RHIC Upgrades for Heavy Ions and Polarized Protons

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eRHIC not covered here – see presentations by
V. Ptitsyn (machine) and R. Fatemi (detector)

RHIC status


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

RHIC status

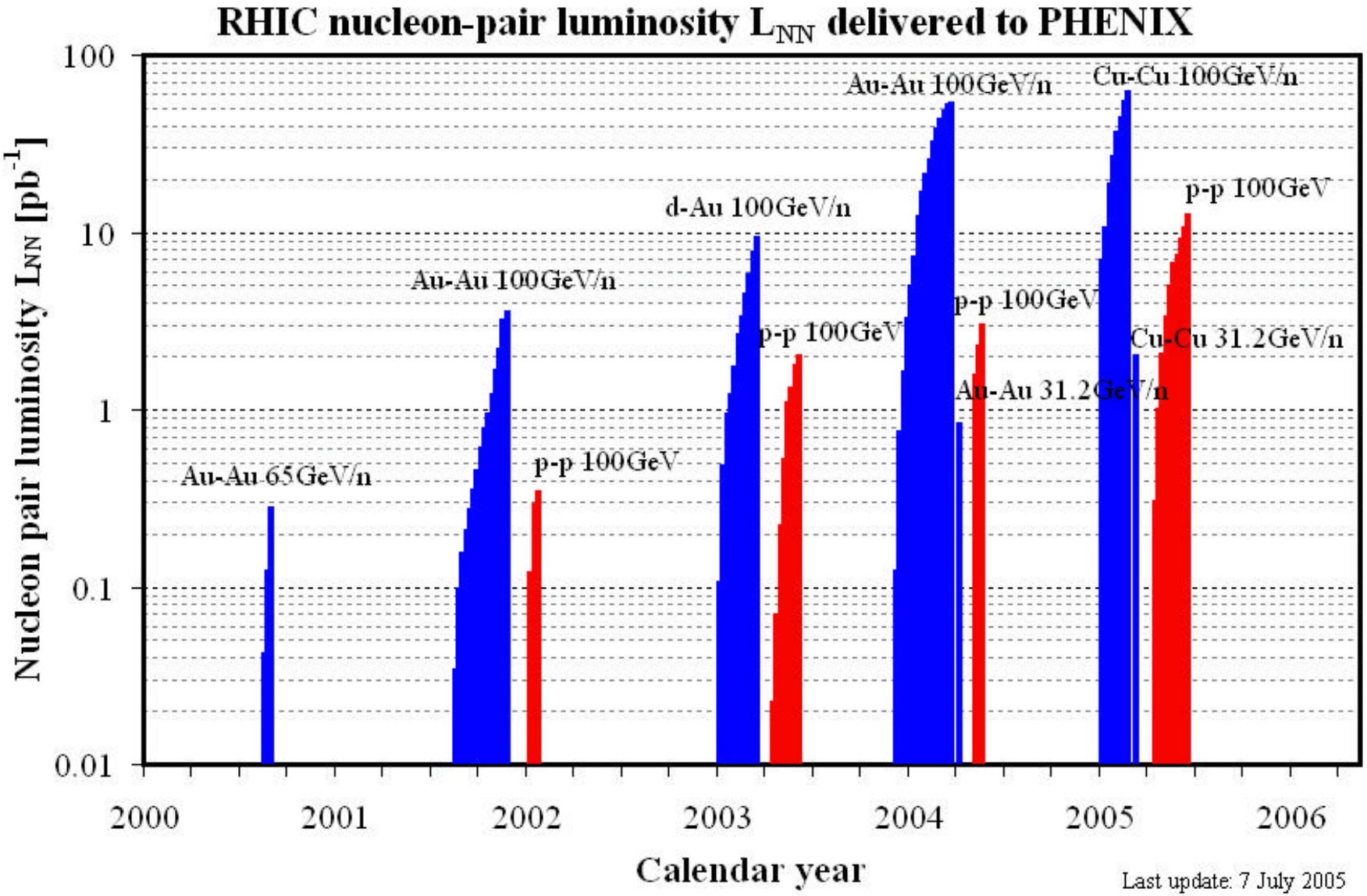
RHIC operating modes and total integrated luminosity delivered to 5 experiments

run	species	particle energy [GeV/n]	total delivered luminosity	averge store polarization
Run-1 2000	Au^{79+}-Au^{79+}	27.9	$< 0.001 \mu b^{-1}$	
	Au^{79+}-Au^{79+}	65.2	$20\ \mu b^{-1}$	
Run-2 2001/02	Au^{79+}-Au^{79+}	100.0	$258\ \mu b^{-1}$	
	Au^{79+}-Au^{79+}	9.8	$0.4\ \mu b^{-1}$	
	pol. p^{+}-p^{+}	100.0	$1.4\ pb^{-1}$	14%
Run-3 2002/03	d^{+}-Au^{79+}	100.0	$73\ nb^{-1}$	—
	pol. p^{+}-p^{+}	100.0	$5.5\ pb^{-1}$	34%
Run-4 2003/04	Au^{79+}-Au^{79+}	100.0	$3740\ \mu b^{-1}$	—
	Au^{79+}-Au^{79+}	31.2	$67\ \mu b^{-1}$	—
	pol. p^{+}-p^{+}	100.0	$7.1\ pb^{-1}$	46%
Run-5 20004/05	Cu^{29+}-Cu^{29+}	100.0	$42.1\ nb^{-1}$	—
	Cu^{29+}-Cu^{29+}	31.2	$1.5\ nb^{-1}$	—
	Cu^{29+}-Cu^{29+}	11.2	$0.02\ nb^{-1}$	—
	pol. p^{+}-p^{+}	100.0	$29.5\ pb^{-1}$	46%
	pol. p^{+}-p^{+}	204.9	$0.1\ pb^{-1}$	30%

Since 2000:
- 4 ion combinations
- 7 energies
- 46% polarization

RHIC status

Luminosity increased by 2 orders of magnitude in 4 years.



RHIC – Enhanced Luminosity goals – 2008

For Au-Au, average per store, 4 IRs

$L = 8 \times 10^{26} cm^{-2} s^{-1}$ at 100GeV/u

4× design
2× achieved

For p↑-p↑ average per store, 2 IRs

$L = 6 \times 10^{31} cm^{-2} s^{-1}$ at 100GeV

16× design
9× achieved

$L = 1.5 \times 10^{32} cm^{-2} s^{-1}$ at 250GeV

with **70% polarization**

1× design
1.5× achieved

Enhanced Luminosity Upgrades

For all species:

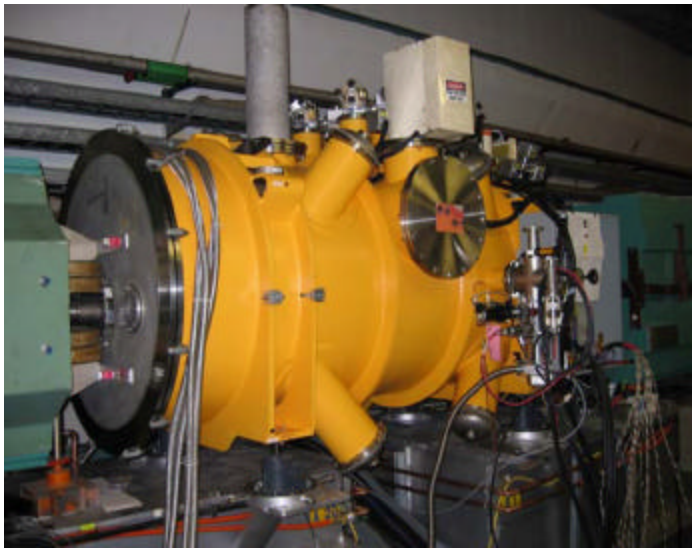
Completion of RHIC vacuum upgrade to suppress e-clouds

- Warm: installation of NEG coated beam pipes
- Cold : additional pumping before cool-down

For polarized protons:

Full commissioning of AGS cold snake

- Leading to 85% spin transmission
- At design bunch intensity 2×10^{11}p



EBIS

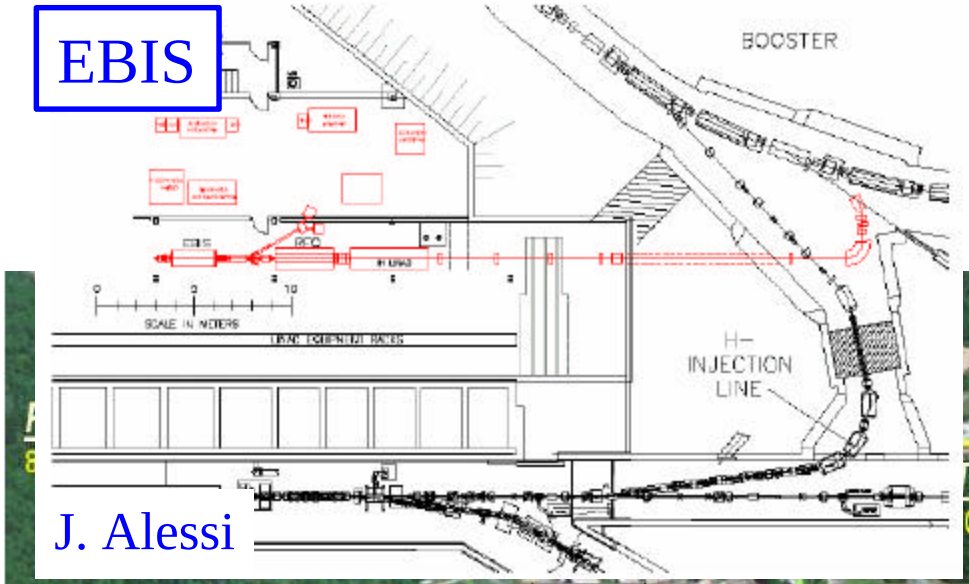
Electron Beam Ion Source

replaces existing 35-year old Tandems (2009)

Main advantages:

- No Tandem reliability upgrade needed
- Simpler operation at reduced costs
- Simpler Booster injection (fewer turns at higher energy)
- Faster species switching (d-Au in sec instead of 5min)
- New species: U, ^{3}He$\uparrow$

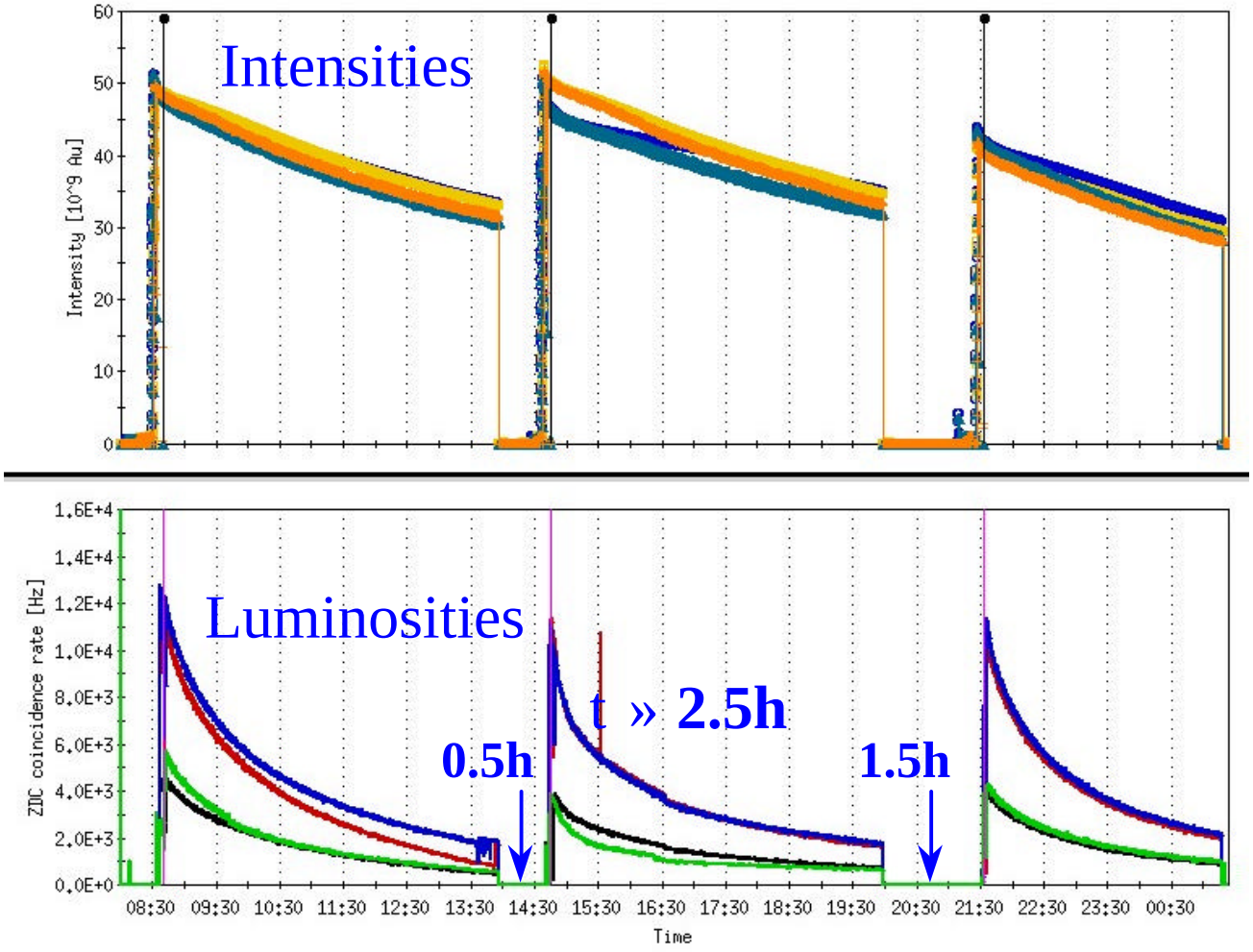
EBIS



Tandem-to-Booster: 840m

EBIS-to-Booster : 30m

RHIC II – Motivation



Beam and luminosity lifetime for Au – Au dominated by IBS

$$t^{-1} \propto \frac{Z^4}{A^2} n$$

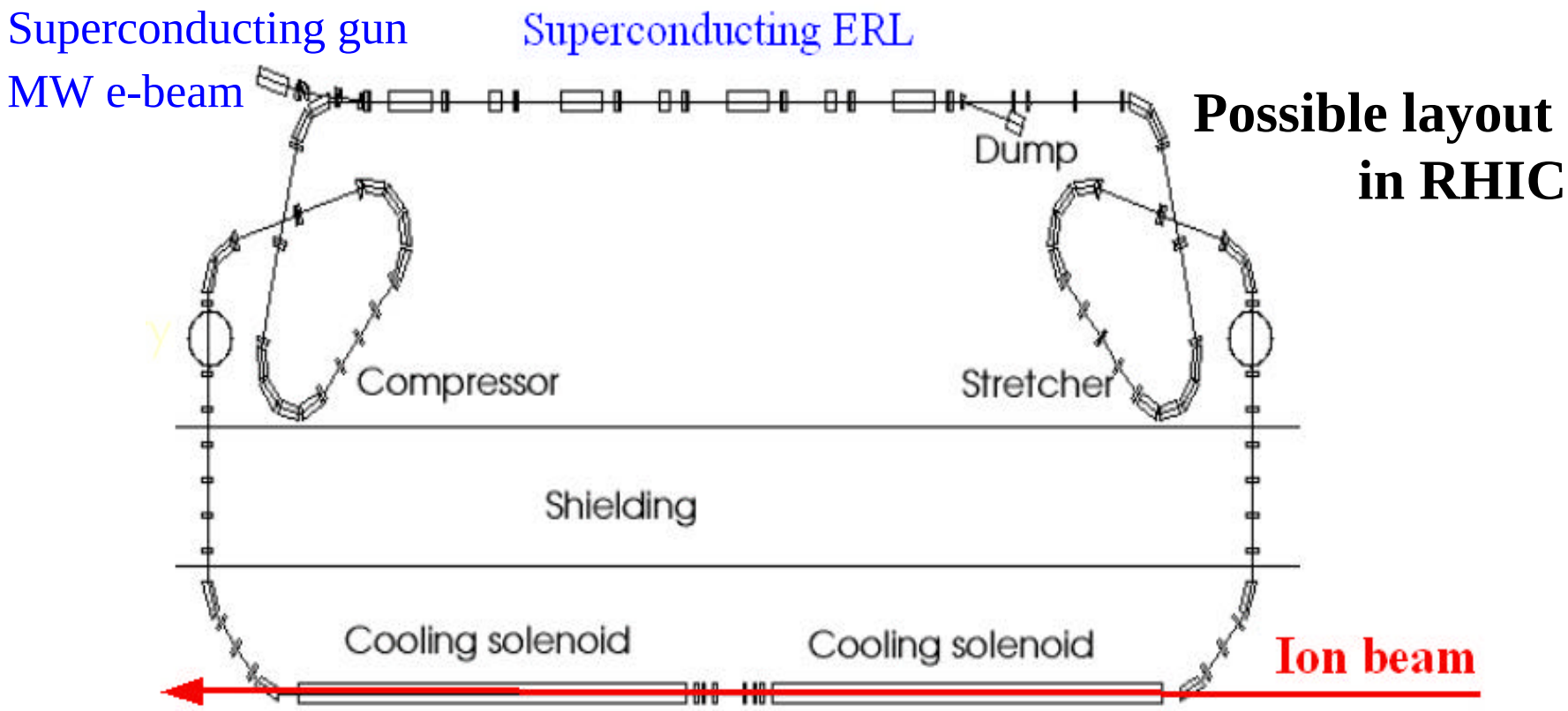
[Factor 10 between Au an p]

- Debunching requires continuous abort gap cleaning
- Luminosity lifetime requires frequent refills
- Ultimately need cooling at full energy

RHIC II – electron cooling at store

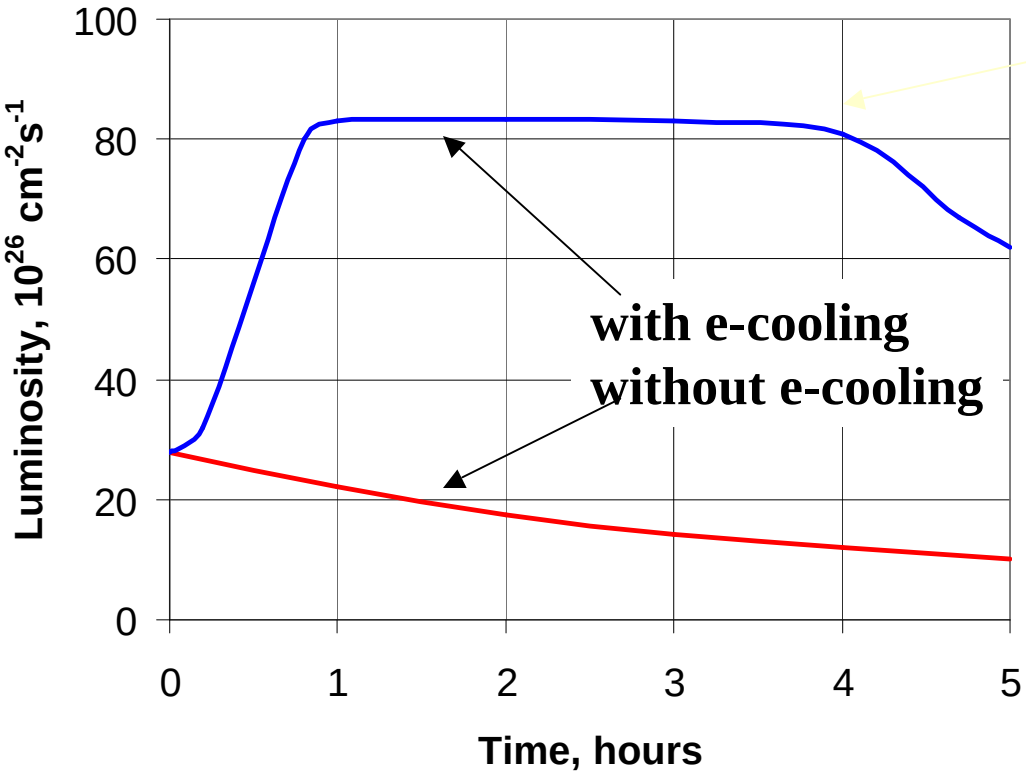
Challenge: electron cooling time $\mu\ \gamma^{7/2}$, existing coolers $\gamma \pounds 8$
[1st cooling in a collider – high brightness, high power ERL]

Need : **54 MeV, 100-200 mA** (= 5-10 MW)
Existing: 88 MeV, 9 mA (Jefferson Lab ERL for IR FEL)



Possible layout in RHIC

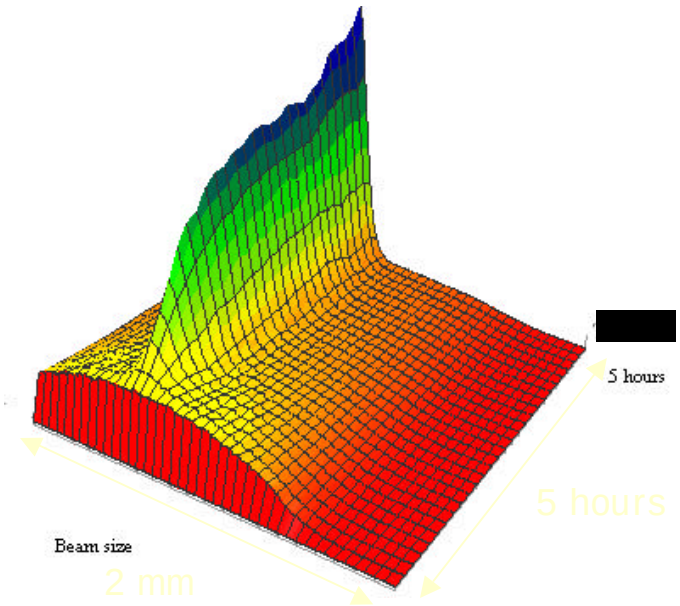
RHIC II – luminosity evolution



Luminosity leveling through continuously adjusted cooling

Store length limited to 4 hours by "burn-off"

Four IRs with two at high luminosity



Transverse beam profile during store

Also may be able to pre-cool polarized protons at injection energy

RHIC II Luminosities with Electron Cooling

Gold collisions (100 GeV/n ´ 100 GeV/n):	**w/o e-cooling**	**with e-cooling**
Emittance (95%) μm	15 → 40	15 → 10
Beta function at IR [m]	1.0	1.0
Number of bunches	112	112
Bunch population [10^9]	1	1 → 0.3
Beam-beam parameter per IR	0.0016	0.004
Peak luminosity [10^{26} $cm^{-2}s^{-1}$]	32	90
Ave. store luminosity [10^{26} $cm^{-2}s^{-1}$]	8	70
Polarized proton collision (250 GeV ´ 250 GeV):		
Emittance (95%) μm	20	12
Beta function at IR [m]	1.0	0.5
Number of bunches	112	112
Bunch population [10^{11}]	2	2
Beam-beam parameter per IR	0.007	0.012
Ave. store luminosity [10^{30} $cm^{-2}s^{-1}$]	150	500

Other possible improvements under study

1. RHIC stochastic cooling [→ up to 50% more AA-luminosity]
2. Energy increase by 30% [→ increased W-production]
3. OPPIS Source upgrade [→ 5-10% more polarization]
4. 2^{nd} cold snake in AGS [→ 5-15% more polarization]
5. RFQ-to-LINAC match [→ p-emittance reduction]
6. RHIC β^*-reduction [→ up to 50% more pp-luminosity 250GeV]
7. RHIC electron lenses [→ up to 50% more pp-luminosity]
8. Very high bandwidth stoch. cooling [→ more pp-luminosity]
9. Superbunches [→ more luminosity, requires new detector]

Summary

- RHIC operation – since 2000
  - 4 combinations of ion species at 7 energies, including d-Au
  - 2 orders of magnitude increase in ion luminosity
  - protons with average store polarization of 46%
- Enhanced luminosity – by 2008
  - 2× more Au-Au luminosity
  - 9× more p-p luminosity, 50 % more polarization
- New ion source EBIS – by 2009
  - U, ^{3}He$\uparrow$, better intensities, emittances and reliability
- RHIC II – by 2012 (← technically constrained)
  - 10× more Au-Au luminosity (over Enhanced luminosity)
  - 2-3× more p-p luminosity (over Enhanced luminosity)
- More ideas for more p-p luminosity