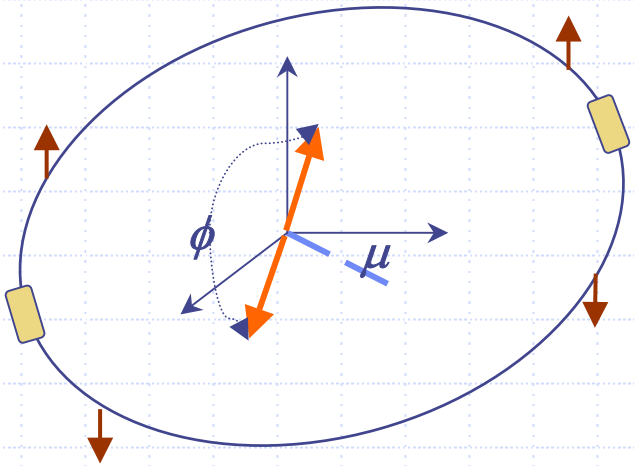
Polarized Beam Manipulations

RHIC 2002 Retreat, Mei Bai

- RHIC polarized proton setup
- Spin manipulation using a dipole with horizontal oscillating magnetic field
- Rhic spin flipper commissioning
- Future plans

RHIC polarized proton setup



- Two full snakes apart from each other by 180° in phase
- Stable spin direction in which the spin precesses around is vertical.
- Spin precession frequency is given by

$$\nu_s = \frac{1}{\pi}\left|\mu_1 - \mu_2\right|$$

and is independent of beam energy.

In RHIC, the two snakes' axes are perpendicular to each other and the nominal spin tune is 1/2.

Spin motion in the presence of the ac dipole

- Thomas BMT equation

$$\frac{d\vec{S}}{dt} = \vec{\Omega} \times \vec{S} = -\frac{e}{\gamma m}(1 + G\gamma)\vec{B}_{\perp} \times \vec{S}$$

where

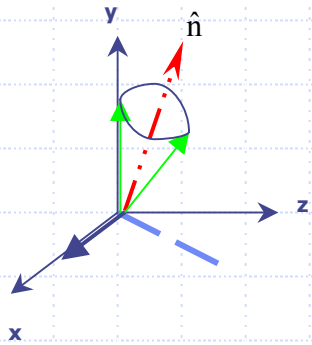
$$\vec{B}_{\perp} = B_m \cos \nu_m \theta \, \hat{x}$$

A spin resonance then happens when $\nu_s = \nu_m$

The strength of this resonance is

$$\varepsilon = \frac{1}{4\pi}(1 + G\gamma)\frac{B_m L}{B\rho}$$

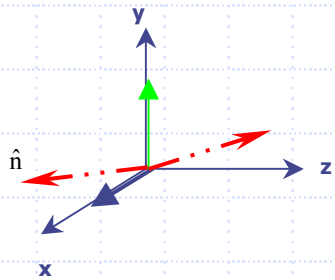
For $B_m L$=100 Gauss-m and 100 GeV/c pp, the resonance strength is 0.00046.



Spin manipulation using ac dipole

- In the frame which rotates at the same frequency as the drive frequency, the stable spin direction becomes

$$\hat{n} = \frac{\delta}{\lambda}\hat{e}_3 + \frac{\varepsilon}{\lambda}\hat{e}_1$$



where: $\delta = \nu_m - \nu_s$ and $\lambda = \sqrt{\delta^2 + \varepsilon^2}$

- fixed drive frequency

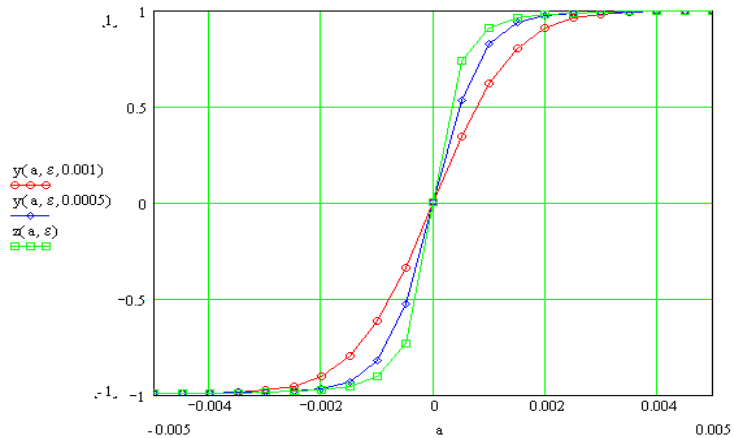
$$P_f = P_i\left(1 - 2\frac{|\varepsilon|^2}{\lambda^2}\sin^2\left(\frac{\lambda}{2}2\pi f_0 \Delta t\right)\right)$$

-- measure the spin tune

- crossing through the resonance

$$P_f = P_i\left(2e^{-\frac{\pi|\varepsilon|^2}{2\alpha}} - 1\right)$$ -- spin flipping

where $\alpha = \frac{|\nu_b - \nu_e|}{2\pi f_0 \Delta t}$

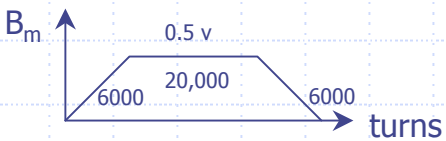


Spin flipper commissioning

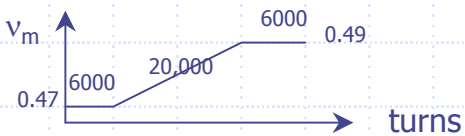
------- Blue Ring

- Setup:
  - snake:
    - inner current=325.06A
    - outter current=106.11A

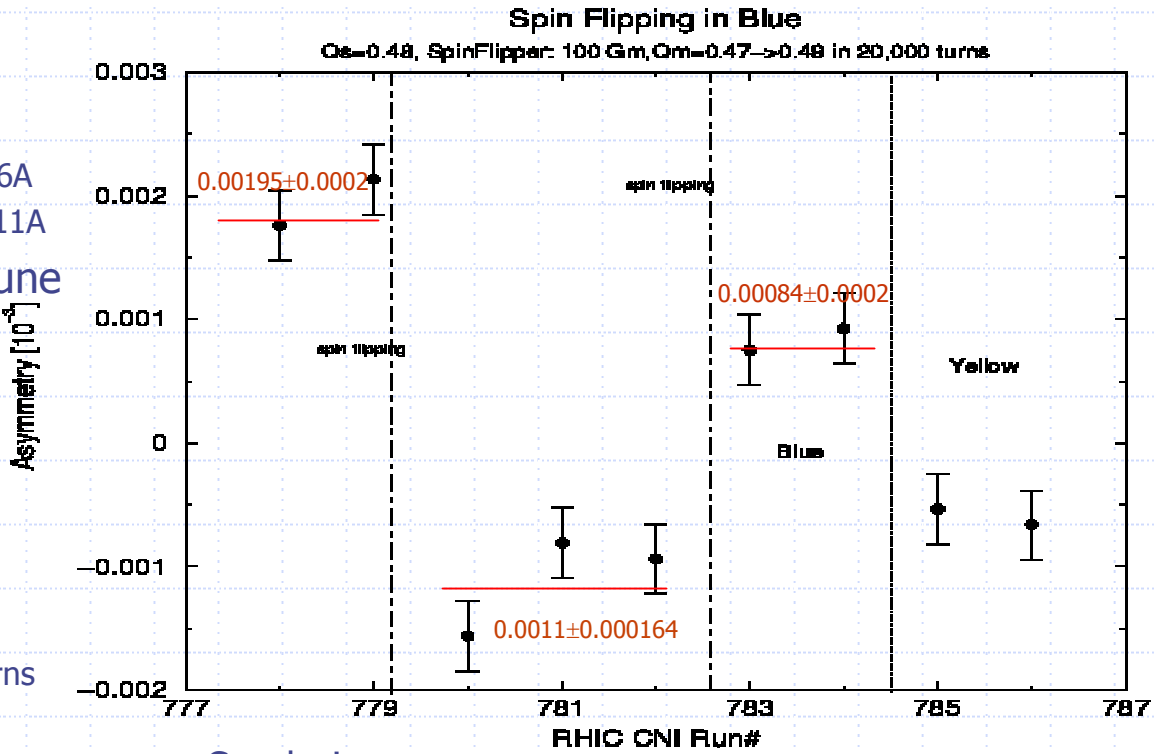
    the predicted spin tune equals to 0.48.
  - Spin flipper:
    - amplitude:



    - frequency



$$\alpha = 1.6 \times 10^{-7}$$



Conclusions:

- spin flip efficiency η

$$P_2 = P_1\eta = P_0\eta^2 \qquad \eta \approx 0.66$$

- yellow beam

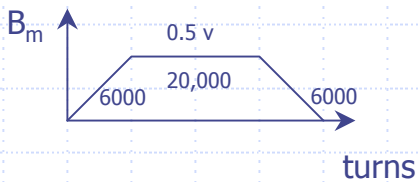
The fact that we measured negative asymmetry after we spin-flipped twice in Blue is very hard to understand is consistent with that the yellow beam was actually fully depolarized. while we were spin flipping the blue beam. This suggests that the yellow beam spin tune is away from 0.5.

Spin flipper commissioning

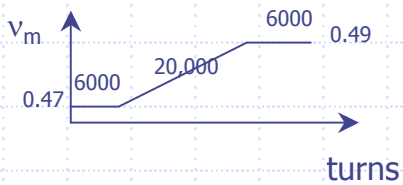
--------- Yellow Ring

- Setup:
  - snake:
    - inner current=106.9A
    - outer current=323.5A

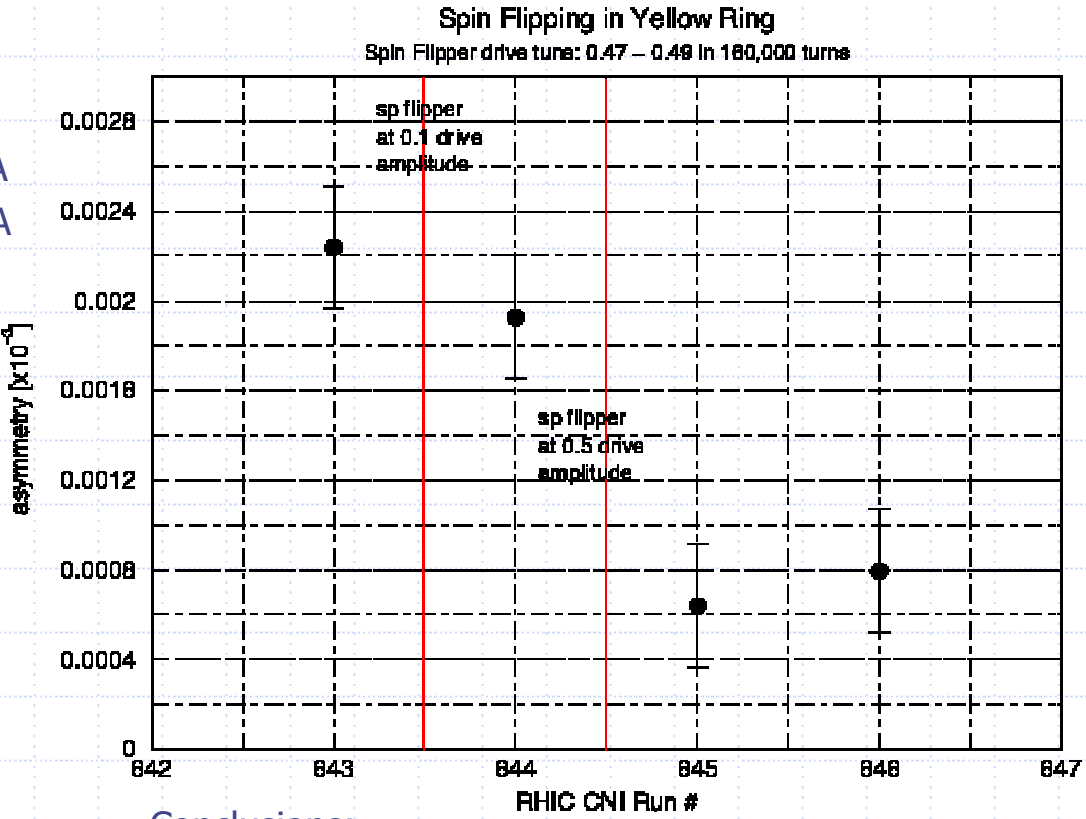
    predicted spin tune equals to 0.48.
  - Spin flipper:
    - amplitude:



    - frequency:



$\alpha = 2.0 \times 10^{-7}$



Conclusions:

No spin flip was achieved in Yellow. Instead, the yellow beam was partially depolarized. This could be because spin tune with the snake setting of (inner106.9A, outer323.5A) doesn't equal to 0.48.

Problems during RHIC pp 2002

- Spin flipper
  - The $\pm$ 0.2mm coherent betatron oscillation caused snake quench twice at injection due to the limitation of the aperture.
  - The resolution of the snake WFG.
- Down ramp
- Not enough time

Plans for the next run

- Commission the spin rotators.
  - two pairs of spin rotators will be installed for next RHIC pp run.
- measure the polarization profile to resolve the puzzle we had at the end of the last run
  - at the end of last RHIC pp run, we measured the asymmetry as function of the yellow target vertical position. The data showed higher asymmetry for the particles further away from the core of the beam.
- downramp. For this, again we need PLL.
- Measure the spin flipping efficiency in both blue and yellow ring
  - this allows us to assess how well the spin flipper behaves
  - prefer to do the measurement at store.
  - No new instrumentation is needed provided the RHIC CNI polarimeter will be available

Plans for the next run

- Measure the spin precession tune to calibrate the snake setting
  - the spin flipping data we took during this run indicates that the spin tune corresponding to the nominal snake setting is away from 0.5.
  - prefer to do this both at injection and at store. However, due to the tight aperture, the measurement at injection requires a local orbit bump in the snake to avoid quenching the magnet.
  - The alternative way to measure the spin tune by measuring the beam polarization before and after turning on the ac dipole at a fixed frequency is to measure the asymmetry while sweeping the ac dipole frequency. The zero crossing of the measured asymmetry is where the spin tune locates. However, this requires to upgrade the current RHIC CNI polarimeter to allow one to measure the beam polarization continuously in couple of seconds.