TPC for ILC

4. Alliance Detector Workshop

March 17th 2011

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PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Momentum resolution:

$\sigma_{1/p} < 5\text{x}10^{-5}$/GeV (1/10 x LEP)

Higgs recoil mass: $e^+e^- \rightarrow ZH$ $(Z \rightarrow \mu\mu/ee) + X$

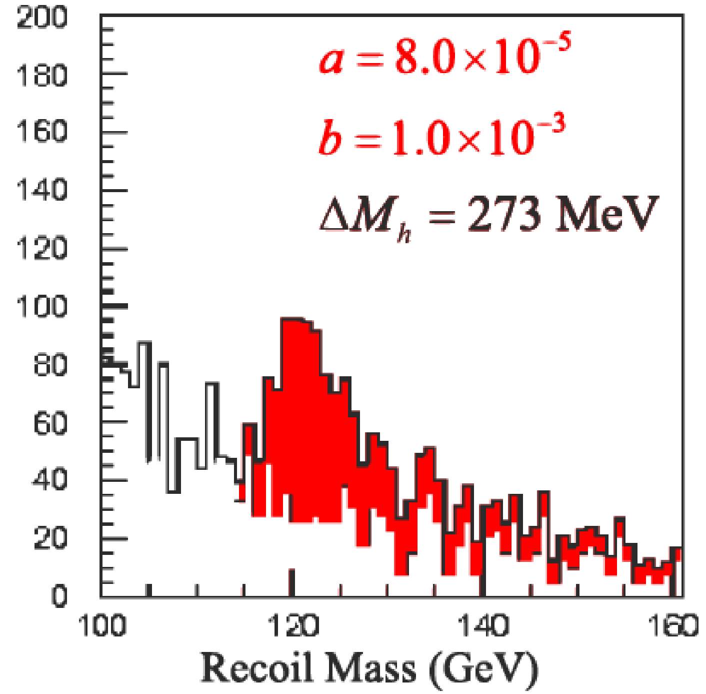
$$\frac{\delta p_T}{p_T^2} = a \oplus \frac{b}{p_T \sin(\vartheta)}$$

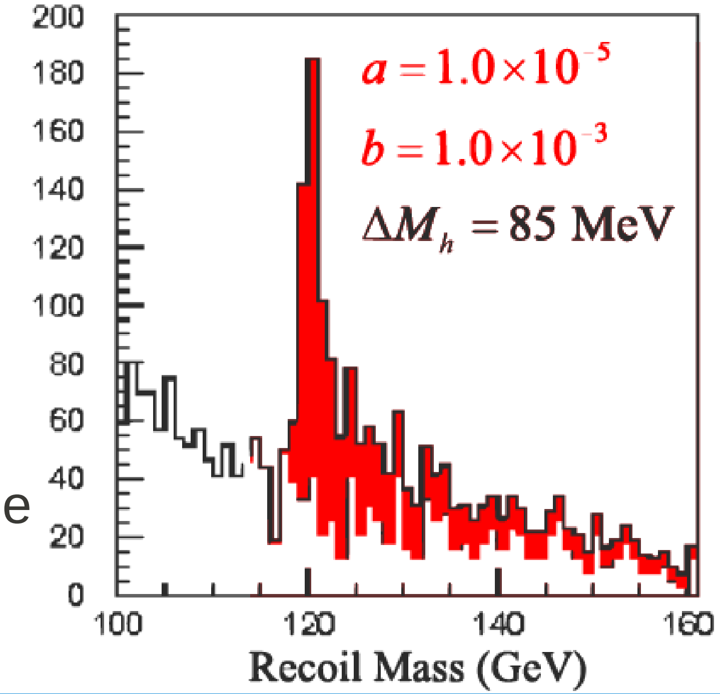
Needs to fit into Particle Flow[*] concept:

- Good track separation
- Very light weight (material budget < $0.04\ X_0$)
- Good pattern recognition

In $e^+e^- \rightarrow ZZ$, WW, hZ and HA more than half of the events contain one or more K^0_S or Λ^0

[*] Particle flow: the aim to reconstruct every particle in the best suited sub detector

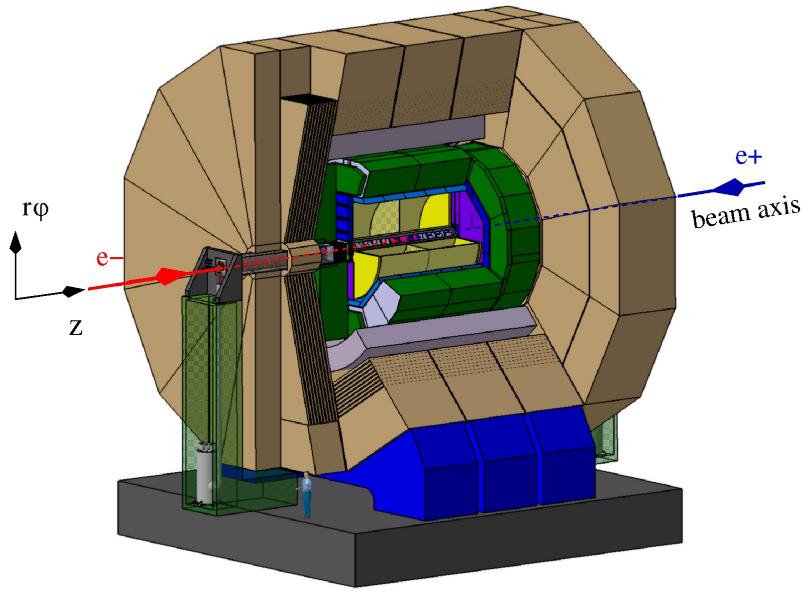




ILD: a multi purpose detector for the ILC

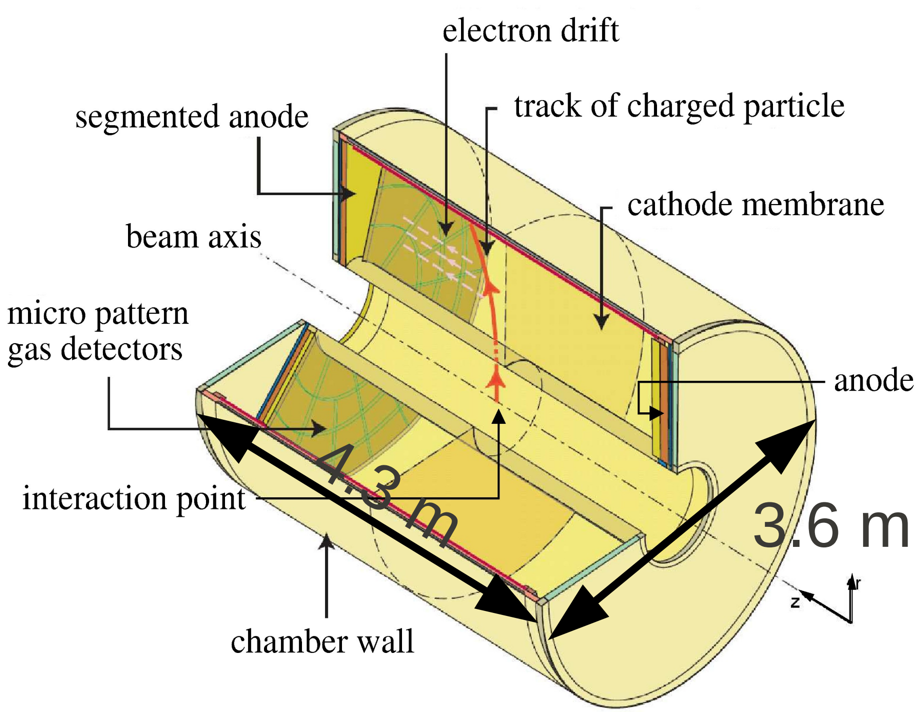
TPC as main tracker

- Robust tracking, ~ 200 space points per track:
  - Easy pattern recognition
  - Robust towards machine backgrounds
- dE/dx-measurement input to particle ID
- σ ~ 100µm (rφ) and ~ 500µm (rz) @ 3.5 T



Well suited for Particle Flow concept:

- Good track separation
- Good pattern recognition
- Very light weight



Outline/Design challenges

Field cage

Mechanical properties

Material budget

Electrical safety and field quality

Amplification structure

Technology choice: MPGD

Electrical and mechanical stability

Reliability

Readout structure

Pixel or pad based

Compactness and Integration issues

Power pulsing capabilities

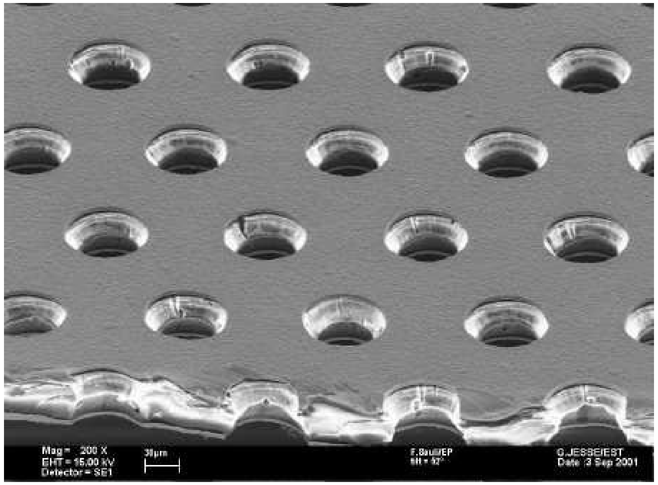
Data processing

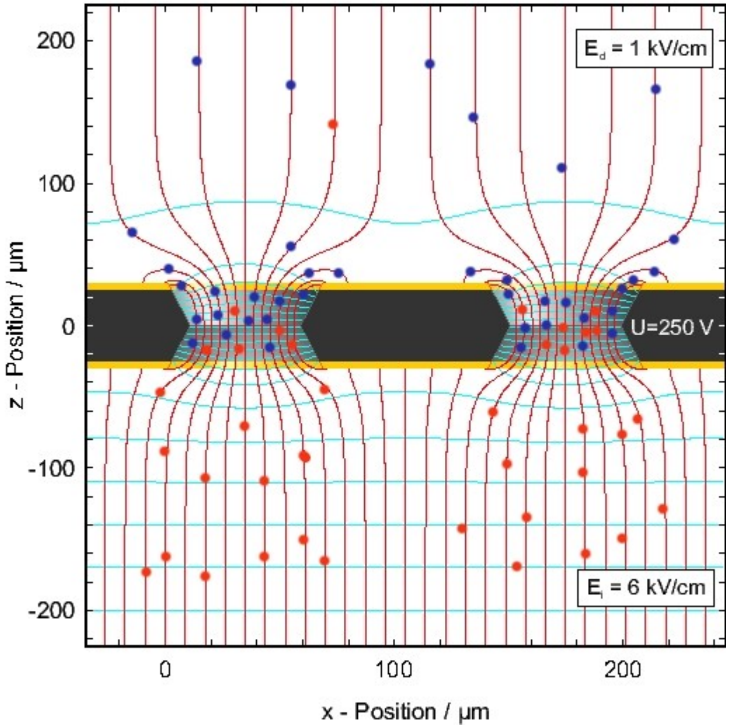
DAQ and Reconstruction

Calibration and Alignment

Micropattern Gas Detectors (MPGDs):

- Micromegas
- Gas Electron Multiplier (GEM):
  - Some 10 µm thick insulator coated on both sides with a few µm of copper
  - Highly perforated (CERN standard: 140 µm pitch, 70 µm hole diameter)
  - Voltage of several hundred volts applied between copper layers → gas amplification within the holes
  - Gain up to about 100 for a single GEM feasible
  - Higher stability (at high gain) + more flexibility with Multi-GEM-Structure
  - Intrinsic ion feedback suppression
  - Only small ExB effects





Small TPC prototypes (dia. ~30 cm)

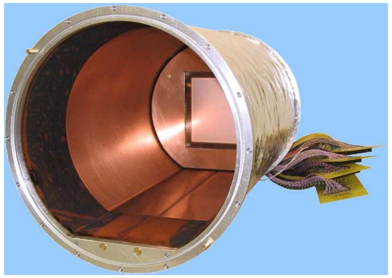
In Germany mostly GEM amplification
with pad readout studied, later also Pixel read-out

Result:

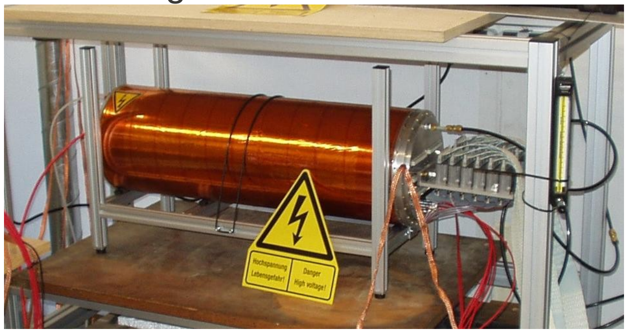
Stable TPC operation with MPGD readout possible

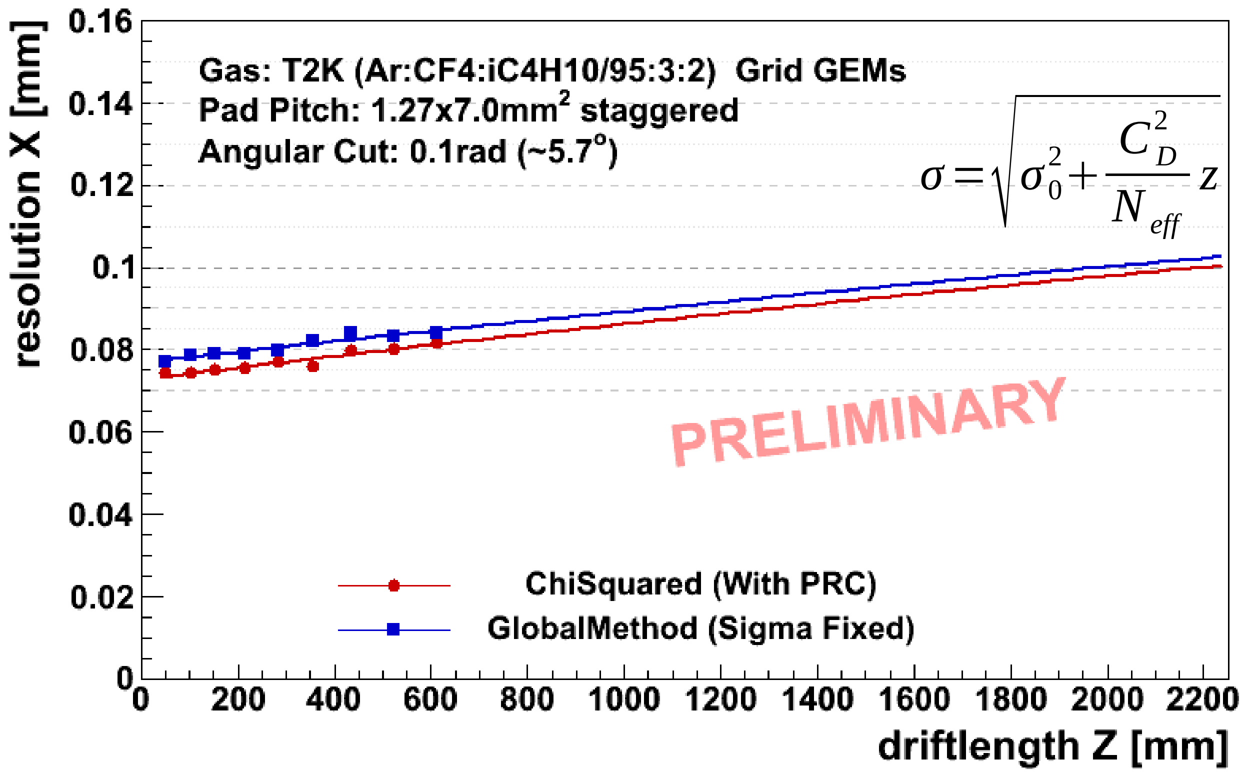
Point resolution goal demonstrated

Aachen



Hamburg



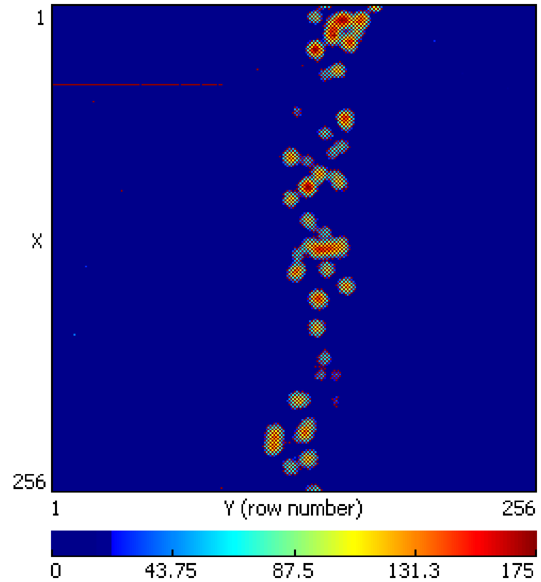


Pads ca. 1x5 mm² → Timepix chip read-out 55x55 µm²

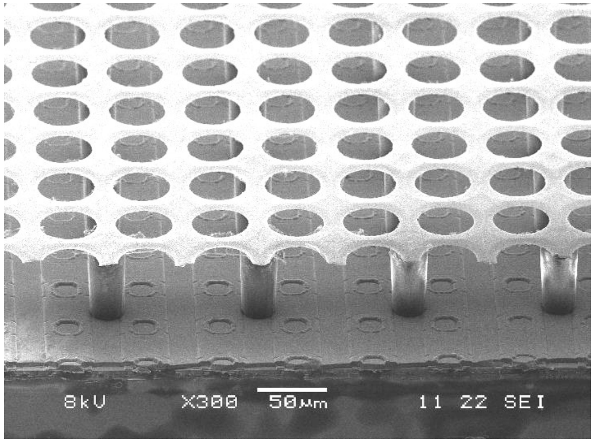
'Ultimate' resolution → limited only by gas diffusion

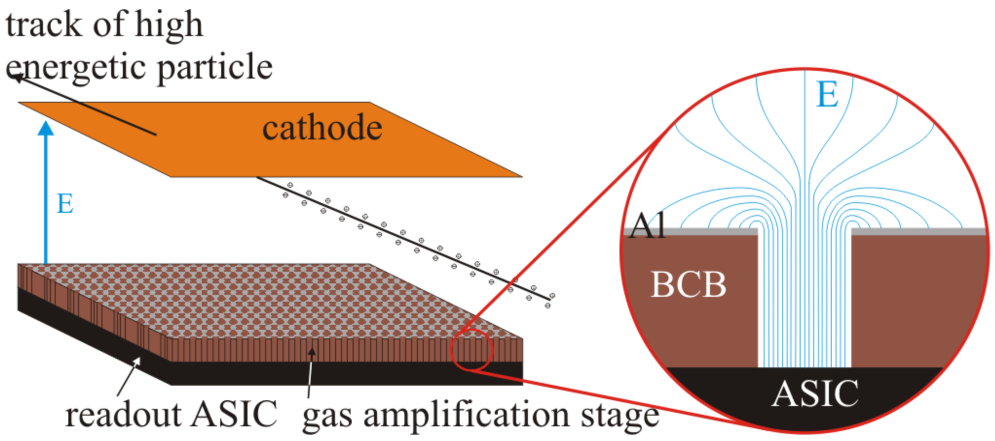
Studied:

- Pixel chip with GEM amplification
- InGrid: Micromegas on top of a Timepix chip
  - Mesh holes aligned to read-out pixels
  - Measures single electrons
- GEMGrid: grid rests on an insulating layer
  - Mechanical stability
  - First test have started

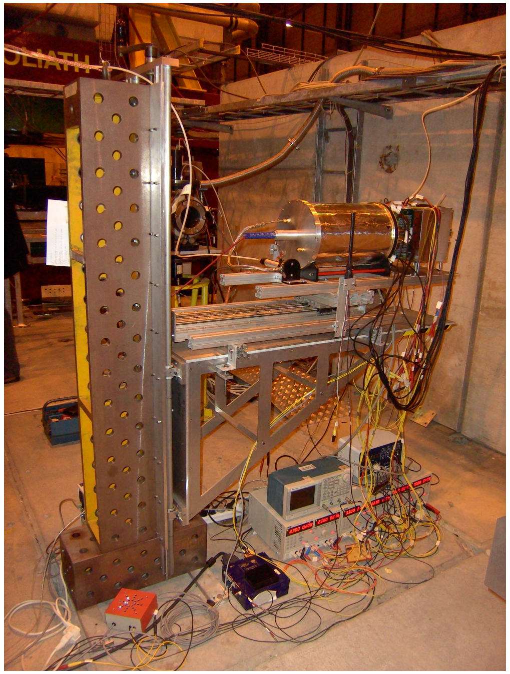


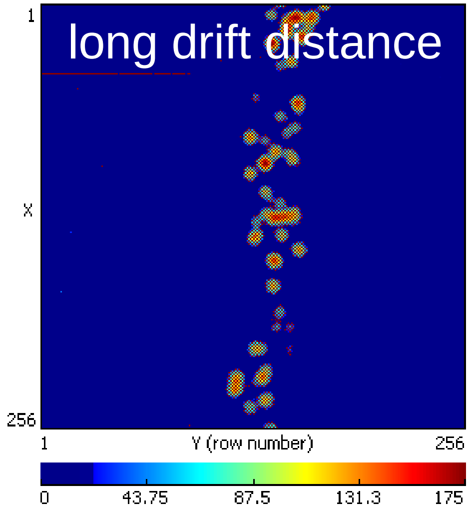
Triple GEM with Timepix

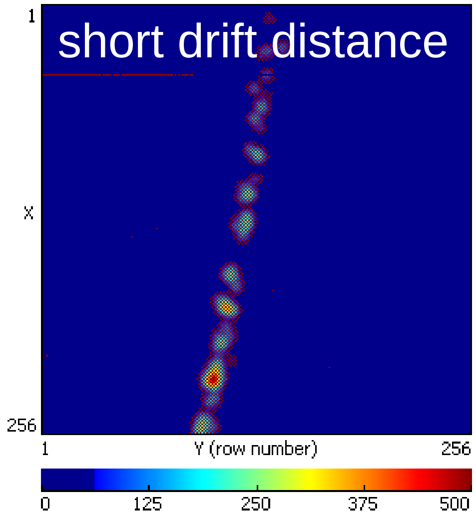


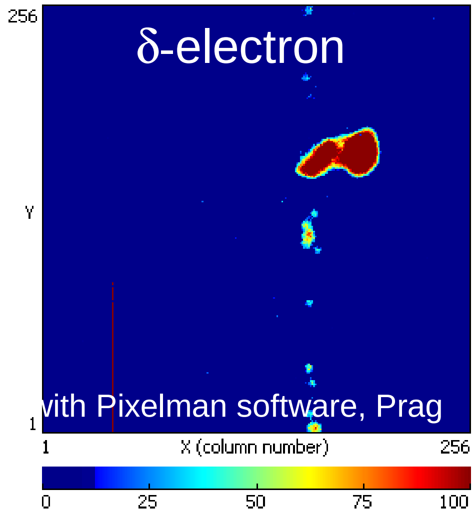


Timepix chip below a triple GEM stack

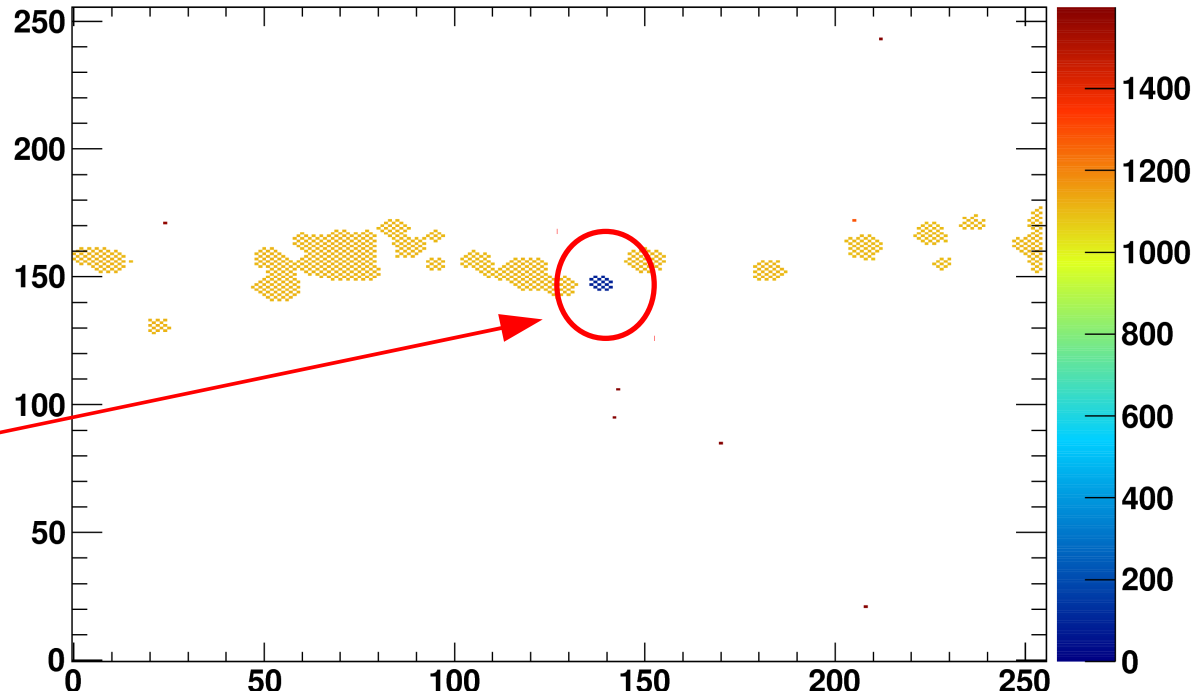


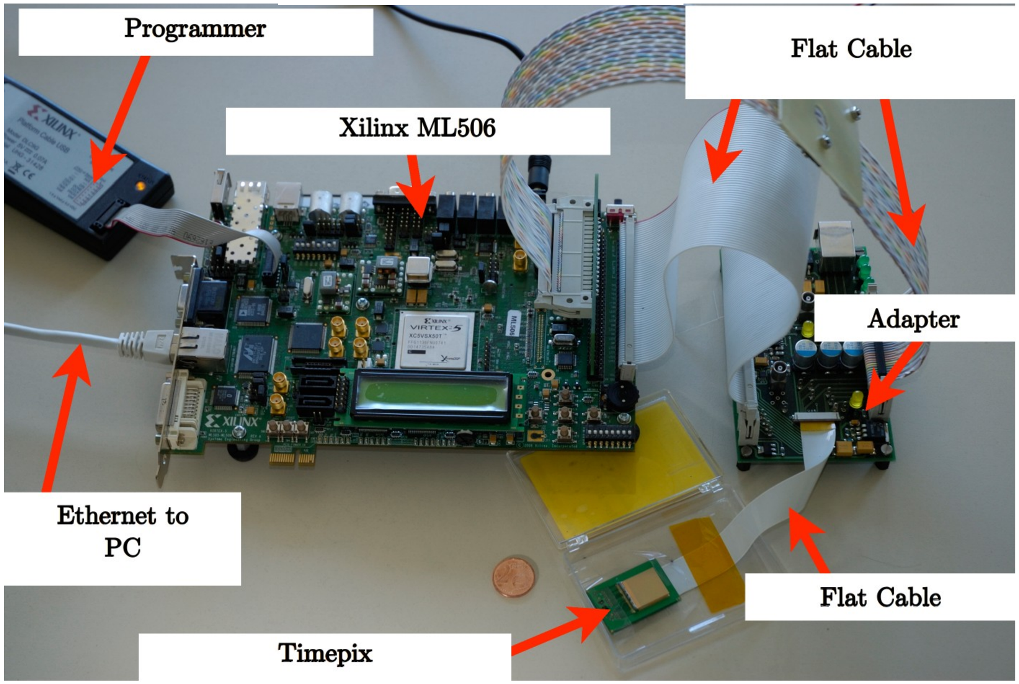


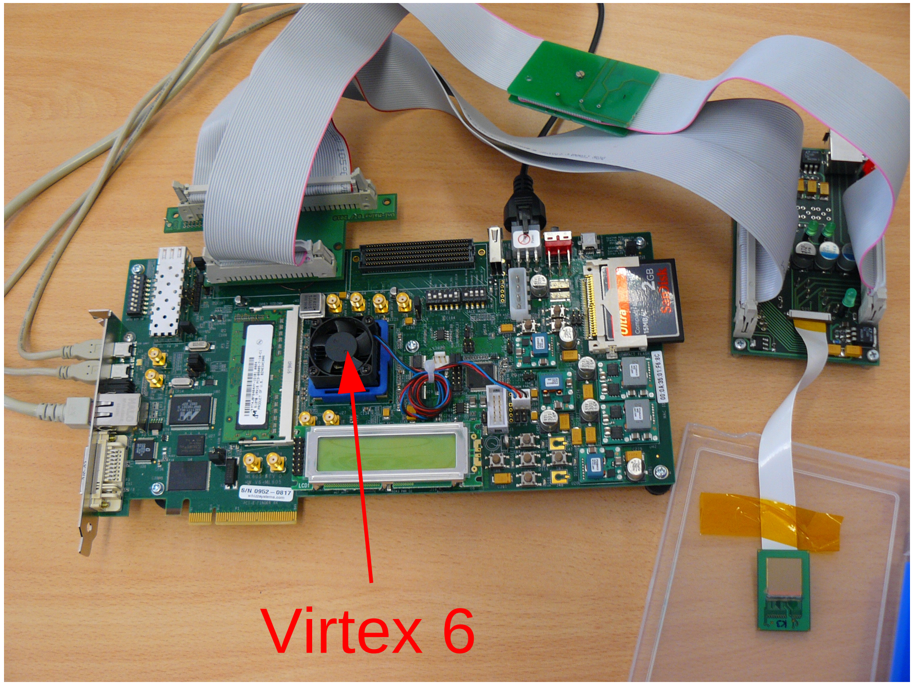




Detailed study of data is ongoing:
- Calibration implemented in MarlinTPC
- Pixel effects are corrected
- Observation and study of single late clusters







Readout electronics designed by U. of Mainz commissioned at Bonn:

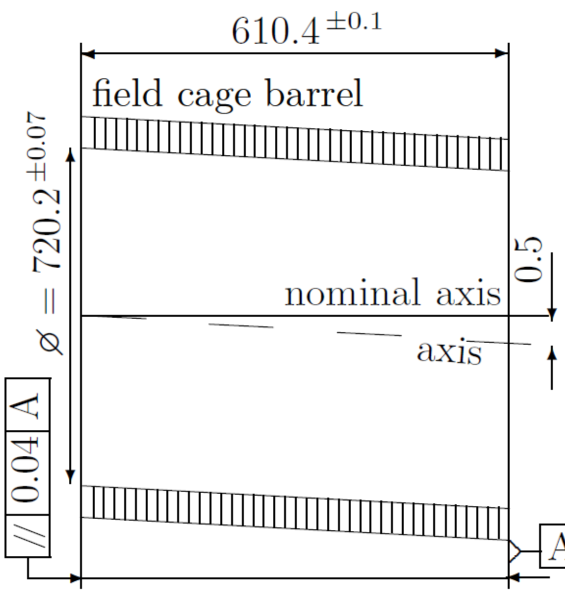
Currently working on migration from a Virtex 5 to a Virtex 6 board/chip

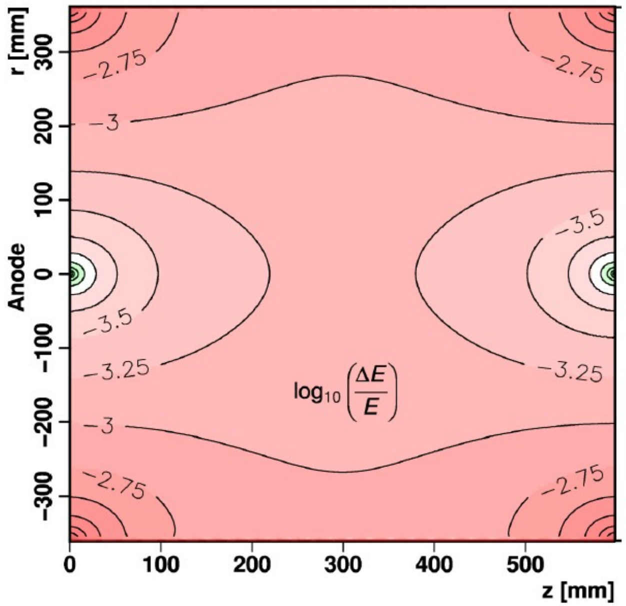
Next steps: implementation of multi-chip readout (up to 8 chips)

Final goal: merge the readout with Scalable Readout System of RD51

Electric field requirement $\Delta E/E < 10^{-4}$

Due to imperfections in construction of Large Prototype homogeneity goal not met

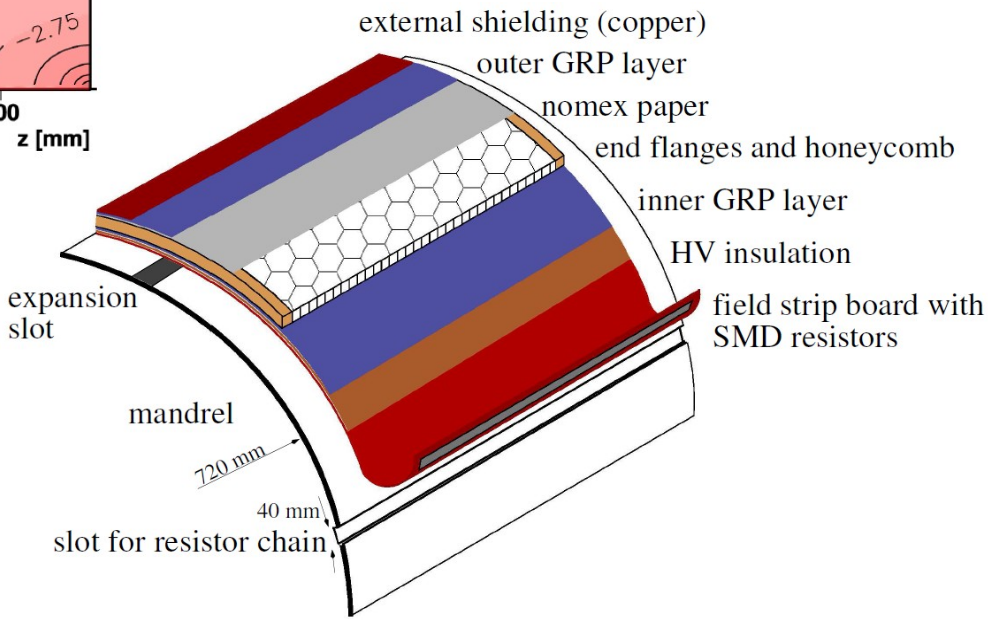




Second field cage planned

Mandrel has been worked over: meets now requirements

Contact to external companies established



Field Homogeneity: B-Field

PCMAG as EUDET infrastructure:

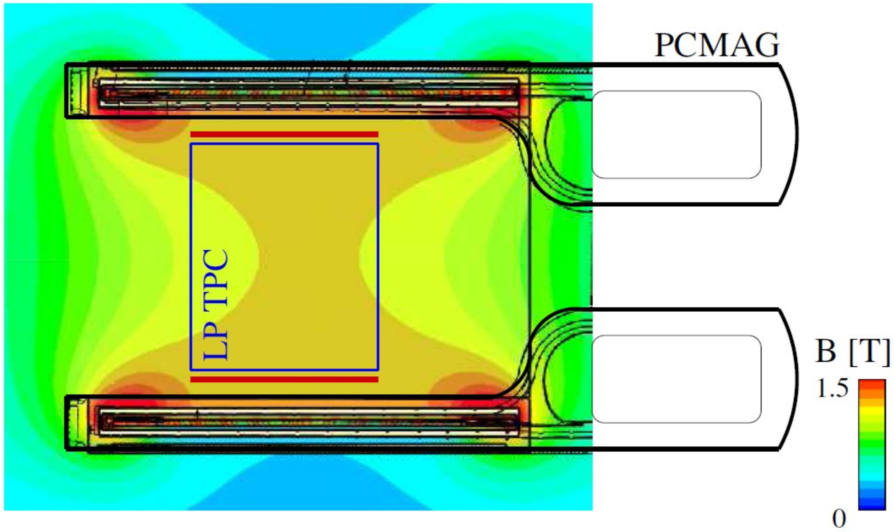
- 1.25 T magnet
- Installed at DESY test beam
- Mounted on movable stage

AIDA: cooling setup will be upgraded

B-Field has been measured to an accuracy of 10^{-4}

Implemented in reconstruction software

Next step: Correction algorithms



Big challenge: cover several m² with MPGDs

New mounting structure for GEMs developed:

ceramic grid to support the GEM foils

Advantages:

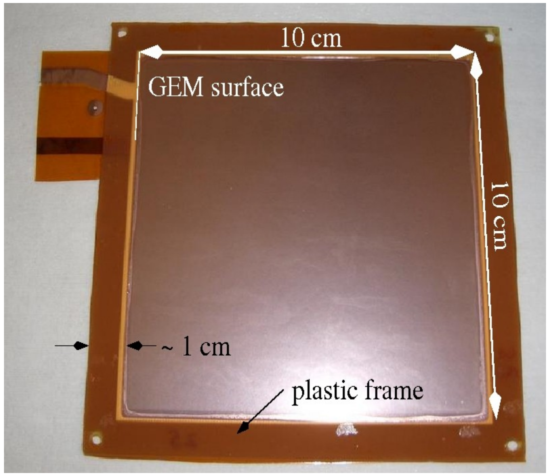
Integrated, lightweight structure

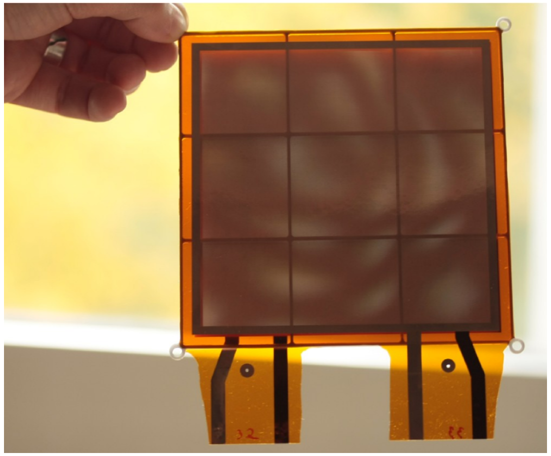
Improved flatness of GEM foil:
less gain variations + better E-field homogeneity

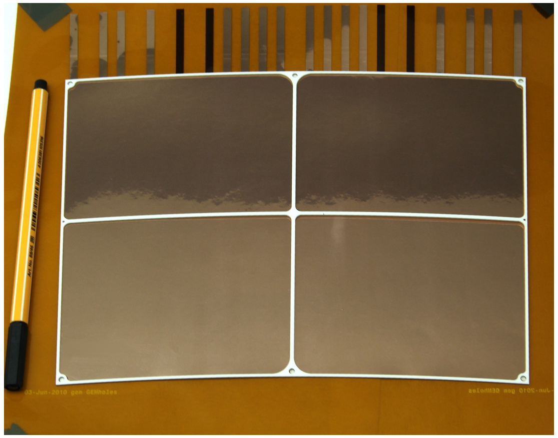
Possibility to cover large areas with minimal dead space

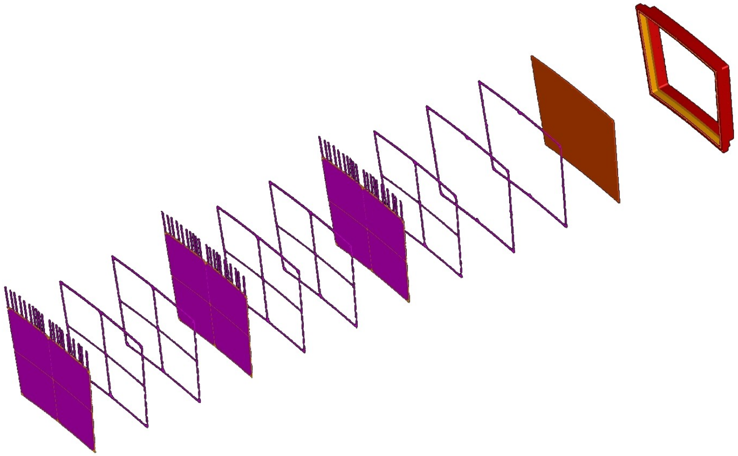
Test in small prototype successfully finished

First LP module tested in December, next in preparation



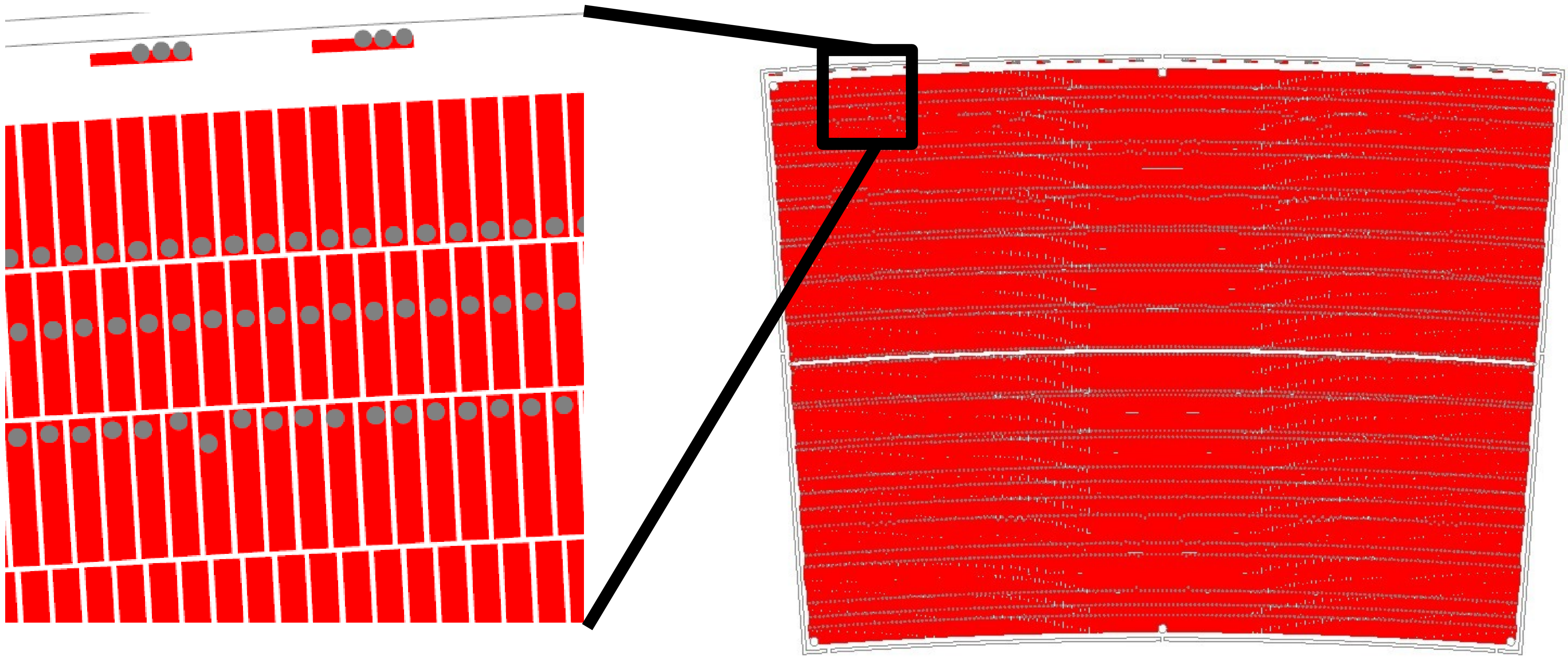






Design of pad plane for DESY module done by Virtual Detector Lab Bonn

Two different designs done, currently the first in production



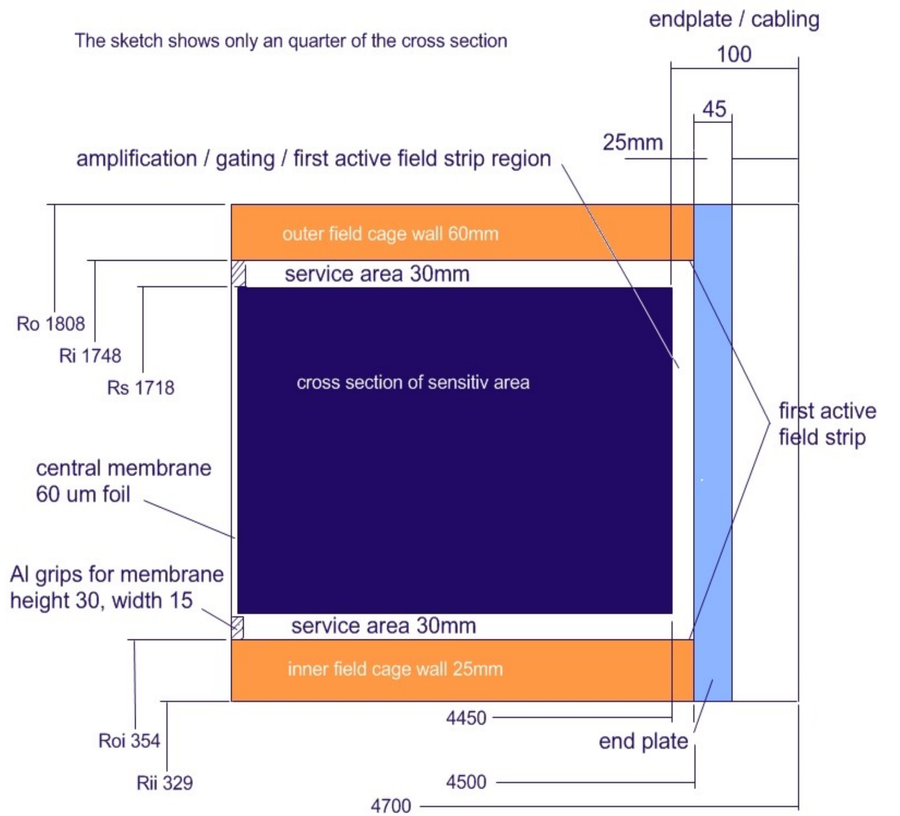
28 rows with
4839 pads of the pitch $5.85 \times 1.265\,\mathrm{mm}^2$

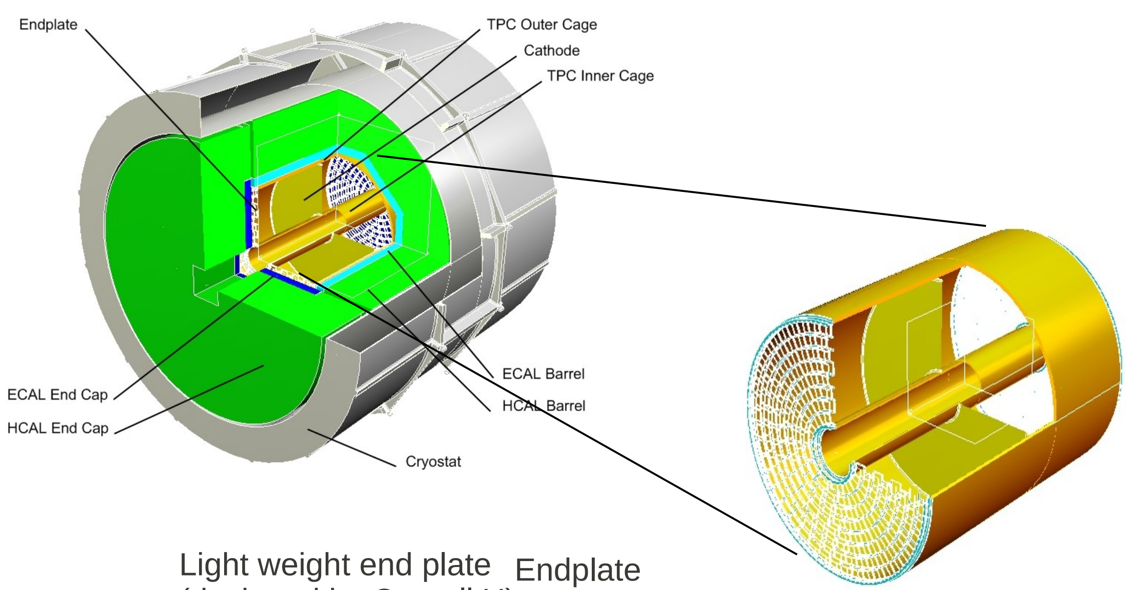
Design of a big ILD TPC has started

Contact to an external company has been established to calculate mechanical properties of the field cage

Design of end plate ongoing

Exchange with Star and Alice for cathode membrane design





Light weight end plate
(designed by Cornell U)

Endplate
n

TPC Placeholder model

MarlinTPC (LCTPC software package):

- Enables R&D groups to do detailed studies
- Comprises simulation, reconstruction and analysis
- Status: recently Large Prototype GEM/pad data reconstructed using the full processor chain
- Recent additions: Hough Transformation Track Finder
- Next Steps:
  - Calibration and correction methods (inhomogeneous fields, alignment)
  - Revise and extend the included detailed simulation for TPC prototypes

Interaction with general ILC software:

- Kalman Filter track fitting moved from MarlinTPC to main ILC software
- Design of ILD TPC input to model for Mokka physics and benchmark simulations
- Simulations feed back into design process:
  e.g. study of influence of thickness of the end plate (in radiation lengths)

Small Prototypes

- Proof of Principle of MPGD Detector
- Ionization and diffusion (TPC gas)
- Electronics
- First field cage designs

Point resolution

Large Prototype

- Tracking including all corrections:
  - E- & B-field
  - Alignment
  - Calibrations
- Electronics
- Software

Momentum resolution

Track separation

dE/dX

LC TPC

- Advanced end plate
- Electronics
- More simulations (ion disks)
- System engineering
- Cooperation with other detectors

“ Conceptual” engineering design

Conclusion

German groups involved in many topics and studies for a TPC at the ILC (only a selection has been presented here)

Resolution Studies with GEM/pad readout:
DESY, Hamburg, Bonn, Freiburg, Siegen, Rostock, Aachen, Karlsruhe

Pixel read-out with GEMs or Micromegas:
Bonn, Freiburg, Mainz, Siegen

Large Prototype and test beam setup:
DESY, Hamburg, Rostock, Siegen

Ion backdrift studies and gating:
Bonn, Siegen, DESY

Software (MarlinTPC and ILD):
DESY, Hamburg, Bonn

Design of ILC TPC:
DESY, Hamburg

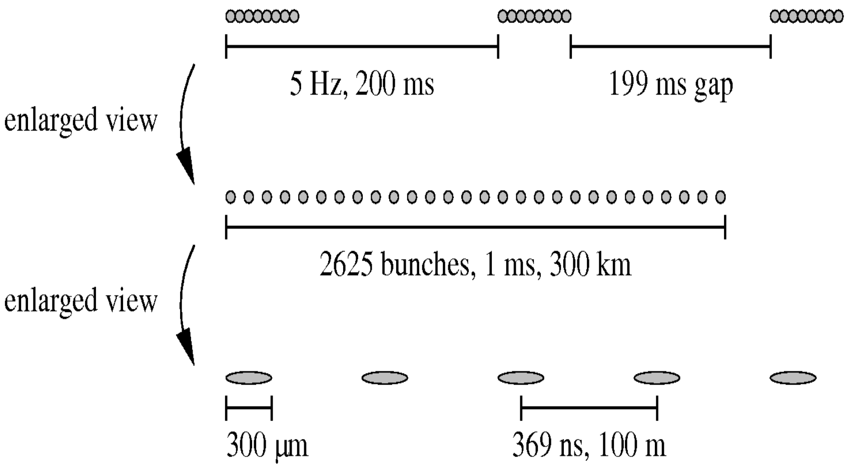
Activities well embedded in international efforts of LCTPC

Feasibility of many crucial aspects shown, open issues are being addressed

We believe that we could build an ILD TPC

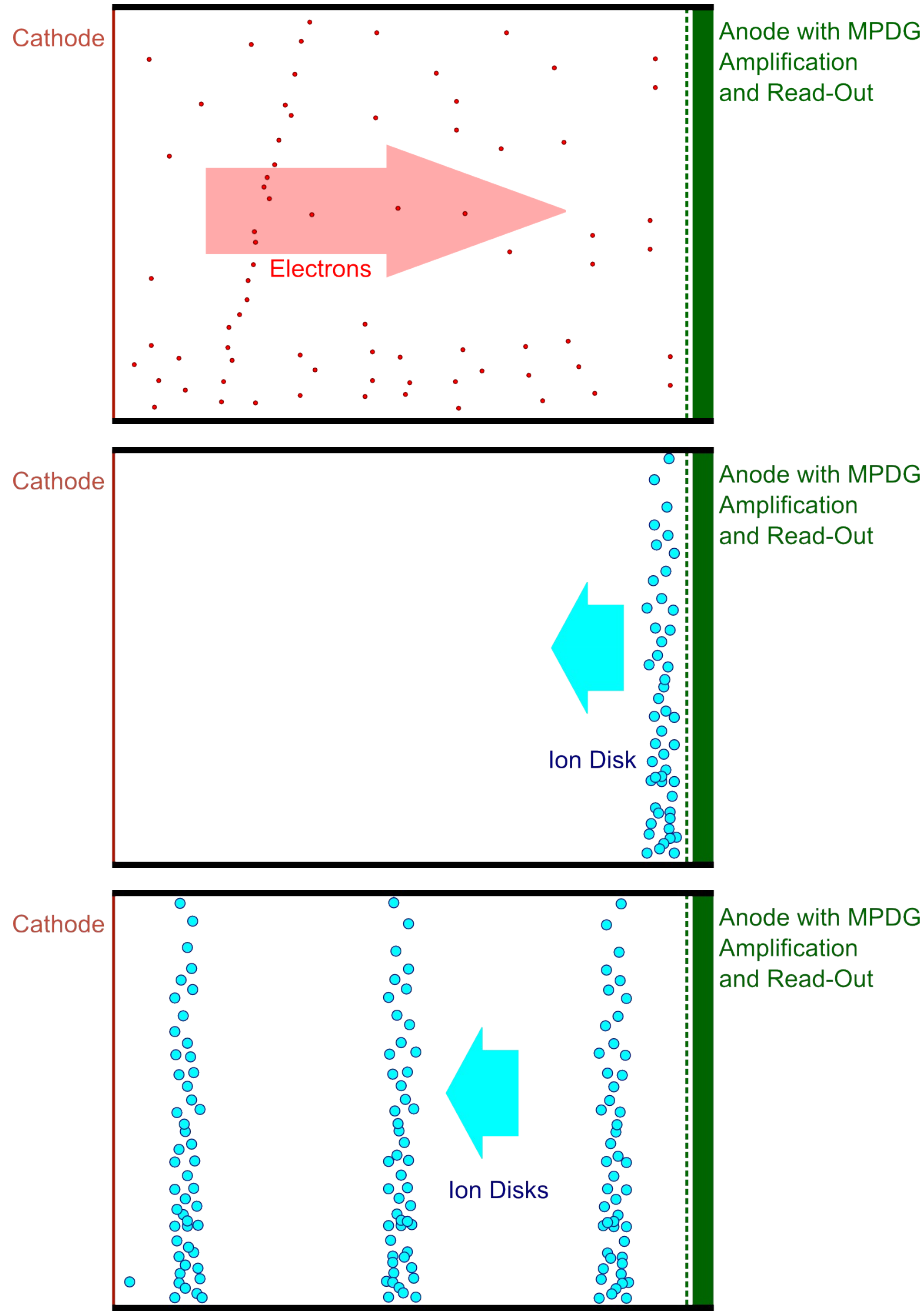
TPC for ILC   Ion Back Drift

After each bunch train, a disk of positively charged ions from the amplification stage drifts back into the TPC volume

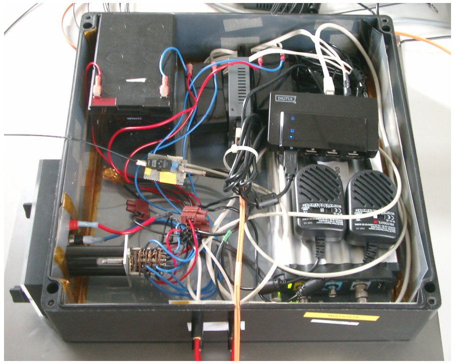


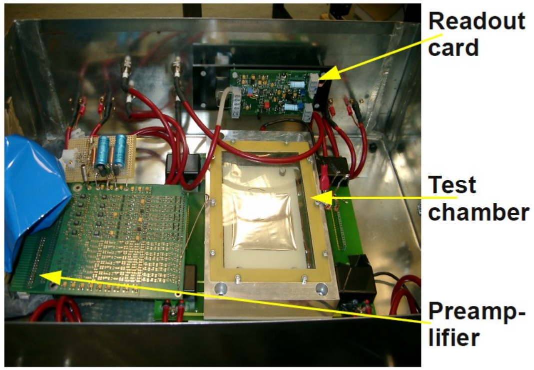
Due to the very slow drift of ions up to three disks simultaniously in the gas volume
→ Field distortions

With adjusted GEM settings, the ion back drift can be minimized, but not to zero

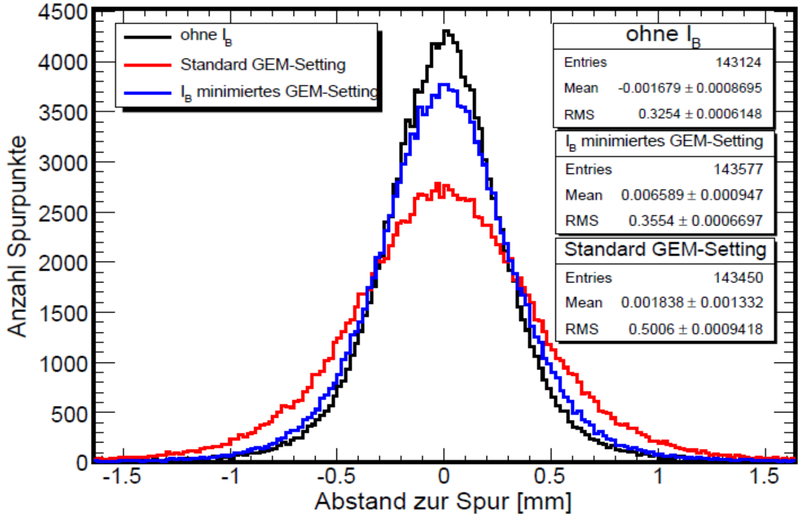


- Simulations of ion disks after each bunch train currently under revision
- Cathode current measurement to analyze ion back drift at Siegen





Impact of ion disks on resolution (Bonn)



- Different ideas how to “gate” the ion disks:
  - Gating with GEMs, mesh or wires
  - Started to build a simple test setup at DESY
  - First test with an additional gating GEM is planned