STAR Plans for the BES-II and Beyond

RHIC-BES Theory and Experiment Online Seminar Series
Helen Caines - Yale

BES first proposed to PAC 2006
STAR BES campaign started in 2010
Extra point at 15 GeV requested in 2012
BES-II officially requested in 2014
BES-II starts 2019(18)

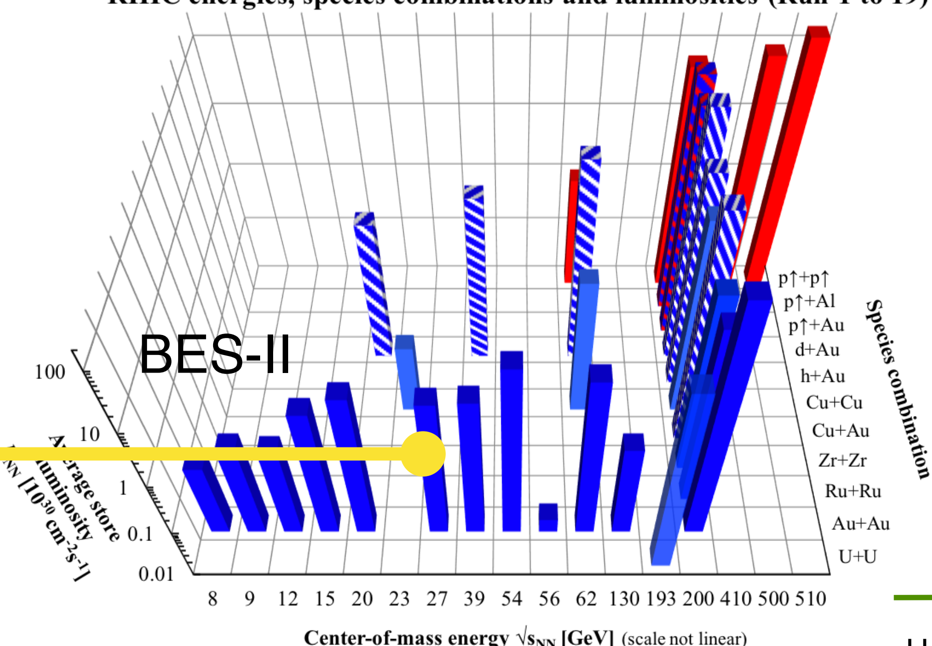
20 Years of RHIC and STAR

Over 20 years STAR has installed major upgrades to improve DAQ, PID, vertexing, ..

Pioneered using new technologies: MRPC, MAPS, GEM and siPM.

Estimate 35M(initial +75M(upgrades)$.

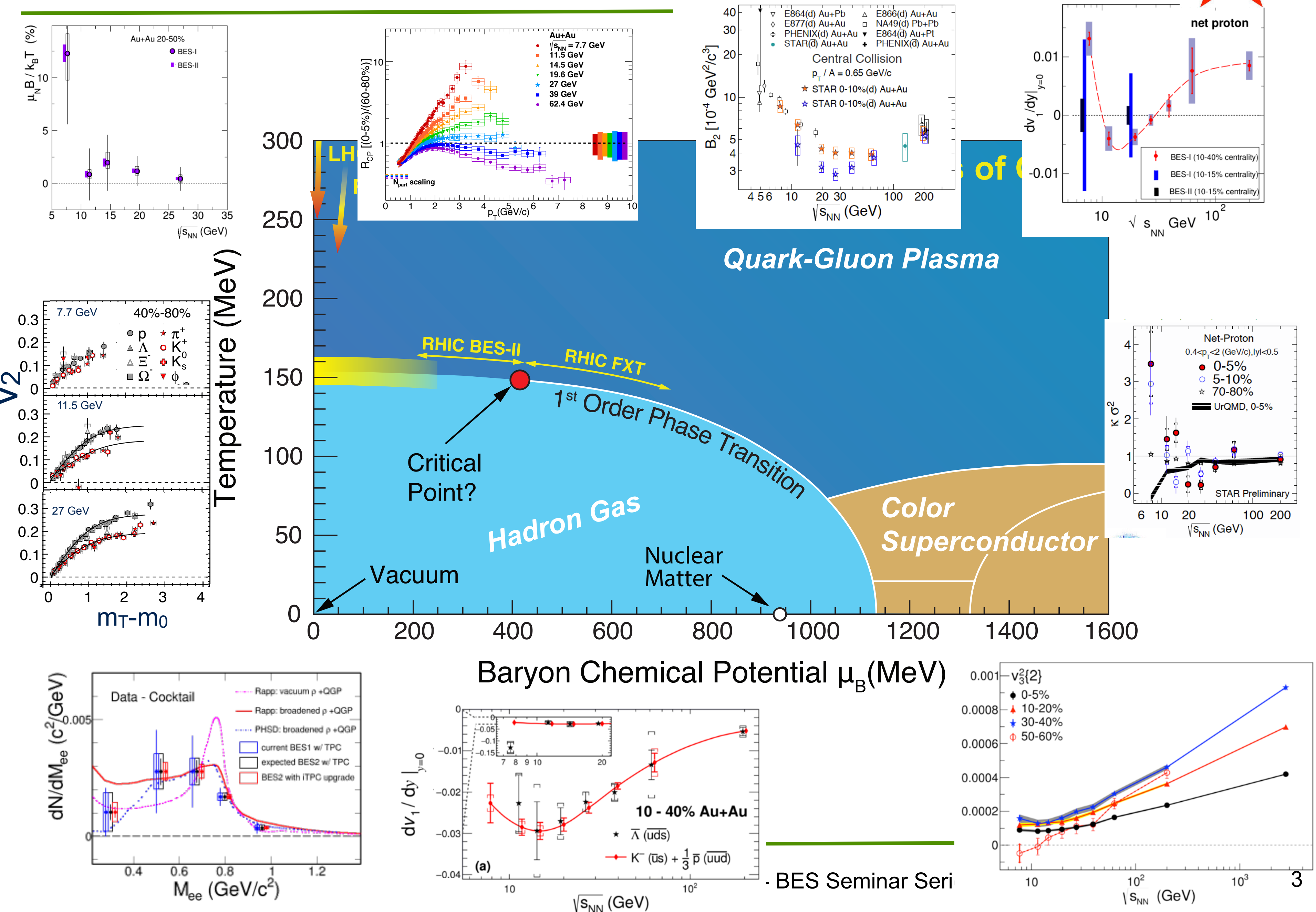
RHIC energies, species combinations and luminosities (Run-1 to 19)



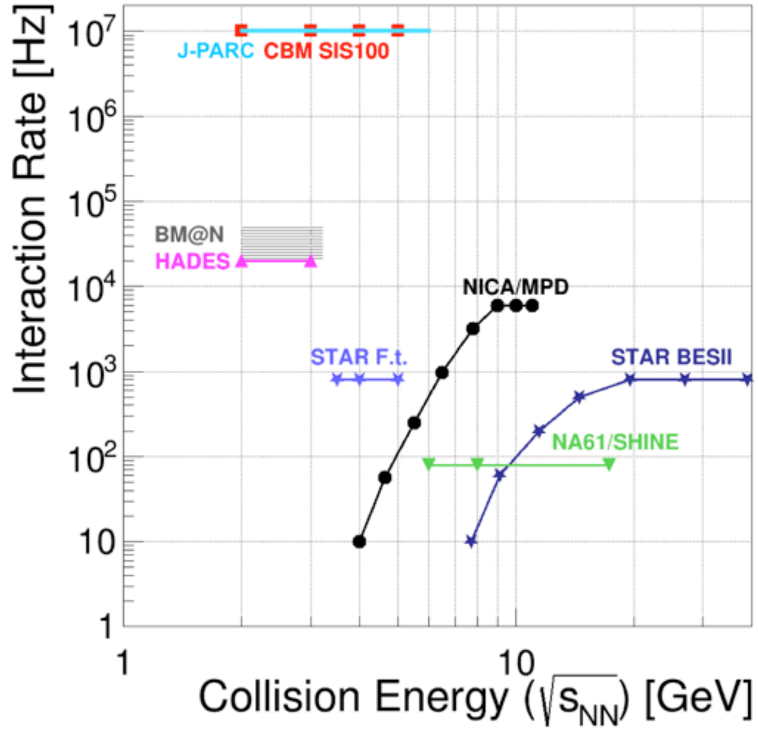
Detector	primary functions	DOE+(in-kind)	year
TPC+Trigger	$\lvert\eta\rvert < 1$ Tracking		1999-
Barrel EMC	$\lvert\eta\rvert < 1$ jets/γ/π^0/e		2004-
FTPC	forward tracking	(Germany)	2002-2012
L3	Online Display	(Germany)	2000-2012
SVT/SSD	V0/charm	(France)	2004-2007
PMD	forward photons	(India)	2003-2011
EEMC	$1 < \eta < 2$ jets/π^0/e	(NSF)	2005-
Roman Pots	diffractive		2009-
TOF	PID	(China)	2009-
FMS/Preshower	$2.5 < \eta < 4.2$	(Russia)	2008-2017
DAQ1000	x10 DAQ rate		2008-
HLT	Online Tracking	(China/Germany)	2012-
FGT	$1 < \eta < 2$ $W^{\pm}$		2012-2013
GMT	TPC calibration		2012-
HFT/SSD	open charm	(France/UIC)	2014-2016
MTD	muon ID	(China/India)	2014-
EPD	event plane	(China)	2018-
RHICf	$\eta > 5$ π^0	(Japan)	2017
iTPC	$\lvert\eta\rvert < 1.5$ Tracking	(China)	2019-
eTOF	$-2 < \eta < -1$ PID	(Germany/China)	2019-
FCS	$2.5 < \eta < 4$ calorimeter	(NSF)	2021-
FTS	$2.5 < \eta < 4$ Tracking	(NCKU/SDU)	2021-

Most recent: iTPC, eTOF and EPD
Still evolving today:
Extending forward with tracking and calorimetry

The Case for the BES-II



BES-II Original Proposal



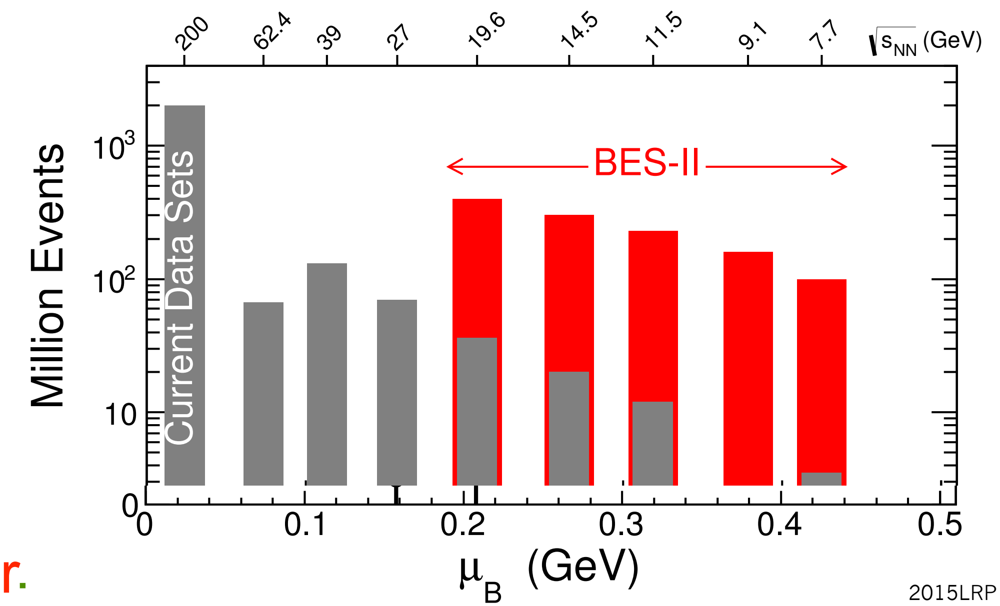
BES-I:
Hints that at low √s
- QGP turns off
- Ordered phase transition
- Critical Point

Turn trends and features into definitive conclusions

BES-II:
- Examine regions of interest
- Probe lower √s

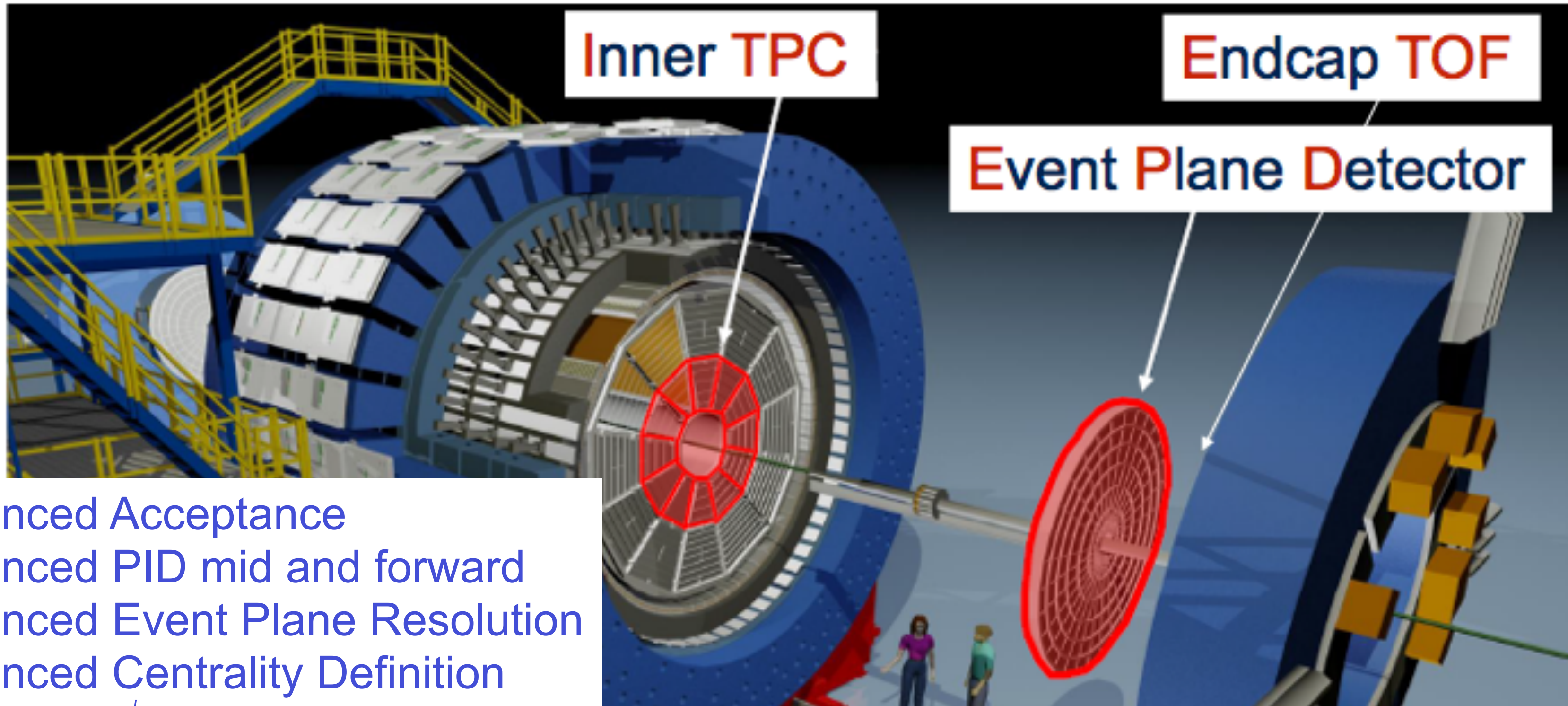
Need to maximize fraction particles measured

Need to drop below energies RHIC can operate at in collider mode

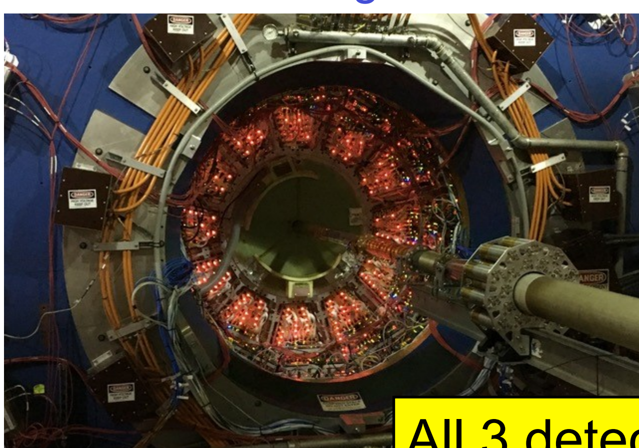


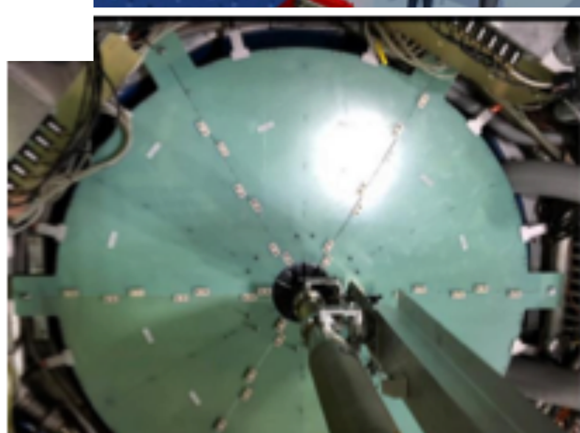
2015LRP

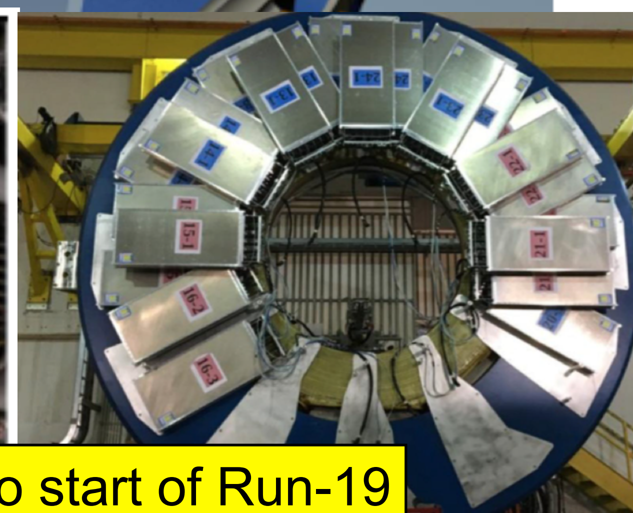
The BES-II Upgrades



Enhanced Acceptance
Enhanced PID mid and forward
Enhanced Event Plane Resolution
Enhanced Centrality Definition
Enhanced √s range







All 3 detectors fully installed prior to start of Run-19

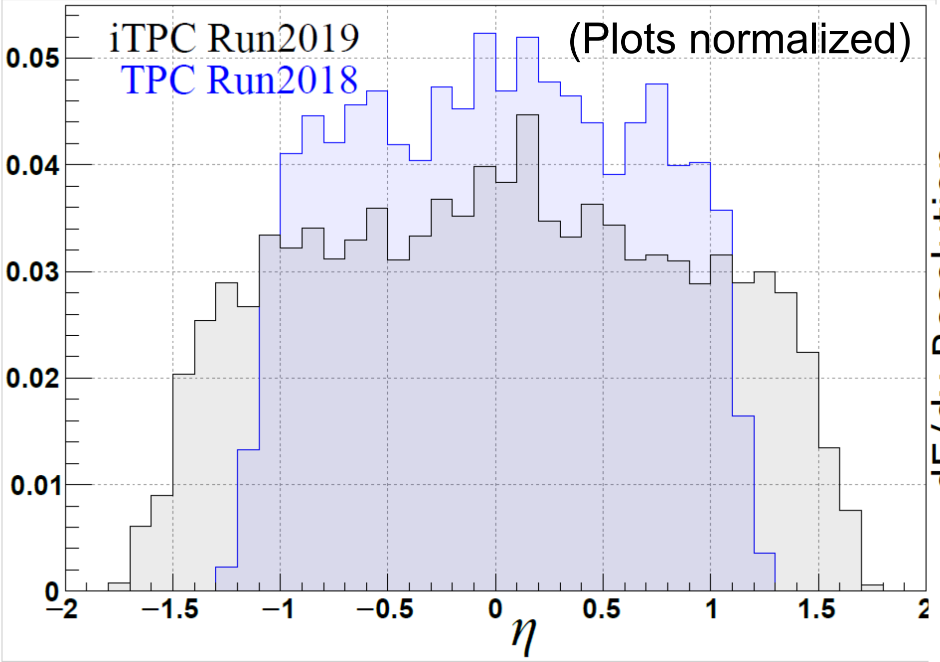
iTPC: Enhanced Acceptance

Successfully integrated into data-taking since day 1 of Run-19

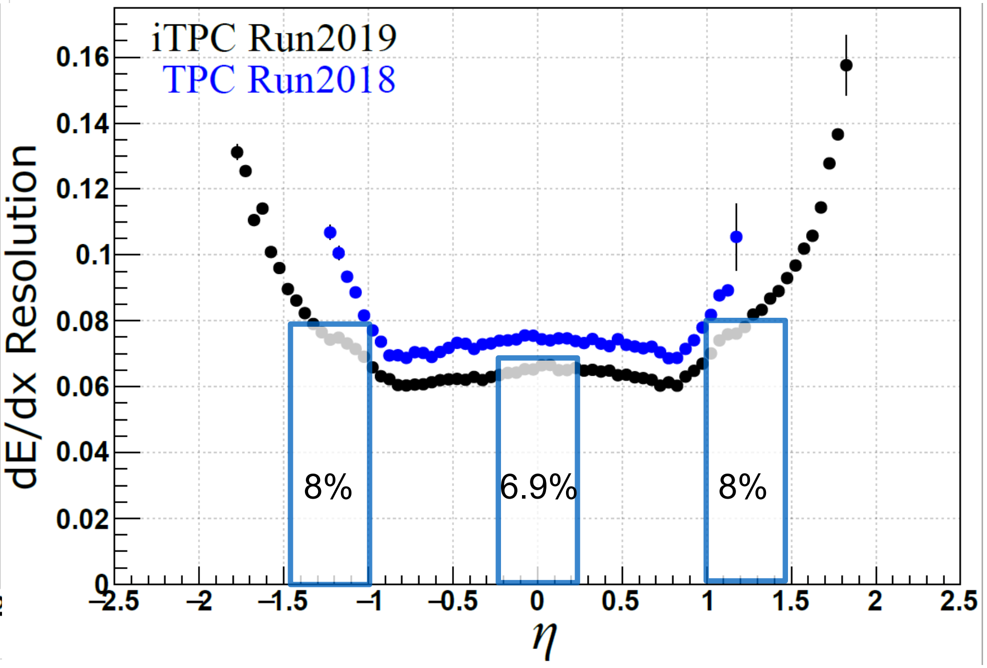
Projected detector performance criteria met

Demonstrated improvement:

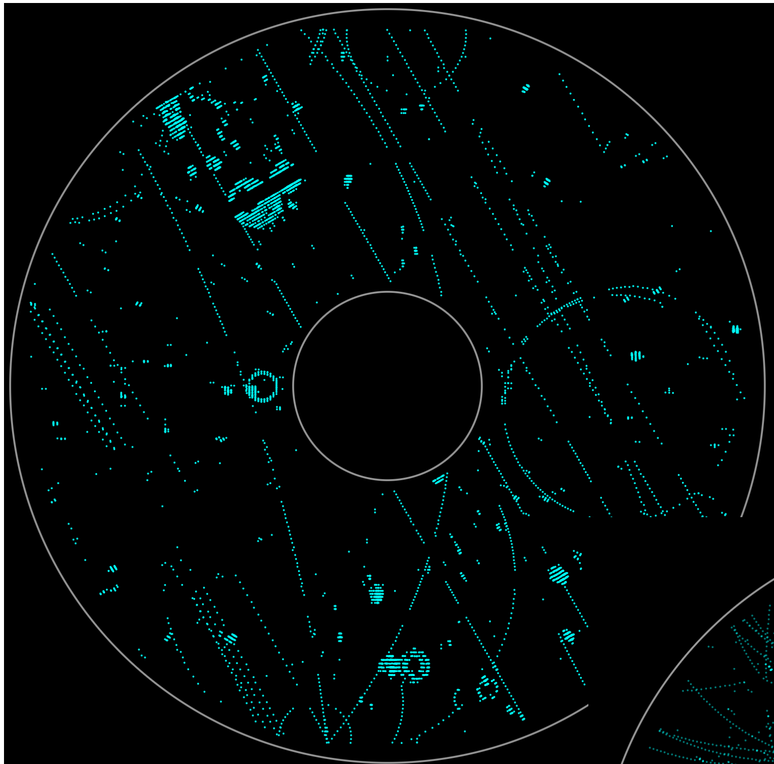
Increased pseudorapidity coverage

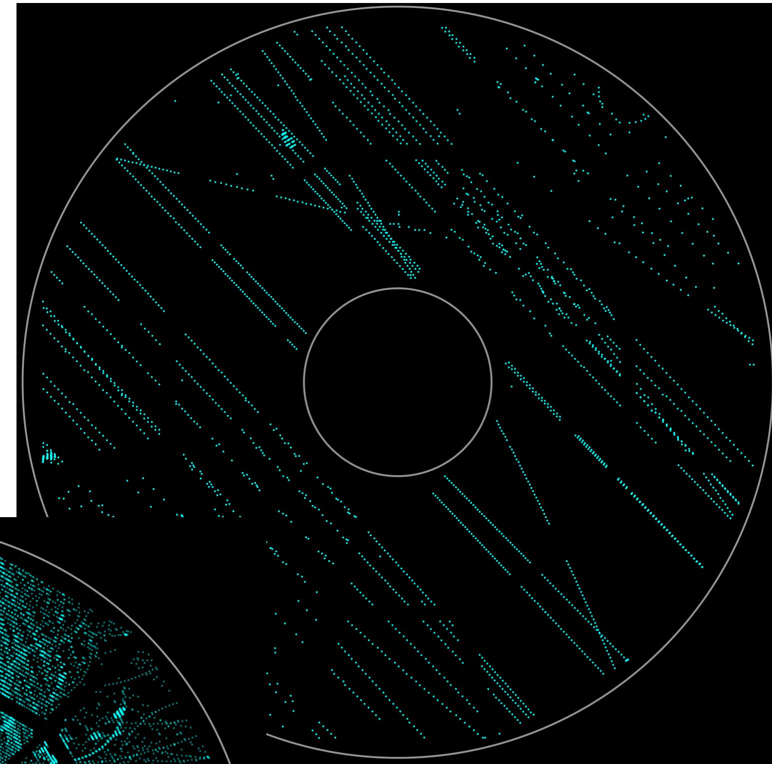


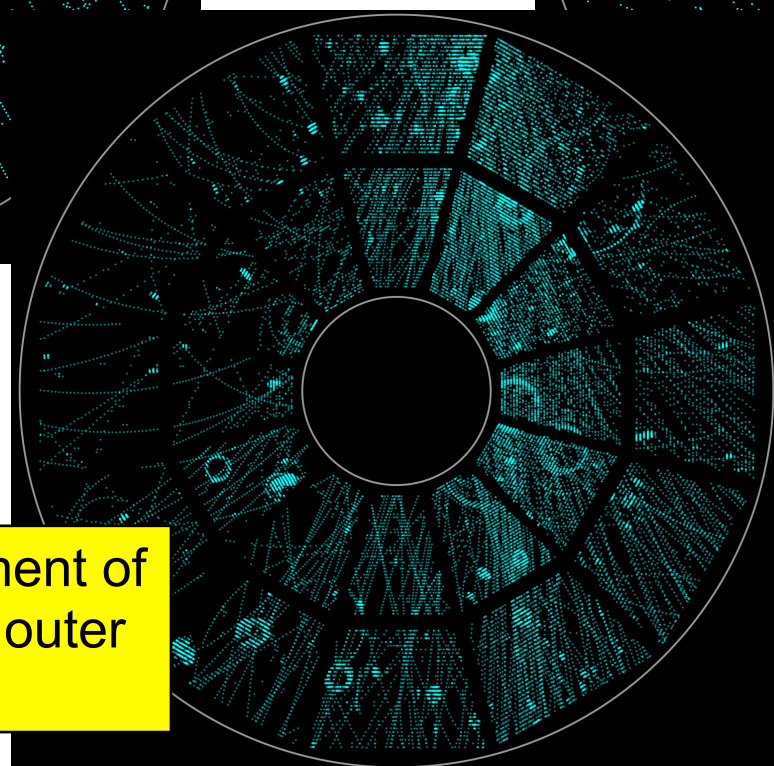
Improved dE/dx resolution



Cosmic Commissioning of iTPC







Cosmics: Enable alignment of new inner sectors with outer TPC

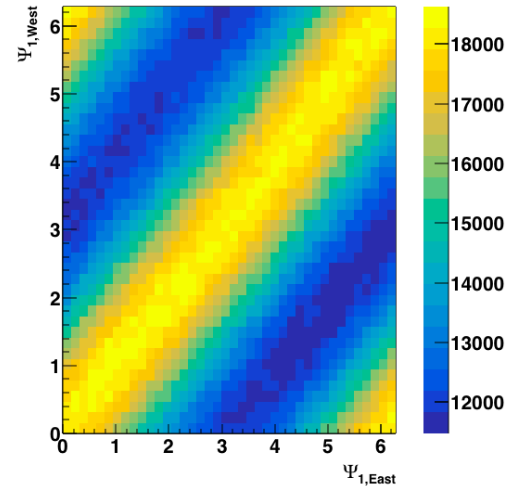
https://www.bnl.gov/newsroom/news.php?a=217048

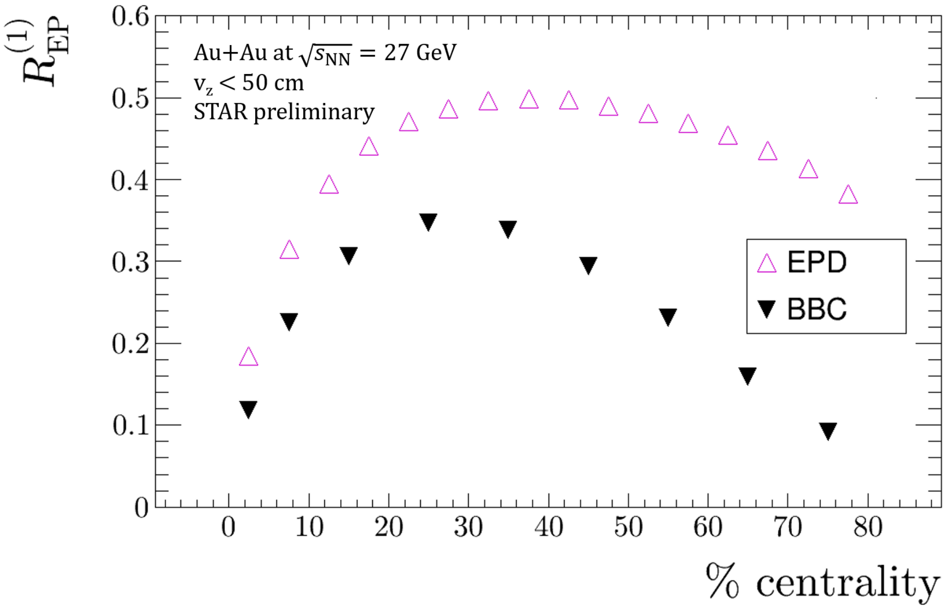
Generated lots of interest from general public

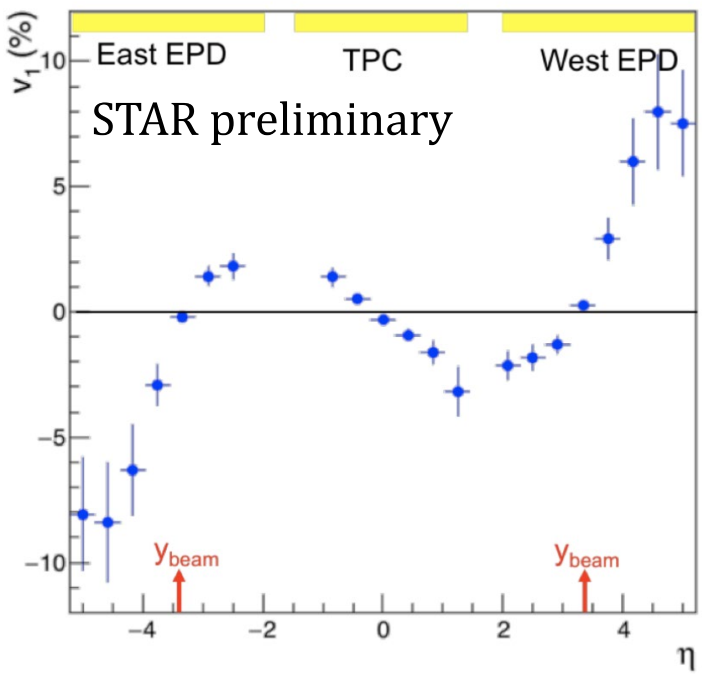
EPD: Enhanced Event Plane Resolution

All tiles operational for Run-18 and Run-19 :
2.1 < |η| < 5.1

BES-II: Main trigger detector
Greater acceptance than VPD or ZDC
Better timing resolution than BBC
(0.75 ns)







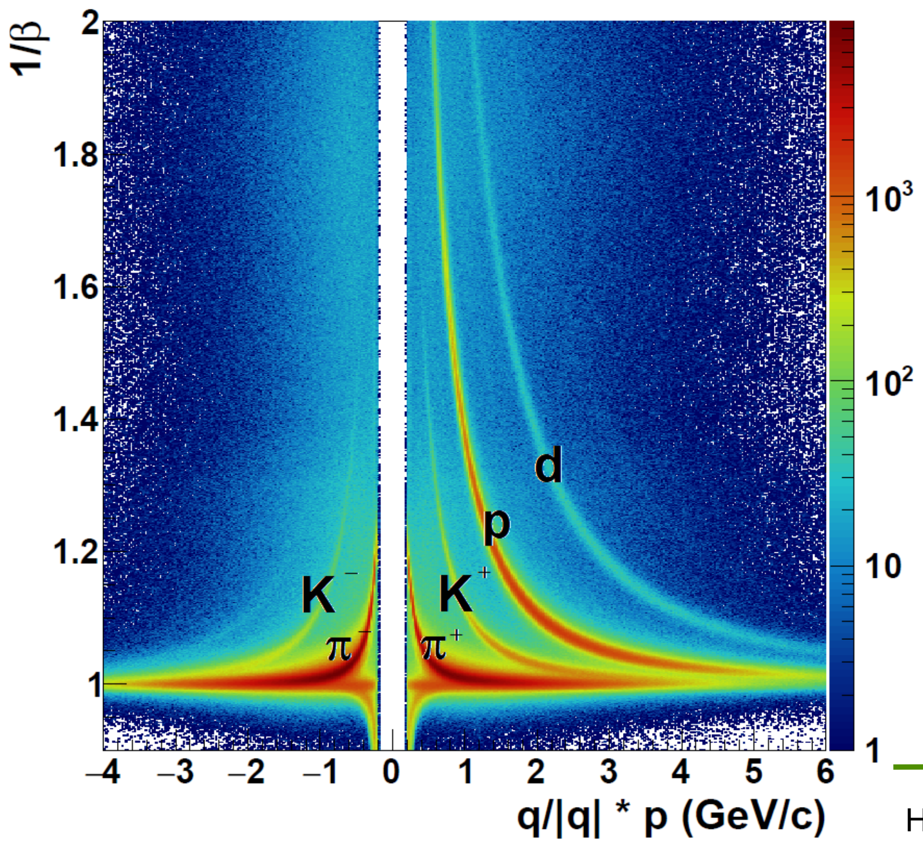
Event plane (and centrality) outside of iTPC acceptance

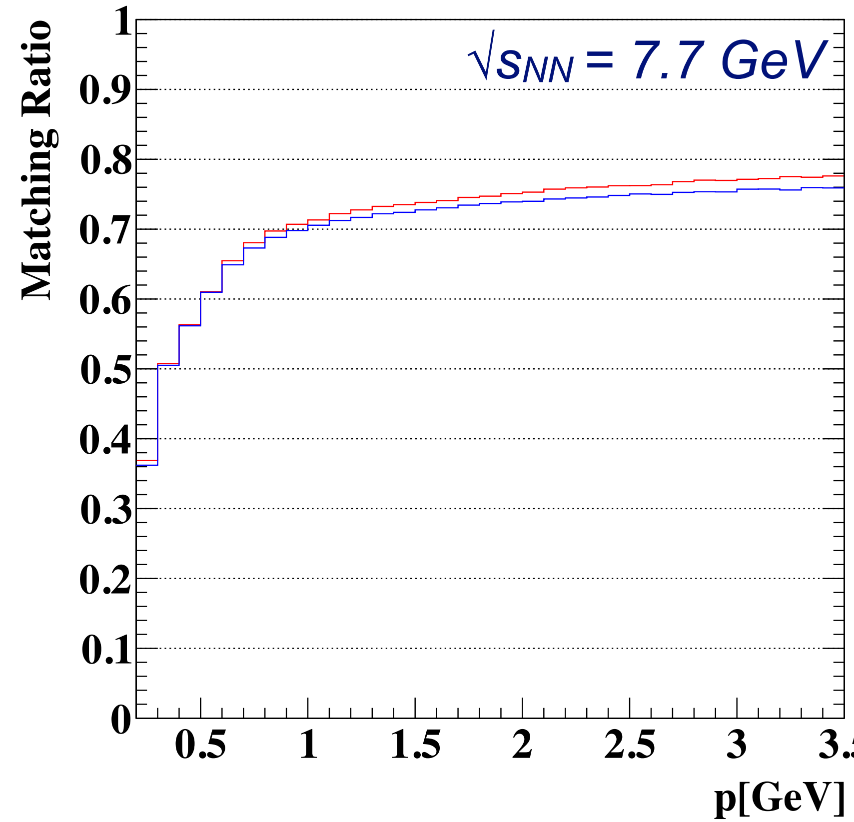
eToF - Joint STAR-CBM Initiative

Matching efficiency >70% above 1 GeV/c

Timing ~80ps

K/π separation up to p = 2.5 GeV/c





Critical for Fixed-target data

BES-II: Critical Fluctuations

Current data: Suggestive of non-trivial √s dependence of net proton cumulant ratios

iTPC:

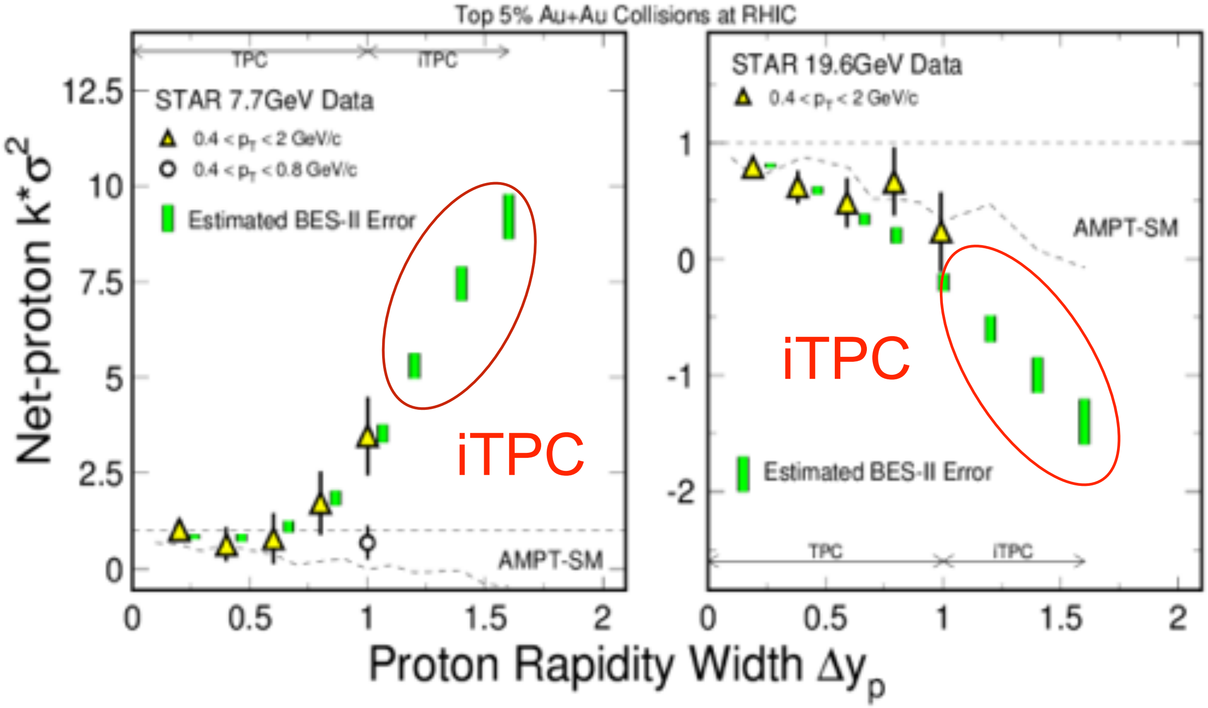
Increase Δy_p acceptance

$\Delta y_p > \Delta y$ correlation

EPD:

Improved centrality selection

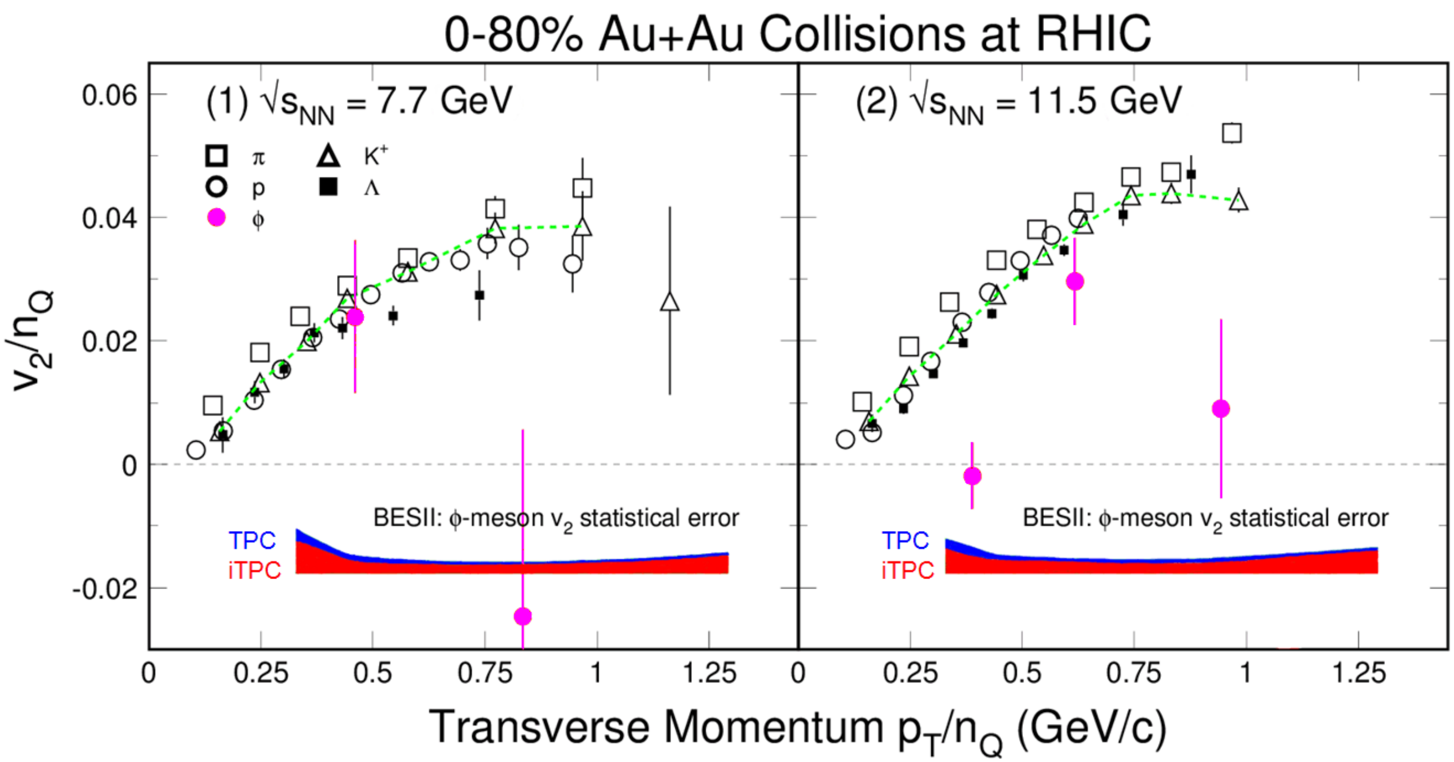
Use all TPC for measurement



Establish true nature of correlation

Subject actively pursued theoretically

BES-II: Quark Elliptic Flow

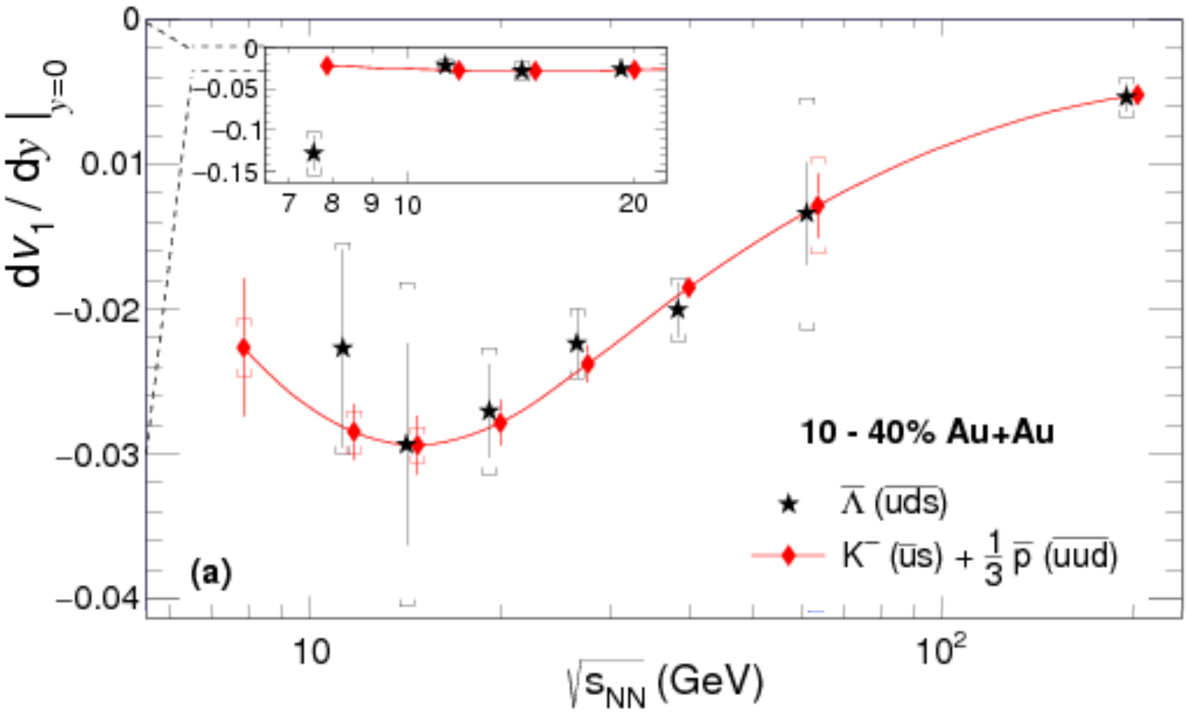


Precision measurement of the ϕ (and other) flow

BES-II: Coalescence of "produced" particles

Assumptions:

- v_1 is developed in prehadronic stage
- Hadrons are formed via coalescence: $(v_n)_{hadron} = \Sigma(v_n)_{constituent\ quarks}$
- $(v_1)_{\bar{u}} = (v_1)_{\bar{d}}$ and $(v_1)_s = (v_1)_{\bar{s}}$



anti-Λ predicted from quark values deduced from K and p

Fails for 7.7 GeV - At least one assumption incorrect

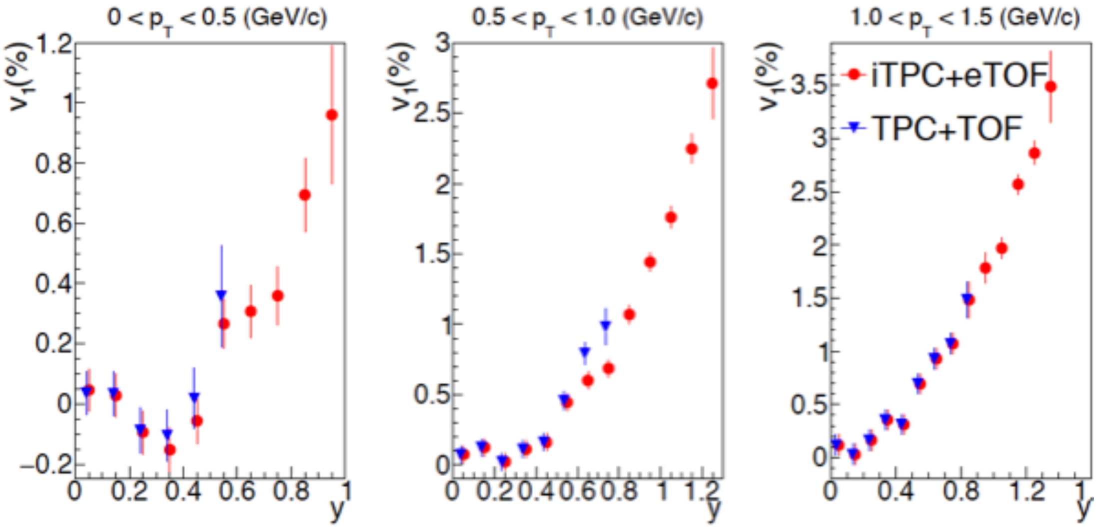
What happens at lower √s?
Finer centrality bins?

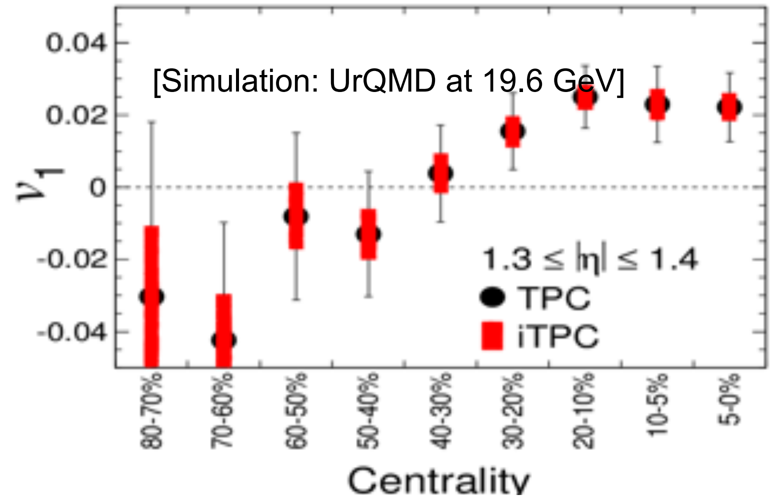
STAR, Phys. Rev. Lett. **120** (2018) 62301

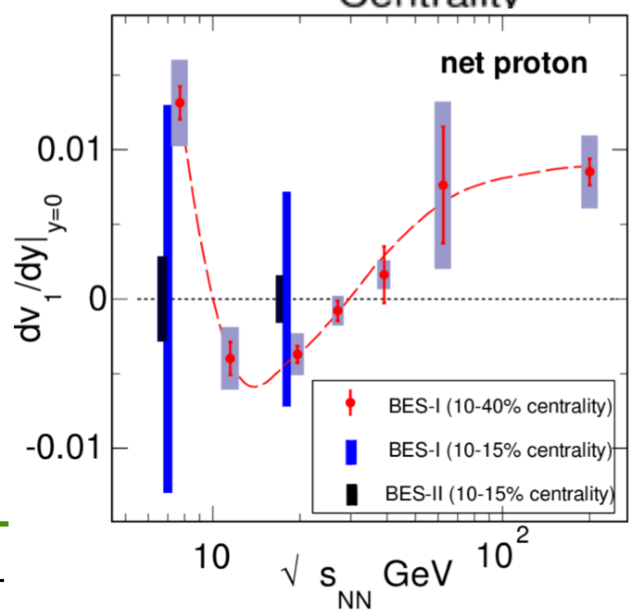
BES-II: Directed Flow Improvements

Current data: Double sign change of v_1

Precision measurement of dv_1/dy as function of centrality







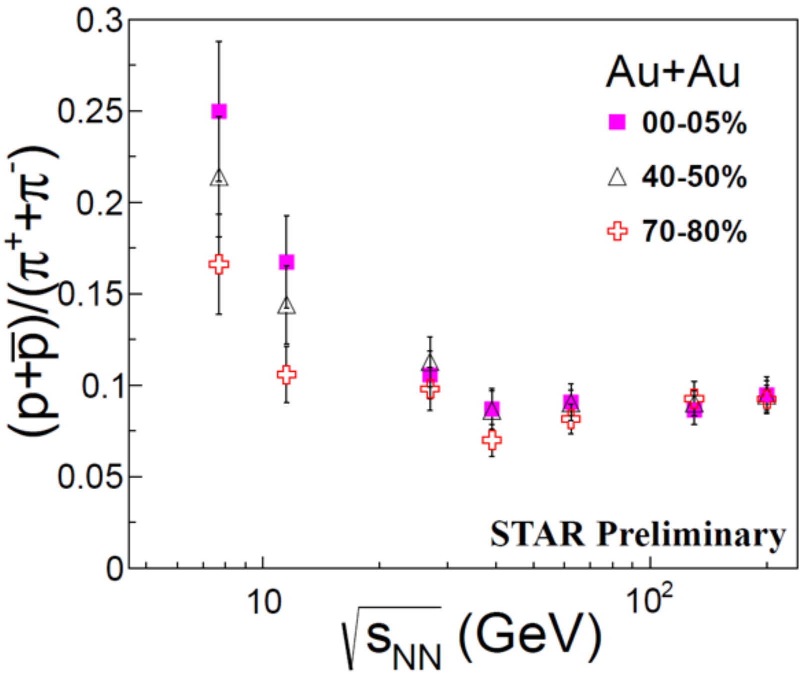
iTPC+ eTOF:

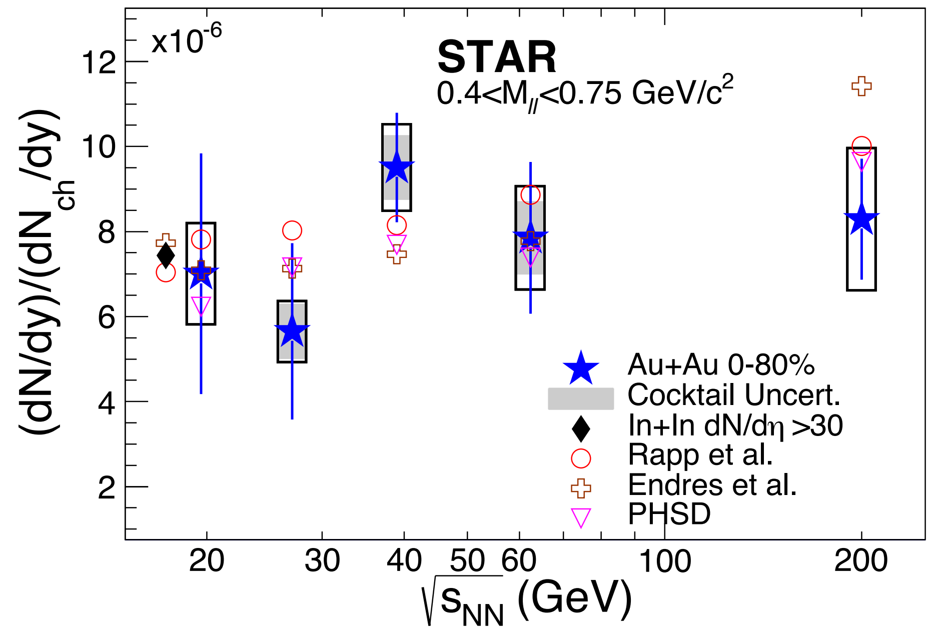
- Enhanced coverage at forward y
  - Signal larger - role of baryon stopping

EPD:

- Enhanced 1st order EP resolution
  - Reduced systematics

Low Mass Di-lepton Excess





Above 20 GeV
Total baryon density ~ constant

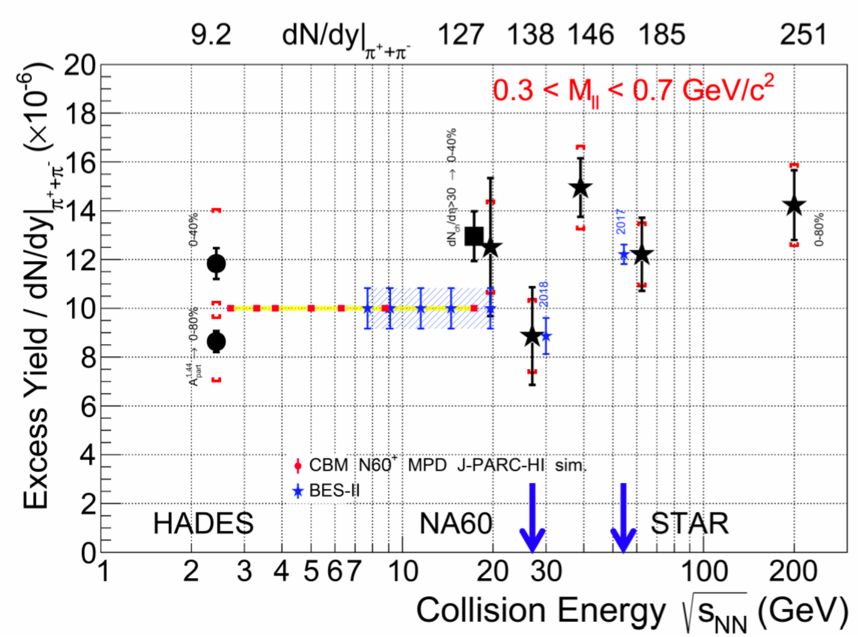
Low mass excess constant for large range of beam energies and centralities

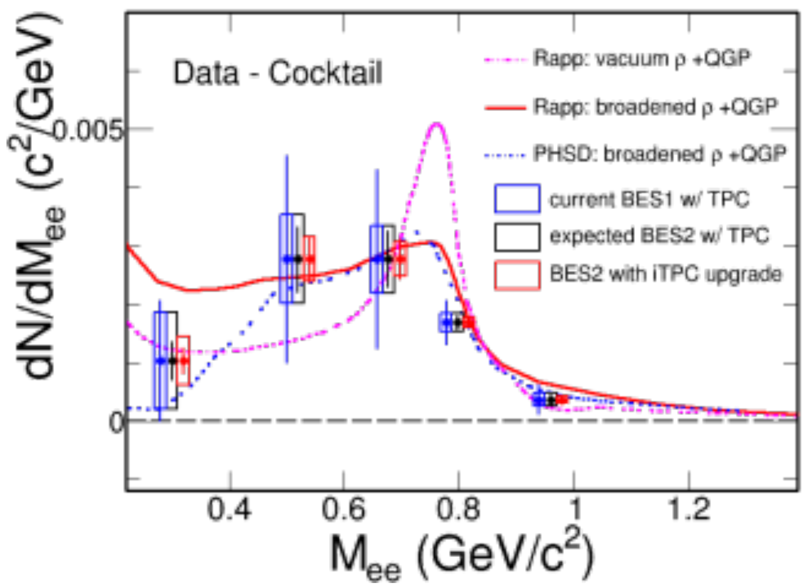
Results suggest excess driven by convolution of **total baryon** density, **hot dense** medium effects and the medium's **lifetime**

Consistent with models incorporating ρ broadening

STAR: PLB 750 (2015) 64, arXiv:1810.10159 [nucl-ex]

BES-II: Change Total Baryon Number





Low Mass Region:

iTPC: Significant reduction in sys. and stat. uncertainties

Disentangle total baryon density effects

ρ-meson broadening:

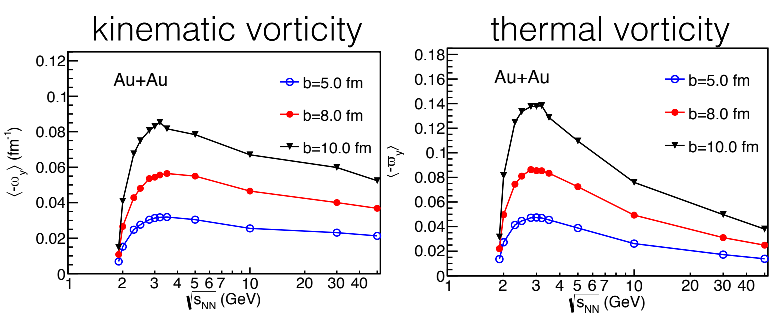
different predictions for di-electron continuum (Rapp vs PHSD)

iTPC: Significant reduction in sys. and stat. uncertainties

Enables to distinguish between models for √s =7.7-19.6 GeV

BES-II: Significant Λ Polarization

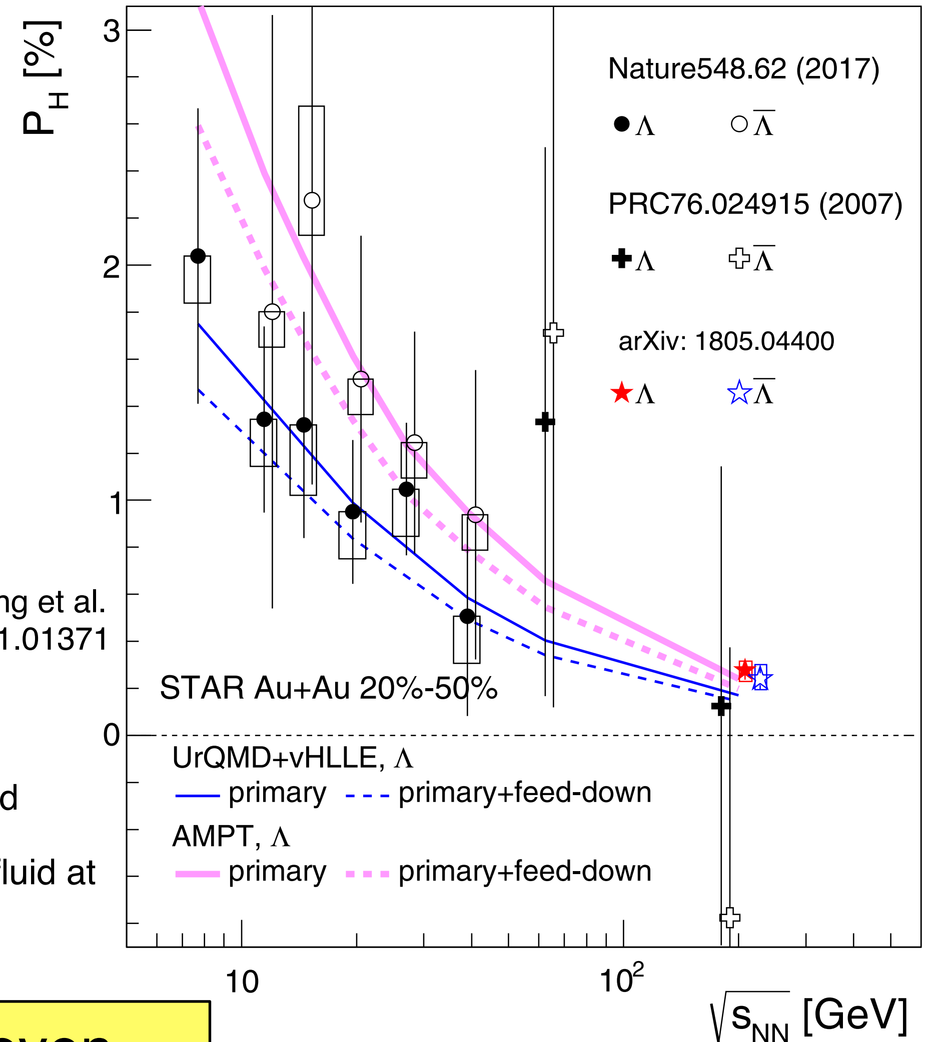
HADES Preliminary (SQM19)
Au+Au at $\sqrt{s_{NN}}$ = 2.4 GeV
$P_{\Lambda}(\%) = 3.672 \pm 0.699$ (stat.)
$P_{BG}(\%) = 3.689 \pm 1.133$ (stat.)



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

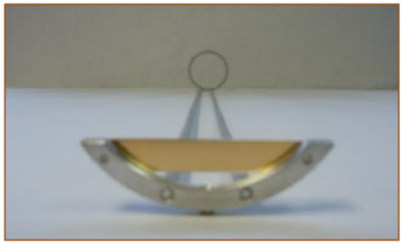
kinematic vorticity: measures local angular velocity of fluid

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



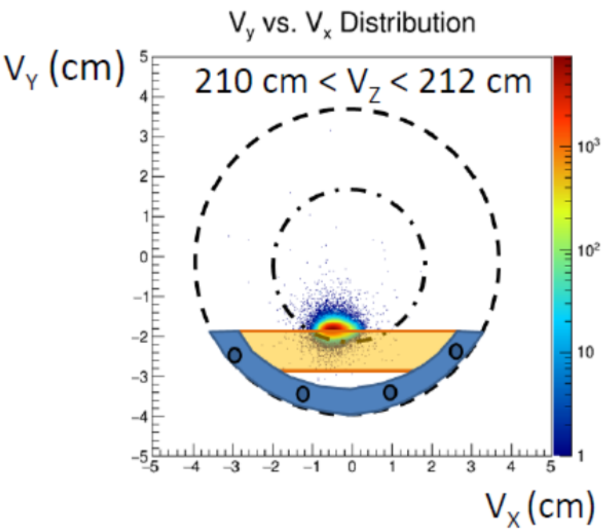
Can large vorticies be created even without QGP formation?

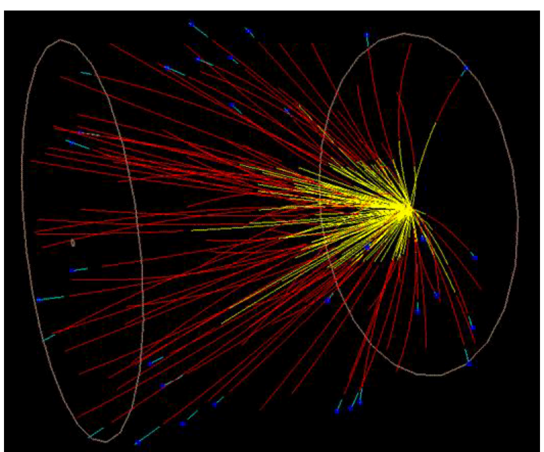
Fixed Target Program - FXT

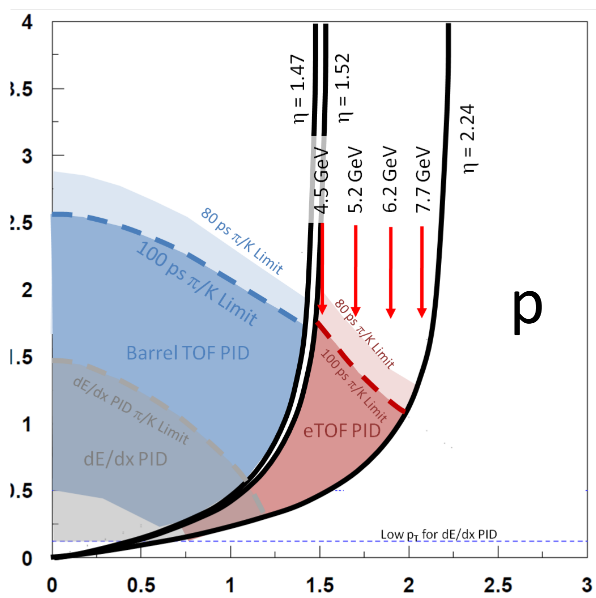


Gold target placed in beam linear entrance to STAR

Access to collision energies below that possible in collider mode

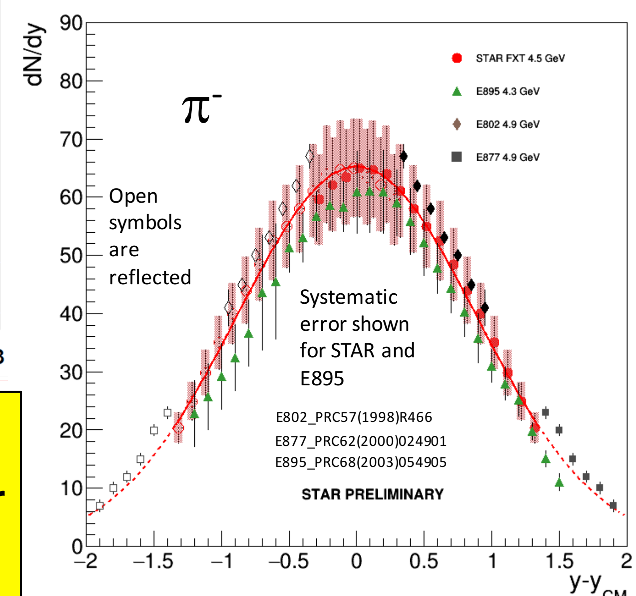




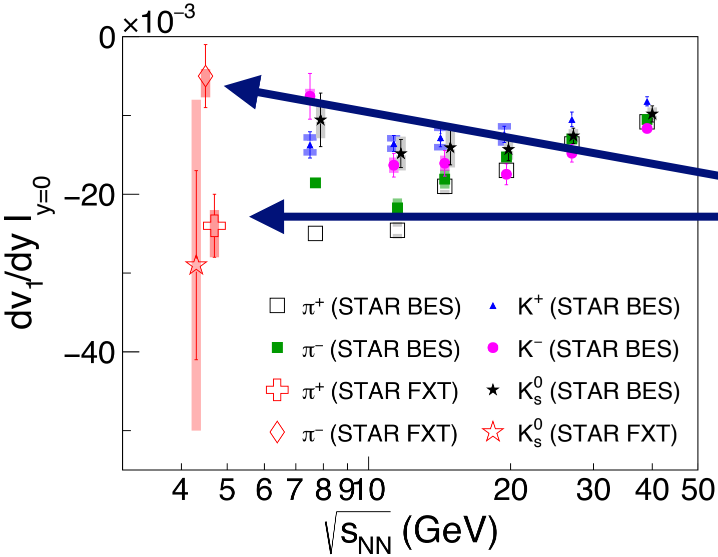


7.7 GeV - Essential bridge between collider and FXT data

eTOF and iTPC allow mid-y measurements



(pre)BES-II: Flow and HBT



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

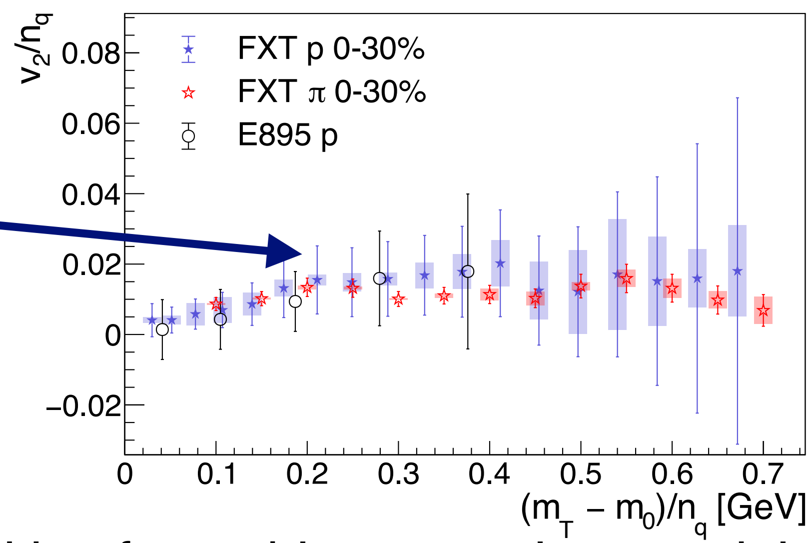
First π v_1 and v_2 results

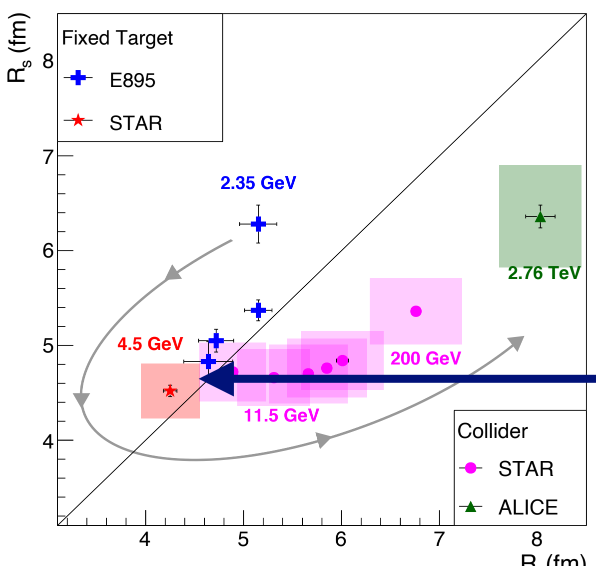
Difference in v_1 slope for π^+ and π^-

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 submitted

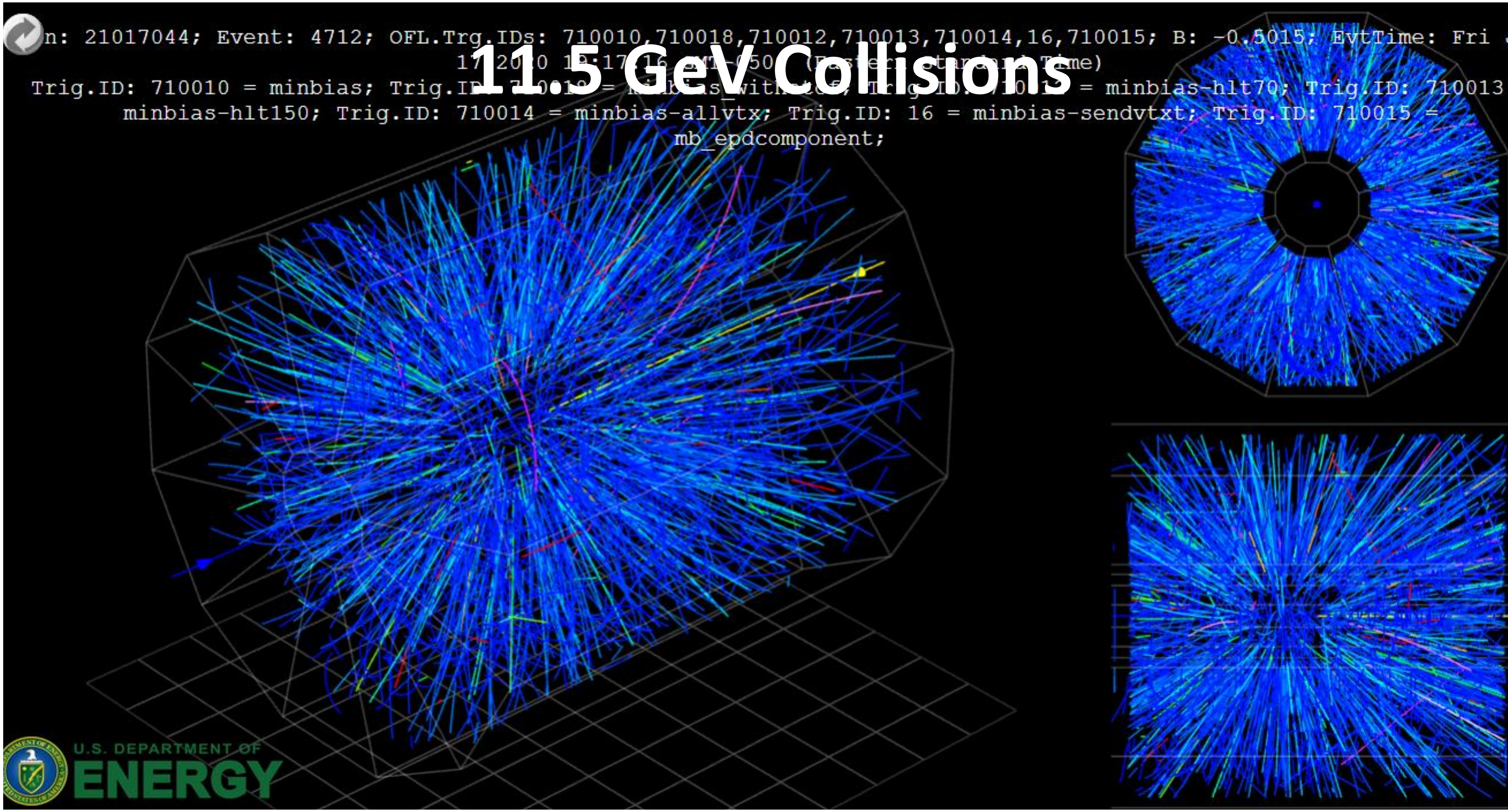
arXiv:1809043

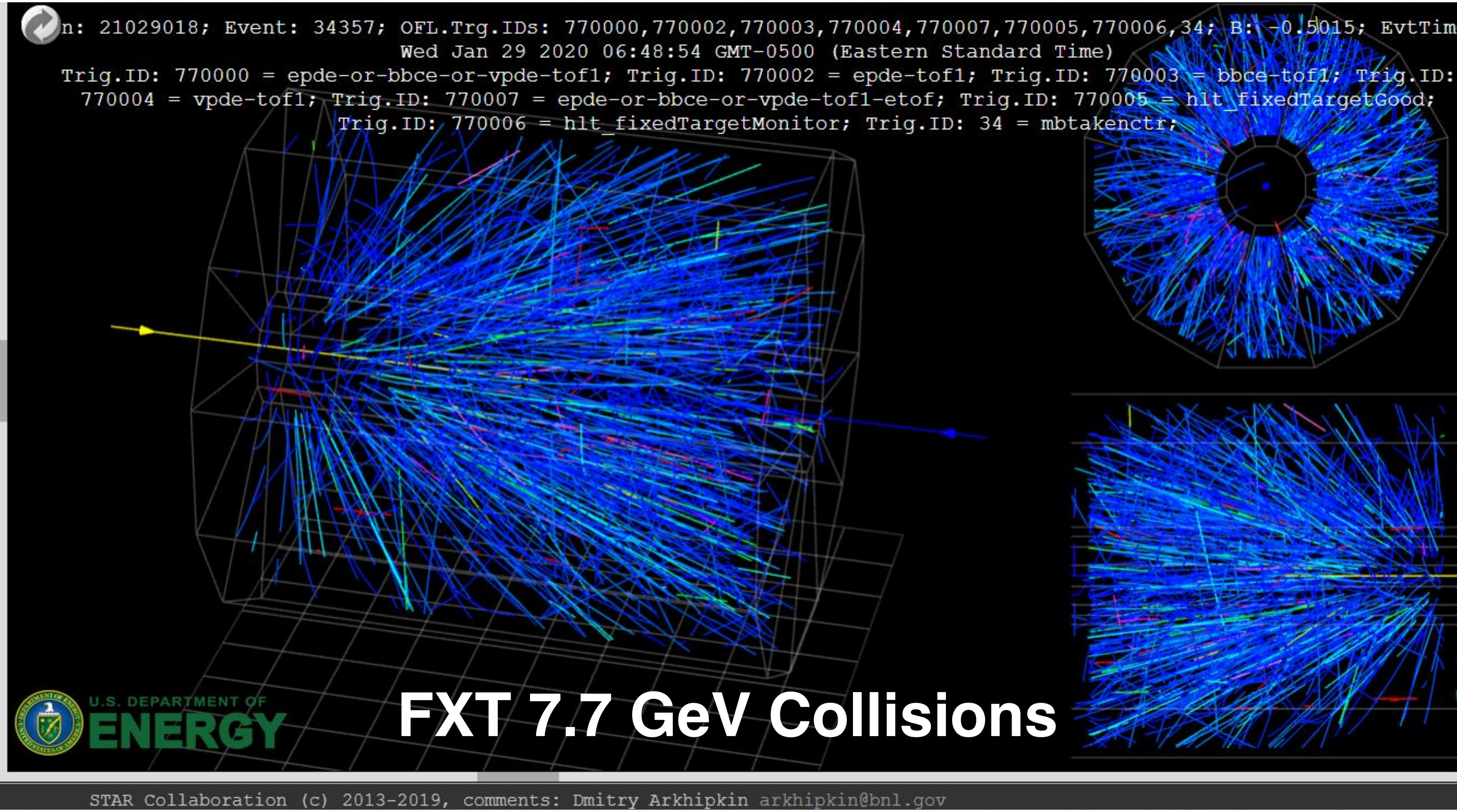
BES-II Progress Report

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)[1]	Run-20+20b
31.2	7.7 (FXT)	420	0.5+1.1 days	100 M (50 M+112 M)	Run-19+20
19.5	6.2 (FXT)	487	1.4 days	100 M (118 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 (108 M)	Run-20
7.3	3.9 (FXT)	633	1.1 days	100 M (117 M)	Run-20
5.75	3.5 (FXT)	666	0.9 days	100 M (116 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[2]

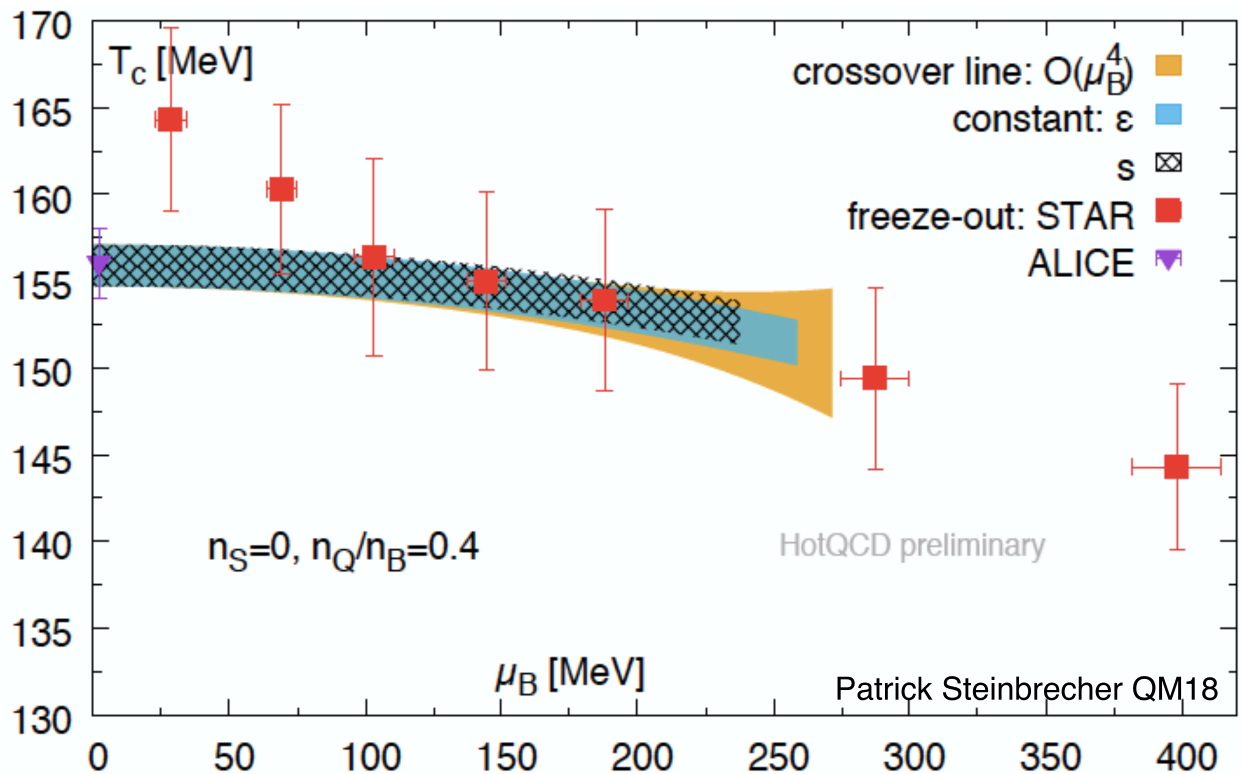
We have collected all originally proposed BES-II and FXT data except for $\sqrt{s_{NN}}$ = 7.7 in collider mode - approved for Run-21

11.5 GeV Collisions




n: 21029018; Event: 34357; OFL.Trg.IDs: 770000,770002,770003,770004,770007,770005,770006,34; B: -0.5015; EvtTim
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

Precision Mapping of Phase Diagram



Significant systematic errors from BES-I data

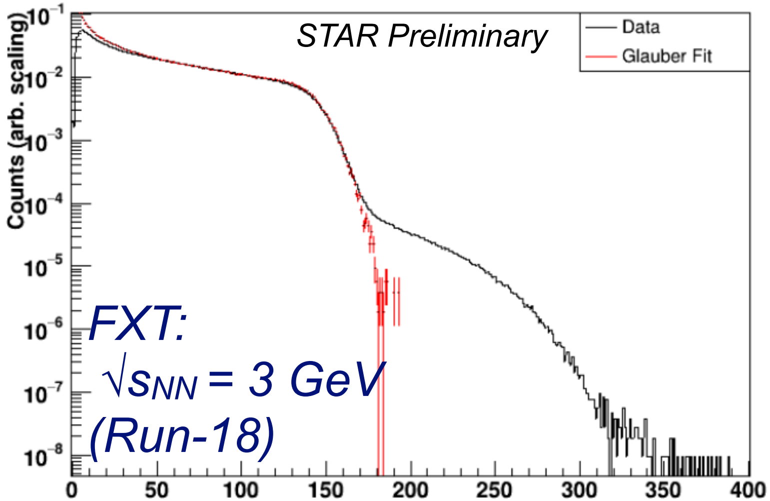
Now have BES-II and ~140 M top energy data with iTPC from Run-19

Reduce chemical fit uncertainty

- smaller extrapolation, higher efficiency

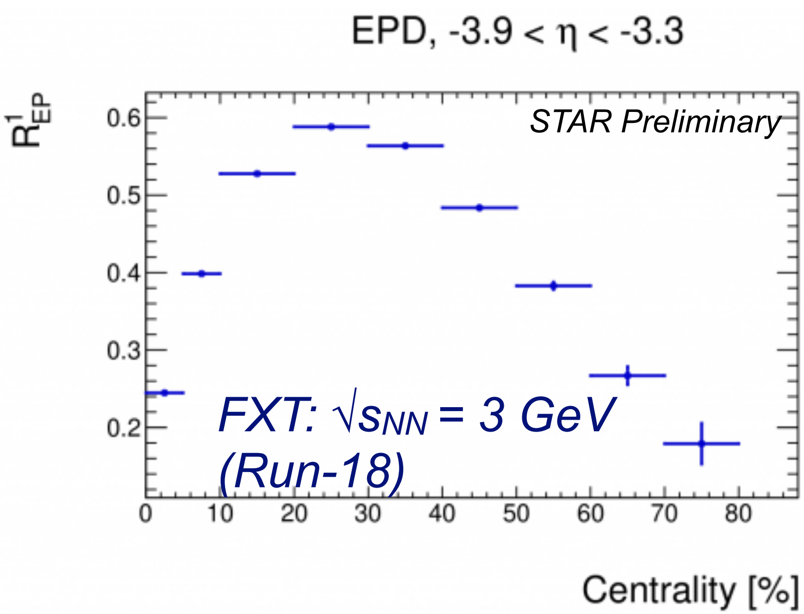
Test Flow models at low p_T (<0.5GeV/c) with heavy particles (p, Ξ, Ω)

BES-II: Preliminary Analyses

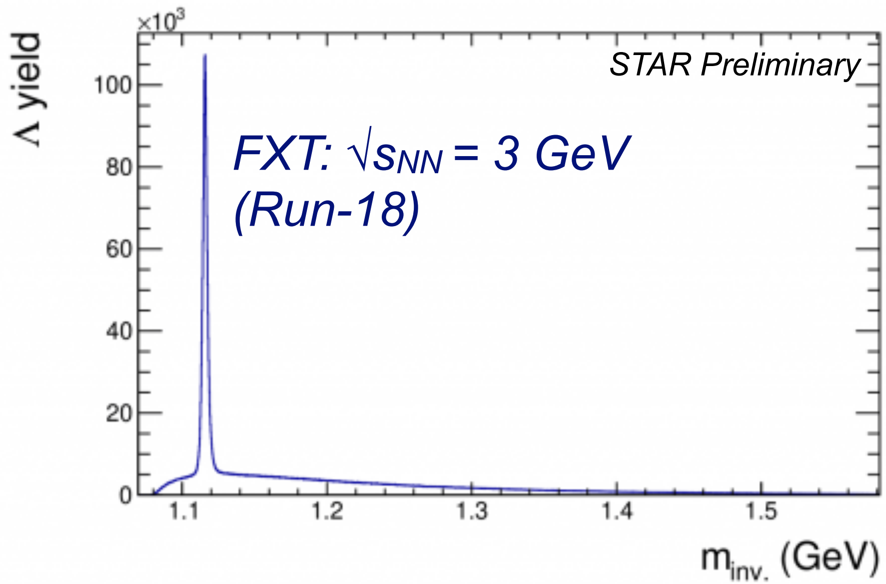


Identify and reject "pile up": Centrality and Glauber fit completed for 3.0 GeV

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

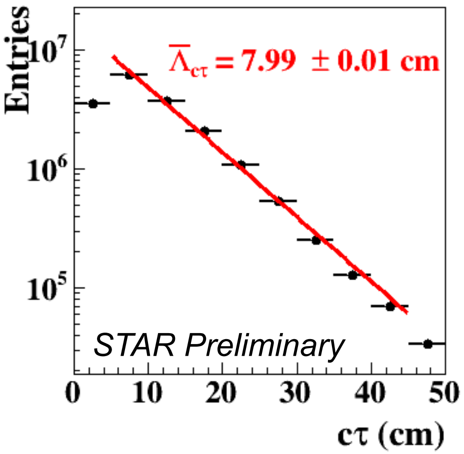


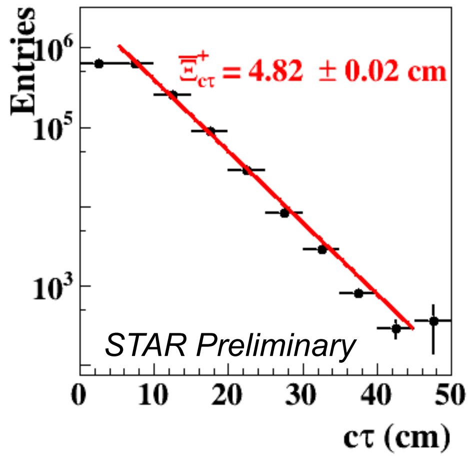
EPD being used for reaction plane related studies



Very clean V^0 signals

BES-II: Online QA/analyses

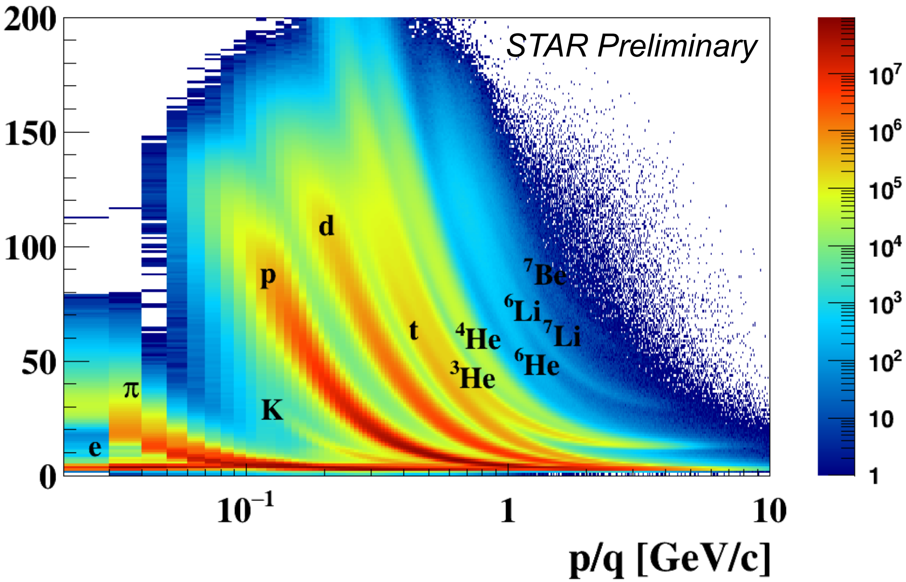




Run-20 $\sqrt{s_{NN}}$=11.5:

Excellent statistics

cτ in agreement with PDG

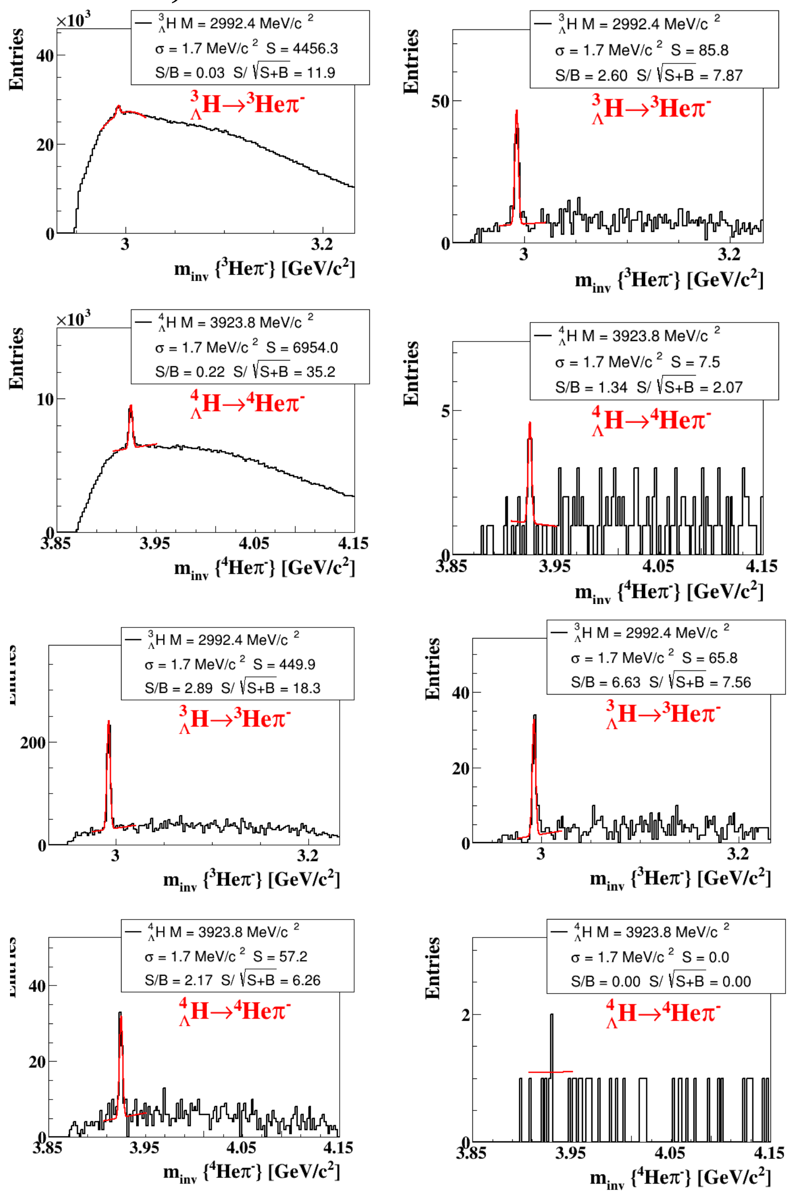


Run-18 FXT $\sqrt{s_{NN}}$ =3 GeV:

Heavy fragments up to ^{7}Be

BES-II: Online Hypernuclei

3 GeV, 285M **9.2 GeV, 23M**



11.5 GeV, 216M **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.

Fold back to use lifetime to extract yields vs $\sqrt{s_{NN}}$

Unique studies possible

Extensions to the BES-II

Highest priority additional FXT data:

Au+Au $\sqrt{s_{NN}}$ = 3 GeV (FXT) 300 M minbias 3 days

- Net proton fluctuations, GCE vs CE, light hypernuclei production

Au+Au $\sqrt{s_{NN}}$ = 9.2, 11.5, 13.7 GeV (FXT) 50 M minbias 3 days

- Enhanced understanding of baryon stopping

Very interested in also collecting:

O+O $\sqrt{s_{NN}}$ = 200 GeV 400 (200) M minbias (central) 1 week

- Enhanced understanding of early conditions in small systems

Au+Au $\sqrt{s_{NN}}$ = 17.1 GeV 250 M minbias 2.5 weeks

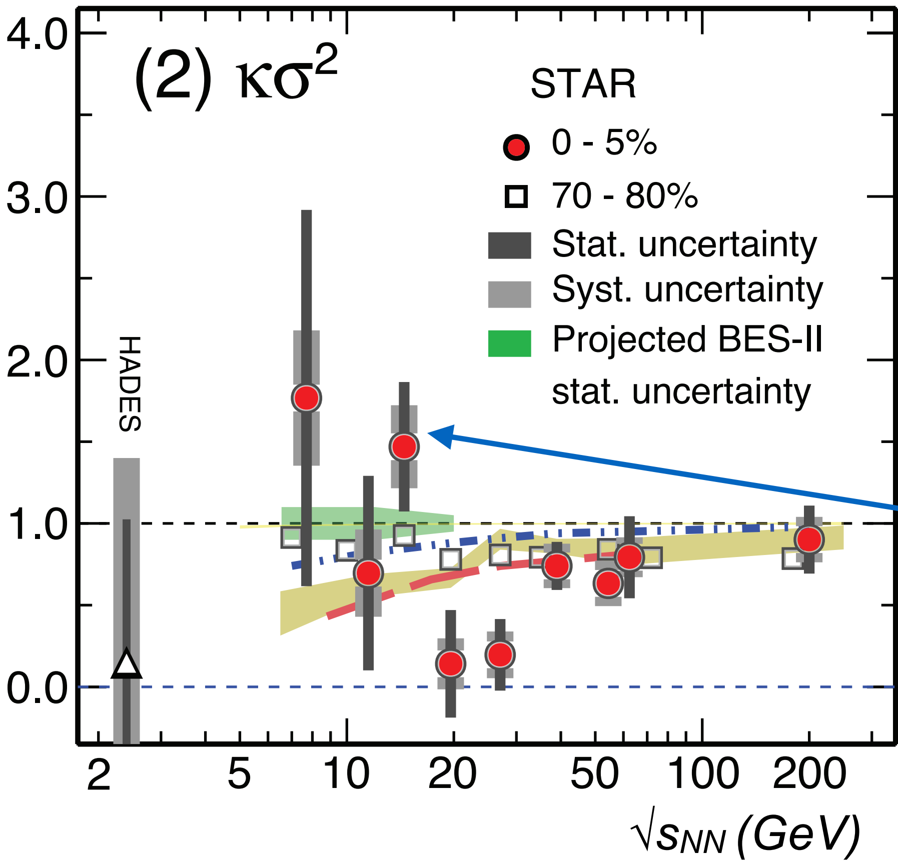
- Probe for CP via non-monotonic behavior of higher order moments

Au+Au $\sqrt{s_{NN}}$ = 3 GeV (FXT) 2 B minbias 3 weeks

Higher order (>4) moments, ϕ flow, double-Λ hypernuclei

Case for Au+Au $\sqrt{s_{NN}}$ = 17.1 GeV

STAR



First order phase transition could cause large increase in net-p kurtosis

Entering spinoidal region (mixed phase)

Closer investigation of possible 2nd peak in non-monotonic energy dependence

17.1 GeV —> μ_B = 235 MeV

Equal spacing in μ_B

Table 10: Event statistics (in millions) needed in a Au+Au run at $\sqrt{s_{NN}}$ = 17.1 GeV for fourth order net-proton fluctuations ($\kappa\sigma^2$) and neutron density fluctuation (Δn) measurements.

Triggers	Minimum Bias	Net-proton $\kappa\sigma^2$ (0-5% Cent.)	Δn (0-10% Cent.)
Number of events	250 M	6% error level	3.6% error level

Case for Au+Au $\sqrt{s_{NN}}$ = 17.1 GeV

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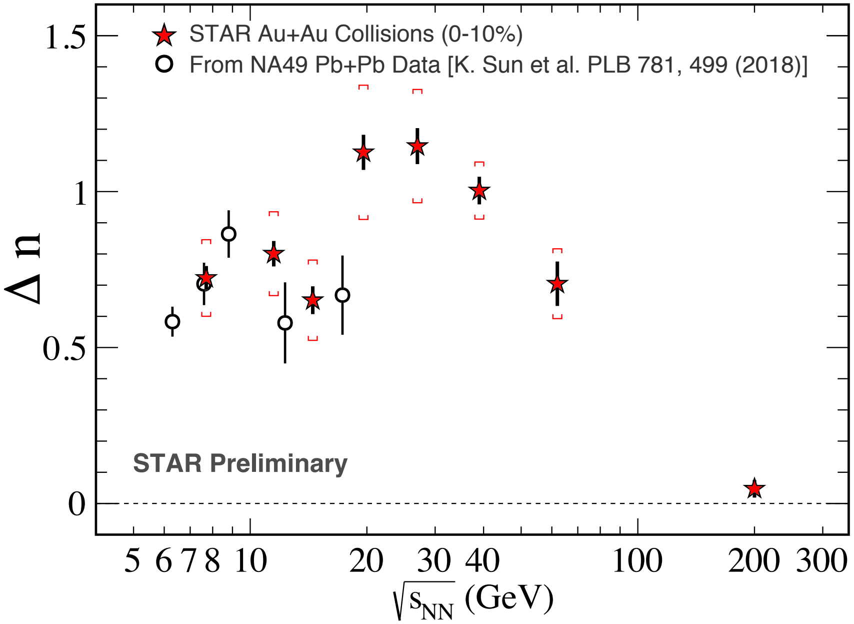
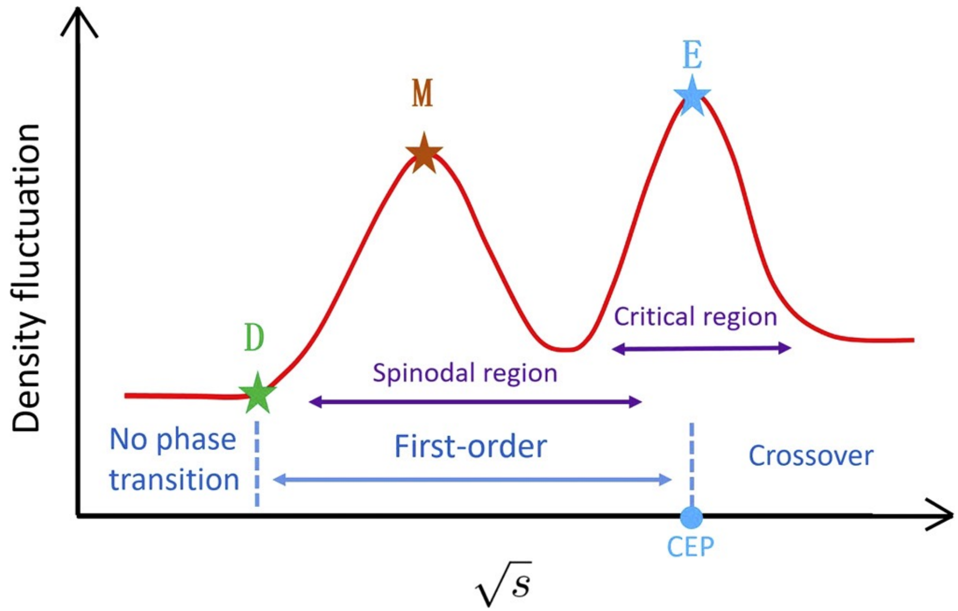




Ratio of light nuclei yields sensitive to neutron relative density fluctuations
Neutron relative density fluctuations increase near CP and/or 1st order PT

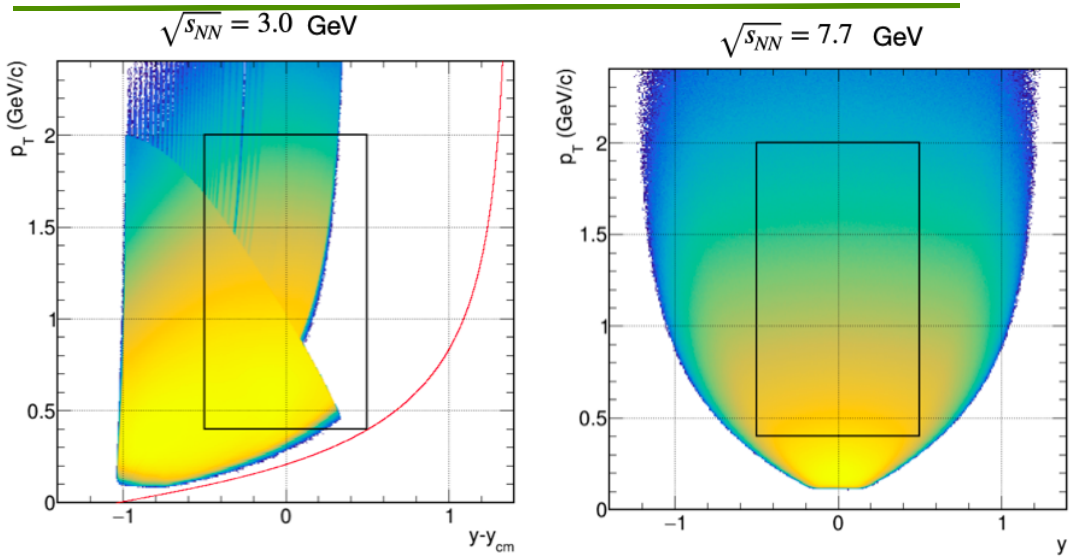
$$\Delta(n) = \langle(\delta n)^2\rangle / \langle n \rangle^2 = \frac{1}{g}\frac{N_t \times N_p}{N_d^2} - 1$$

Sudden drop below 19.6 GeV
- Consistent with NA49

Second peak?

Propose to collect 250 M minbias events
- 2.5 weeks of running

Case for Au+Au $\sqrt{s_{NN}}$ = 3 GeV (FXT)

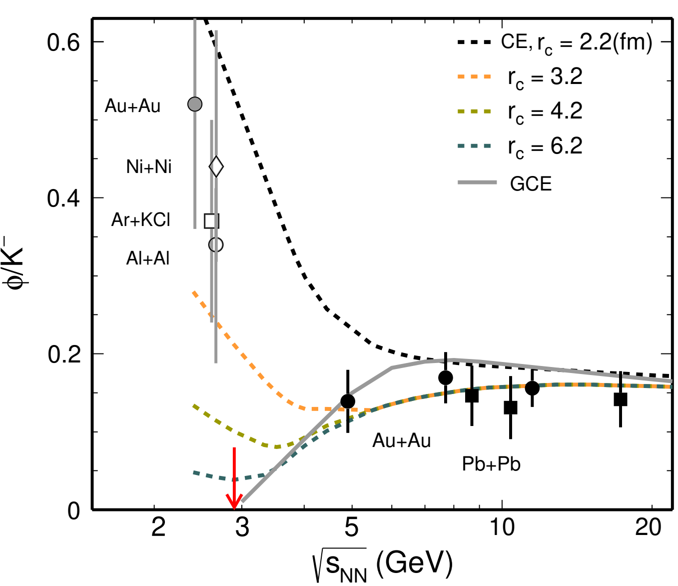


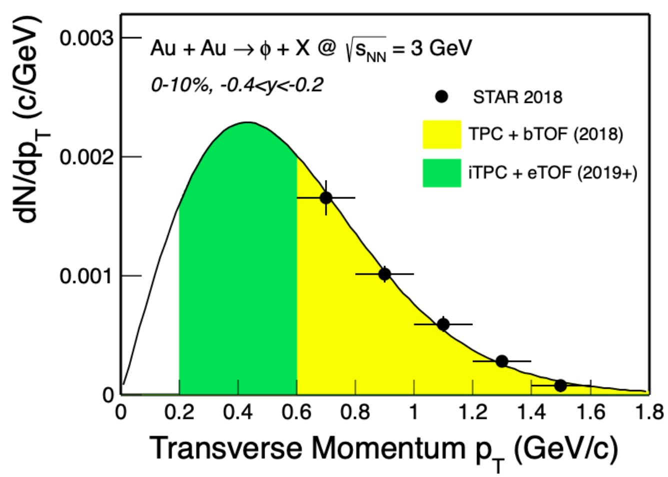
Net-proton fluctuations:

Run-21: iTPC and eTOF —> similar proton acceptance to 7.7 GeV collider data

GCE or CE appropriate at low beam energy?

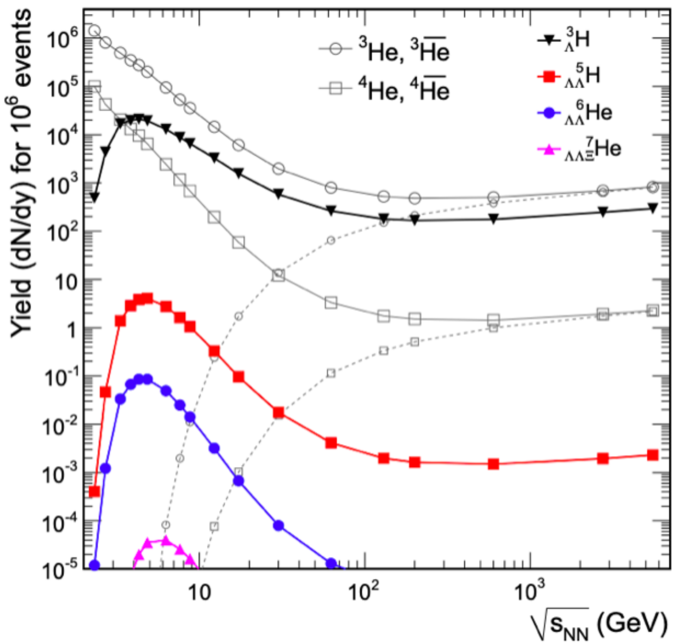
Sensitivity to r_C:

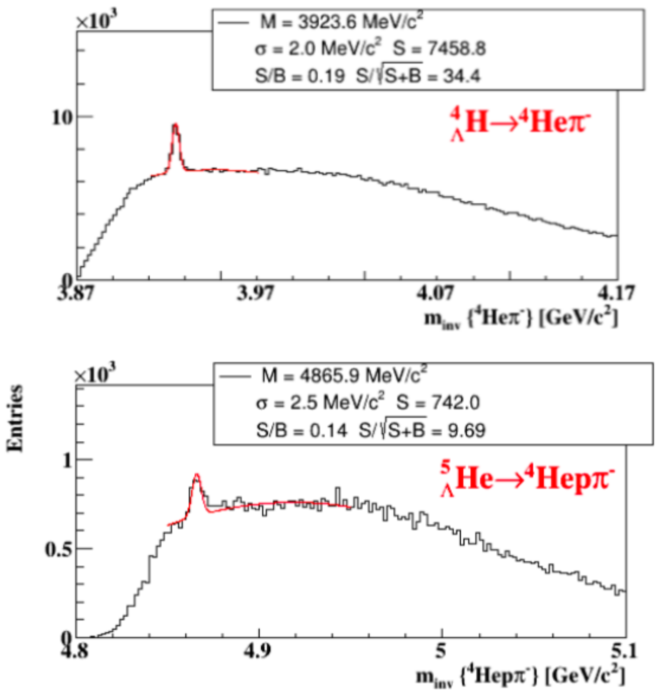




Run-21: iTPC and eTOF —> ~90% of ϕ yield measured at mid rapidity

Case for Au+Au $\sqrt{s_{NN}}$ = 3 GeV (FXT)





Run-21: iTPC and eTOF —>

Light hypernuclei lifetime, BE, yields and flow

Propose to collect at least 300 M minbias events - 3 days of running

If time permits propose to extend to 2B events - 3 weeks

Access to:

C_5, C_6

Centrality dependence of ϕ studies

Double-Λ hypernuclei

Case for Au+Au $\sqrt{s_{NN}}$ = 9.2, 11.5, 13.7 GeV (FXT)

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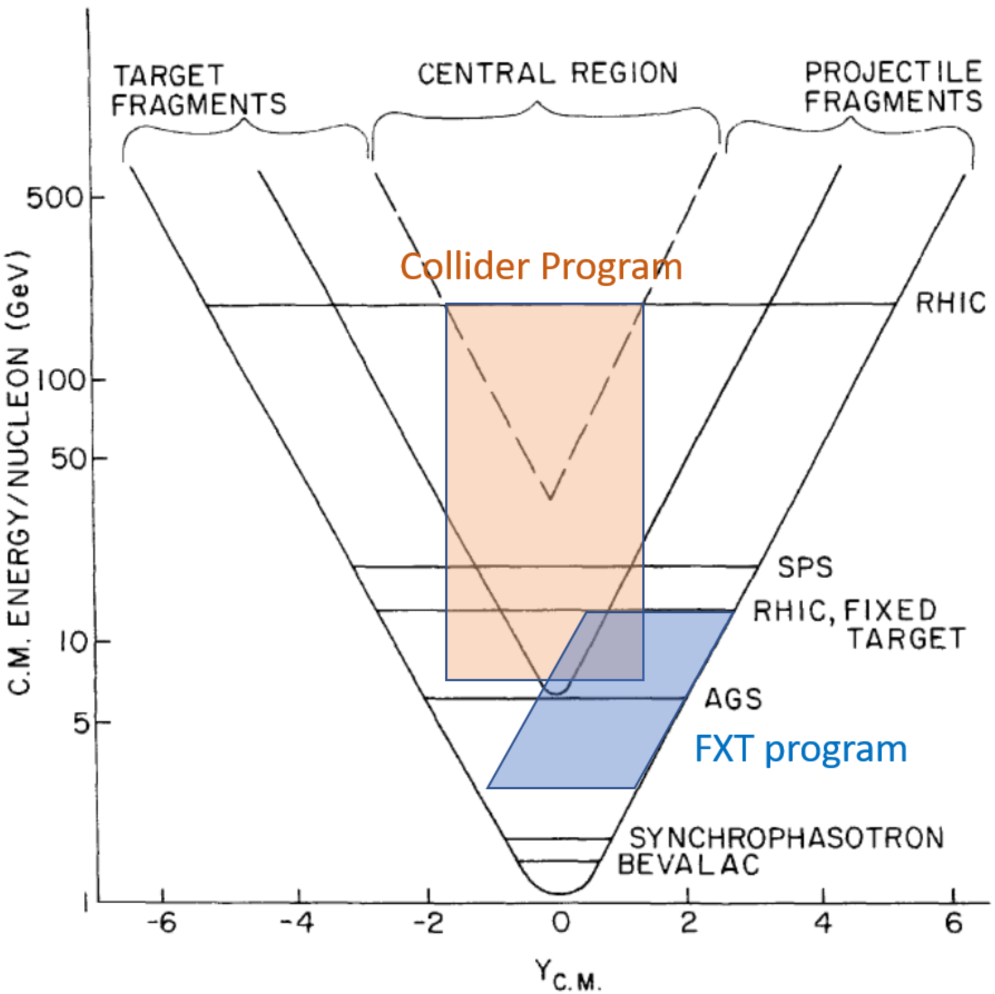


y_{cm} = 2.28, 2.5 and 2.68 respectively

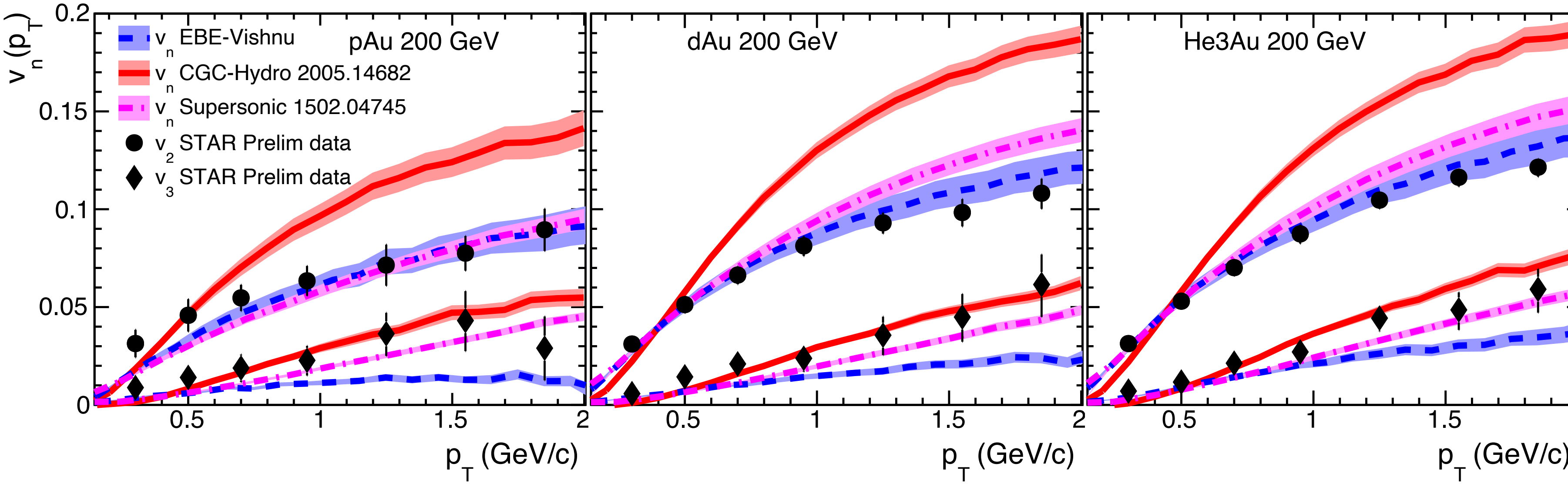
In combination with collider data near full rapidity coverage

High rapidity tails of dN/dy critical for constraining shear viscosity dependence on T and μ_B

Stall in rapidity shift of stopped protons - reveals softening of equation of state

Propose to collect 50 M minbias events at each energy
- 3 days of total running

Correlations in Small Systems

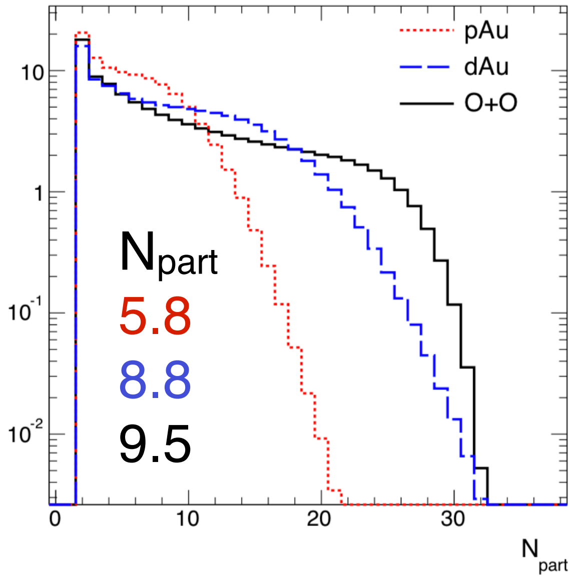


Models fail to describe all the current STAR data

Initial State Correlations or Final State Interactions in small systems?

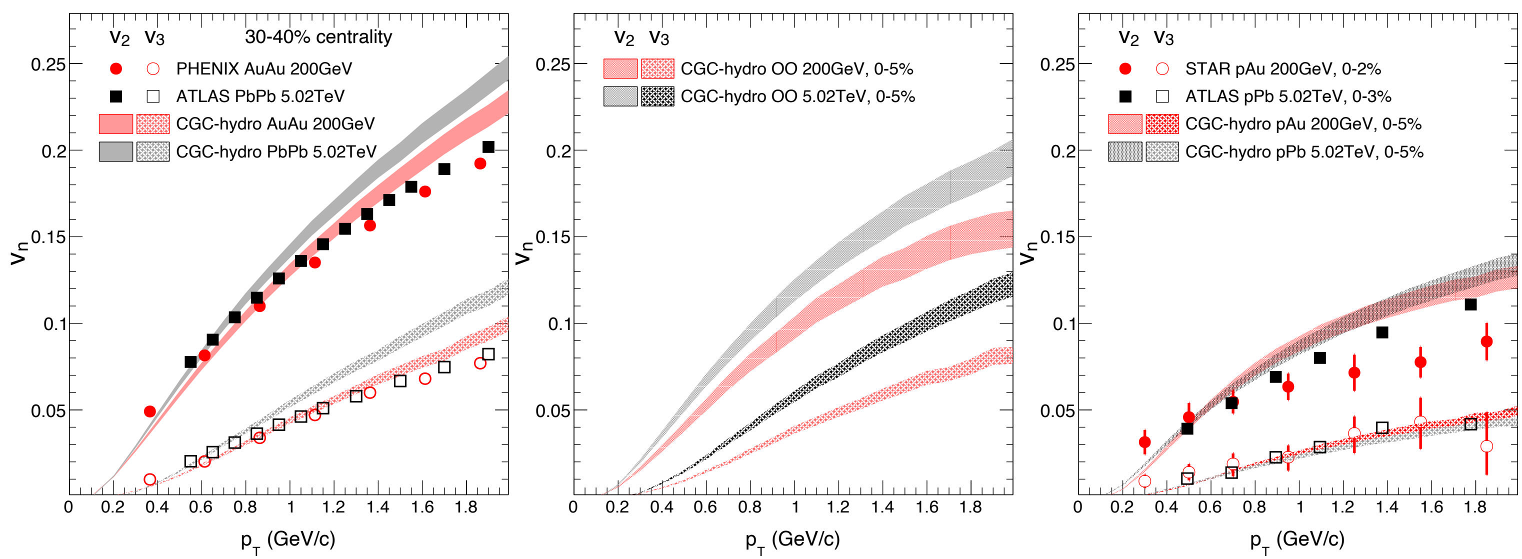
If Final state: is collectivity fluid-like or off-equilibrium few scatterings?

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



Why O+O:

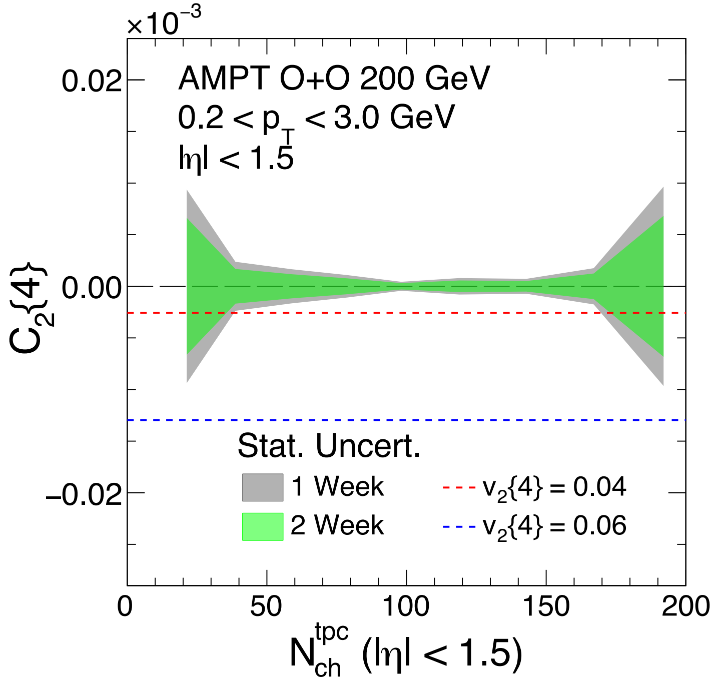
- Prediction of different $\sqrt{s_{NN}}$ dependence for symmetric and asymmetric systems
- Cu+Au, ^{3}He+Au results consistent with dominance of FSM, need system with small N_{part}~60
- Small symmetric system with similar N_{part} to p/d+Au but different nucleon/subnucleon fluctuations

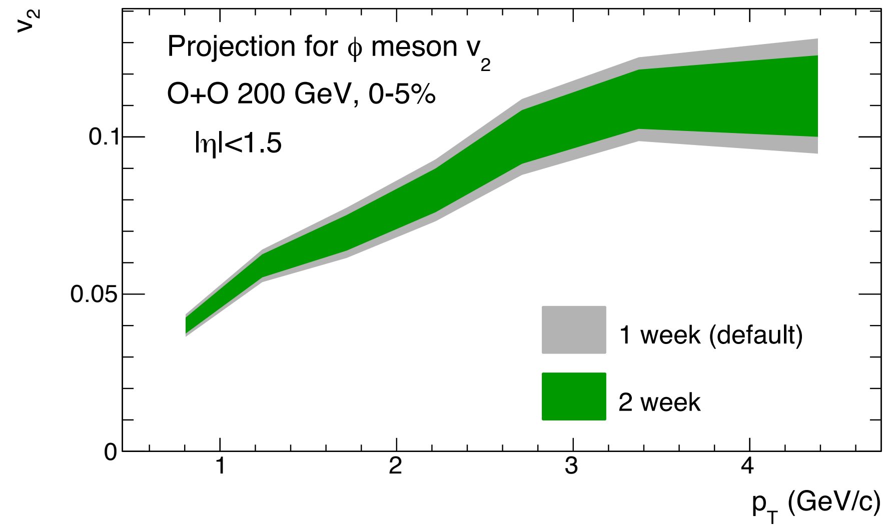


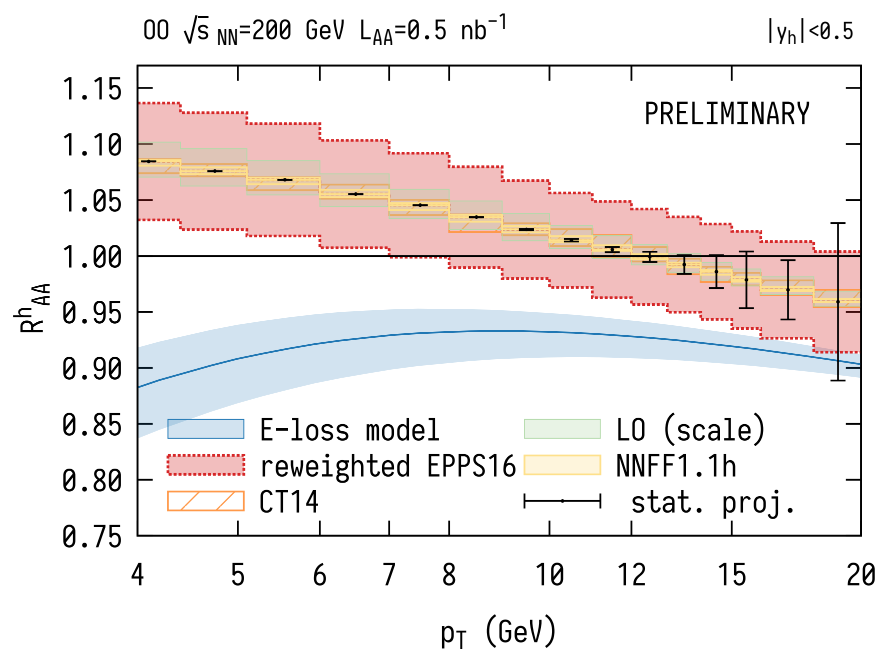
arXiv: 2005.14682, Schenke,Shen,Tribedy

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

STAR







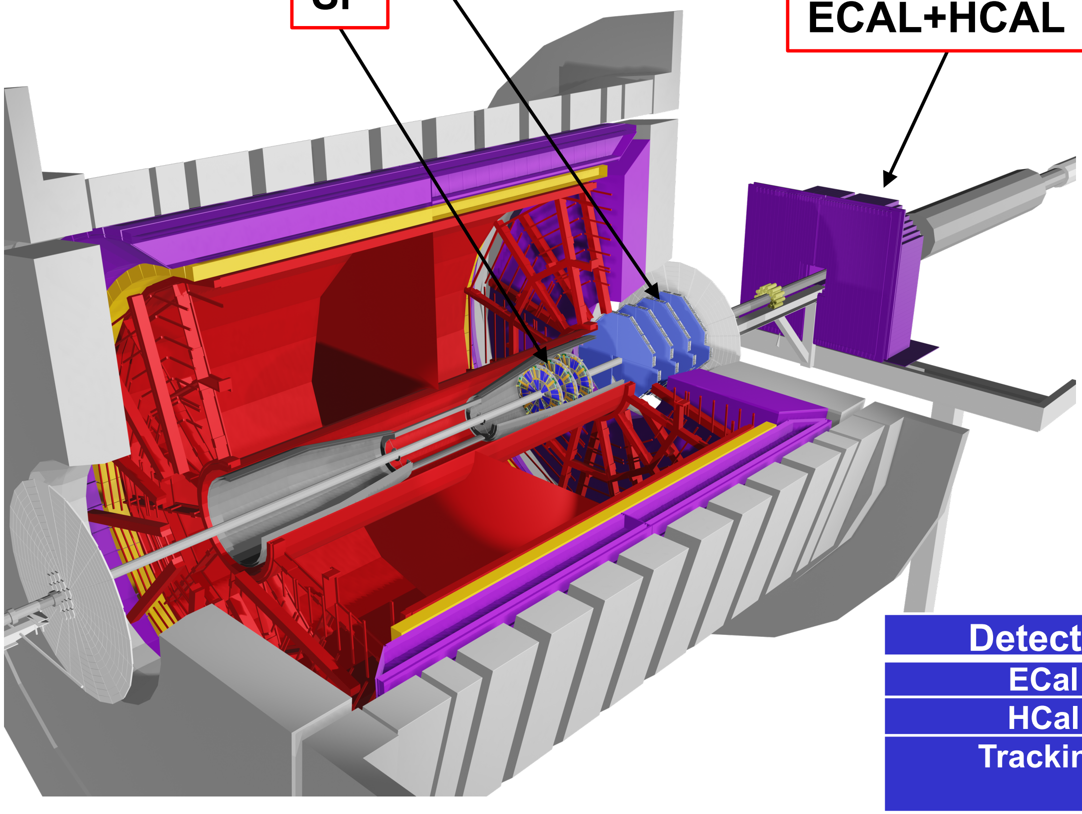
Multi-particle cumulants - event by event fluctuations of collectivity

π, K, p and ϕ flow with good precision - NCQ scaling?

R_{AA} - E_{loss} in small systems?

Propose to collect 400(200) M minbias(central) events - 1 week of running

Next Steps: Forward Upgrades



At $2.5<\eta<4$

- Jets
- PID (π^0, γ, e, Λ)
- charged particle momentum resolution 20-30% at $0.2<p_T<2$ GeV/c
- event-plane reconstruction and trigger capability

Detector	pp and pA	AA
ECal	~10%/√E	~20%/√E
HCal	~50%/√E+10%	---
Tracking	charge separation photon suppression	$0.2<p_T<2$ GeV/c with 20-30% $1/p_T$

All detectors on track for data taking in FY-22 costs so far as projected

Run-22: Transverse p+p 510 GeV

Inaugural run with Forward Upgrades
Minimum of 16 weeks to collect at least 400 pb^{-1} for rare/non-rescaled triggers

Not to mention first p+p run with BES-II upgrade detectors

By going to 510 GeV and wide η range (up to $\eta \sim 4.2$)
probe down to x ~2×10^{-3} (gluons) and up to x~0.5 (valence quarks) regions possible

Transversely polarized beams:

Quark transversity (net transverse polarization of quarks in a transversely polarized proton) in the large x valence region

Current results statistics limited

Looking Forward to 2023-2025

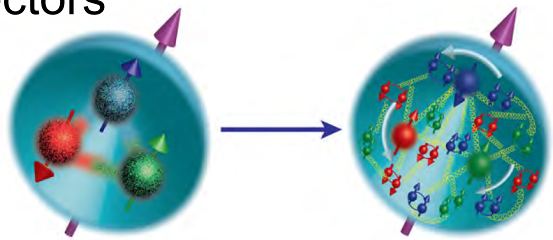
Unique program addressing fundamental questions in QCD

- strongly endorsed by the PAC

Exploits BES-II mid-rapidity upgrades and new forward detectors

pp

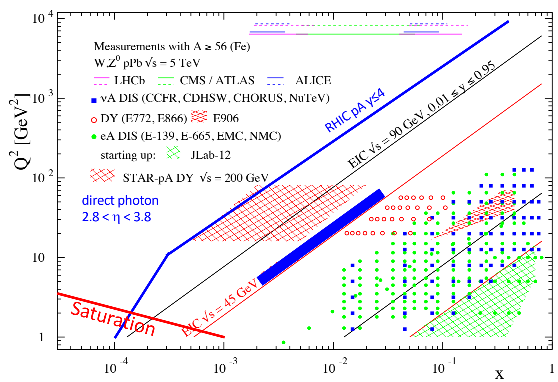
- 3D characterization of proton in momentum and spatial coordinates



p+A

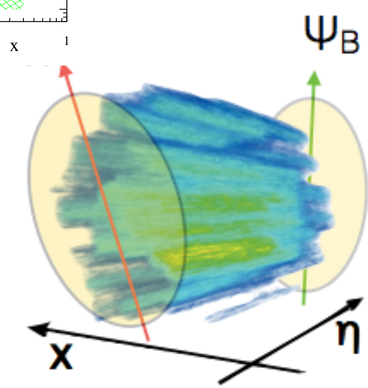
- Nature of initial state and hadronization in nuclear collisions
- Onset and A-dependence of saturation

pA@RHIC: unique kinematics



A+A

- Longitudinal medium characterization
- Precision flow measurements via long range correlations
- Rapidity dependence of Λ global polarization
- QGP response to B field via low-p_T dielectrons



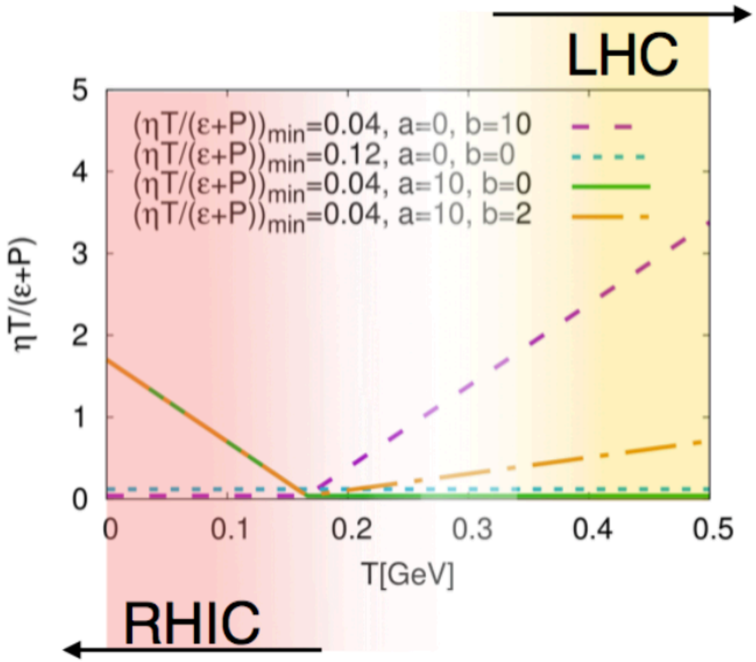
Essential input to RHIC's cold **and** hot QCD programs and realizing the scientific promise of the EIC

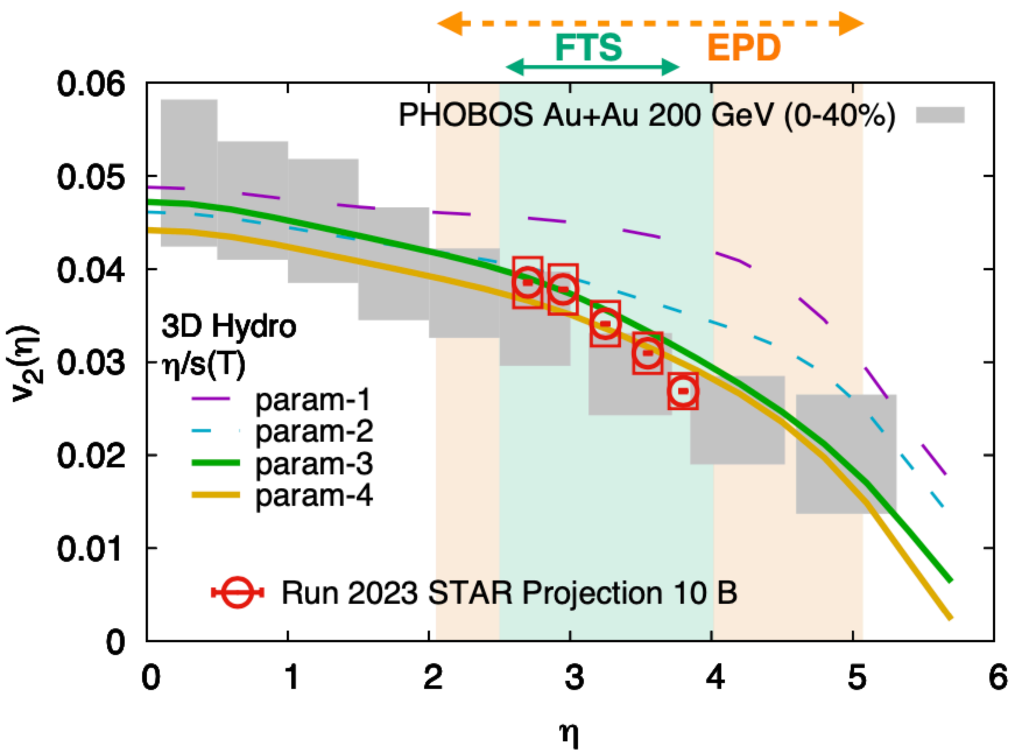
Physics opportunities in 2023-2025

To address important questions about the inner workings of the QGP

- What is the precise temperature dependence of shear and bulk viscosity?
- What is the nature of the 3-dimensional initial state at RHIC energies?
- How is global vorticity transferred to the spin angular momentum of particles on such short time scales? How can the global polarization of hyperons be reconciled with the spin alignment of vector mesons?
- What is the precise nature of the transition near $\mu_B=0$?
- What is the electrical conductivity, and what are the chiral properties of the medium?
- What can be learned about confinement and thermalization in a QGP from charmonium measurement?
- What are the underlying mechanisms of jet quenching at RHIC energies? What do jet probes tell us about the microscopic structure of the QGP as a function of resolution scale?

Constraining T dependence of η/s



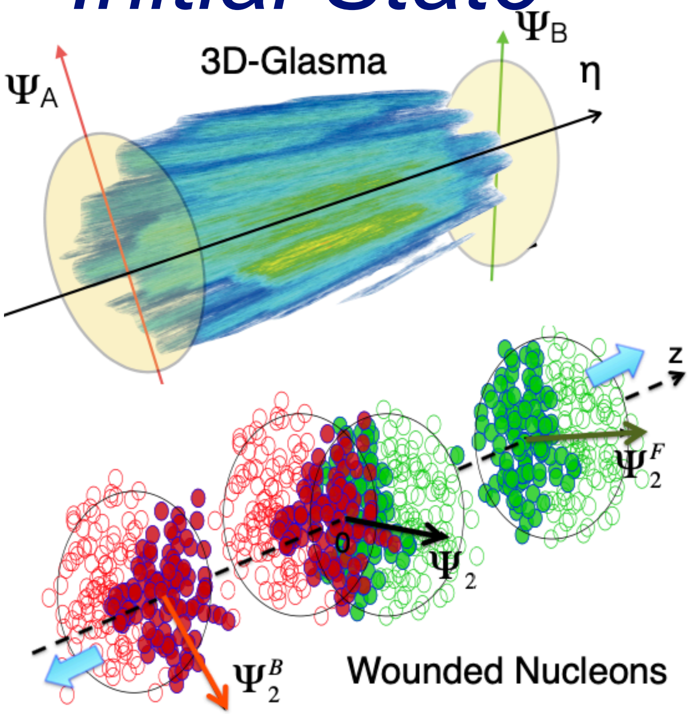


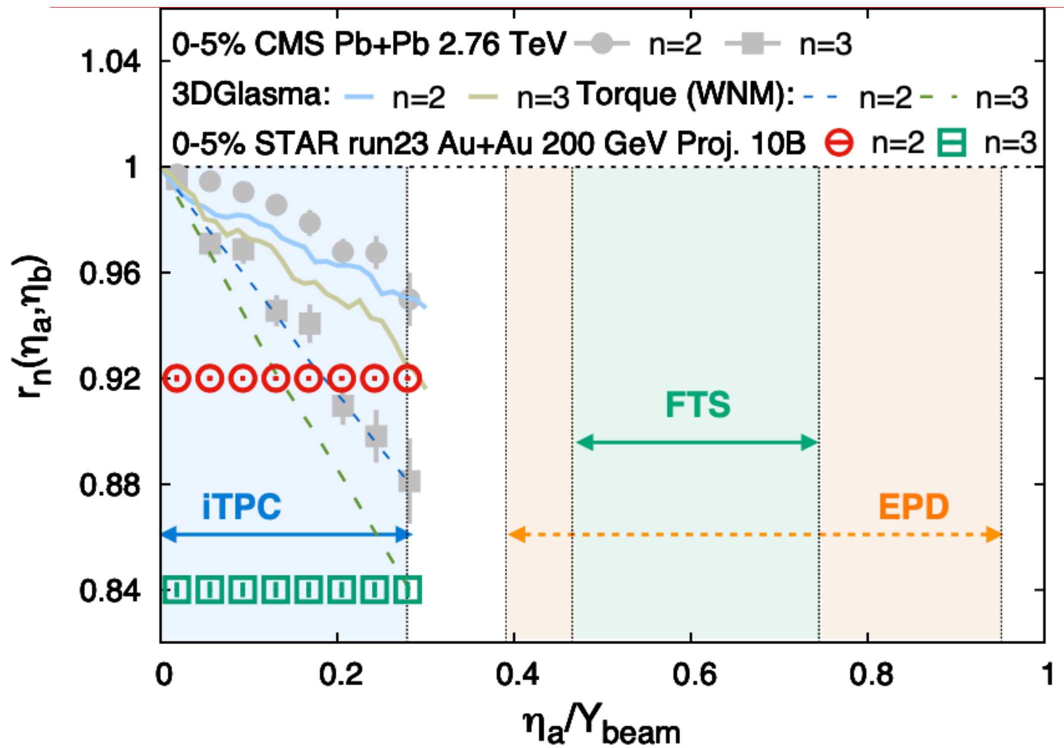
Flow measurements at forward rapidity sensitive to η/s as a function of T.

Much more precise than previous PHOBOS measurements.

Forward tracking critical

Constraining Longitudinal Structure of Initial State





$$r_n(\eta_a, \eta_b) = V_{n\Delta}(-\eta_a, \eta_b)/V_{n\Delta}(\eta_a, \eta_b)$$

$V_{n\Delta}$ the Fourier coefficient calculated with pairs of particles in different rapidity regions

r_n sensitive to different initial state inputs:

- **3D glasma model: weaker decorrelation, describes CMS r_2 but not r_3**
- **Wounded nucleon model: stronger decorrelation than data**

Precise measurement of r_n over a wide rapidity window will provide a stringent constraint

Summary

- Excellent performance from RHIC and STAR
- BES-II upgrades performing at or above expectations
- New Cold QCD program enabled by forward upgrades

Collected virtually all BES-II data

- Many analyses already ongoing, those in the original BES-II proposal and many new ideas
- Run-21:

  Assuming 7.7 GeV running goes well opportunistically take:

  Au+Au at 3, 9.2, 11.5, 13.7 (FXT) - higher moments and baryon stopping

  Au+Au at 17.1 GeV - location of CP

  O+O at 200 GeV - initial conditions of small systems

  Last chance to answer these critical HI questions at RHIC

- Run-22-25:

  Exciting physics program enabled by BES-II and Forward Upgrades

  collection of RHIC legacy data prior to EIC

BACK UP

Looking Forward

	Year	$\sqrt{s}$ (GeV)	Delivered Luminosity	Scientific Goals	Observable	Required Upgrade
Scheduled RHIC running	2023 to 2025	$p^{\uparrow}p$ @ 200	300 pb^{-1} 8 weeks	Subprocess driving the large A_N at high x_F and η	A_N for charged hadrons and flavor enhanced jets	Forward instrum. ECal+HCal+Tracking
		$p^{\uparrow}Au$ @ 200	1.8 pb^{-1} 8 weeks	What is the nature of the initial state and hadronization in nuclear collisions Clear signatures for Saturation	R_{pAu} direct photons and DY Dihadrons, γ-jet, h-jet, diffraction	Forward instrum. ECal+Hcal+Tracking
		$p^{\uparrow}Al$ @ 200	12.6 pb^{-1} 8 weeks	A-dependence of nPDF, A-dependence for Saturation	R_{pAl}: direct photons and DY Dihadrons, γ-jet, h-jet, diffraction	Forward instrum. ECal+HCal+Tracking
		AuAu @ 200	1 Billion Minbias Events	Longitudinal de-correlation	$C_n(\Delta\eta)$ and $r_n(\eta_a,\eta_b)$	Forward instrum. ECal+HCal or Tracking
				η/s(T) and ζ/s(T)	$V_{n\Delta}(\eta)$	Forward instrum. Tracking
				Mixed flow Harmonics	$C_{m,n,m+n}$	Forward instrum. ECal+HCal or Tracking
				Rapidity dependence of Hyperon Polarization	$P_H(\eta)$	Forward instrum. Tracking
				Ridge	$dN/d(\Delta\eta)d(\Delta\phi)$ & $V_{n\Delta}$	Forward instrum. ECal+HCal or Tracking
Potential future running	2021	$p^{\uparrow}p$ @ 510	1.1 fb^{-1} 10 weeks	TMDs at low and high x	A_{UT} for Collins observables, i.e. hadron in jet modulations at η > 1	Forward instrum. ECal+HCal+Tracking
	2021	$\vec{p}\vec{p}$ @ 510	1.1 fb^{-1} 10 weeks	$\Delta g(x)$ at small x	A_{LL} for jets, di-jets, h/γ-jets at η > 1	Forward instrum. ECal+HCal

Running just endorsed by 2020 BNL RHIC PAC

Progress with the Forward Upgrades

First Forward detector (ECal) successfully installed in Oct 2019
- reusing PHENIX Pb-scintillator
- tests ongoing during BES-II running

HCal:
- first hadronic cal. in STAR
- FNAL test beam data show performance sufficient for requirements
- All orders planned / ready to go

Prototypes exist for each of the subsystems

All detectors on track for data taking in FY-22
costs so far as projected

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

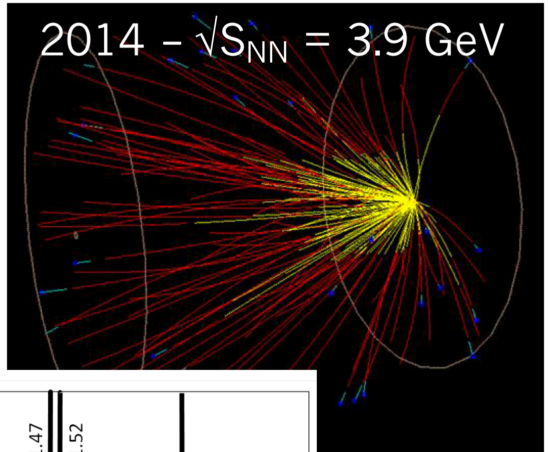
Typically factor 20 more than for BES-I

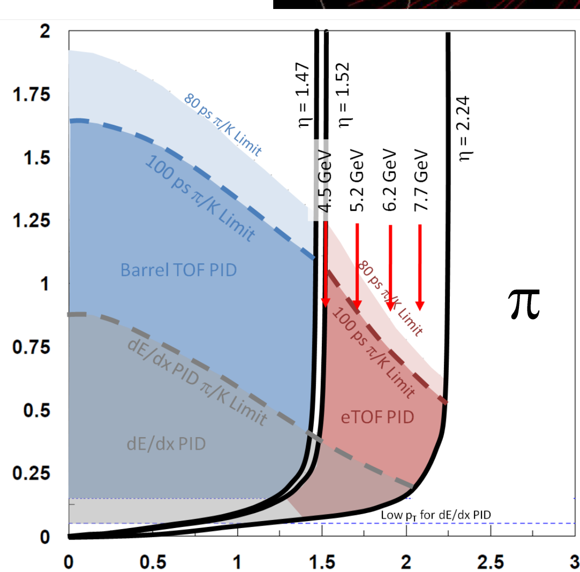
Event statistics requirements: FXT

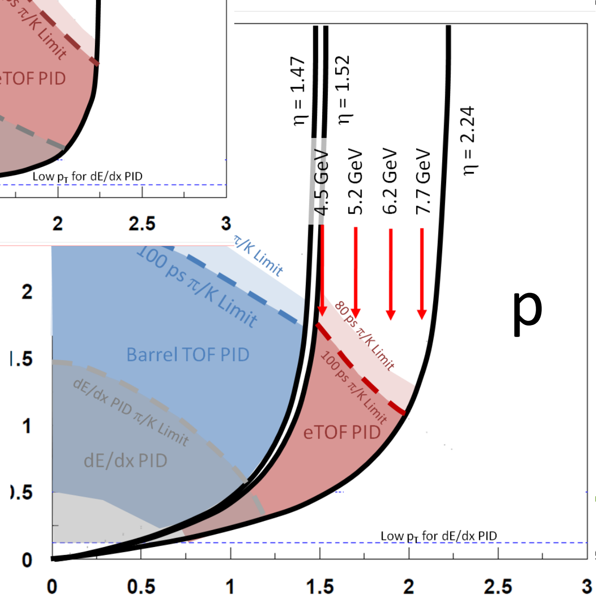
Table 8: Event statistics (in millions) needed in the fixed-target part of the BES-II program for various observables.

$\sqrt{s_{NN}}$ (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

BES-II: Onset of deconfinement







NA49 - claim onset of deconfinement at $\sqrt{s}$ = 7.7 GeV

Fixed target program
- Collider can't run below 7.7GeV
- Target in beam pipe at z=210cm

Dedicated short runs
- More efficient
- Successful tests completed

TOF+iTPC:
- Forward acceptance in fixed target mid-rapidity range
  - Reach 7.7 GeV for fixed target too

Precision investigation with new techniques and same detector