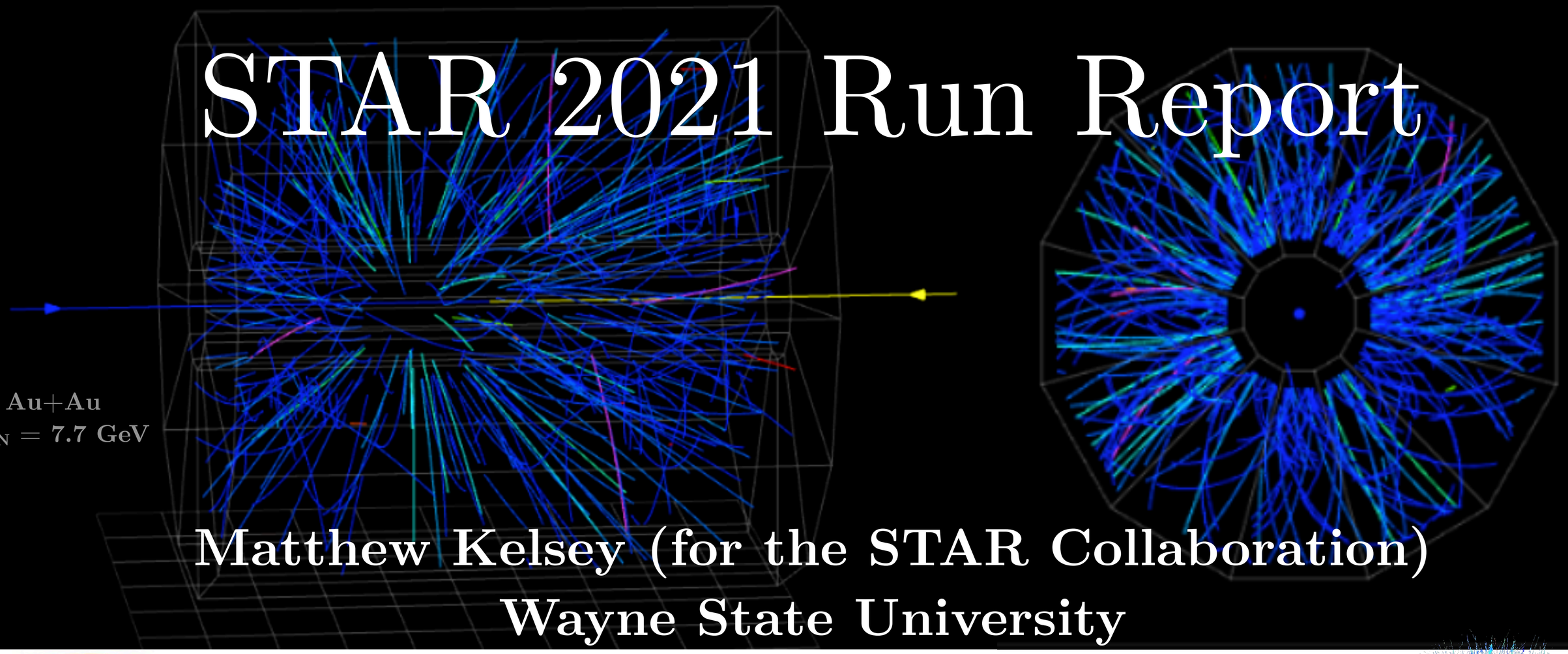
STAR 2021 Run Report



Matthew Kelsey (for the STAR Collaboration)
Wayne State University

RHIC & AGS Annual Users Meeting June 8-11 2021

Supported in part by
U.S. DEPARTMENT OF ENERGY | Office of Science

Beam Energy Scan II: 2019-2021

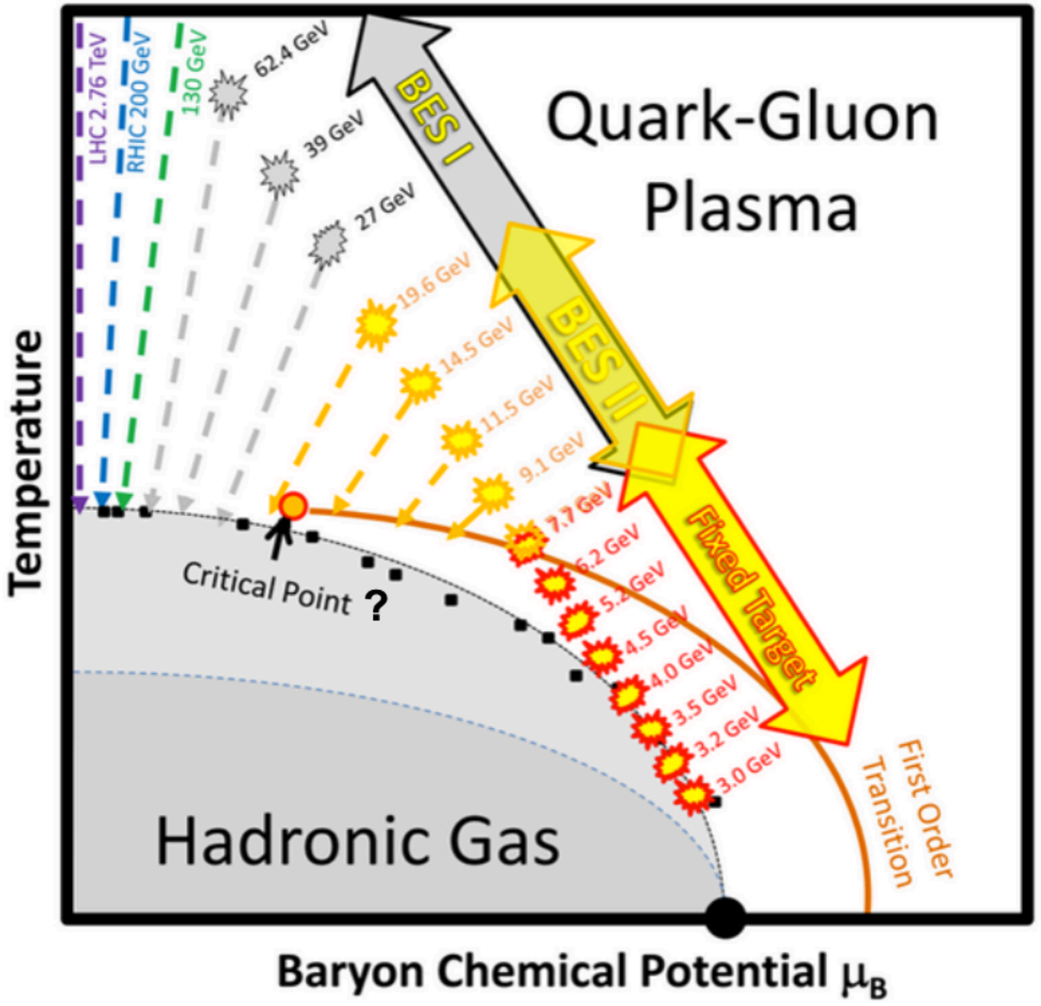
Mapping of the QCD phase diagram by varying collision energies

- Critical point? 1st order transition? ...

BESII is focused on lower energies where BESI statistics were limited (but produced compelling data)

Fixed target mode probes baryon-rich region of phase diagram

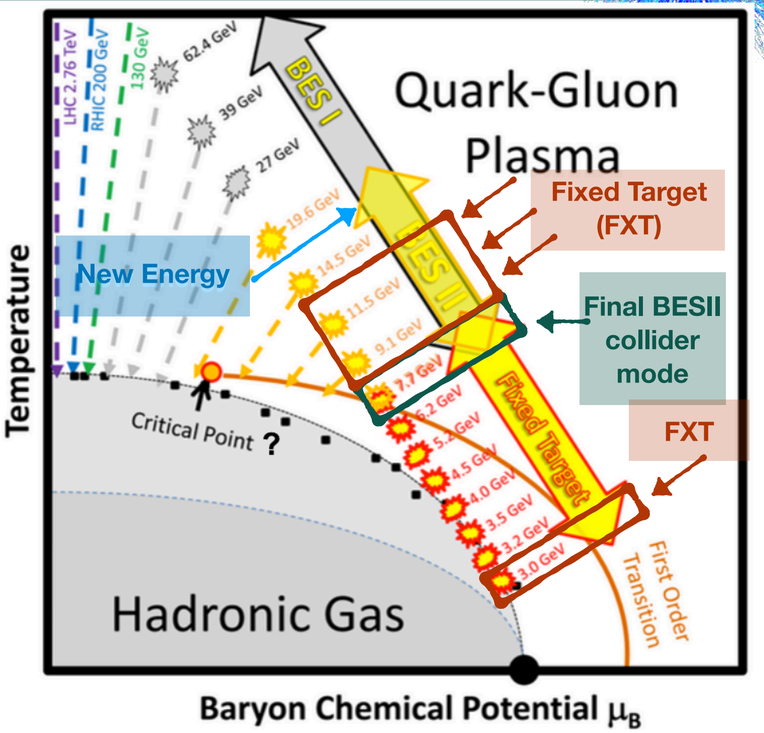
- Improved acceptance with iTPC and eTOF detectors
- Combined with collider program data we have full mid-to-beam rapidity coverage



Beam Usage Request for 2021

Assumed 20-24 cryo-weeks

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
8.65	17.3	2.5 weeks	Au+Au	250 M	3
3.85	3 (FXT)	3 weeks	Au+Au	2 B	3



Highest priority to collect $\sqrt{s_{NN}}$ = 7.7 GeV Au+Au collisions to finish BESII (collider) program

Four FXT energies as "priority 2": First at $\sqrt{s_{NN}}$ = 3 GeV (Min. transition from collider mode) and three at higher energies

- Provide more $\sqrt{s_{NN}}$ overlap with collider running

Priority 3 program contingent on $\sqrt{s_{NN}}$ = 7.7 GeV running

- Note: Au+Au 17.1 GeV request changed to 17.3 GeV (convenient for machine)

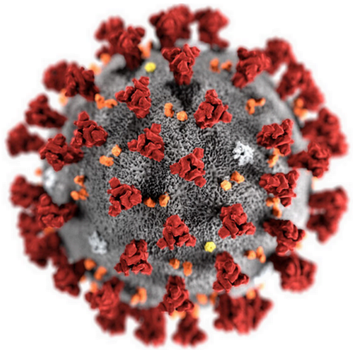
Dedicated machine time split between APEX, CeC dev., and STAR physics

STAR Shift Paradigm in the Covid Era

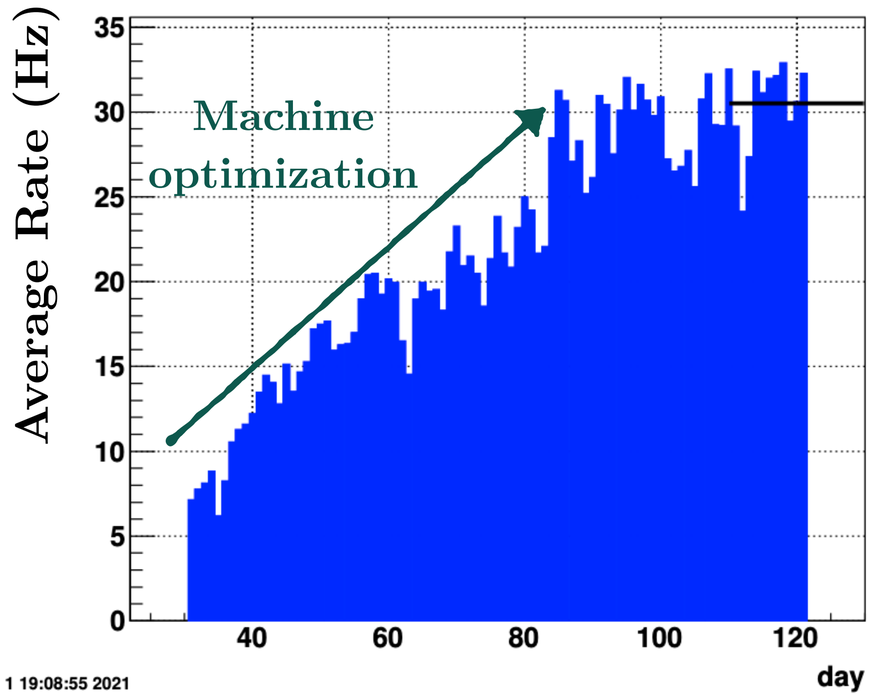
2021 shift-taking adopted similar protocols as Run 20b

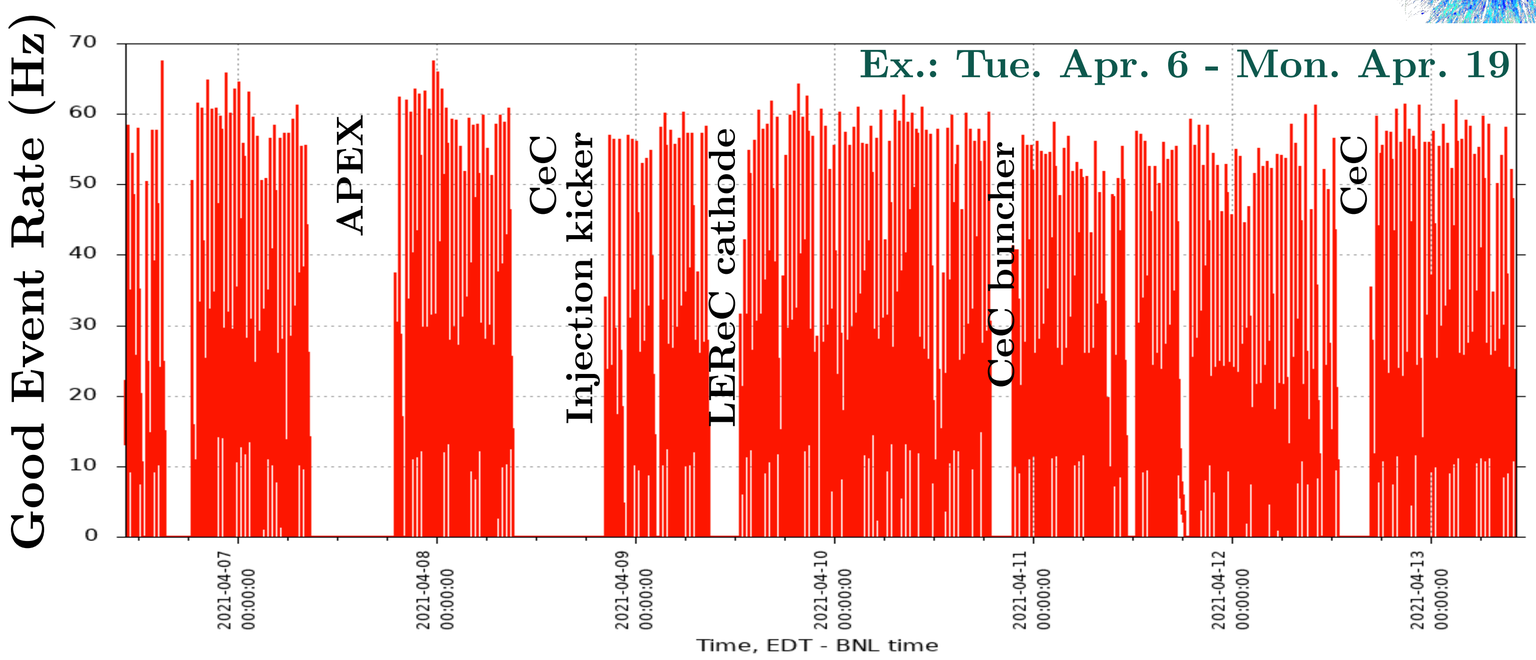
- Onsite shift persons reduced from four to two: Shift leader and detector operator; Period coordinator and one shift crew now remote
- Onsite cleaning per shift and minimal face-to-face interaction
- Continuous onsite Zoom feed for remote operations crews
- All opts. meetings online and open to STAR collaboration

Onsite shift-takers still limited by state/country regulations, but with these shift protocols STAR has been able to fill all necessary shifts while maintaining a safe work environment



Au+Au $\sqrt{s_{NN}} = 7.7$ GeV Run





Technically challenging as beam quality deteriorates at low energies; Improved with electron cooling (LEReC)

Very smooth running

- Consistent fills with low backgrounds, very little downtime between fills
- Run-averaged good event rate consistent with expected 19-24 Hz from BUR; Exceeded expected rate at end of run

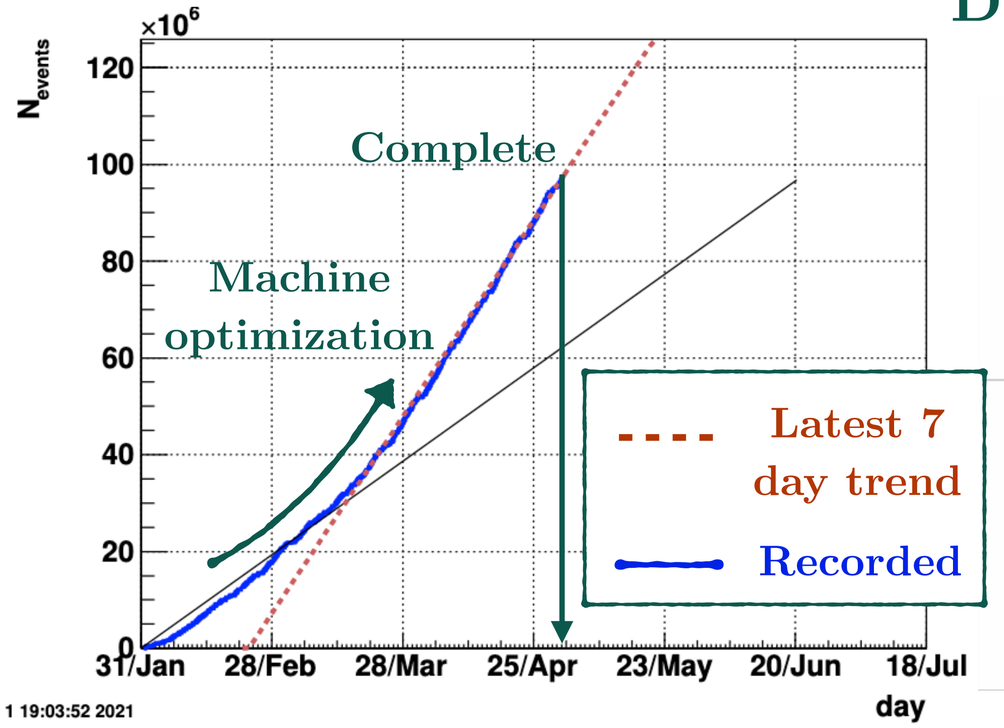
Fill length	Average Running Time	Average Rate	# Good Events Per Day
20-25 min	**12.5 hrs/day**	**22 Hz (Entire run) 31 Hz (Final week)**	**1.4 M (final week)**

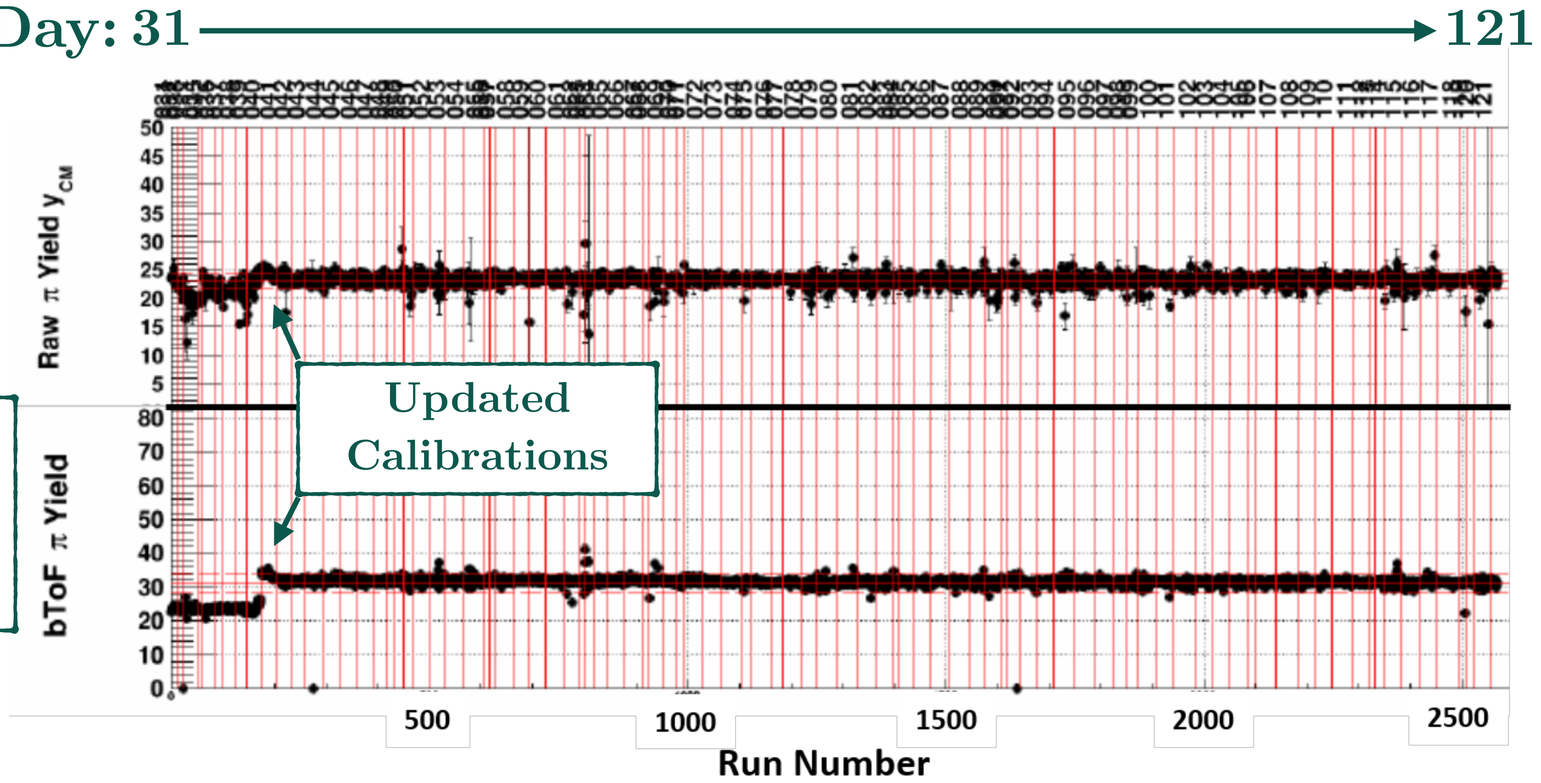
Au+Au $\sqrt{s_{NN}}$ = 7.7 GeV Run Cont.

From BUR: 11-20 weeks needed to reach 100 M event goal*

7.7 GeV run finished in 12.9 weeks (May 1)!

From ongoing weekly data QA: Data quality looks very stable





Au+Au $\sqrt{s_{NN}} = 7.7$ GeV Run Cont.

From BUR: 11-20 weeks needed to reach 100 M event goal*

7.7 Ge

From

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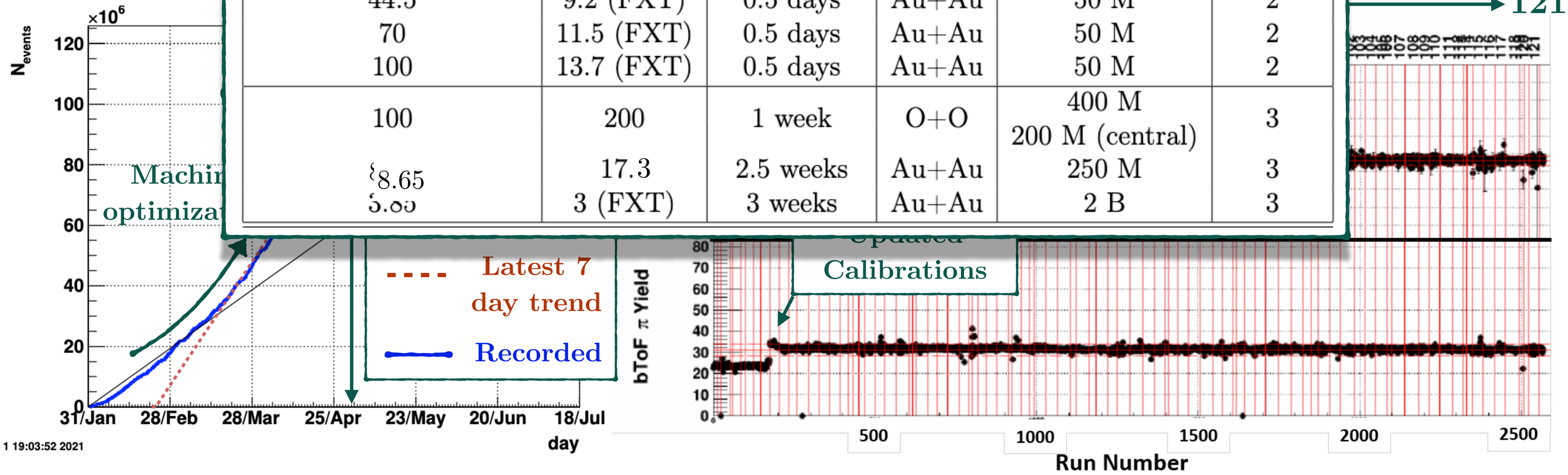
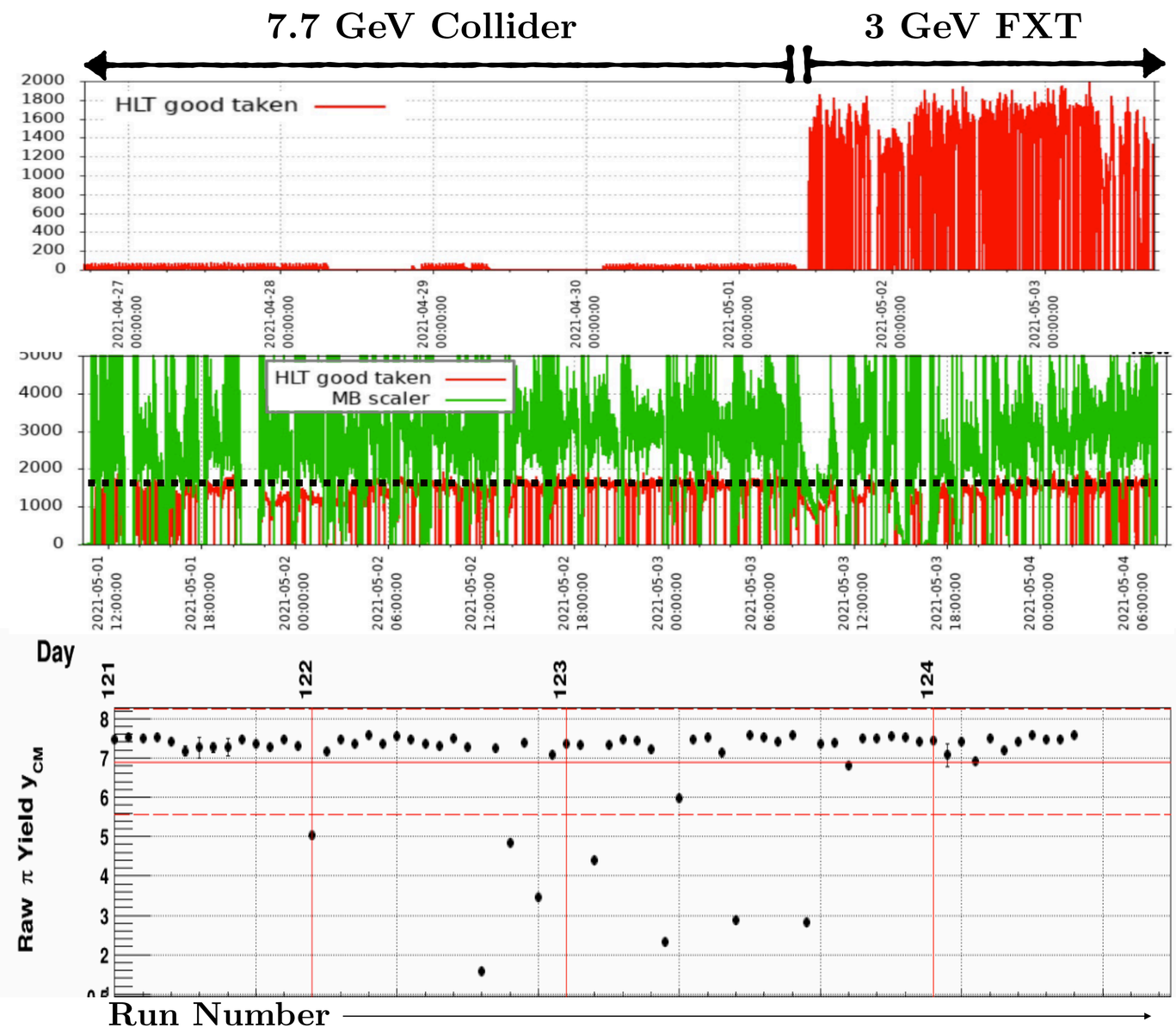


Fixed Target Running: $\sqrt{s_{NN}} = 3$ GeV

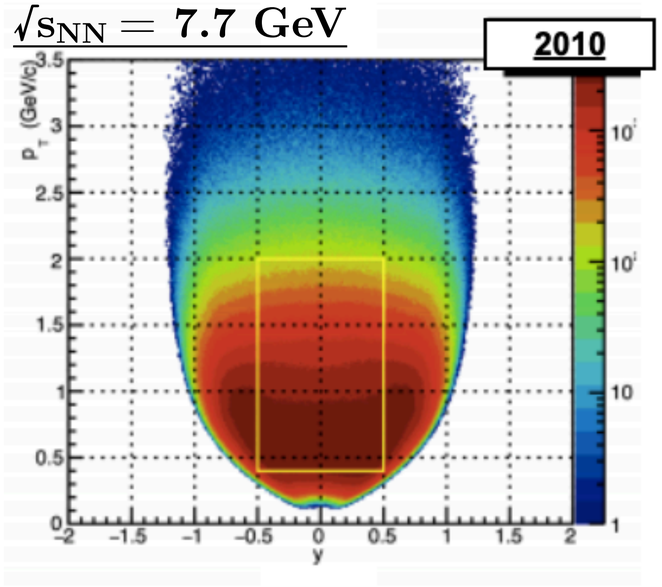


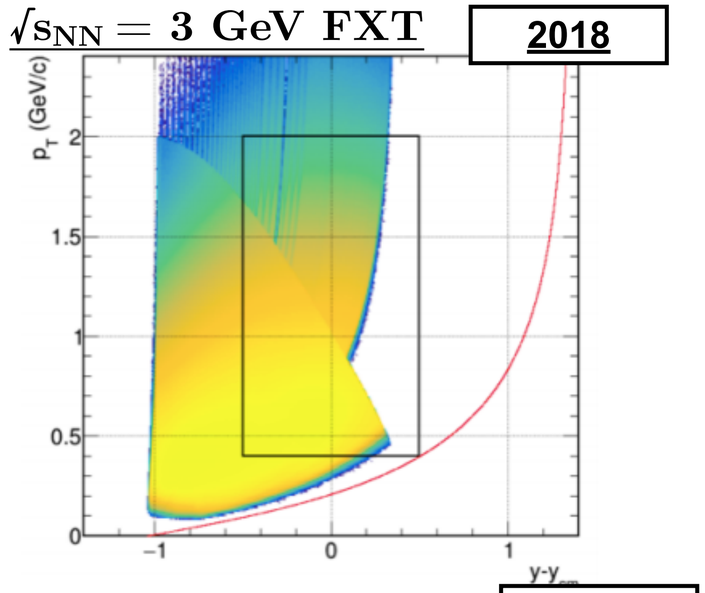
FXT $\sqrt{s_{NN}}$	Start	Stop	# Good Events
3 GeV	Sat 5/01 12:41 PM	Wed 5/05 7:30 AM	303 M
9.2 GeV	Thur 5/06 3:01 AM	Thur 5/06 2:27 PM	50.3 M
11.5 GeV			
13.7 GeV	Sat 5/08 12:15 AM	Sat 5/08 10:23 PM	52.3 M

Smooth running with ~1.6 kHz good event rate with low backgrounds

300 M good event goal reached in $<$ 4 days w/ 12 hrs. for APEX (From BUR: 3 days)

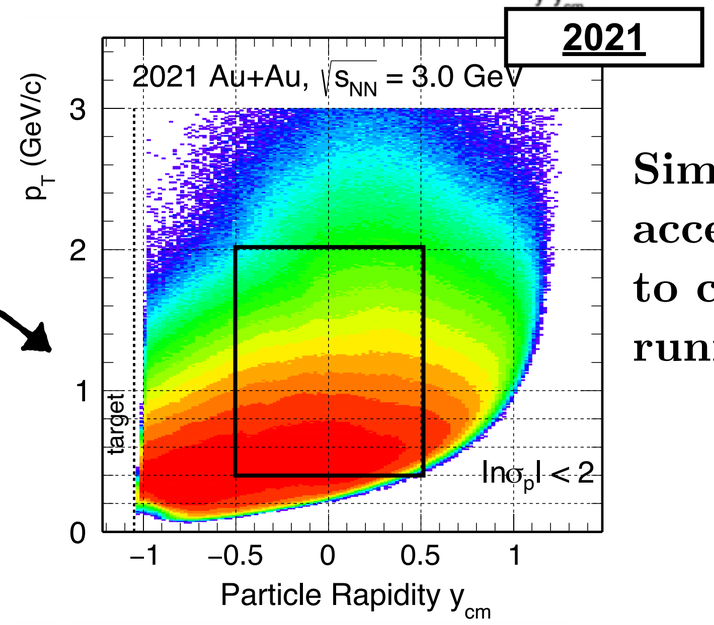
Proton Acceptance 2021





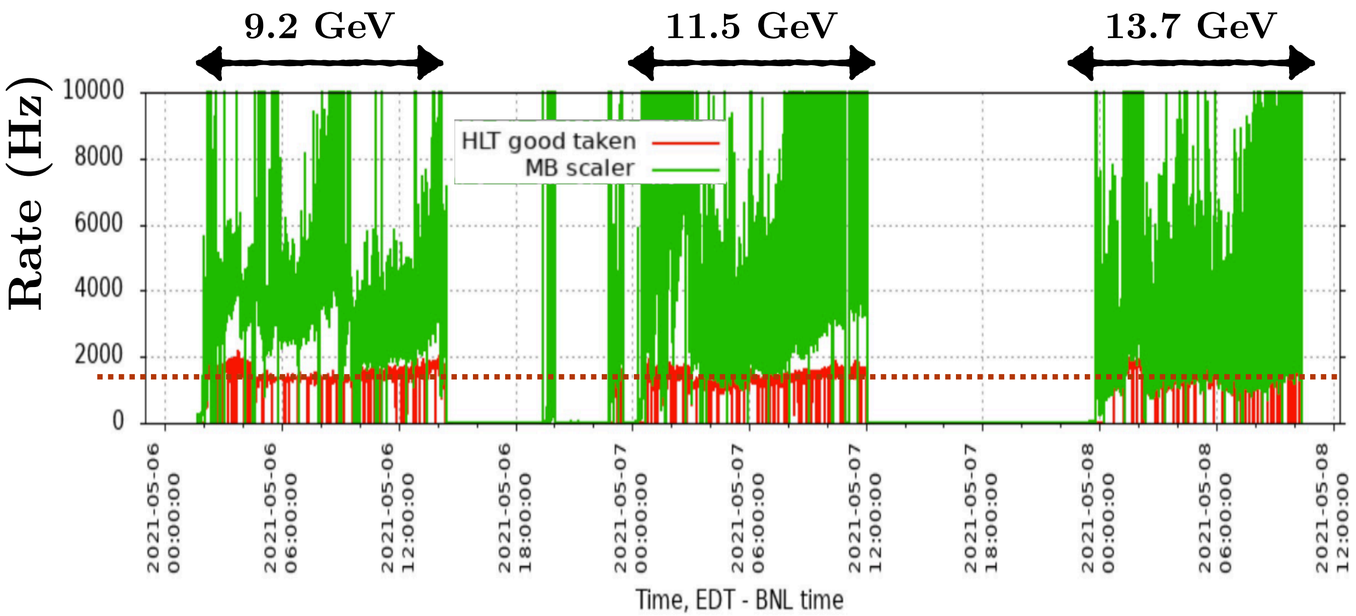
Improved acceptance from iTPC!

Essential for proton fluctuations analyses



Similar acceptance to collider running

Fixed Target Running: $\sqrt{s_{NN}}$ = 9.2/11.5/13.7 GeV



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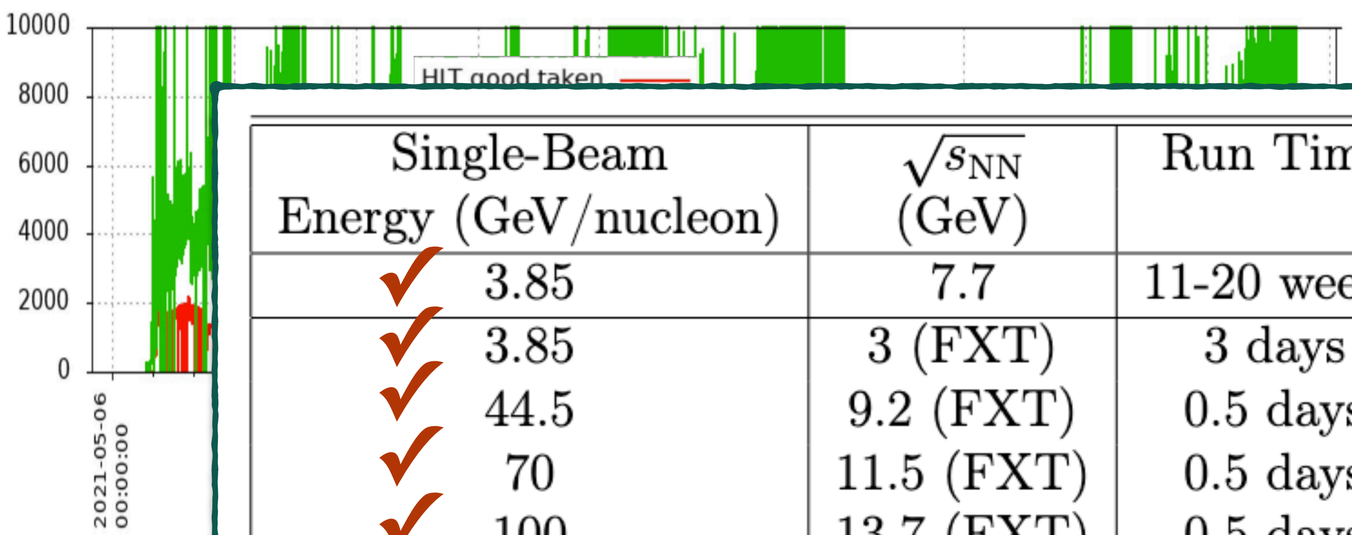
11.5 GeV	Thur 5/06 11:16 AM	Fri 5/07 12:04 PM	50.4 M
13.7 GeV	Sat 5/08 12:15 AM	Sat 5/08 10:23 PM	52.3 M

Smooth running with ~1.6 kHz good event rate with low backgrounds for higher energy FXT runs

50 M good events/$\sqrt{s_{NN}}$ goal reached in about 0.5 days per energy as projected

- Comparable downtime in between runs; RHIC tuning for new single beam energies for $\sqrt{s_{NN}}$ = 9.2/11.5

Fixed Target Running: $\sqrt{s_{NN}}$ = 9.2/11.5/13.7 GeV



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FXT $\sqrt{s_{NN}}$	Start	Stop	# Good Events
			303 M
			50.3 M
			50.4 M
			52.3 M

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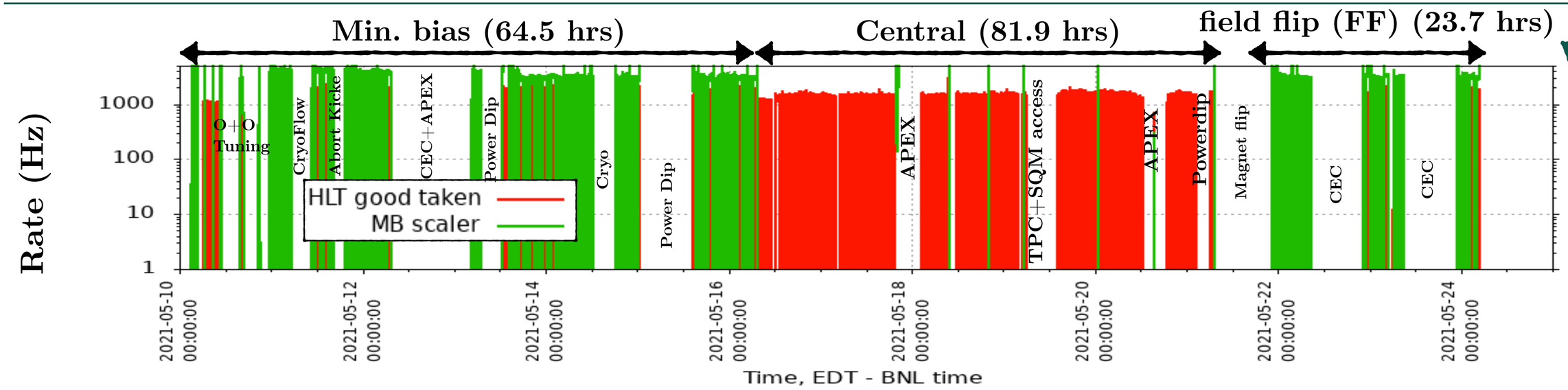
50 M good events/$\sqrt{s_{NN}}$ goal reached in about 0.5 days per energy as projected (w/ comparable downtime in between runs)

O+O @ $\sqrt{s_{NN}}$ = 200 GeV

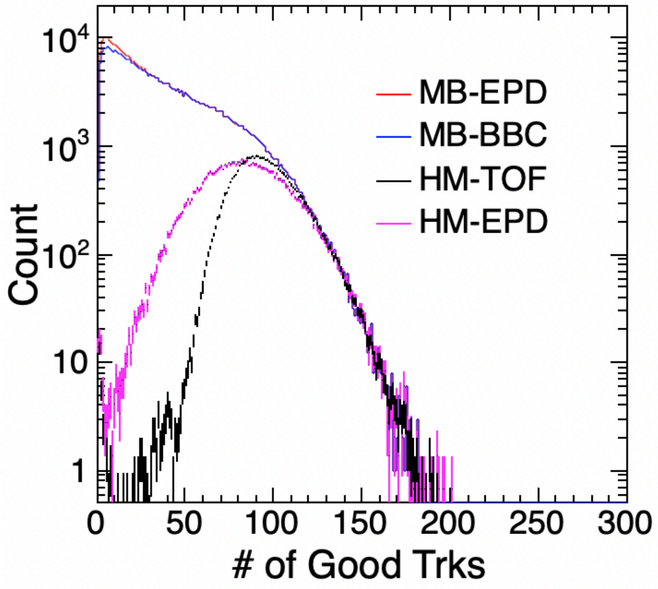


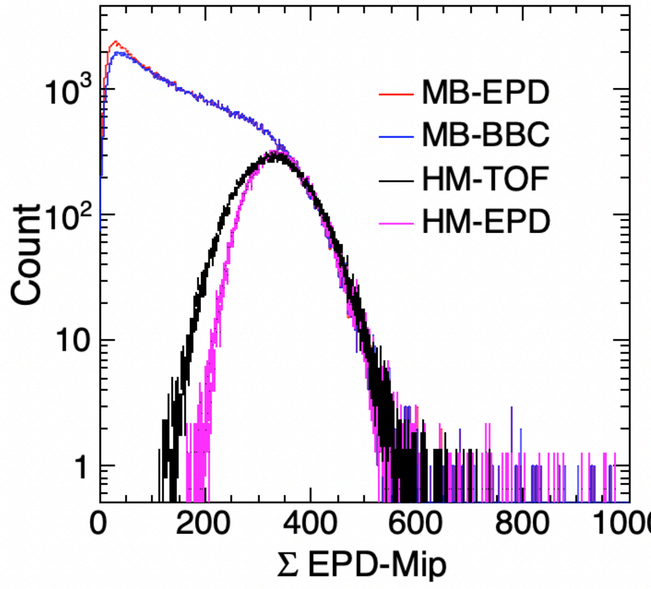
Magnet flip excellent for control of systematics!

Long fills+low backgrounds, average good event rate maintained around 1.6(0.72) kHz for min. bias (central) triggers

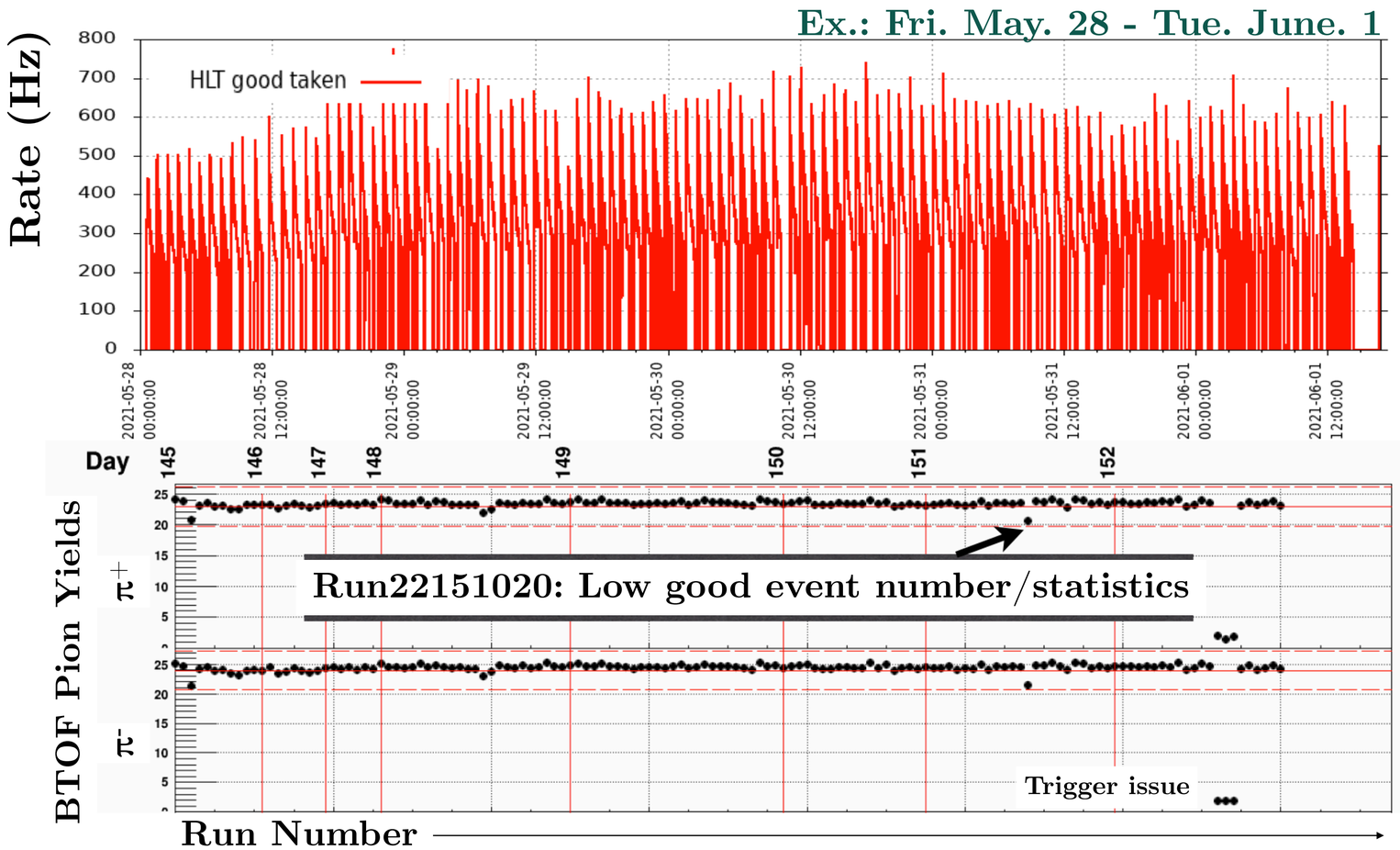
- Min. bias goal: 400 M events(collected 402 M)
- Central goal: 200 M events(collected 212 M)
- 2nd min. bias goal: 100 M events(collected 125 M)

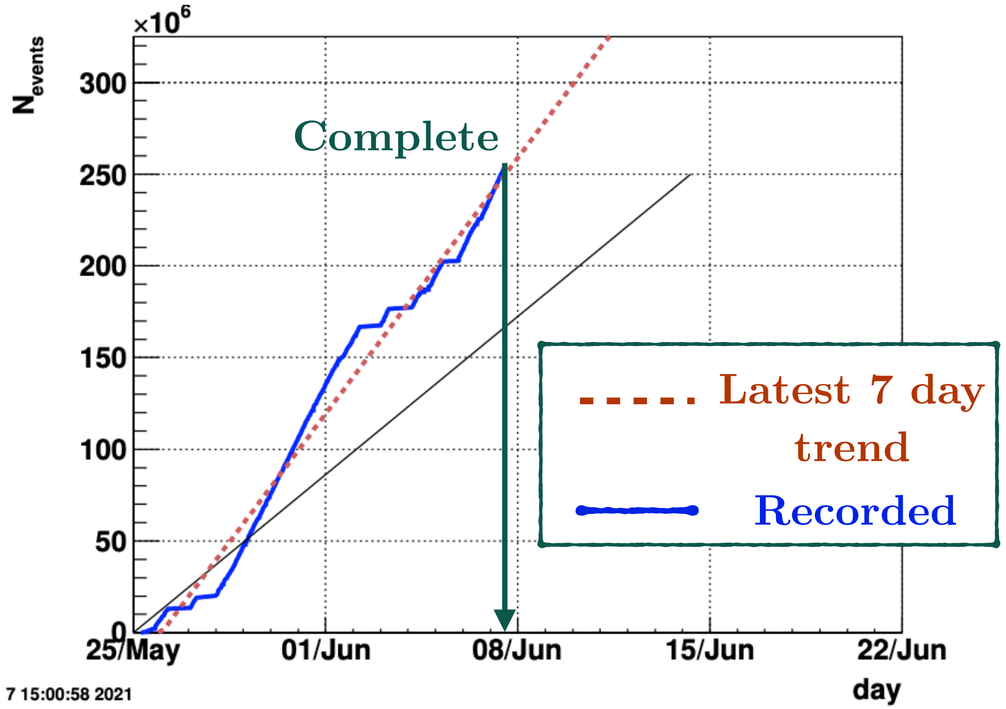
Large [×5(EPC)/×10(TPC)] boost in central events with high-multiplicity/central (HM) triggers





Au+Au $\sqrt{s_{NN}} = 17.3$ GeV Run

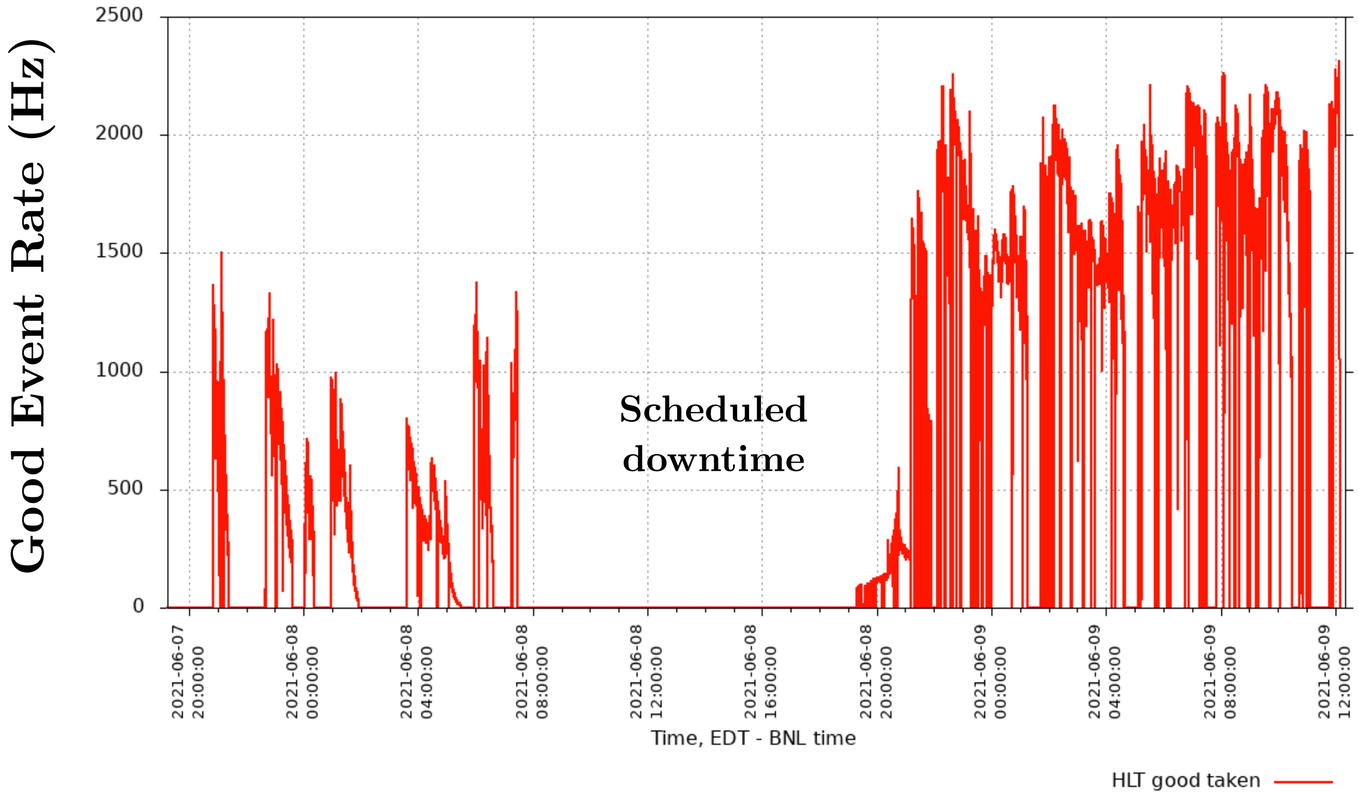




Very consistent fills with minimal downtime and low backgrounds; Average good event rate 450 Hz in latter half of run (improved with machine tuning w.r.t. first few days)

250 M goal reached on June 7th (2 weeks running - 256 M recorded; 2.5 weeks projected in BUR)

On-going FXT $\sqrt{s_{NN}} = 3$ GeV Run



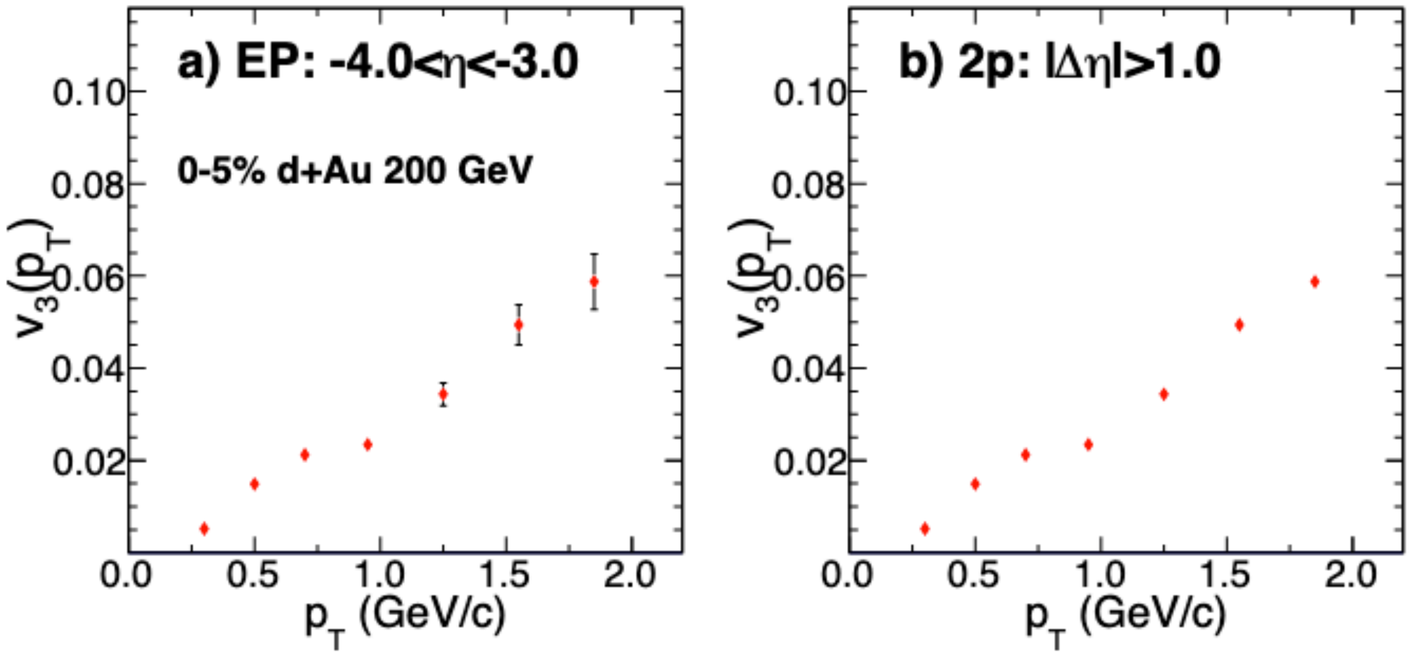
Switch backed to final FXT $\sqrt{s_{NN}} = 3$ GeV running June 7

Running conditions being optimized to finish 1.7 B good event goal within three calendar weeks (goal changed from 2 B)

73 M good events have been collected since 2 PM June 9

Potential d+Au $\sqrt{s_{NN}}$ = 200 GeV Run

STAR 2022 BUR



An appended d+Au 2021 run would provide invaluable data to pin down the role of geometry on collectivity in high multiplicity events (<u>time permitting</u>)

- Triangular anisotropy and mini-QGP (PHENIX: Nature Phys.15, 214 (2019)) vs. sub-nucleon fluctuations/geometry (STAR: Nucl. Phys. A1005, 122041 (2021))
- Improved forward acceptance (iTPC) + Event Plane Detector($2.1<|\eta|<5.1$) will enable more systematic studies

Proposed additional three day run to collect 190 M min. bias and 95 M central events (assuming 2.2 kHz rate w/ 12 hours/day)

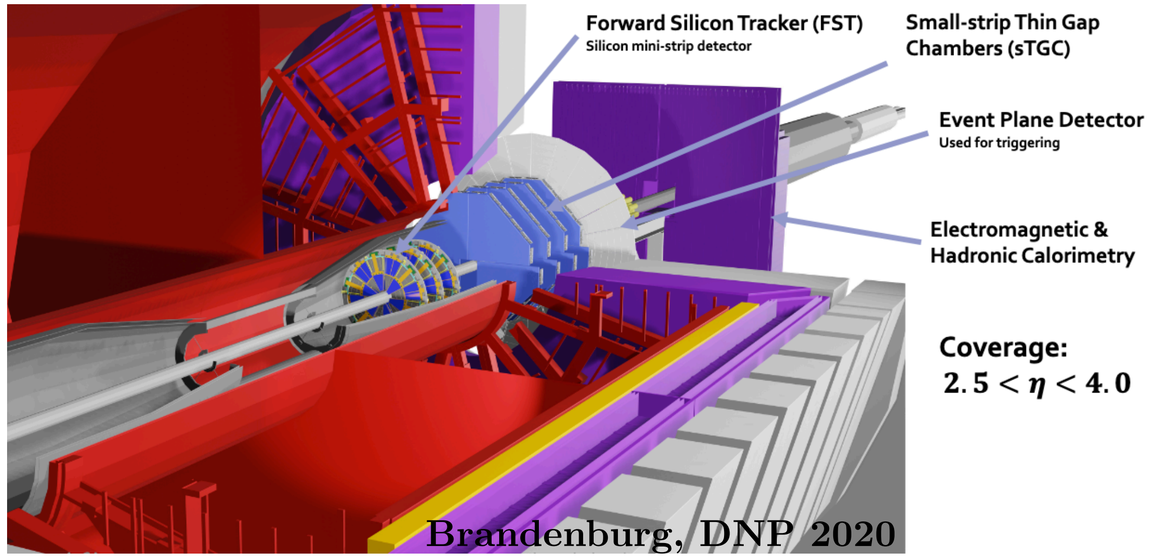
Plan for Run 22

Table 3: Proposed Run-22 assuming 20 cryo-weeks, including an initial one week of cool-down and a two weeks set-up time.

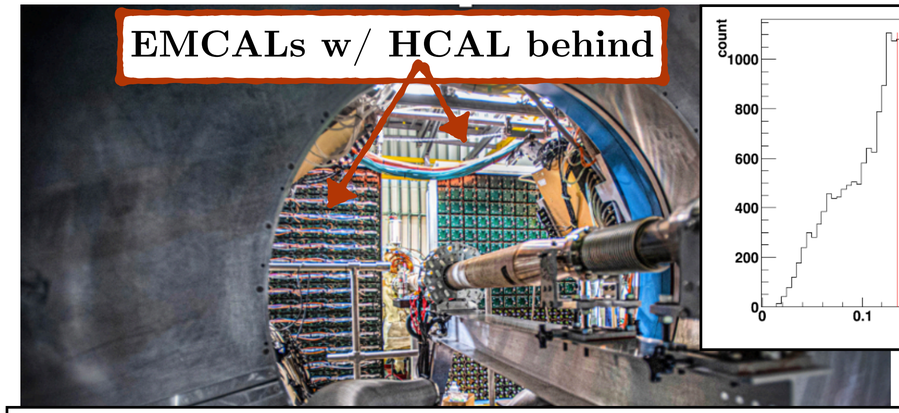
$\sqrt{s}$ (GeV)	Species	Polarization	Run Time	Sampled Luminosity	Priority
510	p+p	Transverse	16 weeks	400 pb^{-1}	1

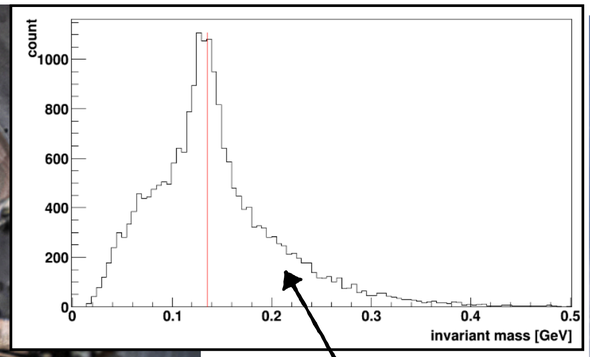
Forward tracking system (FST+sTGC) and EM+Hadronic calorimeters (FCS) open up (vast) forward physics avenues with STAR

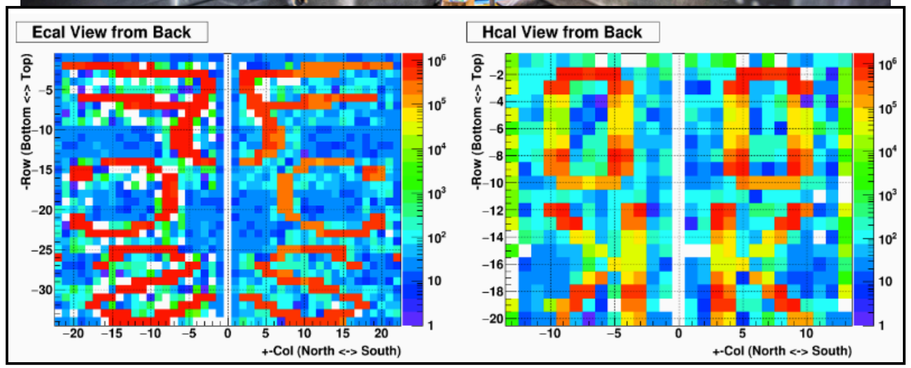
- $2.5 < \eta < 4.0$
- Access to low and high-x partonic regions



Forward Upgrade Status

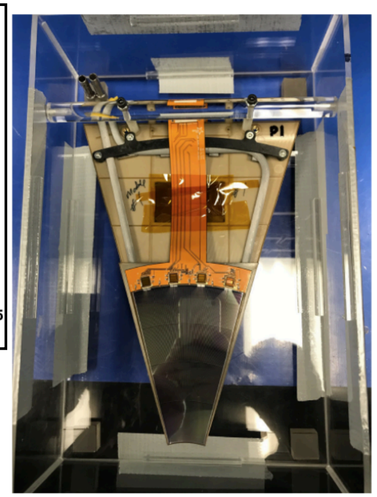




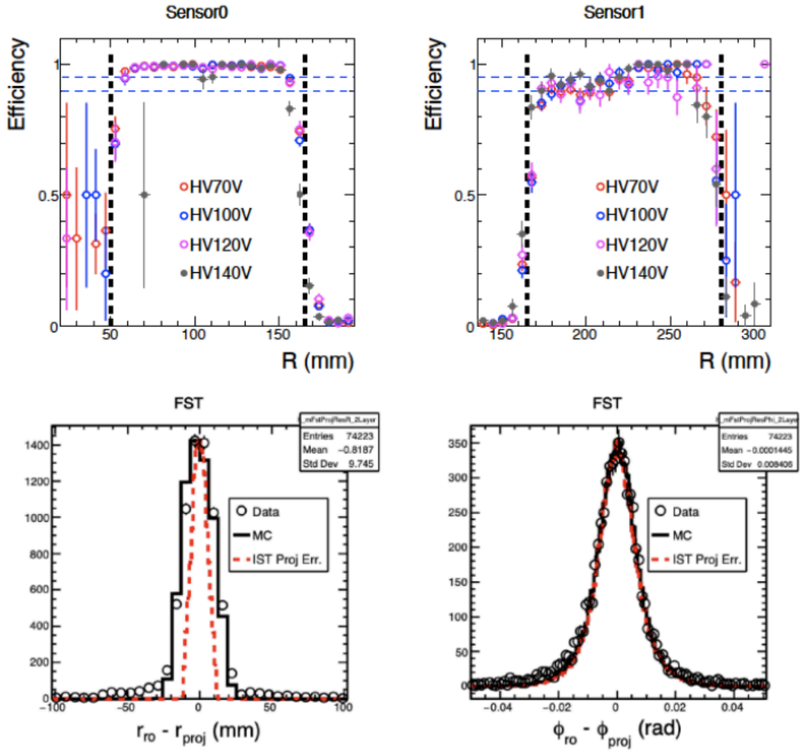


π^0 mass in EMCAL

FST Module



Cosmic Ray Tests



FCS system construction completed in August 2020 and commissioned in 2021 run (with very little problems!)

FST construction expected to be finished August 2021 and installed prior to Run22

sTGC module production complete, installation expected early October

Summary

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✓ 3.85	7.7	11-20 weeks	Au+Au	100 M	1	← May 1
✓ 3.85	3 (FXT)	3 days	Au+Au	300 M	2	← May 5
✓ 44.5	9.2 (FXT)	0.5 days	Au+Au	50 M	2	← May 6
70	11.5 (FXT)	0.5 days	Au+Au	50 M	2	← May 7
✓ 100	13.7 (FXT)	0.5 days	Au+Au	50 M	2	← May 8
✓ 100	200	1 week	O+O	400 M (+100 M FF) 200 M (central)	3	← May 24
✓ 8.65	17.3	2.5 weeks	Au+Au	250 M	3	← June 7
Ongoing 3.85	3 (FXT)	3 weeks	Au+Au	2 B	3	

STAR has had a very successful run while adopting a safe covid-era shift paradigm

Thanks to very consistent and excellent RHIC performance, STAR has completed all priority 1 and 2 programs from 2021 BUR; Priority 3 nearly complete

Data collected this year should yield some very interesting physics results!

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