

© Foto: Ra Boe / Wik

The 18<sup>th</sup> International Conference on  
**Strangeness in Quark Matter**  
10-15 June 2019, Bari (Italy)

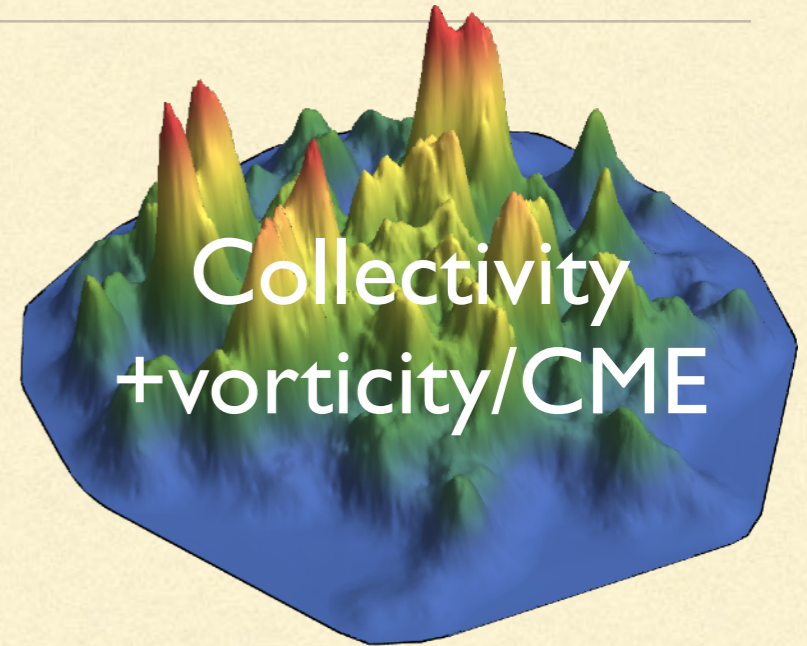


# THEORY SUMMARY

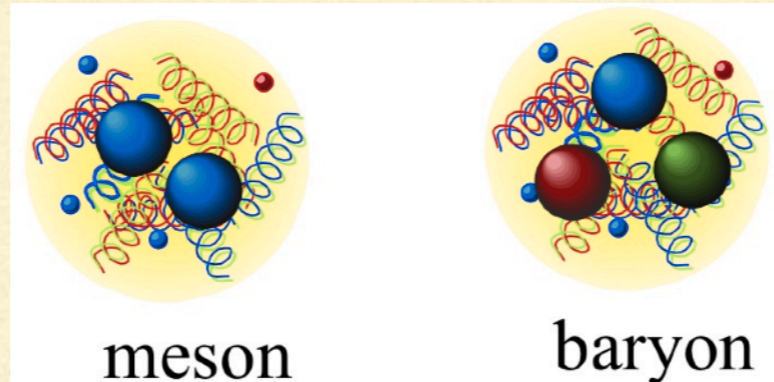
Jacquelyn Noronha-Hoster  
Rutgers University



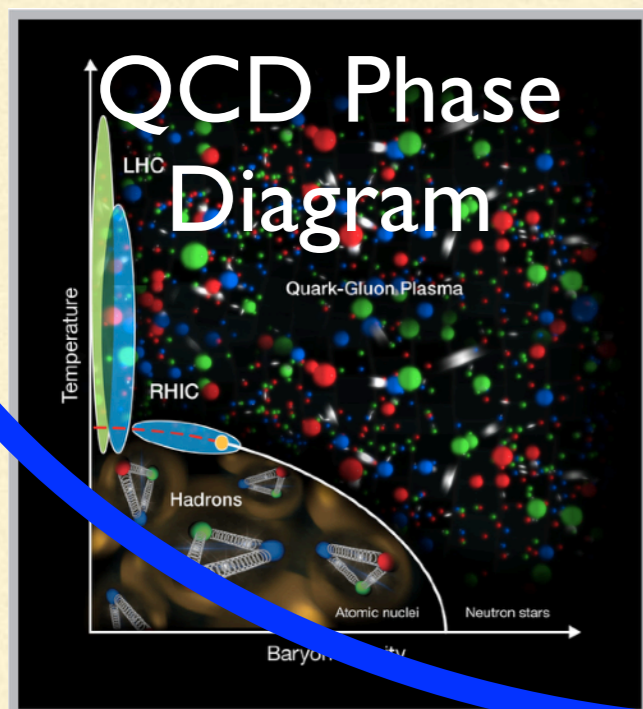
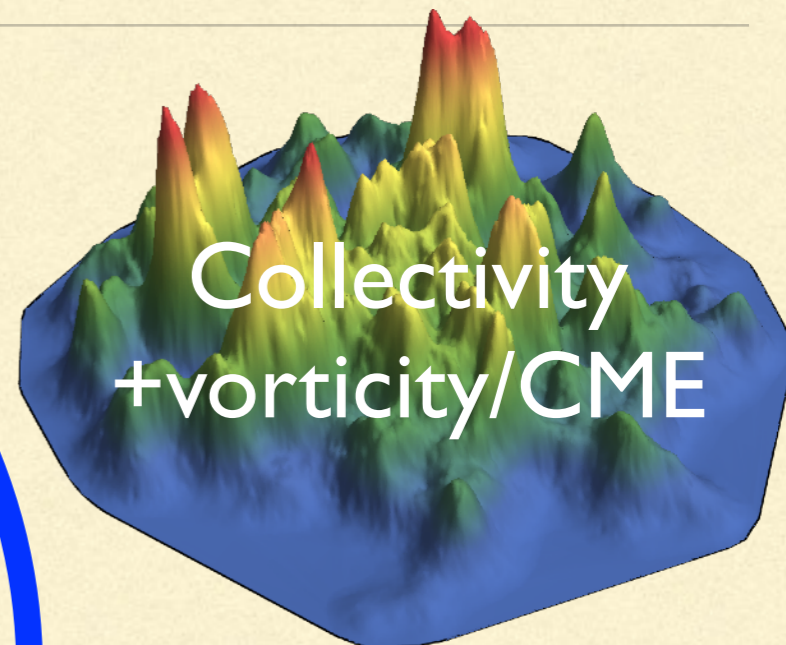
# MANY DIFFERENT TOPICS



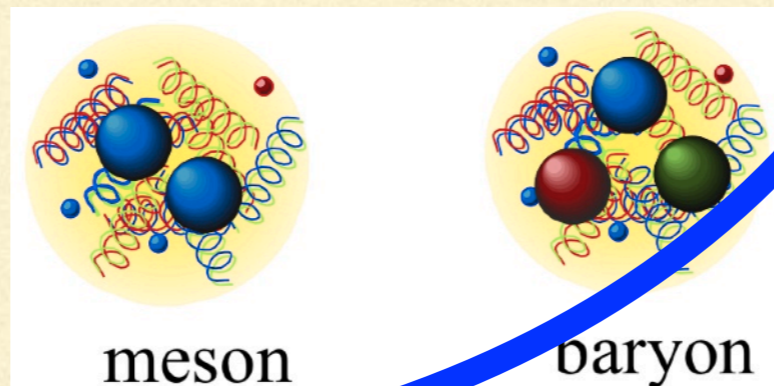
## Hadrons/coalescence



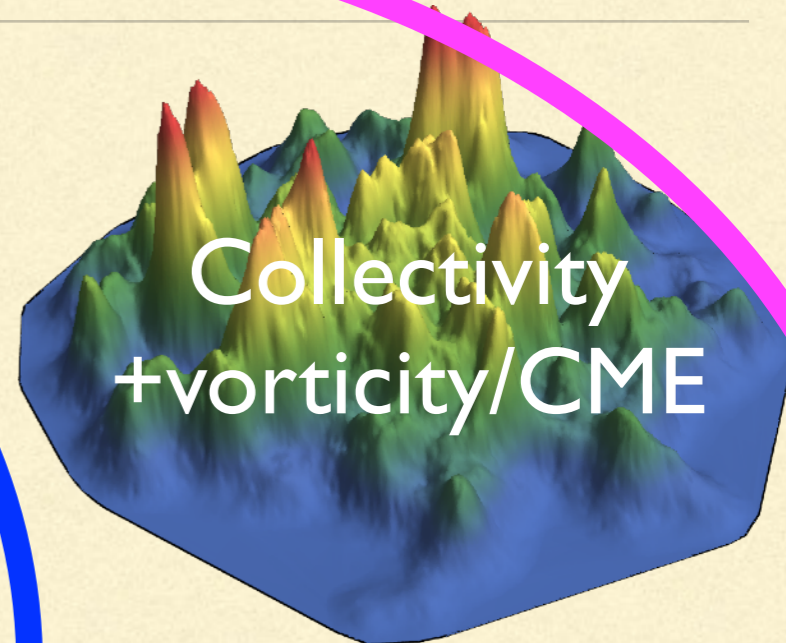
# +INTERESTING OVERLAP



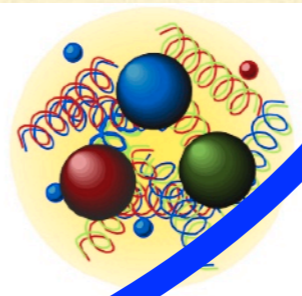
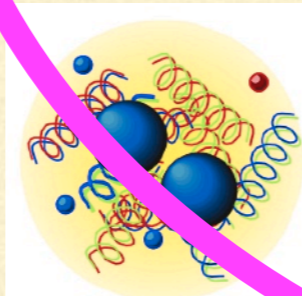
Hadrons/coalescence



# +INTERESTING OVERLAP



Hadrons/coalescence



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# THEORY TALKS

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Tuesday Parallels = 15  
Thursday Parallels = 12  
+ Plenary = 15

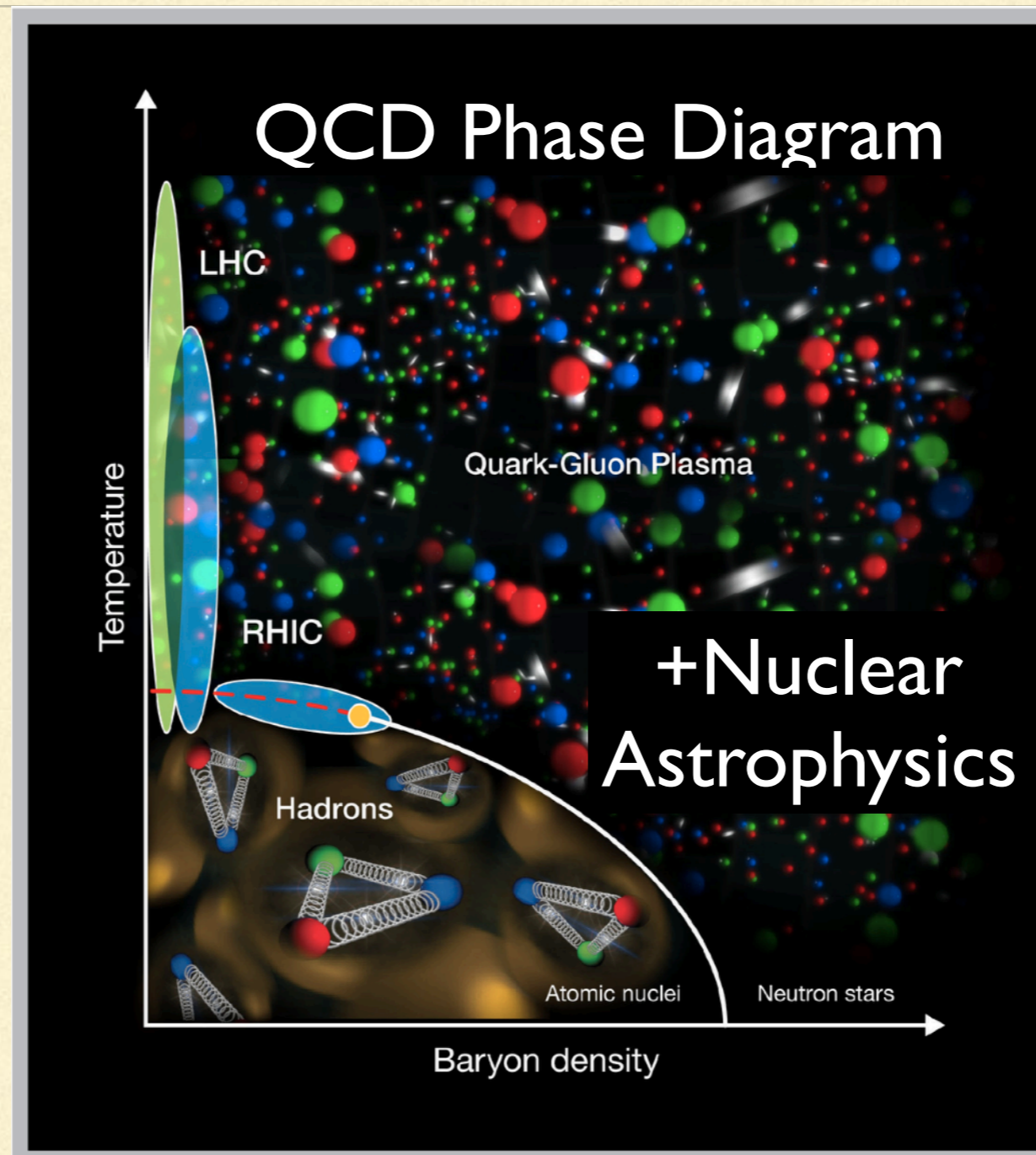
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=42 talks+many excellent posters!

**Caveat:** At best I can give a brief overview, please follow up with the wonderful speakers for detailed questions!

**Warning:** I've reorganized the categories of certain talks to tell a clearer story.

# QCD PHASE DIAGRAM

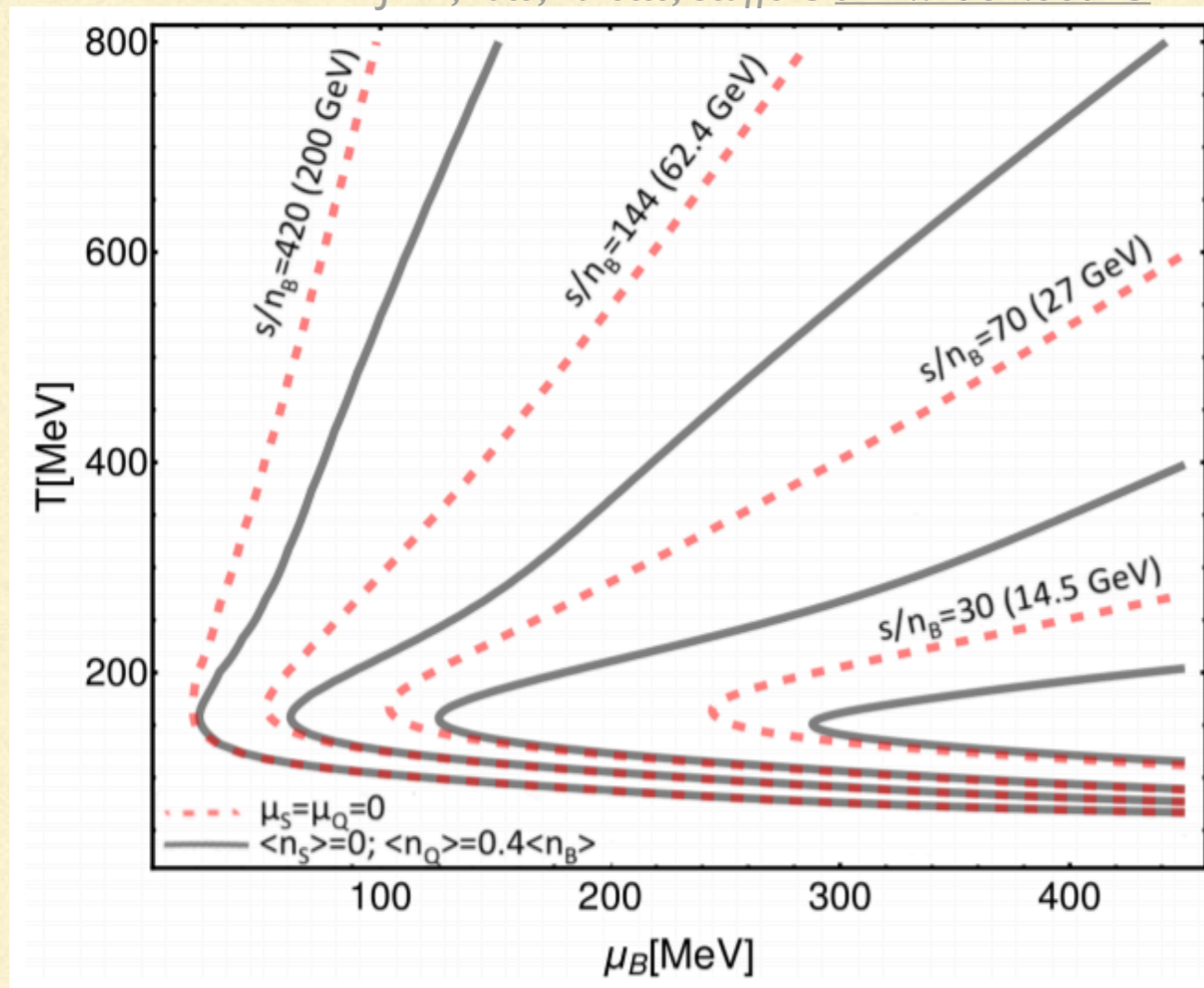


# RECONSTRUCTING THE EOS

C. Ratti Friday 9:00

Isentrope trajectories

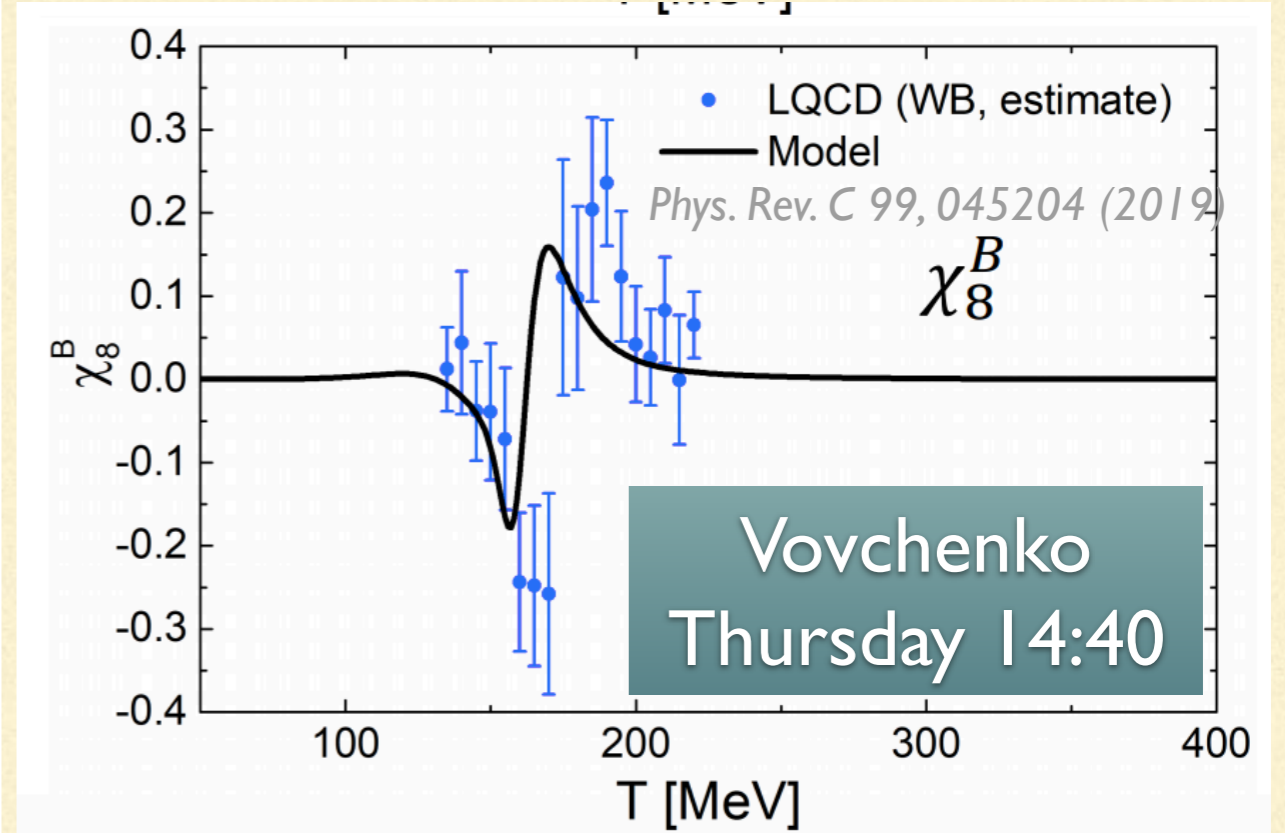
JNH,Ratti, Parotto, Stafford *arXiv:1902.06723*



Reaches larger chemical potentials

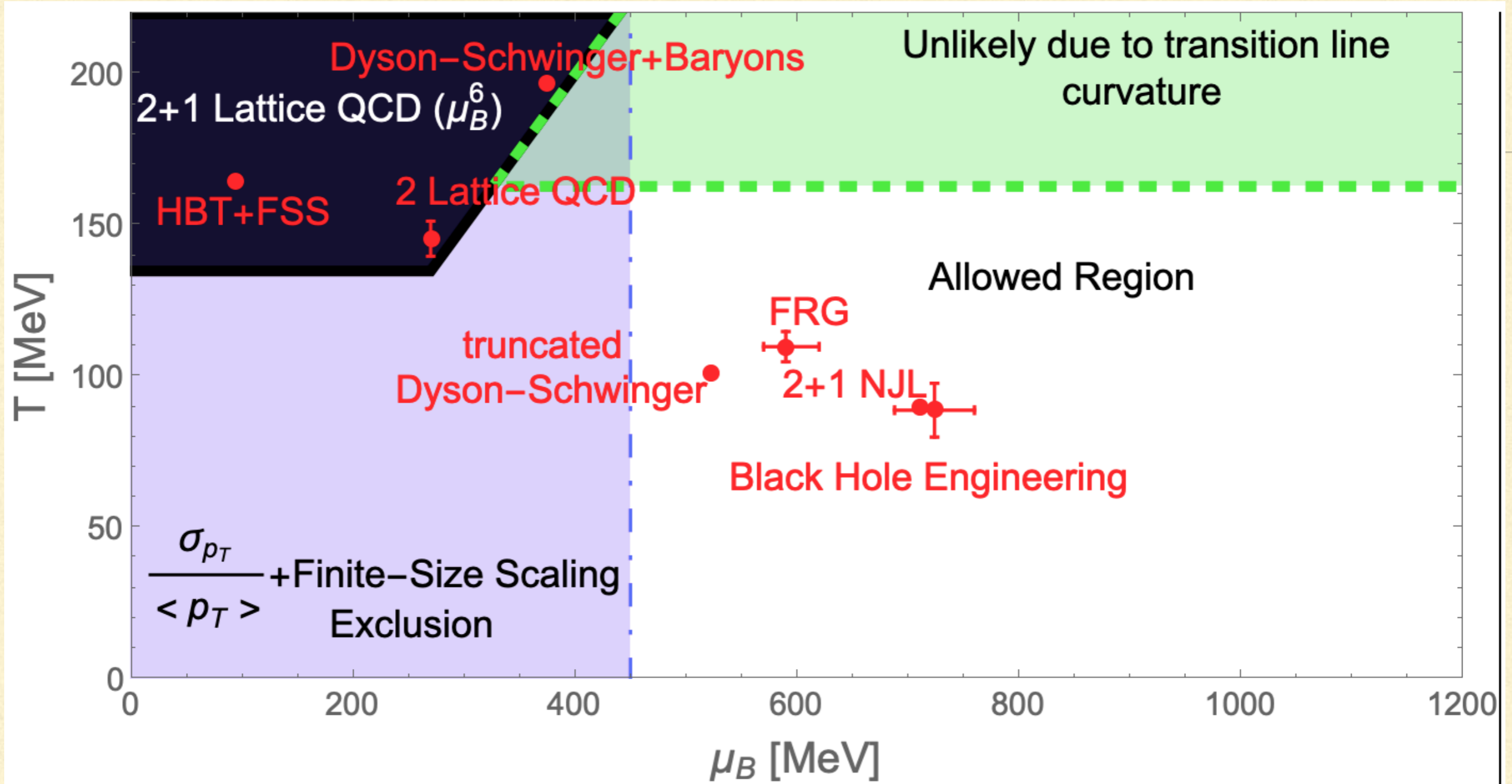
See also Monnai, Schenke, Shen, *arXiv:1902.05095*

## Hagedorn States+Bag Model to Lattice



See also Gomez Nicola Friday 10:00

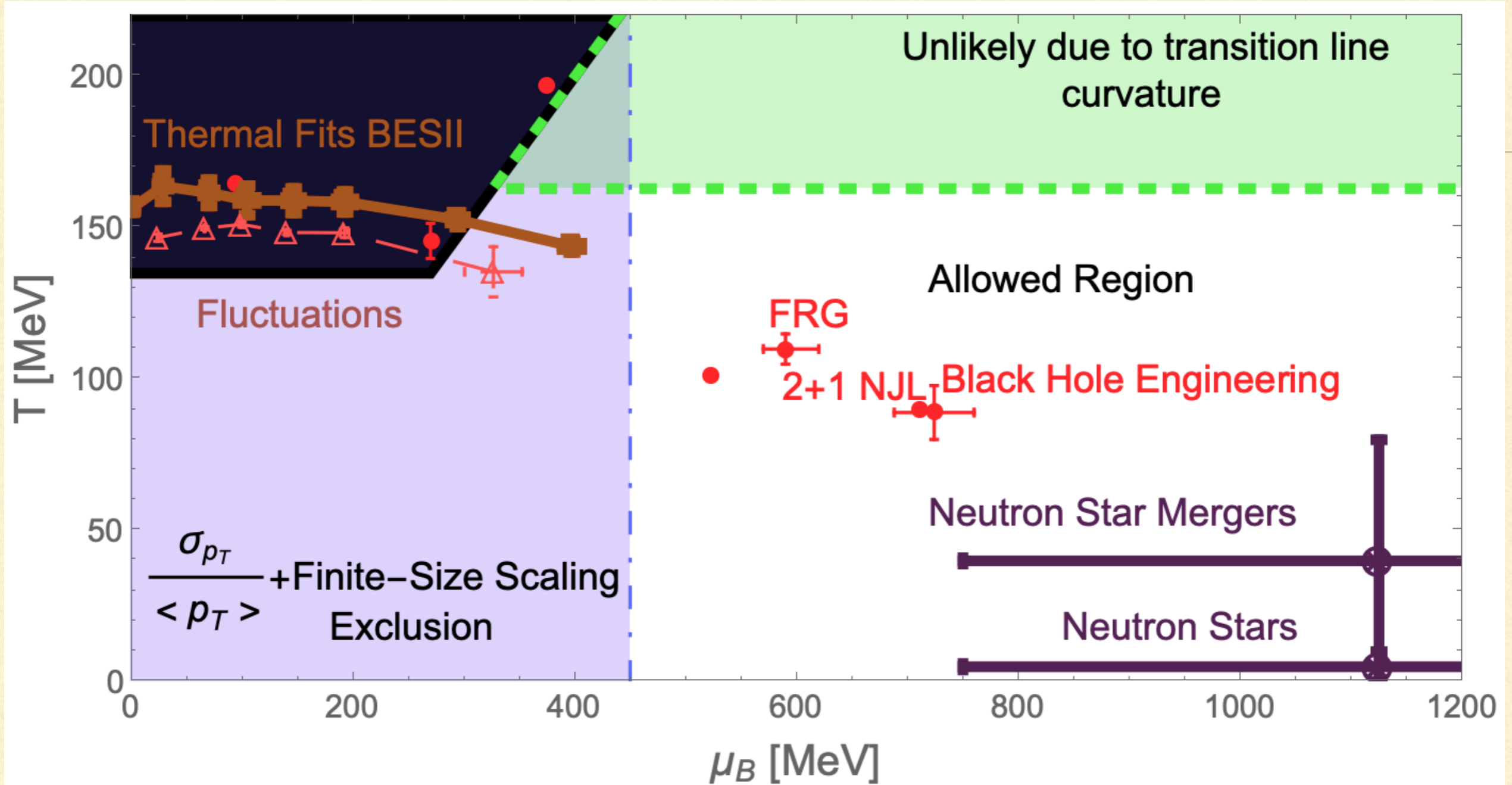
# CP EXCLUSION PLOT



Lattice QCD [HotQCD]PRD95(17)no.5,054504; Finite-Size ScalingPRC84,011903(11); R. Lacey PRL114(15)no.14,142301; Black Hole Engineering arXiv:1706.00455; 2+1 Polyakov LoopPLB732(14)273; Dyson-SchwingerPRD93(16)no.3,034013; DGGPRD95(17)no.5,054512; 2+1 NJLIJMPA32(17)no.11,1750061; FRG Rennecke RHIC User's meeting 19; Older summary: Stephanov PoS

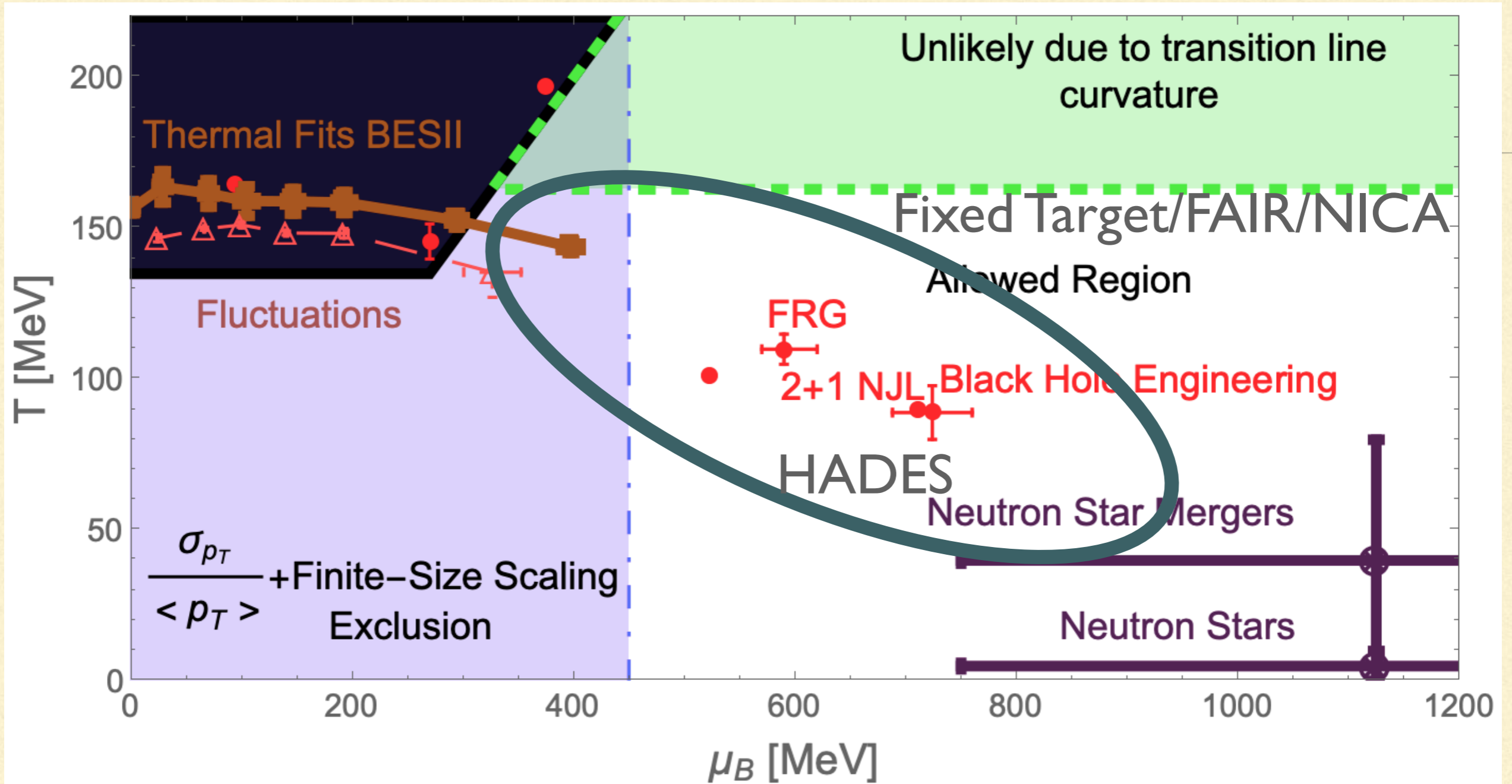


# CP EXCLUSION PLOT



Lattice QCD [HotQCD]PRD95(17)no.5,054504; Finite-Size ScalingPRC84,011903(11); R. Lacey PRL114(15)no.14,142301; Black Hole Engineering arXiv:1706.00455; 2+1 Polyakov LoopPLB732(14)273; Dyson-SwingerPRD93(16)no.3,034013; DGGPRD95(17)no.5,054512; 2+1 NJLIJMPA32(17)no.11,1750061; FRG Rennecke RHIC User's meeting 19; Older summary: Stephanov PoS

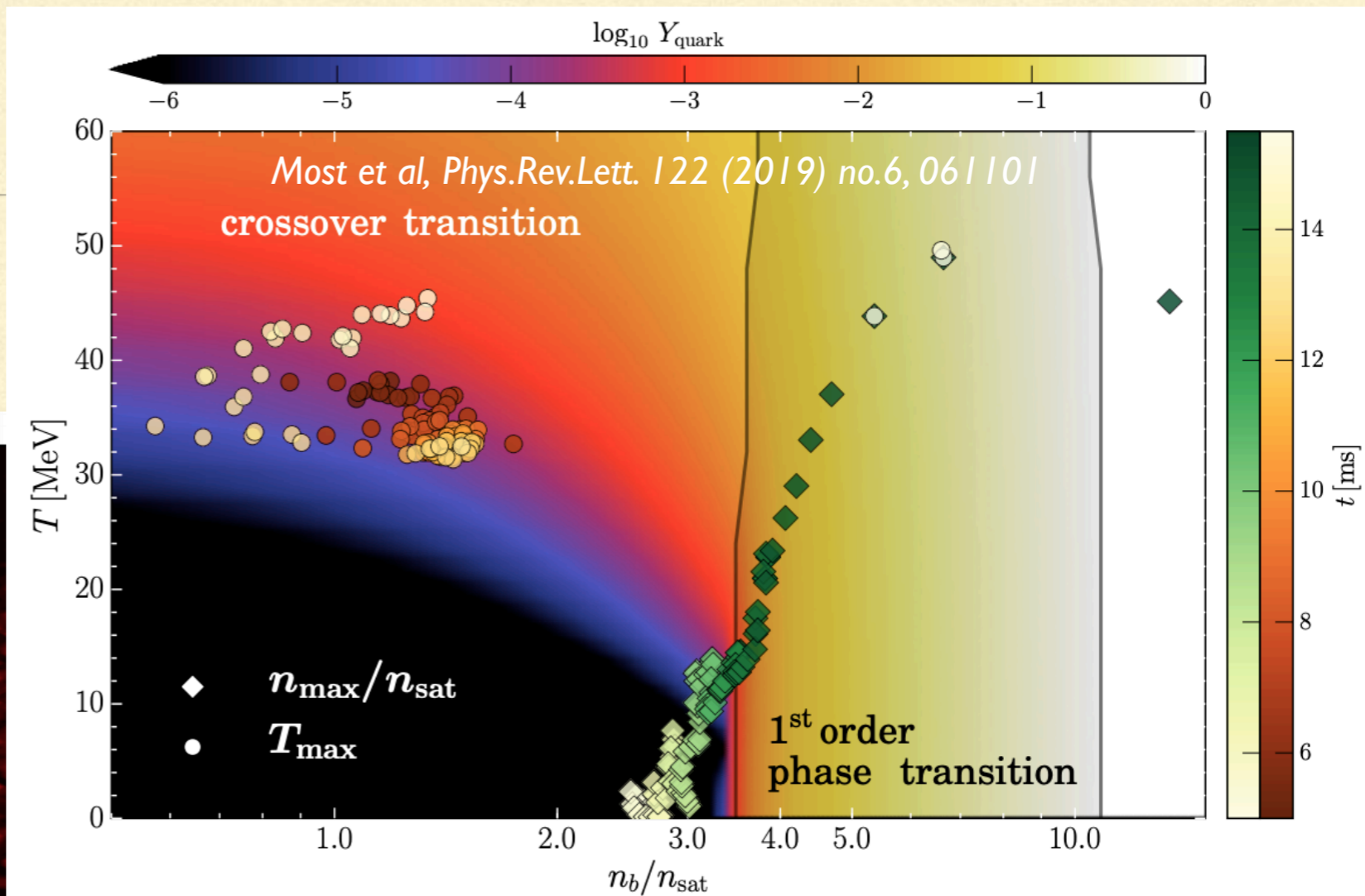
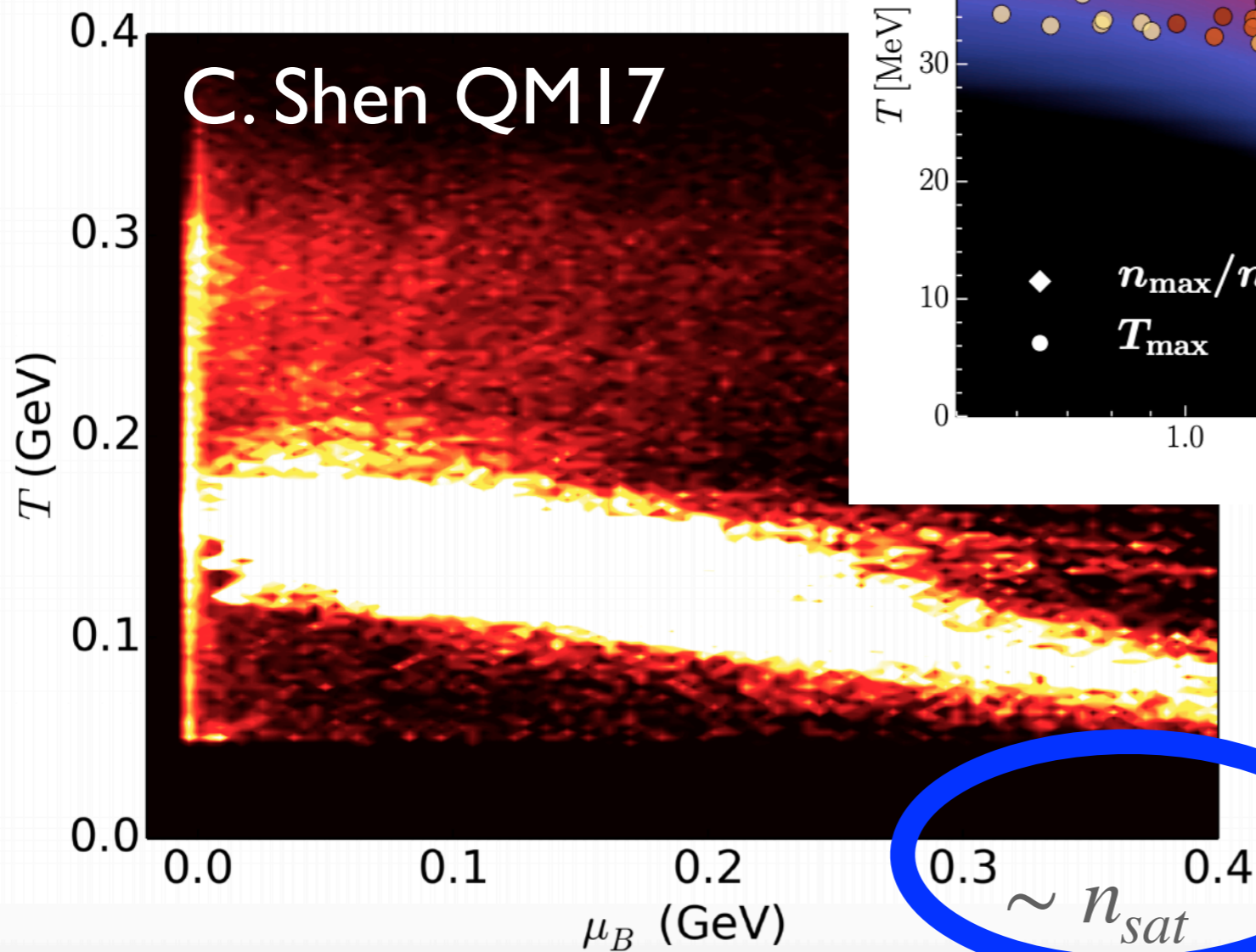
# CP EXCLUSION PLOT



Lattice QCD [HotQCD]PRD95(17)no.5,054504; Finite-Size ScalingPRC84,011903(11); R. Lacey PRL114(15)no.14,142301; Black Hole Engineering arXiv:1706.00455; 2+1 Polyakov LoopPLB732(14)273; Dyson-SwingerPRD93(16)no.3,034013; DGGPRD95(17)no.5,054512; 2+1 NJLIJMPA32(17)no.11,1750061; FRG Rennecke RHIC User's meeting 19; Older summary: Stephanov PoS

# PASSING THROUGH THE PHASE DIAGRAM

L. Rezzolla Tuesday 15:20



<25% uncertainty on EOS in neutron stars

Barnaföldi Tuesday 15:00

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# STEFAN SCHRAMM

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“I liked Stefan so much, it breaks my heart when I think about him.”  
-Horst Stoecker

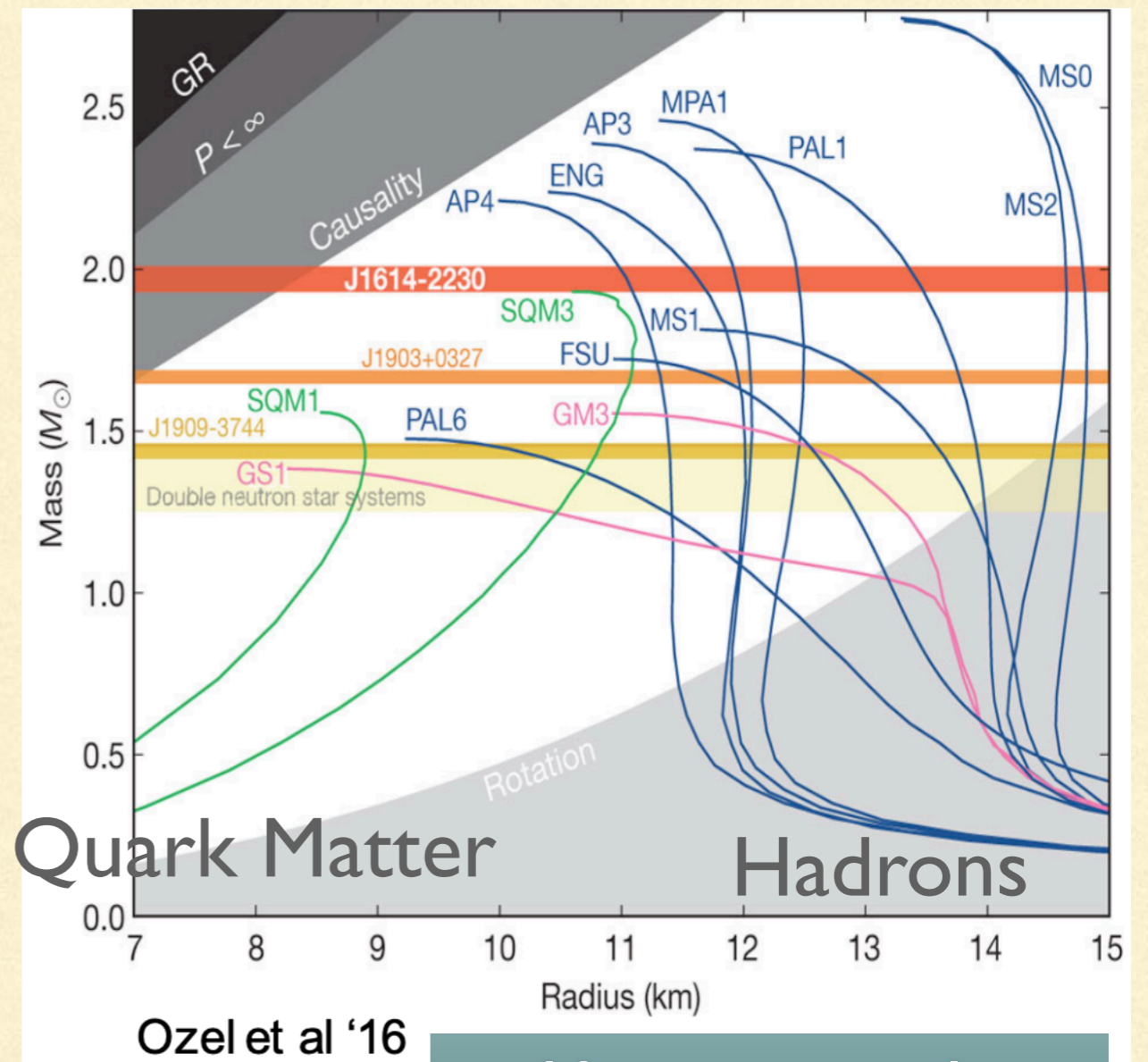
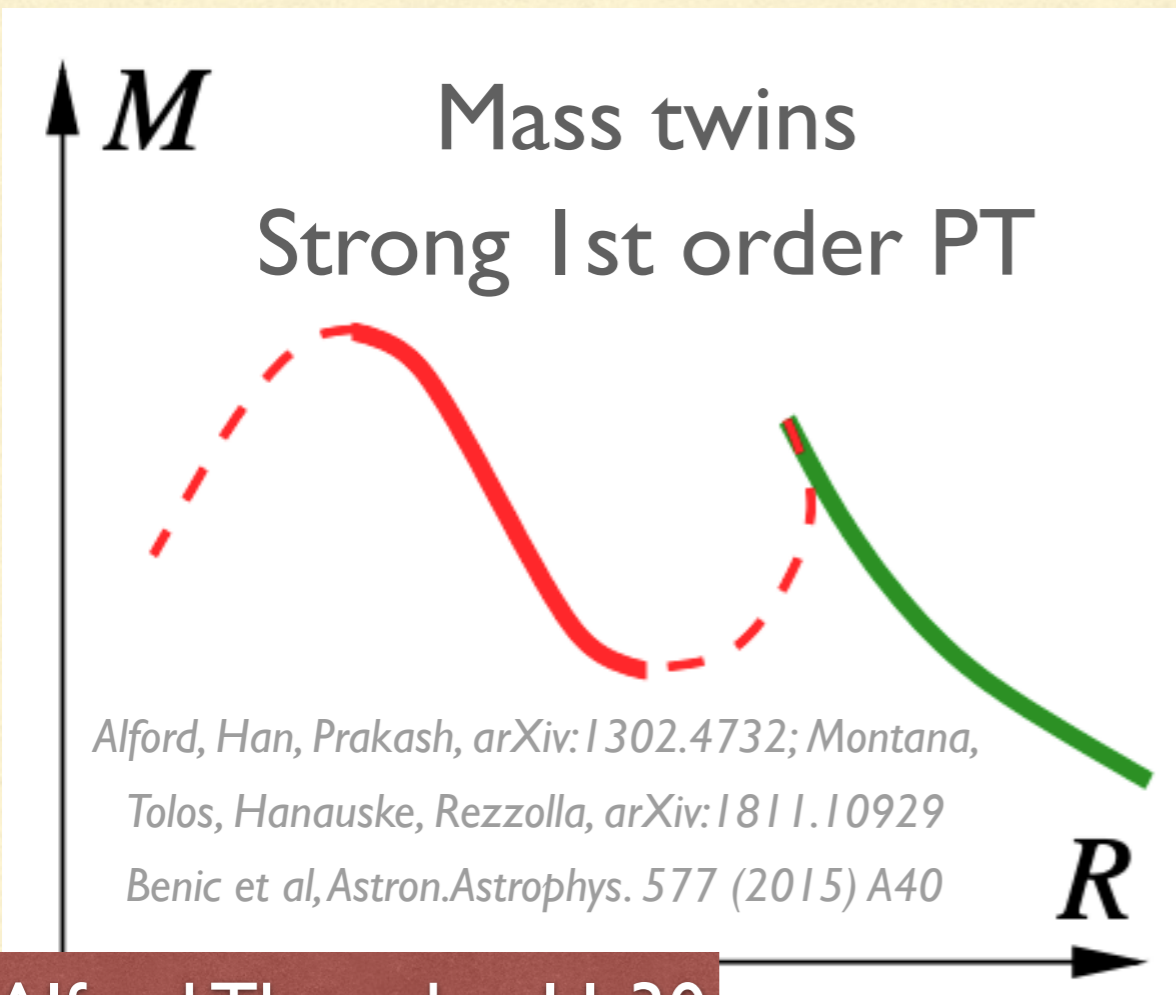
"Stefan is still our active collaborator and will remain for a long time. Every day we interact with him through papers he published and books he wrote, codes he implemented and ideas we have discussed with him. His mastery and legacy in astrophysics, QCD studies, renewable energy research, and artificial intelligence is phenomenal. It guides numerous scientists and students in Frankfurt and around the world to develop these fields further. We are very fortunate that Stefan was among us, pushing his ideas through the hard work. We wish it could have lasted longer.."

-Stefan's colleagues in Frankfurt

“He was humble, respectful, polite, and usually in a very good mood. My favorite thing he did was to build a device to recognize the sound of bats using machine learning, which sent a signal to his phone and flashed the image of a bat anytime a bat flew outside his house.”

-Veronica Dexheimer

# Phase transition in Neutron Stars

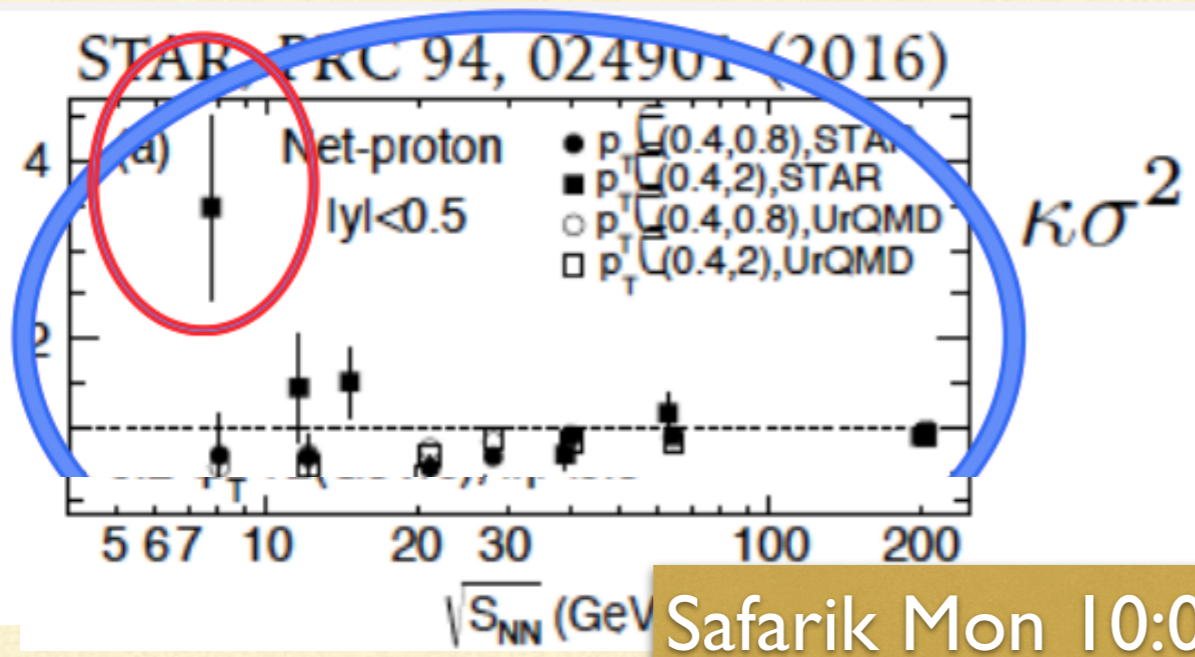


Alford Thursday 11:30

Frequency  
 Rezzolla Tuesday 15:20

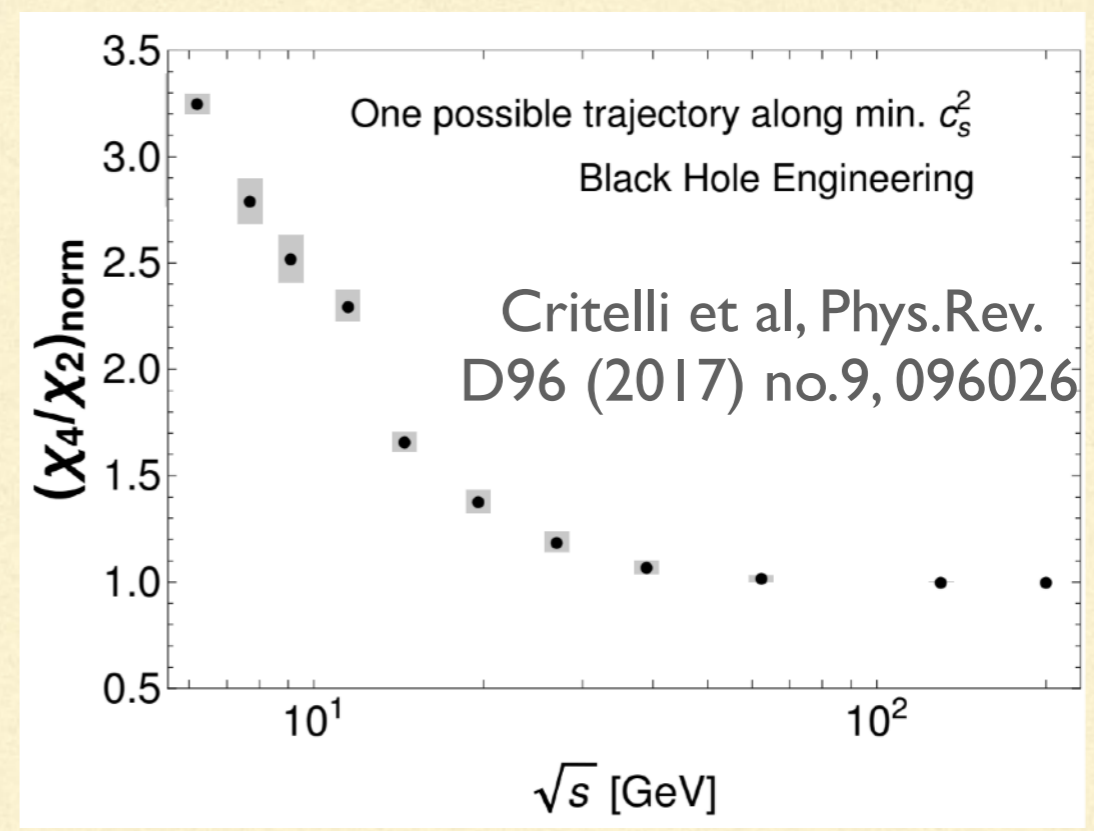
Hyperon puzzle  
 L Tolos Thursday 12:00

# SEARCHES FOR CRITICALITY

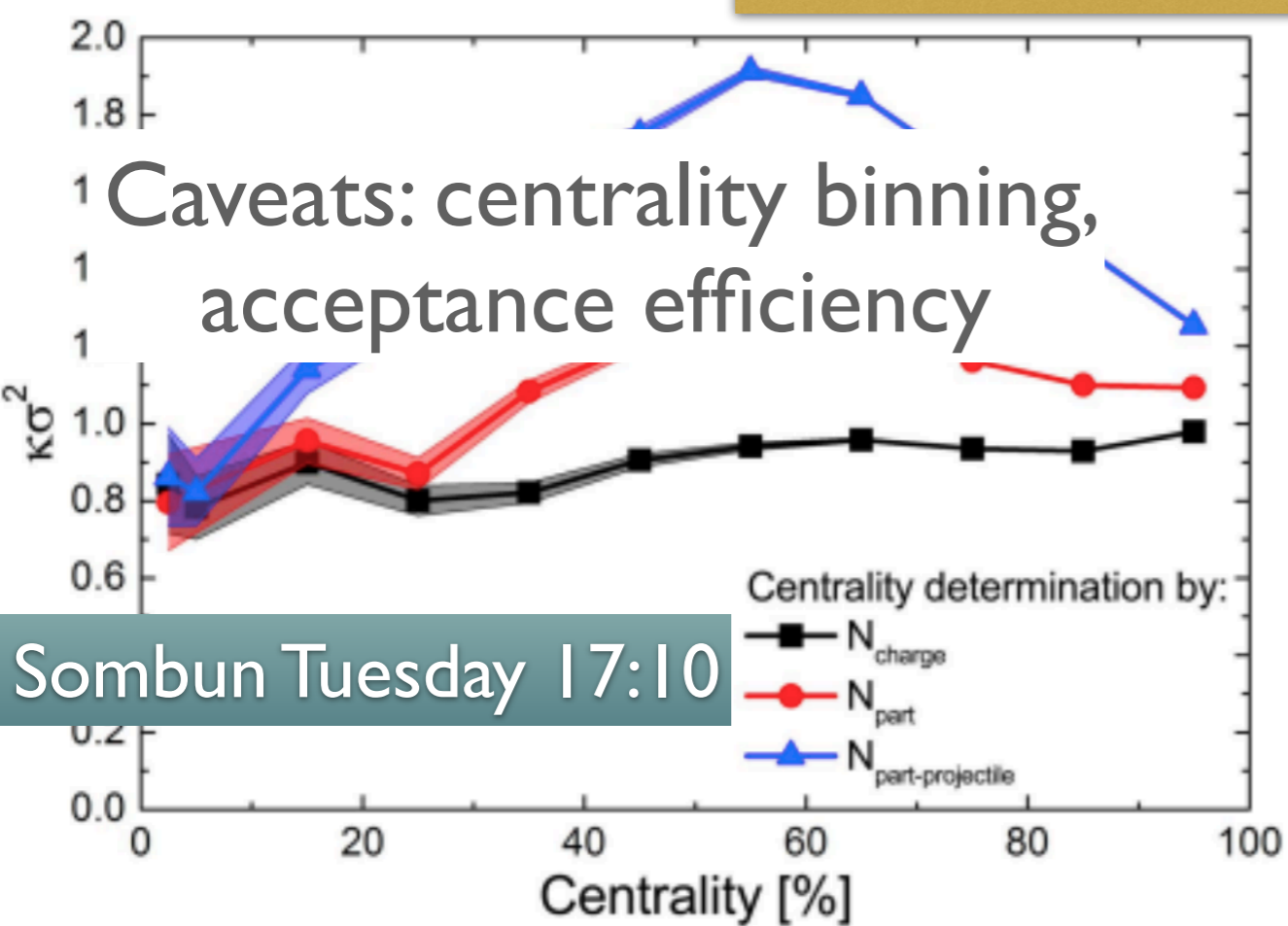


Safarik Mon 10:00

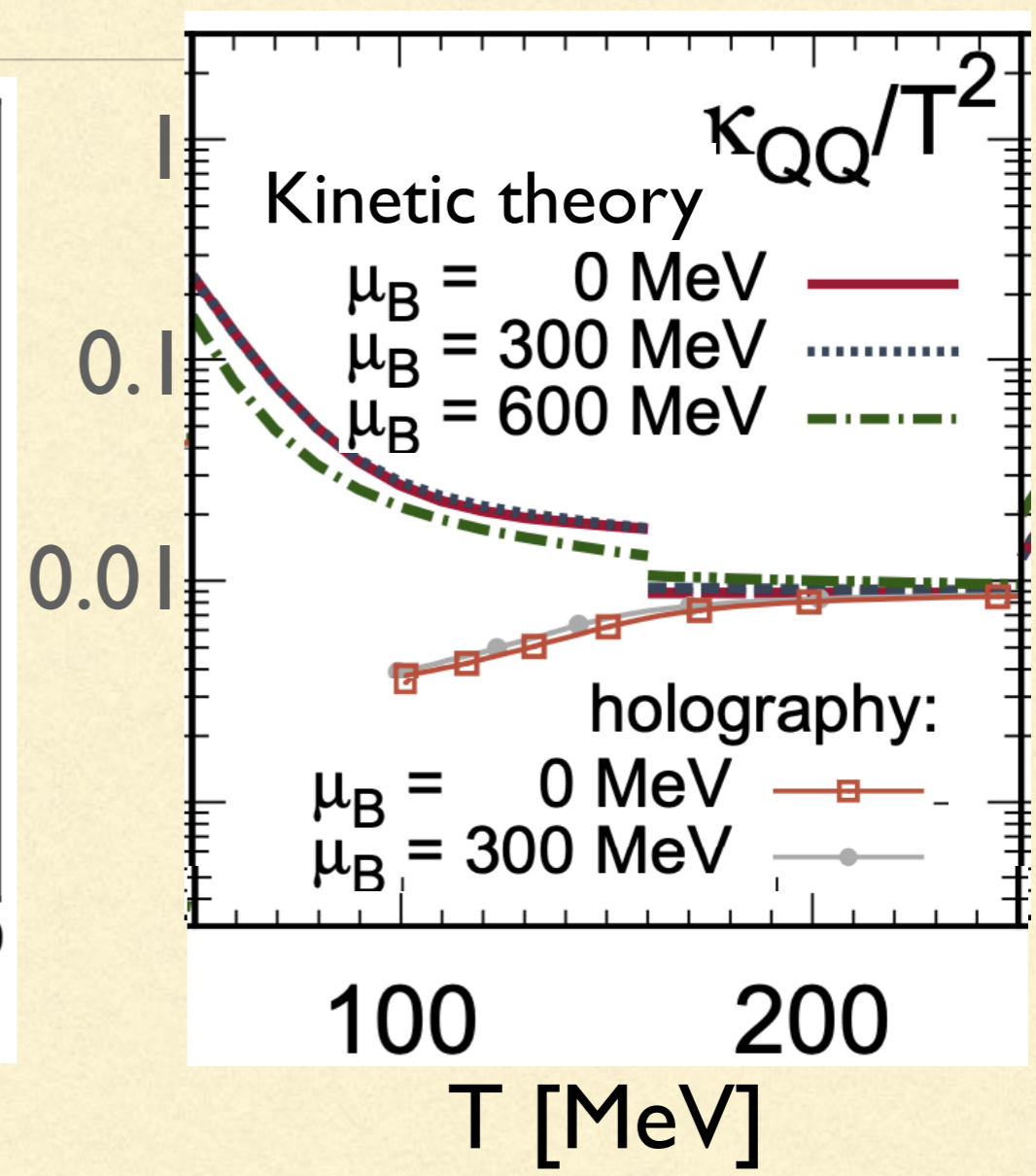
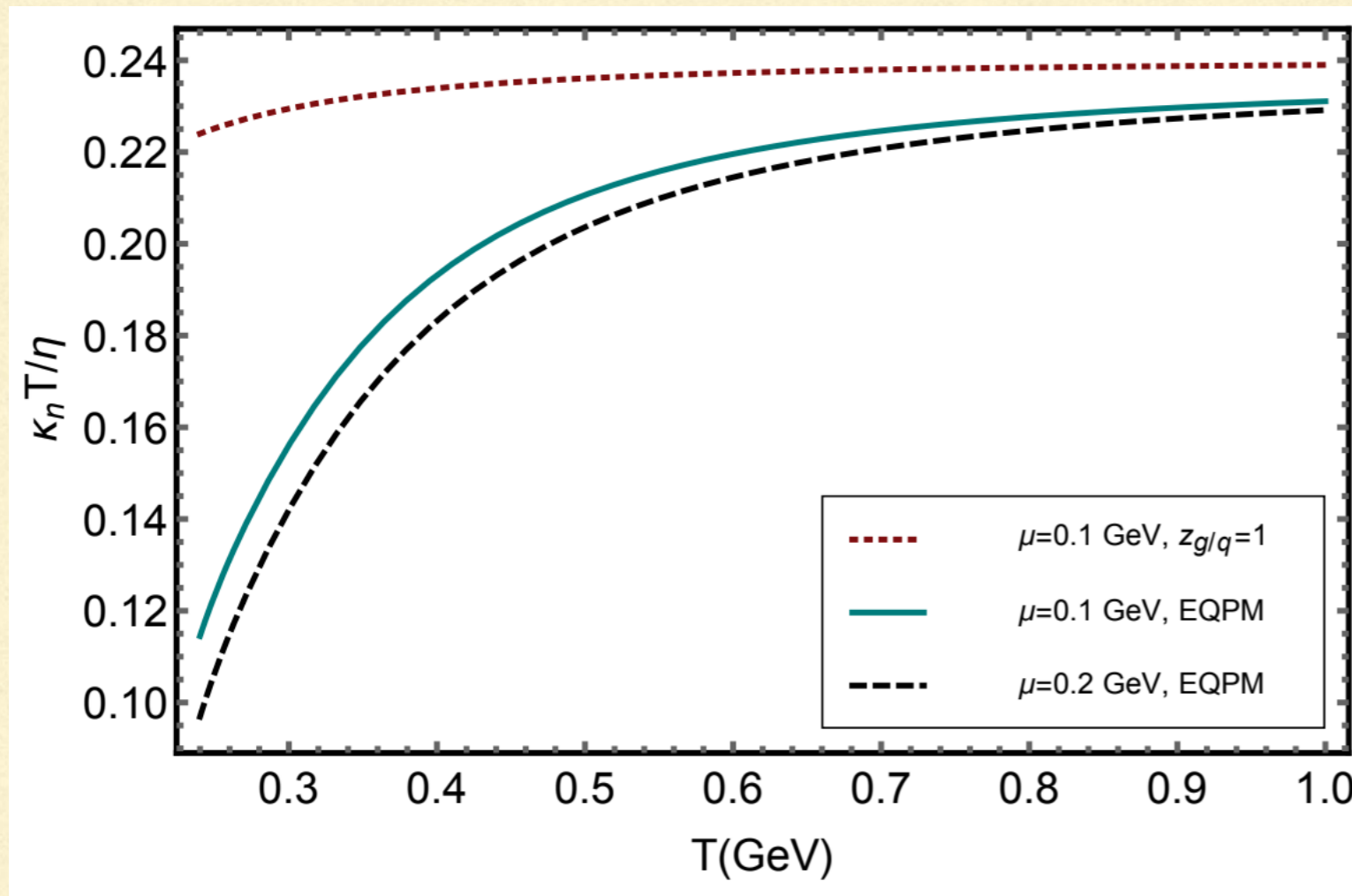
Kurtosis sensitive to CP  
 Stephanov, M.A. (2011). Phys. Rev. Lett., 107:052301



Caution on finite size effects!  
 Bluhm Thursday 14:00



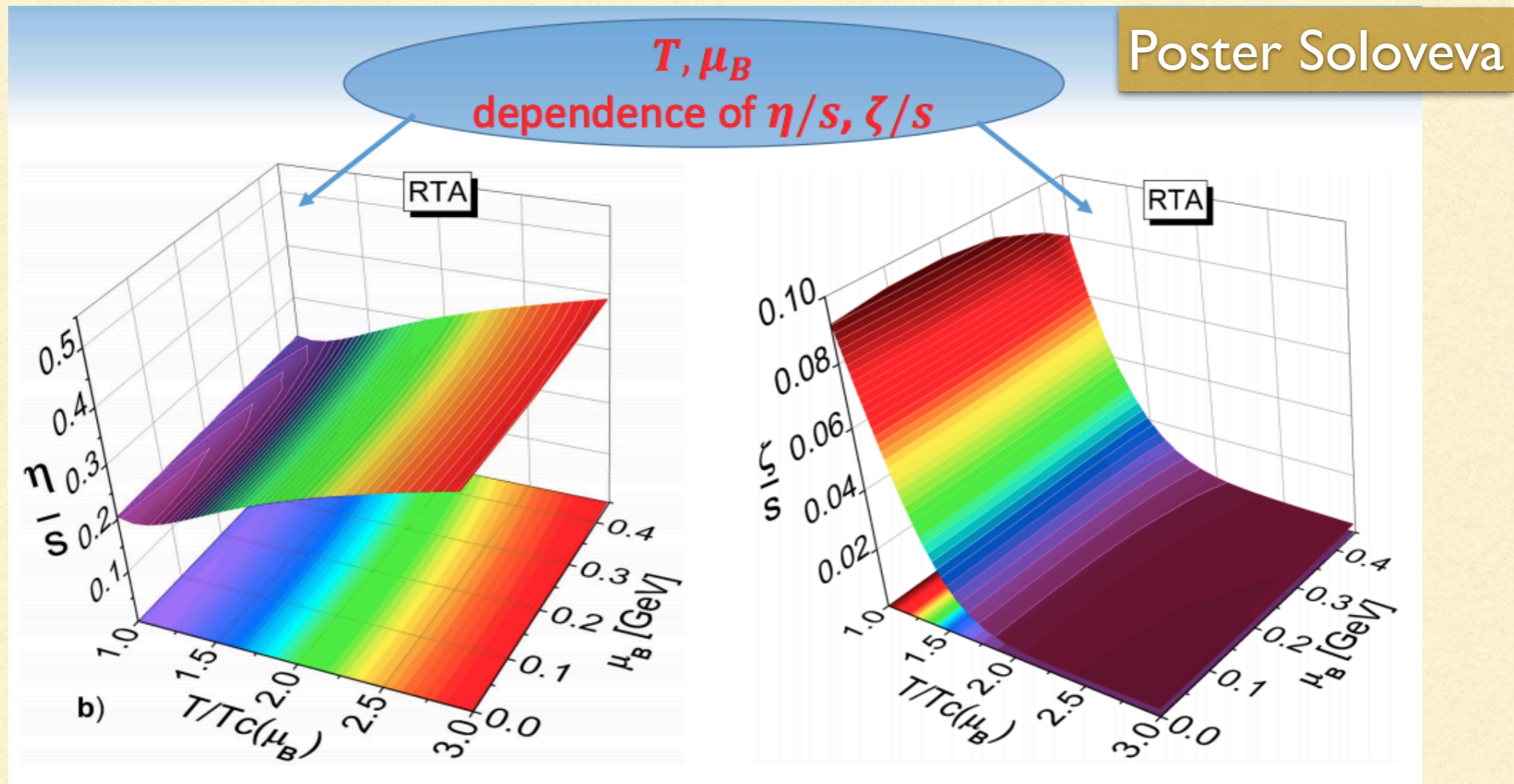
# BSQ HYDRO- DIFFUSION



S. Bhadury Tuesday 17:30

KT Greif et al Phys.Rev.Lett. 120 (2018) no.24, 242301  
 Holography Rougemont et al Phys.Rev. D96 (2017) no.1, 014032

# VISCOSITY AT FINITE BARYON DENSITIES



Maybe next SQM?  
Bulk viscosity arises from  
different mechanisms!



Neutron Stars Mergers+bulk viscosity:

Bemfic, Disconzi, Noronha, Phys.Rev.Lett. 122 (2019) 221602

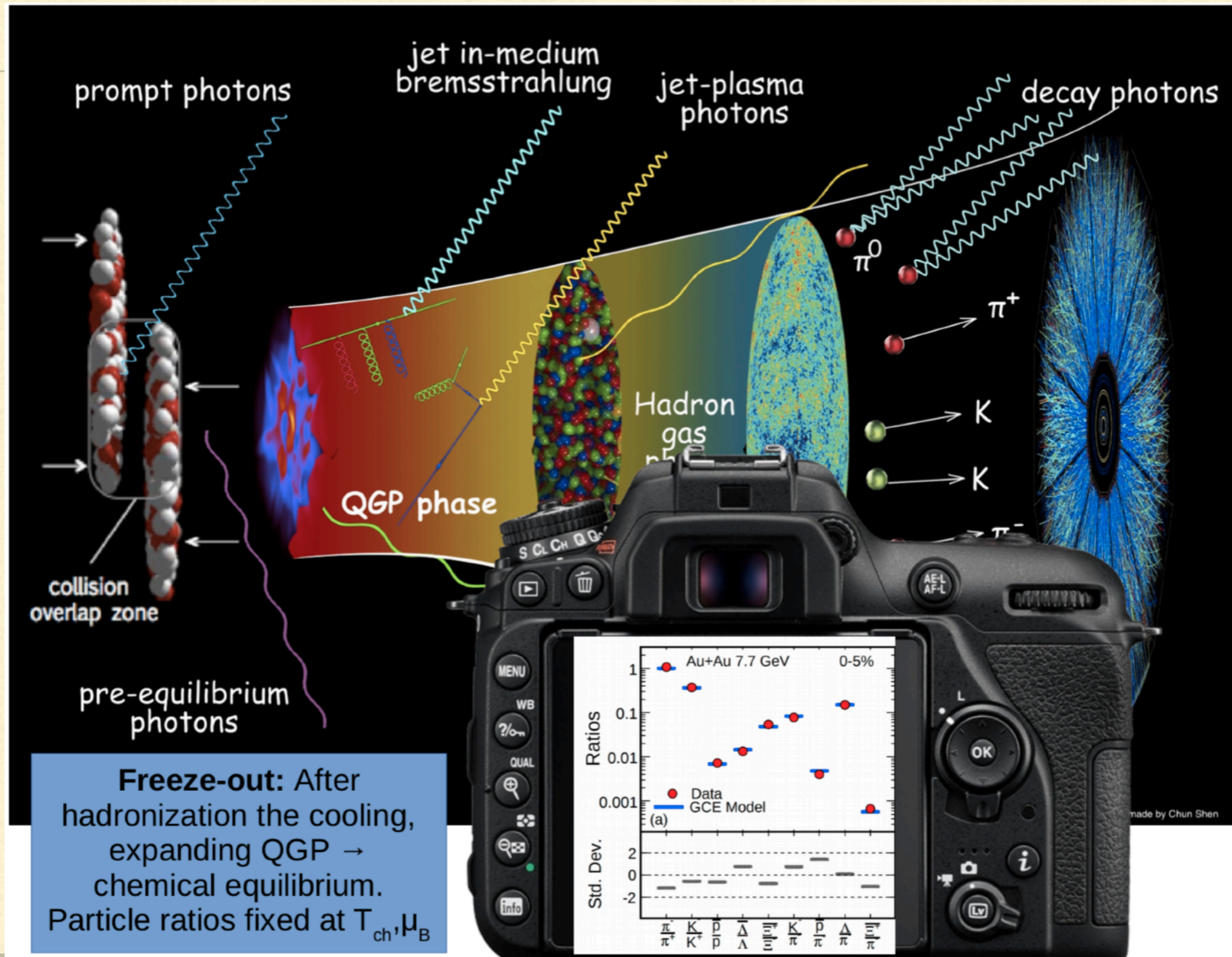
Alford, et al, Phys.Rev.Lett. 120 (2018) no.4, 041101



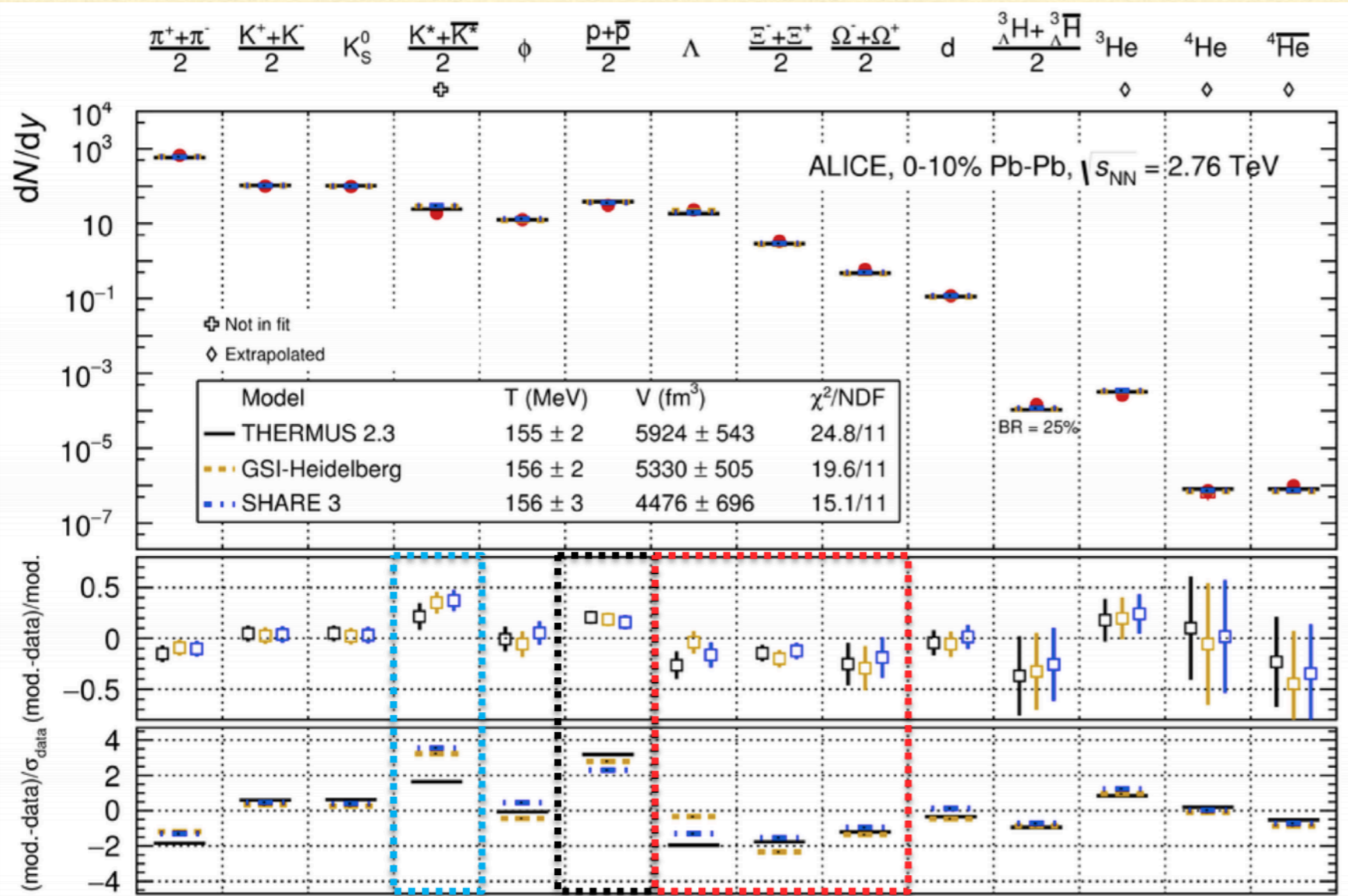
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WHAT DOES THE PHASE  
TRANSITION LOOK LIKE?

# FREEZE-OUT: $T$ & $\mu_B$



# THERMAL FITS: PROTONS VS. STRANGE



ALICE, Nucl. Phys. A 971 (2018) 1-20

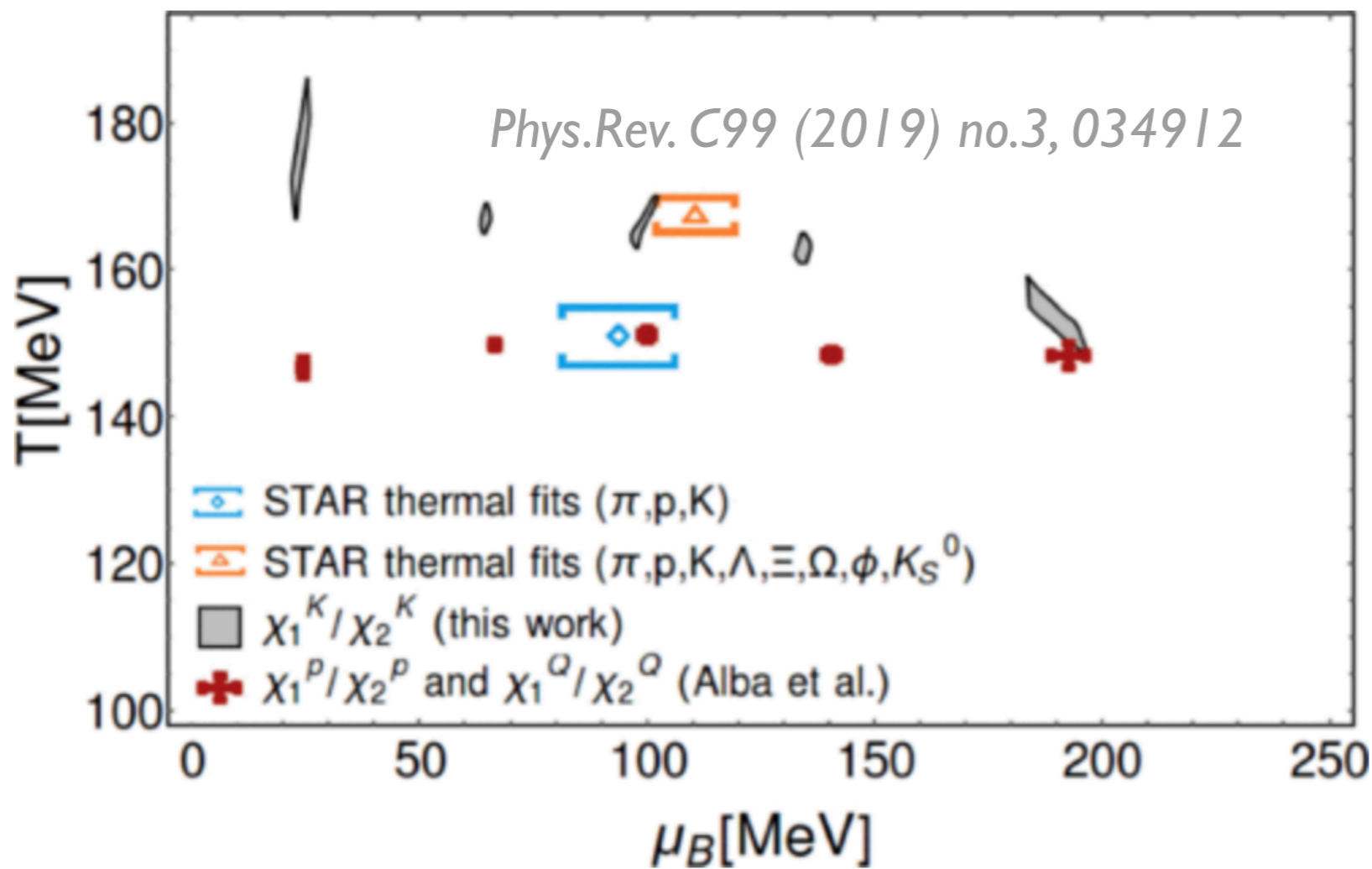
Production of (most) light-flavour hadrons in Pb-Pb at 2.76 TeV is described ( $\chi^2/ndf \sim 2$ ) by thermal models with a single chemical freeze-out temperature

$$T_{ch} \approx 156 \text{ MeV at } 2.76 \text{ TeV}$$

Deviation for short-lived  $K^{*0}$   
Tensions between **protons** and **multi-strange baryons**

# CHEMICAL FREEZE-OUT: NET-K VS. NET-P/NET-Q

Incompatibility between the light and strange freeze-out



Different PDG lists see  
same effect

Jamie Stafford  
Thursday 14:00

UrQMD different FO  
depending on species  
→ affects  $\nu_1$

Bravina Thursday 16:00

net-K+yields consistent

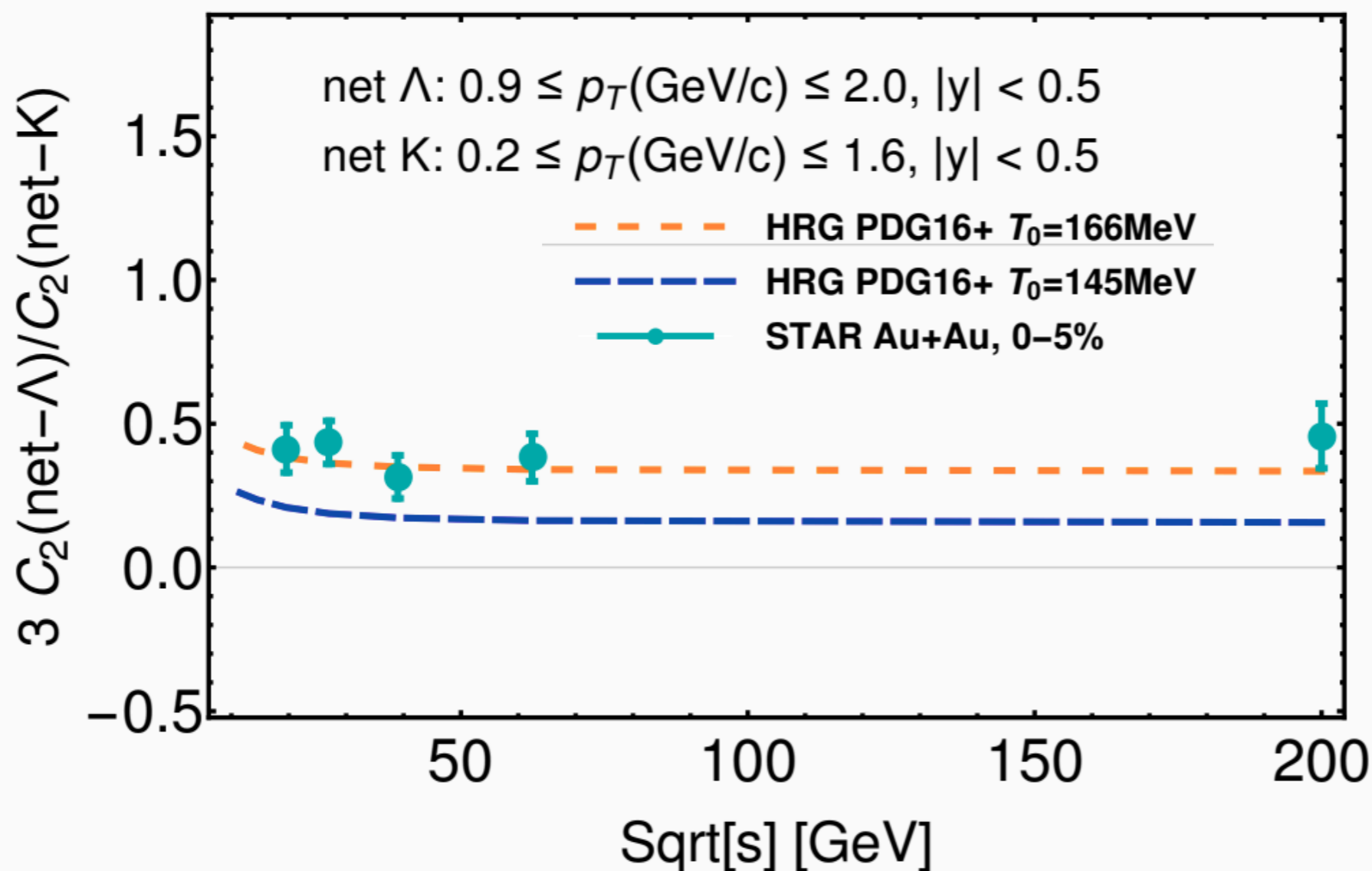
Bluhm & Nahrgang *Eur.Phys.J. C79* (2019) no.2, 155

# OBTAIN BARYON-STRANGENESS CORRELATIONS

$\sigma_{pK}^{11} / \sigma_K^2 \sim 0$  Measured in STAR [arXiv:1903.05370](https://arxiv.org/abs/1903.05370)

Bellwied  
Thursday 15:20

Strongly depends on the hadrons considered



$\Lambda K$  best choice

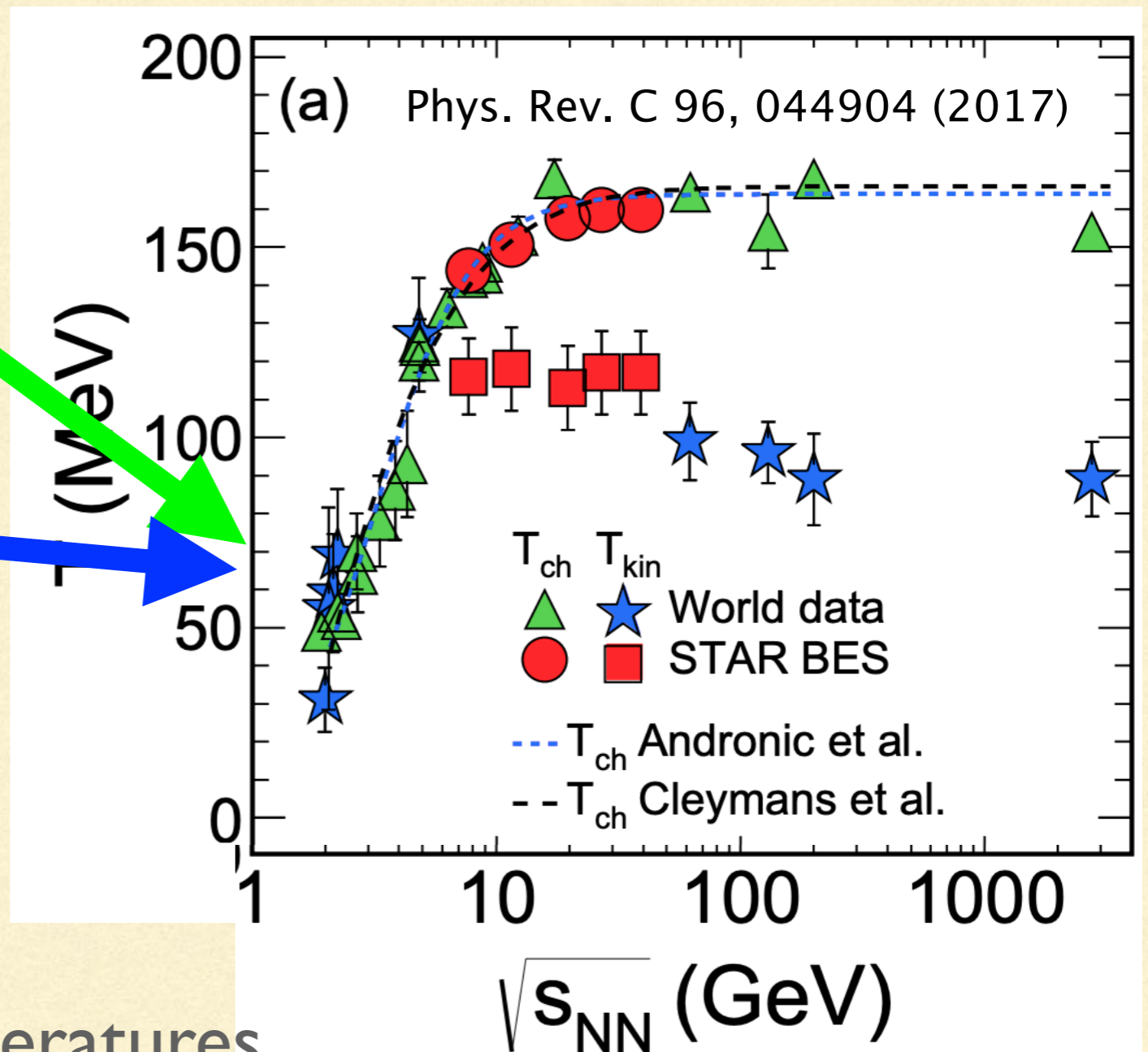
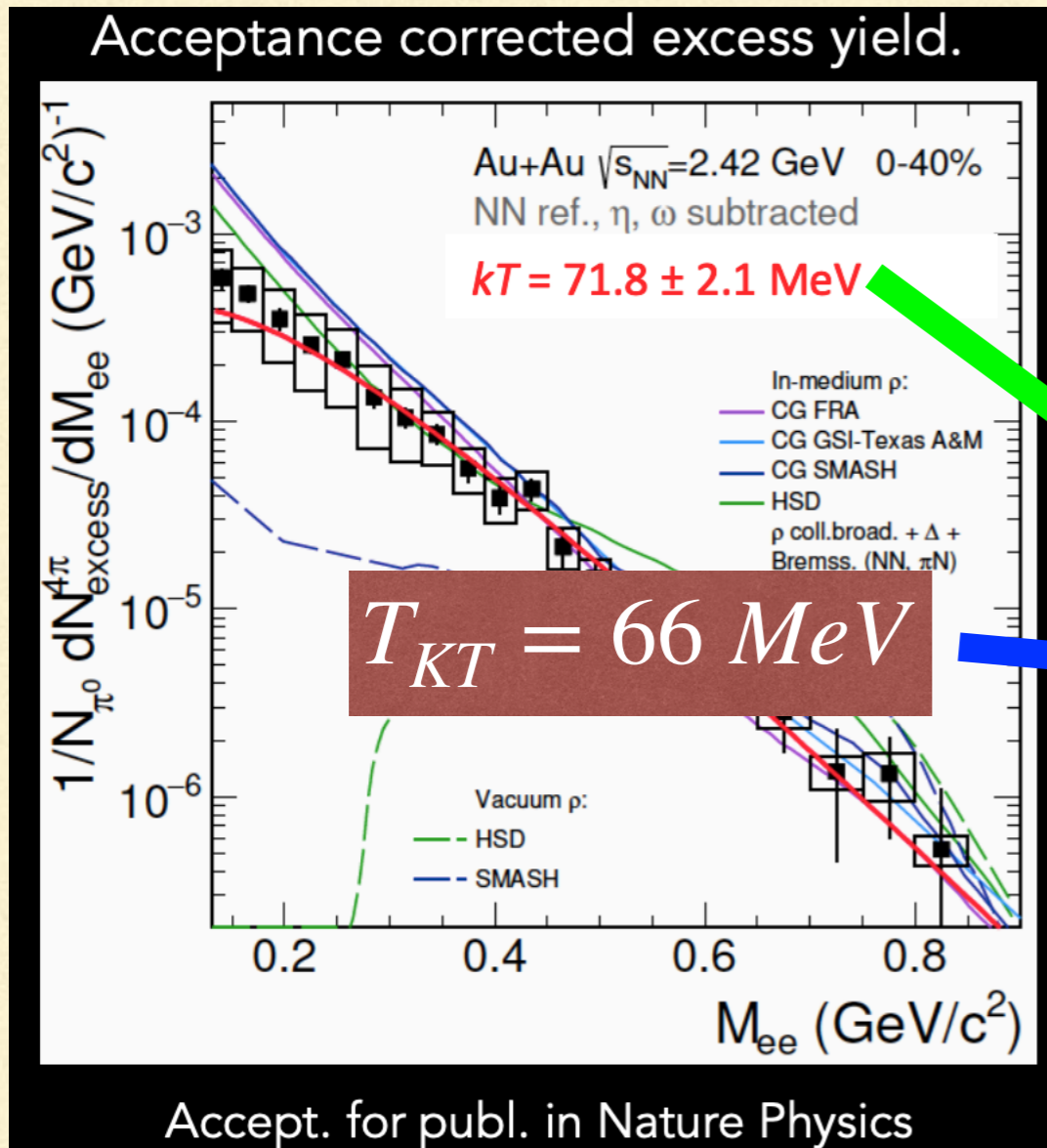
PDG 16+

[WB] Phys.Rev. D96 (2017) no.3, 034517

Paolo Parotto  
Thursday 14:00

# KINETIC FREEZE-OUT: AT HIGH END

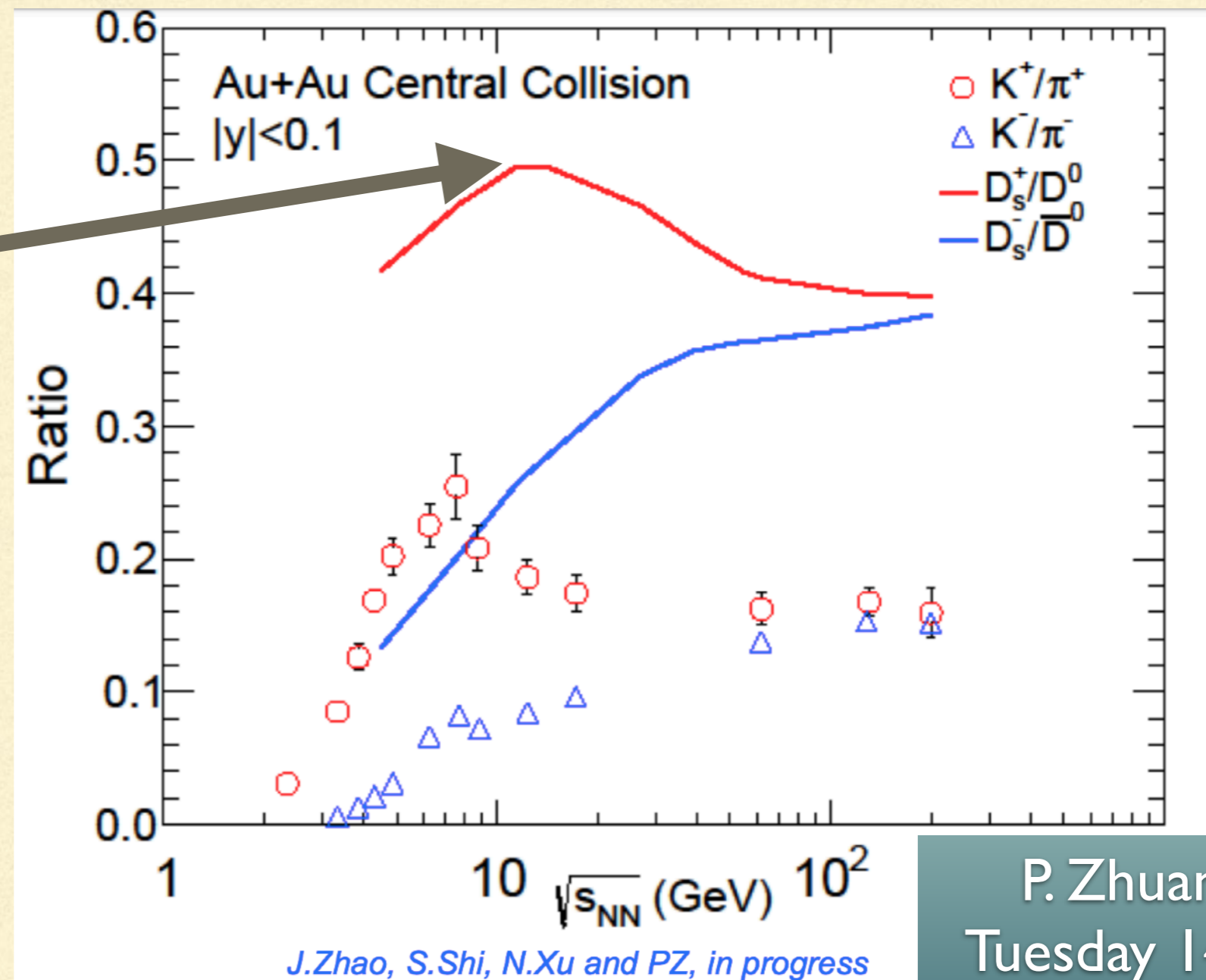
M. Lorenz Monday



Hades measures higher temperatures

# CHARM CONSERVATION?

Predicts  
enhancement of  
 $D_s/D_0$  like  $K/\pi$

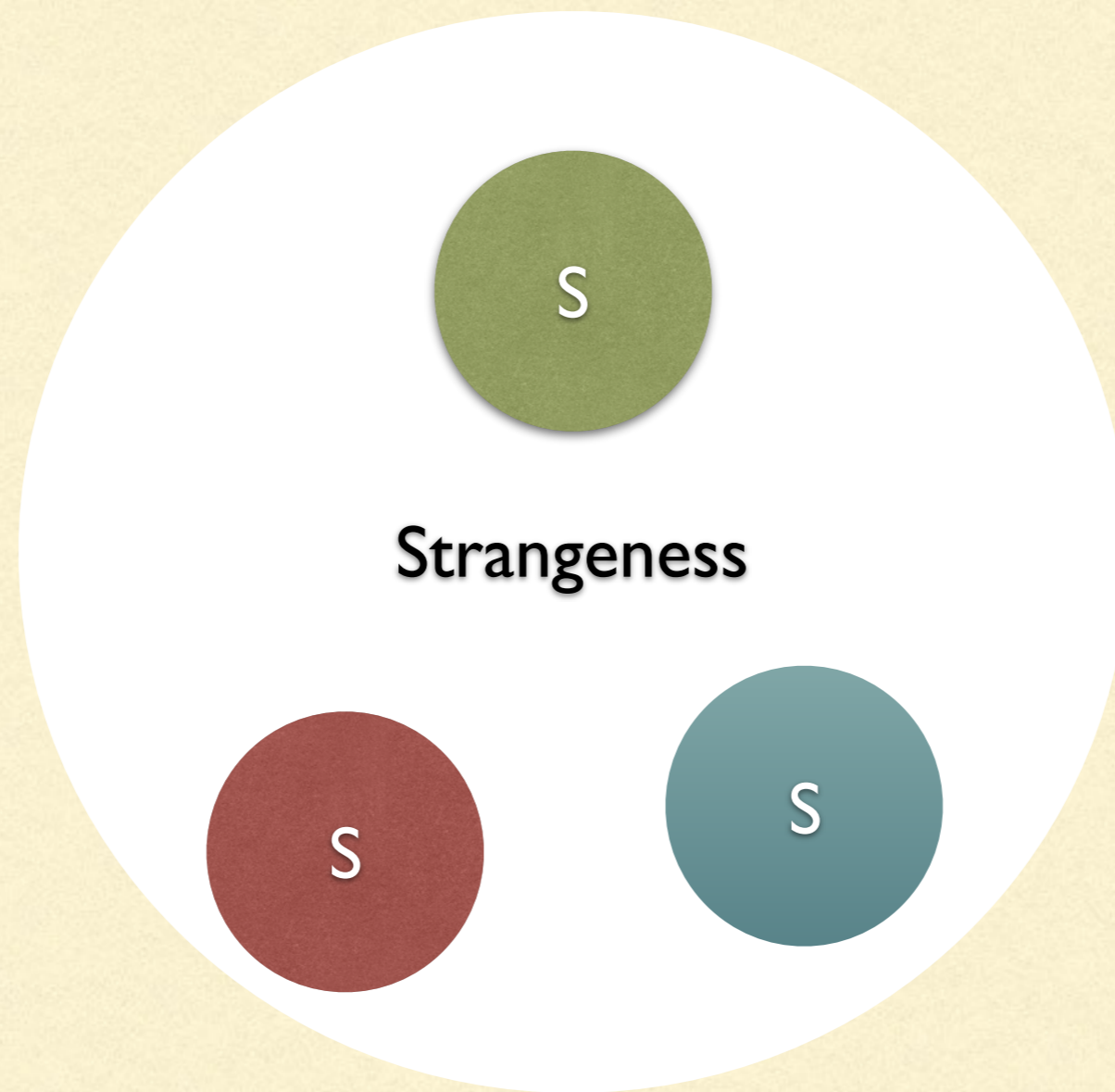


P. Zhuang  
Tuesday 14:00

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# STRANGENESS & HADRONS

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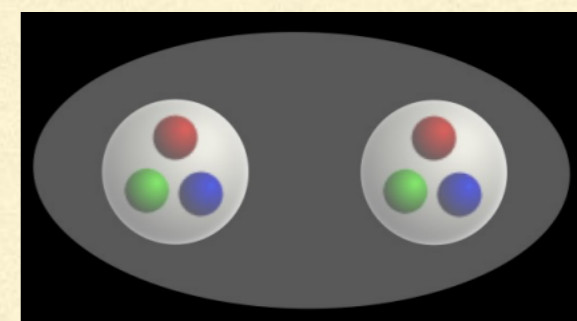
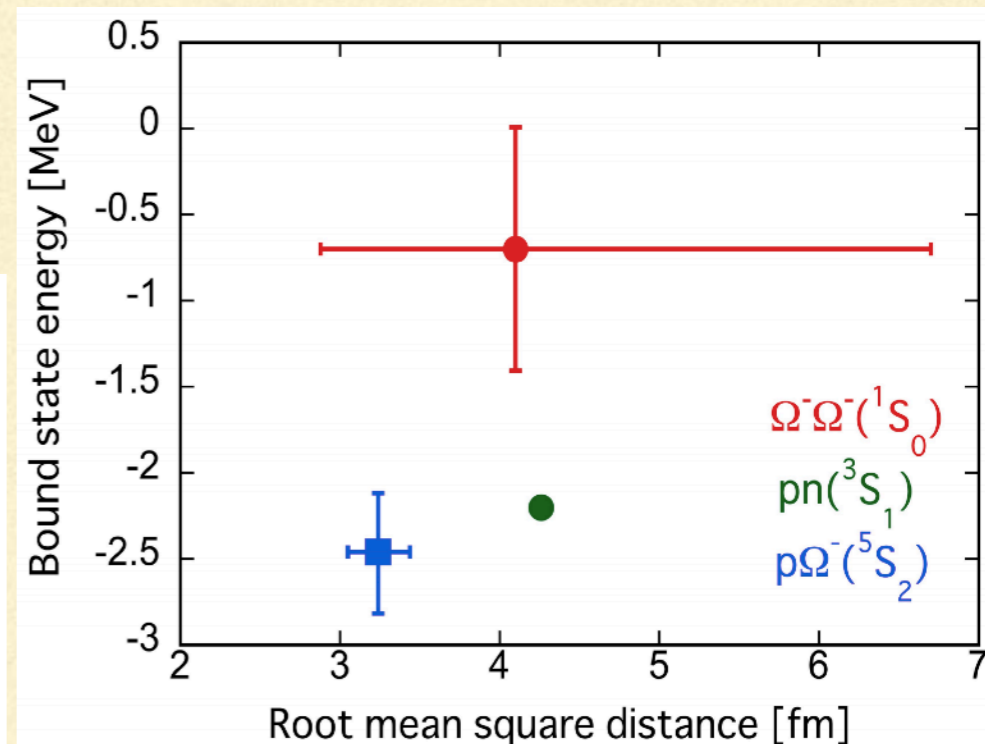
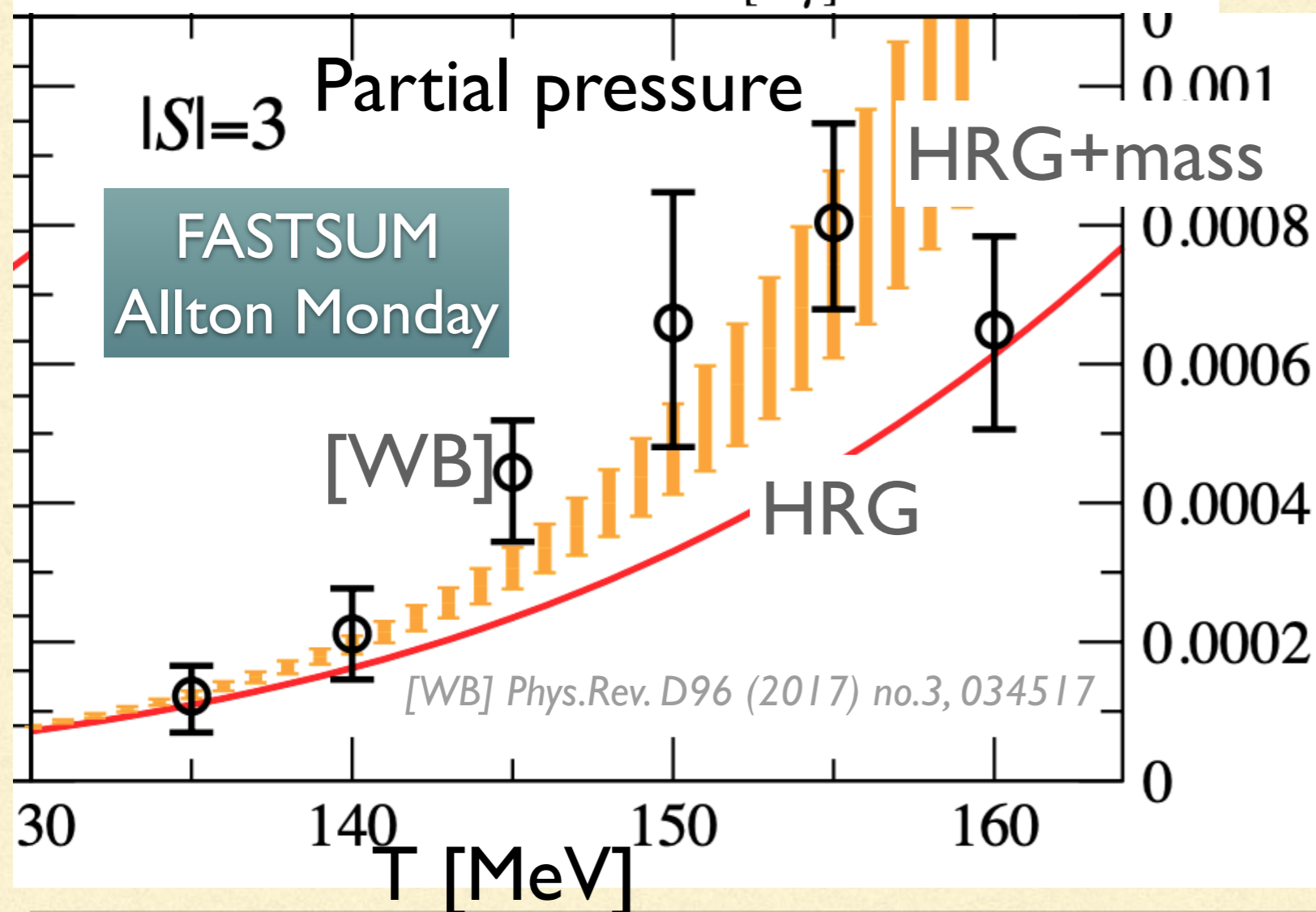


# HADRONS FROM LATTICE QCD

Parity<0 resonances, change mass

**Fit:**  $m_-(T) = \omega(T, \gamma) m_-(0) + [1 - \omega(T, \gamma)] m_-(T_c)$

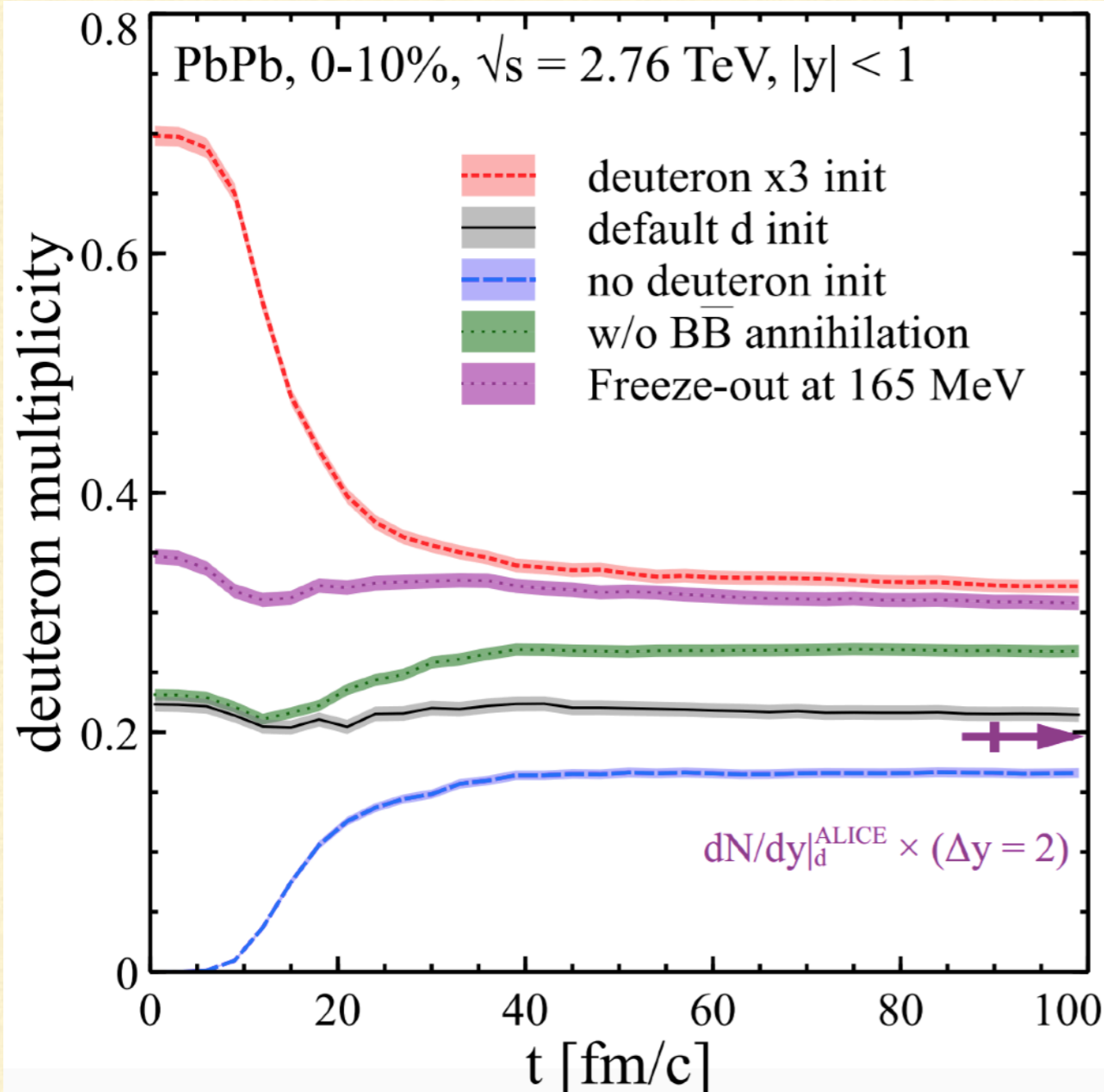
where  $\omega(T, \gamma) = \frac{\tanh[(1 - T/T_c)/\gamma]}{\tanh[1/\gamma]}$   $\gamma \sim \text{width}$



Hatsuda Tuesday 9:30

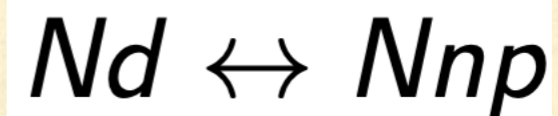
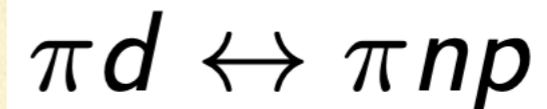
# SMALL NUCLEI & THERMALIZATION

Oliinychenko Weds 11:00



Hydrodynamics does well, but finer points regarding initial production

$2 \leftrightarrow 3$  reactions in SMASH!



Oliinychenko Phys. Rev. C 99, 044907 (2019)

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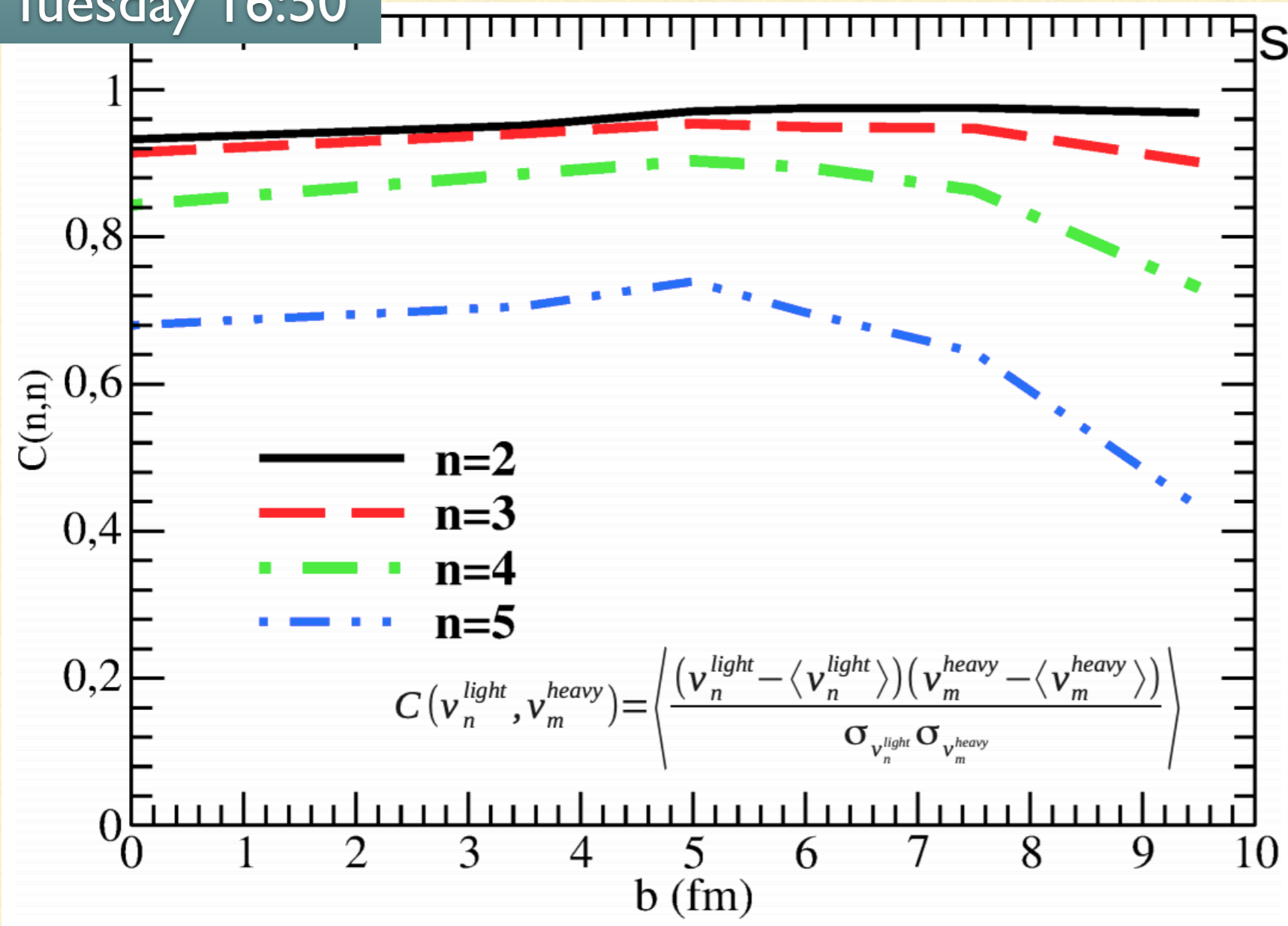
# HEAVY FLAVOR

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# LIGHT-HEAVY CORRELATIONS

S. Plumari  
Tuesday 16:50



## Decorrelation of event plane angle of higher harmonics

*J. Jia Phys.Rev. C87 (2013) no.6, 061901; JNH et al Phys.Rev. C95 (2017) no.4, 044901; Prado et al, Phys.Rev. C96 (2017) no.6, 064903*

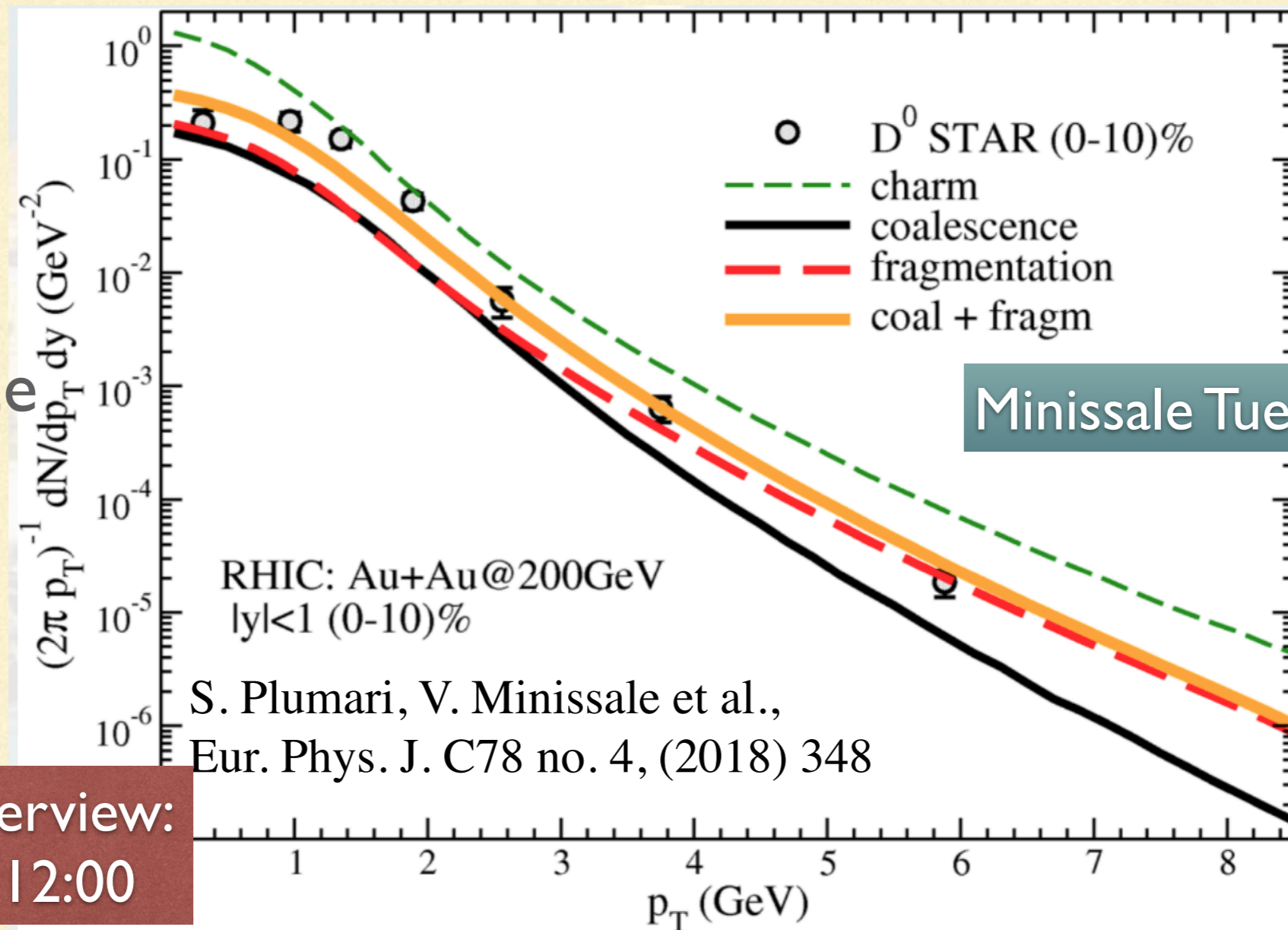
## First D meson v3

*Nahrgang et al, Phys.Rev. C91 (2015) no.1, 014904*

Heavy vs. light transport coefficients in AdS/CFT  
Hambrock Thursday 16:10

# PRODUCTION OF D MESONS

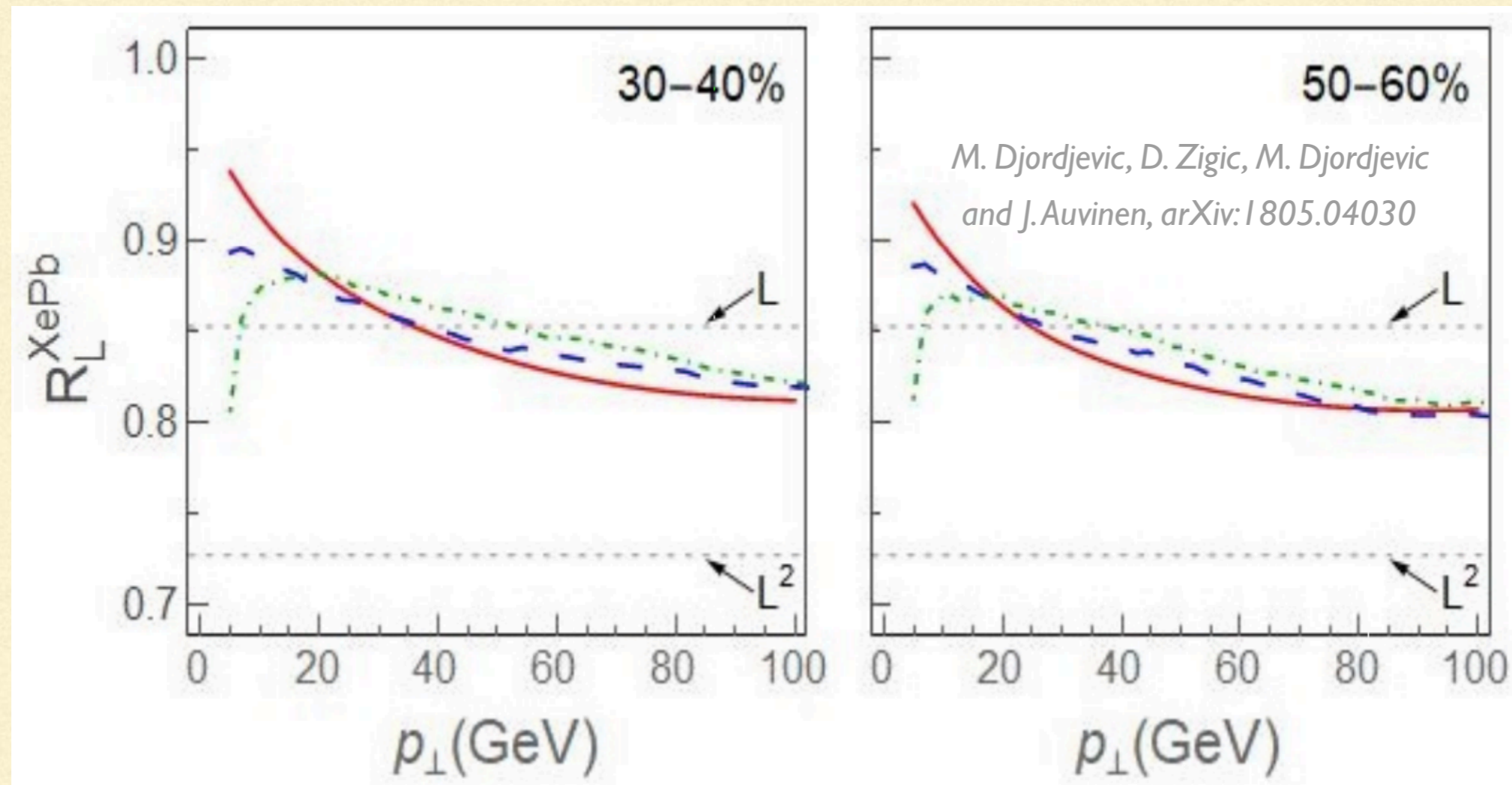
D mesons spectra requires both fragmentation+coalescence



Coalescence overview:  
Prino Tuesday 12:00

# PATH LENGTH EXTRACTION

Ratio of  $R_{AA}^{Xe}/R_{AA}^{Pb}$  indicates path length



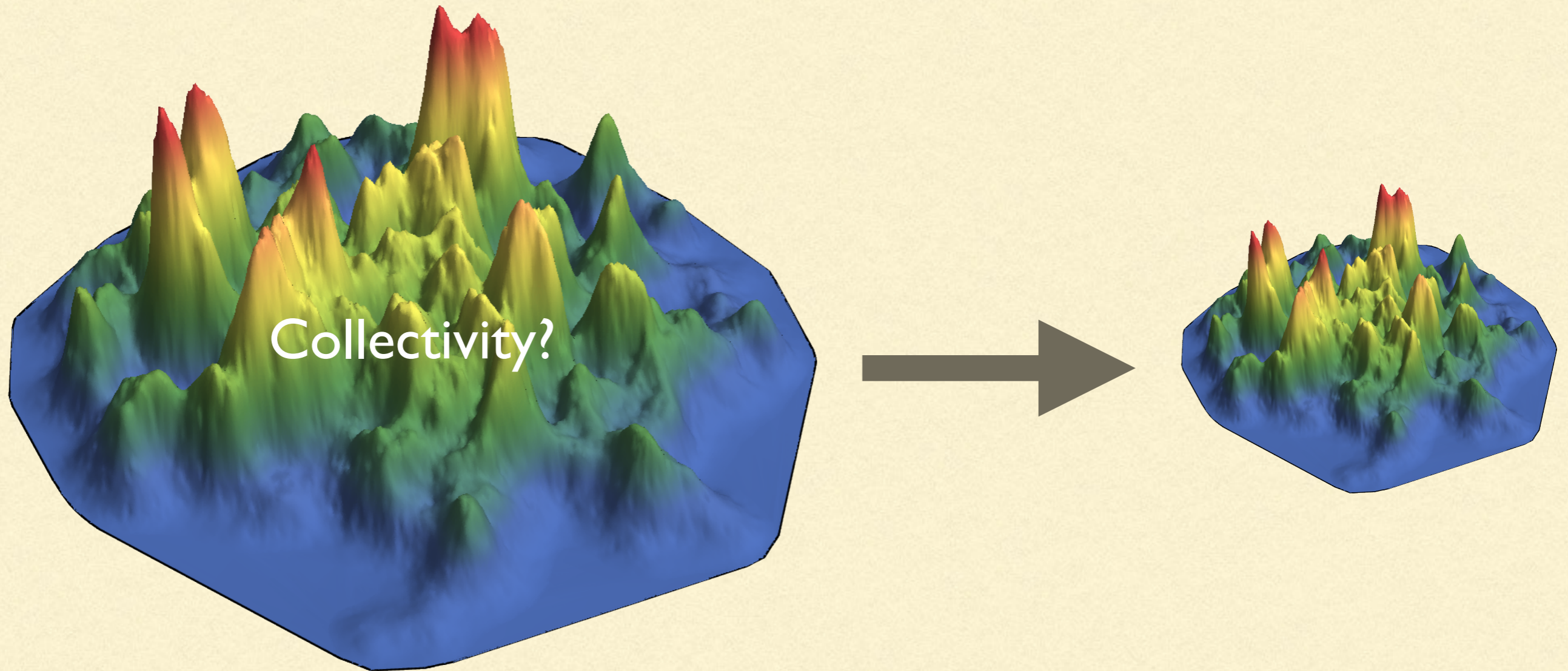
Posters: Beyond soft gluon approximation Blagojevic

Djordjevic Tuesday 14:00

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# SMALL SYSTEMS

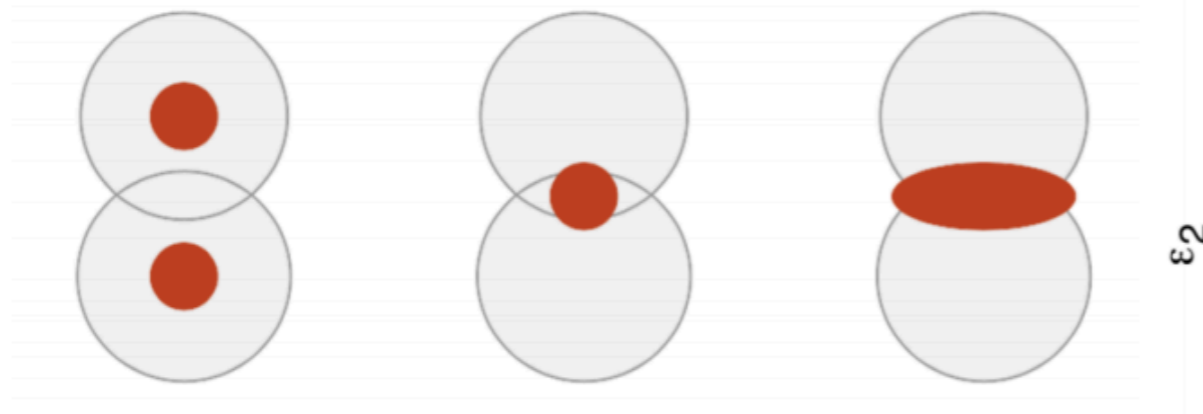
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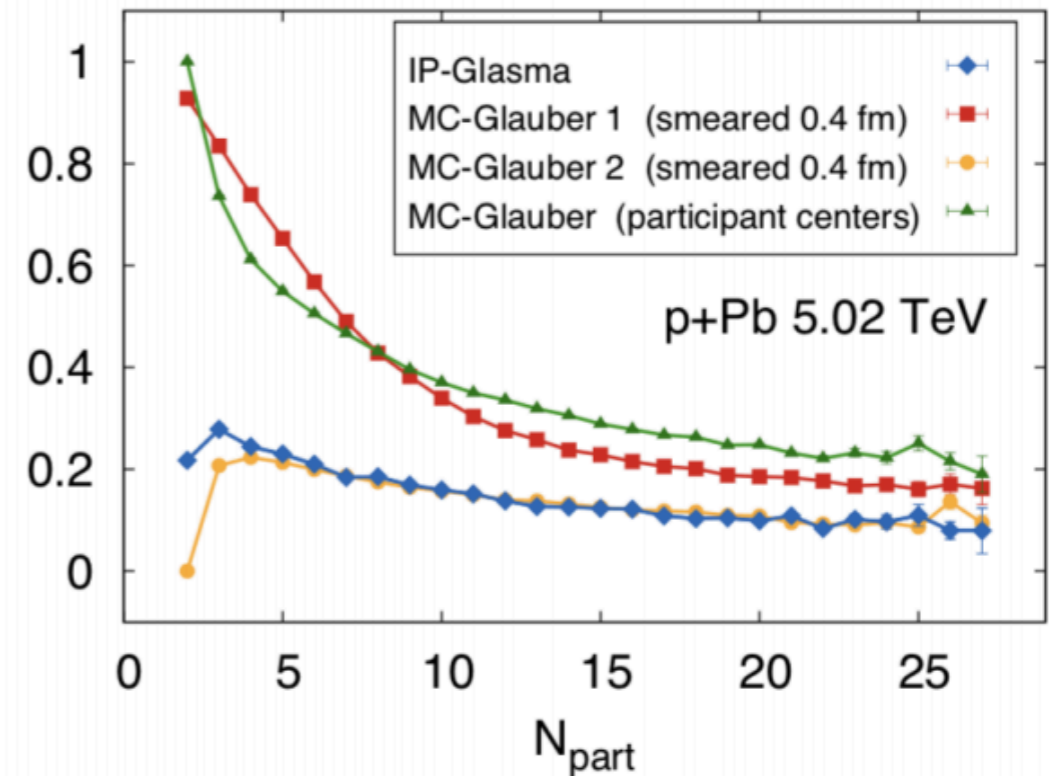
# HYDRO CAN DESCRIBE MUCH BUT MANY OPEN QUESTIONS

## Uncertainties in initial conditions

Bzdak,Schenke,Tribedy,RV, 1304.3403



$\epsilon_2$



Very little theory guidance

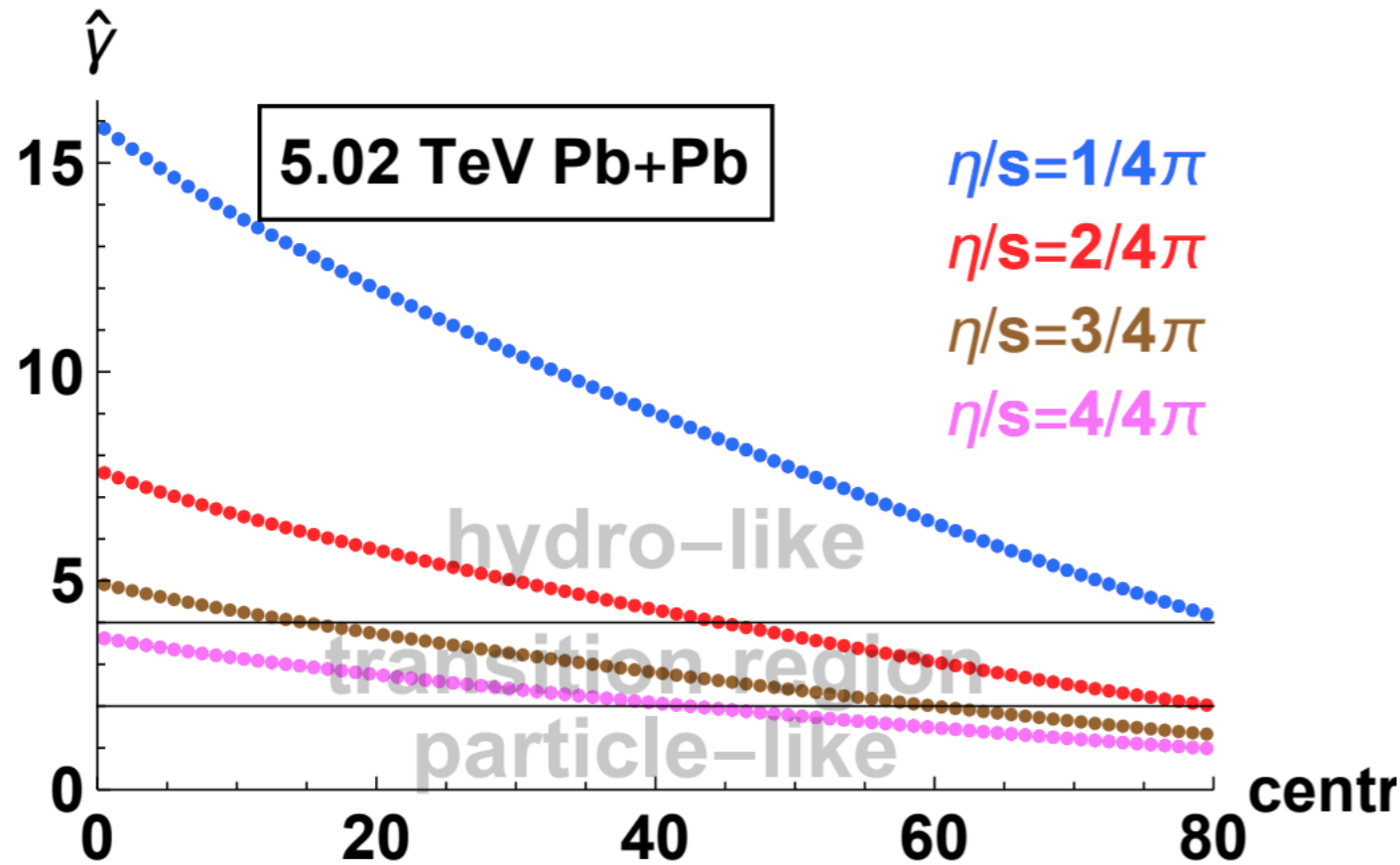
+many other kinetic descriptions still to explore



# HOW DO WE REACH HYDRO?

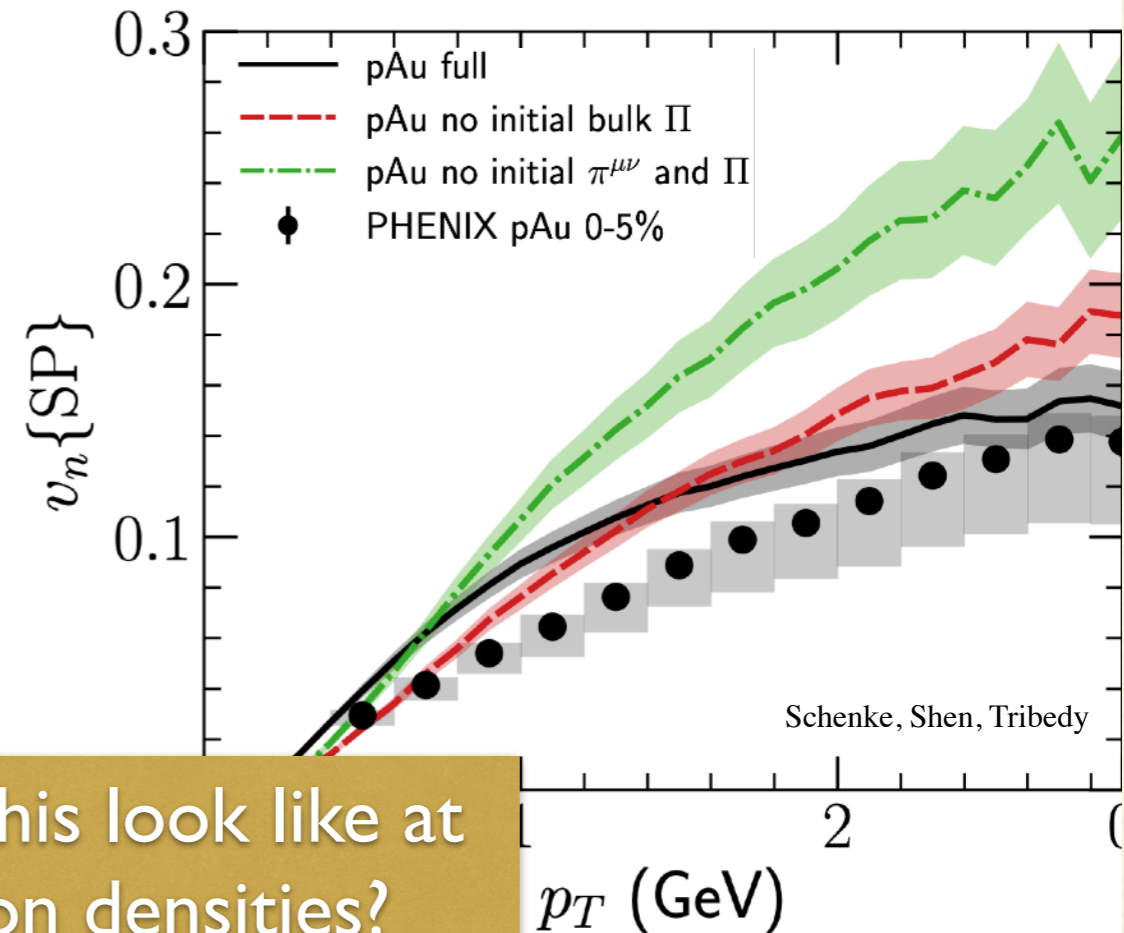
Kurkela, Mazeliauskas, Paquet,  
Schlichting, Teaney *Phys.Rev.Lett.*  
122 (2019) no.12, 122302;  
*Phys.Rev. C*99 (2019) no.3,  
034910

(Kurkela, Wiedemann & Wu, arXiv:1905.05139)



KOMPOST

Attractors Heinz Friday 14:00



$$\frac{\eta}{s} = \frac{1}{5} \tau_R T = \frac{1}{5\gamma} \frac{T}{\epsilon^{1/4}} \Big|_{\text{QCD}} = \frac{0.11}{\gamma}$$

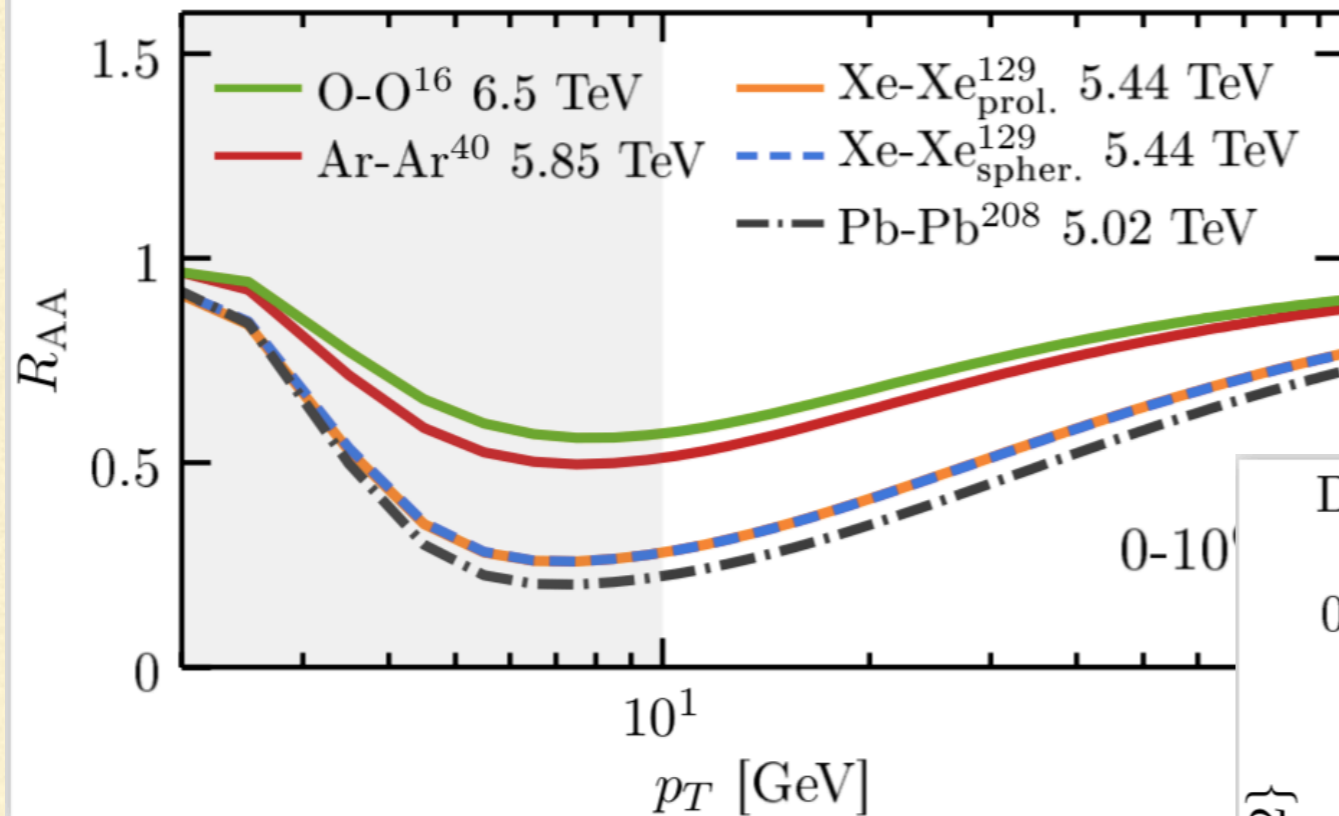
What does this look like at large baryon densities?

Wiedemann Monday 9:30

# HARD PROBES IN SMALL SYSTEMS

Poster: PbPb/XeXe Zigic

$D^0$  meson, Trento, Langevin, frag. & coal.,  $T_d = 160$  MeV



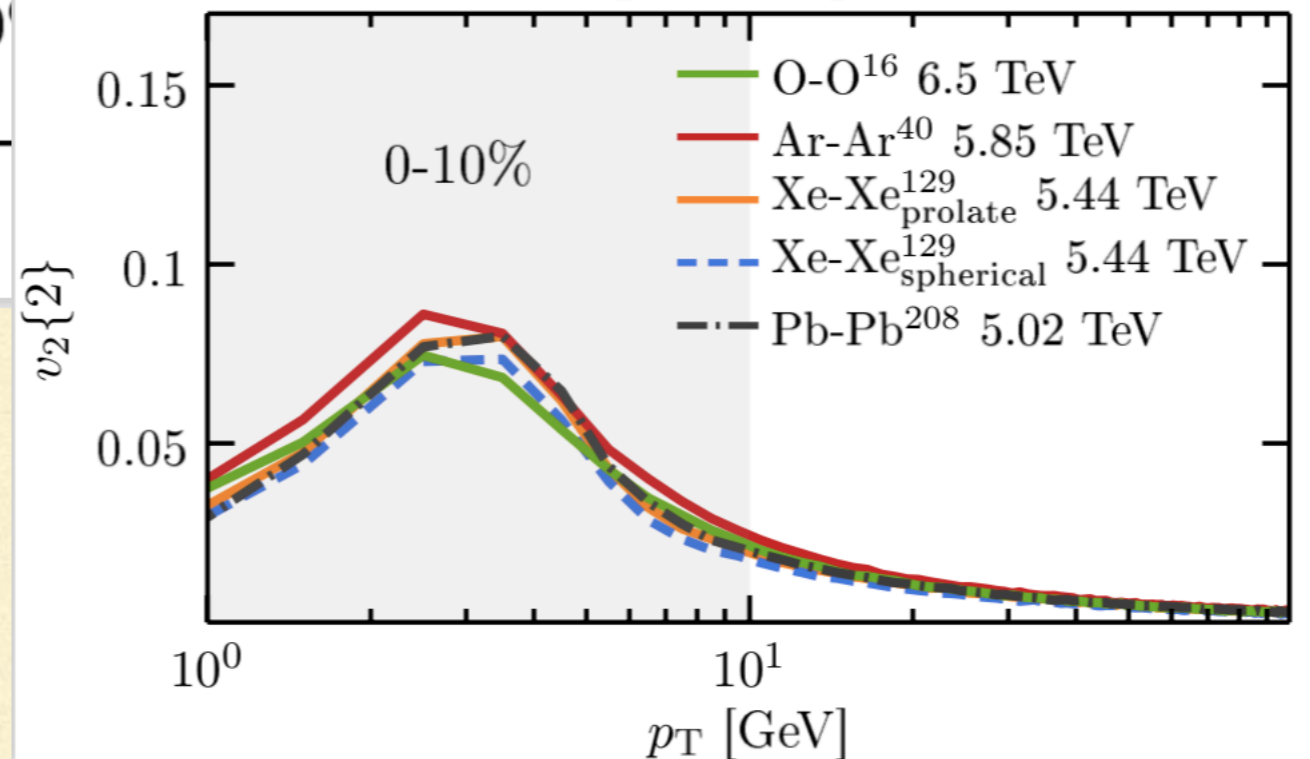
$v_2 \sim const$  with system size  
Complicated interplay  
between size and  
eccentricities

As system size decreases,

$$R_{AA} \rightarrow 1$$

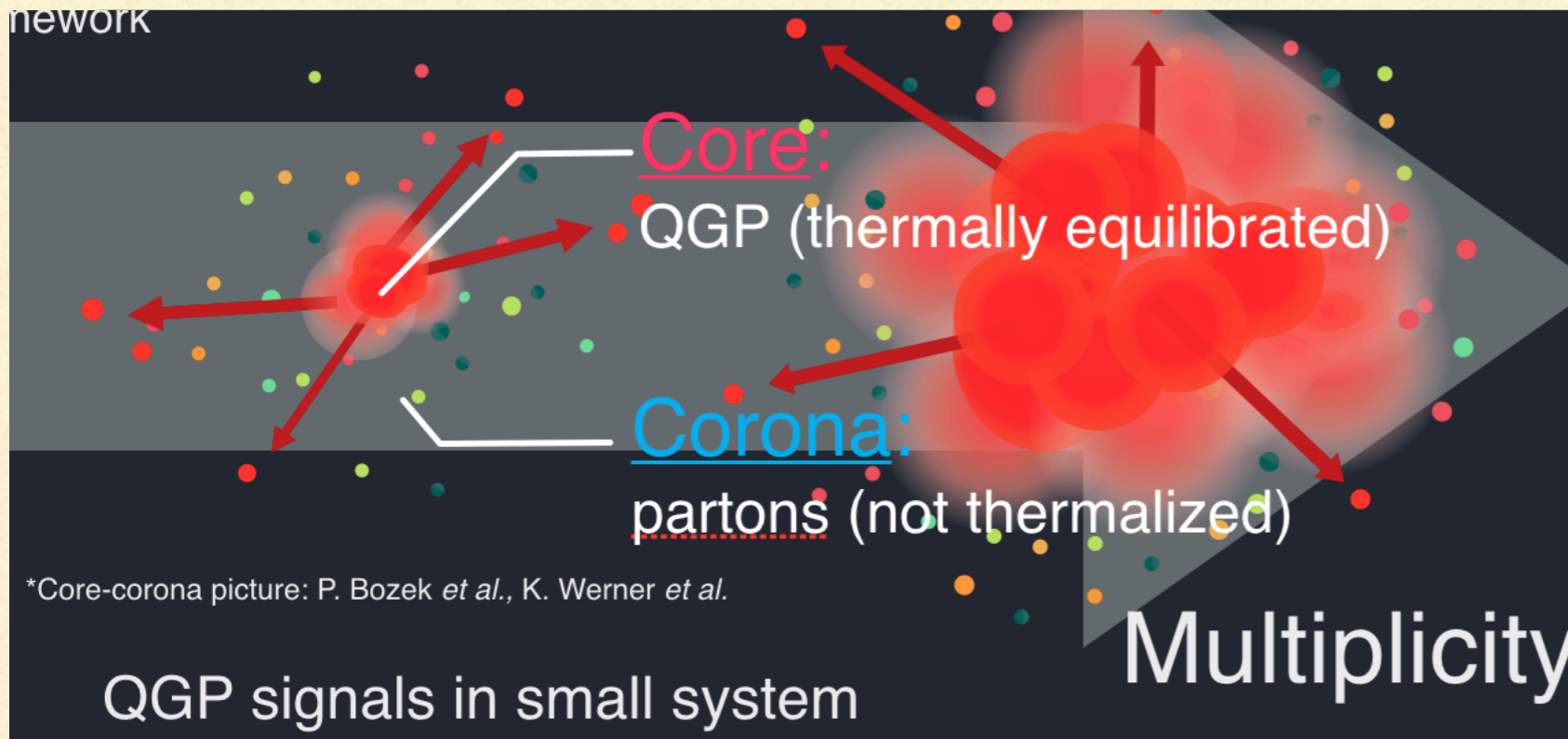
Roland Katz Tues. 14:40

$D^0$  meson, Trento, Langevin, frag. & coal.,  $T_d = 160$  MeV



# STRANGENESS: CORE+CORONA

Kanakubo Tuesday 14:20

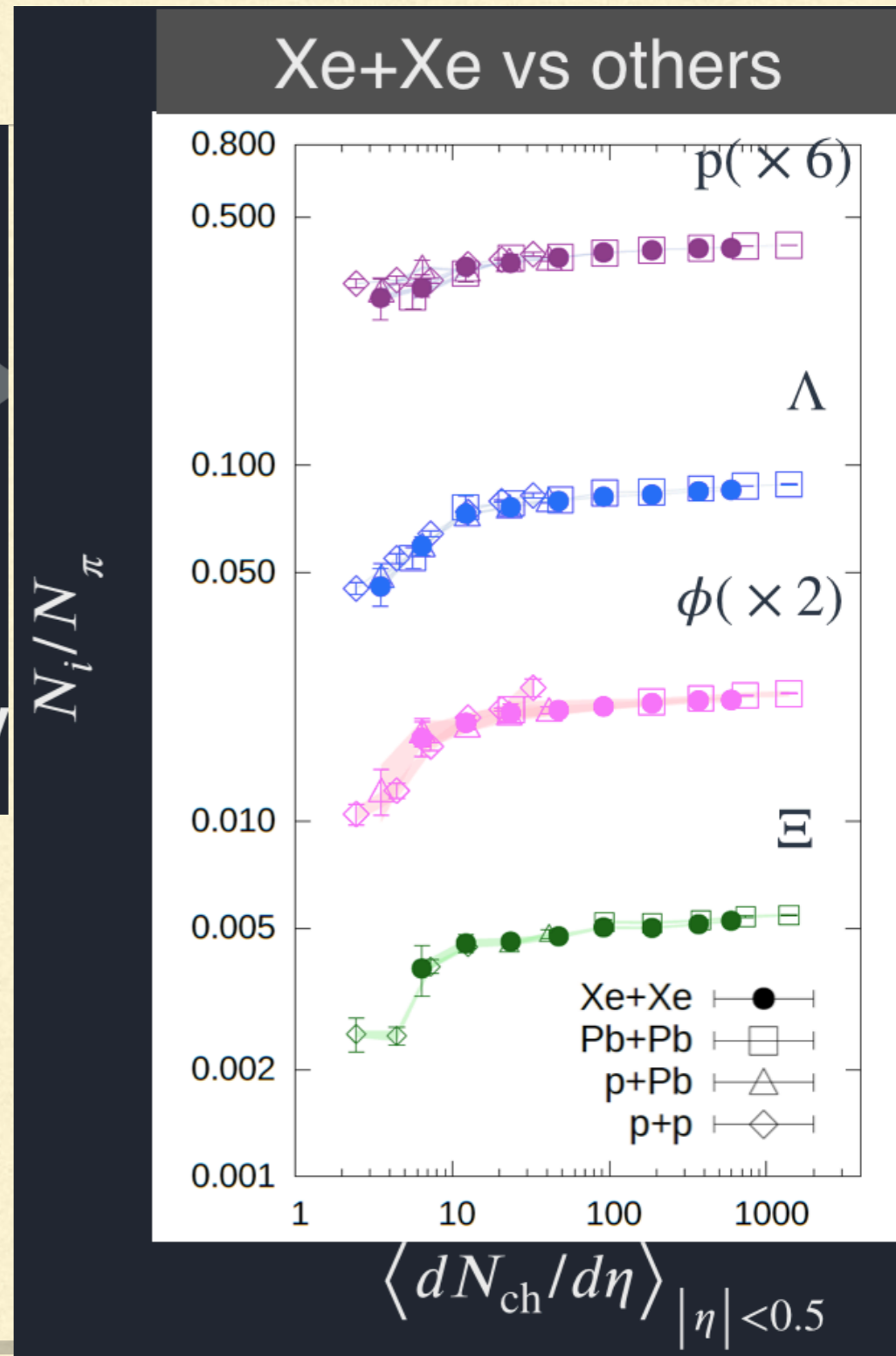


## Two hadronization scenarios:

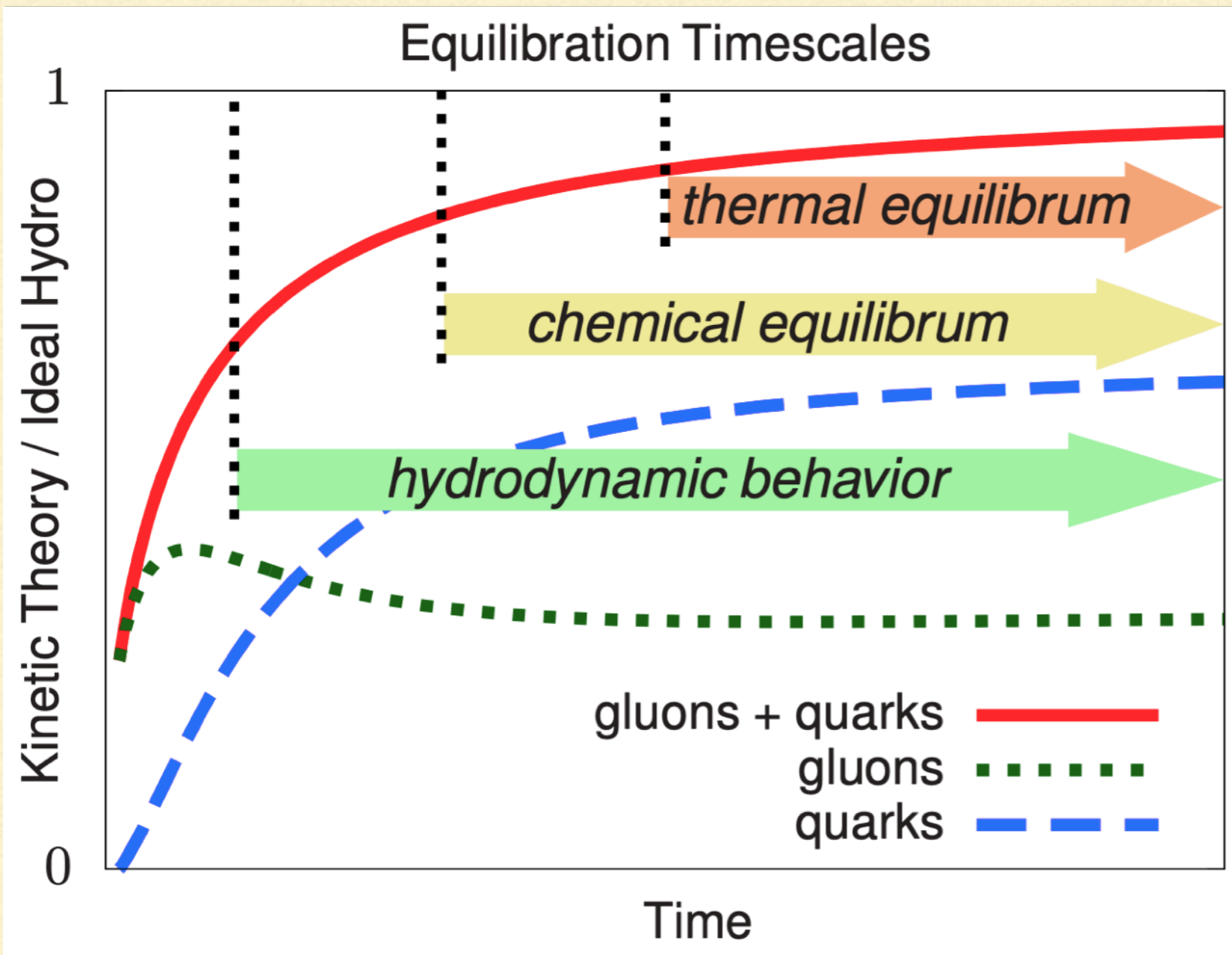
Core with Cooper Frye+decays  
Corona with string fragmentation

Mostly fluid for  $dN/d\eta \gtrsim 10$ .

Kanakubo *et al* PTEP 2018 (2018) no.12, 121D01



# CONNECTION BETWEEN TRANSPORT COEFFICIENTS, SYSTEM SIZE, AND HADRONS



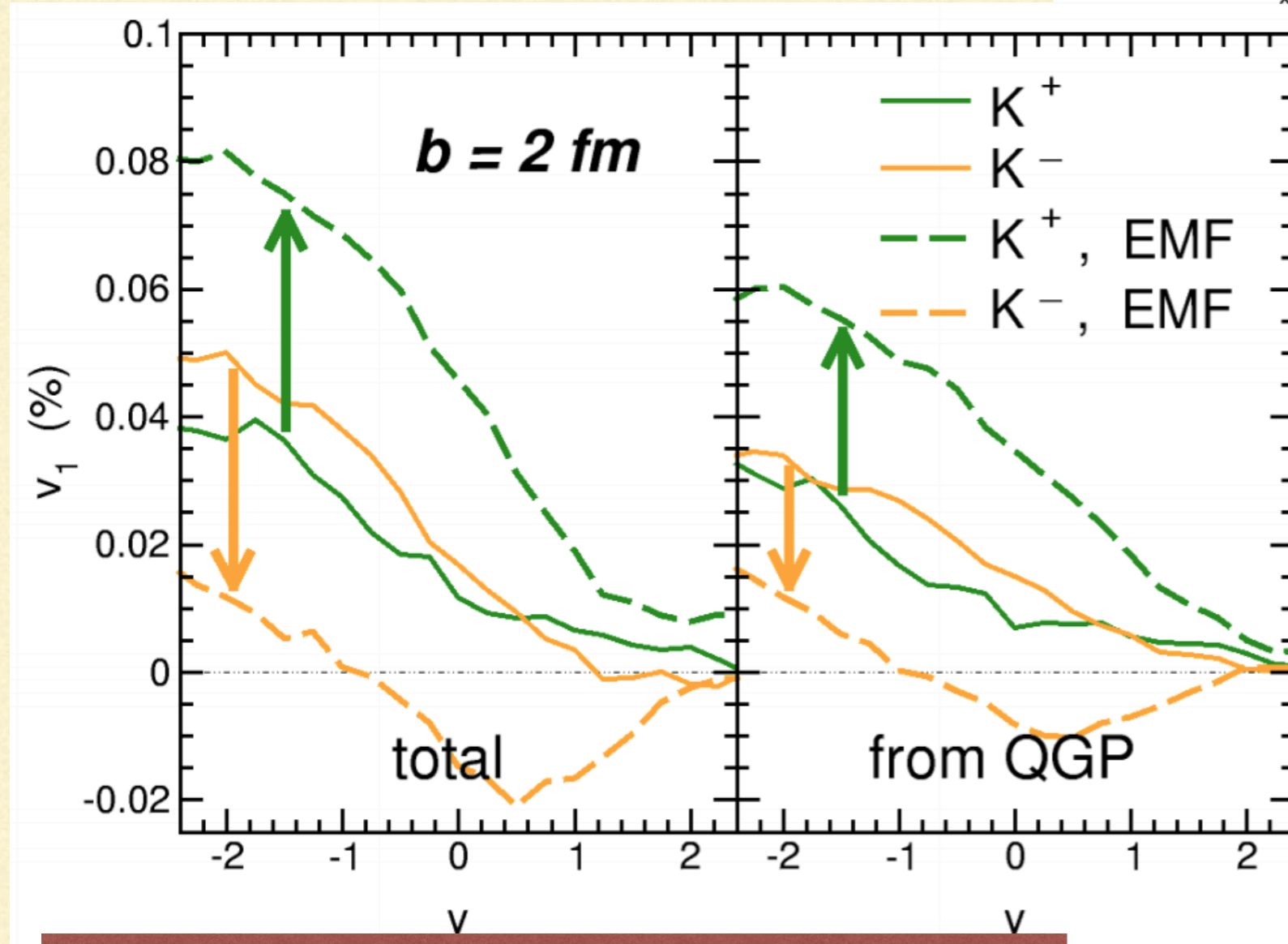
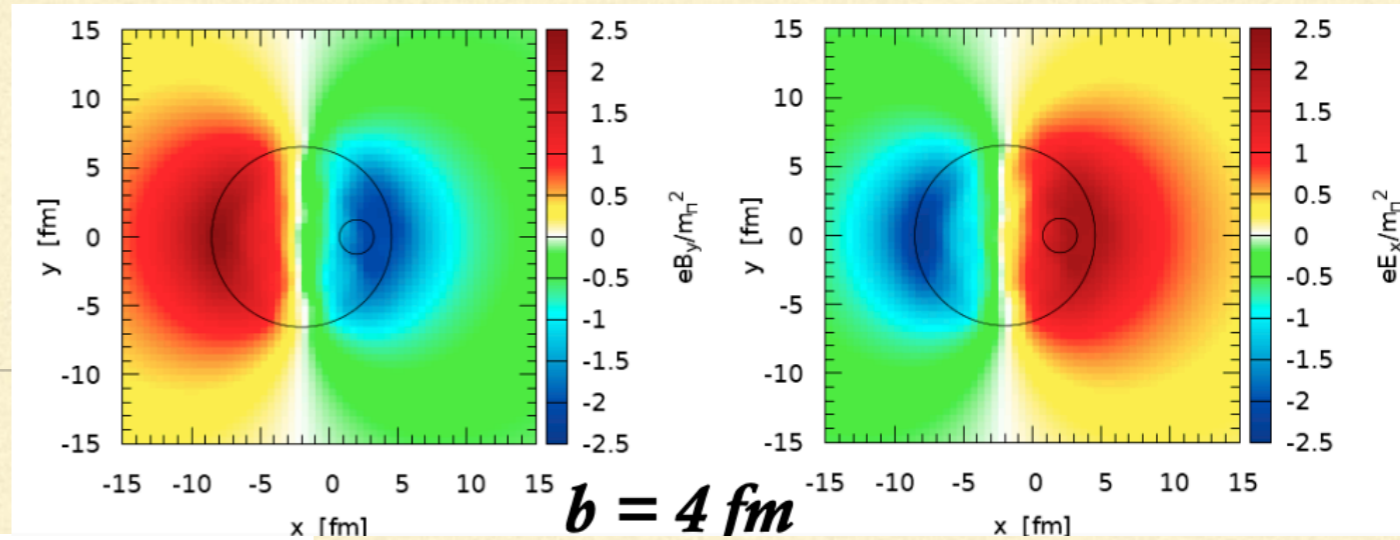
$$dN/d\eta \gtrsim 100$$

Are able to reach  
chemical equilibrium

Mazeliauskas  
Tuesday 15:20

# CME/VORTICITY

Able to produce splitting in pPb!



PHSD predicts large splitting of  $K^+$   $K^-$  for E&M fields

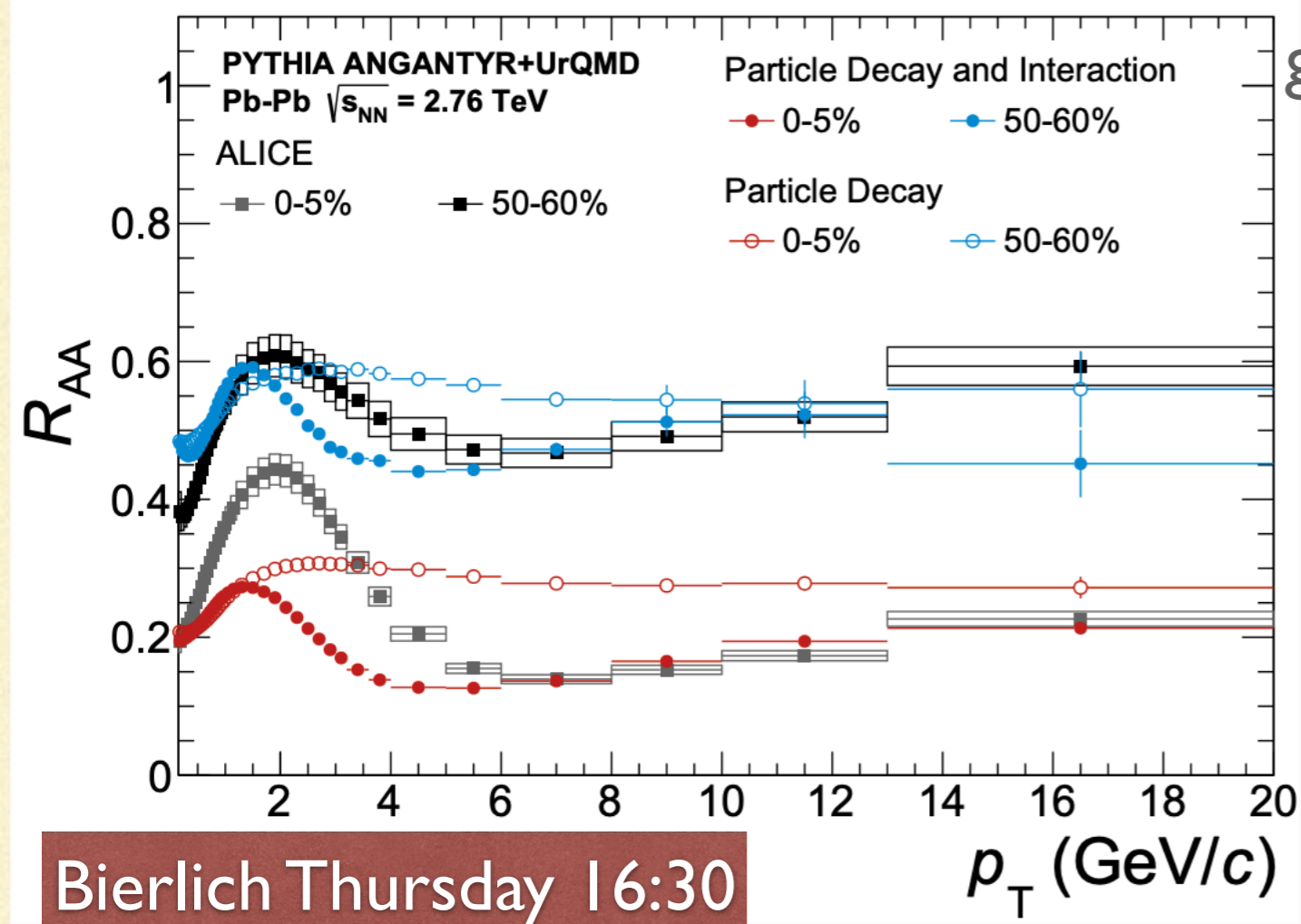
Lucia Oliva Tuesday 16:30

Magnetohydro  
Moghaddam  
Thursday 17:10

PHQMD Bratkovskaya Thursday 14:40

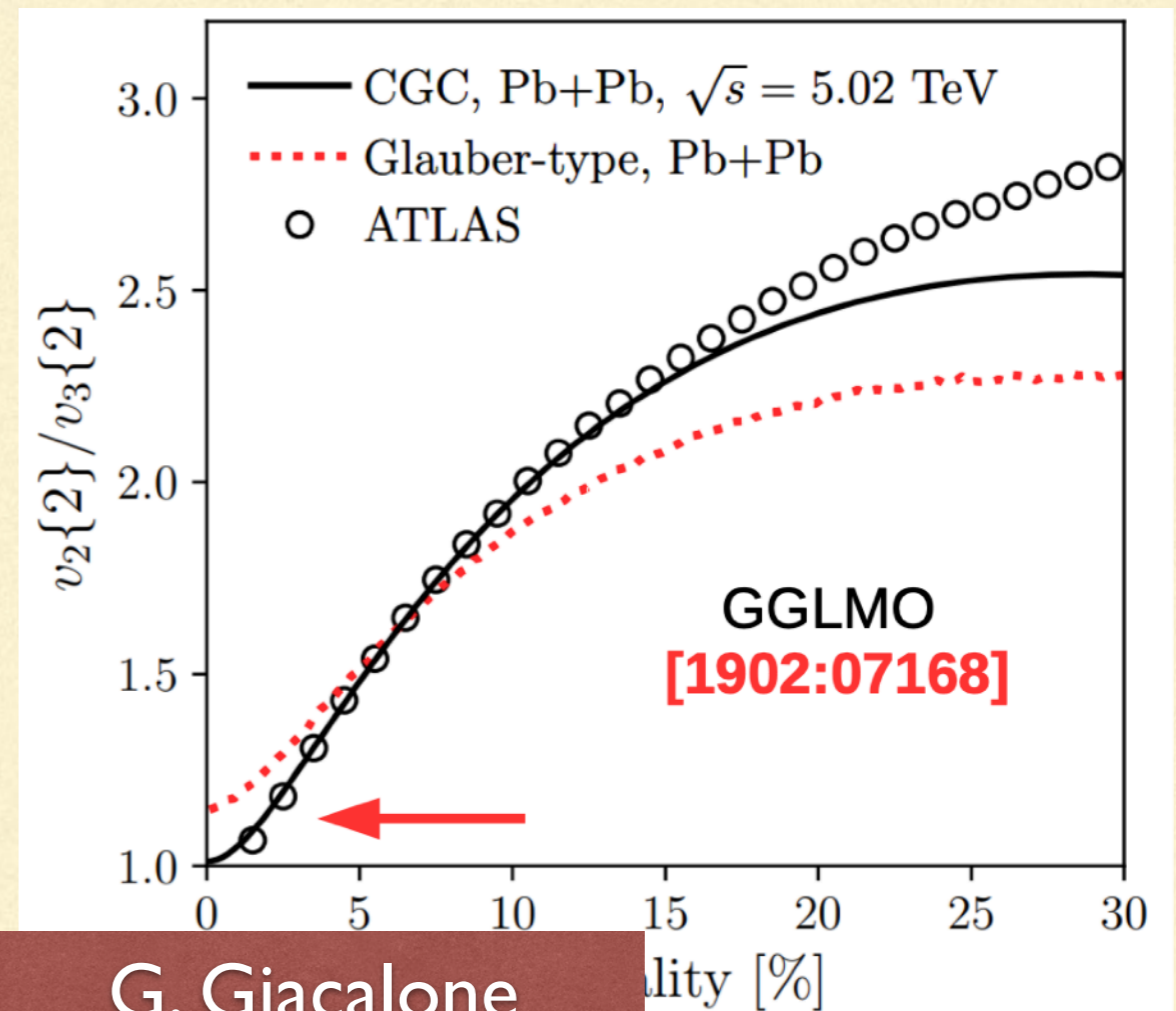
# QUESTIONING IC+QGP PARADIGM

## PYTHIA+URQMD in PbPb



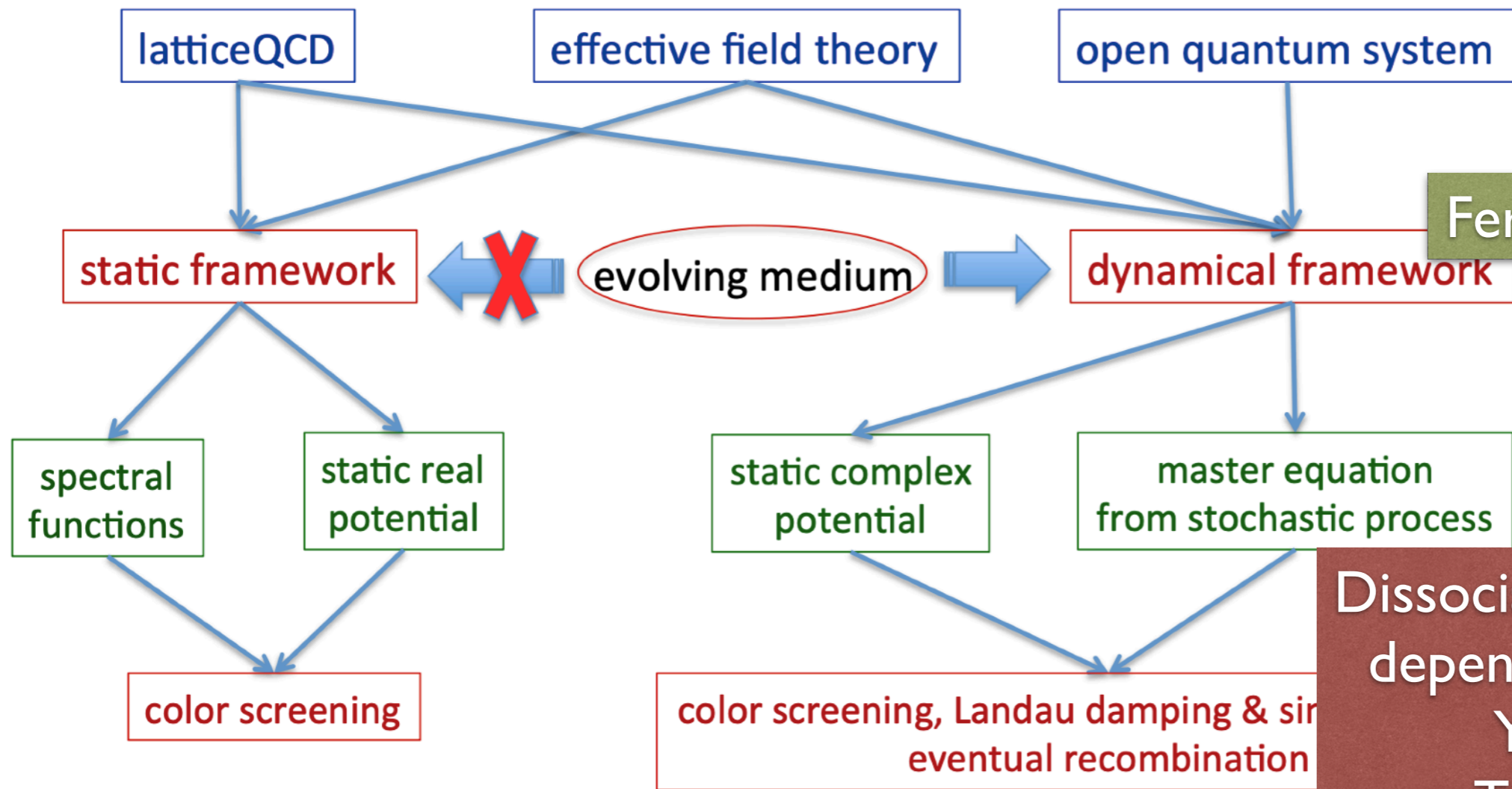
Small influence of jets on  $v_2$   
 Karpenko Tuesday 16:50

Beyond Glauber: fluctuations generated by QCD interactions (CGC)



# Quarkonium pA to AA connection

**Caveat I:** we need firm theoretical understanding of quarkonium production in pp collisions

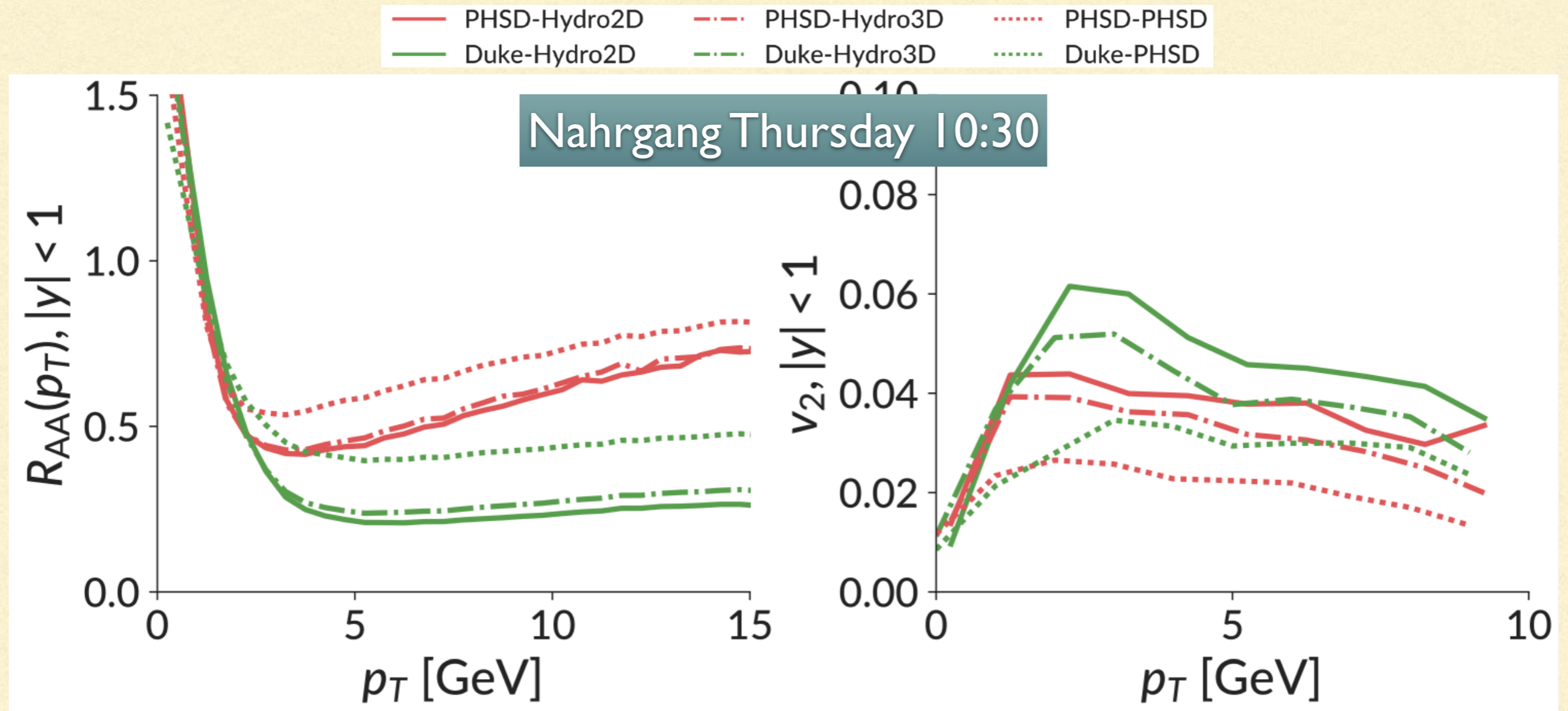


Ferreiro Tuesday 9:30

Dissociation temperature depends on anisotropy  
Yousuf Jamal  
Tuesday 15:00

**Caveat II:** how to extrapolate pA effects –initial & final- to AA? Factorization?  
If yes... nature of the medium in pA?

# TESTING EQUILIBRATION WITH HEAVY FLAVOR



Begging to be applied to small systems



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# Predictions for Future SQMs

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- Small system scan with more information about heavy flavor?
- Crosstalk on the EOS between Lattice QCD/HIC & neutron stars (constraints from new experiments and astronomy?)
- Dynamical behavior of BSQ charges
- Magnetohydro/vorticity calculations
- Deeper understanding of # of strange hadrons and their interactions
- New BESII data!