Small system, flow-correlation

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This talk :

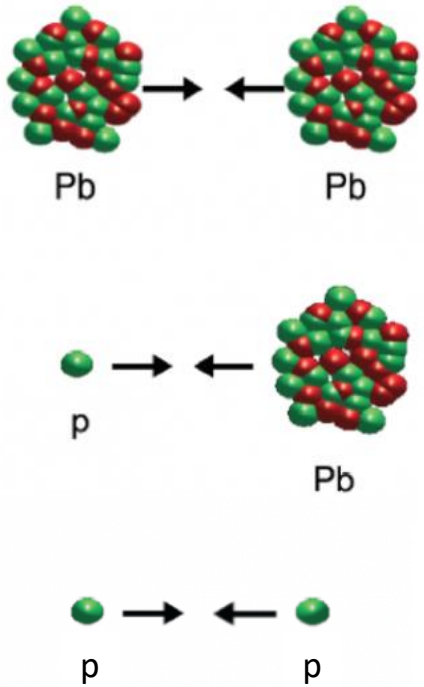
- radial and elliptic flow in small to large system
- non-flow subtraction in small system

Our recent interest : at Beam Energy Scan program at RHIC/STAR

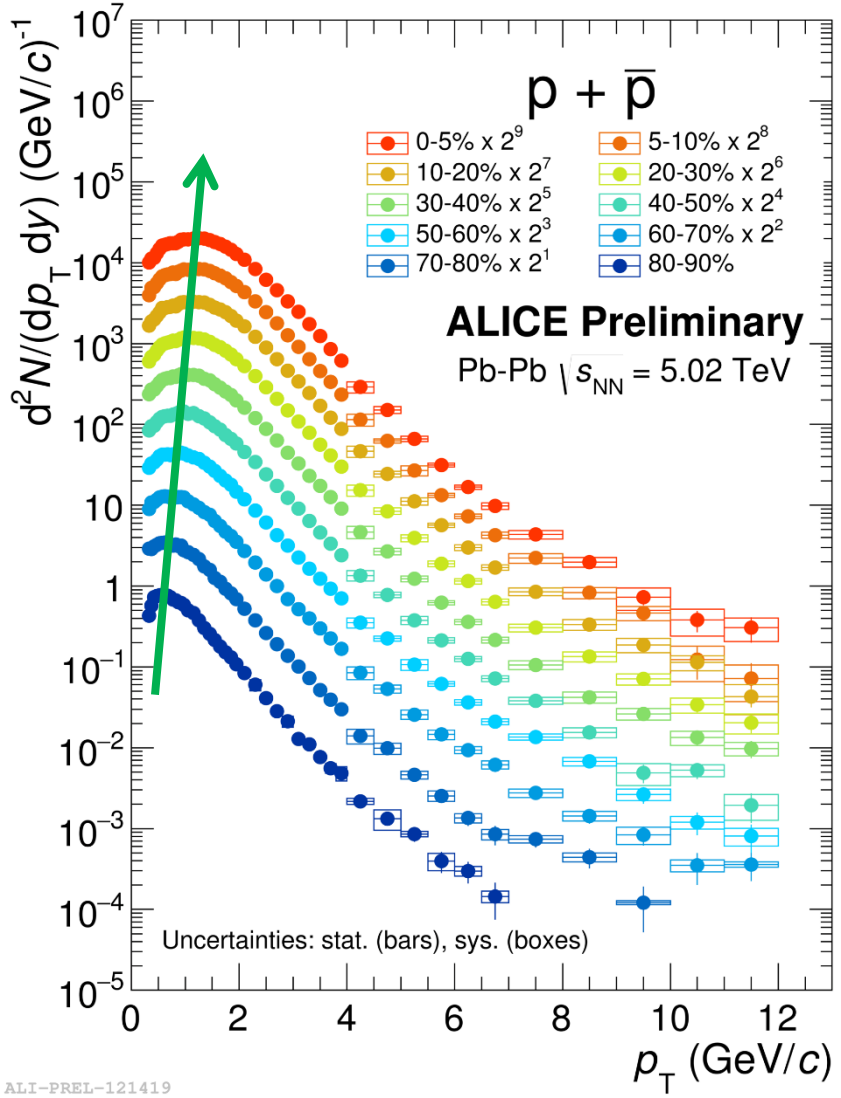
- fluctuation (conserved number, temperature and flow) and critical end point
- directed flow related correlation (eps1, tilt, vorticity) and 1st order phase transition

Radial flow

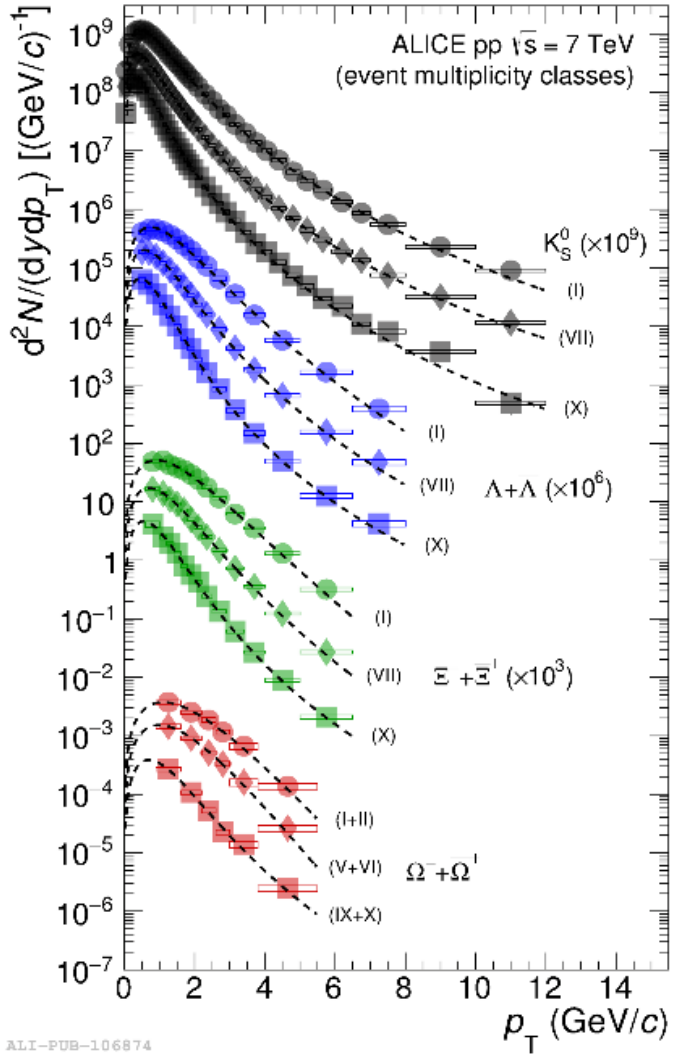
Centrality and particle mass dependence of pT distribution



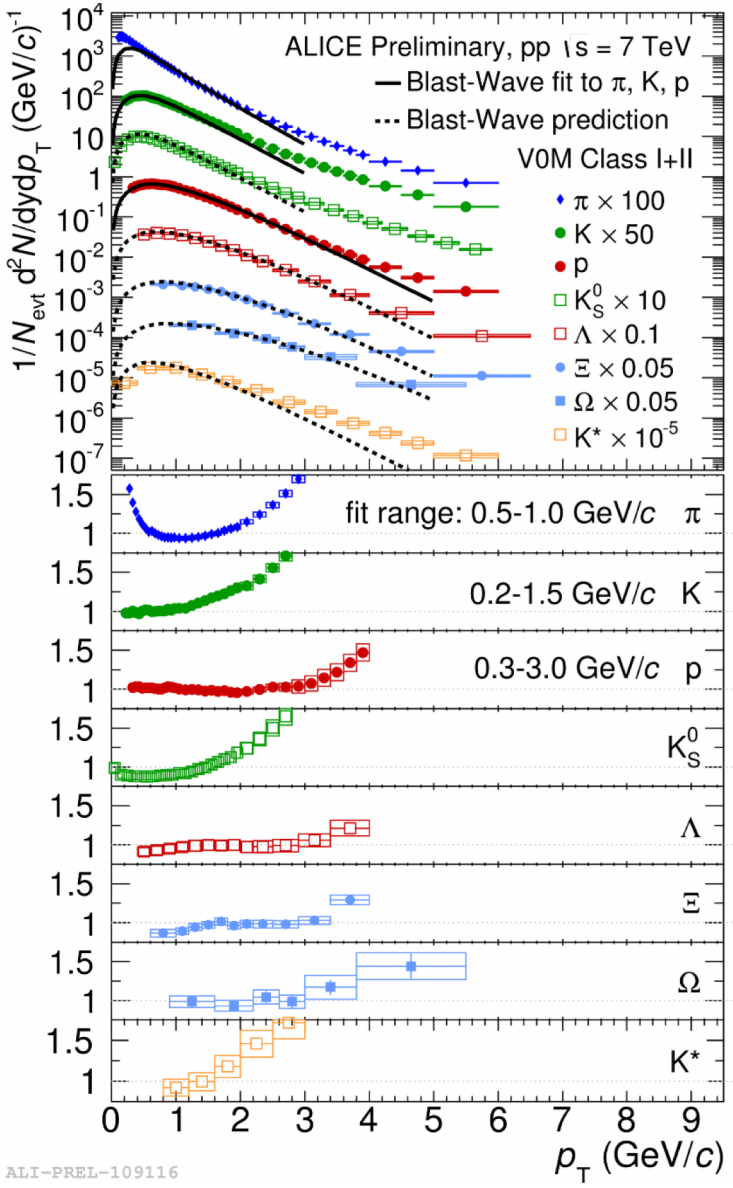
5.02 TeV Pb+Pb



7 TeV p+p



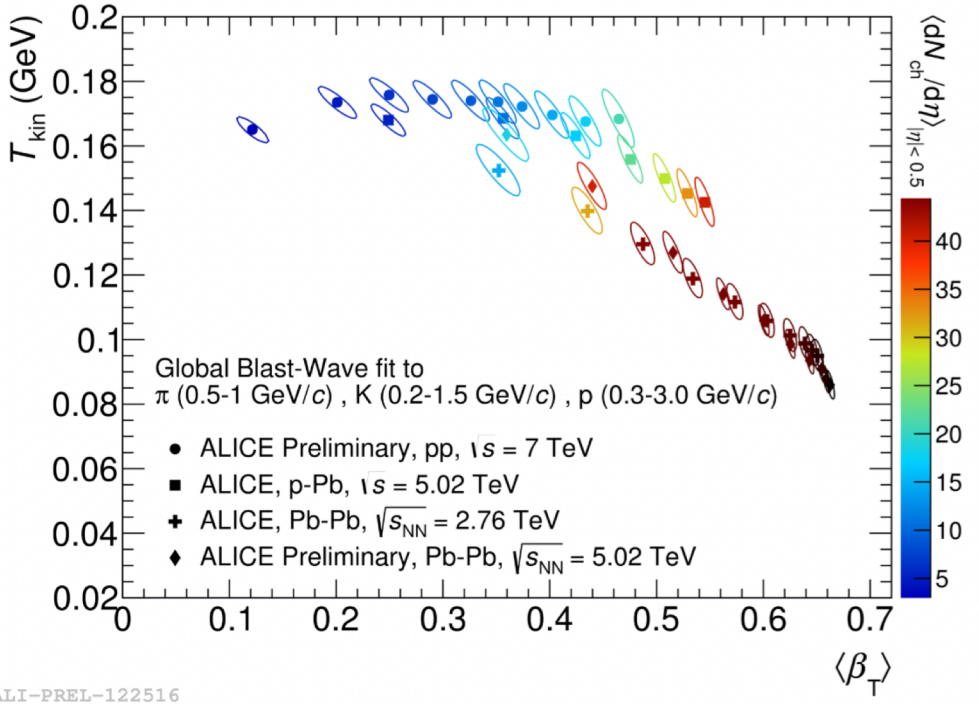
7 TeV p+p collisions

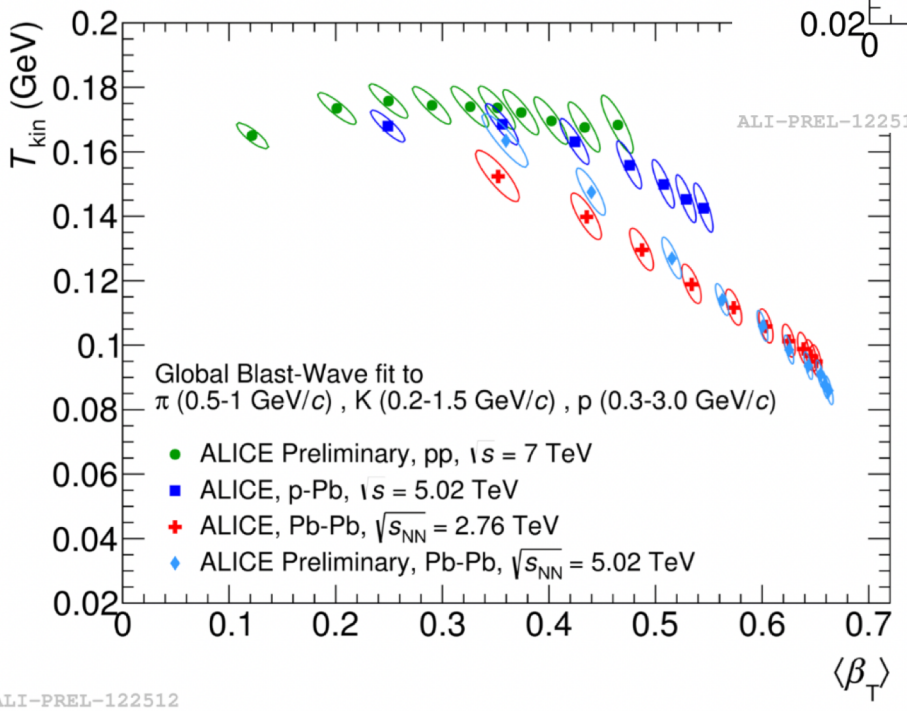


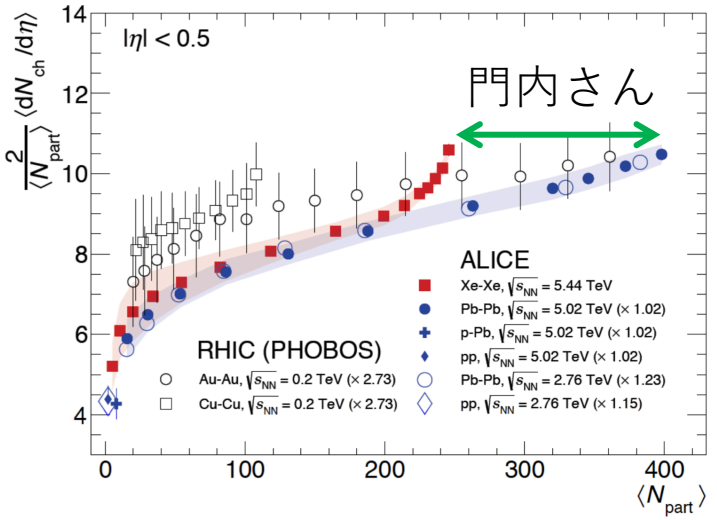
Blast wave model fitting

(hydro inspired)

$T_{eff.} \sim T_{F.O.} + 0.5\ m\ \beta^2_{Trans.}$

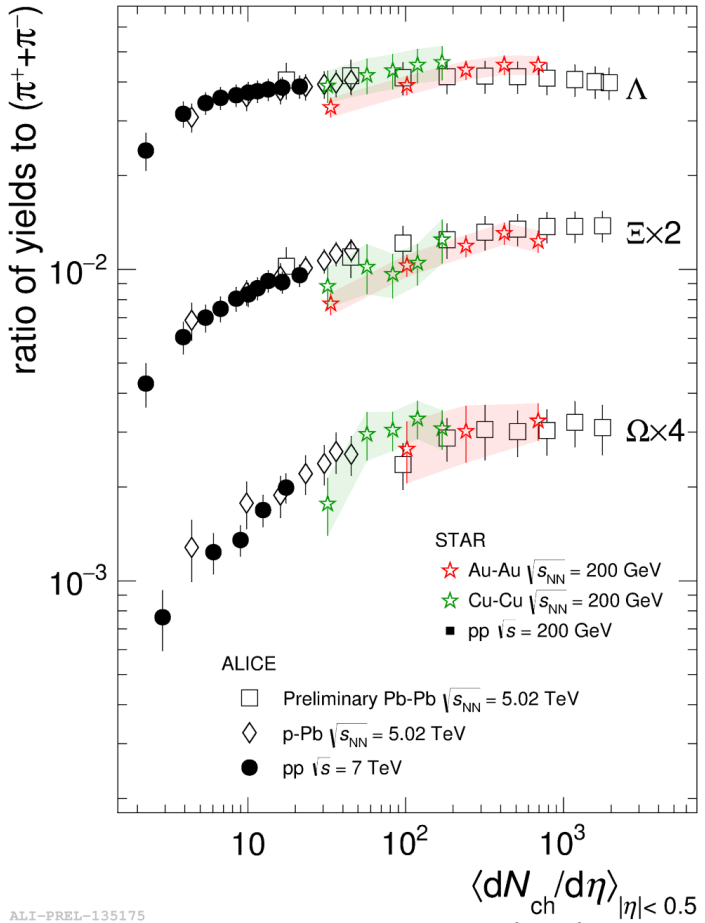


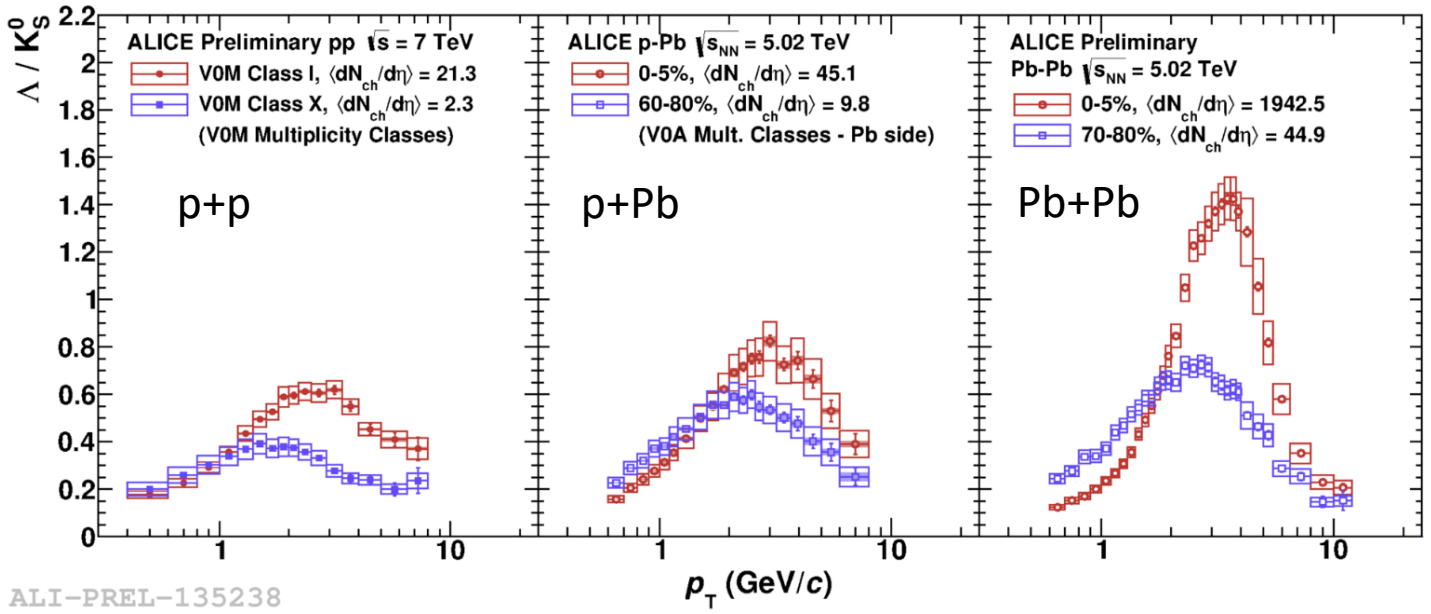




Baryon to meson enhancement

Mass (N quark) dependence
Strangeness enhancement





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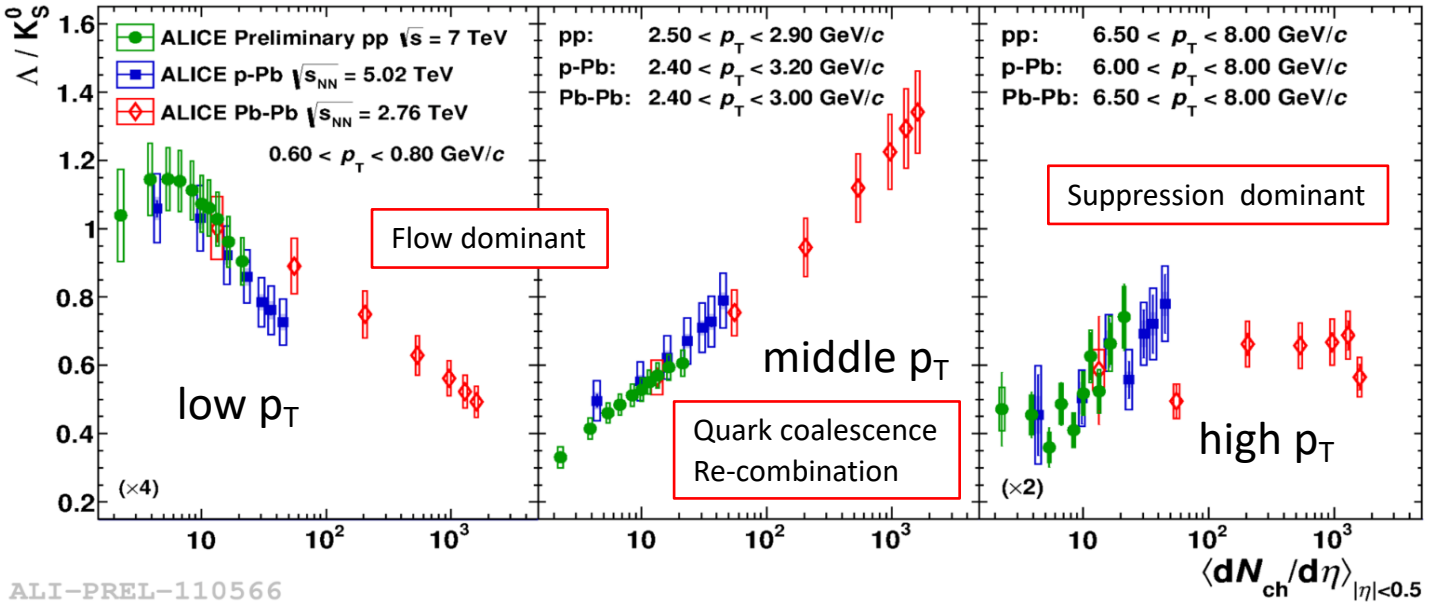

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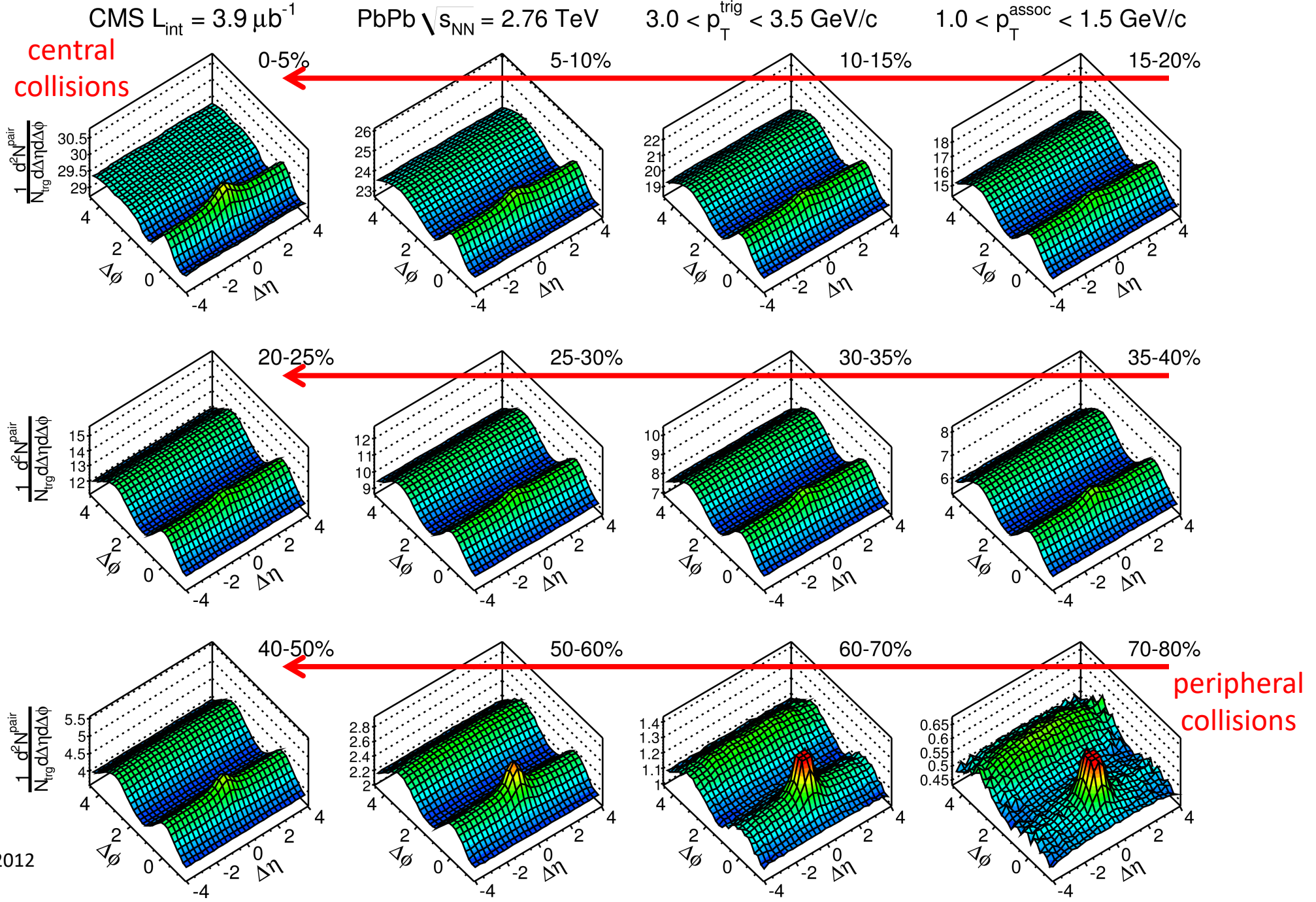
Two particle $\Delta\phi - \Delta\eta$ correlation



Higher order flow

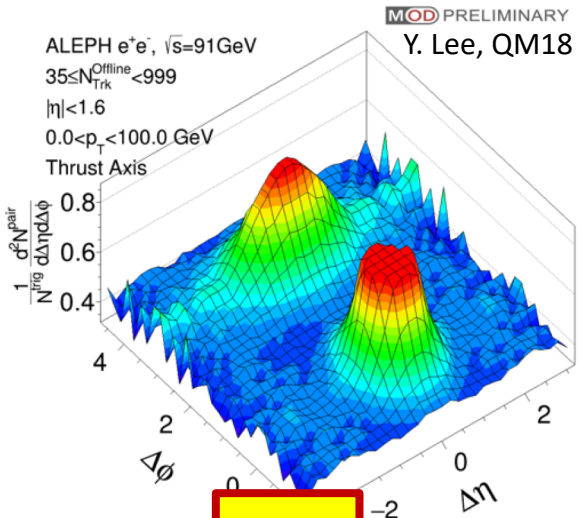
Elliptic flow

Di-jet

centrality

EPJC 72 (2012) 2012

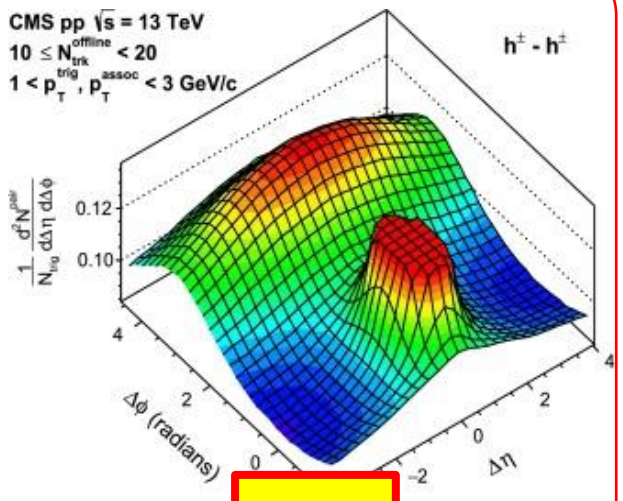
Ridge in small system



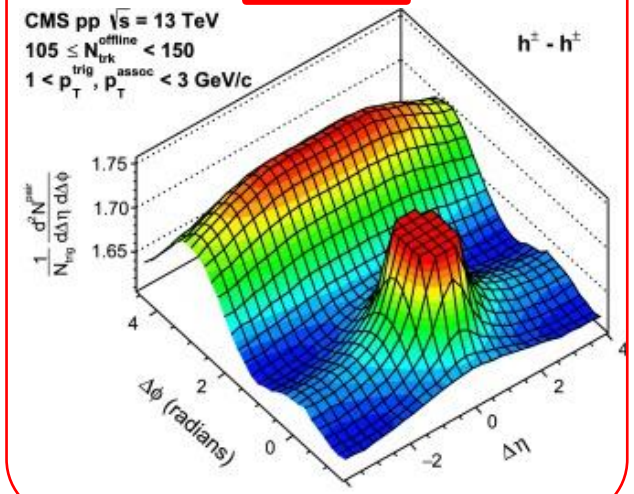
Y. Lee, QM18

e+e

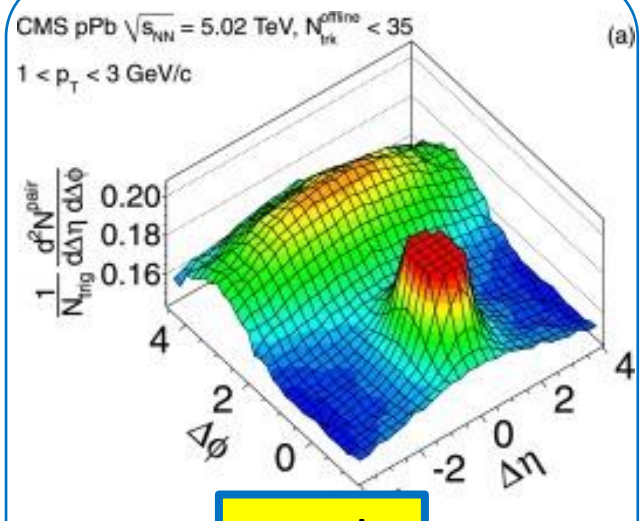
PLB 765 (2017) 193



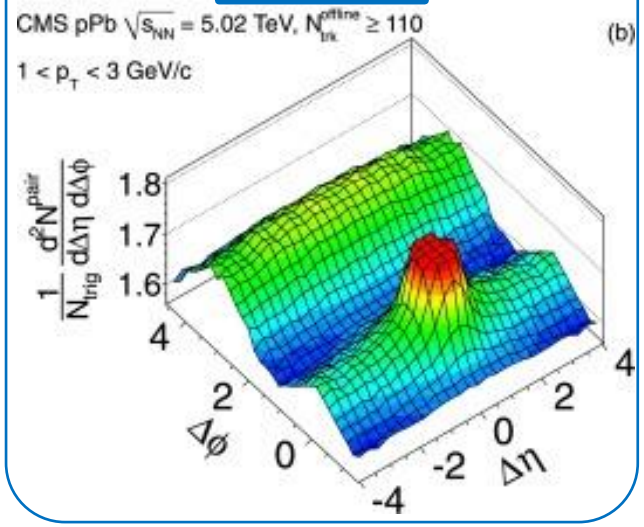
p+p



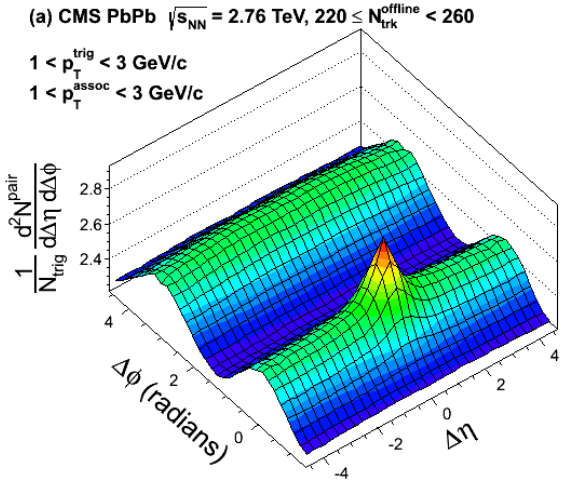
PLB 718 (2013) 795



p+Pb



Pb+Pb

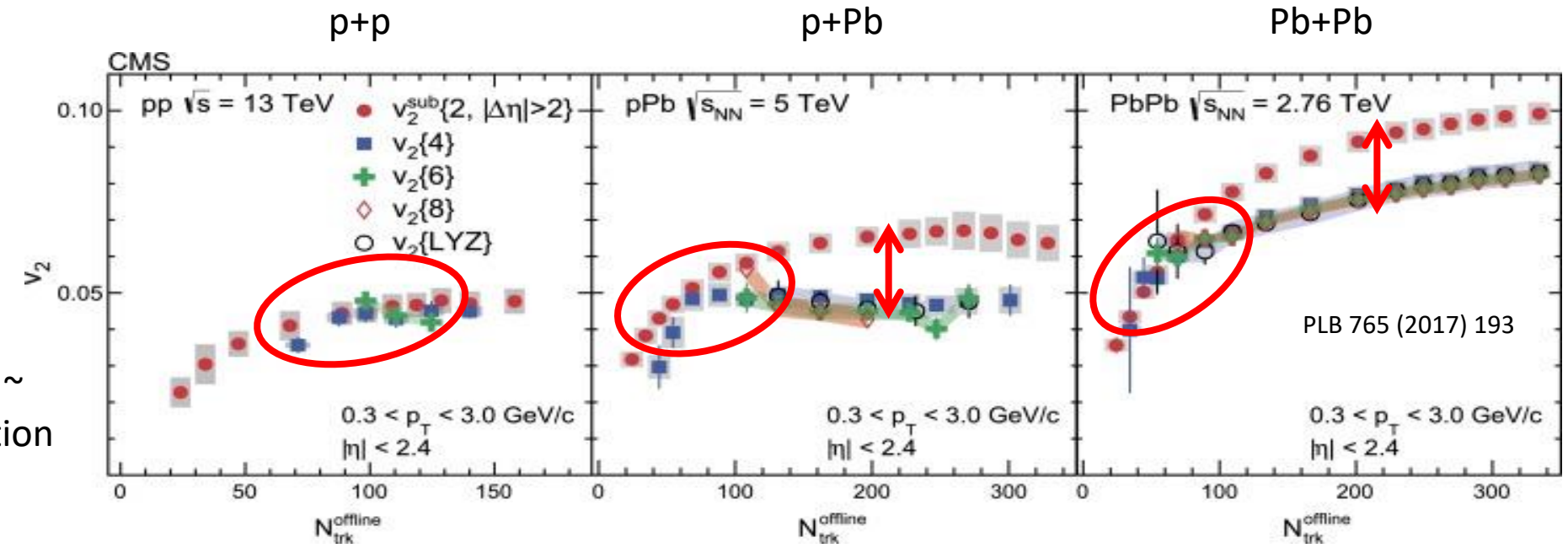


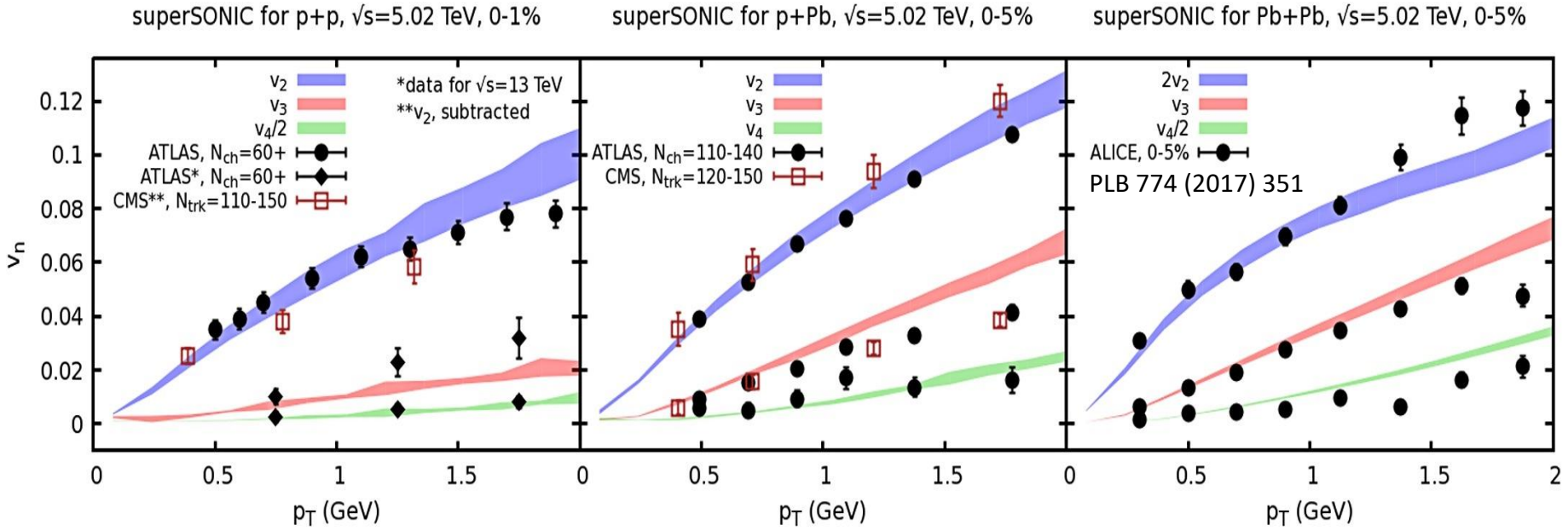
JHEP 07 (2011) 076

Flow evolution with system size

v2{2-part.} - v2{multi.} ~ non-flow + flow fluctuation

v2, v3, v4 ~ hydro-model works with quark Glauber, pre-equilibrium flow, viscous hydro and hadronic re-scattering



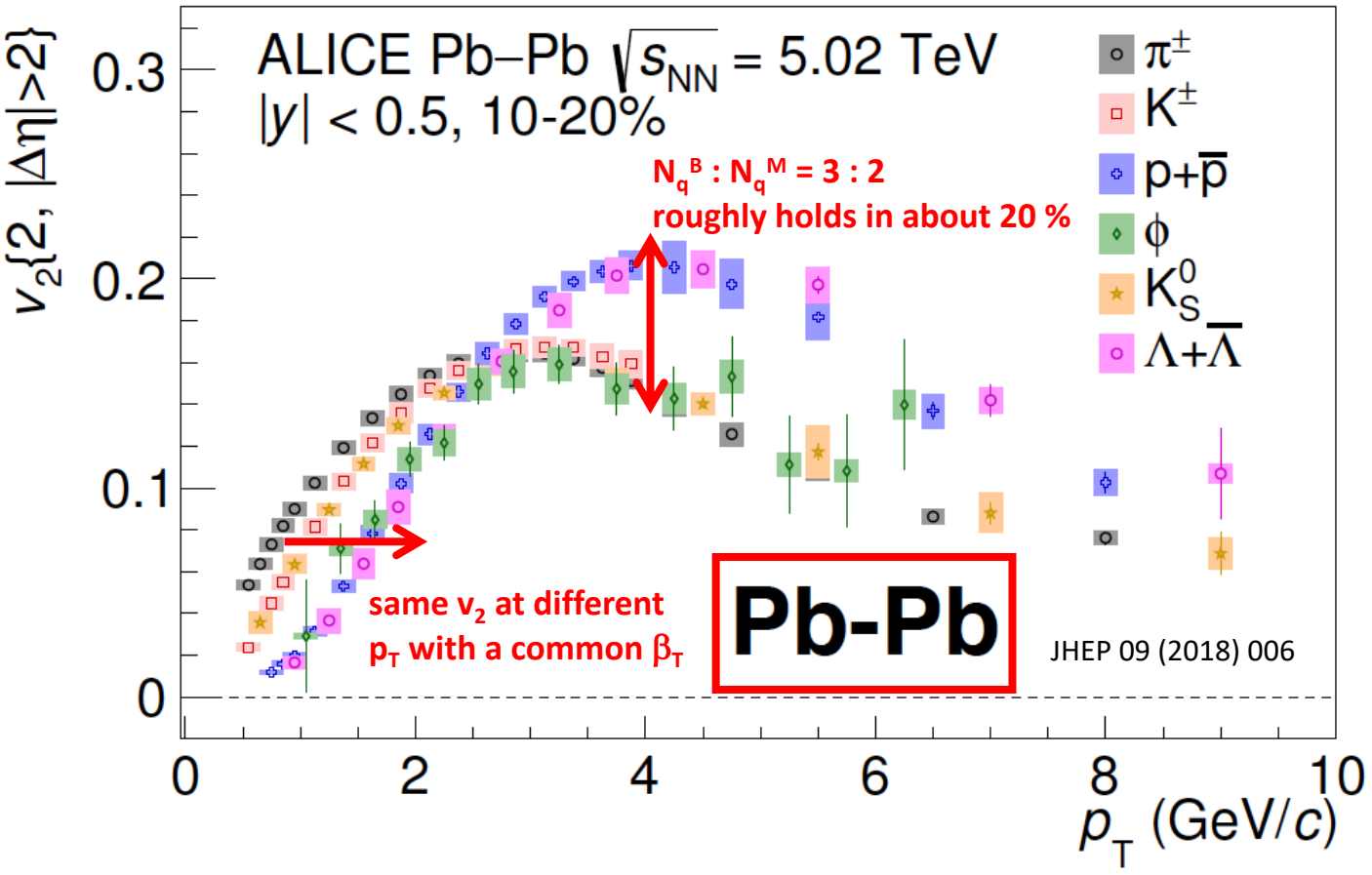


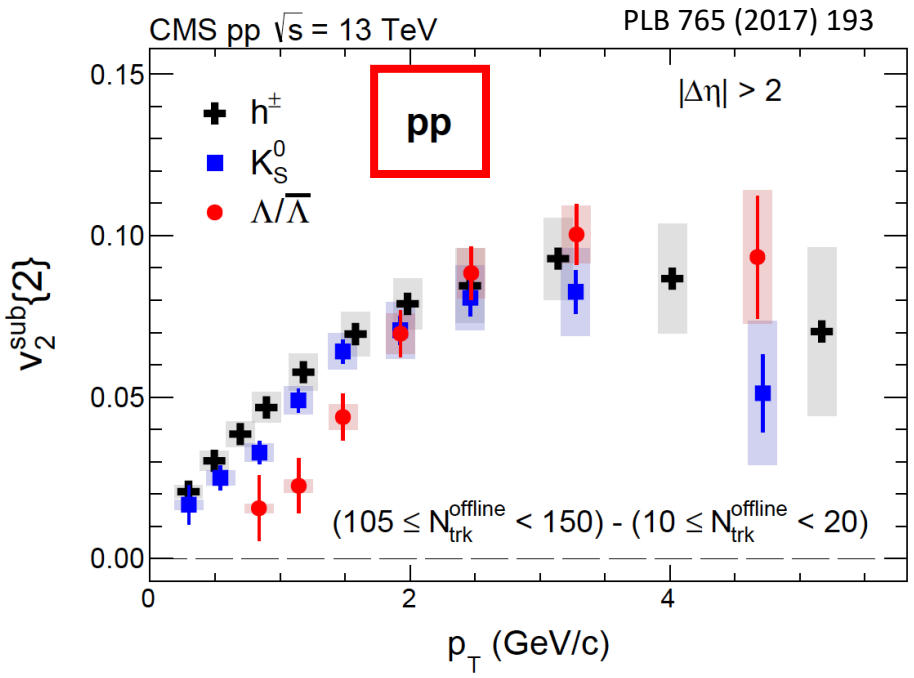
Mass and N-quark dependence of v_2

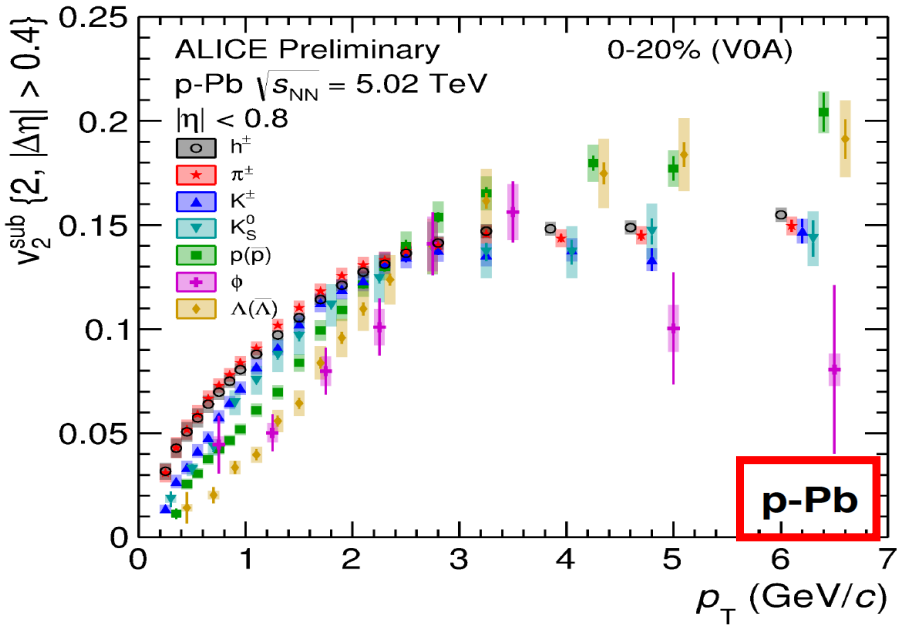
(hydro works the best at 200 GeV : accidental m_T-scaling)

$T_{eff.} \sim T_{F.O.} + 0.5\ m\ \beta^2_{Trans.}$

$v_2/N_q\ (p_T/N_q)$ - scaling

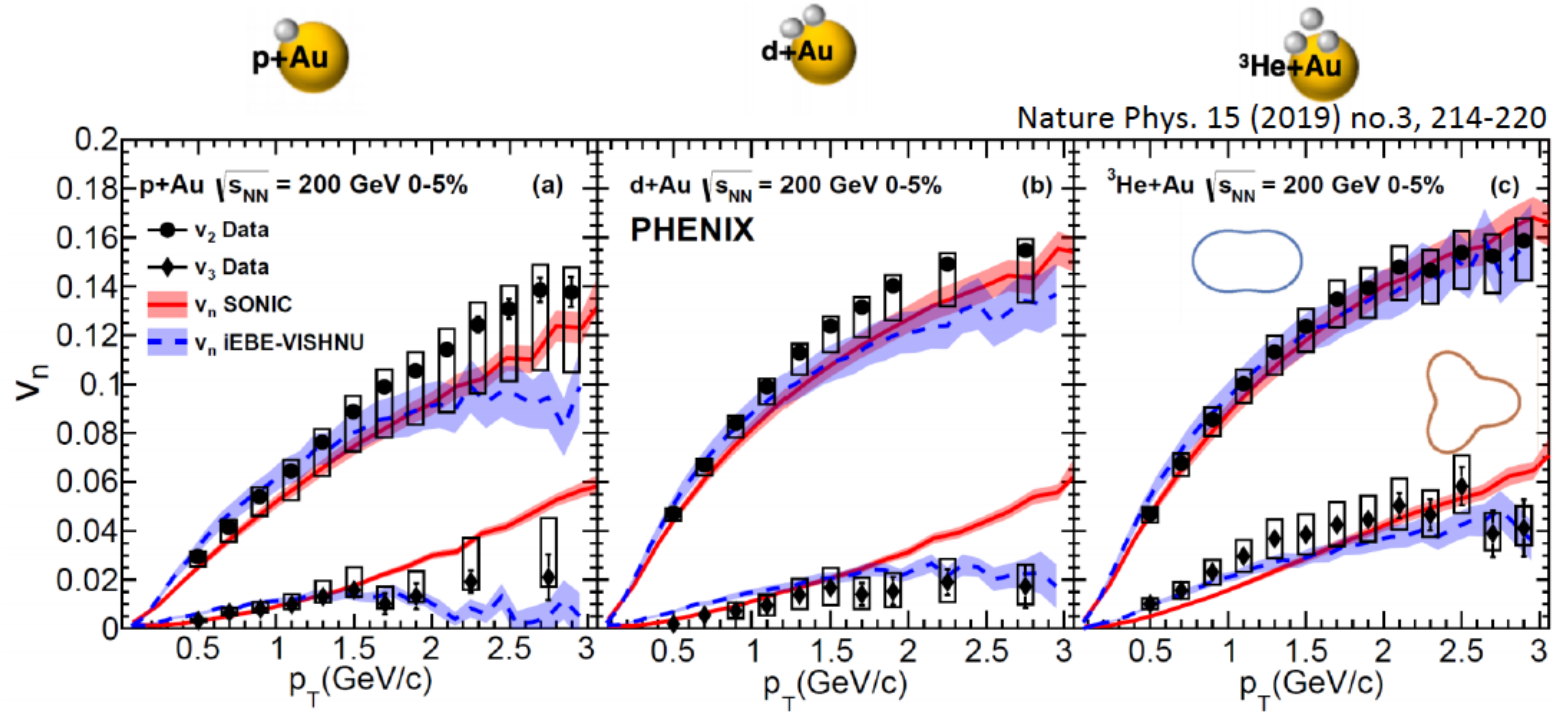


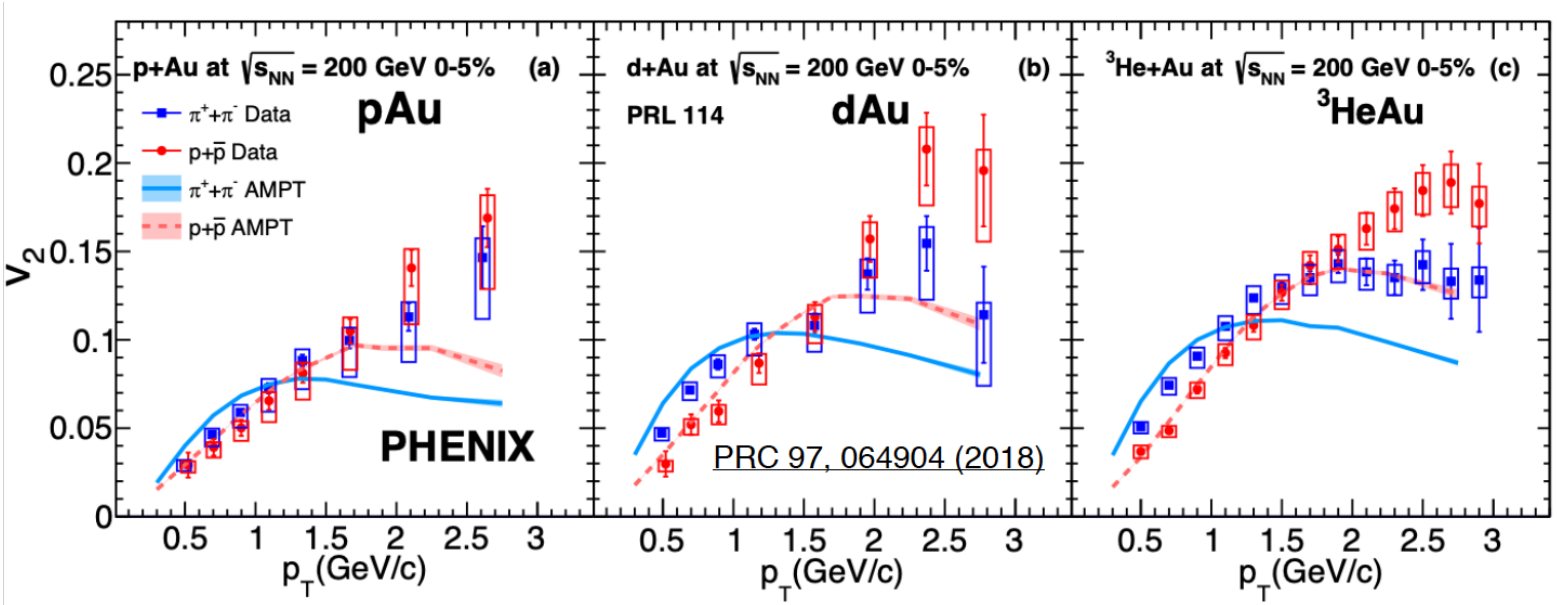




Small system geometry test at RHIC

hydro description, v2, v3
Mass dependence
N-quark dependence



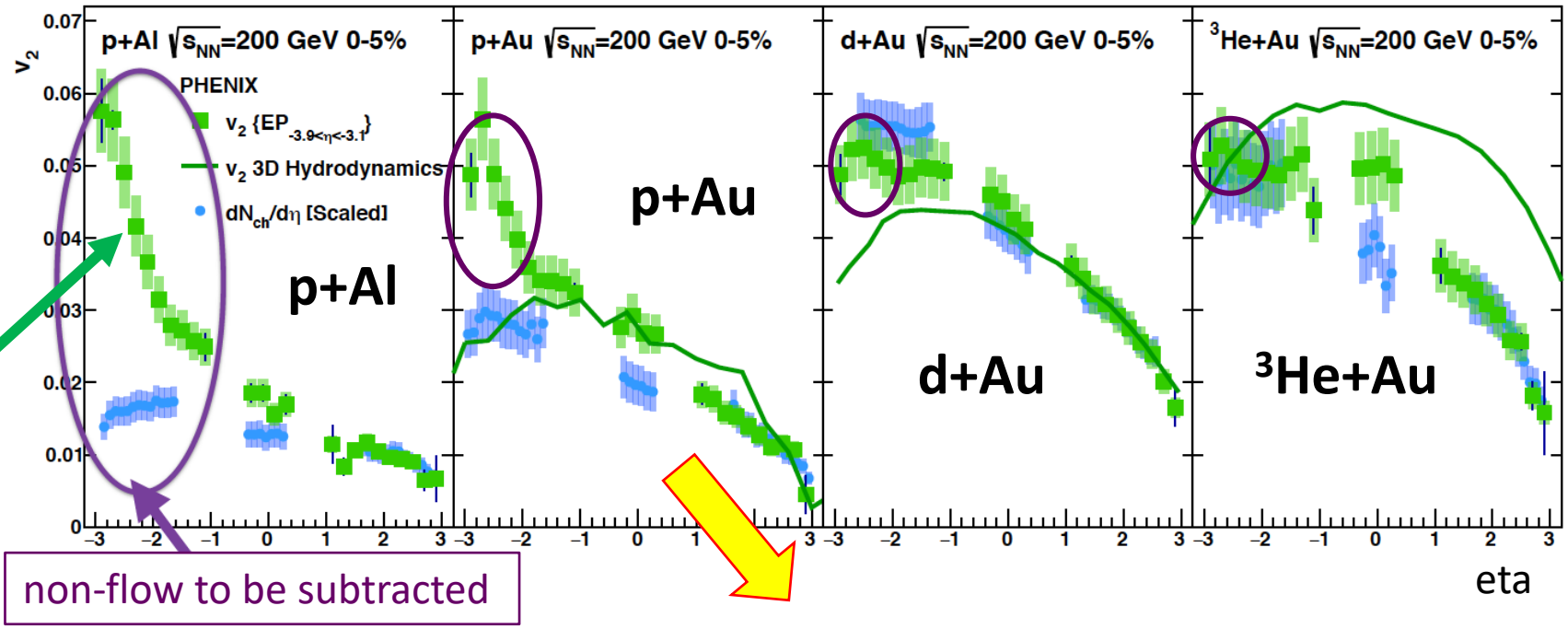


Rapidity dependence of v2 in small systems

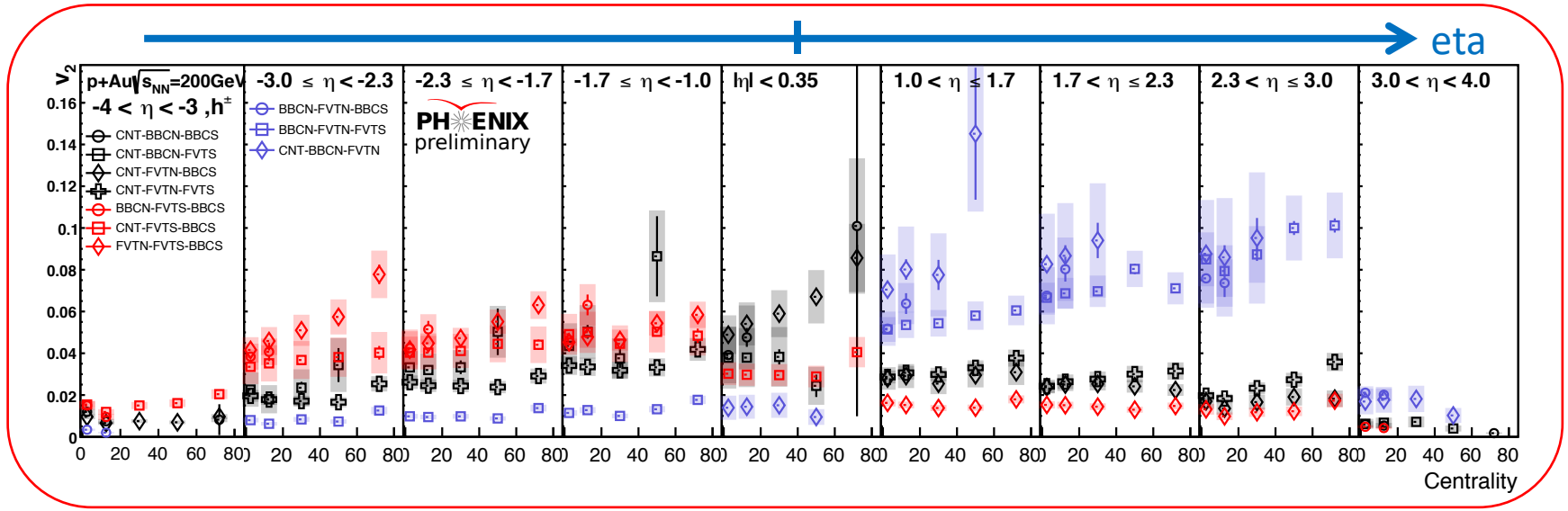
PRL 121 (2018) 222301

forward/backward
v2 asymmetry ~
dN/dη distribution

very strong "trivial"
non-flow contribution



non-flow to be subtracted



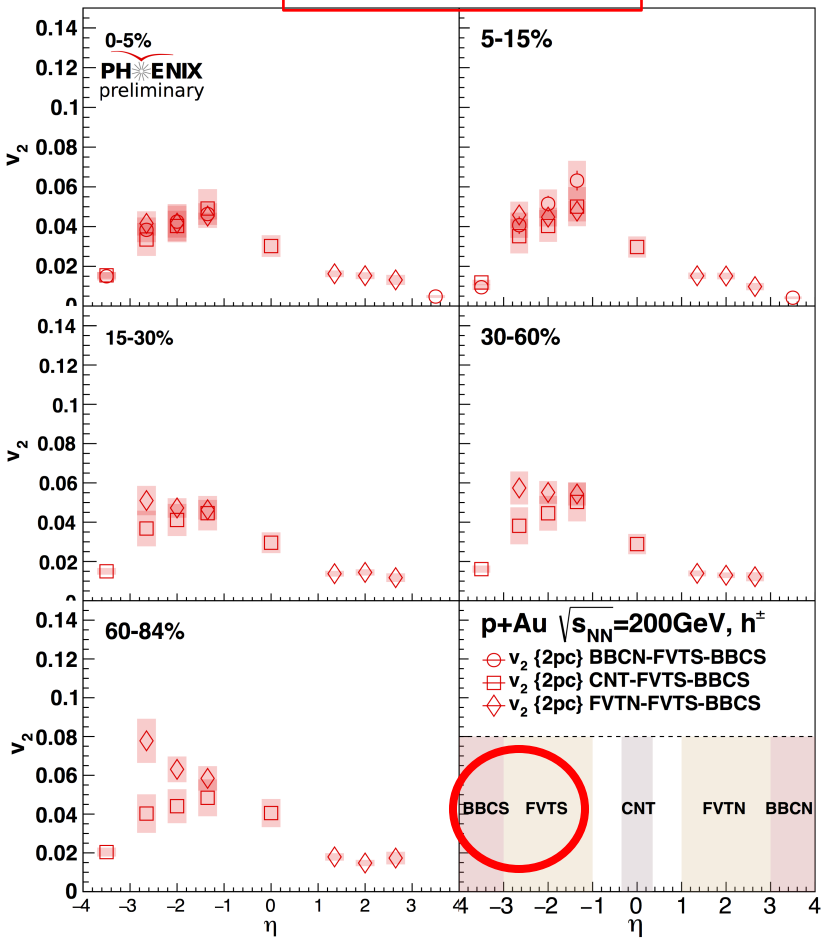
centrality dependence
and 3-sub combinations

more details
In the next slide

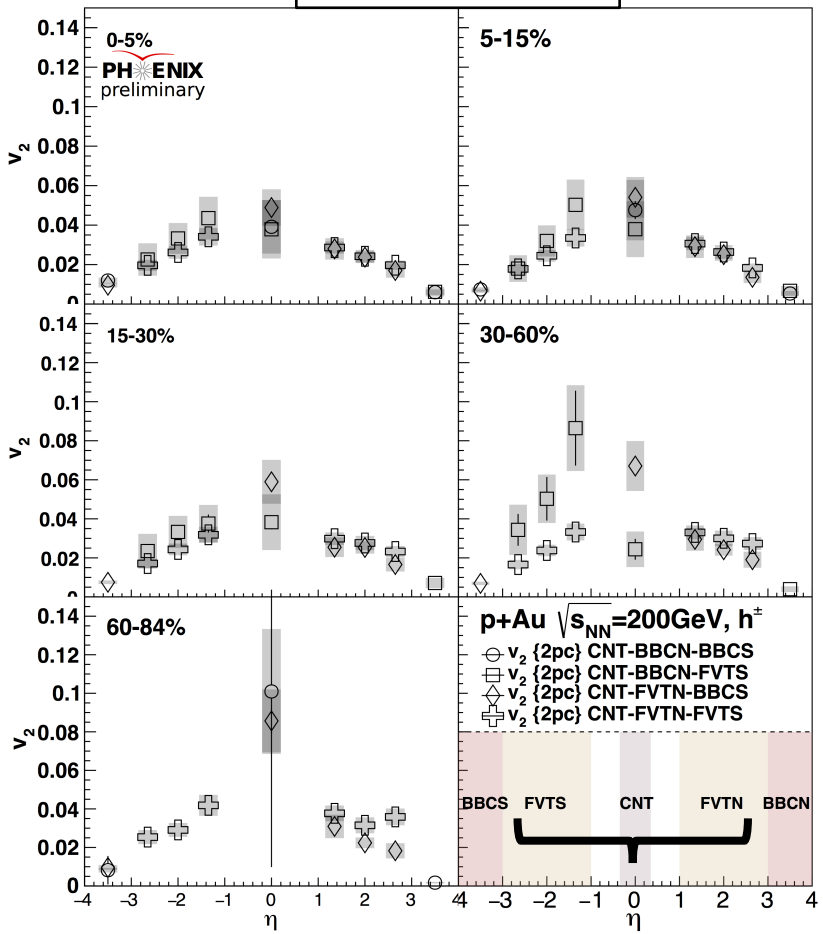
Rapidity and centrality dependence of v2 in small systems

without non-flow subtraction

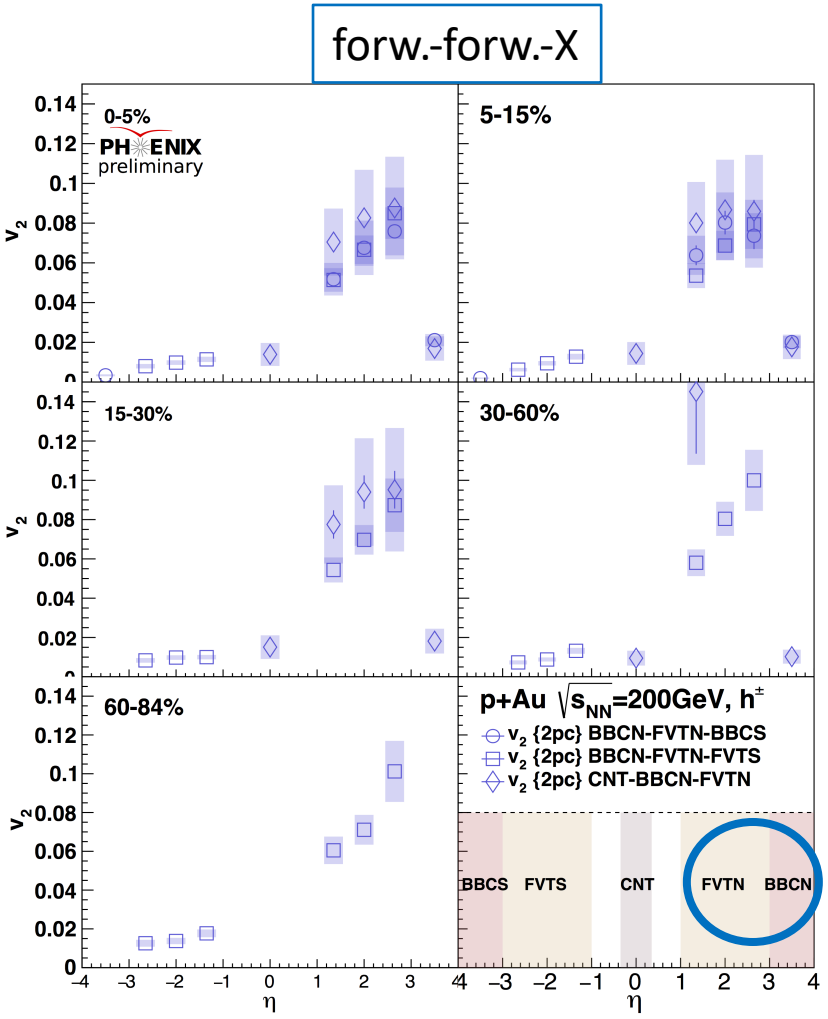
backw.-backw.-X



forw.-backw.-X



forw.-forw.-X

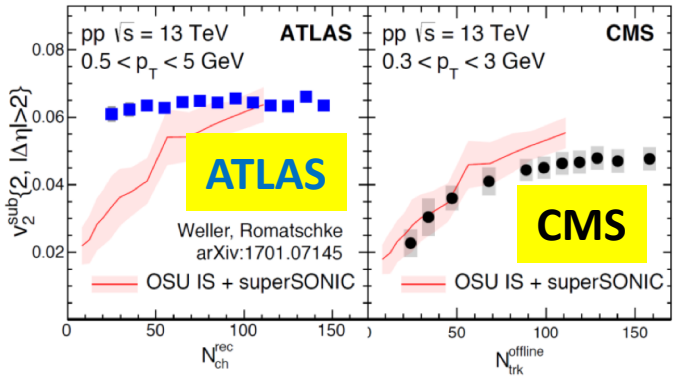


- strong dependence on how 3-sub regions are chosen
- strong relation to the rapidity de-correlation

dAu collisions BES at RHIC-STAR

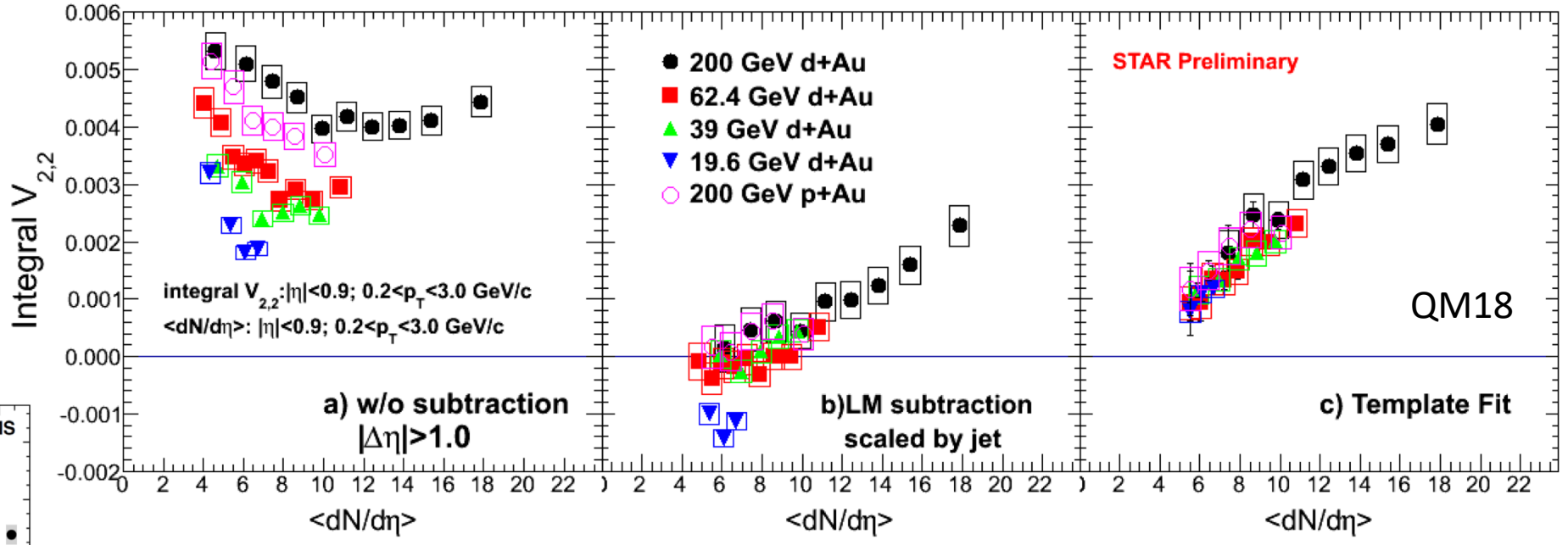
with and without non-flow subtraction

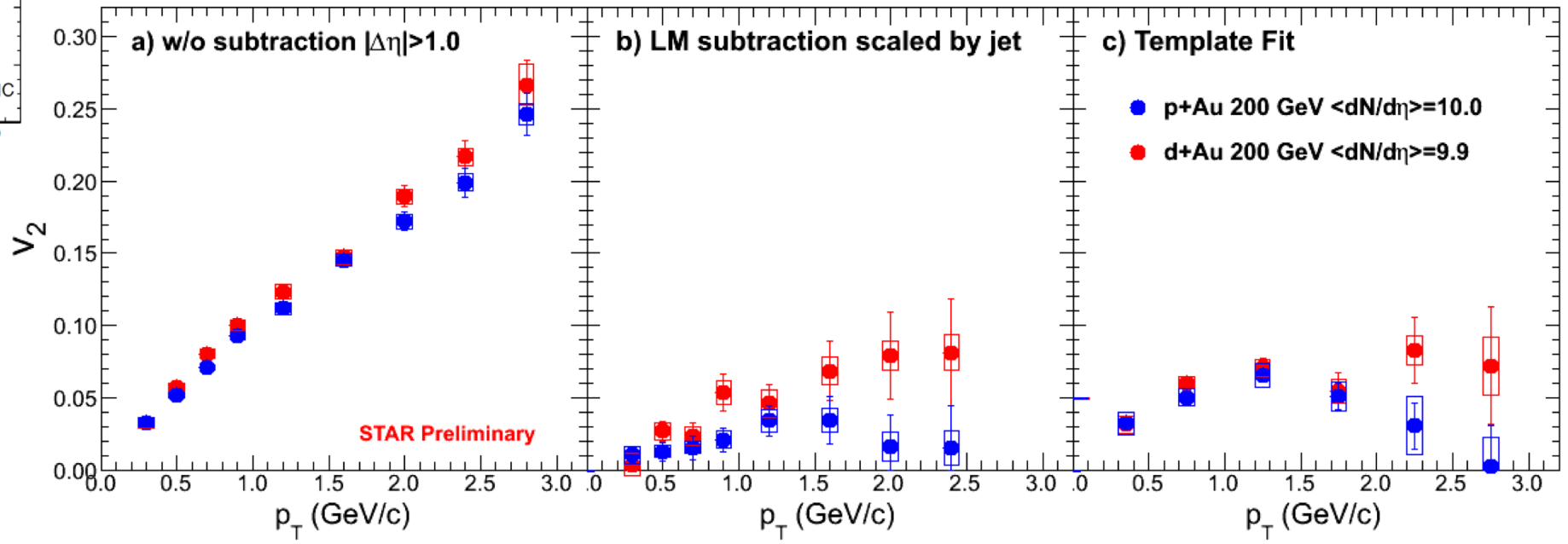
LHC p+p v2 comparison



depends strongly on how one does the non-flow subtraction

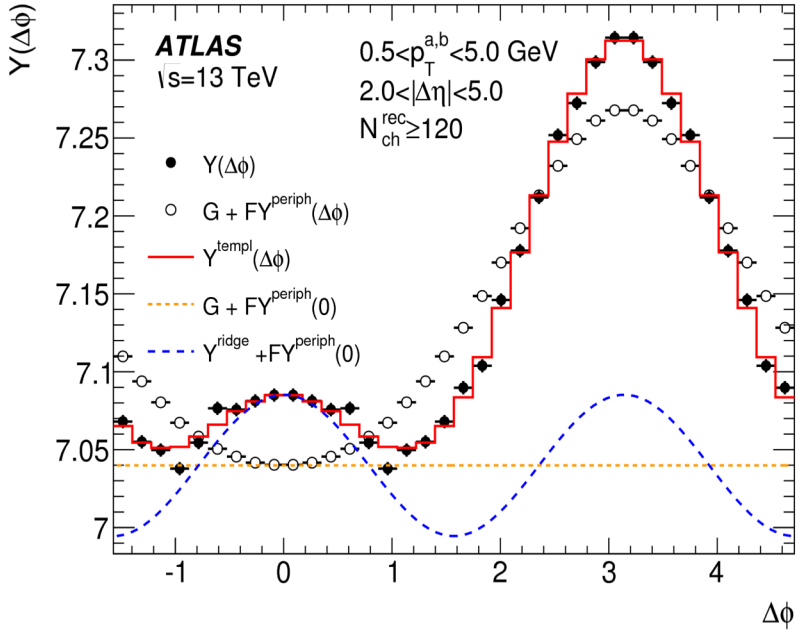
No subtraction | CMS method | ATLAS method

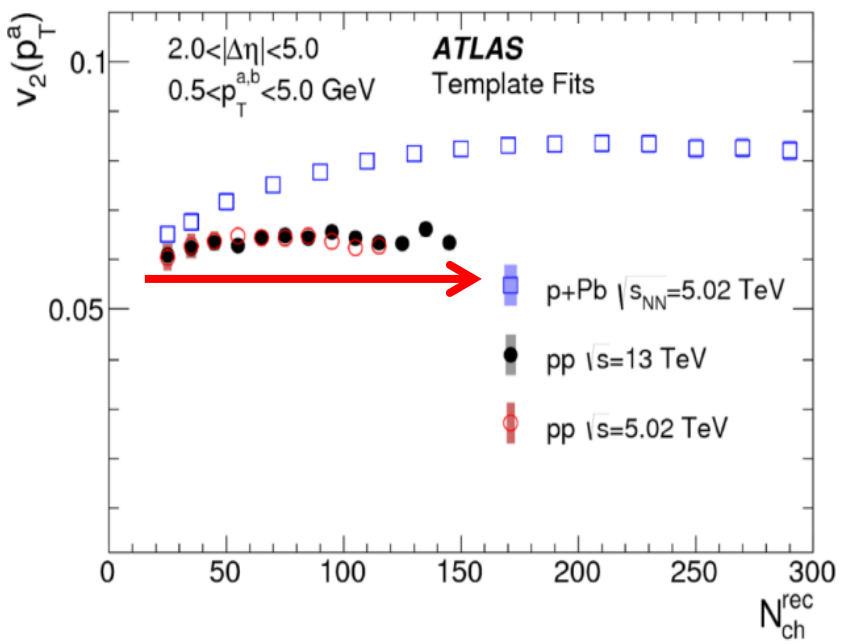


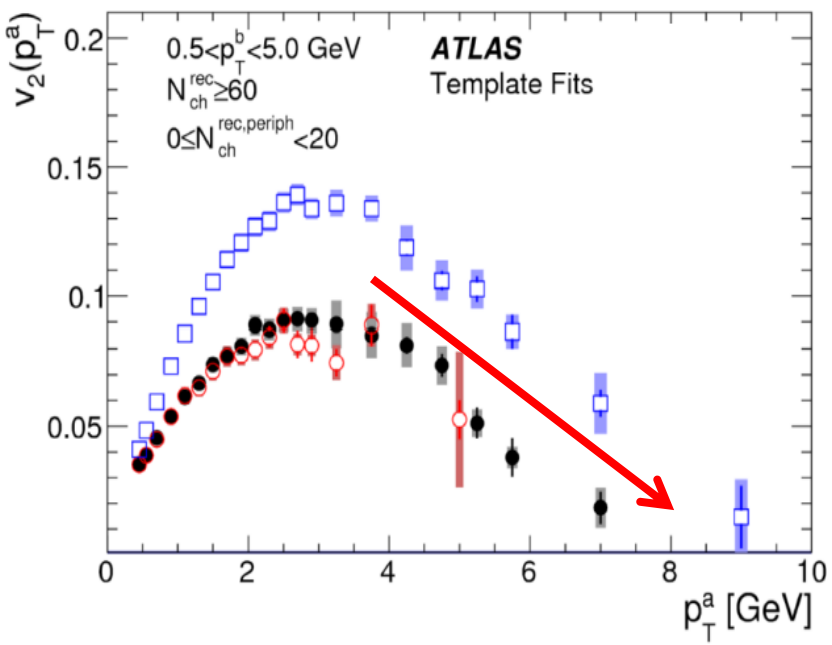


ATLAS Template fitting method in small system flow analysis

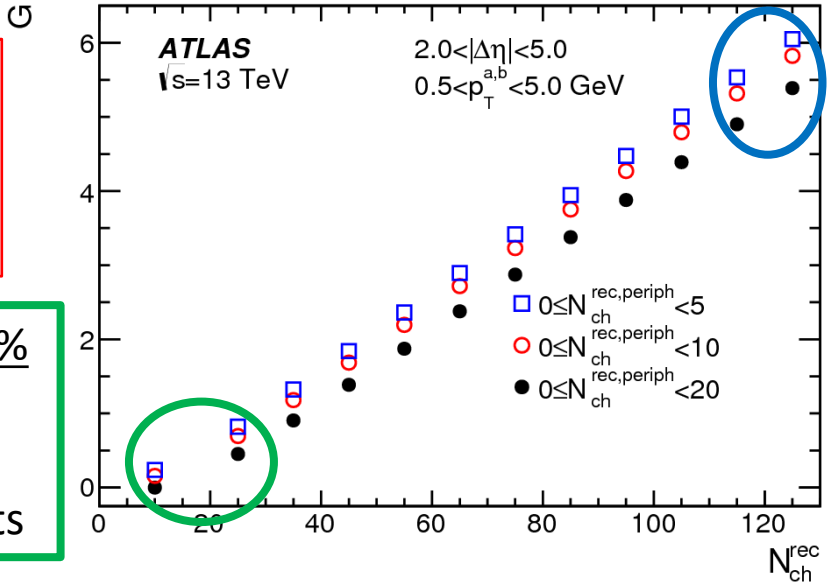
PRC 96 (2017) 024908





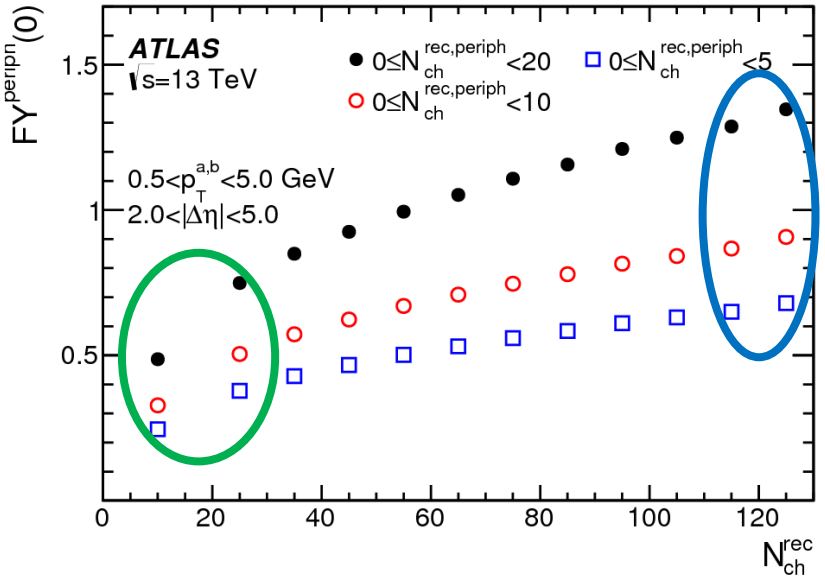


Flow yield



less than 30-60% flow fraction in peripheral or low-mult. events

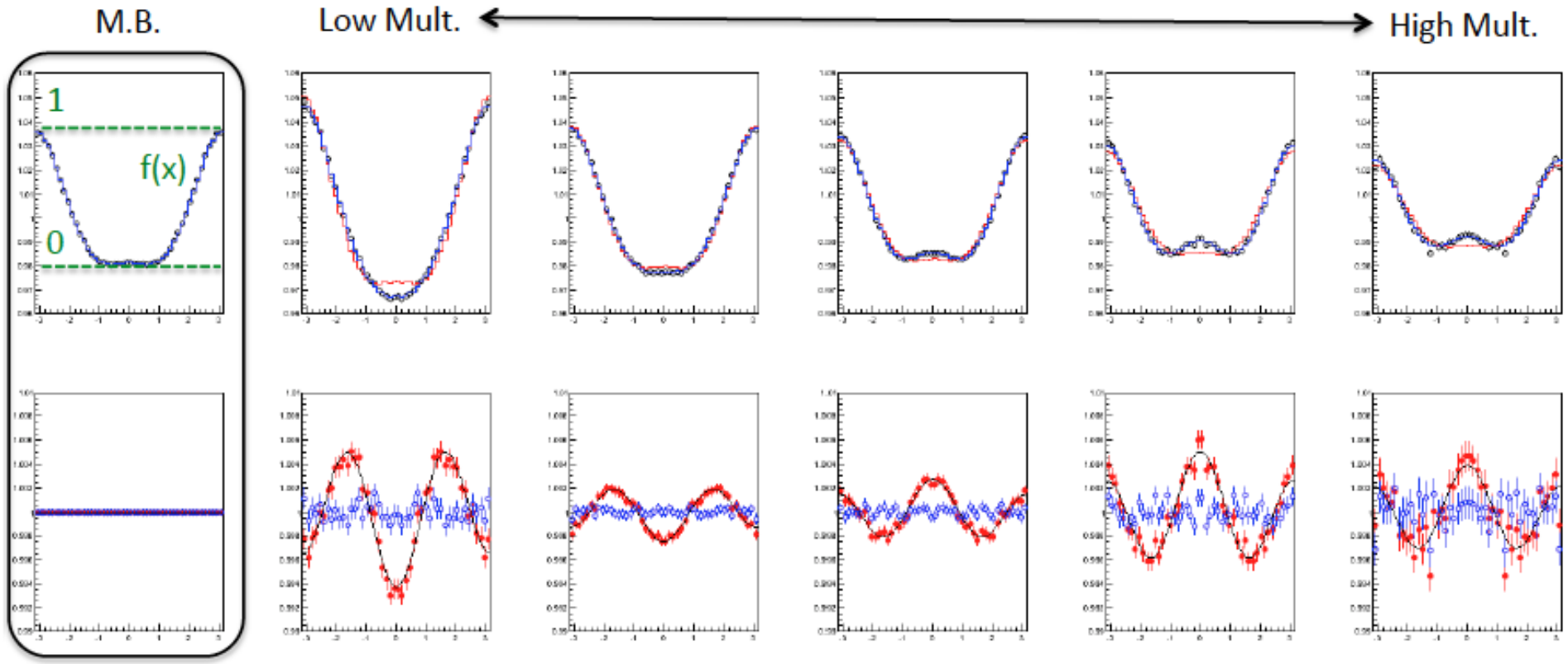
Jet (non-flow) yield



close to 80-90% flow fraction in central or high-mult. events

AMPT (quark and hadron cascade) model
p+p test with reference fitting method

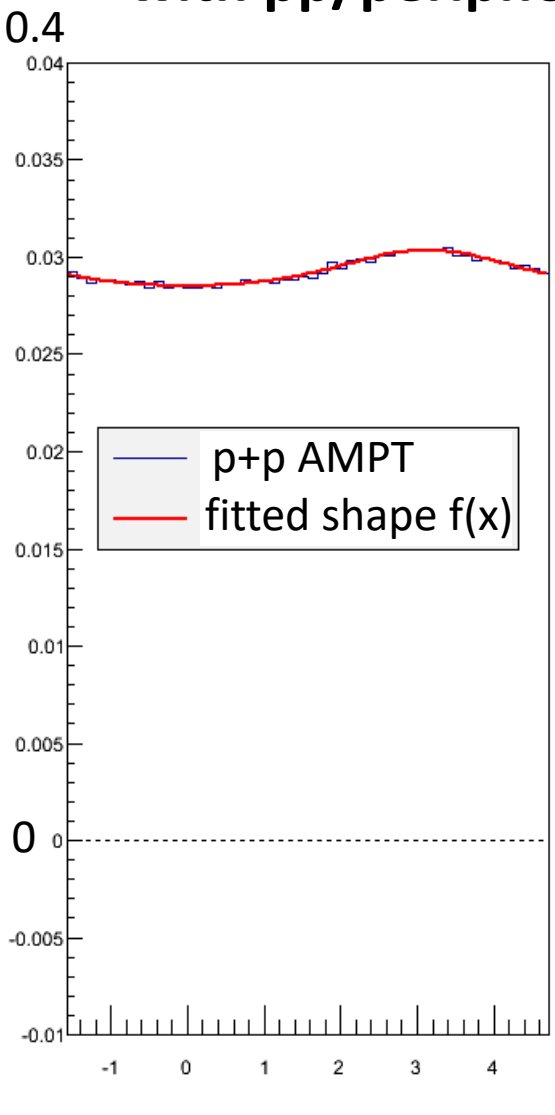
- AMPT data
  - Reference fitting : F(x) = a + b f(x)
  - Reference fitting + v2 term : F(x) = a + b f(x) + 2 c cos(2x)

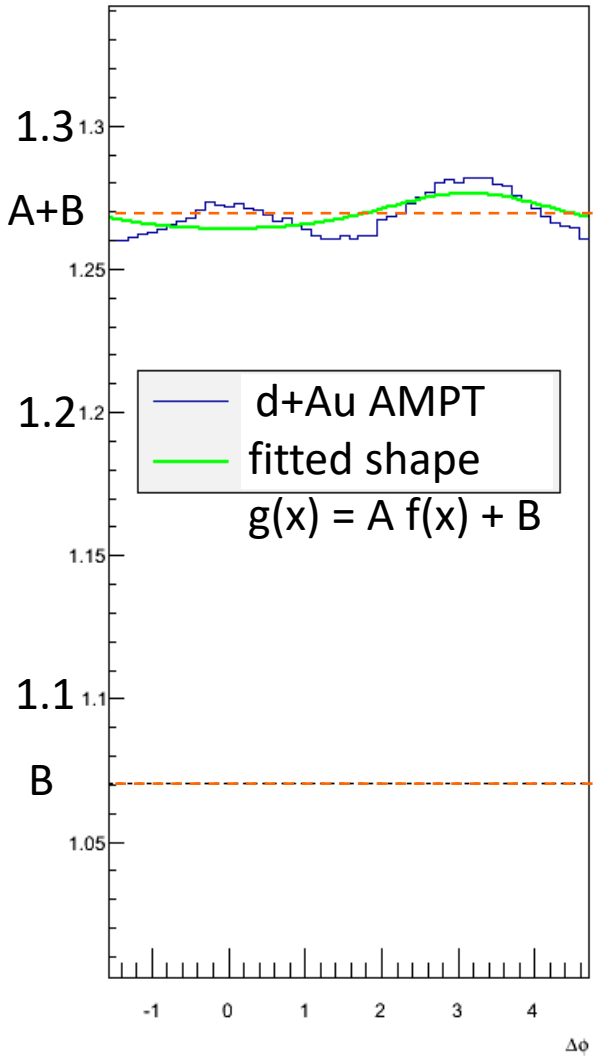


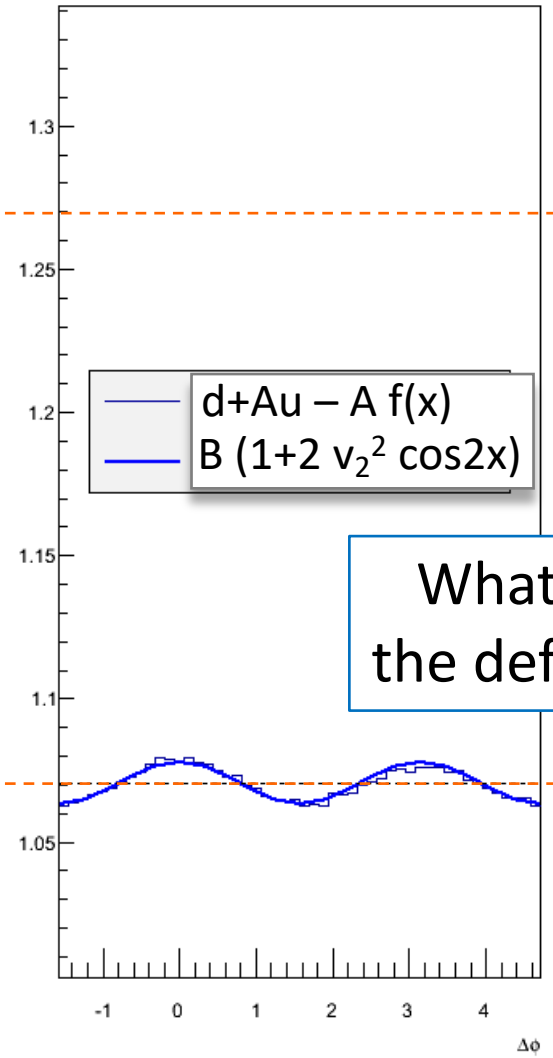
- AMPT data - Reference fitting + 1
- AMPT data - (Reference fitting + v2 term) + 1

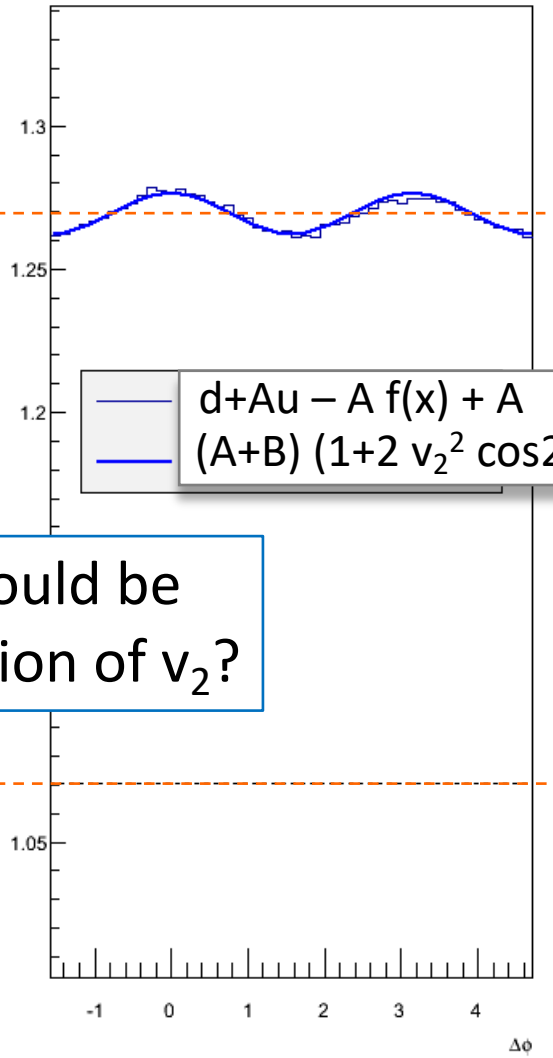
Reference/template function fitting with pp/peripheral/low_mult. shape

Template Fitting or Reference Fitting









What should be the definition of v_2?

Summary

- radial and elliptic flow in small to large system
- non-flow subtraction in small system

- 小さい系でQGPができているもしくは流体的な振る舞いがあるとされる実験的な証拠は信頼できるのか。QGPもしくは流体的な解釈が可能な実験の解析手法を無意識に選んでしまっている可能性はないのか (そもそも何を以て物理的に"QGP"と考えるのか)。
- どれぐらい細かいスケールまで流体的な記述が良いのか? 小さい系を流体で取り扱うとき、何処まで定量的なのか。
- small systemでQGPの生成の最近の理解、たとえばRpA~1の大きなpt領域での大きなv2は、AAにおけるエネルギーロスとは異なるだろうけど、pAでの理解。集団運動測定におけるnon flowの取扱い。
- small systemにおいて、次に何を実験的に測ればいいのか。
- small systemでもQGPが作られているか。作られていると解釈される場合、これまでの重イオン衝突実験の理解にどのような影響があるか。
- 小さい系でのQGP生成を詳細に調べることで熱化（流体化）時間を定量的に求めることはできるか？また熱化や流体化のメカニズムを実験的に検証することは可能か(長相関や電磁プローブ？)
- 小さい衝突系でdirect photonのフローの観測は期待できないのだろうか？
- 小さい系のフローが議論される際に、non flow subtractionが行われるが、例えばtemplate fitやlow multiplicityのsubtractionなどさまざまな手法がある。もう少し系統的にその違いを知りたい。
- 小さい衝突系で見つかったフローの理解を反映させて、それまでの全ての原子核衝突実験の解析をもう一度行ったら何か質的に新しい事はあるのか？
- QGPを研究して何が嬉しいのかを非専門家に説明する際、よく「QGPで満たされていた初期宇宙について理解が進む」と説明していますが（そもそも初期宇宙のことがわかって何が嬉しいのでしょうか）、初期宇宙以外に何か非専門家に説明できるような嬉しい点はあるのでしょうか。あるいは一般に、QGPについて研究して何が嬉しいのでしょうか。

d+Au collisions Beam Energy Scan at RHIC-PHENIX (20 - 200 GeV) without non-flow subtraction