

Finale of RHIC Beam Energy Scan II Operation

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June 11, 2021

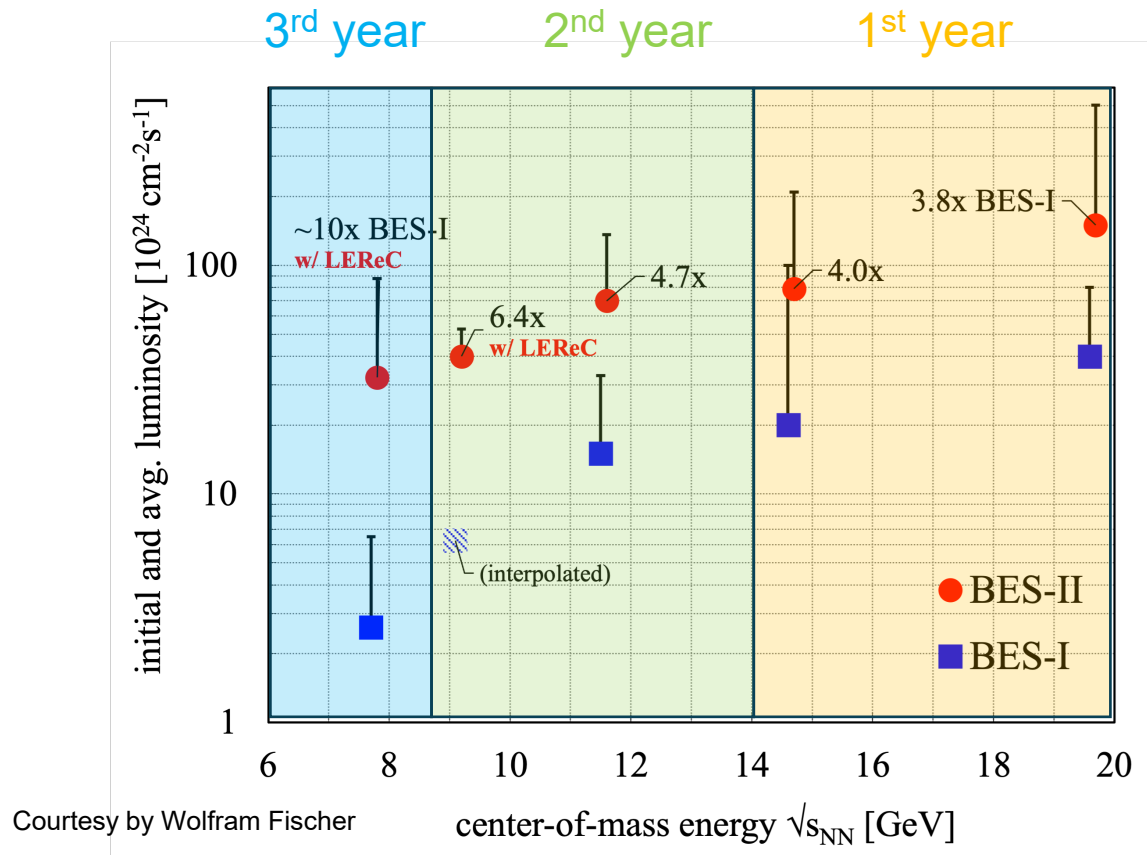


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Outline

- Overview of Run-21
- Run-21 programs
- Summary

Trilogy of BES-II



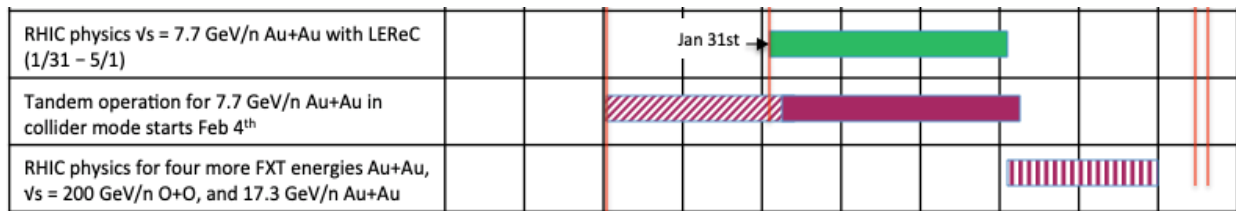
The third year of BES-II operation is the most challenging, exciting and rewarding one of the three.

Major changes between BES-I and BES-II

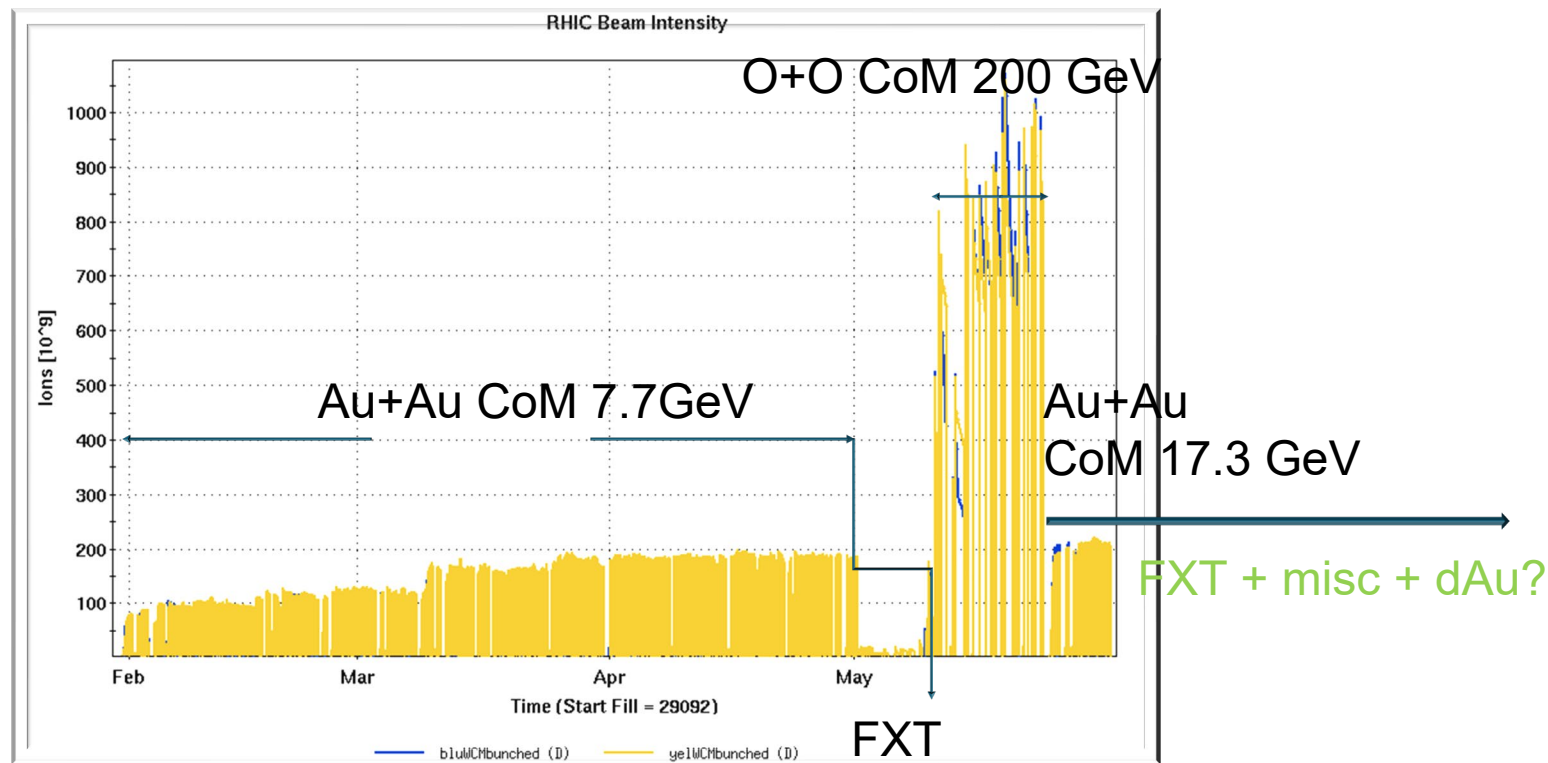
- 4 bunches per AGS cycle with 2.3×10^9 Au ions per bunch at AGS extraction with Tandem ion source.
- Implementation of third harmonic cavity to flatten bunch profile for reduced space charge, therefore high intensity in RHIC.
- Stable LEReC cooling operation, improved cooling performance with long electron bunches made possible by 1.4 GHz cavity. Beta squeeze in the middle of stores.
- Switching to lower tune for better ion beam lifetime therefore higher intensity, and scanning of e beam current.
- Implementation of bunch-by-bunch damper ensured higher intensity operation.
- Orbit corrector controller upgrade and improved measurement and control of beam properties.
- Reduce lattice nonlinearity due to persistent current and stabilize the magnetic field with wiggle ramp (demagnetization cycle).
- Employment of three 9 MHz cavities per ring.
- injection kicker reconfiguration for short rise time and longer flat-top.

Run-21 programs and schedule

Single-Beam Energy (GeV/nucleon)	$\sqrt{s_{NN}}$ (GeV)	Run Time	Species	Events (MinBias)	Priority	
3.85	7.7	11-20 weeks	Au+Au	100 M	1	✓
3.85	3 (FXT)	3 days	Au+Au	300 M	2	✓
44.5	9.2 (FXT)	0.5 days	Au+Au	50 M	2	
70	11.5 (FXT)	0.5 days	Au+Au	50 M	2	
100	13.7 (FXT)	0.5 days	Au+Au	50 M	2	
100	200	1 week	O+O	400 M 200 M (central)	3	✓
8.35	17.1	2.5 weeks	Au+Au	250 M	3	✓
3.85	3 (FXT)	3 weeks	Au+Au	2 B	3	✗



Run-21 timeline

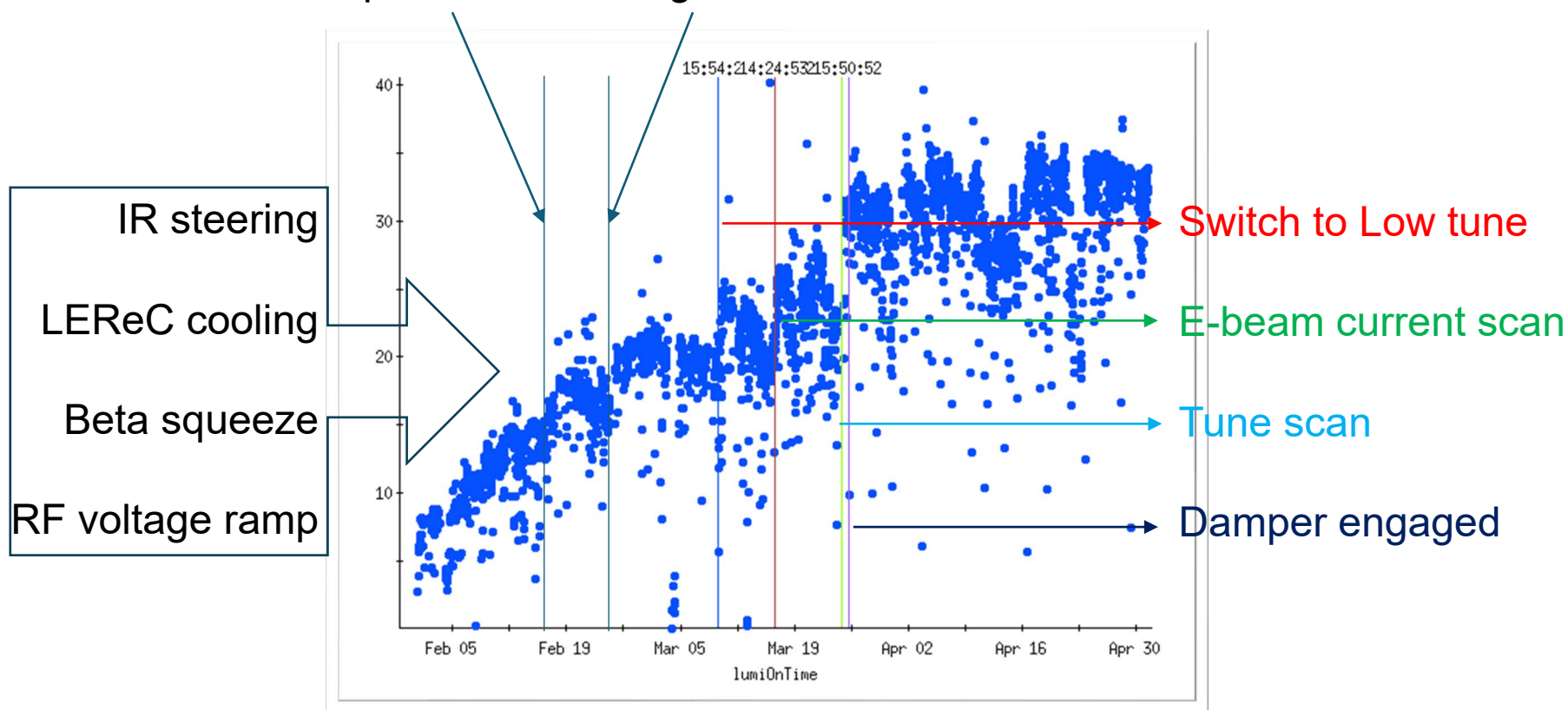


Operation of Au+Au at 7.7 GeV

The lowest energy in collision mode

Non-stop performance improvement of Au+Au collision at 7.7 GeV

LEReC optimization & long bunch

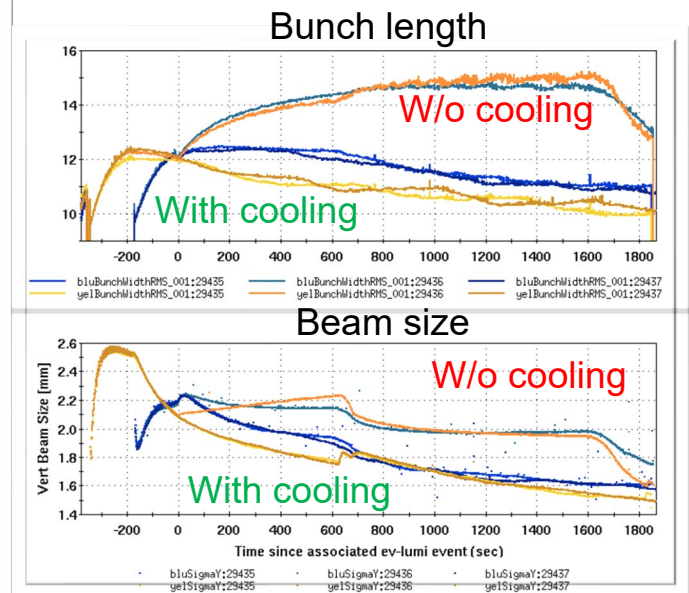
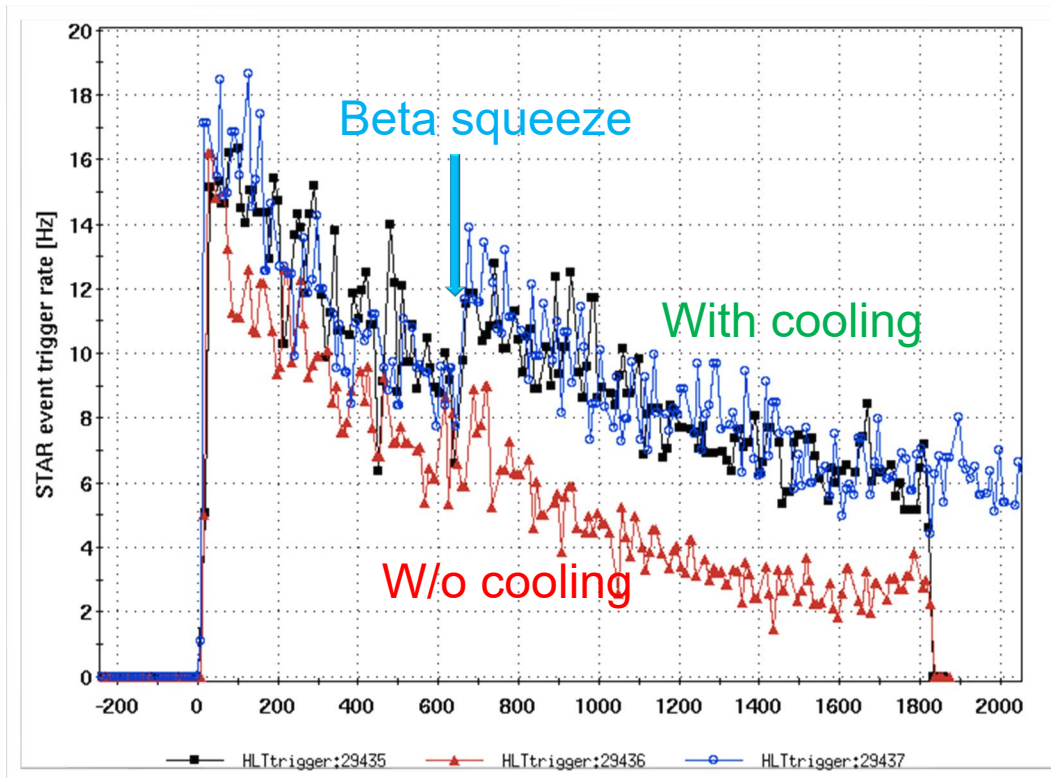


(as such, a prototype of high-energy cooler)



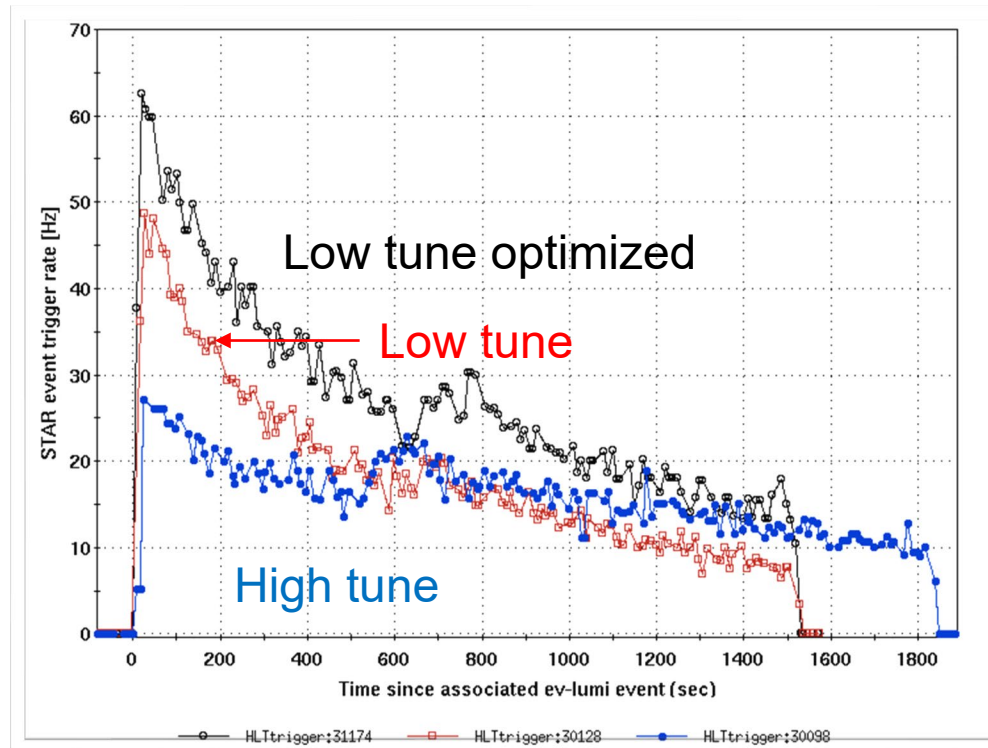
New 1.4 GHz RF cavity allows LEReC operation with longer electron bunches which helps to reduce “heating” effect on ions from the electrons.

Cooling vs no-cooling



Cooling reduces/maintains the longitudinal and transverse size of the beam therefore reduces the luminosity decay rate. In addition, it enables beam size reduction by squeezing the beta (envelope) function at IP.

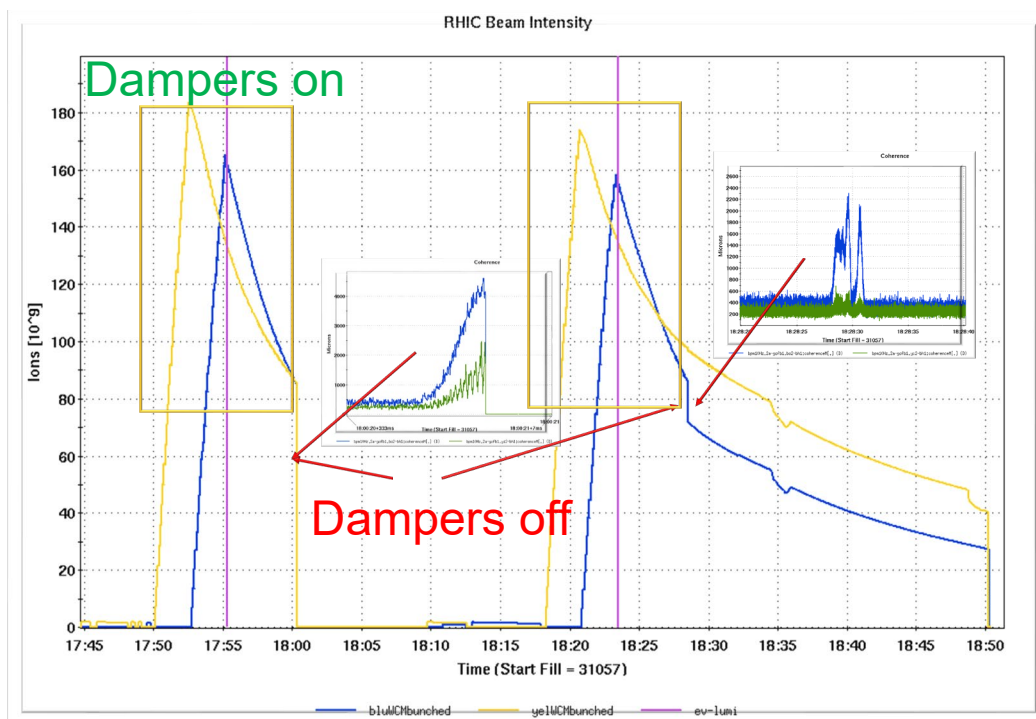
High tune vs low tune



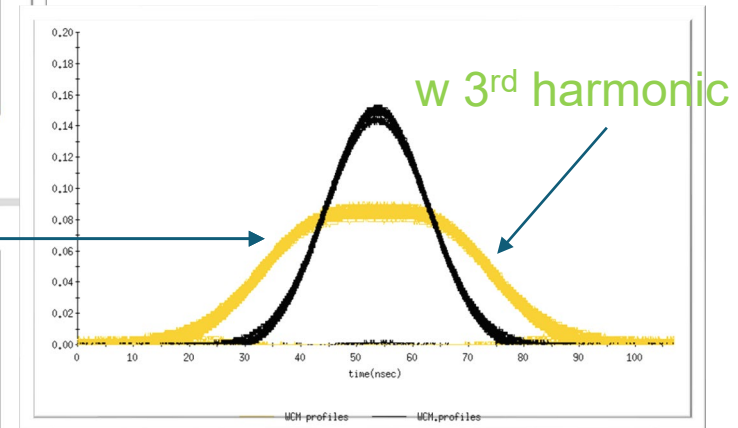
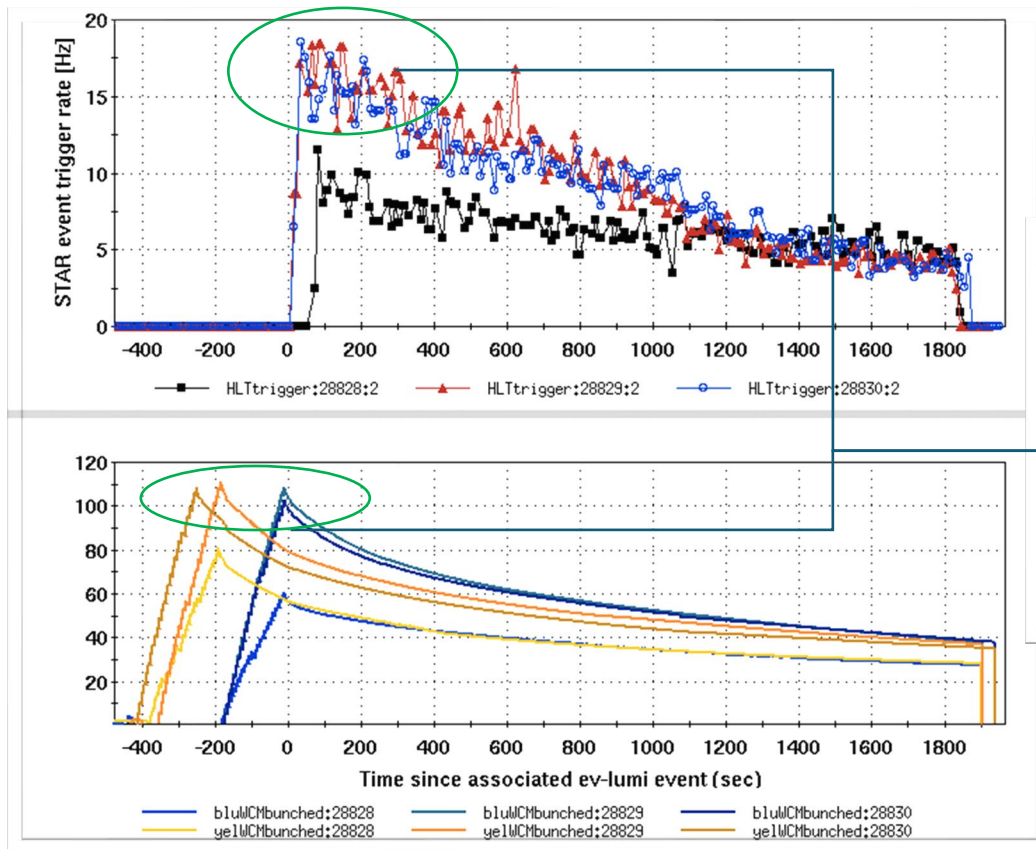
At low tune (0.12), beam lifetime is better than that at high tune (0.23) so RHIC can take more beam from the Tandem source. Even the cooling is less efficient at low tune, higher integrated lumi was achieved.

Suppressing beam instability by bunch-by-bunch damper

- Bunch-by-bunch feedback system was engaged operational in 2021 to enable 10-15% more intensity.
- Feedback has been on from start of injection to the start of physics data taking.



Alleviating space charge effect

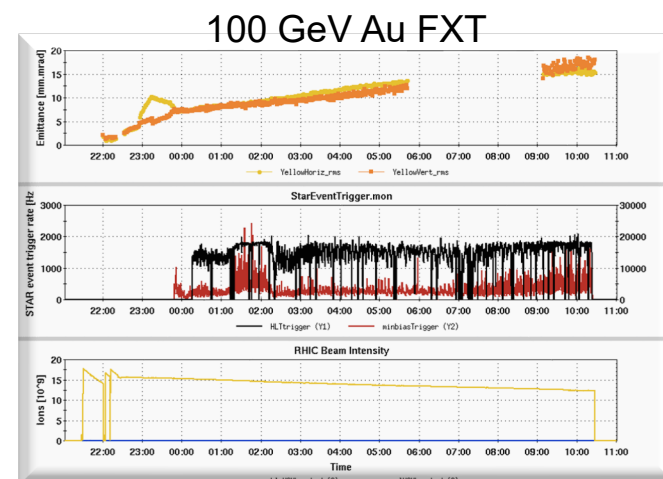
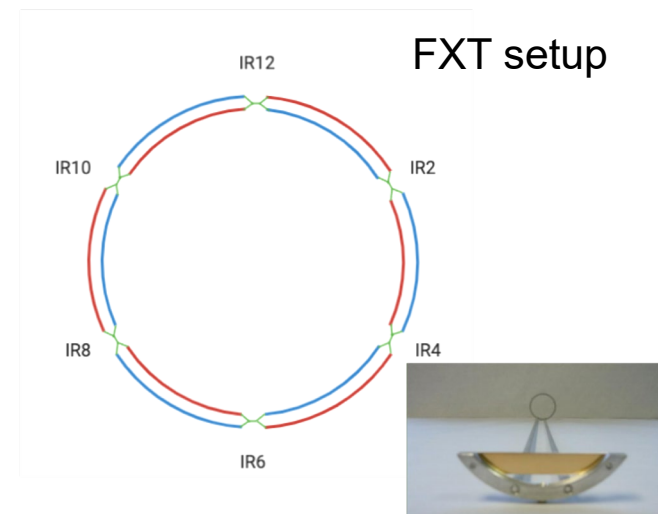


The reduction of peak current by engaging 3rd harmonic cavities improves greatly the beam lifetime.

Operation of FXT, O+O, Au+Au at 17.3 GeV

Fixed target operation

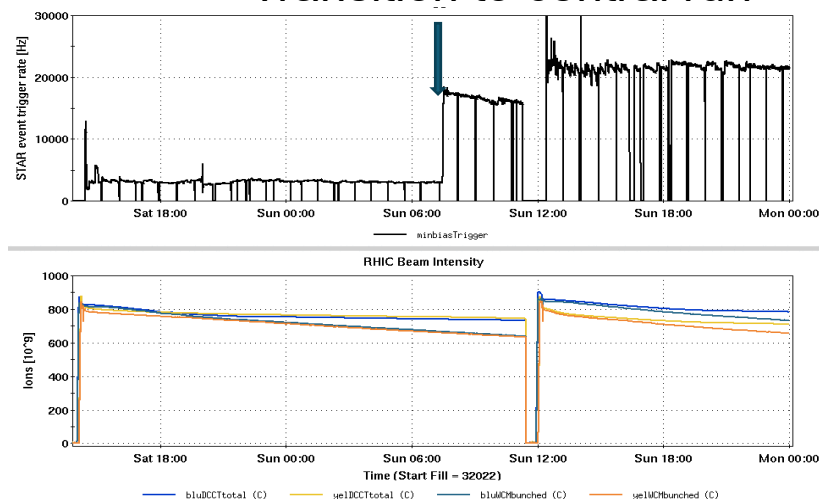
- Fixed target at beam energy 3.85, 44.5, 70 and 100 GeV.
- 12 bunches with moderate intensity ($1.5E9$ ions per bunch) equally distributed in the yellow ring.
- Vertical orbit bump to bring beam close to the target and maintain the rate.
- 100 GeV FXT was performed with big challenges on machine side.
 - An orbit bump of ~ 17 mm was set up with maximum available strength on IR correctors.
 - All available methods were used to blow up emittance: Injection mismatch, ARTUS kicker, IBS & coupling, BBQ kicker.



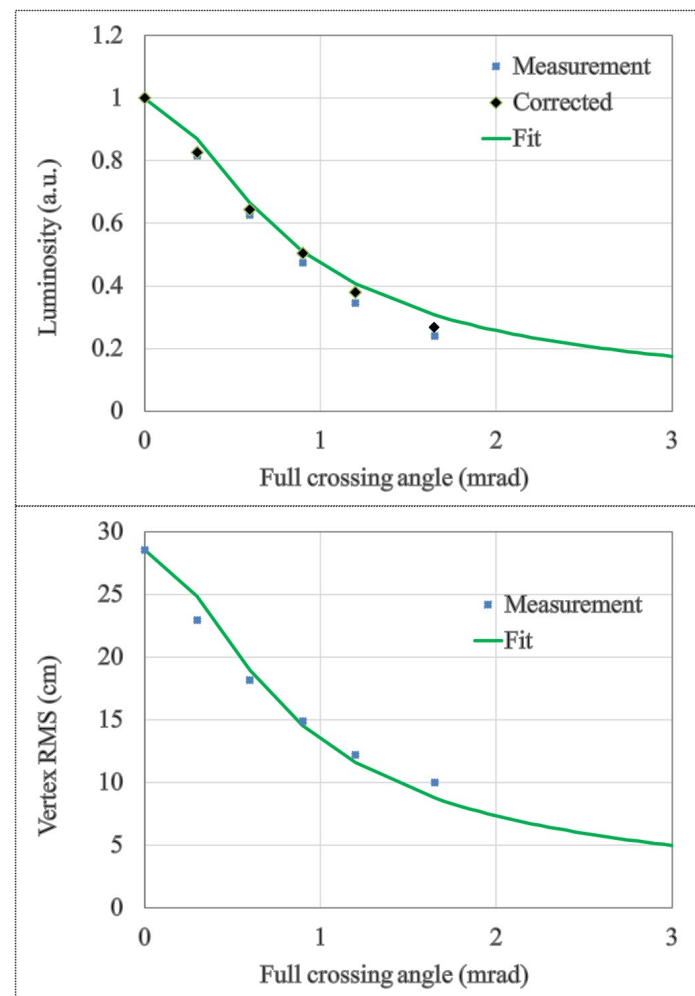
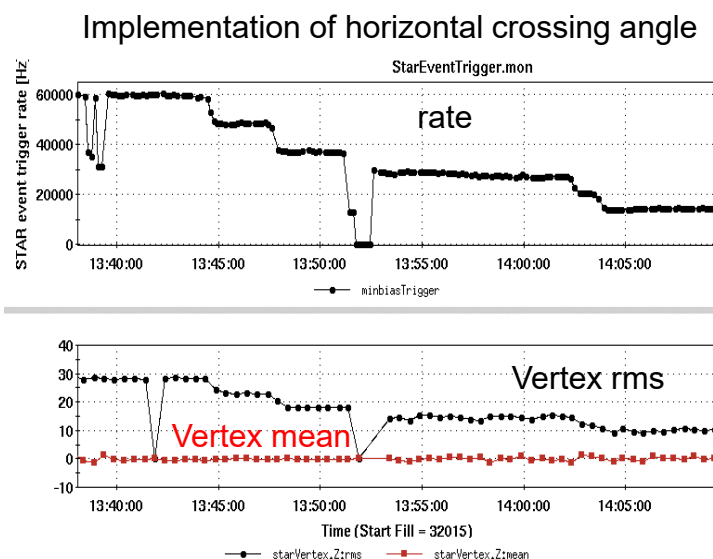
O+O at CoM 200 GeV

- Oxygen is a new species for RHIC. The setup took 3 calendar days with FXT running overnight.
- Store length was over 20 hours and 15 hours for the min-bias and central run.
- Calibration run for a day with STAR solenoid polarity reversed.
- To reduce vertex longitudinal rms to 10 cm, beam was rebucketed and crossing angle of 1.65 mrad was put in.

Transition to central run



Crossing angle effects

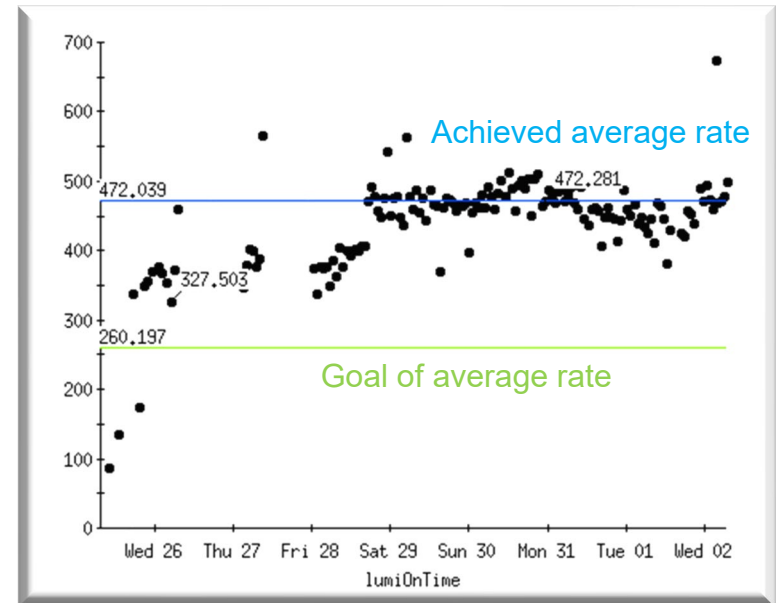


The crossing angle was less effective than predicted to reduce the vertex rms due to non-gaussian bunch profile.

The fittings on the right plots were performed with bunch length as a variable.

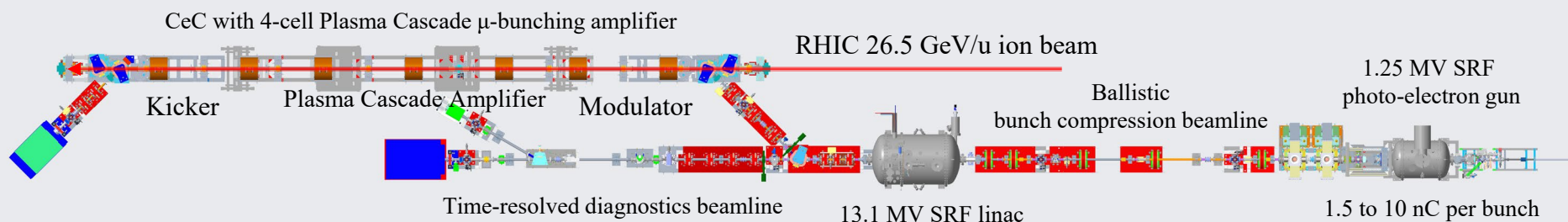
Au+Au at 17.3 GeV

- New energy for collision mode.
- Experience of low energy operation gained in the past two years gave us guidance on the optimal configuration of RHIC for this energy.
- Careful evaluation of the exact energy due to its proximity to AGS transition energy.
- Beam setup in AGS needed more care but went smoothly.



Coherent electron Cooling experiment at RHIC in Run-21

Courtesy V.N. Litvinenko



- Current CeC system has seven high field solenoids, five of which serve as a 4-cell Plasma-Cascade μ -bunching amplifier with 15 THz bandwidth and amplitude gain exceeding 100.
- All necessary electron beam parameters – the beam energy and peak current, the beam emittances and energy spread, the low noise in the beam (critical and most not-trivial requirement) - had been demonstrated. The full CW beam was propagated with low losses through the newly built PCA CeC
- The CeC run achieved the following last year:
 1. Demonstrating KPP for the e-beam
 2. Plasma Cascade amplification
 3. Ion imprint
- The team worked on solenoid alignment, ion and electron beam alignment this year.
- Parasitic fixed target data acquisition during CeC studies.
- The project plans are to demonstrate longitudinal CeC in 2021 and 3D (both longitudinal and transverse) CeC in 2022.

Accelerator Physics Experiments (APEX)

➤ Cooling studies:

- Electron-ion heating
- Bayesian optimization
- Coherent excitation
- Dispersive cooling
- Painting cooling
- Recombination study
- Electron-ion focusing

>120 hours

➤ Electron-ion collider studies:

- Radial shift test
- Fine decoupling

Summary

- The final year of BES-II was most challenging. Both LEReC and RHIC performance were greatly improved.
- A few good decisions were made for the Au+Au at 7.7 GeV to make use of the full potential of the source, injector and RHIC.
- Switching between multiple physics programs was again demanding.
- Physics programs, CeC experiment, APEX studies and other tests coexisted in harmony.

Section Break

Subtitle

Print-friendly Section Break

Subtitle