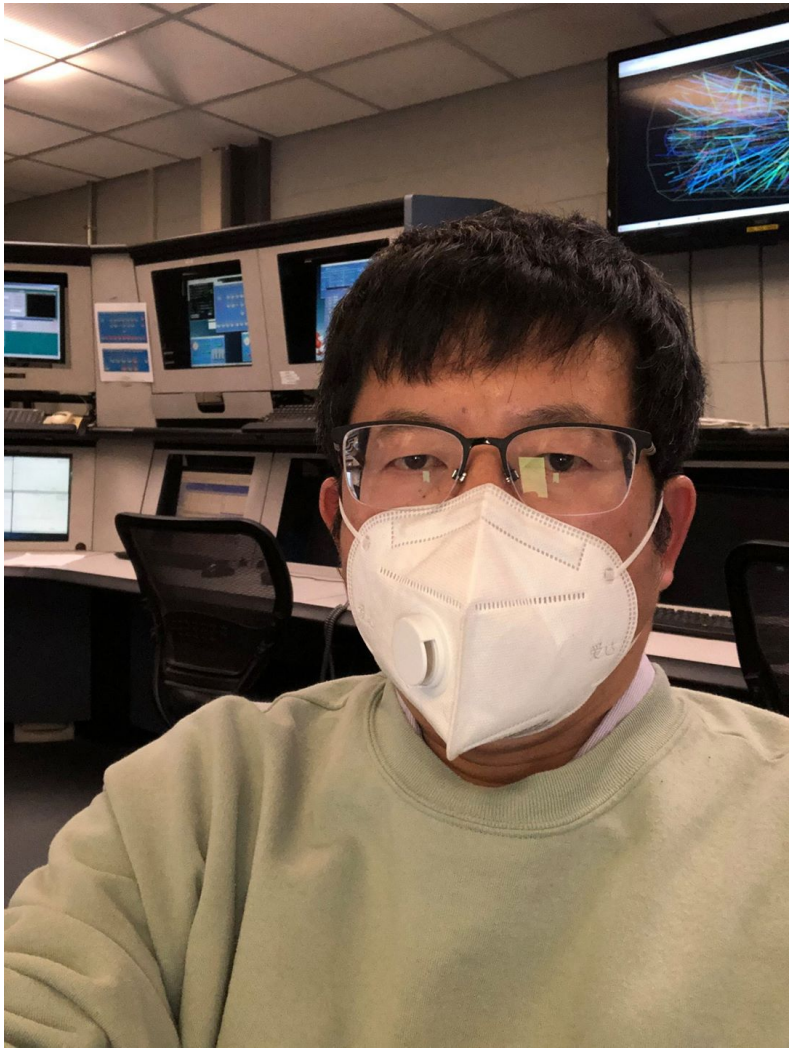
Update on BES-II progress
Mini-PAC meeting
Helen Caines - Yale
STAR

Huge thanks to Zhangbu whose term as (co)Spokesperson of STAR ended May 1

Looking forward to working for the next 3 years with Lijuan

Last days of Run-20a



BES-II: going into Run-20

Beam Energy (GeV/nucleon)	$\sqrt{s_{NN}}$ (GeV)	μ_B (MeV)	Run Time	Number Events requested / collected	
9.8	19.6	205	4.5 weeks	400M	582M
7.3	14.5	260	5.5 weeks	300M	324M
5.75	11.5	315	9.5 weeks	230M	
4.55	9.1	370	9.5 weeks	160M	
3.85	7.7	420	12 weeks	100M	
31.2	7.7 (FXT)	420	2 days	100M	51M
19.5	6.2 (FXT)	487	2 days	100M	
13.5	5.2 (FXT)	541	2 days	100M	
9.8	4.5 (FXT)	589	2 days	100M	
7.3	3.9 (FXT)	633	2 days	100M	53M
5.75	3.5 (FXT)	666	2 days	100M	
4.55	3.2 (FXT)	699	2 days	100M	201M
3.85	3.0 (FXT)	721	2 days	100M	3.7M+300M (run18)

"Good"

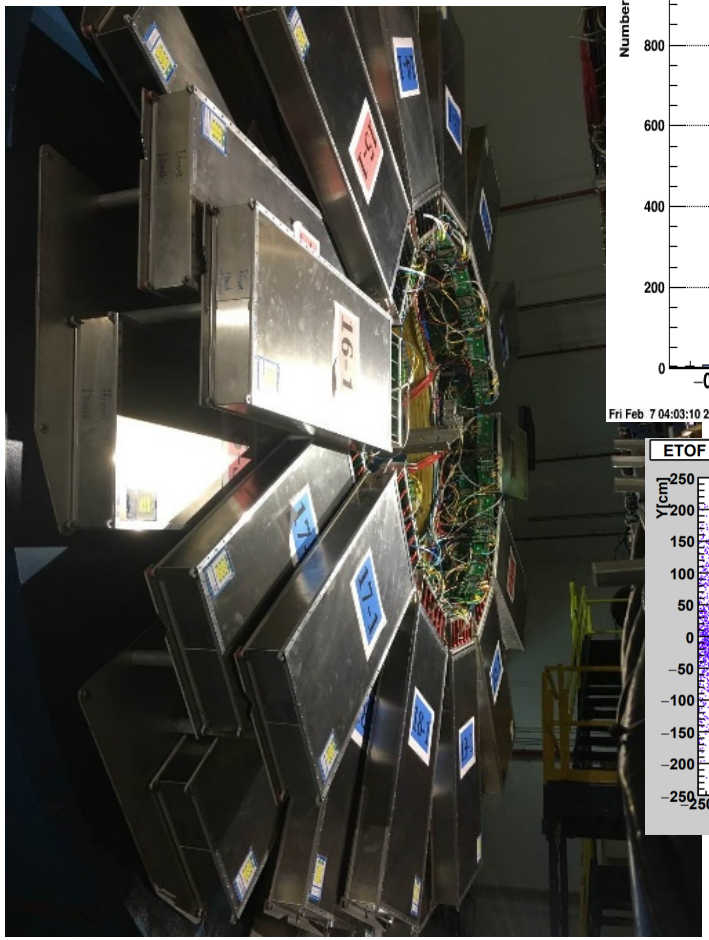
Run20

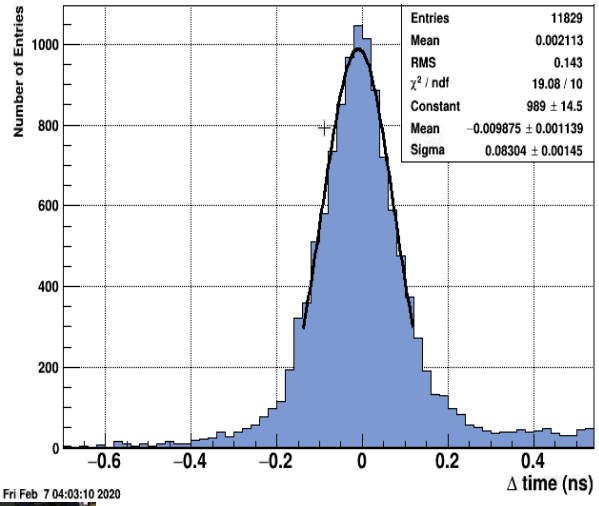
Run20

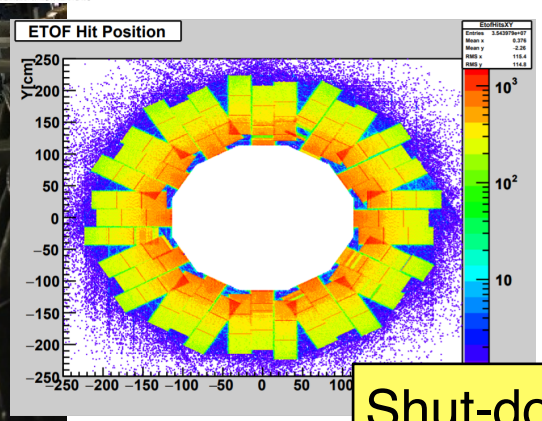
Top priorities for Run-20:
- $\sqrt{s_{NN}}$ = 11.5 and 9.1 GeV in collider mode
- $\sqrt{s_{NN}}$ = 7.7-3.5 GeV in FXT mode

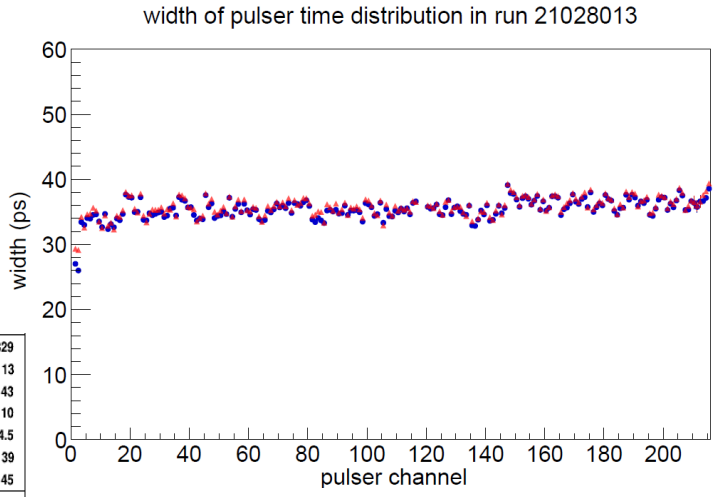
eTOF in Run-20

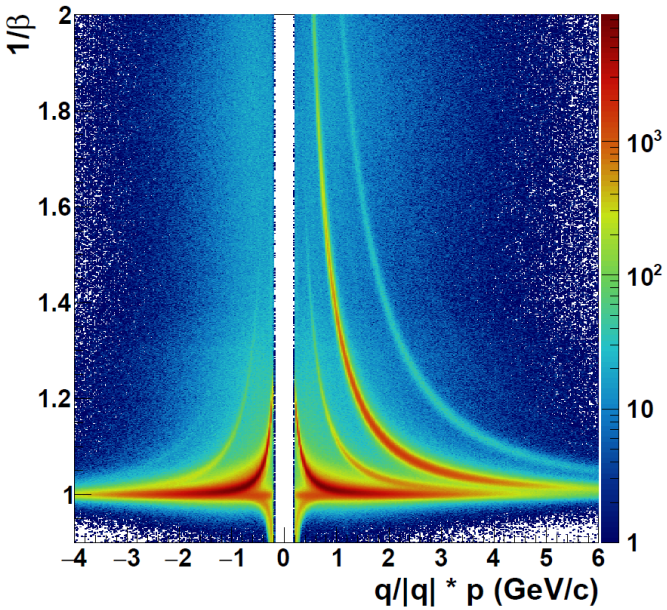
System synchronization on level of 35 ps
System time resolution better than 85 ps
PID capability demonstrated
Physics analysis started











Shut-down mitigation work a success
stable eTOF operation during Run-20

Run-20 summary

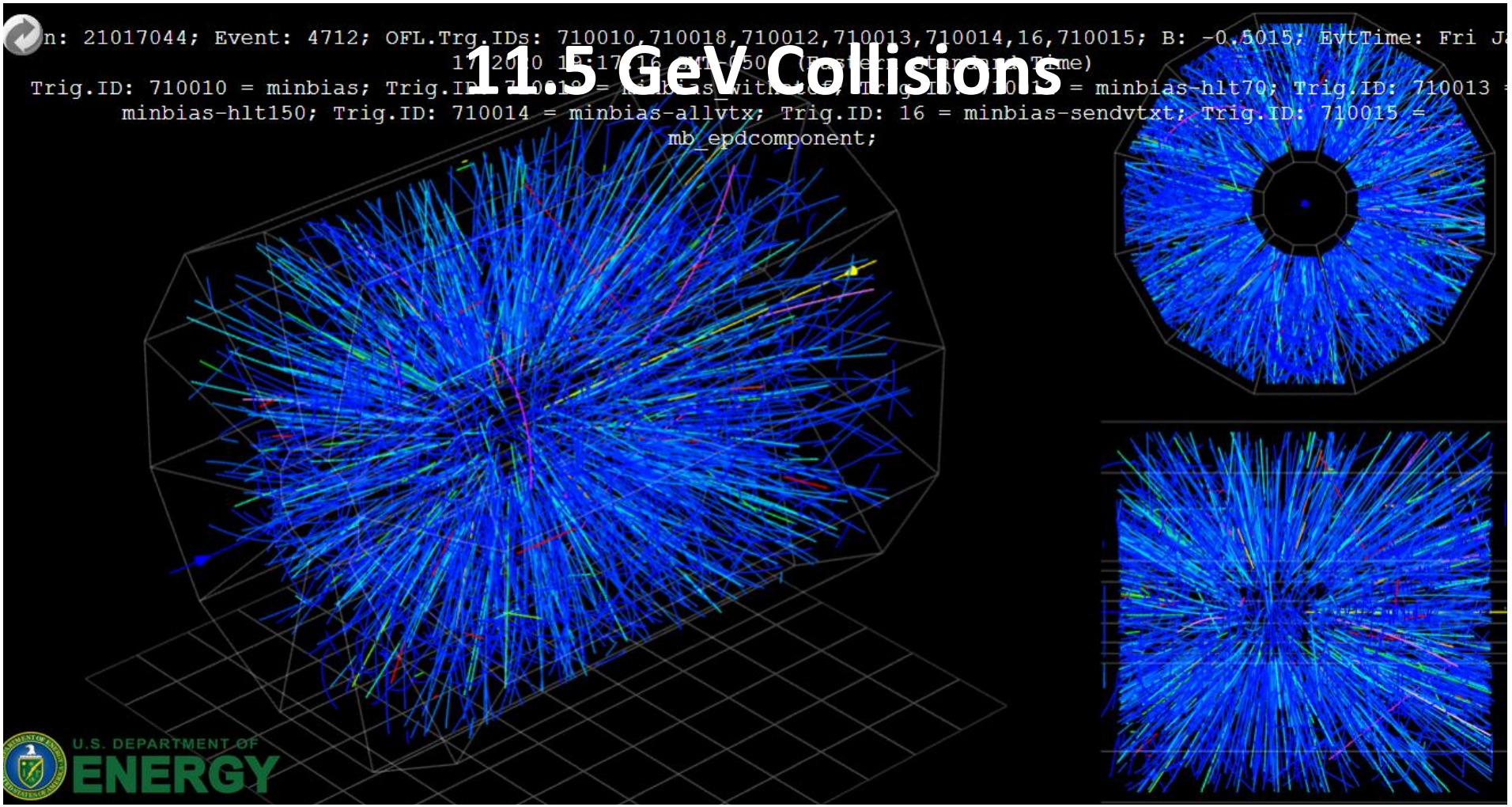
Started 2-person shifts on 11/25
Cosmic data take started 11/26
First beam 12/5

Energy	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)	Jan 28th	Jan 29th	21028011	21029037	**112.5 M**	100 M ✓
9.8 FXT (4.5)	Jan29th	Feb 1st	21029051	21032016	**108 M**	100 M ✓
19.5 FXT (6.2)	Feb 1st	Feb 2nd	21032049	21033017	**118 M**	100 M ✓
13.5 FXT (5.2)	Feb 2nd	Feb 3rd	21033026	21034013	**103 M**	100 M ✓
7.3 FXT (3.9)	Feb 4th	Feb 5th	21035003	21036013	**117 M**	100 M ✓
5.75 FXT (3.5)	Feb 13th	Feb 14th	21044023	21045011	**115.6 M**	100 M ✓
9.2 GeV	Feb 24th	March 20th	21055032		45 M	160 M

Data taking interleaved with LEReC and CeC running
Run ended early - hoping to return to Run-20b

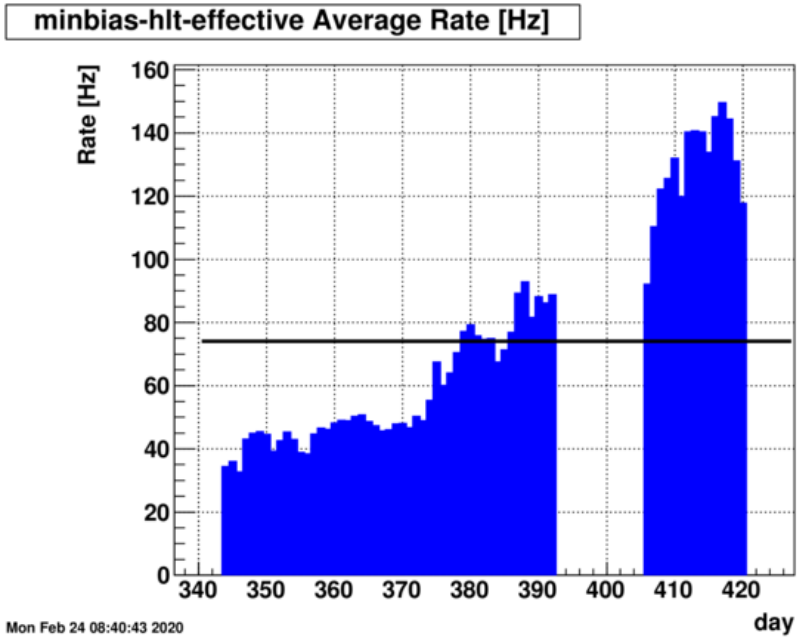
Were on target to reach all goals

11.5 GeV Collisions



Details of $\sqrt{s_{NN}}$ =11.5 GeV data-taking

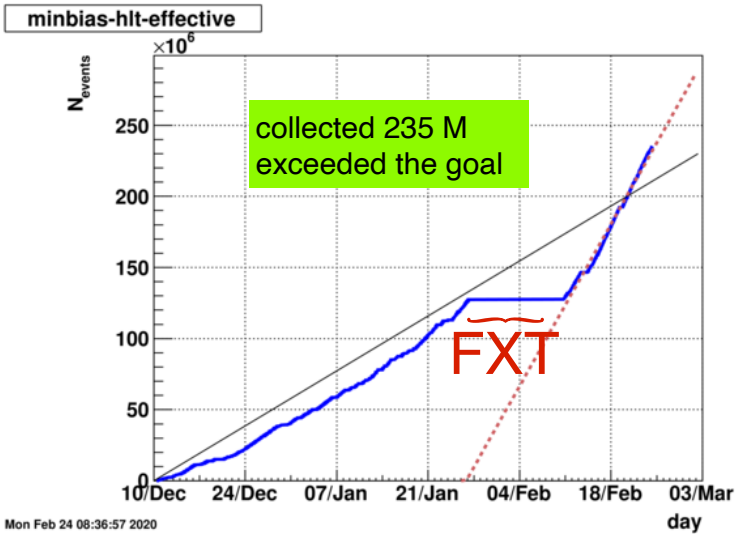
	2010	predicted	achieved
Average HLTgood event rate (Hz)	30	60-80	**140**
Data taking (hours per day)	12	15	**14-18**
Fill Length (minutes)	20	40	**25**
DAQ Rate at start of fill (Hz)	140	250	**550**
Ratio of HLTgood/triggers (%)			**40%**

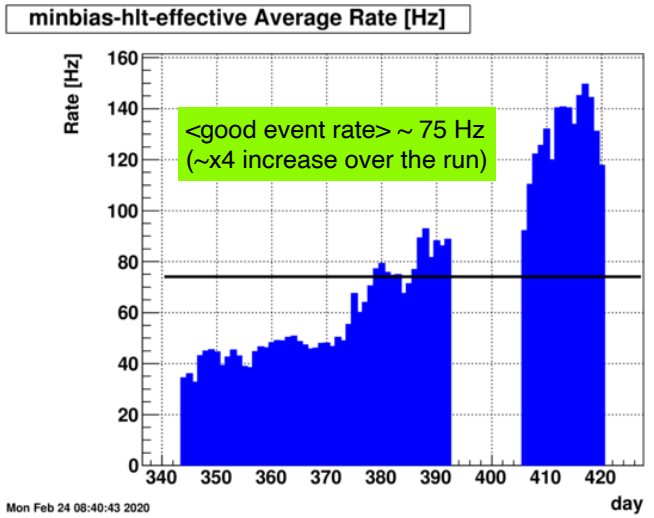


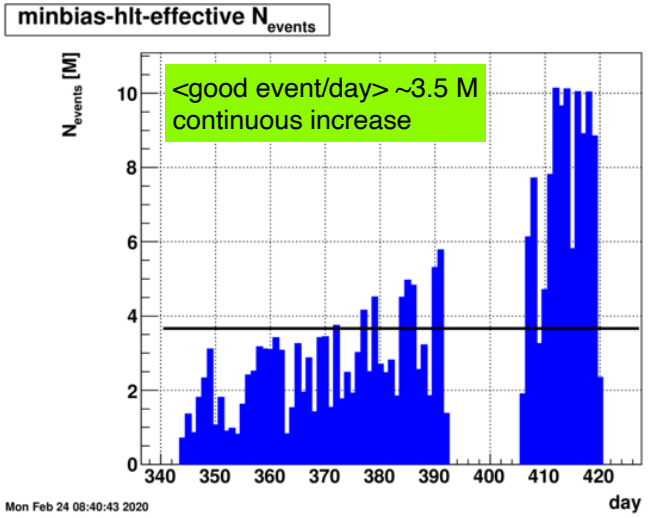
Dramatic improvements during the run

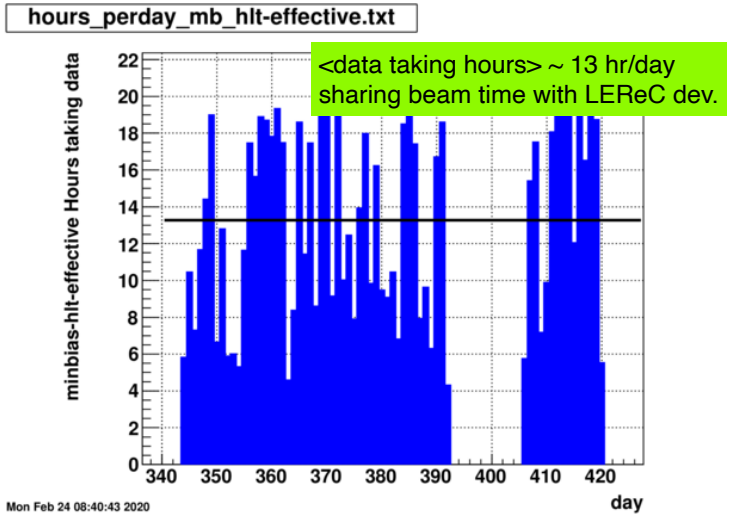
Running conditions exceeded predictions

Optimized RHIC and STAR operations

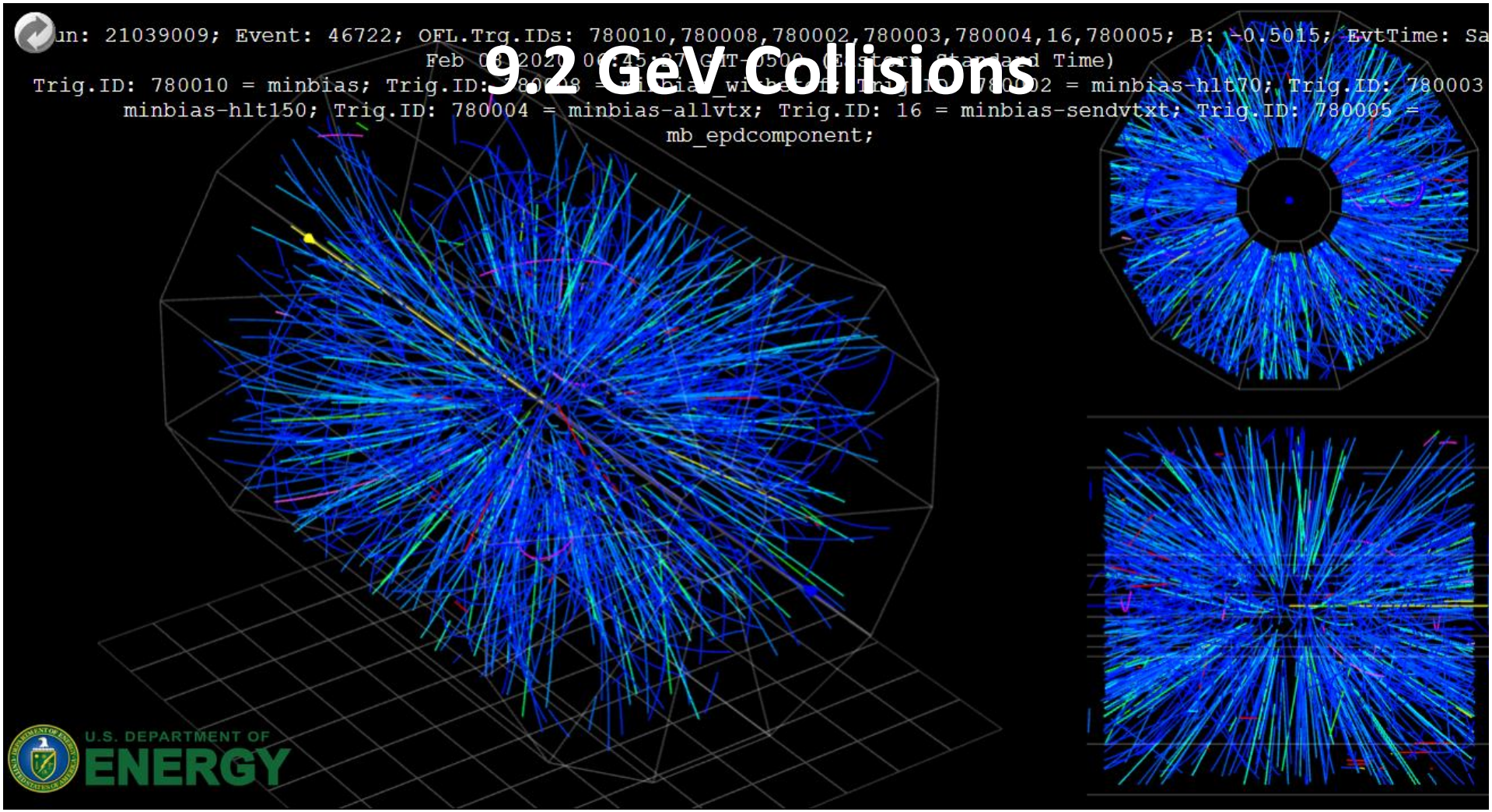








9.2 GeV Collisions



Details of $\sqrt{s_{NN}}$ =9.2 GeV data-taking

	2019	predicted	Achieved
Average HLTgood event rate (Hz)	6.2	33-53	**36**
Data taking (hours per day)	8	14	**15**
Fill Length (minutes)	45	30	**45**
DAQ Rate at start of fill (Hz)	60	160	**700**
Ratio of HLTgood/triggers (%)	10%	25%	**18%**

Running conditions:

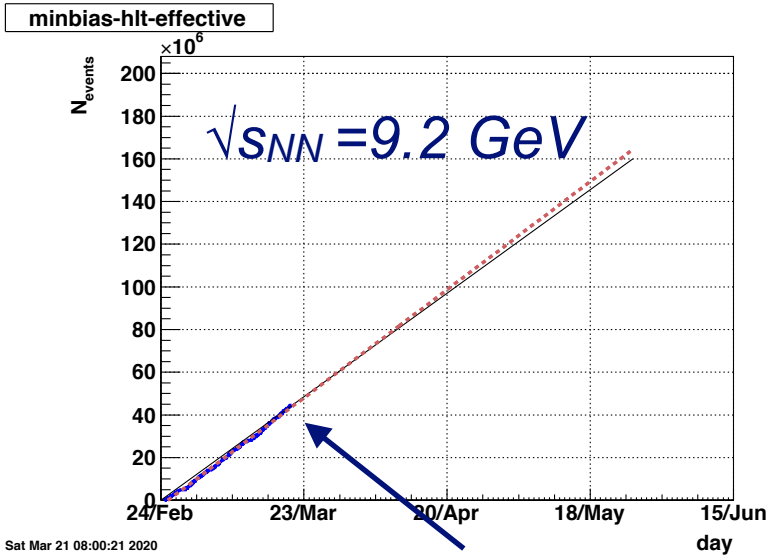
Dramatic improvements compared to last year

Average statistics (and still improving):

30 Hz good event rate

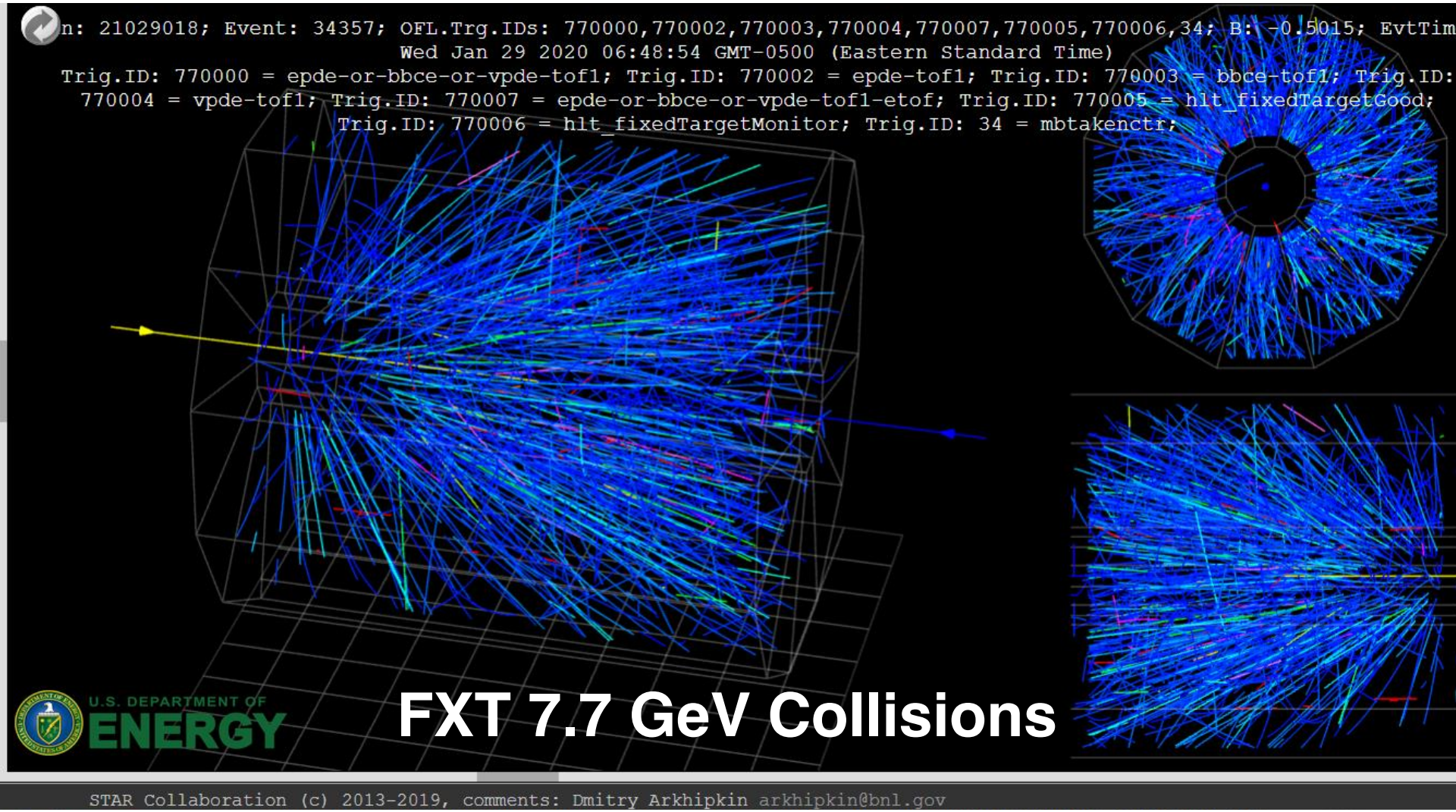
14 hours/day

1.6 M good events/day



Have just over 1/4 events on tape

Were expecting to reach goals by end of run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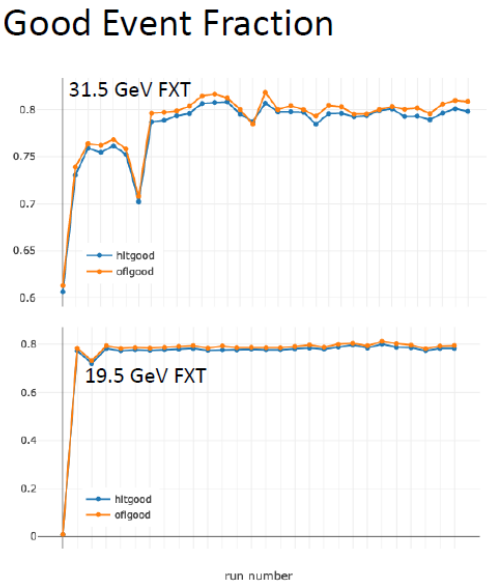
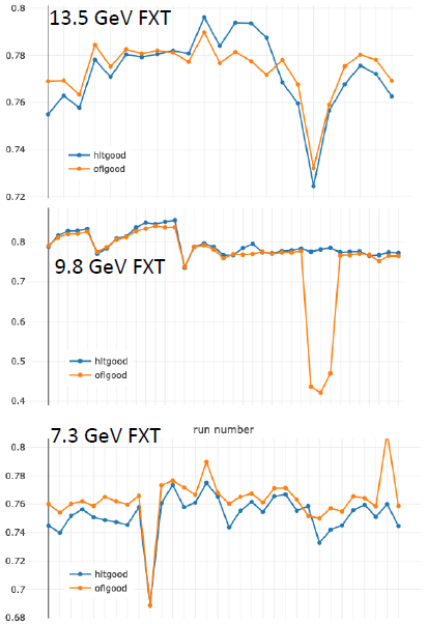
Wed Jan 29 2020 06:48:54 GMT-0500 (Eastern Standard Time)
Trig.ID: 770000 = epde-or-bbce-or-vpde-tof1; Trig.ID: 770002 = epde-tof1; Trig.ID: 770003 = bbce-tof1; Trig.ID:
770004 = vpde-tof1; Trig.ID: 770007 = epde-or-bbce-or-vpde-tof1-etof; Trig.ID: 770005 = hlt_fixedTargetGood;
Trig.ID: 770006 = hlt_fixedTargetMonitor; Trig.ID: 34 = mbtakenctr;
U.S. DEPARTMENT OF
ENERGY
FXT 7.7 GeV Collisions
STAR Collaboration (c) 2013-2019, comments: Dmitry Arkhipkin arkhipkin@bnl.gov

FXT running

Single beam (12 bunch yellow beam) - long stores
Sustained clean (good event rate> 70%) and high rate (~1.5 kHz)
Trigger and scalar rates feedback were crucial for beam steering

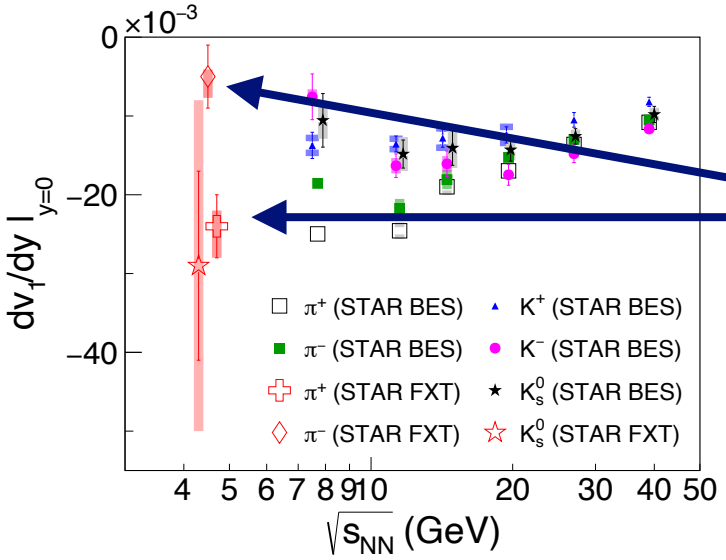




	HLT Good (M)	with EToF (M)
31.2 GeV	113.5	101.7
19.5 GeV	119.2	80.4
13.5 GeV	103.1	88.9
9.8 GeV	108.9	72.7
7.3 GeV	114.8	106.4
5.75 GeV	114.3	99.8

All goals (including eTOF event goals) reached or surpassed

(pre)BES-II: Flow and HBT



FXT $\sqrt{s_{NN}}$ =4.5 GeV (~1.3M 0-30%)

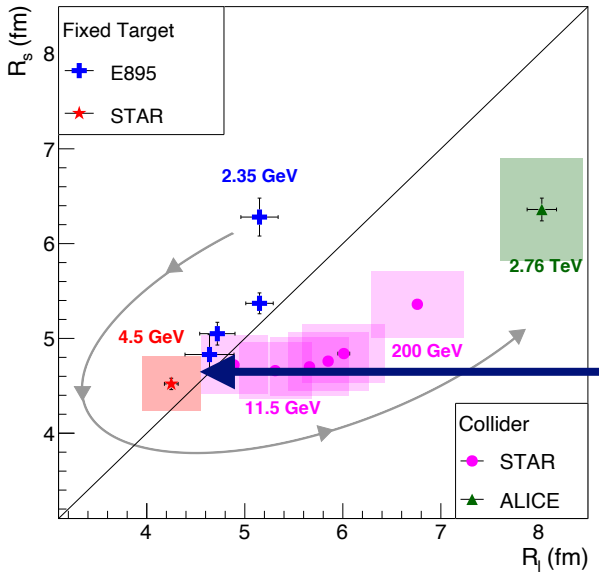
First π v_1 and v_2 results

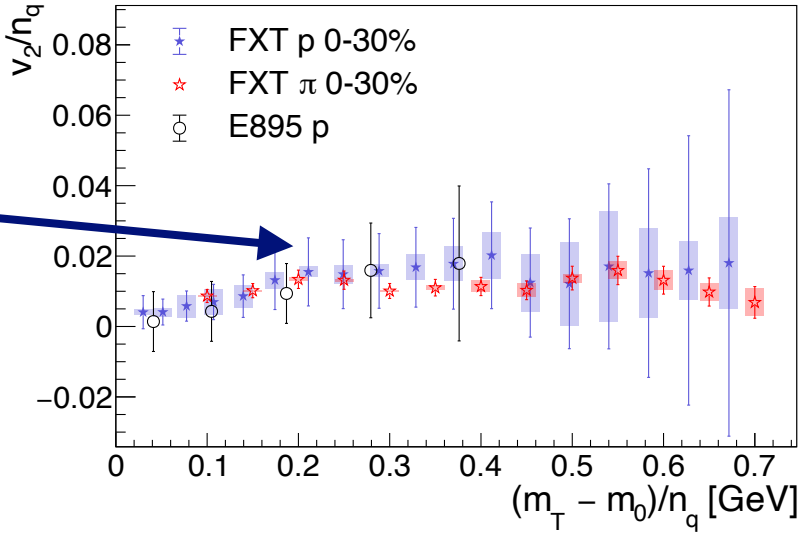
Difference in v_1 slope for π^+ and π^-

Isospin and/or Coloumb dynamics becoming prominent

Similar observation reported by FOPI at lower energies (arXiv:nucl-ex/0610025)

Hint of NCQ scaling: large errors

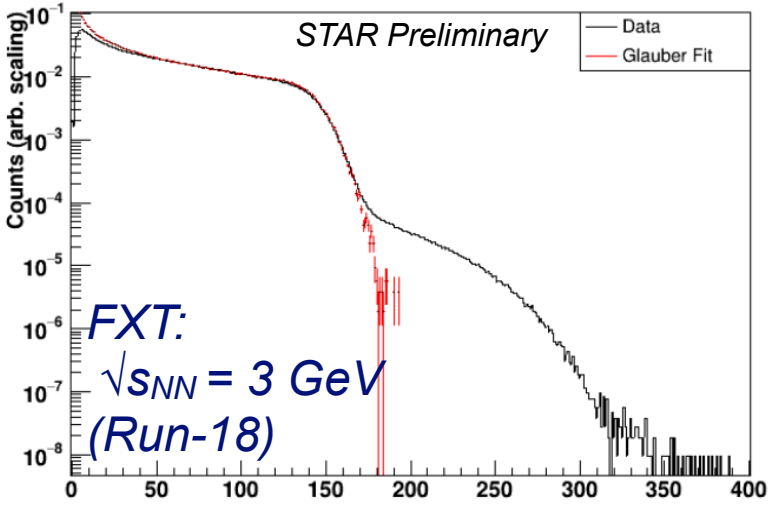




At transition from oblate to prolate spatial source

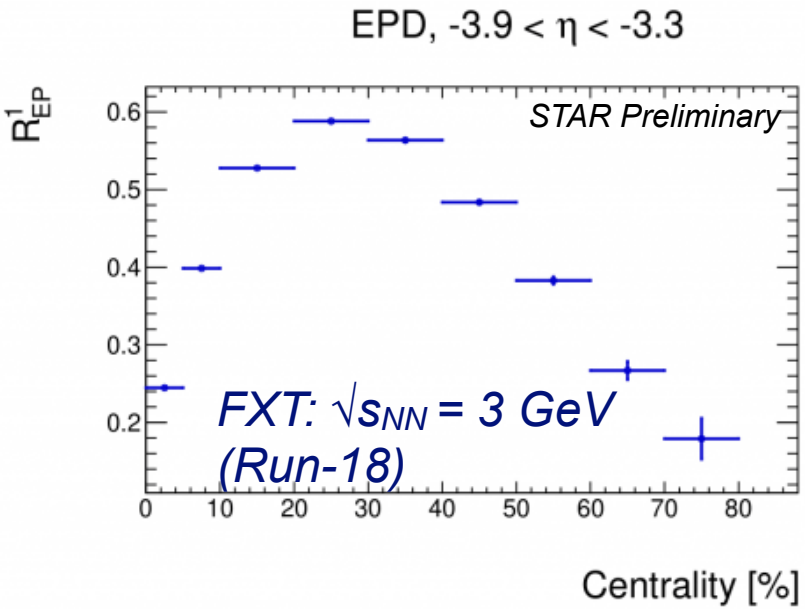
Results to be submitted soon

BES-II: Preliminary analyses

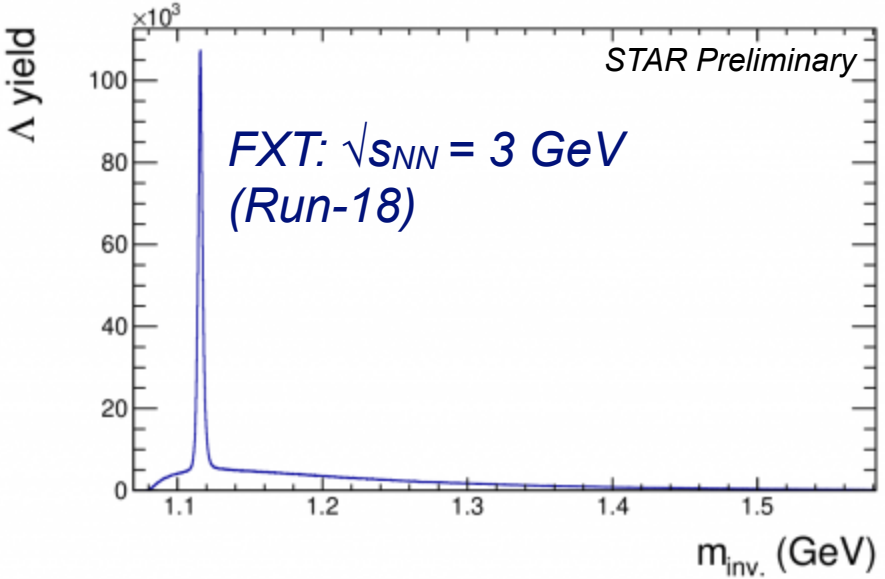


Identify and reject “pile up”: Centrality and Glauber fit completed for 3.0 GeV

Preliminary studies made for other BES-II Run-19 datasets



EPD being used for reaction plane related studies



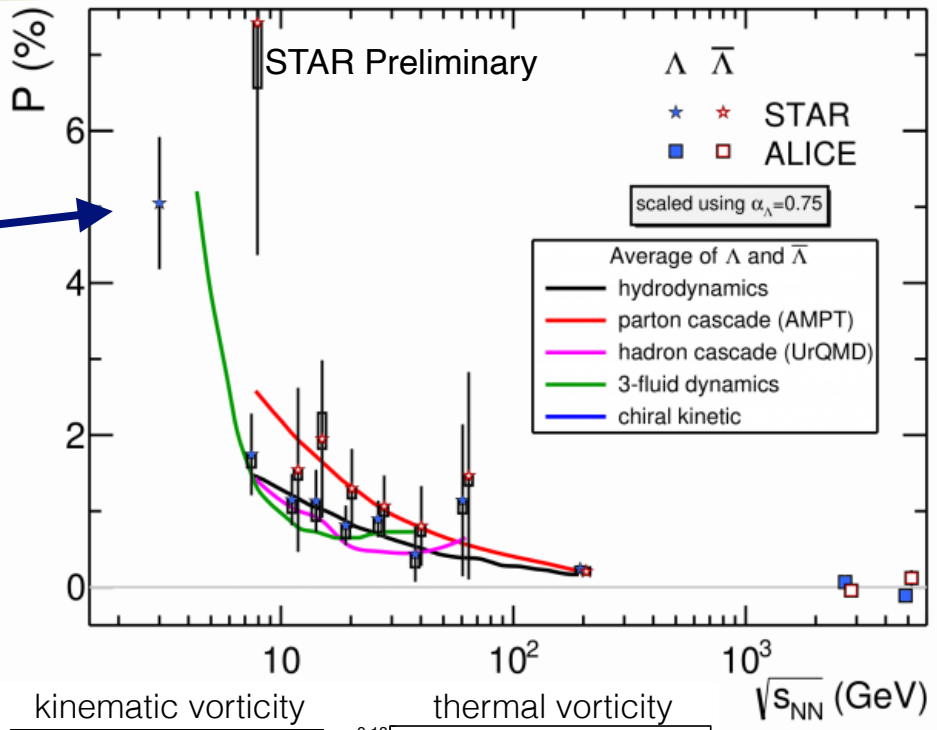
Very clean V^0 signals

BES-II: Significant Lambda polarization

Run-18: FXT $\sqrt{s_{NN}}$ =3 GeV

Non-zero polarization observed

consistent with previous data trend

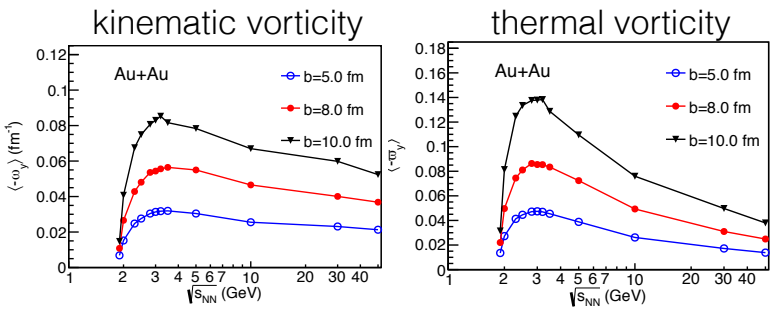


HADES Preliminary (SQM19)

Au+Au at $\sqrt{s_{NN}}$ = 2.4 GeV

$P_\Lambda(\%) = 3.672 \pm 0.699$ (stat.)

$P_{BG}(\%) = 3.689 \pm 1.133$ (stat.)



UrQMD:
X.-G. Deng et al.
arXiv:2001.01371

Indicates extremely large vorticies created even without QGP formation

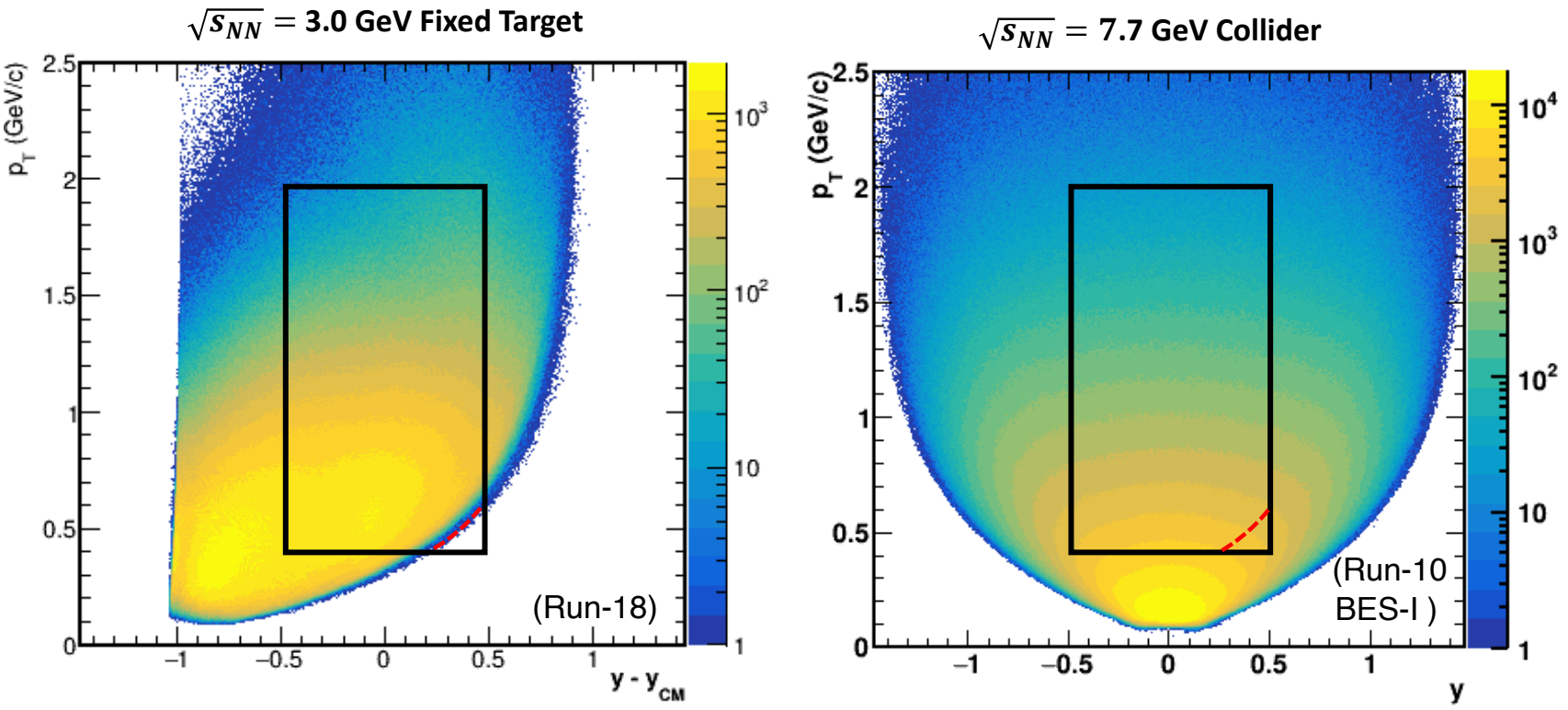
kinematic vorticity: measures local angular velocity of fluid

thermal vorticity: determines spin polarization density of fluid at global equilibrium

Results going into GPC soon

BES-II: Identified protons - real data

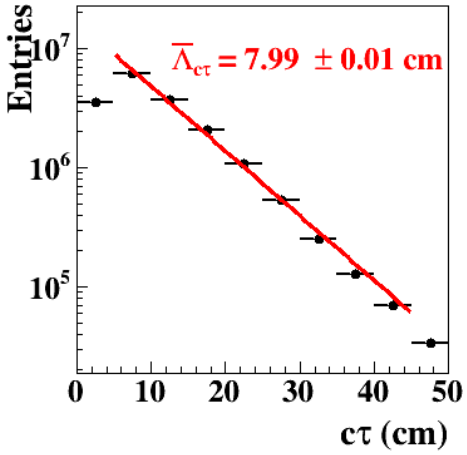
Identification via dE/dx @3 GeV purity(p_T>1 GeV/c) >95%

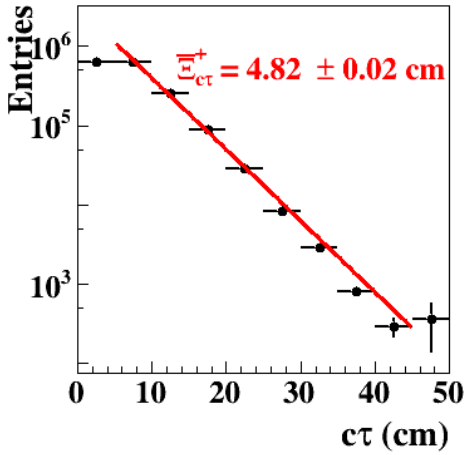


Proton coverage similar for FXT 3 GeV and collider at 7.7 GeV

Boxes: kinematic range of previous kurtosis analysis
Missing coverage could be recovered with iTPC run

BES-II: Online QA/analyses

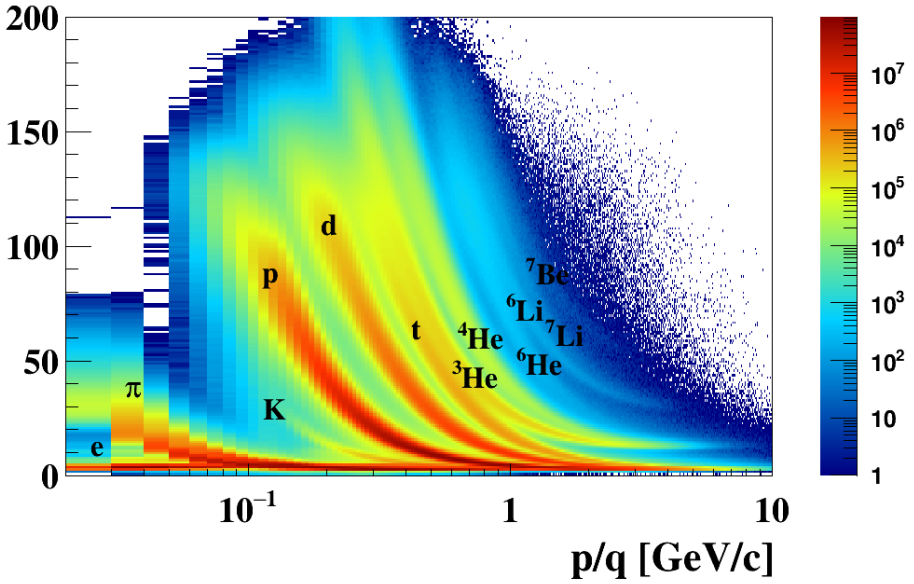




Run-20 $\sqrt{s_{NN}}$ =11.5:

Excellent statistics

cτ in agreement with PDG

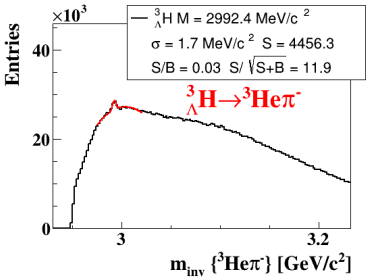


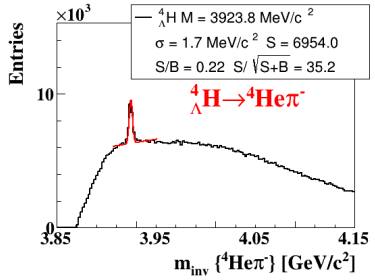
Run-18 FXT $\sqrt{s_{NN}}$ =3 GeV:

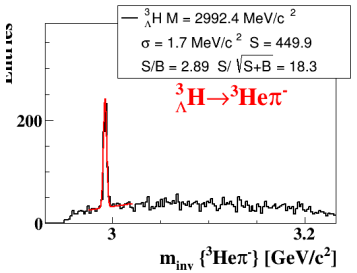
Heavy fragments up to ^{7}Be

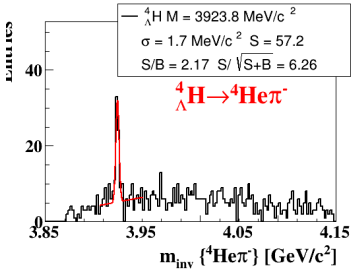
BES-II: Online hypernuclei

3 GeV, 285M



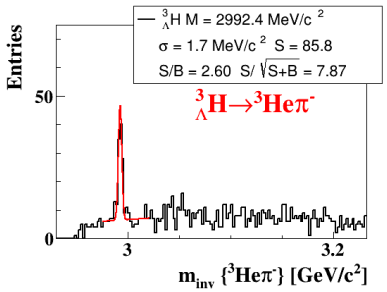


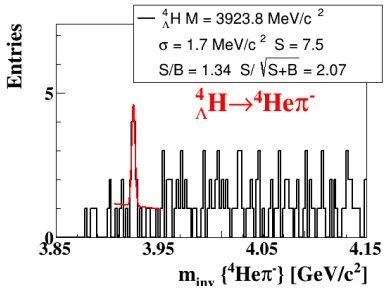


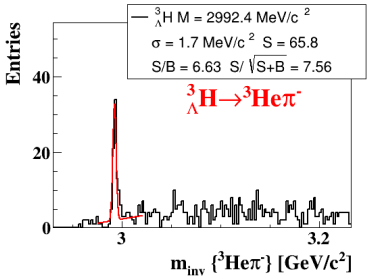


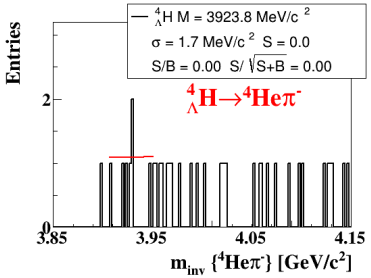
11.5 GeV, 216M

9.2 GeV, 23M









27 GeV, 300M

Run-18-20:

At FXT energies
- yields of fragmentation nuclei rising.

Significant increase of observed hypernuclei

After corrections can merge dataset to get precision lifetime measurements.

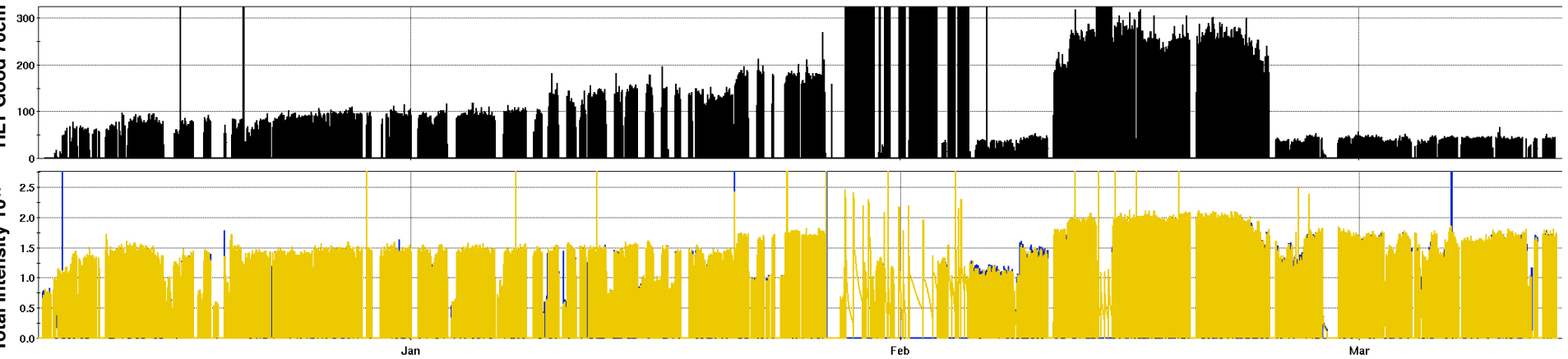
Can use lifetime can extract yields vs $\sqrt{s_{NN}}$

Unique studies possible

Summary

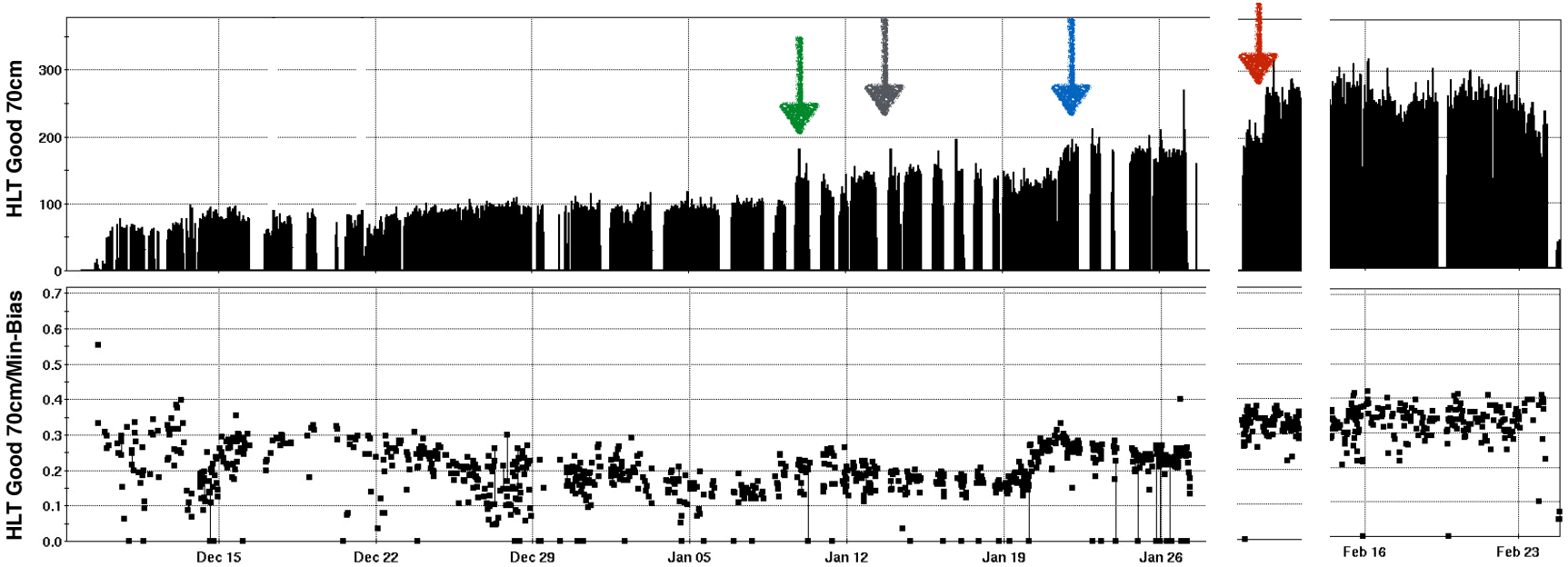
- Very successful data collection
  - RHIC performing beyond expectations
  - No major detector or operations issues
  - eTOF working well in Run-20
    - Retake early FXT data with eTOF and iTPC present?
  - 11.5 GeV data set completed, exceeded goal
  - 6 FXT data sets completed
  - 9.2 GeV on route to completion by end of run
    - 1/4 events collected so far
- First BES-II results heading to publication
  - More than I was able to show today

Challenging goals



- **Challenging Goals**: need
  - all the **luminosity** increase and optimization from the machine
  - **efficient data taking** to maximize yield
- Many energy settings to cover: timing and trigger setup
- Frequent changes between physics data taking and development: minimize overhead with machine operation and data taking
- 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)

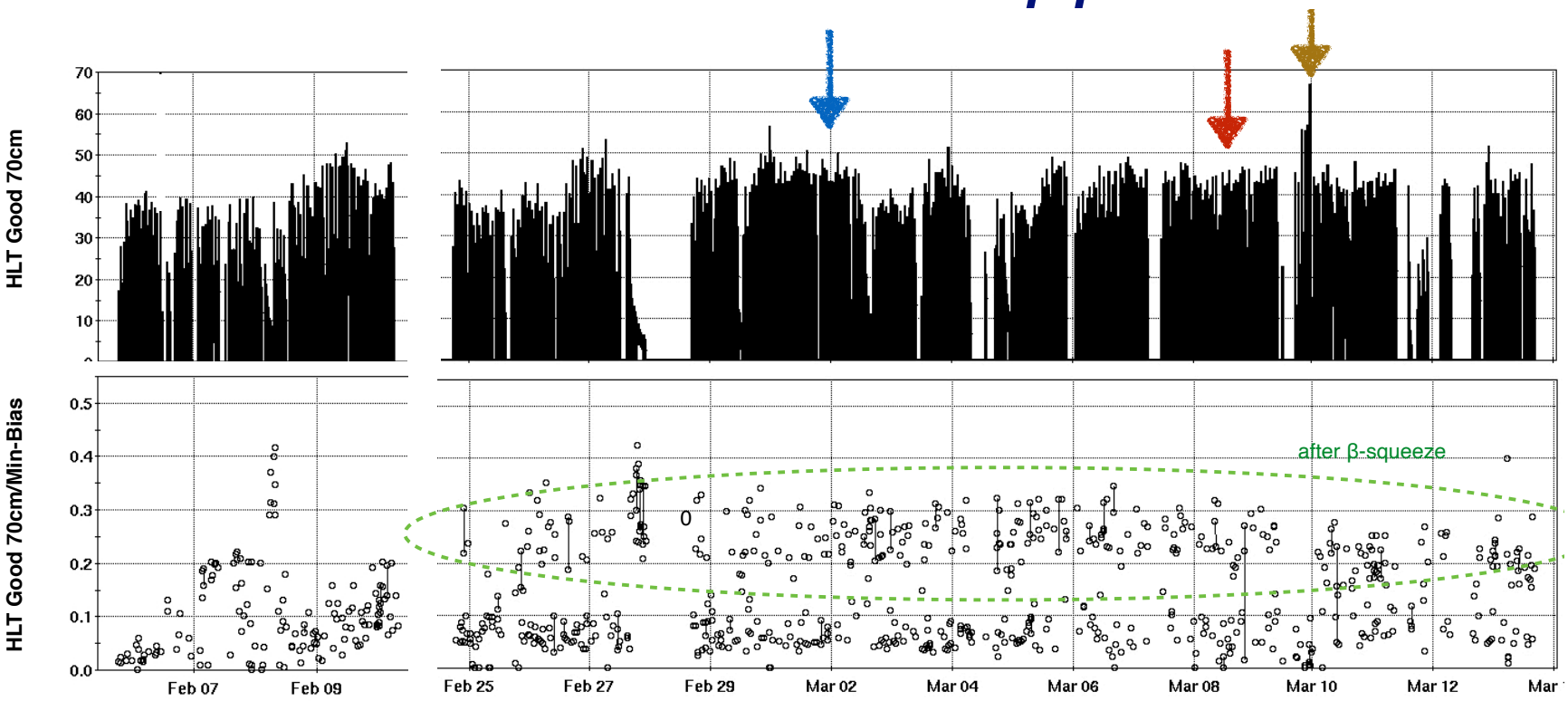
$\sqrt{s_{NN}}$ =11.5 GeV



- Beam from Tandem for smaller emittance. 28 MHz RF (h=363) concurrently with 9MHz for longitudinal focusing and reducing debunching
- **Continuous increase of luminosity during the run**
  - tune ("working point") change/optimization
  - 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

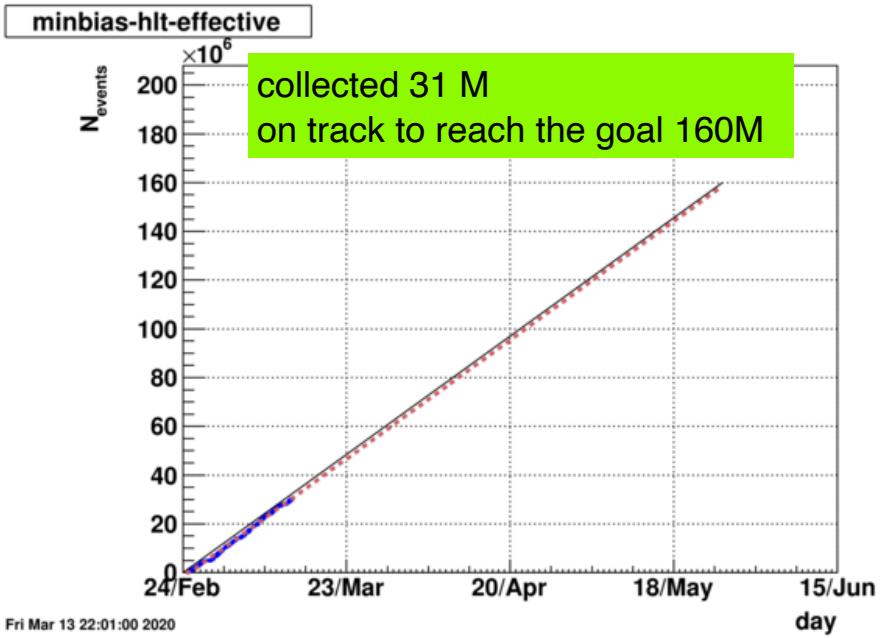
5

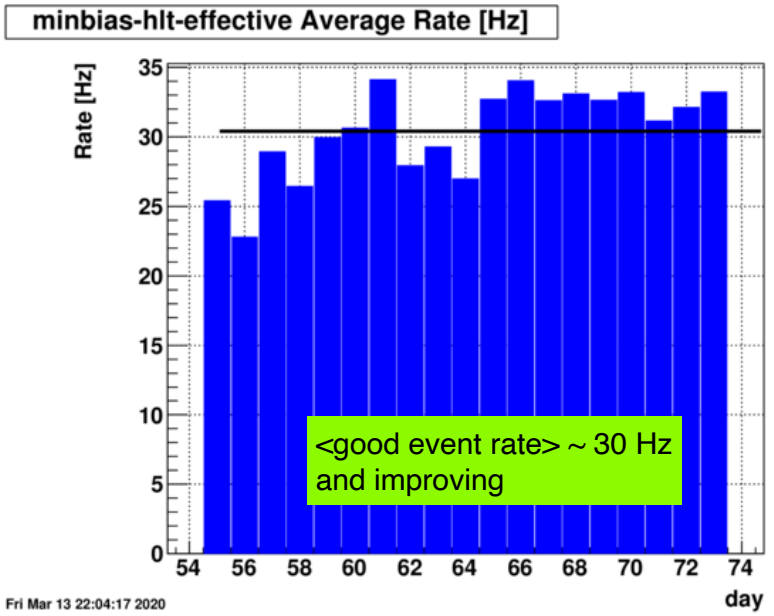
$\sqrt{s_{NN}}$ =9.2 GeV - RHIC stopped

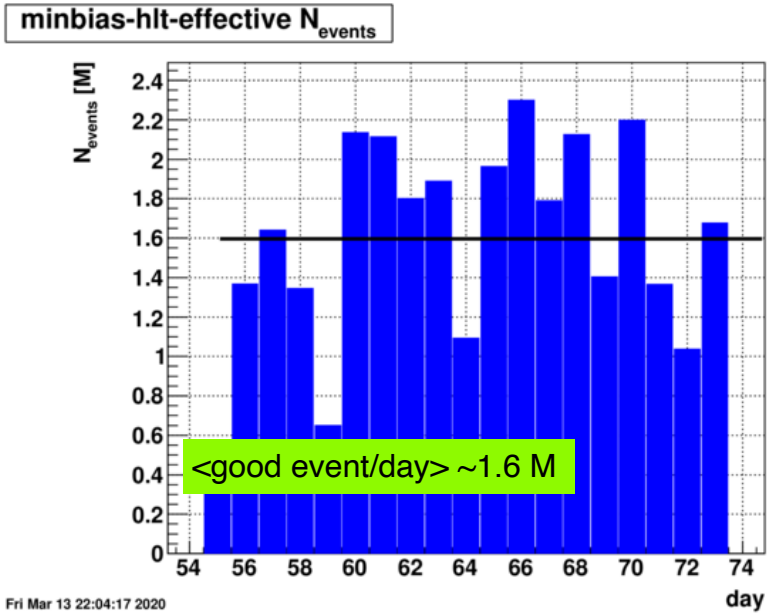


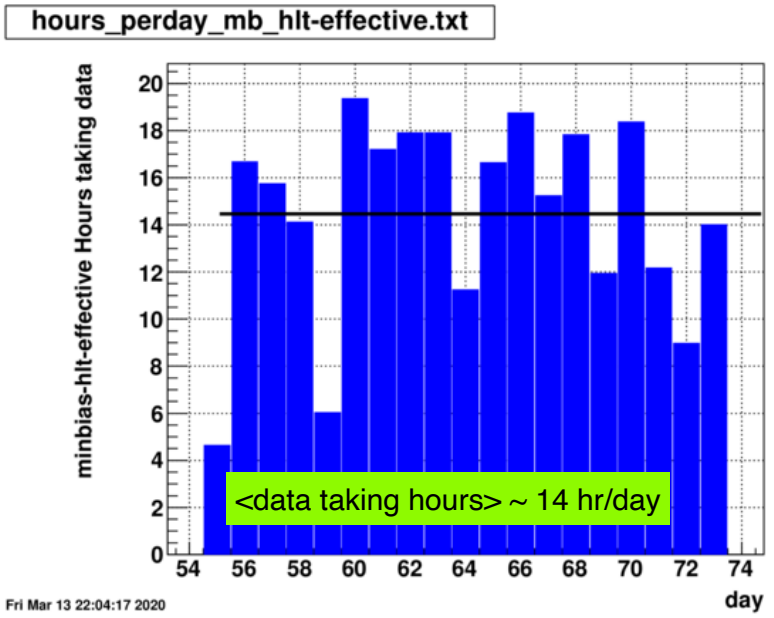
- Au from EBIS (large longitudinal emittance for 9MHz RF)
- First LEReC in operation for physics
- AGS bunch 4-1 merge (12-3) for higher bunch intensity
- **Luminosity improvement and optimization**
  - β squeeze 4.5 - 3.5 - 3 meter (in 0-15-30 min) during store (with cooling)
  - 9MHz RF voltage ramping down 180kV - 120kV during store for better lifetime and cooling
  - new (lower) working point and compatibility with cooling: under development
  - vertex z fine adjustment (cogging)
- "Effective good event" rates ~1.29 * rates in good event rates in ±70cm

9.2 GeV data taking





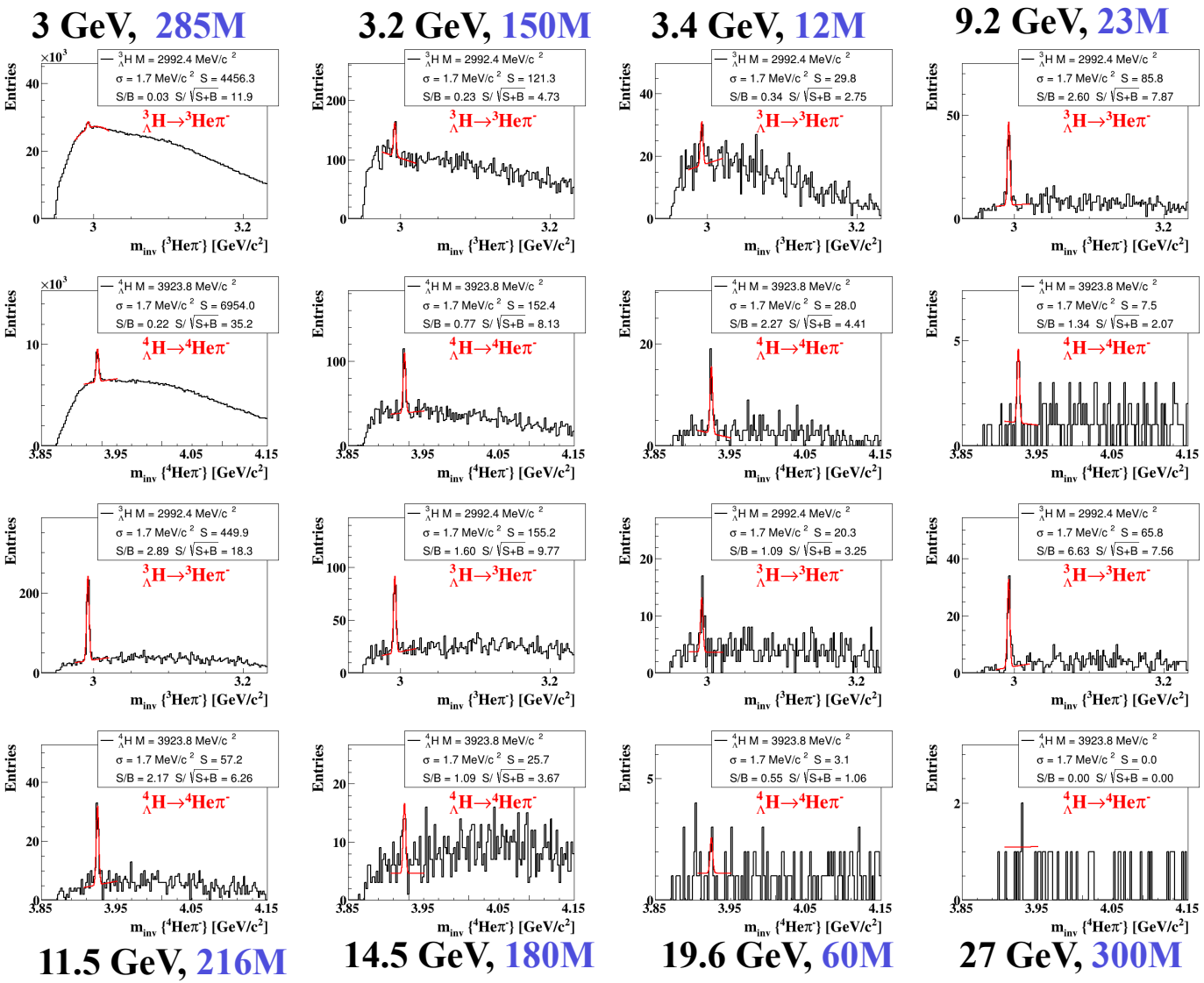




FXT and eTOF summary

Energy	HLTgood w/ eTOF	Target w/ eTOF
31.2 FXT	101.7 M	100 M
19.5 FXT	80.4 M	80 M
13.5 FXT	88.9 M	70 M
9.8 FXT	72.7 M	65 M
7.3 FXT	106.4M	50 M
5.75 FXT	99.4 M	70 M

BES-II: Online Hypernuclei



Run-18-20:

Yields increase with decreasing energy.

•At low energies of the fixed target program the yields of nuclei fragment production is raising. This leads to significant increase of observed hypernuclei (~10 000) and opens new

ctives in

idies.

Event statistics requirements: Collider

Table 7: Event statistics (in millions) needed in the collider part of the BES-II program for various observables. This table updates estimates originally documented in STAR Note 598.

Collision Energy (GeV)	7.7	9.1	11.5	14.5	19.6
μ_B (MeV) in 0-5% central collisions	420	370	315	260	205
Observables					
R_{CP} up to $p_T = 5$ GeV/c	-	-	160	125	92
Elliptic Flow (ϕ mesons)	80	120	160	160	320
Chiral Magnetic Effect	50	50	50	50	50
Directed Flow (protons)	20	30	35	45	50
Azimuthal Femtoscopy (protons)	35	40	50	65	80
Net-Proton Kurtosis	70	85	100	170	340
Dileptons	100	160	230	300	400
$>5\sigma$ Magnetic Field Significance	50	80	110	150	200
Required Number of Events	100	160	230	300	400

Typically factor 20 more than for BES-I

Event statistics requirements: FXT

Table 8: Event statistics (in millions) needed in the fixed-target part of the BES-II program for various observables.

$\sqrt{s_{NN}}$ (GeV)	3.0	3.2	3.5	3.9	4.5	5.2	6.2	7.7
Single Beam Energy (GeV)	3.85	4.55	5.75	7.3	9.8	13.5	19.5	31.2
μ_B (MeV)	721	699	666	633	589	541	487	420
Rapidity y_{CM}	1.06	1.13	1.25	1.37	1.52	1.68	1.87	2.10
Observables								
Elliptic Flow (kaons)	300	150	80	40	20	40	60	80
Chiral Magnetic Effect	70	60	50	50	50	70	80	100
Directed Flow (protons)	20	30	35	45	50	60	70	90
Femtoscopy (tilt angle)	60	50	40	50	65	70	80	100
Net-Proton Kurtosis	36	50	75	125	200	400	950	NA
Multi-strange baryons	300	100	60	40	25	30	50	100
Hypertritons	200	100	80	50	50	60	70	100
Requested Number of Events	300	100	100	100	100	100	100	100