

LHRS Analysis for d_2^n

Optics Study

D. Flay



Hadronic & Nuclear Physics Group
Temple University Physics Department

4/24/10

Outline

- 1 Optics
 - Coordinate Systems
 - Optimization Matrix
 - Characteristic Plots
- 2 Summary

Optics (1)

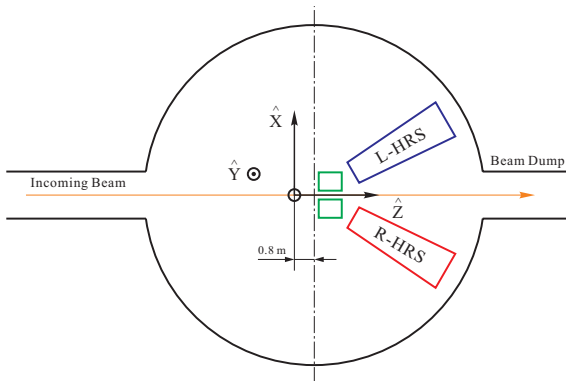
Coordinate Systems

- The optics of the spectrometer serves to transform variables from one set of coordinates to another
- We have five coordinate systems:
 - Hall Coordinate System (HCS)
 - Target Coordinate System (TCS)
 - Detector Coordinate System (DCS)
 - Transport Coordinate System (TRCS)
 - Focal Plane Coordinate System (FCS)

Optics (2)

Coordinate Systems: Hall Coordinate System

- The origin of the HCS is defined by the intersection of the e^- beam and the vertical symmetry axis of the target coordinate system



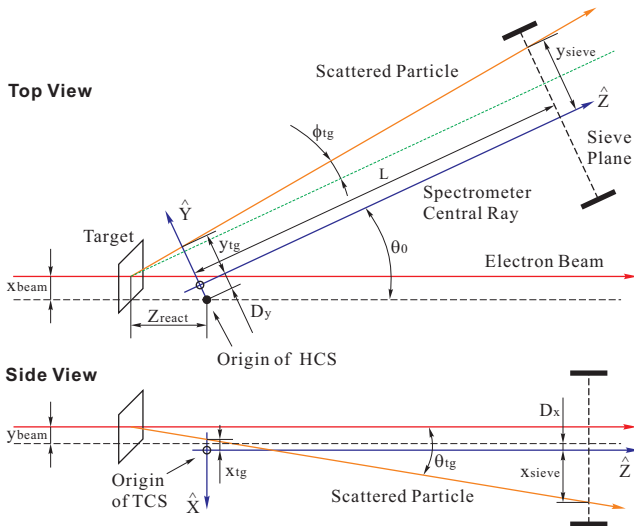
Optics (3)

Coordinate Systems: Target Coordinate System

- The LHRS has its own TCS
- \hat{z}_{tg} is defined by the spectrometer's central ray passing through the center of the sieve collimator
 - The sieve is placed **right before** the dipole magnet, used for calibration purposes
- Looking along the central ray, \hat{y}_{tg} points to the left, while \hat{x}_{tg} points vertically down
- See next slide for a diagram of the TCS

Optics (4)

Coordinate Systems: Target Coordinate System



Optics (5)

Coordinate Systems: Target Coordinate System

- Careful examination of the previous slide reveals:

$$z_{\text{react}} = -(y_{tg} + D_y) \frac{\cos \phi_{tg}}{\sin(\Theta_0 + \phi_{tg})} + x_{\text{beam}} \cot(\Theta_0 + \phi_{tg})$$

$$y_{tg} = y_{\text{sieve}} - L \tan \phi_{tg}$$

$$x_{tg} = x_{\text{sieve}} - L \tan \theta_{tg}$$

$$x_{\text{sieve}} = -\tan \phi_{tg} \frac{z_{\text{react}} \cos \Theta_0}{\cos \phi_{tg}} - y_{\text{beam}} + L \tan \theta_{tg}$$

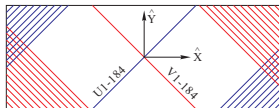
- These quantities will be important for the check of our current optics matrix, so we list them here

Optics (6)

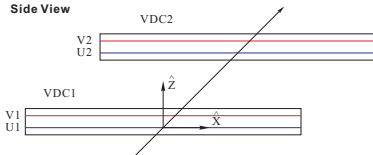
Coordinate Systems: Detector Coordinate System

- The intersection of wire #184 of plane u_1 and the perpendicular projection of wire #184 from the v_1 plane forms the origin of the DCS
- \hat{z} points vertically up, with \hat{x} along the (longer) symmetry axis of the lower VDC plane, away from the Hall center

Top View



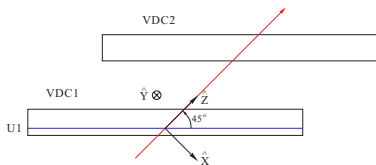
Side View



Optics (7)

Coordinate Systems: Transport Coordinate System

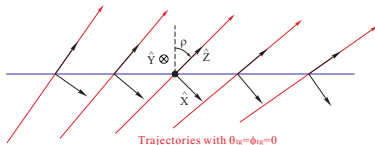
- The TRCS is a **rotated** coordinate system, with the DCS rotated clockwise about the \hat{y} -axis by 45°
- Ideally, \hat{z} of the TRCS coincides with the central ray of the spectrometer
- Serves as an intermediate stage to get from the DCS to FCS



Optics (8)

Coordinate Systems: Focal Plane Coordinate System

- Another **rotated** coordinate system
- Due to the focusing of the magnets, particles incident on the detector package at different angles that have the same $|\vec{p}|$ will be focused at the focal plane
- Therefore, the relative momentum $\delta \equiv \Delta p/p = (p - p_0)/p_0$ is a function of only x_{tr} and p_0
- The FCS is obtained by rotating the DCS about its \hat{y} -axis through an angle $\rho(x_{tr})$ with the \hat{z} -axis parallel to the **local** central ray
 - This has the condition $\theta_{tg} = \phi_{tg} = 0$ for a given δ, x_{tr}



Optics (9)

Connecting the Coordinate Systems

- For each event, the two angular coordinates (θ_{det}, ϕ_{det}) and two spatial coordinates (x_{det}, y_{det}) are measured at the focal plane (S1)
 - x_{det}, θ_{det} give the position of the particle and the **tangent** of the angle made by the trajectory along the **vertical (dispersive)** direction
 - y_{det}, ϕ_{det} give the position of the particle and the **tangent** of the angle made by the trajectory along the **horizontal (lateral)** direction
- Corrections to these variables are made to account for any detector offsets from the ideal central ray, which yields the focal plane coordinates ($x_{fp}, \theta_{fp}, y_{fp}, \phi_{fp}$)
- The focal plane variables are then used to determine the corresponding target system variables by use of the **optics matrix**

Optics (10)

Optimization Matrix: First Order

- The optics matrix **transforms** our variables from the detector system to the target system
 - Allows for the realization of the full potential of the hardware
- To first order, due to the mid-plane symmetry of the LHRS, we have:

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

Optics (11)

Optimization Matrix: Fourth Order

- The optimization is usually performed to fourth order, using:

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

- The explicit equations for each variable take the form:

$$\begin{aligned} \delta &= D_{jkl} \theta_{fp}^j y_{fp}^k \phi_{fp}^l \\ \theta_{tg} &= T_{jkl} \theta_{fp}^j y_{fp}^k \phi_{fp}^l \\ y_{tg} &= Y_{jkl} \theta_{fp}^j y_{fp}^k \phi_{fp}^l \\ \phi_{tg} &= P_{jkl} \theta_{fp}^j y_{fp}^k \phi_{fp}^l \end{aligned}$$

Optics (12)

Optimization Matrix: Fourth Order

- The tensors $D_{jkl}, T_{jkl}, Y_{jkl}, P_{jkl}$ are polynomials in x_{fp} :

$$D_{jkl} = C_{ijkl}^D x_{fp}^i$$

$$T_{jkl} = C_{ijkl}^T x_{fp}^i$$

$$Y_{jkl} = C_{ijkl}^Y x_{fp}^i$$

$$P_{jkl} = C_{ijkl}^P x_{fp}^i$$

- We sum over repeated indices (pp. 11-12)

Optics (13)

Characteristic Plots

- In order to test our current matrix, we need certain plots to see how 'aligned' our coordinates are
- We examine six plots:
 - z_{react} : shows where the **reaction vertex** for each foil from the **multi-Carbon foil target** is, as compared to the nominal (survey) values
 - θ_{tg} vs. ϕ_{tg} for each foil
 - y_{tg} vs. ϕ_{tg} for each foil
 - dp_{kin} for each foil: shows the elastic peak reconstruction when performing a **delta (momentum) scan** on the Carbon target
 - x_{sieve} vs. y_{sieve} : shows how well the sieve is reconstructed w.r.t. nominal values
 - $p_0(1 + \delta)$ for each foil

What's Next?

- Investigate the significance behind a few of the plots I've mentioned (θ_{tg} vs. ϕ_{tg} , y_{tg} vs. ϕ_{tg} , $p_0(1 + \delta)$) as the phase space plots seem to be superfluous w.r.t. x_{sieve} vs. y_{sieve} , and the latter being superfluous w.r.t. the dp_{kin} plot. . .
- Get together needed data (d_2^n /transversity?) and generate the plots mentioned