TPC Overview

Studies and Current Status

Dimitra Tsionou
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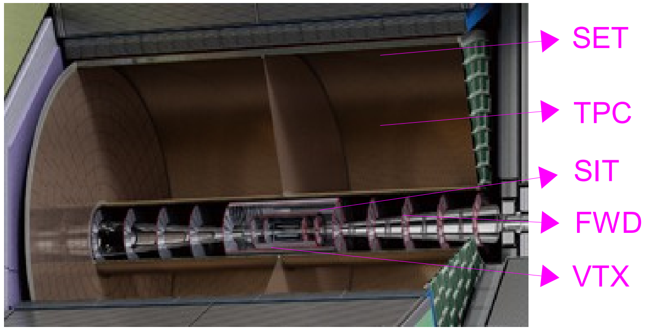
HELMHOLTZ
ASSOCIATION

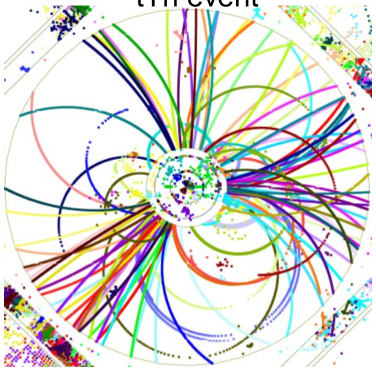
DESY

International Large Detector – Tracking Requirements

> The International Large Detector (ILD) is one detector concept for the International Linear Collider (ILC)



tTh event



> Momentum resolution:

- $\sigma(\Delta p_T/p_T^2) = 2{\cdot}10^{-5}$ 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 at zero drift and 1.4mm at full drift
- 5% X_0 for barrel & 25% X_0 for endcaps (including field cage and readout)

Large Prototype TPC and Current Infrastructure

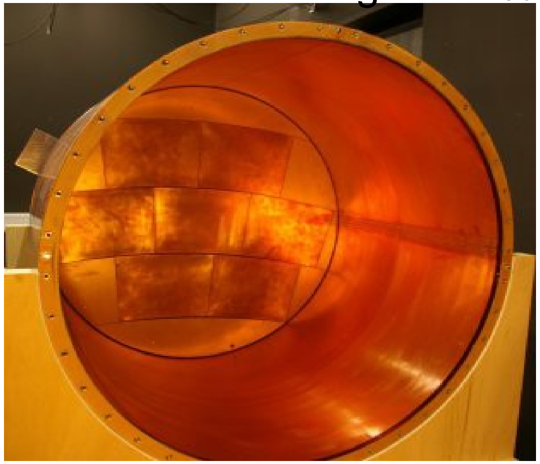
- Test beam area T24/1 at DESY (1-6 GeV e^- beams)

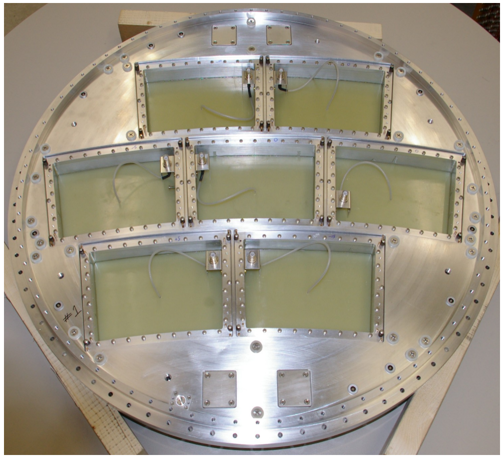
- Large Prototype TPC built and installed

- Infrastructure includes a large bore 1T magnet
  - 25% X_0 material budget

- LP field cage parameters:
  - Length: 61 cm, Diameter: 72 cm
  - Up tp 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)



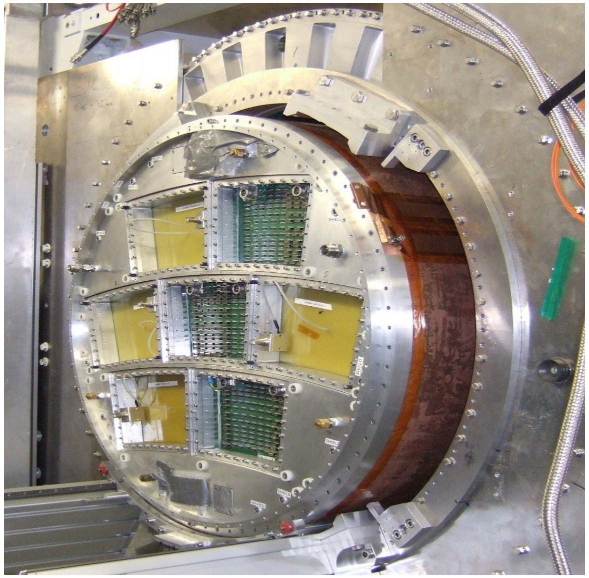


Large Prototype & Test Beams

> During the last two years, all different technologies have had test beams at DESY

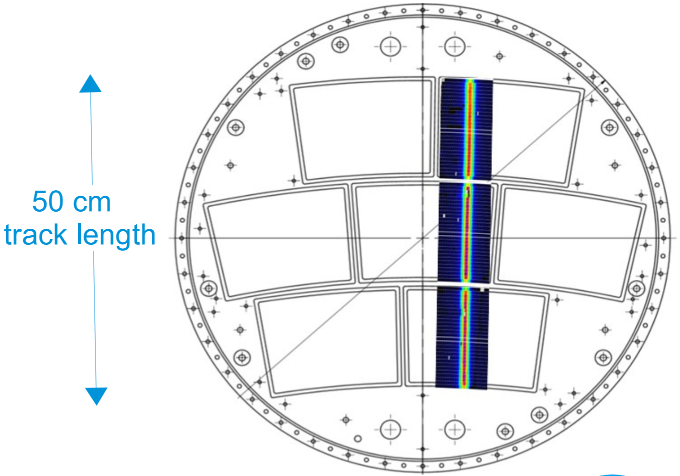
> Experimental setup

- 1-7 readout modules equipped with readout electronics
- Default drift field 240 V/cm (maximum drift velocity) or 130 V/cm (minimal diffusion)
- T2K gas mixture: 95% Ar, 3% CF_4, 2% iC_4H_{10}



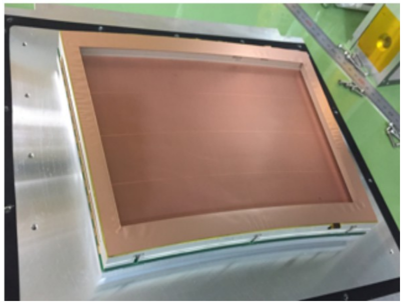
> Aim

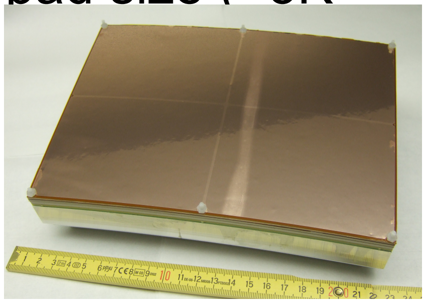
- Validation of module design and performance understanding



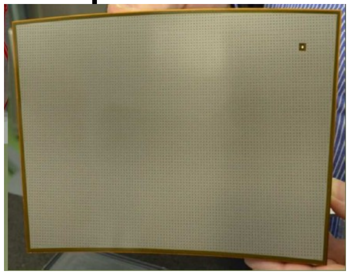
LP Modules

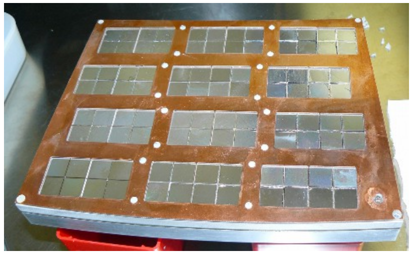
- GEM modules
- Asian: 2 GEM stack, no side support, ~1x6 mm^2 pad size
- DESY: 3 GEM stack, ceramic frame support, ~1x6 mm^2 pad size (~5K channels per module)
- They both use ALTRO electronics





- Micromegas
- ~3x7 mm^2 pad size (~2K channels per module) → resistive foil used for charge spreading
- AFTER electronics (compact)



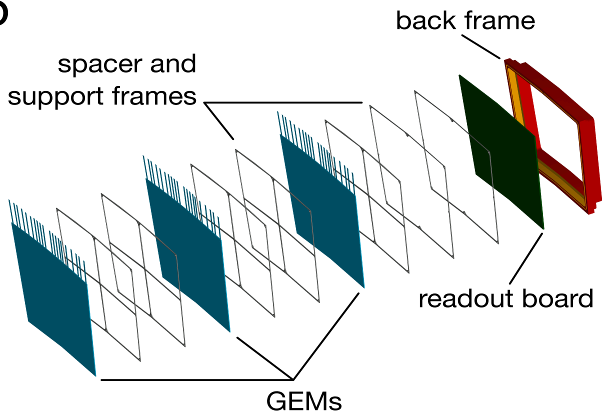


- GridPix (Micromegas+Timepix)
- Pixel TPC. 96 Timepix chips per module. SRS readout system (RD51)

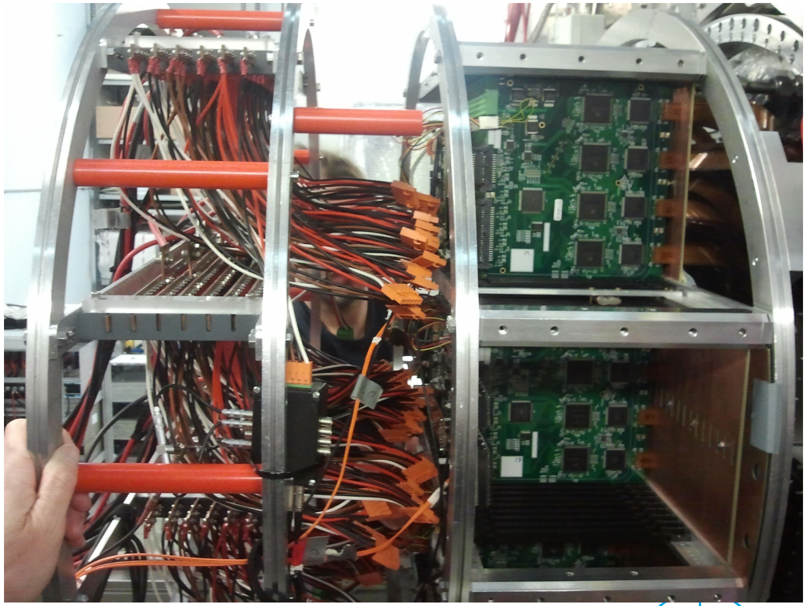
DESY

GEM

- Asian and DESY module testbeams end of 2016
- Preliminary analysis compatible with previous results
  - Stability of modules
- First tests of gating GEM
- First test with minimum ion backflow settings

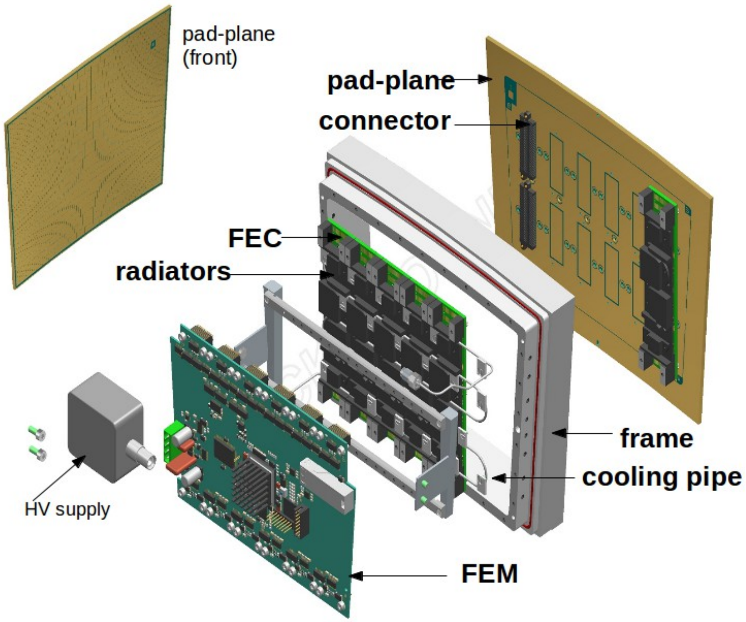


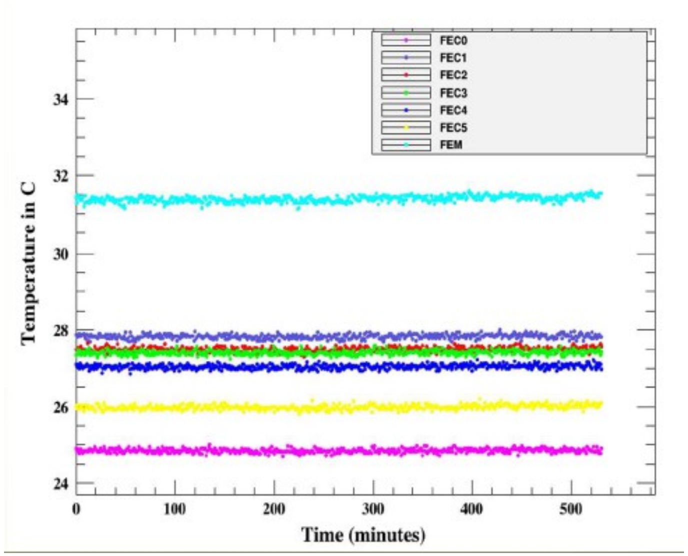
- S-ALTRO developments
- Higher sampling frequency (40MHz from 20MHz currently)
- Higher integration
- Partial power pulsing

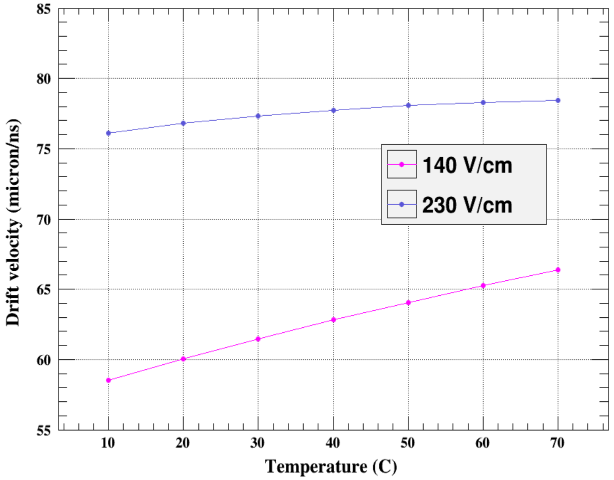


Micromegas

- Compact and integrated electronics
- 2-phase CO_2 cooling
- Last test beam used modules with either carbon loaded kapton or diamond-like carbon as resistive layer

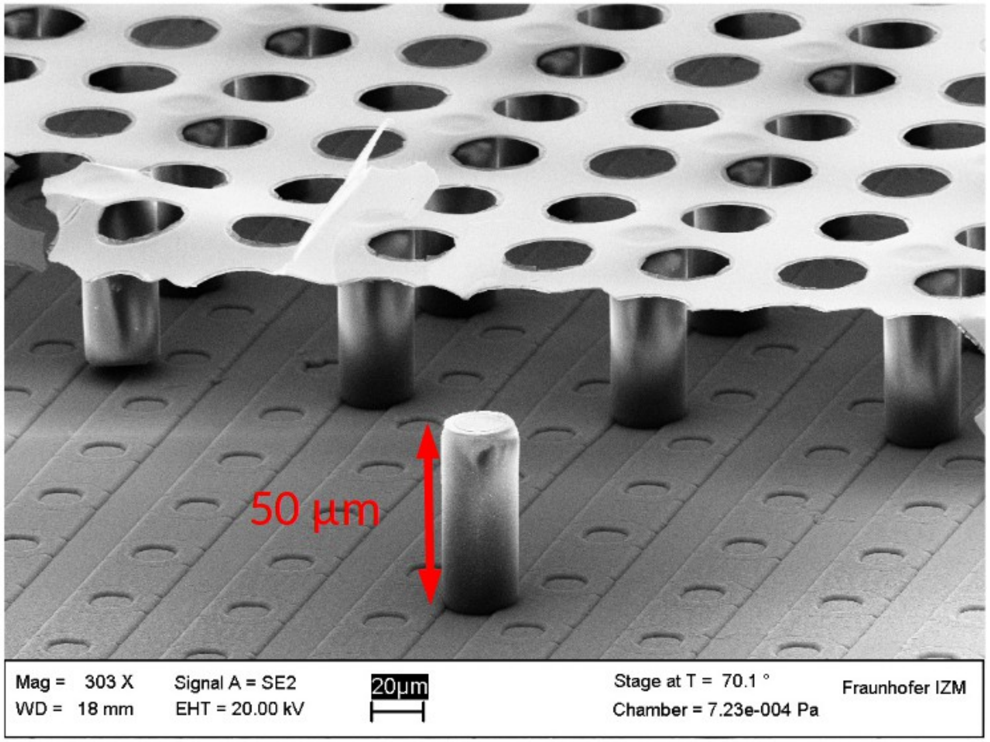






GridPix

- Micromegas with pixel readout (Timepix)
- Using smaller pads to improve resolution
- Demonstrated using 96 timepix chips per module
- Timepix pixel size: 55x55 μm^2, ~65K channels
- Integrated readout electronics. ~7M channels per module



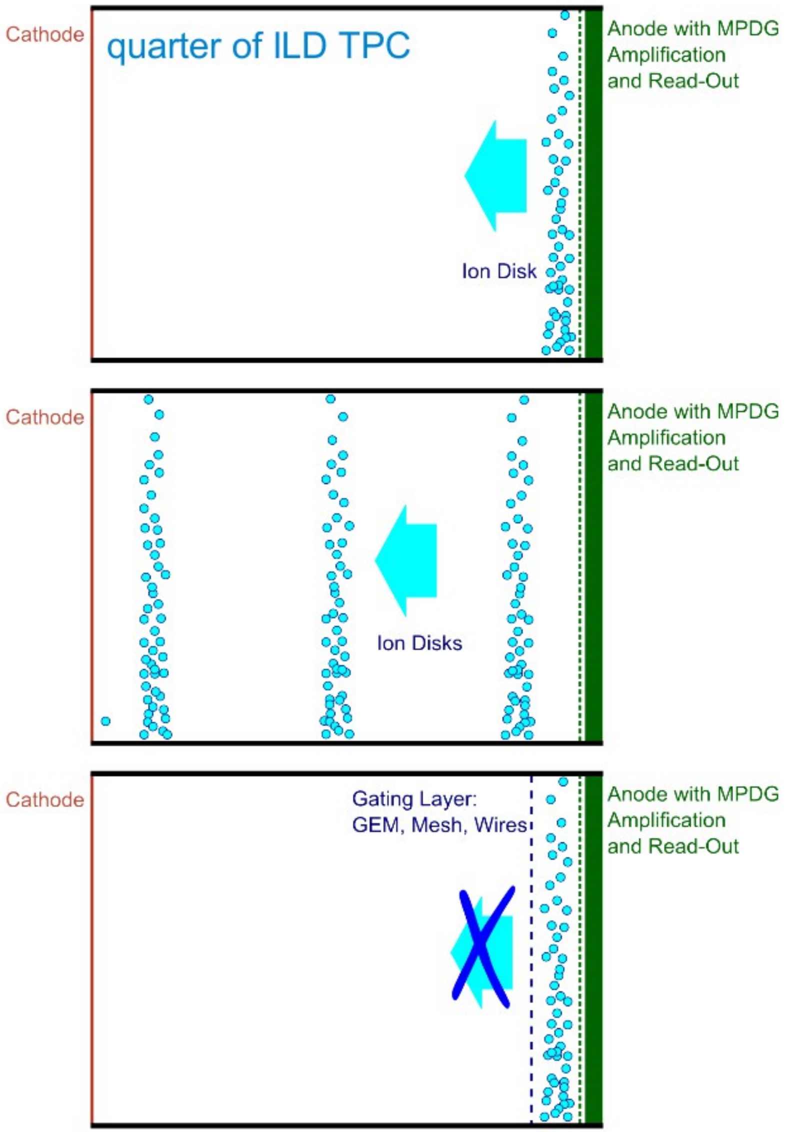
Bump bond pads used as charge collection pads

Gating

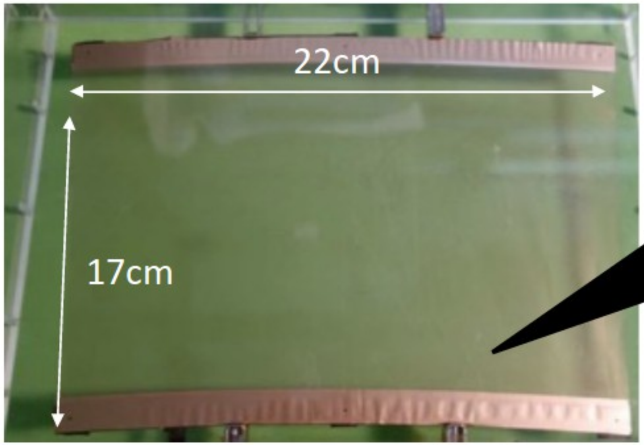
- From the gas amplification, ion disks are formed and drift in the TPC volume (low drift velocity). These ion disks can cause field distortions and impact the resolution
  - 3 ion disks can form in the TPC volume corresponding to 3 bunch trains (5Hz running)

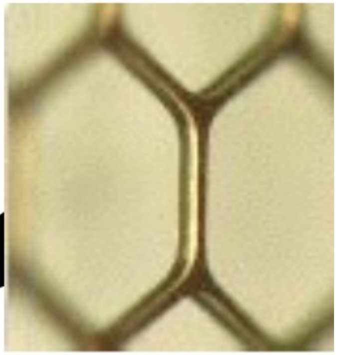
- MPGDs have an inherent ability of ion absorption but it's not perfect. Therefore, there is a need of a dedicated device to prevent amplification ions from drifting back in the TPC sensitive volume

- First test beam with ion gating GEM in Nov 2016

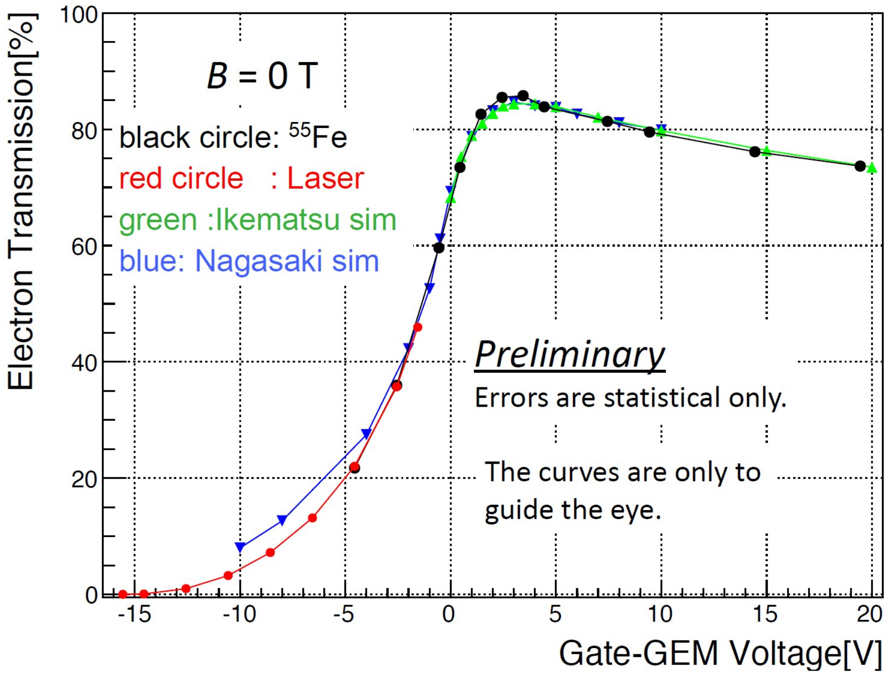


Test beam with gating



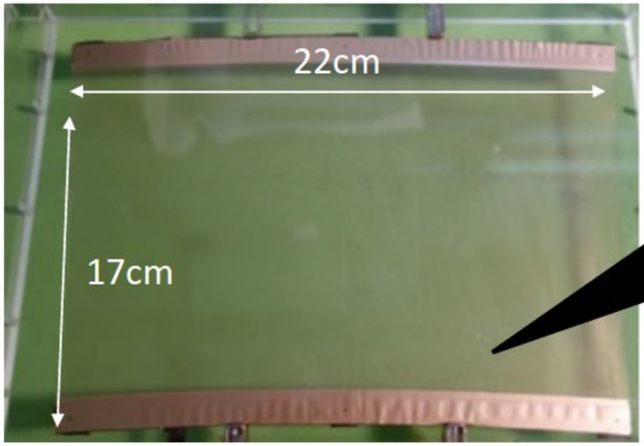


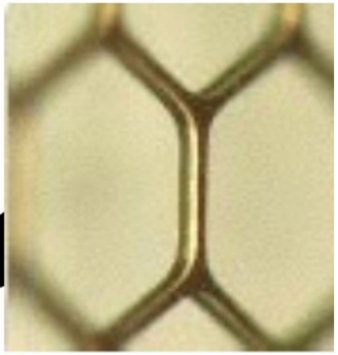
- Gating GEM provides high transparency for drift electrons (~85%) and should provide high blocking power for positive ions (10^{-4})



- Electron transmission rate measurements and simulations

Test beam with gating





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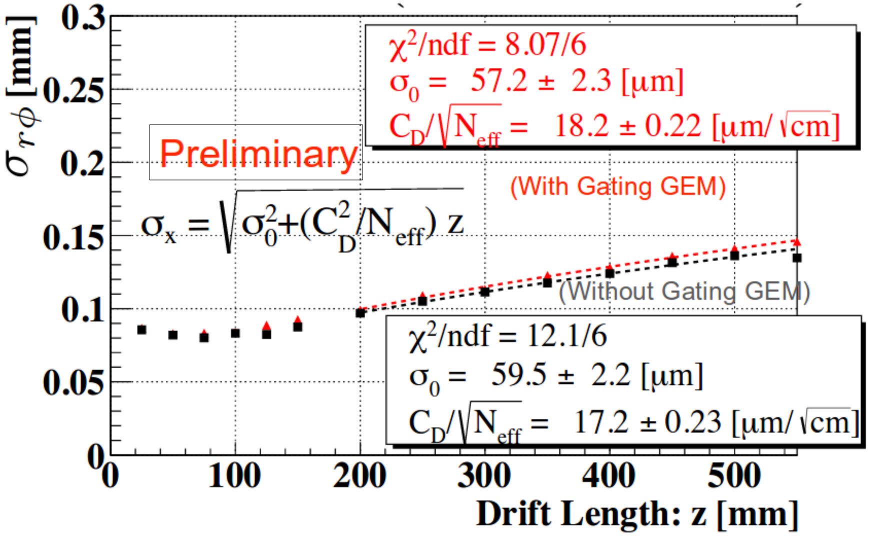
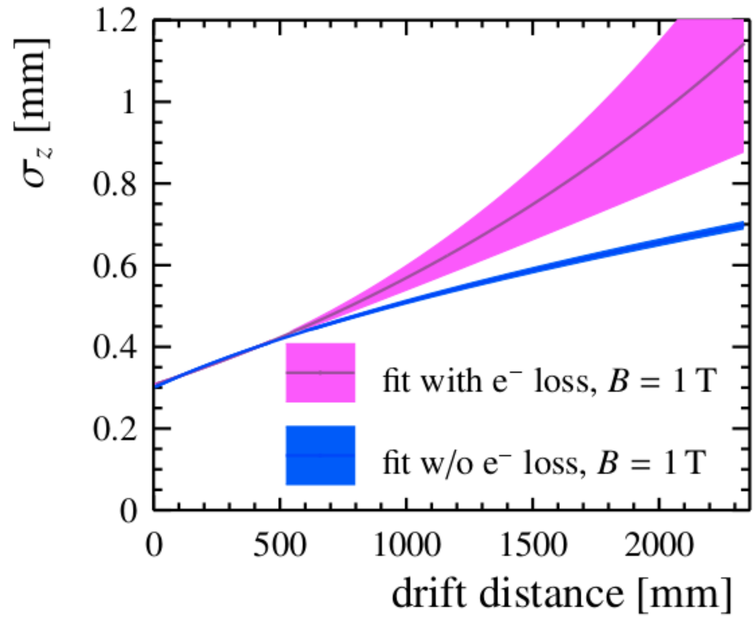
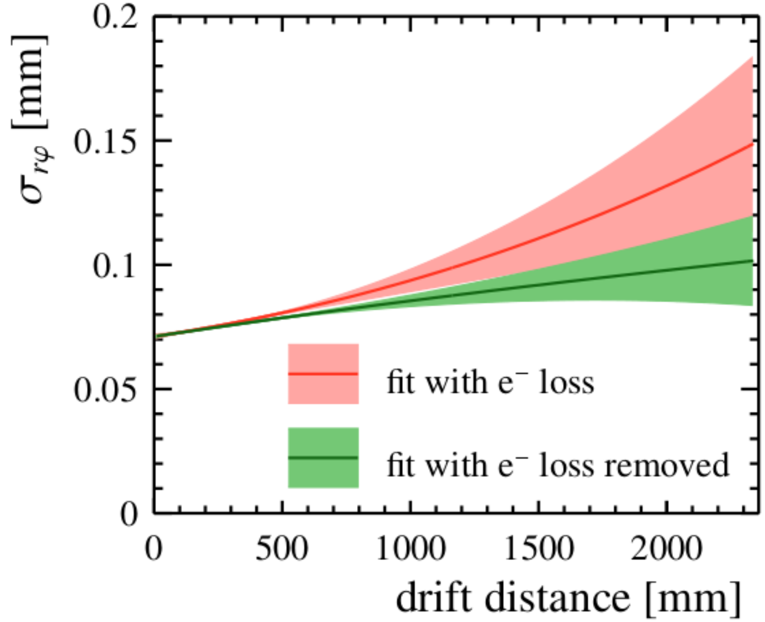


- Preliminary results
- Marginal difference between module with and without gating GEM
- Further tests with gating GEMs to come!

Extrapolation to ILD scale

- From previous test beams, the point resolution was measured and extrapolated to the ILD scale
  - Shown here from the test beam analysis of the GEM pad-based module





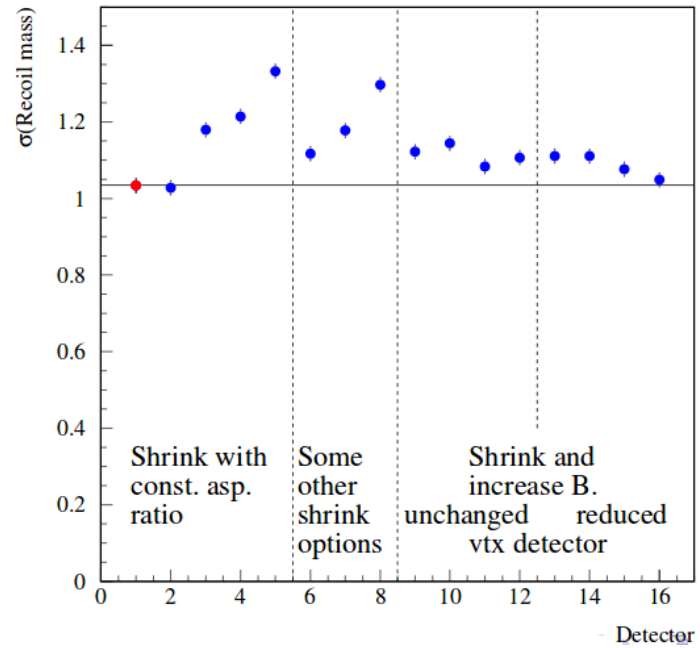
- Meets the requirement for the ILD detector σ_z<1.4mm
- The $\sigma_{r\varphi}$<100 μm resolution can be achieved if the gas quality is tightly controlled and therefore the electron attachment is insignificant

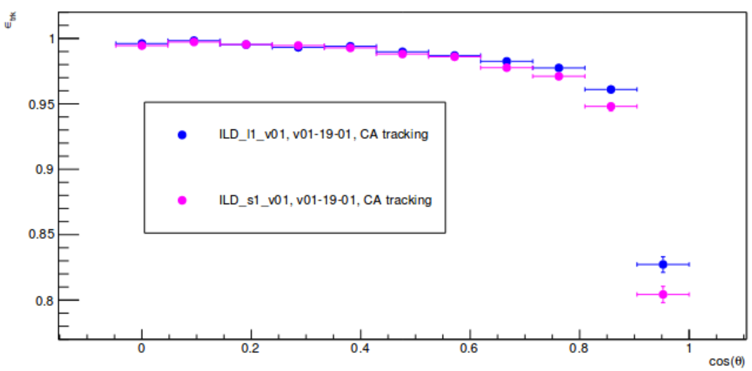
Detector model

- Different detector models studied by M. Berggren

- Currently, two models are under investigation

Detector	DBD (ILD-L)	Small ILD (ILD-S)
B-Field	3.5 T	4 T
VTX inner radius	1.6 cm	1.6 cm
TPC inner radius	33 cm	33 cm
TPC outer radius	180 cm	146 cm
TPC length (z/2)	235cm	235 cm
Inner ECAL radius	184 cm	150 cm
Outer ECAL radius	202.5 cm	168.5 cm
Inner HCAL radius	206 cm	172 cm
Outer HCAL radius	335 cm	301 cm
Coil inner radius	344 cm	310 cm



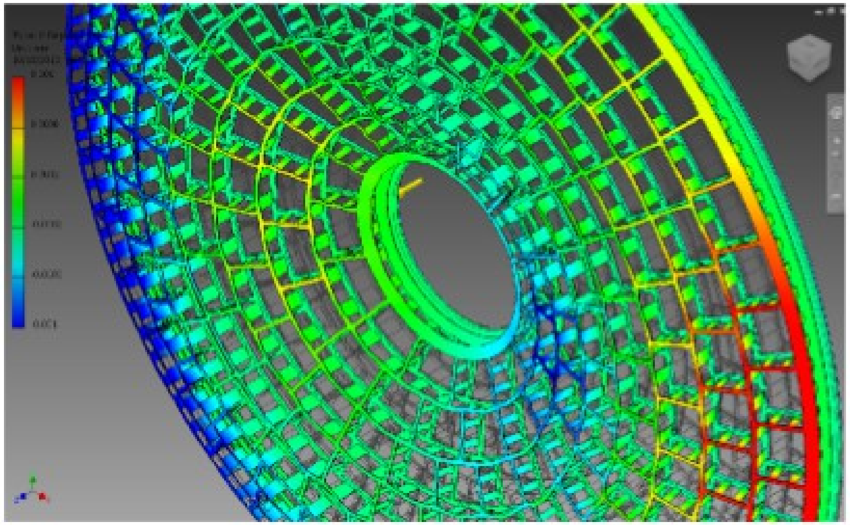


Field cage

> Current mechanical projects: new field cage, designs for gating GEM module integration, support for external silicon tracker

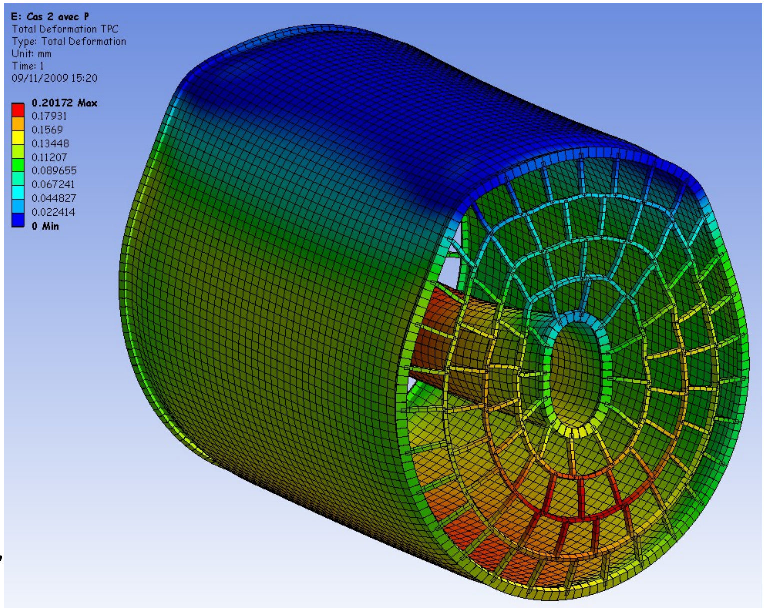
> New lightweight endplate for the LP (Cornel) to be tested

> Goal: Same stability with half material budget (ILD requirements)



> New field cage production

> Difficult to simulate mechanical deformation due to composite materials



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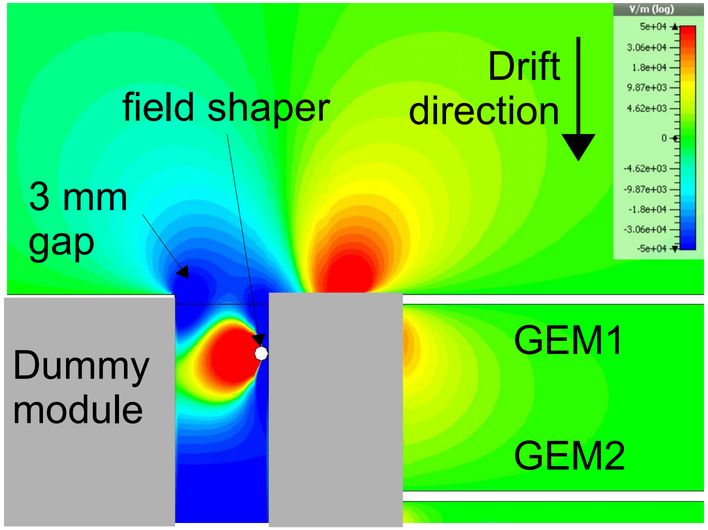
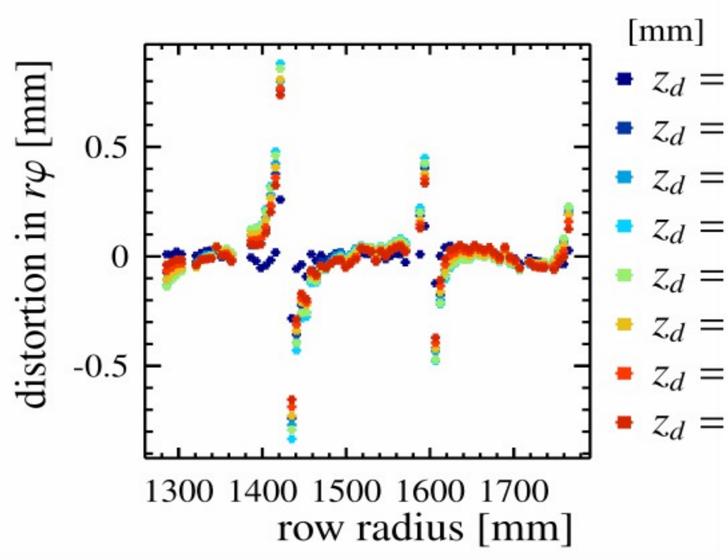
Field distortions in TPC

- Inhomogenities in Electric fields can cause distortions
- Magnetic field parallel to the electric field
  - ExB terms pronounced at module edges

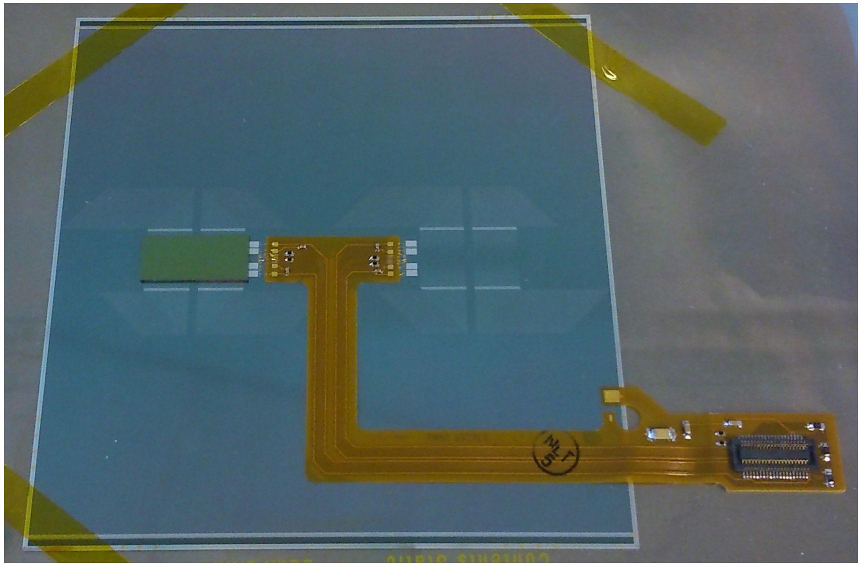


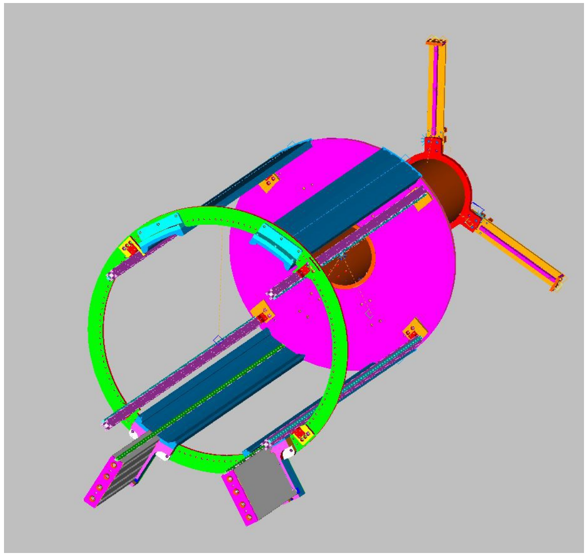
- E and B field present
- A curved fit (helix) is used for the track (distortions can be partially absorbed in the track curvature)
- Distortion effects more pronounced on module edges



External Tracker

- In order to correct for field distortions and measure the momentum resolution of the LP, we need an external reference tracker
- Sensors (Hamamatsu) to arrive to DESY this summer
- Chip already under testing
- Mechanical support discussions ongoing





Summary & Outlook

- Different technologies pursued and demonstrating they can achieve the requirements for the ILD TPC
  - GEMs, MM, GridPix
- Common analysis framework
- Highlight of the year: Test beam with ion gating GEM!

- Short term plans
- TPC detector radius effects on physics measurements
- Preparation of the new field cage
- Further tests and implementation of gating GEM on current modules
- Momentum resolution measurements with external silicon tracker

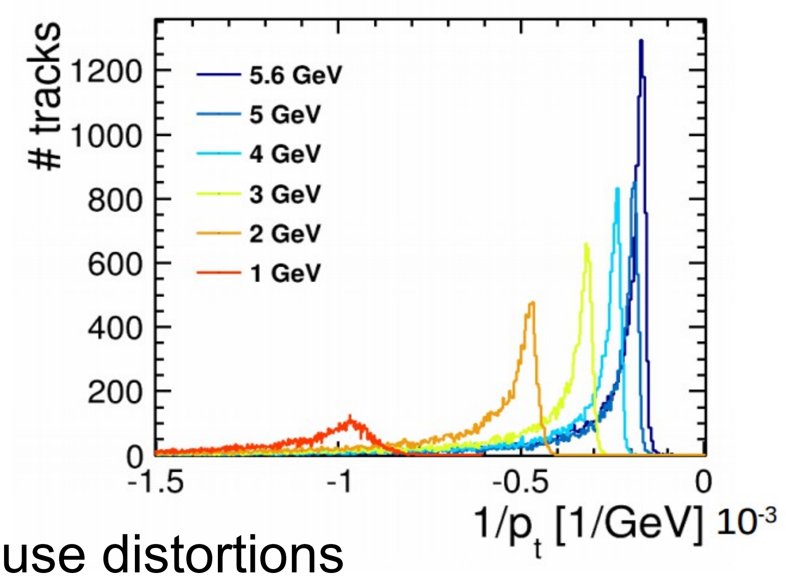
Back-Up

Mometum resolution measurement

- Determination of the momentum resolution in a tracking detector (Gluckstern formula)

$$\sigma_{p_T} = \sqrt{\frac{720}{n+4}} \frac{\sigma \cdot p_T^2}{0.3\, B\, L^2}$$

- In the Large Prototype TPC case, there is a broad energy spectra due to beam energy spread and the energy loss in the magnet



- In addition, field inhomogenities can cause distortions

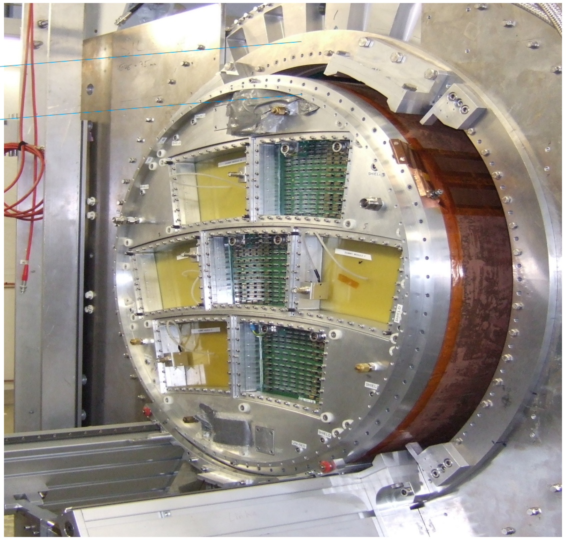
  → Hits appear to be displaced

  → This has an impact on the momentum determination

External Si tracker for Large Prototype TPC

- Solution: Build an external Si tracker (Si telescope) to provide reference tracks (entry and exit hits)

- Prototype for ILD TPC exists at DESY
- Goal: Combined test beam with LPTPC → track reference, field distortion corrections, momentum resolution measurements
- The Silicon tracker should be versatile and simple to be used as a telescope by other groups during test beams



- Challenge: The Silicon system needs to fit in the existing infrastructure (available space is ~3.5 cm)