

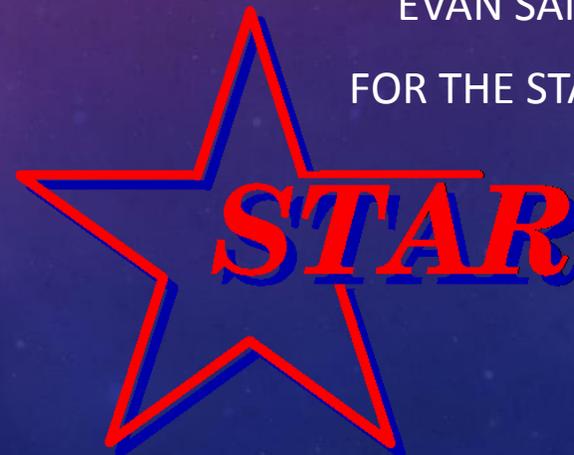


STAR BES-I RESULTS AND BEYOND

EVAN SANGALINE (UC DAVIS)

FOR THE STAR COLLABORATION

2014/06/19



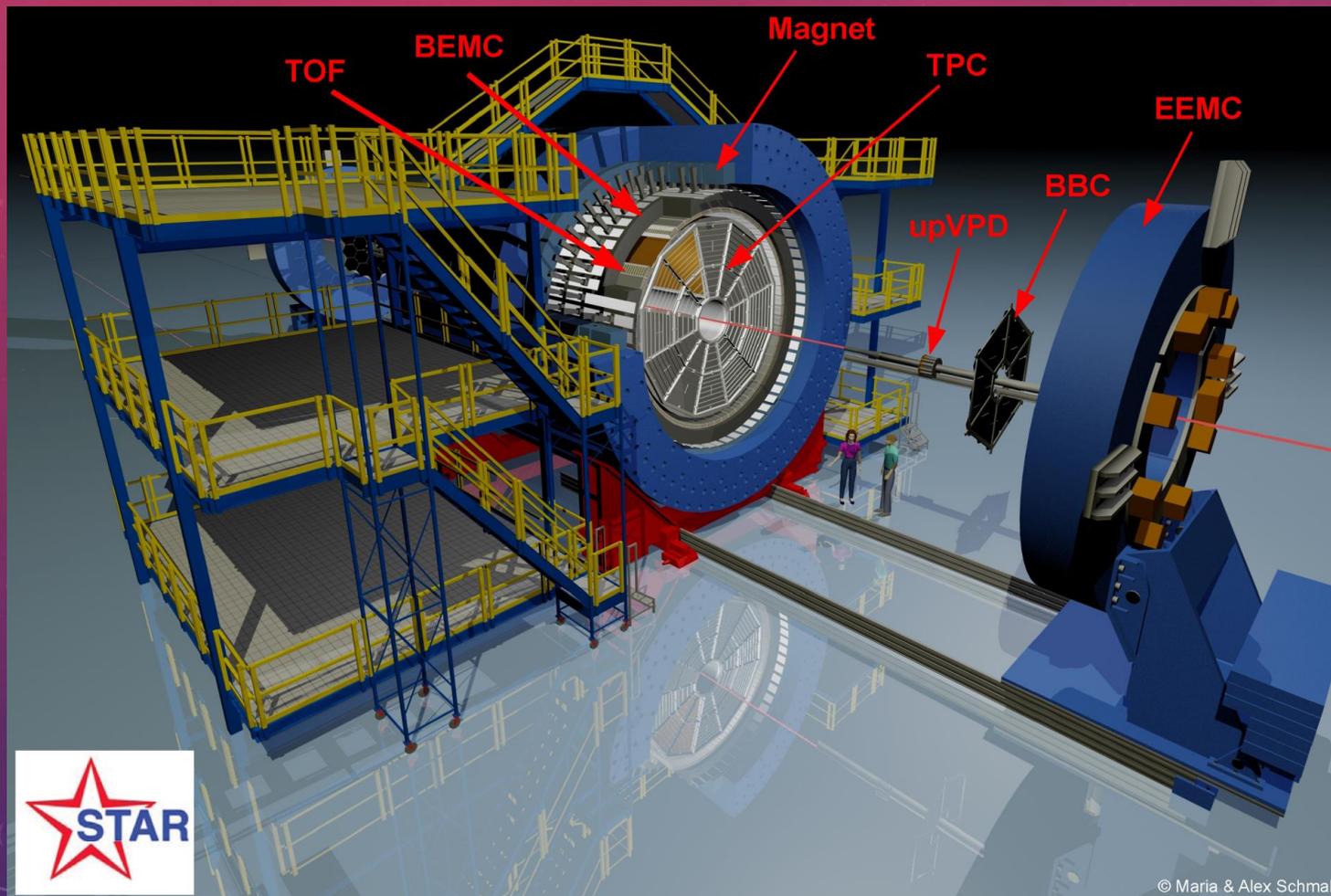
THE LINEUP



- Quick sampling of a few out of many STAR BES-I results
 - More detailed overview: Alex Schmah at 9:30AM on Friday
 - Focus on fluctuations: Rene Bellwied at 9:30AM today
- What to expect from the 14.5 GeV run
- Looking forward to the BES-II and STAR fixed target program



A QUICK REMINDER...



The STAR Detector

Acceptance

- Full 2π azimuthal coverage
- $|\eta| < 1$

Particle Identification

- dE/dx measurements in TPC
- $1/\beta$ measurements from TOF



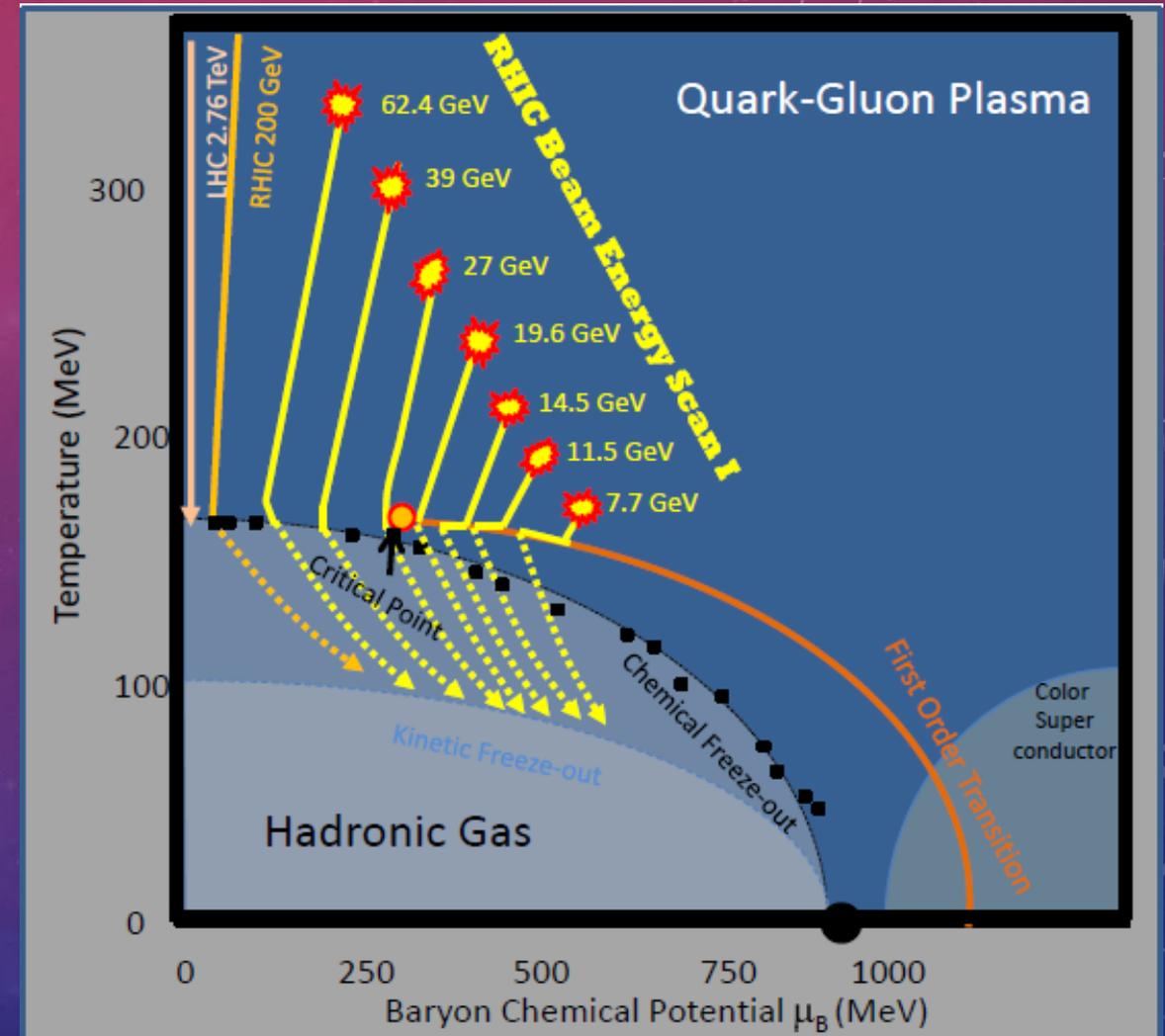
BEAM ENERGY SCAN THE FIRST

Search the QCD phase diagram for evidence of:

The Turn-off of QGP Signatures

A First Order Phase Transition

Critical Point Fluctuations



[Daniel Cebra](#)



THE BES-I DATA SETS

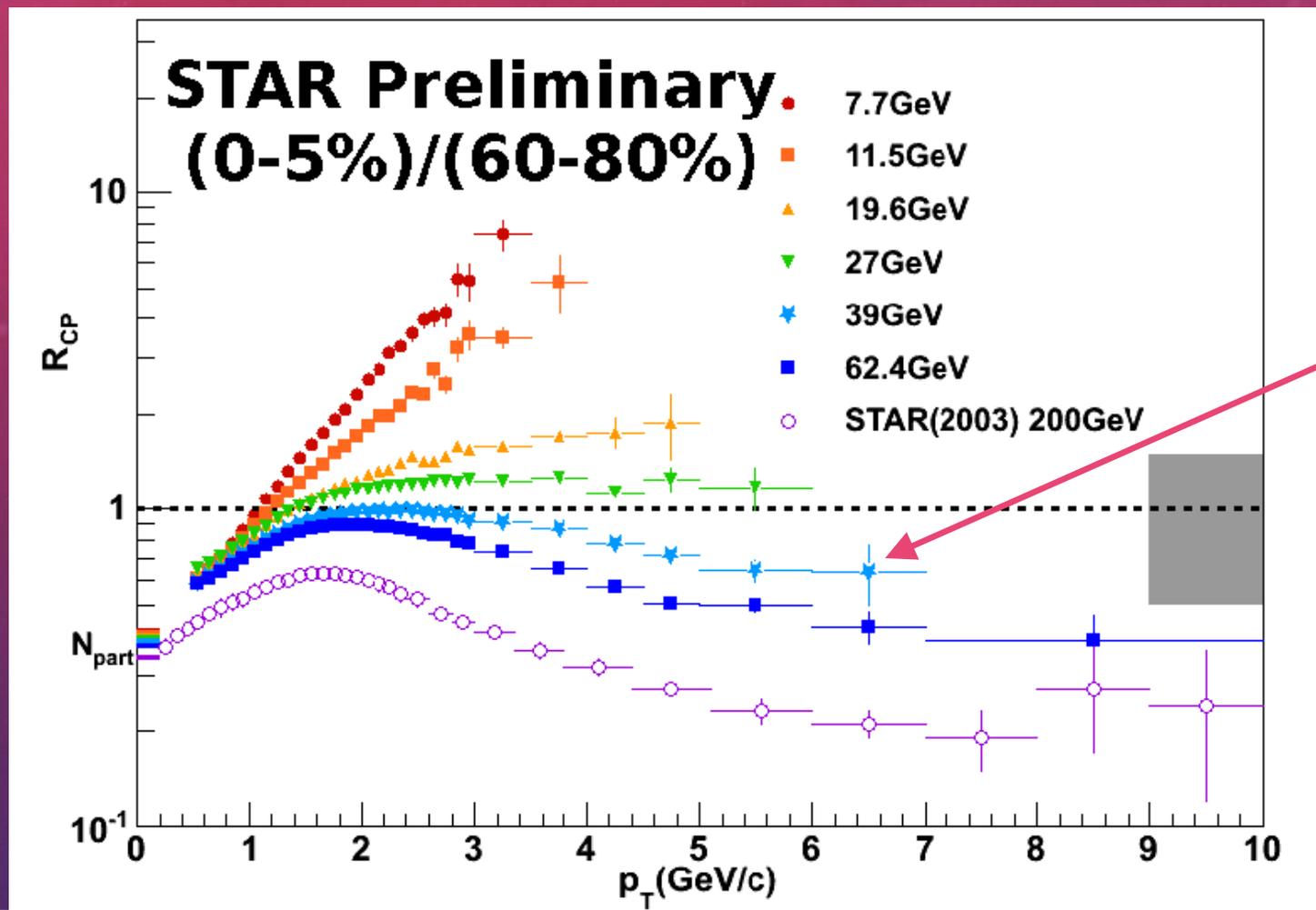
$v_{s_{NN}}$ (GeV)	μ_B (MeV)	MinBias Events (10^6)	Time (weeks)	Year
7.7	420	4.3	4	2010
11.5	315	11.7	2	2010
14.5	260	24.0	3	2014
19.6	205	35.8	1.5	2011
27.0	155	70.4	1	2011
39.0	115	130.4	2	2010
62.4	70	67.3	1.5	2010

New!
Fills in a
large μ_B gap.
(more on that later)





QGP SIGNATURE: CHARGED HADRON R_{CP}



High p_T
suppression
observed at 39,
62.4, and 200 GeV

Signature “turns off”
between 27 and 39 GeV

Stephen Horvat QM14

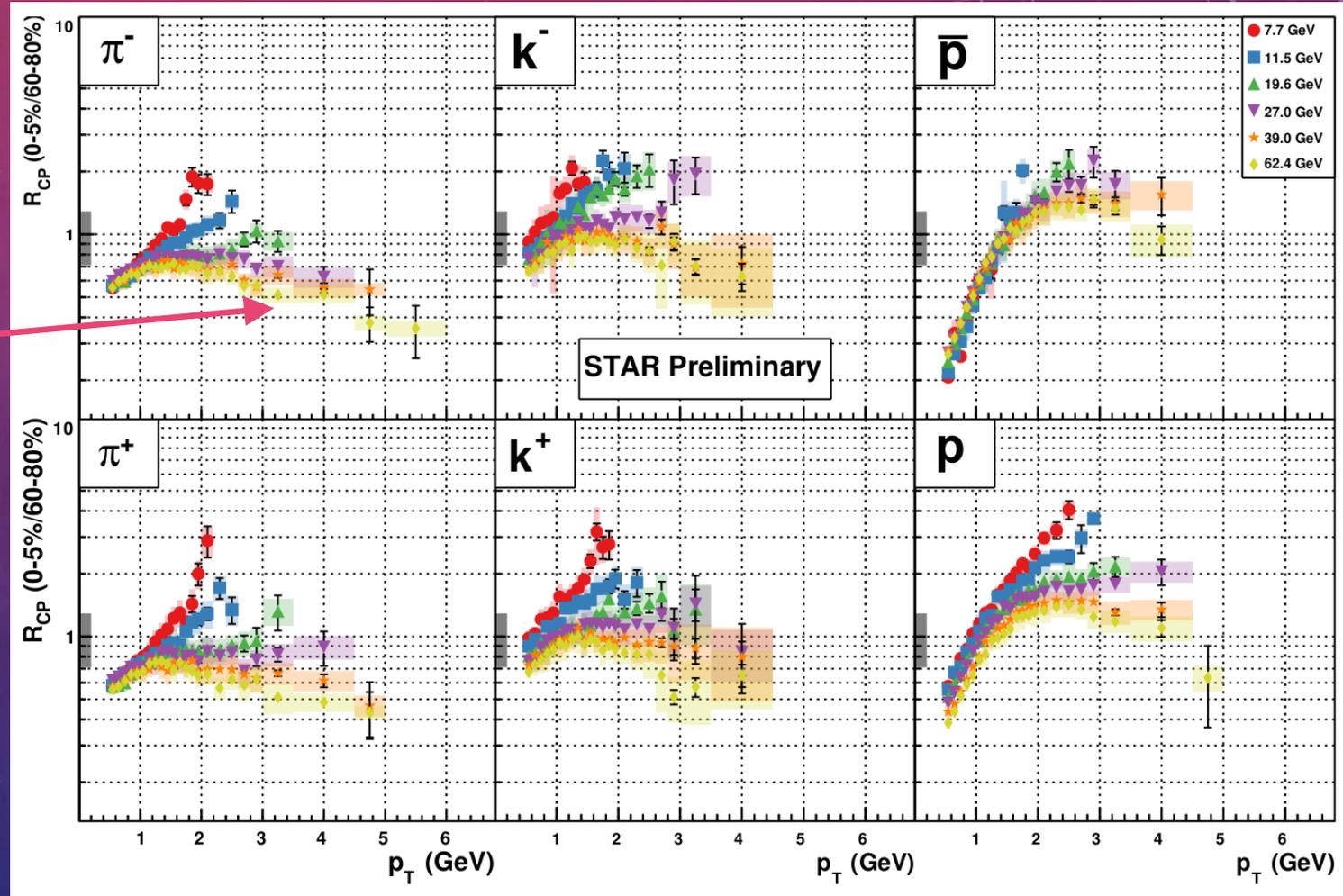


QGP SIGNATURE: IDENTIFIED HADRON R_{CP}

Protons are dominated by radial flow

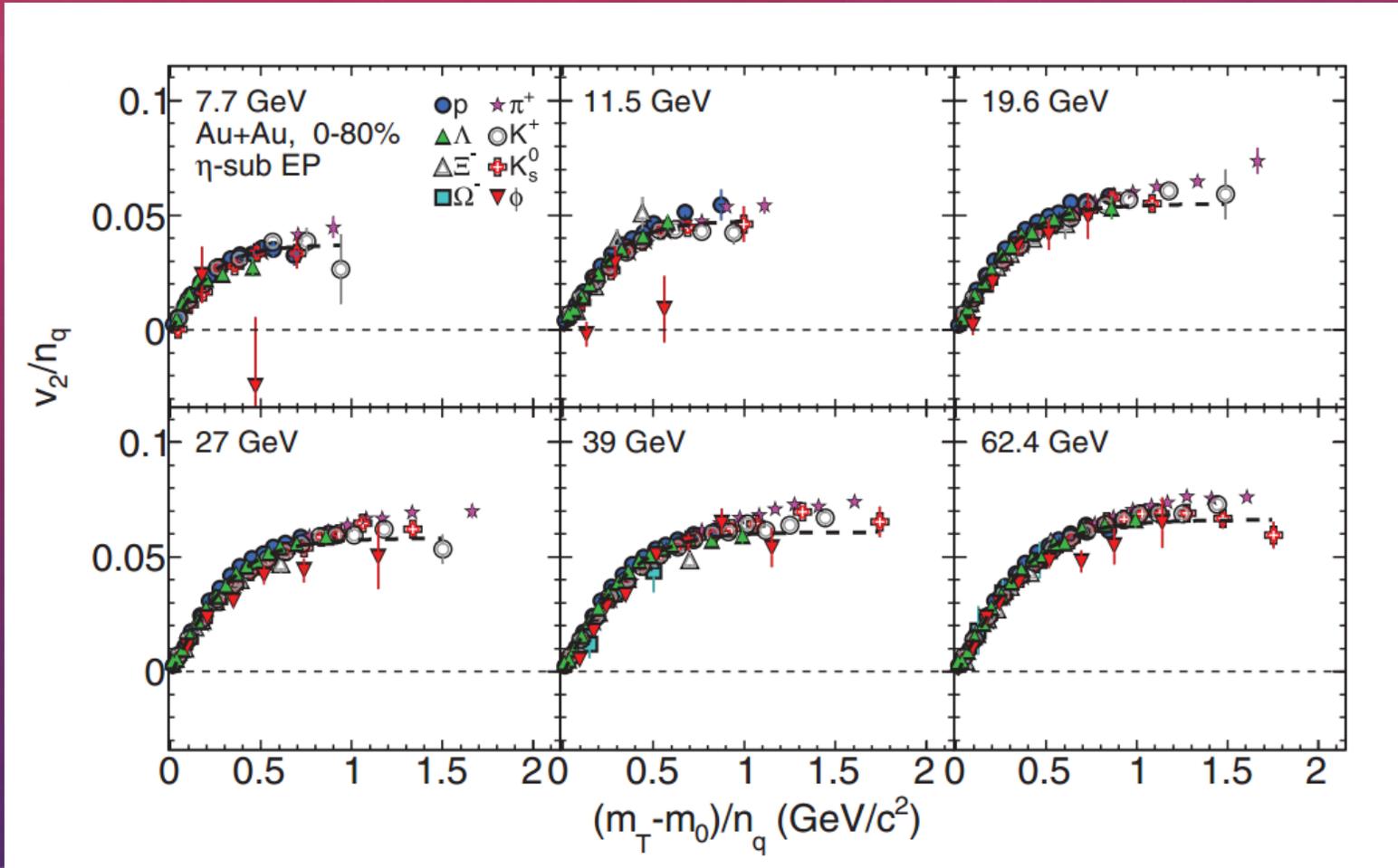
Pions exhibit suppression at 27 GeV

19.6 GeV is ambiguous, higher statistics needed at lowest energies





QGP SIGNATURE: N_Q SCALING



n_q scaling is observed
at all collision energies

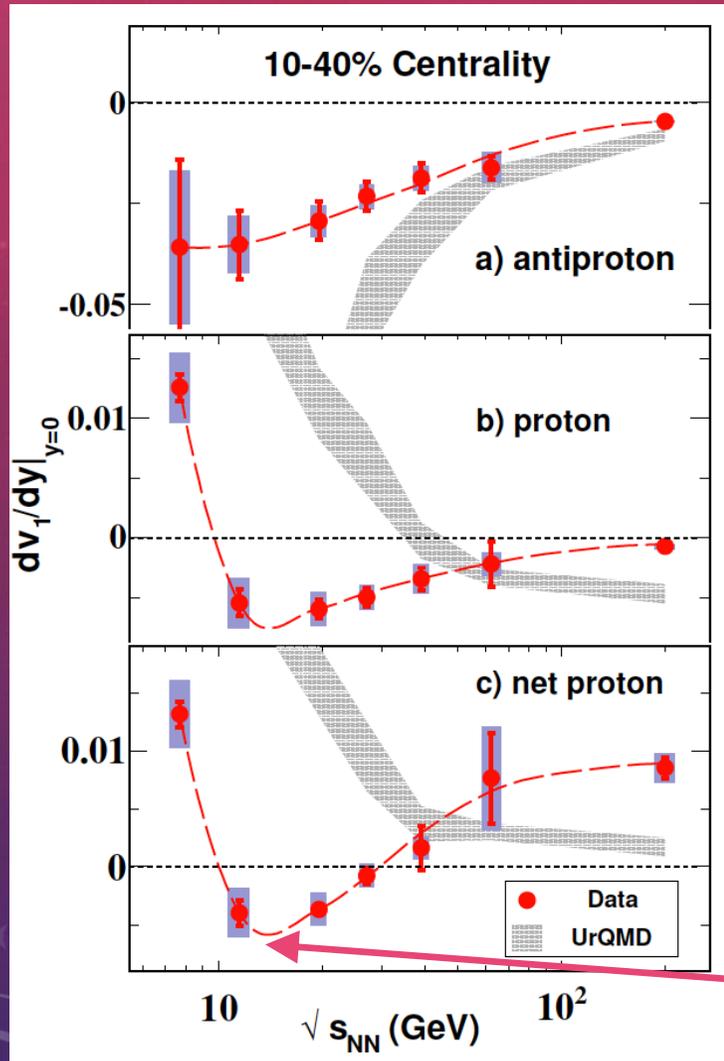
Deconfinement
at 7.7 GeV?

ϕ is key for
differentiating hadronic
and partonic flow but
has large errors

[Phys Rev C 88 \(2013\) 014902](#)



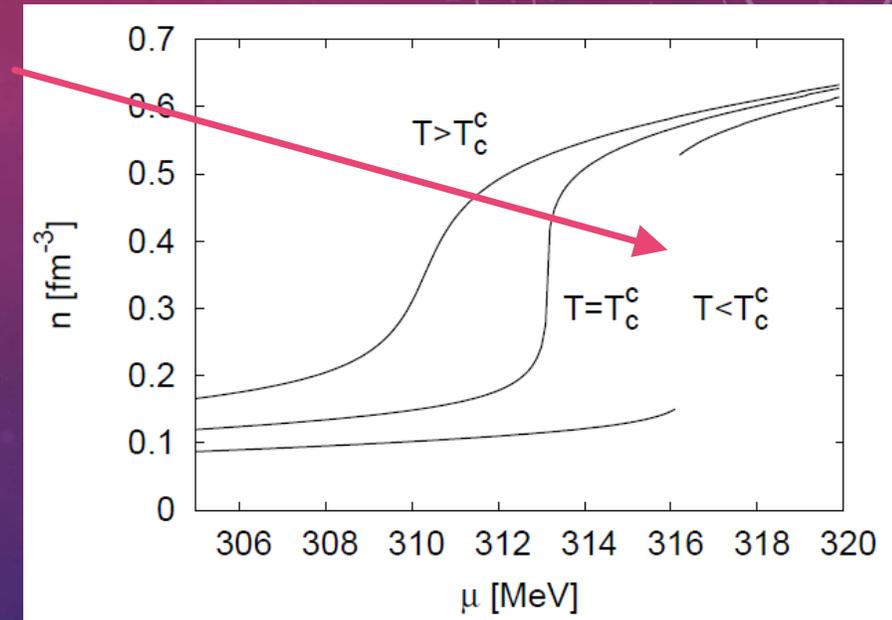
FIRST ORDER PHASE TRANSITION: NET PROTON v_1



Effective models predict a first order phase transition with a discontinuity in the density

Transition is characterized by spinodal region with high compressibility

v_1 is a manifestation of compressibility at early times after collisions



[Phys Rev D75 \(2007\) 085015](#)

Softest point in the equation of state?

[Nucl. Phys. A 750 \(2005\)](#)

[PRL 112 \(2014\) 162301](#)

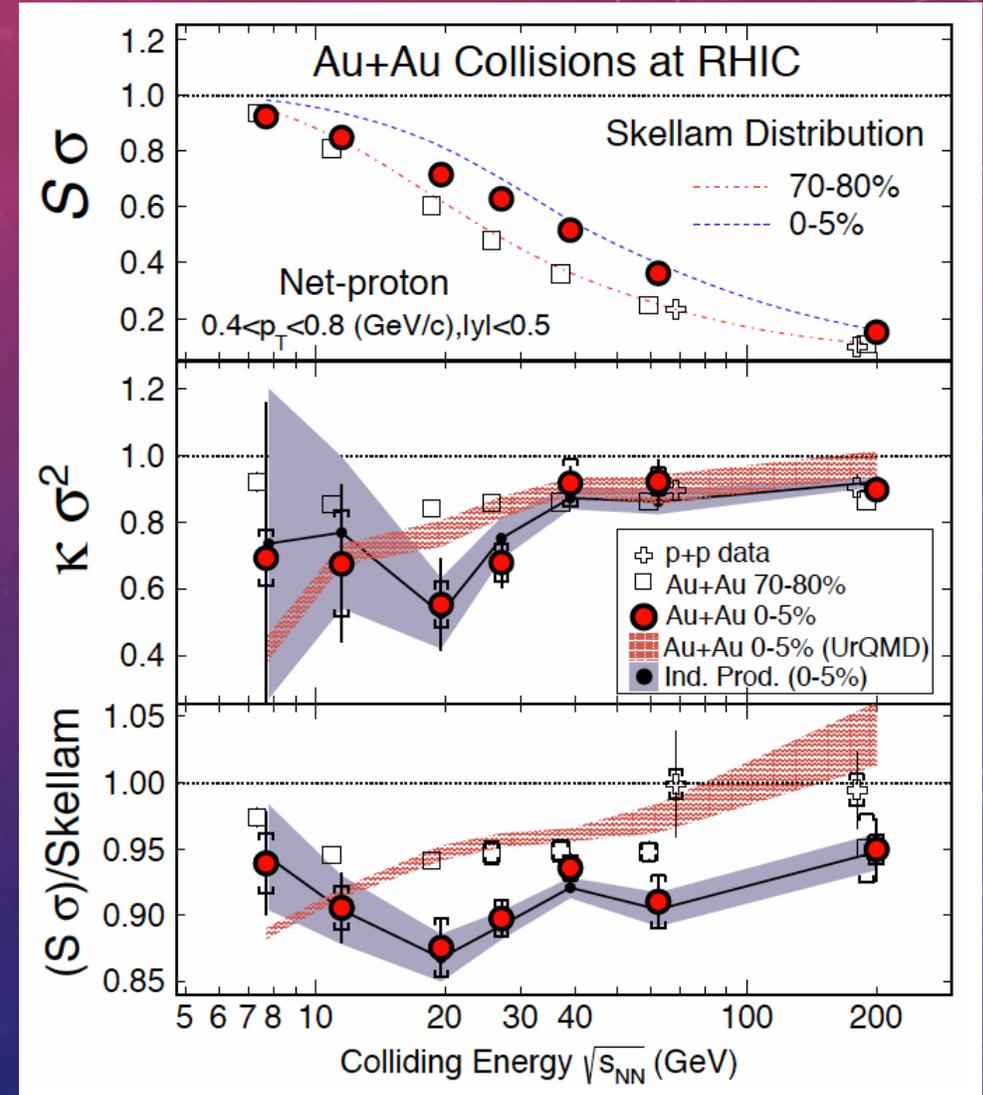


CRITICAL FLUCTUATIONS: NET PROTON MOMENTS

Cumulants of conserved quantities proportional to susceptibilities

No statistically significant evidence of critical fluctuations, but possible structure around 19.6 GeV

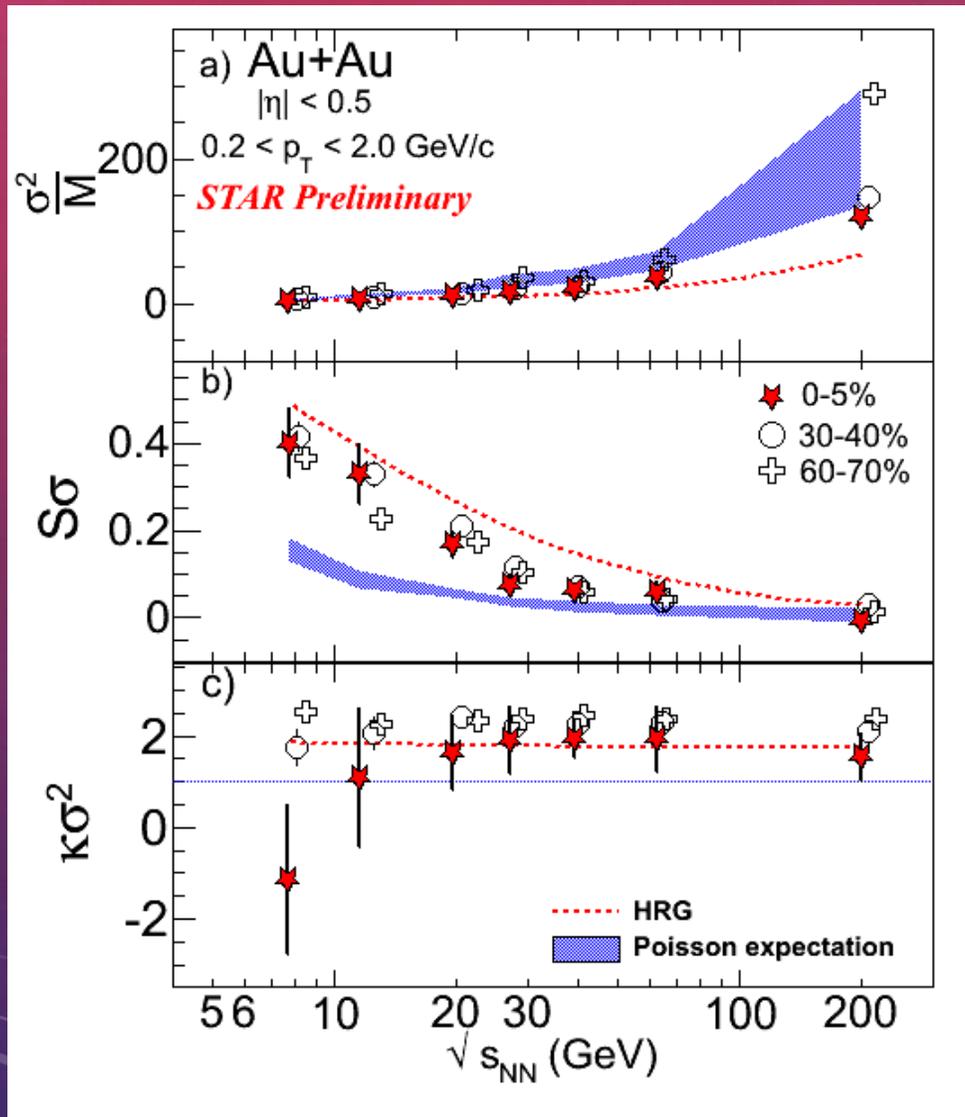
Large gap between theory and experiment (efficiency, centrality resolution, etc), but STAR has led the way in developing techniques for correcting these



[PRL 112 \(2014\) 32302](#)



CRITICAL FLUCTUATIONS: NET CHARGE MOMENTS



Statistical errors are large compared to the differences between baselines

Higher event numbers are needed to more accurately resolve the kurtosis



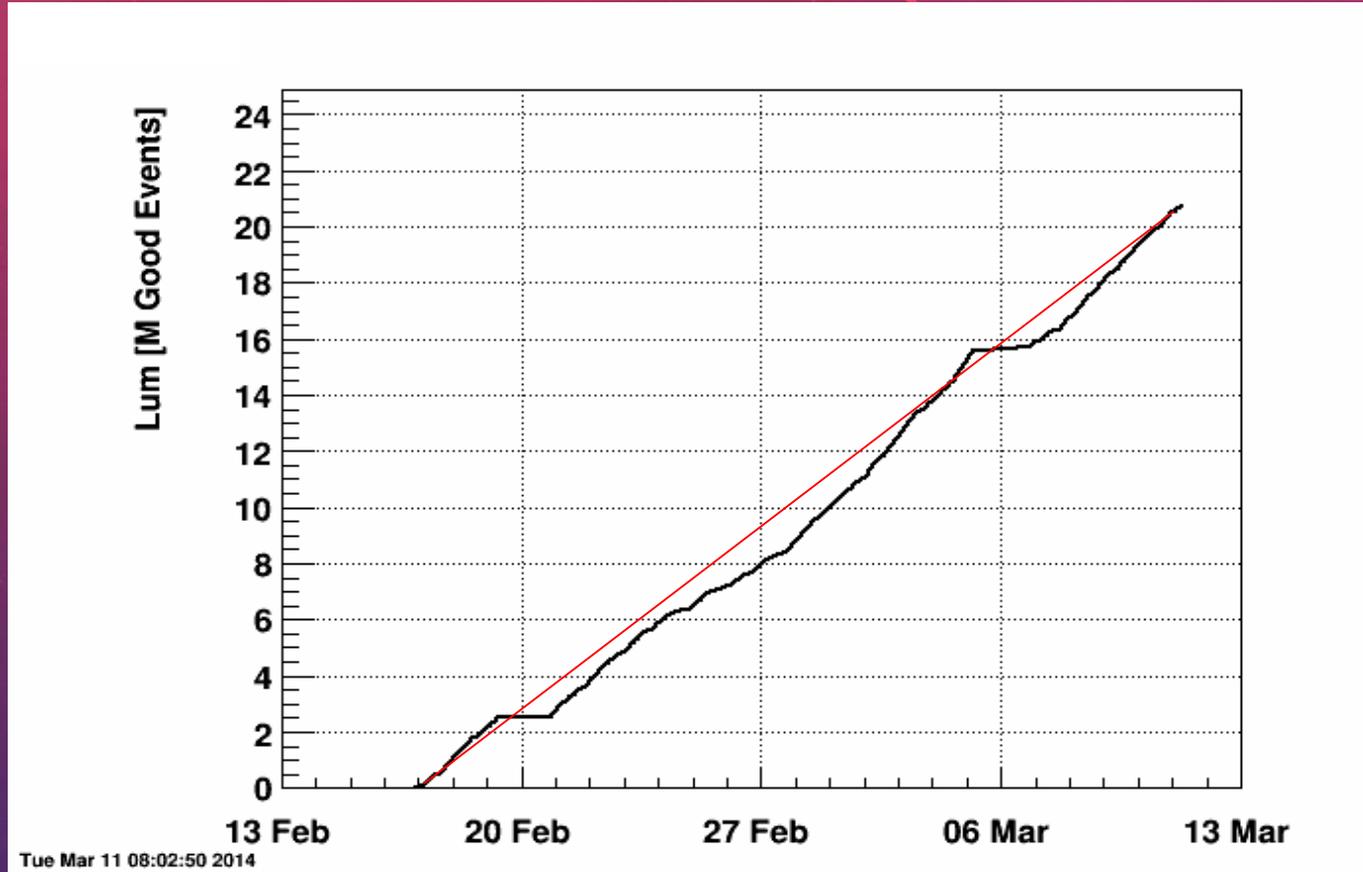
BES-I SUMMARY

- Evidence of deconfinement down to at least 27.0 GeV
 - Hard probes become less accessible at lowest collision energies
 - “Turn-off” of hard signatures does not imply the absence of deconfinement
- Evidence for a first order phase transition around 11.5-19.6 GeV
- Suggestive signs of critical fluctuations?
 - Highly statistics hungry analysis
 - Possibly missed due to large gap in μ_B between 11.5 and 19.6 GeV?



HOT OFF THE PRESSES: 14.5 GEV DURING RUN 14

Goal of 20 M events met



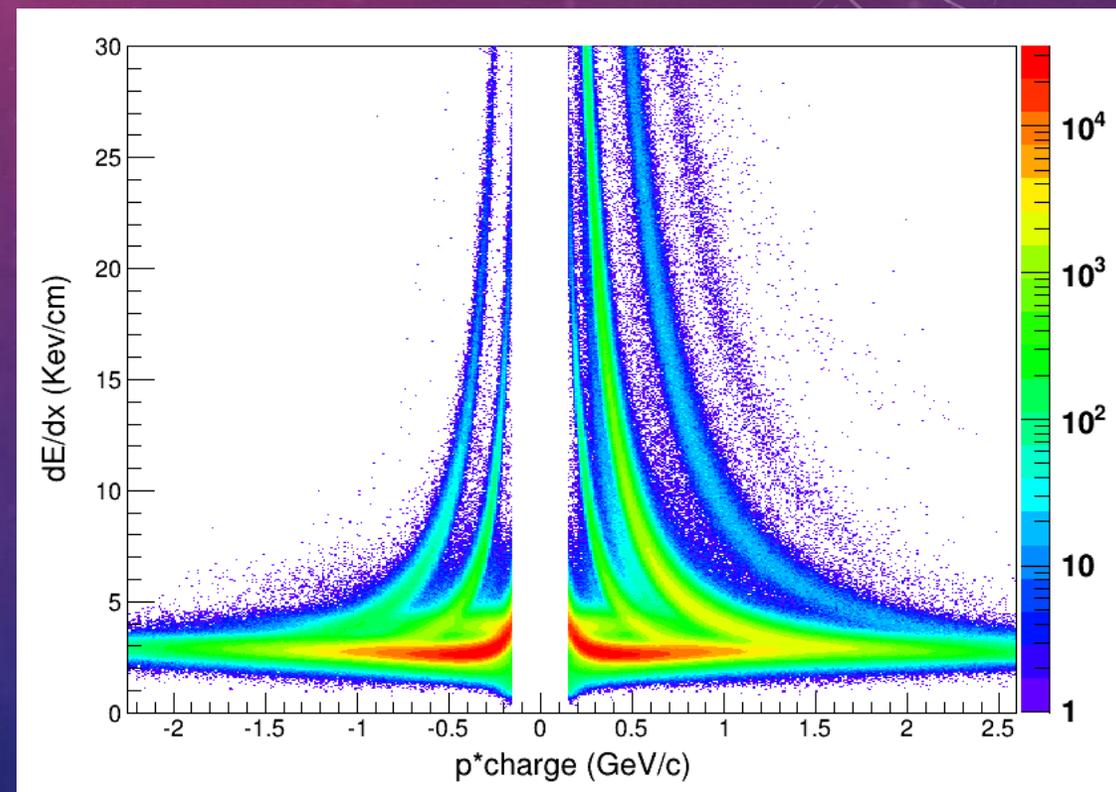
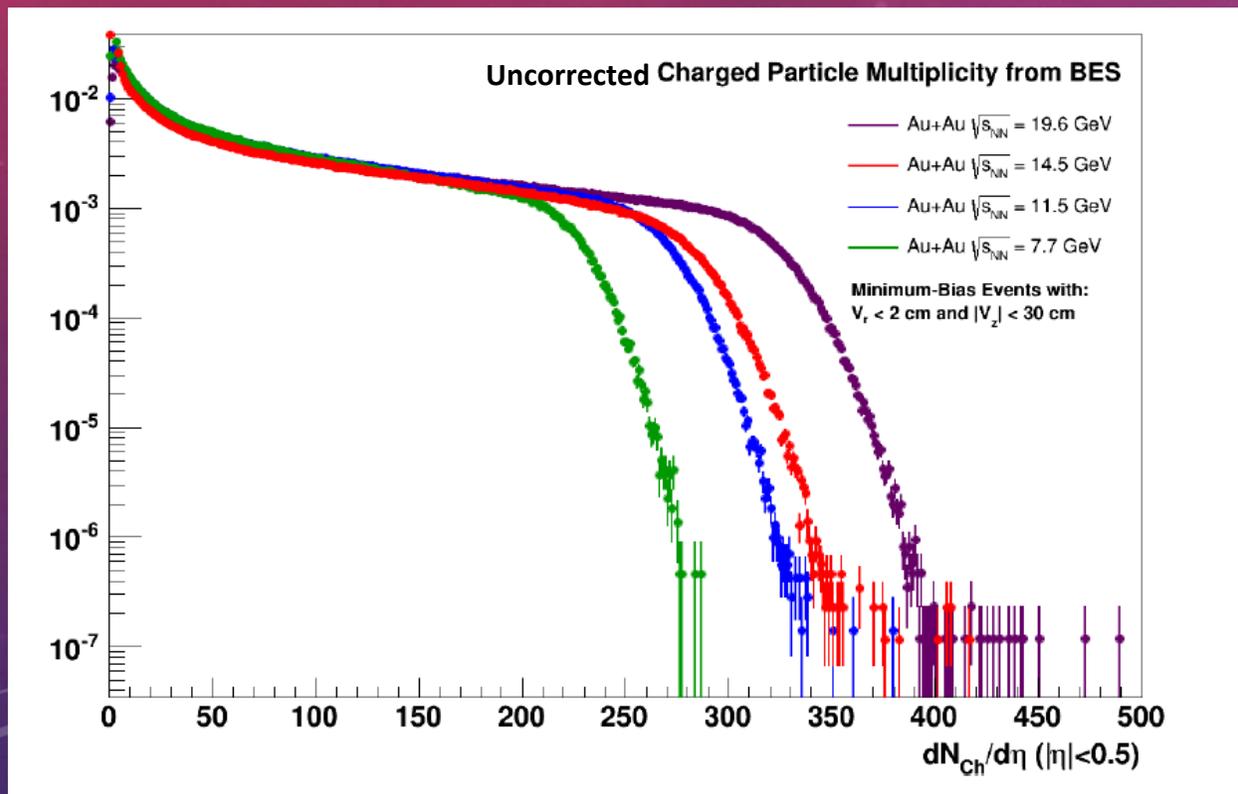
We've recorded 24 million good TPC centered events, 21 million of which are minimum bias triggers using the Vertex Position Detector.

First collisions



BASIC QA FOR 14.5 GEV

A fast production of the data (without final calibrations) was run to ensure quality and to get a look at new physics results.

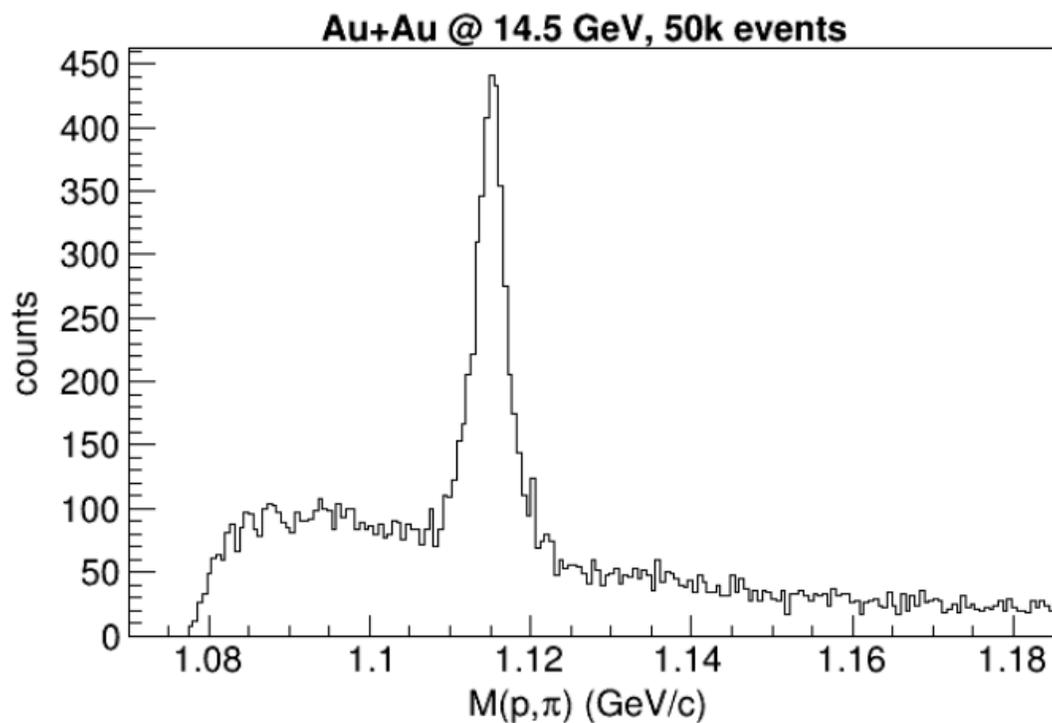




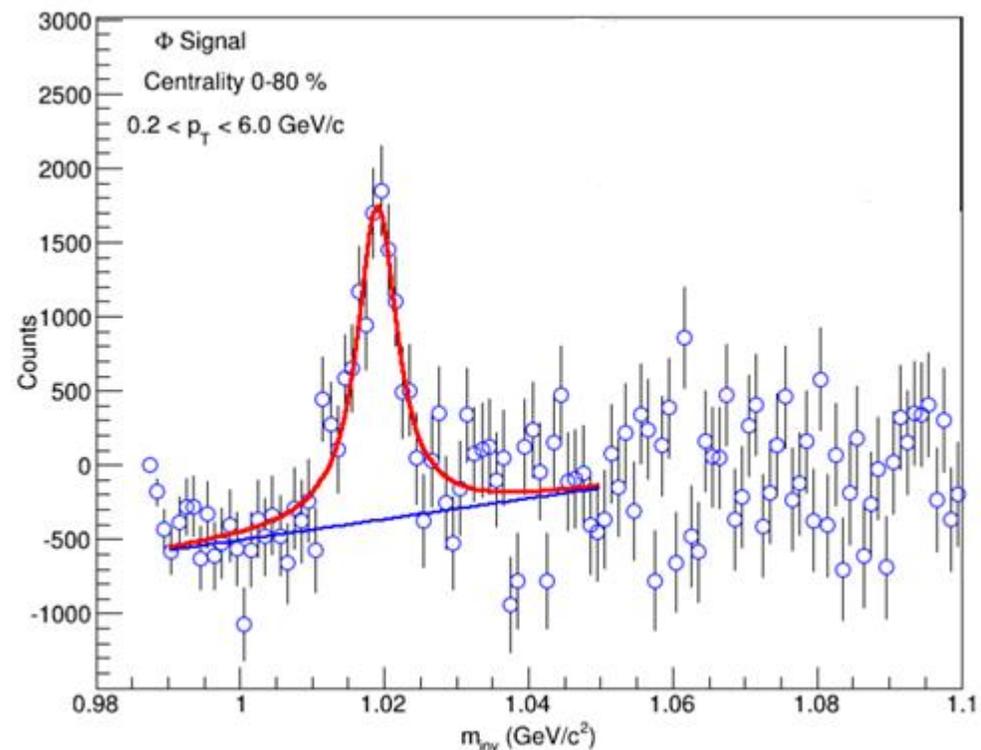
TOPOLOGICAL PID FOR 14.5 GEV

Everything has been looking great and the final production is being prepared.

Λ Signal



ϕ Signal





14.5 GEV, LOOKING FORWARD

- Current analyses are being extended to include 14.5 GeV
 - Preliminary spectra, v_2 , proton v_1 , and higher moments results already produced from a fast preview production
- Preliminary results not yet ready to show, waiting for full production of the data
 - but they're interesting...



THE BES PHASE II

- Higher statistics are needed to fully address the goals of the BES
 - Primary QGP signatures (R_{CP} , n_q scaling of ϕv_2) require large numbers of high p_T particles to evaluate
 - Critical point fluctuations via higher moment fluctuations require extremely large event numbers
 - EM probes offer a unique way to study QGP thermal radiation but intermediate mass dileptons are rare and require high event numbers



EVENTS NEEDED IN BES PHASE II

Collision Energies (GeV):		7.7	9.1	11.5	14.5	19.6
Chemical Potential (MeV):		420	370	315	260	205
Observables		Millions of Events Needed				
QGP	R_{CP} up to p_T 4.5 GeV	NA	NA	160	92	22
	Elliptic Flow of ϕ meson (v_2)	100	150	200	300	400
	Local Parity Violation (CME)	50	50	50	50	50
1 st P.T.	Directed Flow studies (v_1)	50	75	100	100	200
	asHBT (proton-proton)	35	40	50	65	80
C.P.	net-proton kurtosis ($\kappa\sigma^2$)	80	100	120	200	400
EM Probes	Dileptons	100	160	230	300	400
	Proposed Number of Events:	100	160	230	300	400



Many physics opportunities in revisiting 7.7-19.6 GeV...

but what if some of the physics
we're interested in happens
below 7.7 GeV?

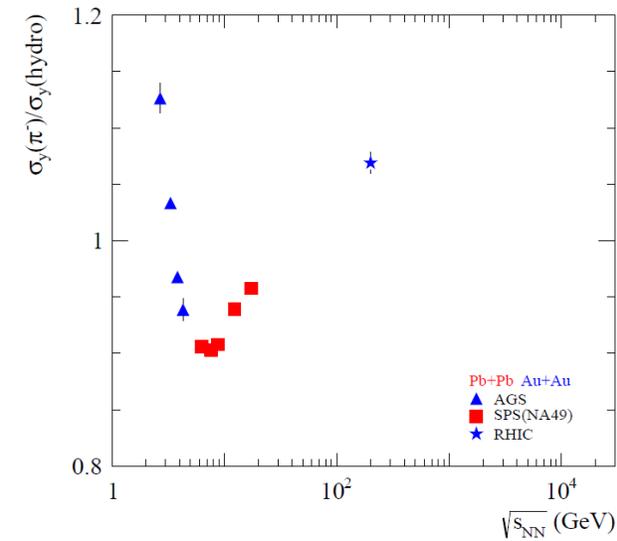
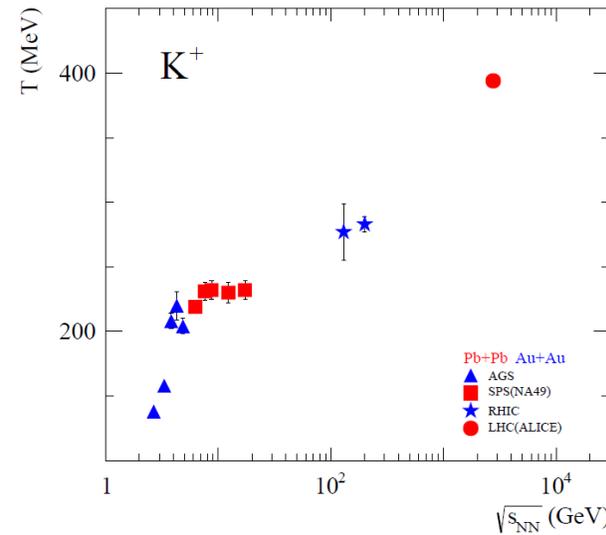
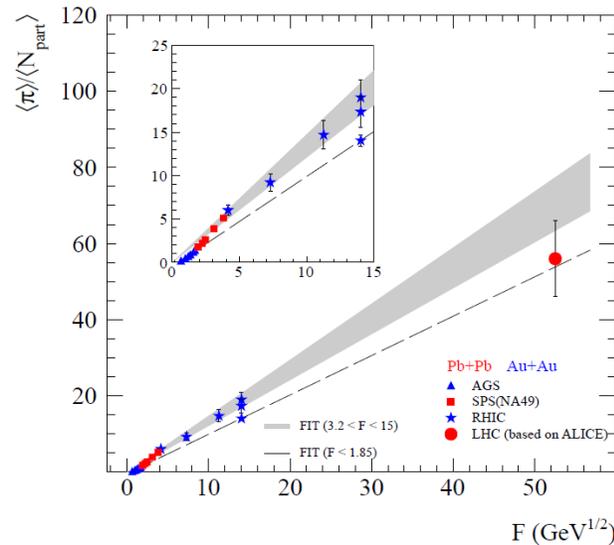
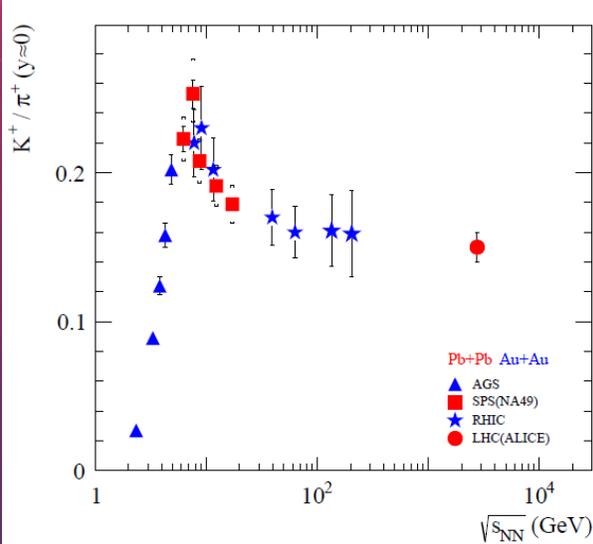


THE ONSET OF DECONFINEMENT

Claimed by NA49 to occur at 7.7 GeV.

It's crucial to measure collisions below this.

arXiv:1201.4520



The
Horn

The
Kink

The
Step

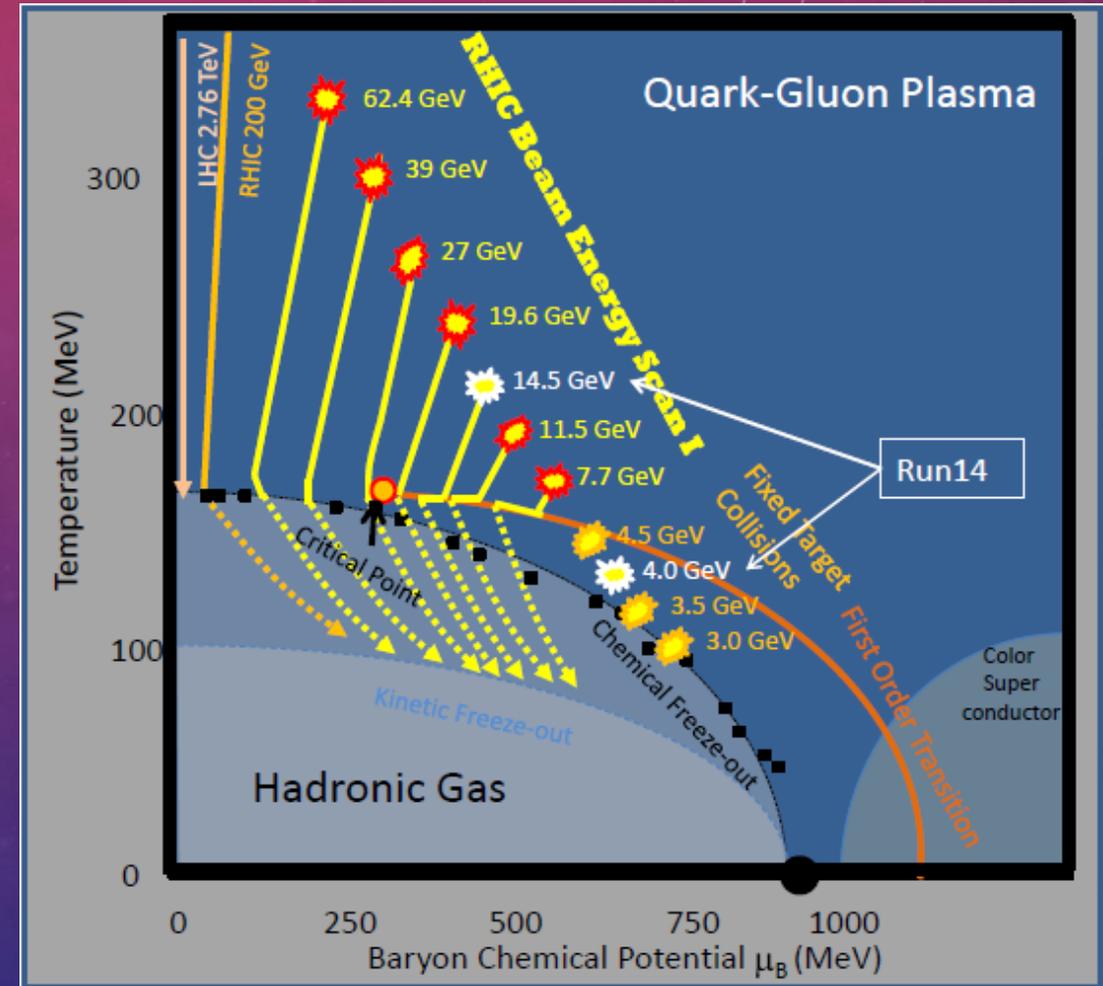
The
Dale



THE STAR FIXED TARGET PROGRAM

By inserting a gold target into the beam pipe we can produce collisions below 7.7 GeV to explore the onset of deconfinement within a single experiment.

Collision mode $\sqrt{s_{NN}}$ (GeV)	Fixed Target $\sqrt{s_{NN}}$ (GeV)	Fixed Target μ_B (MeV)	Fixed Target y_{CM}
7.7	3.0	720	1.05
11.5	3.5	670	1.25
14.5	3.9	633	1.37
19.6	4.5	585	1.52



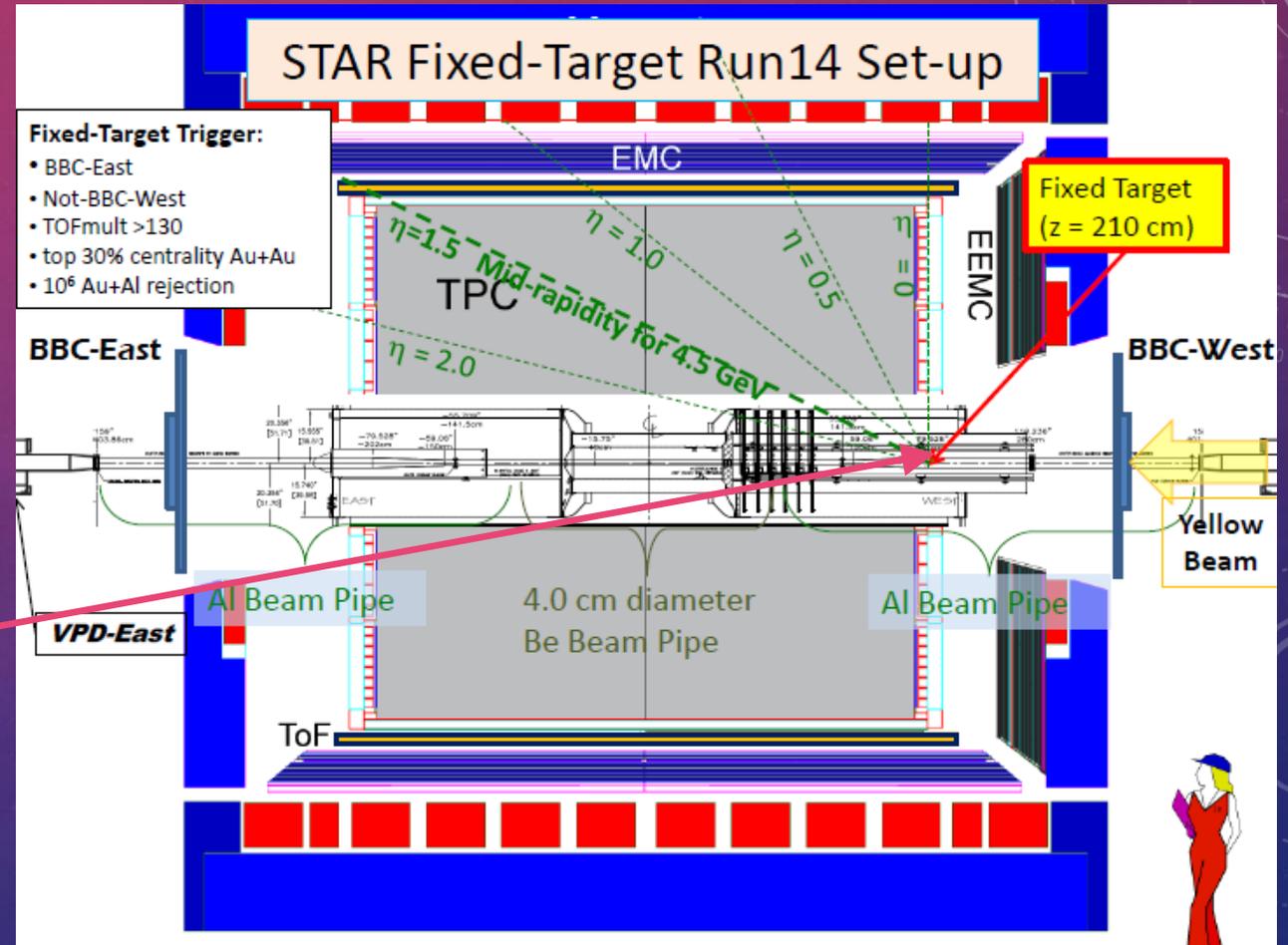
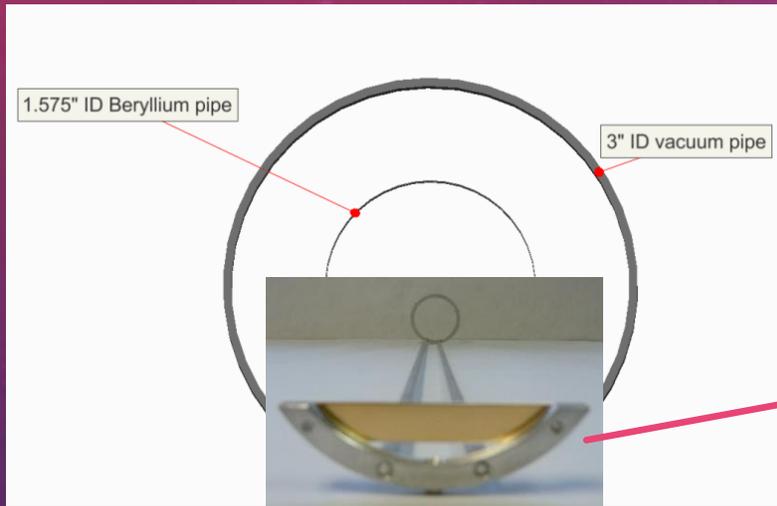
[Daniel Cebra](#)

Run in parallel to the BES collision energies. Low impact to that program.



THE TARGET IS IN PLACE

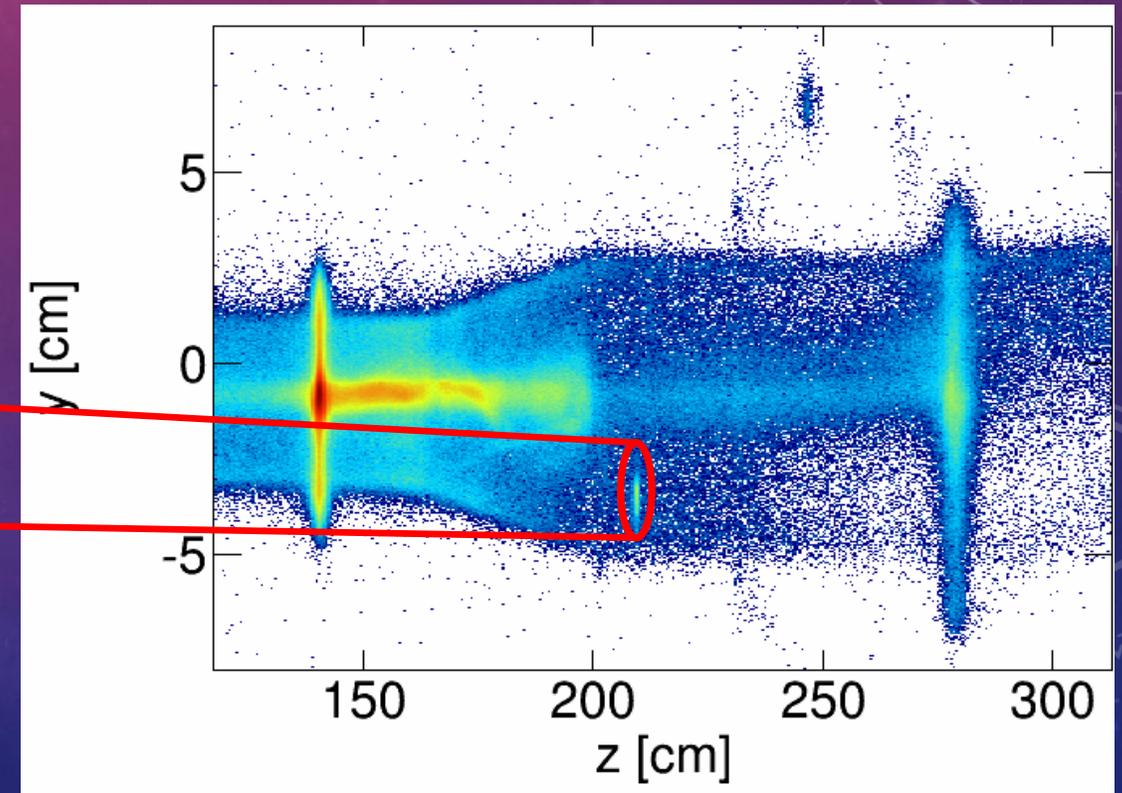
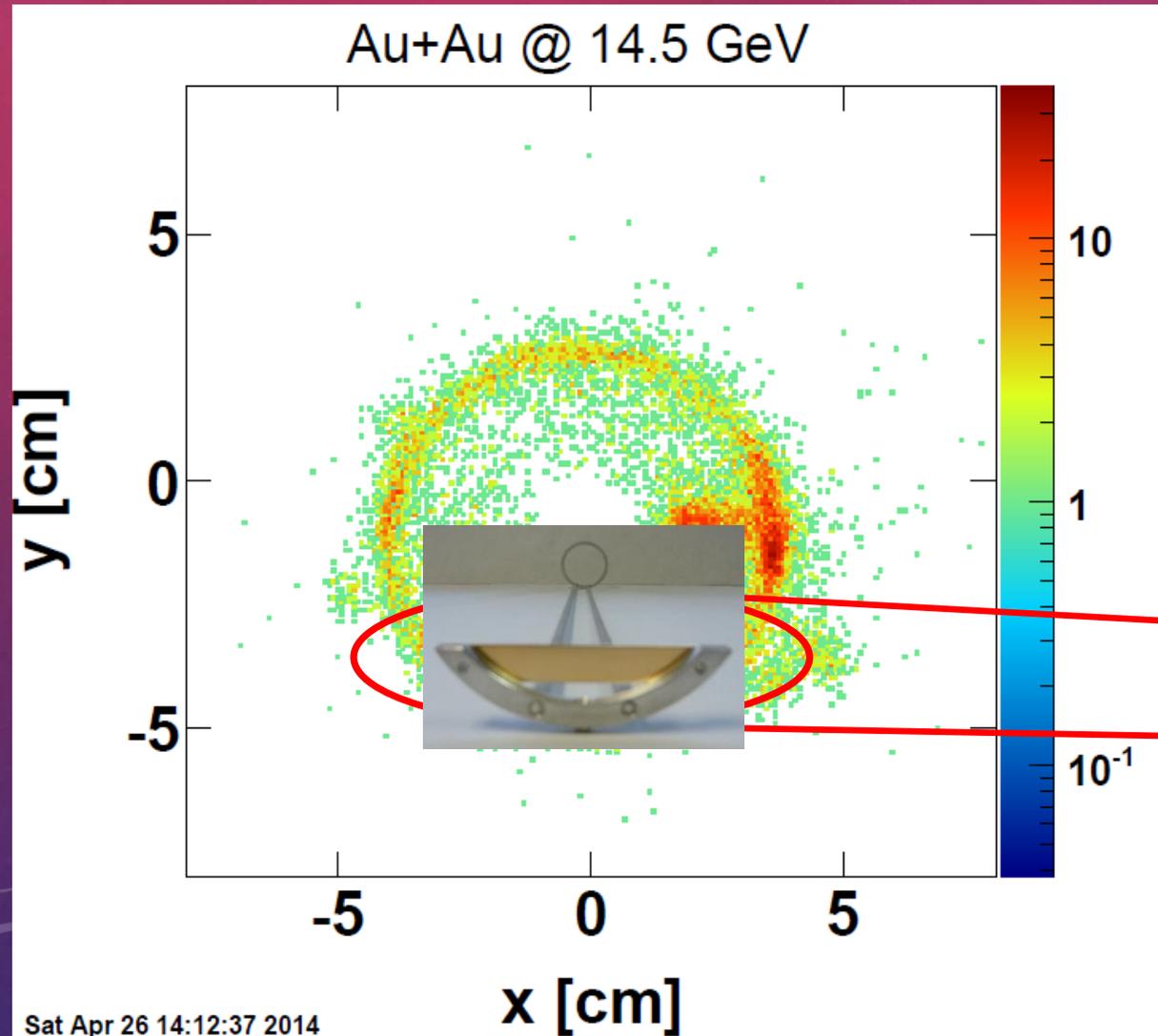
The gold target has already been in the beam pipe for Run 14.





AU+AU COLLISIONS HAVE BEEN RECORDED

~50k 3.9 GeV Au+Au events during Run 14.

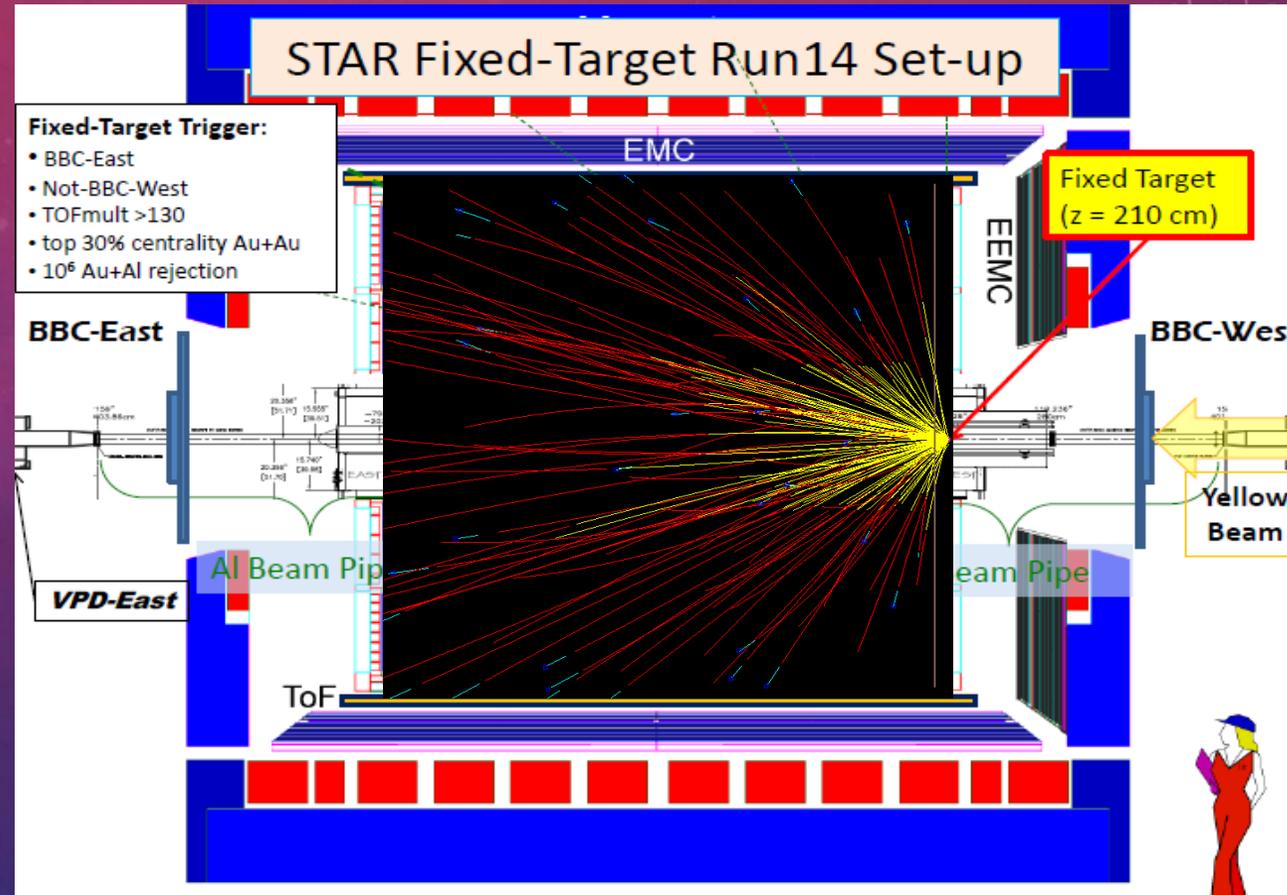




PHYSICS ANALYSES ARE PLANNED

Tracking and PID look good.

With 50k events, spectra analyses are possible (the dale?).





CONCLUSIONS

- Many interesting STAR results have come out of the BES-I
 - Softest point in the equation of state around 11.5-19.6 GeV
 - Signs of deconfinement down to at least 27 GeV
 - Possibly suggestive evidence of critical fluctuations
- The BES Phase II will make new physics accessible, particularly at the lowest collision energies
 - High p_T probes, higher moment fluctuations, dileptons, ϕ v_2 , etc
- The fixed target program will add additional collision energies: 3.0, 3.5, 3.9, and 4.5 GeV
 - Extends the μ_B reach of the scan to 720 MeV
 - Allows us to evaluate the possibility of the onset of deconfinement at 7.7 GeV