FY2001 Polarized Proton Commissioning

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RHIC Spin Collaboration Meeting
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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

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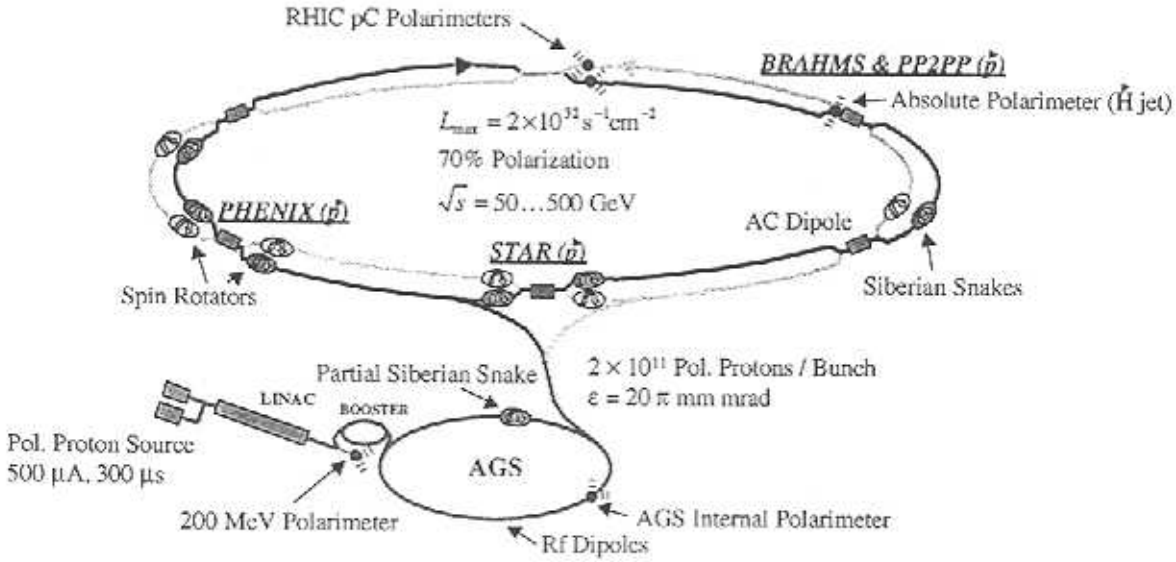
Polarized Protons in RHIC



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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.

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Injection and Storage Energies

	Injection	Nominal Store	Top Energy
$G\gamma$	46.5	192	477.6991
γ	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_{dipole}	473.923 A	1954.18 A	5067.303 A

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

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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 β-squeeze at 100 GeV

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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.

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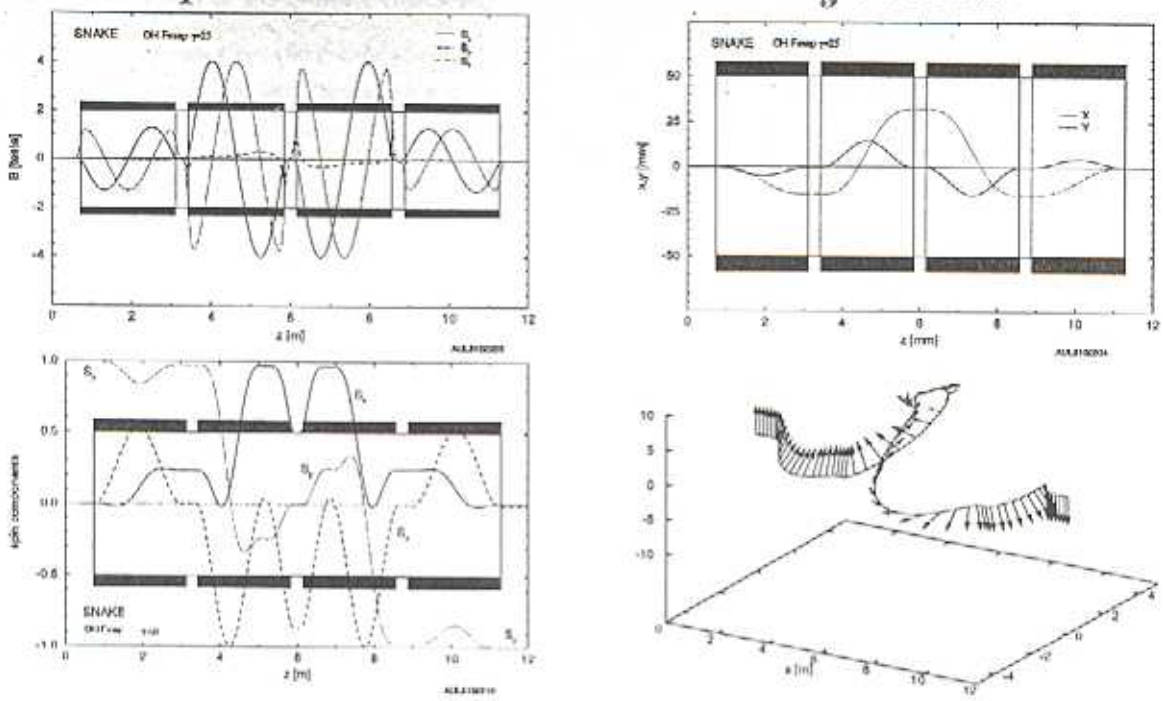
Operation of Snake at Injection



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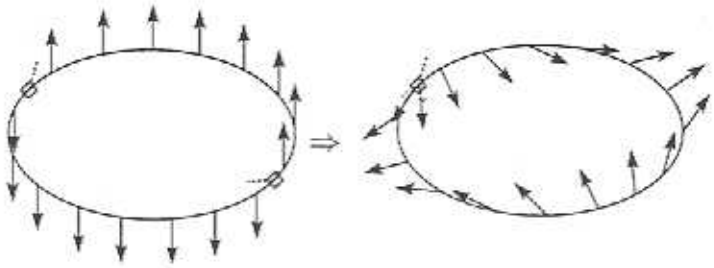
Longitudinal Polarization in RHIC

- 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.)



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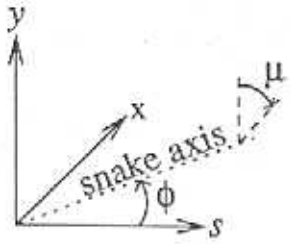
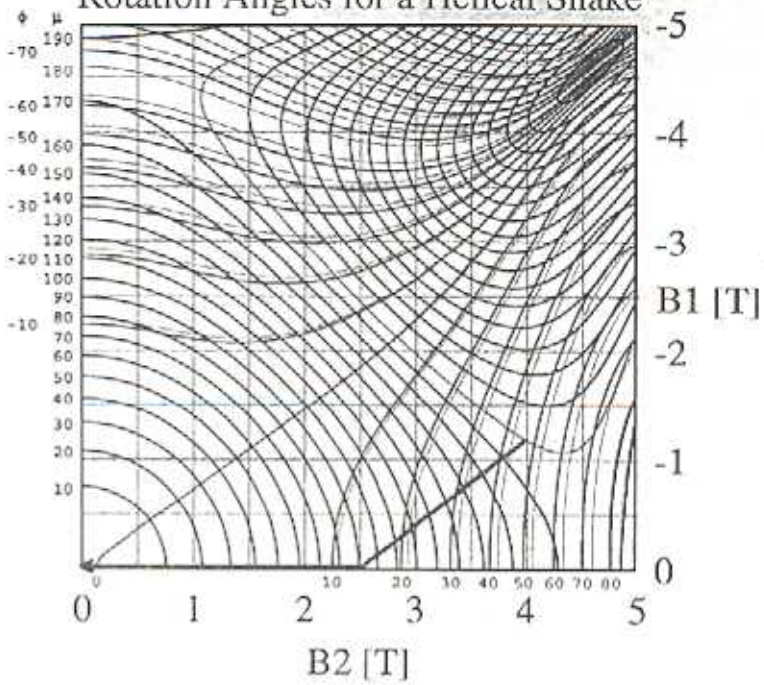


The rotation axis of the snake is ϕ, and μ is the rotation angle.

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

Rotation Angles for a Helical Snake



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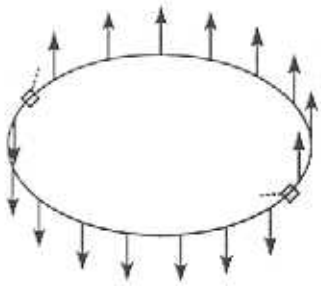
Spin tune with two snakes $[\mu_1, \phi_1]$ and $[\mu_2, \phi_2]$ on opposite sides of ring: $\nu_{sp} = \delta/2\pi$ where



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

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 $\phi_2 - \phi_1 = 90°$.

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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.

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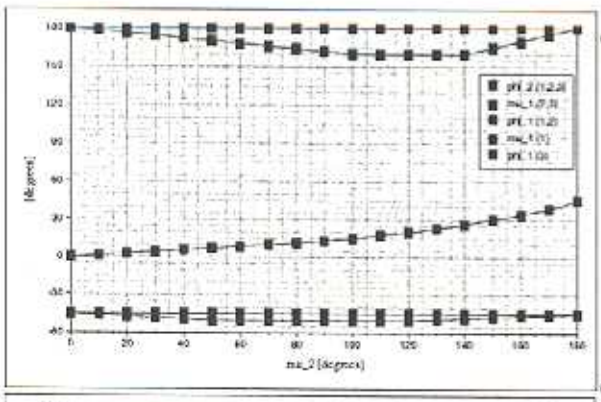

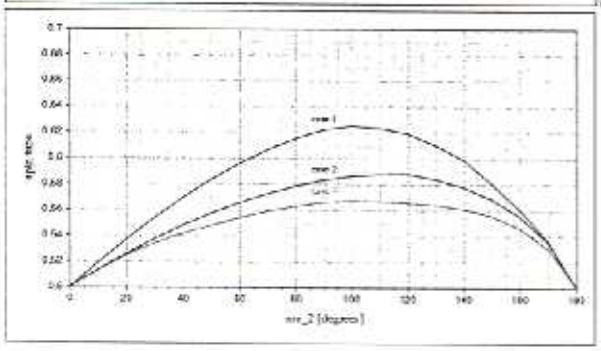

	Snake one		Snake two					
G*gamma	mu1	phi1	mu2	phi2	cos(pi*nu)	nu	1-nu	case 2
192	180	-45	180	45	0.0000	0.5000	0.5000	
192	175	-45	170	38.5	-0.1069	0.5347	0.4653	
192	170	-45	160	34	-0.1721	0.5550	0.4450	
192	165	-45	150	30	-0.2141	0.5687	0.4313	
192	160	-45	140	26	-0.2410	0.5778	0.4222	
192	150	-45	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	

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

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