# RHIC Status and Plans

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for
RHIC Spin Collaboration Meeting VIII
RIKEN BNL Research Center

# RHIC Status and Plans

Brief summary of RHIC RUN2001/2

Plans and goals for RUN2003

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Thomas Roser
RHIC Retreat
March 5-7, 2002

# FY2001 - 02 RHIC Gold Parameters

- **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 $\pi$ $\mu$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: $5 \times 10^{26}$ cm$^{-2}$ s$^{-1}$** (2.5 × design average) ✓
- **Bunch length: 5ns** (200 Mhz operational, diamond length: $\sigma$ = 20 cm) ✓

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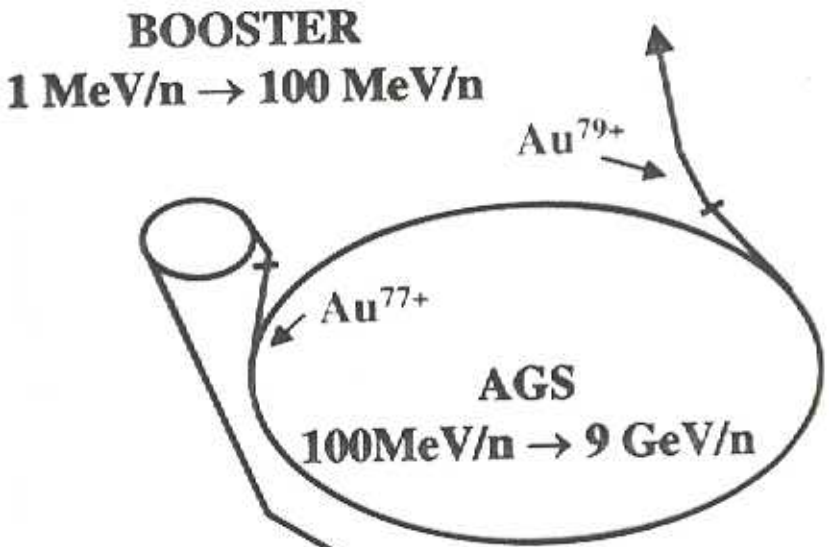
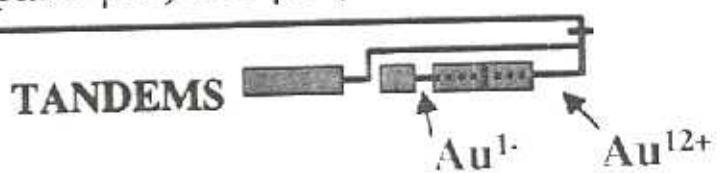
# Au Injector Performance (needs update)




| | 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. | $1.1(0.9) \times 10^9$ | 92 (95) |
| Total | | 20 (23) |

$Au^{32+}$ : 1.4(1.1) part. μA, 530 μs ( 40 Booster turns)

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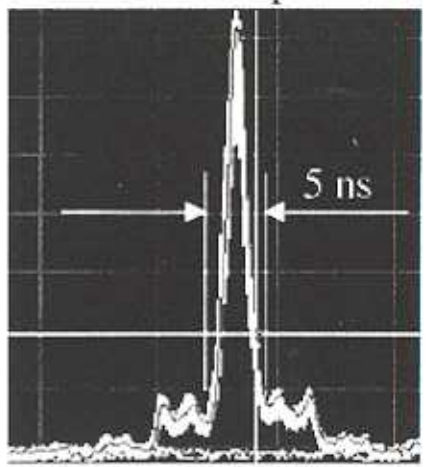
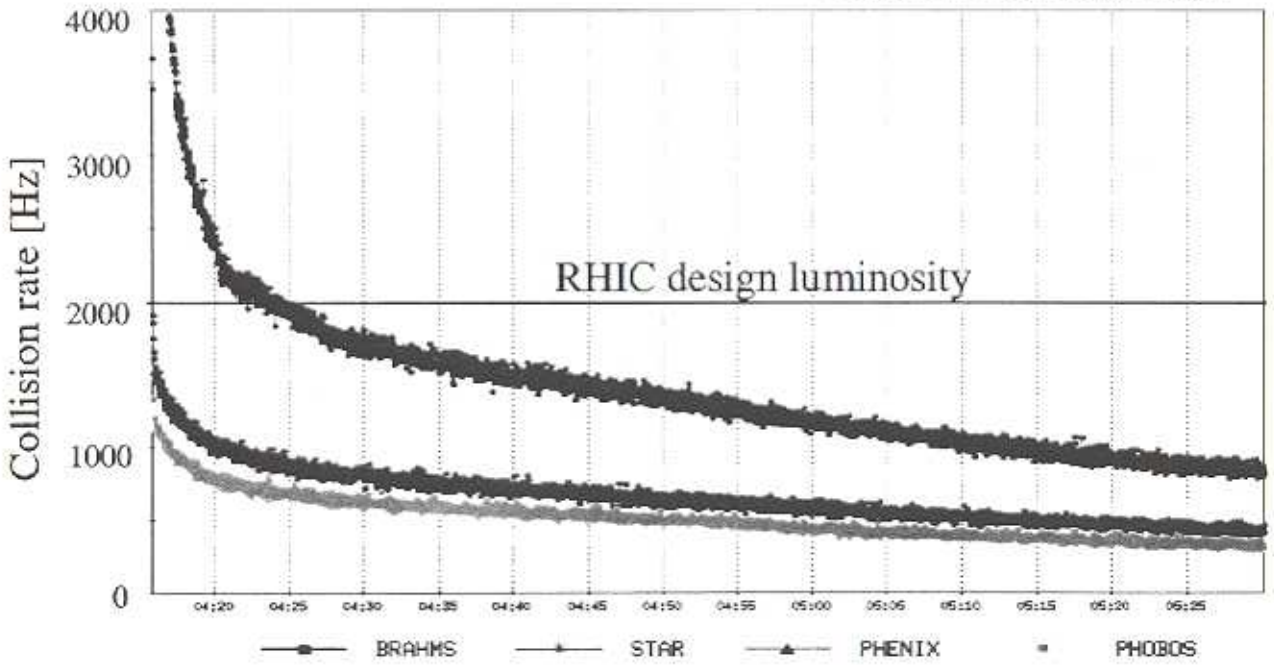
# RHIC performance

- 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 $2 \times 10^{26}$ cm$^{-2}$ s$^{-1}$
- 40% availability is limiting total integrated luminosity

RHIC bunch profile

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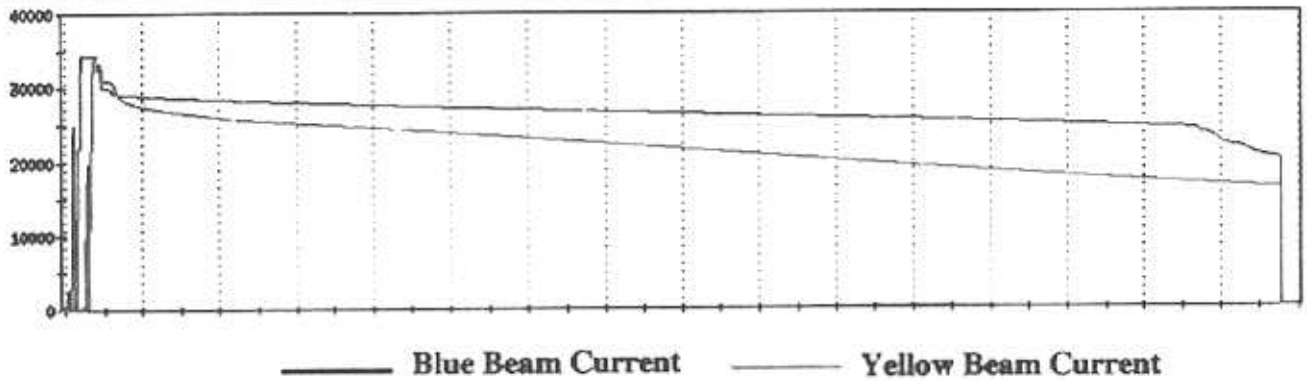
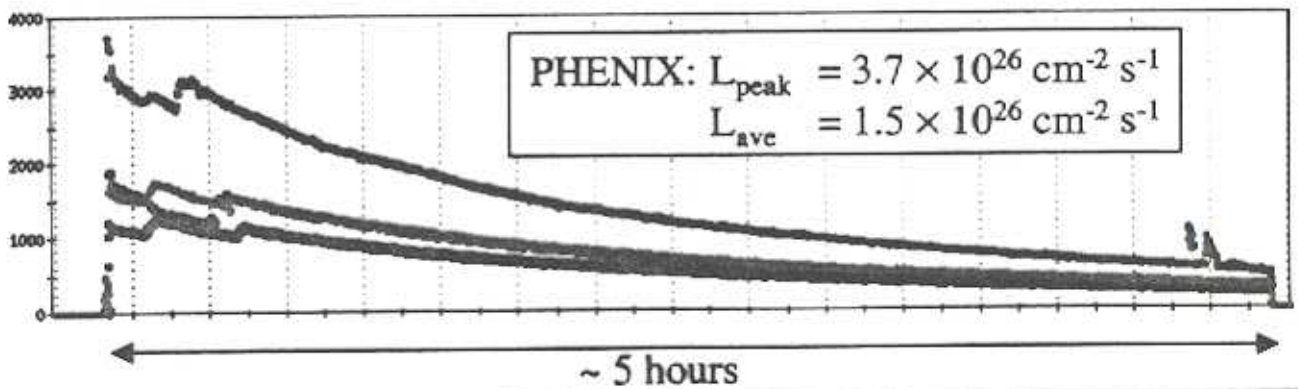
# "Typical Store" # 1812

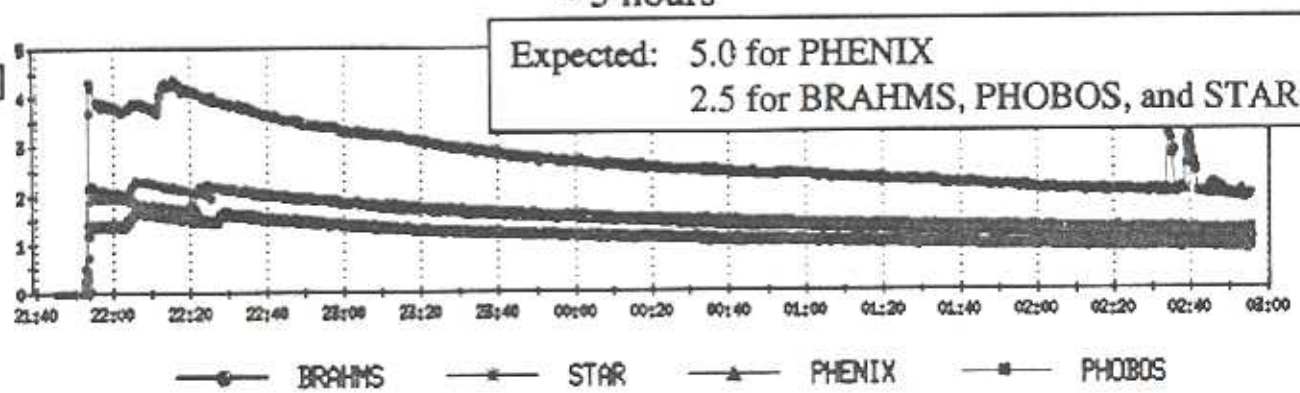
Beam currents [x$10^6$ ions]




Collision rate [Hz]




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

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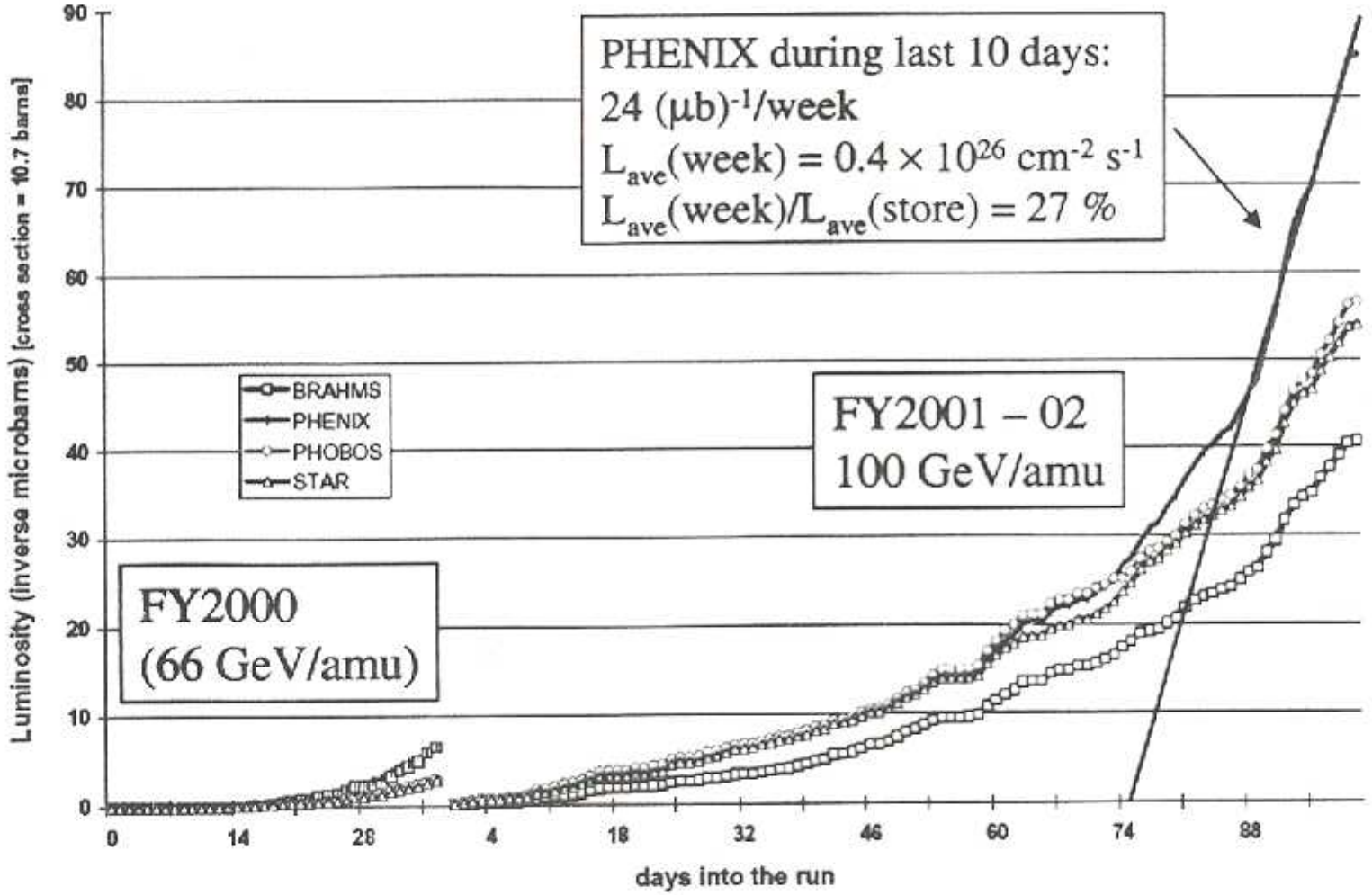
# Integrated Au-Au luminosity

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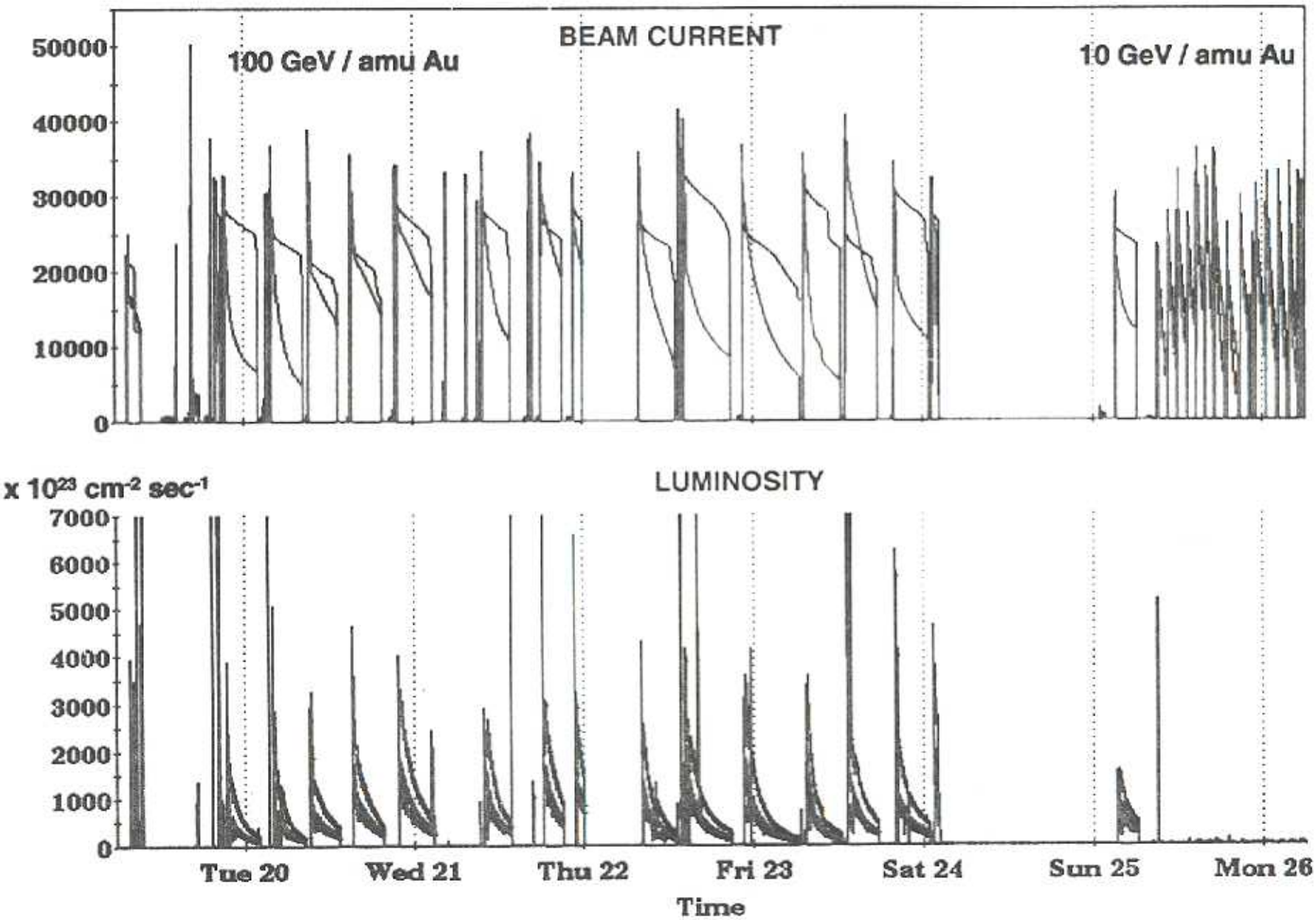
# RHIC Performance



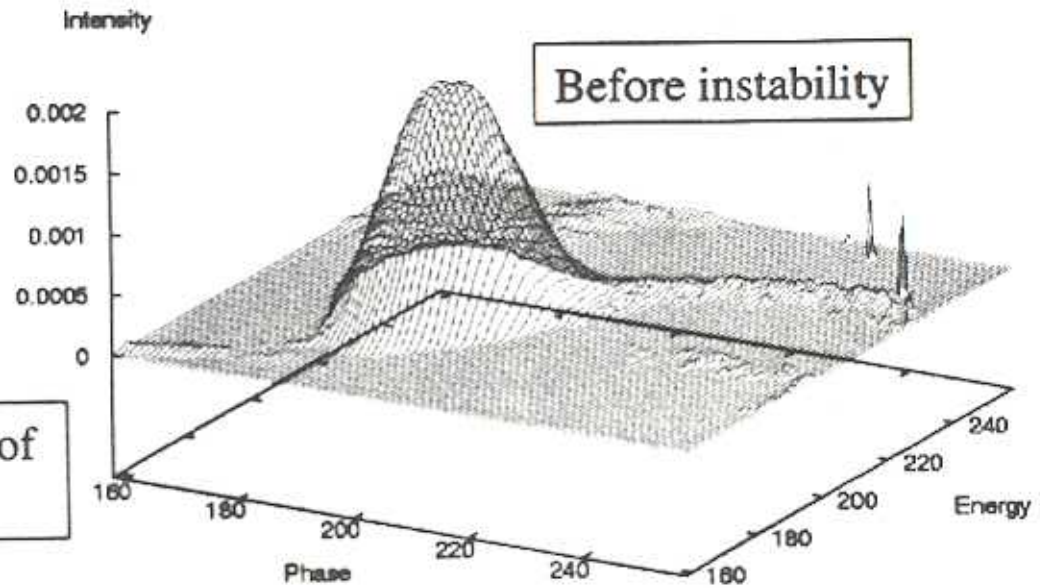
# Transverse instabilities in RHIC

High sensitivity around transition

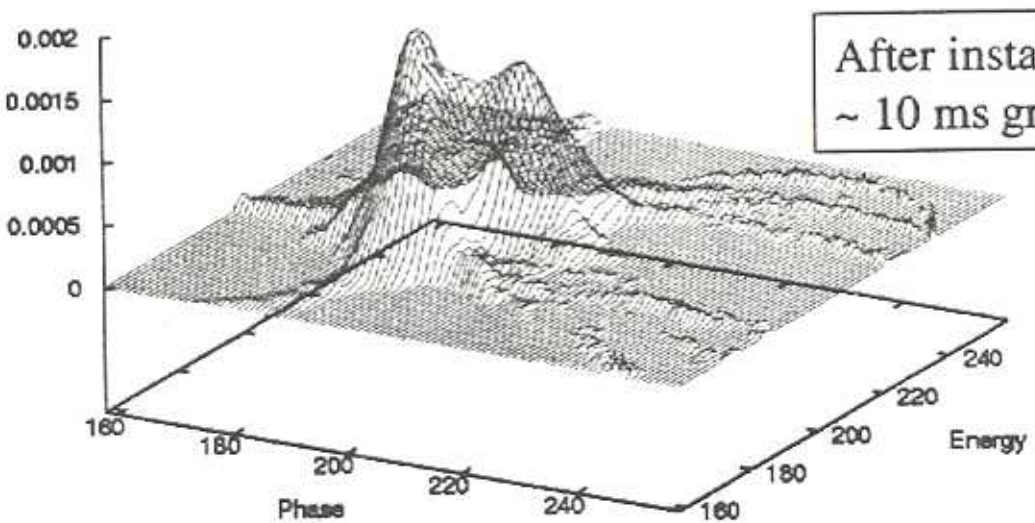
Effect of vacuum chamber impedance, electron cloud (?)

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

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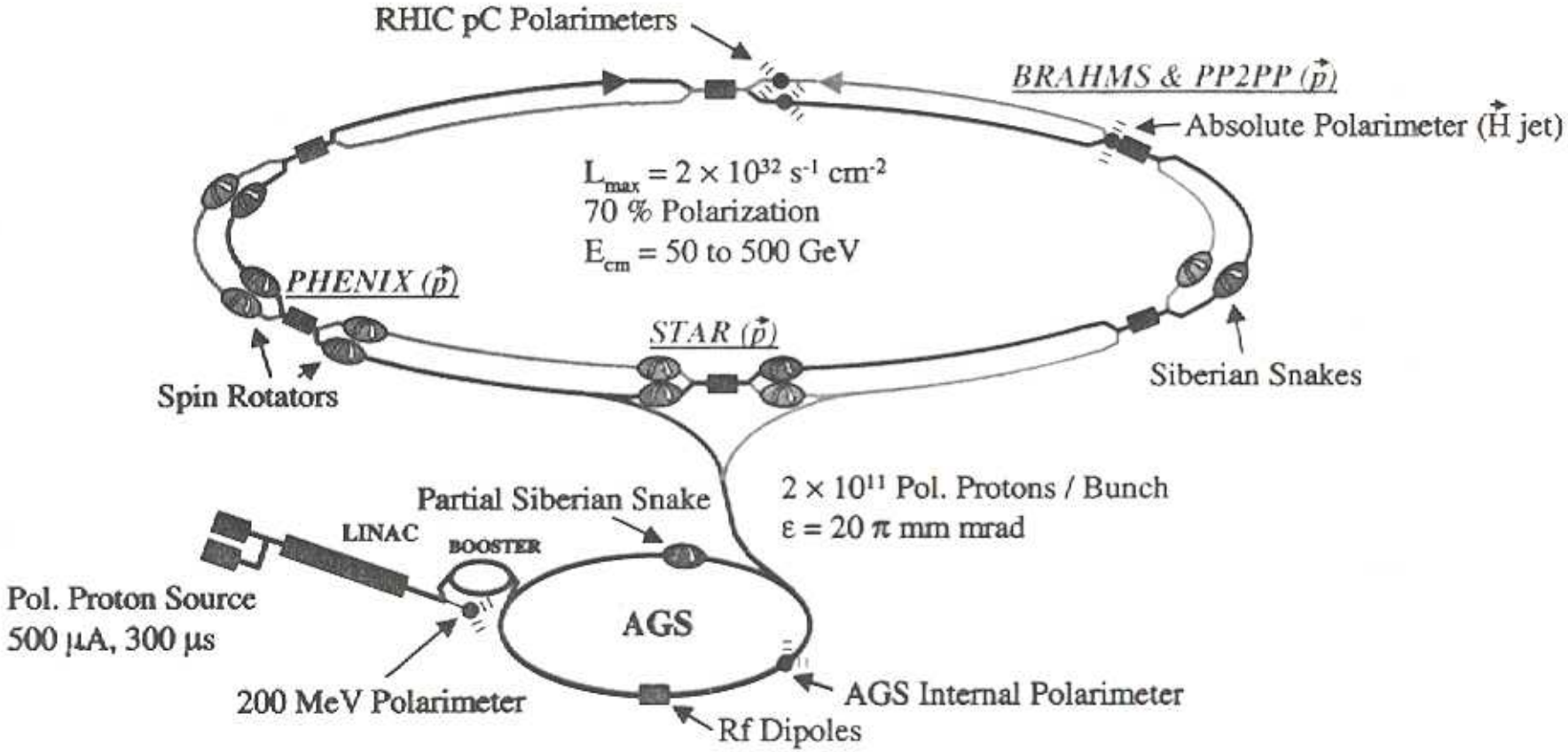
# RHIC intensity limitations

- Single- and multi-bunch instabilities
  - **Effect of vacuum chamber impedance, electron cloud (?)**
- Intensity limitation due to vacuum break-down
  - **Limited to about $40 \times 10^9$ Au/ring**
    - **Electron cloud ? Ion or electron desorbtion ?**
- Intra-Beam Scattering (IBS) (only Au)
  - **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)**

# Polarized Proton Collisions in RHIC

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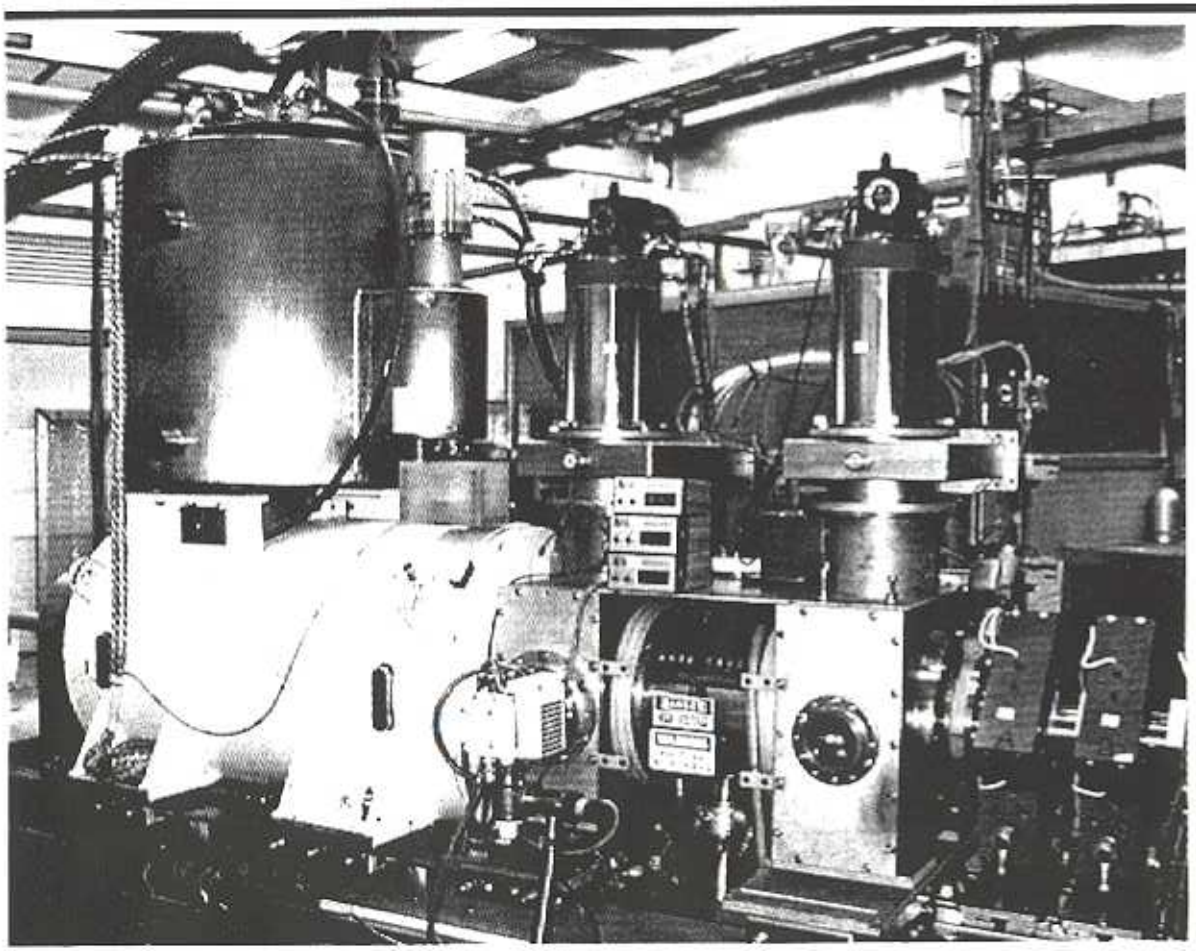
# High intensity polarized $H^-$ source



KEK OPPIS
upgraded at TRIUMF

75 - 80 % Polarization

$15\times10^{11}$ protons/pulse
at source

$6\times10^{11}$ protons/pulse
at end of LINAC

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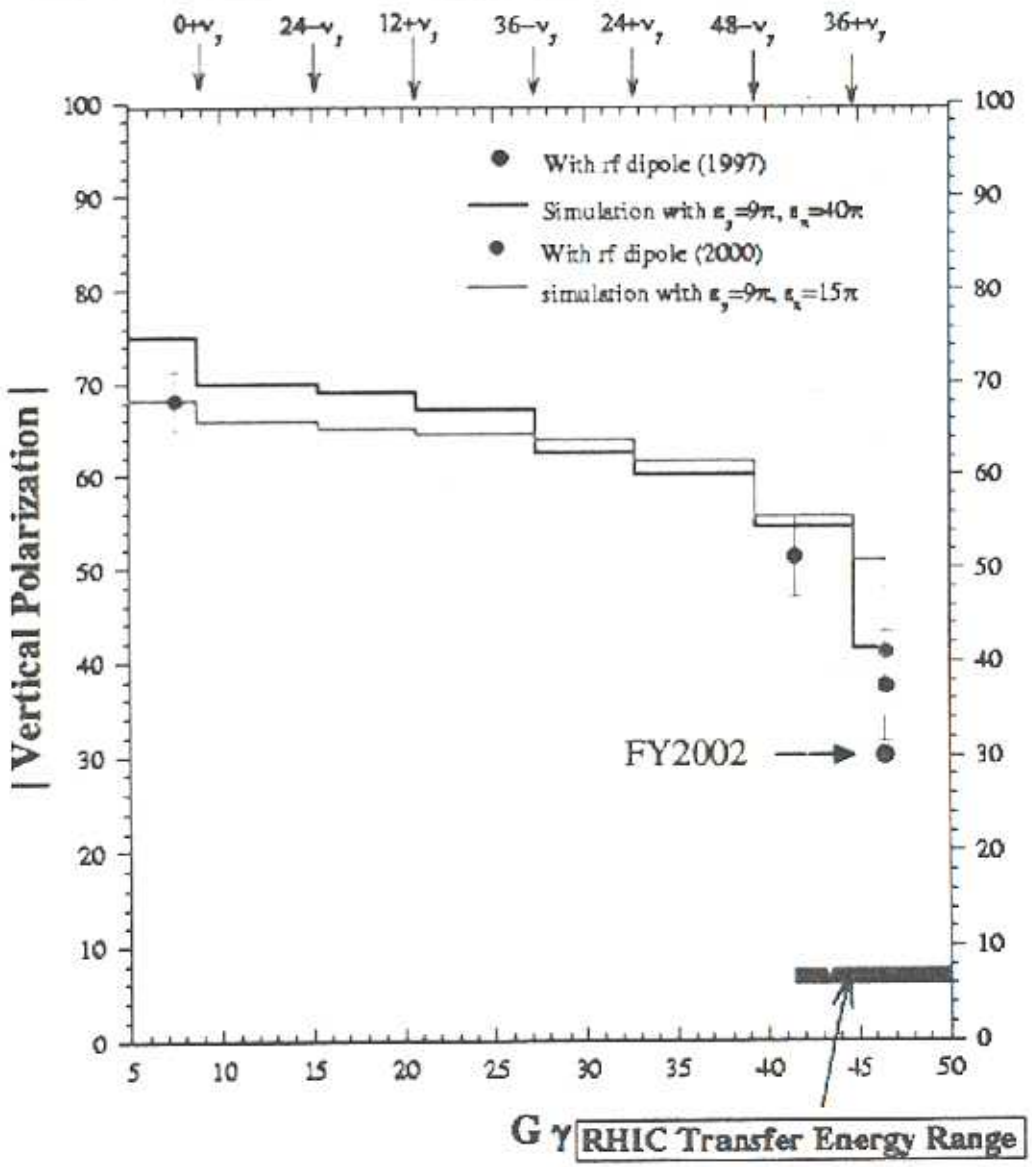
# Proton polarization at the AGS

- 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 and higher bunch intensity (?)

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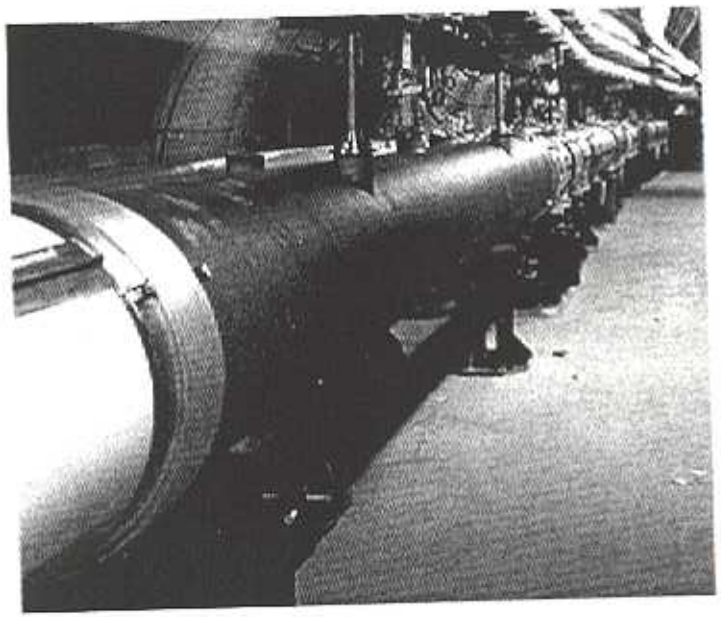
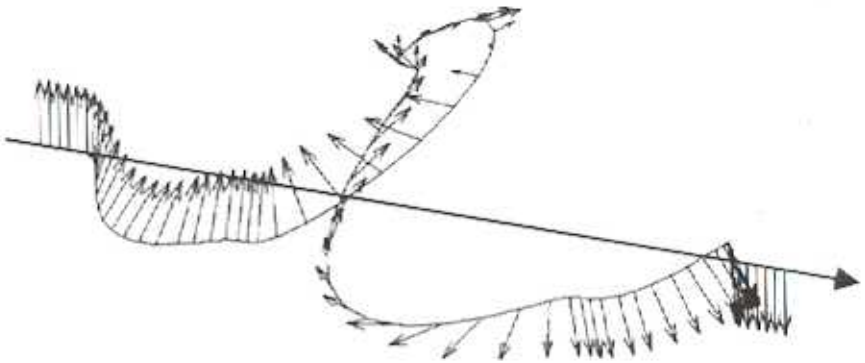
# First Siberian Snake in RHIC Tunnel

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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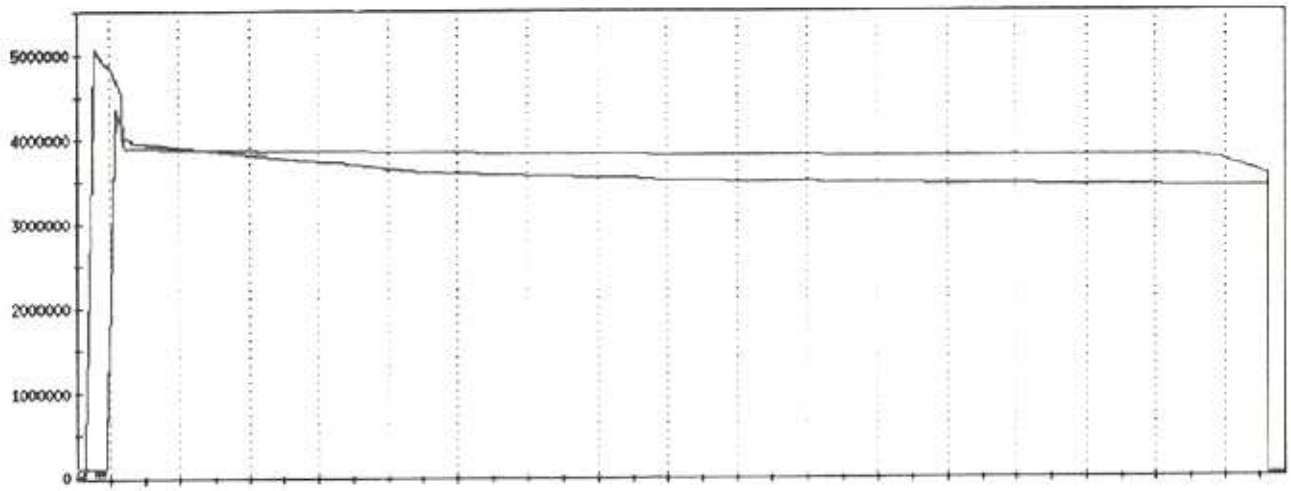
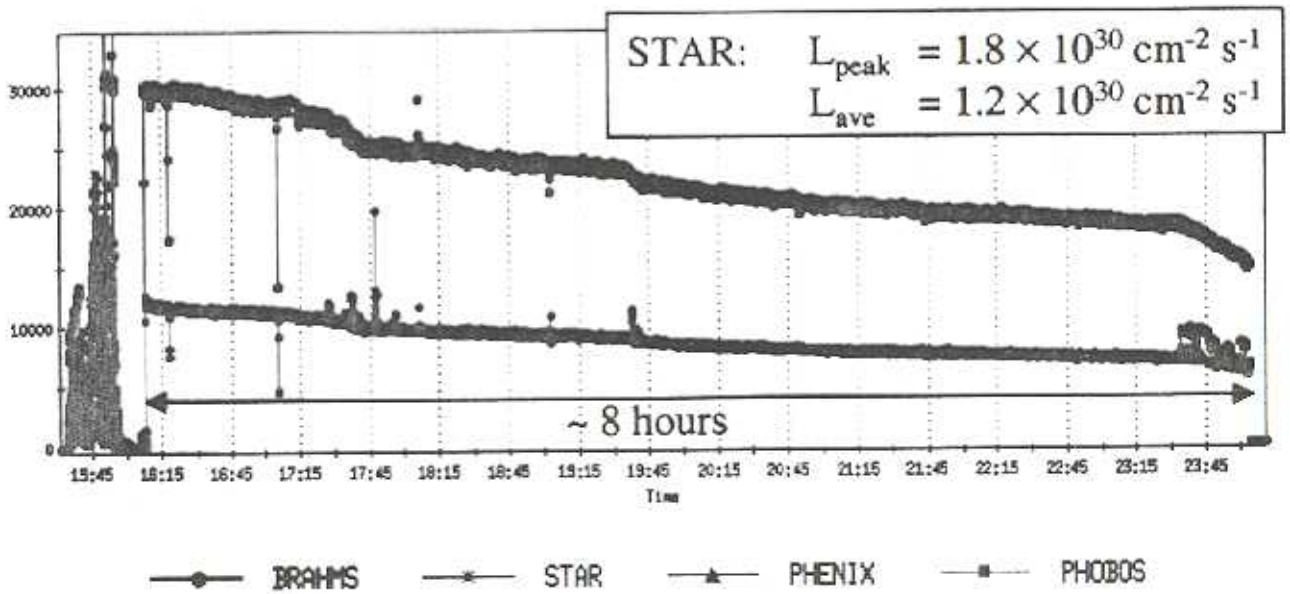
# "Typical Store" # 2304

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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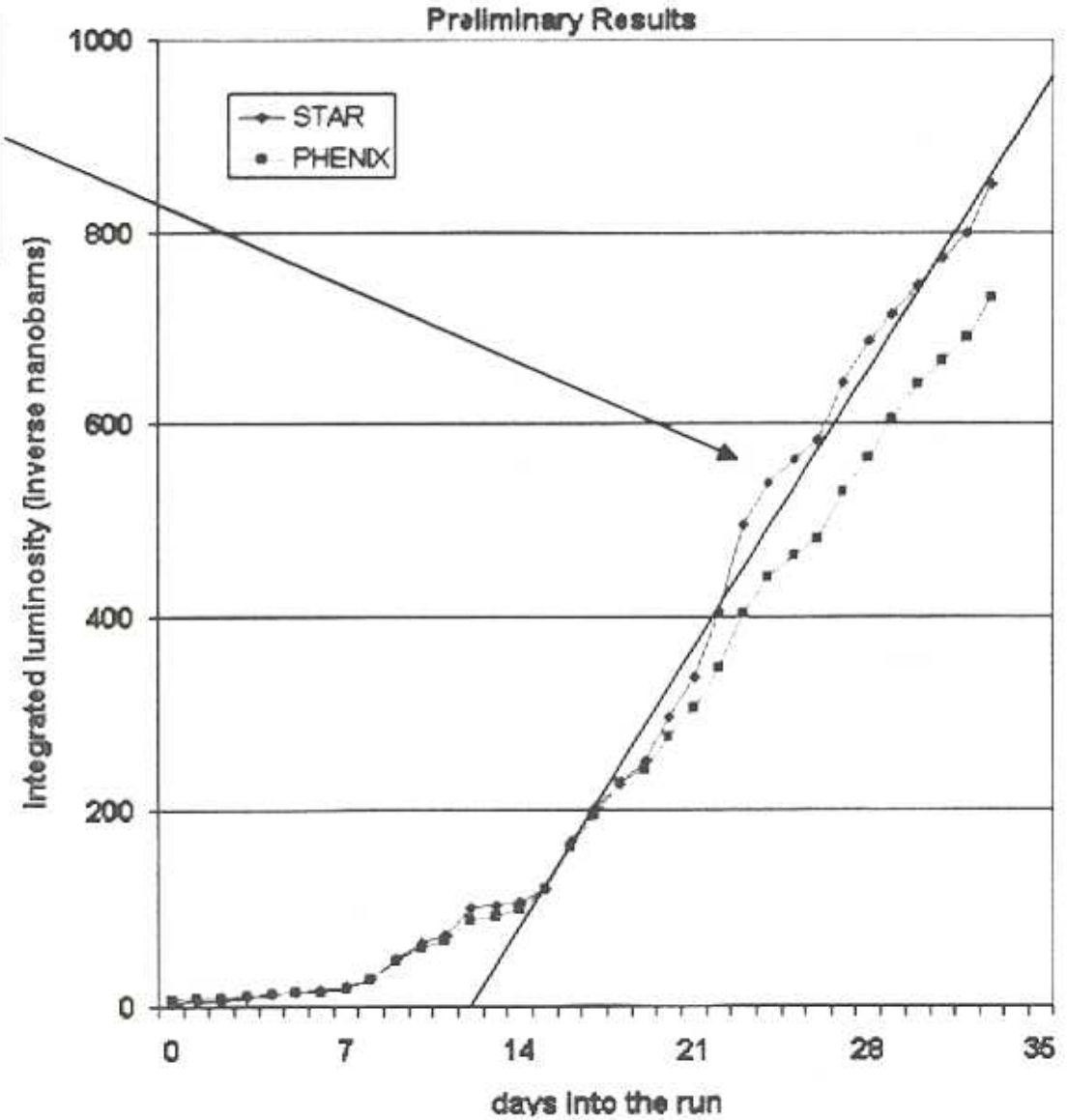
# Integrated p - p luminosity

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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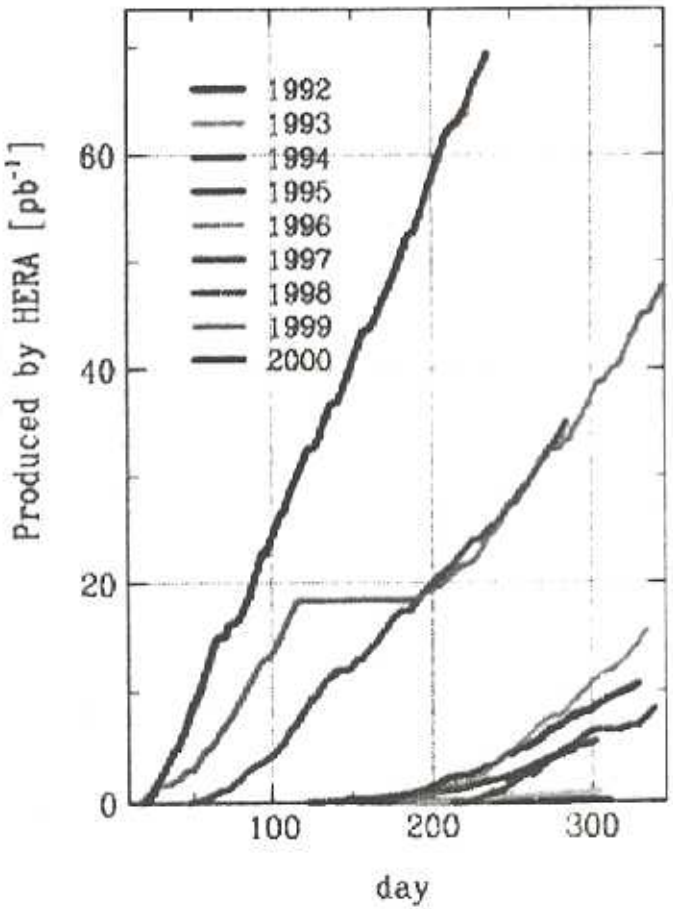
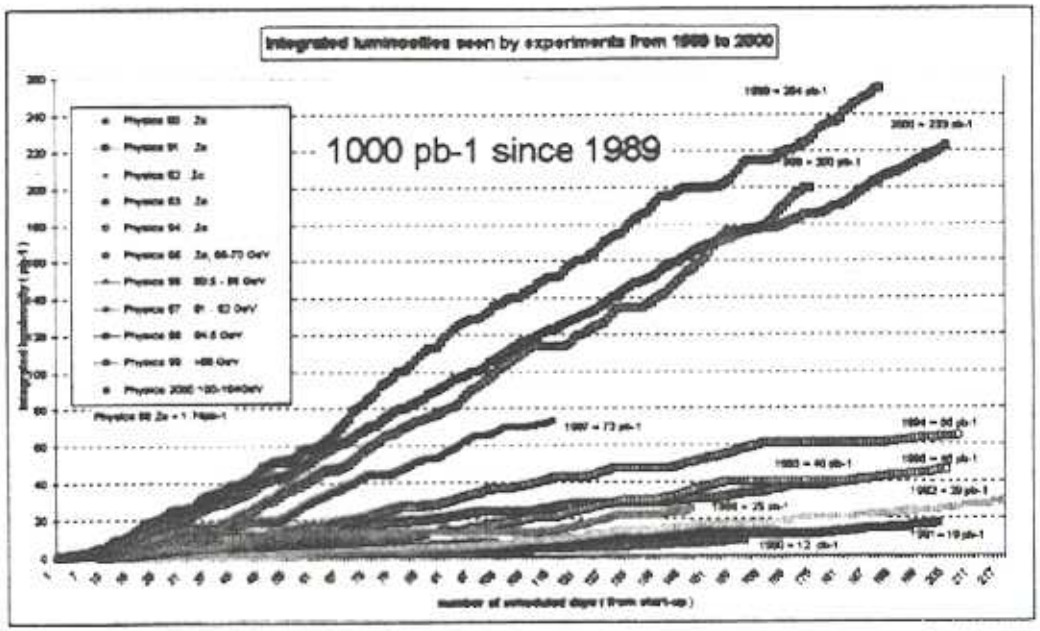
# Results from first RHIC polarized proton run

- 55 bunches per ring with 0.8 x $10^{11}$ p↑/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: $1.5 \times 10^{30}$ $cm^{-2}$ $s^{-1}$
- 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
- **Strong Siberian snake in AGS (~ 30 % of full snake) could avoid all depolarization in the AGS**

# HERA and LEP luminosity evolutions

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# RUN2003 Goals (~ 3-4 weeks into run)

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

| Mode | # bunches | Ions/bunch [$\times 10^9$] | $\beta^*$ [m] | Emittance [$\pi\mu$m] | $L_{peak}$ [$cm^{-2}s^{-1}$] | $L_{ave}$(store) [$cm^{-2}s^{-1}$] | $L_{ave}$(week) [$week^{-1}$] |
|---|---|---|---|---|---|---|---|
| Au-Au | 56 | 1 | 1 | 15-40 | $14\times10^{26}$ | $3\times10^{26}$ | 70 $(\mu b)^{-1}$ |
| (p↑-p↑)* | 112 | 100 | 1 | 25 | $16\times10^{30}$ | $10\times10^{30}$ | 2.8$(pb)^{-1}$ |
| d-Au | 56 | 100(d), 1(Au) | 2 | 20 | $5\times10^{28}$ | $2\times10^{28}$ | 5 $(nb)^{-1}$ |
| Si-Si | 56 | 7 | 1 | 20 | $5\times10^{28}$ | $2\times10^{28}$ | 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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# 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$^{-1}$] | Int. Lumi. 2 modes | Int. Lumi. 3 modes | $L_{ave}$ (week) [week$^{-1}$] | Int. Lumi. 2 modes | Int. Lumi. 3 modes |
|---|---|---|---|---|---|---|
| Au-Au | 24(μb)$^{-1}$ | 168(μb)$^{-1}$ | 72(μb)$^{-1}$ | 70 (μb)$^{-1}$ | 490(μb)$^{-1}$ | 210(μb)$^{-1}$ |
| (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)$^{-1}$ |

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