Ongoing R&D at DESY
for a GEM based TPC for the ILC

Resolution Studies:
Techniques and Results

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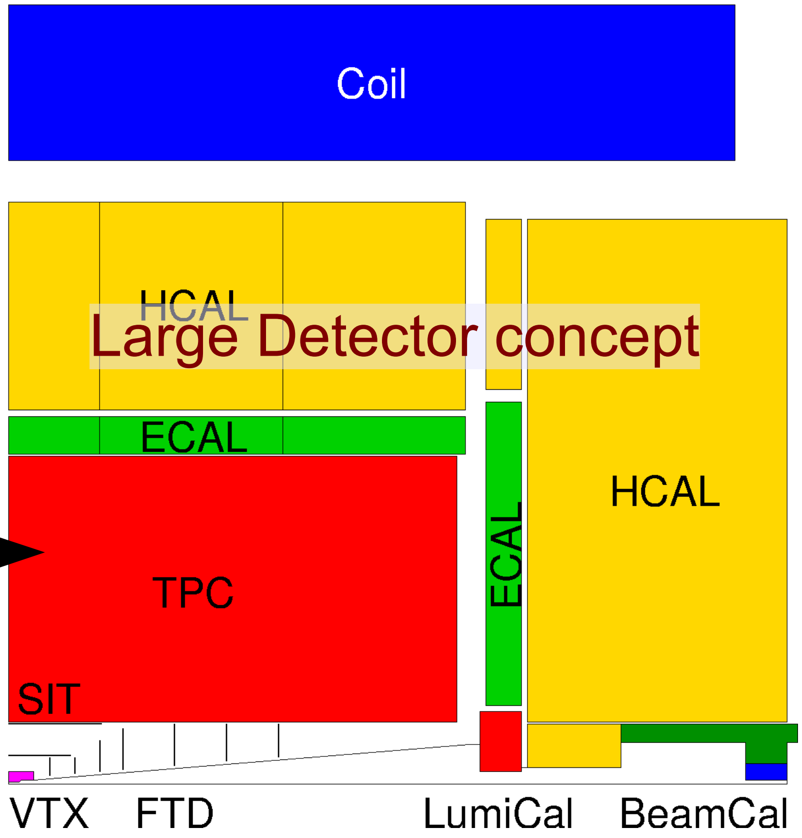
A Tracker for the ILC

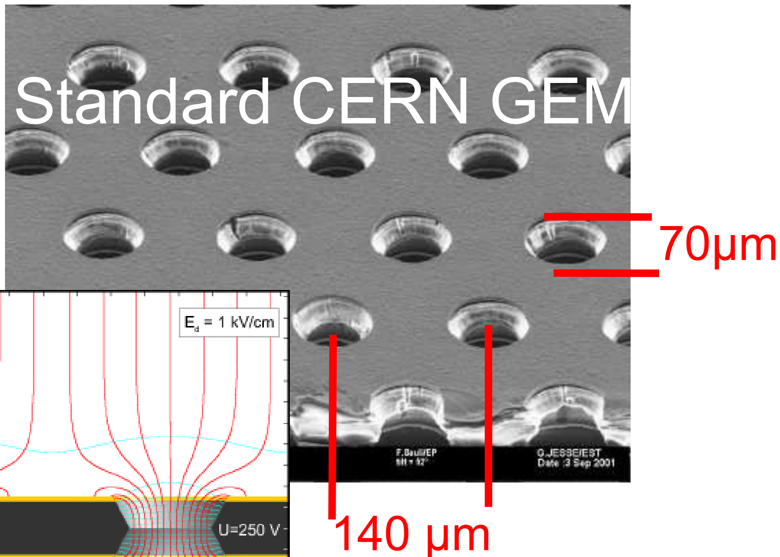
- requirements: excellent precision and excellent reliability
- physics demands: (e.g. model independent Higgs analysis)
  - high resolution $\Delta p_T/p_T^2 = 5 \cdot 10^{-5}$ GeV^{-1}
    (overall tracker, inclusive vertex detector)
- particle flow
  - low material budget
  - robust and efficient pattern recognition

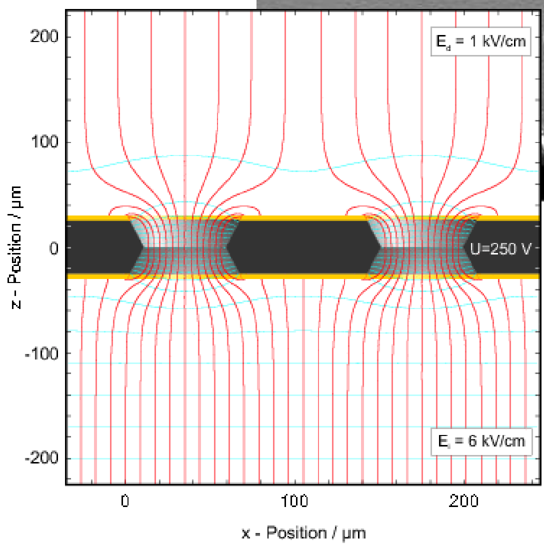


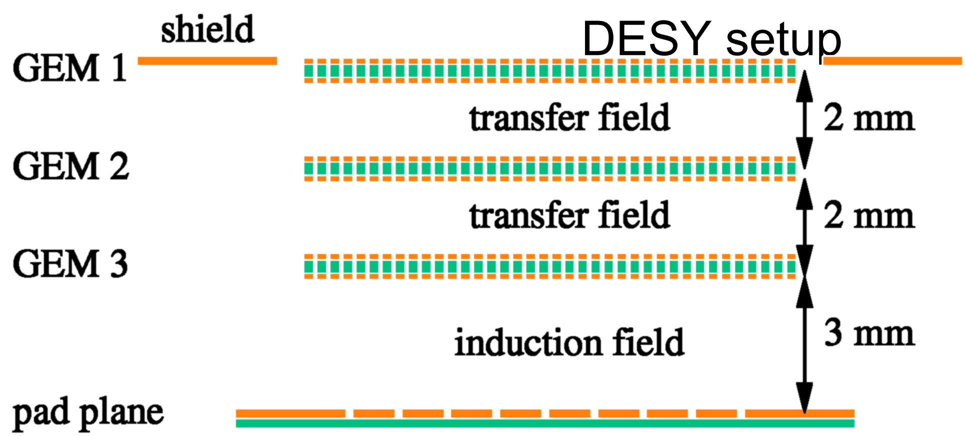
- LDC chose a TPC to meet these demands
  - spatial resolution (rφ) ~100µm

Gas Electron Multiplier

- GEM (Gas Electron Multiplier): Kapton foil with copper layers on both sides and double conical holes
- amplification through gas ionization inside the GEM holes (field strength: several 10 kV/cm)
- advantages
  - fast and direct electron signal is measured on the pad plane
  - intrinsic ion-backdrift suppression improved in multi-GEM setups

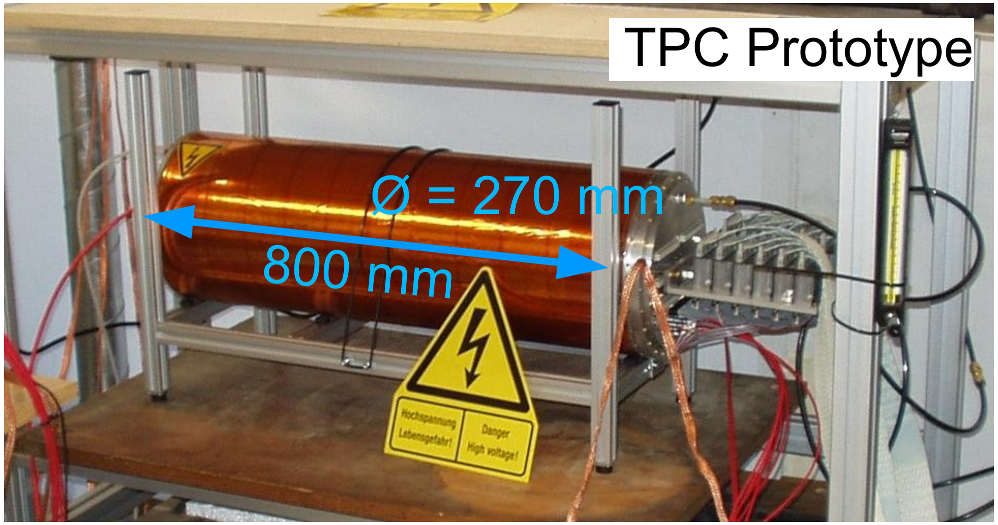


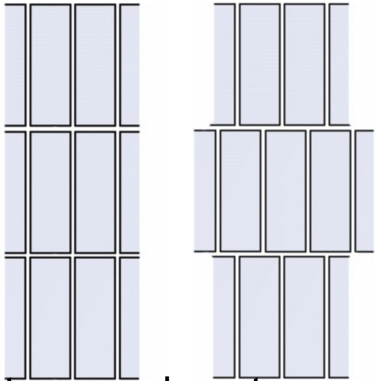


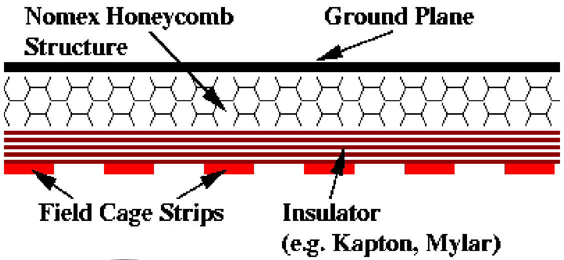


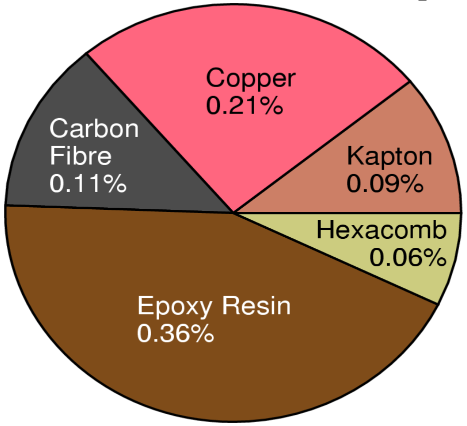
TPC Prototype and Measurement Setup

- MediTPC: prototype for resolution studies with long drift distances in high magnetic fields
  - sensitive volume: 666.0 x 49.6 x 52.8 mm^3
- triple-GEM amplification structure
- pad layout
  - rectangular pads, pitch: 2.2 x 6.2 mm^2
  - staggered and non-staggered
  - 24 pads in 8 rows
    - crosstalk in outer rows
    - → using inner 6 rows for analysis




non staggered   staggered





in X_0:
$\sum \approx 1\%$

Data Sets

- cosmic muons
- different gases
  - TDR (Ar-CH_4-CO_2: 93-5-2)
  - P5 (Ar-CH_4: 95-5)
  - diffusion coefficient D and defocussing constant σ_0

	P5		TDR	
B (T)	D (mm) 10^{-4}	σ_0 (mm^2)	D (mm) 10^{-4}	σ_0 (mm^2)
0	571	0.288	202	0.180
1	24.05	0.227	34.1	0.142
2	7.24	0.190	11.5	0.110
4	1.92	0.140	3.00	0.070

calculated with MAXWELL 7.0

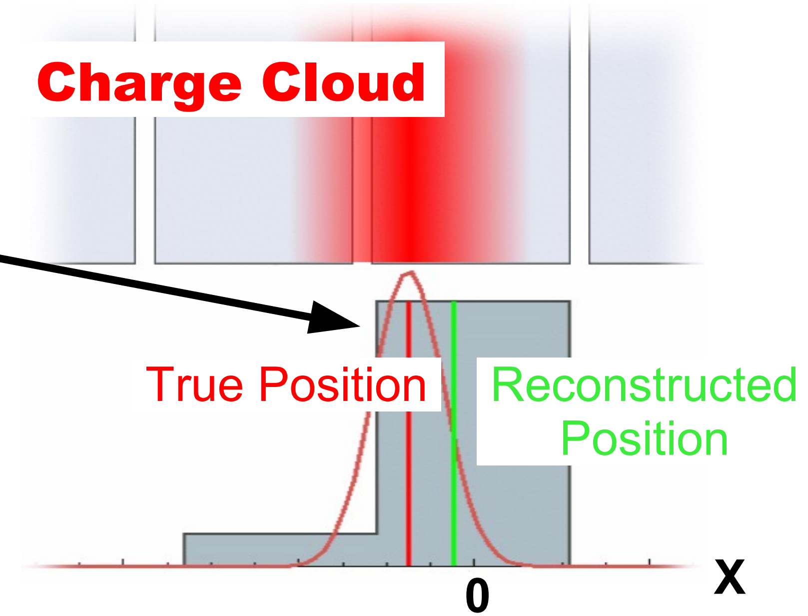
- pad layouts
  - non-staggered
  - staggered

- several magnetic fields
  - 0 T, 1 T, 2 T, 4 T

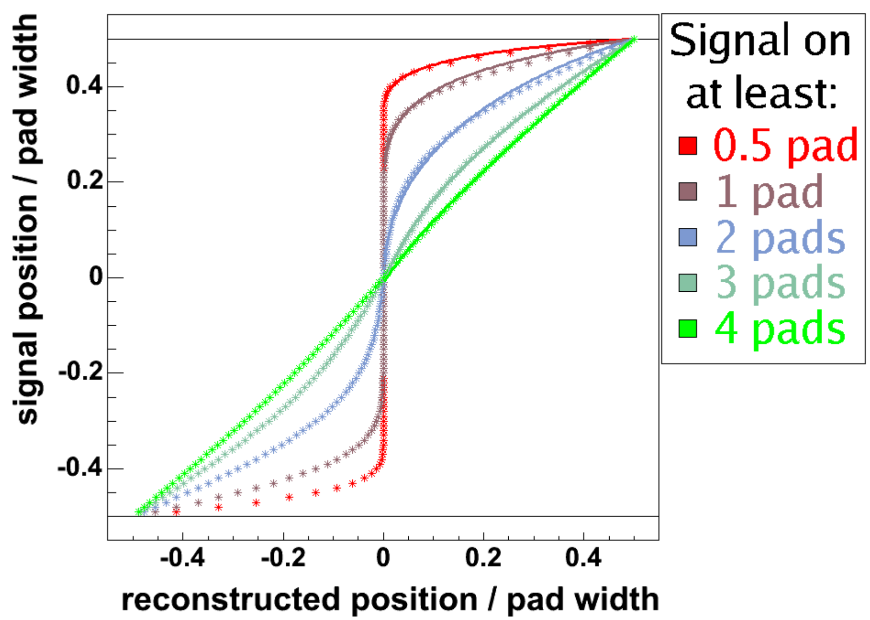
Test Magnet

Traditional Approach for Track Finding&Fitting

- reconstruct space points in each row using a center of gravity method (charge)
  - for narrow signals position is shifted
  - correction of this effect using the pad response function (PRF) (Gaussian signal assumption)
    - input parameter : signal width (calculated out of diffusion and defocussing)

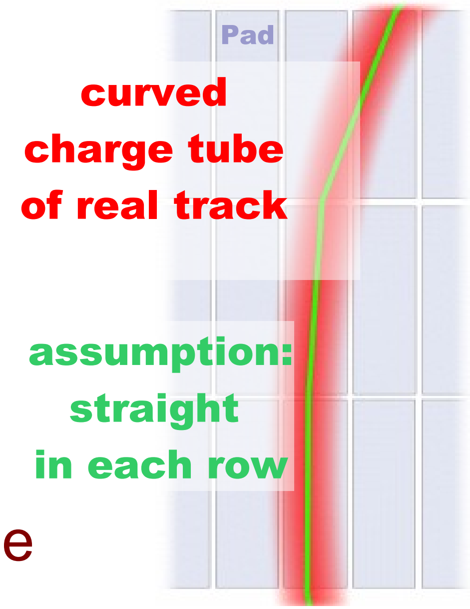


- combine the points to tracks using a track following algorithm and a simple χ^2 fit

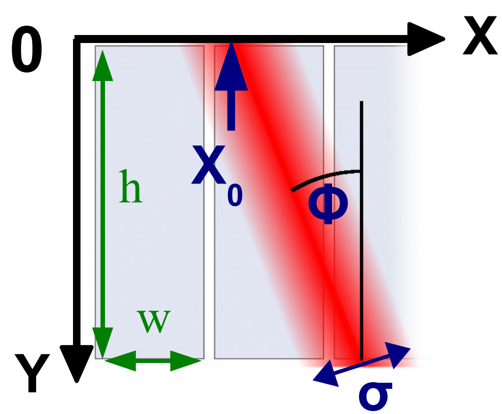


Global Fit Method

- global fit method[1)]:
  - do not form separate hits
  - fit in one step the pad hits
    - assuming a Gaussian charge cloud to a track model
    - In each row the track can be described by a straight line
    - effectively fit the PDF and track at the same time



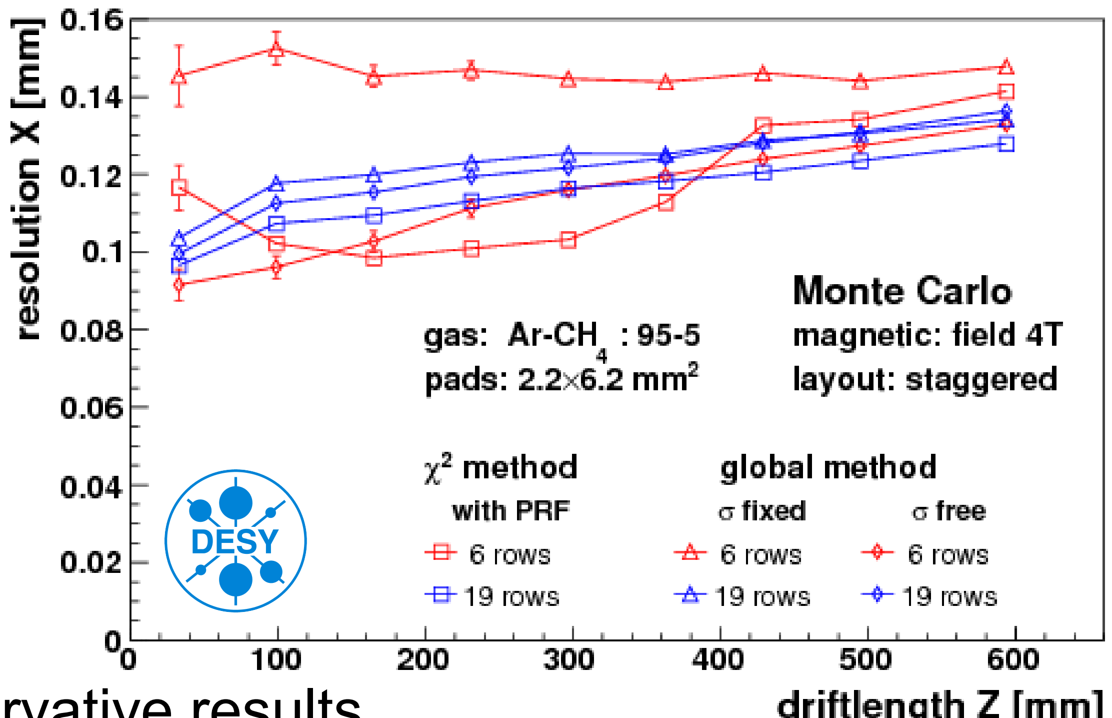
- four (three) parameter fit:
  - Intercept X_0 (x at y=0)
  - azimuthal angle Φ
  - curvature C
  - width of the charge cloud σ
    - possibility to fix the width
    - σ is calculated for each row using the z information



1) introduced by Dean Karlen: NIM A555 (2005) 80-92, TPC Performance in Magnetic Fields with GEM and Pad Readout

Monte Carlo Tests

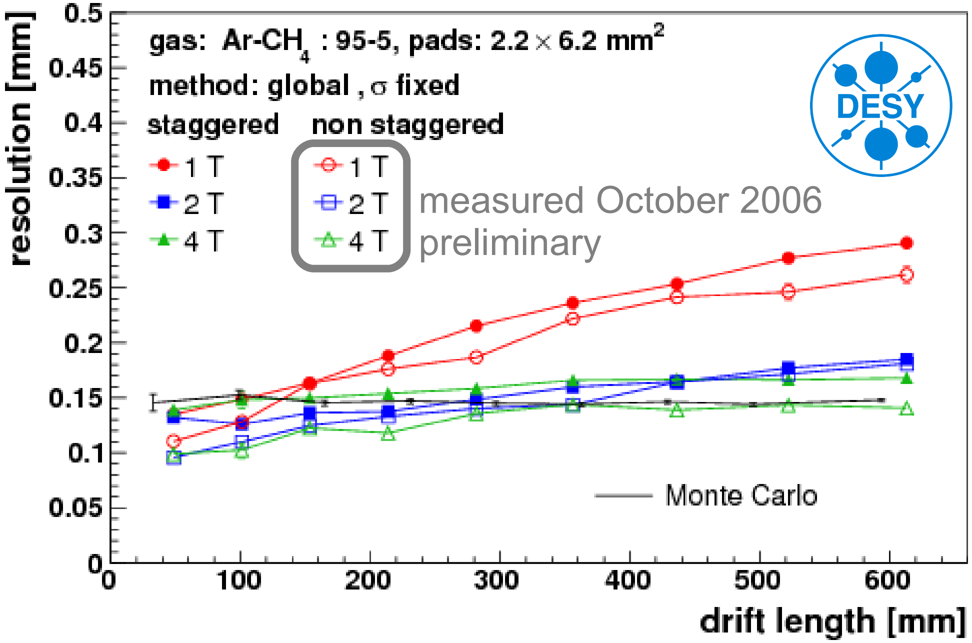
- Monte Carlo: detailed simulation of primary ionization, drift, amplification and pulse information
  - realistic modeling of experimental setup (dead channels, noise, etc).
    - χ^2 method shows strange dependence on drift distance → unstable
    - Global Method depends strongly on freedom of track width σ
  - testing of algorithms: model with 19 rows studied (all pads working)
    - both algorithms
      - are stable
show the expected dependence on drift length
      - produce compatible results

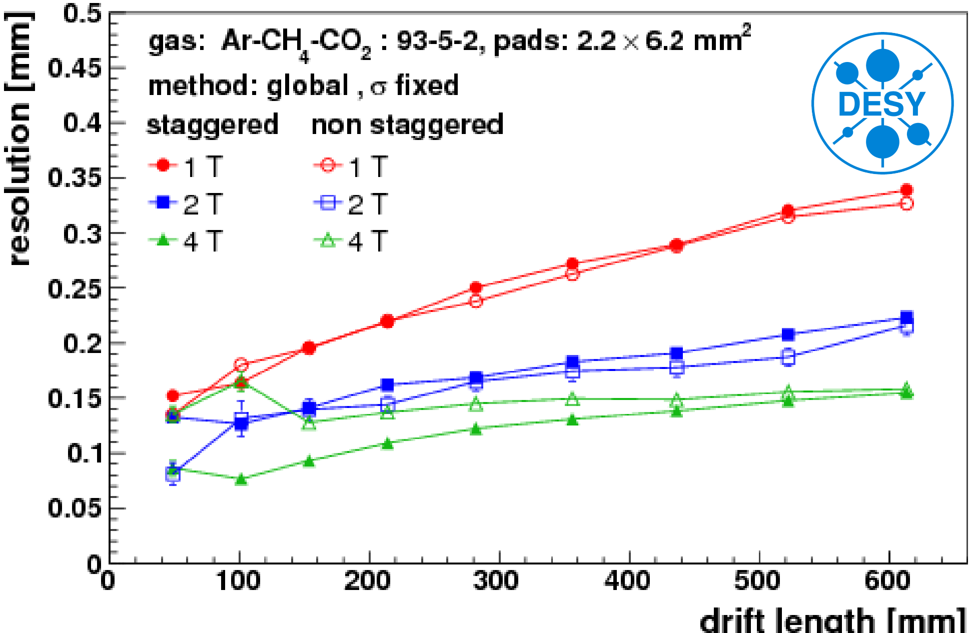


- using global fit with fixed track width σ
  - stable and produces conservative results

Results

- resolution of 120 um for 0 drift length reached
  - dependence on drift length is as expected and limited by diffusion
  - for lower fields: good agreement between staggered and non staggered data sets
- in high fields there are still some indications that pads are too small
  - results for different layouts are not totally compatible
    - in particular at short drift distances





Summary And Outlook

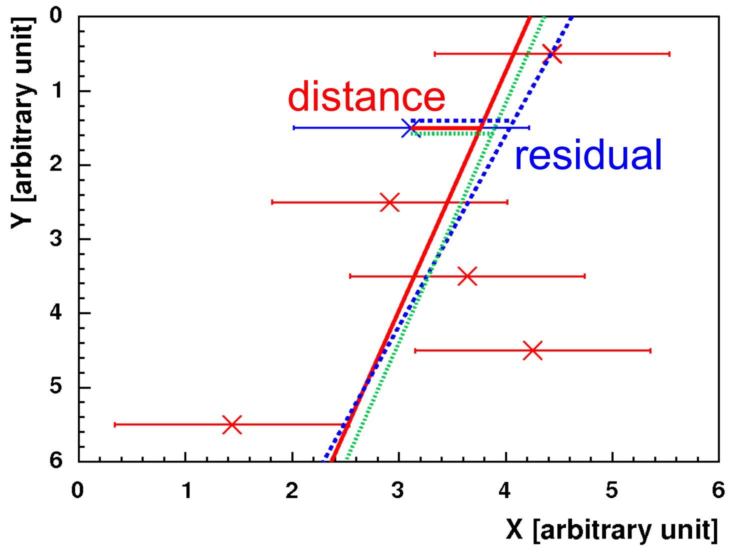
- GEMs are a good amplification device for TPCs
- spatial resolution of 120 μm can be achieved for 0 drift distance in the rφ
  - use of conservative algorithms (can be improved)
- resolution can still be optimized to reach the goal of 100 μm by
  - reducing the pad size
  - changing of the GEM setup (larger defocussing)
  - choice of the gas

- measure the spatial resolution
  - with smaller pads and
  - more rows (for fit stability)
- measurement of double track resolution (using laser)
  - is affected by optimizing the parameters for spacial resolution for single tracks

BACKUP SLIDES

Point Resolution: Geometric Mean Method

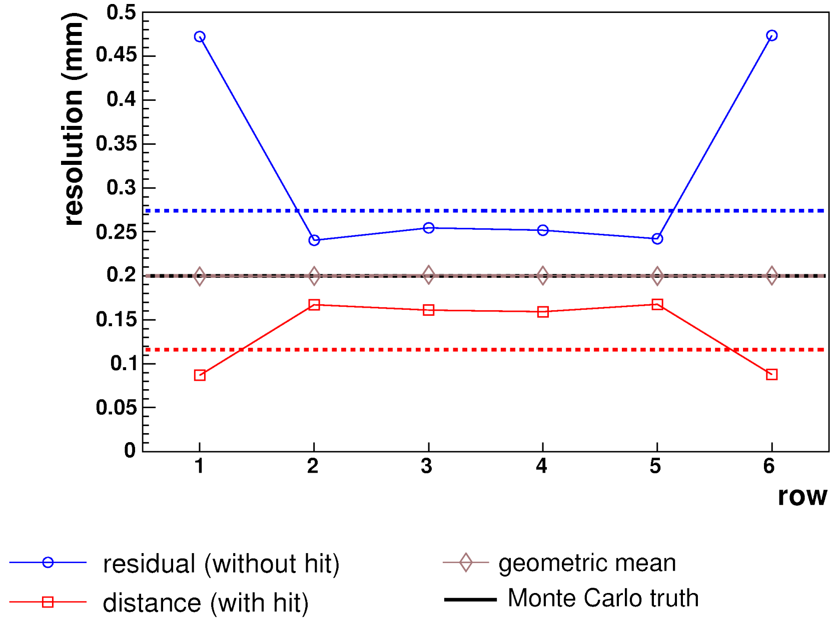
- True track position not known
  → calculate two residuals
  - once for track fit including the point
    (denoted "*distance*")
  - once for track fit without the point
    (denoted "*residual*")



- Determine the width of both distributions by Gaussian fit
- Resolution calculated from geometric mean of both values:

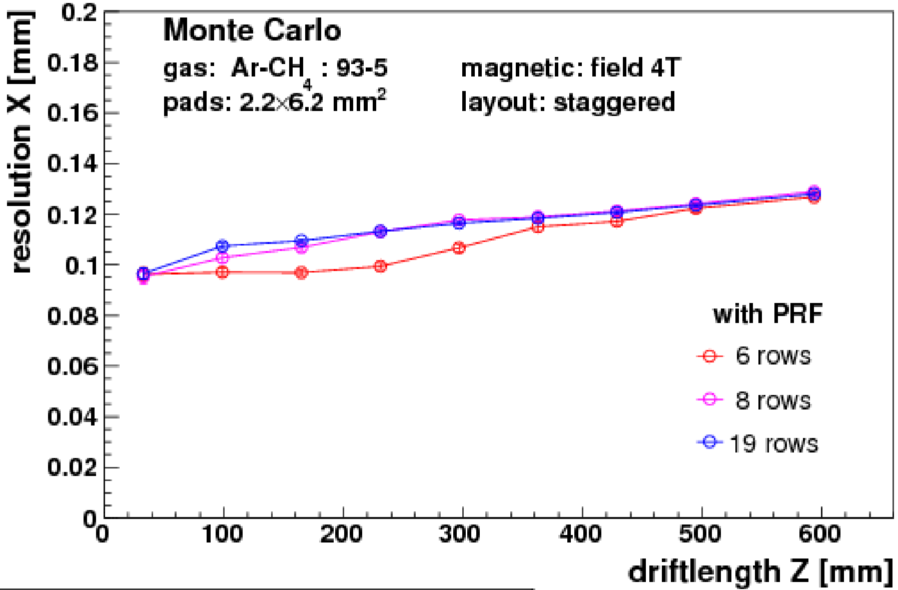
$$\sigma = \sqrt{\sigma_{with} \cdot \sigma_{without}}$$

  - Proven for
    - straight tracks : analytically
    - curved tracks : MC studies

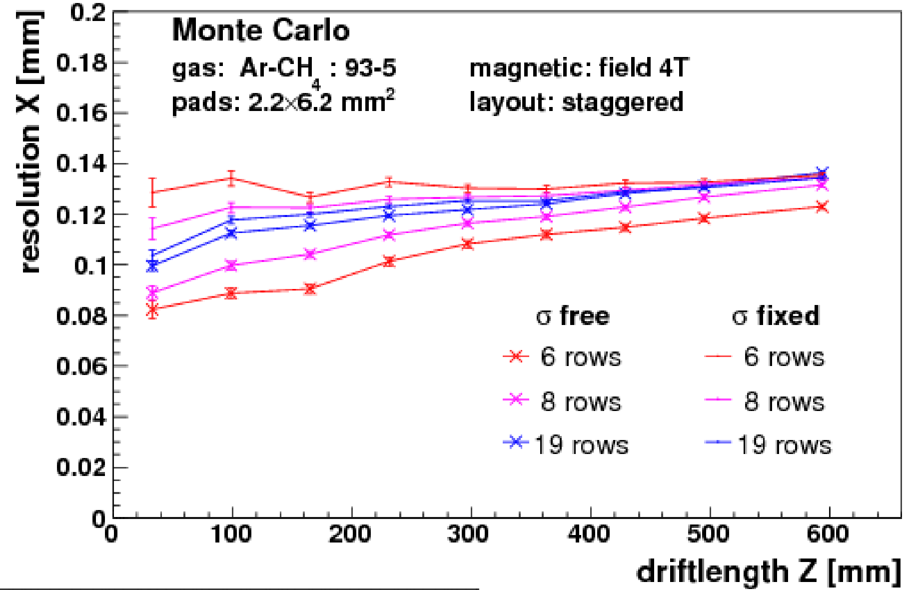


Damaged Pads

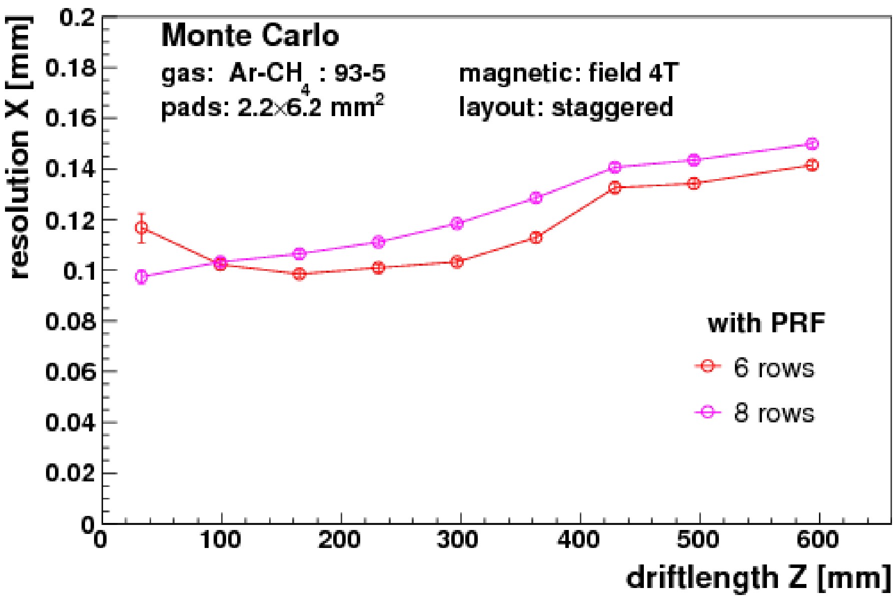
chi square method with working pads



global method with working pads



chi square method with damaged pads



global method with damaged pads