Precision Spectrometer Optics for GMp Experiment

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For E12-07-108 Collaboration

2015 APS April meeting

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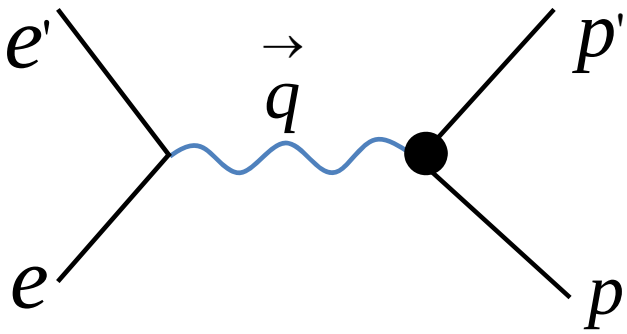
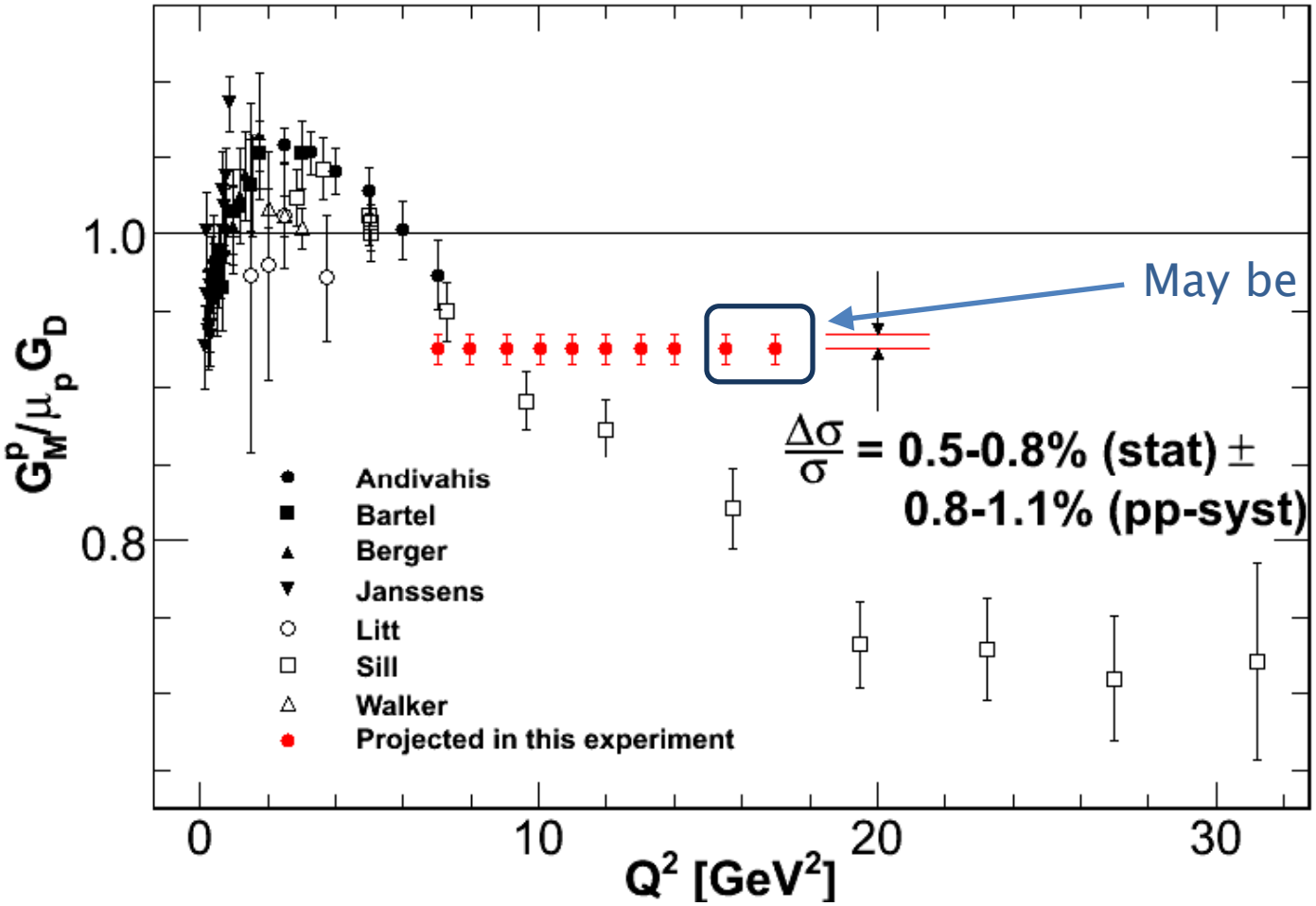


Goal: improve the accuracy of the elastic e-p scattering cross section to better than **2%**.



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Motivations

- Accurately measure e-p elastic cross section in kinematics similar to other JLab form factor measurements ($Q^2 = 7\text{–}14\ GeV^2$).
- Aim to improve the accuracy of the cross section to better than 2%.
- Important for all form factor measurements, and many of other experiments where elastic scattering is used for cross section normalization.

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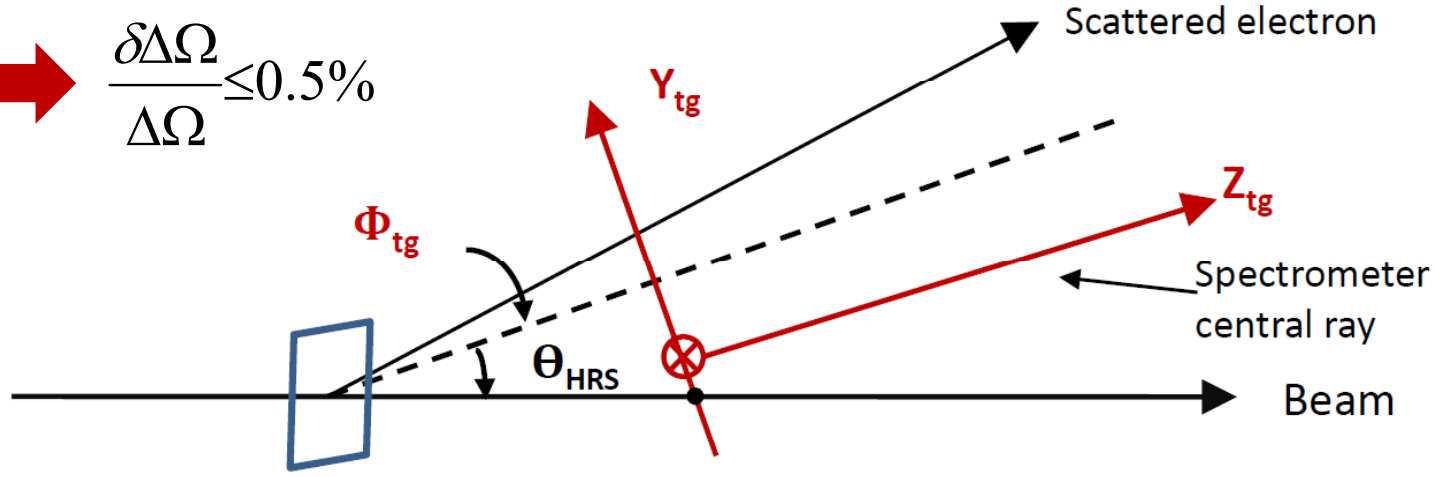
Optics requirements

$$|Form\ factors|^2 = \frac{\sigma(structured\,object)}{\sigma(point like object)} = \frac{\sigma(\theta_{ep})}{\sigma_{Mott}}$$

$$\sigma(\theta_{ep}) = \frac{N_{event}}{\Delta\Omega \cdot \int Idt \cdot L}$$

where $\int Idt$ is the beam charge and L is the luminosity.

$$\frac{\delta\sigma}{\sigma} \leq 2\% \Rightarrow \frac{\delta\Delta\Omega}{\Delta\Omega} \leq 0.5\%$$



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$$\frac{\delta\sigma}{\sigma} \le 2\% \Rightarrow \frac{\delta\Delta\Omega}{\Delta\Omega} \le 0.5\% \Rightarrow \frac{\delta\Delta\theta_{tg}}{\Delta\theta_{tg}} \le 0.35\%,\ \frac{\delta\Delta\phi_{tg}}{\Delta\phi_{tg}} \le 0.35\%$$

Optics requirements:

$$\delta\Delta\theta_{tg} \le 0.35\% \times 100mrad = 0.35mrad$$

$$\delta\Delta\phi_{tg} \le 0.35\% \times 50mrad = 0.18mrad$$

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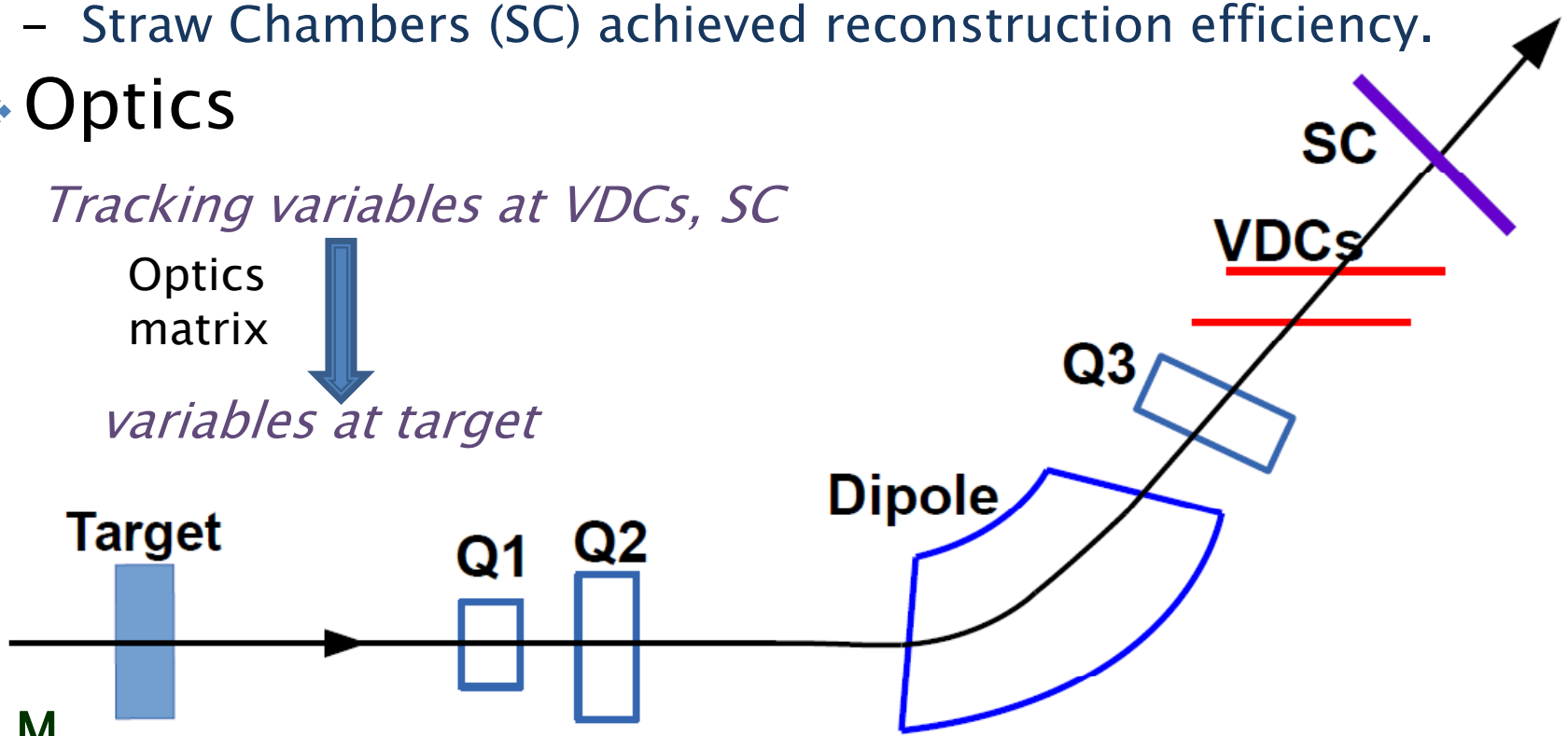
Magnetic Spectrometer Optics

- Setup
  - QQDQ, vertical bending 45 degrees.
  - Vertical Drift Chambers (VDCs) for tracking.
  - Straw Chambers (SC) achieved reconstruction efficiency.
- Optics

Tracking variables at VDCs, SC

Optics matrix

variables at target



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Magnetic Spectrometer Optics

Focal plane coordinate system

Y_{fp}

Z_{fp}

X_{fp}

SC

VDCs

First order matrix

$$\begin{pmatrix} \delta \\ \theta \\ y \\ \phi \end{pmatrix}_{tg} = \begin{bmatrix} \langle \delta|x \rangle & \langle \delta|\theta \rangle & 0 & 0 \\ \langle \theta|x \rangle & \langle \theta|\theta \rangle & 0 & 0 \\ 0 & 0 & \langle y|y \rangle & \langle y|\phi \rangle \\ 0 & 0 & \langle \phi|y \rangle & \langle \phi|\phi \rangle \end{bmatrix} \begin{pmatrix} x \\ \theta \\ y \\ \phi \end{pmatrix}_{fp}$$

$X = 0$

Y_{tg}

Z_{tg}

Target

Magnets

Target coordinate system

Optics matrix allows for the reconstruction of the interaction vertex in the target from focal plane detected variables.

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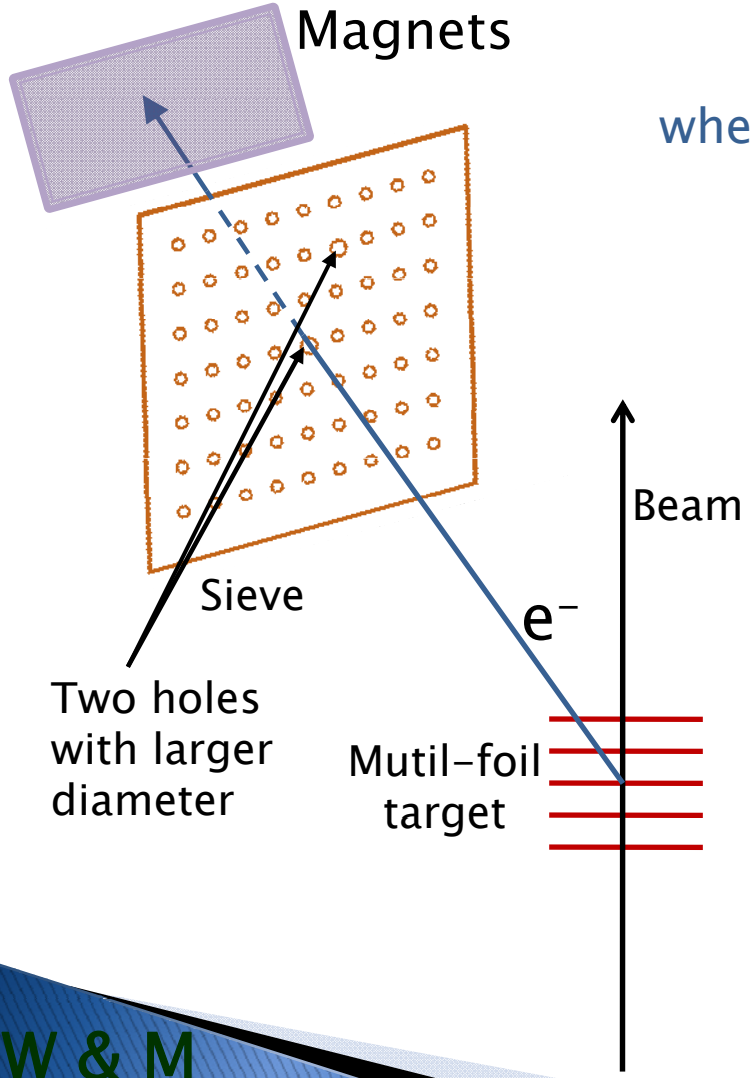
Optics Matrix Calibration



$$\alpha_{tg} = \sum_{i=0}^{m} C^{x}_{i,j,k,l} x^{m}_{fp} \sum_{j,k,l} \theta^{j}_{fp} y^{k}_{fp} \phi^{l}_{fp}$$

where α_{tg} can be any target variables θ_{tg}, ϕ_{tg}, y_{tg}, δ

- 3 groups of calibration
  - Angles: θ_{tg}, ϕ_{tg} *Sieve slit data*

$$\chi^2(\theta_{tg}) = \sum_{i=1}^{\text{Nevent}} \sum_{j=1}^{\text{N-hole}} (x^{\text{recon.}}_{i,j} - x^{\text{survey}}_{i})^2$$

Varying $C^{x}_{i,j,k,l}$ to minimize $\chi^2(\theta_{tg})$

  - Vertex: y_{tg}
    Multi-foil targets data
  - Momentum: $\delta = p/p_{central} - 1$
    Elastic data

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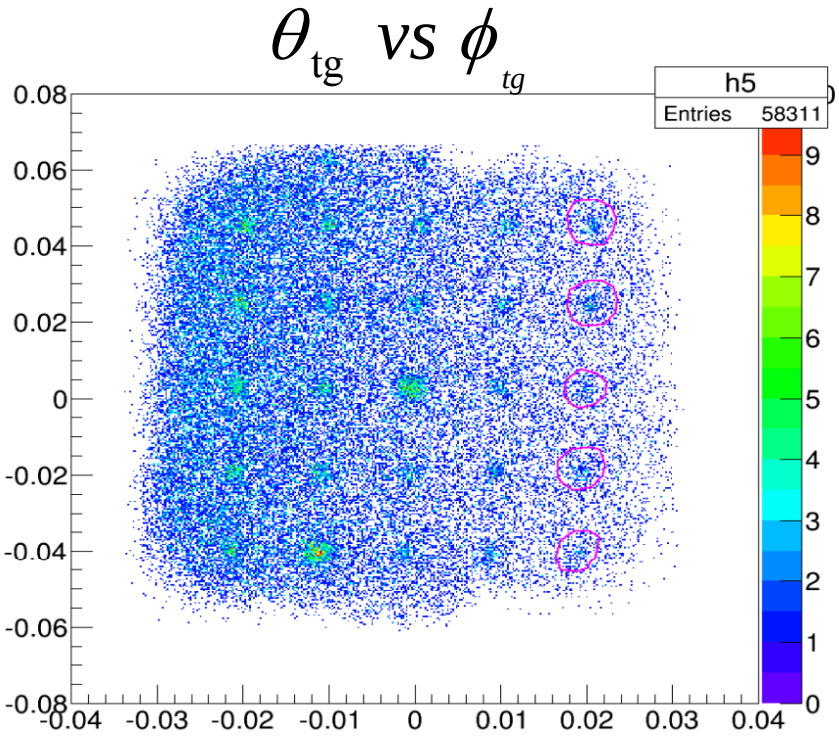
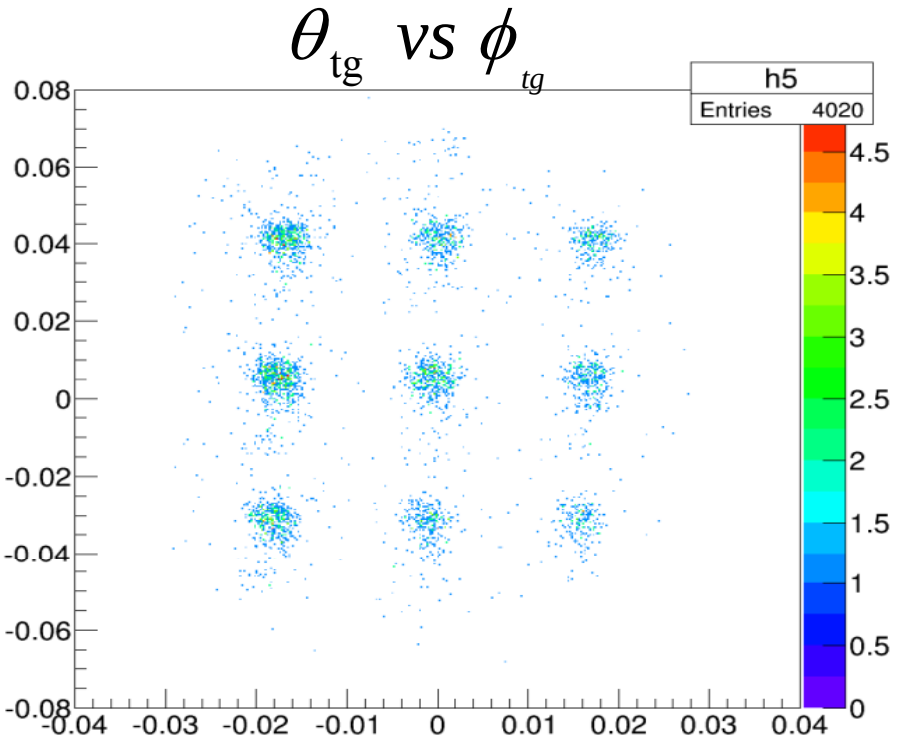
GMp optics with DIS data

- Small e-p elastic cross section -> DIS run for optics calibration



5mm stainless steel sieve slit, 7x7
March, 2014



1.5 inch lead sieve slit, 5x5
March, 2014

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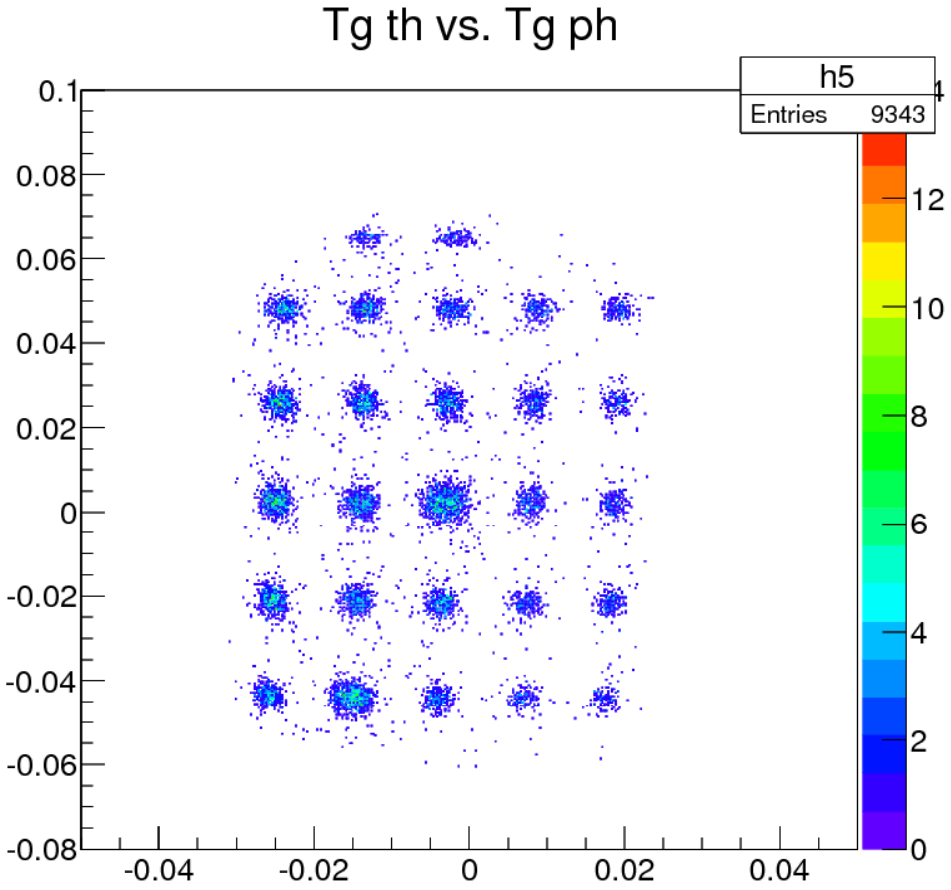
GMp optics with DIS data

- With a new designed sieve, the electron events which punched through the holes are clearly distinguished from the background.



New sieve:

2 inch thick,
lead,
7 rows,
9 columns,
hole diameter:
4mm,
big hole diameter:
6mm

Dec, 2014

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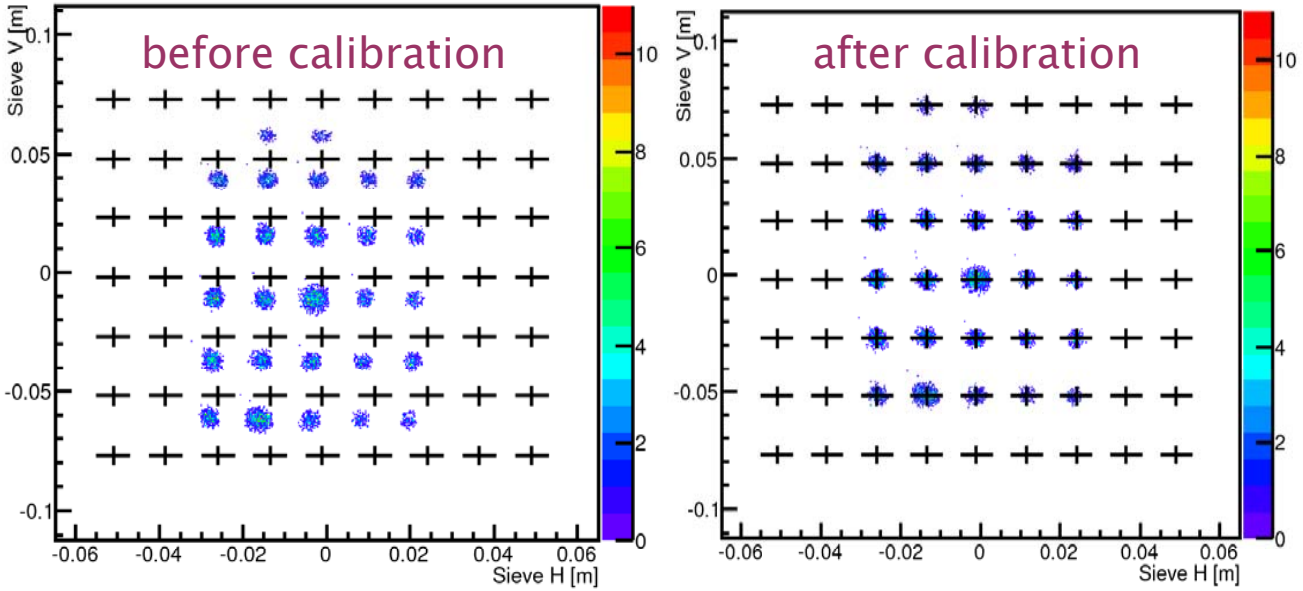
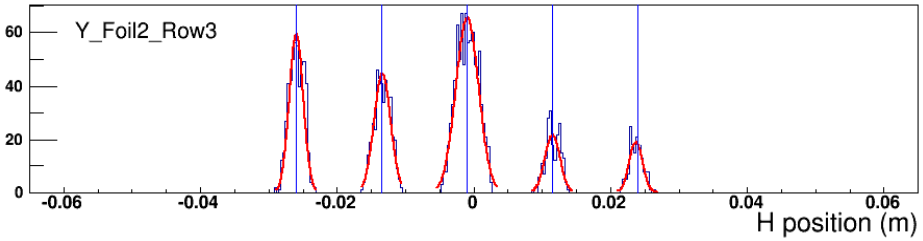
Angle calibration results



Optics precision study:



-Gaussian fitting
- survey position

- project reconstructed points to horizontal and vertical directions.
- make a Gaussian fitting for each sieve hole
- compare with the surveyed hole center

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Optics precision

Tables of $P_{real} - P_{fitting}$ for the central sieve

V direction, require $\delta V \leq 0.35mm$

Unit (mm)	Col3	Col4	Col5	Col6	Col7
Row1	0.23	0.12	−0.04	0.27	−0.14
Row2	0.01	0.25	−0.02	0.07	−0.06
Row3	0.07	−0.21	0.00	0.30	−0.11
Row4	0.06	0.59	−0.11	−0.05	−0.16
Row5	0.34	0.43	0.18	0.65	−0.06

Vertical distance of sieve holes next to each other is **25.0 mm**

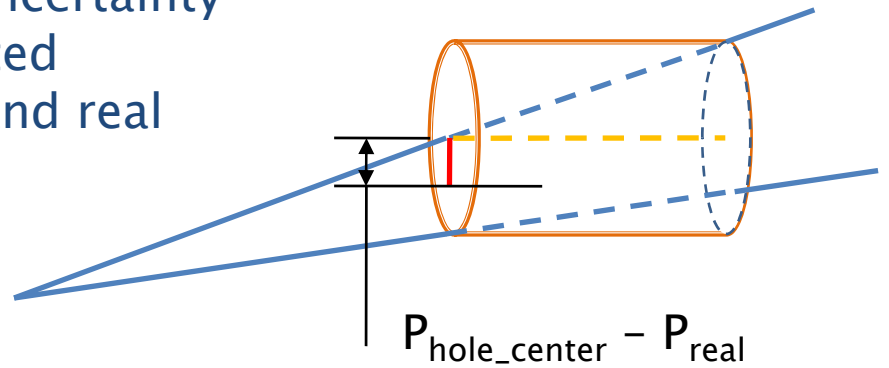
H direction, require $\delta H \leq 0.18mm$

Unit (mm)	Col3	Col4	Col5	Col6	Col7
Row1	0.29	−0.14	−0.10	−0.04	−0.37
Row2	0.17	0.04	−0.03	0.22	−0.07
Row3	0.03	0.13	0.04	0.03	−0.27
Row4	0.17	−0.03	−0.02	0.14	−0.16
Row5	0.36	−0.16	0.03	0.18	−0.69

Horizontal distance of sieve holes next to each other is **12.5 mm**

Next steps:

- more data to reduce statistical uncertainty
- data of more holes to be calibrated
- difference between hole center and real distribution center considered



Summary

- Achieved optics calibration with DIS data.
- Developed analysis allows for optics angle calibration with required precision.
- Spring 2015:
  - some production data.
  - perform precision study of optics vertex calibration.
- Fall 2015 and spring 2016
  - more production data.

Manpower

- Spokespeople:

  J.Arrington, E.Christy, S.Gilad, B.Moffit, V.Sulkosky, B.Wojtsekhowski (contact)
- Postdoc:

  Kalyan Allada
- Graduate Student:

  Thir Narayan Gautam(Hampton U)

  Longwu Ou(MIT)

  Barak Schmookler(MIT)

  Yang Wang(W&M)

Thank you!

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