High Resolution Spectrometer (HRS) Optics Calibration

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For the E05-102 Collaboration

HRS optics

Reconstruct target coordinate system variables from detector coordinate system variables

Detector coordinate system and variables

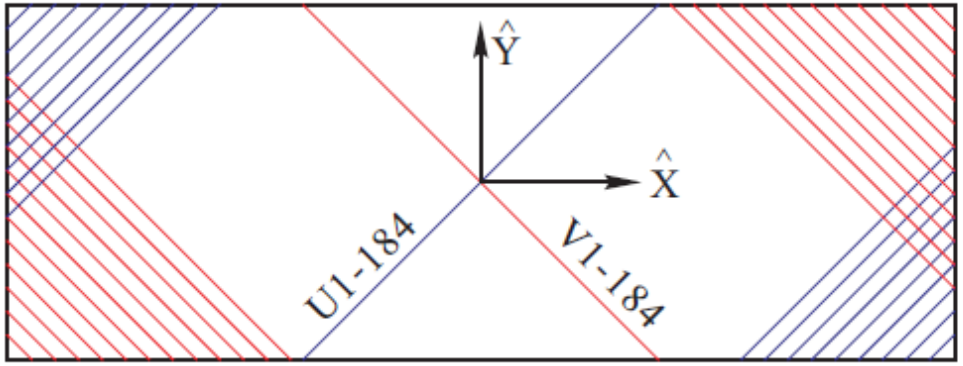
Detector coordinate system:

- Originates from HRS VDC center
- Z-axis perpendicular to VDC plane

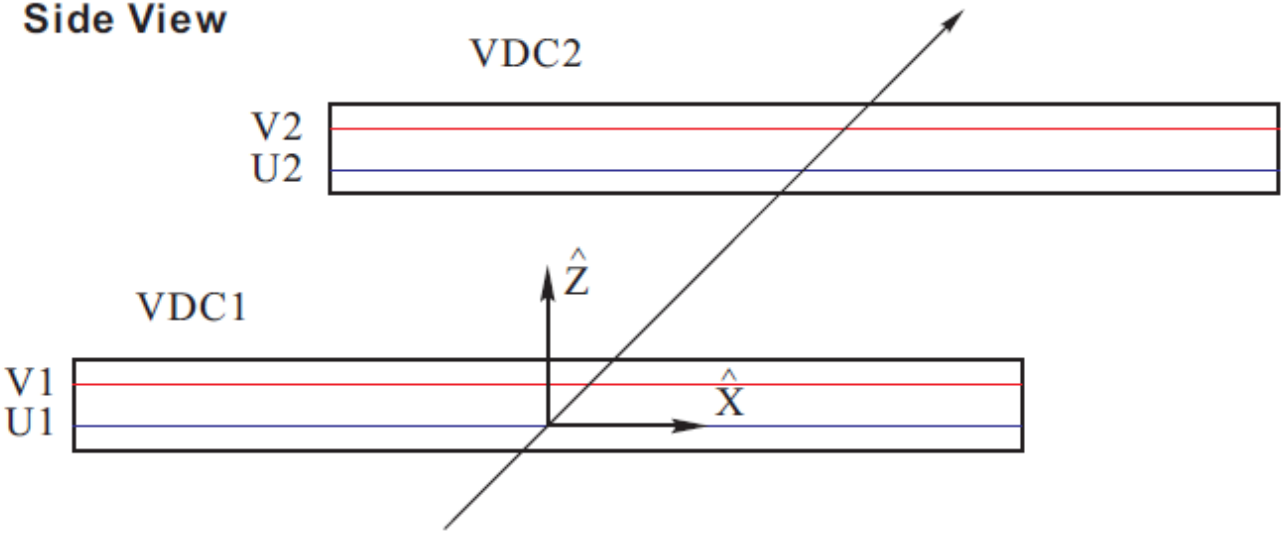
Variables:

- x
- y
- In-plane angle θ
- Out-of-plane angle φ

Top View



Side View



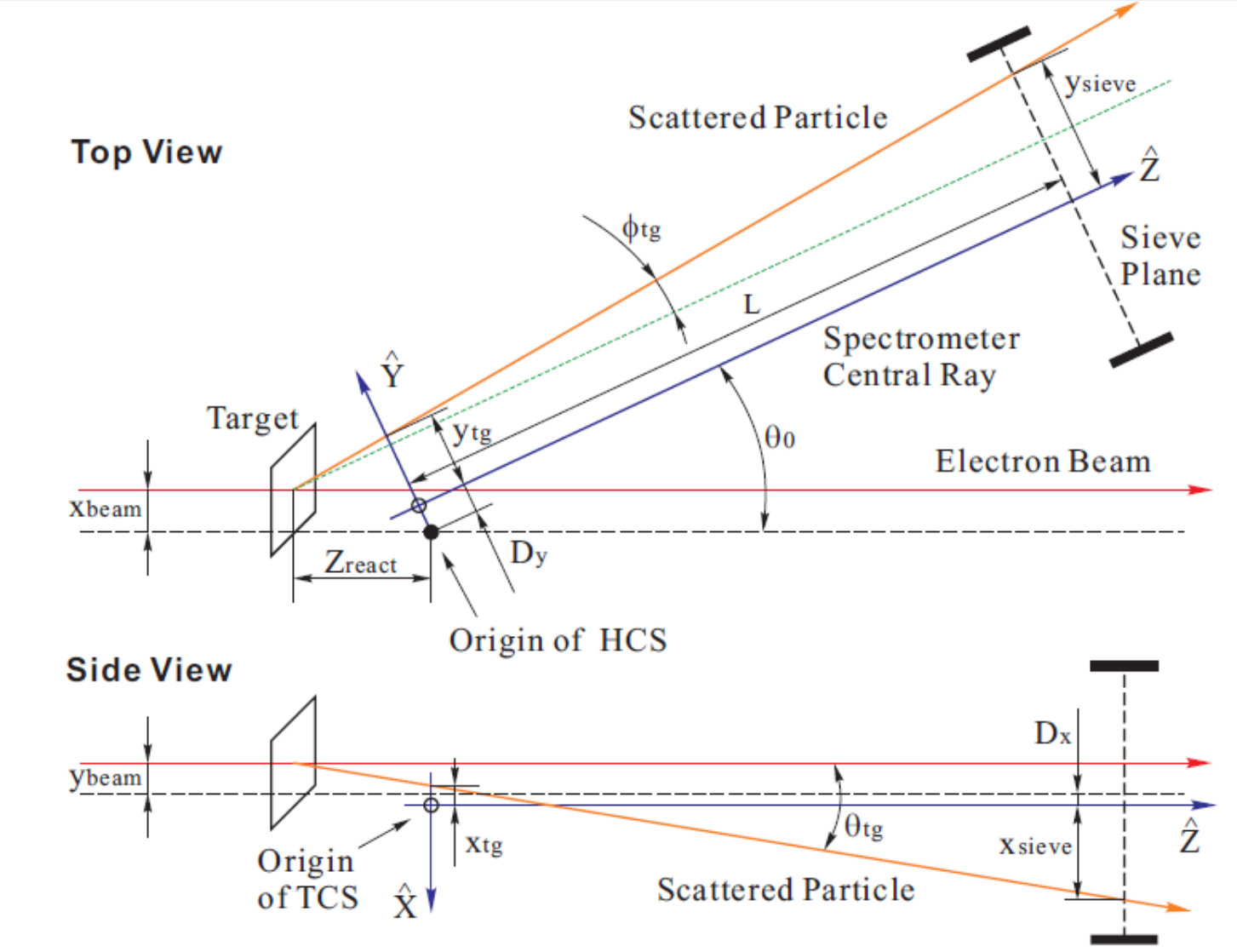
Target coordinate system and variables

Target coordinate system

- Originates ideally from hall center
- Z-axis same as spectrometer central ray

Variables:

- Momentum dp
- Target y (closed related with reaction point z)
- In-plane angle θ
- Out-of-plane angle φ


Top View
Scattered Particle
ysieve
$\hat{Z}$
ϕ_{tg}
Sieve
Plane
L
Spectrometer
Central Ray
$\hat{Y}$
Target
y_{tg}
θ_0
Electron Beam
x_{beam}
Z_{react}
D_y
Origin of HCS
Side View
D_x
y_{beam}
θ_{tg}
x_{tg}
x_{sieve}
$\hat{Z}$
Origin
of TCS
$\hat{X}$
Scattered Particle

Matrix approach

- Target variables are the sum of expansion of detector variables in polynomials
- Coefficients of expansions saved as matrix elements in HRS databases

$$
\begin{aligned}
\delta &= \sum_{j,k,l} D_{jkl}\theta_{\rm fp}^{j} y_{\rm fp}^{k} \phi_{\rm fp}^{l} \\
\theta_{\rm tg} &= \sum_{j,k,l} T_{jkl}\theta_{\rm fp}^{j} y_{\rm fp}^{k} \phi_{\rm fp}^{l} \\
y_{\rm tg} &= \sum_{j,k,l} Y_{jkl}\theta_{\rm fp}^{j} y_{\rm fp}^{k} \phi_{\rm fp}^{l} \\
\phi_{\rm tg} &= \sum_{j,k,l} P_{jkl}\theta_{\rm fp}^{j} y_{\rm fp}^{k} \phi_{\rm fp}^{l},
\end{aligned}
$$

$$
D_{jkl} = \sum_{i=0}^{m} C_{ijkl}^{D} x_{\rm fp}^{i}.
$$

Software used in calibration

- Nilanga Liyanage's TreeToAscii:

  Select sample events for each optimized region from a root tree

- Jin Huang's optimization code:

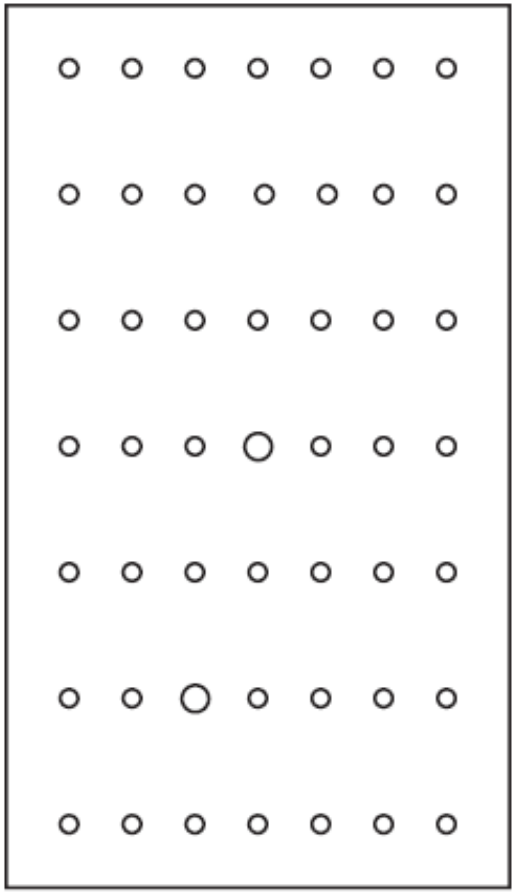
  Fit polynomials that achieve minimum RMS in optics reconstruction

Corrections applied in optimization

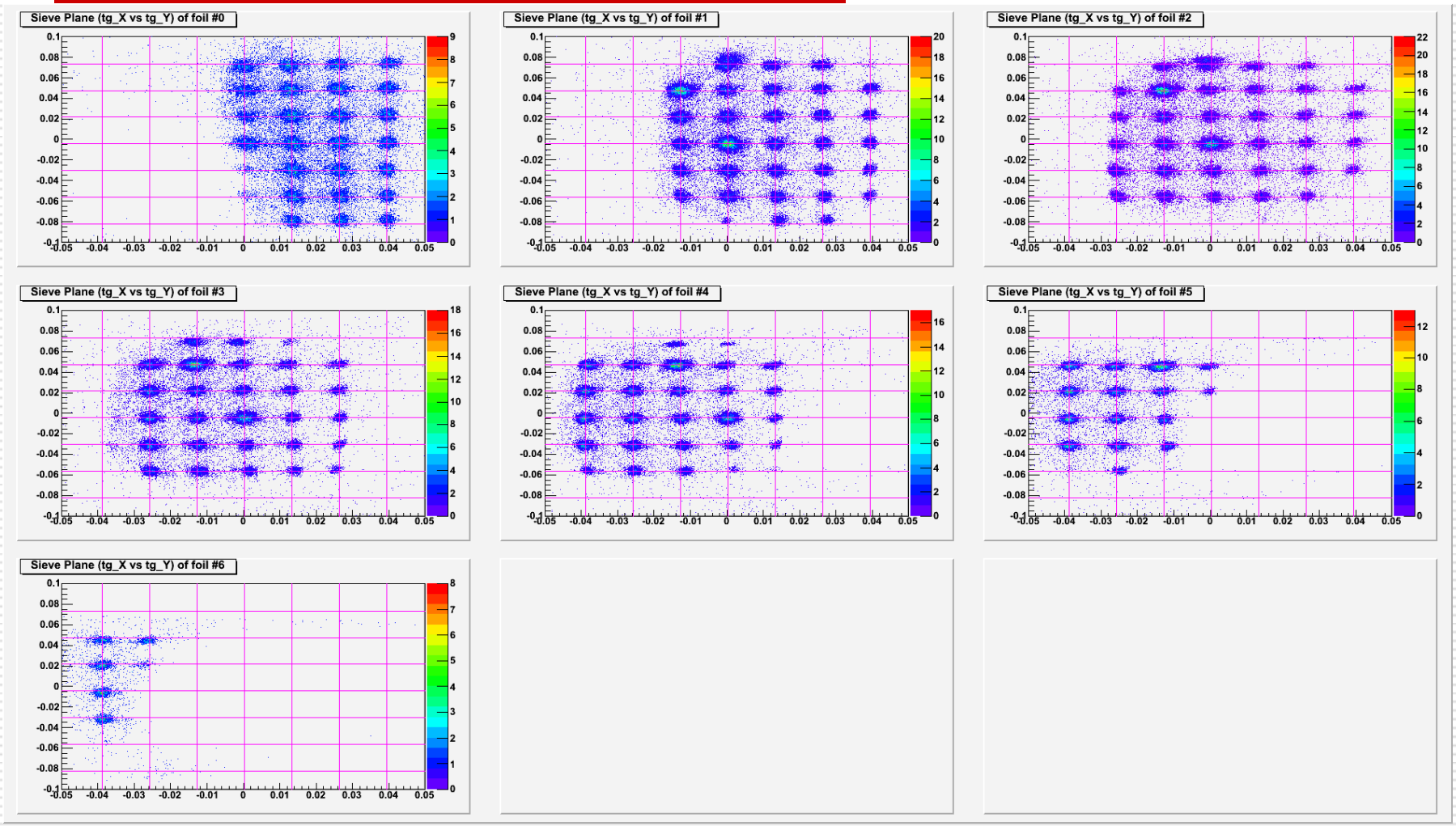
- Spectrometer misalignment correction
- Extended target correction and beam position correction (by raster)
- Energy loss correction

In- and out-of-plane angle calibration

- Sieve: 7 rows by 7 columns of holes to cover angular acceptance
- Particles only punch through sieve slit at the position of the holes
- Direction of tracks reflected by sieve pattern

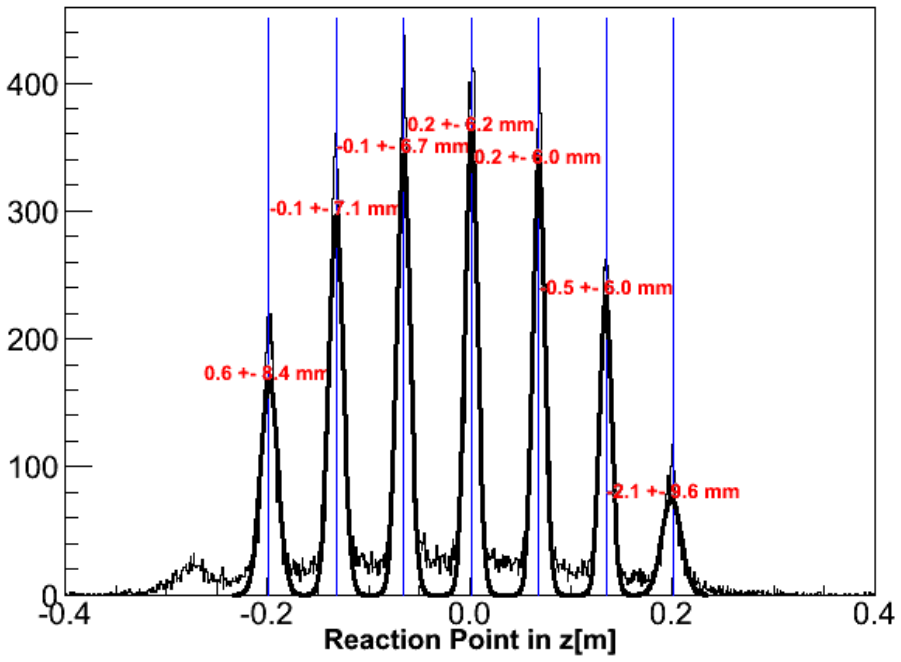


Sieve reconstruction from a multi-carbon foil target



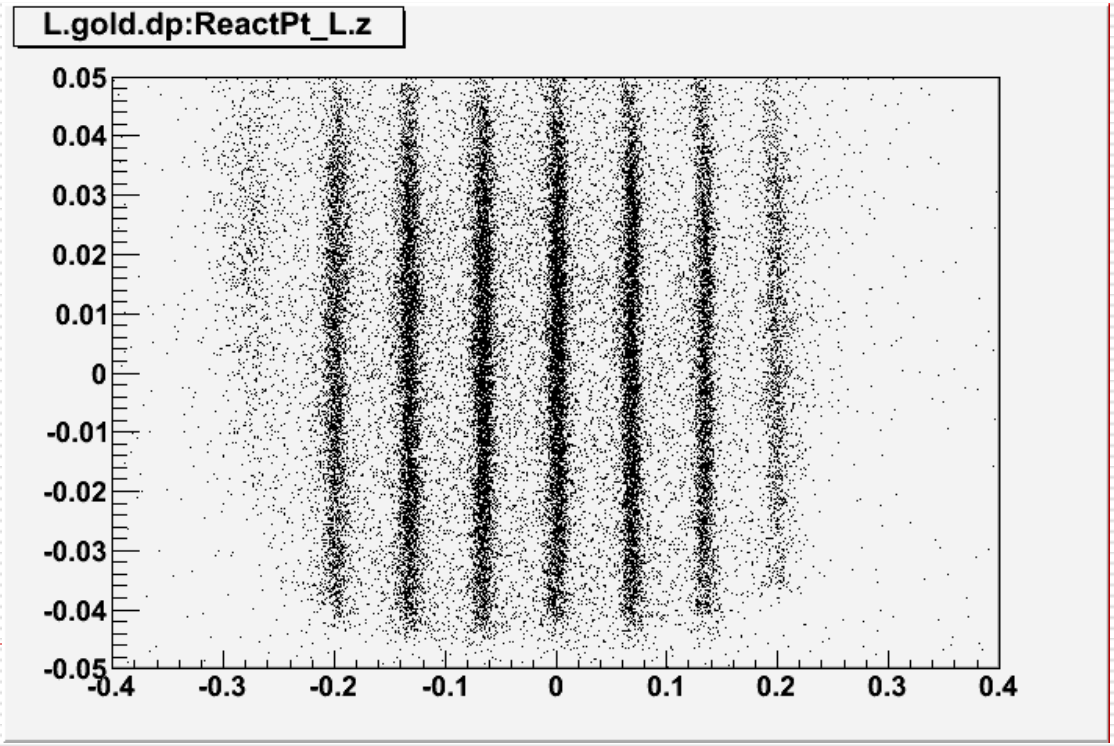
Target y (reaction point z) calibration

- 7-carbon foil target to cover 40 cm range
- Reconstruction error ~.5 mm, resolution ~6 mm



Reaction point z reconstruction at different momenta

- Reaction point z reconstruction should be independent of momentum distribution
- Sample same number of events at different momentum regions

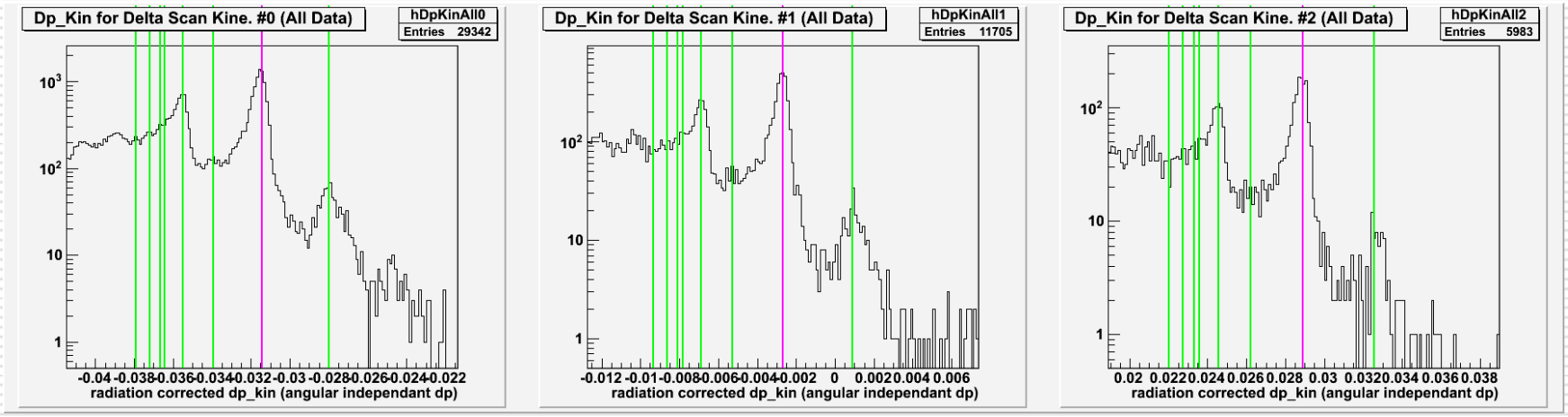


Momentum calibration and dp_kin

- Dp_kin is modified momentum
- Minor difference from dp
- No dependence on scattering angle
- Calibrating dp_kin by electron scattering from carbon at different excited states

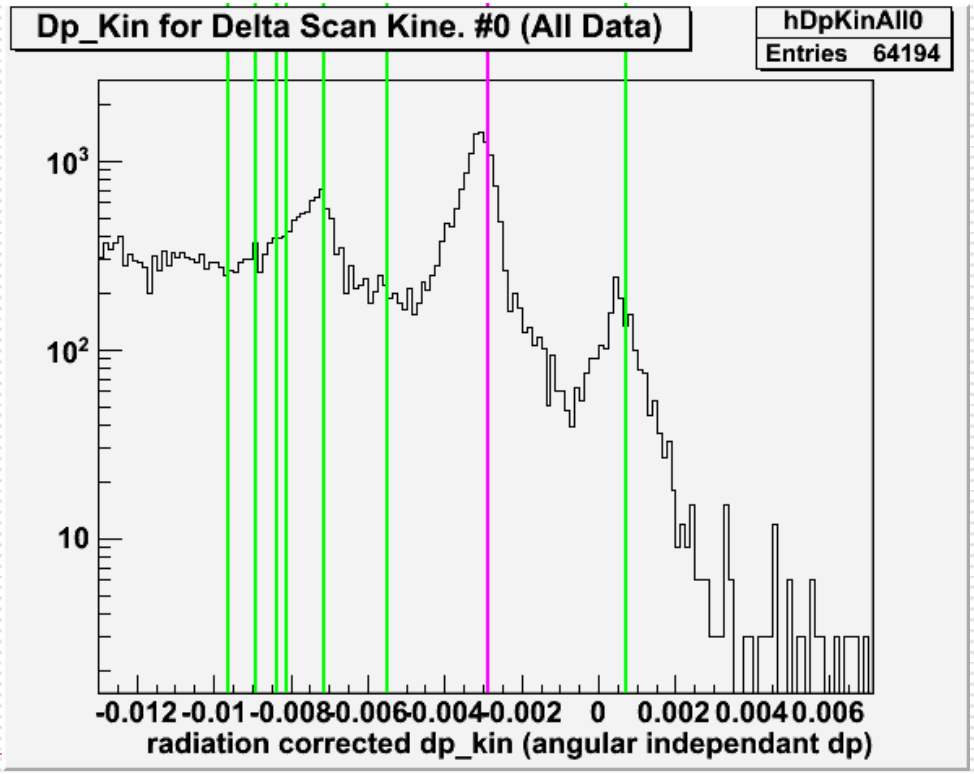
Dp_kin of electron carbon scattering

- Start with a matrix with reasonable resolution and reconstruction
- Fine tune the 0^{th} and 1^{st} order terms by hand



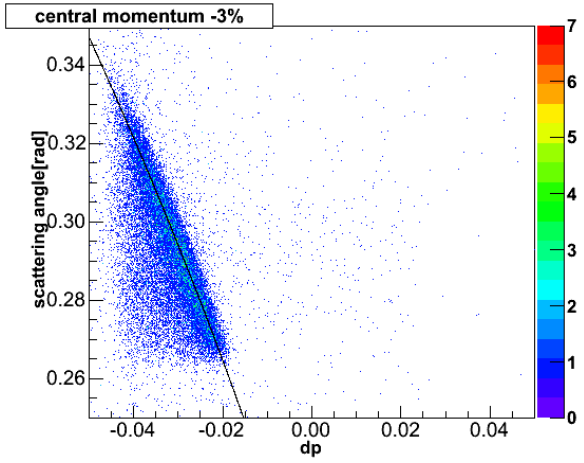
This momentum matrix works on transversity experiment data

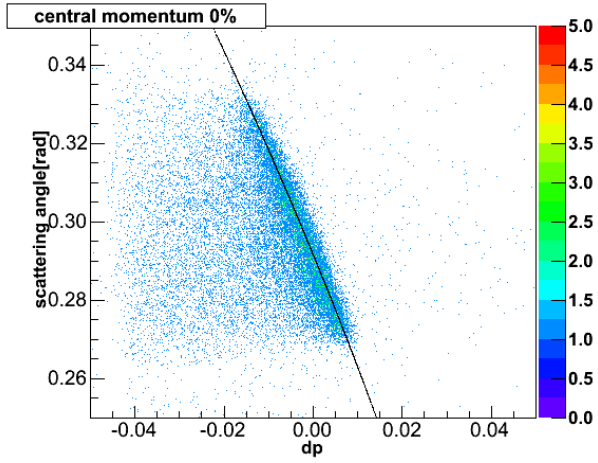
- 1 GeV momentum
- Reconstruction error ~200 keV
- Error due to uncertainty in energy loss

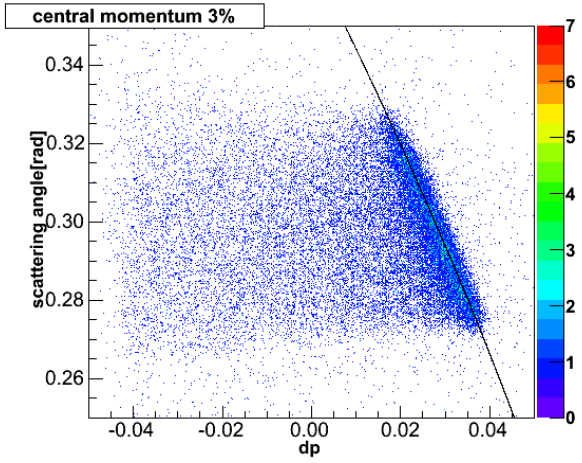


Fine tuning of target φ

- ~2 mm uncertainty in sieve positioning
- Hydrogen elastic scattering momentum closely correlated with scattering angle (target φ)
- Fine tune target φ by our control of electron momentum







Pitfall: over-optimization

- Over-optimization: only selected regions are optimized. Other regions appear weird in reconstruction
- Normally caused by excessive high order terms in matrix (high order terms make a polynomial curvaceous)
- Can be avoided by testing one matrix at different kinematics settings and optics ranges

To avoid over-optimization in this work

- Matrix terms kept in similar order to a classic database used in 1989
- Matrix tested at wide kinematics ranges

  Momentum: 1.2~3.6 GeV/c

  LHRS angle: 12.5~17 degrees

  RHRS angle: 16~18 degrees

  40 cm long target

Acknowledgements

- Douglas Higinbotham
- Vincent Sulkosky
- Jin Huang
- Yi Qiang
- Nilanga Liyanage
- Huan Yao

Back up

- Angular resolution: ~1 mrad out-of-plane and ~2 mrad in-plane
- Momentum resolution: 2×10^{-3}