Baryon spectra and antiparticle/particle ratios from the improved AMPT model

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Mostly based on:
Y. He, Z. W. Lin, PRC 96, 014910 (2017)

Outline

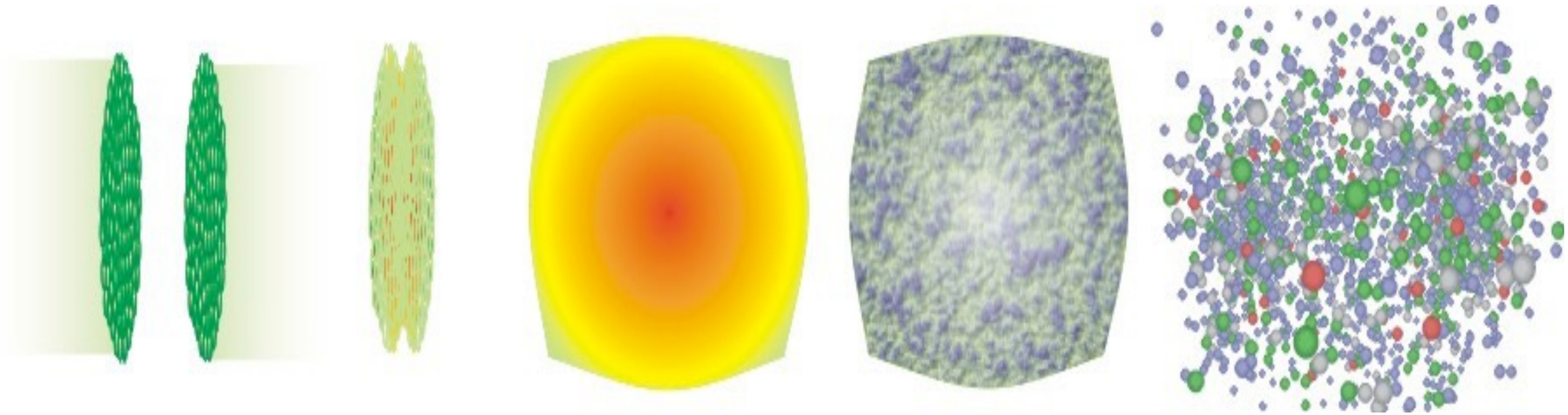
Current AMPT model

Improvement of quark coalescence in AMPT

Results for baryons

Summary

Heavy ion collisions

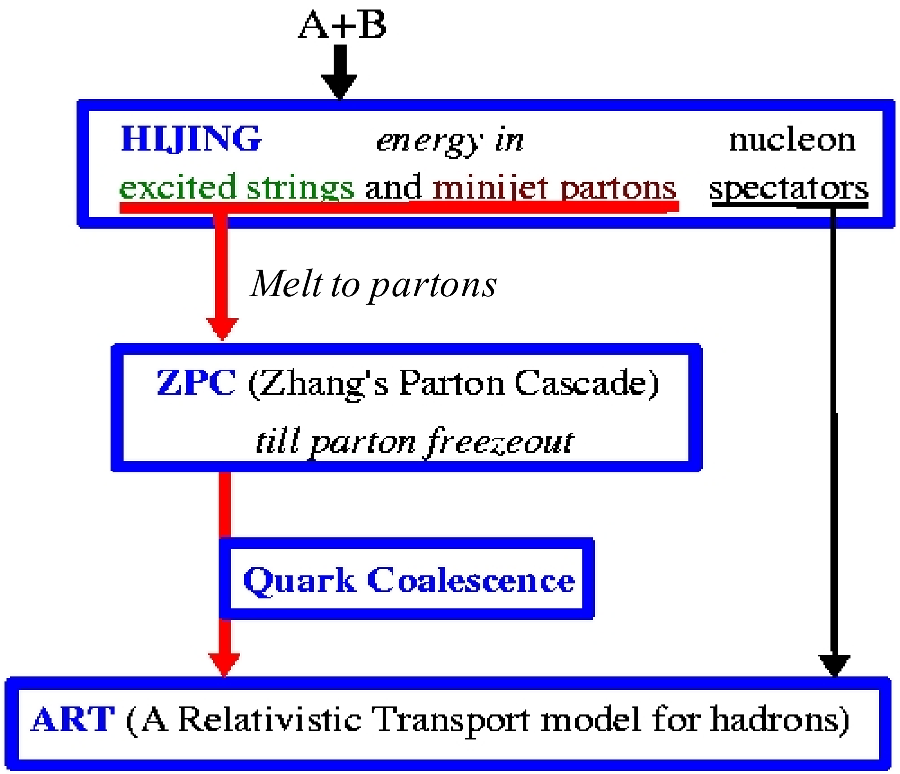


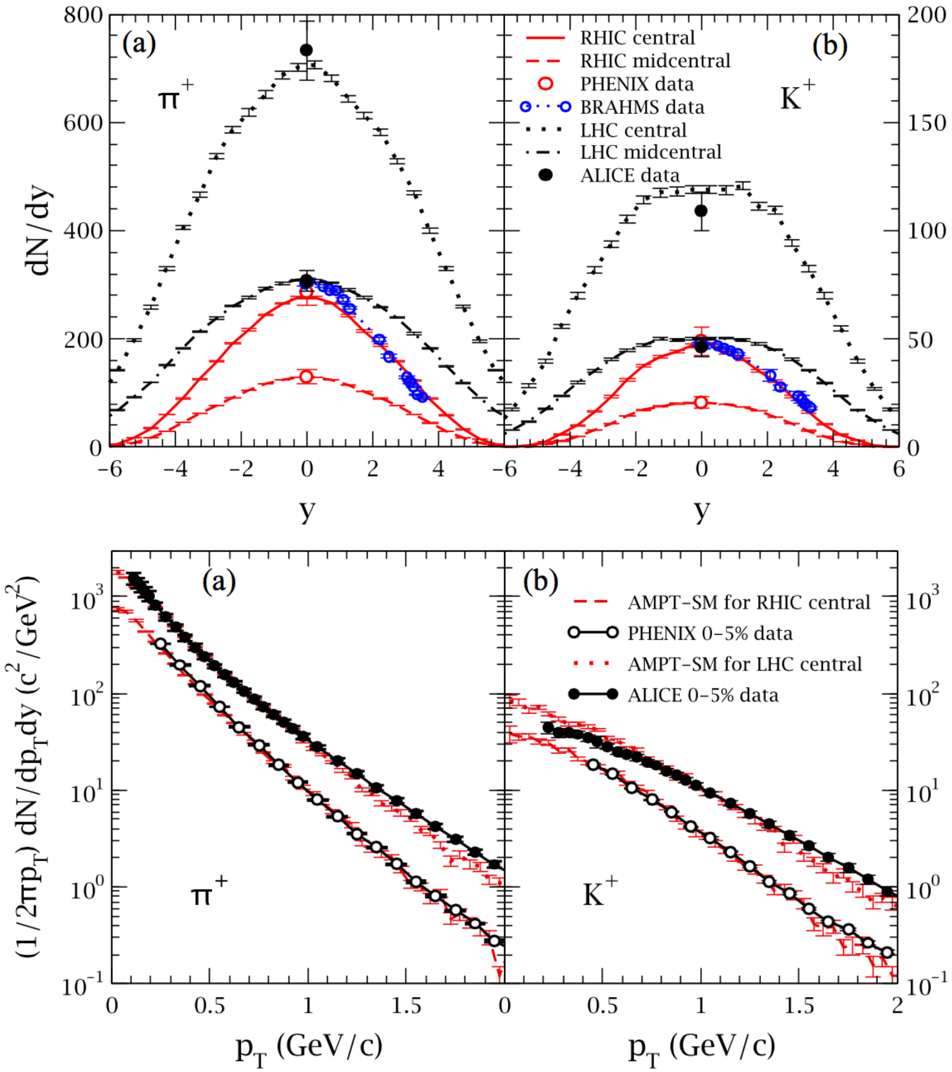
A Multi-phase Transport (AMPT) Model

incorporates four stages to simulate the heavy ion collisions:

1. Initial Condition 2. Partonic Cascade 3. Hadronization 4. Hadronic Rescatterings

String Melting AMPT





Well describes the yields, momentum spectra of mesons, and π/K/p flows below ~2GeV/c

Z. W. Lin, Phys. Rev. C 90, 014904 (2014)

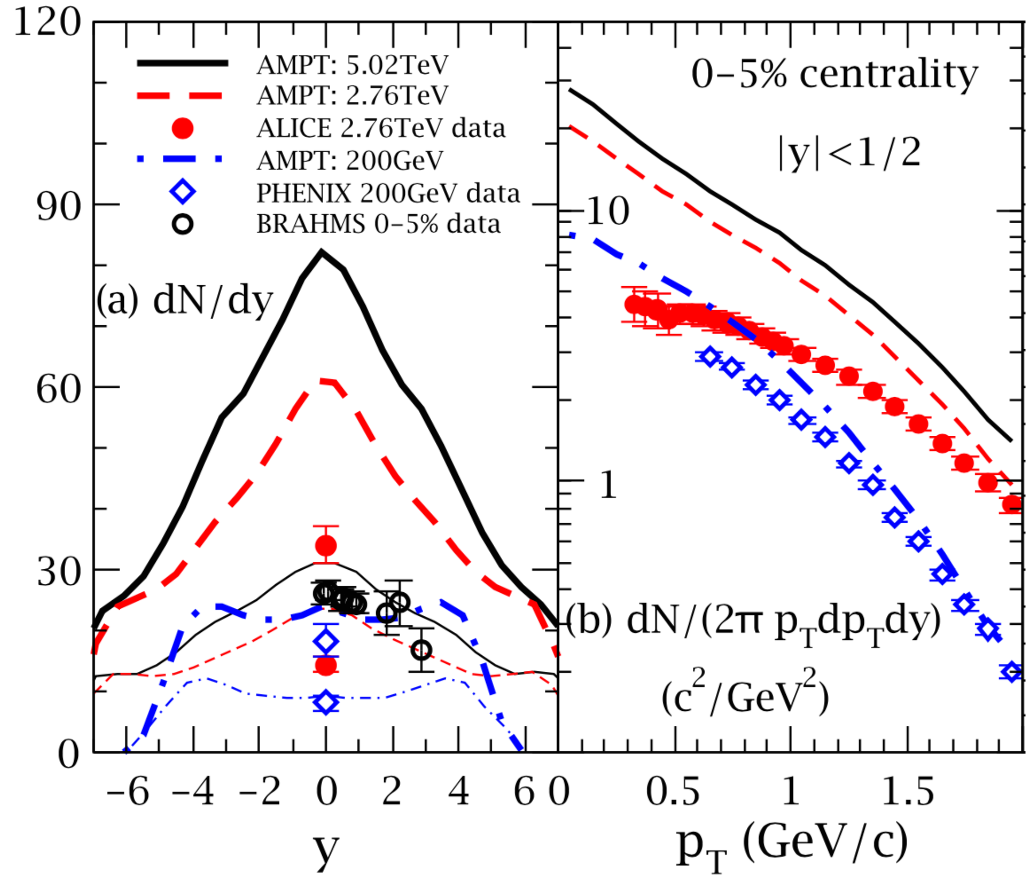
Problems for baryons

The current AMPT model:

overestimates the proton yield at mid-rapidity

underestimates the slope of proton p_T spectra

anti-baryon to baryon ratios for strange baryons are often above one, especially for multi-strangeness



G. L. Ma, Z. W. Lin, Phys. Rev. C 93, 054911 (2016)

Old coalescence *(coalescence in the current AMPT model)*

$\longrightarrow$ t

$q_{\overline{B}}$ q_m q_B $\overline{q}_m$ ....

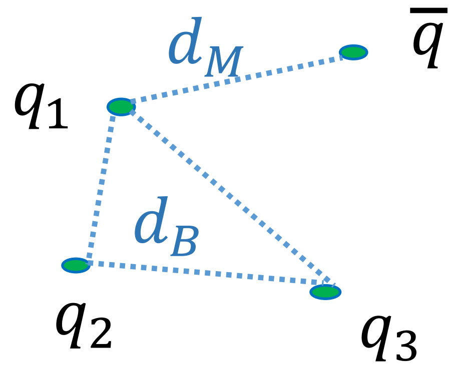
Forces the separate conservation of the numbers of mesons, baryons and antibaryons for each event (*an artificial constraint*)

First, quarks from the melting of mesons search all antiquarks and choose the closest antiquark to form mesons.

Then, quarks from the melting of baryons search all remaining quarks and choose the closest two quarks to form baryons (same for anti-baryons).

New coalescence

We remove the artificial constraint that forces the separate conservation of the numbers of mesons, baryons and antibaryons for each event.



For example, for a quark q_1:

d_M: the closest distance to an antiquark

d_B: the average distance among the 3 quarks after finding closest q_2 & q_3.

If $d_B < d_M * r_{BM}$, q_1 will coalesce to a baryon;

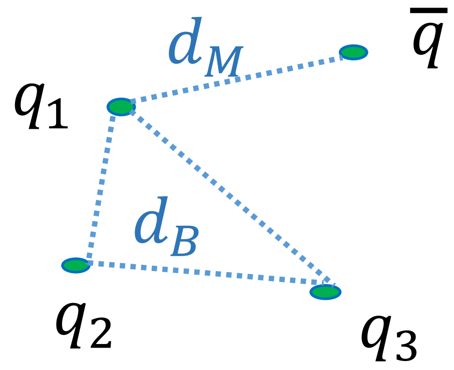
otherwise, q_1 will coalesce to a meson.

New coalescence parameter r_{BM}

New coalescence

New coalescence parameter r_{BM}

In the limit of $r_{BM} \to 0$,
there would be no antibaryon
formation at all
(when netbaryon ≥0).

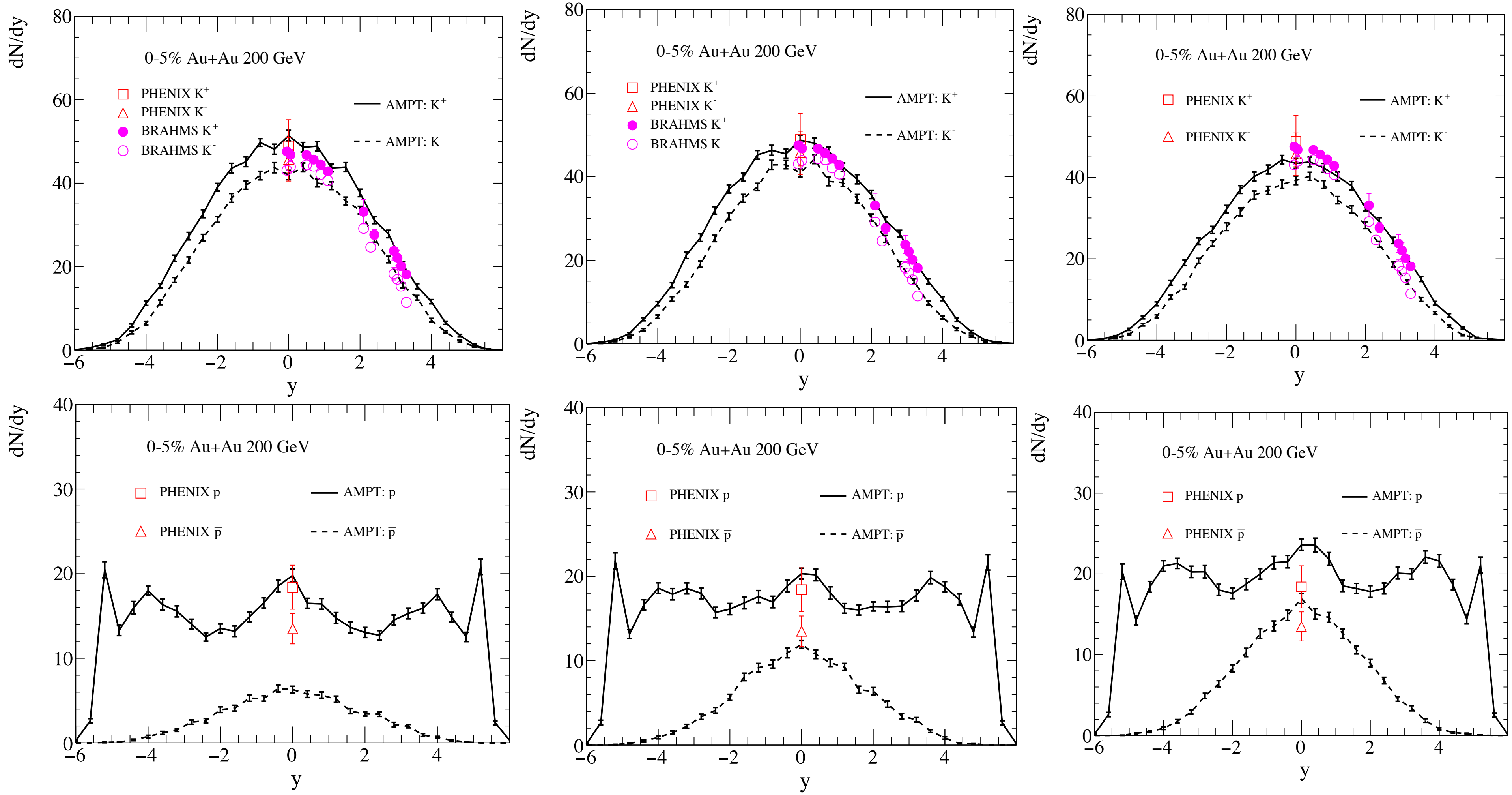


In the limit of $r_{BM} \to \infty$,
there would be
almost no meson formation.

If $d_B < d_M * r_{BM}$, q_1 will coalesce to a baryon;
otherwise, q_1 will coalesce to a meson.

New coalescence

$r_{BM} = 0.5$ $r_{BM} = 0.61$ $r_{BM} = 0.7$



r_{BM} strongly affects the yields of baryons and antibaryons.

r_{BM} =0.61 is used in all following calculations.

Summary of Improvement

Old coalescence

Numbers of mesons, baryons and antibaryons are forced to be conserved separately for each event.

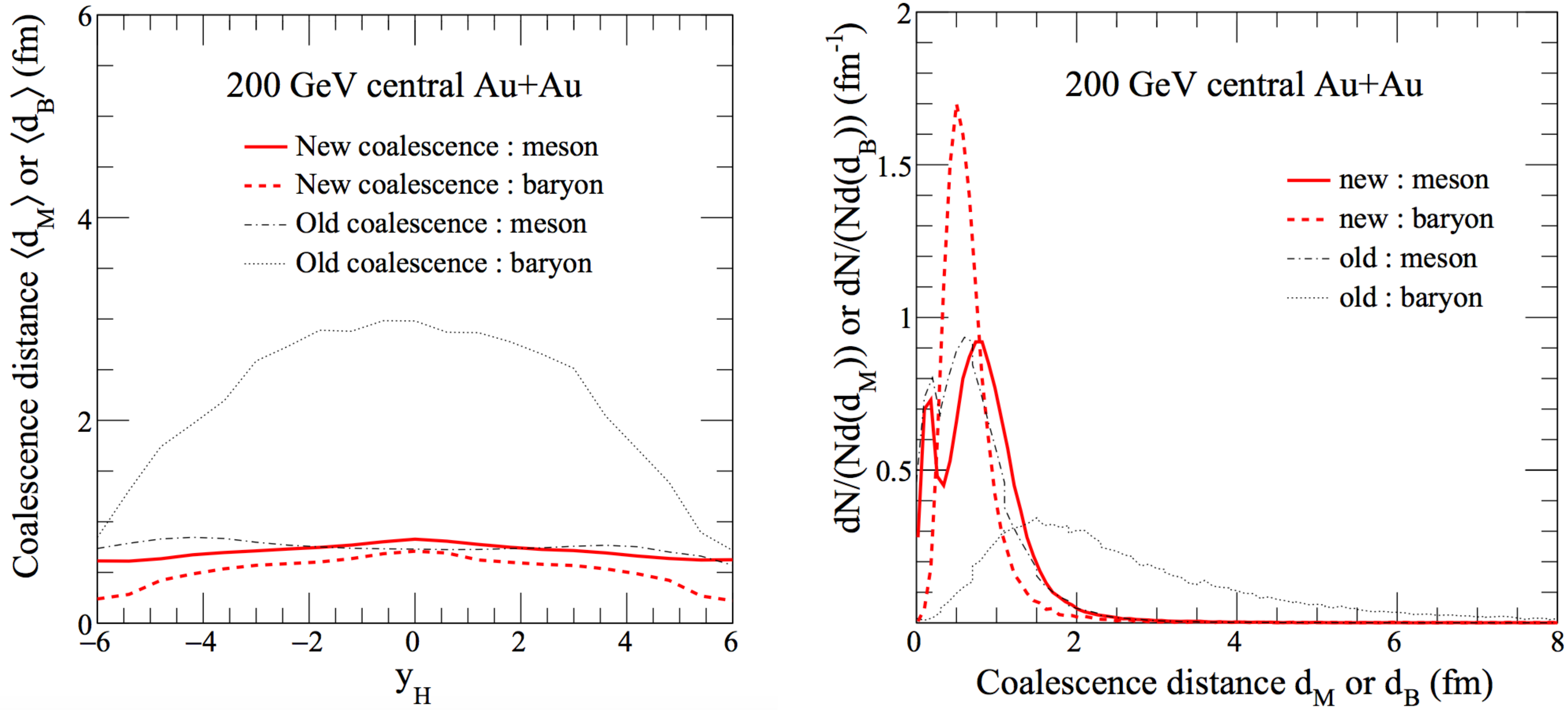
E.g. quark from melting of a meson can only form a meson.

New coalescence

Remove the artificial separate conservation *(conservation of net-baryon number is automatically satisfied)*.

A quark has the freedom to form either a meson or a baryon (*depending on the distance to potential coalescence partners*).

Coalescence distance

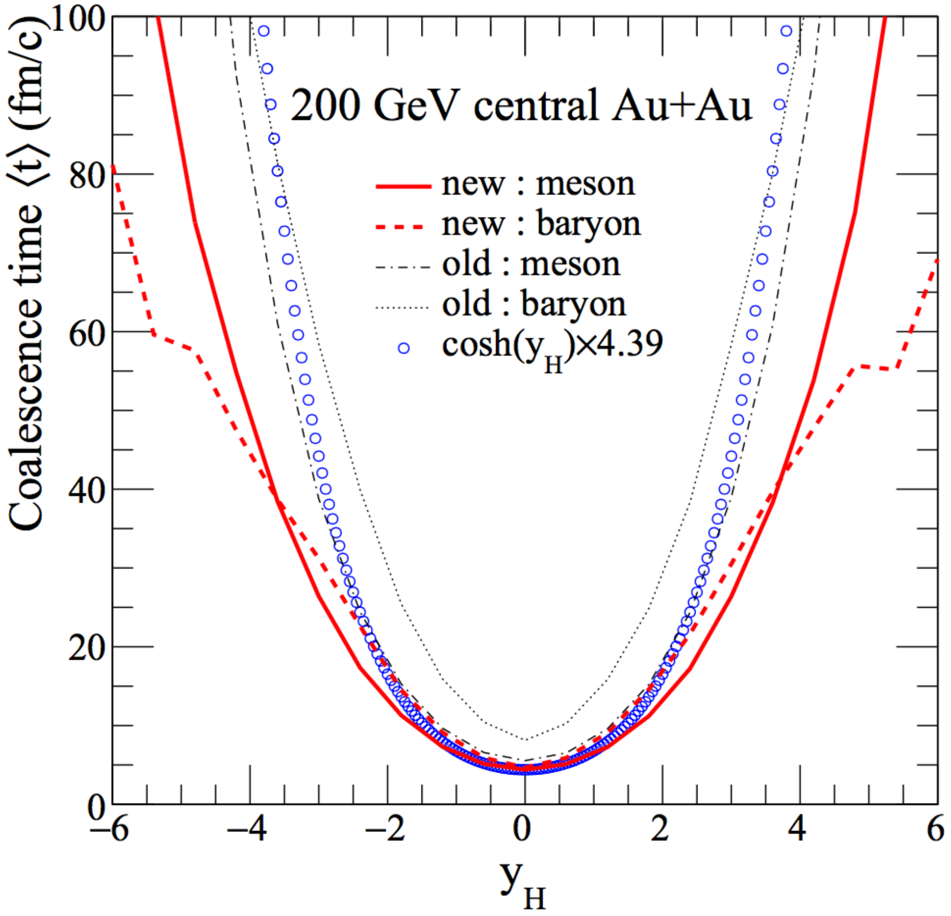


The average distance for (anti)baryons from the new quark coalescence (dashed curves) is much lower than that from the old quark coalescence (dotted curves) .

The distance for mesons is similar to the old model.

The new quark coalescence is more efficient, especially for baryons.

Coalescence time

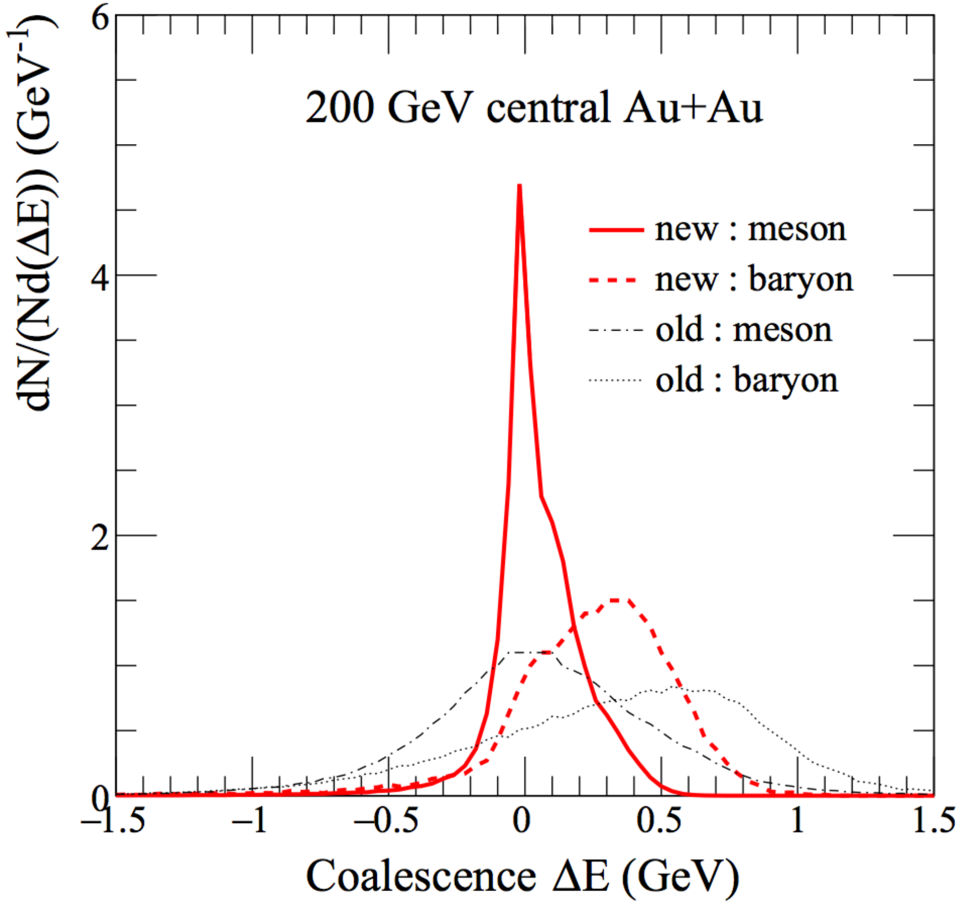


In the old coalescence (black curves) , (anti)baryons are formed about 2.6 fm/c later than mesons at midrapidity.

In the new coalescence, baryons and anti-baryons (red dashed curves) are now formed much earlier than before(black dotted curves).

Due to boost invariant , the coalescence time has a cosh dependence on rapidity (circles) as expected.

Coalescence ΔE



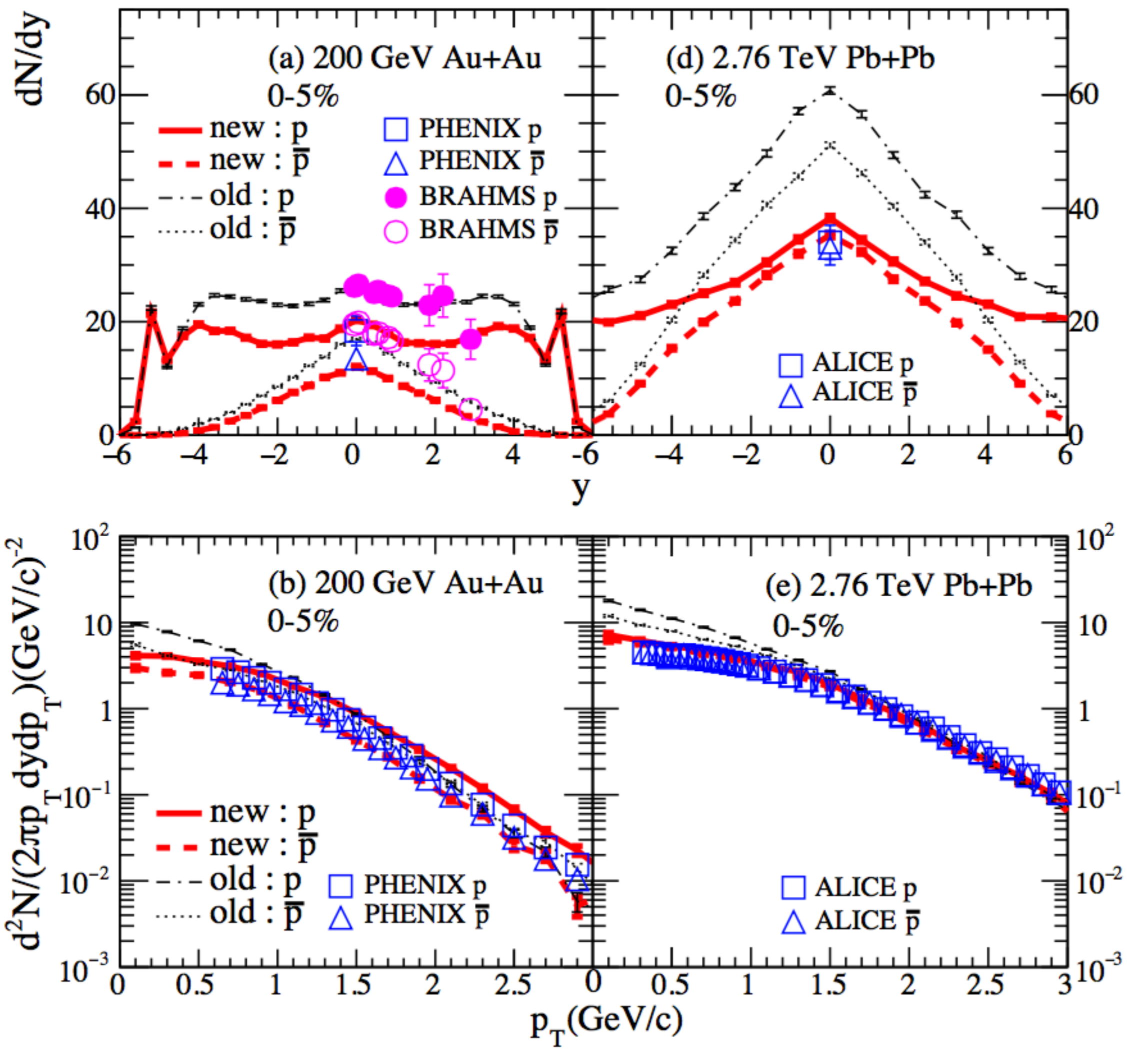
The string-melting AMPT model conserves the three-momentum while violating energy conservation.

$\Delta E = E_H\text{-}\sum E_p$

The widths from the new quark coalescence(red) are narrower than the old results (black).

The new quark coalescence performs better in terms of energy conservation.

Proton yields and spectra



The proton yields at mid-rapidity from the new coalescence(red curves) are more closed to the data at RHIC and LHC.

The new coalescence(red curves) describes the proton p_T spectra with proper slopes.

Note: 200GeV data from BRAHMS do not include feed-down corrections.

Strange baryon yields

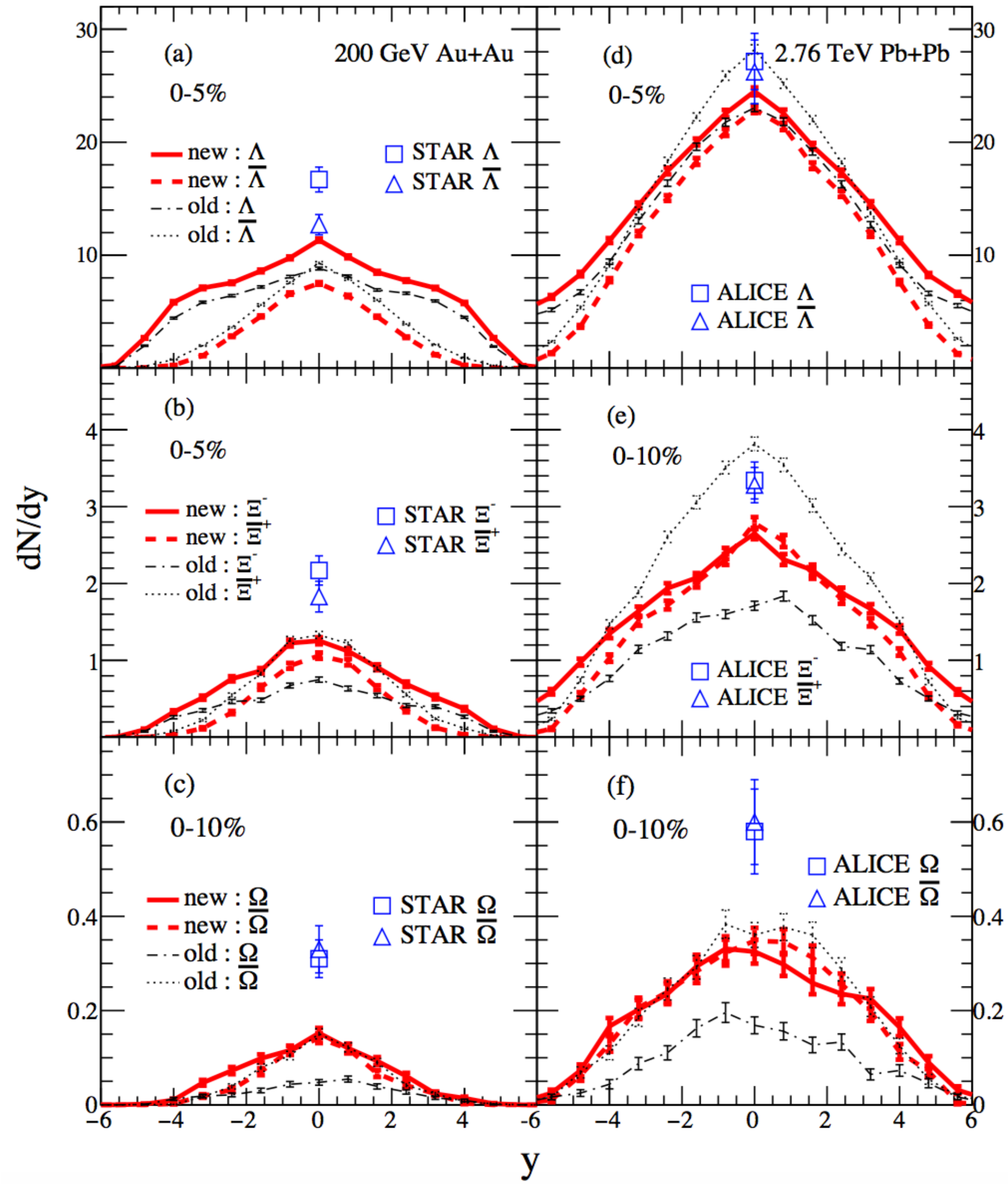
In the new coalescence(red curves):

Yield of strange baryons increases,

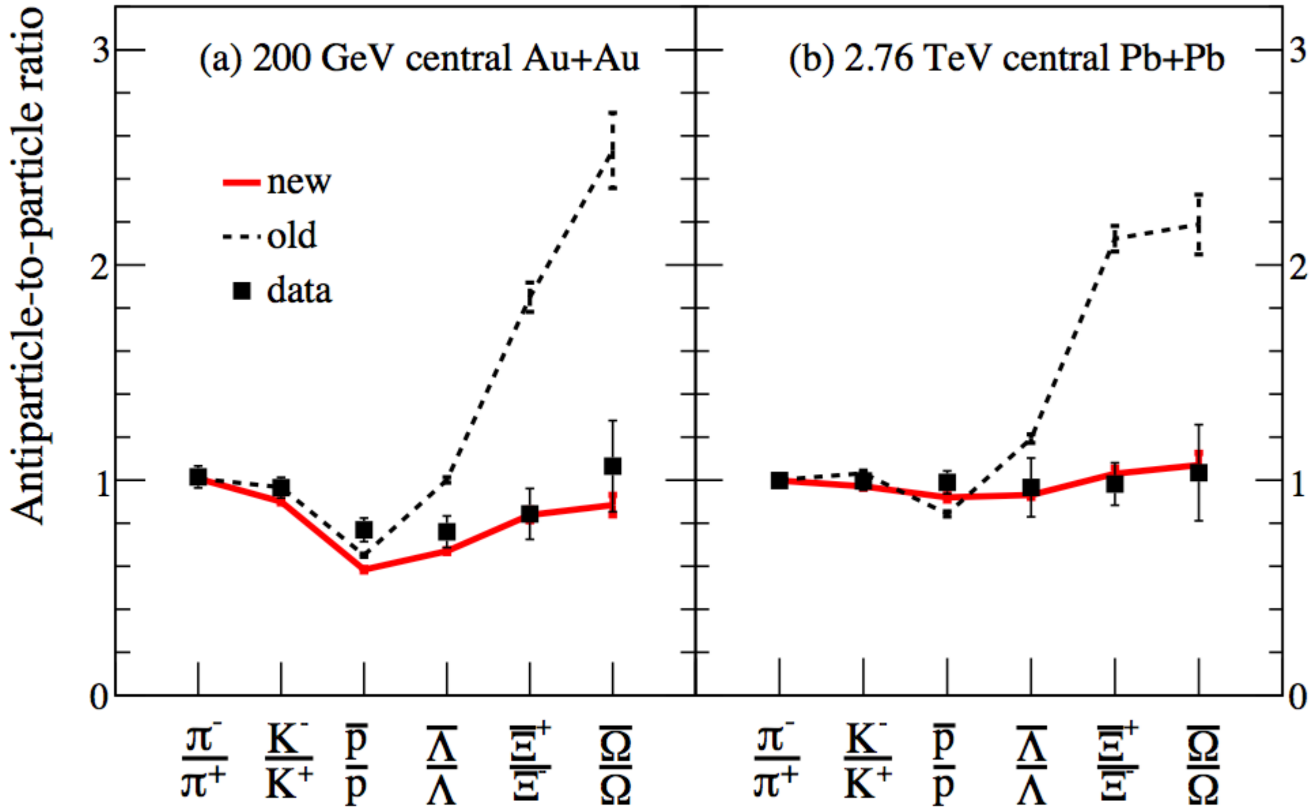
yield of strange antibaryons decreases,

as a result,
anti-baryon to baryon ratios for strange baryons are no longer above one.

Yields are still often below data (*should be related to lack of strangeness production in the parton cascade of AMPT*).

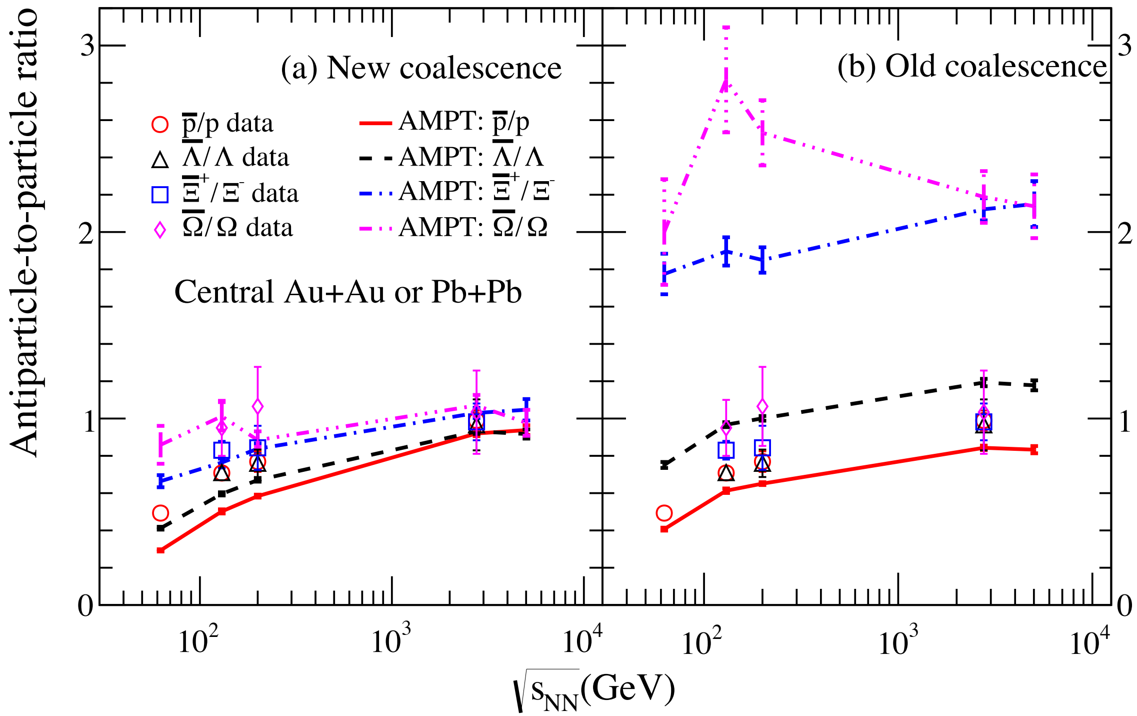


Anti-particle to particle ratio



Anti-particle to particle ratios around mid-rapidity from new coalescence(red curves) are more consistent with data, especially for strange (anti)baryons.

Anti-particle to particle ratio



Energy dependence of the antibaryon-to-baryon ratio around mid-rapidity from new coalescence(left) is more consistent with data, especially for strange (anti)baryons.

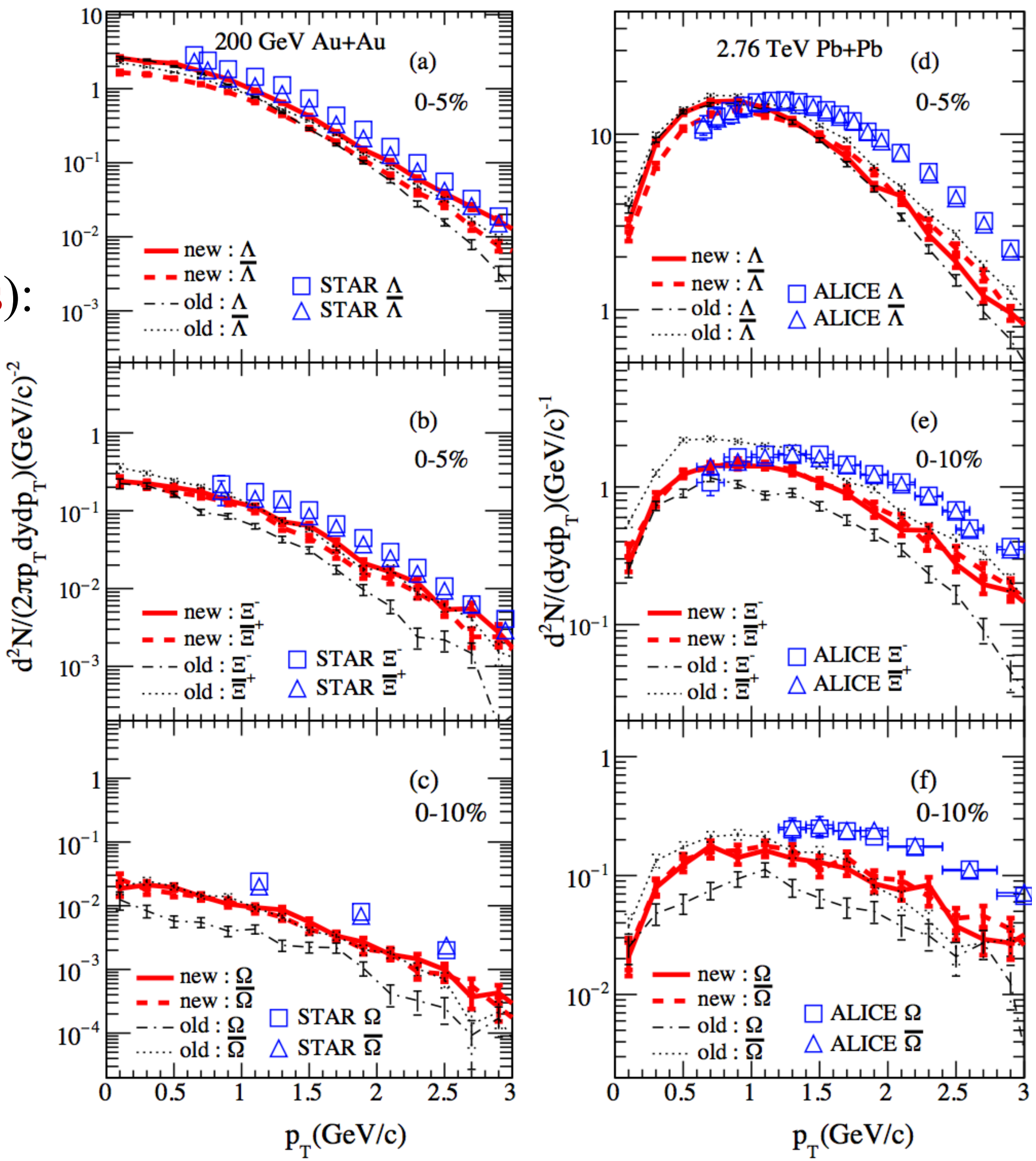
Strange baryon spectra

In the new coalescence(red curves):

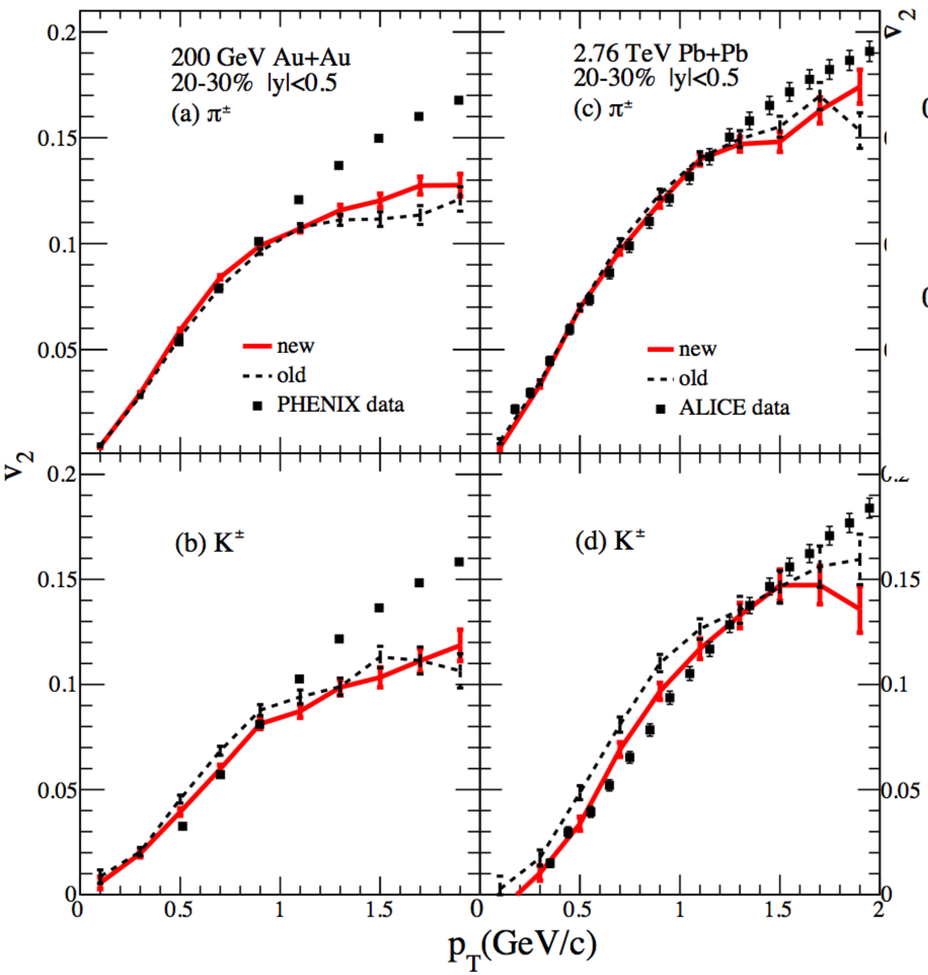
spectra of strange baryons increase,

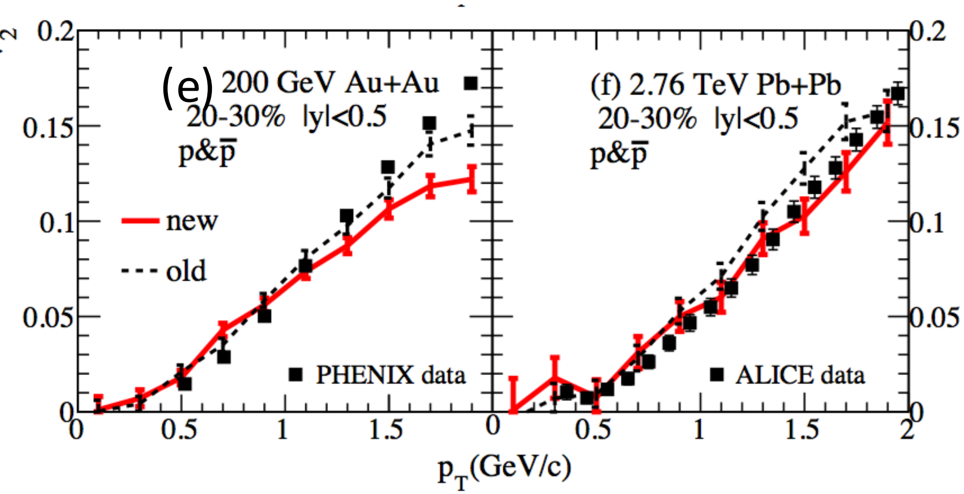
spectra of strange antibaryons decrease.

Slopes are more consistent with data overall,
still sometimes too steep at LHC.



V_2 results show little change





Since v2 is a normalized variable.

Meson results also show little change.

Summary

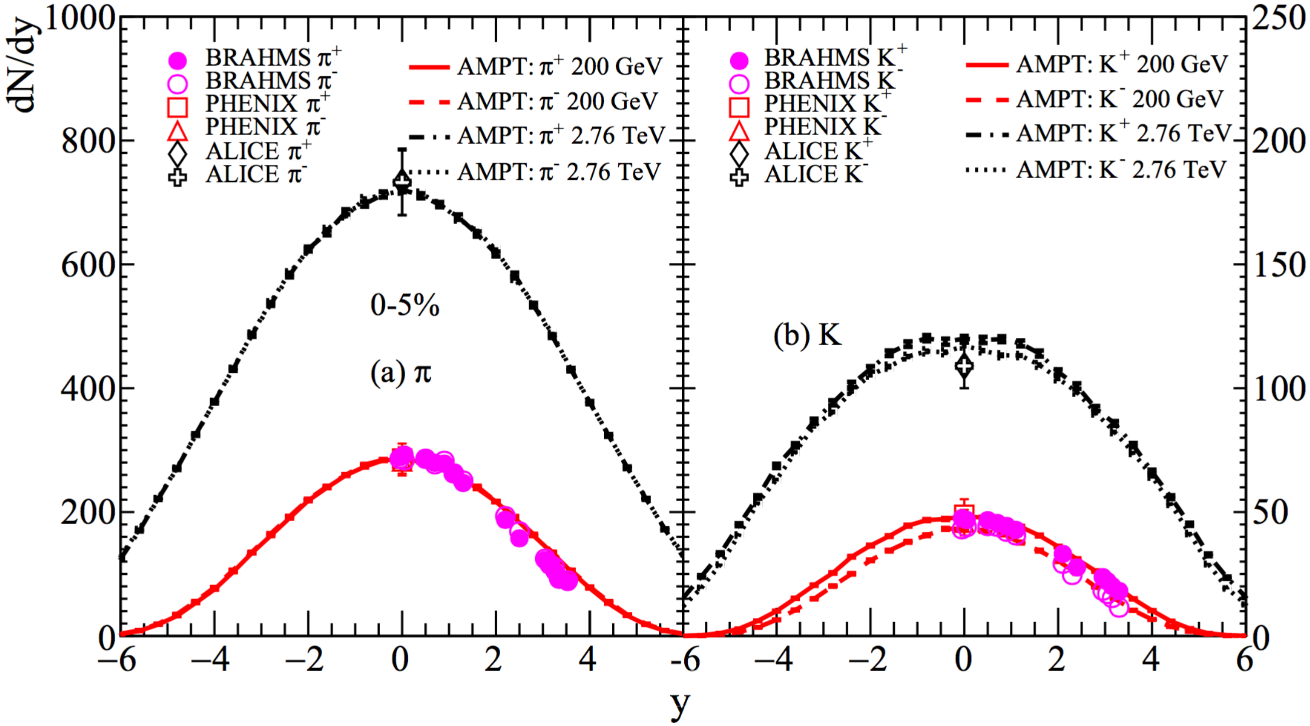
The new quark coalescence in AMPT has removed the artificial constraint on the separate conservation of the numbers of mesons, baryons, and antibaryons.
A quark now has the freedom to form either a meson or a baryon.

The new quark coalescence improves the (anti)baryon yields and momentum spectra in comparison with data, including antibaryon-to-baryon ratios for strange baryons.

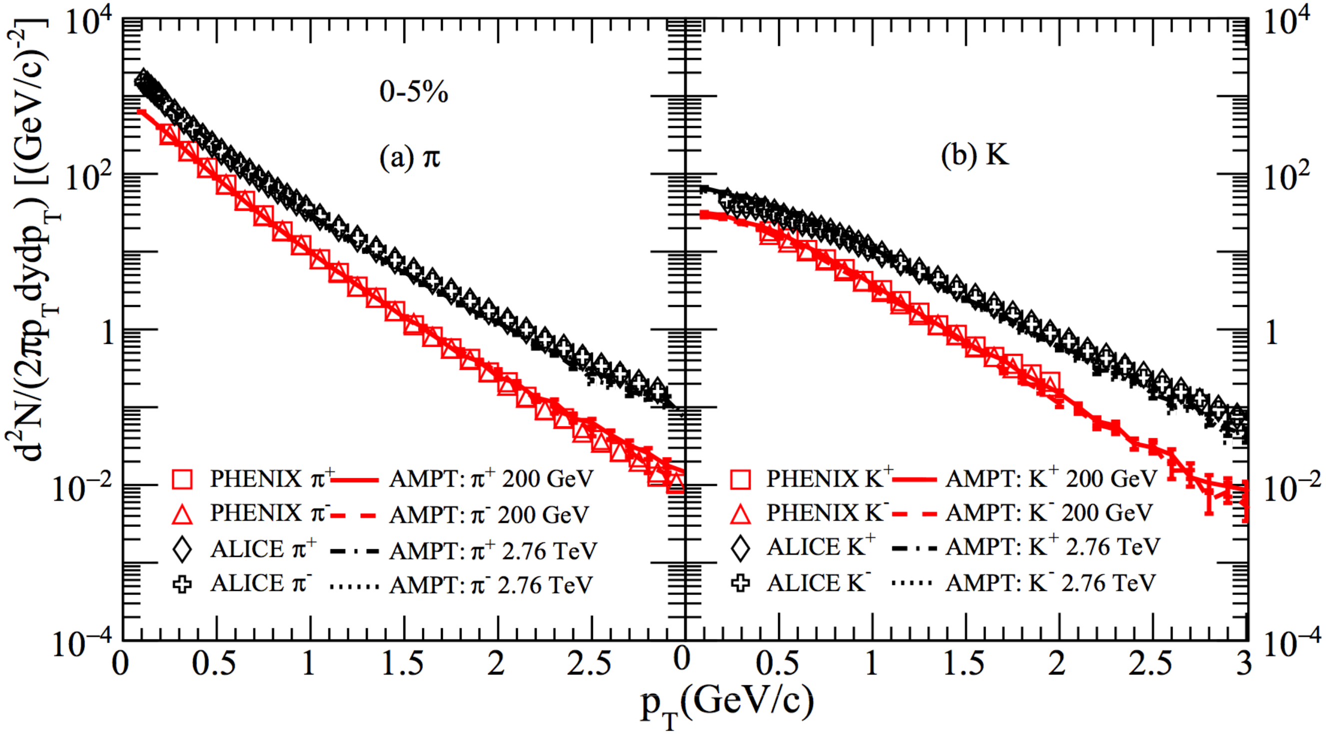
Mesons spectra and elliptic flows of mesons & (anti)protons show little change.

Thank you!

Backup



the yields of π/K



the spectra of π/K