A Time Projection Chamber for the International Linear Collider

R&D Studies

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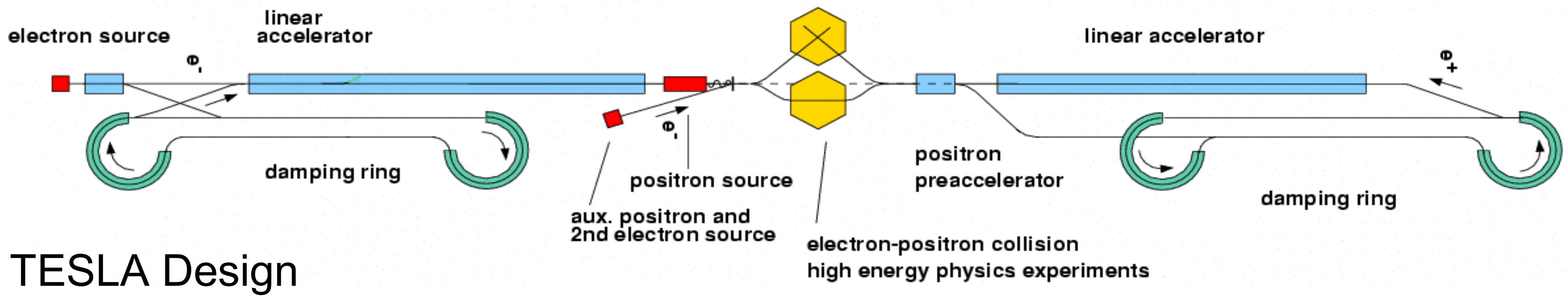
DESY

Overview

- International Linear Collider
  - requirements for tracking at the ILC
  - future tasks & ongoing developments
- ongoing R&D studies
  - building & running of TPC prototypes with GEM-amplification-system
    - setups to use cosmic muons and laser beams
  - achievements
    - GEM-System
    - energy loss
    - general properties
  - resolution-studies with cosmic muons in magnetic fields
  - measurement of track separation capability with laser-beams

International Linear Collider

- e^+e^- linear collider
- centre of mass energy: (90) 500 - 1000 GeV
- high luminosity (first phase ≈ $2 \cdot 10^{34}$ $cm^{-2}s^{-1}$)
- polarised beams
- superconducting RF-technology

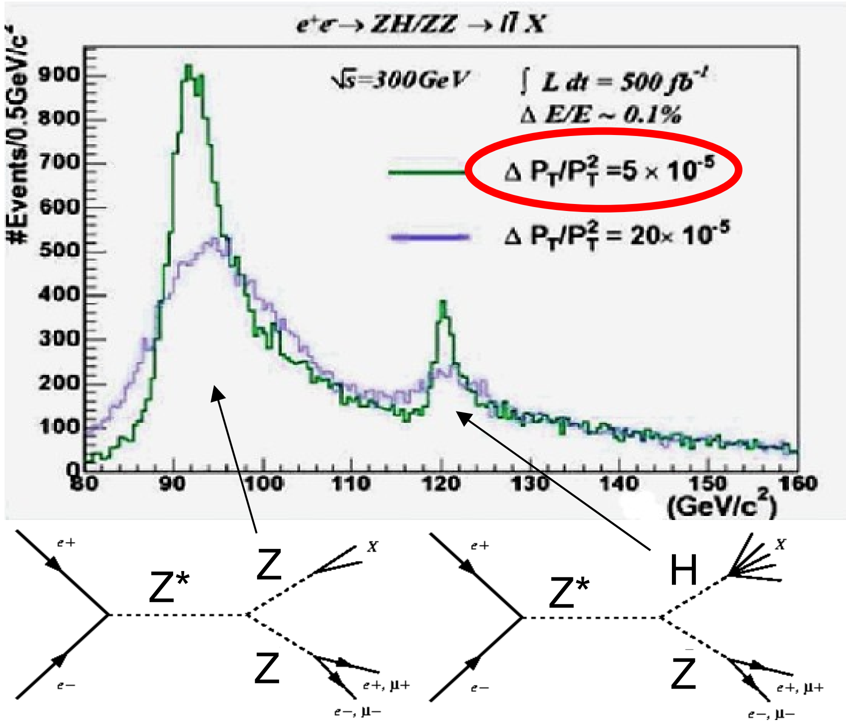


TESLA Design

www.linearcollider.org

Requirements for the Tracking at the ILC

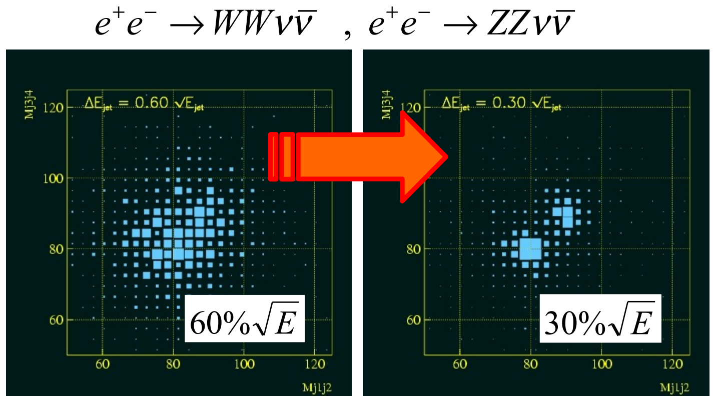
- model independent measurement of Higgs properties
  - using recoil mass of Higgs-strahlung-process
  - high precision
    - $\Delta p_T/p_T^2 = 5 \cdot 10^{-5}$ GeV $^{-1}$

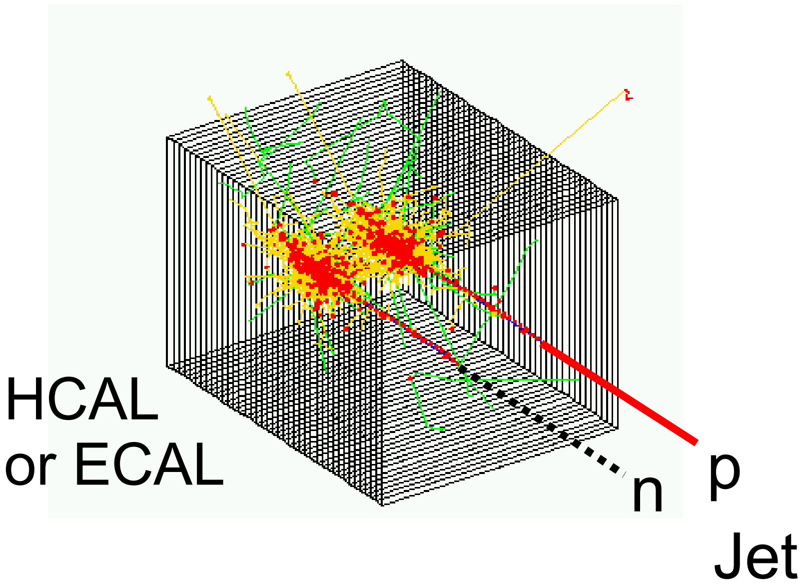


- time structure
  - 5 trains per second
  - ~3000 bunches in a train distance 330 ns
  - continuous readout / no hardware trigger

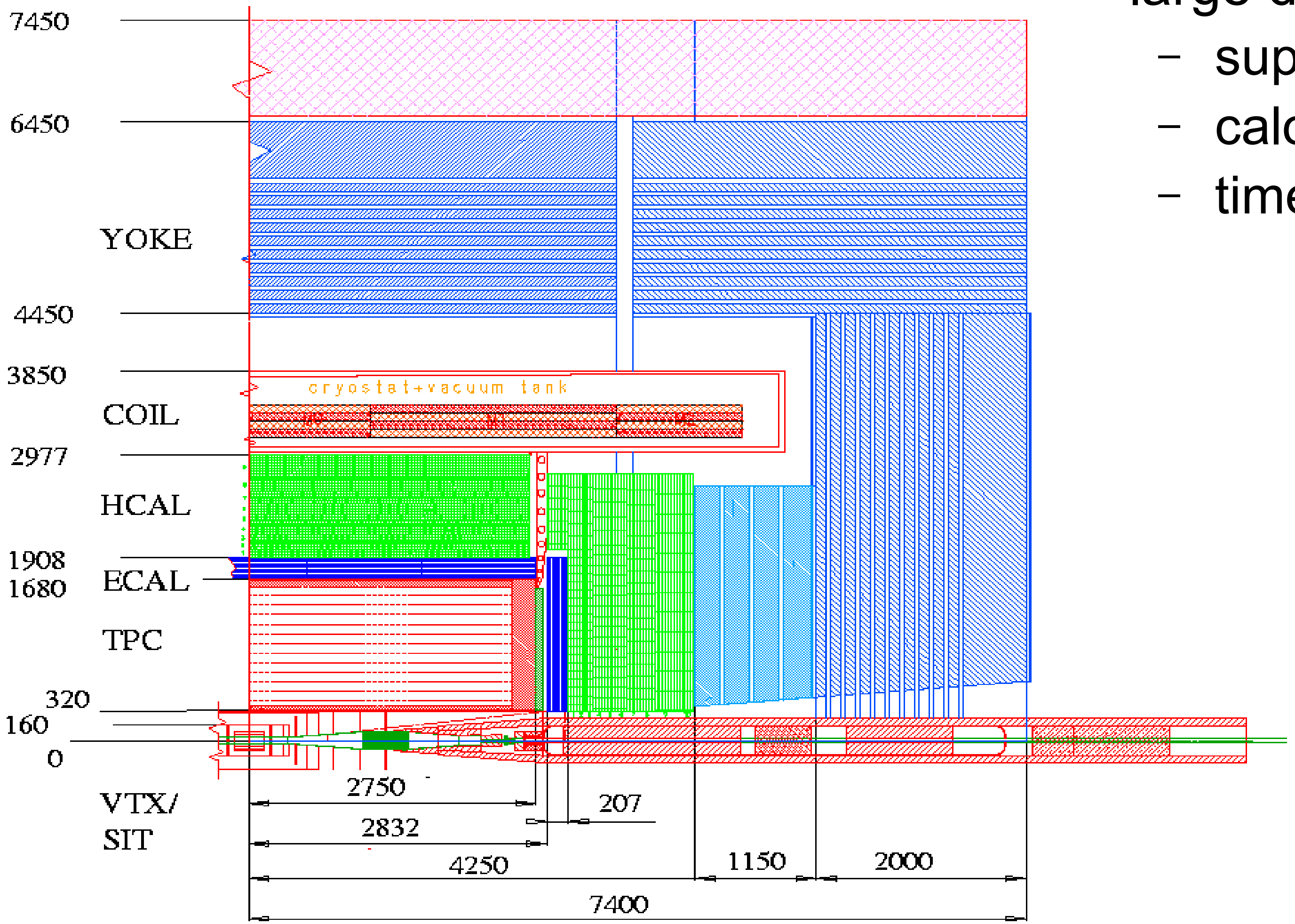
Requirements for the Tracking at the ILC

- separation of ZZ- and WW-events
  - di-jet resolution of 30%/√E
  - particle flow concept
    - reconstruction of every particle (charged & neutral)
    - highly granular calorimetry (tracking calorimeter)
    - high efficiency tracking
    - precise calorimeter-tracking assignment





A Detector for the ILC

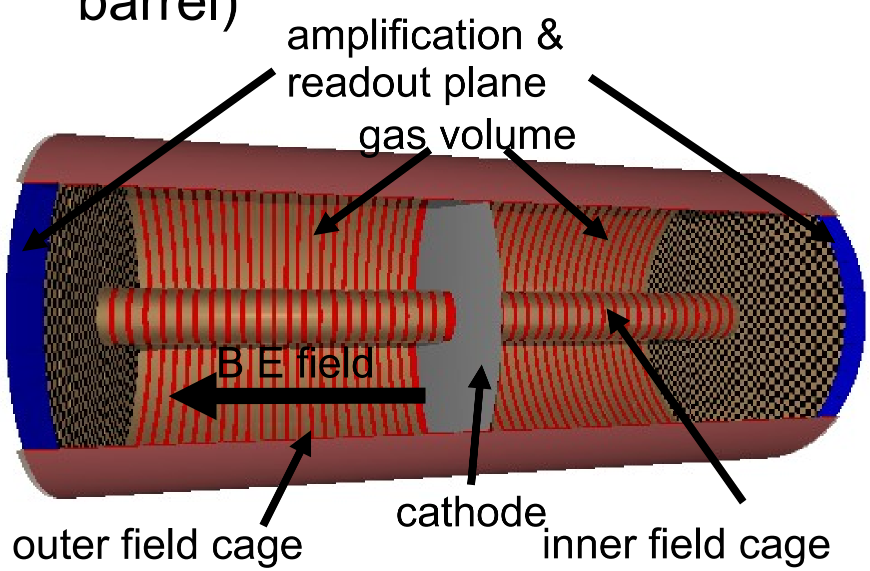


- large detector concept
  - superconducting solenoid (4T)
  - calorimeter inside the coil
  - time projection chamber

Why a TPC

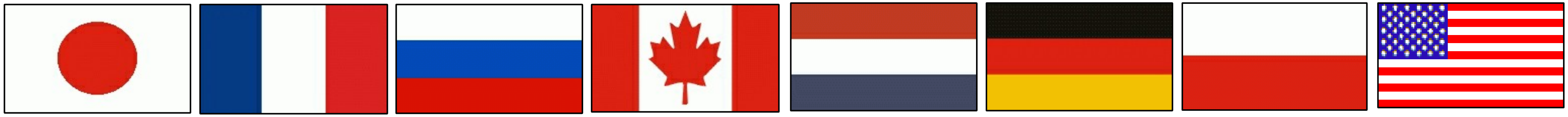
- advantages
  - a huge number of 3D space points per track (~200)
    - good and robust pattern recognition
  - low material budget
    - < 3% X_0
    - allows a good particle flow measurement
  - particle identification
    - measurement of dE/dx
    - resolution ≈ 5%

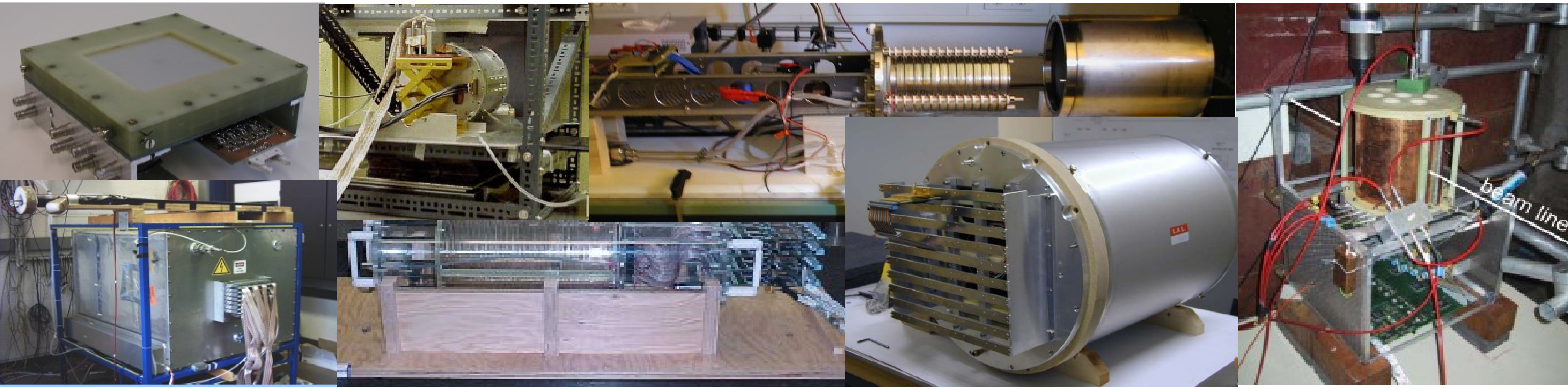
- disadvantages
  - slow
    - overlaying events
  - 'bad' single-point-resolution
  - rate dependent behaviour
  - inhomogeneous material distribution (end plate − barrel)



Global R&D Effort

- 20 institutes from 8 countries working on TPC@ILC
  - field cage
  - amplification-system
  - read out electronic

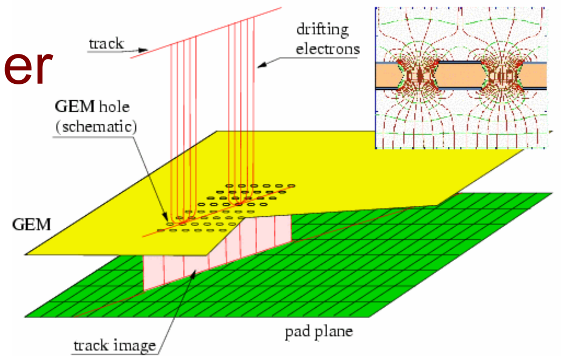


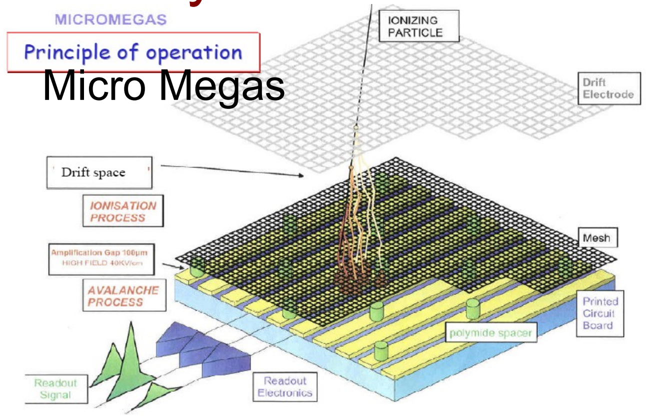


Tasks & Ongoing Developments

- continuous readout during one train
  - no gating possible to avoid ion backdrift
- single point resolution
  - for momentum resolution: required 140 μm, goal 100 μm
- good double track separation (z and rφ)
  - narrow and fast signal
- possible solution:
  use of micro-pattern gas detectors as amplification system
  - micro megas
  - gas electron multiplier (GEM)

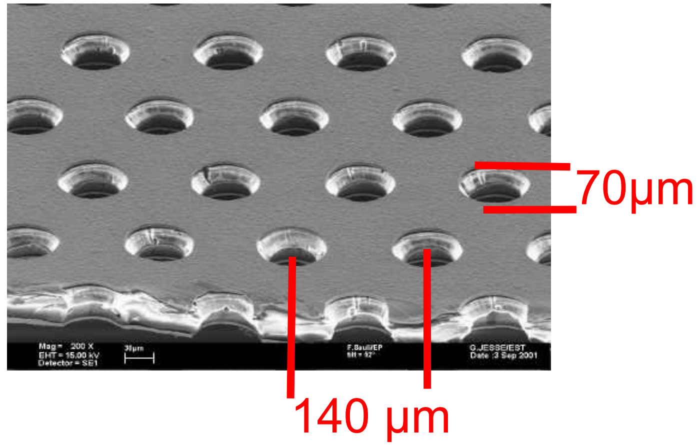
GEM



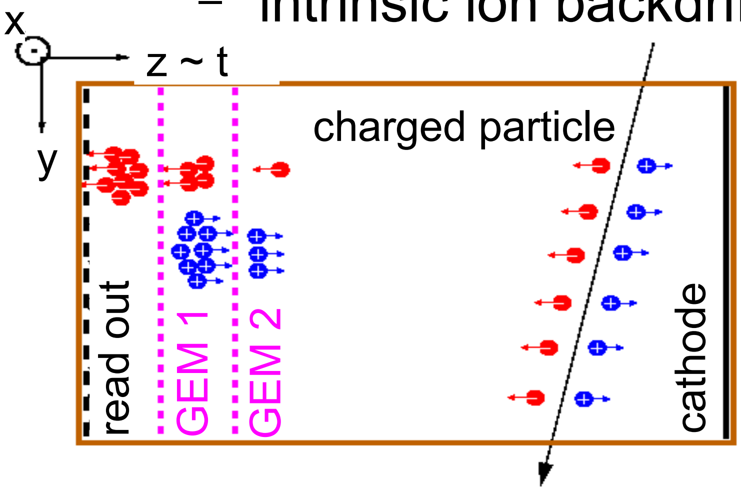


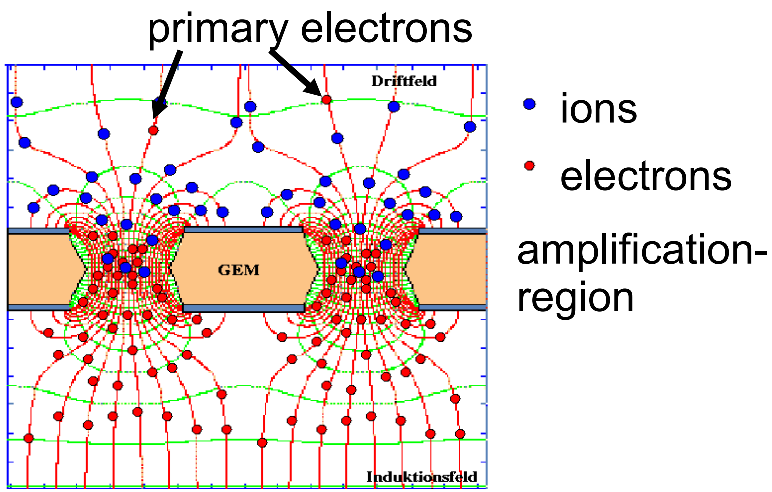
GEM based Amplification System

- GEM
  - kapton foil
  - coated with copper an both sides
  - with conical etched hole



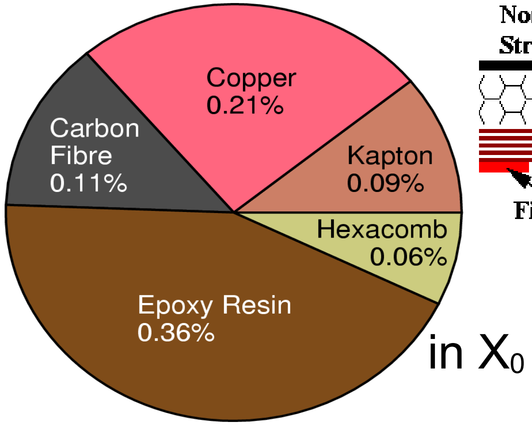
- amplification
  - primary electrons drift to the GEM tower
  - avalanche take place in high electric field in GEM-holes
  - intrinsic ion backdrift suppression

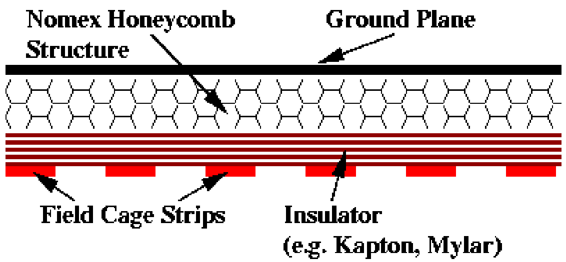


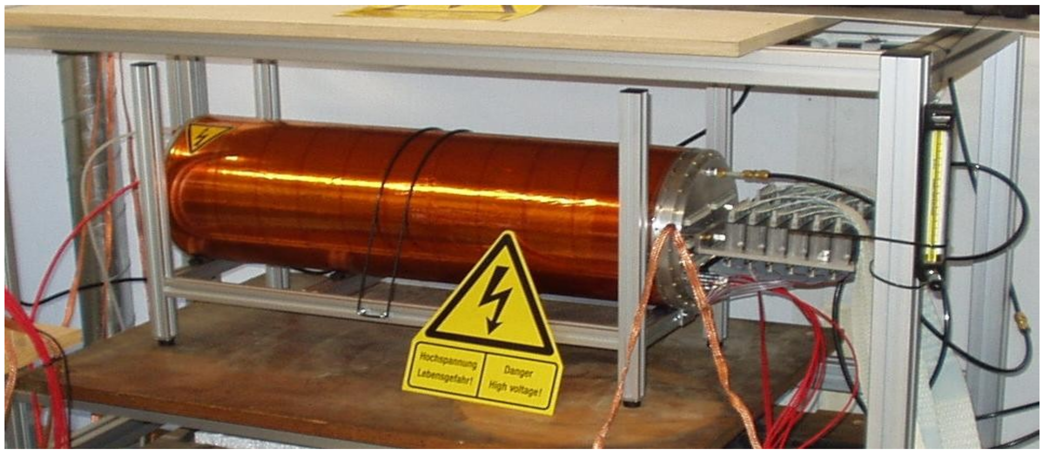


Studies with Cosmic Muons

- goal
  - resolution studies in magnetic field (max . 5.3T)
  - test of field cage structure (<1% X_0)
- prototype: MediTPC
  - length 800 mm, Ø 260 mm
  - max. drift length 670 mm
- amplification structure
  - 3 GEM tower
  - 2.2 x 6.2 mm^2 rectangular pads [non]-staggered
  - 24 pads in 8 rows
- gas
  - P5 (Ar:CH_4 – 95:5)
  - TDR (Ar:CH_4:CO_2 - 93:5:2)

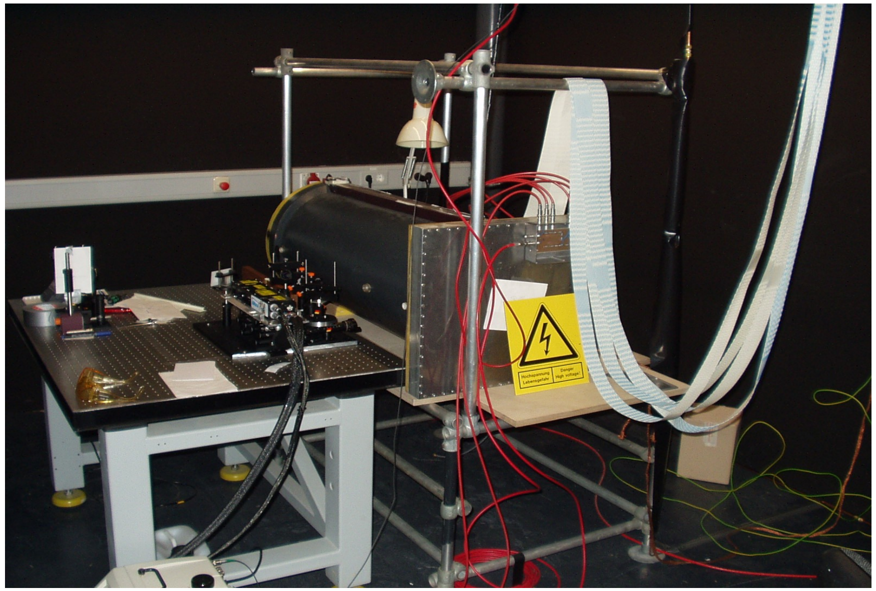






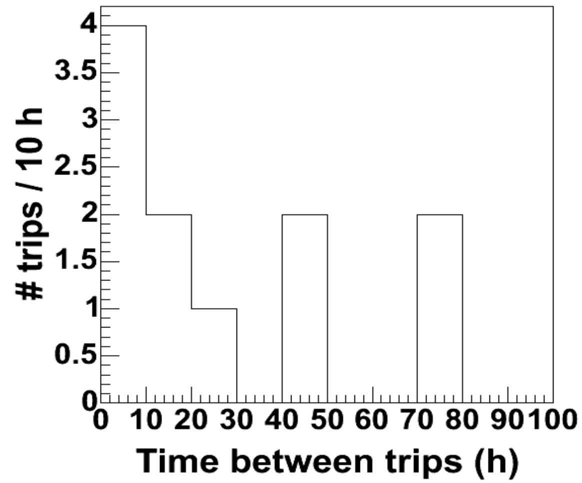
Studies with Laser beams

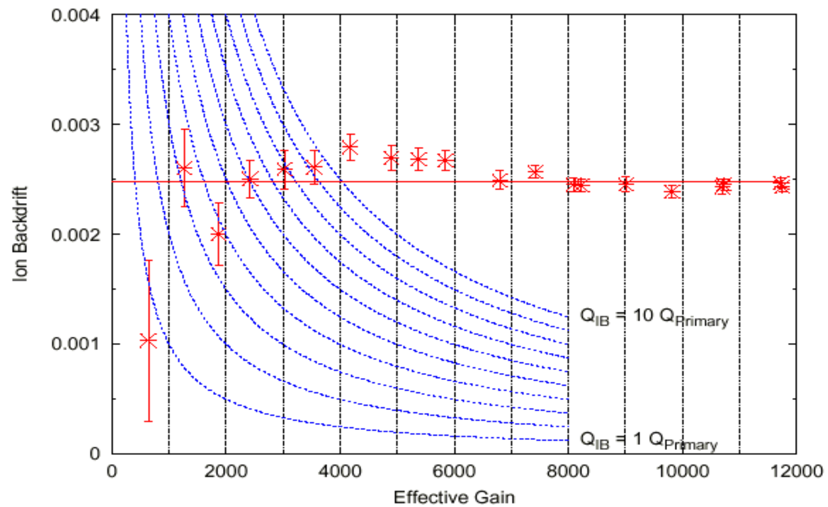
- goals
  - testing of track separation capability
  - measurements of gas properties: drift velocity, diffusion
- UV-Laser
  - wave length: λ = 266nm (NdYAG)
  - pulse length: < 6ns
- advantage
  - controllable and reproducible tracks
- disadvantages
  - different ionization mechanism: laser v. MIP (cosmic muon)
- BigTPC
  - quartz windows: 5.5, 30.5, 95.5 mm



Achievements: GEM-Svstem

- stable running of GEMs
  - 11 trips in 14 days
  - 3 month measurement without damages
- gain:
  - 10^4 with 3 GEMs
  - large number of ions produced during amplification process
- ion backdrift suppression
  - 2.5 ‰
  - reduction: ~primary ions

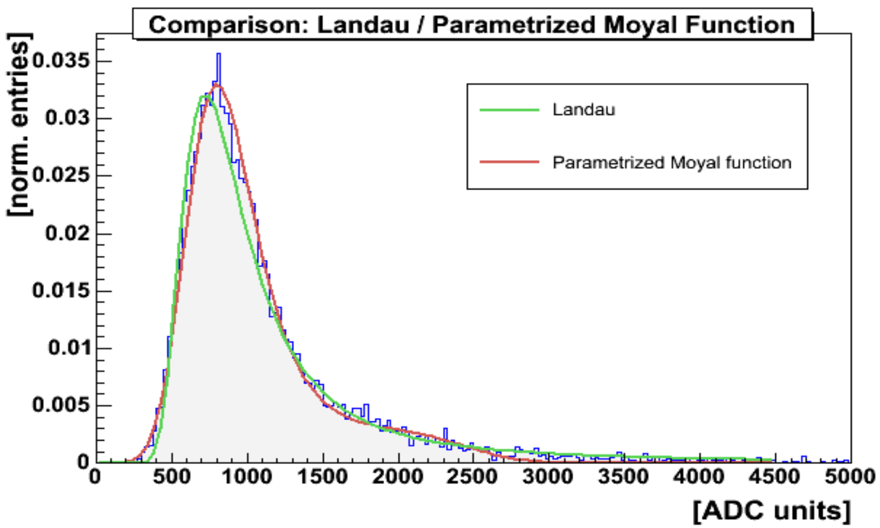


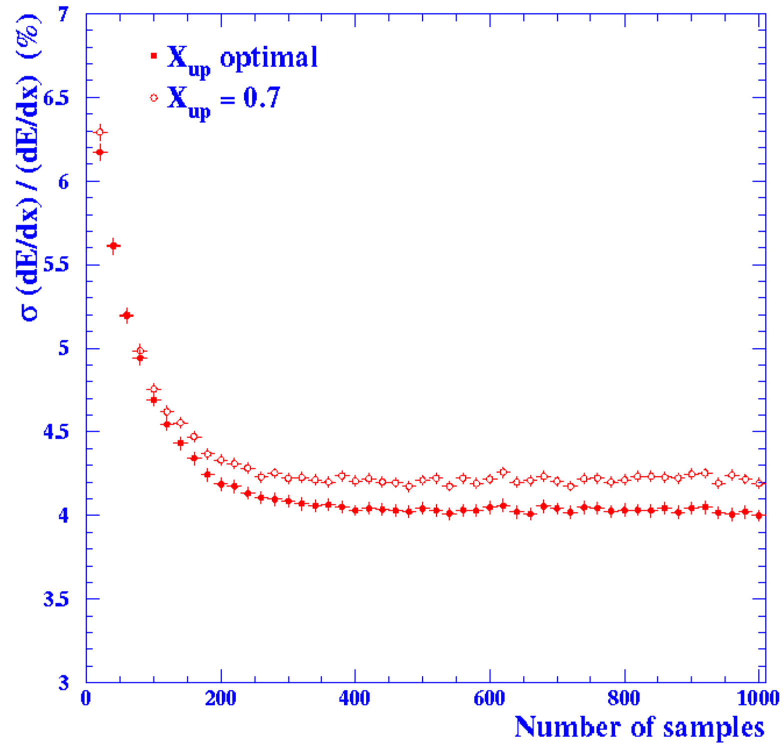


Mnich et al, "LC TPC R&D in Aachen – Status Report of September 2004", LC-Det-2004-023

Achievements: dE/dx

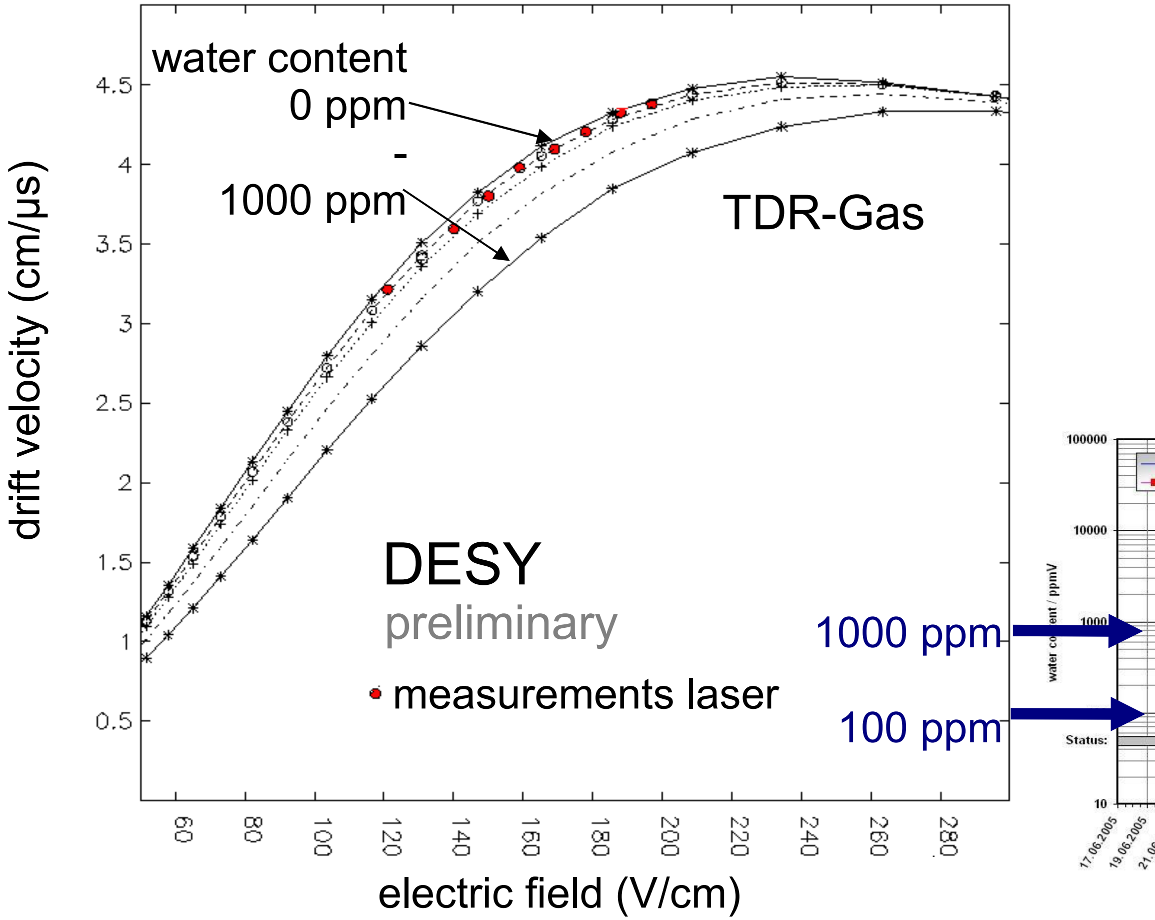
- dE/dx resolution of 5% → 200 samples
- energy loss per pad row
  - thin layer (6mm): not described by landau
  - studies ongoing
    - find better description
    - influence of GEM-amplification

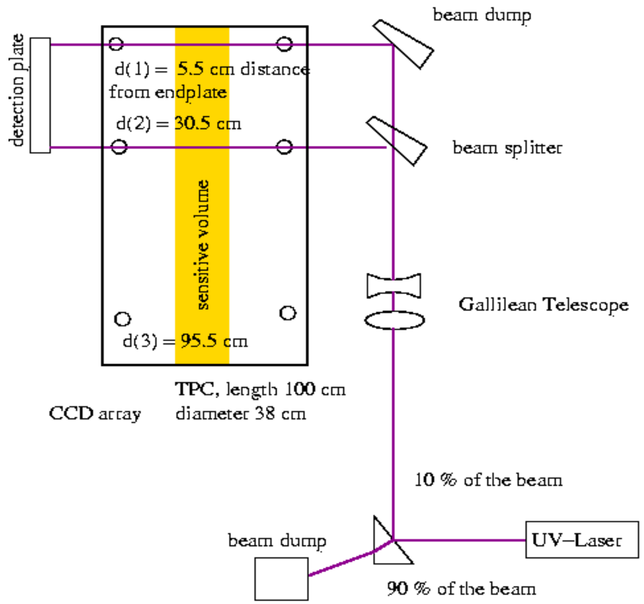


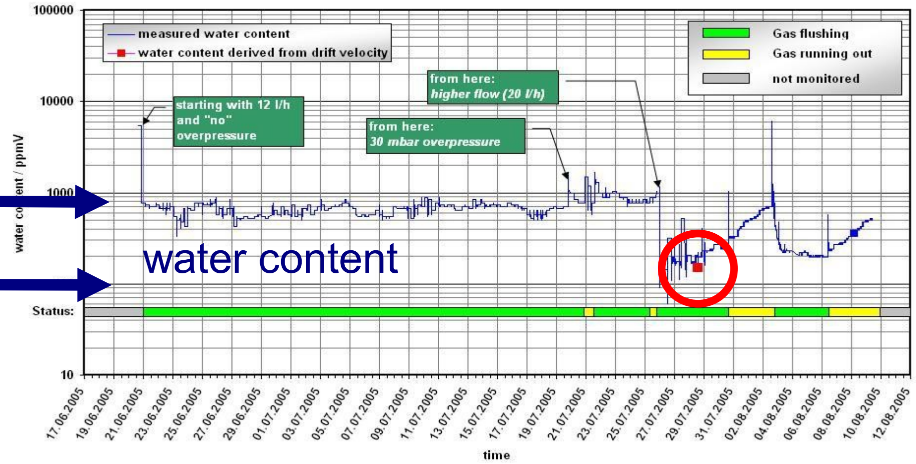


Achievements: General Properties

- control of gas properties
  - drift velocity

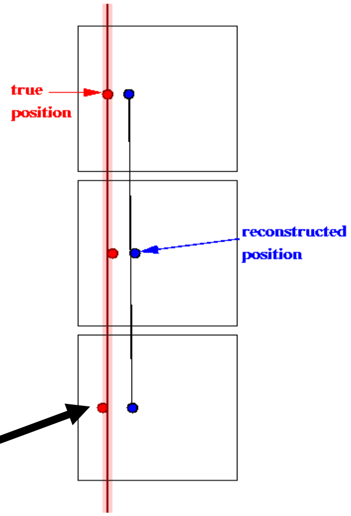


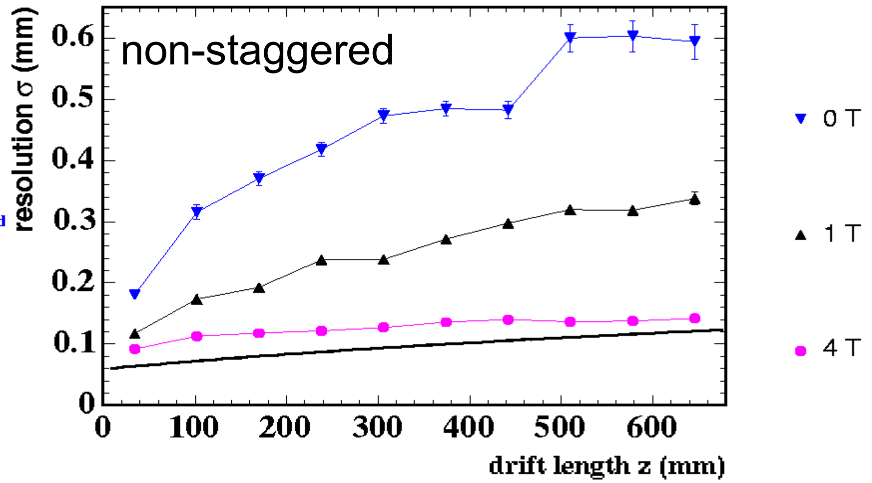


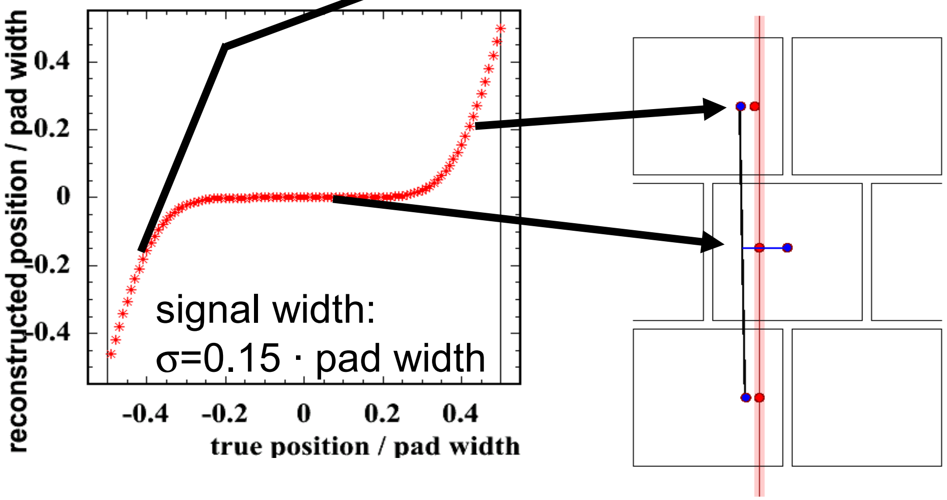


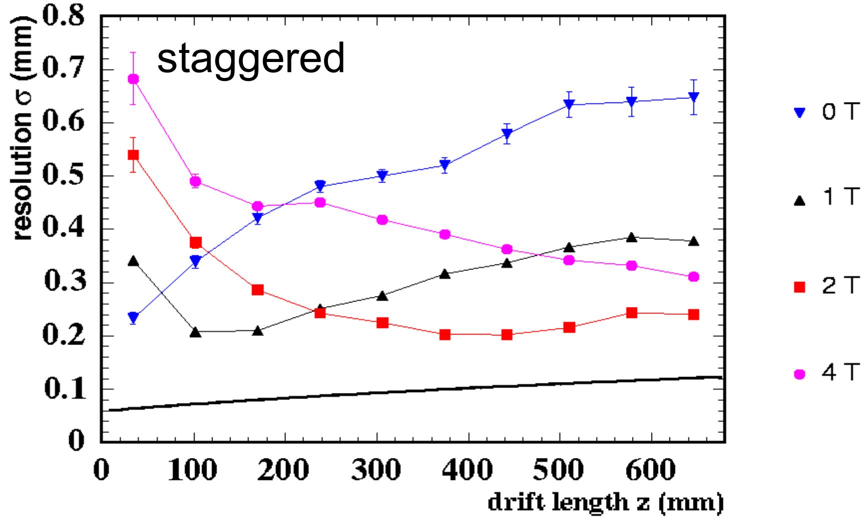
Resolution

- magnetic field reduces signal width (~400μm)
- less than 3 active Pads (width 2.2 mm)
- centre of gravity show systematic effects





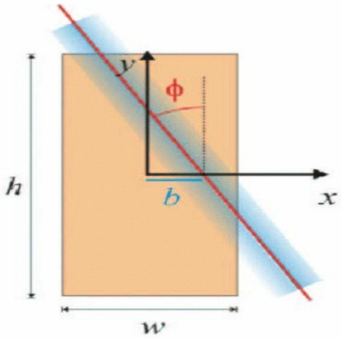




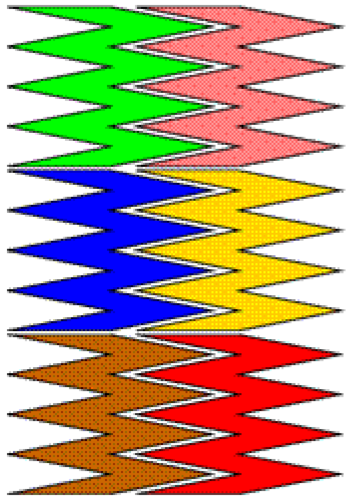
Narrow Signal Problem

- smaller pads (limited by total no. of channels / costs)
- charge spread close to the pads
- alternative pad geometries
- more sophisticated reconstruction methods

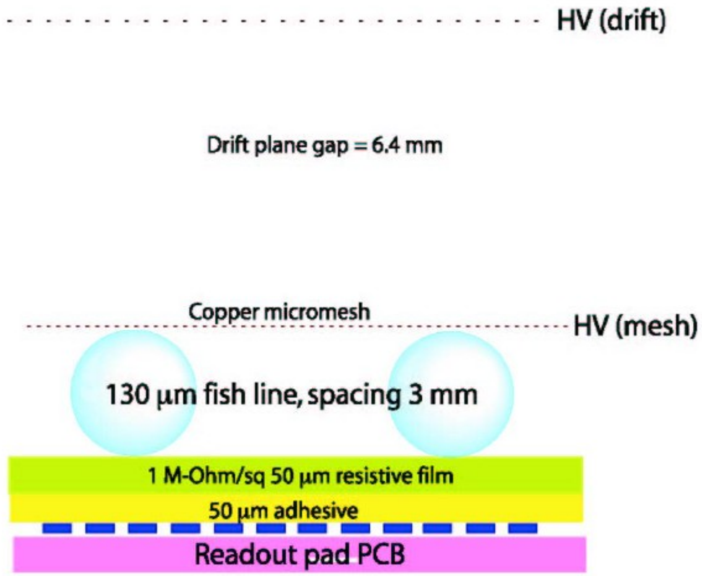
$$C_{Pad} = \int_{-\frac{h}{2}}^{\frac{h}{2}} dy \int_{-\frac{w}{2}}^{\frac{w}{2}} dx \frac{1}{2\pi\sigma} e^{\frac{1}{2\sigma^2}[(x-b)\cos(\phi)-y\sin(\phi)]^2}$$



PRF



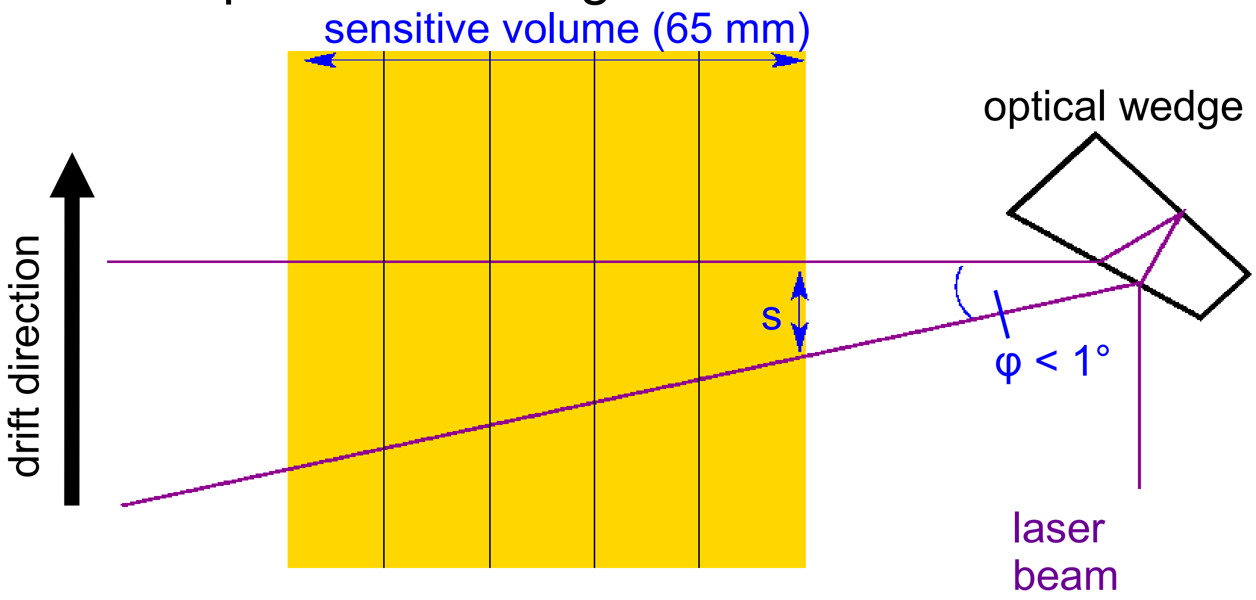
Chevrons

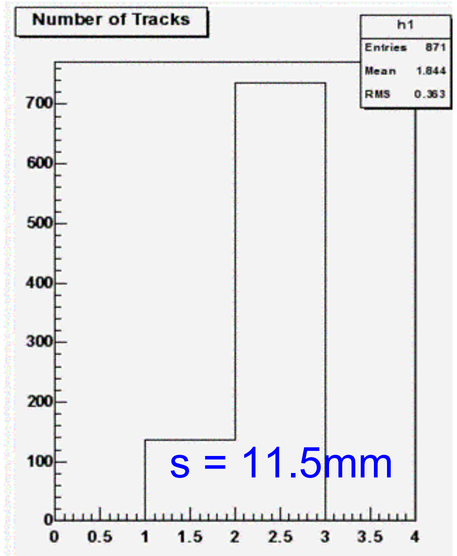


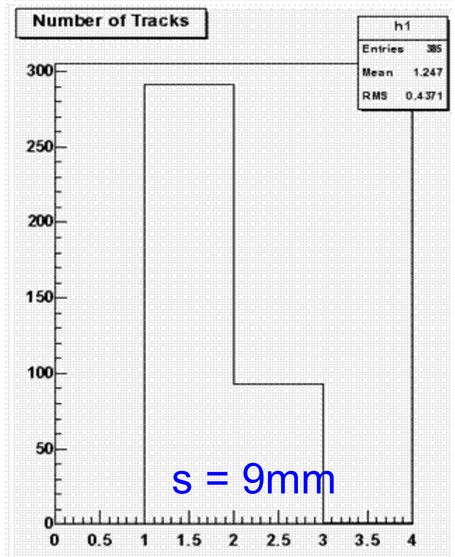
Resistive Foil

Track Separation

- preliminary results for track separation capability in drift direction
  - independent of magnetic field







  - reconstruction algorithm not optimised for separation
  - results not fully understood
  - goal (<1cm in drift direction) seems to be achievable

Conclusion & Outlook

- stable running of a TPC prototypes with GEM amplification system
- other groups: same with micro megas
- resolution studies are promising
  - the problem of narrow signal must be solved
  - goal of 100 μm seems to be achievable
- track separation
  - in drift direction: <1cm seems to be achievable
  - ongoing studies in the rφ-plane (with magnetic field)

- solution for narrow signal
  - optimisation of GEM-setup and pad-plane
- build a larger scale prototype