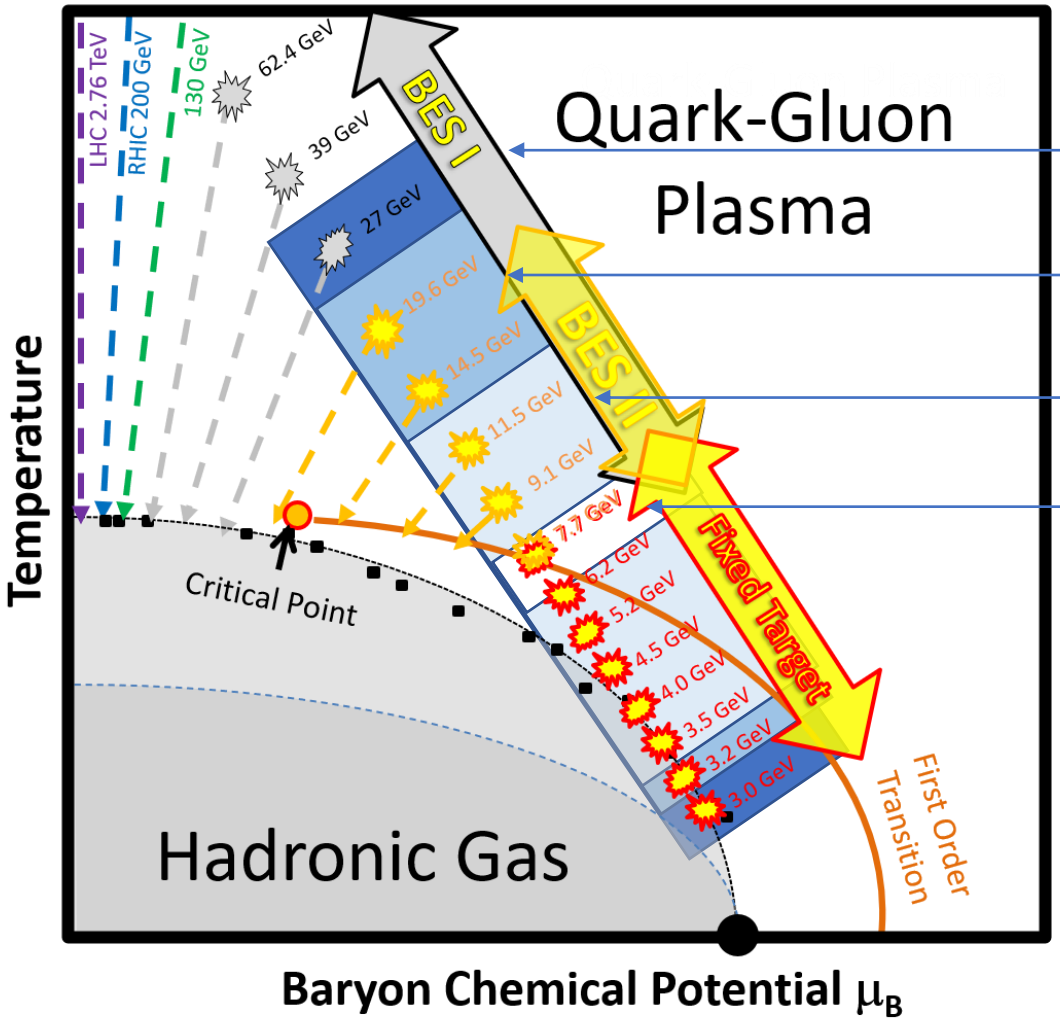
STAR Run 20 Performance Report

STAR Beam Energy Scan II – Mapping the QCD Phase Diagram



Go from easiest to hardest

Run 18 -- 27 GeV, FXT 3.0
Beams are accelerated

Run 19 – 19.6, 14.6, FXT 3.2 GeV
No acceleration in RHIC

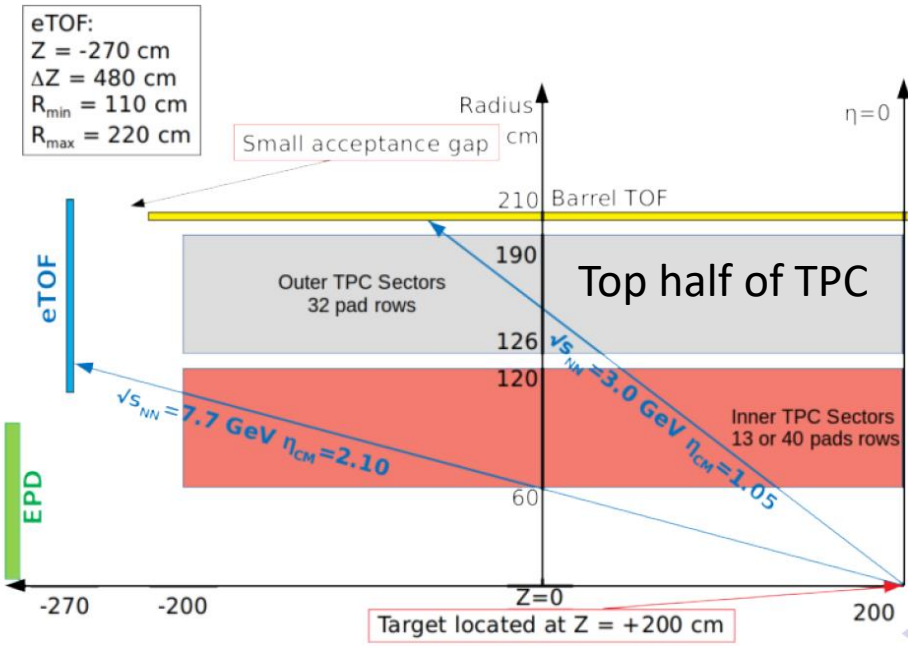
Run 20 – 11.5, 9.2, many FXT
Needs cooling at 9.2 GeV

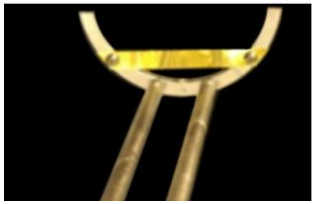
Run 21 – 7.7 GeV Collider

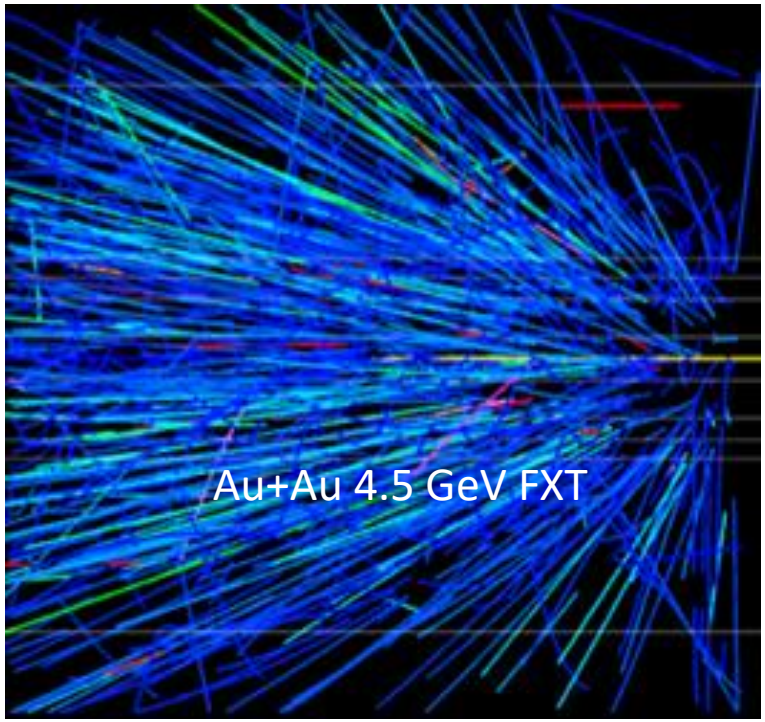
The BESII collider program maps the approach to the transition from the QGP side of the QCD phase diagram.

The FXT program maps the baryon-rich side of the phase diagram

Why Are Lower Fixed-Target Energies Easier?







As the beam energy is increased, the midrapidity particles are focused further forward.

The detector upgrades (iTPC, EPD, and eTOF become increasingly important. (Especially eTOF)

Beam Use Request (and achieved) for Run20

	Beam Energy (GeV/nucleon)	$\sqrt{s_{NN}}$ (GeV)	μ_B (MeV)	Run Time	Number Events Requested (Recorded)	Date Collected
	13.5	27	156	24 days	(560 M)	Run-18
	9.8	19.6	206	36 days	400 M (582 M)	Run-19
	7.3	14.6	262	60 days	300 M (324 M)	Run-19
	5.75	11.5	316	54 days	230 M (235 M)	Run-20
	4.59	9.2	373	102 days	160 M (162 M)	Run-20+20b
Run20	31.2	7.7 (FXT)	420	0.5+1.1 days	100 M (50 M+ 114 M)	Run-19+20
Run20	19.5	6.2 (FXT)	487	1.4 days	100 M (119 M)	Run-20
Run20	13.5	5.2 (FXT)	541	1.0 day	100 M (103 M)	Run-20
Run20	9.8	4.5 (FXT)	589	0.9 days	100 M (109 M)	Run-20
Run20	7.3	3.9 (FXT)	633	1.1 days	100 M (115 M)	Run-20
Run20	5.75	3.5 (FXT)	666	0.9 days	100 M (114 M)	Run-20
	4.59	3.2 (FXT)	699	2.0 days	100 M (200 M)	Run-19
	3.85	3.0 (FXT)	721	4.6 days	100 M (259 M)	Run-18
Run21	3.85	7.7	420	11-20 weeks	100 M	Run-21

"Good"

3.2

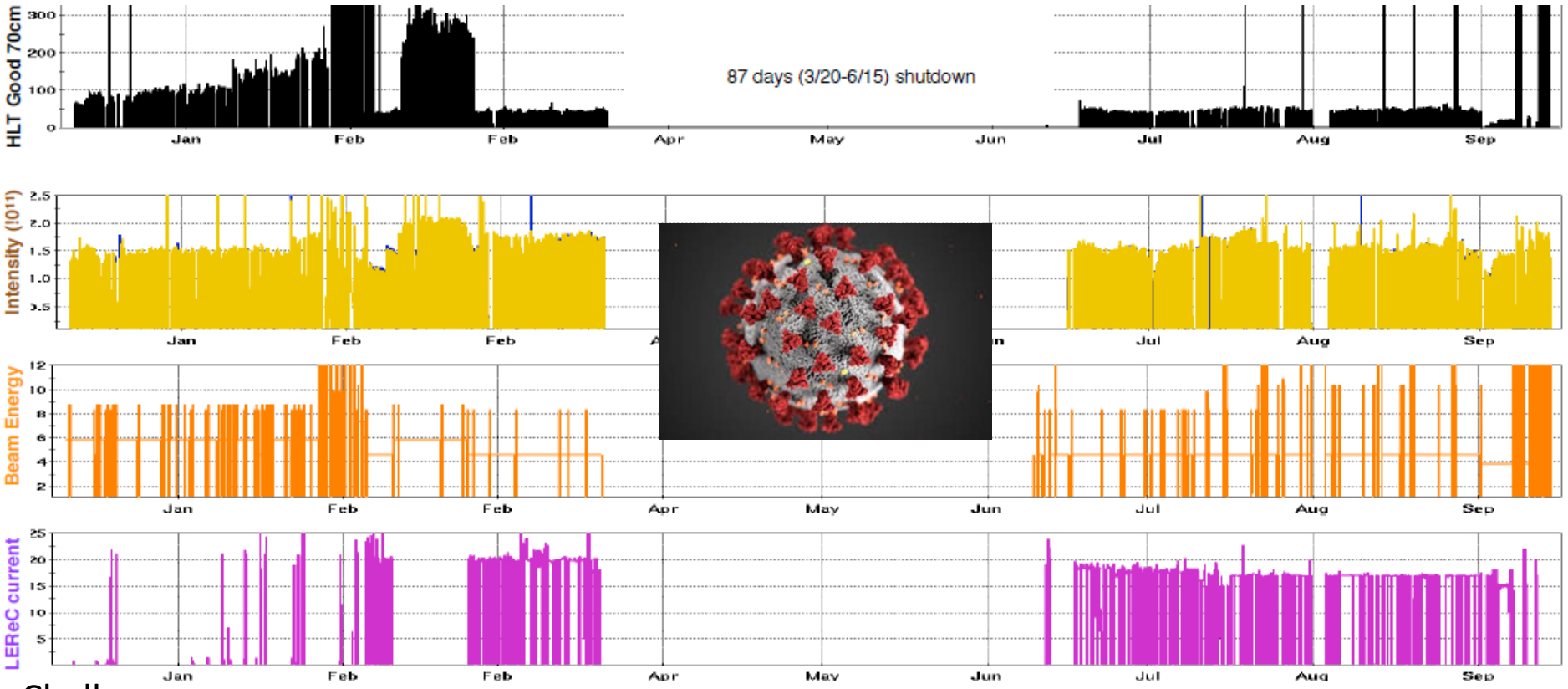
- Top priority for Run20: measuring next two energies in BES-II at **$\sqrt{s_{NN}}$= 11.5 GeV and 9.2 GeV**
- **Fixed target** measurements at $\sqrt{s_{NN}}$ = 3.5, 3.9, 4.5, 5.2, 6.2, 7.7 GeV

Overall Run Status

Energy	$\sqrt{s_{NN}}$	Start	Finish	First Run	Last Run	HLTgood	Target
11.5 GeV		Dec 10th	Feb 24th	20056032	21055017	235 M	230 M
31.2 FXT	7.7 GeV	Jan 28th	Jan 29th	21028011	21029037	112.5 M	100 M
9.8 FXT	4.5 GeV	Jan29th	Feb 1st	21029051	21032016	108 M	100 M
19.5 FXT	6.2 GeV	Feb 1st	Feb 2nd	21032049	21033017	118 M	100 M
13.5 FXT	5.2 GeV	Feb 2nd	Feb 3rd	21033026	21034013	103 M	100 M
7.3 FXT	3.9 GeV	Feb 4th	Feb 5th	21035003	21036013	117 M	100 M
5.75 FXT	3.5 GeV	Feb 13th	Feb 14th	21044023	21045011	115.6 M	100 M
9.2 GeV		Feb 24th	Sep 1st	21055032	21245010	161.8 M	160 M
26.5 FXT	7.2 GeV	July 29th	Sep 14th	21211028	21258004	317 M	(300 M)
7.7 GeV		Sep 2nd	Sep 11th	21246012	21255021	3.19 M	(2.5 M)

- We achieved all of our event statistics targets
- Comparison of HLTgood to good events seen in analysis of FastOffline show 98% overlap
  ➔ Therefore HLTgood is a good estimator
- Weekly QA meeting reviews of each data set do not indicate any major issues
  ➔ Expect bad run rejection to be less than 5% of any given data set

Overview of Run 20 Operations



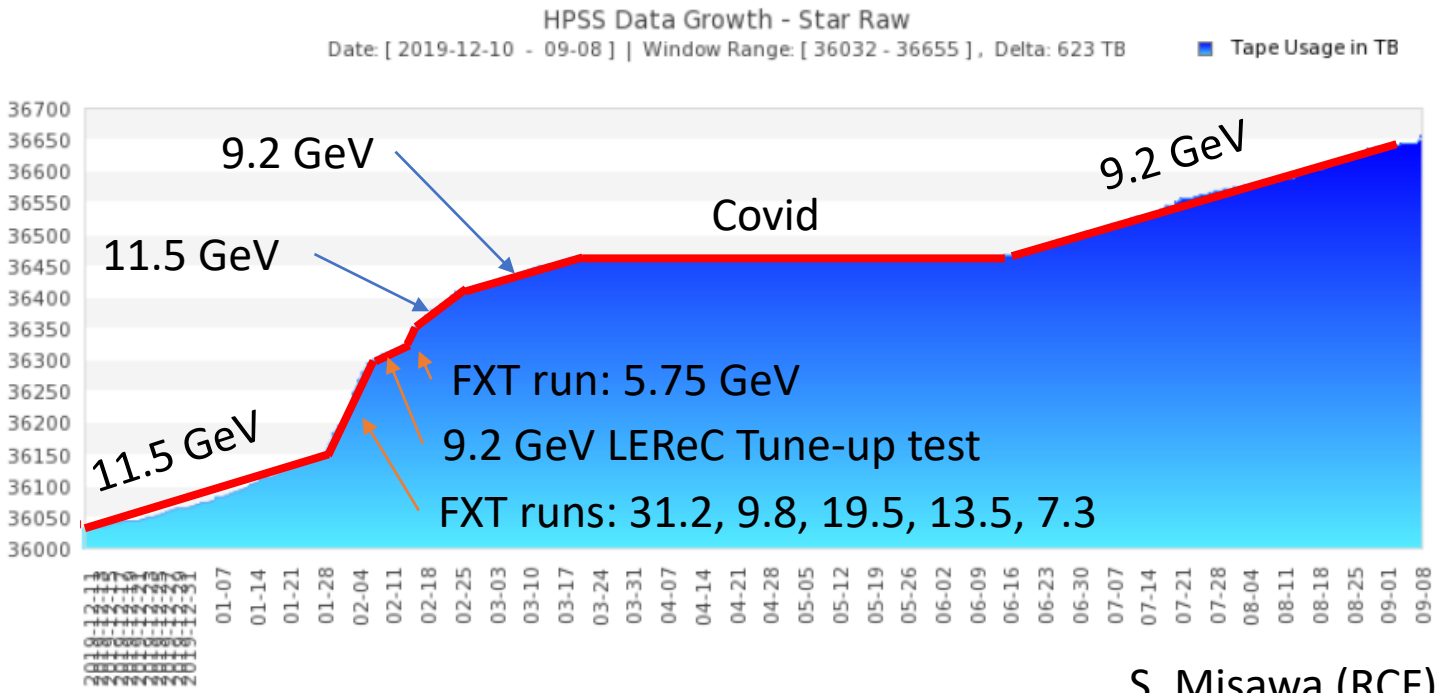
Challenges:

- Luminosity limited ➔ needed all the intensity that we could get
- Needed efficient data taking to hit targets in the required time
- Many mode changes ➔ required frequent changes to operations
- Covid-19 Interruption and changes to the conduct of operations
- Summer running conditions

Let's Look at the Data Transfer for the Entire Run 20

This is really a series of line segments

STAR Run Total – 623TB



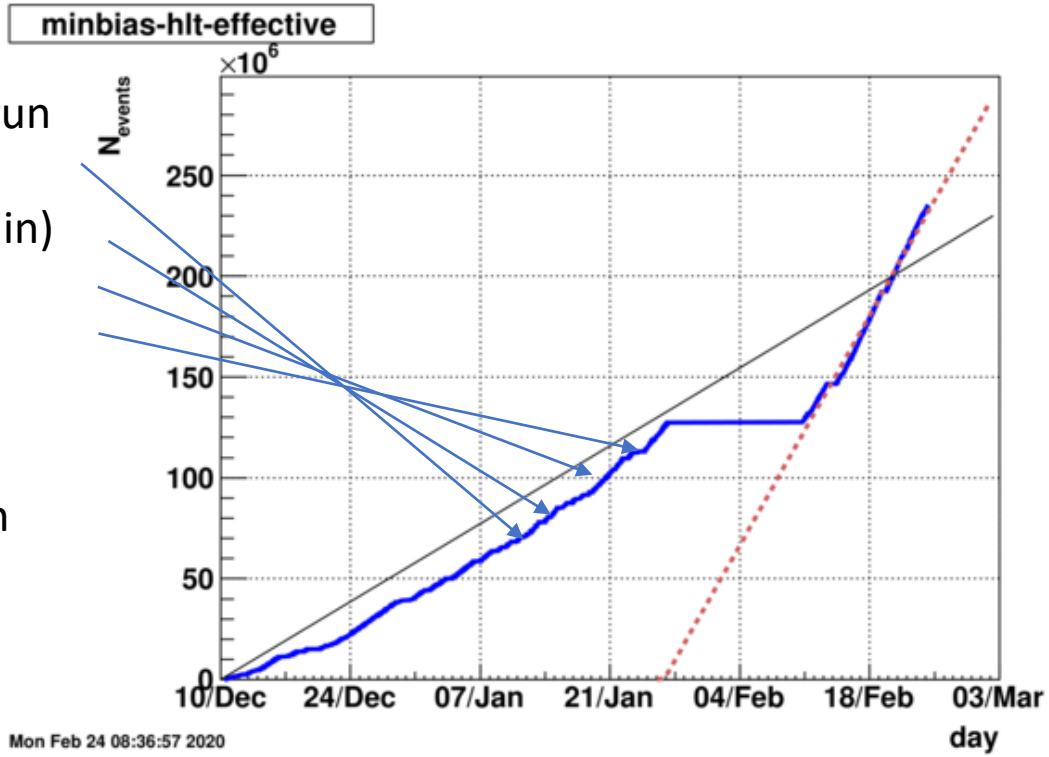
FXT at 2.65

S. Misawa (RCF)

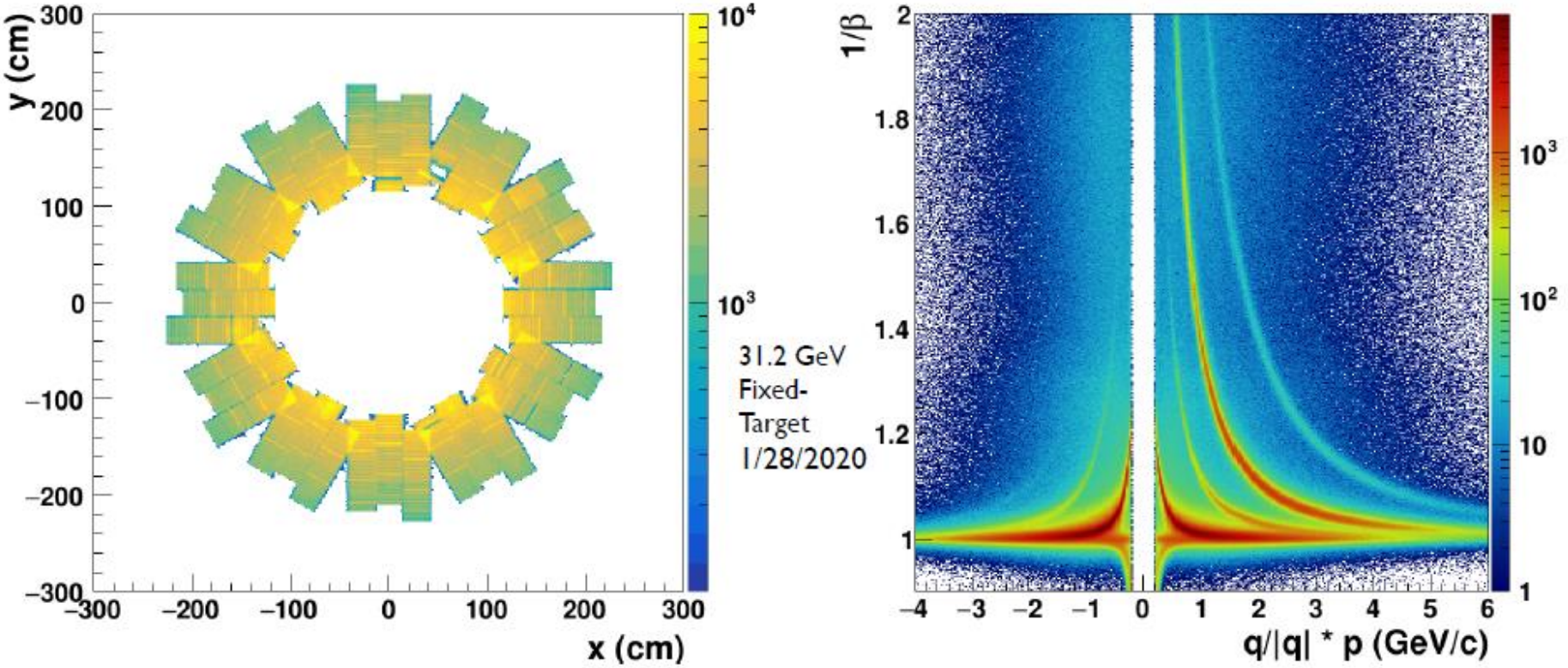
11.5 GeV Overview

	2010	predicted	achieved
Average HLTgood event rate (Hz)	30	60-80	**80**
Data taking (hours per day)	12	15	**13**
Fill Length (minutes)	20	40	**25**
DAQ Rate at start of fill (Hz)	140	250	**550**

- Continuous improvements through run
  - Tune change/optimization
  - Store length optimization (25 min)
  - AGS intensity limit increase
  - Dynamic working point
- Scheduled a two-week switch to FXT runs and LEReC 7.7 GeV optimization
- Came back to finish 11.5 GeV very efficiently

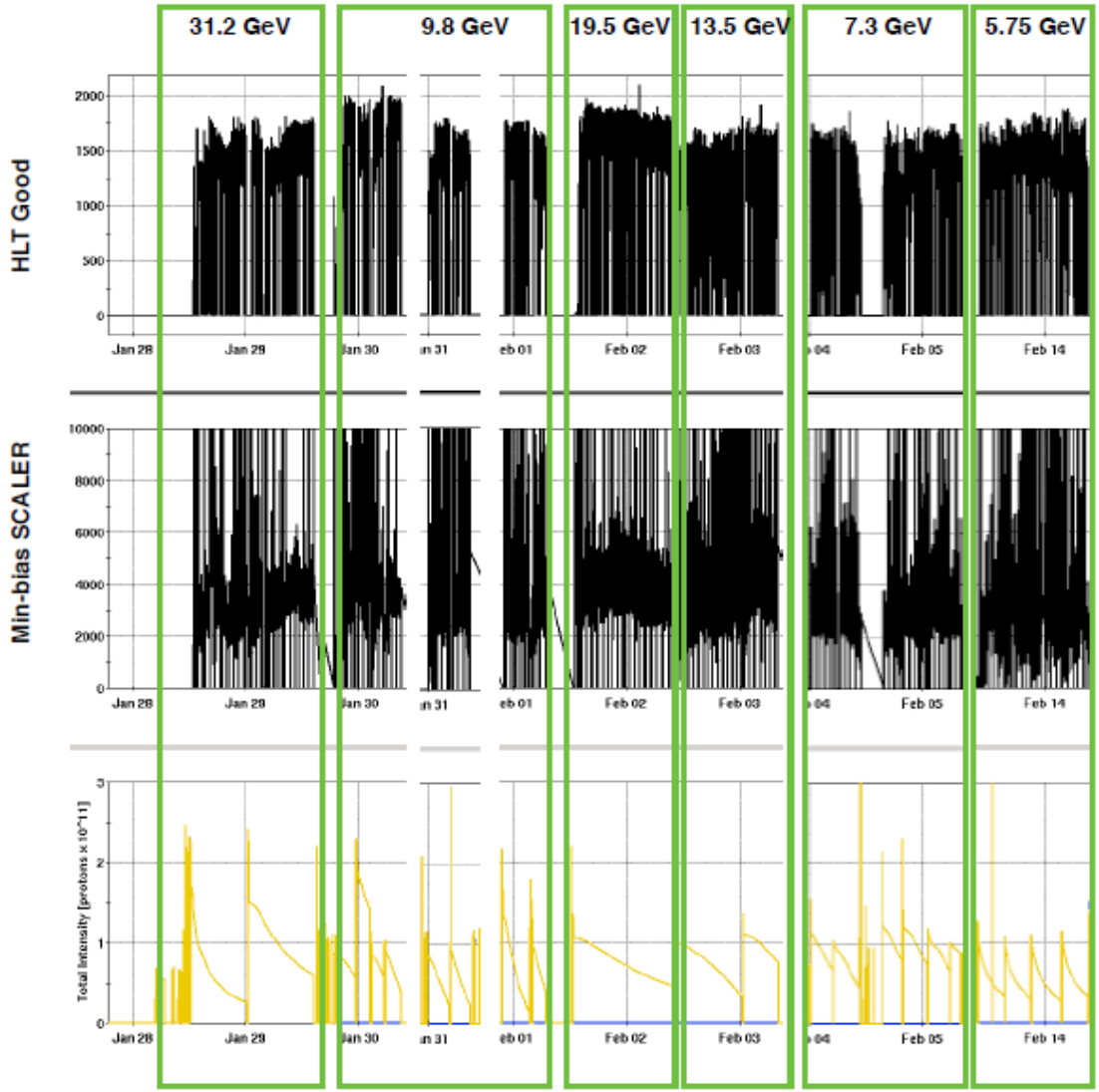


End-cap Time-of-Flight Detector (eTOF)



- Full detector was installed in 2019, but was damaged one month into that run.
- Over the shutdown, the electronics board's overcurrent protection was upgraded.
- This system is critical for all but the lowest energy Fixed-target systems.
- This was the only detector system ramped down between fills for protection.

Fixed-Target Runs



- Target is 2 cm below axis
- Yellow beam, 12 bunches
- Needed a large β^* lattice to reduce backgrounds
- Injected at new energy
- Beam is lowered to graze top edge
- DAQ rate Limited
- Rate controlled by lowering and/or defocusing the beam
- STAR scalers sent to MCR
- Fills lasted four to twenty hours
- Very beam and efficient trigger
- Interleaved with LEReC testing to maximize efficiency of operations
- Parasitic FXT running at 26.5 (7.2) GeV during CeC dedicated time

➢ **Achieved all physics goals in the planned amount of time**

Overall FXT Runs with eTOF

Beam Energy	CM Energy	HLTgood w/ eTOF	Minimum w/ eTOF
31.2 FXT	7.7 GeV	101.7 M	100 M
26.5 FXT	7.2 GeV	298.7 M	NA
19.5 FXT	6.2 GeV	80.4 M	80 M
13.5 FXT	5.2 GeV	88.9 M	70 M
9.8 FXT	4.5 GeV	72.7 M	65 M
7.3 FXT	3.9 GeV	106.4M	50 M
5.75 FXT	3.5 GeV	99.4 M	70 M

- eTOF was damaged in run 19 at the start of the 14.6 GeV run
  - ➔ Therefore chose to postpone FXT runs until 2020
- eTOF had some development period during the early stage of the run 20
- We chose a period of time when we felt that eTOF was reliable “enough” to run FXT
  - ➔ Wanted to complete these runs before damaging eTOF again
- eTOF was still not included in all events, but we set eTOF specific goals for each energy

9.2 GeV Overview

	2019	predicted	Achieved
Average HLTgood event rate (Hz)	6.2	33-53	**33**
Data taking (hours per day)	8	14	**13**
Fill Length (minutes)	45	30	**45**
DAQ Rate at start of fill (Hz)	60	160	**200**

Initial Test :

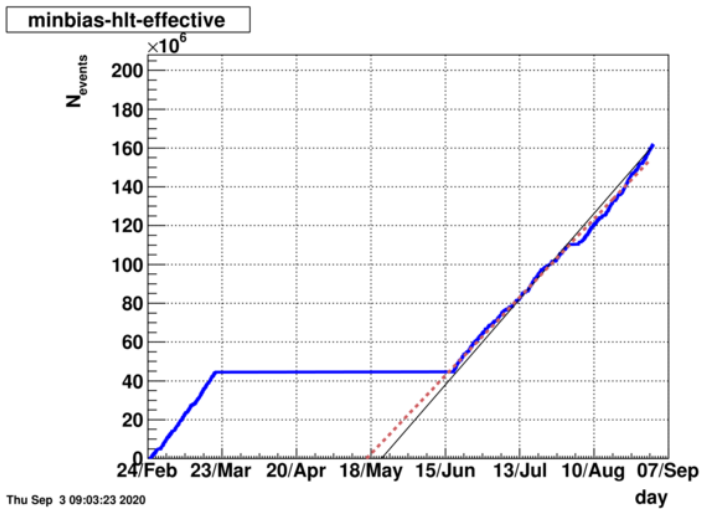
- January 30th 8:20 PM to 10:25 PM
- Runs 21030030 to 210330033
- Accumulated 35 k HLTgood70 events
- Good event rate = 8 Hz

Electron Cooling Commissioning :

- Feb 5th 6:30 PM to Feb 10th 8:00 AM
- Runs 21036022 to 21041013
- Accumulated 7.2 M HLTgood
- Good Event rate = 33 Hz

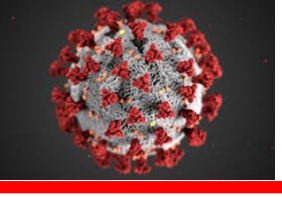
First Physics Production :

- Feb 24th to Mar 20th
- Runs: 21055032 to 21088027
- Accumulated: 44.5 M HLTgood



Second Physics Production :

- Jun 17th to Sep 01st
- Runs: 21169036 to 21245010
- Accumulated: 161.8 M (1st and 2nd period)



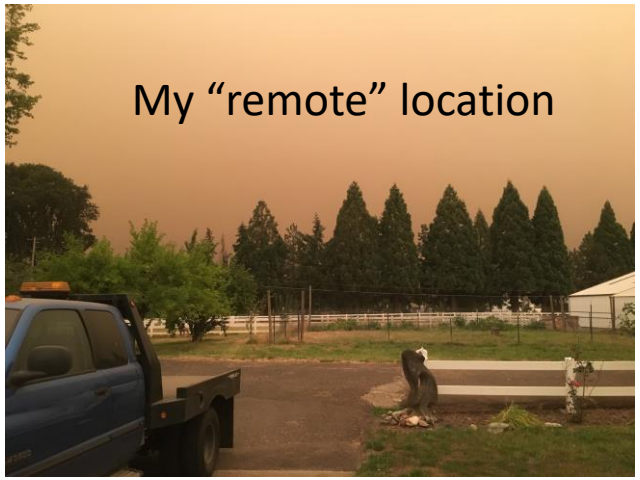
Covid-19 Protocols

- In mid-March, RHIC bravely carried on operations until New York State shut down ➔ Early Covid-19 protocols were developed, but supplies were very short.

- RHIC restarted after an 87 day break, and everything came back up very quickly, with similar conditions.

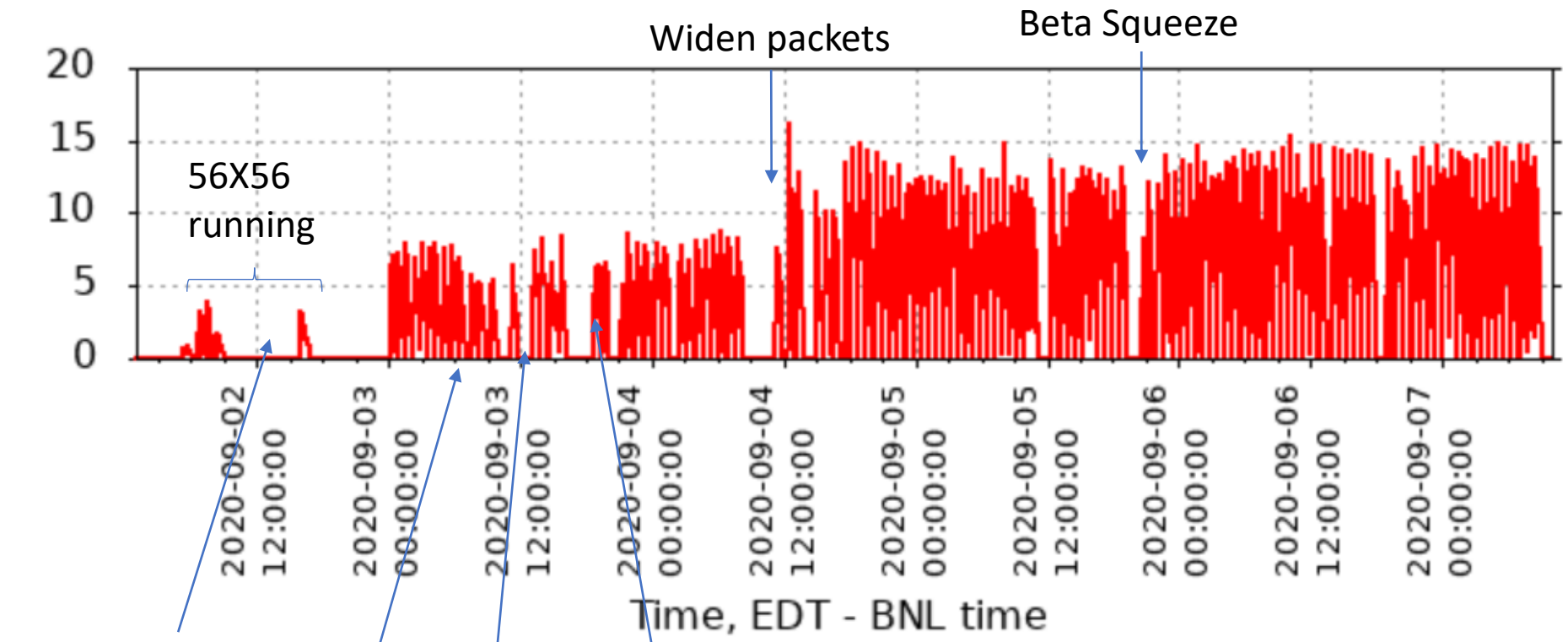
- STAR Covid-19 Operations:
  - Shift crew reduced from 4 to 2+1(remote), PC remote
  - The onsite crew members were in separate buildings
  - Online QA plots were made available remotely
  - Detector operator station set up in the trailer
  - 24 hour live bluejeans link for crew and operations team
  - End-of-shift cleaning, no face-to-face shift change
  - All teams staffed by “local” STAR group

- Many “good developments ➔ 24 hour bluejeans link, all meetings available to off-site folks



Not so good ➔ Thunderstorms

7.7 GeV Collider Running



First run: 21246010

Switch from EBIS to Tandem: 21247009

Global timing change: 21247014

MCR shifted the vertex Z: 21247034-35

Achieved the goals for the test

Plans for Run 21

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

Highest priority ➔ Finishing BES II (i.e. 7.7 GeV Collider run) ➔Confident based on test run

Second priority ➔ FXT runs at 3.0, 9.2, 11.5 and 13.7 GeV

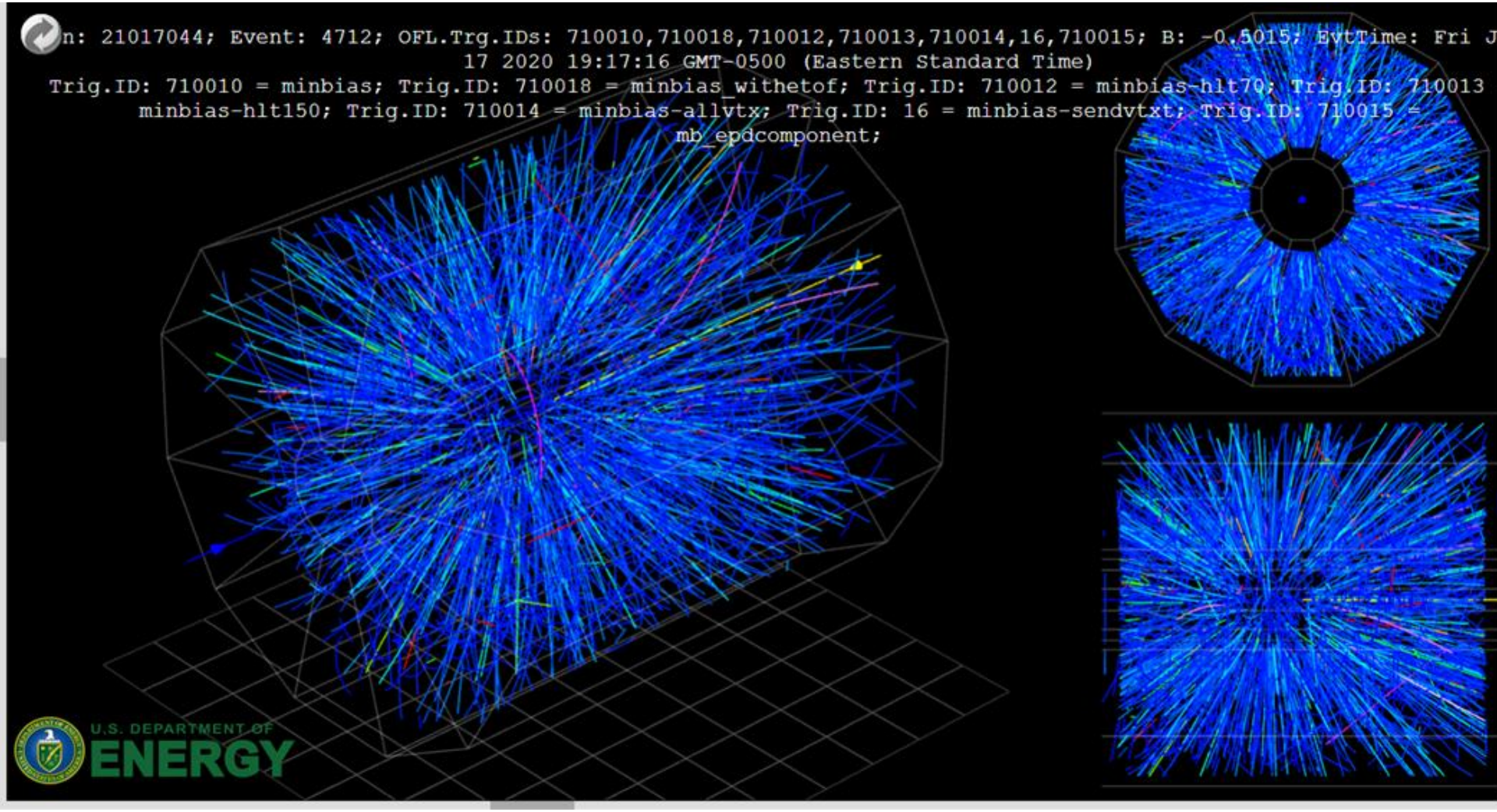
Third priority ➔ 17.1 GeV Au+Au collisions, 200 GeV O+O collisions, and/or 2 B 3.0 GeV FXT

Requesting 53 GeV Au+Au collisions to be run parasitically as time permits during CeC running

Summary

- All physics goals for run 20 were met or exceeded.
- 3 Collider and 7 FXT data sets.
- Performance for all energies met the expected targets.
- Efficient operations through Covid-19 and thunderstorms.
- Many thanks to all those who worked so hard for so long to make this a very successful run ➔ RHIC operators, RHIC experts, LEReC team, CeC team, STAR operations group, the “local” BNL group.
- Looking optimistically forward to Run 21.

Extras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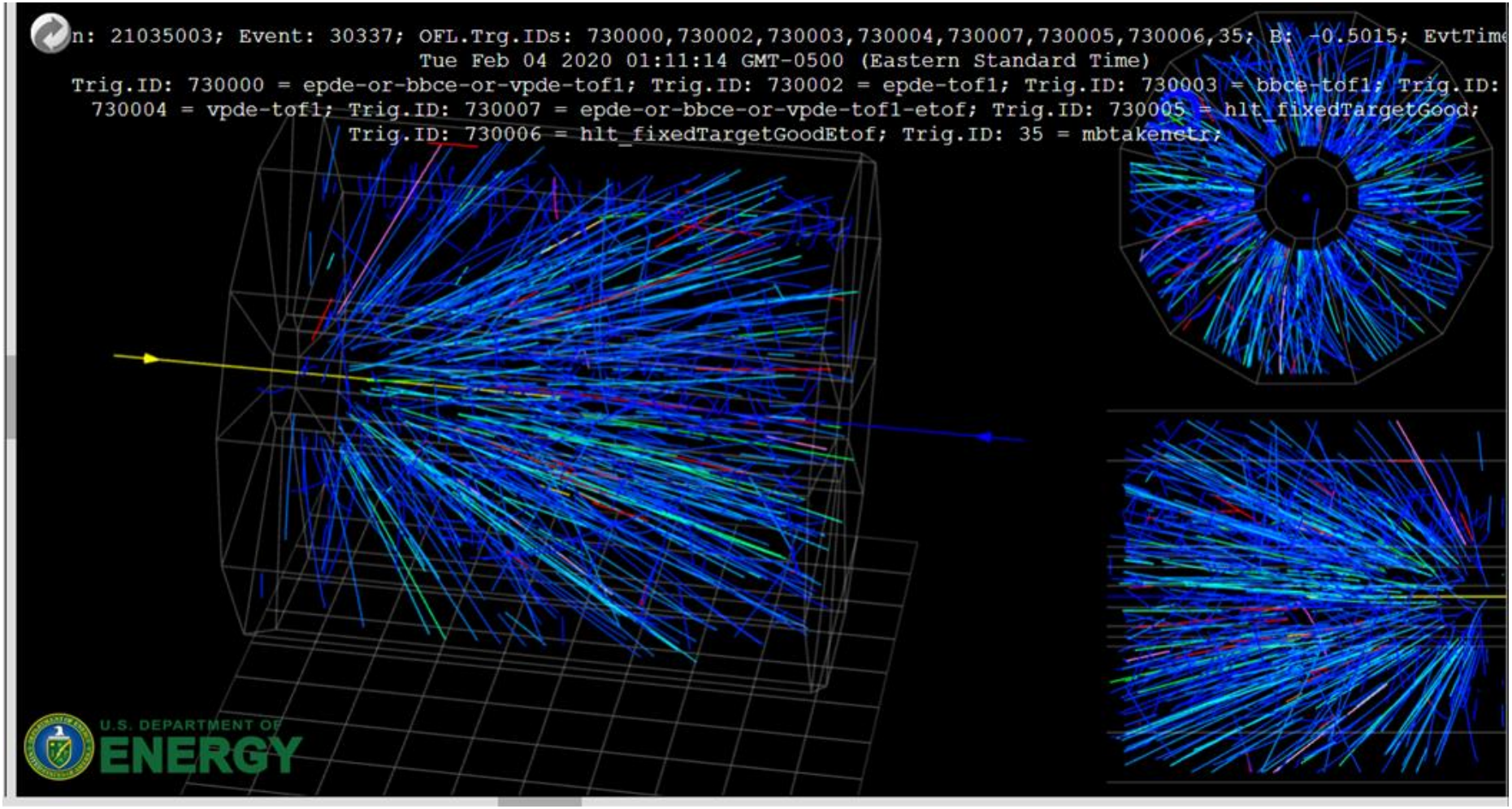
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PAC closeout note for Run21 BUR

- **Accumulating the required data at 7.7 GeV (100M events) needed to complete the BES II program is the highest priority.** We commend CAD for successfully improving the beam performance to enable the collection of the 7.7 GeV data within 15-20 weeks. Given the strong scientific motivations for other elements of the proposed Run 21 program, see below, we strongly encourage CAD to explore any further incremental improvements of the luminosity that they can envision,
- **FXT measurements at 4 energies, 1 week in total, have been identified by STAR as their second priority for Run 21. We concur with this prioritization; these are important measurements and should be carried out if the beam time is available.** Collecting 300M events in fixed target running at sqrt(s) = 3 GeV, now with the iTPC and eTOF in place, will allow statistically significant measurements of the most important BES-II observables at this lowest energy, which is significant because the acceptance for fixed target measurements at this energy is similar to that for collider measurements at sqrt(s) = 7.7 GeV. This will allow quantitative comparison of systematic effects in these measurements that differ between collider and fixed target collisions.
- **In its BUR, STAR presented three different proposed runs as third priorities for Run 21, without providing a priority ordering. The PAC considers the proposed 1 week O+O run at sqrt(s) = 200 GeV (200M central events) and the proposed 2.5 week Au+Au run at sqrt(s) = 17.1 GeV (250M events) both to be important to the RHIC scientific program. At present, the PAC would rank the O+O run higher in priority**, but STAR may choose to flip this priority-ordering if within a few months they can look at preliminary results from at least half of the BES-II data at sqrt(s) = 14.6 and 19.6 GeV. The third run among STAR's third priorities is a long (3 week) fixed target run to collect 2B events at sqrt(s) = 3 GeV. The PAC ranks this as third priority among these three.