Flow and Fluctuation : Beam Energy Scan at RHIC

ShinIchi Esumi, Tomonaga Center for the History of the Universe (TCHoU), Inst. of Physics, Univ. of Tsukuba

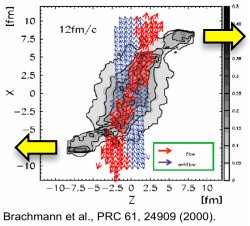
Contents

- Directed and elliptic flows
- Higher order flow and small systems
- Fluctuation of conserved quantities
- Higher order cumulants
- Next plan

筑波大学 University of Tsukuba

筑波大学 宇宙史研究センター Tomonaga Center for the History of the Universe

PID directed flow v1 vs rapidity, energy



10-40% Au+Au Collisions at RHIC (STAR 1708.07132)

$\sqrt{s_{NN}}$ = 7.7 GeV | 11.5 GeV | 14.5 GeV | 19.6 GeV | 27 GeV | 39 GeV | 62.4 GeV | 200 GeV

p pbar

Λ Λbar

ϕ

K^+ K^- K^0

π^+ π^-

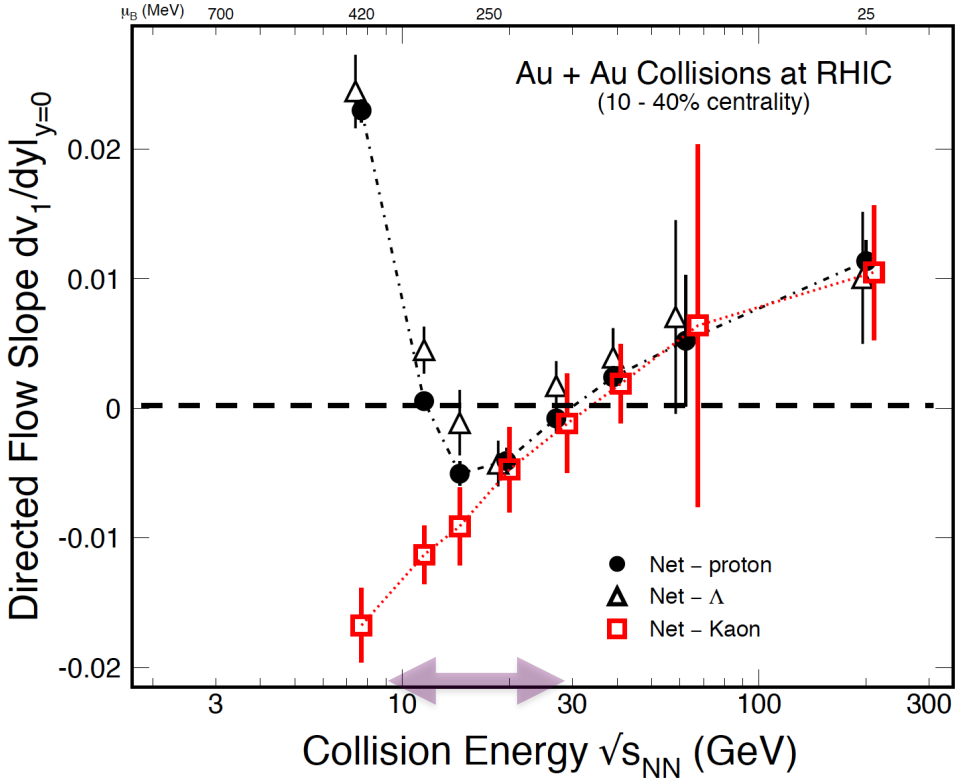
Particle Aisotropy Flow First Harmonic v_1

Particle Rapidity

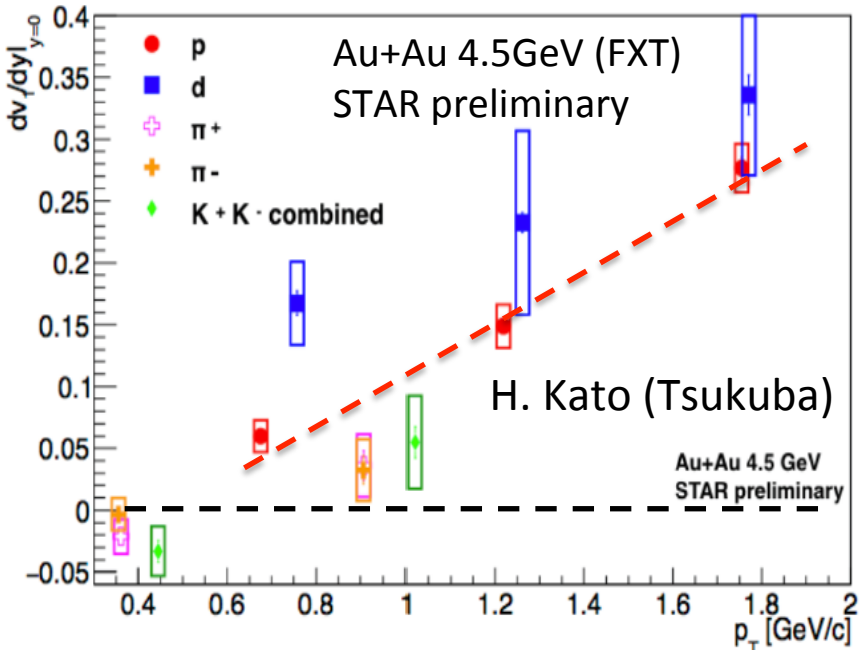
7.7 GeV → 200 GeV

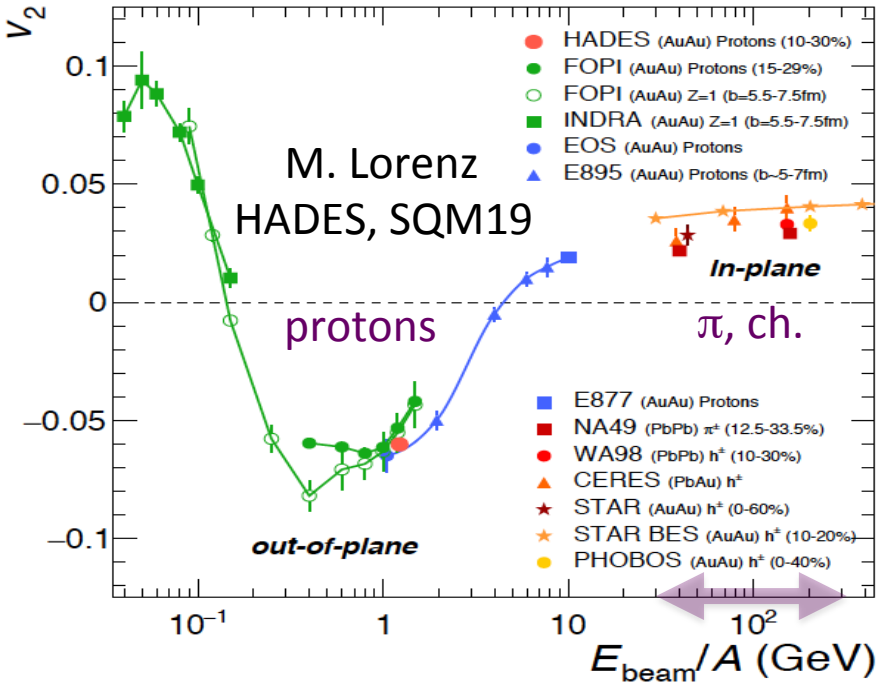
STAR : PRL120, 62301(2018)

Directed and elliptic flow vs beam energy



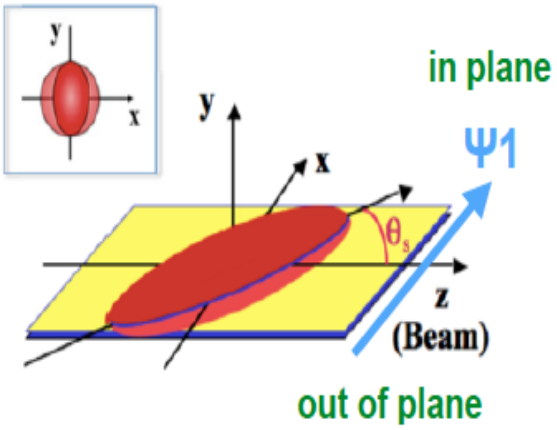
STAR: PRL112, 162301(2014),
PRL120, 62301(2018)



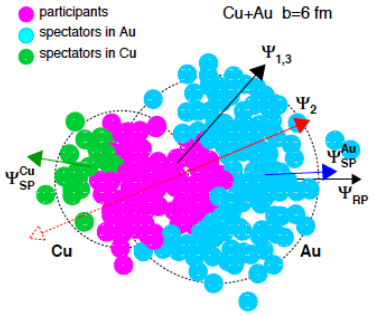


Directed flow origin and source tilt

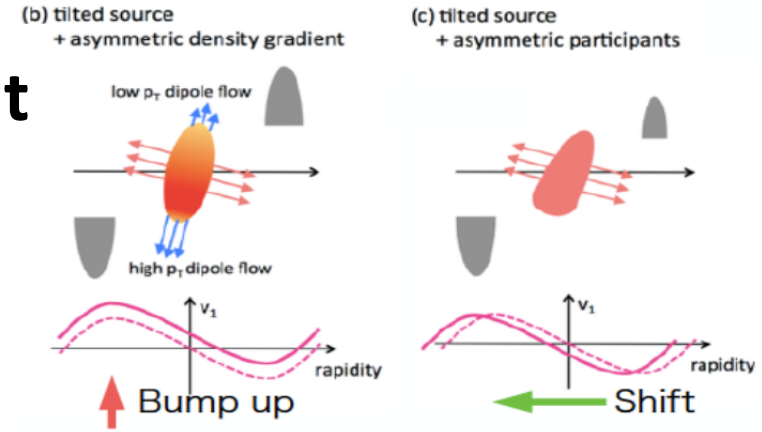
M A Lisa et al. New J. Phys. 13 (2011) 065006

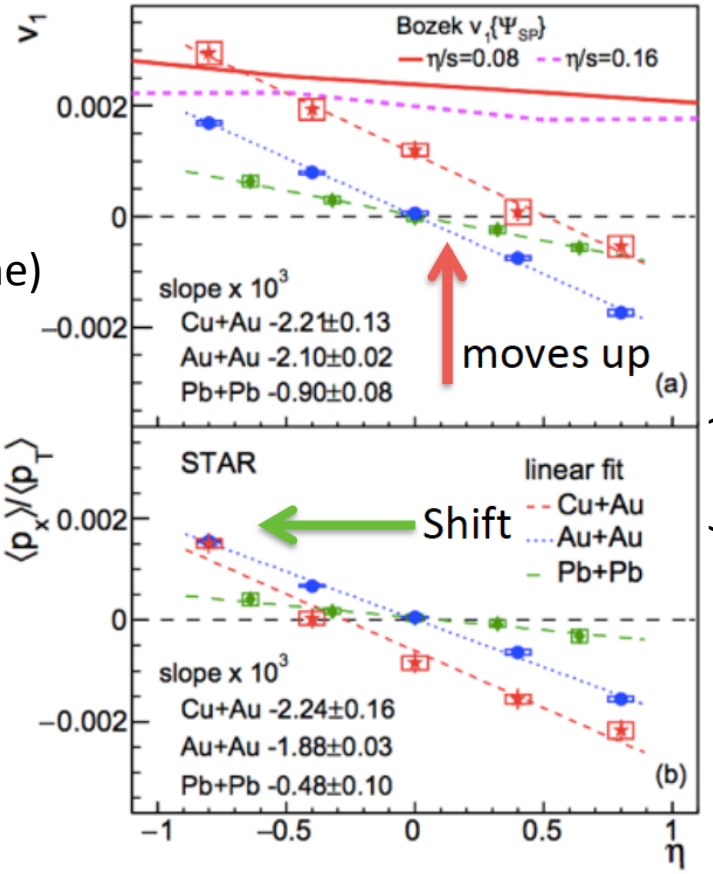


Cu+Au 200 GeV



T. Niida (Wayne)

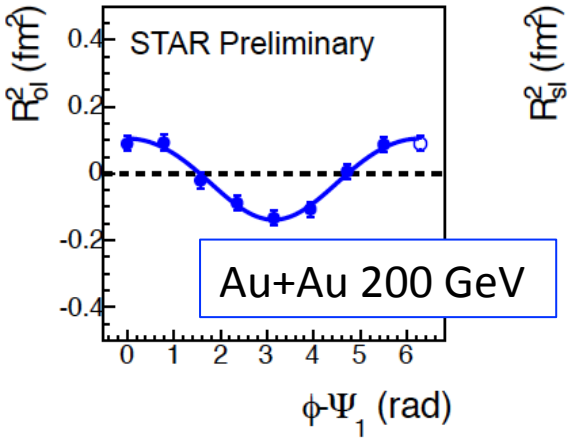


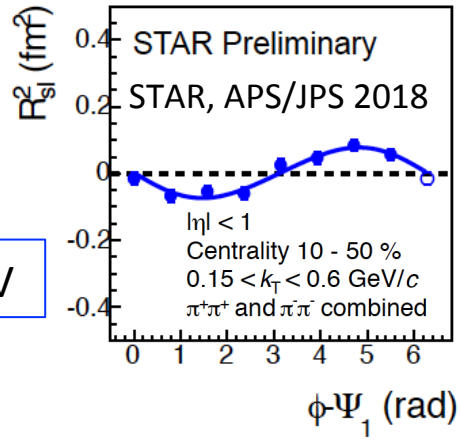


STAR : PRC 98 (2018) 014915

source tilt

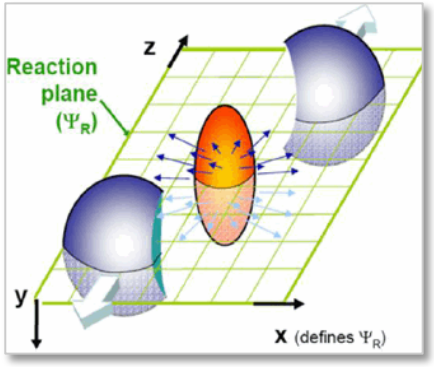
Y. Kawamura (Tsukuba)

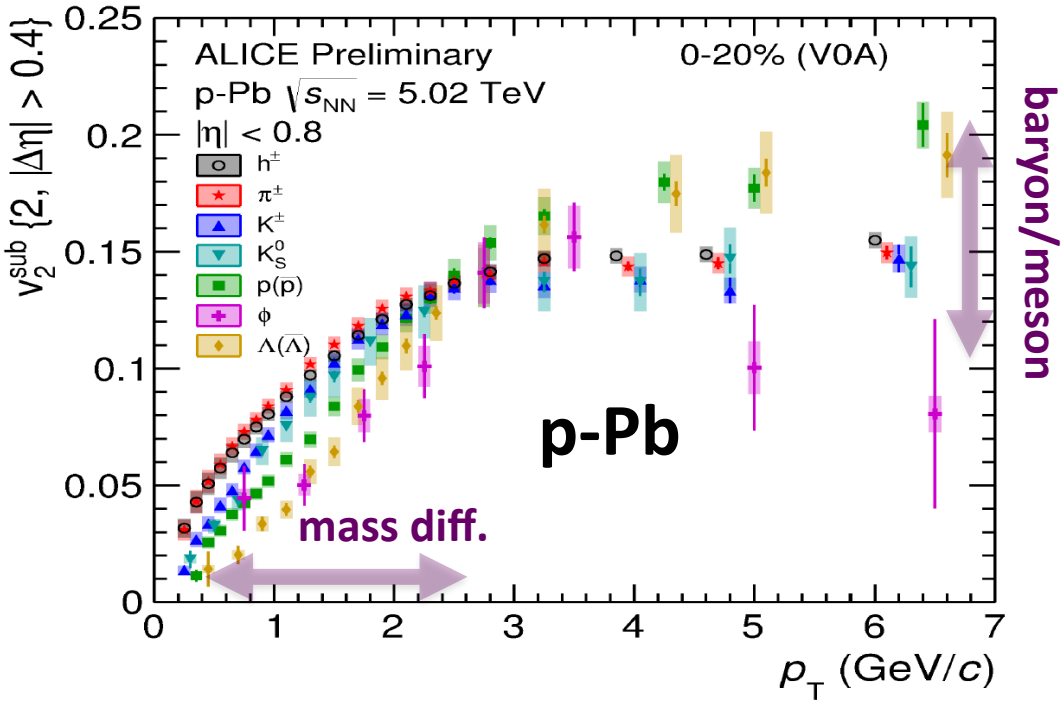


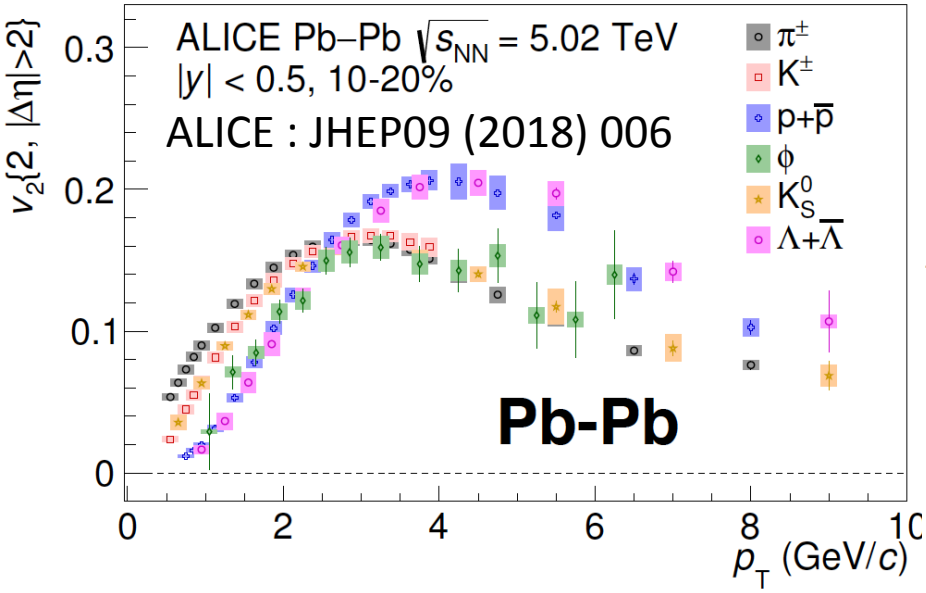


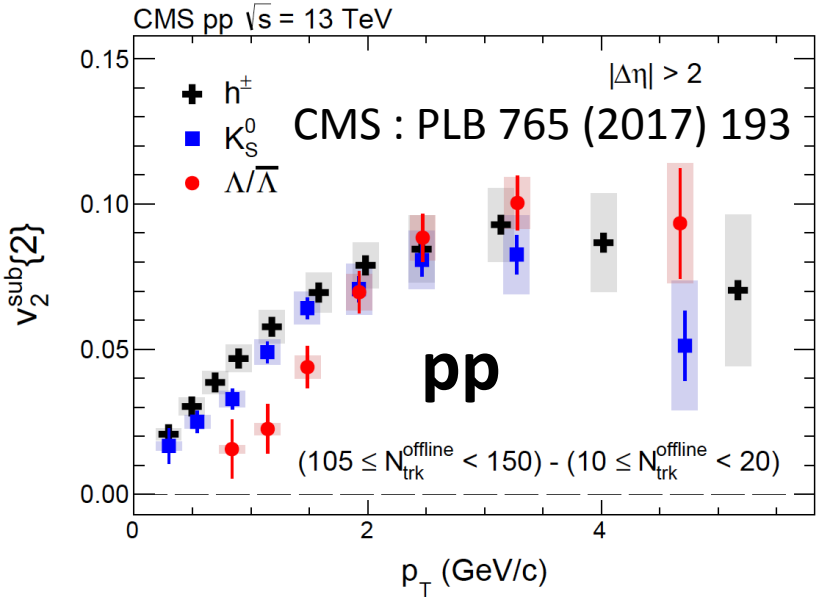
Mass and N_{CQ} scaling of elliptic flow

--- Pb-Pb, p-Pb, pp ---



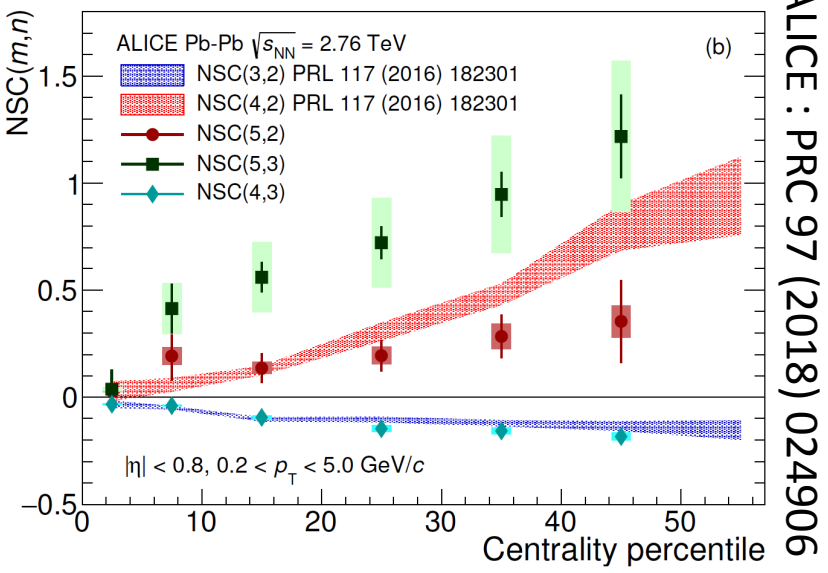




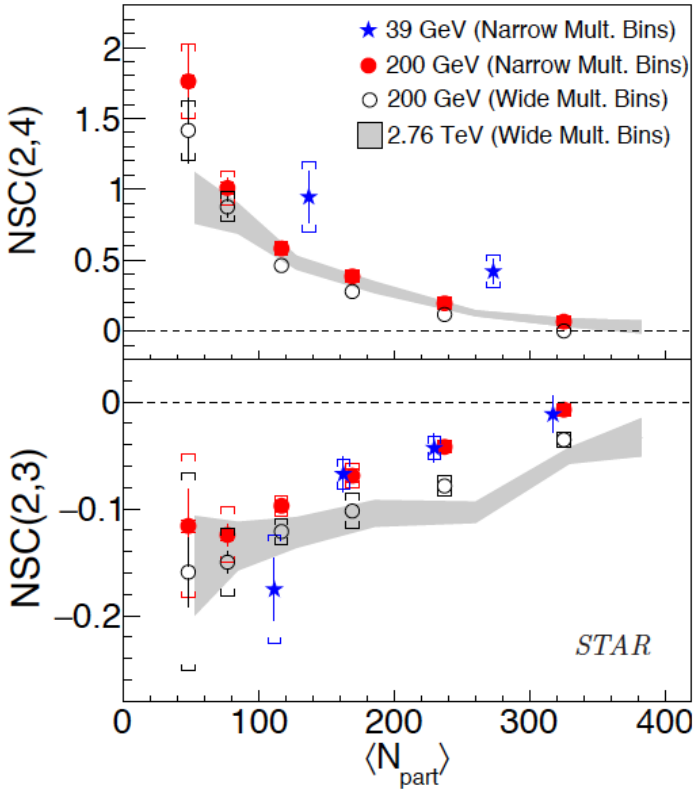


Correlation between v_n and v_m

--- (2,3) < 0 and (2,4) > 0 ---



ALICE : PRC 97 (2018) 024906



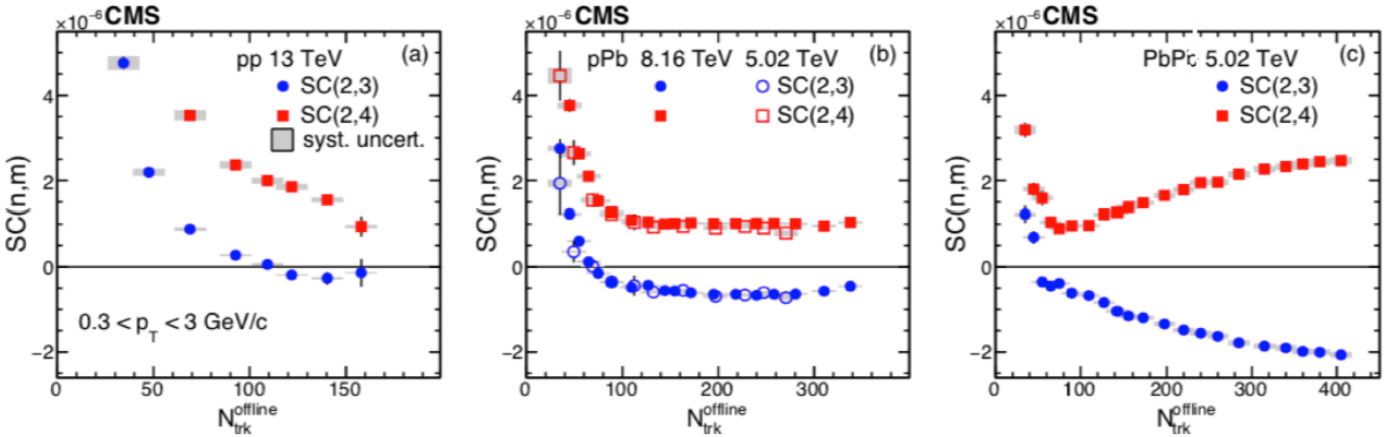
STAR : PLB 783 (2018) 459

CMS : Phys. Rev. Lett. 120, 092301 (2018)

v2

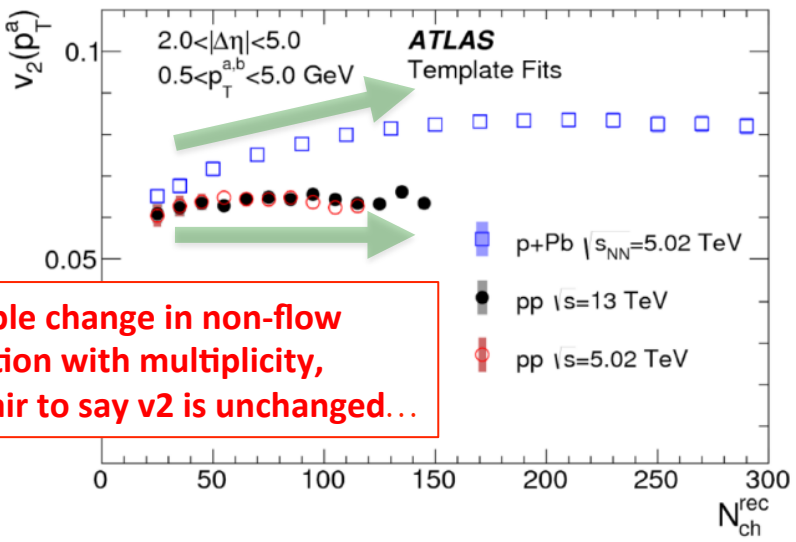
v3

v4

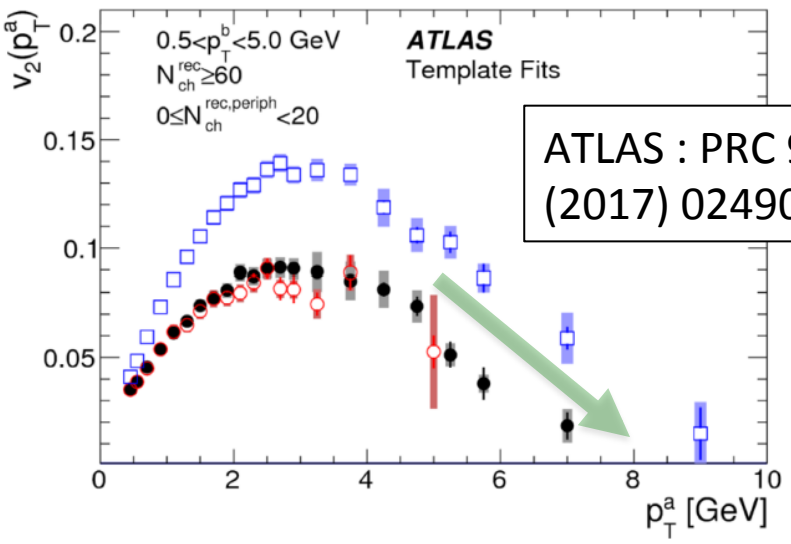


pp *p*+Pb Pb+Pb

Elliptic flow in small system (with non-flow subtraction)

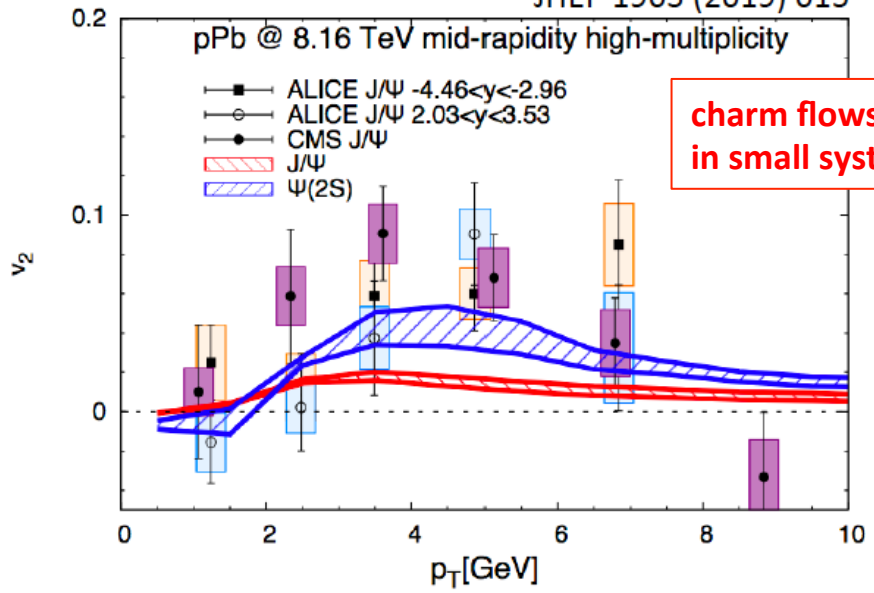


sizable change in non-flow fraction with multiplicity, Unfair to say v2 is unchanged…



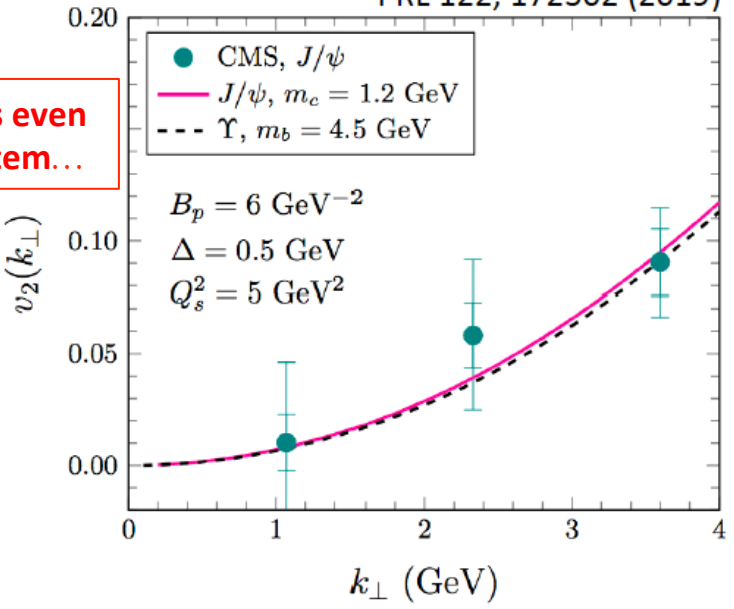
ATLAS : PRC 96 (2017) 024908

JHEP 1903 (2019) 015



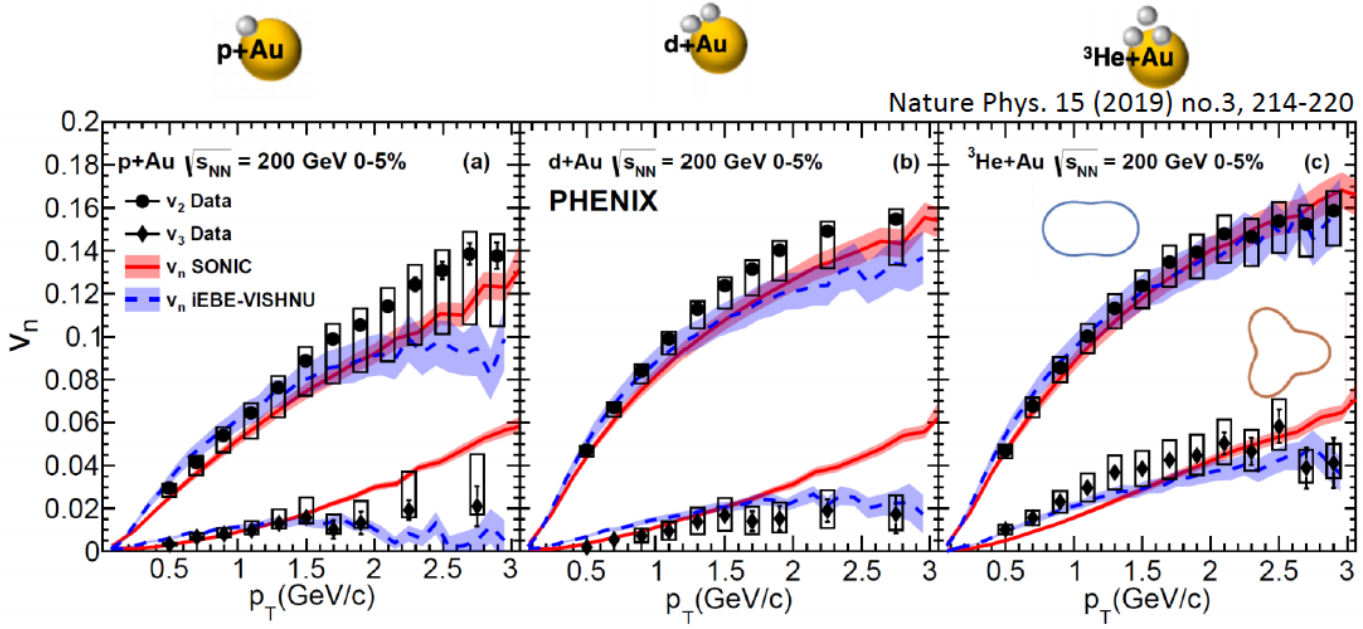
charm flows even in small system…

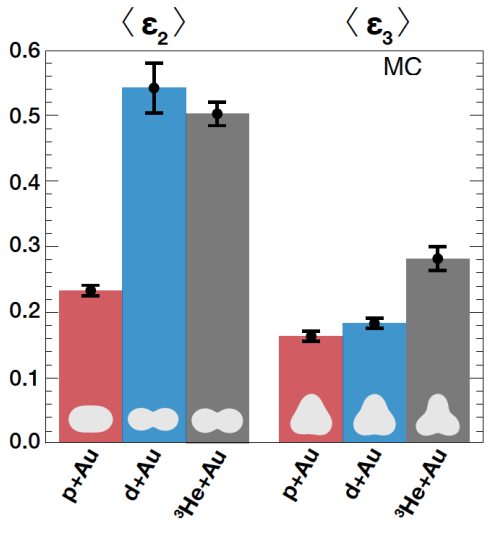
PRL 122, 172302 (2019)

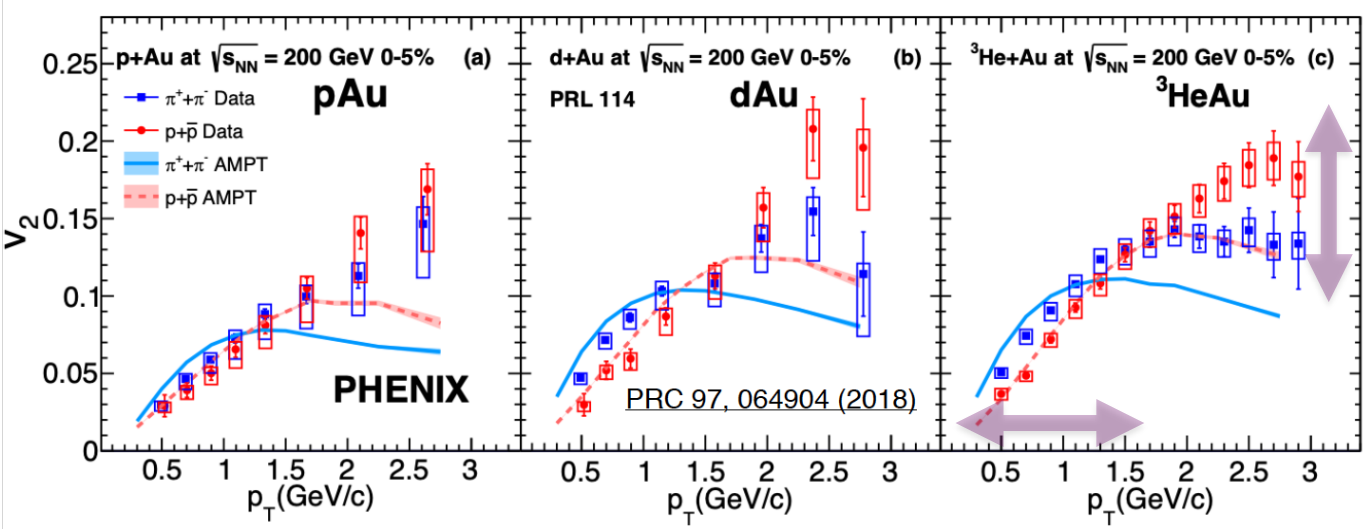


Small system scan at RHIC (p+Au, d+Au, ^{3}He+Au)

Creation of quark–gluon plasma droplets with three distinct geometries





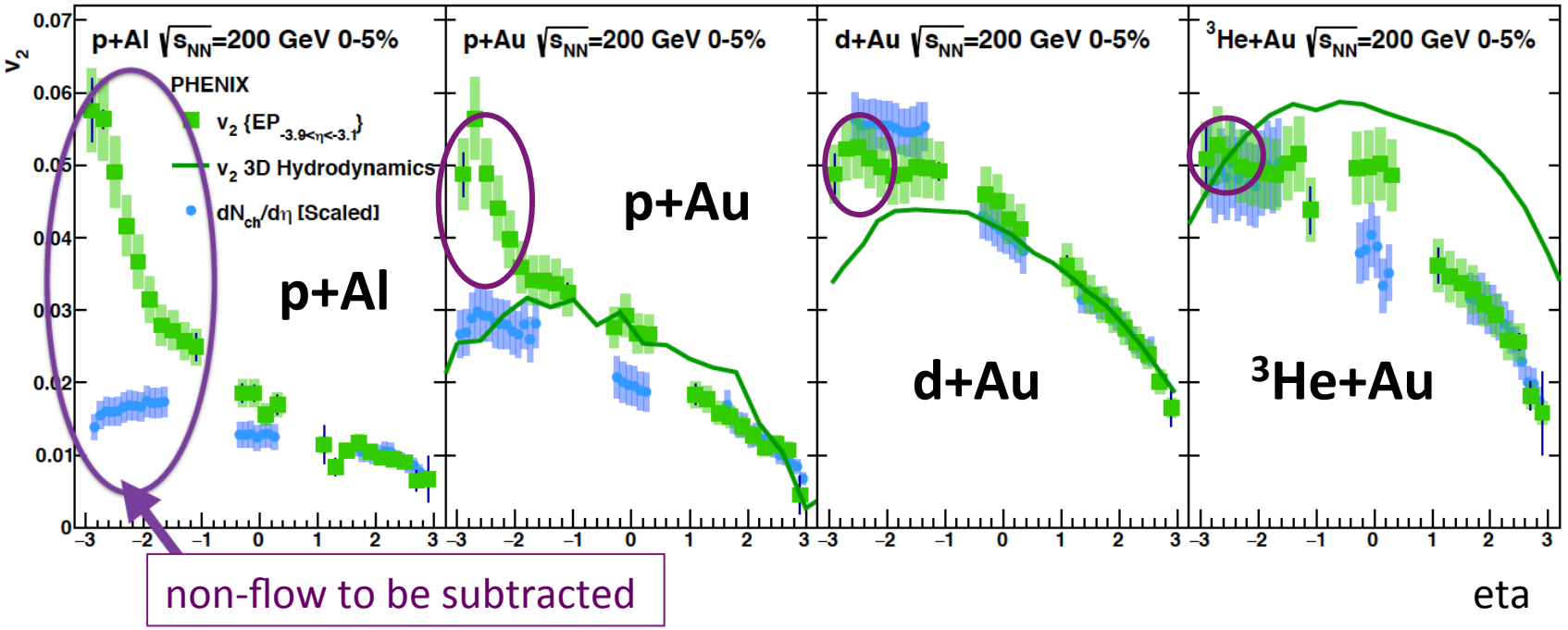


similar mass dependence and baryon/meson difference

Eta dependence in small system (p+Al, p+Au, d+Au, ^{3}He+Au)

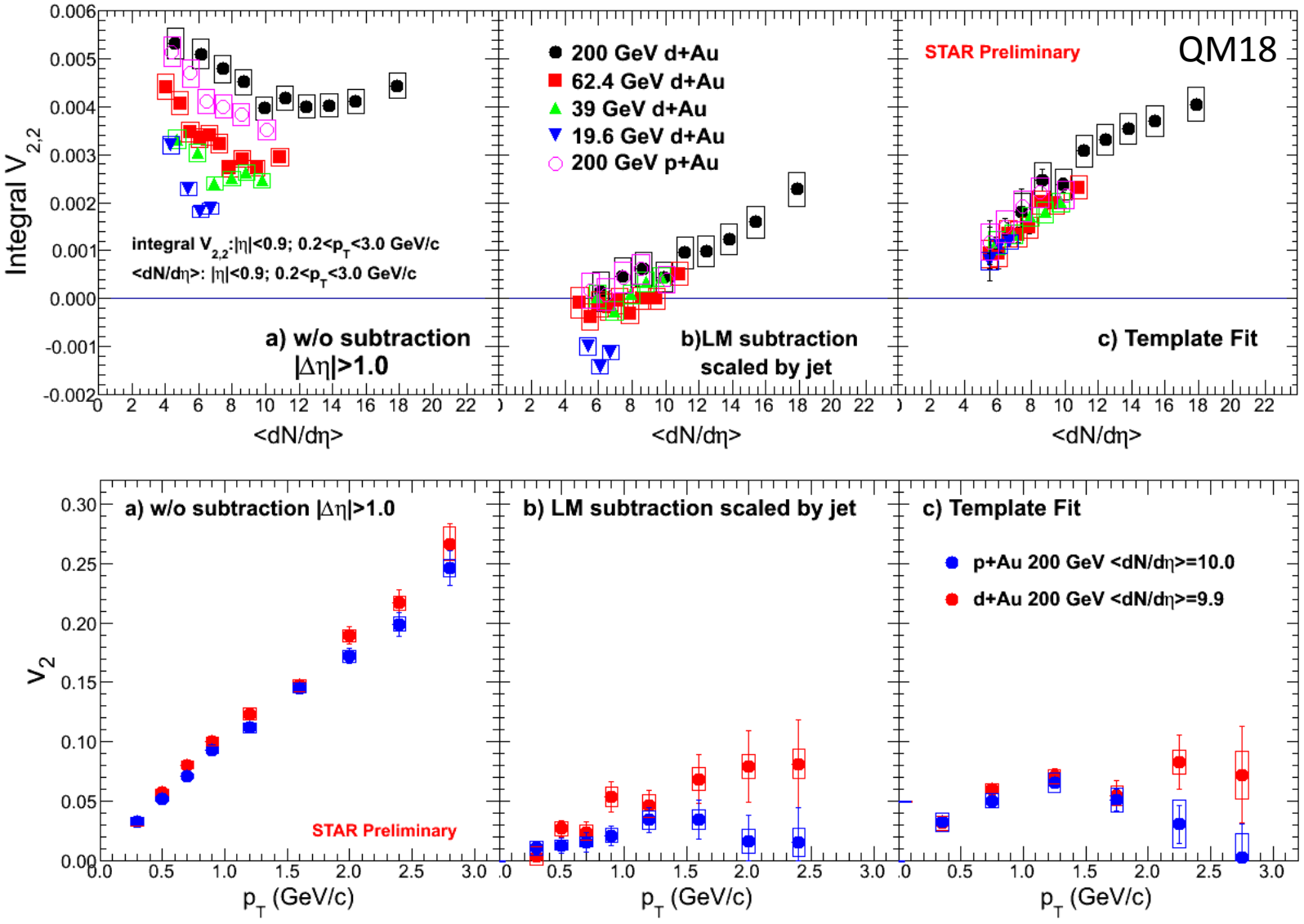
only in central collisions 0-5%

PHENIX : PRL 121 (2018) 222301



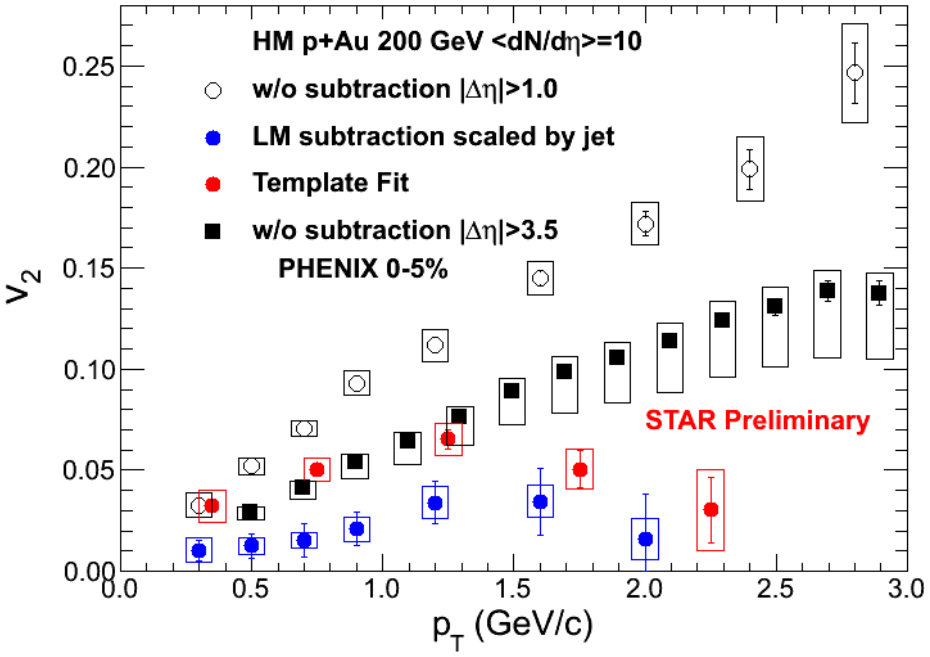
Centrality dependence with
"full" non-flow subtraction to come soon

v2 in small system (with/without non-flow subtraction)

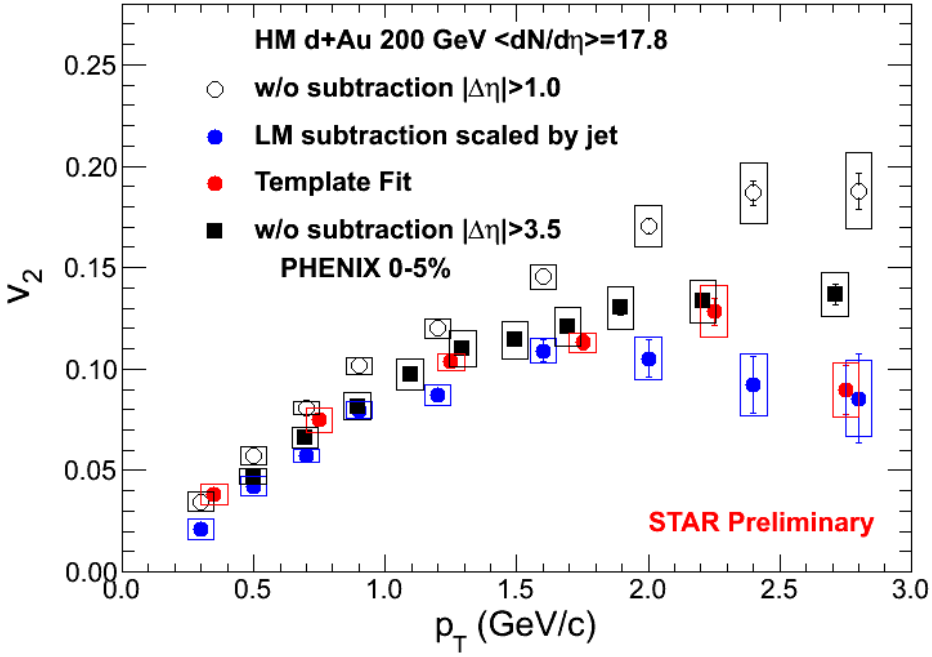


Comparison of v2 in small system (PHENIX/STAR)

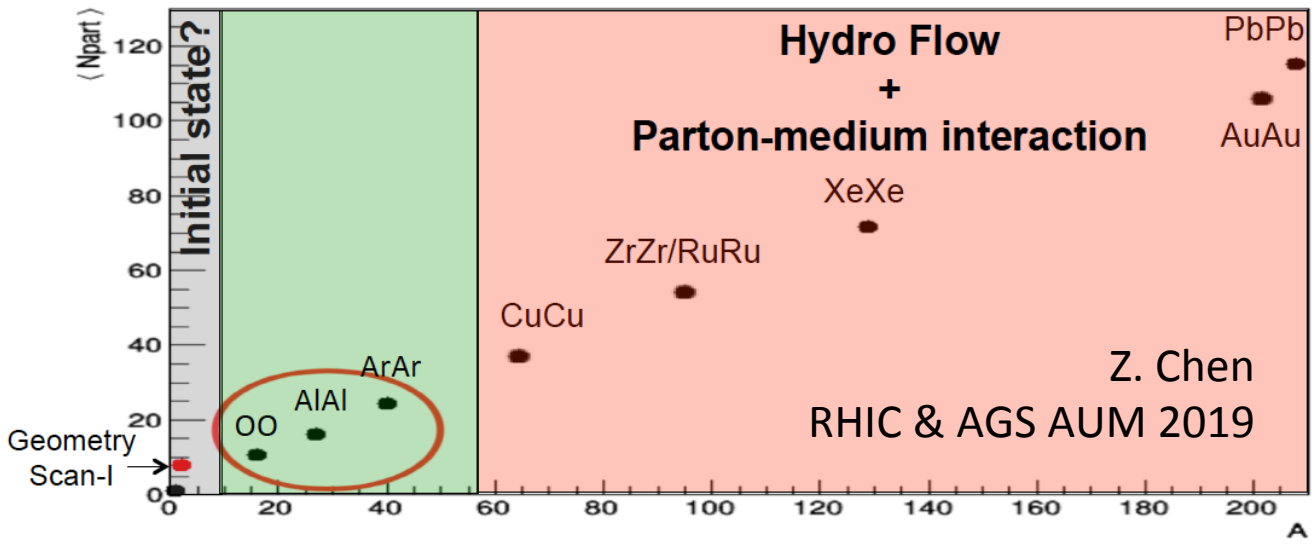
p-Au

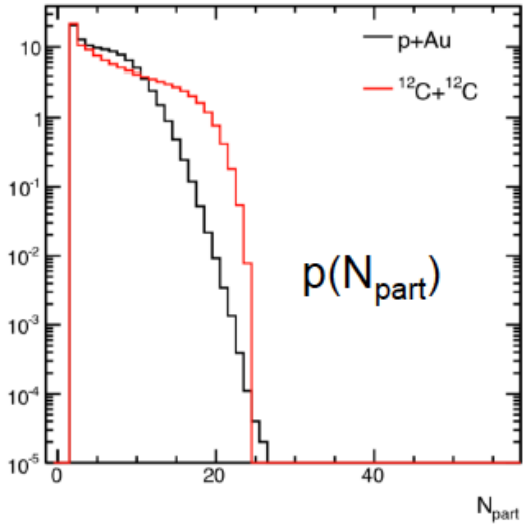


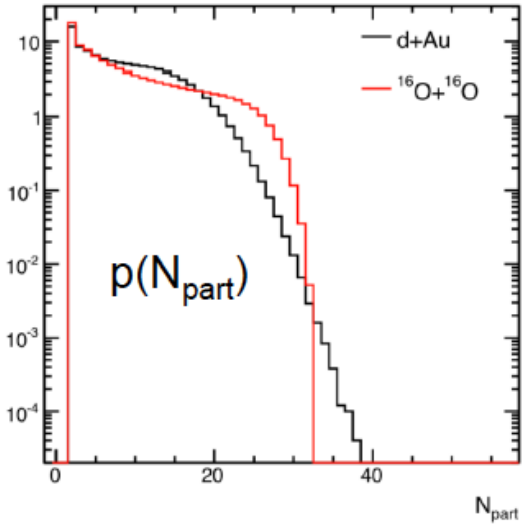
d-Au

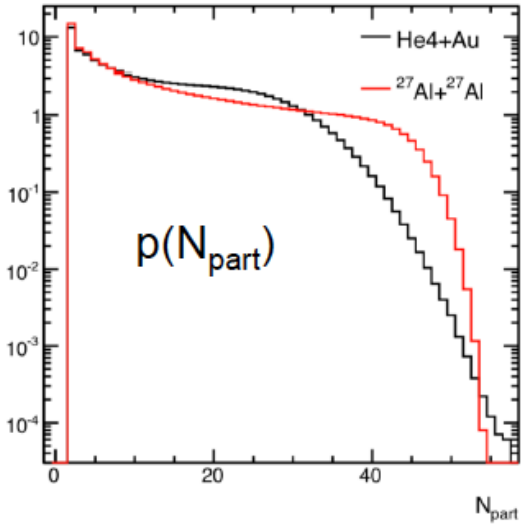


System scan in small (symmetric) systems

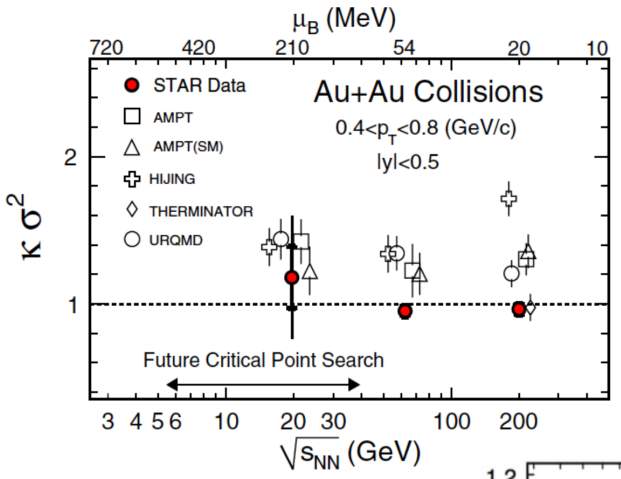






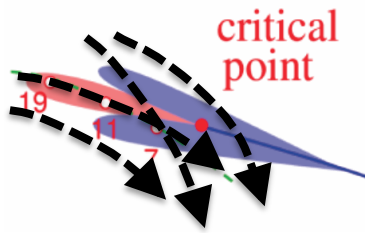


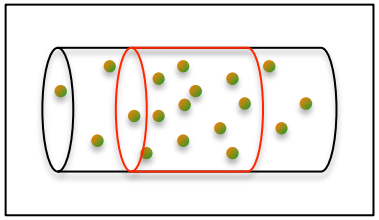
Higher order fluctuation of net-proton (History)



1st publication

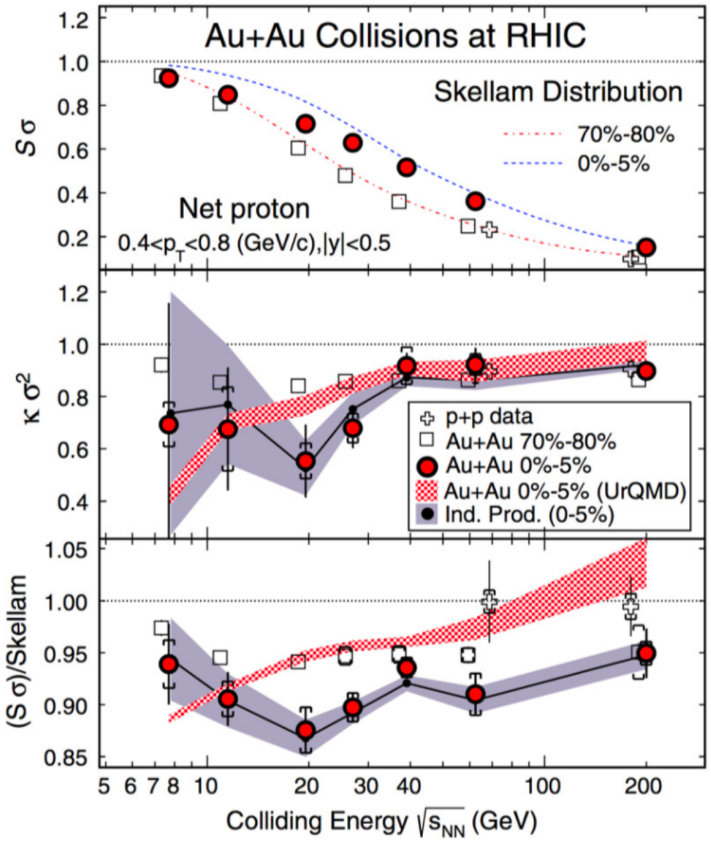
PRL105, (2010) 022302





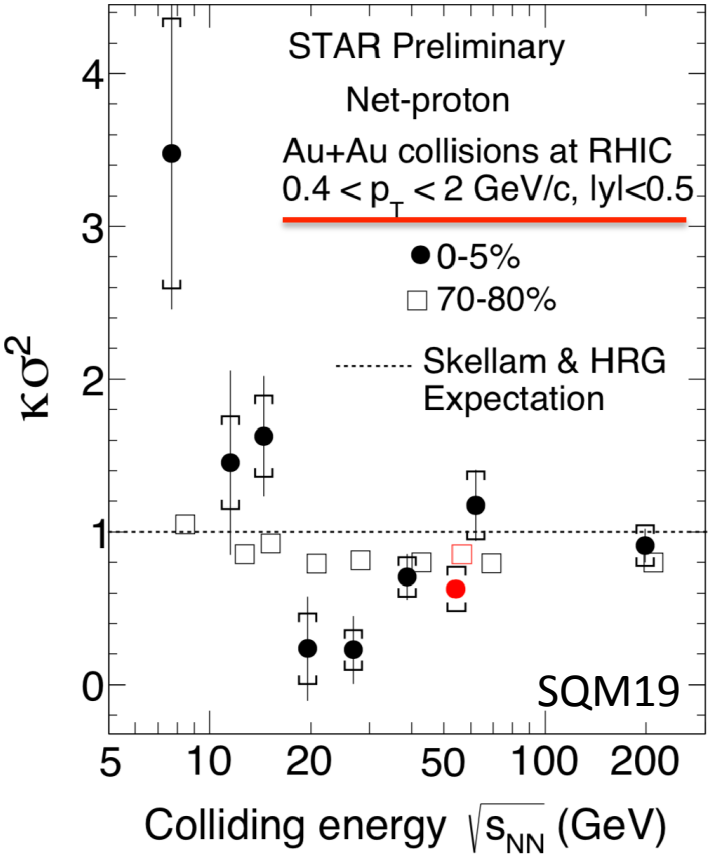
2nd publication

PRL112, (2014) 032302



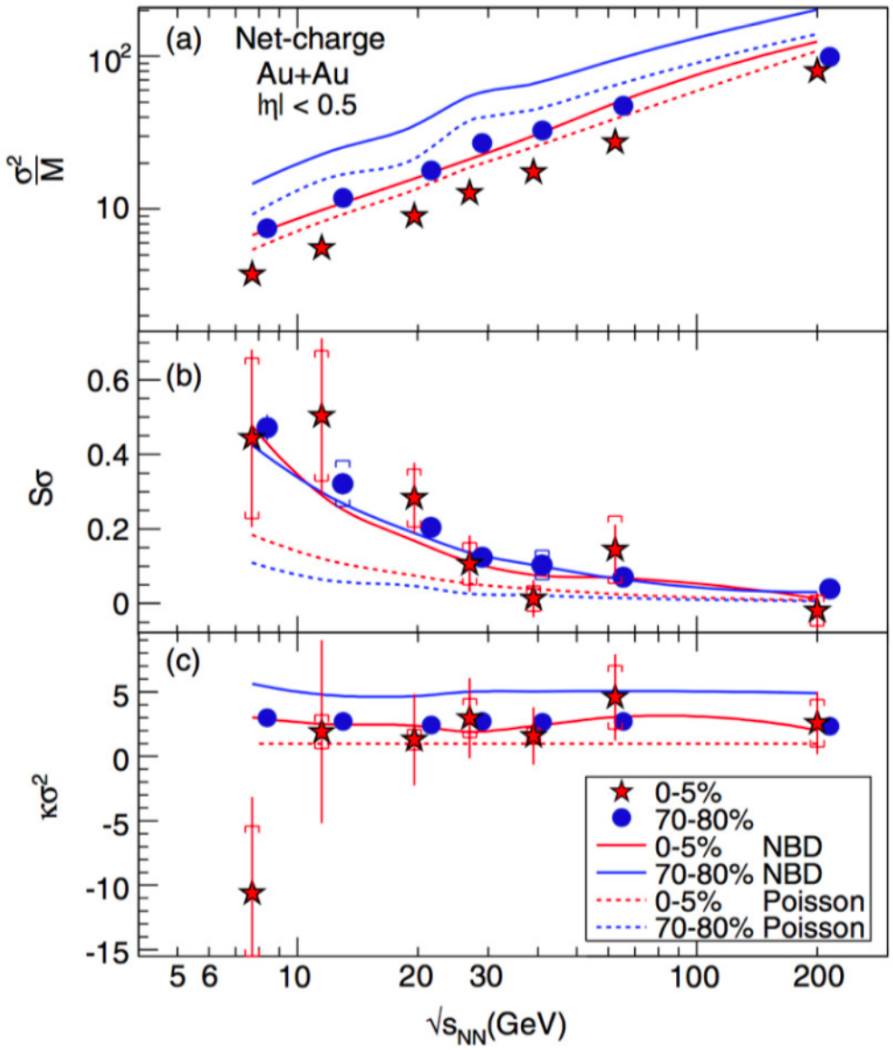
next publication

STAR, PoS CPOD2014 (2015)019

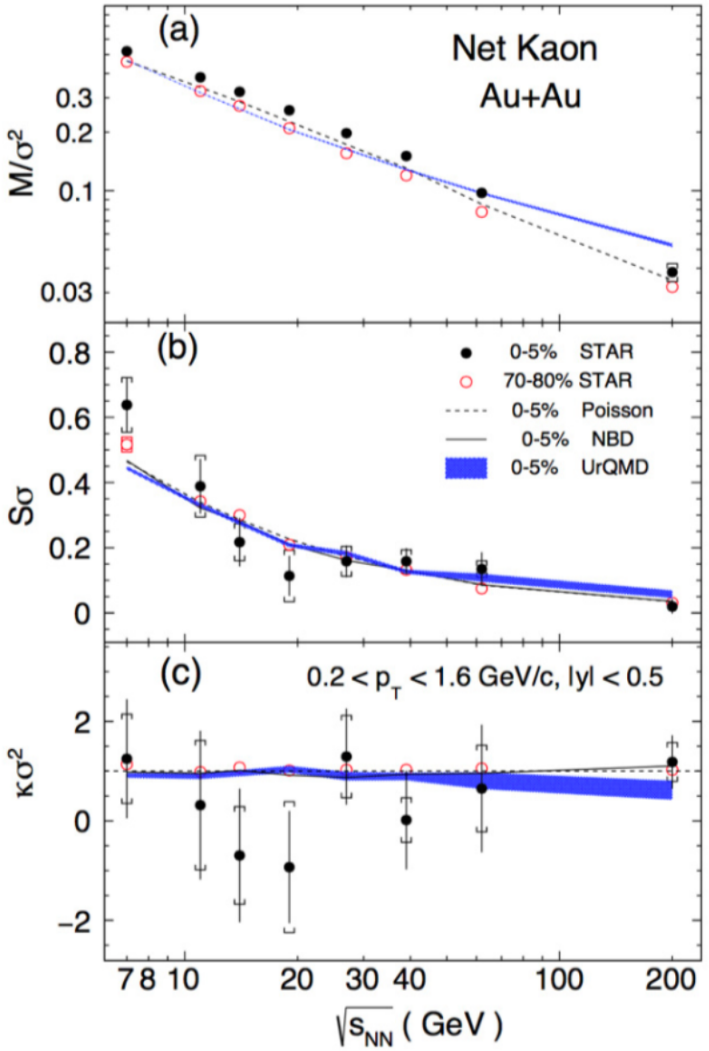


Higher order fluctuation of net-charge and net-kaon

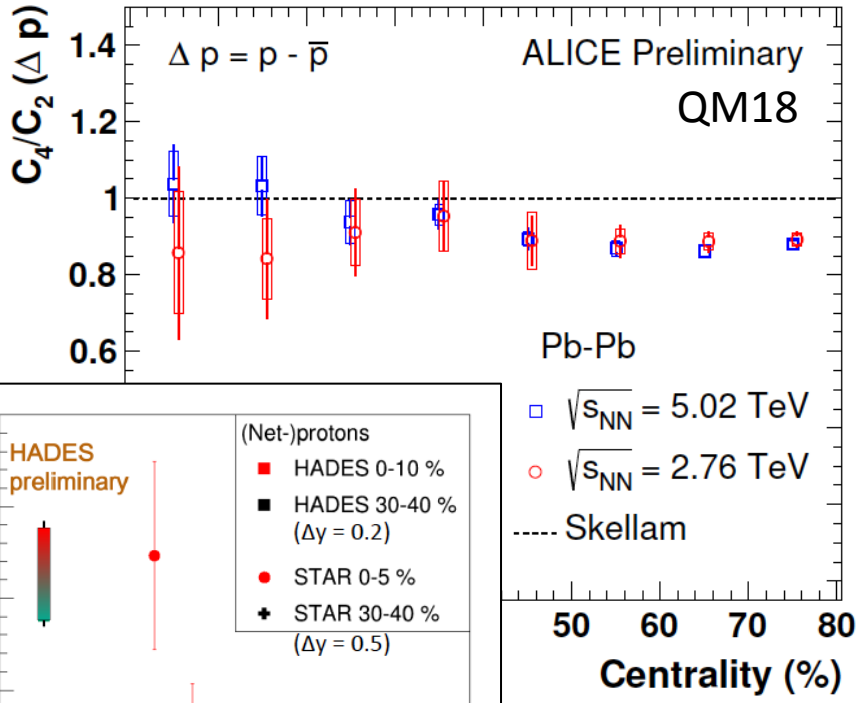
PRL113, 092301(2014): STAR

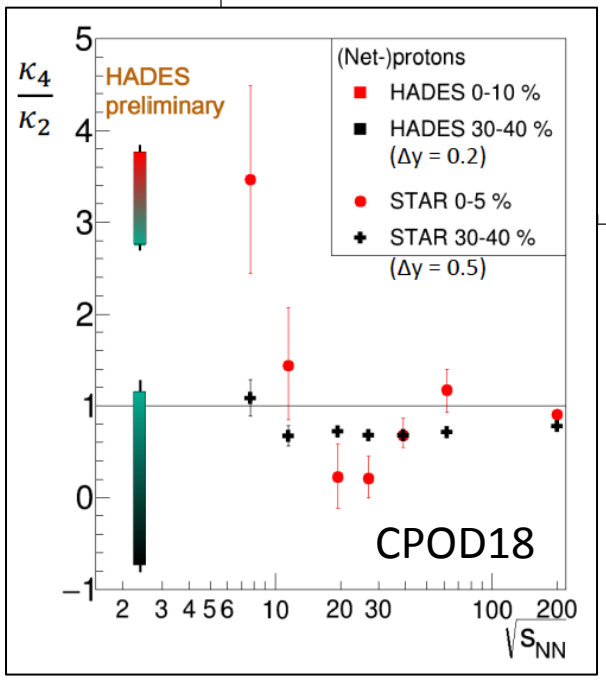


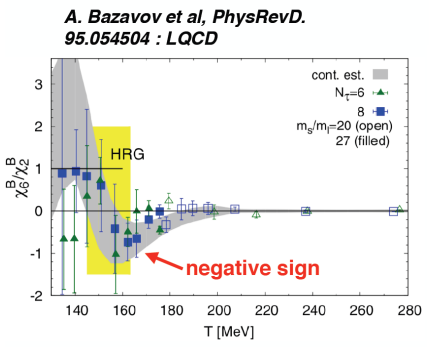
PLB, 785, 551(2018): STAR

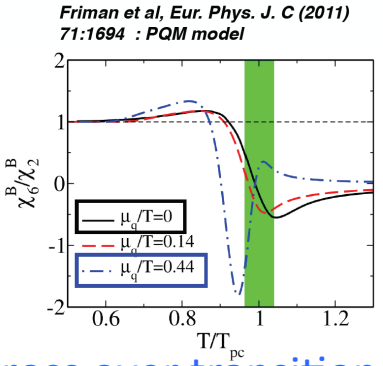


4th order measurements from HADES/ALICE and even higher (6th) order measurement

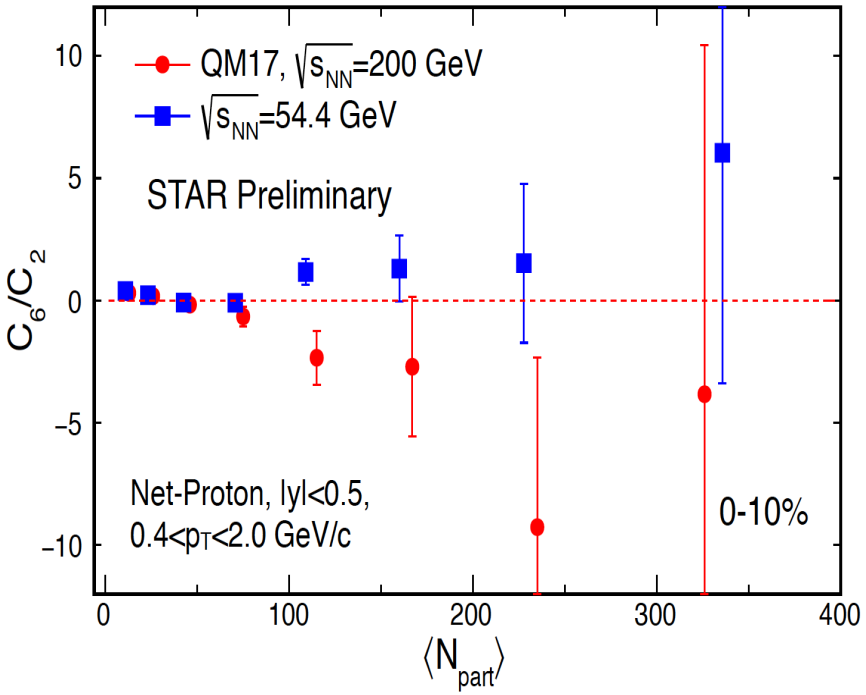




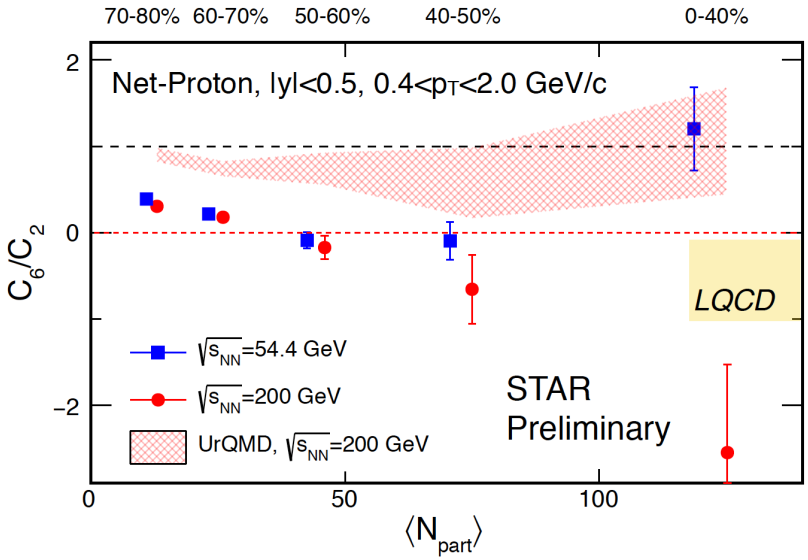




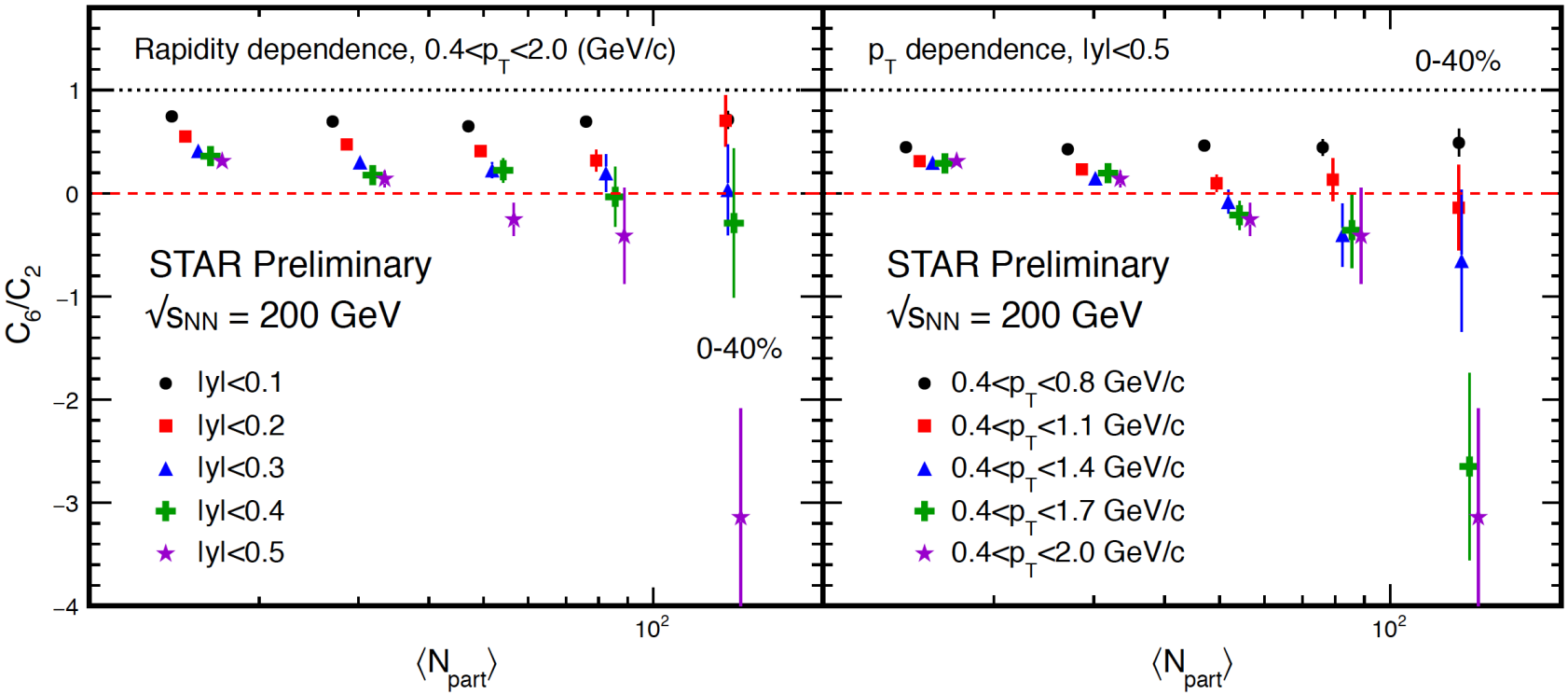
Possible signal from cross over transition



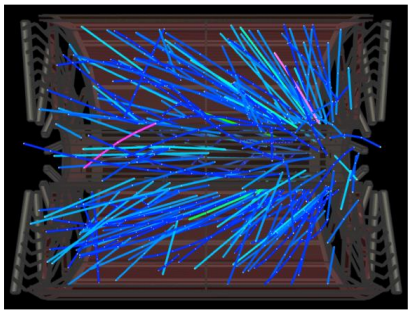
6th order fluctuation of net-proton : eta and p_T acceptance dependence

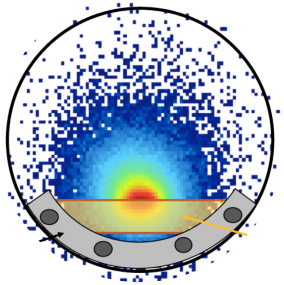


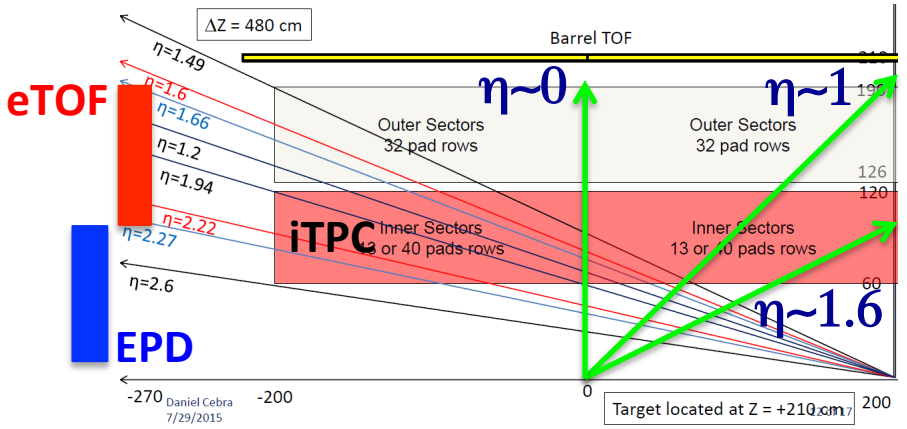
Toshihiro Nonaka (CCNU)

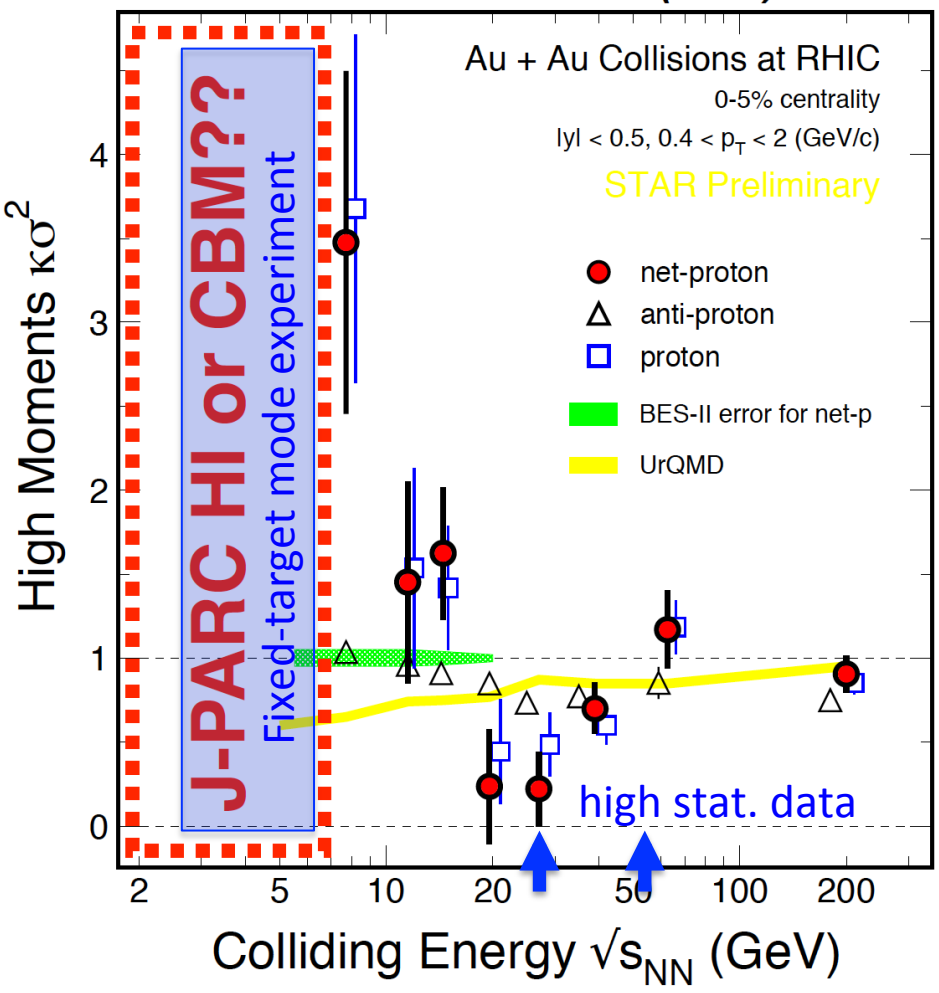


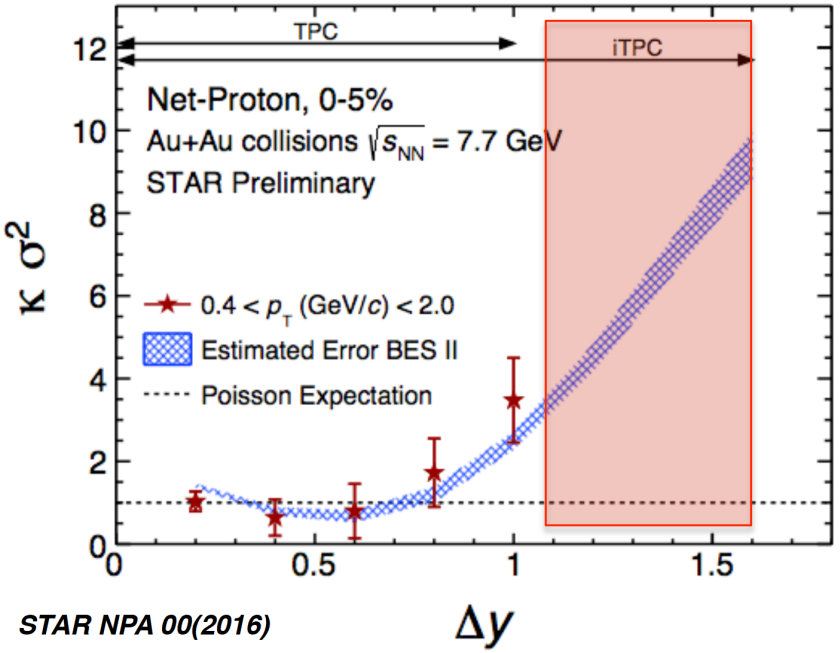
Detector upgrades and fixed-target experiment











Near future plan at RHIC and LHC

2019

BES2 plan RHIC-STAR

2020

2021

19.6 GeV, 14.5 GeV, 7.7 GeV (LEReC), 4-7 GeV(FXT)

Single-Beam Energy (GeV/n)	$\sqrt{s_{NN}}$ (GeV)	Run Time	Species	Events (MinBias)	Priority	Sequence
5.75	11.5	9.5 weeks	Au+Au	230M	1	1
4.55	9.1	9.5 weeks	Au+Au	160M	1	3
19.5	6.2 (FXT)	2 days	Au+Au	100M	2	5
13.5	5.2 (FXT)	2 days	Au+Au	100M	2	6
5.75	3.5 (FXT)	2 days	Au+Au	100M	2	2
4.55	3.2 (FXT)	2 days	Au+Au	100M	2	4
3.85	3.0 (FXT)	2 days	Au+Au	100M	2	7
100	200	1 week[2]	O+O	400M 200M (central) (0-5%)	3	8

Single-Beam Energy (GeV/n)	$\sqrt{s_{NN}}$ (GeV)	Run Time	Species	Events (MinBias)	Priority	Sequence
3.85	7.7	12 weeks	Au+Au	100M	1	1
8.35	16.7	5 weeks	Au+Au	250M	2	2
100	200	1 week[4]	O+O	400M 200M (central) (0-5%)	2	3

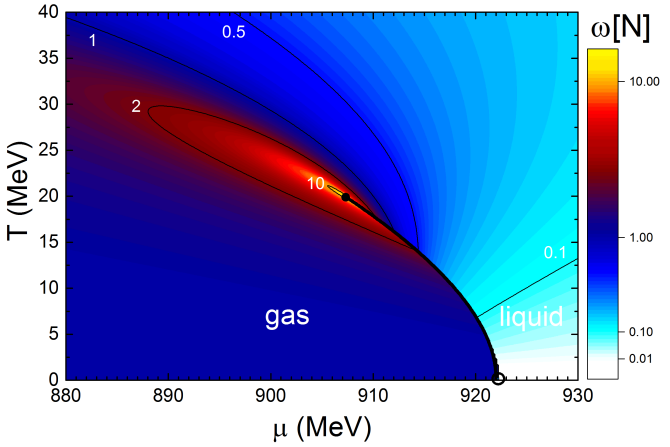
Proposed LHC run schedule

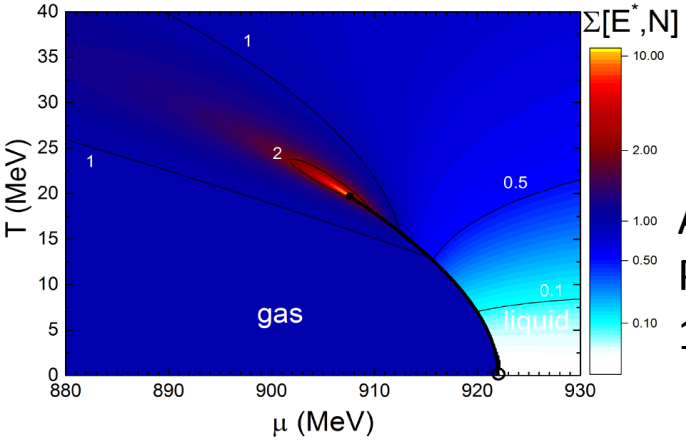
Arxiv.1812.06772

Year	Systems, $\sqrt{s_{NN}}$	Time	L_{int}
2021	Pb–Pb 5.5 TeV	3 weeks	2.3 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2022	Pb–Pb 5.5 TeV	5 weeks	3.9 nb^{-1}
	O–O, p–O	1 week	500 μb^{-1} and 200 μb^{-1}
2023	p–Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2027	Pb–Pb 5.5 TeV	5 weeks	3.8 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2028	p–Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2029	Pb–Pb 5.5 TeV	4 weeks	3 nb^{-1}
Run-5	Intermediate AA	11 weeks	e.g Ar–Ar 3–9 pb^{-1} (optimal species to be defined)
	pp reference	1 week	

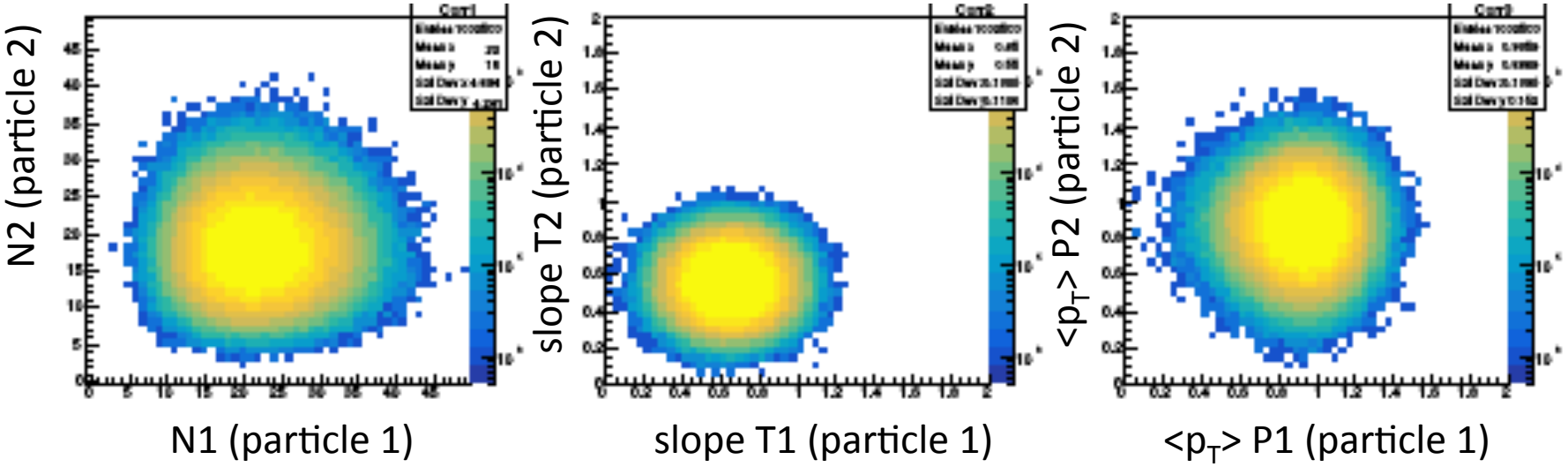
Correlated fluctuation between conserved number (net-baryon) vs temperature <p_T>

total multiplicity (N) - total transverse momentum (Σp_T) fluctuation





Acta Phys. Polon. Supp. 10 (2017) 753



Summary

- Directed and elliptic flows
- Higher order flow and small systems
- Fluctuation of conserved quantities
- Higher order cumulants
- Next plan

Global polarization (yesterday by Okubo)
Chiral magnetic effect/wave
Isobar ($_{40}$Zr+$_{40}$Zr, $_{44}$Ru+$_{44}$Ru) at 200GeV ~3G events
Switching the beam day-by-day
Full reconstruction has just started for blinding analysis