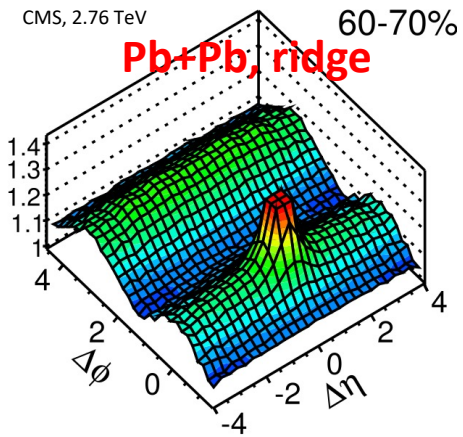
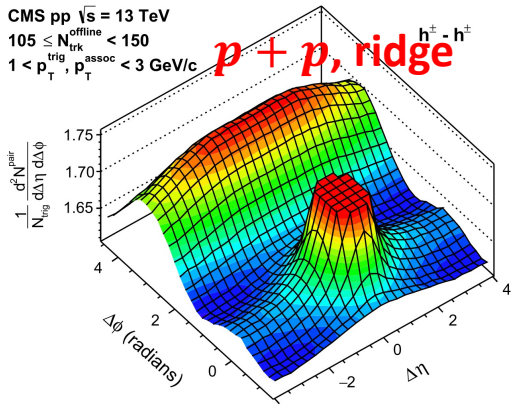
Sub-nucleon geometry and multiparticle cumulants including $c_2\{4\}$ in $p+p$ collisions

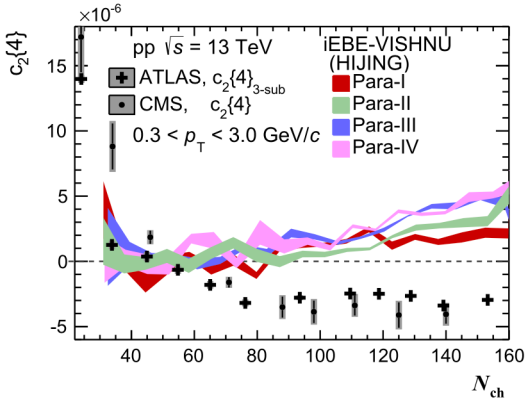


CMS, Eur. Phys. J. C (2012) 72:2012



CMS, Physics Letters B 765 (2017) 193–220

hydrodynamics-based hybrid model



W. Zhao et al., Physics Letters B 780 (2018) 495–500

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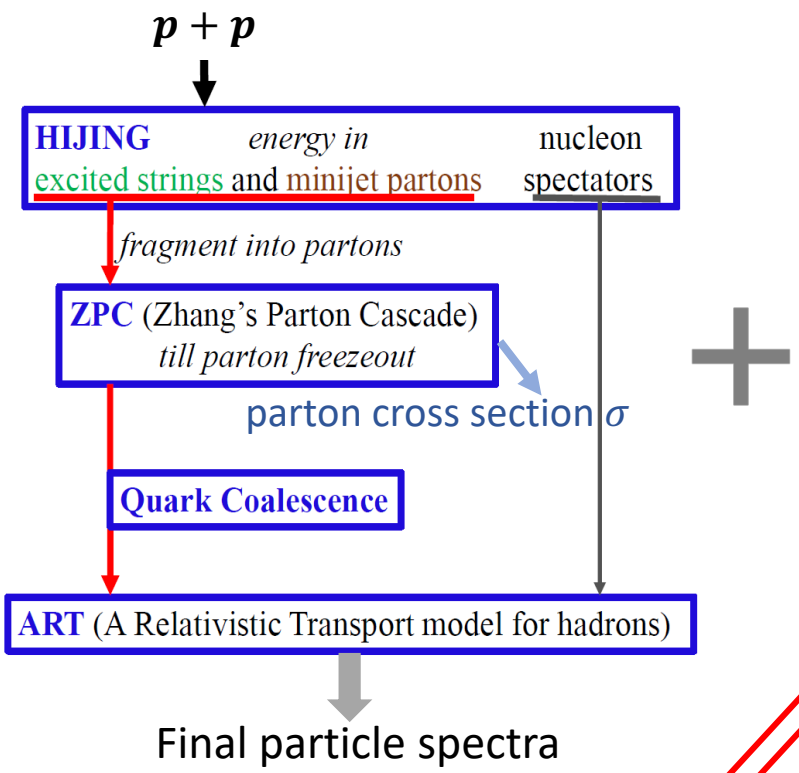
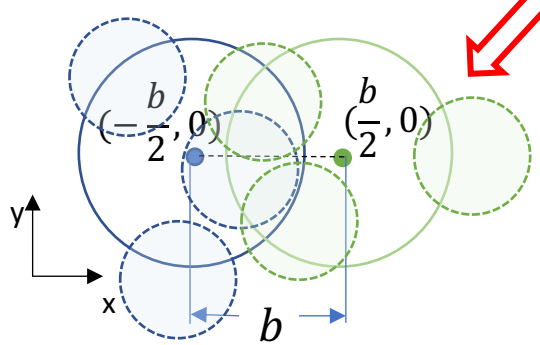
Developed Versions of the String Melting AMPT

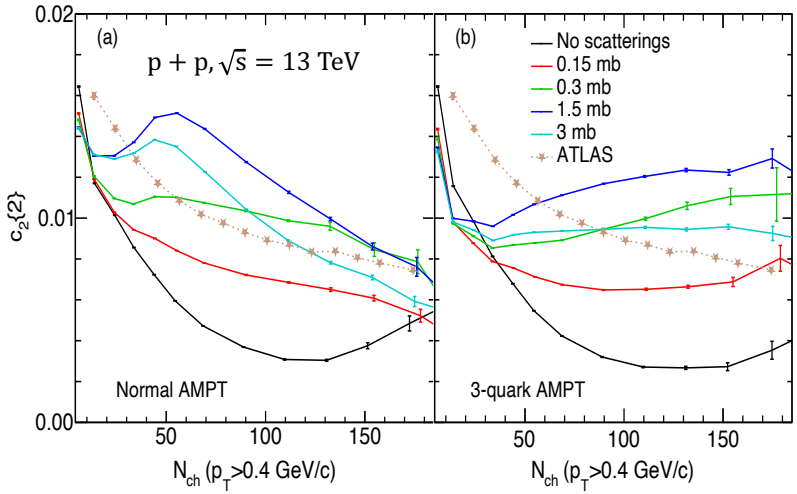


1. New quark coalescence model.
2. Improved heavy quark productions.
3. Modern set of parton distribution functions in proton and impact parameter-dependent nuclear shadowing.
4. Sub-nucleon geometry of the proton which consists of 3 constituent quarks.

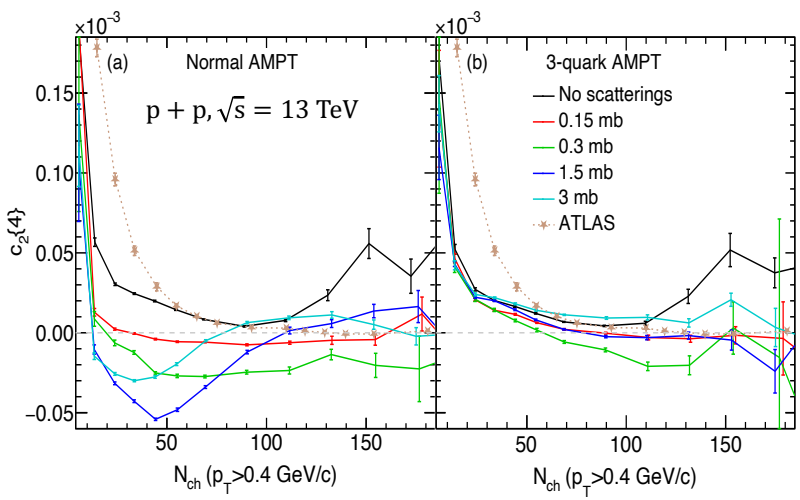


- **Normal AMPT** includes 1-3.
- **3-quark AMPT** includes 1-4.

N_{ch} Dependences of $c_2\{2\}$ & $c_2\{4\}$



- In normal AMPT, $c_2\{2\}$ for 0.3 mb and 3 mb are close to the data.
- In 3-quark AMPT, $c_2\{2\}$ for 3 mb is close to the data.



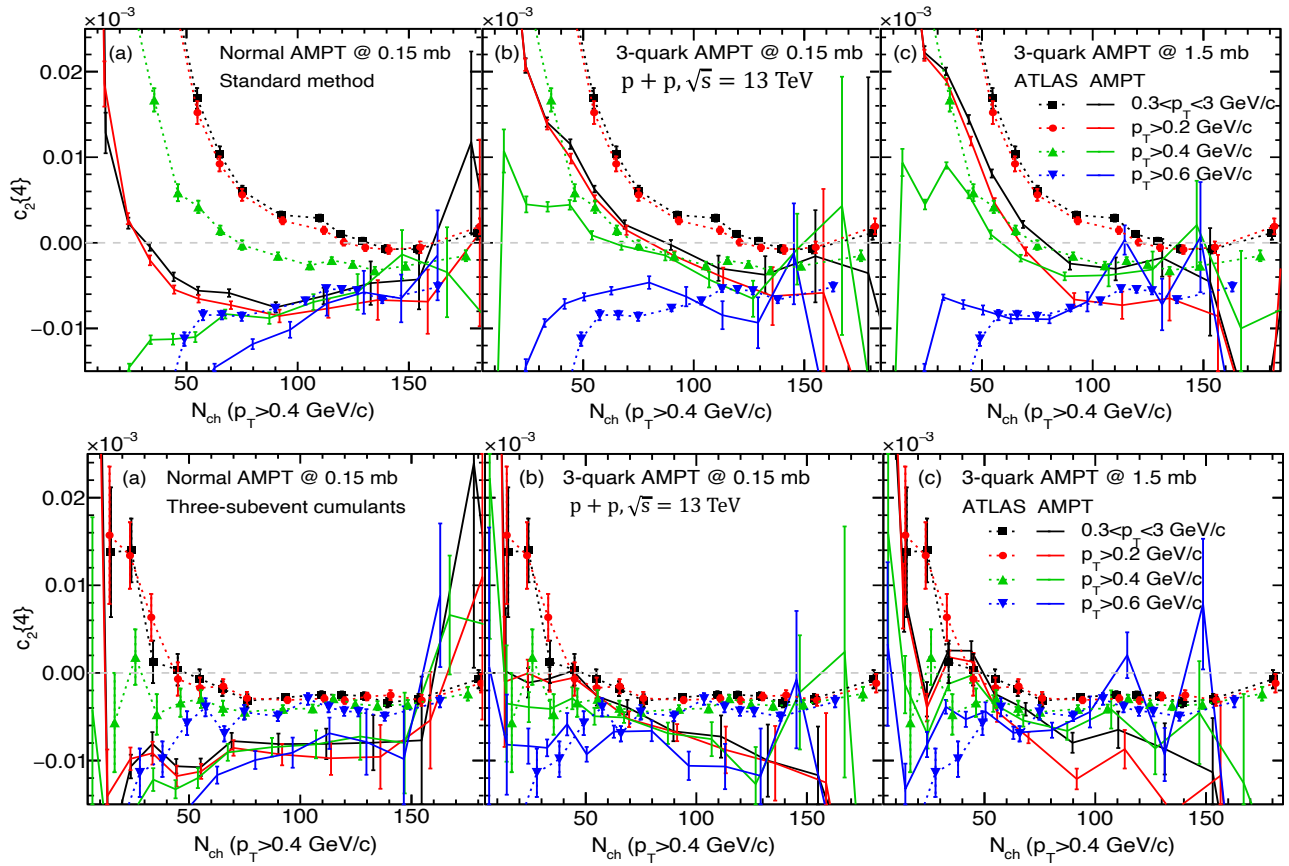
- In normal AMPT, $c_2\{4\} < 0$ at $N_{\mathrm{ch}} > 32$ for 0.3 mb.
- In 3-quark AMPT, $c_2\{4\}$ results have a similar multiplicity dependence as the data.
- $c_2\{4\}$ has a non-monotonous dependence on σ.

arXiv:2112.01232

Various p_T Selections of $c_2\{4\}$

Standard method

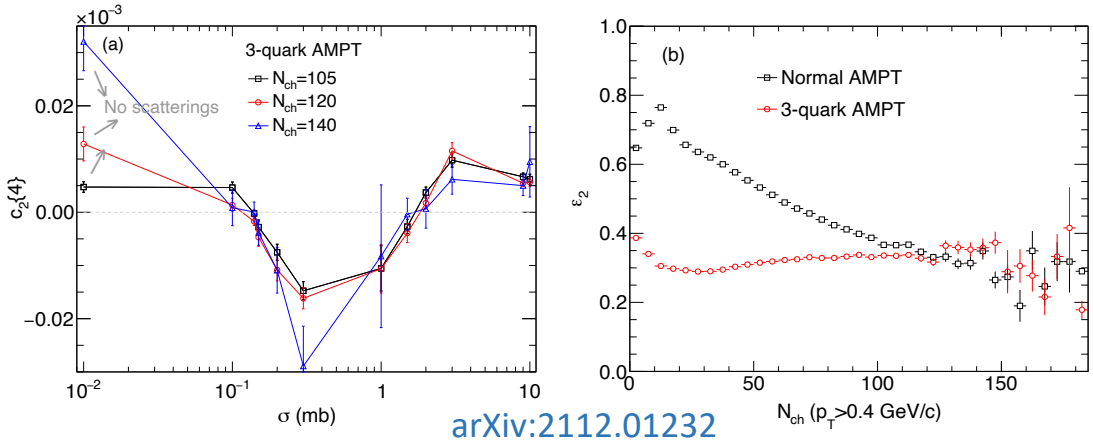
3-subevent method



arXiv:2112.01232

- The model results show the same qualitative behavior as data.
- $c_2\{4\}$ magnitudes from AMPT are often quite different from data.
- $c_2\{4\}$ and its sign-changed location depend sensitively on the sub-nucleon geometry for proton.

Discussion and Summary



arXiv:2112.01232

- $c_2\{4\}$ is so sensitive to σ as it changes sign at a very small σ value.
- The different spatial eccentricities partially cause the different results from the two AMPT models.

- $c_2\{4\}$ in normal AMPT and 3-quark AMPT produce negative values at high multiplicities.
- $c_2\{2\}$ and $c_2\{4\}$ depend strongly on σ and the dependences at high multiplicities are non-monotonous.
- AMPT results with a constant σ can't well reproduce the ATLAS $c_2\{2\}$ and $c_2\{4\}$ data.
- 3-quark AMPT results are in better agreements with the experimental data than the normal AMPT. This indicates the importance of including the sub-nucleon geometry of the proton in studies of multiparticle cumulants in $p+p$ collisions.