Polarized proton operation for Run24

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Run24 schedule

25 cryo weeks (including approved 6 week carryover from Run23)

Setup p↑p↑ at $\sqrt{s_{NN}}$=200 GeV	April 15-29
p↑p↑ at $\sqrt{s_{NN}}$=200 GeV	April 30-August 25
Setup AuAu	August 26-September 1
AuAu at $\sqrt{s_{NN}}$=200 GeV	September 2-October 7

The timing of the AuAu run is tentative and will be as required by STAR and sPHENIX.

Original start date for Run24 was January 4, 2024 but was delayed to support necessary sPHENIX and RHIC work.

Major Installations

1. 56 MHz cavity reinstalled for Run23
   - used to provide more narrow Au bunches at collisions, not used for protons
   - has a fundamental mode damper and two fundamental power couples to damp higher order modes
2. sPHENIX detector installed starting Run23
   - Commissioning during Run23+Run24
   - Currently taking physics data with jet and photon detectors
   - beampipe reinstalled with large misalignment required horizontal bump at injection
3. Repaired 9 o'clock blue helical dipole reinstalled following Run22 failure
   - two of four coils failed in Run22 forced it to be used as a partial snake
4. Sector 4 DX magnet reinstalled following failure that ended Run23
   - the normal conducting to super conducting transition for RHIC PSs arced, resulting in damage to the DX and to the transition housing (valve box)
   - the DX magnet was replaced with a spare during the shutdown period
   - caused by thermal fluctuations that weakened mechanical joints and led to development of new cooling algorithm

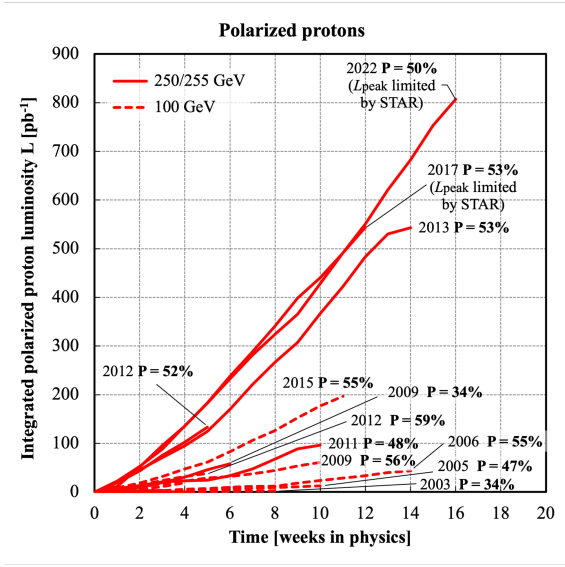
Run24 Schedule

Polarized protons at RHIC
Current Status and Issues

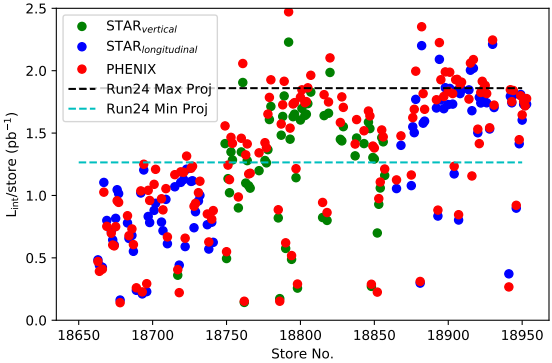
Continuation of Au+Au at 100 GeV

Polarized protons at 100 GeV

- Run15 is the highest luminosity run at 100 GeV and almost highest polarization run.
- Given performance from Run23, Run24 $p\uparrow$ performance is not expected to exceed that of Run15.
- We use Run15 as our performance metric.



Polarized protons at 100 GeV, Run15



Looking at Run15 details

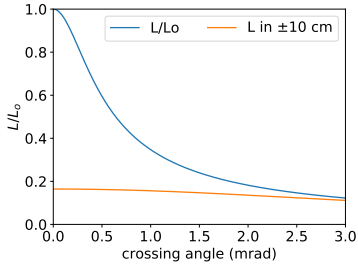
- Run15 started with relatively low luminosity which continued to scale up during STAR's longitudinally polarized run.
- Run15 we had a peak intensity of 2.38×10^{11} ions/bunch at ev-lumi.
- The average intensity/store from the 10 best stores was 2.27×10^{11} ions/bunch.

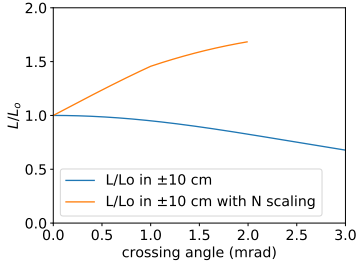
Run24 has a target intensity of 2.5×10^{11} ions/bunch at store.

Luminosity with a crossing angle

sPHENIX desires maximum collisions within a $\pm$10 cm vertex.

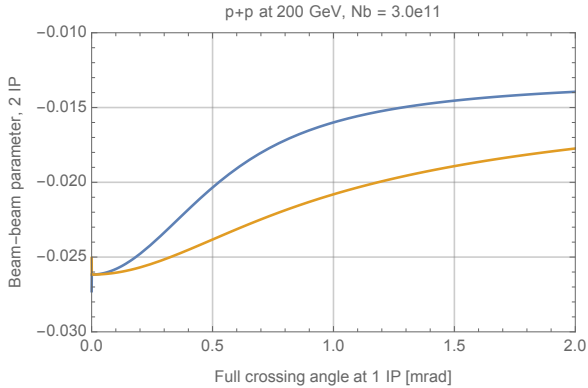
- Top: Luminosity reduction with crossing angle and within $\pm$10 cm
- Bottom: Luminosity reduction with crossing angle normalized to L_o within $\pm$10 cm and luminosity increase that maintains beam-beam tune spread
- Because of the L in $\pm$10 cm, benefits from changing the crossing angle are not as substantial.
- collapsing the crossing angle from 2 to 1 mrad mid-store would provide a 17% increase in instantaneous luminosity within $\pm$10 cm.





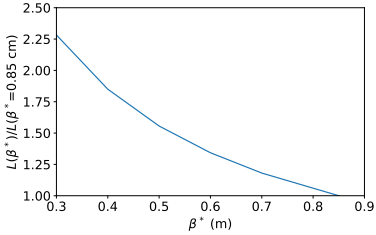
Beam-beam suppression

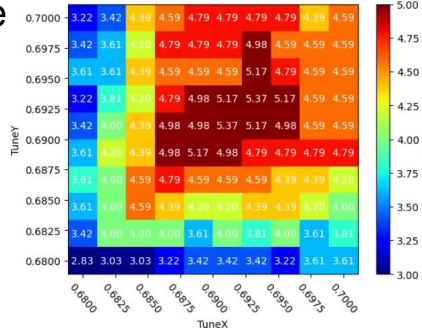
- During Run15, the two electron lenses partially compensated beam-beam effects from one IP by colliding protons with electrons.
- A crossing angle at either IP will also reduce beam-beam tune shift, which is sufficient to not require the e-lenses.
- The crossing angle of 2 mrad at one IP will support a maximum intensity of 3×10^{11} protons/bunch, according to simulations.
- Colliding with a crossing angle excites higher order betatron resonances and strong synchro-betatron resonances

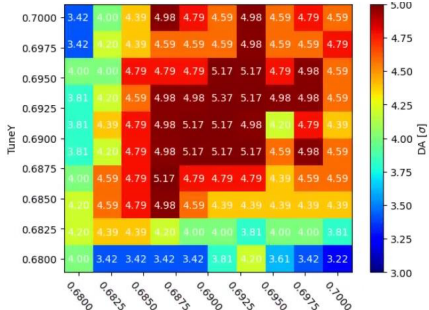


Beta-squeeze and Dynamic Aperture

- After analysis of physical aperture, a β^* squeeze to 60 cm is planned and supported by dynamic aperture simulations.
- This reduction in β^* corresponds to a 47% increase in instantaneous luminosity.
- Dynamic aperture simulations with β^* =60 cm, including beam-beam effects, at $\theta = 0$ mrad (top) and $\theta = 2$ mrad (bottom).







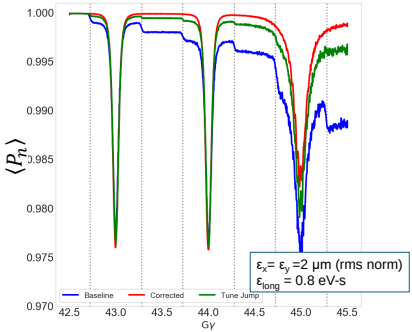
PP in the Injectors

How to get 2.5×10^{11}

- Typical RHIC ramp efficiency 98-100%
- Typical AGS to RHIC injection efficiency 92-96%
- This corresponds to a minimum of $\sim2.8\times10^{11}$/bunch at AGS extraction.

What about 57% polarization

- Typically $\sim2.8\times10^{11}$/bunch would have degraded polarization of 62% (extrapolated from $\sim2.5\times10^{11}$/bunch)
- The skew quads should provide lossless transmission (seen on right), giving this bunch 75+% polarization at AGS extraction and 65% at store in RHIC.

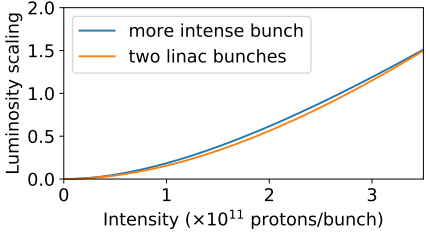


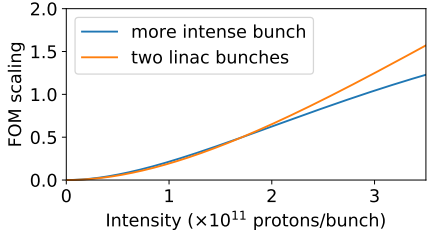
This system will be commissioned prior to the run, pending PS delivery.

Comparison of Injector Setups

For $\varepsilon_{x,y}$, values in () and bold correspond to more realistic emittances.

	Nominal	Two LINAC Pulses	Split+Merge
Intensity $\times 10^{11}$	2.1	3.0	3.0
$\varepsilon_{x,y}$ (μm)	2.11, 2.27	1.96, 2.08 (1.96, 2.39)	2.51, 2.71 (2.51, 2.79)
ε_s (eVs)	1.0	2	1.2
Polarization	57%	59%	51%
Geometric Scaling	1.00	0.71	0.92
Luminosity Scaling	1.00	1.53 (**1.43**)	1.64 (**1.53**)
FOM Scaling	1.00	1.68 (**1.57**)	1.41 (**1.31**)

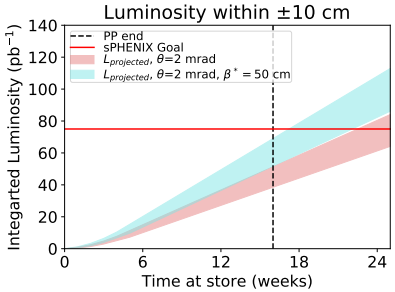


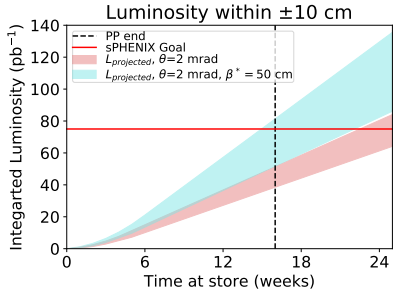


Integrated Luminosity Outlook with reduced β^* and higher intensity

Squeezing the β^* from 85 to 50 cm 3 hours into the store, in combination with exceeding 2.25×10^{11} protons/bunch, sPHENIX will reach their luminosity goals in the expected time at store. Intensity beyond 2.25×10^{11} assumes three additional weeks after the nominal 4-week ramp up time.

Parameter	Run15	Run24-A	Run24-B	Run24-C	Run24-D
β^* (cm)	85	85	85	50	60
θ	0	2	2	2	2
$N_{1,2}$ (10^{11})	2.25	2.25	2.5	2.25	2.5
$L_{max}/week$ pb^{-1}	25	3.8	4.7	5.1	5.7
Weeks to 75 pb^{-1}	-	22	19	17	16

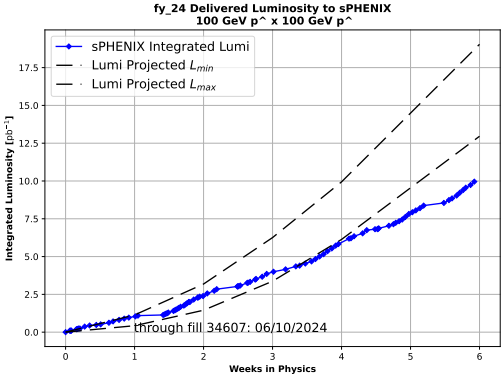


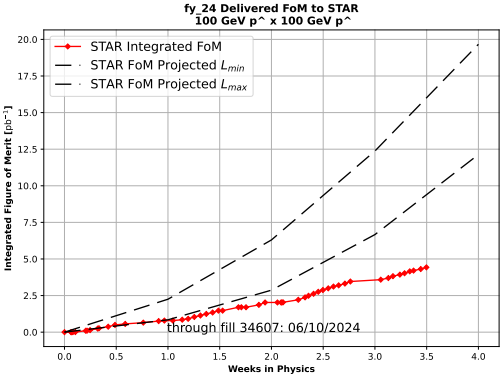


RHIC status and delivered luminosities

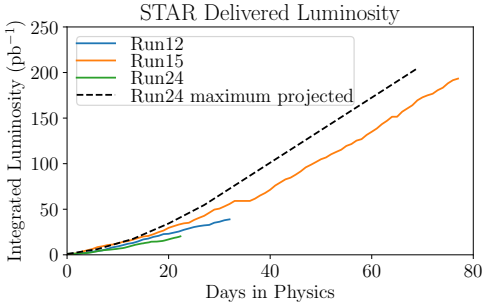
- 111x111 physics running since 4/30.
- STAR successfully completed their low-luminosity run over the first few weeks of physics data taking.
- sPHENIX has a target of 75 pb^{-1} delivered luminosity
- STAR has a target of 55 pb^{-1} for their delivered FOM, and 175 pb^{-1} for delivered luminosity

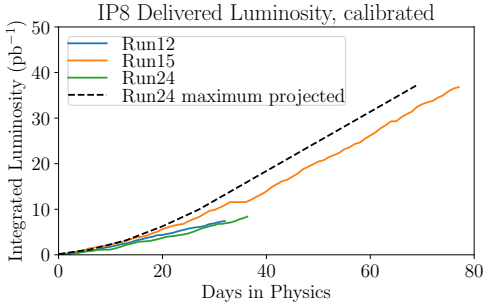
Preliminary luminosity accounting





Comparison with previous runs



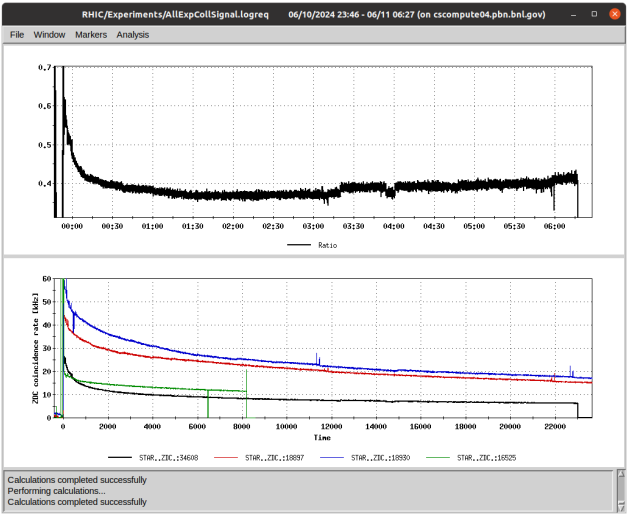


Run15 and Run12 scaled based off of emittances and calculated crossing angle for IP8

A factor of 2 improvement would put STAR at the projected Luminosity/day

sPHENIX needs ~60% increase

Comparison with previous runs, II



18930 is best store of Run15

18897 is arbitrary good store from Run15

16525 is best store of Run12

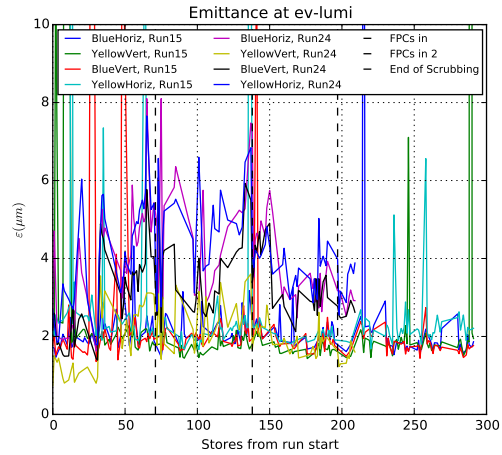
34608 is arbitrary good store from Run24

Luminosity lifetime is worse now than Run12 and Run15

Initial rates are above Run12

ZDC rates at store are 40% of good Run15 rates

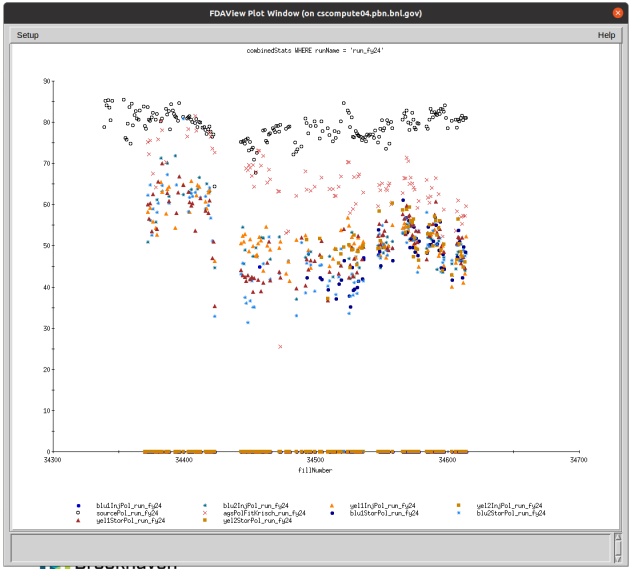
Emittance comparison



A large intensity-dependent emittance growth was observed which has now been resolved

- initially degraded vacuum due to newly installed components was suspected
  - vacuum scrubbing reduced vacuum response from beam to nominal levels
- second, electron cloud formation as a result of non-coated pipes for newly installed components
  - reduced number of bunches alleviated emittance growth, minimal other signatures of electron cloud formation
- Beam driving higher order modes in the 56 MHz leading to transverse emittance growth
  - FPC1+2 full inserted to provide maximum damping

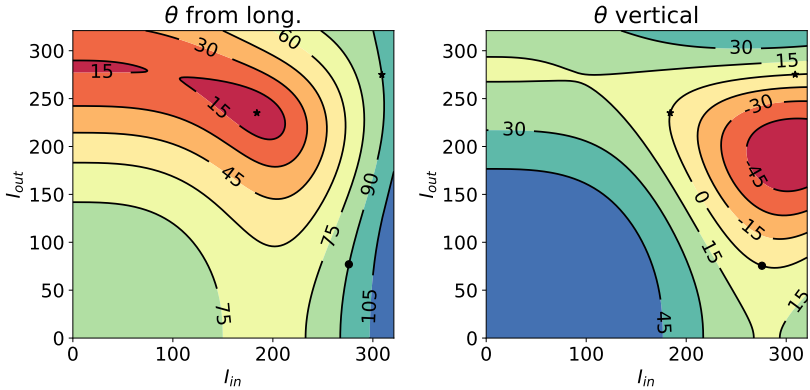
Polarization Performance



- Polarized source stability suffered early on due to contamination in the He cell
- Large emittance-dependant drop in RHIC polarization transmission prior to resolution of 56 MHz
- Current downward trend correlated with reduced polarization in the AGS
- Following adjustments to the new blue snake, yellow:blue polarization now within 3%, previously 10%.

Rotator currents for radial and longitudinal collisions

STAR requested radially polarized collisions, which requires use of the rotator magnets



- For radial polarization, I_{out}, I_{in}= 275, 309 and I_{out}, I_{in}=76, 276
- For longitudinal polarization,
- Scanning along the pure vertical line runs into PS limit (quenching at 300 A)
- Scanning vertically has more scanning range

Improvements

STAR needs 2x higher ZDC rates, sPHENIX slightly less to hit the projections.

Will need to exceed maximum projection to hit luminosity goals for both experiments

1. The cause of the current emittance growth is under investigation
   - This is the top priority and would provide us with a near factor of 2 improvement to luminosity
2. Nominal beam intensity per bunch for physics fills currently 2.1×10^{11}, can be improved up to 3.0×10^{11}
3. β^* squeeze at sPHENIX will provide further luminosity gains

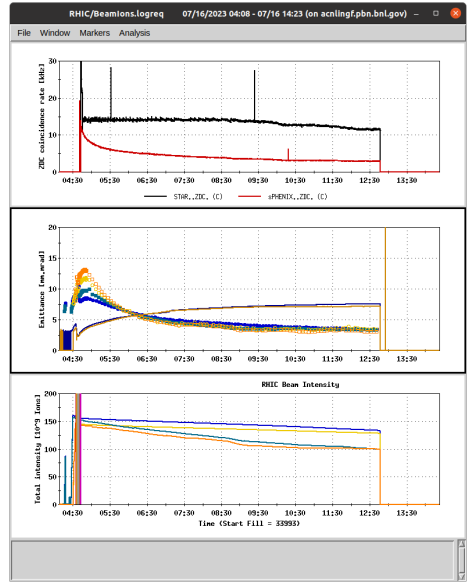
Run24 Schedule

Polarized protons at RHIC
Current Status and Issues

Continuation of Au+Au at 100 GeV

Continuation of Au+Au at 100 GeV

- Continue to collect data and commission sPHENIX.
- Investigate cause for emittance increase on ramp (possibly undamped 56 MHz cavity).
- Commission 56 MHz cavity.
- Stochastic cooling to cool beams at store.
- As intensity improves, the longer the rates can be sustained.



Summary

- So far, Run24 has been an exciting and interesting run.
- There are a number of problems to solve before we can provide experiments with higher luminosities.
- Nominal conditions need to be restored and improved on to achieve luminosity goals.
- C-AD is working diligently to meet STAR and sPHENIX physics goals

Thank you

Thank you and questions.