Run-8 Accelerator Performance Highlights

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Run-8 Time-Line

- October 26: Start of cooldown.
- November 26: Start of d-Au physics run.
- January 28: End of d-Au run, switch-over to polarized protons.
- February 14: Start of polarized protons physics run.
- March 10: End of polarized protons run, switch-over to low-energy Au-Au.
- March 11: End of Run-8, start warm-up.

d-Au accomplishments during Run-8

- Commissioning of IBS suppression lattice in the Yellow ring, resulting in reduced IBS rates and improved luminosity lifetime.

- β^*-reduction to 0.7 m (from 2 m in d-Au Run-3).

- Automatic periodic (30 min) vertical orbit correction.

- Longitudinal stochastic cooling operational in Yellow ring (commissioned during Run-7).

- Longitudinal quadrupole oscillation damper commissioned in Yellow.

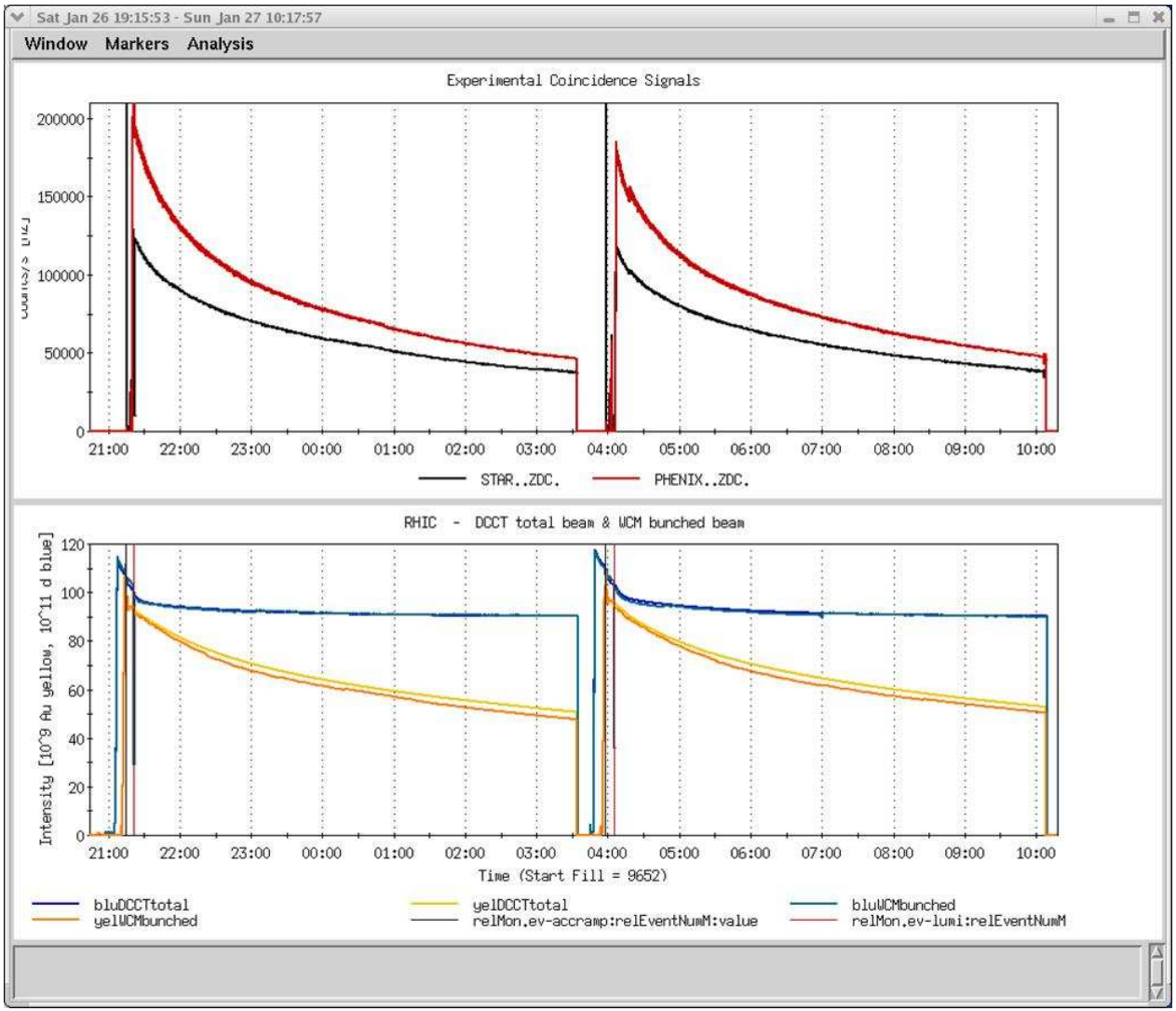
Some d-Au mysteries during Run-8

- Blue transverse emittance significantly increased by an unknown noise source during four consecutive week-ends.

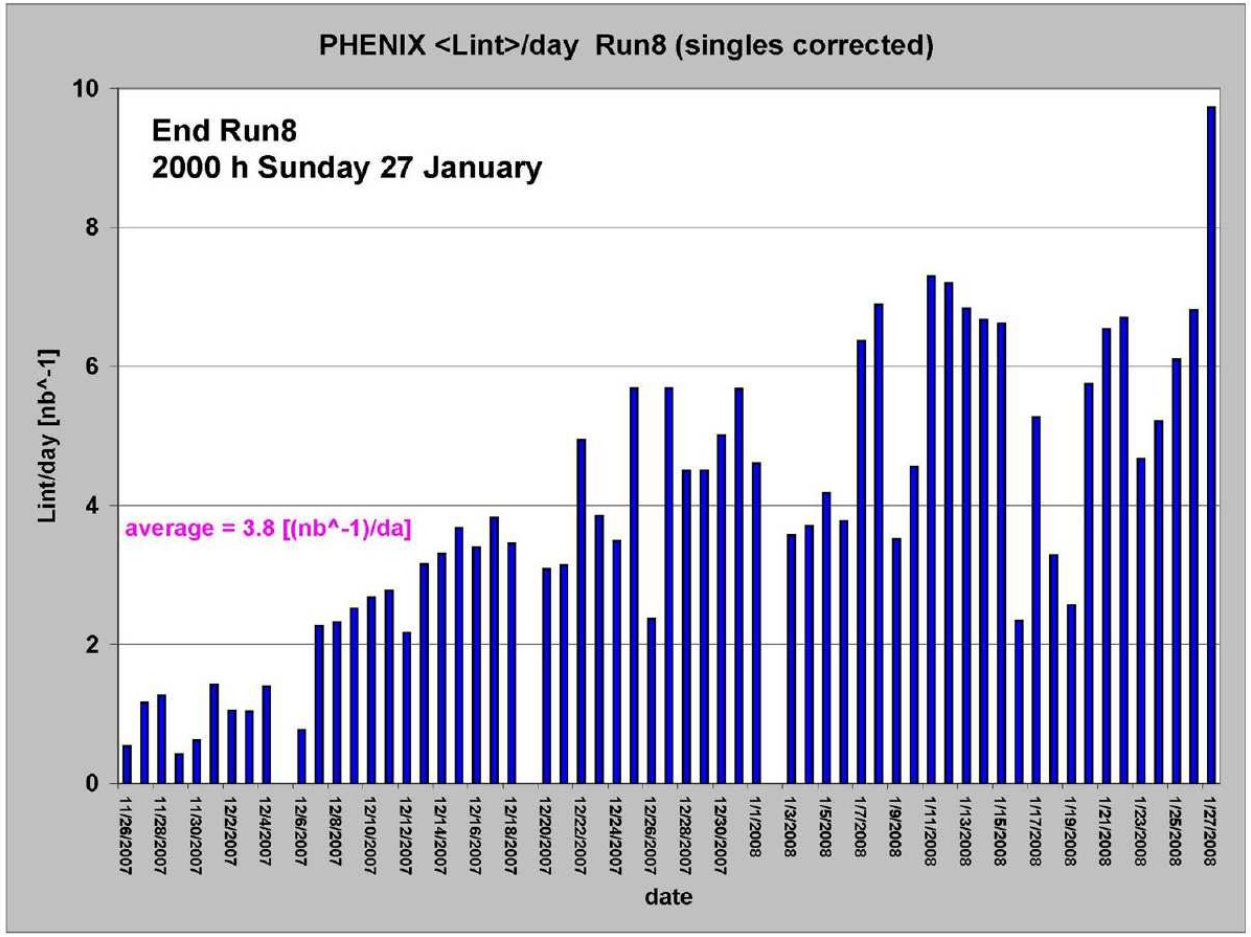
- Inability to accelerate as much gold beam as during Run-7 through transition.

- Yellow (gold) beam lifetime significantly shorter (10 h, d-Au) than during Run-7 (30 h, Au-Au).

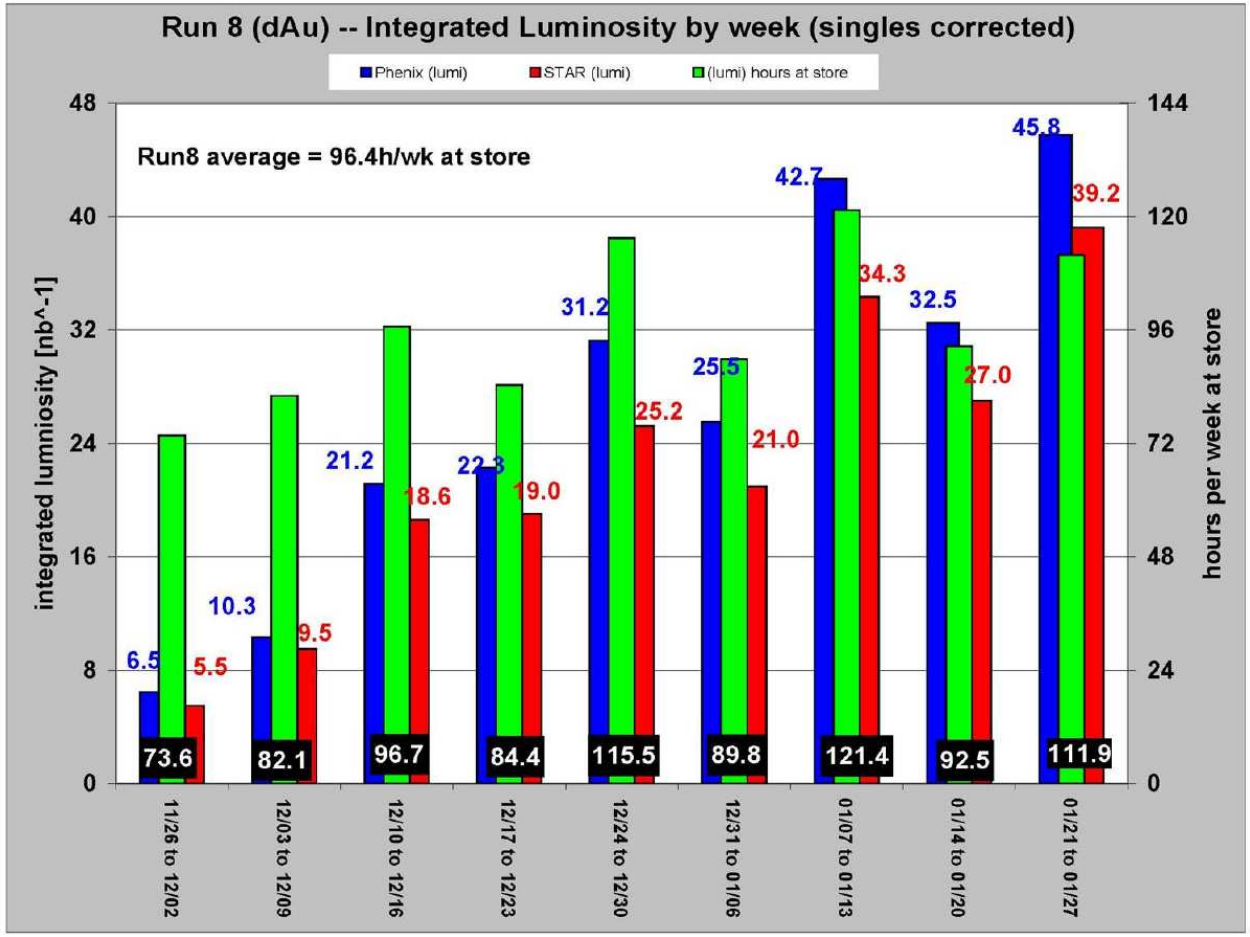
Two exemplary d-Au stores



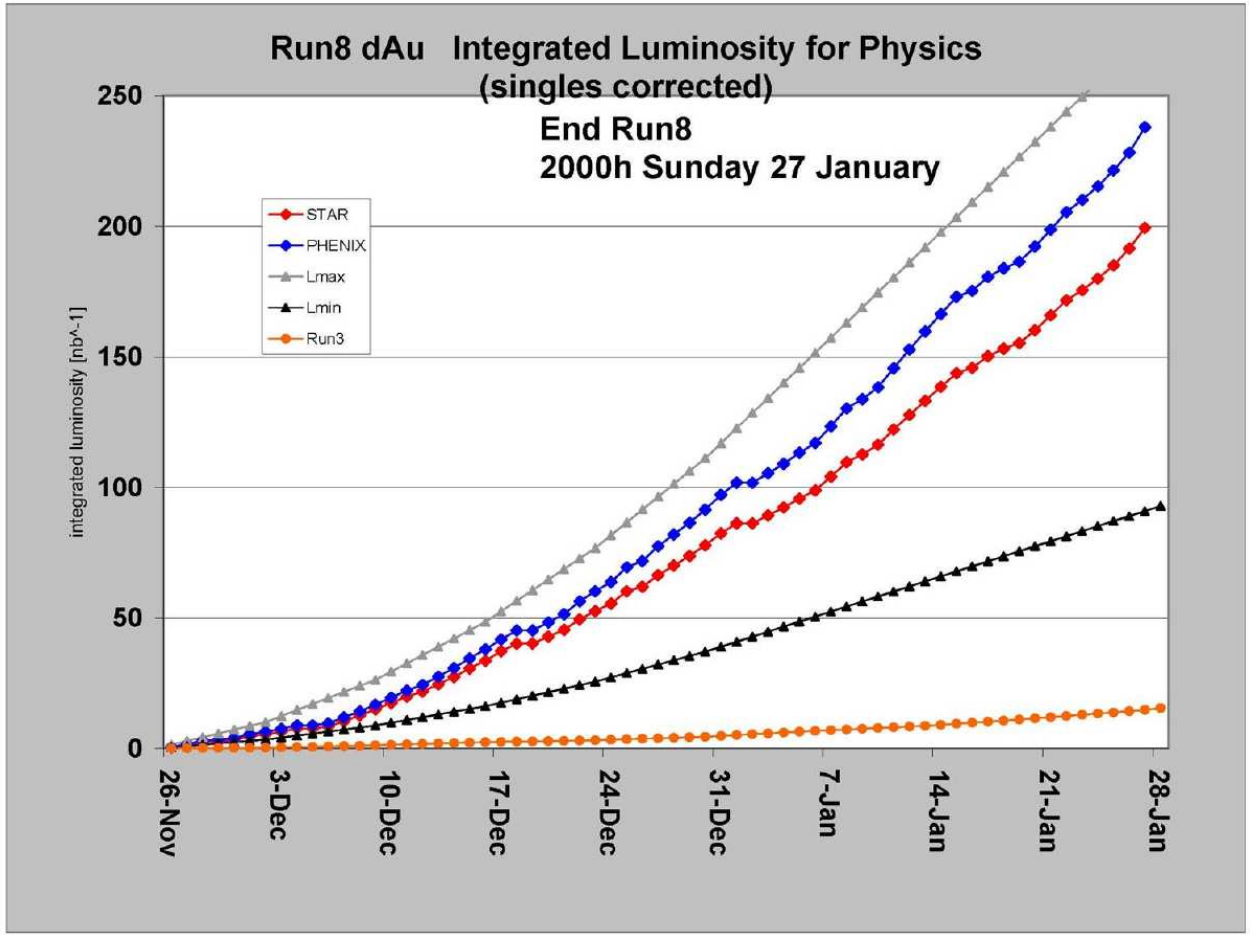
d-Au integrated luminosity by day



d-Au performance by week



d-Au total integrated luminosity



Delivered d-Au luminosity

- STAR: $199\,\mathrm{nb}^{-1}$.
- PHENIX: $238\,\mathrm{nb}^{-1}$.
- Ten times higher delivered luminosity than in Run-3.

d-Au luminosity performance exceeded goals/expectations.
$\rightarrow$ Remaining 6 weeks dedicated to Polarized Protons instead.

Polarized Proton Goals (in a nutshell)

- STAR:
  1. Unpolarized comparison data for d-Au.
  2. Transverse (vertical) spin running.

- PHENIX:
  1. 250 GeV (did not happen).
  2. Transverse (radial) spin running.
  3. Machine development towards higher luminosity.

Goals (cont.)

- RHIC:

  1. Satisfy all customers in terms of physics running.

  2. Machine development towards higher luminosity in Run-9 and beyond.

$\Rightarrow$ High expectations, conflicting goals – and only six weeks of running!

The short, sad life of the near-integer working point

Motivation:

- In Run-6, performance was beam-beam limited. With working points on opposite sides of the diagonal, the beam above the diagonal inevitably suffered.

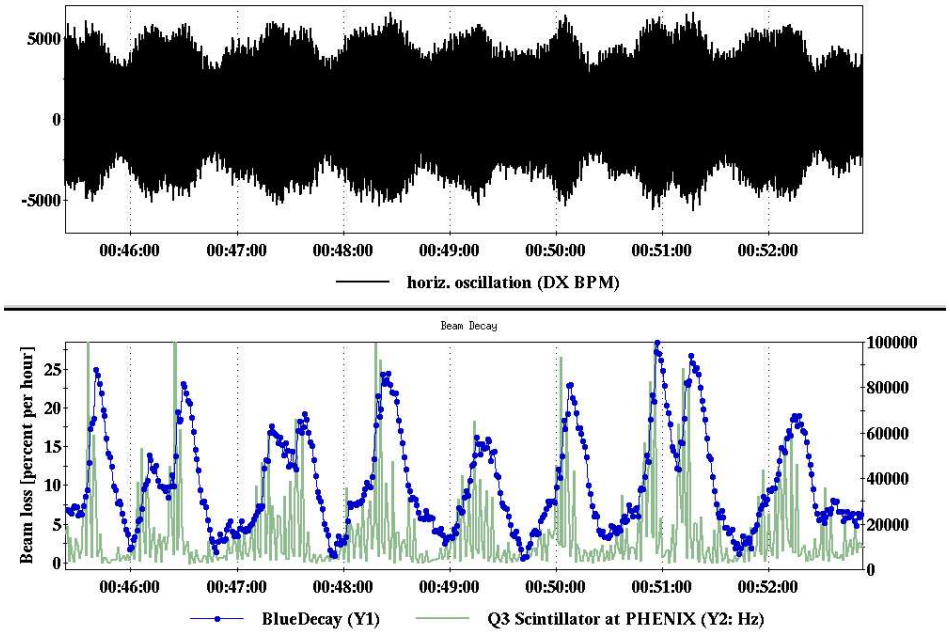
- To overcome this, a new (better) working point was necessary.

- Best candidate: near-integer (.96/.95).

Known challenges:

- β-beat scales as $1/\sin(2\pi Q)$.
- Orbit distortion scales as $1/\sin(\pi Q)$.
- 10 Hz beam-beam offset (= modulated orbit distortion) increases – but we have a dedicated feedback for that.

Blue beam decay and orbit jitter – perfect correlation!



High beam decay causes background – too much for experiments. Abandoned after one week.

Back to Run-6 configuration

- Reloaded pp28 as pp83.
- Two-person shifts for shorter start-up time.
- Colliding beams within 24 hours!
- Increased injected bunch intensity up to 1.84e11 (Blue)/ 1.76e11 (Yellow).
- No hard beam-beam limit observed. Both beams are below the diagonal.

- RHIC ramp is an "intensity filter" – as in Run-6.

- Higher beam-beam parameter needs to come from smaller emittances.

- Yellow injection efficiency deteriorates towards the end of the run – X/Y-arcs never get enough attention during start-up.

- Need faster feedback on lumi (Vernier scan analysis).

Polarization

- Polarization was significantly lower than in Run-6.
- AGS performance lower than in Run-6. Initially injection on-the-fly, later returned to Run-6 configuration to improve performance.
- Poor Yellow polarization transmission (≈ 75 percent).
- Insufficient time to really diagnose the problem - ramp polarization measurements, chromaticity measurements require a significant amount of time, which time is extremely precious during a short run.

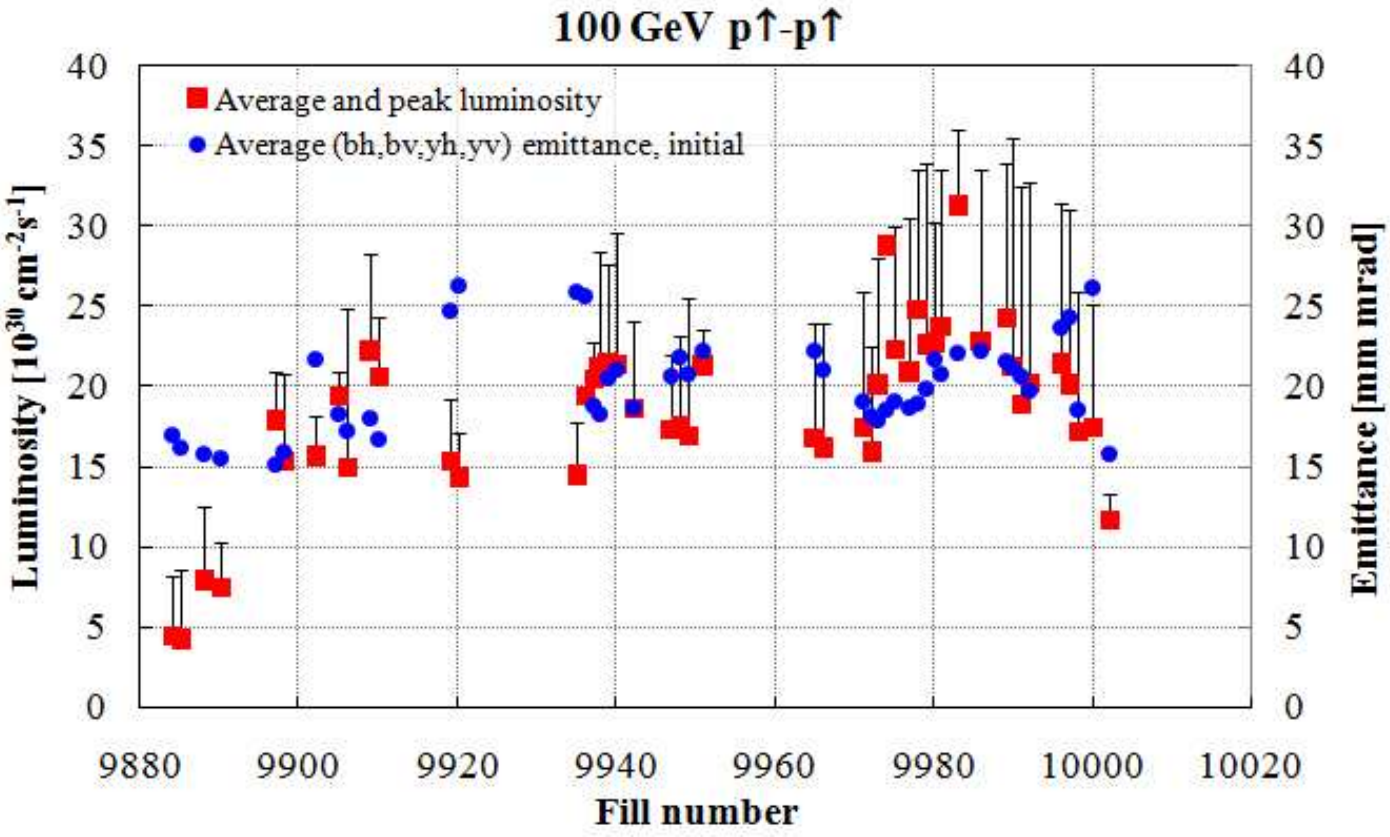
- Due to the short run, there were simply not enough ramps to scan various parameters (tunes, snake currents, snake angles,...) systematically.

- Cross-calibration of various polarimeters (CNI, Jet, Experiments, AGS) needed to detect polarization losses early.

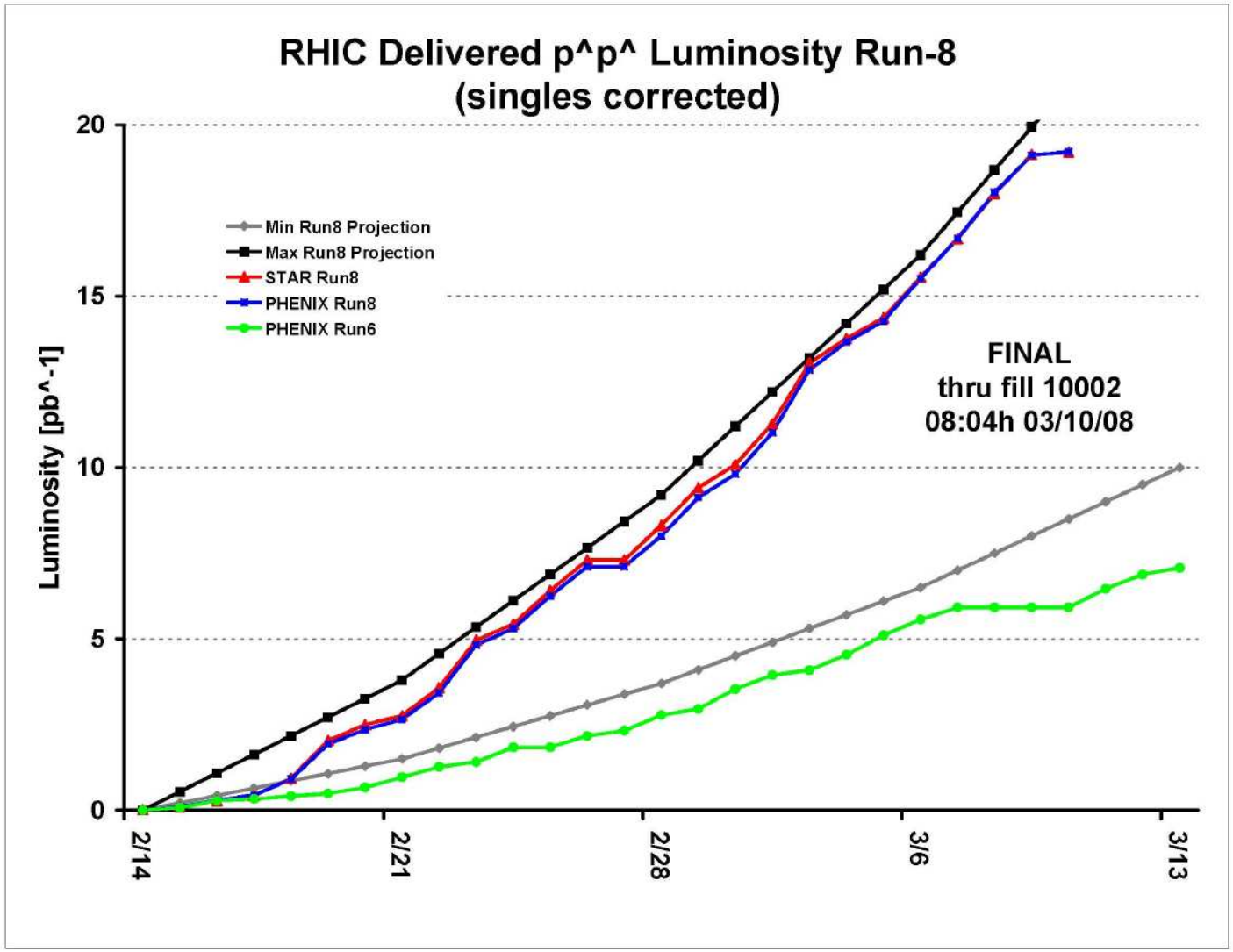
- Two-beam mode at the Jet should help to get results much faster due to simultaneous measurement of both beams.

β^*-squeeze

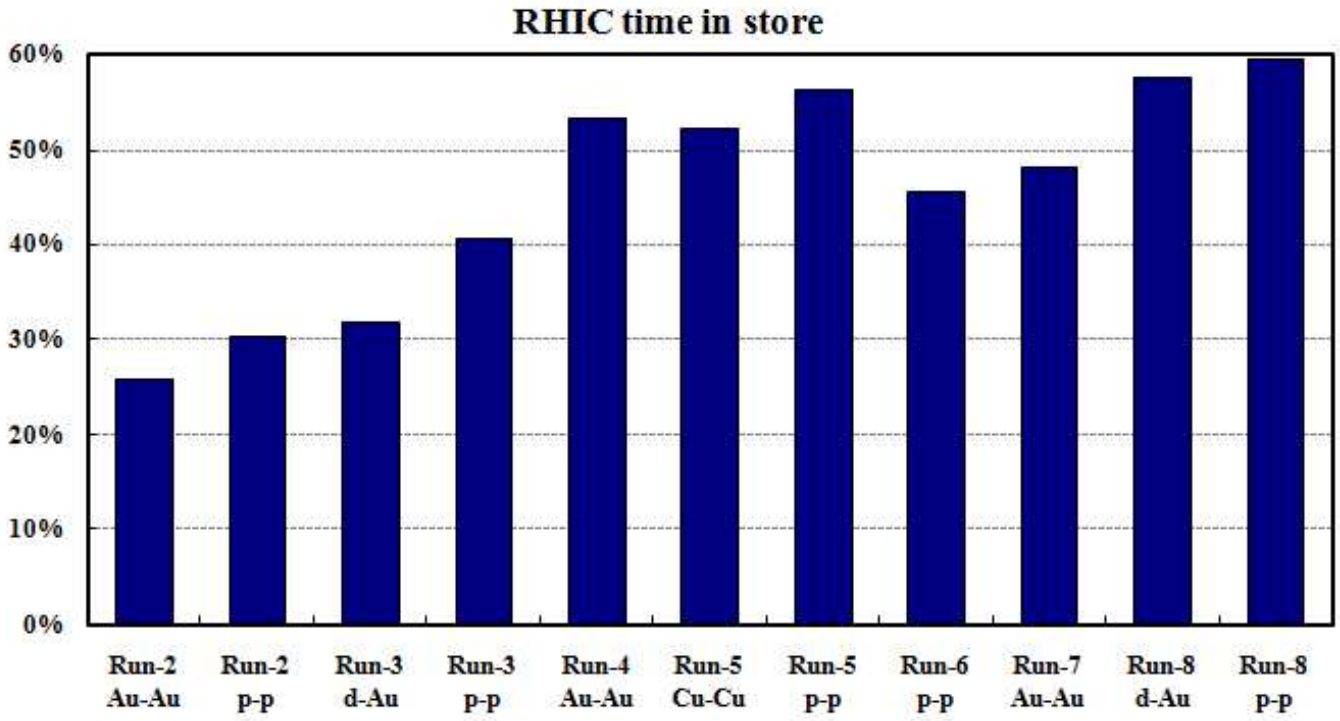
- Several attempts during APEX and Machine Development to squeeze to $\beta^* = 0.68\,\mathrm{m}$.
- Each and every time, we almost made it operational – but not quite. Reasons: Lack of time, human error,...
- Achieved so far: 56 bunches at store.
- Backgrounds are as low as for $\beta^* = 1.0\,\mathrm{m}$.
- Lifetime at store requires nonlinear chromaticity correction.



Courtesy Wolfram Fischer



Courtesy Peter Ingrassia



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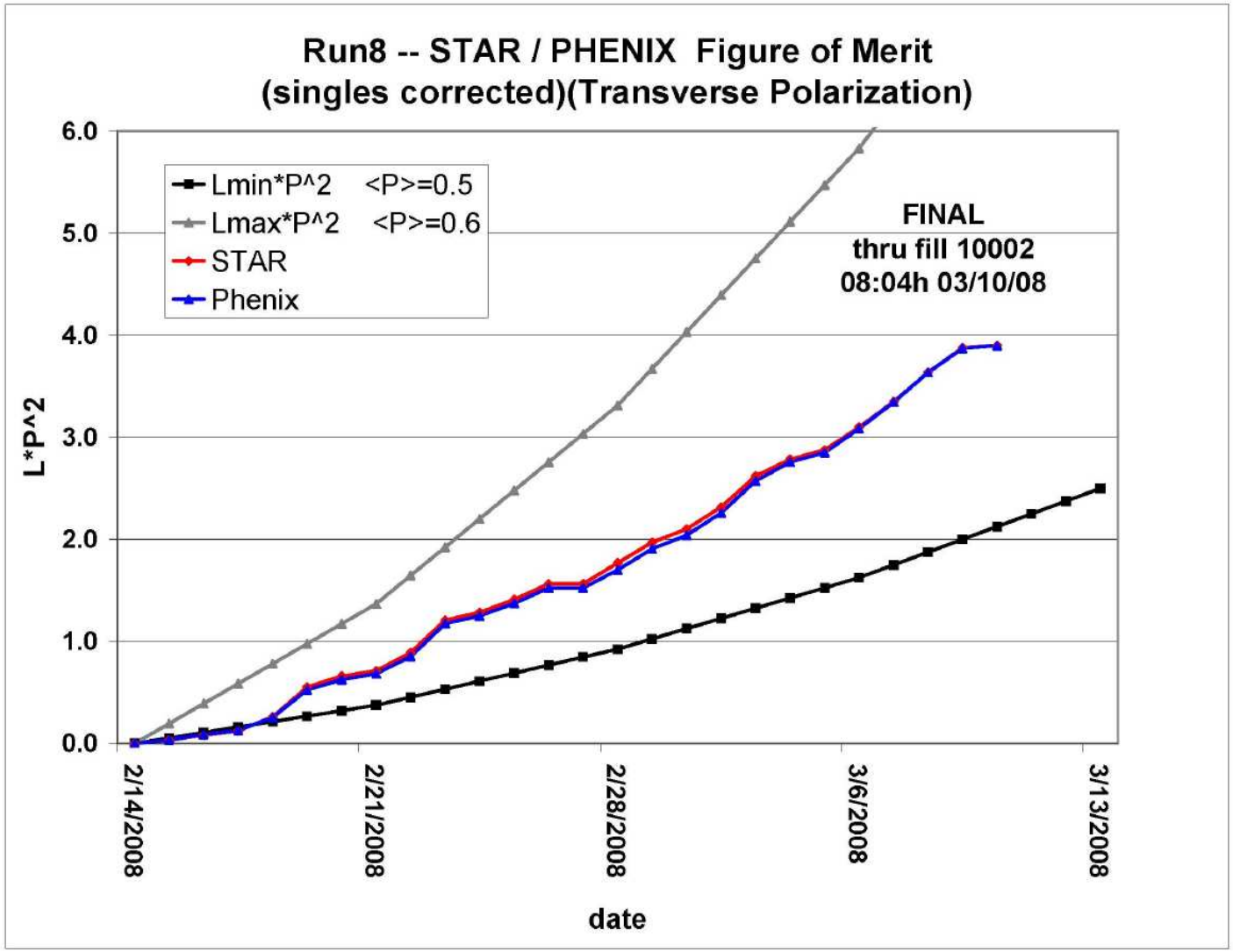

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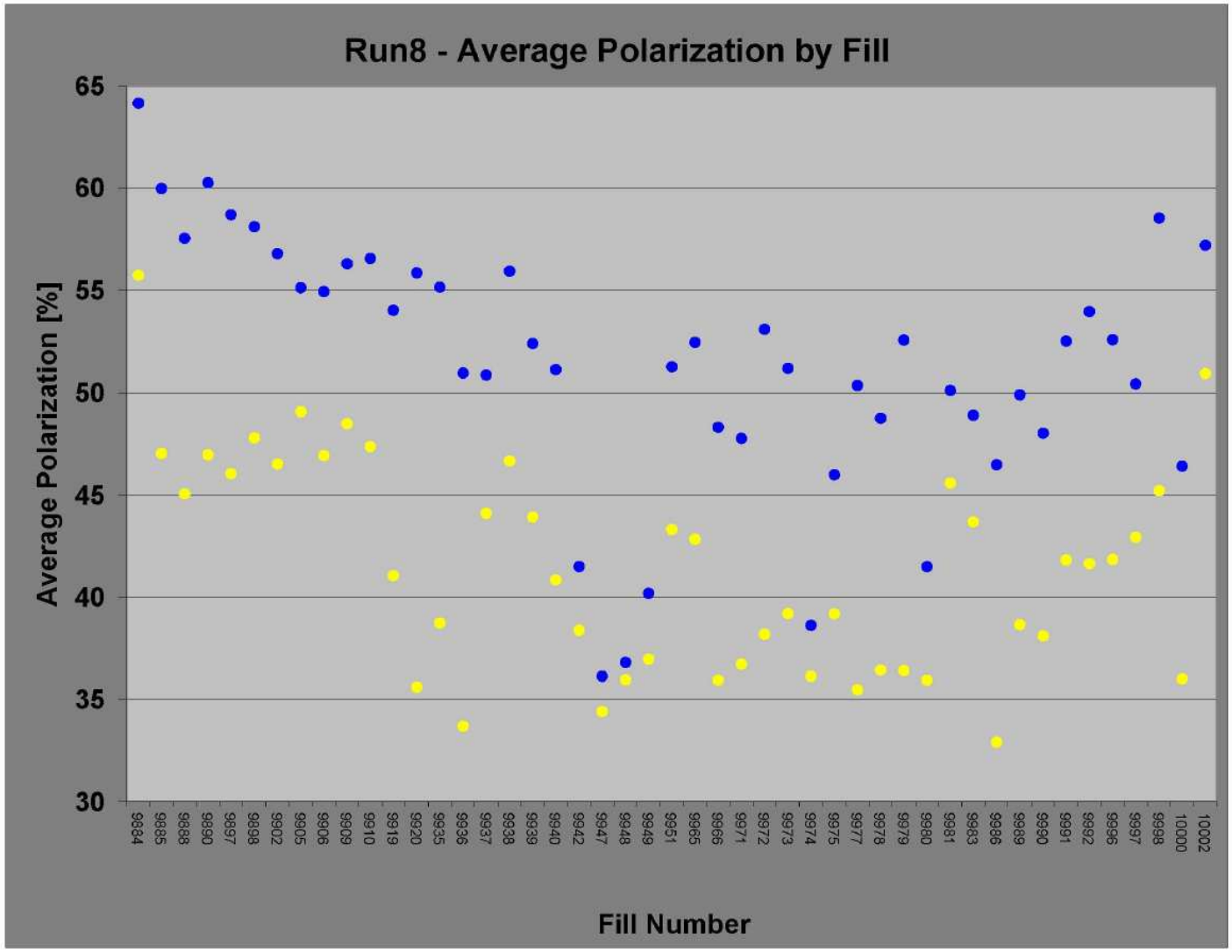
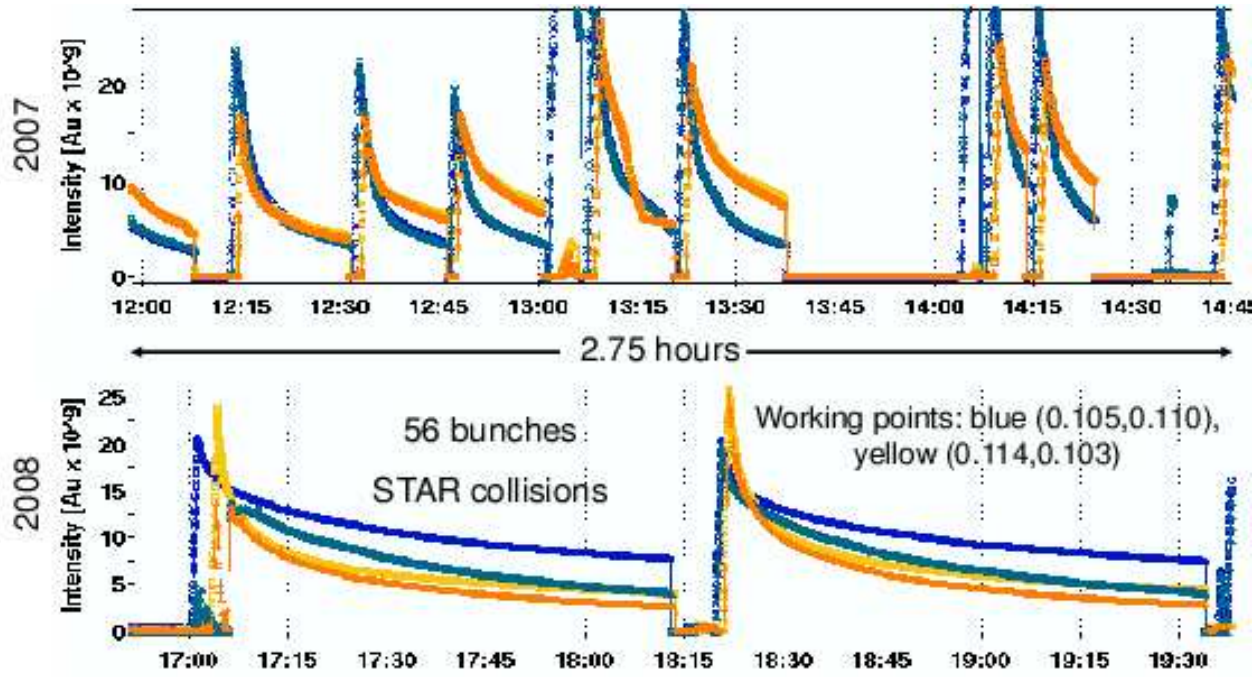


Courtesy Peter Ingrassia

Low-energy Au-Au

- Two different energies, $\sqrt{s} = 9\,\text{GeV}$ and $\sqrt{s} = 5\,\text{GeV}$.
- Different harmonic numbers due to limited tunability of RHIC RF: $h = 366$ at 9 GeV, $h = 387$ at 5 GeV.
- Defocusing sextupoles at opposite polarity to compensate dipole b_2.

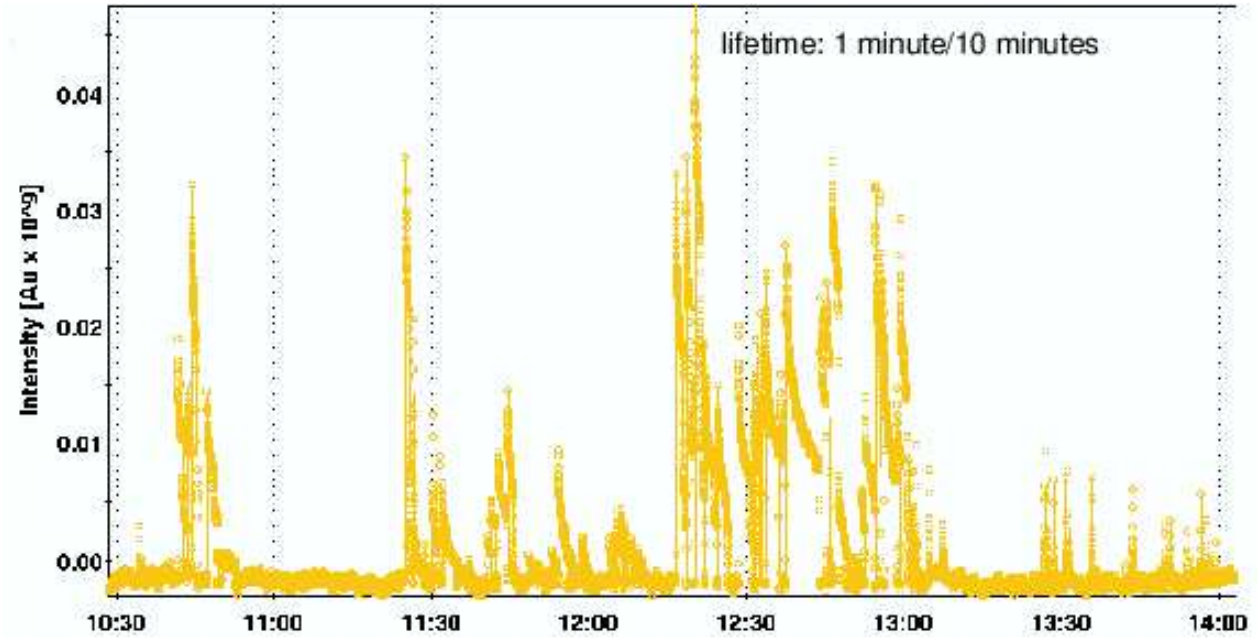
Beam lifetimes at $\sqrt{s} = 9\,\mathrm{GeV}$



- 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

Beam activity at $\sqrt{s} = 5\,\mathrm{GeV}$

Blue ring unavailable due to power supply failure



- Bunched beam signal in BPMs never exceeded 20 turns (usually 3-5)
- Injection efficiencies of about 10%; orbit correction hardly worked at all
- Very nonlinear lattice; need to include in transfer functions and model

Conclusion

- The d-Au run was a great success, exceeding luminosity goals.
- Due to this fantastic performance, the d-Au run was cut short to allow for six weeks of polarized protons operations.
- After two years, it was certainly important to run protons at all.
- Goals on delivered polarized protons luminosity and FOM were met according to projections. However, PHENIX did not get radial polarization.

- Time in store reached a new record: $(60 - \epsilon)$ percent for polarized protons.

- However, six weeks are too short to make real progress.

- β^*-squeeze was an important development towards higher proton luminosity in Run-9.

- The low-energy Au-Au run was very successful. We did not only learn a lot about the machine, but were actually able to deliver good physics data at $\sqrt{s} = 9\,\mathrm{GeV}$.

- At $\sqrt{s} = 5\,\mathrm{GeV}$, RHIC is dominated by nonlinearities. We need to learn how to deal with these to be able to successfully run at that energy.