Spectrometer Optics Calibration for g2p Experiment

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On Behalf of the E08-027 Collaboration

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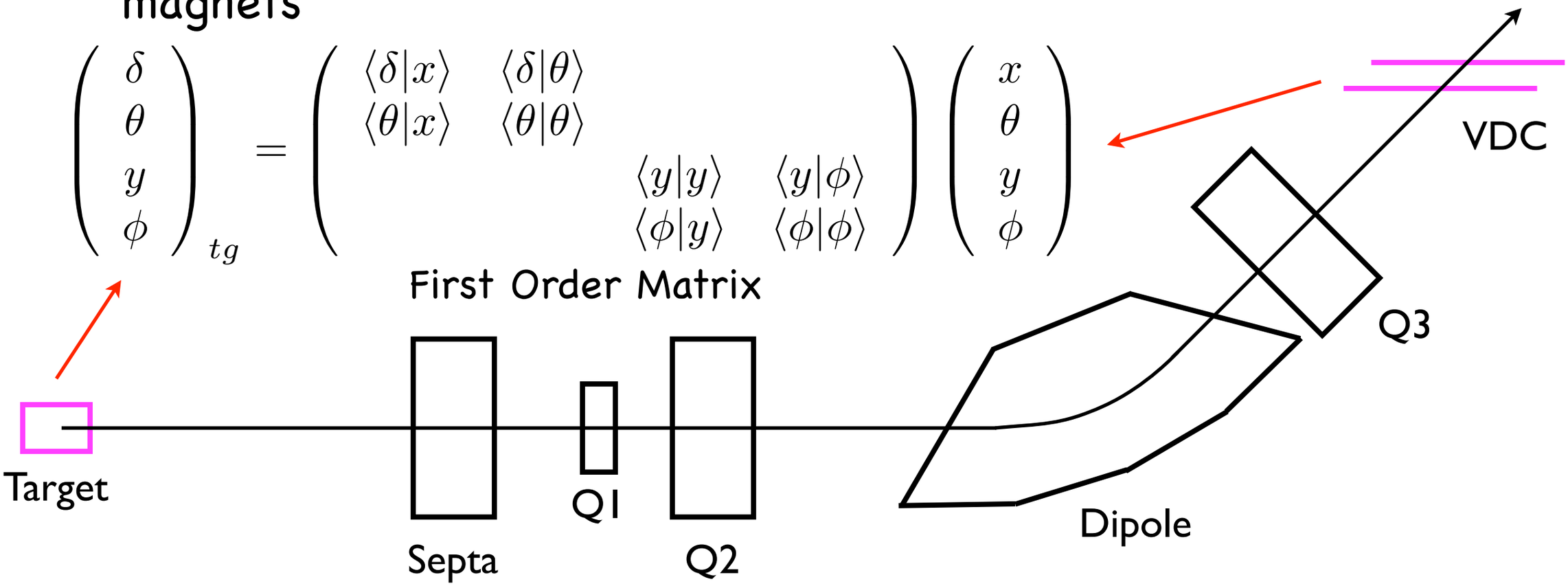
HRS Optics

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



HRS Optics

- 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
- Optics Goal:
  - <1.0% systematic uncertainty of scattering angle, which will contribute <4.0% to the uncertainty of cross section

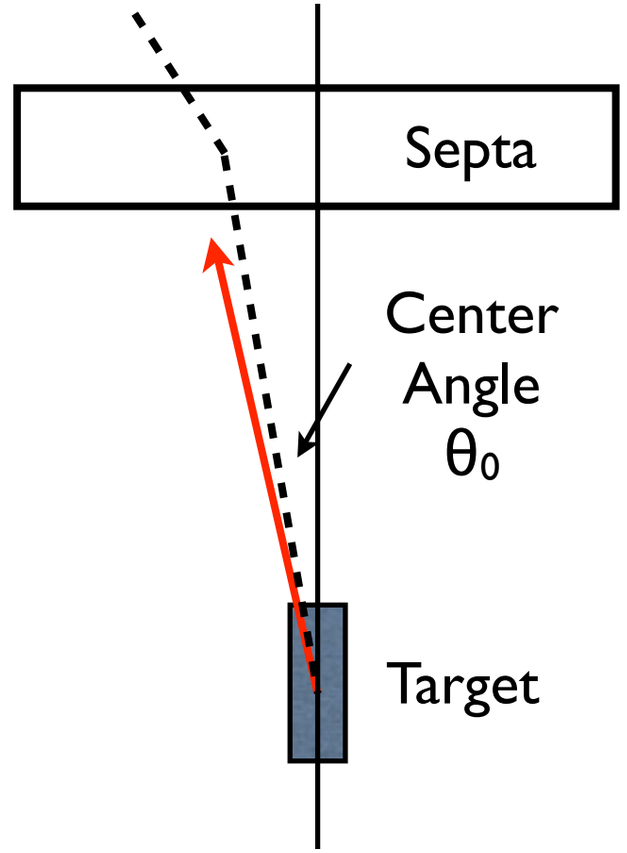
$$\sigma \sim 1/\sin^4(\theta/2)$$

  - Momentum uncertainty is not sensitive, but it is not hard to reach 10^{-4} level

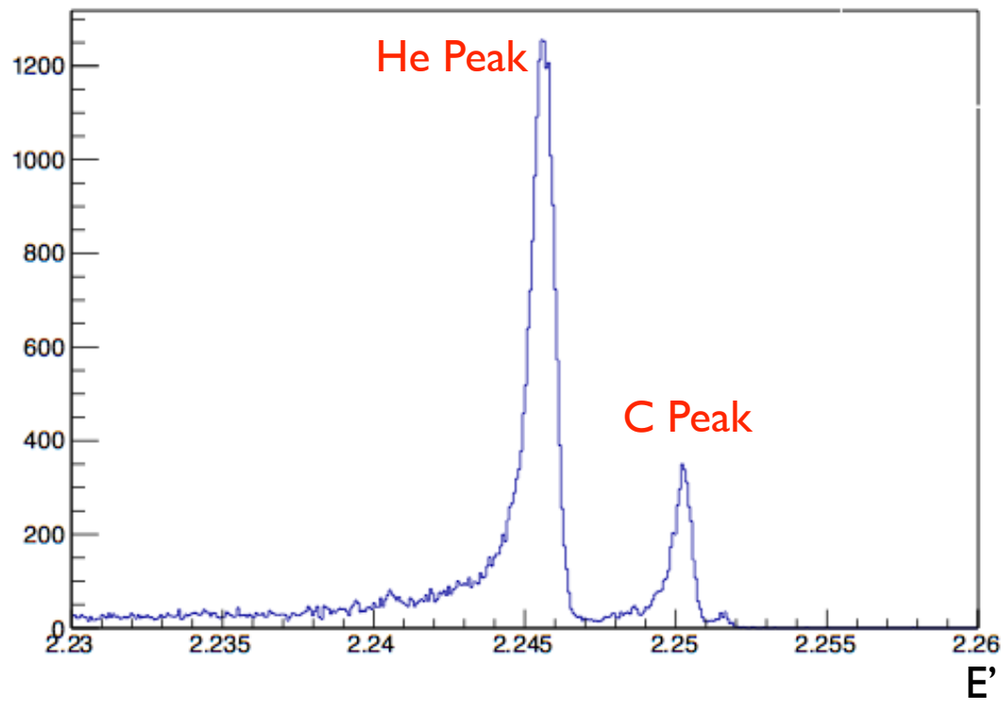
Angle Calibration

- Decide the center scattering angle
  - Direct measurement: ~1mrad
  - Idea: Use elastic scattering on different target materials

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

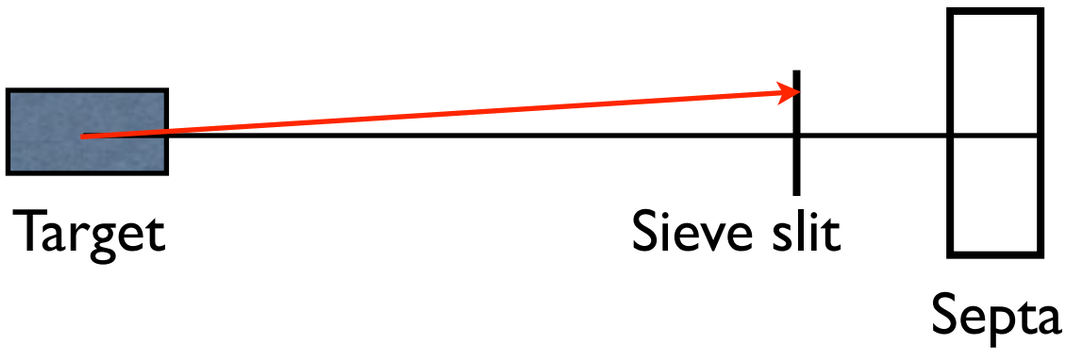


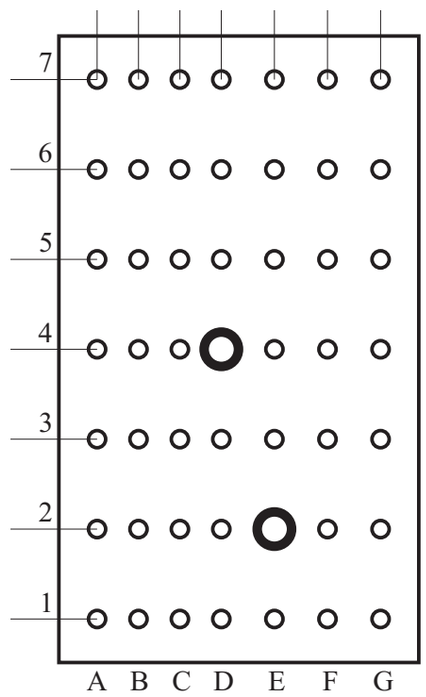
- Data taking: Carbon foil in LHe, or CH_2 foil
- The accuracy to determine this difference is <50KeV -> <0.5mrad



Matrix Calibration

- Calibrate the angle and momentum matrix elements:
  - Use carbon foil target and point beam
  - Use sieve slit to get the real scattering angle from geometry
  - Angle: Fit with data which we already know the real scattering angle
  - Momentum: Use the real scattering angle to calculate elastic scattering momentum of carbon target

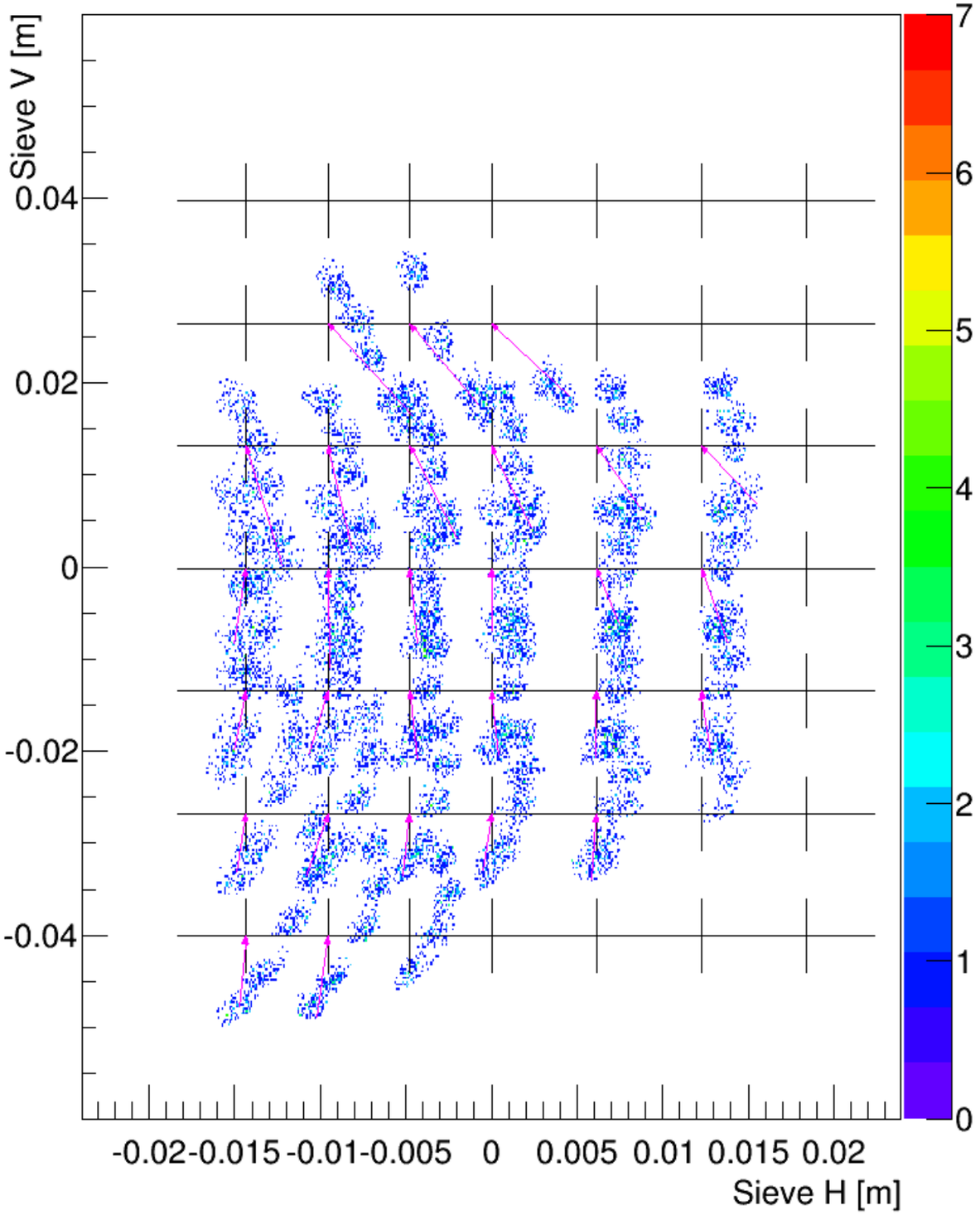




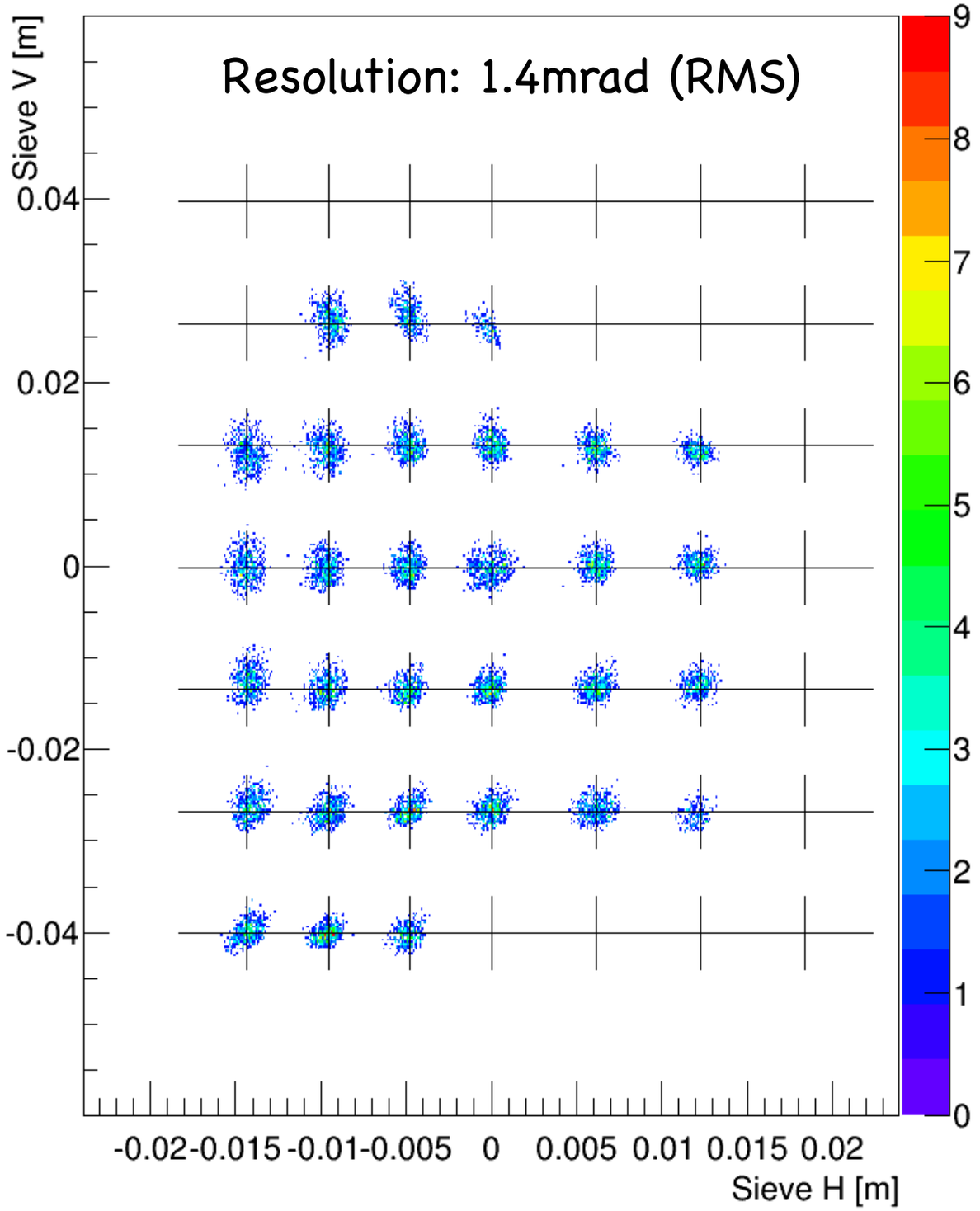
Matrix Calibration: Angle

LHRS

Before Calibration



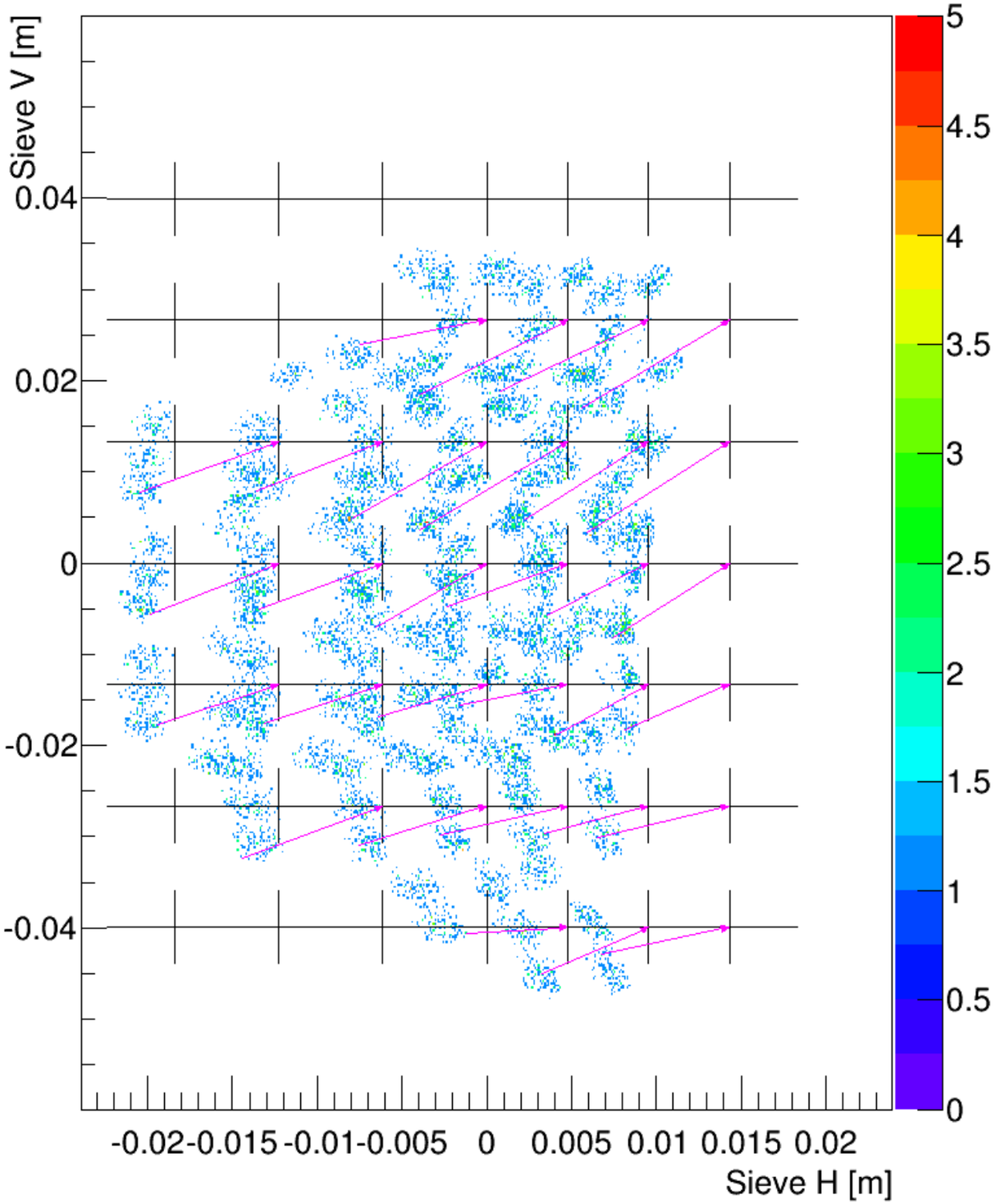
After Calibration



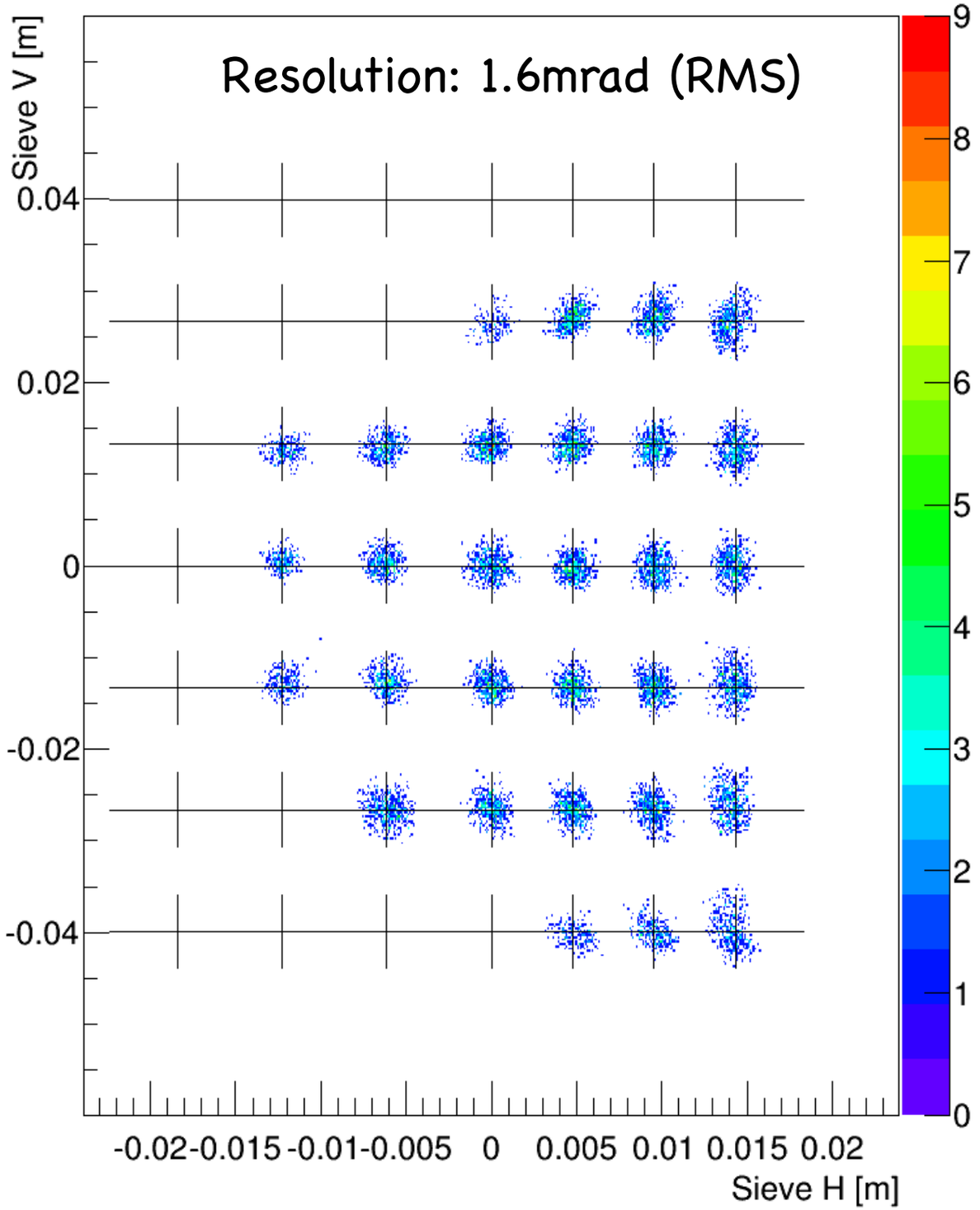
Matrix Calibration: Angle

RHRS

Before Calibration



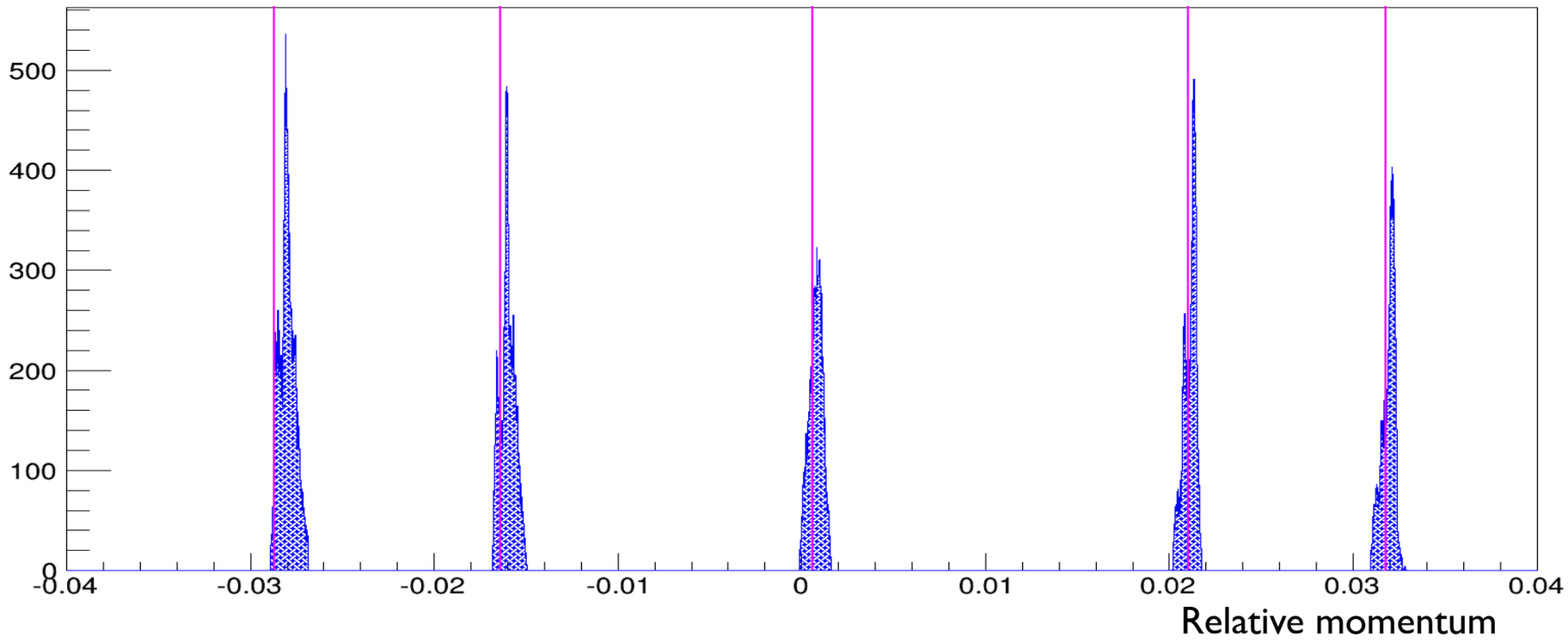
After Calibration



Matrix Calibration: Momentum

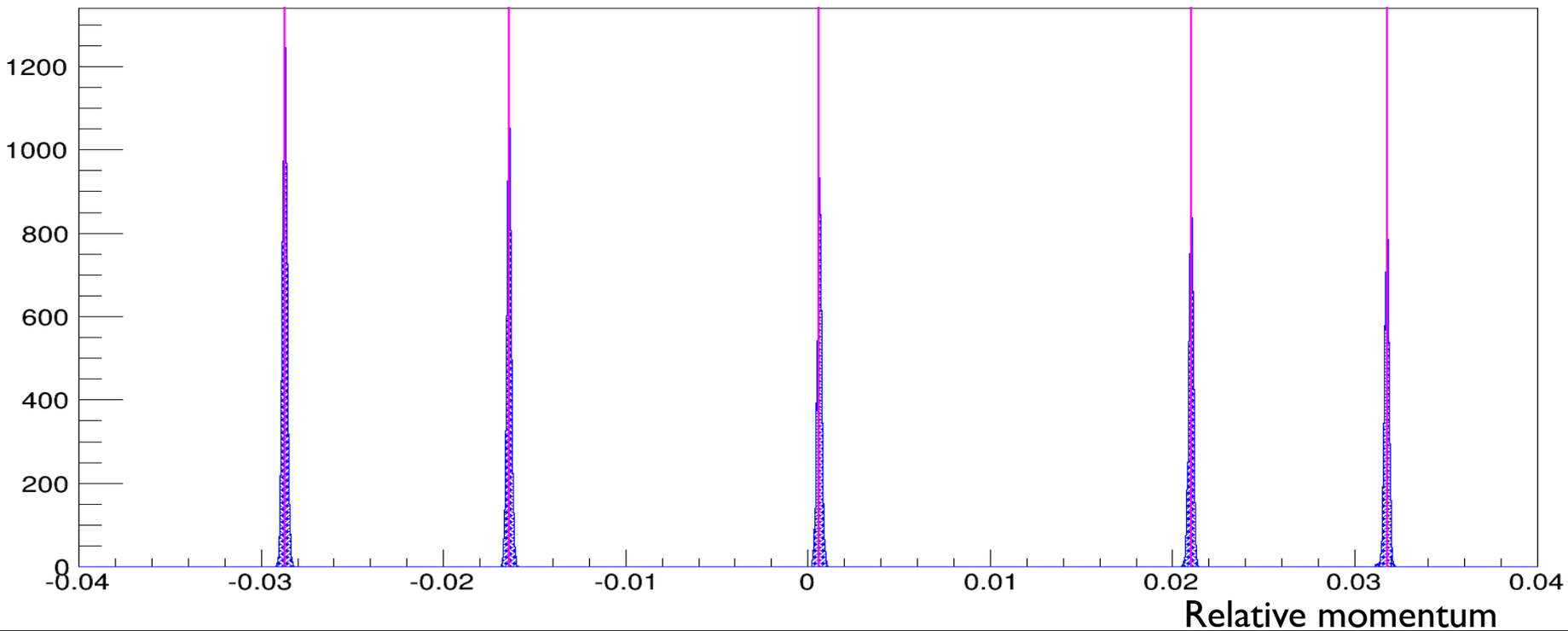
LHRS

Before Calibration



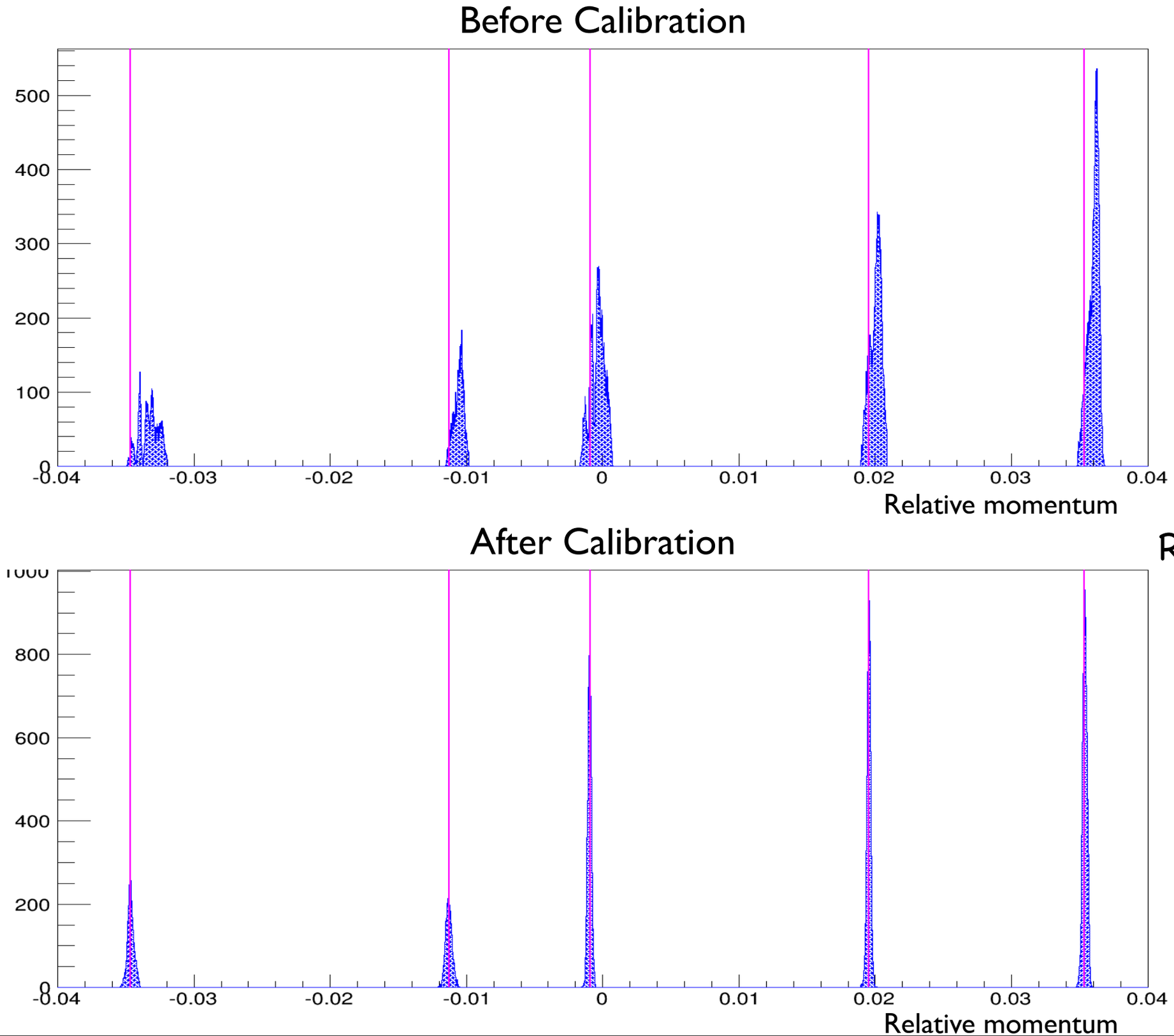
After Calibration

RMS: 1.4×10^{-4}



Matrix Calibration: Momentum

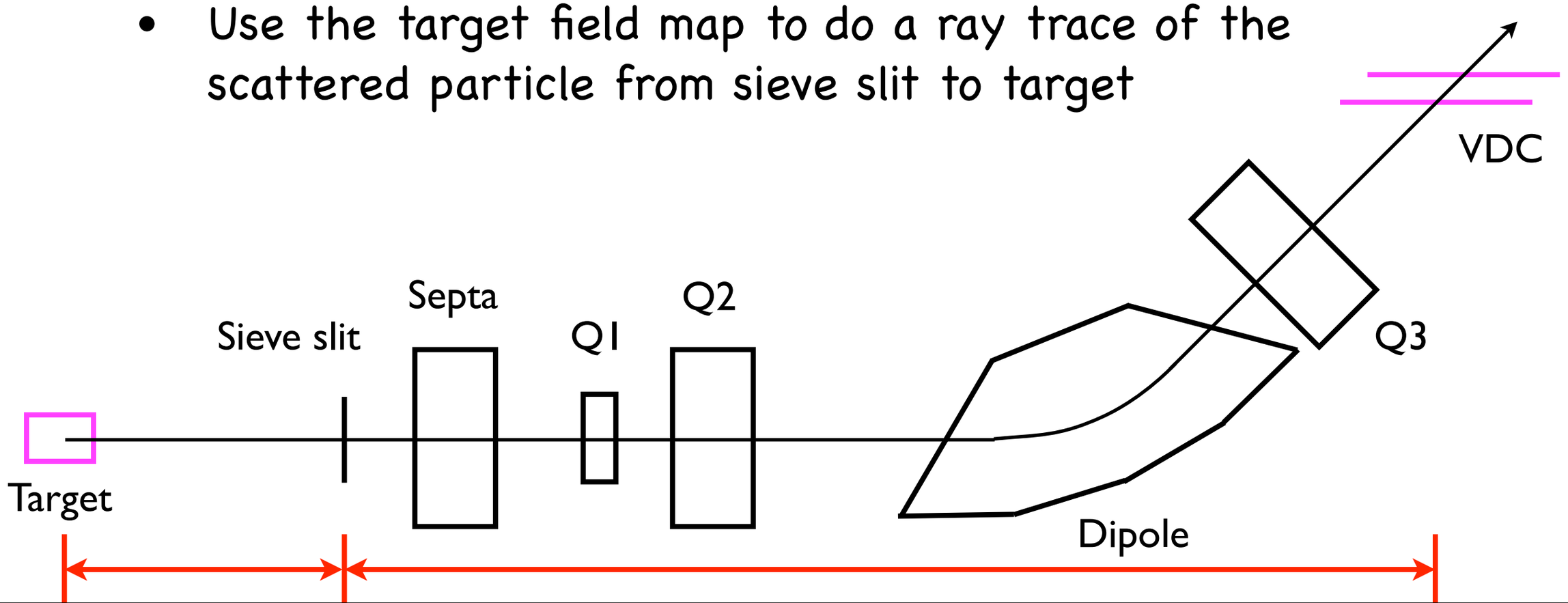
RHRS



RMS: 1.7×10^{-4}

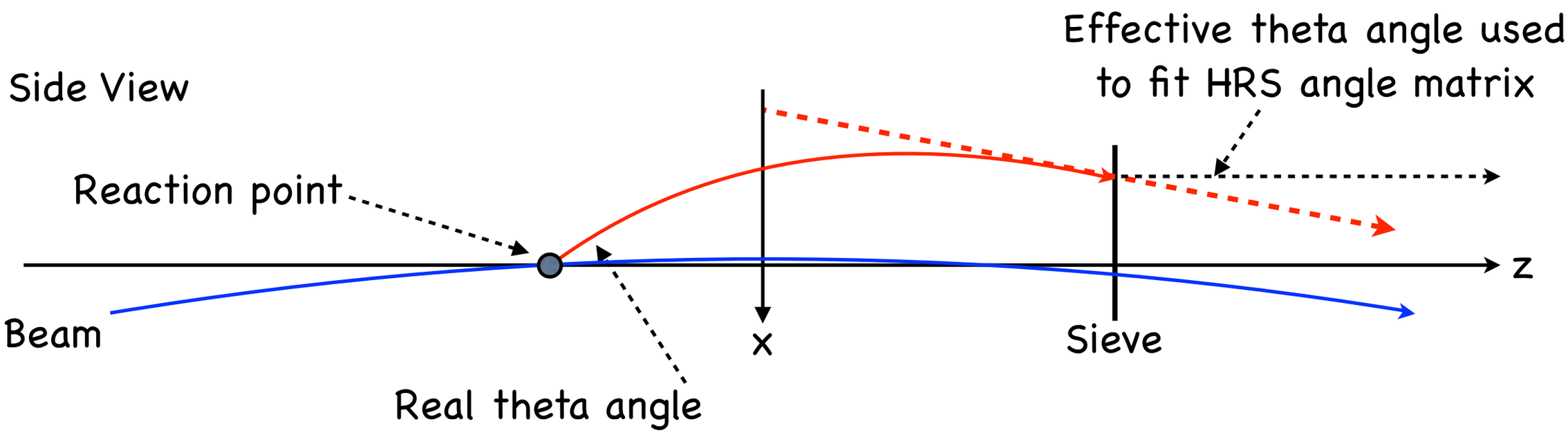
Optics Study with Target Field

- To include target field
  - Normal sieve slit method is not useful
- Idea: separate reconstruction process to 2 parts:
  - Use HRS transform matrix to do the reconstruction from VDC to sieve slit
  - Use the target field map to do a ray trace of the scattered particle from sieve slit to target



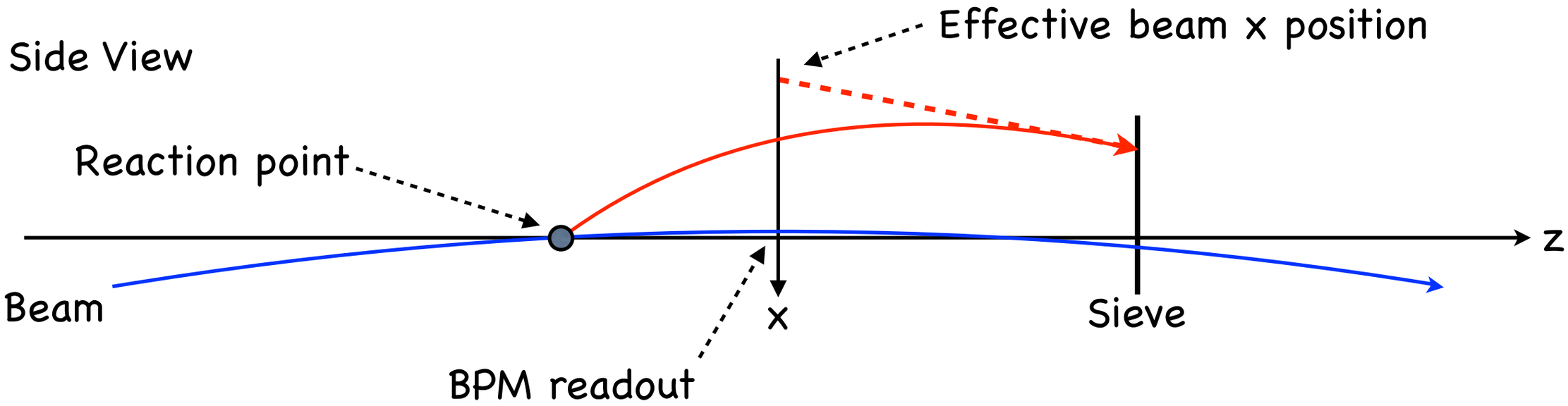
Optics Study with Target Field

- Recalibrate the angle matrix elements:
  - Start with the transform matrix without target field
  - To fit the matrix element, need to know the effective theta and phi angle
  - Use a modified SAMC simulation to get these effective angles



Optics Study with Target Field

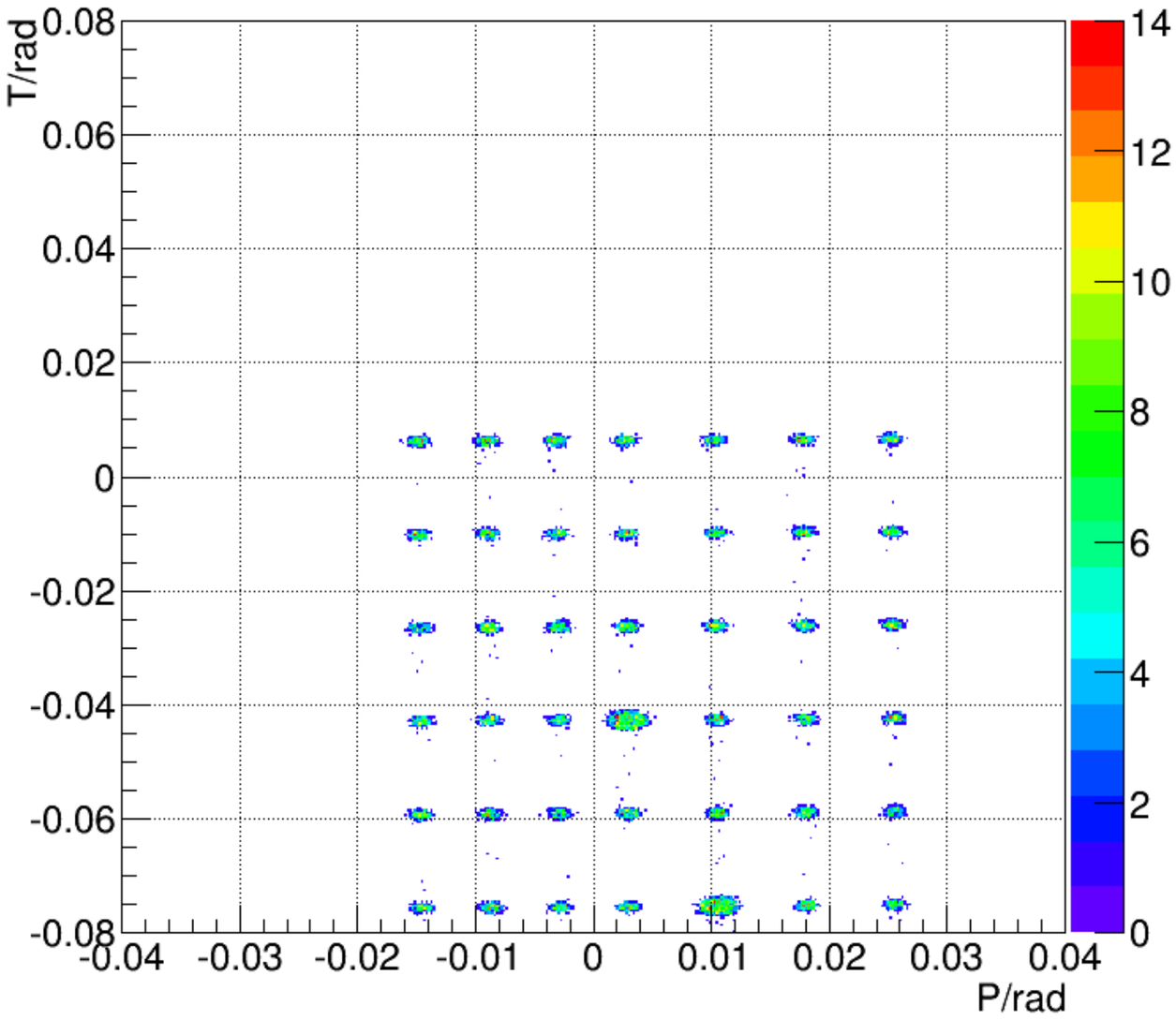
- Reconstruct the scattering angle:
  - Use the HRS transform matrix to get the effective target variables
  - Project the effective target variables to sieve slit
  - Use the field map to calculate the trajectory of the scattered electron, which will tell us the real scattering angle



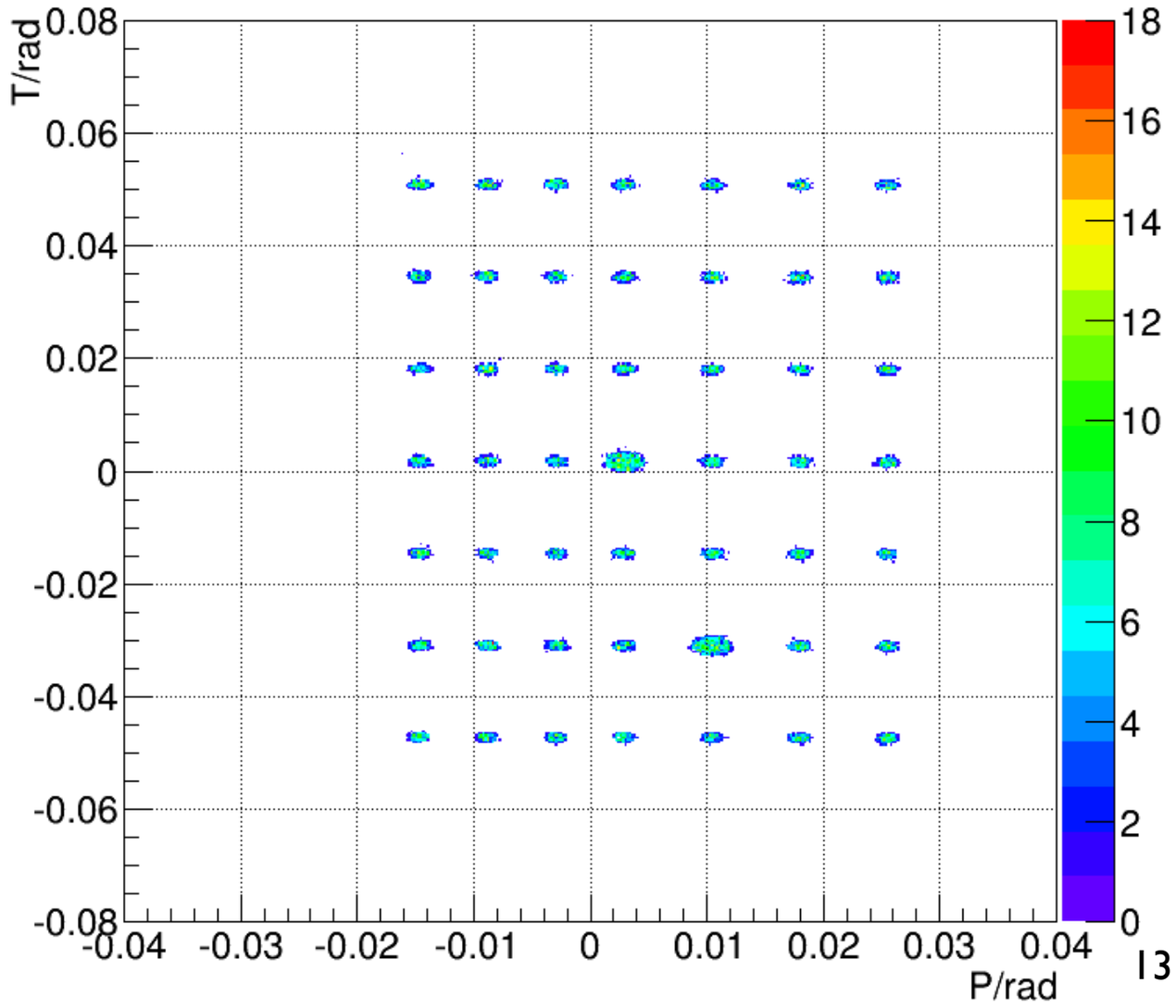
Optics Study with Target Field

- Run simulation to decide the effective theta and phi
  - Assuming point beam
  - Beam energy 2.254GeV, Target field 2.5T

Initial angle in simulation



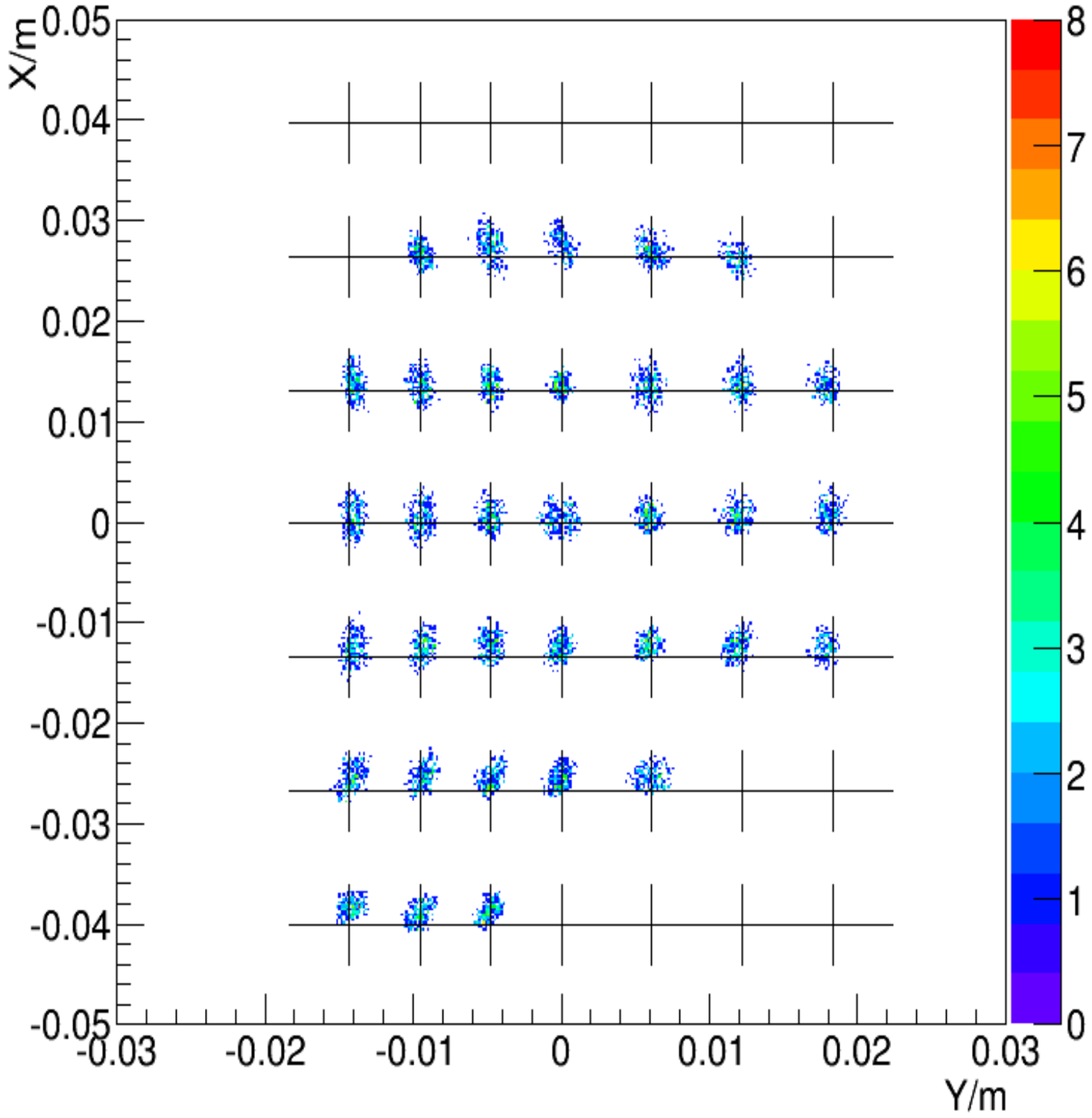
Effective angle to do the fitting



Optics Study with Target Field

- Use carbon foil target and point beam
- Sieve pattern is decided by both the beam position and the reconstructed angle
- Directly use BPM readout to provide beam position here

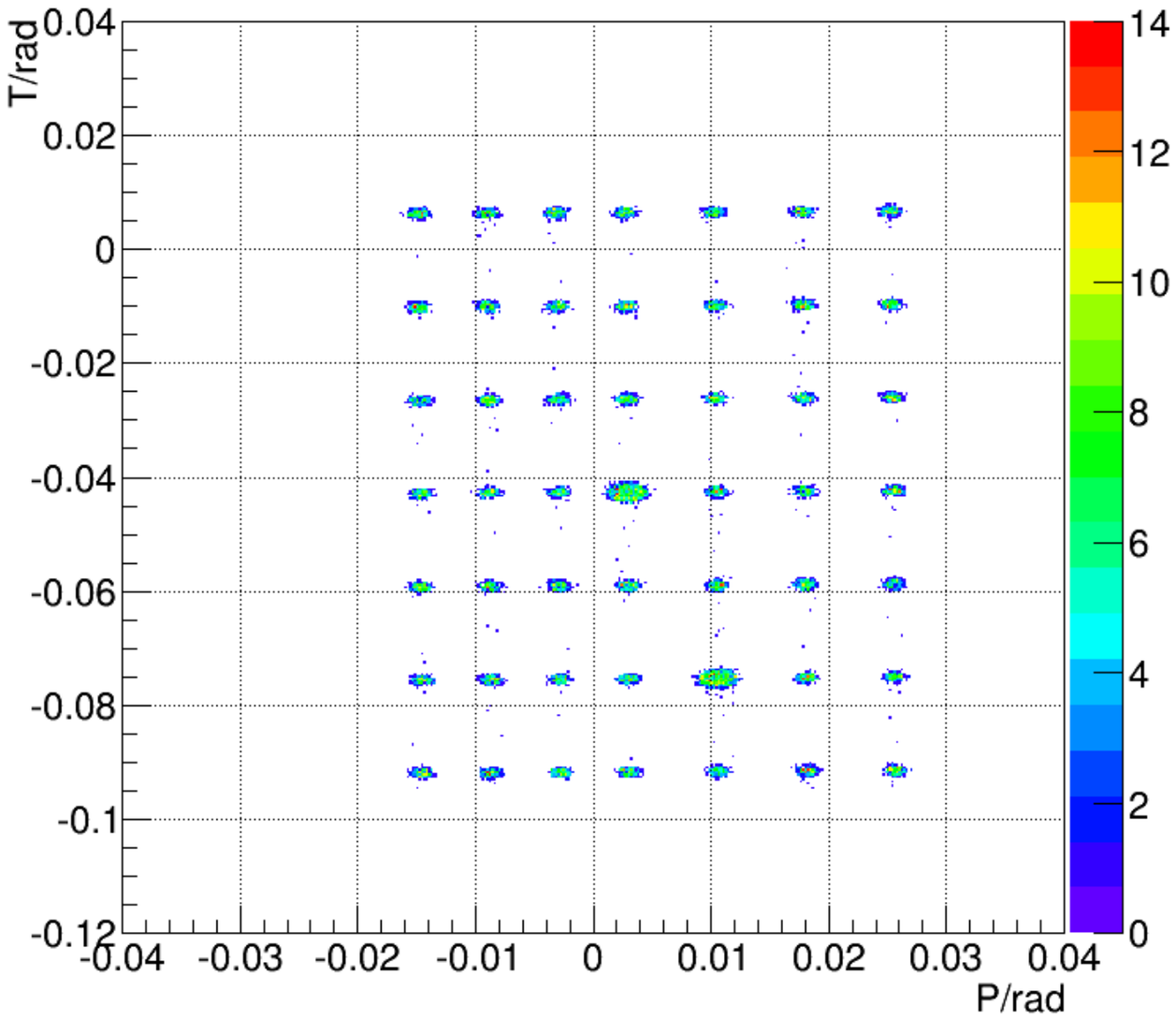
Sieve pattern after calibration



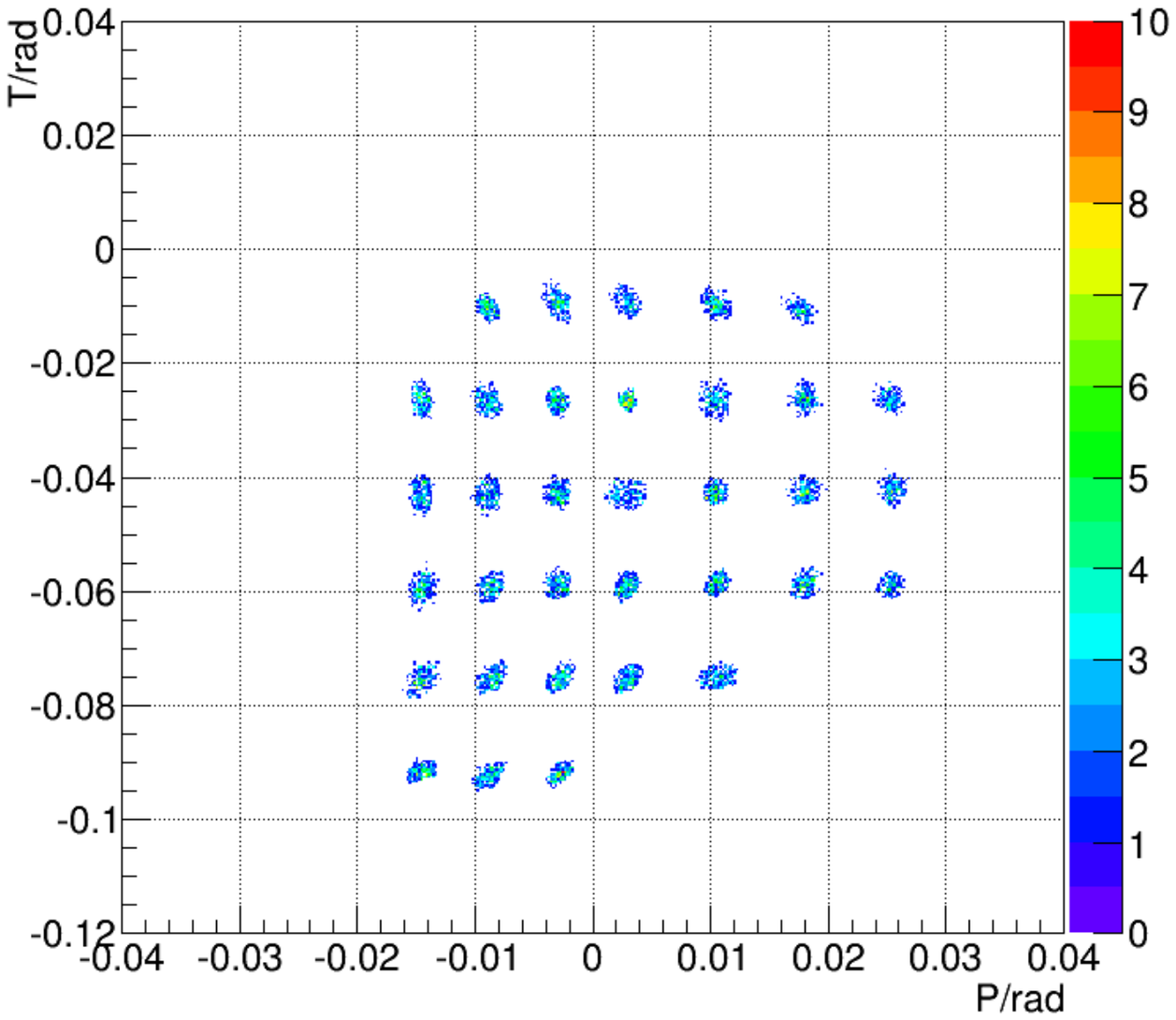
Optics Study with Target Field

- Compare reconstructed target theta and phi angle with the calculated result

Calculated theta and phi



Reconstructed theta and phi



Conclusion

- Optics study with out target field works well
- Optics study with target field
  - The reconstructed procedure is designed with help of simulation
  - The method is tested with 1 set of the data and could do the reconstruction
  - Will test the method on different settings

E08-027 Collaboration

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