BJÖRN SCHENKE, BROOKHAVEN NATIONAL LABORATORY

INITIAL STATE WORKING GROUP

BEST COLLABORATION

INITIAL STATE WORKING GROUP

- New collision geometry-based 3D initial condition (Shen,Alzhrani)
- Progress in 3D dynamical input for hydrodynamics (Shen,Schenke)
- Initial conditions for B,S,Q (Martinez, Sievert, Wertepny, Noronha-Hostler)
- Uncertainty in longitudinal profiles for net baryon density (Du, Heinz)

NEW 3D INITIAL CONDITION

C. Shen and S. Alzhrani, arXiv:2003.05852

- Impose energy and momentum conservation:
  Assumption: All of the energy and momentum is deposited into the medium

$$
\begin{aligned}
E(x,y) &= [T_A(x,y) + T_B(x,y)] m_N \cosh(y_{\rm beam}) \\
&\equiv M(x,y) \cosh(y_{\rm CM}(x,y)) \\
P_z(x,y) &= [T_A(x,y) - T_B(x,y)] m_N \sinh(y_{\rm beam}) \\
&\equiv M(x,y) \sinh(y_{\rm CM}(x,y)).
\end{aligned}
$$

$$
y_{\rm CM}(x,y) = \operatorname{arctanh}\left[\frac{T_A - T_B}{T_A + T_B}\tanh(y_{\rm beam})\right]
$$

$$
M(x,y) = m_N \sqrt{T_A^2 + T_B^2 + 2T_A T_B \cosh(2y_{\rm beam})}
$$

- Assume Bjorken flow for the velocity profile $u^\mu(x,y,\eta_s) = (\cosh(\eta_s), 0, 0, \sinh(\eta_s)).$
- Energy density given by (model for the longitudinal profile)

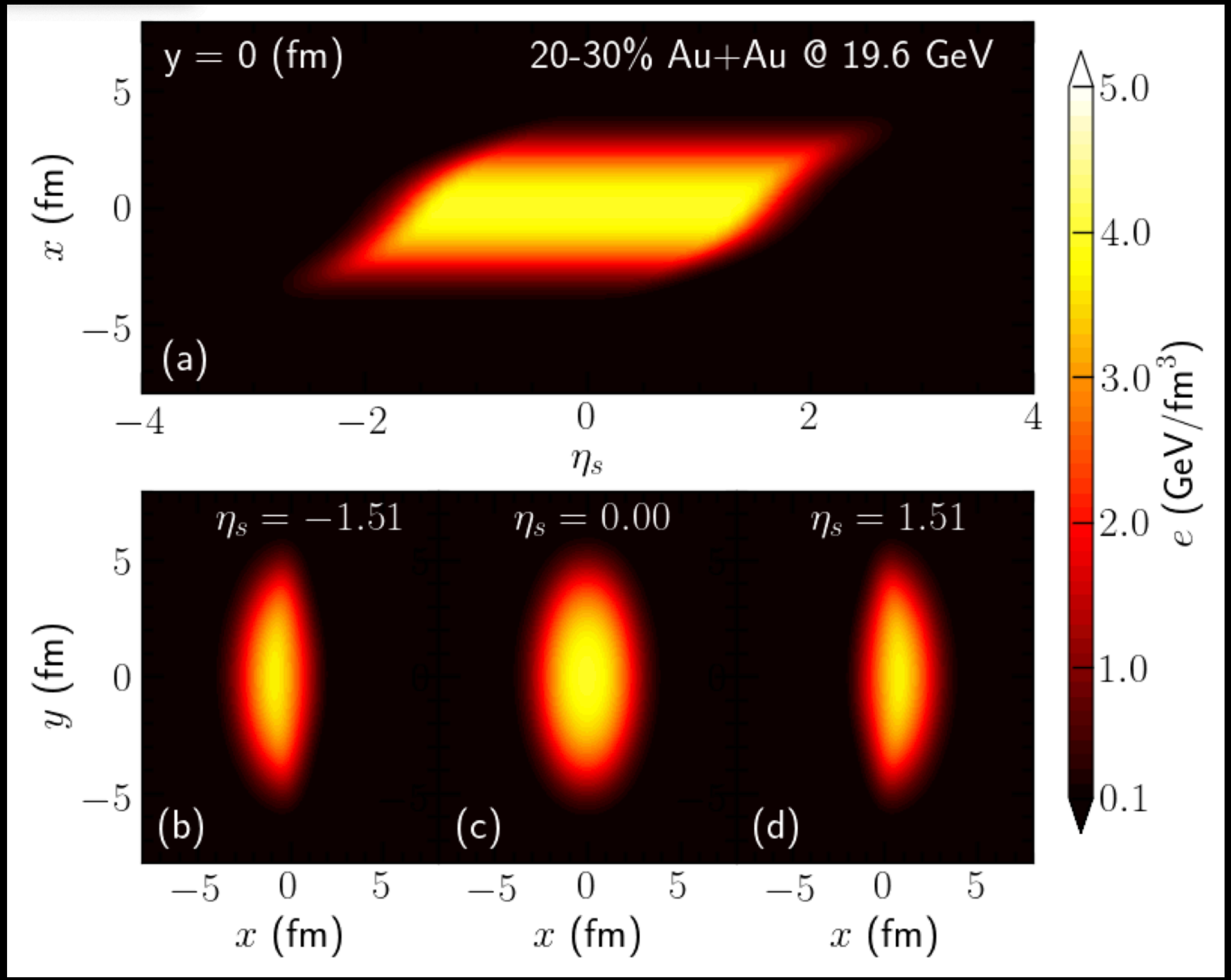
$$
e(x,y,\eta_s; y_{\rm CM}) = \mathcal{N}_e(x,y) \times \exp\left[-\frac{(|\eta_s - y_{\rm CM}| - \eta_0)^2}{2\sigma_\eta^2}\theta(|\eta_s - y_{\rm CM}| - \eta_0)\right]
$$

where $\mathcal{N}_e(x,y) \propto \mathcal{M}(x,y)$, the invariant mass

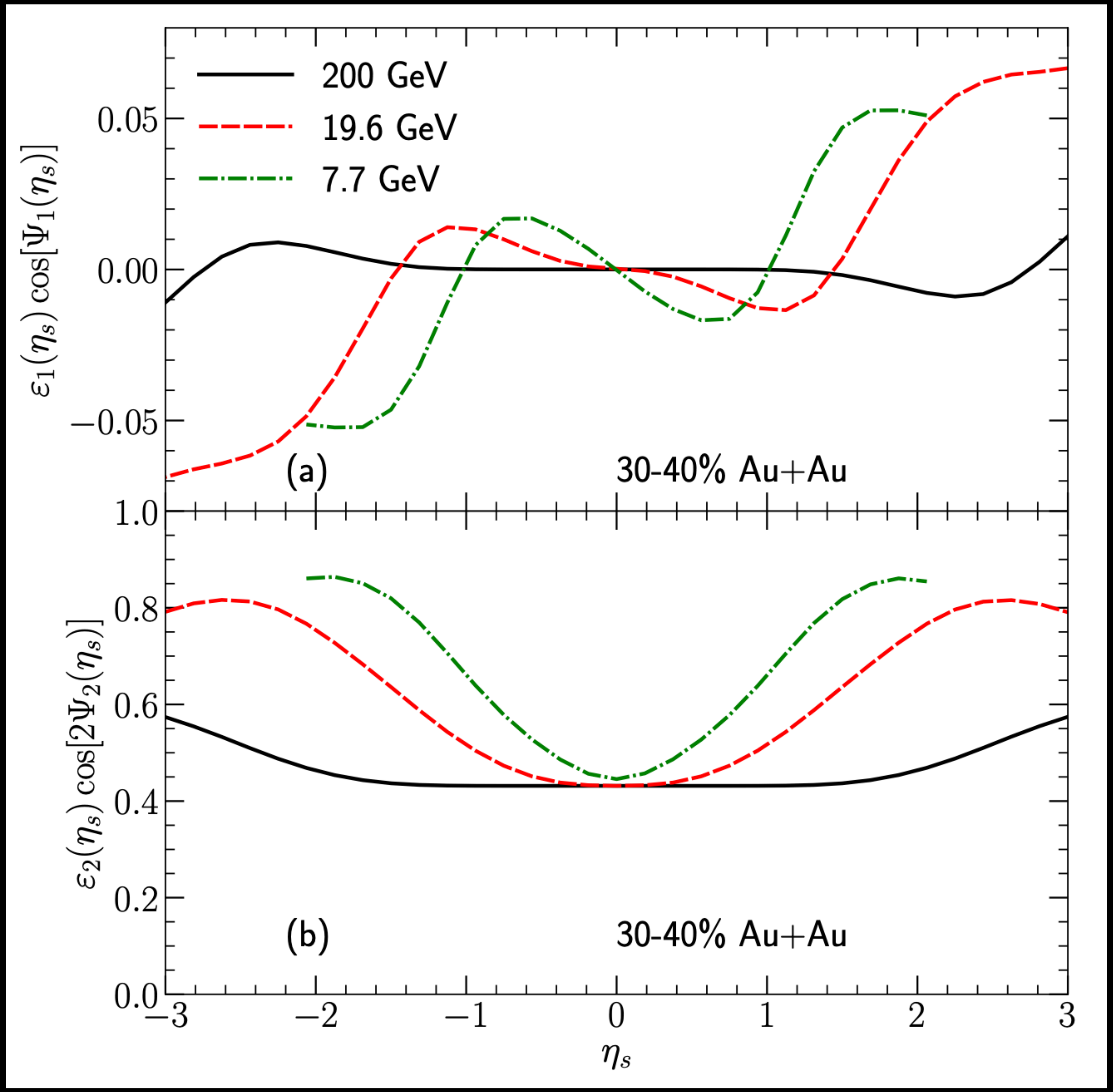
- At large $\sqrt{s}$ this leads to $e \propto \sqrt{T_A T_B}$

NEW 3D INITIAL CONDITION

C. Shen and S. Alzhrani, arXiv:2003.05852



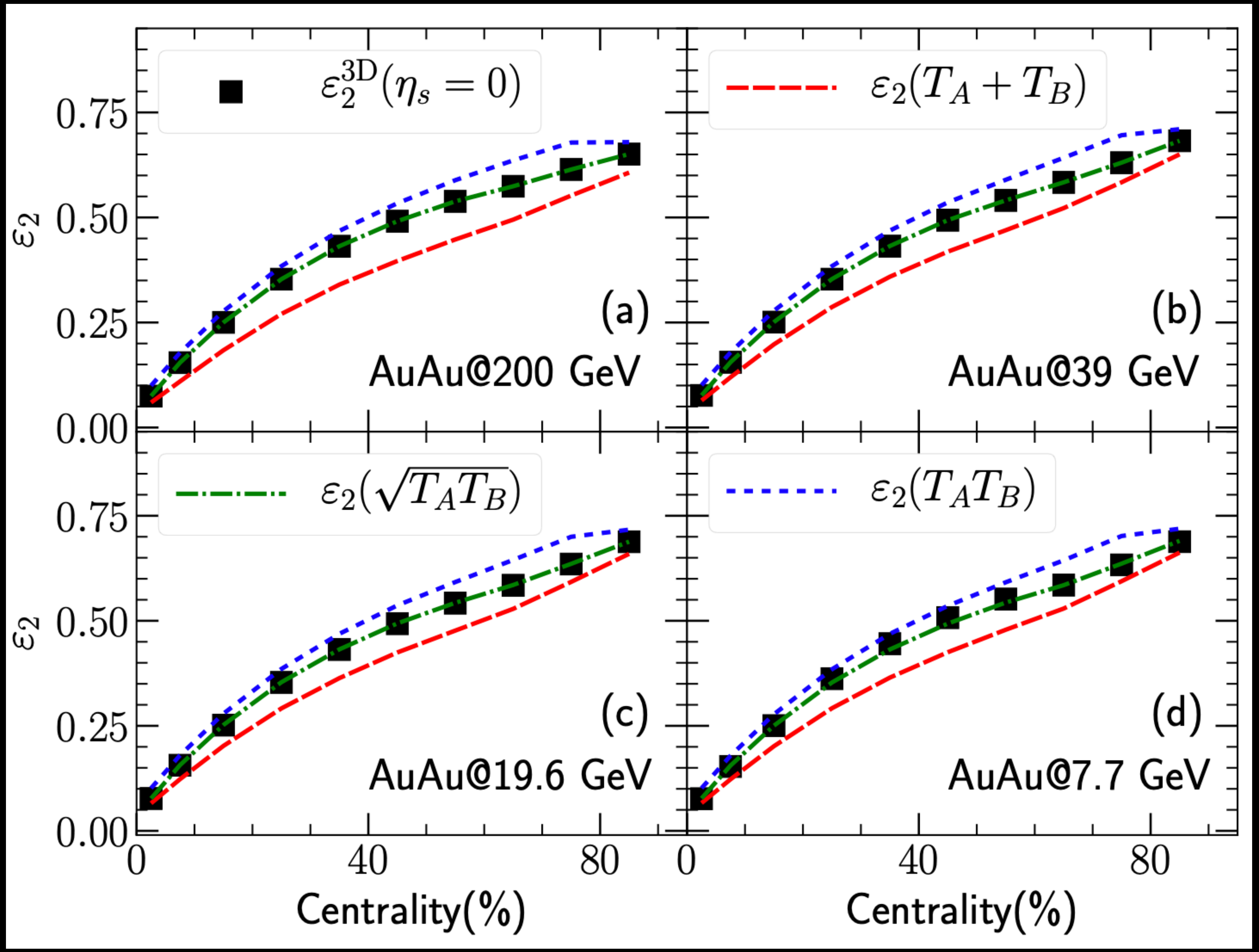
Local energy density distribution at τ = 1.8 fm/c



Initial eccentricity coefficients $\varepsilon_1(\eta_s)$ and $\varepsilon_2(\eta_s)$

NEW 3D INITIAL CONDITION

C. Shen and S. Alzhrani, arXiv:2003.05852



Centrality dependence of the initial eccentricity ε_2

Imposing local energy-momentum conservation in 3D initial conditions leads to a non-trivial transverse energy density profile.

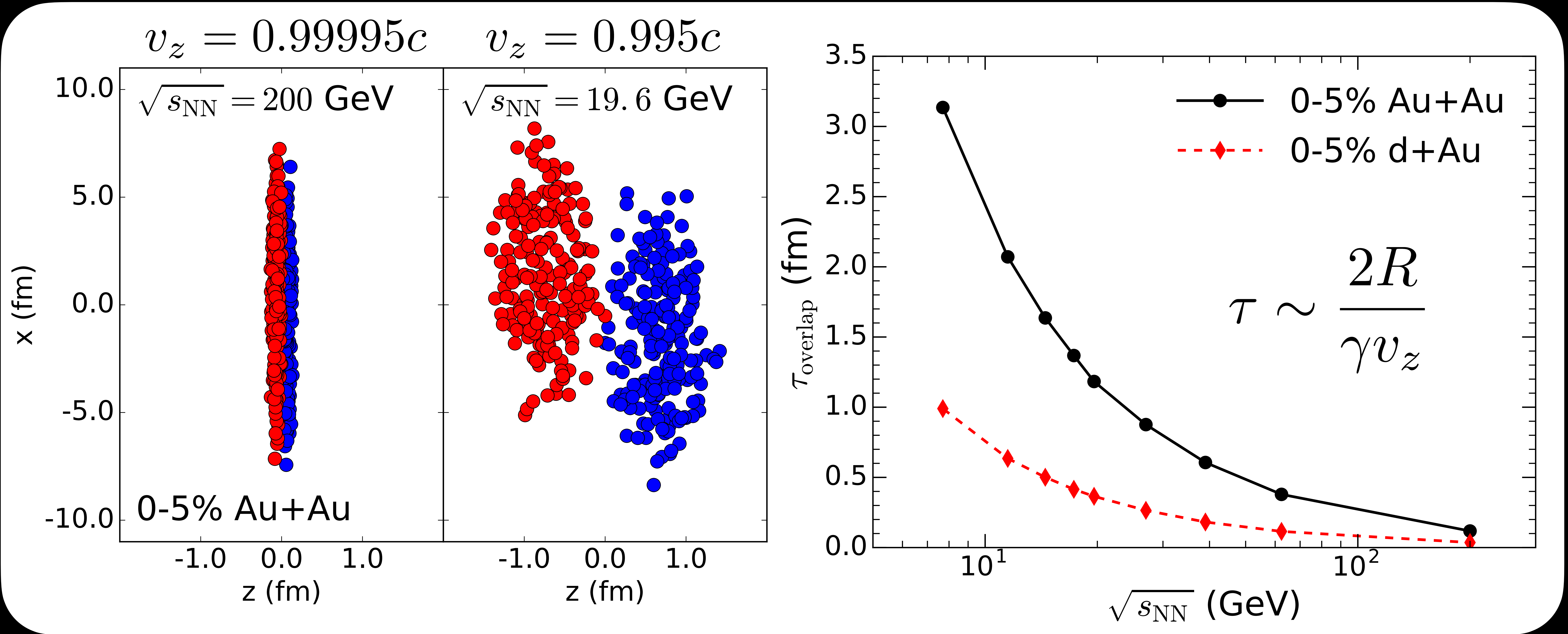
Numerically cheap (+ for Bayesian analysis) and straightforward to extend to event-by-event simulations.

Baseline for more realistic initial conditions including pre-equilibrium dynamics.

For results from this model + hydrodynamics see Chun's talk right after.

COLLISION DYNAMICS IN BES COLLISIONS

I. A. Karpenko, P. Huovinen, H. Petersen and M. Bleicher, Phys. Rev. C91 (2015) 064901
C. Shen and B. Schenke, Phys. Rev. C97 (2018) 024907

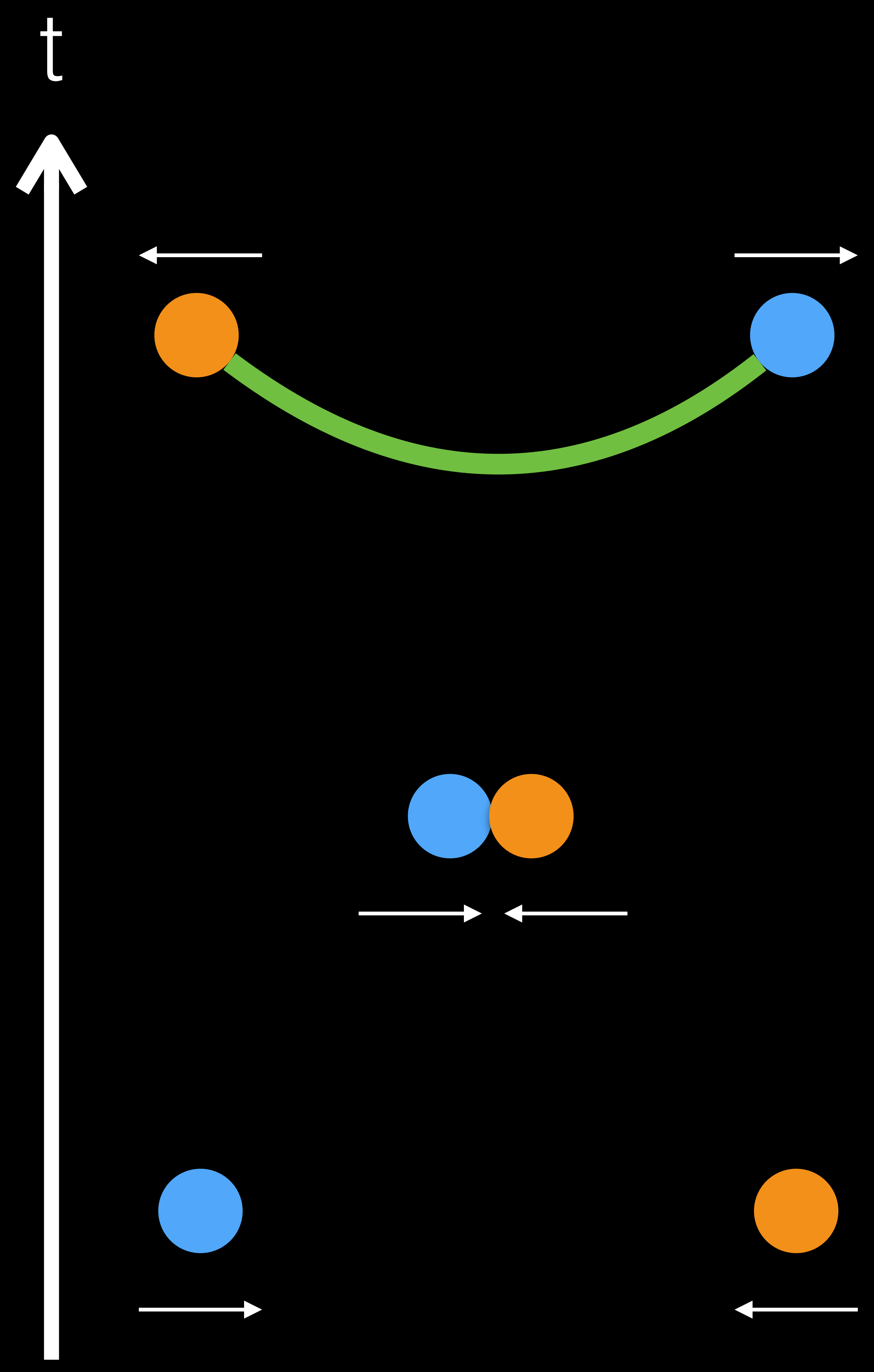


- Nuclei overlapping time is large at low collision energy
- Pre-equilibrium dynamics can play an important role

note: total evolution time ~ 10 fm

PROGRESS FOR THE DYNAMICAL INITIAL STATE MODEL

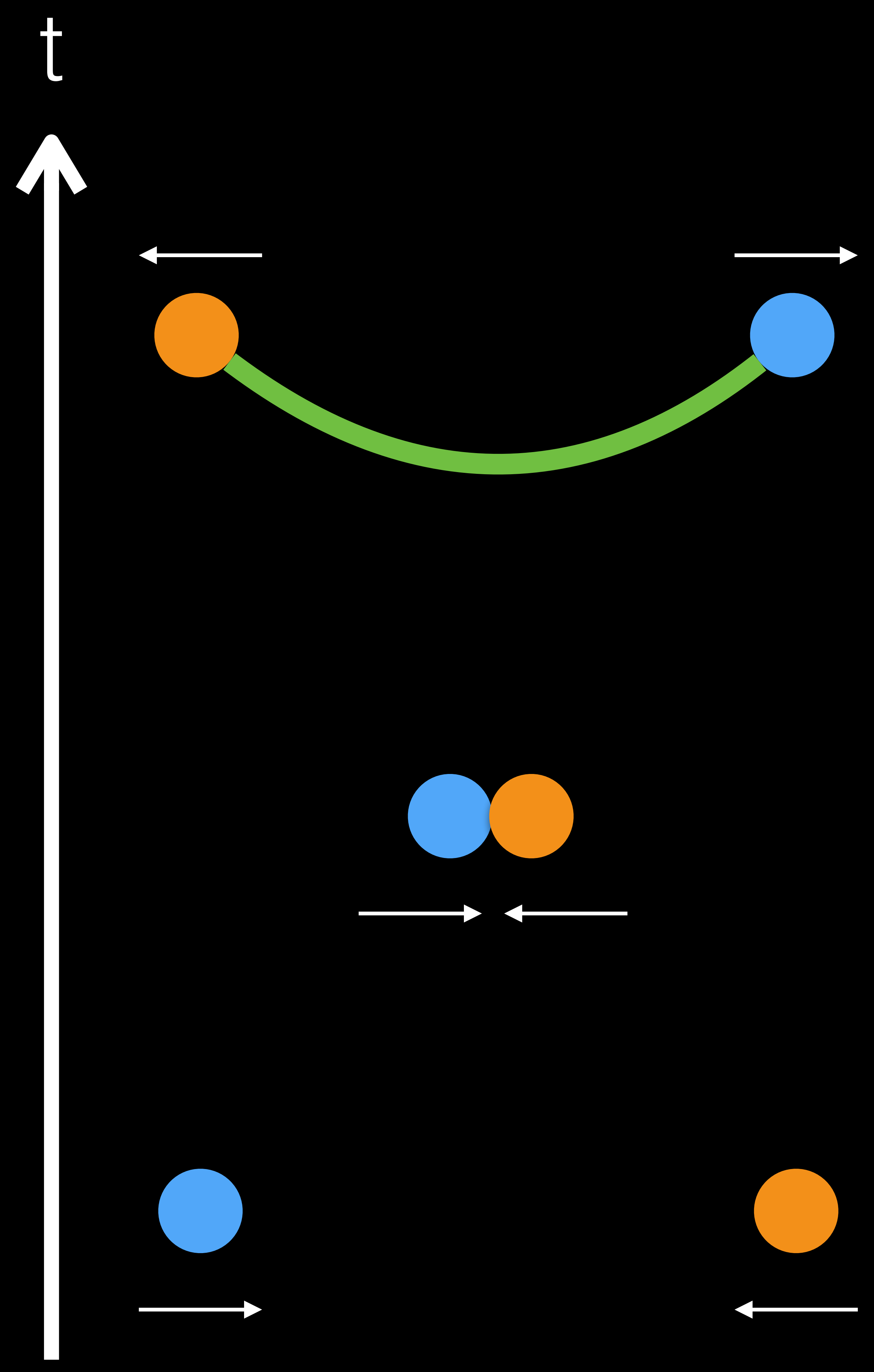
C. Shen and B. Schenke, Phys.Rev. C97 (2018) 024907



- Collisions between nucleons determined from usual MC-Glauber criteria
- Randomly pick one of 3 quarks (that are not yet connected to a string) to connect a (color-) string to (if all are connected already, pick one randomly to attach a second string to…)
- Quarks initial rapidities depend on beam rapidity and sampled x value

SPACE TIME POSITION OF THE STRING

C. Shen and B. Schenke, Phys.Rev. C97 (2018) 024907



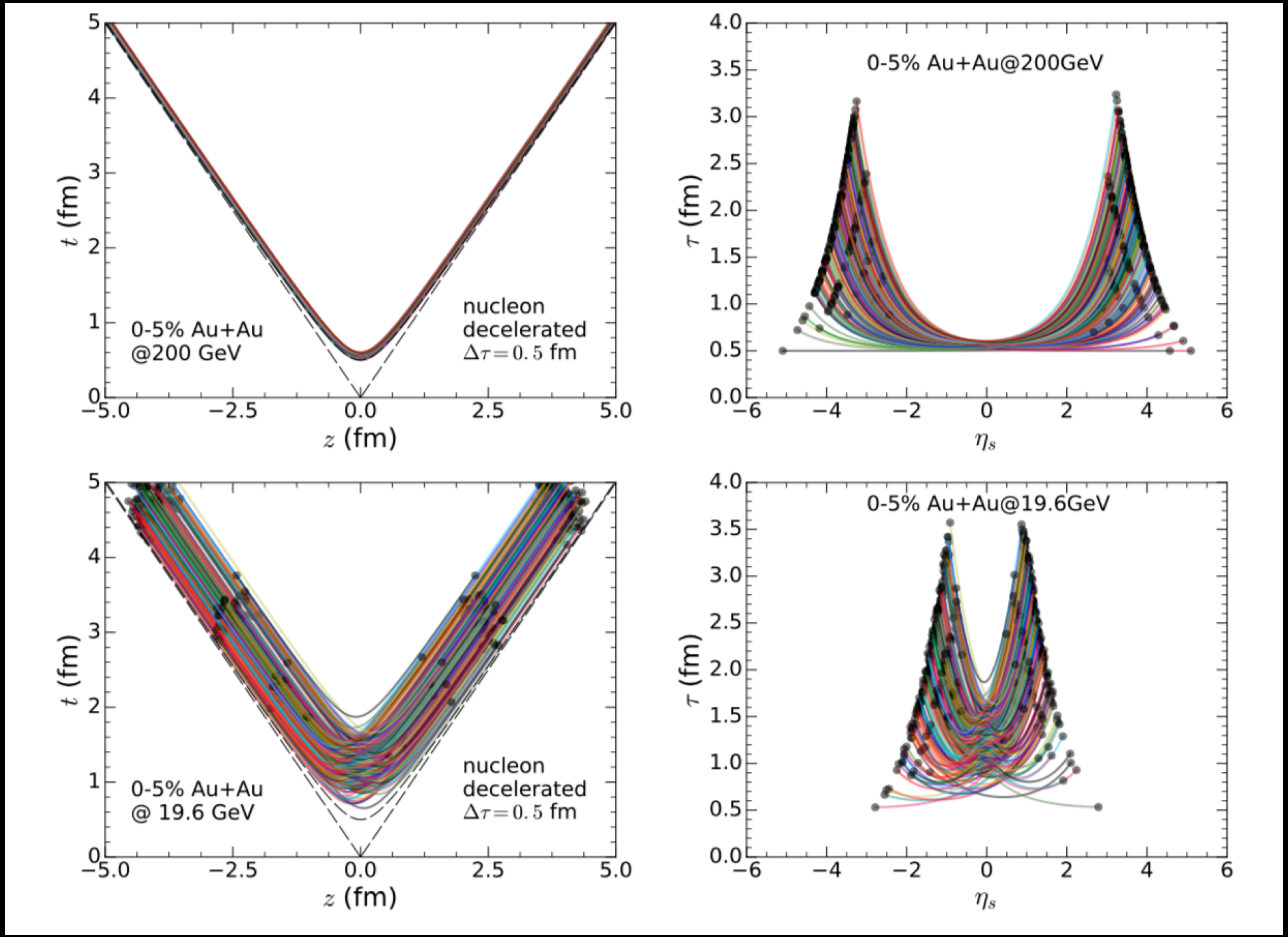
- String breaks after a constant time in its rest frame
- In the lab frame the string's space time positions are determined by

$$(t - t_c)^2 - (z - z_c)^2 = \Delta\tau^2$$

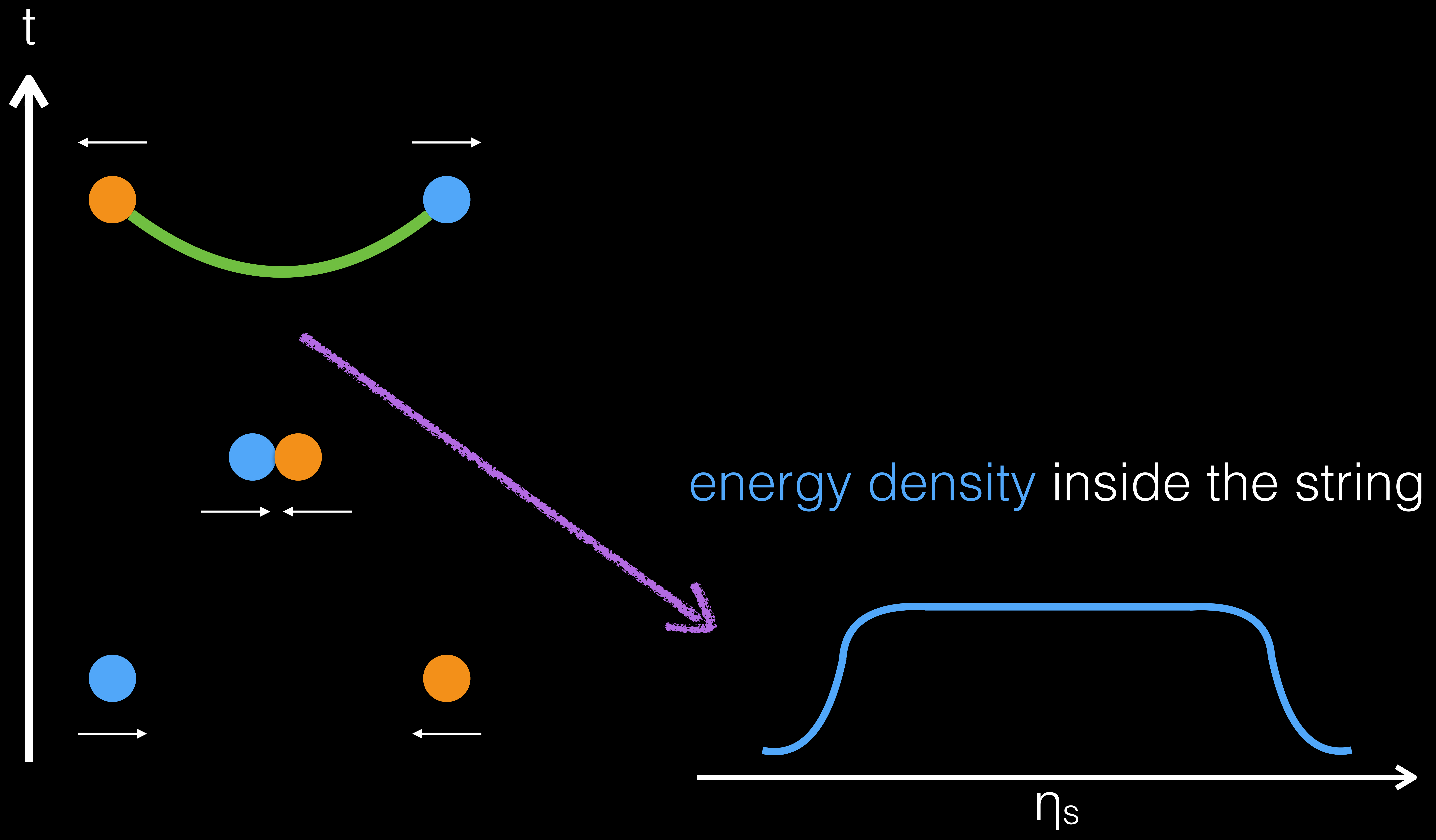
- Because of the shifted position in z the source term determined by the string position will not sit at a fixed τ

SPACE TIME POSITION OF THE STRING

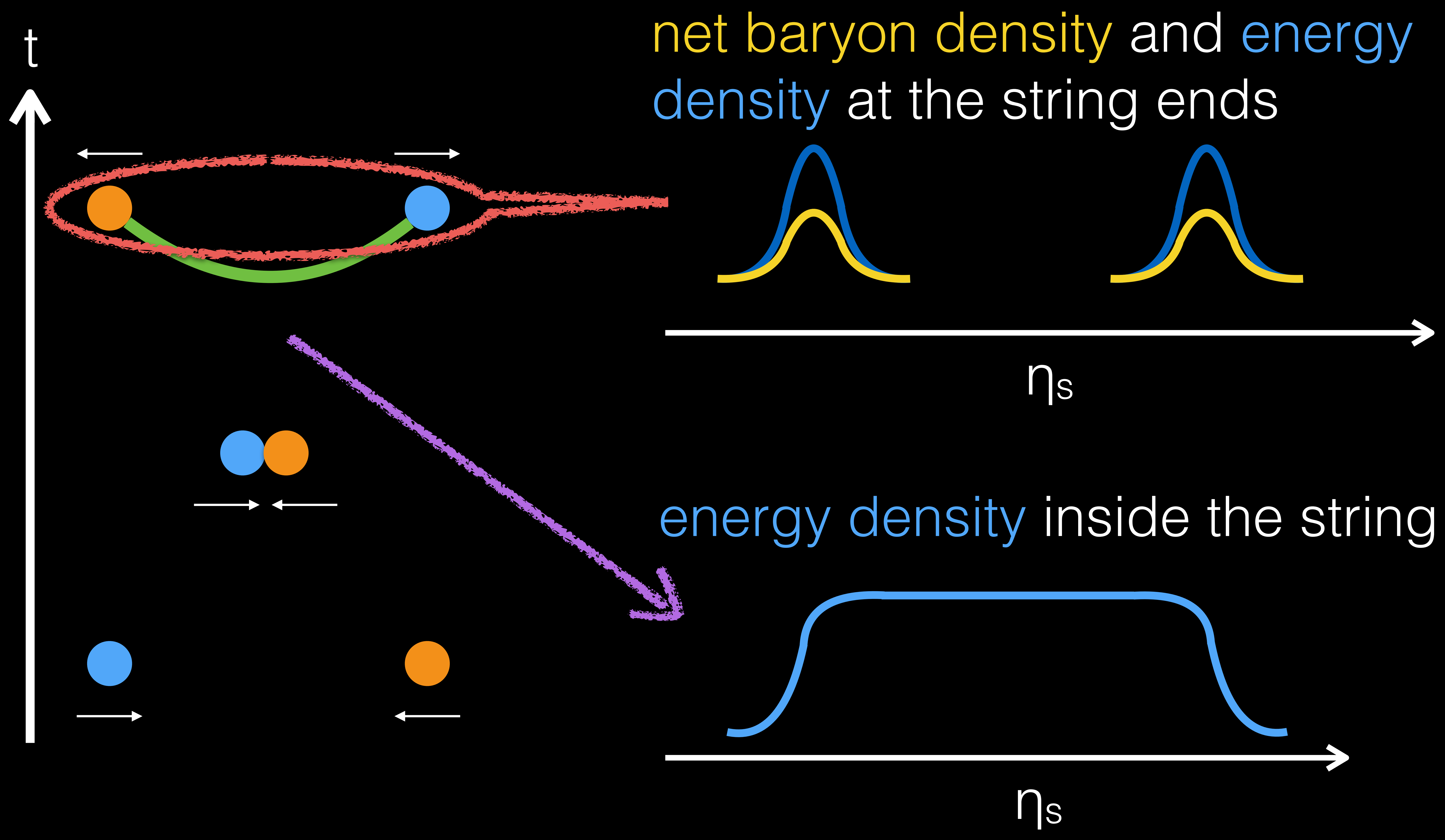
C. Shen and B. Schenke, Phys.Rev. C97 (2018) 024907



SOURCE TERM FOR HYDRODYNAMICS



SOURCE TERM FOR HYDRODYNAMICS



Conserve energy, momentum, and net-baryon number

UPDATES ON DYNAMICAL INITIAL STATE

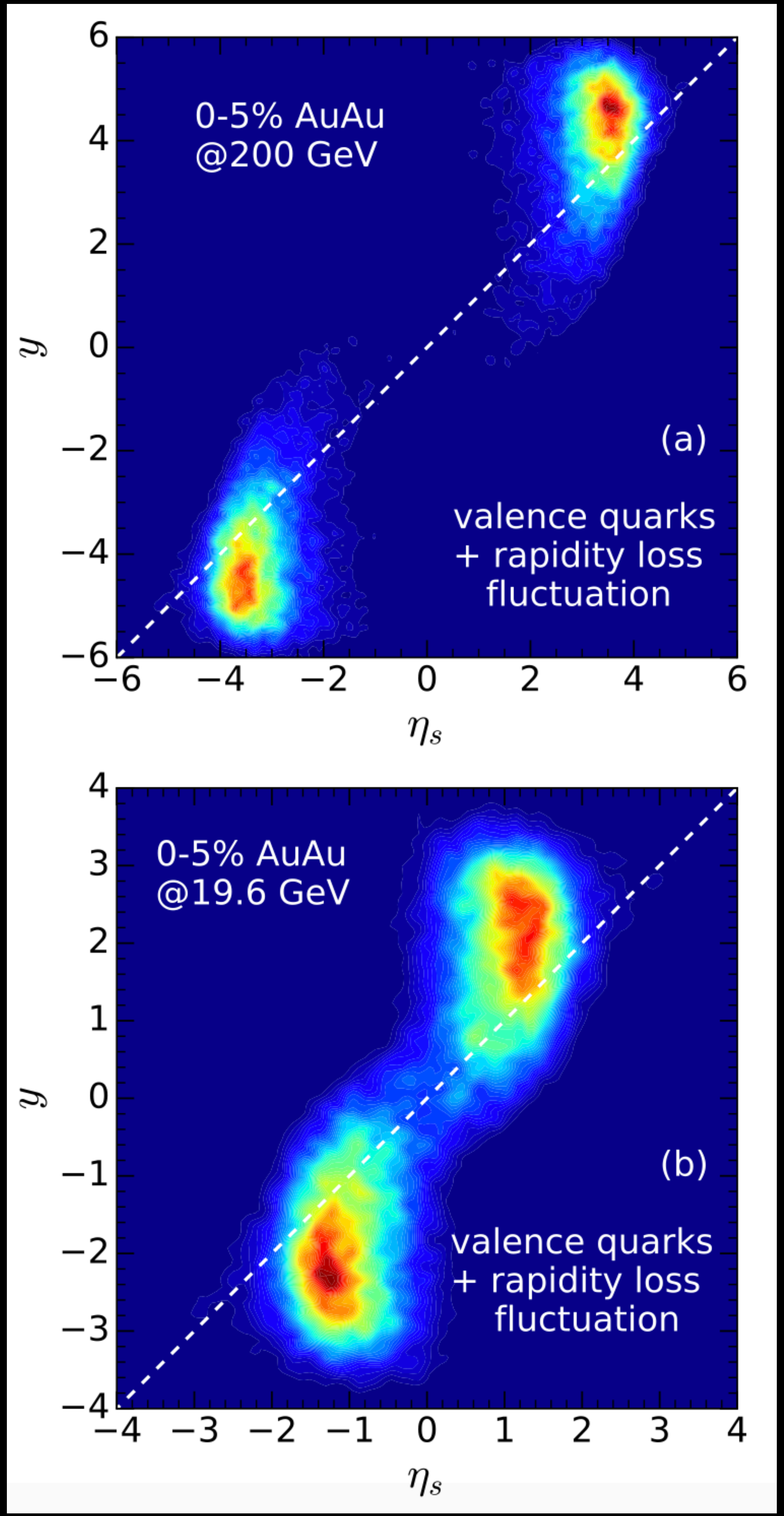
C. Shen and B. Schenke, in preparation

- Now includes local (in transverse plane) conservation of longitudinal momentum in addition to energy conservation
- Lost energy (from slowing down) is deposited along the string
- Left over energy deposited at string ends (string remnants)
- Beam remnants (“unused” quarks of wounded nucleons) also contribute energy (before we rescaled energy in strong to conserve momentum) - makes a big difference in peripheral events
- Improved sampling of PDF with constraint that sum(x)<1
- Baryon junctions transport net baryon number towards midrapidity

BARYON JUNCTIONS

- Based on **D. Kharzeev, Phys.Lett. B378 (1996) 238-246** we treat baryon number as detached from the valence quarks (located at "baryon junctions" in a baryon)
- Sample rapidity y* of baryon number along the string after the interaction from an exponential $\exp[\pm y^*(\alpha_P(0) - \alpha_0^J(0))] \approx \exp(\pm y^*/2)$ with + for the right moving and - for the left moving nucleon
- There is also a constant (uniform) component, which we do not yet include
- Introduce additional parameter $0<\lambda_B<1$ which determines probability for baryon number to fluctuate away from the string end

UPDATES ON DYNAMICAL INITIAL STATE

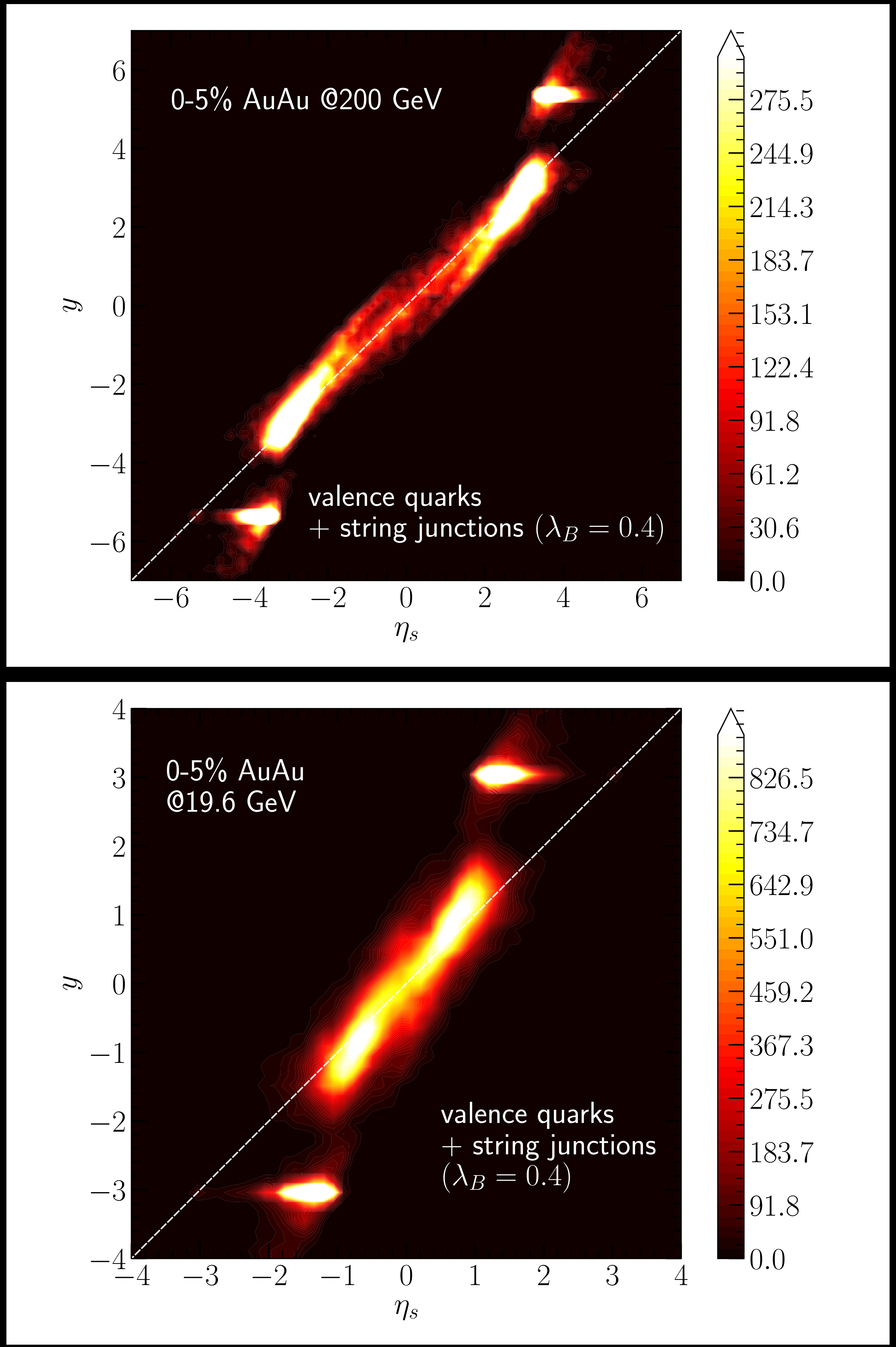


Shen, Schenke, 1710.00881

baryon densities

include
baryon junctions
and "beam remnants"

old



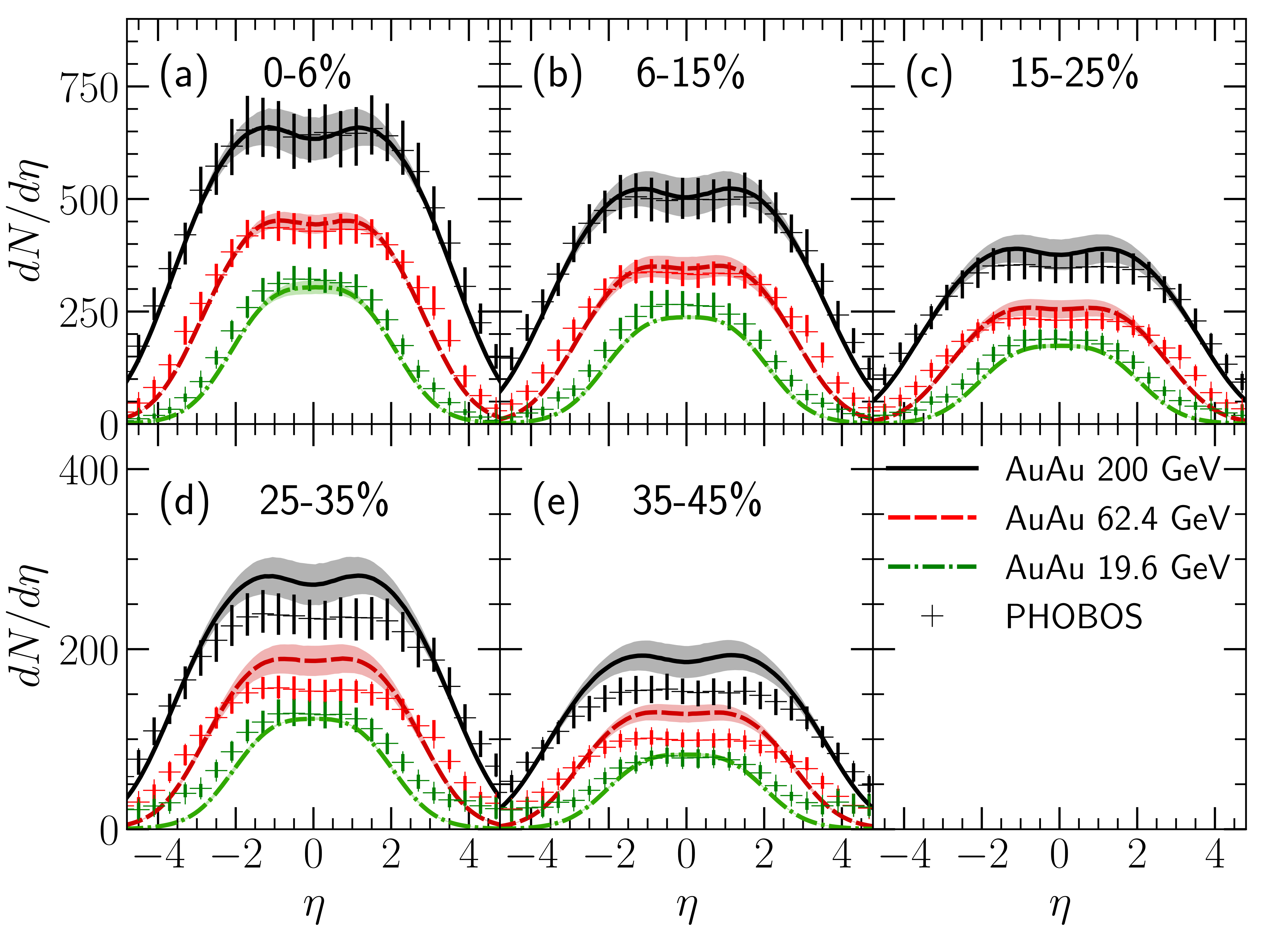
Shen, Schenke, in preparation

new

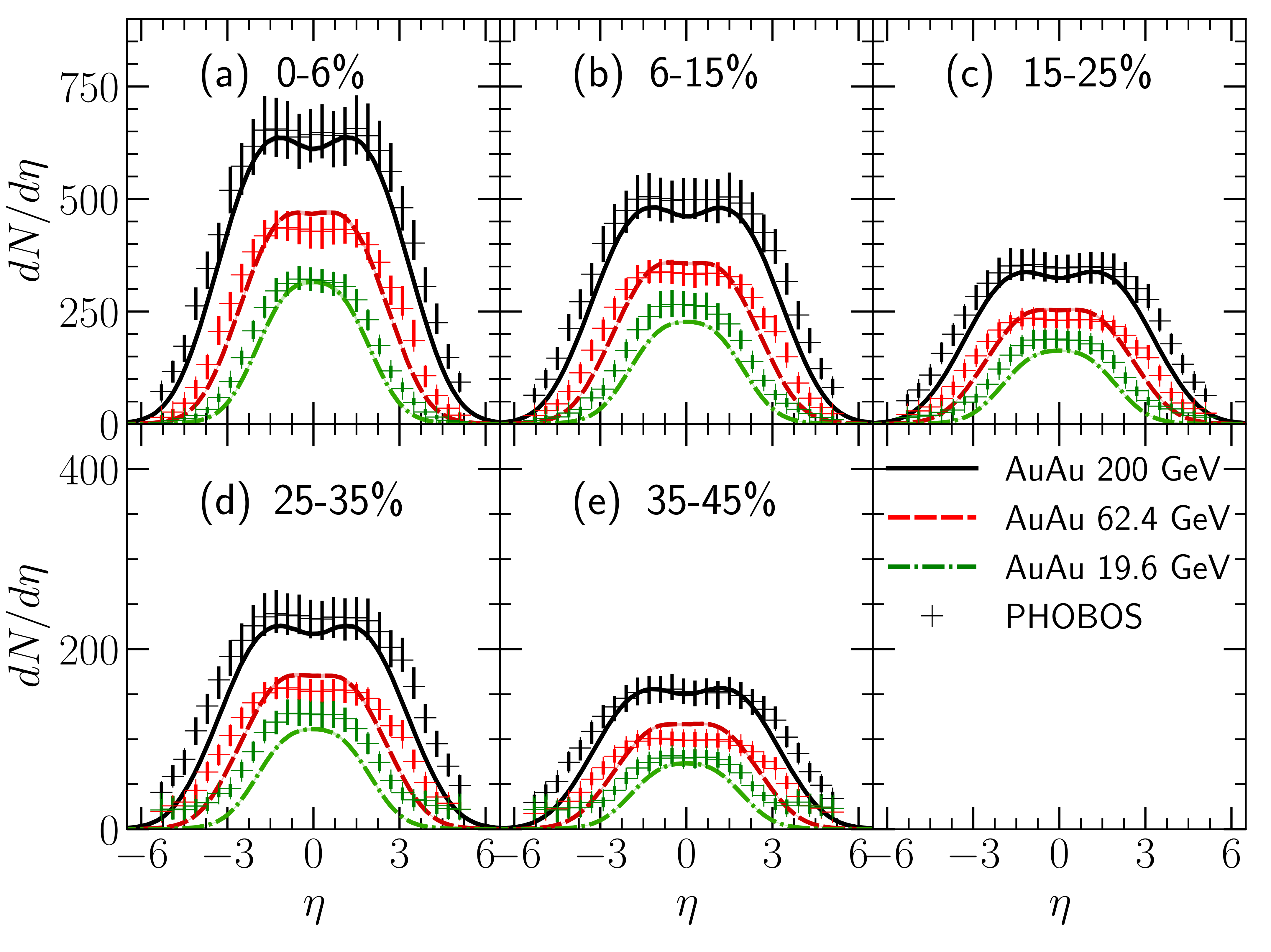
CHARGED PARTICLE DISTRIBUTION Au+Au

C. Shen and B. Schenke, in preparation

old: rescaling to conserve energy



new: energy in "beam remnants"

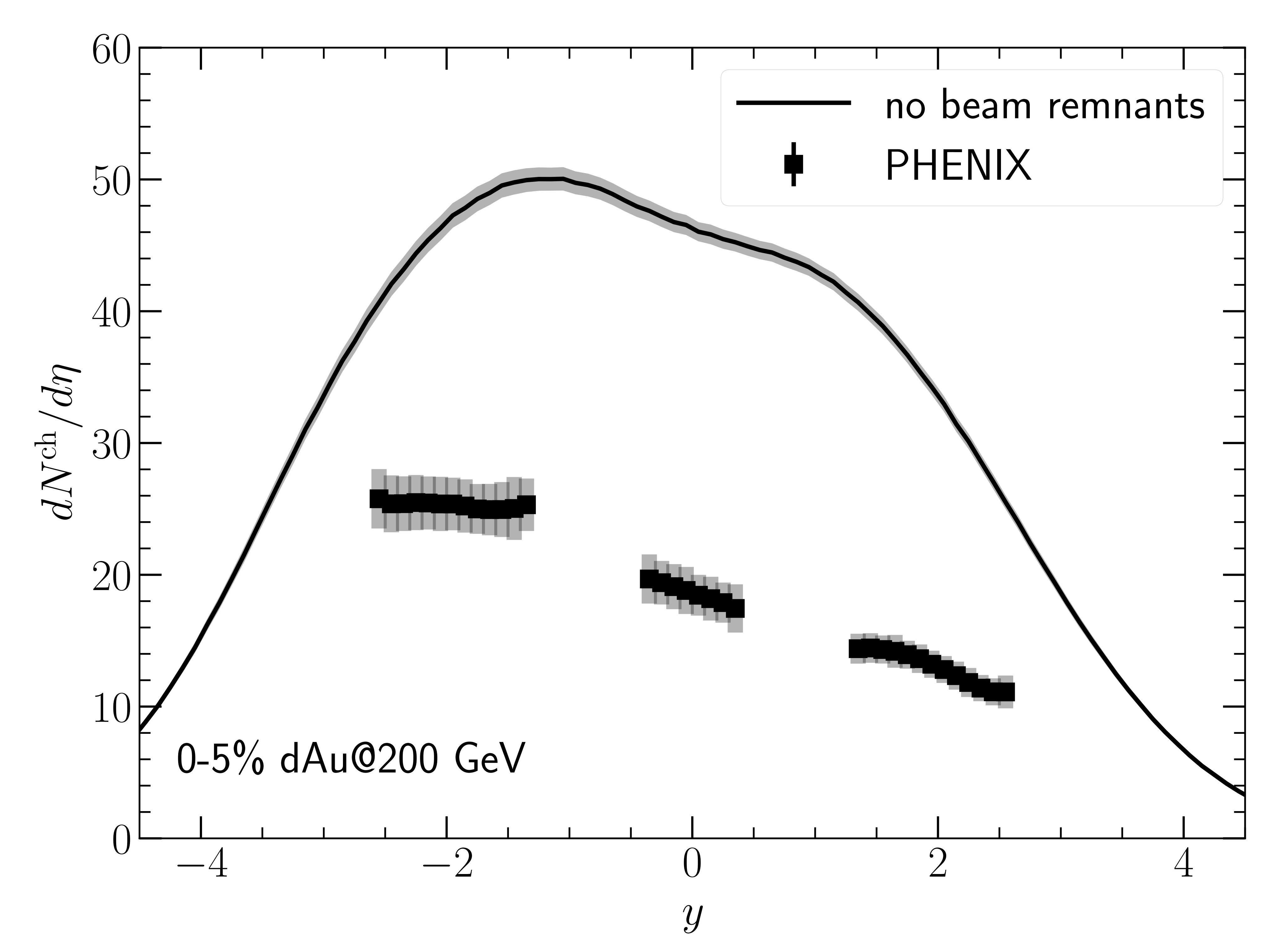


Spectator nucleons do not contribute in either case

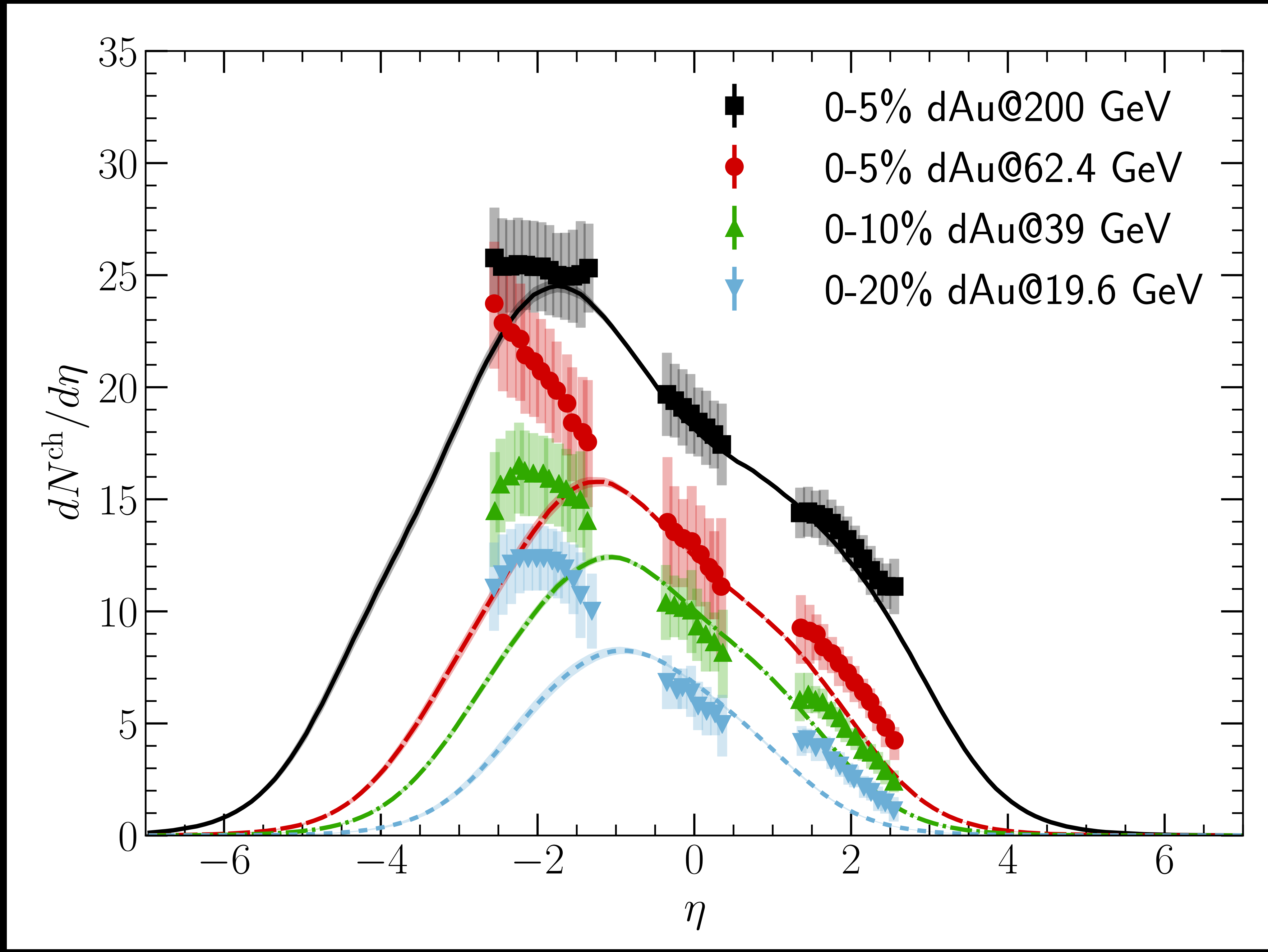
CHARGED PARTICLE DISTRIBUTION d+Au

C. Shen and B. Schenke, in preparation

old: rescaling to conserve energy

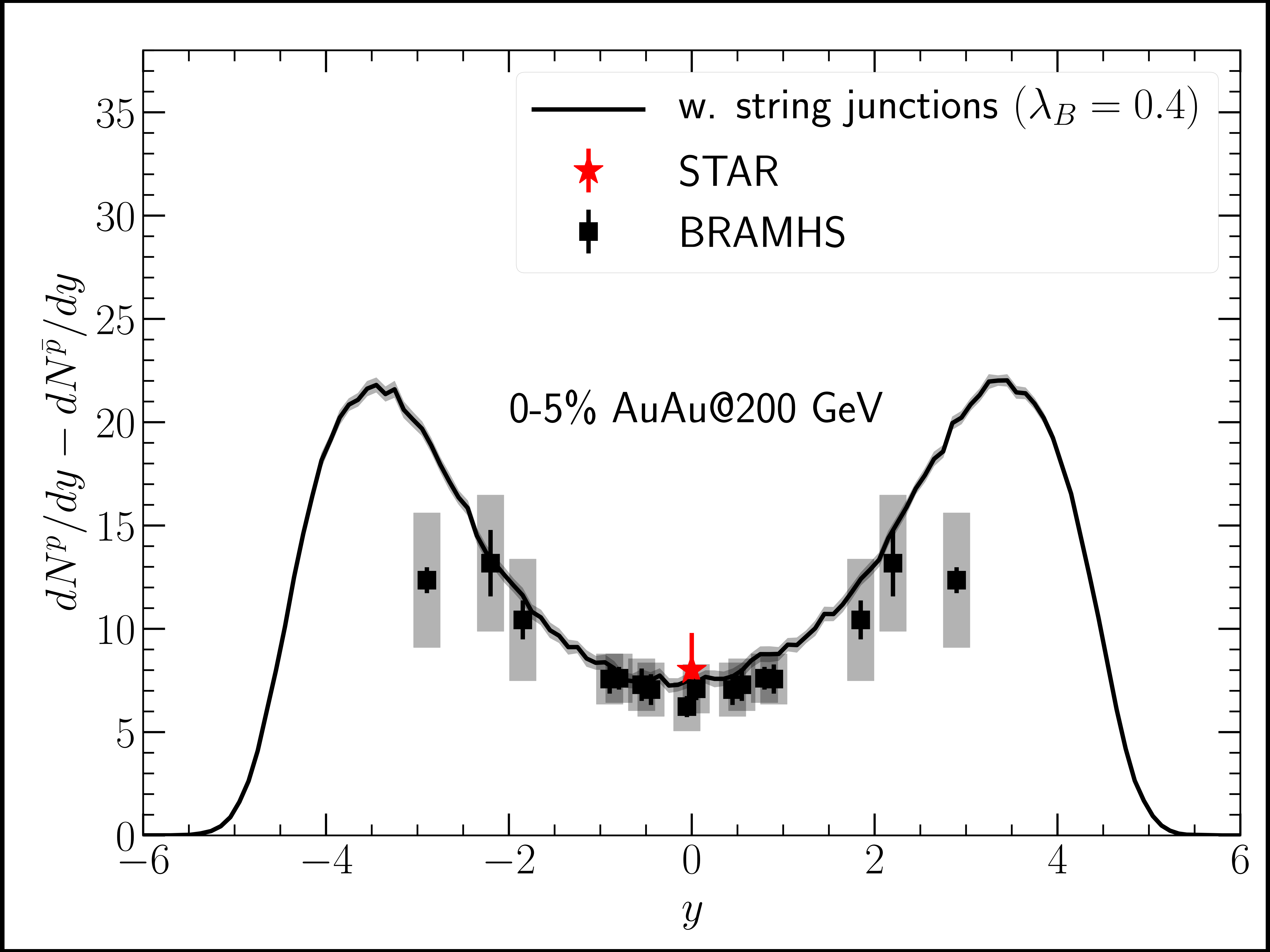


new: energy in "beam remnants"



NET PROTON DISTRIBUTION

C. Shen and B. Schenke, in preparation

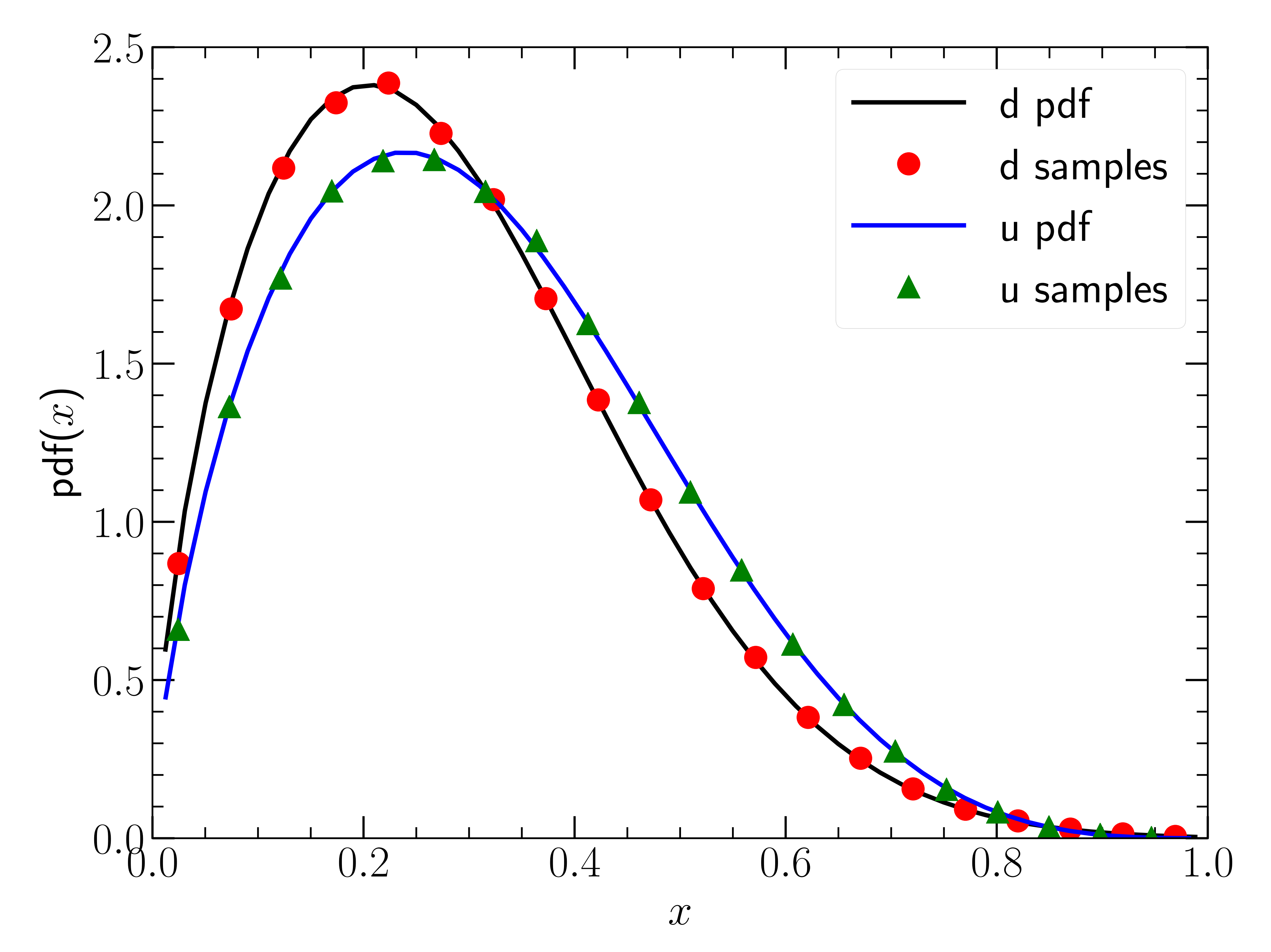


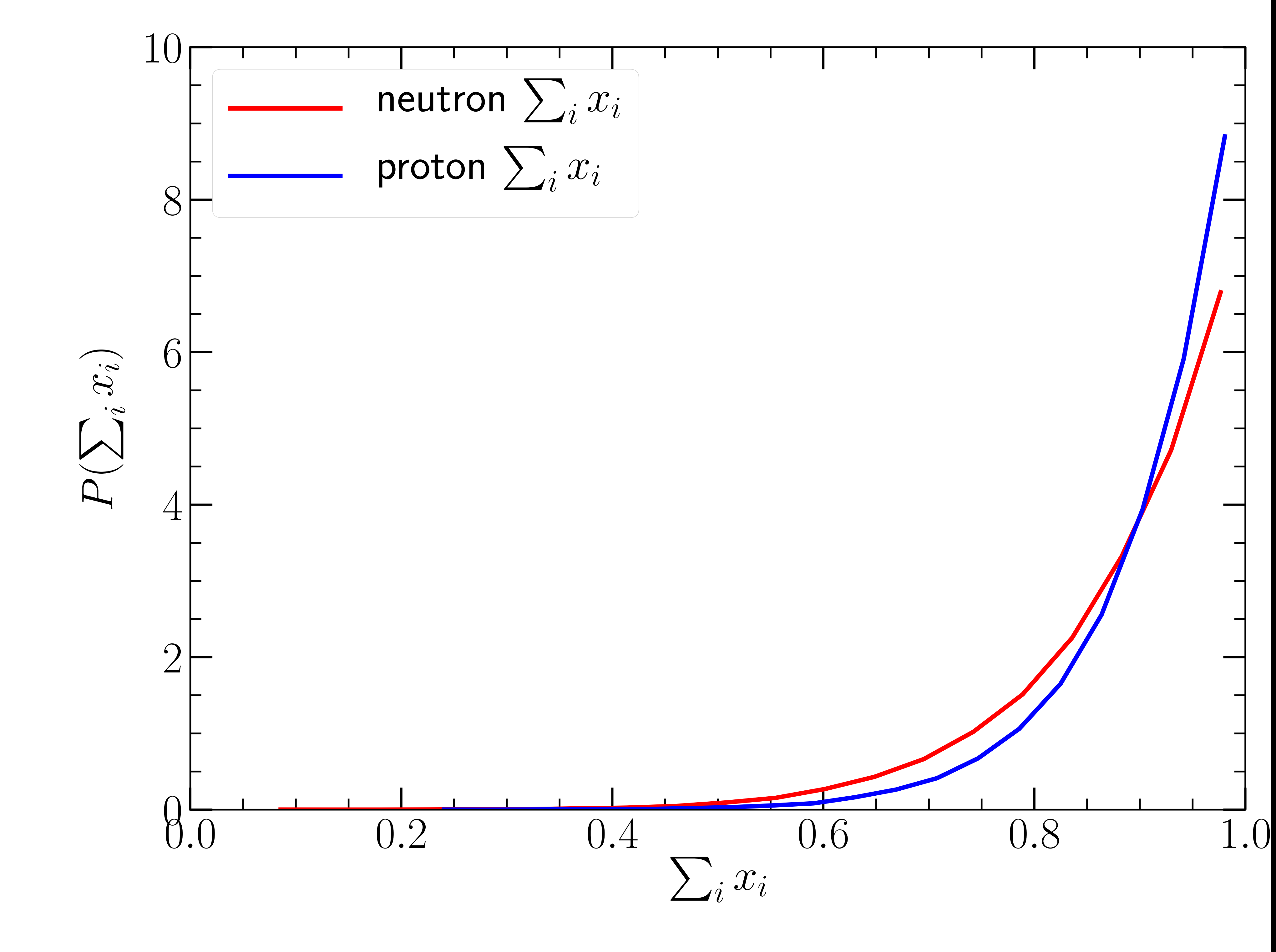
IMPROVED PDF SAMPLING

C. Shen and B. Schenke, in preparation

Sample PDFs with constraint $\sum_i x_i < 1$:

1) Sample without constraint 2) Reshuffle quarks between nucleons until all fulfill $\sum_i x_i < 1$

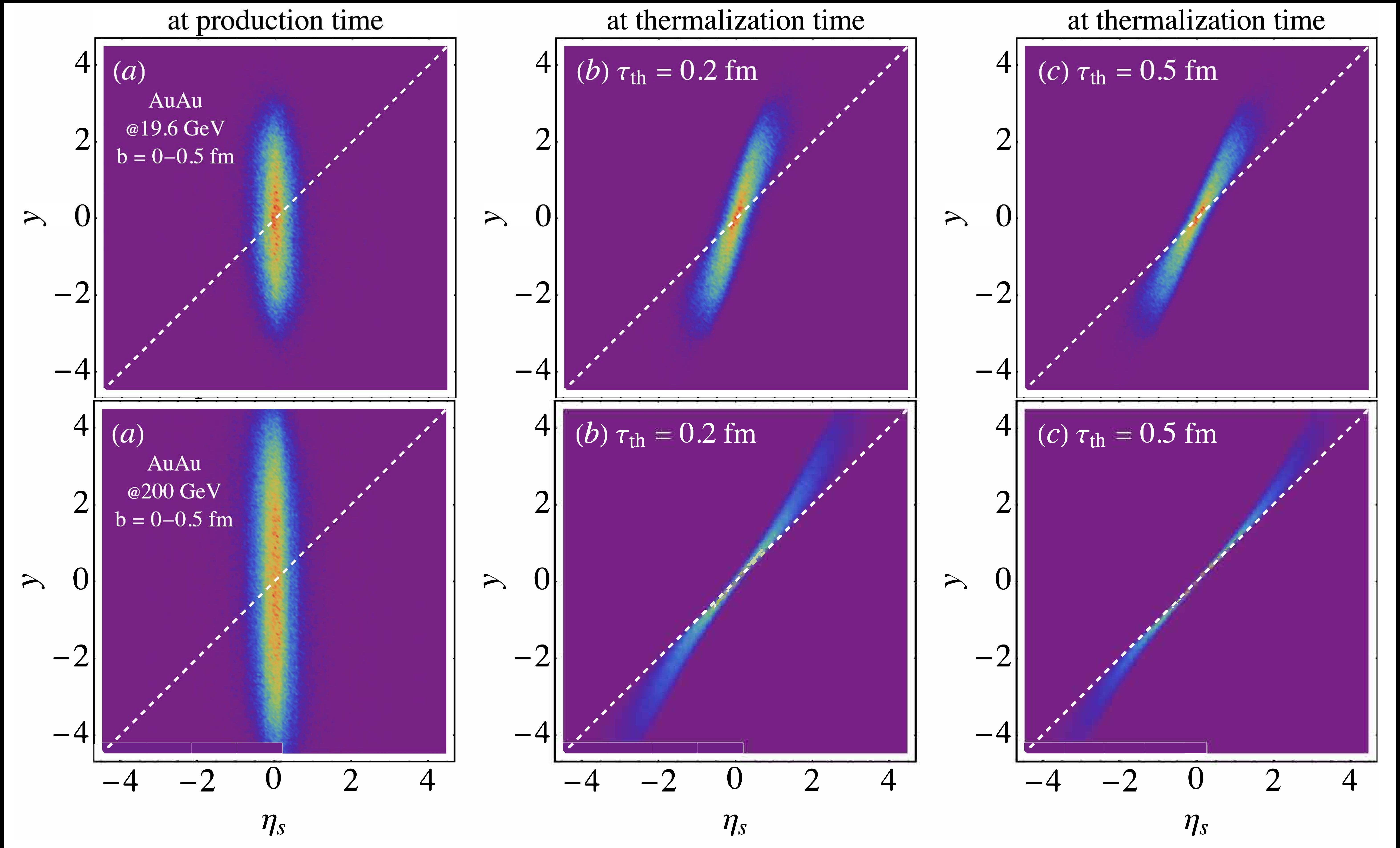




URQMD INITIAL CONDITION - ENERGY

L. Du and U Heinz, in preparation

momentum rapidity

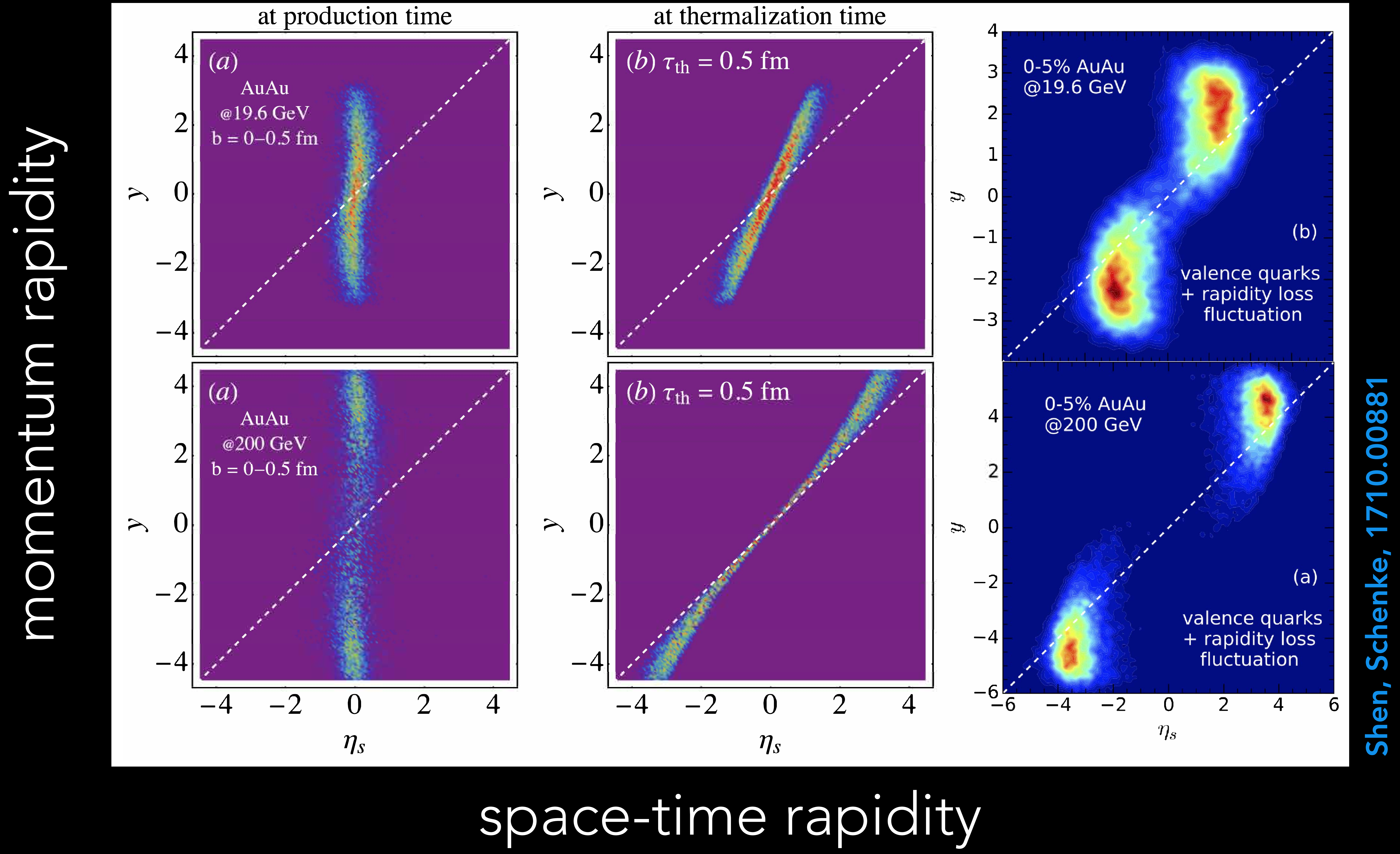


space-time rapidity

- Energy deposition
- UrQMD
- free streaming up to τ_{th}
- boost-invariance is approached over time

URQMD INITIAL CONDITION - BARYONS

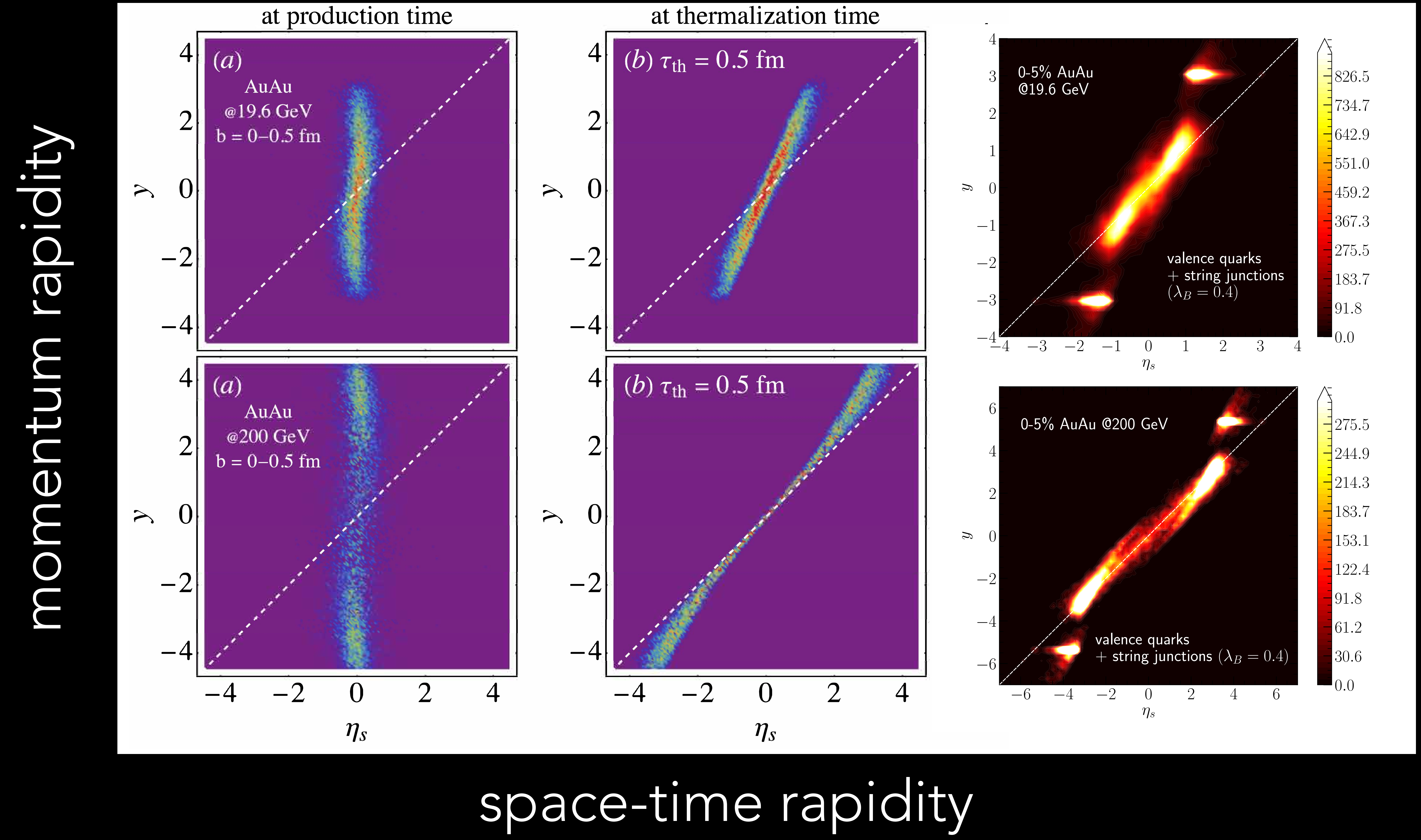
L. Du and U Heinz, in preparation



- Baryon deposition
- UrQMD
- free streaming up to τ_{th}
- boost-invariance is approached over time
- large model uncertainty

URQMD INITIAL CONDITION - BARYONS

L. Du and U Heinz, in preparation

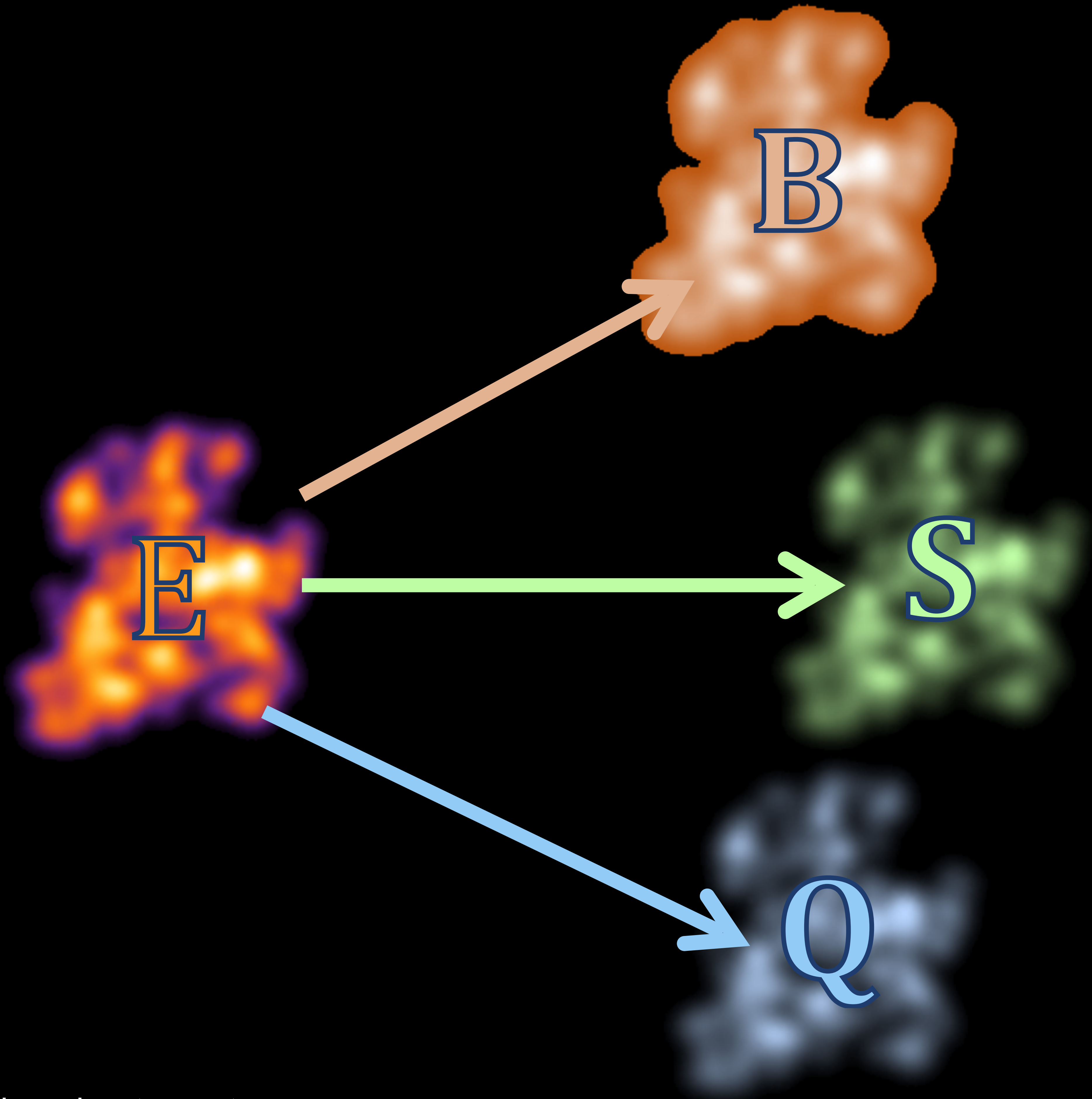


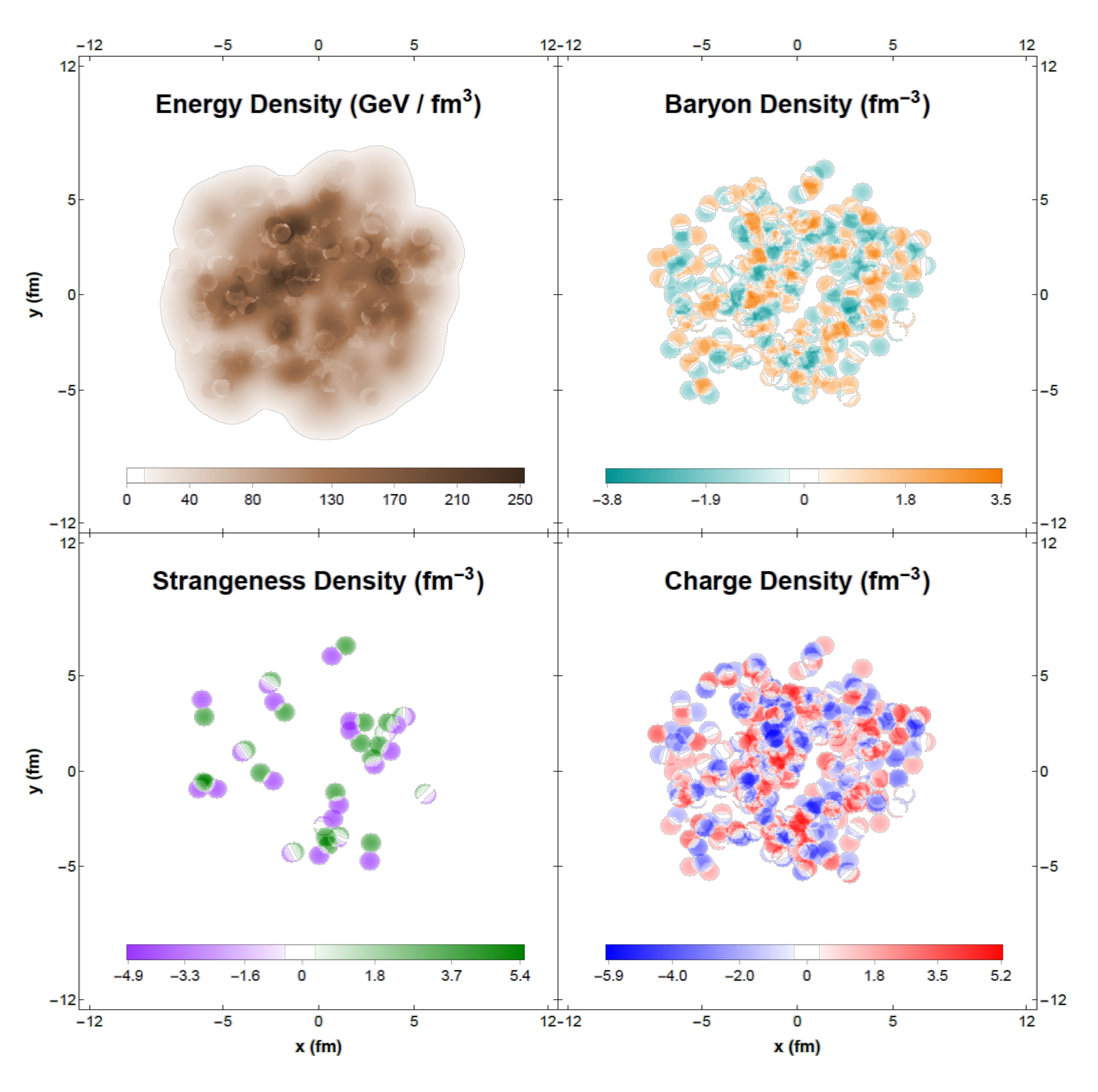
Update with baryon junctions: baryons get transported towards midrapidity

INITIAL CONDITION GENERATOR FOR B/S/Q AT $\mu_B = 0$

M. Martinez, M. Sievert, D. Wertepny, J. Noronha-Hostler, arXiv: 1911.10272, arXiv: 1911.12454

Re-sample the initial energy density using $g \to q\bar{q}$ splitting





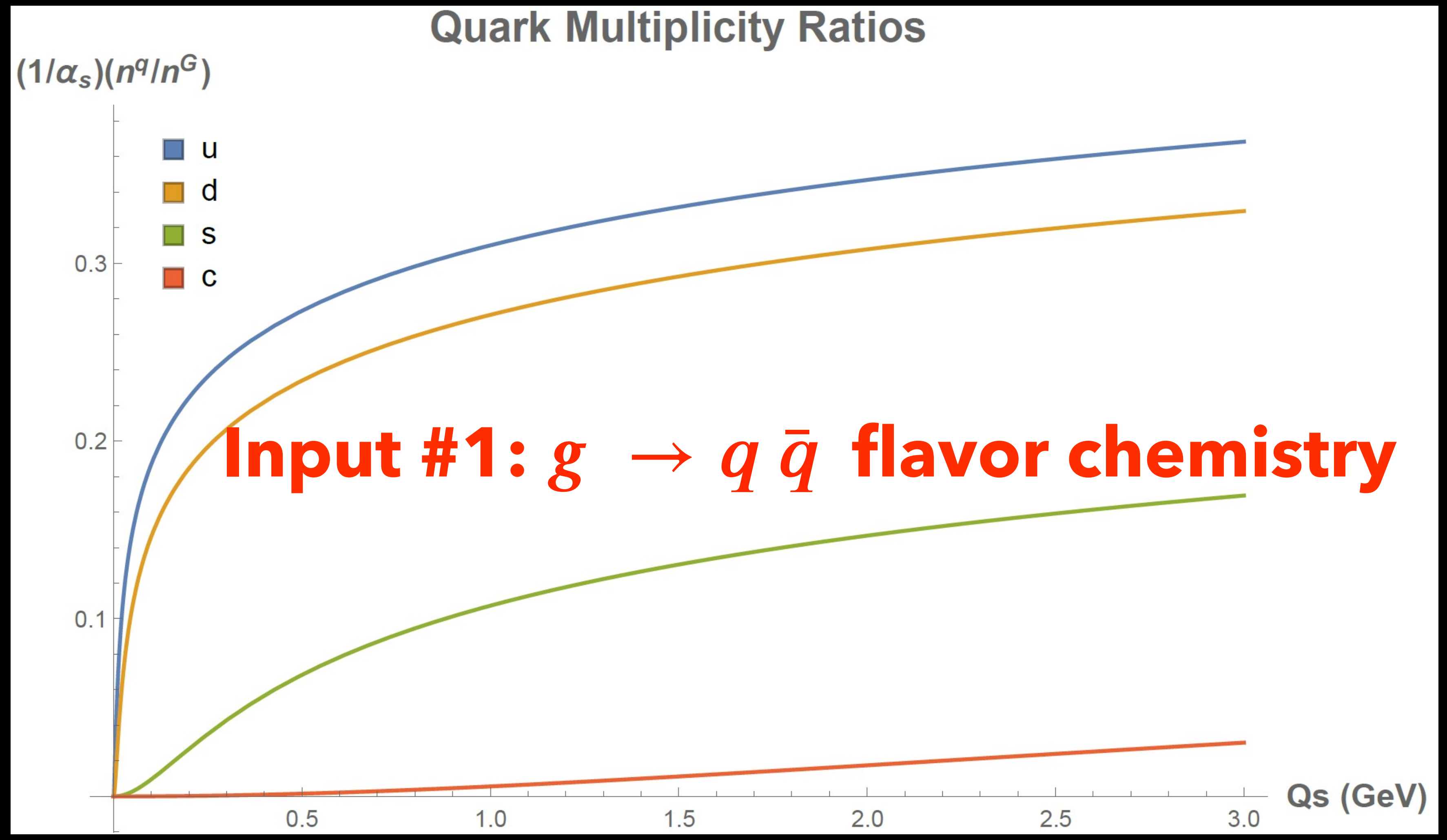
MONTE CARLO SAMPLING STRATEGY

M. Martinez, M. Sievert, D. Wertepny, J. Noronha-Hostler, arXiv: 1911.10272, arXiv: 1911.12454

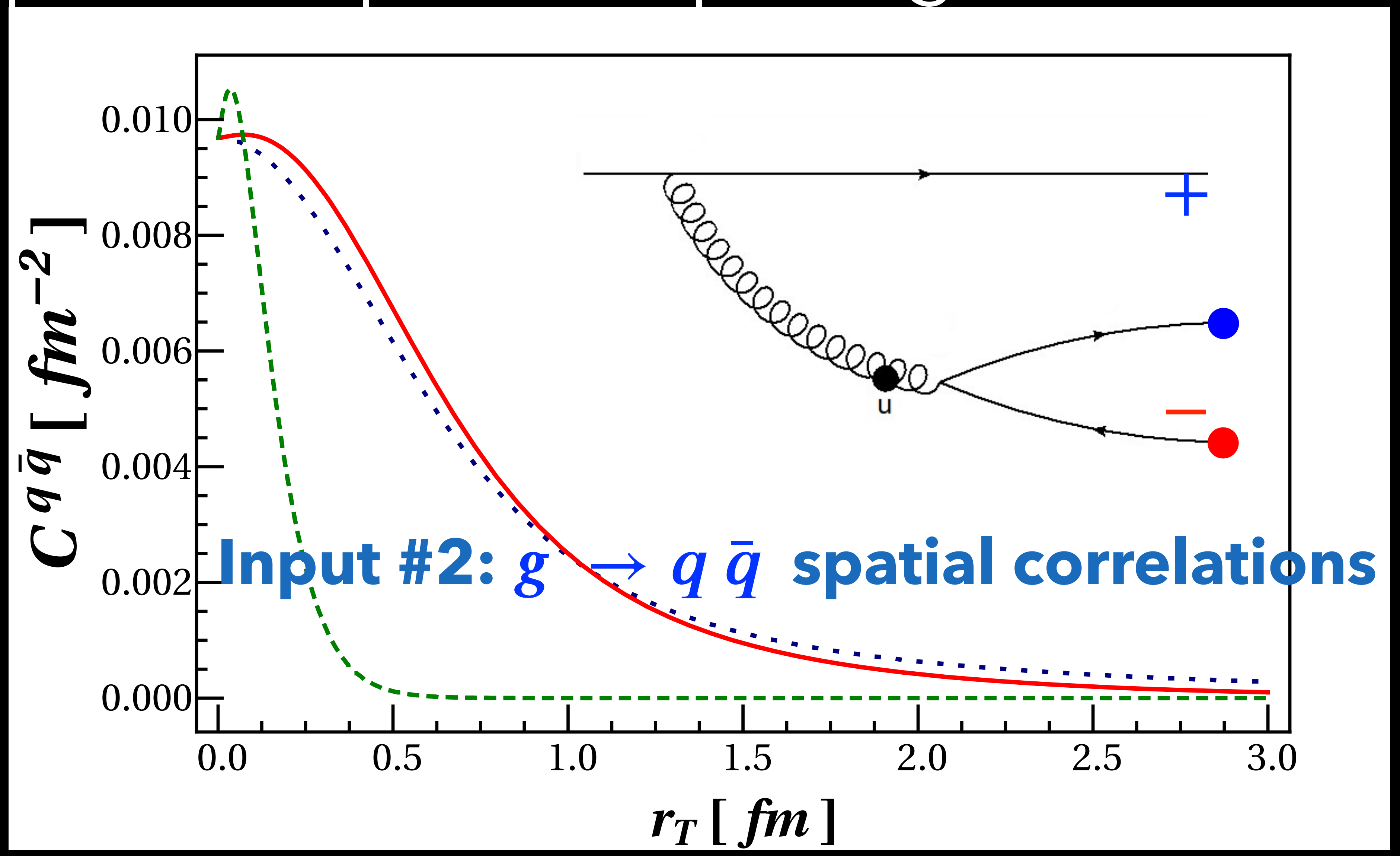
Input: Initial Energy

Initial energy profile (gluons)

Step 1: Sample the Chemistry



Step 2: Sample the Splitting

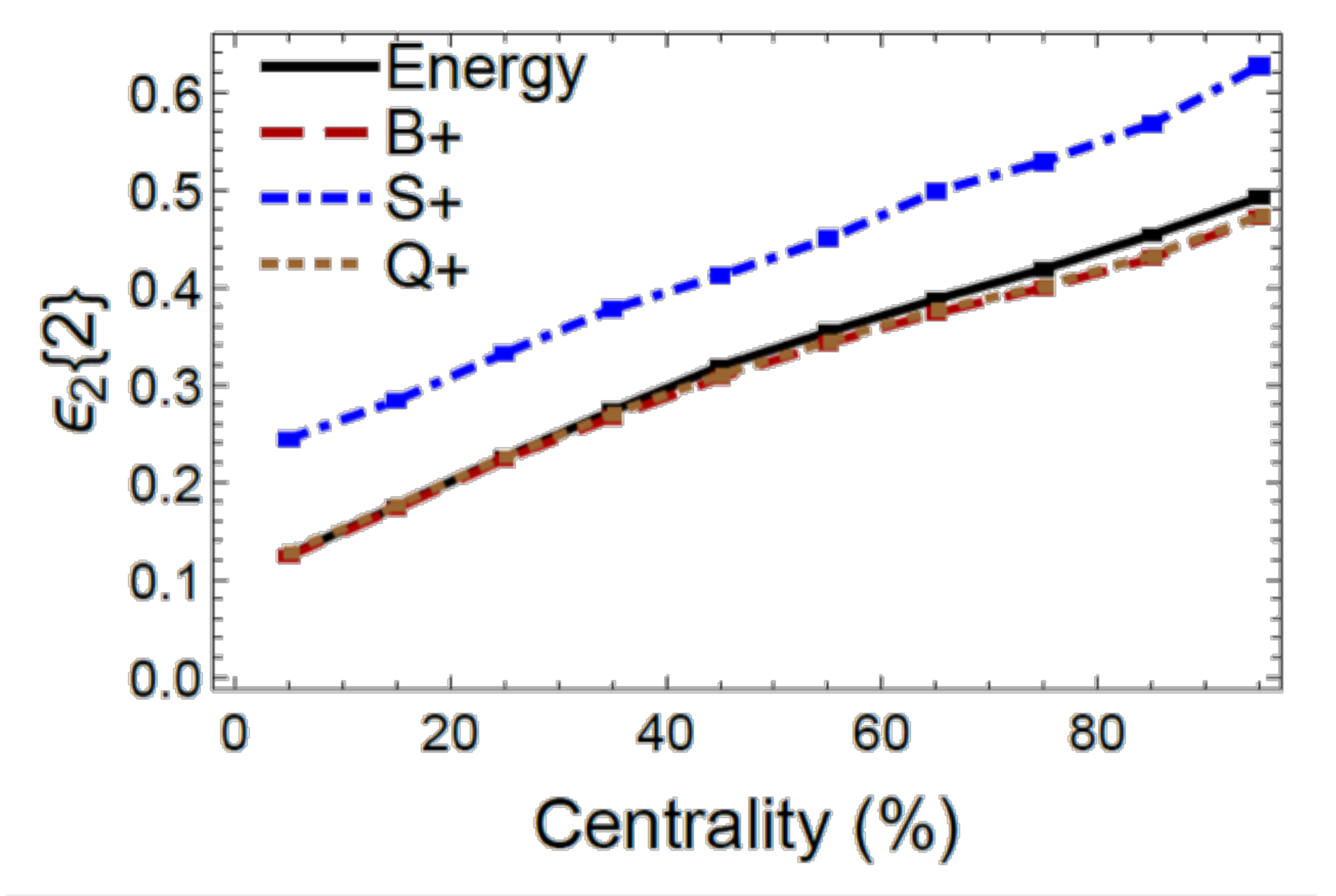


Output: Baryon #, Strangeness, Charge

STRANGENESS ACCESSES A DIFFERENT INITIAL-STATE GEOMETRY

M. Martinez, M. Sievert, D. Wertepny, J. Noronha-Hostler, arXiv: 1911.10272, arXiv: 1911.12454

- Strange Quarks not produced uniformly
- Couple to hot spots which exceed the $s\bar{s}$ threshold
- Strangeness is much more eccentric in ε_2 and ε_3



SUMMARY

- New progress on dynamical initial state
  - Improved description of the data
- Development of new (non-dynamic) 3D initial condition
  - fast and useful for e.g. Bayesian studies
- Compared different 3D initial conditions, effect of pre-hydro evolution
- Development of initial condition for S/B/Q densities based on splitting into q-qbar dipoles