Some questions from Lecture 2 (Berg):

1) Does COSY allow implementation of higher order corrections in dipoles?
2) Why dipoles doublets instead of one large dipole?
3) Definition of K, T, and C in dispersion matching.
4) Define fringe field.
5) Define Rogowski profile.
6) Explain H and K coil in K600 Spectrometer. Why quad inside K600?
7) Explain HO in K600 Spectrometer.
8) How to use reconstruct the scattering angle at target from focal plane measurement? Setup of multi-slit for angle calibration, drift between target and multi-slit.
9) Discuss only one spectrometer (e.g. K600, Grand Raiden, Big Karl).
10) Explain magnetization of ferro-magnetic material.
11) p. 14 Why not 0 deg with beam (for dispersion matching)?
12) Will permanent magnet saturate material. Similar to coil generated fields?
13) Why is dispersion matching needed?
14) Can EFL be measured?

Question 1)

Does COSY allow implementation of higher order corrections in dipoles?

Answer: Yes!

- For midplane radial field dependence use e.g. COSY command MS
- For entrance and exit pole shapes use e.g. MC command

Question 2)

Why dipoles doublets instead of one large dipole?

Answer: Many possible reasons

- Two dipole have more (four) entrance and exit edges allowing higher order corrections (MC command)
- Correction of beam misalignment (dog leg) in dispersive directions, without additional space.
- One magnet design may not be practical, e.g. too heavy, too different, different gaps, etc.

Question 3)

Definition of K, T, and C in dispersion matching.

Answer: See kinematics example at right for K and see next slide

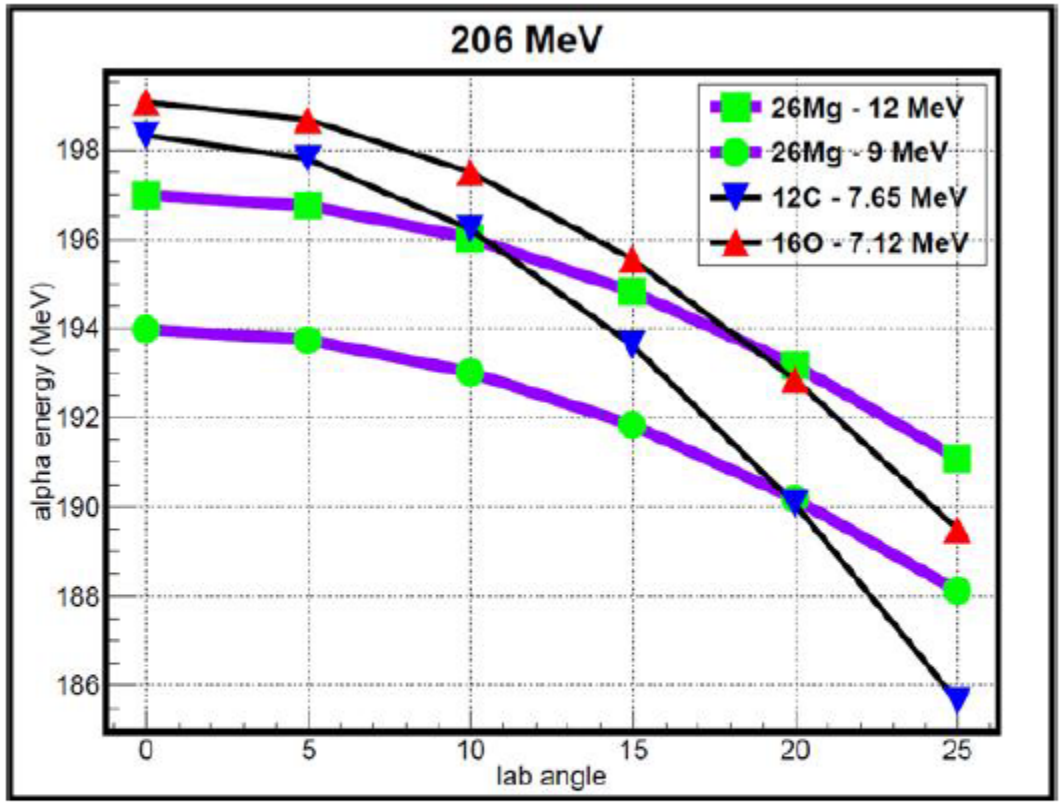


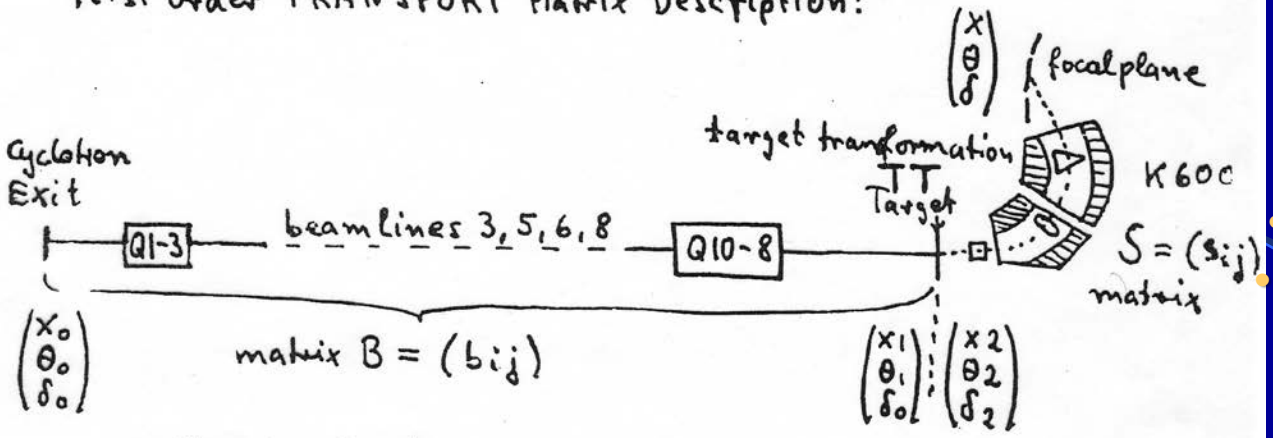
Figure 3.9. Outgoing alpha energy versus lab angle for α beam at 206MeV. Shown in purple is the 9 MeV - 12 MeV energy range in ^{26}Mg covering the region of interest (10.61 MeV - 11.32 MeV). The up and down triangles denote the 7.12 MeV peak in ^{16}O and 7.65 MeV peak in ^{12}C.

Dispersion Matching

- High resolution experiments
- Secondary beam (large dp/p)

Matching between beam line and spectrometer

First Order TRANSPORT Matrix Description:



$$B = \begin{pmatrix} b_{11} & b_{12} & b_{16} \\ b_{21} & b_{22} & b_{26} \\ 0 & 0 & 1 \end{pmatrix} \qquad S = \begin{pmatrix} s_{11} & s_{12} & s_{16} \\ s_{21} & s_{22} & s_{26} \\ 0 & 0 & 1 \end{pmatrix}$$

TT:

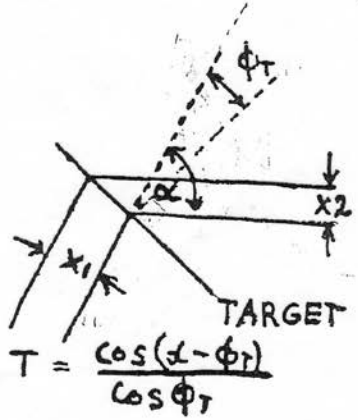
$$x_2 = T\,x_1$$

$\theta_2 = \Theta + \theta_1$

θ_2 = random angle within acceptance of spectrom.

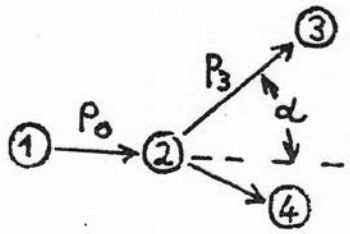
$$\delta_2 = K(\theta_2 - \theta_1) + C\,\delta_0$$

Θ is random



$$T = \frac{\cos(\alpha - \phi_T)}{\cos\phi_T}$$

Reaction Kinematics



$$P_3 = P_3(P_0, \alpha, Q)$$

$$K = \frac{\partial P_3}{\partial \alpha}\frac{1}{P_3} \qquad C = \frac{\partial P_3}{\partial P_0}\frac{P_0}{P_3}$$

$$\begin{pmatrix} x \\ \theta \\ \delta \end{pmatrix} = S \cdot TT \cdot B \cdot \begin{pmatrix} x_0 \\ \theta_0 \\ \delta_0 \end{pmatrix}$$

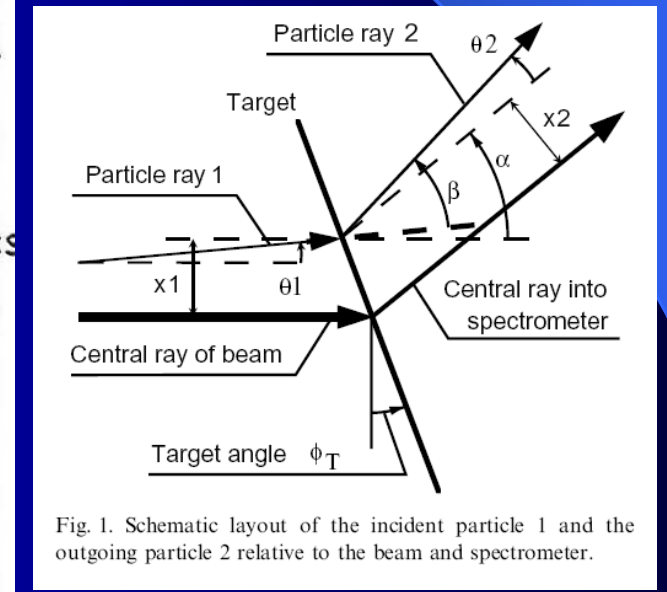


Fig. 1. Schematic layout of the incident particle 1 and the outgoing particle 2 relative to the beam and spectrometer.

Question 4)

Define fringe field.

Answer: See COSY Beam Manual p 20 Chapter 3.3.2

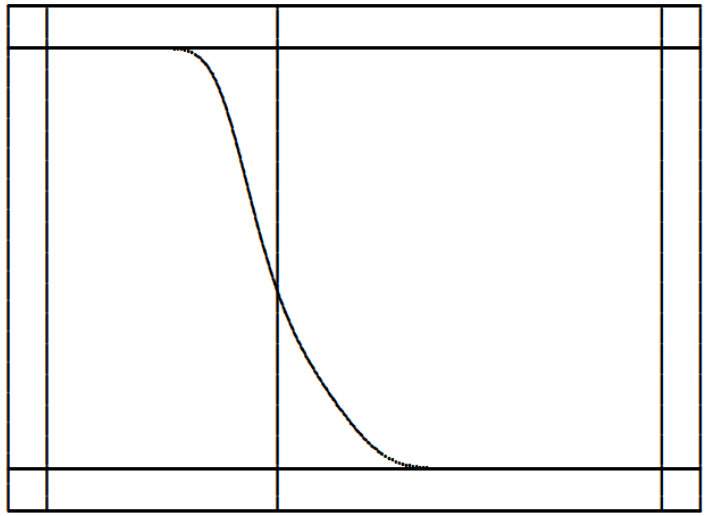


Figure 2: COSY LaTeX picture of the S800 D1 magnet's entrance Enge function.

a_1	a_2	a_3	a_4	a_5	a_6
0.1122	6.2671	−1.4982	3.5882	−2.1209	1.723

Table 5: Enge coefficients of a room temperature quadrupole at GSI.

FR 3 & FR 2.9

This mode is the most accurate fringe field mode. The fringe field falloff is based on the standard description of the s-dependence of multipole strengths by a six parameter Enge function. The Enge function is of the form

$$F(z) = \frac{1}{1 + \exp(a_1 + a_2 \cdot (z/D) + ... + a_6 \cdot (z/D)^5)},$$

where z is the distance perpendicular to the effective field boundary. In the case of multipoles, the distance coincides with the arc length along the reference trajectory. D is the full aperture (i.e., in case of multipoles

Question 5)

Define Rogowski profile.

Answer: Curve that follows equipotential lines, e.g. in magnet end profiles to minimize saturation effects.

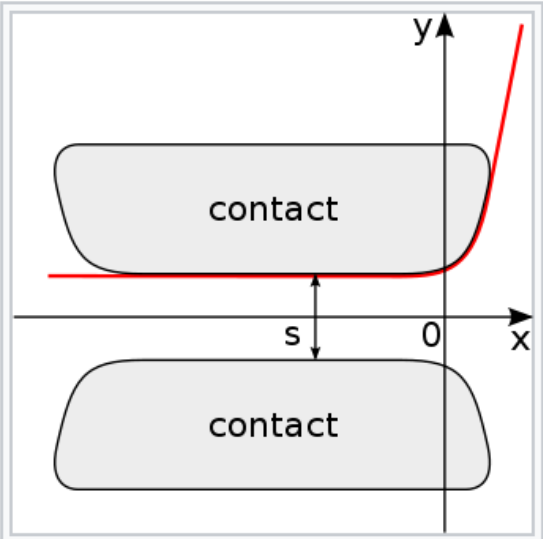
Rogowski-Profil

Ein **Rogowski-Profil** dient der räumlichen Formgebung von elektrischen Elektroden wie den Platten eines elektrischen Kondensators mit dem Ziel, an den Rändern der Elektroden einen abnehmenden Verlauf der elektrischen Feldstärke zu erzielen. Typischerweise findet dieses Profil bei der Gestaltung von Plattenkondensatoren Anwendung, da so eine Feldüberhöhung an den Kanten und damit ein elektrischer Durchschlag im Randbereich vermieden werden kann.[1] Nachteilhaft ist die räumlich große Bauweise und die Abhängigkeit des Profils von dem Plattenabstand. Somit kann der Abstand nicht einfach variiert werden, was bei Hochspannungselektroden allerdings häufig erwünscht ist.

Erste Vorarbeiten zu dieser Form wurden von James Clerk Maxwell getätigt,[2] und in Arbeiten von dem Namensgeber Walter Rogowski zu der heute üblichen Form erweitert.[3]

Die beschreibende Funktion, wie in nebenstehender Abbildung mit roten Verlauf dargestellt, lautet:

$$f(x) = y = \frac{s}{\pi}\left(\frac{\pi}{2} + e^{x\pi/s}\right)$$



Funktionsdarstellung an einem Plattenkondensator

Durch Spiegelung der beschreibenden Funktion können die Platten, in nebenstehender Abbildung in Schwarz dargestellt, gebildet werden. Die höchste elektrische Feldstärke tritt bei dieser Formgebung zentrisch in der Mitte der Platten auf und kann durch den Parameter s, welcher den Plattenabstand beschreibt, verändert werden.

Question 6)

Explain H and K coil in K600 Spectrometer. Why quad inside K600?

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Answer: H and K coil in the K600 Spectrometer are the names for the hexapole and quadrupole coil inside the gaps of Dipole 1 and Dipole 2, respectively. See next slide.

Compact design.

K600 Spectrometer

Bending radius ρ_0 = 2.0 m
B_{max} = 1.7 T
Gap = 5 cm (D 1), 6cm (D2)
Weight = ~ 30 tons (D1)
~ 45 tons (D2)

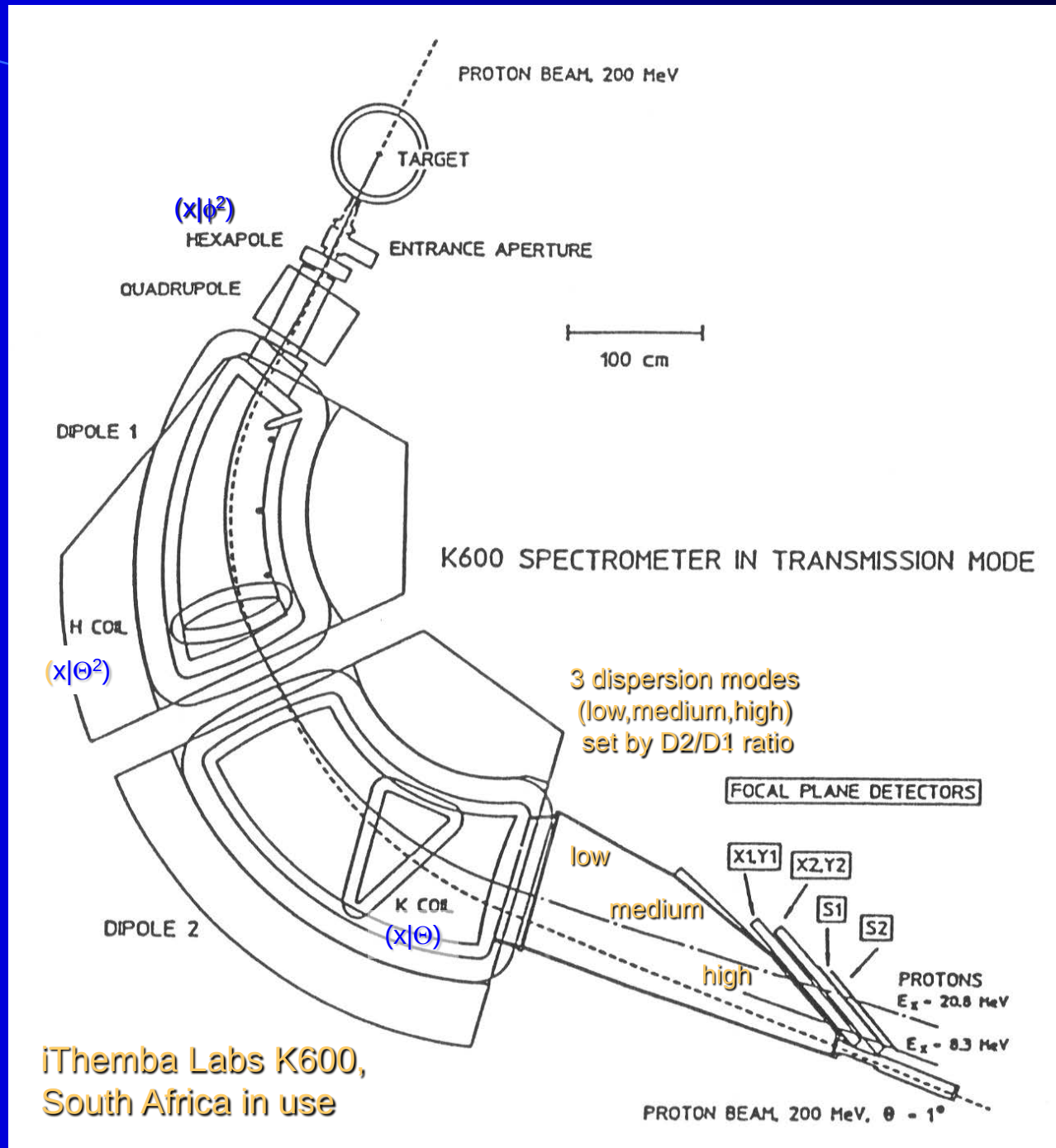
Medium Dispersion: B(D1)= B(D2)
Resolving power: p/Δp = 20000
Dispersion = 12 cm/% (= 12 m)
Magnification M_x = 0.41
Large range: E_{min} /E_{max} = 1.14

Kinematic correction: K coil
Hexapole correction: H coil

The K600 is shown in 0^o Transmission mode

High Dispersion Plane
B(D1) > B(D2)

IUCF K600,decommissioned
In 1999, now in WS line RCNP



iThemba Labs K600,
South Africa in use

Question 7)

Explain HO in K600 Spectrometer.

Answer: These are the first and second higher order aberrations of the spectrometer that can be corrected by the magnet next to the aberrations. See previous slide.

Question 8)

How to use reconstruct the scattering angle at target from focal plane measurement?
Setup of multi-slit for angle calibration, drift between target and multi-slit

Answer: Multi-silt as shown below, see result next page

statistics to perform the calibration. Within each region, the horizontal and vertical scattering angles, denoted θ_{tar} and ϕ_{tar} respectively, were calibrated using a third order polynomial as functions of the horizontal focal plane angle and the vertical focal plane position.

$$\theta_{\text{tar}} = \sum_{i=0}^{3} \sum_{j=0}^{3-i} p_{ij}(x_{\text{fp}}) \theta_{\text{fp}}^{i} y_{\text{fp}}^{j}$$
$$\phi_{\text{tar}} = \sum_{i=0}^{3} \sum_{j=0}^{3-i} q_{ij}(x_{\text{fp}}) \theta_{\text{fp}}^{i} y_{\text{fp}}^{j} \qquad (5.5)$$

The fit parameters, $p_{ij}(x_{\text{fp}})$ and $q_{ij}(x_{\text{fp}})$, are displayed with their focal plane position (x) dependence explicitly shown. From the geometry of the sieve slit, the target scattering angles can be calculated for each group of tritons in the focal plane spectra. Using the focal plane coordinates of each group of tritons, it was possible to determine the fit parameters, p_{ij} and q_{ij}, for each of the four focal plane position regions.

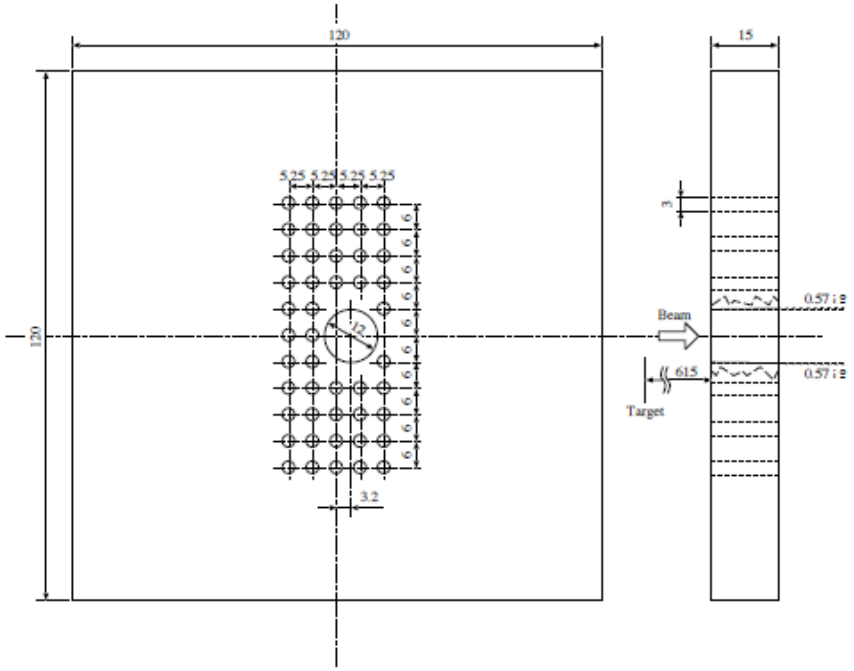
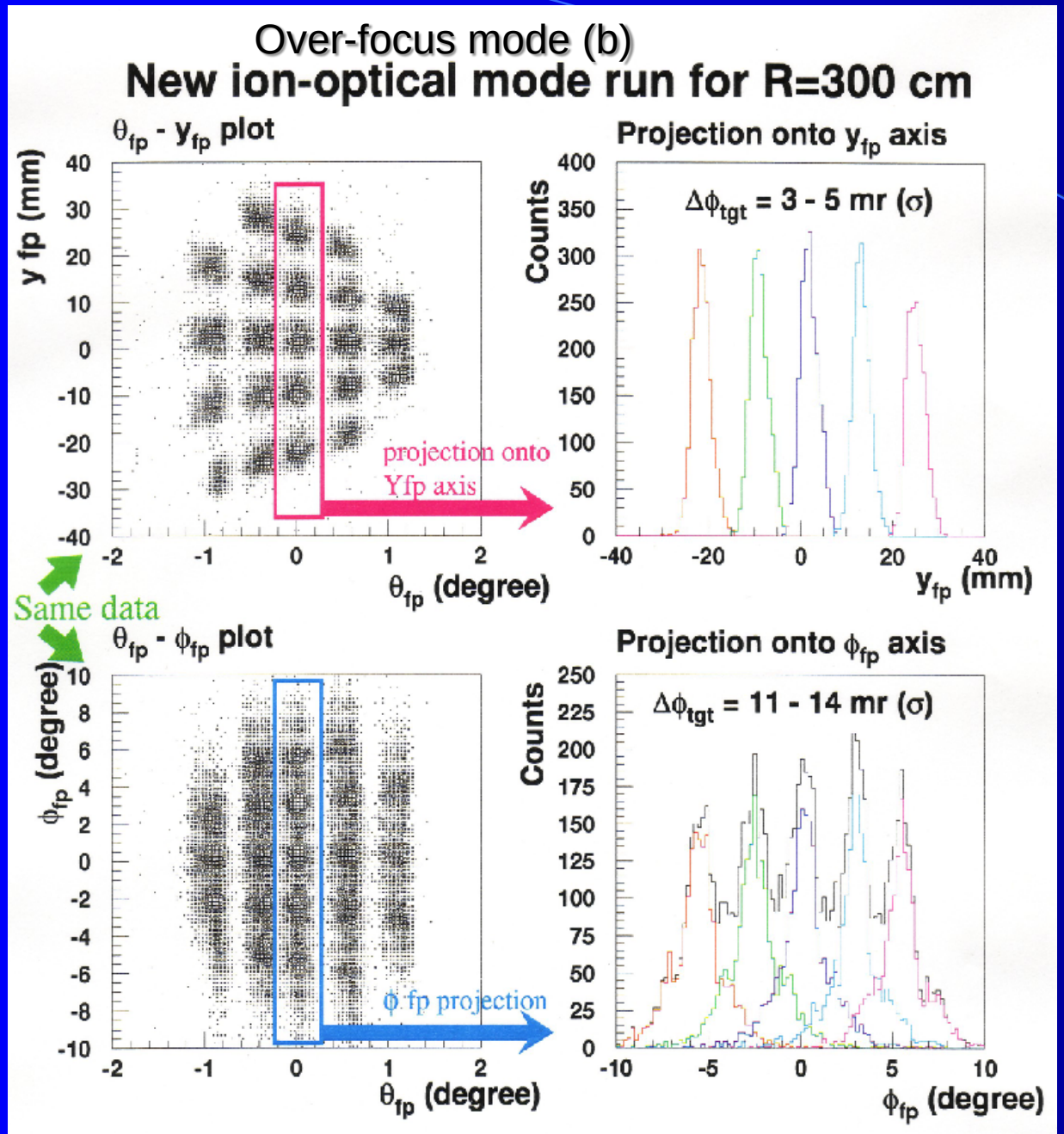


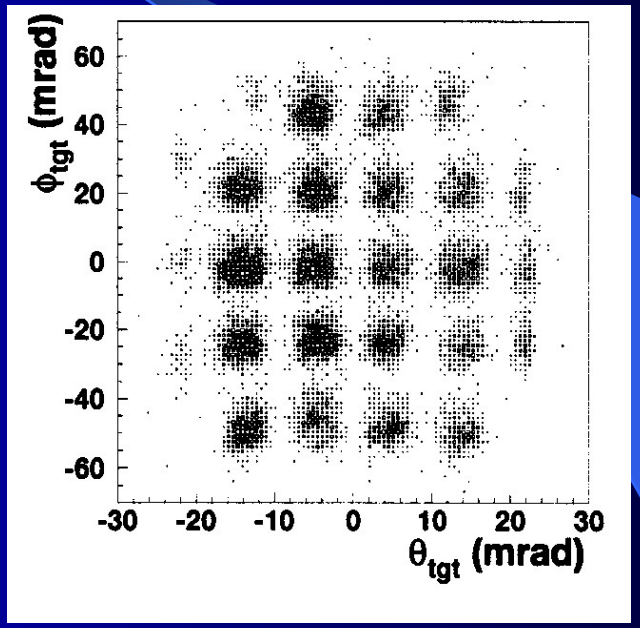
Figure 5.4. The sieve slit is used to create spectra with definite scattering angles. The dimensions in the figure are in mm. Based on the geometry of the target and sieve slit, the horizontal and vertical scattering angles of the particles reaching the focal plane can be calculated, and an angular calibration can be established.

Grand Raiden Angle Calibration

Data suggest: Use y_{fp} not Φ_{fp} to calibrate angle!



Calibrated!



Question 9)

Discuss only one spectrometer (e.g. K600, Grand Raiden, Big Karl) to explain dispersion matching

Answer: The discussion of 3 spectrometers were meant to show specific features of these spectrometers

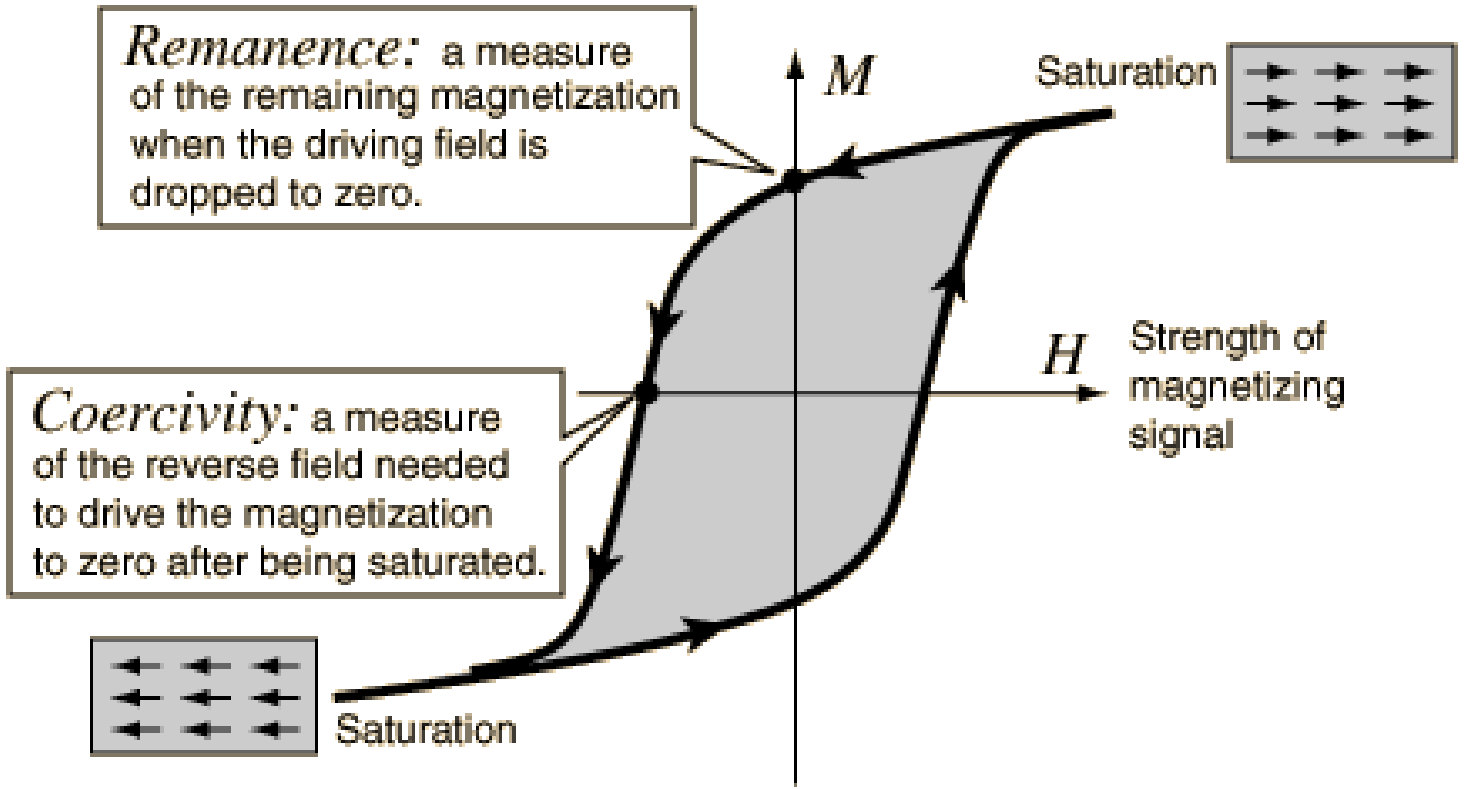
The dispersion matching applies to all three. I will make that clearer the next time.

Question 10)

Explain magnetization of ferro-magnetic material.

Answer:

Ferromagnetic materials (like **iron**) are composed of microscopic regions called magnetic domains, that act like tiny permanent magnets that can change their direction of **magnetization**. ... The **magnetization** remains nearly constant, and is said to have saturated. The domain structure at saturation depends on the temperature.



Question 11)

p. 14 Why not 0 deg with beam (for dispersion matching)?

Answer: Dispersion matching at 0 deg for k= 0 is possible with faint (attenuated beam), see slide 5, also 4

Question 12)

Will permanent magnet saturate material.

Similar to coil generated fields?

Answer: Yes.

Question 13)

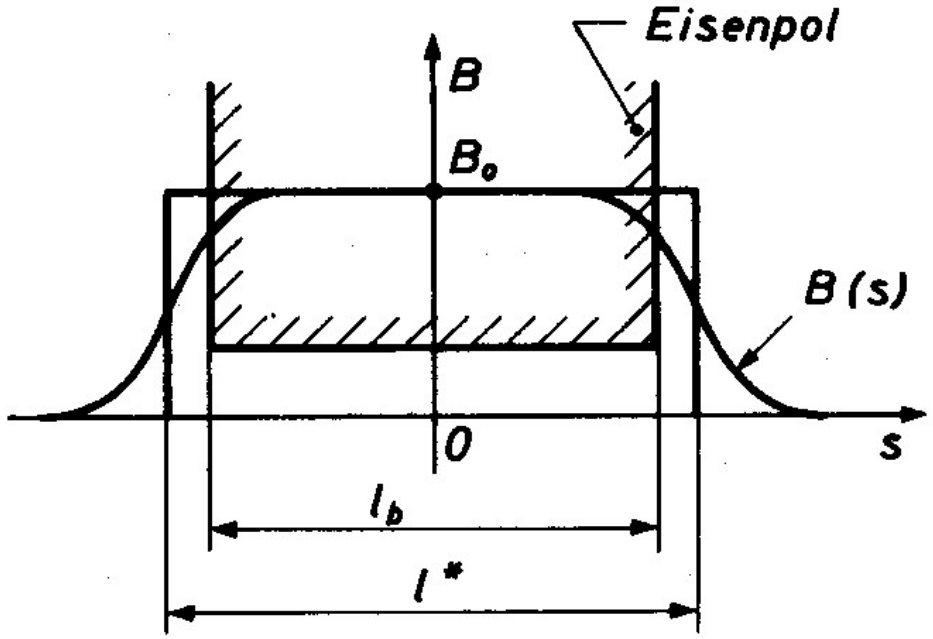
Why is dispersion matching needed?

Answer: To achieve high resolution in spectrometer if resolving power is higher than beam energy spread.

Question 14)

Can EFL be measured?

Answer: The best method is to measure the field distribution along the central ray (or a ray parallel to the central ray) and use the definition, see below.



$$L_{eff} = \int_0^{\infty} B \, ds / B_0$$