

A New Working Point for Polarized Protons in RHIC

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The goal for Run-8 and beyond

- Achieved $\mathcal{L}_{\text{store, avg}} = 20 \cdot 10^{30} \text{ cm}^{-2}\text{sec}^{-1}$ in Run-6
- $\mathcal{L}_{\text{store, avg}} = 40 \cdot 10^{30} \text{ cm}^{-2}\text{sec}^{-1}$ in Run-8,
 $\mathcal{L}_{\text{store, avg}} = 60 \cdot 10^{30} \text{ cm}^{-2}\text{sec}^{-1}$ in Run-9
- Maintain polarization transmission in RHIC (presently close to 100 percent up to 100 GeV)

How can we get there?

Luminosity formula:

$$\mathcal{L} = \frac{N^2 f_c}{4\pi\epsilon\beta^*}$$

Collision frequency f_c is already **maximized** (111 bunches).
Remaining “**free**” **parameters** are bunch intensity N , emittance ϵ , and β^* .

What are the limitations on these?

Beam-beam formula:

$$\begin{aligned}\xi &= \frac{r_0 N \beta^*}{4\pi\gamma\sigma^2} \\ &= \frac{r_0 N}{4\pi\gamma\epsilon}\end{aligned}$$

Beam-beam is independent of β^* .

\Rightarrow squeeze β^* as much as possible.

Limitations on β^* :

- magnet strength and triplet aperture
- hourglass effect (need shorter bunches)

Main **luminosity improvement** has to come from **higher intensity** ($N = 2 \cdot 10^{11}$ /bunch). Fortunately, **AGS polarization** seems largely **intensity-independent**.

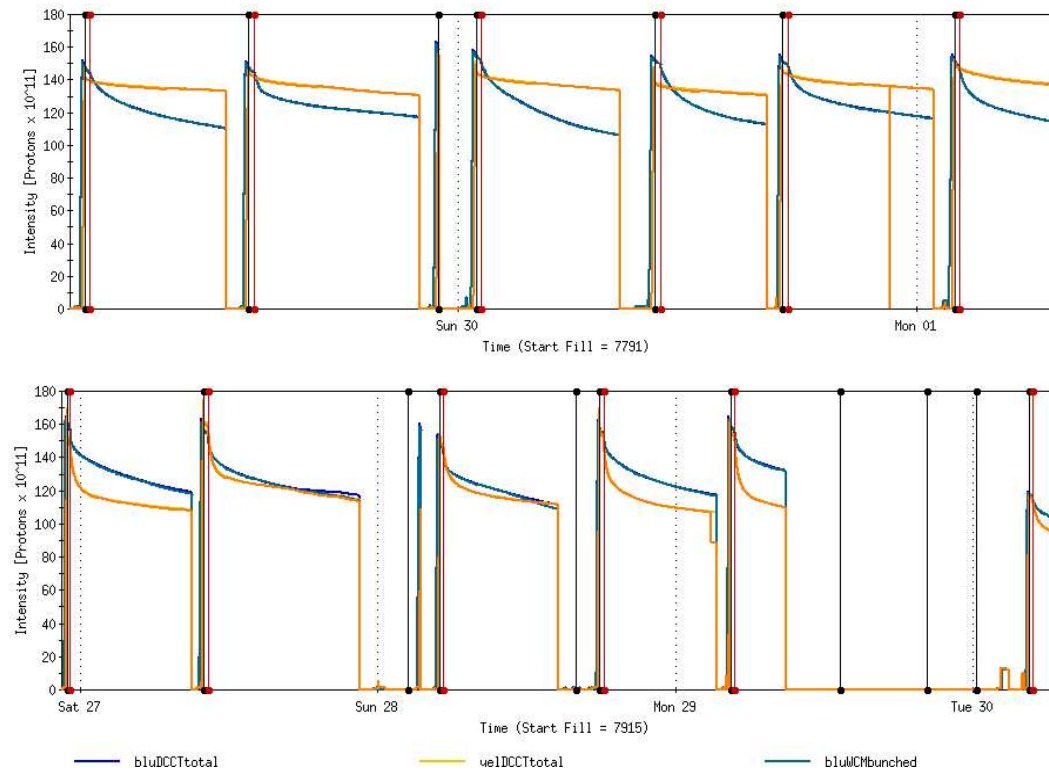
But: higher intensity (or smaller emittance) **increases beam-beam tuneshift**.

Large tuneshift parameters make **working point search** very **delicate**. **Working points in the two rings** need to be **different** to avoid coherent beam-beam effects.

FY06 pp-run was already largely **beam-beam limited**.

Run-6 intensities before and after working point swap

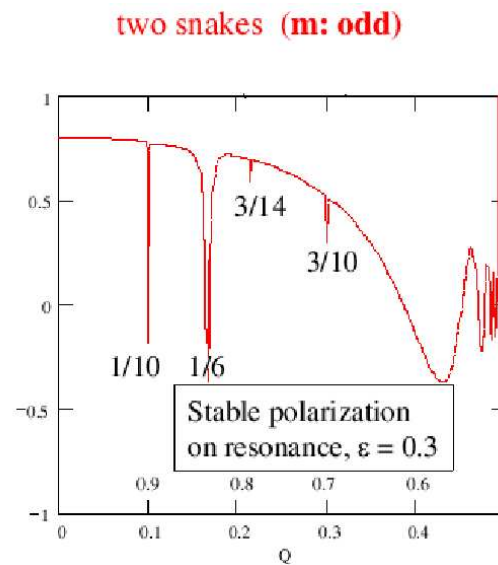
Working point constrained by 2/3 and 7/10



$Q_x = 2/3$ limits lifetime and luminosity performance

Choosing a new working point

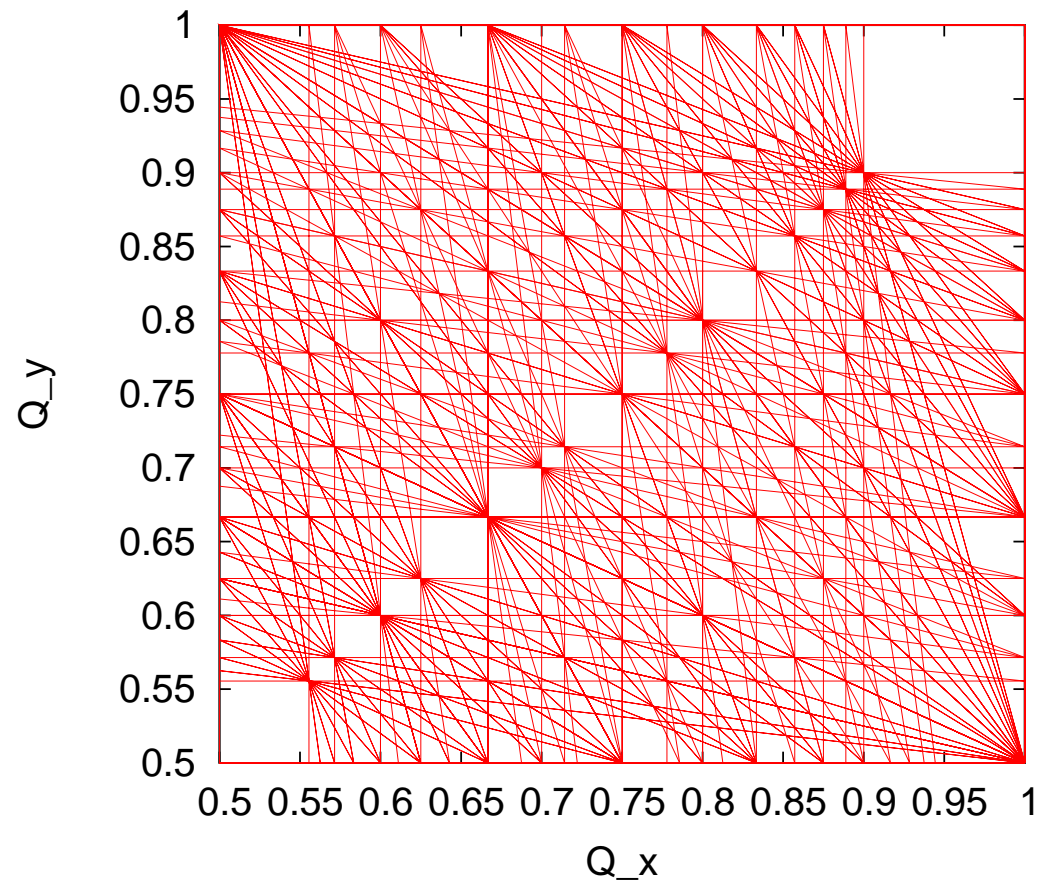
Snake resonances:



Resonance condition: $Q_y = \frac{k}{2 \cdot m}$

Near-integer tunes best for polarization

Nonlinear resonances, up to 10th order:



Near-integer working point provides largest tune space

Nonlinear dynamics

Near the integer, the spacing between resonance lines is largest.

However, the integer resonance includes ALL nonlinear resonances: $2/2$, $3/3$, $4/4$, $5/5$,...

Dynamic aperture needs to be determined by tracking

Tracking studies

- Tracking studies were performed to compare dynamic aperture at current and proposed working points
- Latest IR magnet multipole data were included in the model
- Tune modulation added, based on experimental data
- Two interaction points, $N = 2 \cdot 10^{11}$, $\epsilon_n = 15\pi$ mm mrad (95 percent)

Dynamic apertures in σ at the Run-6 working point

29.695	< 4	5.7	6.8			
29.69	< 4	4.9				
29.685	< 4				7.1	
29.68				7.5	7.7	
29.675			7.1	6.5	6.6	
		28.675	28.68	28.685	28.69	28.695

Above the diagonal, tune space is very limited, consistent with observations.

Dynamic apertures in σ for tunes below the integer

28.965	5.3	5.3	5.5	5.8	6.0		
28.96	5.6	5.8	6.1	6.3			
28.955	6.0	6.0	6.4				7.1
28.95	6.2	6.1				7.3	6.9
28.945	6.0				6.9	6.9	6.8
28.94				6.4	6.6	6.7	6.8
28.935			6.5	6.5	6.5	6.9	6.9
	27.935	27.94	27.945	27.95	27.955	27.96	27.965

Broad region of large dynamic aperture ($\approx 7\sigma$) below the diagonal.

Dynamic apertures in σ for tunes above the integer

29.085	5.5	6.3	6.2	5.6	5.8		
29.08	5.0	5.1	5.3	5.3			
29.075	5.8	5.8	5.5				5.2
29.07	5.9	5.8				5.5	5.3
29.065	6.2				5.8	5.5	5.6
29.06				5.9	6.0	5.7	5.5
29.055			6.2	6.1	6.2	5.6	5.5
	28.055	28.06	28.065	28.07	28.075	28.08	28.085

Not as good as below the integer.

Depolarizing resonances

7th order depolarizing resonance $Q_y = \pm \frac{1}{2.7}$ is a potential concern

Difficult to investigate in tracking studies, because required polarization lifetime is many hours

Therefore, resonance strength was artificially increased until depolarization occurred

Application of the same model to $Q_y = 10/14$ showed that $Q_y = \pm 1/14$ has factor 10 longer polarization lifetime

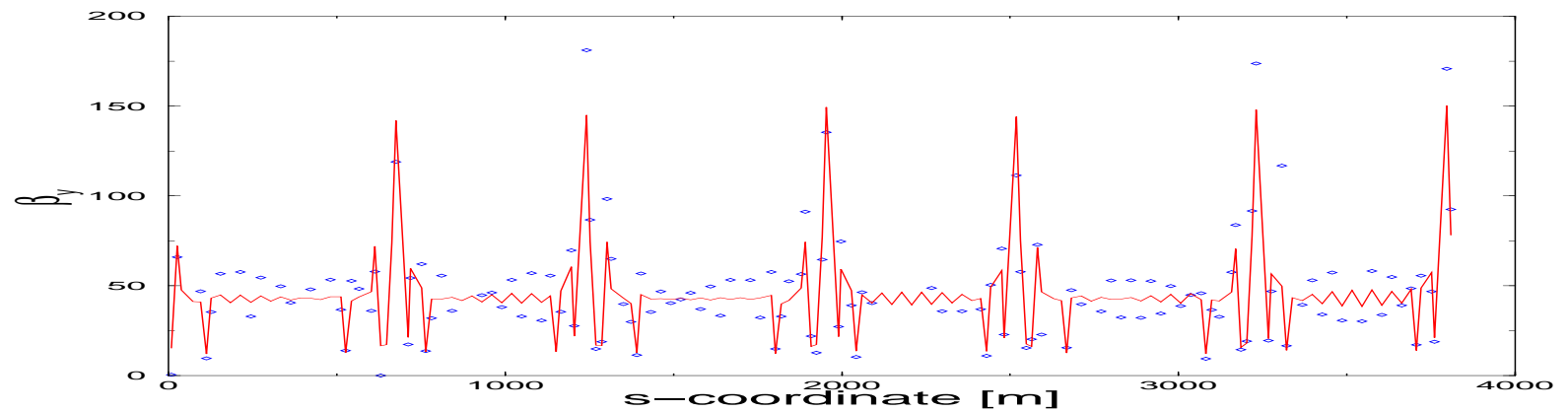
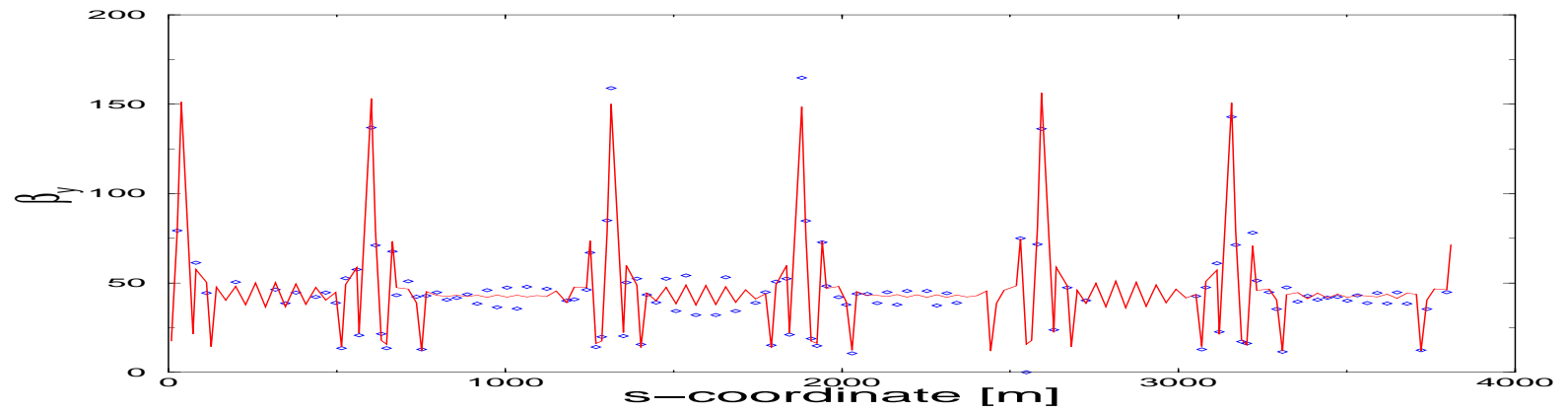
Measurements show polarization lifetime of several hours at $Q_y = 10/14$

→ $Q_y = \pm 1/14$ expected to have sufficient polarization lifetime

Experimental studies

- Near-integer working point was studied during FY07 Au-Au run (injection only)
- β -beat is a major concern due to $1/\sin(2\pi Q)$ dependence
- Tunes set to (28.08, 29.05) in Blue, (27.93, 28.94) in Yellow
- Optics measurements with AC dipole

Vertical β -functions in Blue and Yellow



Harmonic β -beat correction under development

Summary

- At the current working point, RHIC polarized proton luminosity is limited by $Q_x = 2/3$ resonance
- A near-integer working point overcomes this limitation
- Tracking studies indicate significant increase in dynamic aperture for tunes around (27.96, 28.95)
- Beam experiments with Au show significant β -beat at these tunes; harmonic correction being developed
- Working points for Run-8:
Yellow at (28.695, 29.685), Blue at (27.96, 28.95)