RHIC Performance

RHIC commissioning and first operation

Plans and goals for RUN2001

Future luminosity upgrade possibilities

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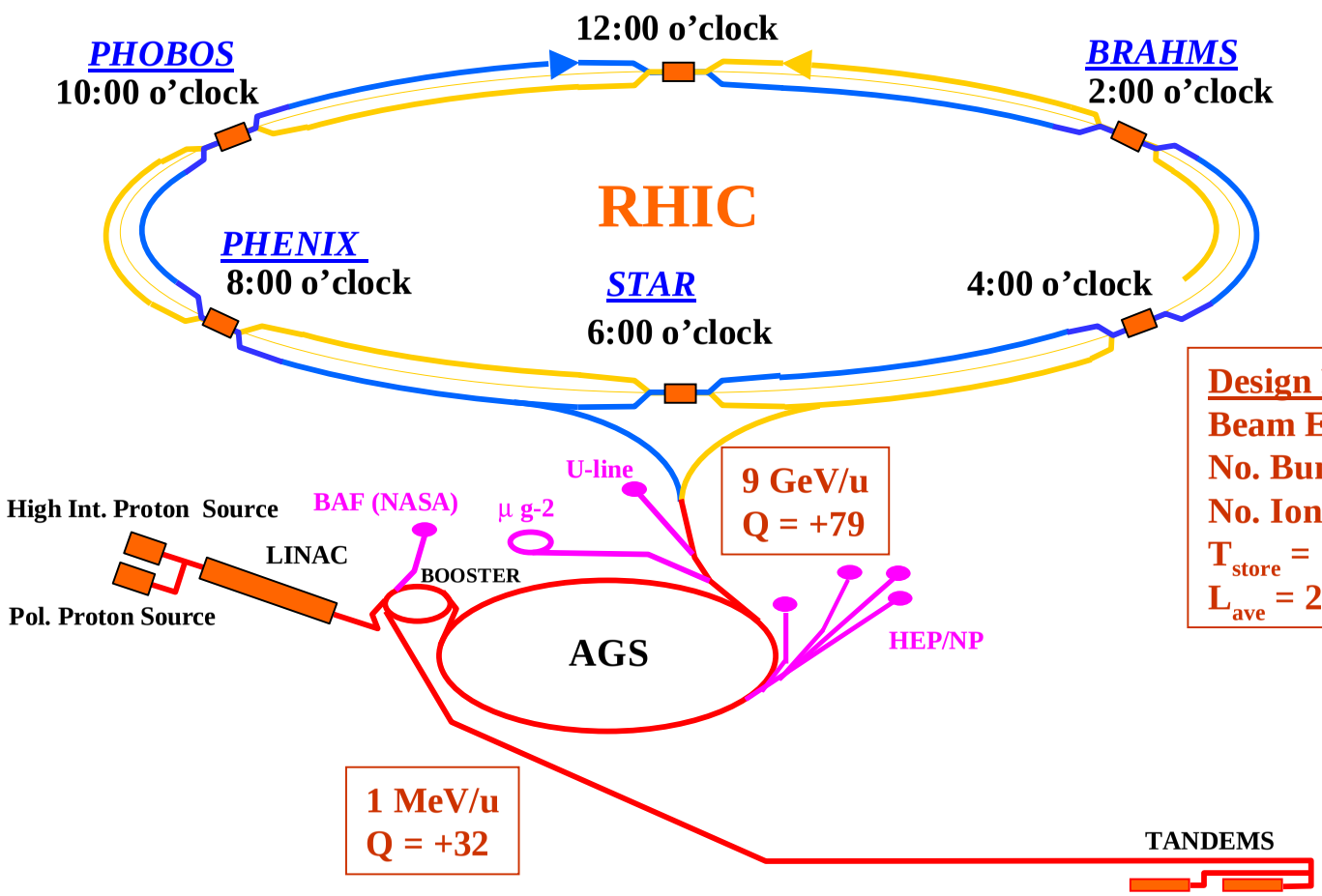
Thomas Roser
Quark Matter 2001
January 15 - 20, 2001

Gold Ion Collisions in RHIC



Design Parameters:

Beam Energy = 100 GeV/u

No. Bunches = 57

No. Ions /Bunch = 1×10^9

T_{store} = 10 hours

$L_{ave} = 2 \times 10^{26}\ cm^{-2}\ sec^{-1}$

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Parameters and goals for RHIC RUN2000

- 60 bunches per ring ✓
- 5×10^8 Au/bunch ✓
- Longitudinal emittance: 0.3 eVs/nucleon/bunch (at injection ✓)
- Transverse emittance at storage: 15 π μm (norm, 95%) ✓
- Initial storage energy: $\gamma = 70$ [66 GeV/nucl.] ✓ (This energy is below the lowest quench of any DX magnet. Full operating current for 100 GeV/nucl. reached at end of run)
- Lattice at interaction regions: $\beta^* =$ 3 m @ 2, 4, 8, and 12 o'clock
  $\beta^* =$ 8 m @ 6 and 10 o'clock
- Luminosity: 2×10^{25} cm^{-2} s^{-1} ✓
- Integrated luminosity: a few (μb)$^{-1}$ ✓

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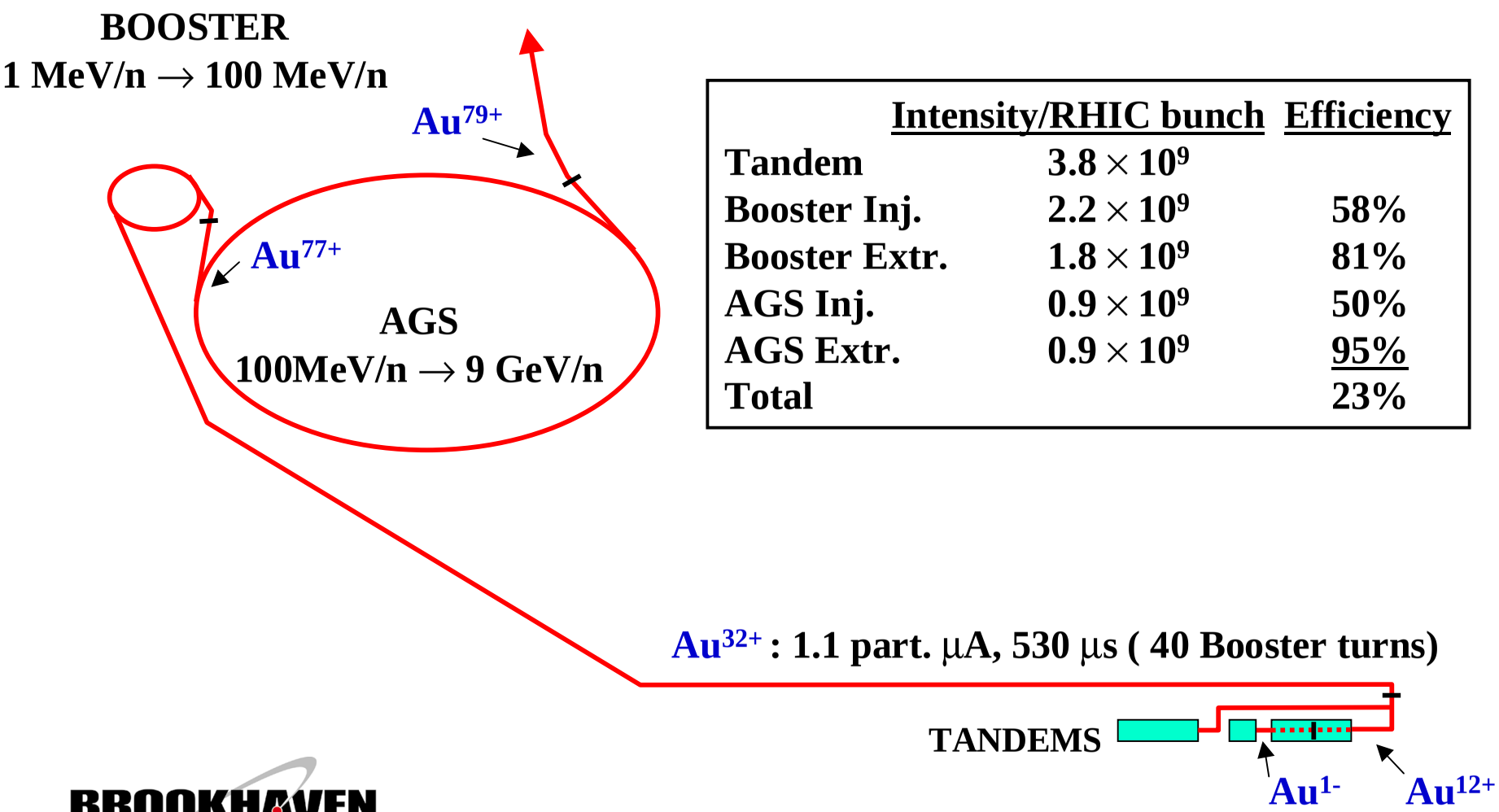
RHIC Injector Performance



	Intensity/RHIC bunch	Efficiency
Tandem	3.8×10^9	
Booster Inj.	2.2×10^9	58%
Booster Extr.	1.8×10^9	81%
AGS Inj.	0.9×10^9	50%
AGS Extr.	0.9×10^9	95%
Total		23%

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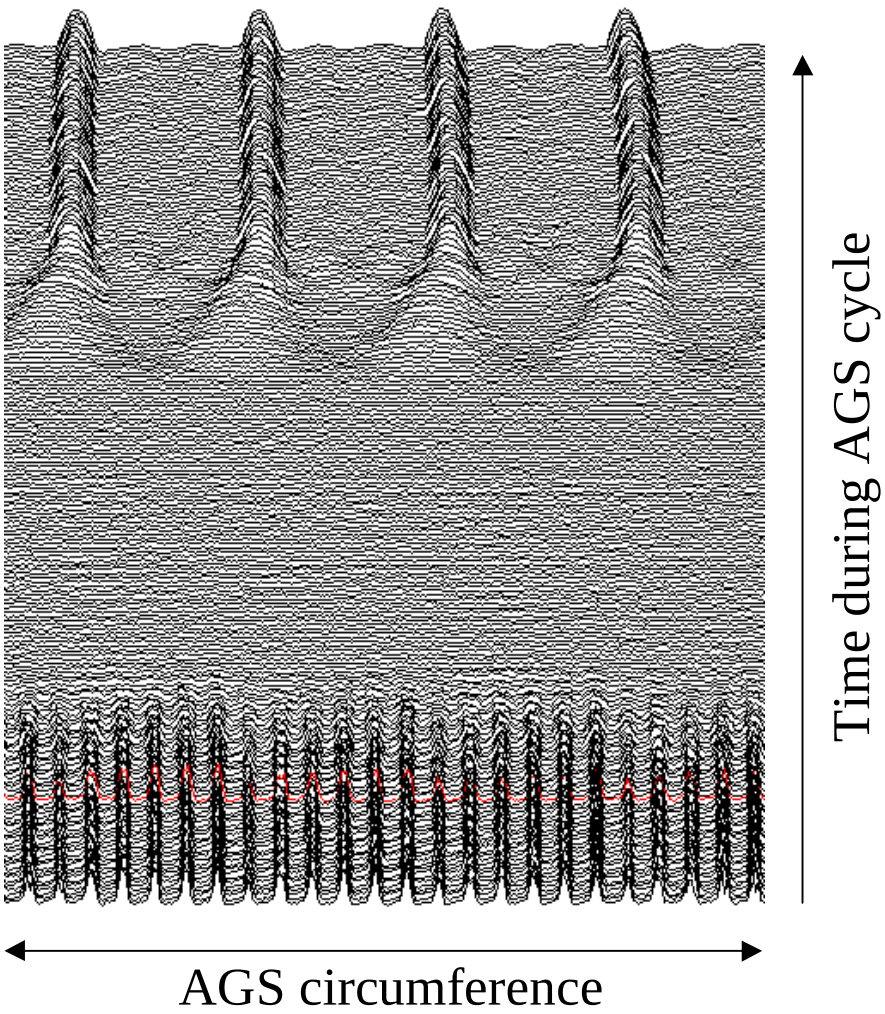
RF bunch merging in AGS

- 4×6 bunches injected from Booster
- Debunch / rebunch into 4 bunches at AGS injection
- Final longitudinal emittance: 0.3 eVs/nuc./bunch
- Achieved 4×10^9 Au ions in 4 bunches at AGS extraction



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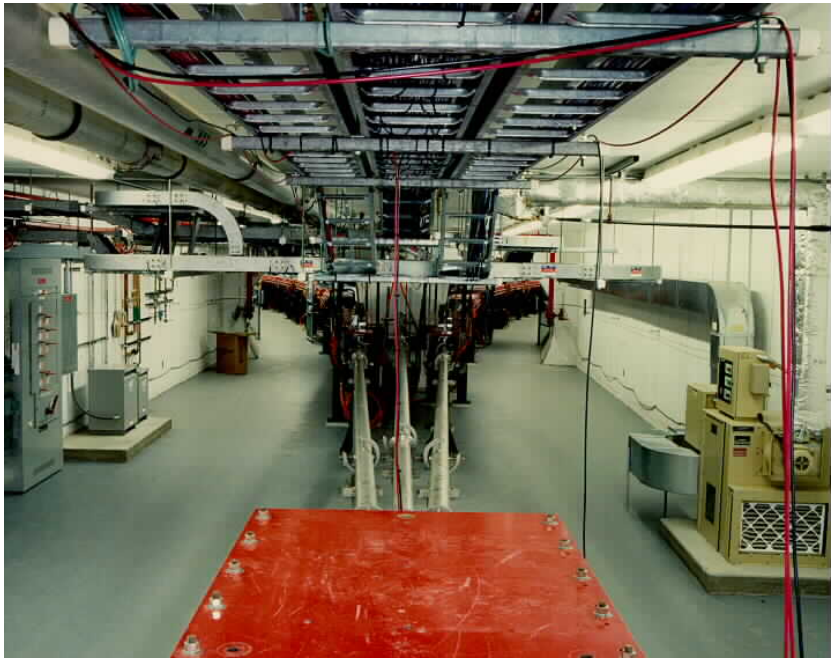
RHIC Pictures (1)



Injection arcs to
blue and yellow rings

Blue and yellow rings

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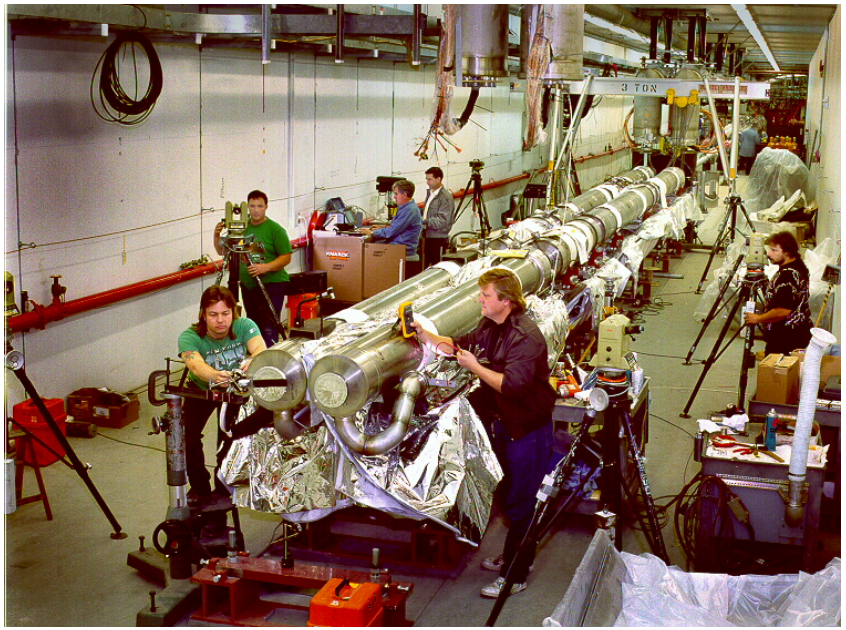
RHIC Pictures (2)



Installation of final focussing triplets

Rf storage cavities

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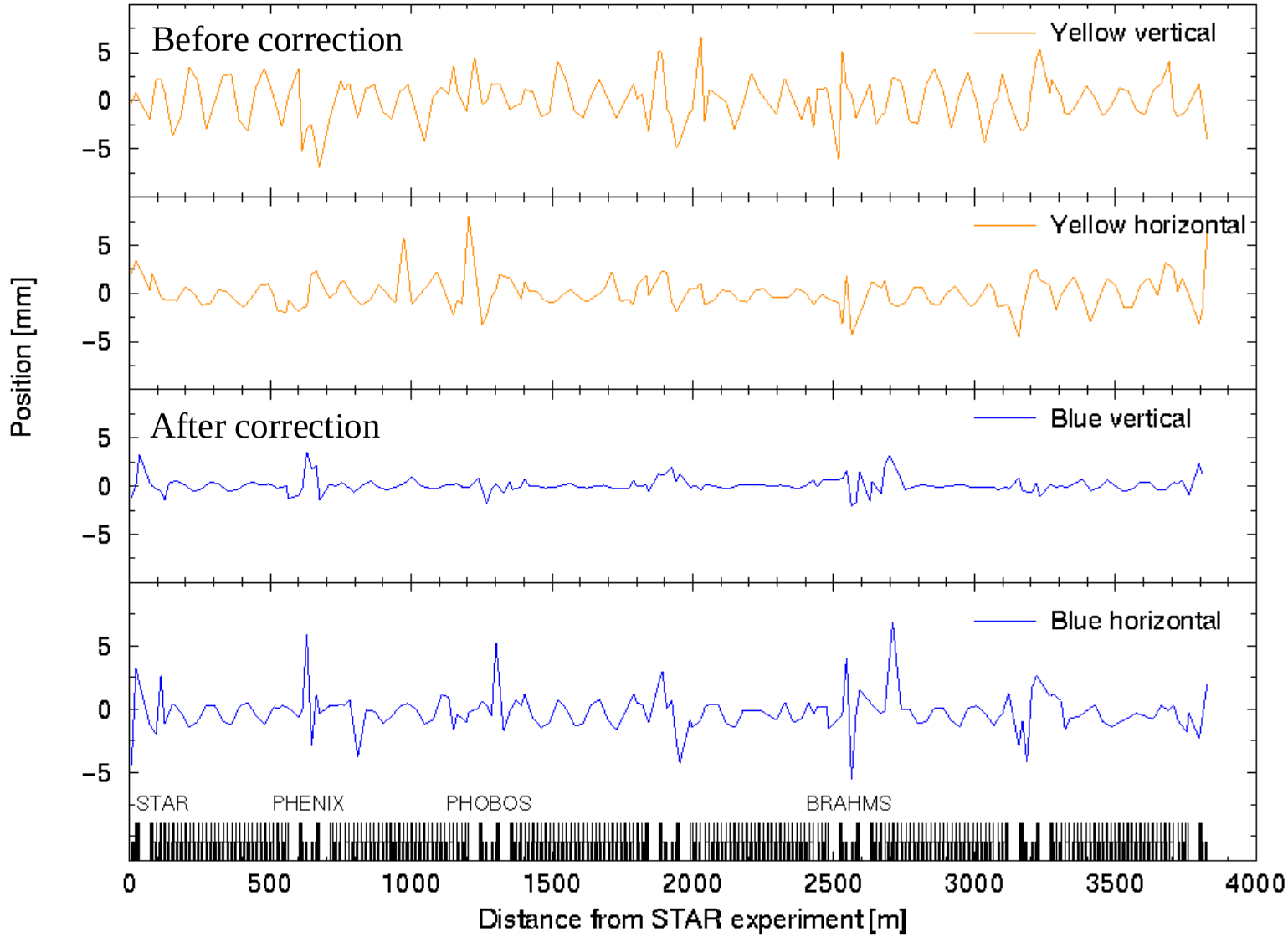
Typical closed orbits at injection



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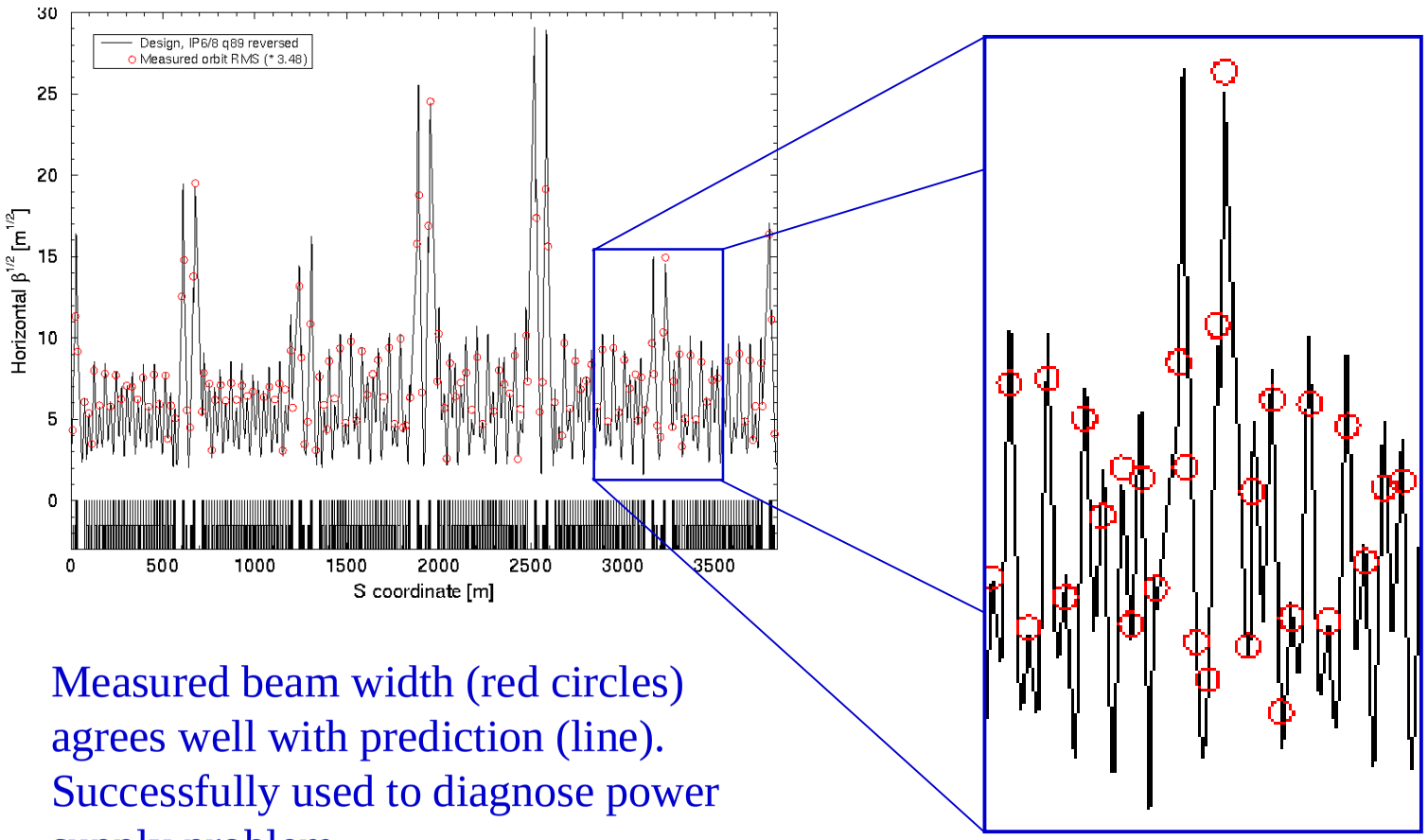
RHIC beam measurements



Measured beam width (red circles) agrees well with prediction (line). Successfully used to diagnose power supply problem.

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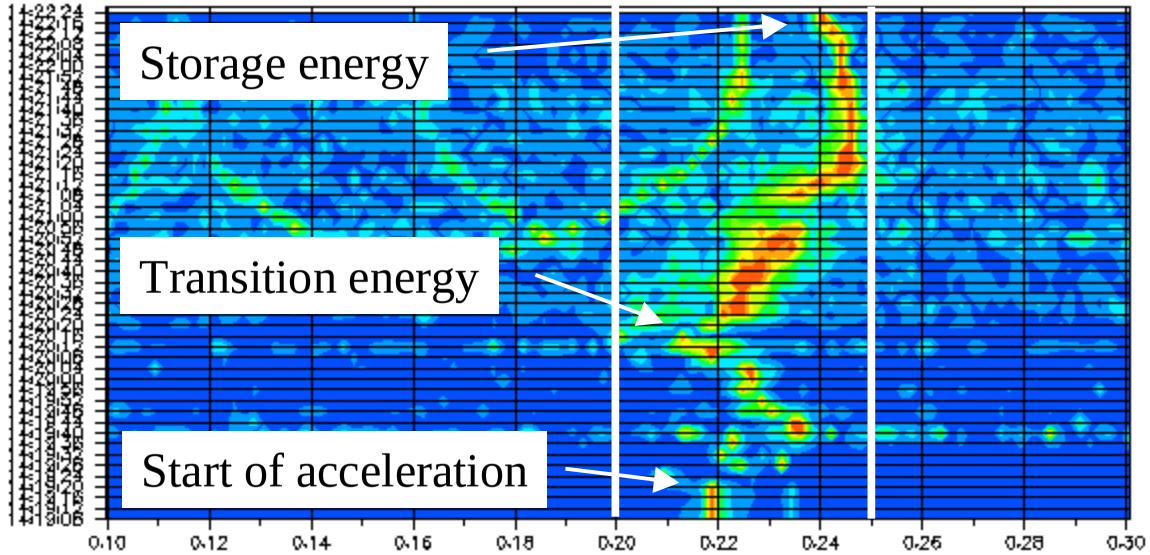
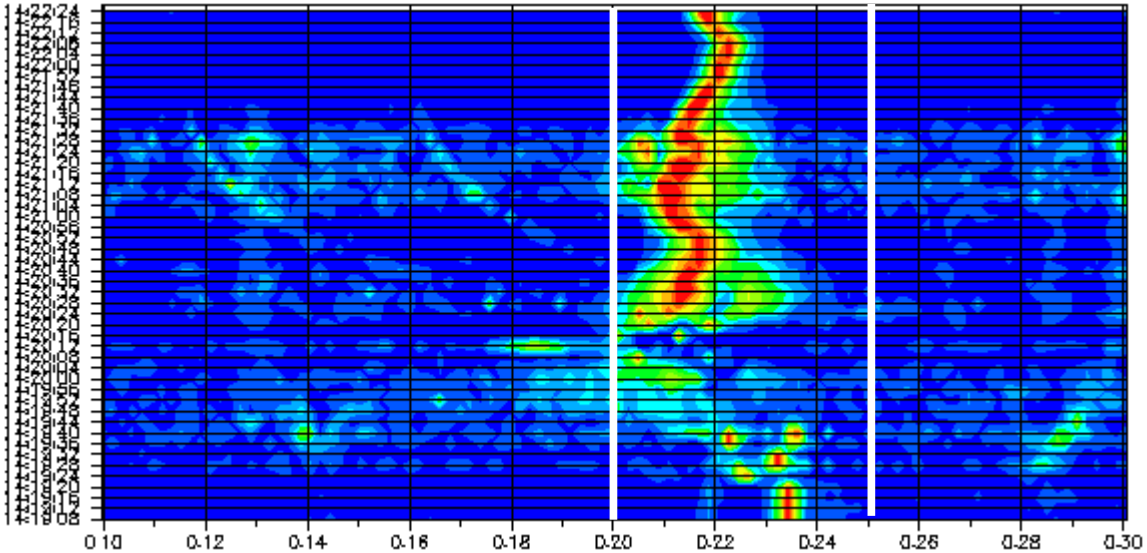
Tune measurements during acceleration ramp

Blue ring
Horizontal



Blue ring
Vertical



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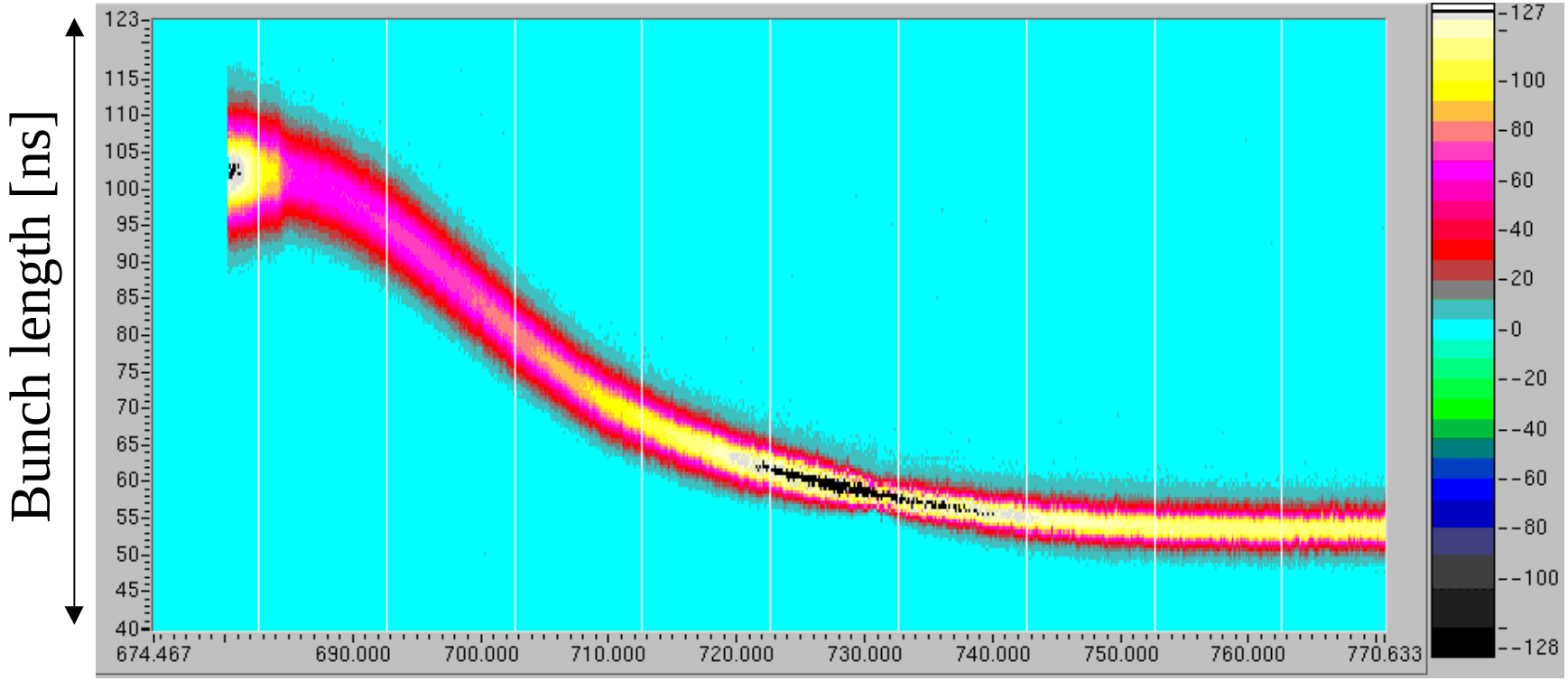
Accelerating a gold bunch in RHIC



Injection

Transition energy

Storage energy

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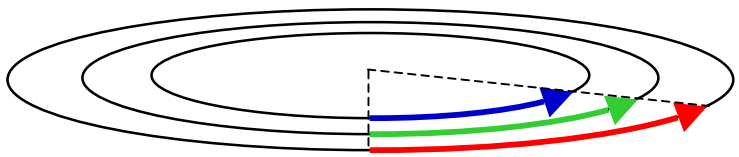
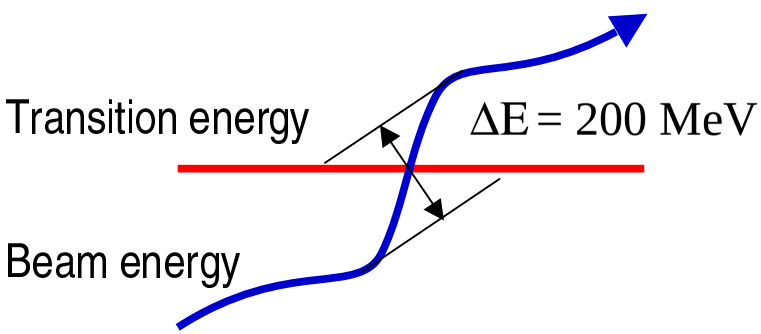
Transition energy crossing

RHIC is first superconducting, slow ramping accelerator to cross transition energy:

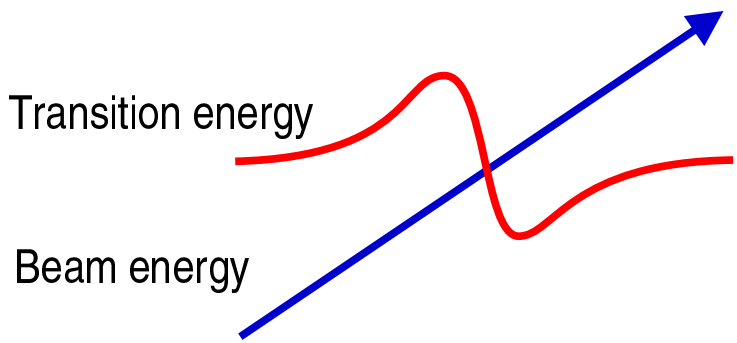


Slow and fast particles remain in step.
⇨ increased particle interaction (space charge)
⇨ short, unstable bunches

Cross unstable transition energy with radial energy jump (2000):



Cross unstable transition energy by rapidly changing transition energy (2001):



Avoids beam loss and longitudinal emittance blow-up

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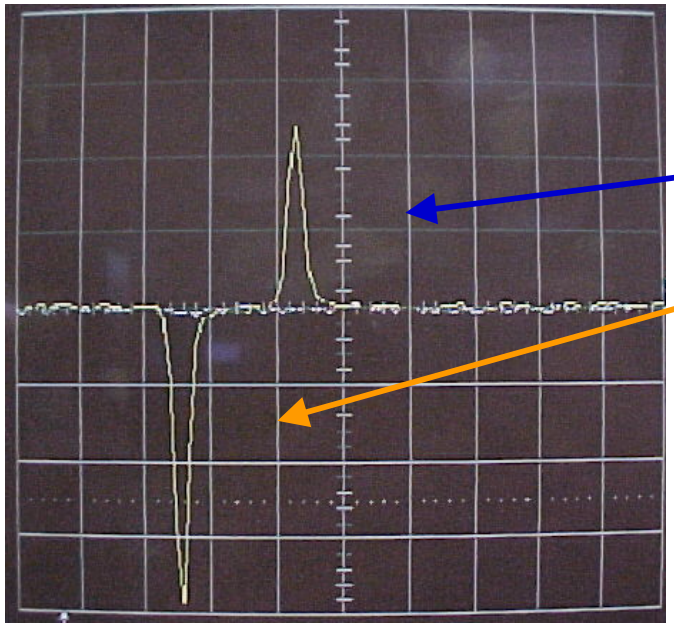
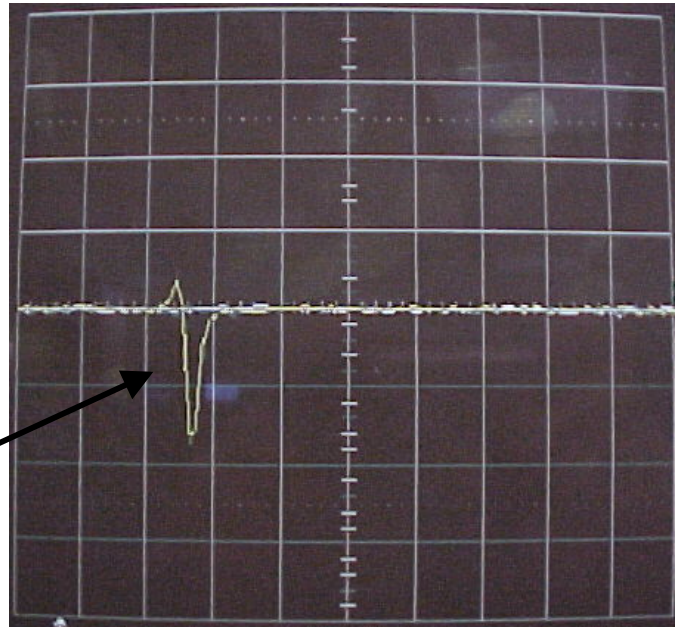
Bringing beams into collision



Beam in blue ring

Beam in yellow ring

200 ns (60 m)



Beams in collision at the interaction regions

200 ns (60 m)

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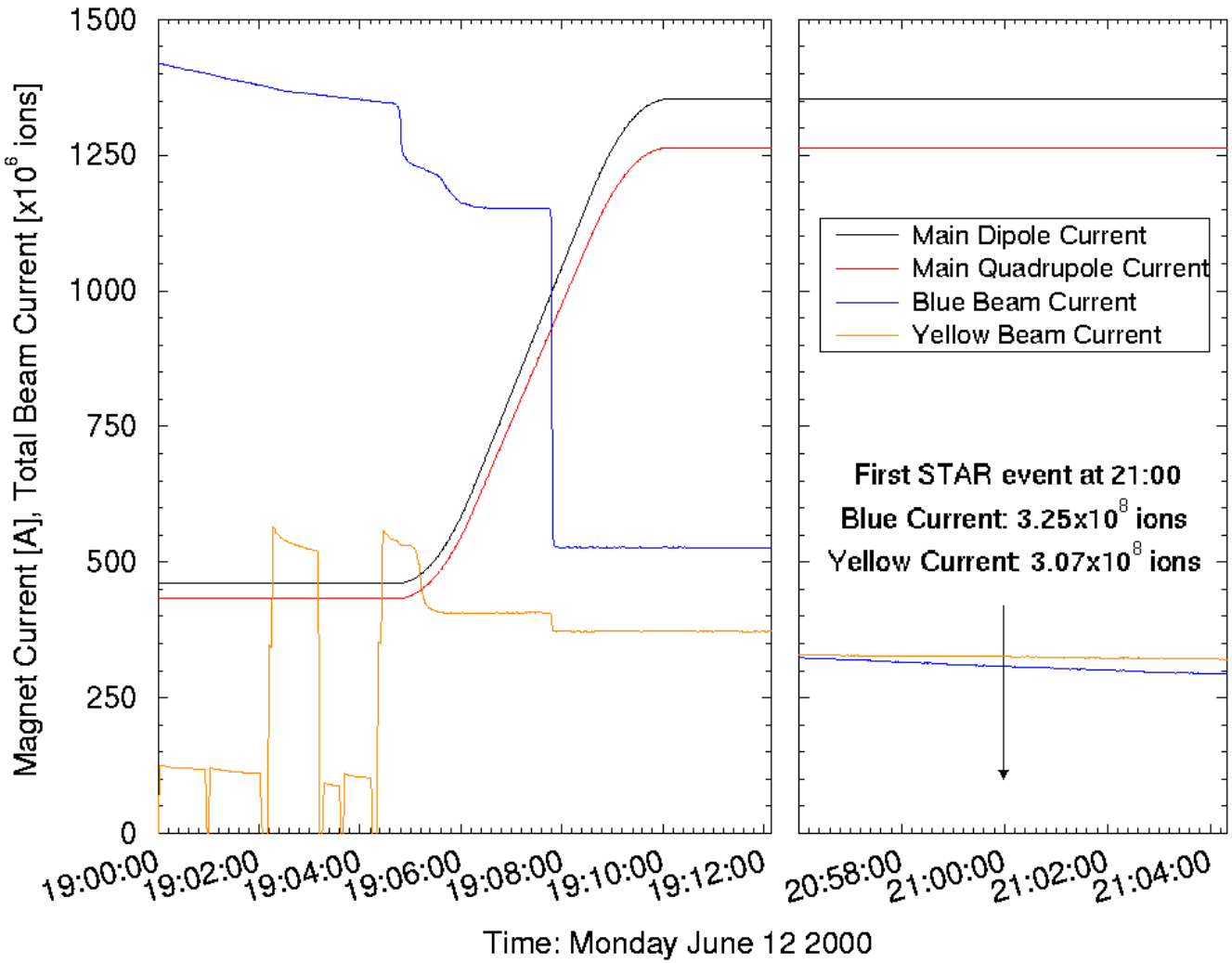
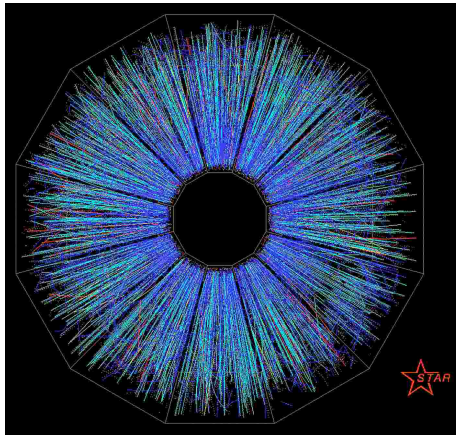
Ramp to first collision





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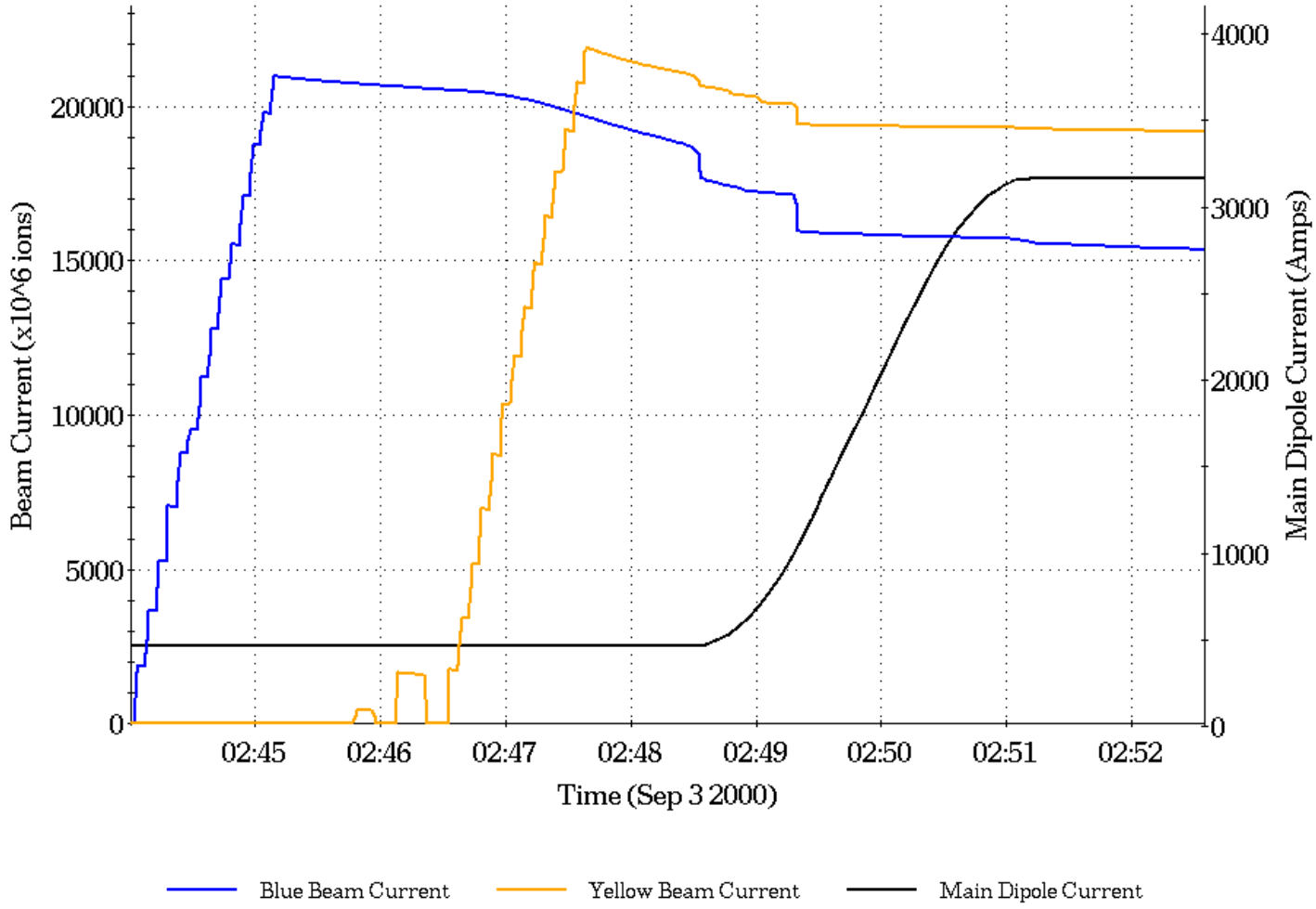
RHIC Injection and Acceleration

(3.6×10^8 Au/bunch)



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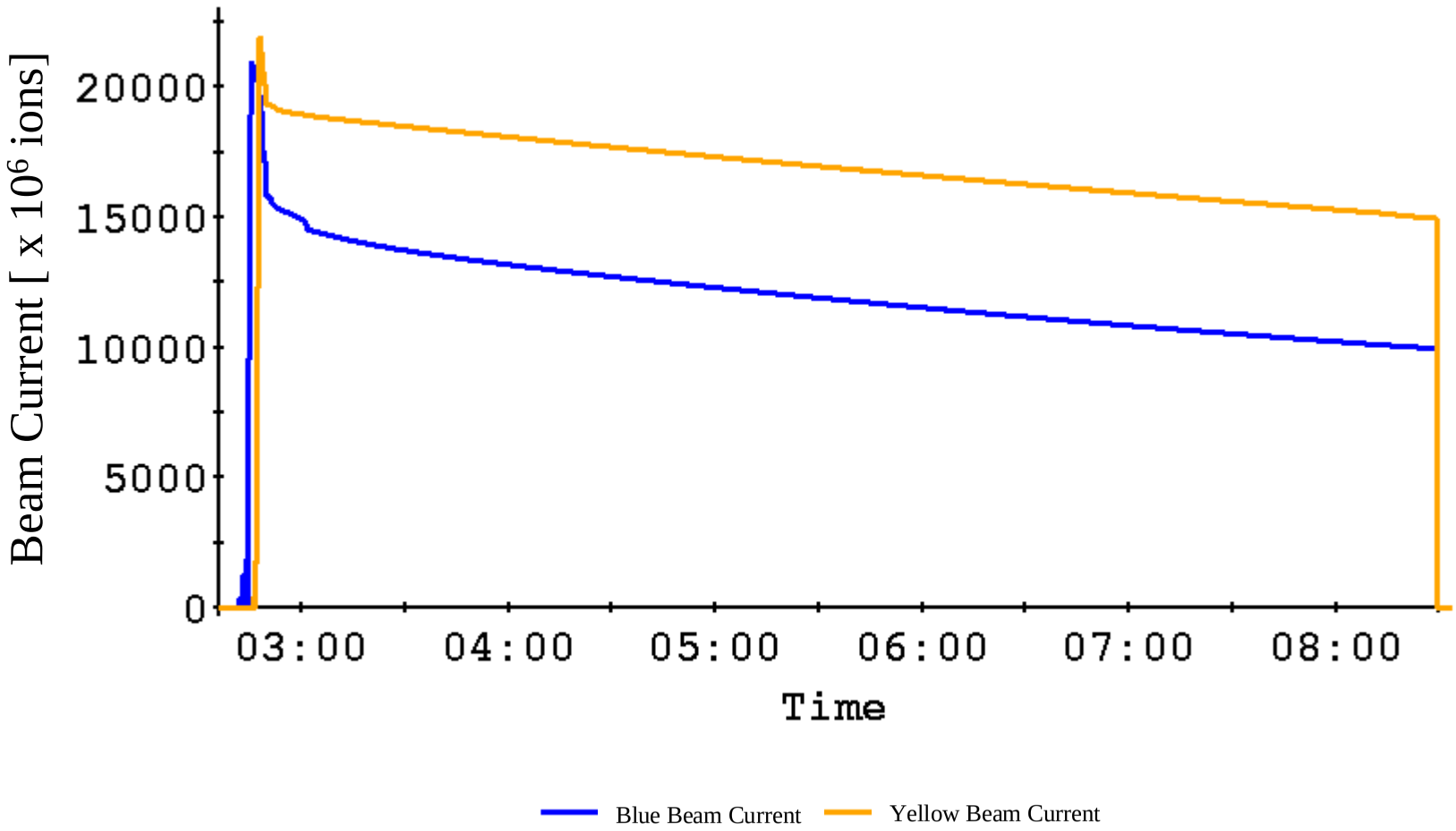
Typical Store



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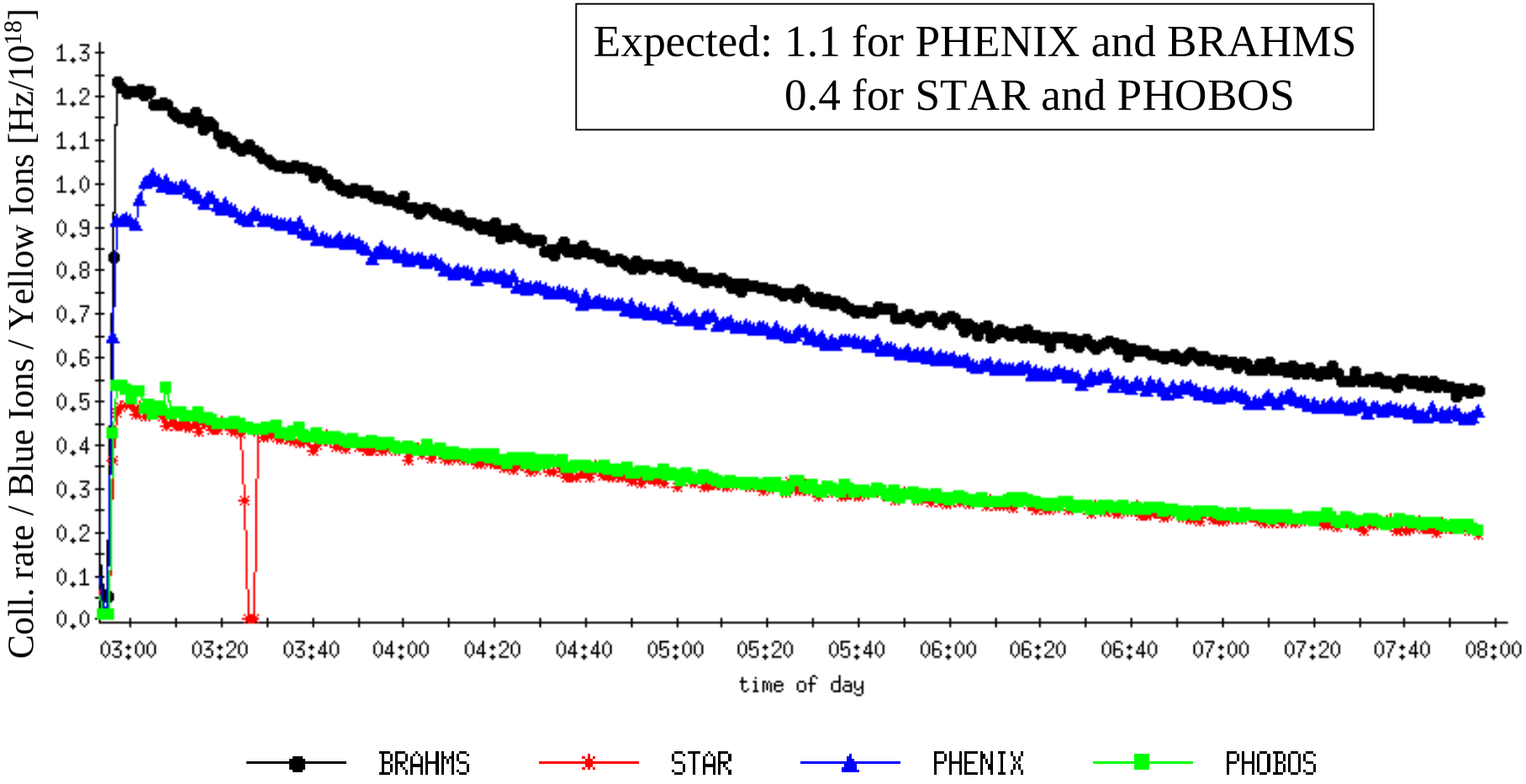
Specific luminosity



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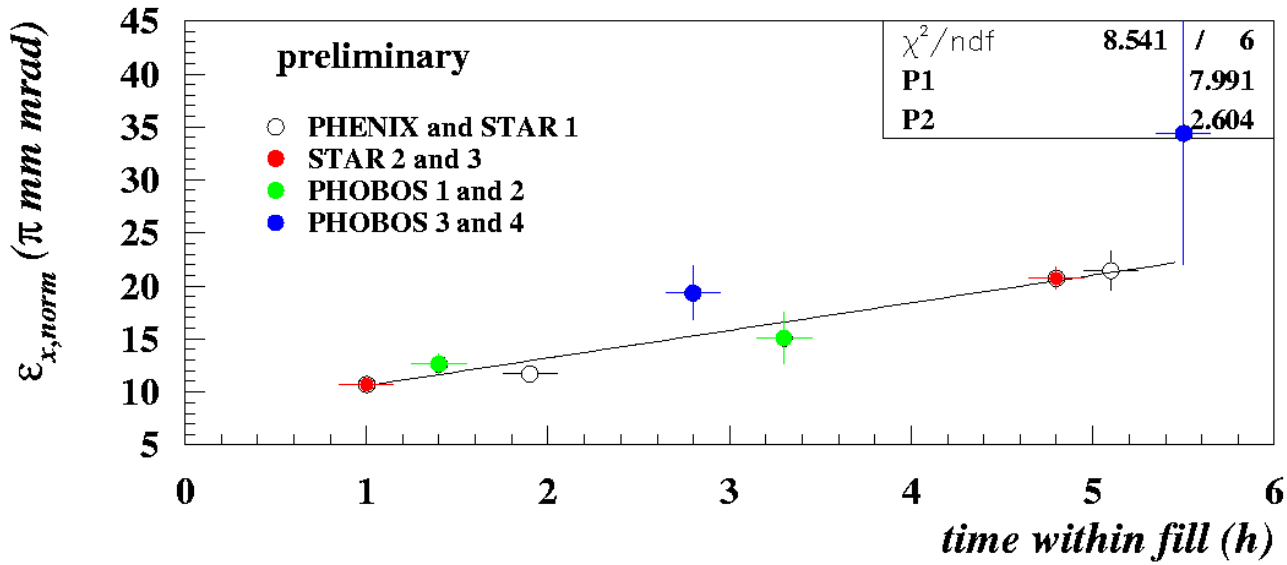
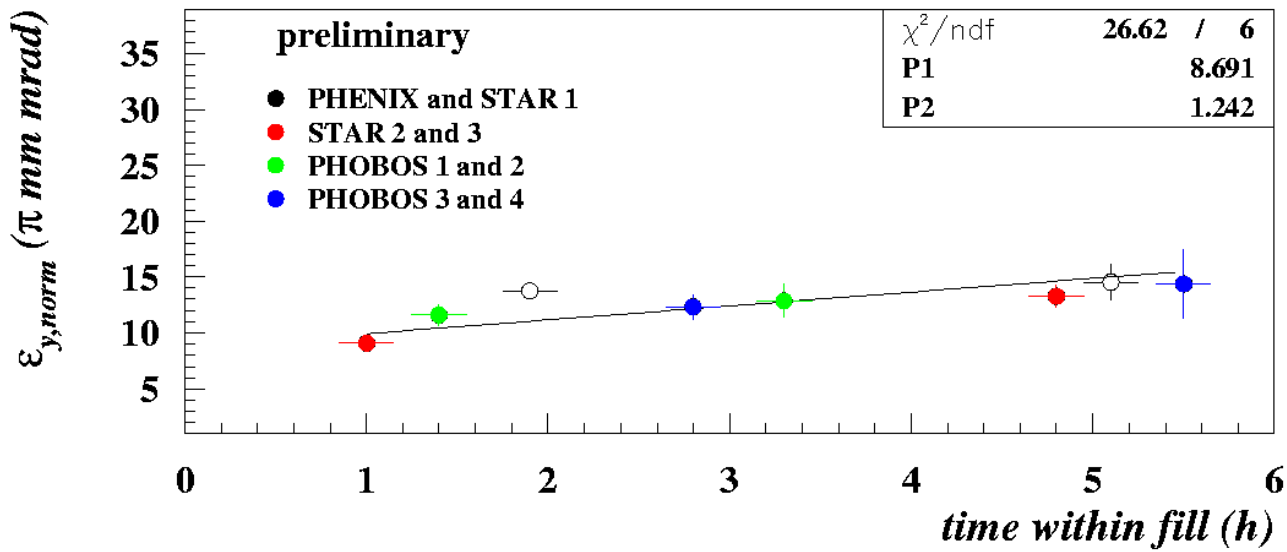
Transverse beam emittance during store





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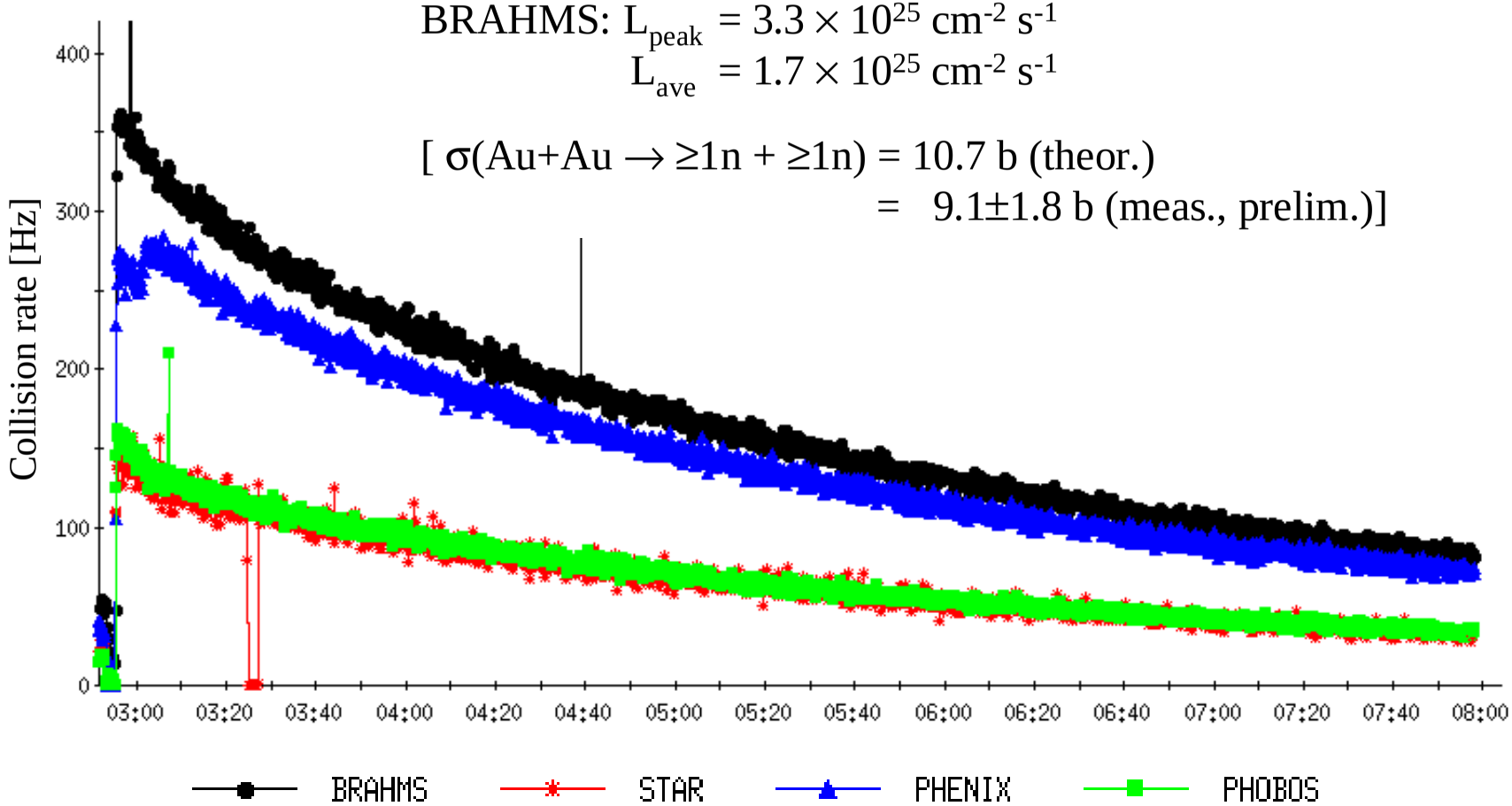
Collision rate at detectors

BRAHMS: $L_{peak} = 3.3 \times 10^{25}\ cm^{-2}\ s^{-1}$
$L_{ave} = 1.7 \times 10^{25}\ cm^{-2}\ s^{-1}$

[$\sigma(Au+Au \rightarrow \geq 1n + \geq 1n) = 10.7$ b (theor.)
$= 9.1 \pm 1.8$ b (meas., prelim.)]



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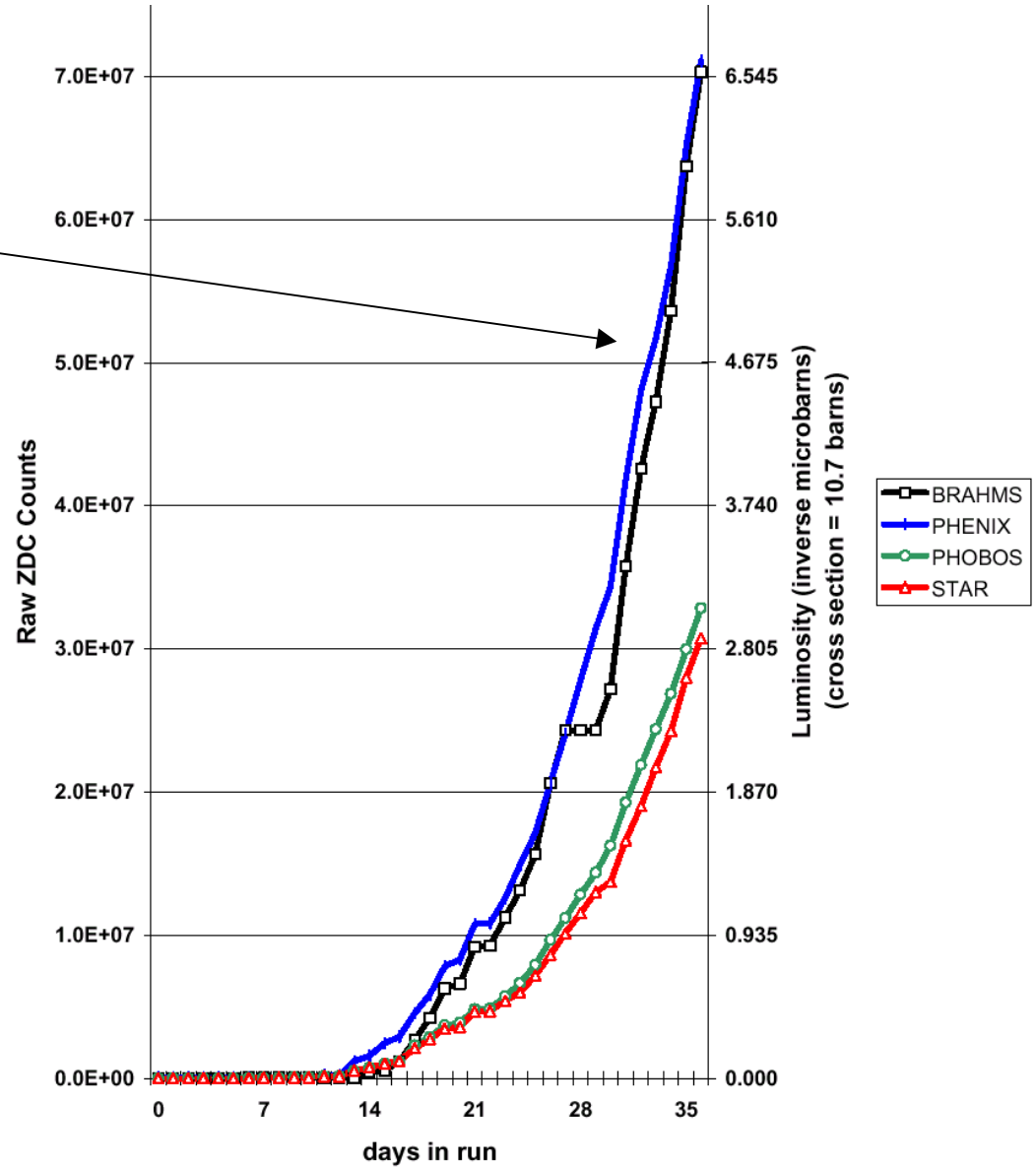
RUN2000 integrated Au-Au luminosity

BRAHMS during last 6 days:
$L_{ave} = 0.8 \times 10^{25}\ cm^{-2}\ s^{-1}$
Availability: 47 %



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RUN2001 Goals

- Au - Au: 56 bunches per ring with 1×10^9 Au/bunch
  Design average luminosity: 2×10^{26} cm^{-2} s^{-1} [60 (μb)$^{-1}$/week]
  Design energy/beam: 100 GeV/nucl.
  Design diamond length: σ = 20 cm
- p↑ - p↑: 56 bunches per ring with 1×10^{11} p↑/bunch
  Average luminosity: 5×10^{30} cm^{-2} s^{-1} [1.5 (pb)$^{-1}$/week]
  Energy/beam: 100 GeV (Acceleration to 250 GeV)
  Beam polarization ≥ 50 %
- To reach these goals the following new hardware is being installed:
  - All remaining IR power supplies
  - Transition energy pulsed power supplies
  - 200 MHz storage rf system
  - All four Siberian snakes
  - Both RHIC polarimeters

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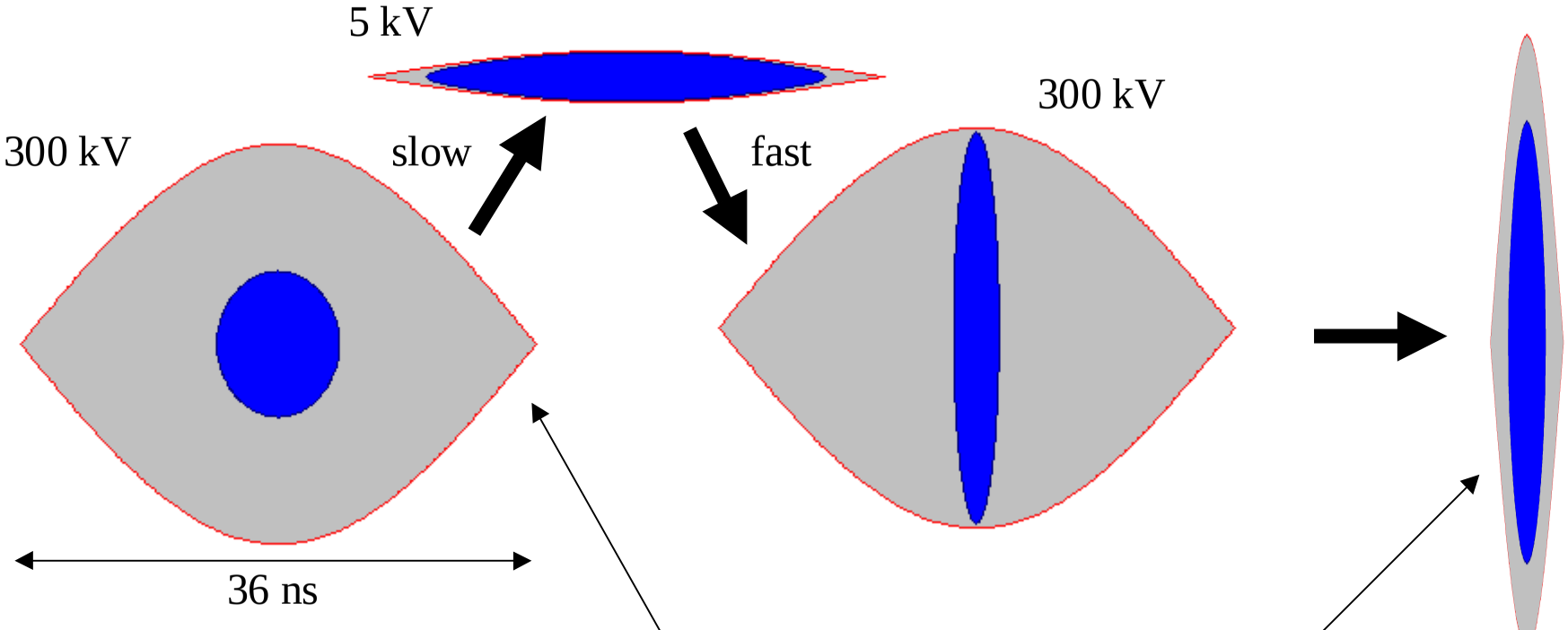
Making short bunches



28 MHz / 300 kV accelerating cavities
0.5 - 5 eVs → σ_{diam} = 0.36 - 1.5 m

200 MHz / 6 MV storage cavities
0.7 - 1.1 eVs → σ_{diam} = 0.15 - **0.20 m**

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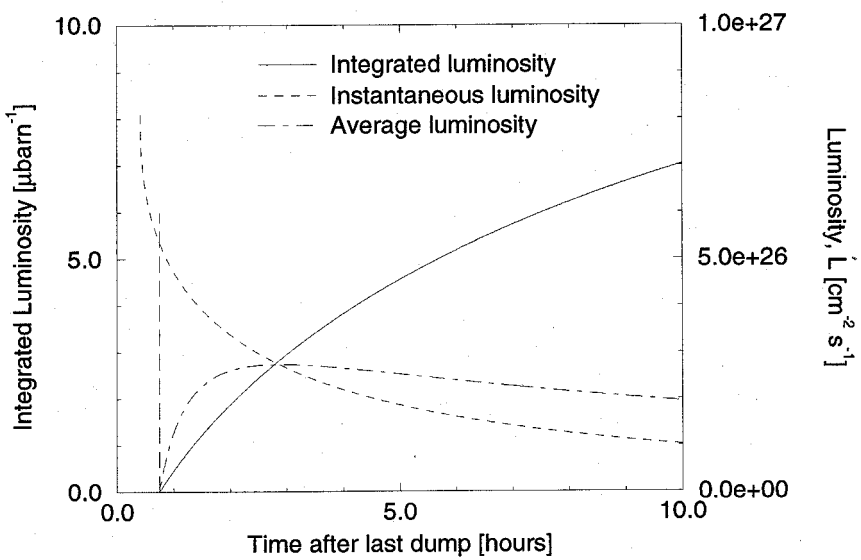
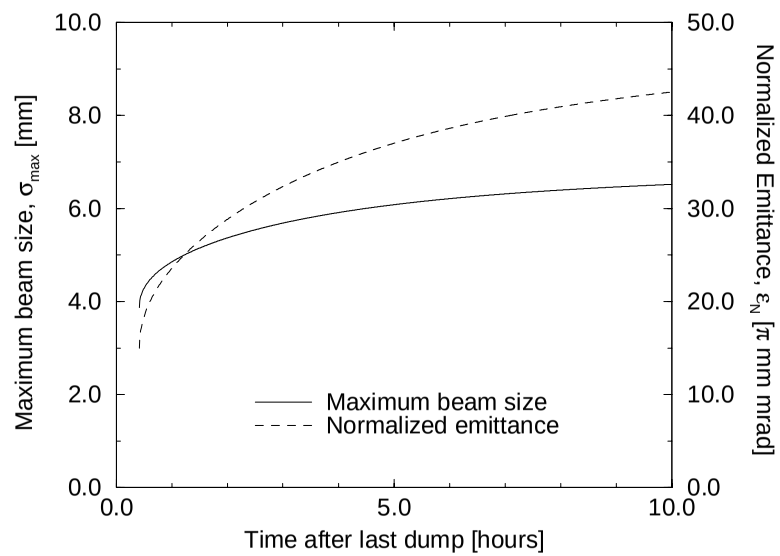
RHIC design luminosity

$$L = \frac{3 f_{rev} \gamma}{2} \frac{N_b N^2}{\varepsilon \beta^*} = 9 \ldots 1 \times 10^{26} cm^{-2} s^{-1} \text{ over 10 hours}$$

$$N_b = 60 ; N = 1 \times 10^9 ; \varepsilon = 15 \ldots 40 \pi \mu m ; \beta^* = 2m$$





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Luminosity upgrade possibilities

- ‘Enhanced’ luminosity possible with existing machine:
  - Increase number of bunches to 120
  - Decrease β^* from 2 m to 1m
- Further luminosity upgrades:
  - Decrease β^* further with modified optics
  - Increase bunch intensity
  - Decrease beam emittance
- Last two (three) items are limited by intra-beam scattering and require beam cooling at full energy!

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Beam Cooling at RHIC Storage Energy

- Electron beam cooling of RHIC beams:
  - Bunched electron beam requirements (prelim.):
    100 GeV gold beams: E= 54 MeV; I= 3 A peak / 10 mA average
  - Requires high brightness, high power, energy recuperating superconducting linac, almost identical to Infra-Red Free Electron Laser at TJNAF
  - Collaboration with BINP, Novosibirsk, on the development of RHIC electron cooling
  - $\times$ 10 luminosity increase possible (prelim.)
- Stochastic cooling of low intensity gold beams may also be possible.

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Summary

- RUN2000 RHIC commissioning and first operation was very successful
- Full design Au luminosity and collisions of polarized protons are planned for RUN2001
- RHIC Au luminosity upgrades:
  - with existing machine: $\times$ 4
  - with full energy electron cooler: $\times$ 10 possible

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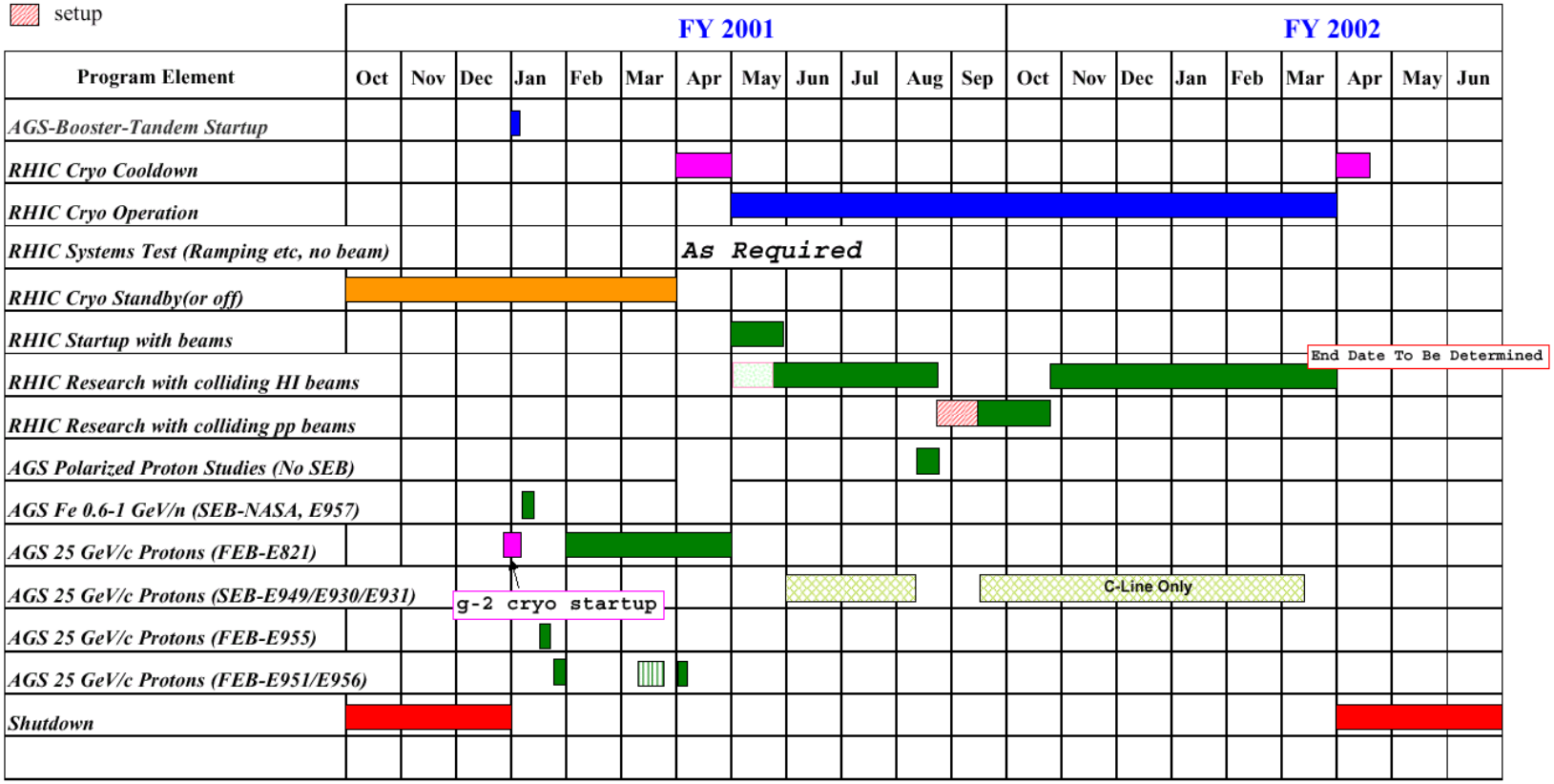
C-A Operations-FY01-02

4 Dec 00

Preliminary schedule, subject to funding and other issues

- to be determined
- concurrent with RHIC operations
- setup