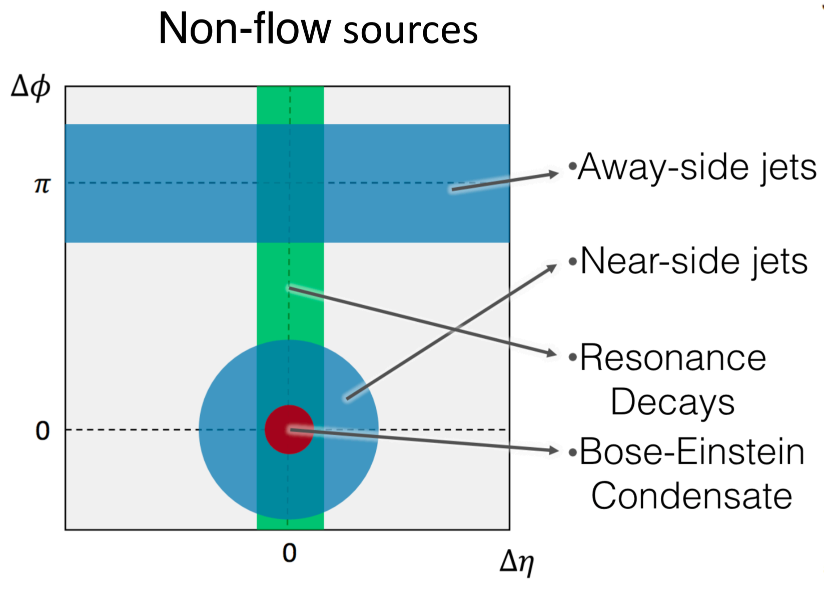
Measurement of multi-particle azimuthal correlations with the subevent method in *pp* and *p*+Pb collisions with the ATLAS detector

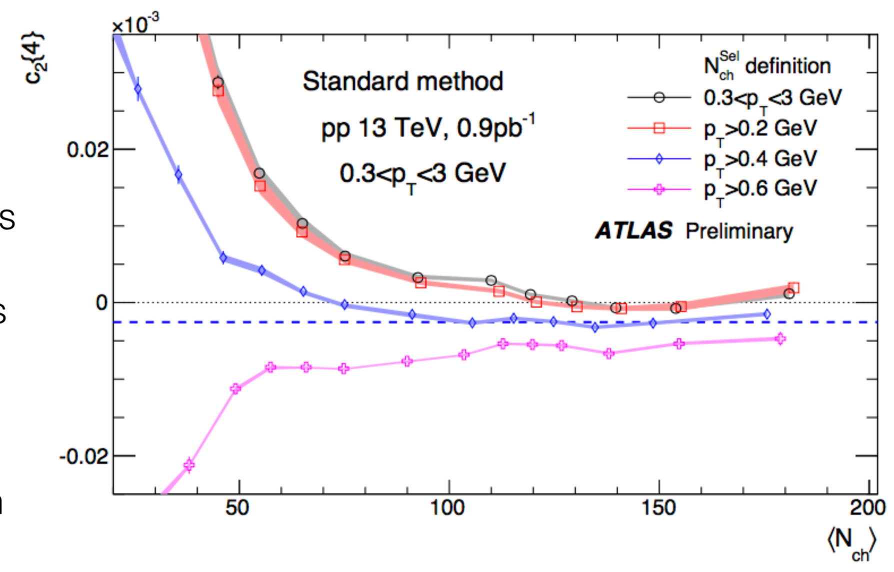
Arabinda Behera *for the ATLAS Collaboration*

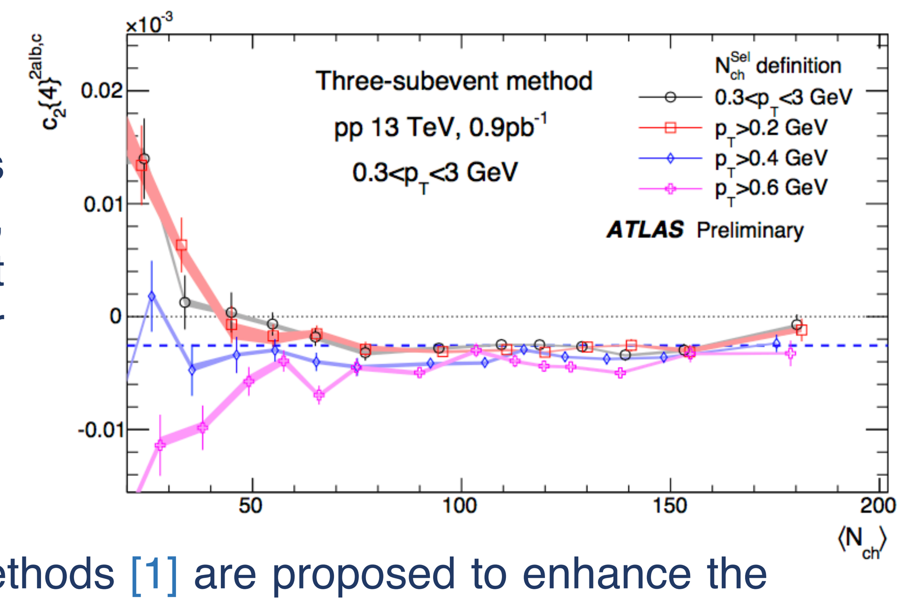
Stony Brook University

Motivation

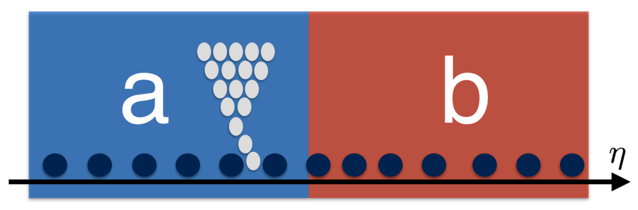
- Multiparticle cumulants [2] are useful to study the origin of ridge observed in small systems like *pp* and *p*+Pb.



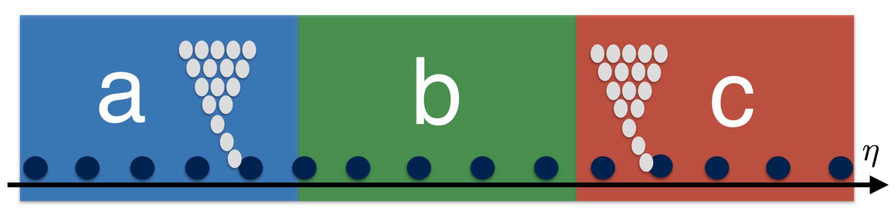




- Standard cumulant method [3] losses efficiency due to residual non-flow, has some dependence on the event selection and show sign change for different $\langle N_{ch}\rangle$ and p_T ranges.
- Two-subevent and three-subevent methods [1] are proposed to enhance the suppression of non-flow and remove any dependence on event selection.
- Two-subevent can suppress most non-flow contributions like near-side jets.



- Three-subevent can further remove away-side jets.



Analysis Method

- In multi-particle cumulant method, 2k-particle azimuthal correlations $\langle 2k\rangle$ and cumulants $c_n\{2k\}$ are calculated using per-particle normalised flow vectors q_k and factor ω_k

$$q_{n;k} \equiv \frac{\sum_i w_i^k e^{in\phi_i}}{\sum_i w_i^k} \equiv q_{n;k} e^{in\Psi_n}, \omega_k \equiv \frac{\sum_i w_i^{k+1}}{(\sum_i w_i)^{k+1}}$$

- Two-subevent method [1] :

$$\langle 2\rangle_{a|b} = \langle e^{in(\phi_1^a - \phi_2^b)}\rangle = Re[\mathbf{q}_{n,a}\mathbf{q}^*_{n,b}]$$

$$\langle 4\rangle_{2a|2b} = \langle e^{in(\phi_1^a+\phi_2^a-\phi_3^b-\phi_4^b)}\rangle = \frac{(\mathbf{q}_n^2 - \omega_1\mathbf{q}_{2n})_a (\mathbf{q}_n^2 - \omega_1\mathbf{q}_{2n})_b^*}{(1-\omega_1)_a(1-\omega_1)_b}$$

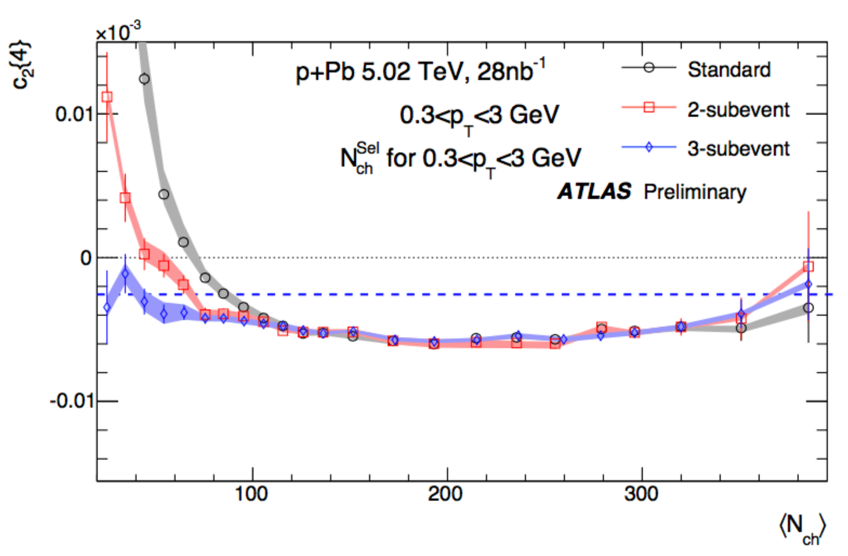
$$c_n^{2a|2b}\{4\} = \langle\langle 4\rangle\rangle_{2a|2b} - 2\langle\langle 2\rangle\rangle^2_{a|b}$$

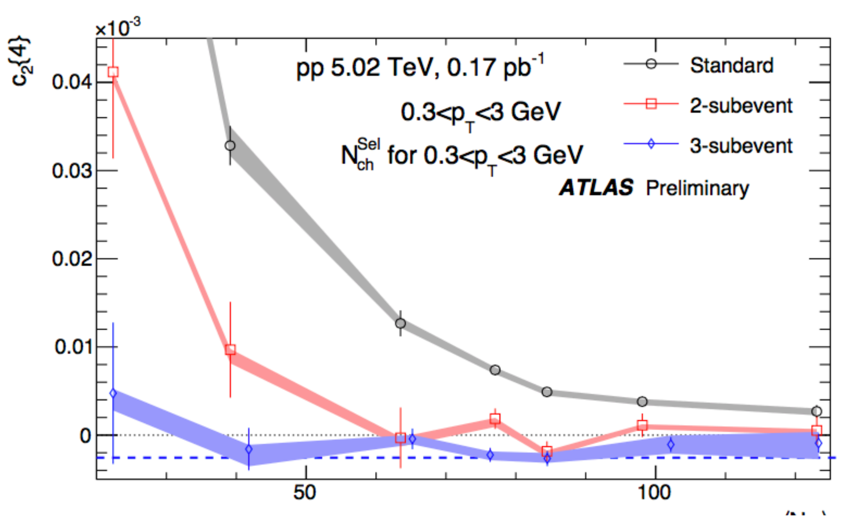
- Three-subevent method [1] :

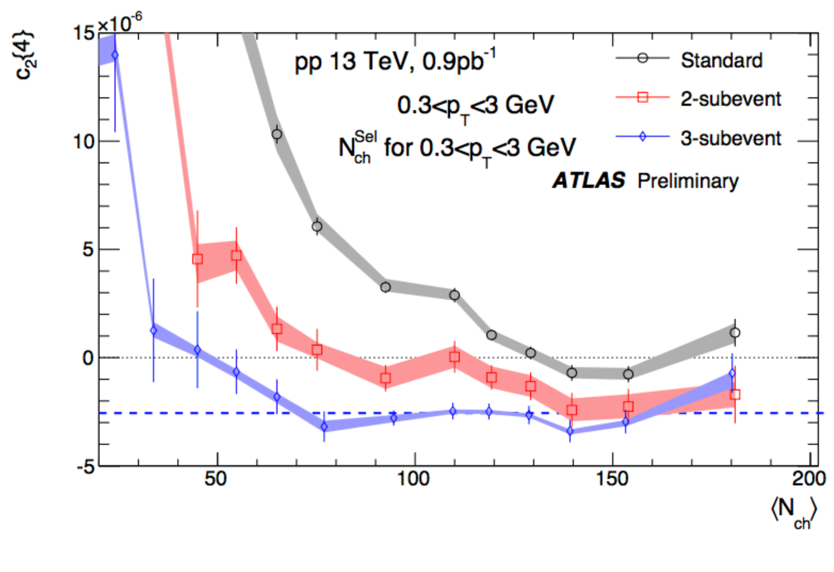
$$\langle 4\rangle_{2a|b,c} = \langle e^{in(\phi_1^a+\phi_2^a-\phi_3^b-\phi_4^c)}\rangle = \frac{(\mathbf{q}_n^2 - \omega_1\mathbf{q}_{2n})_a \mathbf{q}^*_{n,b}\mathbf{q}^*_{n,c}}{1-\omega_{1,a}}$$

$$c_n^{2a|b,c}\{4\} = \langle\langle 4\rangle\rangle_{2a|b,c} - 2\langle\langle 2\rangle\rangle_{a|b}\langle\langle 2\rangle\rangle_{a|c}$$

Comparison of three methods

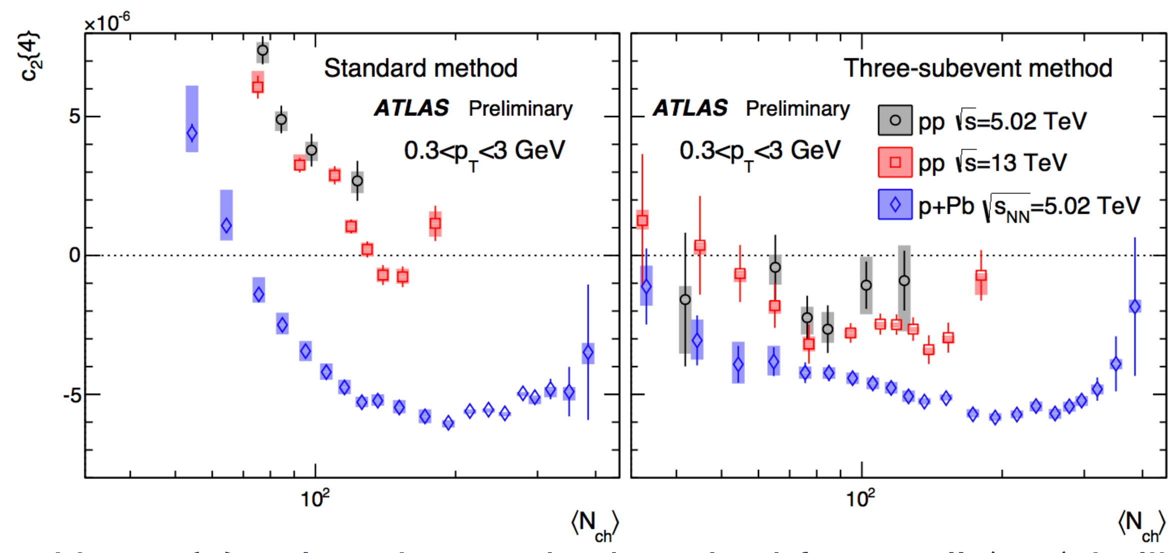




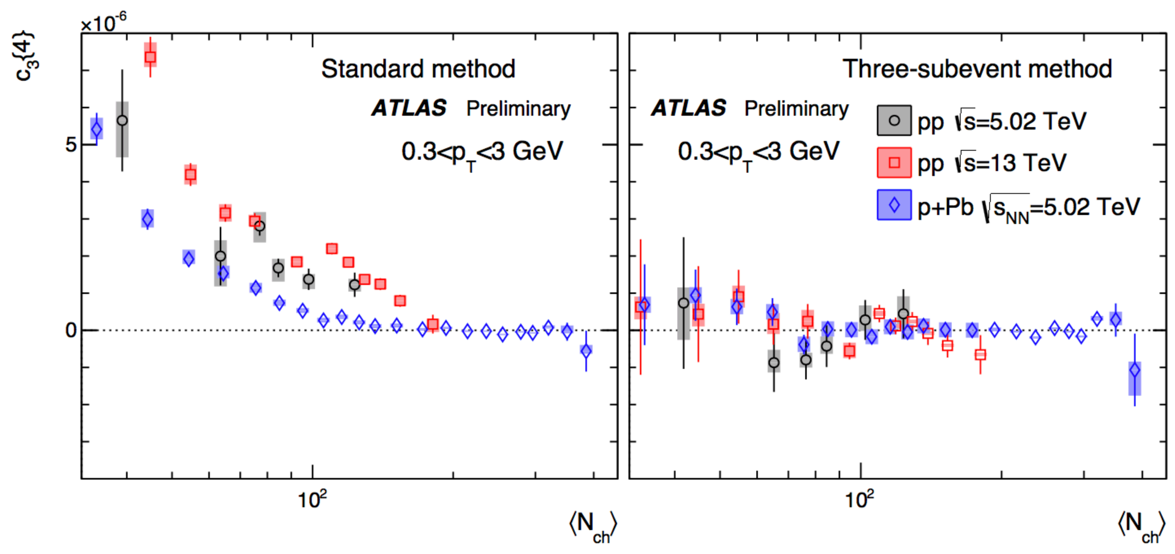


- In *p*+Pb, all three methods give consistent results for $\langle N_{ch}\rangle$ >100.
- In *pp*, in both energies, standard method gives wrong sign.
- Three subevent method gives the correct sign and lowest value in all three systems.
- Higher non-flow effect in *pp* than in *p*+Pb.

Comparison among collision systems

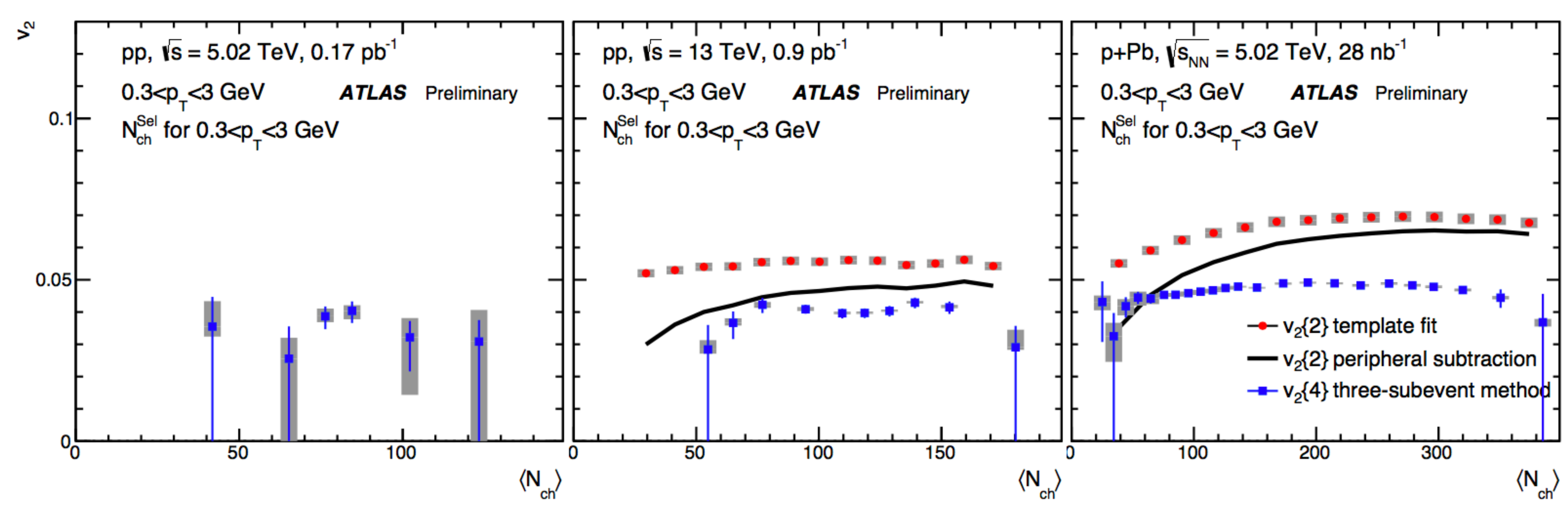


- Large positive $c_2\{4\}$ values in standard method for small $\langle N_{ch}\rangle$ is likely due to non-flow correlations.
- Three subevent-method shows correct sign for $c_2\{4\}$ in all collision systems.
- In both methods the hierarchy is : (*pp* data at $\sqrt{s} = 5.02\,TeV$) > (*pp* data at $\sqrt{s} = 13\,TeV$) > (*p*+Pb data $\sqrt{s} = 5.02\,TeV$)



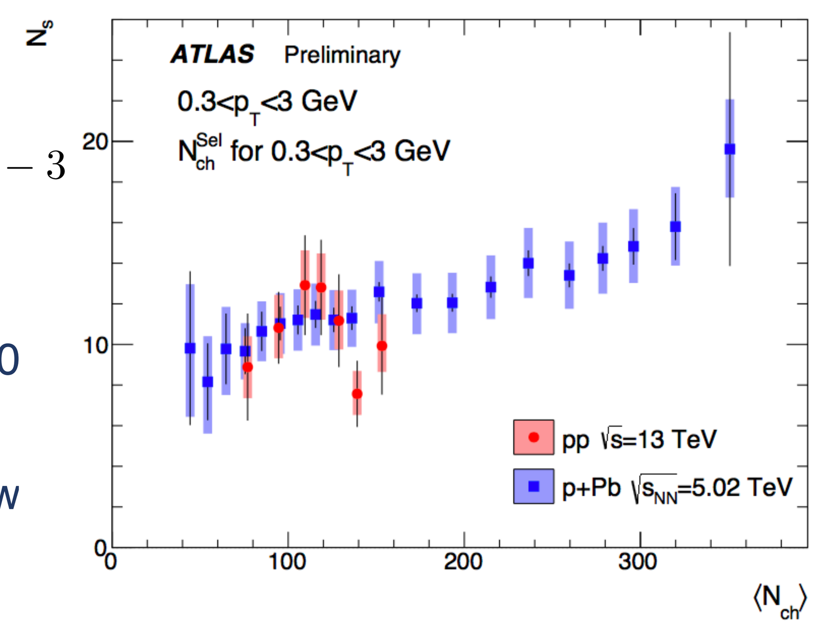
- In three-subevent $c_3\{4\}$ values are consistent with 0 in all collision systems.
- Standard method shows hierarchy in $c_3\{4\}$ due to non-flow.

Comparison of $v_2\{4\}$ with $v_2\{2\}$ and relation to N_S



- $v_2\{4\}$ from three-subevent method is smaller than $v_2\{2\}$ from two particle correlation analysis.
- The difference is interpreted as effect of event-by-event flow fluctuation associated with the effective number of sources of particle production [4].

$$\frac{v_2\{4\}}{v_2\{2\}} = \left[\frac{4}{(3+N_s)}\right]^{1/4} \quad or \quad N_s = \frac{4v_2\{2\}^4}{v_2\{4\}^4} - 3$$



- Model calculation shows increase in with $\langle N_{ch}\rangle$ in *p*+Pb collisions upto $N_S \sim 20$ the highest multiplicity class.
- For *pp* , N_S is approximately consistent w *p*+Pb for comparable $\langle N_{ch}\rangle$.

Summary

- Sensitivity to event class averiging of $c_2\{4\}$ is high in standard cumulant method, small in two-subevent and almost negligible in three-subevent method.
- Negative $c_2\{4\}$ is observed in all three collision system, with the magnitude independent of $\langle N_{ch}\rangle$, except in p+Pb having a slight decrease at high $\langle N_{ch}\rangle$.
- Single particle $v_2\{4\}$ is smaller than $v_2\{2\}$ from two-particle correlation and the ratio is used, in a model framework, to infer the number of sources N_S in initial state collision geometry.
- N_S is found to increase with $\langle N_{ch}\rangle$ in *p*+Pb and reaches 20 in high multiplicity events.

Reference

[1] J. Jia, M. Zhou, and A. Trzupek, arXiv:1701.03830 [nucl-th].

[2] N. Borghini, P. M. Dinh, and J.-Y. Ollitrault, Phys. Rev. C 63 (2001) 054906

[3] A. Bilandzic, R. Snellings, and S. Voloshin, Phys. Rev. C 83 (2011) 044913

[4] L. Yan and J.-Y. Ollitrault, Phys. Rev. Lett. 112 (2014) 082301, arXiv:1312.6555 [nucl-th]