IMPORTANCE OF MULTIPLICITY FLUCTUATIONS IN ENTROPY SCALING

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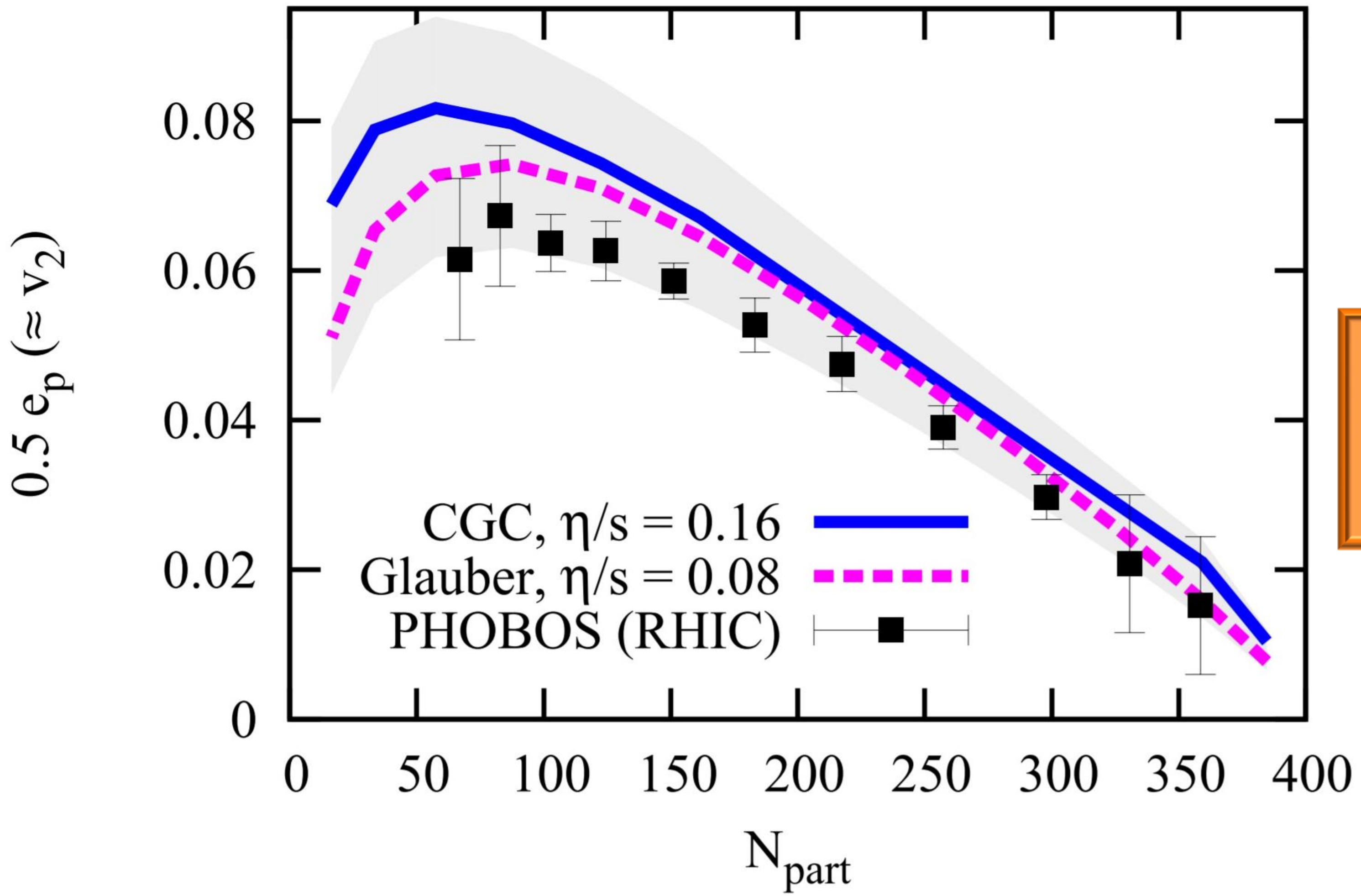
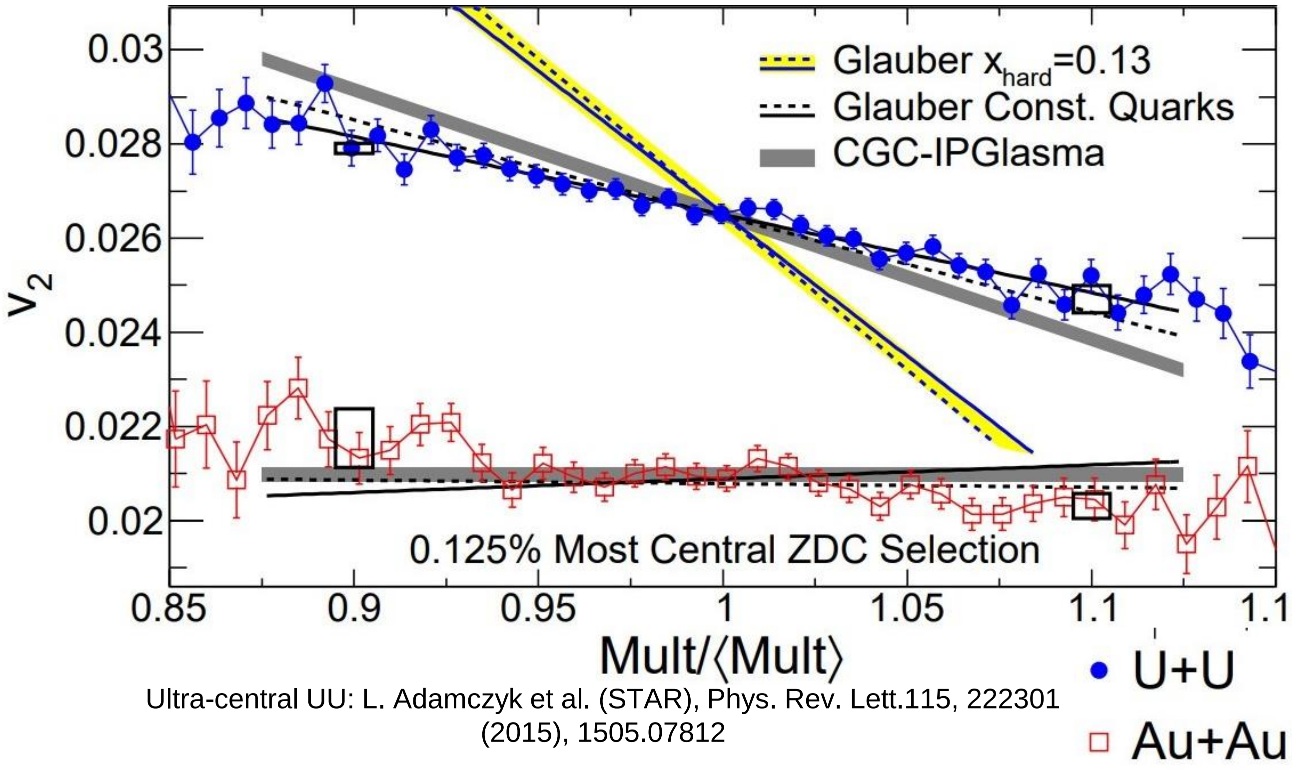
Initial Conditions and Small Systems



Shear viscosity is dependent on choice of initial condition

η/s depends on IC: M. Luzum and P. Romatschke, [arXiv:0901.4588 [nucl-th]]

Functional Form of Initial Entropy Density



Ultra-central UU: L. Adamczyk et al. (STAR), Phys. Rev. Lett.115, 222301 (2015), 1505.07812

Scaling Relation:

$$f_p(cT_A, cT_B) = cf(T_A, T_B)$$

Model Agnostic Generalized Mean:

$$f_p(T_A, T_B) = \left(\frac{T_A^p + T_B^p}{2}\right)^{\frac{1}{p}}$$

From Bayesian Analysis ($p = 0$):

$$\sqrt{T_A T_B}$$

TRENTO used ultra-central U+U collisions to exclude entropy scaling models from their analysis

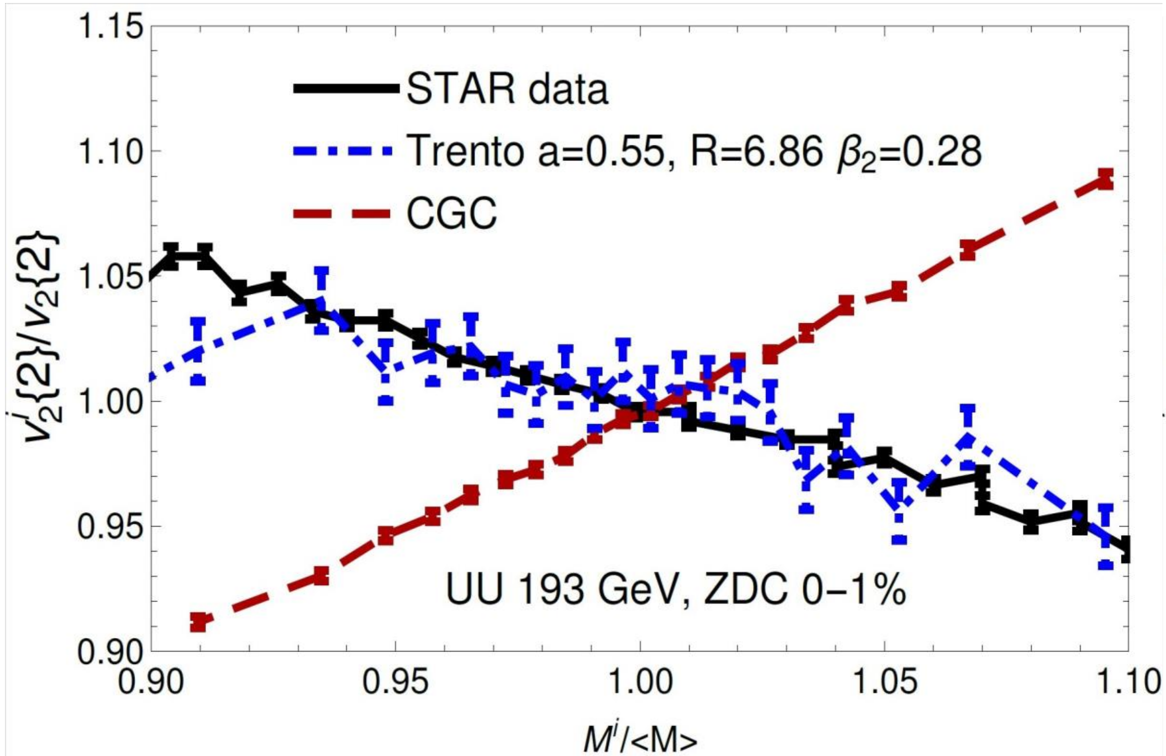
TRENTO: J. S. Moreland, J. E. Bernhard, and S. A. Bass, Phys. Rev.C92, 011901 (2015), 1412.4708
J. E. Bernhard, J. S. Moreland, S. A. Bass, J. Liu, and U. Heinz, Phys. Rev.C94, 024907(2016), 1605.03954

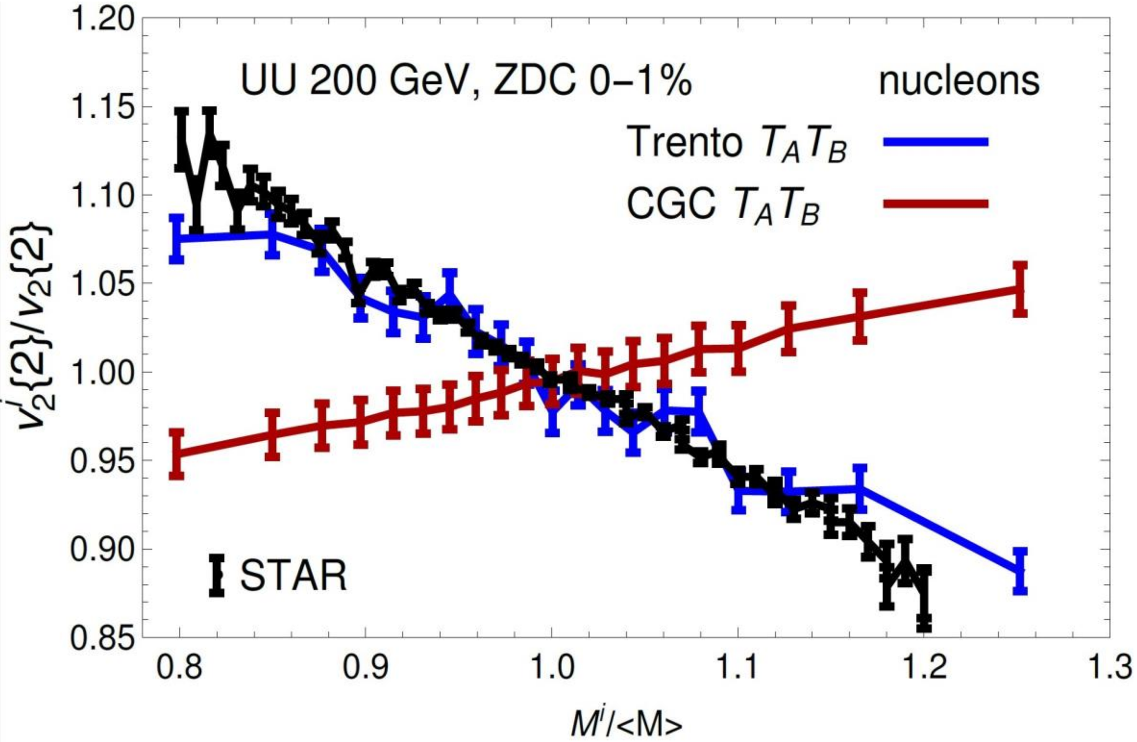
Linear Functional Form

Initial Energy Density in CGC:

$\sqrt{T_A T_B} \in f_p$

$T_A T_B \notin f_p$



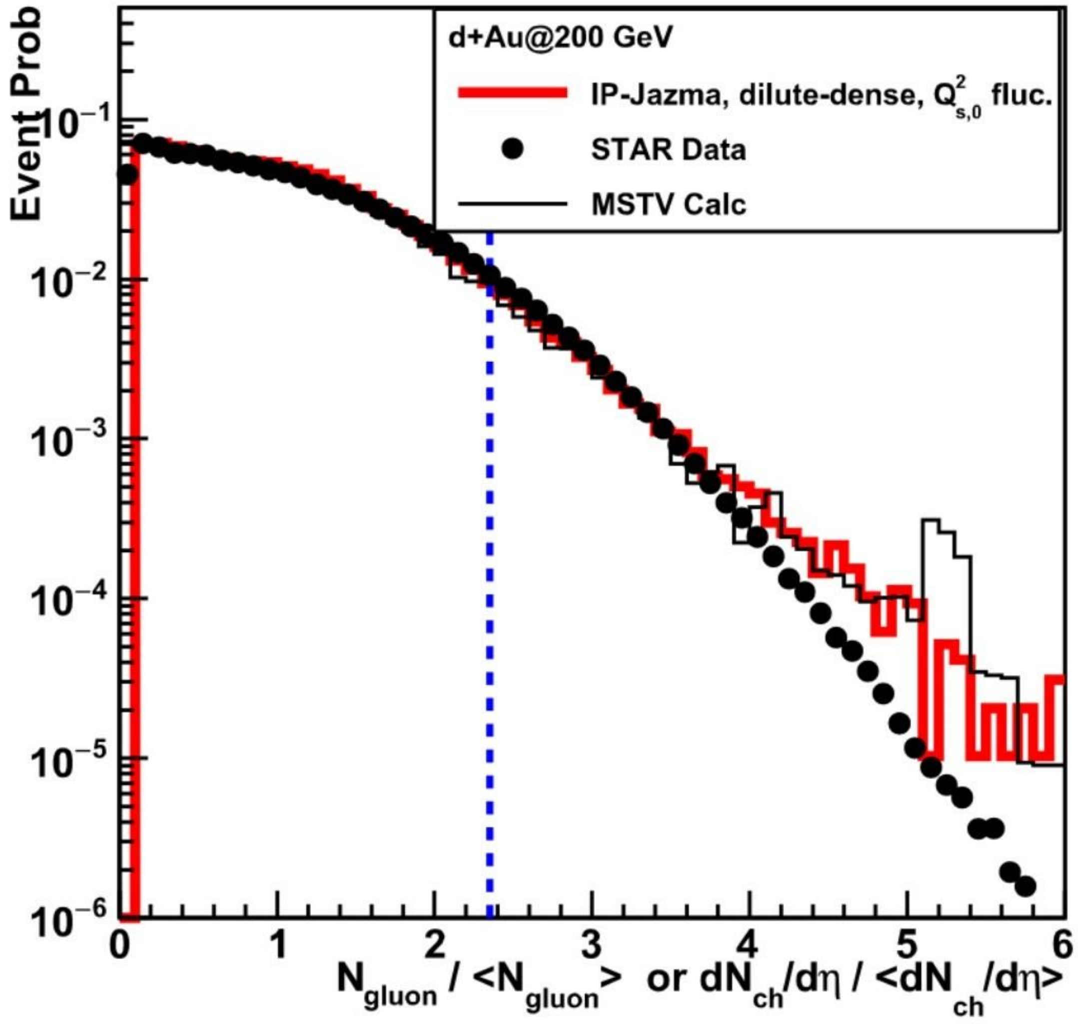


UU Scaling: J. Noronha-Hostler, N. Paladino, S. Rao, M. D. Sievert and D. E. Wertepny,[arXiv:1905.13323 [hep-ph]]

While TRENTO can reproduce UU well, there are other models that can do so that were not considered in the Bayesian analysis.

$T_A T_B$ scaling: J. L. Nagle and W.A. Zajc,[arXiv:1808.01276[hep-th]], T. Lappi, Phys. Lett. B643, 11 (2006), arXiv:hepph/0606207 [hep-ph] G. Chen, R. J. Fries, J. I. Kapusta and Y. Li, [arXiv:1507.03524 [nucl-th]], P. Romatschke and U. Romatschke, [arXiv:1712.05815 [nucl-th]]

IP-JASMA



IP-Jasma: J. L. Nagle and W.A. Zajc,[arXiv:1808.01276[hep-th]]

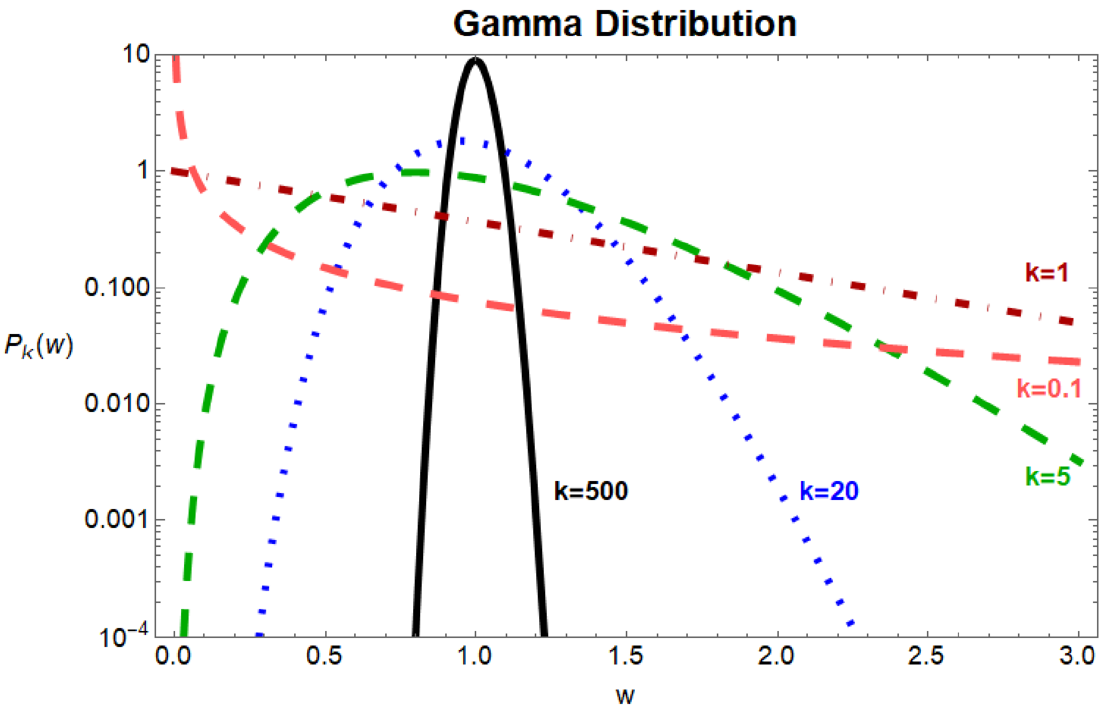
IP-Jasma using another functional form needed Lognormal multiplicity fluctuations

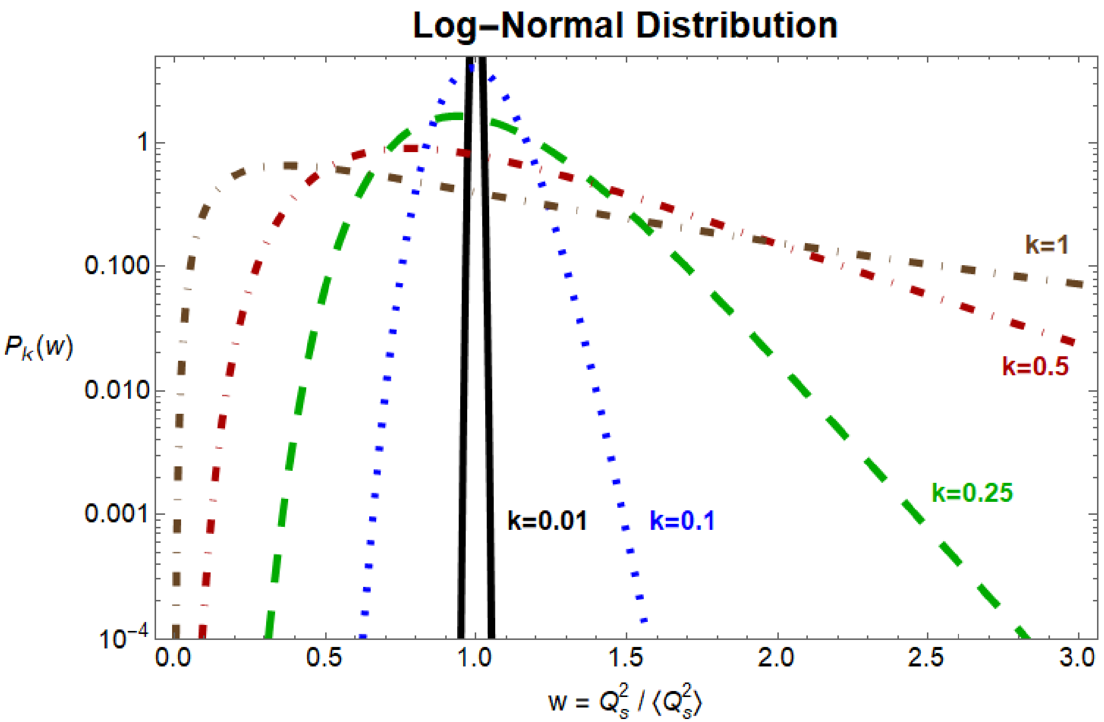
Multiplicity Distributions

$$T_{A,B}(x,y) = w_{A,B} \int dz\, \rho_{A,B}(x,y,z)$$

$$P_k(w) = \frac{k^k}{\Gamma(k)} w^{k-1} e^{-kw}$$

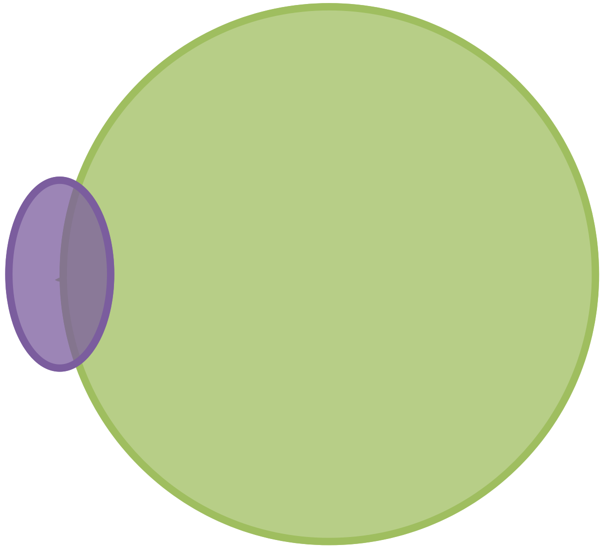
$$P_k(w) = \frac{2}{wk\sqrt{2\pi}} e^{-\frac{\log^2(w^2)}{2k^2}}$$





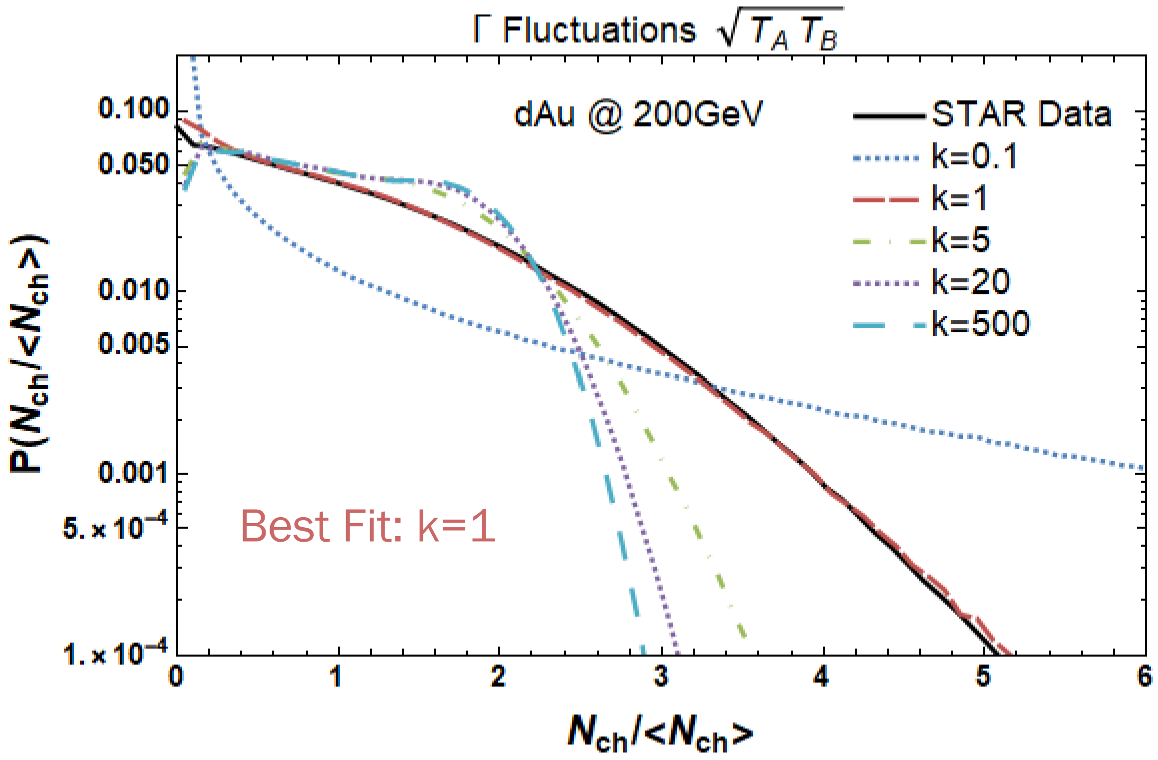
Updates to TRENTO: I added $T_A T_B$ scaling and Lognormal Fluctuations

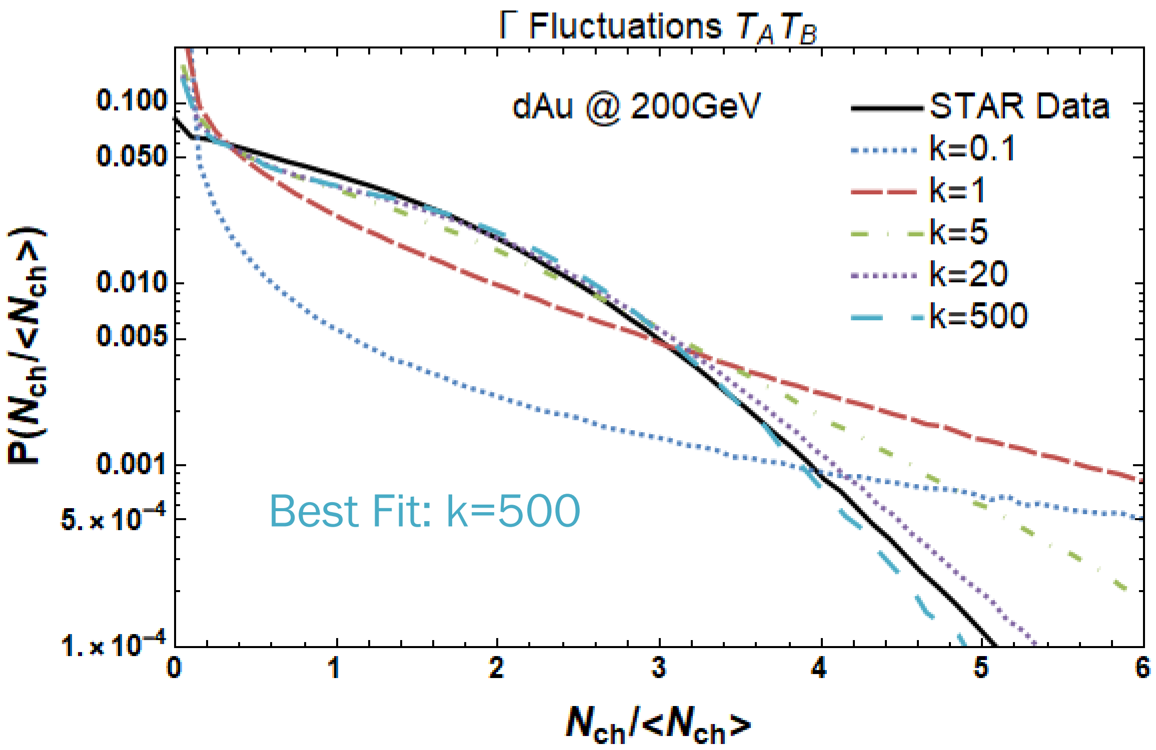
dAu



Multiplicity: Γ Fluctuations

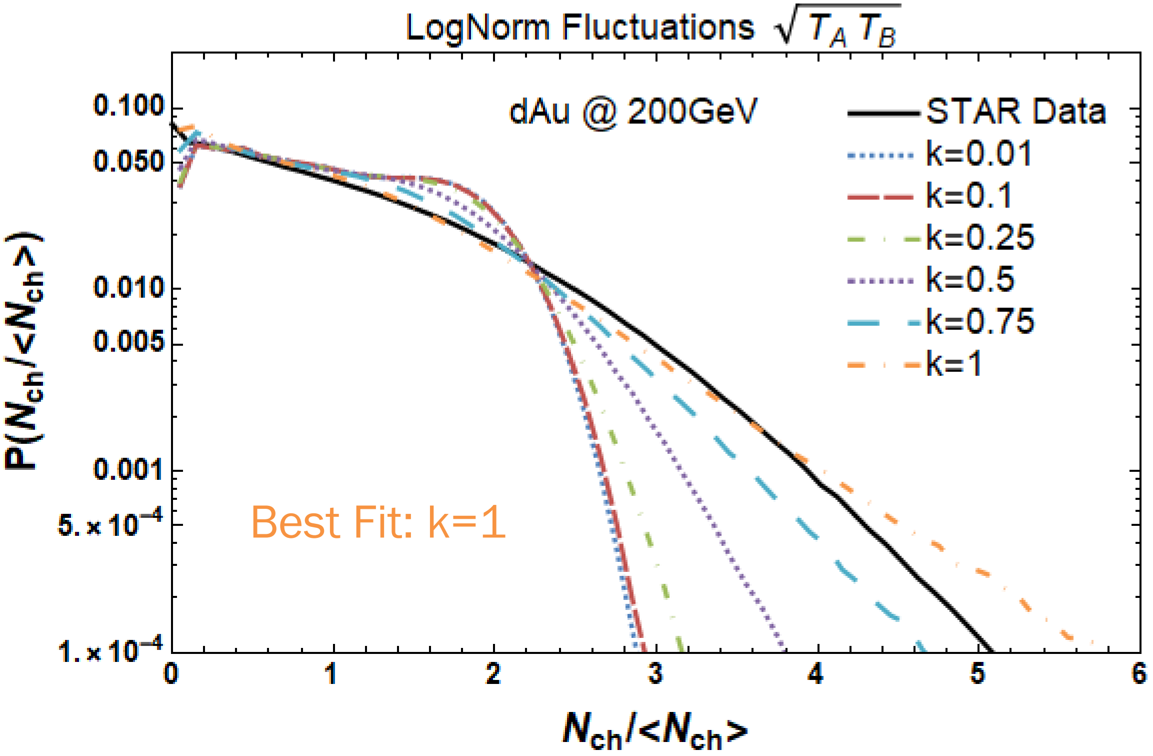
$N_{ch} \propto S_0$

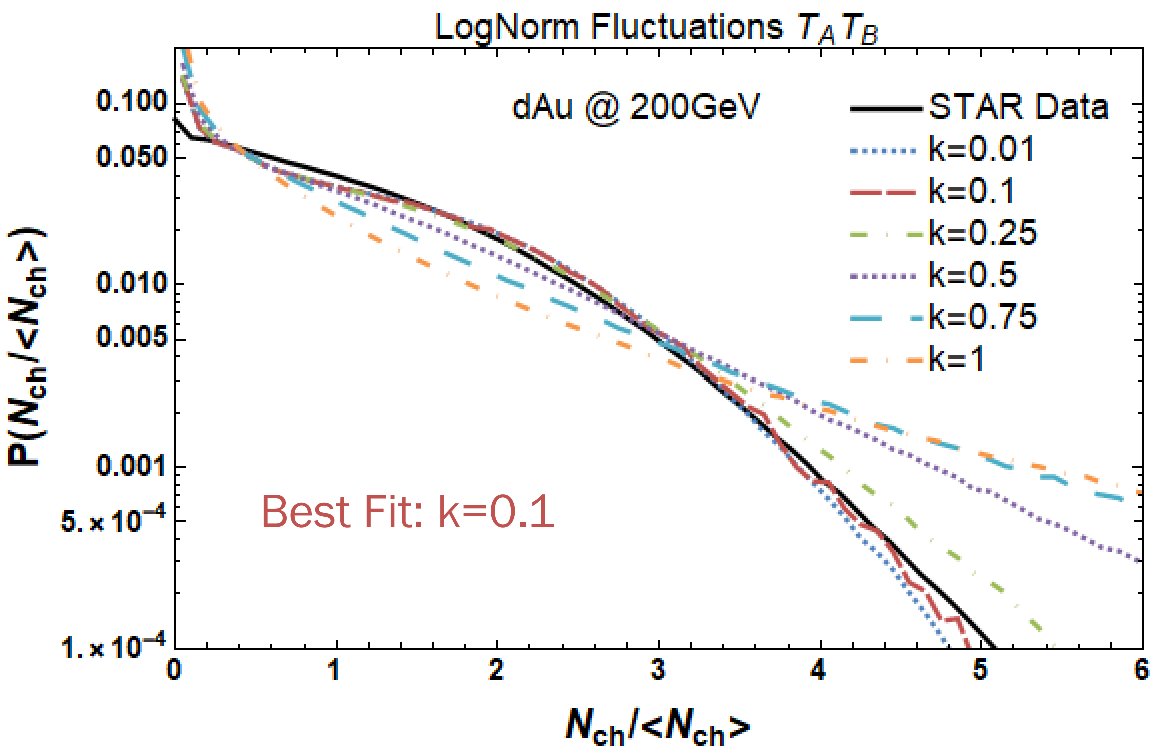




$\sqrt{T_A T_B}$ needs more fluctuations to reproduce data than $T_A T_B$ which matches data with no fluctuations

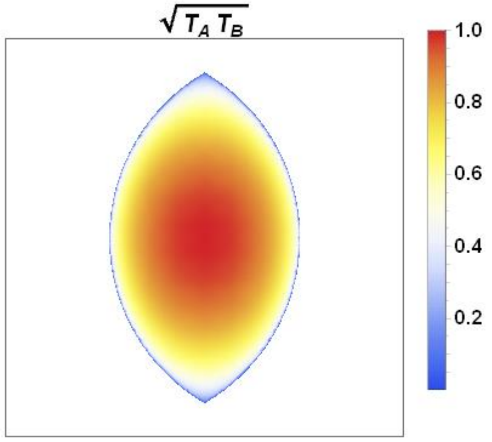
Multiplicity: Lognormal fluctuations

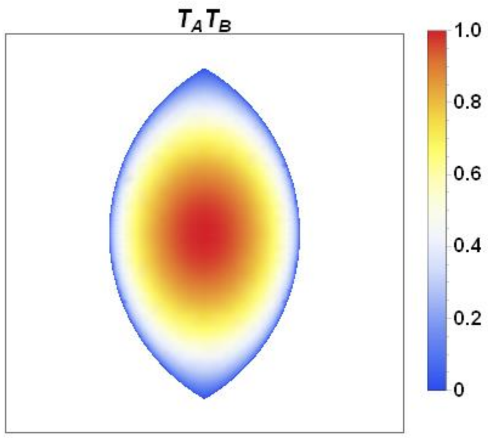




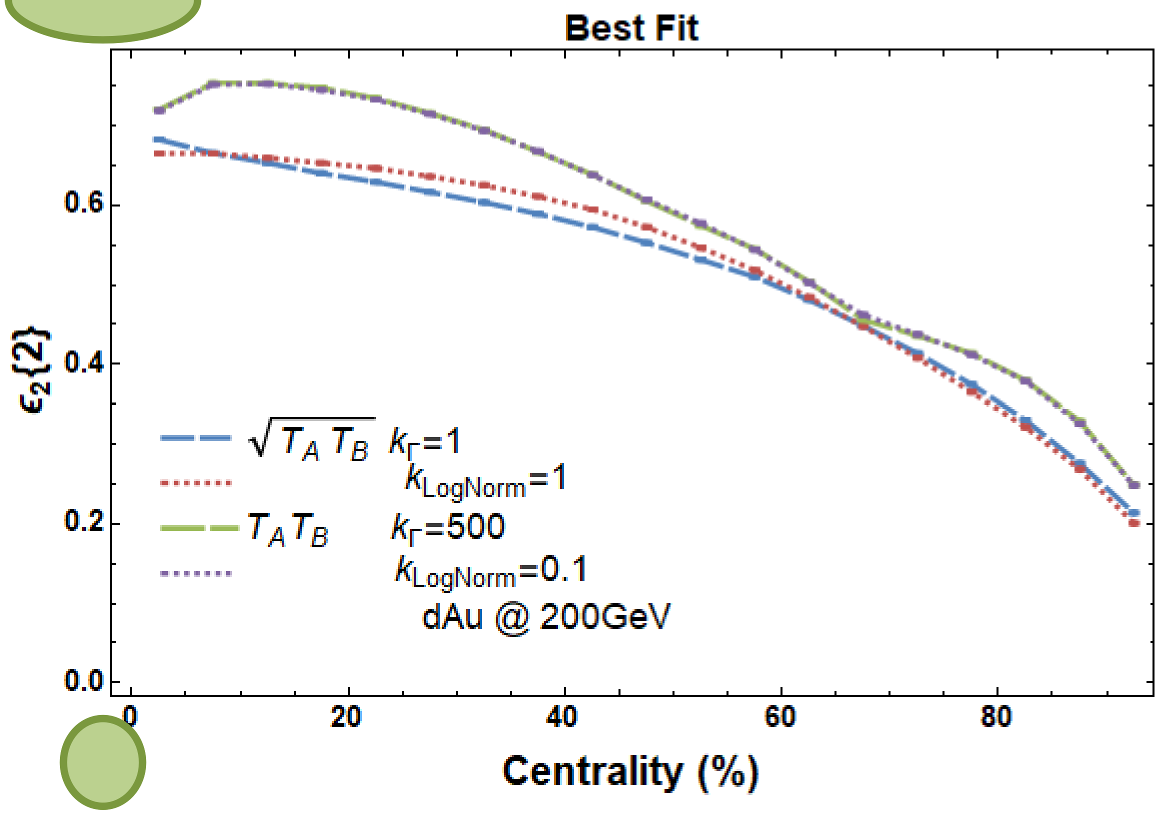
$\sqrt{T_A T_B}$ plays well with Γ but not Lognormal

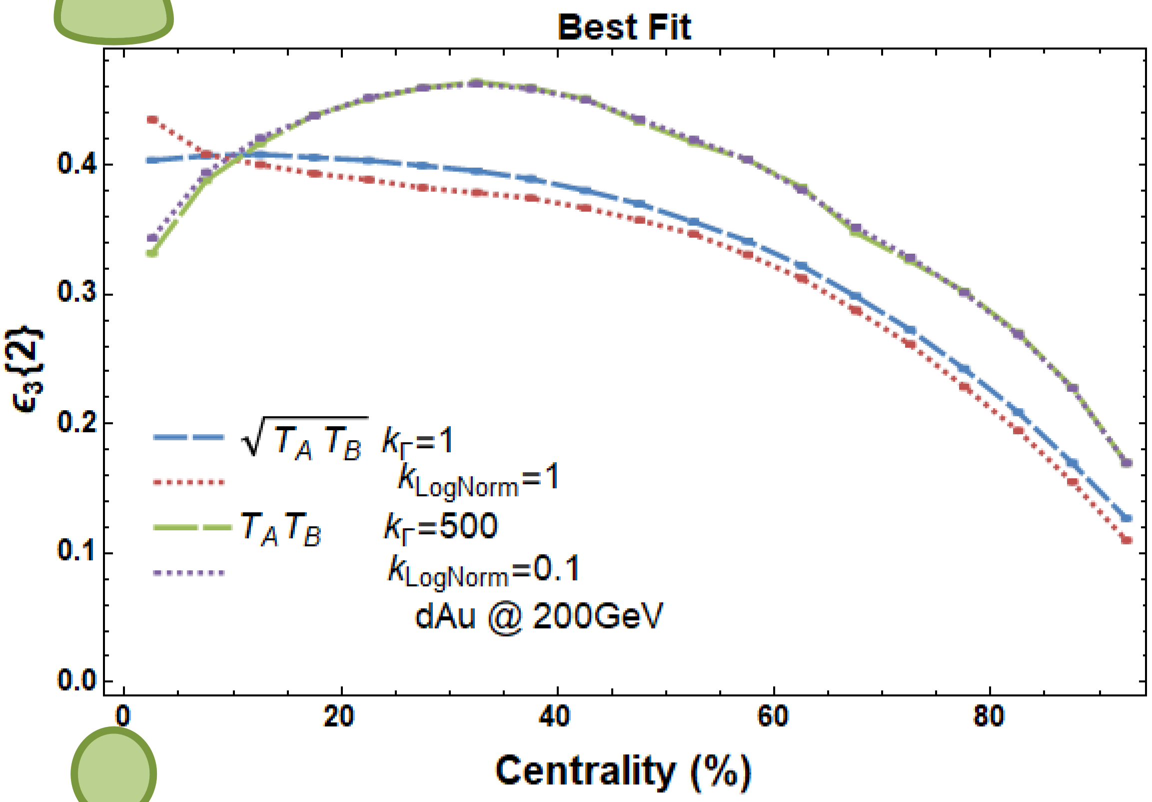
$\sqrt{T_A T_B}$ smooths out entropy more than $T_A T_B$ meaning it needs more fluctuations





Eccentricities





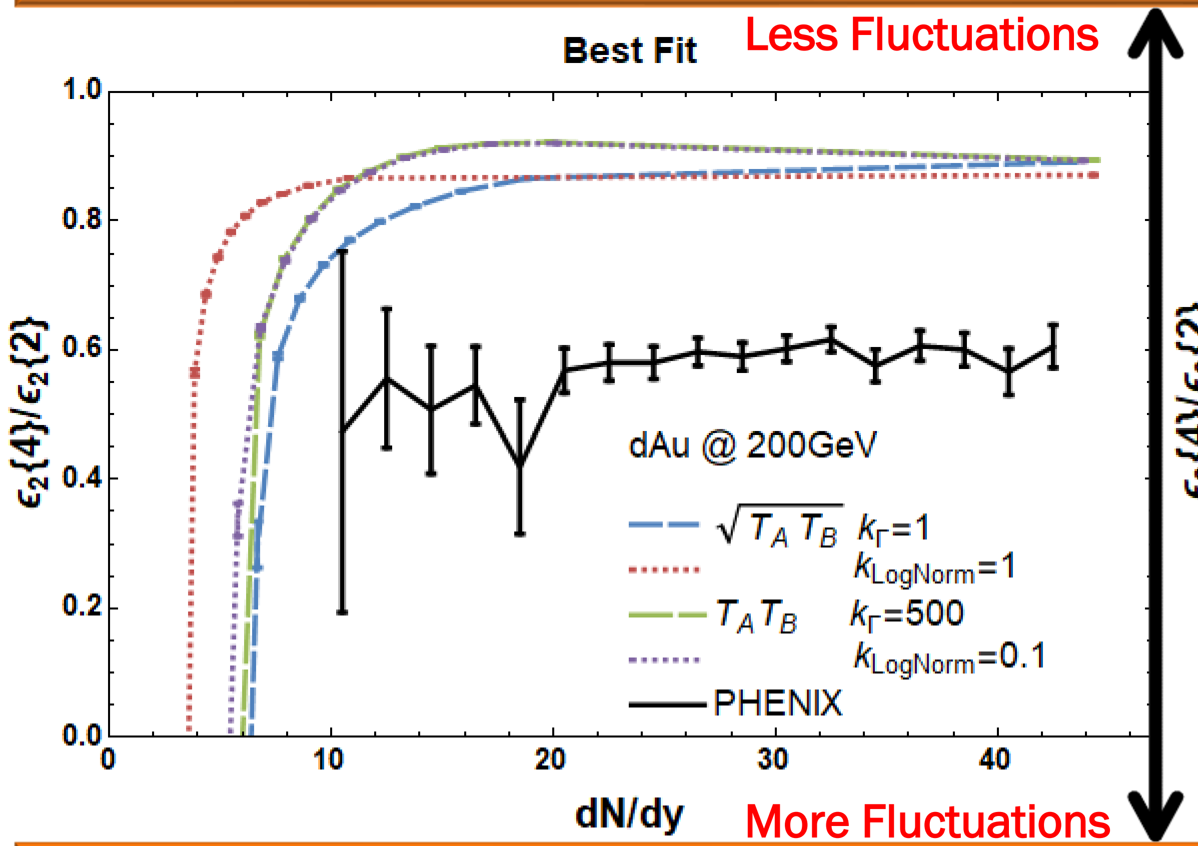
Different ϵ_n affect the extraction of η/s from v_n

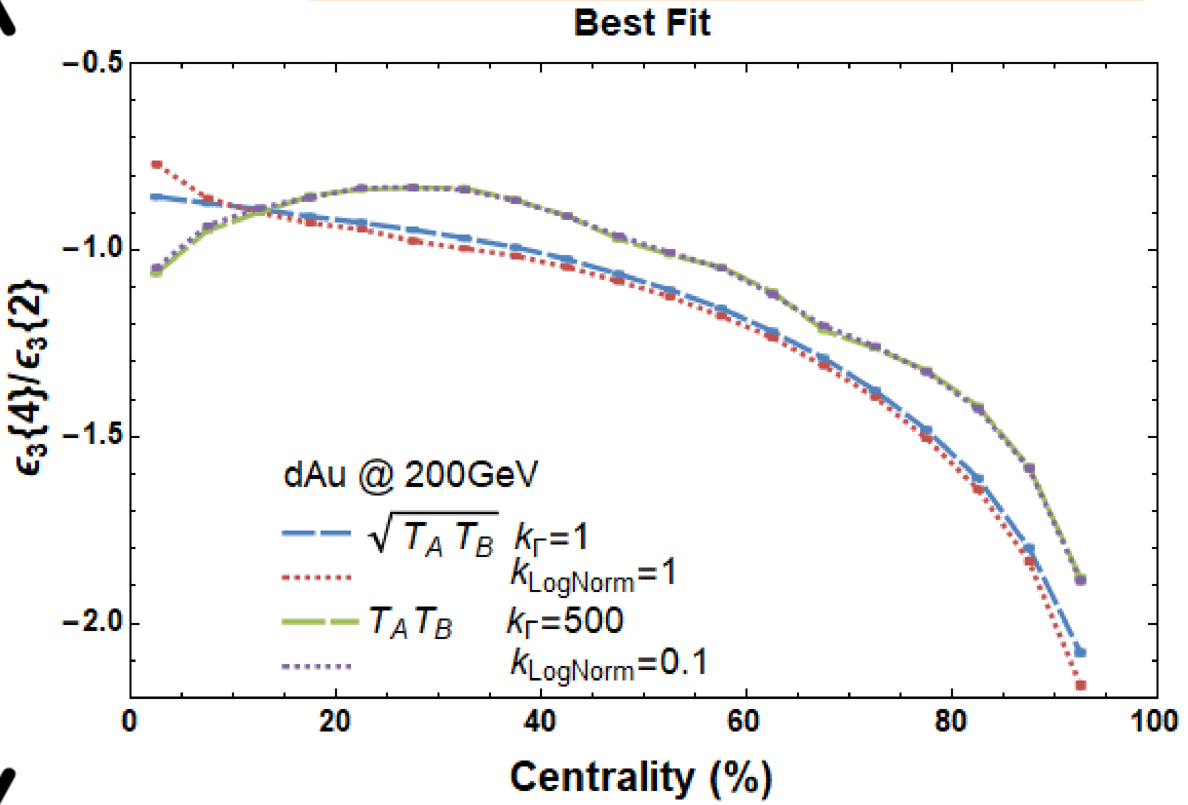
Response across system size: M. Sievert and J. Noronha-Hostler, *Phys. Rev.* C100, (2019) 2, 024904

4 Particle Cumulants

Plotting $\frac{\epsilon_n\{4\}}{\epsilon_n\{2\}}$ to see the event by event fluctuations

Using absolute value of $\epsilon_n\{4\}$ to portray negative values rather than leave them imaginary

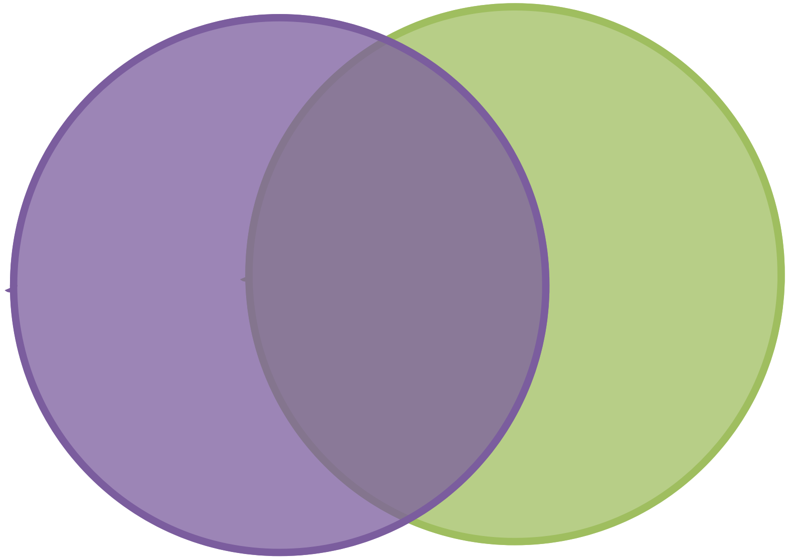




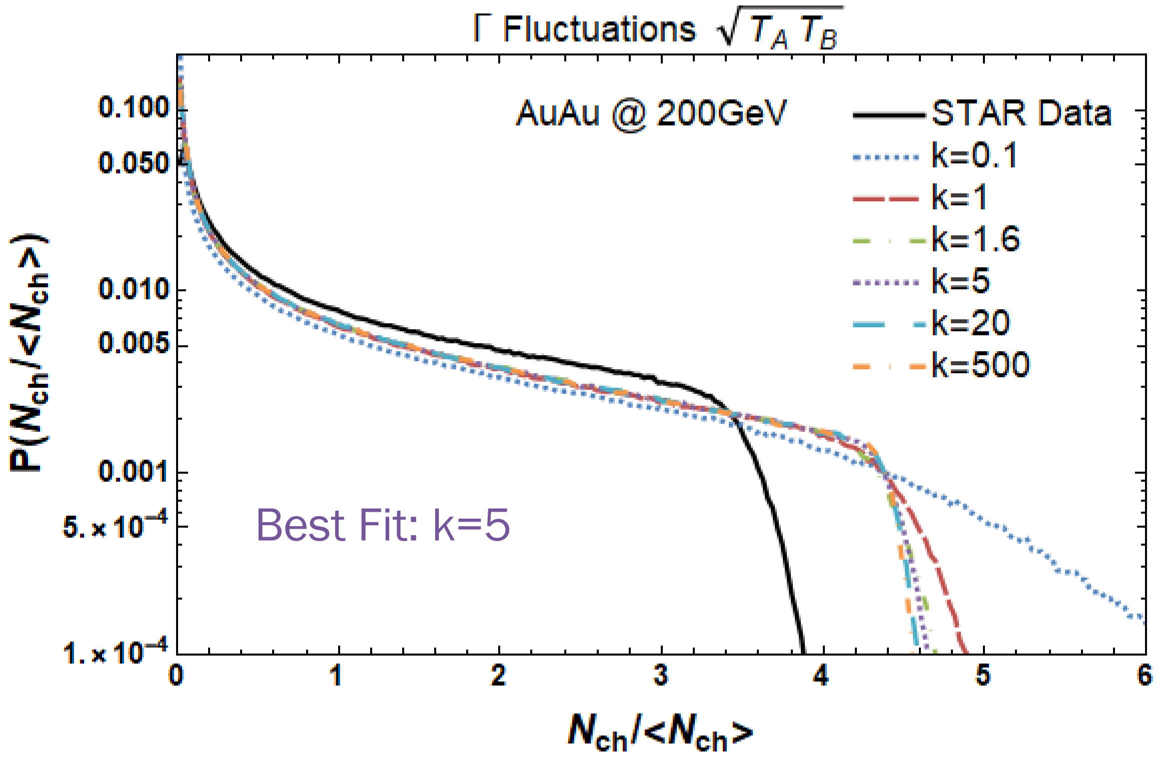
Small systems have both linear and non-linear results so hydro simulations will give a more accurate description of $\frac{v_2\{4\}}{v_2\{2\}}$

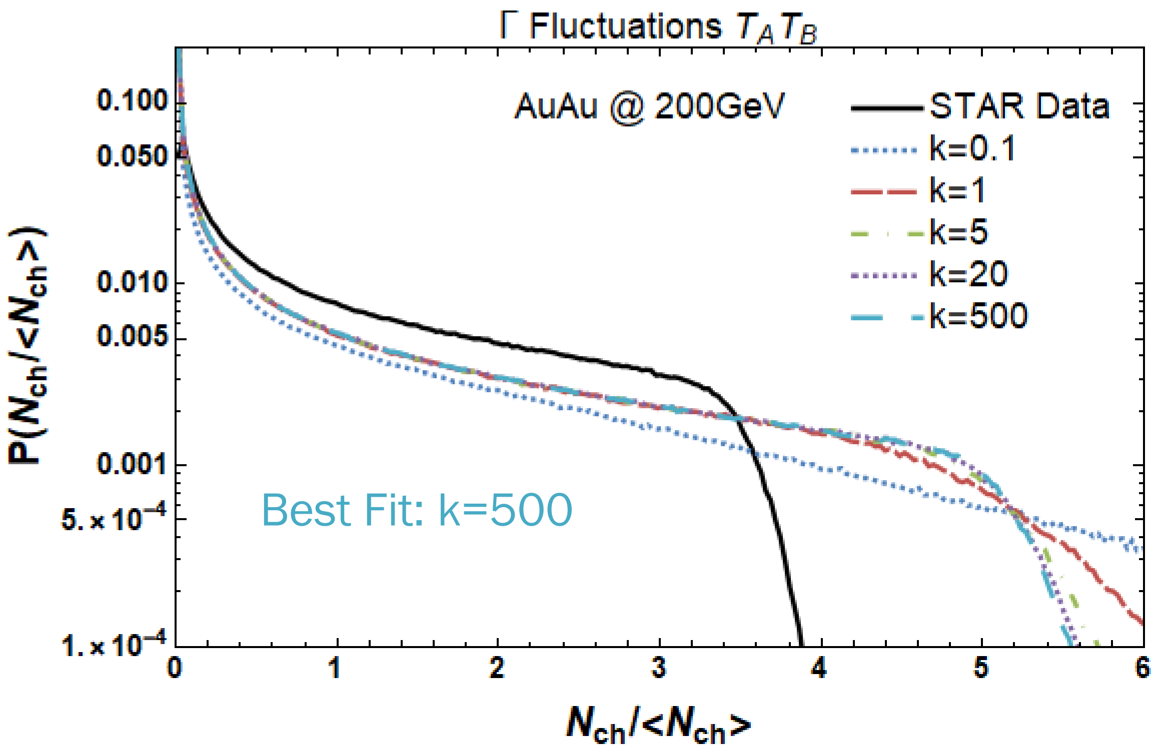
V24/v22 in small systems: M. Sievert and J. Noronha-Hostler, *Phys. Rev.* C100, (2019) 2, 024904

AuAu



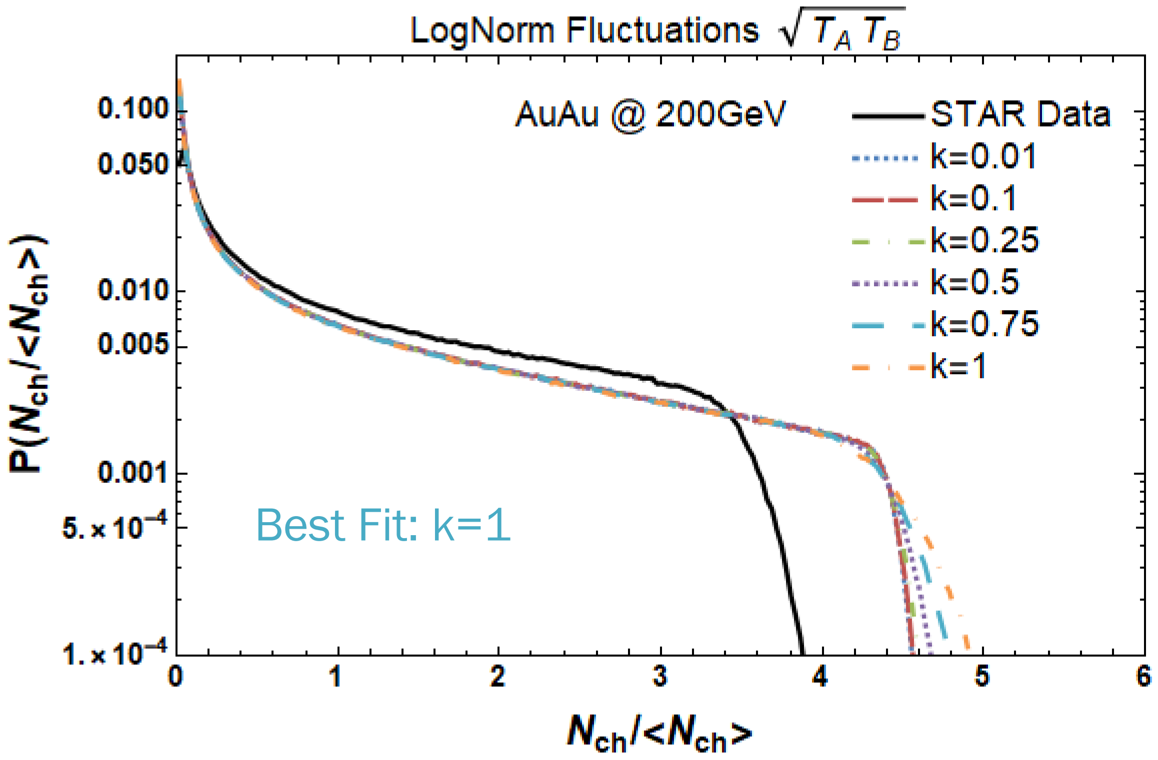
Multiplicity: Γ Fluctuations

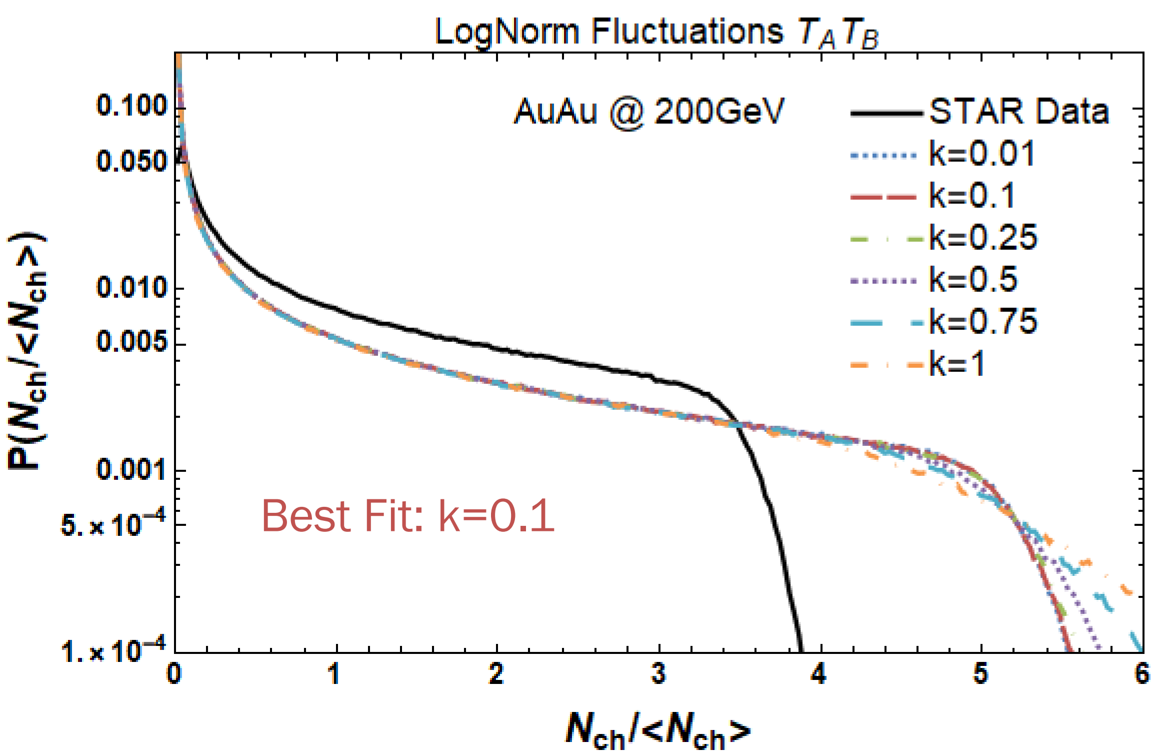




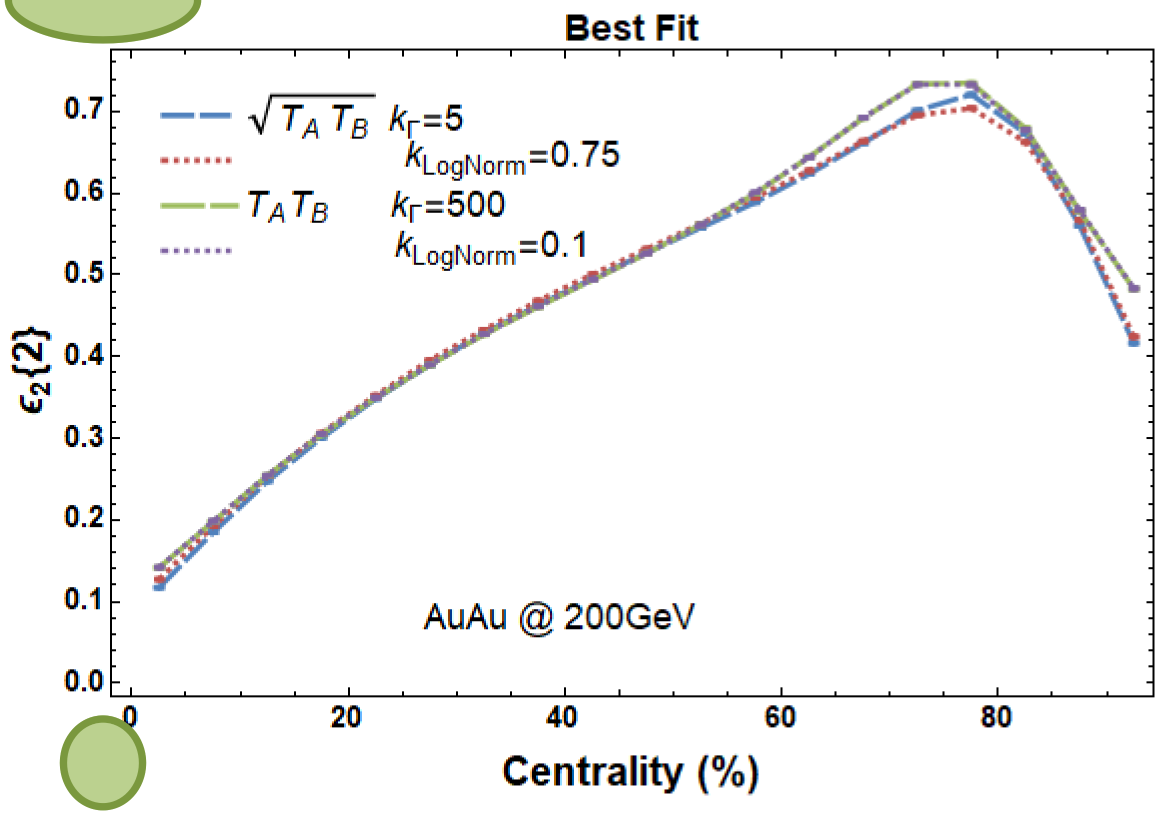
Effect is decreased in larger systems

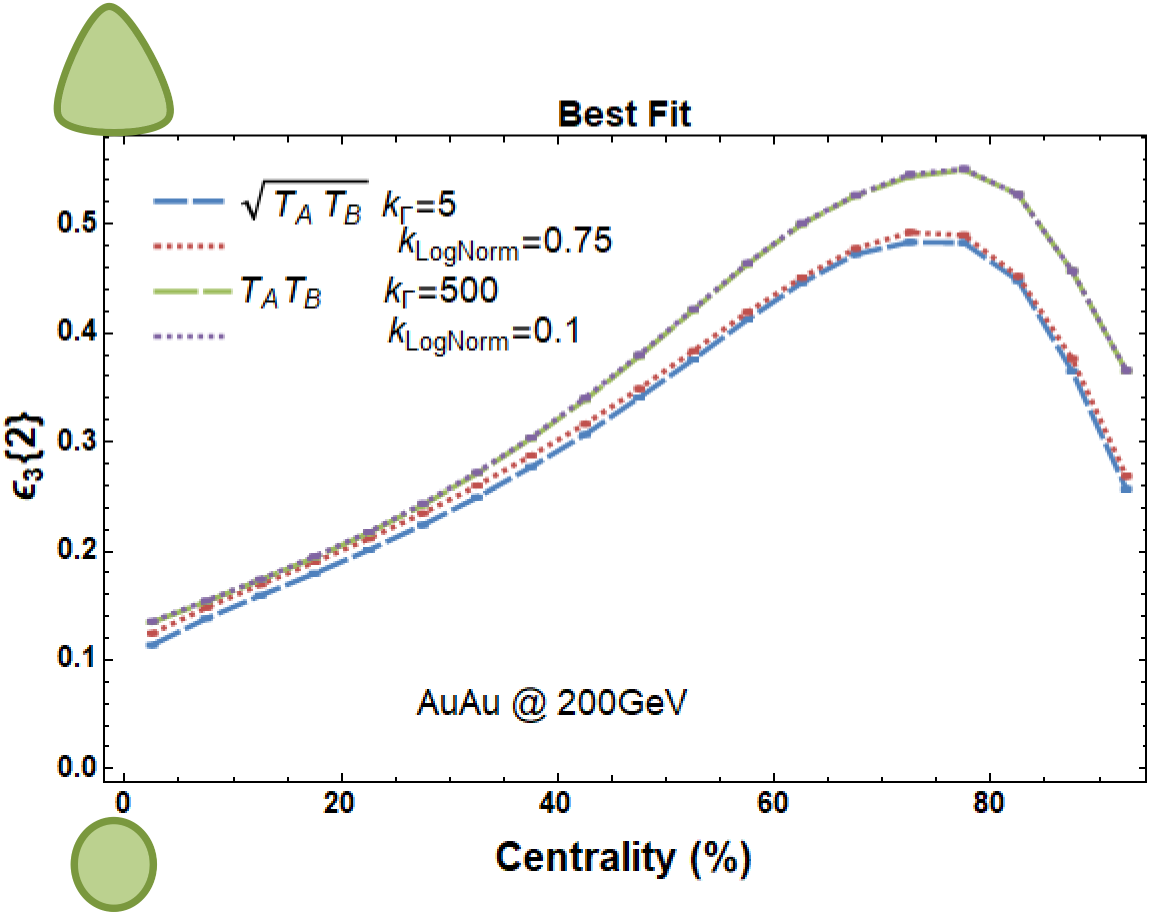
Multiplicity: Lognormal Fluctuations





Eccentricities

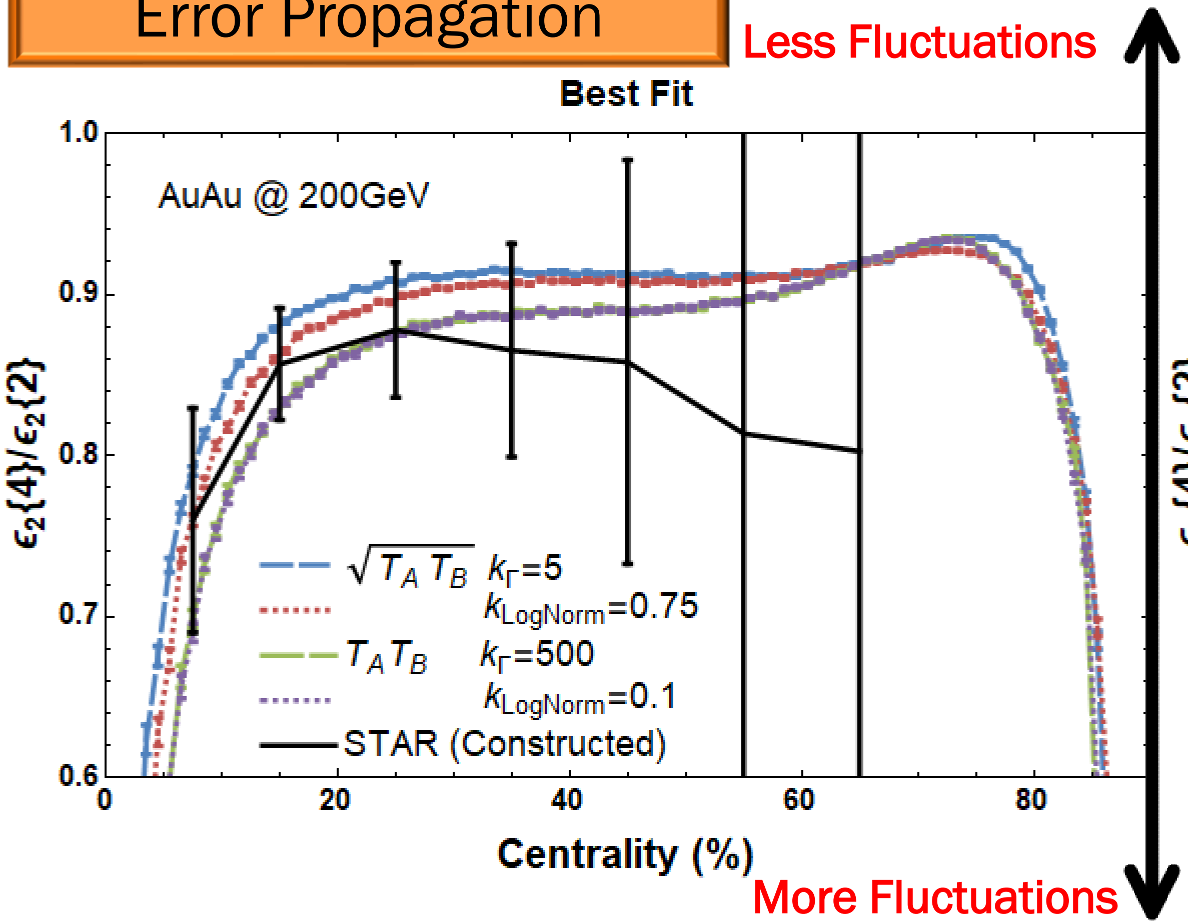


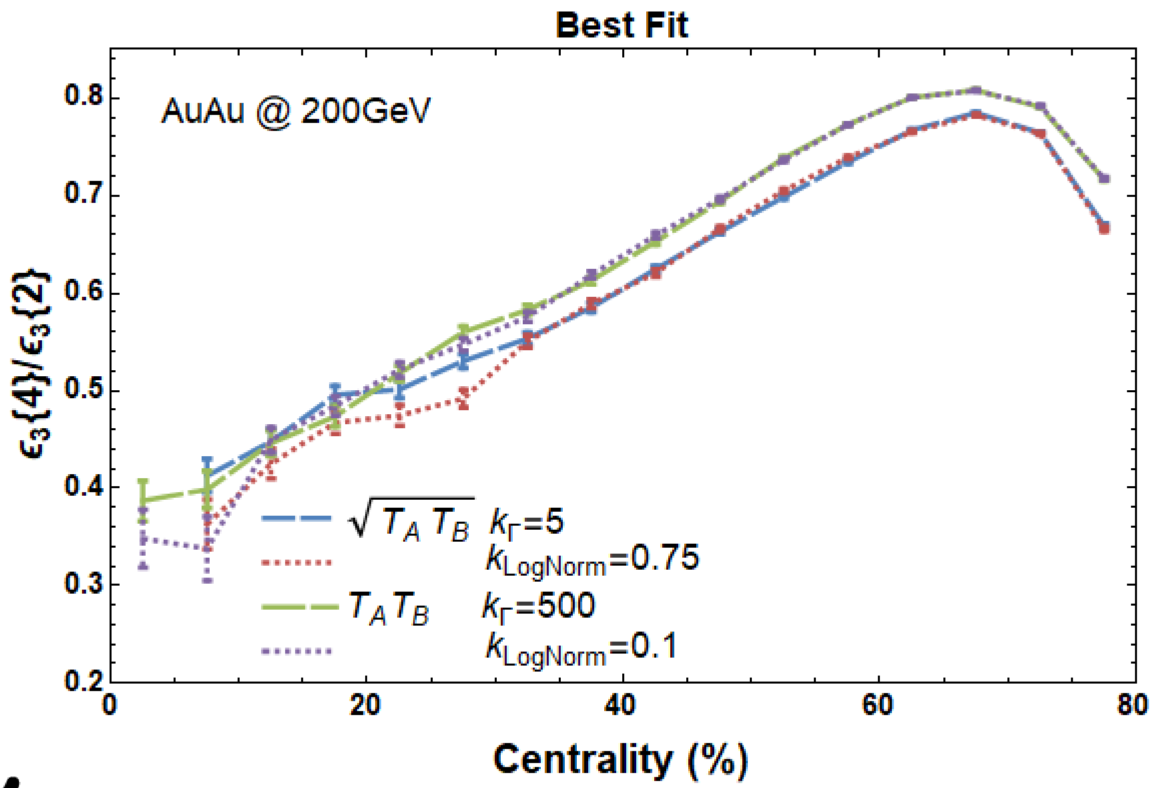


$T_A T_B$ gives a larger $\epsilon_3\{2\}$ than $\sqrt{T_A T_B}$, but they are the same in $\epsilon_2\{2\}$

4 Particle Cumulants

Error Propagation





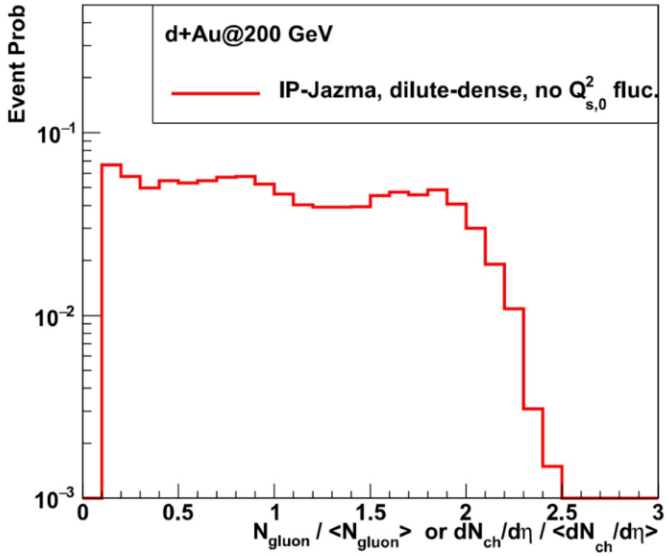
If error bars of $\frac{\epsilon_2\{4\}}{\epsilon_2\{2\}}$ data can be decreased by factor of 2 then the two models can be distinguished from each other.

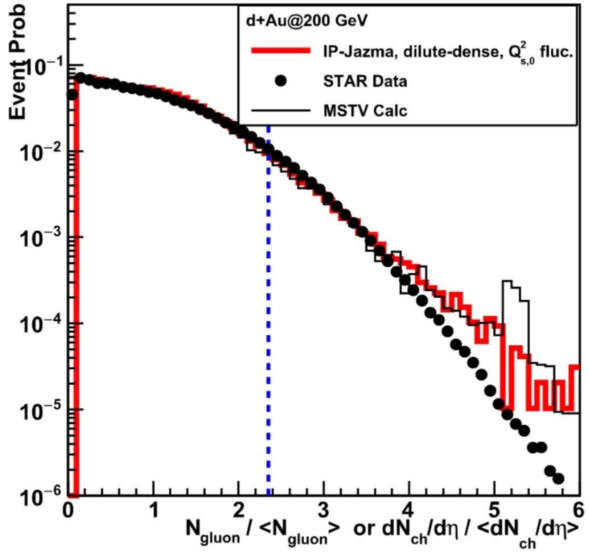
Conclusion

- Choice of functional form and multiplicity fluctuations can have an effect on extracted viscosity
- The effect on extracted viscosity is greater for small systems and less for large systems
- $\frac{\epsilon_2\{4\}}{\epsilon_2\{2\}}$ is good for distinguishing models

Future

- Both functional forms are symmetric, IP-JASMA used an asymmetric form with lognormal fluctuations
- Test sampling directly from the gluon spectrum
- Quantify the amount of an effect this would have on extracted viscosity





Asymmetric functional form: J. L. Nagle and W.A. Zajc,[arXiv:1808.01276[hep-th]]

BACKUP SLIDES