Hall A Spectrometer Optics: An Overview

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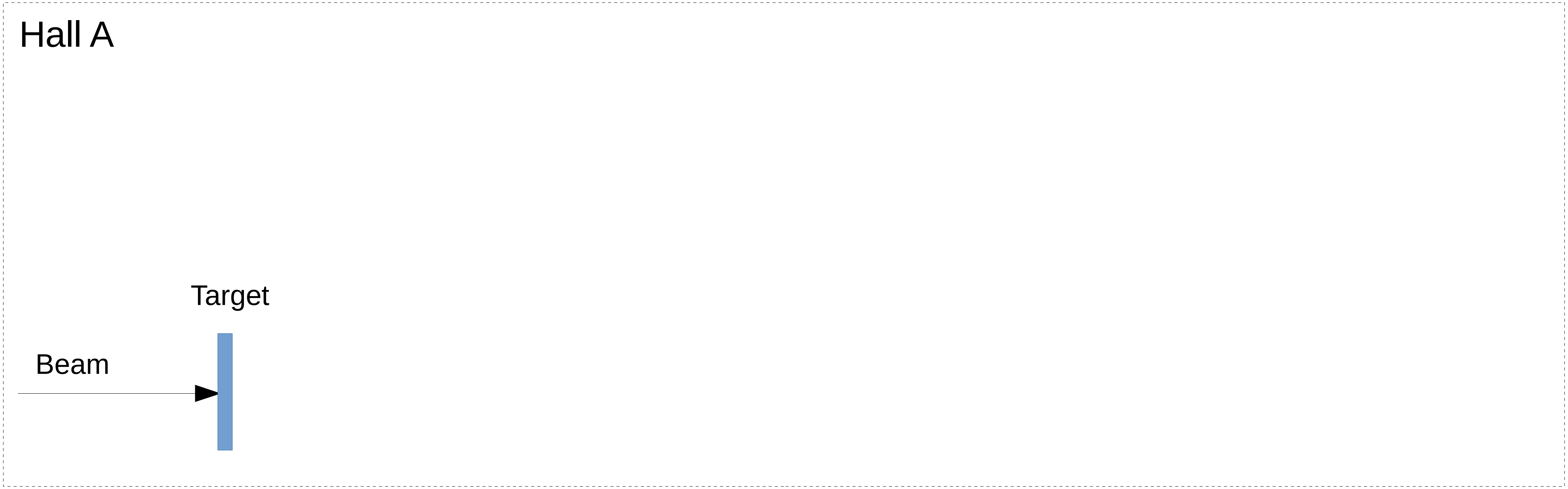
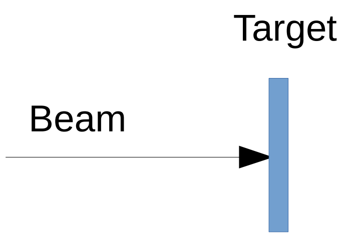


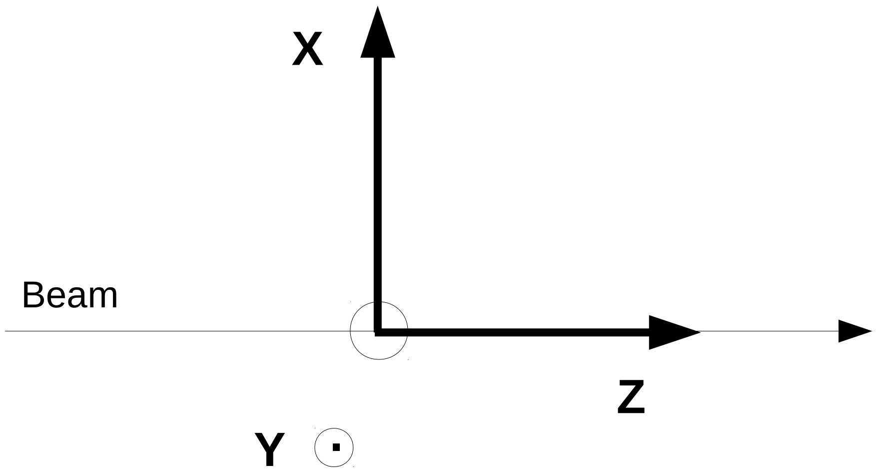
Hall A
Target
Beam

Hall A

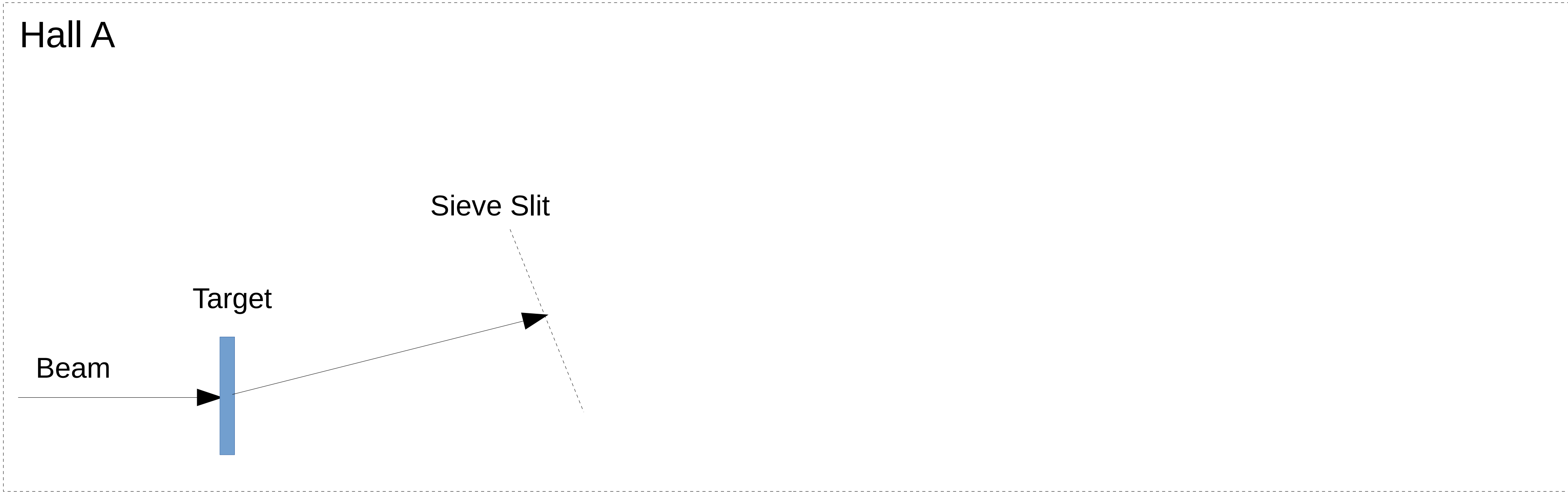


1. Hall Coordinate System (HCS)

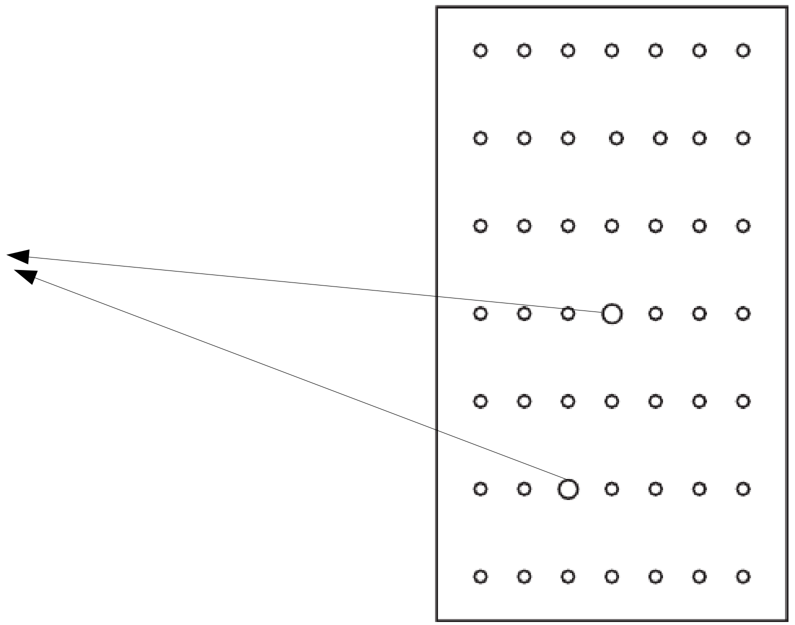
Top view



- Origin is at the intersection of the electron beam and the vertical symmetry axis of the target system.

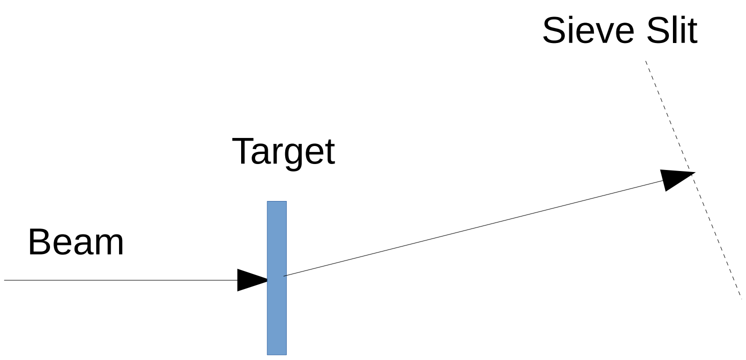


Sieve Slit



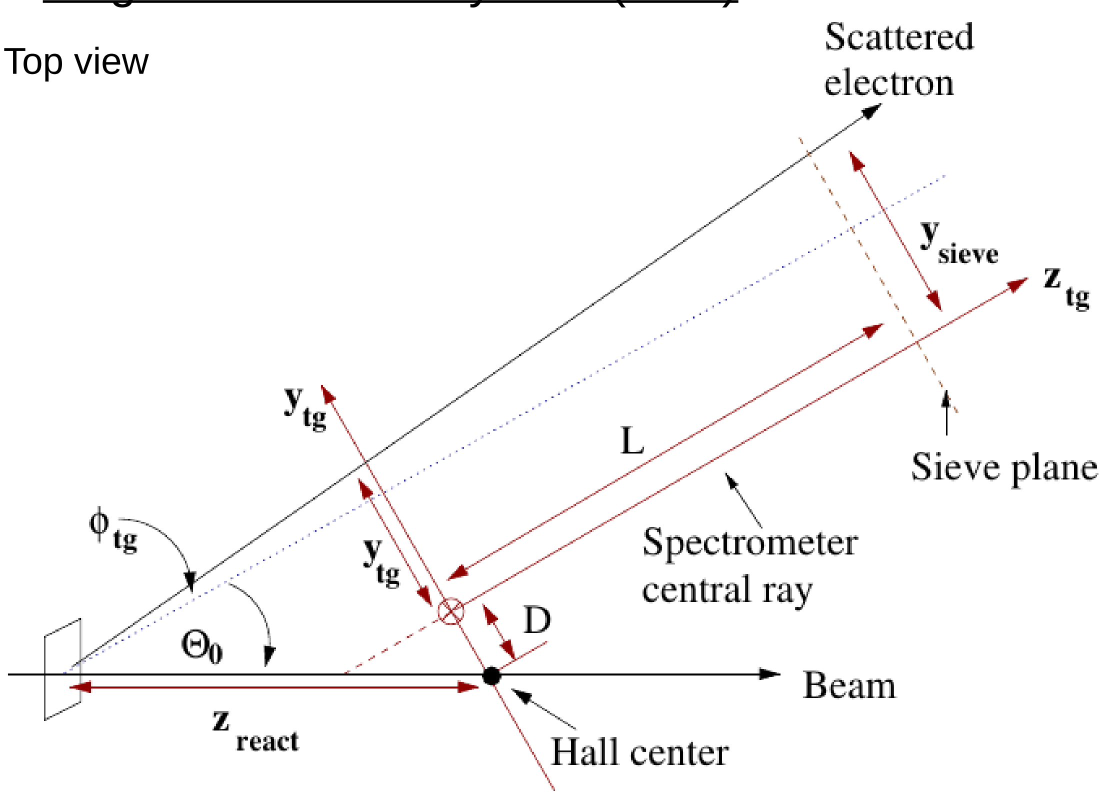
- The large holes allow the identification of the orientation of the image at the focal plane.

Hall A

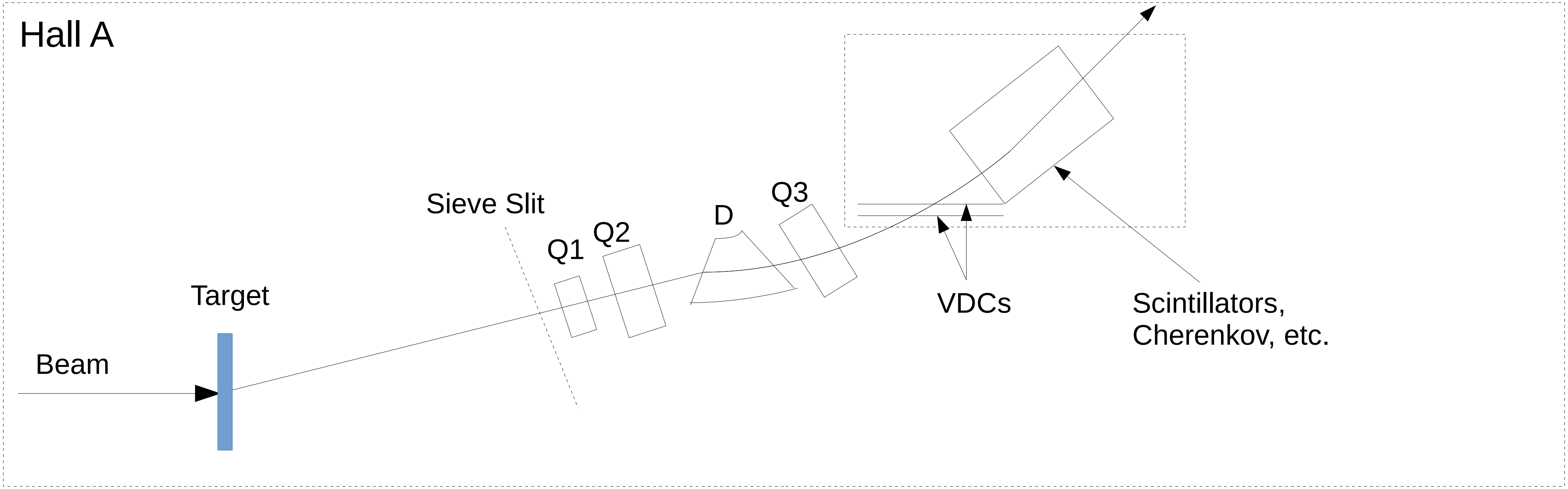


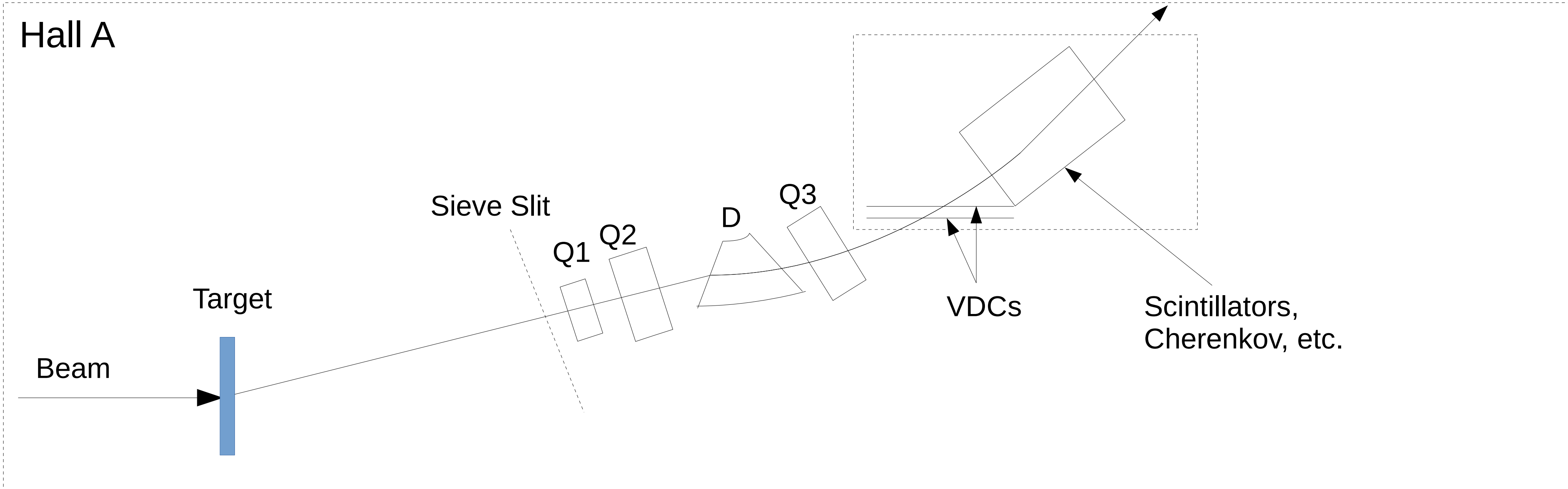
2. Target Coordinate System (TCS)

Top view



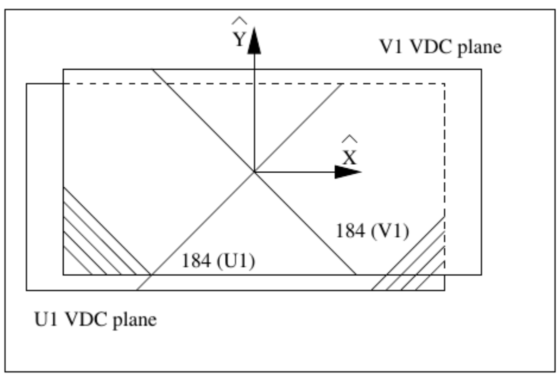
- A line perpendicular to the sieve slit surface of the spectrometer and going through the midpoint of the central sieve slit hole defines the z axis.
- In an ideal case, the origin of the TCS coincides with the hall center.


Hall A
Sieve Slit
Q1
Q2
D
Q3
Target
Beam
VDCs
Scintillators,
Cherenkov, etc.

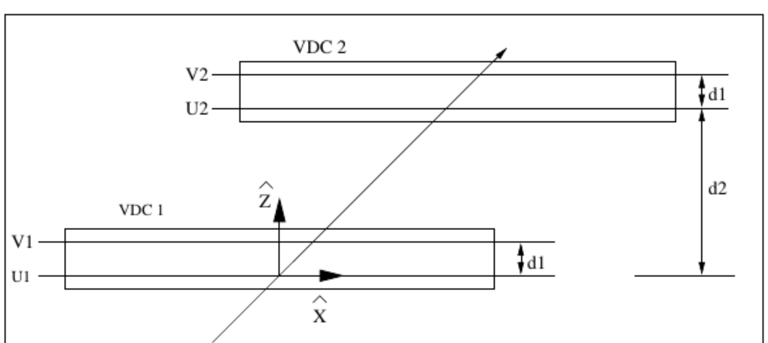


3. Detector Coordinate System (DCS)

Top view



Side view



- The intersection of wire 184 of the VDC1 U1 plane and the perpendicular projection of wire 184 in the VDC1 V1 plane onto the VDC1 U1 plane defines the origin of the DCS.
- Using the trajectory intersection points $p_{vdc,n}$,the coordinates of the detector vertex can be calculated according to

$$\tan\,\eta_1 = \frac{p_{vdc,3} - p_{vdc,1}}{d_2},$$

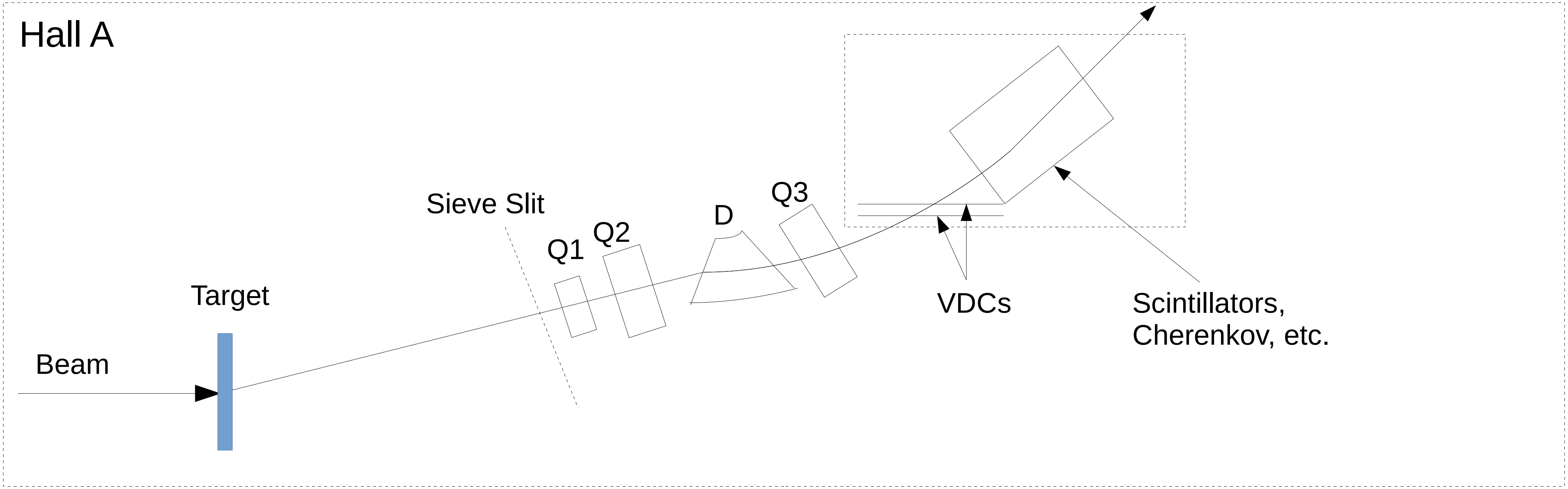
$$\tan\,\eta_2 = \frac{p_{vdc,4} - p_{vdc,2}}{d_2},$$

$$\theta_{det} = \frac{1}{\sqrt{2}}\left(\tan\,\eta_1 + \tan\,\eta_2\right),$$

$$\phi_{det} = \frac{1}{\sqrt{2}}\left(-\tan\,\eta_1 + \tan\,\eta_2\right),$$

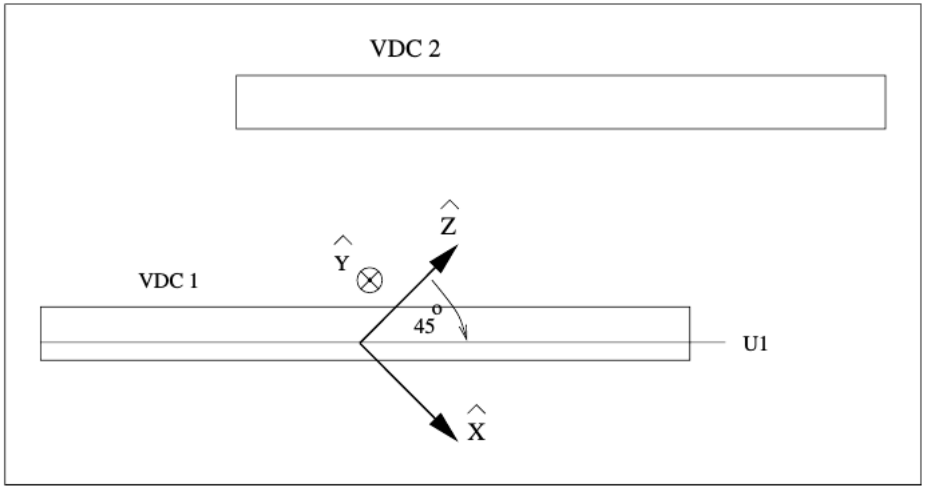
$$x_{det} = \frac{1}{\sqrt{2}}\left(p_{vdc,1} + \left(p_{vdc,2} - d_1 \tan\,\eta_2\right)\right),$$

$$y_{det} = \frac{1}{\sqrt{2}}\left(-p_{vdc,1} + \left(p_{vdc,2} - d_1 \tan\,\eta_2\right)\right)'$$



4. Transport Coordinate System (TRCS) at the focal plane

Side view



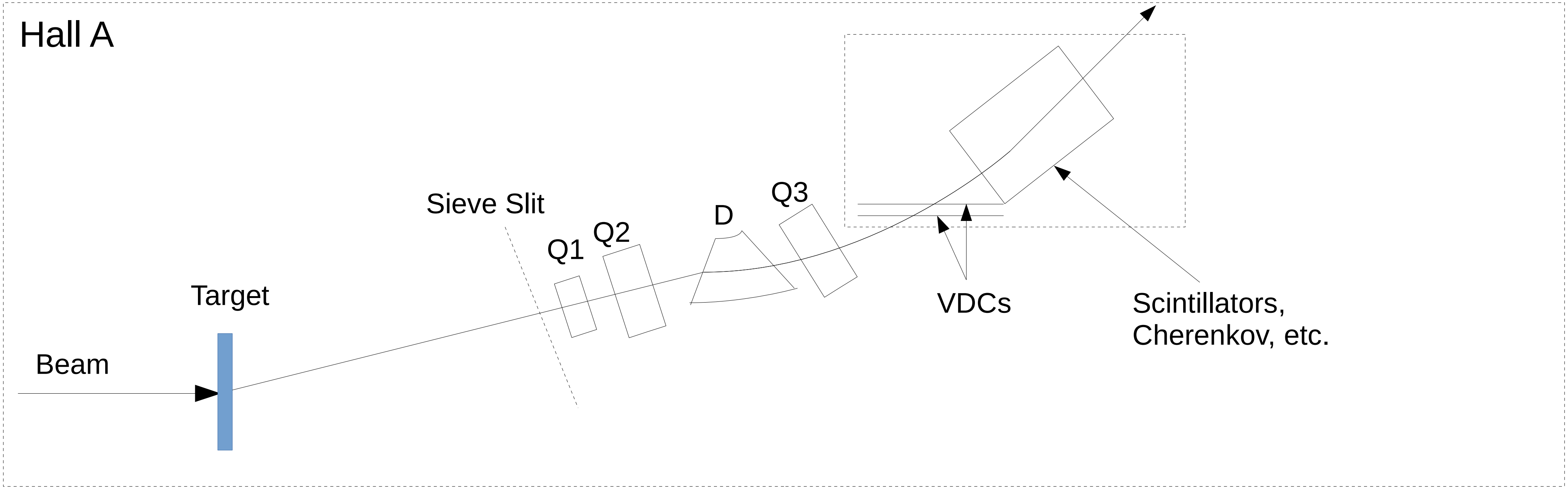
- The TRCS at the focal plane is generated by rotating the DCS clockwise around its y-axis by 45 degrees .
- Ideally, the z-axis of the TRCS coincides with the central ray of the spectrometer.

$$\theta_{tra} = \frac{\theta_{det} + \tan\ \rho_0}{1 - \theta_{det} \tan\ \rho_0}$$

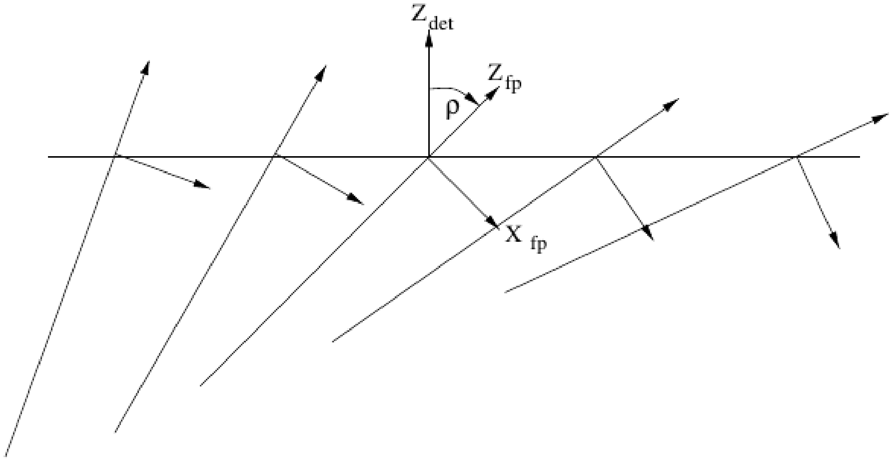
$$\phi_{tra} = \frac{\phi_{det}}{\cos\ \rho_0 - \theta_{det} \sin\ \rho_0}$$

$$x_{tra} = x_{det} \cos\ \rho_0\ (1 + \theta_{tra} \tan\ \rho_0)$$

$$y_{tra} = y_{det} + \sin\ \rho_0 \phi_{tra} x_{det}$$



5. Focal Plane Coordinate System (FCS)



- This coordinate system is obtained by rotating the DCS around its y -axis by an angle ρ, where ρ is the angle between the local central ray and the z-axis of the DCS.
- As a result, the z-axis of the FCS rotates as a function of the relative momentum Δp/p.

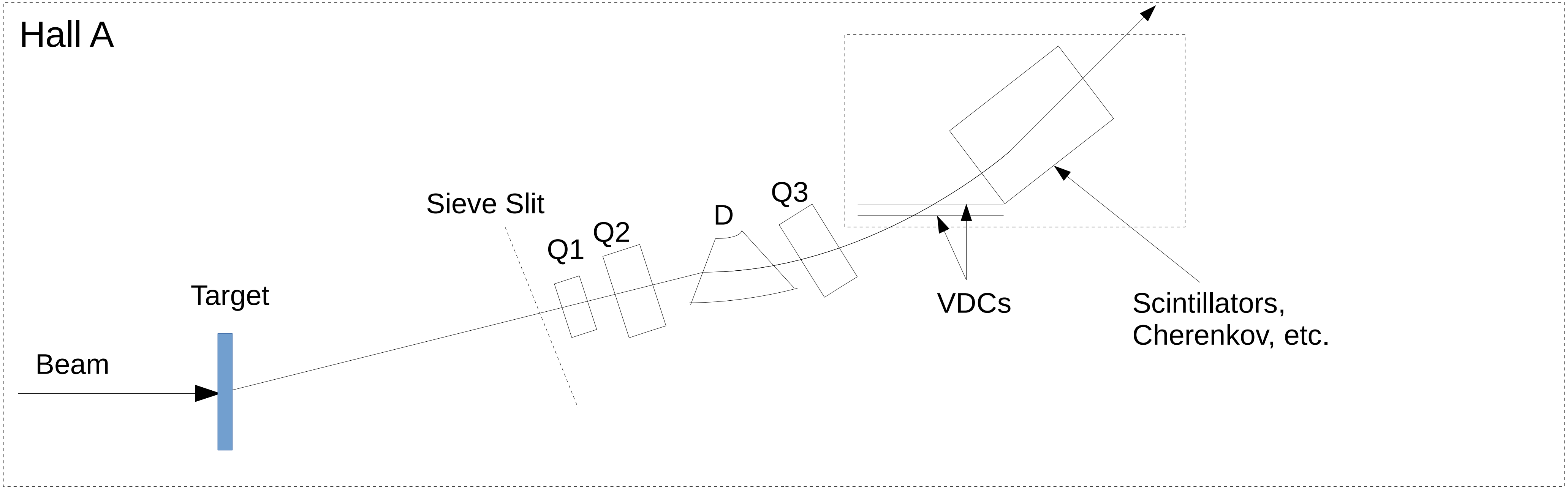
$$y_{fp} = y_{tra} - \sum y_{i000} x_{fp}^{i}$$

$$x_{fp} = x_{tra}$$

$$\theta_{fp} = \frac{\theta_{det} + \tan\,\rho}{1 - \theta_{det} \tan\,\rho}$$

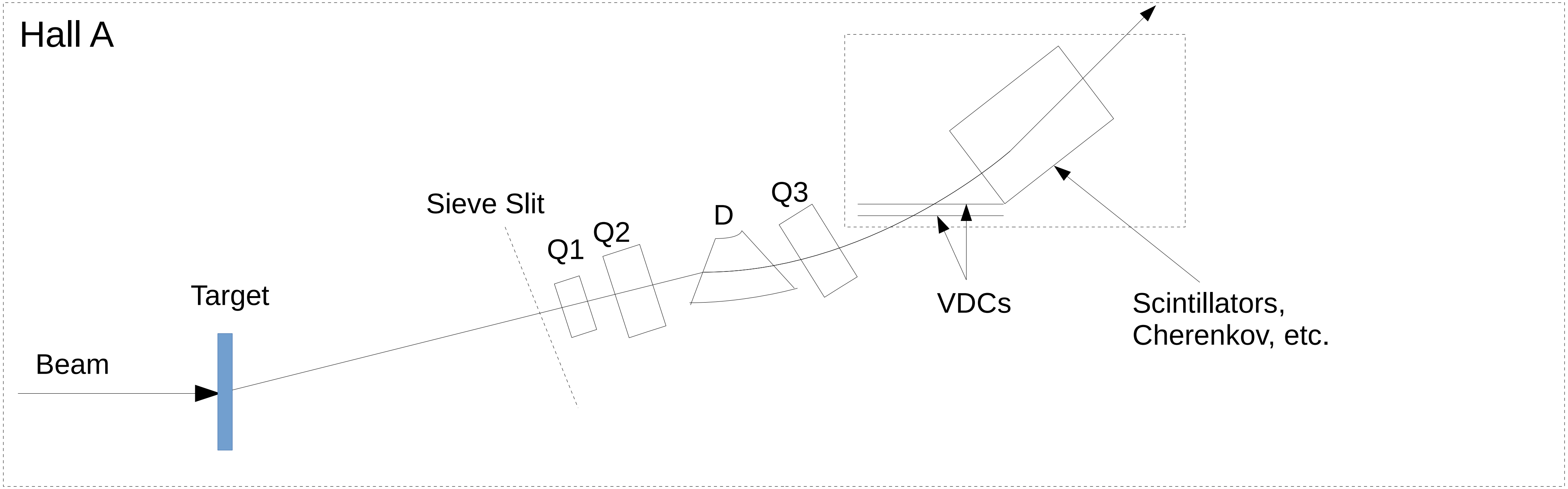
$$\phi_{fp} = \frac{\phi_{det} - \sum p_{i000} x_{fp}^{i}}{\cos\,\rho - \theta_{det} \sin\,\rho},$$

$$\tan\,\rho = \sum t_{i000} x_{fp}^{i}.$$



Approach:

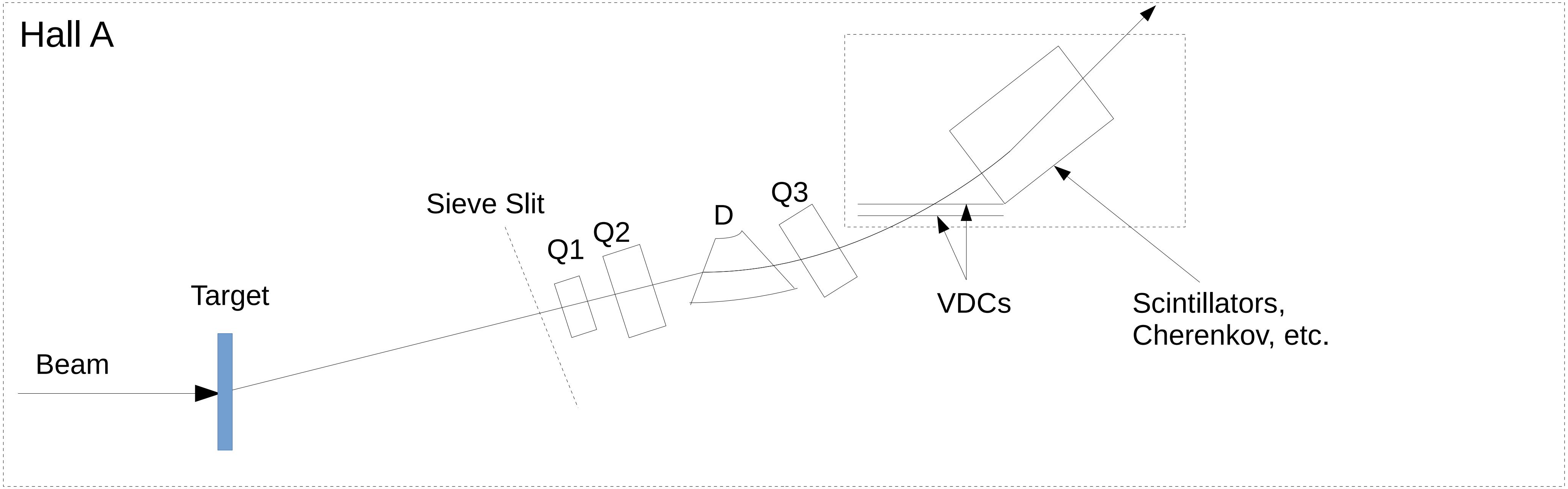
$$\begin{bmatrix} x \\ \theta \\ y \\ \phi \end{bmatrix}_{fp}$$



Approach:

$$\begin{bmatrix} \delta \\ \theta \\ y \\ \phi \end{bmatrix}_{tg}$$

$$\begin{bmatrix} x \\ \theta \\ y \\ \phi \end{bmatrix}_{fp}$$



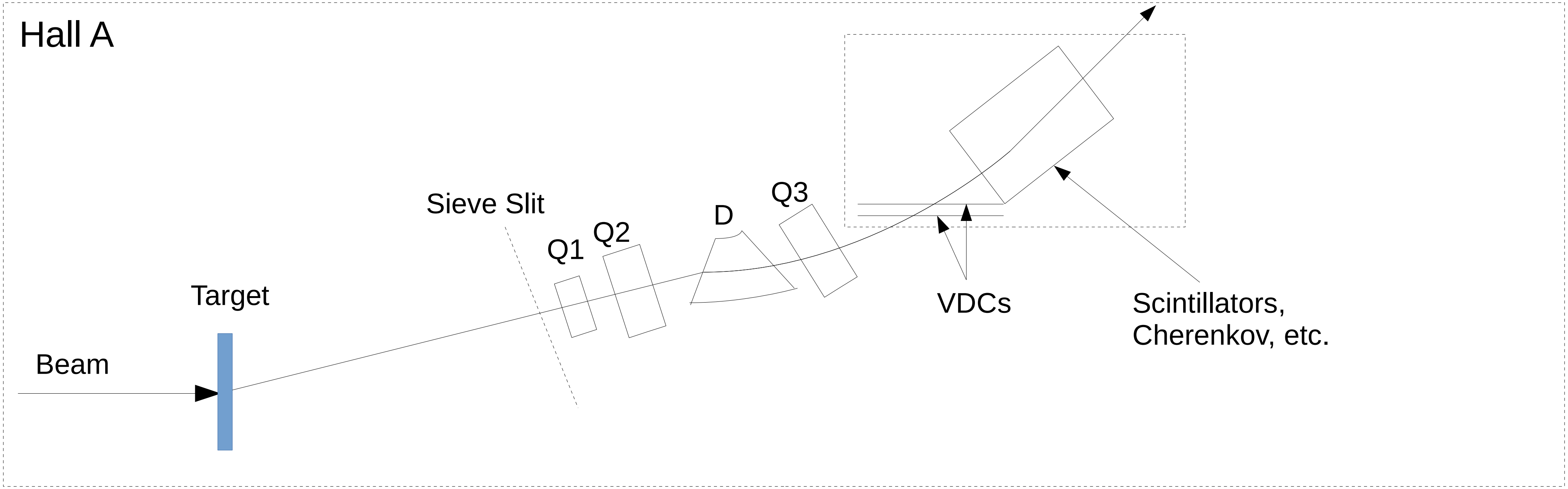
Approach: Optics Matrix

First-order approximation

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

$\delta = (p-p_0)/p_0$

- The optics matrix elements allow the reconstruction of the interaction vertex from the coordinates of the detected particles at the focal plane.



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$\delta = (p-p_0)/p_0$

$$y_{tg} = \sum_{j,k,l} Y_{jkl}\theta^j_{fp} y^k_{fp}\phi^l_{fp},$$

$$\theta_{tg} = \sum_{j,k,l} T_{jkl}\theta^j_{fp} y^k_{fp}\phi^l_{fp},$$

$$\phi_{tg} = \sum_{j,k,l} P_{jkl}\theta^j_{fp} y^k_{fp}\phi^l_{fp},$$

$$\delta = \sum_{j,k,l} D_{jkl}\theta^j_{fp} y^k_{fp}\phi^l_{fp},$$

$$Y_{jkl} = \sum_{i=1}^{m} C_i^{Y_{jkl}} x^i_{fp}$$

$$y_{tg} = \sum_{j,k,l}\sum_{i=1}^{m} C_i^{Y_{jkl}} x^i_{fp}\theta^j_{fp} y^k_{fp}\phi^l_{fp}$$

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