Large Prototype TPC Development for ILD Detector at Linear Collider

Madhu Dixit
TRIUMF & Carleton University

presented on behalf of
LC TPC Collaboration

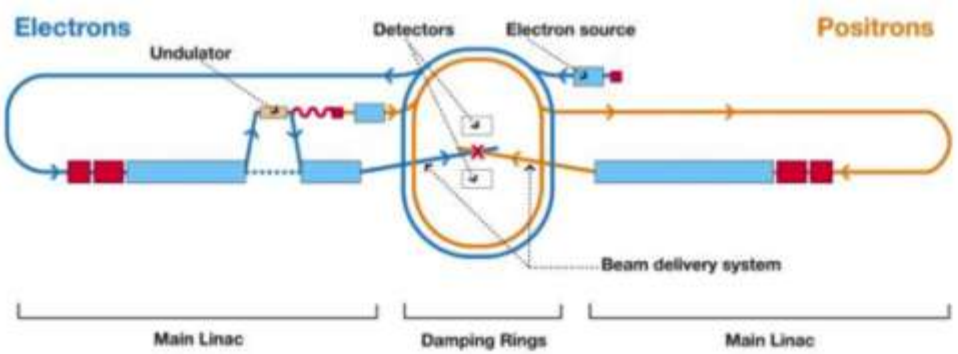
2010 IEEE Nuclear Science Symposium & Medical Imaging Conference
Session N52 High Energy and Nuclear Physics Instrumentation
Knoxville Tennessee, 3 November 2010

Outline

- Introduction
- A TPC read out with Micro Pattern Gas Detectors (MPGD) for the ILD detector at Linear Collider
- R&D for the ILD MPGD-TPC
  - Worldwide effort, groups from Europe, Asia, America
- The first Large Prototype TPC (LP) to develop the design for ILD-TPC
- LP beam test setup at DESY
- Results for GEMs and Micromegas
  - Pixel results reported this morning
- Future plans

A future e^+e^- collider will be essential to fully understanding LHC discoveries

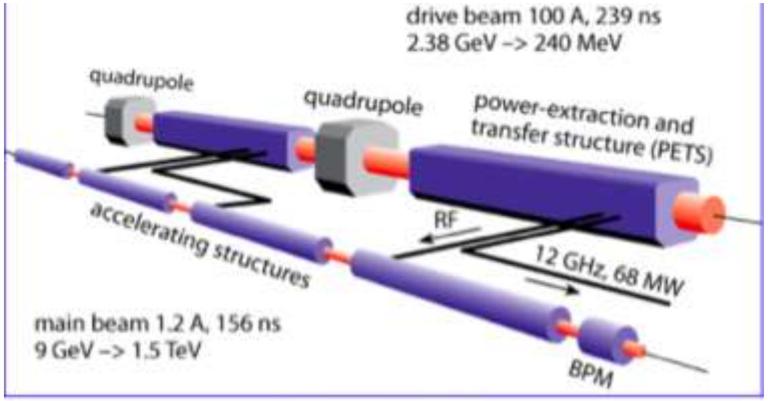
The International Linear Collider (ILC), E_{CM}= 0.5 to 1 TeV



- No technological hurdles
- Super-conducting RF
- Ready to build Engineering design report ~ 2012
- Approval & start of construction depends on LHC results

Compact Linear Collider (CLiC), E_{CM}= 0.5 to 3 TeV

- R&D for a higher energy Linear Collider
- Drive beam transfers power to electrons
- High accelerating gradients ~ 100 MV/m
- Conceptual design report ~ 2011



CLIC module layout

The ILD detector concept for physics at ILC

- One of two detector concepts approved to produce a Detailed Baseline Design by 2012
- The ILD has a 2 m drift TPC in a 3.5T magnet for charged particle tracking

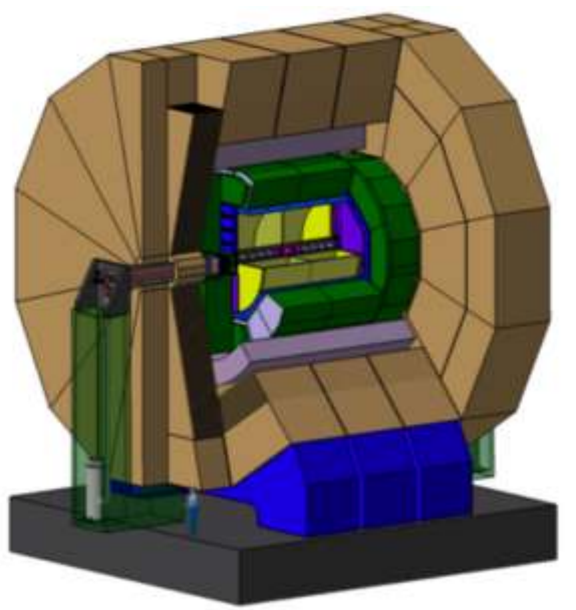


Figure 2: A schematic view of the International Large Detector concept (the TPC is the yellow cylinder inside the blue electromagnetic calorimeter).

Unprecedented TPC resolution goals driven by model independent Higgs measurements which will be limited only by the precision of collision energy

- $\sigma(r, \varphi) \leq 100\ \mu m$
- $\sigma(z) \approx 500\ \mu m$
- 2 hit resolution
  - $\approx$ 2mm in (r,φ)
  - $\approx$ 6 mm in z
- dE/dx ~ 5%

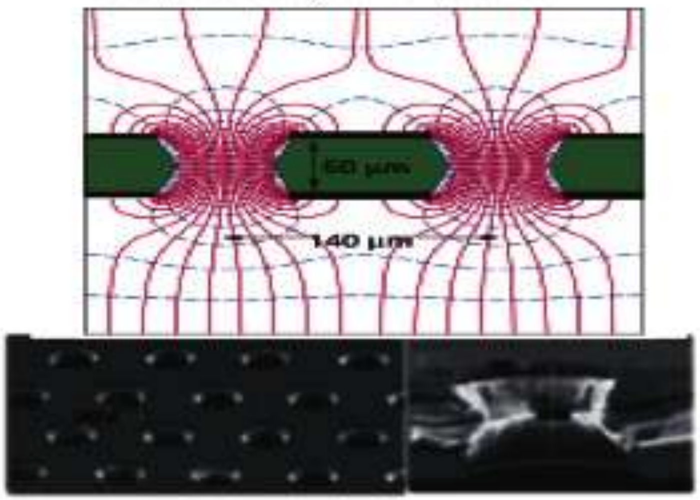
Wire/pad TPC resolution unavoidably limited by intrinsic ExB effects

Micro-Pattern Gas Detectors (MPGD) have negligible ExB effect

MPGD-TPC readout proven in Small Prototype Tests

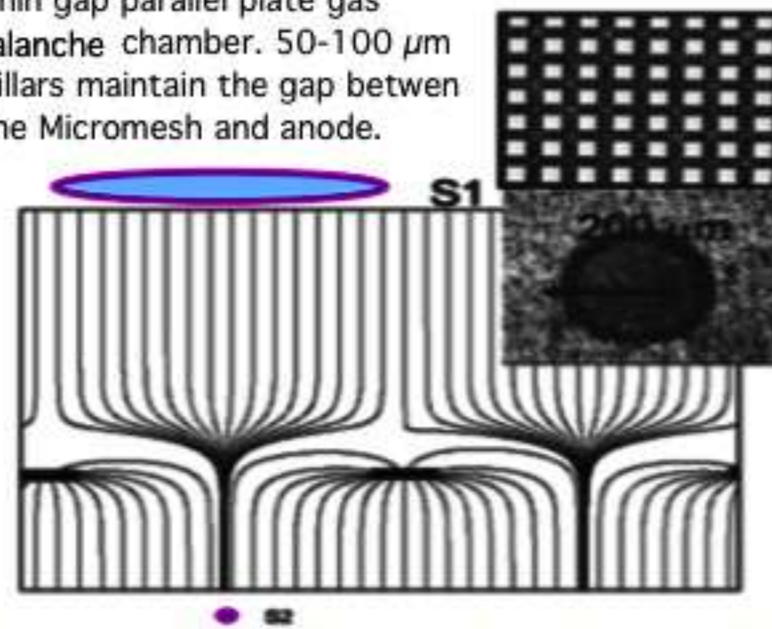
GEM

Polyimide film 50 μm thick, copper clad on both sides, highly perforated with ~70 μm holes. High electric field in holes produces gas multiplication

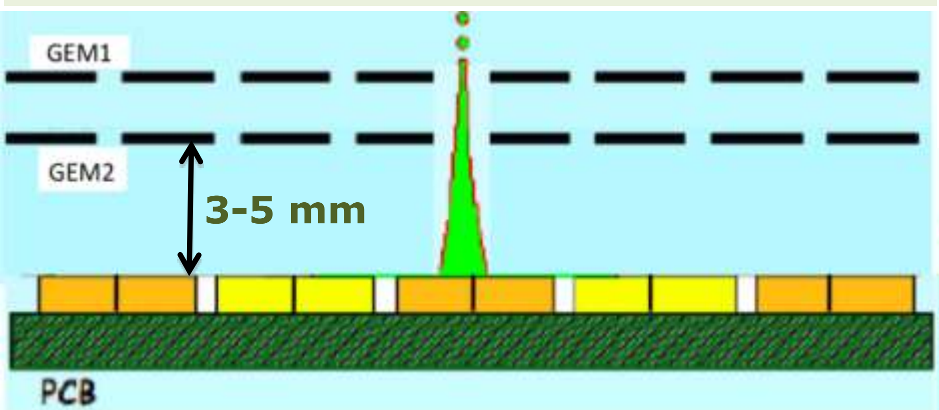


Micromegas

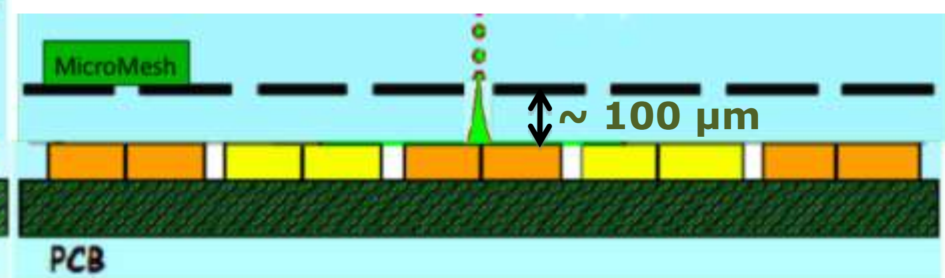
Thin gap parallel plate gas avalanche chamber. 50-100 μm pillars maintain the gap betwen the Micromesh and anode.



GEM resolution ok ~ 1 mm wide pads



Signal too narrow for Micromegas to achieve good resolution even with 1 mm wide pads

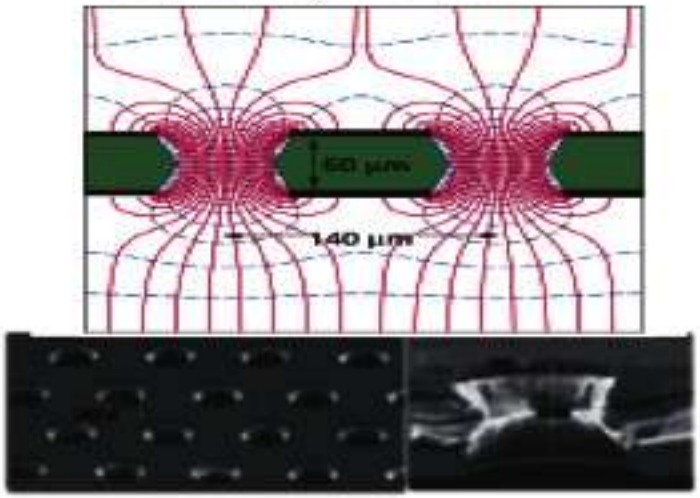


Micro-Pattern Gas Detectors (MPGD) have negligible ExB effect

MPGD-TPC readout proven in Small Prototype Tests

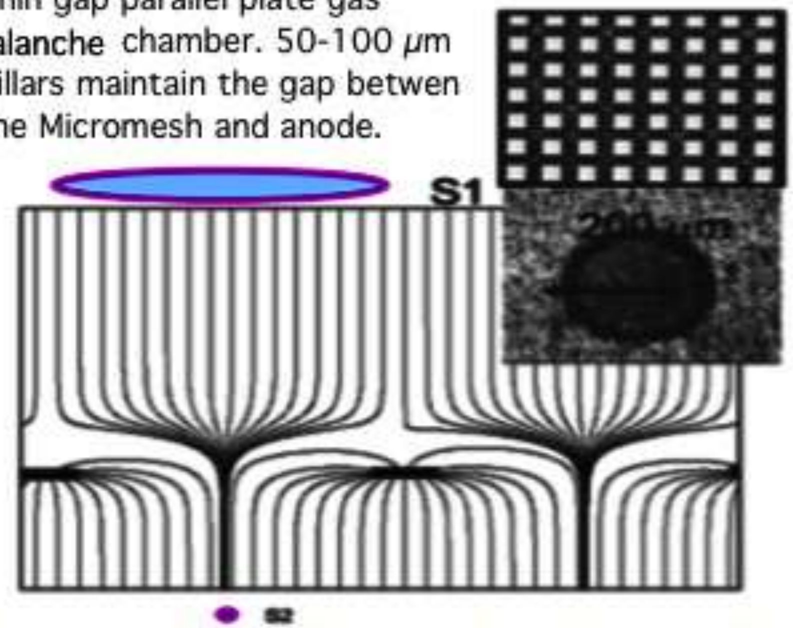
GEM

Polyimide film 50 μm thick, copper clad on both sides, highly perforated with ~70 μm holes. High electric field in holes produces gas multiplication

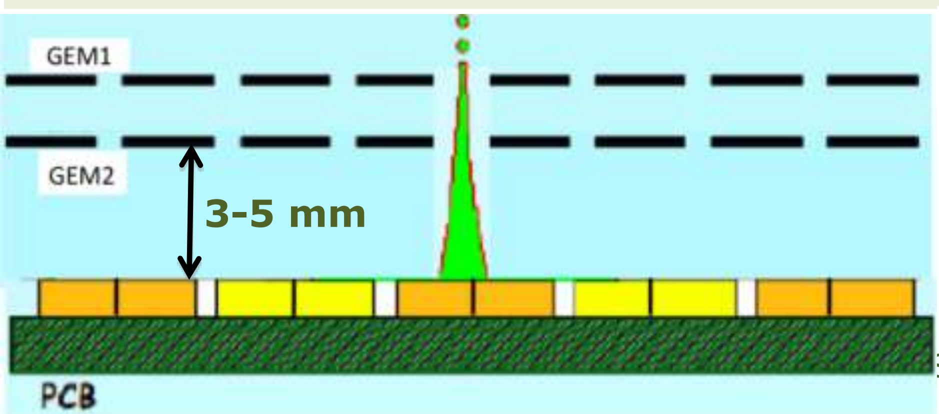


Micromegas

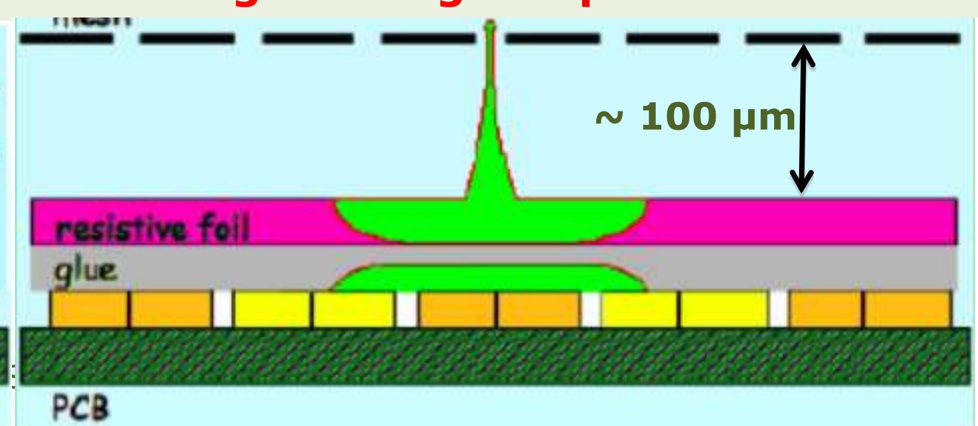
Thin gap parallel plate gas avalanche chamber. 50-100 μm pillars maintain the gap betwen the Micromesh and anode.



GEM resolution ok ~ 1 mm wide pads



Micromegas charge dispersion readout

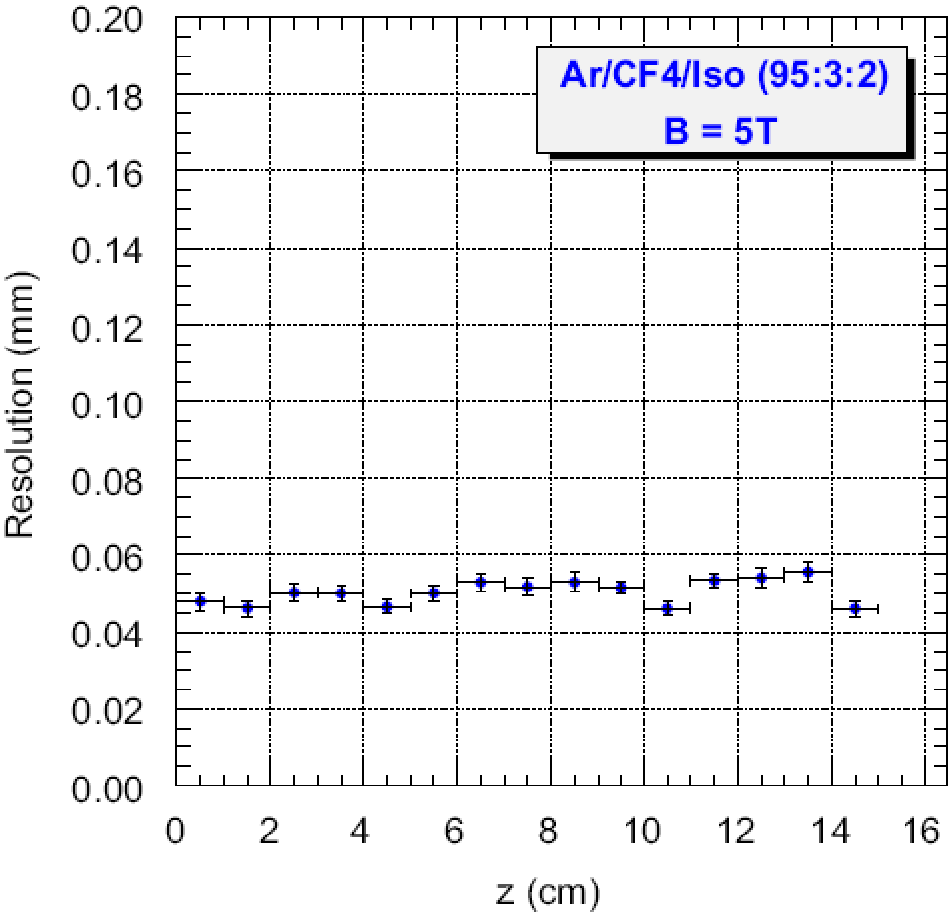


A Small Prototype TPC result – DESY Cosmic ray tests at 5 T

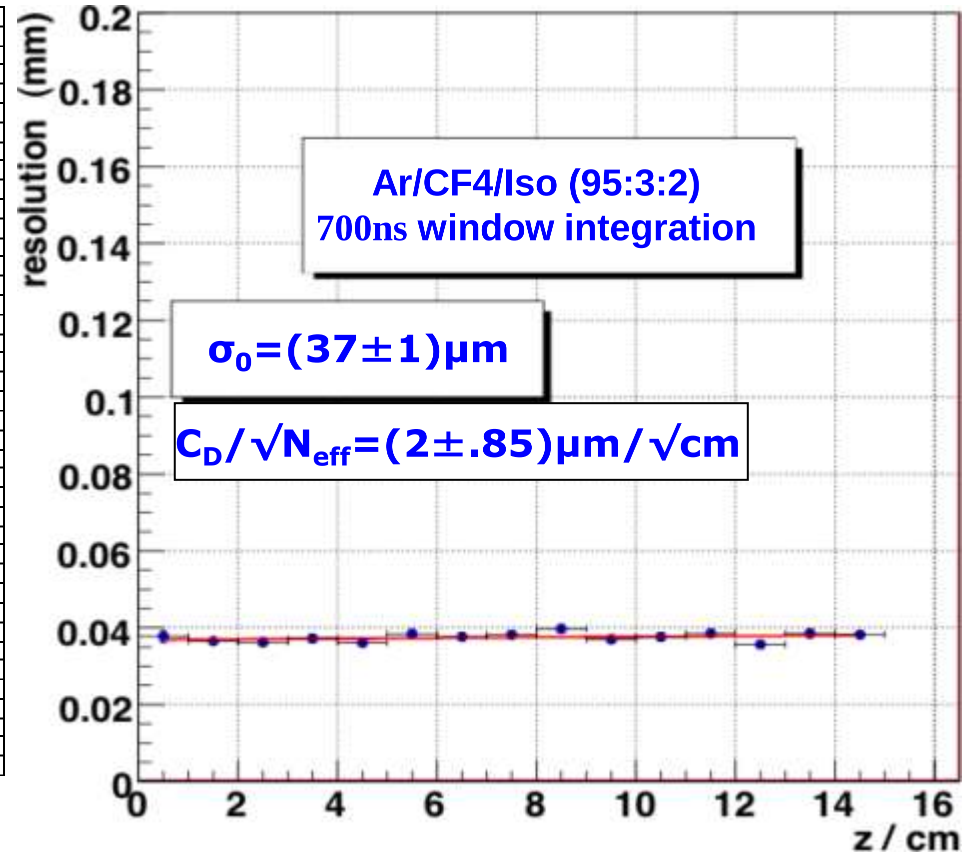
Transverse resolution, Micromegas TPC, Charge dispersion readout
Published result vs new analysis using an improved algorithm

2 mm x 6 mm pads

(NIM A 581 (2007) 254)

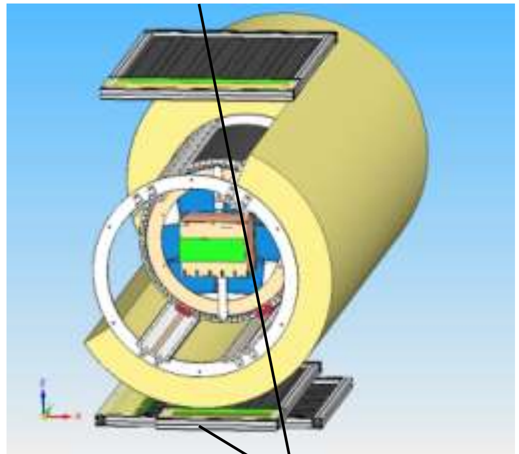


New analysis (to be published)



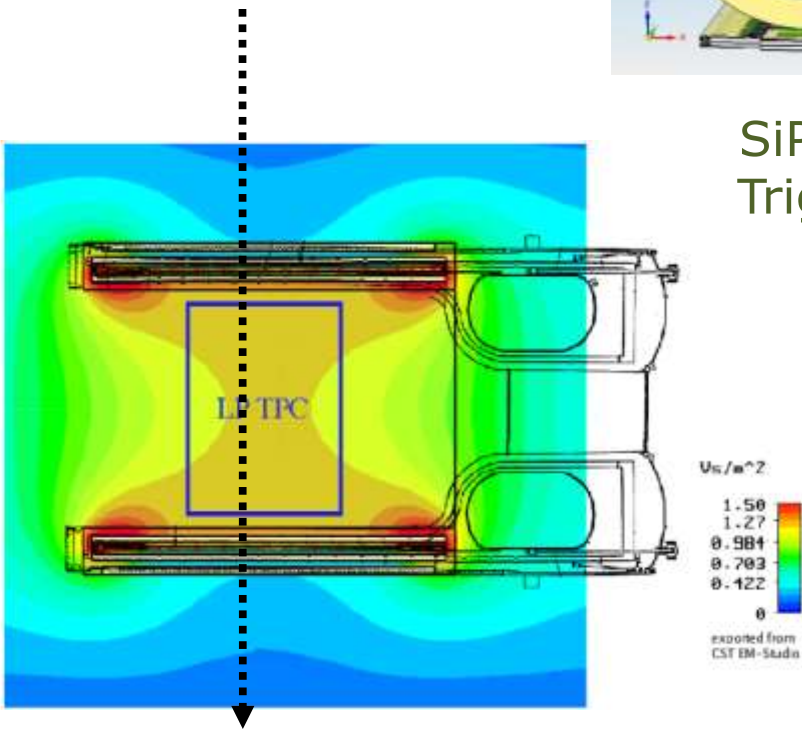
Large Prototype (LP) TPC - EUDET Test Facility at DESY

PCMAG: superconducting solenoid, B = 1.2T
e$^-$ test beam at DESY
(1GeV/c<p<6GeV/c)

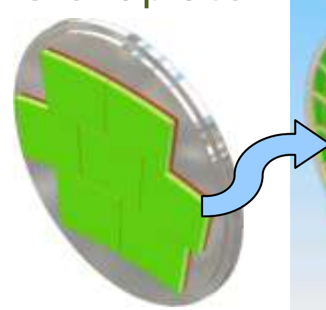


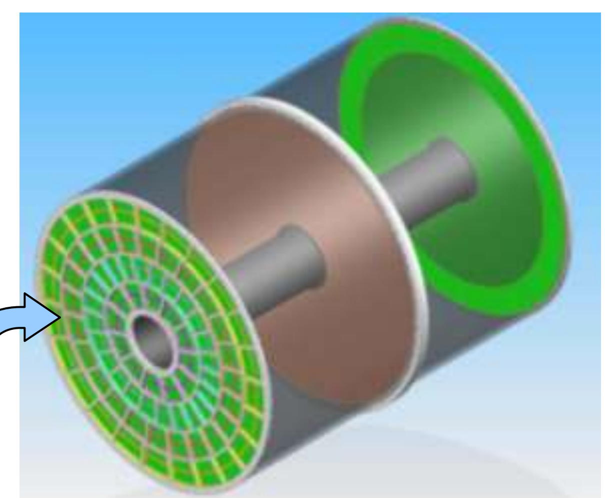
SiPM Cosmic Trigger Setup

Moving frame



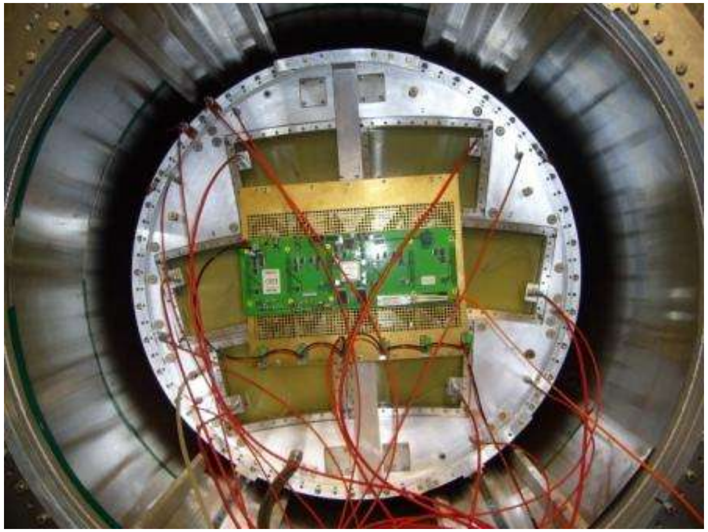
LP : part of a TPC endplate





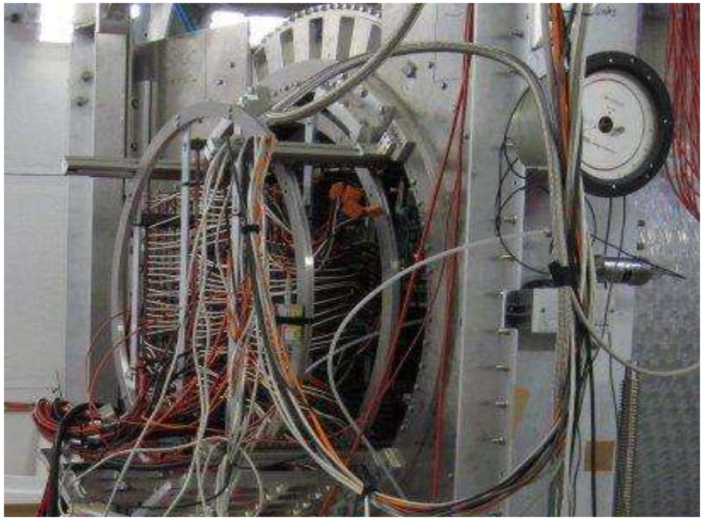
LP beam tests at DESY

Micromegas



Readout based on AFTER electronics developed for T2K TPCs at JPARK

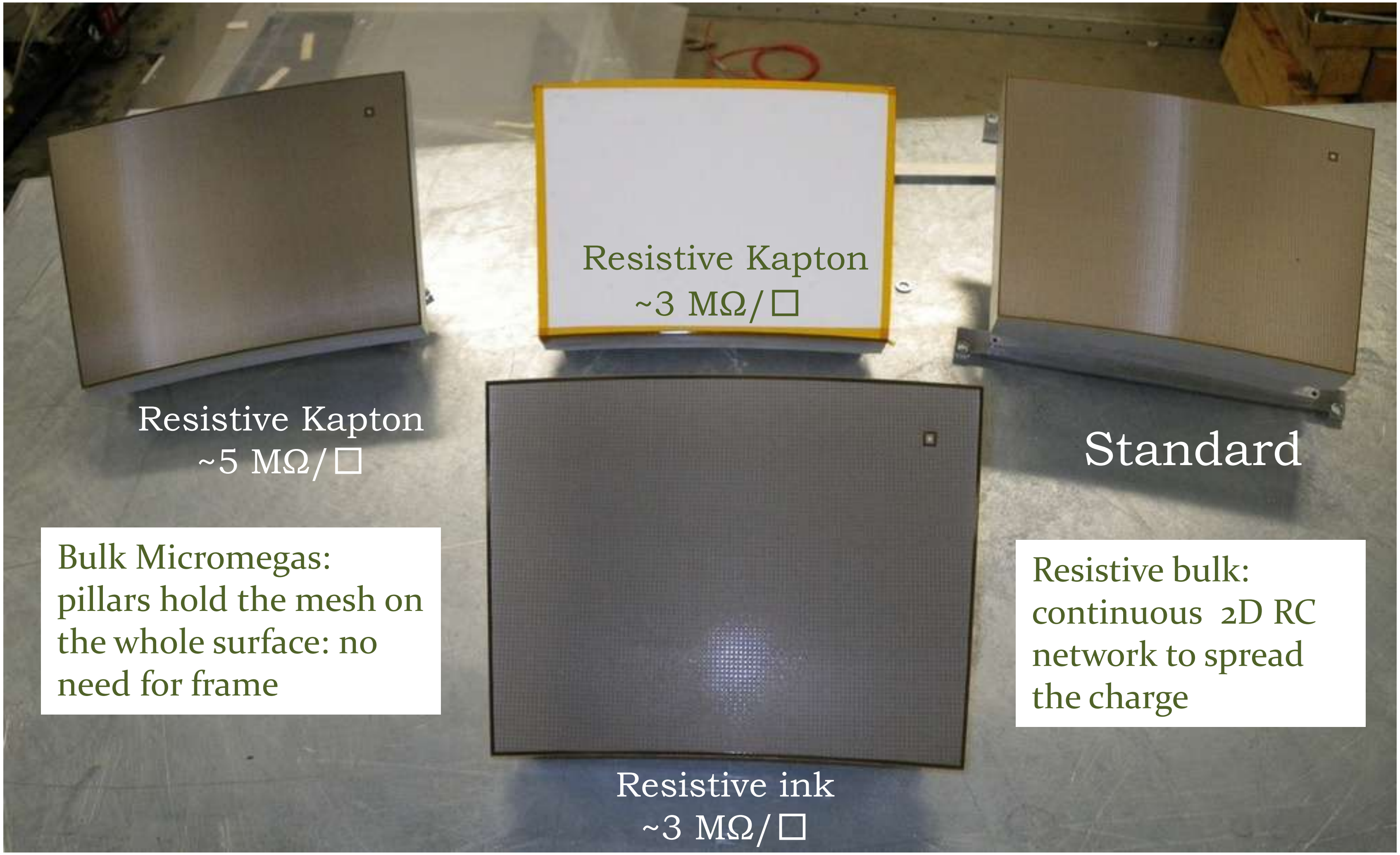
GEM



Readout based on ALTRO system developed for ALICE TPC at CERN

From October 2008 to September 2010 several GEM and Micromegas modules were tested with electron beam

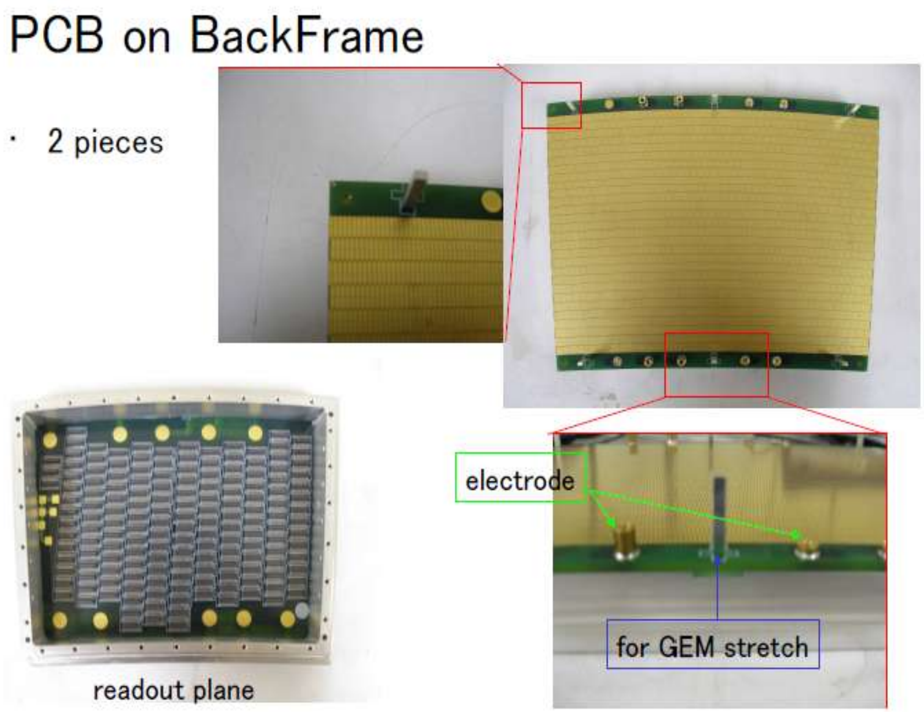
A number of Micromegas Modules were tested



24 rows x 72 pads, 2.7-3.2 mm wide, 7 mm long

LP GEM Modules being tested

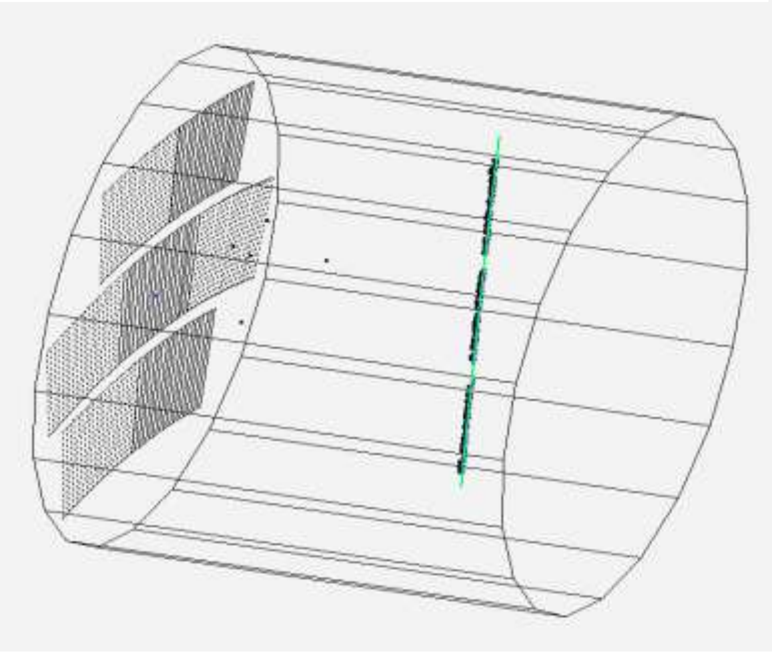
- Double-GEM, laser etched, 100 μm thick from SciEnergy, Japan
  GEMs pegged down by the two arc-shaped stiffeners



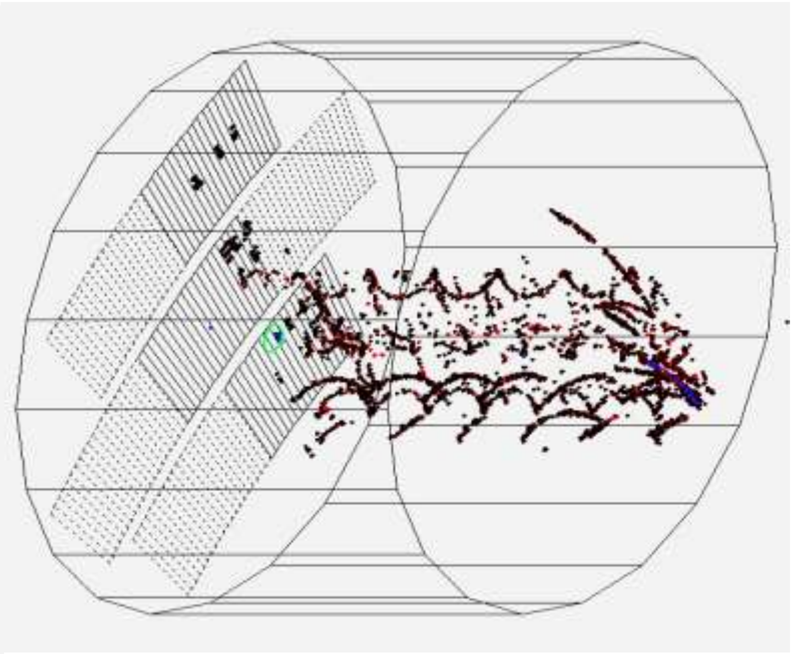
- New thin ceramic frame grid GEMs developed at DESY

Test of GEM modules (SciEnergy, Japan) at 1T

- 28 pad-rows of 176 -194 pads (pad size ~ 1.1 x 5.4 mm^2)
- Total 5152 pads/modules
- 3 modules partially equipped (7616 channels)



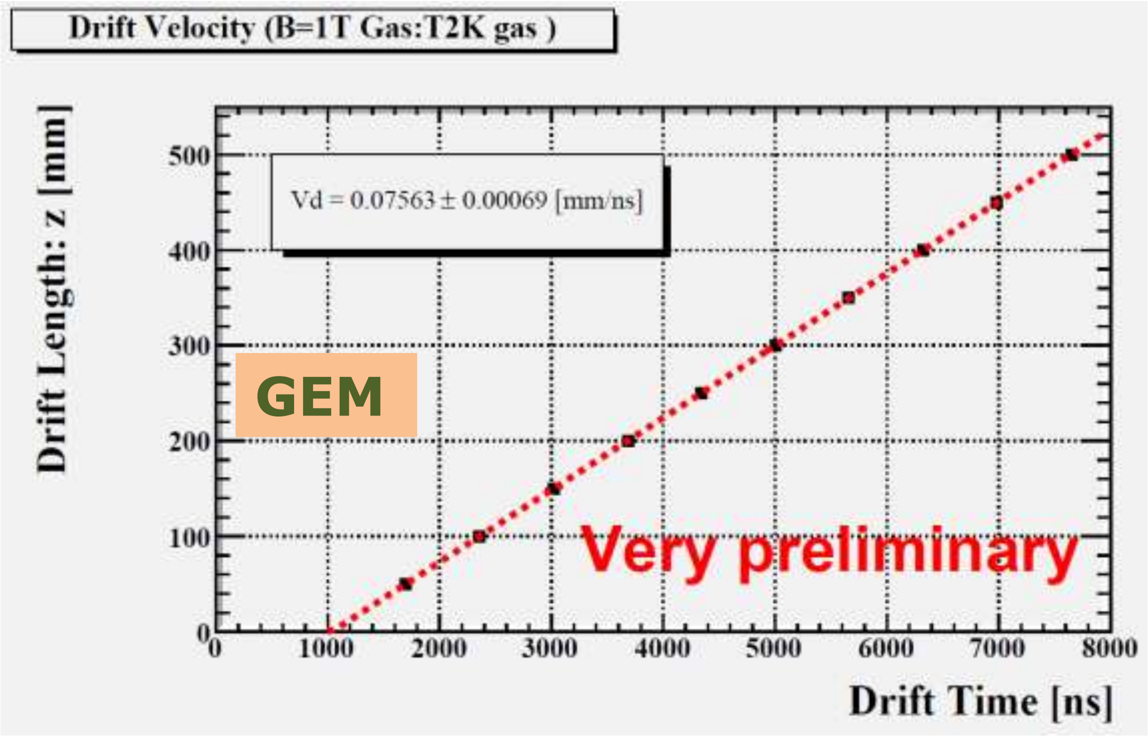
A single electron track



Low energy particles produced by a beam electron hitting the cathode curl up in the B field

Drift velocity measured with GEMs and Micromegas

T2K gas (Ar:CF4:iso=95:3:2) used for both GEMS & Micromegas



GEM, with P=1013 hPa, T=290 K, 200 ppm H_20
V_{drift} = 7.563 +- 0.069 cm/μs at E=230 V/cm (Magboltz : 7.509+-0.024(gas comp.))
Micromegas, with P=1035 hPa, T=292 K, 35-50 ppm H_20
V_{drift} = 7.698 +- 0.040 cm/μs at E=230 V/cm (Magboltz :7.583+-0.025(gas comp.))

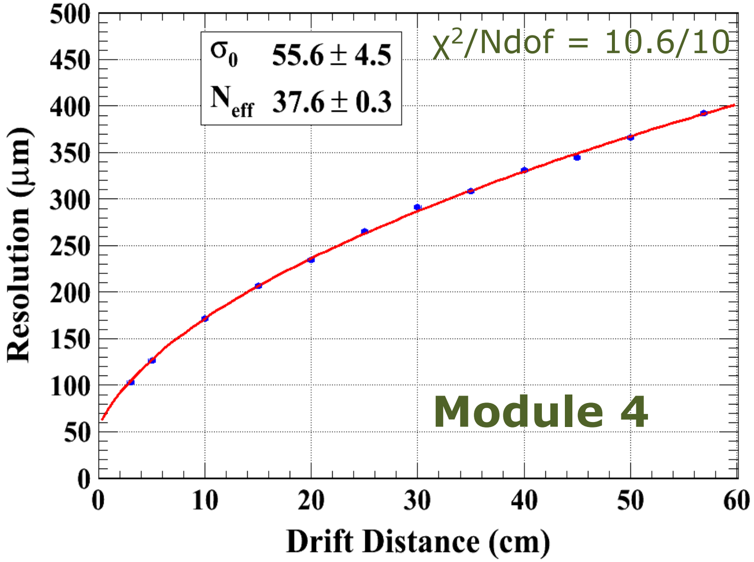
Transverse resolution for Micromegas (B = 0T & 1T) Carbon-loaded Kapton resistive anode

$$\sigma = \sqrt{\sigma_0^{\ 2} + \frac{C_d^2 \cdot z}{N_{eff}}}$$

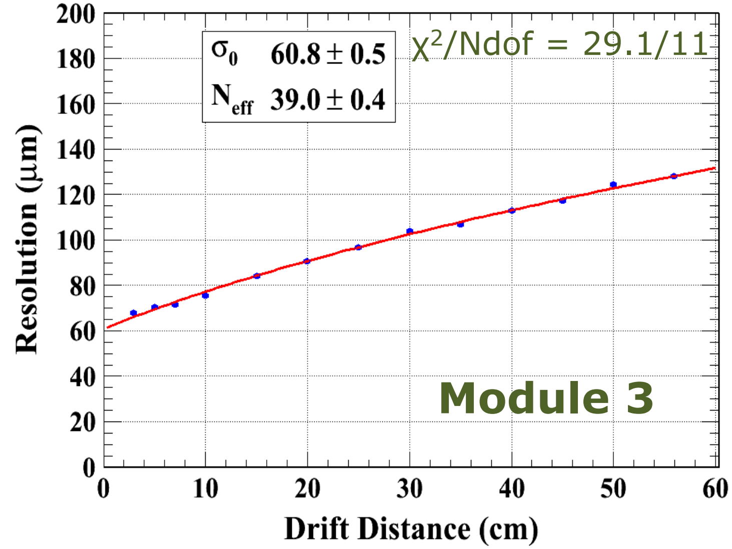
σ_0 : the resolution at Z=0

N_{eff} : the effective number of electrons

B=0 T C_d = 315.1 μm/√cm (Magboltz)



B=1 T C_d = 94.2 μm/√cm (Magboltz)



Average of B=0T data and B=1T data

- N_{eff} = 38.0±0.2(stat) ±0.8 (C_d syst)
- σ_0= 59 ± 3 μm

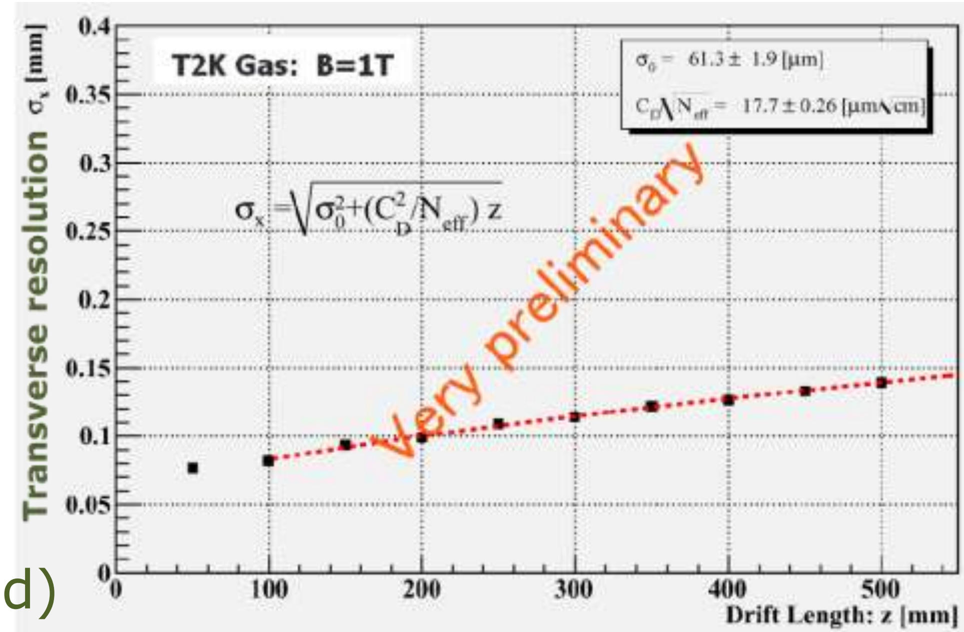
80 μm resolution at 2m in B=3.5 T !

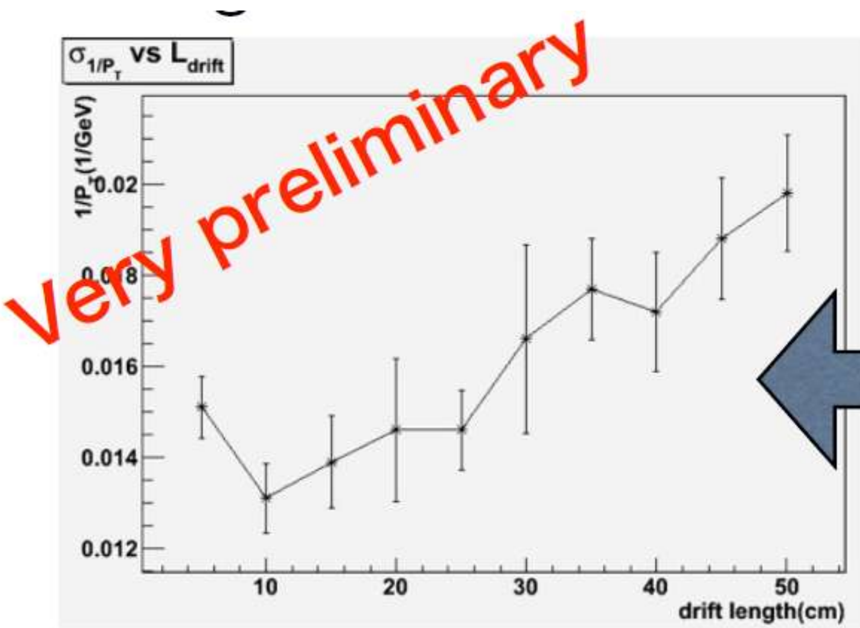
Resolution with GEMs

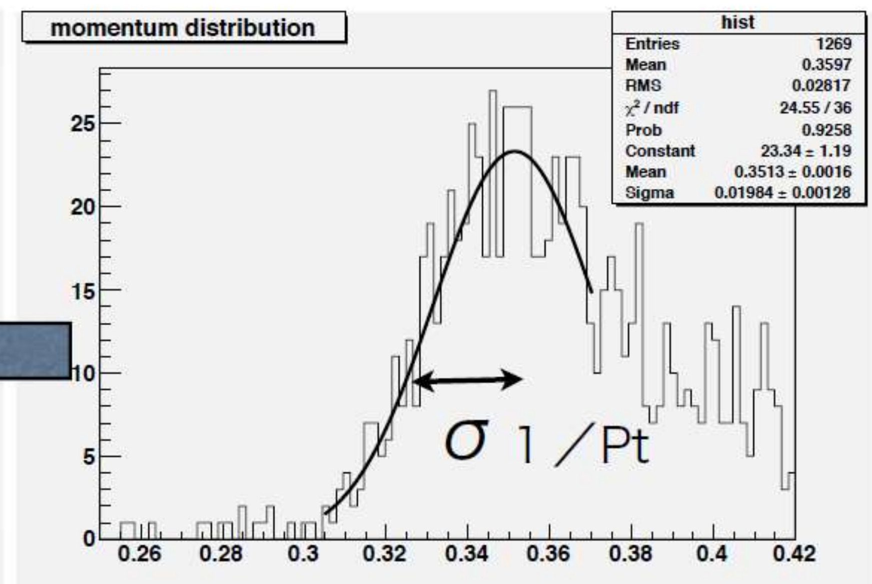
- With 3 modules, one can track particles and measure momenta
- A first rough attempt to measure momentum resolution using Marlin TPC software

$\Delta[1/p_T](z \longrightarrow 0) \approx 0.083\ \text{GeV}^{-1}$

$(0.081\ \text{GeV}^{-1}$ expected)







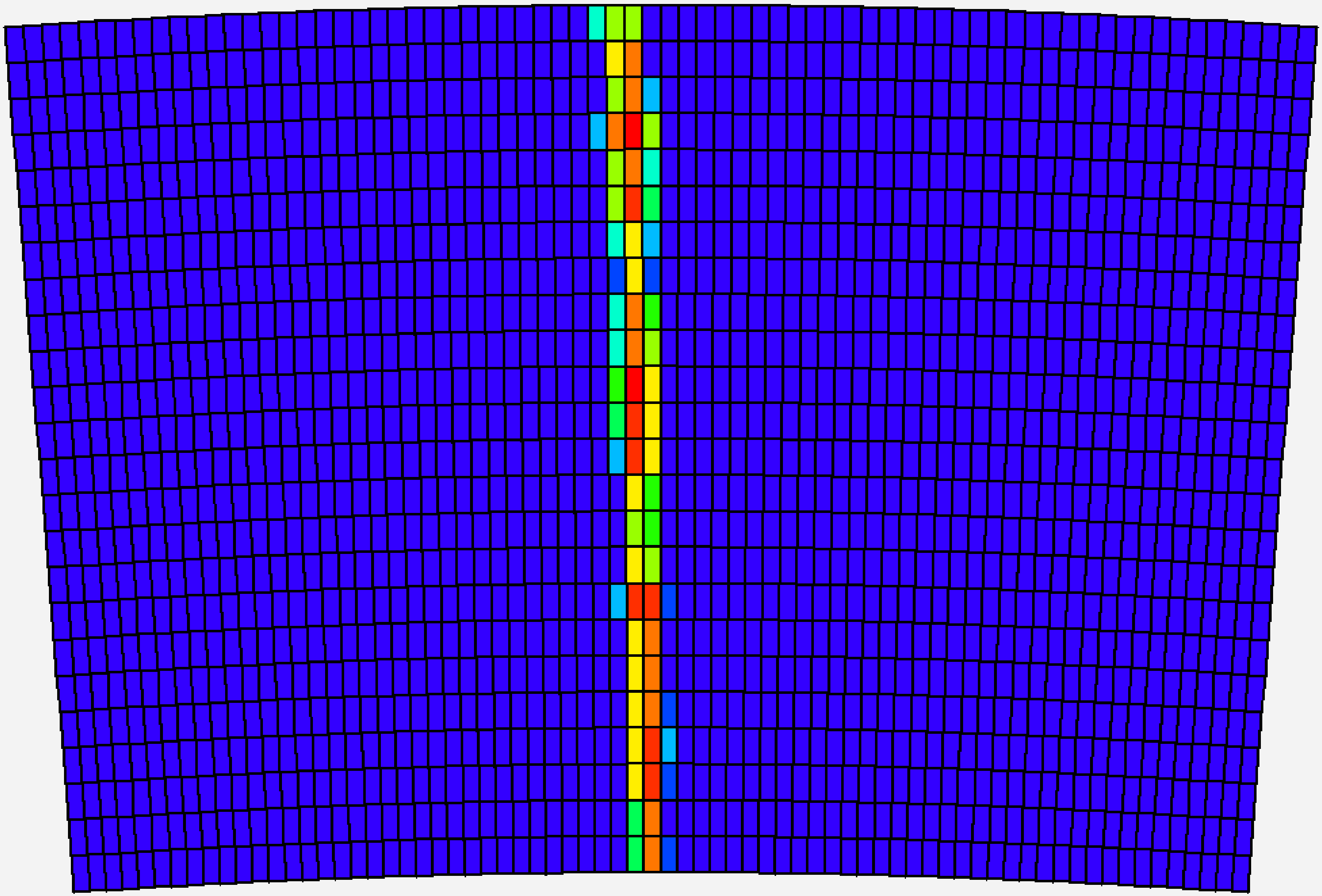
Future plans

-DESY GEM modules on thin ceremic frames
-7 module Micromegas modules with onboard AFTER electronics
-Laser calibration and silicon envelop
-Cooling and power pulsing tests in a 5 T magnet
-Tracking in an in-homogeneous magnetic field and momentum resolution measurement
-High density S-ALTRO electronics for both GEMs and Micromegas
-Low mass endplate and field cage design
-Toward the Detailed Baseline Design by 2012

Backup slides

Goals for performance and design parameters for an LCTPC with standard electronics.

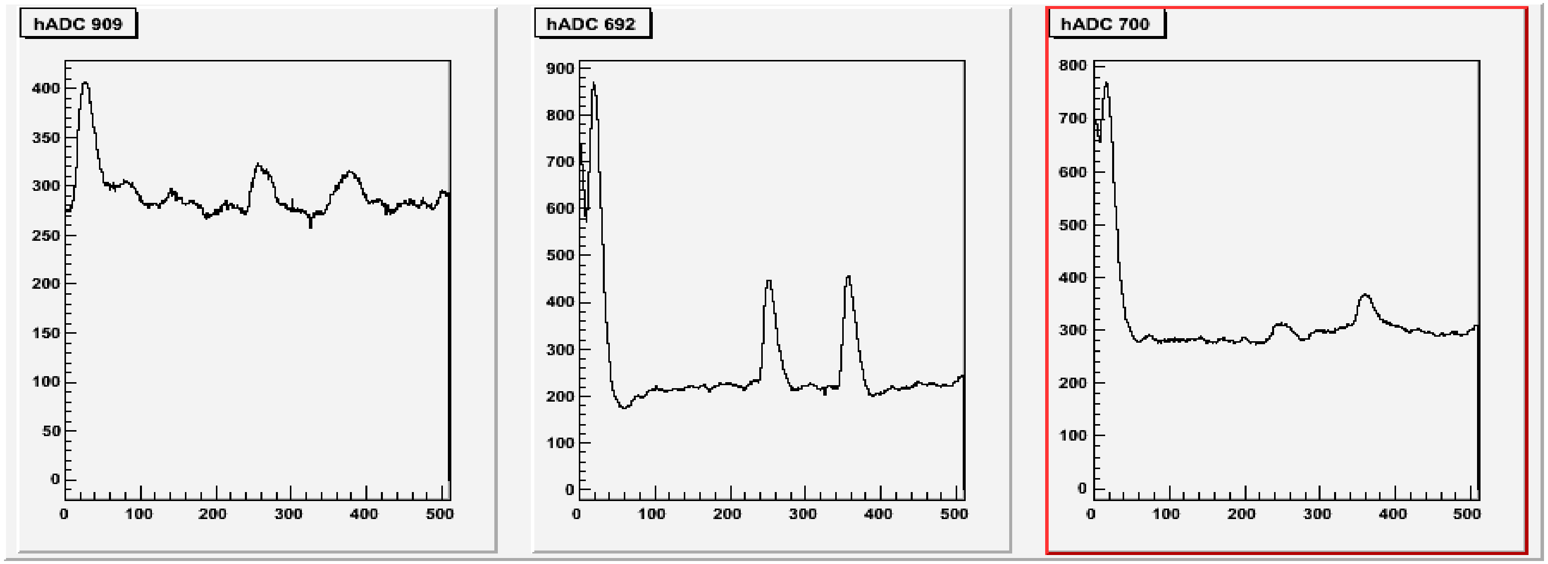
Size	$\phi = 3.6$m, L = 4.3m outside dimensions
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 9 \times 10^{-5}$/GeV/c TPC only ($\times$ 0.4 if IP incl.)
Momentum resolution (3.5T)	$\delta(1/p_t) \sim 2 \times 10^{-5}$/GeV/c (SET+TPC+SIT+VTX)
Solid angle coverage	Up to $\cos\theta \simeq 0.98$ (10 pad rows)
TPC material budget	$\sim 0.05X_0$ including the outer fieldcage in r
	$\sim 0.25X_0$ for readout endcaps in z
Number of pads/timebuckets	~ 1 - 2×10^6/1000 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	~ 0.5 mm (modulo track θ angle)
2-hit resolution in $r\phi$	~ 2 mm (modulo track angles)
2-hit resolution in rz	~ 6 mm (modulo track angles)
dE/dx resolution	~ 5 %
Performance	$> 97\%$ efficiency for TPC only ($p_t > 1$GeV/c), and
	$> 99\%$ all tracking ($p_t > 1$GeV/c)[6]
Background robustness	Full efficiency with 1% occupancy,
	simulated for example in Fig. 1.2(right)
Background safety factor	Chamber will be prepared for 10 $\times$ worse backgrounds
	at the linear collider start-up



Micromegas modules - 24 rows x 72 pads, 2.7-3.2 mm wide, 7 mm long

Charging and timing issues with the resistive foils?

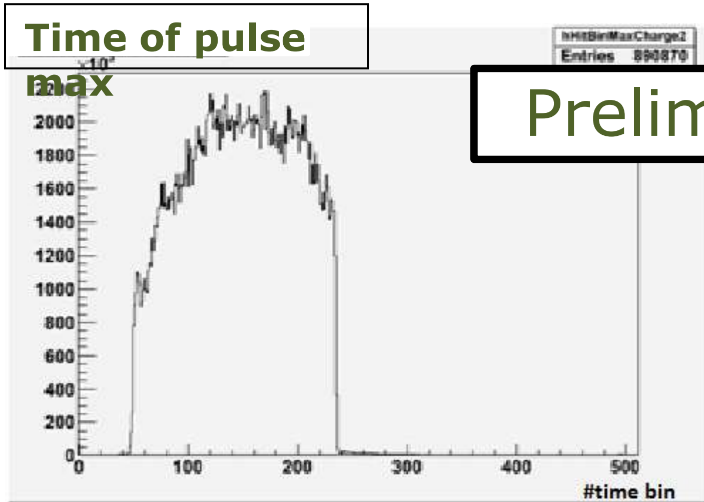
- Test at CERN (July 2010) at 180 kHz (5 x 2 cm² beam) showed no charging up and stable operation
- Peaking time of 200 ns is enough to obtain the best resolution -> 300 ns suffice to distinguish 2 tracks on the same pad



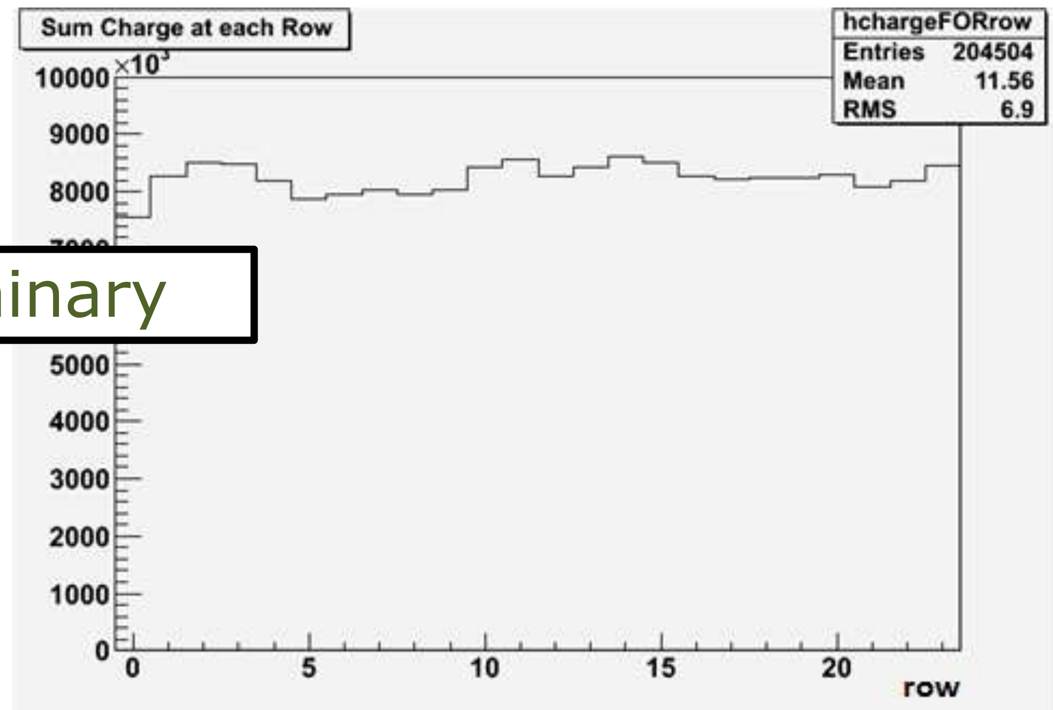
Uniformity (B = 0T)

from cosmic-ray tracks

Time of pulse max



Preliminary



Total charge by row using cosmic-ray events

Uniformity

MEAN RESIDUAL vs ROW number

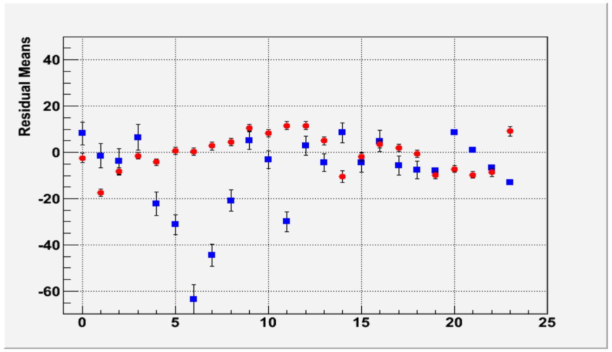
Z-independent distortions

Distortions up to 50 microns for resistive ink (blue points)

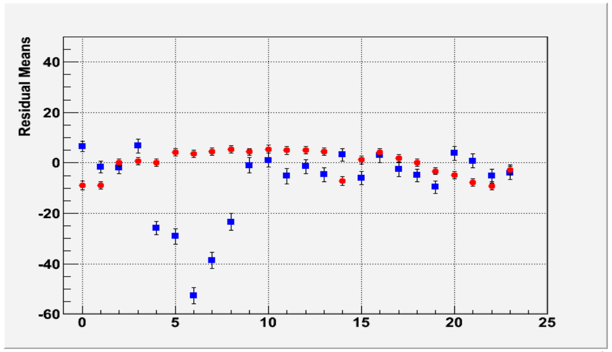
Rms 7 microns for CLK film (red points)

Carbon loaded Kapton is much more uniform than resistive ink

Z=5cm



Z=35cm



Z=50cm