

# RHIC Status and Plans

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Brief summary of RHIC RUN2001/2

Plans and goals for RUN2003



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RHIC Retreat  
March 5-7, 2002

# FY2001 - 02 RHIC Gold Parameters

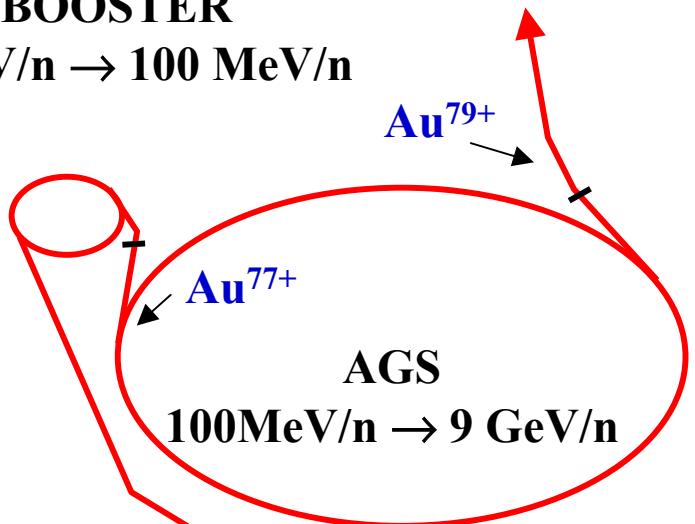
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- **55 - 56 bunches per ring ✓** (110 bunches per ring tested, intensity limited)
- **$7.5 \times 10^8$  Au/bunch @ storage energy** (intensity limited during acceleration)
- **$1 \times 10^9$  Au/bunch achieved @ injection ✓**
- **Longitudinal emittance: 0.5 eVs/nucleon/bunch (0.3-0.6 Design) ✓**
- **Transverse emittance at storage:  $15 \pi \mu\text{m}$  (norm, 95%) ✓**
- **Storage energy: 100 GeV/ amu ( $\gamma = 107.4$ ) ✓ 10 GeV / amu ( $\gamma=10.5$ ) ✓**
- **Lattice with  $\beta^*$  squeeze during acceleration ramp:**
  - $\beta^* = 3$  m and 10m @ all IP at injection ✓
  - $\beta^* = 1$  m @ 8 and 2 m @ 2, 6 and 10 o'clock at storage ✓
- **Peak Luminosity:  $5 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1}$  (2.5 × design average) ✓**
- **Bunch length: 5ns (200 Mhz operational, diamond length:  $\sigma = 20$  cm) ✓**

# Au Injector Performance (needs update)

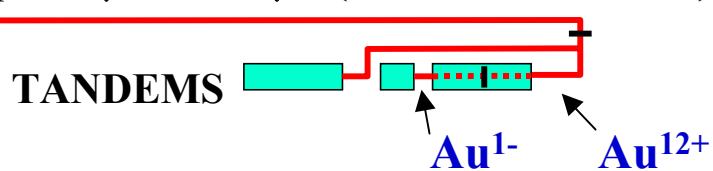
## BOOSTER

1 MeV/n → 100 MeV/n



	Intensity/RHIC bunch	Efficiency[%]
Tandem	$5.4(3.8) \times 10^9$	
Booster Inj.	$2.9(2.2) \times 10^9$	54 (58)
Booster Extr.	$2.4(1.8) \times 10^9$	83 (81)
AGS Inj.	$1.2(0.9) \times 10^9$	50 (50)
AGS Extr.	$1.1(0.9) \times 10^9$	<u>92 (95)</u>
Total		20 (23)

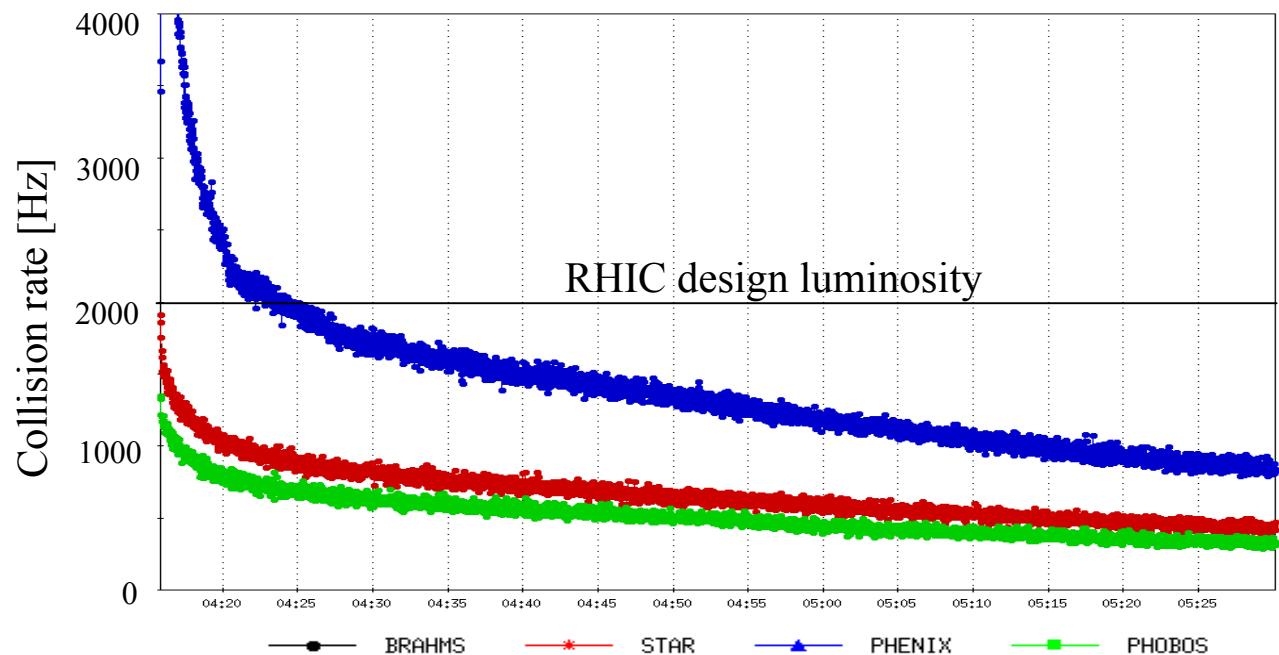
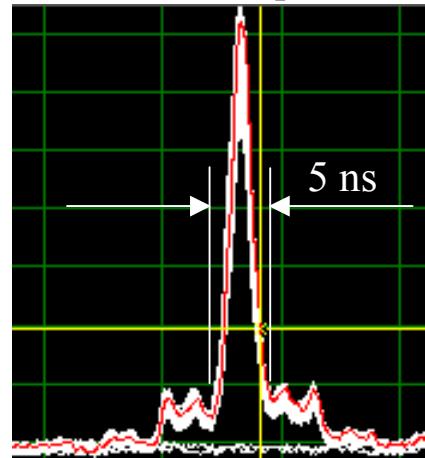
$\text{Au}^{32+}$ : 1.4(1.1) part.  $\mu\text{A}$ , 530  $\mu\text{s}$  ( 40 Booster turns)



# RHIC performance

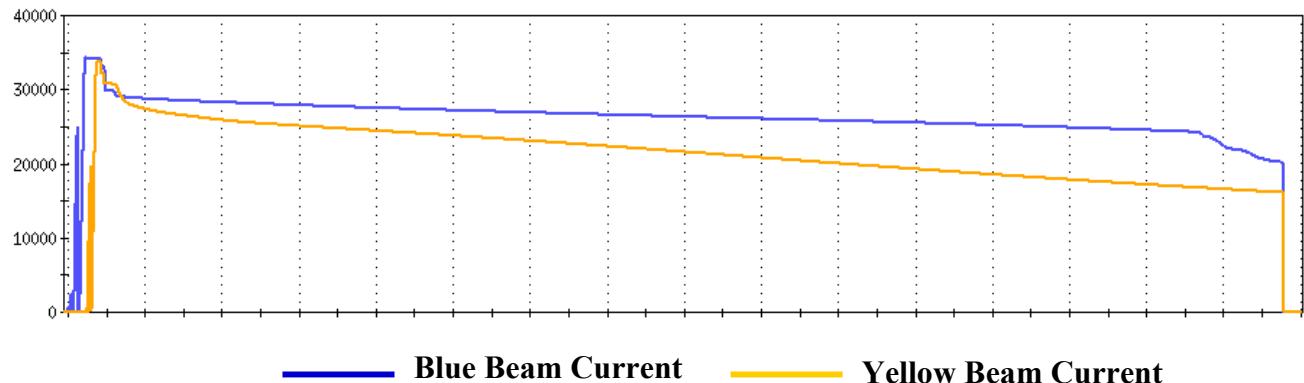
- Collisions at RHIC design beam energy (100 GeV/nucl)
- 200 MHz rf system operational
  - 5 ns bunch length and an interaction region with  $\sigma \sim 25$  cm
- Luminosity exceeding RHIC design luminosity of  $2 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1}$
- 40% availability is limiting total integrated luminosity

RHIC bunch profile

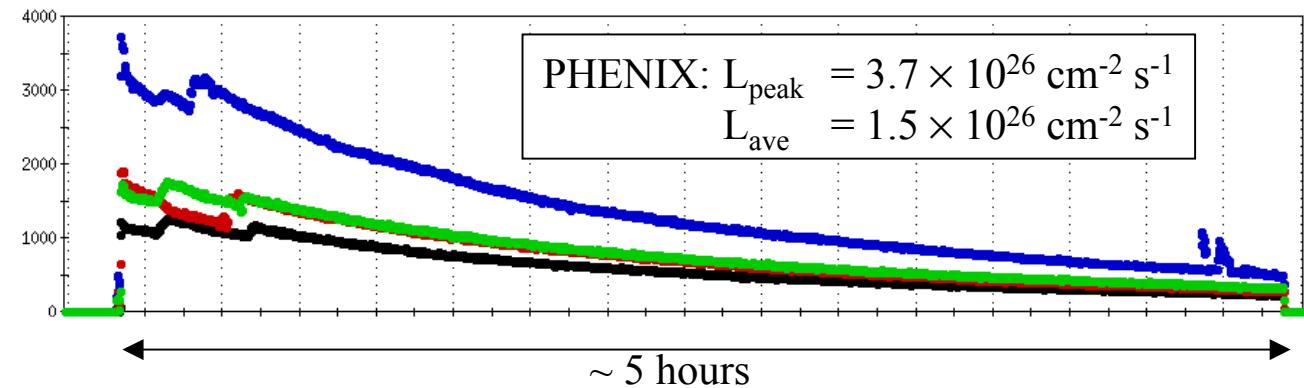


# “Typical Store” # 1812

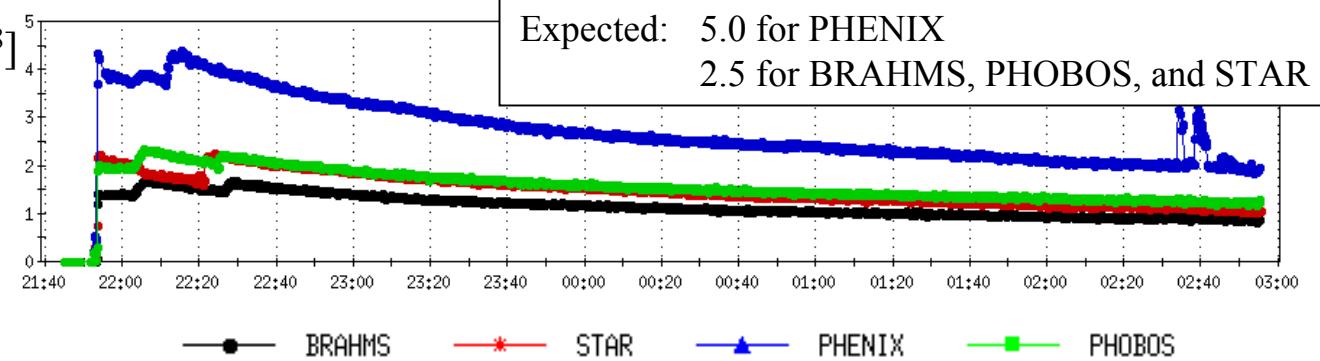
Beam currents [ $\times 10^6$  ions]



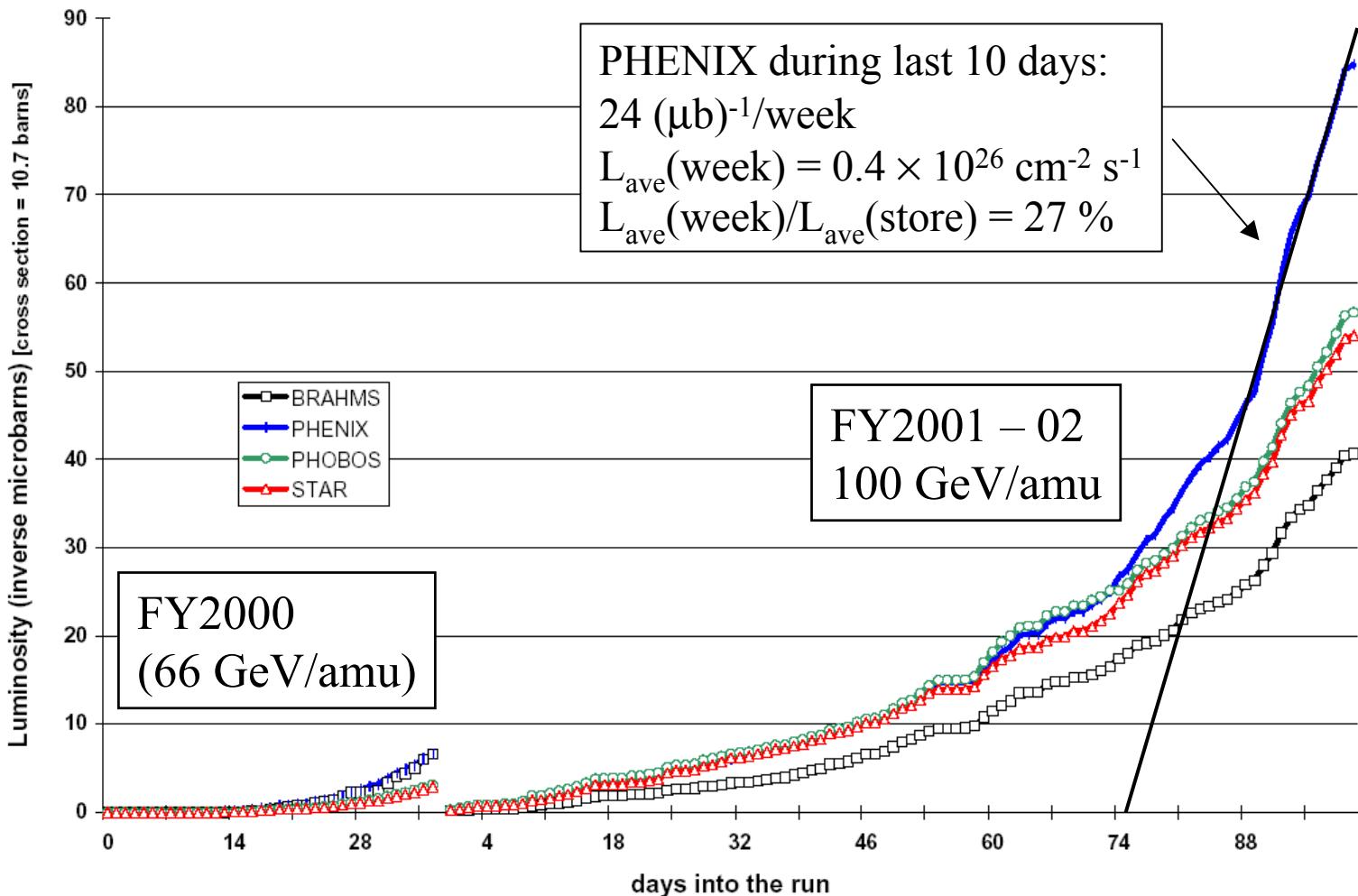
Collision rate [Hz]



Specific luminosity [Hz/ $10^{18}$ ]

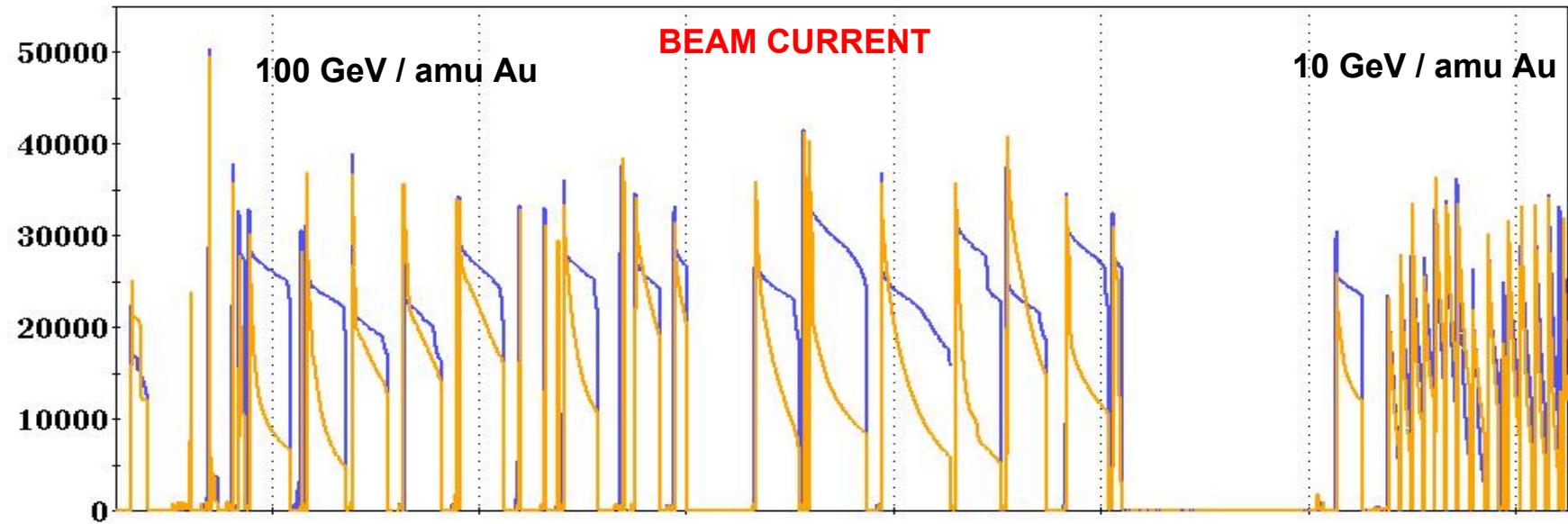


# Integrated Au-Au luminosity



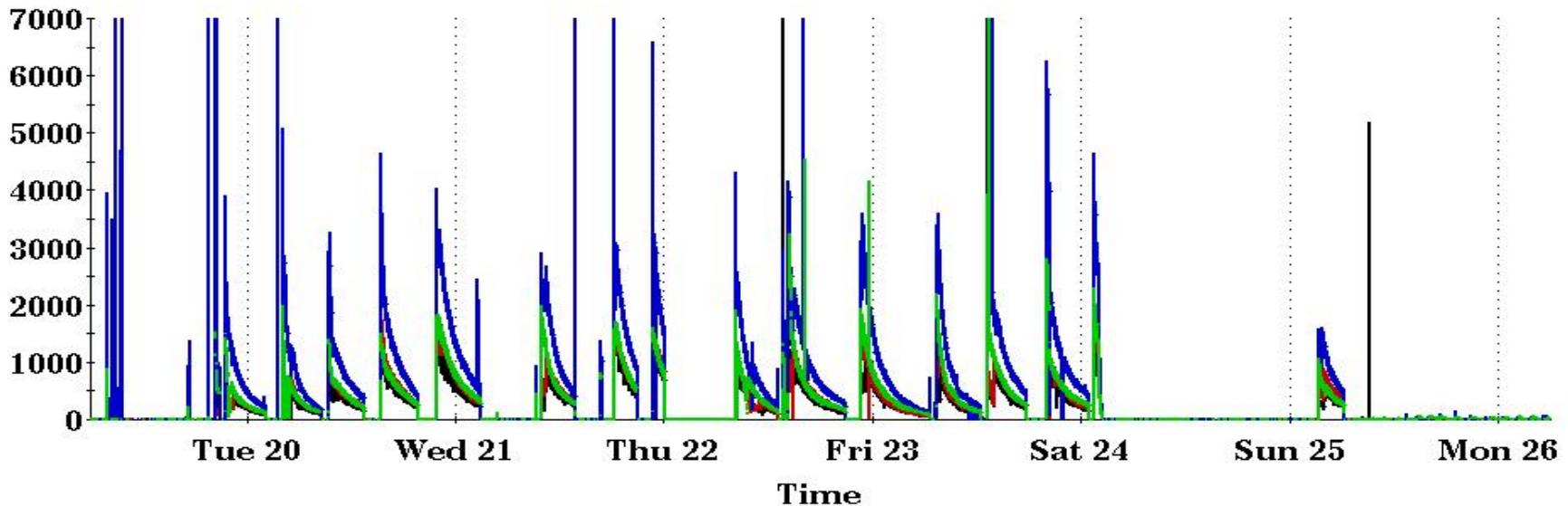
$\times 10^6$  Au

# RHIC PERFORMANCE



$\times 10^{23}$  cm $^{-2}$  sec $^{-1}$

## LUMINOSITY



# RHIC Au commissioning and challenges

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- Single- and multi-bunch instabilities
  - Effect of vacuum chamber impedance, electron cloud (?)
- Intensity limitation for gold (?) due to vacuum break-down
  - Limited to about  $40 \times 10^9$  Au/ring
    - Electron cloud ? Ion or electron desorption ?
- Intra-Beam Scattering (IBS)
  - Transverse and longitudinal emittance growth
  - Eventually will need electron cooling (see below)
- Beam-beam tune shift and spread
  - First strong-strong hadron collider (after ISR)

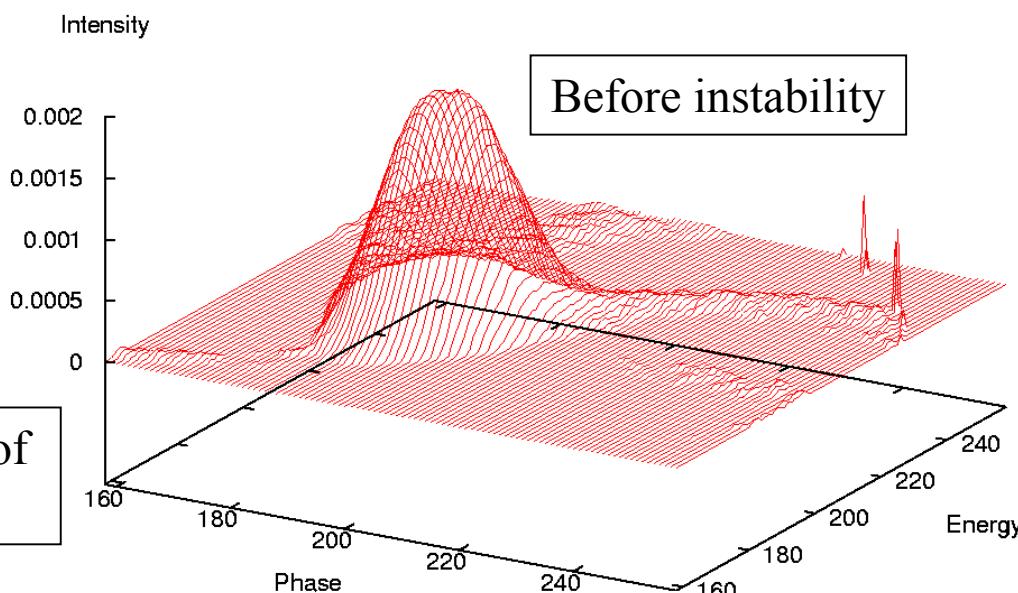
# Transverse instabilities in RHIC

High sensitivity around transition

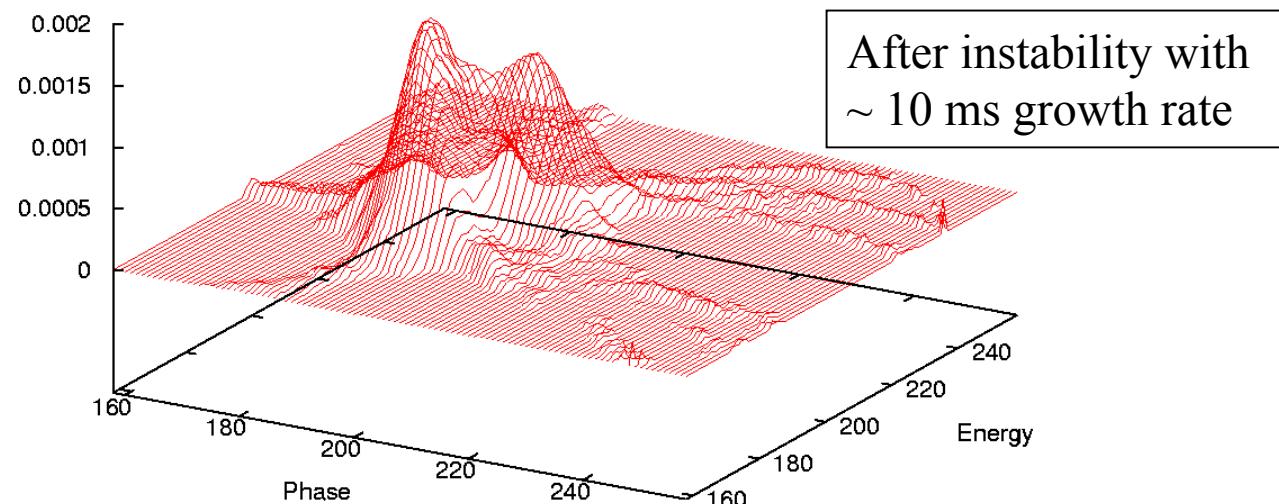
Effect of vacuum chamber impedance,  
electron cloud (?)

Cures: beam-beam tune spread,  
**octupoles**, transverse dampers, rf  
quad, ...

Tomographic reconstruction of  
2D bunch density

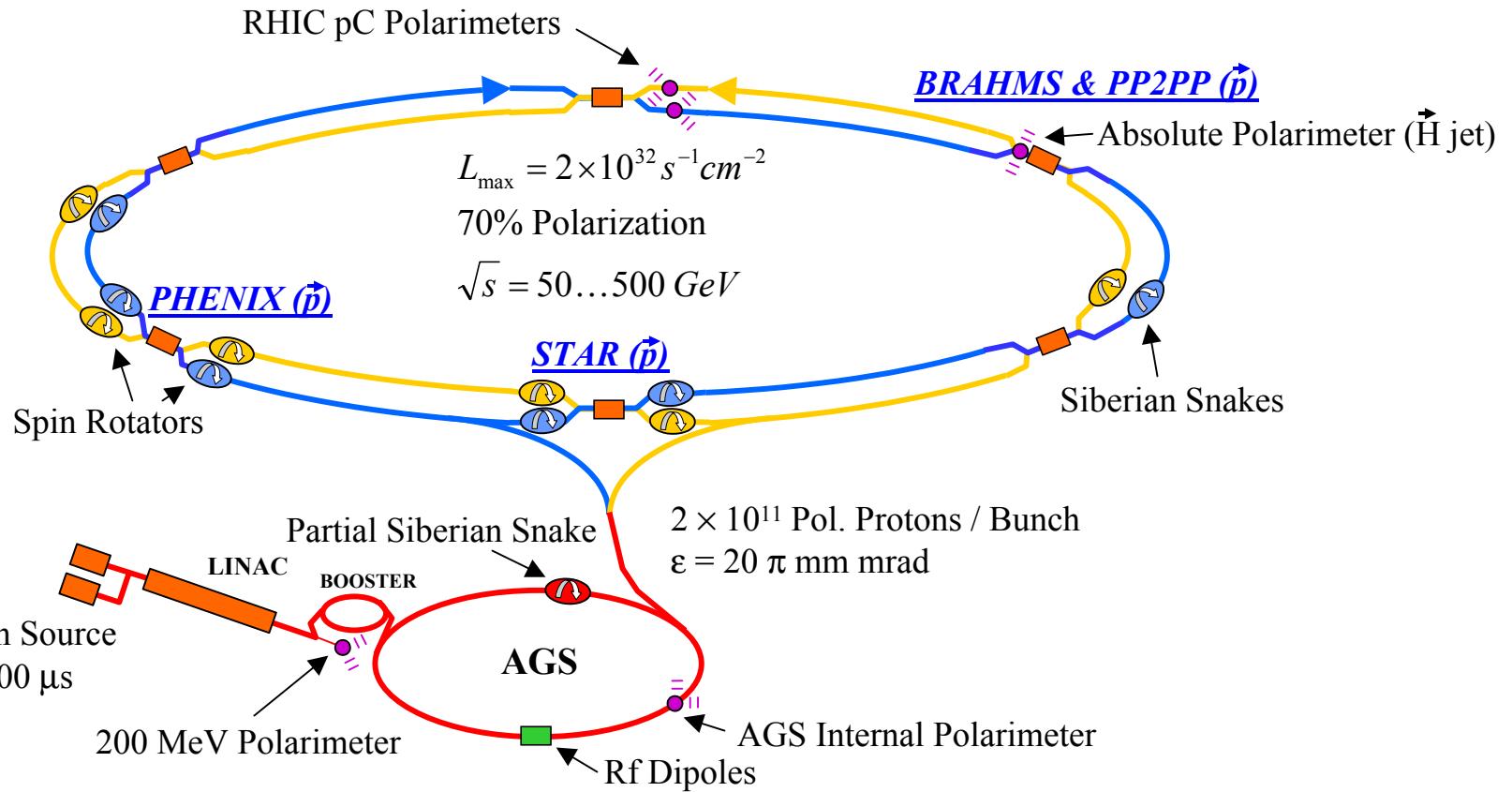


Before instability

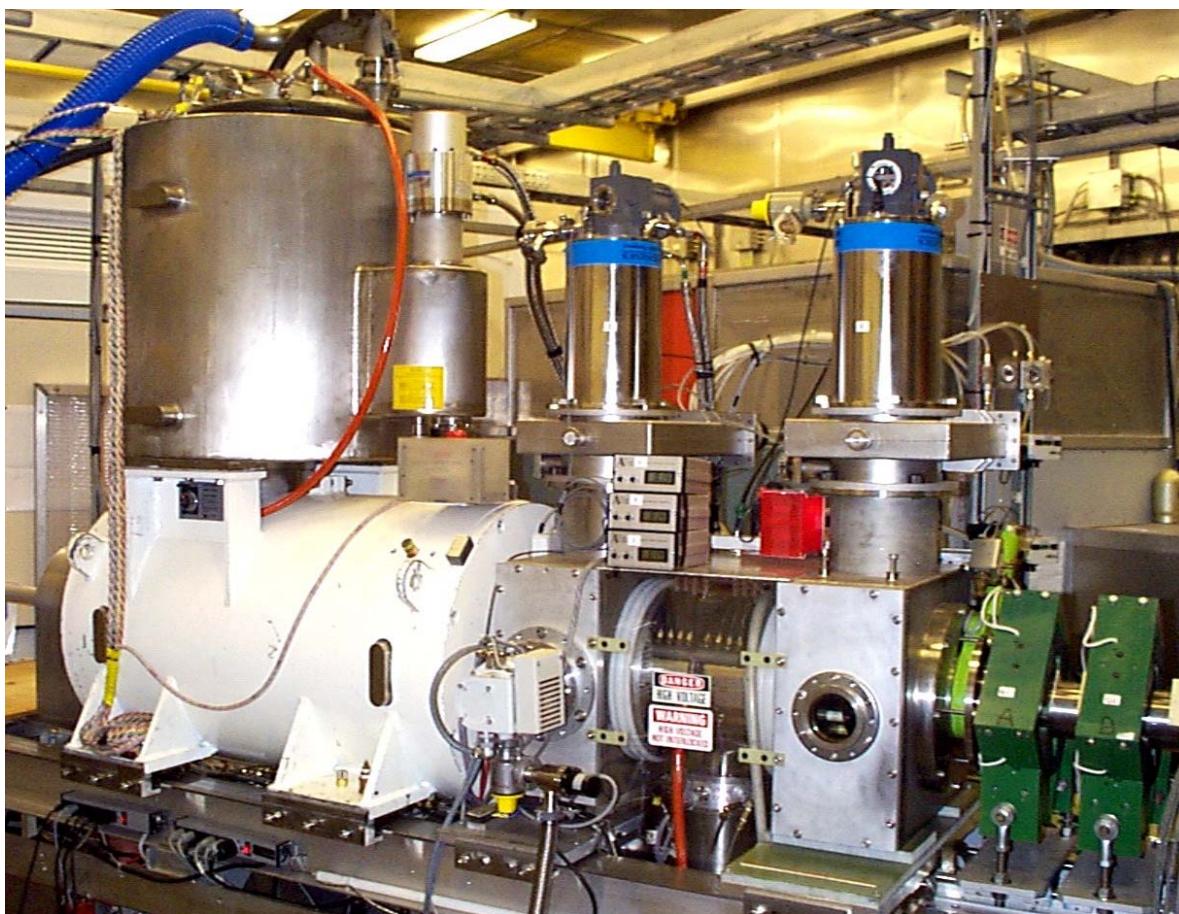


After instability with  
~ 10 ms growth rate

# Polarized proton collisions in RHIC



# High intensity polarized H<sup>-</sup> source



KEK OPPIS  
upgraded at TRIUMF

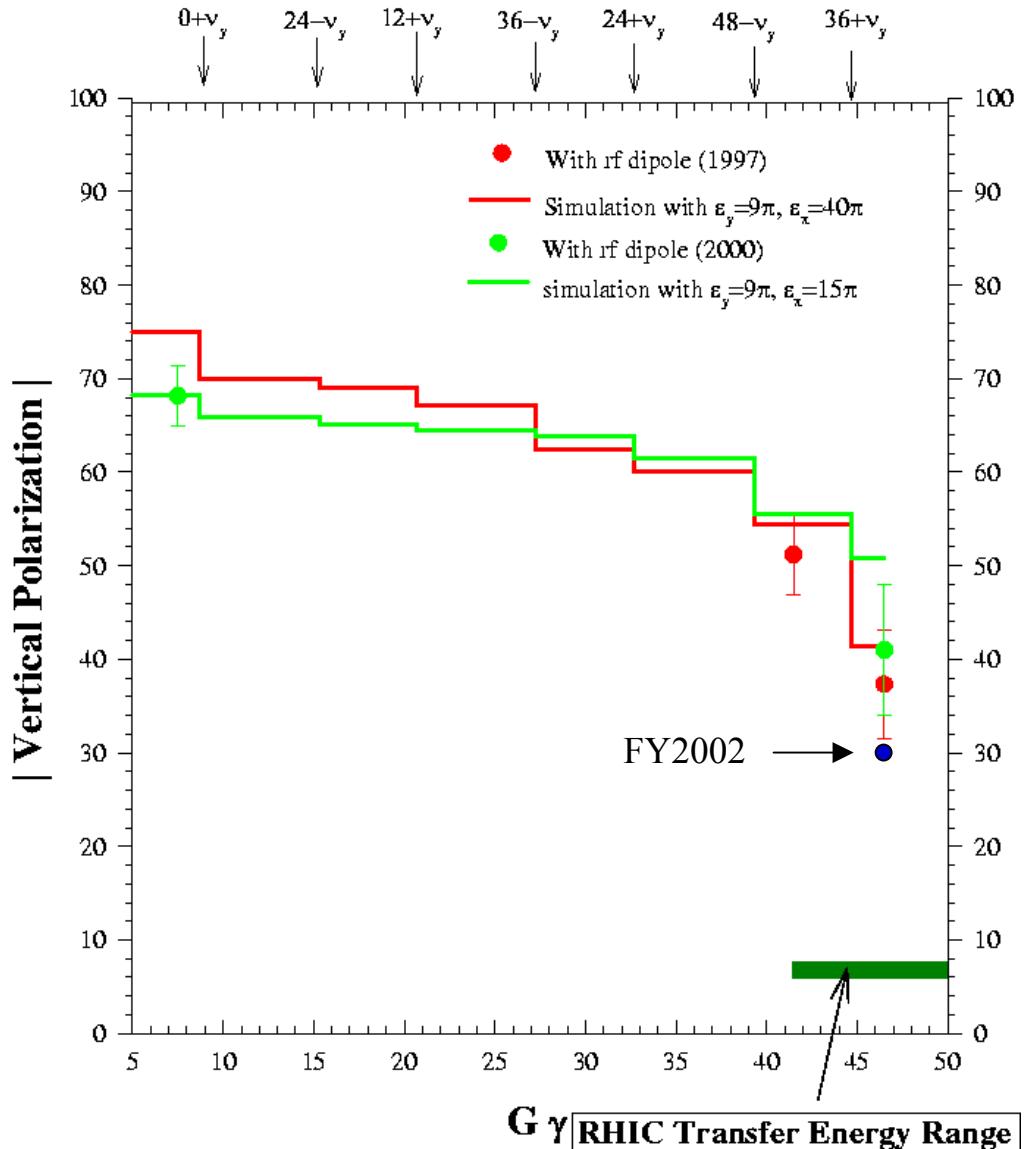
70 - 80 % Polarization

$15 \times 10^{11}$  protons/pulse  
at source

$6 \times 10^{11}$  protons/pulse  
at end of LINAC

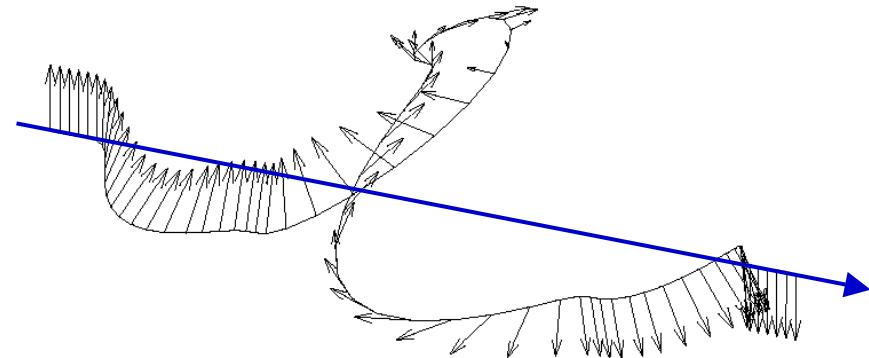
# Proton polarization at the AGS

- 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 and higher bunch intensity (?)

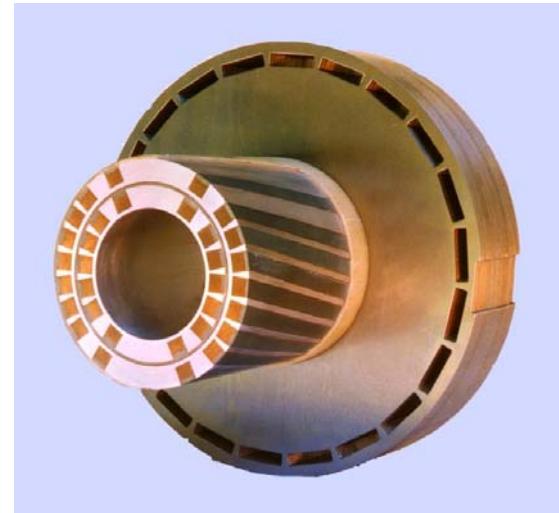


# First Siberian Snake in RHIC Tunnel

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

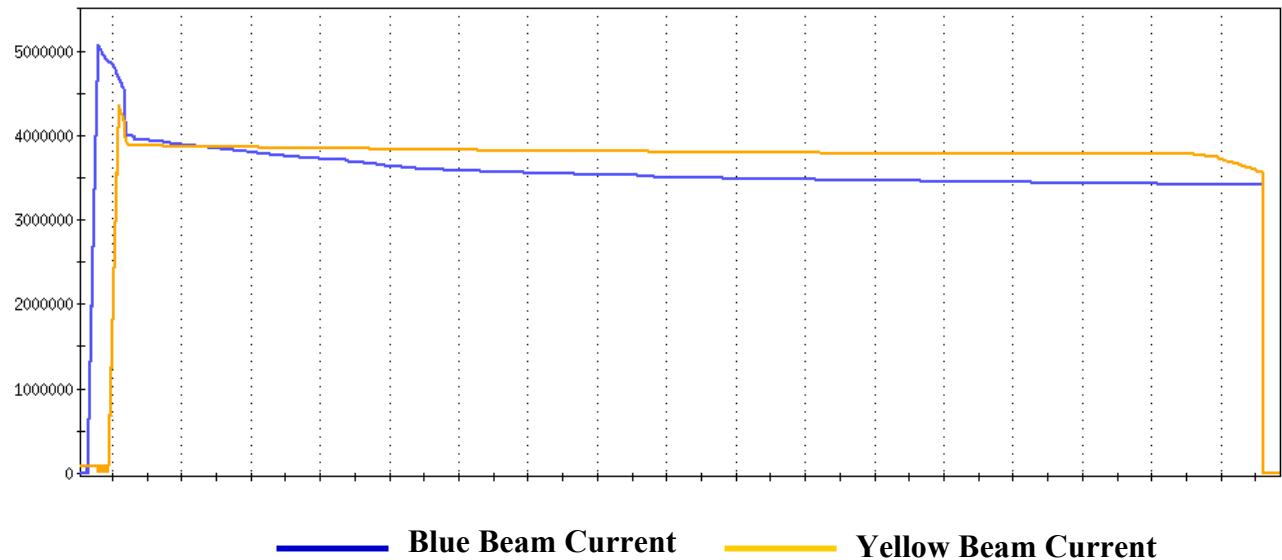


Funded by RIKEN, Japan  
Designed and constructed at BNL



# “Typical Store” # 2304

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

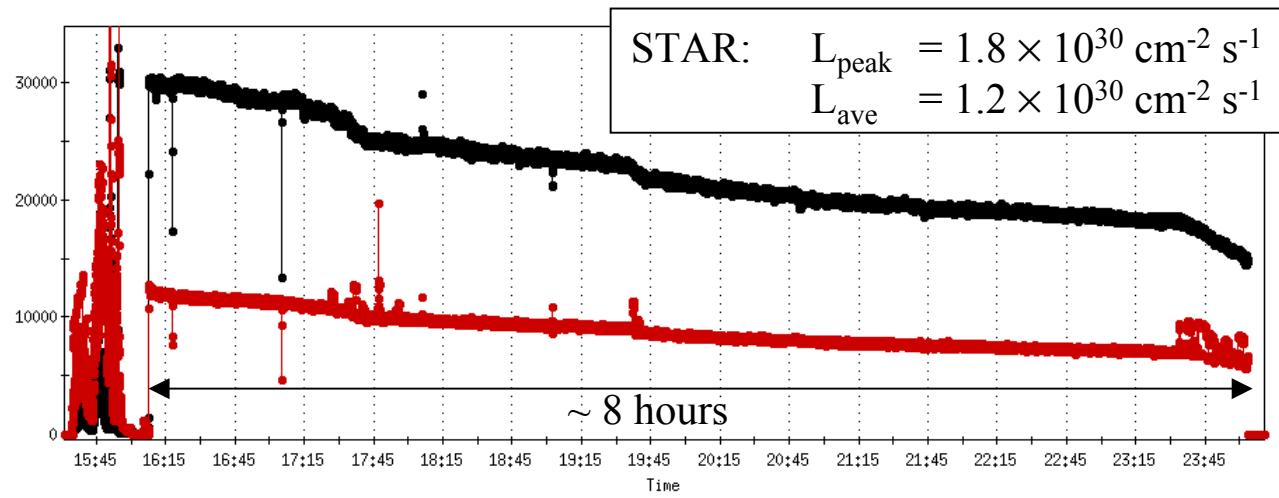


Collision rate [Hz]

Vernier scans:

STAR:  $10^4 \rightarrow 0.6 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$

PHENIX:  $10^4 \rightarrow 1.6 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$



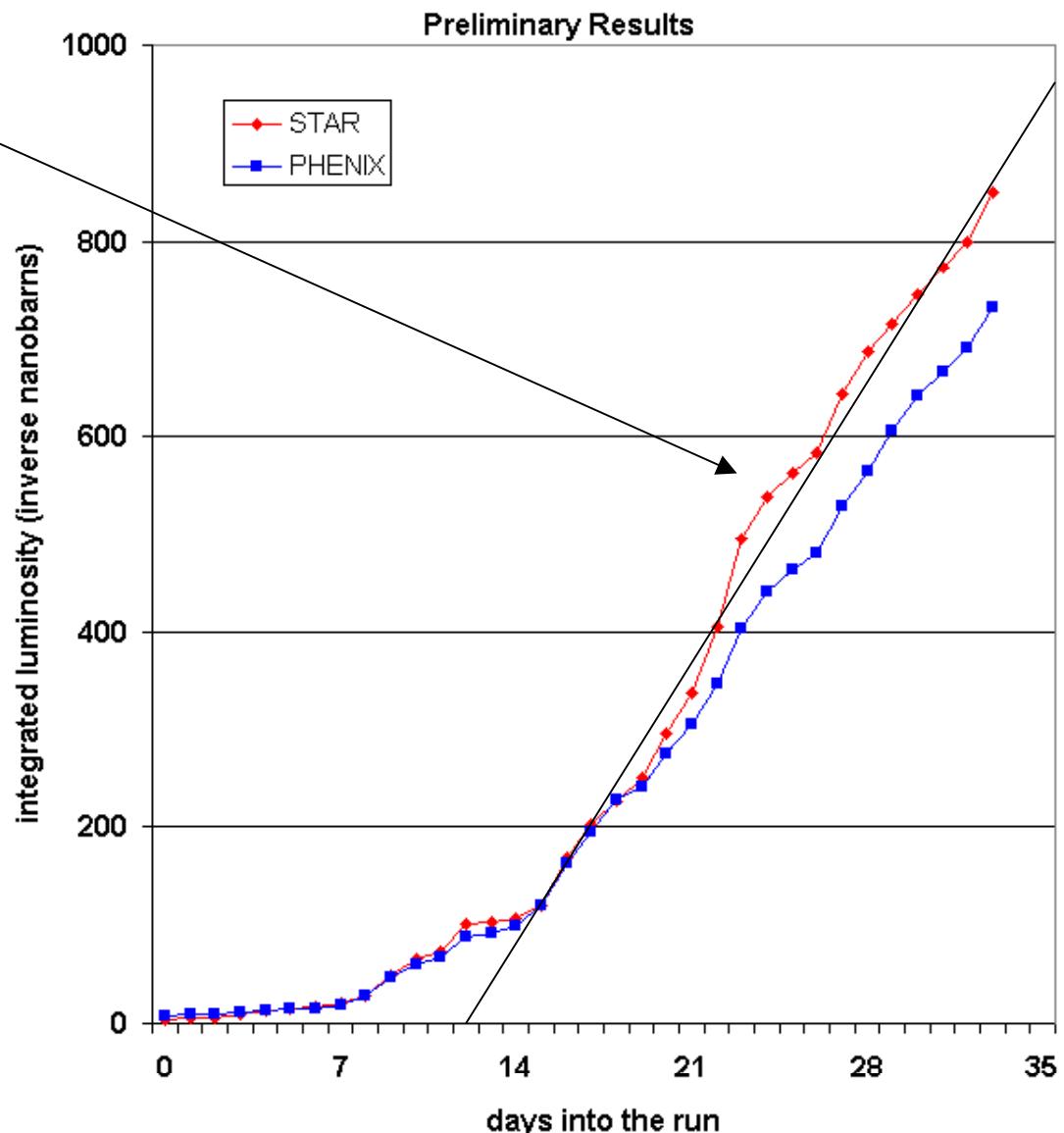
# Integrated p - p luminosity

STAR during last 20 days:

290 (nb)<sup>-1</sup>/week

$$L_{ave}(\text{week}) = 0.5 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$$

$$L_{ave}(\text{week})/L_{ave}(\text{store}) = 42 \%$$

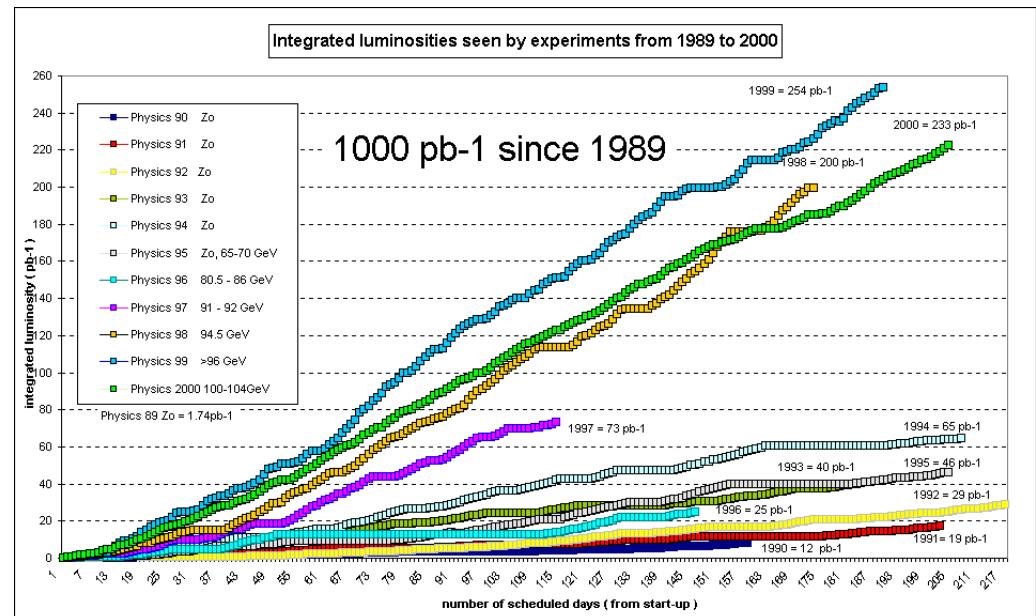
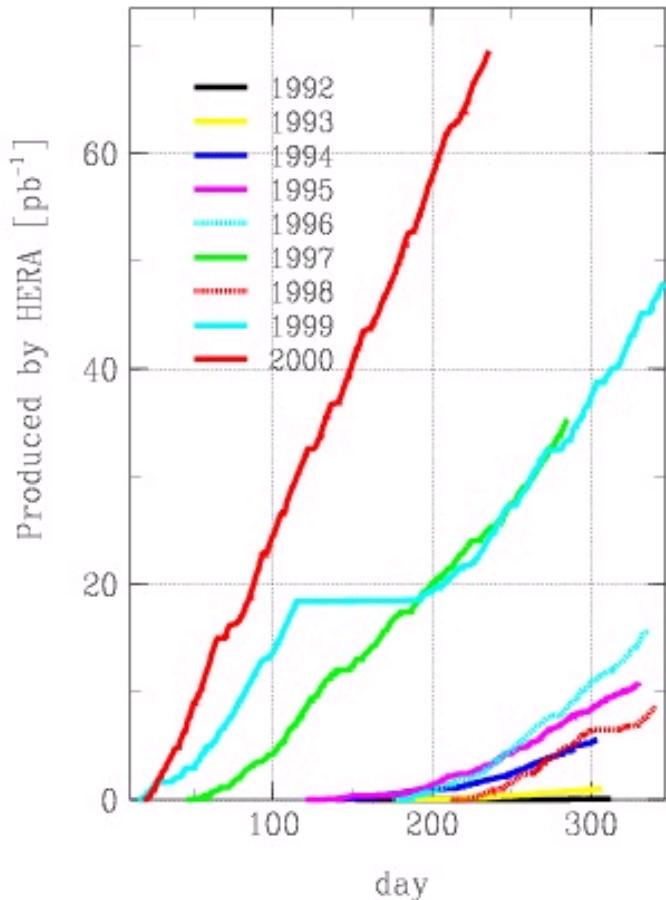


# Results from first RHIC polarized proton run

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- 55 bunches per ring with  $0.8 \times 10^{11} p\uparrow/\text{bunch}$
- Charge/bunch and total charge higher than with gold beams
- Lattice with constant  $\beta^*$  of 3 m during ramp
- Peak luminosity at beginning of store:  $1.5 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$
- Energy/beam: 100 GeV
- Beam polarization  $\sim 25 \%$   
**RHIC polarimeters work reliably**
- Little if any depolarization in RHIC during acceleration and store  
**Siberian Snakes work**
- $\sim 60 \%$  polarization loss in AGS; aggravated by lower ramp-rate from Westinghouse motor-generator
- **Strong Siberian snake in AGS ( $\sim 30 \%$  of full snake) could avoid all depolarization in the AGS**

# HERA and LEP luminosity evolutions



# RUN2003 Goals ( $\sim$ 3-4 weeks into run)

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- Prepare for four modes; all with:  
Energy/beam: 100 GeV/nucl., diamond length:  $\sigma = 20$  cm,  $L_{ave}(\text{week})/L_{ave}(\text{store}) = 40\%$

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

\* Beam polarization  $\geq 50\%$ ; Acceleration test to 250 GeV

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

# RUN2003 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.:      2 modes: 7 weeks at “final” luminosity / mode  
                                  3 modes: 3 weeks at “final” luminosity / mode  
                                  4 modes: 1 week at “final” luminosity / mode

- Minimum: performance at end of FY2001/02 run
- Maximum: luminosities from previous slide

Mode	$L_{ave}$ (week) [week <sup>-1</sup> ]	Int. Lumi. 2 modes	Int. Lumi. 3 modes	$L_{ave}$ (week) [week <sup>-1</sup> ]	Int. Lumi. 2 modes	Int. Lumi. 3 modes
Au-Au	$24(\mu b)^{-1}$	$168(\mu b)^{-1}$	$72(\mu b)^{-1}$	$70 (\mu b)^{-1}$	$490(\mu b)^{-1}$	$210(\mu b)^{-1}$
(p↑-p↑)*	$0.3(pb)^{-1}$	$2.1(pb)^{-1}$	$0.9(pb)^{-1}$	$2.8(pb)^{-1}$	$19.6(pb)^{-1}$	$8.4(pb)^{-1}$
d-Au	?	?	?	$5 (nb)^{-1}$	$35 (nb)^{-1}$	$15 (nb)^{-1}$
Si-Si	?	?	?	$5 (nb)^{-1}$	$35 (nb)^{-1}$	$15 (nb)^{-1}$