Development of a GEM-based High Resolution TPC for the ILC

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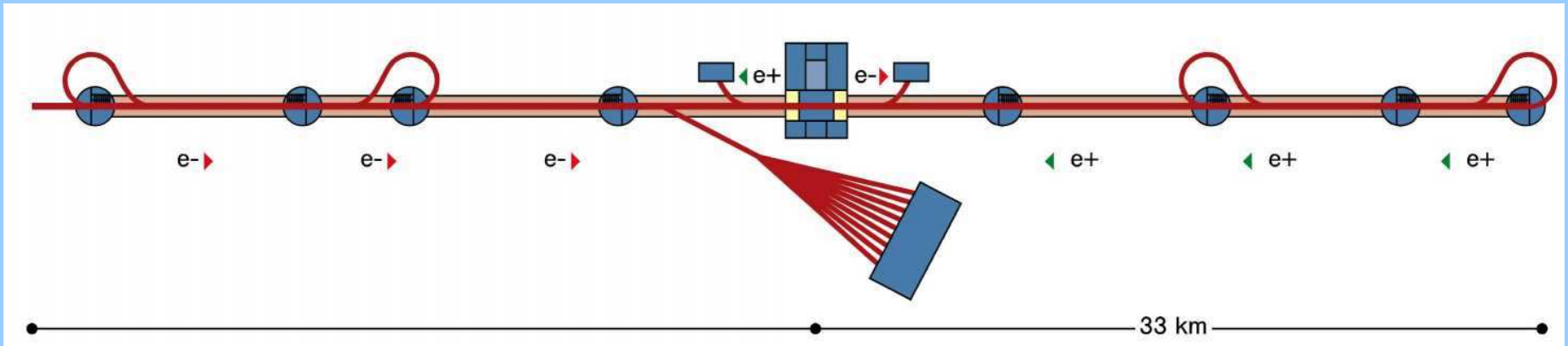
Worldwide Study of the Physics and Detectors for Future Linear e^+e^- Colliders

bmb+f Großgeräte der physikalischen Grundlagenforschung

Overview

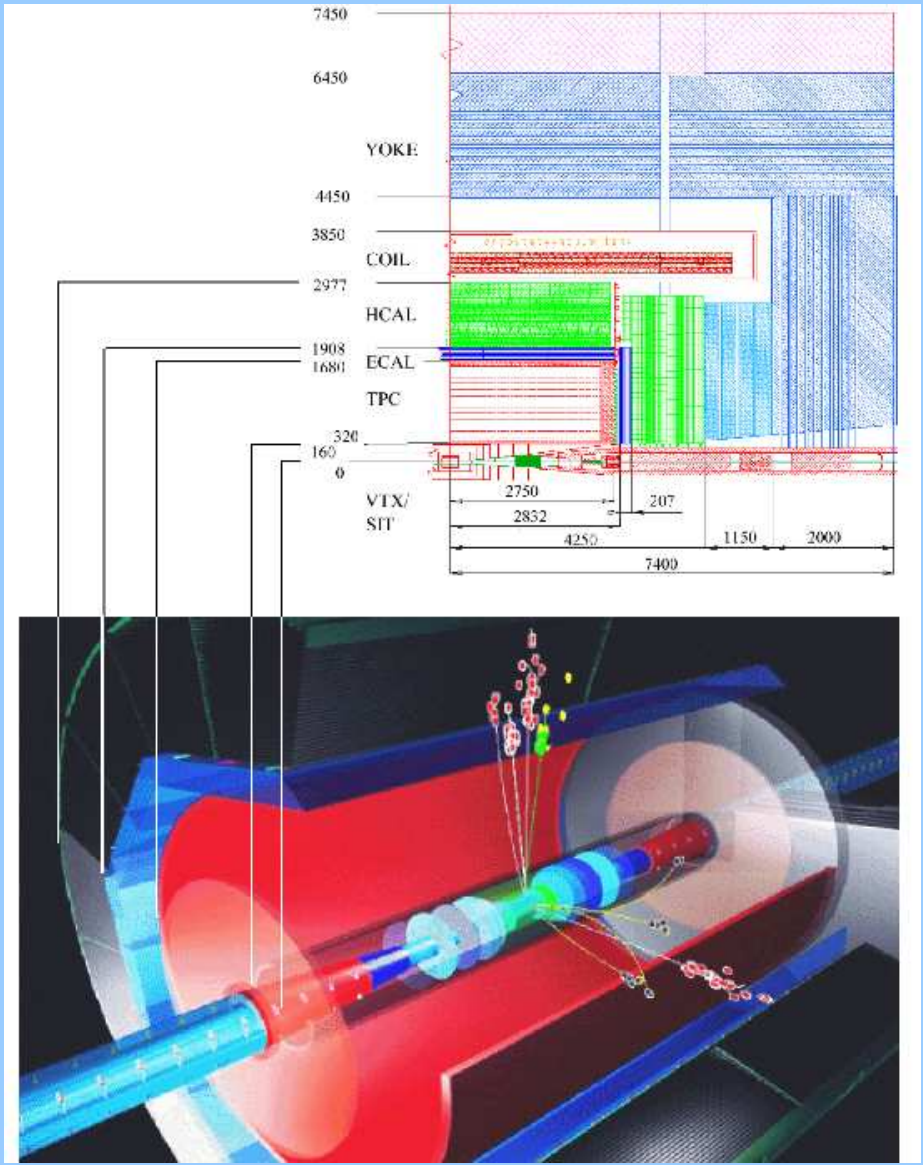
- Introduction
  - International Linear Collider (ILC)
  - Time Projection Chamber (TPC)
  - Gas Electron Multiplier (GEM)
- Test Setup
  - TPC Prototype
  - Hodoscope
- Simulation Studies
  - Modular Structure
  - Comparison with Measurements

The International Linear Collider



- Electron Positron Collider at energies up to 1 TeV
- Precision machine to complement the discoveries of the LHC by precise measurements of various parameters
  $\Rightarrow$ concurrent running with LHC is strongly recommended
- Advantages of e^+e^--machines:
  - exactly known, simple initial states
  - low background
  - beam polarisation

TPC as Central Tracker



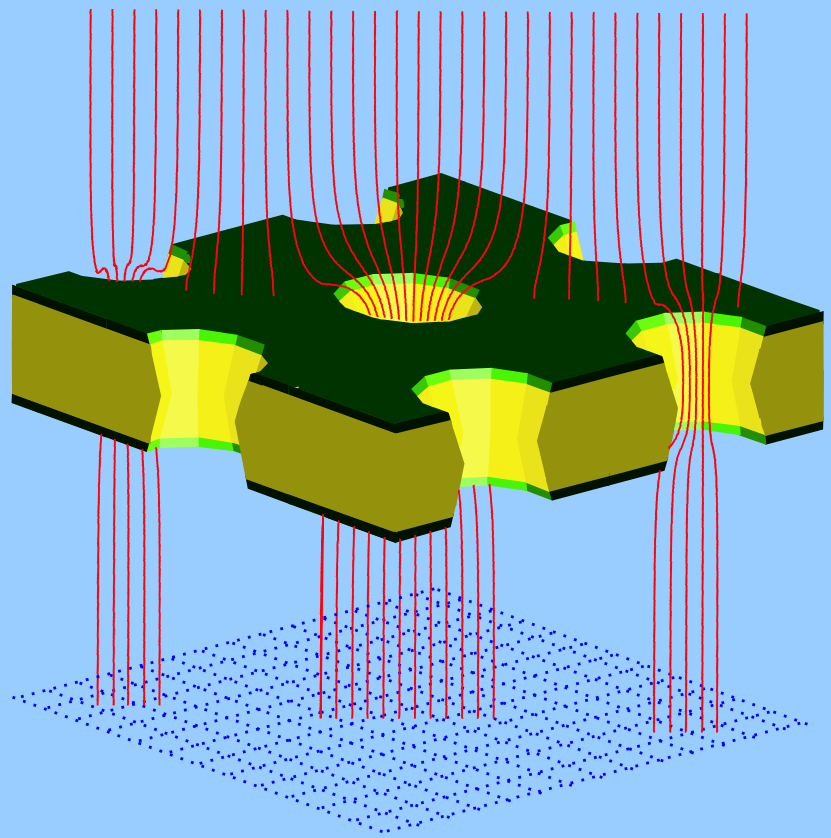
4T magnetic field

Advantages of a TPC:

- Large volume (R=1.7m)
- Simple 3-d track reconstruction (Goal: 200 points per track)
- Very low material budget before the Calorimeters: 3% X_0 in barrel, 30% X_0 in readout
- Good measurement of specific ionisation $\left(\frac{dE}{dx}\right)$ along the track (Goal: 5% resolution)

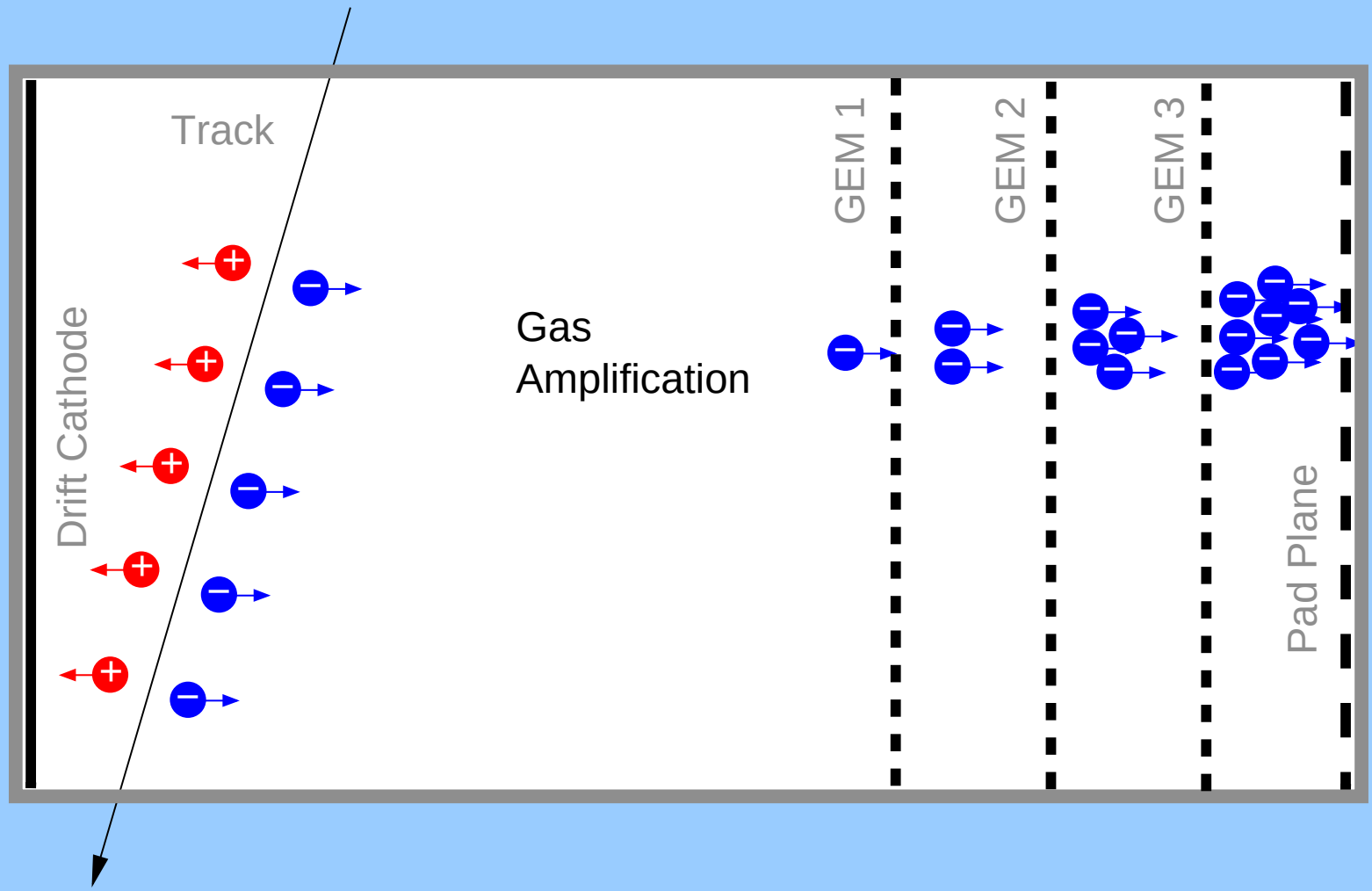
Advantages of a GEM Readout

- Smaller structures (140 μm pitch): Potential for improved spatial resolution (Goal: $100 \mu m$ single point resolution)
- 2-d symmetry $\rightarrow \vec{E} \times \vec{B}$ effects smaller than with wires
- Fast e^- signal on pads
- Intrinsic suppression of Ion Backdrift $\rightarrow$
  No active gating needed?

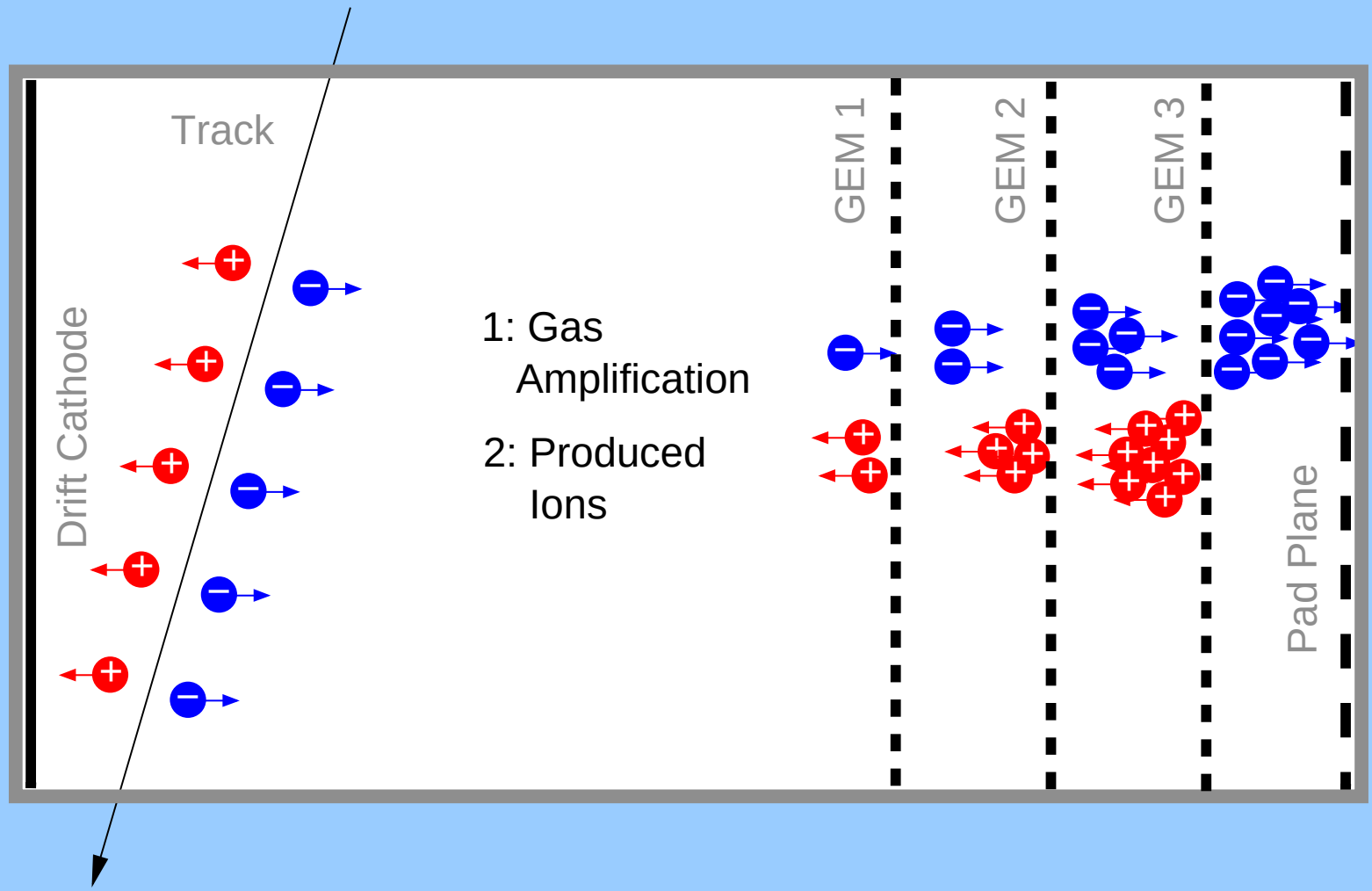


GEM: Gas Electron Multiplier (Sauli, 1996)

A TPC with GEM Readout

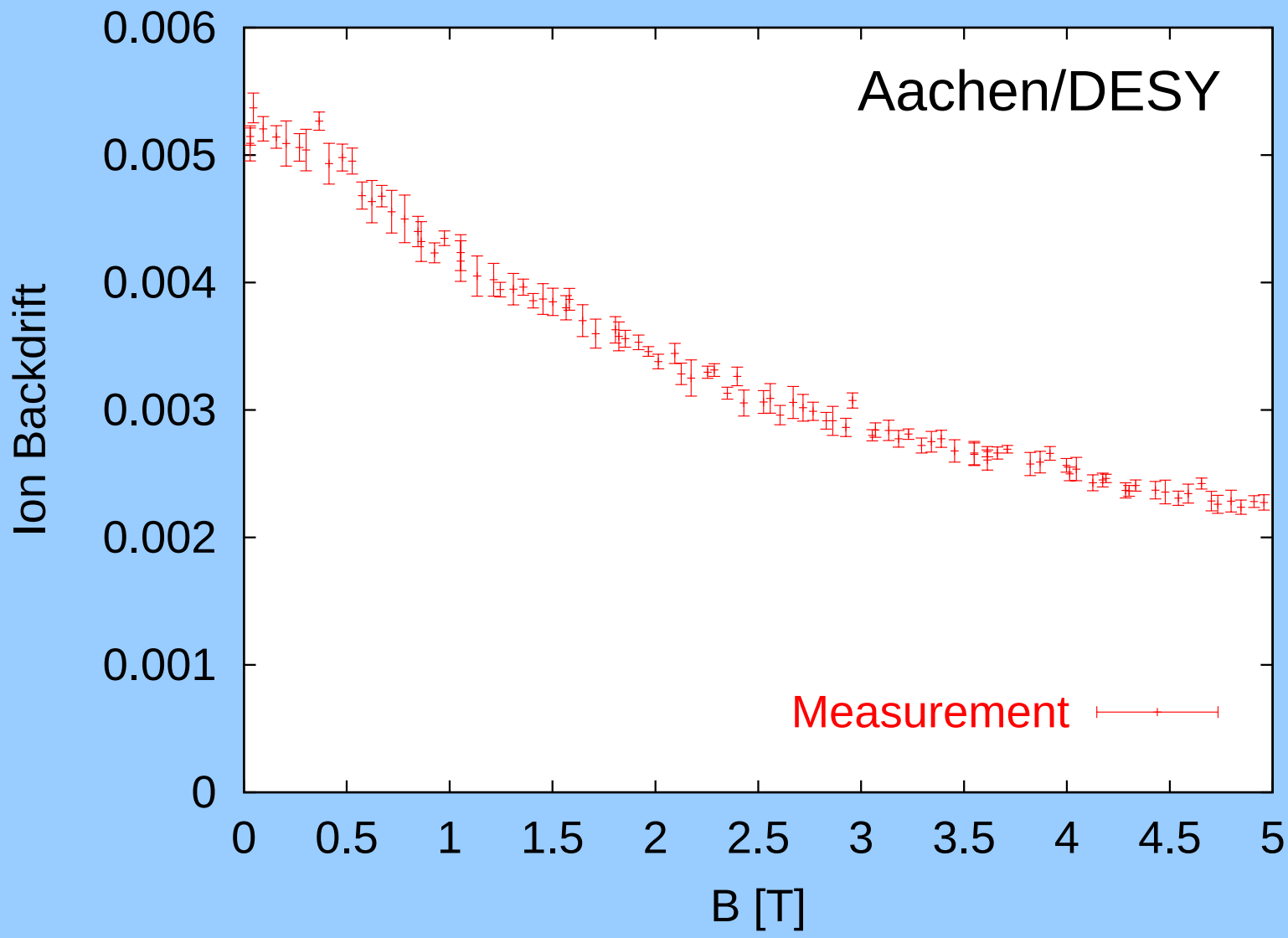


A TPC with GEM Readout



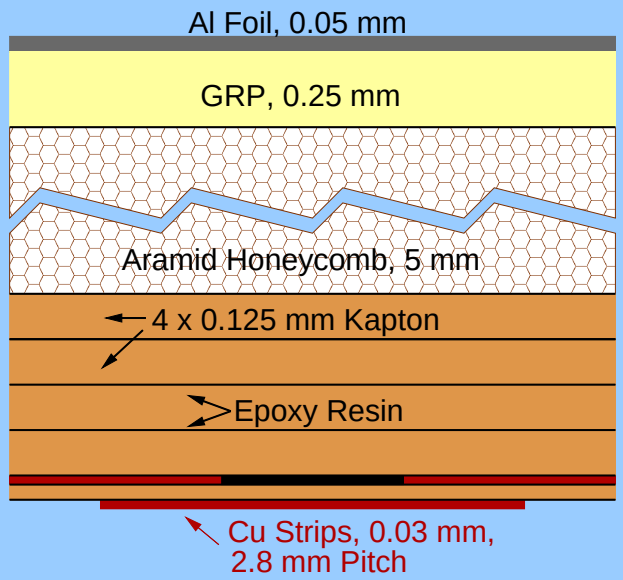
Ion Backdrift

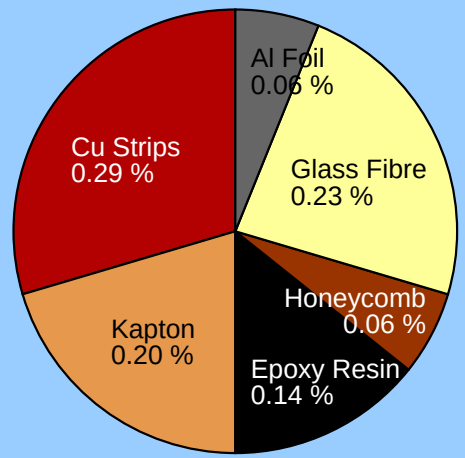
Reduction of ion backdrift with optimised GEM setting:



TPC Prototype

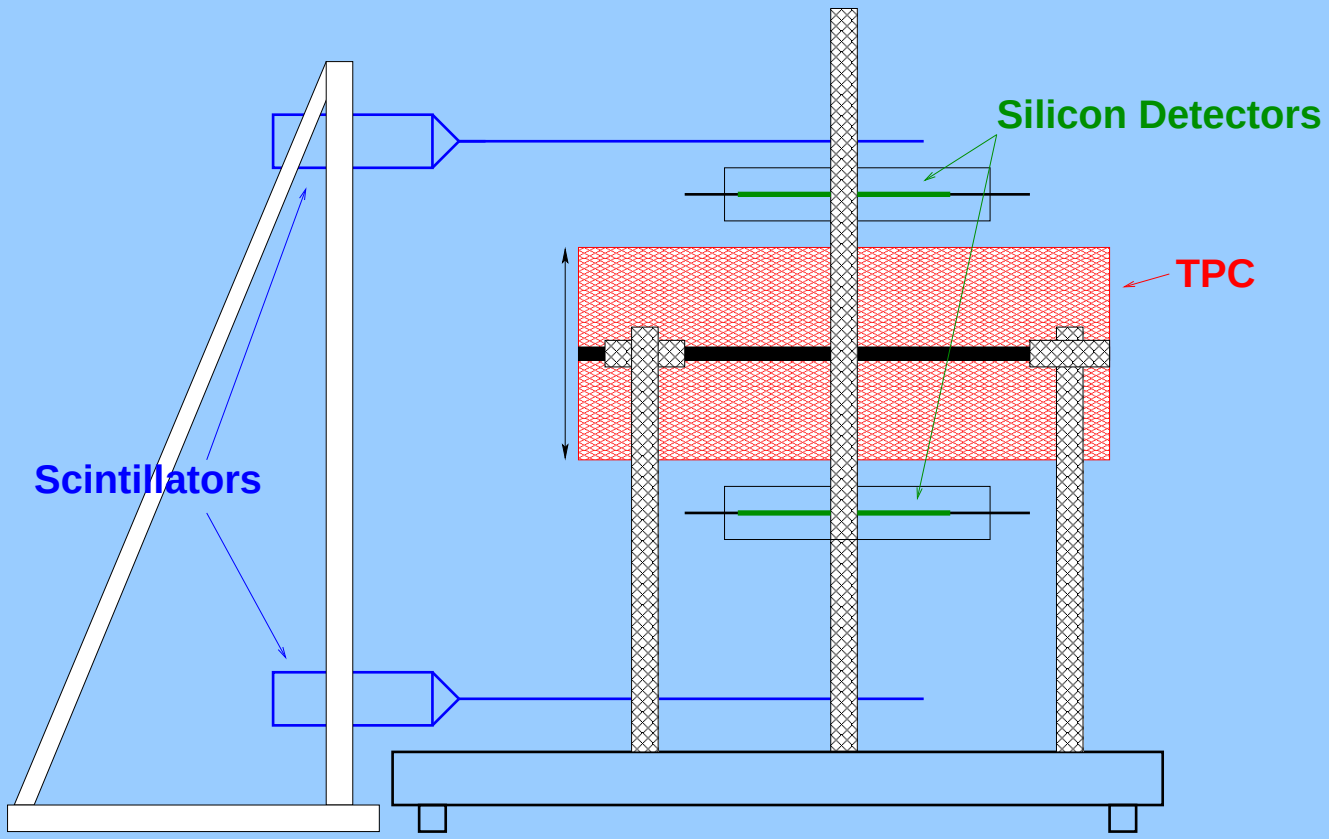
- 5T Magnet at DESY Hamburg
- Triple GEM readout is used
- Drift distance = 260 mm
- Maximum drift field = 1000 $\frac{V}{cm}$
- Materials with low density:

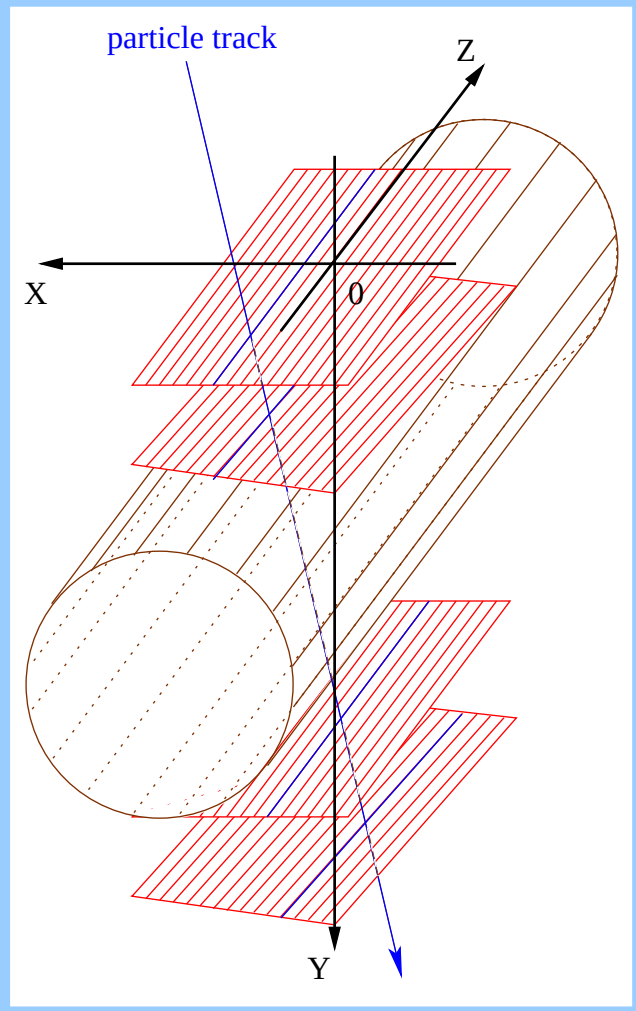




3% radiation length possible

TPC Prototype: Hodoscope Test Stand

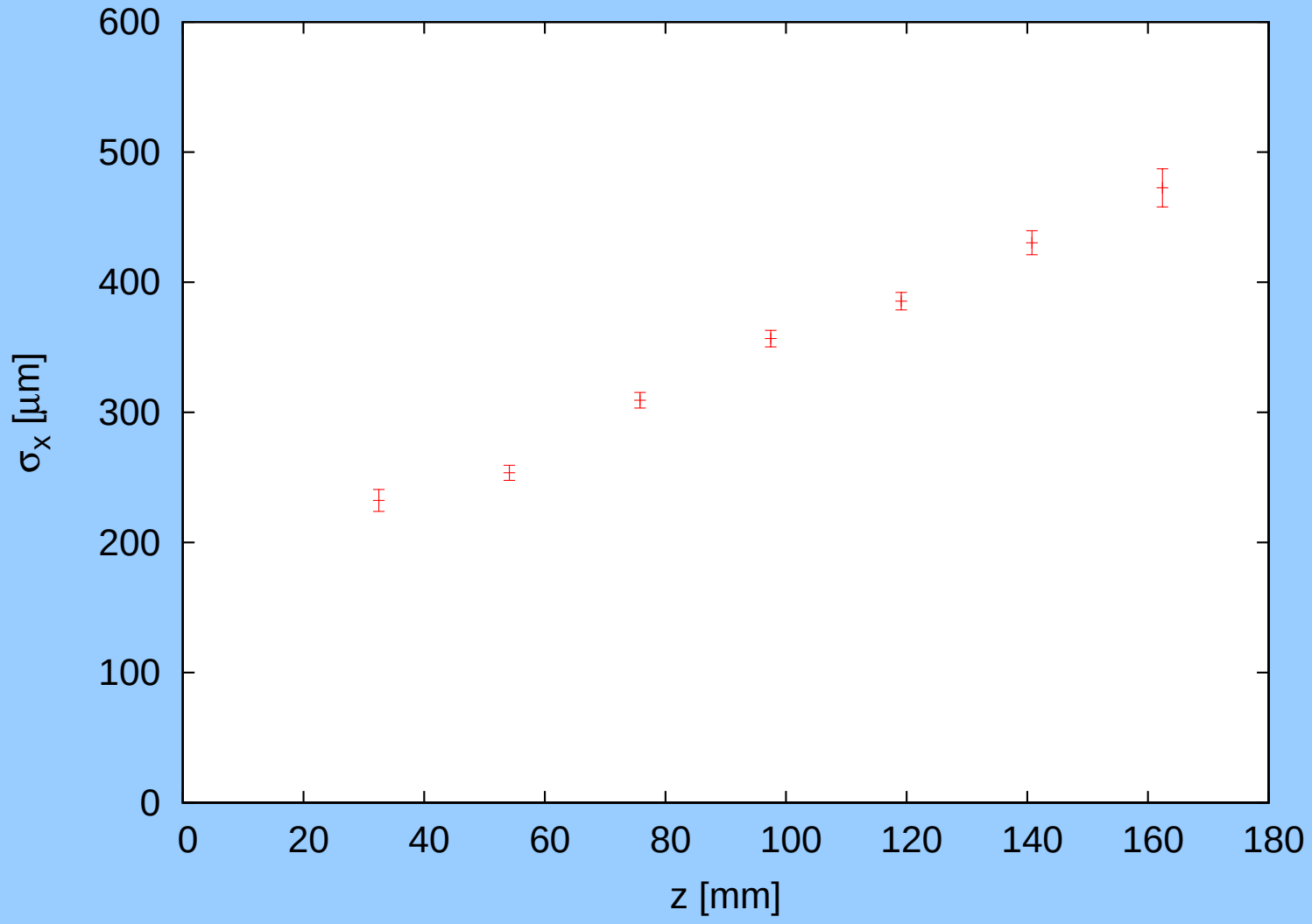




Hodoscope resolution in x: 60 μm

TPC Prototype: Single Point Resolution

Compare points from TPC with hodoscope tracks:



Measurement without magnetic field, pad size 2.4×6.4 mm^2

Simulation Studies

Goals: Study influence of

- Electric and magnetic fields
- GEM settings
- Pad response, pad geometry
- Ion backdrift

on the spatial resolution of a TPC.

4 Modules:

1. Primary ionization
2. Drift of electrons
3. Gas amplification with GEMs
4. Electronics (shaper, ADC)

Simulation Steps 1 and 2:

Primary Ionization:

- Parametrization of distributions calculated by HEED
  Randomly generate:
  - Distance between clusters
  - Number of electrons per cluster
- Place electrons on track (helix with magnetic field, straight line without)

Drift of Electrons:

- Gaussian distribution in x, y and z according to parametrization of longitudinal and transverse diffusion calculated by MAGBOLTZ for the particular gas mixture.

Simulation Step 3: Amplifi cation with GEMs

Input from measurement:

- Detailed parameterization of charge transfer coefficients (collection, gain, extraction) as a function of GEM settings.
- Charge broadening between GEMs mainly determined by diffusion.

  $\Longrightarrow$ Use diffusion from parametrized MAGBOLTZ calculations.

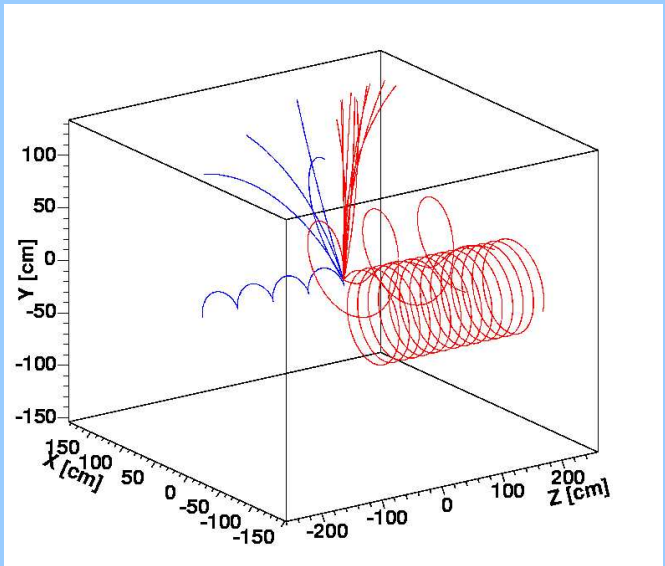
Simulation steps:

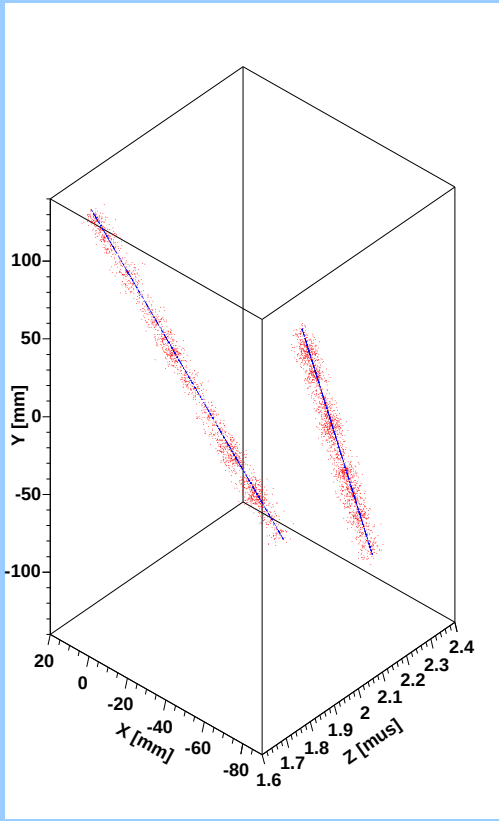
- Calculate number of electrons according to GEM settings.
- Apply charge broadening according to diffusion.
- Map electrons onto pads.

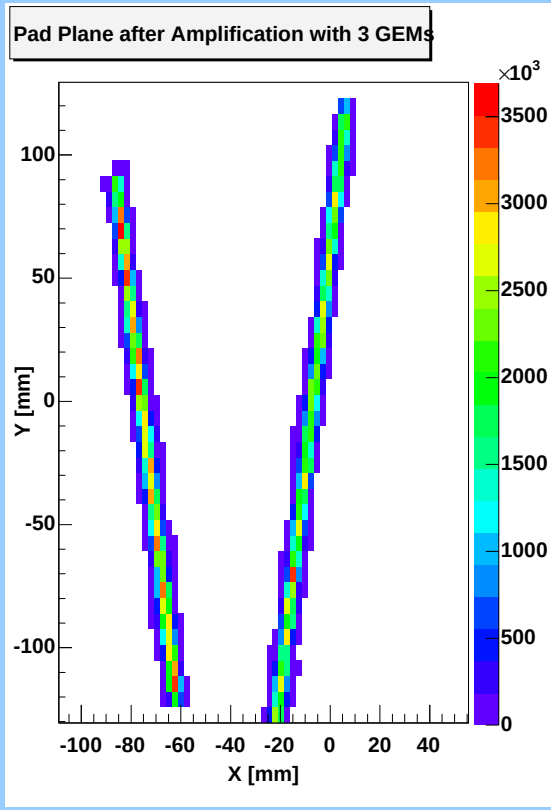
Simulation Step 4: Shaping and ADC

- Calculate center of gravity of electrons in pulse.
- Apply shape smearing of electronics (currently gauss).
- Fill the electrons into time bins.
- Map charge per time bin to the ADC range.

Simulation Summary

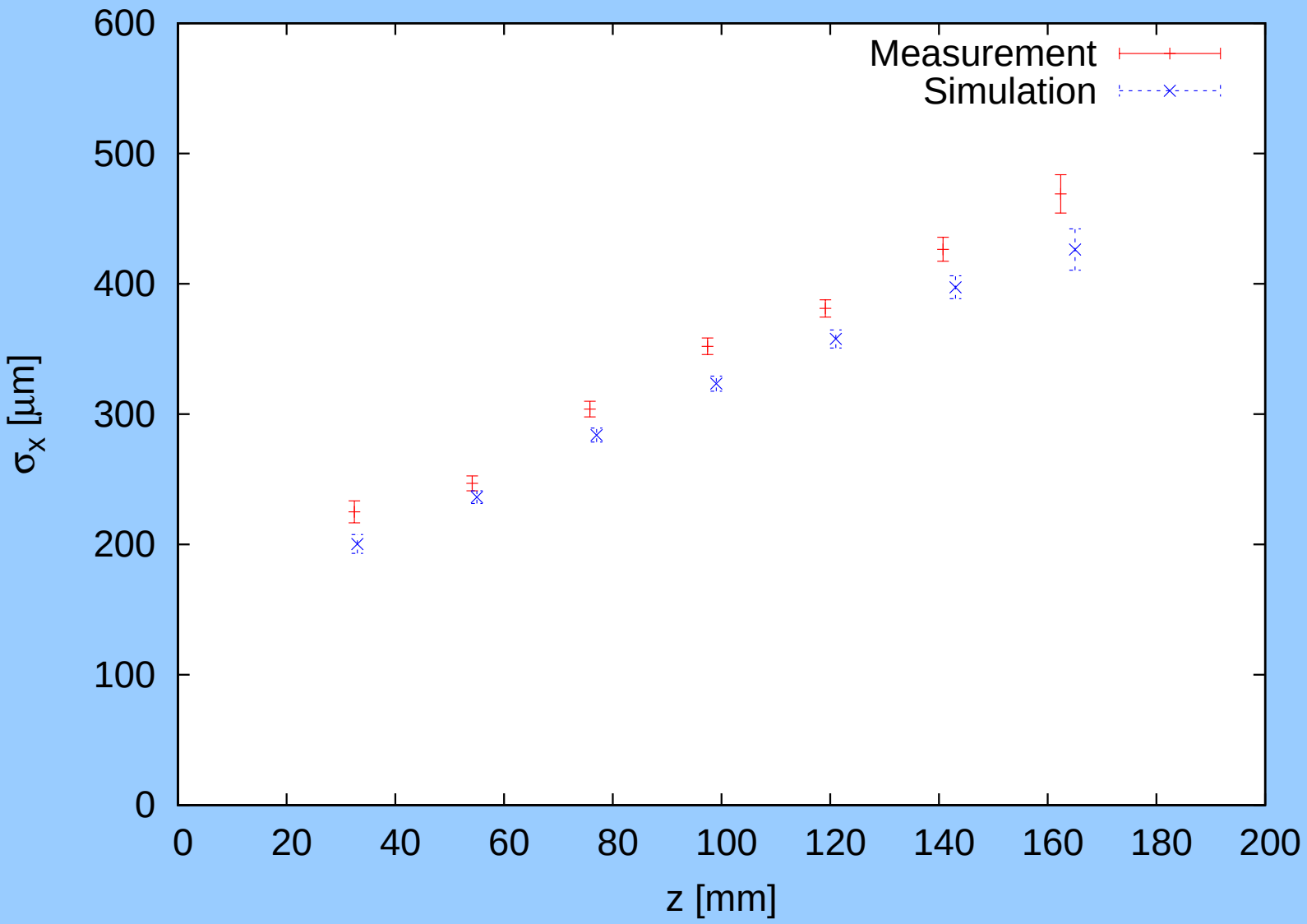






Simulation: Comparison with Measurement

Single Point Resolution :



Conclusions and Outlook

Prototype ready for test beam in October:

- Detailed measurements of field homogeneity and spatial resolution
- Test new readout electronics
- Check simulation predictions

Questions for the ILC TPC:

Requirements for optimal spatial resolution?

- Readout frequency?
- Pad size and shape?
- GEM settings?