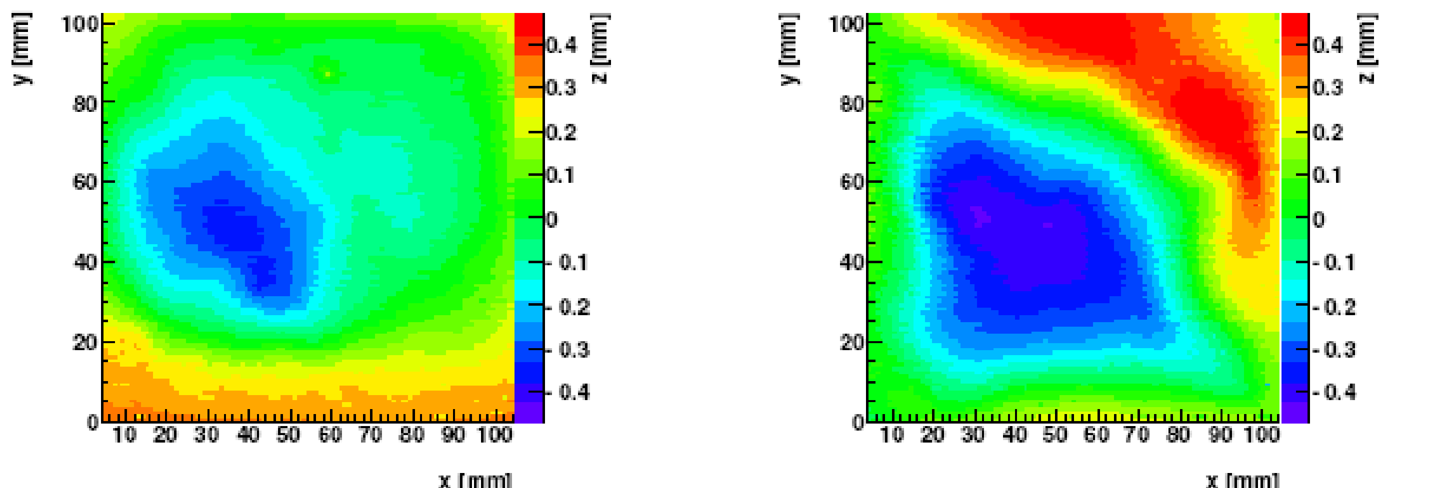


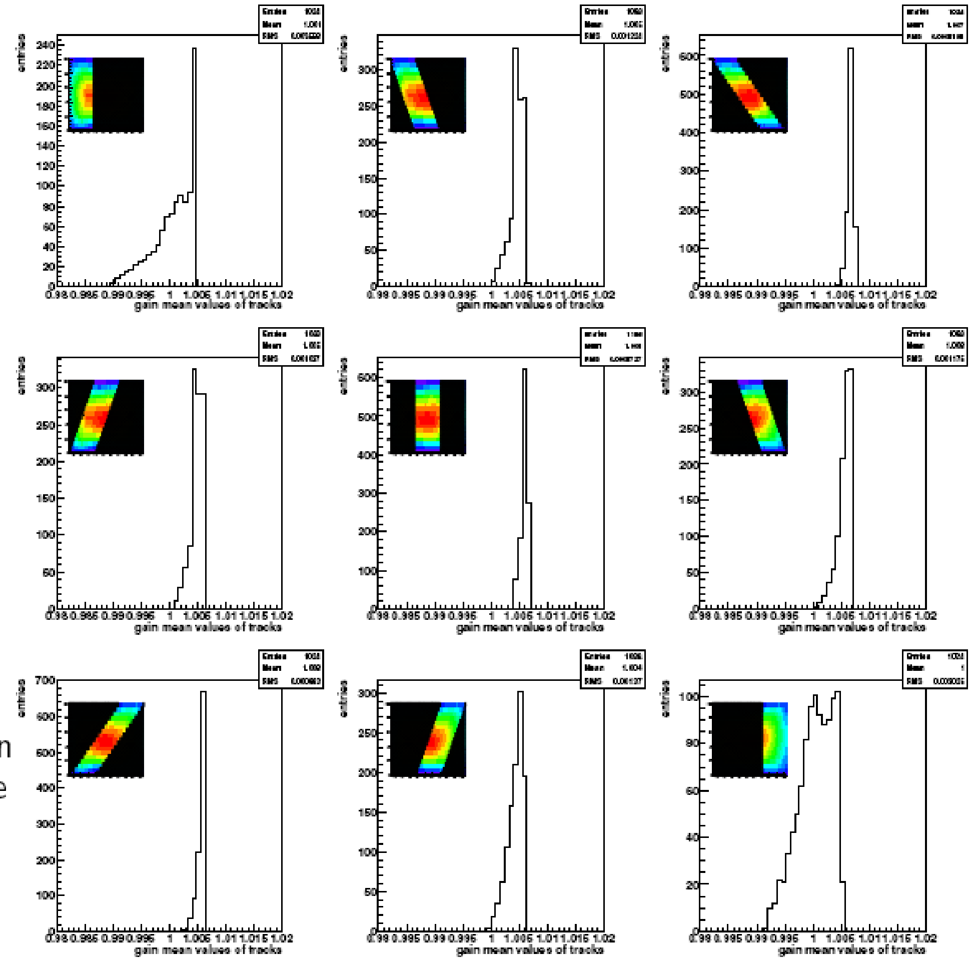
Figure: GEM 18 (Δz: 733 μm) - GEM 26 (Δz: 922 μm) - GRP frames

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 %

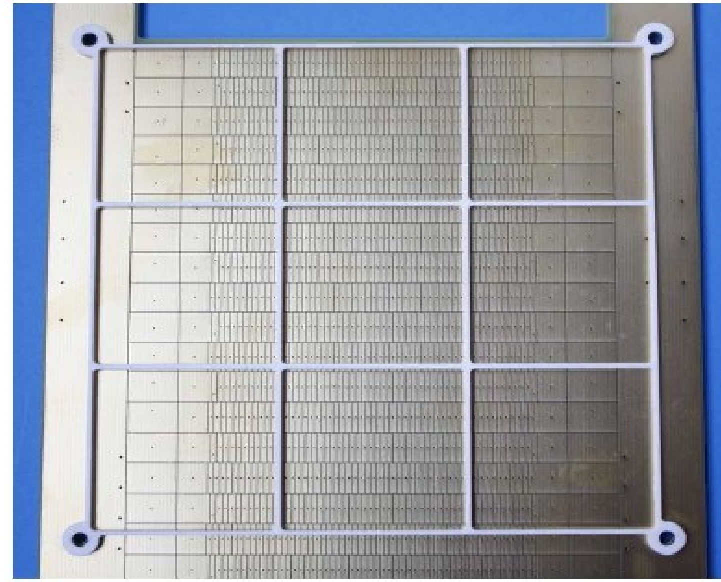
Table: Mean values and root mean squares of averaged track gains in different regions. The RMS represents the fluctuation of the effective gain corresponding to tracks within one region.

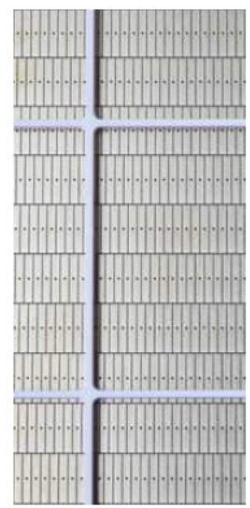


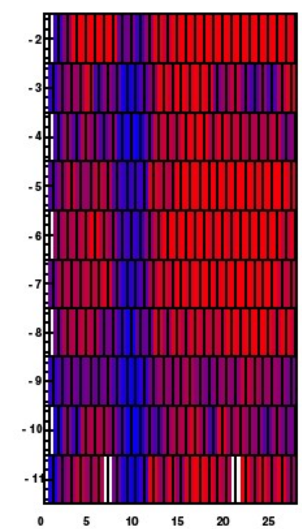
L. Hallermann, DESY

Standard CERN-GEM

- triple grid GEM
- sensitive volume
  $10 \times 10 \times 66\,\mathrm{cm}^3$
- pad size: $1,27 \times 7\,\mathrm{mm}^2$
- 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:

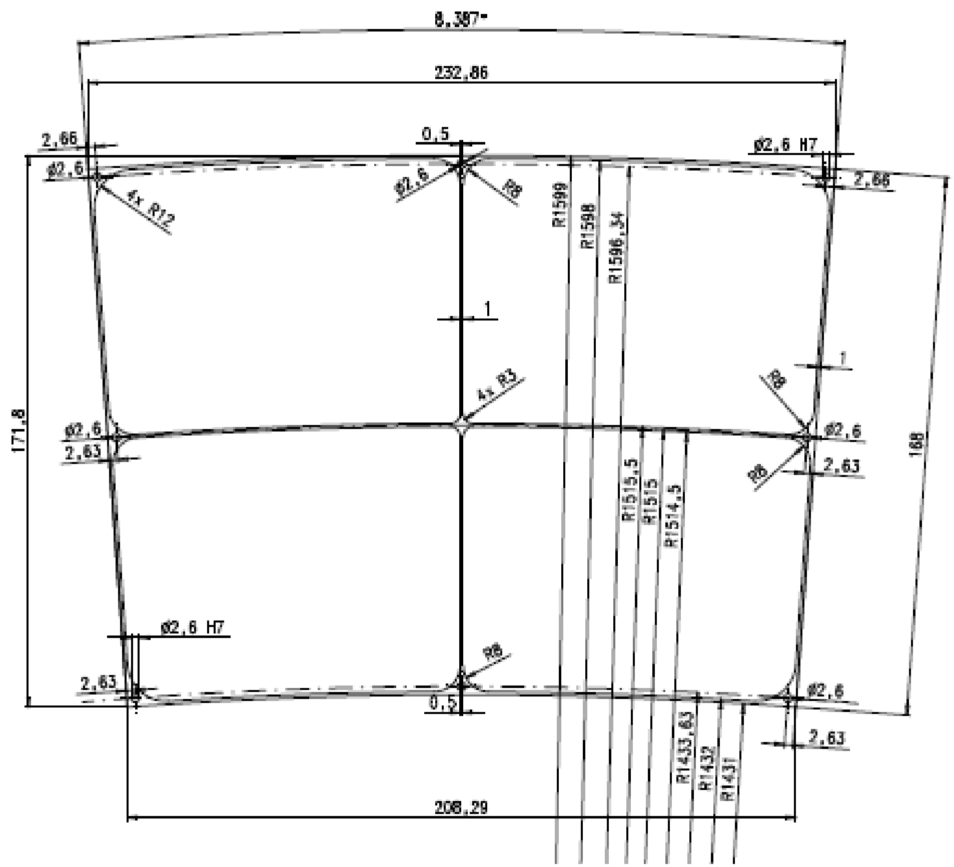
  d = 70 µm

  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



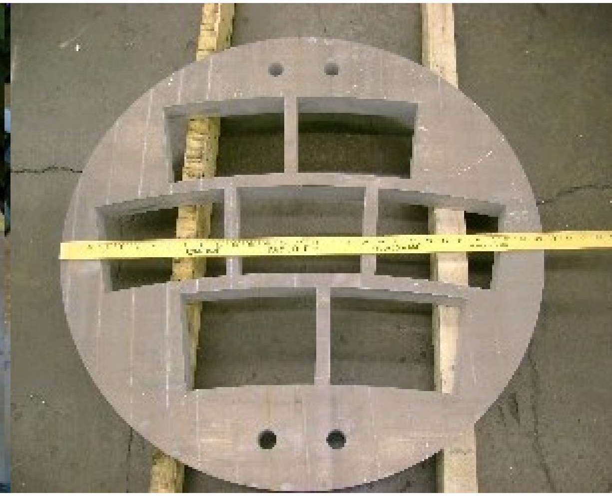
S. Caiazza, DESY

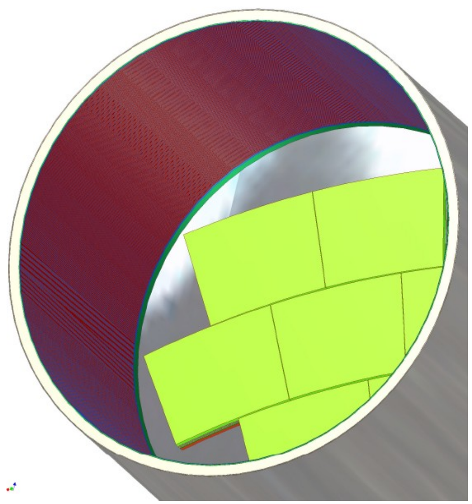
Summary & Outlook

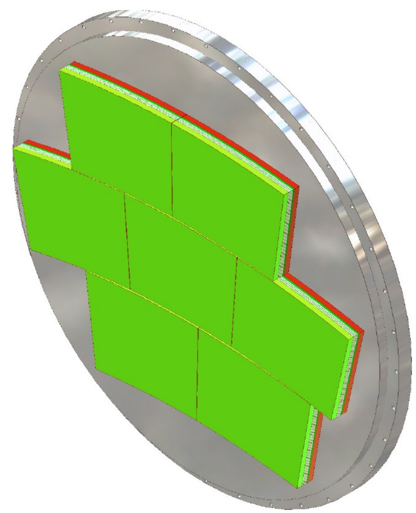
- A Large Prototype of a TPC has been built and is being assembled/tested/commissioned by the LCTPC collaboration
- Two MPGD technologies (with three electronics techniques) are being tested
- Infrastructure for Large Prototype has been constructed
- e^- test beam (DESY) in conjunction with PCMAG (*1T* 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

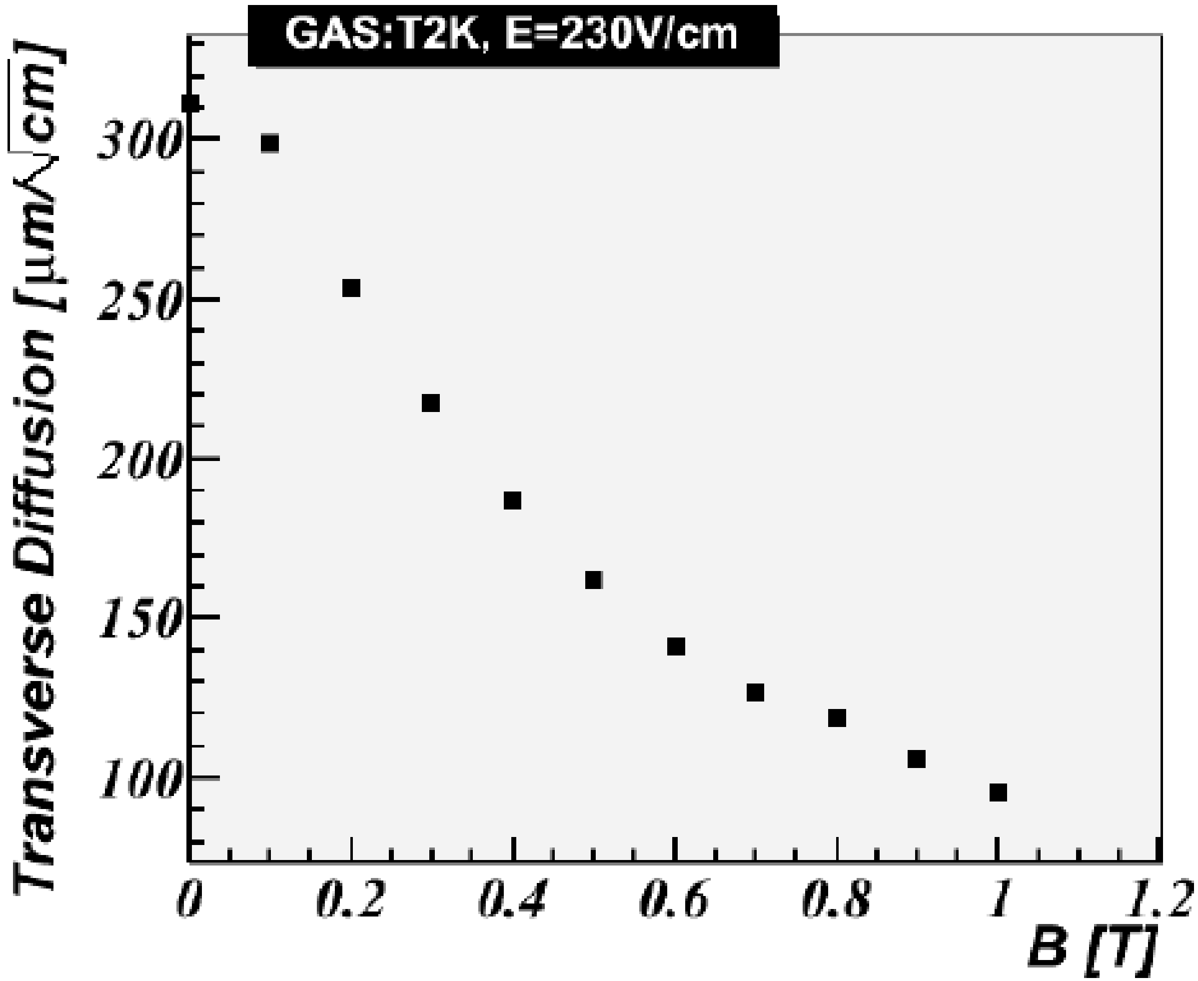




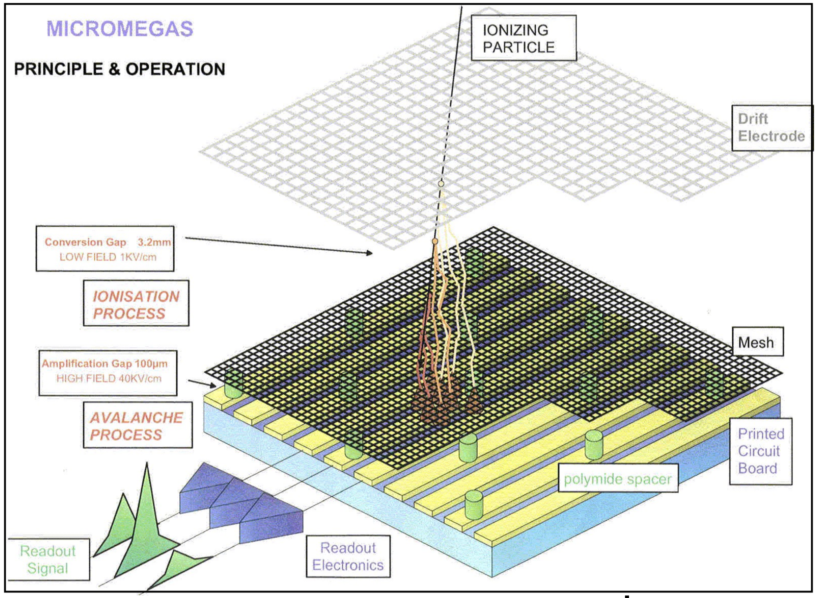


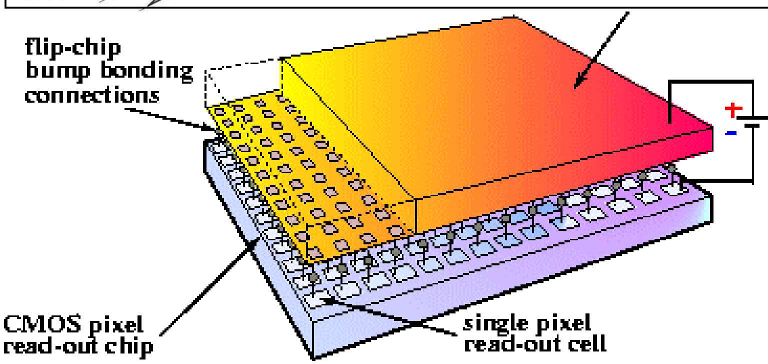
D. Peterson, Cornell

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)

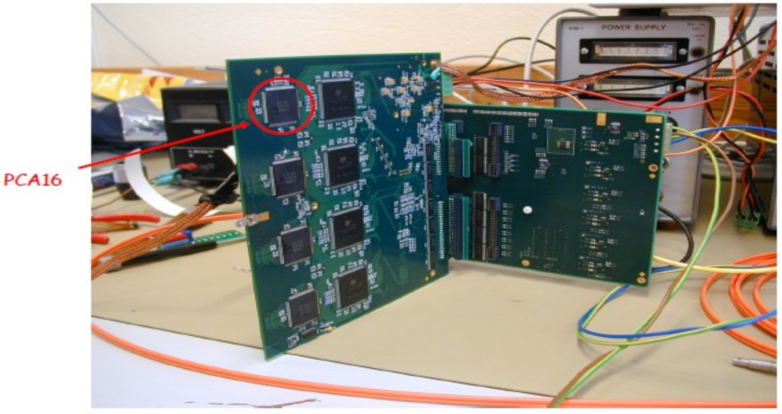
- TDC based:
  ASDQ chip + TDC (EUDET & Uni Rostock)

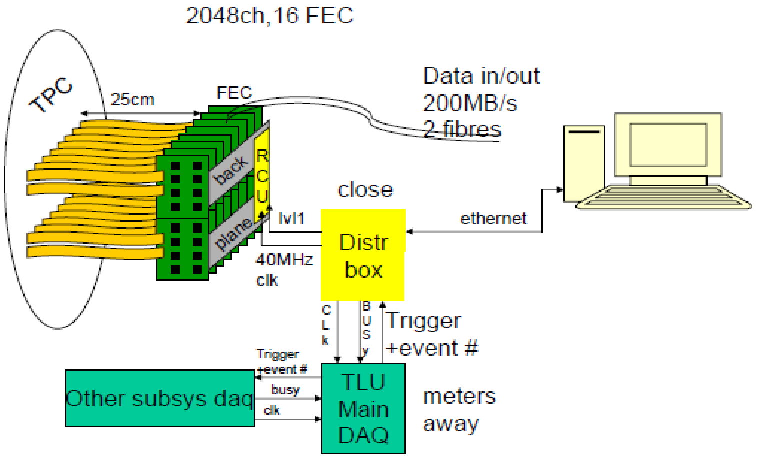
AFTER electronics for MicroMeGAS (resistive anode readout)
ALTRO and TDC based electronics will be hooked to the GEM detector modules (connector compatibility)

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

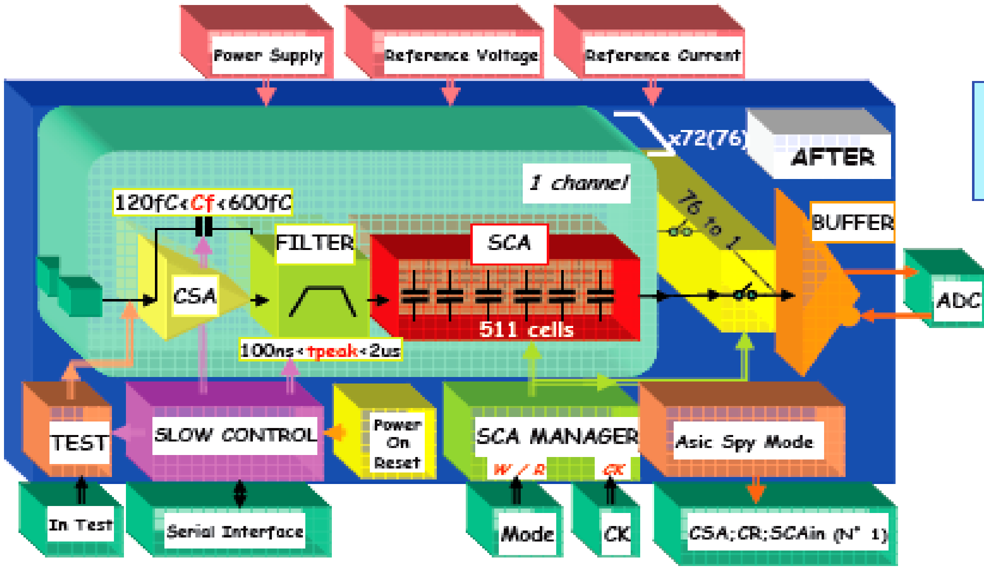




Readout Electronics: AFTER

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

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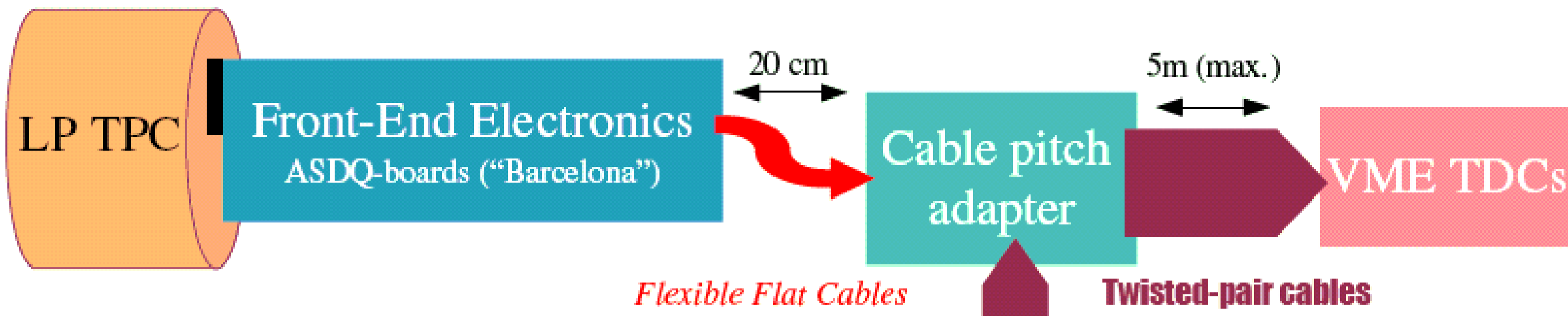
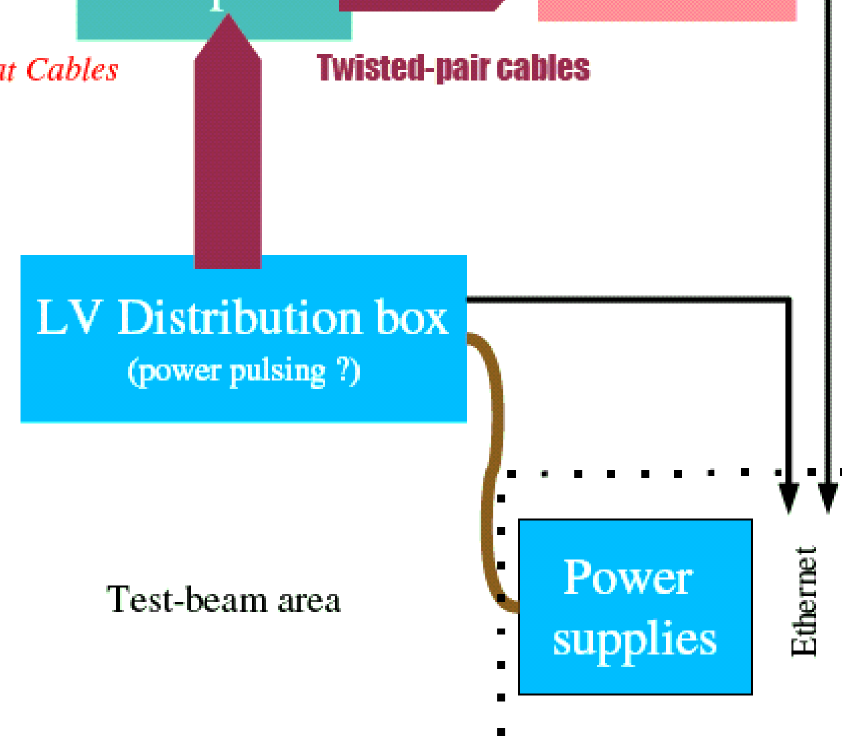
Readout Electronics: TDC

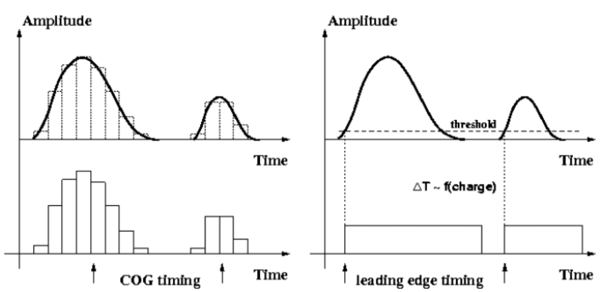


32 channels
Board size: 30 mm x 100mm*

Boards will be installed directly onto the endplate.



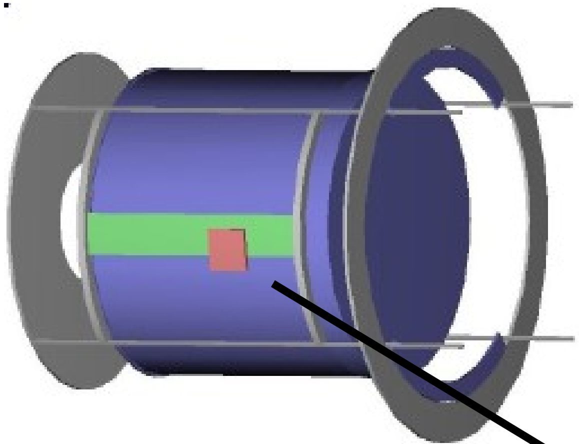
TPC signal processing with Time-to-Digit Converter

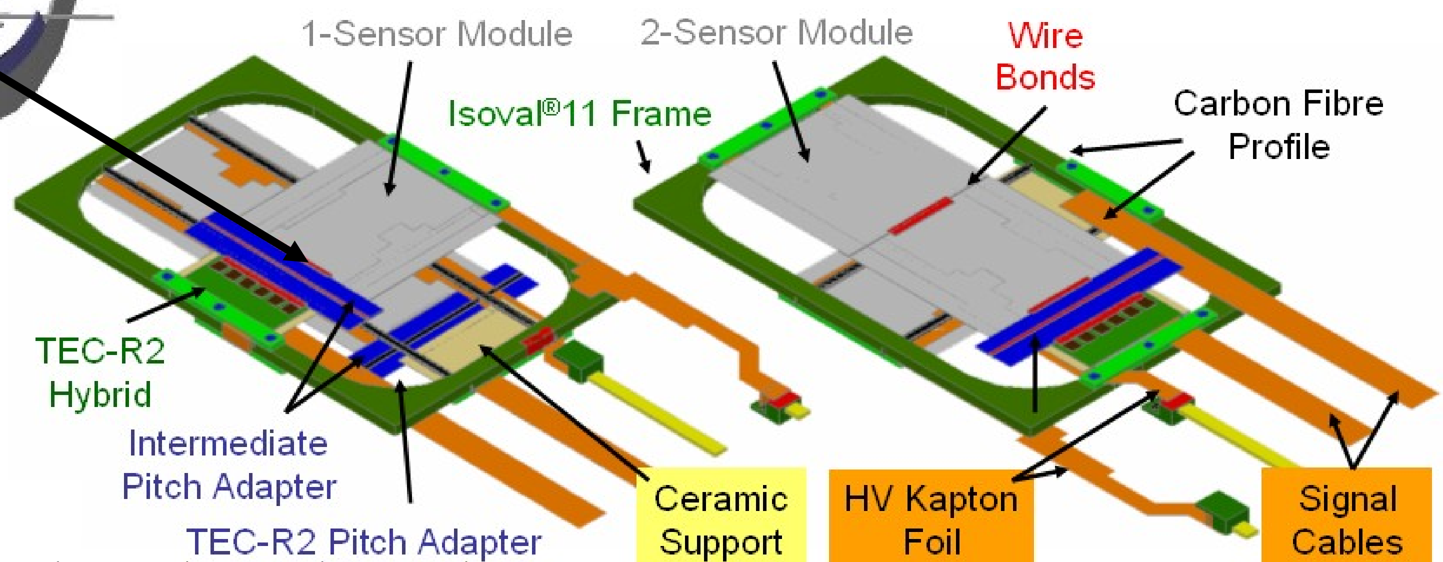


- The time of arrival is derived using the leading edge discriminator.
- The charge of the input signal is encoded into the width of output digital pulse.

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 mm²
    (only the intersecting readout area of the two modules on top of each other is interesting)