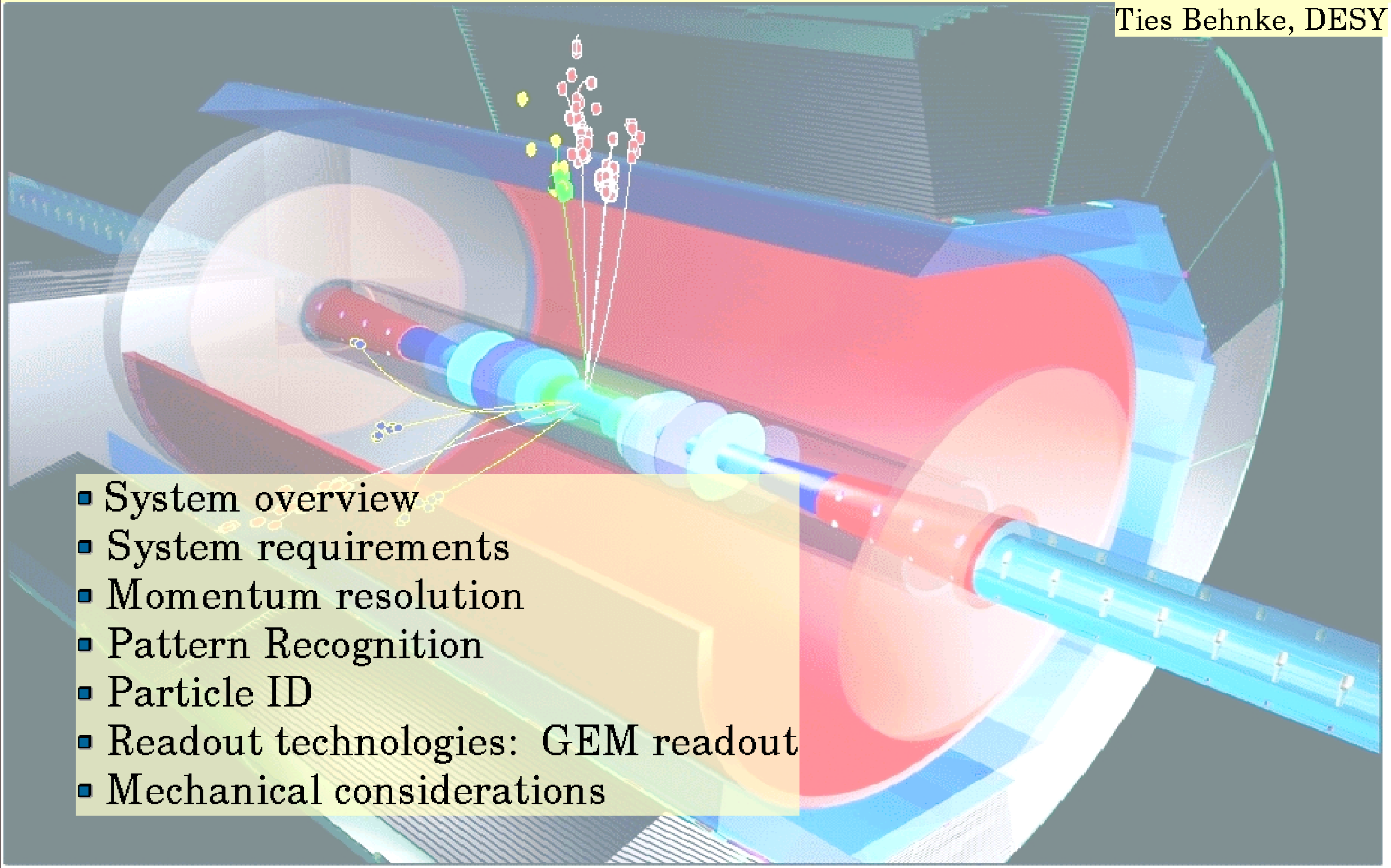
The TESLA Tracking System

Ties Behnke, DESY

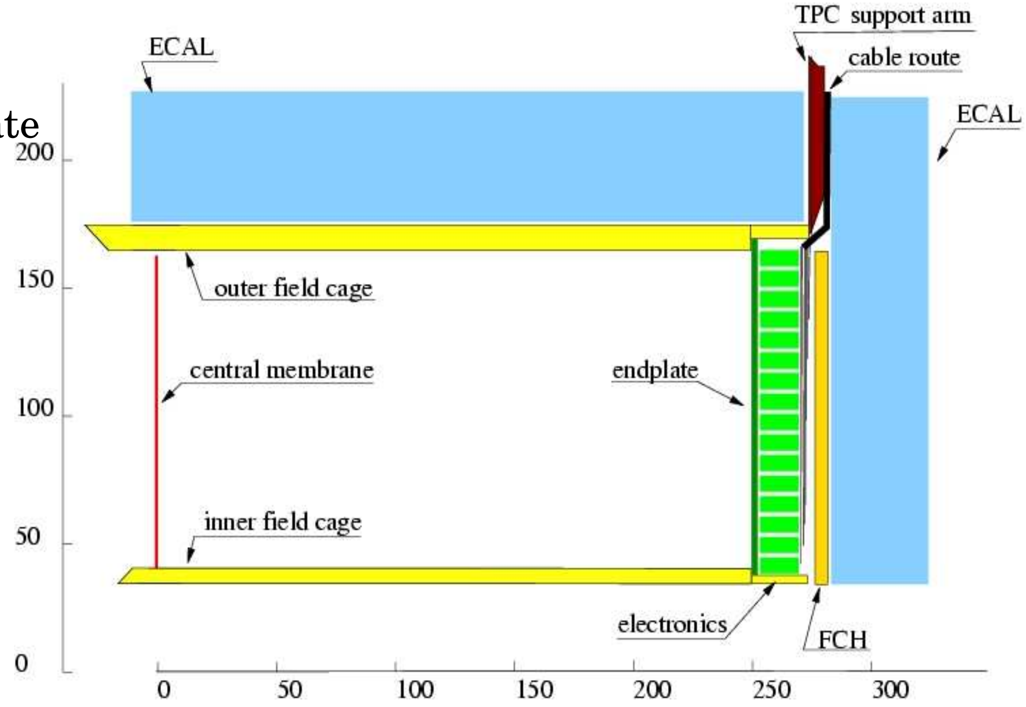


- System overview
- System requirements
- Momentum resolution
- Pattern Recognition
- Particle ID
- Readout technologies: GEM readout
- Mechanical considerations

Overall Layout

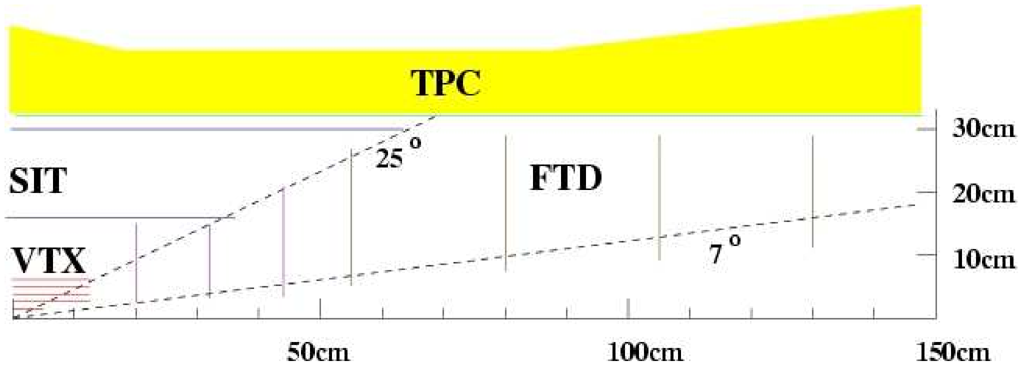
Central detector layout:

- Large volume TPC
- Forward chamber behind TPC endplate
- Silicon tracker at
  - Inner radius of TPC
  - Forward direction
- High precision VTX detector



Main purpose:

- Efficient pattern recognition
- Precision momentum measurement
- Precision vertex reconstruction
- Particle identification via dE/dx



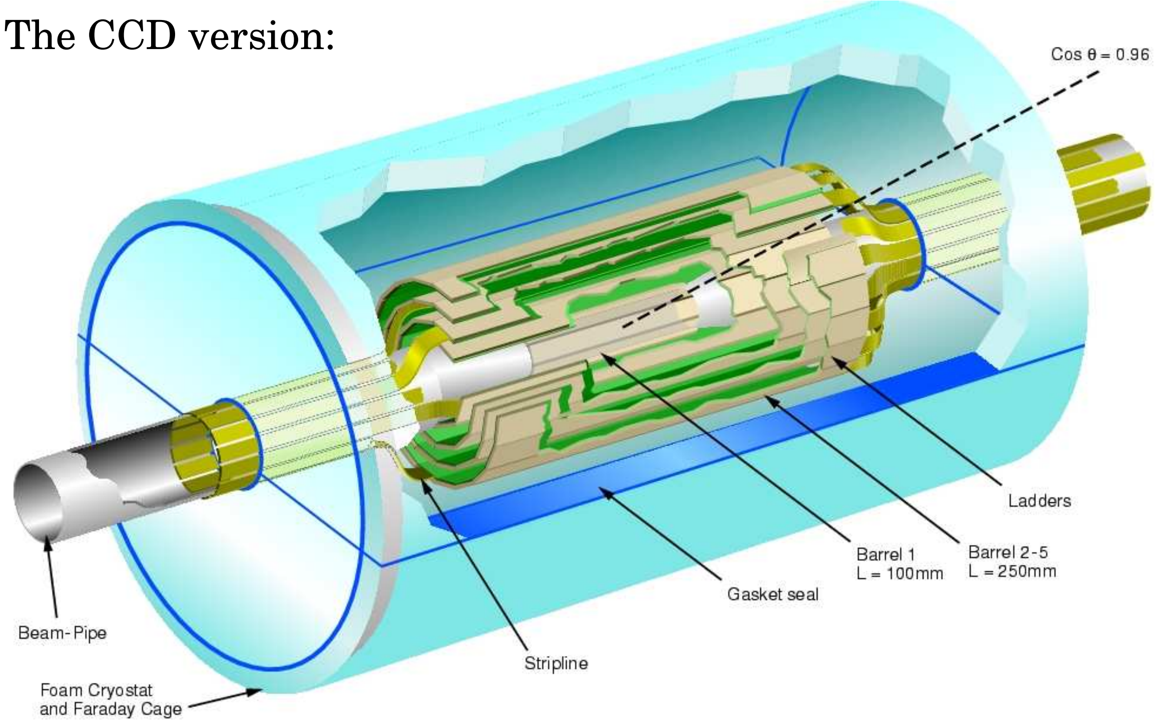
Environment:

- High magnetic field (4T)
- Background from beamstrahlung
- TESLA bunch structure:
  ~3000 bunches, 337ns apart

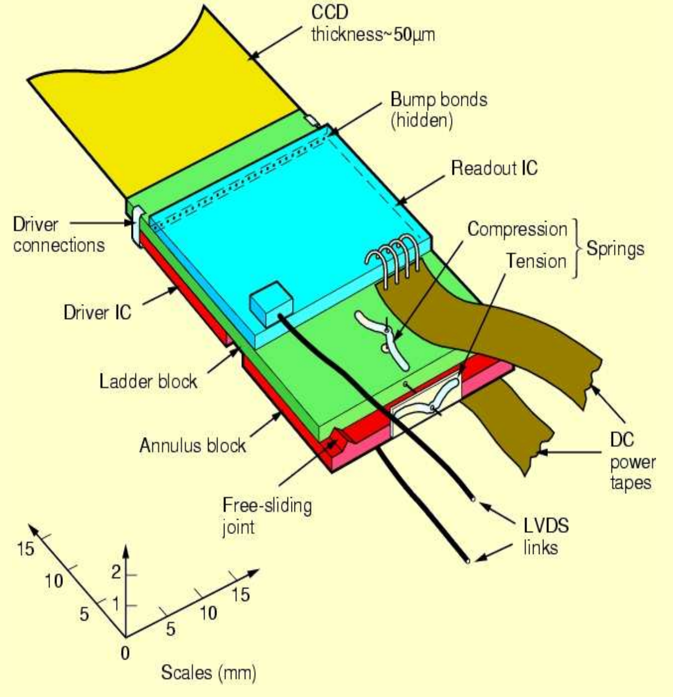
The VTX Detector

- High precision detector close to the beam pipe (R(min) = 1.5 cm)
- Several technologies are under discussion
  - Active pixel sensors (a la LHC technology)
  - CCD based sensors (SLD technology)
  - CMOS based sensors (new development)

The CCD version:



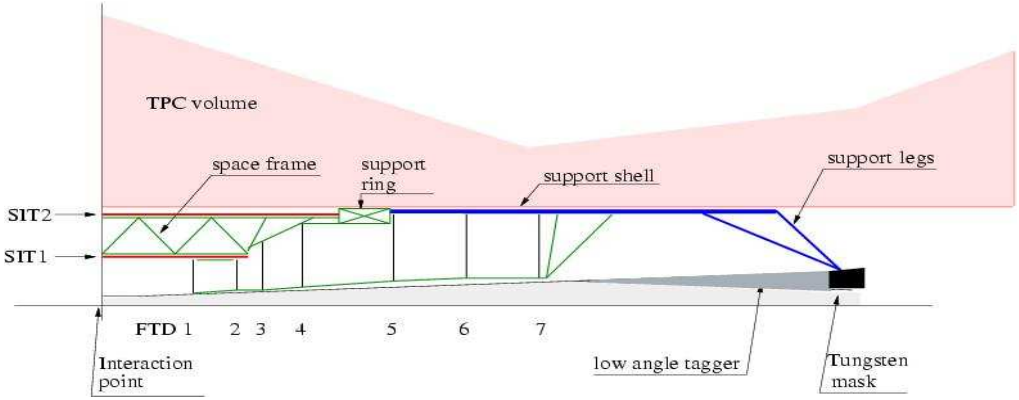
SI ladders are "stretched"



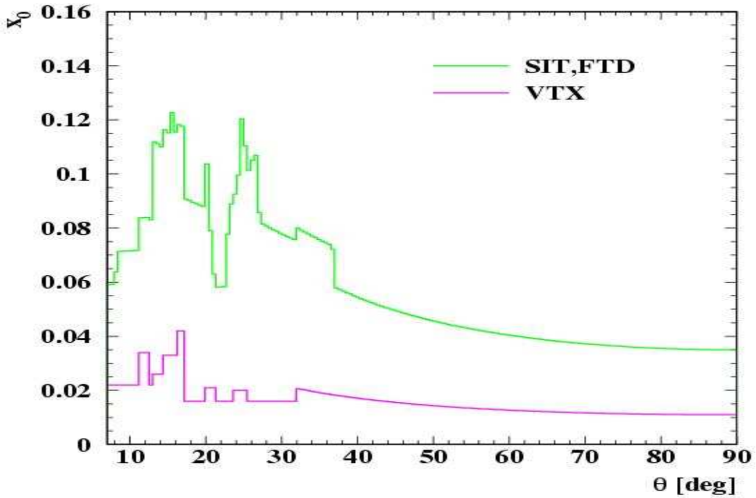
The SIT and the FCH

SI intermediate tracker system:

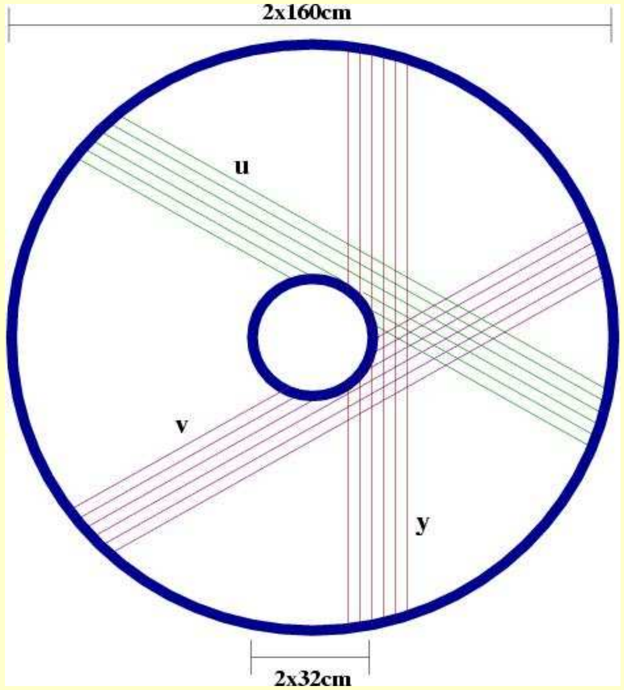
- SIT: 2 SI detector cylinders
- FTD: 7 SI detector disks



Material up to the TPC

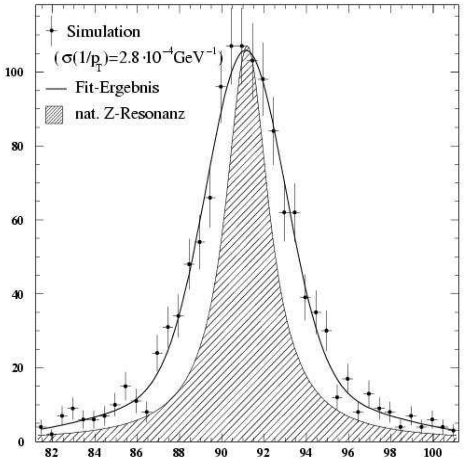


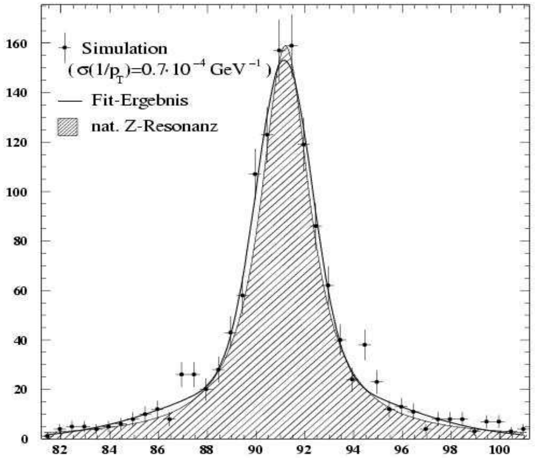
(Drift)–chamber behind the TPC endplate:



Momentum Resolution

Goal: recoil mass distribution not limited by detector effects

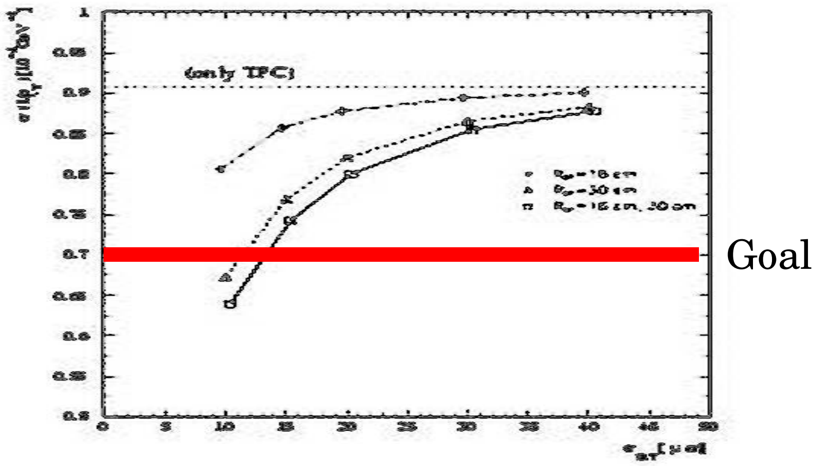




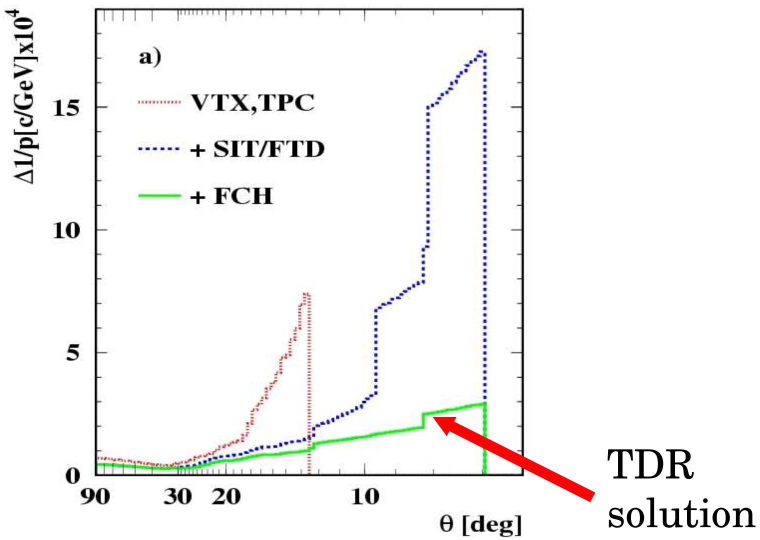
Momentum resolution:

$$\Delta(1/p)=0.7\times10^{-7}GeV^{-1}$$

Dependence on SIT radius and resolution



Dependence on the polar angle



TPC Readout Technology

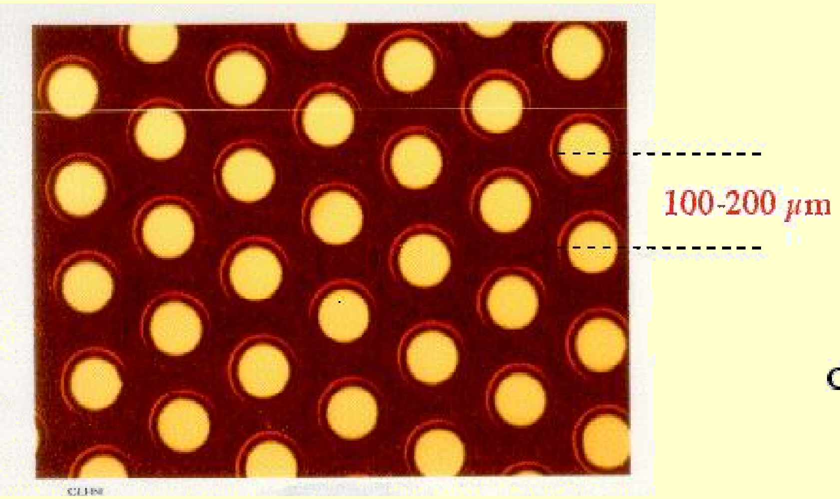
"traditional" wire chamber readout:

- Well understood, stable system
- "large" granularity
- Mechanically complicated
- Systematic effects through $\vec{E} \times \vec{B}$ effect

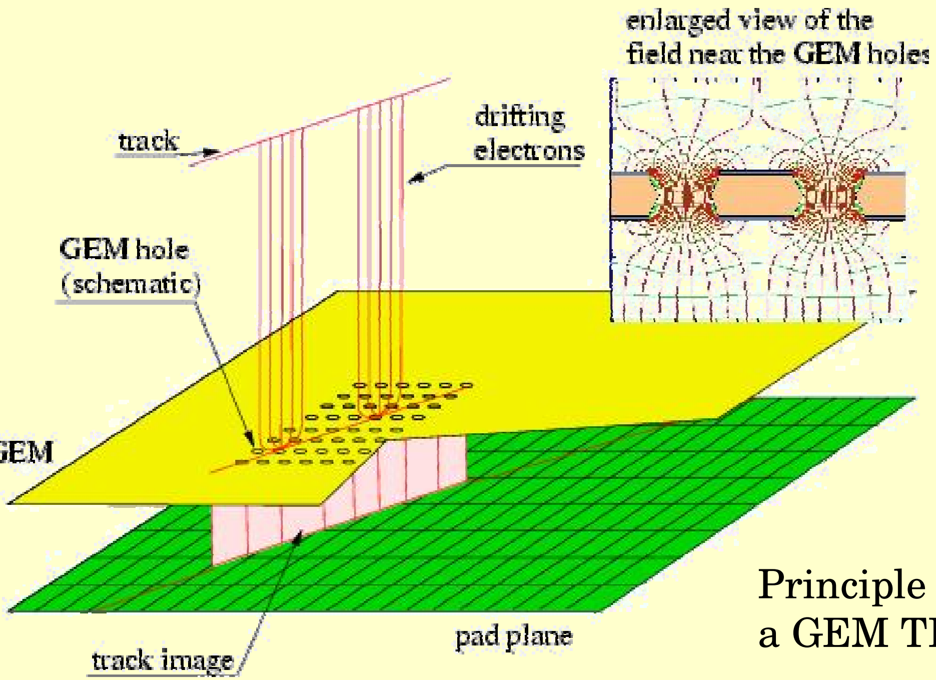
Alternative solution:

- Based on micro–pattern gas chambers
- GEM/ micromegas / ... chambers
- Mechanically potentially simpler
- Less material
- Less systematic effects (potentially)
- Not yet prooven in large scale projects

GEM: Gas Electron Multiplier



Enlarged view of a GEM

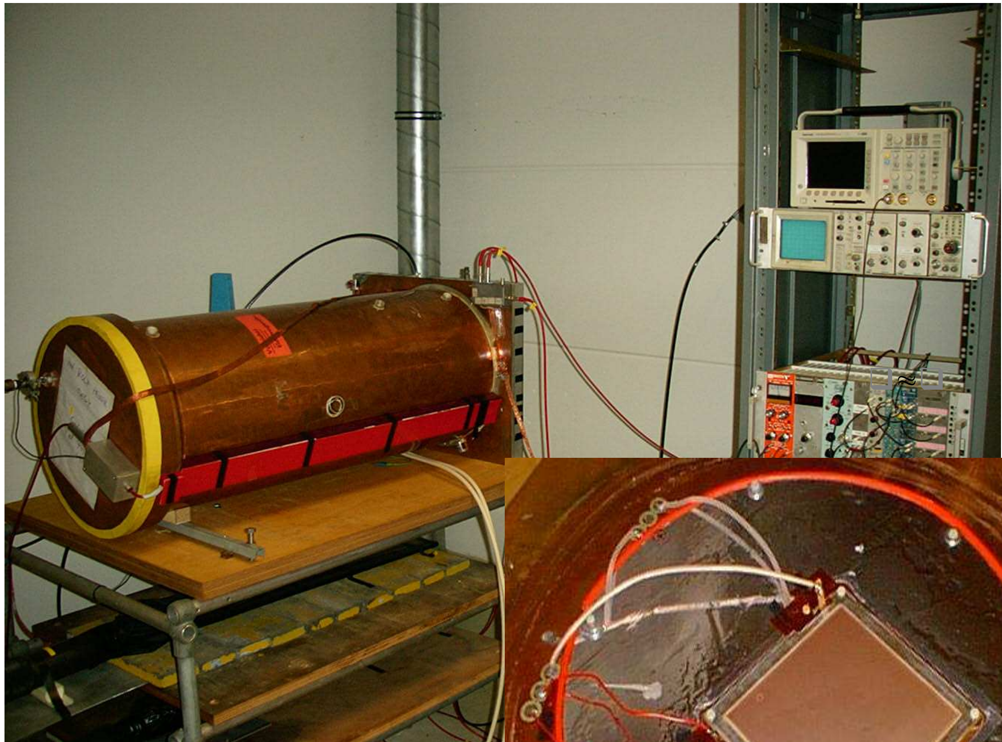


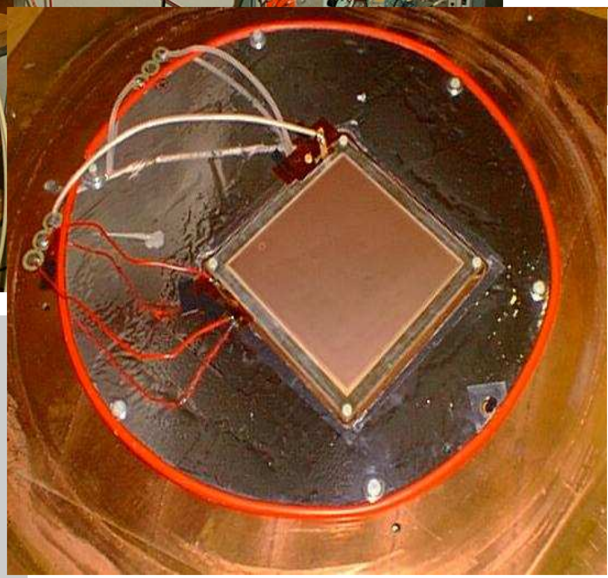
Principle of a GEM TPC

Protoype Results

TPC prototype equipped with GEM readout exists in Hamburg

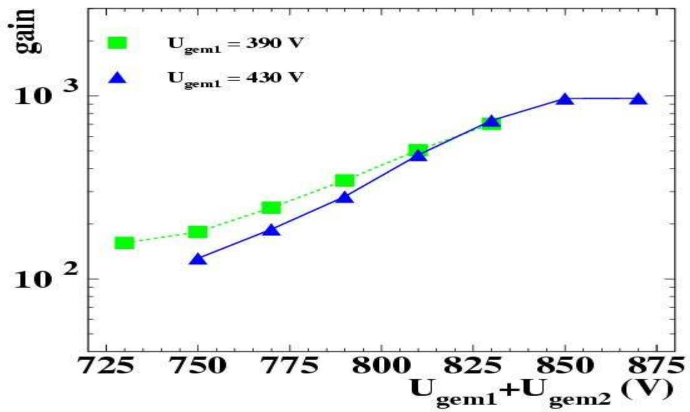
Thanks to Ron Settles for providing the TPC fieldcage



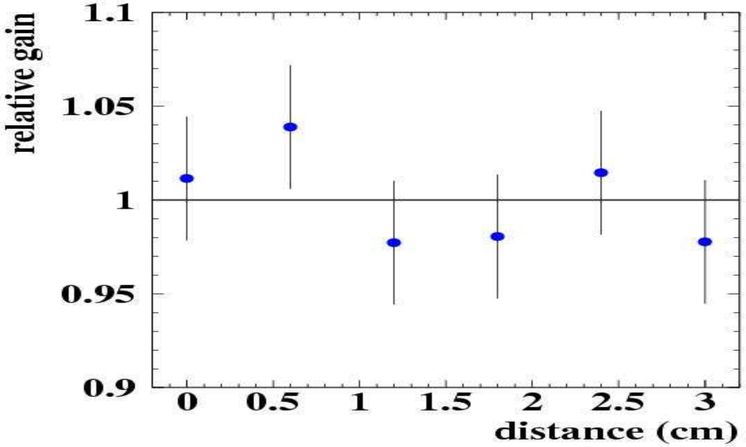


l(drift) ~ 1m
32 rectangular pads
2 GEM readout
cosmic events
gas: $Ar\,CH_4\,CO_2(93-4-3)$

Measured gain



Measured gain uniformity

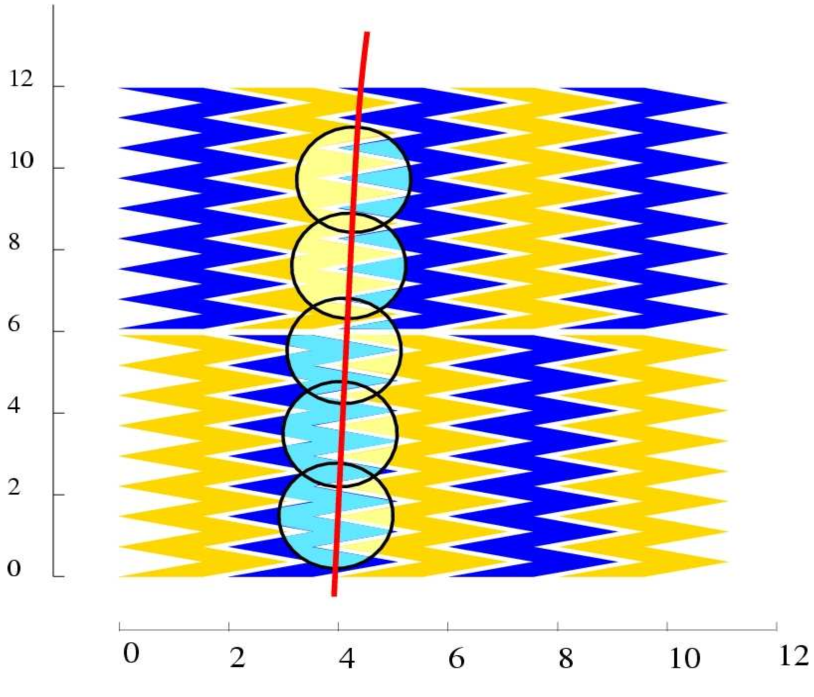


Single Point Resolution

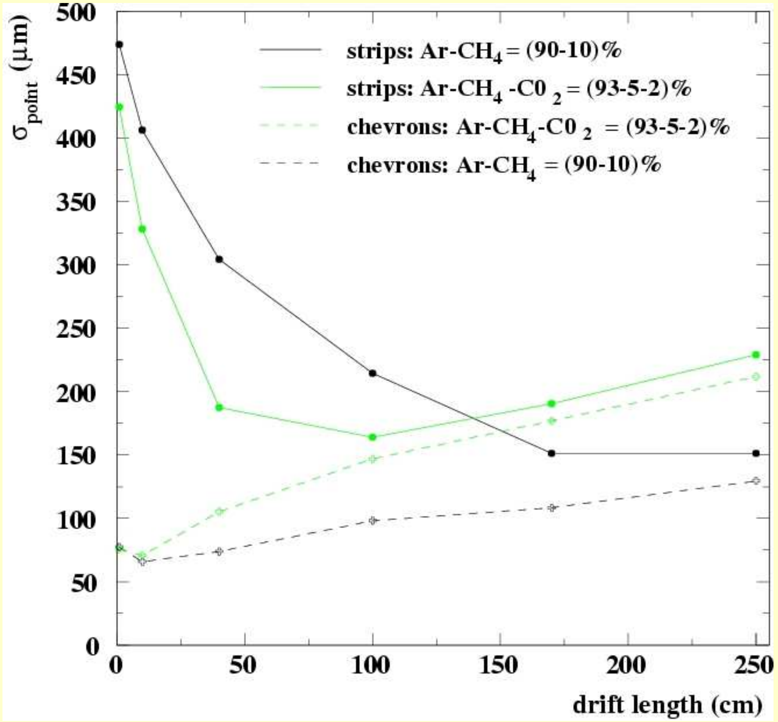
GEM readout:

- 2D readout possible
- Intrinsic dimension of the GEM is 100um
  - ➔ Much too large number of pads

One possible solution: specially shaped pads ("Chevron")
enlarge the charge sharing between neighbor pads
improve the resolution



Results from simulation:

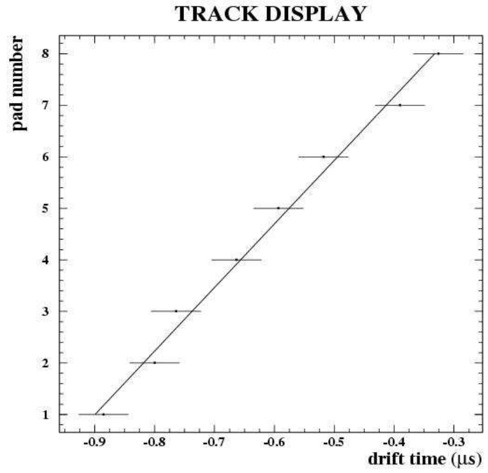


Chevron: small dependence on drift
good resolution (100–150 um)

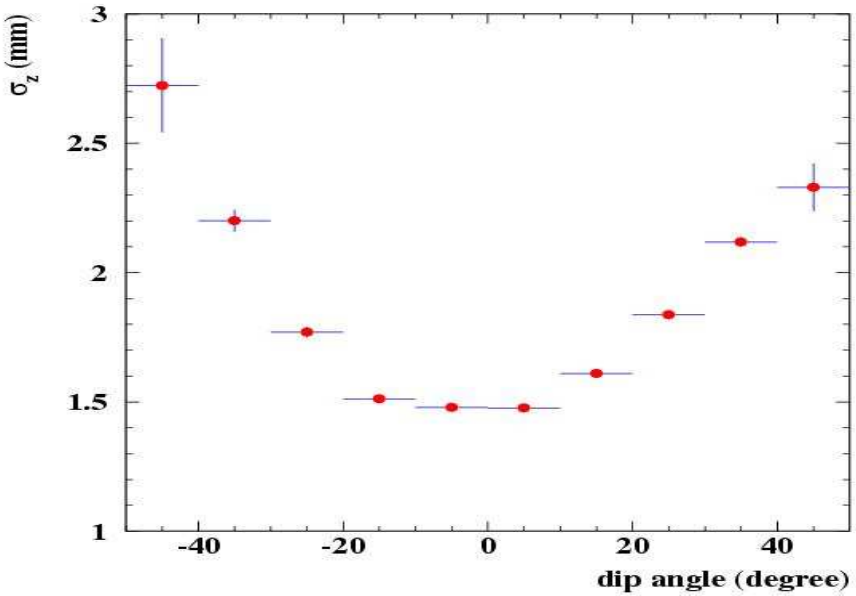
Protoype under construction

Prototype Results

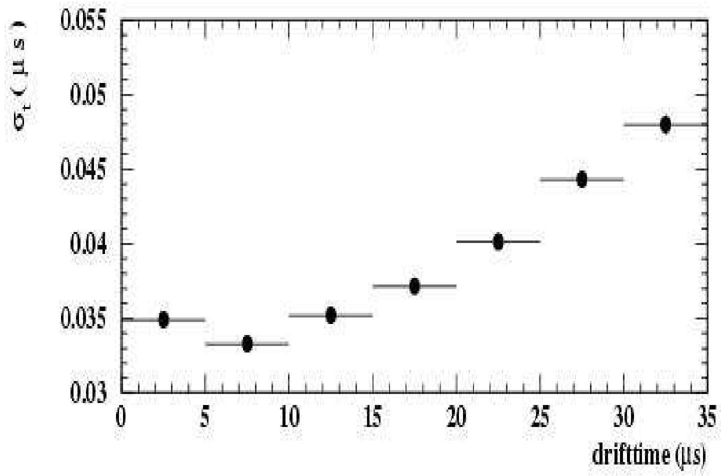
Measure the z–resolution using cosmic muons:



Resolution vs dip–angle



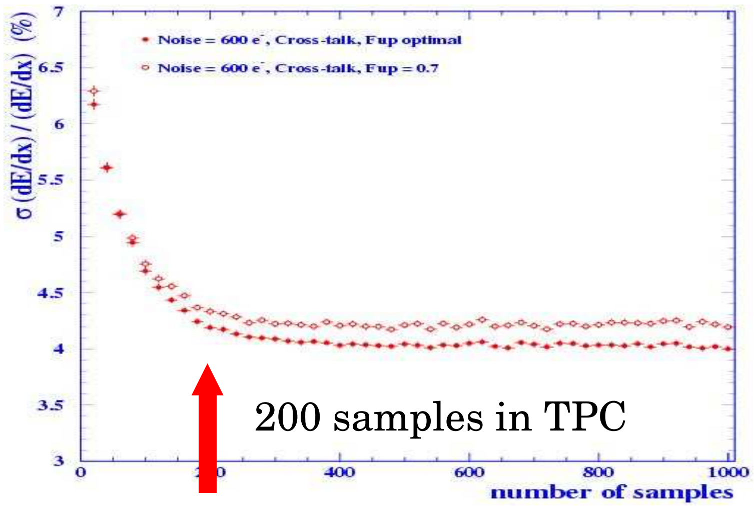
Resolution versus drift time



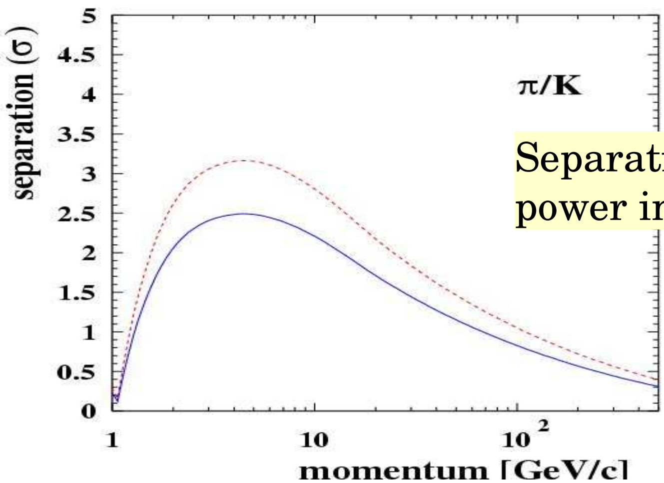
Overall performance as expected from the pad geometry in the prototype

dE/dx Resolution

Particle identification through dE/dx



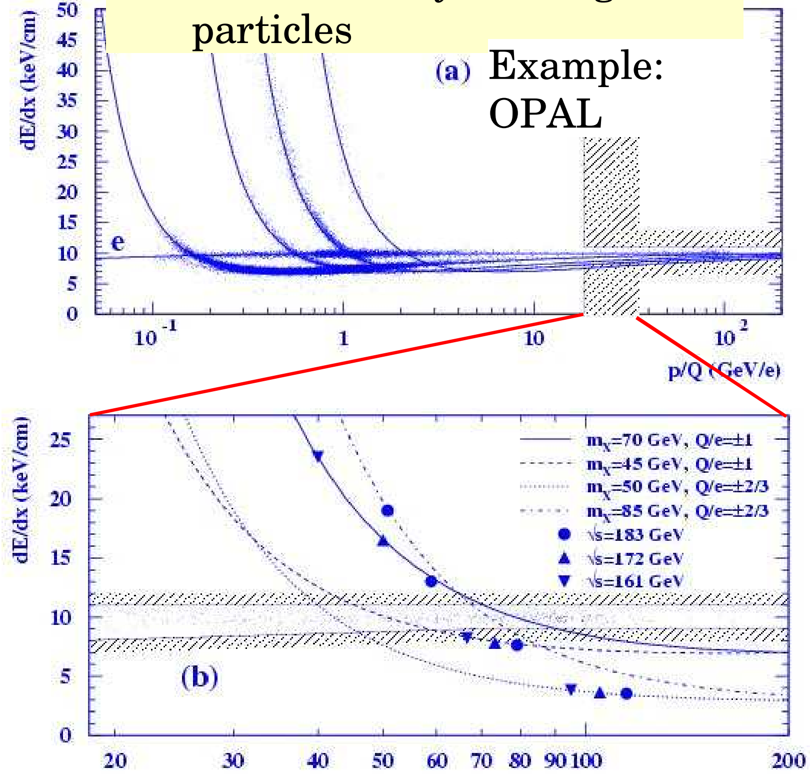
200 samples in TPC



Separation power in TPC

Possible applications:
search for heavy ionising particles

Example: OPAL

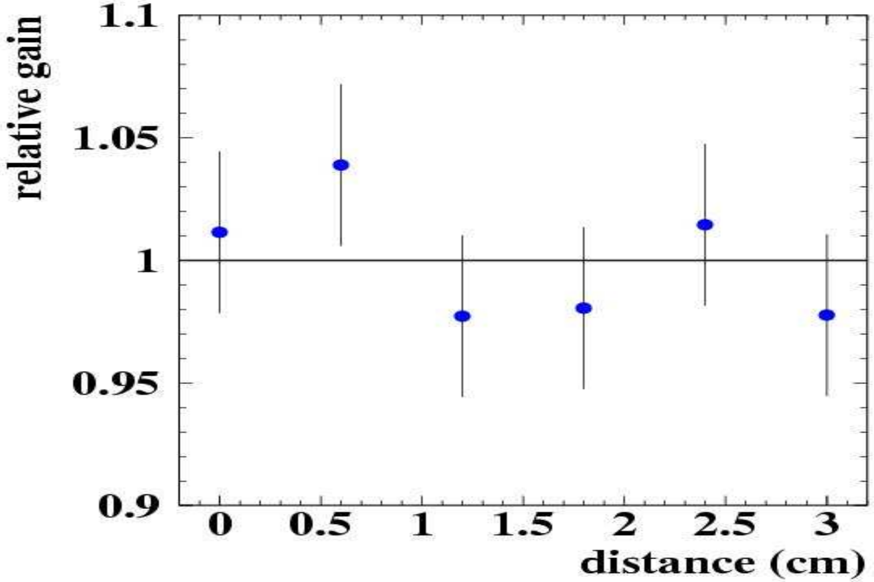


(Hadronic) particle ID not as important for LC as it is (was) for LEP/ SLD, but should nevertheless not be forgotten

Particle Identification

- Main requirement for particle identification:
  gain uniformity

Prototype test results:



Observed variations:
around 5% across a GEM

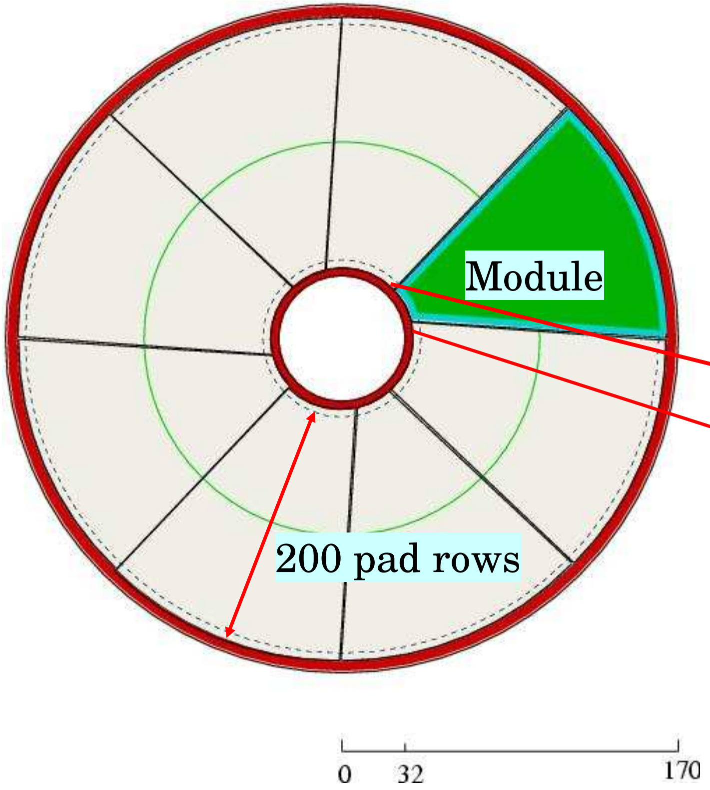
Problem

- need <2% for decent performance
- GEM production not optimised for uniformity
- Technology for better GEM exists at CERN, but needs to be tested and verified
- Calibration?

Endplate Design

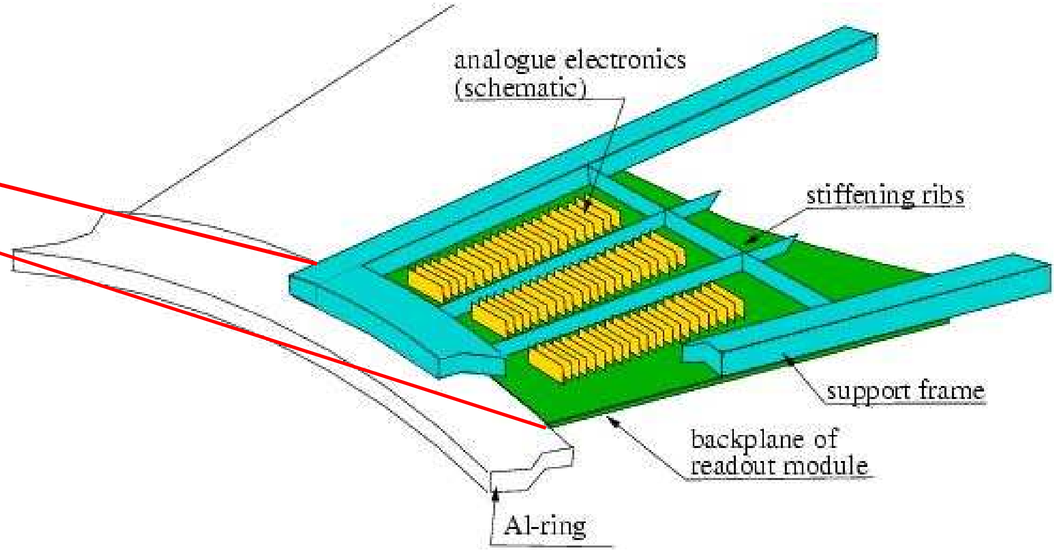
Overall endplate layout:

8 modules (follow ECAL geometry)
non–pointing boundaries



Schematic module layout:

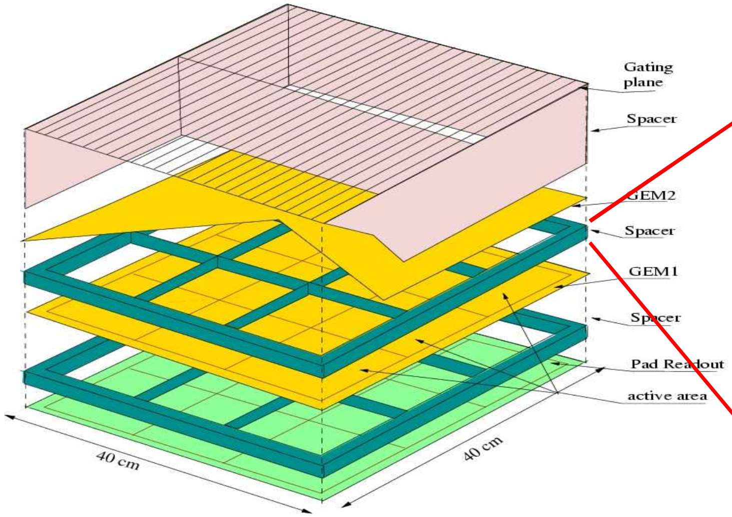
- backplane carries GEM tower
- stiffening ribs ensure rigidity
- electronics supported by backplane



Endplate Design

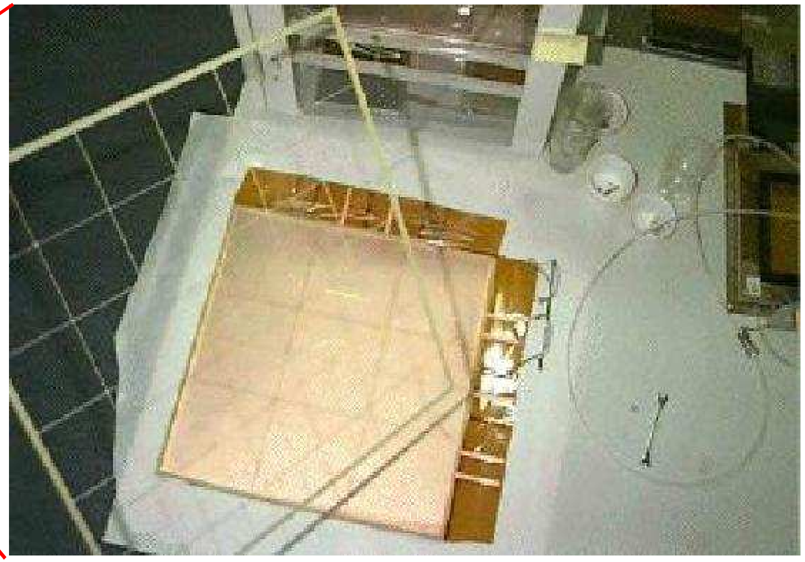
First iteration of a design for a GEM based endplate

Basic element: a GEM tower:



2 amplification GEMs
1 gating GEM to suppress the positive ions

Spacer frame to separate two GEMs:



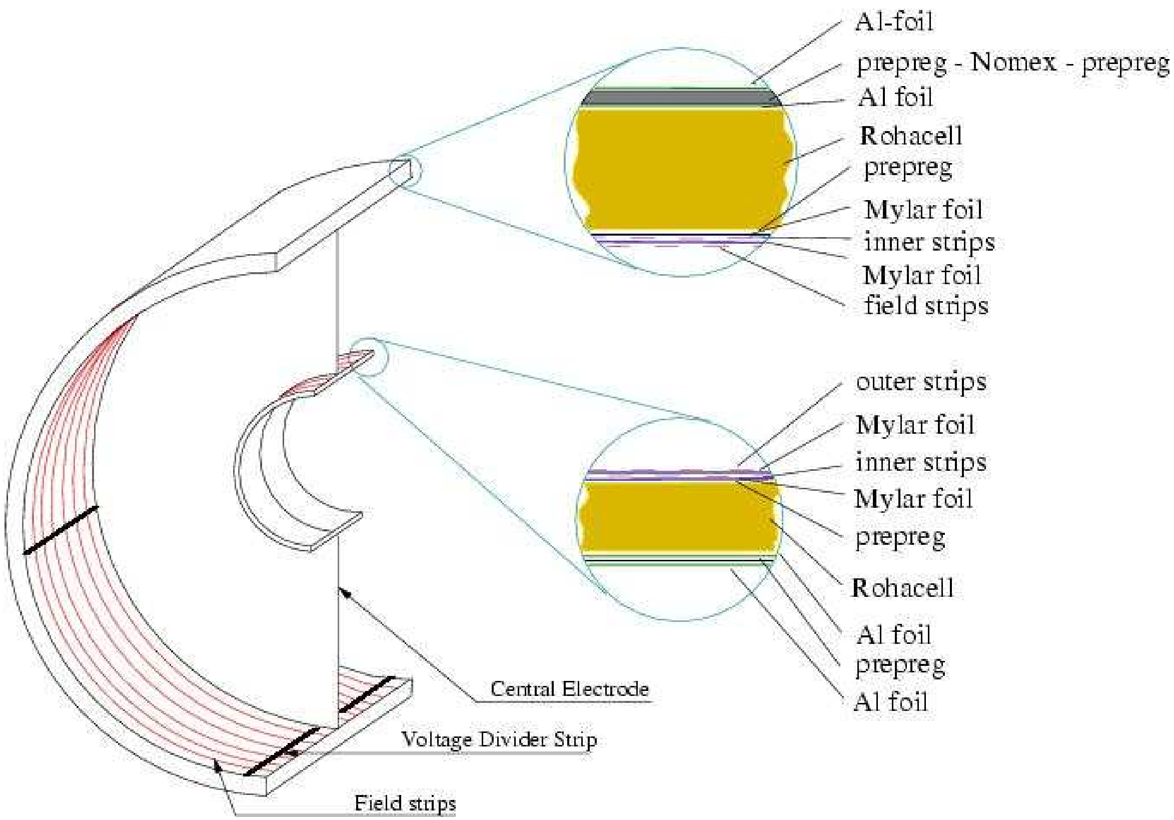
COMPASS prototype, Sauli, CERN

Prototype GEM tower is currently being constructed at DESY for test in the TPC

Field Cage

Fieldcage:

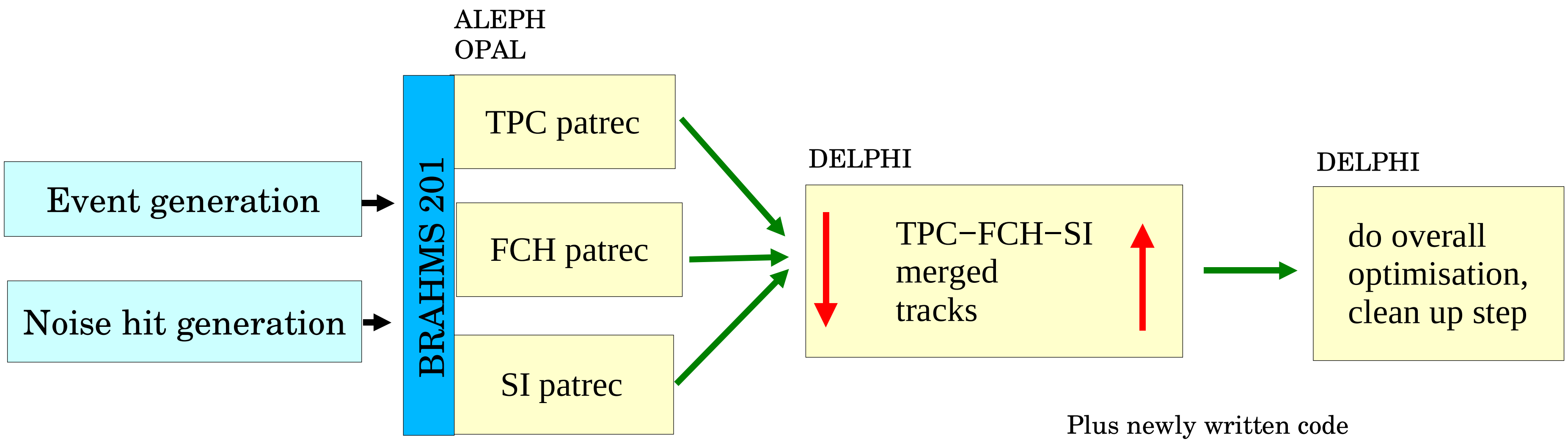
- Based on ALEPH/ALICE type field cage
- STAR solution (gas insulator) disfavored because of space
- Designed for V<100kV



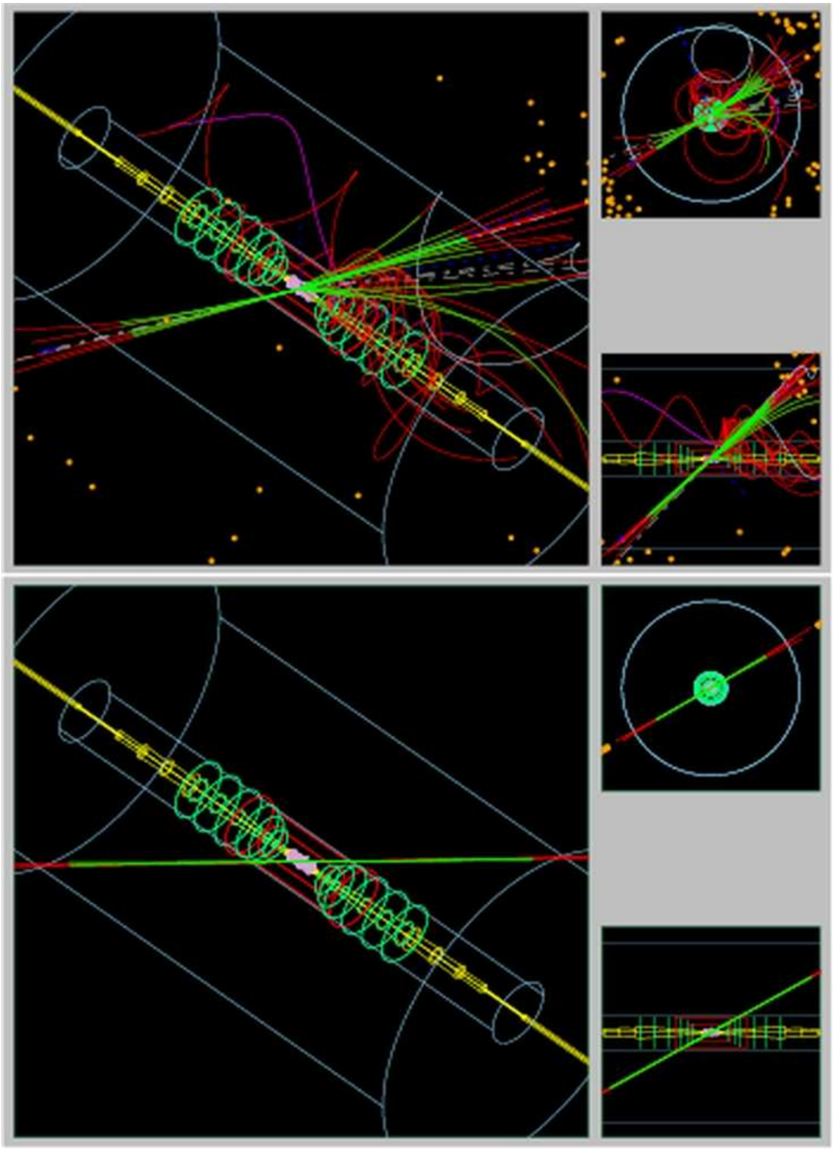
- Mechanical rigidity:
  Rohacell – Epoxy – honeycomb structure
- Electrical properties:
  multiple mylar sheets + Rohacell/epoxy
- Voltage divider:
  use miniature surface mount devices: test in Karlsruhe sucessful
- Further R&D is needed to optimise the design

Pattern Recognition

- Intense simulation effort within the ECFA DESY study:
  - Based on standard technology: GEANT3, Fortran, etc.
  - Complete simulation framework BRAHMS has been developed
    - Full simulation
    - Pattern recognition for central detector
  - Event visulation tool based on open GL
  - Reuse as much as possible existing software tools (LEP/ SLD/ ...)



Event Display



Visualisation software based on openGL toolkit

Easily interfaced to BRAHMS (full simulation)
SIMDET (fast simulation)

status:

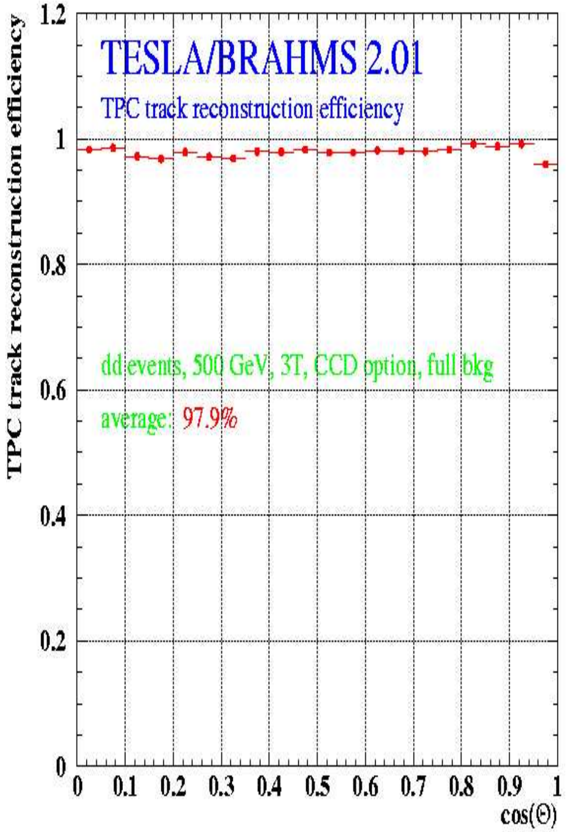
- software exists in released form
- still somewhat unstable, but basically usuable
- independent of GEANT3/ GEANT4

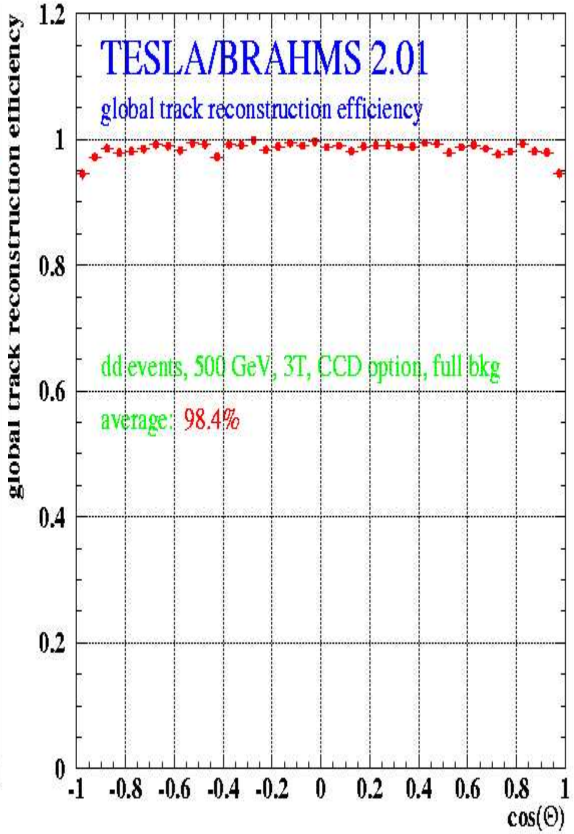
Contact: Harald.Vogt@desy.de

http://www-zeuthen.desy.de/linear_collider

Tracking Performance

- preliminary results for tracking performance:
  - look at dd events





Fake rate: 0.4%
CCD only: 97.4% / 10%
APS only: 92.4% / 0.7%
split tracks 3%

Simulation includes full background, including backsplashes from the outer detectors

- excellent reconstruction efficiencies even in complicated environment

Conclusions

Tracking system for a detector at TESLA:

- Large TPC
- High precision VTX detector
- Basic performance goals have been met in simulation
- R&D is commencing for
  - SI detectors (CCD/APS/CMOS options)
  - TPC
    - Overall design, especially endplate
    - GEM characteristics/ optimisation
    - Electronics/ readout
  - Simulation
  - Calibration

Development work is happening in framework beyond just TESLA:
groups involved are from Europe
Canada
USA