Studies for the Linear Collider TPC at DESY/Hamburg University

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Outline

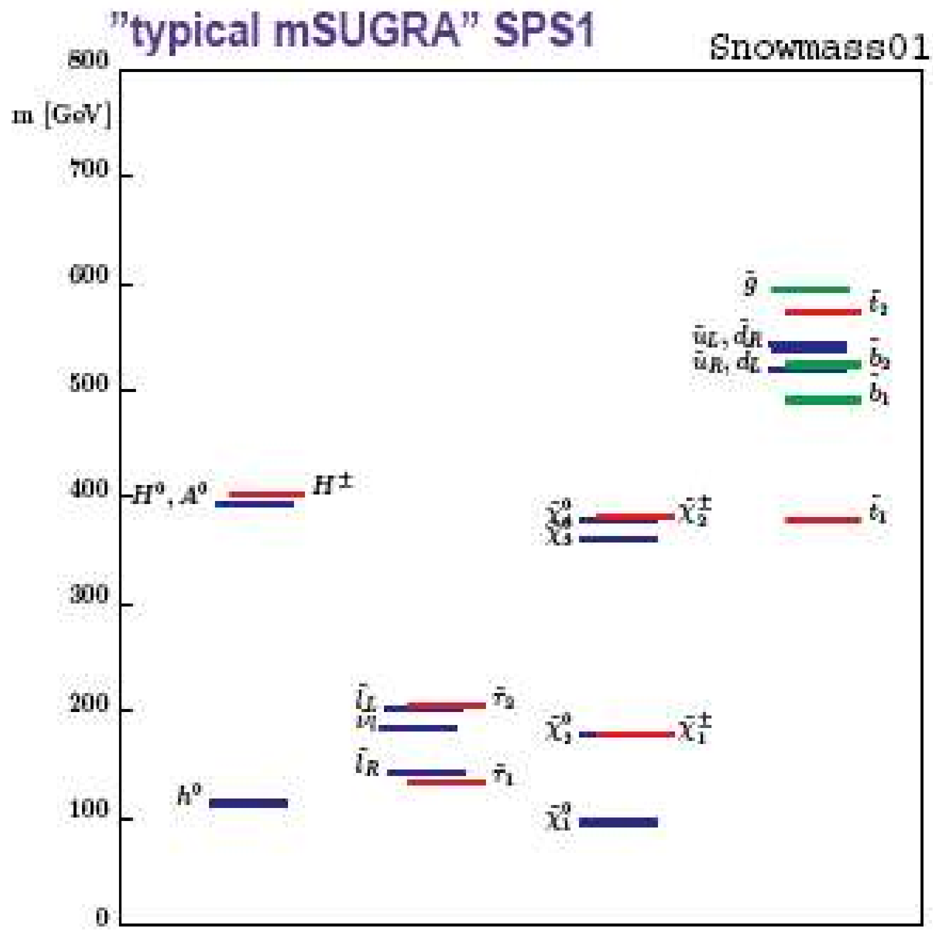
- **The Linear Collider TPC**
- **TPC R&D in Hamburg: GEM readout**
- **GEM TPC Activities at KEK**

Short Motivation for a LC

- Compementarity to the LHC
  - well defined initial state
  - precisely adjustable centre-of-mass energy
  - low background;

➔ suitable for

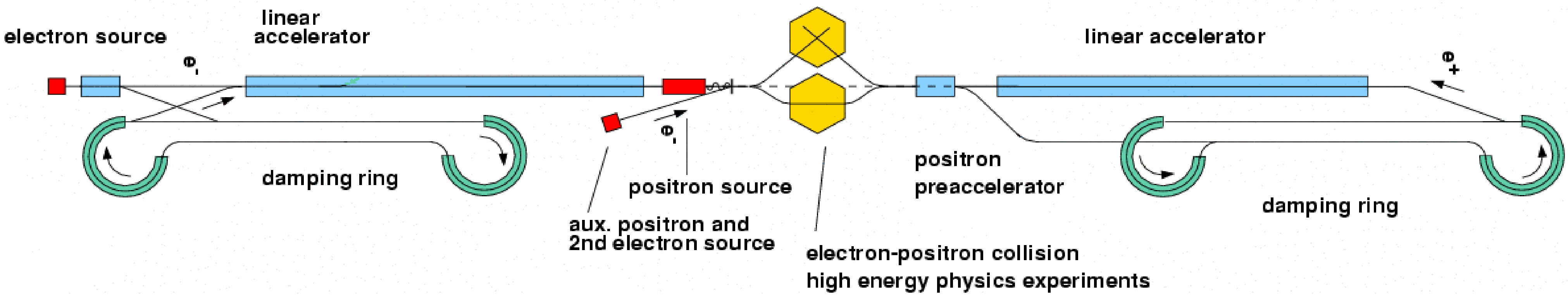
- precision measurements, e.g. mechanism of EW symmety breaking, SUSY spectroscopy, and
- the discovery of new phenomena, e.g. SUSY;



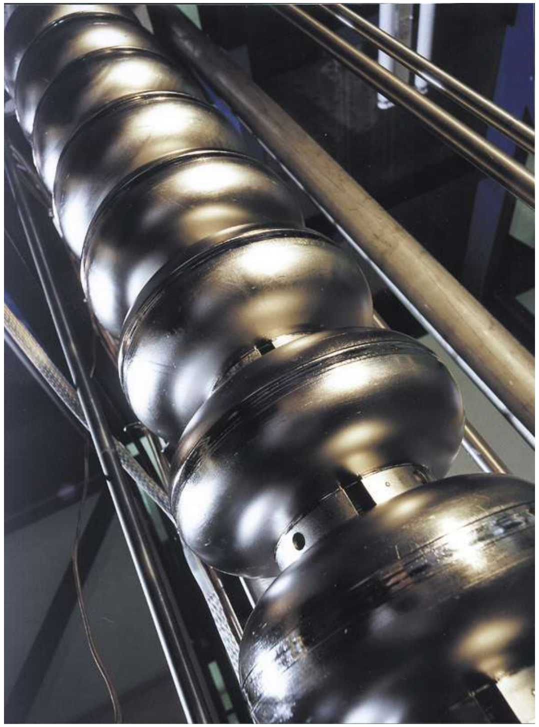
requirement: high luminosity (≈ 1000 x LEP)

→ high precision detector

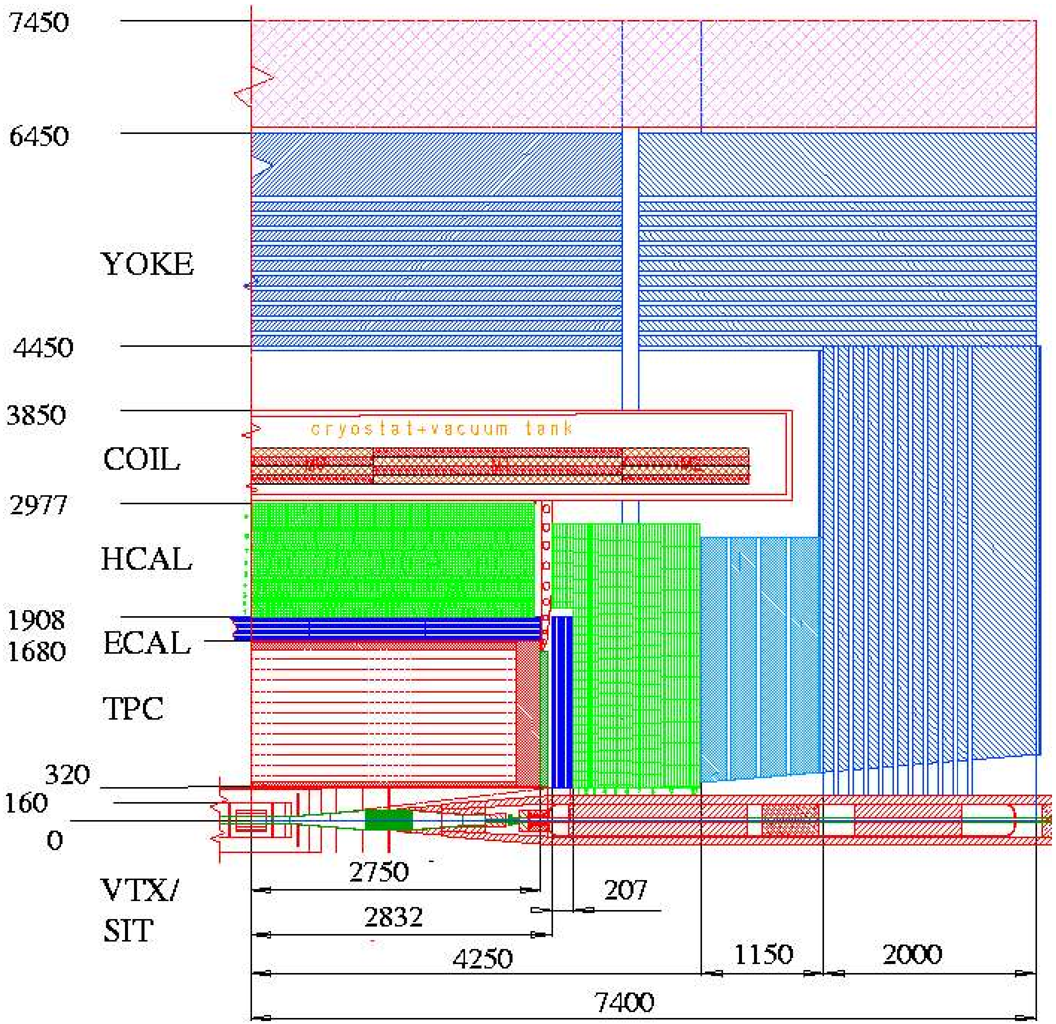
DESY LC Proposal: TESLA



- based on superconducting technology
- energy range: 90 - 500 (800) GeV
- luminosity: $3.4 \cdot 10^{34}$ cm^{-2} s^{-1}
- polarised beams
- several other running options: $\gamma\gamma$, γe, $e^- e^-$, (ep)



The Detector Concept

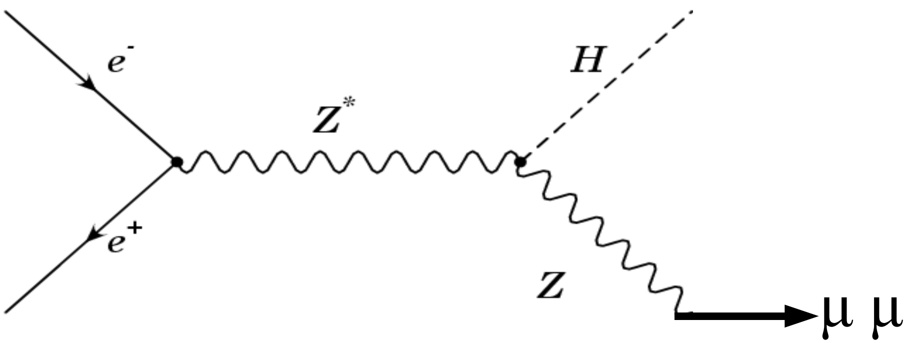


- precise vertex detectors
- large tracking detectors
- high granularity calorimeter
- B = 4 T
- yoke

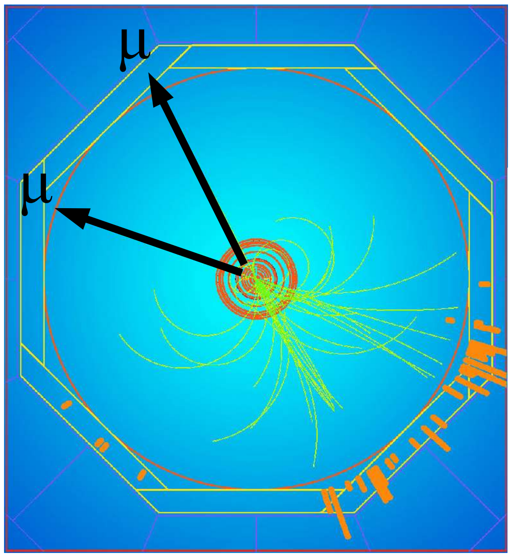
Physics Requirements

- Higgs searches
  dilepton recoil mass for
  Z H events,
  goal: δM(μ,μ) < 0.1 x σ(Z).

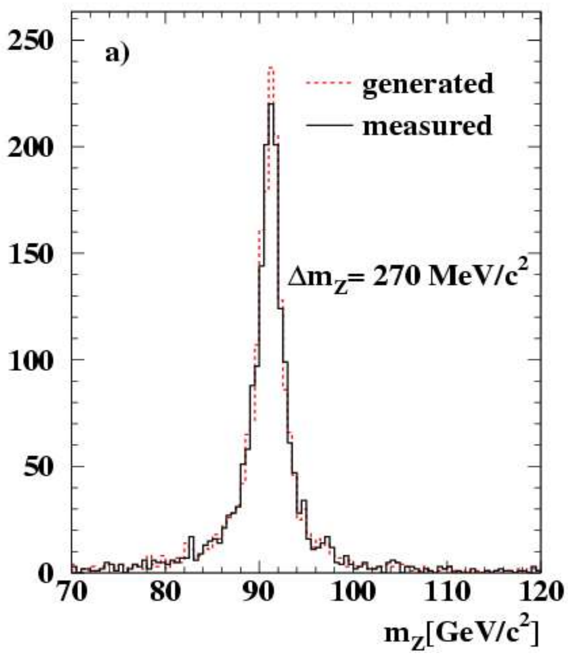
  impose

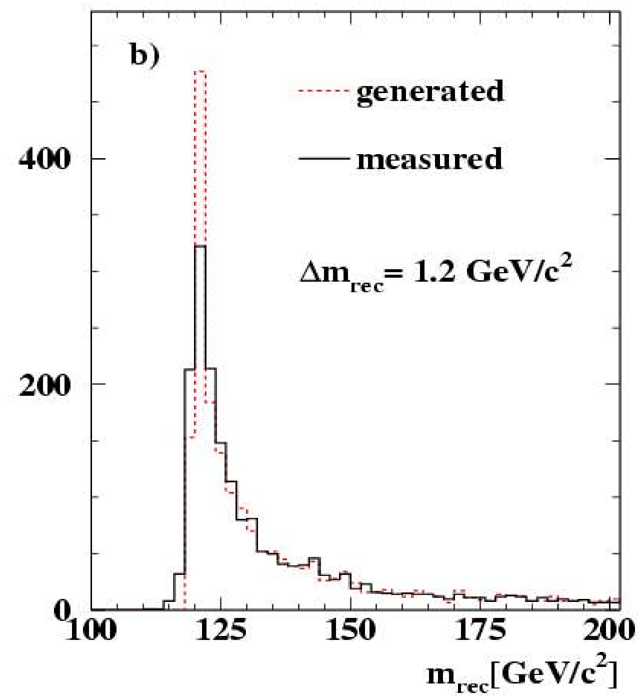


- **high momentum res.**
  $\delta p_t/p_t^2$ = 5x10^{-5} GeV^{-1} (1/10 LEP)



(M. Schumacher)

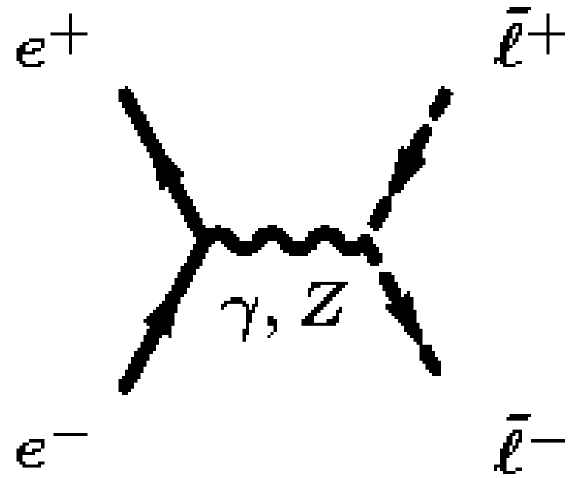


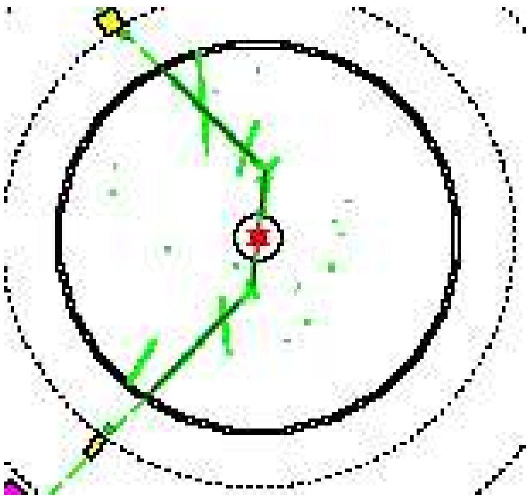


Physics Requirements

- Searches for new particles

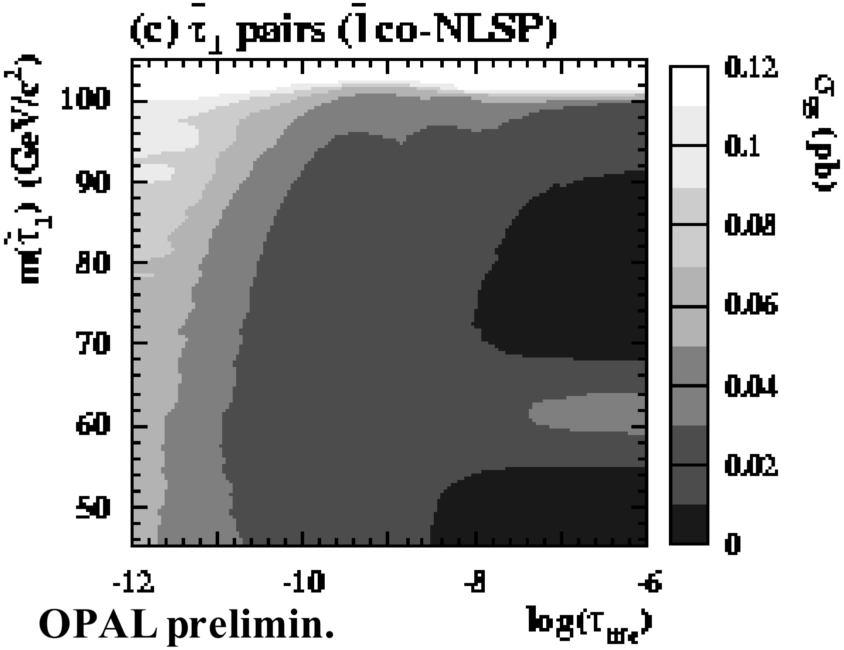
  e.g. charged particles with different lifetimes in GMSB models:
  - highly ionising tr. (t >10e-6 s)
  - kinked tracks (t >10e-9 s)



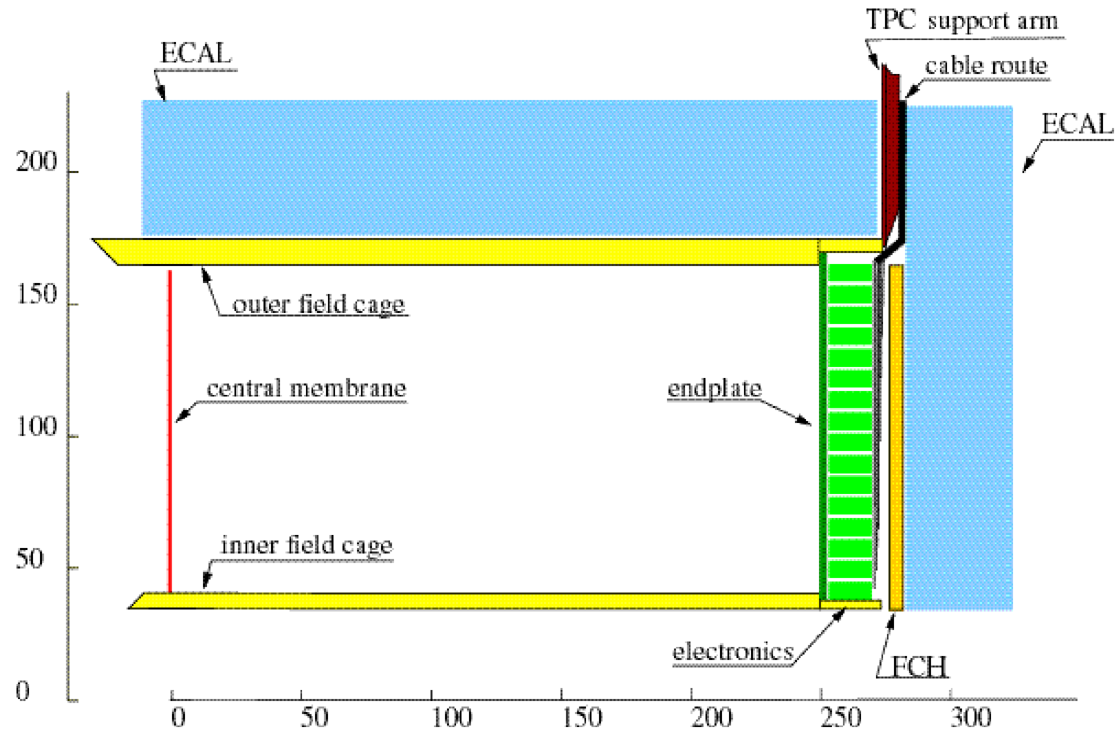


impose

- **large sensitive volume**
- **good dE/dx resolution (≤ 5 %)**
- **efficient pattern recognition**



The TESLA TPC



General TPC properties

- 3 dim., unambigous space points
- E and B parallel, no E x B effects

Specifications

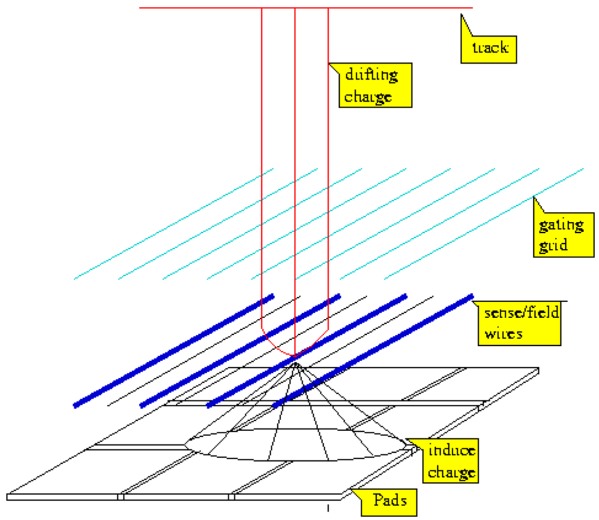
- Gas: 93% Ar, 5% CH_4, 2% CO_2
- large volume:
  - L = 5.46 m,
  - d = 3.4 m.
- Field cage: 3% X_0 → calorimetry.
- 1.2×10^6 channels,
- 200 points per track → robust track finding, efficient pat.rec.

Envisaged precision:

- momentum resolution: $\delta p_t/p_t^2 = 1.5 \times 10^{-4}\ \mathrm{GeV}^{-1}$ (1/10 x LEP),
- single point resolution in r-φ ≈100 μm (ALEPH TPC: 200 - 400 μm),
- dE/dx resolution = 5 %.

R&D needed

R&D Issue: Gas Amplification

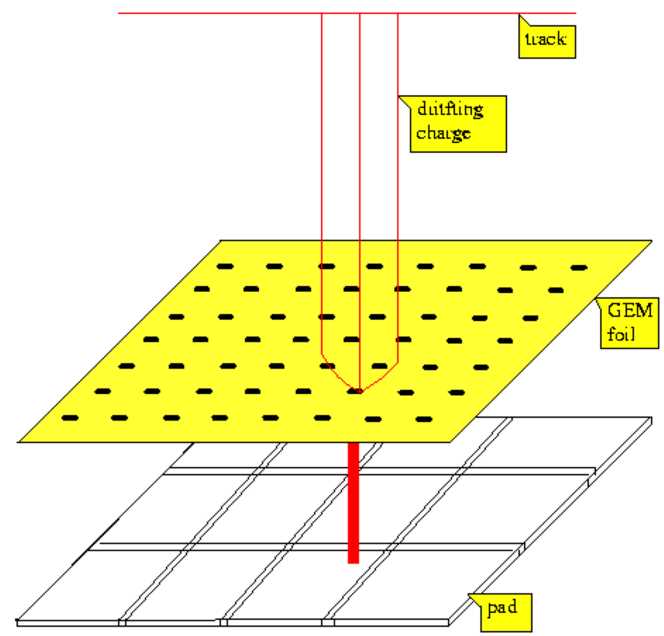


Conventional readout: WIRE CHAMBER

- Broad induction signal on pads
- Resolution limited due to E x B effects
- Large ion feedback without gating

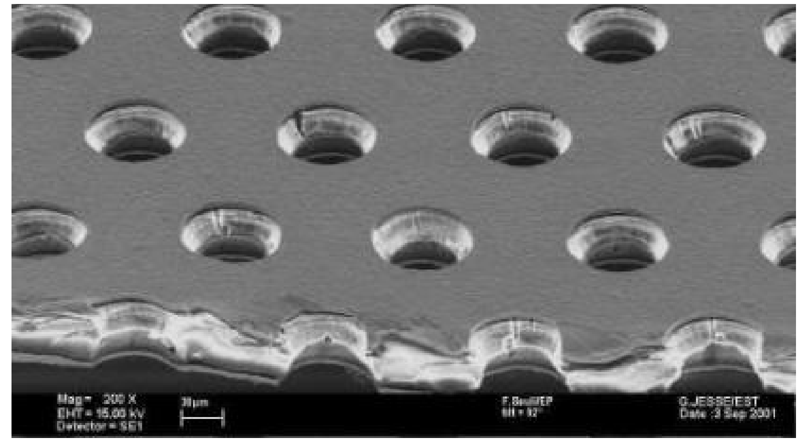
New approach: MICRO PATTERN GAS DETECTORS

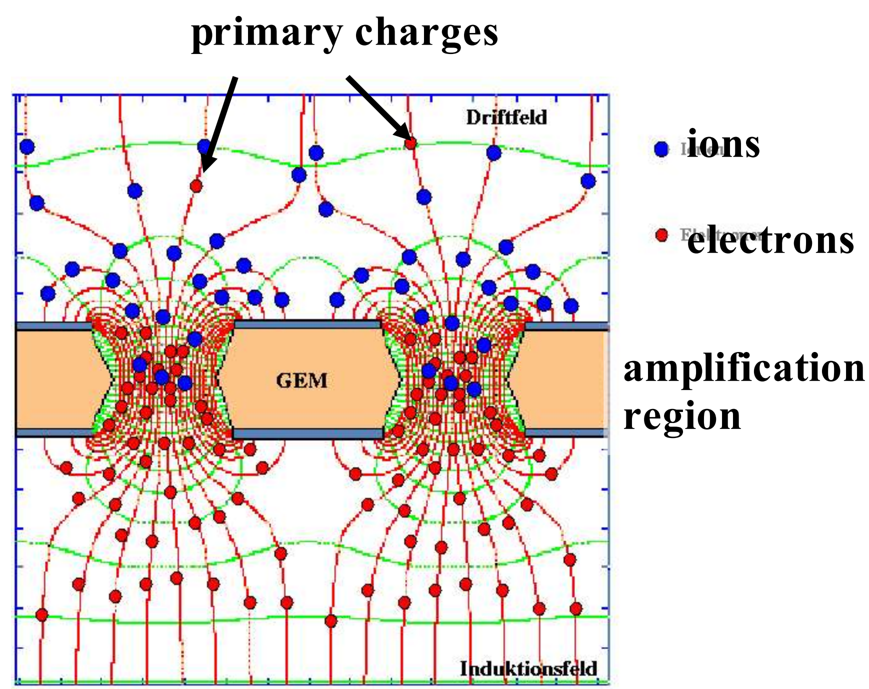
- Sharp electron signal on pads
- 2-D symmetry
- Intrinsically better resolution
- Natural suppression of ion feedback



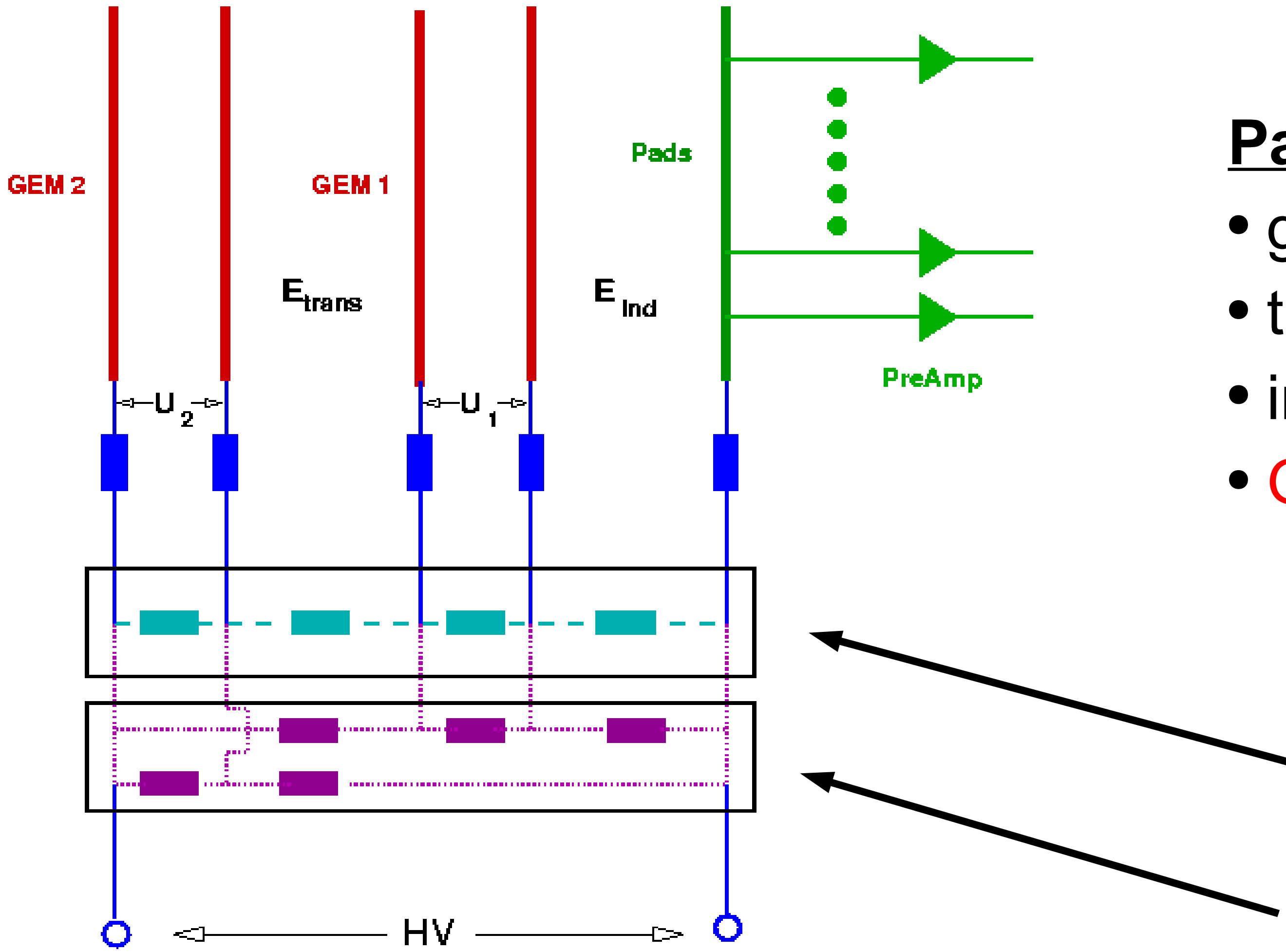
Gas Electron Multiplier (GEM)

- 50 μm thick kapton
- coated with 5 μm layers of copper
- perforated (140 μm pitch, 70 μm hole diameter)
- voltage of several hundred volts applied between copper layers
- amplification within the holes
- gain up to 10^4 for a single GEM feasible
- higher stability (at high gain) with multi-GEM-structure





Double GEM Module



Parameters

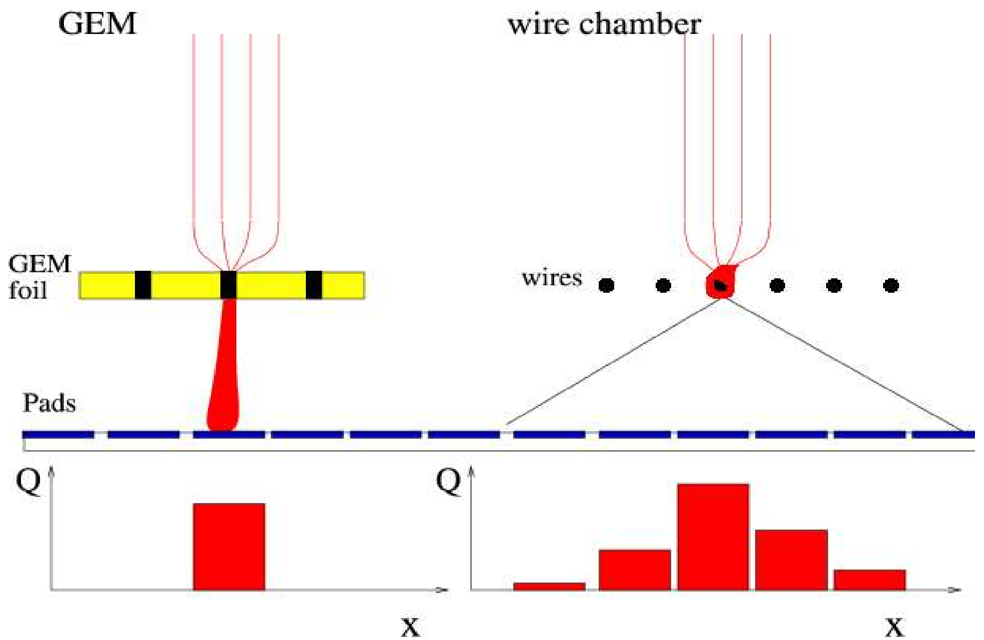
- gap sizes
- transfer field
- induction field
- GEM voltages

Voltage supply:

a) one voltage divider for both GEMs

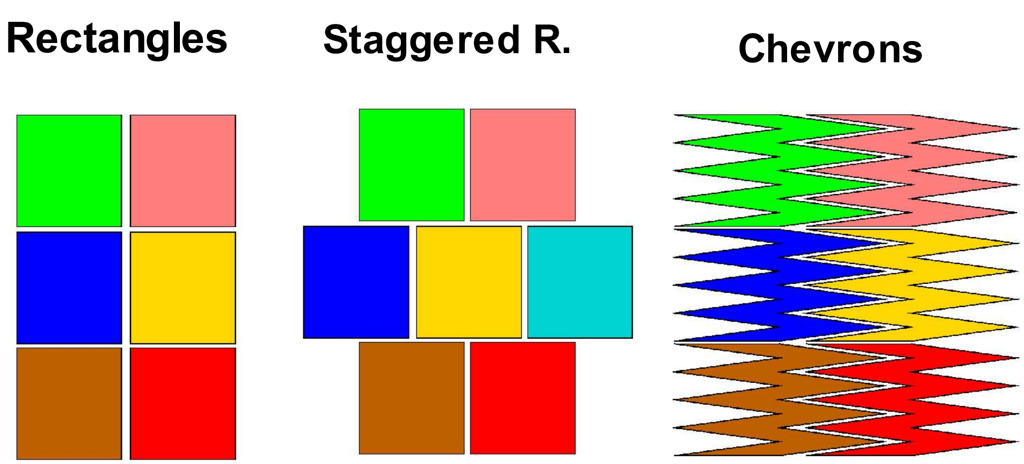
b) preferable: decoupled voltage dividers

Tracking with GEMs



Drawbacks:

- Narrow electron signal is only collected on few pads.
- Calculation of the charge centre-of-gravity unprecise.

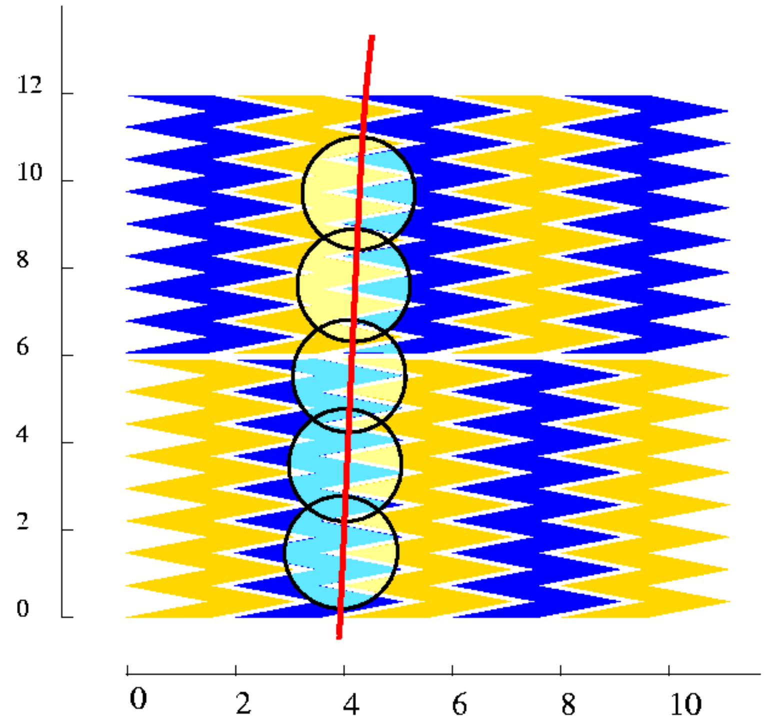


Possible Solutions:

- Smaller pads ... but: total number of readout channels increases
- pixel readout
- capacitive or resistive coupling of adjacent pads
- alternative pad geometries

Alternative Pad Geometries

Increase charge sharing without increasing the total number of pads
(TESLA TPC: 1 200 000)



TPC R&D Activities at DESY/Hamburg U

Determination of TPC properties with GEM readout using software simulation and measuremnts:

1) **point resolution in magnetic fields up to 5 T**
2) **gain homogeneity**
3) **double track resolution**
4) ion feedback
5) ...

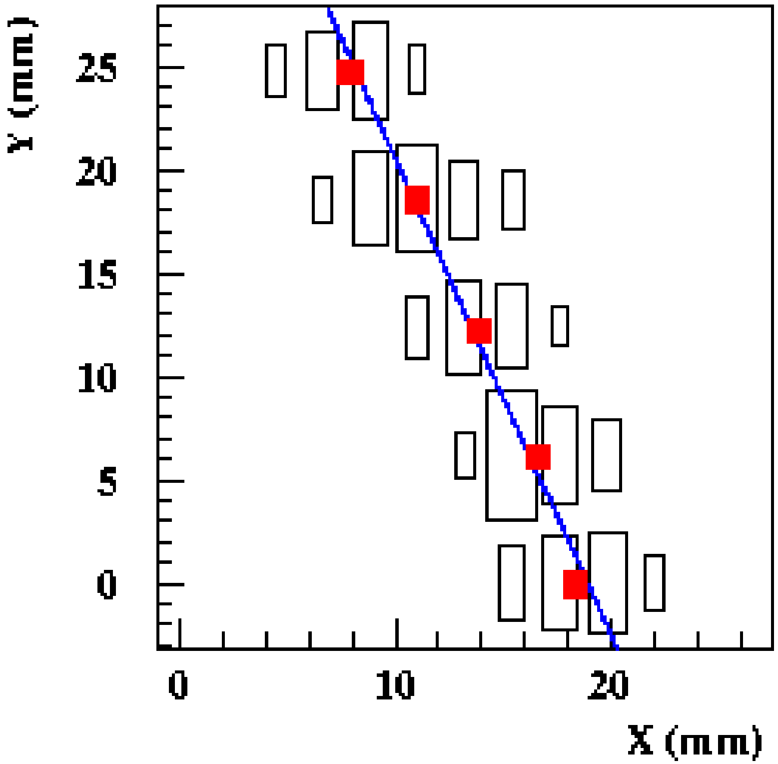
Software Simulation Tool

Stand-alone Fortran program which includes

- simulation of the gas properties using MAGBOLTZ,
- simulation of the primary ionisation using HEED,
- Polya distribution for the description of the gas gain inside GEM holes.

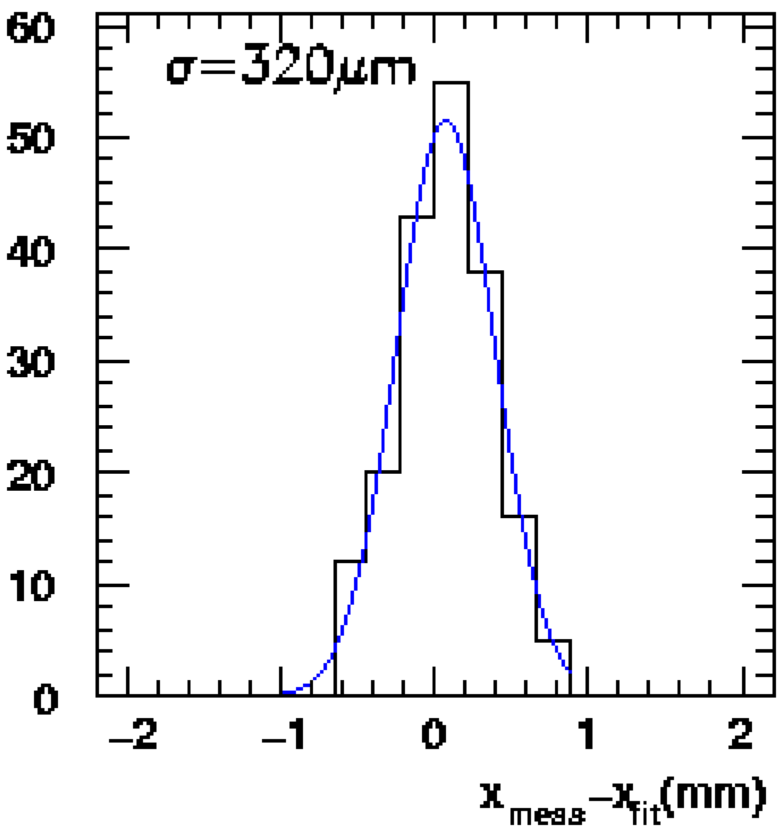
Parameters in the presented study:
E_{ind}=E_{trans}= 2 kV/cm, E_{drift}= 230 V/cm, gain/GEM = $\sqrt{1000}$, B = 4T,
pad size = 2mm x 6mm, chevrons: 4 'zig zags', number of pad rows = 21

Determination of the Point Resol.

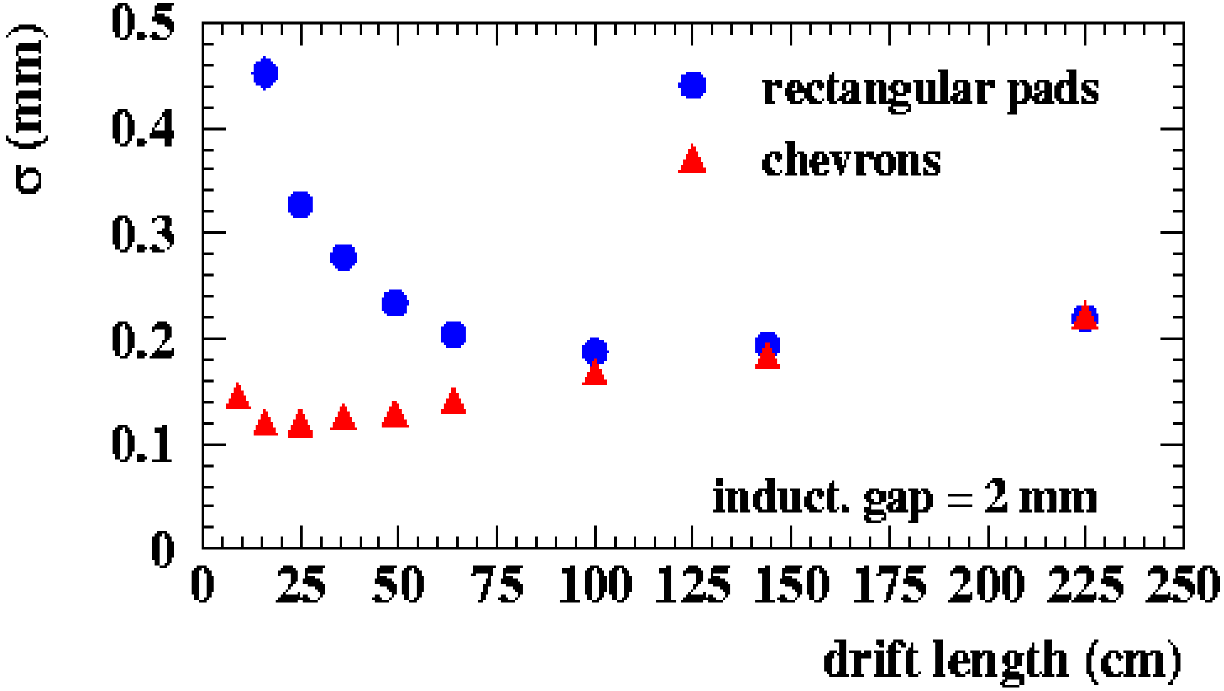


- calculation of the center-of-gravity of charge clusters
- (linear) $\chi2$-track fit

→ calculation of residuals:



Point Resolution

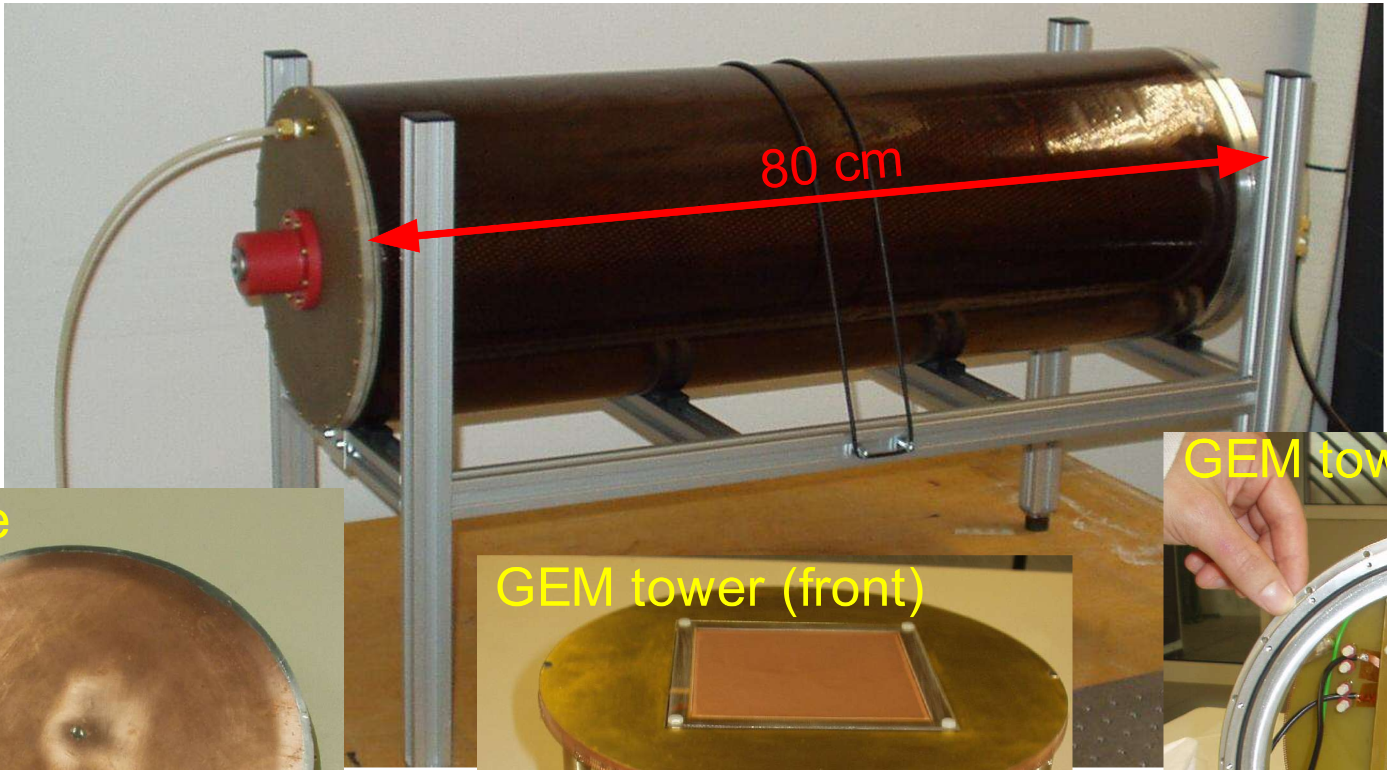


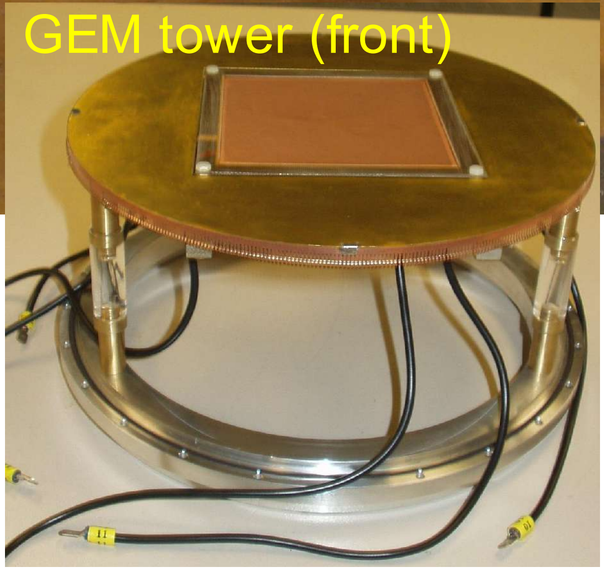
<u>Simulation parameters:</u>

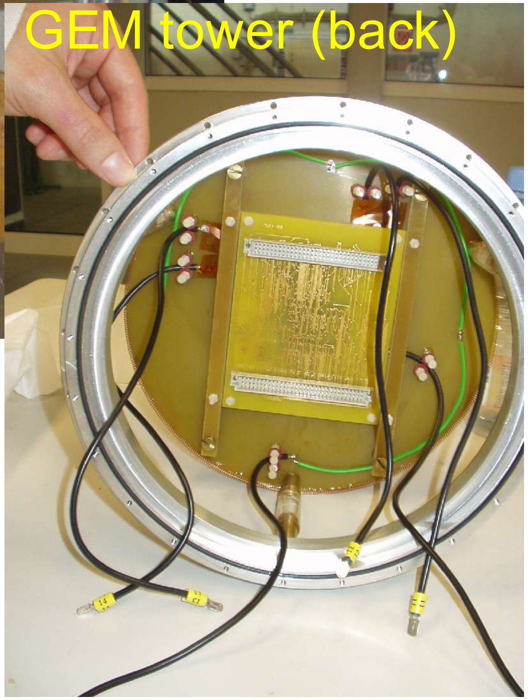
- B = 4 T
- pad size = 2 mm x 6 mm
- gas: 93% Ar, 5% CH_4, 2% CO_2

Measurement: TPC Setup

Completed a new GEM-TPC prototype for resolution measurements in high magnetic fields last autumn

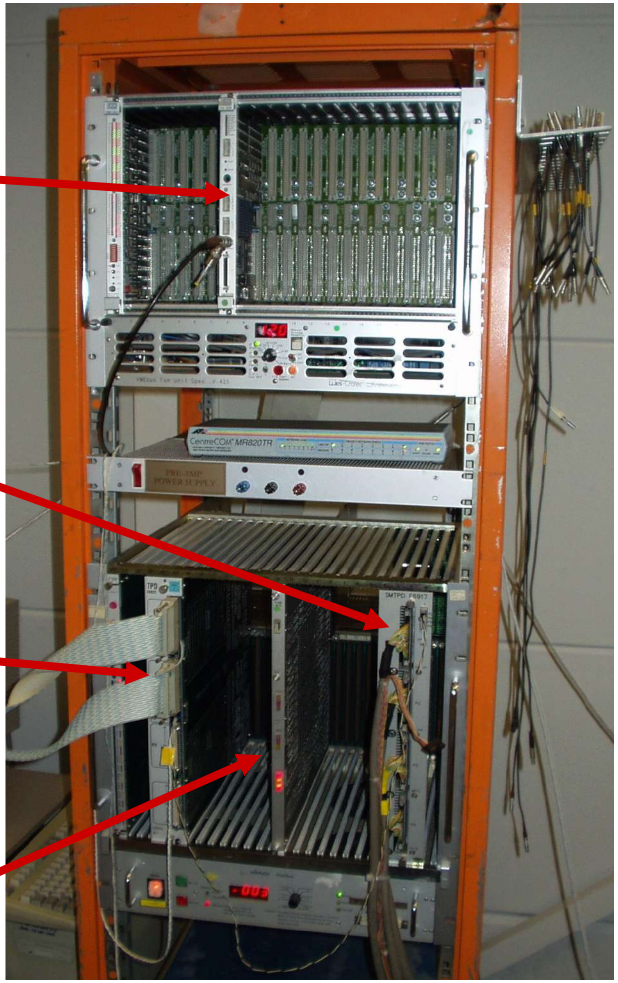






Improved DAQ System

- based on ALEPH technology
- Switched from Mac to VME CPU
- full exploitation of TPD features (e.g. hardware based pedestal subtraction)
- some software optimisation still has to be done (e.g. zero suppression)



Measurements in 5 T Magnet

The Magnet:

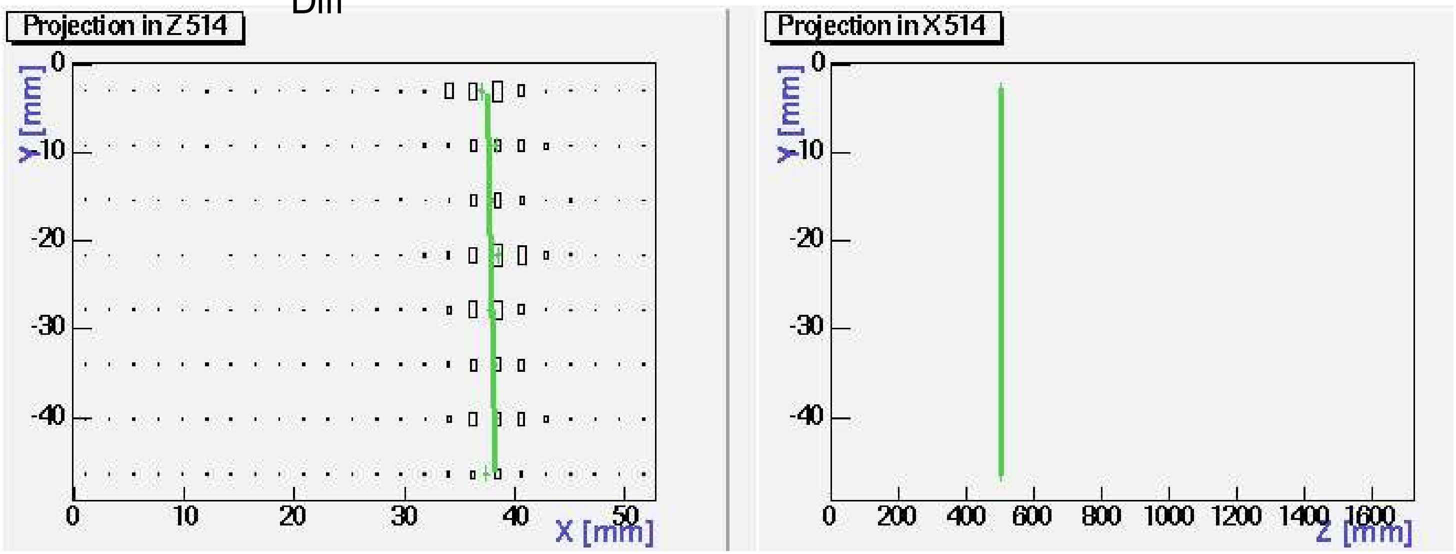
- Superconducting magnet
- 5.3 T maximal field
- 28 cm aperture
- 187 cm cryostat length

The Chamber:

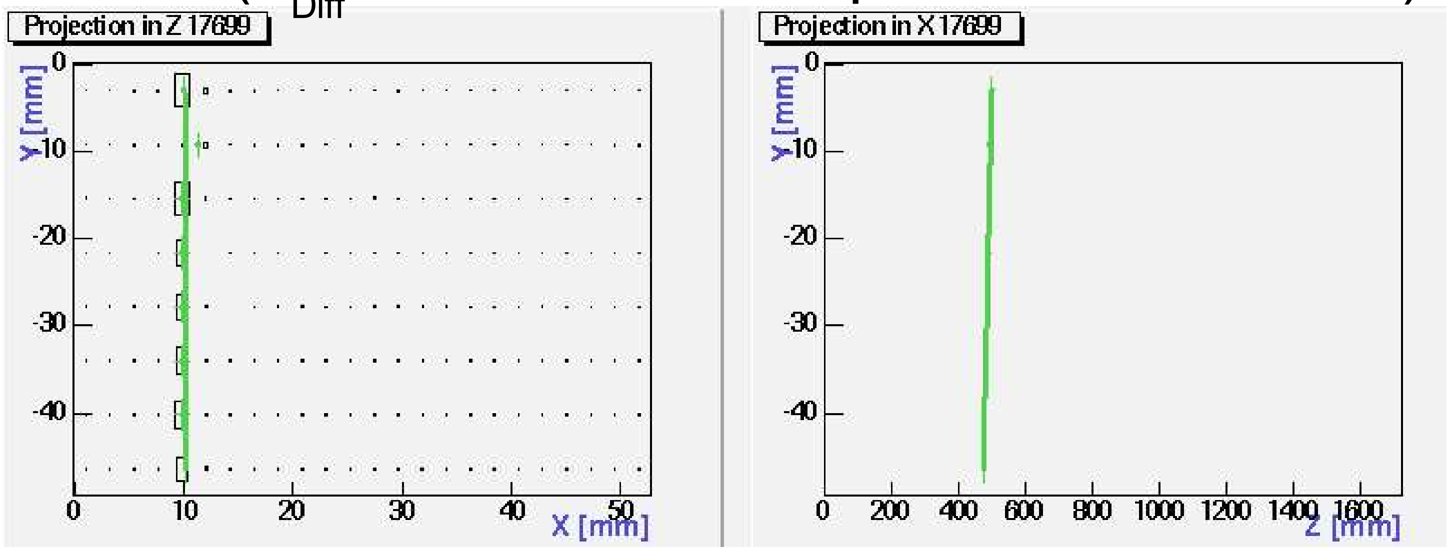
- 192 readout channels
- 6 x 2 mm readout pads
- Active area 5.28 x 4.96 cm^2
- Gas $Ar\text{-}CH_4\text{-}CO_2$ (93-5-2)
- cosmic muons

Two Events

0 Tesla (σ_{Diff} = 3.9 mm ≈ 2 pads for 50 cm drift):



4 Tesla (σ_{Diff} = 0.5 mm = 0.25 pads for 50 cm drift):



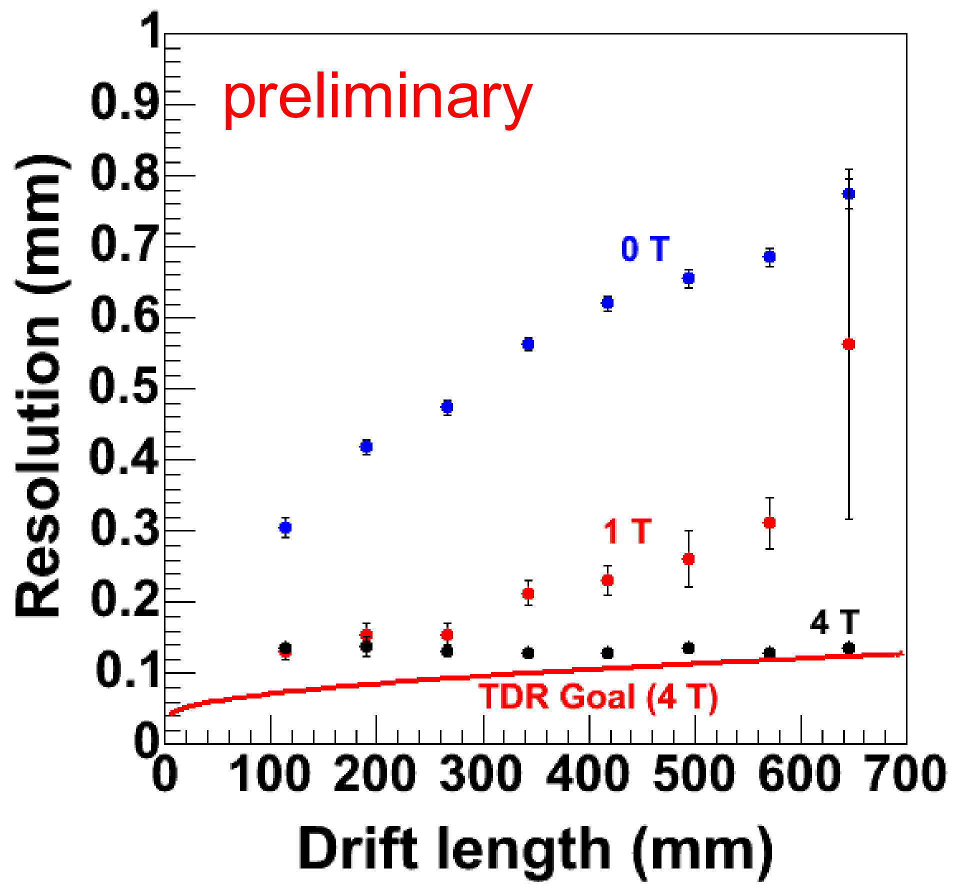
Point Resolution in r-φ

Large drift volume of prototype allows resolution measurements up to 70 cm drift distance

- resolution rises with drift length due to diffusion for 0 T and 1 T.
- at 4 T, even at 70 cm drift distance no rise in the resolution seen

Resolution achieved with first preliminary analysis:

$\approx 130\ \mu m$ at 4 T



- more investigations needed to determine systematic effects
- more statistics for short drift lengths

Gain Homogeneity

→ Importance for dE/dx resolution (TDR goal: 5 %).

→ Measurement of gain homogeneity requires good **calibration** of each readout channel.

Calibration method

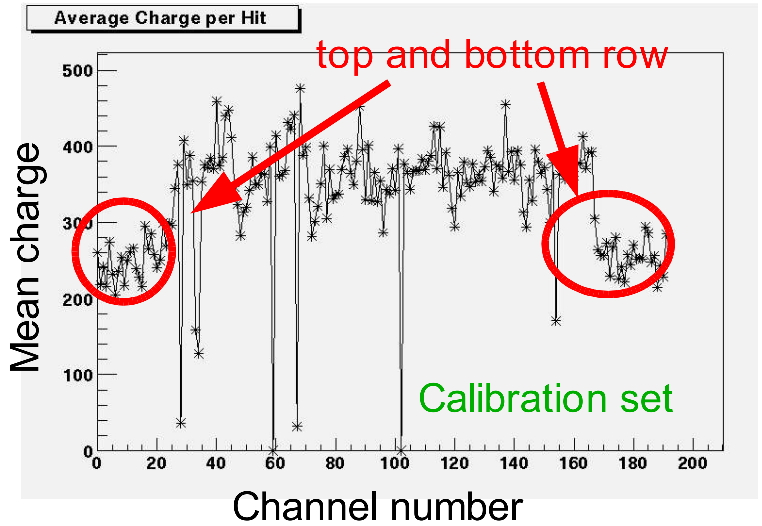
Split data sample into two sets:

- calibration set
- analysis set

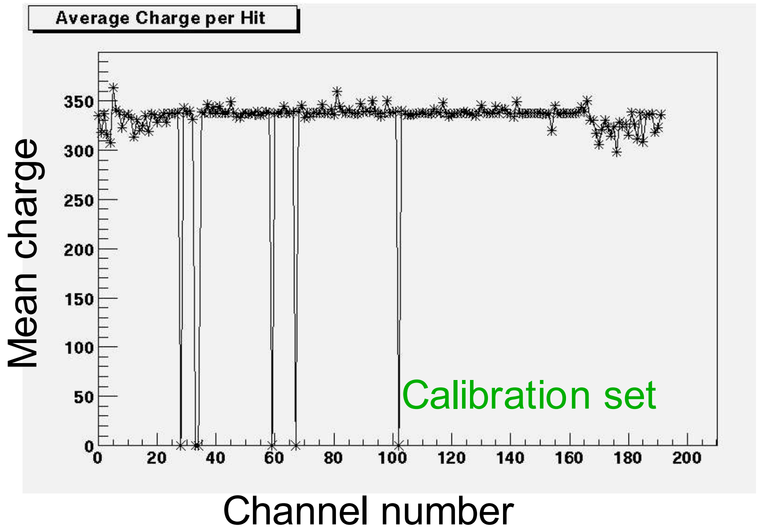
Take calibration set and re-weight mean charge in each channel to be equal to the channel averaged charge

Gain Homogeneity

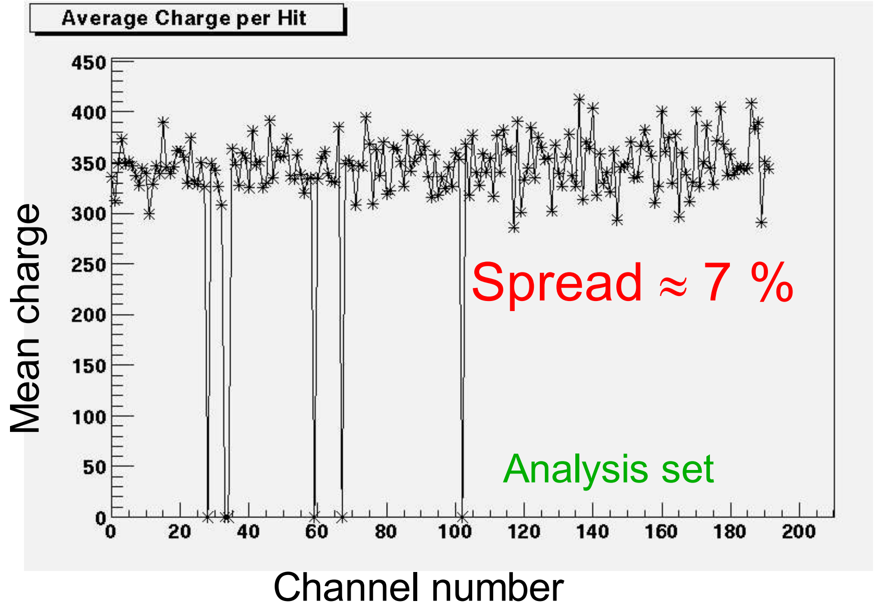
Before calibration:



After calibration:



Analysis set:



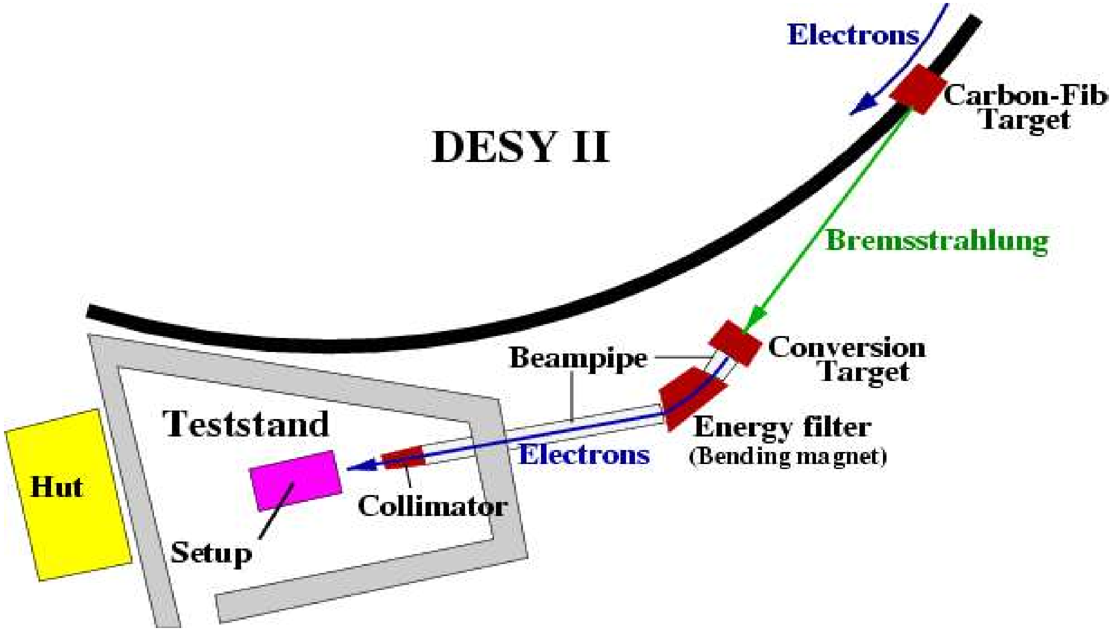
7% spread still contains statistical, thermal, ..., fluctuations

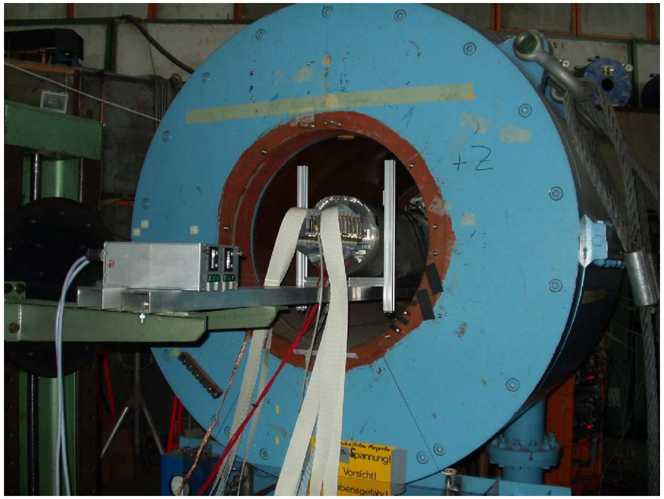
→ more work and data needed

DESY Electron Test Beam

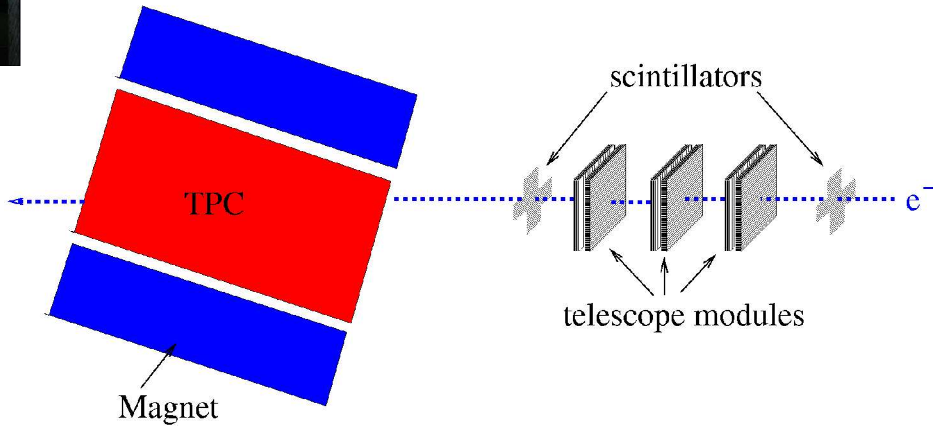
Motivation:

- High statistics in short time
- Study field distortions systematically
- double track resolution (target)

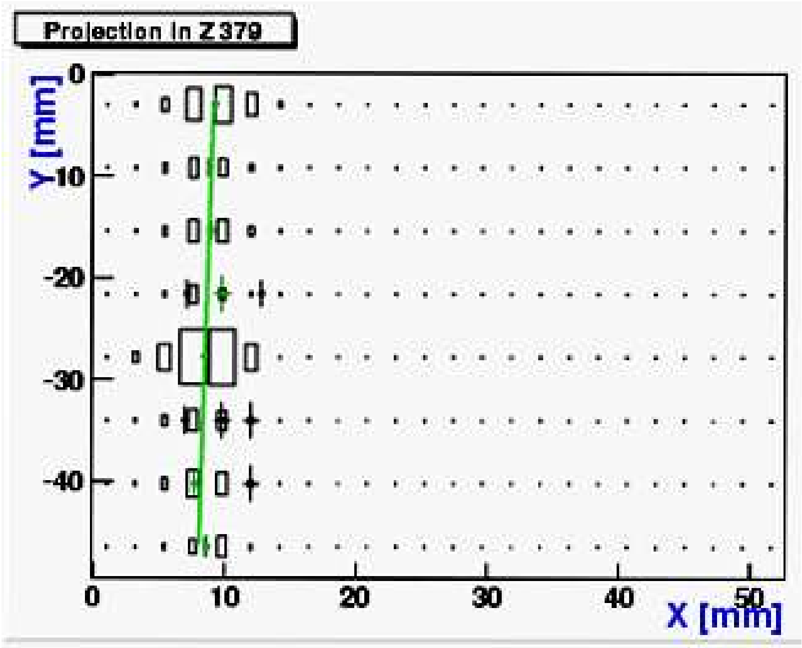


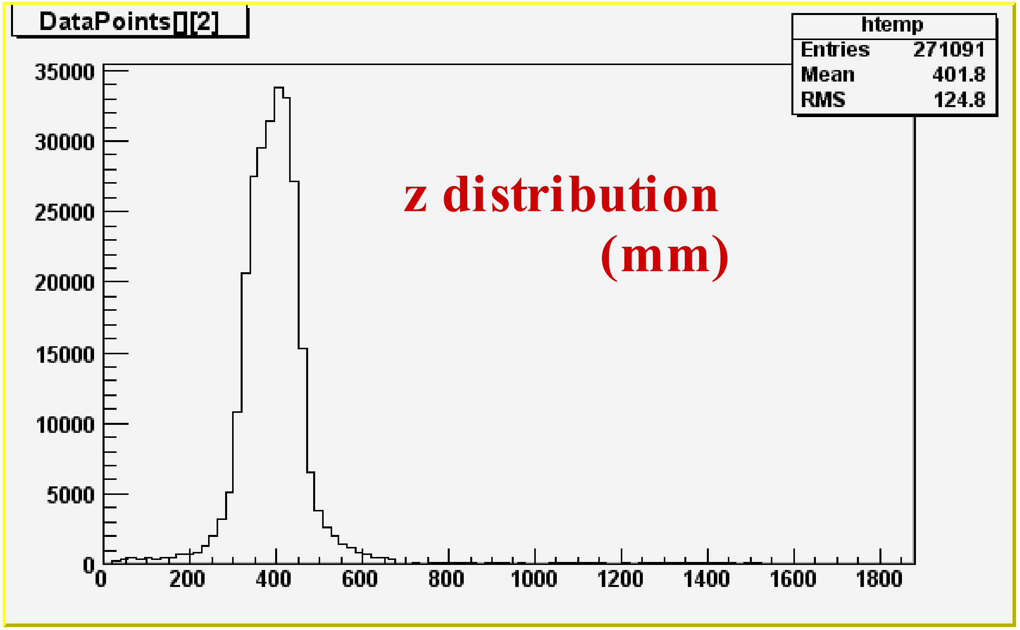


- up to 6 GeV e^-/e^+ beam
- 0.75 T magnet
- trigger: 2 finger scintillators
- silicon beam telescope



First Events



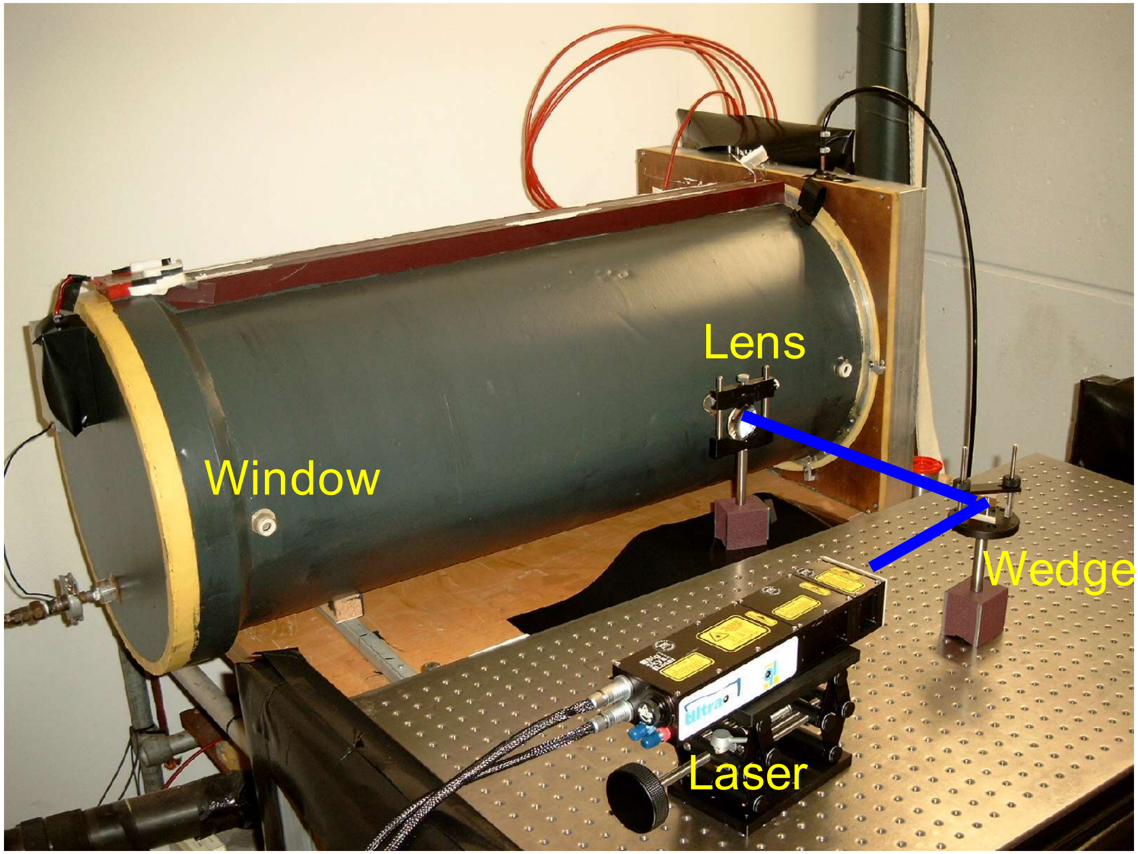


Status

- first data taking period finished
- data analysis just started

UV Laser System

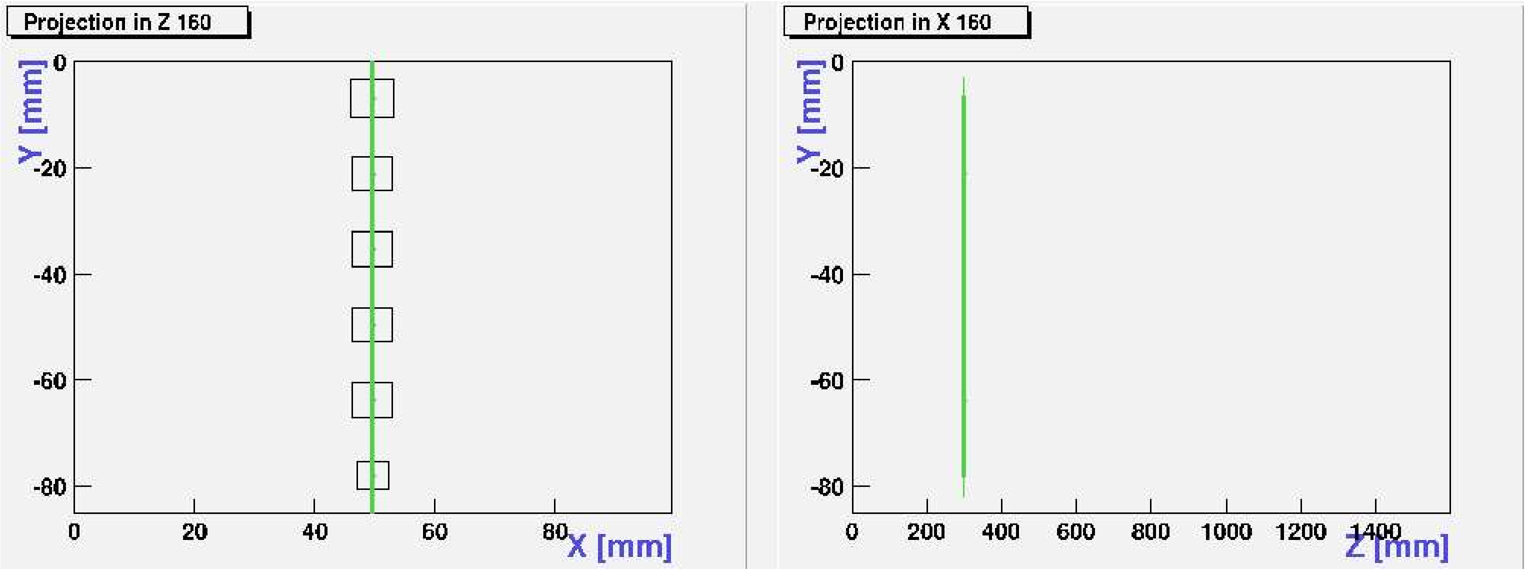
The laser tests are carried out with our ***old large chamber***.



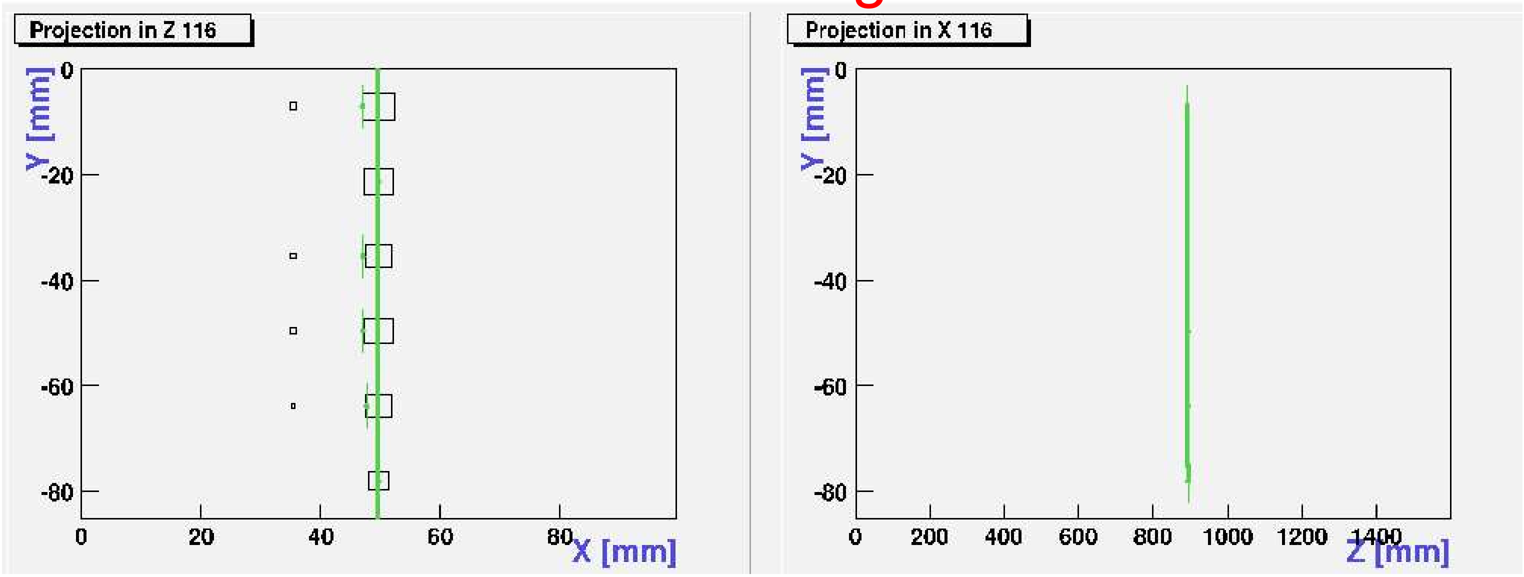
Setup used to produce laser tracks in the TPC

Laser Tracks

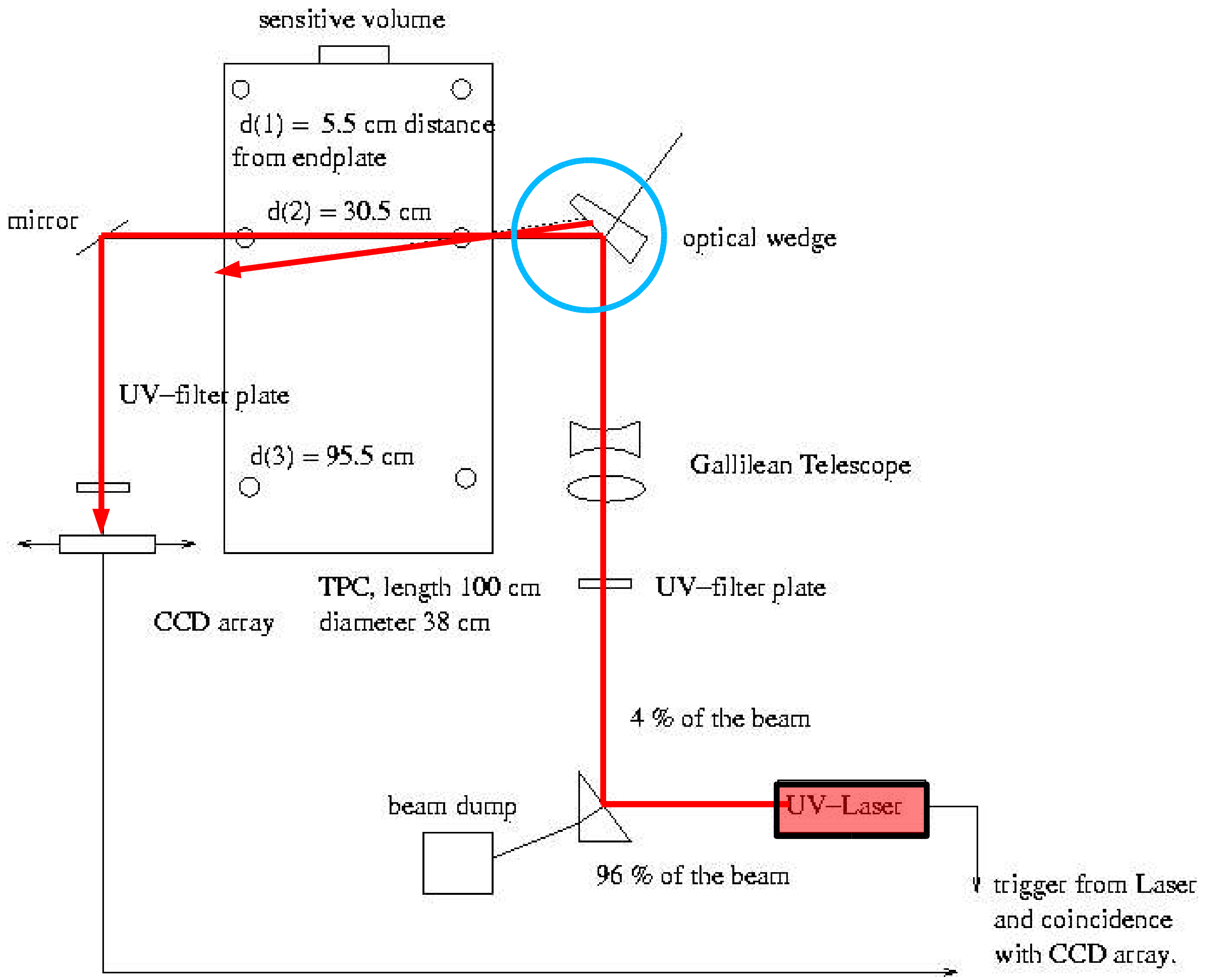
30 cm drift length:



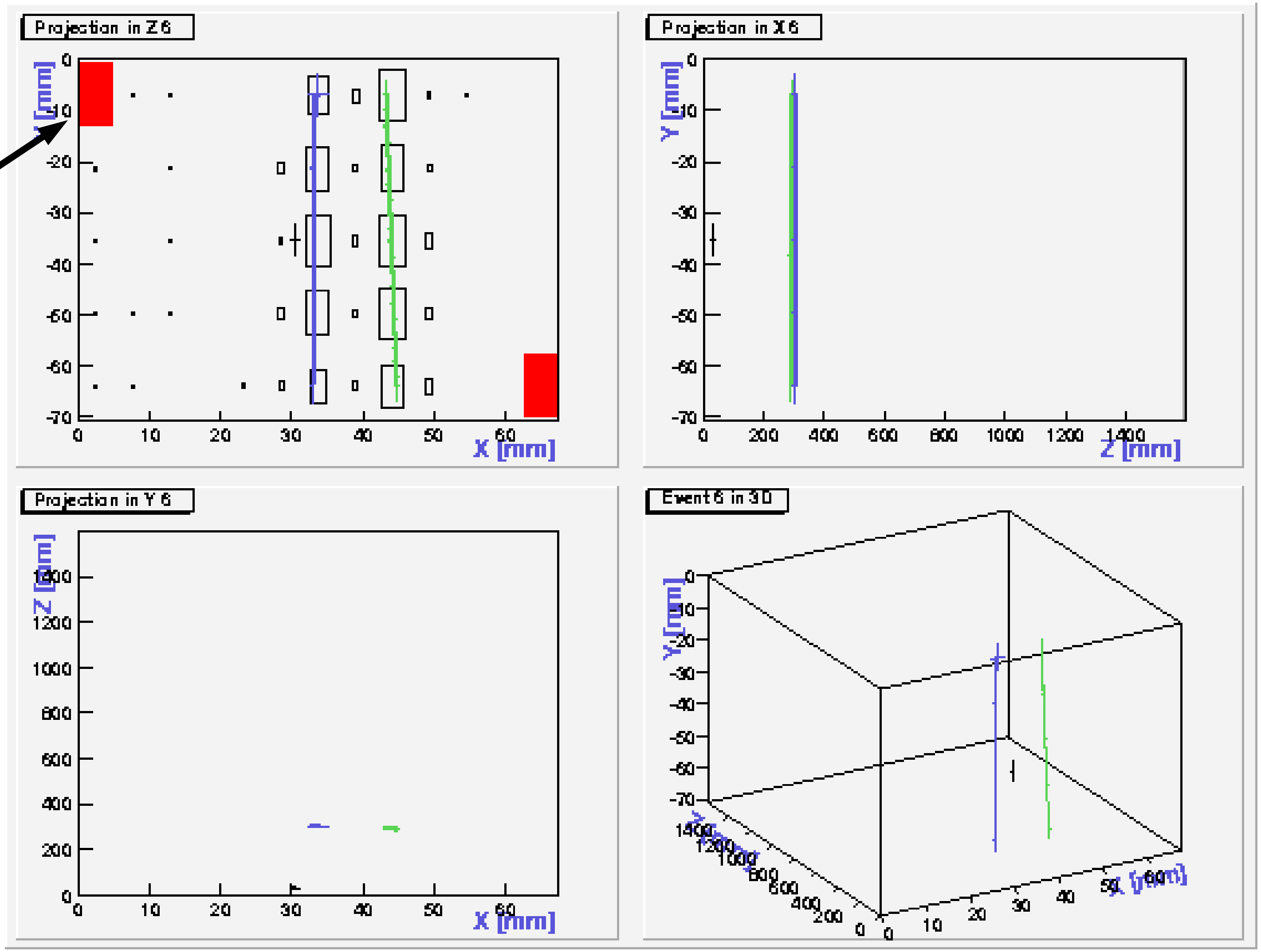
90 cm drift length:



Setup f. Laser Double Track Studies



A Laser Double Track Event



dead channel

Summary and Outlook

- **Successful data taking with different TPC prototypes**
  - cosmic muons in magnetic fields up to 5 T
  - electron test beam in fields up to 0.75 T
  - laser beam → two track resolution
  - measurement of ion feedback (not mentioned)

➔ **GEM (MPGD) readout promising for the linear collider TPC.**

- **Analysis of huge amount of data to be done, e.g. implementation of PRF into track fit, determination of double track resolution.**

- **More measurements planned, e.g. with different pad arrangements and geometries aiming $\sigma_{r\varphi}$=100μm.**

GEM TPC Studies at KEK

Purpose

- compare basic chamber performances of MWPC and MPGD readout
  - spacial resolution
  - 2-track separation
  - dE/dx capability
- use the readout plane of the same TPC for MWPC and MPGD (GEM)
- comparison of data with simulation
- establish design procedure for a full scale MPGD TPC

GEM TPC Studies at KEK

International Collaboration

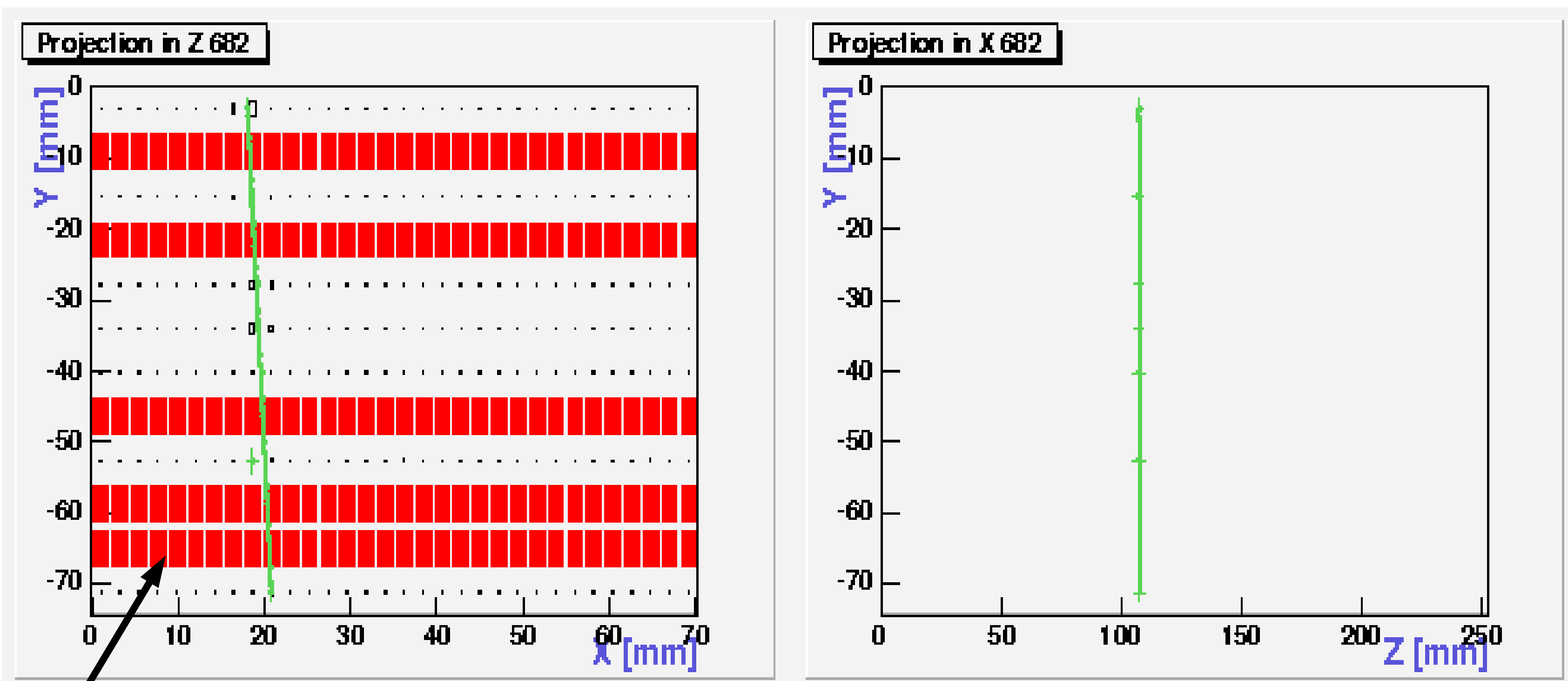
- GLC CDC Group

  Hiroshima, KEK, Kogakuin, Kinki, MSU, Saga, Tokyo, Tsukuba, TUAT

- MPI/DESY Group, Germany
- IPN Orsay Group, France

GEM TPC Studies at KEK

- Hadron beam measurements with MWPC readout from 16/June/04 until 01/July/04,
- O(100 000) evts. already recorded; data analysis started.

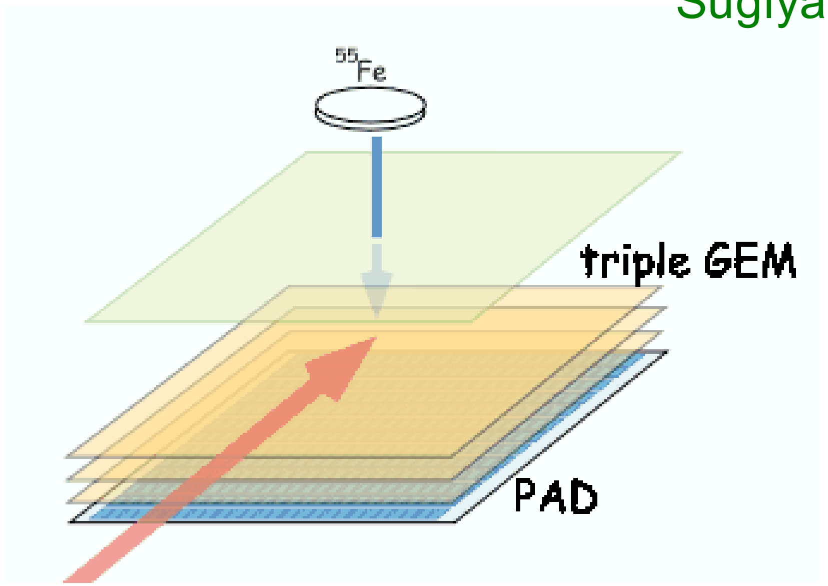


pads not
being read out

Event recorded at p = 4 GeV, π^- trigger, B=1T.

GEM test for gLC/TPC @KEK

Sugiyama et al.



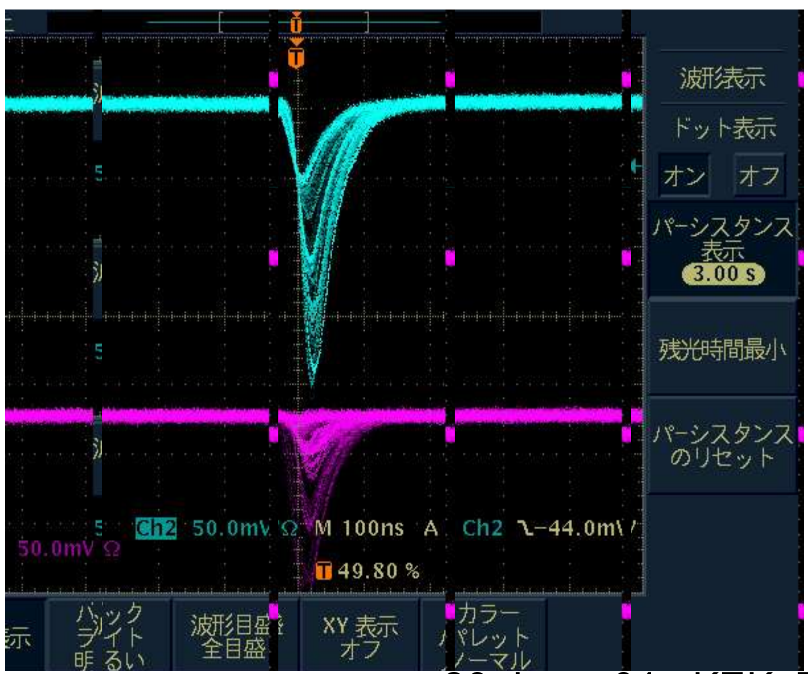
triple GEM

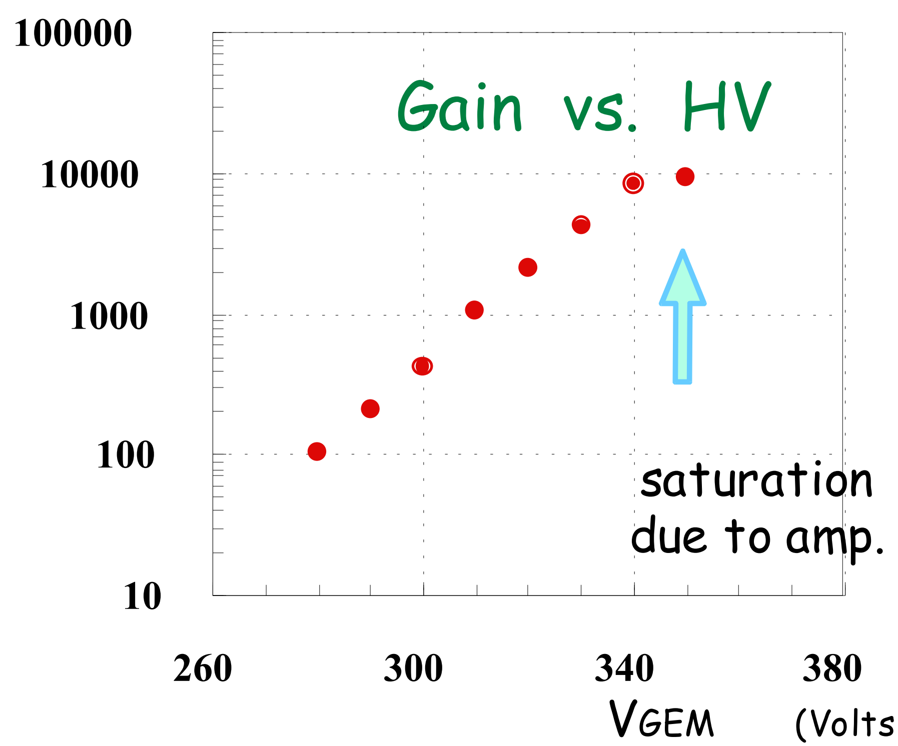
10 x 10 cm2

2 types
- Japanese(CNS/Fuchigami)
- CERN

Readout
- MPI TPC pads (2mm x 6mm)
- Belle CDC's Pre/Post amplifier
- ADC only (24ch)

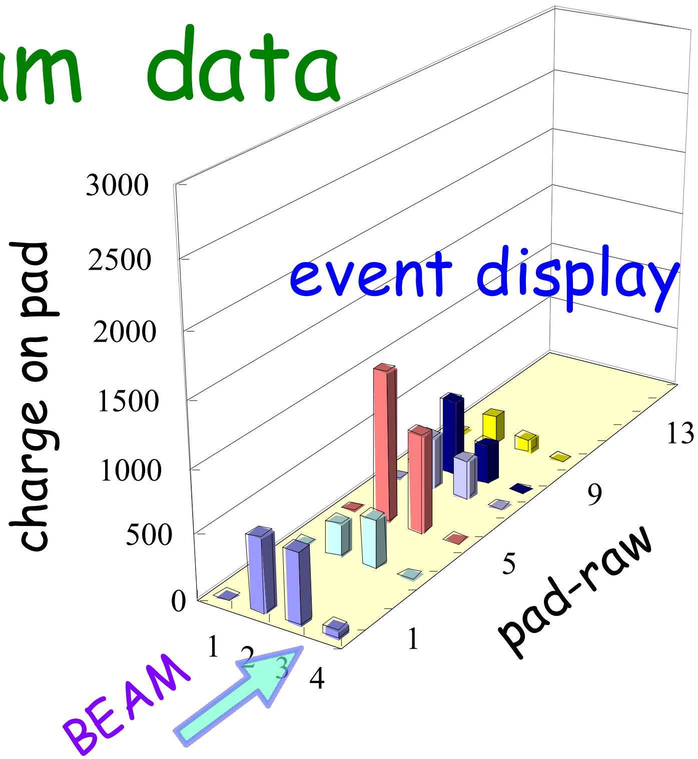
Signal from Fe 5.9keV X-ray





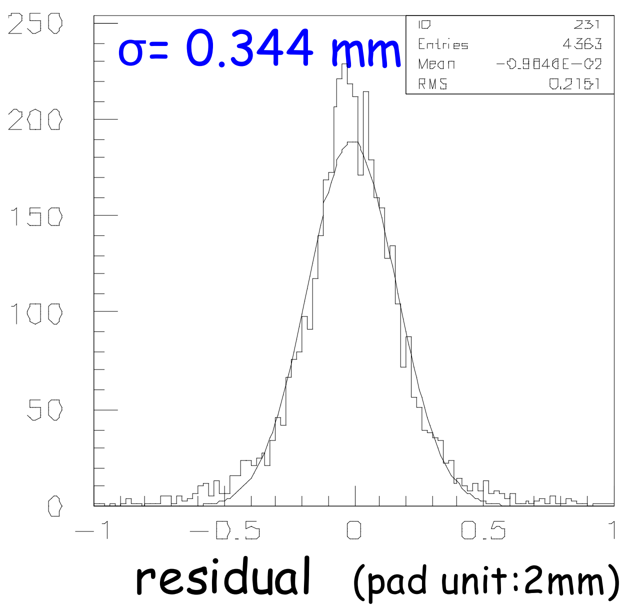
Beam data

readout 6 pad-raws : 4 pads/raw



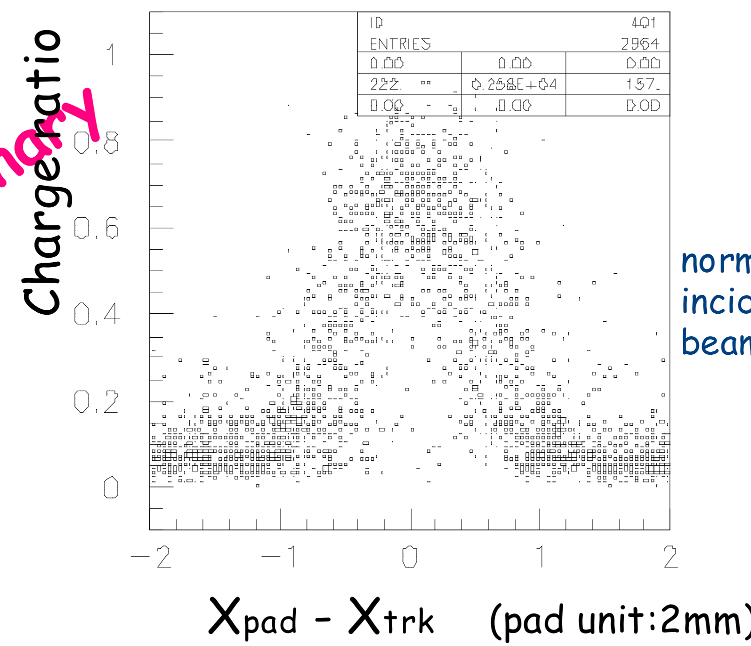
Charge distribution on pads
@ raw 8
Xtrk -> COG(9)

position <- COG of 4 pads
residual = COG(6) - 0.5*(COG(1) + COG(11))



Very Preliminary

signal response fcn.



normal incident beam

GEM TPC Studies at KEK

- Next: Careful and systematic data analysis and
- GEM installation in the TPC readout plane,
  - measurements with cosmic muons in magnet,
  - GEM measurements in hadron beam planned for spring 2005.