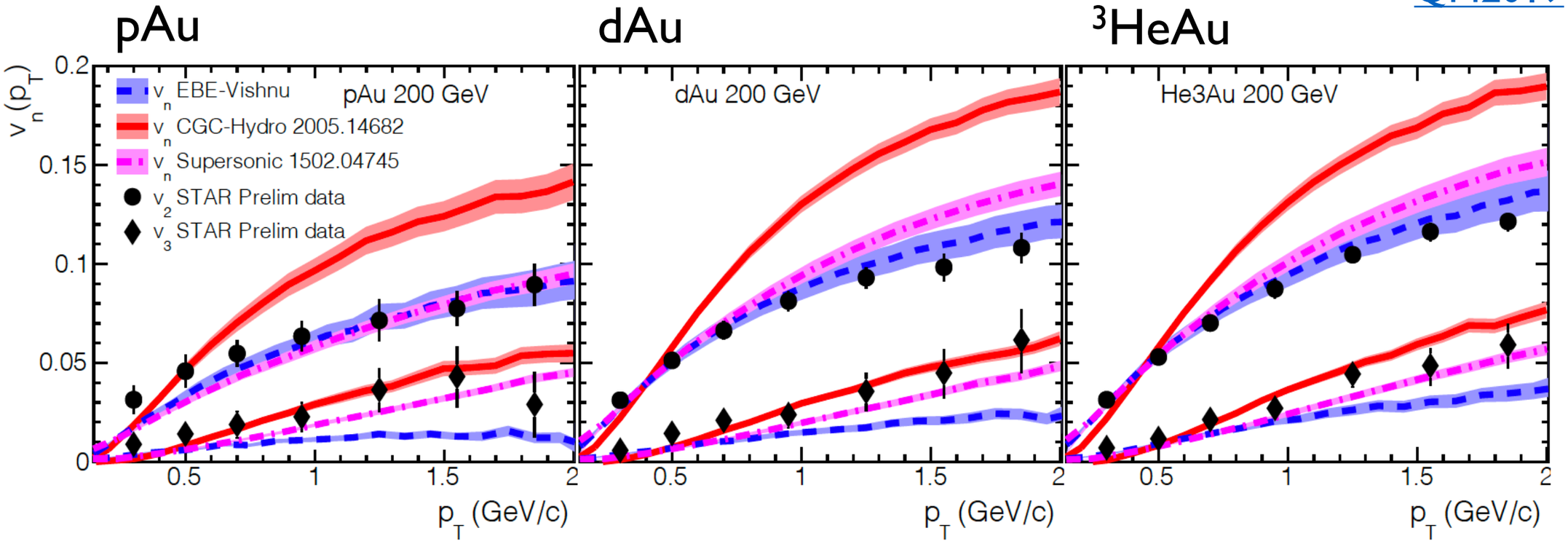
Opportunities of OO collisions at STAR

Wei Li (Rice University)
for the STAR collaboration

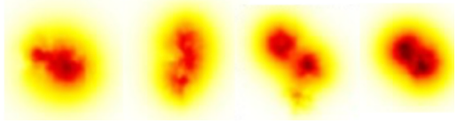
Workshop on pO/OO collisions at the LHC
February 10, 2021

QGP droplet in small systems

STAR BUR21
QM2019



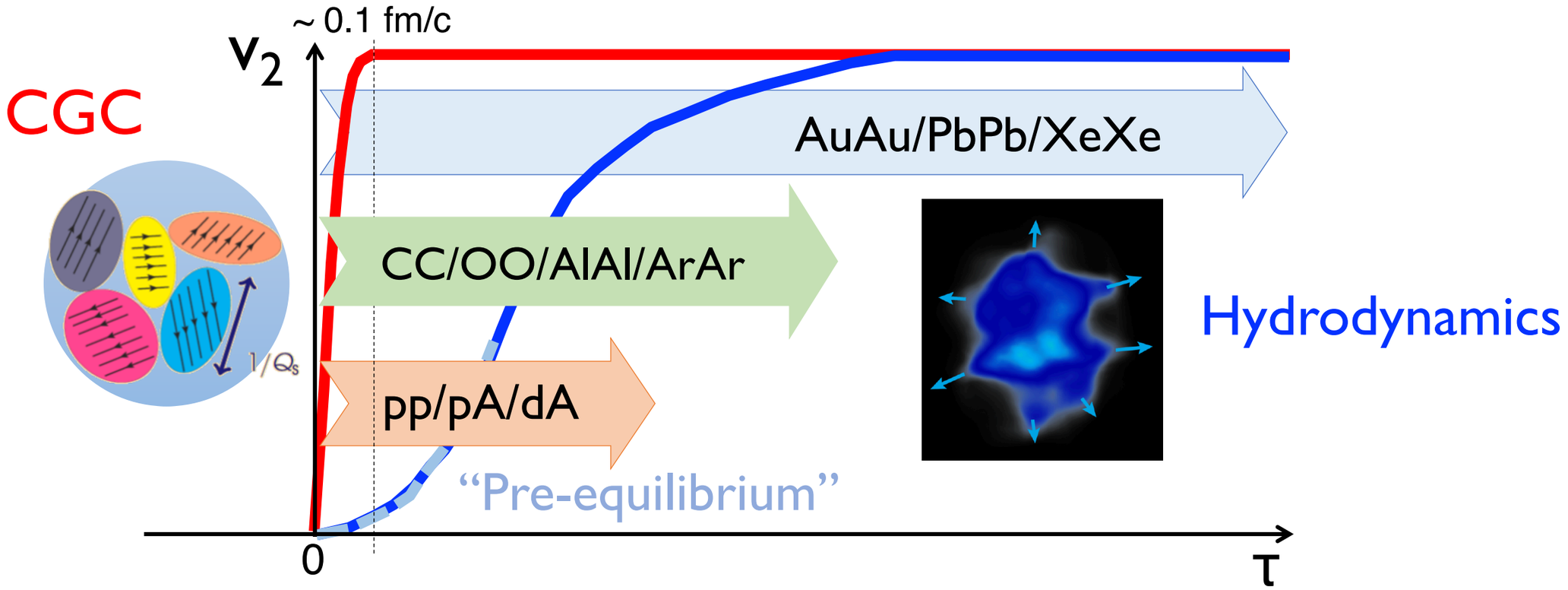
Success of hydro. models in small systems but still many open questions, e.g.,:

- Role of sub-nucleonic fluctuations  'eccentric proton'
- Contribution of initial momentum correlations (unrelated to geometry)
- Pre-equilibrium vs hydrodynamics?

QGP droplet in small systems

What is the time-scale (origin) for the emergence of collectivity?

Initial momentum correlations



A comprehensive scan of (a)symmetric systems + improved detectors at RHIC!

Proposal of an exploratory OO run at RHIC Run21

Expect a total of 24 cryo-weeks

STAR Bean User Request 2021

Single-Beam Energy (GeV/nucleon)	$\sqrt{s_{NN}}$ (GeV)	Run Time	Species	Events (MinBias)	Priority
3.85	7.7	11-20 weeks	Au+Au	100 M	1
3.85	3 (FXT)	3 days	Au+Au	300 M	2
44.5	9.2 (FXT)	0.5 days	Au+Au	50 M	2
70	11.5 (FXT)	0.5 days	Au+Au	50 M	2
100	13.7 (FXT)	0.5 days	Au+Au	50 M	2
100	200	1 week	O+O	400 M 200 M (central)	3
8.35	17.1	2.5 weeks	Au+Au	250 M	3
3.85	3 (FXT)	3 weeks	Au+Au	2 B	3

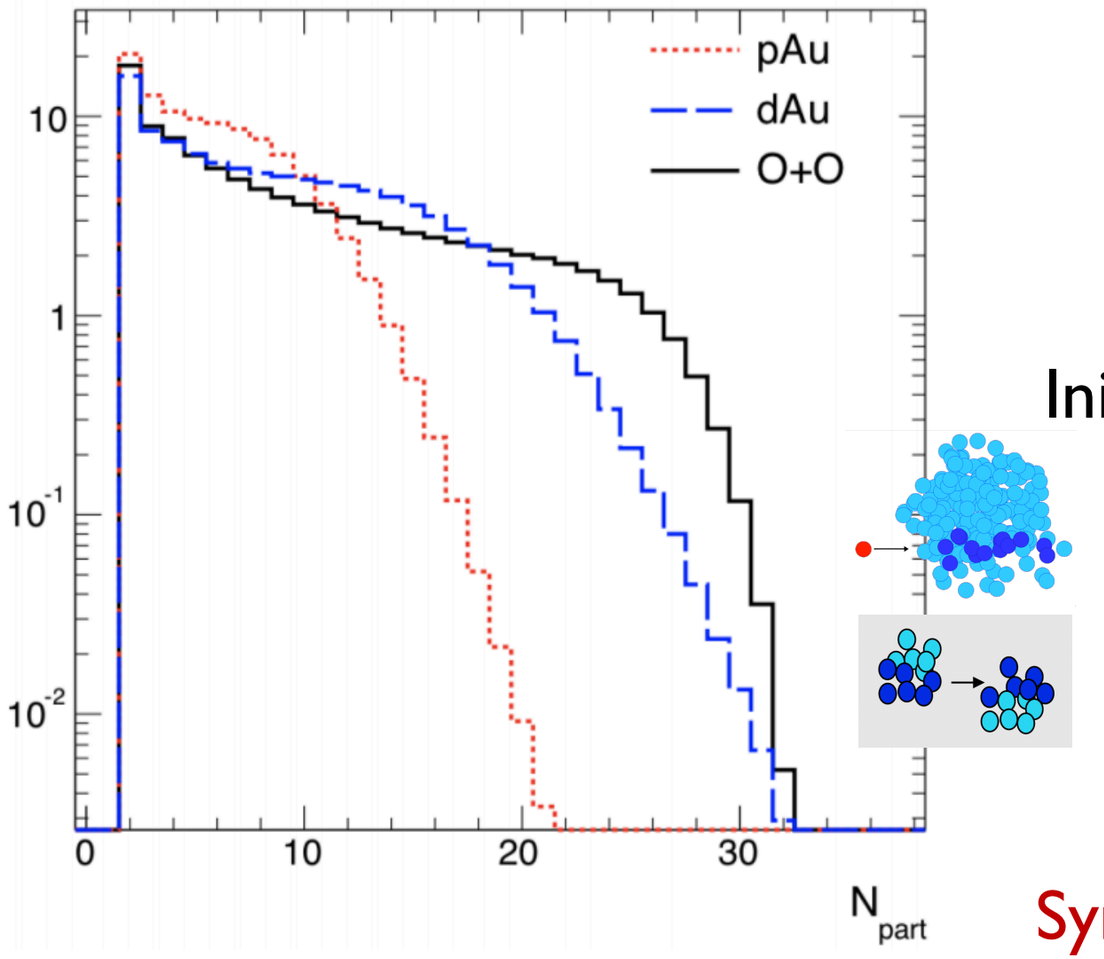
~0.5 nb^{-1}

BNL PAC report

"The PAC considers as important to the overall RHIC scientific program and a third priority for STAR data-taking ***an exploratory 1 week O+O run*** *at √sNN = 200 GeV (200M central)."*

" The O+O run would be novel and exploratory, and offers the chance to shed new light on questions related to whether, and if so how, droplets of QGP can form in small-size collisions. Although an O+O run could also be considered in a future year, these questions are pressing and topical now."

Why OO at RHIC?



Comparable N_{part} reach of small systems

	pAu	dAu	$^{16}O+^{16}O$
$\langle N_{part} \rangle$	5.8	8.8	9.5

Initial-state geometry:

Asymmetic: sub-nucleon fluct. more important

Symmetric: nucleon fluct. more important→ better control of *b* and geometry?

Synergy with pO/OO program at LHC energies

Collective flow in OO at RHIC and the LHC

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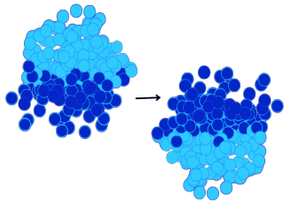
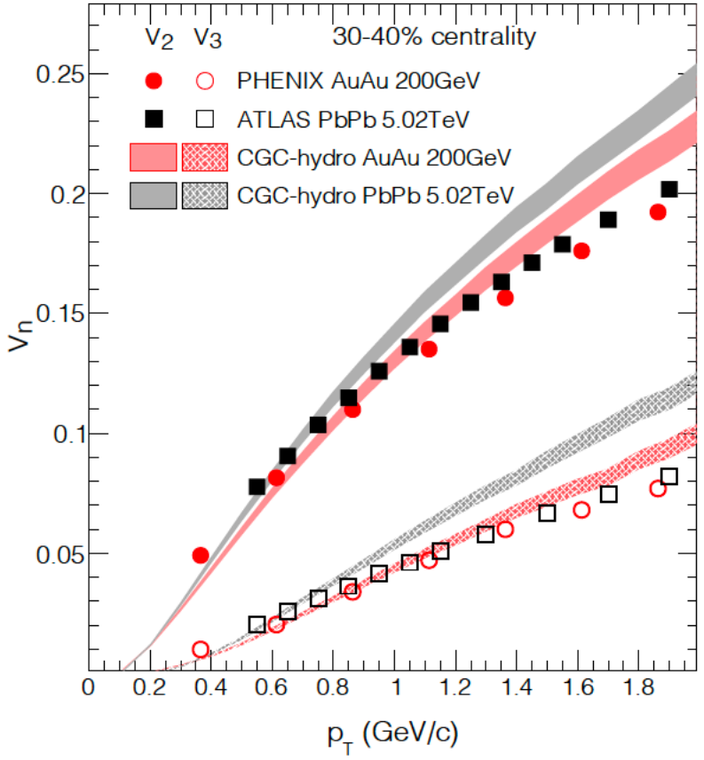
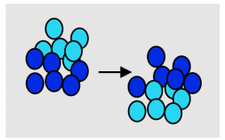
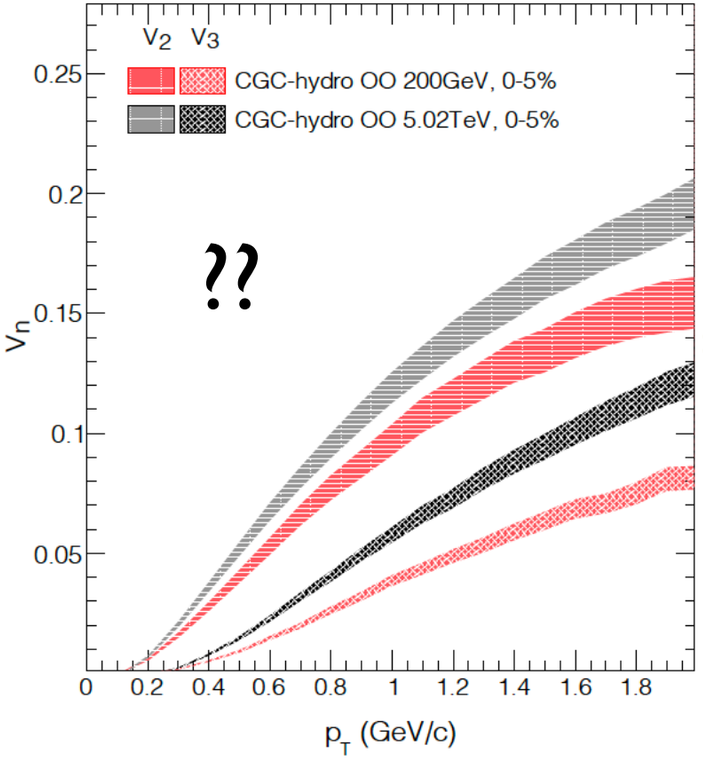


AuAu/PbPb

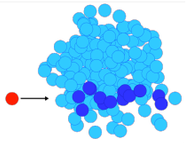


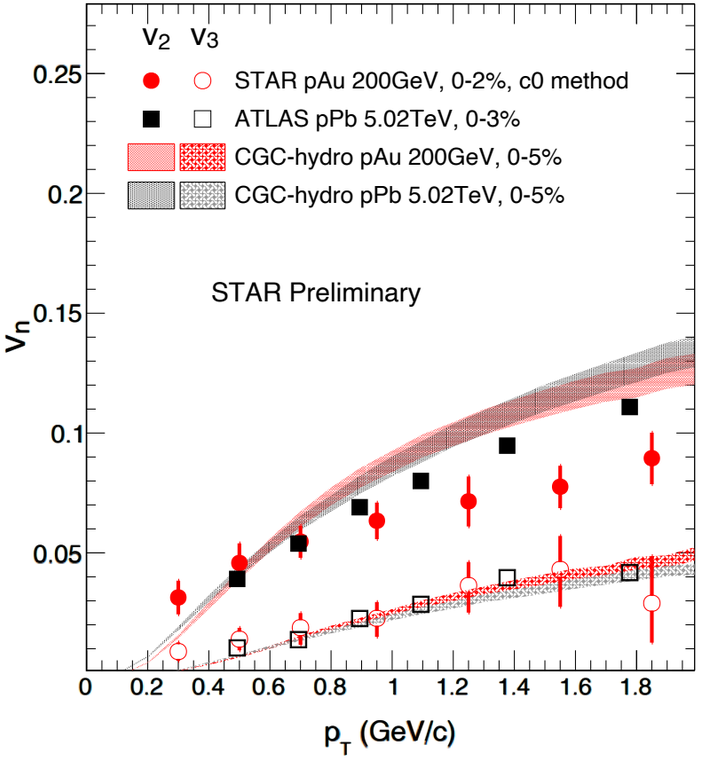
OO





pAu/pPb





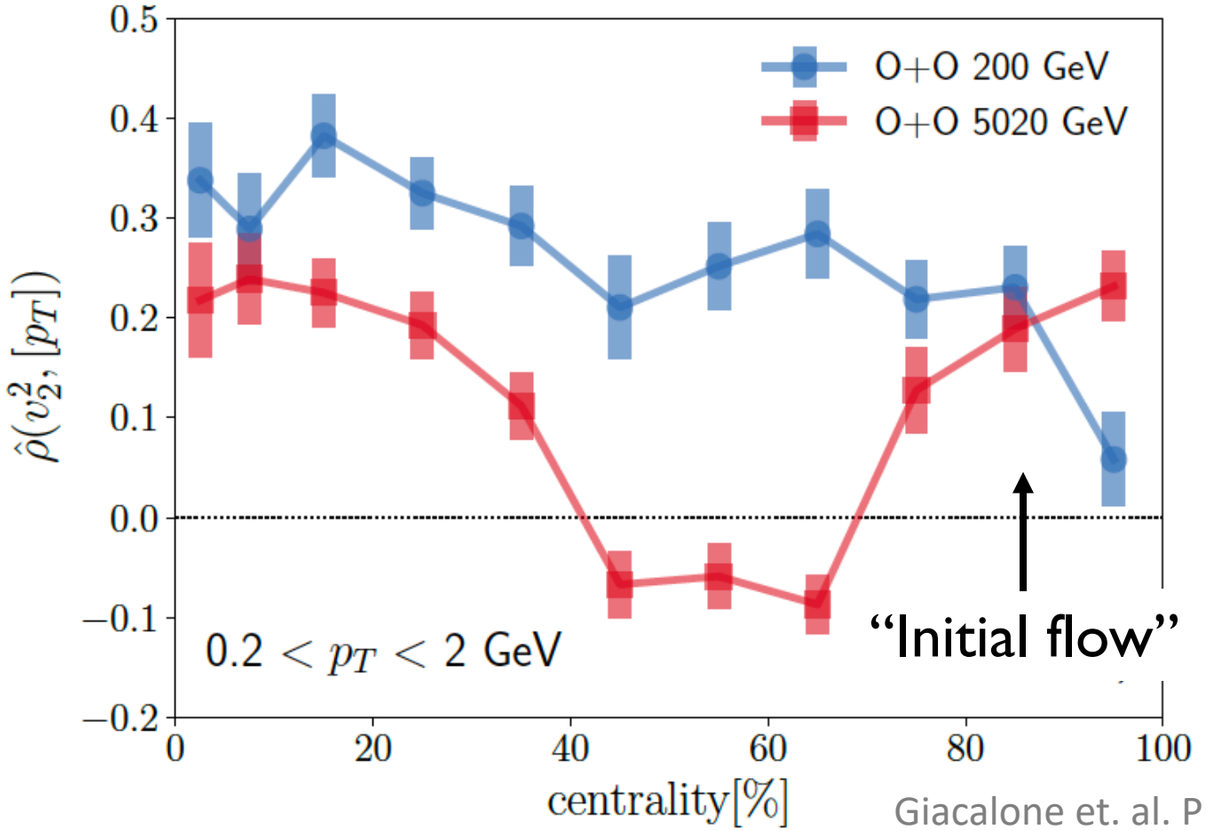
Energy indep. of $v_n(p_T)$ from 0.2 to 5 TeV in largest and smallest systems

How about OO? nucleonic vs. sub-nucleonic fluctuations at different energies?

Collective flow in OO at RHIC and the LHC

v_2-$\langle p_T \rangle$ correlation

hybrid IP-Glasma+MUSIC+UrQMD model

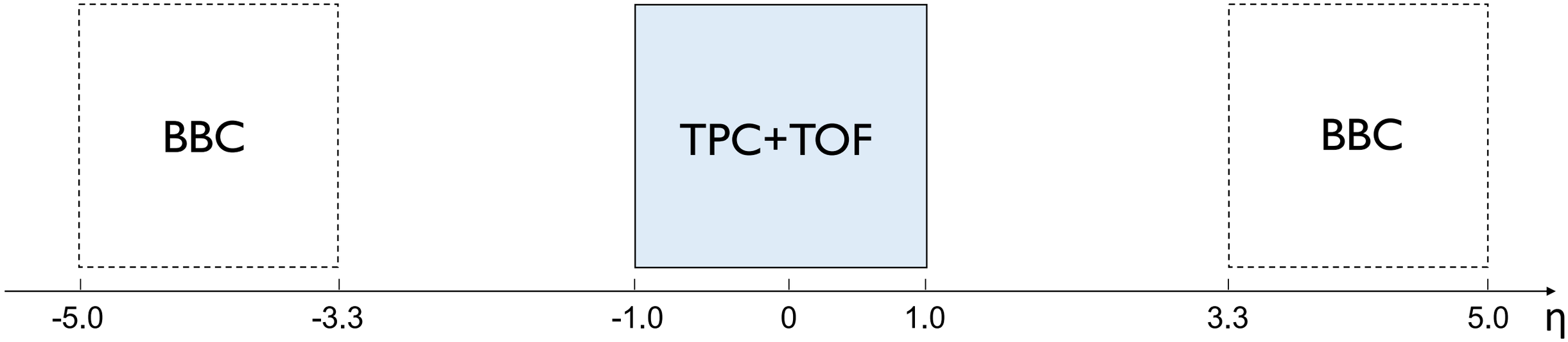


Giacalone et. al. PRL 125, 192301 (2020)

Unambiguous observation of initial momentum correlations?

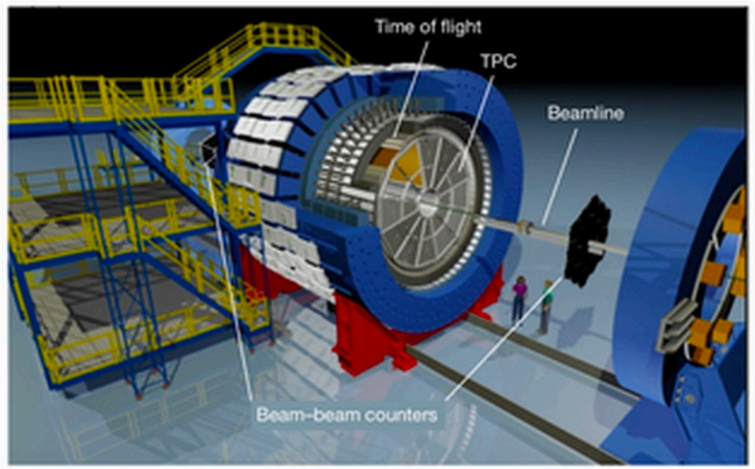
(caveat: behavior of nonflow to be investigated)

STAR detector at small system scans (till 2017)

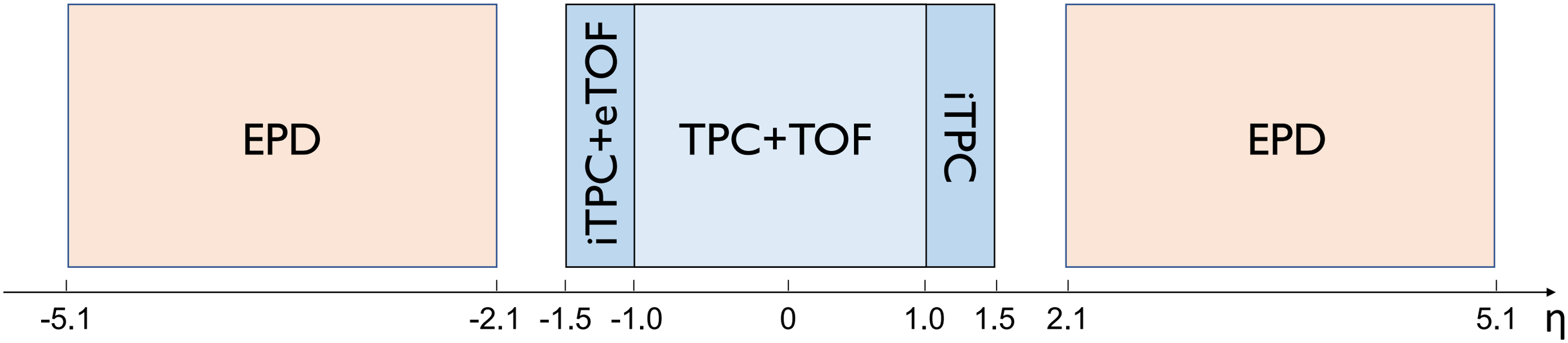


Earlier small system results mostly limited at **|η|<1**

- BBC resolution not ideal
- Nonflow uncertainties large



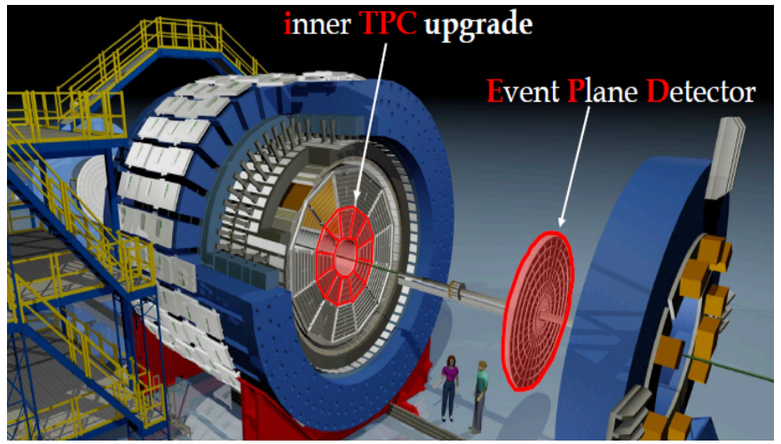
STAR detector now and beyond (2019+)



Extended η, p_T, PID coverage of central detector

New forward EPD:

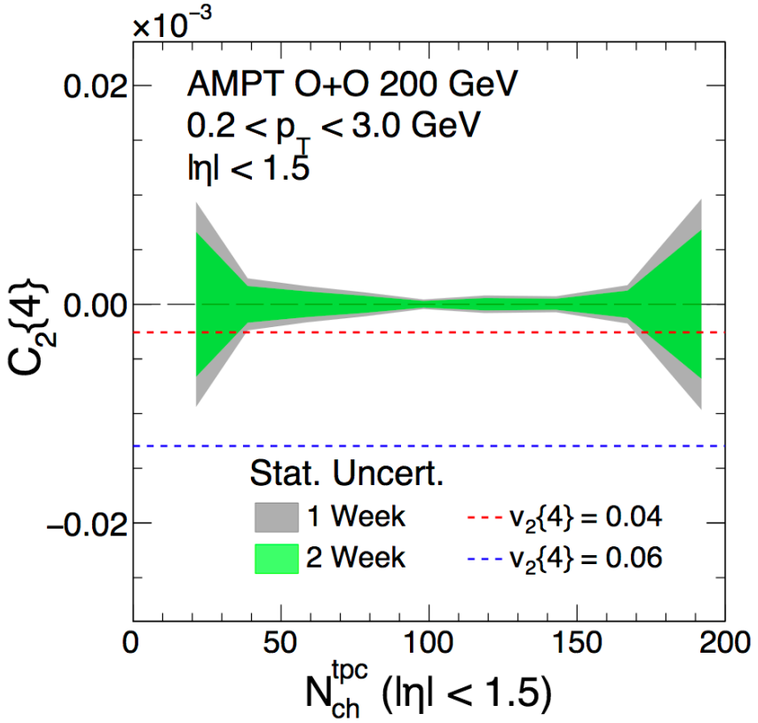
- better EP resolution and handle of nonflow
- forward centrality → check biases



Projected performance - collectivity

- Precise measurement of $v_2\{4\}$ signal $\geq$ 0.04-0.06 over wide centrality/multiplicity ranges

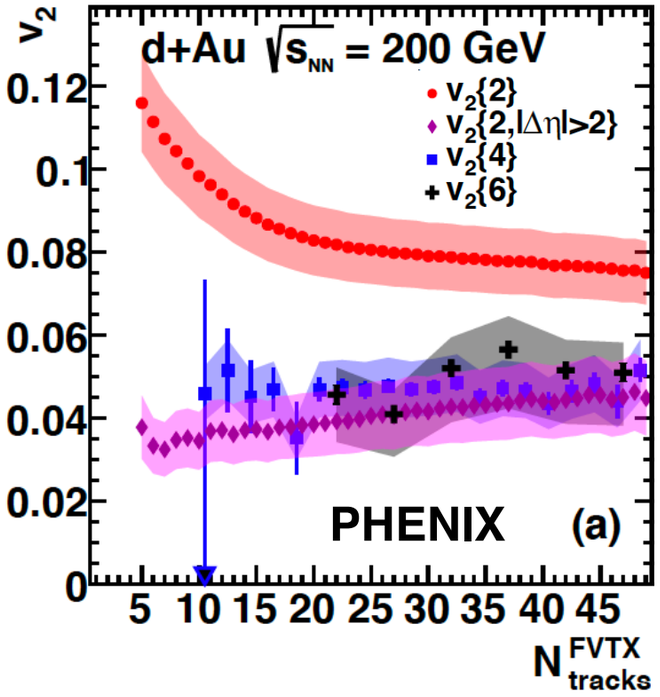
OO $v_2\{4\}$ projection



Std. cumulant

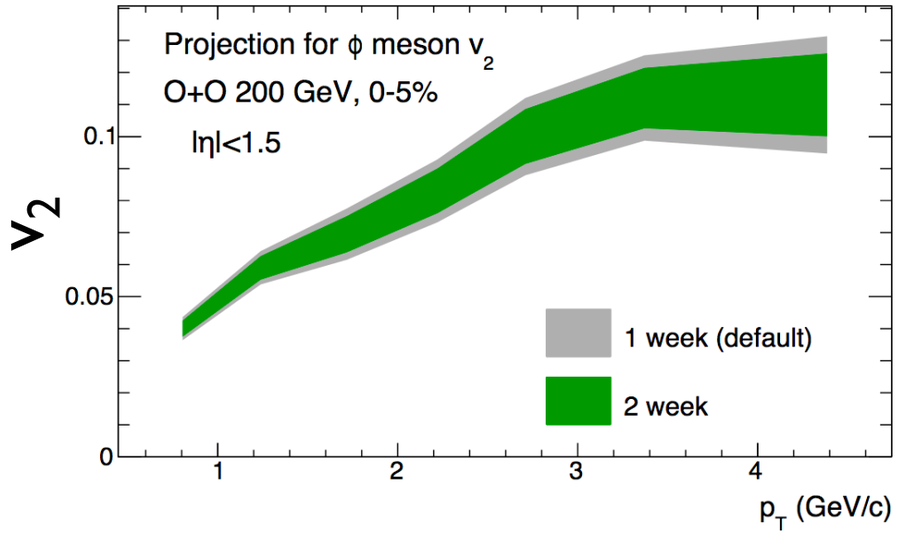
$v_2\{4\}$ ~ 0.05 in dAu

PRL 120, 062302 (2018)



- High precision PID v_2, v_3 and spectra

$\phi \rightarrow K^+K^-$



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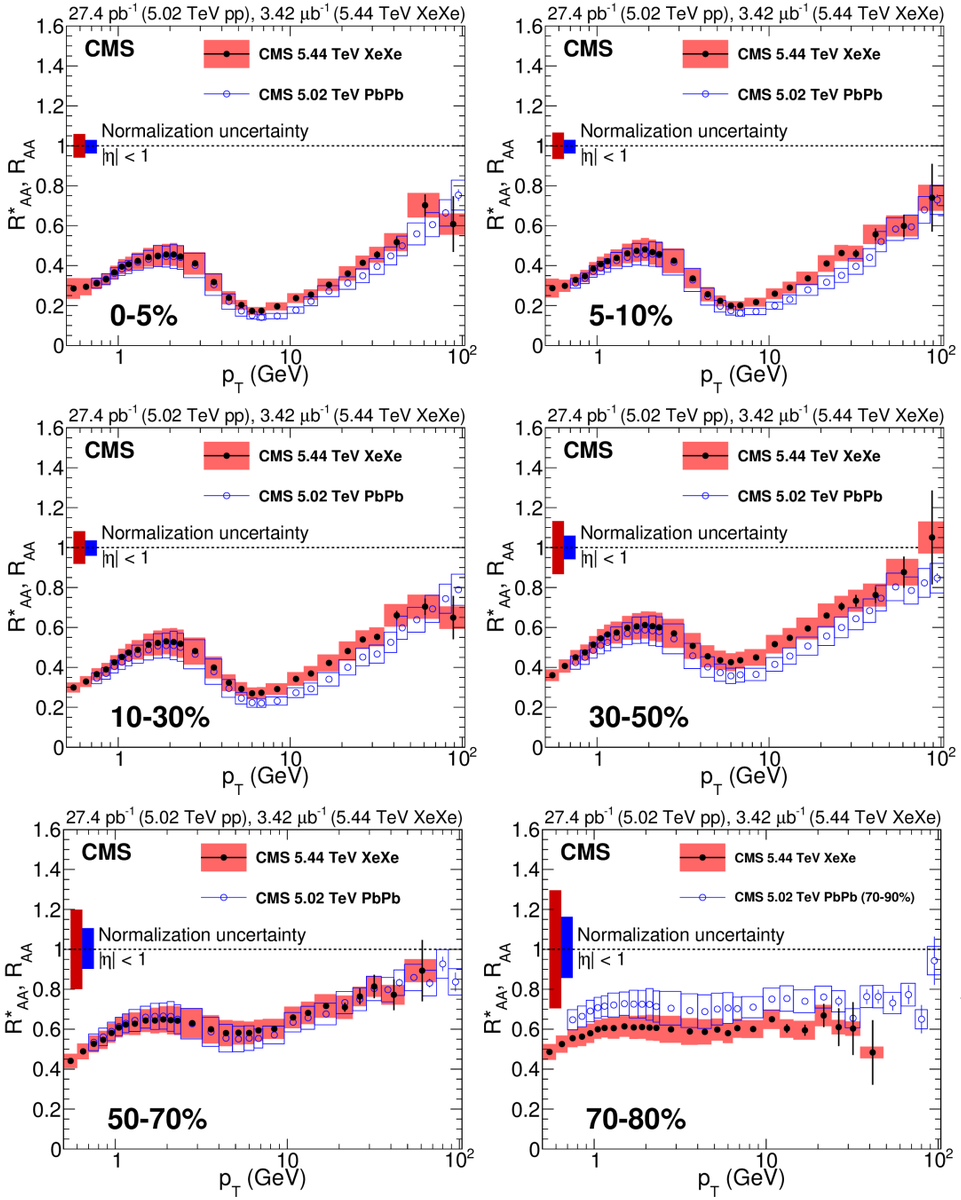
Projected performance – jet quenching

At the LHC

JHEP 10 (2018) 138



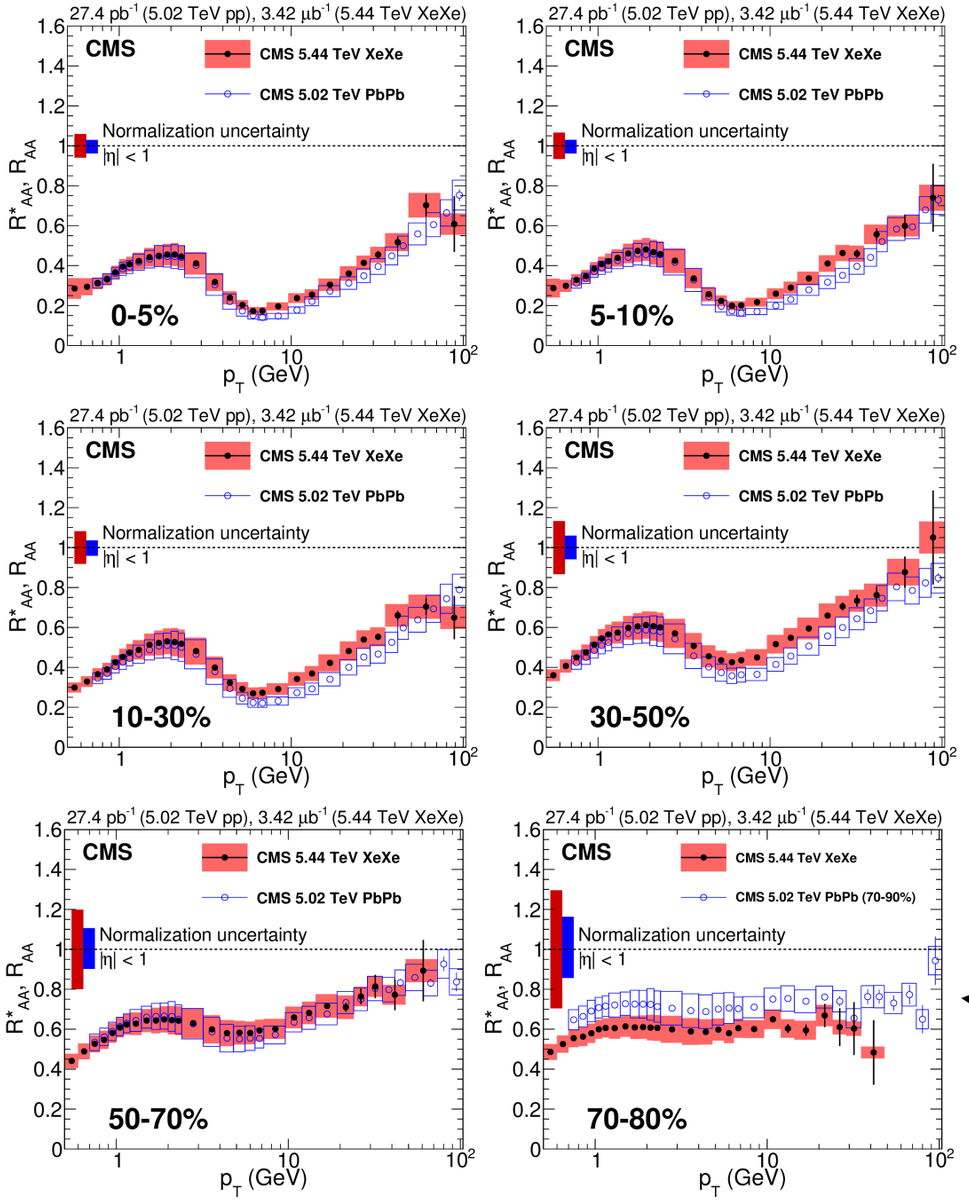
Search for onset (?) of jet quenching

← Apparent suppression for <N_{part}>~6

Projected performance – jet quenching

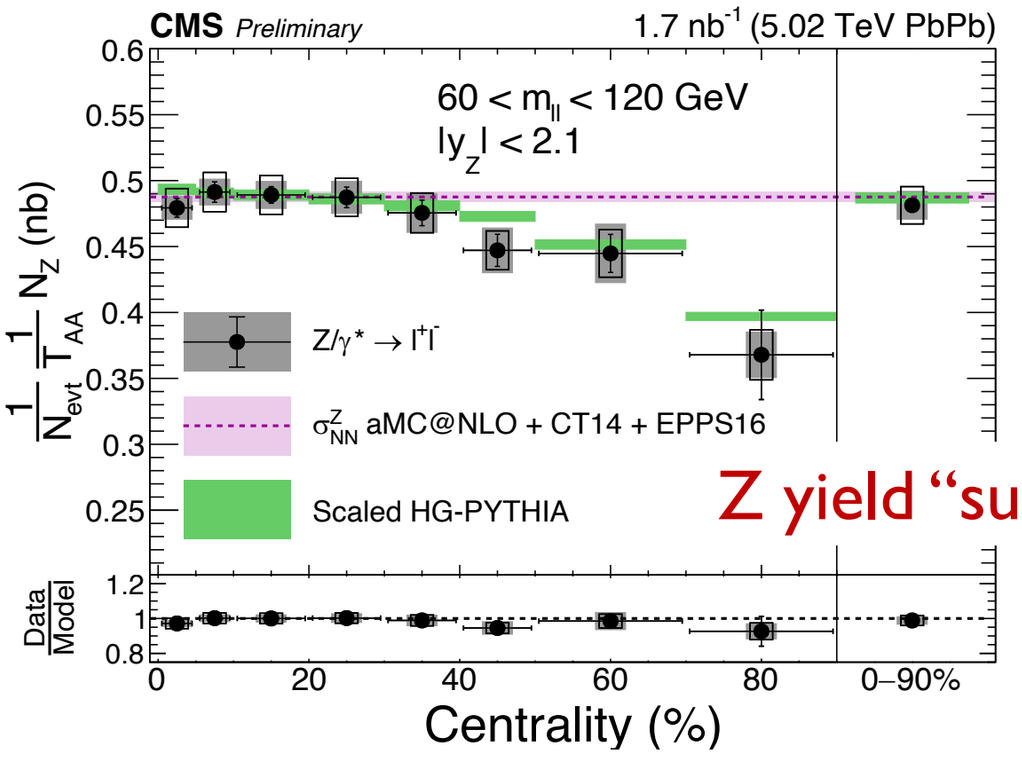
At the LHC

JHEP 10 (2018) 138



Search for onset (?) of jet quenching

CMS-PAS-HIN-19-003



Z yield "suppressed"!

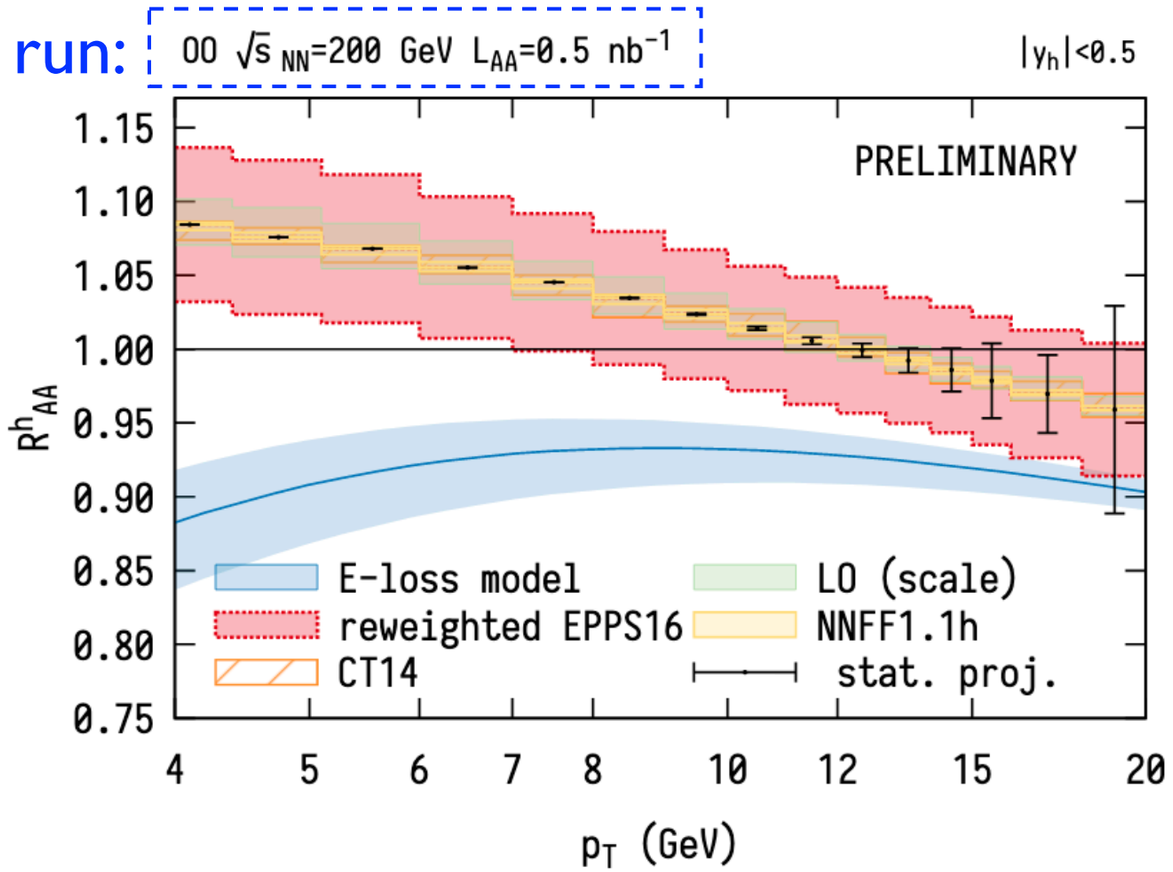
Apparent suppression for <N$_{part}$>~6

- can be explained by centrality bias

Projected performance – jet quenching

Minimum Bias OO: no centrality bias

1-week RHIC run:



Based on
arXiv:2007.13754
arXiv:2007.13784

$\langle N_{part} \rangle \sim 9.5$

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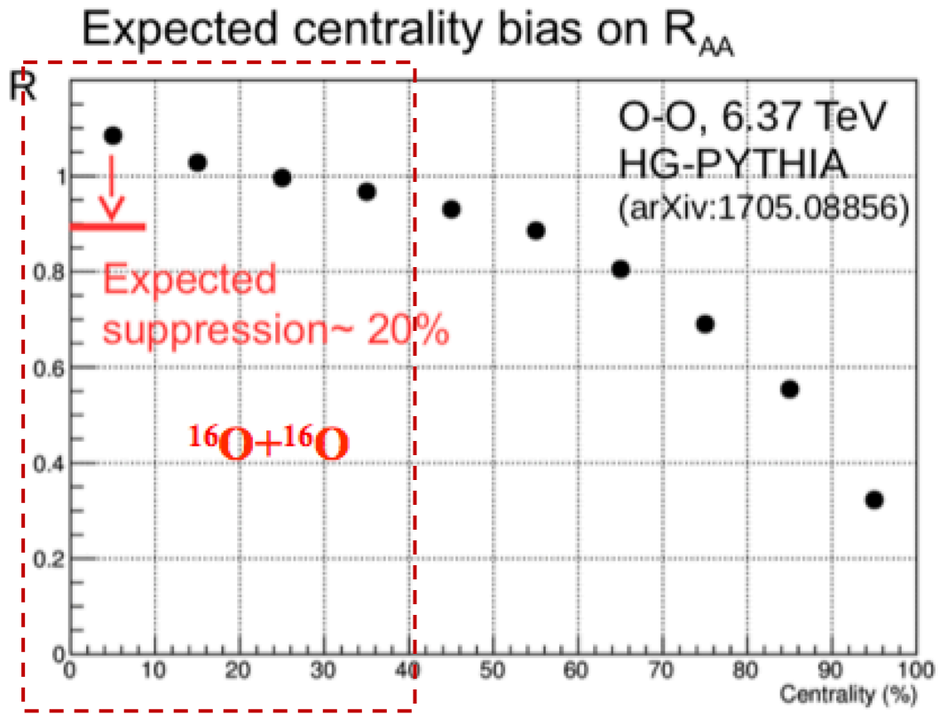
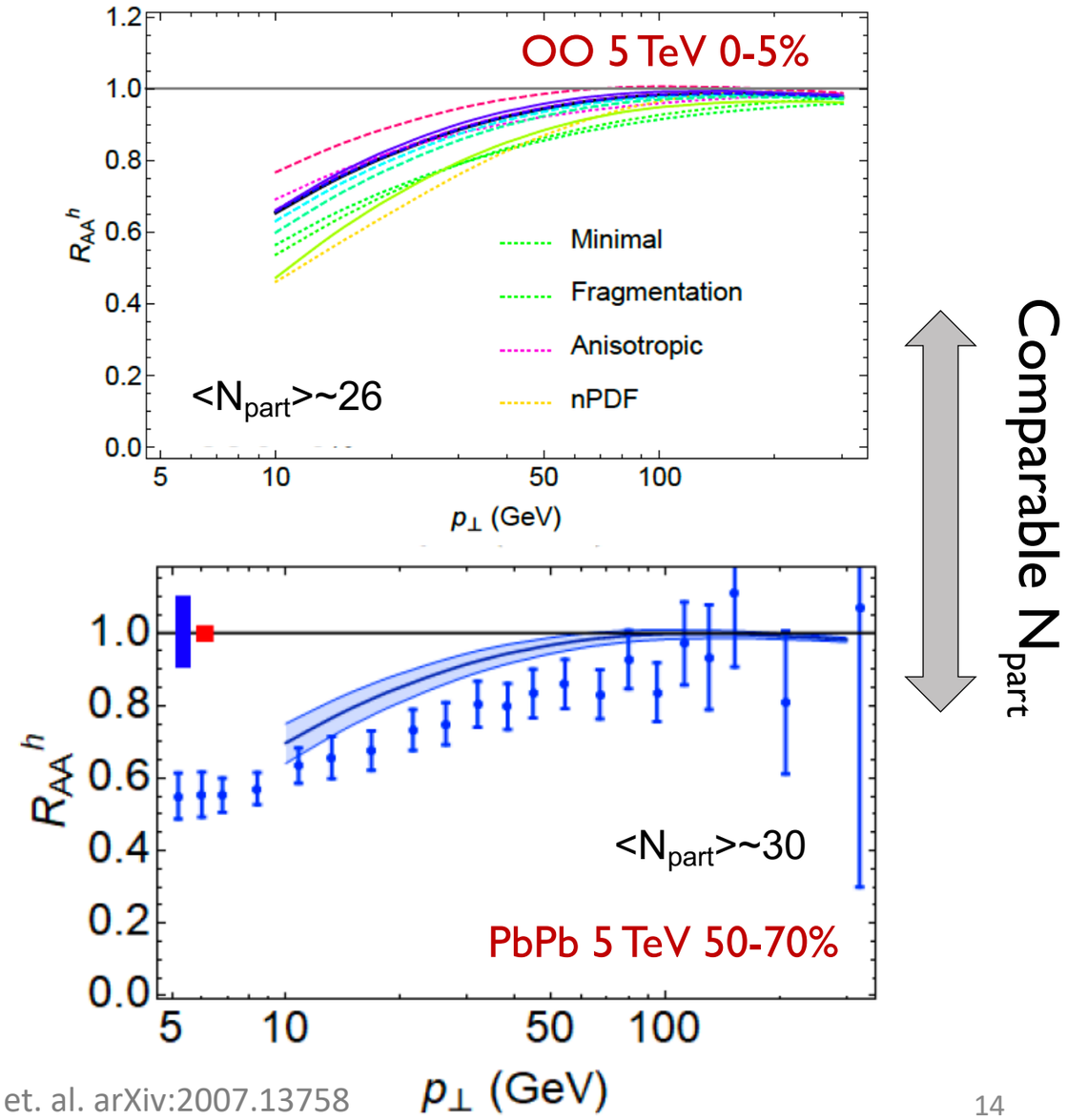
High precision up to $p_T \sim 12$ GeV to differentiate various model scenarios

Projected performance – jet quenching

Centrality dependence: smaller bias in OO



to be updated for 200 GeV



Huss et. al. arXiv:2007.13758

Summary

Lighter-ion systems important in providing new insights to many open questions on collectivity in small systems

STAR proposed a one-week exploratory OO run at RHIC in 2021, aiming to

- To further constrain the role of sub-nucleonic fluctuations and "initial flow" in the observed final-state collectivity
- Unambiguous observation of jet quenching in small systems (N_{part} ~ 10-20)?

OO as a cornerstone to motivate future scans of lighter ions at RHIC and LHC!

Acknowledgement

U.S. DEPARTMENT OF
ENERGY

Office of Science

Alfred P. Sloan
FOUNDATION

Backups