RHIC Status

RHIC performance

Au – Au collisions [RUN-2 (2001/2002)]

d – Au collisions [RUN-3 (2002/2003)]

Polarized proton collisions [RUN-2 and RUN-3]

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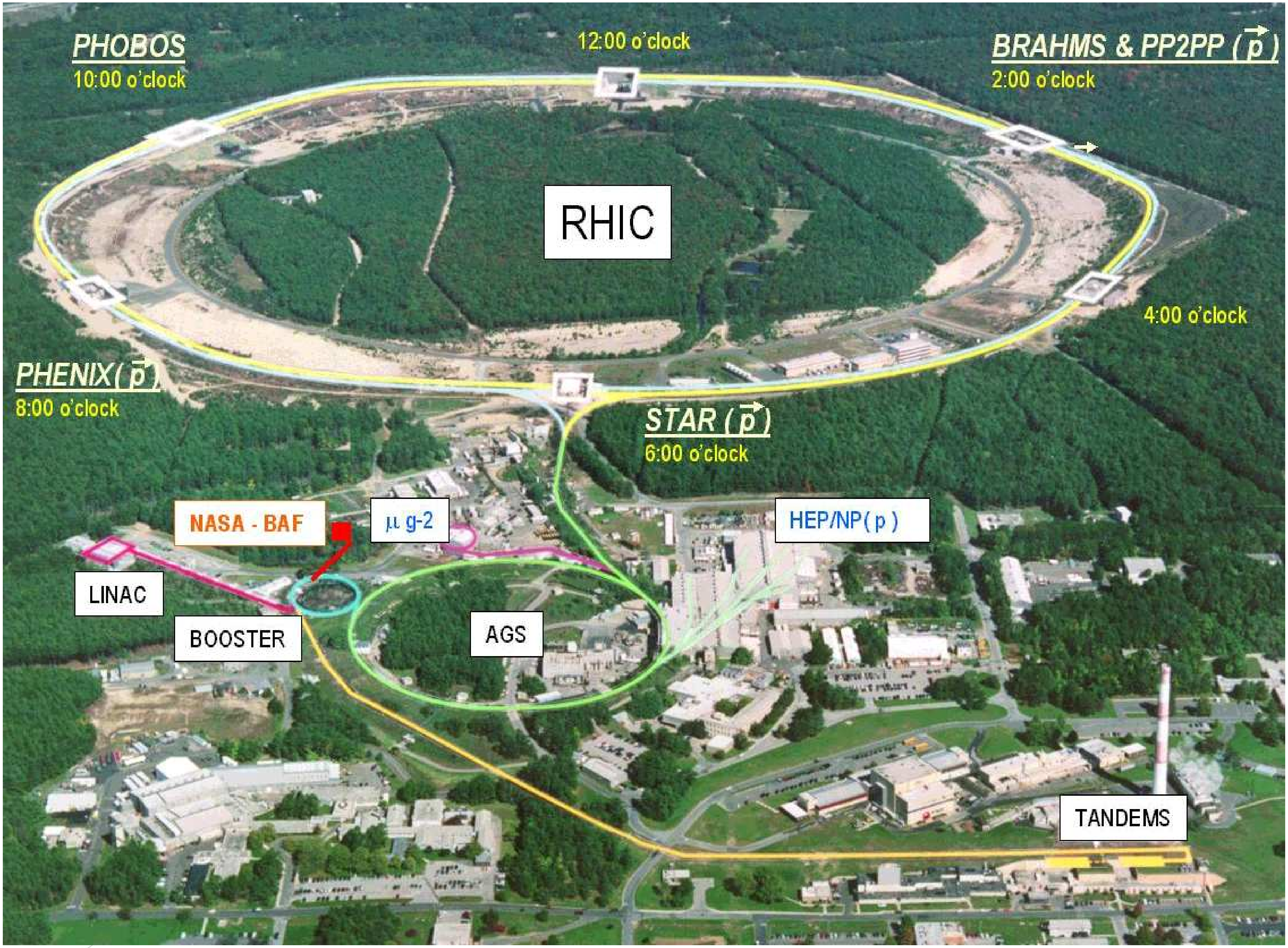
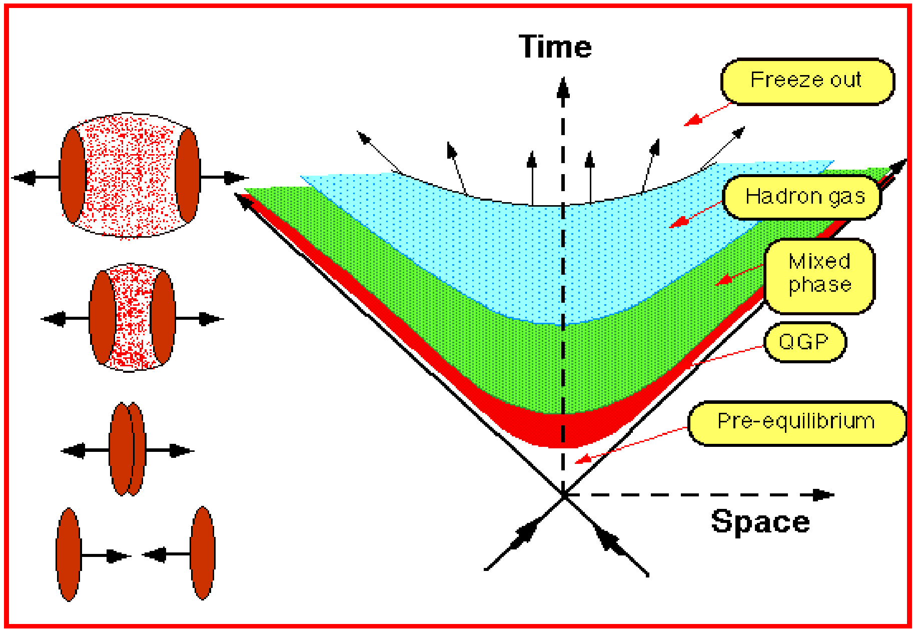
Thomas Roser
eRHIC meeting
May 29 - 30, 2003


PHOBOS
10:00 o'clock
12:00 o'clock
BRAHMS & PP2PP ($\vec{p}$)
2:00 o'clock
RHIC
4:00 o'clock
PHENIX($\vec{p}$)
8:00 o'clock
STAR ($\vec{p}$)
6:00 o'clock
NASA - BAF
μ g-2
HEP/NP(p)
LINAC
BOOSTER
AGS
TANDEMS

A Mini-Bang:

Nuclear matter at extreme temperatures and density

Colliding gold at 100 + 100 GeV/nucleon (40 TeV total cm energy)



a. **Formation phase -**
   parton scattering

b. **Hot and dense phase -**
   quark-gluon plasma and hadron gas

c. **Freeze-out –**
   emission of hadrons

Produce and explore a new state of matter-- quark-gluon plasma

Excite the QCD vacuum on a large scale

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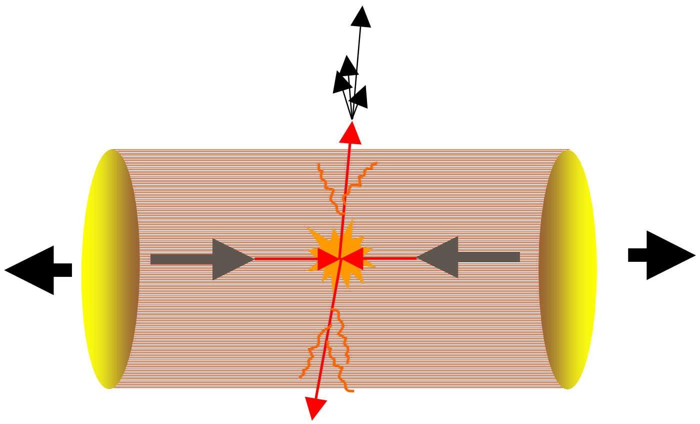
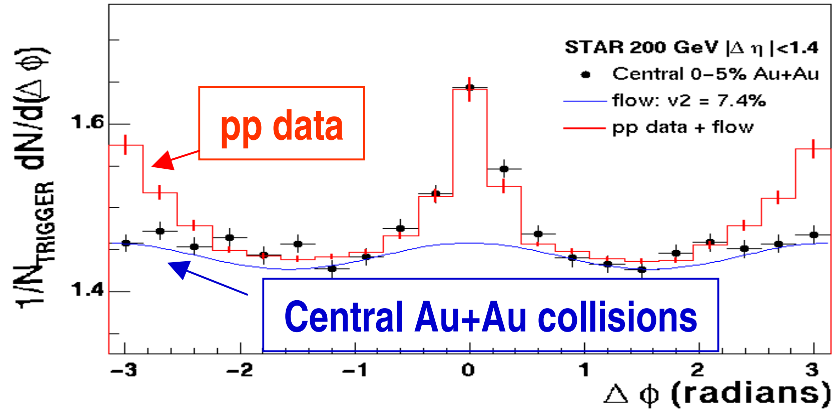
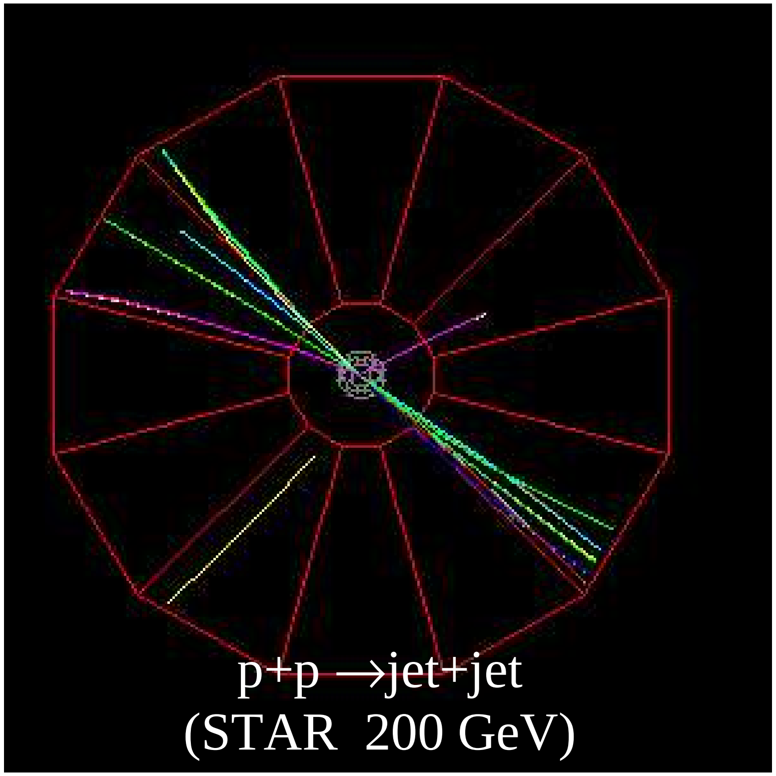
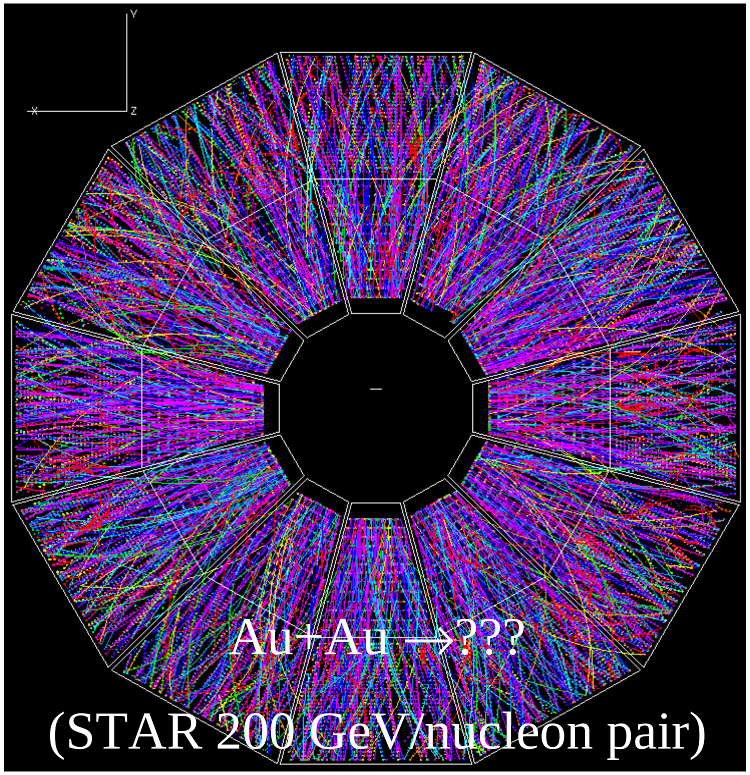
Hard Scattering at RHIC

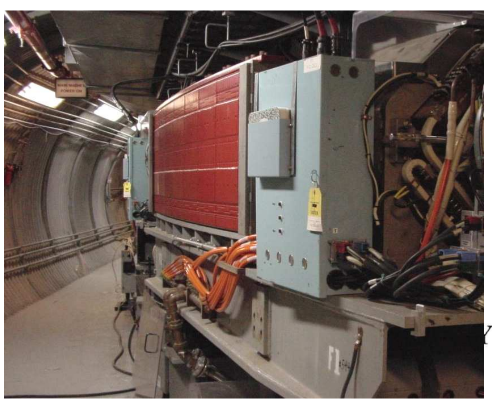


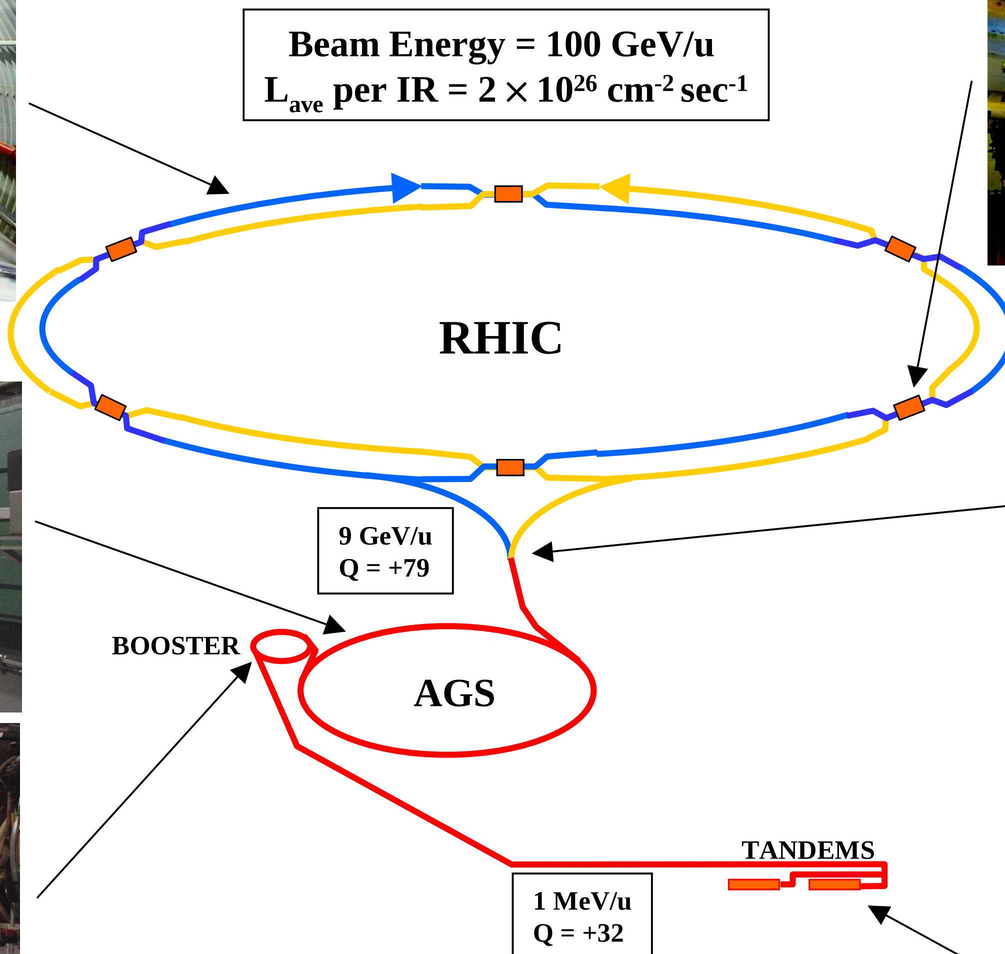


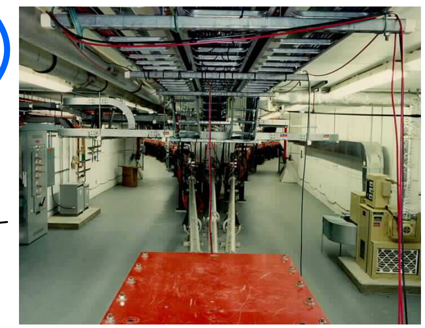


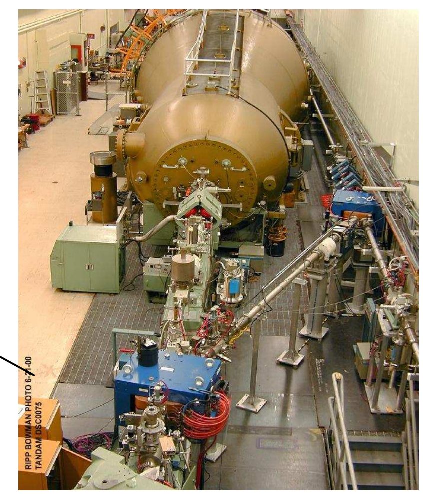


Gold Ion Collisions in RHIC





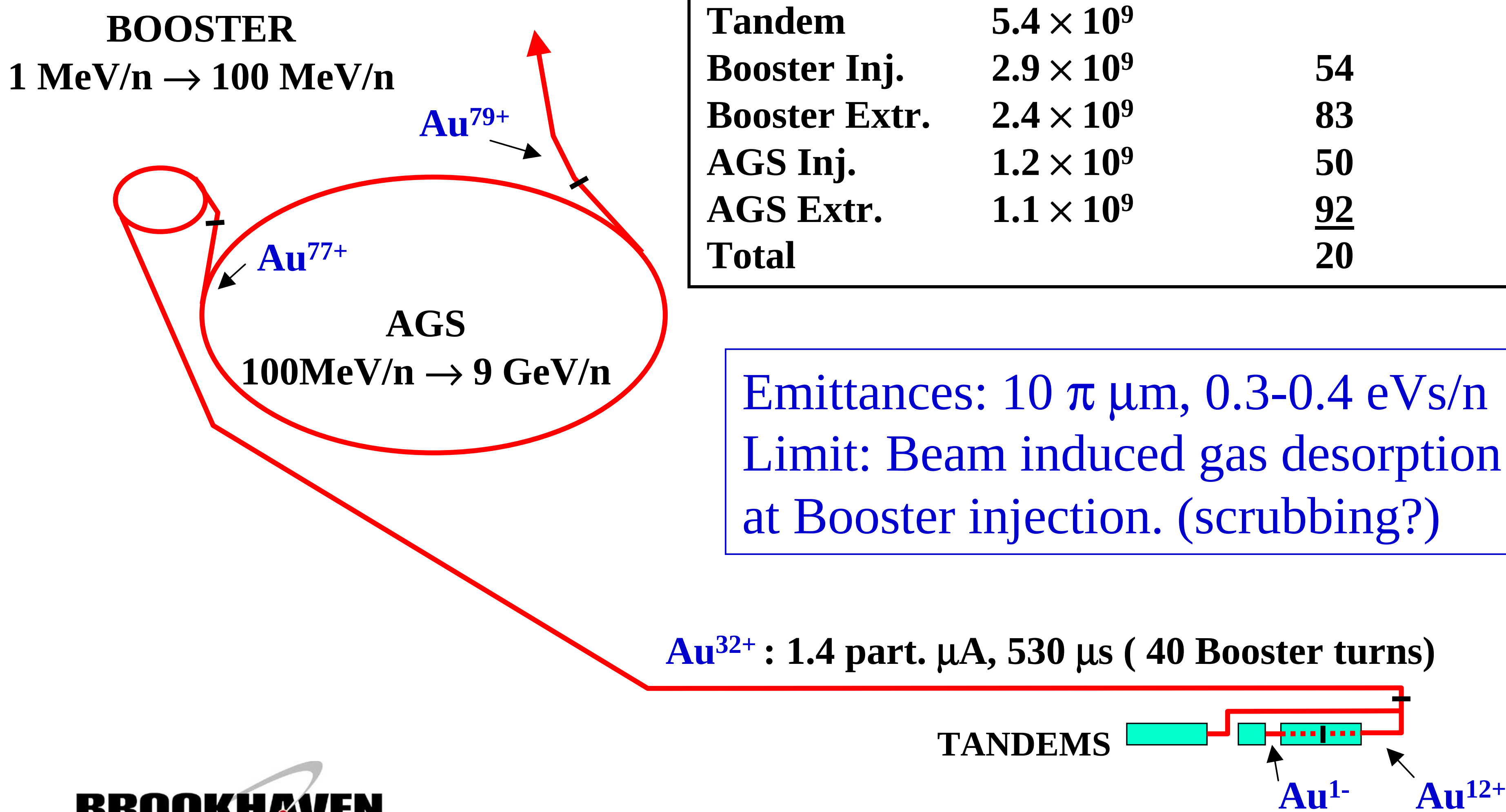




Au Injector Performance

	Intensity/RHIC bunch	Efficiency[%]
Tandem	5.4×10^9	
Booster Inj.	2.9×10^9	54
Booster Extr.	2.4×10^9	83
AGS Inj.	1.2×10^9	50
AGS Extr.	1.1×10^9	92
Total		20

Emittances: 10 π µm, 0.3-0.4 eVs/n
Limit: Beam induced gas desorption at Booster injection. (scrubbing?)



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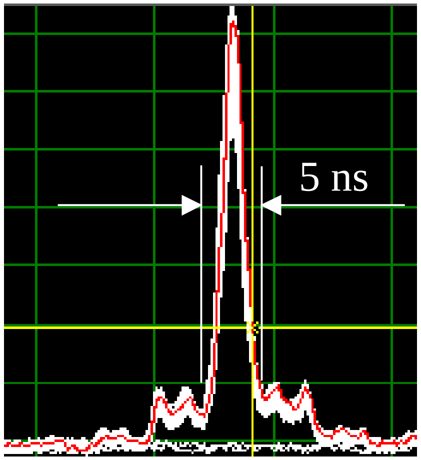
RHIC RUN-2 Gold Parameters

- **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 ✓
- **Transverse emittance** at storage: **15 π μm** (norm, 95%) ✓
- **Storage energy: 100 GeV/n (γ = 107.4)** ✓ **10 GeV/n (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}**
- **Ave. Luminosity: 1.5 × 10^{26} cm^{-2} s^{-1}** (75% of design)
- **Bunch length: 5ns** with 200 MHz storage rf system (diamond length: σ = 25 cm) ✓



RHIC bunch profile

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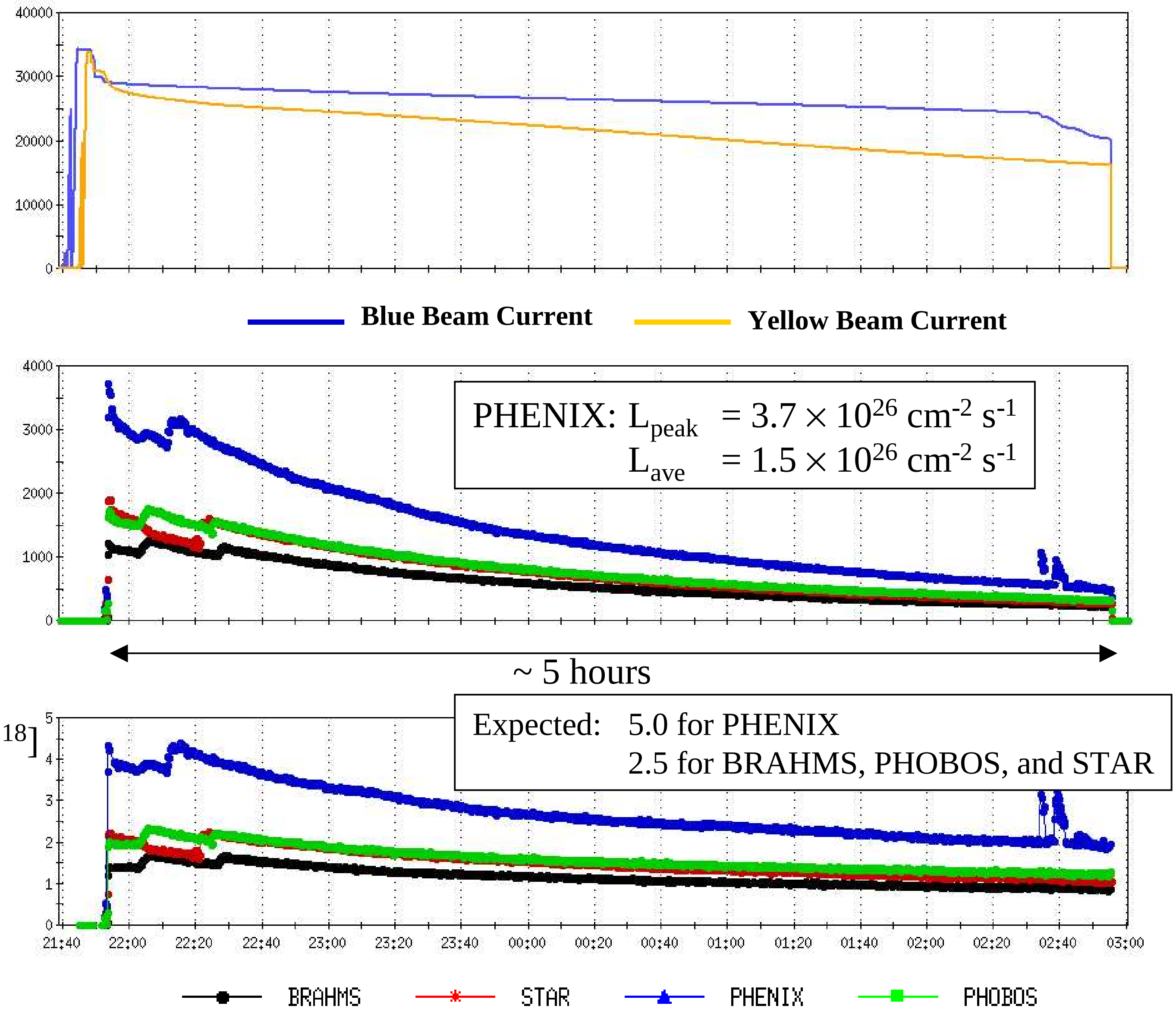
“Typical Store” # 1812

Beam currents [x10^{6} ions]

Collision rate [Hz]

Specific luminosity [Hz/10^{18}]



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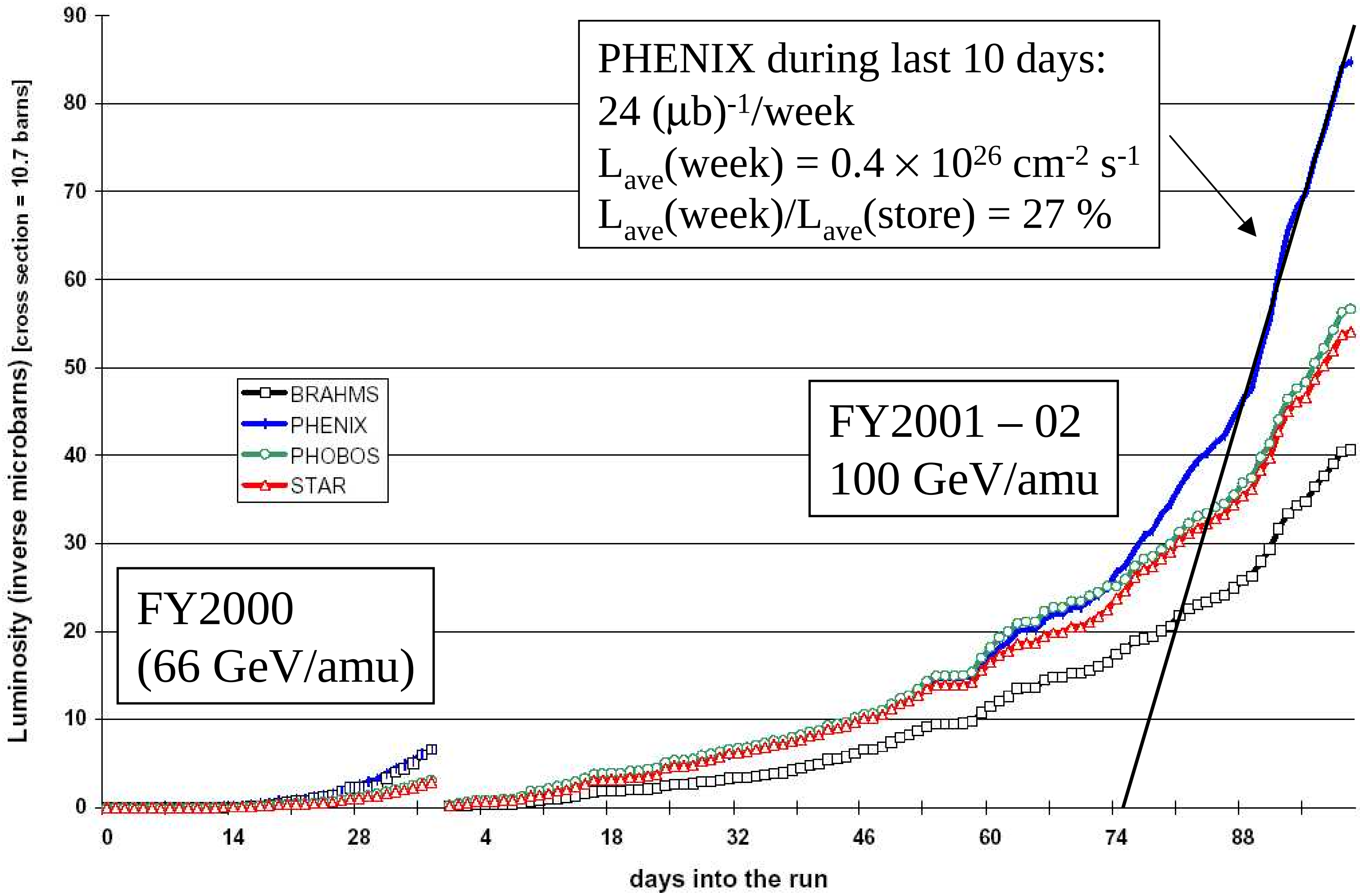
Integrated Au-Au luminosity



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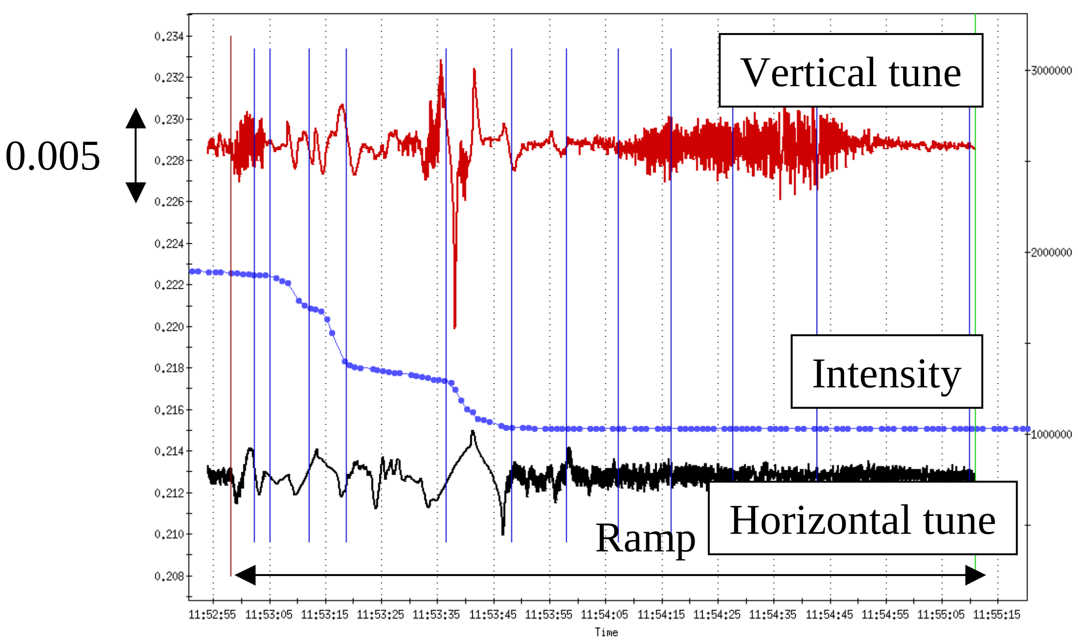
New Developments at RHIC

- First order linear transition energy jump
- Beam based non-linear correction of triplet errors
- 10^{-5} betatron tune measurement and tune feed-back to better than 0.005 using PLL with resonant pick-up
- Emittance preserving coherent beam excitation and high precision lattice measurements using a 60 kHz AC dipole



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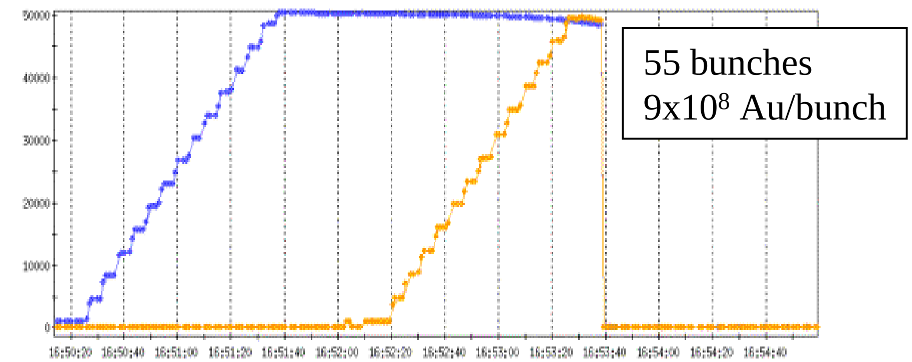
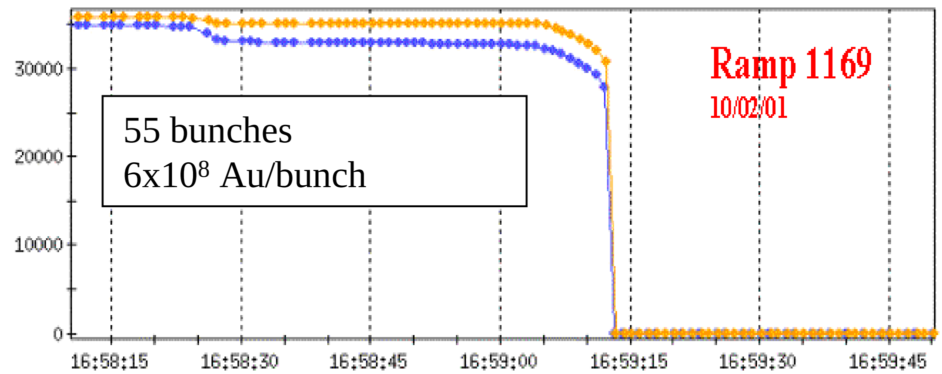
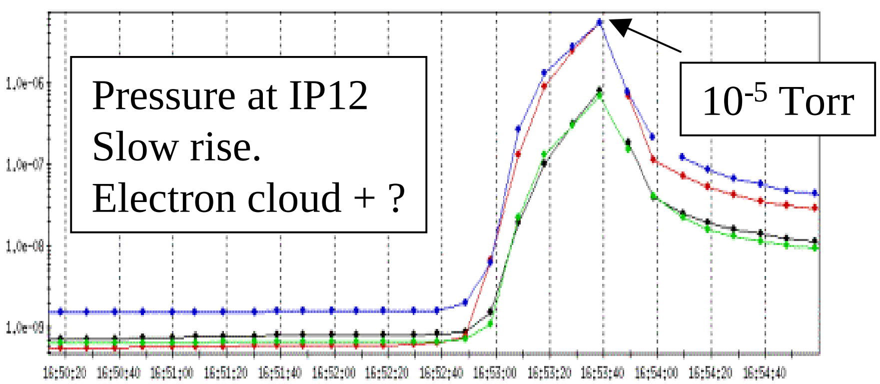
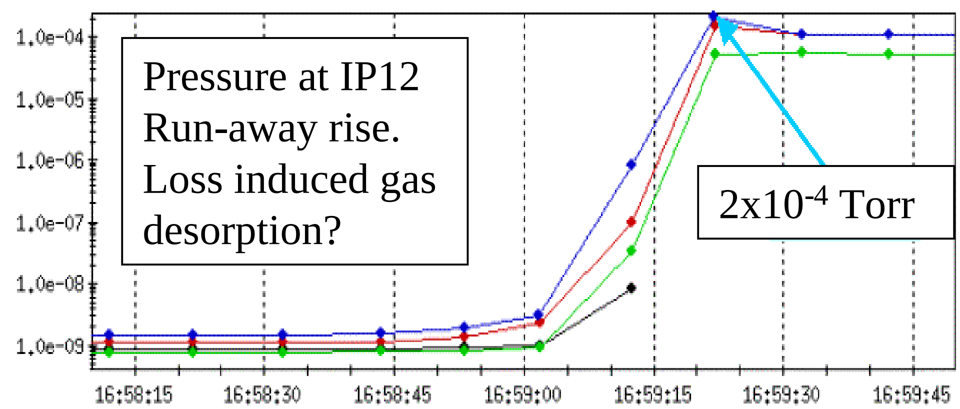
Vacuum break-down

- 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; plan for "scrubbing" with beam









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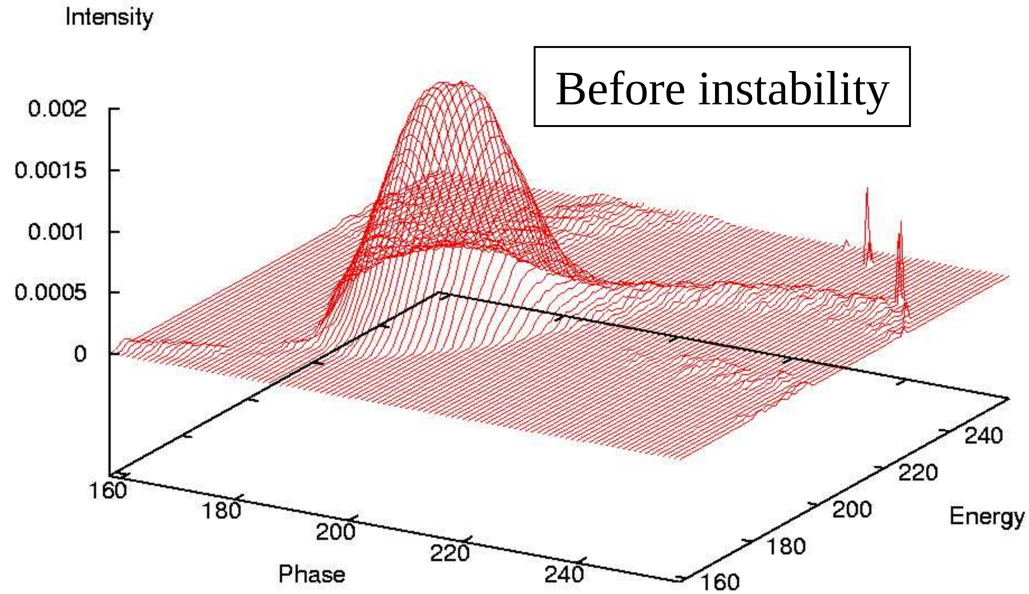
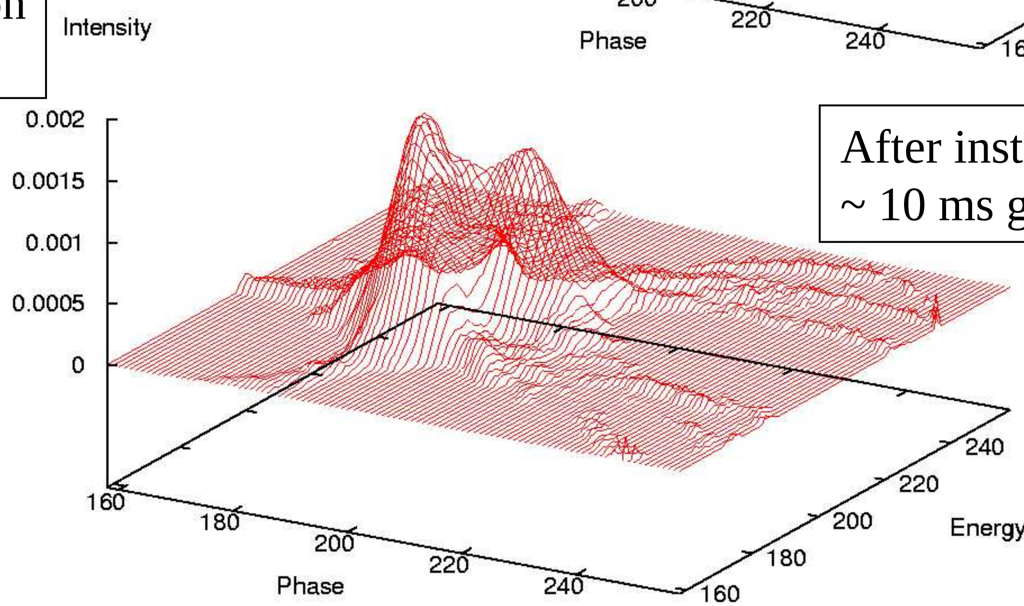
Transverse instabilities in RHIC

- Fast transverse instability (~ GHz)
- High sensitivity around transition
- Effect of broadband impedance, electron cloud (?)
- Cures: beam-beam tune spread, **octupoles,** cross zero-chromaticity before transition (why?)

Tomographic reconstruction of 2D bunch density





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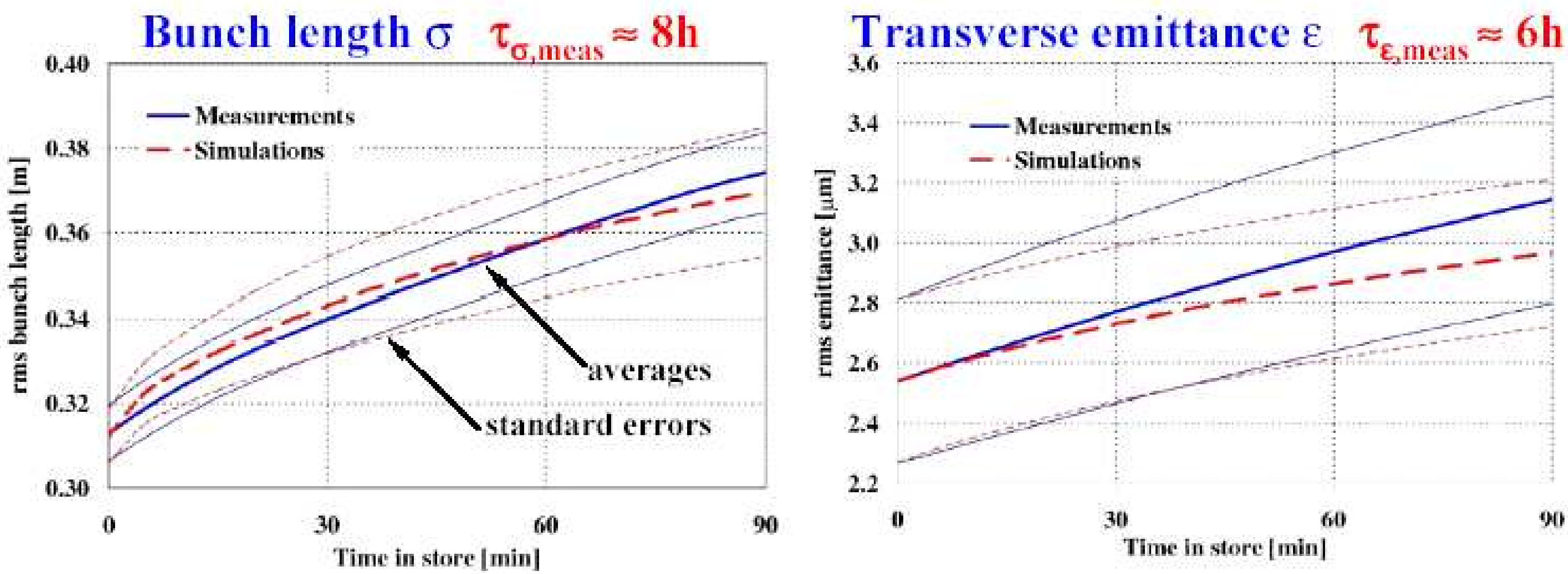
Intra-Beam Scattering (IBS) in RHIC



Longitudinal and transverse emittance growth agrees well with model

Some additional source of transverse emittance growth

IBS determines RHIC Au performance

Eventually will need electron cooling

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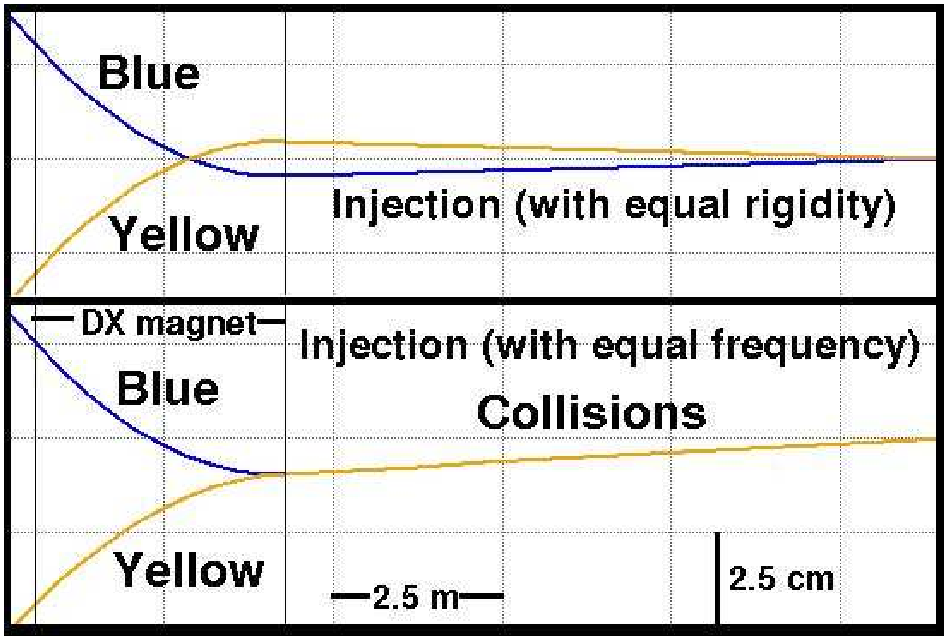
Deuteron-Gold Collisions in RHIC (RUN-3)

- Important comparison measurement: will not produce quark-gluon plasma
- Collisions at 100 GeV/nucleon requires 20% different rigidities
- Use two Tandems; add. bunch merging in Booster:
  1.1×10^{11} d/bunch, $\varepsilon[95\%] = 12\ \pi\ \mu m$; 0.7×10^{9} Au/bunch, $\varepsilon[95\%] = 10\ \pi\ \mu m$
- Initial injection with equal rigidity failed because of beam loss from modulated beam-beam interactions during acceleration ramp
- Injection and acceleration with same energy was successful.



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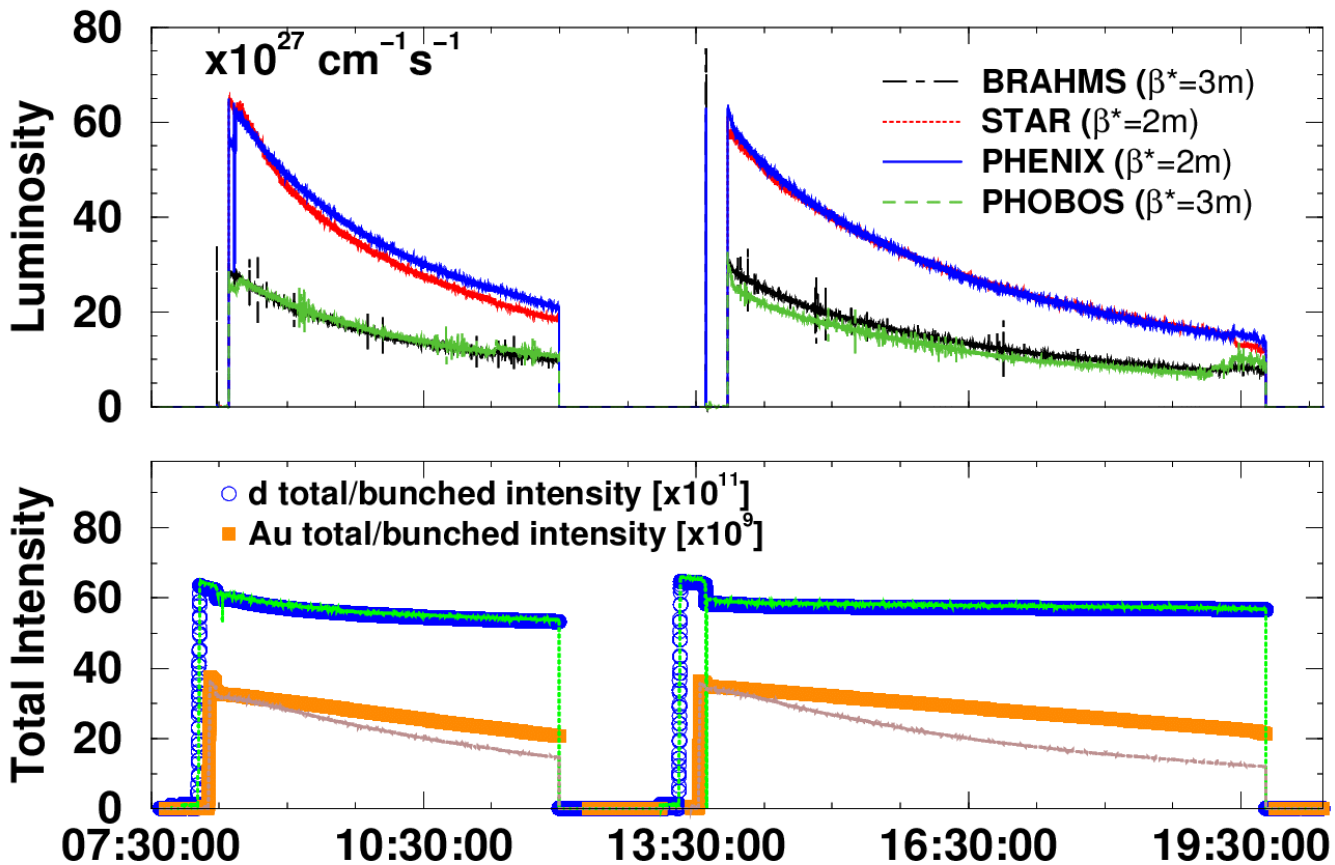
“Typical” Deuteron-Gold Stores

- Vacuum pressure rise limits total charge (both beams) to 10^{13}
- Transverse instability cured by crossing zero-chromaticity before transition
- Need Landau cavities to avoid coherent longitudinal oscillation during acceleration.
- Intra-beam scattering affects gold beam



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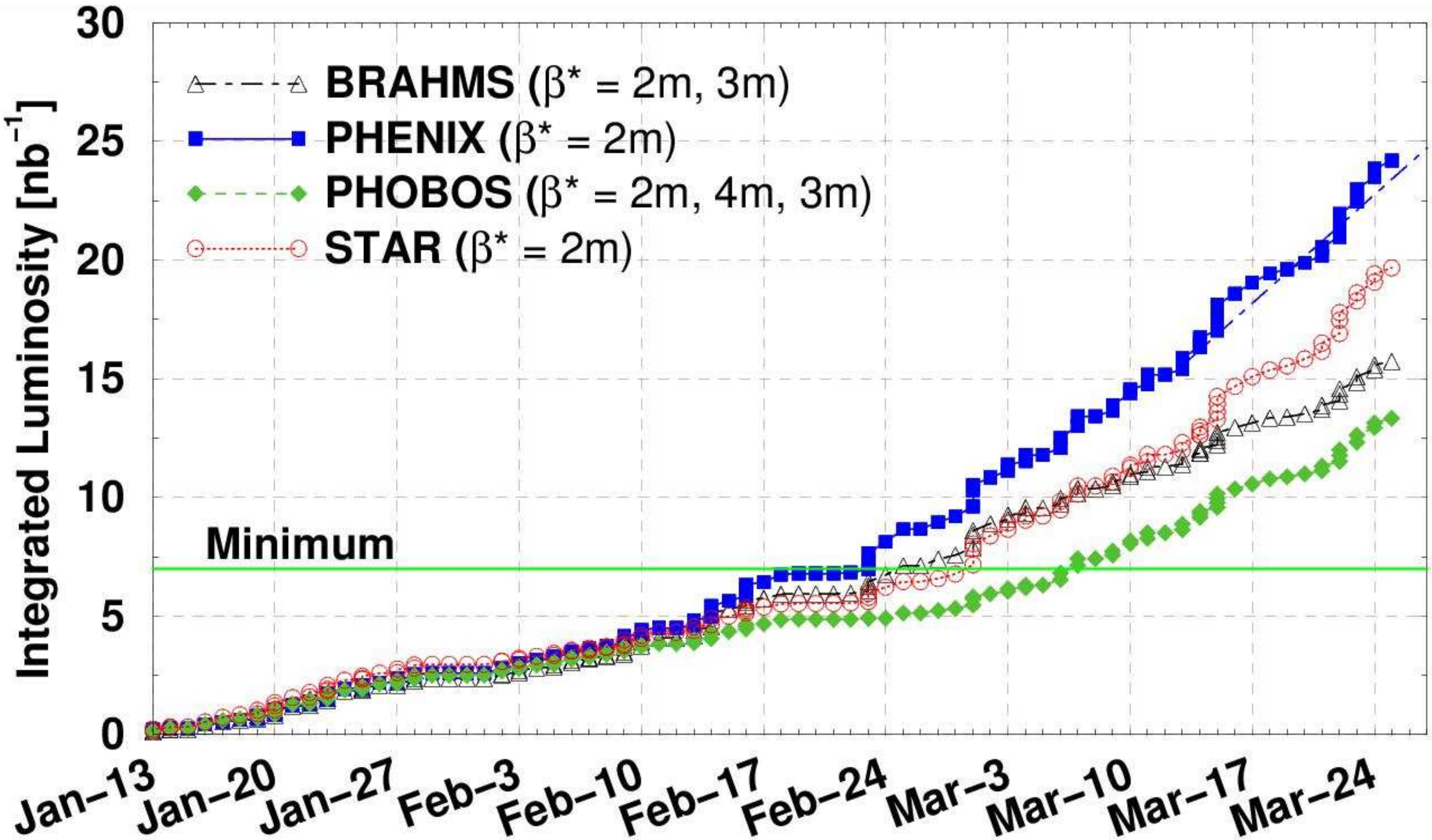
Deuteron-Gold Integrated Luminosity



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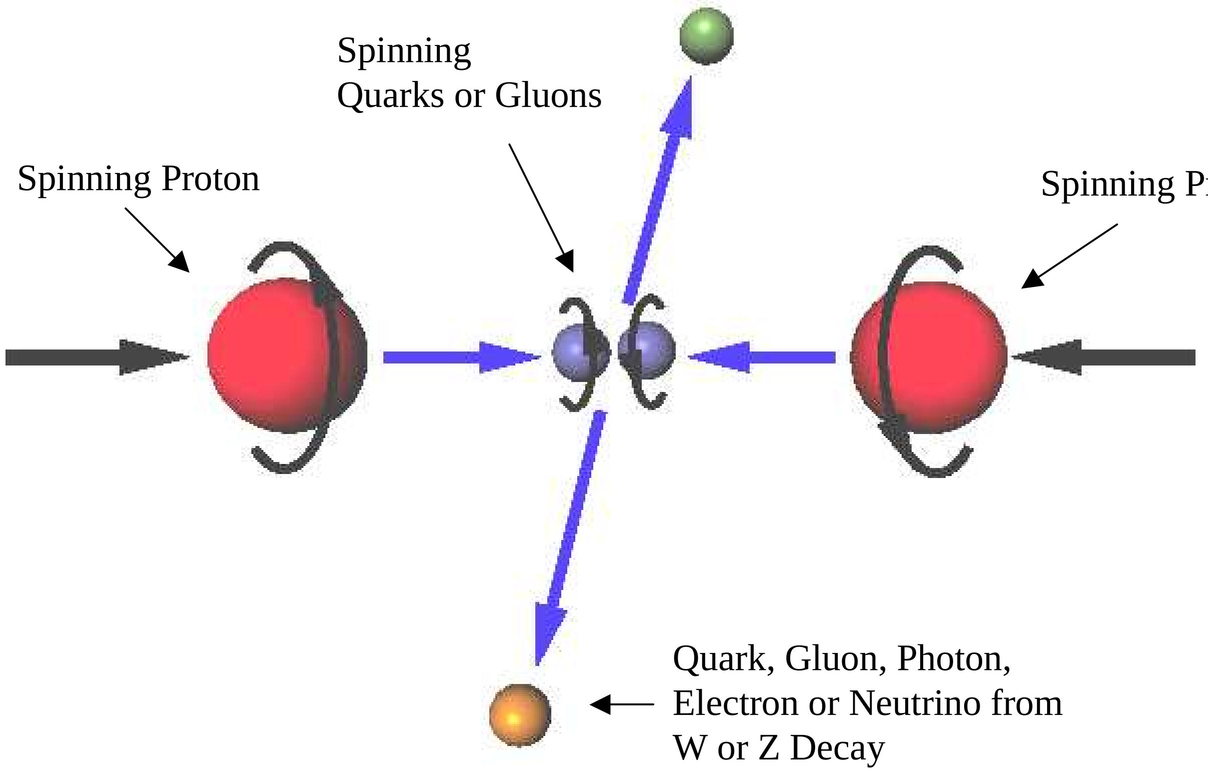
RHIC Spin Physics



- Spin structure functions of gluon and anti-quarks
- Parity violation in parton-parton scattering

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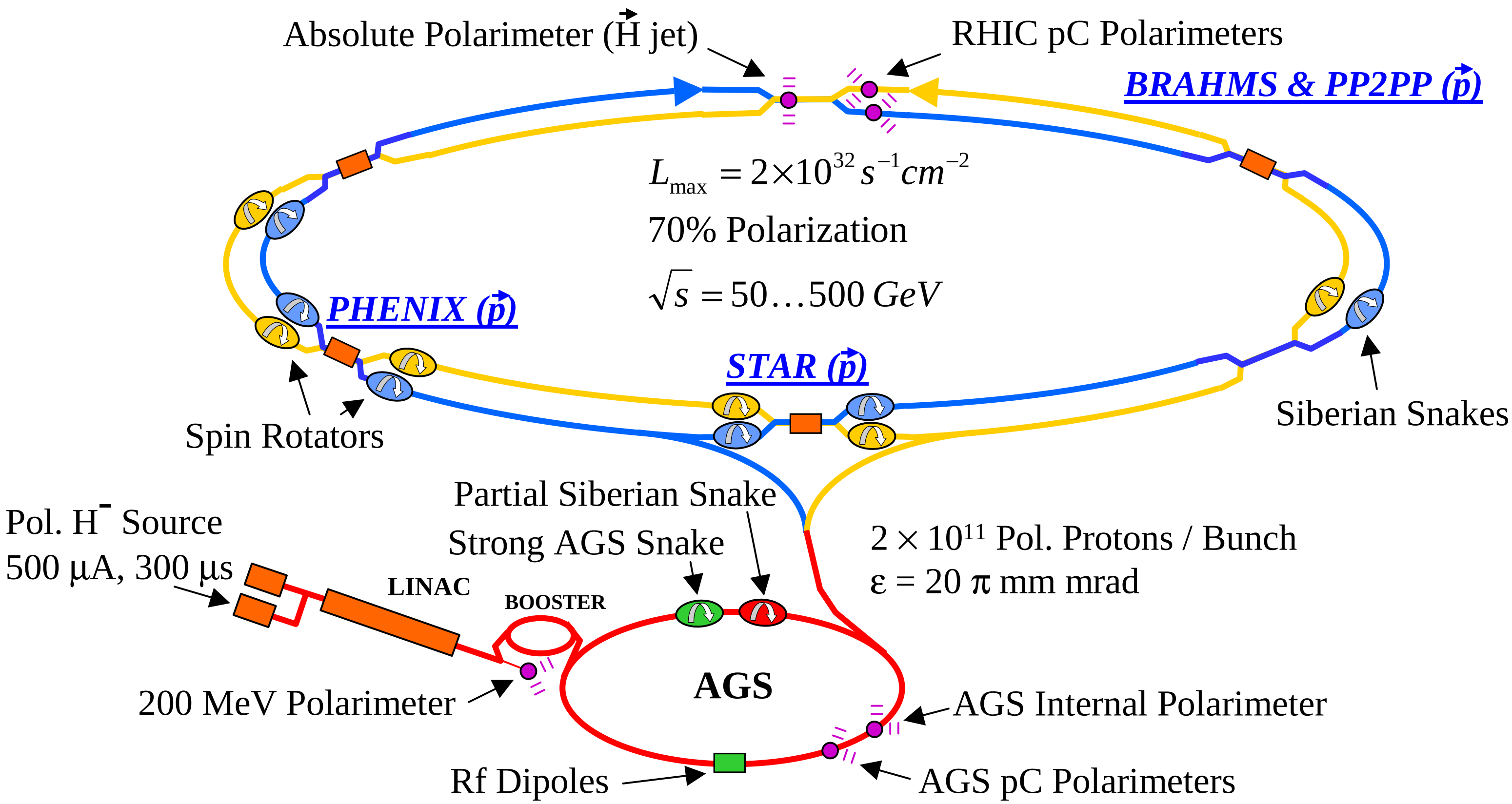
Polarized Proton Collisions in RHIC



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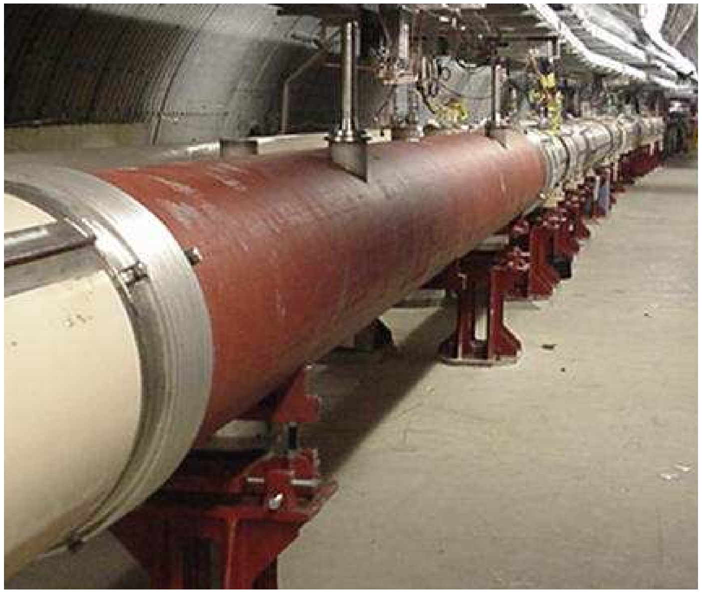
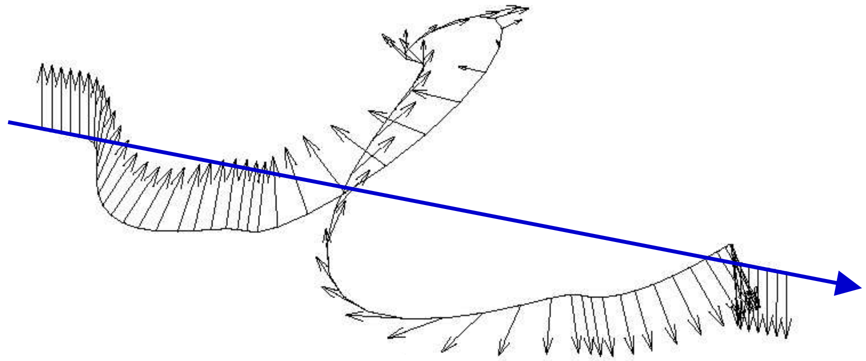
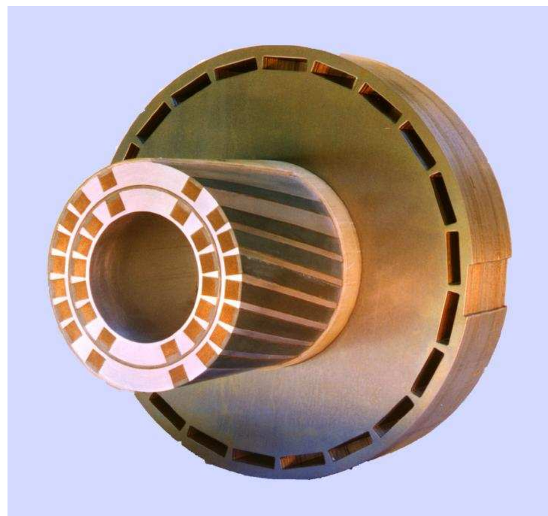
Siberian Snake in RHIC Tunnel

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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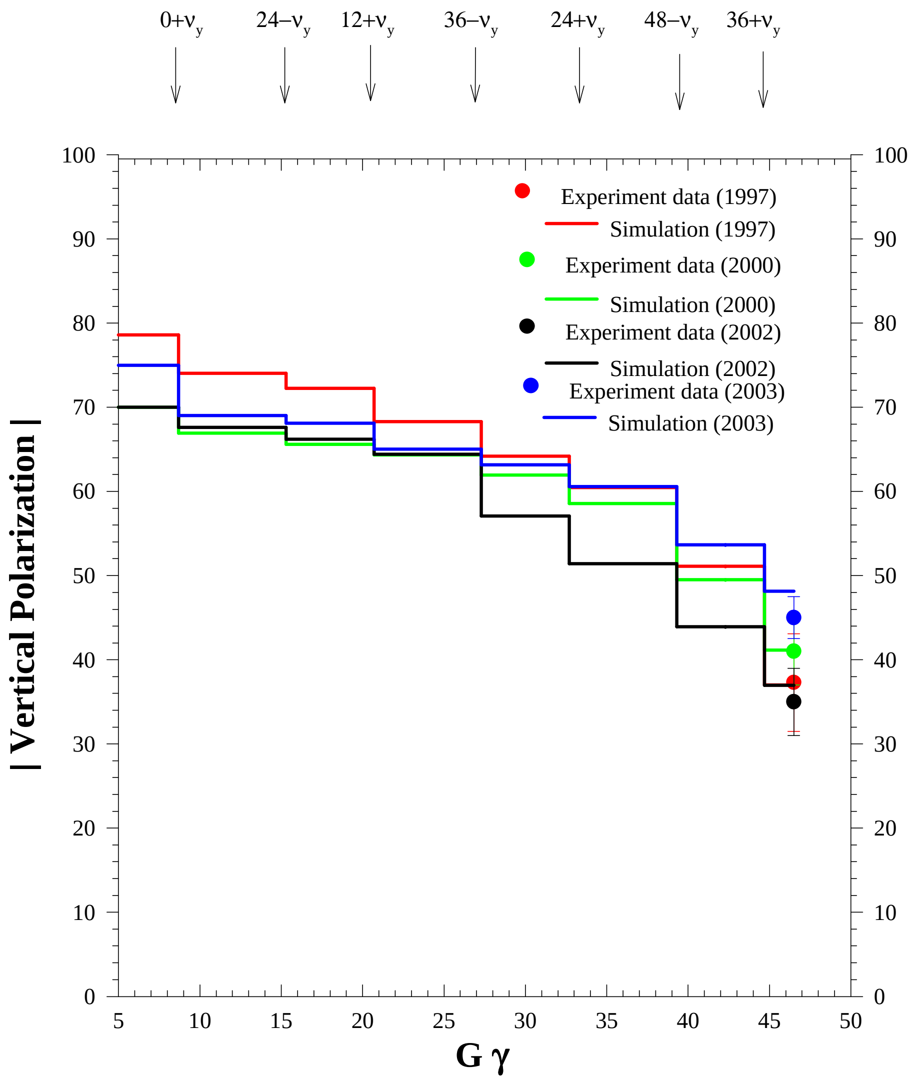
Proton Polarization at the AGS

- Full spin flip at all imperfection resonances using a partial Siberian snake
- Full spin flip at strong intrinsic resonances using an ac dipole
- Remaining polarization loss from coupling and weak intrinsic resonances
- Polarization at the AGS extraction is strongly dependent on beam emittances. RHIC injection also requires 0.5 eVs long. emittance. Scraping beam in three dimension in Booster.
- Polarization can be maintained above 40% for intensity of 7.5*10^10.
- To avoid all depolarization in AGS, build a strong AGS helical Siberian snake (Installation in 2004).



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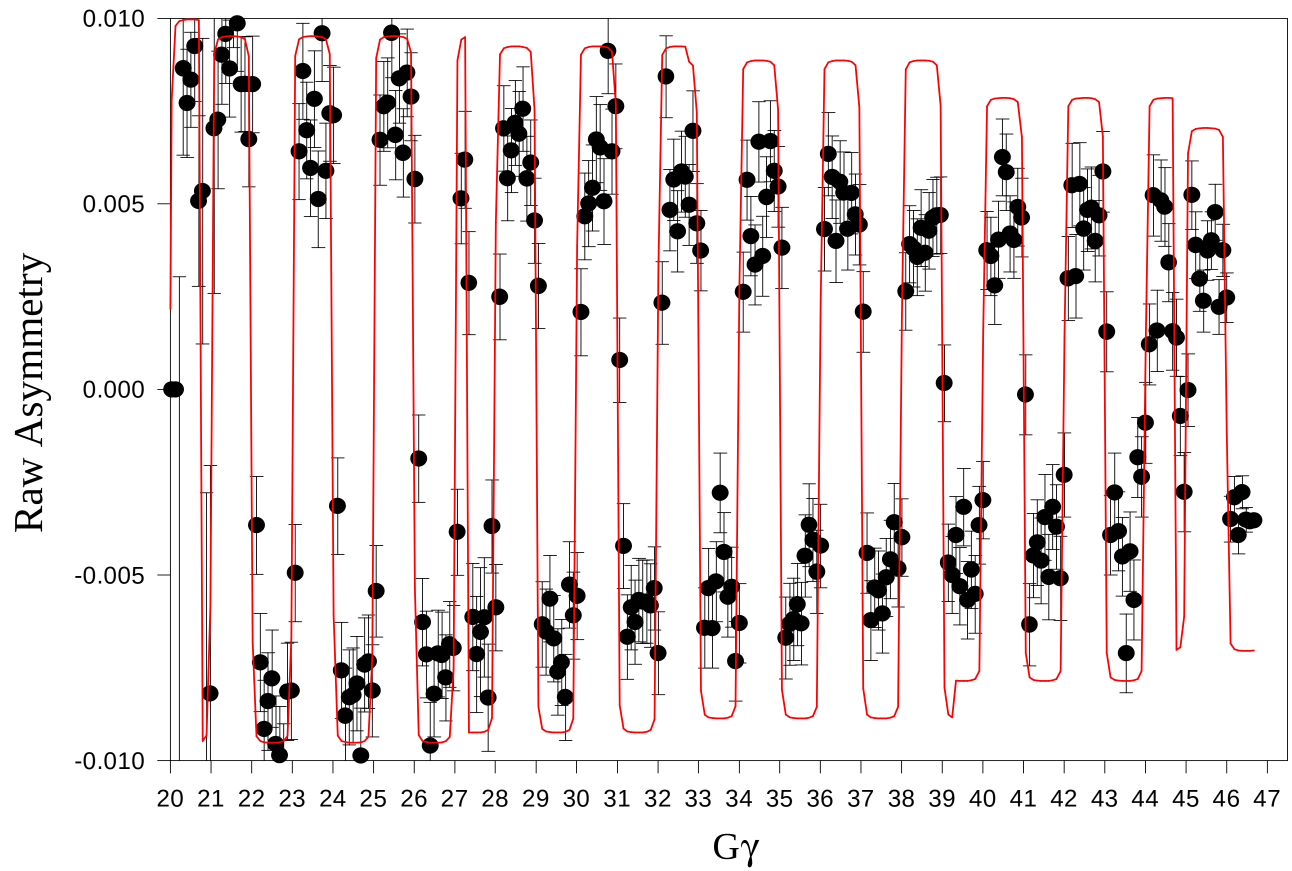
AGS ramp measurement



Partial snake flips spin at every integer of Gγ. The deviation between red curve and experiment data indicates that analyzing power is not a constant in this energy range.

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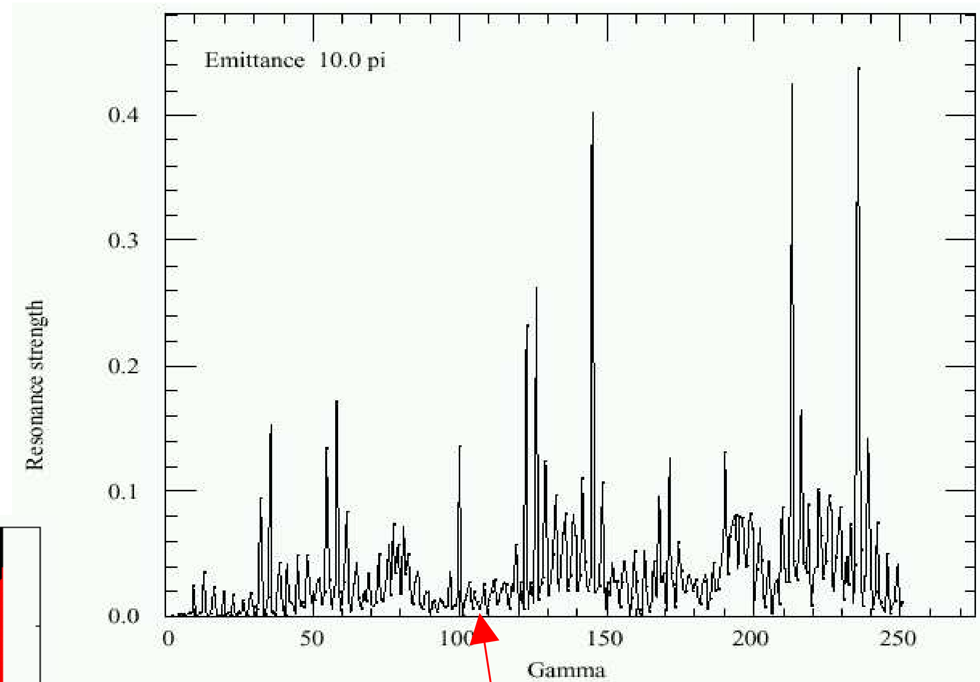
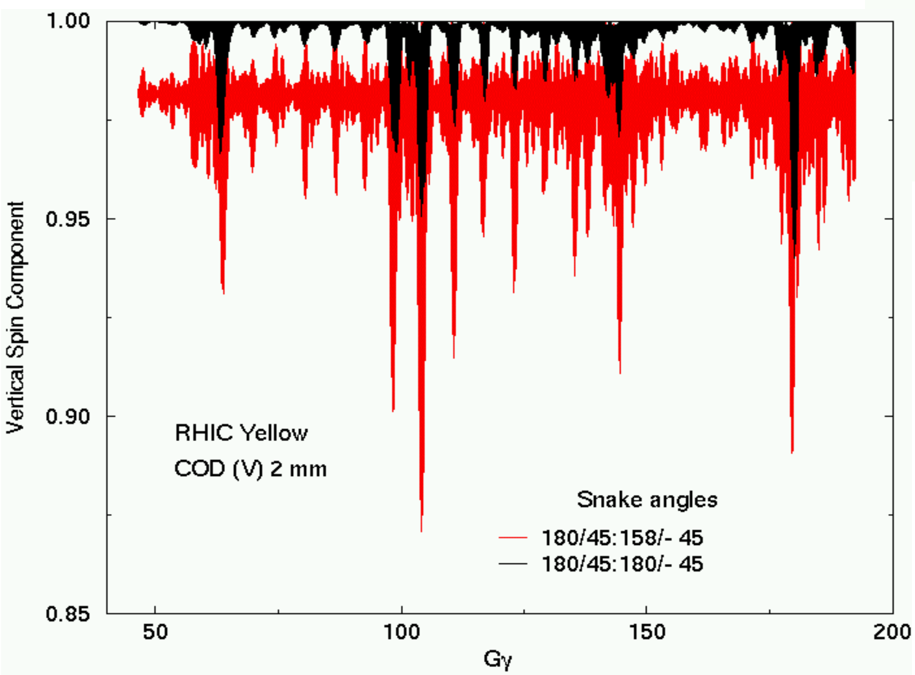
Polarization Preservation with snakes

One helical magnet of a Yellow snake failed. Currently configured as 1+0.88 snake in Yellow ring: more sensitive to spin tune in Yellow.



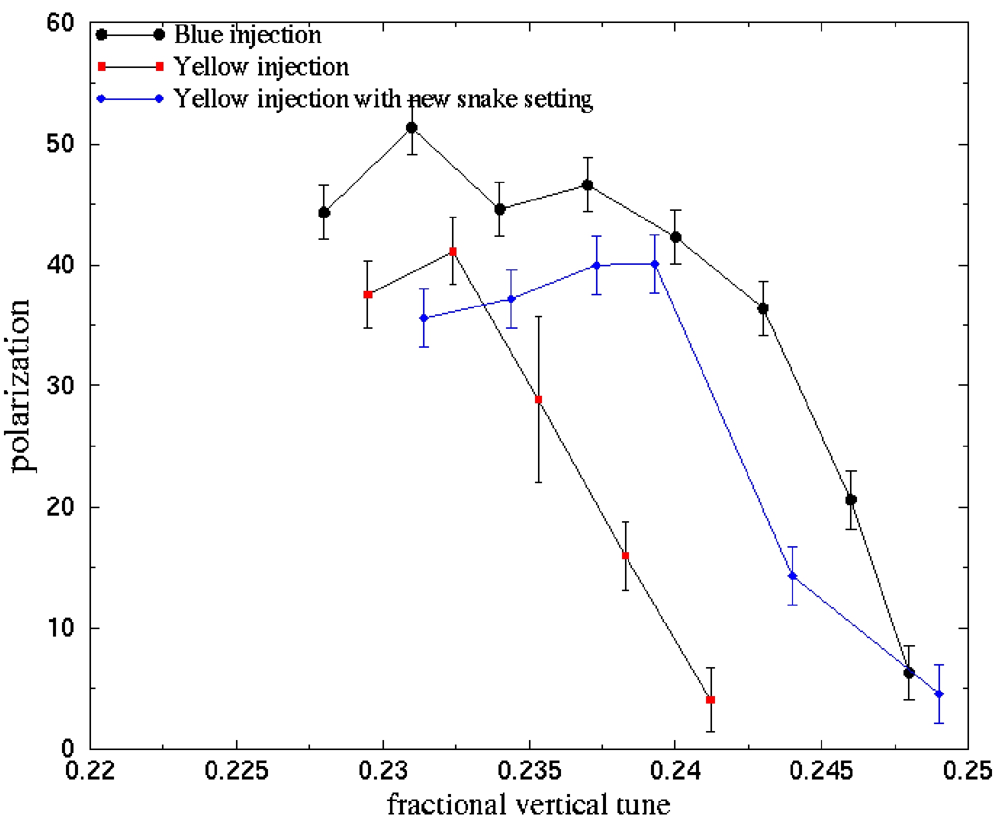
Flattop energy for this run



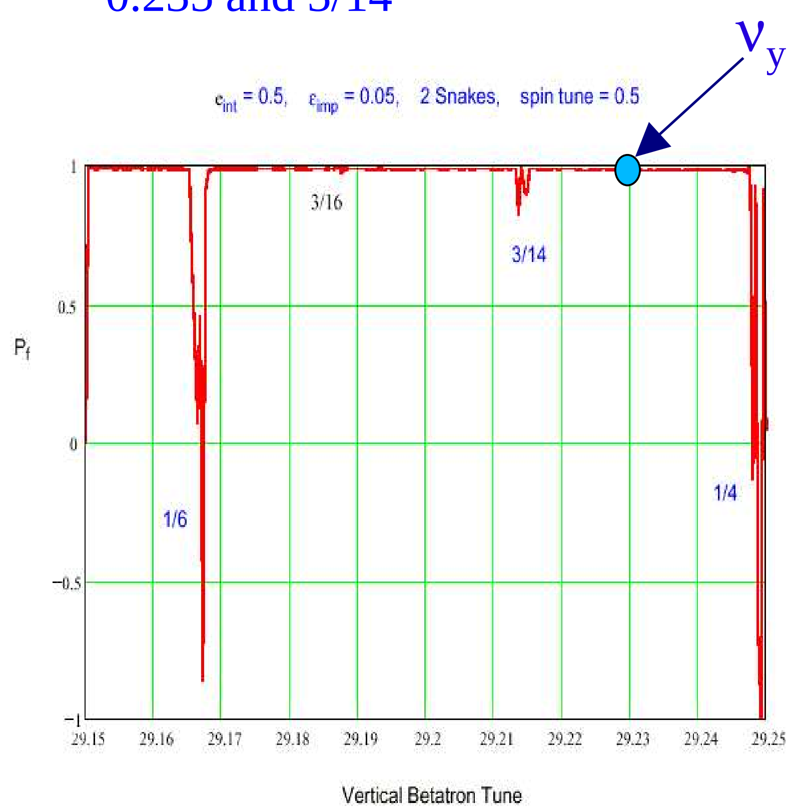
RHIC Polarization Set-up

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



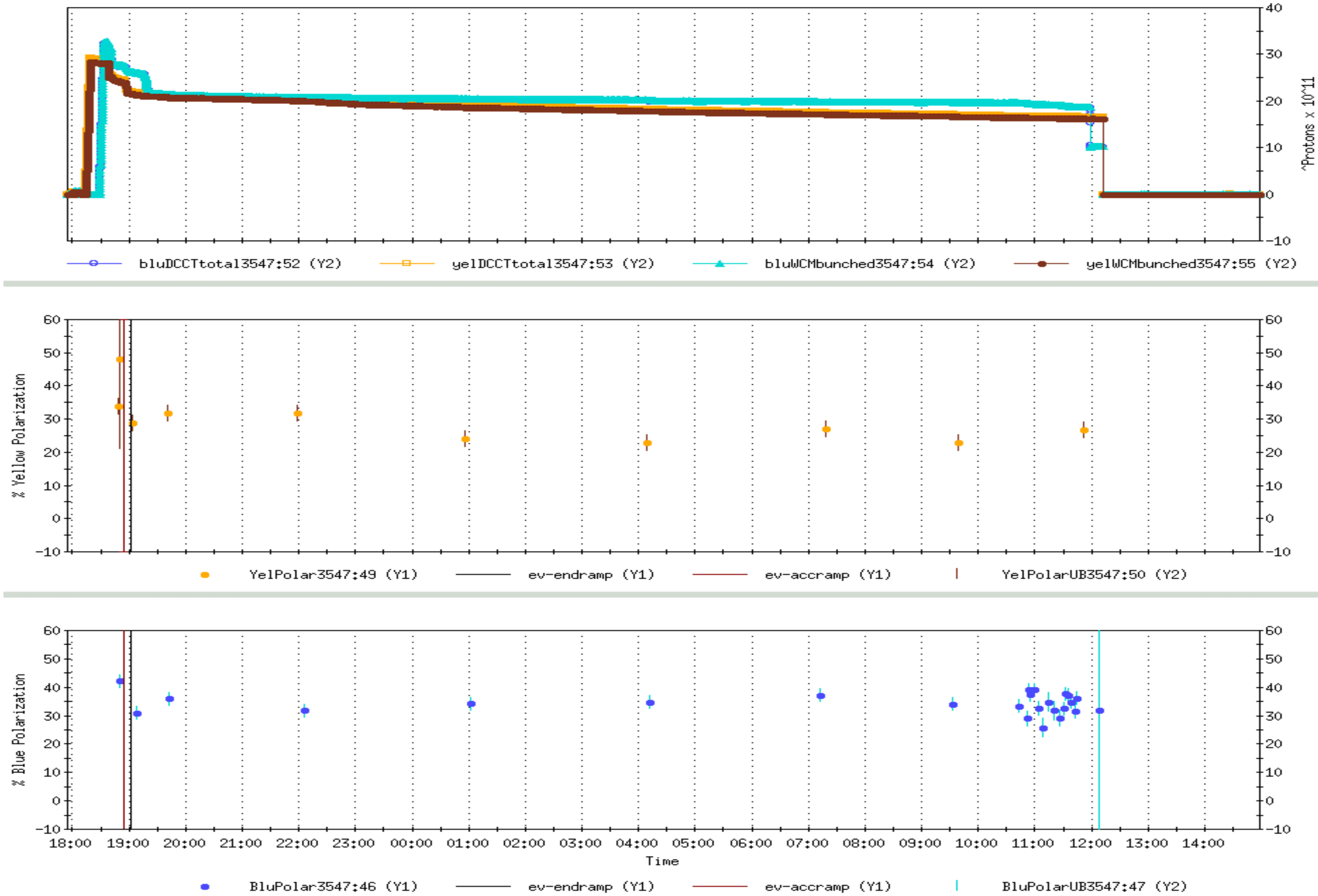
Keep the vertical tune between 0.235 and 3/14



Snake Resonances

$$\nu_{sp} = k \pm n\nu_y$$

RHIC Beam Polarization



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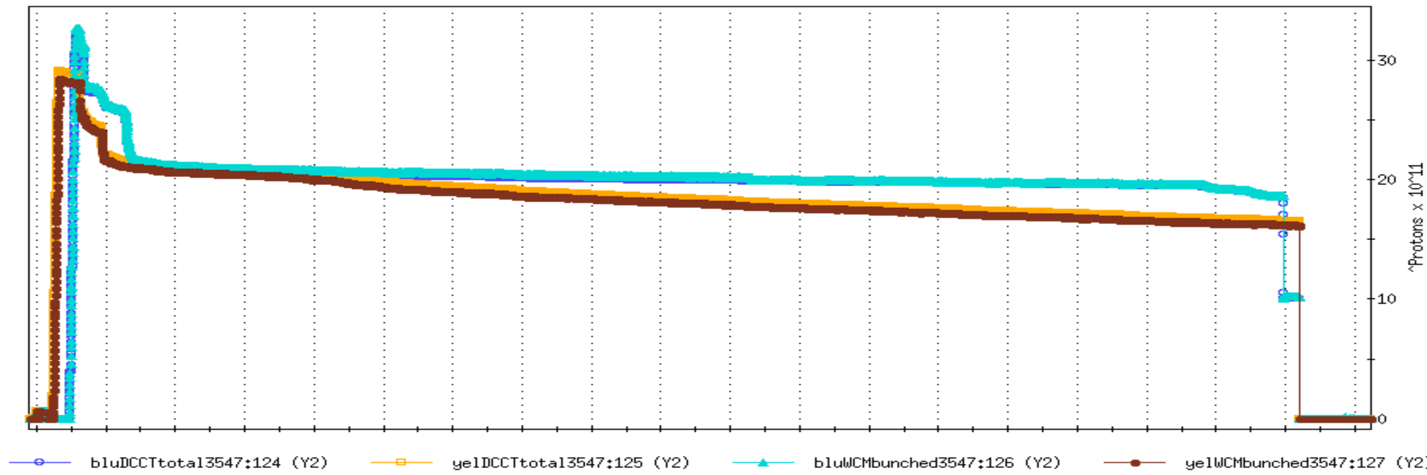
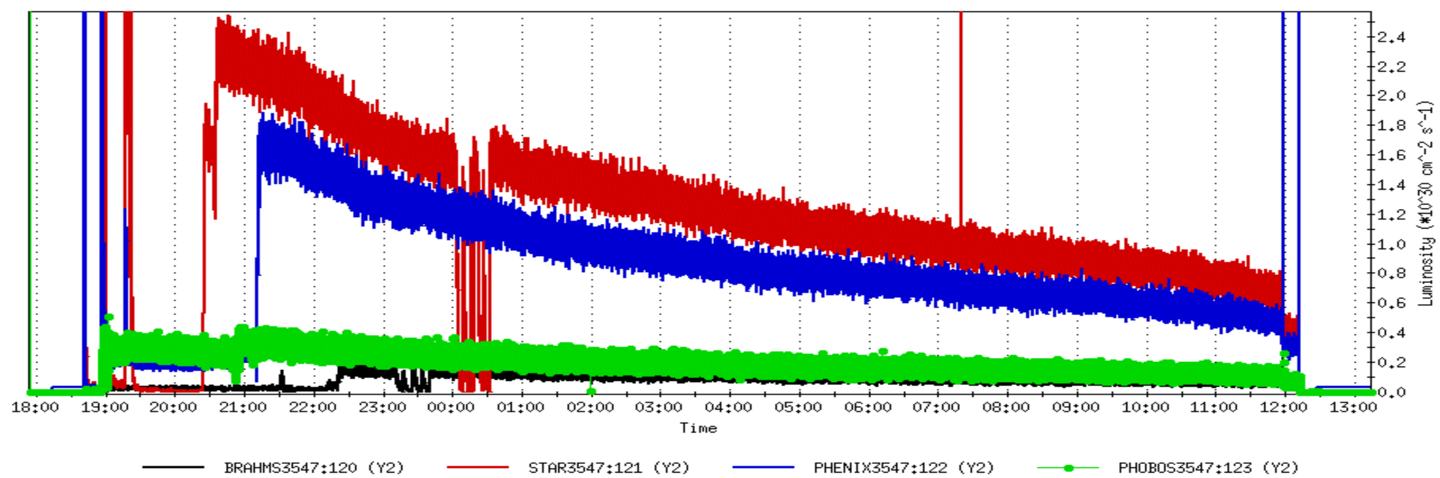
RHIC Luminosity





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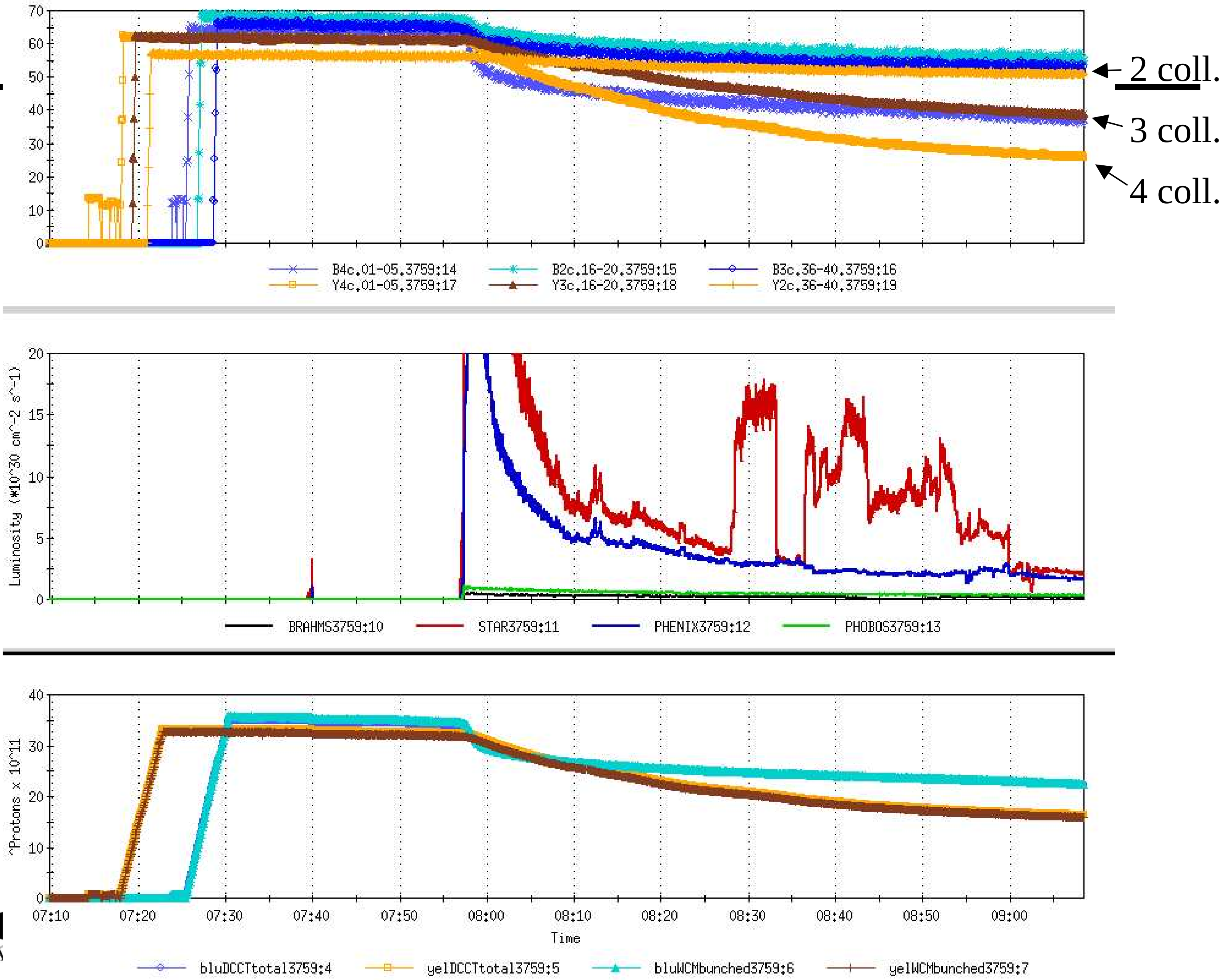
Four collisions



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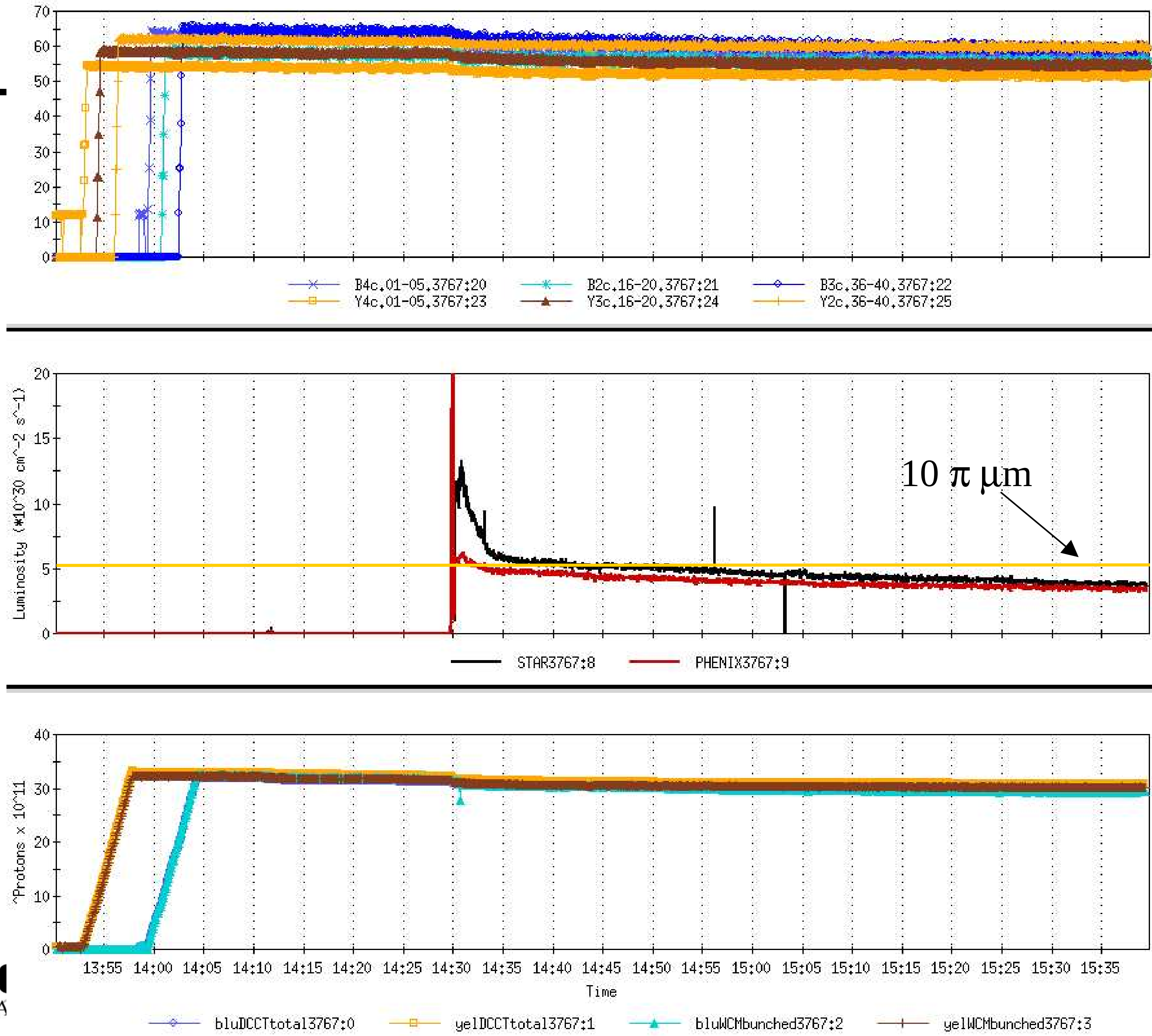
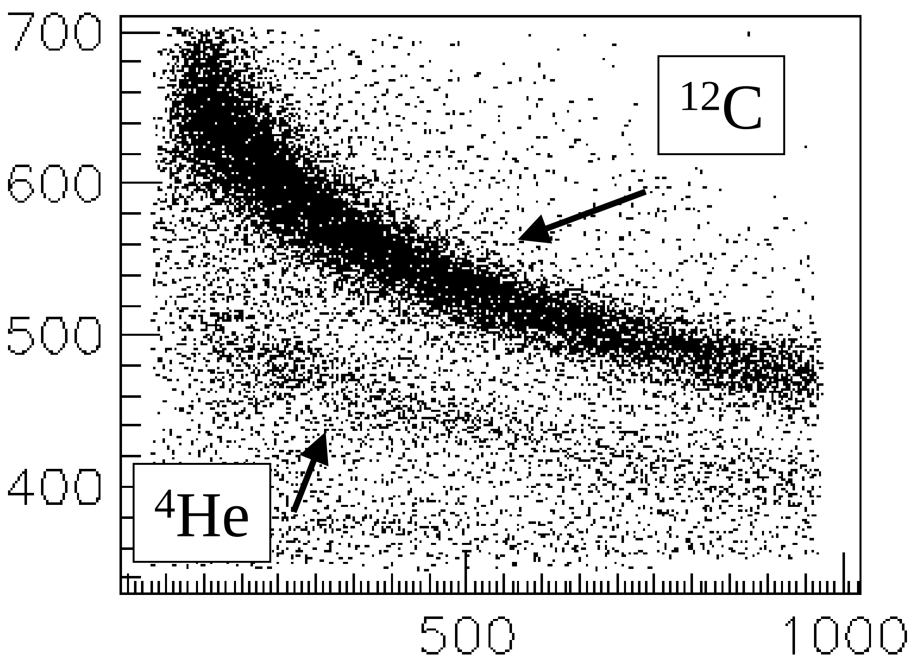
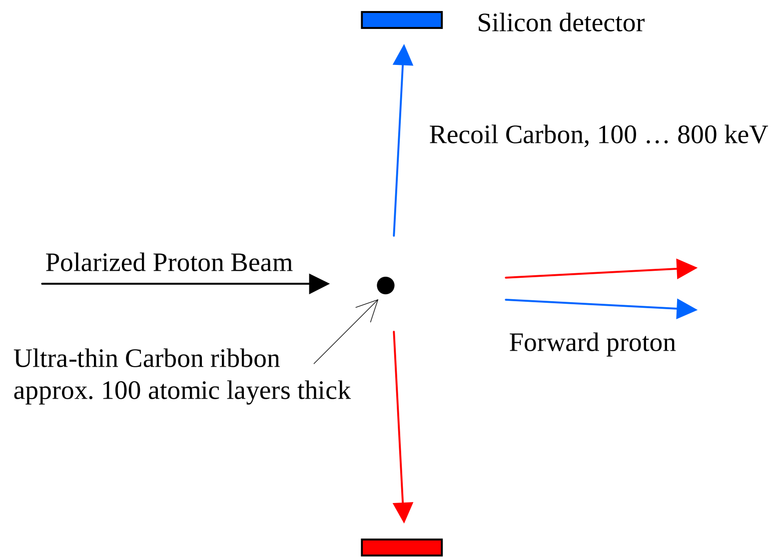
Only two collisions



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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Results from p-p operation during RUN-3

- 55 bunches per ring with 0.6×10^{11} p/b, ε[norm. 95%] = 12 π μm,
  Beam polarization ~ 35 %
- Spin rotators have been used to provide longitudinal polarization at two IRs
- Peak Luminosity per IR (1 m betastar): ~ 5×10^{30} cm^{-2} s^{-1}
- Beam-beam tune shift parameter per IR: 0.0038; for 4 IRs: 0.015 !
  - largest beam-beam tune shift parameter for strong-strong hadron collider
  - Observed beam-beam coherent modes
- Better beam control on the ramp is necessary
  - Tune feedback (PLL)
  - Improved orbit correction (below 0.3mm rms)
  - Coupling control on the ramps
- Intensity limitation due to vacuum pressure rise
  - for 110 bunch mode, need 12 bunch +8 gap
  - Scrubbing

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Summary

- Successful operation of RHIC with 100 GeV/n beams in three modes:
  - Gold – gold collisions, peak luminosity = 5×10^{26} cm^{-2} s^{-1}
  - Deuteron – gold collsions, peak luminosity = 6×10^{28} cm^{-2} s^{-1}
  - Polarized proton collsions, peak luminosity = 5×10^{30} cm^{-2} s^{-1}

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