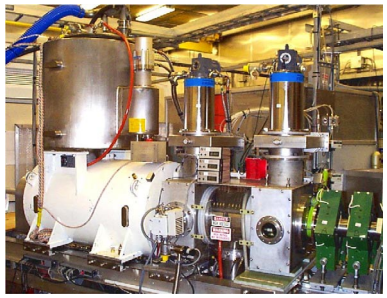
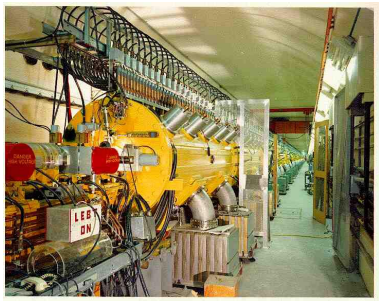
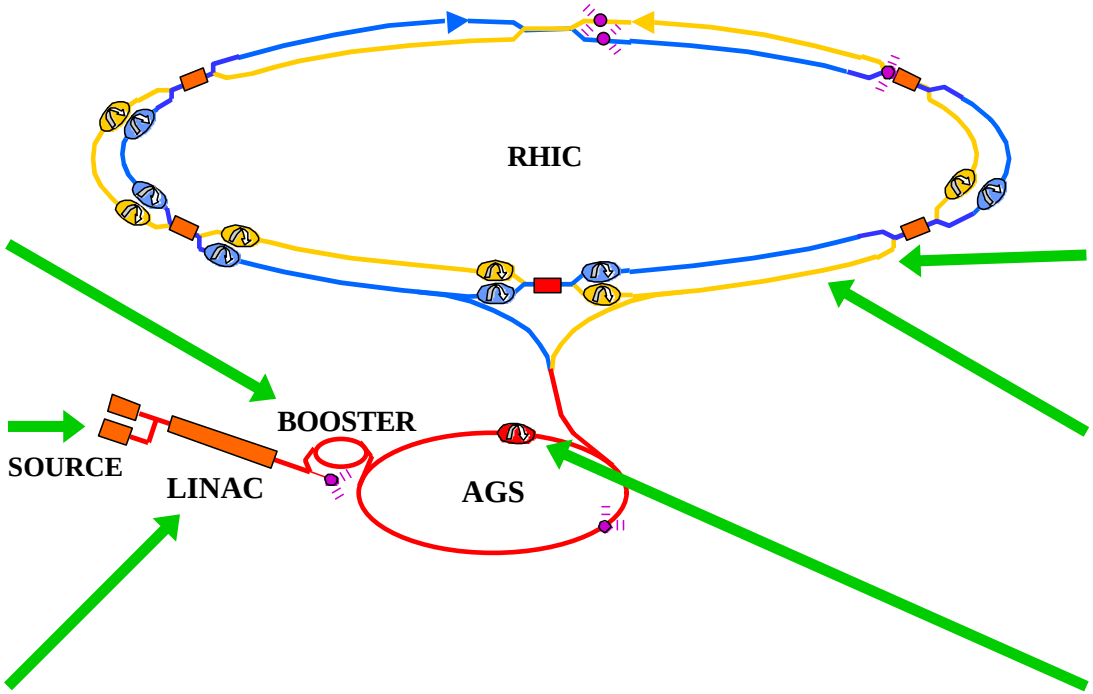
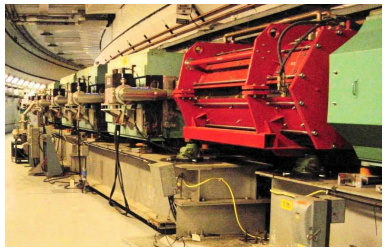
Accelerator Complex (Pol. Protons)



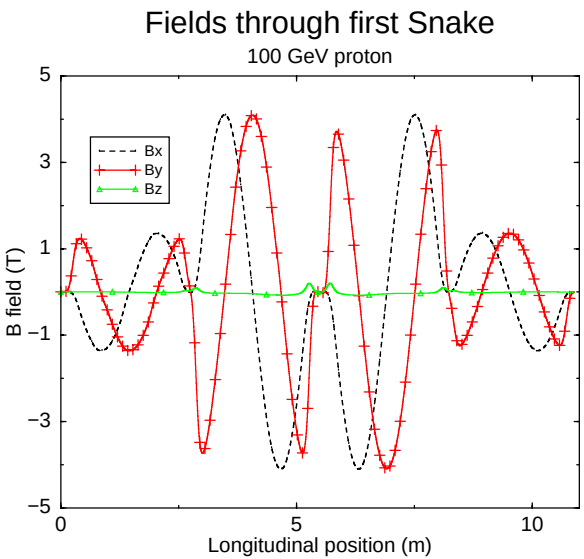


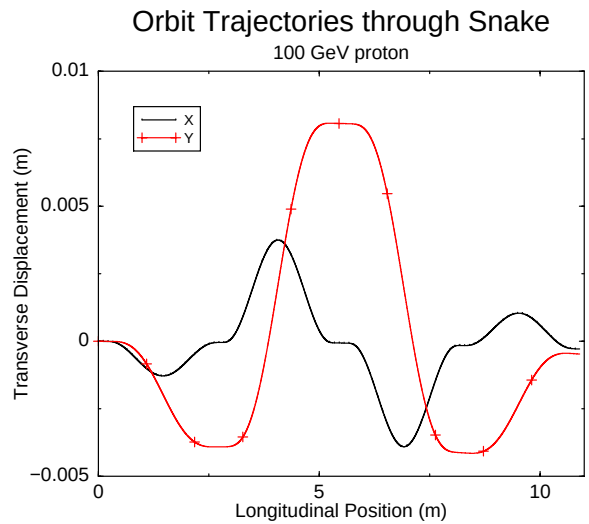


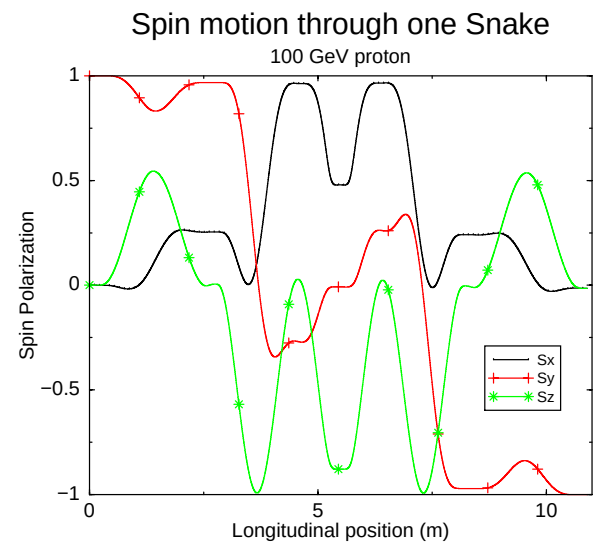


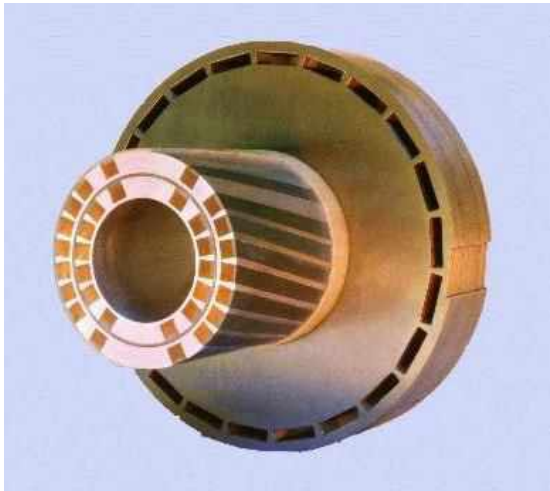
LINAC: Linear Accelerator
AGS: Alternating Gradient Synchrotron
RHIC: Relativistic Heavy Ion Collider

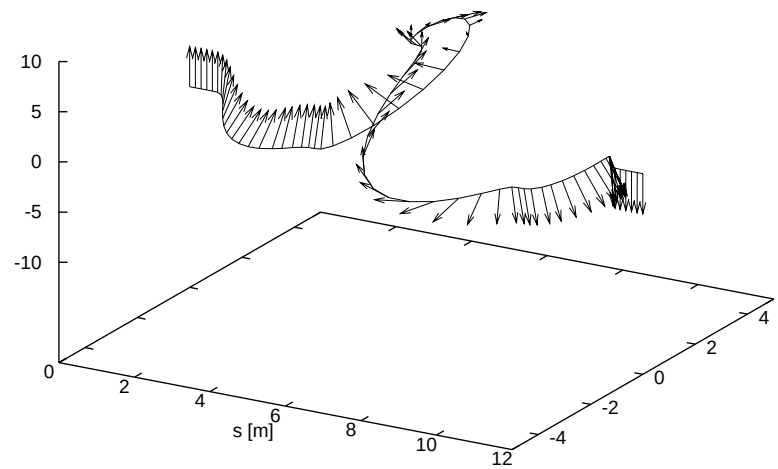
Trajectory and Spin through Snakes

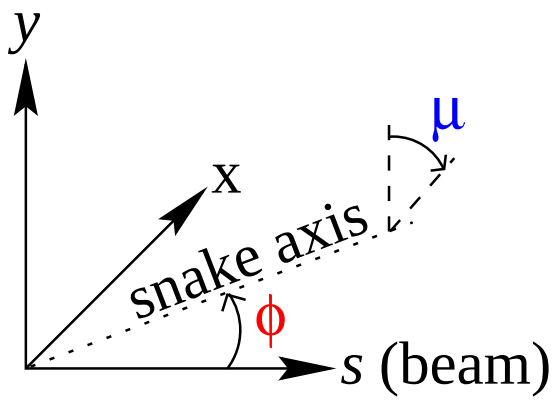






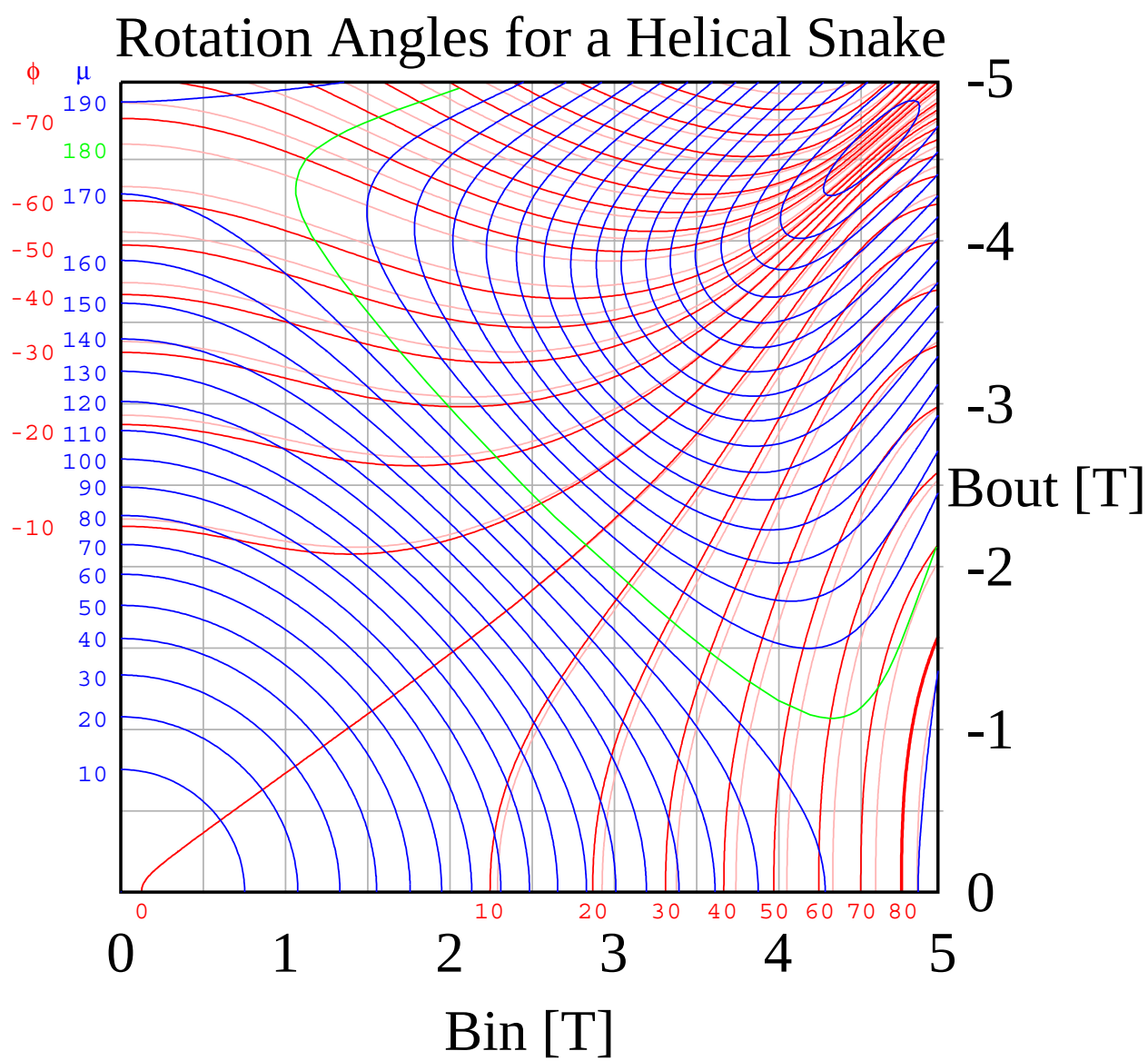




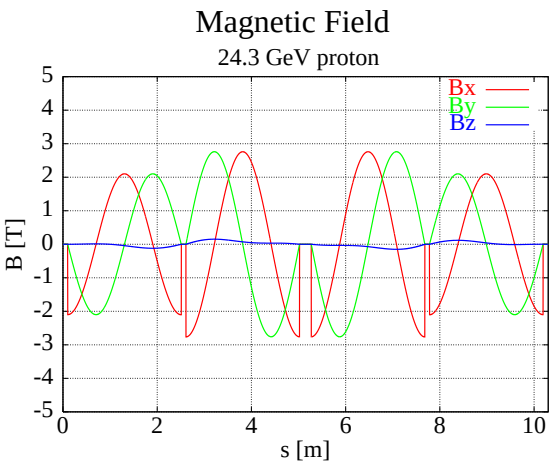


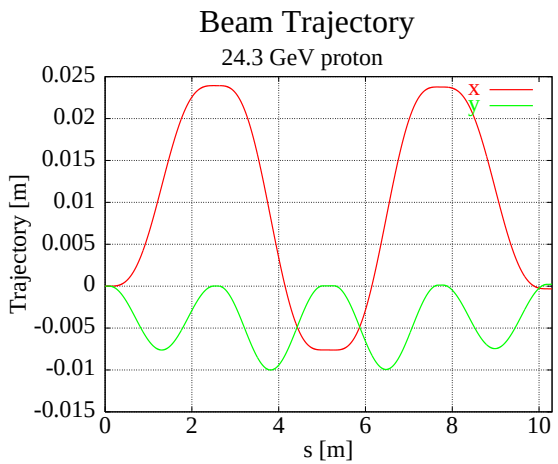
The rotation axis of the snake is ϕ, and μ is the rotation angle.

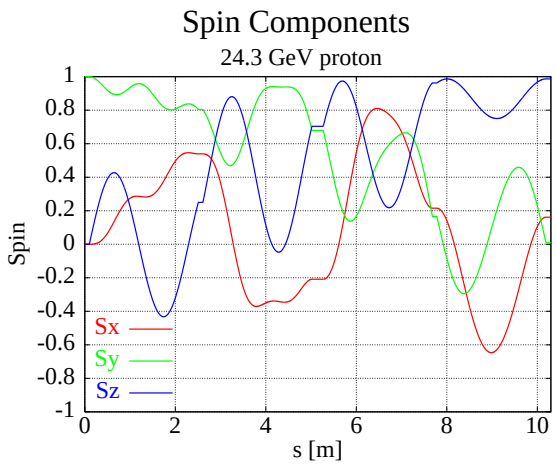
Note that the ϕ contours shift slightly from injection (red) at 25 GeV to storage (pink) at 250 GeV.

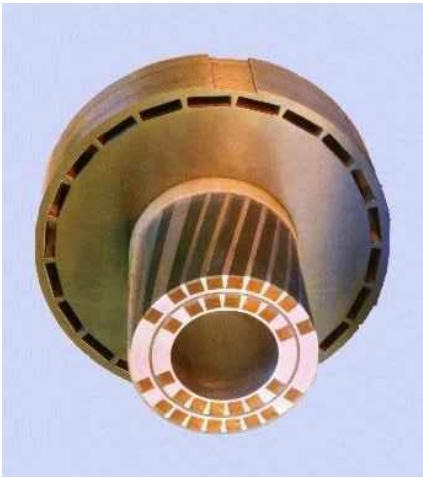


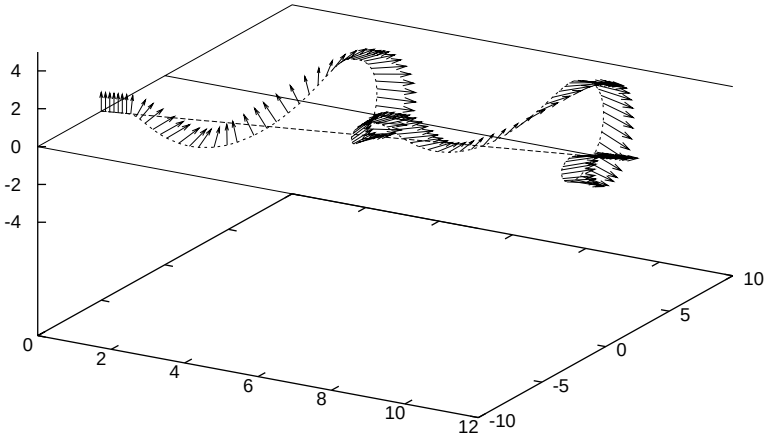
Helical Spin Rotators

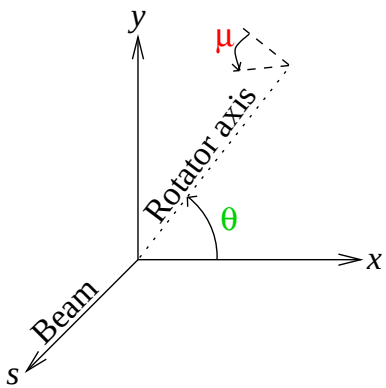






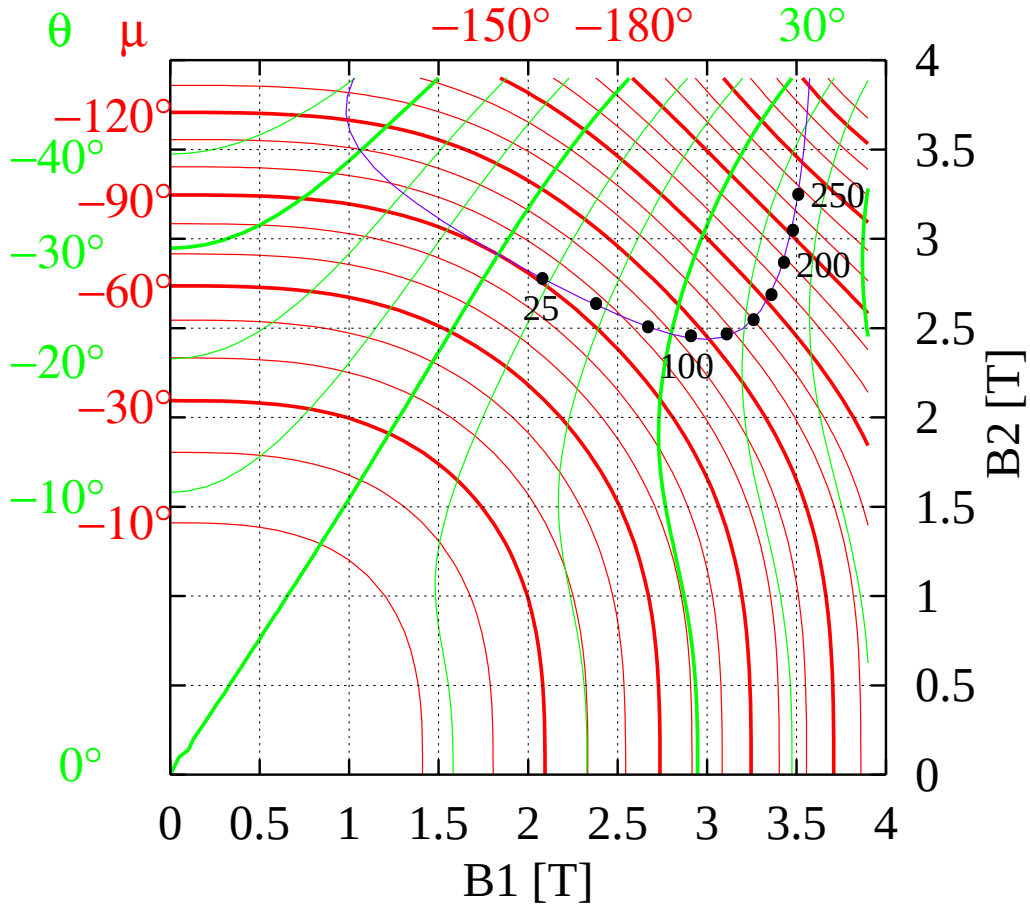






The rotation axis of the spin rotator is in the x-y plane at an angle θ from the vertical. The spin is rotated by the angle μ around the rotation axis.

Rotation Angles for a Helical Spin Rotator



Note: Purple contour for rotation into horizontal plane. Black dots show settings for RHIC energies in increments of 25 GeV from 25 to 250 GeV.

Rotator Axes and Precession

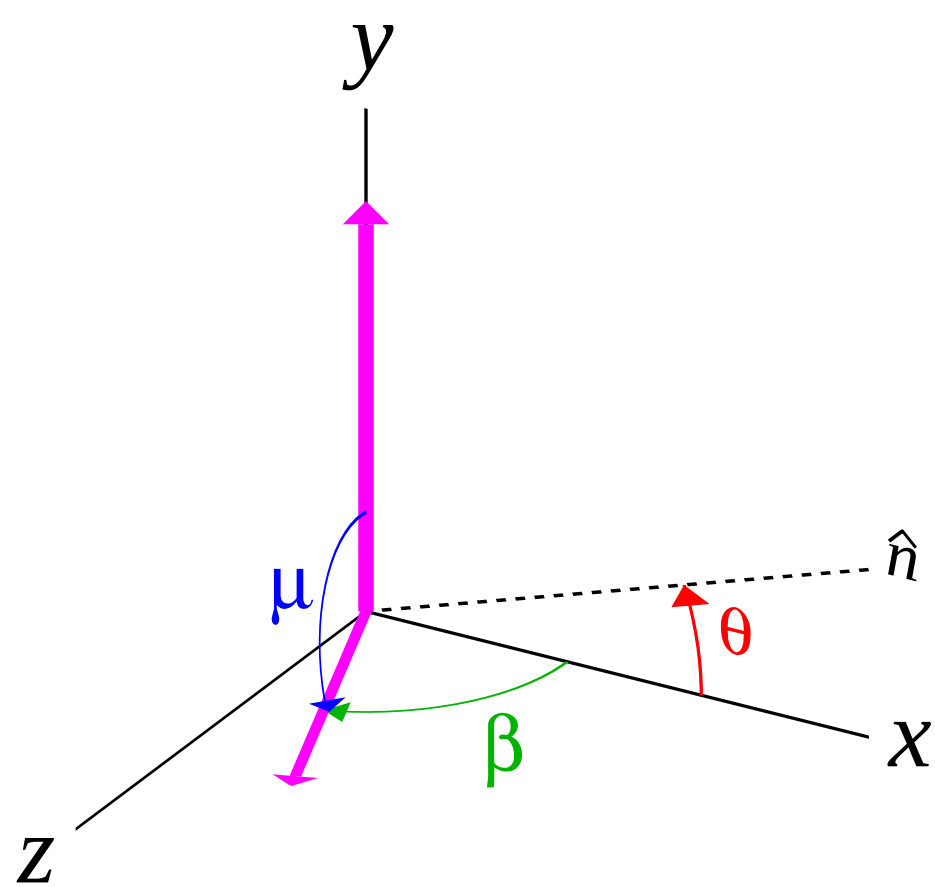
To precess the spin from vertical into the horizontal plane:

$$\sin\beta = \sin\mu\cos\theta$$
$$\cos\mu = -\tan^2\theta$$

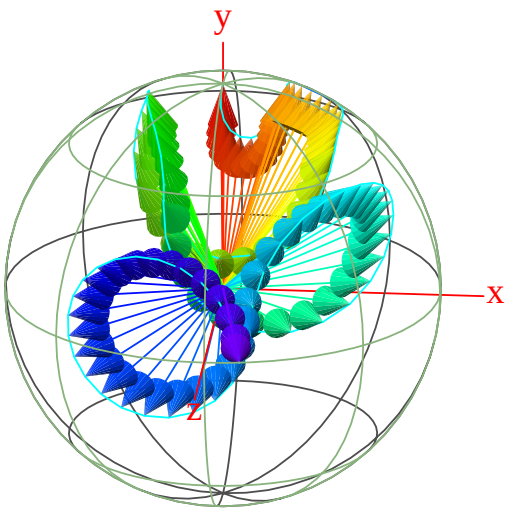
$$\mu \in [90°, 270°]$$
$$\theta \in [-45°, 45°] \cup [135°, 225°]$$

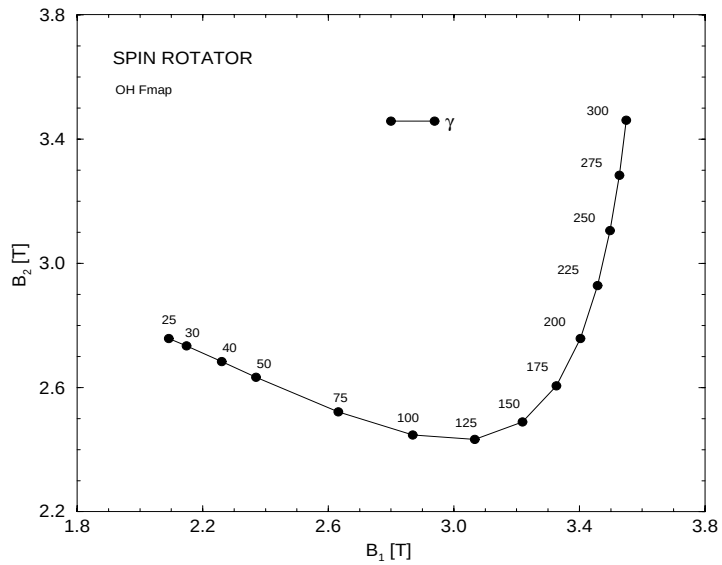
For longitudinal polarization want:

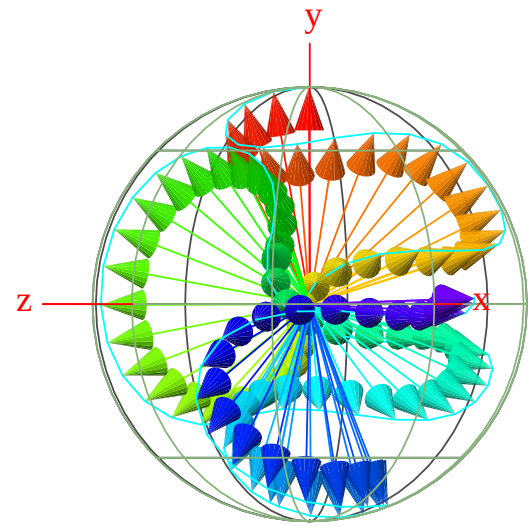
$$\beta = G\gamma \times \theta_{\mathrm{D0DX}}$$



Compensation for D0-DX Bends

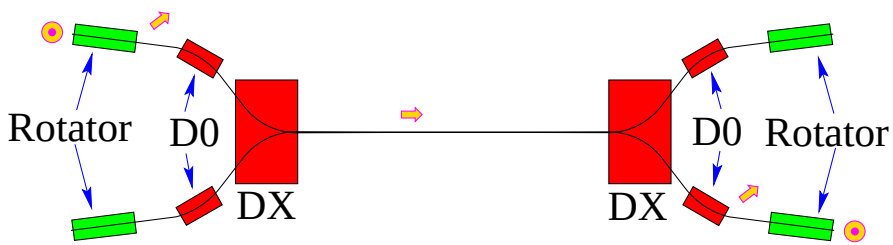






$E = 25$ GeV
D0DX: 10° precession

$E = 250$ GeV
D0DX: 100° precession



Formulae for a Single Rotator Helix

Parameters for a single RHIC rotator helix

Pitch: $k = \frac{2\pi}{\lambda}, \quad \lambda = 2.41$ m $\qquad$ [+(−) for right(left)-handed]

$\kappa = \frac{q}{p}(1 + G\gamma)B$

Rotation axis: $\hat{n} = \dfrac{k\hat{z} + \kappa\hat{x}}{\sqrt{\kappa^2 + k^2}}$

Precession angle: $\alpha = 2\pi\left(\sqrt{1 + \left(\frac{\kappa}{k}\right)^2} - 1\right)$

Transverse offset: $\Delta x = \dfrac{q}{p}\dfrac{B\ell}{k} = \dfrac{q}{p}\dfrac{\lambda^2}{2\pi}B$

Scaling Snakes and Rotators to He^3

Scaling of the field at maximum energy:

The maximum rigidity of the beams must the same: $r_{\max} = \frac{p}{q} = 834$ Tm

$$\gamma_{He^3} \simeq \frac{Z}{A}\gamma_p$$

Want the same precession, so κ must be the same.

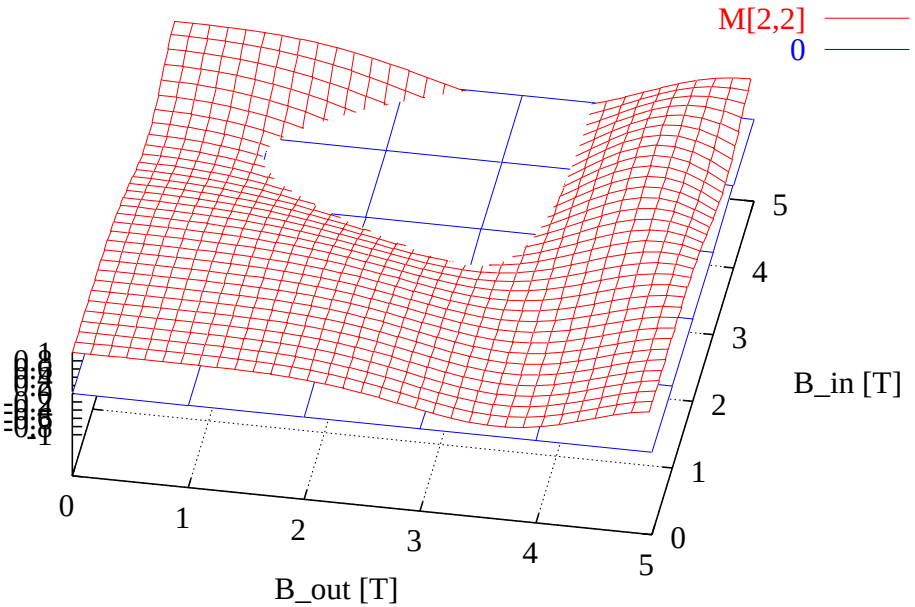
$$B_{He^3} \simeq \frac{1 + G_p\gamma_p}{1 + G_{He^3}\gamma_{He^3}} B_p$$
$$\simeq \frac{AG_p}{ZG_{He^3}} \simeq -0.643$$

Snake excursion at injection $r_{inj} = 81.1$ Tm (for protons):

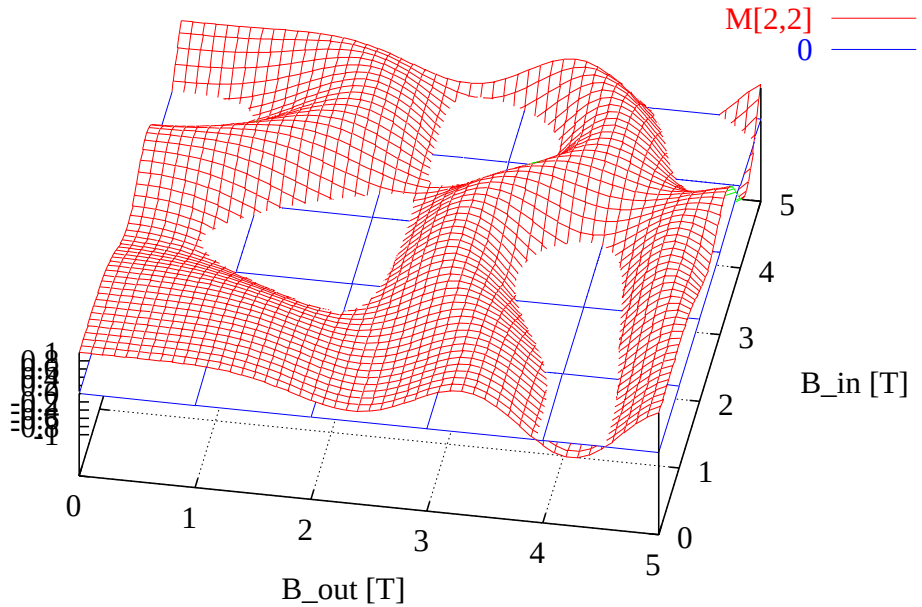
$$\Delta y = \begin{cases} 3.2 \text{ cm}, & \text{for protons} \\ -2.1 \text{ cm}, & \text{for } He^3 \end{cases}$$

Comparison of Rotators for He^3 and p

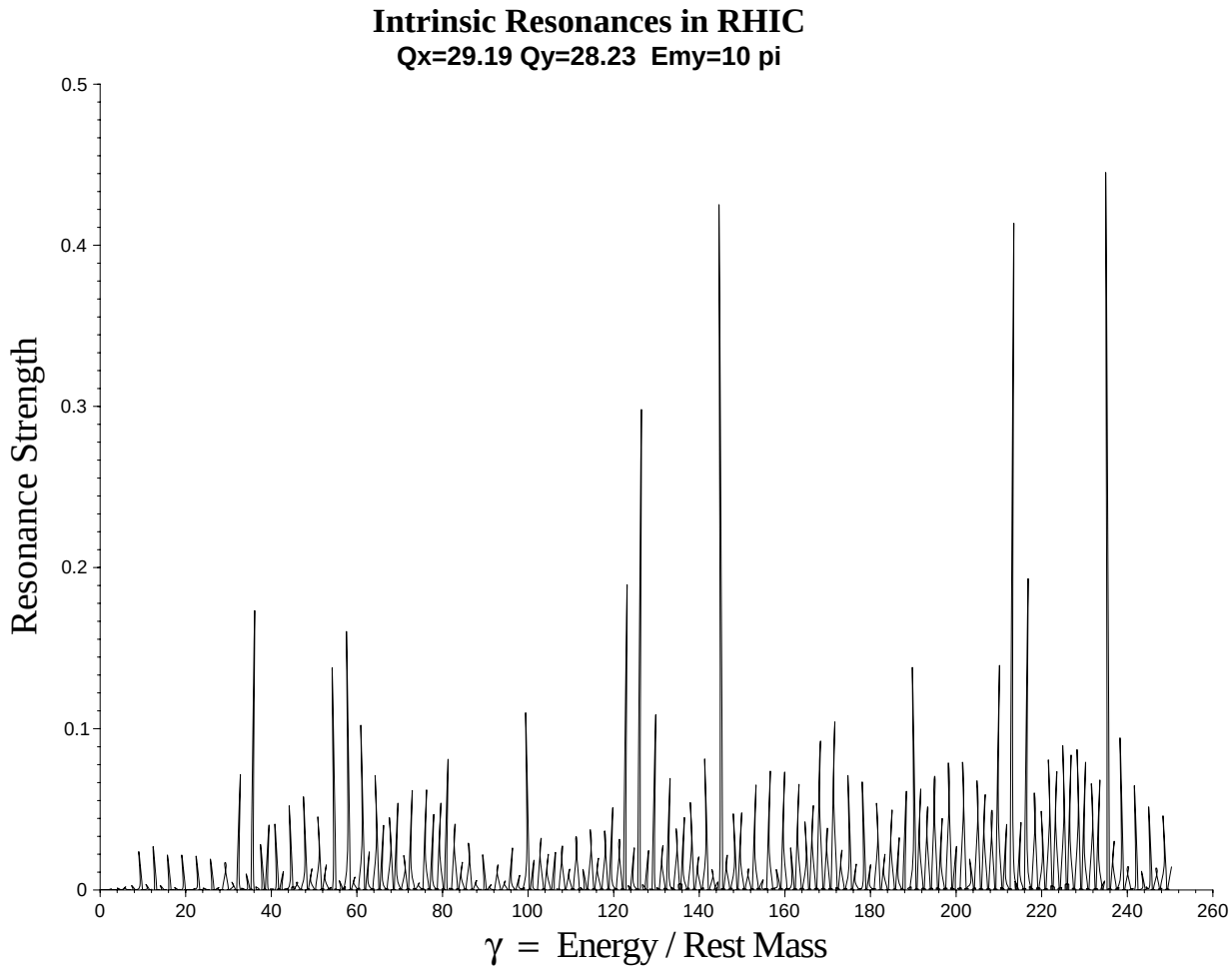
Spin rotator contours for protons at 250 GeV



Spin rotator contour for He3 at 500 GeV



Depolarizing Resonances for Protons



Will depolarize beam during acceleration.

Increase in strength with energy.

$$|G\gamma|_{\max} = \begin{cases} 477, & \text{p} \\ 743, & \text{He}^3 \end{cases}$$

Summary

- Spin precession and orbit excursions in snakes and rotators should work for protons eRHIC.
  - Snakes the same for protons.
  - If no "D0DX" bends for IR, then fields in rotators are essentially constant for all energies (like the snakes).

- He^3 requires less field in snakes and rotators.
  - Injection orbit excursions reduced.

- $|G\gamma|_{\max}$ is higher for He^3.
  - This needs to be investigated.