A Large TPC Prototype for an ILC Detector

Klaus Dehmelt

DESY

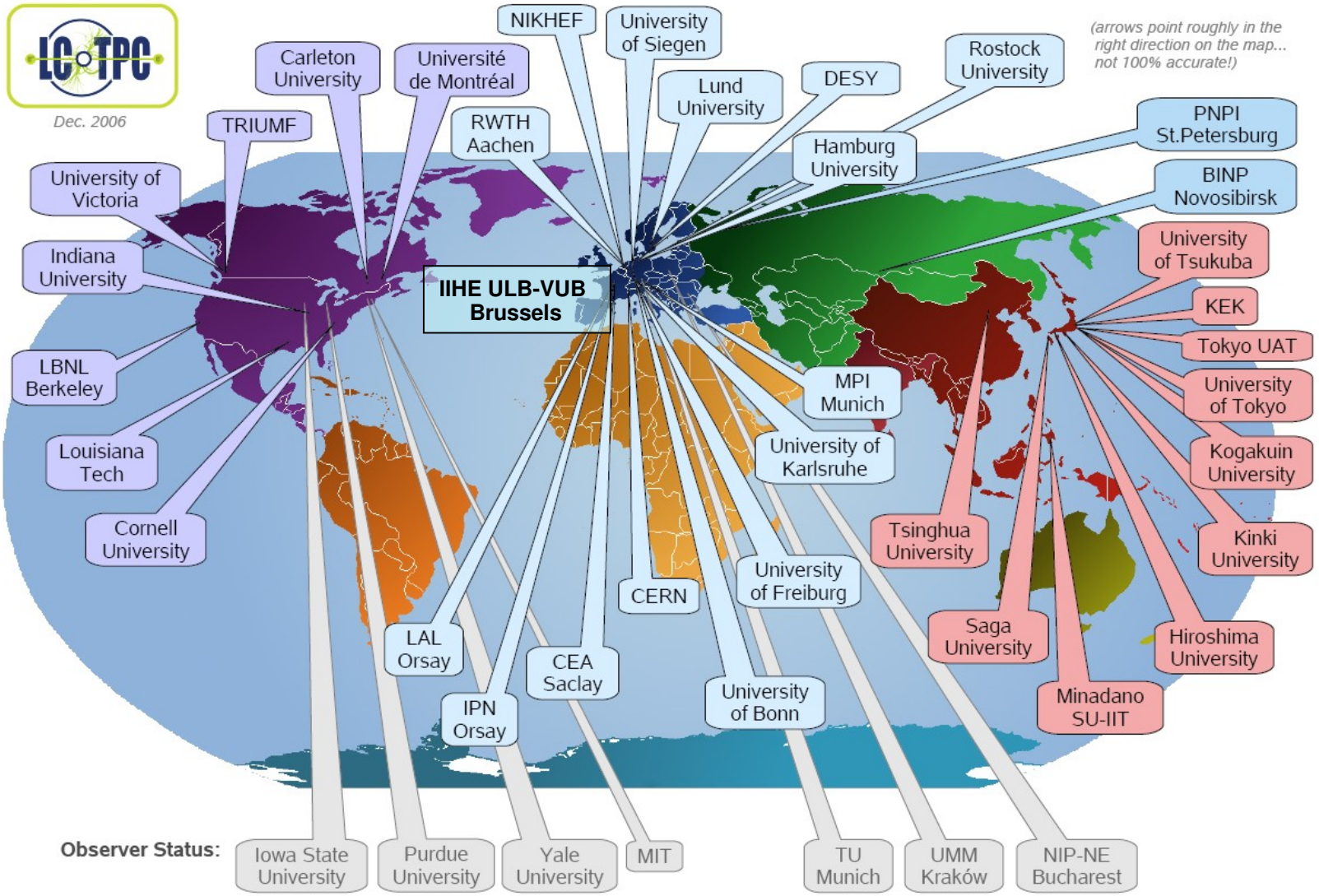
On behalf of the LCTPC Collaboration

The 2009 Europhysics Conference on High Energy Physics

Kraków, Poland,

July 18, 2009

LCTPC Collaboration



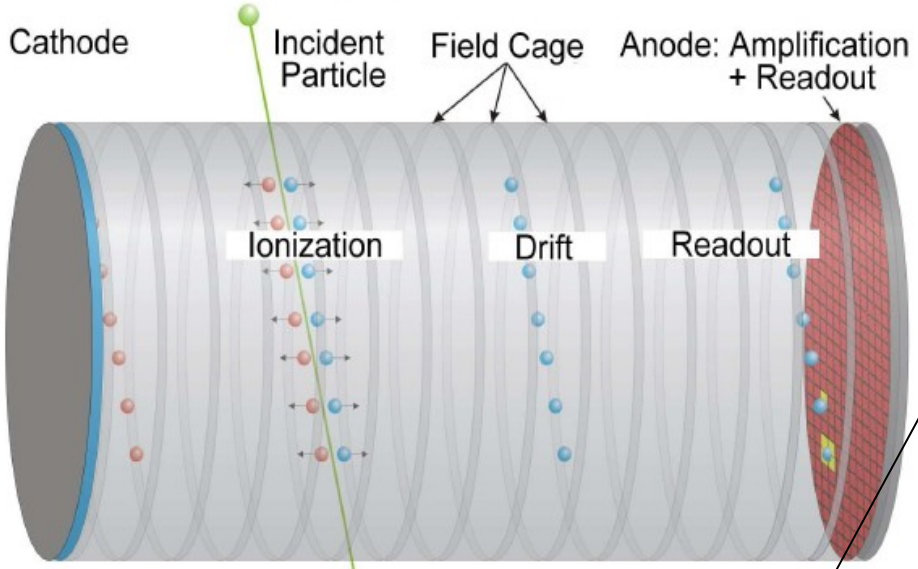
LCTPC Collaboration

- 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	$\sim 1{\times}10^6$/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 ($p_t > 1$GeV/c), and
	$>$ 99% all tracking ($p_t > 1$GeV/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

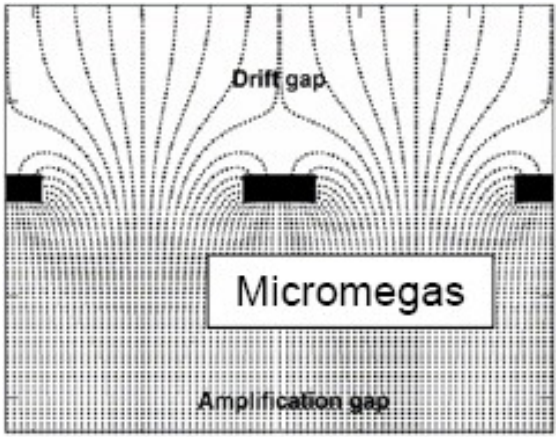
with MPGD

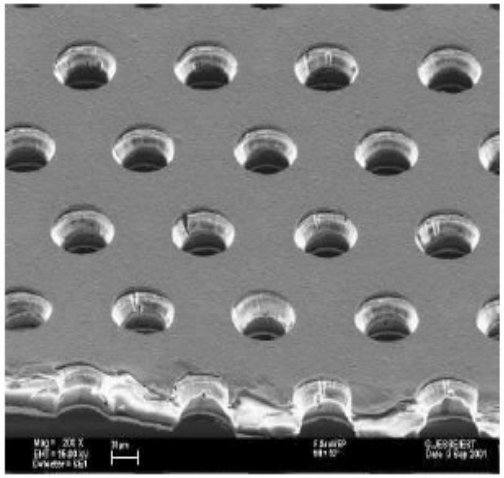
TPC with MPGD

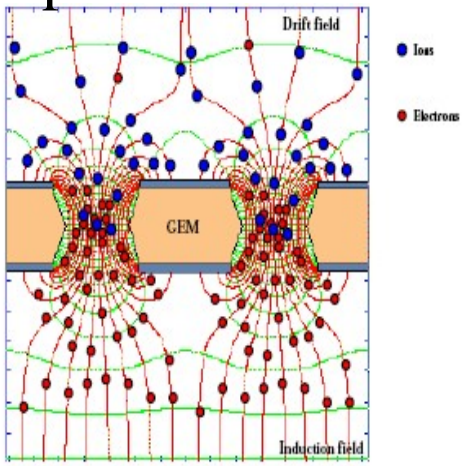


MicroPatternGasDetector
MPGD
not limited by **E** x **B** effects

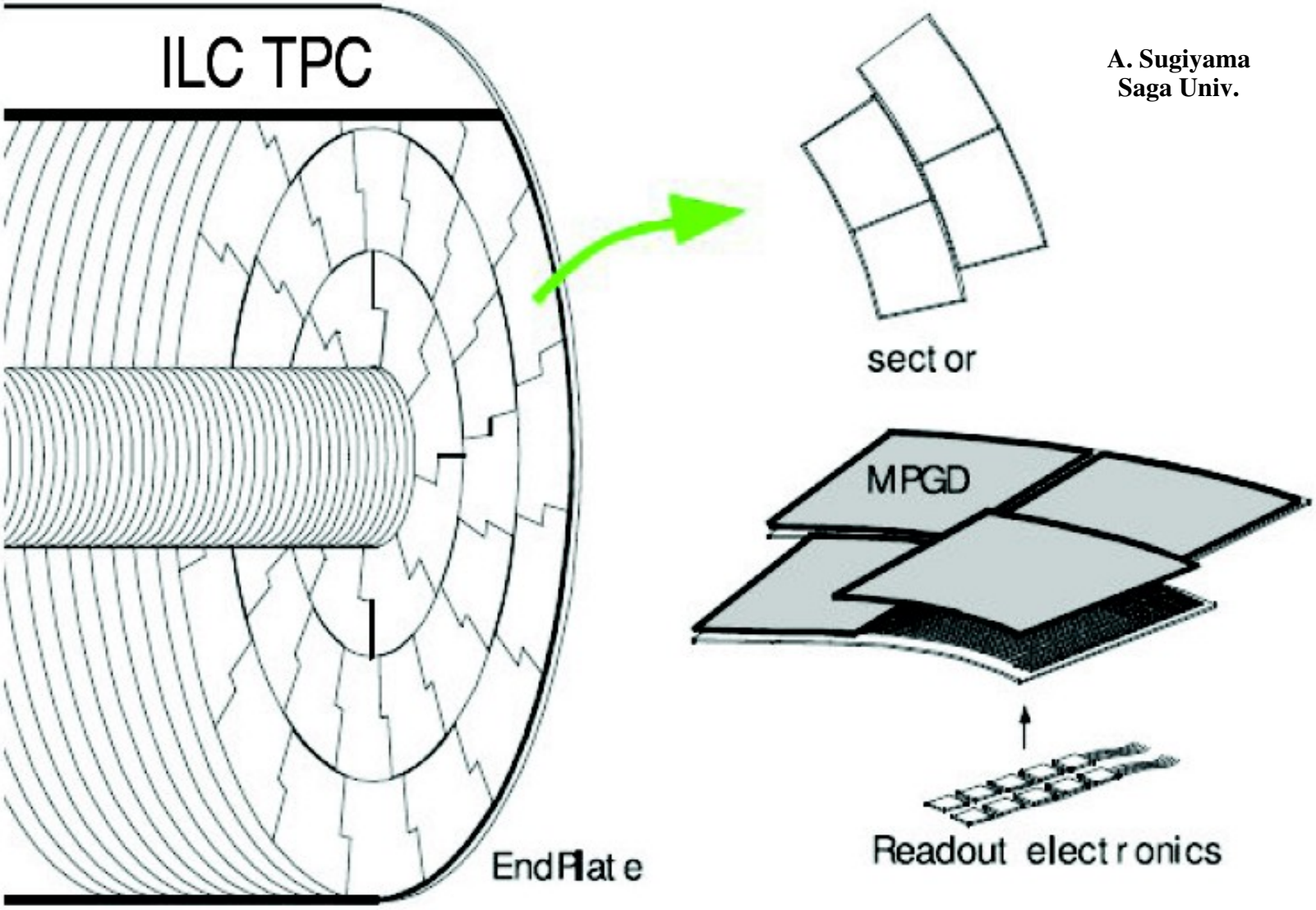
Gas Electron Multiplier GEM





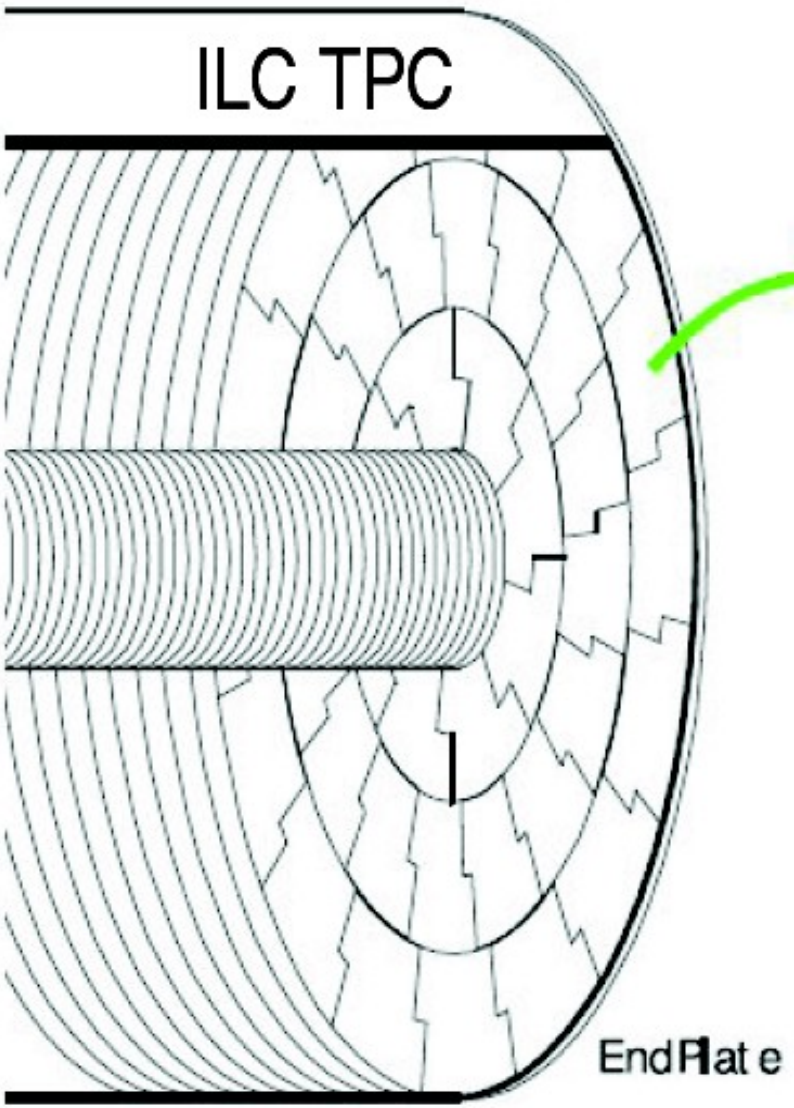


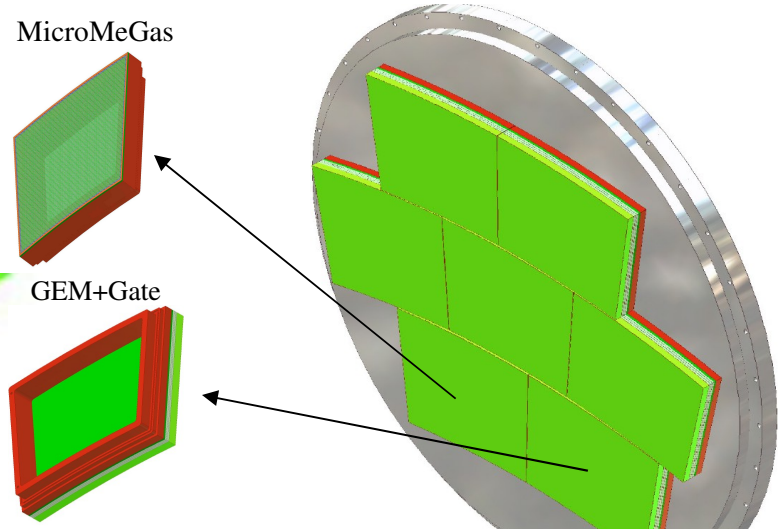
TPC with MPGD



A. Sugiyama
Saga Univ.

TPC with MPGD



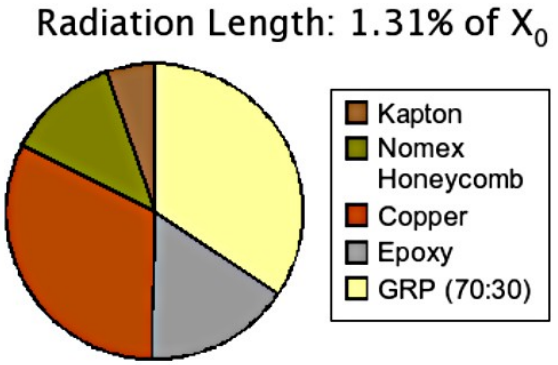


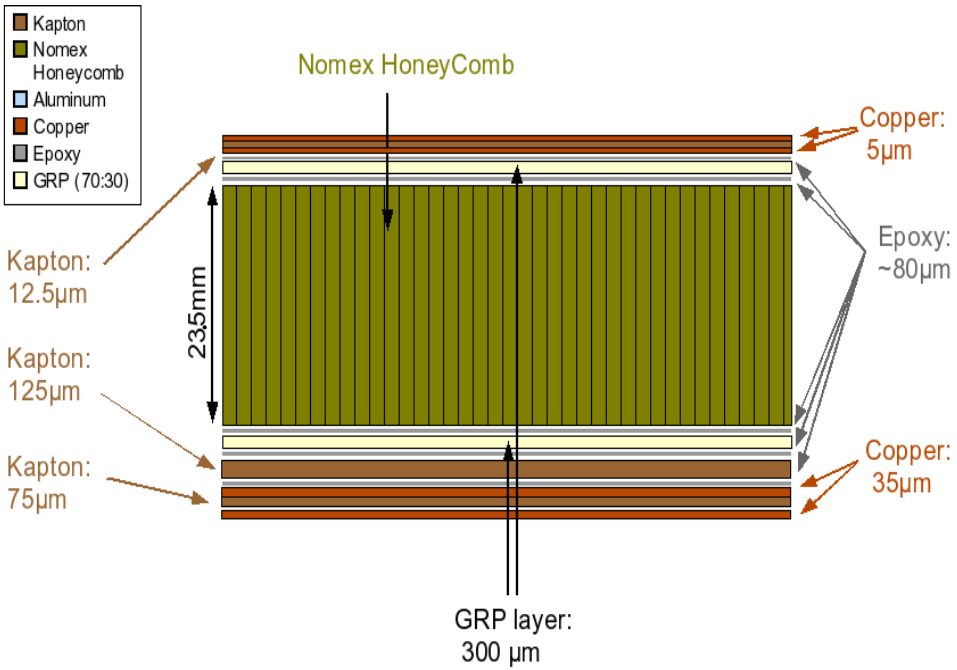
D. Peterson, Cornell

Endplate:

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

LP-TPC Field Cage (FC)



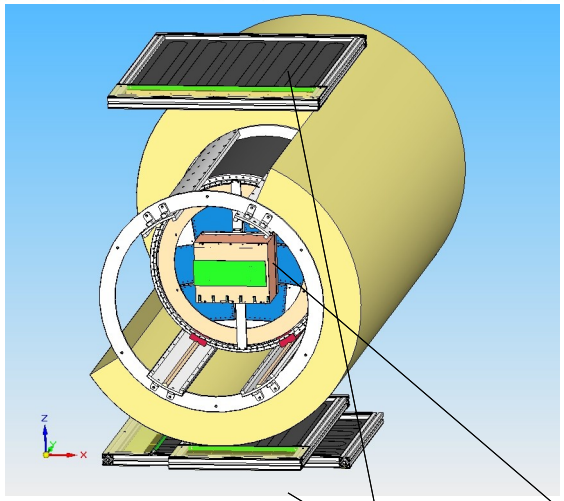


Diameter: Inner 720 mm,
Outer 770 mm
Wall thickness 25 mm
Length 610 mm
HV to be applied: up to 20 kV

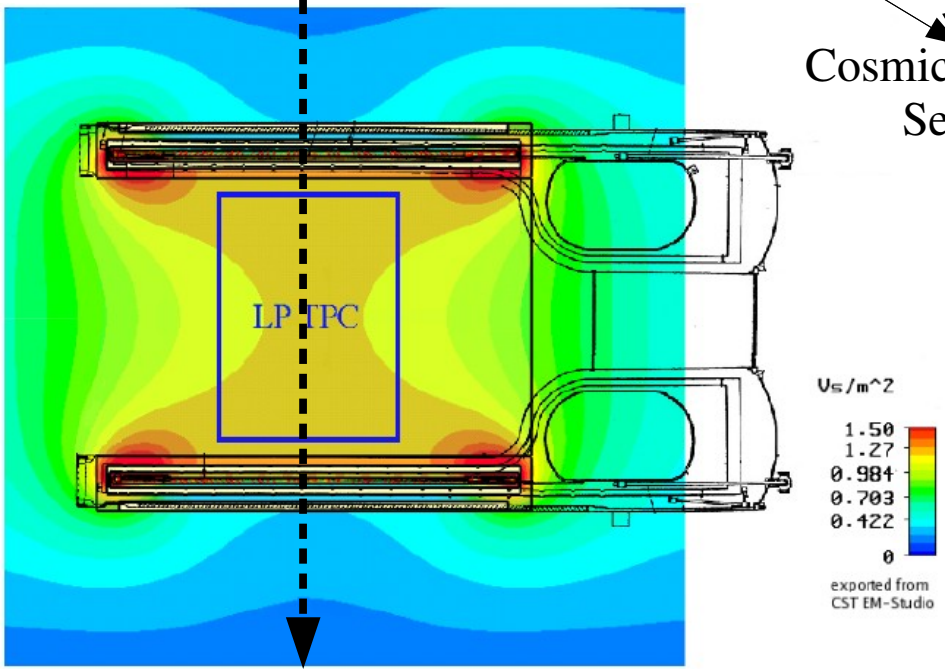
DESY Setup

PCMAG:
superconducting magnet, up to 1.25 T

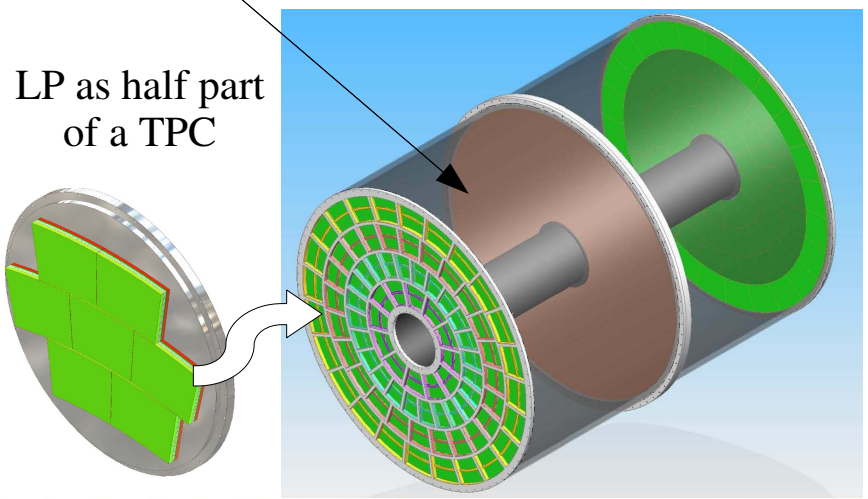
- e^- test beam @DESY (1GeV/c<p<6GeV/c)



Cosmic Trigger Setup

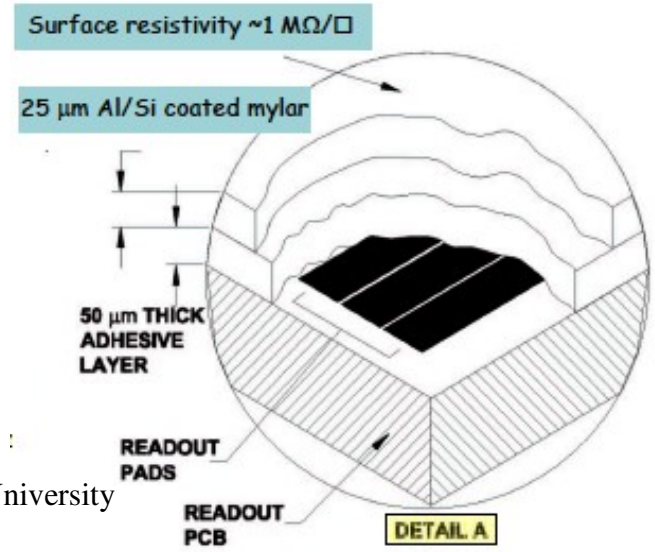


LP as half part of a TPC



MicroMeGaS Structure

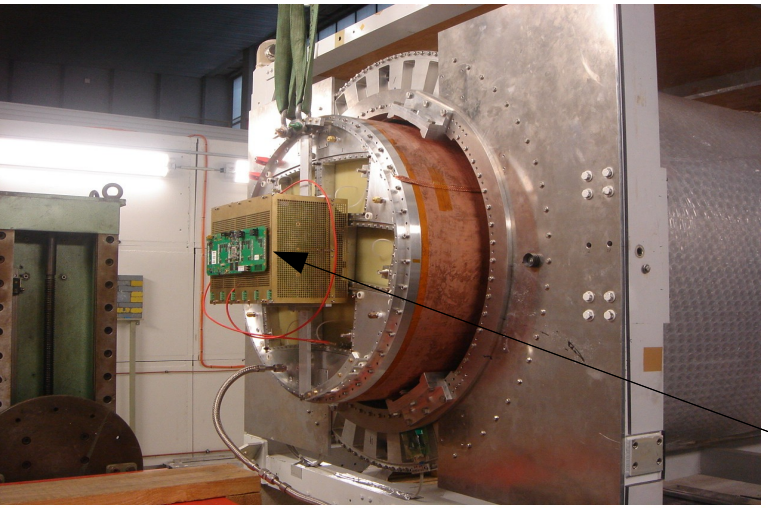
'Bulk Micromegas' panels, without resistive foil and with resistive carbon-loaded kapton, have been produced at CERN (Rui de Oliveira)

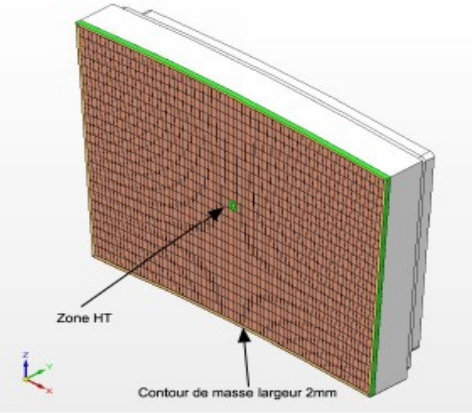


P. Colas, CEA Saclay
M.S.Dixit, Carleton University

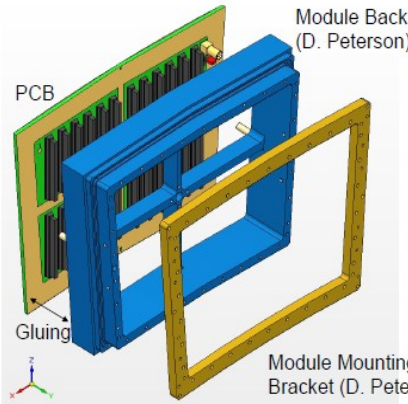
MicroMeGaS for LP:

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





Detector side



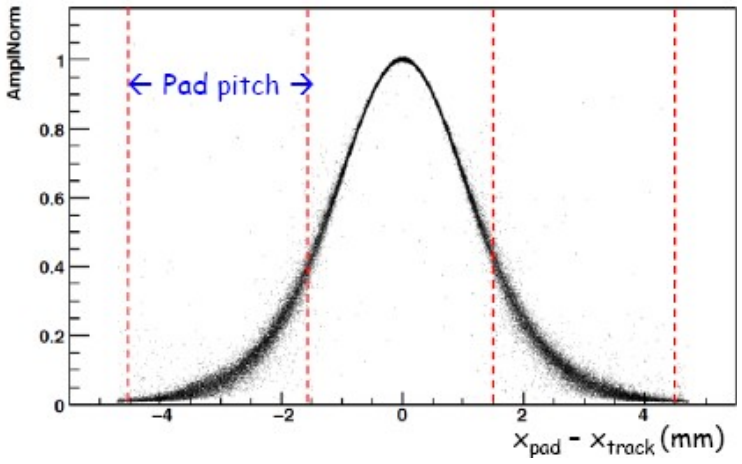
Readout electronics: AFTER (T2K TPC)

MicroMeGaS Structure

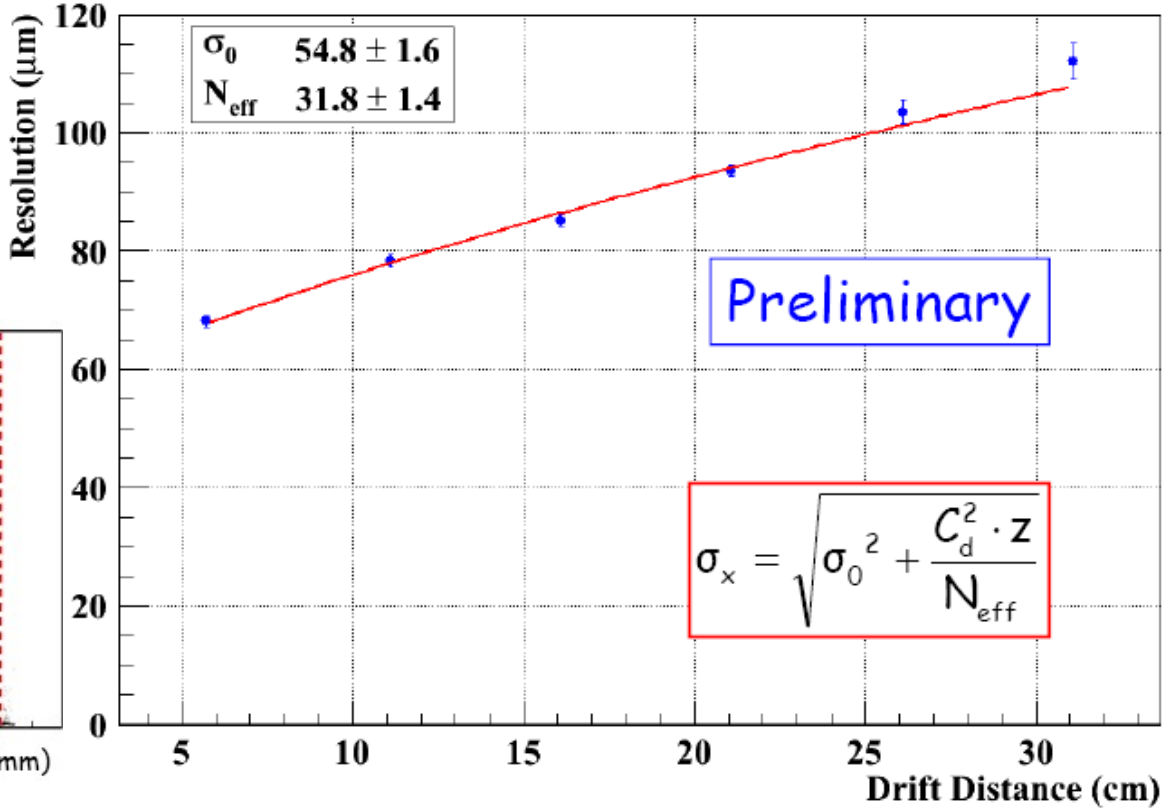
Electrons (5 GeV), Magnetic field (B=1T)

- 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)



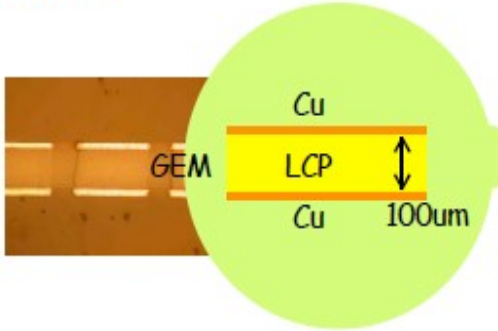
- Resolution at z=0: σ_0 = 54.8±1.6 µm with 2.7-3.2 mm pads (w_{pad}/55)
- Effective number of electrons: N_{eff} = 31.8±1.4 consistent with expectations

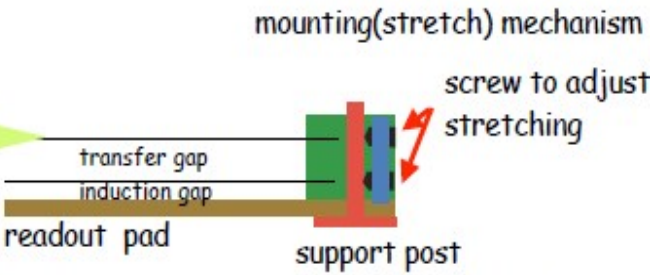


P. Colas, CEA Saclay

Double GEM Structure

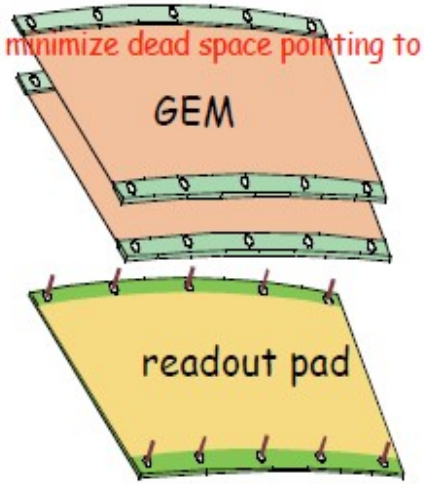
GEMs

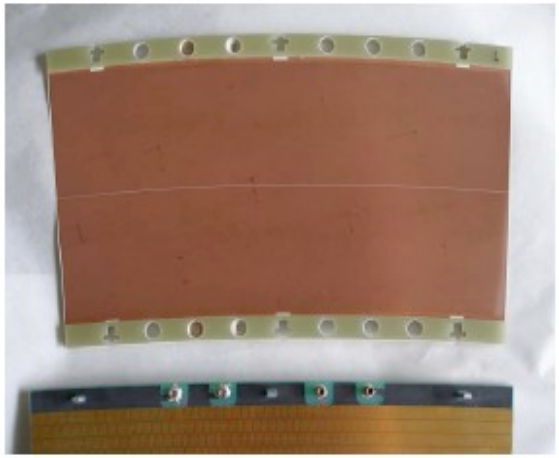




Transfer gap ~ 4mm (+2mm) : enlarge signal distribution width > 0.3* pad pitch

frame : top & bottom frame.
no side frame



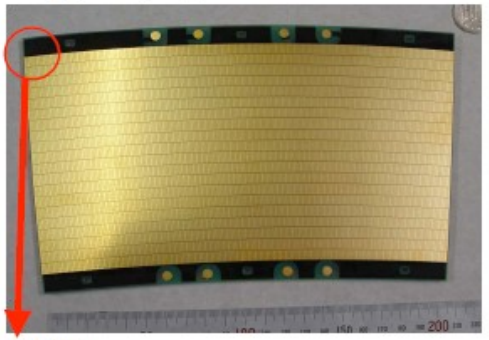


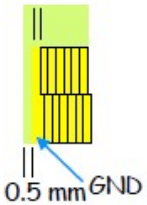
Optional: gating GEM

A. Sugiyama, Saga Univ.

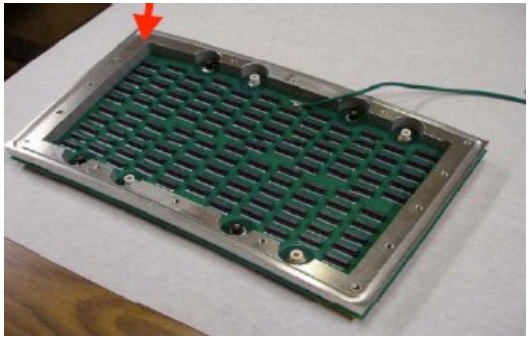
28 pad raws (176/192 pads/raw)
~1.2(w) x 5.4(h) mm^2
staggered every each layer

Total 5,152 ch/module

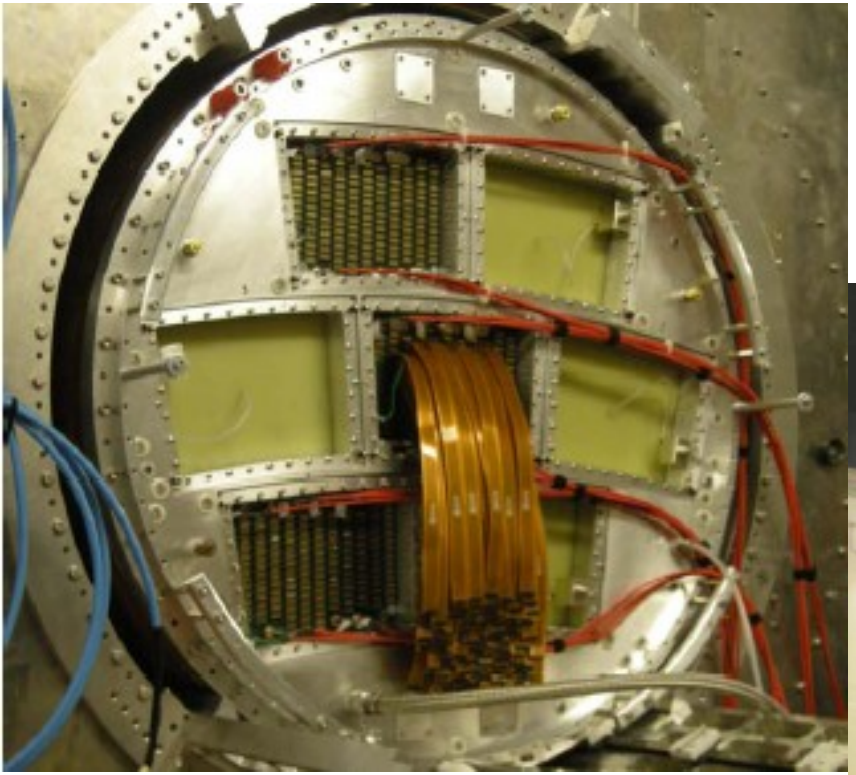




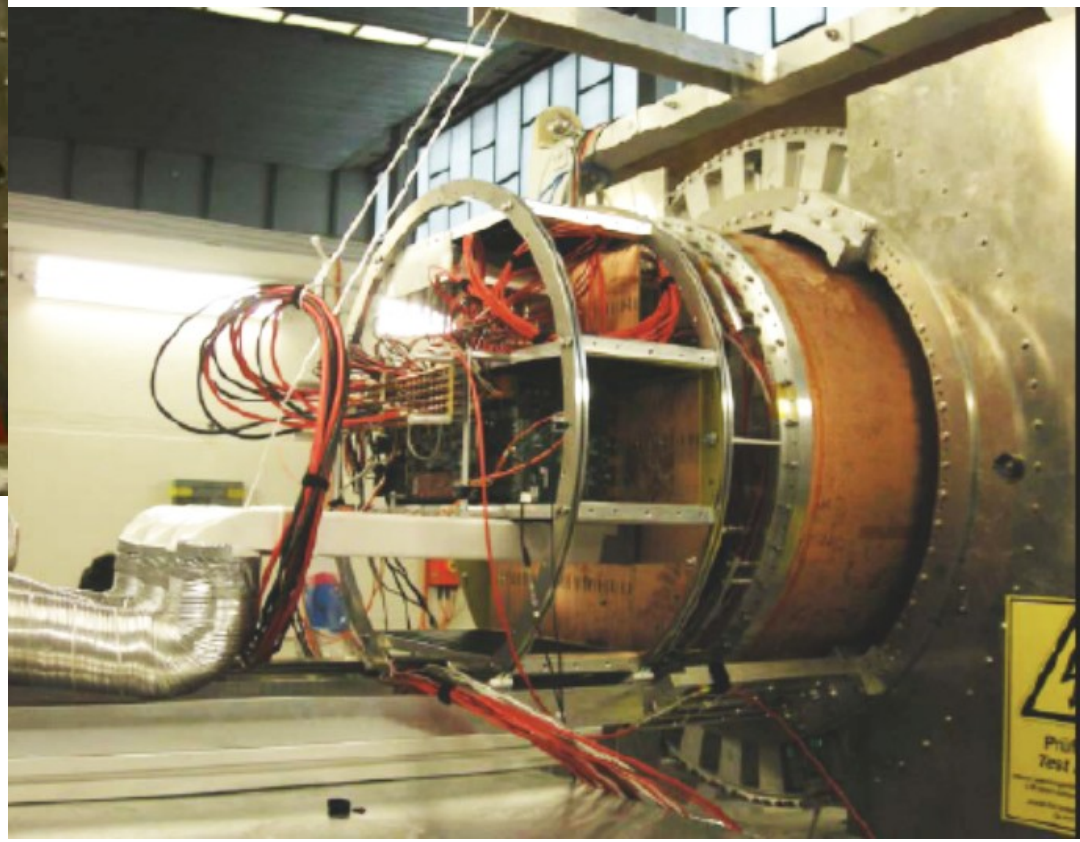
6 layers PCB
one GND layer



Double GEM Structure



About 3200 channels readout electronics

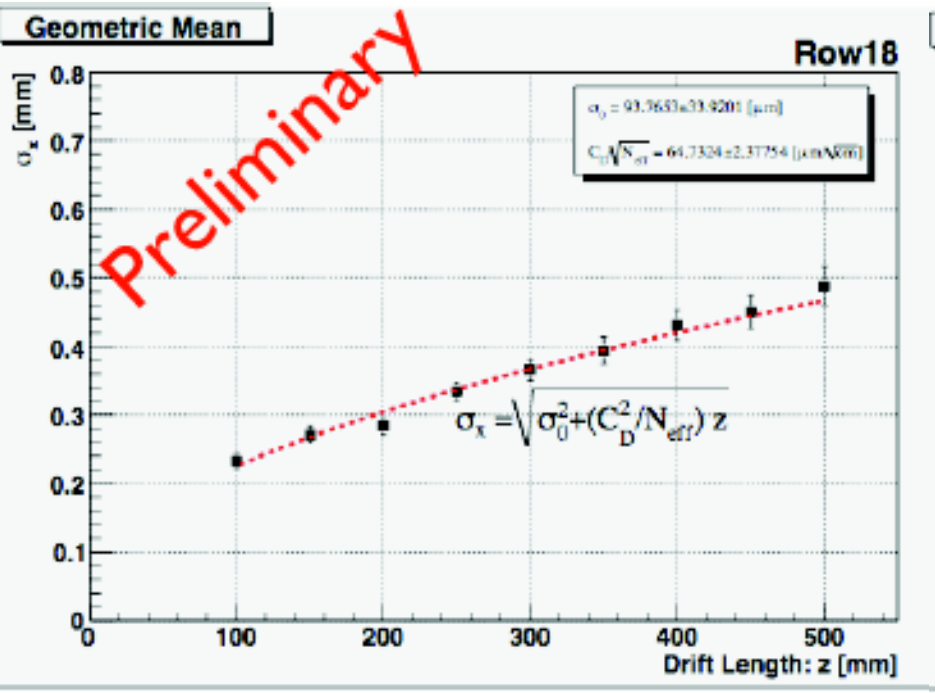


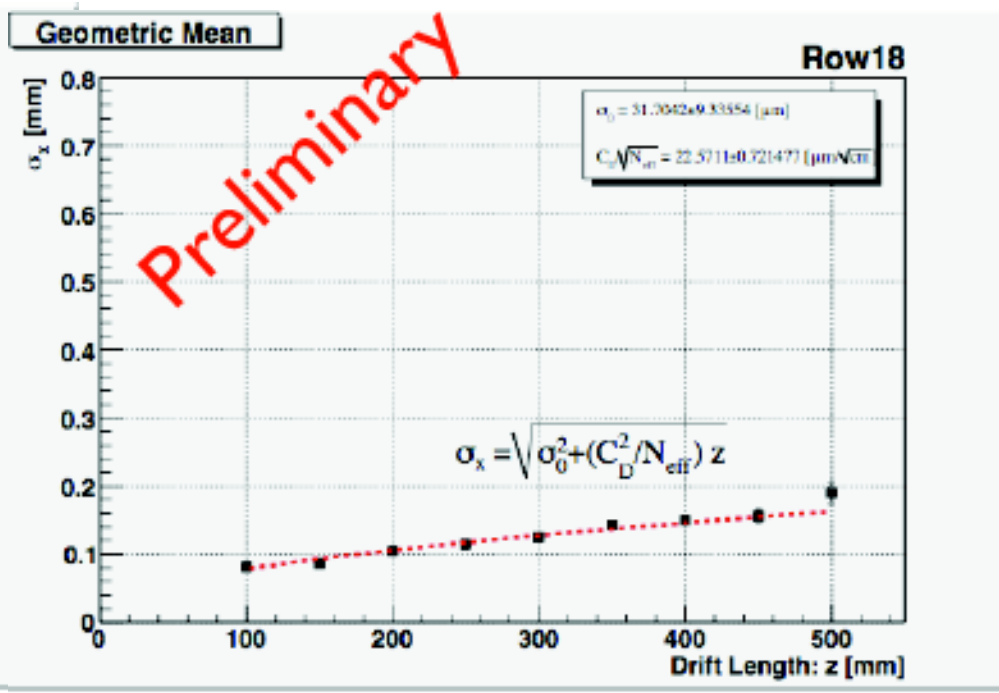
Readout electronics:
Based on ALTRO (ALICE TPC)
L. Joensson, LUND University

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

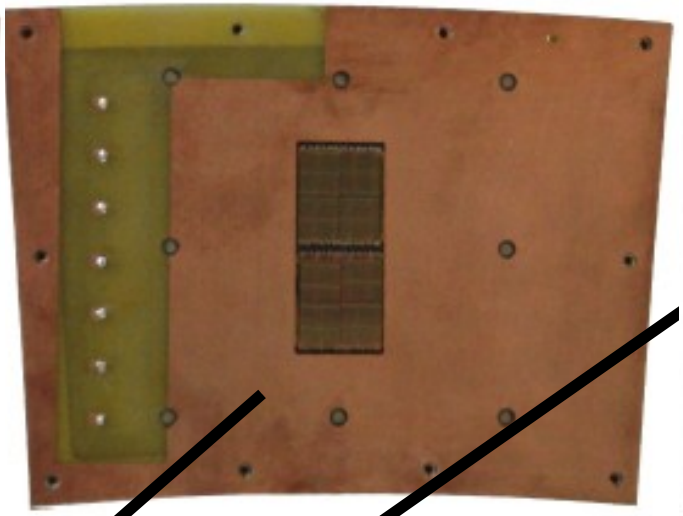
$$\begin{cases} C_D = 101.6 \pm 0.4 [\mu/\sqrt{cm}] \\ \dfrac{C_D}{\sqrt{N_{eff}}} = 22.6 \pm 0.7 [\mu m/\sqrt{cm}] \end{cases}$$

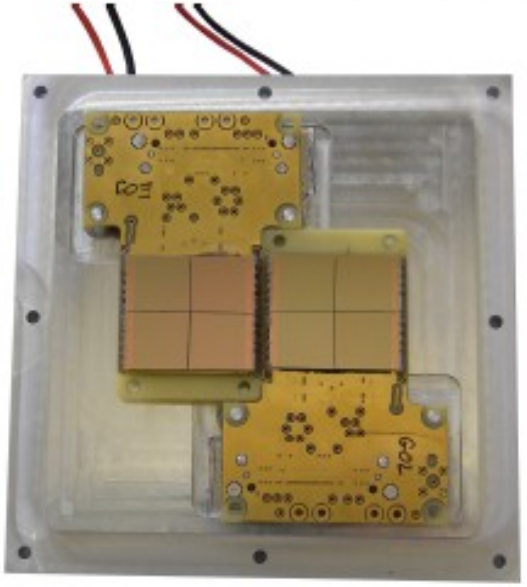
$\longrightarrow N_{eff} \sim 20 \pm 1$

Garfield

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

3-GEM Structure & TimePix





anode plane

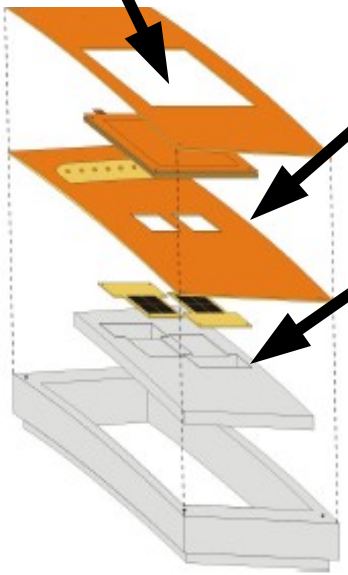
GEMs

readout plane

quad-boards

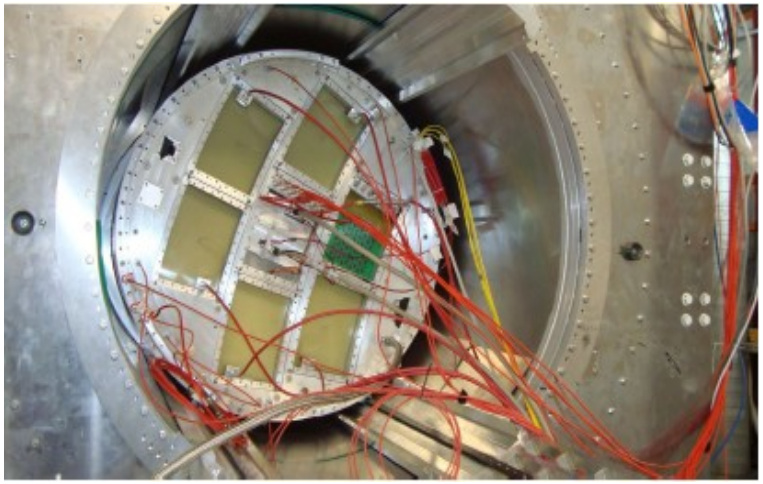
reinforcement of anode plane

redframe



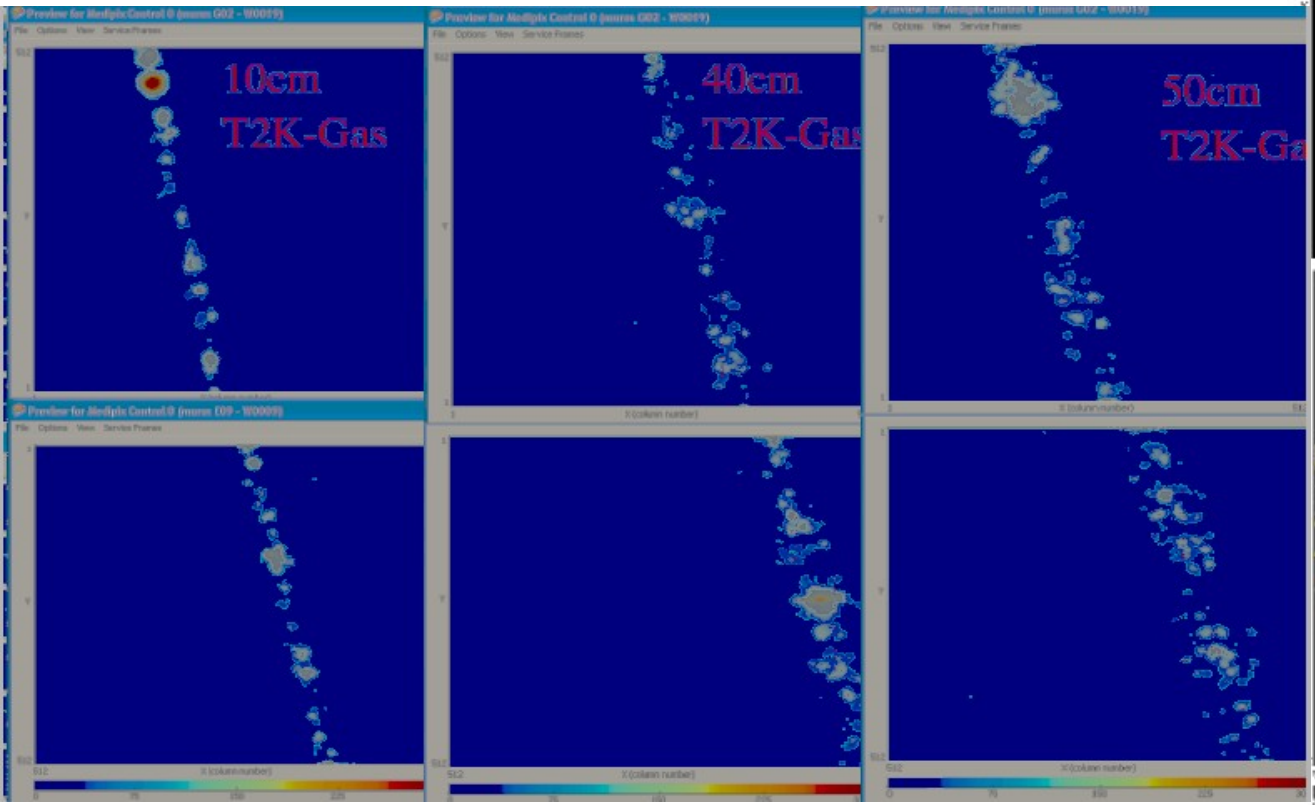
Readout:
2 quadboards
(4 TimePix
Chips each)

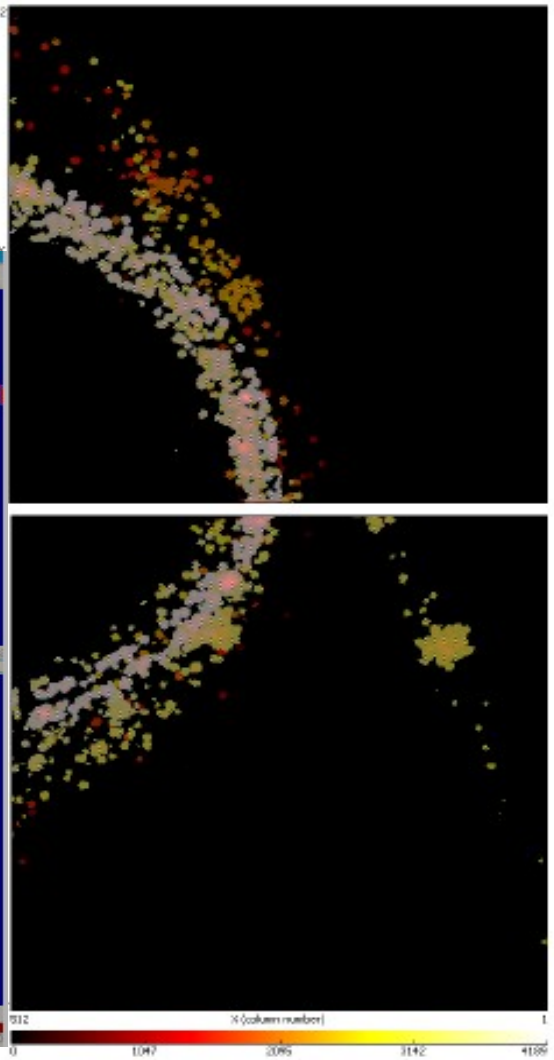
J. Kaminski, Univ. of Bonn



3-GEM Structure & TimePix

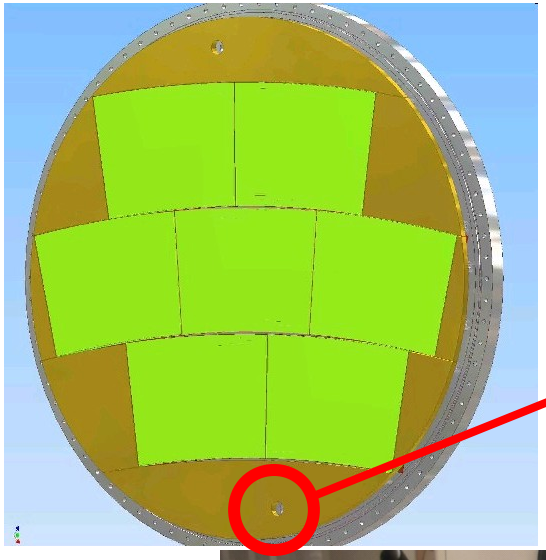
Largest amount of readout channels
on one anode for a TPC so far: # ch ≅ 500 k

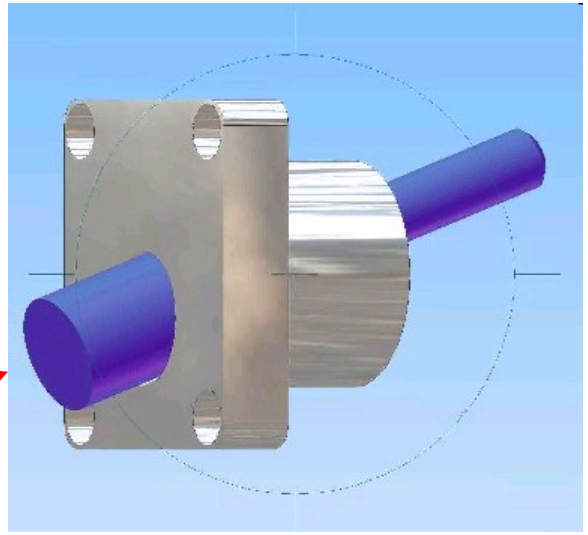


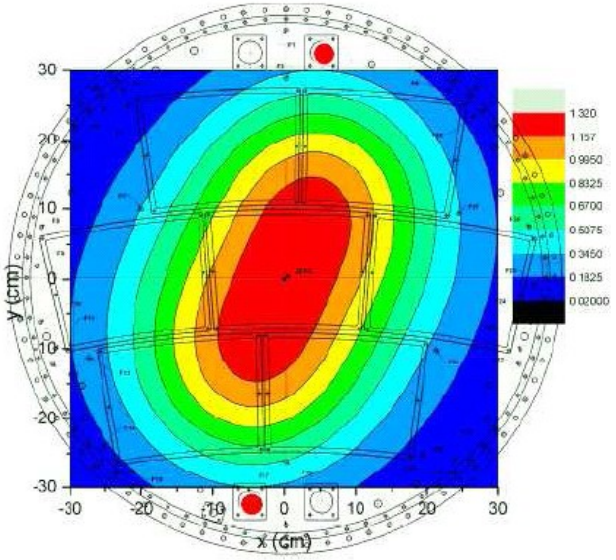


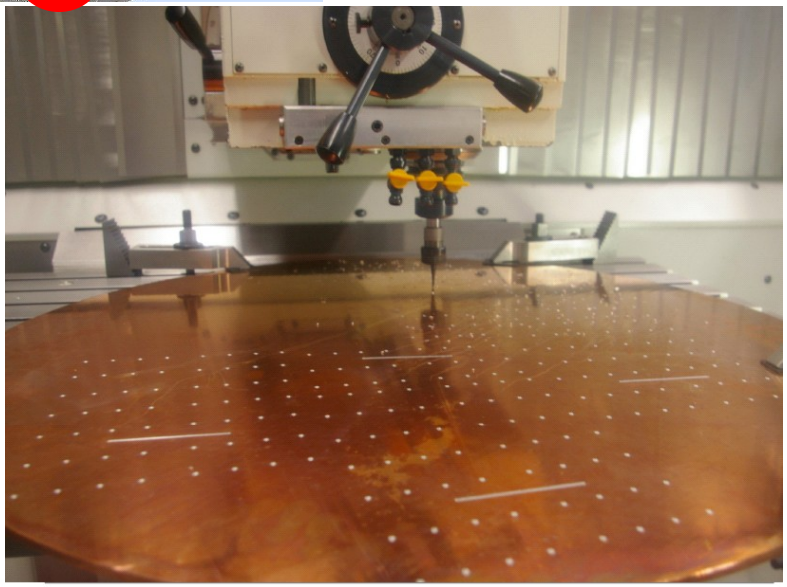
J. Kaminiski, Univ. of Bonn

Laser Calibration Setup

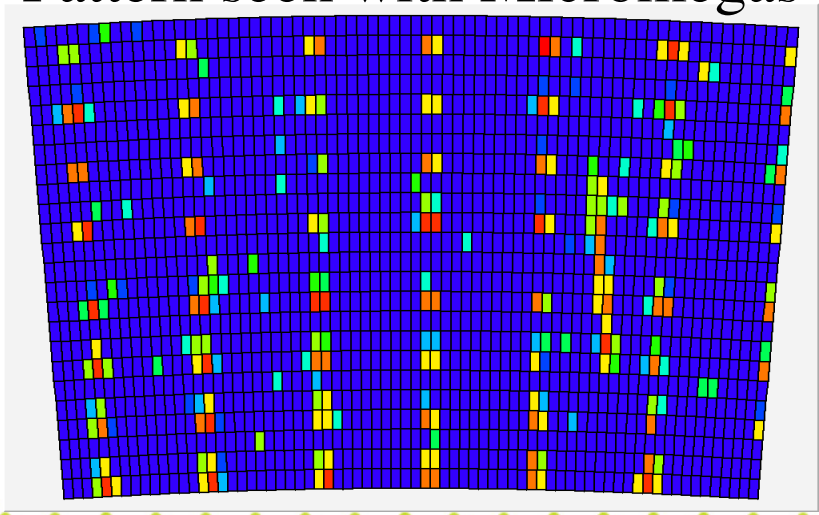








Pattern seen with Micromegas



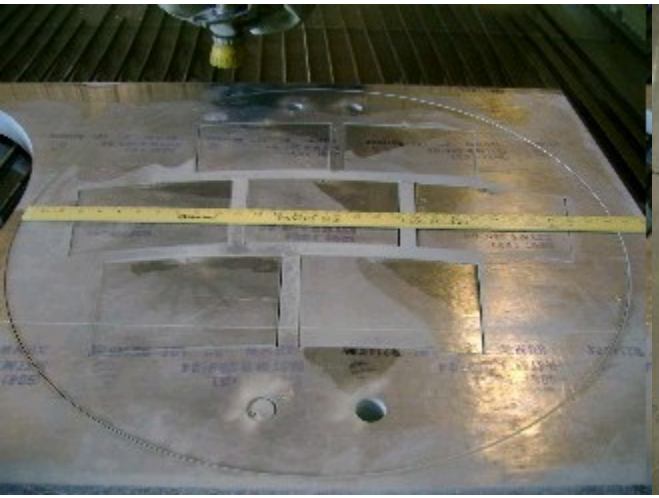
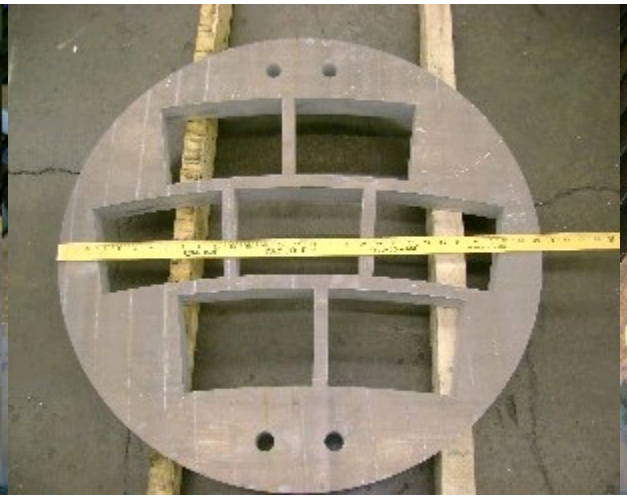
Summary & Outlook

- 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:
  - Micromegas
  - GEM
- 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

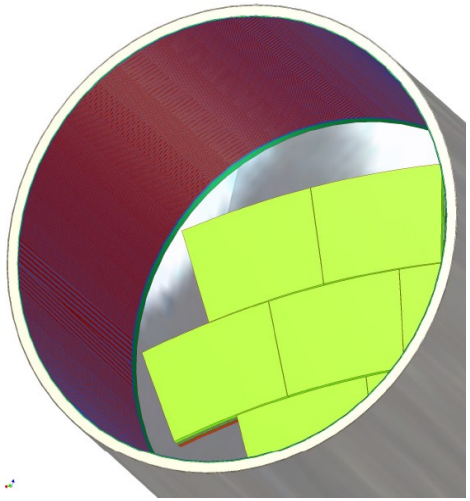
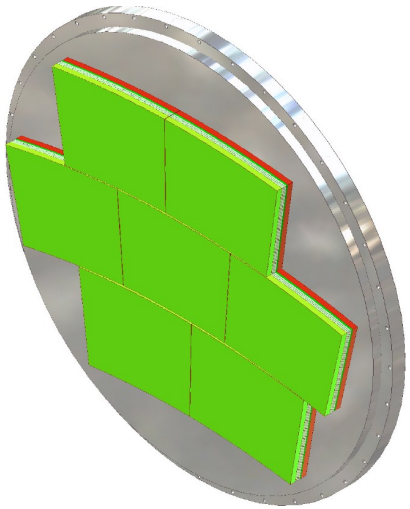
Summary & Outlook

Backup Slides

LP-TPC Endplate

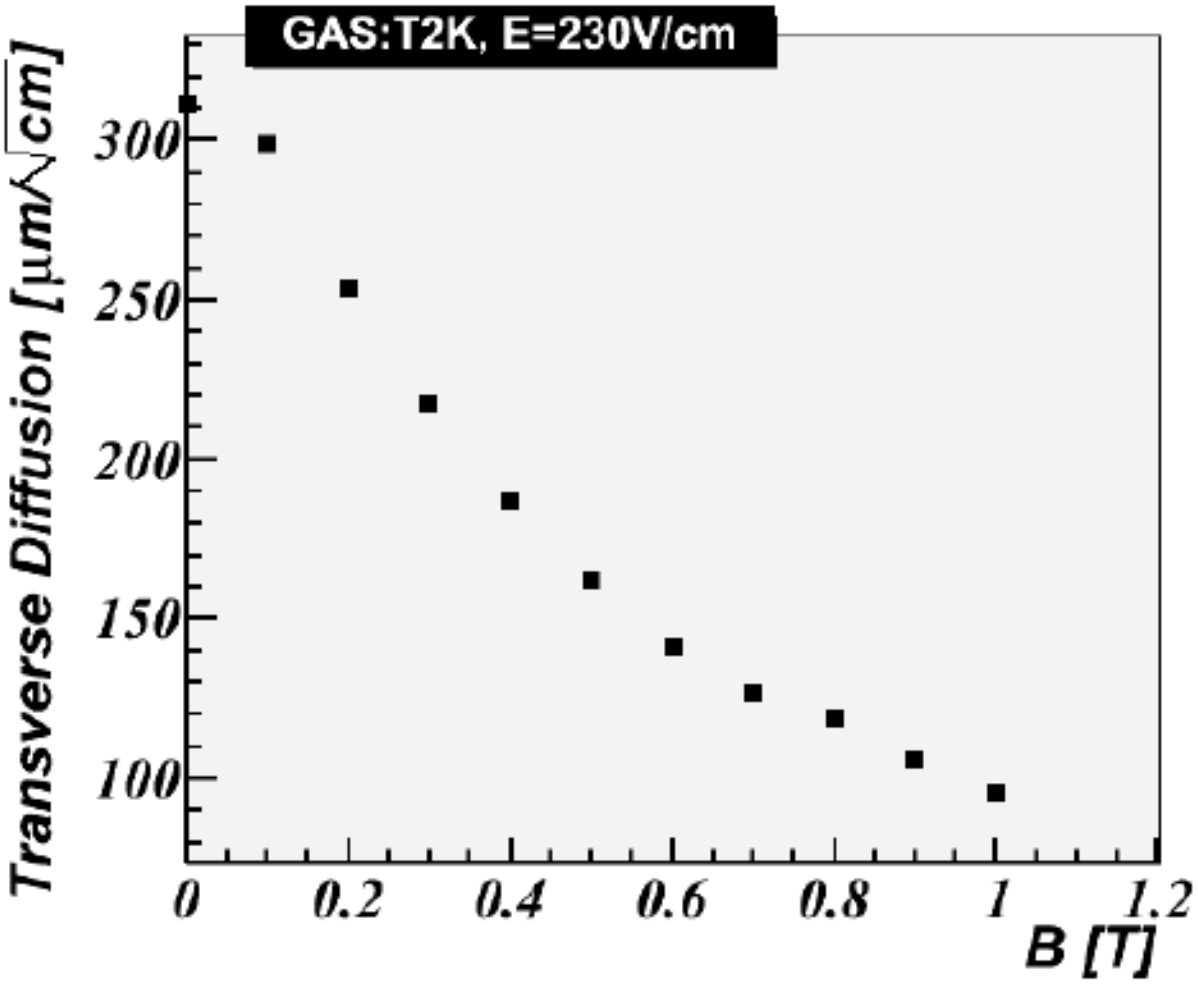





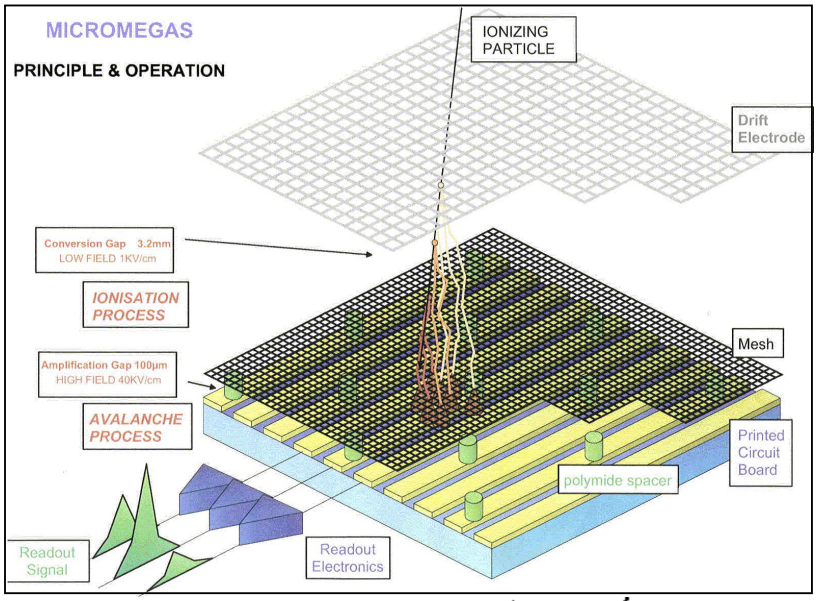



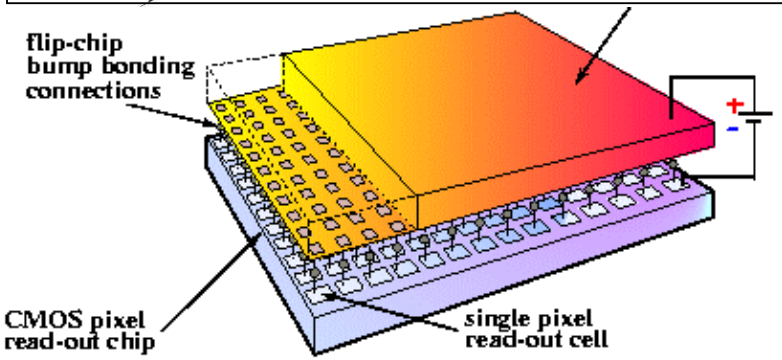
D. Peterson, Cornell

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)

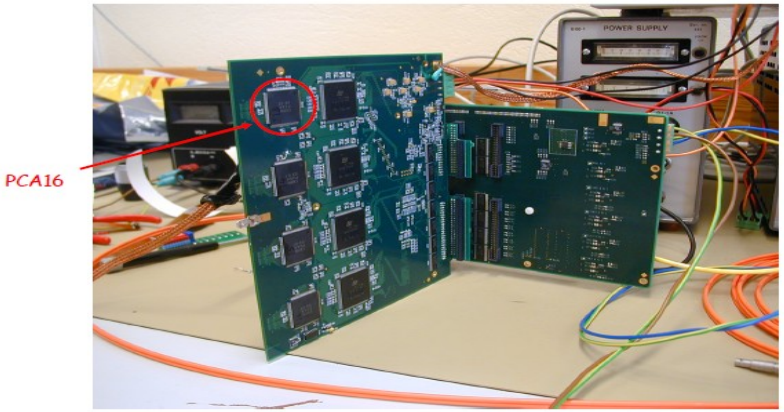
AFTER electronics for MicroMeGAS (resistive anode readout)
ALTRO and TDC based electronics will be hooked to the GEM detector modules (connector compatibility)

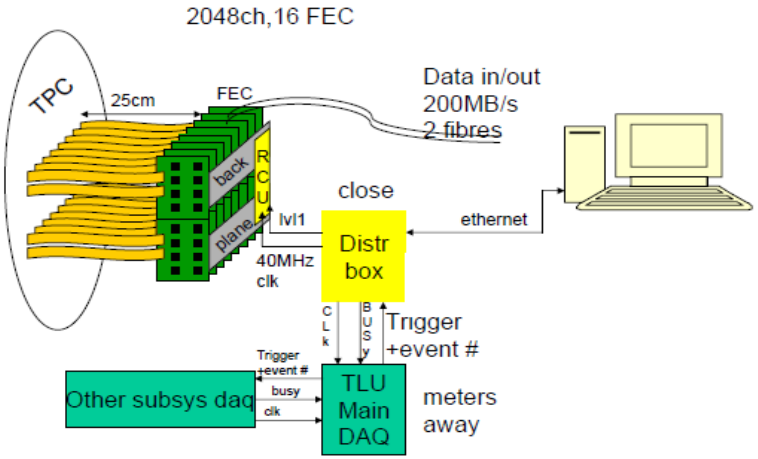
Readout Electronics: ALTRO

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

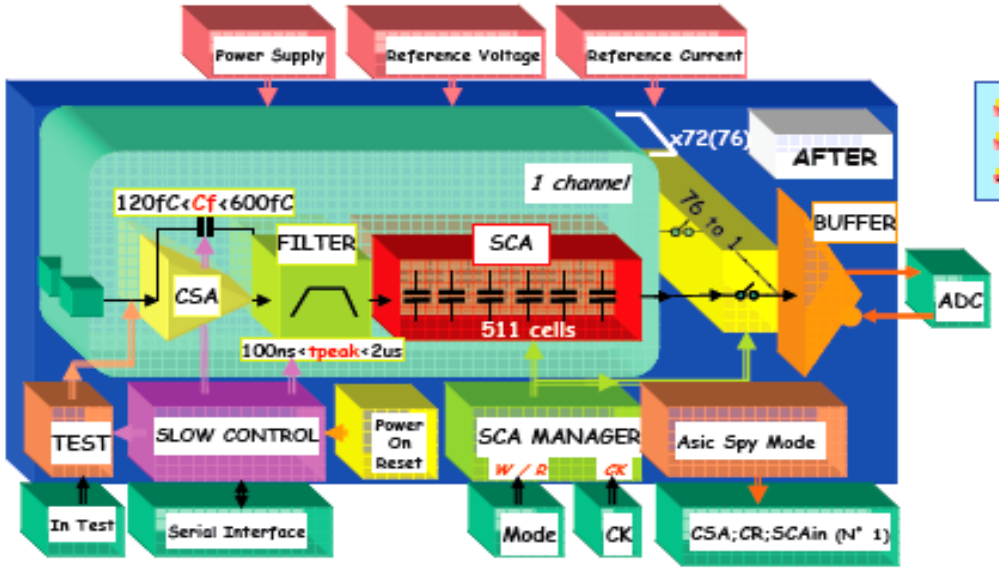
The test set up with a fully equipped front end board





Readout Electronics: AFTER

AFTER Main Features



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

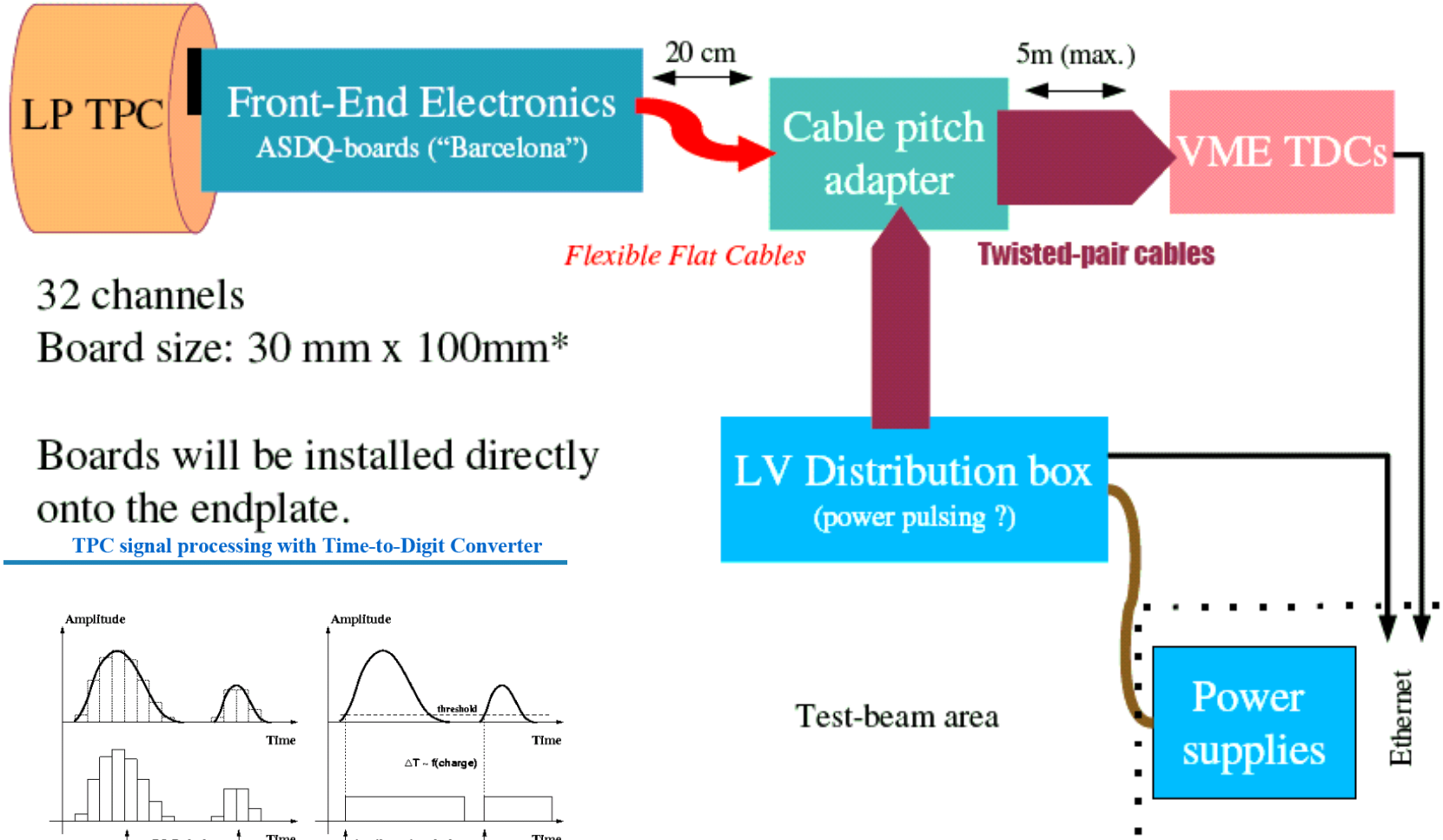
Main features:

- **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

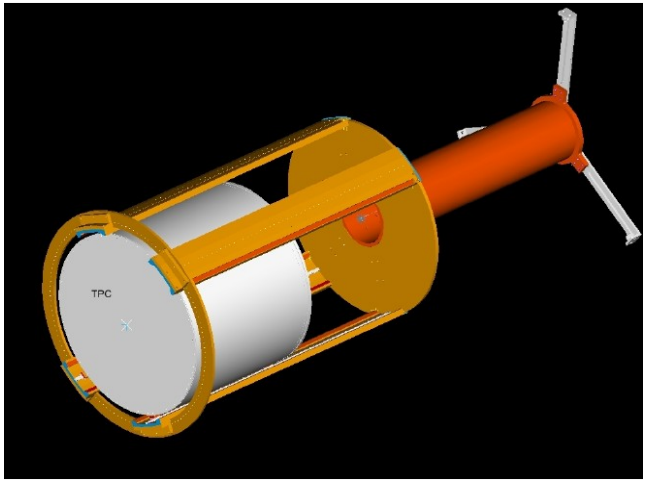
Readout Electronics: TDC

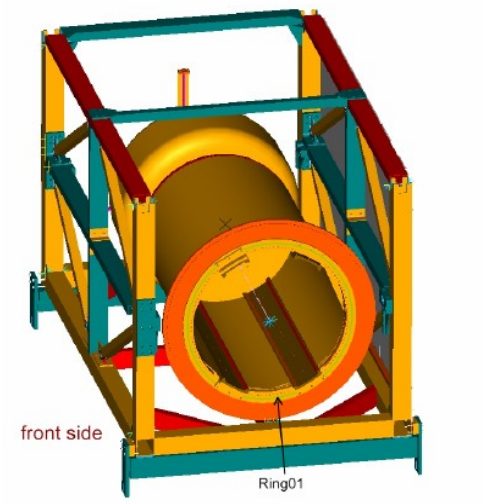


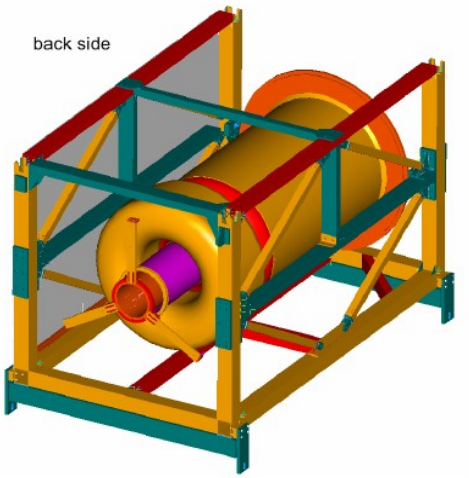
- The time of arrival is derived using the leading edge discriminator.
- The charge of the input signal is encoded into the width of output digital pulse.

A. Kaukher, Univ. Rostock

LP Mechanics

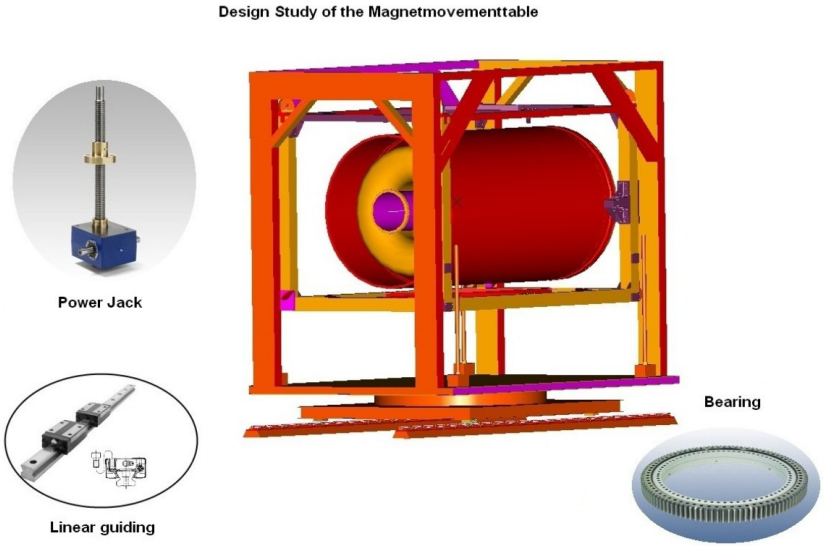






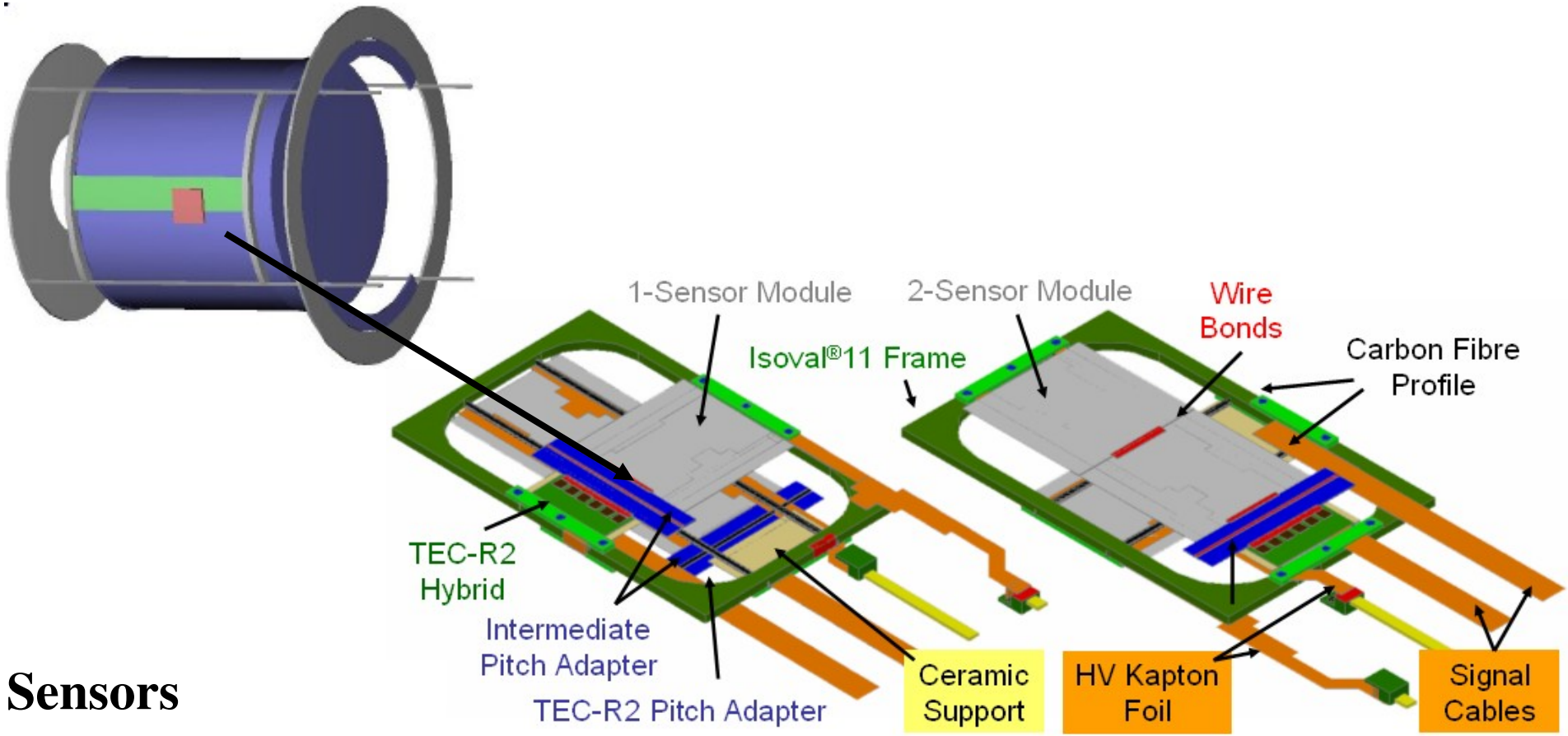
Support structures:

- TPC
- PCMAG



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

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)