Studies on GEM modules for a Large Prototype TPC for the ILC.

Dimitra Tsionou
On behalf of the FLC-TPC DESY group
LCWS 2015 - Whistler, 03-Nov-2015

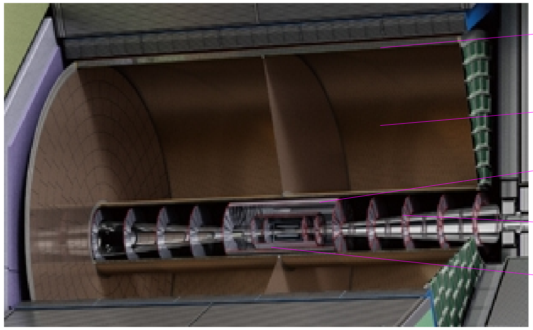
Outline

- ILD & Large Prototype TPC
- Test beam measurements
- Ongoing optimisation studies
- External Silicon tracker

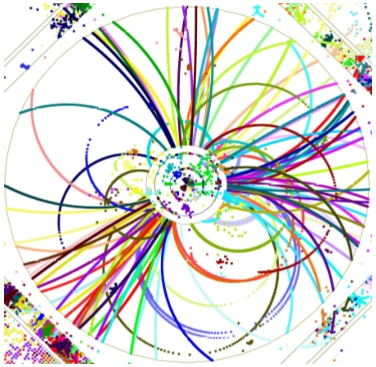
Outline

- ILD & Large Prototype TPC
- Test beam measurements
- Ongoing optimisation studies
- External Silicon tracker

ILD tracking requirements



tTh event



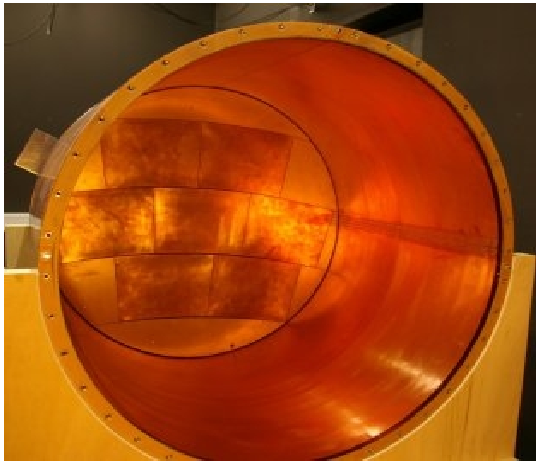
- Momentum resolution:
  - $\sigma(\Delta p_T/p_T^2) = 2\cdot10^{-5}$ GeV^{-1}
  - TPC alone: 10^{-4} GeV^{-1}
- Tracking efficiency
  - close to 100% down to low momenta for Particle Flow
- Minimum material
- Full angular coverage and high hermeticity

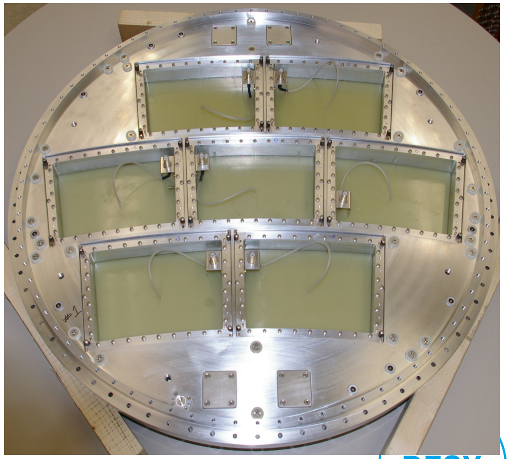
- TPC provides
  - ~200 space points along the track
  - σ~100 µm in the rφ plane (full drift)
  - σ~400 µm in the z direction (zero drift)
  - 5% X_0 for barrel & 25% X_0 for endcaps (including field cage and readout)

- SIT and/or SET
  - Provide entry point to TPC and calorimeter respectively
  - Require low material budget (0.5% X_0 per layer)

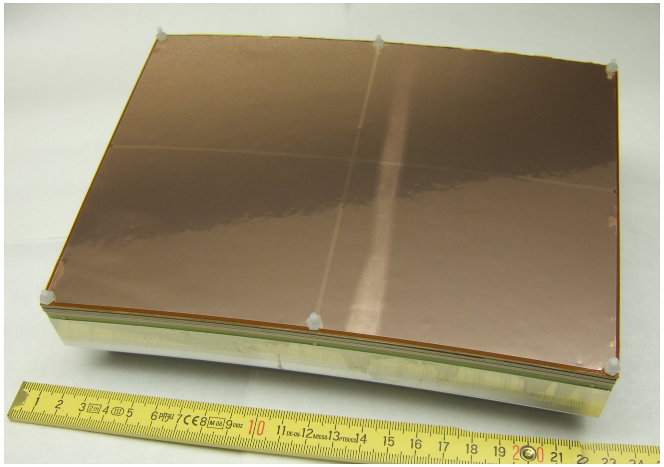
Large Prototype TPC

- Test beam area at DESY (1-6 GeV e^- beams)
  - Infrastructure includes a large bore 1T magnet
- Large Prototype built and installed in order to test and compare different readout technologies
- LP field cage parameters:
  - Length: 61 cm, Diameter: 72 cm
  - Up to 25 kV → E_{drift} up to 350 V/cm
  - Wall material budget: 1.3% X_0
- The endplate is able to host 7 readout modules (dimensions 22x17 cm^2)



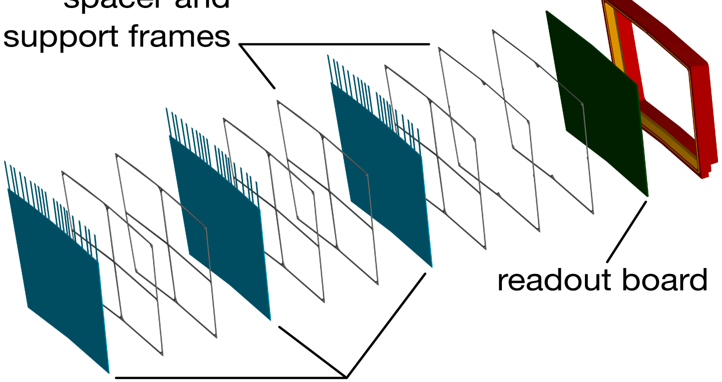


DESY GEM module



Goals

- Maximum active area
- Minimum material budget
- Flatness of GEMs
- Stable operation
- Minimal field distortions (field shaping wire)



GEM design and characteristics

- Thin ceramic mounting grid
- Anode divided into 4 sectors
- No division on cathode side
- Triple GEM stack (→ stable operation at high gain and flexibility)
- Pad size 1.26 x 5.85 mm^2 (~5k pads per module)

Outline

ILD & Large Prototype TPC

> Test beam measurements

Ongoing optimisation studies

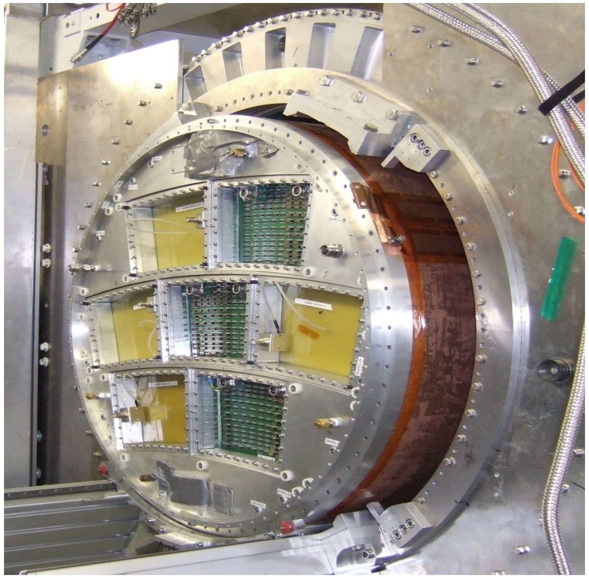
External Silicon tracker

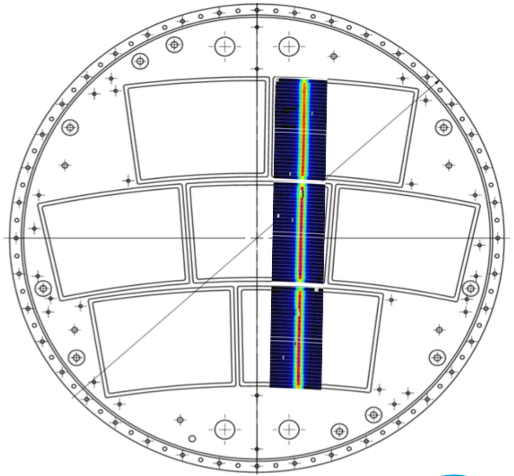
Test beam setup

- DESY GEM module test beam campaign 2013

- Experimental setup
  - 3 GEM modules, partly equipped with readout electronics (~7k channels)
  - Default drift field 240 V/cm (maximum drift velocity) or 130 V/cm (minimal diffusion)

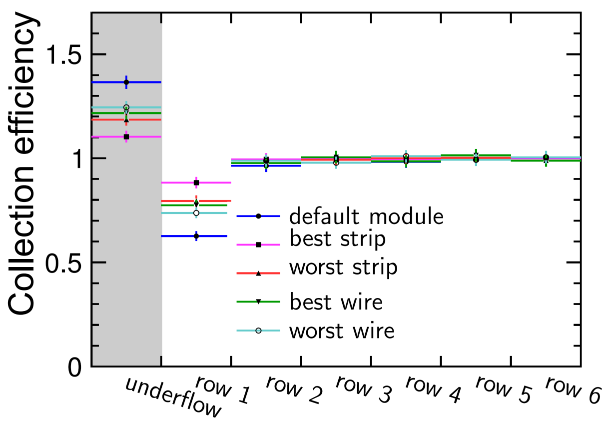
- Aim
  - Validation of module design and performance understanding
  - Test of field shaping wires

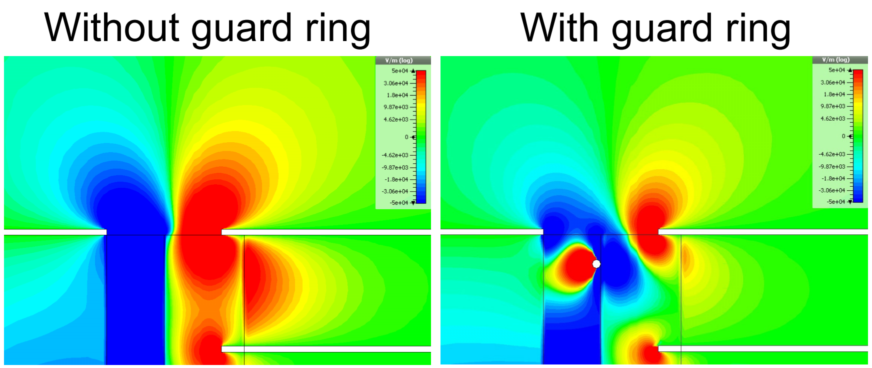




Field Distortions

- Inhomogeneities in the electric field can result in loss of signal and have an impact on the resolution
- Electric field distortions more pronounced at module edges
  - Guard ring introduced to minimise local field distortions at module borders

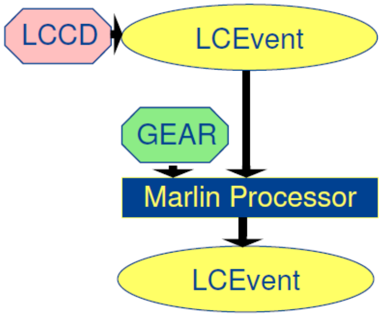


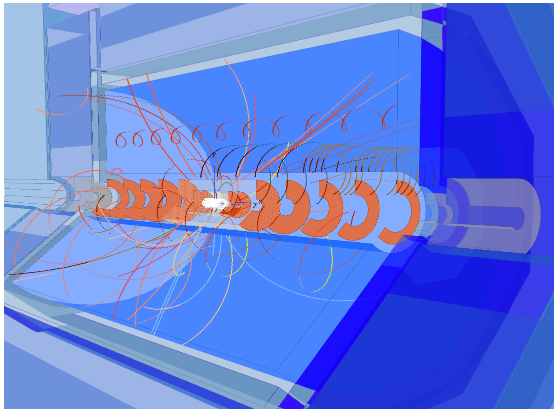


- Loss of signal close to module edge partially recovered when introducing a guard ring

LCTPC Software Overview

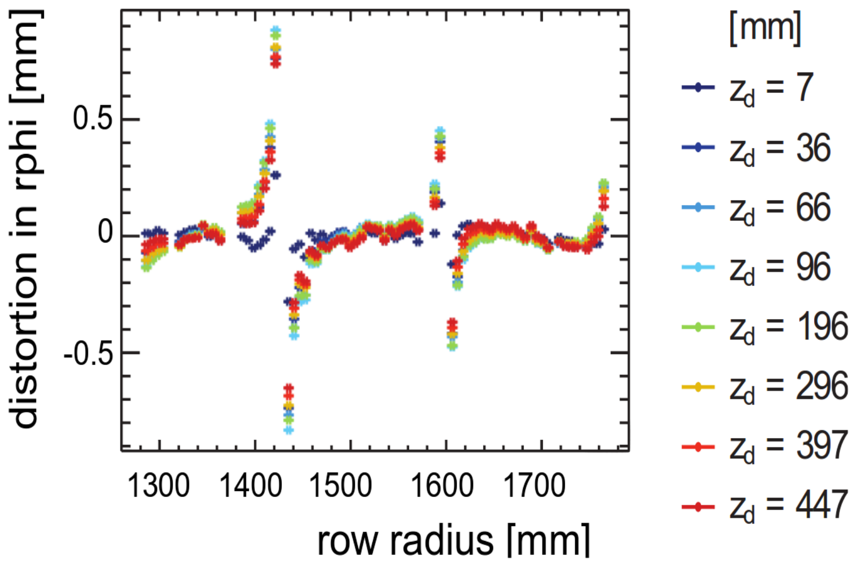
- MarlinTPC framework used → ILC software
- Common reconstruction chain for the LCTPC collaboration
- Data stored on grid and available to whole collaboration
- Ongoing effort on simulation
- General Broken Lines (GBL) used for track fitting
- Millipede II used for alignment procedure

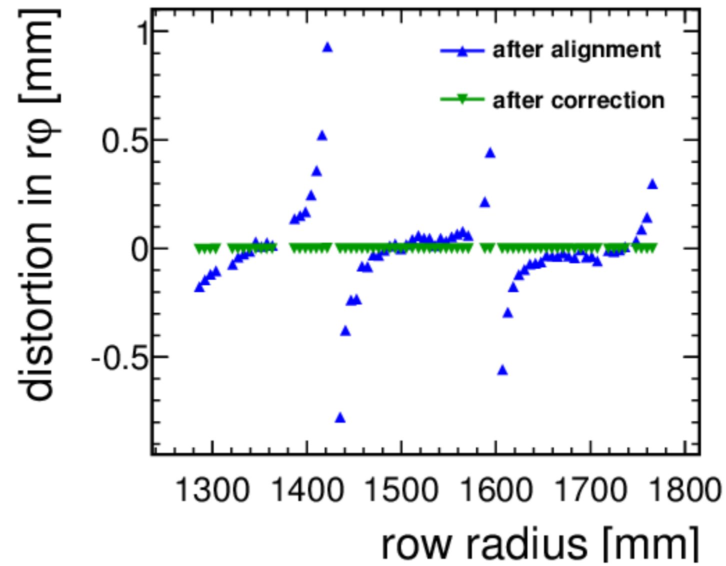




tT event

Alignment & Distortions Corrections





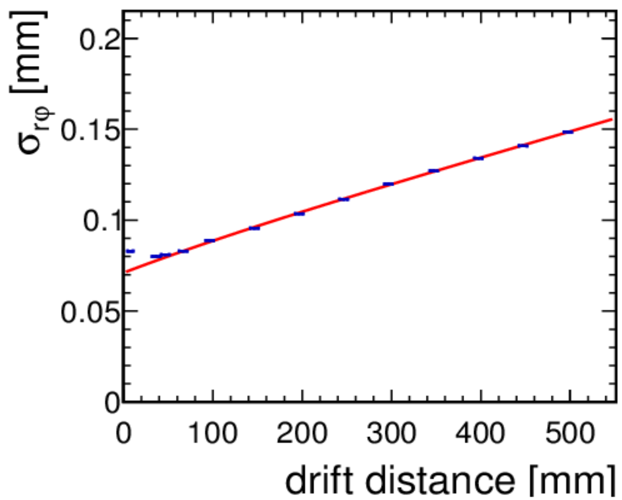
- Displacement and rotation of GEM module
- Use B=0 T data where ExB effects not present
- Corrections up to 0.1 mm and a few mrad

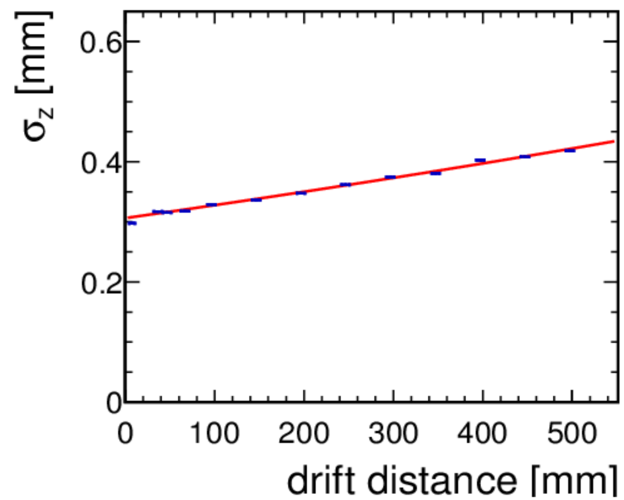
- Field distortion caused by inhomogeneities in magnetic and drift fields
  - ExB terms pronounced at module edges
- Distortions derived from 10% of events and applied to the rest

Resolution

> Single point resolution

$$\sigma_{r\varphi/z}(z) = \sqrt{\sigma^2_{0_{r\phi,z}} + \frac{D^2_{t/l}}{N_{\text{eff}} \cdot e^{-Az}} z}$$



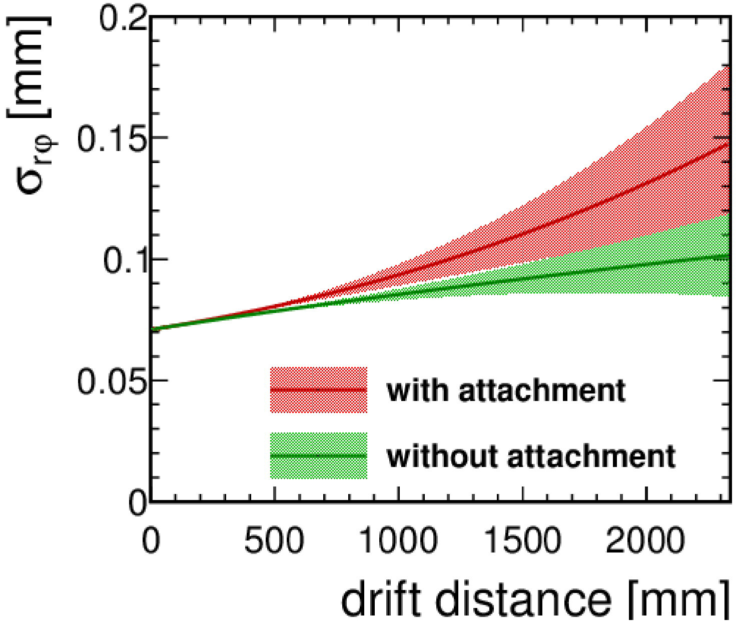


σ	$\sigma_{0_{r\phi,z}}$[µm]	N_{eff}	$A[\text{m}^{-1}]$	$D_{l/t}[\text{mm}/\sqrt{\text{cm}}]$ (fixed)
$r\varphi$	71.0 ± 1.2	39.8 ± 2.0	0.495 ± 0.097	0.103
z	306.3 ± 0.8	39.5 ± 1.6	0.529 ± 0.084	0.226

> The ILD TPC requirement of rφ resolution <100 µm for full drift distance at 4T corresponds to an rφ resolution <150 µm for the large prototype TPC at 1T

> z resolution ~300 µm at zero drift distance (ILD TPC requirement)

Resolution – Extrapolation to ILD scale

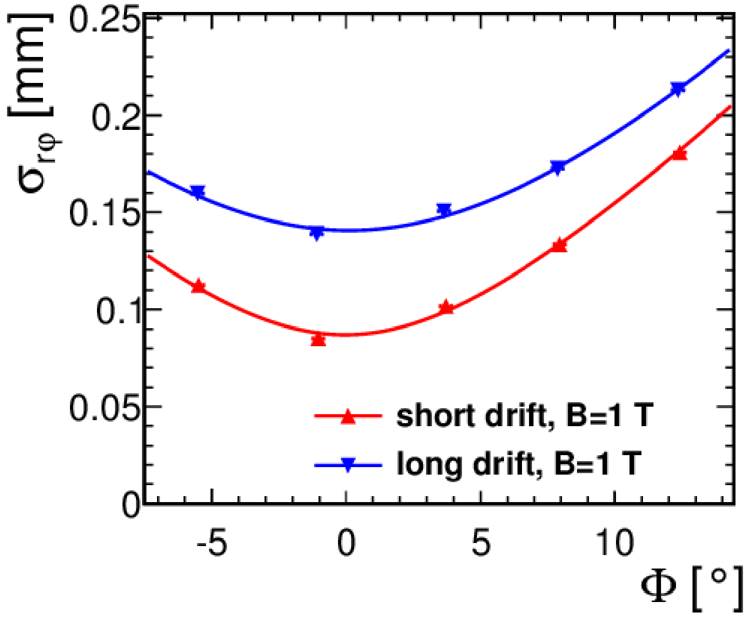


- Extrapolation of the rφ resolution from the Large Prototype conditions to the ILD planned detector
  - 3.5 T magnetic field and 2.35 m drift length
- Gas quality and impurities need to be under control at ILD

Resolution – Φ dependence

- For inclined tracks, a dependence of the resolution on the azimuthal angle Φ is expected

$$\sigma_{r\varphi}(\Phi) = \sqrt{\sigma^2_{0_{r\phi}}(z) + \frac{L^2}{12\hat{N}_{\rm eff}}\tan^2(\Phi)}$$



- Tracks for short (10 cm) and long (40 cm) drift distances are shown

- tan(Φ) behaviour as expected

Outline

ILD & Large Prototype TPC

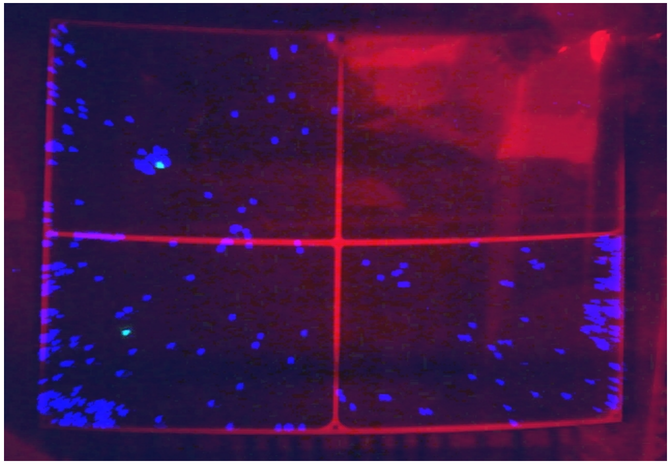
Test beam measurements

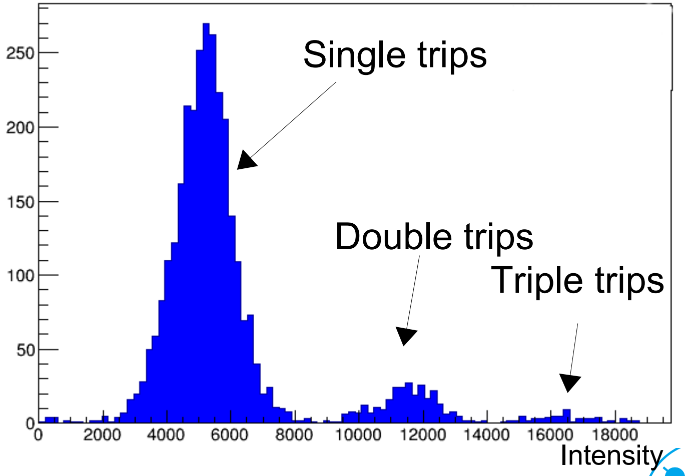
> Ongoing optimisation studies

External Silicon tracker

GEM stability

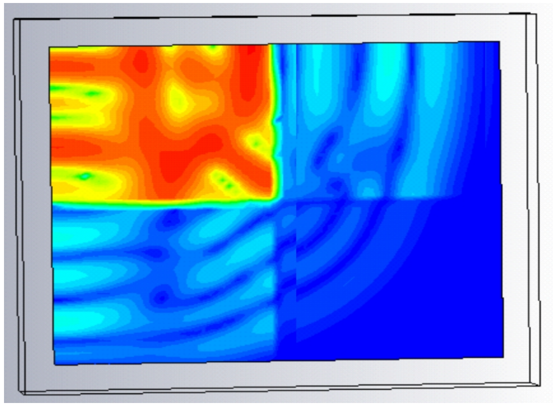
- Following the 2013 test beam campaign, a case of broken sector was observed
- Need to investigate and improve long-term stability
- Ongoing studies to understand discharges and why some are destructive
  - Optical and electrical observations of sparks of single GEMs in module-like setup
  - Simulations of the system to understand the behaviour
- Double and triple trips have been observed





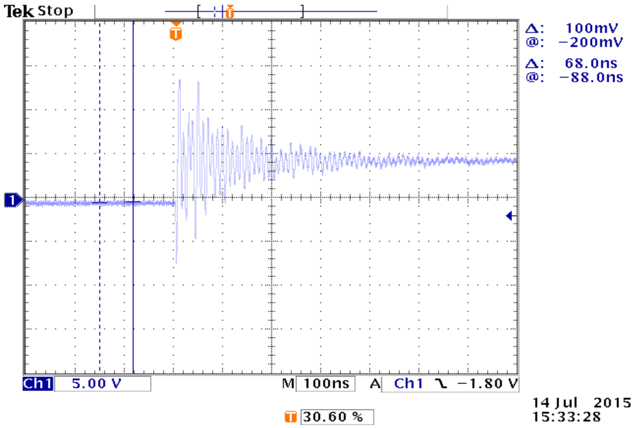
GEM stability (2)

- Discharge causes current oscillations on GEM surface in different sectors
  - CST® simulations

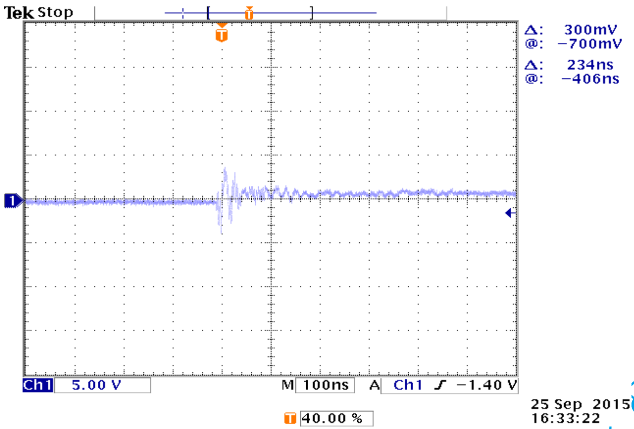


- Test setup using an R-C circuit to drain the oscillations and reduce the number of double discharges
  - Further ongoing studies to decide whether this will be included in the next module iteration

Tripping sector without RC circuit

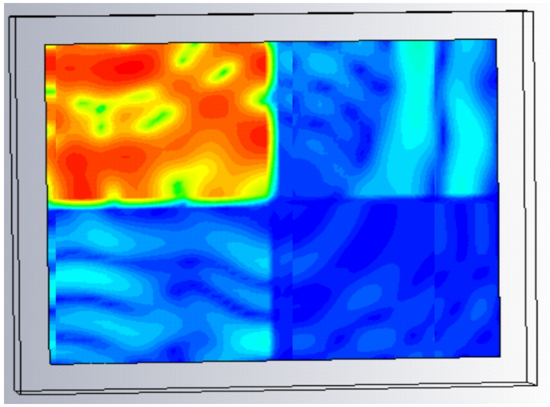


Tripping sector with RC circuit



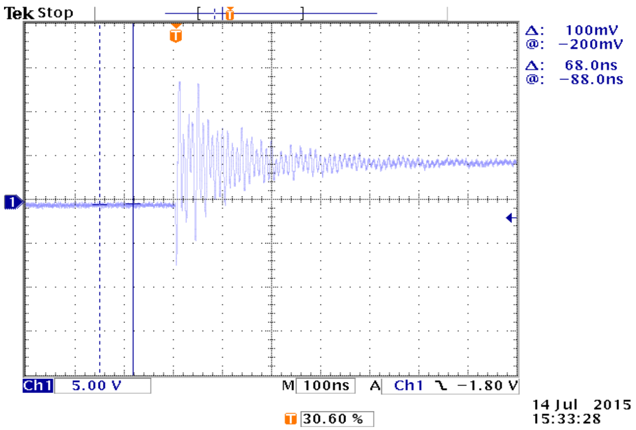
GEM stability (2)

- Discharge causes current oscillations on GEM surface in different sectors
  - CST® simulations

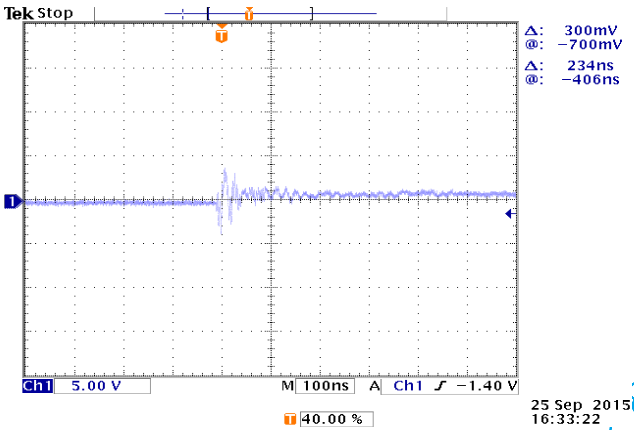


- Test setup using an R-C circuit to drain the oscillations and reduce the number of double discharges
  - Further ongoing studies to decide whether this will be included in the next module iteration

Tripping sector without RC circuit



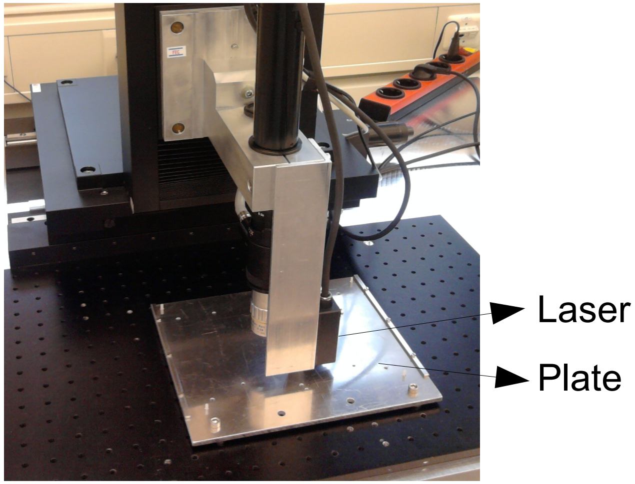
Tripping sector with RC circuit



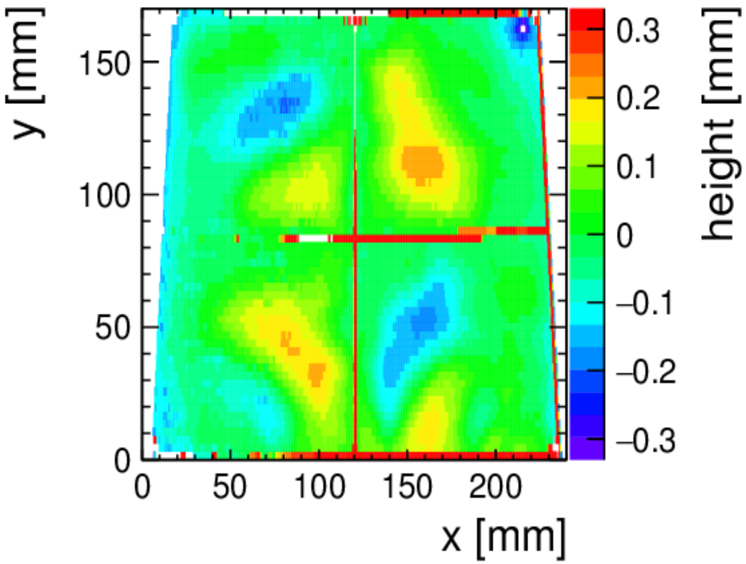
GEM flatness

- Flatness of GEMs guarantees
  - a uniform gain distribution → precise dE/dx measurements
  - electric field homogeneity

- Measurements performed on XYZ table using a laser measurement head
  - GEM mounted on a precise plate

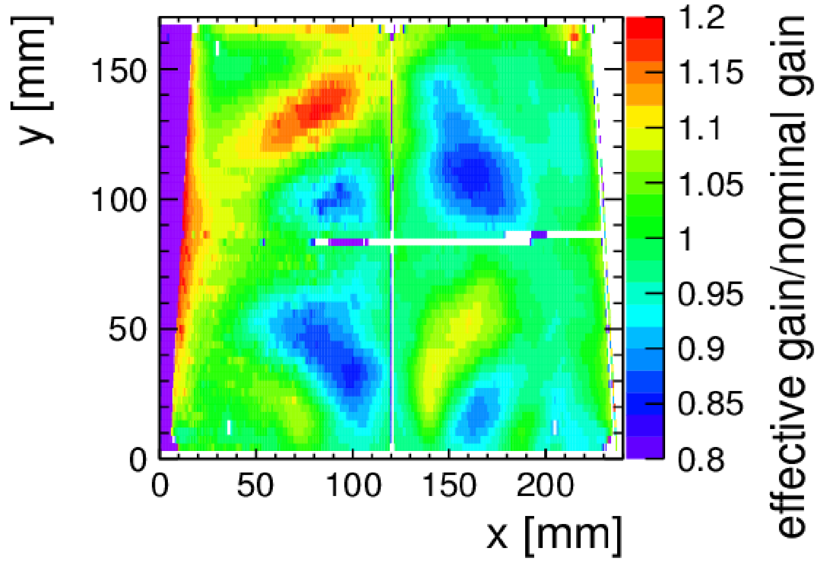


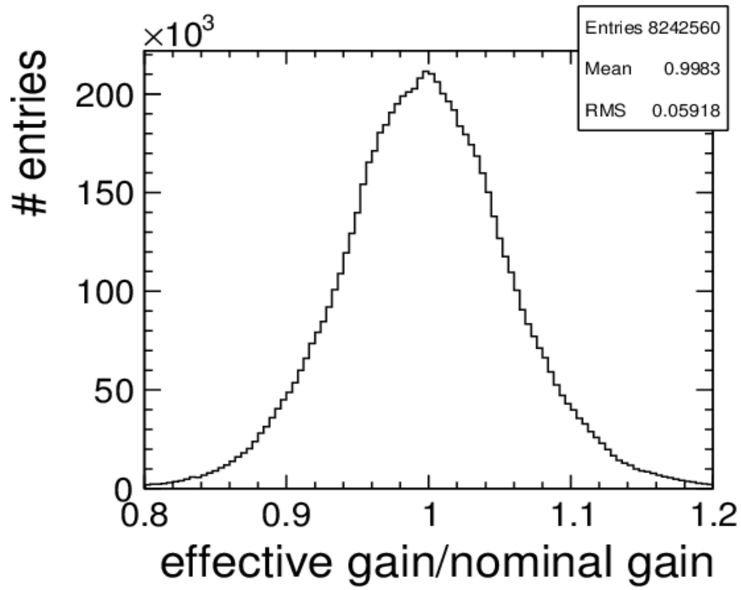
- Flatness of GEMs at the level of 150 μm (rms)



GEM flatness (2)

- 3 GEM profiles used to simulate an operating GEM module
- RMS of effective/nominal gain ~6%





- Considering new ceramic frame design
- Developing optimised tools and procedures & reproducible mounting process

Outline

ILD & Large Prototype TPC

Test beam measurements

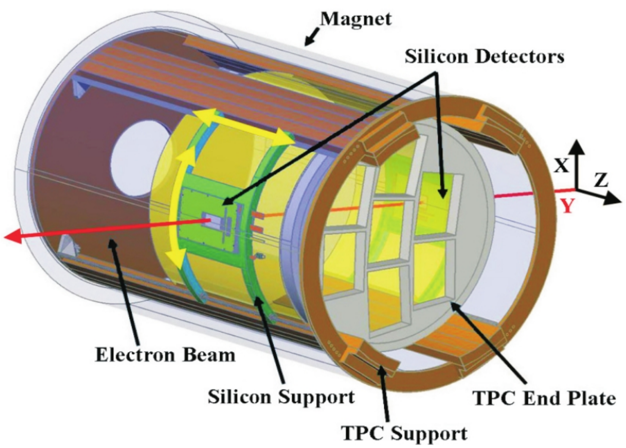
Ongoing optimisation studies

> External Silicon tracker

Silicon telescope

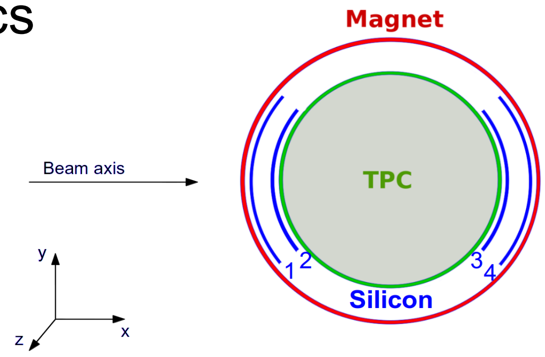
- Ongoing effort to build an external Silicon tracker to provide reference tracks for the TPC
  - Motivation: ability to correct for field distortions and measure the momentum resolution during combined test beams with the TPC system

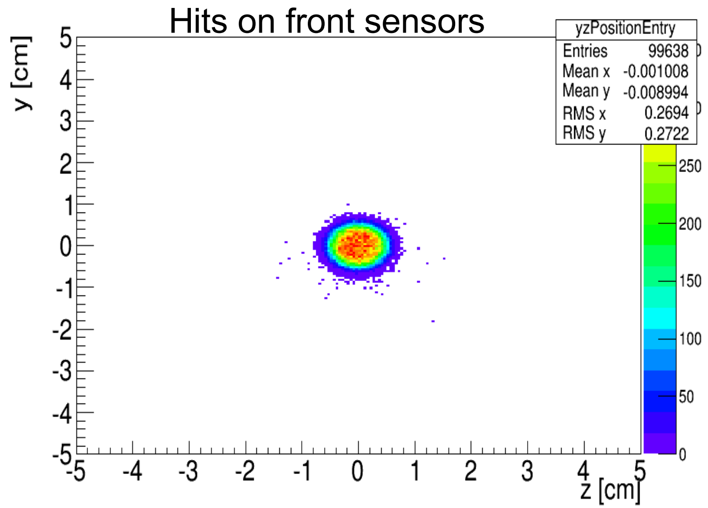
- Si tracker needs to fit in the existing TPC infrastructure
  - 3.5 cm available space between magnet and TPC field cage
- Si tracker needs to provide excellent momentum resolution
  - Better than the TPC simulated momentum resolution in order to be used as a reference

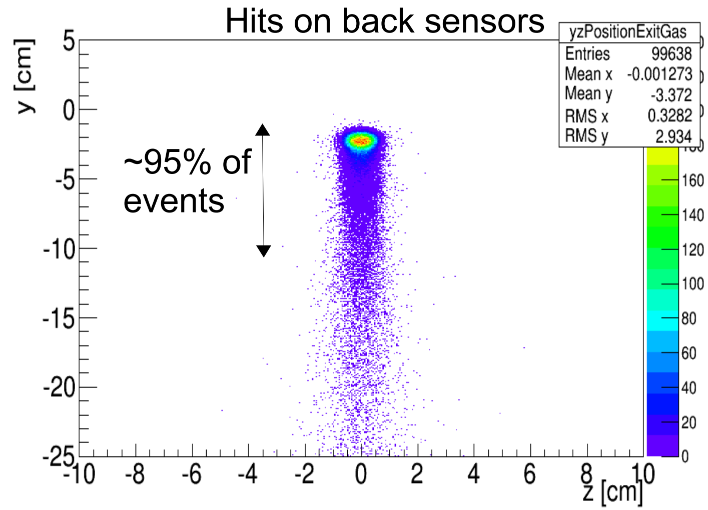


Silicon telescope – Requirements

- Simulation studies to decide on sensor characteristics
  - Spatial resolution, number of Si layers, material budget, system geometry, coverage area
- Results driven by limited available space
  - Sensors with spatial resolution of 10 μm or better are needed
- Coverage area of the system (simulation)
  - Minimum area 2x2 cm^2 for the front and 4x10 cm^2 for the back sensors







Conclusion (1)

- Successful previous test beam campaign
  - Showing excellent performance of the LPTPC and GEM modules
  - Understanding of the system
  - Extrapolation shows we can achieve the resolution requirements of the ILD TPC

- Ongoing optimisation process for Large Prototype TPC and GEMs
  - New field cage built to improve field homogeneity
  - Stability of GEMs : Fatal discharges observed
    - Possible solution: Addition of RC to damp current oscillations
    - Looking into Chromium GEMs
  - Investigating optimised ceramic frame design and mounting procedure to improve flatness of GEMs

- These topics are under investigation in order to be included in the next FLC TPC test beam campaign at DESY (Spring 2016)

Conclusion (2)

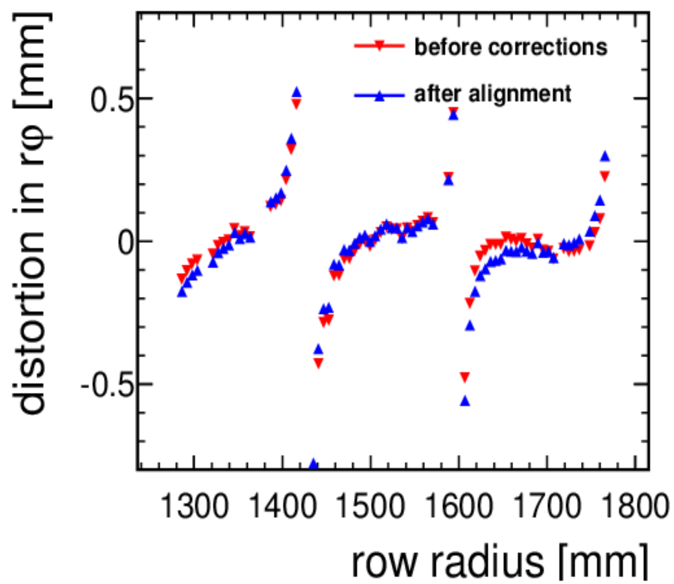
- Silicon tracker to accompany the Large Prototype TPC

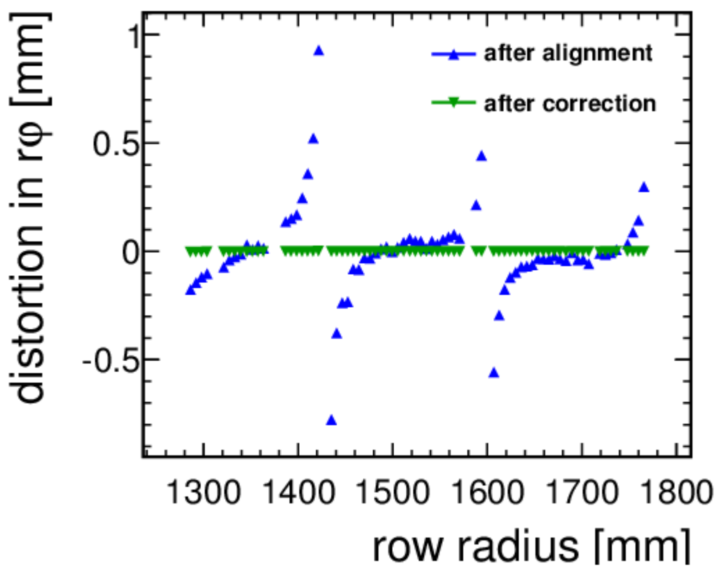
- Simulation studies in order to define the characteristics of the system
  - 4 Silicon layers
  - Sensors with 10 μm or better spatial resolution
  - Mimimum coverage area

- Ongoing effort
  - Identify and obtain hardware (sensors, ASIC, DAQ)
  - Design of the support structure

BackUp

Alignment and Distortions





- Displacement and rotation of GEM module
- Use B=0 T data where ExB effects not present
- Corrections of 0.1 mm and a few mrad

- Distortions derived from 10% of events and applied to the rest