Research in Germany for a TPC at the ILC

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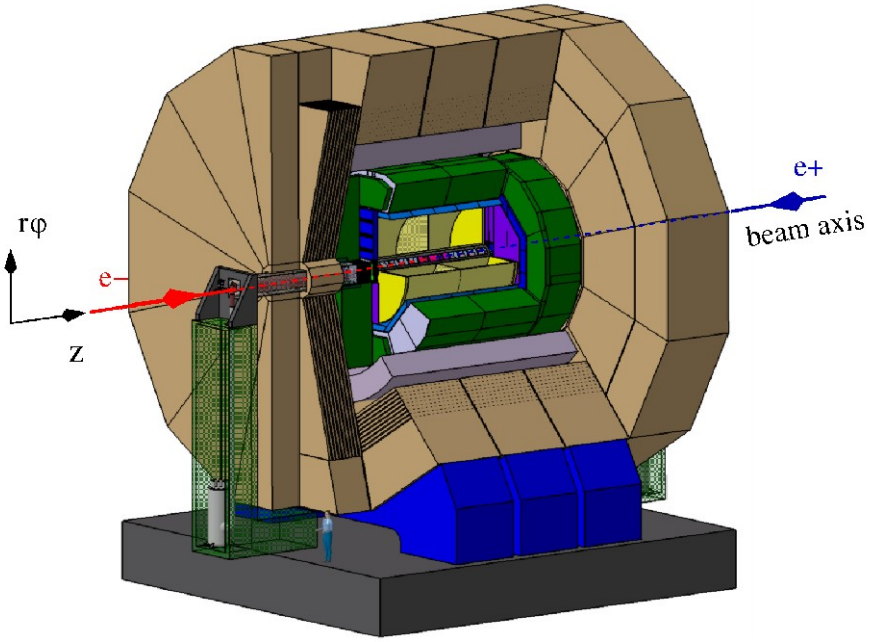
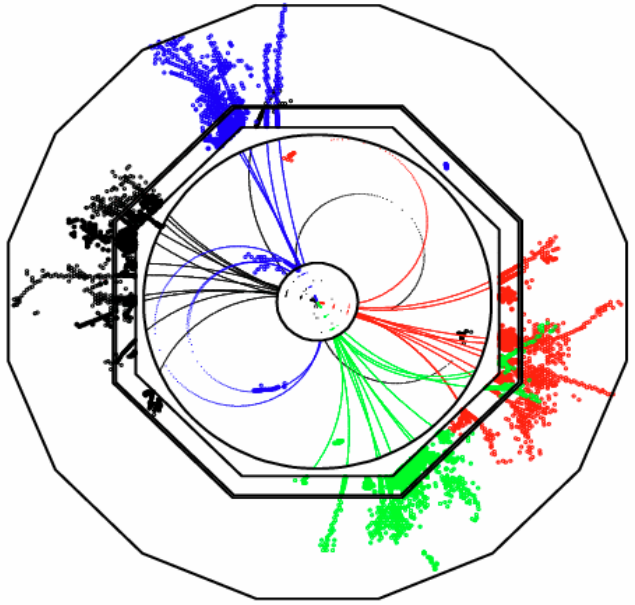
R. Diener, C. Rosemann
DESY

A TPC at the ILC

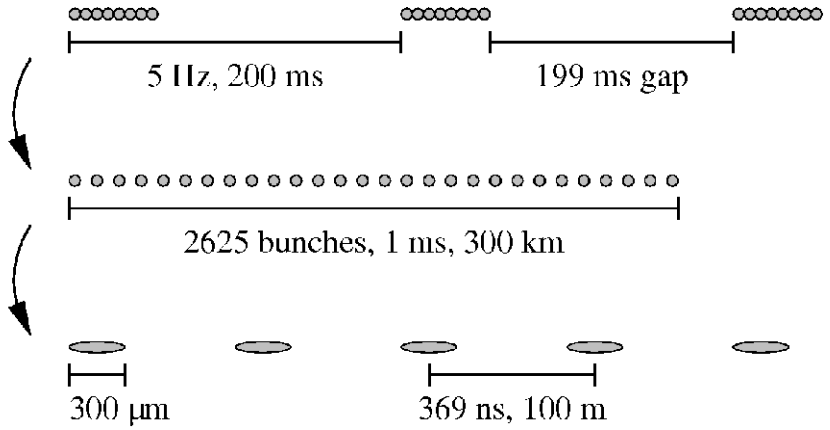
- ILD: a multi purpose detector for the ILC
- TPC as main tracker
  - Robust tracking: ~ 200 space points per track (ILD TPC with pad readout)
  - Robust towards machine backgrounds (~99% tracking efficiency)
  - dE/dx-measurement input to particle ID
  - Low material budget



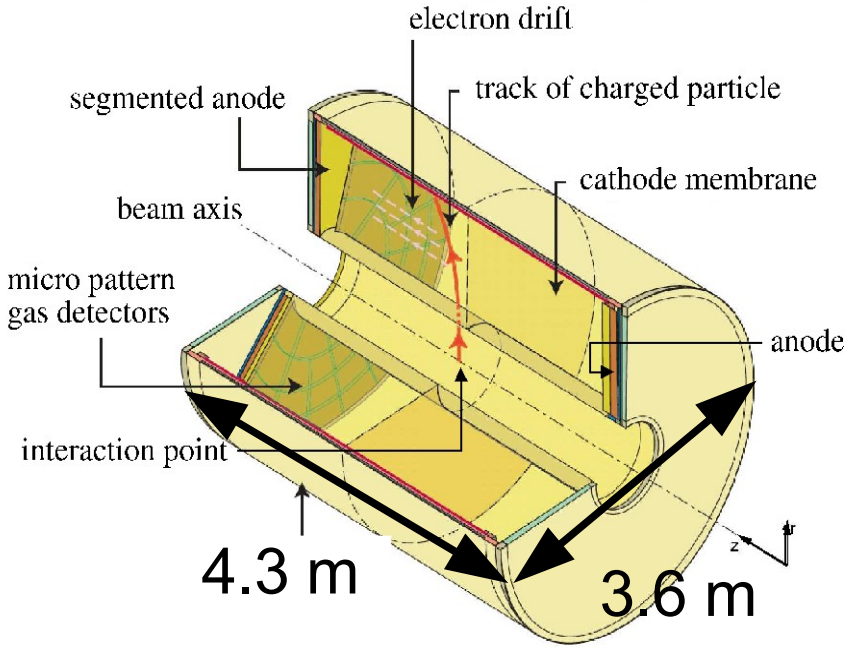
- Requirements for an ILC TPC
  - Minimum of X_0 inside Calorimeter (<4% barrel, <15% endcaps)
    → lightweight design of field cage and anode
  - σ ~ 100μm (rφ) and ~ 500μm (rz) @ 3.5 T
    → stringent requirements on field homogeneity
  - 2-track resolution <2mm (rφ) and <5-10mm (rz)
  - dE/dx res. <5% → e/pi separation, for example



- Challenges for the TPC
  - Resolution goal unprecedented by previous TPCs in collider experiments
  - Pile up of many bunch crossings → ion back drift
  - Lightweight readout electronics and field cage



- TPC readout: based on Micro Pattern Gas Detectors (MPGDs):
  - Gas Electron Multiplier (GEMs) or Micromegas
- MPGD not used for TPC readout in collider experiments yet
- Advantages:
  - Intrinsic Ion feedback suppression
  - Can be mounted on lightweight structures
  - Homogeneous surface of readout plane
- Pad or silicon pixel readout



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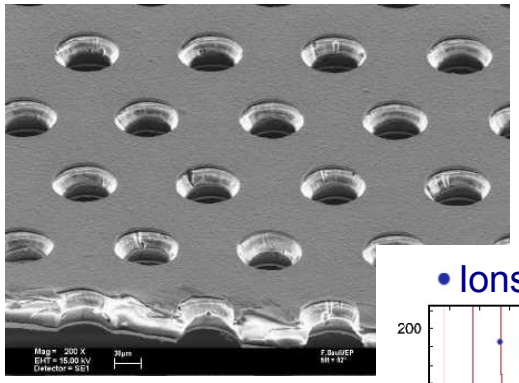

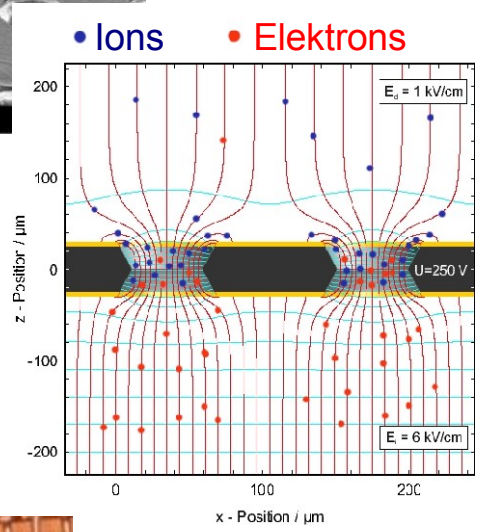

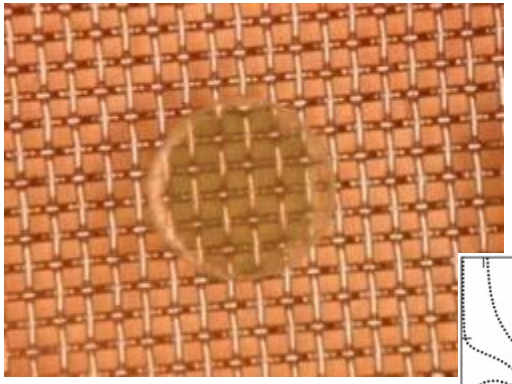

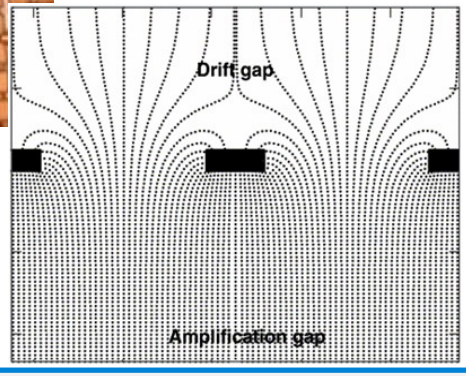

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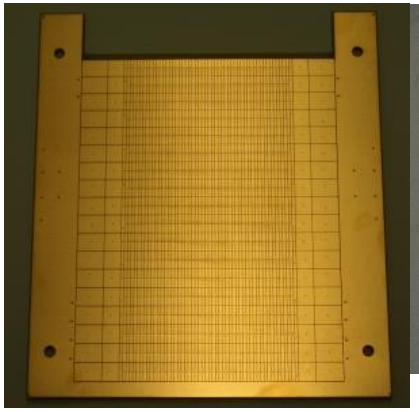
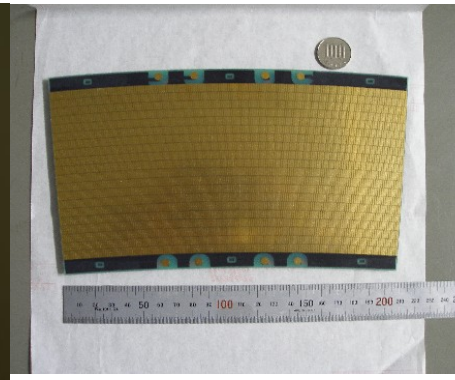
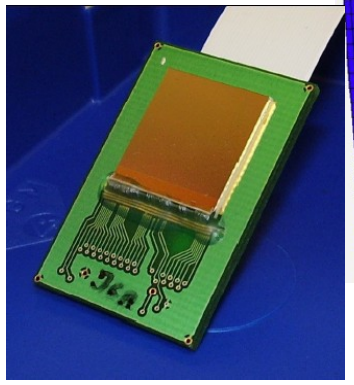
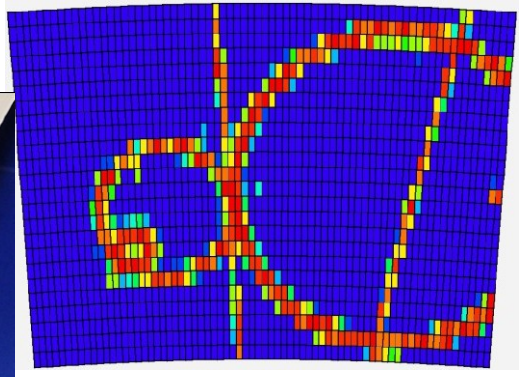
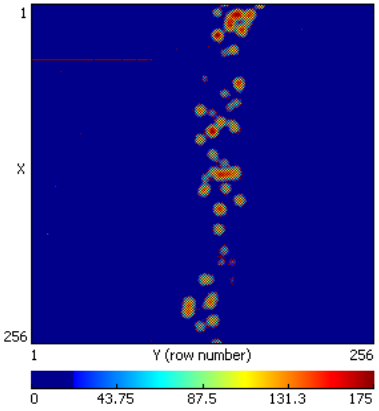
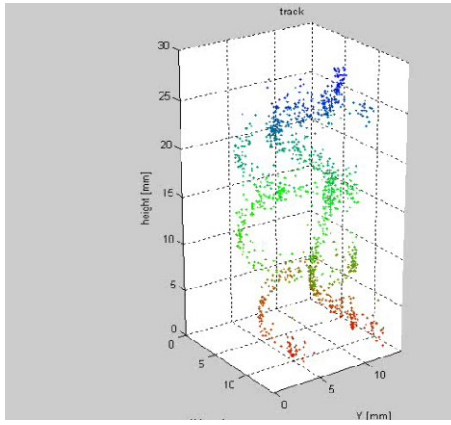




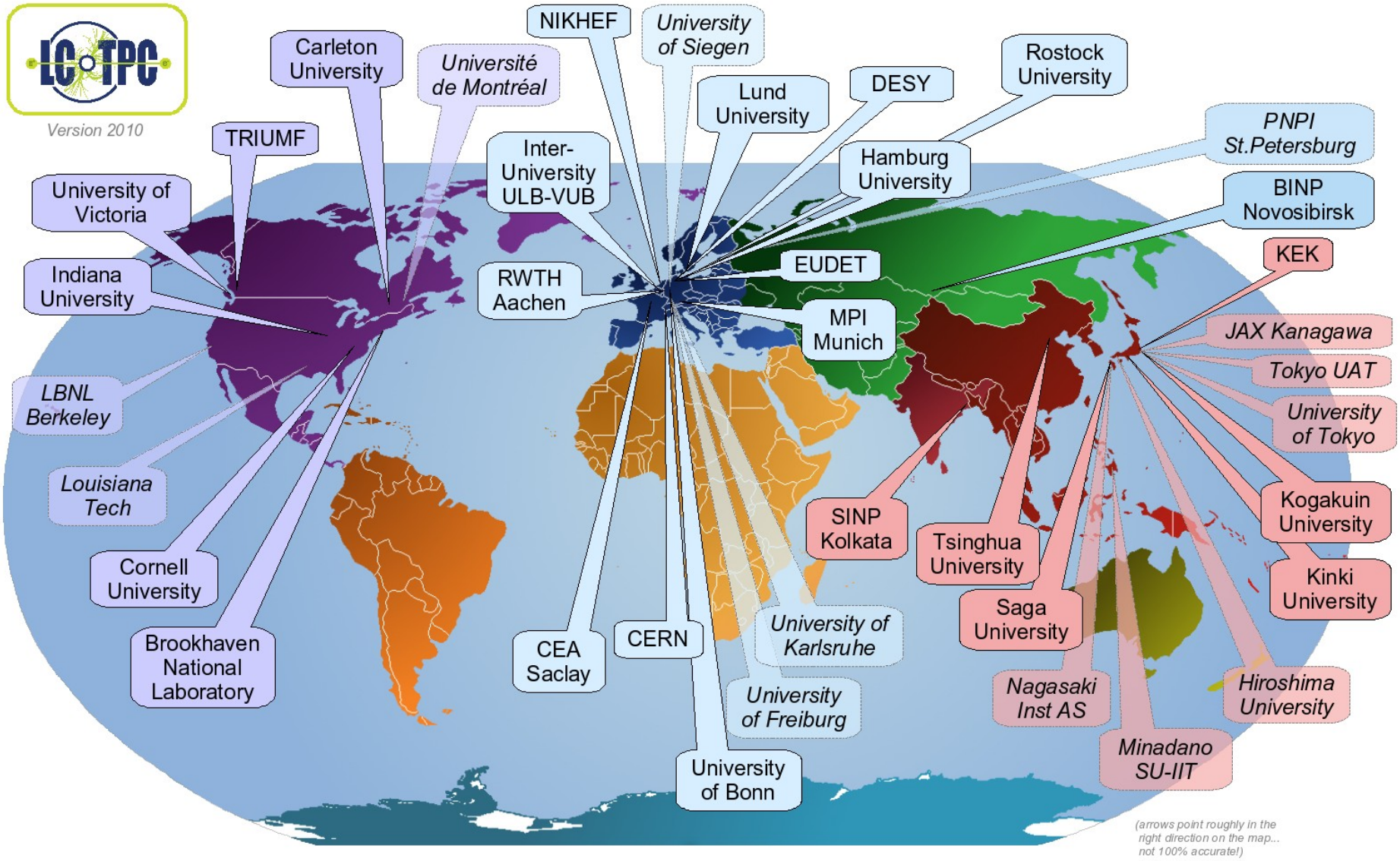




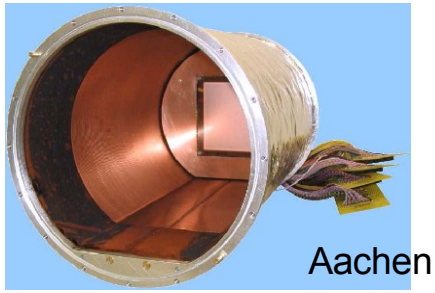


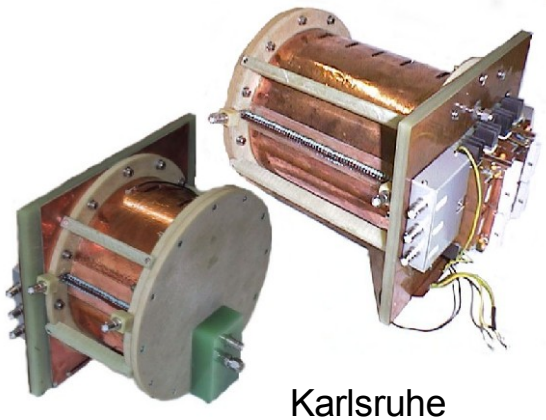


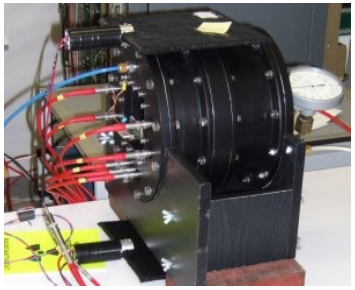
- German efforts embedded in international collaboration (LCTPC)



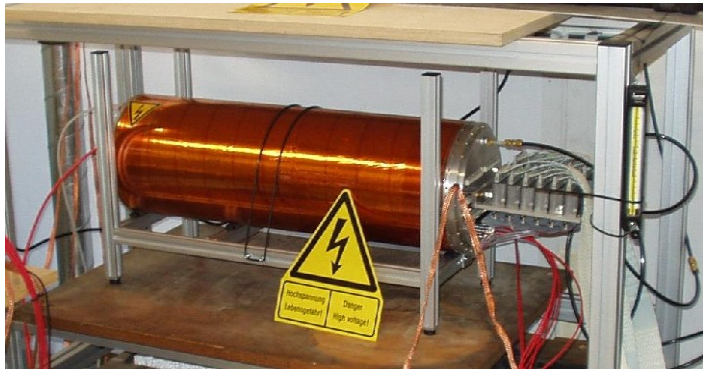
- Goals: Proof of principle
  - Operation of TPC with MPGD readout
  - Study working parameters
    → stable operation
  - Demonstrate the point resolution
  - Lightweight field cage design


Aachen

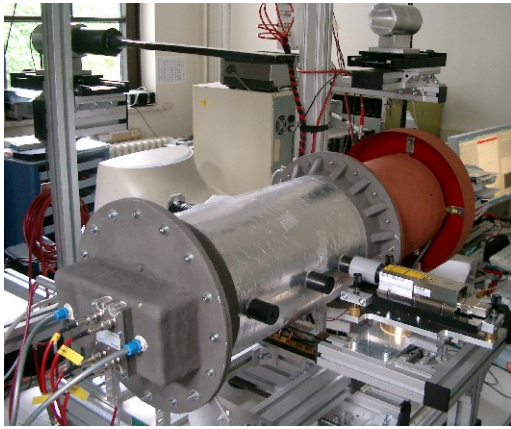

Karlsruhe

Rostock


- Small TPC prototypes (dia. ~30 cm)
  - Mostly GEM amplification
    with pad readout studied


Hamburg

- Result:
  - Stable TPC operation with
    MPGD readout possible
  - Resolution goal demonstrated


Siegen

Groups involved:
DESY, Aachen, Karlsruhe,
Bonn, Rostock, Freiburg, Siegen

Demonstration Phase

- Goals: Proof of principle
  - Operation of TPC with MPGD readout
  - Study working parameters → stable operation
  - Demonstrate the point resolution
  - Lightweight field cage design
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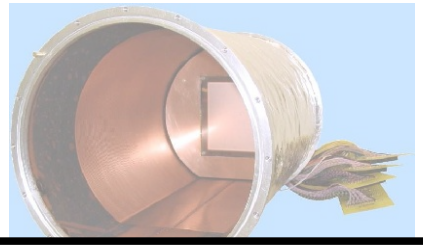
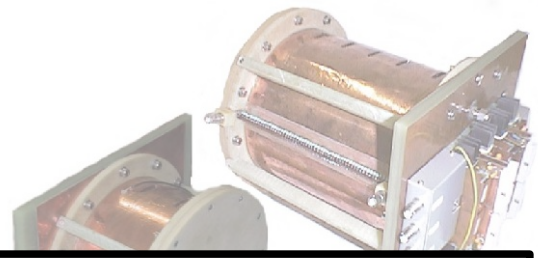
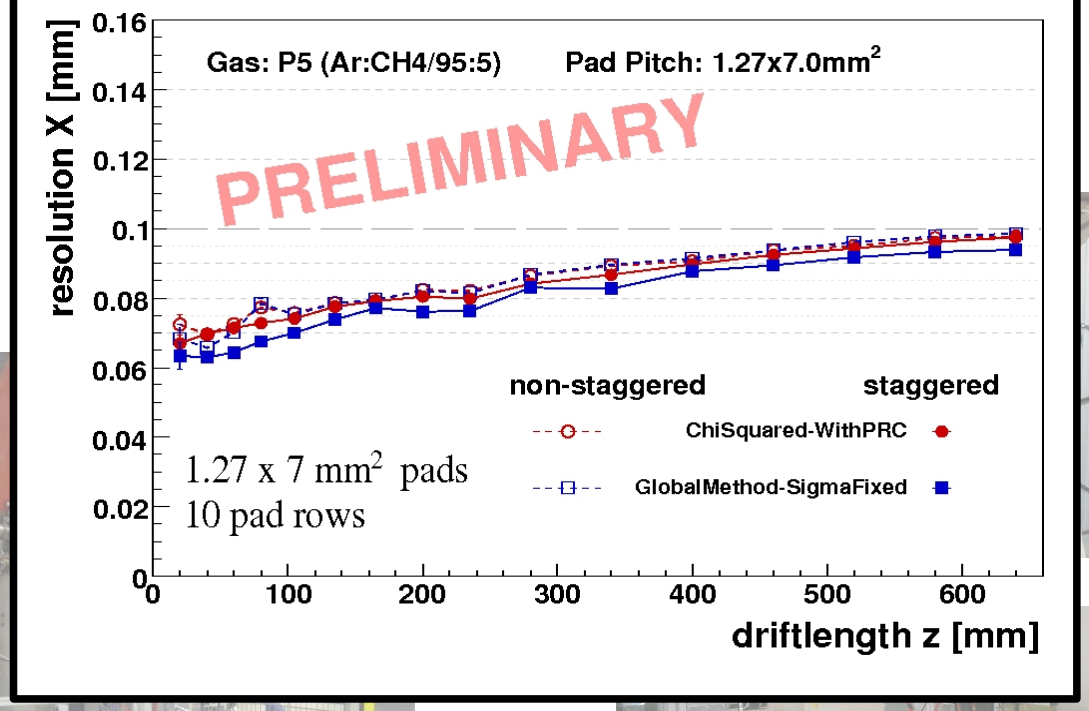
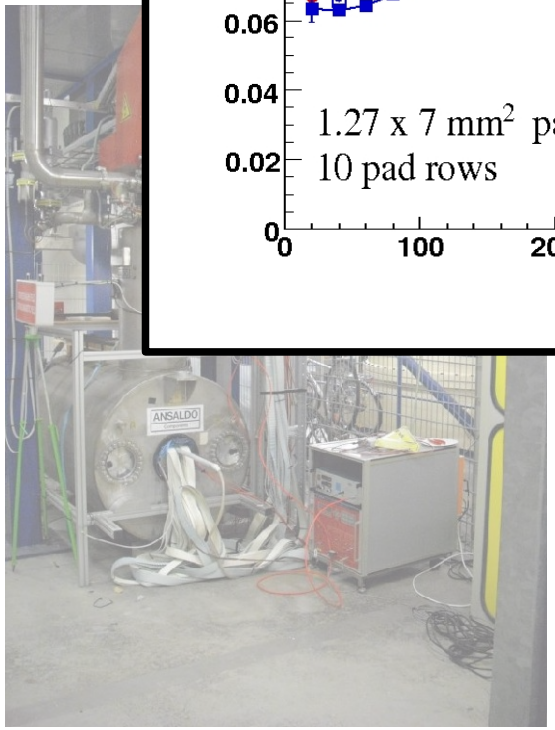
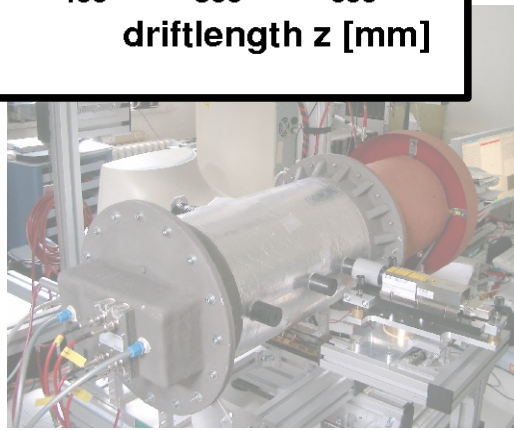








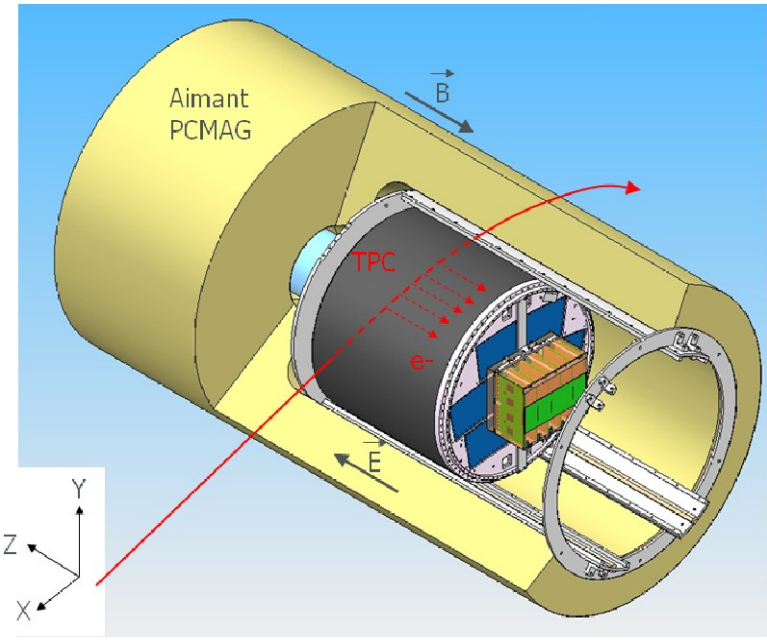


Siegen

- Goals:
  - Move from small-size prototypes to realistic prototypes
    - Large surface MPGD structures
    - Several readout modules in parallel → study joints between modules
    - Realistic field cage design
    - Operation in a test beam area

Groups involved:
DESY / Hamburg, Bonn, Siegen
Rostock, Freiburg, Mainz

- Installed at DESY in test beam T24/1
- In large parts funded by European EUDET project
- Comprises:
  - Large prototype field cage (d = 72 cm)
  - Modular read-out end plate
  - Superconducting 1T magnet from Japan
  - Movable stage for the magnet
  - Gas and slow control system
  - HV system
  - Beam and cosmic trigger
  - Planned: external reference via silicon detector
- Setup became available in November 2008



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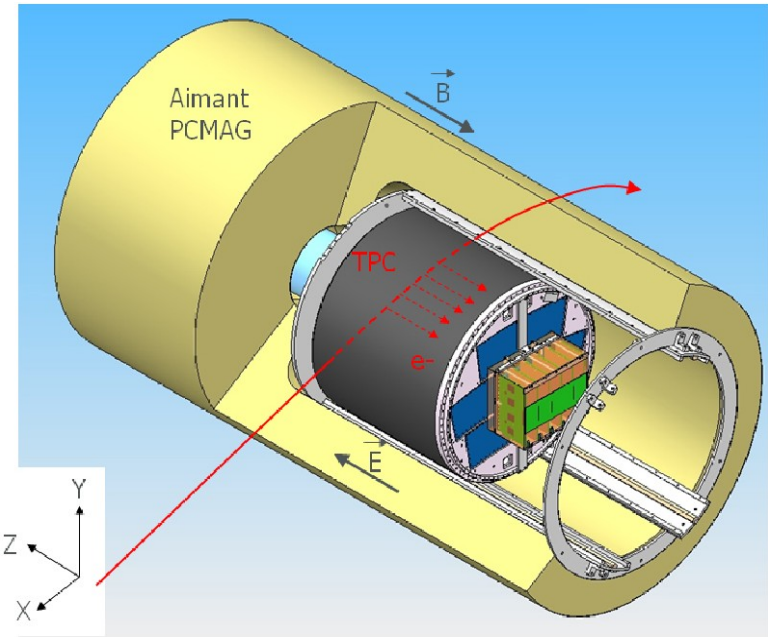

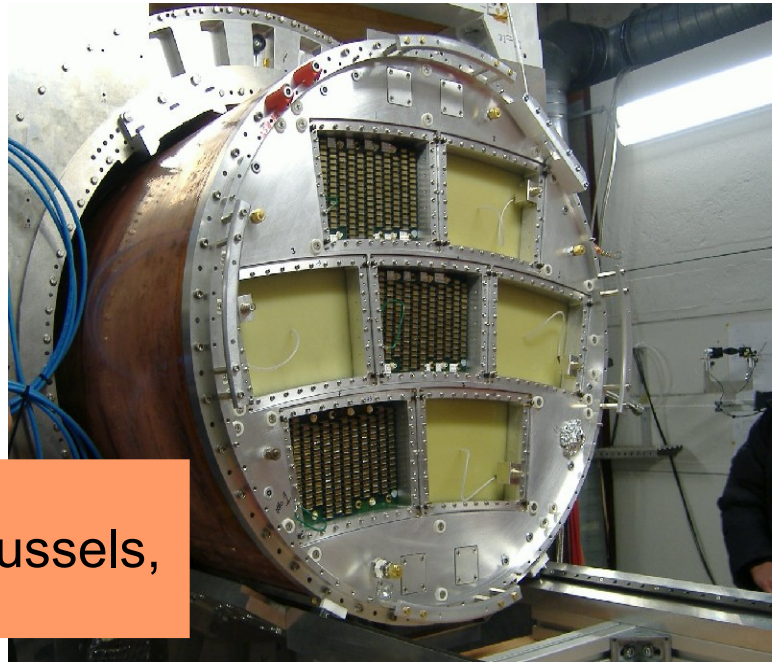

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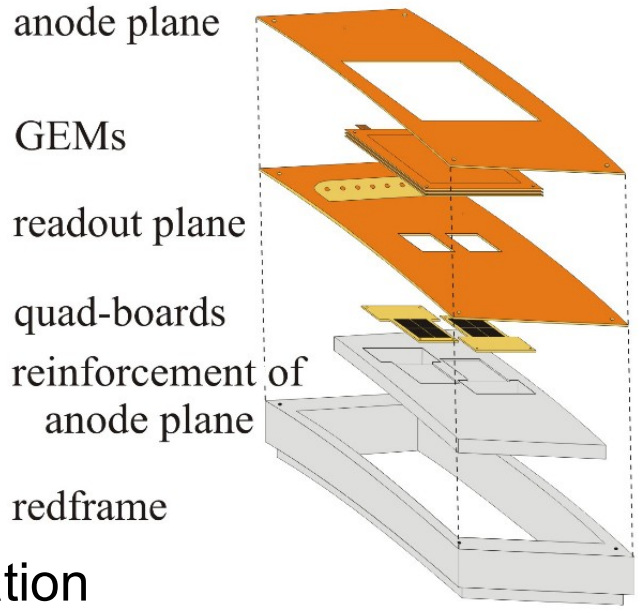
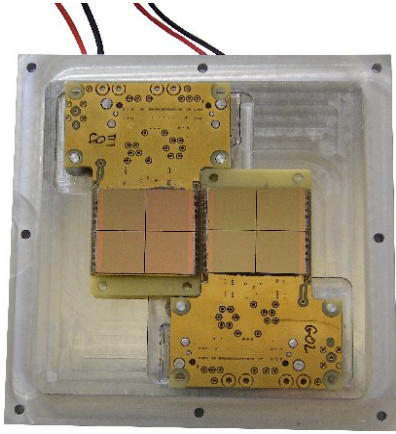
Pixel Readout

- Advantage of pixelized readout
  - 'Digital TPC'
    → pixel chip with integrated electronics
    - Integrated and lightweight anode
  - In theory: best possible resolution
    → limited only by gas diffusion
  - Single clusters become clearly visible
    → cluster counting





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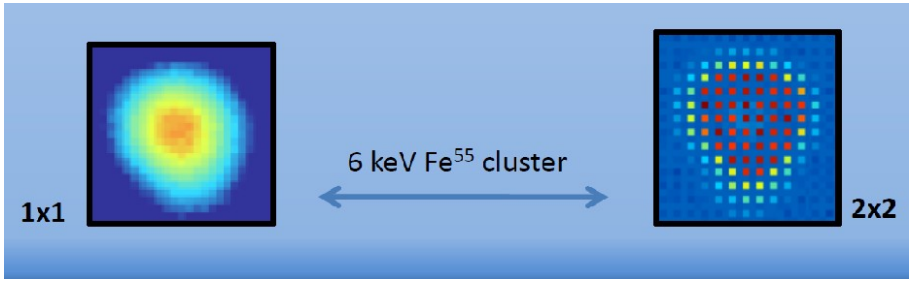
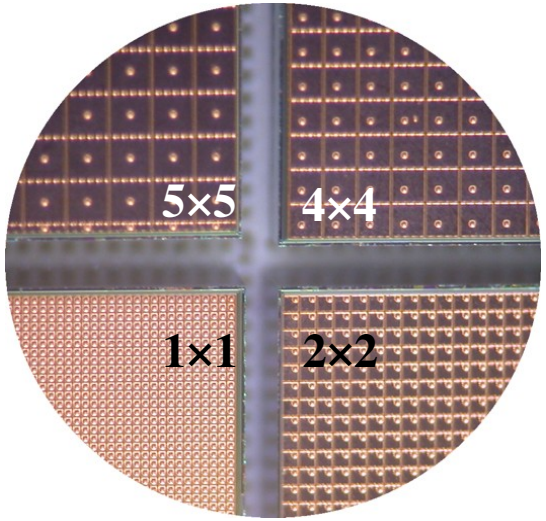
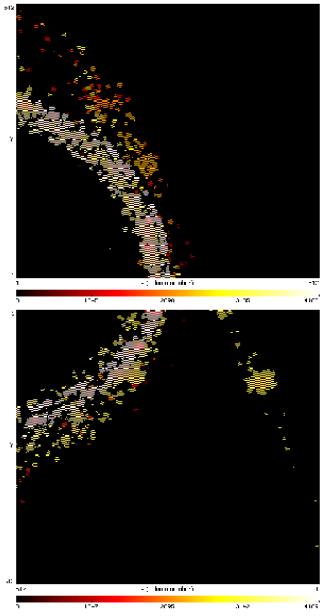
  - Test beam operations with LP module and in small prototypes
  - Optimization studies for pixel size







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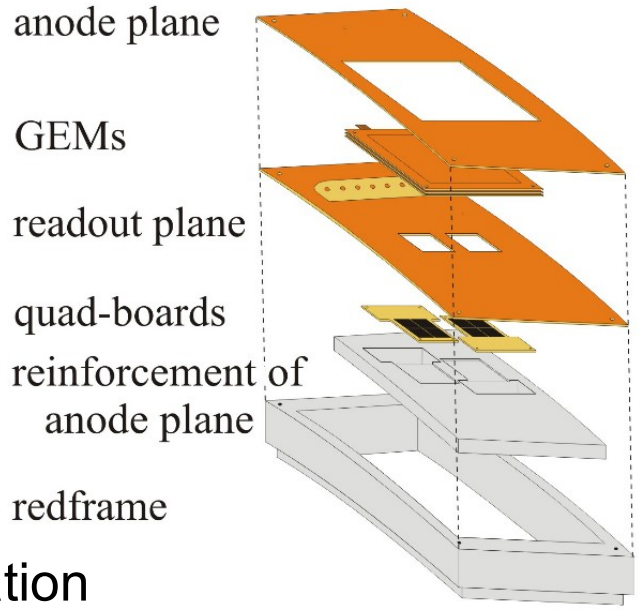

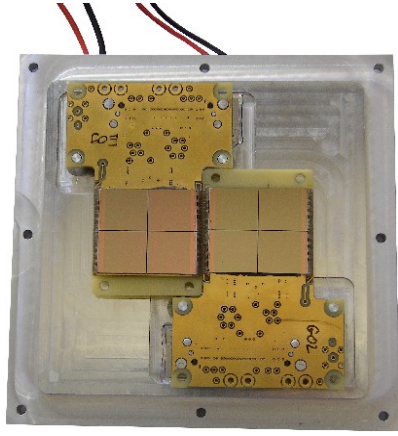

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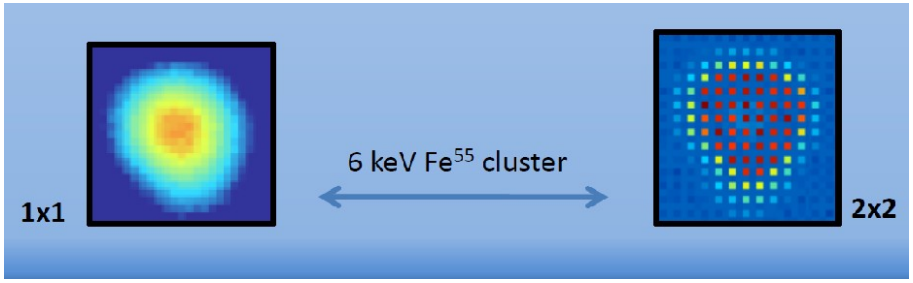
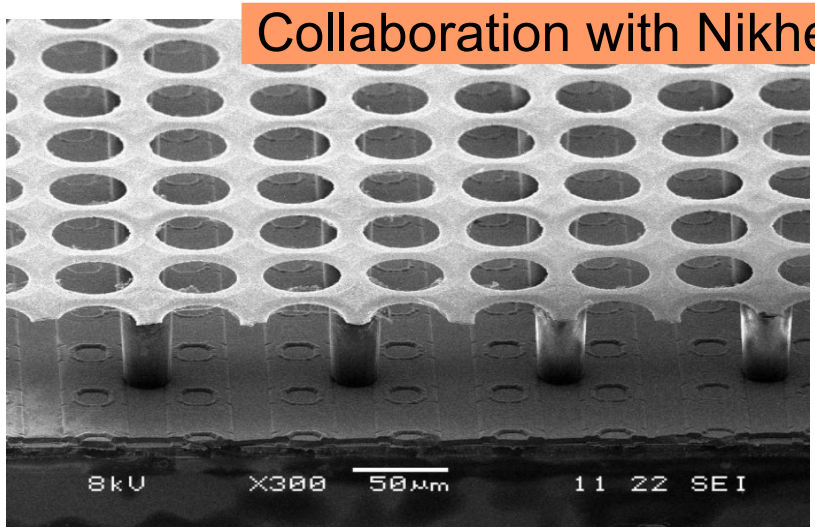


Collaboration with Nikhef



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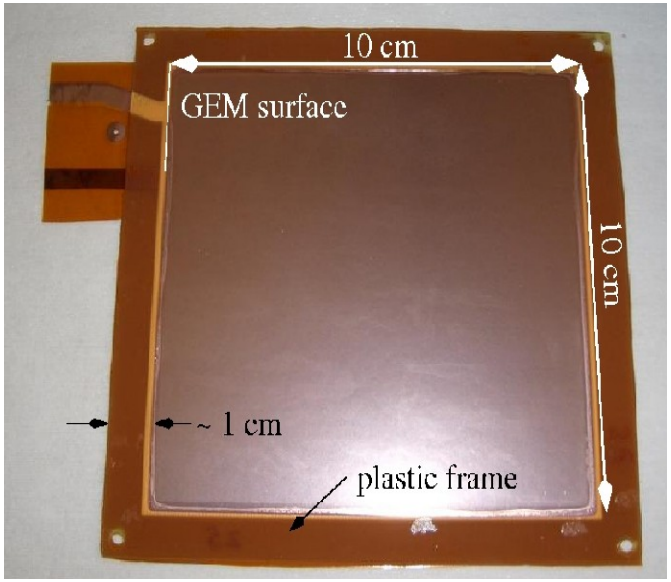
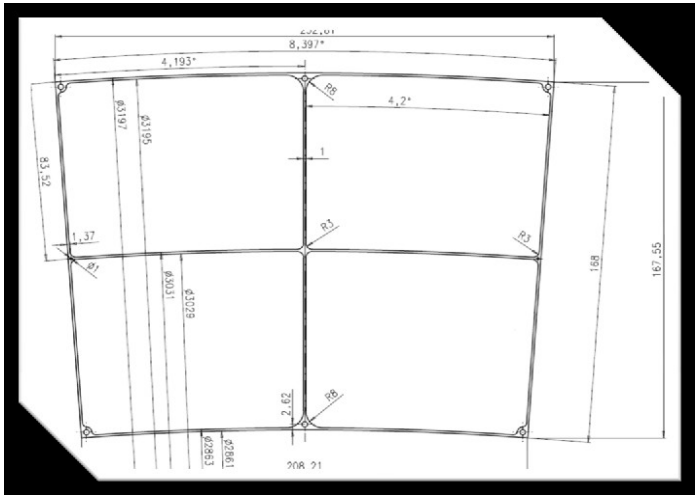
Bonn, Freiburg, Siegen

- New mounting structure for GEMs
  - Ceramic grid to support the GEM foils
  - Instead of stretching with broad frames
- Advantages:
  - More lightweight structure
  - Improved flatness of GEM foil:
    - less gain variations
    - better electric field homogeneity in the TPC
  - Simpler construction and possibility to cover large areas with minimal dead space
- Test in small prototype successfully finished
  - Now development of a read-out module for the LP Module frame is ready
    - GEMs, ceramic frames and pad plane are in development/production





Groups involved:
DESY, Bonn

GEM Amplification

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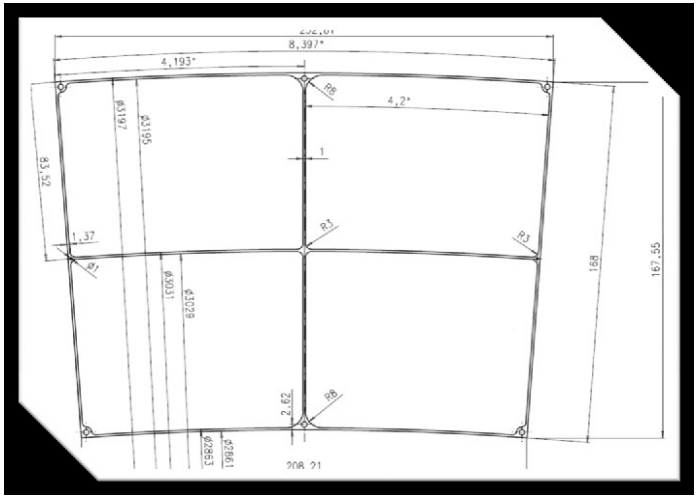
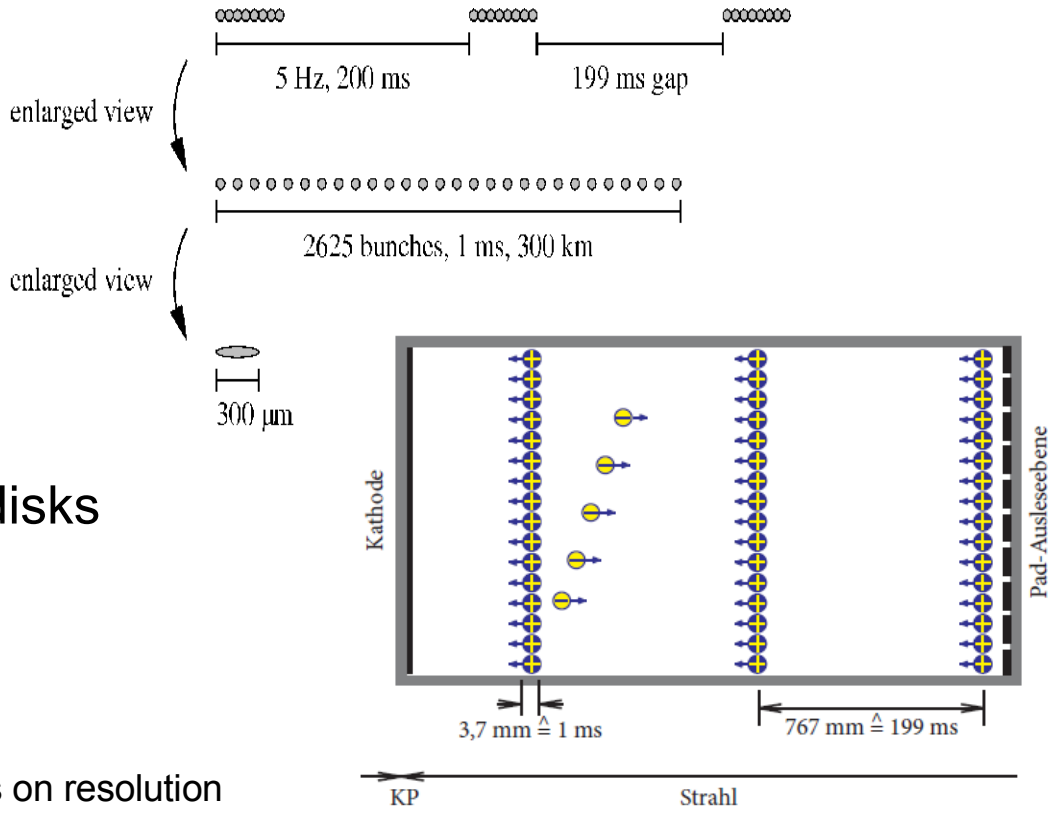


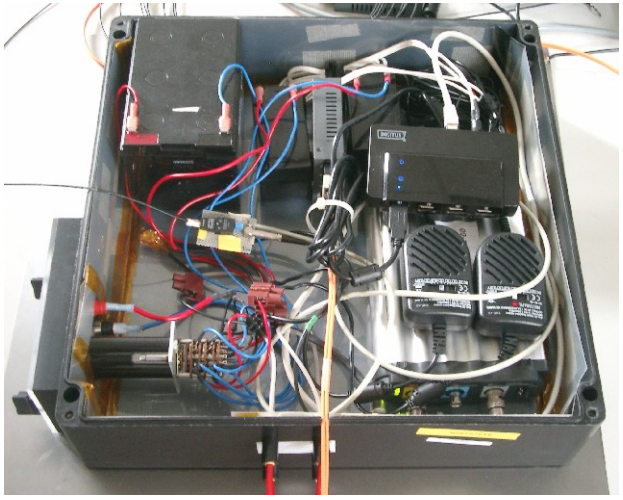
Groups involved:
DESY, Bonn

Ion backdrift

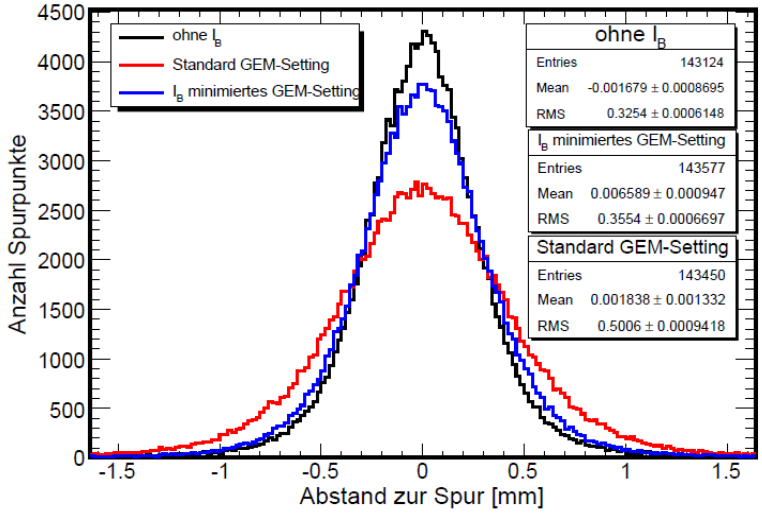
- Simulations of ion disks after each bunch train
- With adjusted GEM settings, the ion back drift can be minimized
- Measurement of ion back drift with a dedicated test setup
- Different ideas how to “gate” the ion disks



Cathode current measurement



Impact of ion disks on resolution

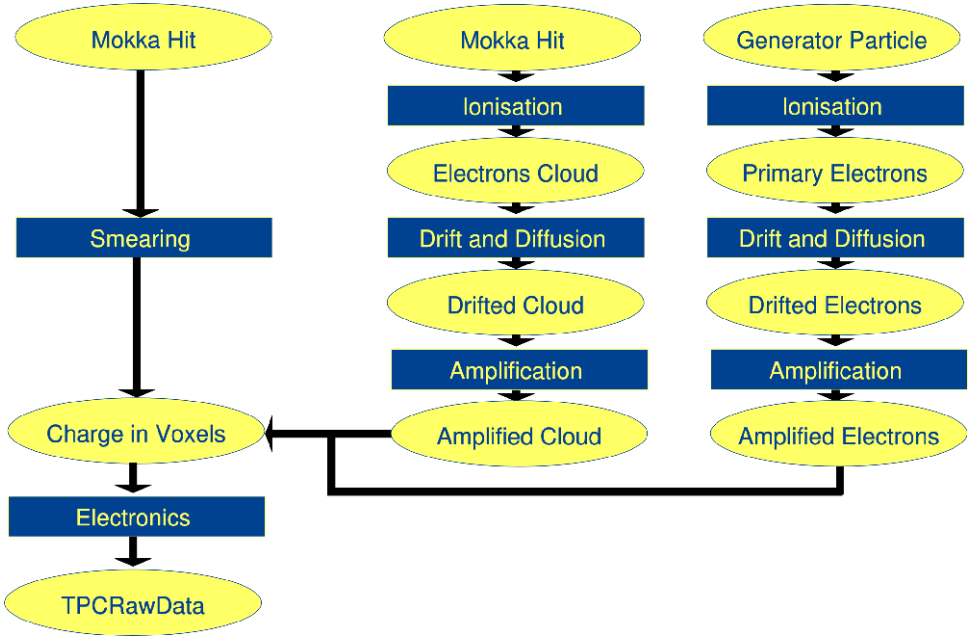


Groups involved:
Bonn, Siegen

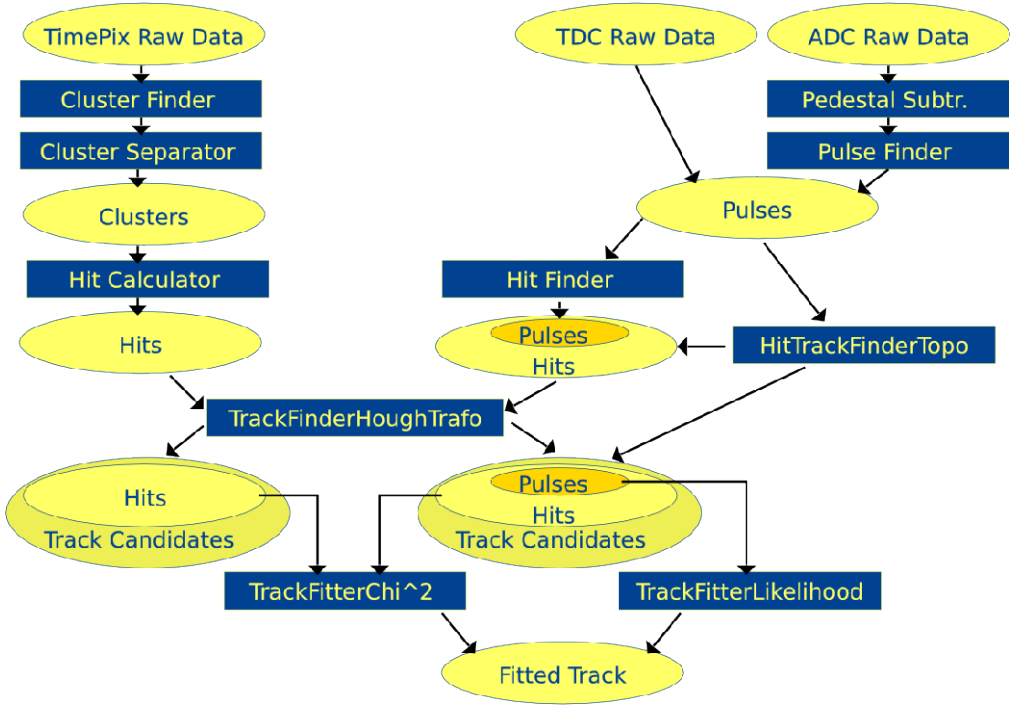
- International development of the MarlinTPC software: Simulation, reconstruction and analysis of MPGD TPC data
- Software uses the ILC software framework (Marlin, Gear, LCCD)
- Modular software design allows to easily compare algorithms and reuse existing solutions

Groups involved:
DESY/Hamburg, Bonn

Simulation



Reconstruction



Summary and Outlook

- LCTPC collaboration performs R&D work for a TPC at the ILC
- German groups involved in many topics and studies
- GEMs and Micromegas with standard pad or pixel read-out are under investigation for the TPC read-out
  - Feasibility of the principle demonstrated
  - Many studies with small TPC prototypes still ongoing
- R&D on realistic size readout modules and electronics has started
  - Large TPC Prototype test beam setup

- Next steps involve the design of a ILD TPC:
  - Concept for a final field cage → experience from the construction of the LP
  - Development of a lightweight, stable read-out end plate
  - Construction of large scale read-out modules
  - Read-out electronics including cabling and cooling
  - Finalization of a TPC software framework for data and simulation