Driven Spin Coherent Precession at RHIC and RHIC Spin Flipper

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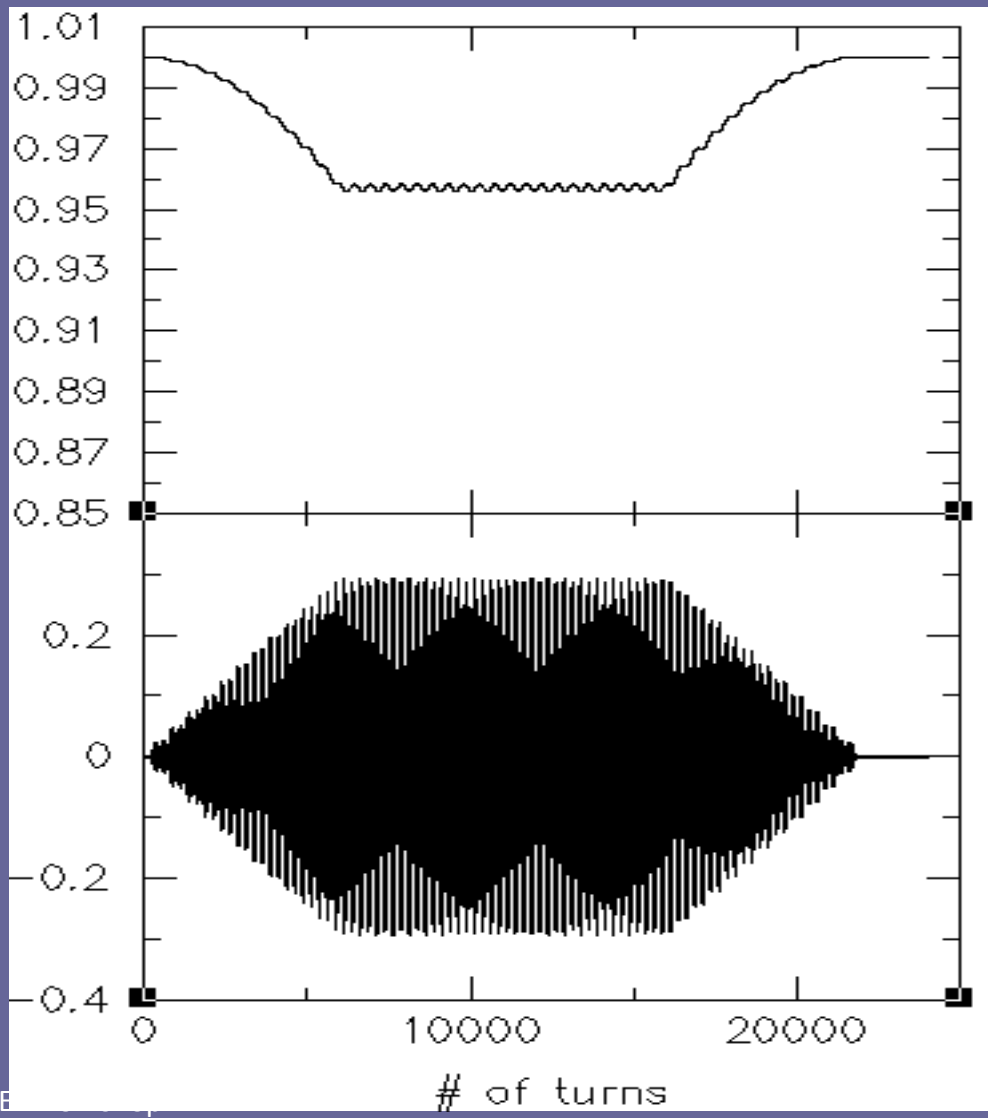
Spin coherent precession nearby an isolated resonance

- Vertical component

$$< P_y >= \frac{Q_{res} - Q_{spin}}{\sqrt{\left|Q_{res} - Q_{spin}\right|^2 + \left|\frac{\phi_{res}}{2\pi}\right|^2}}$$

- Horizontal component

$$P_x = \frac{\frac{\phi_{res}}{2\pi}}{\sqrt{\left|Q_{res} - Q_{spin}\right|^2 + \left|\frac{\phi_{res}}{2\pi}\right|^2}} \cos(Q_{res}\theta)$$

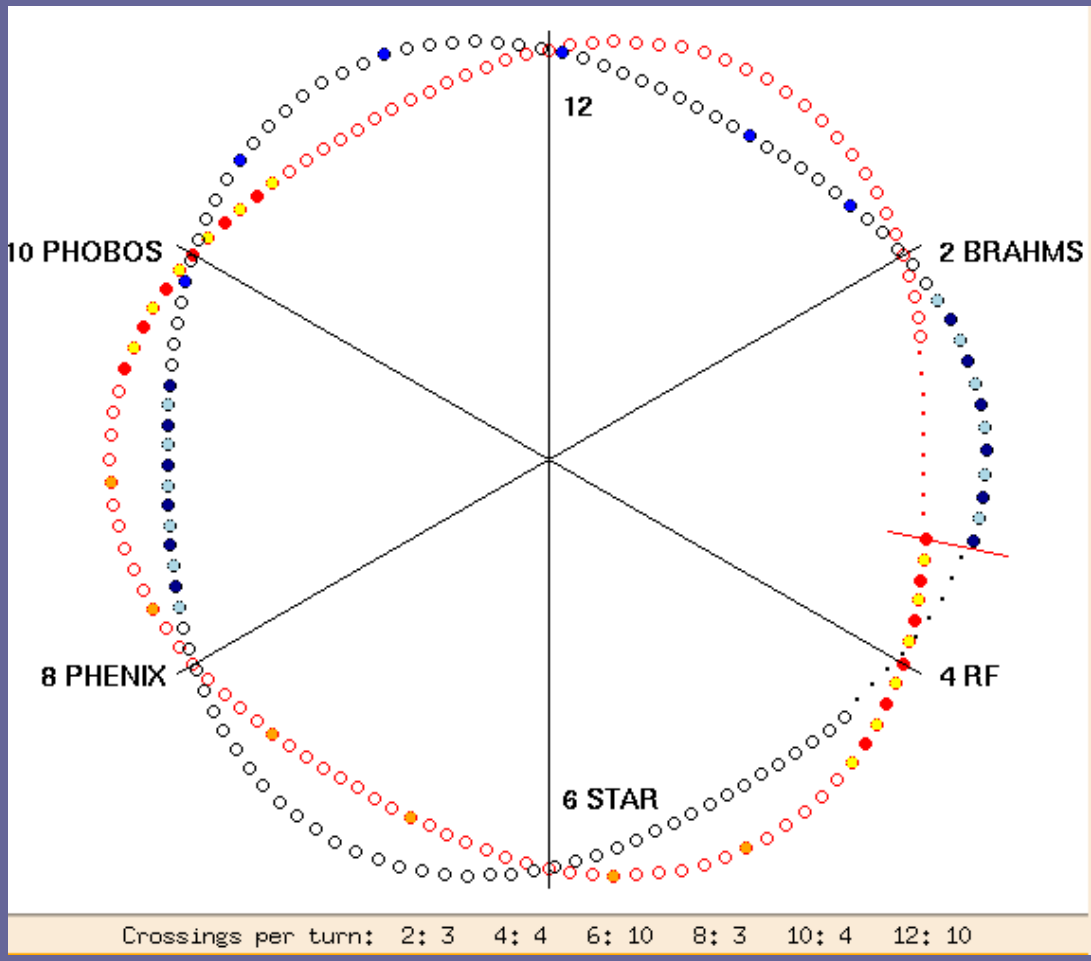


Experimental Setup

- RHIC injection Gγ=45.5
- RHIC polarization setup:
  - two Siberian snakes opposite side of the ring

    axes about which spin rotates: perpendicular
  - spin tune Qs=1/2
- A single ac dipole at 4RF
  - Maximum strength:
    - 79 Gauss-m

Fill pattern: two sets of 12 bunches with alternating spin signs



Data Analysis

- Data was taken with the RHIC CNI polarimeter
- Events for each detector each orbital revolution
- Horizontal asymmetry Y45 and vertical asymmetry X45 for each bunch in the frame which rotates at the ac dipole frequency

$$asymmetry = \frac{N_{top,j_bin} - N_{bottom,j_bin}}{N_{top,j_bin} + N_{bottom,j_bin}}$$

$$N_{k,j_bin} = \sum_{i}^{nturn} N_{k,i}$$

$$for\ i : (j_bin - 1)\frac{2\pi}{N_{bin}} \langle \sin(2\pi Q_{sp} i + \chi) \rangle\ j_bin \frac{2\pi}{N_{bin}}$$

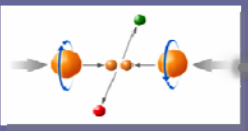
Data Analysis

- Average all the asymmetries for all bunches with the same spin sign, either up or down
- Asymmetry due to the coherent spin precession

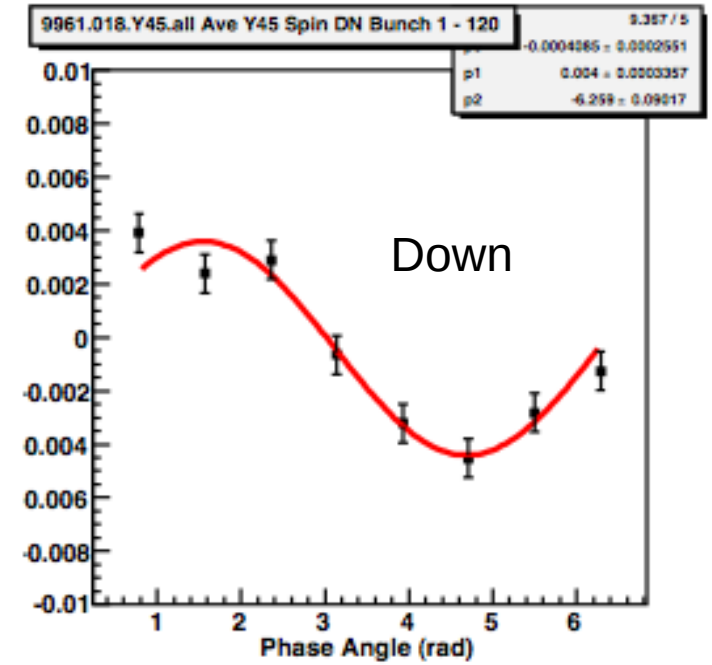
$$\frac{average_asymmetry_{spin\ up} - average_asymmetry_{spin\ dn}}{2}$$

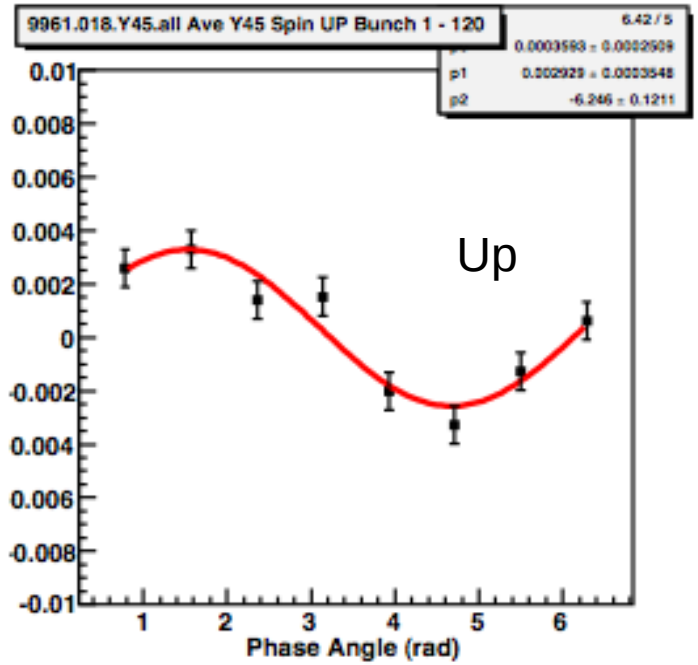
- False asymmetry due to systematic

$$\frac{average_asymmetry_{spin\ up} + average_asymmetry_{spin\ dn}}{2}$$

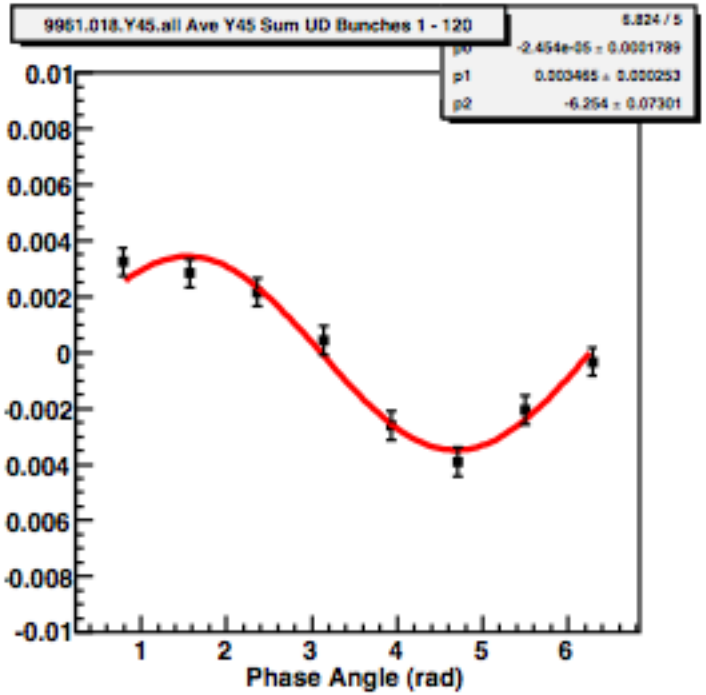


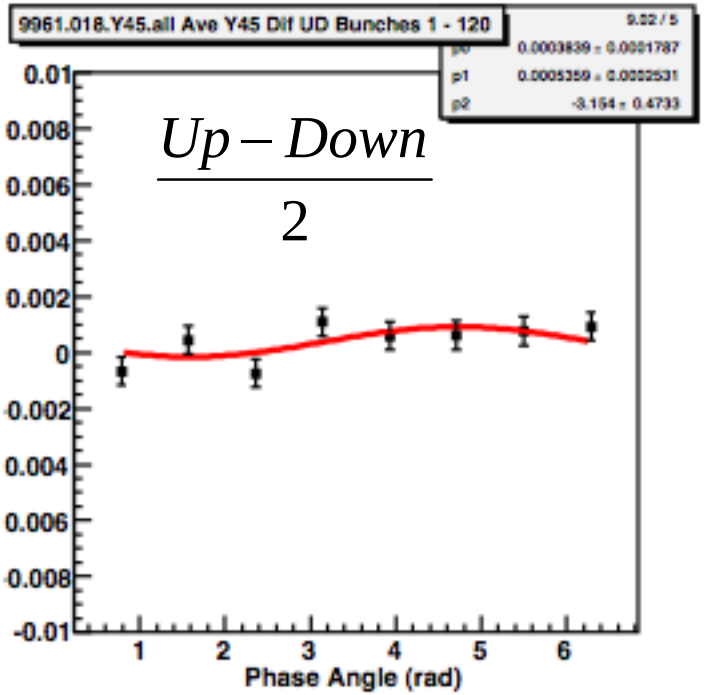
Average horizontal asymmetry for all the spin **down (left)** and spin **up (right)** bunches

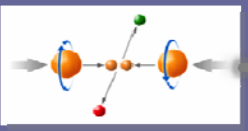




$$\frac{Up + Down}{2}$$

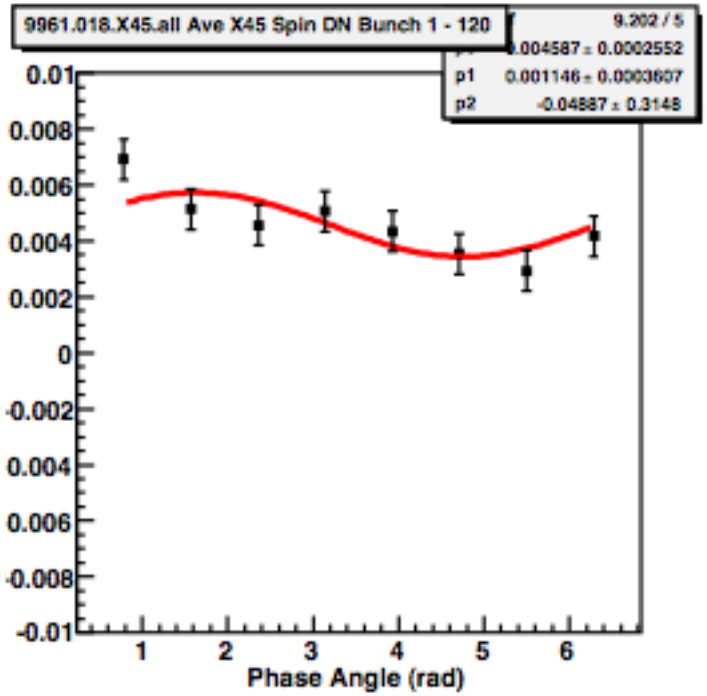


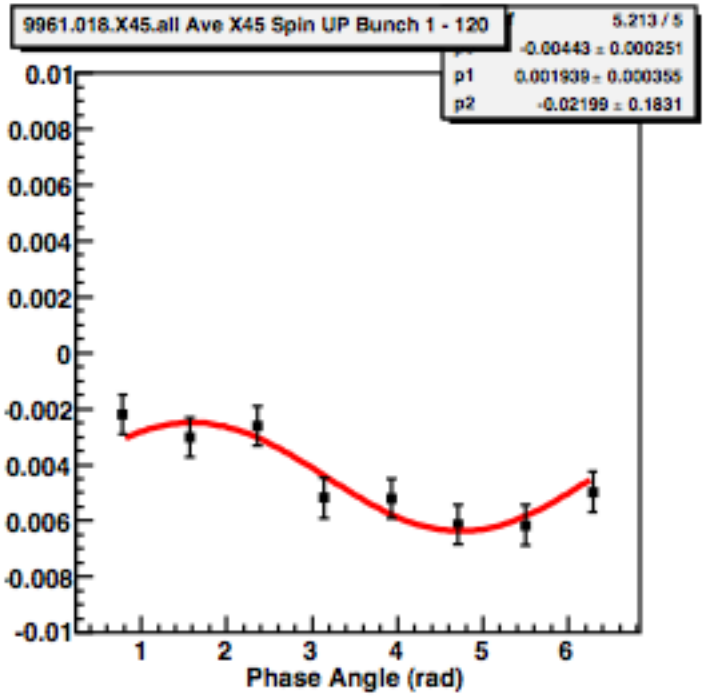


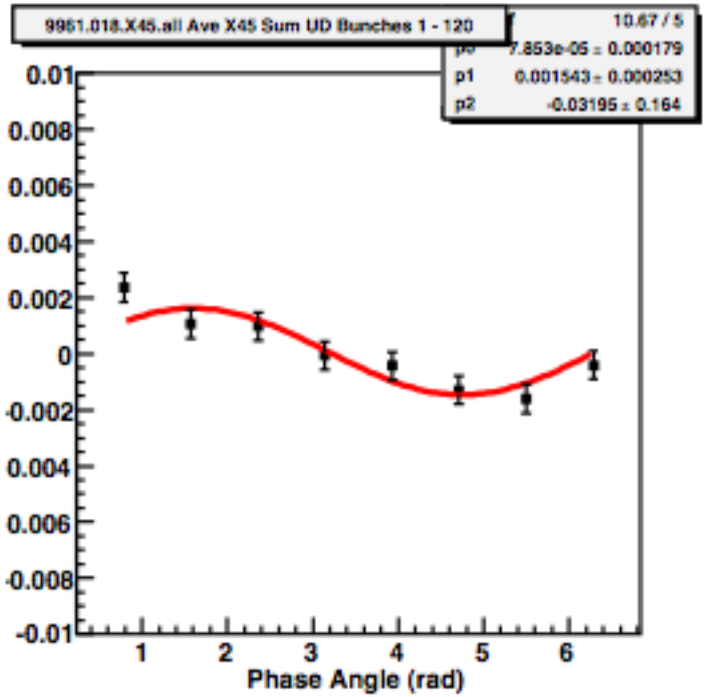


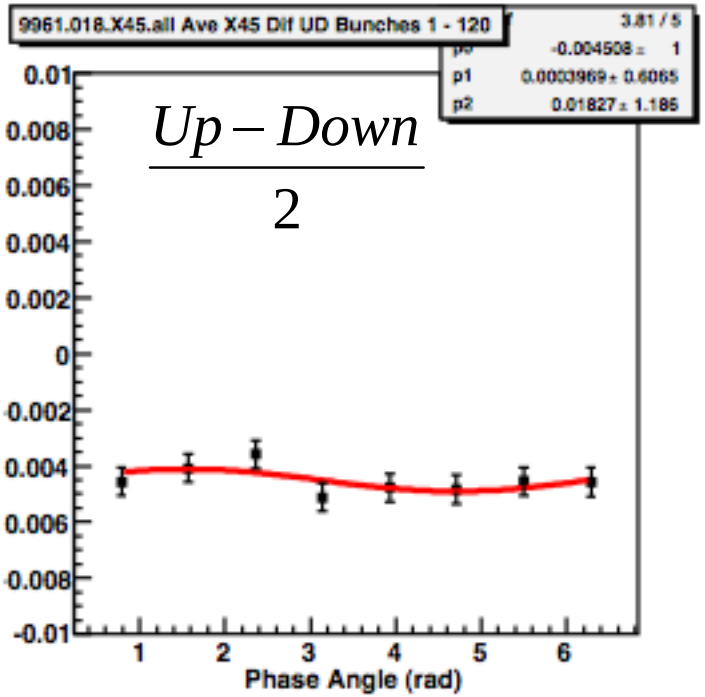
Average vertical asymmetry for all the spin **down (left)** and spin **up (right)** bunches

$$\frac{Up + Down}{2}$$









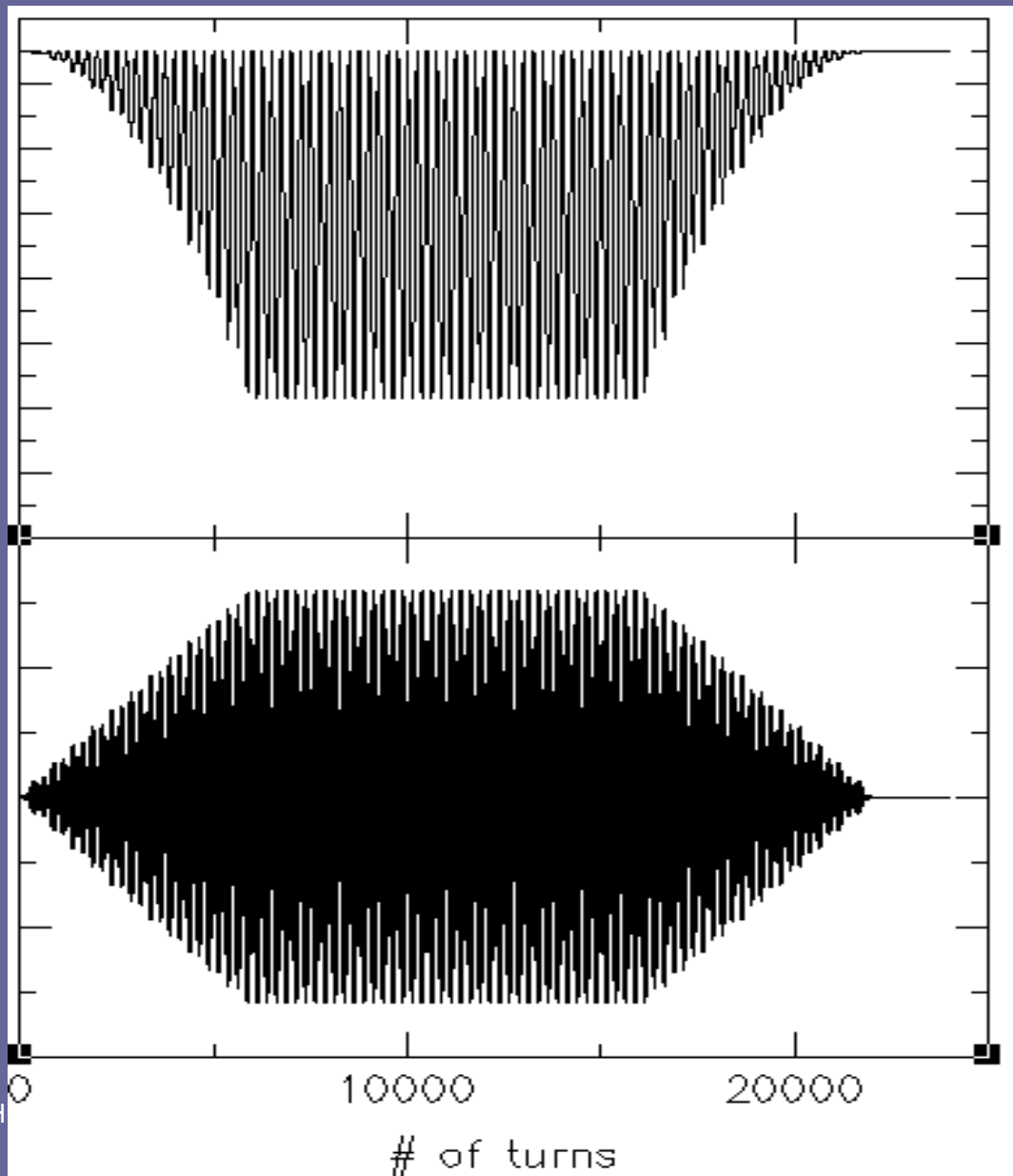
$$\frac{Up - Down}{2}$$

Summery

- A large fault asymmetry was observed due to the systematic
- The measured coherent spin precession was statistically insignificant. Suspect this is because it is difficult to adiabatically excite coherent spin precession with a single ac dipole
- Plan is to repeat the experiment with the new design of RHIC spin flipper

Single ac dipole

- Spin vector not only gets bent away from vertical but also wobbles from turn to turn

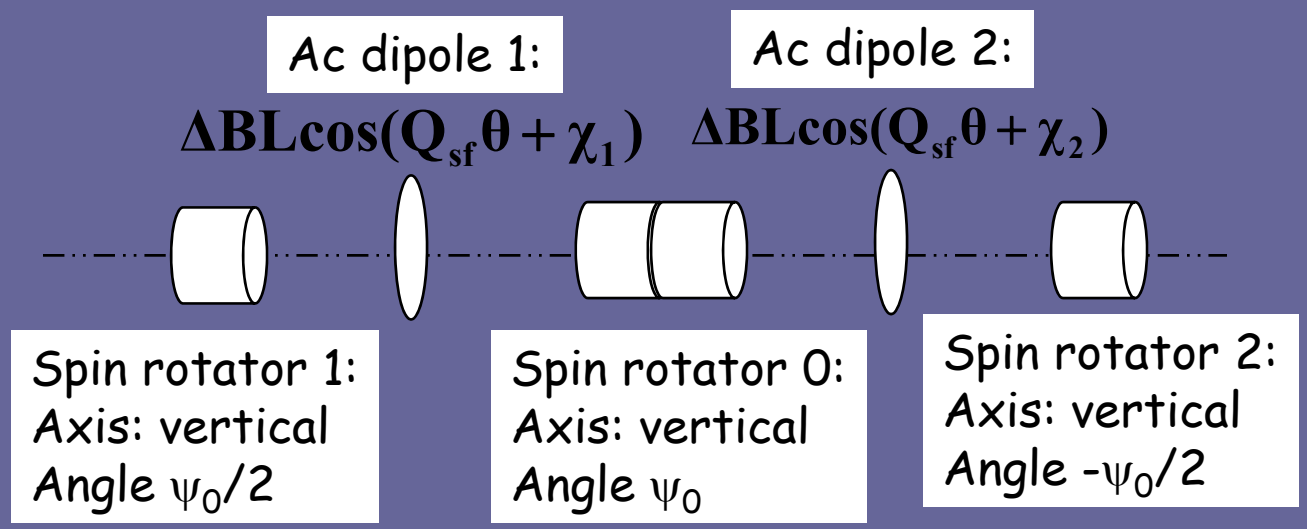


What is RHIC spin flipper

- Goal: Full spin flip with spin tune at ½

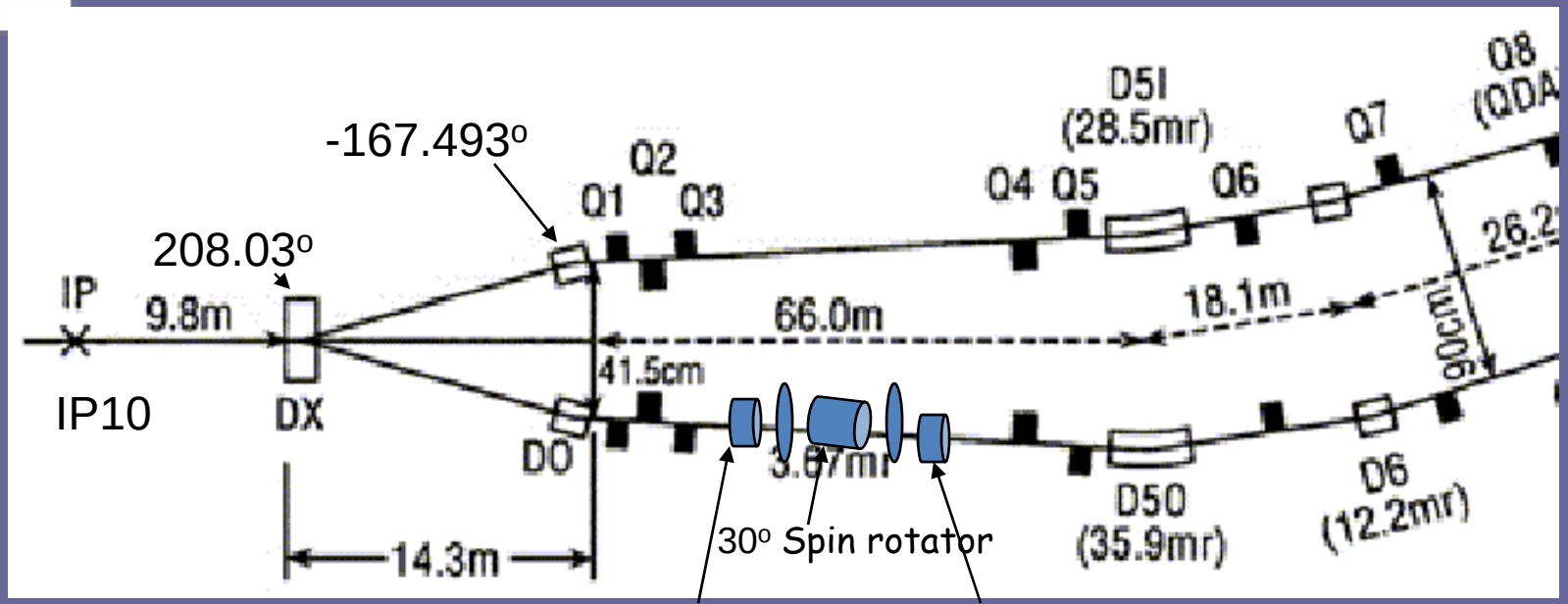
$$M_{\text{idealSpinFliper}} = e^{-\frac{i}{2}\psi(\cos Q_{sf}\theta\sigma_1 + \sin Q_{sf}\theta\sigma_2)}$$

- Schematic layout



$$\chi_1 - \chi_2 = 180^o + \psi_0$$

RHIC spin flipper Layout

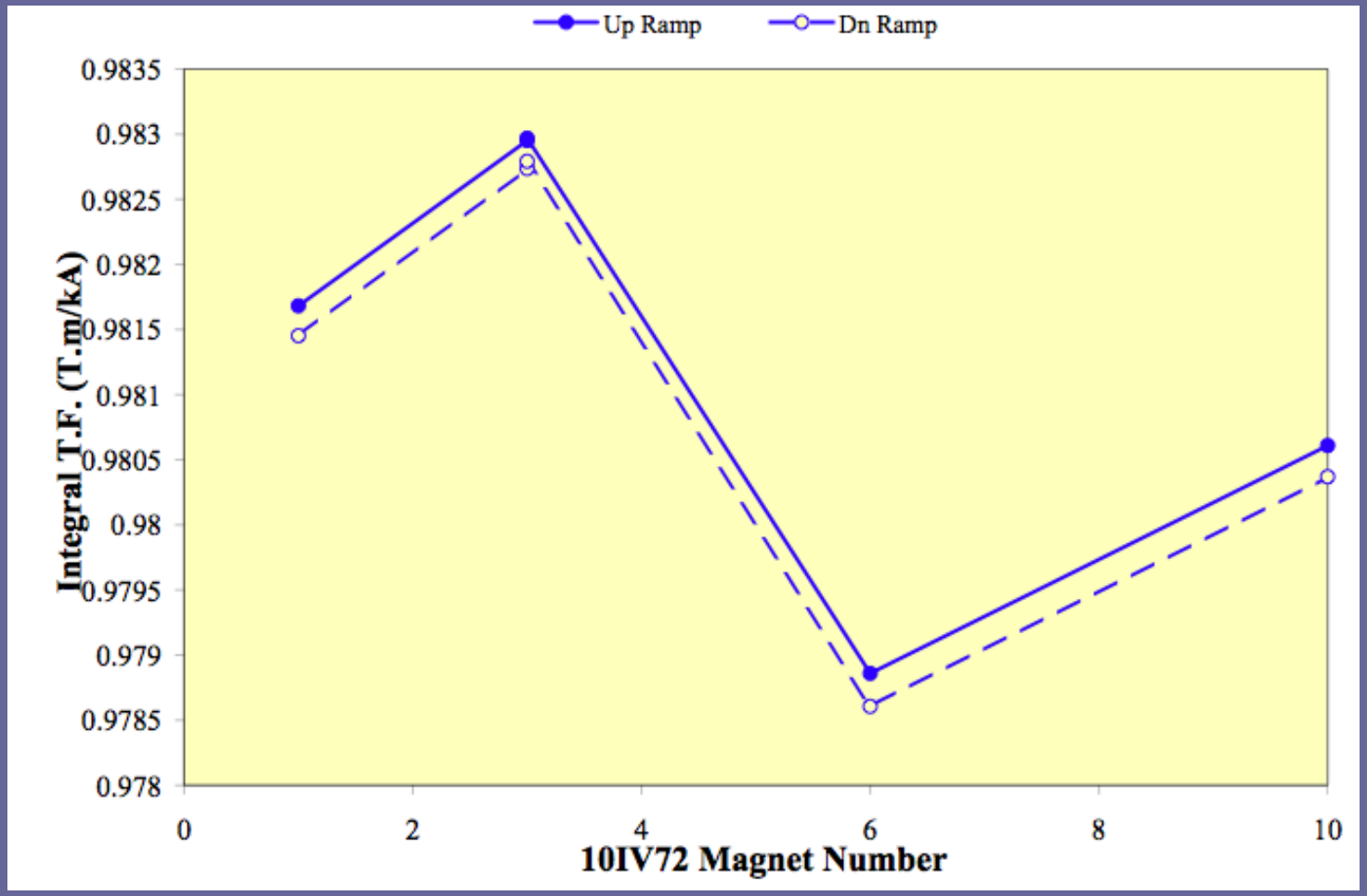


Specs:

- Ac dipole:
  - maximum field amplitude: 100 Gauss-m
  - frequency sweep range: ±400 Hz
- DC Spin rotator: DC dipole with vertical field
  - integrated field strength per magnet: 0.45 Tesla-m
  - dipole deflection:
    - 100 GeV: 1.35 mrad
    - 250 GeV: 0.54 mrad

RHIC spin flipper Status

- 4 DC dipoles were assembled and measured. By pairing, we can have an arrangement which yields less than 10^-3 integrated field strength of the 4 dipoles as expected



RHIC spin flipper Status

- The power supply which drives all 4 dipoles are tested and ready
- Two ceramic tubes were coated with TiN. The measured end2end resistance is about 250 Ohms.
- Resonant circuit design is done and parts were ordered
- Dynamic tuning was demonstrated with a half meter Litz wire air core magnet

RHIC spin flipper Status

- AC dipole coils expect to arrive mid of Dec.

RHIC spin flipper Plan

- To install DC dipoles and ceramic beam pipes in Dec and early Jan.
- Install AC dipole and others in mid to late January
- System ready end of January
- With beam
  - Check the 4 dipole polarity and calibrate their strength at injection
  - Check whether the local orbit bump induced by the 4 DC dipoles is closed at store. If not, we then need to turn them on somewhere during the ramp and keep it as part of the ramp
  - calibrate ac dipole strength at injection and check the tune sweep
  - Commission spin flipping at store

Backup slides

Conclusion

- Large polarization loss at the vicinity of the spin tune

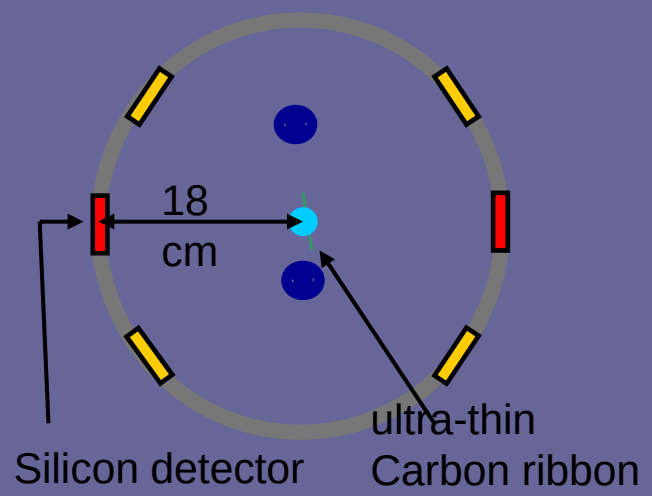
- The data suggests a rather large spin tune spread
- In the presence of two full snakes, the source of spin tune spread
  - Difference in the divergence of the beam at the two snakes: ~ 0.002 for a 25 pi mm-mrad
  - Difference between the snake orbital angle due to dispersion: ~ 0.0001

- Simulation indicates spin tune spread modulate at low frequency like synchrotron oscillation can lead to large polarization loss

Conclusion

- The vertical coherent oscillation. This causes the oscillation of
  - solid angle Ω
    - False asymmetry ~ Ω^2
  - Scattering angle θ
    - False asymmetry due to coulomb scattering cross section θ dependence

$$\sigma_c \sim \frac{1}{\sin^4(\frac{\theta}{2})}$$

    - Need actual geometry of the CNI polarimeter to estimate

$$\begin{pmatrix} \theta \\ \Omega \end{pmatrix} \sim \sin\left(Q_{sp} 2\pi i + \chi\right)$$