Run-8 Polarized Protons Plan

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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)

Overcoming the beam-beam limit

- In Run-6, luminosity performance was limited by the beam-beam tuneshift. Depending on the exact working point, one beam always suffered due to the vicinity of the $Q_x = 2/3$ resonance.

- To overcome this, a new working point near the integer will be commissioned in the blue ring.

Polarized Protons Working Points

Yellow: $(Q_x, Q_y) = .695, .685$ (as in Run-6)

Blue: $(Q_x, Q_y) = .96, .95$ (at store, near-integer working point)

Near-integer working point will be operationally challenging

Operational challenges near the integer

Orbit and β-beat will be more sensitive at near-integer tunes, and will in fact be strongly tune-dependent

$\rightarrow$ Stay away from the integer during the ramp as much as possible

$\rightarrow$ Ramp tunes: $(Q_x, Q_y) = .885, .895$ (between 7/8 and 9/10)

Tune/coupling feedback/replay is a must to keep tunes under control

Persistent current drifts at injection may push tunes outside that narrow window between 7/8 and 9/10

Need feed-forward to counteract these drifts

Feed-forward has to be commissioned during d-Au run to be ready for polarized protons

β-beat becomes worse at near-integer tunes, since it scales as $1/\sin(2\pi Q)$

Optics correction (at store) is a must, both globally (harmonic correction) and locally

$\rightarrow$ Test/commission during d-Au run, at near-integer tunes (injection only)

β*-knobs are expected to be a useful tool to optimize luminosity and/or correct β-beat at the IPs

Tested in APEX sessions a few years ago (W. Wittmer et al.), but never made operational as a "knob"

Dynamic "knobs" desirable that can be changed operationally

What else can be done to increase luminosity?

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:

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

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)

Hourglass effect

Luminosity reduction due to hourglass effect:

$$R = \frac{\mathcal{L}}{\mathcal{L}_0} = \int_{-\infty}^{\infty} \frac{\mathrm{d}t}{\sqrt{\pi}} \frac{\exp(-t^2)}{1 + \frac{\sigma_z^2}{\beta^2} t^2}$$

For $\sigma_z = 0.75\,\mathrm{m}$, this factor becomes:

0.83 at $\beta^* = 1.0\,\mathrm{m}$
0.76 at $\beta^* = 0.75\,\mathrm{m}$
0.64 at $\beta^* = 0.5\,\mathrm{m}$

$\rightarrow$ squeezing from $\beta^* = 1.0\,\mathrm{m}$ to $\beta^* = 0.5\,\mathrm{m}$ results in only 50 percent improvement, not a factor 2. But...

9 MHz cavity

- A new 9 MHz RF cavity has been installed for pp acceleration
- This will result in $\approx$factor 2 smaller longitudinal emittance
- Bunch length σ_z will be smaller by $\sqrt{2}$
- Hourglass factor for $\beta^* = 0.5\,\mathrm{m}$ and $\sigma_z = 0.5\,\mathrm{m}$ is $R = 0.76$

$\rightarrow$ Together with the squeeze to $\beta^* = 0.5\,\mathrm{m}$, this would increase the luminosity by a factor 1.8

Necessary tools

- Nonlinear chromaticity correction to reduce tune footprint, which can then be filled up by beam-beam

- Tune feedback, with full replay capability

- Local and global (harmonic) β-beat correction

- 10 Hz IR orbit feedback to counteract larger oscillations at near-integer tunes

- Instrumentation/controls applications need to be modified to allow different working points in the two rings (example: ARTUS)

Summary

- New near-integer working point in Blue is expected to increase the beam-beam limit

- Near-integer tunes are operationally challenging and require new tools that are currently being developed and will be tested with d-Au

- Nonlinear chromaticity correction will free some tune space that can subsequently be filled up by beam-beam tunespread

- β^*-squeeze to 0.5 m together with shorter bunches will significantly increase the luminosity; to be tested during d-Au APEX