Hall C Spectrometer Optics and Optimization

Hall A/C Analysis Meeting, June 2018
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Transport:

+X: down/vertical/dispersive

+Y: beam left/horizontal/non-dispersive

+Z: Along central ray/into spectrometer/downstream

Hall C BPMs (EPICS/Fast Raster):

Scattered particle

Target foil

Z Vertex

HMS (θ is negative)

To be consistent, implies +yTar is downstream for HMS and upstream for SHMS!

SHMS (θ is positive)
Variables in replayed ROOT files

- **Focal plane** quantities are from *drift chamber* variables:
  - P.dc.x_fp \( x_{\text{focal plane}} \)
  - P.dc.y_fp \( y_{\text{focal plane}} \)
  - P.dc.xp_fp \( x'_{\text{focal plane}} \)
  - P.dc.yp_fp \( y'_{\text{focal plane}} \)

- **Target** reconstructed quantities are *golden track* variables:
  - P.gtr.dp \( \Delta \)
  - P.gtr.x \( x_{\text{target}} \)
  - P.gtr.y \( y_{\text{target}} \)
  - P.gtr.ph \( y'_{\text{target}} \)
  - P.gtr.th \( x'_{\text{target}} \)

- **Raster**
  - P.react.x \( \text{raster x position, cm} \)
  - P.react.y \( \text{raster y position, cm} \)

Technically, tangents of the angles:

\[
x' = \frac{dx}{dz}
\]
\[
y' = \frac{dy}{dz}
\]

Small approx, same as angle in radians.
DATFILES has a README to explain the various recon Matrix Elements

Point to your desired ME for recon in here:

\textit{PARAM/SHMS/GEN/pcana.param}

Offsets, noted in the README and/or header file of ME are put here:

\textit{PARAM/SHMS/GEN/shmsflags.param}:

From 0\textsuperscript{th} order ME, put in $X'_{\text{target}}$ offset (labeled as $\phi_{\text{offset}}$...yeah, I know....)

\begin{verbatim}
! reconstruction matrix elements for SHMS, 23 Mar 2018
! $<$theta y phi delta $|$ nmpq$>$;($x^**n x^**p y^**p y^**q$
! as of 03/23/18, no z offset included
! created: 03/23/18
! zeroth order matrix elements from fitting:
! $<$theta$>$ 0.000483 rad
! $<$y$>$ 5.613501015e-04 m
! $<$phi$>$ 6.628772870e-04 rad
! $<$p$>$ 0.0 %
! $<$theta y phi delta $|$ nmpq$>$;($x^**n x^**p y^**p y^**q$

\end{verbatim}

$p\phi_{\text{offset}}$ here = 0.000483

From actual SHMS offsets found this past spring, we shifted the $y_{\text{focal plane}}$ (in \textit{pdc_geom.param}) by -0.429871 cm.
Also 0\textsuperscript{th} order Matrix Element
Offsets: $X', Y'$

Beam offsets:
$X, Y, X', Y'$

From BPMs in Fall17/Spring18 runs, this was all 0

Mis-pointings from survey.
Vary with angle, could also vary with other spectrometer angle!

Mis-pointing:
$X, Y$
During optimization, HMS MP were offset. SHMS MP flat for all runs.

HMS surveys:
HMS mispointing in X and Y as a function of HMS angle.

SHMS surveys:
HMS mispointing in X and Y as a function of HMS angle.
Matrix Optimization codes:

https://github.com/hszumila/HMS_optics (detailed README to run on ifarm)
https://github.com/hszumila/SHMS_optics

Adapted from:
https://github.com/brash99/HMS_optics

Good note from Jure:

Changes from before:
• Mis-pointings can be input run by run
• Flag in SHMS for sieve or shifted sieve

Plan going forward:
• Combine optimization codes with appropriate sieve flags
• All spectrometer angles are positive in config file, but should correspond to standard.kinematics

Notice: yfp of center foil is low
Matrix Optimization

We begin with the focal plane quantities from the drift chambers: yfp, xfp, ypfp, xpfp

We ultimately want to reconstruct the events at the interaction point.

General procedure:
1. Reconstruct events using the best reconstruction matrix we have (from COSY)
2. Determine the true values (events passing through sieve)
3. Minimization of difference between reconstructed variables with true values
4. Calculate optimized matrix

\[
x_{\text{tar}}' = \sum_{i,j,k,l,m} X'_{i,j,k,l,m} \cdot x'_{\text{fp}} x'_{\text{fp}} y'_{\text{fp}} y'_{\text{fp}} y_{\text{tar}}
\]

\[
y_{\text{tar}}' = \sum_{i,j,k,l,m} Y_{i,j,k,l,m} \cdot x_{\text{fp}} x_{\text{fp}} y_{\text{fp}} y_{\text{fp}} y_{\text{tar}}
\]

\[
y_{\text{tar}}' = \sum_{i,j,k,l,m} Y'_{i,j,k,l,m} \cdot x_{\text{fp}} x_{\text{fp}} y_{\text{fp}} y_{\text{fp}} y_{\text{tar}}
\]

\[
\delta_{\text{tar}} = \sum_{i,j,k,l,m} D_{i,j,k,l,m} \cdot x_{\text{fp}} x_{\text{fp}} y_{\text{fp}} y_{\text{fp}} y_{\text{tar}}
\]

Matrix elements reconstruction file contains the coefficients and powers:

\[
X'_{i,j,k,l,m} \quad Y_{i,j,k,l,m} \quad Y'_{i,j,k,l,m} \quad D_{i,j,k,l,m} \quad ijklnm
\]
Take runs at various angles and central momenta:

- First pass through data, determine which foil events came from.
- Second pass, selecting events in each foil, plot the x,y sieve distributions. Select events from each sieve hole.
- For the same number of events in each sieve hole, perform Singular Value Decomposition on the difference between data events and real sieve hole position.
- Minimize over $y_{Tar}$, $x_{Tar}$, $y_{pTar}$. 

![Graphs showing sieve distributions and yTar for run 1808](image)
A good starting point matters!!!
Centered sieve, 30 deg, central $P = -2$ GeV

Centered sieve, 22 deg, central $P = -3.2$ GeV
At high Pcentral, with Q1 and Q3 effects, can we simulate and correct the trends we saw in data?

Simulation:

Run 3231, Pcentral = -7.2 GeV
Using the same Singular Value Decomposition method as previously, we can optimize delta and fine tune corrections in the data.

To fine tune corrections, use COSY to find fit order and trend for correction, then use $H(e,e'p)$ data to correct.

Simulation with mismatch optics recon

Simulation with corrected optics recon
Can correct Emiss for various H(e,e’p) checks by extracting a correction function for events in the Emiss core where we know what Emiss should be (in progress).
Summary and Future work:

• Initial SHMS delta off by 1.8%
• Found initial spectrometer offsets and mis-pointings
  Will this stand up to the H(e,e’p) checks?
• Write a note on SHMS matrix optimization and results (priority)
• Combine the optimization codes for HMS and SHMS, update documentation (good housekeeping)
• H(e,e’p) data (analyze!!)