# FY2001 Polarized Proton Commissioning

*W. Mackay*

RHIC Spin Collaboration Meeting
October 1, 2001
RIKEN BNL Research Center, Brookhaven National Laboratory

# FY2001 Polarized Proton Commissioning

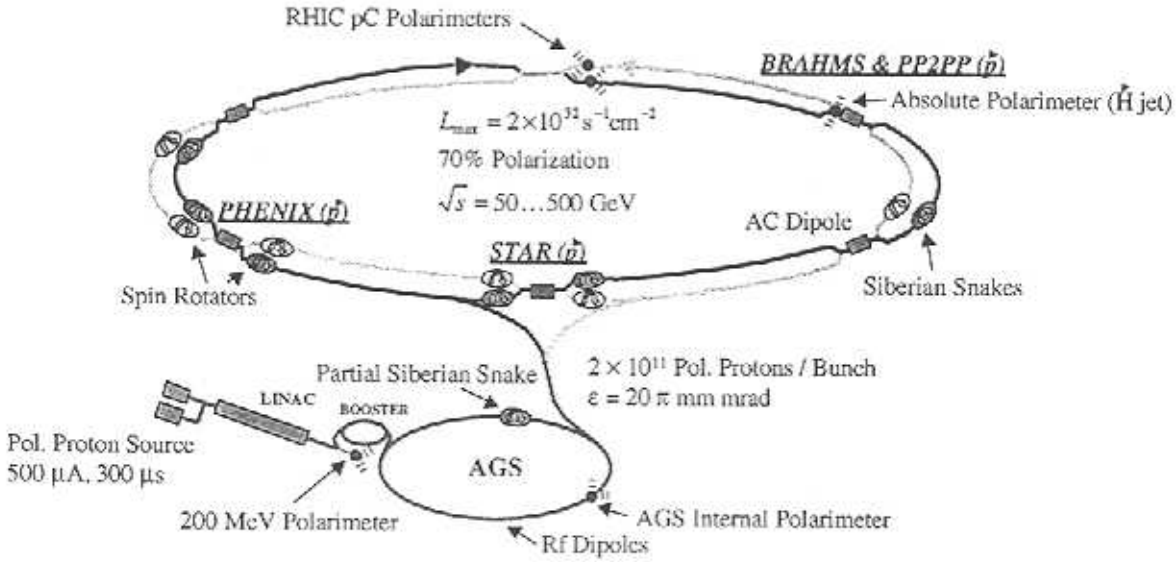
- Layout of Accelerator Complex.
- Goals for FY2001 Run.
- Setup for Snake Charming.
- How the snakes work.
- $2 \Rightarrow 1$ snake ramp for longitudinal polarization.
- Schedule

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

1

# Polarized Protons in RHIC




BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

# Goals for FY2001 Run

- 2 pC-CNI polarimeters (1 per ring) installed.✓
- 4 snakes (2 per ring) installed.✓
- 8 power supplies (2 per snake).
  - installed.✓
  - not yet operational.

- Provide 100 GeV × 100 GeV collisions with long. pol. at all IR's.
  - Hope to achieve at least 50% polarization per beam.
- Accelerate polarized protons to 250 GeV.

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

3

# Injection and Storage Energies

| | Injection | Nominal Store | Top Energy |
|---|---|---|---|
| $G\gamma$ | 46.5 | 192 | 477.6991 |
| $\gamma$ | 25.9364 | 107.0922 | 266.4472 |
| $U$ (total energy) | 24.3354 GeV | 100.4817 GeV | 250 GeV |
| $p/q$ | 81.1138 Tm | 335.1561 Tm | 833.9044 Tm |
| $I_{\text{dipole}}$ | 473.923 A | 1954.18 A | 5067.303 A |

$$(G = 1.7928474 \quad mc^2 = 0.93827231 \text{ GeV} \quad c = 299792458\text{m/s})$$

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

## Setup for Snake Charming

Systems to commission:

1. 2 polarimeters (yellow, and new electronics for blue)
2. ac dipole (spin flipper)
3. 4 snakes (8 power supplies): orbit; spin
4. phase-locked loops for betatron-tune control
5. polarization info transfer to experiments (CDEV)
6. injection pattern program (new version)

New ramps ($\beta^* = 10$ m):

1. acceleration $G\gamma : 46.5 \Rightarrow 192$ (all snakes on)
2. deceleration $G\gamma : 192 \Rightarrow 46.5$ (all snakes on)
3. at fixed field $2 \Rightarrow 1$ snakes at fixed energy
4. possible commissioning of $\beta$-squeeze at 100 GeV

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001



## Considerations

Orbit correction:

- Locally correct the orbit at snakes.
- Flatten vertical orbit in ring ($\sigma_v \lesssim 0.2$ mm).
- Keep orbit flattened during the ramps.

Energy ramps:

- ○ May have to ramp snakes slightly with energy ($\sim$6 A).
- ○ Ramp local corrections to snake orbits?
  (First snake required 0.18 mr vertical correction at injection.)
- First try with constant currents in snakes.
- Decelerate beam back to injection energy.

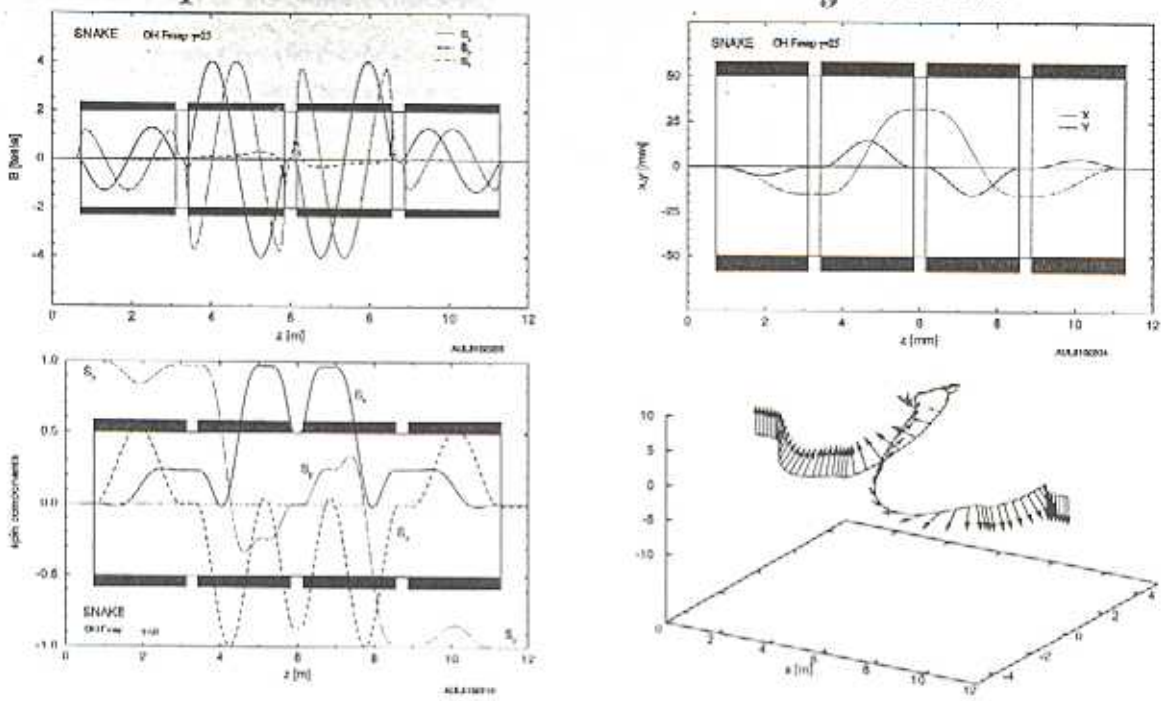
Polarimeters:

- Vert polarization with both snakes at injection.
- Horiz polarization with single snake at storage
- ○ Measure polarization during certain intervals during energy ramps.

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

# Operation of Snake at Injection



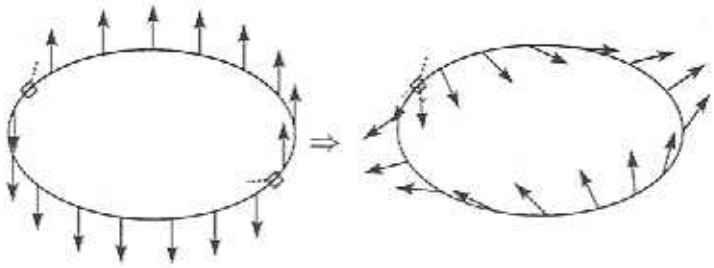

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001



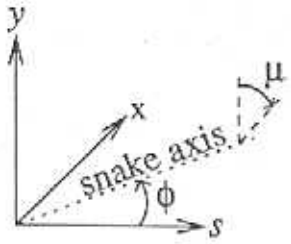
# Longitudinal Polarization in RHIC

- Inject vertically polarized protons with both snakes on.
  $E \sim 24.3$ GeV ($G\gamma \sim 46.5$)
- Accelerate beams to 100.48 GeV ($G\gamma = 192$)
- Turn off one snake in each ring: polarization $\Rightarrow$ horizontal plane.
  (Long. Pol. at IR's.)



BROOKHAVEN NATIONAL LABORATORY

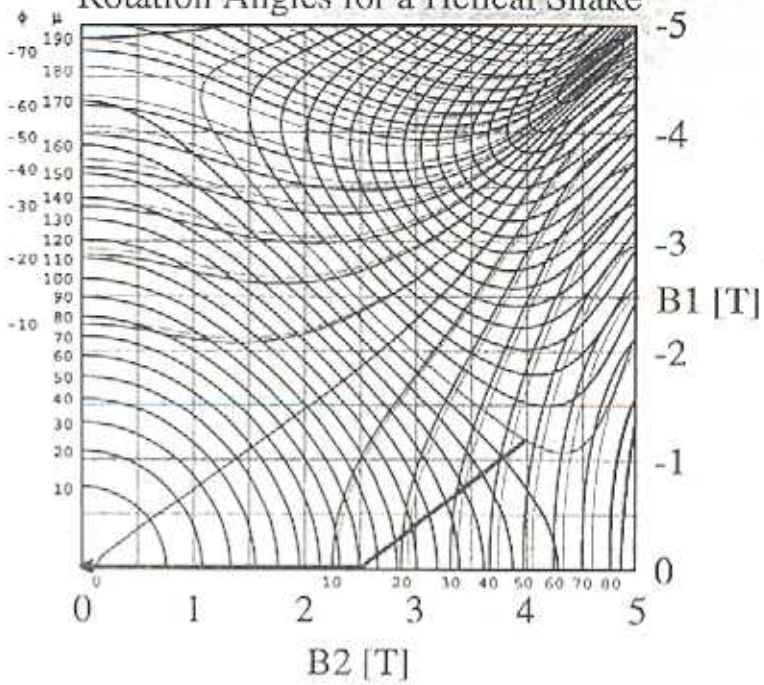
RHIC Spin Collaboration
1 October, 2001




The rotation axis of the snake is $\phi$, and $\mu$ is the rotation angle.

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

## Rotation Angles for a Helical Snake

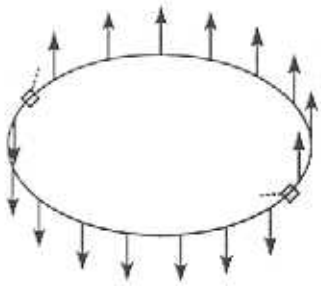



BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

9

Spin tune with two snakes $[\mu_1, \phi_1]$ and $[\mu_2, \phi_2]$ on opposite sides of ring: $\nu_{sp} = \delta/2\pi$ where



$$\cos\frac{\delta}{2} = \cos\frac{\mu_2}{2}\cos\frac{\mu_1}{2}\cos G\gamma\pi - \sin\frac{\mu_2}{2}\sin\frac{\mu_1}{2}\cos(\phi_2 - \phi_1).$$

and $G = \frac{g-2}{g} = 1.7928$ for protons.

For $\mu_1 = \pi$,

$$\cos\frac{\delta}{2} = -\sin\frac{\mu_2}{2}\cos(\phi_2 - \phi_1),$$

$\nu_{sp} = 0.5$ for either $\mu_2 = 0°$ or $\phi_2 - \phi_1 = 90°$.

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

# Calibration of Snakes

Two snakes:

- Set two snakes in one ring for best guess at $\mu_{1,2} = 180°$ and $\phi_{1,2} = \pm 45°$.
- Adjust currents to move along $\mu = 180°$ contour to have $\Delta\phi = 90°$ ($\nu_{sp} = 0.5$).
  We can assume equal but opposite currents for the 2 snakes.

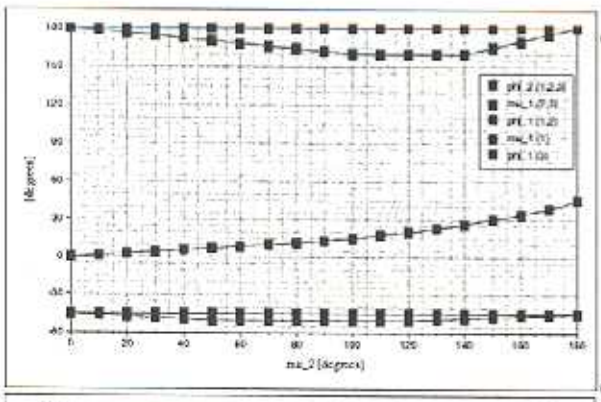
$2 \Rightarrow 1$ snake ramp:

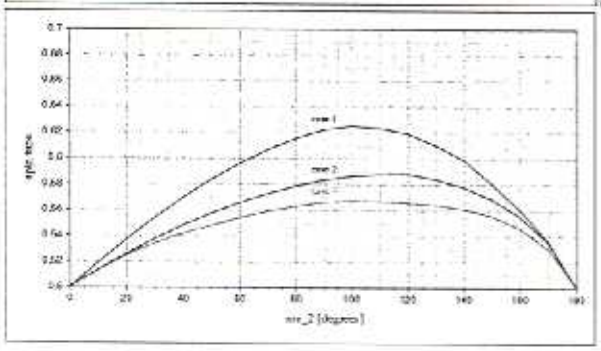
- Ramp down one snake and measure horizontal polarization.
- Do energy scan through at least one full unit of $\Delta(G\gamma)$.
  This should give a calibration of energy vs current.

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

11





| | Snake one | | Snake two | | | | | |
|---|---|---|---|---|---|---|---|---|
| G*gamma | mu1 | phi1 | mu2 | phi2 | cos(pi*nu) | nu | 1-nu | case 2 |
| 192 | 180 | -45 | 180 | 45 | 0.0000 | 0.5000 | 0.5000 | |
| 192 | 175 | -45 | 170 | 38.5 | -0.1069 | 0.5347 | 0.4653 | |
| 192 | 170 | -45 | 160 | 34 | -0.1721 | 0.5550 | 0.4450 | |
| 192 | 165 | -45 | 150 | 30 | -0.2141 | 0.5687 | 0.4313 | |
| 192 | 160 | -45 | 140 | 26 | -0.2410 | 0.5778 | 0.4222 | |
| 192 | 150 | -45 | 130 | 23 | -0.2610 | 0.5840 | 0.4160 | |
| 192 | 150 | -45 | 120 | 20 | -0.2736 | 0.5882 | 0.4118 | |
| 192 | 150 | -45 | 110 | 17.5 | -0.2729 | 0.5880 | 0.4120 | |
| 192 | 150.5 | -45 | 100 | 15 | -0.2666 | 0.5866 | 0.4134 | |
| 192 | 152 | -45 | 90 | 13 | -0.2596 | 0.5836 | 0.4164 | |
| 192 | 154 | -45 | 80 | 11.5 | -0.2447 | 0.5787 | 0.4213 | |
| 192 | 156 | -45 | 70 | 10 | -0.2267 | 0.5728 | 0.4272 | |
| 192 | 158 | -45 | 60 | 8.5 | -0.2053 | 0.5658 | 0.4342 | |
| 192 | 170 | -45 | 50 | 7.1 | -0.1796 | 0.5575 | 0.4425 | |
| 192 | 172 | -45 | 40 | 5.7 | -0.1500 | 0.5481 | 0.4519 | |
| 192 | 174 | -45 | 30 | 4.4 | -0.1176 | 0.5375 | 0.4625 | |
| 192 | 176 | -45 | 20 | 3 | -0.0818 | 0.5261 | 0.4739 | |
| 192 | 178 | -45 | 10 | 1.5 | -0.0426 | 0.5136 | 0.4864 | |
| 192 | 180 | -45 | 0 | 0 | -0.0000 | 0.5000 | 0.5000 | |
| G*gamma | mu1 | phi1 | mu2 | phi2 | cos(pi*nu) | nu | 1-nu | case 3 |
| 192 | 180 | -45.0 | 180 | 45 | 0.0000 | 0.5000 | 0.5000 | |
| 192 | 175 | -45.8 | 170 | 38.5 | -0.0945 | 0.5301 | 0.4699 | |
| 192 | 170 | -46.7 | 160 | 34 | -0.1440 | 0.5460 | 0.4540 | |
| 192 | 165 | -47.5 | 150 | 30 | -0.1735 | 0.5555 | 0.4445 | |
| 192 | 160 | -48.3 | 140 | 26 | -0.1905 | 0.5610 | 0.4390 | |
| 192 | 150 | -49.2 | 130 | 23 | -0.2000 | 0.5641 | 0.4359 | |
| 192 | 150 | -50.0 | 120 | 20 | -0.2049 | 0.5657 | 0.4343 | |
| 192 | 150 | -50.0 | 110 | 17.5 | -0.2091 | 0.5671 | 0.4329 | |
| 192 | 150.5 | -50.0 | 100 | 15 | -0.2102 | 0.5674 | 0.4326 | |
| 192 | 152 | -50.0 | 90 | 13 | -0.2065 | 0.5662 | 0.4338 | |
| 192 | 154 | -50.0 | 80 | 11.5 | -0.1971 | 0.5632 | 0.4368 | |
| 192 | 156 | -50.0 | 70 | 10 | -0.1848 | 0.5592 | 0.4408 | |
| 192 | 158 | -50.0 | 60 | 8.5 | -0.1693 | 0.5541 | 0.4459 | |
| 192 | 170 | -50.0 | 50 | 7.1 | -0.1497 | 0.5478 | 0.4522 | |
| 192 | 172 | -49.0 | 40 | 5.7 | -0.1316 | 0.5420 | 0.4580 | |
| 192 | 174 | -48.0 | 30 | 4.4 | -0.1071 | 0.5342 | 0.4658 | |
| 192 | 176 | -47.0 | 20 | 3 | -0.0772 | 0.5246 | 0.4754 | |
| 192 | 178 | -45.0 | 10 | 1.5 | -0.0415 | 0.5132 | 0.4868 | |
| 192 | 180 | -45.0 | 0 | 0 | -0.0000 | 0.5000 | 0.5000 | |

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

# Comments on Luminosity

$$L = f_{\rm rev}\frac{N_1 N_2 N_b}{4\pi\sigma_x\sigma_y} = f_{\rm rev}\frac{N_1 N_2 N_b}{4\pi\frac{\epsilon^N_{95\%}}{6\beta\gamma}\beta^*}$$

$$\simeq 78\ \text{kHz} \times \frac{10^{11}\times 10^{11}\times 55}{2\times\frac{2\times10^{-5}\ \text{m}}{100}\times 10\ \text{m}} \quad \text{(Here } \beta^* = 10\ \text{m for scaling.)}$$

$$\simeq 1\times 10^{30}\ \text{cm}^{-2}\text{s}^{-1}$$

- For the energy ramps we, want equal and constant $\beta^*$ at all IR's.
  - We plan injection studies to see if $\beta^*$ =3 m works at PHOBOS.
- Can we accelerate $55\times 10^{11}$ protons per ring?
  - So far with gold, we have reached only $\sim 30\%$ of design intensity.

BROOKHAVEN NATIONAL LABORATORY

RHIC Spin Collaboration
1 October, 2001

15