Experimental results from STAR

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Contents

- Collective flow and jet correlations
- Vortical, chiral magnetic fluid
- Critical fluctuations
- Beam energy scan II

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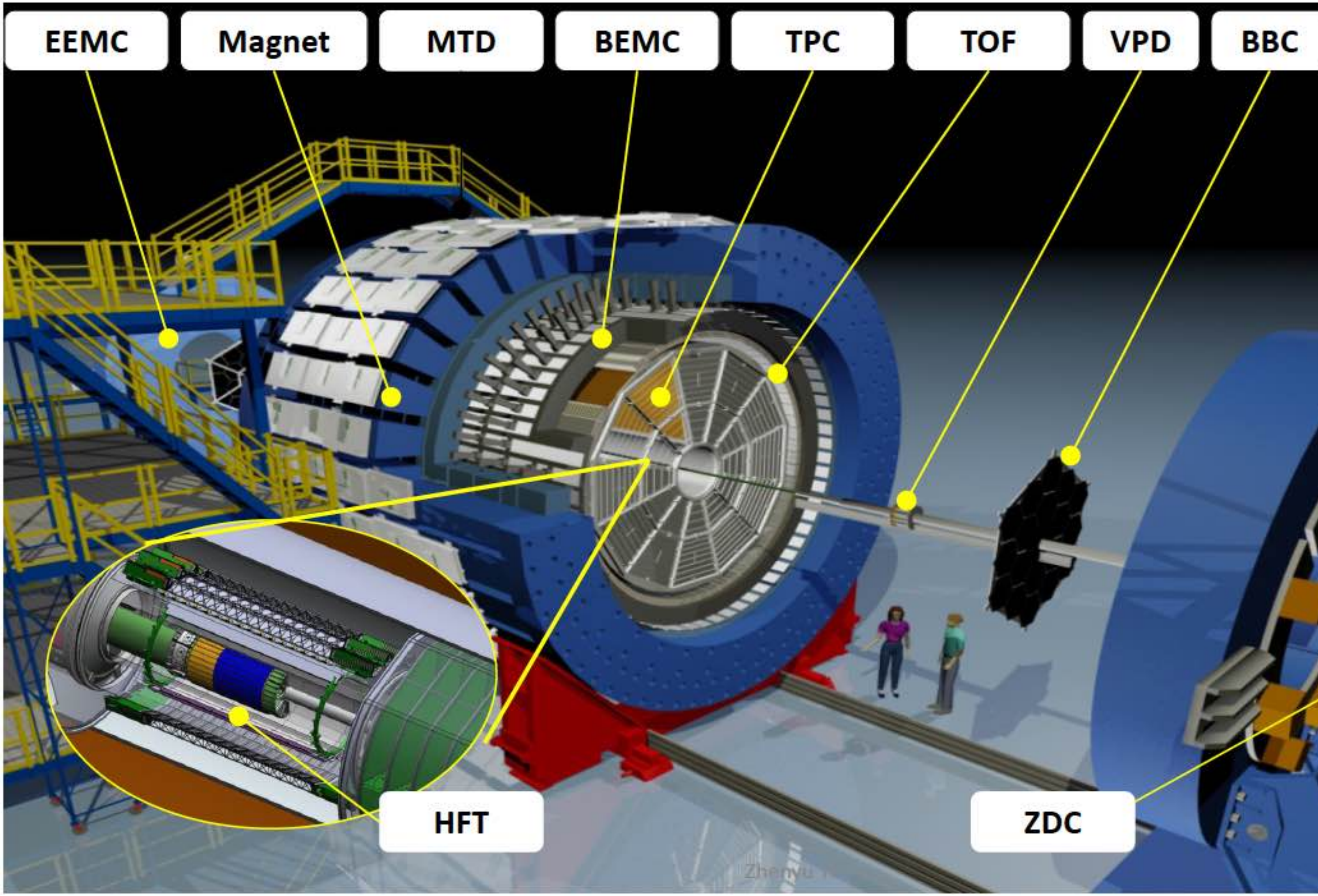
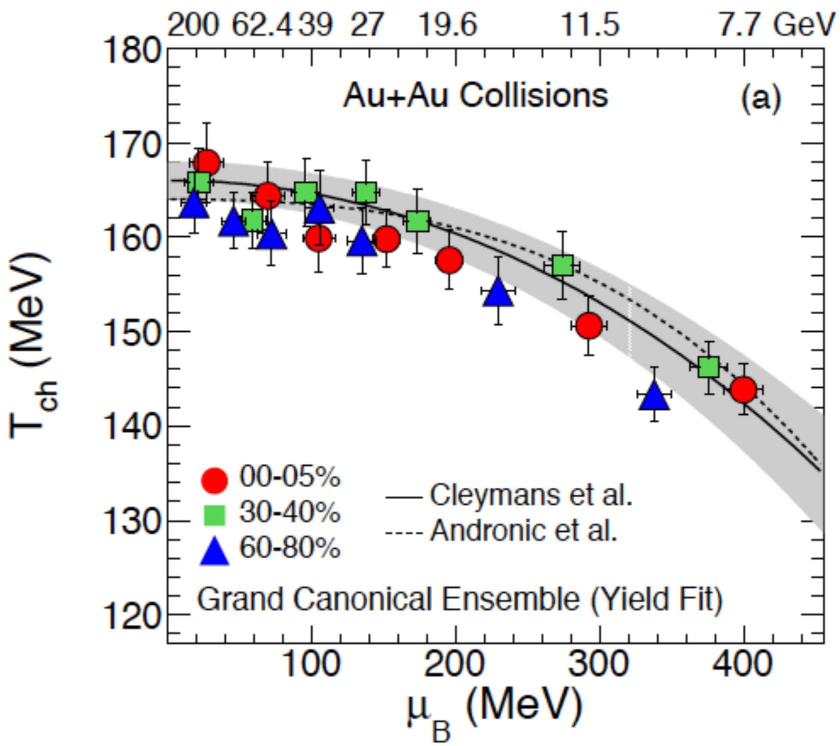
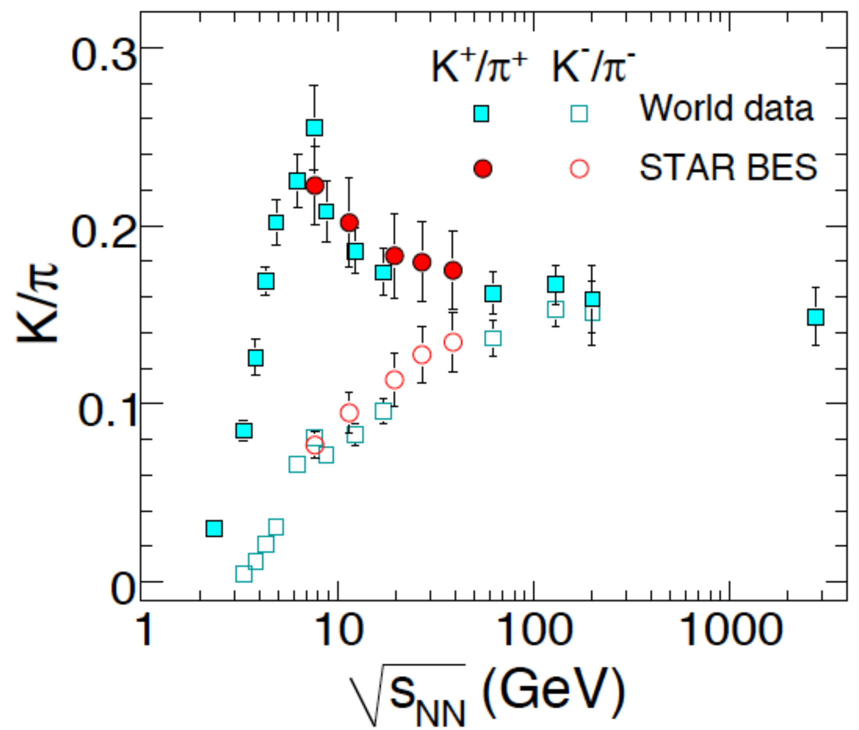
The STAR experimental setup



Chemical freeze-out and Baryon density



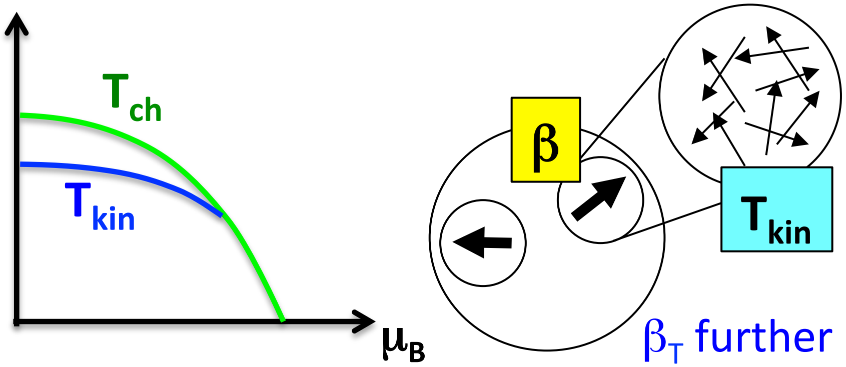
STAR, Phys. Rev. C **96** (2017) 44904



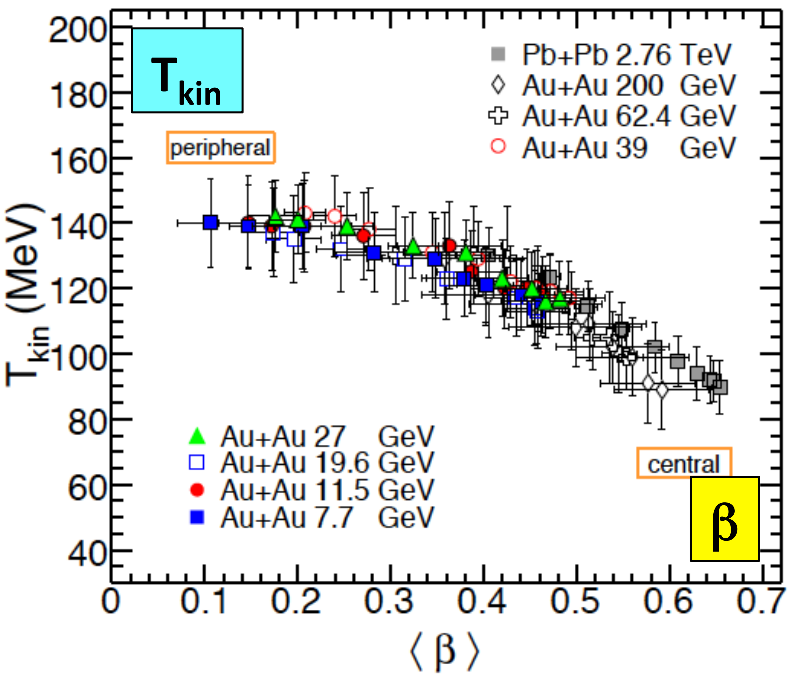
Baryon density increases with decreasing beam energy.

Baryon density is also known to have a peak at about 8 GeV based on transport models.

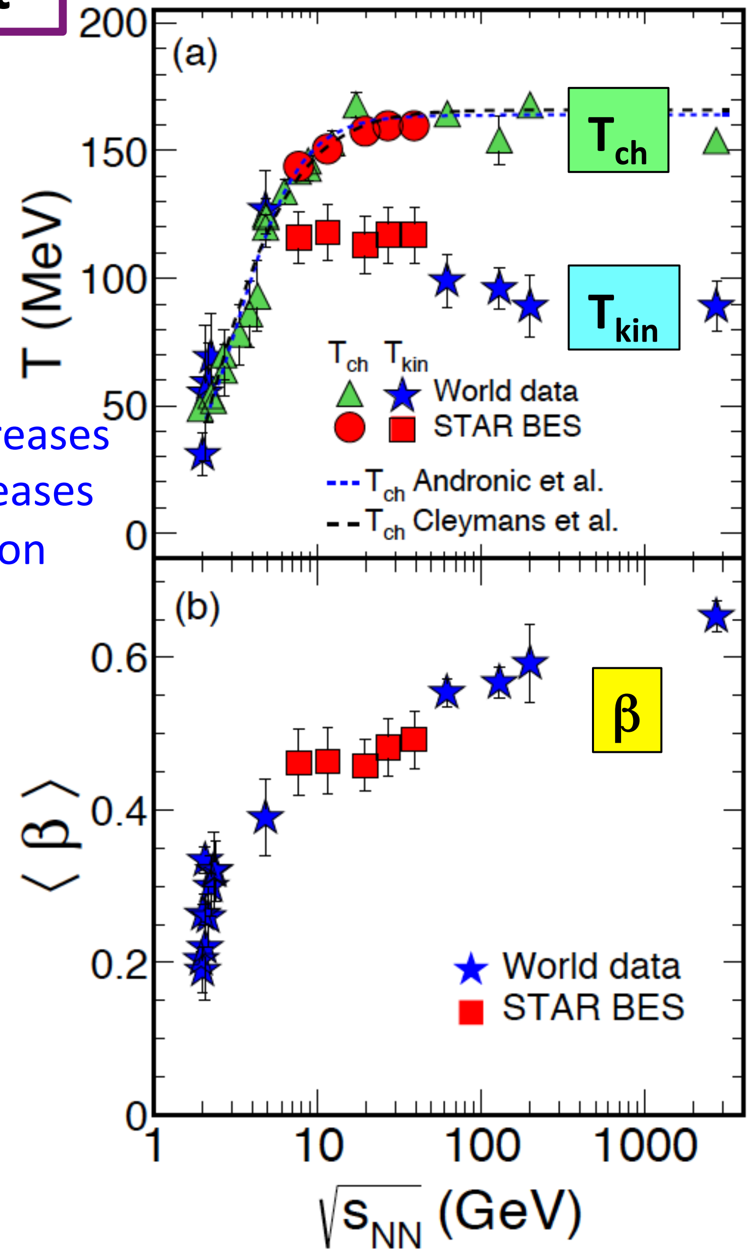
Blast-wave fit at kinetic freeze-out



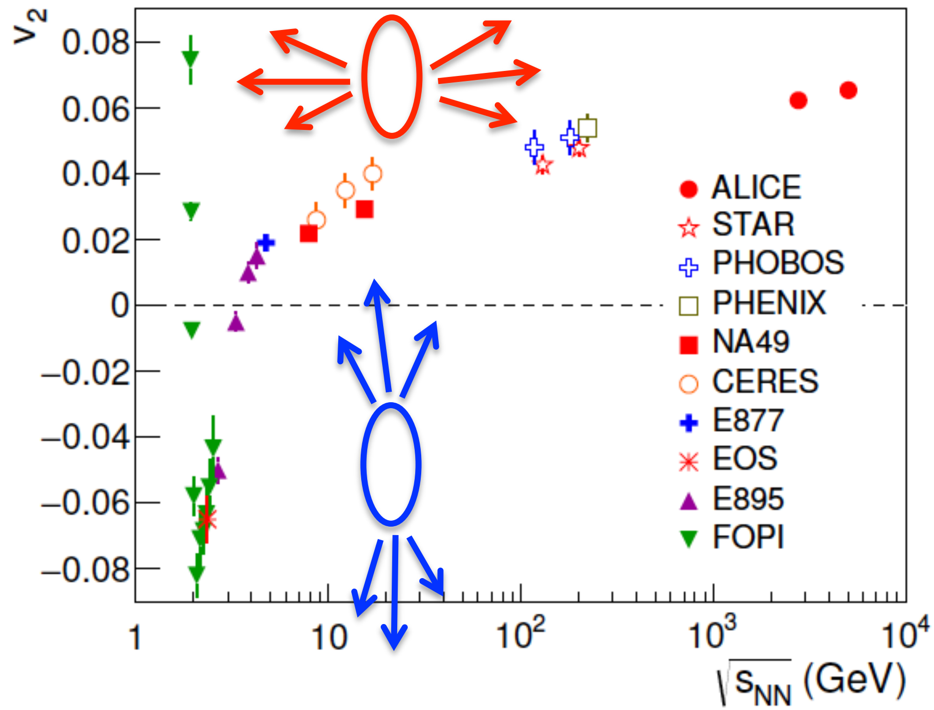
β_T further increases and T_{kin} decreases by expansion



STAR, Phys. Rev. C 96 (2017) 44904

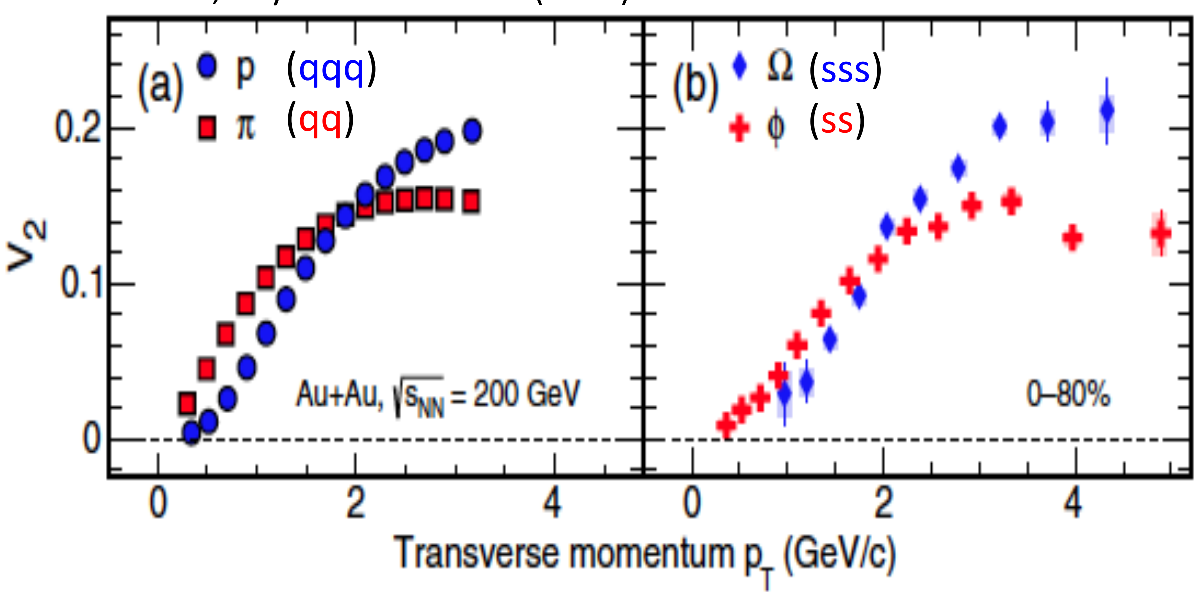


v_2 evolution with beam energy and quark coalescence

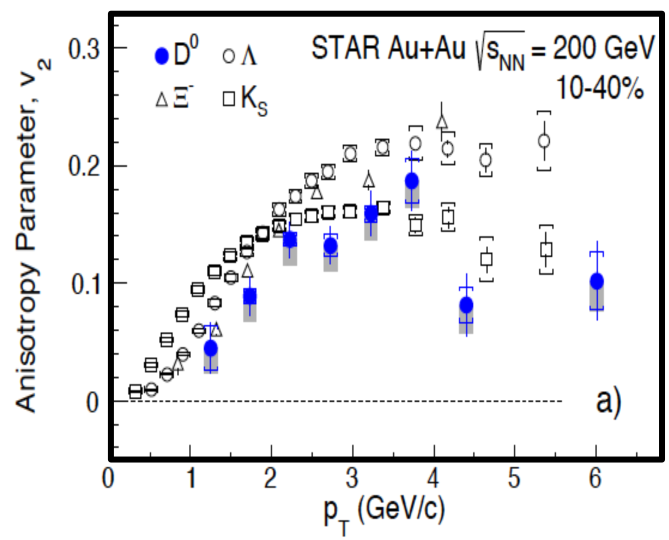


- Squeeze-out and sign change
- Mass splitting from hydro expansion
- Number of constituent quark scaling

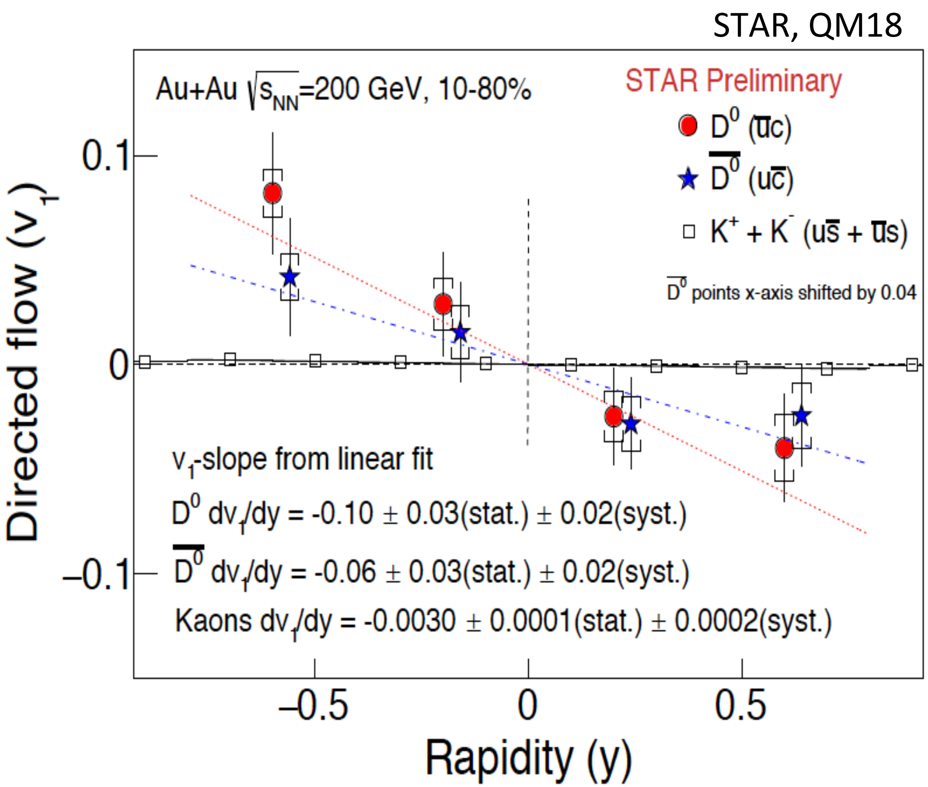
STAR, Phys. Rev. Lett. 116 (2016) 062301

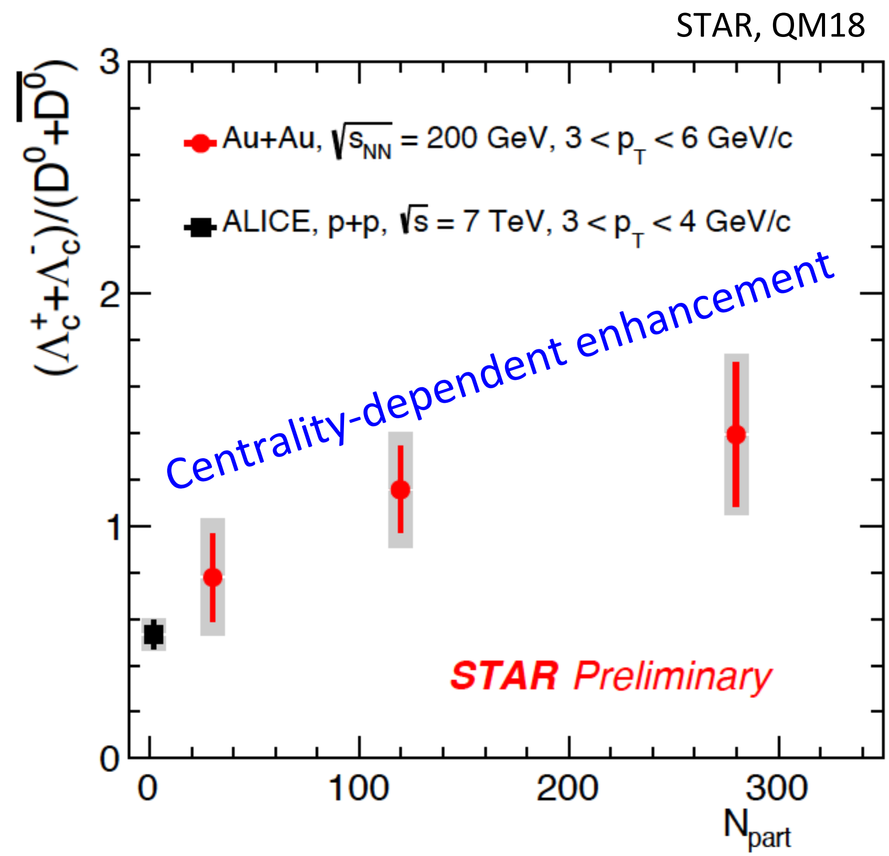


STAR, Phys. Rev. Lett. 118 (2017) 212301



Large directed flow of open charm and Λ_c enhancement

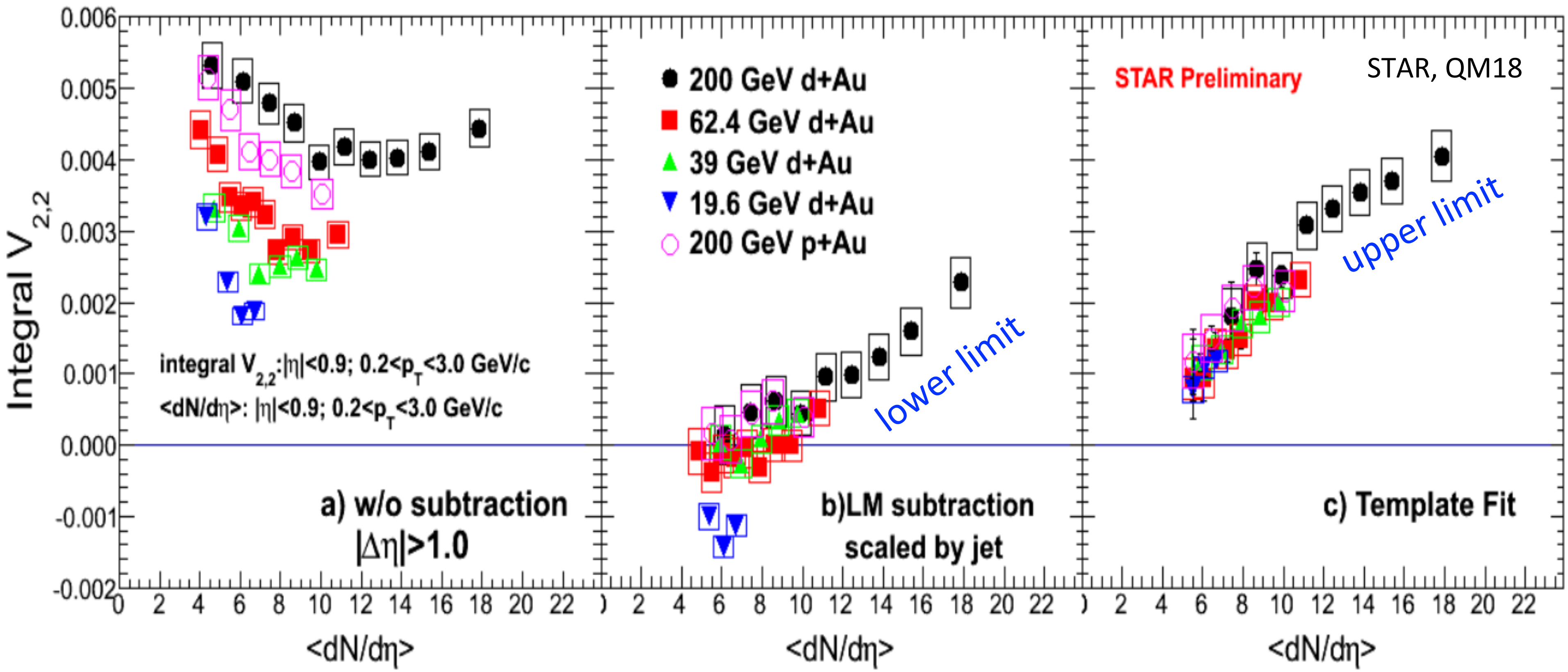




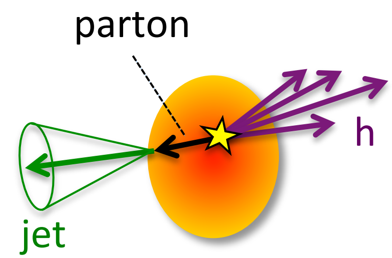
much larger slope (dv_1/dy) than other particles

Elliptic flow extraction in small system

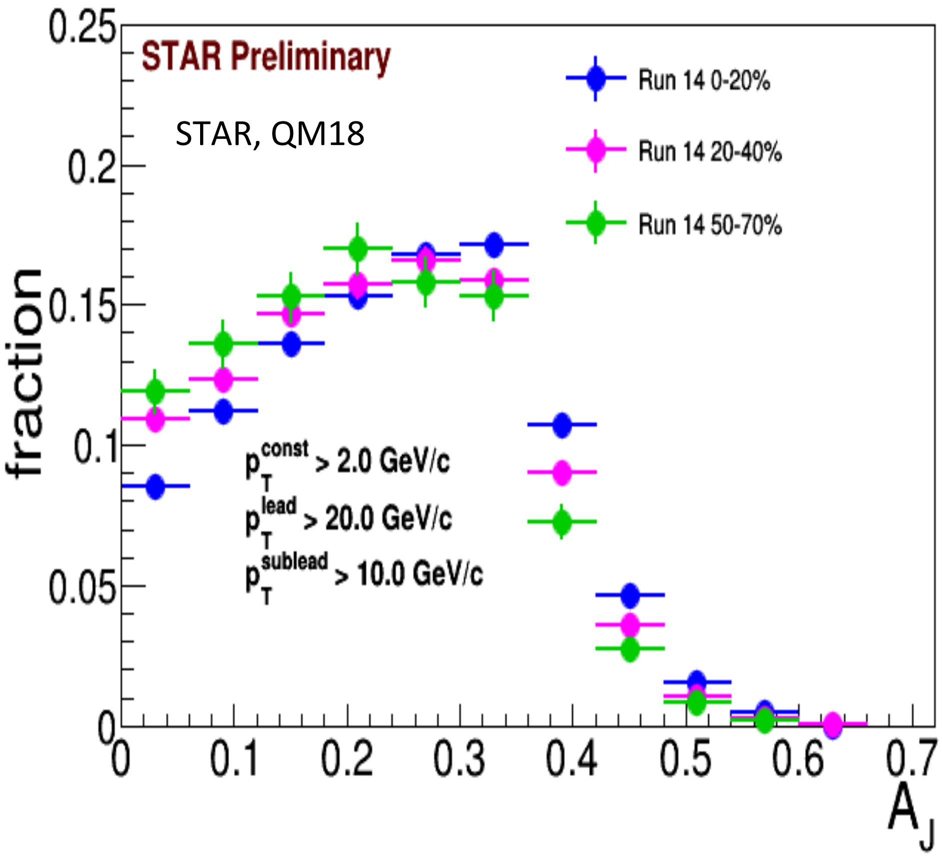
Beam energy scan with d+Au collisions at RHIC, Multiplicity- (initial density-) dependent elliptic flow is observed in small systems with two extreme non-flow subtractions.



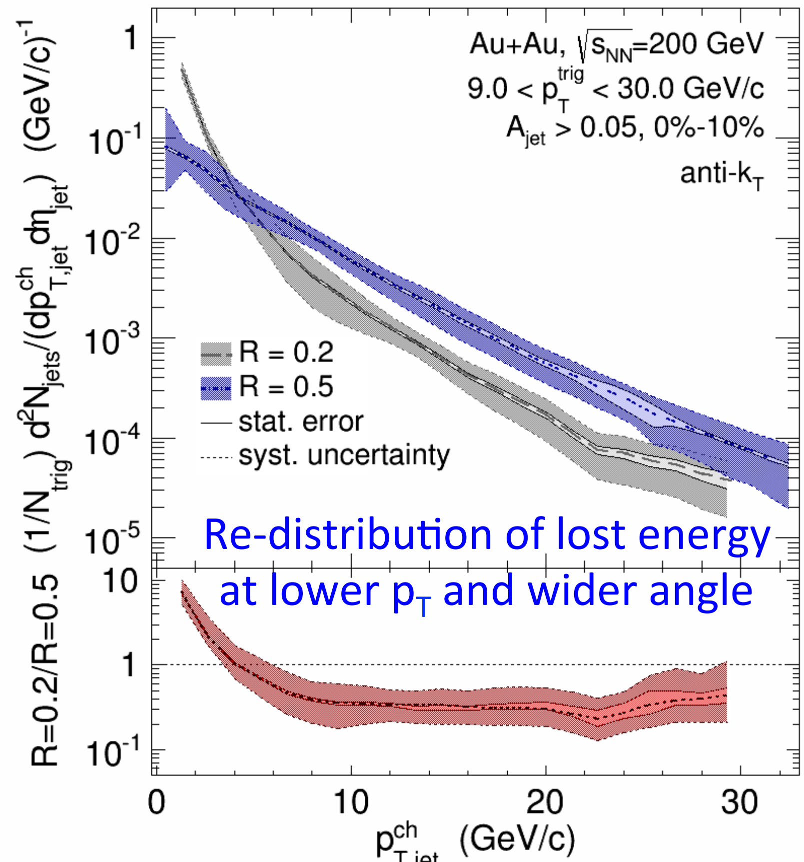
Di-jet asymmetry and hadron-jet spectra



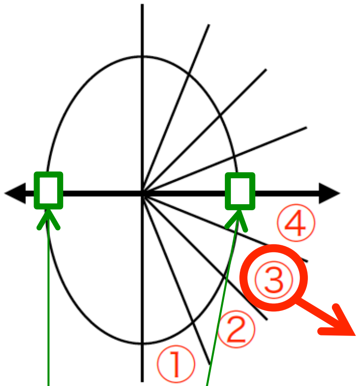
Centrality dependence of A_j at RHIC

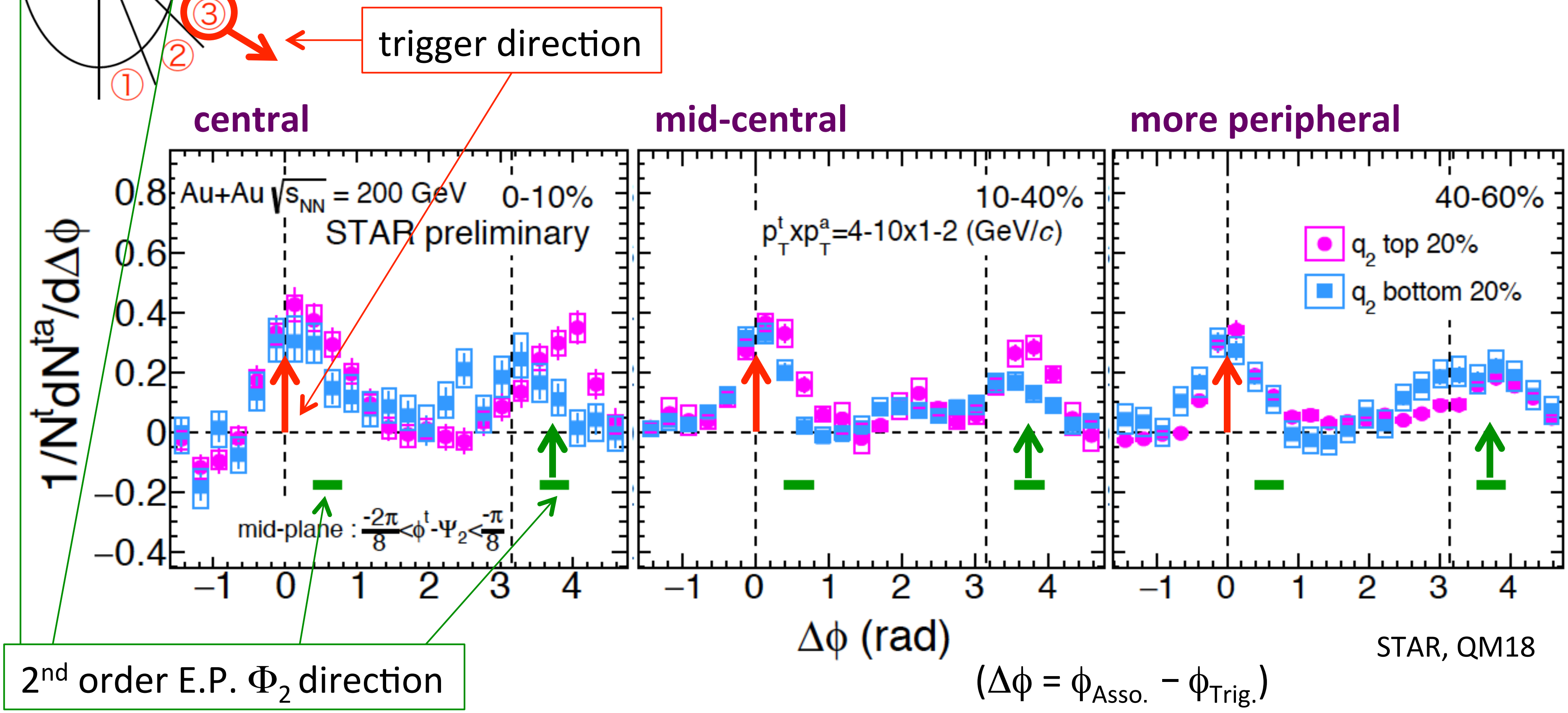


STAR, PRC 96 (2017) 24905



Jet quenching/modification and relation with v_2



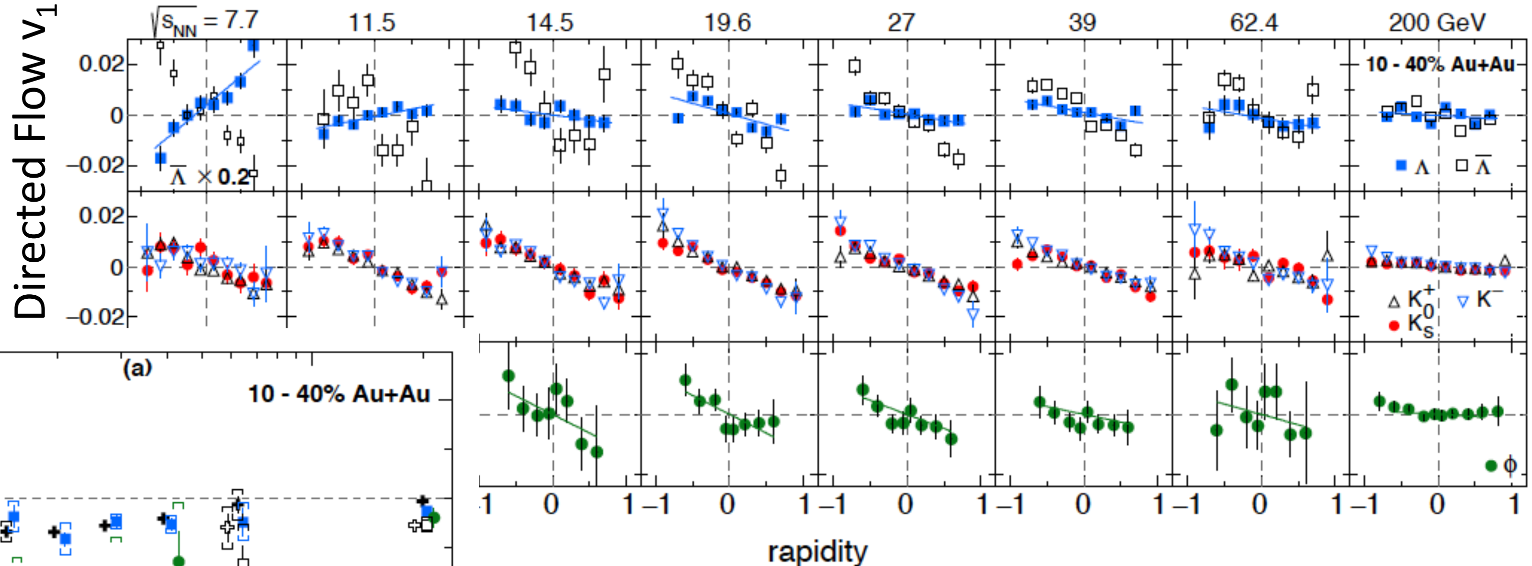


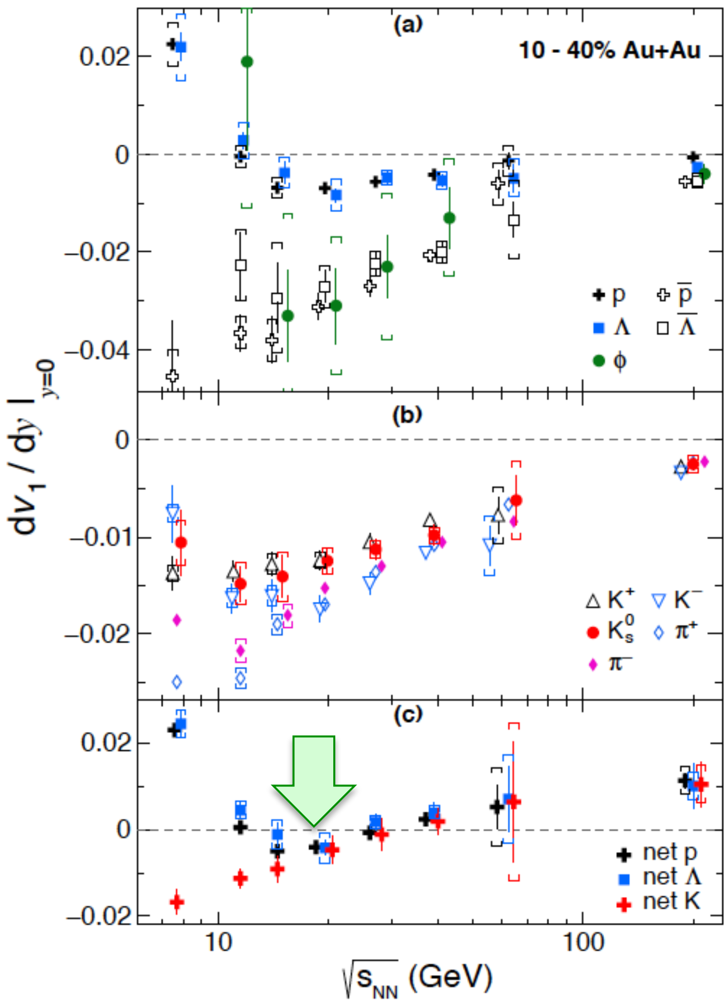
Event Shape Engineering cut is applied

Large q_2 selection -> **Large v_2 event** for a given centrality

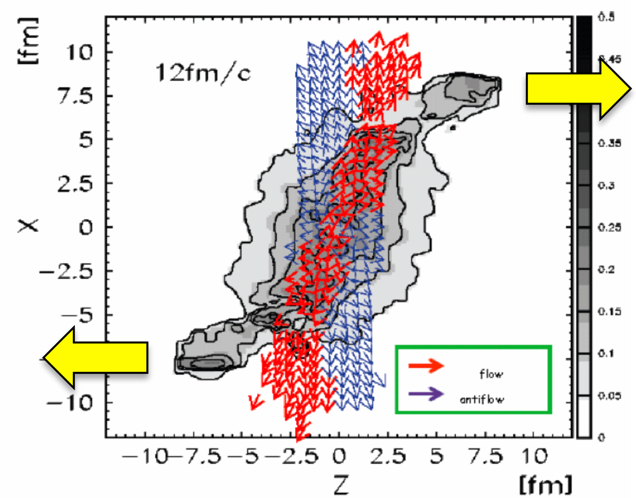
- Jet shape is modified by v_2
- v_2 is affected by jet

STAR, PRL **120** (2018) 62301





Directed flow v_1 and its slope with respect to rapidity

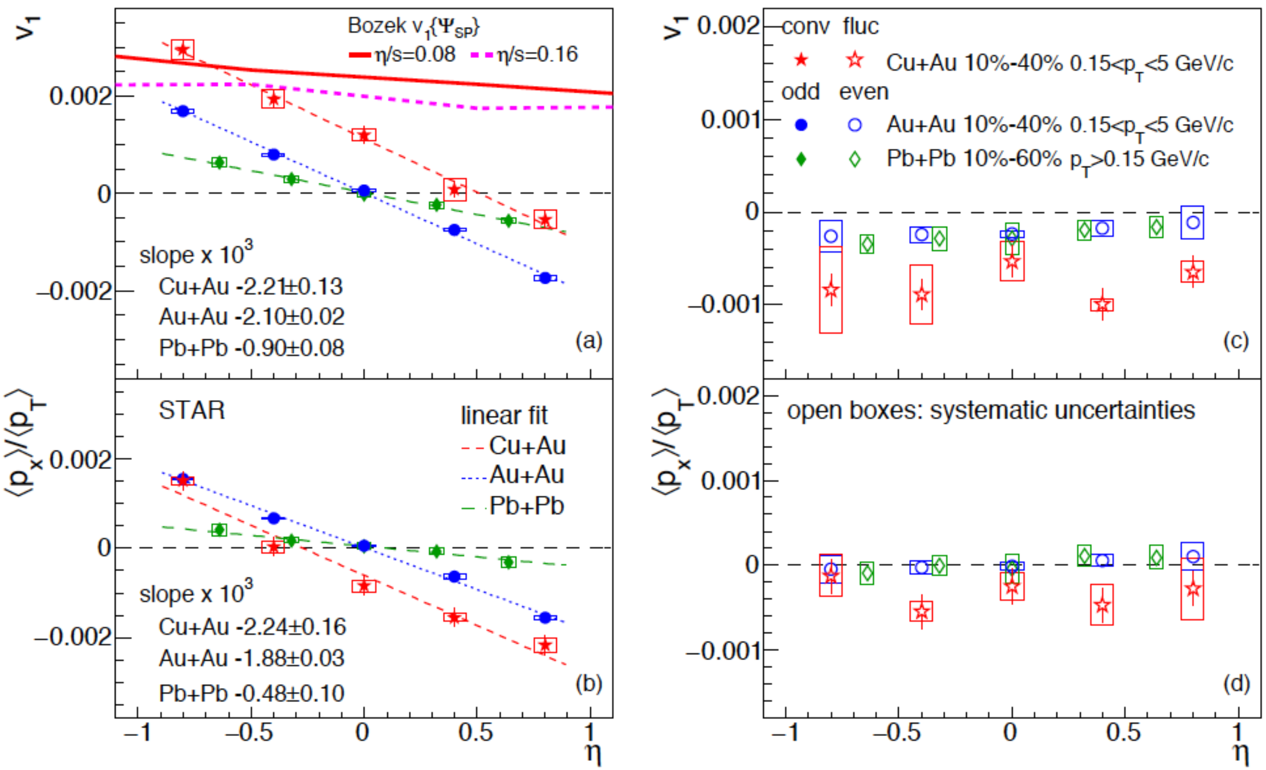


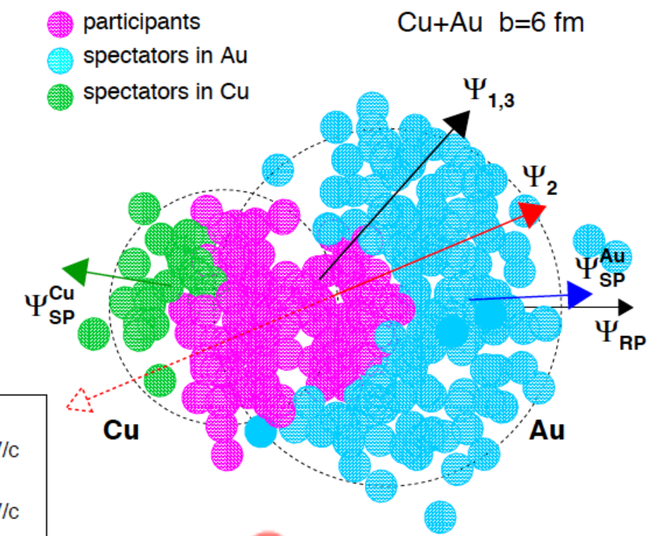
J. Brachmann et al., PRC 61, 24909 (2000).

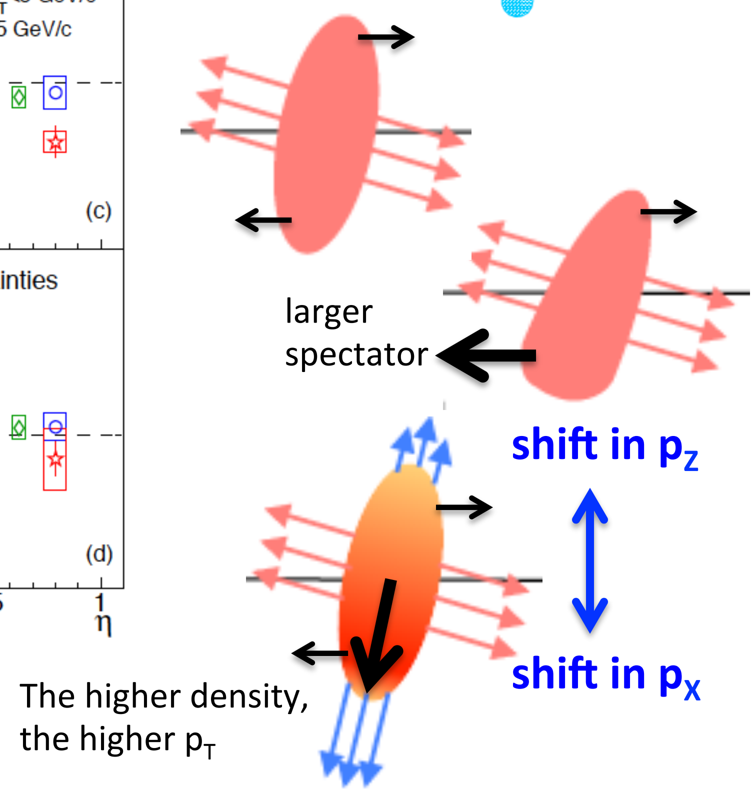
- Density
- Pressure
- E.O.S.

Directed flow v_1 in asymmetric system Cu+Au

STAR, Phys. Rev. C 98 (2018) 14915

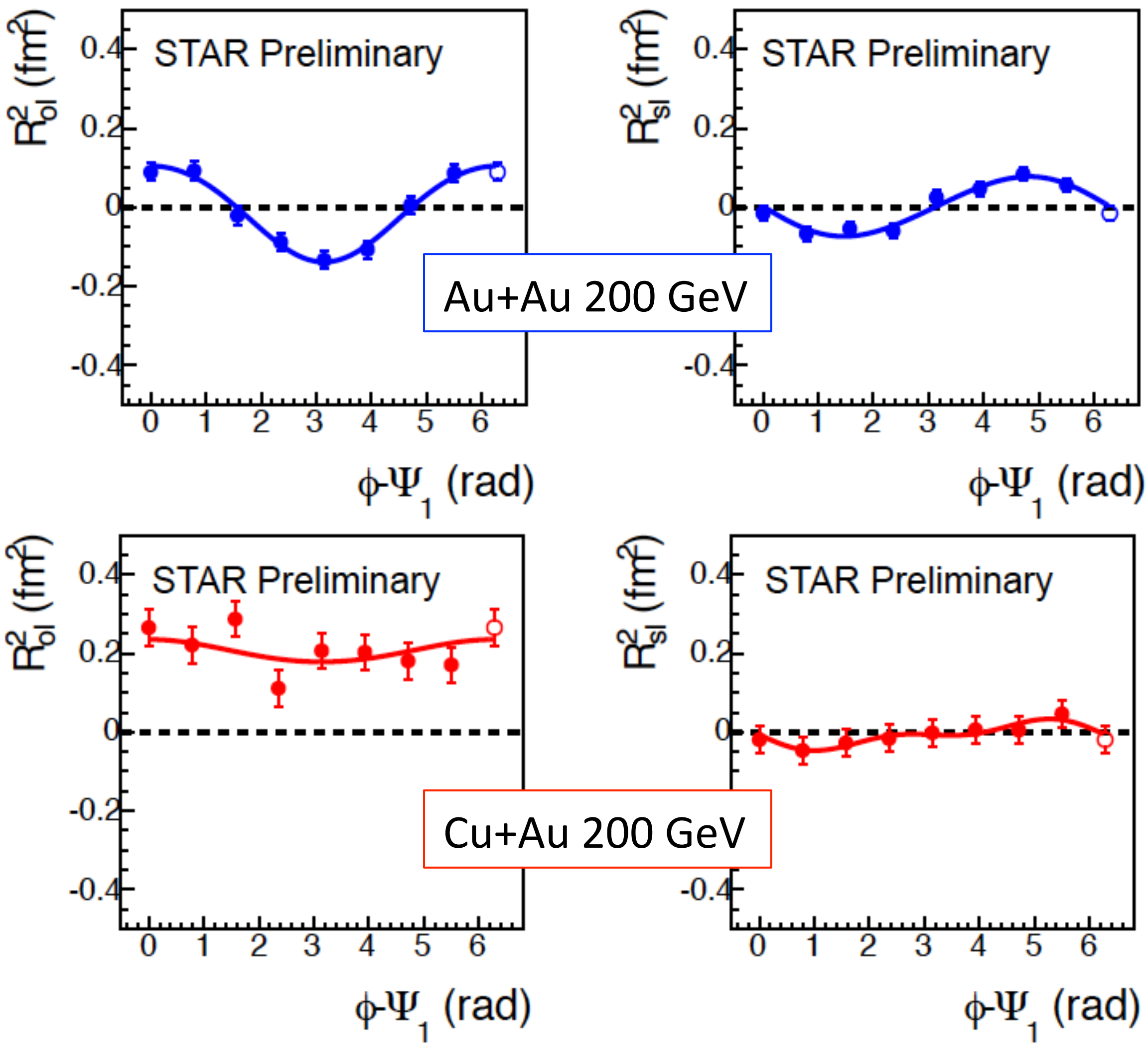




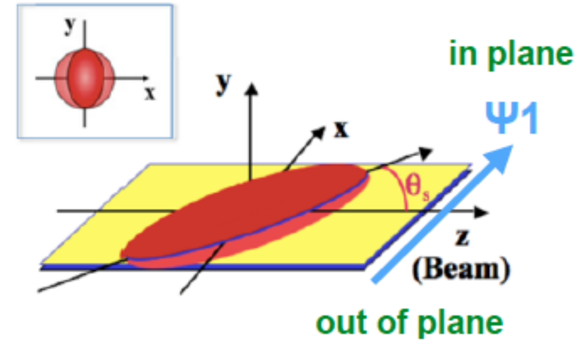


Source tilt via HBT w.r.t. Φ_1 plane

STAR, APS/JPS 2018



M A Lisa et al. New J. Phys. 13 (2011) 065006



$|\eta| < 1$
Centrality 10 - 50 %
$0.15 < k_T < 0.6$ GeV/c
$\pi^+\pi^+$ and $\pi^-\pi^-$ combined

note : E.P. resolution correction has not yet been applied for both data sets. (σ_{EP} : 0.2-0.3)

Positive tilt, which is expected to be much smaller than earlier AGS data

Global polarization via Lambda decay

#38

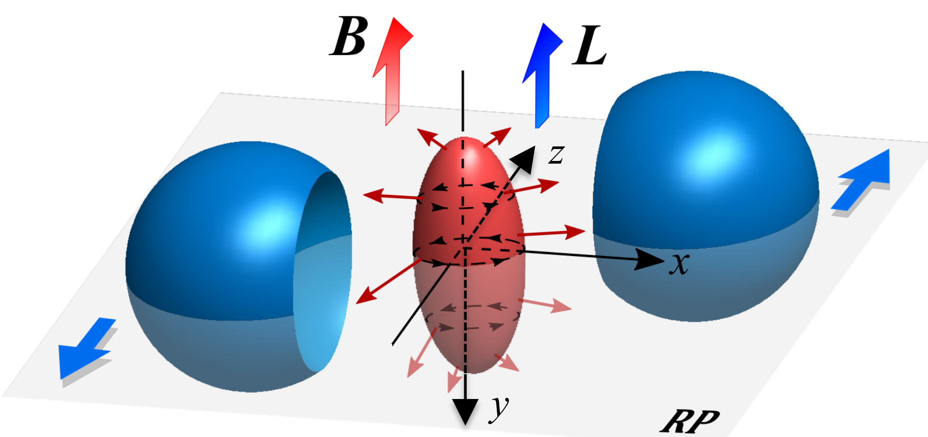
The Fastest Fluid

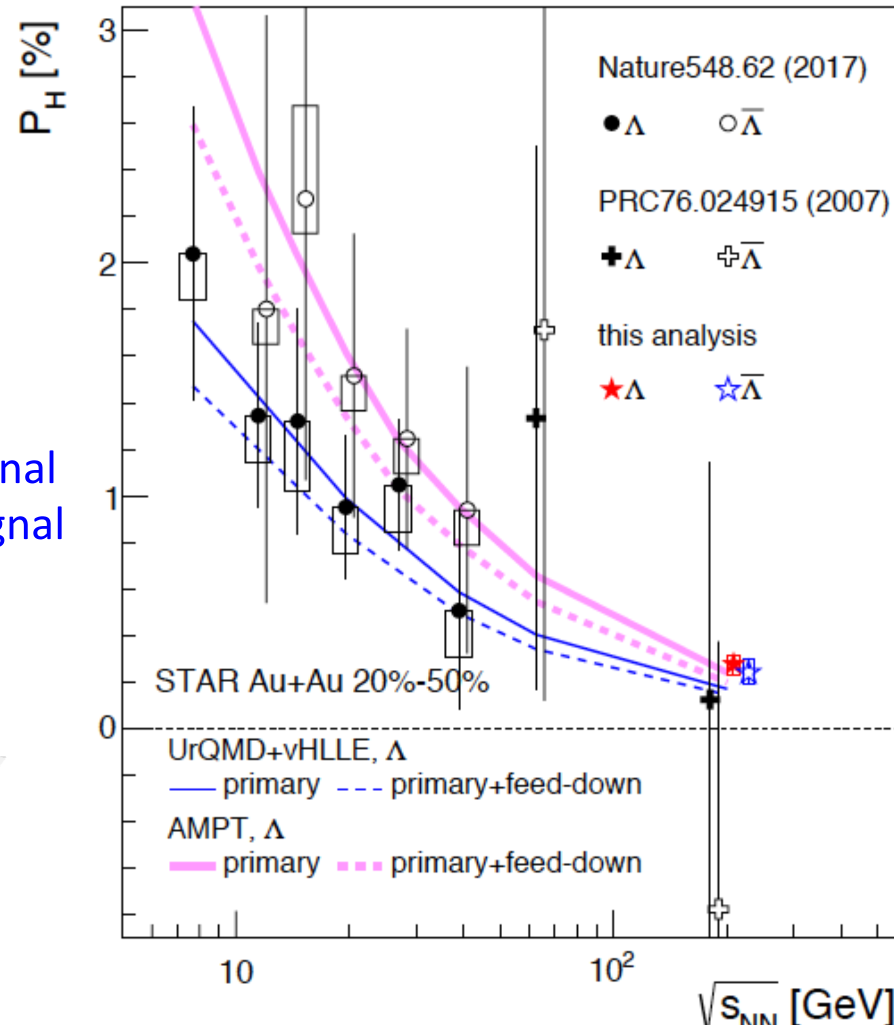
by Sylvia Morrow

Superhot material spins at an incredible rate.

Clearly positive **L** signal

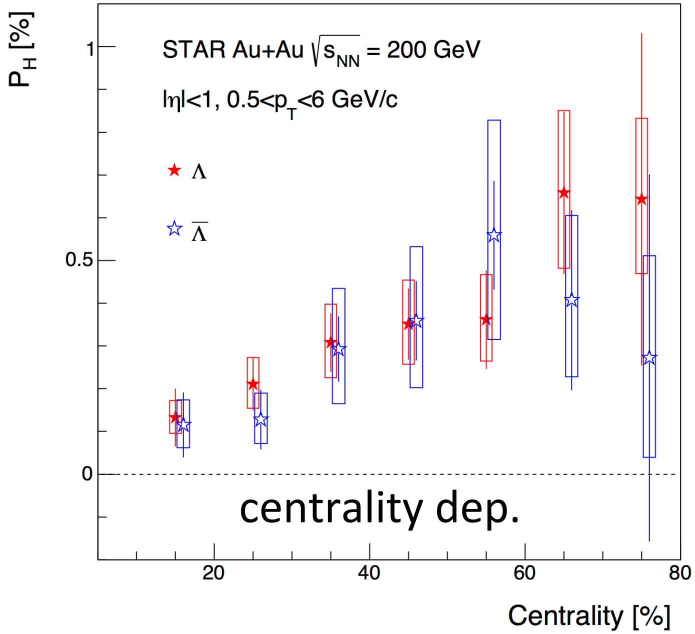
Possible hint of **B** signal





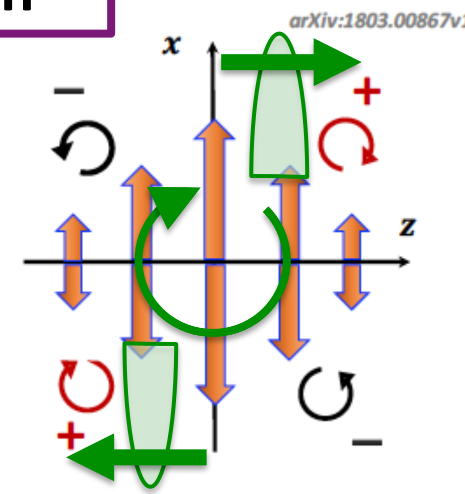
STAR, Phys. Rev. C 98 (2018) 14910

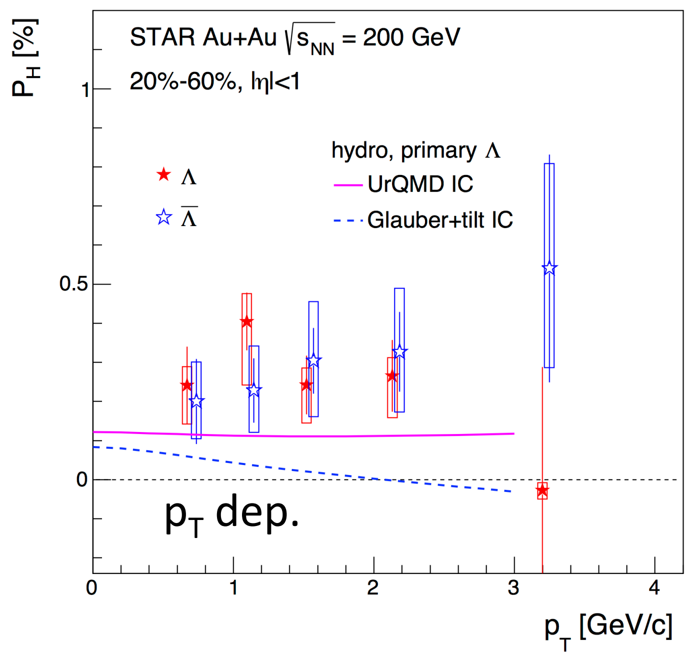
STAR, Phys. Rev. C 98 (2018) 14910

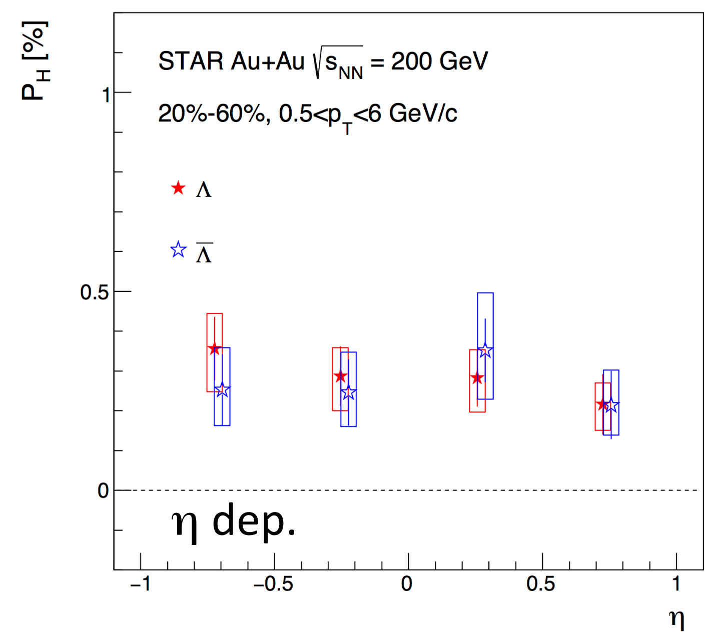


Lambda polarization

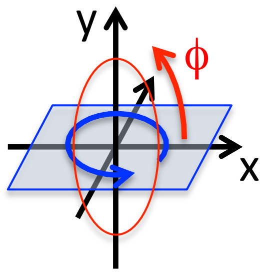
- Strong centrality dependence
- No significant p_T and η dependence



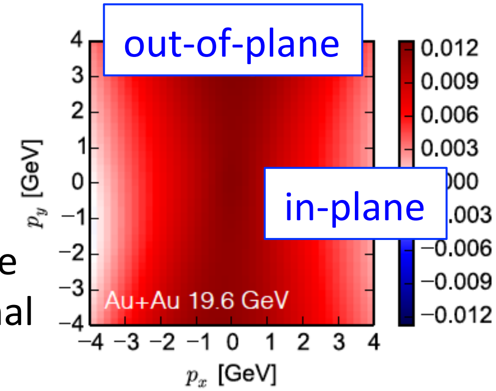




Lambda polarization



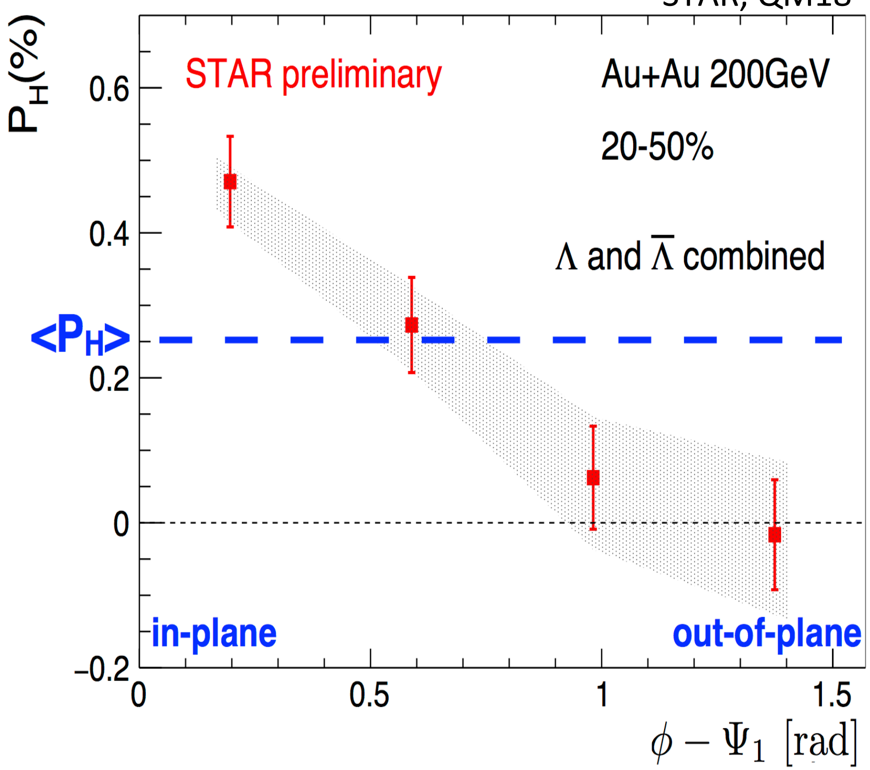
Hydrodynamics predicts opposite trend in azimuthal dependence.



$$A_{ch} = \frac{N_+ - N_-}{N_+ + N_-}$$

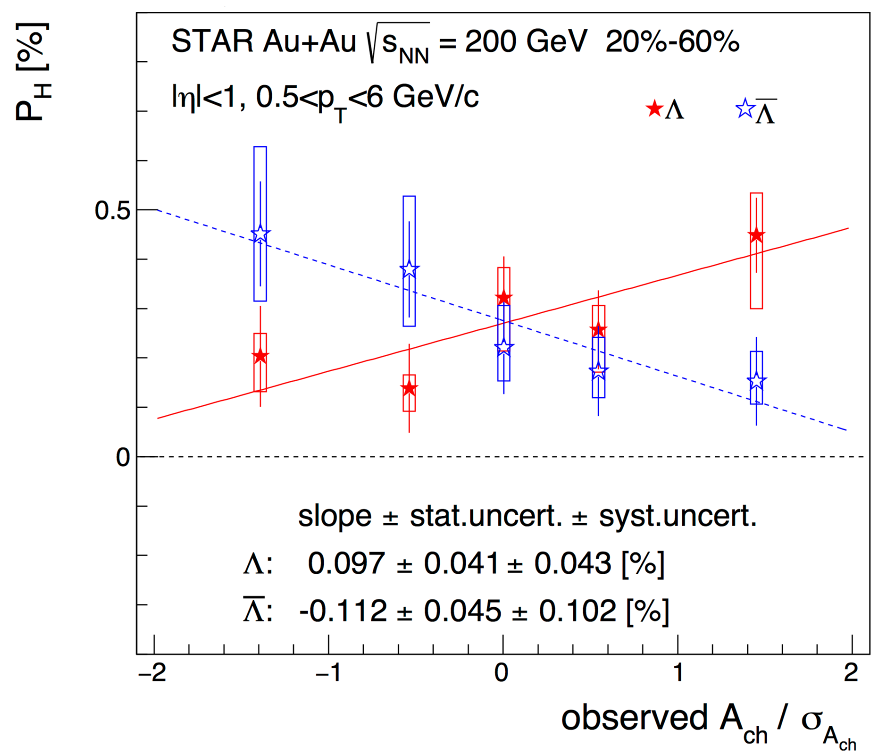
Significant azimuthal angle dependence

STAR, QM18

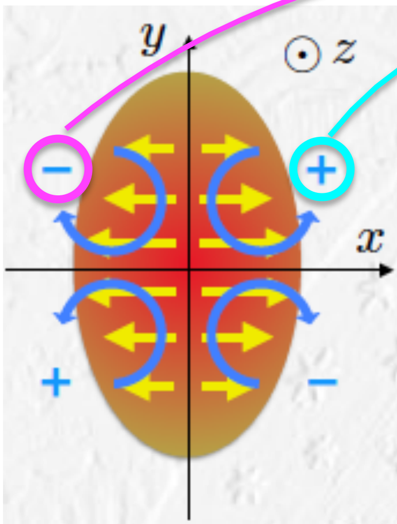


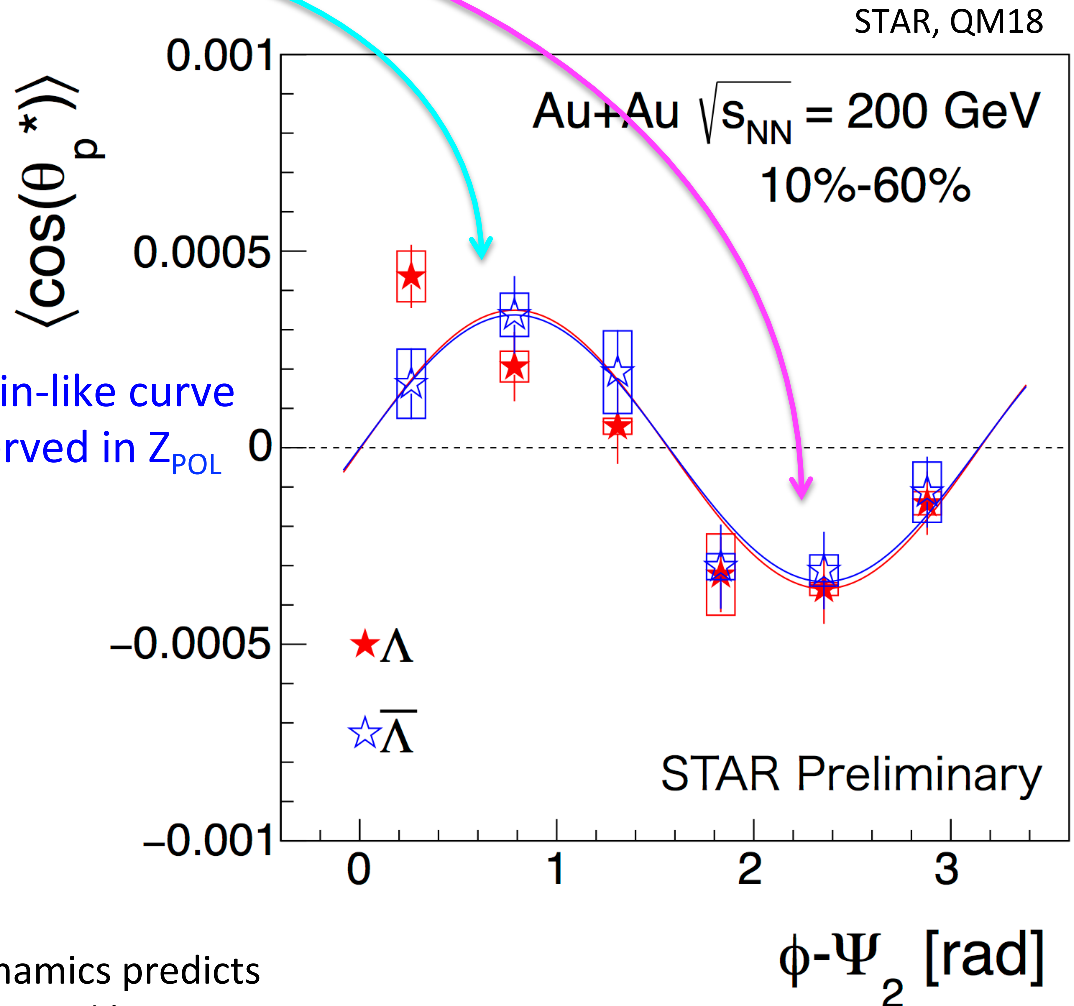
Sizable charge asymmetry dependence

STAR, Phys. Rev. C 98 (2018) 14910

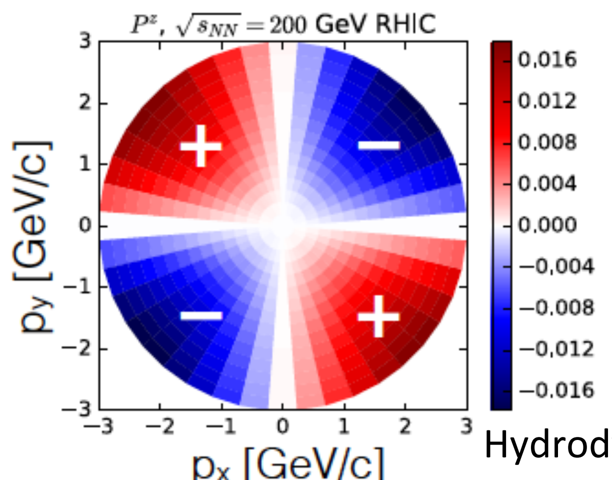


Lambda longitudinal-local polarization





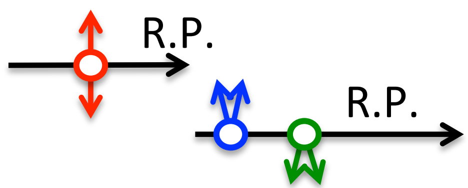
Clear sin-like curve is observed in Z_{POL}

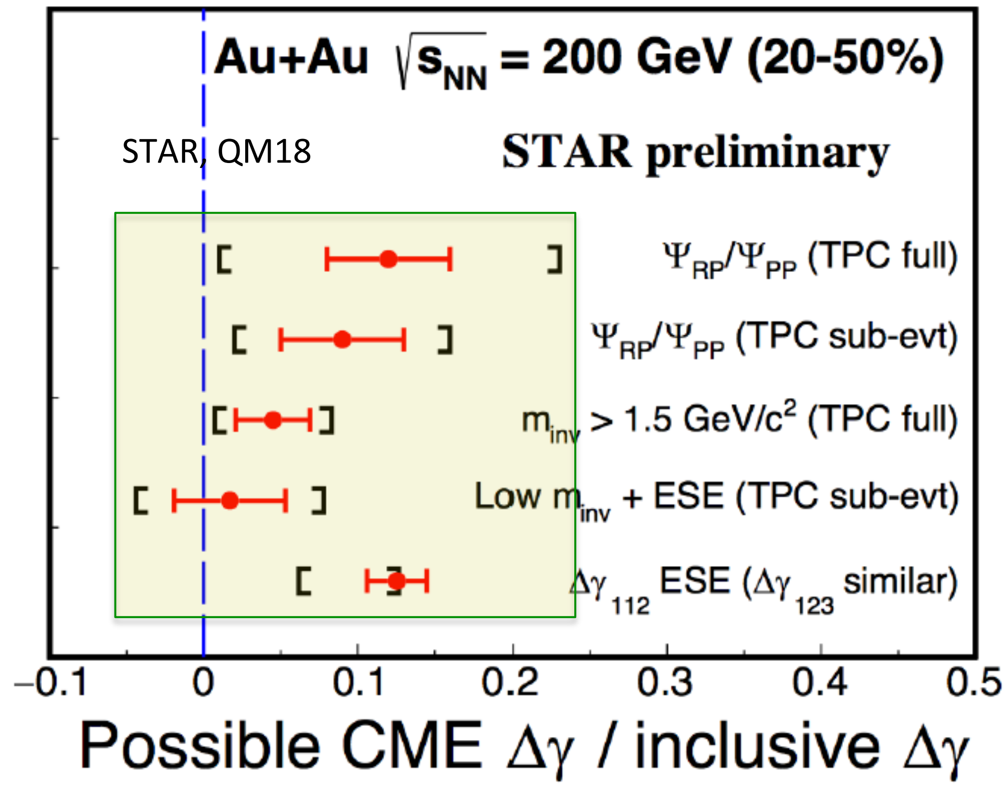


Hydrodynamics predicts opposite trend here again ...

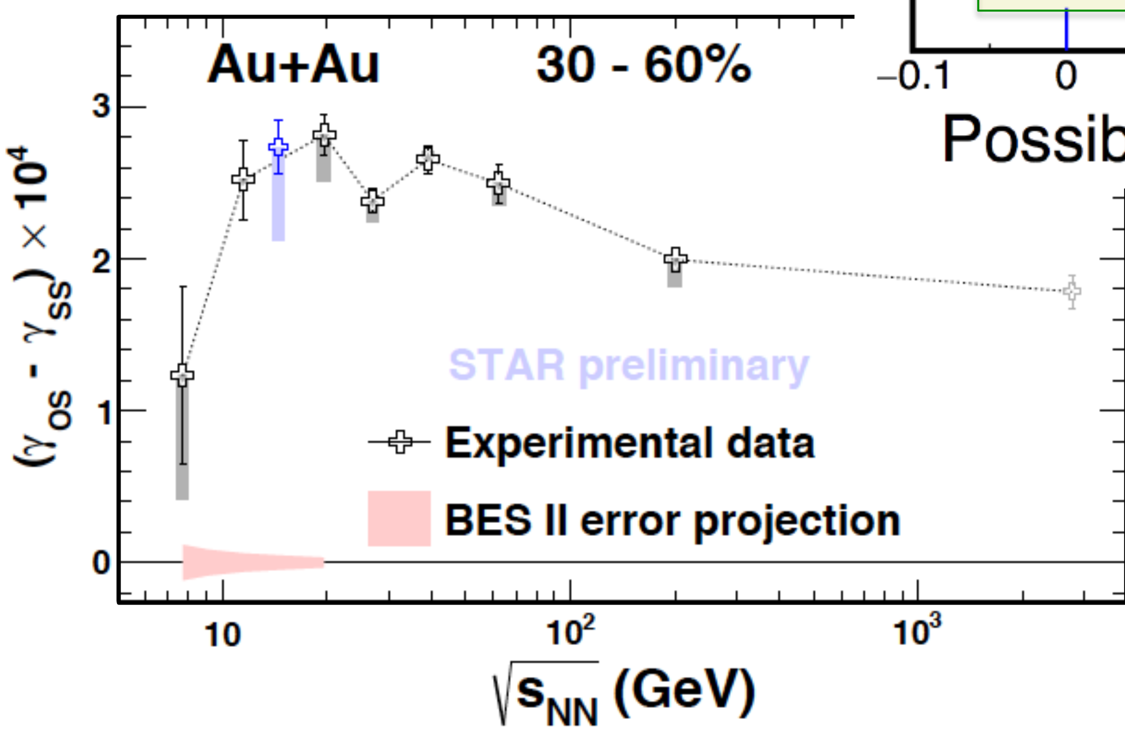
Chiral magnetic effect via $\gamma_{os,ss}$ correlator

$\gamma = < \cos(\phi_A + \phi_B - 2\Phi_{RP}) >$

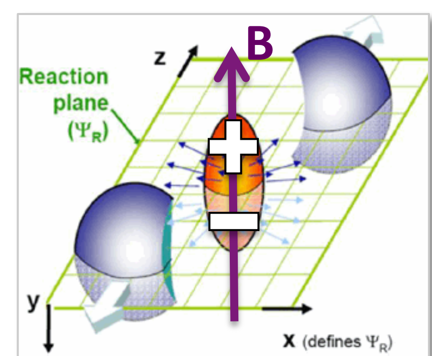




Phys. Rev. Lett. 113 (2014) 052302



Possible signal over the BG is seen in about 1-2 sigma



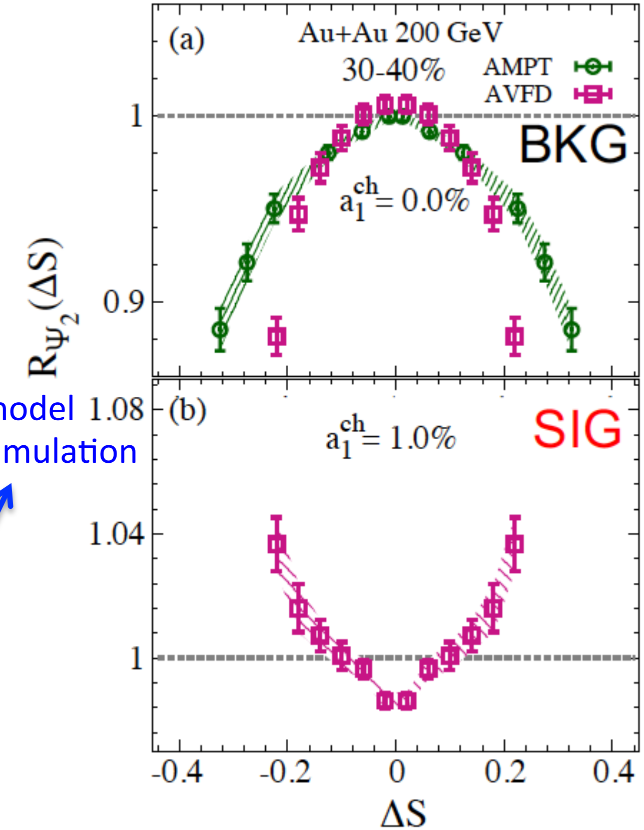
Chiral magnetic effect

via R.P. projected event-by-event charge asymmetry distribution

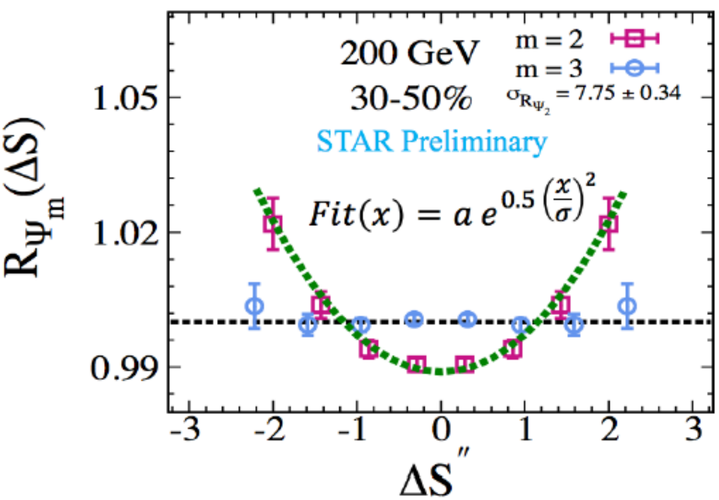
$\langle \sin\phi_+ \rangle - \langle \sin\phi_- \rangle$

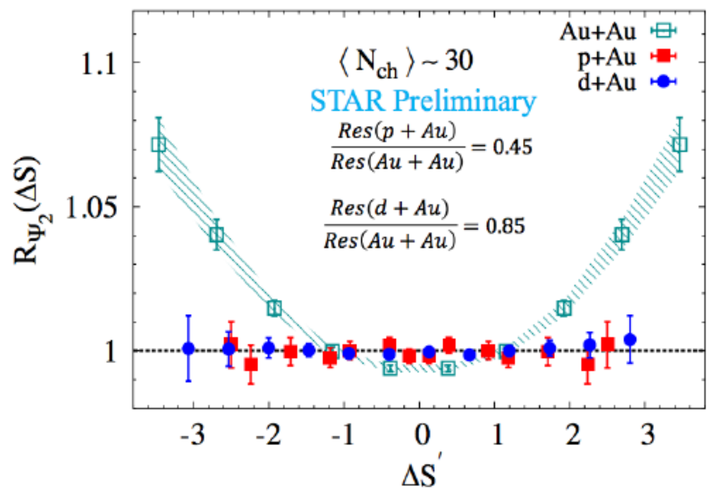
with "charge shuffling + cos term" normalization
--- Ajit correlator ---

model simulation



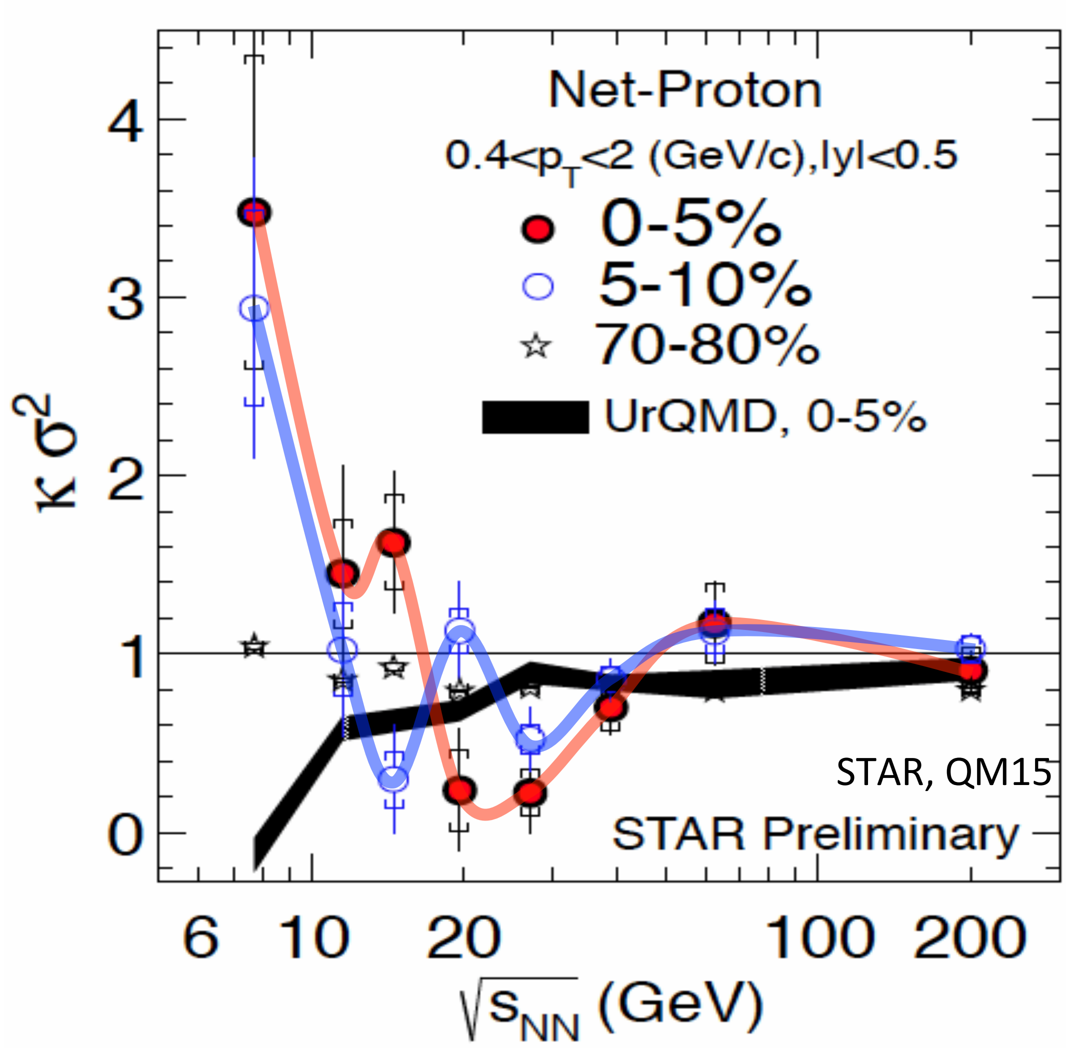
STAR, QM18, Chirality workshop 2018, experimental data

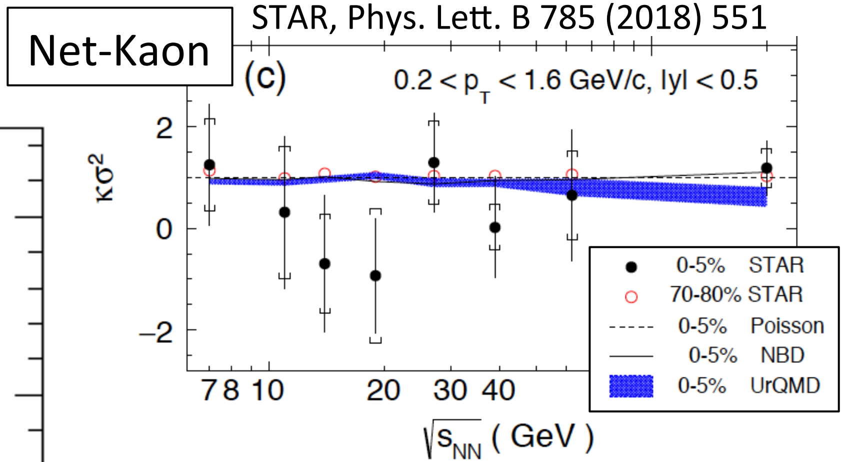




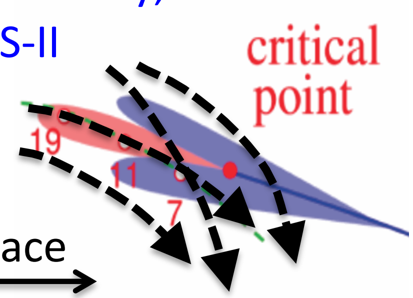
Possible CME signal with a different way by integrating the charge separately instead of taking all pair combinations

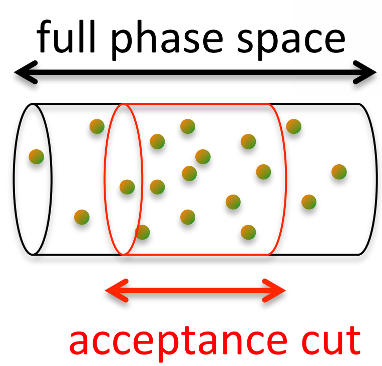
Net-proton as a proxy for conserved net-baryon fluctuation





Possible critical fluctuation depending on centrality, more data in BES-II

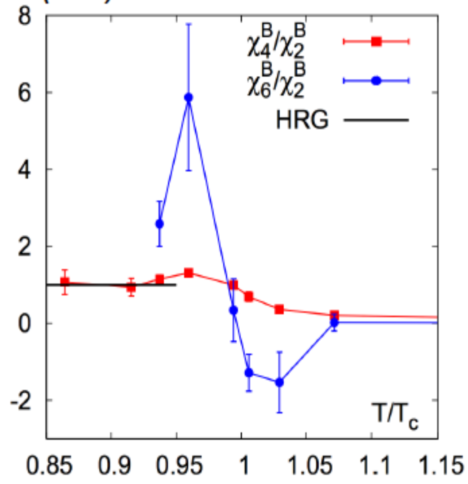




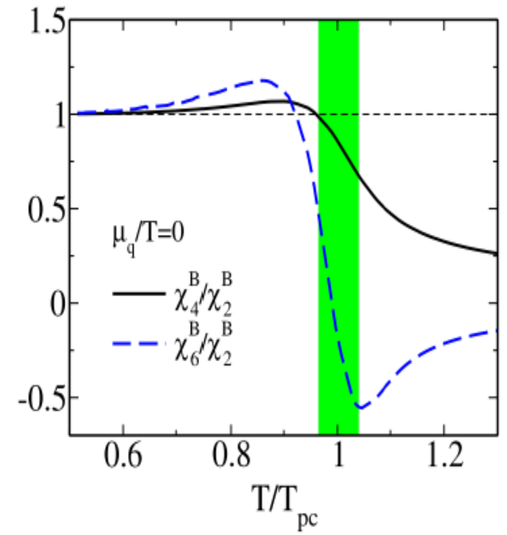
6th-order cumulants of net-proton and net-charge

Higher-order cumulants are expected to be more sensitive to the critical fluctuation than lower orders.
Even more statistics needed though ...

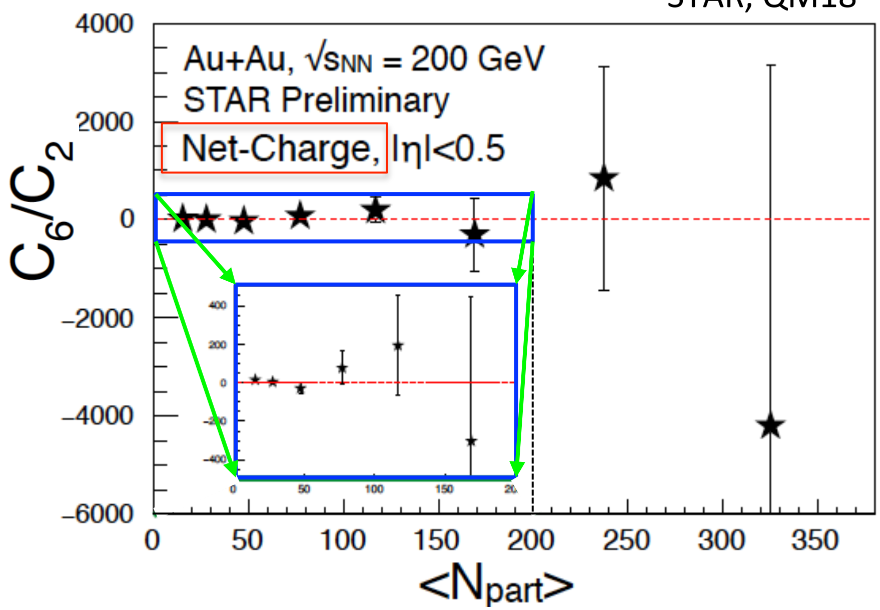
Cheng et al, Phys. Rev. D 79, 074505 (2009) : Lattice QCD



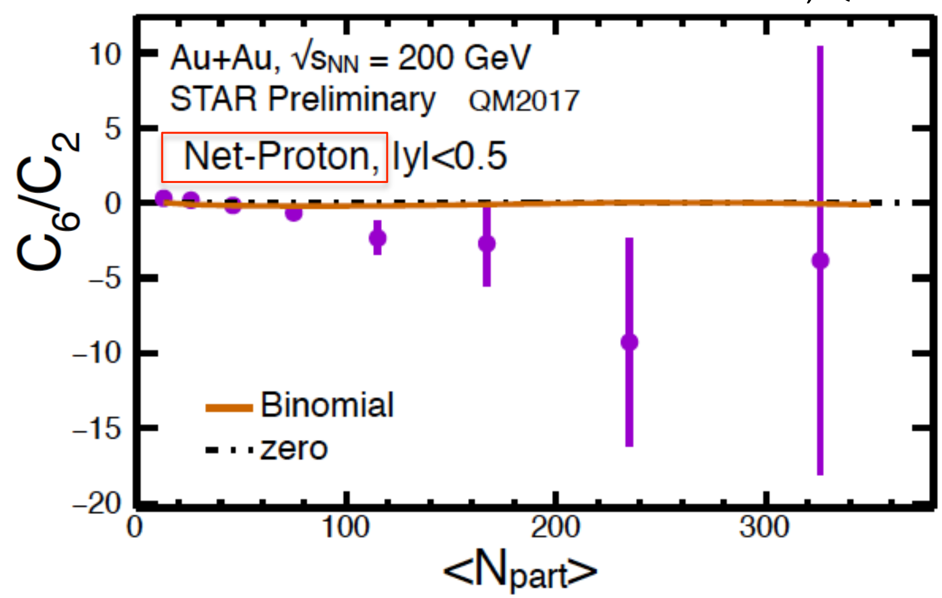
Friman et al, Eur. Phys. J. C (2011) 71:1694 : O(4) scaling functions



STAR, QM18

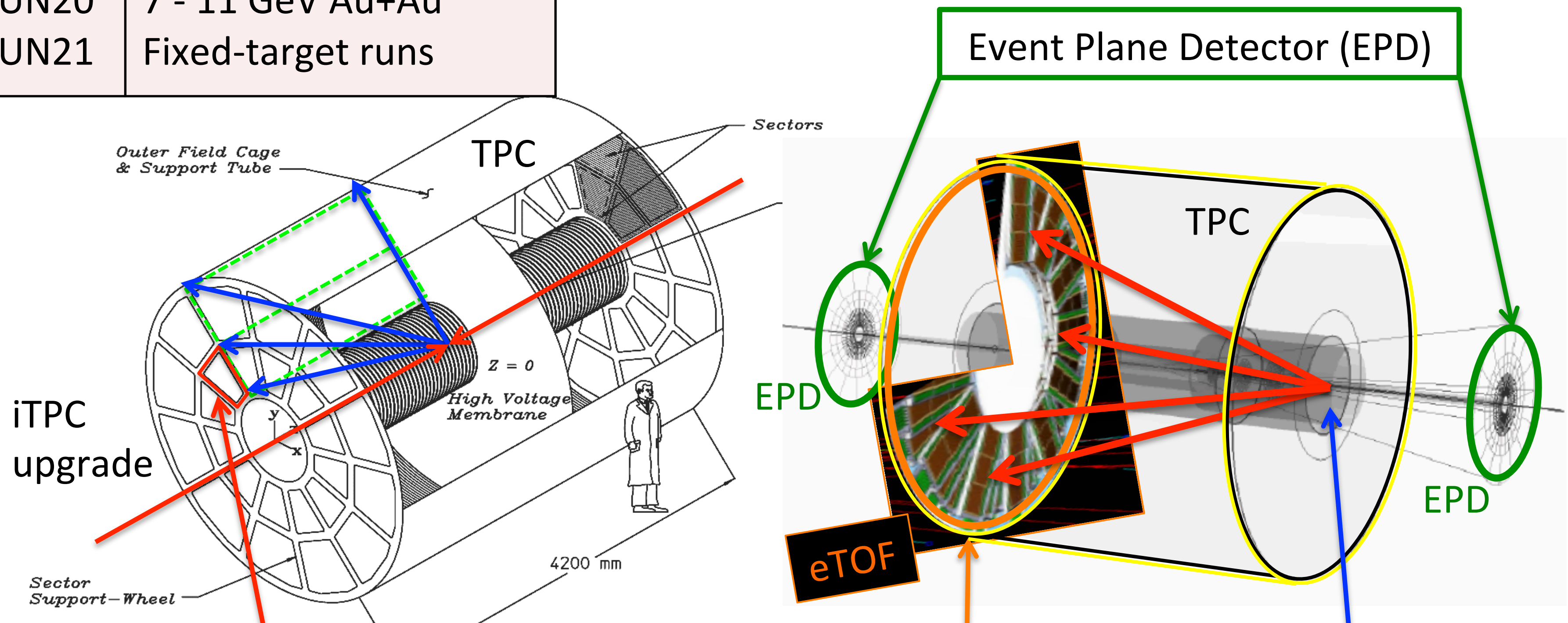


STAR, QM17



RUN17	500 GeV p+p 54 GeV Au+Au
RUN18	200 GeV Zr+Zr, Ru+Ru 27 GeV Au+Au Fixed-target test run
RUN19	14.5 - 20 GeV Au+Au
RUN20	7 - 11 GeV Au+Au
RUN21	Fixed-target runs

STAR detector upgrade for BES-II



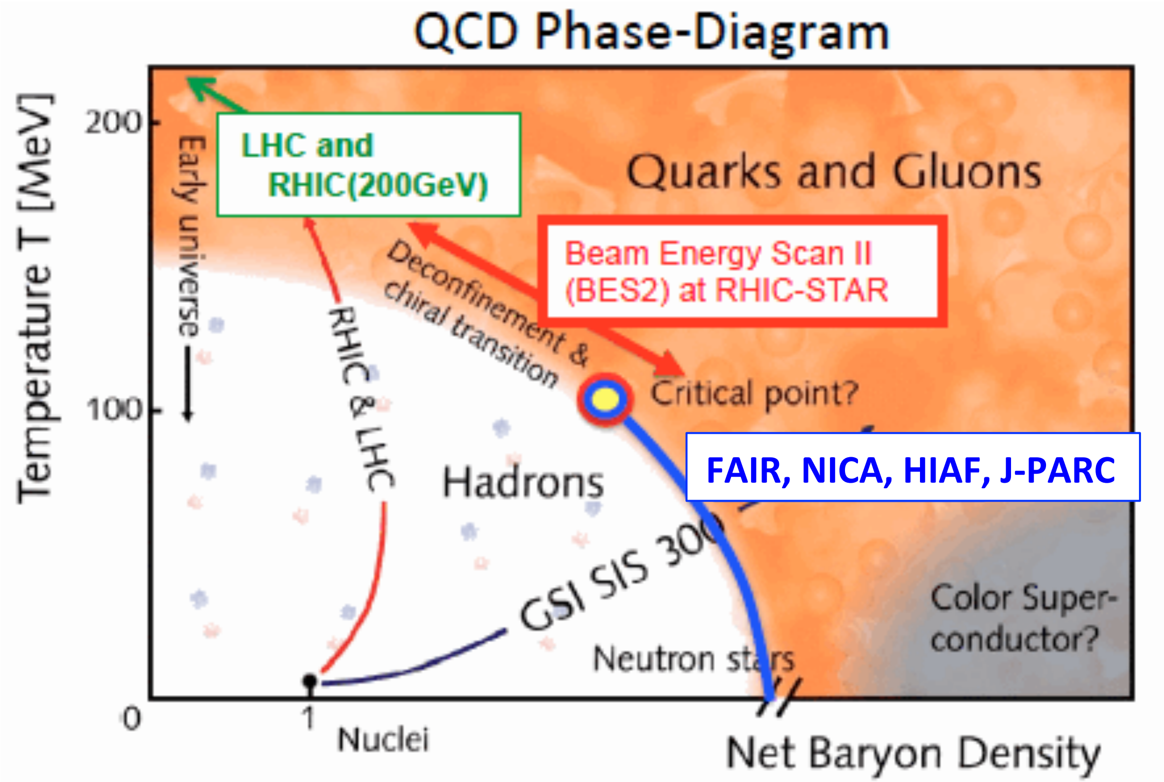
TPC inner sector readout with more segmentation

Endcap Time-of-Flight (eTOF) from FAIR-CBM

Fixed-target mode

Summary

- Collective expansion and thermal freeze-out
- Flow correlation with jet quenching, energy loss
- Vortical correlation, chiral magnetic fluid
- Critical fluctuation to look for critical point
- BES-II plans for fluctuation, vorticity, CME and v_1



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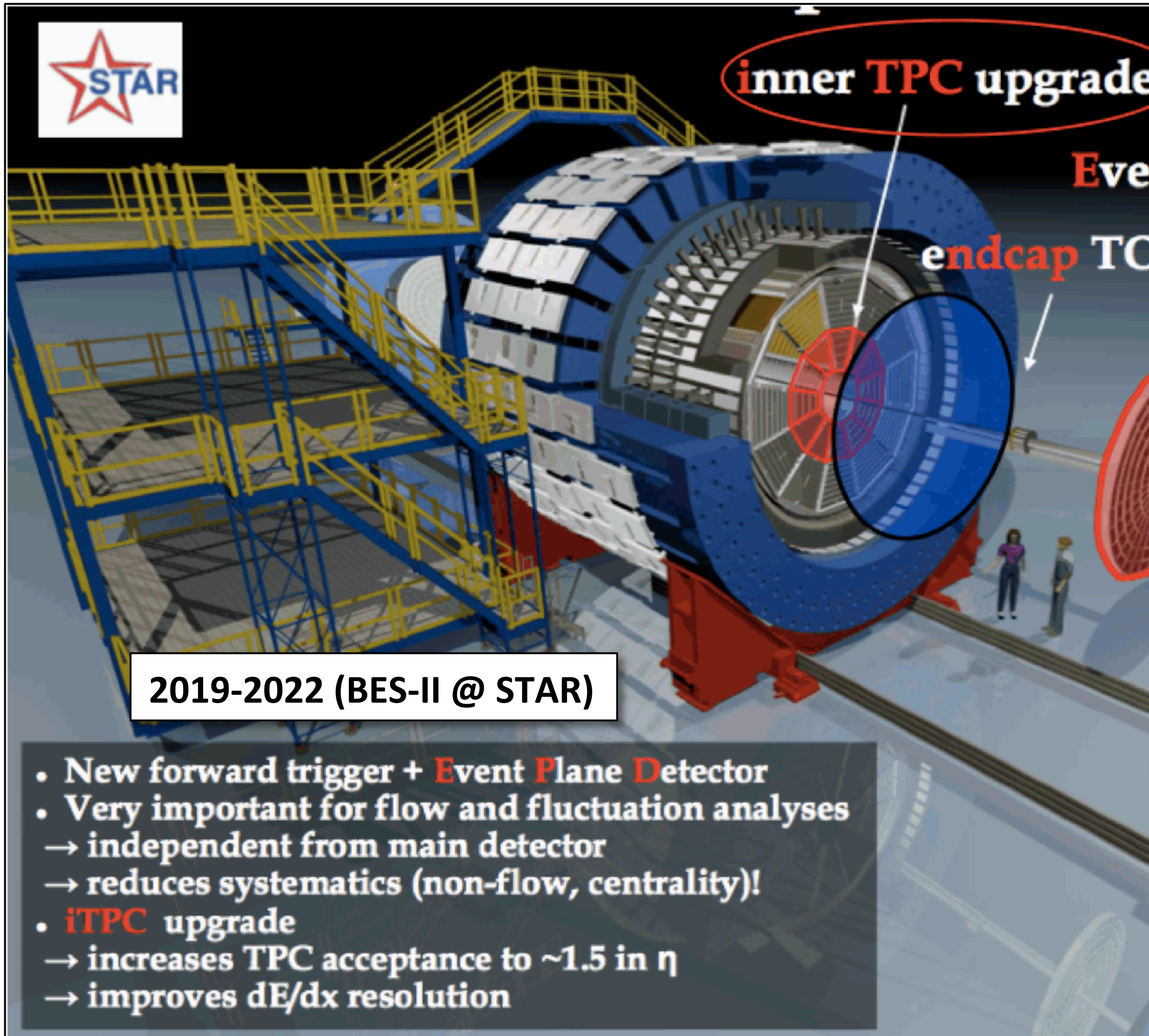
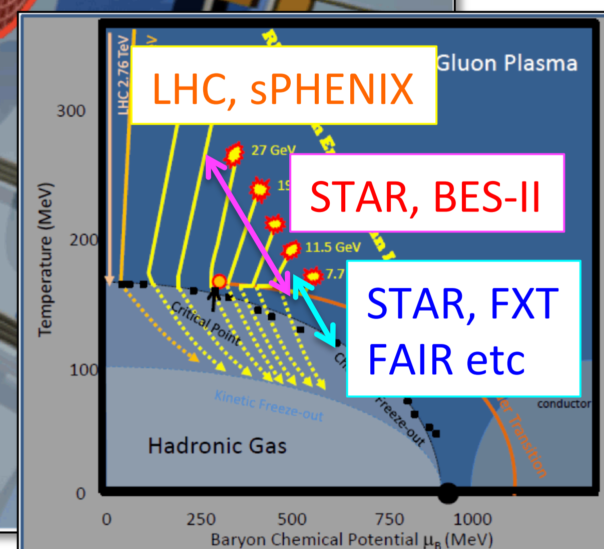
筑波大学 University of Tsukuba

Back-up slides

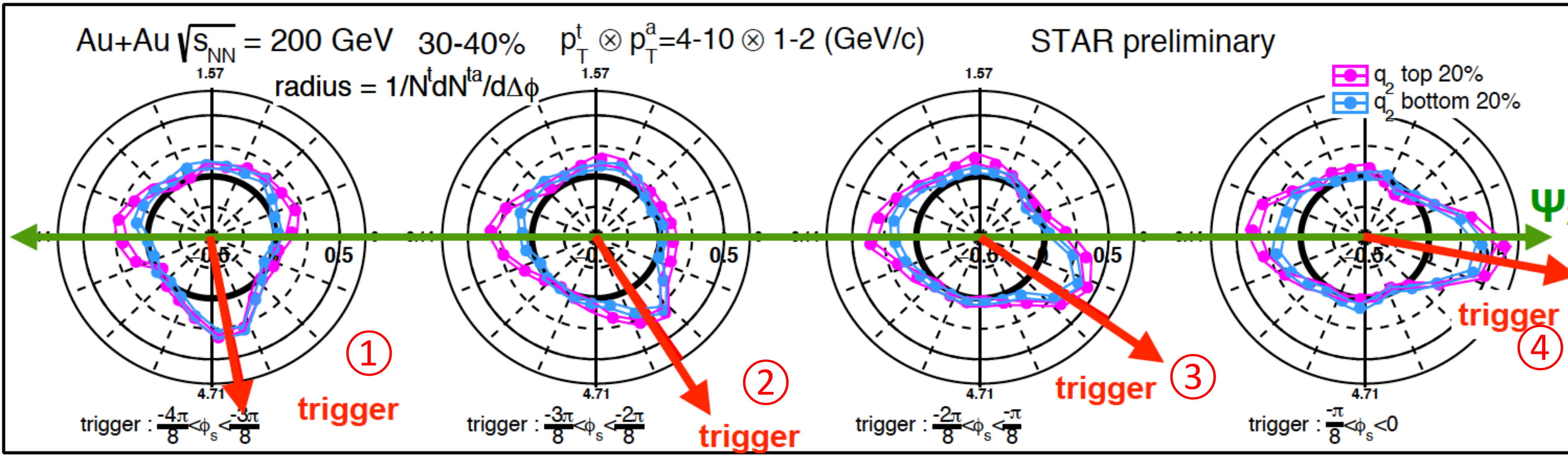
Beam Energy Scan II @ STAR

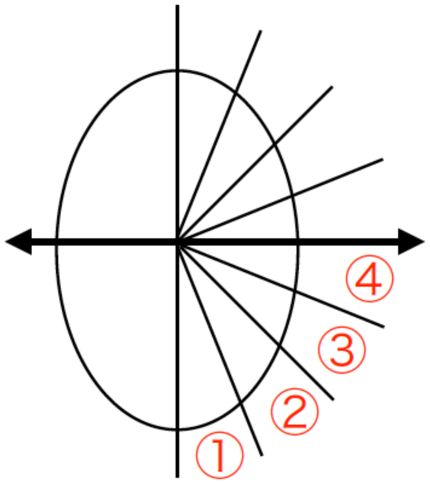




Jet quenching/modification and relation with v_2

STAR, QM18, APS/JPS2018

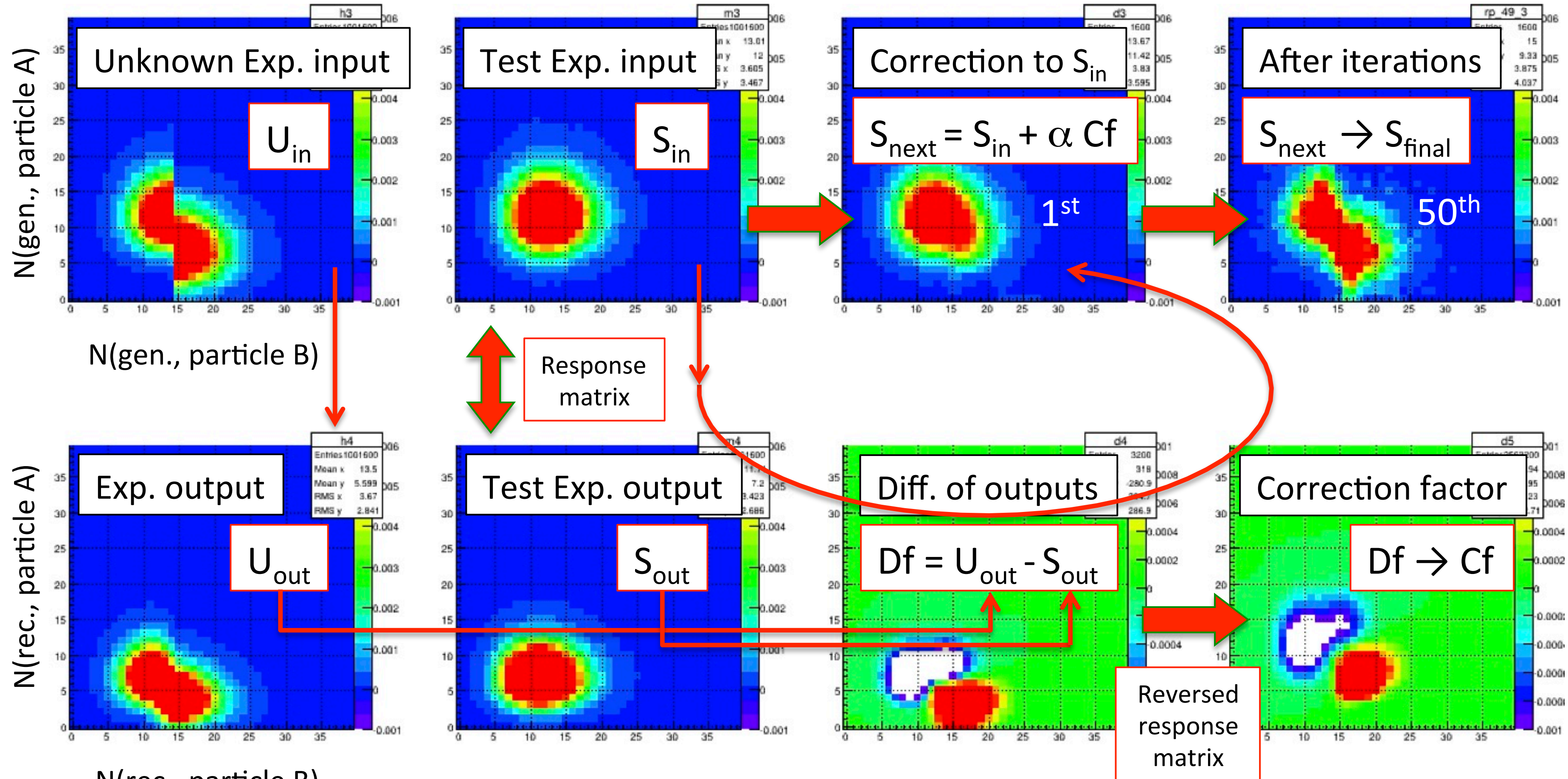




- Trigger angle dependence of di-hadron correlation
- Flow subtracted shape shows strong trigger angle dependence.
- More associated particles are seen in Φ_2 E.P. direction.
- The effect is stronger in large q_2 (v_2) events.

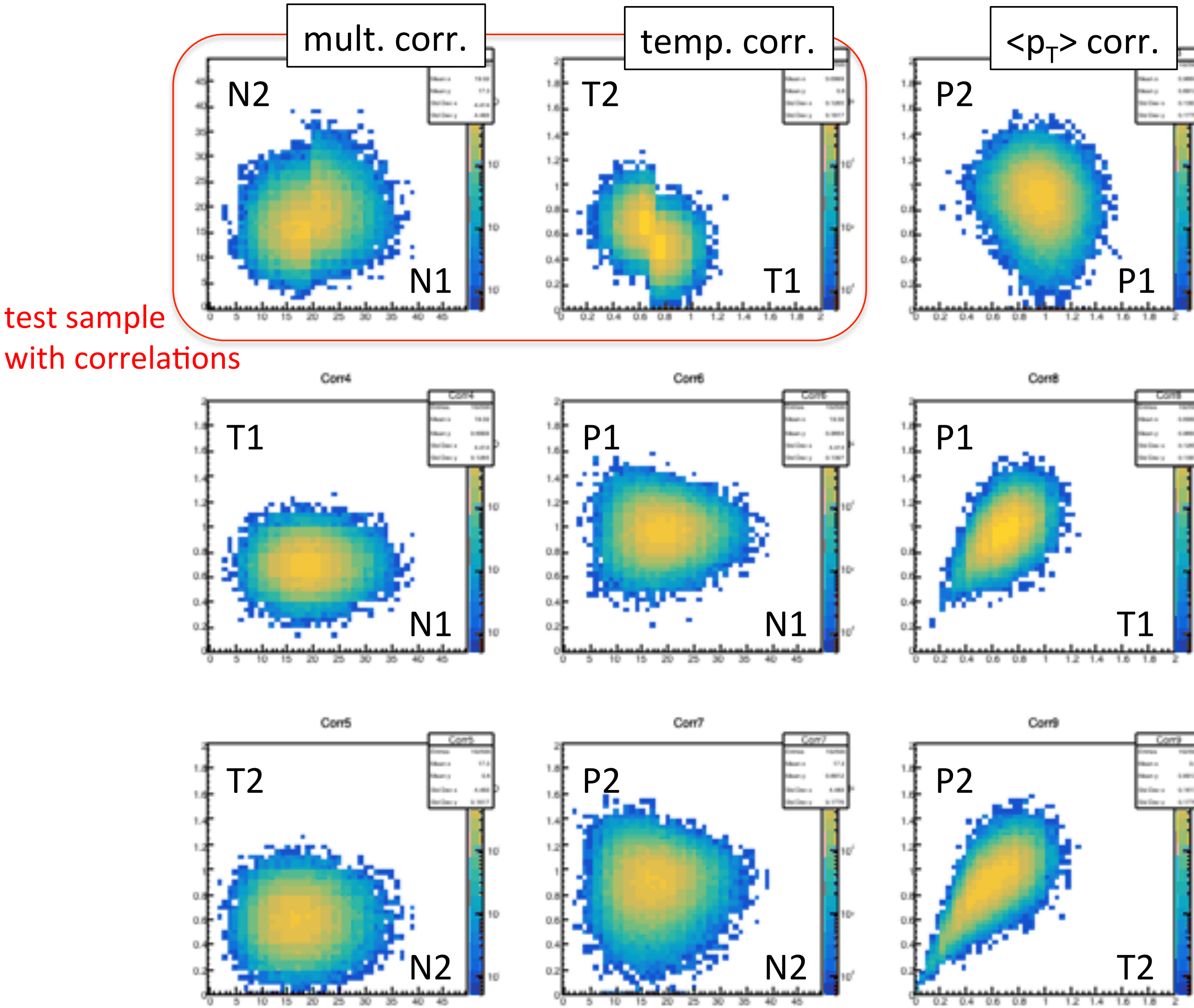
Unfolding of “unkown and critical” net-distribution

test simulation

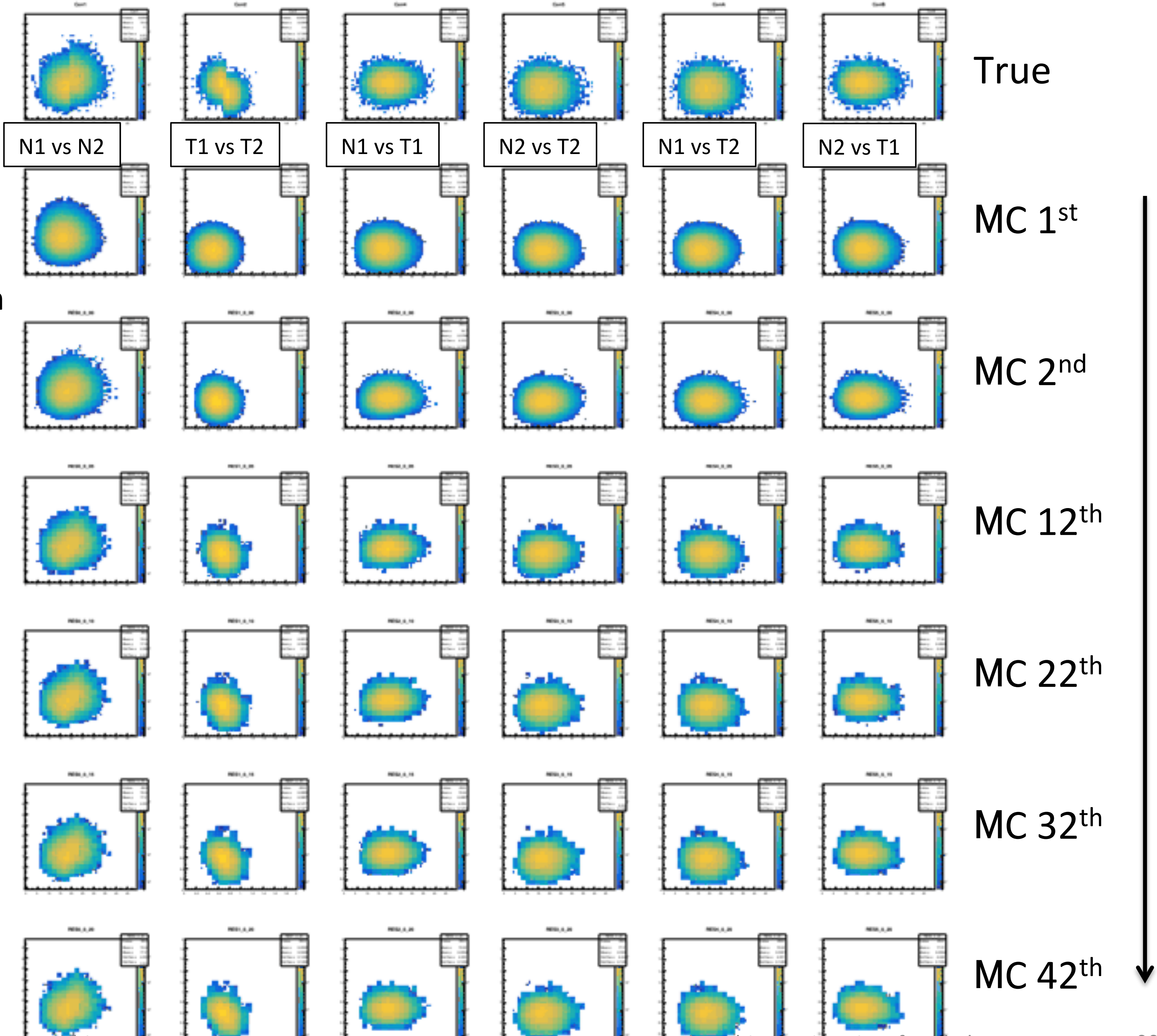


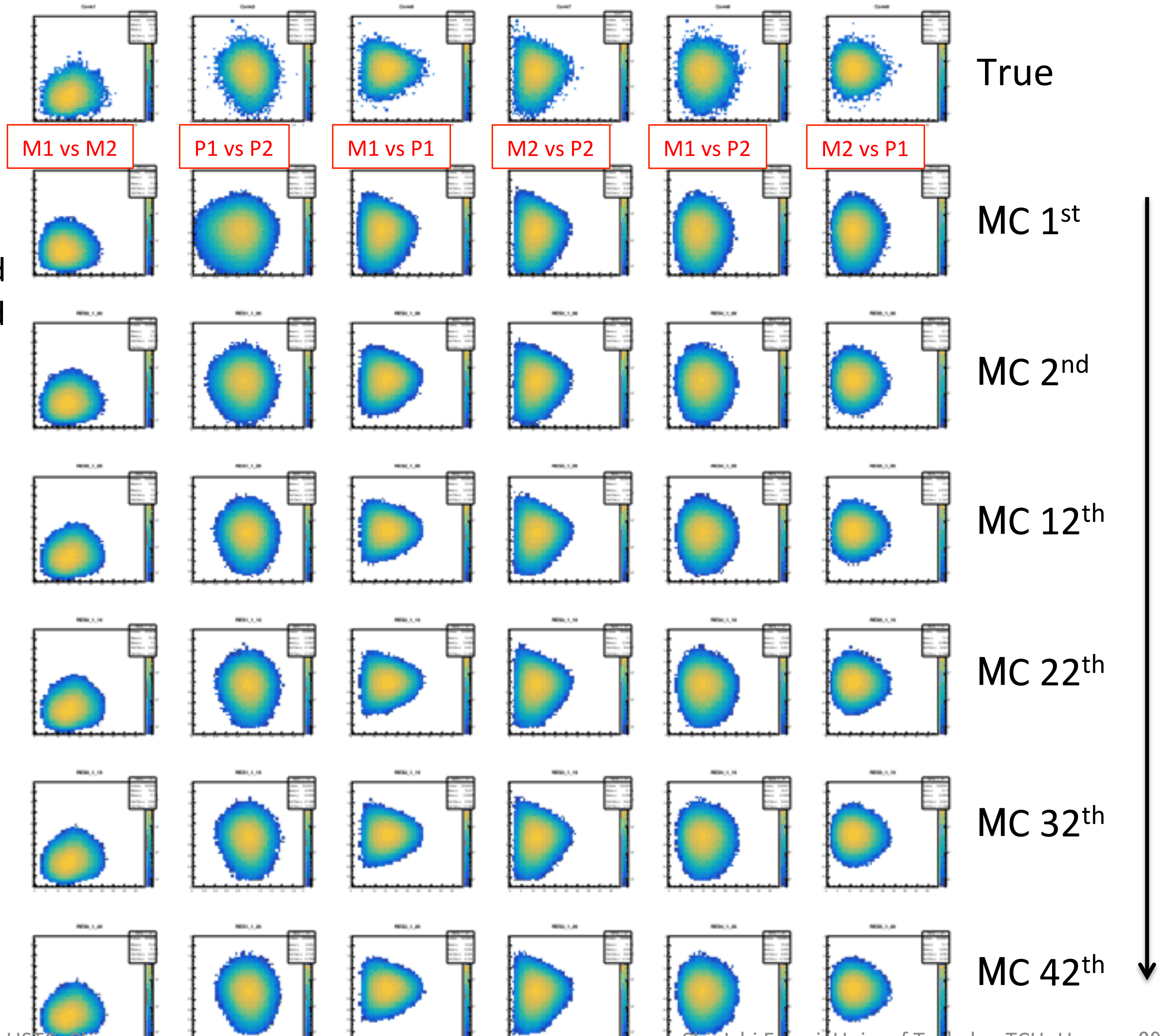
EMMI workshop
in Wuhan 2017

- volume fluctuation can be included as a part of response matrix
- temperature fluctuation could be unfolded via <p_T> fluctuation together with the number fluctuation, which is done in 4D-R.M.


mult. corr.
temp. corr.
$\langle p_T \rangle$ corr.
test sample
with correlations
N2
N1
T2
T1
P2
P1
Corr4
T1
N1
Corr6
P1
N1
Corr8
P1
T1
Corr5
T2
N2
Corr7
P2
N2
Corr9
P2
T2

6 different 2D projections of 4D correlation (N_1, N_2, T_1, T_2) along with iteration

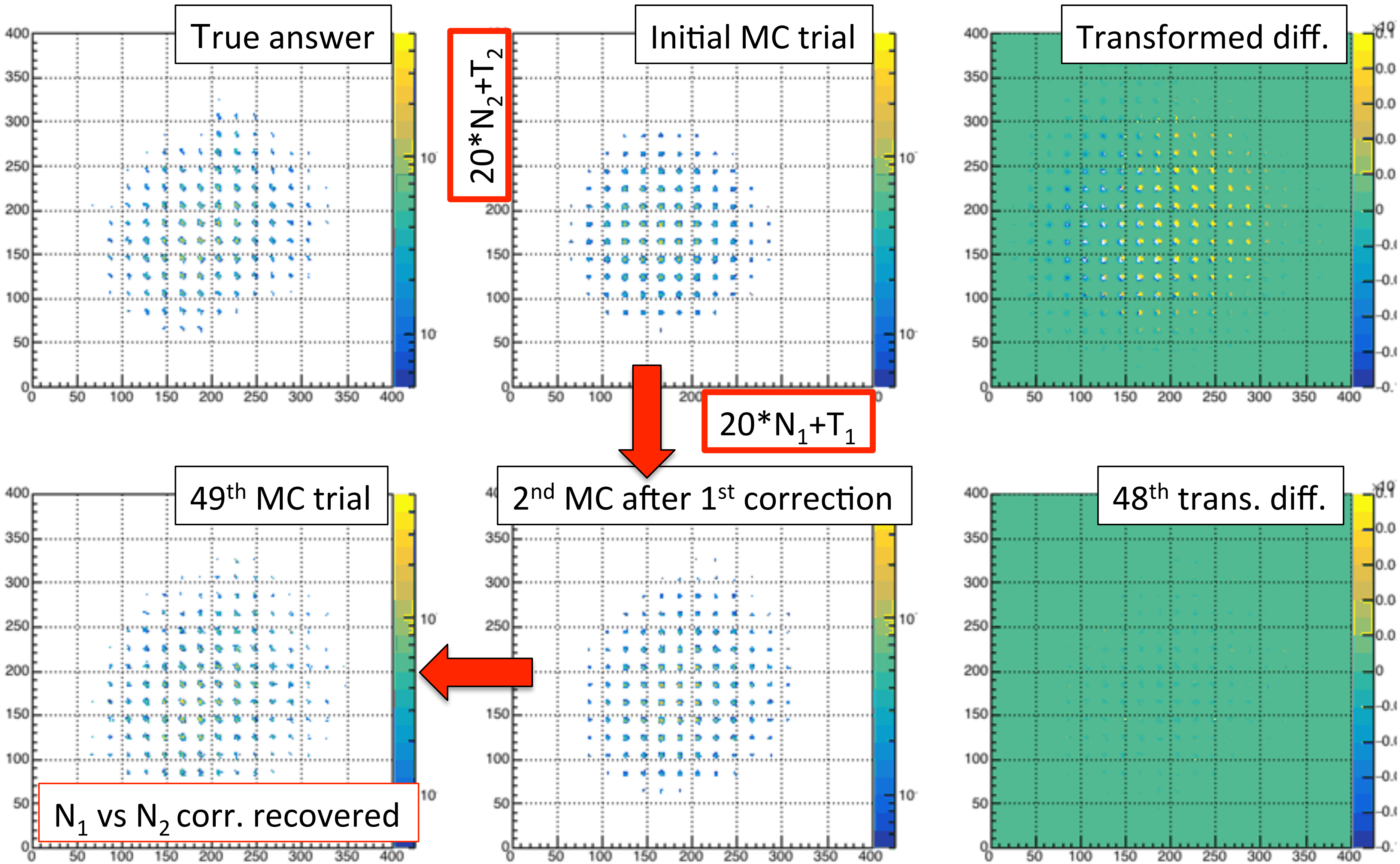




the same iteration viewed in the measured coordinates : (M_1, M_2, P_1, P_2)

$M_i = N_{measured}$
$P_i = \langle p_T \rangle_{measured}$

4D-correlation (N_1, N_2, T_1, T_2) plotted as { f(N_1, T_1), f(N_2, T_2) }



Expanded view, to show the recovery of correlation (T_1 vs T_2)