RHIC Status and RUN-3 Overview

RUN-2 performance

RHIC commissioning topics

RUN-3 plans

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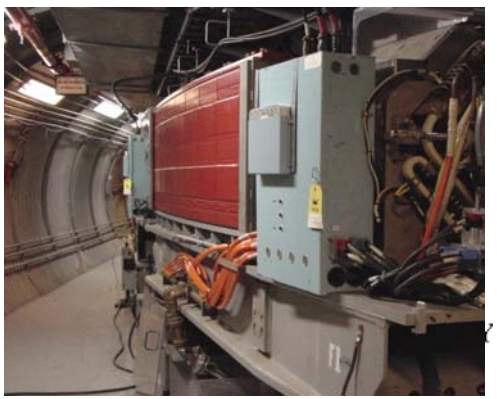
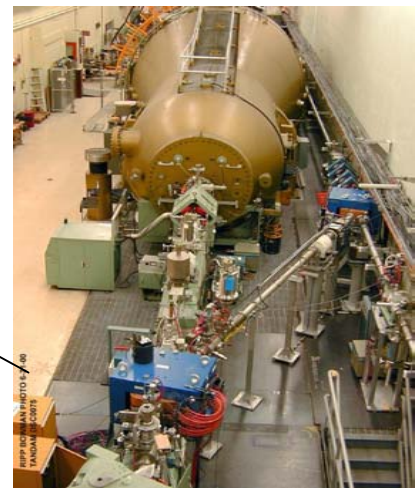
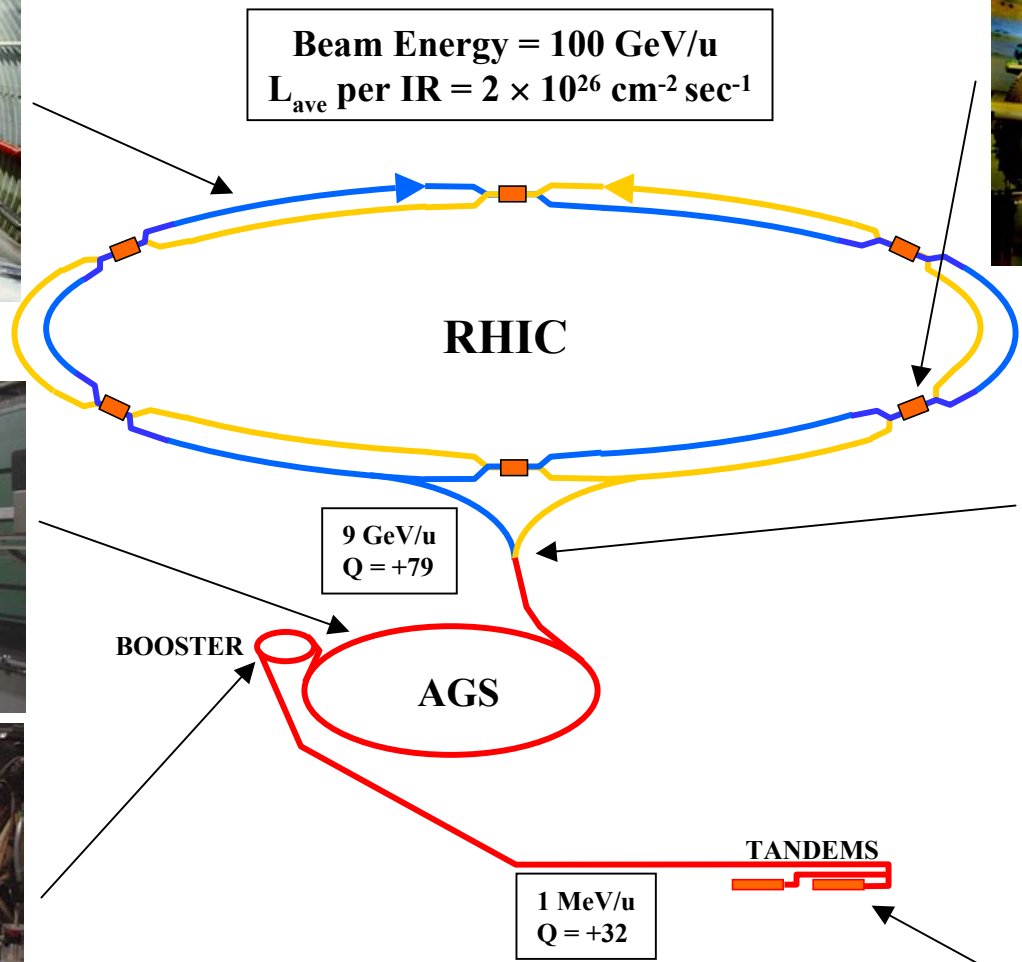
Thomas Roser
RHIC Beam Experiments Workshop
September 26 - 27, 2002

Gold Ion Collisions in RHIC

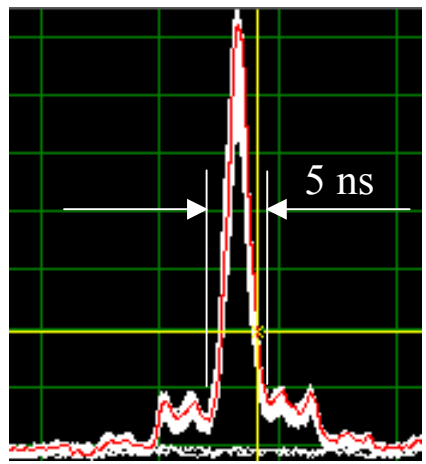






RHIC RUN-2 Gold Parameters

- **55 - 56 bunches** per ring ✓ (110 bunches per ring tested, intensity limited)
- **7.5×10^8 Au/bunch @ storage energy** (intensity limited during acceleration)
- **1×10^9 Au/bunch achieved @ injection** ✓
- **Longitudinal emittance**: 0.5 eVs/nucleon/bunch (0.3-0.6 Design) ✓
- **Transverse emittance** at storage: **15 π μm** (norm, 95%) ✓
- **Storage energy: 100 GeV/ amu (γ = 107.4)** ✓ **10 GeV / amu (γ=10.5)** ✓
- **Lattice with β^* squeeze during acceleration ramp:**
  - β^* = 3 m and 10m @ all IP at injection ✓
  - β^*= 1 m @ 8 and 2 m @ 2, 6 and 10 o'clock at storage ✓
- **Peak Luminosity: 5×10^{26} cm^{-2} s^{-1}** (2.5 × design average) ✓
- **Bunch length: 5ns** with 200 MHz storage rf system (diamond length: σ = 25 cm) ✓



RHIC bunch profile

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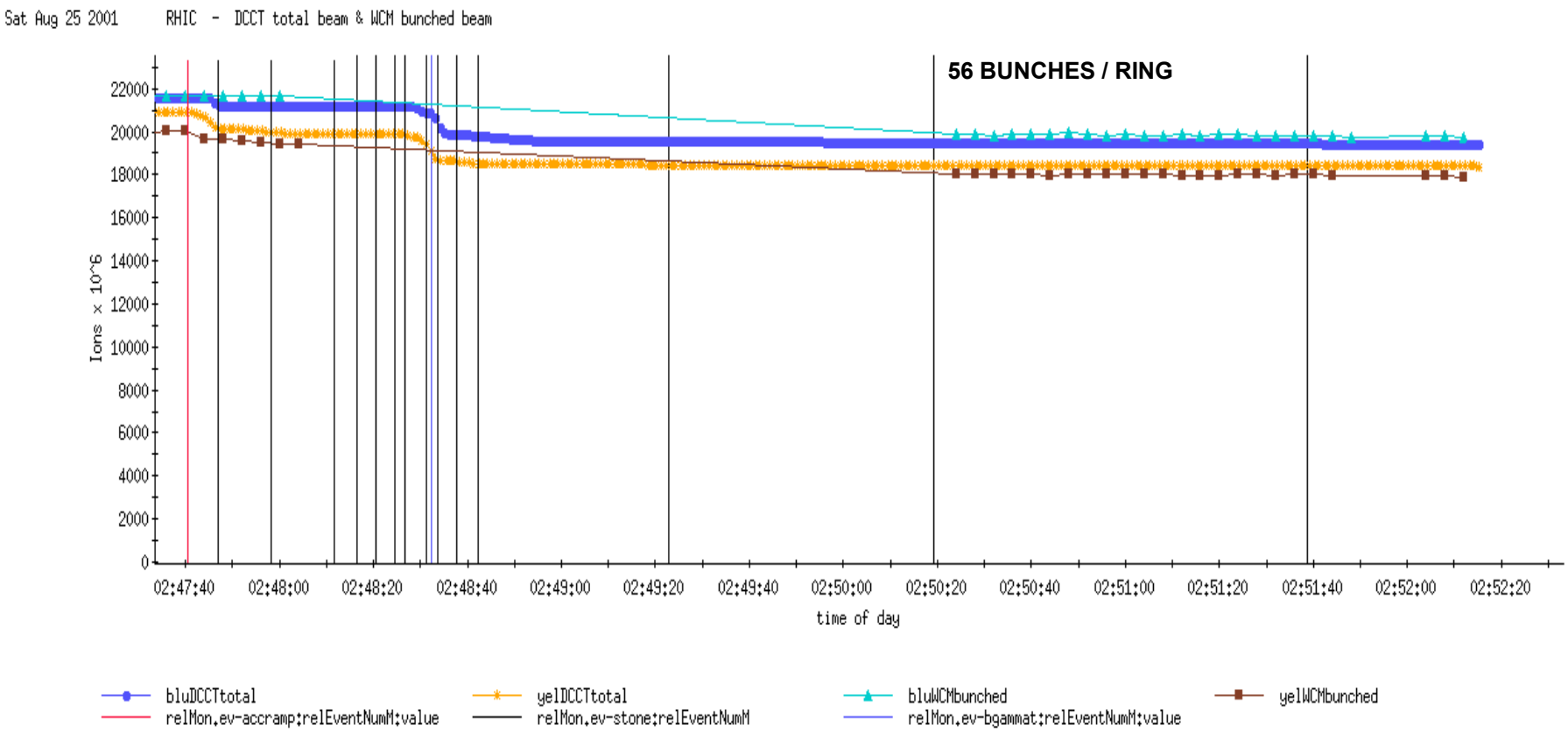
Transmission During Acceleration



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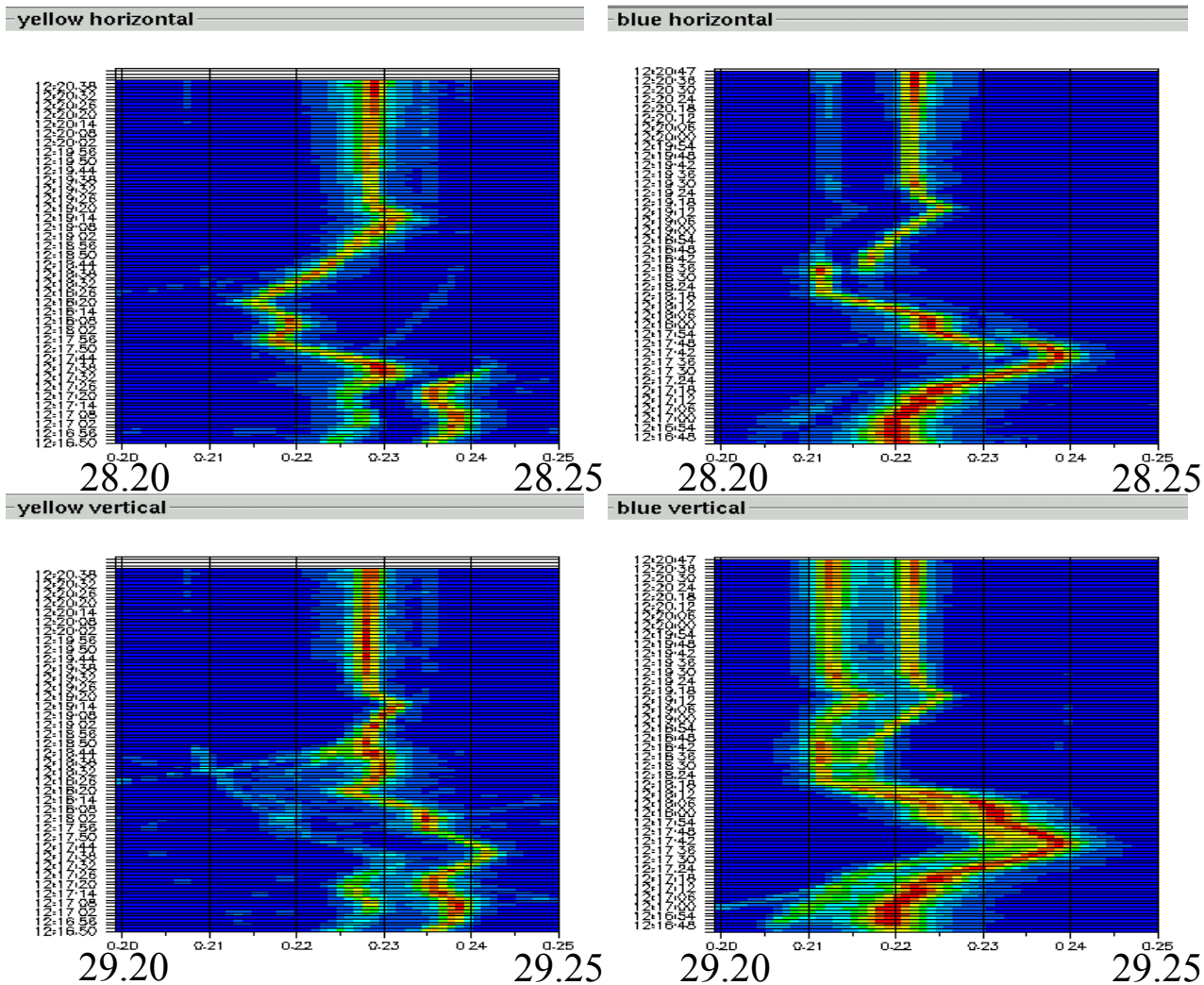
Betatron Tunes on Ramp



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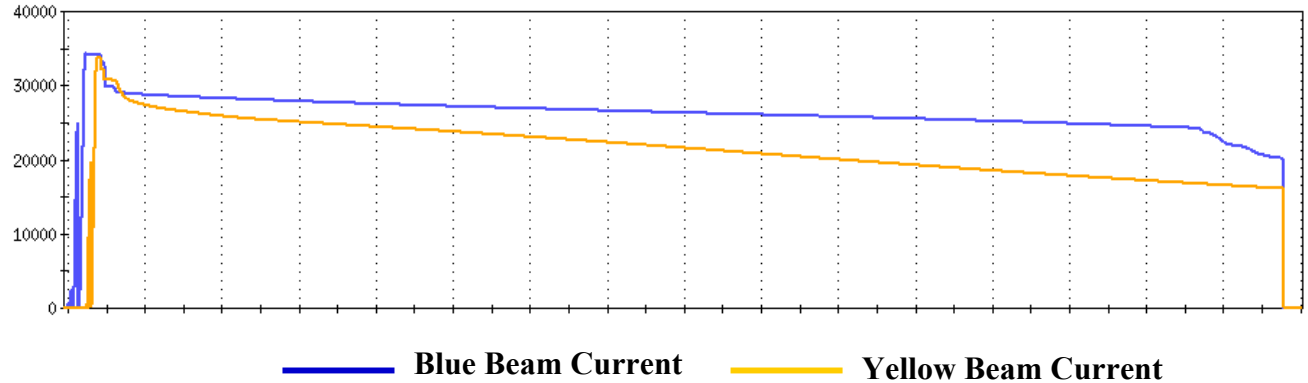
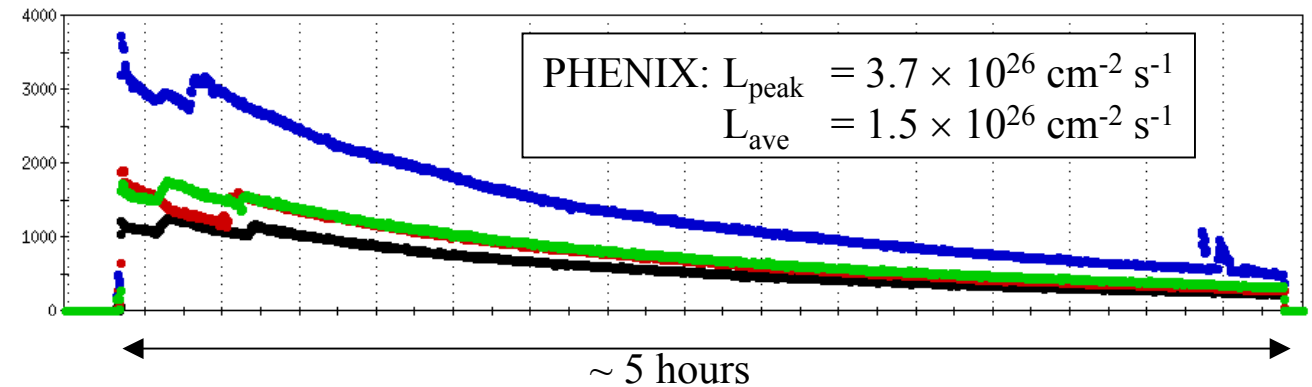
“Typical Au Store” # 1812

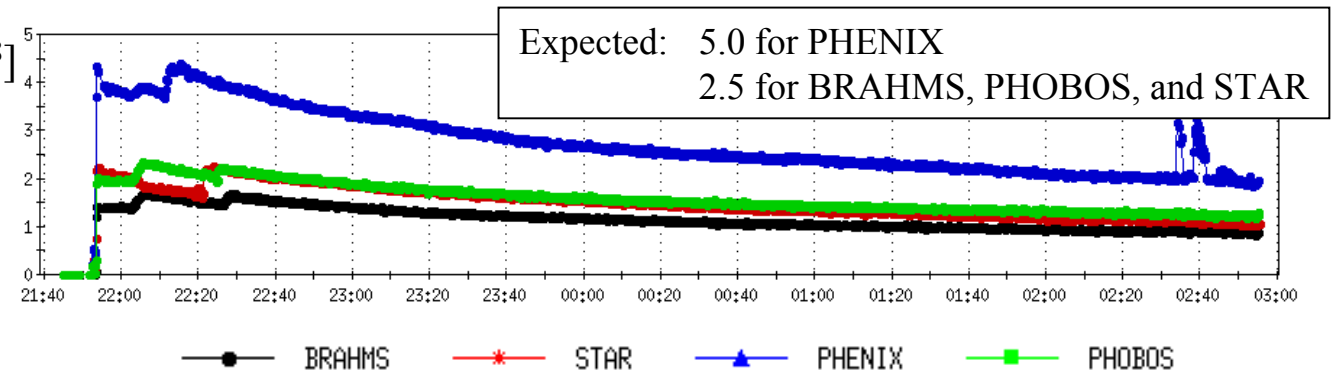
Beam currents [x10^6 ions]



Collision rate [Hz]



Specific luminosity [Hz/10^{18}]



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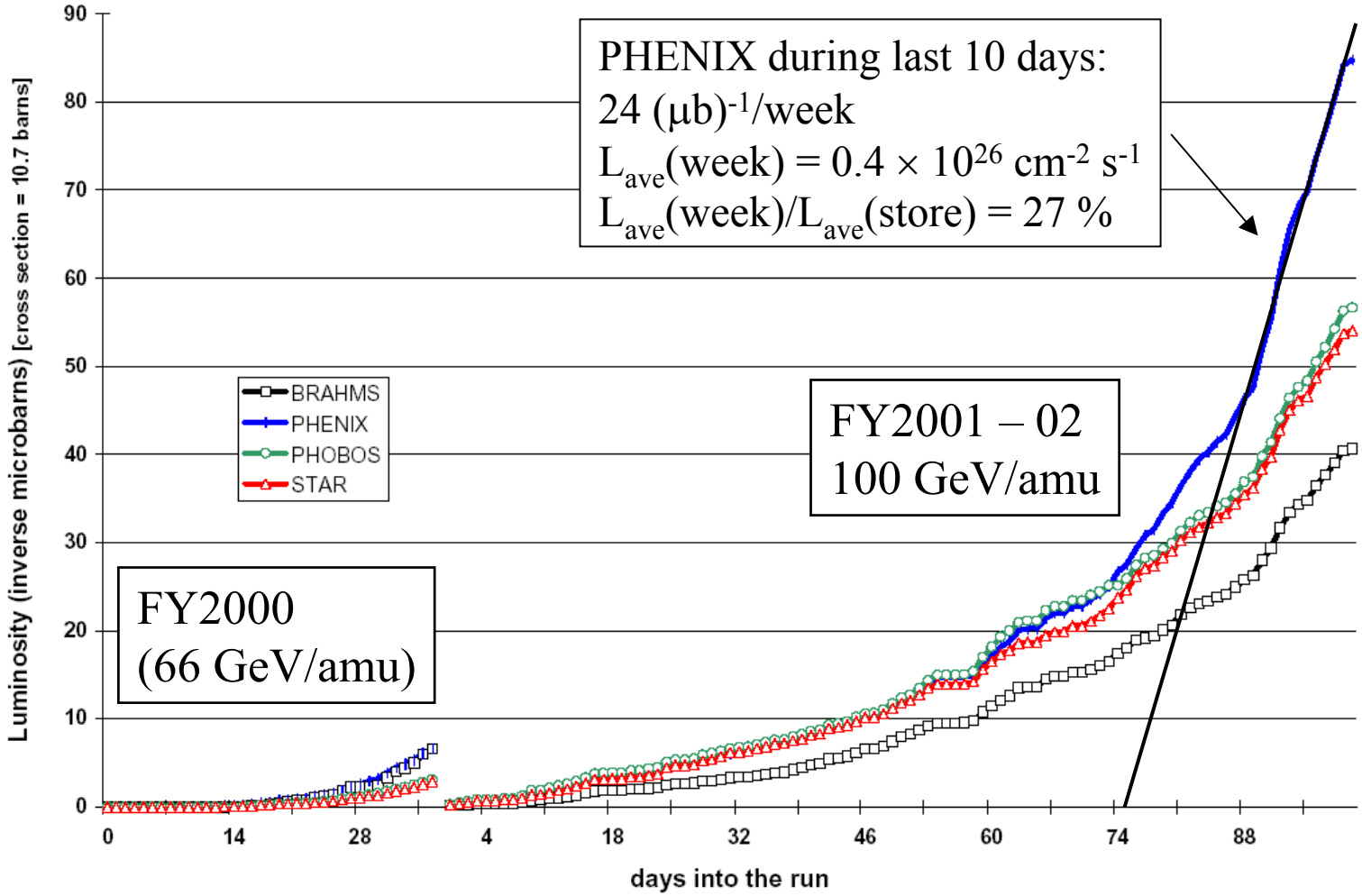
Integrated Au-Au luminosity



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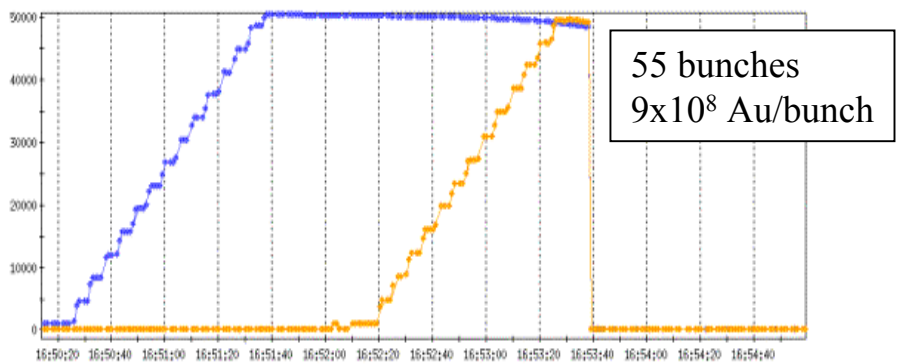
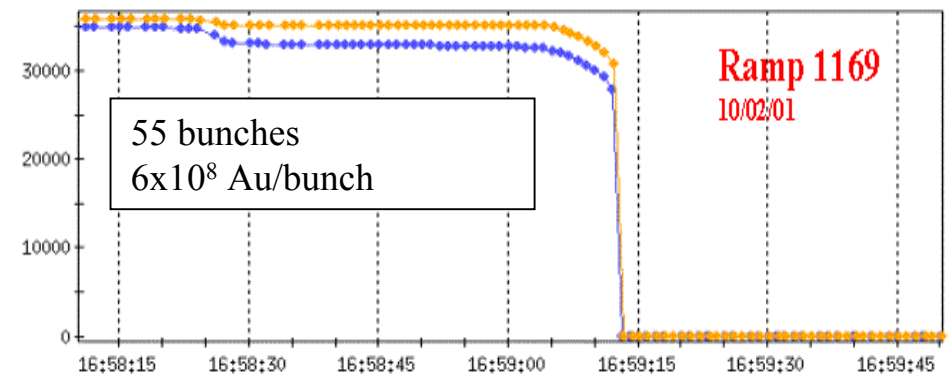
RHIC R&D Challenges and Developments

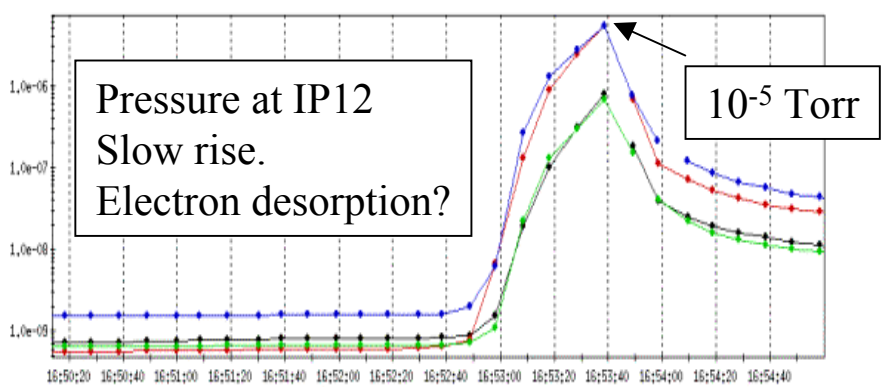
- Intensity limitation for gold due to vacuum break-down (HI)
- Single- and multi-bunch instabilities (HI & PP)
- Tune feedback (PLL) (HI & PP)
- “Flat” orbits to avoid depolarization (PP)
- Intra-Beam Scattering (IBS) (HI)
  - Determines RHIC Au performance
  - Eventually will need electron cooling

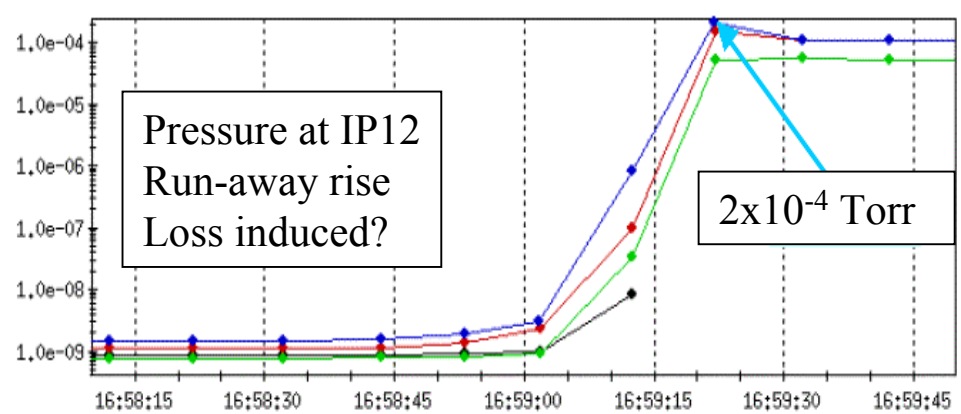
Vacuum break-down

- Only in warm sections that didn't have bake-out; worse with 110 bunches/ring
- Ion desorption, electron desorption, electron multi-pacting, electron cloud?
- Installed electron detectors in IP12 and IP2 and solenoids for electron suppression in IP12.
- Vacuum bake-out of most warm sections









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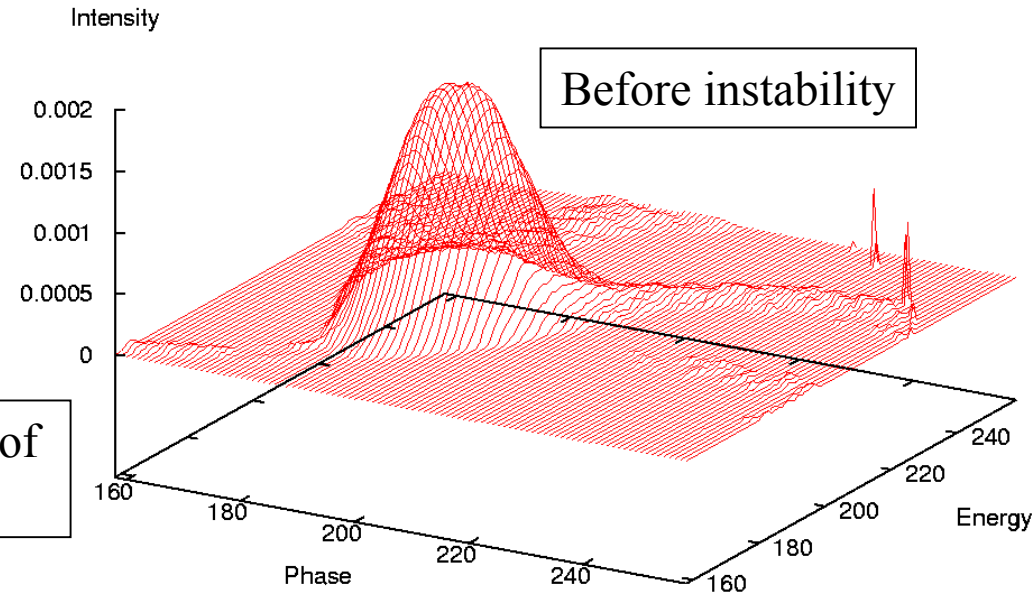
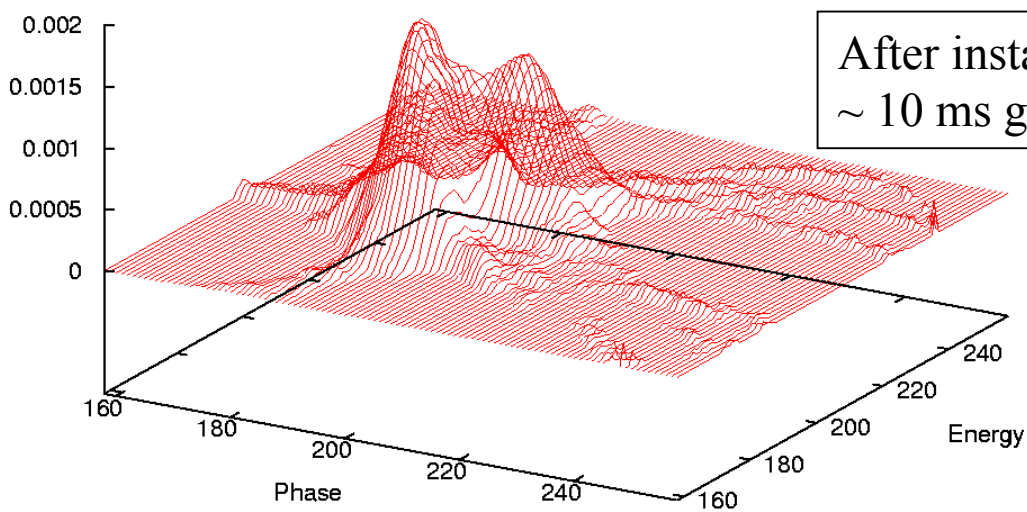
Transverse instabilities in RHIC

- Fast transverse instability (~ GHz)
- High sensitivity around transition
- Effect of broadband impedance, electron cloud (?)
- Cures: beam-beam tune spread, **octupoles,** transverse dampers, …

Tomographic reconstruction of 2D bunch density



Before instability



After instability with ~ 10 ms growth rate

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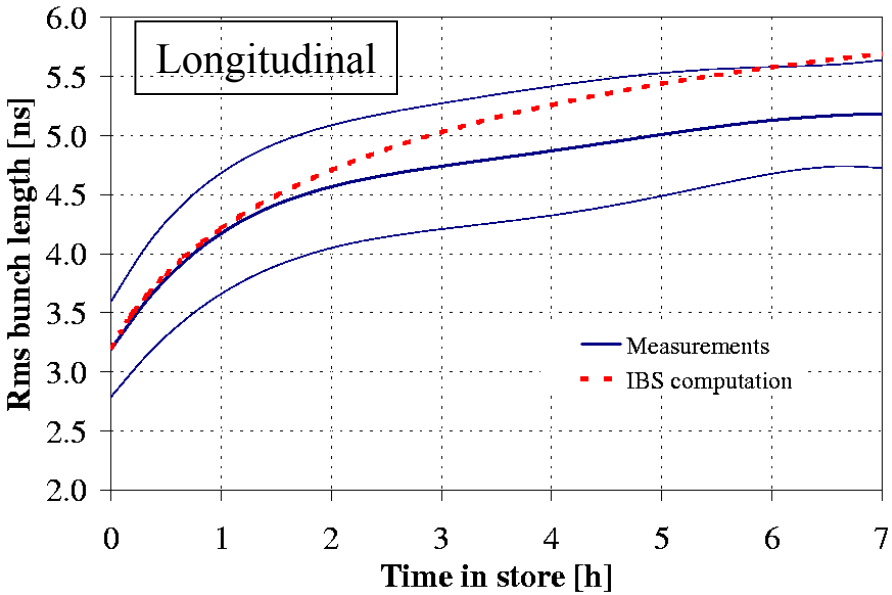
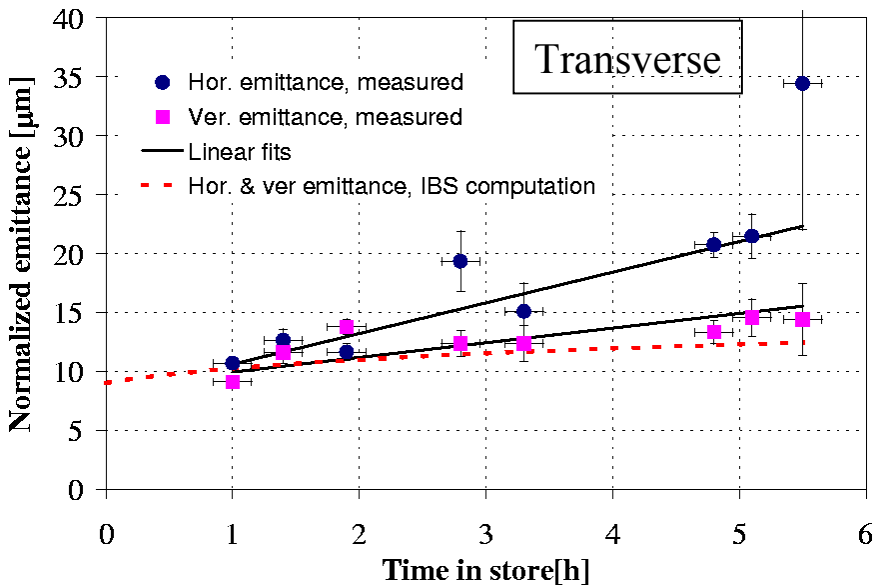
Intra-Beam Scattering (IBS) in RHIC





Longitudinal emittance growth agrees well with model

Additional source of transverse emittance growth (Beam-beam, dynamic apert.)

IBS determines RHIC Au performance

Eventually will need electron cooling (see below)

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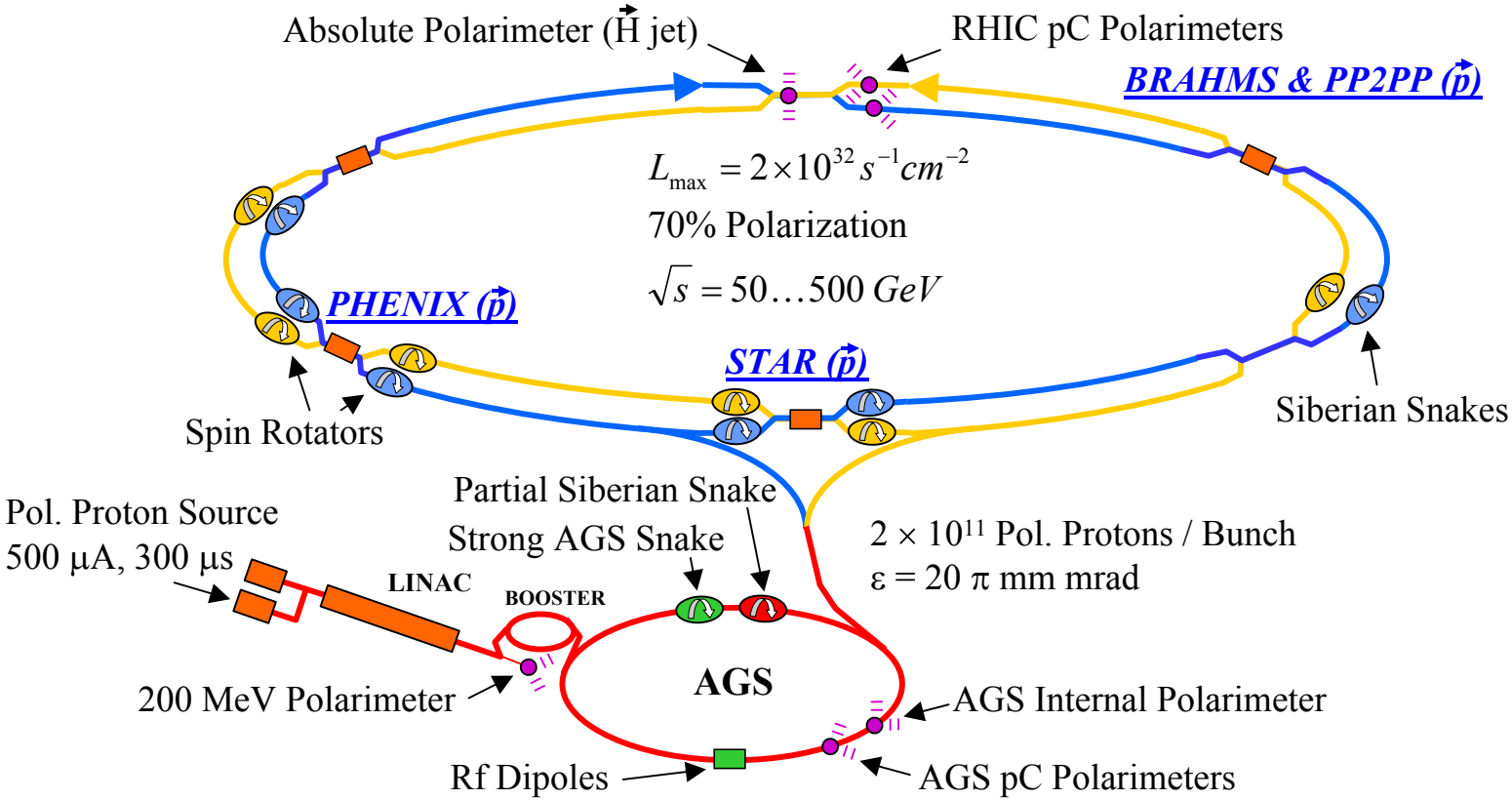
Polarized Proton Collisions in RHIC



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Results from first RHIC polarized proton run

- 55 bunches per ring with 0.8×10^{11} p↑/bunch
- Charge/bunch and total charge higher than with gold beams
- Lattice with constant β^* of 3 m during ramp
- Peak luminosity at beginning of store: 1.8×10^{30} cm^{-2} s^{-1}
- Energy/beam: 100 GeV
- Beam polarization ~ 25 %
  RHIC polarimeters work reliably
- Little if any depolarization in RHIC during acceleration and store
  Siberian Snakes work
- ~ 60 % polarization loss in AGS; aggravated by lower ramp-rate from Westinghouse motor-generator

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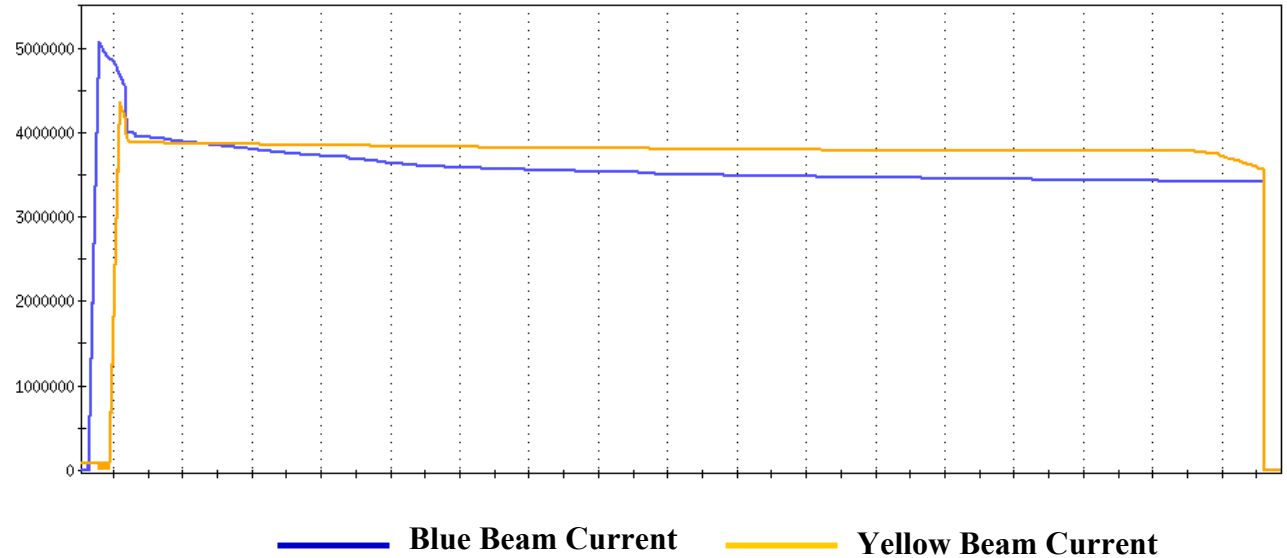
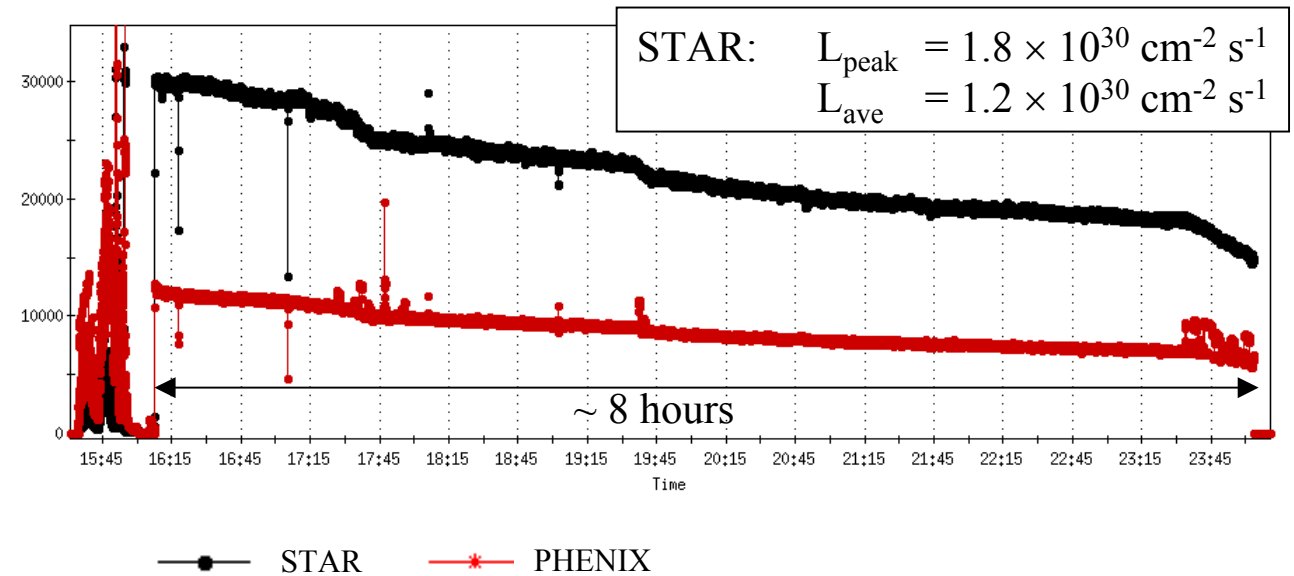
"Typical Proton Store" # 2304

Beam currents [$\times 10^6$ ions]



Collision rate [Hz]

Vernier scans:
STAR: $10^4 \rightarrow 0.6 \times 10^{30}$ cm^{-2} s^{-1}
PHENIX: $10^4 \rightarrow 1.6 \times 10^{30}$ cm^{-2} s^{-1}



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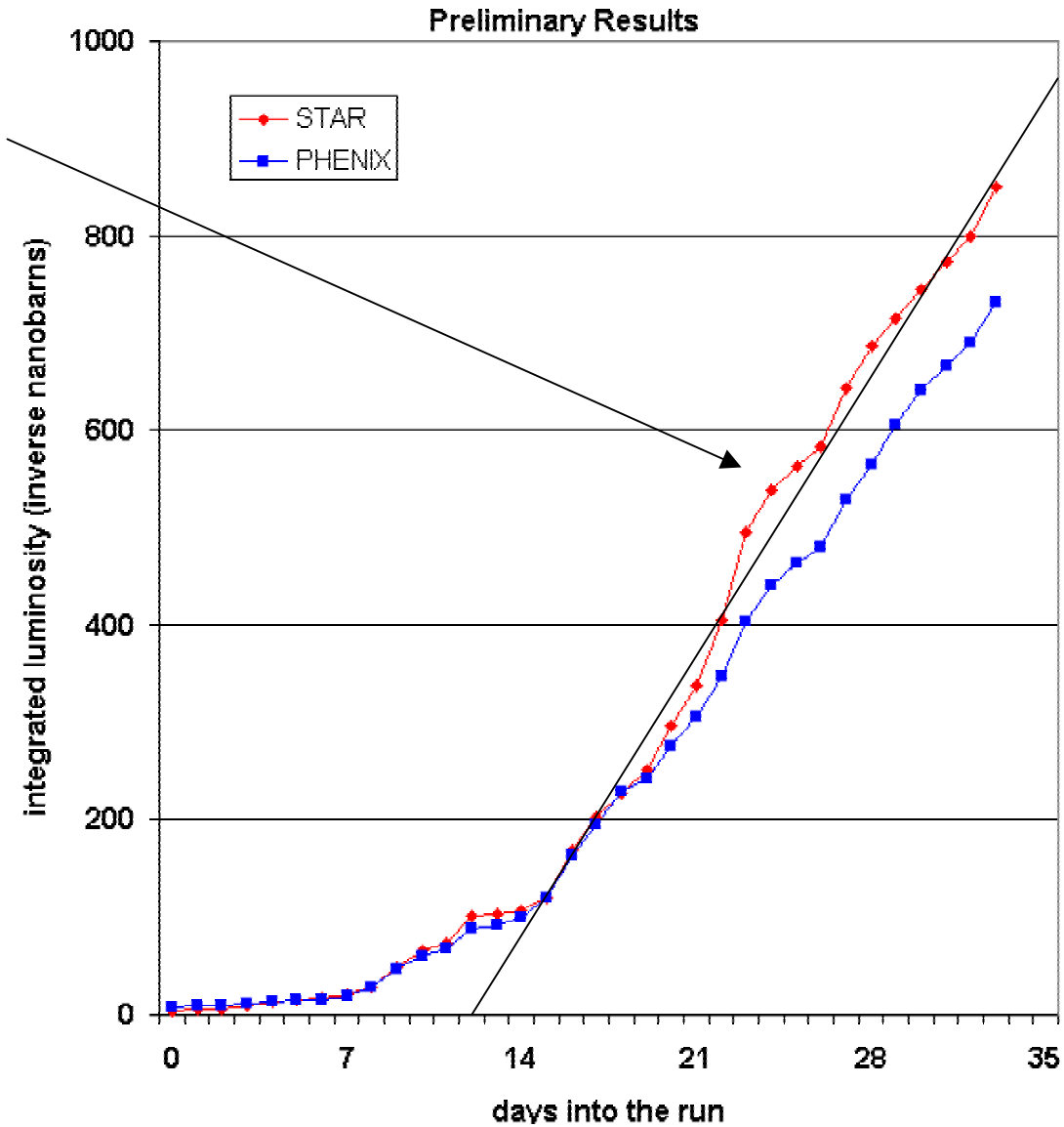
Integrated p - p luminosity

STAR during last 20 days:
290 $(nb)^{-1}$/week
$L_{ave}(week) = 0.5 \times 10^{30}\ cm^{-2}\ s^{-1}$
$L_{ave}(week)/L_{ave}(store) = 42\ \%$



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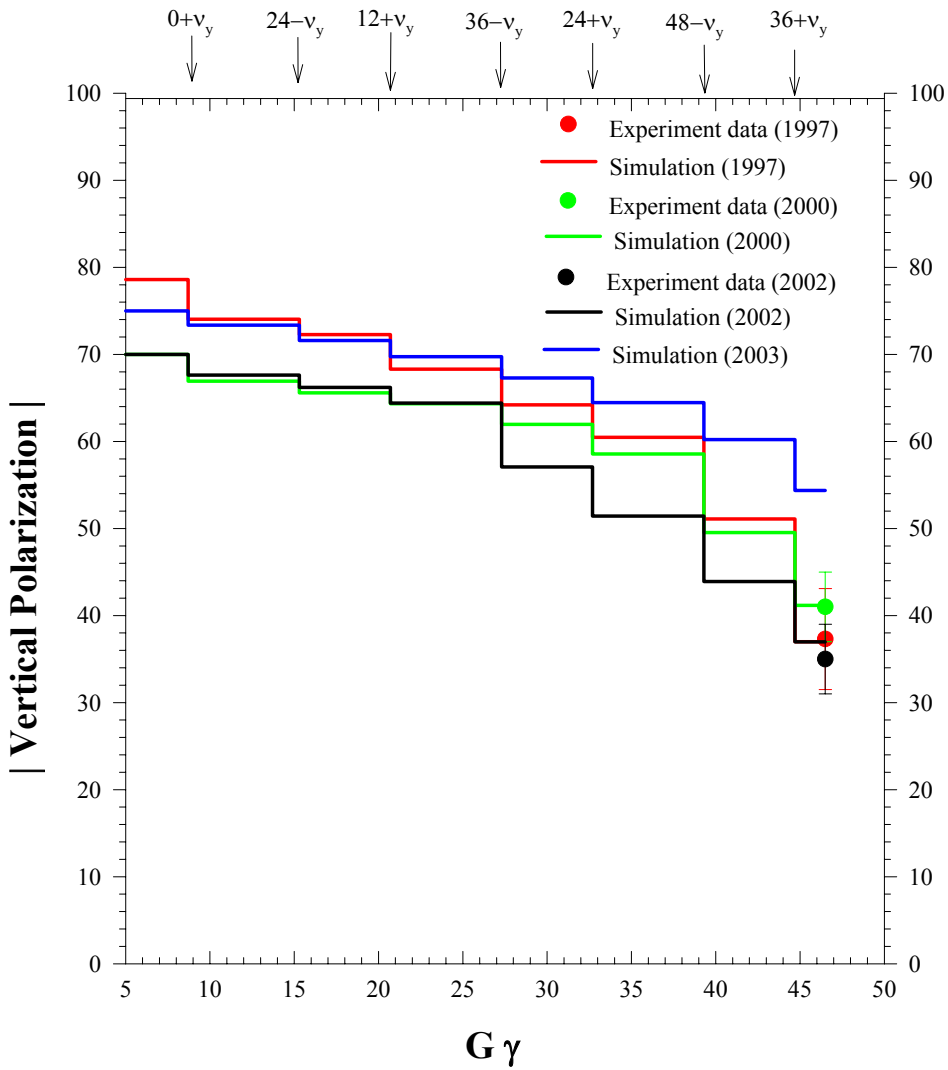
Proton polarization at the AGS

- Full spin flip at all imperfection resonances using partial Siberian snake
- Full spin flip at strong intrinsic resonances using rf dipole
- Remaining polarization loss from coupling and weak intrinsic resonances
- Larger polarization loss in FY2002 due to lower ramp-rate motor-generator
- With high ramp rate MG, higher source polarization, and new AGS pC polarimeter expect more than 50 % AGS polarization
- To avoid all depolarization in AGS build strong AGS helical Siberian snake!



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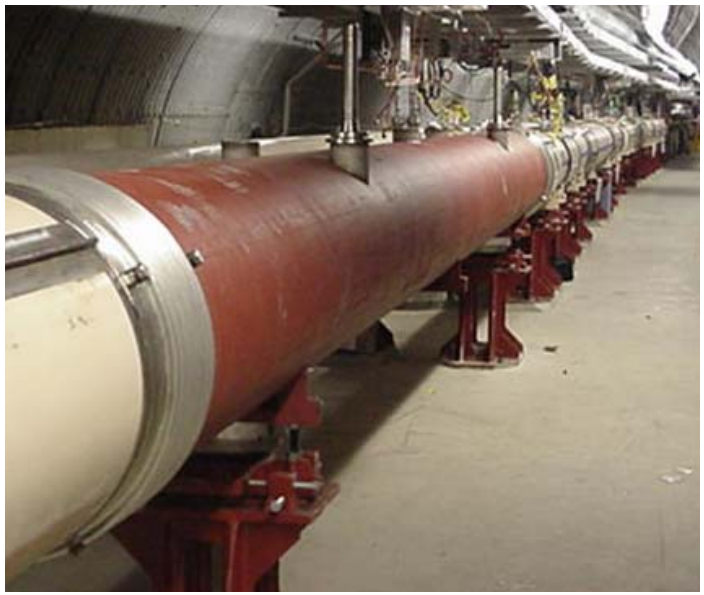
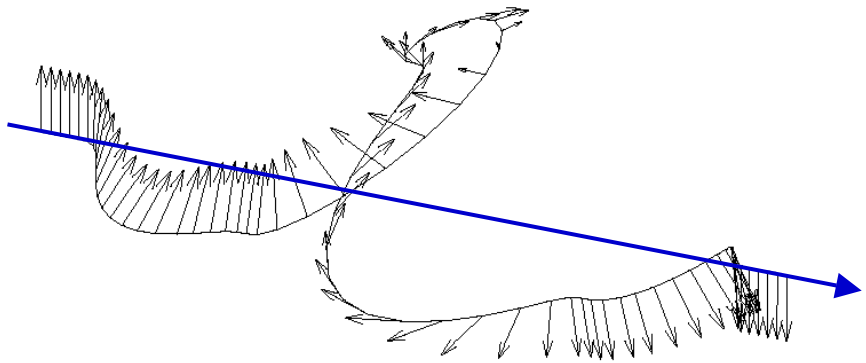
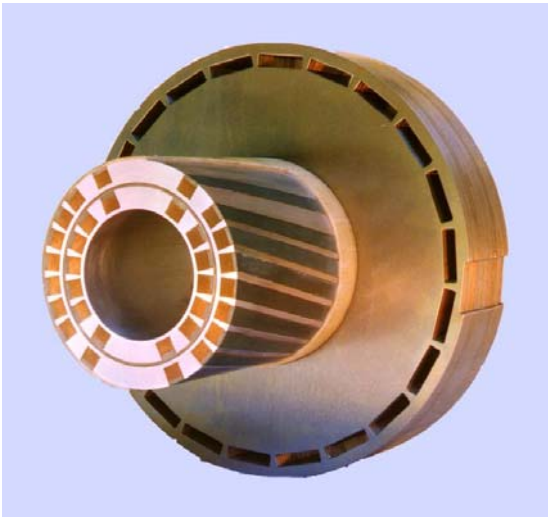
First Siberian Snake in RHIC Tunnel

Siberian Snake: 4 superconducting helical dipoles, 4Tesla,
2.4 m long with full 360° twist







Funded by RIKEN, Japan
Designed and constructed at BNL

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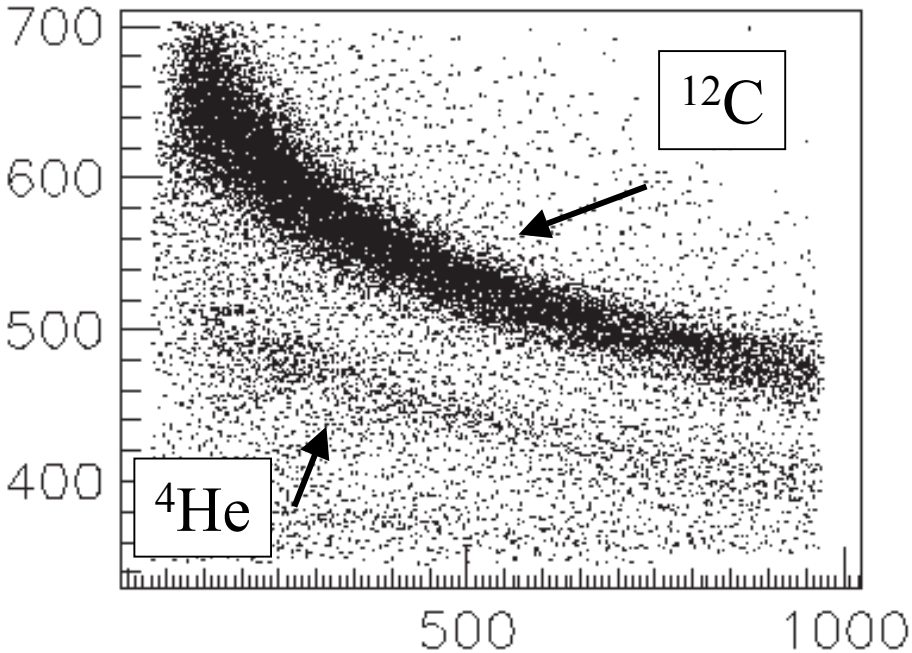
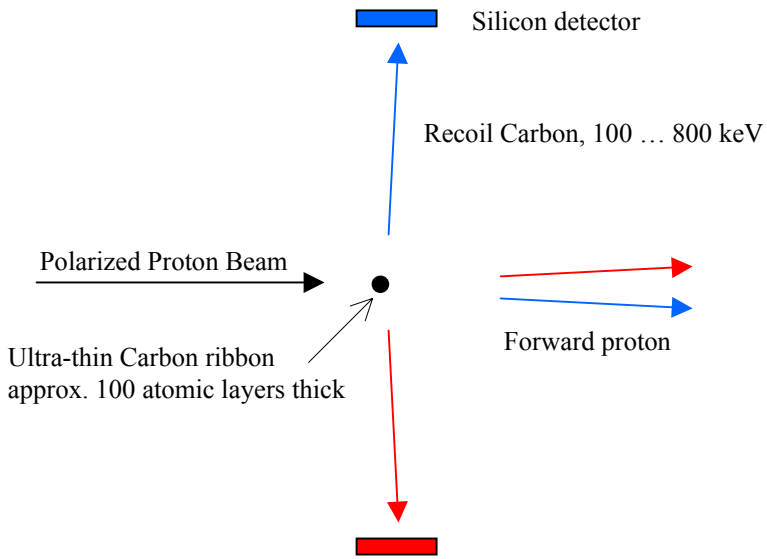
RHIC proton-carbon polarimeter



Energy vs. ToF spectrum



- ~ 1.2 % energy independent analyzing power for small-angle elastic scattering in the Coulomb-Nuclear Interference (CNI) region
- Slow recoil Carbon detected in between bunch crossings
- Fiber target allows for polarization profile measurement

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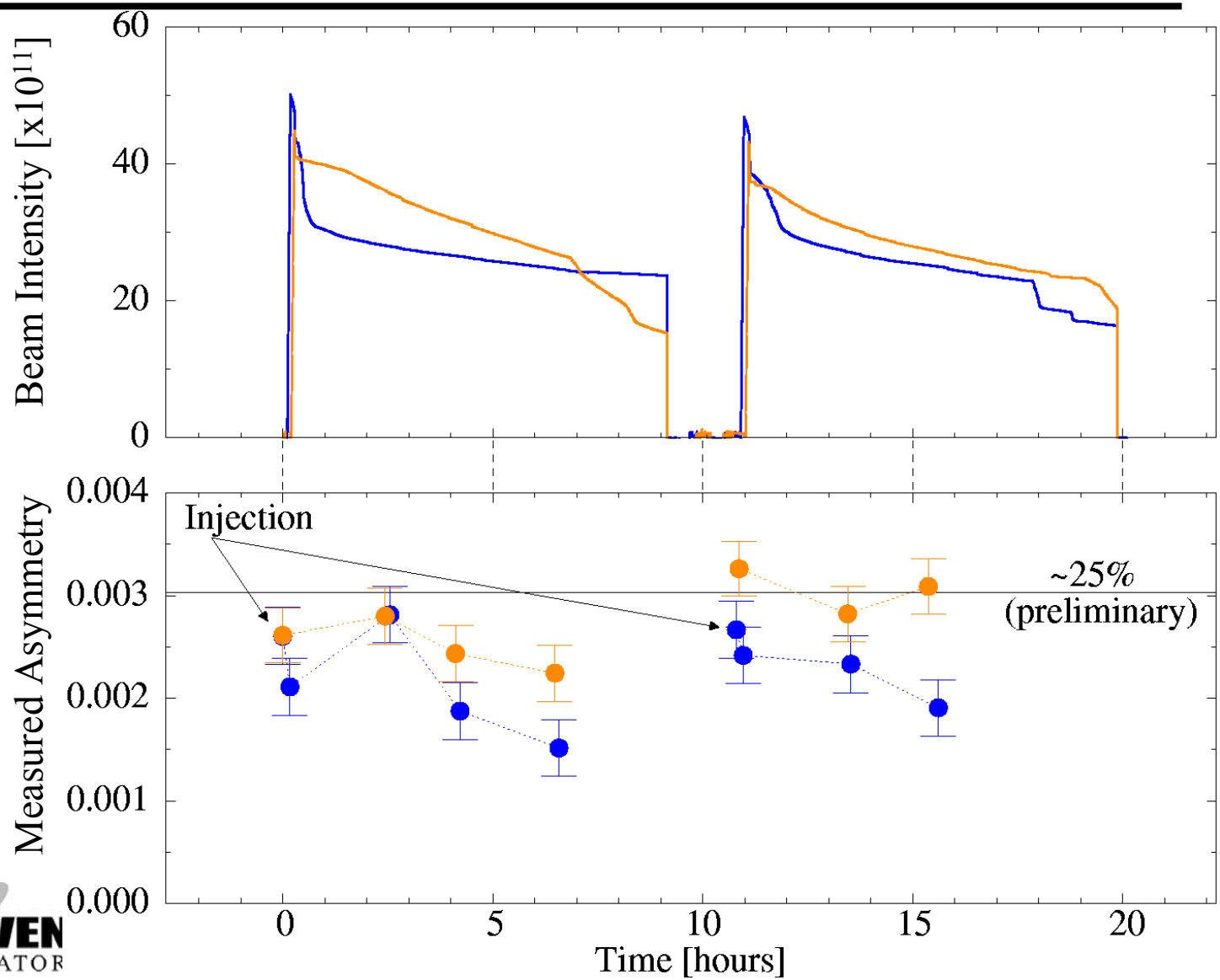
RHIC Beam Polarization



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RHIC Polarization Set-up

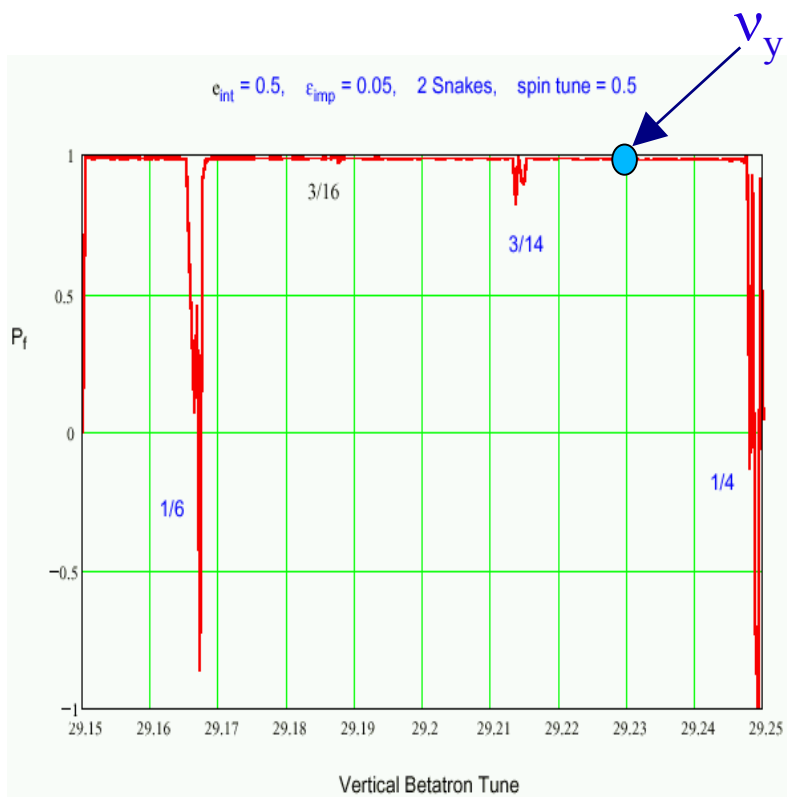
2 Siberian Snakes per ring hold the spin tune ½ all the way up during the acceleration

The vertical tune was chosen at 0.23, between 2 high-order spin resonances:

- 1/4=0.25 ; depends on vertical orbit
- 3/14=0.2143; exists even without orbit errors

The special vertical orbit, "really" flat was used as the ideal orbit

- Using measured misalignment data (3 years old), new measurements show up to 5 mm misalignment! -> realignment underway
- The goal number for vertical orbit correction is 0.5mm rms
- Development of beam based orbit “flattening”



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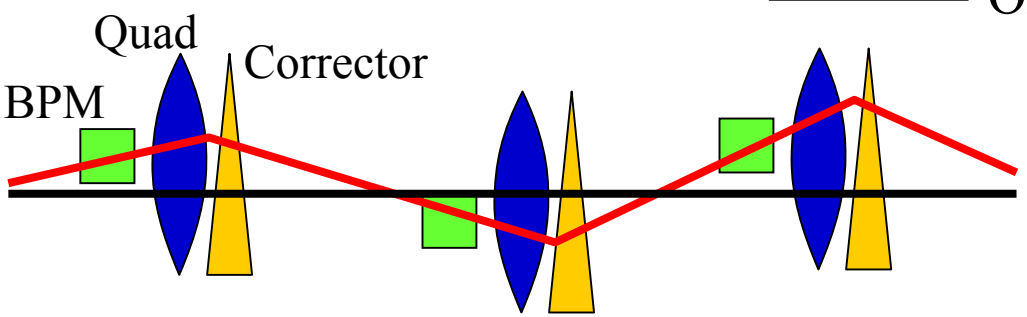
Ideal Orbit for Polarization

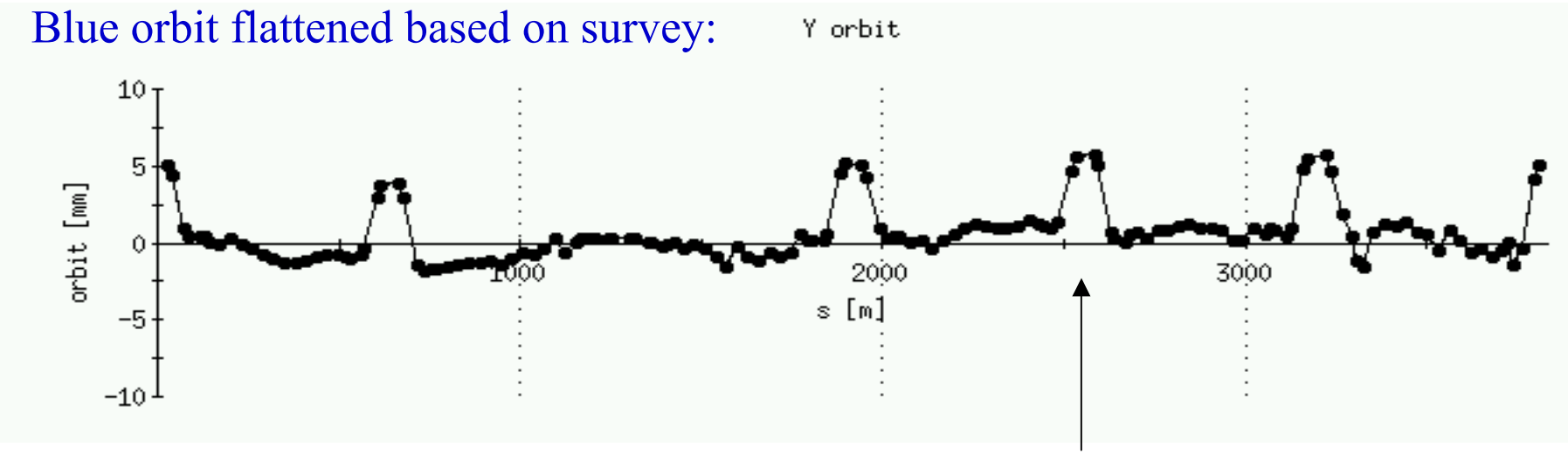
Correct orbit to minimize kicks:

Orbit going through center of BPM's

Orbit without kicks



Blue orbit flattened based on survey:



Vertical bumps to avoid collisions

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Tune and orbit control during ramp

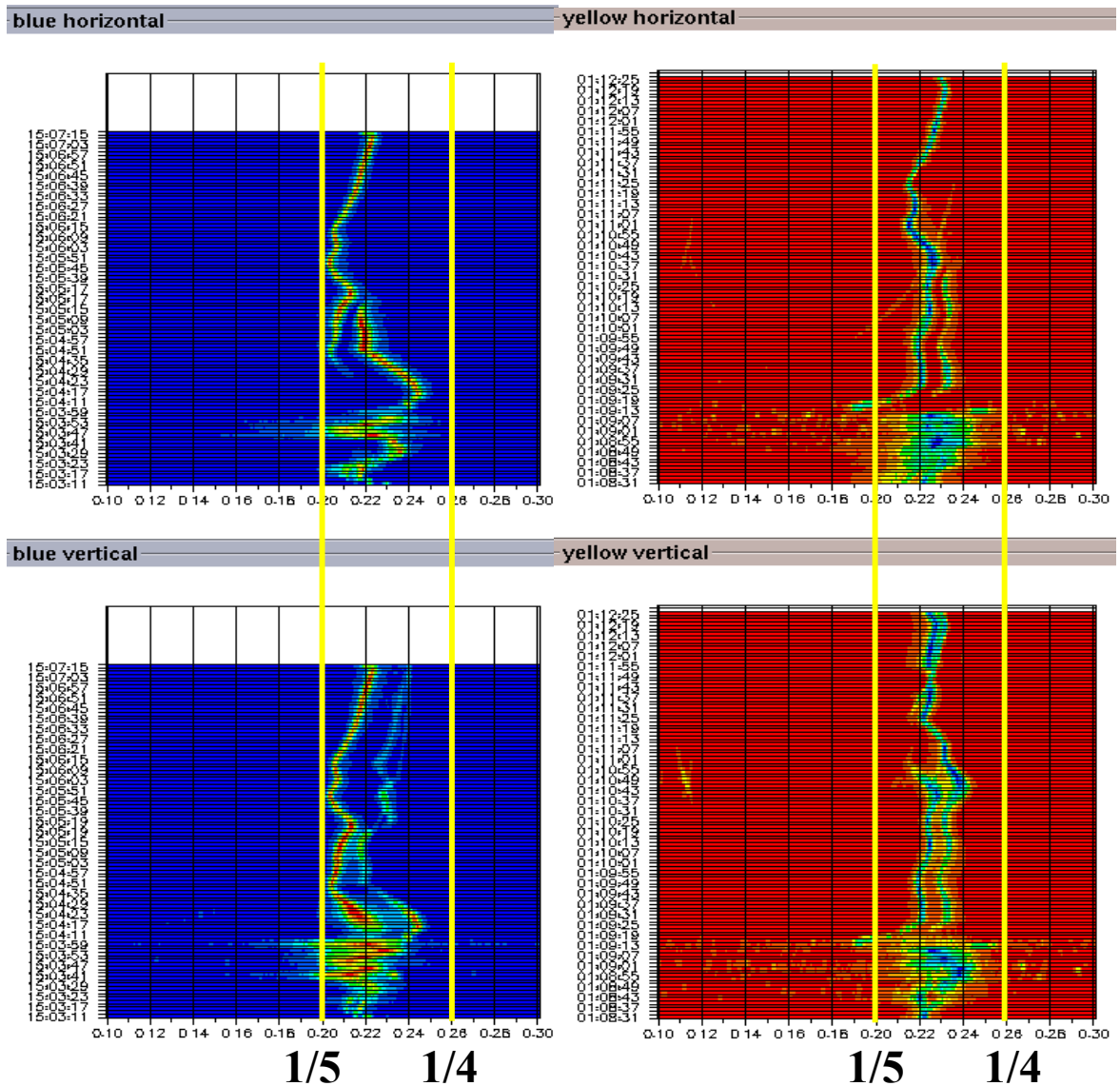
Requirement for polarized proton acceleration:

Closed orbit correction to better than 0.5 mm rms

→ orbit correction feed-forward

Betatron tune control to better than 0.005 (DQ/Q ~ 0.0001)

→ Active PPL tune feed-back system



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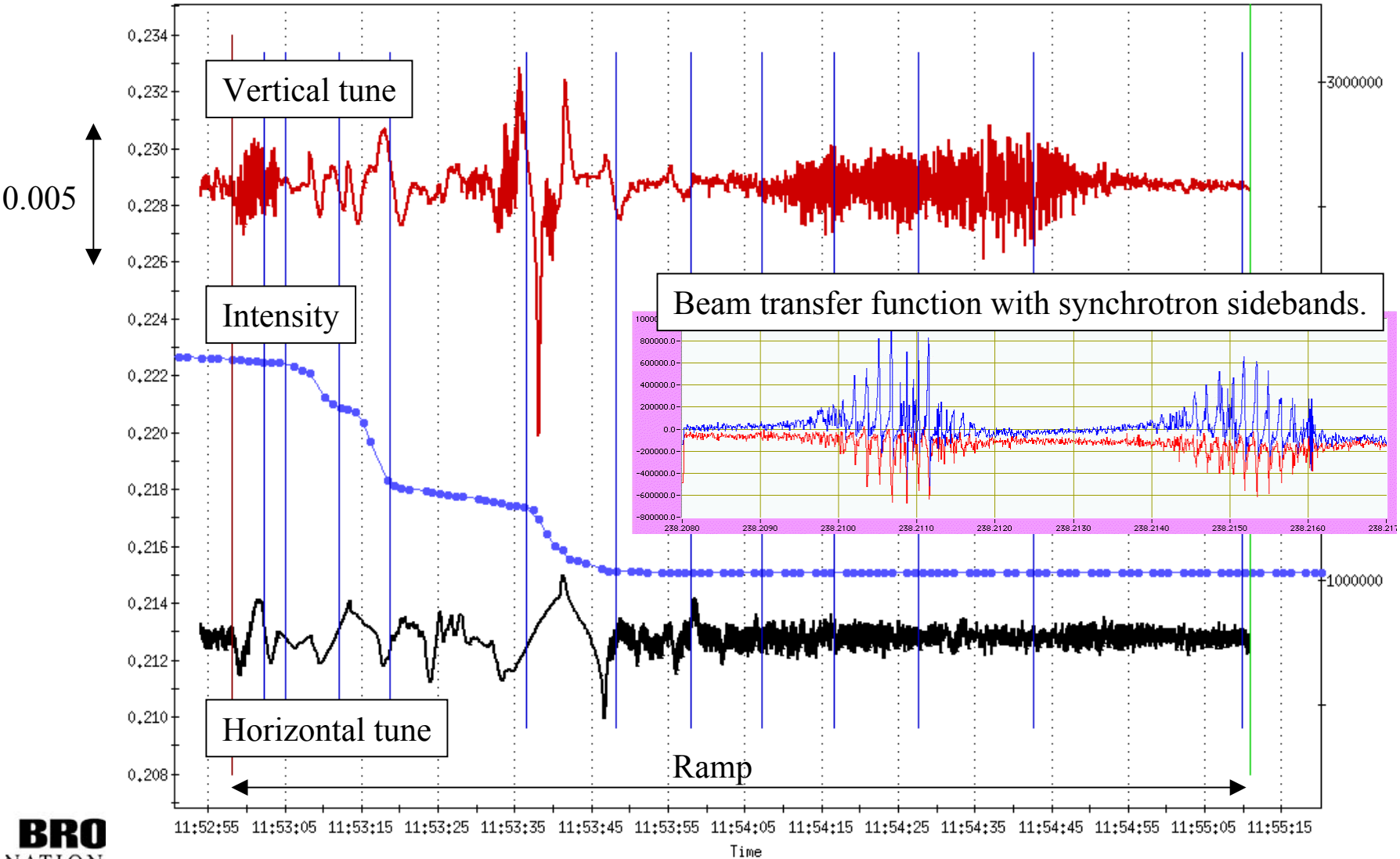
First successful pp ramp with tune feedback



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RUN-3 Goals (~ 3-4 weeks into run)

Energy/beam: 100 GeV/nucl., diamond length: σ = 20 cm, L_{ave}(week)/L_{ave}(store) = 40 %

Mode	# bunches	Ions/bunch [$\times 10^9$]	β^* [m]	Emittance [$\pi\mu$m]	L_{peak} [$cm^{-2}s^{-1}$]	L_{ave}(store) [$cm^{-2}s^{-1}$]	L_{ave} (week) [$week^{-1}$]
d-Au	**56**	**80(d), 1(Au)**	**2**	**20**	**4×10^{28}**	**1.6×10^{28}**	**4 $(nb)^{-1}$**
(p↑-p↑)*	**112**	**100**	**1**	**25**	**16×10^{30}**	**10×10^{30}**	**2.8$(pb)^{-1}$**
Au-Au	56	1	1	15-40	14×10^{26}	3×10^{26}	70 $(\mu b)^{-1}$
Si-Si	56	7	1	20	5×10^{28}	2×10^{28}	5 $(nb)^{-1}$

* Beam polarization ≥ 50 %; Acceleration test to 250 GeV

- New hardware installed and to be commissioned:
  - All eight spin rotators for PHENIX and STAR

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RUN-3 Integrated Luminosity Estimate

Estimate for integrated luminosity for 29 week FY2003 run (starting October 1, 2002):

- 4 weeks cool down, 1 week warm-up, 2 weeks setup (for each mode), 3 weeks ramp up (for each mode): →

  29 weeks of cryo ops.: d-Au: 11 weeks at "final" luminosity

  p-p: 3 weeks at "final" luminosity
- Minimum: performance at end of FY2001/02 run
- Maximum: luminosities from previous slide

Mode	L_{ave} (week) [week^{-1}]	Int. Lumi.	L_{ave} (week) [week^{-1}]	Int. Lumi.
(p↑-p↑)	0.3(pb)$^{-1}$	0.9(pb)$^{-1}$	2.8(pb)$^{-1}$	8.4(pb)$^{-1}$
d-Au	?	?	4 (nb)$^{-1}$	44 (nb)$^{-1}$

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Run-4 Tentative Runplan

2 weeks cool down, 1 week warm-up, 2 weeks setup (for each mode),
3 weeks ramp up (for each mode): →

29 weeks of cryo ops.:	Au - Au:	12(11) weeks at "final" luminosity
	p - p:	4(3) weeks at "final" luminosity

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Summary

- Highly successful operation of RHIC with gold beams at design energy and luminosity
- First RHIC Spin data run with 100 GeV on 100 GeV polarized proton collisions and ~ 25 % polarization. Little or no polarization loss in RHIC.
- Run-3 operation with d-Au and p-p. Expect ~ 14 weeks of data running with (8hrs + 4 hrs)/week opportunity for beam experiments.