First Polarized Proton Collision at RHIC

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Outline

- Introduction
  - Spin dynamics in RHIC
  - RHIC polarized proton setup

- RHIC 250 GeV polarized proton run
  - Luminosity performance
  - Polarization performance

- Summary & Future Plan
Spin Dynamics: Thomas-BMT Equation

\[ \frac{dS}{dt} = \Omega \times S = -\frac{e}{\gamma m} \left[ G \gamma B_\perp + (1 + G) B_\parallel \right] \times S \]

Spin vector in particle’s rest frame

- G is the anomalous g-factor, for proton, \( G = 1.7928474 \)
- \( \gamma \): Lorenz factor

Magnetic field along the direction of the particle’s velocity

Magnetic field perpendicular to the particle’s velocity

Spin tune \( Q_s \): number of precessions in one orbital revolution.

\[ Q_s = G \gamma \]
Depolarizing Mechanism

- **Spin depolarizing resonance**: when the spin vector gets kicked at a frequency close to the frequency it processes. The location of a spin depolarizing resonance is at

\[ Q_s = \text{tune of the kick on the spin} \]

- **Source of depolarizing resonance**: horizontal field kicks the spin vector away from its vertical direction, and lead to polarization loss
  - Imperfection resonance: vertical closed orbit distortion
    - \( G_\gamma = k \)
      - \( k \) is an integer
  - Intrinsic resonance: vertical betatron oscillation
    - \( G_\gamma = kP^{\frac{1}{2}}Q_y \)
      - \( Q_y \) is the vertical betatron tune, \( P \) is the periodicity of the lattice
RHIC intrinsic resonance spectrum
Siberian Snakes:
- two Siberian snakes located on the opposite sides of ring
- their axes perpendicular
  - Spin tune = 1/2

**Diagram:**
- Absolute Polarimeter (H jet)
- RHIC pC Polarimeters
- PHENIX (p)
- STAR (\(\vec{p}\))
- RF cavities
- Solenoid Partial Siberian Snake (longitudinal polarization)
- Spin Rotators
- Pol. H\(^-\) Source
- 200 MeV Polarimeter
- LINAC
- BOOSTER
- AGS
- Helical Partial Siberian Snake
- AGS Polarimeters
- Strong AGS Snake

**Note:** SpinFest, August 7, 2008
RHIC polarized proton setup

- Precise control of work point and closed orbit distortion to avoid snake resonances at

\[ mQ_y = Q_s + k \]

- odd \( m \): odd order resonance: driven by the intrinsic resonance
- even \( m \): even order resonance

![Diagram showing current working point, old working point, and working point candidate](image-url)
RHIC 250 GeV polarized proton run performance
- beta*: 0.7m
- # of bunches: 109
- Bunch intensity: $1.2 \times 10^{11}$ protons
Integrated Luminosity

RHIC Delivered $p^+p^-$ Luminosity Run-9 ($\sqrt{s}=500$ GeV)

- Min Run9 Projection
- Max Run9 Projection
- STAR Run9 (NOT singles corrected)
- PHENIX Run9 (singles corrected)

thru fill 10536
Monday 13 April

Courtesy of
P. Ingrassia
Weekly Luminosity

Run9 $p^+p^-$ Integrated Luminosity by Week

thru fill 10536 Monday 13 April

- STAR Run9
- PHENIX Run9
- STORE hours/wk

Courtesy of P. Ingrassia
Polarization performance

- Average beam polarization: ~42%
- Best polarization achieved: ~54%
- No polarization loss up to 136 GeV
- Candidate of depolarization location: the three strong intrinsic resonances after 100 GeV, around 136 GeV, 199 GeV and 221 GeV
Summary & Plan

- Achieved operational 109x109 with $1.2 \times 10^{11}$ protons per bunch
- An average of ~42% polarization was achieved at 250~GeV
- Demonstrated that the current 250 GeV machine setup was able to accelerate/collide 56x56 with $1.8 \times 10^{11}$ bunch. Polarization was ~30% in both rings
- To preserve 100% polarization to 250GeV, following options are under investigation
  - Minimize the width of $3Q_y=2$ resonance to accommodate $Q_y \leq 0.675$
  - Accelerate with near integer work point $\sim (0.96, 0.97)$