Brookhaven National Laboratory

U.S. DEPARTMENT of ENERGY

RHIC Ops: Considerations for p-p, p-Au, fixed-target, and A-A (O-O, He-He and isobars)

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PAC Meeting October 16, 2025

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Considerations for PP

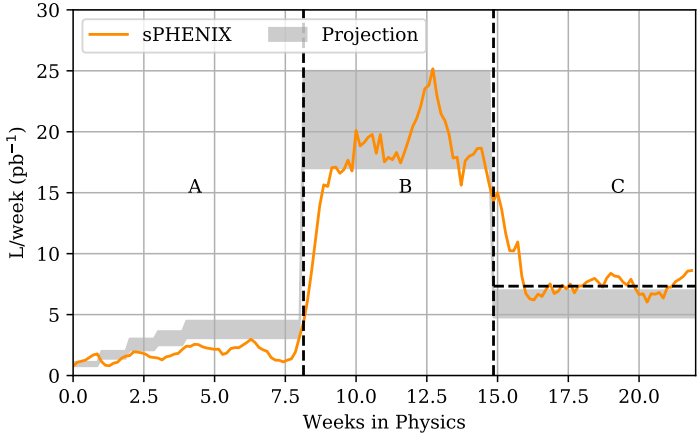
Pre-beam requirements

- → Setup of polarized protons in AGS beforehand
  - → 2 days if setup cannot be completed prior to switch.
- → Checkout of snake PS
  - → 16 hours with two teams.
  - → Snake checkout can be performed ahead of time during maintenance days pending PS personnel priorities and availability
- → Installation of polarimeter targets (yellow)
  - → 12 hour installation.
  - → 3-4 days for vacuum recovery which will not prohibit setup.
  - → Cannot be done during AuAu running due to vacuum degradation.

Beam setup

- → 7 days to physics.
- → 1/2 day included for polarimeter target conditioning.
- → An additional 2 weeks to 50% of the maximum projected luminosity.

Run24 PP Performance

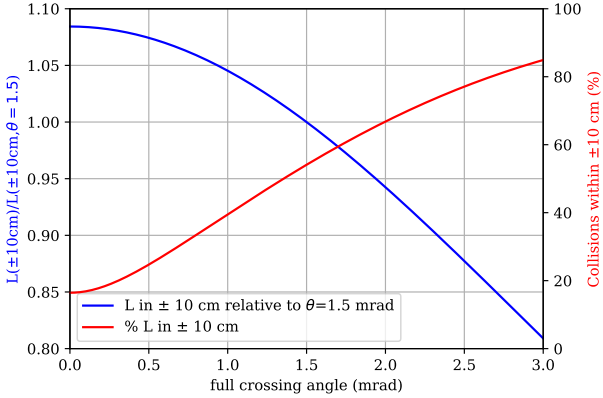


In the final weeks operating with a 1.5 mrad full crossing angle, Luminosity delivered per week was approximately the maximum projection.

Run25 Projection

Due to the degraded performance of Run24, the maximum projected luminosity is 17 pb^{-1}, noted in the projections document here.

The projections document only provides guidance for luminosity with head-on collisions



Angle	L/week(pb^{-1})	% in $\pm$10 cm
0	17.00	17.3
0.5	11.54	25.3
1	7.14	39.8
1.5	5.09	54.3
2	3.83	66.9

→ Delivered L/week given over all vertices.

→ Average delivered luminosity for Run24 at 1.5 mrad is L/week(1.5 mrad)=7.3 pb^{-1}.

Intensity limitations from Run24 (RF power, losses at rebucketing, and aperture limitations at injection) were resolved allowing for increases in intensity.

Considerations for unpolarized protons

Pre-beam requirements

→ none

Beam setup

→ 4 days from injection to physics, an additional 1 week to reach 50% of the maximum projected luminosity.

Notes

→ Polarimeter targets and the subsequent bakeout are not required, expediting time to physics.

→ Without polarization measurements, approximately 5 minutes is saved in lumi-to-lumi time.

→ Through reduced limitations on the intensity, the luminosity is expected to be 20% higher than the polarized case.

→ Through reduced complexity of RHIC and its injectors, the time to reach 50% maximum L/week.

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Considerations for PAu

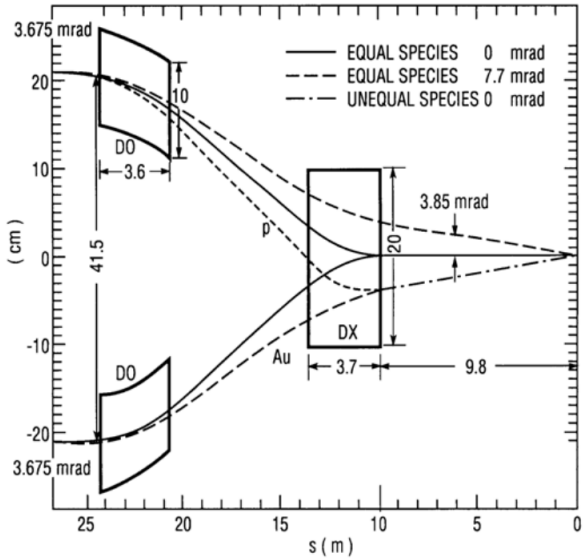
Pre-beam requirements

- → Setup of polarized protons in AGS beforehand
  - → 2 days if setup cannot be completed prior to switch.
- → Checkout of snake PS
  - → 16 hours with two teams.
  - → Snake checkout can be performed ahead of time during maintenance days pending PS personnel priorities and availability

Beam setup

- → 3 days to move DX magnets inside the ring. Cannot be done while Au is operating.
- → 10 days from first injection to physics, +1 week to reach 50% of projected maximum L/week.

Why move the DX magnets?



→ Due to the difference m:q of protons with Au operation at $\gamma_p = \gamma_{Au}$, $B\rho_p$=334 Tm and $B\rho_{Au}$ =849 Tm.

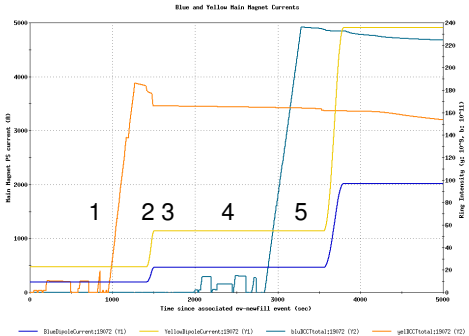
→ The DX must be shifted to accommodate the asymmetric orbits of the two beams.

→ Moving these superconducting magnets while cold comes with non-zero risk.

Considerations for PAu

The RHIC configuration:

1) Tune+fill yellow with Au.
2) Ramp yellow+blue up to proton injection energy
3) Ramp up AGS cold snake
4) Tune+fill blue with protons.
5) Confirm polarization and ramp to top energy.

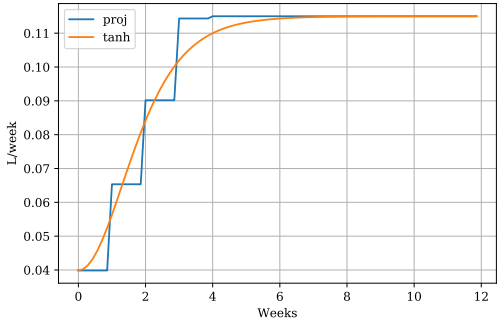


Notes:

→ If there is a problem after 1 requiring Au beam to be dumped, a minimum of 20 minutes is needed to return to 1, dictated by the cold snape ramping time.

→ Ramp up/down time (new)=20/20 minutes. The AGS cold snake can not ramp as fast now due to magnet protection, extending fill-times (Ramp up/down time (old)=5/3 minutes).

Considerations for PAu



→ A 4-week ramp up of luminosity is expected.

→ Initial luminosity of 40 nb^{-1} and a maximum projected luminosity of 115 nb^{-1}.

→ From initial physics to 50%L_{max} is approximately 1 week.

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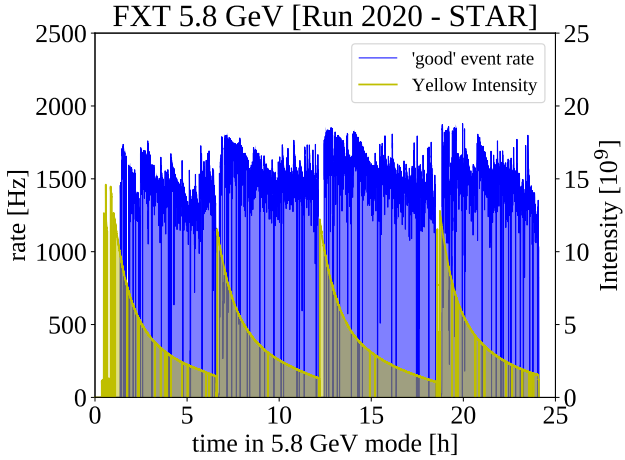
Considerations for Fixed-target

- → Au+Au at $\sqrt{s}$=4.2 and 4.5 GeV.
- → STAR's estimate is 3 weeks to reach 2 B minbias events at 4.2 and 4.5 GeV.
- → 1 day total expected to setup both energies in the AGS (can be done before the switch).
- → 1 day total expected to setup both energies in RHIC.



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Considerations for OO

STAR in Run21 was leveled at 1.5 kHz. 6 hour store lengths. Emittances 1.25-1.75 μm. Intensity 4 to 10 $\times 10^9$ ipb.

- $\rightarrow$ Expected intensity in RHIC is 8×10^9 ions per bunch.
- $\rightarrow$ 1 day to setup in AGS if not done previously.
- $\rightarrow$ 4 days to setup with beam. An additional week to reach 50% of the projected luminosity

Ions/bunch ($\times 10^9$)	β^* (m)	ϵ_{rms} (μm)	Time at store (%)	L_{peak} ($10^{28} cm^{-2} s^{-1}$)	L_{store} ($10^{28} cm^{-2} s^{-1}$)	L_{week} (nb^{-1})
4	0.7	1.5	60	11.3	6.8	24.5
8	0.7	1.5	60	45.0	27.0	93.7
10	0.7	1.5	60	70.4	42.2	146.3

Projection:

Week	L_{max}/week (nb^{-1})
1	61.3
2	94

Maximum intensity reached during Run21 was 8×10^9 ions per bunch.

Considerations for HeHe

He has never been run before in RHIC.

→ Intensity from source to RHIC is expected to be equivalent to helium-3 in Run24.

→ This is up to 1.3×10^{10} helium ions/bunch in RHIC.

→ Helium-3 has only been run in single rings for studies or in asymmetric collisions.

Parameter	Value
β^*	0.7 m
Intensity/bunch	1.3×10^{10} ipb
Emittance	1.5×10^{-6} m
L_{init}	160×10^{28} cm^{-2}s^{-1}
L_{avg}/L_{init}	0.6
L_{avg}	95×10^{28} cm^{-2}s^{-1}
Time at store	60%
L_{max}/week	344 nb^{-1}

Considerations for ZrZr and RuRu at 27 GeV

- → Run20 Zr and Ru were levelled at 21.5×10^{26} $cm^{-2}s^{-1}$ and corresponded to 0.5 nb^{-1}/week.
- → Unlevelled luminosity estimate corresponds to 1.9 nb^{-1}/week.
- → No pre-beam requirements aside from established species in the AGS (4 days expected).
- → 4 days of setup for both beams at 26 GeV.
- → At this lower energy, care needs to be taken when designing a ramp to ensure the store optics are compatible with cooling.

Parameter	Zr Value	Ru Value	Units
β^*	0.7	0.7	m
Intensity/bunch	1.0×10^{9}	1.0×10^{9}	ipb
Emittance	1.2×10^{-6}	1.2×10^{-6}	m
L_{init}	0.23×10^{28}	0.23×10^{28}	$cm^{-2}s^{-1}$
L_{avg}/L_{init}	0.6	0.6	-
L_{avg}	0.14×10^{28}	0.14×10^{28}	$cm^{-2}s^{-1}$
Time at store	60	60	%
L_{max}/week	0.3	0.3	nb^{-1}

Considerations for ZrZr and RuRu at 62 GeV

- → Same requirements as 26 GeV.
- → 4 days of setup for both beamsb at 62 GeV.

Parameter	Zr Value	Ru Value	Units
β^*	0.7	0.7	m
Intensity/bunch	1.0×10^{9}	1.0×10^{9}	ipb
Emittance	1.2×10^{-6}	1.2×10^{-6}	m
L_{init}	0.55×10^{28}	0.55×10^{28}	$cm^{-2}s^{-1}$
L_{avg}/L_{init}	0.6	0.6	-
L_{avg}	0.33×10^{28}	0.33×10^{28}	$cm^{-2}s^{-1}$
Time at store	60	60	%
L_{max}/week	0.6	0.6	nb^{-1}

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Summary

→ PP and PAu both require time before beam can be introduced, for either polarimeter target installation or moving DX magnets.

→ Unpolarized protons, fixed target, and A+A configuratons do not have any requirements ahead of beam delivery, assuming beam has been established in AGS.

→ He (as opposed to helium-3) has never been used by RHIC and may have unforeseen issues. As a result, there are zero established archives, requiring a minimum of 7 days ahead of beam in RHIC to develop the various lattice and ramp files.

Species	AGS time (days)	Time before beam (days)	Setup with beam (days)	Time to 50%$L_{int,max}$ weeks	$L_{int,max}$/week (nb^{-1}/week)
P(unpol.)	1	0	4	1	20400
PP	3	0	7	2	17000
PAu	3	3	10	1	115
FT	-	0	1	-	-
OO	1	0	1	1	94
HeHe[a]	4	0	4[1]	1	340
ZrZr/RuRu (27 GeV)	2/2 (4)	0	4	0.5	0.3/0.3
ZrZr/RuRu (62 GeV)	-	0	4	0.5	0.6/0.6

[a]No prior history of being used in RHIC. Non-zero likelihood of unforeseen issues resulting in delays.

Thank you

Thank you and questions.