

# Overview of RHIC future program and R&D

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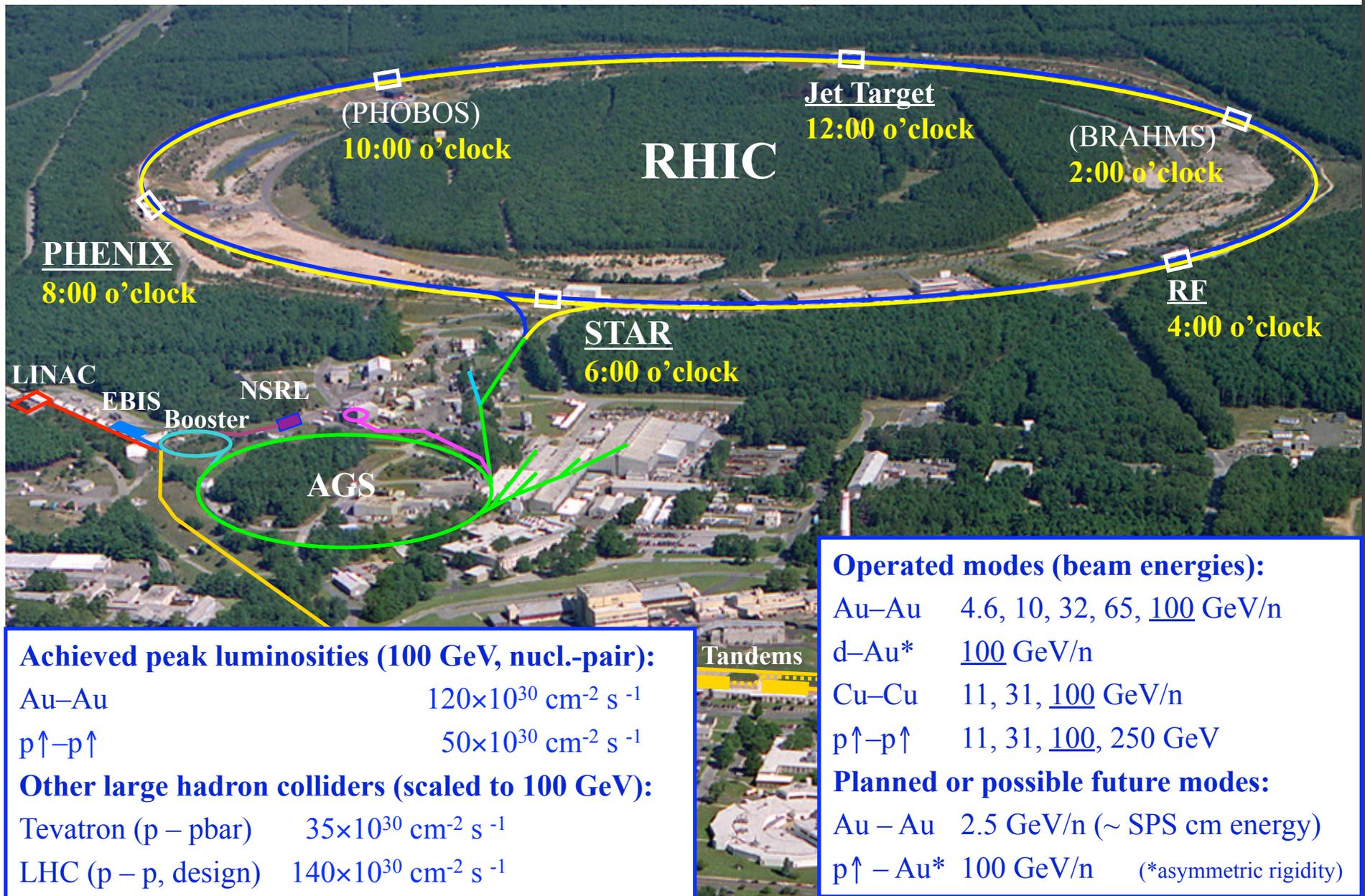
RHIC luminosity and polarization evolution

Plans for luminosity upgrades

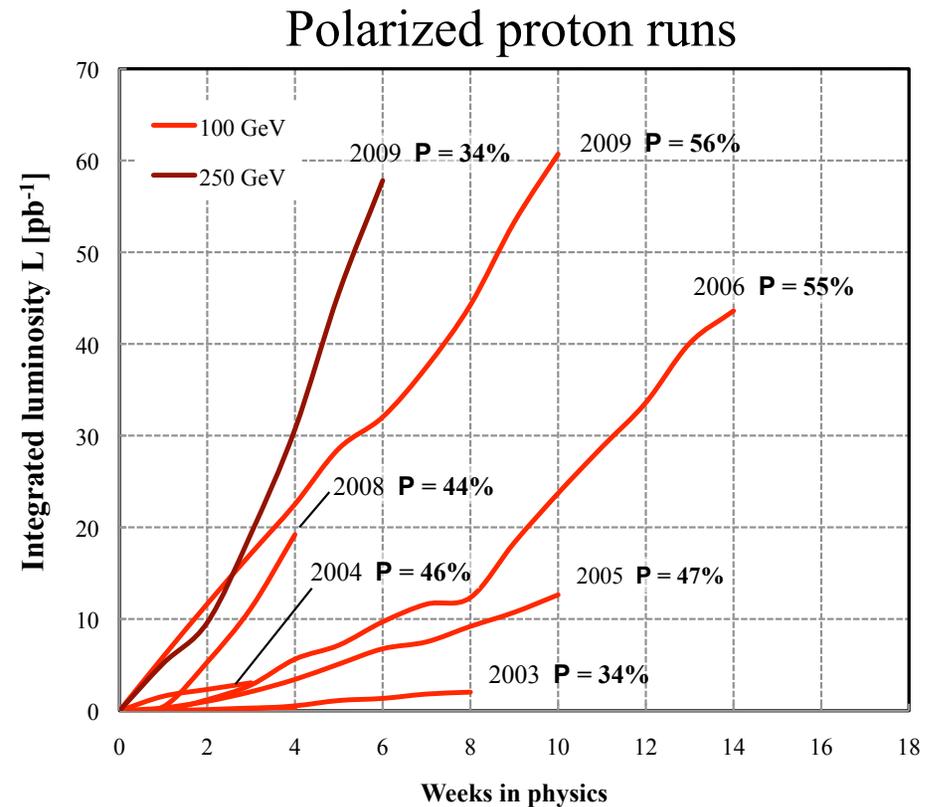
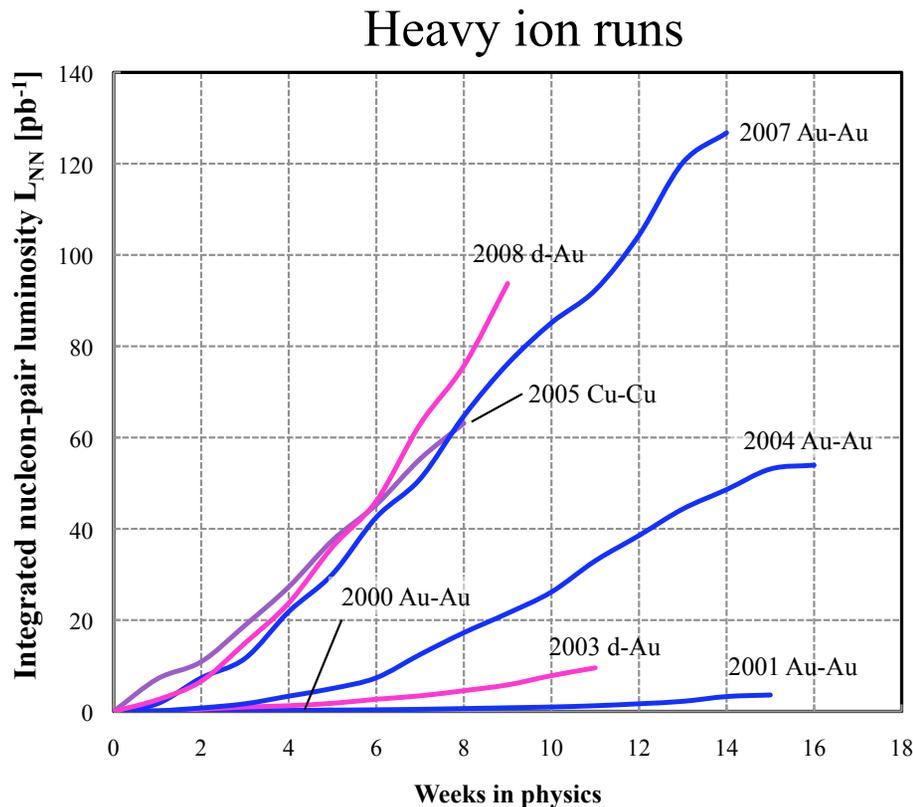
Low energy Au – Au collisions (Critical point search)

Electron-Ion Collider @ BNL (eRHIC and MeRHIC)

# RHIC – a High Luminosity (Polarized) Hadron Collider



## Delivered Integrated Luminosity and Polarization



Nucleon-pair luminosity: luminosity calculated with nucleons of nuclei treated independently; allows comparison of luminosities of different species; appropriate quantity for comparison runs.

## RHIC Facility Upgrade Plans

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- EBIS (~ 2011) (low maintenance linac-based pre-injector; all species including U and polarized  $^3\text{He}$ )
- RHIC luminosity upgrade (~ 2012):  
[Au-Au:  $40 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1} (\times 4)$ ; 500 GeV p-p:  $1.5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ ]
  - 0.5 m  $\beta^*$  for Au – Au and p $\uparrow$  – p $\uparrow$  operation
  - Stochastic cooling of Au beams and 56 MHz storage rf system in RHIC
- Further luminosity upgrade for p $\uparrow$  – p $\uparrow$  operation (~ 2014):  
[500 GeV p-p:  $\sim 3 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ ]
  - 0.3 m  $\beta^*$  for 500 GeV p $\uparrow$  – p $\uparrow$  operation ( $\times 1.6$ )
  - Electron lens in RHIC for head-on beam-beam compensation ( $\times 2$ )
- Low energy ( $\sqrt{s}=5\dots30 \text{ GeV}$ ) Au-Au collisions for critical point search
  - $\sim 1\dots5 \text{ MeV}$  electron cooling of Au beams at injection
- eRHIC: high luminosity ( $\geq 1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ ) eA and pol. ep collider using 4 GeV and later 10 - 20 GeV electron driver, based on an Energy Recovering Linac (ERL), and strong cooling of hadron beams (~ 2020)  
Exploring gluons at extreme density!

## Luminosity and Polarization Goals

Parameter	unit	Achieved	Enhanced Design	Next L upgrade
<b><u>Au-Au operation</u></b>		<b>(2007)</b>		<b>(2012)</b>
Energy	GeV/nucleon	100	100	100
No of bunches	...	103	111	111
Bunch intensity	$10^9$	1.1	1.0	1.0
<b>Average L</b>	<b><math>10^{26}\text{cm}^{-2}\text{s}^{-1}</math></b>	<b>12</b>	<b>8</b>	<b>40</b>
<b><u>p↑- p↑ operation</u></b>		<b>(2009)</b>	<b>(2011/12)</b>	<b>(2014)</b>
Energy	GeV	100 / 250	100 / 250	250
No of bunches	...	109	109	109
Bunch intensity	$10^{11}$	1.3 / 1.1	1.3 / 1.5	2.0
<b>Average L</b>	<b><math>10^{30}\text{cm}^{-2}\text{s}^{-1}</math></b>	<b>28 / 55</b>	<b>30 / 150</b>	<b>300</b>
<b>Polarization P</b>	<b>%</b>	<b>56 / 34</b>	<b>70</b>	<b>70</b>

Had previously a goal of 60 here.

## RHIC Physics Plan 2009 - 2014

Fiscal Year	Colliding Beam Species/Energy	Comments
2009	500 GeV p+p	4 physics weeks to commission collisions, work on polarization & luminosity, obtain first W production signal to meet 2011 RIKEN milestone; STAR DAQ1000 fully operational
	200 GeV p+p	10 physics weeks for 200 GeV ALL measurements
2010	Au+Au at assorted low E	1st energy scan for critical point search – energies and focus signals to be decided; commission PHENIX VTX (at least prototype)
	200 GeV Au+Au	9-10 physics weeks with PHENIX HBD, STARDAQ1000 & TOF permits low-mass dilepton response map and 1 <sup>st</sup> HI collision test of transverse stochastic cooling
2011	200 GeV U+U	1 <sup>st</sup> U+U run with EBIS, to increase energy density coverage
	500 GeV p+p	1 <sup>st</sup> long 500 GeV p+p run, with PHENIX muon trigger and STARFGT upgrades ~ 100 pb <sup>-1</sup> recorded for substantial statistics on W production and ΔG measurements
2012	?	
	200 GeV Au+Au	Long run with full stochastic cooling, PHENIX VTX and prototype STARHFT installed; focus on RHIC-II goals: heavy flavor, γ-jet, quarkonium, multi-particle correlations
2013	500 GeV p+p	Reach ~ 300 pb <sup>-1</sup> to address 2013 DOE performance milestone on W production
	200 GeV Au+Au or 2 <sup>nd</sup> low-E scan	To be determined from 1 <sup>st</sup> low-E scan and 1 <sup>st</sup> upgraded luminosity runs, progress on low-E e-cooling, and on installation of PHENIX FVTX and full STARHFT
2014	200 GeV Au+Au or 2 <sup>nd</sup> low-E scan	Run option not chosen for 2013 run – low-E scan addresses 2015 DOE milestone on critical point, full-E run addresses 2014 (γ-jet) and 2016 (identified heavy flavor) milestones. Proof of principle test of coherent electron cooling.
	200 GeV p+p	Address 2015 DOE performance milestone on transverse SSA for γ-jet; reference data with new detector subsystems; test e-lenses for p+p beam-beam tune spread reduction

## Comments on RHIC Polarization Performance

### Polarization at 100 GeV:

- Source:  $P_{\text{center}} \sim 80\%$        $\langle P \rangle \sim 80\%$
- AGS (25 GeV, high int.,  $A_N$ ?):  $P_{\text{center}} \sim 65\%$        $P(\sigma) = \langle P \rangle \sim 60\%$
- RHIC (100 GeV):  $P_{\text{center}} \sim 61\%$        $\langle P \rangle \sim 56\%$
- Upgrades:
- New OPPIS solenoid:  $P_{\text{center}} : + 5\%$ ;       $\langle P \rangle : + 5\%$       (abs.)
- AGS horizontal tune jump quads:  $P_{\text{center}} : + 5\%$ ;       $\langle P \rangle : + 10\%$       (abs.)
- With both upgrades:
- Source:  $P_{\text{center}} \sim 85\%$        $\langle P \rangle \sim 85\%$
- AGS (25 GeV, high int.,  $A_N$ ?):  $P_{\text{center}} \sim 75\%$        $P(\sigma) = \langle P \rangle \sim 75\%$
- RHIC (100 GeV):  $P_{\text{center}} \sim 71\%$        $\langle P \rangle \sim 71\%$

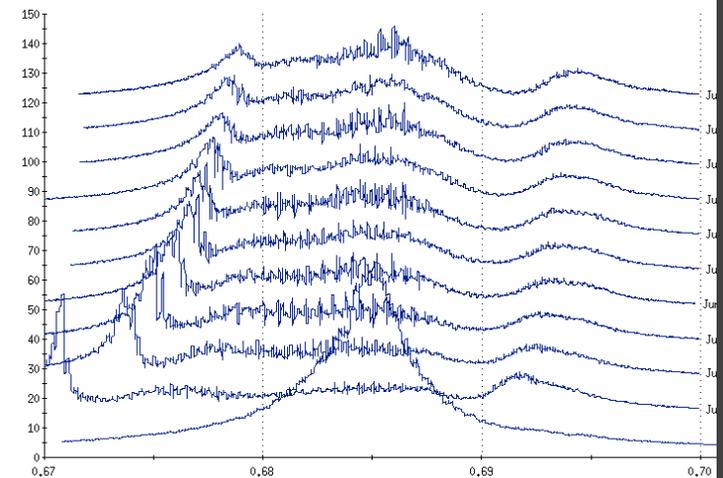
### Polarization at 250 GeV:

- $> 90\%$  polarization transmission at  $\nu_y = 29.677$
- $\sim 80\%$  polarization transmission at  $\nu_y = 29.98$
- Plan to accelerate with  $\nu_y = 29.675$  from 100 GeV to 250 GeV
- Fix ramp/flattop power supplies glitches!

## Comments on RHIC Luminosity Performance

Pol. Proton Collision (100 GeV x 100 GeV):	RHIC Spin design	Run 9
Emittance (95%) $\pi\mu\text{m}$	20	15 $\rightarrow$ 20
Beta function at IR [m]	1.0	0.7
Number of bunches	112	109
Bunch population [ $10^{11}$ ]	2	1.35
Initial beam-beam parameter per IR	0.007	0.006 [calc.]
Total BB parameter times 1.3 (Yokoya factor)	0.019	0.016 [calc]
BB parameter ( $\pi$ mode) measured		0.015
Peak luminosity [ $10^{30} \text{ cm}^{-2} \text{ s}^{-1}$ ]	80	50 [68 calc.]
Ave. store luminosity [ $10^{30} \text{ cm}^{-2} \text{ s}^{-1}$ ]	60	28

How to get to design performance ?  
 BB parameter  $\rightarrow$  split tunes  
 DA  $\rightarrow$  increase betastar  
 Increase beam intensity !?



## Schedule of Upgrades and R&D Projects

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To be completed in FY2009 for Run 10:

- Blue and Yellow longitudinal/vertical stochastic cooling installation/upgrade
- AGS L10 cavity replacement/upgrade
- Remaining 3 IPMs upgraded
- AGS horizontal tune jump system completion
- RHIC 10 Hz orbit feedback test
- Spin flipper test (AC dipole 3-bump)

To be completed in FY2010 for Run 11:

- EBIS (CD4 date: 9/2011)
- 9 MHz rf system
- RHIC 10 Hz orbit feedback
- Spin flipper complete
- P $\uparrow$  LEBT upgrade
- RHIC polarimetry upgrade (?)
- Polarized source upgrade (new solenoid) (maybe in FY2011?)
- Beam dump upgrade (?)
- Collimator upgrade (?)
- Gun-to-dump test and completion of ERL

## Schedule of Upgrades and R&D Projects (cont'd)

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To be completed in FY2011 for Run 12:

- 56 MHz superconducting rf system
- Blue and Yellow horizontal stochastic cooling installation\*
- Electron lenses in blue and yellow ring\*
- ERL commissioning

To be completed in FY2012 for Run 13:

- Transverse damper for transition (?) [modeled on stochastic cooling?]

To be completed in FY2013 for Run 14:

- Low energy electron cooling in RHIC (?)
- Coherent electron cooling test using ERL (?)

## Summary

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- Polarization improvements:
  - New source solenoid and AGS horizontal tune jump
  - New working point (near 2/3?) for 250 GeV acceleration
- Uranium beams from EBIS [Are there any issues in Booster/AGS/RHIC?]
- Luminosity upgrade to  $40 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1}$  through high energy beam cooling
- High luminosity 250 x 250 GeV polarized proton run at  $1.5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$  and later at  $3 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
- Low energy Au-Au collisions for critical point search
- High luminosity polarized electron ion collider
  - MeRHIC: 250 GeV p $\uparrow$   $\times$  4 GeV e $\uparrow$  ;  $1 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
  - eRHIC: 250 GeV p $\uparrow$   $\times$  10 – 20 GeV e $\uparrow$  ;  $3 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$