Spectrometer Optics Calibration for g2p Experiment

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On Behalf of the E08-027 Collaboration

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Introduction

- The g2p experiment will measure the proton structure function g_2 in the low Q^2 region (0.02-0.2 GeV^2) for the first time
- Goal: 5% systematic uncertainty when measuring cross section
- Hall A High Resolution Spectrometer (HRS)
  - 10^{-4} momentum resolution

HRS Optics

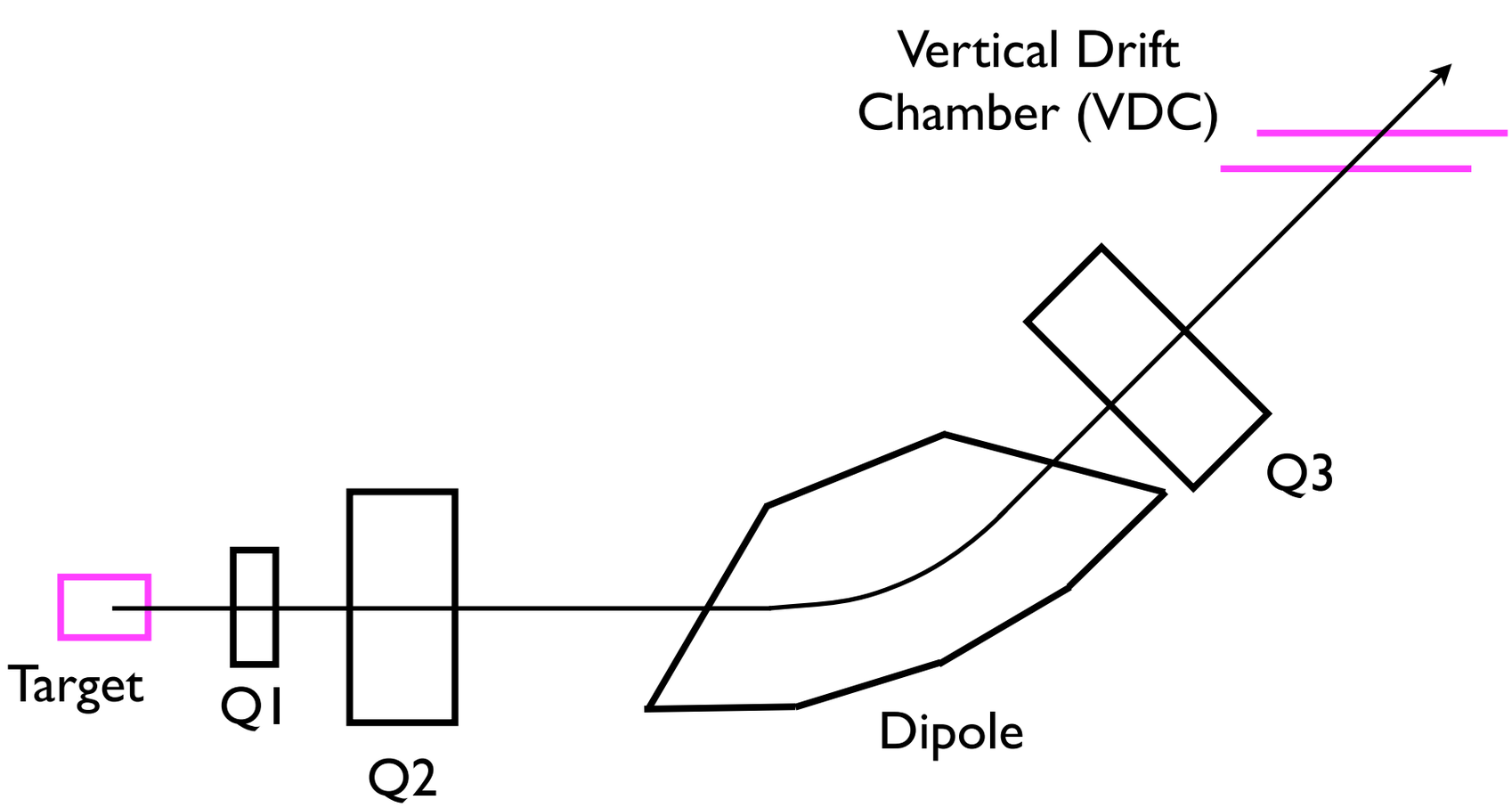
- Optics study:
  - Reconstruct the kinematics variables of the scattered electrons with the tracking information
- Optics Goal:
  - <1.0% systematic uncertainty of scattering angle, which will contribute <4.0% to the uncertainty of cross section

$$\sigma \sim 1/\sin^4(\theta/2)$$

  - The final systematic uncertainty is not sensitive to the uncertainty of the momentum of the scattered electrons

HRS Optics

- HRS has a series of magnets
  - 3 quadrupoles to focus
  - 1 dipole to disperse on momentums



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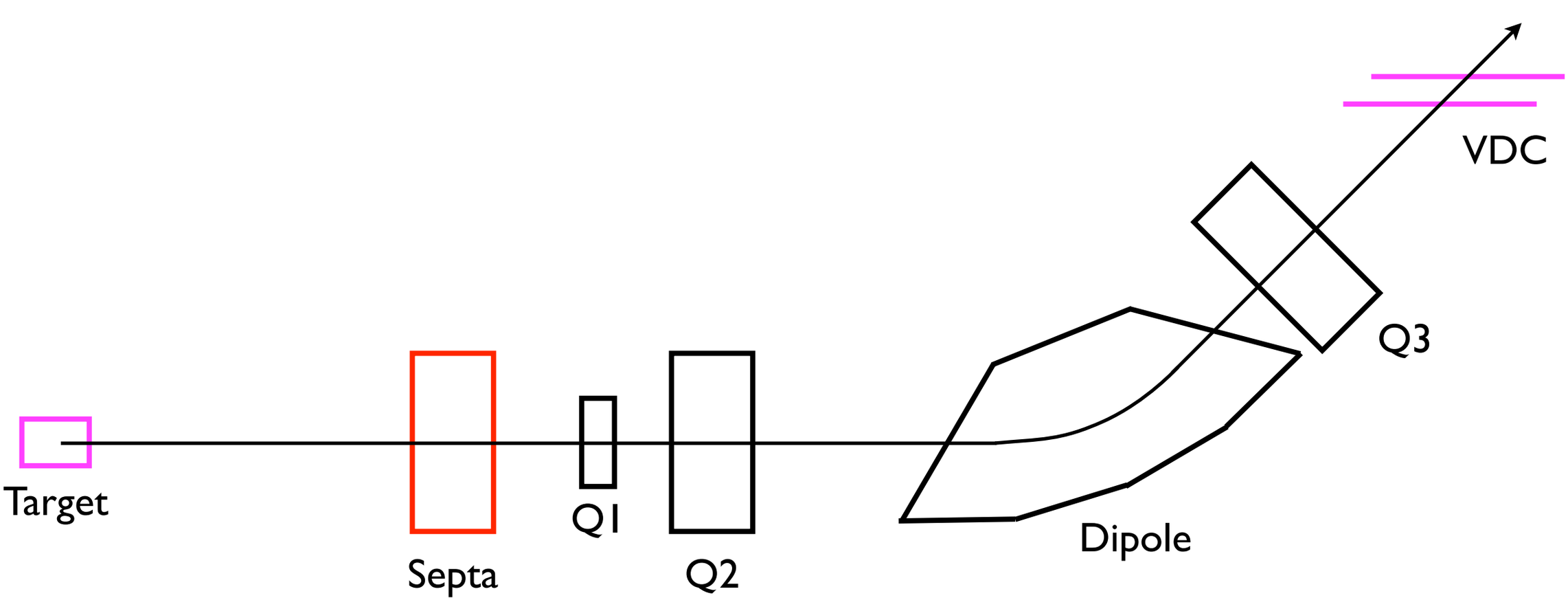
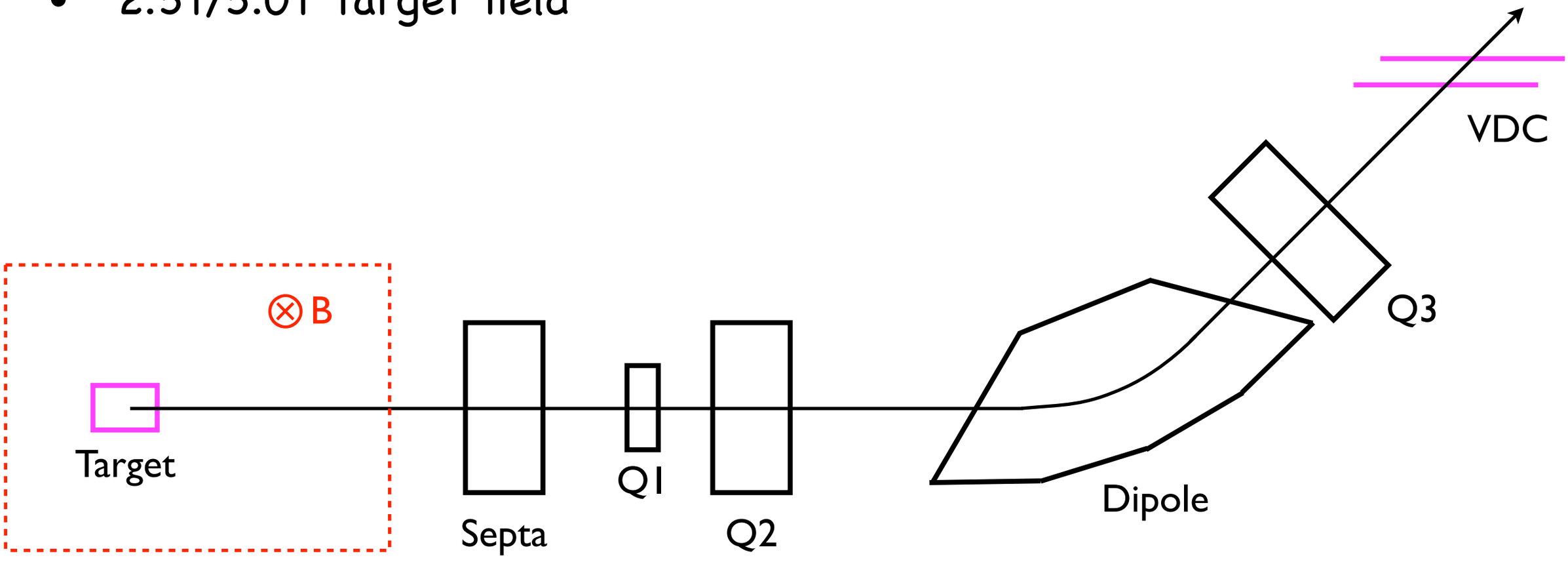


HRS Optics

- HRS has a series of magnets
  - 3 quadrupoles to focus
  - 1 dipole to disperse on momentums
- Septa magnet
- 2.5T/5.0T Target field

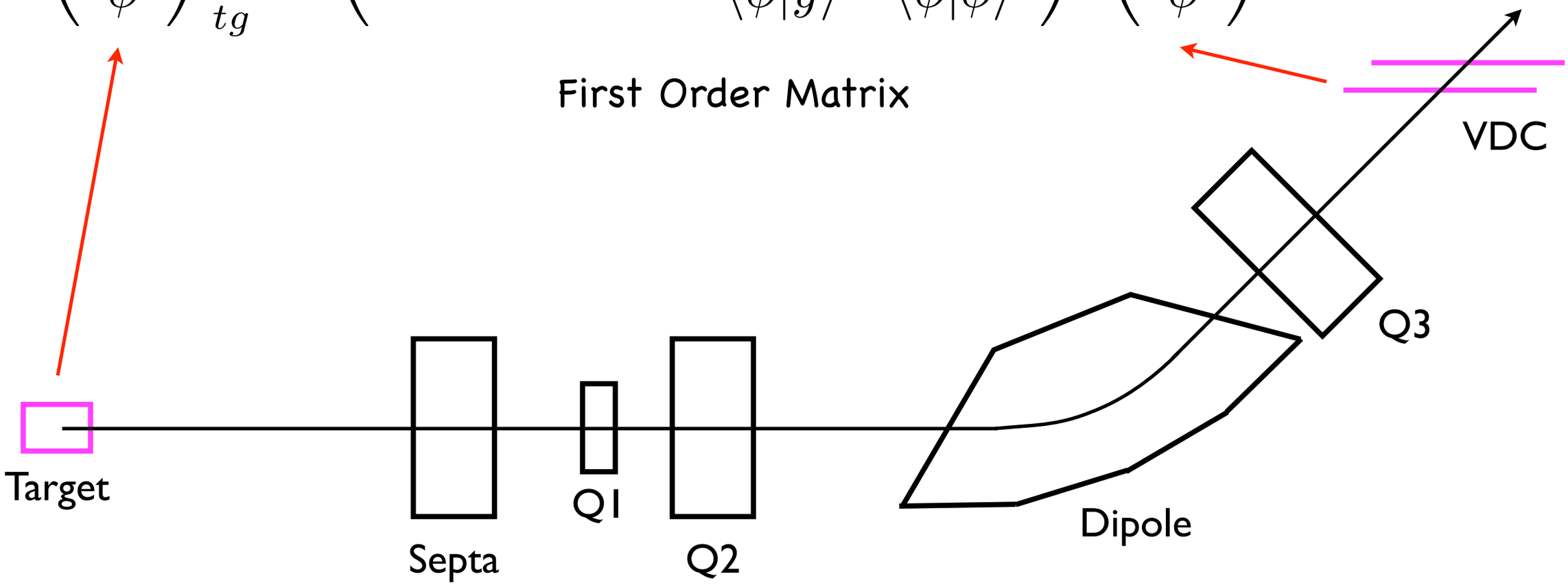


HRS Optics

- Optics study will provide a matrix to transform VDC readouts to kinematics variables which represents the effects of these magnets

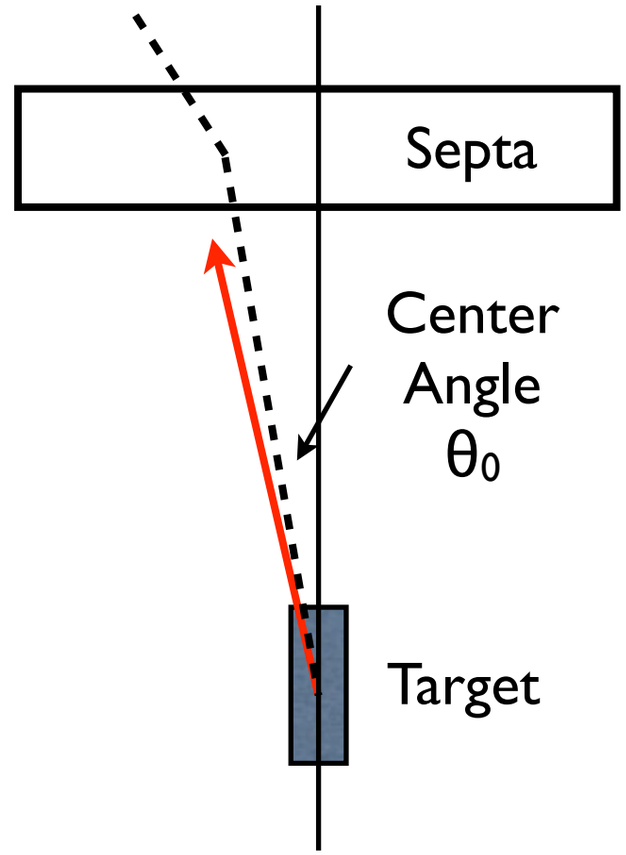
$$\begin{pmatrix} \delta \\ \theta \\ y \\ \phi \end{pmatrix}_{tg} = \begin{pmatrix} \langle\delta|x\rangle & \langle\delta|\theta\rangle & & \\ \langle\theta|x\rangle & \langle\theta|\theta\rangle & & \\ & & \langle y|y\rangle & \langle y|\phi\rangle \\ & & \langle\phi|y\rangle & \langle\phi|\phi\rangle \end{pmatrix} \begin{pmatrix} x \\ \theta \\ y \\ \phi \end{pmatrix}$$

First Order Matrix



Angle Calibration

- Angle Calibration:
  - Decide the center scattering angle
  - Calibrate the angle matrix elements



$$\theta = \arccos \frac{\cos\theta_0 - \phi_{tg}\sin\theta_0}{\sqrt{1 + \theta_{tg}^2 + \phi_{tg}^2}}$$

Angle Calibration

- Angle Calibration:
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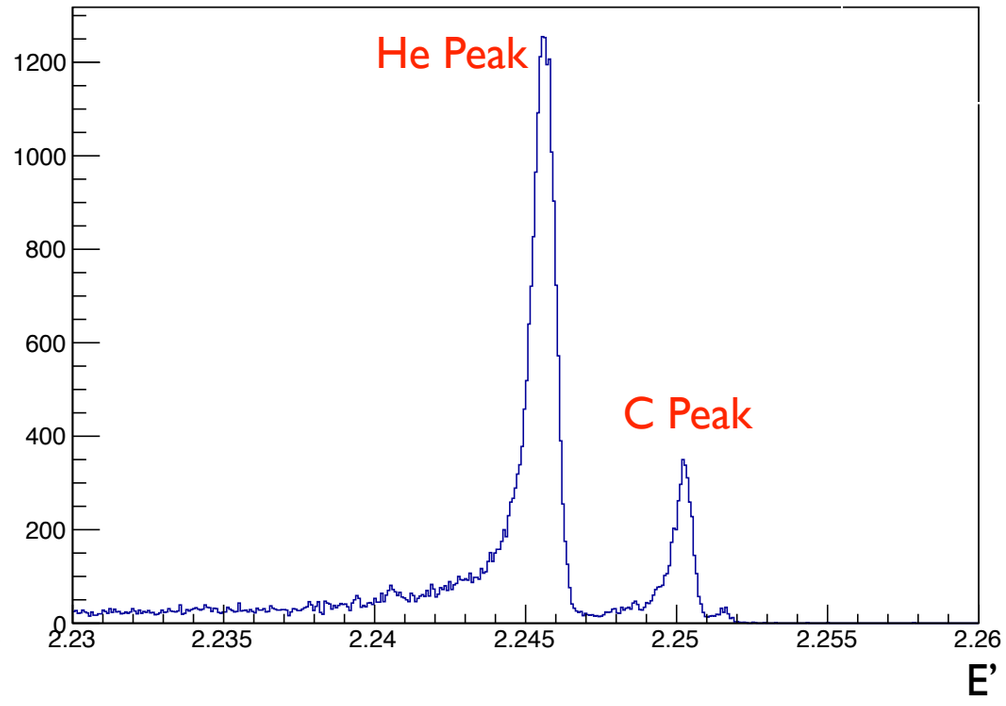
  - Calibrate the angle matrix elements

- Decide the center scattering angle
  - Direct measurement: ~1mrad
  - Idea: Use elastic scattering on different target materials (Carbon foil in LHe, or CH_2)

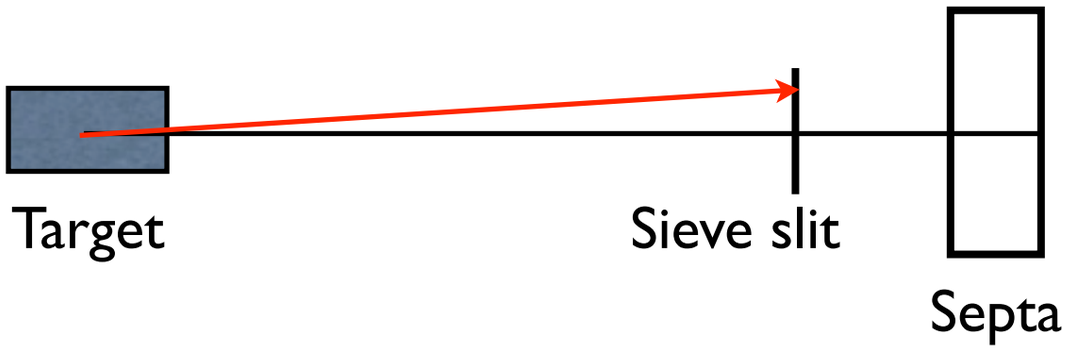
$$\Delta E' = \frac{E}{1+\frac{E}{M_1}(1-\cos\theta)} - \frac{E}{1+\frac{E}{M_2}(1-\cos\theta)}$$

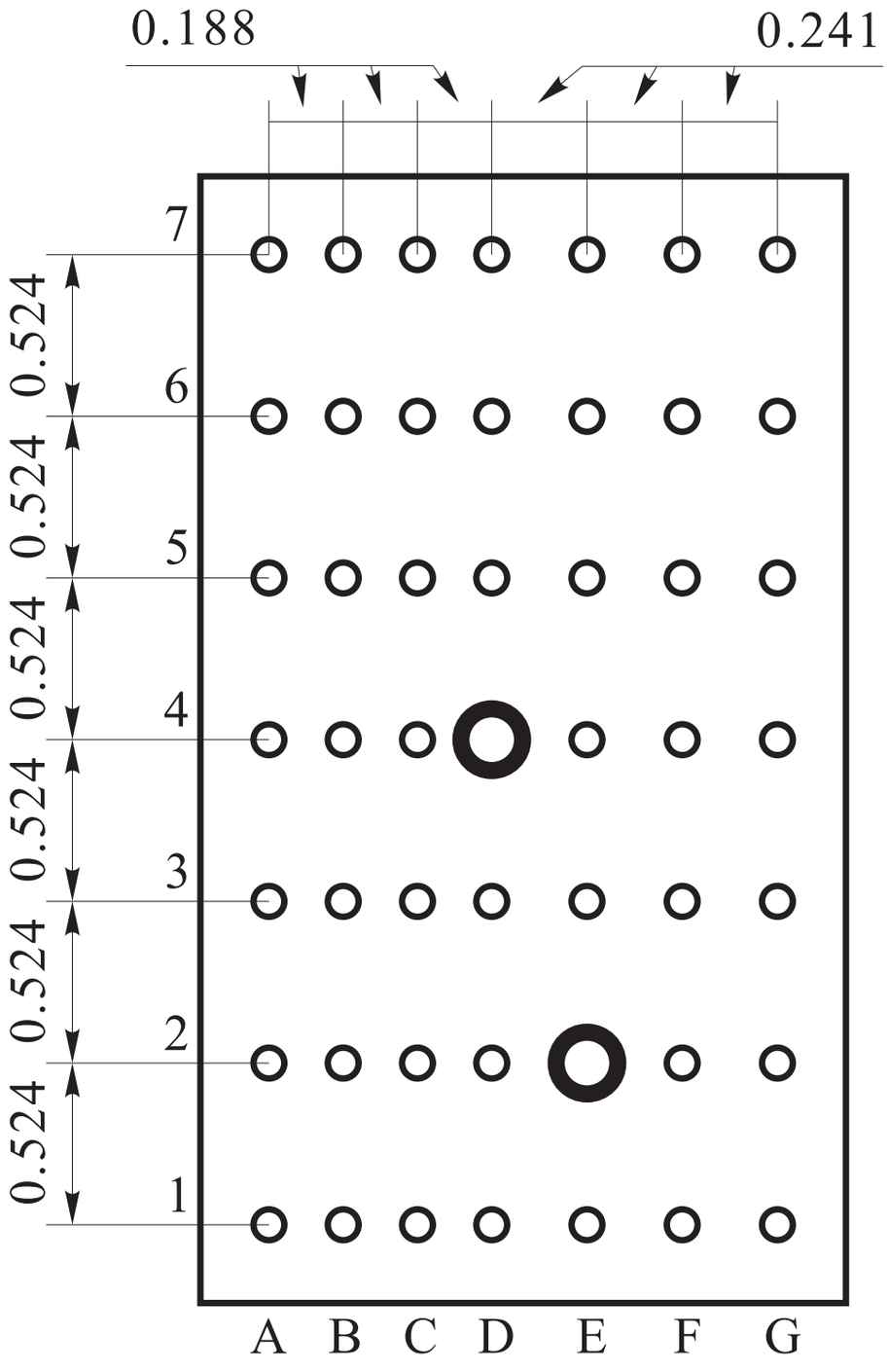
  - The accuracy to determine this difference is <50KeV -> <0.5mrad



Angle Calibration

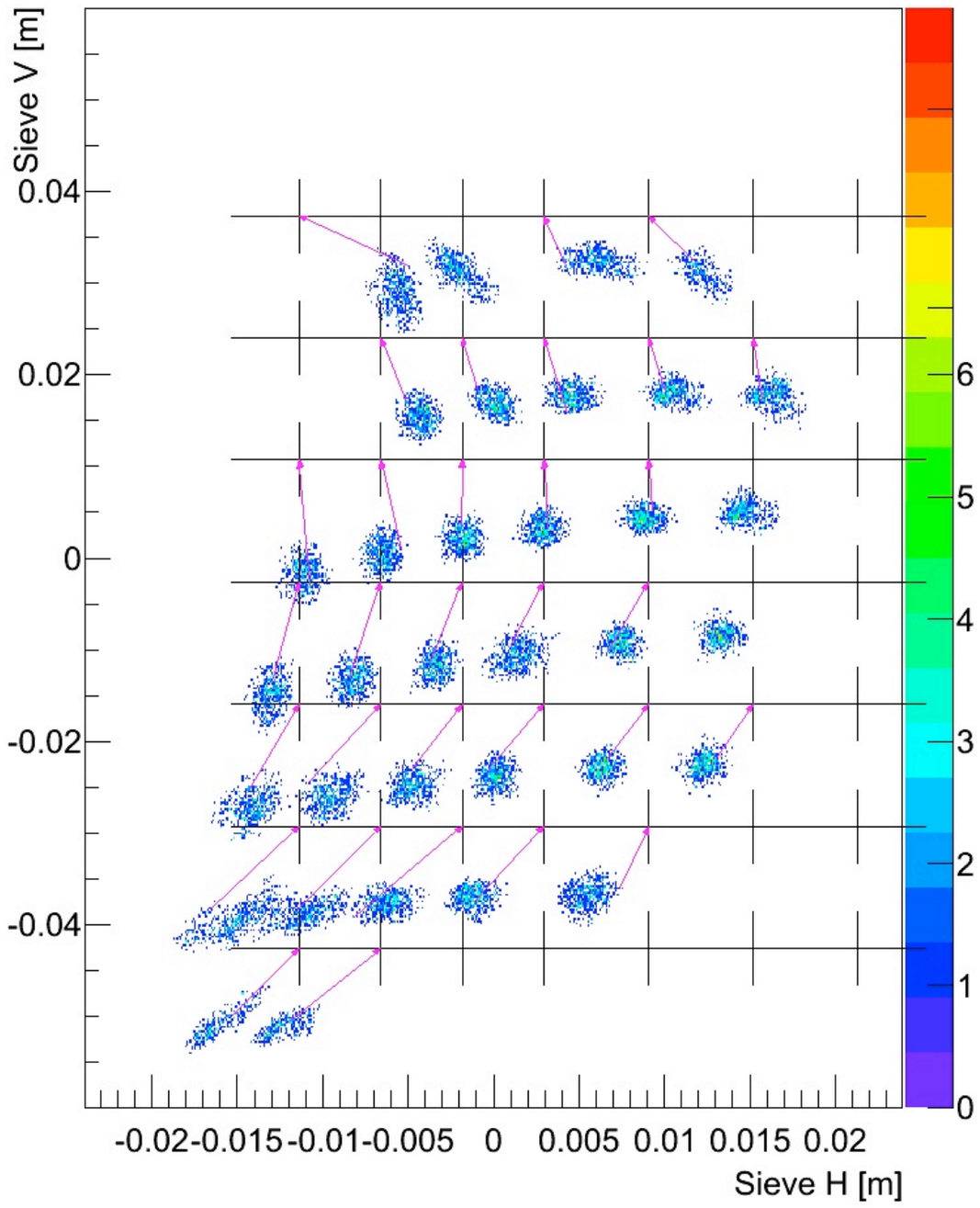
- Calibrate the matrix elements:
  - Fit with data which we already know the real scattering angle
  - Sieve slit
    - Allow to calculate the scattering angle with geometry



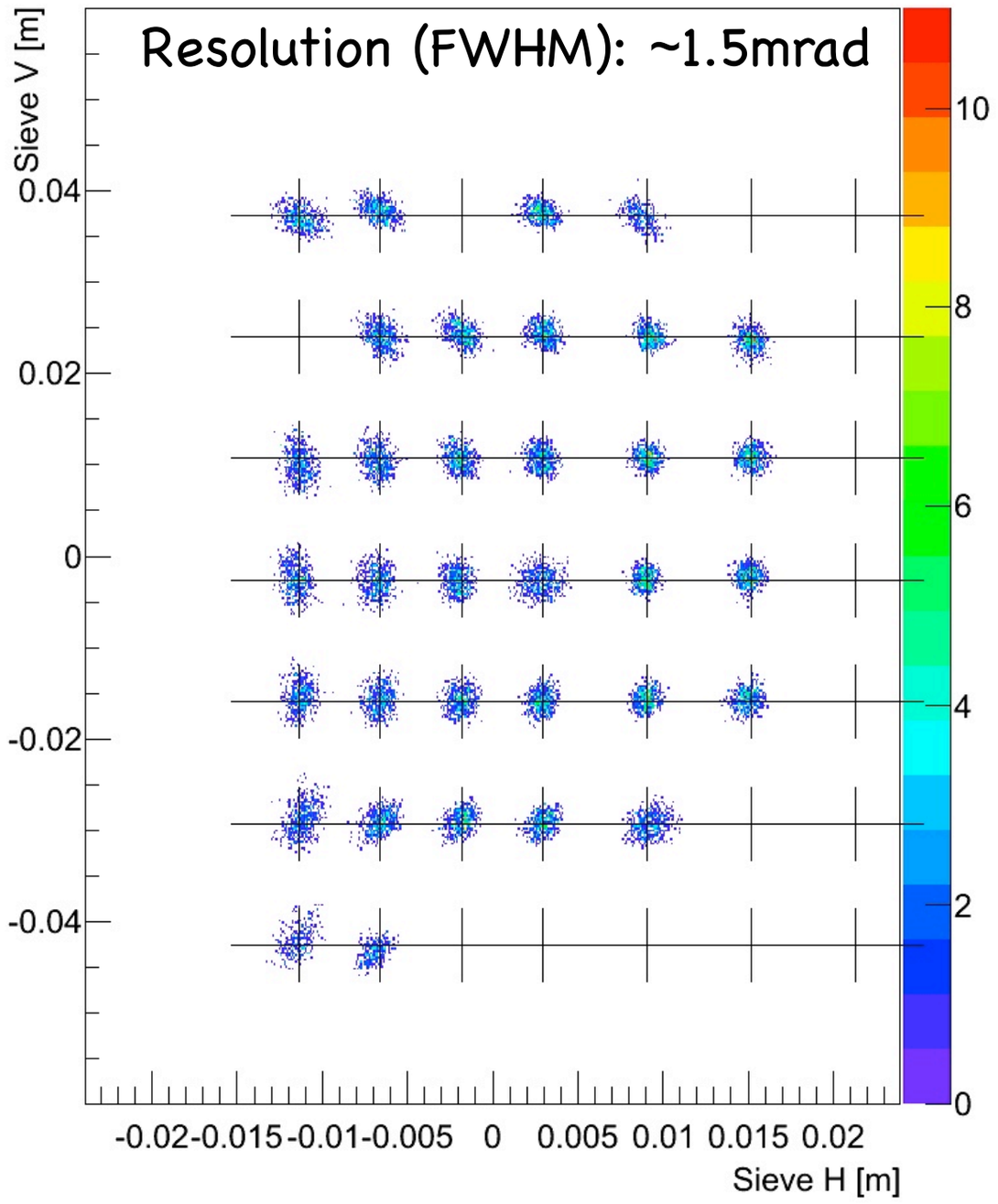


Angle Calibration

Before Optimize

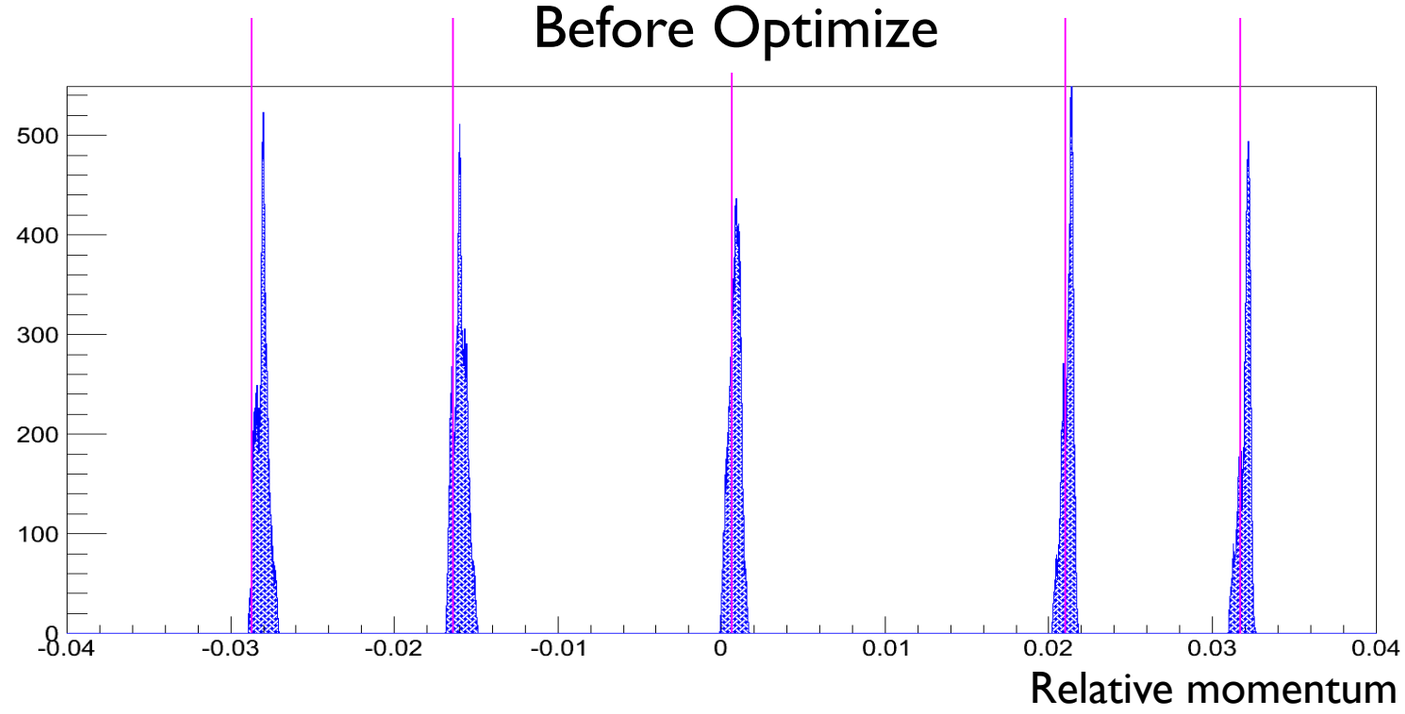


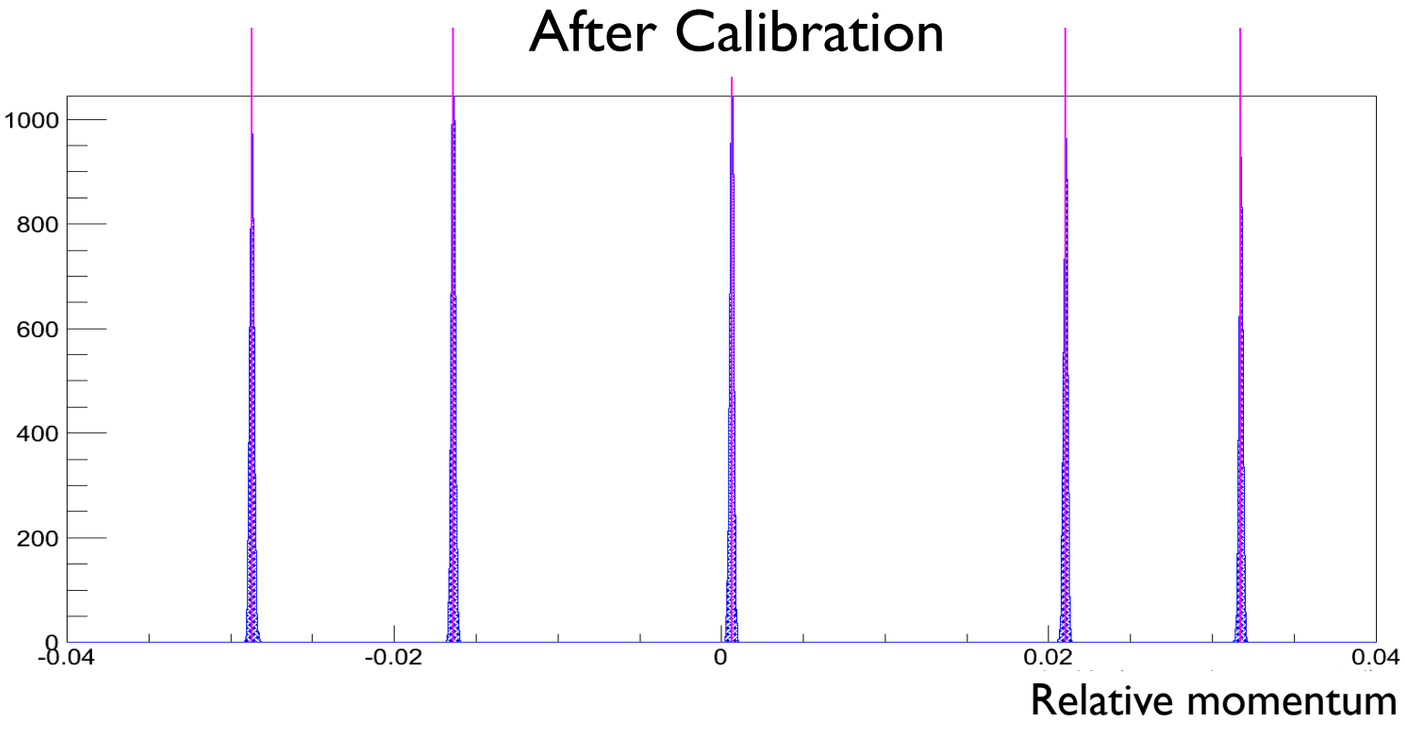
After Calibration



Momentum Calibration

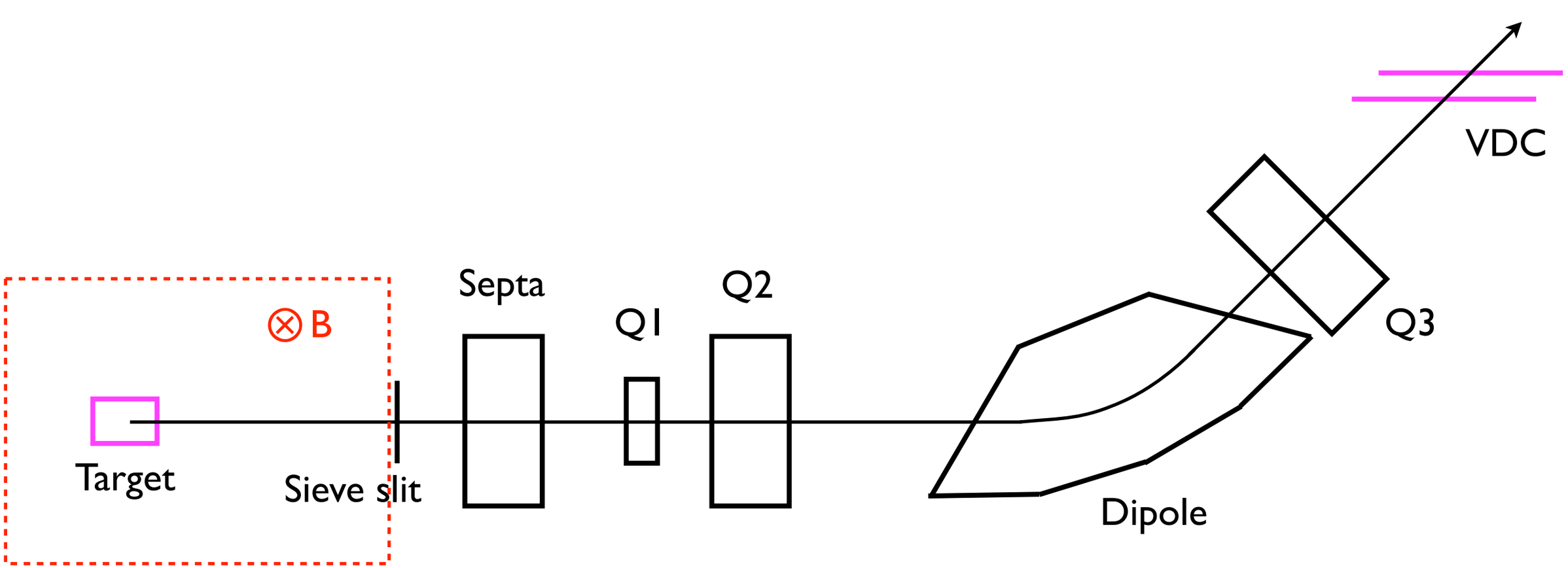
- Idea is same as the calibration of the angle matrix element
- Fit with data which we already know the real scattering momentum
- Elastic scattering on Carbon target
- Resolution (FWHM) ~2×10^{-4}





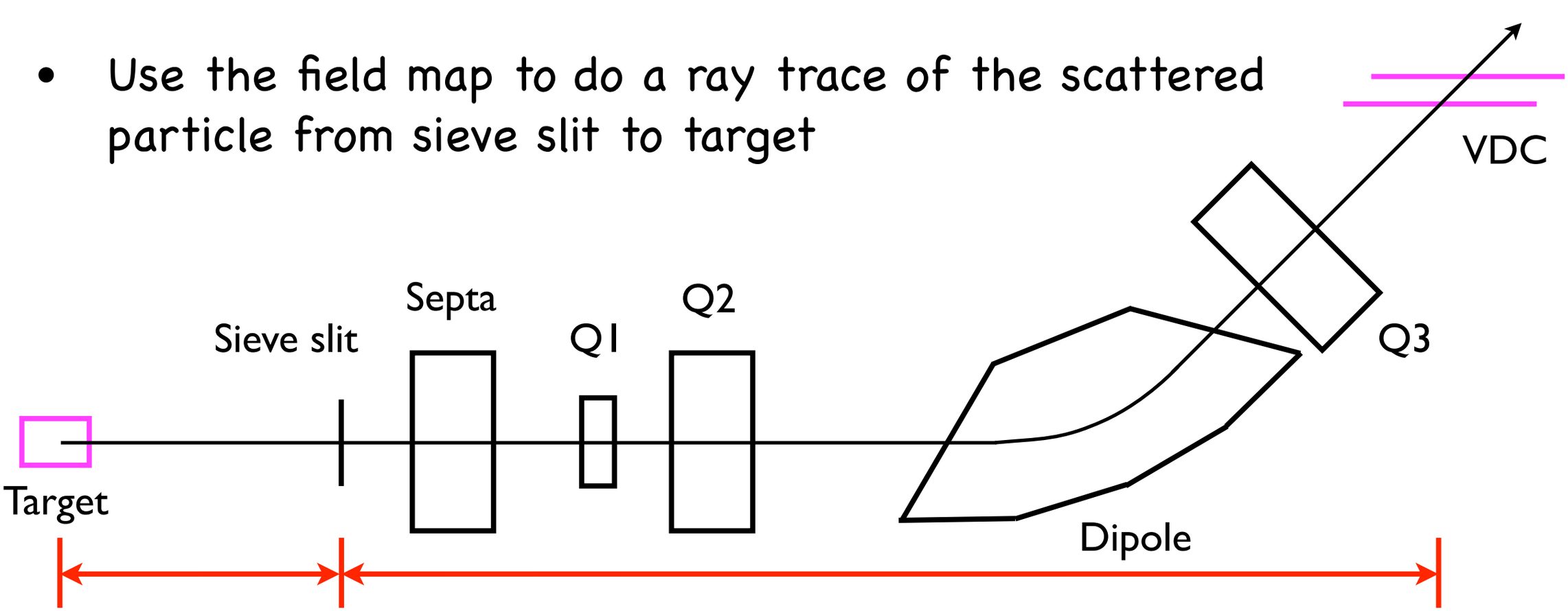
HRS Optics Study

- To include target field
  - Sieve slit method is not useful



HRS Optics Study

- To include target field
  - Sieve slit method is not useful
- Idea: separate reconstruction process to 2 parts:
  - Use the no target field result to deal with the reconstruction from VDC to sieve slit
  - Use the field map to do a ray trace of the scattered particle from sieve slit to target

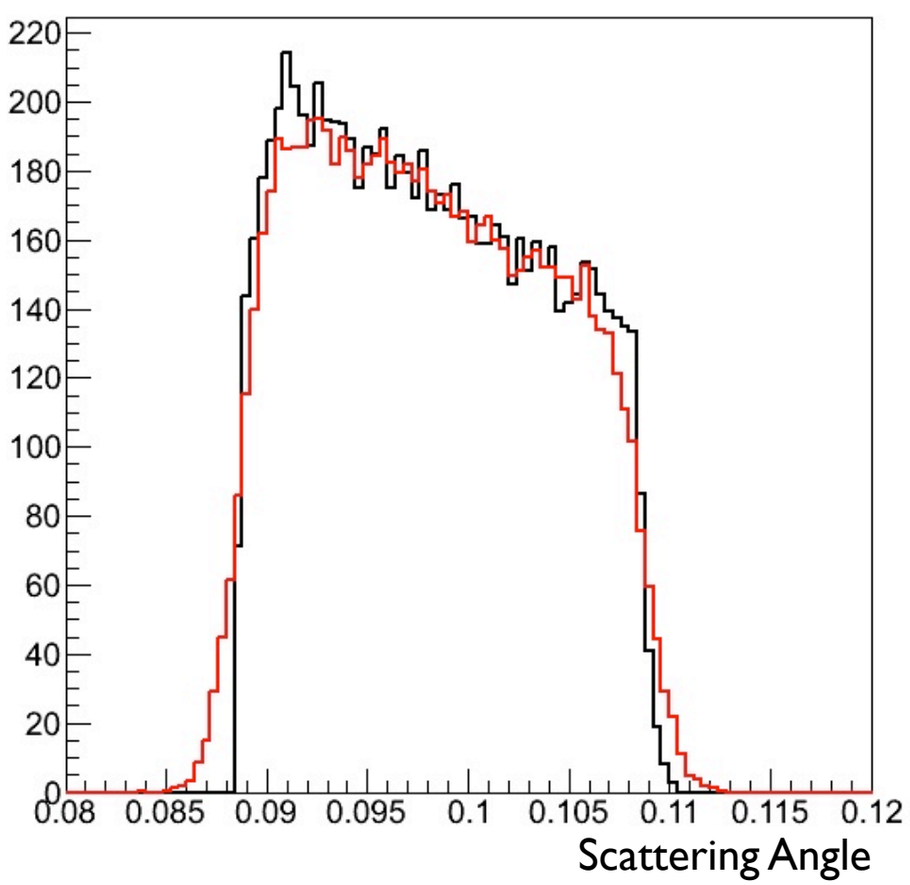


HRS Optics Study

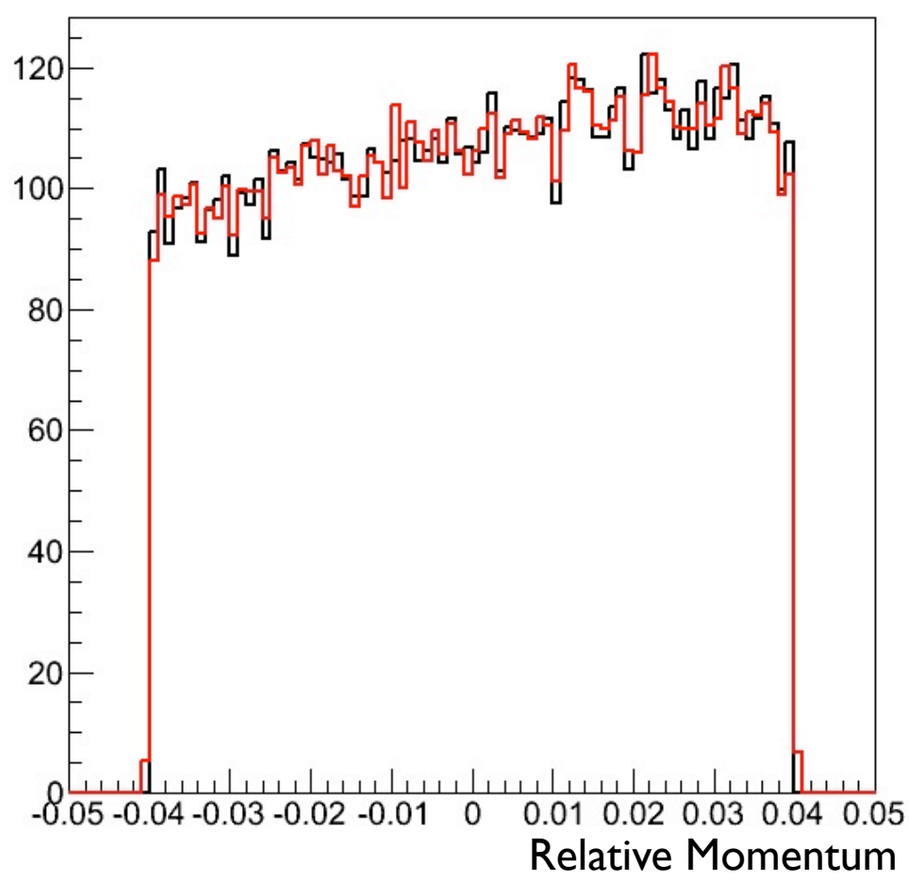
- Use a Monte-Carlo simulation to check this idea
  - Compare the kinematics of the generated electrons and the reconstructed result
  - The result shows a good consistence <1%

Black : generated
Red : reconstructed

Scattering Angle



Relative Momentum



Conclusion

- Optics study with out target field works well
- Optics study with target field
  - Ideas is tested with simulation and appeared to work
  - Need to check with data

Thanks

- I would like to thank the following people for their guidance and helpful discussions!
  - John Lerose
  - Jian-ping Chen
  - Nilanga Liyanage
  - Min Huang, Jixie Zhang, Vince Sulkosky
  - Jin Huang, Xin Qian, Yi Qiang, Zhihong Ye

Backups

Experiment Setup

- Hall A High Resolution Spectrometer
  - High momentum resolution: 10^{-4} level over a range of 0.8-4.0 GeV/c
  - High momentum acceptance: $|\delta p/p| < 4.5\%$
  - Wide range of angular settings: 12.5°~150° for left arm, 12.5°~130° for right arm
  - Angular acceptance: ±30 mrad (Horizontal) and ±60 mrad (Vertical)