Optics and Simulation

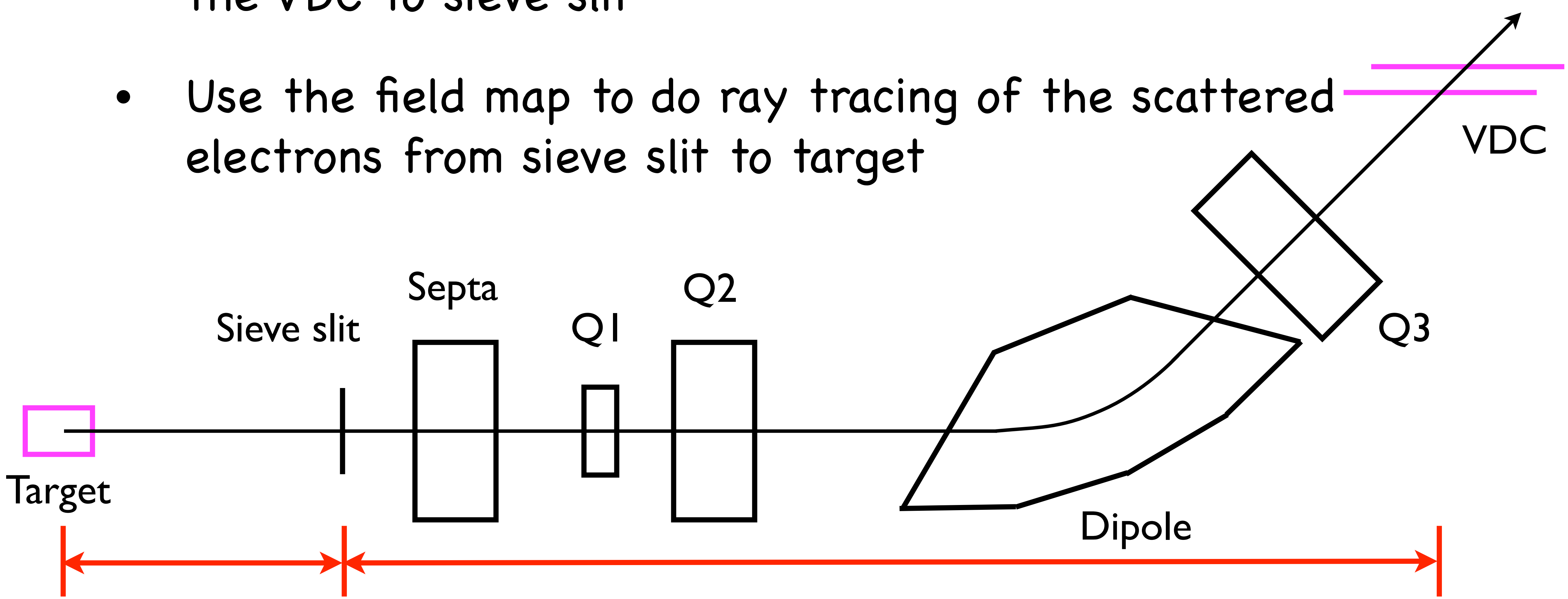
Chao Gu

Overview

- New Helicity Decoder (finished)
- HRS Optics
  - optics calibration without target field (finished)
  - optics calibration with target field (finished a few settings, still in-progress)
- "g2psim" Simulation Package
  - geometry and optics part used by optics calibration (finished, Thanks to Min's input of SNAKE models)
  - cross-section models (collected a few models and tested the compatibility with the simulation package, Jie keeps working on the models, particularly the energy loss models)

Optics Study

- Optics study for g2p: the most important part is how to treat the transverse target field
- Idea: separate reconstruction process to 2 parts:
  - Use the normal analyzer matrix to reconstruct from the VDC to sieve slit
  - Use the field map to do ray tracing of the scattered electrons from sieve slit to target

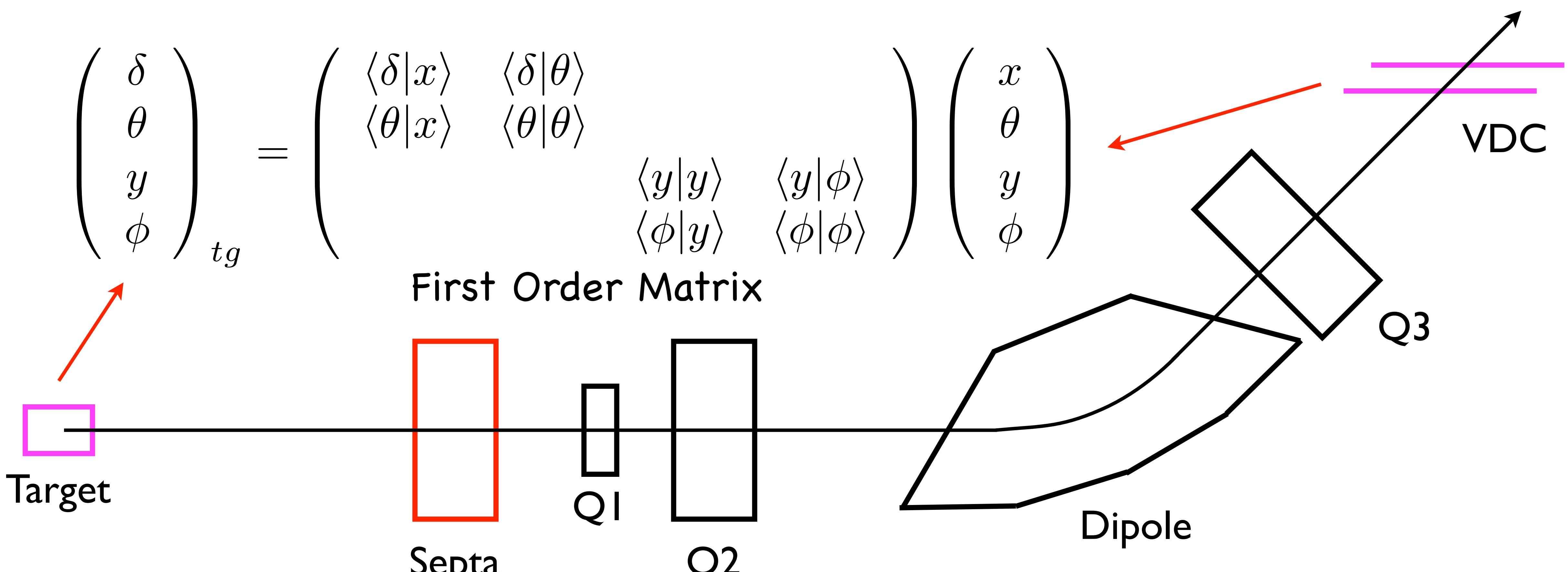


Optics Study: without Target Field

- Optics without target field:
  - Detector central angle calibration (Pointing) is done by Min
  - Angle and Momentum: standard sieve slit method to calibrate theta, phi and delta matrix
  - Vertex: standard method is to use multi-foil target which we do not have , alternatively use the aluminum window of the target chamber to calibrate y matrix

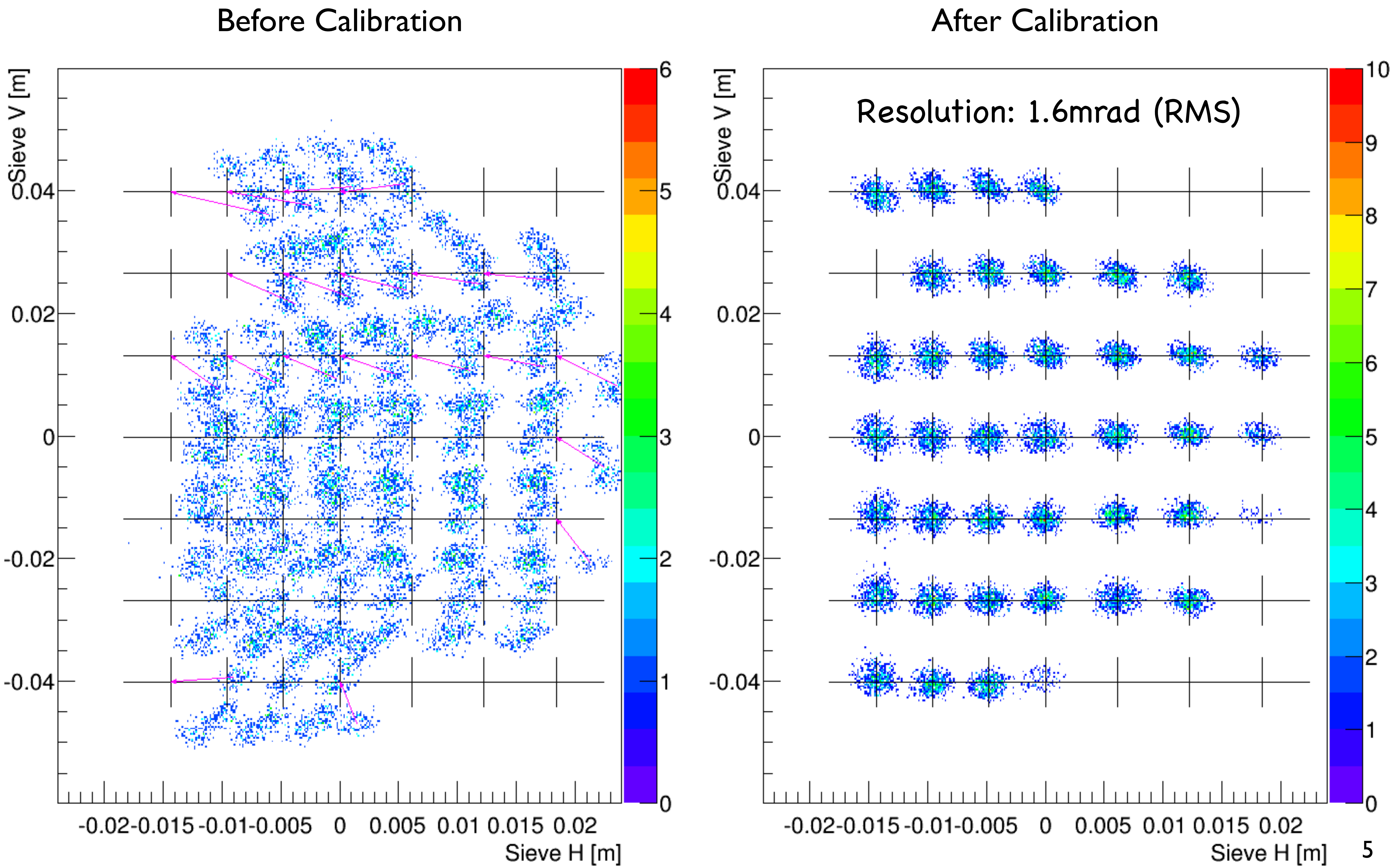
$$\begin{pmatrix} \delta \\ \theta \\ y \\ \phi \end{pmatrix}_{tg} = \begin{pmatrix} \langle \delta | x \rangle & \langle \delta | \theta \rangle & & \\ \langle \theta | x \rangle & \langle \theta | \theta \rangle & & \\ & & \langle y | y \rangle & \langle y | \phi \rangle \\ & & \langle \phi | y \rangle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

First Order Matrix



Matrix Calibration: Angle

LHRS

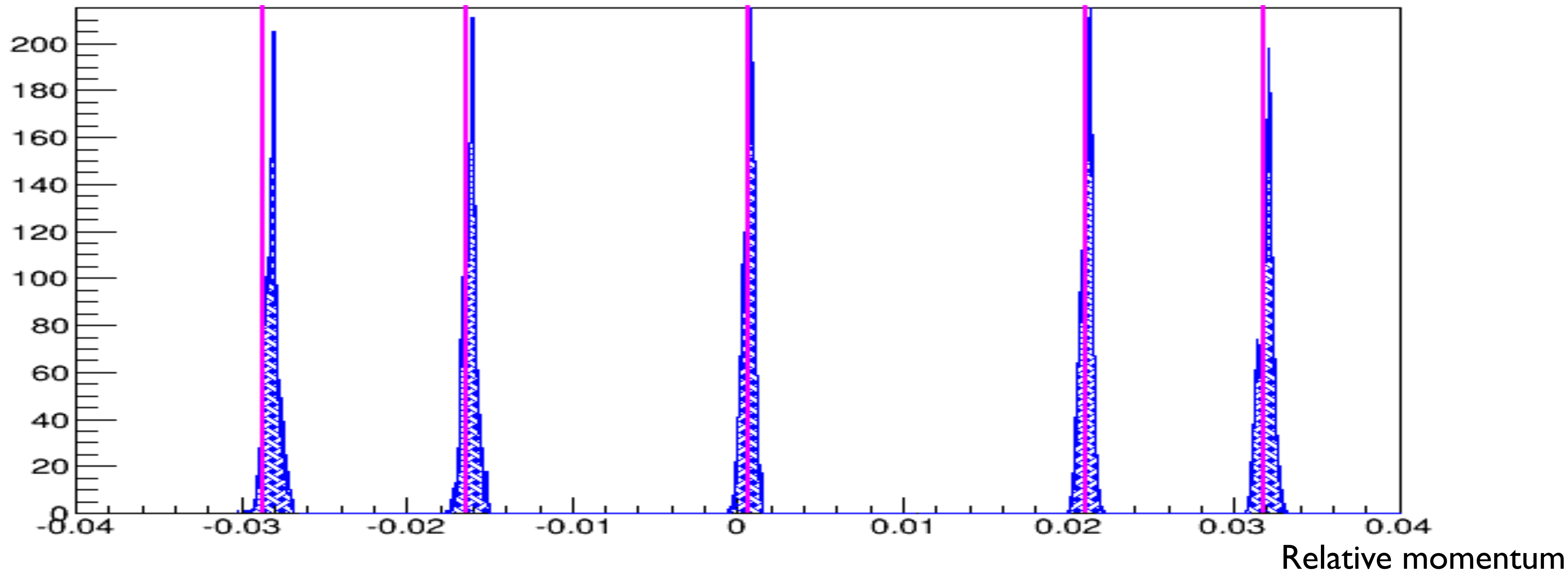


Matrix Calibration: Momentum

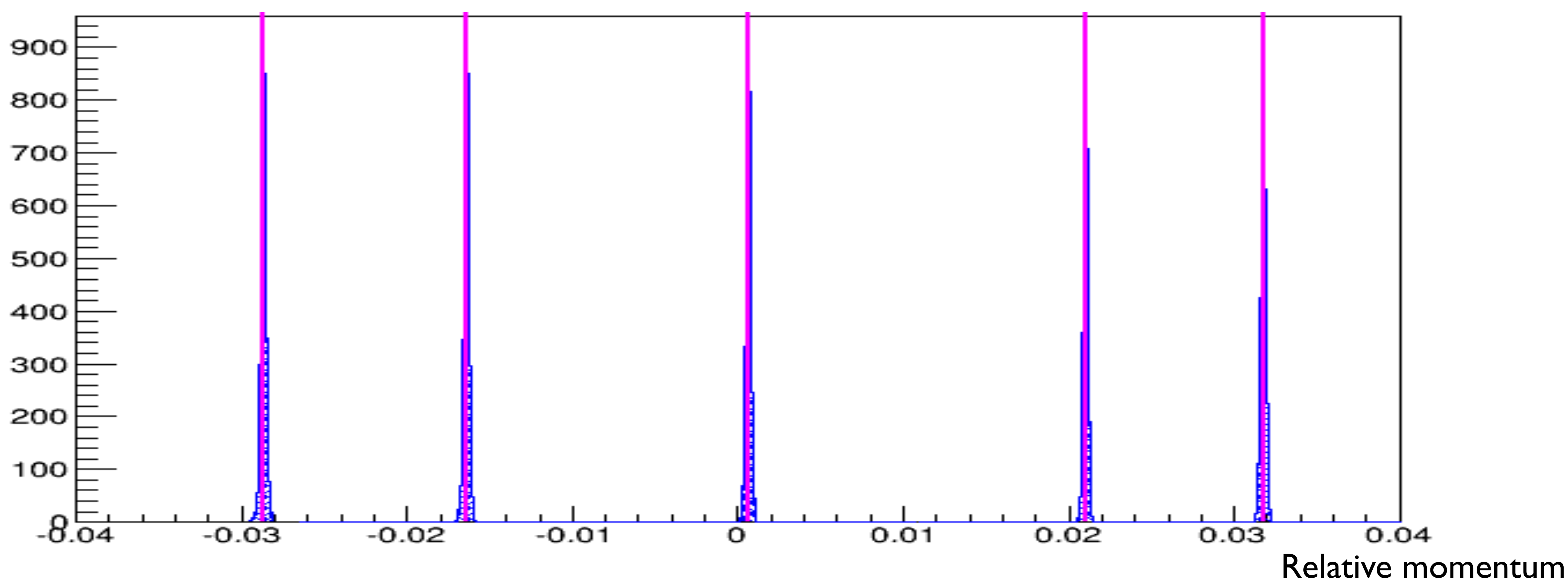
LHRS

RMS: 1.5×10^{-4}

Before Calibration



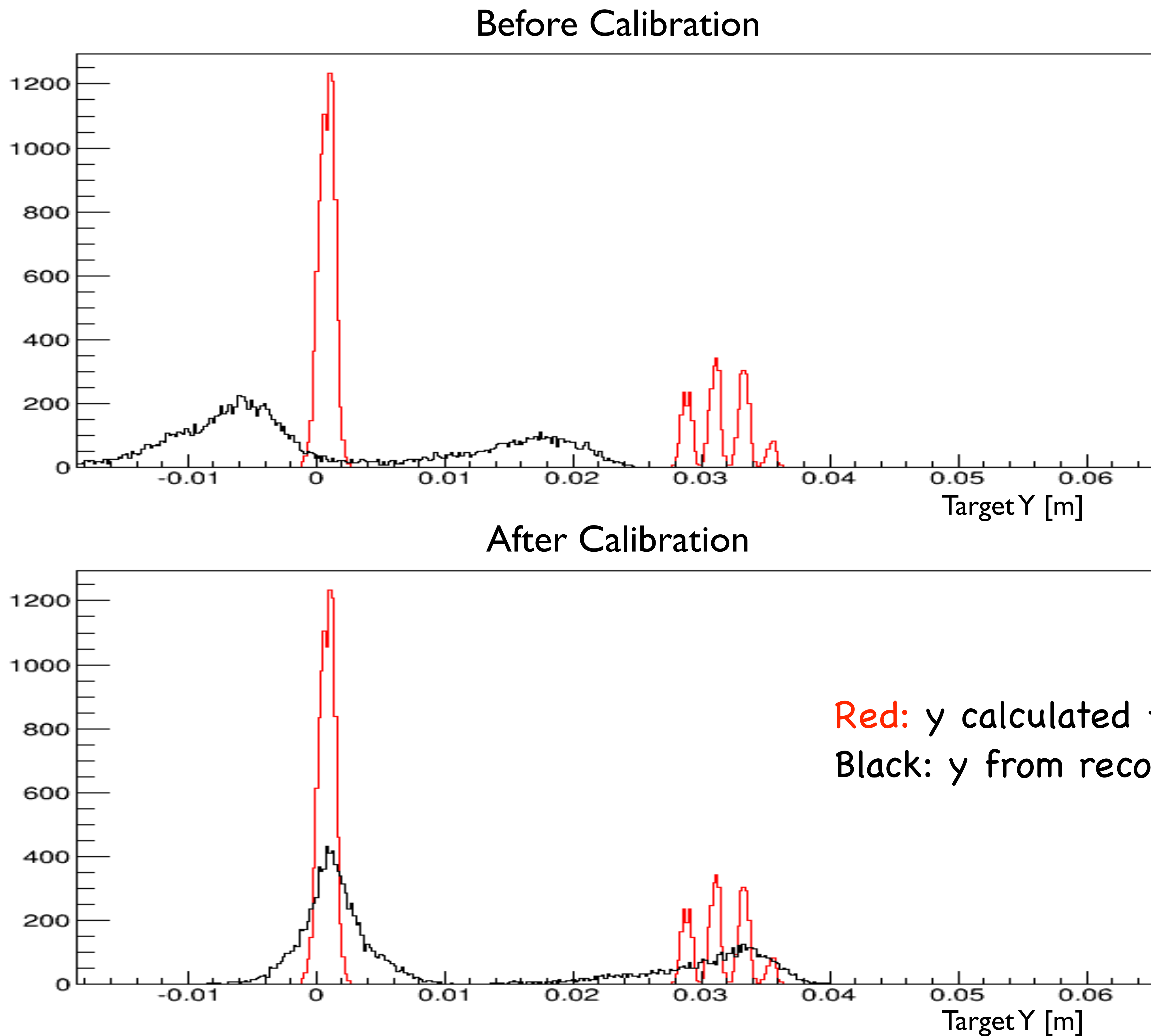
After Calibration



Matrix Calibration: Momentum

LHRS

RMS: 3.3mm



Red: y calculated from survey
Black: y from reconstruction

Summary: Optics without Target Field

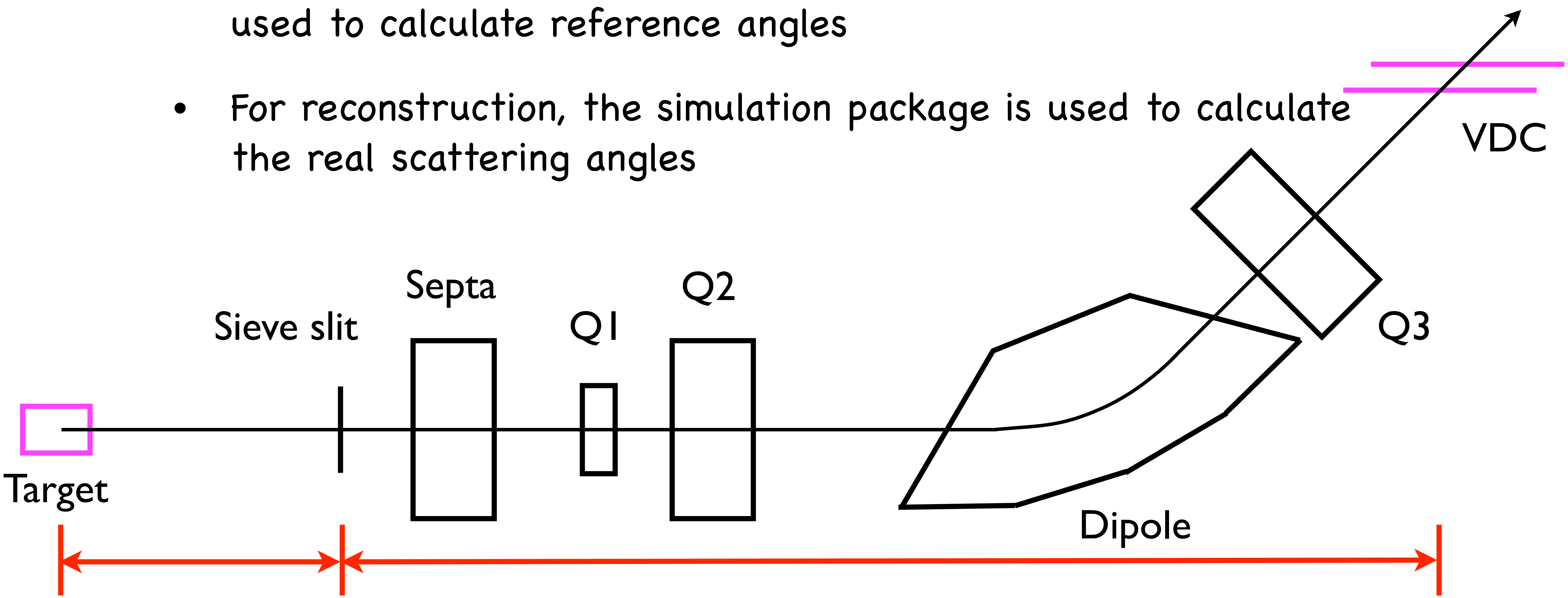
- The performance summary of the optics without target field: the table shows a summary of the RMS values of each kinematic variables after calibration

	LHRS	RHRS
δ [dp]	1.5×10^{-4}	2.4×10^{-4}
θ [out-of-plane angle]	1.59 mrad	1.57 mrad
y	3.3 mm	2.9 mm
φ [in-plane angle]	0.99 mrad	0.82 mrad

- The optics without target field works well
  - good start point for optics with target field

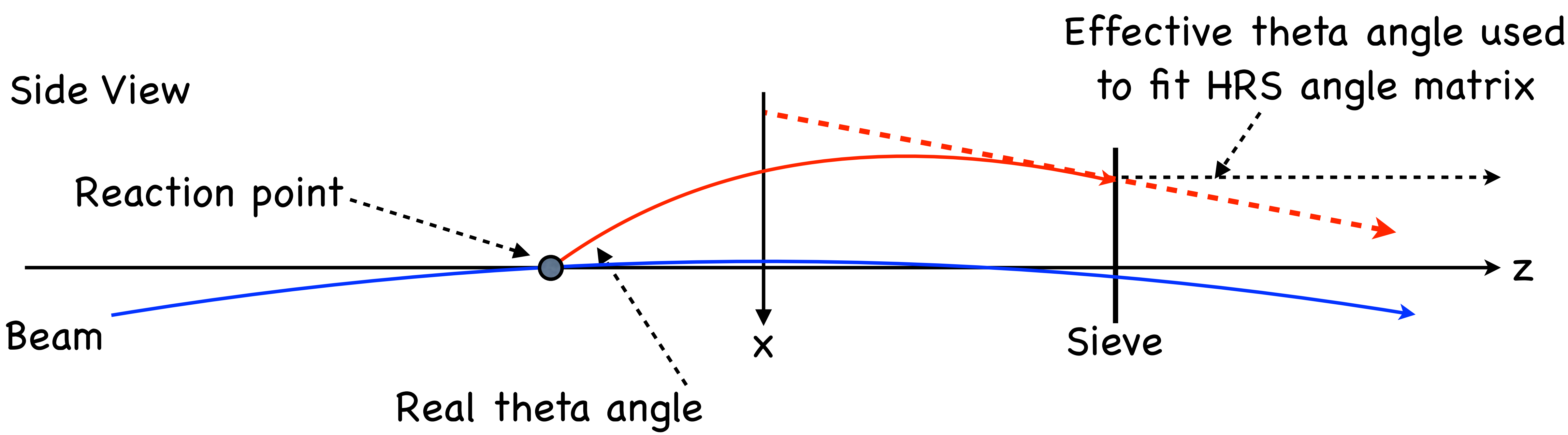
Optics Study

- Optics with target field:
  - Since the septum broke during the experiment, need to use the dat taken with the broken septum to recalibrate angle matrix
  - A simulation package is written to deal with the ray tracing in the target field
    - For the recalibration of the matrix, the simulation package is used to calculate reference angles
    - For reconstruction, the simulation package is used to calculate the real scattering angles



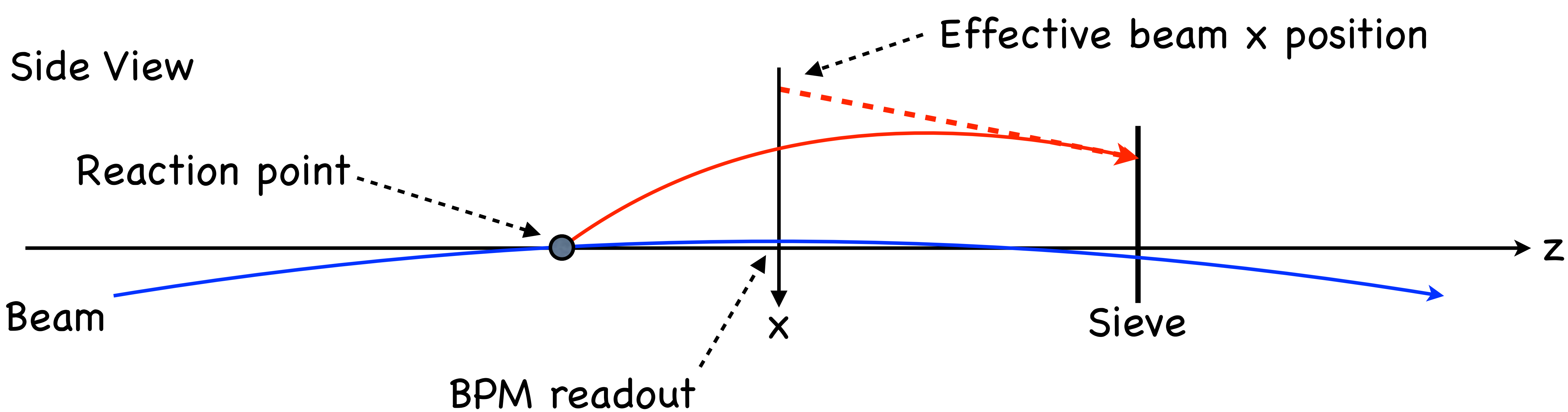
Optics Study with Target Field

- Recalibrate the angle matrix elements:
  - Start with the matrix without target field
  - To fit the matrix element, need to know the effective theta and phi angle
    - What we know is reaction point and the coordinate of the sieve hole
    - Trace the scatted electrons with different initial angles and select out the trajectory which goes though the sieve hole



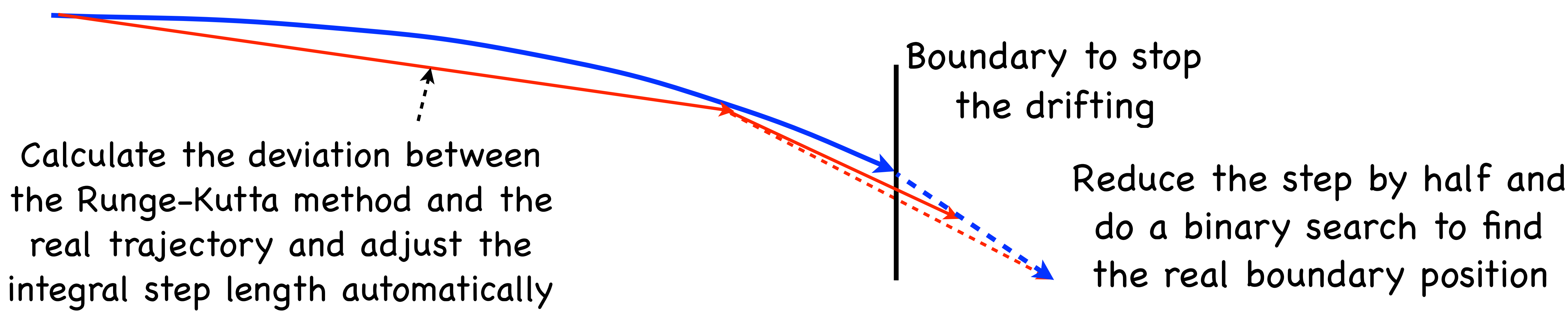
Optics Study with Target Field

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



g2psim package

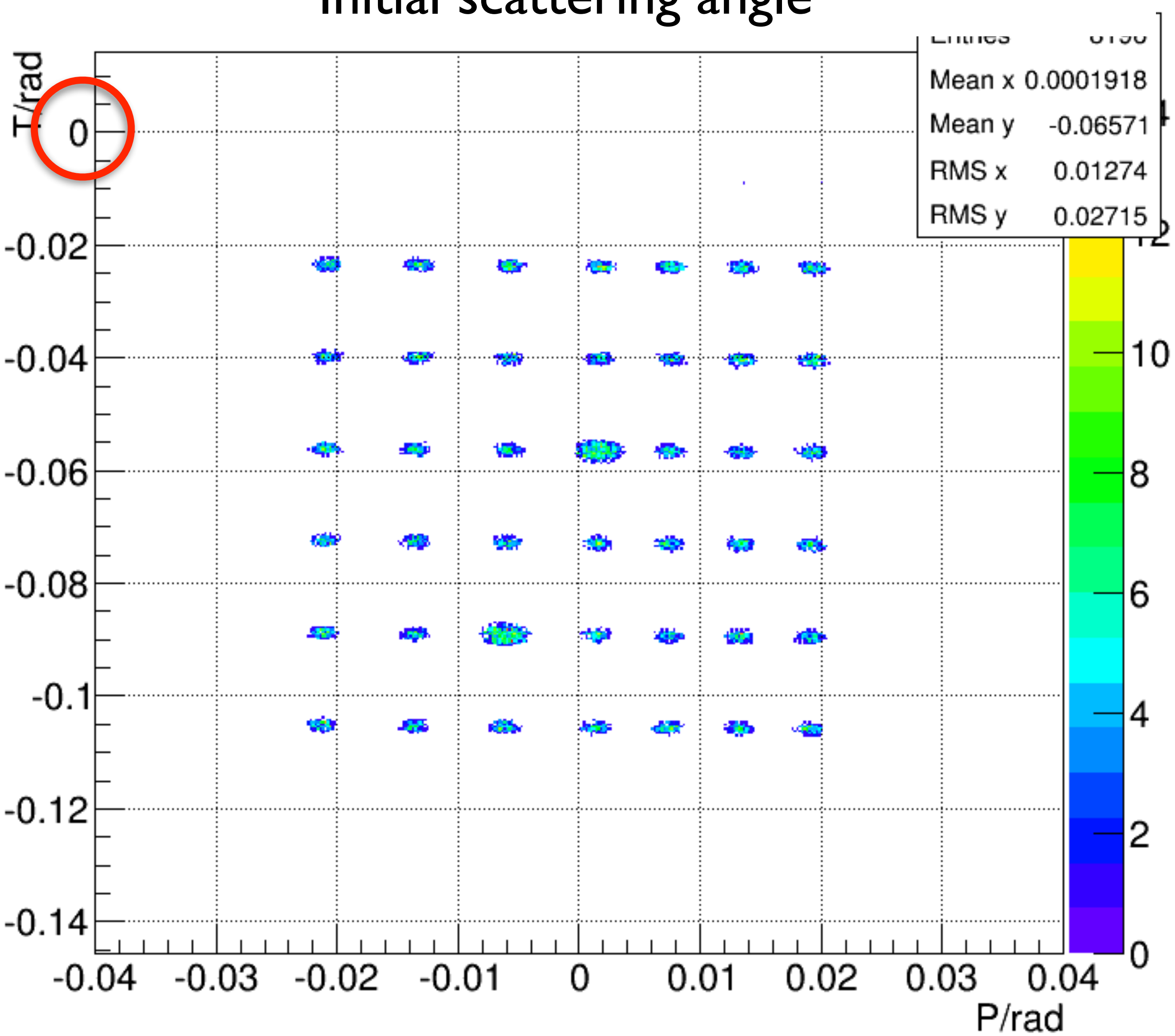
- Original designed to do the ray tracing of scattered electrons in the target field
  - Use Runge-Kutta method with self-adjusting step length to improve speed and accuracy
- Extended to a full simulation of the experiment
  - HRS SNAKE models are included to get the focus plane variables
  - Several cross-section models are also included, an event generator is written with these models



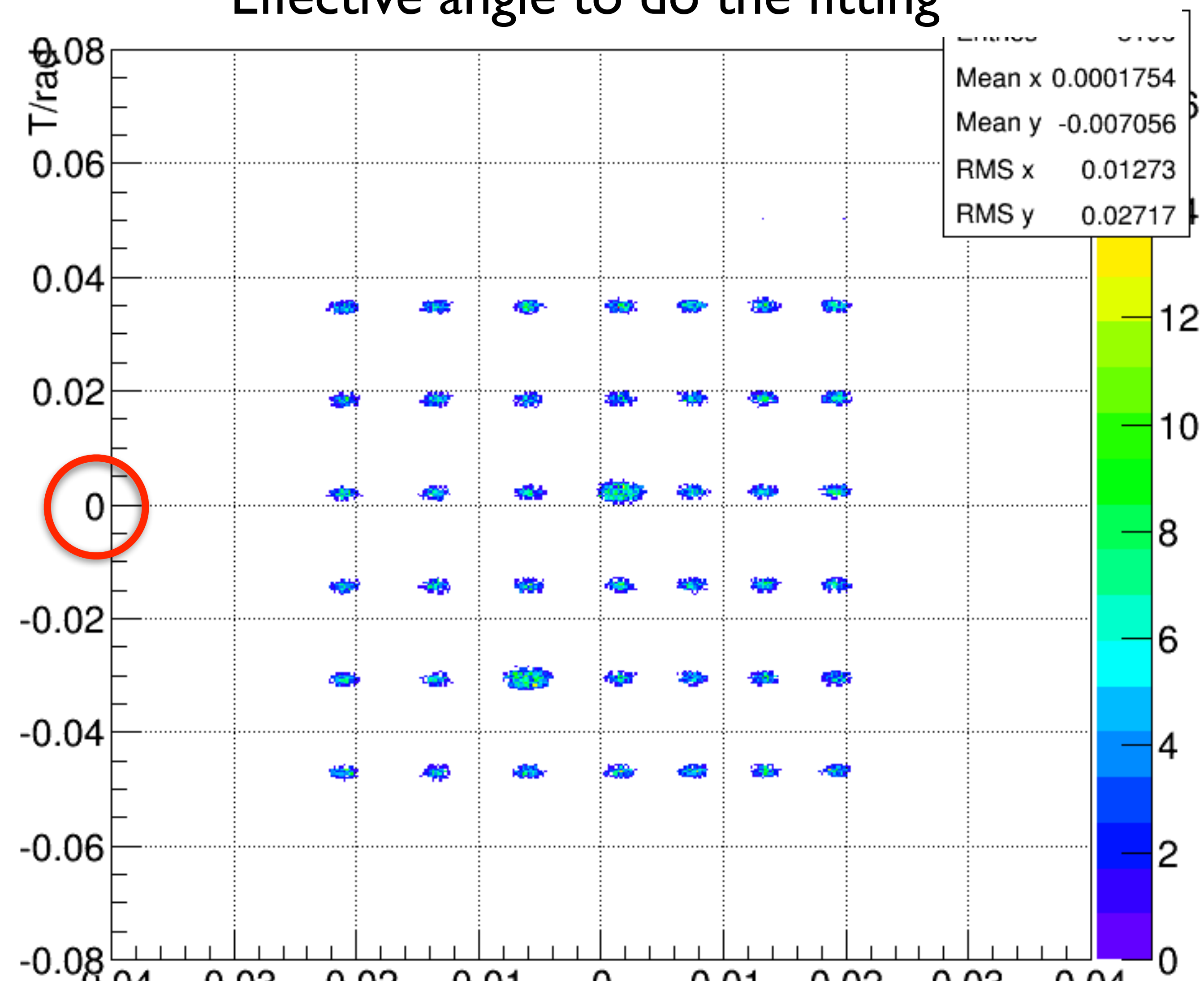
Calibration

- Run simulation to decide the effective theta and phi
  - Use the BPM readout to set the beam position
  - Beam energy 1.706 GeV, target field 2.5T

Initial scattering angle

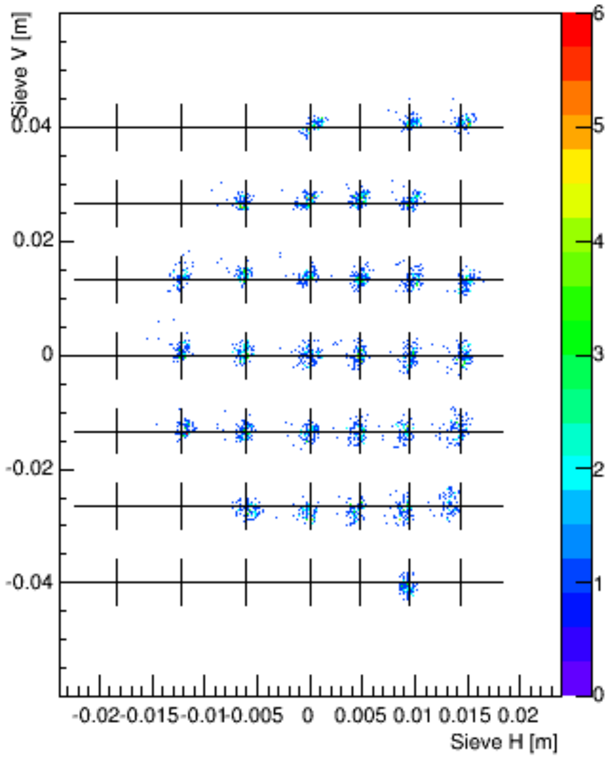


Effective angle to do the fitting



Calibration

-3%



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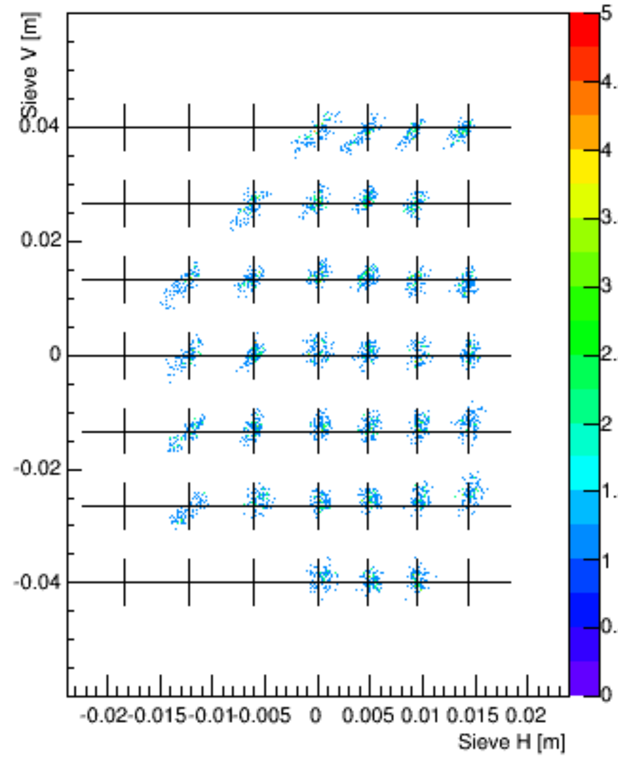

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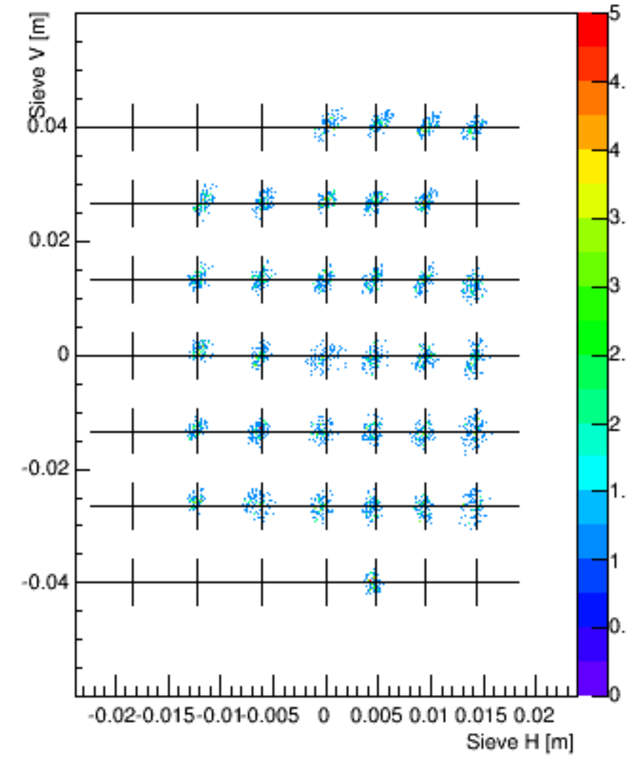

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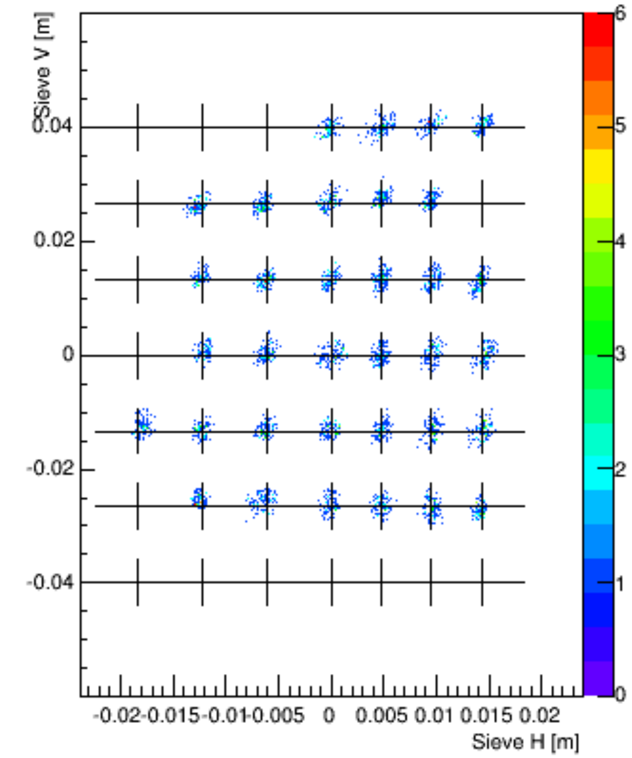

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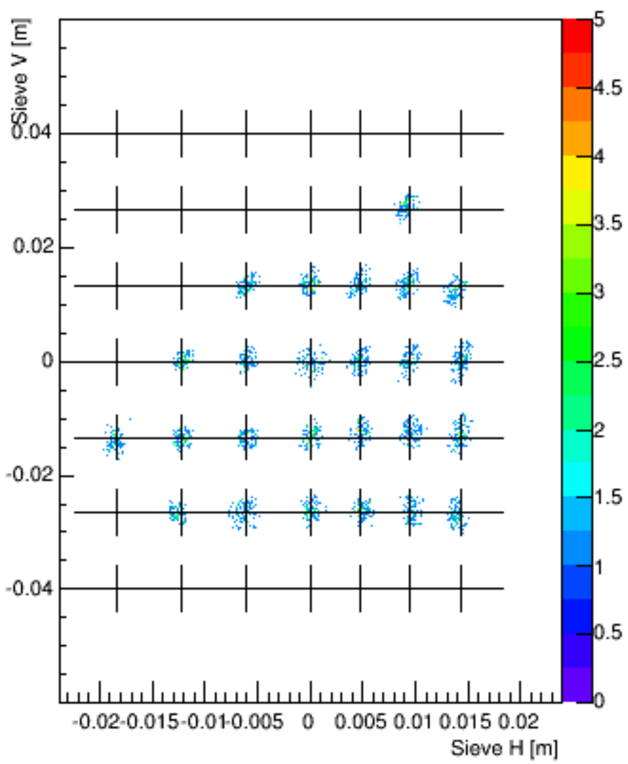


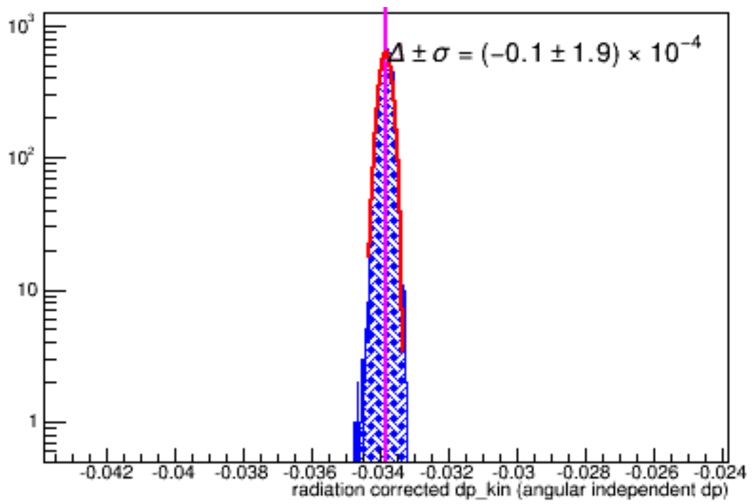
RHRS (1.706GeV, 2.5T)

calibrated with 5 delta scan runs

the calibration still works with the broken septum

Calibration

-3%



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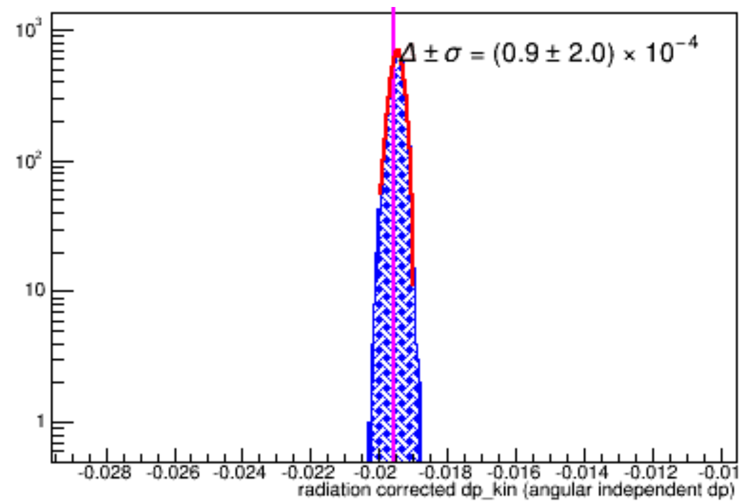

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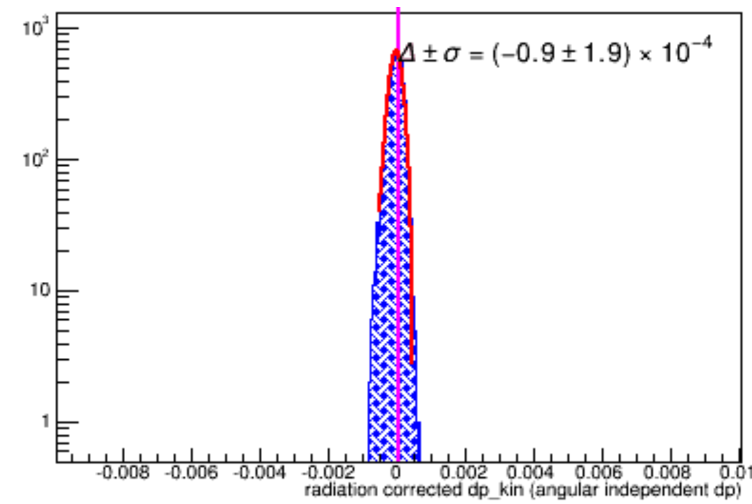

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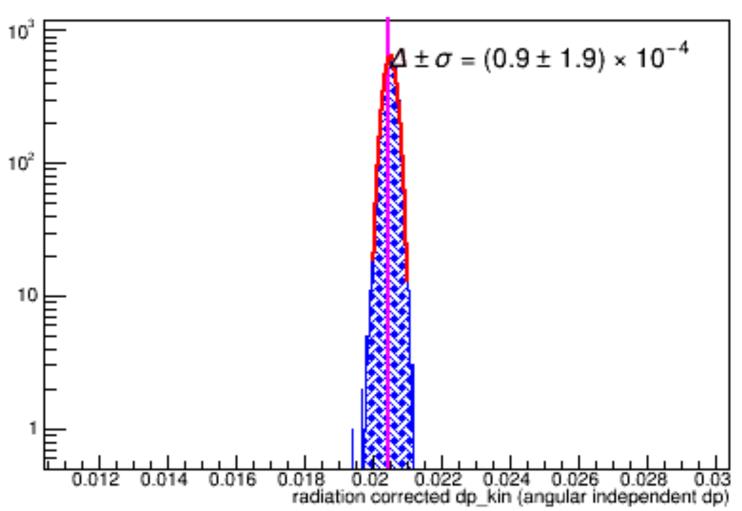

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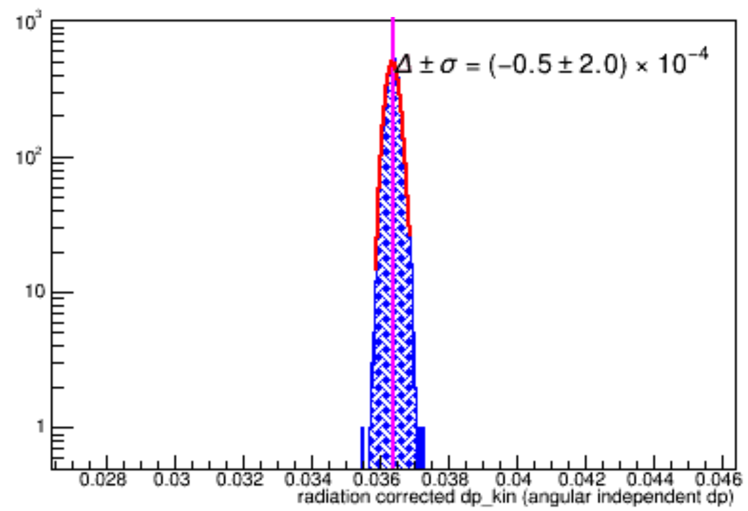

RHRS (1.706GeV, 2.5T)

Optics Status

Green: 2 iteration
Blue: 1 iteration
Red: lack data

- LHRS Optics Status:

Beam Energy (GeV)	Field (T)	Field Angle (deg)	Septum	Backup
2.253	0.0	6	484816	No target field
2.253	5.0	0	400016	Longitudinal
2.253	2.5	90	484816	
2.253	2.5	90	483216	
1.706	2.5	90	400016	
1.158	2.5	90	400016	
2.253	5.0	90	400016	No full dp scan

Optics Status

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Blue: 1 iteration
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- RHRS Optics Status:

Beam Energy (GeV)	Field (T)	Field Angle (deg)	Septum	Backup
2.253	0.0	6	484816	No target field
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1.158	2.5	90	400016	
2.253	5.0	90	400016	No full dp scan

Plans

- Short term plan:
  - Finish the 2nd iteration for all optics settings (possibly in one month)
  - Study the uncertainty of the optics
- Long term plan:
  - NIM paper for optics study (with Min and Jixie)
  - Move on to calculate the cross section after the optics finalized (??)
- Timeline:
  - Plan to graduate in Aug 2015
  - Post graduation: start to look for post-docs

Backups

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

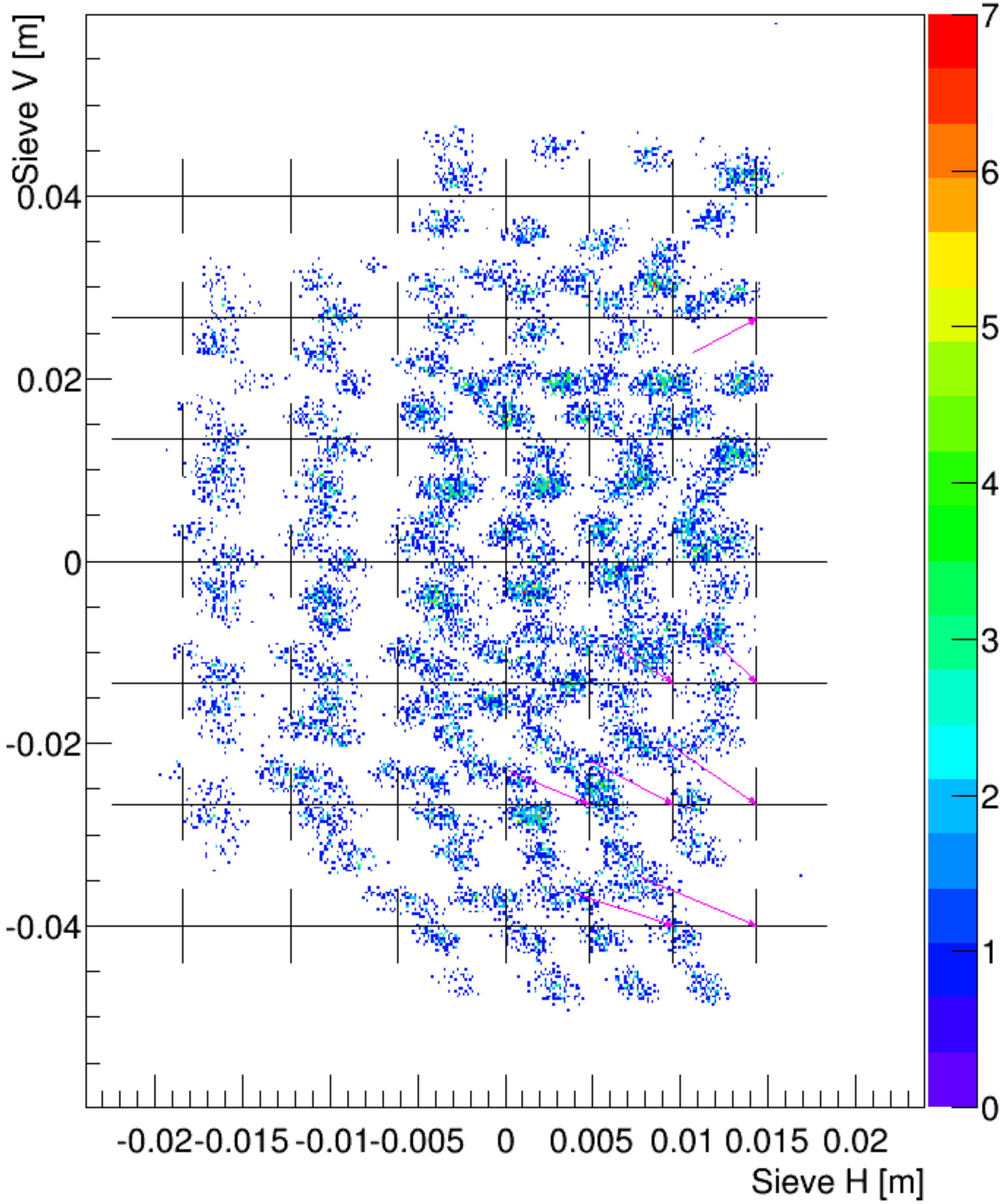
$$\sigma \sim 1/\sin^4(\theta/2)$$

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

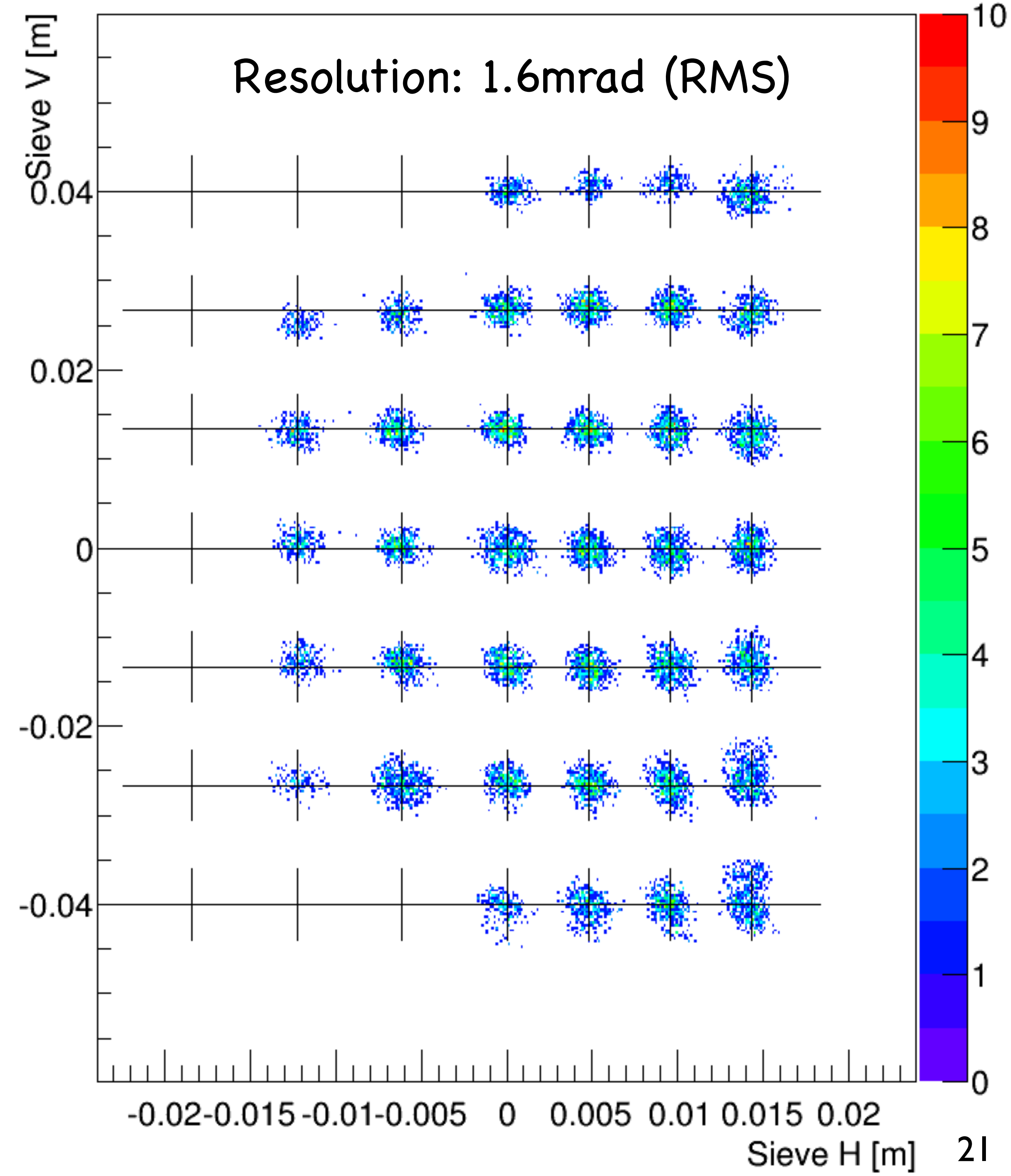
Matrix Calibration: Angle

RHRS

Before Calibration



After Calibration

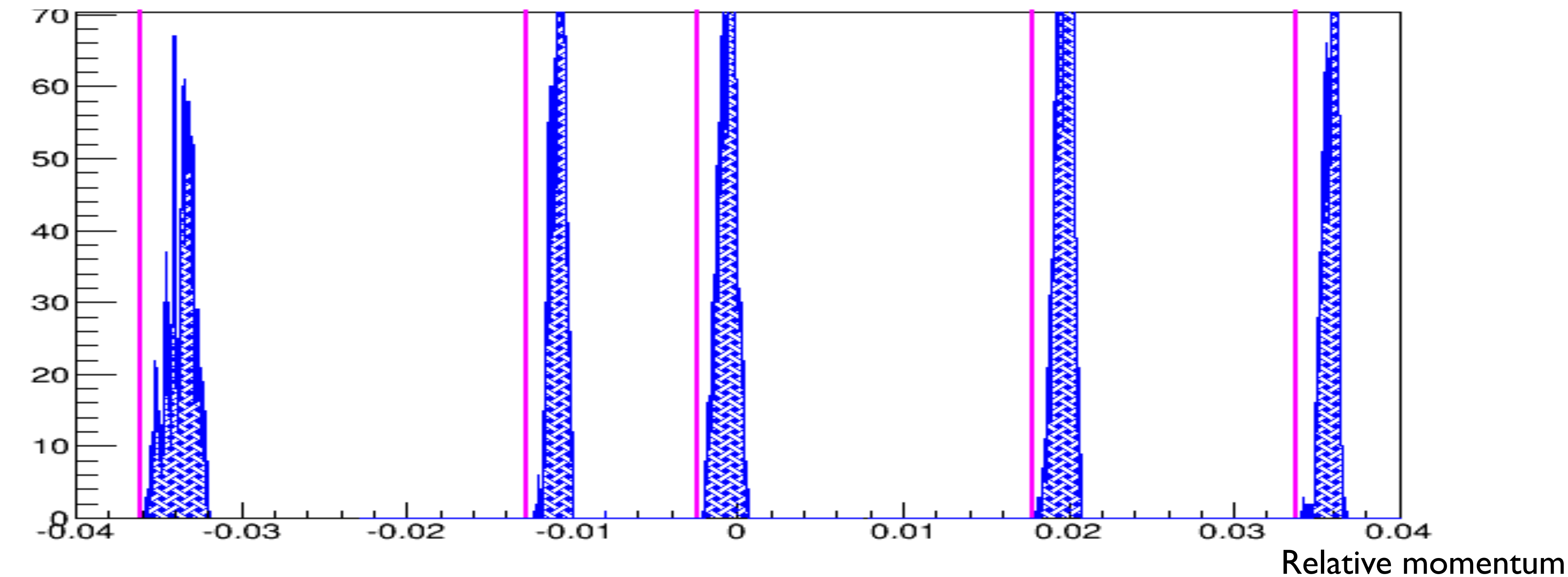


Matrix Calibration: Momentum

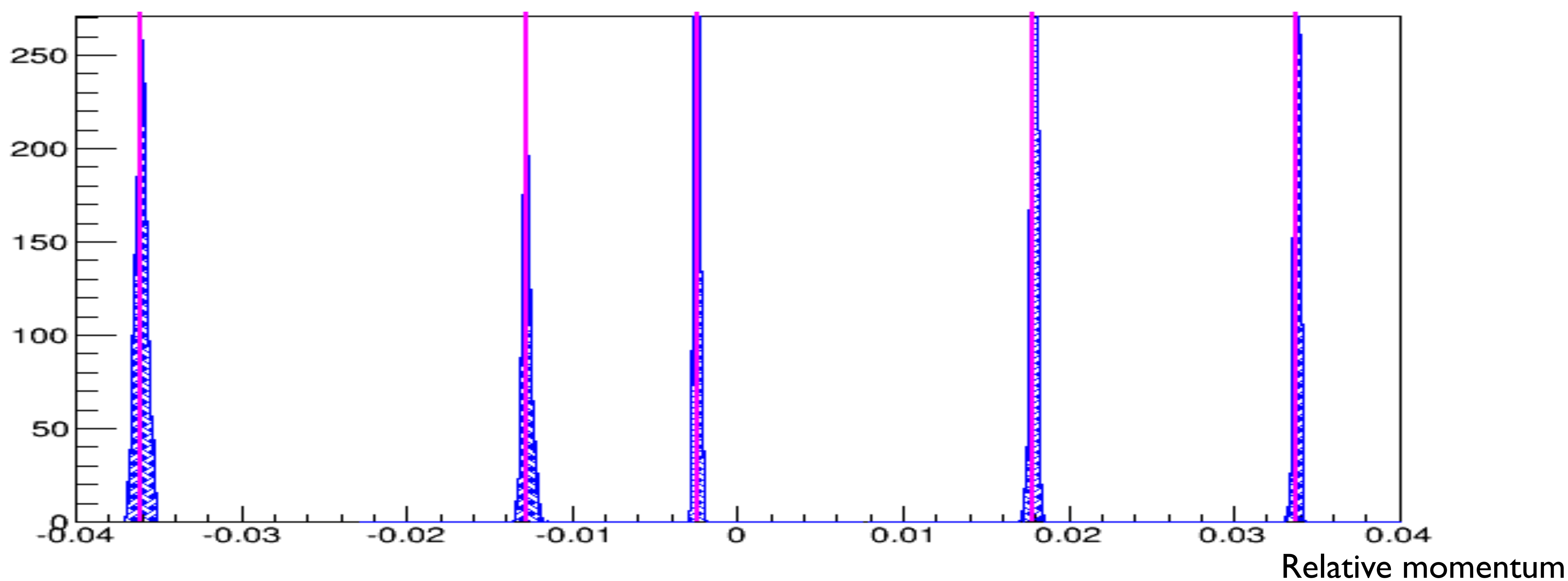
RHRS

RMS: 1.4×10^{-4}

Before Calibration



After Calibration

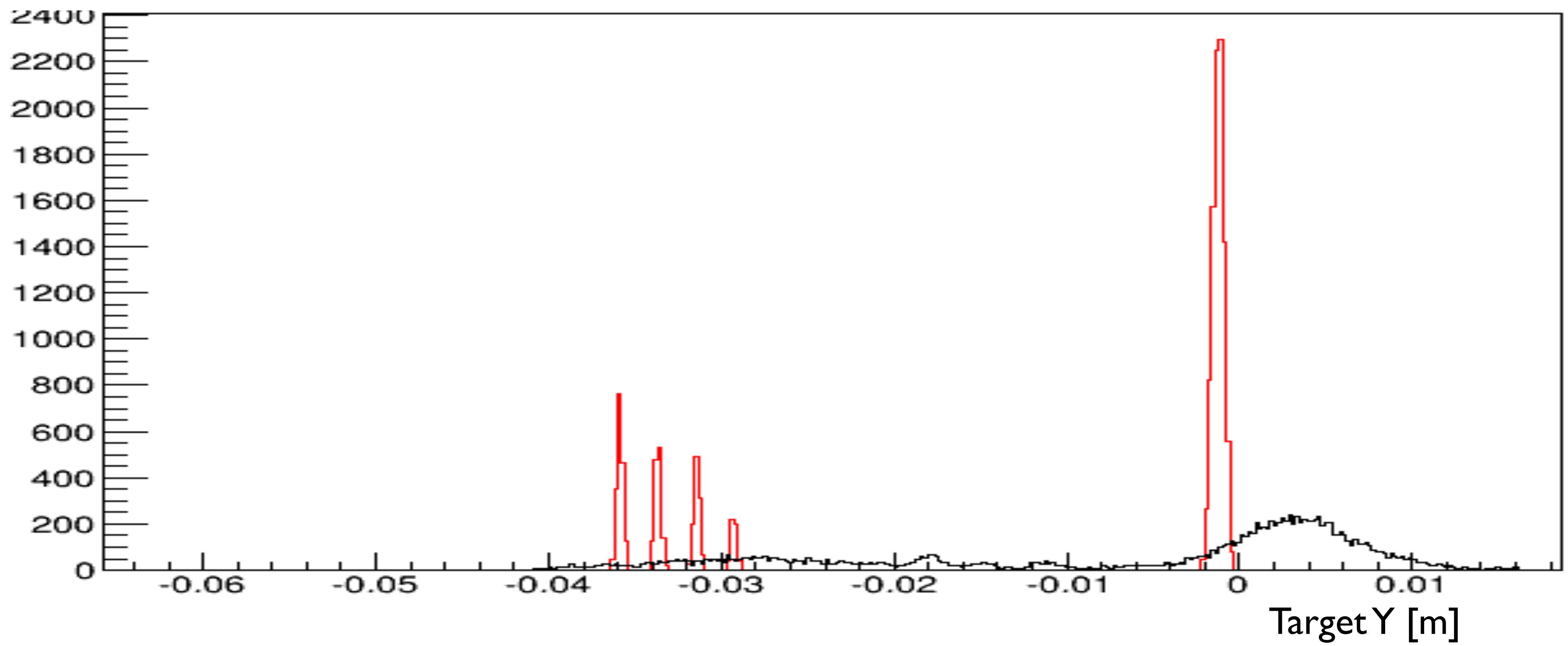


Matrix Calibration: Momentum

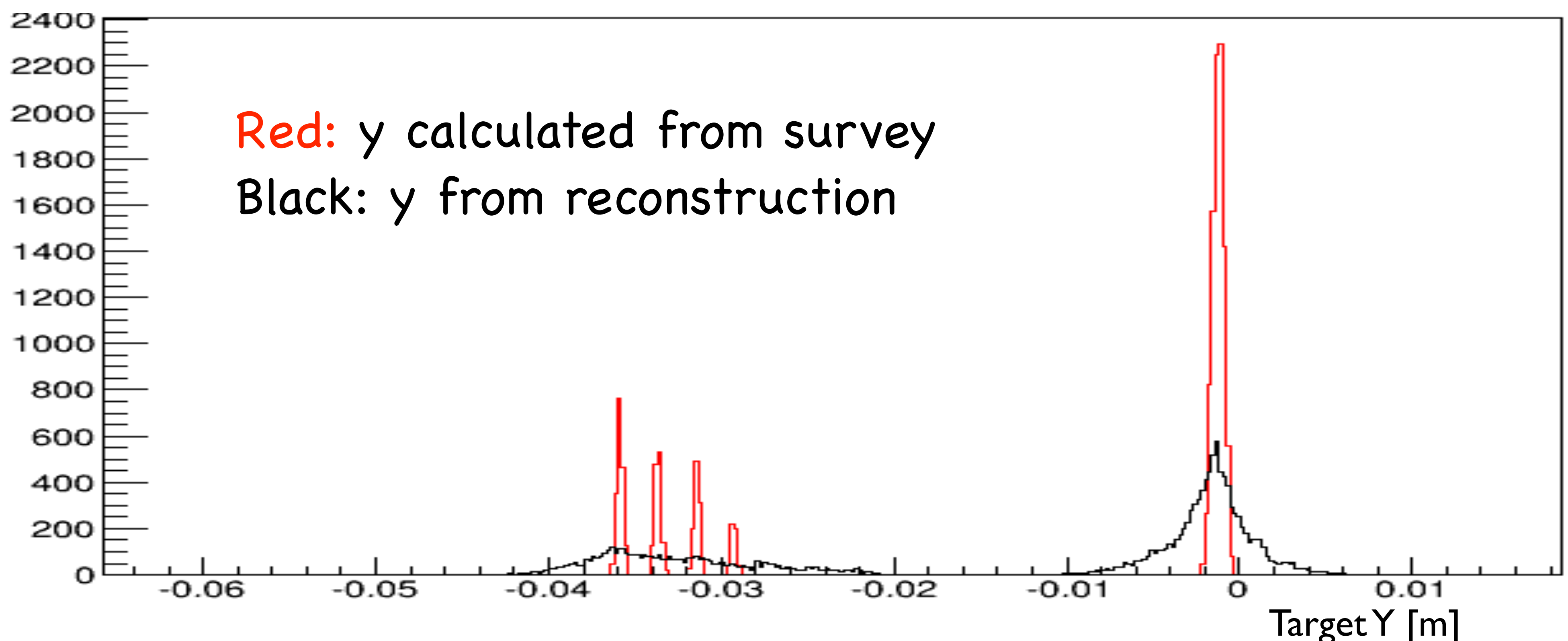
RHRS

RMS: 3.3mm

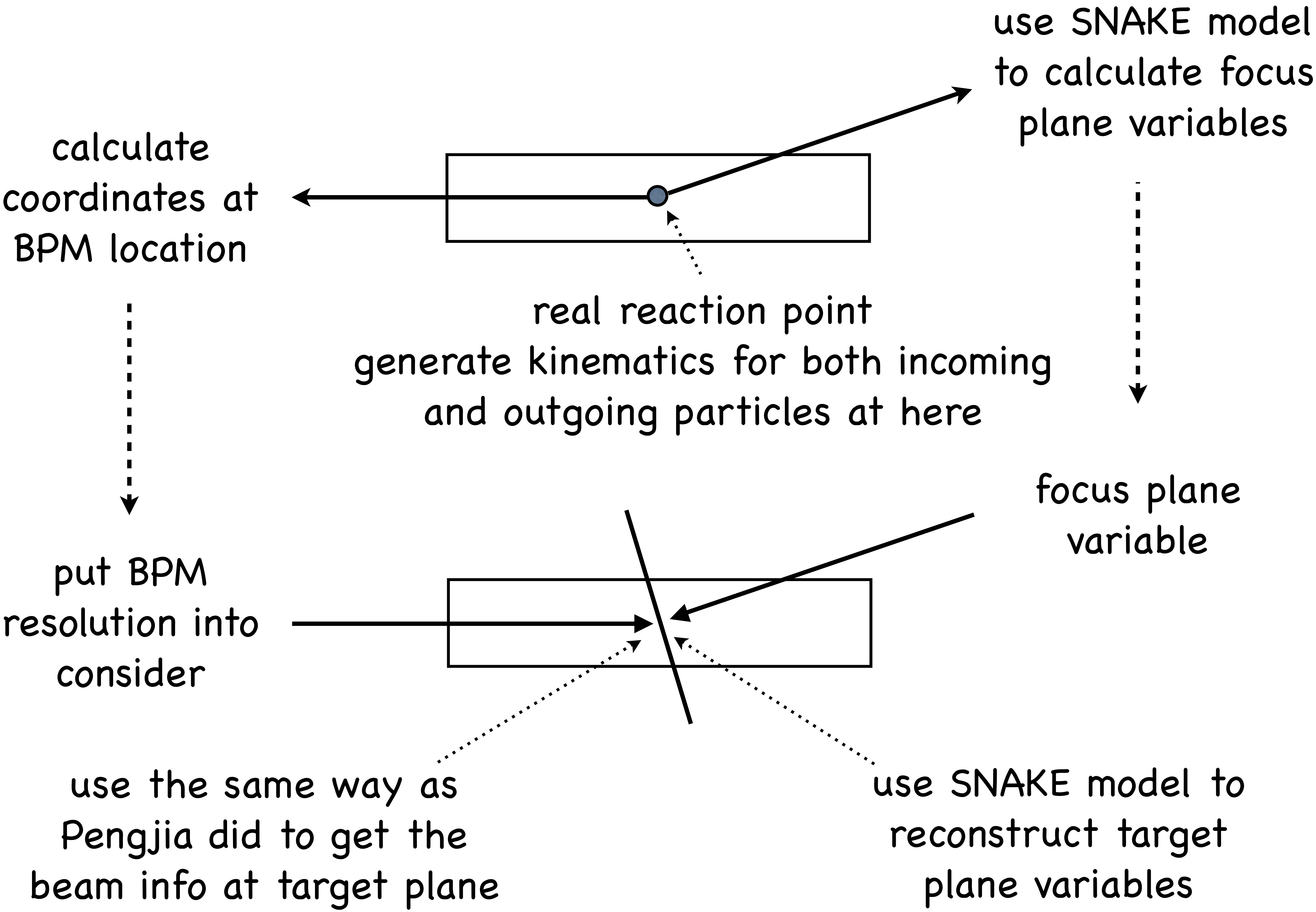
Before Calibration



After Calibration



Simulation


use SNAKE model to calculate focus plane variables
calculate coordinates at BPM location
real reaction point generate kinematics for both incoming and outgoing particles at here
focus plane variable
put BPM resolution into consider
use the same way as Pengjia did to get the beam info at target plane
use SNAKE model to reconstruct target plane variables

Simulation

- Improvement:
  - reduce the integral step length to a very small number only for the last step to keep the accuracy
  - Automatically adjust the integral step length to reduce the calculation, typically a 1mm-2mm step length will already be enough (the deviation < 1um)
- Significant improvement: 20ms for each event -> 1ms