RHIC performance in Run-9, upgrades and projections for Run-10 and Run-11

Wolfram Fischer

– Please comment on assumptions made here –

BROOKHAVEN NATIONAL LABORATORY

CAD AP Meeting

20 May 2008

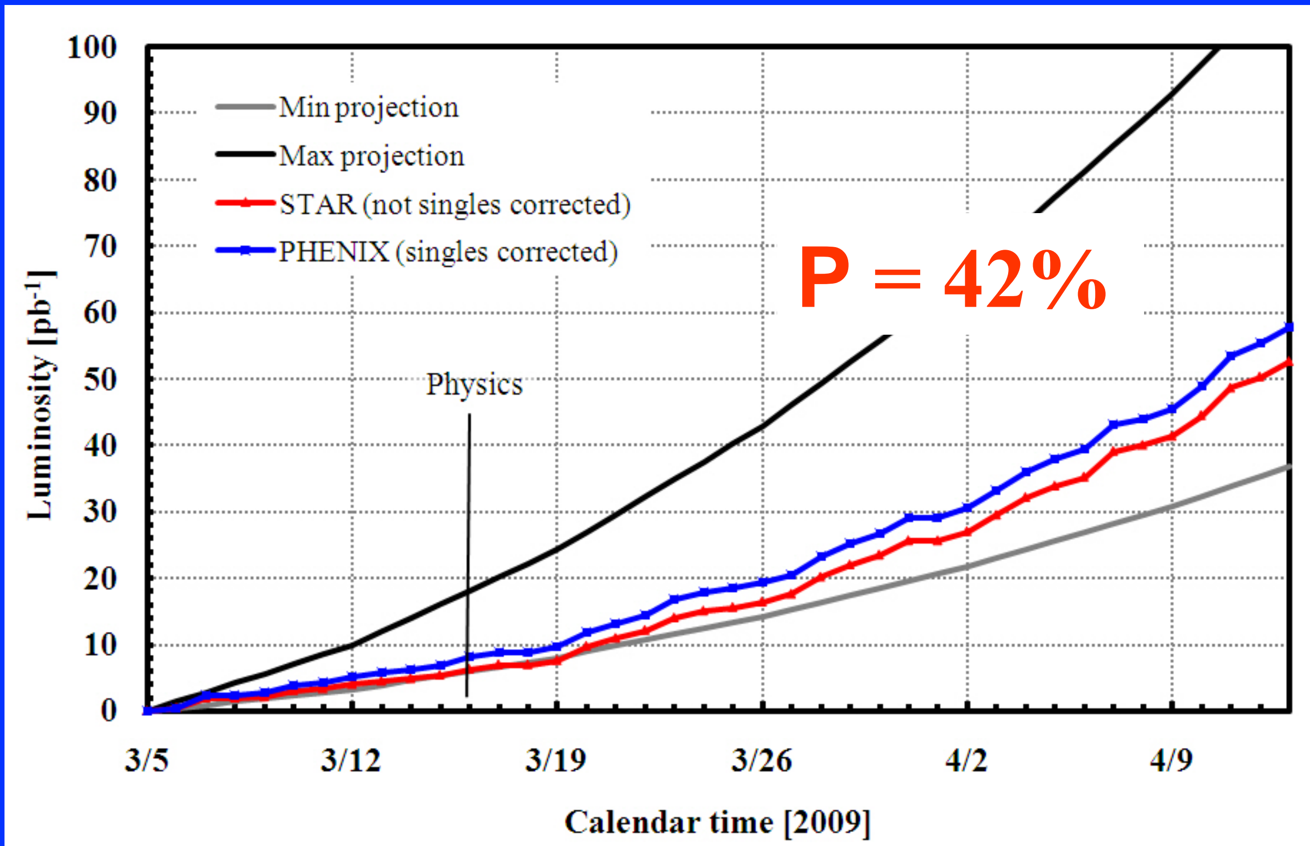
Outline

1. Run-9 performance (250 GeV and 100 GeV p↑-p↑)
   - **250 GeV** p↑-p↑
   - **100 GeV** p↑-p↑
2. Upgrade and projections for Run-11 (p↑-p↑)
3. Upgrade and projections for Run-10 (Au-Au)

Luminosity and polarization goals

Parameter	unit	Achieved	Enhanced design	Next L upgrade
Au-Au operation		**(2007)**		**(2011)**
Energy	GeV/nucleon	100	100	100
No of bunches	…	103	111	111
Bunch intensity	10^9	1.1	1.0	1.0
Average L	**10^{26}cm^{-2}s^{-1}**	**12**	**8**	**40**
p↑- p↑ operation		**(2009)**	**(2011)**	**(2012)**
Energy	GeV	100 / 250	100 / 250	250
No of bunches	…	109	111	111
Bunch intensity	10^{11}	1.3 / 1.1	2.0	2.0
Average L	**10^{30}cm^{-2}s^{-1}**	**23 / 55**	**60 (150)**	**300**
Polarization P	**%**	**58 / 42**	**70**	**70**

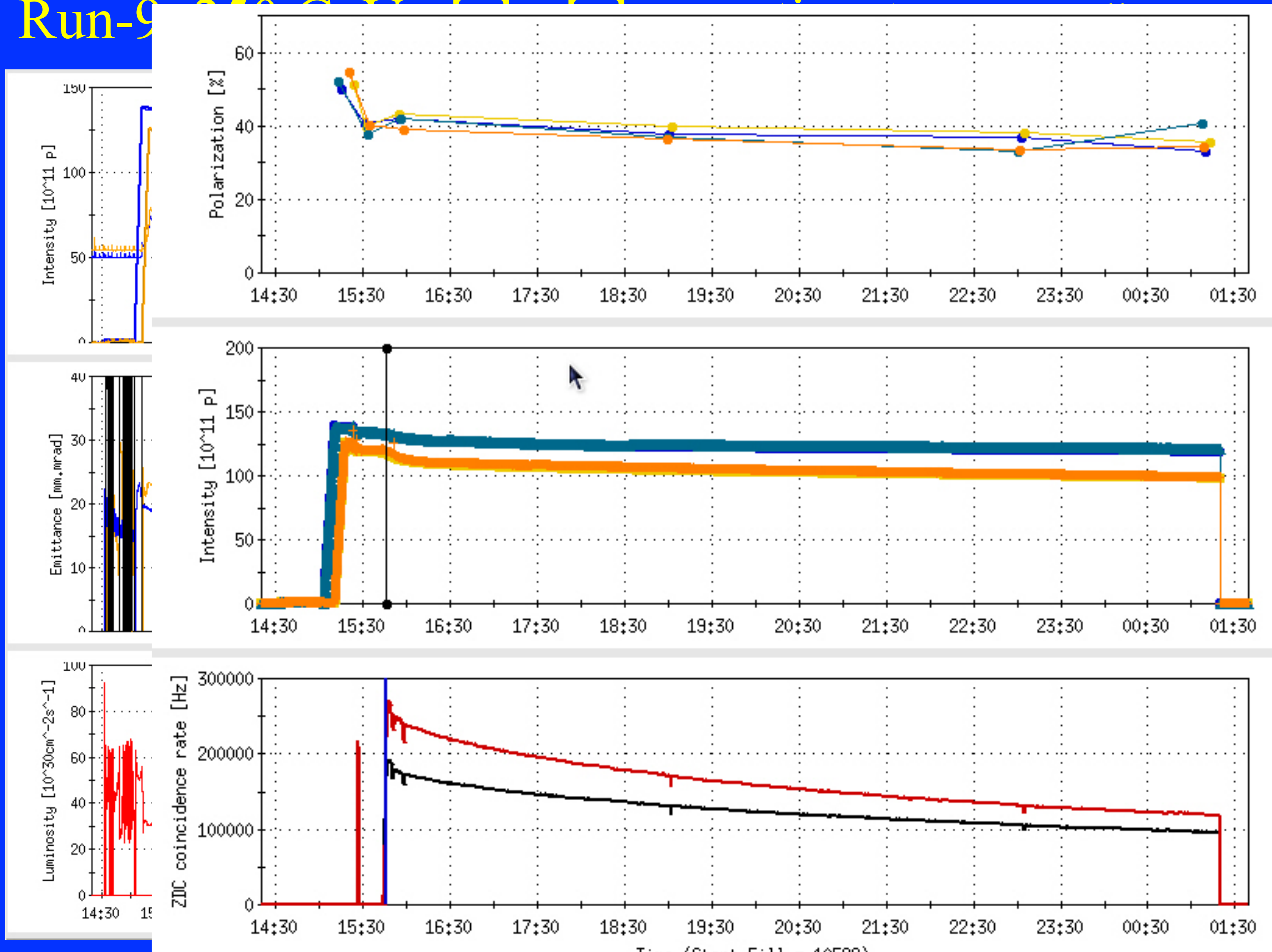
Run-9 250 GeV p↑-p↑ operation (Run Coordinator: M. Bai)



First collider operation with polarized protons at 250 GeV

no of bunches	ions/bunch [10^9]	β^* [m]	emittance [μm]	L_{peak} [$cm^{-2}s^{-1}$]	$L_{store\ avg}$ [$cm^{-2}s^{-1}$]	L_{week} [pb^{-1}]
109	110	0.7	18-23	85×10^{30}	55×10^{30}	18.4
Average store polarization: 42% in Blue, 42% in Yellow						

Run-9 … M. Bai)



vith

b^{-1}

Run-9 250 GeV p↑-p↑ operation (Run Coordinator: M. Bai)

Major accomplishments and events:

- First ever 250 GeV p↑-p↑ collider run
  → makes new spin physics experiments possible
- LEBT/MEBT modified (D. Raparia et al.)
  → 25% emittance reduction in RHIC
- Modification of Booster injection (K. Brown, L. Ahrens et al)
  → emittance reduction still to be quantified
- New AGS main magnet power supply transformer (J. Sandberg et al.)
  → upgraded single point of failure, flawless operation, ripple reduction
- Realignment of magnets near snakes (V. Ptitsyn, F. Karl)
  → better orbit angle control through snakes

Run-9 250 GeV p↑-p↑ operation (Run Coordinator: M. Bai)

Major accomplishments and events continued:

- Setup in 5 weeks (2 longer than planned)
  → more commissioning work than in recent runs
- 2 mrad crossing angle in IP2 and IP10
  → only 6 DX training quenches
- Tune and coupling feedback on every commissioning ramp (M. Minty, T. Russo, R. Michnoff, ...)
  → only 6 DX training quenches
- Upgrade of store orbit corrections to MIKADO
  (V. Ptitsyn, T. Satogata)
  → better orbit stability at store, still some reliability issues

Run-9 250 GeV p↑-p↑ operation (Run Coordinator: M. Bai)

Major accomplishments and events continued:

- Test of 9 MHz acceleration system
  (M. Brennan, A. Zaltsman et al.)
  ⇒ would lead to smaller longitudinal emittance and reduced electron cloud effect on ramp, Yellow beam unstable during flattop-ramp ps switchover
- Use of RHIC Main Quadrupole ramp ps at injection
  (C. Schultheiss)
  ⇒ reduce beam losses during switchover (aborted ramps) and attempt to make 9 MHz rf system operational
- First use of 4-knob nonlinear chromaticity correction
  (Y. Luo, G. Robert-Demolaize)
  ⇒ reduced corrector strength for nonlinear chromaticity correction

Run-9 250 GeV p↑-p↑ operation (Run Coordinator: M. Bai)

Major accomplishments and events continued:

- Upgraded CNI polarimeter (A. Zelenski, et al.)
  → number of targets doubled, better emittance measurement
- 10 Hz triplet cold mass measurements
  and test of cold mass damping (P. Thieberger et al.)
  → 10 Hz triplet vibration mitigation test

250 GeV p↑-p↑ operation

Areas where upgrades are needed/desirable:

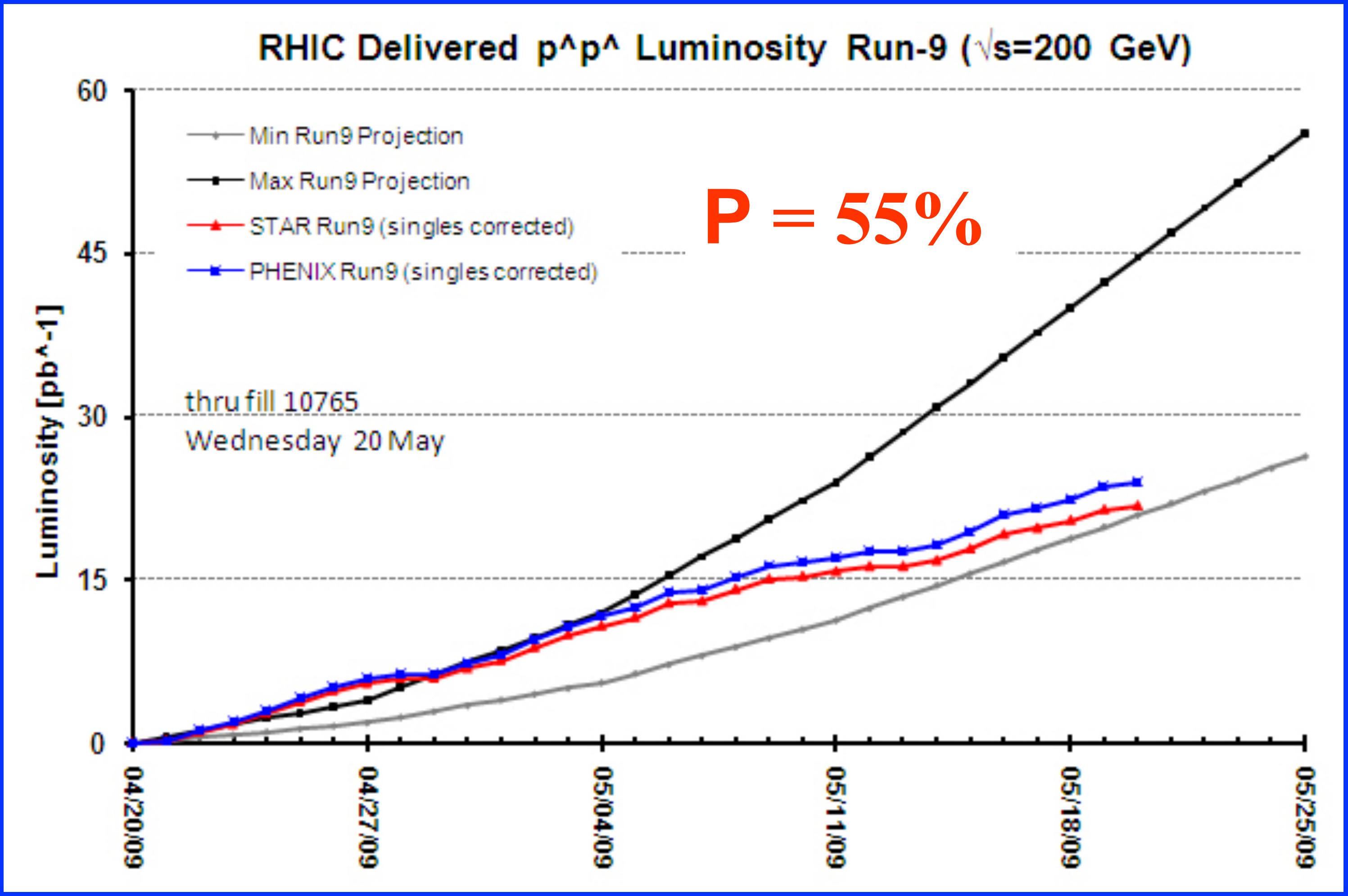
- AGS polarization and bunch intensity
  - horizontal tune quad jump system
- Ramp polarization transmission to 250 GeV
  - test near integer working point (must be done in Run-9)
- Polarimetry
  - CNI polarimeter (rate dependence, setup time)
  - additional PHENIX style polarimeter in IP10 with additional collision)
- More reliable orbit correction in store
  - smaller beam sizes
  - more weights for collimators, collision
- Collimation
- β^* reduction to 0.5 m

250 GeV p-p operation

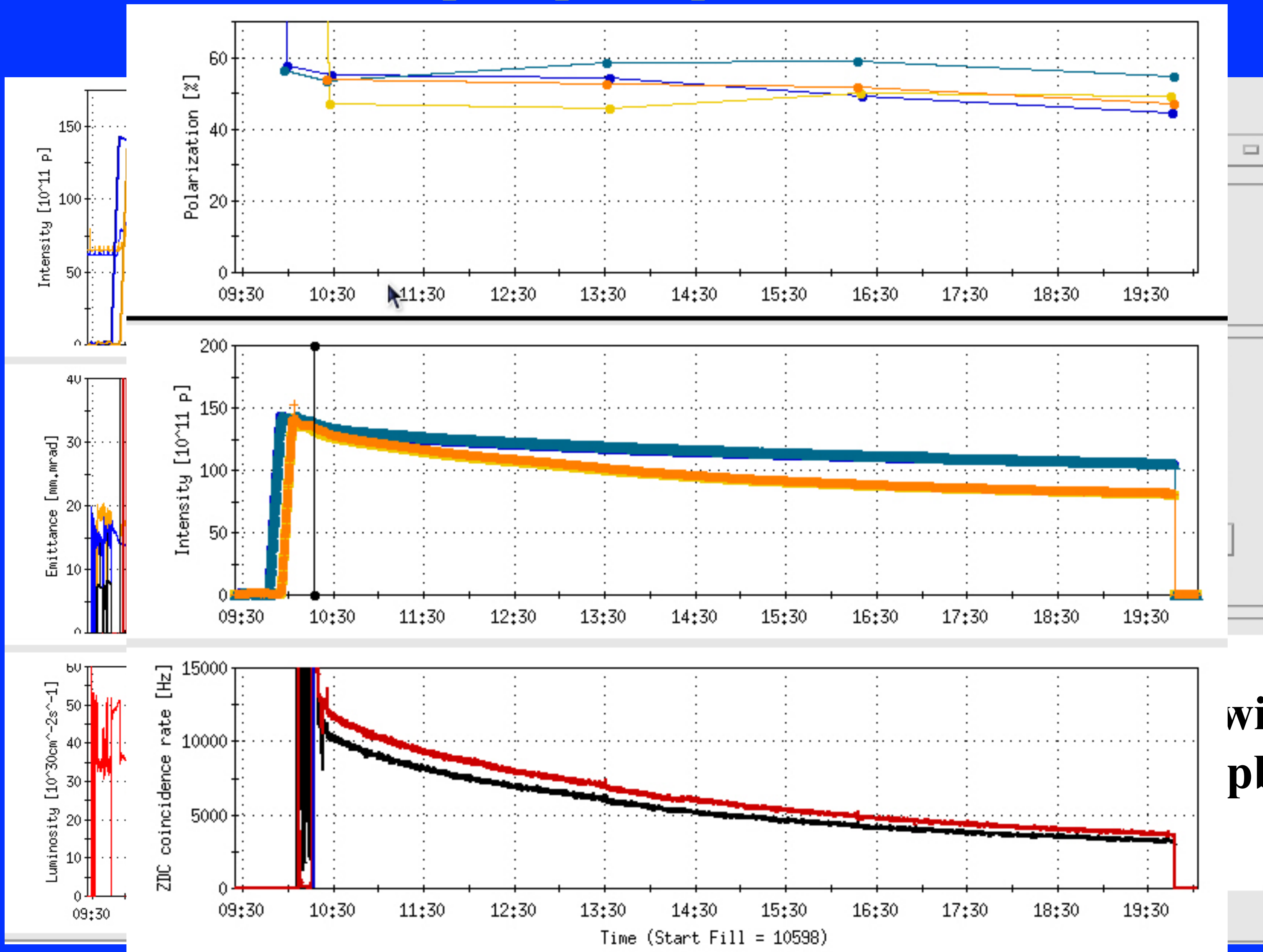
Areas where upgrades are needed/desirable:

- Beam dump
  - Q7 quenches with normal dump
- Spin flipper
- Intensity limits on ramp
  - Limits from e-cloud at beginning of ramp
  - Limits from beam losses
    (flattop-ramp ps switchover, beta-squeeze, …)
- Global 10 Hz orbit correction system
  - Would allow operation at near integer working point
- 24 h vertical orbit motion
- Overall reliability

Run-9 100 GeV p↑-p↑ operation (Run Coordinator: C. Montag)



Run-9 100 GeV p↑-p↑ operation (Run Coordinator: C.



with

pb^{-1}

Run-9 100 GeV p-p operation (Run Coordinator: C. Montag)

Major accomplishments and events

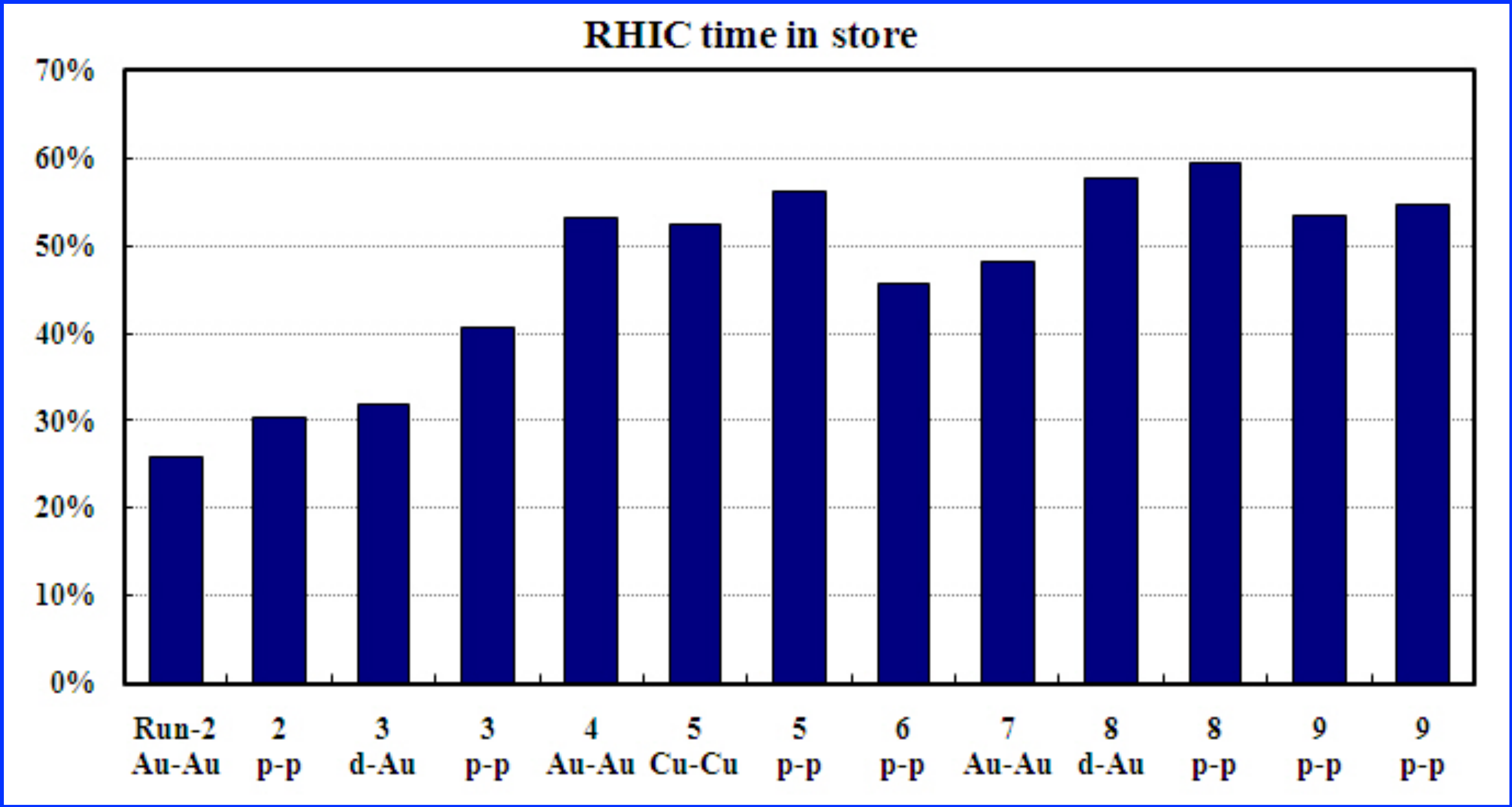
- Setup in less than 1 weeks
  - reached Run-8 performance in less than 1 week in physics
- β^* reduction from 1.0 m to 0.7 m
  - may be too small now (beam lifetime)

Run-9 100 GeV p↑-p↑ operation (Run Coordinator: C. Montag)

Remaining challenges

- Beam lifetime in store ~15 h (~50 h in Run-8)
- Higher peak luminosities than in Run-8 do not translate into higher average luminosity
- Total intensity limit in Yellow
  (no bunch intensity limit up to $2\text{x}10^{11}$)
- Polarization and emittance with high bunch intensities
- Reliability

Run-9 time in store (as fraction of calendar time)



Overall reliability in Run-9 not as good as in previous year.

Luminosity and polarization goals

Parameter	unit	**Achieved**	**Enhanced design**	**Next L upgrade**
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Projections

RHIC Collider Projections (FY2009 – FY2013)

W. Fischer, T. Roser
M. Bai, K. Brown, H. Huang, and C. Montag

Last update: 29 December 2008

This note discusses in Part I the running modes for the RHIC Run-9 (FY2009) operating period including constraints from cryogenic cool-down, machine set-up and beam commissioning. In Part II a 5-year outlook is given. This latest update is based on the experience gained during the Run-8 operation, the planned luminosity upgrades in RHIC, and the physics plans for Run-9. We assume a relatively short polarized proton run at 250 GeV beam energy, possibly followed by a longer polarized proton run at 100 GeV beam energy.

In the following all quoted luminosities are delivered luminosities. Recorded luminosities are smaller due to vertex cuts, detector uptime, and other considerations. An estimate of how much of the delivered luminosity can be recorded must be made by every experiment individually.

Part I – Run-9 Projections

Cryogenic operation – After the shutdown the two RHIC rings will be at room temperature. After bringing the rings to liquid nitrogen temperature, 1 ½ week will be required to cool them down to 4 K. At the end of the run, ½ a week of refrigerator operation is required for the

http://www.cadops.bnl.gov/RHIC/Runs/RhicProjections.pdf

Run-11 p[illegible]-p[illegible] projections

Since max projections were not reached for neither 250 GeV nor 100 GeV so far, maintain min and max projections for Run-11 so far

Run-11 p-p projections 250 GeV

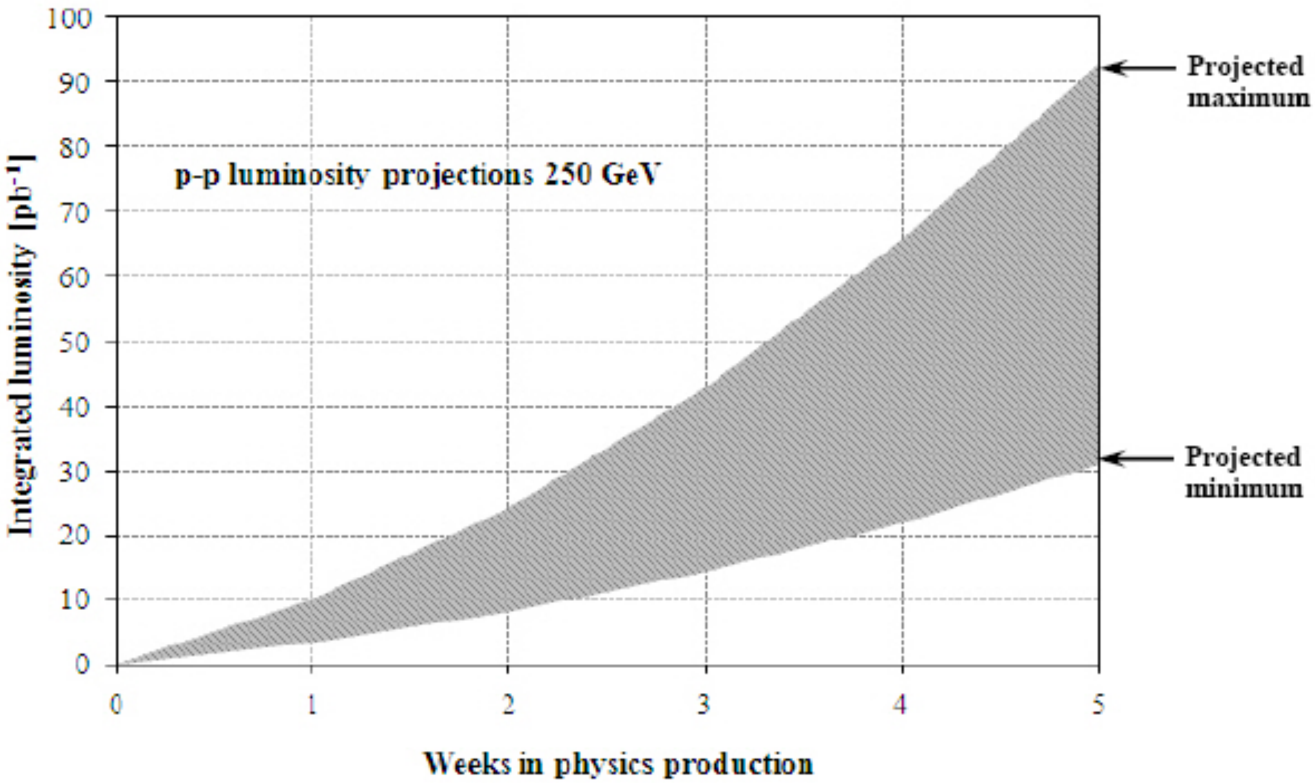


Figure 2: Projected minimum and maximum integrated luminosities for polarized proton collisions at 250 GeV beam energy, assuming linear weekly luminosity ramp-up in 8 weeks. An average store polarization between 50 and 60% is expected.

Should aim for 50% polarization, must do near-integer tune test in Run-9.

Run-11 p-p projections 100 GeV

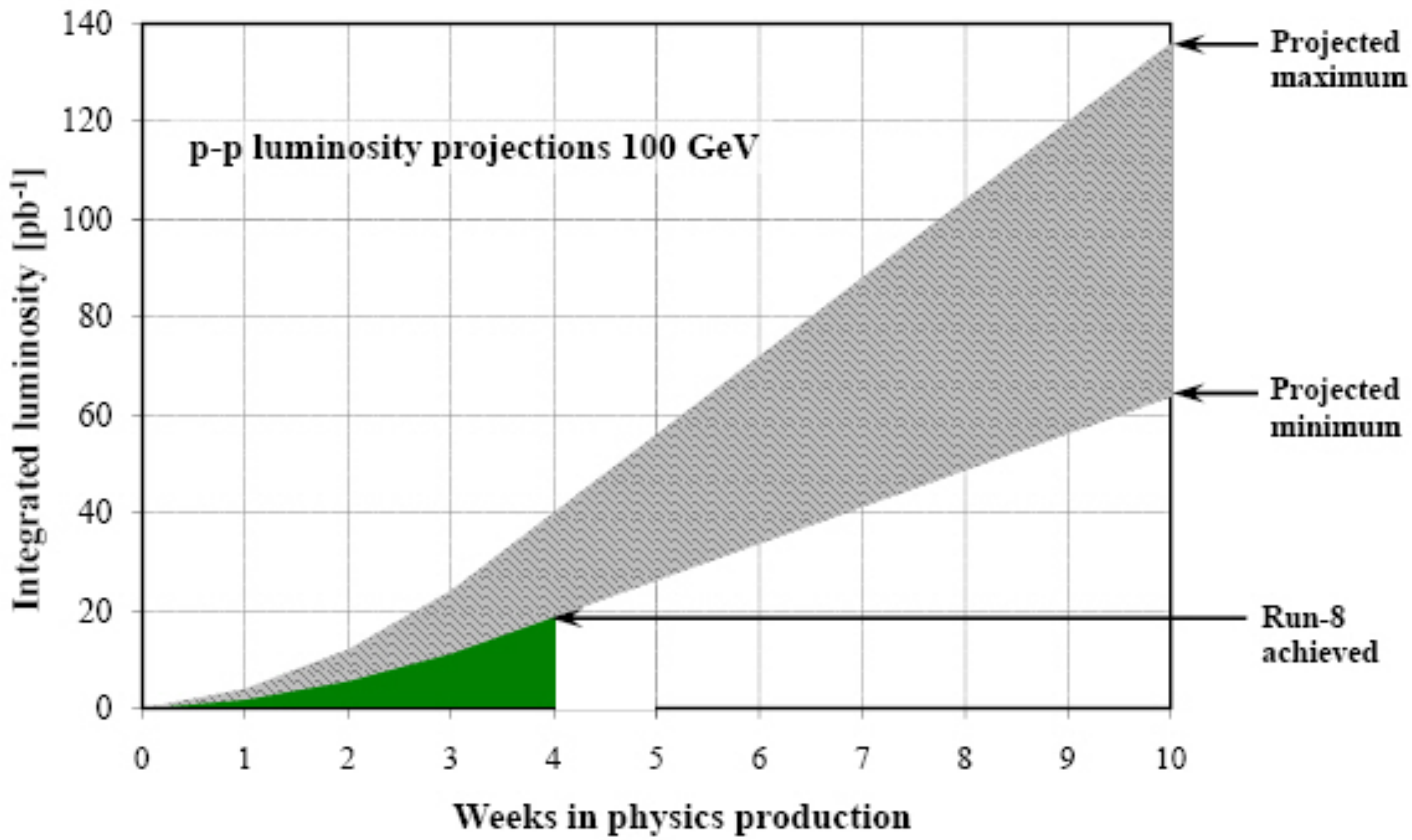


Figure 3: Projected minimum and maximum integrated luminosities for polarized proton collisions at 100 GeV beam energy, assuming linear weekly luminosity ramp-up in 4 weeks. An average store polarization between 50 and 60% is expected.

Run-10 Au-Au projections

Expect:

- Long Run-10 (~30 cryo weeks)
- Emphasis (perhaps all) Au-Au
- Largest fraction of time at 100 GeV/nucleon
- Running below injection energy

Run coordinator Au-Au: Kevin Brown

Low energy Au-Au: Todd Satogata

Run-10 Au-Au projections

Main limits: IBS, transition instability

Improvements for Au-Au compared to Run-8:

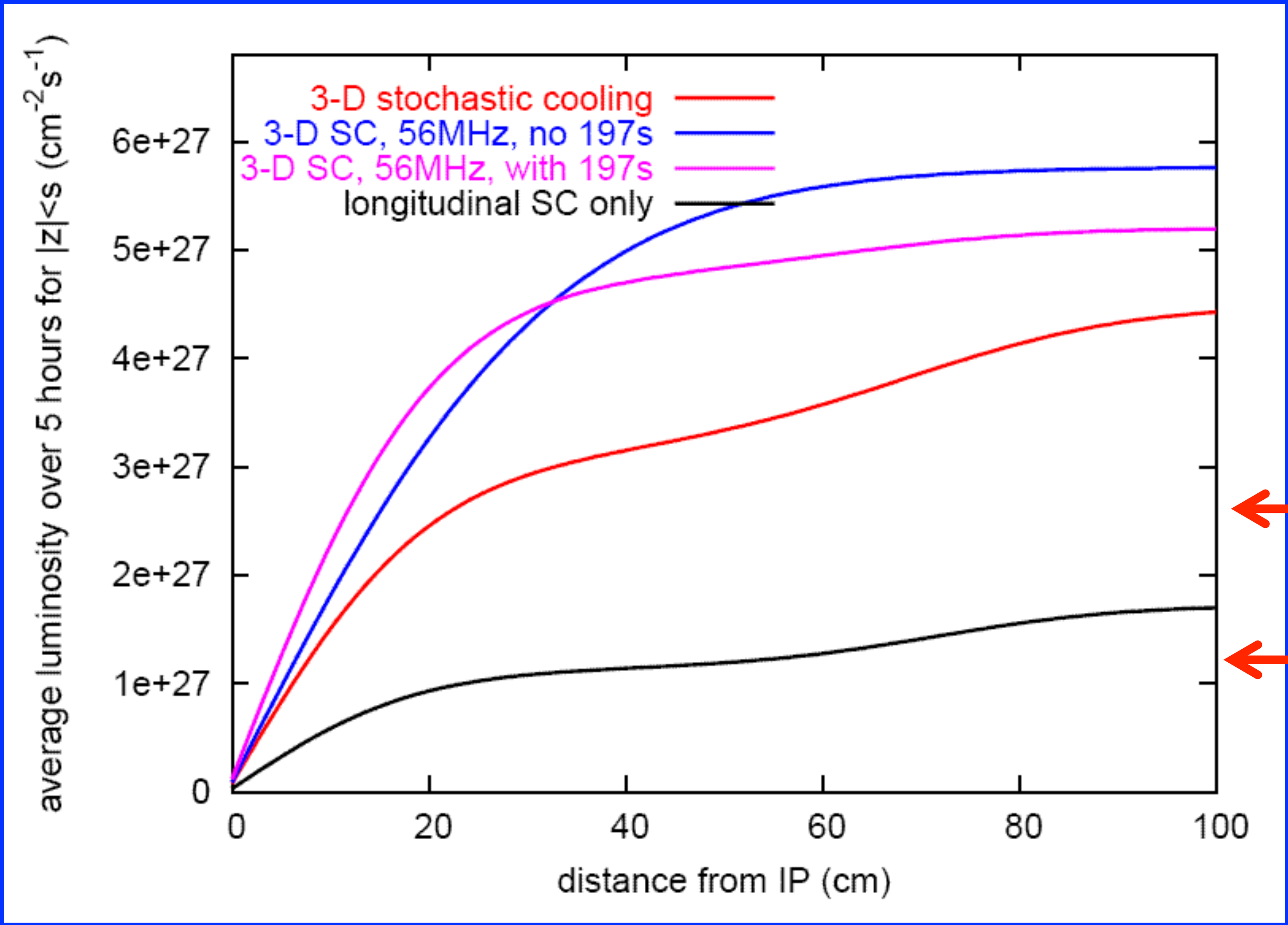
- $\beta^* = 0.5$ m

  reached IBS lattice in both rings, but transition crossing at the same time (still under discussion)

- Stochastic cooling:
  - Yellow longitudinal upgraded (radio link)
  - Blue longitudinal (first operational use)
  - Yellow and Blue vertical (first operational use)

Should approximately double the average luminosity.

Stochastic cooling & 56 MHz SRF – luminosity increase



Run-10 expectation

Achieved in Run-7

Yellow longitudinal stochastic cooling only.

Calculation by M. Blaskiewicz.

Run-10 Au-Au projections

RHIC Run 10 Au-Au Start-up Plan

K.A.Brown*
C-AD Dept., BNL, Upton, NY 11973-5000

I. OVERVIEW

RHIC Run 10 will begin with 100 GeV Au-Au operations, with cooldown to 4.5 K starting in mid-November. The main focus for this run will be the commissioning and development of Stochastic cooling. Both rings will have longitudinal stochastic cooling and the plan is to have vertical transverse cooling installed in both rings, although at a minimum the Yellow ring will be ready to develop vertical transverse cooling.

Another area of improvement will be the use of IBS (intra-beam scattering) suppression lattices. There are two options being looked into. Either both rings will have 93 degree IBS suppression lattices or one ring will have the normal 83 degree lattice and the other ring will have a 93 degree suppression lattice. At issue is the trade off between whether it is better to have separate γ_{tr} times for the two rings or to be able to get to a smaller β^*. Both lattices meet the requirements for transverse stochastic cooling.

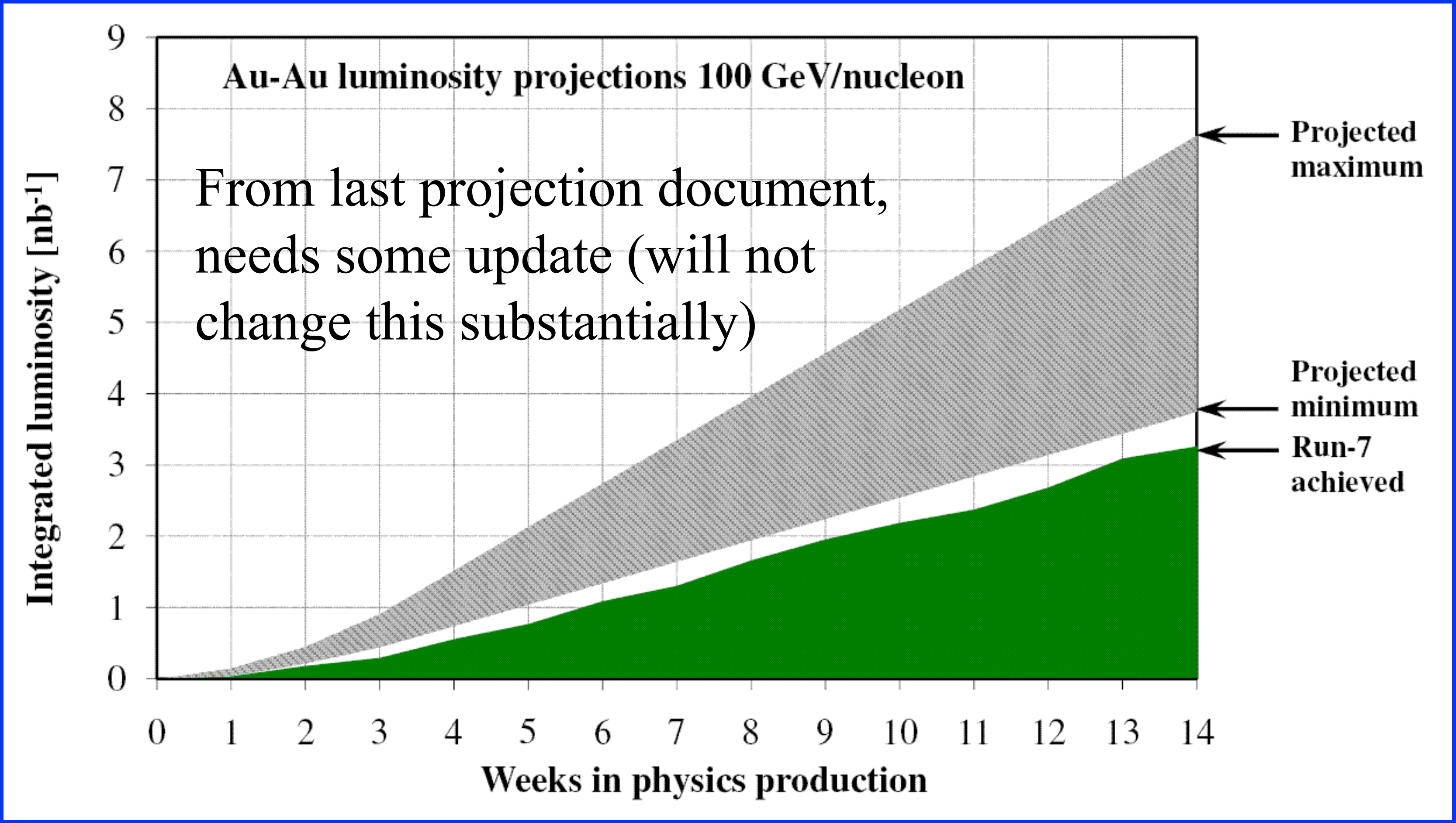
Having one lattice that is at the normal 83 degree phase advance gives betatron tunes of (28.23, 29.22). A second lattice that is at 93 degrees will have tunes that are 3 units higher. This would separate the γ_{tr} by 3 units, but there would be IBS suppression in just one ring. It was found during the d-Au run that having separate γ_{tr} times stabilized the transition jumps. This has the advantage of improving the ramp stability and reducing any resulting emittance blow-up. The disadvantage is that the achievable β^* is larger for the 83 degree lattice (smallest to about 60 to 65 cm).

Having both lattices at 93 degrees will reduce IBS and allow for smaller β^* (to 50 cm). The disadvantage is the transition jumps will occur simultaneously. Previous Au-Au runs always operated with simultaneous transition jumps, but with the normal 83 degree lattices.

Some assumptions that I have used in the planning.

1. Cooldown to 4K can be done in 5 days.
2. We don't need fancy gaps, so the push will be to get to 111 bunches.
3. Scrubbing? I am told it won't help for Au-Au run.
4. Incremental improvements work, but we need to carefully schedule and plan jobs.

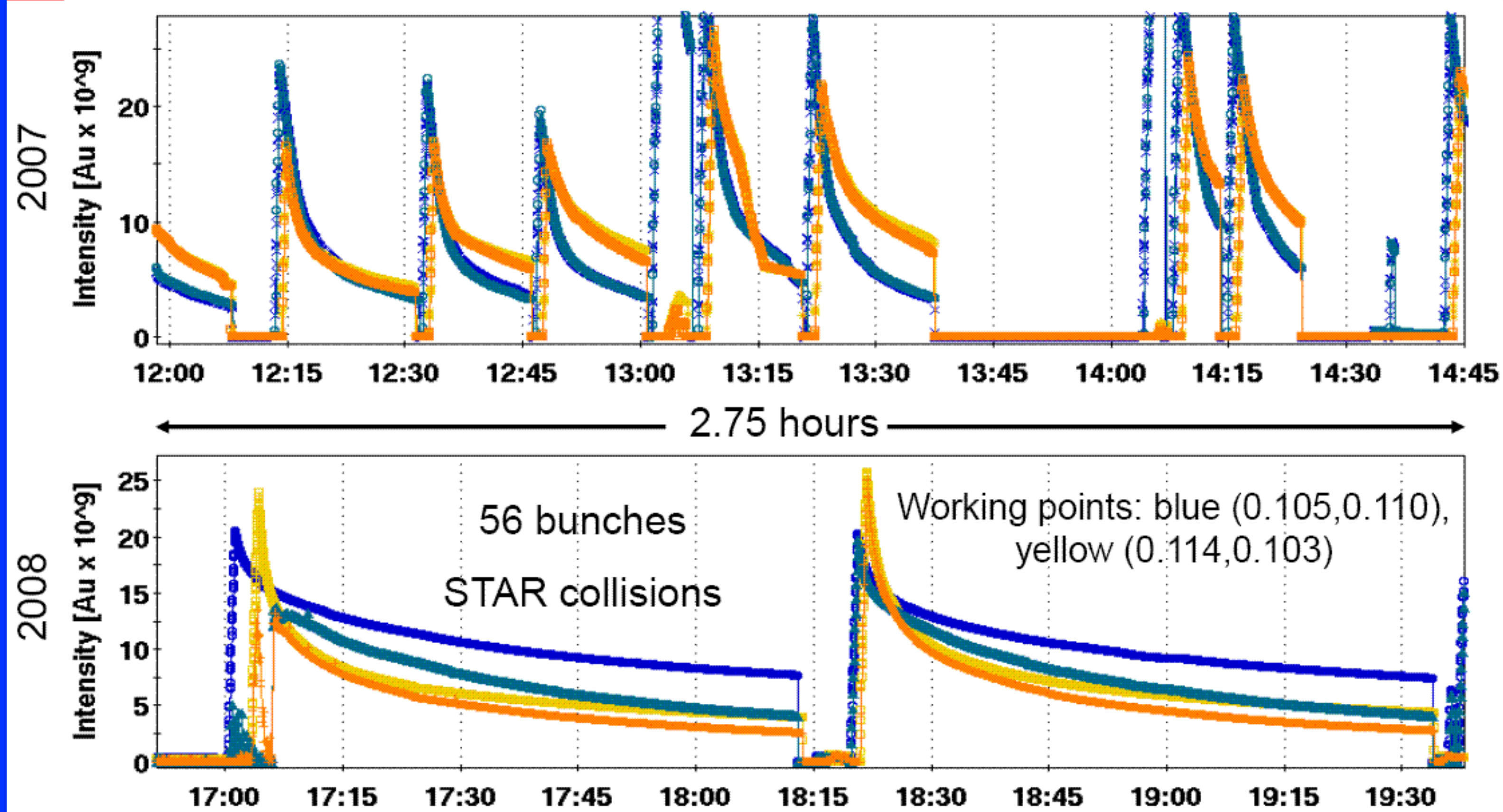
Run-10 projections Au-Au



Expect about 6-8 weeks to reach peak performance.

Run-8 low energy Au-Au operation

2007 vs 2008 Low Energy Test: Beam Lifetime



- 2008 blue beam lifetime: 3.5 minutes (fast), 50 minutes (slow)
- Sextupole reversal and elimination of octupoles clearly helped beam lifetime
- Injection efficiency and yellow beam lifetime can clearly benefit from further tuning

[T. Satogata, RHIC Retreat 2008]

Run-8 low energy Au-Au operation

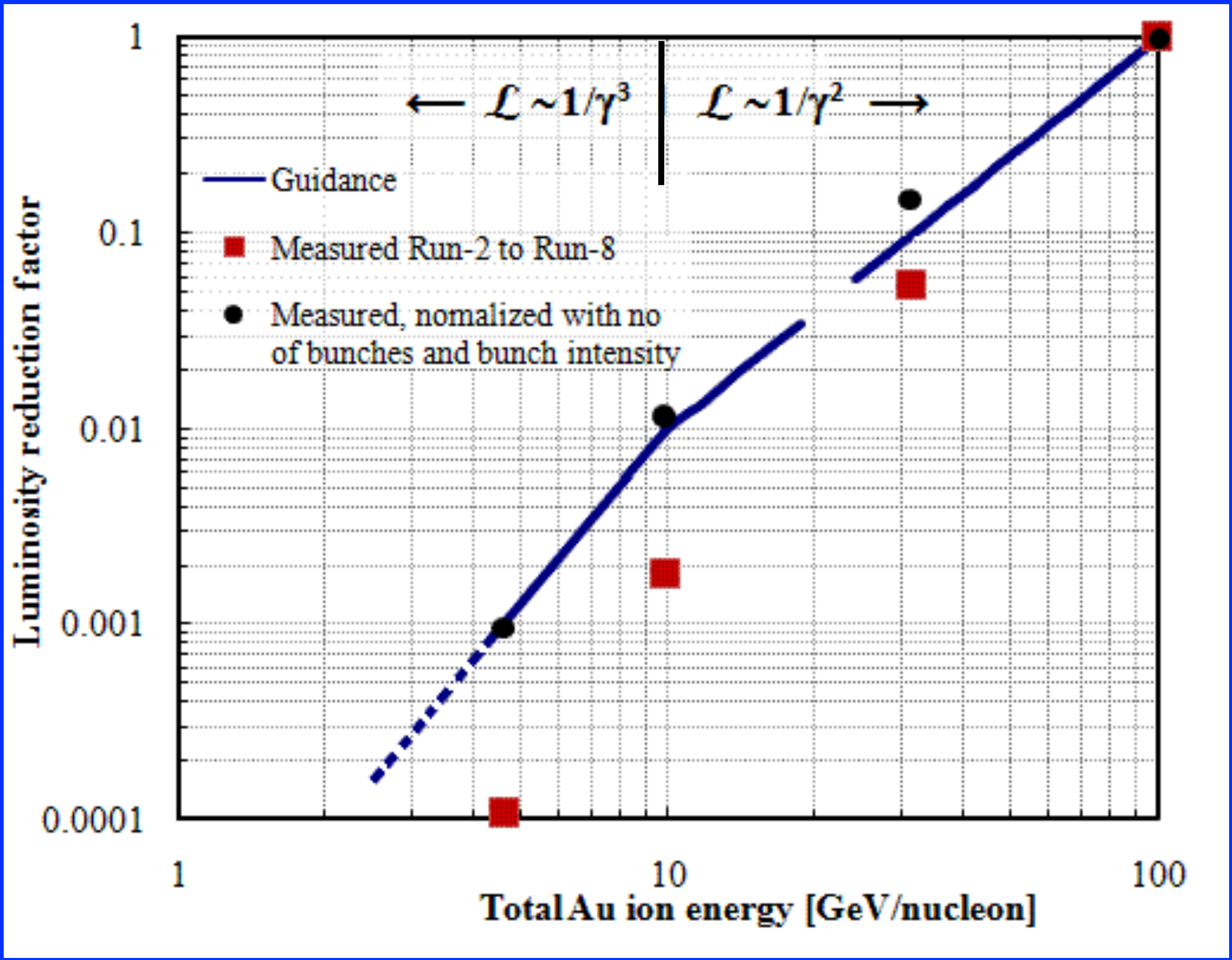
4.6 GeV/nucleon

- $L_{max} = 3.5 \times 10^{23} cm^{-2}s^{-1}$, $L_{avg} = 1.2 \times 10^{23} cm^{-2}s^{-1}$
- With $h = f_{rf}/f_{rev} = 366$ not possible to simultaneously give collisions to both STAR and PENIX
- Should be possible to increase bunch intensity and number of bunches each by about a factor 2

2.5 GeV/nucleon

- Stored some beam in Yellow (Blue ps failure prevented injection)
- Only 10% injection efficiency, very nonlinear lattice, orbit corrections very difficult, bunched beam lifetime only second
- Need to obtain better magnetic field error data (possibly new cold measurements in SMD), nonlinear online model for orbit correction

Luminosity scaling with energy



Low energy Au-Au operation – allowed energies

- Need $h = f_{rf}/f_{rev}$ divisible by 3 for any experiment to operate
- Need h divisible by 9 for both experiments to operate

h divisible by 9 → (360)

Run-8 → (366)

h	Allowed $\sqrt{s_{NN}}$ [GeV]	h	Allowed $\sqrt{s_{NN}}$ [GeV]
360	16.7-107	375	6.3-6.7
363	11.4-15.0	378	5.8-6.1
366	9.0-10.5	381	5.45-5.7
369	7.7-8.6	384	5.15-5.38
372	6.9-7.4	387	4.91-5.1

← Run-8 (387)

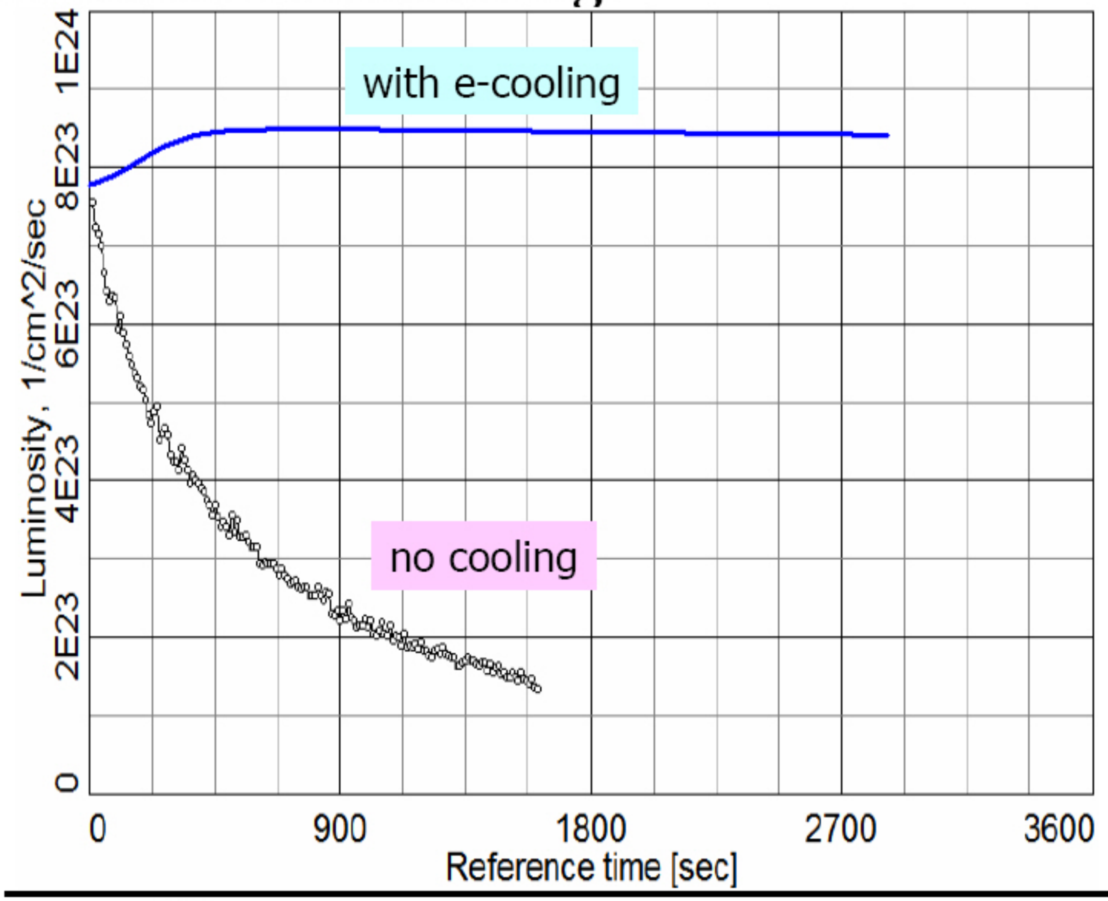
[T. Satogata, RHIC Retreat 2008, BNL C-A/AP/309 (2008)]

Low energy Au-Au operation – upgrade

A. Fedotov et al. investigate electron cooling for low energies
- use of Fermilab Pelletron DC electron beam

Low energy Au-Au operation – upgrade

γ=2.7 – lowest energy point. Luminosity with and without electron cooling.



A. Fedotov, 14 May 2009

Low energy Au-Au operation – upgrade

γ=6.6 – higher energy point
Luminosity with and without electron cooling.

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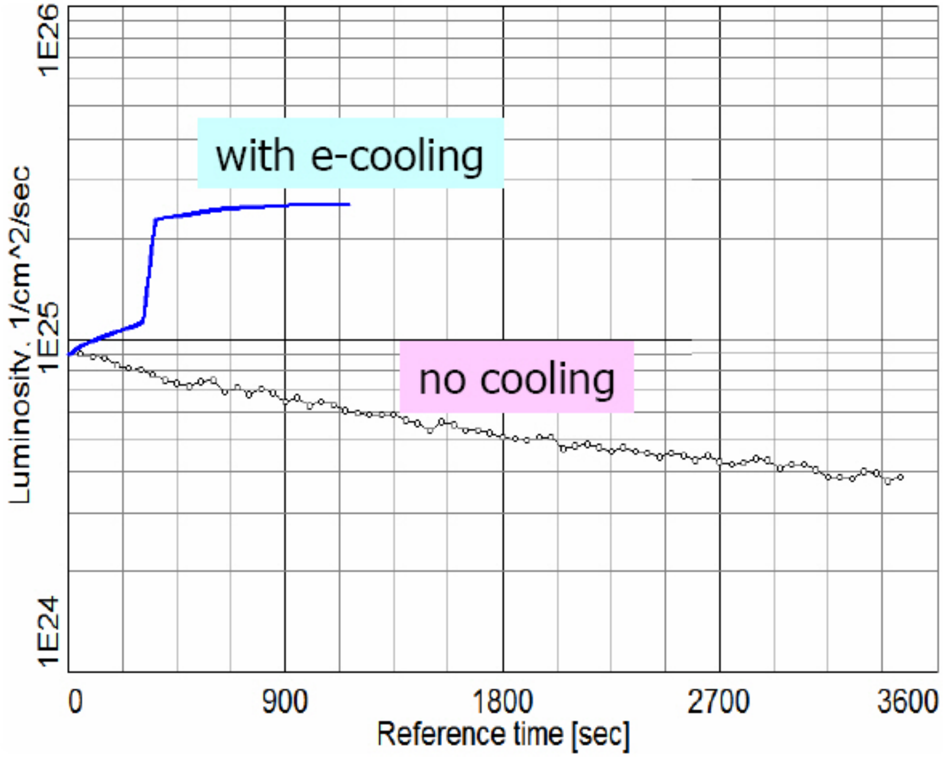

At higher energies, by providing sufficient cooling we can cool emittance of ion beam until space-charge limit, which in turn allows to decrease β*.

In example shown, electron cooling provides a factor of 6 improvement in integrated luminosity.