Topical discussions about small systems

R.Venugopalan B. Schenke, H.Song & P. Christiansen

Evaluation on the fluid behavior for large and small systems

Huichao Song

Peking University

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Evaluation on the fluid behavior for large to small systems

Low P_T region

-observables

-tools

Intermediate P_T region

-observables

-tools

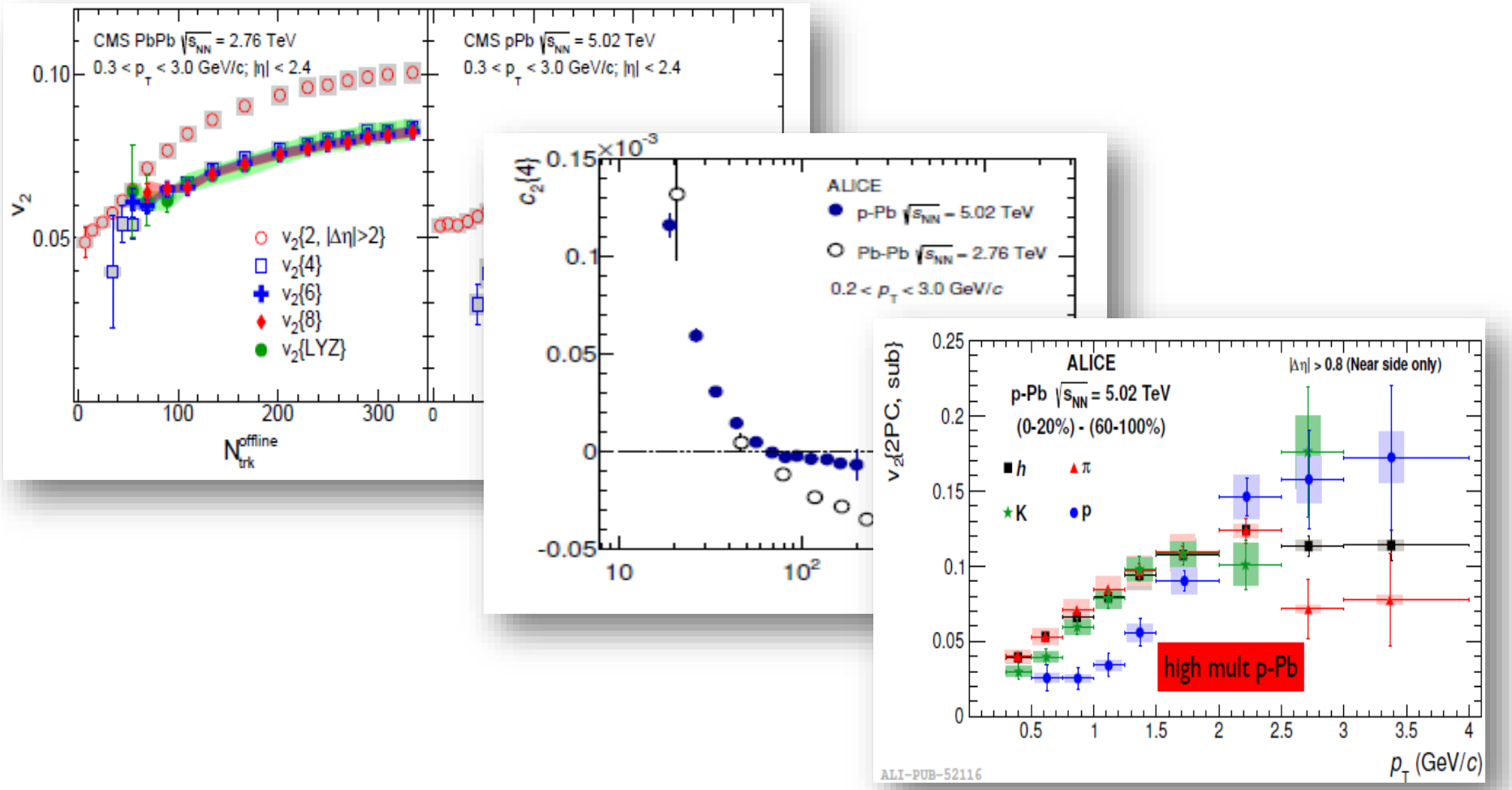
Question to the 4 panellists:

Is the underlying physics identical in small and large systems?

IS geometry shapes/fluctuations -> collective momentum correlations via strong FS interactions?

Low P_T region

-observables : v_2 v_3 mass ordering of v_2 $C_2\{4\}$, etc



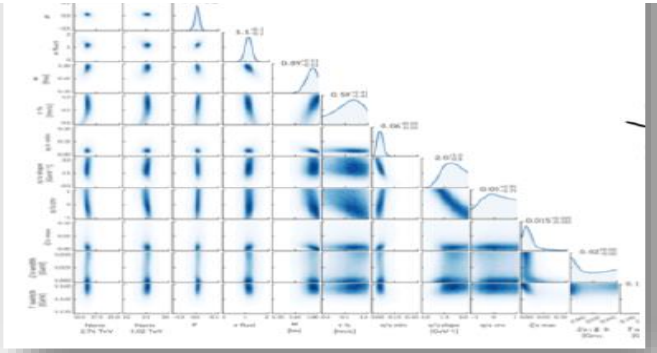
Low P_T region

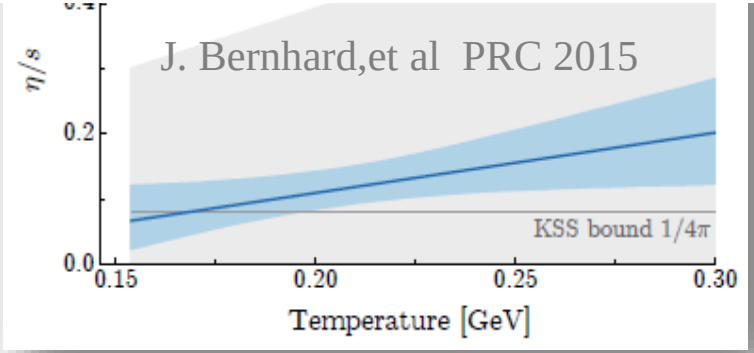
-observables : v_2 v_3 mass ordering of v_2 $C_2\{4\}$, etc

-tools: hydrodynamics, kinetic theory, CGC….

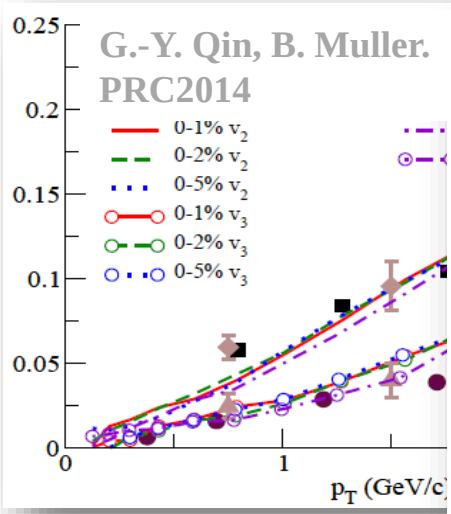
Low P_T region: fluid behavior

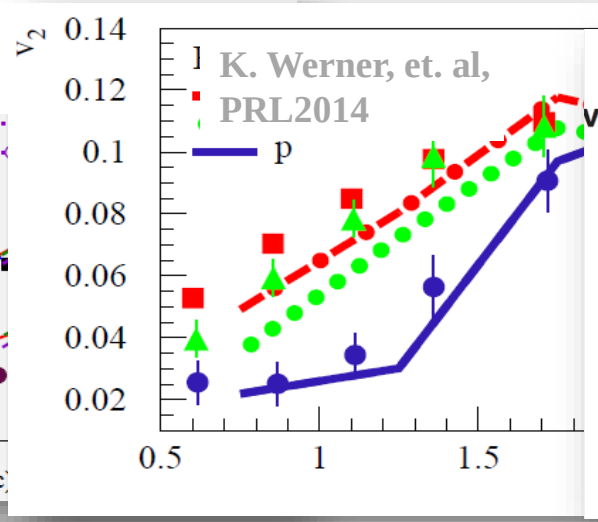
Large systems : hydrodynamics and hybrid model are great success, make powerful predictions & extracted the QGP viscosity.

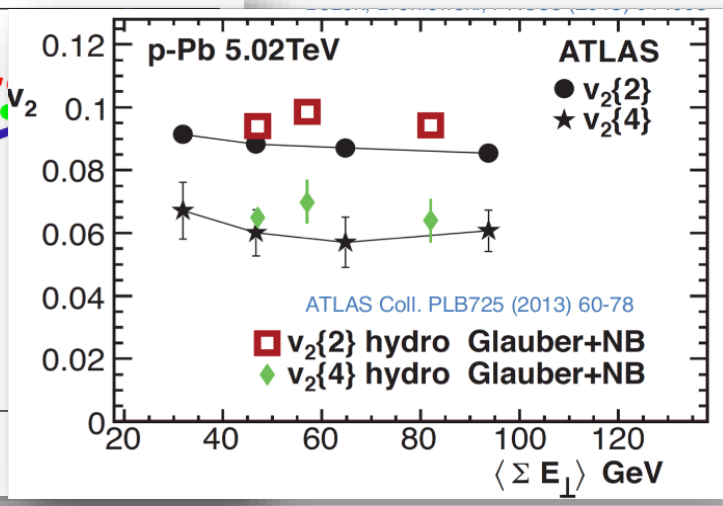




Small systems : hydrodynamics naturally describe many soft observables







Low P_T region: fluid behavior

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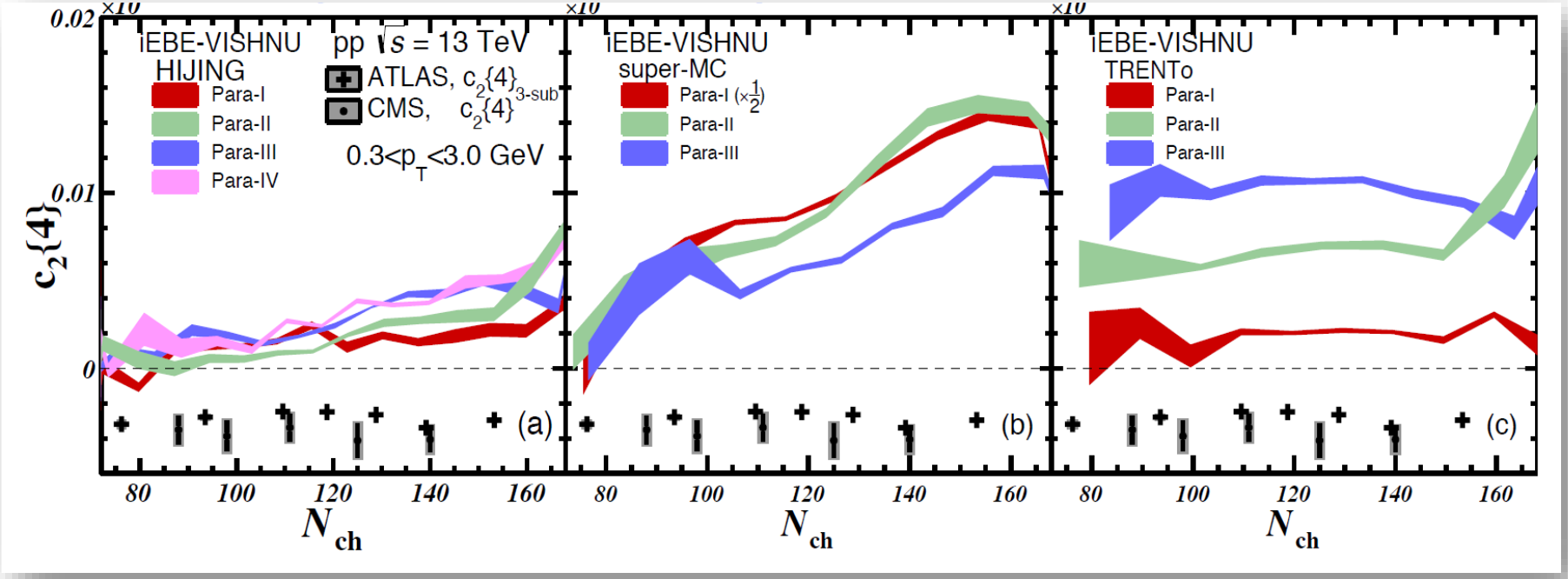

W. Zhao, Y. Zhou, H. Xu, W. Deng and H. Song, Phys. Lett. B 780, 495 (2018);
B. Schenke, C. Shen, and P. Tribedy, arXiv:1908.06212

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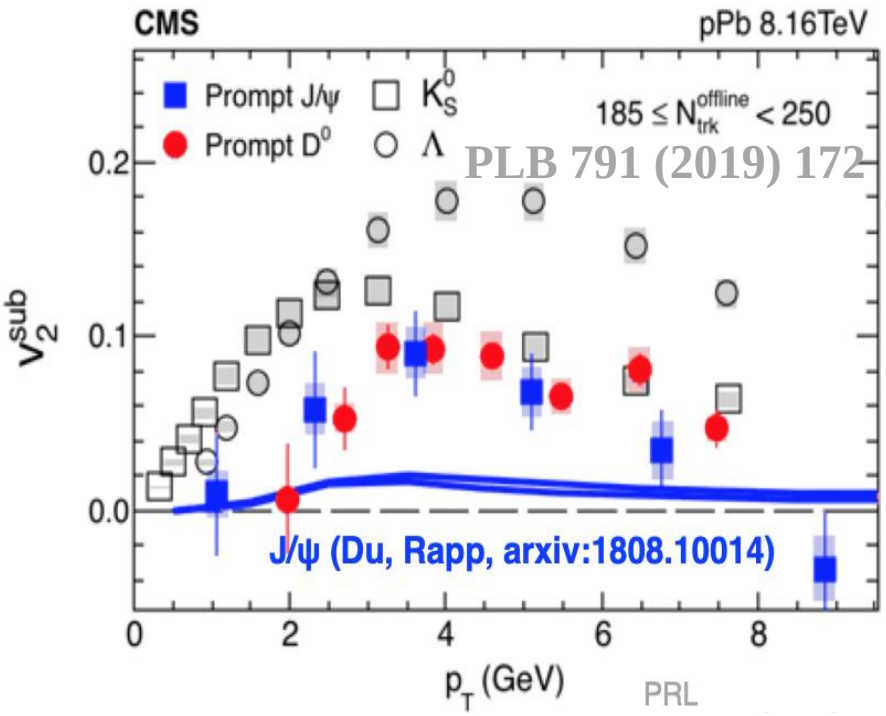
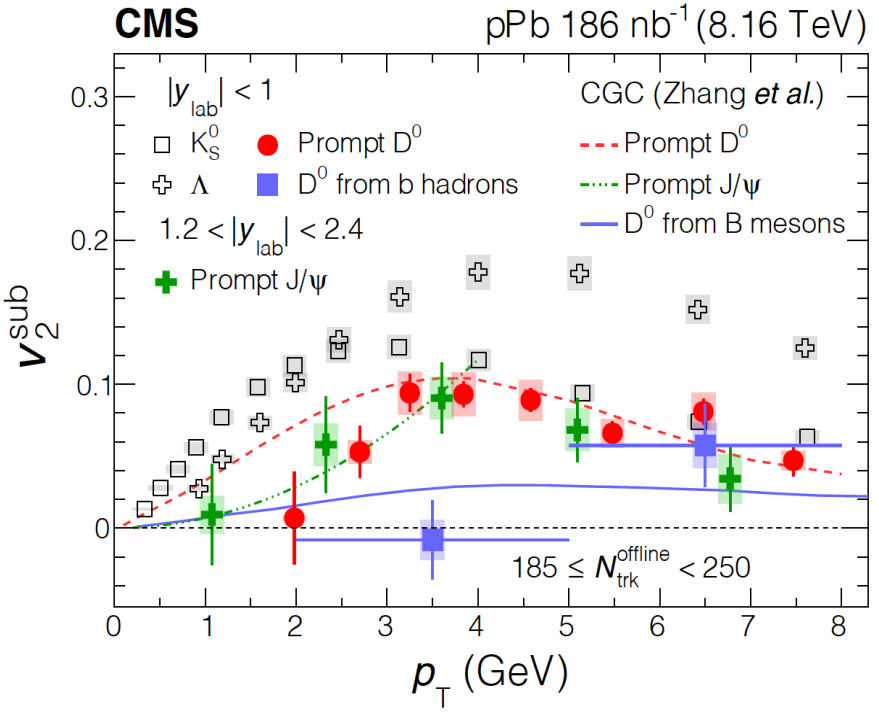
heavy flavor does not have enough flow





Evaluation on the fluid behavior for large to small systems

-Low P_T region

-observables

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-Intermediate P_T region

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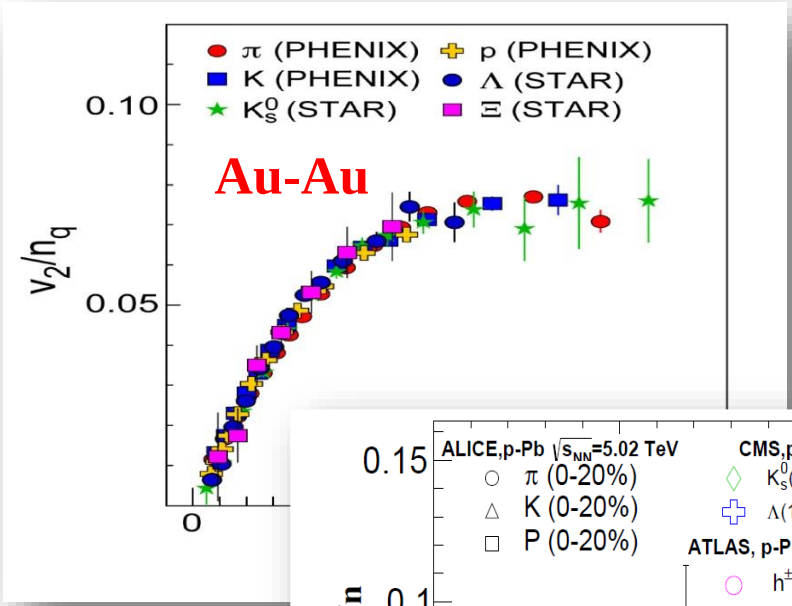
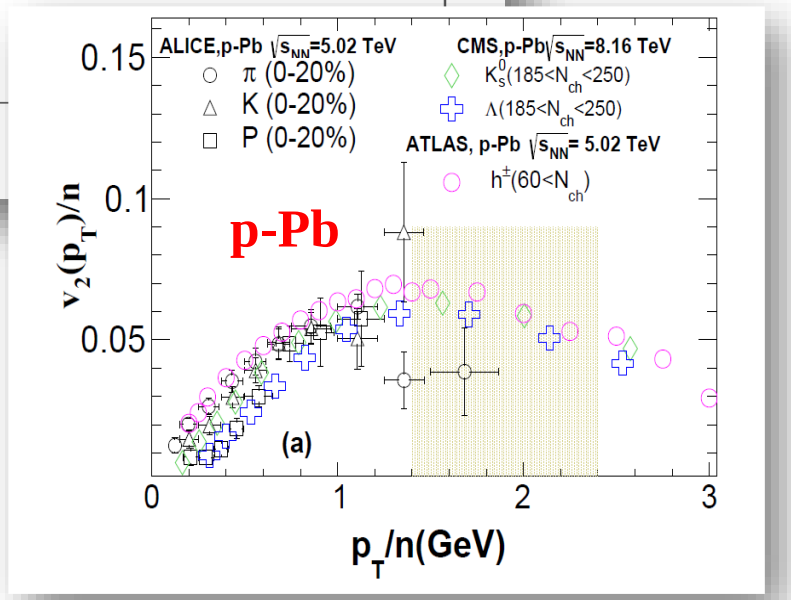




-Intermediate P_T region

-observables (approx.) NCQ scaling

-tools: Hydro-Col-Frag model

Thermal hadrons (VISH2+1 hydro):

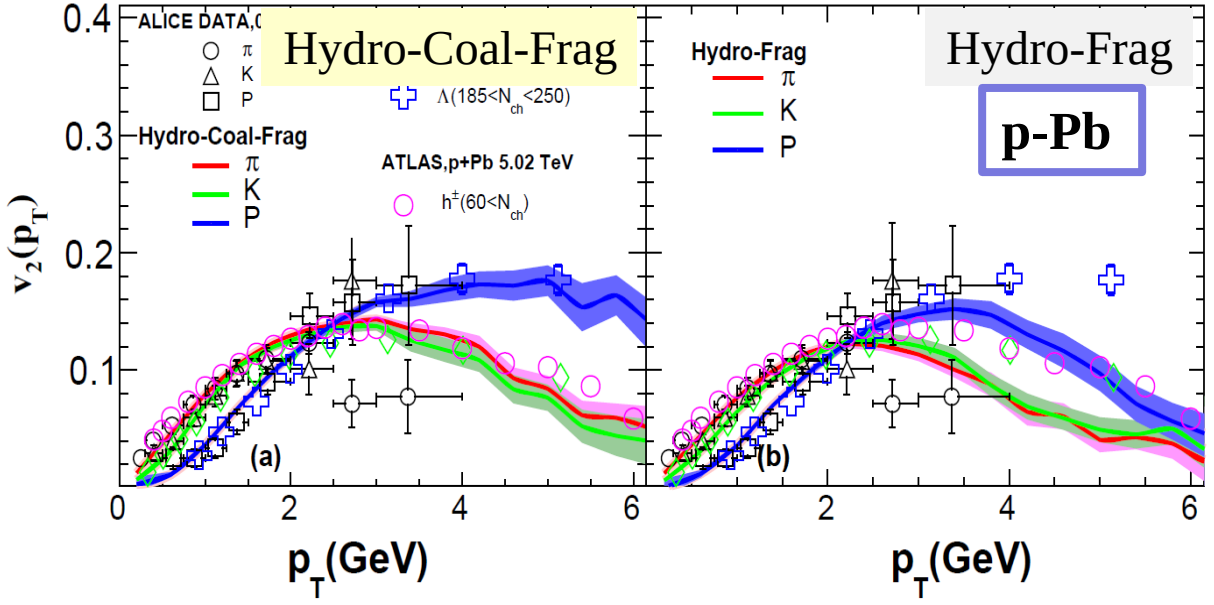
Coalescence hadrons (Coal Model):

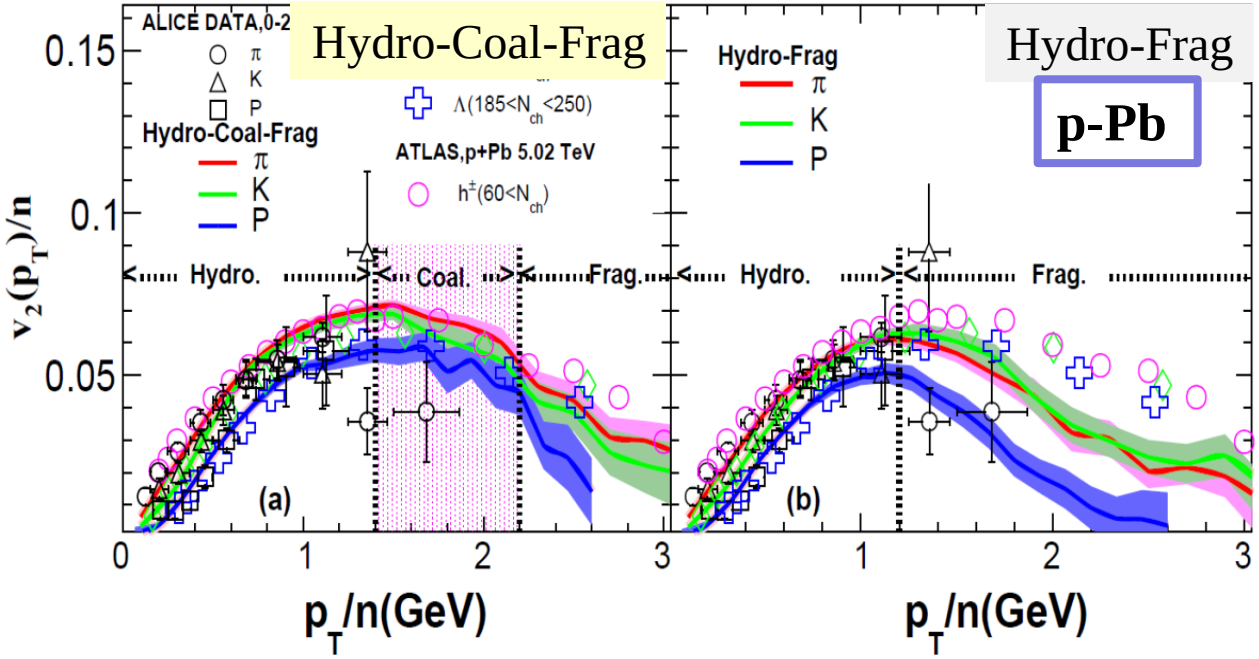
-thermal-thermal, thermal-hard & hard-hard parton coalescence.

Fragmentation hadrons (LBT):

Zhao, Ko, Liu, Qin & Song,
Phys. Rev. Lett. 125 7 072301(2020)

Intermediate PT region: small systems





-At intermediate p_T, Hydro-Coal-Frag model obtains an approximate NCQ scaling

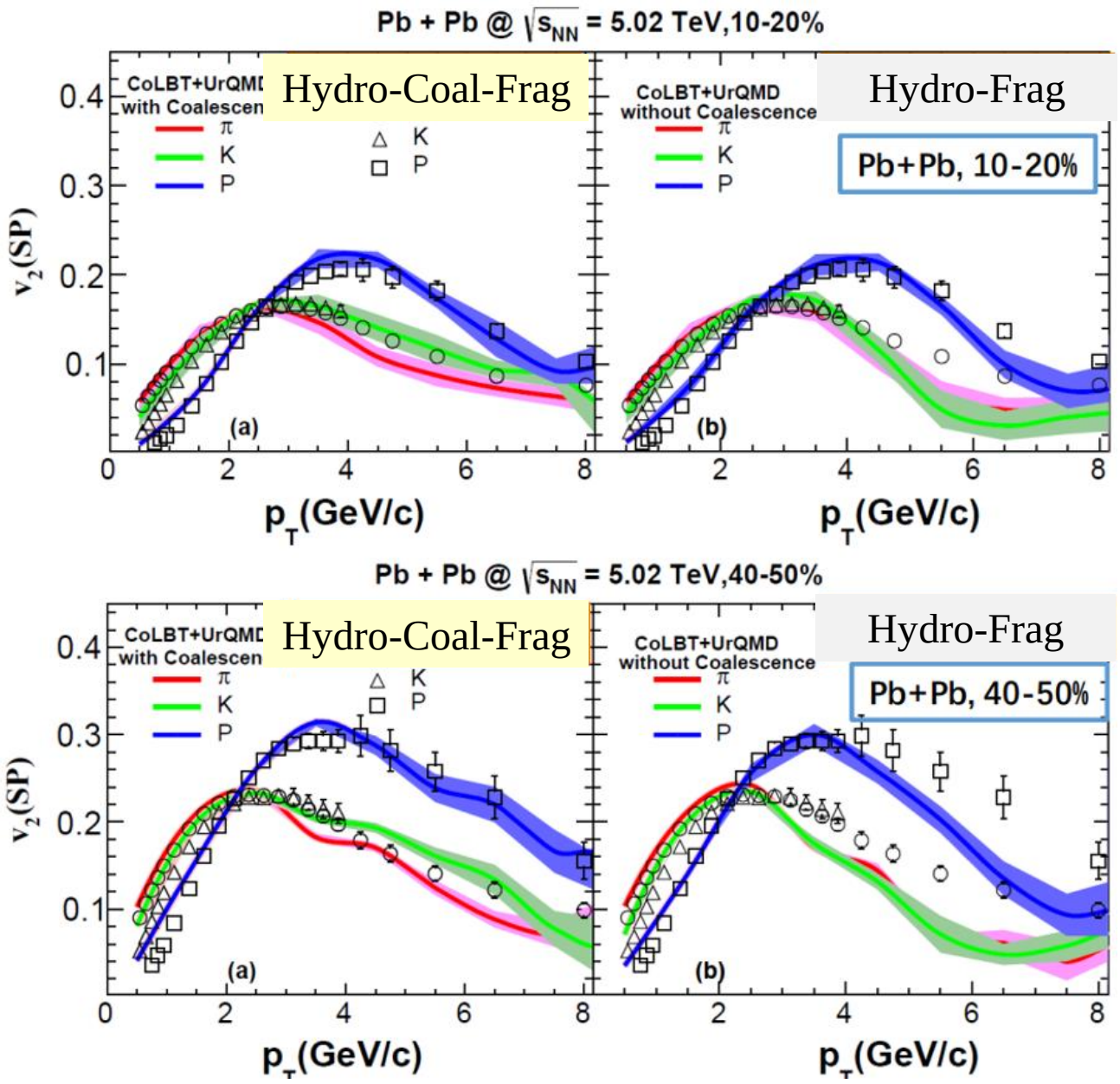
-Without coalescence, underestimates the $v_2(p_T)$ violating the NCQ Scaling of v_2 at intermediate p_T,

-Strongly indication of partonic degree of freedom in small system

-Support collective flow at low P_T

Zhao, Ko, Liu, Qin & Song, Phys. Rev. Lett. 125 7 072301(2020)

Intermediate PT region: large systems



-CoLBT-hydro with Hydro-Coal-Frag works well for PID flow from 0 to 8 GeV.

-Quark coalescence is important for Pb+Pb collisions at intermediate pr ragion.

Zhao, Chen, Luo, Ke & Wang. Phys. Rev. Lett. 128 2 022302(2022).

Evaluation on the fluid behavior for large to small systems

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Question to the 4 panellists:

Is the underlying physics identical in small and large systems?

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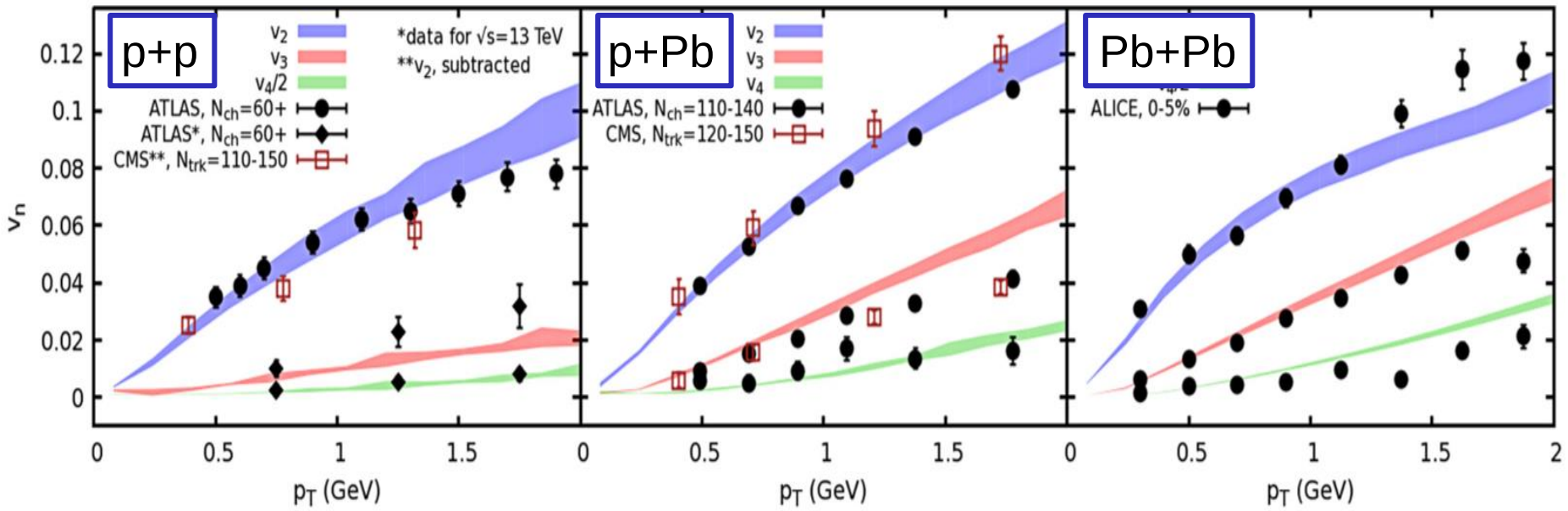
Can one fluid rule it all? (for p-p p-Pb and Pb-Pb collisons)

Low P_T region



-Hydrodynamics can simultaneously describe v2, v3 and v4 for p-p, p-Pb and Pb-Pb collisions.

R.D.Weller and P.Romatschke,Phys. Lett. B 774 (2017), 351

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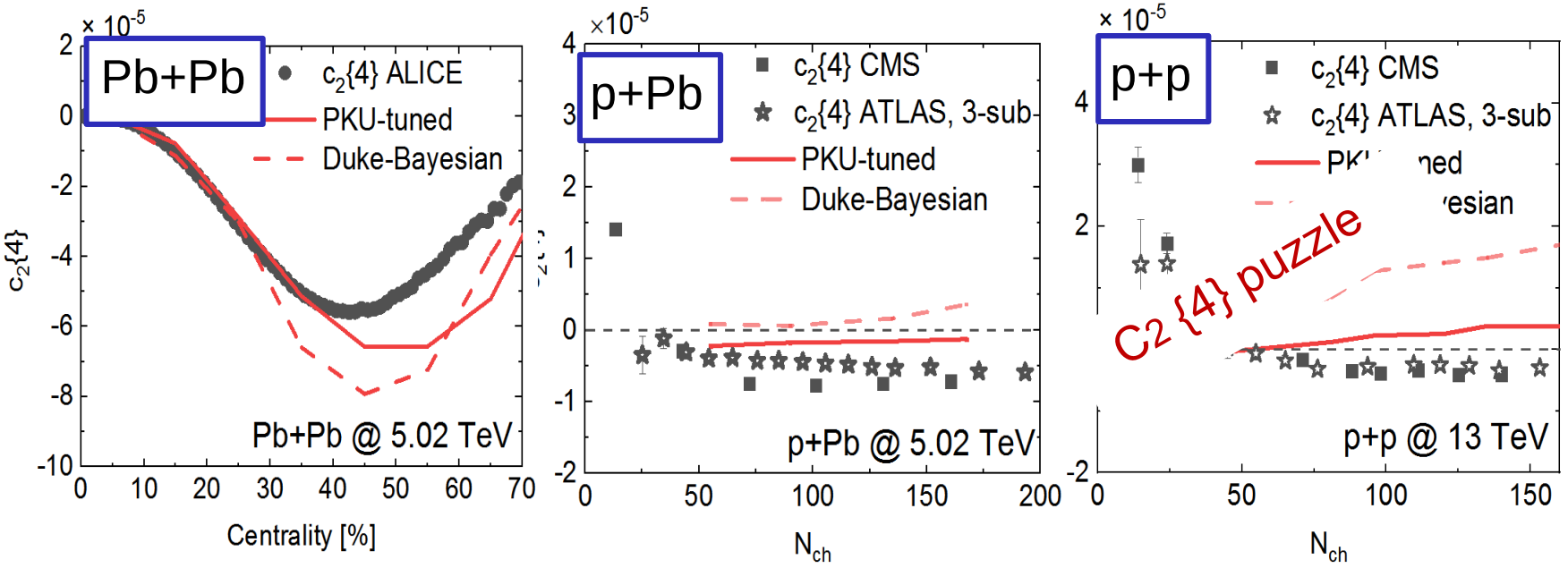
Low P_T region



-**However**, the description of C2{4} become worse and worse from p-Pb to p-p collisions

B.Fu & H.Song, paper in preparation.

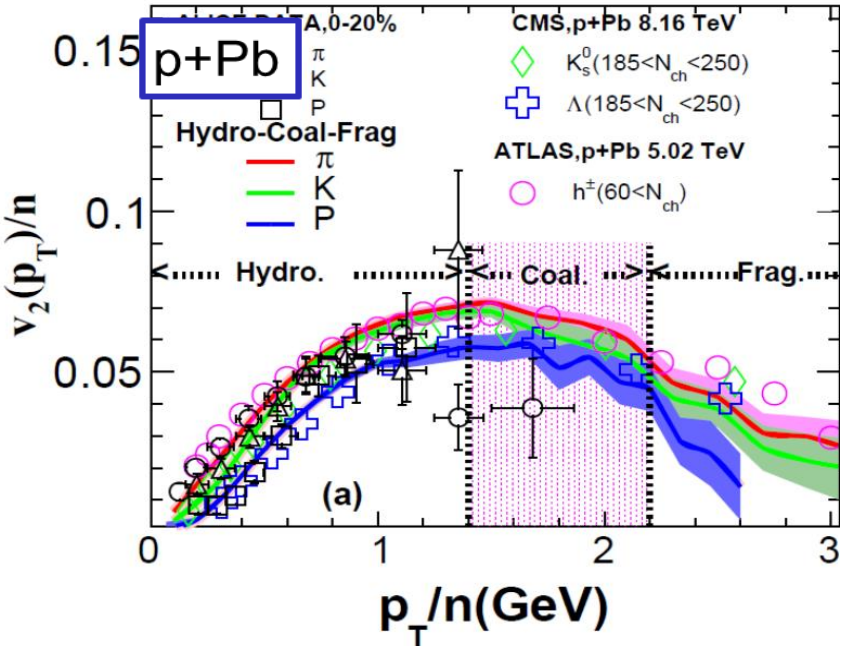
Question to the 4 panellists:

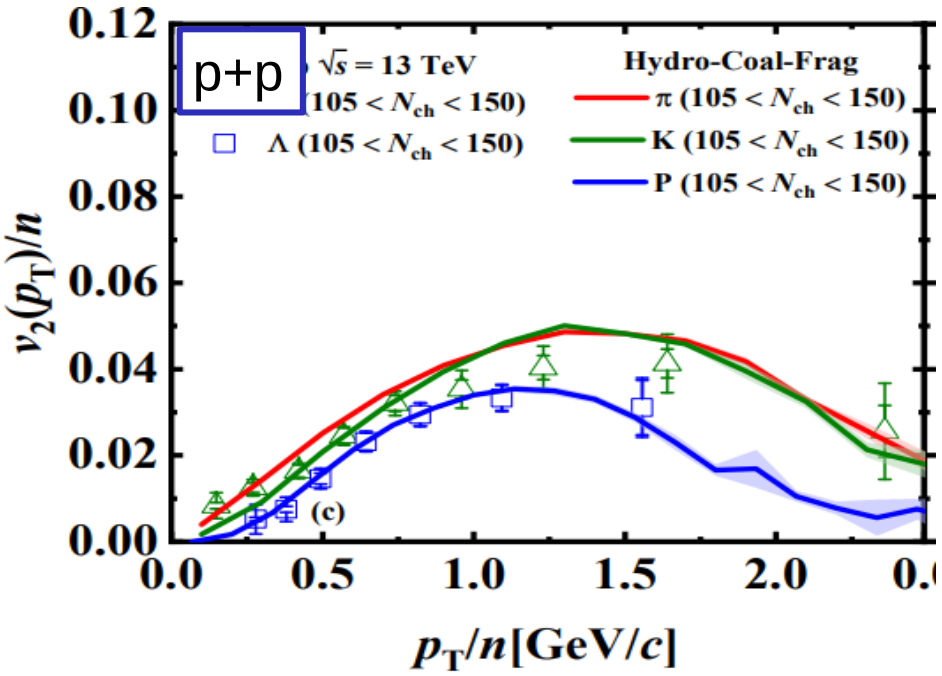
Is the underlying physics identical in small and large systems?

Can one fluid rule it all? (for p-p p-Pb and Pb-Pb collisons)

Intermediate P_T region

Zhao, Ko, Liu, Qin & Song, Phys. Rev. Lett. 125 7 072301(2020); Wang, Zhao, Song, paper in preparation.





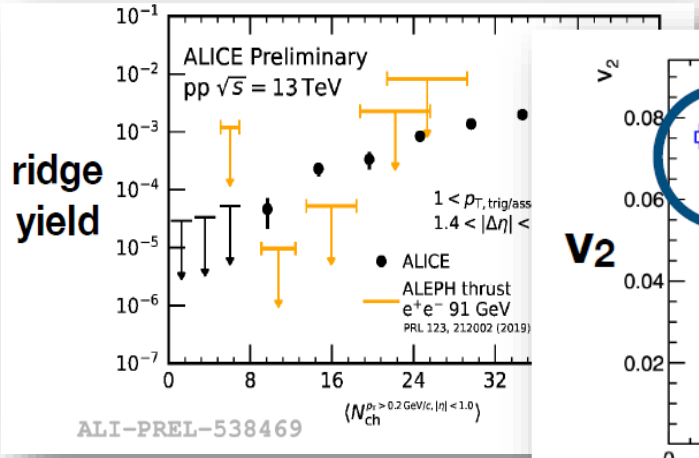
-The NCQ scaling become worse from p-Pb to p-p collisions

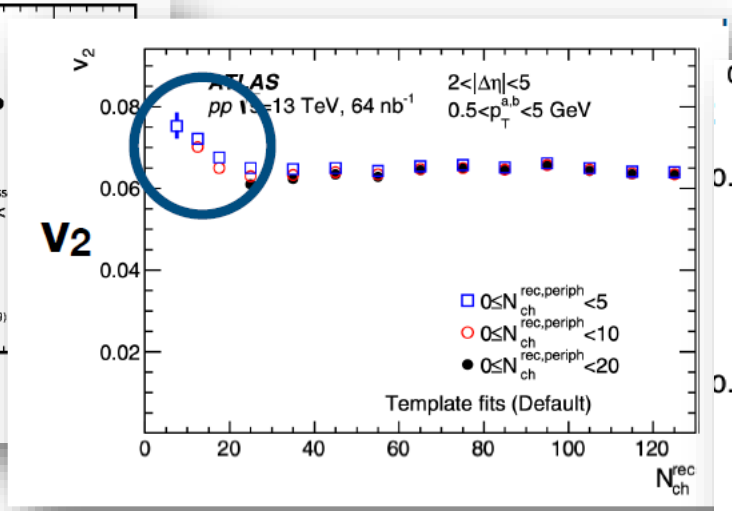
-Fragmentation become important tends to break-up the NCQ scaling

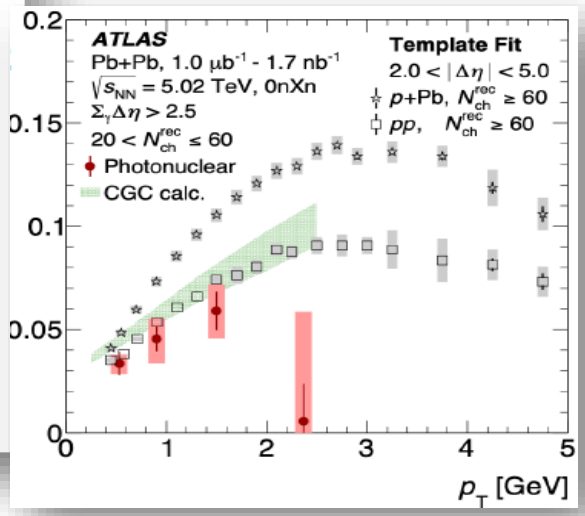
Question to the 4 panellists:

Is the underlying physics identical in small and large systems?

Can one fluid rule it all (min.pp, UPC, ee)?





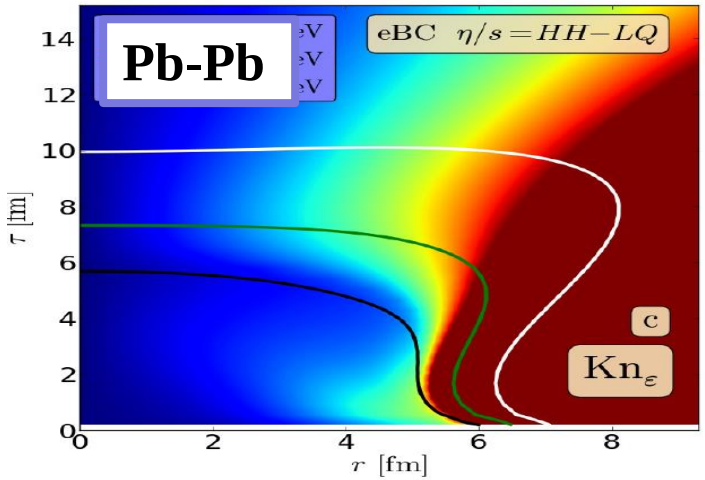


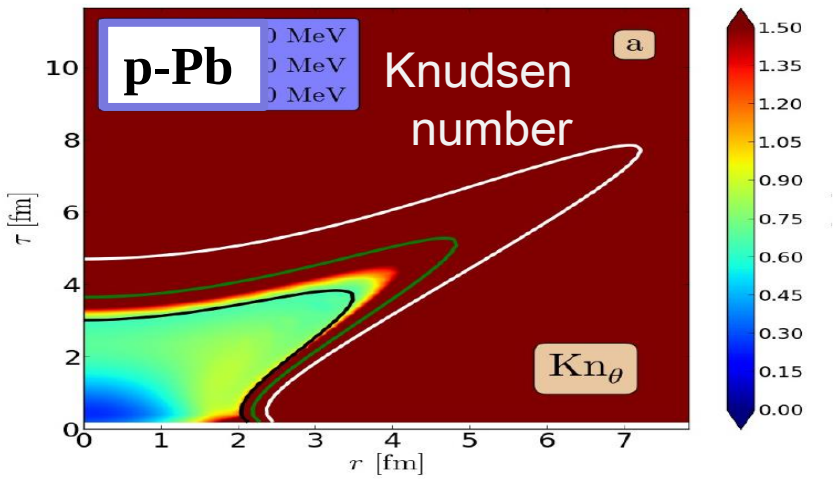
OBSERVABLES	A—A	p—A (high mult.)	pp (high mult.)	pp (low mult.)	UPC	ep	e^+e^- (high mult.)	e^+e^-
Near-side ridge yield	✅ [1,2]	✅ [30,32,33]	✅ [30,31]	✅ [34]	—	❌ [74,75]	✅ [77]	❌ [76]
Anisotropic flow	✅ [3,4]	✅ [36,37,38,39]	✅ [35,37]	✅ [30]	✅ [72,73]	❌ [74,75]	✅ [77]	—
Multiparticle cumulants	✅ [5]	✅ [40-45]	✅ [40,41,45]	—		—	—	—
Mass ordering	✅ [6]	✅ [47-49]	✅ [46,48]	—	—	—	—	—

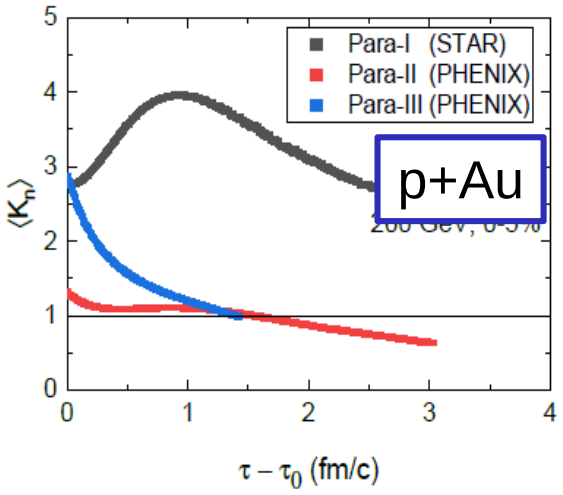
-Not enough flow data to evaluate the fluid behavior

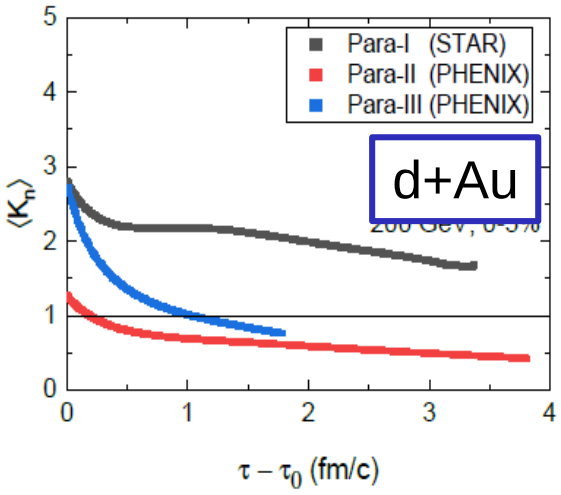
Large systems：traditional hydrodynamics are great success

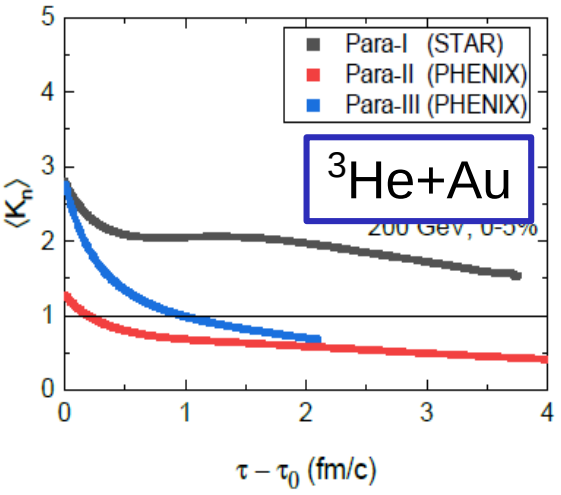
Small systems：hydrodynamics and the fluid behavior is not that good











-Small systems may approach or beyond the limit of hydro; The situation is worse for smaller systems

Wu … Song, paper in preparation.

Question to the 4 panellists:

Is the underlying physics identical in small and large systems?

Can one fluid rule it all? (for p-p p-Pb and Pb-Pb collisons)

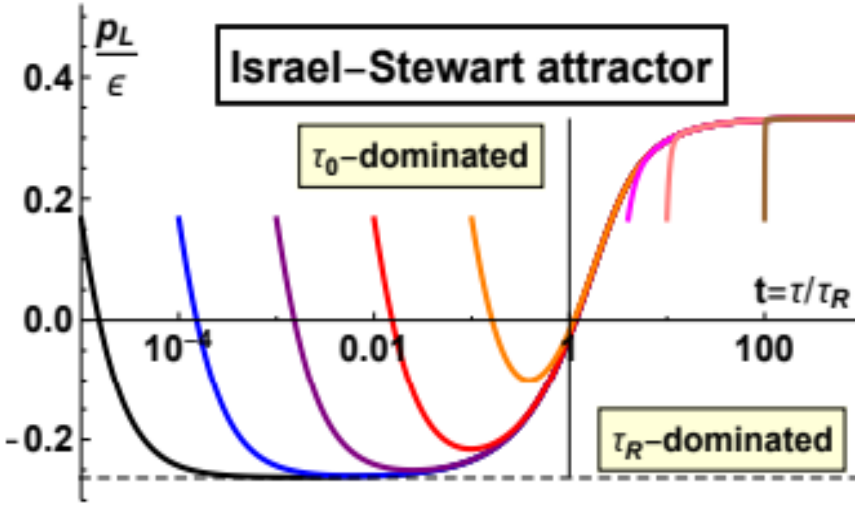
Small systems :

-Phonemically, hydrodynamics and the fluid behavior is not that good

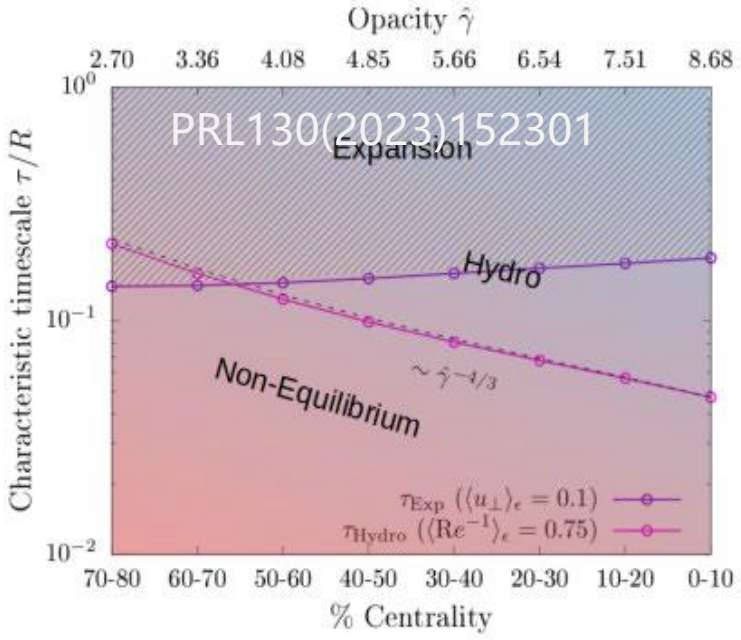
-Fragmentation/mini-jets become more & more important for smaller systems

-Small systems may approach or beyond the limit of hydro

-Isotropization & thermalizations is slower for small systems



A. Kurkela, W. van der Schee, U. A. Wiedemann, PRL124(2020)102301



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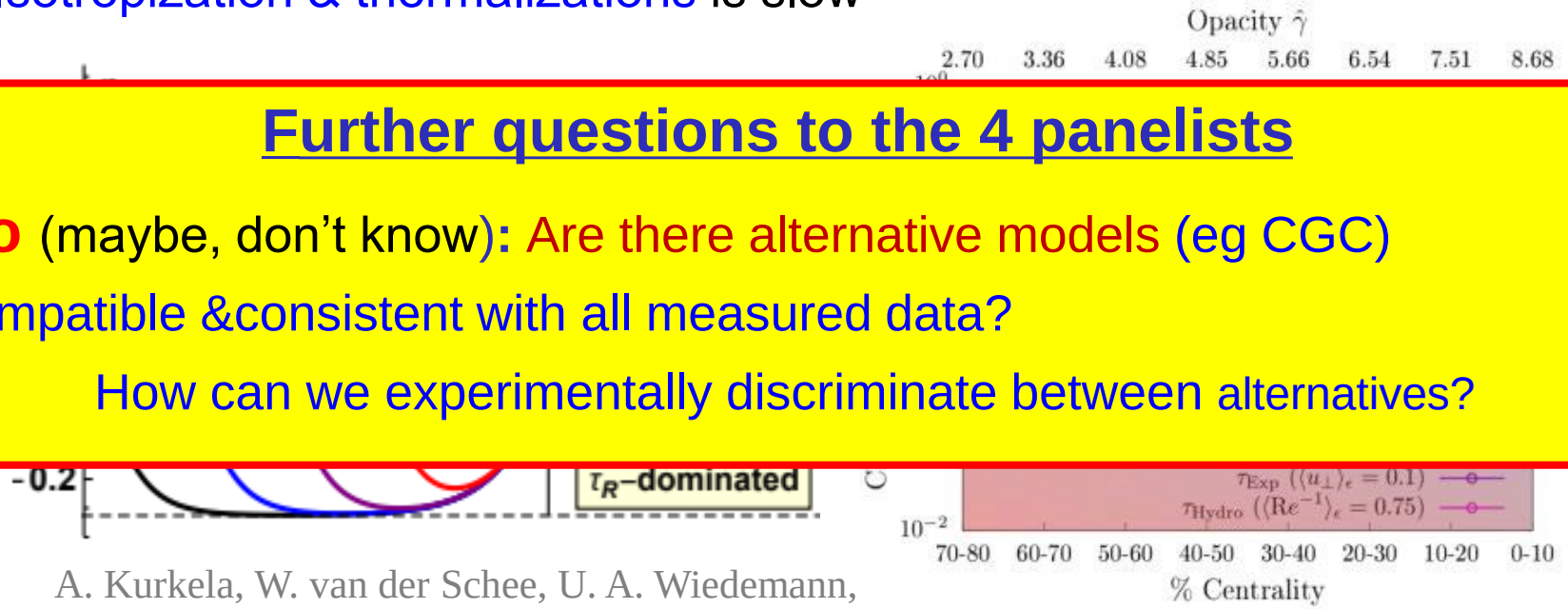


Further questions to the 4 panelists

No (maybe, don't know): Are there alternative models (eg CGC) compatible &consistent with all measured data?

How can we experimentally discriminate between alternatives?

A. Kurkela, W. van der Schee, U. A. Wiedemann, PRL124(2020)102301

Comments & Discussions

Hydrodynamic side:

-Isotropization & thermalizations for Large and small systems (need more efforts)

-Properly treat pre-equilibrium stage /isotropization for small systems

-Anisotropic hydrodynamics

M. Alqahtani, et al Phys. Rev. Lett. 119(2017)042301 … …

-Hybrid approach IP-Glasma+hydro

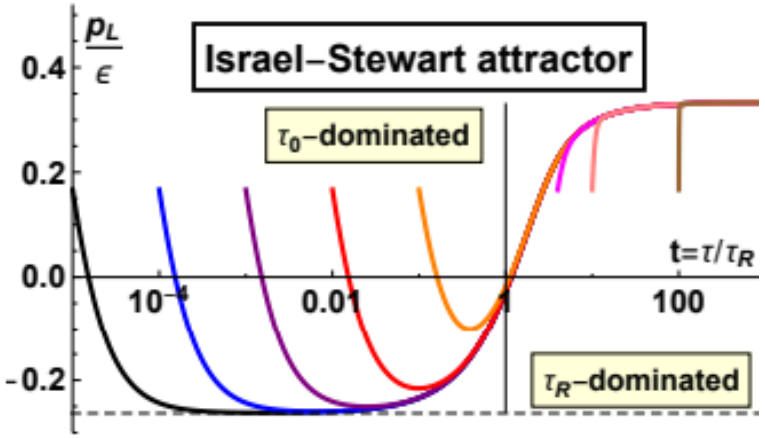
B.Schenke, et al Phys Lett B 803 (2020) 135322…

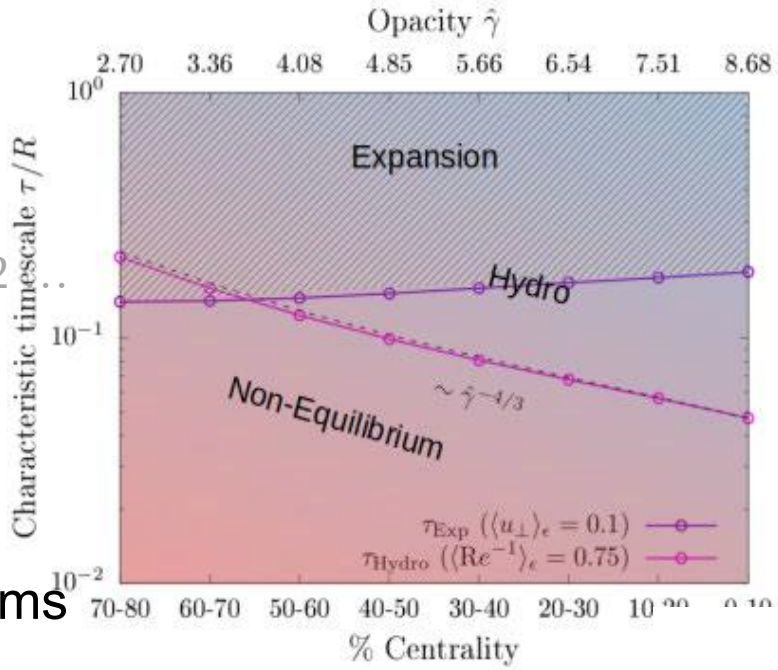
-Hybrid approach core+ corona

Y. Kanakubo, Y. Tachibana, T. Hirano. Phys.Rev.C 106 (2022) 5, 054908 … …

-initial state fluctuations for various systems

Hydrodynamic attractor





Comments & Discussions

Hydrodynamic side:

-Systematically evaluate isotropization & thermalizations from large to small systems

-Properly treat pre-equilibrium stage / isotropization for small systems

Experimental and theoretical side:

-The formation of fluid in small system can not be convincingly evaluated by few flow observables, together with model calculations without predictions

-More soft observables to evaluate flow in small systems (p-p UPC e-e…)

-Put more efforts on intermediate P_T region to evaluate partonic flow

Connection to other field:

-Can cold atom physics helps to evaluate the system size dependence on isotropization, thermalizations / evaluate the emergence of flow from dilute to dense systems?