

# The first RHIC machine run

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FY2000 RHIC heavy ion run

RHIC polarized proton commissioning and plans

RHIC luminosity upgrade plans



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Transversity Workshop  
September 18-20, 2000

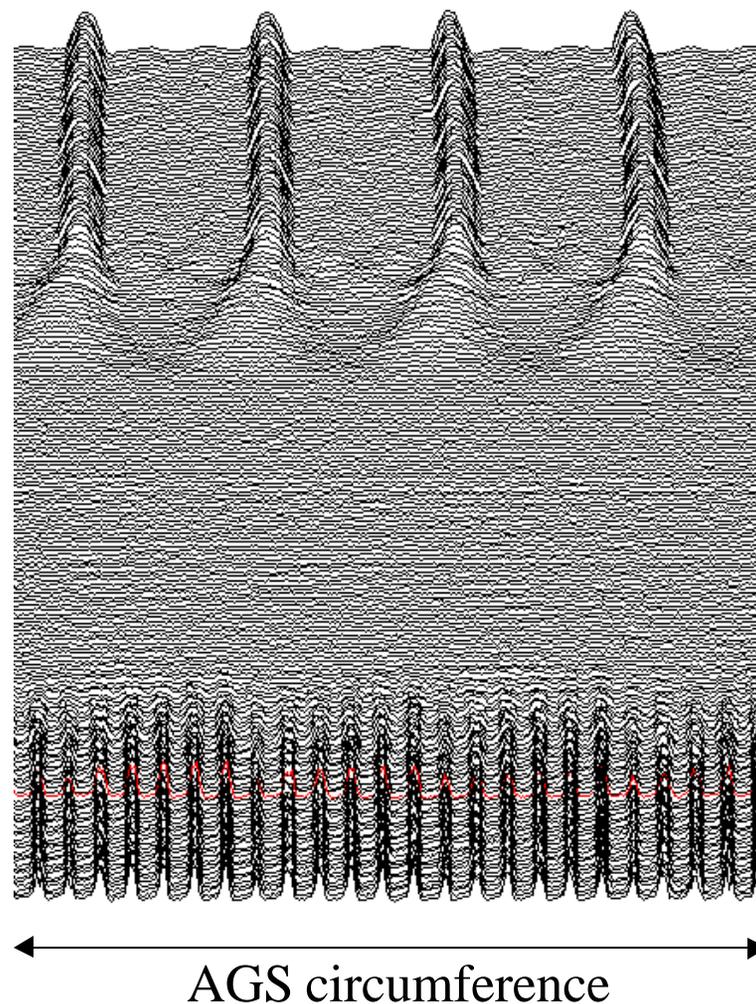
# Parameters and goals for RHIC RUN2000

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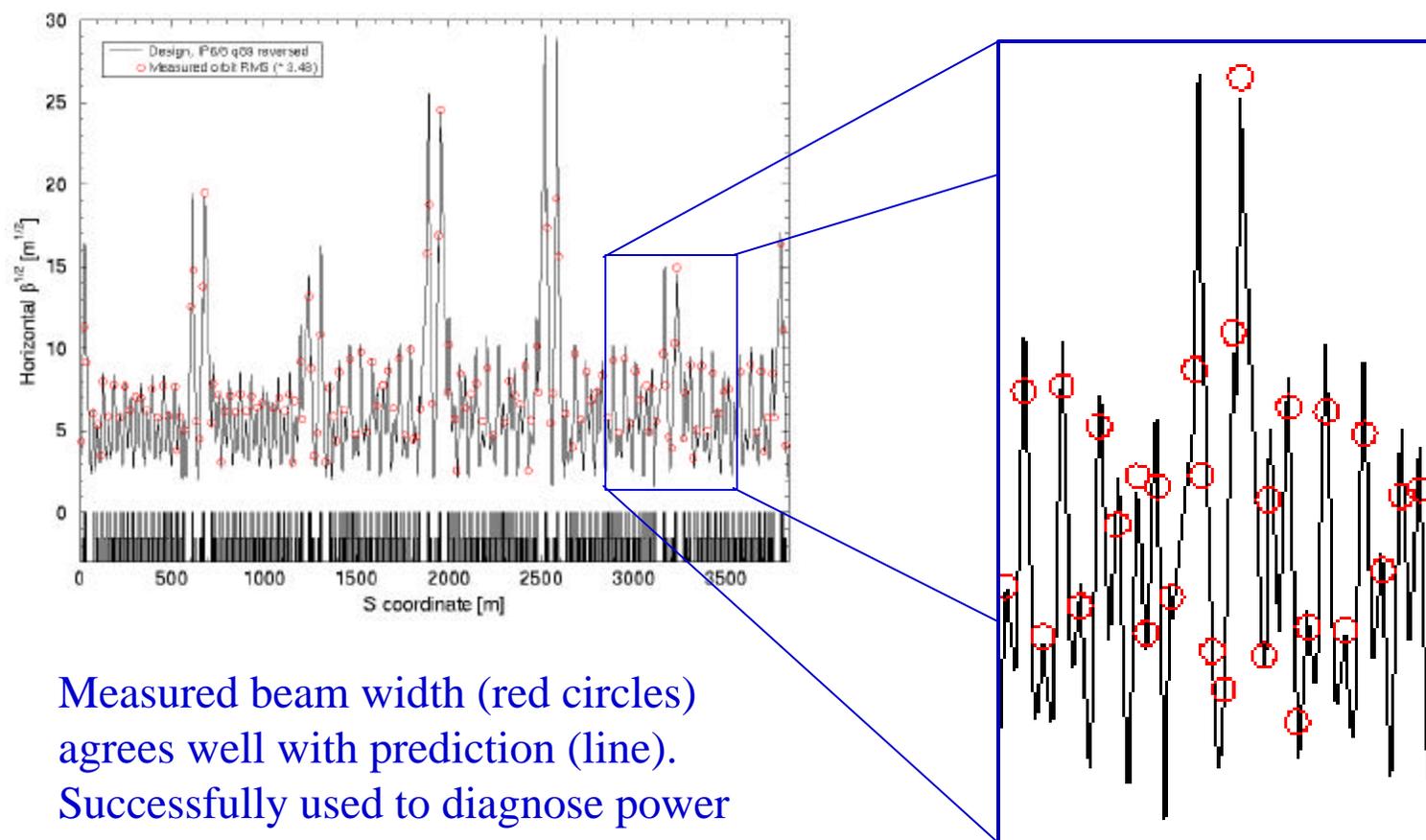
- 60 bunches per ring ✓
- $5 \times 10^8$  Au/bunch ✓
- Longitudinal emittance: 0.3 eVs/nucleon/bunch ✓
- Transverse emittance at storage:  $15 \pi \mu\text{m}$  (norm, 95%) ✓
- Initial storage energy:  $\gamma = 70$  [66 GeV/nucl.] ✓ (This energy is below the lowest quench of any DX magnet)
- Lattice at injection and acceleration:  $\beta^* = 3 \text{ m}$  @ 2, 4, 8, and 12 o'clock  
 $\beta^* = 8 \text{ m}$  @ 6 and 10 o'clock
- Lattice at storage and collision:  $\beta^* = 3 \text{ m}$  @ 2, 4, 8, and 12 o'clock  
 $\beta^* = 2-8 \text{ m}$  @ 6 and 10 o'clock
- Luminosity:  $2 \times 10^{25} \text{ cm}^{-2} \text{ s}^{-1}$  ✓
- Integrated luminosity: a few  $(\mu\text{b})^{-1}$  ✓

# RF bunch merging in AGS

- $4 \times 6$  bunches injected from Booster
- Debunch / rebunch into 4 bunches at AGS injection
- Final longitudinal emittance: 0.3 eVs/nuc./bunch
- Achieved  $4 \times 10^9$  Au ions in 4 bunches at AGS extraction on 8/4/00



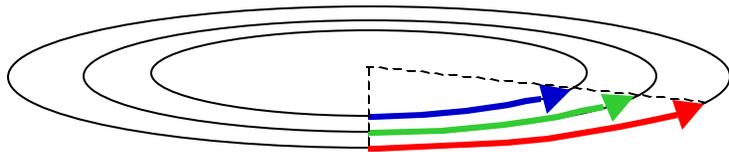
# RHIC beam measurements



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

# Transition energy crossing

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

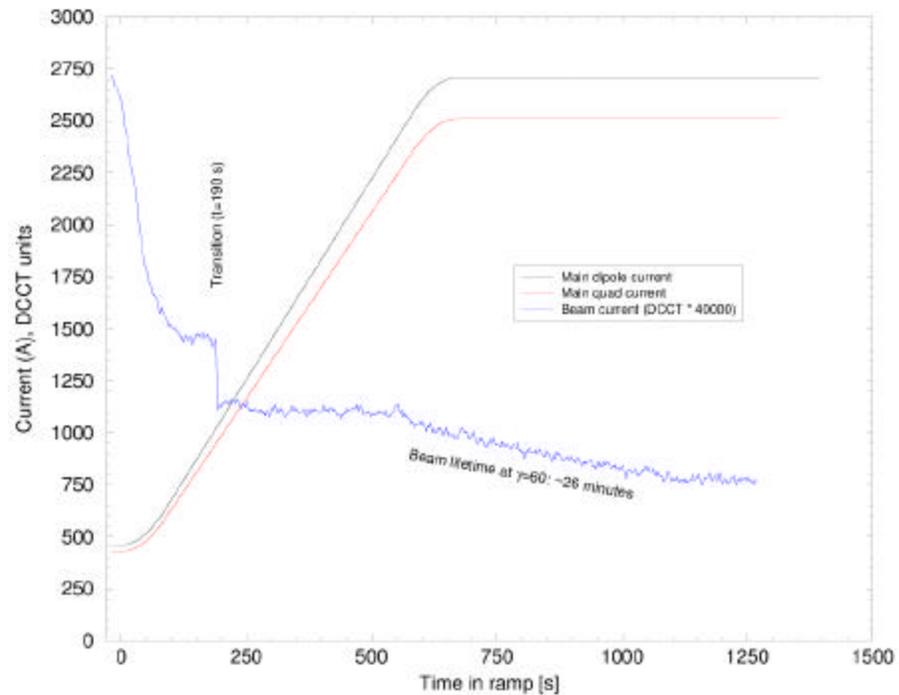
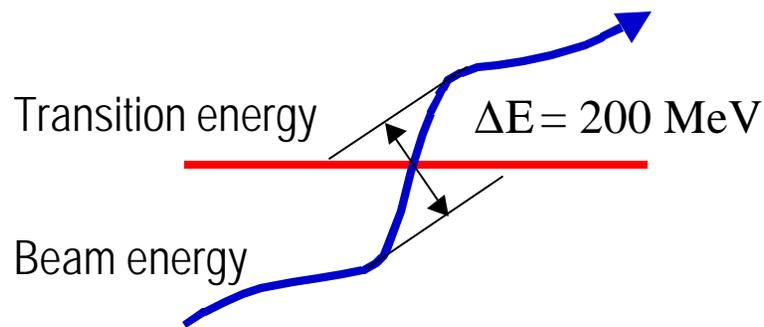


Slow and fast particles remain in step.

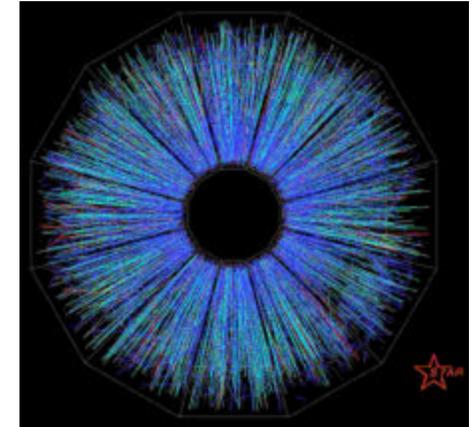
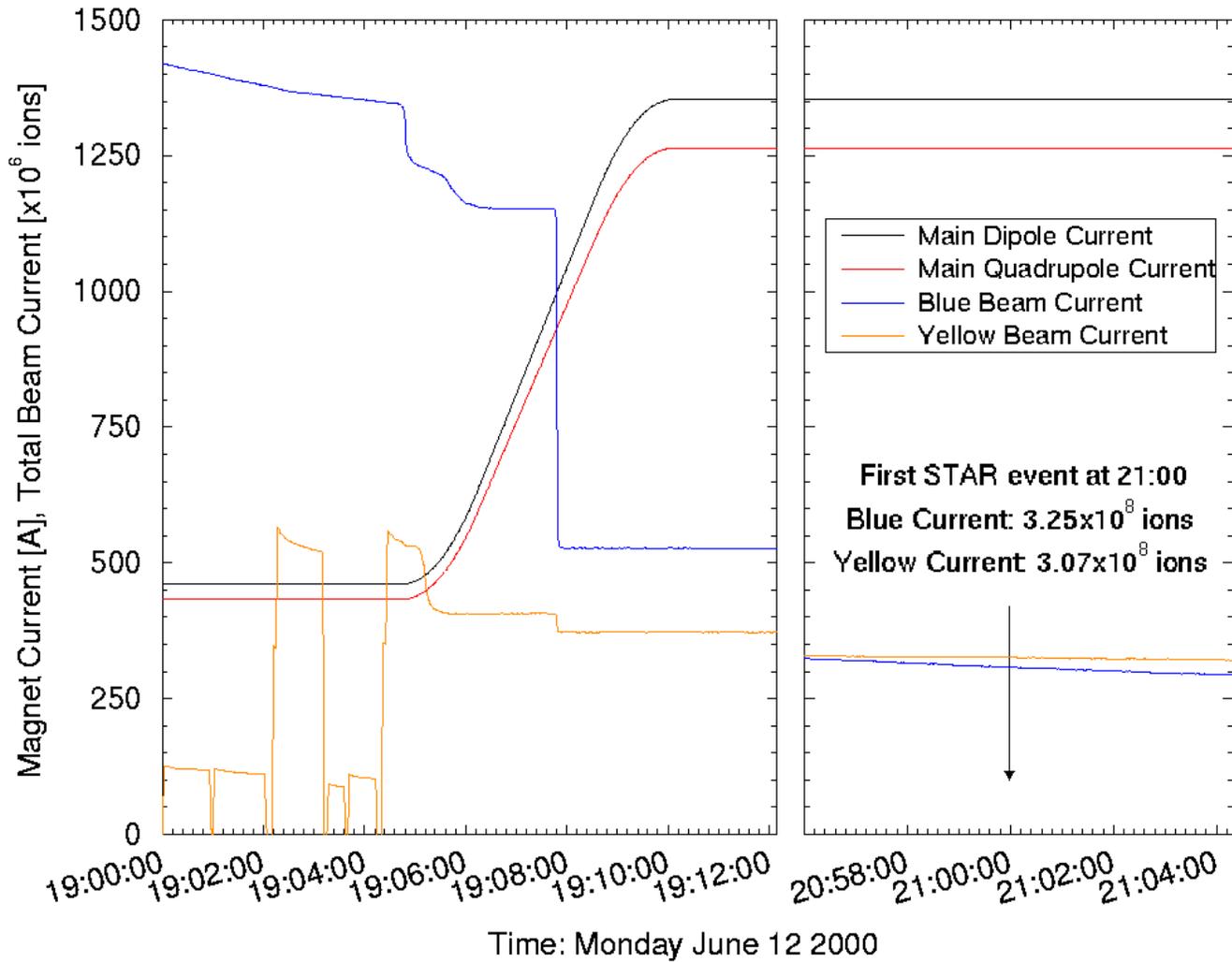
⇒ increased particle interaction (space charge)

⇒ short, unstable bunches

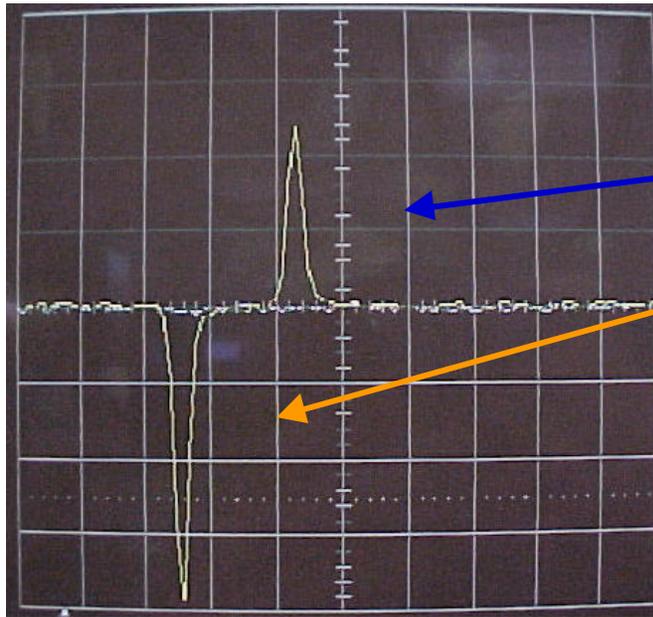
Cross unstable transition energy with radial energy jump:



# Ramp to first collision



# Bringing beams into collision

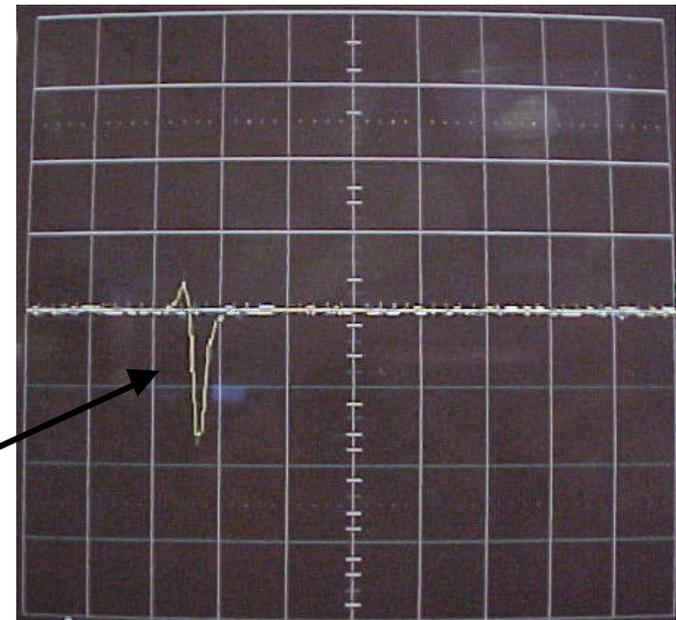


Beam in blue ring

Beam in yellow ring

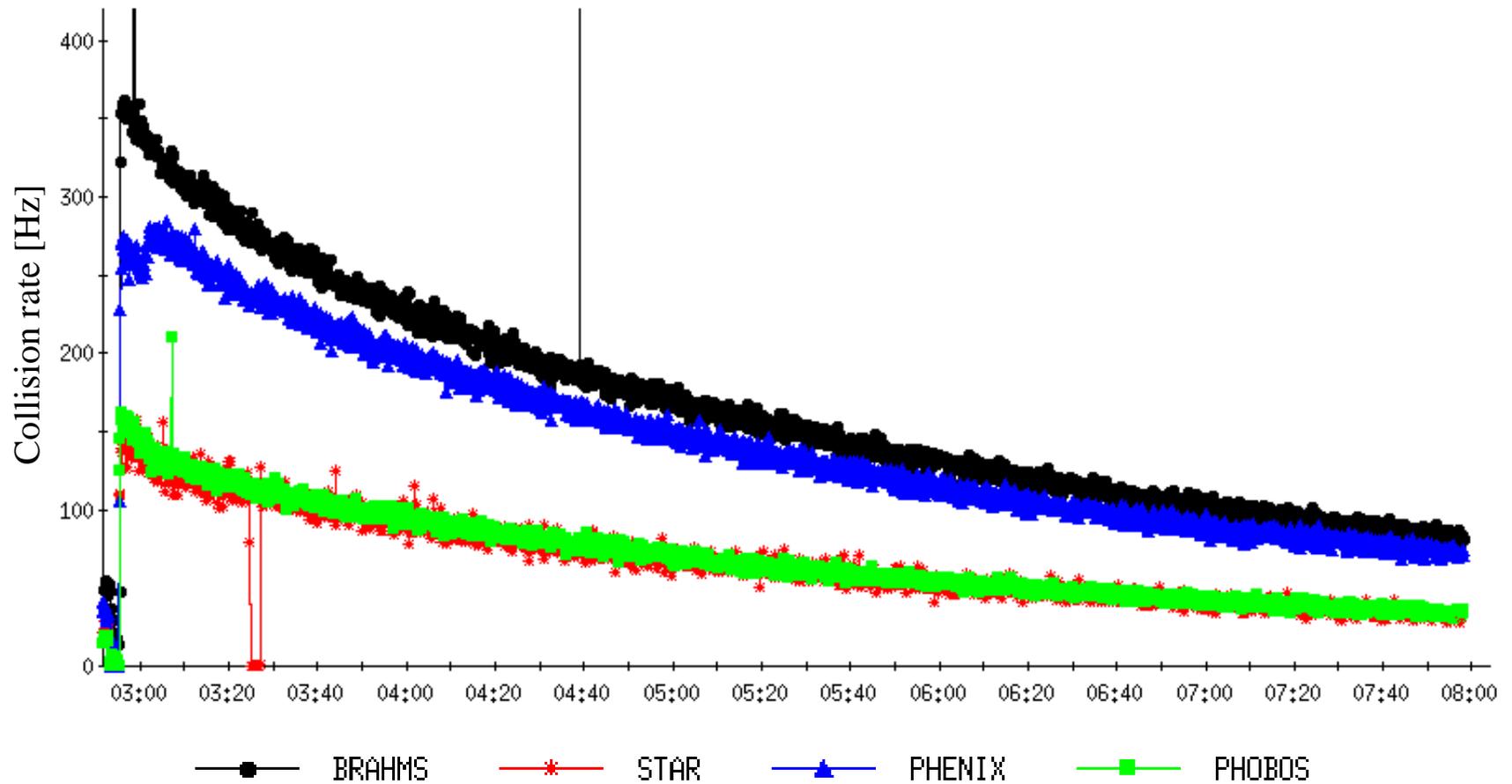
200 ns (60 m)

Beams in collision at the interaction regions

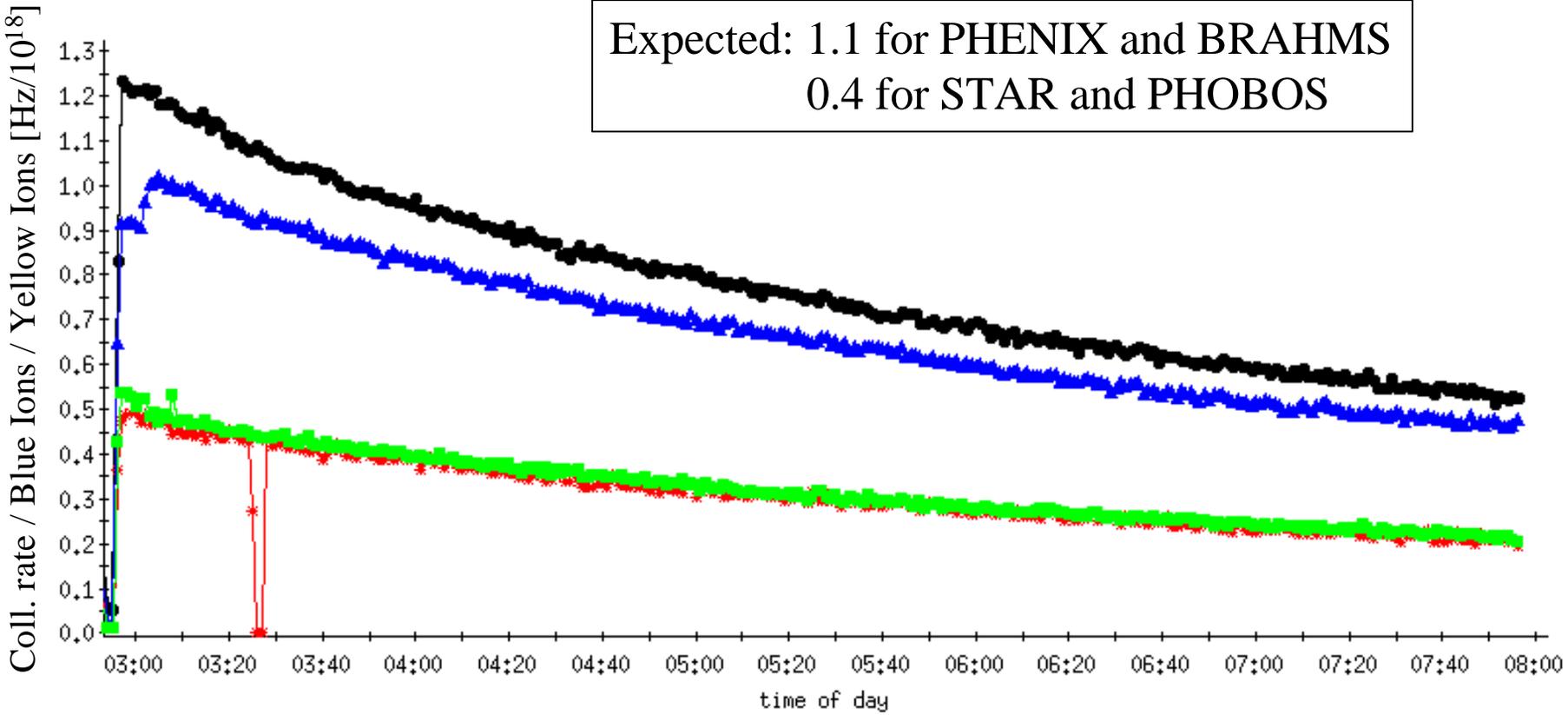


200 ns (60 m)

# Collision rate at detectors



# Specific luminosity



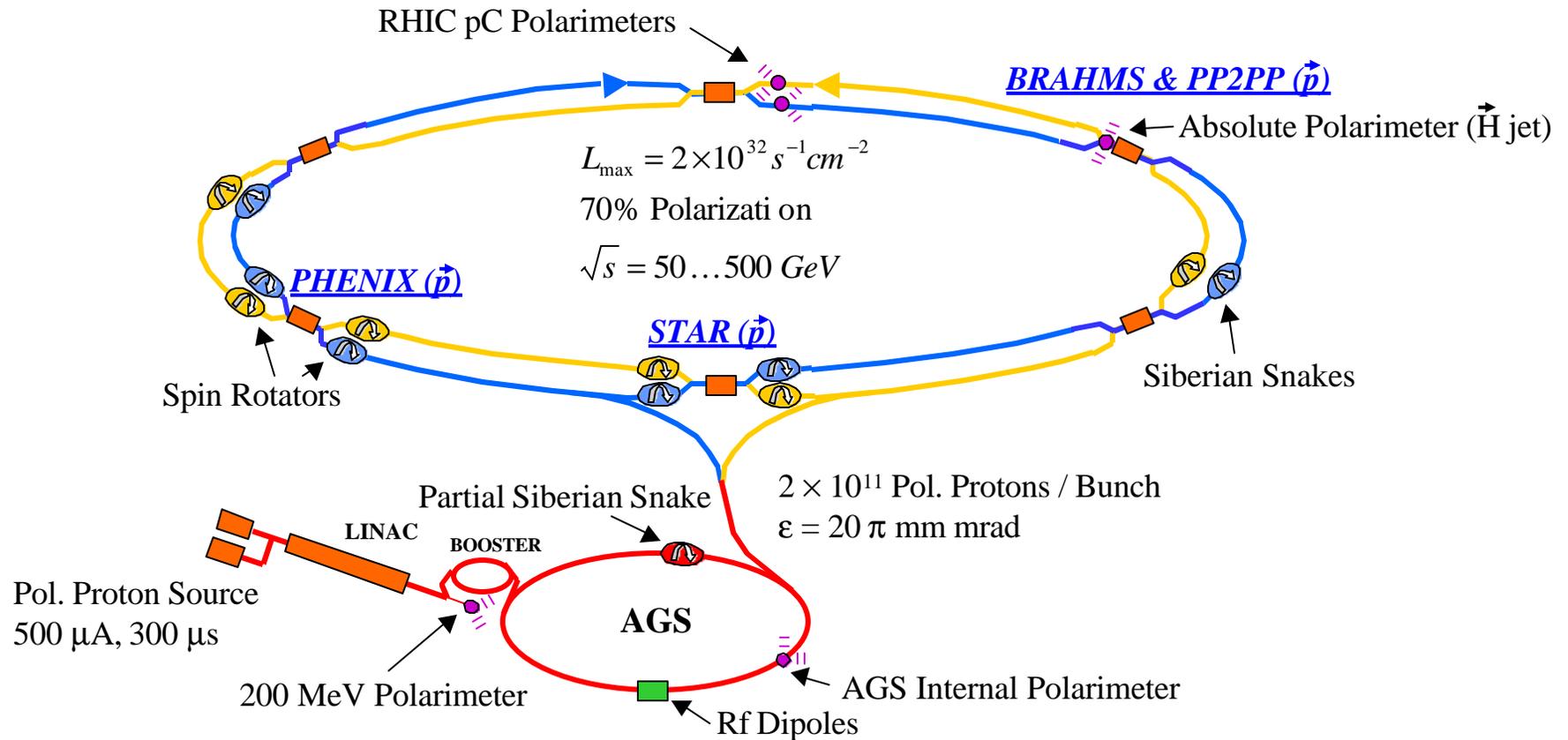
—●— BRAHMS    —\*— STAR    —▲— PHENIX    —■— PHOBOS

# Parameters and goals for RHIC RUN2001

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- Transition energy jump quadrupole power supplies installed
- 60 bunches per ring with  $1 \times 10^9$  Au/bunch
- Storage energy:  $\gamma = 107$  [100 GeV/nucl.]
- All bipolar power supplies installed:
  - Lattice at injection and acceleration:  $\beta^* = 10$  m at all IR's
  - Lattice at storage and collision:  $\beta^* = 2-10$  m at all IR's
- Luminosity goal:  $2 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1}$  (design luminosity)
- Availability:  $\approx 75$  %
- Machine efficiency:  $\approx 50$  %

# Polarized proton collisions in RHIC

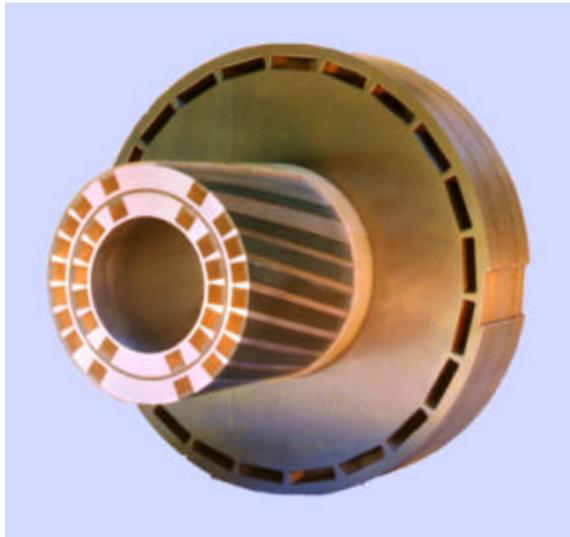


# First Siberian Snake in RHIC Tunnel

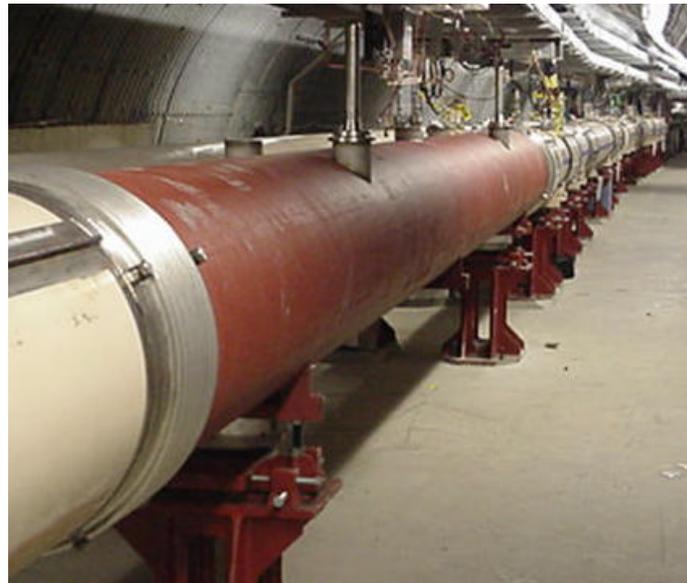
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Siberian Snake: 4 superconducting helical dipoles, 4 Tesla,  
2 m long with full 360° twist

- ⇒ Acceleration of spin polarized protons beams in RHIC
- ⇒ Beam studies in September 2000



Funded by RIKEN, Japan  
Designed and constructed at BNL



# FY2000 commissioning plan

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June-July 2000: (independent of RHIC operation)

- New pol. source (OPPIS) commissioned and beam transp. through linac: 65% polarization measured at 200 MeV polarimeter, 200  $\mu$ A and 300  $\mu$ s beam pulse ( $4 \times 10^{11}$  polarized protons )

August 2000: (during RHIC Au stores)

- Accelerate single bunch ( $10^{11}$  pol. pr. / bunch) in Booster and AGS to  $G\gamma = 46.5$  ( $\gamma = 25.94$ ) ✓
- Commission coupled spin resonance crossing using horizontal rf dipole.

September 2000: (dedicated RHIC operation)

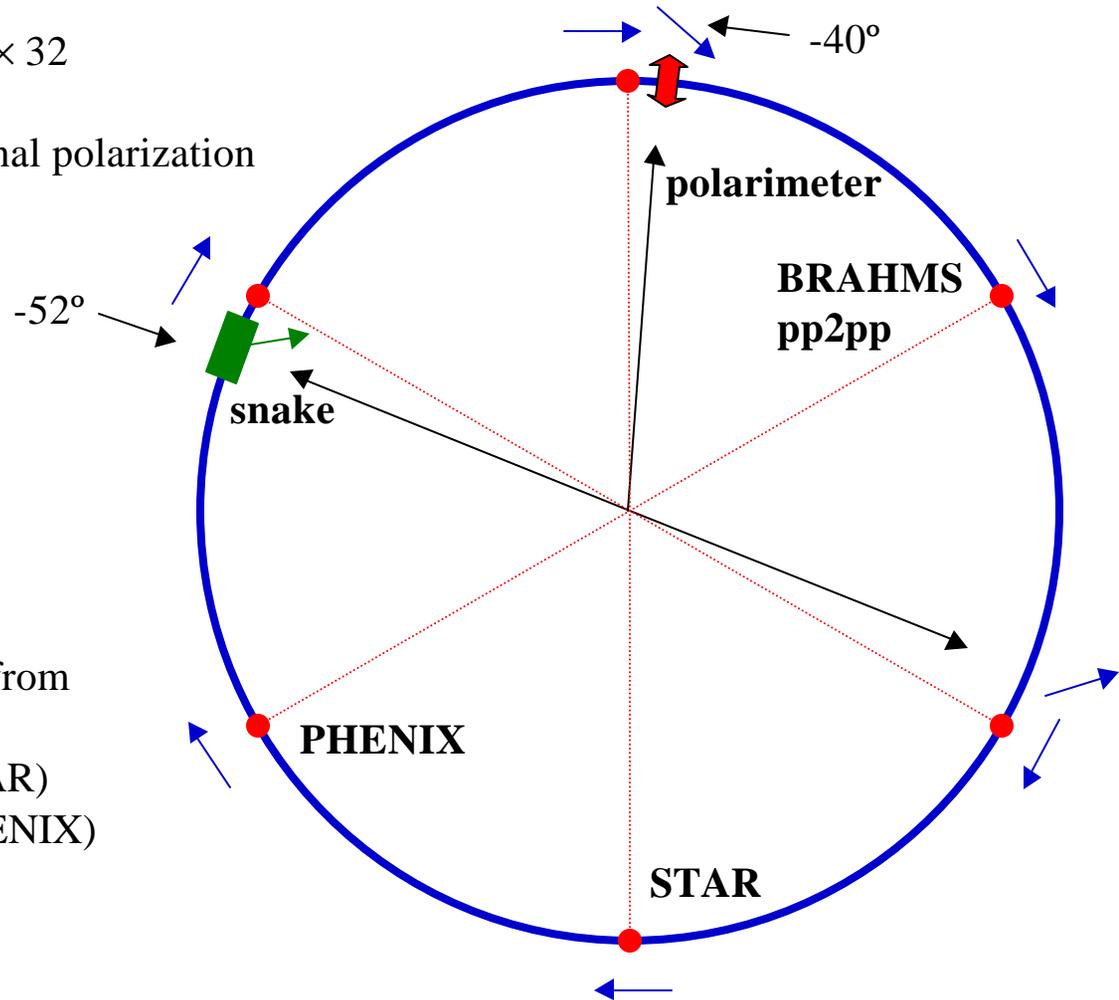
- Inject 6 bunches (+ - + - + -) into RHIC blue ring with snake off. ✓
- Commission pC polarimeter and measure vertical polarization ✓
- Turn on snake and measure radial polarization ✓
- Accelerate and measure polarization

# Single Snake in RHIC (E £ 100 GeV)

At E = 100.53 GeV:  $G\gamma = 192 = 6 \times 32$

→ all IP's have same polarization

For snake axis at  $-52^\circ$  → longitudinal polarization



For  $\Delta p/p = \pm 0.001$  max. deviation from long. polarization:

$32 \times \Delta p/p \times 360^\circ = \pm 12^\circ$  [0.98] (STAR)

$64 \times \Delta p/p \times 360^\circ = \pm 24^\circ$  [0.91] (PHENIX)

# Polarized proton status and plans

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FY2000 run:

- Single Siberian snake and pC polarimeter installed in blue ring
- New polarized proton source:  $\sim 10^{12}$  pol. protons/pulse
- **Goal: Accelerate polarized beam in blue ring**

FY2001 run:

- All four Snakes and pC polarimeters installed in blue and yellow ring
- **Goal: 100 GeV×100 GeV collision with long. pol. at interaction regions**  
**Accelerate polarized beam to 250 GeV**

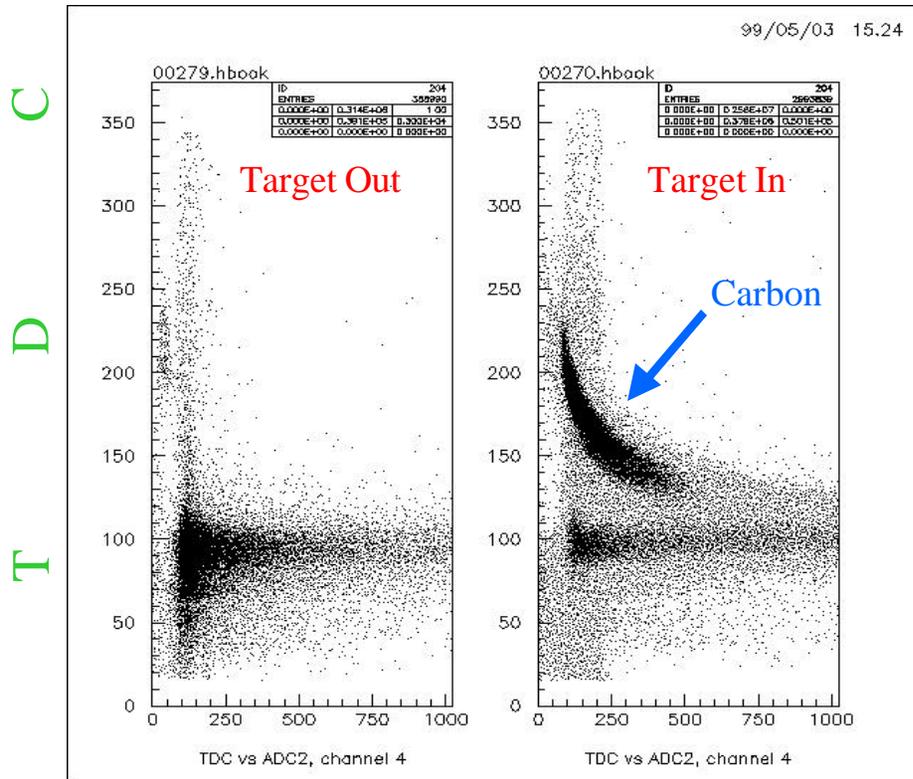
FY2002 run:

- All eight spin rotators installed
- **Goal: 250 GeV×250 GeV collision with long. pol. at STAR and PHENIX**

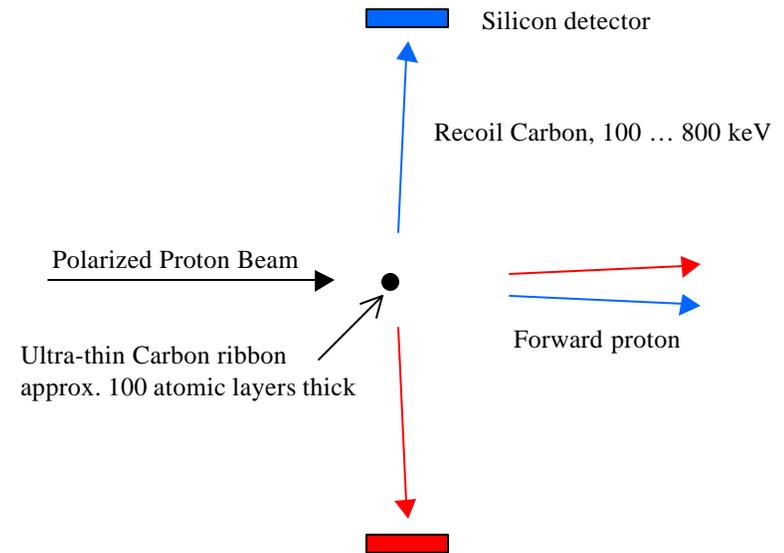
FY2003 run:

- Polarized hydrogen jet target for absolute polarimetry installed

# Proton-Carbon CNI Polarimeter (AGS E950)



ADC distribution



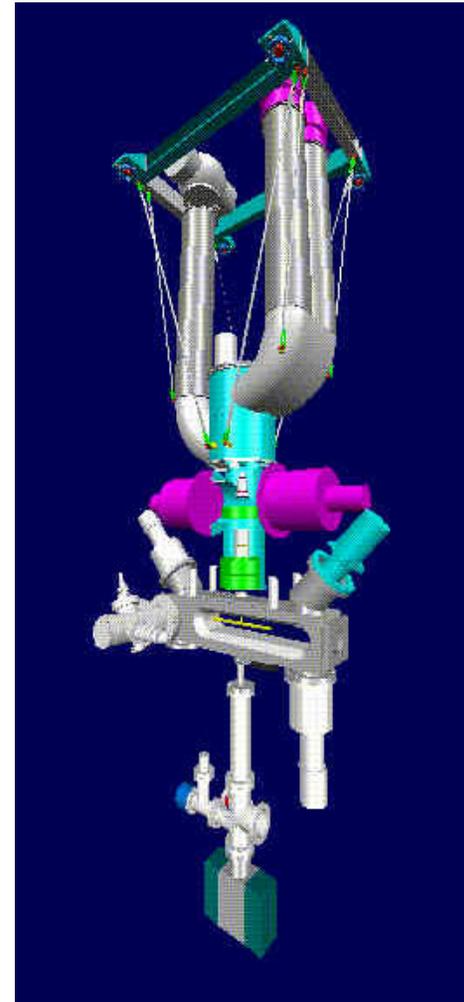
- 2-3% energy independent analyzing power for small-angle elastic scattering in the Coulomb-Nuclear Interference (CNI) region
- Slow recoil Carbon detected in between bunch crossings
- Fiber target allows for polarization profile measurement

# Polarized Hydrogen Jet Target

- pC polarimeter is used as fast relative polarization monitor and was calibrated in AGS at 22 GeV to about 15 %.
- Polarized hydrogen jet target allows for absolute beam polarization measurement:

$$P_{\text{Beam}} = P_{\text{Target}} \frac{N_{B\uparrow T\uparrow} - N_{B\downarrow T\downarrow} + N_{B\uparrow T\downarrow} - N_{B\downarrow T\uparrow}}{N_{B\uparrow T\uparrow} - N_{B\downarrow T\downarrow} - N_{B\uparrow T\downarrow} + N_{B\downarrow T\uparrow}}$$

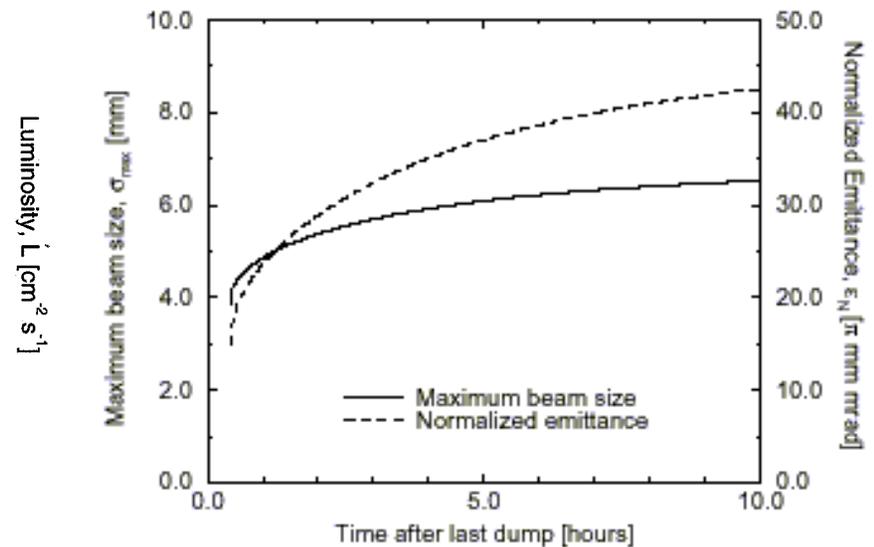
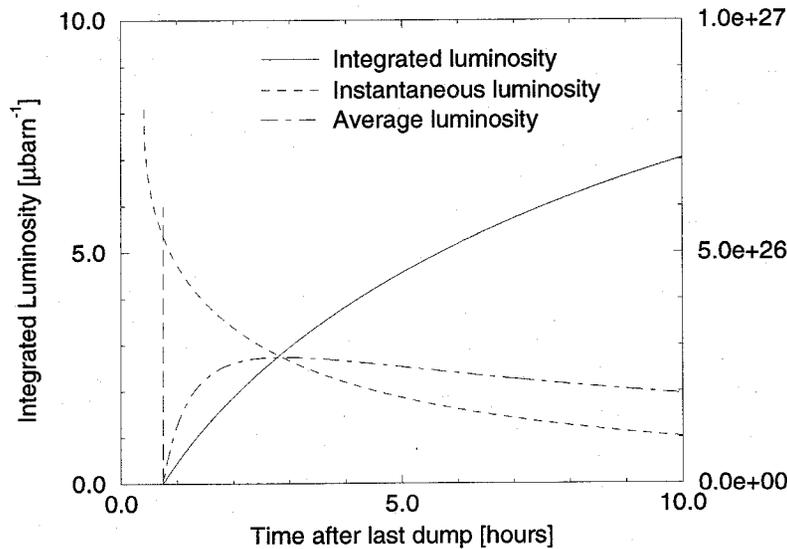
- Jet target thickness of  $3 \times 10^{11} \text{ cm}^{-2}$  achievable (HERMES, PINTEX, NIKHEF)
- Jet polarization measurable to better than 3% using Stern-Gerlach method
- Collaboration started with Wisconsin, IUCF, and Amsterdam



# RHIC design luminosity

$$L = \frac{3 f_{rev} \mathbf{g}}{2} \frac{N_b N^2}{e \mathbf{b}^*} = 9 \dots 1 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1} \text{ over 10 hours}$$

$$N_b = 60 ; N = 1 \times 10^9 ; e = 15 \dots 40 \text{ p mm} ; \mathbf{b}^* = 2 \text{ m}$$



# Luminosity upgrade possibilities

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- ‘Enhanced’ luminosity possible with existing machine:
  - Increase number of bunches to 120
  - Decrease  $\beta^*$  from 2 m to 1m
- Further luminosity upgrades:
  - Decrease  $\beta^*$  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!

# Beam Cooling at RHIC Storage Energy

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- Electron beam cooling of RHIC beams:
  - Bunched electron beam requirements (prelim.):  
100 GeV gold beams:  $E= 54 \text{ MeV}$   $I= 3 \text{ A peak} / 10 \text{ mA average}$   
250 GeV pol. protons:  $E=135 \text{ MeV}$   $I=25 \text{ A peak} / 86 \text{ mA average}$
  - 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.
- However: hadron beam cooling at high energy has not been achieved anywhere!

# Summary

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- Highly successful first RHIC heavy ion run completed
- Commissioning of polarized proton acceleration in RHIC ongoing
- Full design Au luminosity and collisions of polarized protons are planned for FY 2001
- RHIC Au luminosity upgrade:
  - with existing machine:  $\times 4$
  - with full energy electron cooler:  $\times 10$  possible