STAR Run20 summary and expectation for Run21

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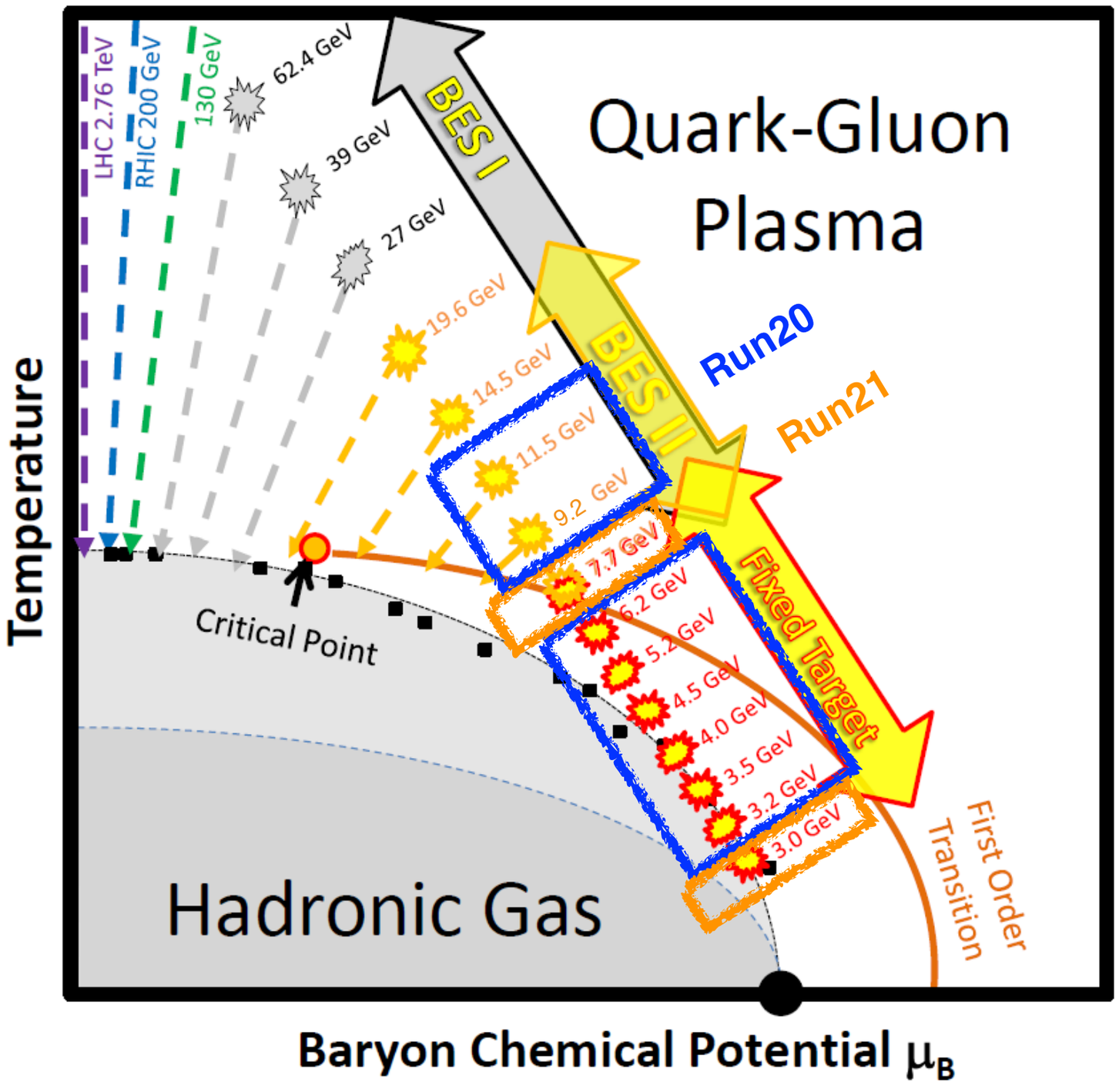
RHIC Retreat 10/15/2020

STAR Run20,21: Beam Energy Scan II
Mapping QCD phase diagram



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

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
31.2	7.7 (FXT)	420	0.5+1.1 days	100 M (50 M+114 M)	Run-19+20
19.5	6.2 (FXT)	487	1.4 days	100 M (119 M)	Run-20
13.5	5.2 (FXT)	541	1.0 day	100 M (103 M)	Run-20
9.8	4.5 (FXT)	589	0.9 days	100 M (109 M)	Run-20
7.3	3.9 (FXT)	633	1.1 days	100 M (115 M)	Run-20
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
3.85	7.7	420	11-20 weeks	100 M	Run-21

"Good"

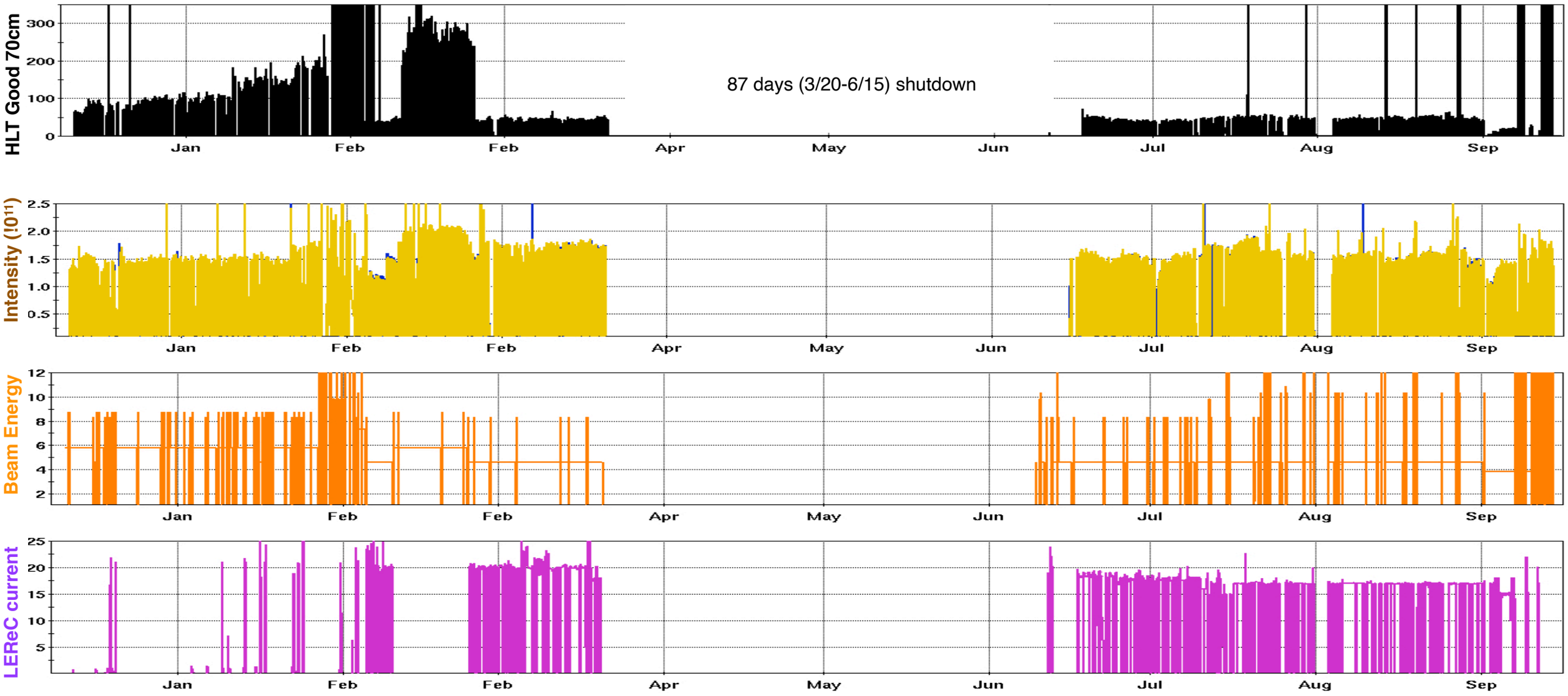
Run20

Run21

3.2

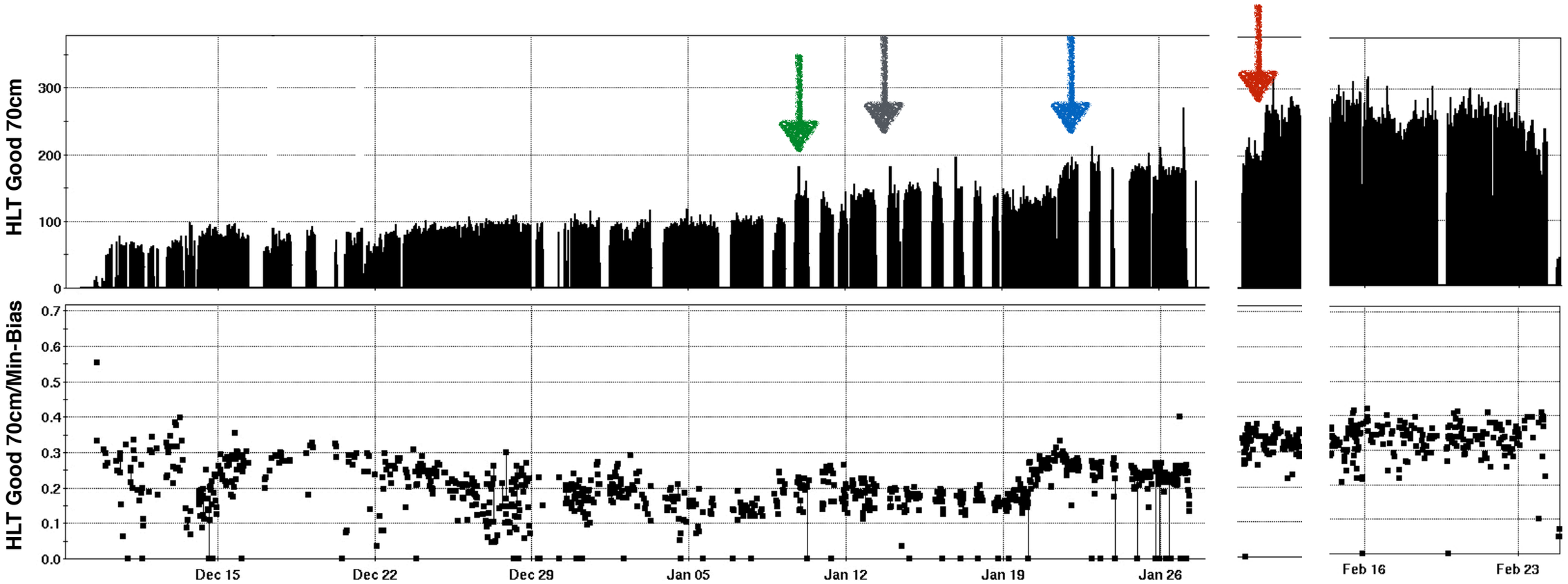
- Top priority for Run20: measuring next two energies in BES-II at **$\sqrt{s_{NN}}$= 11.5 GeV and 9.2 GeV**
- **Fixed target** measurements at $\sqrt{s_{NN}}$ = 3.5, 3.9, 4.5, 5.2, 6.2, 7.7 GeV

Run20 operation



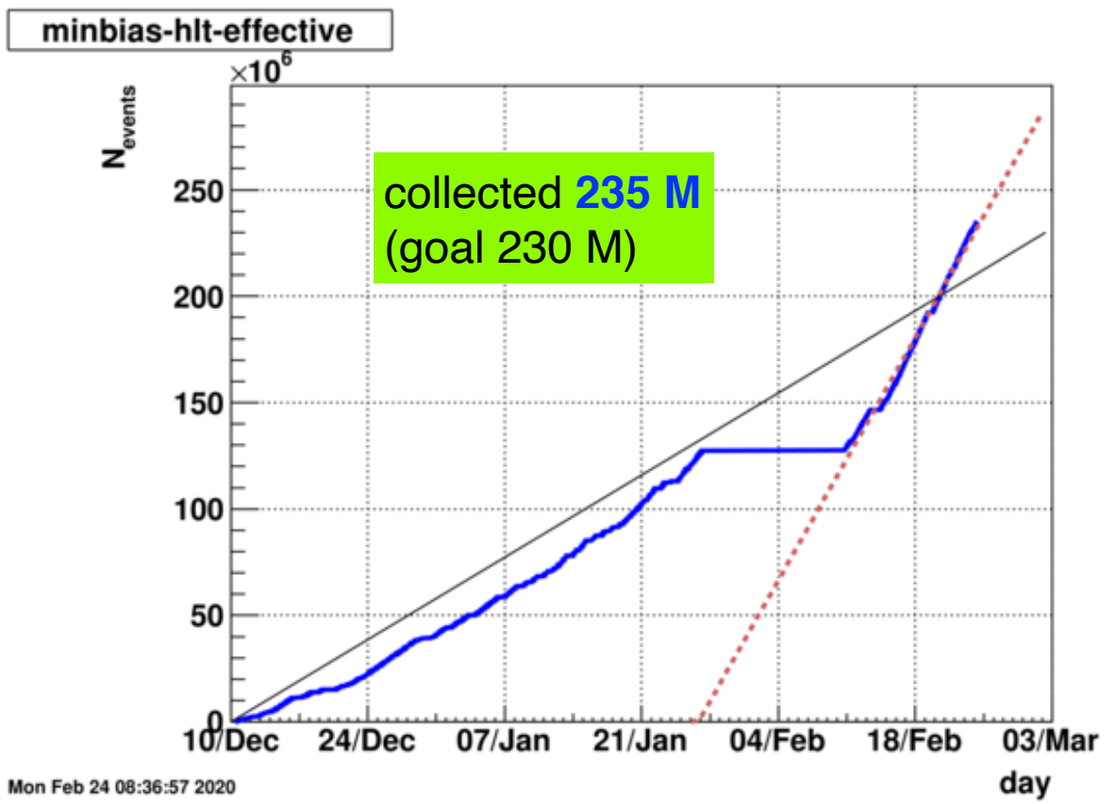
- **Challenging physics goals** required
  - all the luminosity increase and optimization from the machine
  - efficient data taking to maximize yield
- Many energy settings to cover: timing and configurations
- +**Challenging operation** due to COVID19 (limited crew, weather)
- No new subsystems added in STAR detector for Run20. **Keeping all subsystems working at best performance**
- 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)

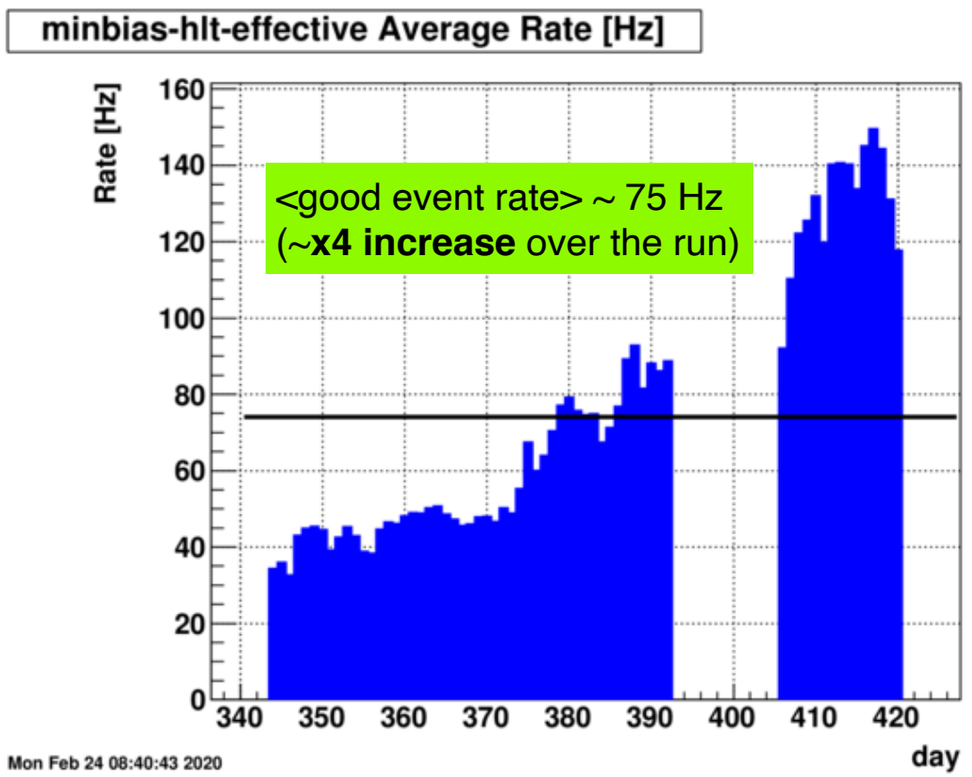
Beam at $\sqrt{s_{NN}}$=11.5 GeV

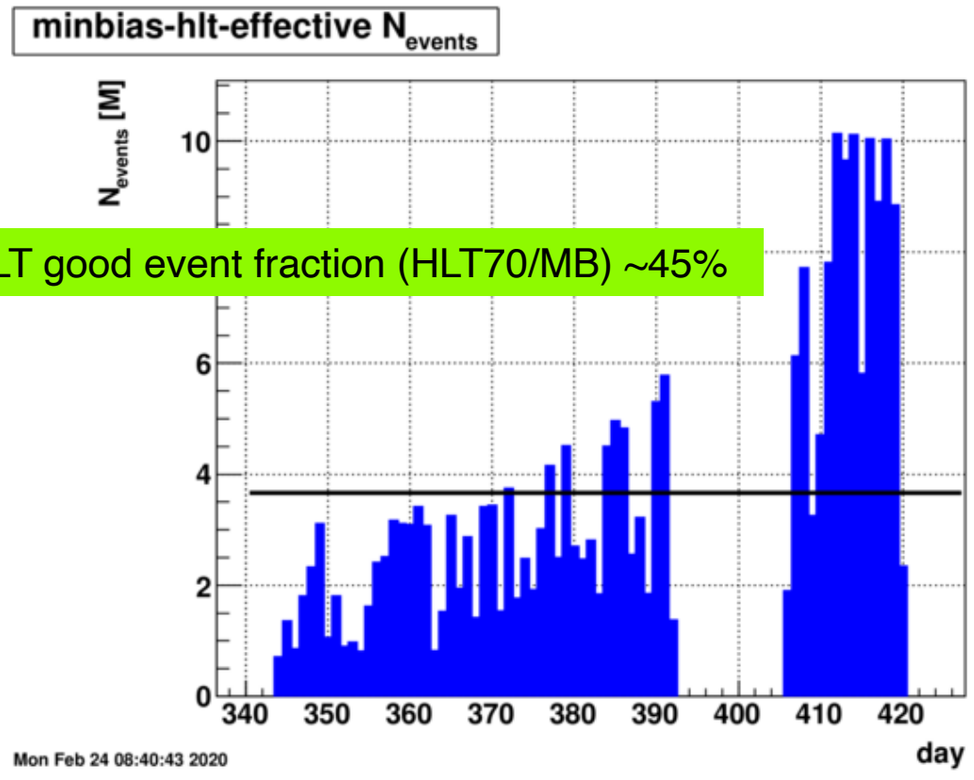


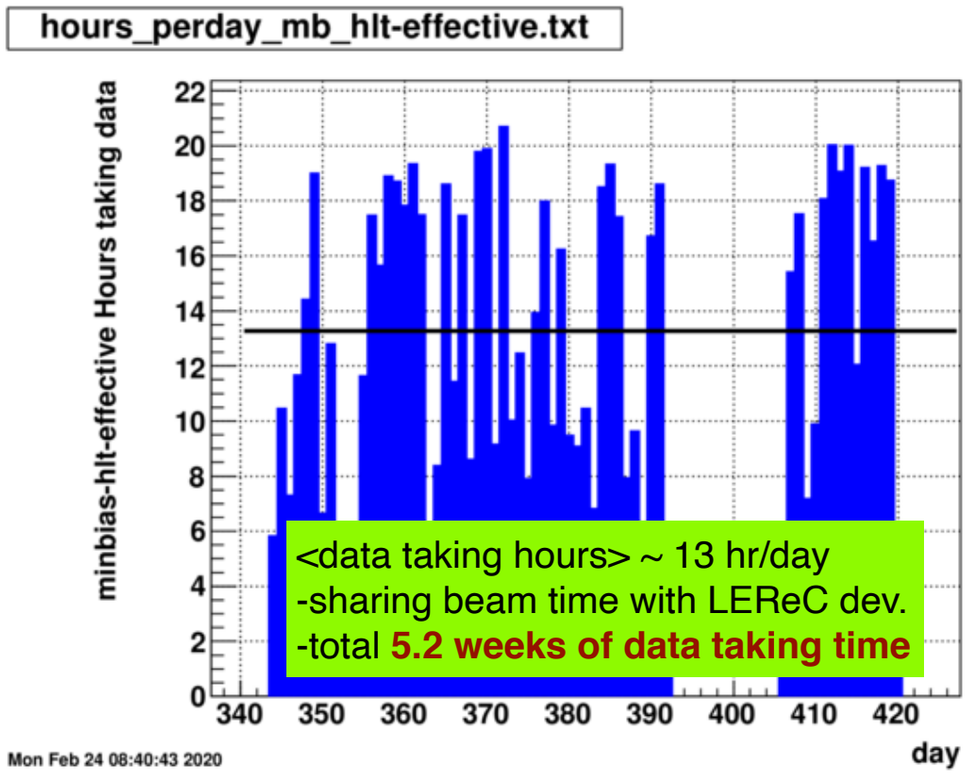
- Beam from Tandem for smaller emittance. 28 MHz RF (h=363) concurrently with 9MHz for longitudinal focusing and reducing debunching
- **Continuous increase of luminosity through the run**
  - tune change/optimization ("higher tunes")
  - AGS intensity limit increase by 20% (8- 8.8 -9.6*10^9 Au ion per cycle)
  - dynamic working point (injection, store) to count for intensity/space-charge dependence
  - store length optimization: 30m ➔ 25m
- "Effective good event" rates ~1.22 * rates in good event rates in ±70cm

Data collection at $\sqrt{s_{NN}}$=11.5 GeV

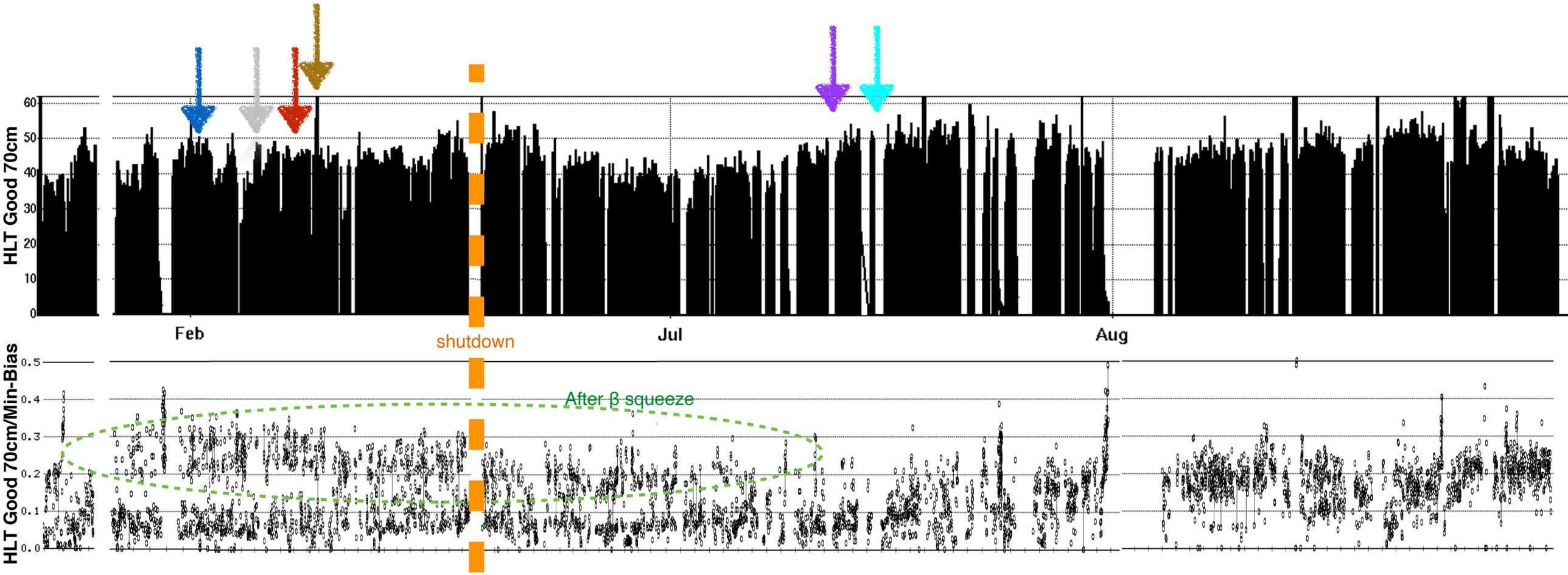








Beam at $\sqrt{s_{NN}}$=9.2 GeV

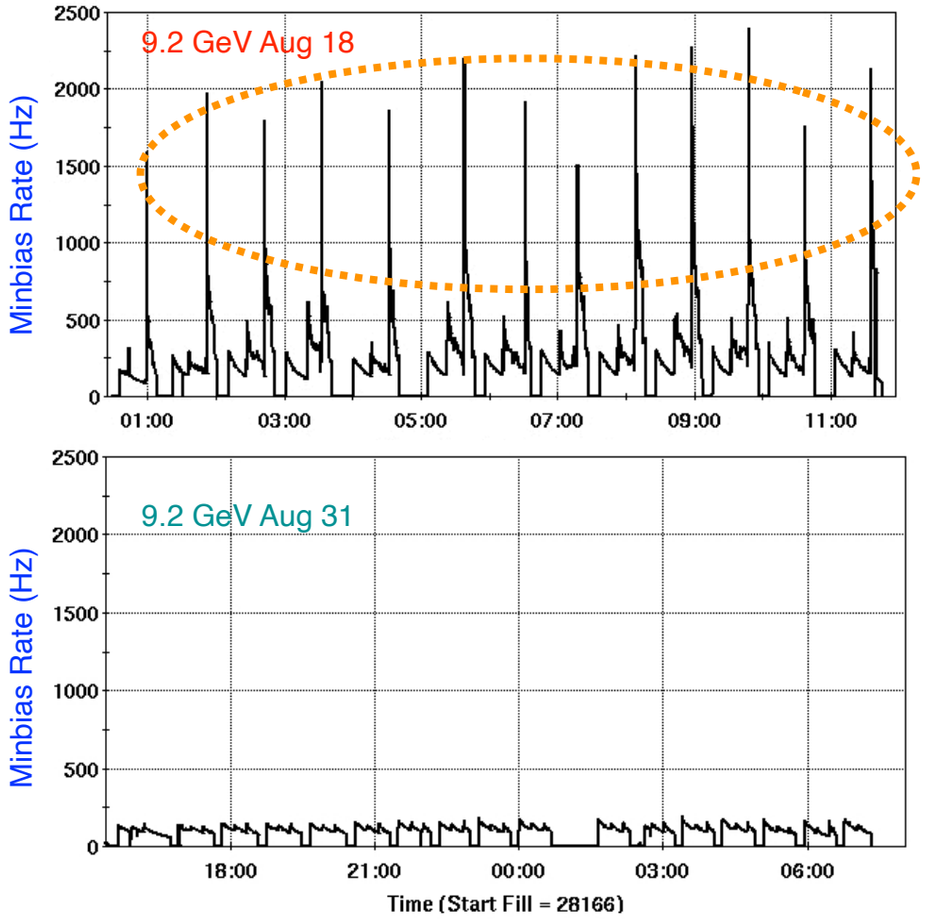


- **First LEReC in operation for physics**
- Au from EBIS (large longitudinal emittance for 9MHz RF)
- AGS bunch 4-1 merge (12-3) for higher bunch intensity
- **Continuous improvement of signal/background**
- Fill length 40min (with cooling), 30min (without cooling)
- "Effective good event" rates ~1.30 * rates in good event rates in ±70cm

- **Luminosity improvement and optimization**
  - β squeeze 4.5 - 3.5 - 3 meter (in 0-15-30 min) during store (with cooling)
  - RF voltage ramping down 180kV - 120kV during store for better lifetime and cooling
  - new (lower) working point test and compatibility with cooling
  - vertex z fine adjustment (cogging)
  - "injection mismatch" resolved
  - fill length 45m → 40m

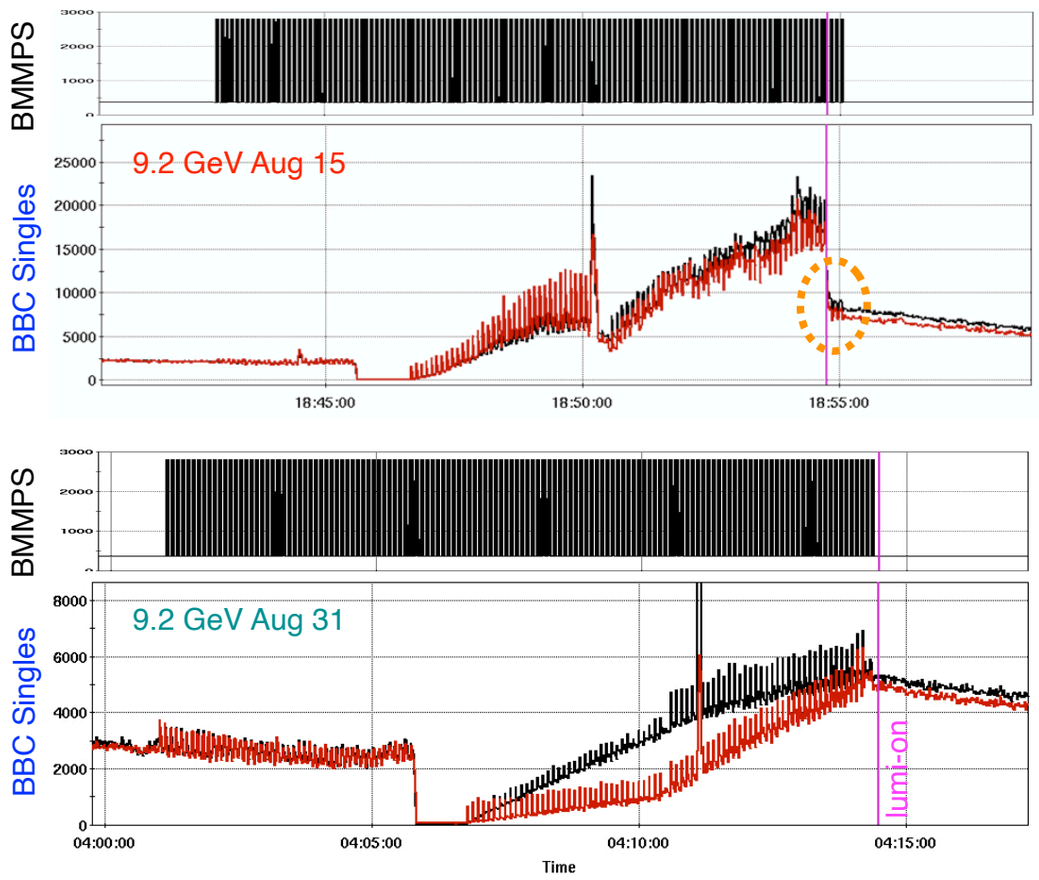
Some background issues (and fixed)

Background during beta squeeze



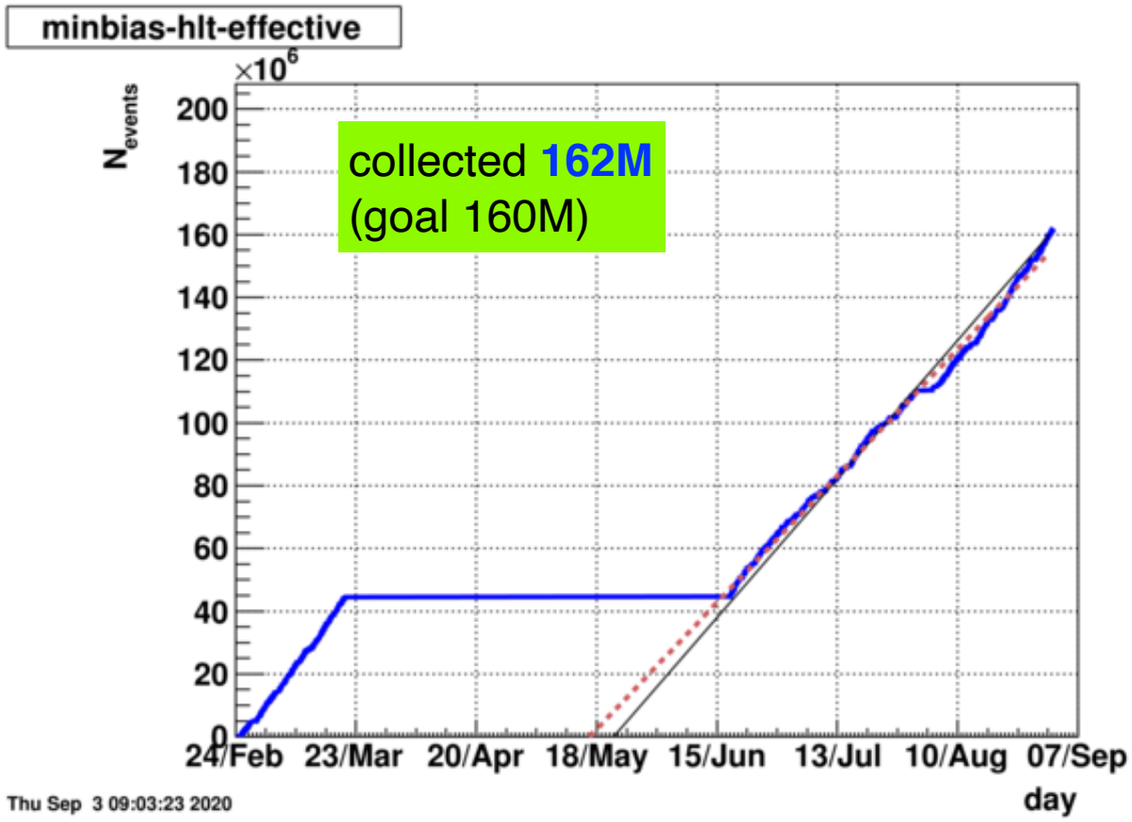
- High background during the squeeze ramps
- Sensitive to various things
- (continuous) **Collimator setting changes** needed
- Beam condition get clean and stabilized near the end of the run

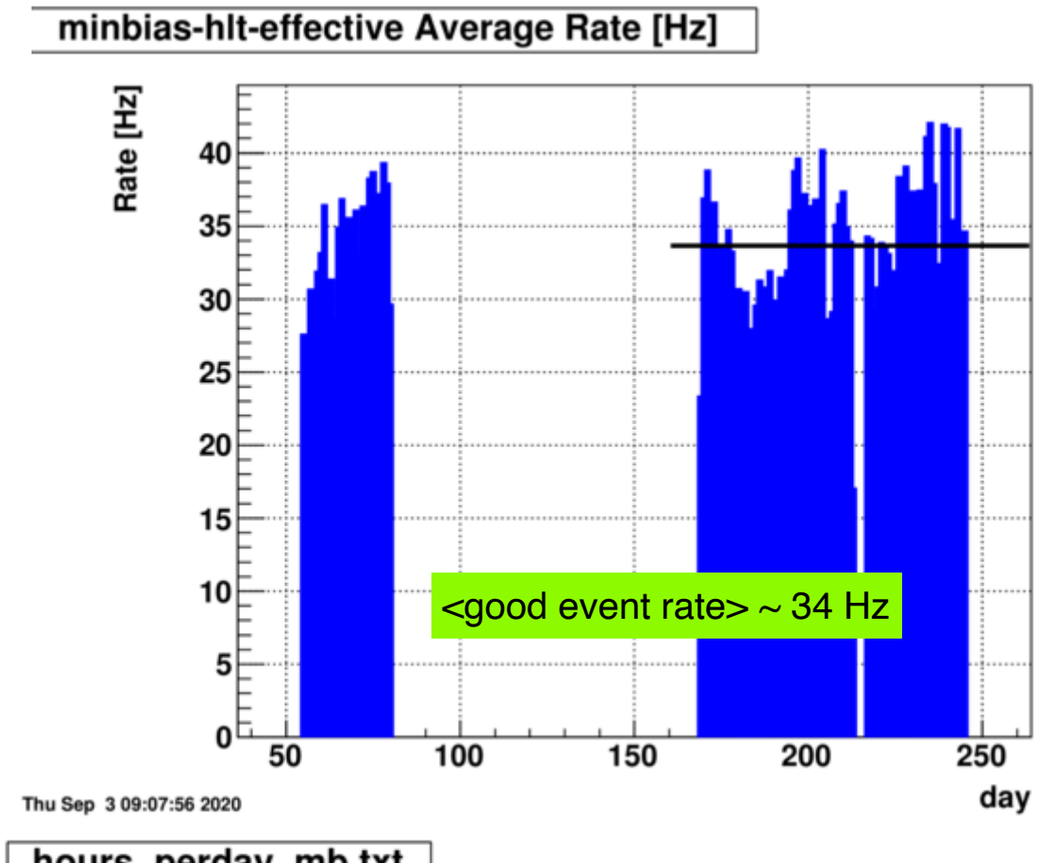
Background from Booster Main Magnet

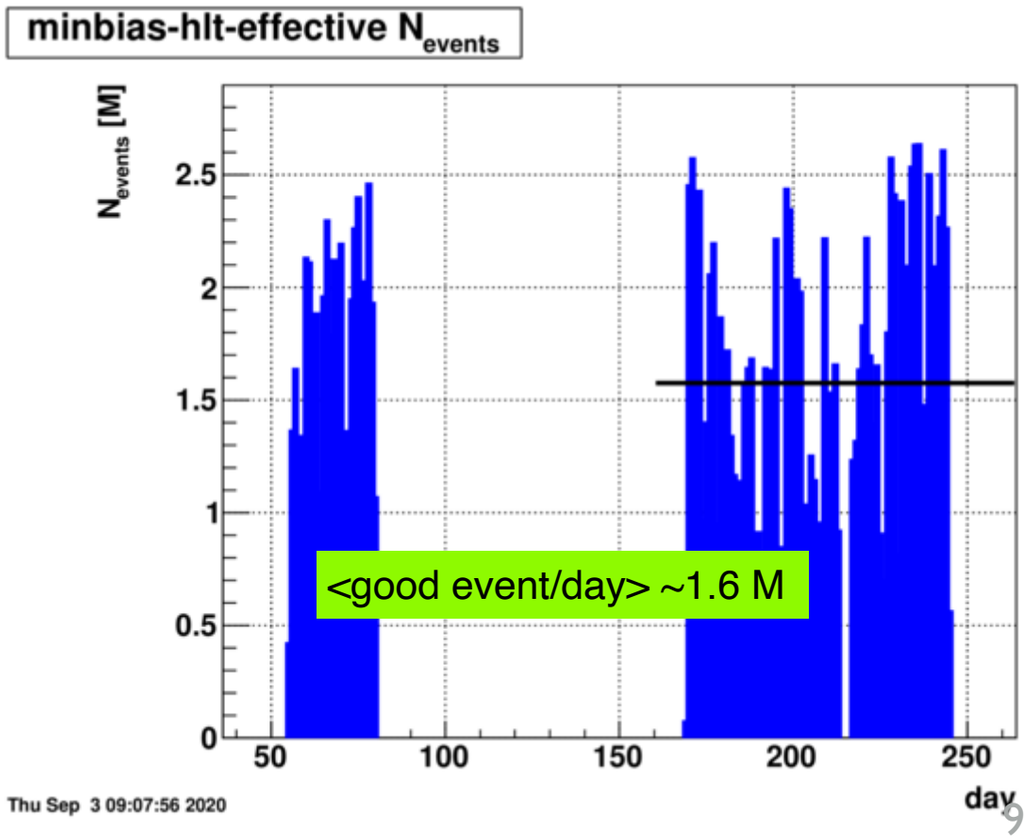


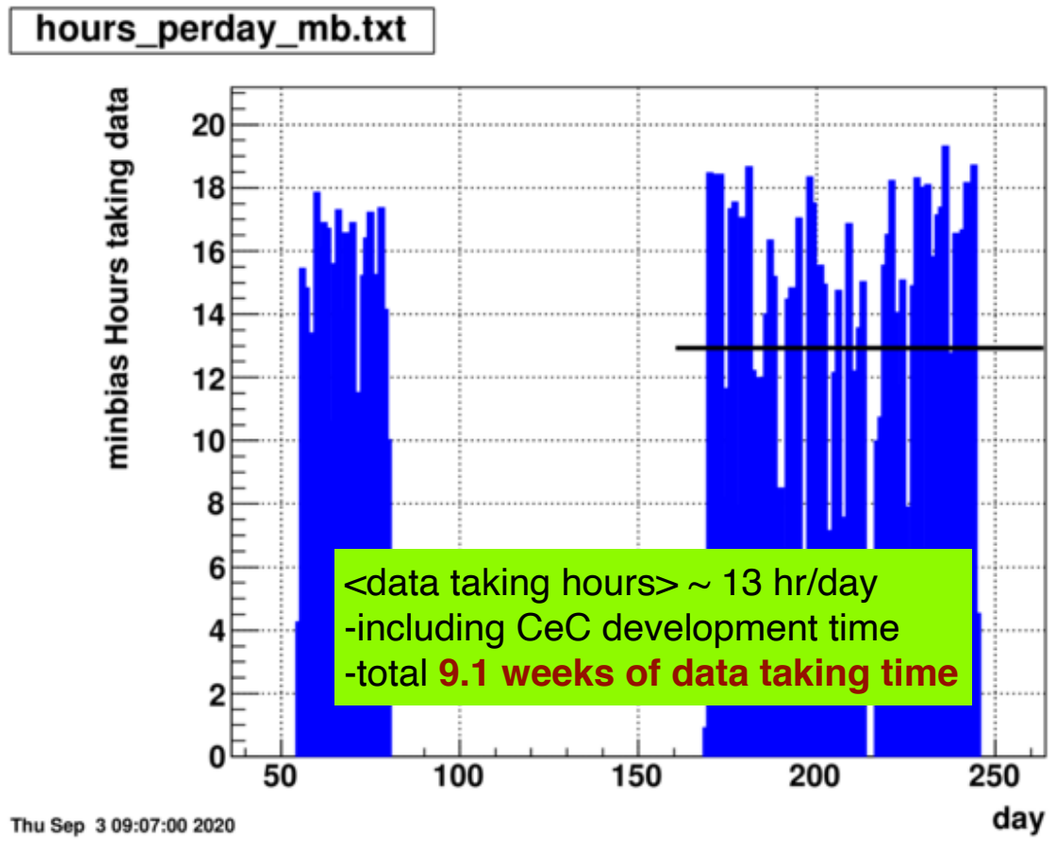
- Background caused by Booster Main Magnet PS every 6 sec
- Large and uneven charge deposition in TPC causing issues at the beginning of the fill
- "physics on" after **collimator at store setting and BMMPS idle**
- No data taking during injection

Data collection at $\sqrt{s_{NN}}$=9.2 GeV

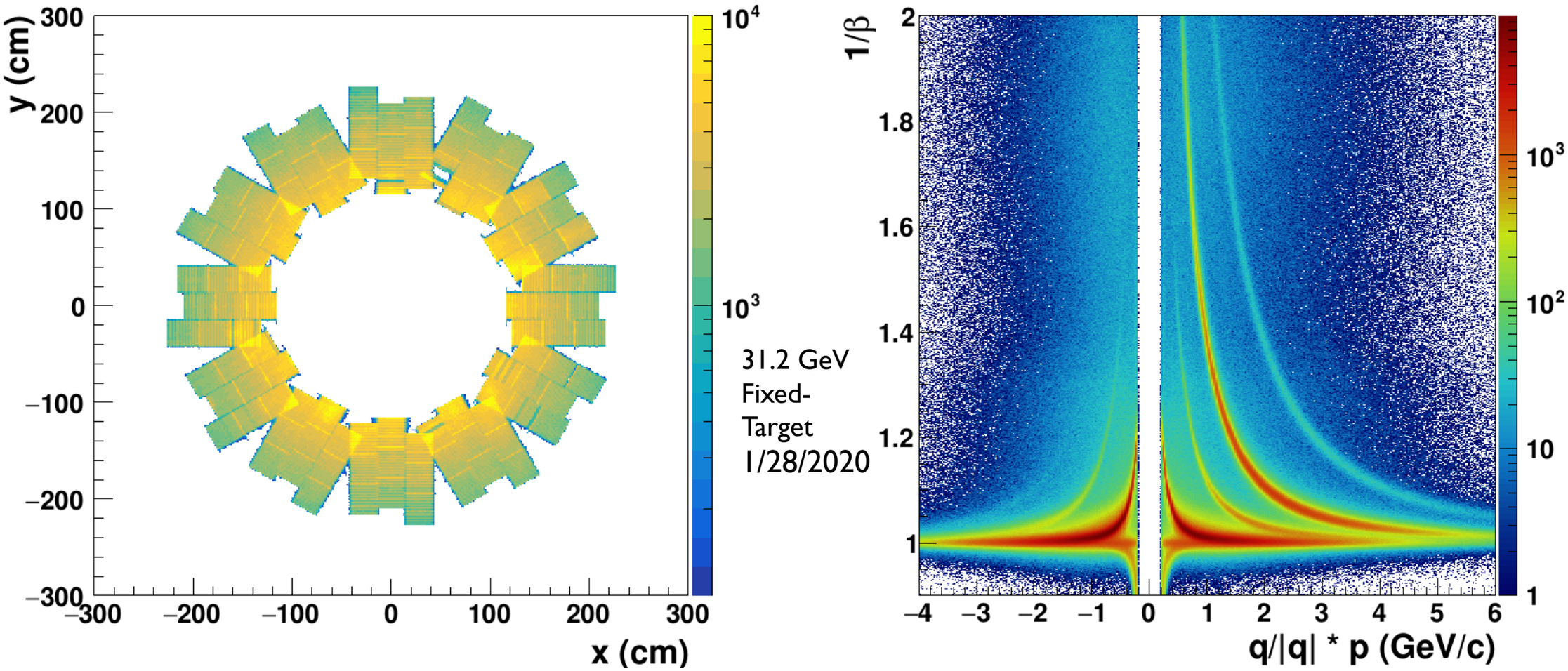






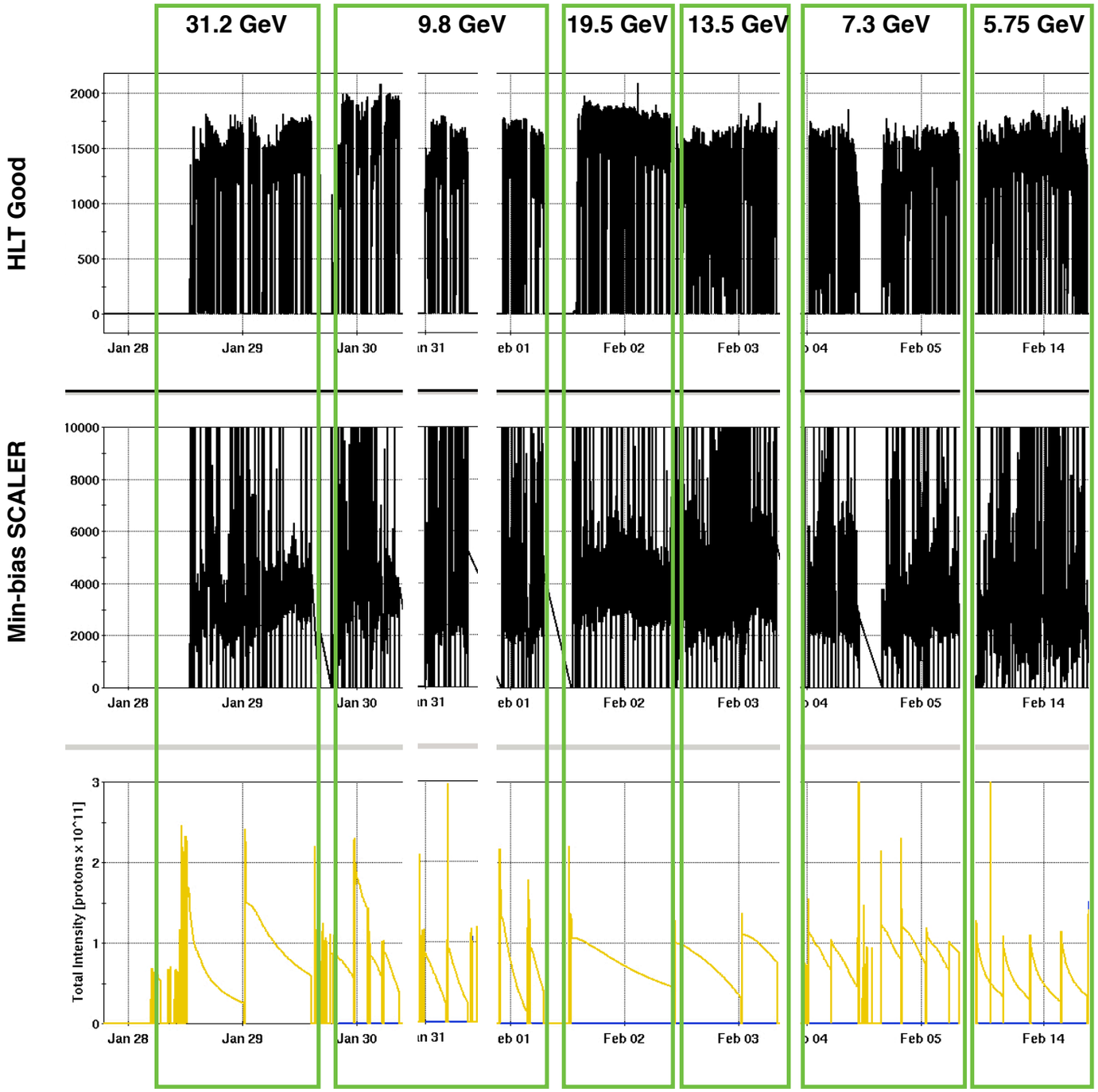


endcap Time-of-Flight Detector



- eTOF electronics improved successfully after Run19
  - No loss of electronics this year
- Critical detector for physics with Fixed target: All fixed target and collider programs completed successfully with eTOF
- Only detector ramped down between fills for protection

Fixed Target Runs



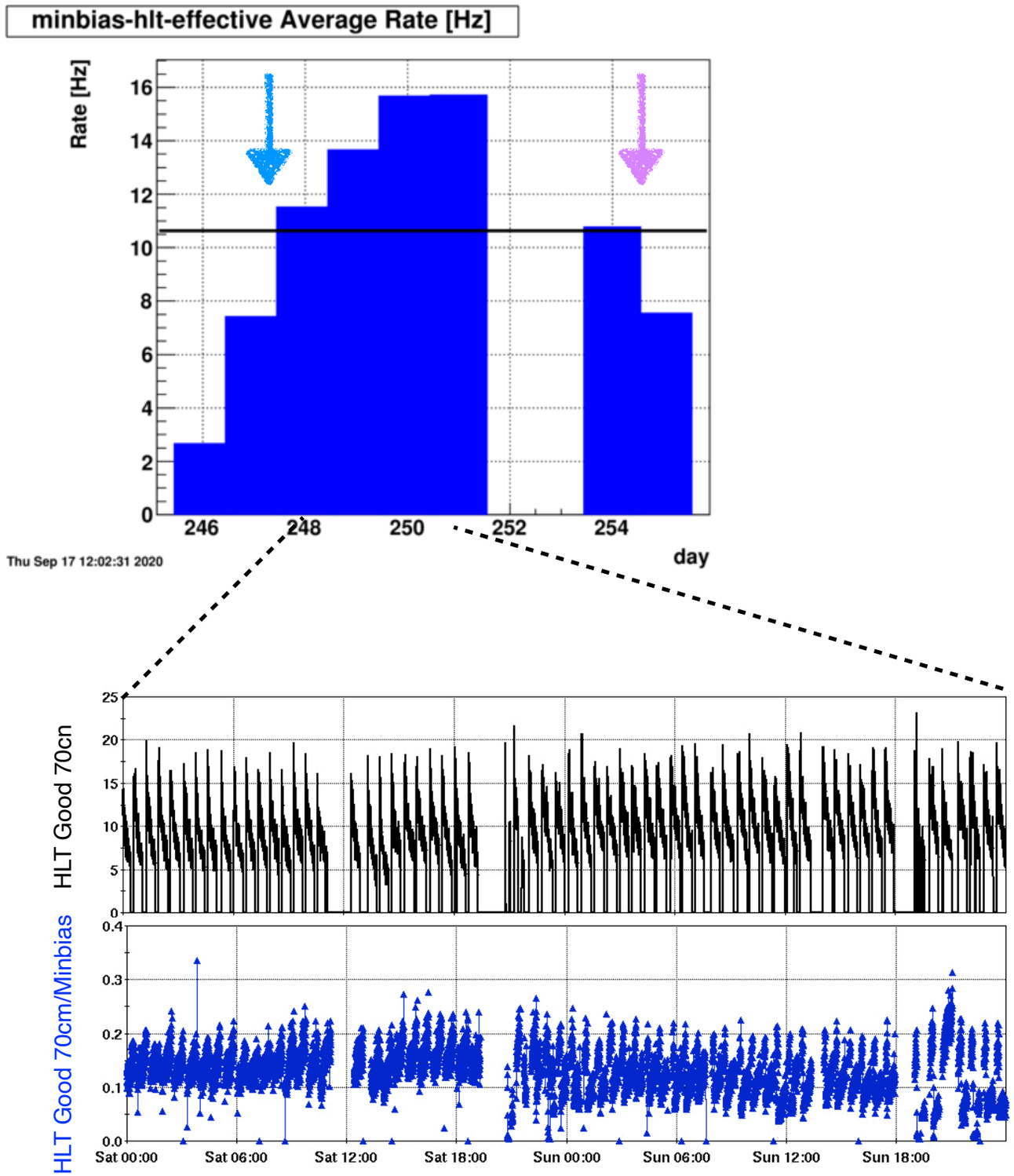
- Long lasting stores with 12 bunch yellow beam
- Needed large β* lattice to reduce background at low energies
- Sustained **clean** (good event rate > 70%) and **high rates** (~1.5 KHz)
- Beam orbit control (vertical bump) works well to keep the rate
- Event trigger and scalar rates feed back crucial for beam steering
- Interleaved with LEReC development (9 MHz change)
- **Achieved the Goals in planned time**

	HLT Good (M)	with EToF (M)
31.2 GeV	114	102
19.5 GeV	119	80
13.5 GeV	103	89
9.8 GeV	109	73
7.3 GeV	115	106
5.75 GeV	114	100
26.5 GeV	315	298

parasitic data taking during CeC: 2.6 (out of 9) days during Run20

Run21:
More opportunities for 26.5 GeV during CeC
STAR requesting parasitic collisions at $\sqrt{s_{NN}}$ = 53 GeV (26.5+26.5) during CeC

Beam development at $\sqrt{s_{NN}}$=7.7 GeV



- Beam from Tandem. 28 MHz RF (h=369) concurrently with 9MHz.
- Continuous **increase of luminosity** during the development
  - Cooling + β-squeeze (4.5 - 3.5/3m)
  - flattening bunch (defocusing RF) and reducing space-charge effect
  - rate ~x3 increase from Run19
  - collected 3.2M good events
  - developed a configuration running without cooling ("low working point")
- good **baseline for Run21** projection
  - 16Hz*15 hrs/day*17 weeks ~ 100M

    (15 hrs/day: average running time without CeC time)

"Run20b"

- Quickly restarted with the beam condition and detectors where left off before the 87 days break

- **Operation with a limited shift crew** 2+1: shift leader, detector operator (separate room) + a remote crew for QA due to restricted manpower and for maximum distancing. Remote period coordinators. All connected trough Bluejeans.

  - with safety protocol: no f-2-f shift change, cleaning workplace, …

  - Unusual operation yet worked with the running condition for Run20

  - Likely this mode of operation continues through Run21 - potential room for improvement for more efficient operation while ensuring safety

- Running through the summer: **weather related issues** affected machine and STAR

  - multiple power failure, various temperature/humidity related issues, weather stand-down

Run21: Beam Use Request

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

- Finishing BES II program
- Highest priority at $\sqrt{s_{NN}}$=7.7 GeV
- Measurements with fixed target at $\sqrt{s_{NN}}$=3, 9.2, 11.5, 13.7 GeV
- 3rd priority not yet ordered: will be determined with preliminary results from data taken at $\sqrt{s_{NN}}$=14.6 and 19.6 GeV
- +Requesting $\sqrt{s_{NN}}$=53 (26.5+26.5) GeV parasitic run during CeC as much as permits (~500 M events projected for 2 weeks of CeC)
- Commissioning new detectors (Forward Calorimeters) for STAR Forward Upgrade with the requested physics program

Summary

- **Run20:** Data collection at highest energies (11.5, 9.2 GeV) in BES II and 6 Fixed target energies in AuAu: **All physics goals are met/ exceeded**

- **CAD delivered successful beam** at all requested energies and **data collection with efficient triggers and operation**. All **detectors performed well**.

- **Successful, despite atypical operation** with a limited shift crew running through the summer due to COVID19

- Excellent progress with machine development at $\sqrt{s_{NN}}$ =7.7 GeV establishing a positive baseline for Run21

- Top priority for **Run21** is completing BES II with **$\sqrt{s_{NN}}$ =7.7 GeV**

- **Thanks to CAD** for the great performance and effort for Run20

- Looking forward to successful beam operation and data taking in Run21

extra

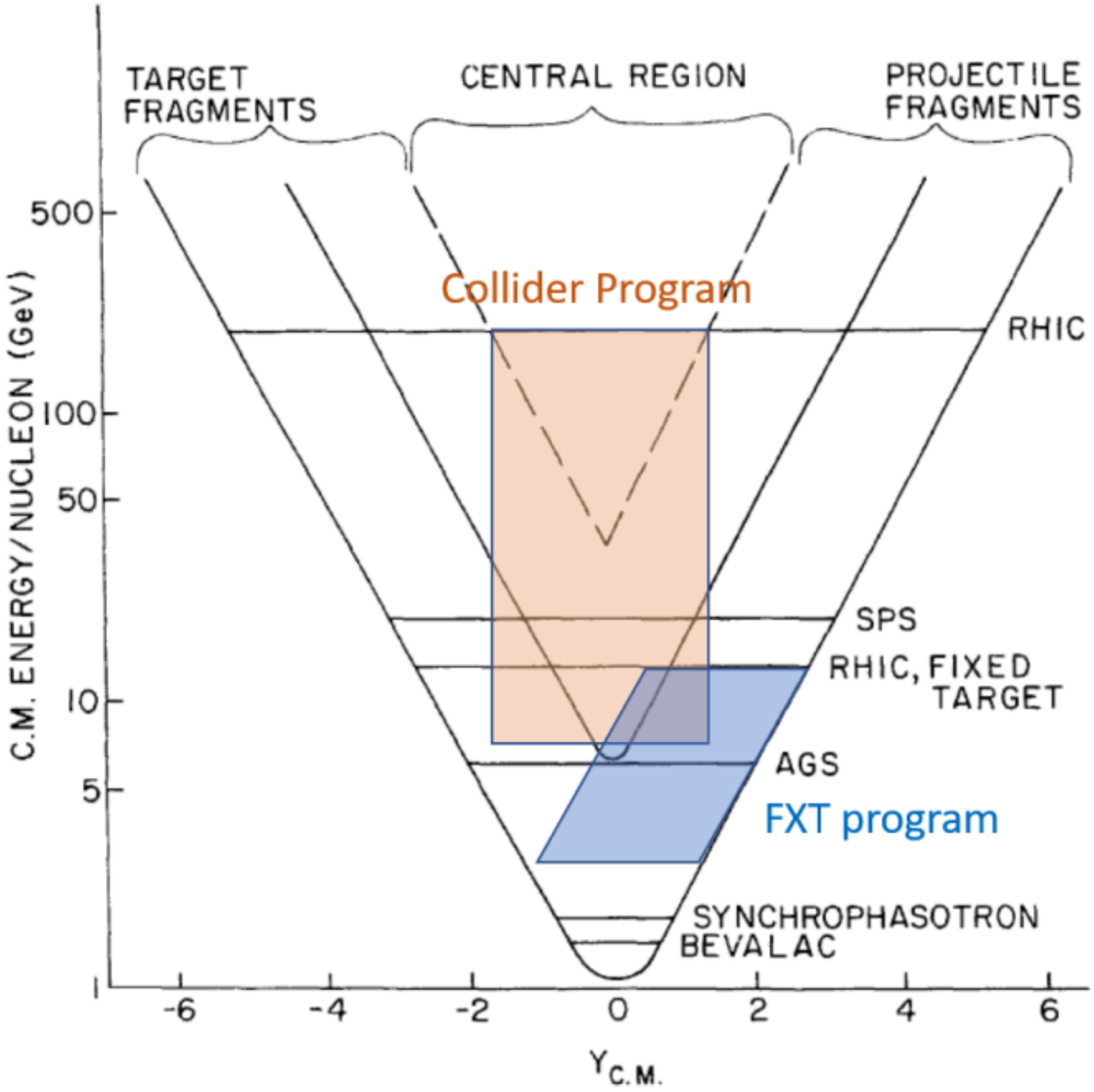
RHIC Run20 operation

- STAR on Shift from 11/25, full (4-person) shift from 12/10
- Cosmic data taking : 11/26/19-
- First beam : 12/5
- Physics 12/10
- **$\sqrt{s_{NN}}$ = 11.5 GeV** : 12/5-2/24
  - interleaved with LEReC9.2, FXT
- **$\sqrt{s_{NN}}$ = 9.2 GeV** : 2/24-9/1
  - interleaved with CeC
- **FXT at 6 Energies** : 1/28-2/5, 2/13-2/14
- Operation halted due to COVID19: 3/20-6/15 (87 days)
- **$\sqrt{s_{NN}}$ = 7.7 GeV** development : 9/1-9/11
- CeC development : 9/7-8, 9/12-13
  - parasitic **26.5 GeV FXT**
- End of beam operation : 9/14

RHIC Run FY20 Run Schedule (Revision date: 9/8/20)

	Calendar 2019				Calendar 2020								
Program Element	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
RHIC Cryo warm scrub starts October 7th													
RHIC Cryo 45 K cool down (Nov 4th – Dec 1st)				Dec 7th								Warm up Cryo Sept 15 - 17	
RHIC Cryo 4.5 K cool down starts December 2nd													
RHIC Cryo off Sept 14													
EBIS startup Sept 3rd, Booster startup Sept 16th, AGS startup Nov 11th, restart all May 18th									May 18th				
LEReC ready on Feb 24th and again on June 17th													
RHIC setup (12/5 - 10, 6/15 – 17 and 9/2 – 14)										June 15th			
RHIC physics Vs = 11.5 GeV/n AuAu (12/10 – 1/27, 2/10 – 2/24, 3.5 GeV FXT on 2/13 - 2/14)			Dec 10th				Feb 24th						
RHIC physics Vs = 9.2 GeV/n AuAu with LEReC (2/24 – 3/20 and 6/18 – 9/1)										June 18th			
RHIC physics for five more FXT energies AuAu (1/28 – 2/5) and 8 days of CeC interleaved					Jan 28th			Operations halted due to COVID-19 on March 20					

Collider vs FXT



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.