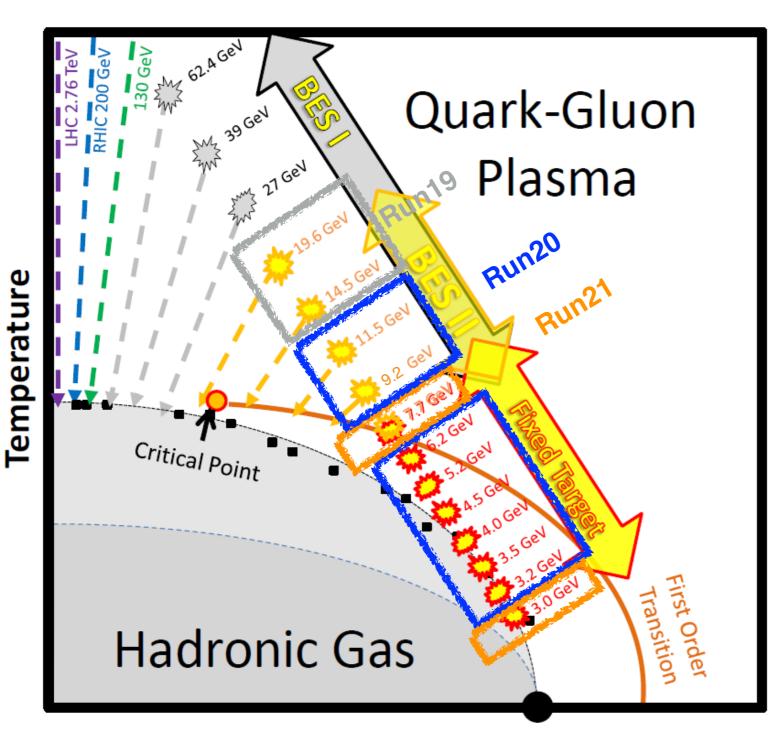


J.H. Lee /BNL

RHIC Retreat 9/16/21

STAR Run 19, 20, 21: Beam Energy Scan II Mapping QCD phase diagram



Baryon Chemical Potential μ_{B}

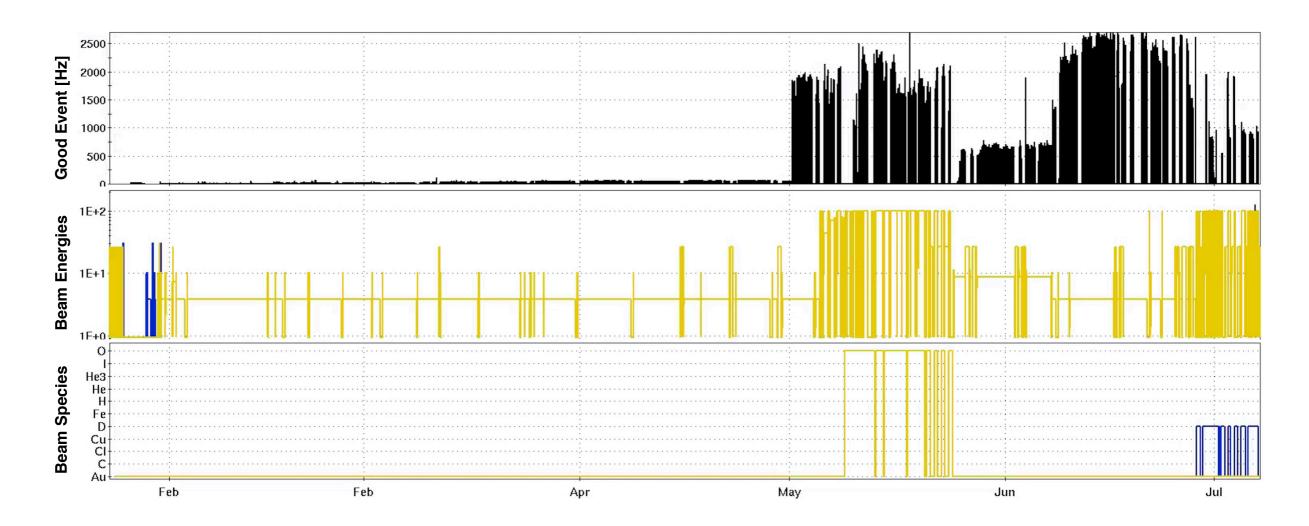
Continuous scanning the beam energy (BES-II) with upgraded detectors for high acceptance and resolution with high statistics

Run21: Beam Use Requests

Single-Beam	$\sqrt{s_{ m NN}}$	Run Time	Species	Events	Priority
Energy (GeV/nucleon)	(GeV)			(MinBias)	
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)	$0.5 \mathrm{days}$	Au+Au	50 M	2
70	11.5 (FXT)	$0.5 \mathrm{days}$	Au+Au	50 M	2
100	13.7 (FXT)	$0.5 \mathrm{days}$	Au+Au	50 M	2
100	200	1 week	О+О	400 M	3 a
				200 M (central)	
8.55 (8.65)	17.1(17.3	3) 2.5 weeks	Au+Au	250 M	3 b
3.85	3 (FXT)	3 weeks	Au+Au	2 B	3 c

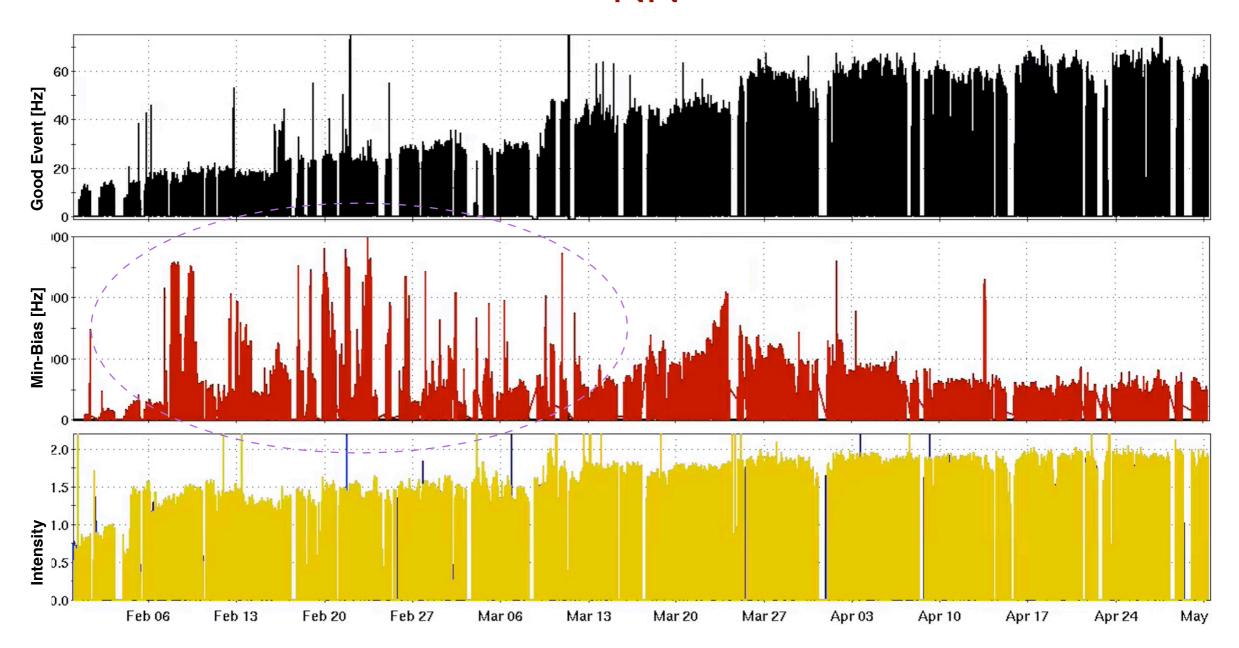
- Completing BES II program
- Highest priority: Au+Au at √s_{NN}=7.7 GeV
- Measurements with fixed target at $\sqrt{s_{NN}}$ =3, 9.2, 11.5, 13.7 GeV
- 3rd priority to be done as 3a, 3b, 3c
- Projected to be challenging to complete the all Requests in Run21 with 24 cryo-weeks

Run21



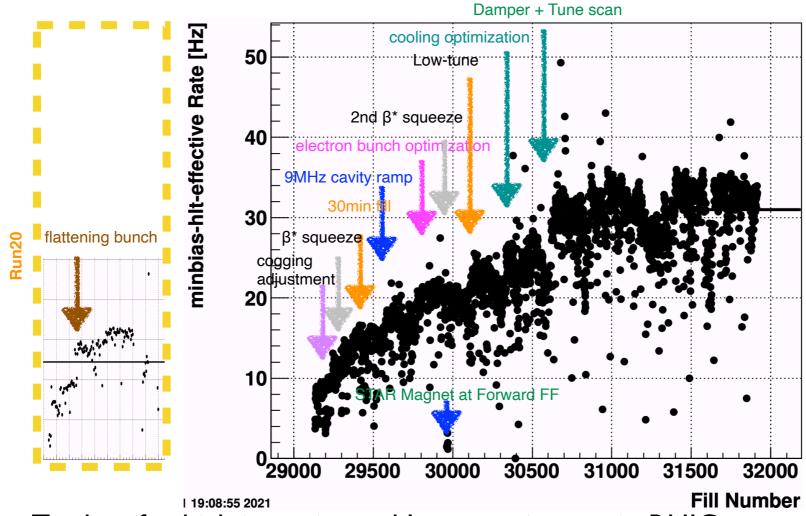
- Demanding Goals
 - Lowest collision energy in BES II
 - Multiple energies and species
 - Need efficient data taking to maximize yield
- +Challenging operation due to COVID19

AuAu at $\sqrt{s_{NN}}=7.7$ GeV



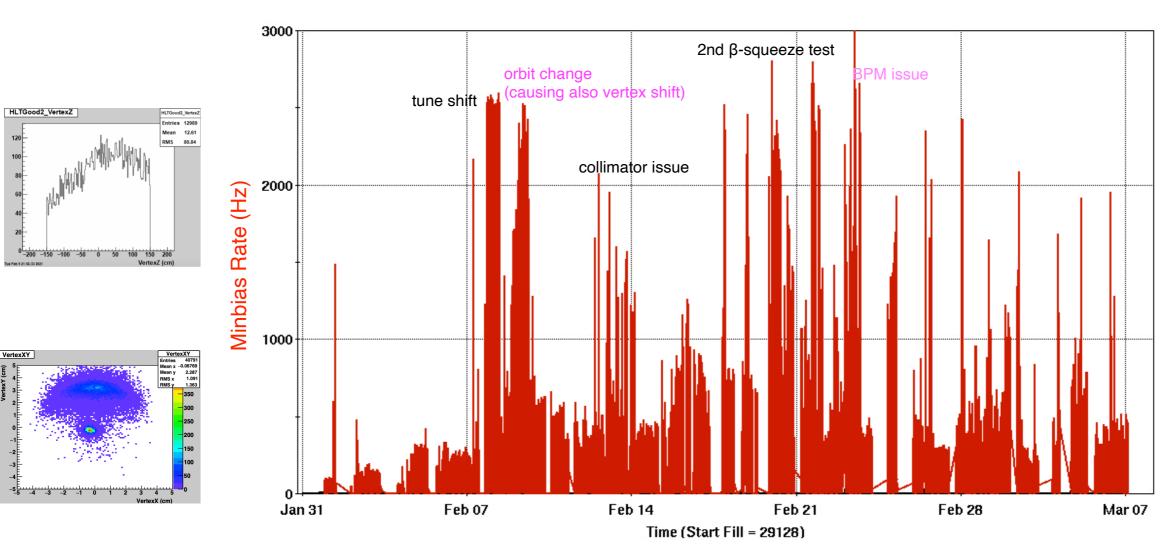
- Jan 29 May 1: 83 days physics, 62% (51.5 days) Store/Physics On
- Tracking the goal with "effective good event": HLT good event rates with z vertex in ±70cm and ±150 cm (with assumed efficiency for physics 30% in 70-150cm) [At 7.7 GeV HLT-Effective = 1.27*HLT-70]

Continuous luminosity improvement



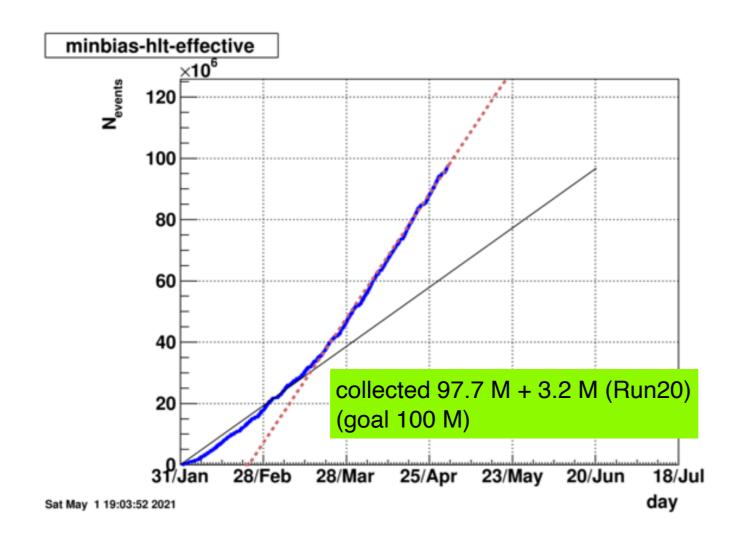
- Beam from Tandem for high intensity and lower emittance in RHIC
- 28 MHz RF (h=369) concurrently with 9 MHz
- Flattening bunch (defocusing RF) and reducing space-charge effect
- 9 MHz RF ramping down (2/3) during injection and squeeze to reduce beam loss
- β^* squeeze 4.5m \rightarrow 3m (8 min) \rightarrow 2.5m (20 min)
- LEReC with new 1.4 GHz cavity for longer electron bunch length to reduce heating effect
- Optimum fill length (30min)
- Tune, Cooling optimization, Damper

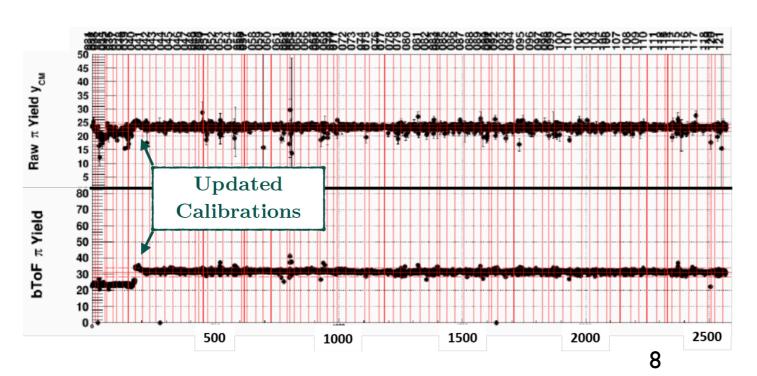
Background issues

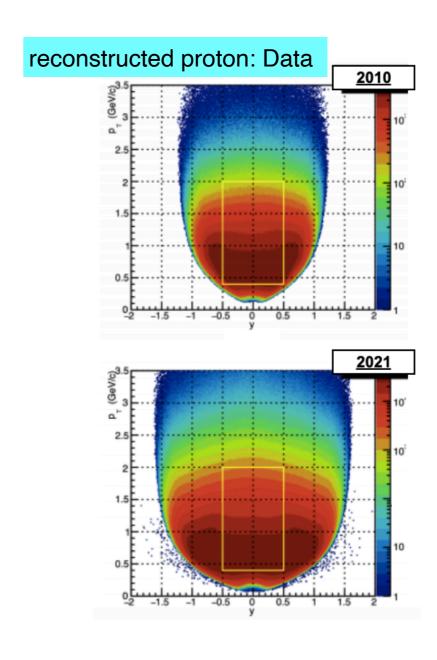


- high min-bias/HLT-good signal indicates high background during a store
- Overall background under control
- Occasional high background mainly associated with β^* squeeze ramps
 - mostly in yellow vertical
- Sensitive to various machine settings
- Collimator setting changes
- Fine (re)tuning machine parameters (tune, chrome..) needed

Data collection at $\sqrt{s_{NN}}=7.7$ GeV

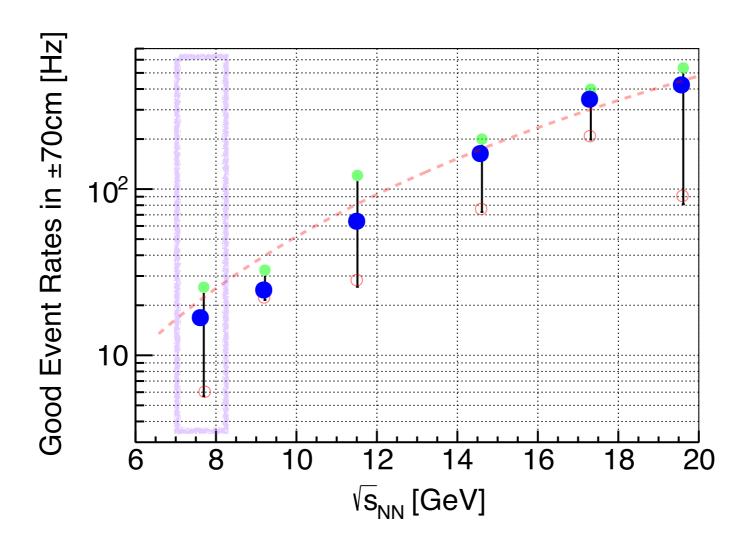






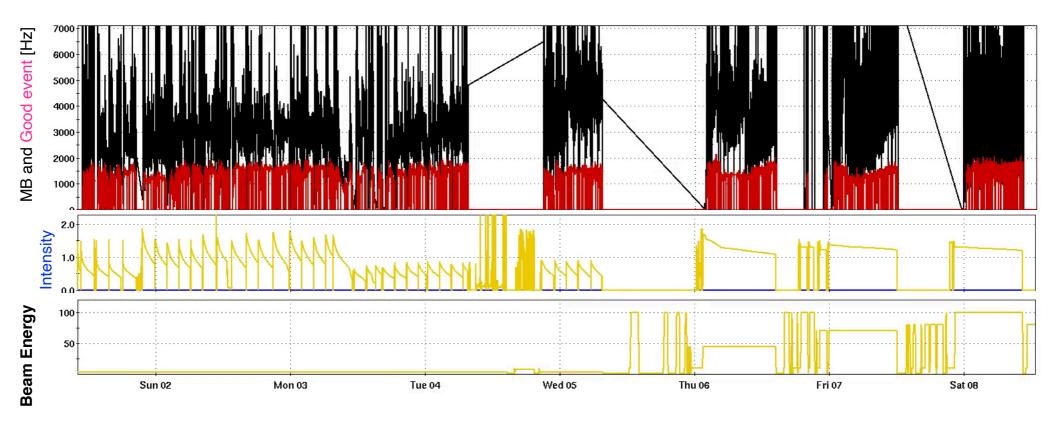
- Reached the goal: IOIM total collected
- Data QA: stable high quality data

√s_{NN}=7.7 GeV: rate vs collision energy in BESII



- Maximum, Average, Minimum (initial) of good event rates
- Average good event rate $\propto E^{3.2}$

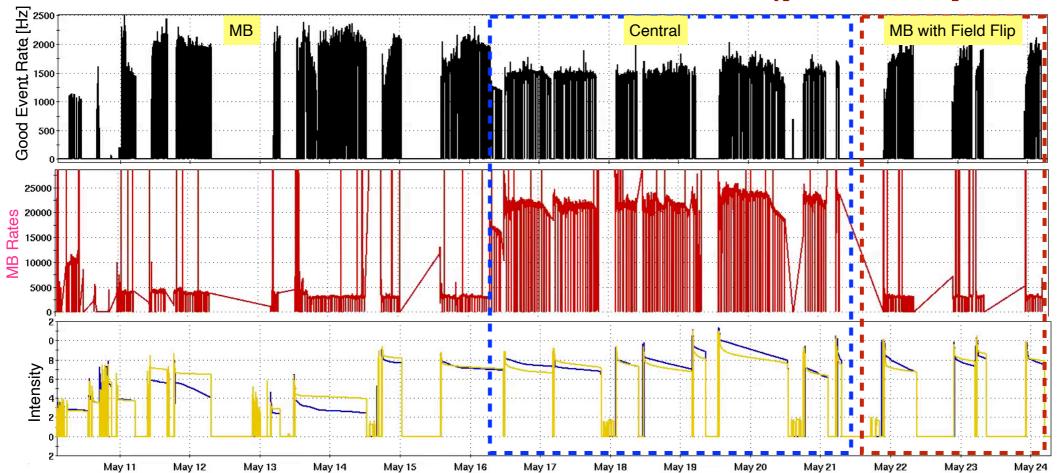
Fixed Target runs (priority 2)

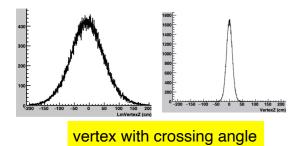


- Measurements with fixed target at $\sqrt{s_{NN}}$ =3, 9.2, 11.5, 13.7 GeV
- Clean Stable and high rate (Good event rate > 1.5 kHz)
- Beam Orbit control (and BBQ) works well keeping the rate optimal
- Event trigger and scalar rates feed back crucial for beam steering
- All data sets reached their goal in the projected time

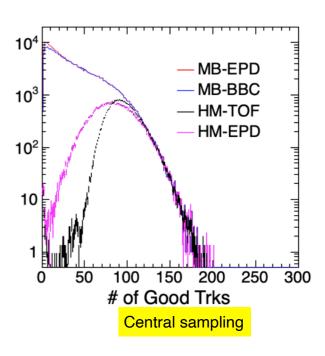
beam	HLT Good (M)	Goal (M)	
3.85 GeV	309	300	
44.5 GeV	53.9	50	
70 GeV	51.7	50	
100 GeV	52.5	50	

O+O at $\sqrt{s_{NN}}=200$ GeV (priority 3a)

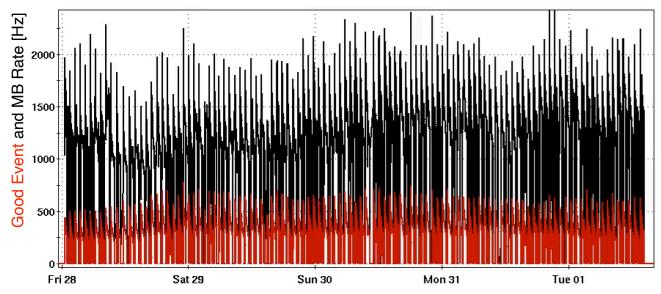


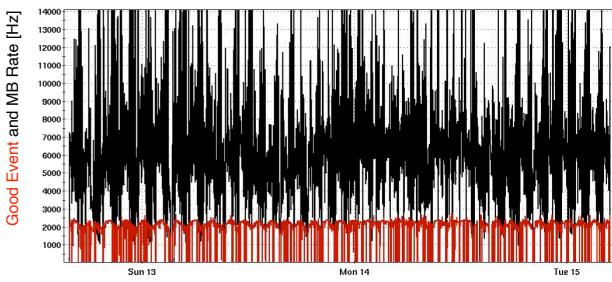


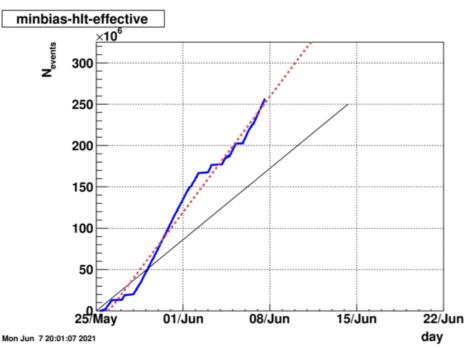
- crossing angle (1.65 mrad) for narrowing vertex: rms 50 18cm
- long fills with low background: stable good event rate ~1.5-2 kHz
- Goals reached: MB 402M (goal 400M), Central 212M (Goal 200M)
- +MB data set with STAR magnetic field flipped 125M

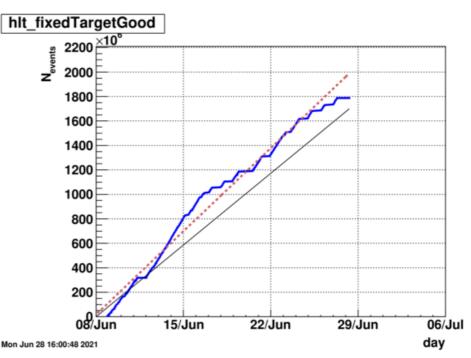


Au+Au at $\sqrt{s_{NN}}=17.3$ GeV (priority 3b) Fixed Target at 3.85 GeV (priority 3c)







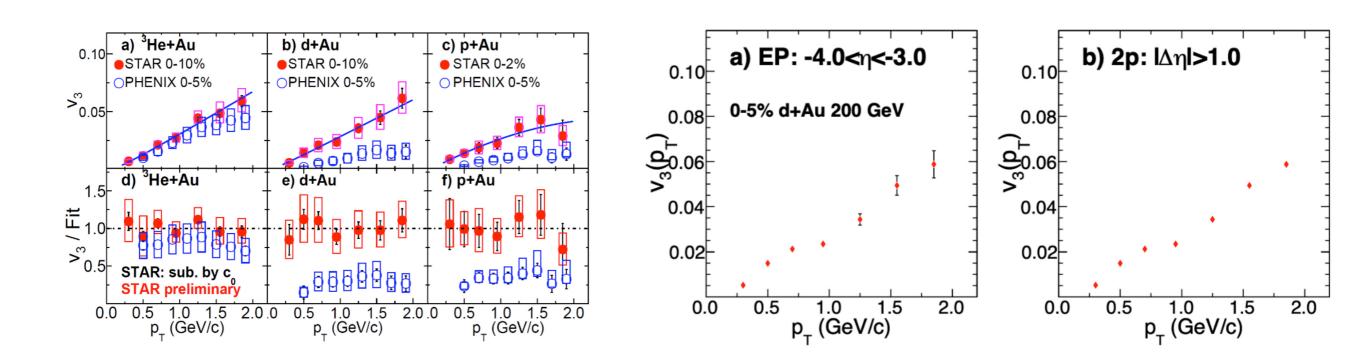


- Au+Au at √s_{NN}=17.3 GeV
 - stable and clean data
 - 256M Good events collected (Goal 200M)
 - 7.0 total data taking days

Fixed Target at 3.85 GeV

- consistent fills, well controlled rates
- Total: 1795M +309M (Goal 2B)
- II.0 total data taking days

Additional physics opportunity in Run21 (BUR June 21)

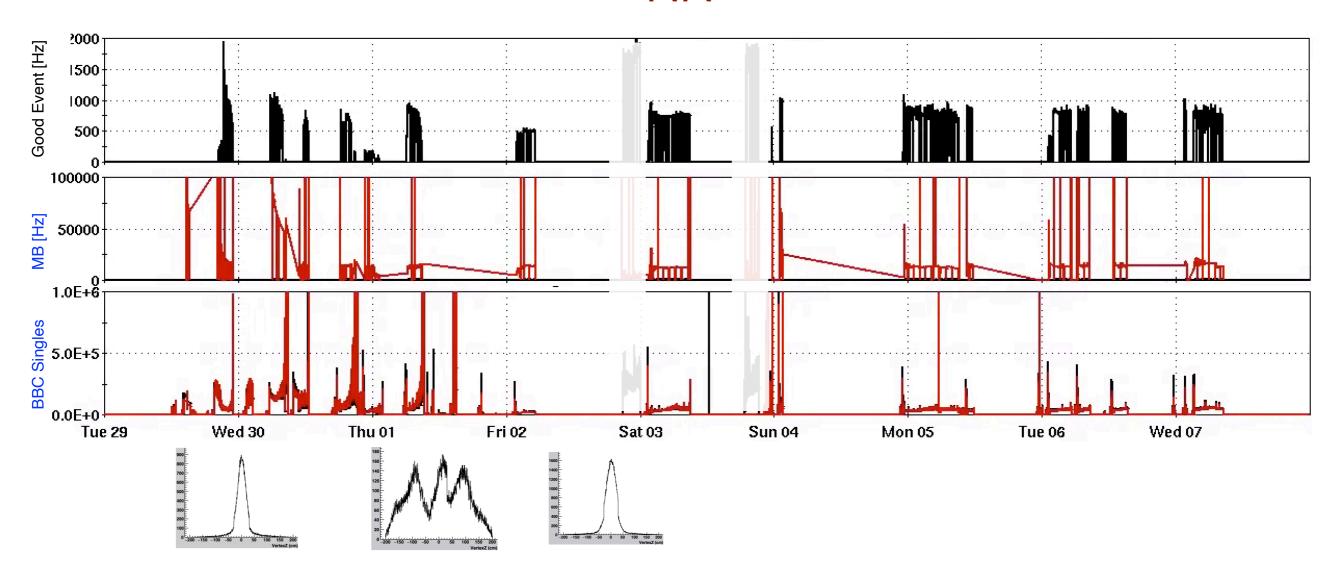


PAC Recommendation (June 2021)

For this final period of Run 21, the PAC sees

the highest scientific priority as being a d+Au run. With the newly extended rapidity coverage provided by its new detector elements, we anticipate that STAR will be able to use the data from such a d+Au run to yield significant new understanding, and hopefully clarity, on the currently incompletely understood differences between data on v_3 in d+Au collisions taken previously by STAR and PHENIX in non-overlapping regions of rapidity.

dAu at $\sqrt{s_{NN}}=200$ GeV



- Total 45 hours physics data taking (6/28 7/7)
- crossing angle (Imrad) causing significant background
- beam offset (for rate control) enhancing satellite collision vertices
- Physics data taking: no crossing angle with timing cut using ZDC: narrow vertex sampling without bias
- Good MB 108M, Good Central 109M collected: Goal achieved

Other data runs not in BUR

- Flipped STAR Magnetic Field: data taking with "Forward" Full Field for disentangling geometry and field effect in TPC calibration
 - difficulty to deliver a reasonable rate (large coupling correction) (March 3-4) during 7.7 GeV.
 - Done at the end of O+O run (May 21-24): 125M MB data accumulated
- Parasitic FXT run with 26.5 GeV beam with CeC: 18 hrs, 89M good collected
 - Requested to run in colliding 26.5+26.5 mode during CeC, but not approved with the current accelerator safety envelope
- New Forward Calorimeters commissioning data taken parasitically during the physics running

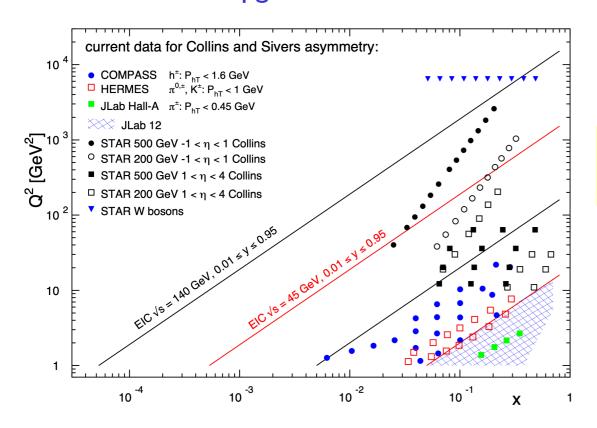
Run21 operations

- Continuing the **new normal operation mode** from Run20b with a limited shift crew 2+1: leader, detector operator (separate room) + a remote crew for QA due to restricted manpower and for maximum distancing. Remote period coordinators. No f-2-f shift change and other safety protocols.
 - All connected through Zoom
 - With the running condition, works efficiently
 - Most detectors are on between fills
 - normal operation high data collection efficiency (~98%) of "physics on"
 - Run22 running conditions expected to require more shift activities
- More communication channels with MCR / CAD
 - Online QA plots, event rates, vertex info. available through CDEV and a direct web link. Fast feedback.
 - Zoom connection with MCR as needed

Beam Use Request for Run22

\sqrt{s}	Species	Polarization	Run Time	Sampled	Priority
(GeV)				Luminosity	
510	p+p	Transverse	16 weeks	$400 \; {\rm pb^{-1}}$	1

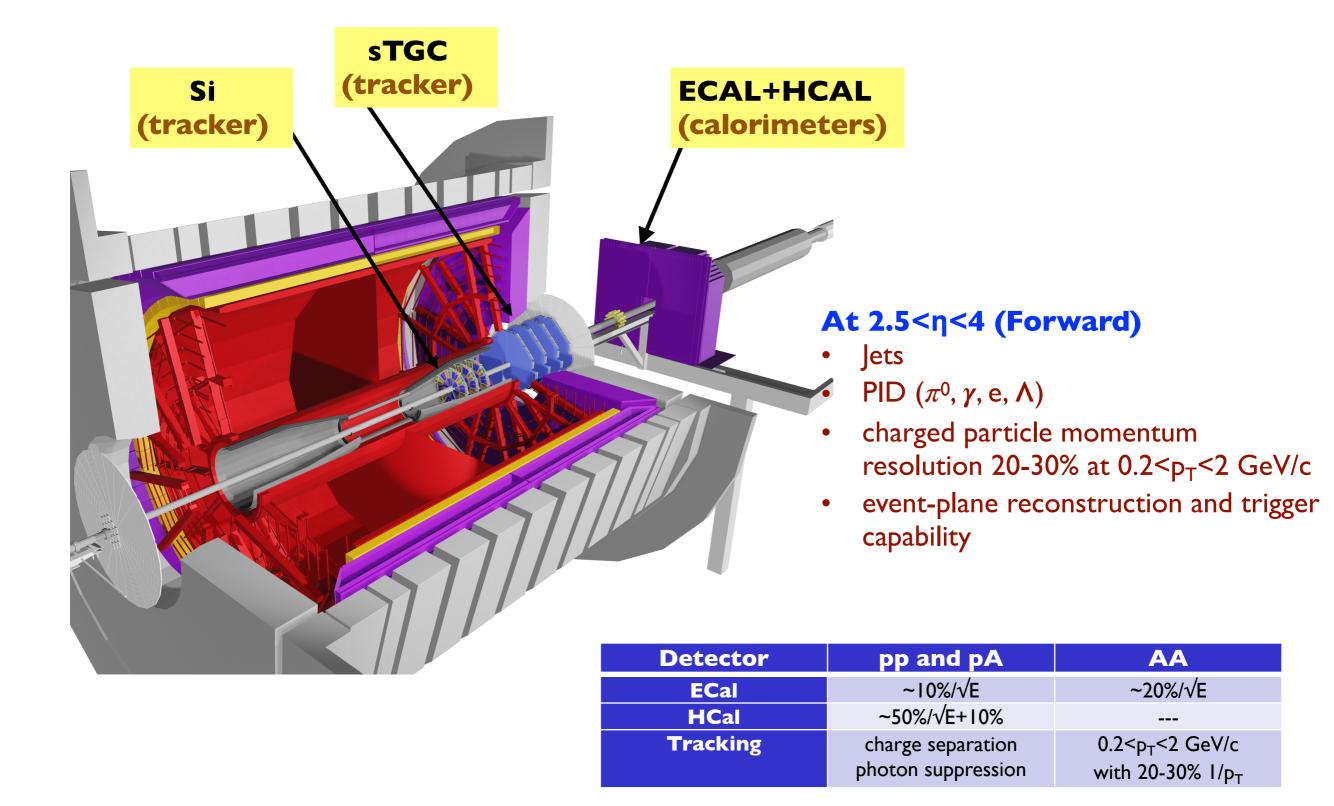
Kinematic coverage for Collins and Sivers Asymmetry: STAR covers 0.005<x<0.5 with Forward Upgrade



p+p 510 GeV up to η ~4.2 probe down to x~2×10-3 (gluons) and up to x~0.5 (valence quarks)

- Forward upgrades will be ready for Run22
- First p+p run with BES-II upgrade detectors

STAR Forward Upgrade



Running condition for Run22

- Request: Sampled luminosity 400 pb-1
- Luminosity leveling for maximum FOM at ZDC ~ 330 KHz $(\mathcal{L} \sim 135*10^{30} \text{ cm}^{-2}\text{s}^{-1})$ and polarization ~55%
- Other beam conditions spin pattern and abort gap : same as in Run 17
 - Run 17 running condition: 356 pb-1 total sampled luminosity from 13.6 physics weeks
 - $<\mathcal{L}> = 127*10^{30} \text{ cm}^{-2}\text{s}^{-1}$ with leveling with β -squeeze
 - <polarization> ~55%
 - sampled/delivered ~ 65%
- Commissioning Forward upgrade detector systems (first weeks)
 - A few special runs will be requested for commissioning and calibration: low-lumi, small number of bunches for setup and calibration
 - Running time optimization: detector experts availability

Summary

- Run21: Successfully completed BES II program with challenging lowest colliding energy at 7.7 GeV
- Archived all physics goals in BUR
- Additional physics done with d+Au
- No significant issues with data and detectors in Run21
- Efficient new normal operation with a limited shift crew
- Thanks to CAD for the excellent performance for Run21
- Looking forward to successful Run22 with new forward upgrades