



TPC Large Prototype Beam Test and the (Next) Future

Klaus Dehmelt

DESY

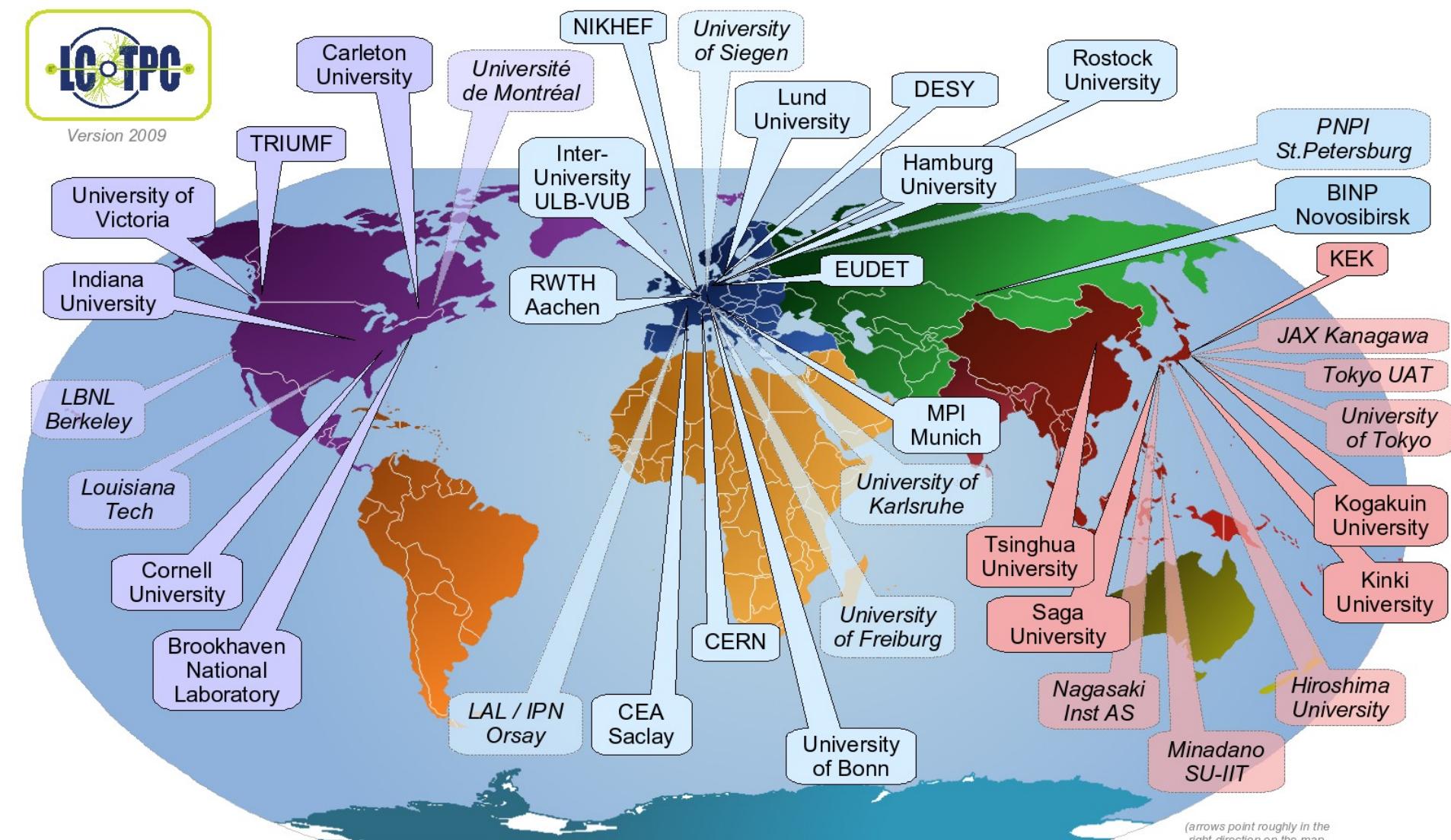
(LCTPC Collaboration)

LCTW09

LAL Orsay, France

November 04, 2009

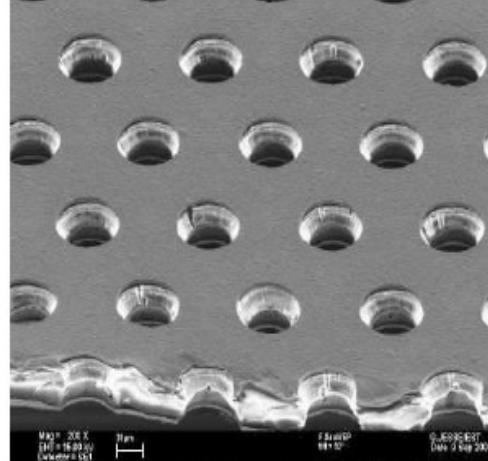
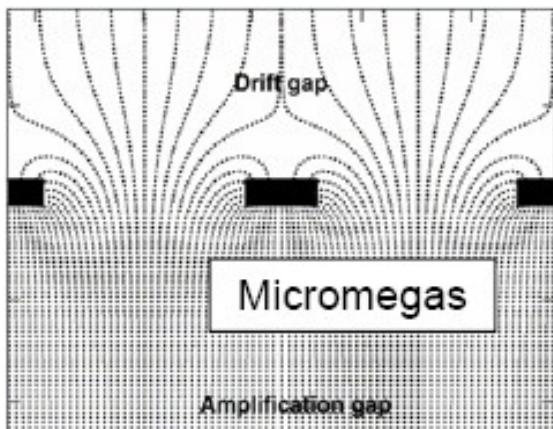
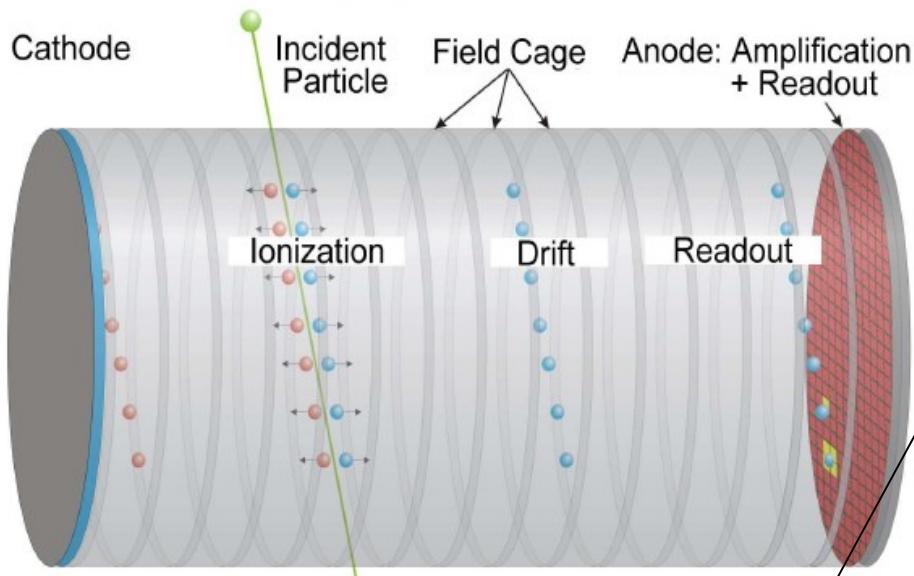
LCTPC Collaboration



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

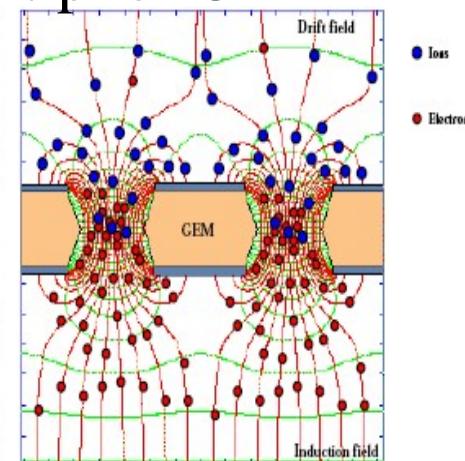
Size	$\phi = 3.6\text{m}$, $L = 4.3\text{m}$ outside dimensions
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 9 \times 10^{-5}/\text{GeV}/c$ TPC only ($\times 0.4$ if IP incl.)
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 2 \times 10^{-5}/\text{GeV}/c$ (SET+TPC+SIT+VTX)
Solid angle coverage	Up to $\cos \theta \simeq 0.98$ (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	$\sim 1\text{mm} \times 4\text{-}6\text{mm}/\sim 200$ (standard readout)
σ_{point} in $r\phi$	$< 100\mu\text{m}$ (average over $L_{\text{sensitive}}$, modulo track ϕ angle)
σ_{point} in rz	$\sim 0.5 \text{ mm}$ (modulo track θ angle)
2-hit resolution in $r\phi$	$\sim 2 \text{ mm}$ (modulo track angles)
2-hit resolution in rz	$\sim 6 \text{ mm}$ (modulo track angles)
dE/dx resolution	$\sim 5 \%$
Performance	> 97% efficiency for TPC only ($p_t > 1\text{GeV}/c$), and >> 99% all tracking ($p_t > 1\text{GeV}/c$)
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

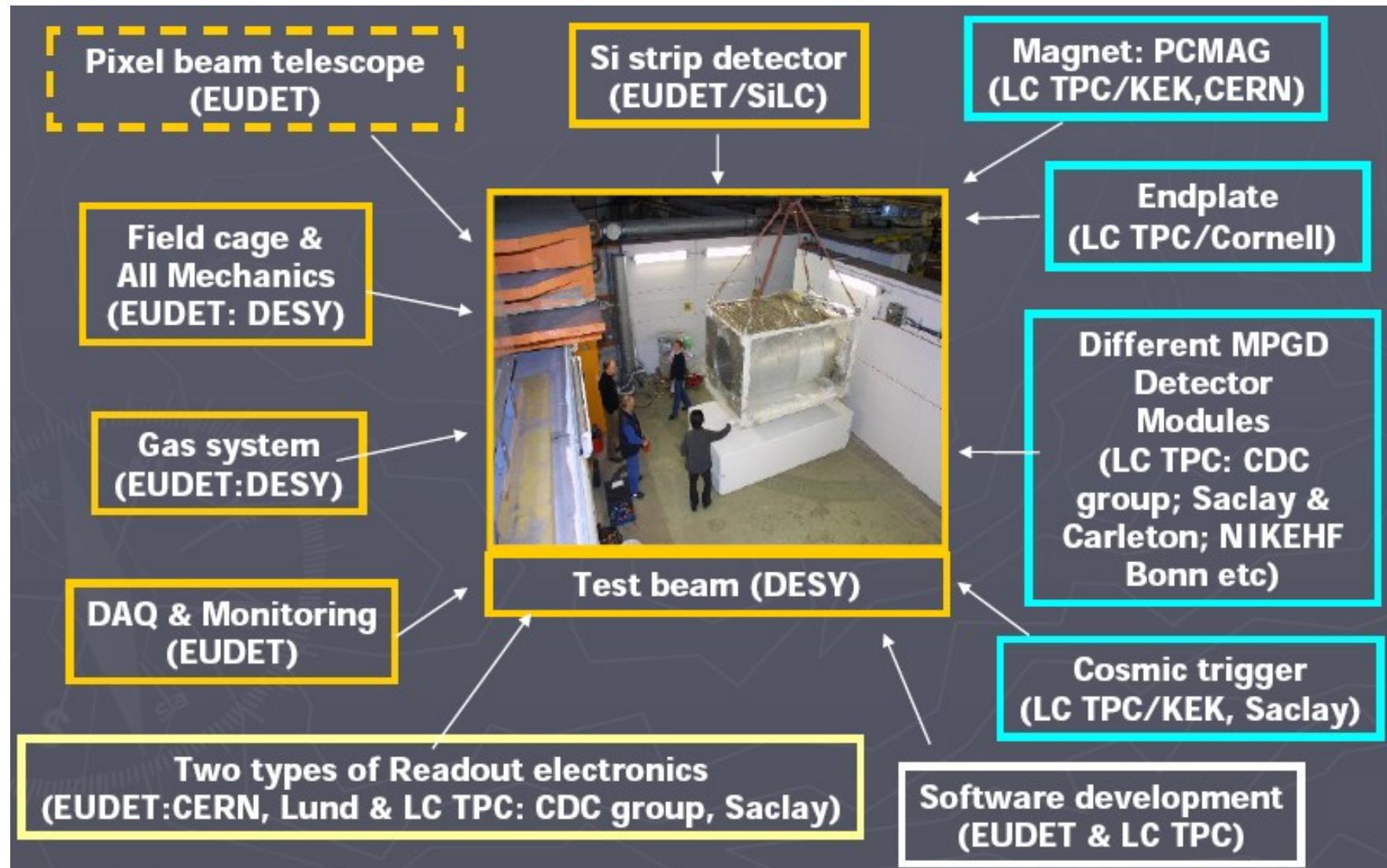
with MPGD

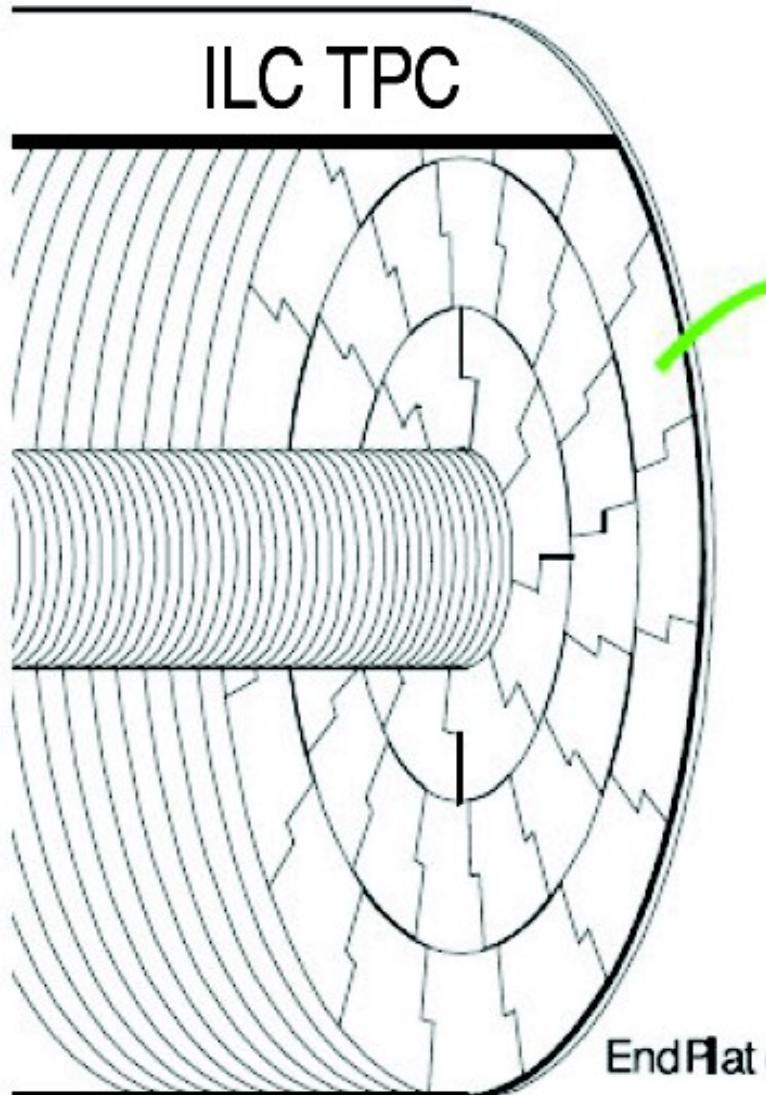


MicroPatternGasDetector
MPGD
not limited by $E \times B$ effects

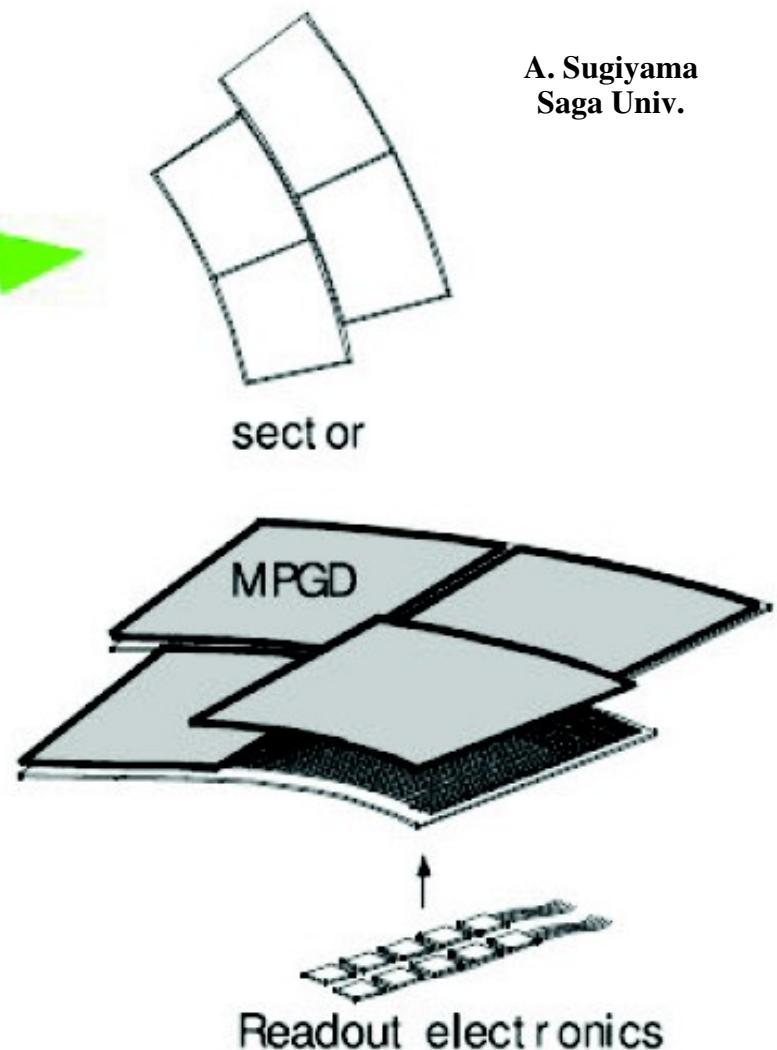
Gas Electron Multiplier GEM

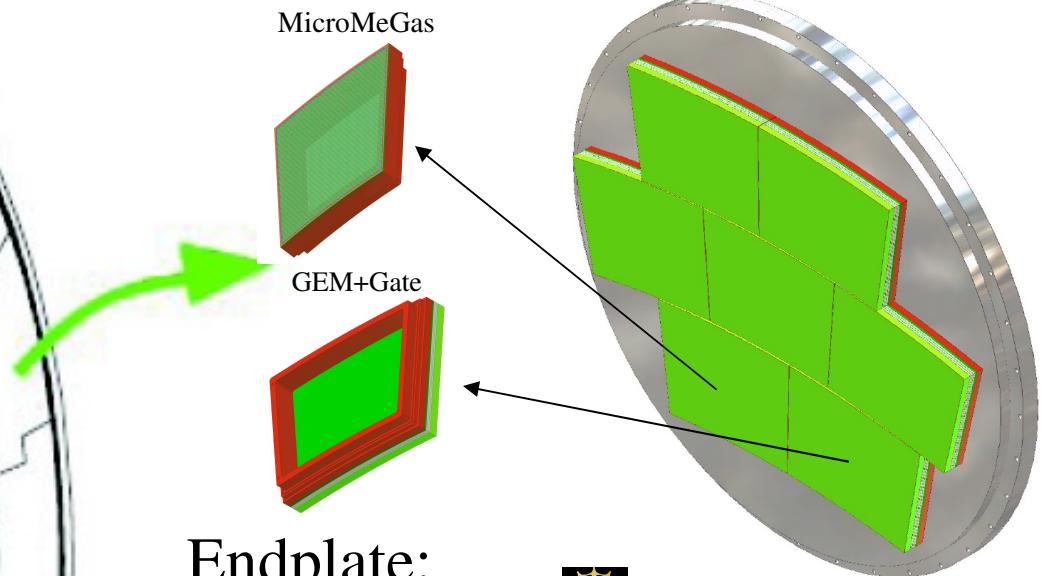
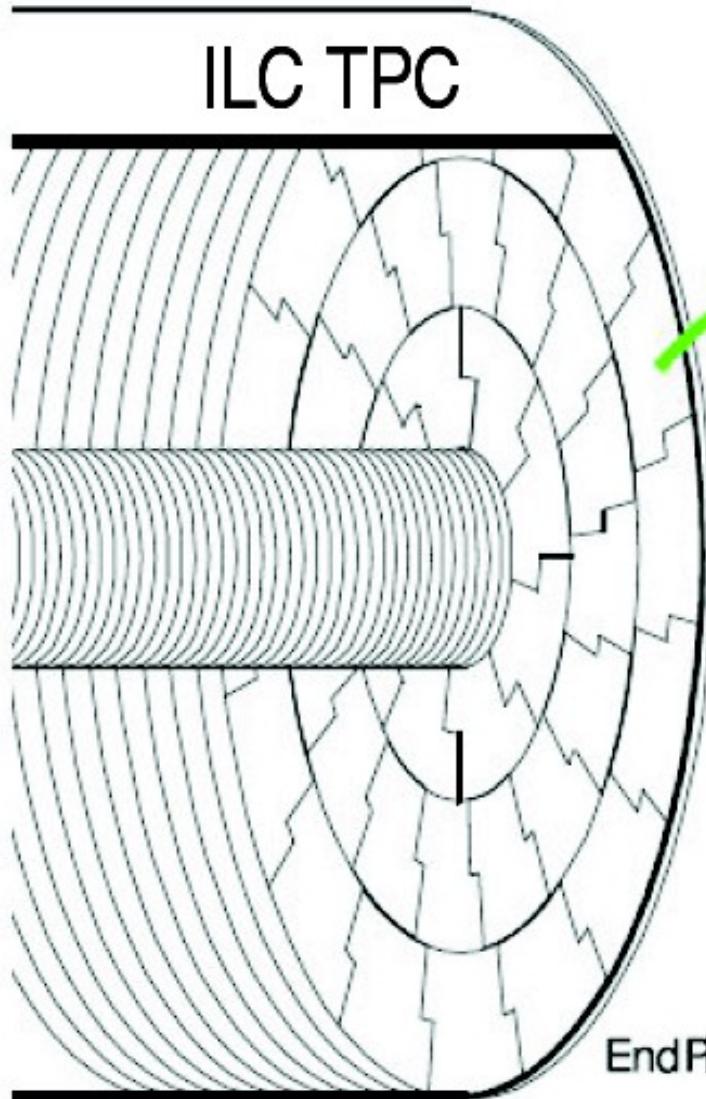






A. Sugiyama
Saga Univ.





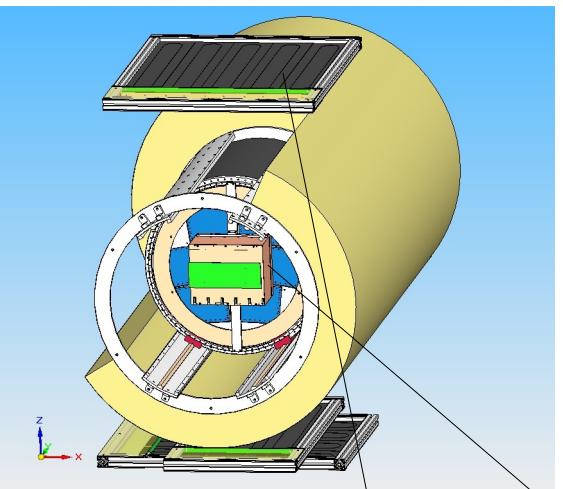
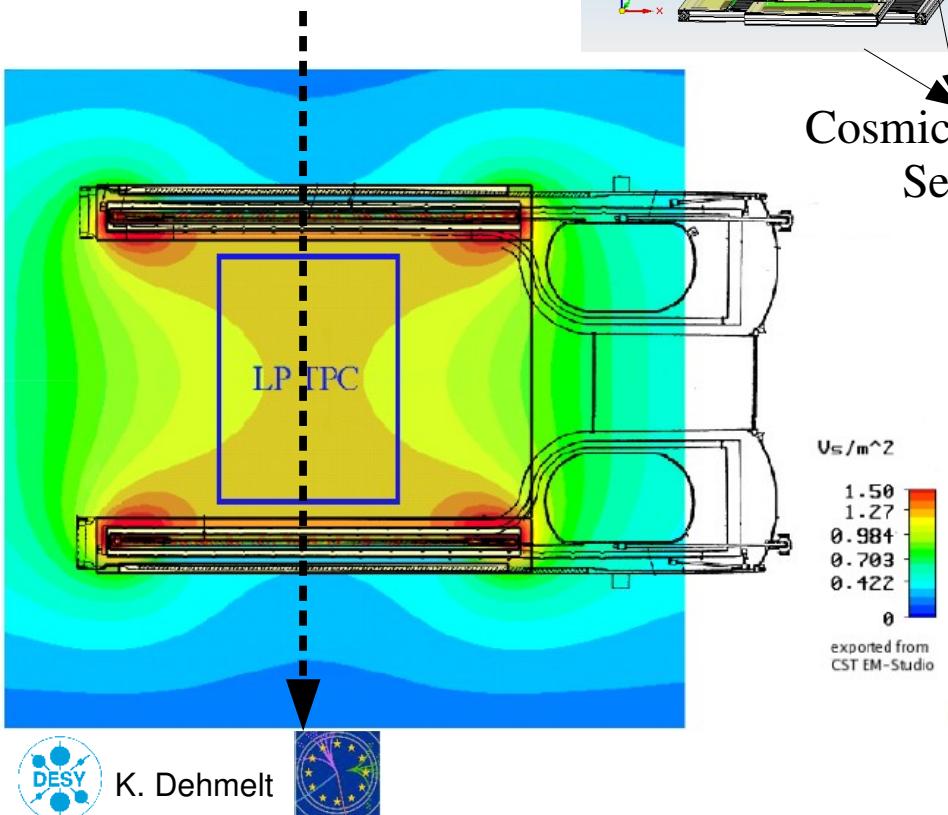
Endplate:



D. Peterson, Cornell

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

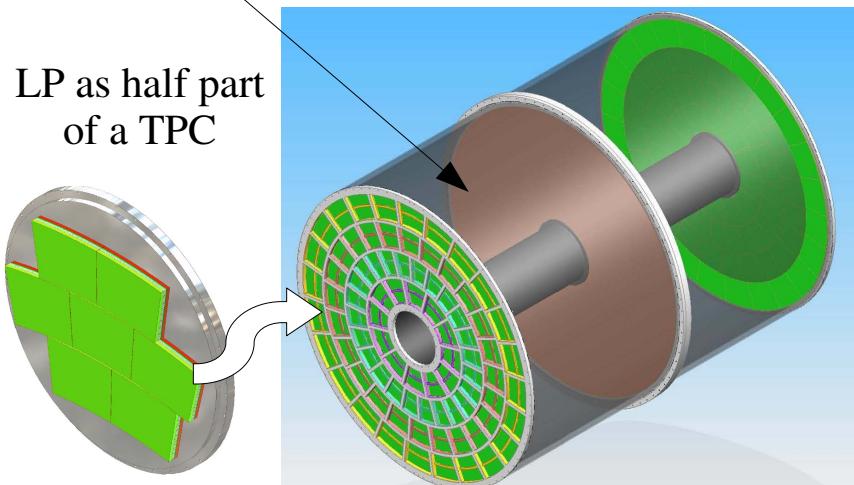
PCMAG:
superconducting
magnet, up to 1.25 T
• e^- test beam @DESY
($1\text{GeV}/c < p < 6\text{GeV}/c$)



Cosmic Trigger
Setup



LP as half part
of a TPC



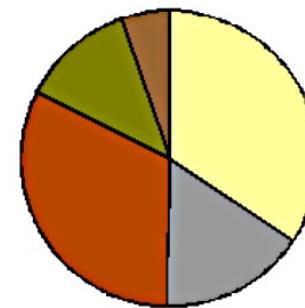


Diameter: Inner 720 mm,
Outer 770 mm

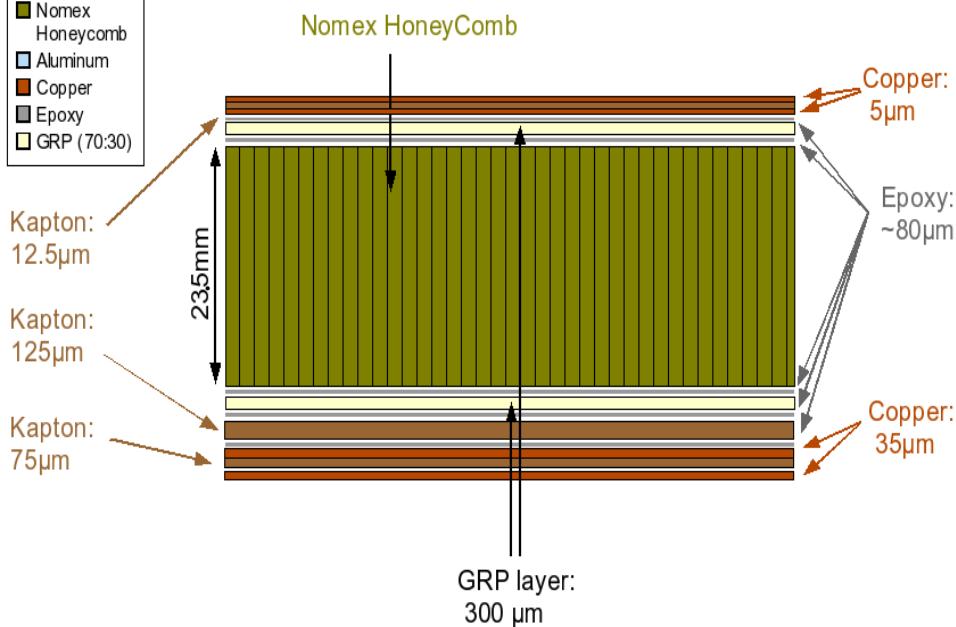
Wall thickness 25 mm
Length 610 mm

HV to be applied: up to 20 kV

Radiation Length: 1.31% of X_0



- Kapton
- Nomex
- Honeycomb
- Aluminum
- Copper
- Epoxy
- GRP (70:30)

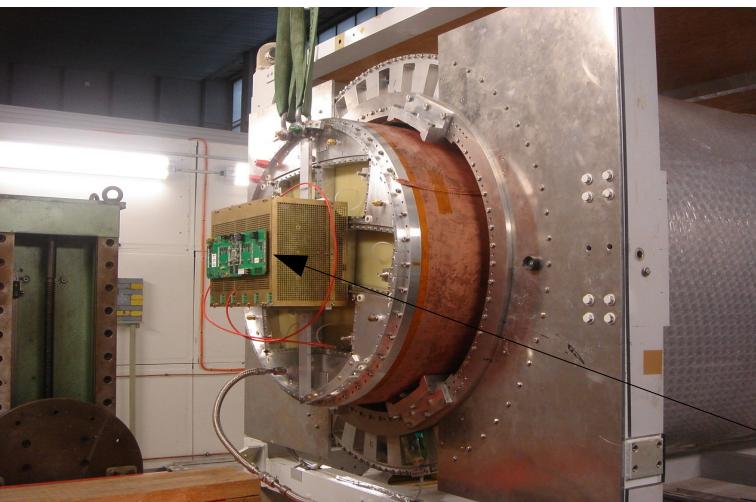


'Bulk Micromegas' panels, without resistive foil and with resistive carbon-loaded kapton, have been produced at CERN (Rui de Oliveira)

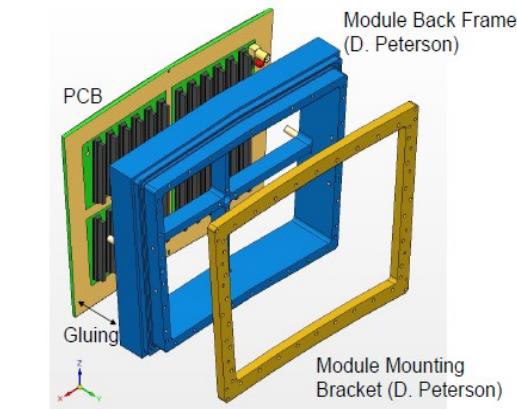
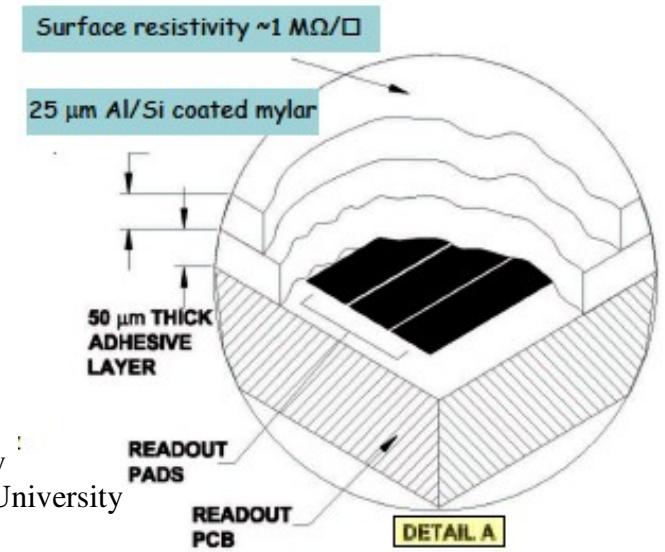
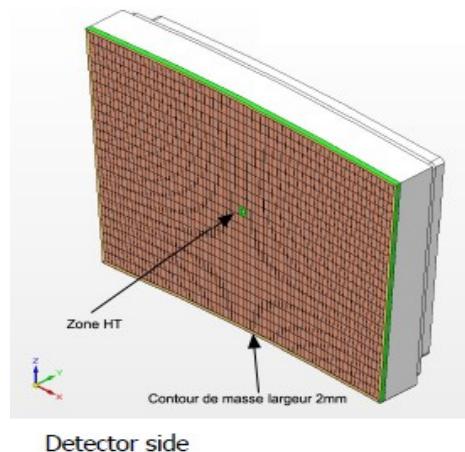
MicroMeGaS for

LP:

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



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



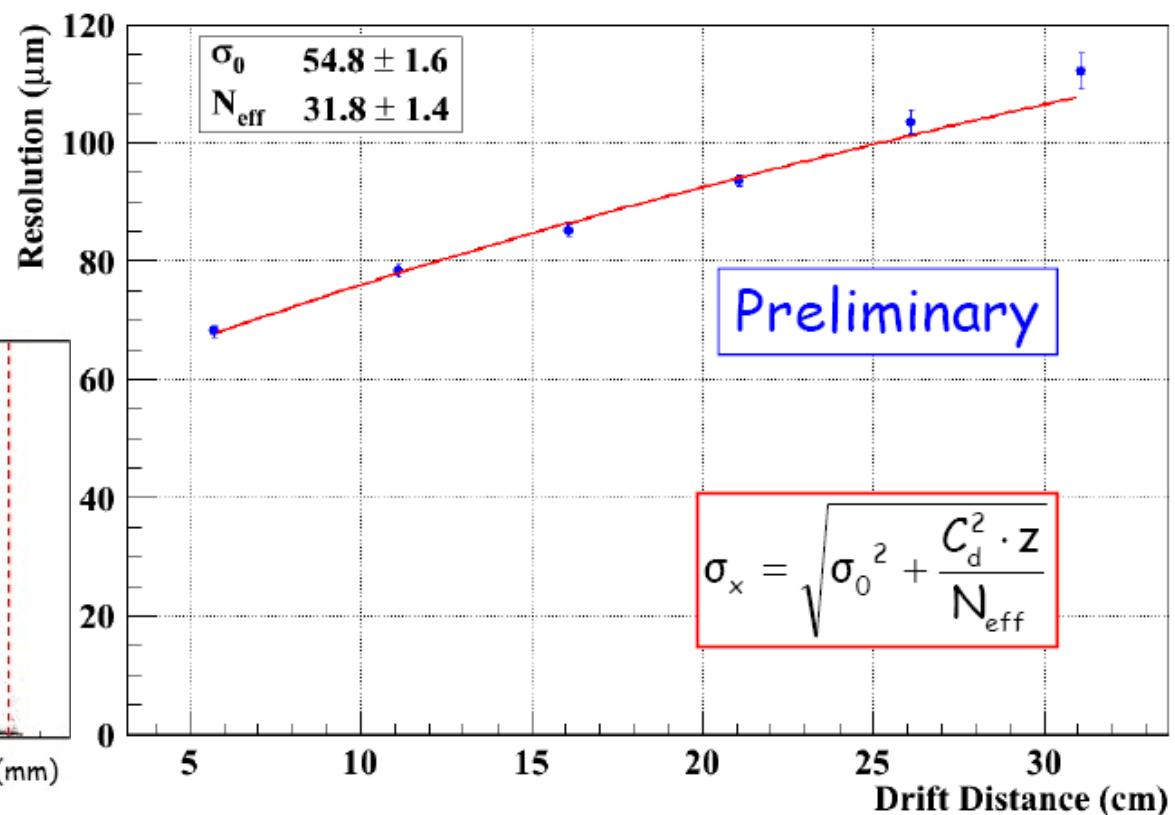
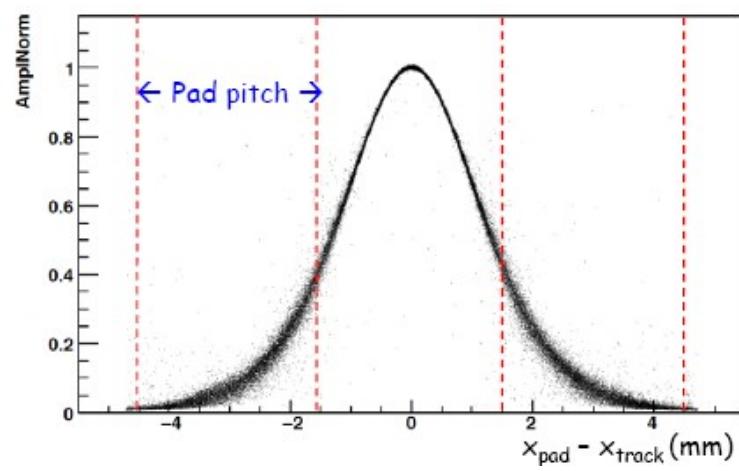
Readout electronics: AFTER (T2K TPC)



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

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

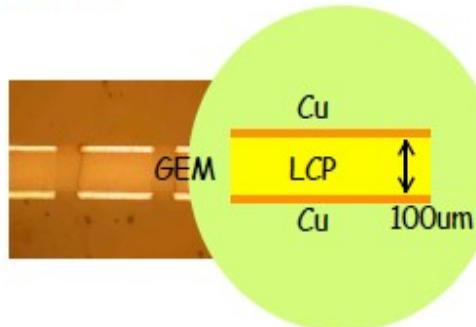
→ Clearly shows charge spreading
over 2-3 pads
(data with 500 ns shaping)



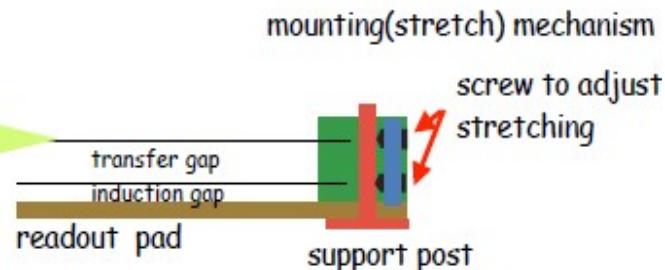
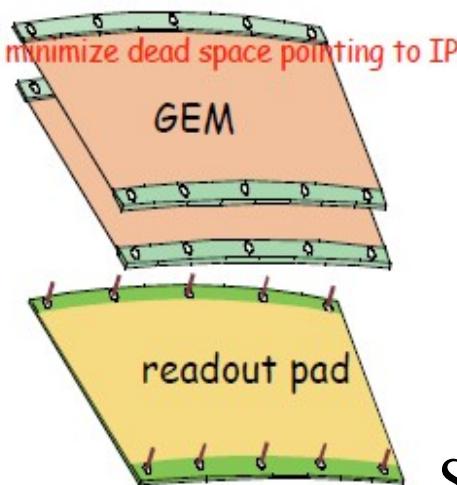
P. Colas, CEA Saclay

Double GEM Structure

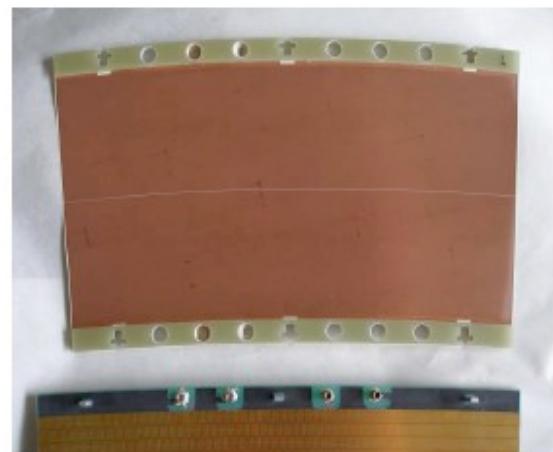
GEMs



frame : top & bottom frame.
no side frame



Transfer gap $\sim 4\text{mm}$: enlarge signal distribution
(+2mm) width $> 0.3^*\text{ pad pitch}$

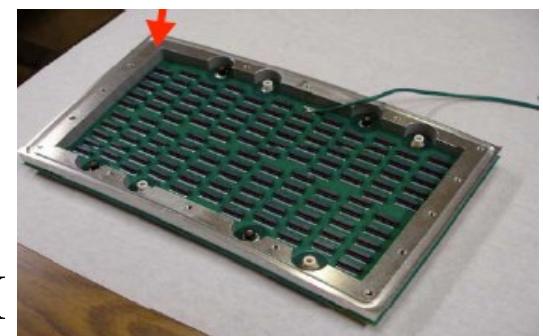
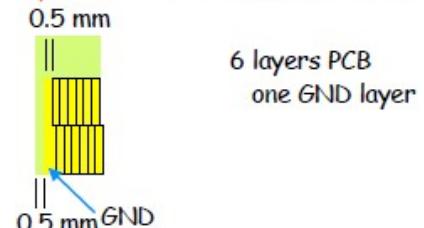
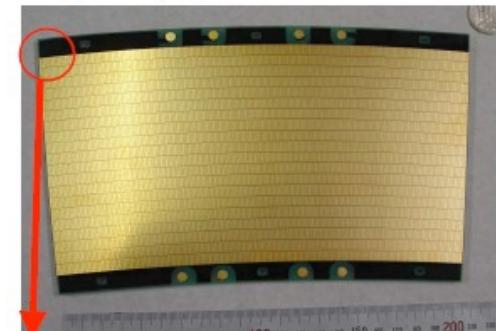


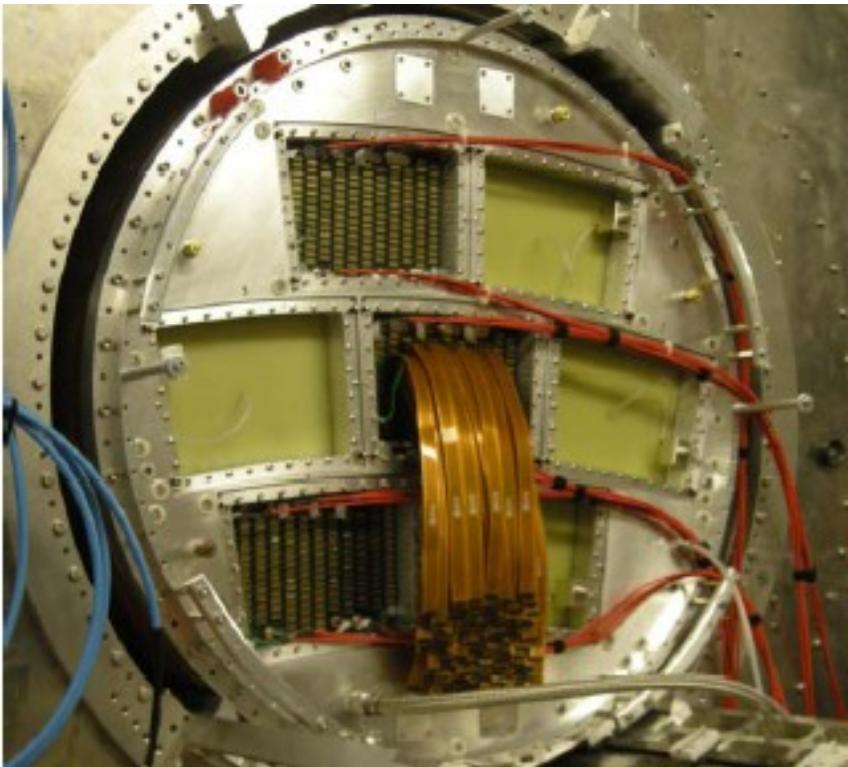
Setup planned w/ gating GEM

A. Sugiyama, Saga Univ.

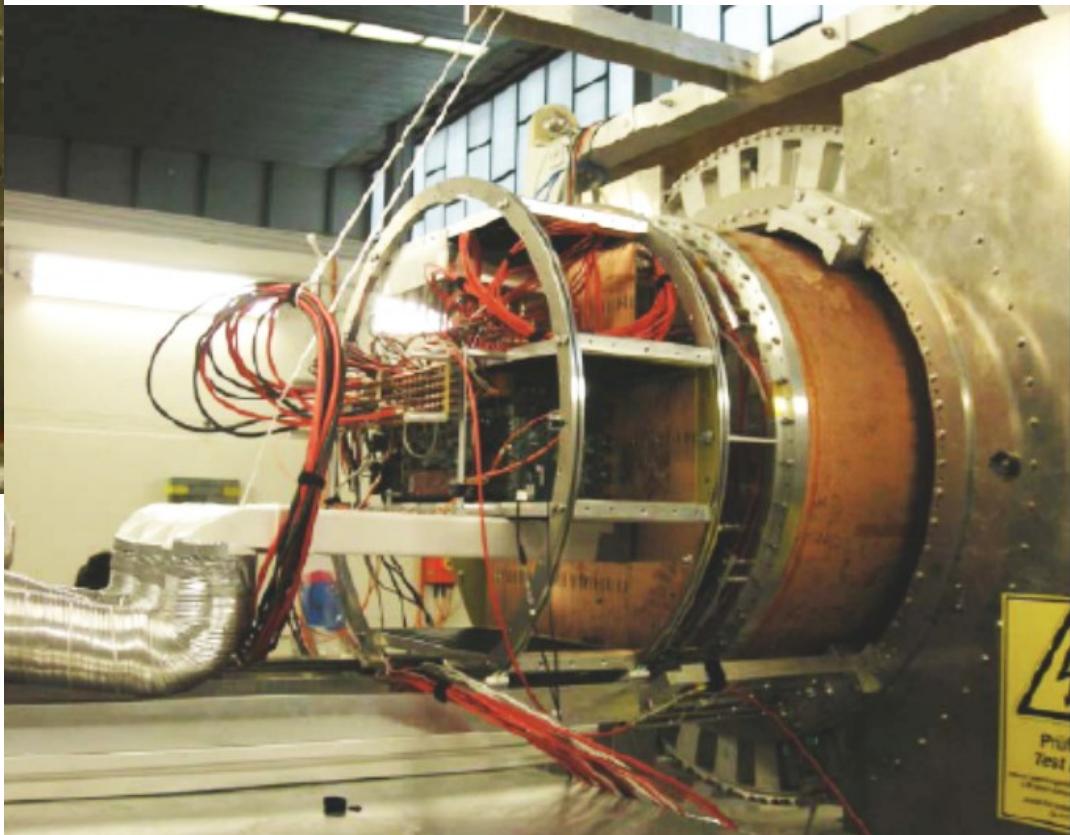
28 pad rows (176/192 pads/raw)
 $\sim 1.2(\text{w}) \times 5.4(\text{h}) \text{ mm}^2$
staggered every each layer

Total 5,152 ch/module





About 3200 channels readout
electronics

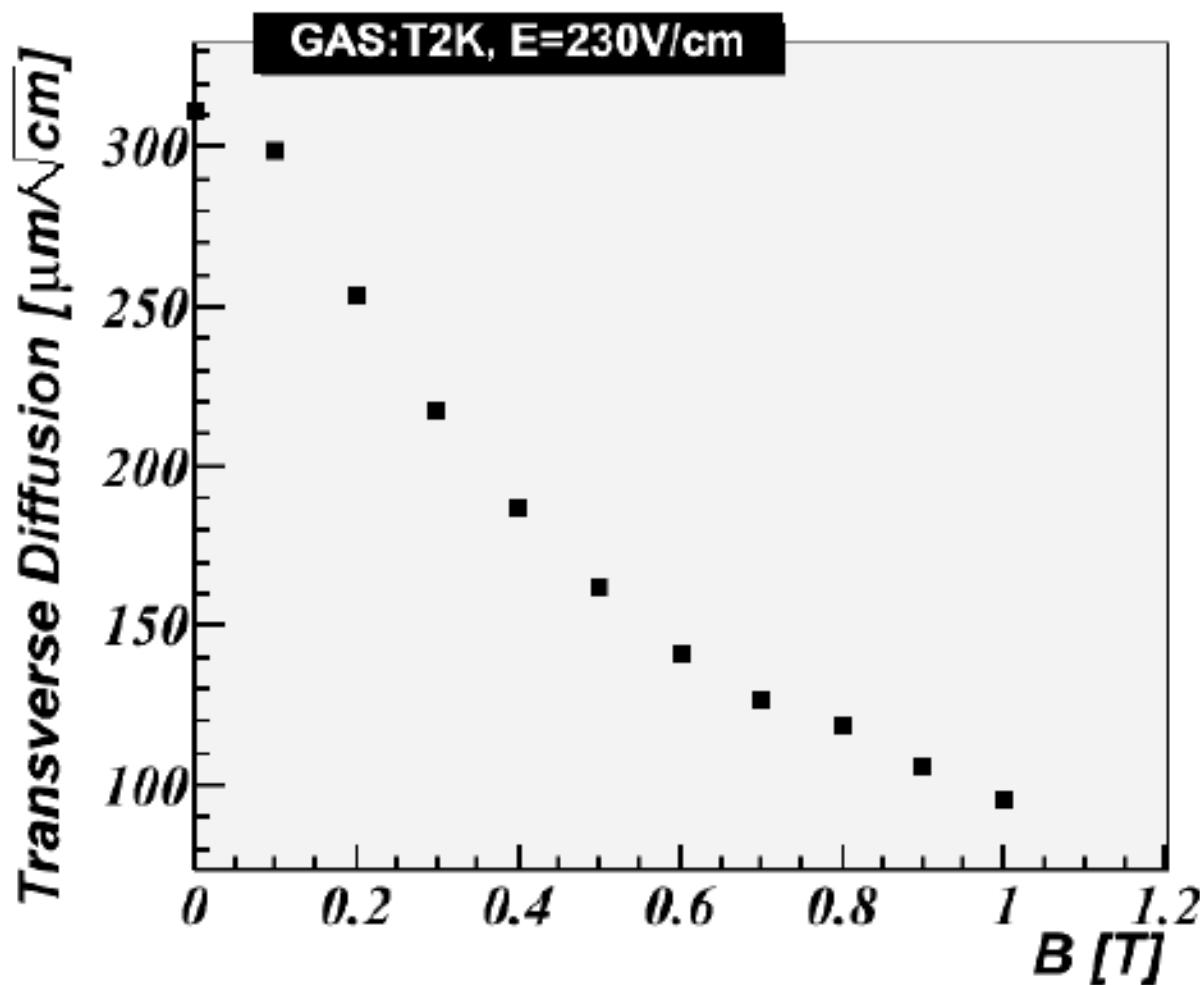


Readout electronics:
Based on ALTRO (ALICE TPC)

L. Joensson, LUND University

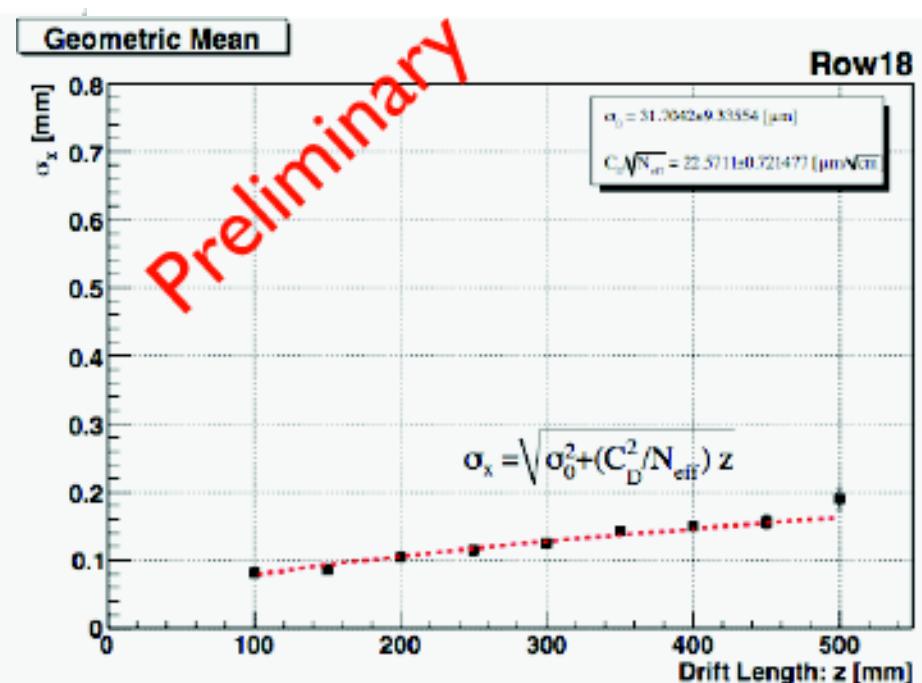
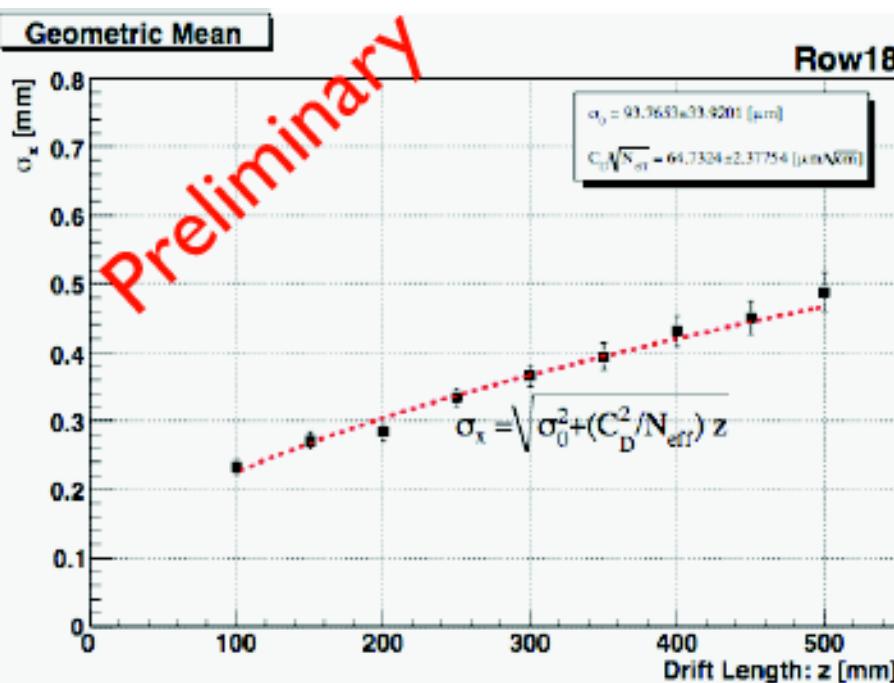
Charge Spreading

R. Yonanime, KEK



Resolution as a function of drift distance

R. Yonanime, KEK



B=0T

$$\left\{ \begin{array}{l} C_D = 303 \pm 1 \text{ } [\mu/\sqrt{\text{cm}}] \\ \frac{C_D}{\sqrt{N_{eff}}} = 65 \pm 2 \text{ } [\mu\text{m}/\sqrt{\text{cm}}] \end{array} \right.$$

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

Garfield

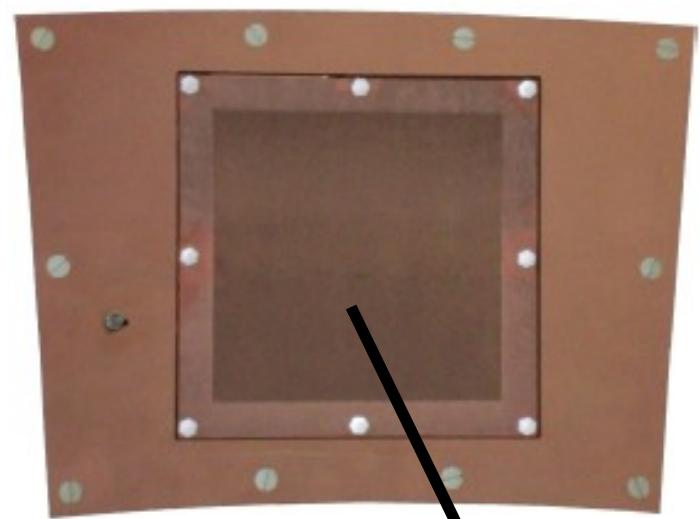
$$C_D = 311.8 \text{ } [\mu\text{m} / \sqrt{\text{cm}}]$$

Result of MP-TPC
 $N_{eff} = 21 \pm 2$

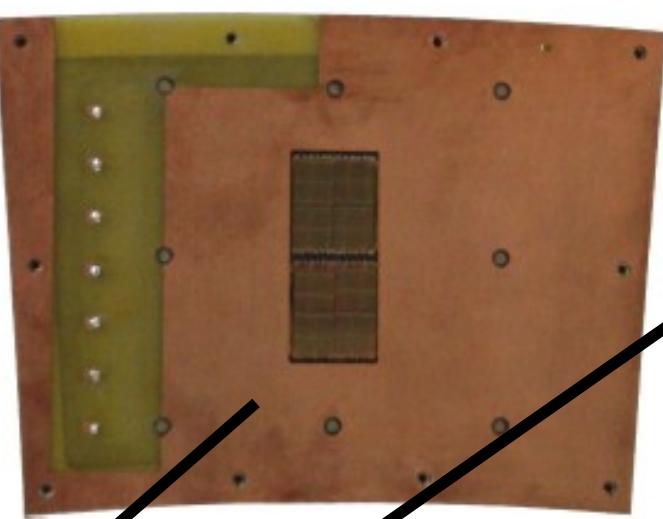
B=1T

$$\left\{ \begin{array}{l} C_D = 101.6 \pm 0.4 \text{ } [\mu/\sqrt{\text{cm}}] \\ \frac{C_D}{\sqrt{N_{eff}}} = 22.6 \pm 0.7 \text{ } [\mu\text{m}/\sqrt{\text{cm}}] \end{array} \right.$$

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



anode plane



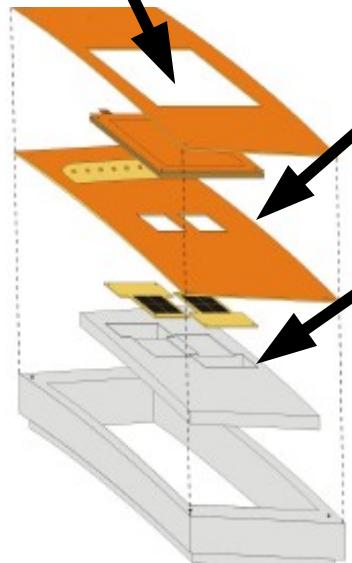
GEMs

readout plane

quad-boards

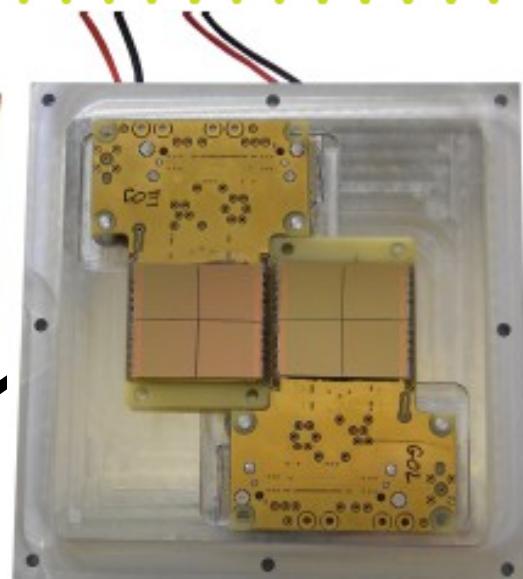
reinforcement of
anode plane

redframe

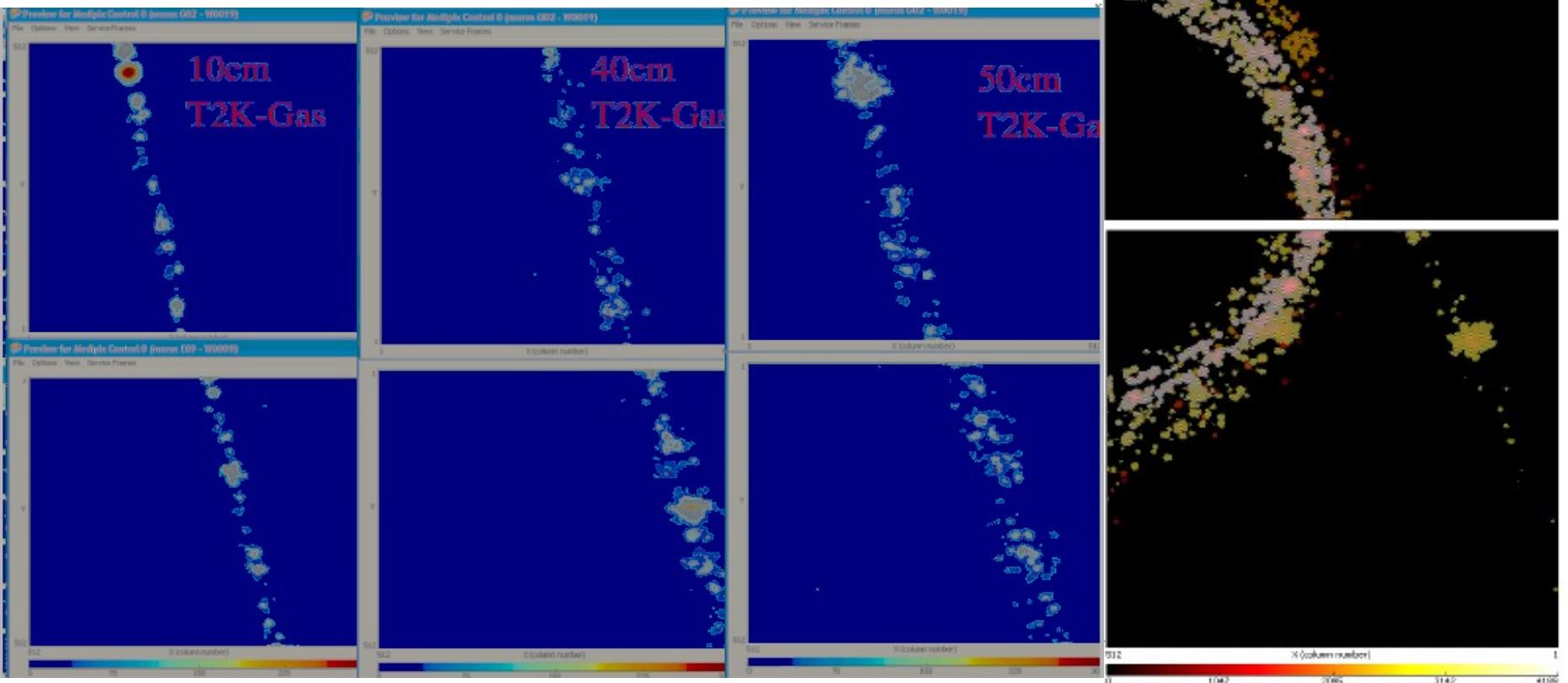


Readout:
2 quadboards
(4 TimePix
Chips each)

J. Kaminski, Univ. of Bonn



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



J. Kaminiski, Univ. of Bonn



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)

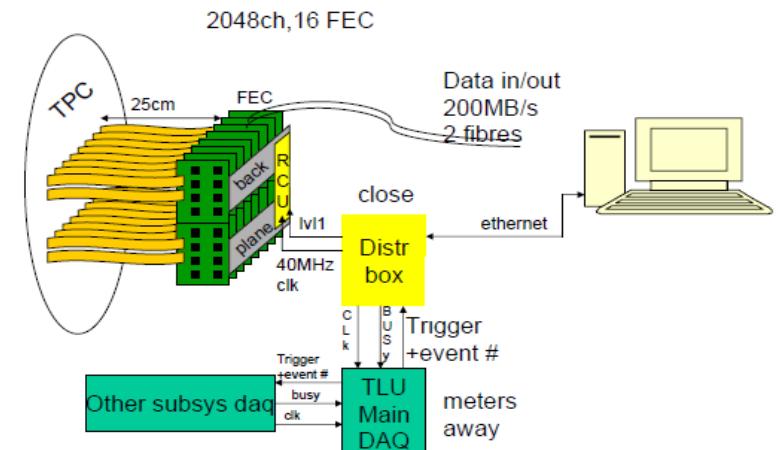
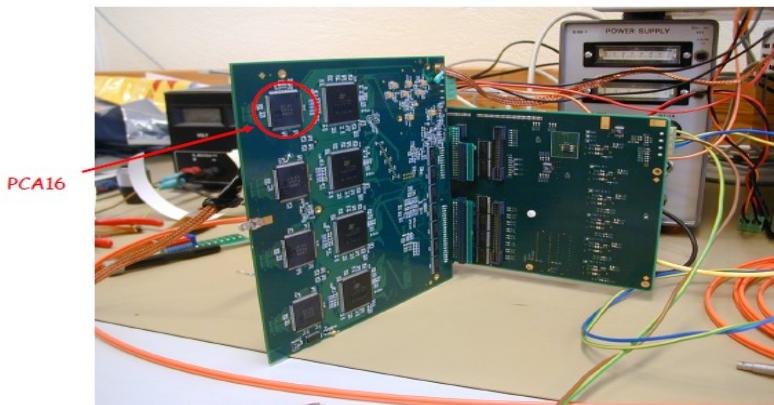
**ALTRO and TDC based electronics will be hooked to the GEM detector modules
(connector compatibility)**



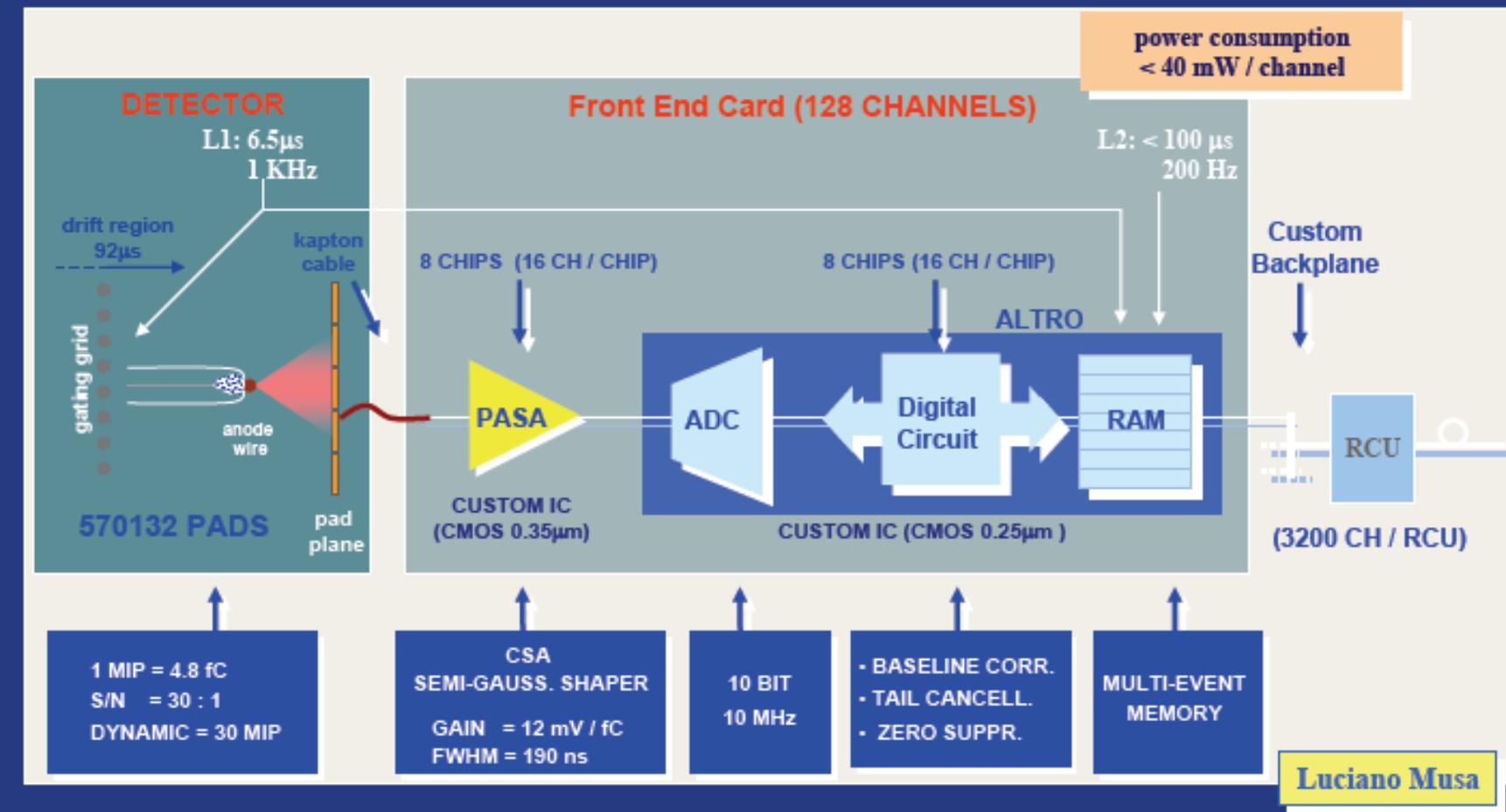
PCA16:

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



Based on the existing PASA + Altro electronics designed for the Alice TPC



P. Aspell, CERN

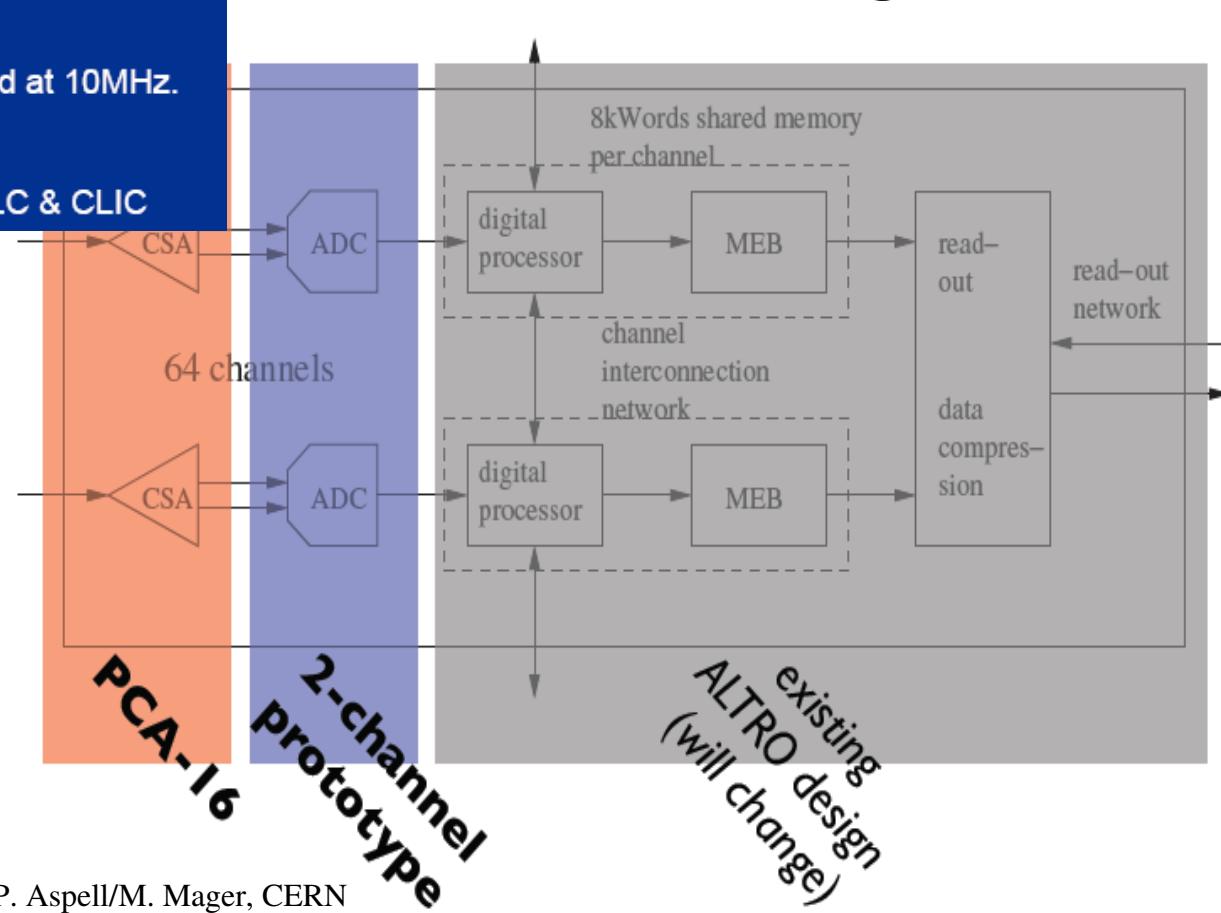


Goal :

To demonstrate integration per channel of an analog front-end, an ADC and digital signal processing in a single chip.

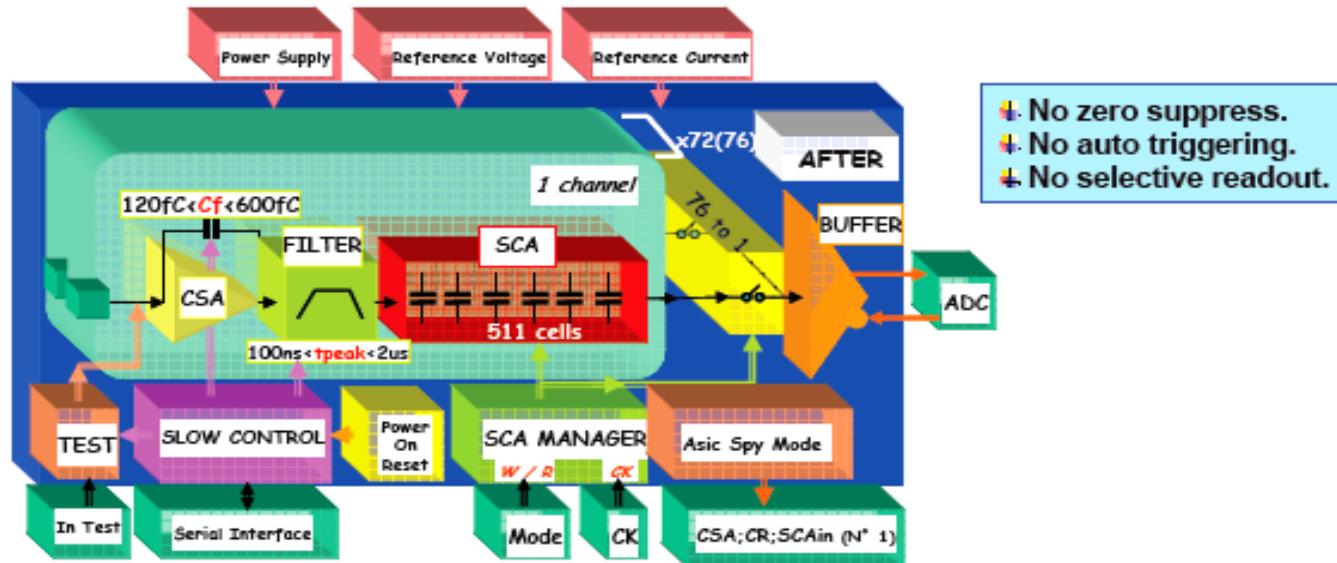
Data processing of 100us of data sampled at 10MHz.

Prepare ideas for TPC readout in the ILC & CLIC



P. Aspell/M. Mager, CERN

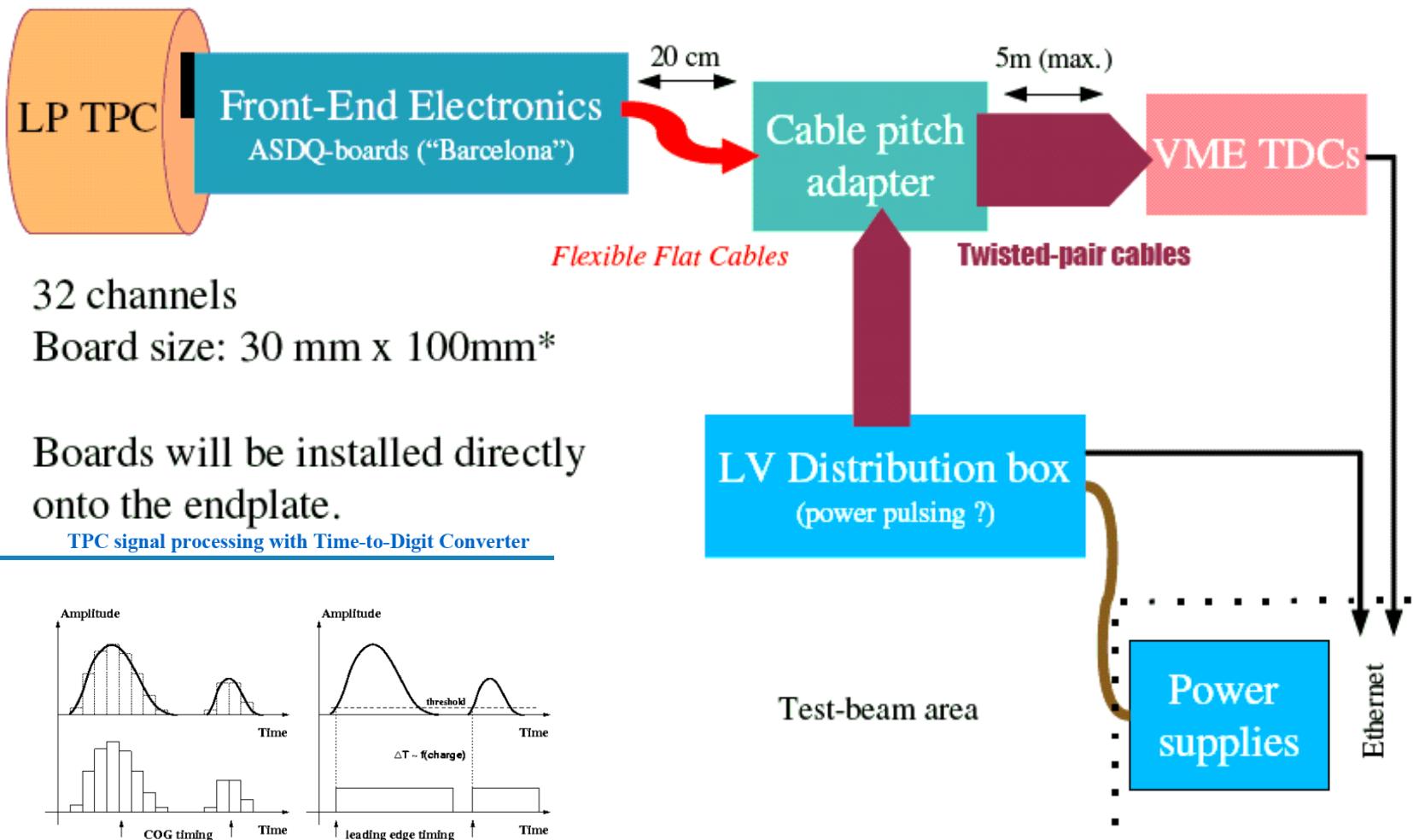
dapnia
cea
saclay



Main features:

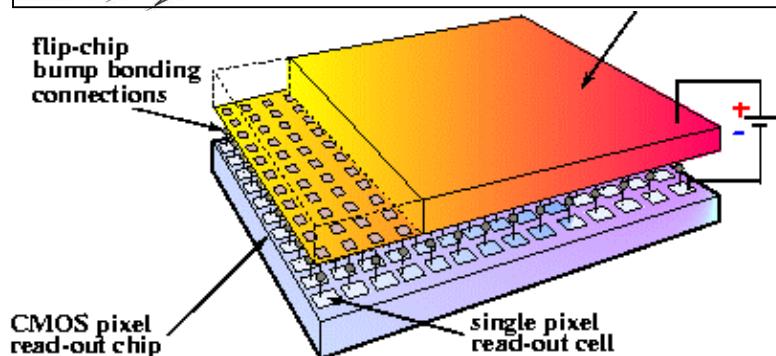
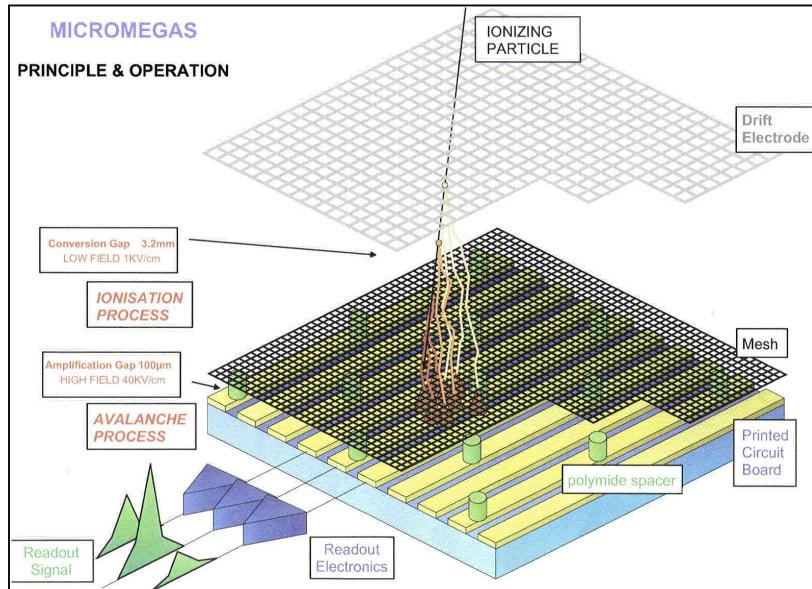
- Input Current Polarity:** positive **or** negative
- 72 Analog Channels**
- 4 Gains:** $120fC$, $240fC$, $360fC$ & $600fC$
- 16 Peaking Time values:** (100ns to 2 μ s)
- 511 analog memory cells / Channel:**
Fwrite: 1MHz-50MHz; Fread: 20MHz

- 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



- 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

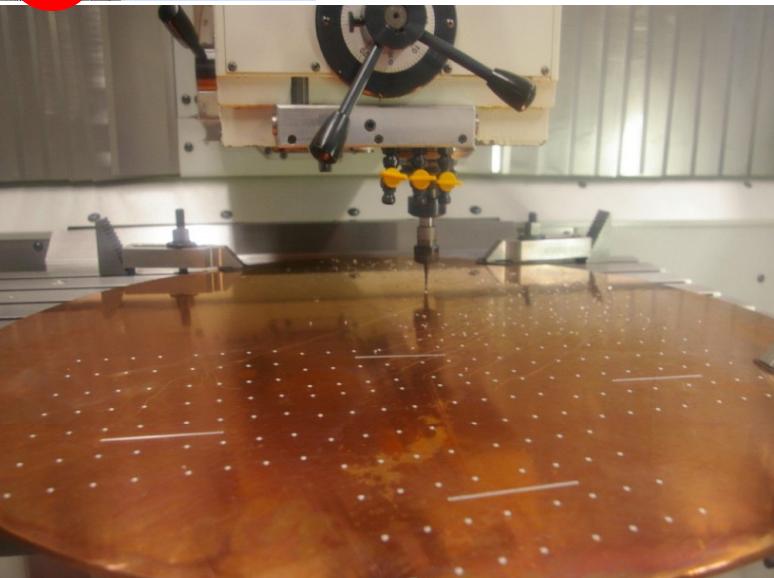
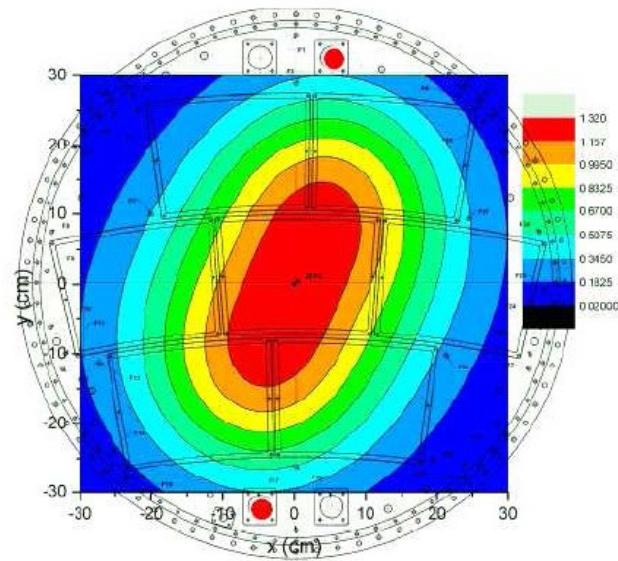
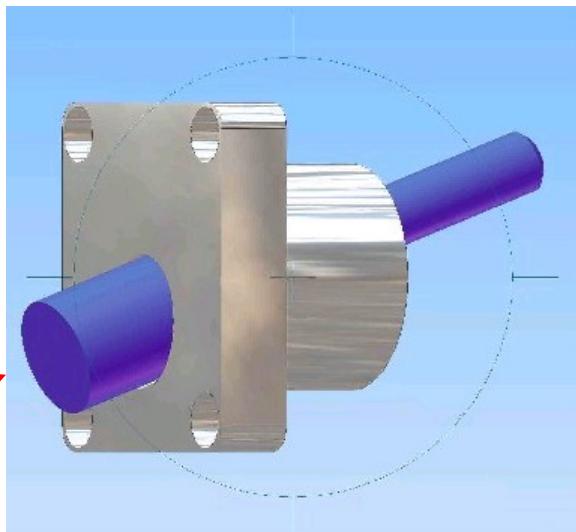
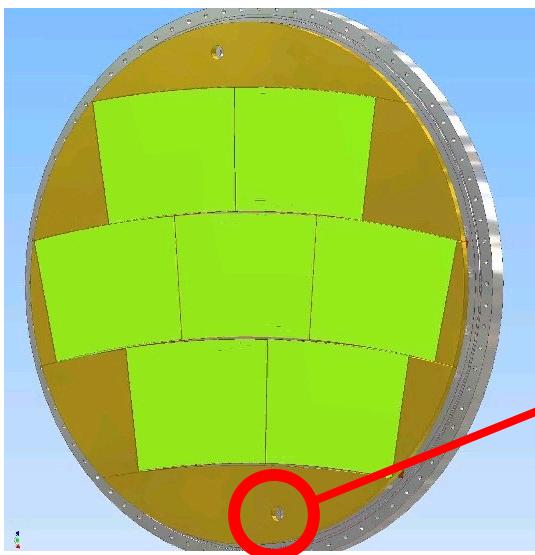


- High field created by Gas Gain Grids
- Most popular: GEM and Micromegas

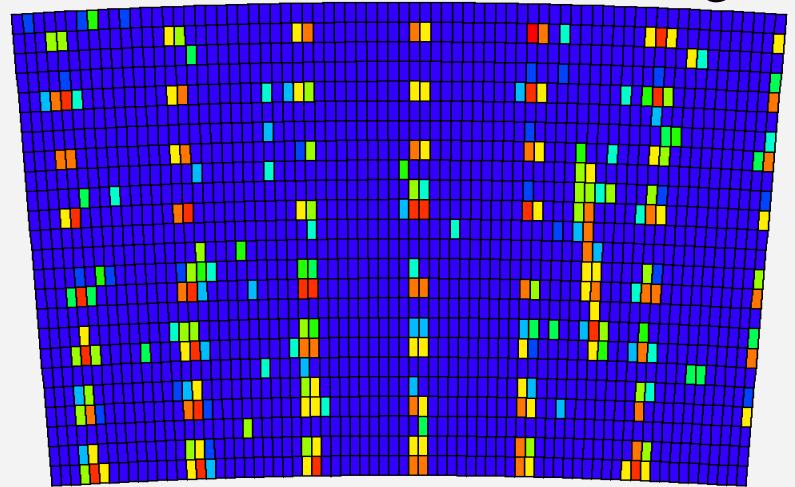
Use 'naked' CMOS pixel readout chip as anode

J. Timmermans
NIKHEF

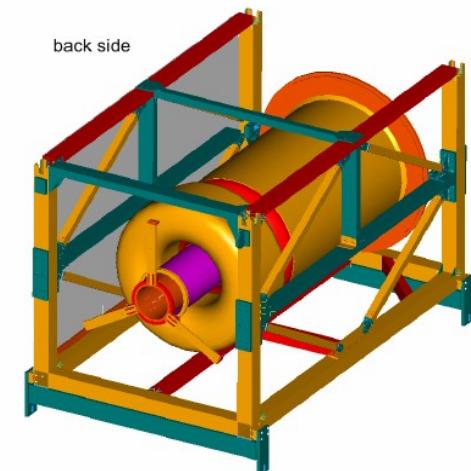
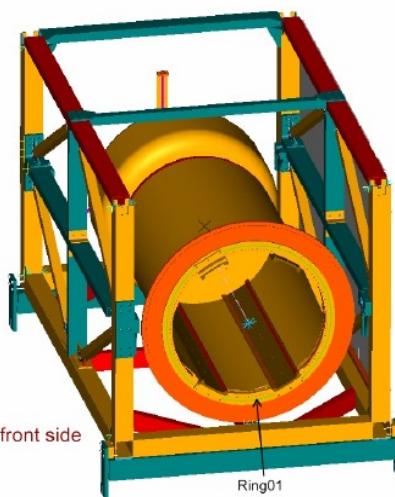
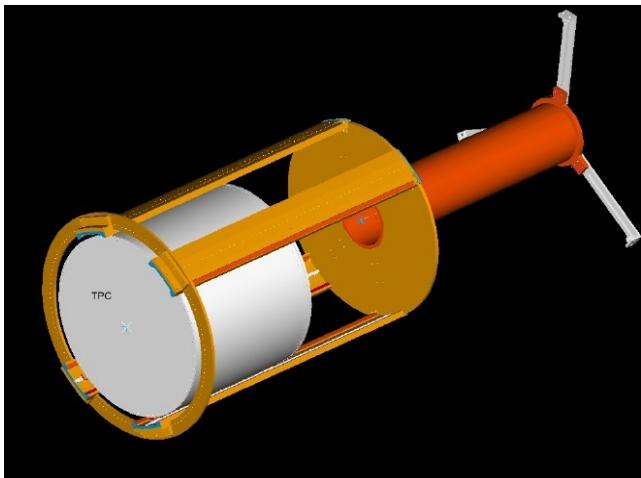
Laser Calibration Setup



Pattern seen with Micromegas



P. Conley
Victoria Univ.

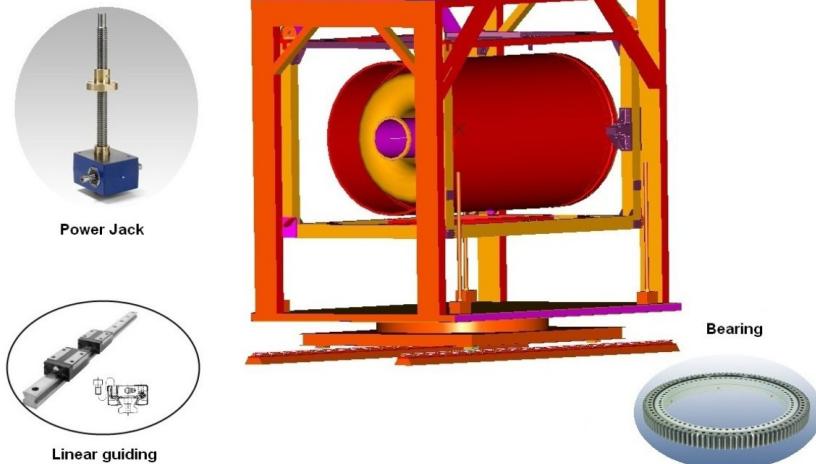


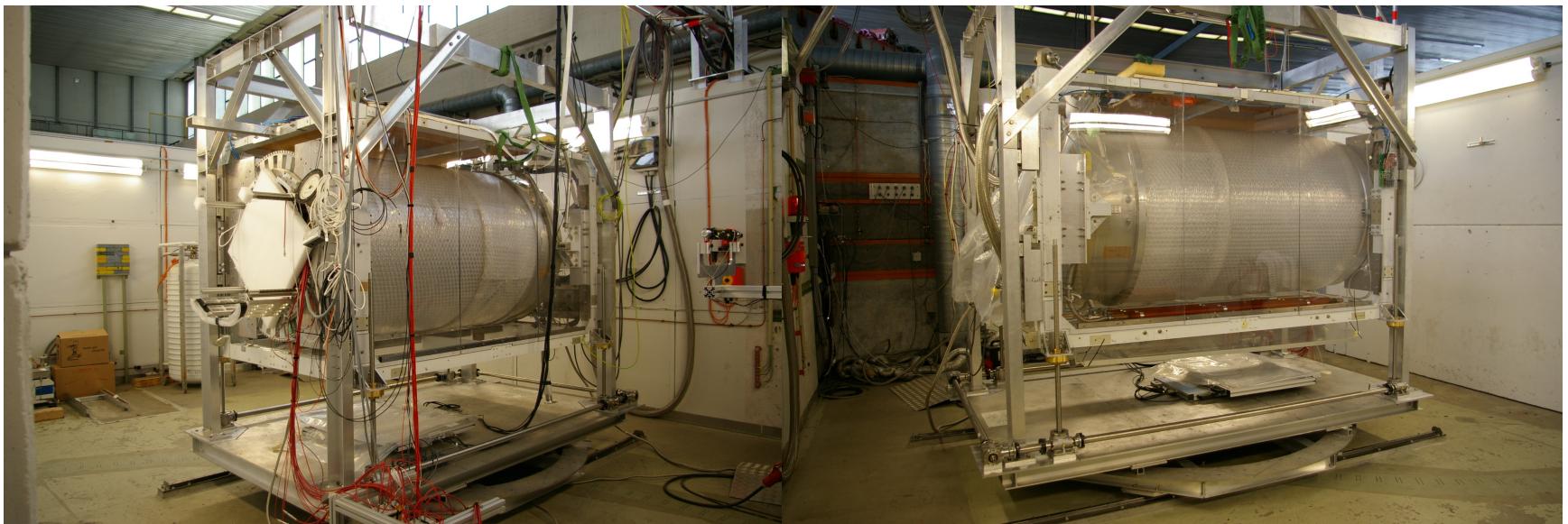
Design Study of the Magnetmovementtable

Support structures:

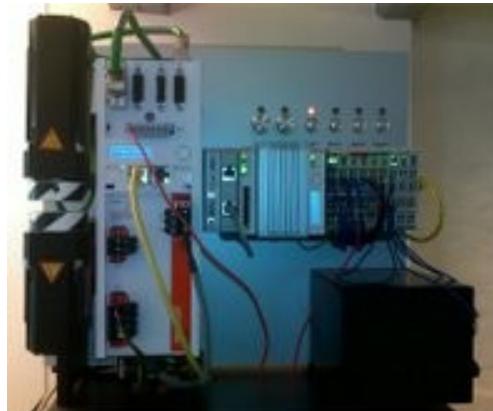
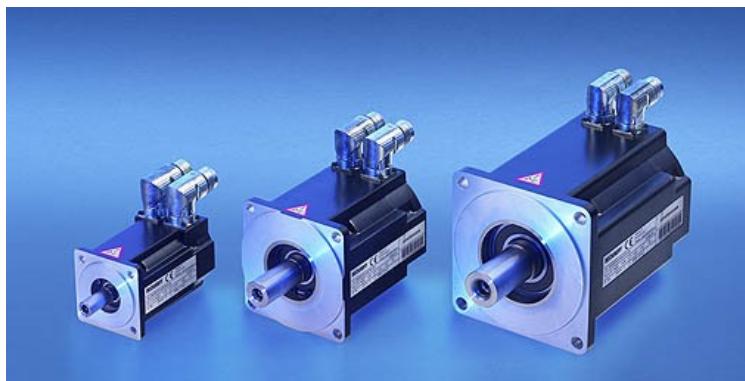
- TPC
- PCMAG

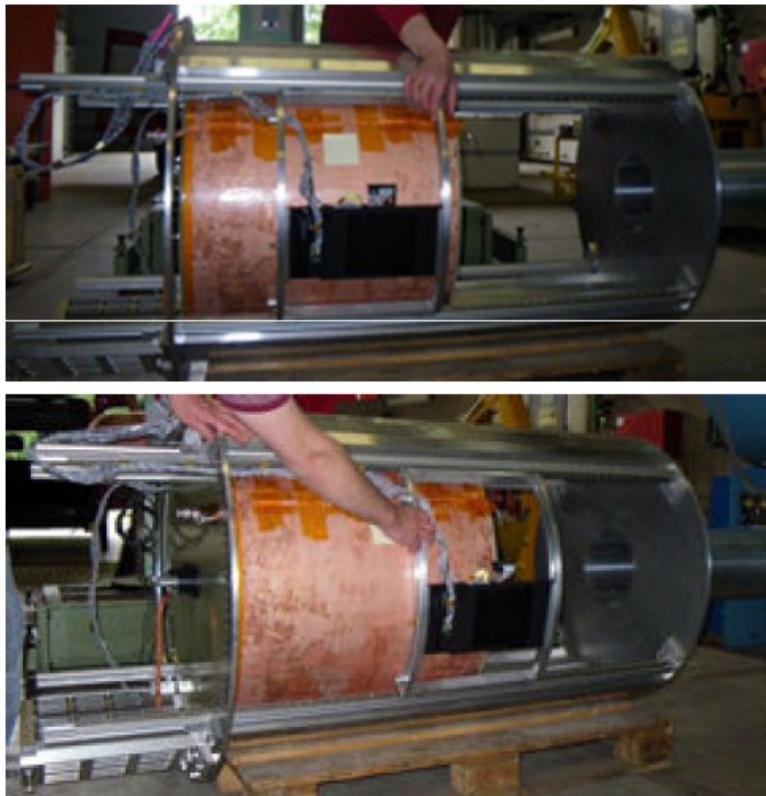
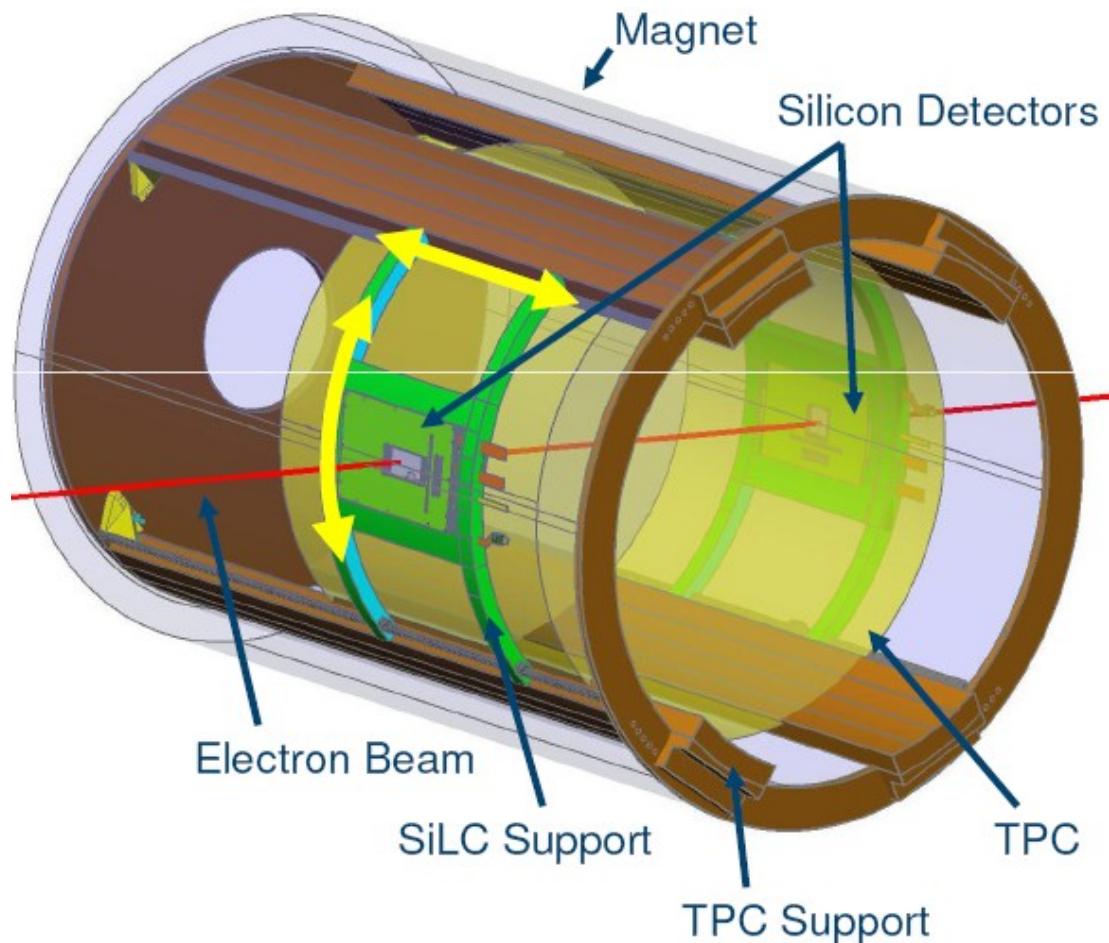
F. Hegner, V. Prahl, R. Volkenborn, DESY

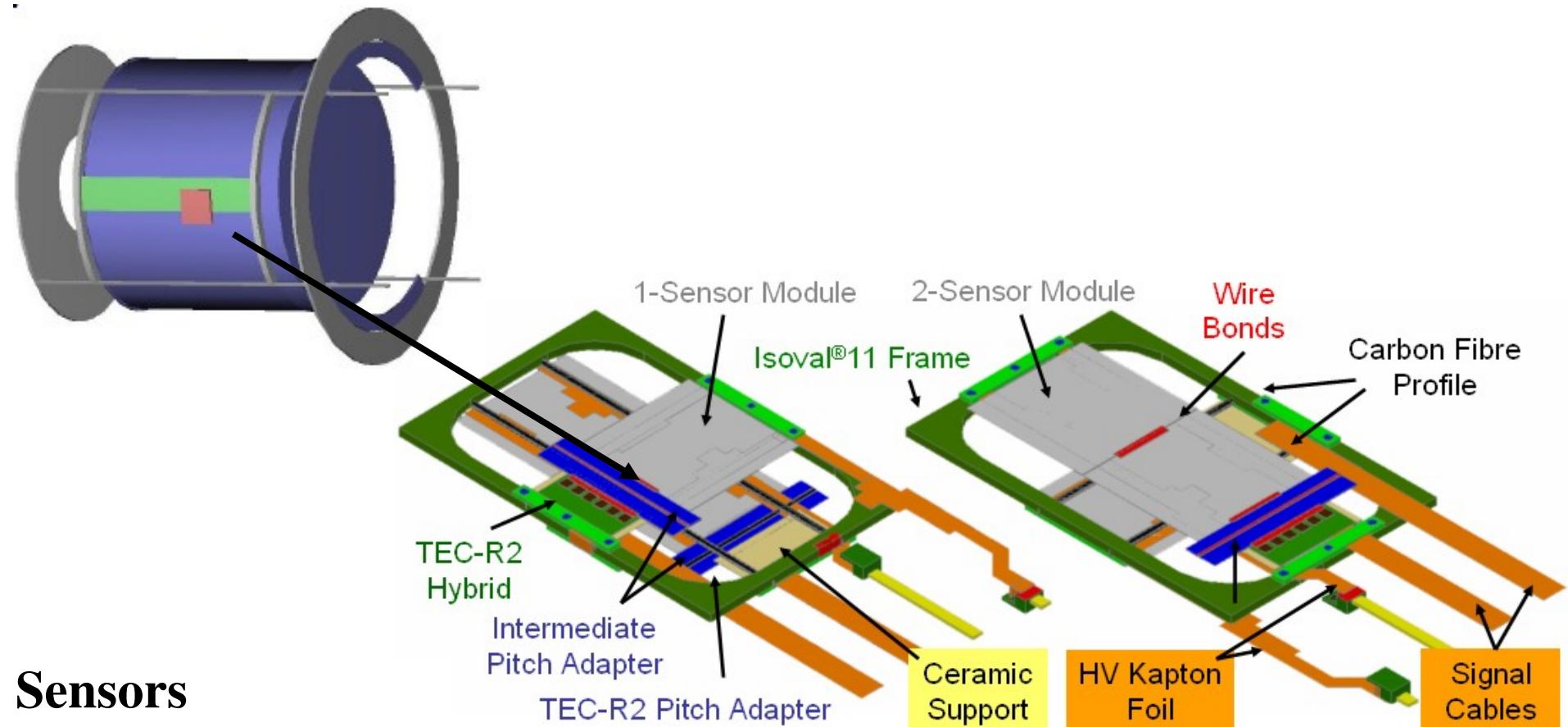




Actuation and Control







Sensors

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

- **Build and operate a “Large Prototype LP”**
- **First iteration of TPC-design details of the LCTPC can be tested**
- **Larger area readout can be operated**
- **Tracks with a large number of measured points are available for analyzing correction procedures**
- **Tasks have been divided into WorkPackages (WP)**

- Confirmation of $\sigma_{r\phi}$ of MicroMegas and GEM
observed with SP → **partially confirmed**
- Test of larger and resistive anodes for
MicroMegas → **ongoing**
- Commissioning of electronics:
 - ALTRO with PCA16 → **ongoing**
 - AFTER (T2K) → **ongoing**
- Field mapping of PCMAG to high precision
→ **done**
- Test of calibration method: laser-cathode pattern
→ **ongoing**
- Si envelope → **ongoing**



10 x 10 cm²
CERN GEM:

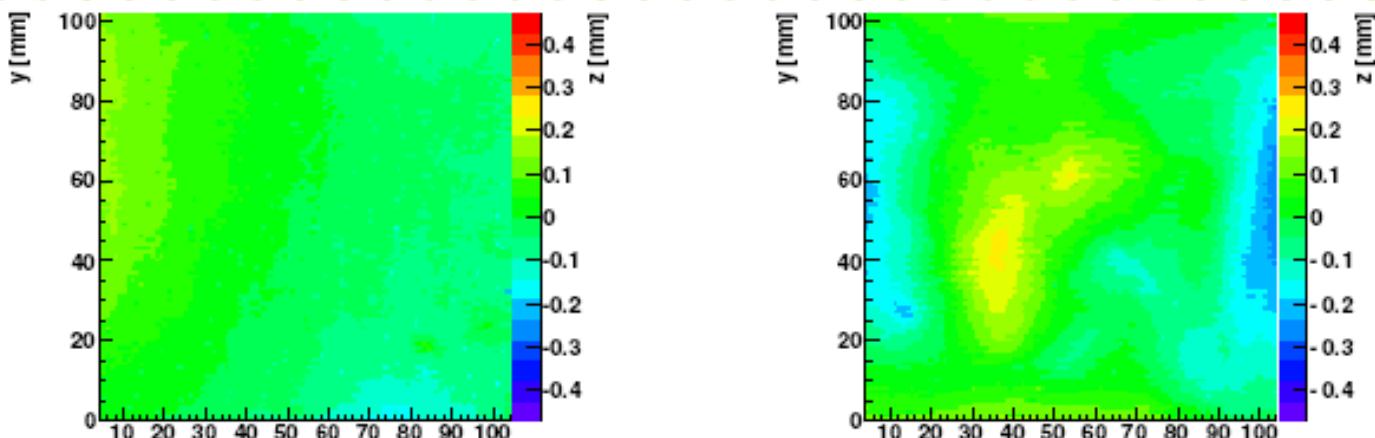


Figure: GEM 7 (Δz : 355 μm) - GEM 17 (Δz : 509 μm) - GRP frames

Flatness study

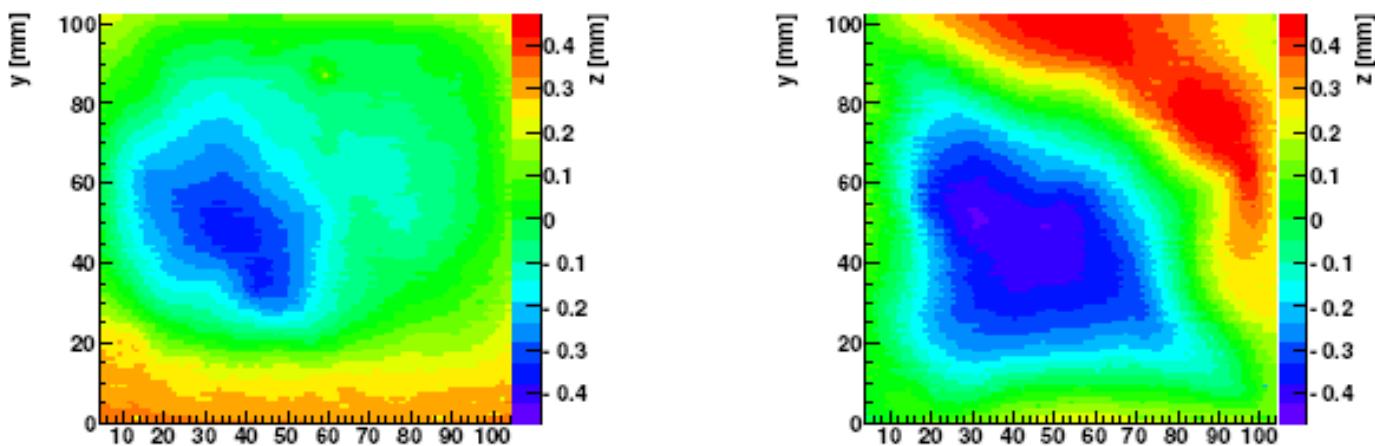
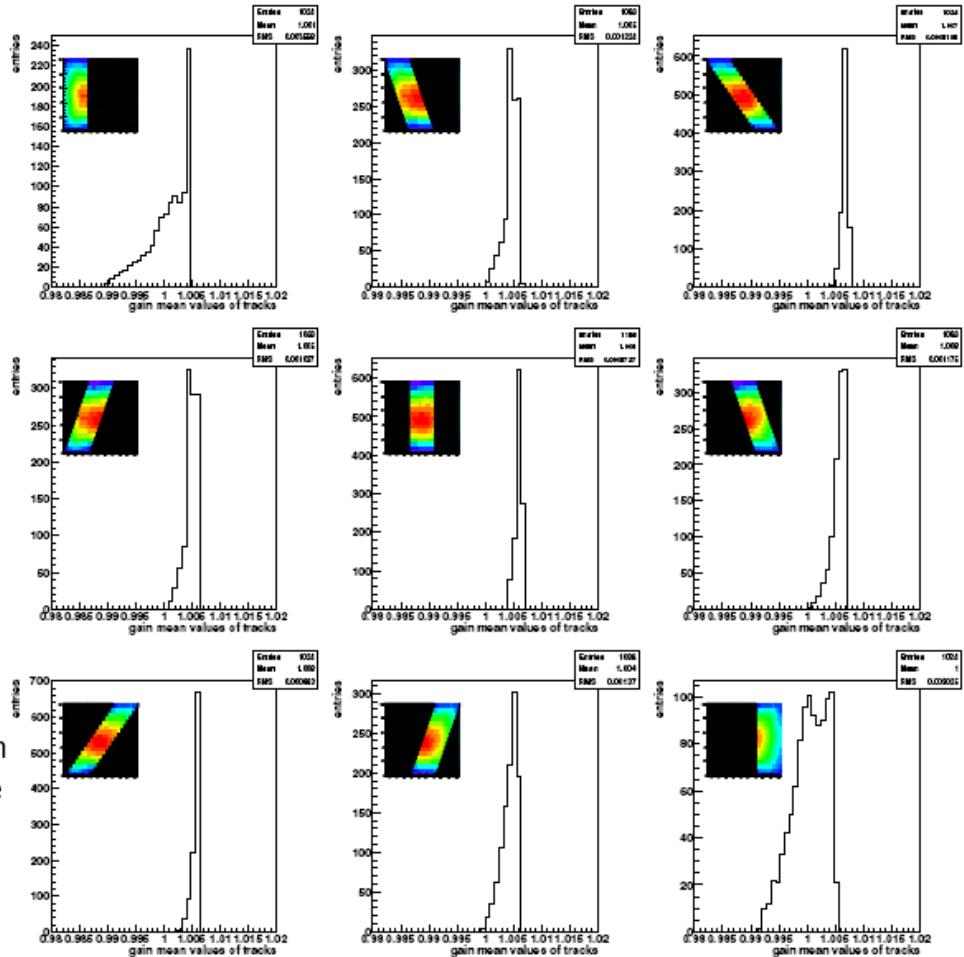


Figure: GEM 18 (Δz : 733 μm) - GEM 26 (Δz : 922 μm) - GRP frames

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

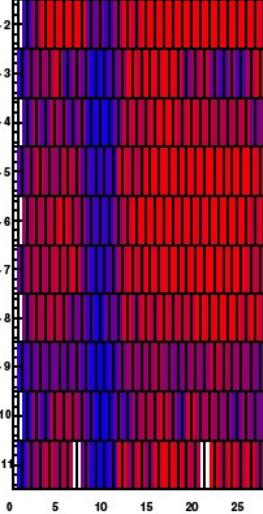
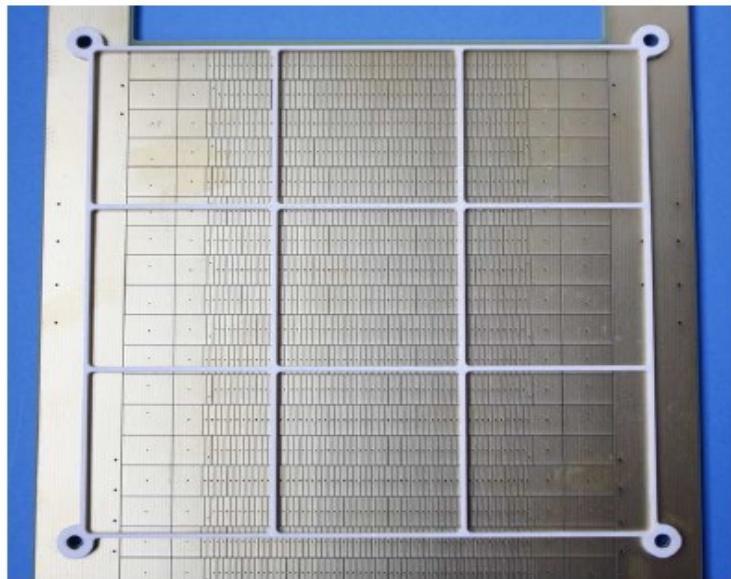


K. Dehmelt

- 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% CH₄
- magnetic field up to 4 T

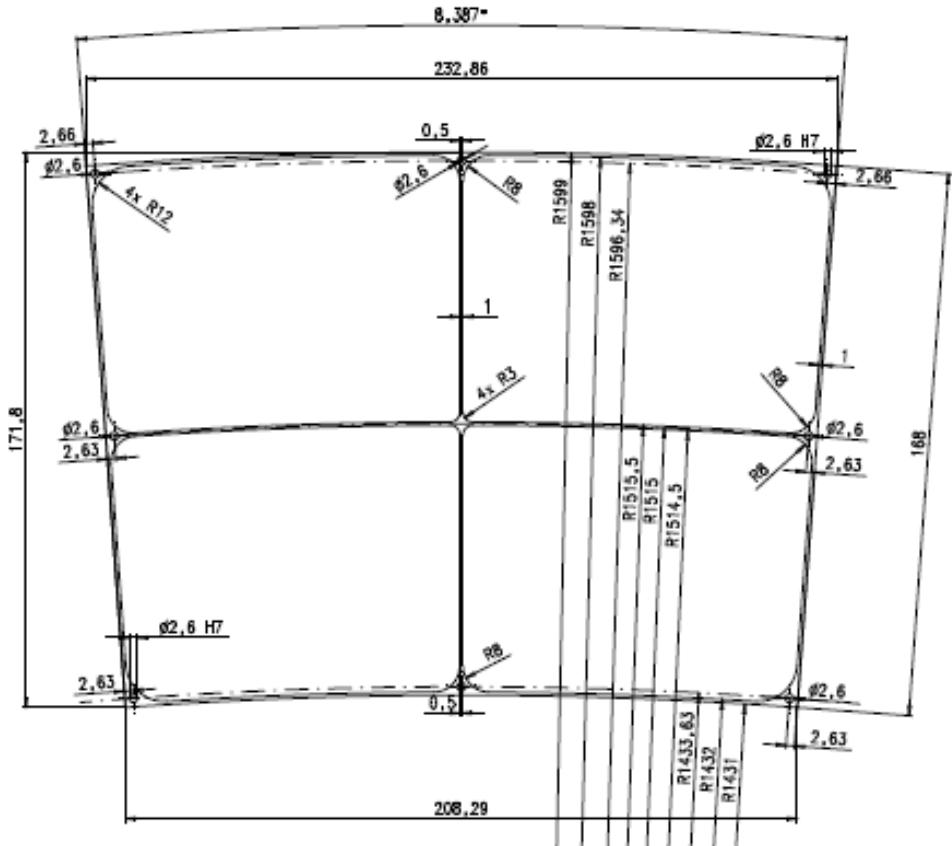


L. Hallermann, DESY



Design studies started

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



S. Caiazzo, DESY

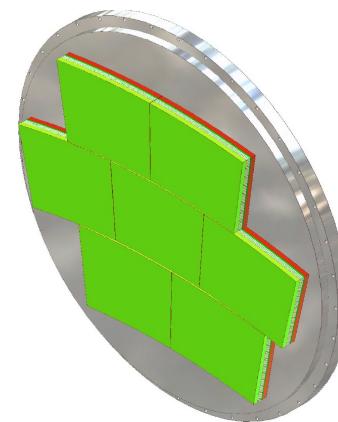
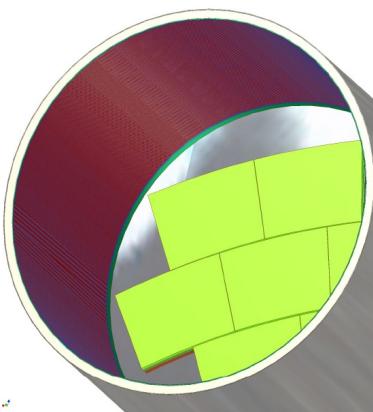


K. Dehmelt

Important R&D goals which will be pursued in ≥ 2010

- Advanced end plate design/development
- Ion feedback, ion disk

Present end plate made out “massive” Al



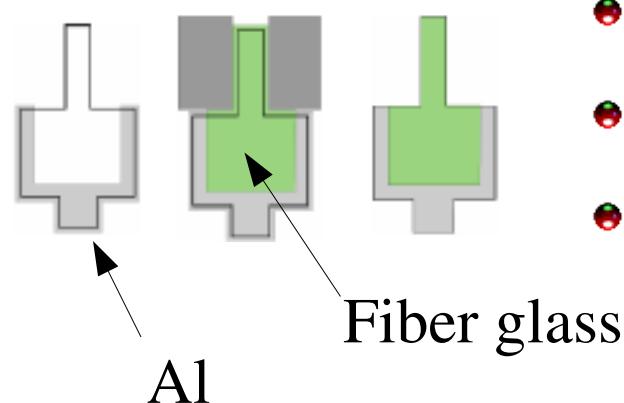
D. Peterson,
Cornell



Present end plate made out “massive” Al

- Material makes up for $\sim 30\% X_0$

- $\sim 14\text{mm}$ Al on average
- $\sim 26\text{mm}$ with modules



- Thinning the outer support area
- Hybrid composite/metal
- Study more advanced designs
 - Composite structure
 - Space frame construction

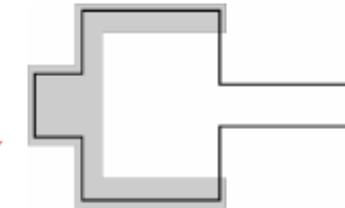
A possible scenario

The process (for the hybrid aluminum/composite)

The outline at right shows the current "mullion".

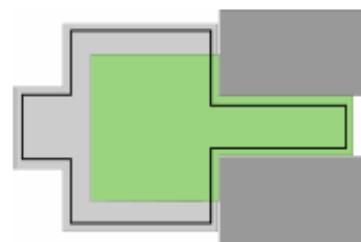
multi-stage fabrication...

Start with aluminum shape, oversize, with cut-out.

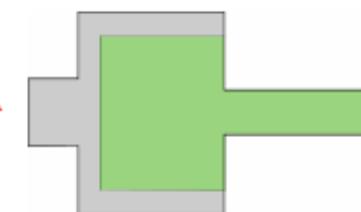


Add temporary mold. Fill with fiberglass.

Cut to final shape.



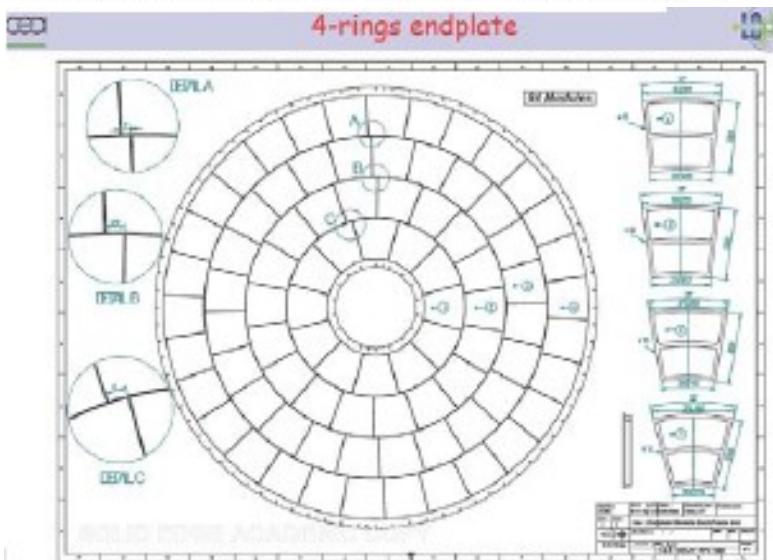
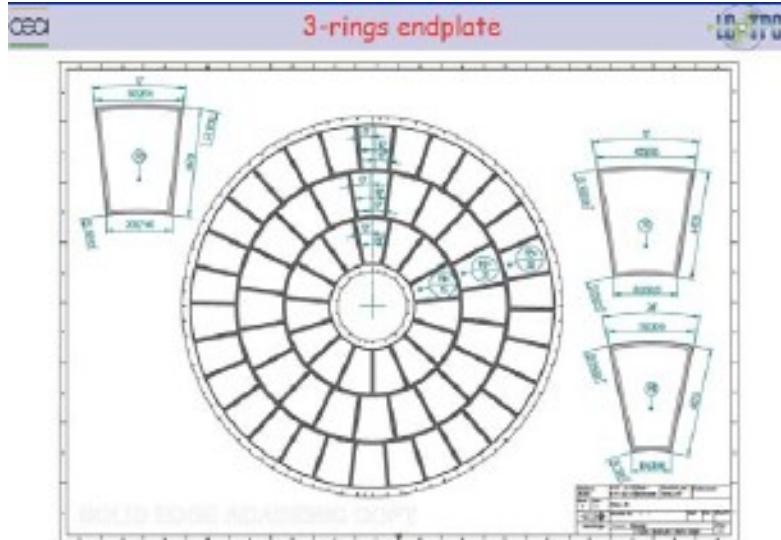
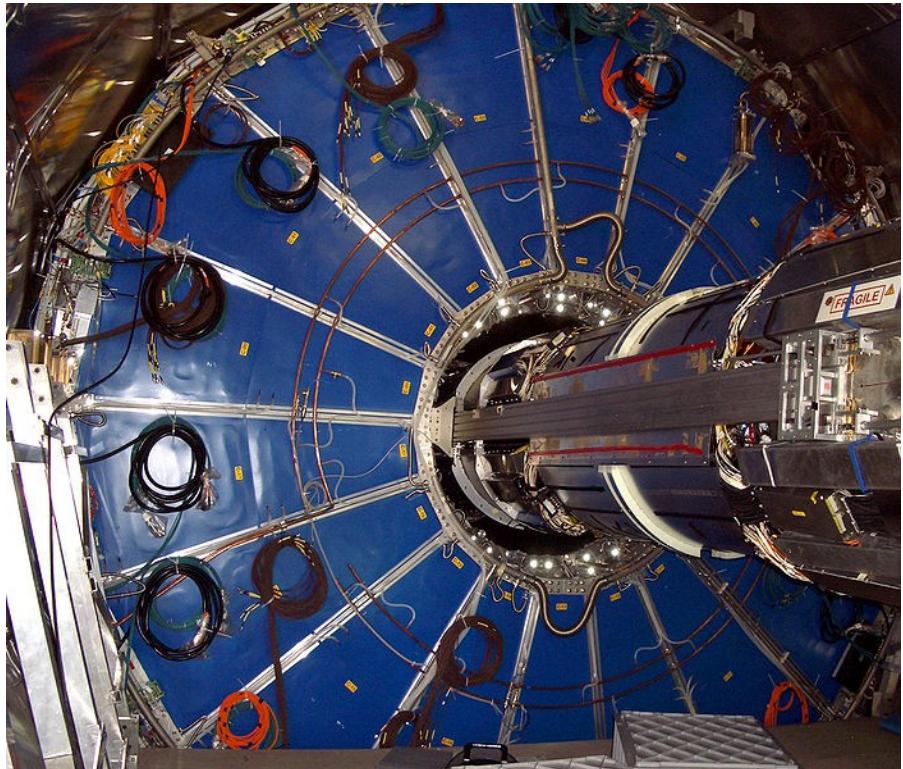
The resulting endplate meets ILD TPC material goals.

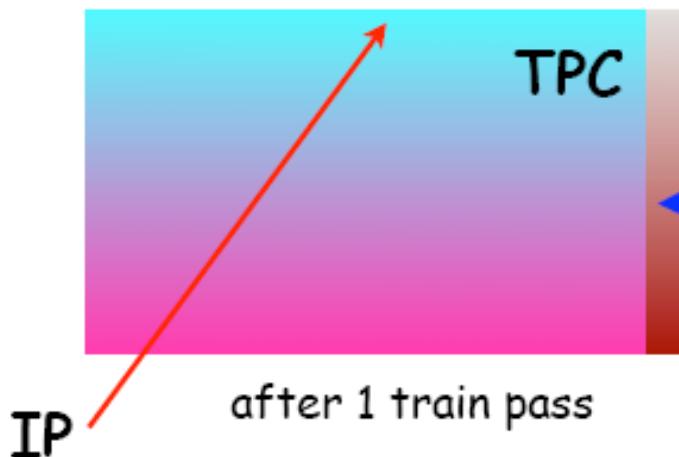


D. Peterson,
Cornell

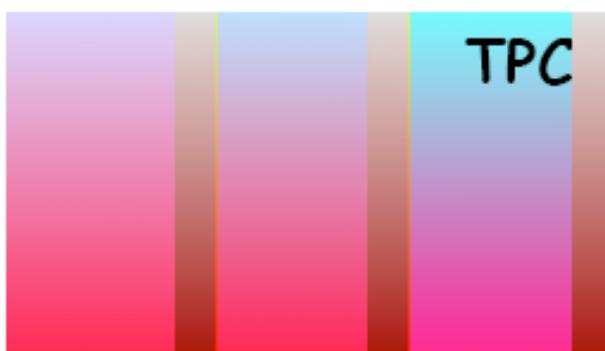


ALICE end plate





Ions @ drift may be accumulate for a few trains
as ions drift is slow



Ions produced at gas multiplications

Ions @ MPGD will form like a ion-dense disc
which travel in drift region slowly
if we don't have any gate mechanism to block ions

this disc may deteriorate drifting electron by E,
ExB ...
and these effects are not stable as ions are moving.

Ions produced at gas multiplications
must be shut off by **GATE**

A. Sugiyama, Saga Univ.
after several trains

Gating for back-drift ions

ILC case : ions feedback must be smaller than 10^{-3} (ie. no ions from MPGD)

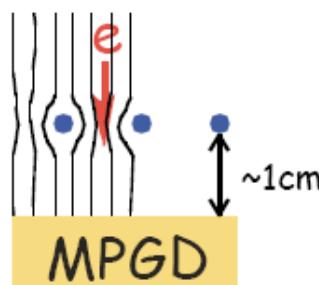
Gate can be open for **1 msec** and be closed following **199 msec.**

ion can drift < 1cm

Gate: wire

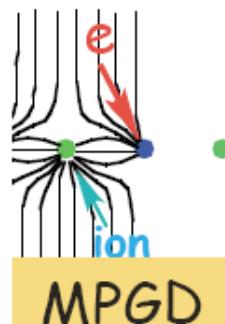
3 candidates

open



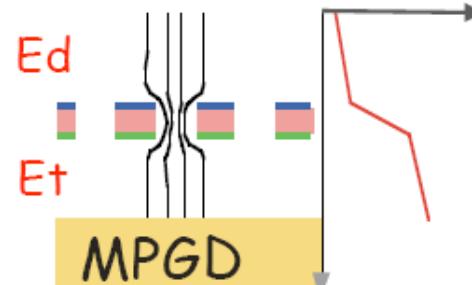
MPGD

close

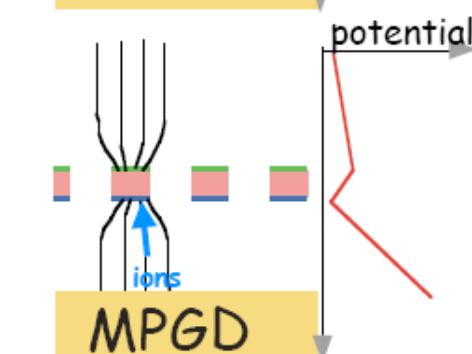


local change of E
wire tension
 $E \times B$

GEM

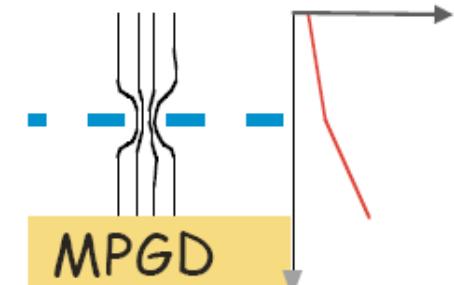


MPGD

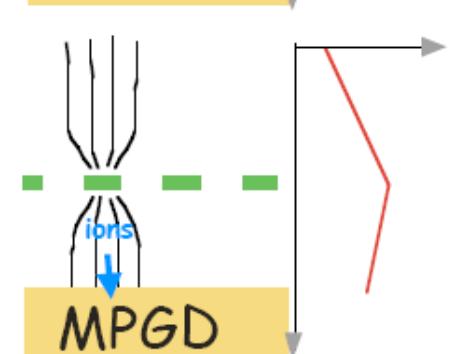


local change of E
electron transmission

micromesh



MPGD



change of drift E
electron transmission

A.Sugiyama, Saga Univ.

- Further test beam campaigns in the next year:
 - ✚ Back plane integrated 10,000 channel readout system, based on ALTR0 electronics
 - ✚ Seven Micromegas modules with AFTER electronics attached to the modules
 - ✚ DESY GEM w/ ceramic grid

Perfection of LP test beam setup and transfer experience to LP2.

- Need to move to hadron beam line:
CERN ? FNAL?
 - ✚ S-ALTRO
 - ✚ Advanced end plate
 - ✚ ILC like beam structure ?
 - ✚ Large bore magnet with $B > 1\text{ T}$?
 - ✚ PCMAG ?
 - ✚ Combined test beam with ECAL/HCAL ?

Many question marks ? need decisions