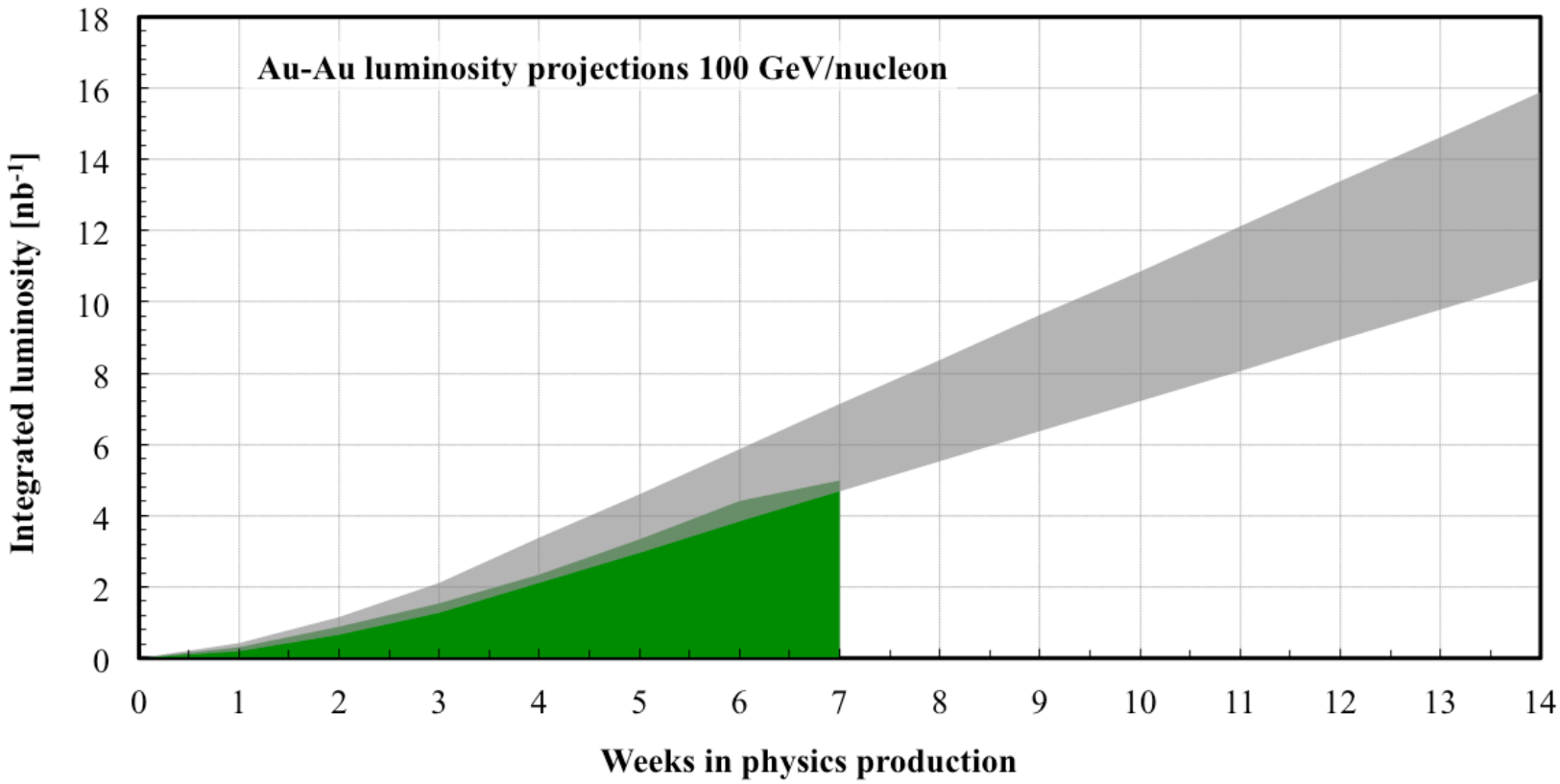
Status of Run14 – 100 GeV Au-Au

G. Robert-Demolaize for C-AD

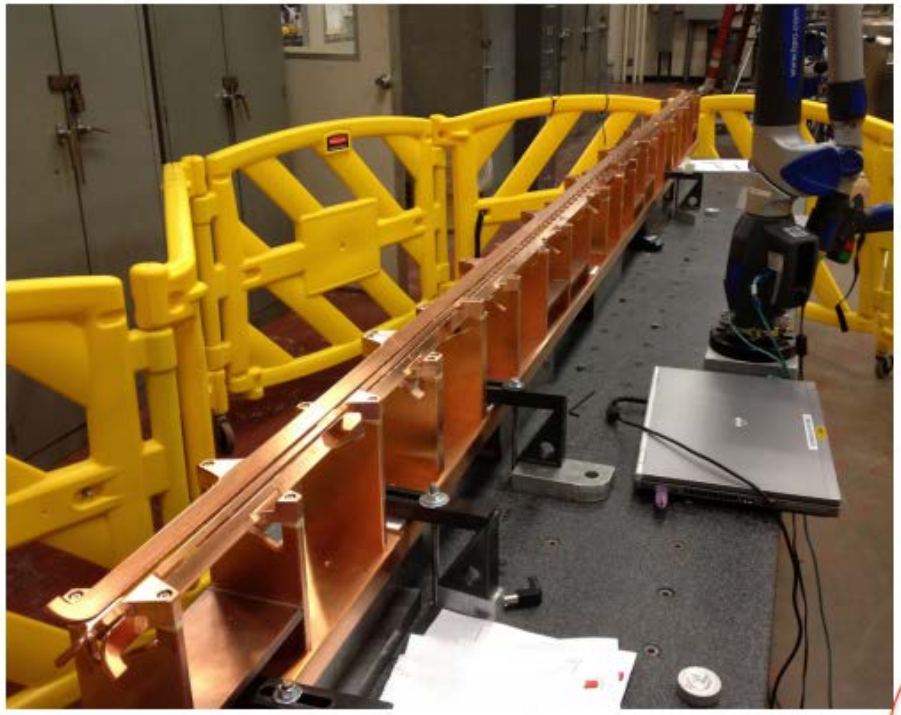
- Schedule for Run14: from recommendations, in order:
  - 3 weeks of 15 GeV Au-Au;
  - 14 weeks of 200 GeV Au-Au, with fixed Au target test ran parasitically;
  - 2 weeks of 100 GeV ^{3}He-Au.
- Strategy for the 200 GeV Au-Au run in Run14:
  - Run13 highlighted by the efficiency of its startup, driven by the Operations Coordinator team => need a repeat performance!
  - use the U-U lattice from Run12, which provided the best off-momentum aperture (highly relevant for operations with 56 MHz cavity) and clearly showed improvements in lifetime over previous lattices;
  - full 3D cooling, with new longitudinal pickup and kicker for improved reliability;
  - prepare an additional ramp to dynamically squeeze STAR (IR6) and PHENIX (IR8) from β^* = 0.7m to 0.5m to take full advantage of Stochastic Cooling;
- Goals for Run14: L_{ave} = 40x10^{26} cm^{-2}s^{-1} (0.7m β^*, 1.5 ions/bunch), 60% time at store.



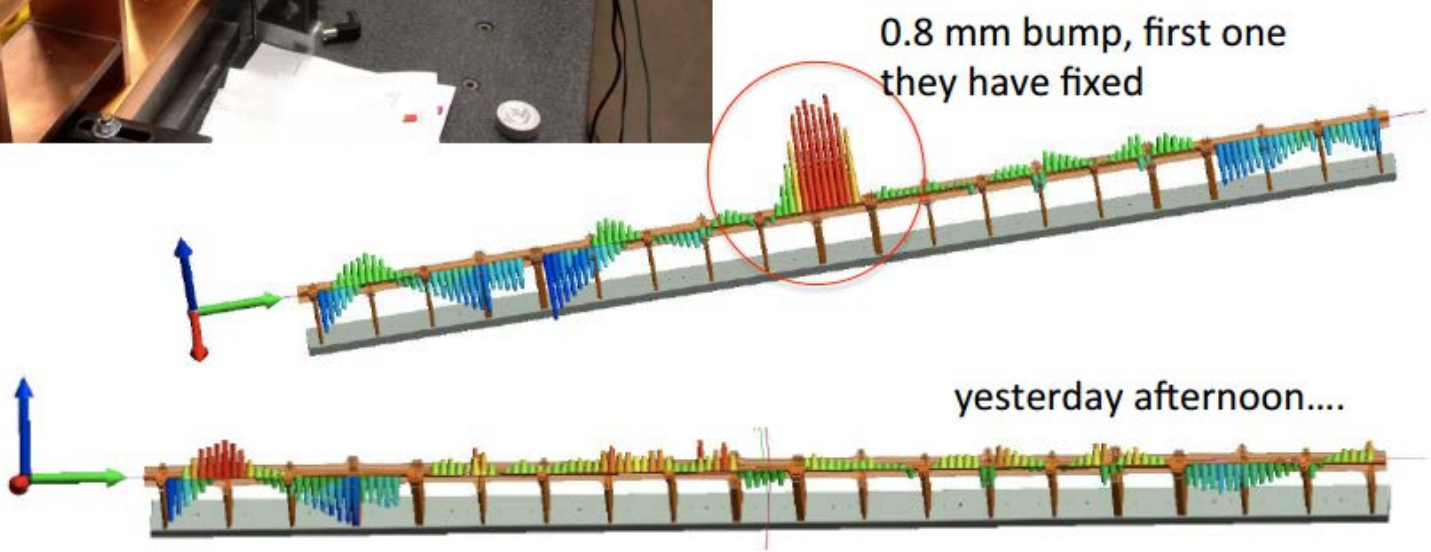
Improvements compared to Run-11: 3D cooling, new longitudinal pick-up and kicker for stochastic cooling, higher bunch intensity (long proton run with high intensity provided scrubbing – expect higher instability threshold at transition), 56 MHz SRF and electron lens commissioning.

(W. Fischer, 2013 RHIC Retreat)

- Injectors:
  - intensities out of EBIS and through the RFQ/Linac: if improved by 30%, we could drop the last merge => realign RFQ, MEBT, Linac and dowsntream Triplet magnetic centers remeasured;

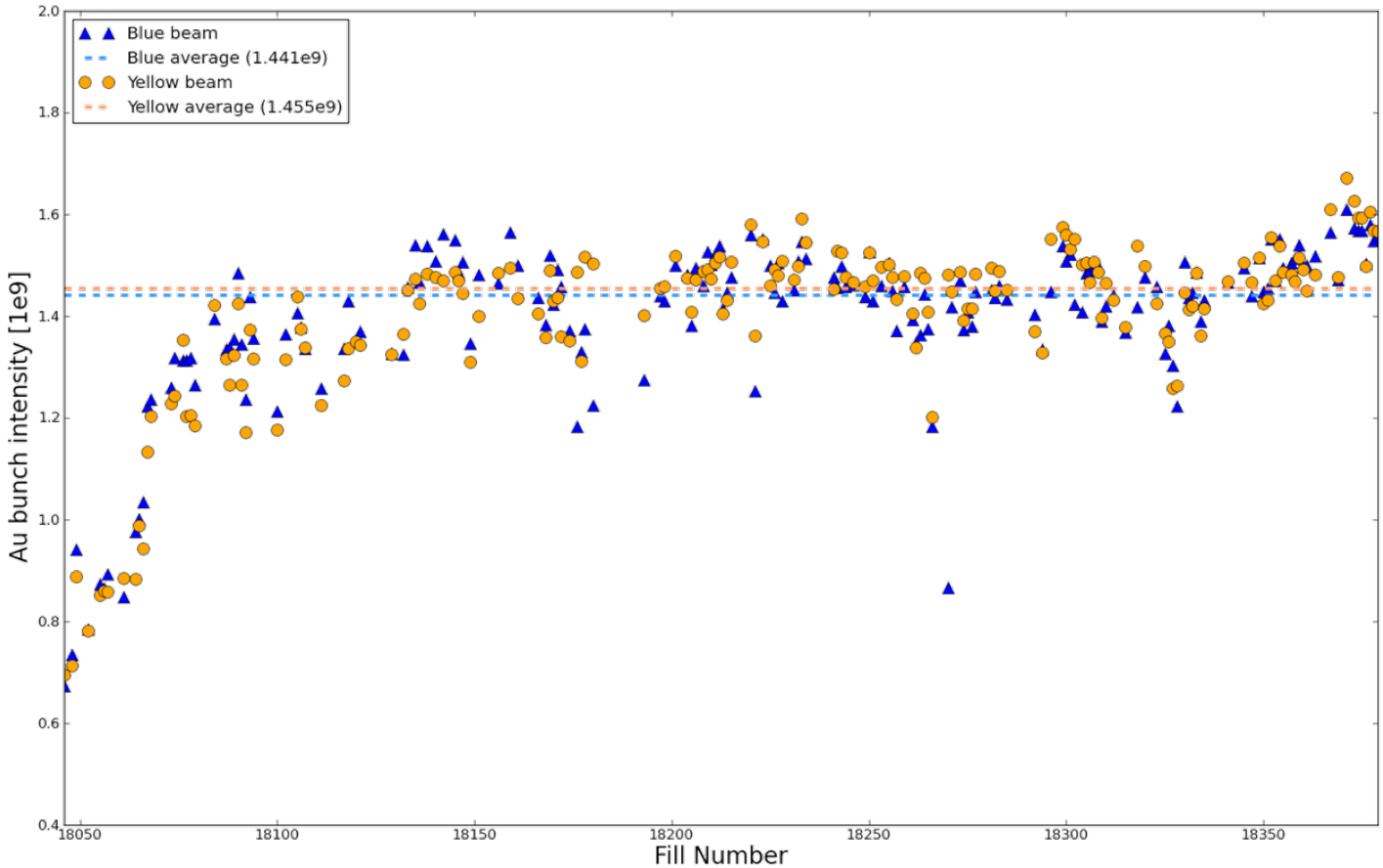


Frank Karl, Matt Iiardo,
Ming Ke, Don Von Lintig

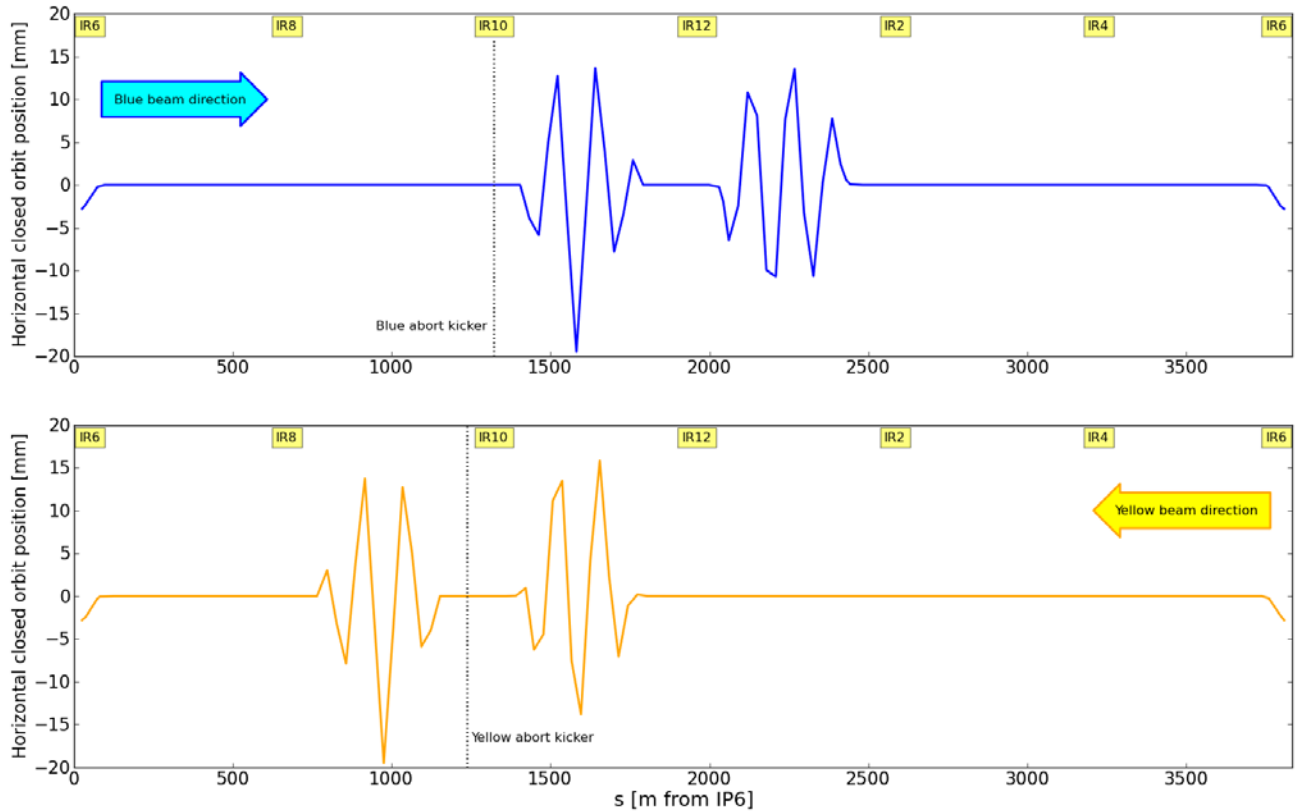


(J. Alessi, 2013 RHIC Retreat)

- Injectors:
  - intensities out of EBIS and through the RFQ/Linac: realign RFQ, MEBT, Linac and dowsntream Triplet magnetic centers remeasured;
  - with a better bunch merging gymnastics and improved Booster low-level RF system, the amount of beam in the satellite bunches was brought from 8% in Run 12 to about 2% this run. Longitudinal losses from the main buckets were also reduced resulting in an overall improvement in the maximum intensity per bunch at AGS extraction to around 2.1×10^9, which is about **30% higher than in Run12**.



- RHIC Lattice:
  - New this run for the STAR experiment is the Heavy Flavor Tracker (HFT), a state-of-the-art micro-vertex detector utilizing active pixel sensors and silicon strip technology. Abort kicker prefires have the highest probability of driving the beam close to or into the cold aperture of the triplet quadrupoles of the STAR interaction region (IR6), inducing particle showers onto the HFT.
  - A specific closed orbit scheme was devised to send these bunches to the cold aperture in the arc immediately downstream of the abort kicker locations instead of the closest downstream triplet quadrupole of a low-beta IR (i.e. the STAR IR for the Blue beam). This scheme changes the regular path length of the beam, and an additional closed orbit bump had to be implemented to compensate for this change.



  - During the FY14 high energy Au-Au run to date, 8 blue and 11 yellow abort kicker prefires occured, but **no damage to the HFT was reported by the STAR collaboration.**

- RHIC subsystems:
  - Stochastic Cooling (SC) featured new longitudinal pickups with a keyhole design, reducing the vertical aperture and boosting the cutoff frequency for microwave propagation, subsequently improving the flatness of the response. New longitudinal kickers (6 cells per cavity) were also installed. The kickers are designed to run at an elevated temperature: incandescent lamps are used to warm the system through glass windows and reduce the illumination when the microwave drive is on, leading to a constant temperature without cooling water in the vacuum. With Au beam in both rings all cooling could be run at maximum gain for even better efficiency than what was achieved in Run12 with (already) full 3D cooling.

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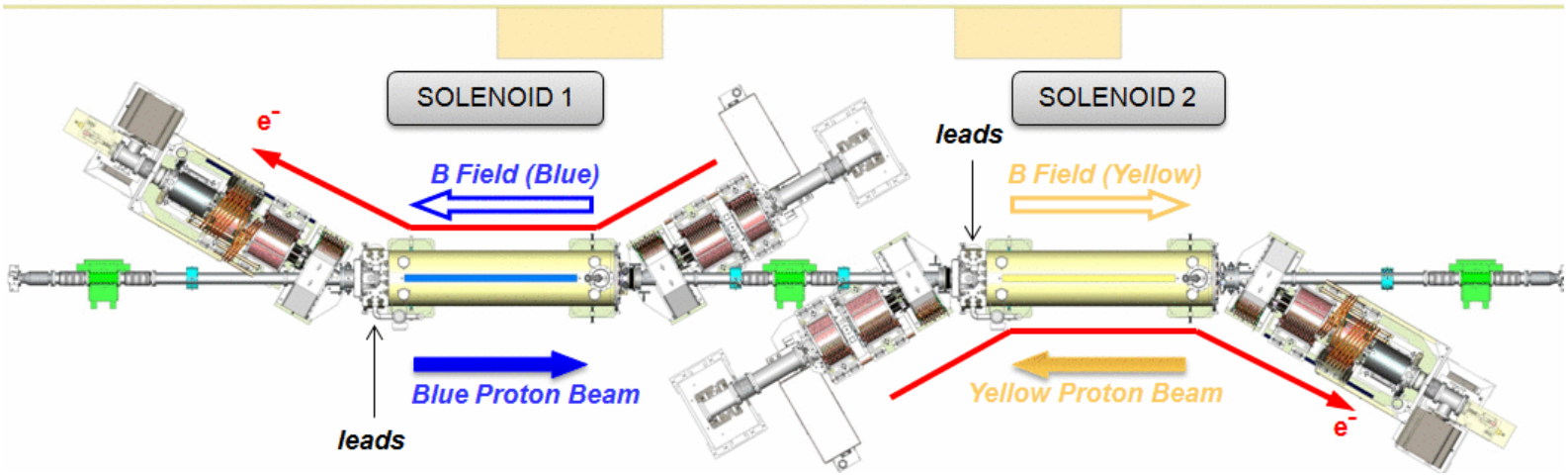
  - Two electron lenses were fully installed for Run-14, and have been commissioned with Au beams. The lenses are designed for partial head-on beam-beam compensation of colliding proton beams in future runs. The beam-beam parameter with Au+Au collisions is only about half the value with p+p collisions, and beam losses of cooled Au beams are dominated by burn-off not beam-beam effects. During the run the magnetic structure was commissioned, and the electron beam current and profile needed for proton beam-beam compensation were demonstrated. Instrumentation was tested including a novel detector for backscattered electrons that measures the overlap of electron and hadron beams. The effect of the electron beam on orbit, tune and tune distributions was measured. Pulsed and DC operation did not show any additional emittance growth (with a growth time resolution of about 1h).



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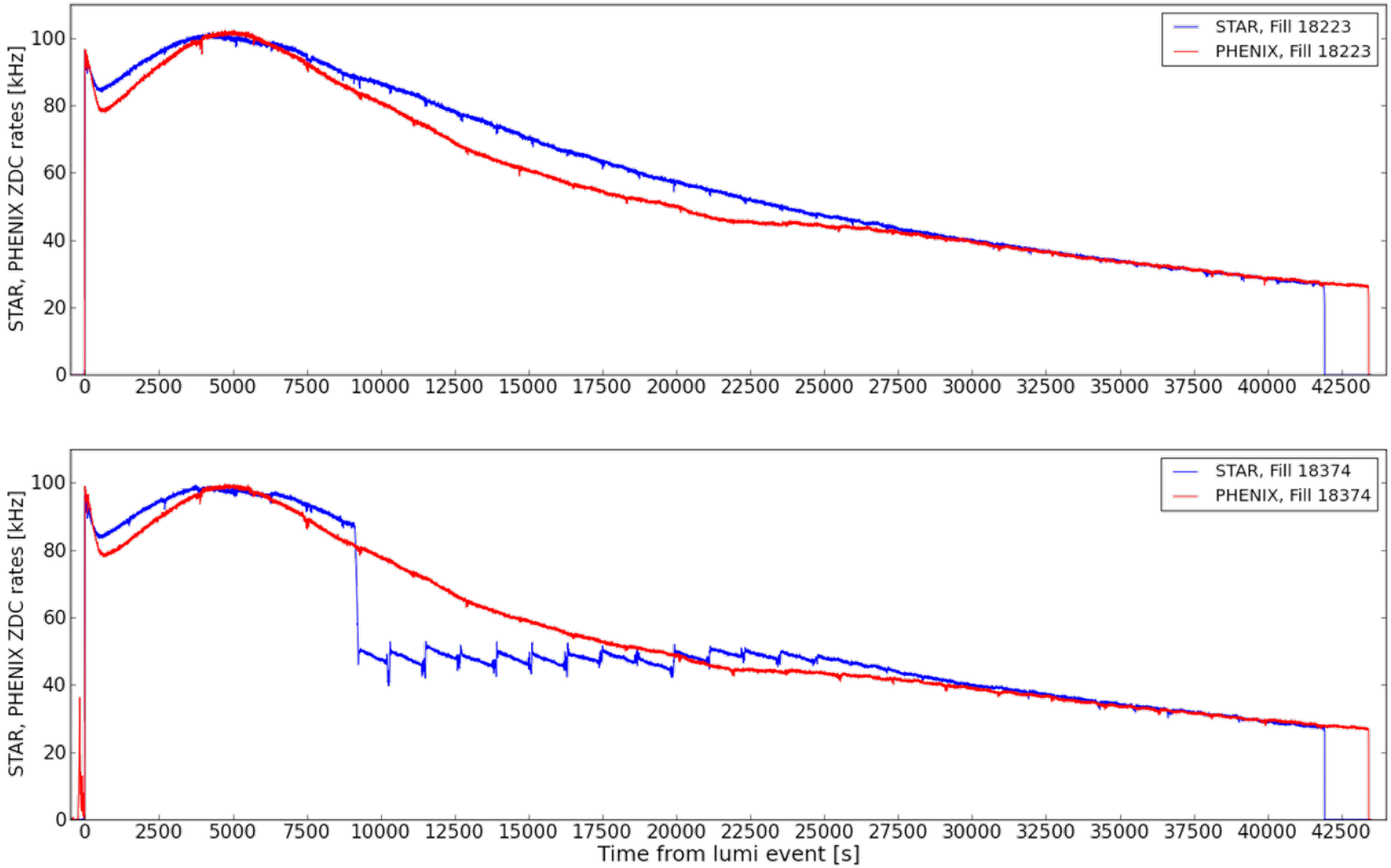
  - A 56MHz 2MV passive superconducting RF (SRF) storage cavity was installed and commissioned in RHIC for the start of Run 14. The purpose of this cavity, common to both Blue and Yellow rings, is to provide a very large RF bucket, reducing longitudinal diffusion from IBS during Au stores and generating as much as a 30% improvement in integrated luminosity. Beam driven testing exposed what appears to be a ponderomotive instability which was not observed without beam. Investigation and data analysis is continuing, but a cavity mechanical resonance seems to be the source. For nominal RHIC store currents (~330 mA DC), the cavity detuning frequency appears to be significantly higher than the detuning frequency at which the ponderomotive instability occurs though.

- Achieved machine parameters:

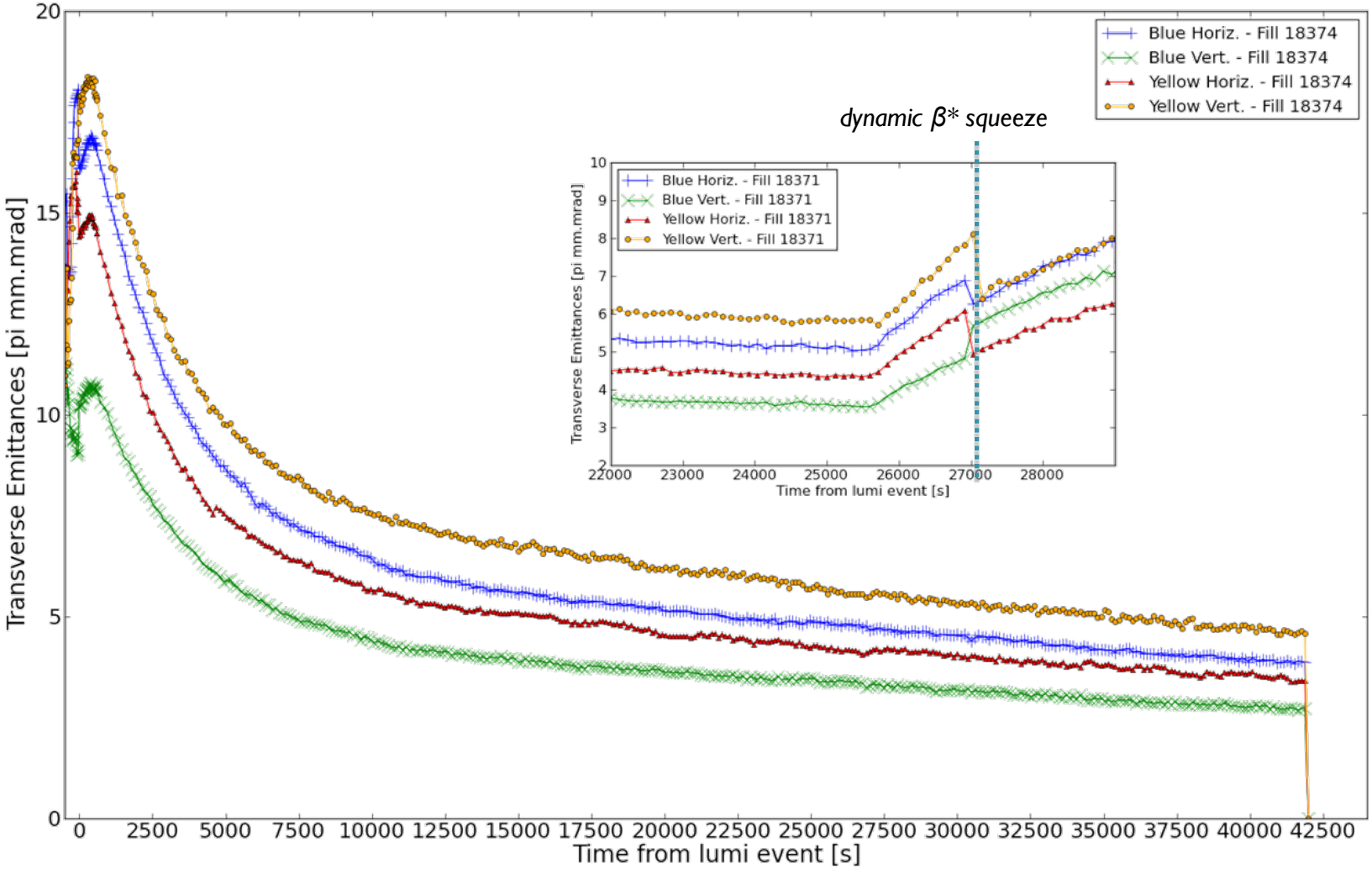
Parameter	Run11 Au-Au	Run14 Au-Au
# of bunches	111	111
Intensity [1e9]	1.3	1.8
β^* [m]	0.7	0.7 → 0.5
Emittance [μm]	10 → 7	15 → 5
Peak luminosity [$10^{26}cm^{-2}s^{-1}$]	50	90
Avg. store luminosity [$10^{26}cm^{-2}s^{-1}$]	30	50
Luminosity per week [μb^{-1}/week]	1000	2000
Run length [weeks in physics]	6.4	13.3
Time in store [% of calendar time]	59	68

- Commissioning started on March 11, 2014 with the first overnight store 4 days later, with a beam intensity of 0.9×10^9 ions/bunch.
- Slowly ramped to 1.6×10^9 ions/bunch (design value for Run14) to prevent the vacuum pressure to rise to high levels in both STAR and PHENIX experimental insertions, as well as the e-lens area (IR10).
- In previous years the bunch intensity was limited by a fast transverse instability during transition crossing in RHIC. During Run14 no instabilities were observed, likely the result of beam scrubbing from the high intensity proton run in the previous year.

- As the run progressed, it appeared that the high collision rates were causing triggering issues for the STAR HFT. To allow the experiment to reach both of its high and low luminosity goals, the ZDC rates were dropped to 50 kHz three hours into each store, which maximizes the usable integrated luminosity for each physics fill:



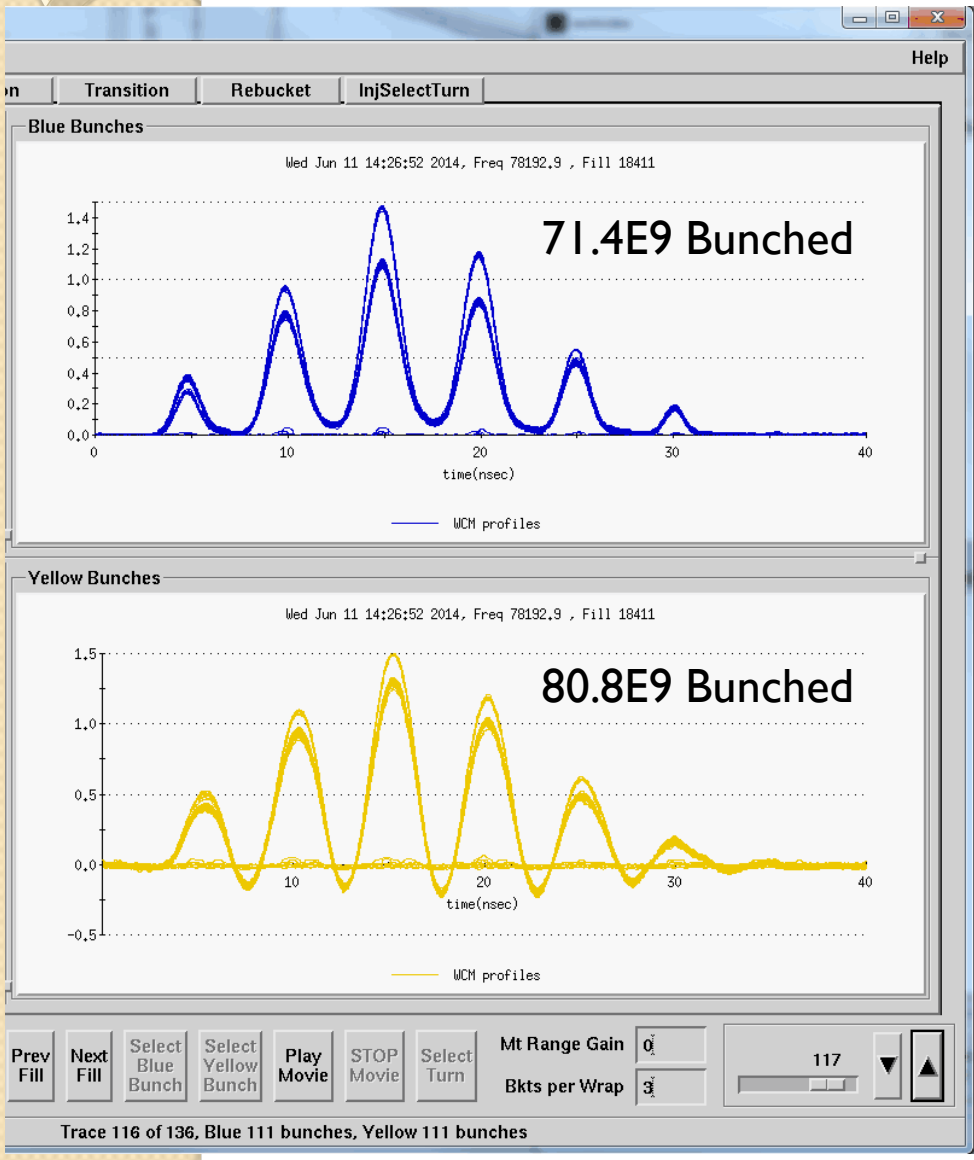
- The performance of the RHIC SC allowed for a reduction of a factor 2.5-3 on all transverse beam emittances from the beginning of store, down to about 5π after 11 hours.



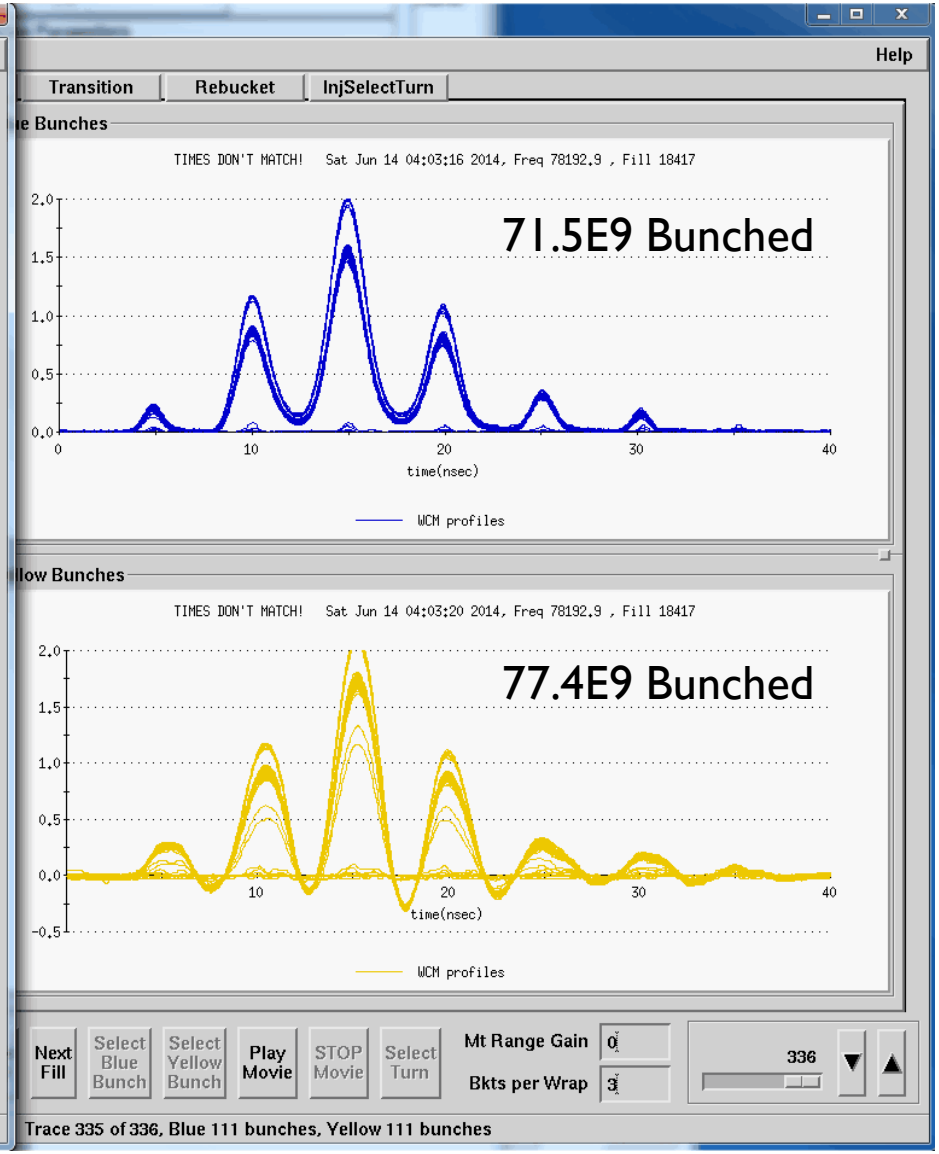
- Turning SC off during one of the dynamic β^* squeeze test shows rapidly growing emittances in all four planes (1-2π in just about 20 minutes).

- Effect of 56MHz Cavity on Bunch Profile: central peak vs satellites (6 Hours Into Store)

(Fill 18411) Without 56MHz Cavity

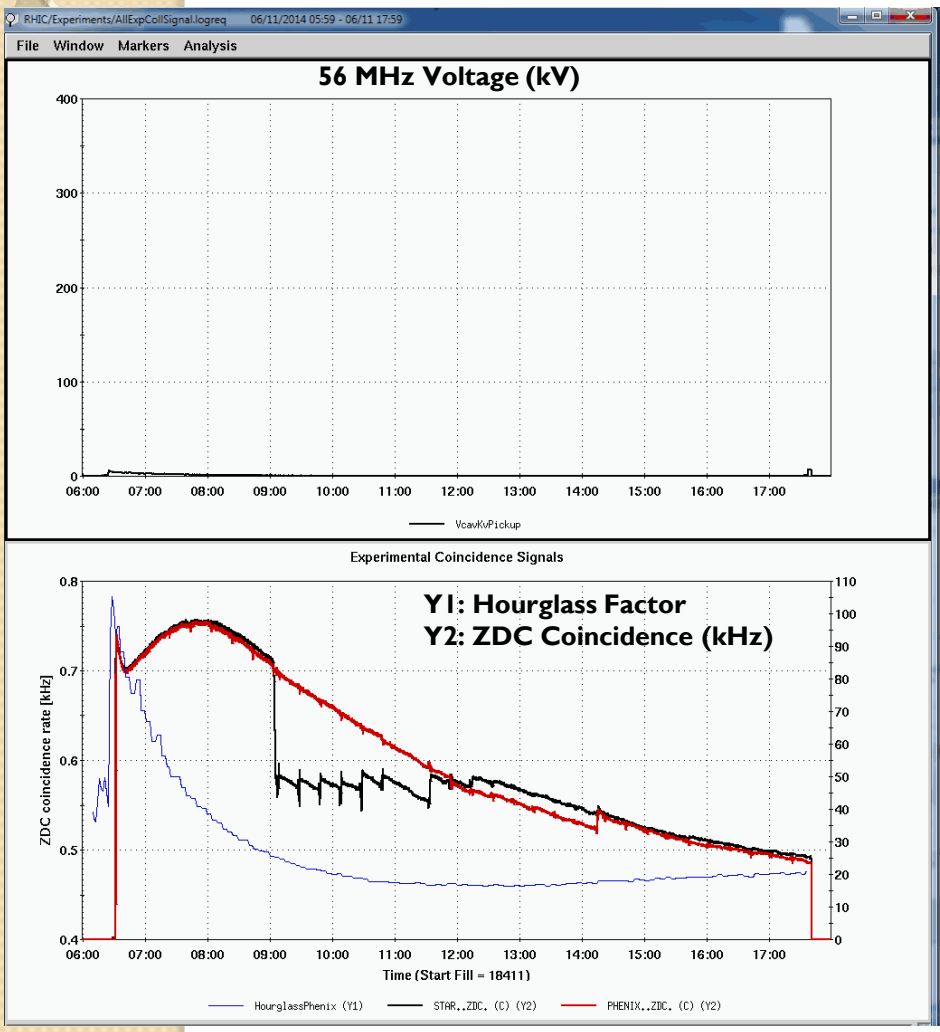


(Fill 18417) With 56MHz Cavity @ 300kV



- Effect of 56MHz Cavity on Hourglass Factor along a physics Store:

(Fill 18411) Without 56MHz Cavity



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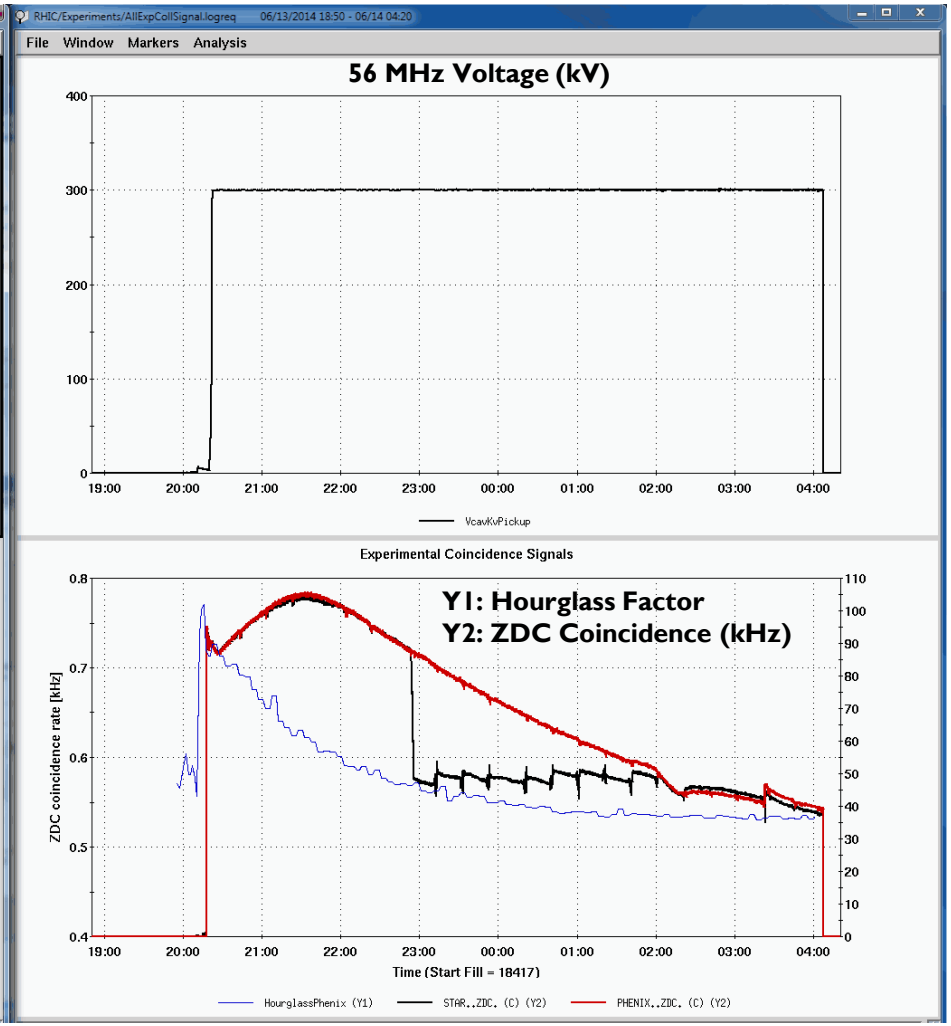
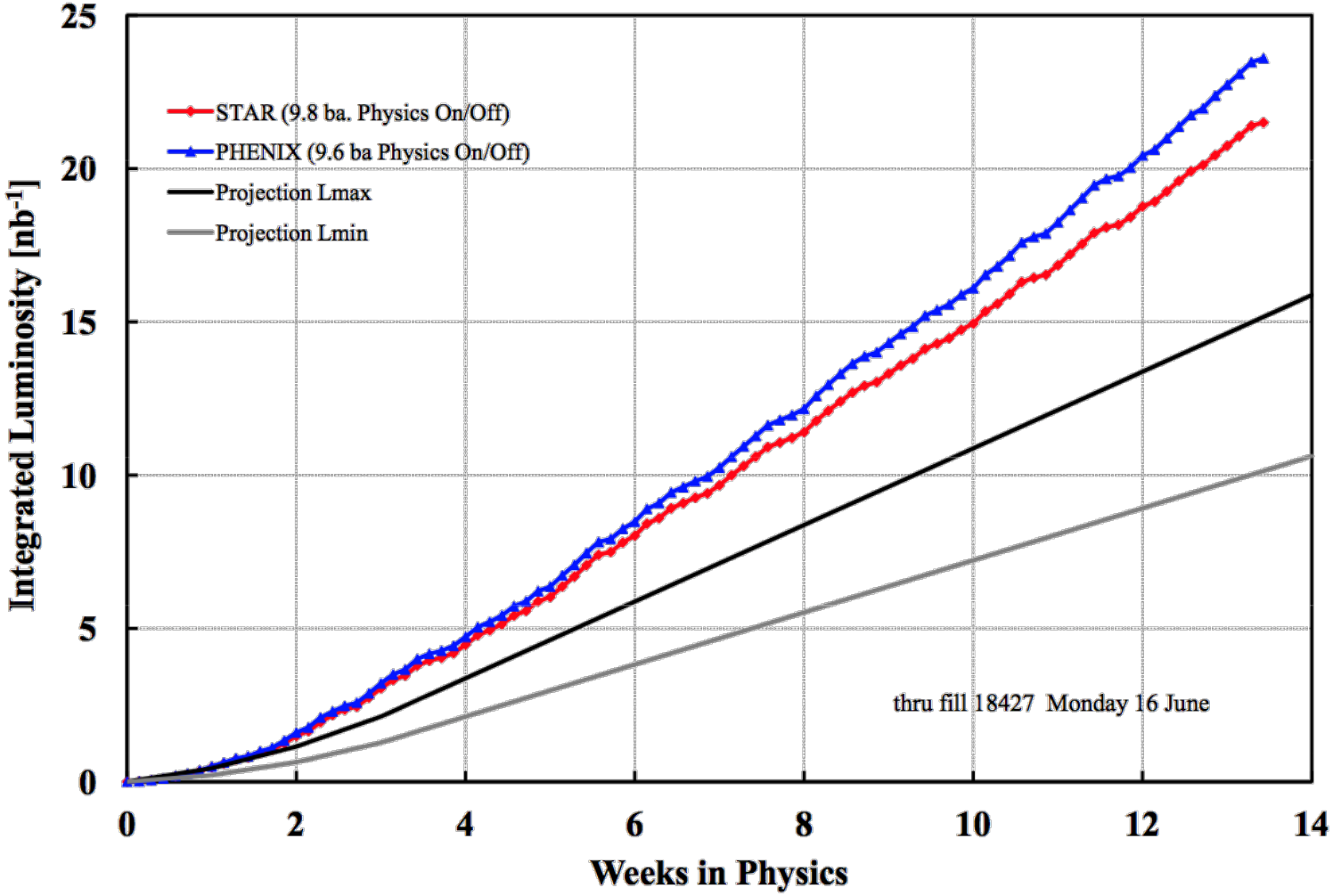
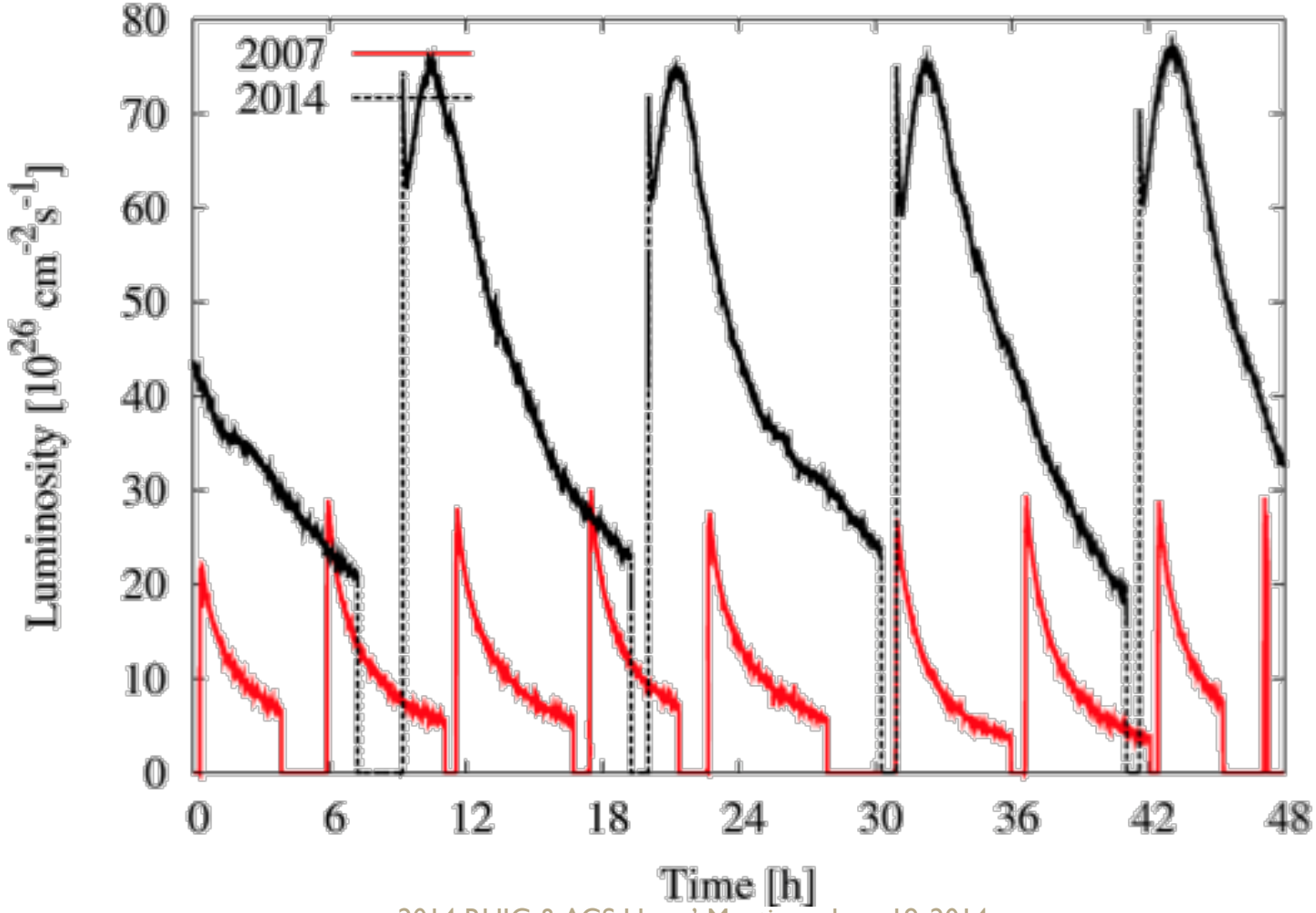


- Delivered integrated luminosity compared to projections:



- The cross sections used here (21.5 nb^{-1} for STAR and 23.6 nb^{-1} for PHENIX) are from one vernier scan only. The singles correction used here takes the different electronic dead-times at STAR and PHENIX into account (i.e. there is practically no change for PHENIX and about 11% change for STAR).

- The RHIC 100 GeV Au-Au Run14 delivered record breaking bunch intensities and integrated luminosity to both STAR and PHENIX experiments. Integrated luminosities exceeded the initial design goals by nearly 50% by the end of the run in large part due to the high performance of the injectors and the Stochastic Cooling system. Two electron lenses and a 56 MHz superconducting RF cavity were also installed and commissioned to keep pushing achievable luminosity and optics even further, thus completing the RHIC-II upgrade.