Studies of Resolution and Reconstruction Methods for a TPC

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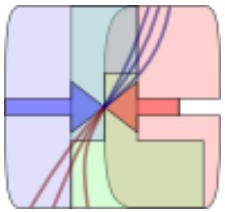

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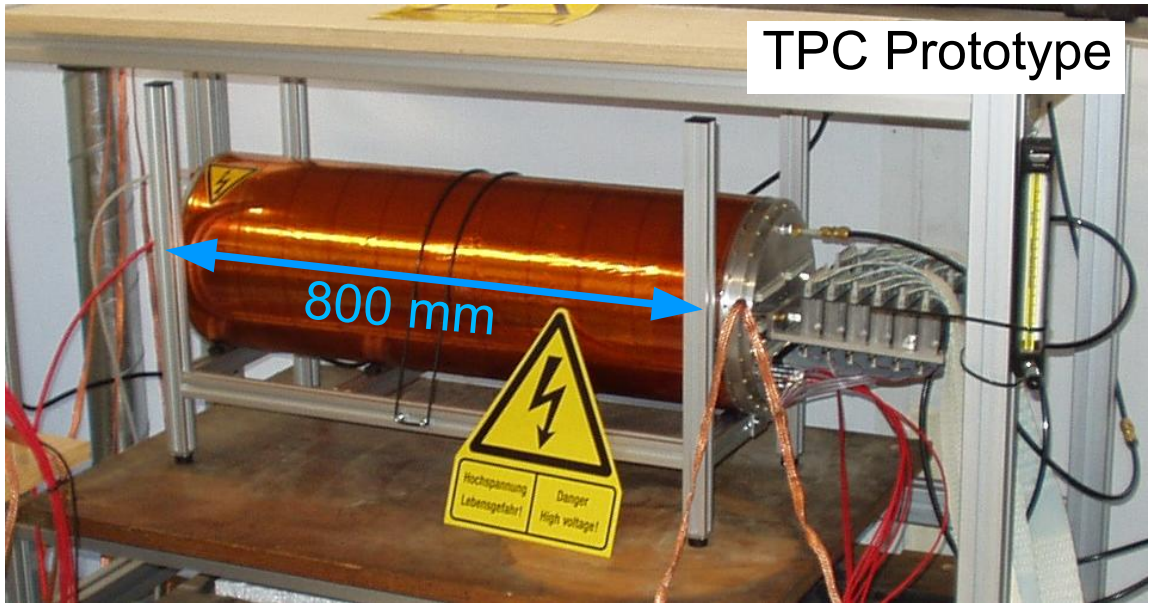
Outline

- TPC Prototype and Reconstruction Software
- Pad Response Function
  - Measured resolution and reconstruction problems for staggered and non-staggered pad layout
  - Pad Response Function
  - Resolution results with Pad Response Function
- Monte Carlo Simulation
  - Simulation
  - First results: efficiency studies
- Summary and Outlook

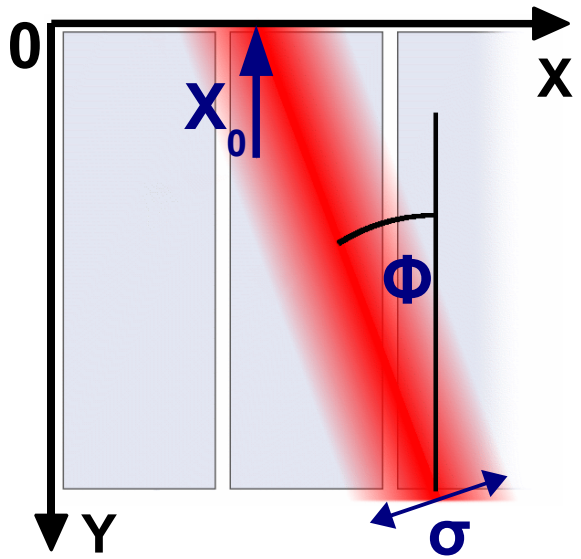
TPC Prototype and Measurement Setup



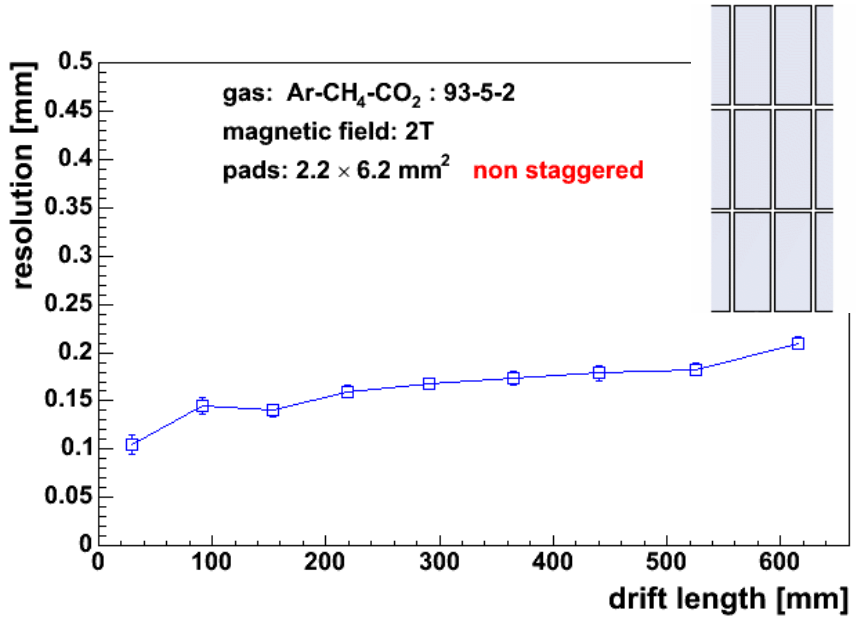
- Prototype: MediTPC
  - Lenght: 800 mm, diameter: 270 mm
  - Sensitive volume: 666.0 x 49.6 x 52.8 mm^3
  - Triple-GEM amplification structure
  - Staggered and non-staggered layout pad planes (Pitch: 6.2, 2.2 mm)
  - Magnetic field up to 5.25 T

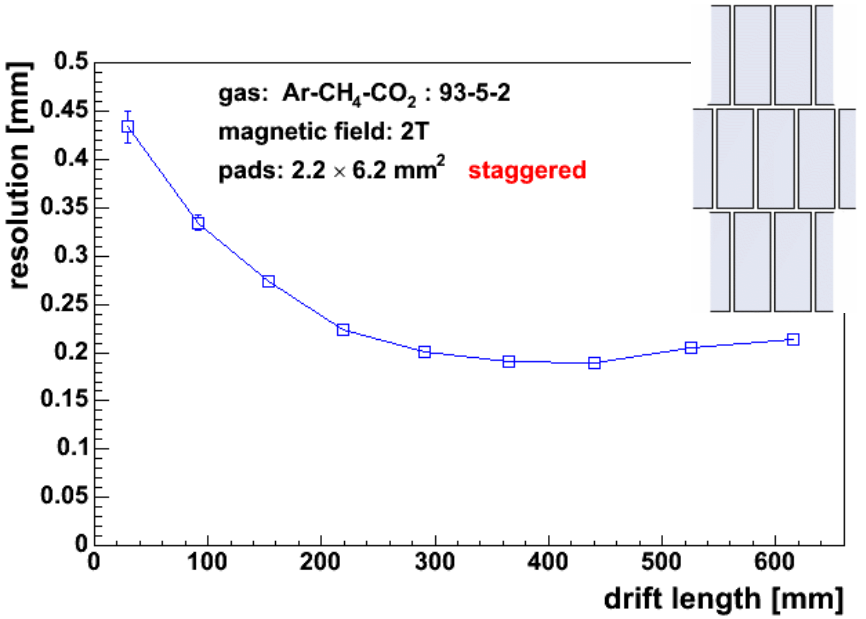
Fitting Software: Multifit

- Input Formats: LCIO, ROOT
- 3 Step Process: Hit Reconstruction → Track Finding → Track Fitting
- Implemented Fitting Methods (each for straight and curved tracks)
  - Chi Squared Method (optional with Pad Response Function)
  - Advanced Fit Method (*TPC-Group Carleton University, Canada*):
    - XY track fit uses a Gaussian model for charge cloud
    - Three/Four parameter fit:
      Intercept X_0 (x at y=0), ϕ (azimuthal angle),
      σ (transverse size of the cloud), C (curvature)
    - Maximizes the likelihood of the observed charge on each pad



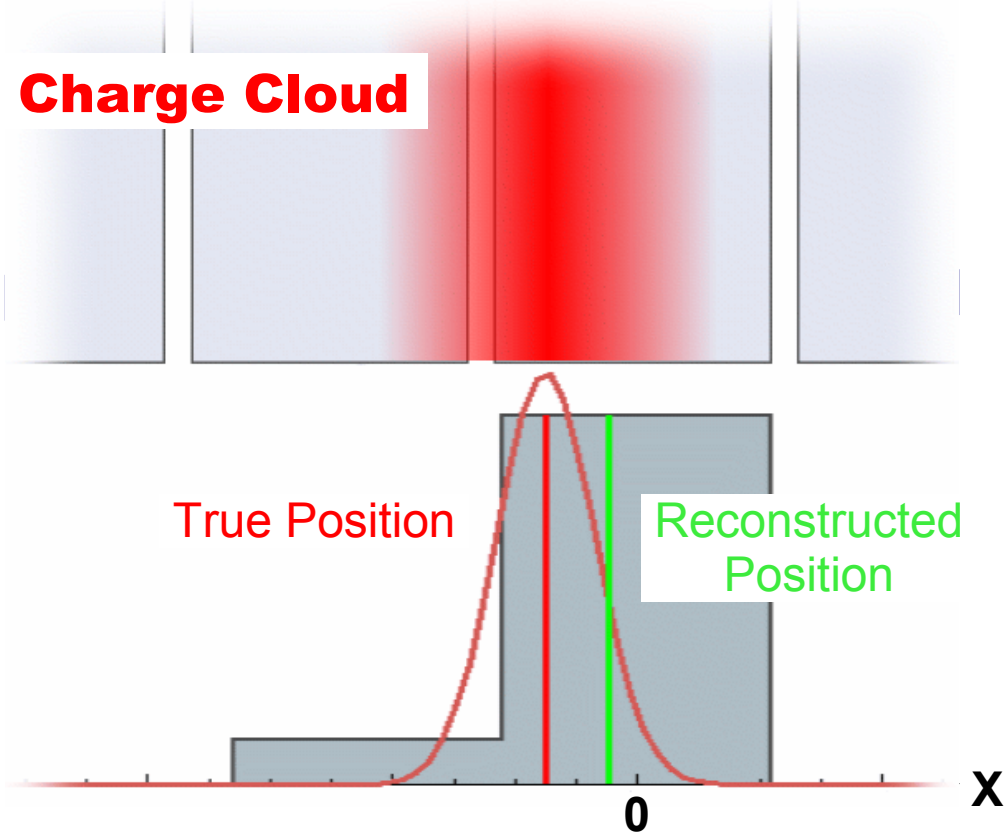
Measured Point Resolution

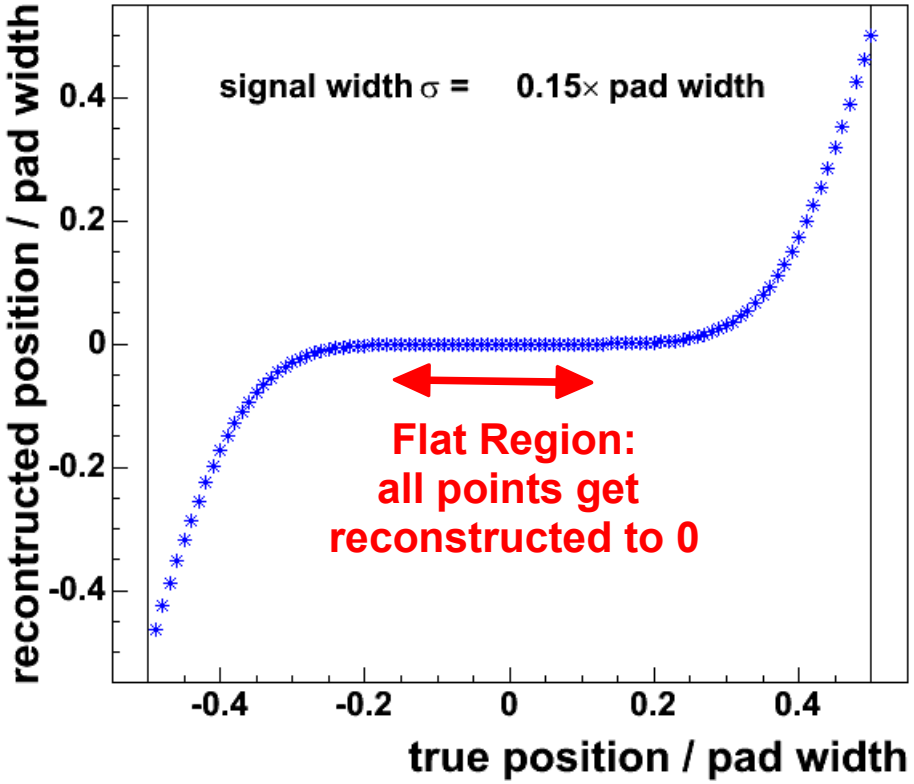




- Point resolution for non-staggered pad layout:
  - Reasonable dependency of drift length
- Point resolution for staggered pad layout:
  - Increasing values at small drift lengths
  - Explanation: not enough charge sharing for correct reconstruction of point positions and residuals (Pad Response)

Pad Response Function





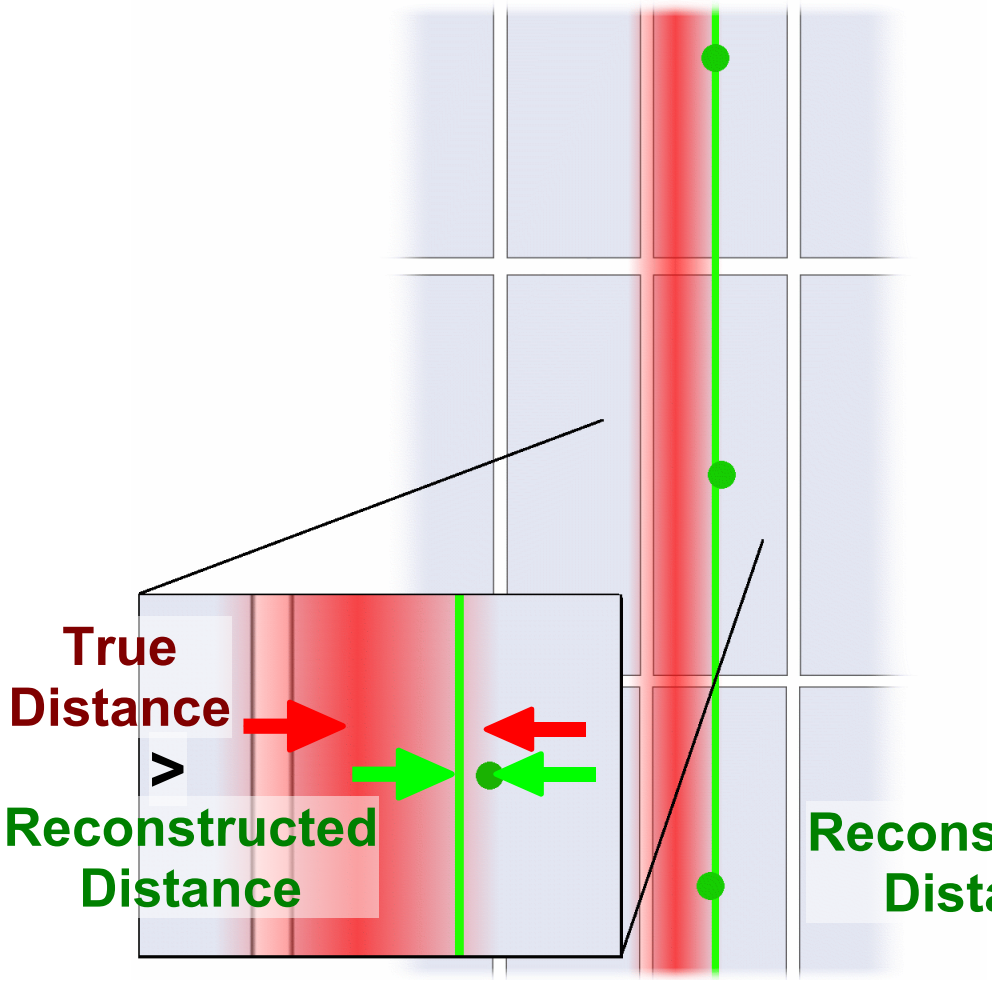
- Signal on „not enough“ pads → too small charge sharing
- Instead of at the true position, hits get reconstructed towards the middle of the pad with highest signal

Effects of Pad Response

Non-staggered Pads:

reconstructed track “gets drawn” towards the reconstructed points

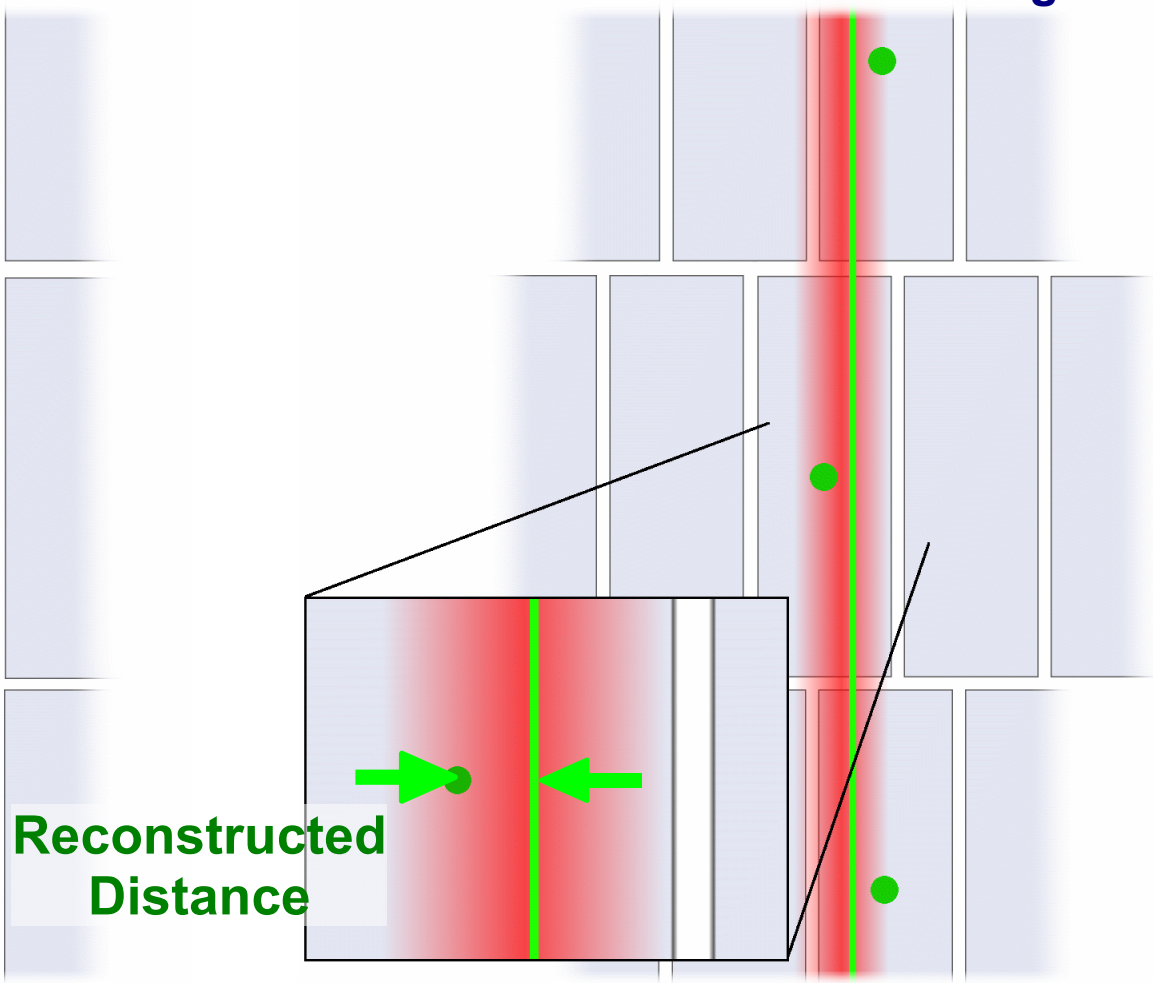
calculated residuals too small



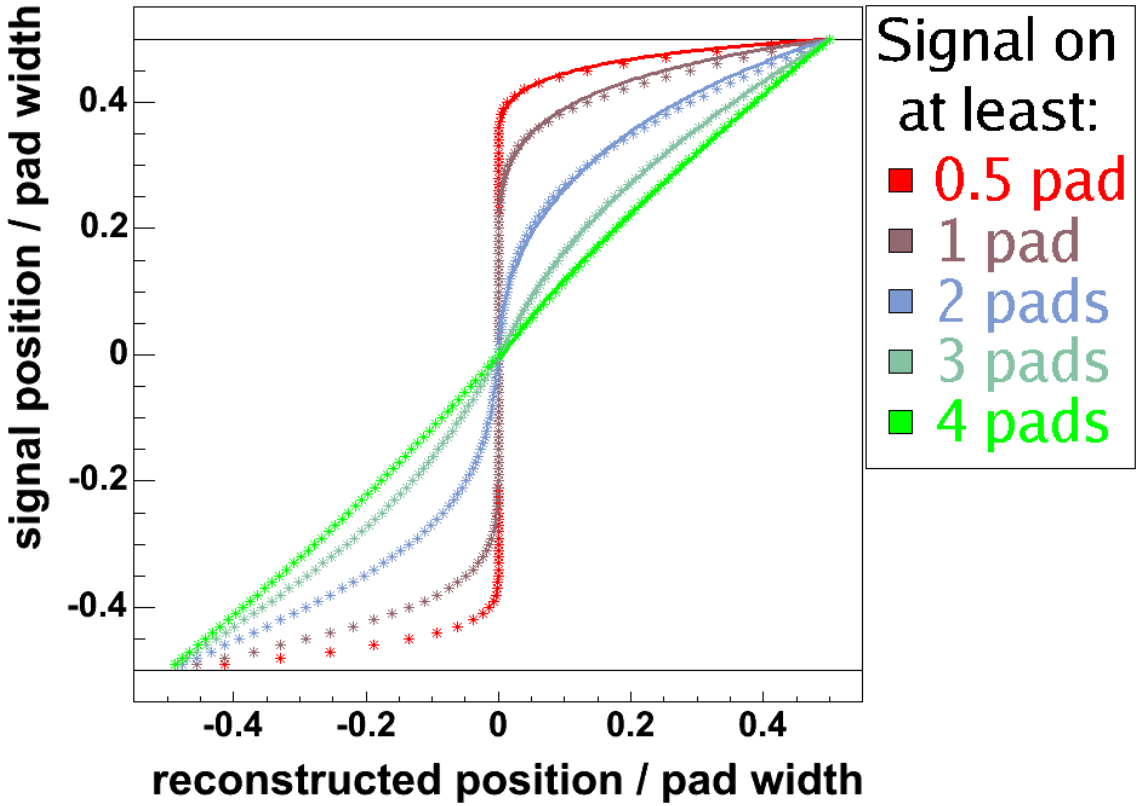
Staggered Pads:

points get reconstructed too far from track

calculated residuals too big

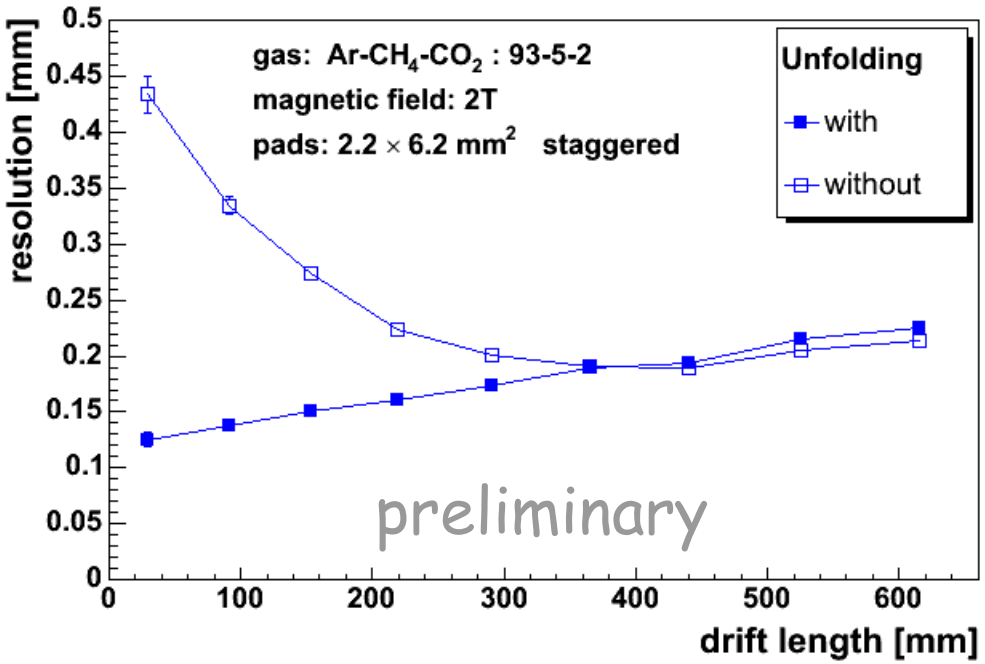


Implementation of Pad Response Function



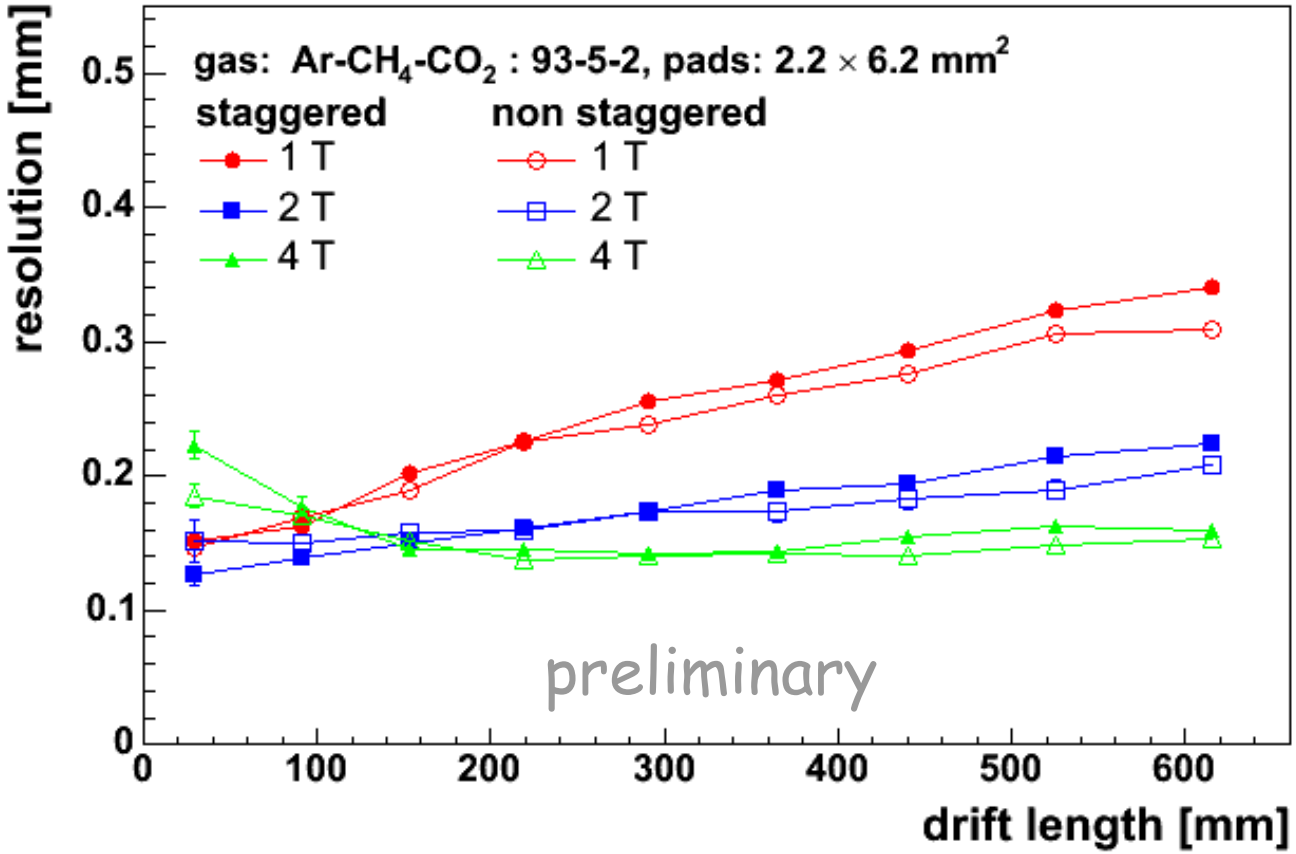
- Parametrized Pad Response Function
- Input: diffusion and defocussing coefficients (values from MAGBOLTZ)
- Properties:
  - No flat region if Signal on at least 2 pads
  - Straight Line (no unfolding needed) for Signal on more than 4 pads

Point Resolution with Pad Response Function



- Use of Pad Response Function in the point reconstruction brings significant improvement of the point resolution calculation for staggered pad layout

Point Resolution with Pad Response Function

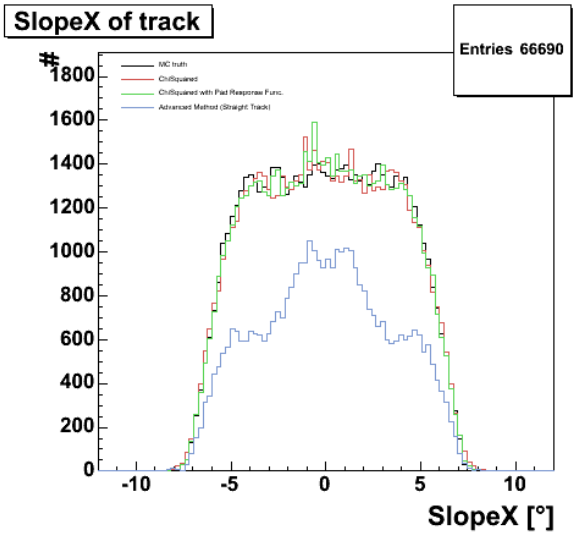


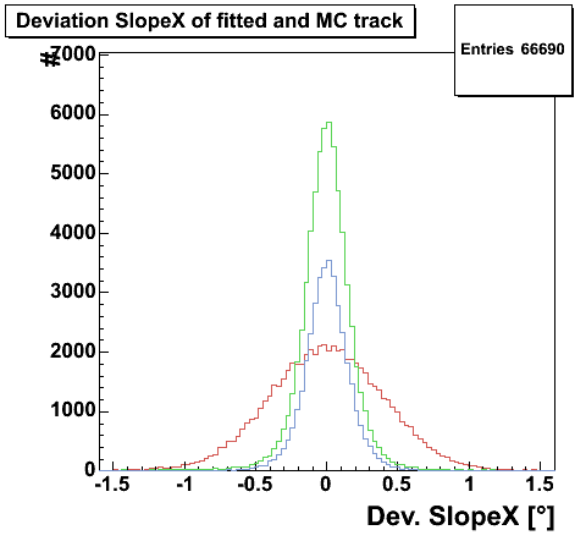
- Staggered and non-staggered measurements get comparable
- Bigger values for small drift lengths in 4T (2T) data still indicate not enough charge sharing

Monte Carlo Simulation

- Goal: Flexible Simulation Tool for TPC Test Setup
  - Cosmic muons, testbeam
  - Adjustable geometries for different setups
  - 3 GEM structure with separatly adjustable effective gains
  - Different readout geometries (pad shapes and layouts)
- Working Principle
  - Muon generator produces straight tracks with realistic energy and angular spectra
  - Prototype geometry and trigger system
  - In the following steps: taking into account E- and B-field, gas mixture, pressure, water content etc.
  - Primary ionization simulated with HEED
  - Expectation values for diffusion, drift velocity from MAGBOLTZ
  - Gas amplification and diffusion in 3 GEM structure
  - Readout at padplane

Efficiency Results of Monte Carlo Studies





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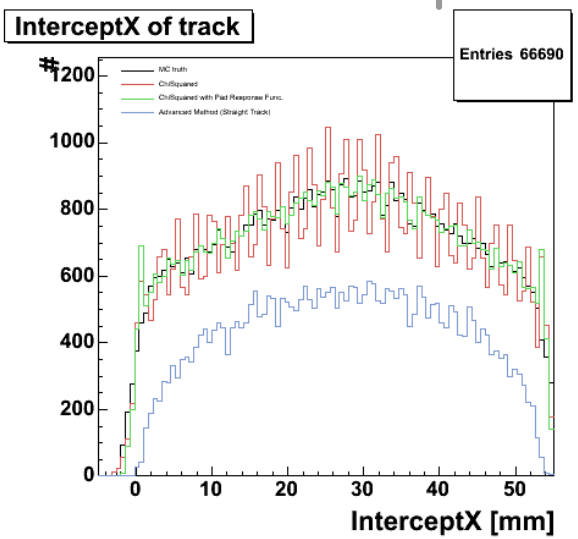
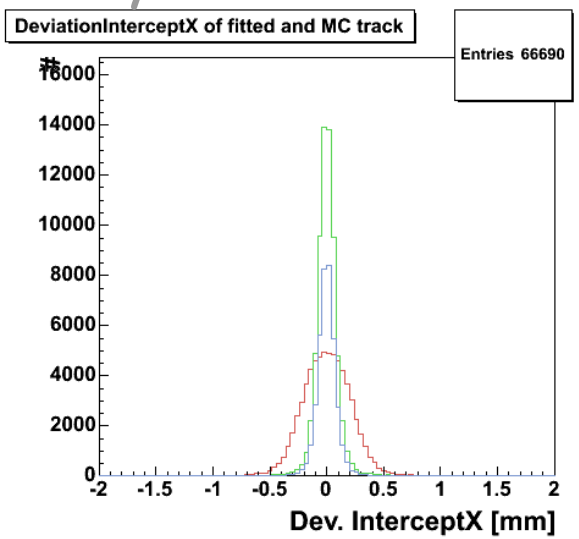
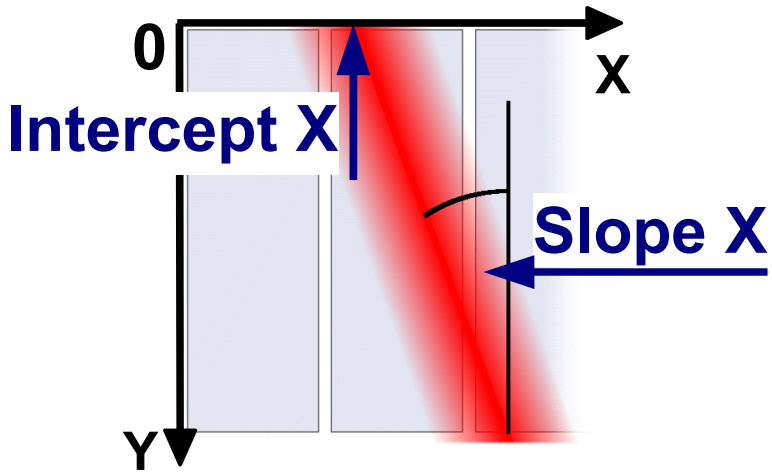




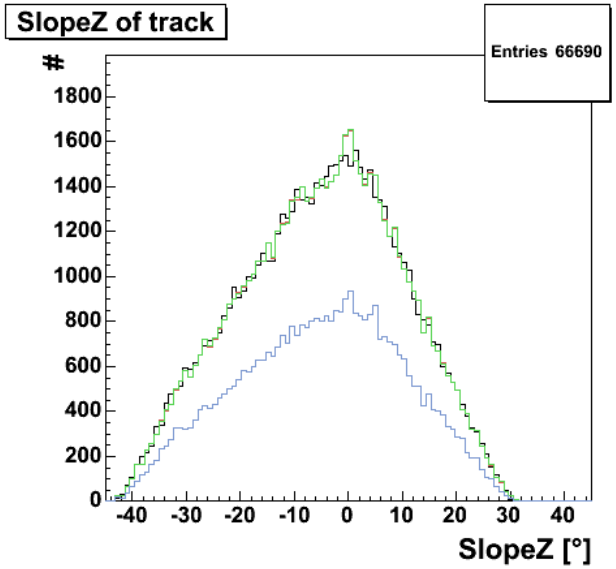
- Efficiency results
  (4T, P5 Gas, 150ppm H_2O)
  - Chi Squared 99.57
  - Chi Squ. (PRF) 99.56
  - Adv. Method 57.99
- Positive effects of Pad Response Function clearly visible

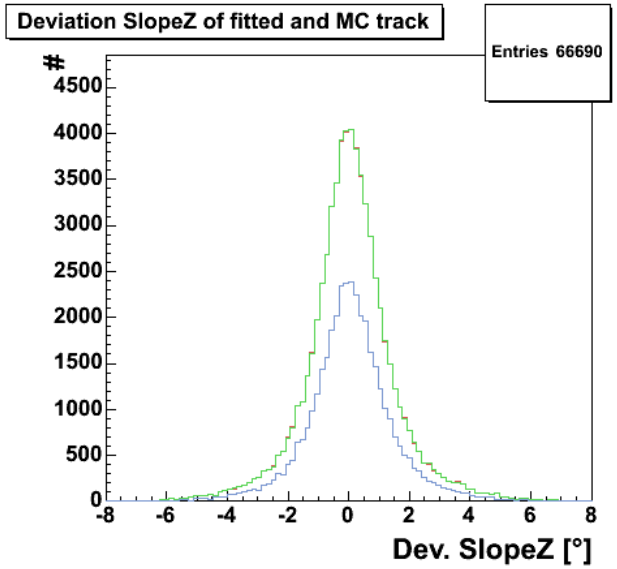


Summary and Outlook

- Summary
  - Implementation of Pad Response Function results in more reliable:
    - Hit Reconstruction (Track Fitting)
    - Point Resolution Calculation
  - Working Monte Carlo Simulation
- Outlook
  - Further studies of Pad Response Function implementation
  - Improvement of the Monte Carlo simulation
  - Simulation and analysis of different pad sizes, shapes and layouts
  - Further analysis of efficiencies and sources
  - More detailed comparison of different fitting methods

More Efficiency Results





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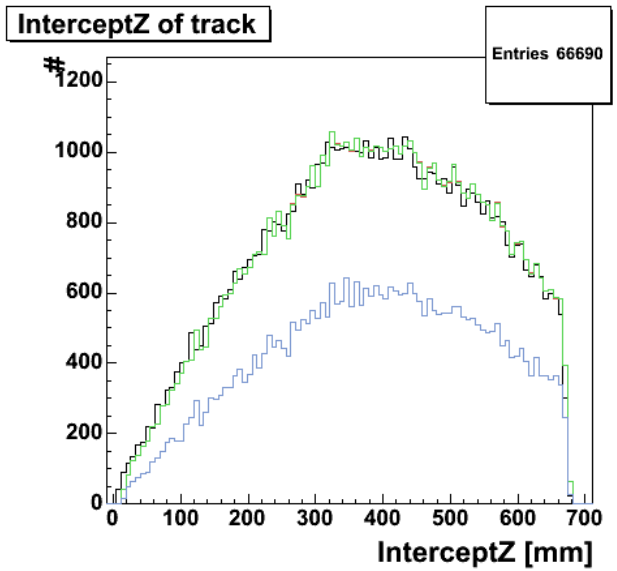
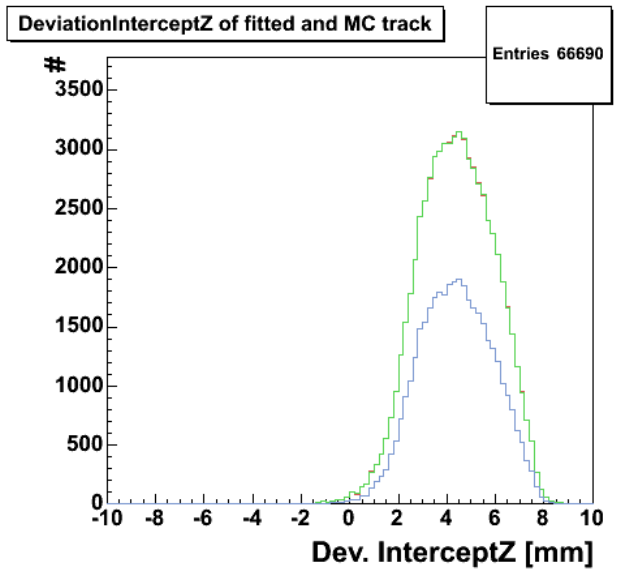
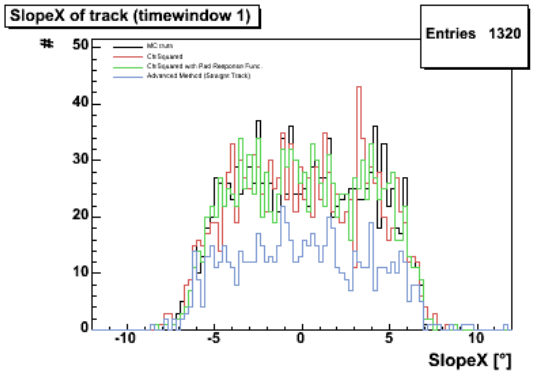
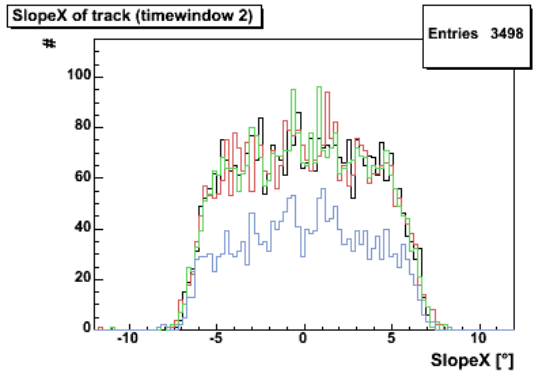
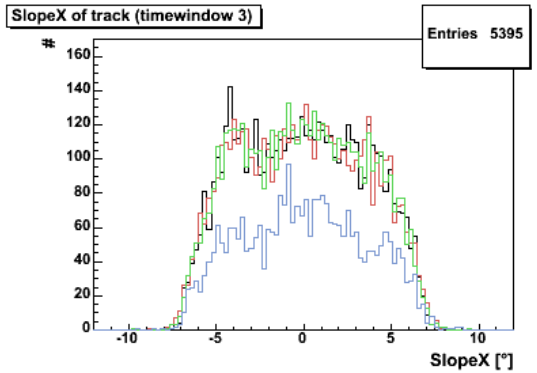


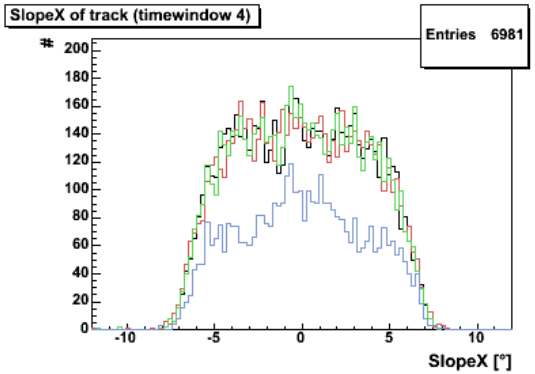


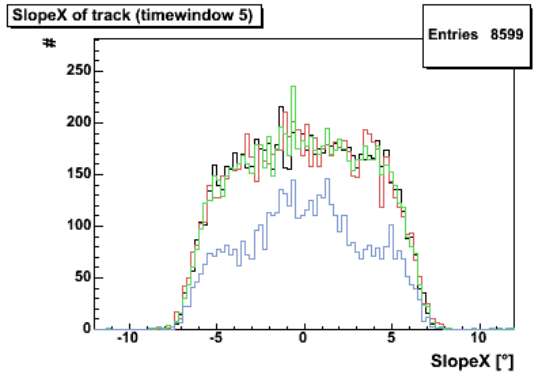
Phi for Different Time Windows

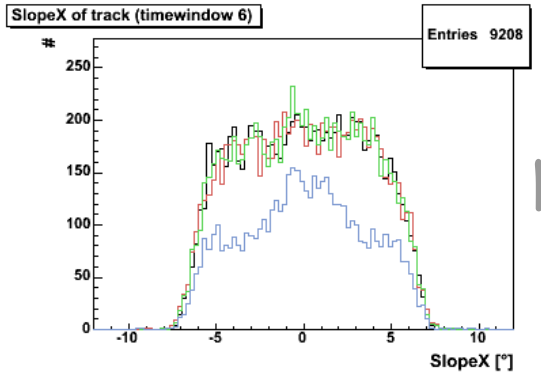












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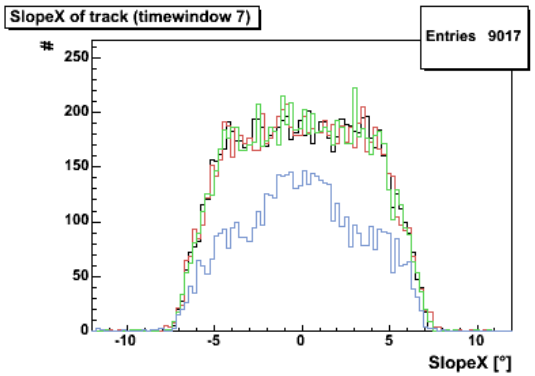
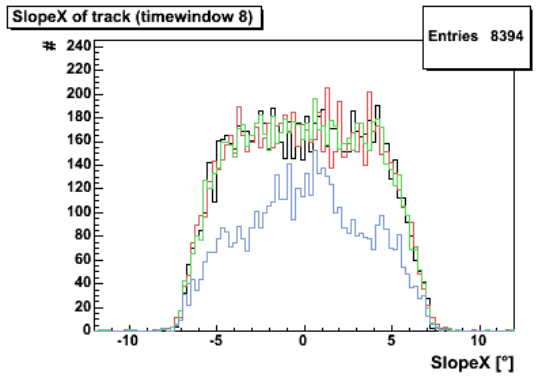
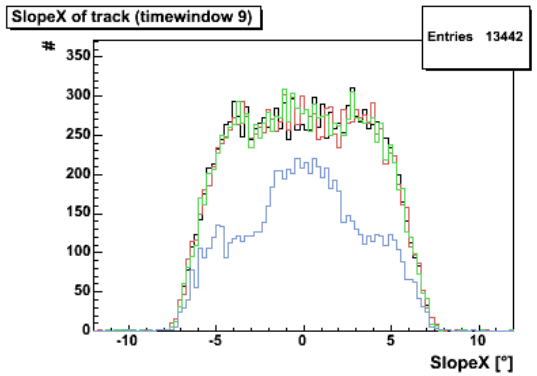
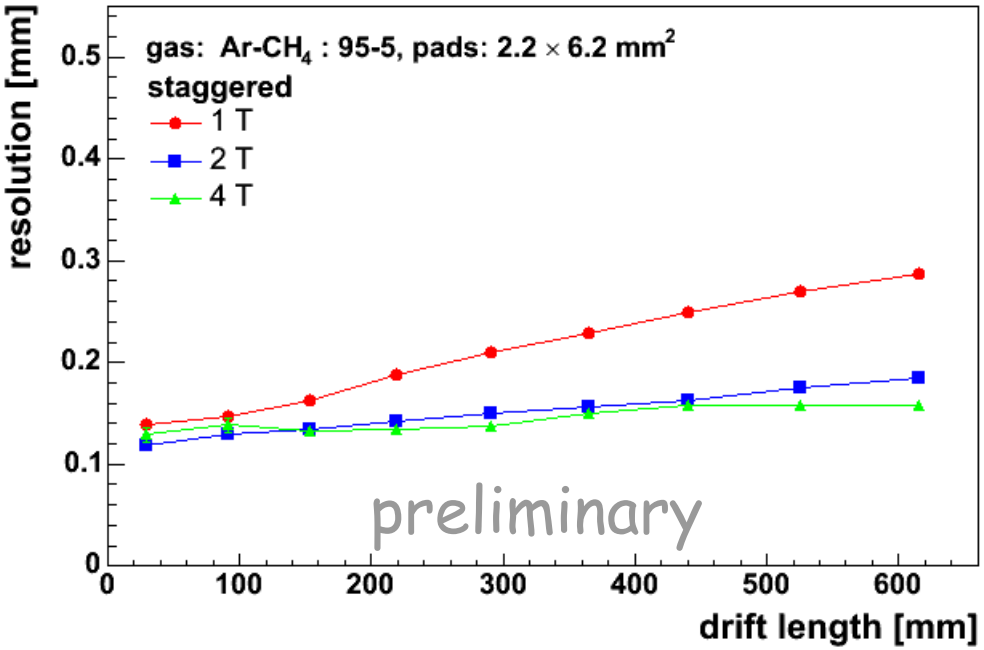






Point Resolution with P5 gas



- For P5 gas no increasing values at small Z distances are seen:
  Indicates enough charge sharing