Energy dependence of particle production in Au+Au collisions at BES energies using A Multiphase Transport Model

by

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Outline

- Introduction
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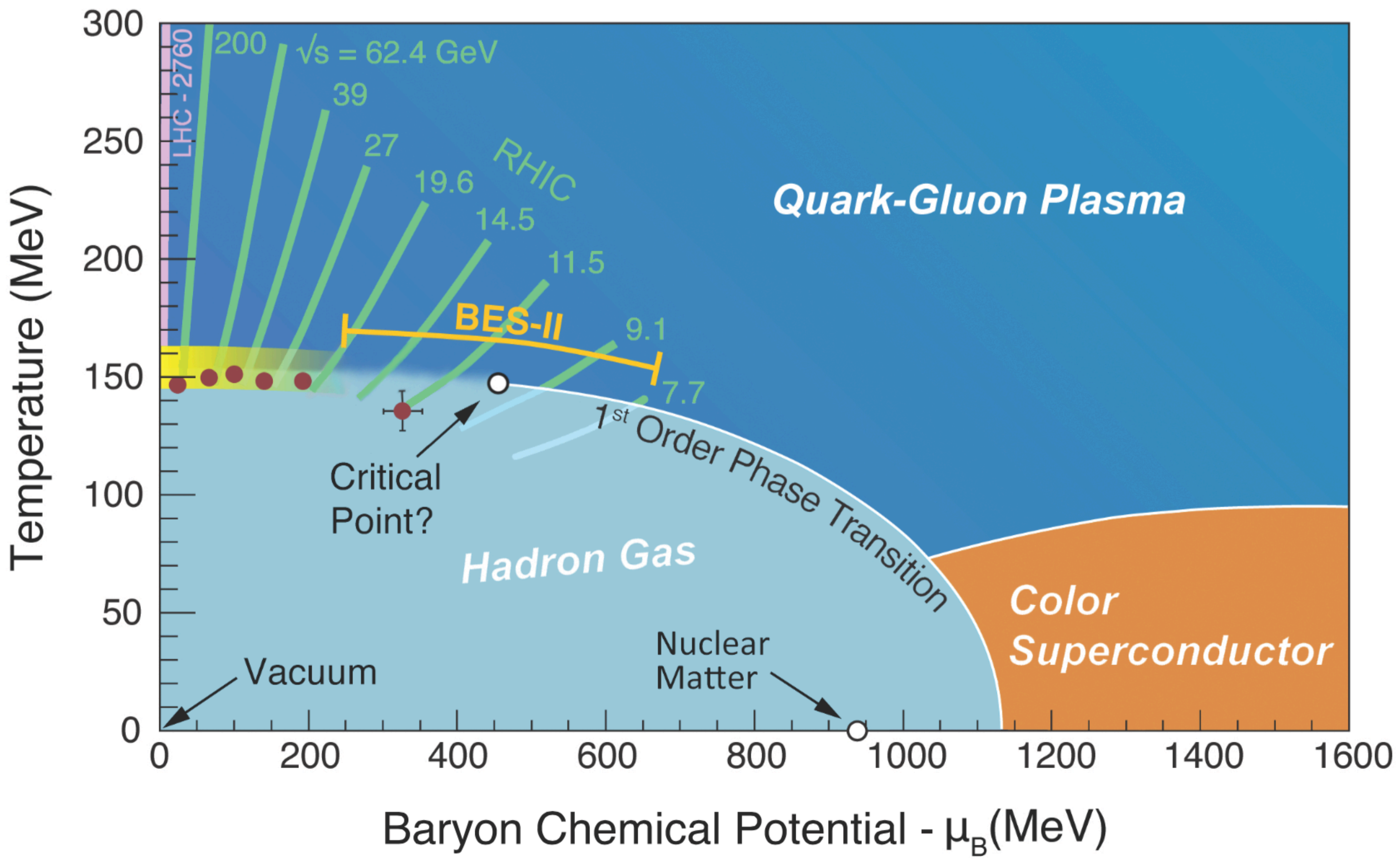


Ref: https://deixismagazine.org/2016/06/early-universe-soup/

RHIC BES Program:

- ➢ To search the predicted first-order phase transition
- ➢ To search for a critical end point
- ➢ To investigate the turn-off of the QGP signatures

Phase I

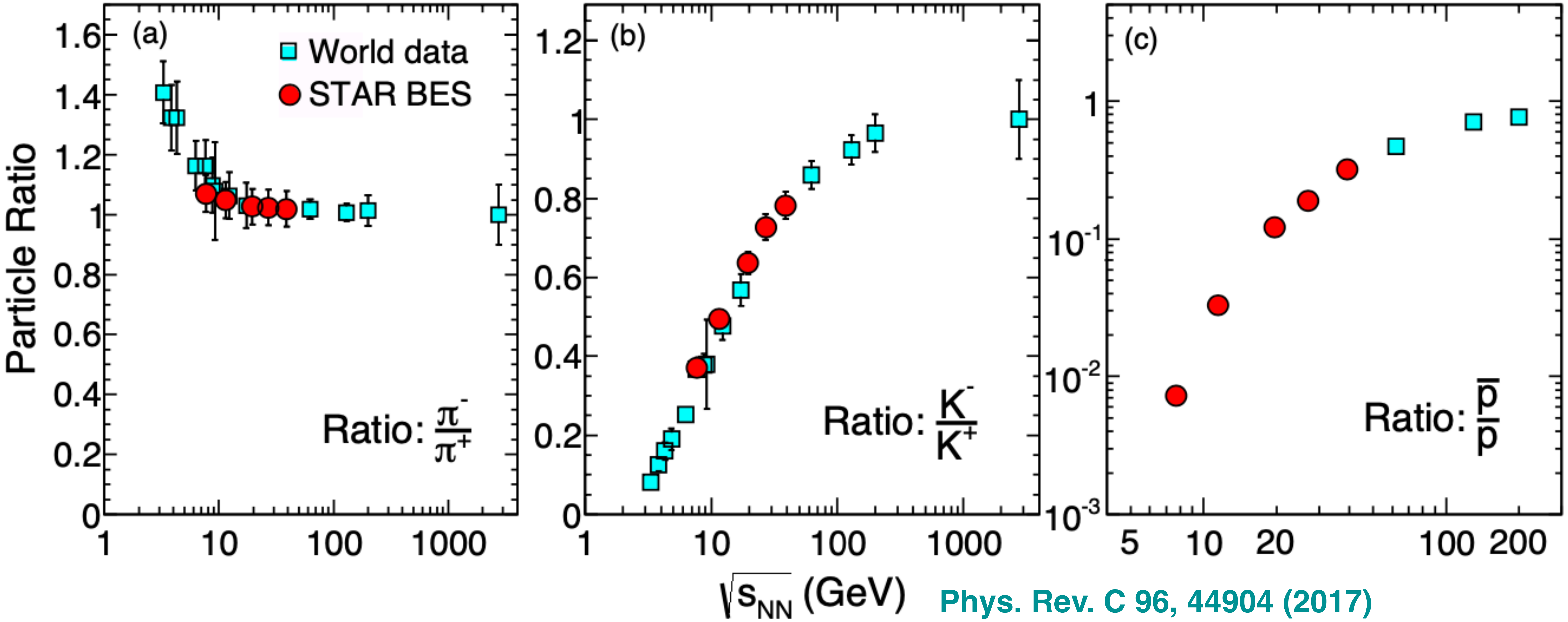
$\sqrt{s_{NN}}$ = 7.7, 11.5, 14.5, 19.6, 27, 39, 62.4, and 200 GeV

Phase II

$\sqrt{s_{NN}}$ = 7.7, 9.2, 11.5, 14.6,17.3,19.6, 27 and 54.4 GeV

$\sqrt{s_{NN}}$ = 3.0, 3.2, 3.5, 3.9, 4.5, 5.2, 6.2, 7.2, 7.7, 9.2, 11.5, and 13.7 GeV (FXT)

Introduction



Phys. Rev. C 96, 44904 (2017)

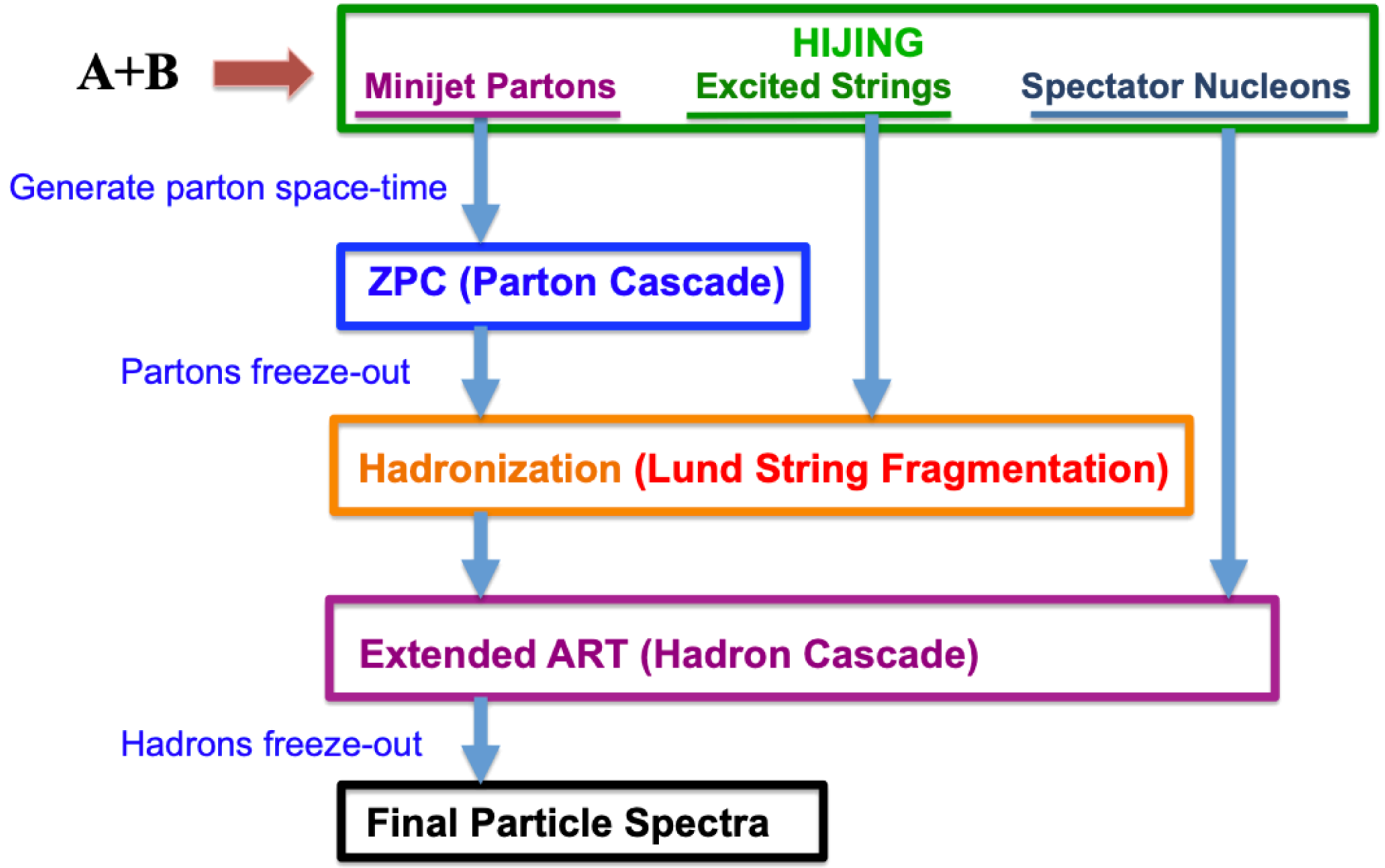
- ➢ The study of identified hadrons is essential to understand the bulk properties of the system
- ➢ Anti-particle to particle ratios for identified hadrons change from lower to higher energies → Particle production mechanism
- ➢ AMPT Model has been used successfully to understand the particle production at higher RHIC energy

A Multi-Phase Transport Model

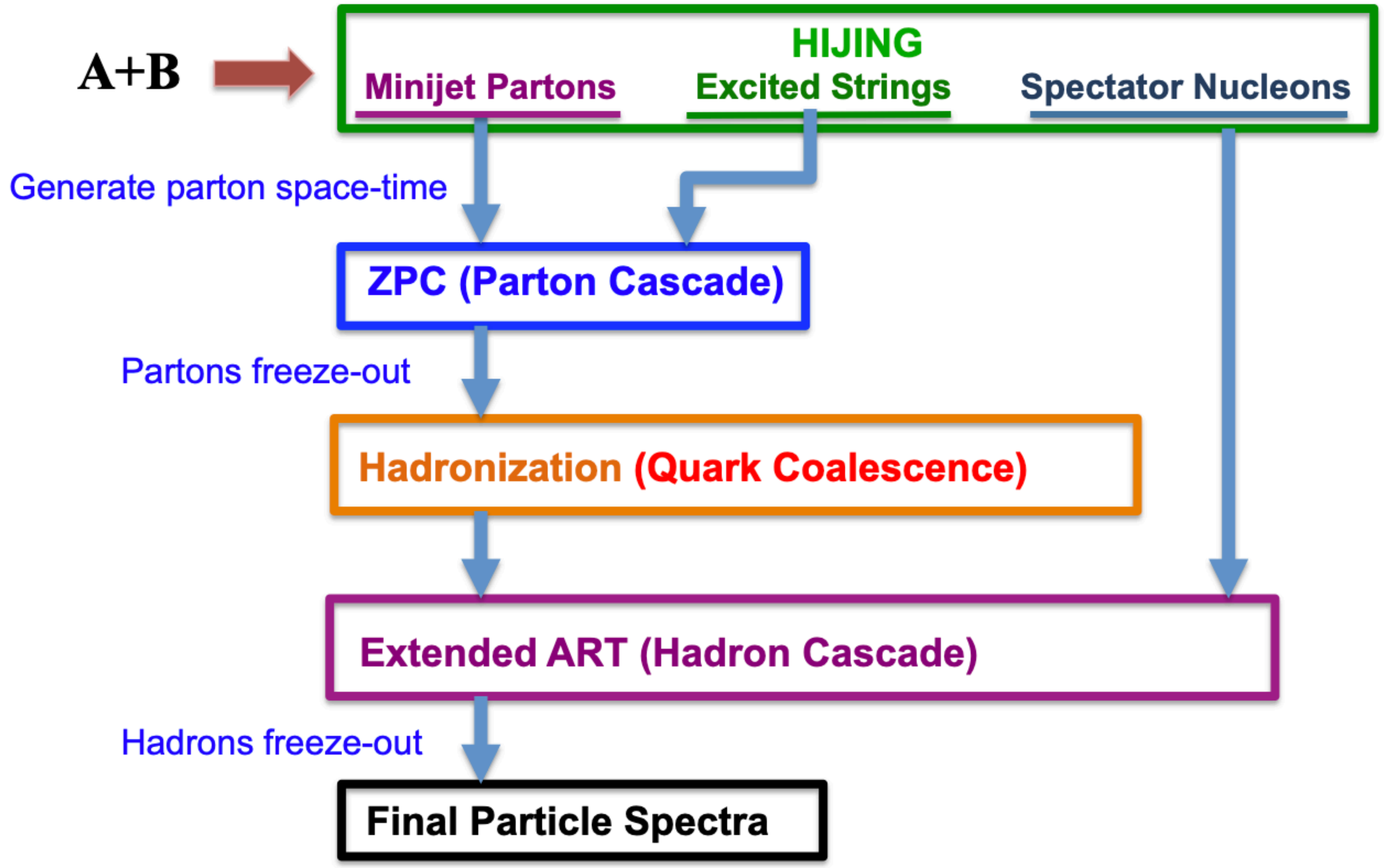
- A Multi-Phase Transport (AMPT) is a Monte Carlo transport model for heavy ion collisions at relativistic energies
    - → Initial conditions
    - → Parton Interactions
    - → Hadronization
    - → Hadron Cascade
- It is used for A+A and p+A collision systems in the range of 5-5500 GeV collision energies
- It provides individual particles position and momentum at the initial stages of the collision

AMPT-Versions

Default



String Melting



Z.W.Lin et al. PRC 61, 067901(2001)

Z.W. Lin et al., PRC 65, 034904 (2002)

Analysis Details

AMPT model used in both String Melting and Default configuration

Au+Au Collisions at $\sqrt{s_{NN}}$ = 200, 54.4, 39, 27, and 7.7 GeV

Number of events ~ 300k

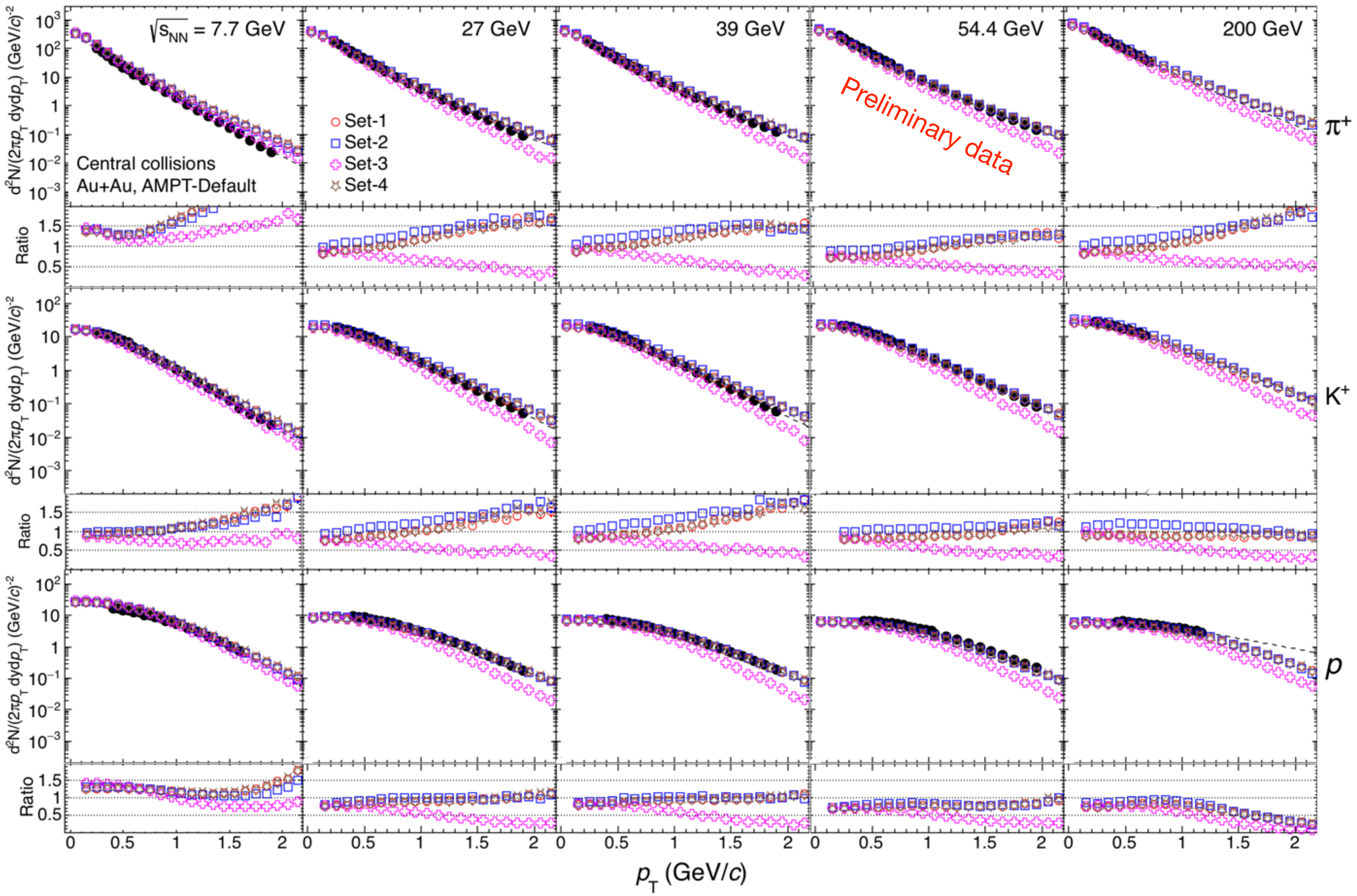
Set	α_s	**Cross section (σ)**	***a***	***b* (GeV^{-2})**	**μ (fm^{-1})**
Set 1	0.33	3 mb	0.55	0.15	2.265
Set 2	0.33	3 mb	2.2	0.15	2.265
Set 3	0.33	1.5 mb	0.5	0.9	3.2
Set 4	0.33	6 mb	0.55	0.15	3.9

The parton scattering cross section is given as: $\sigma \approx 9\pi \frac{\alpha_s}{2\mu^2}$

The average squared transverse momentum of the produced particles is proportional to the string tension: $\kappa \propto < p_T^2 > = \frac{1}{b(2+a)}$

"a" and "b" are the Lund string fragmentation parameters

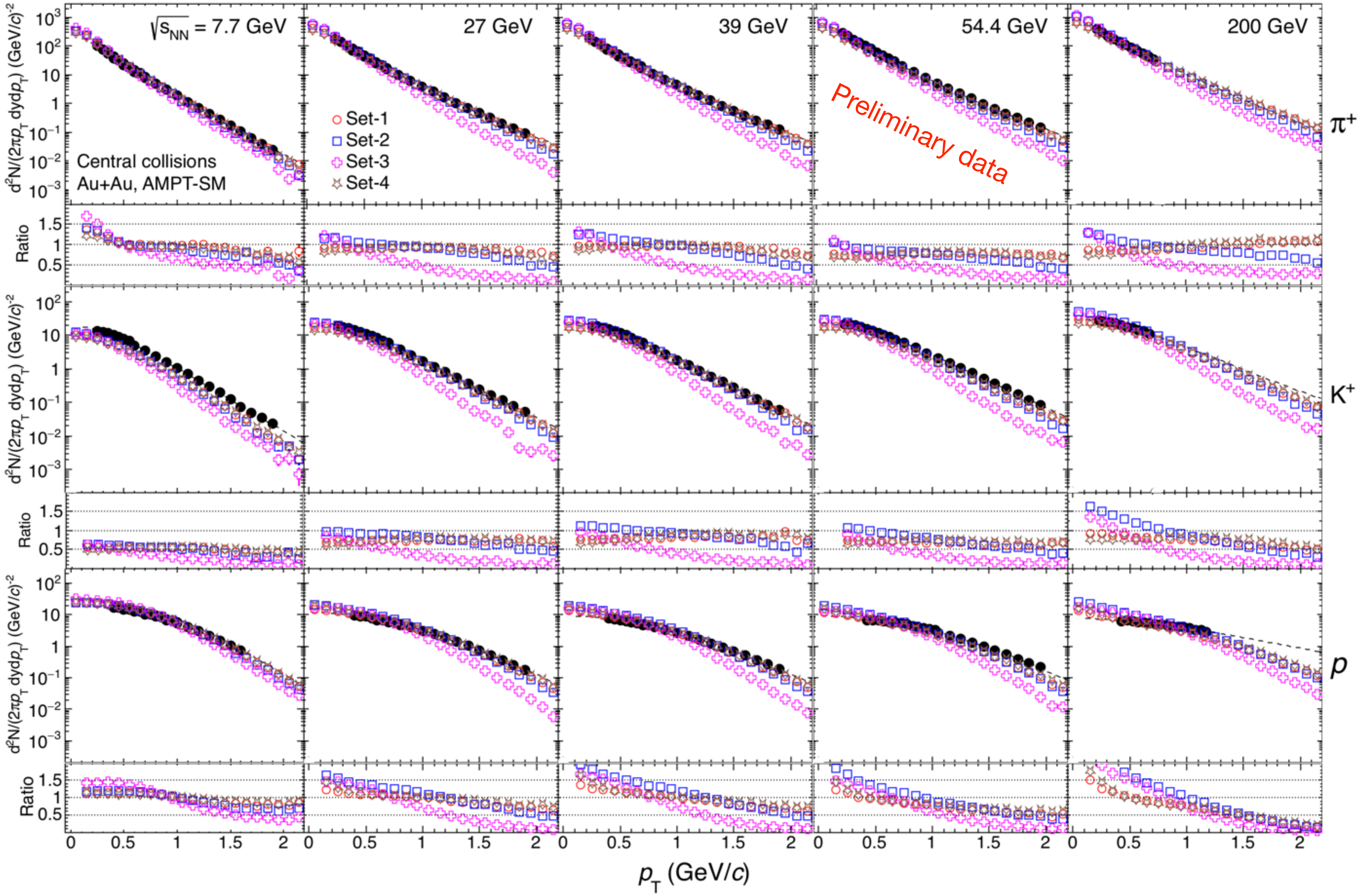
Invariant yield of π^+, K^+ and p: AMPT-Default



✓ Set 2 (σ = 3 mb, a = 2.2, and b = 0.15) of AMPT-Def describes the particle spectra better at lower energies

Phys. Rev. C 96 (2017) 44904

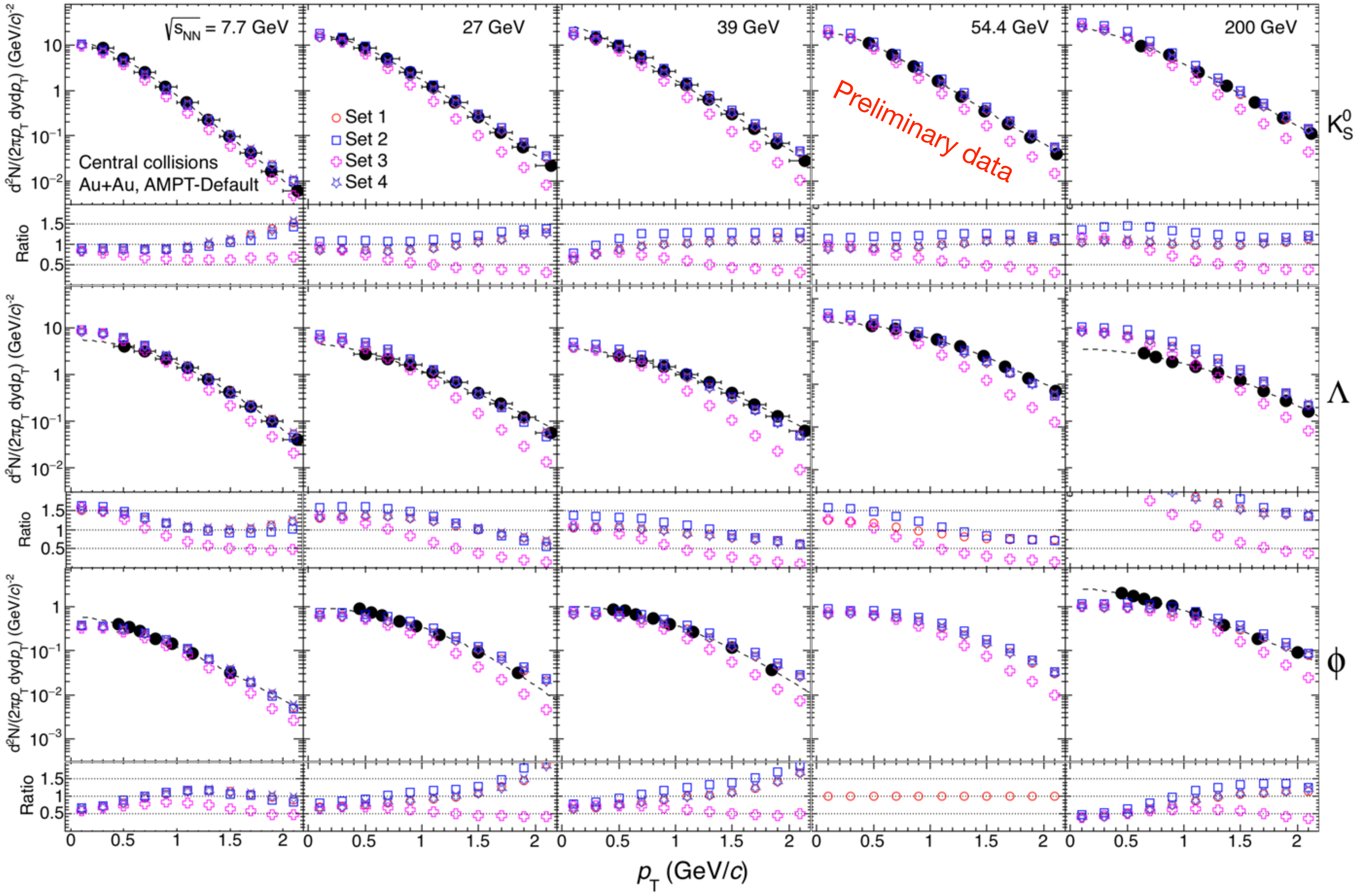
Invariant yield of π^+, K^+ and p: AMPT-SM



✓ Set 2 (σ = 3 mb, a = 2.2, and b = 0.15) of AMPT-SM describes the particle spectra better at higher energies

Phys. Rev. C 79, 034909 (2009)

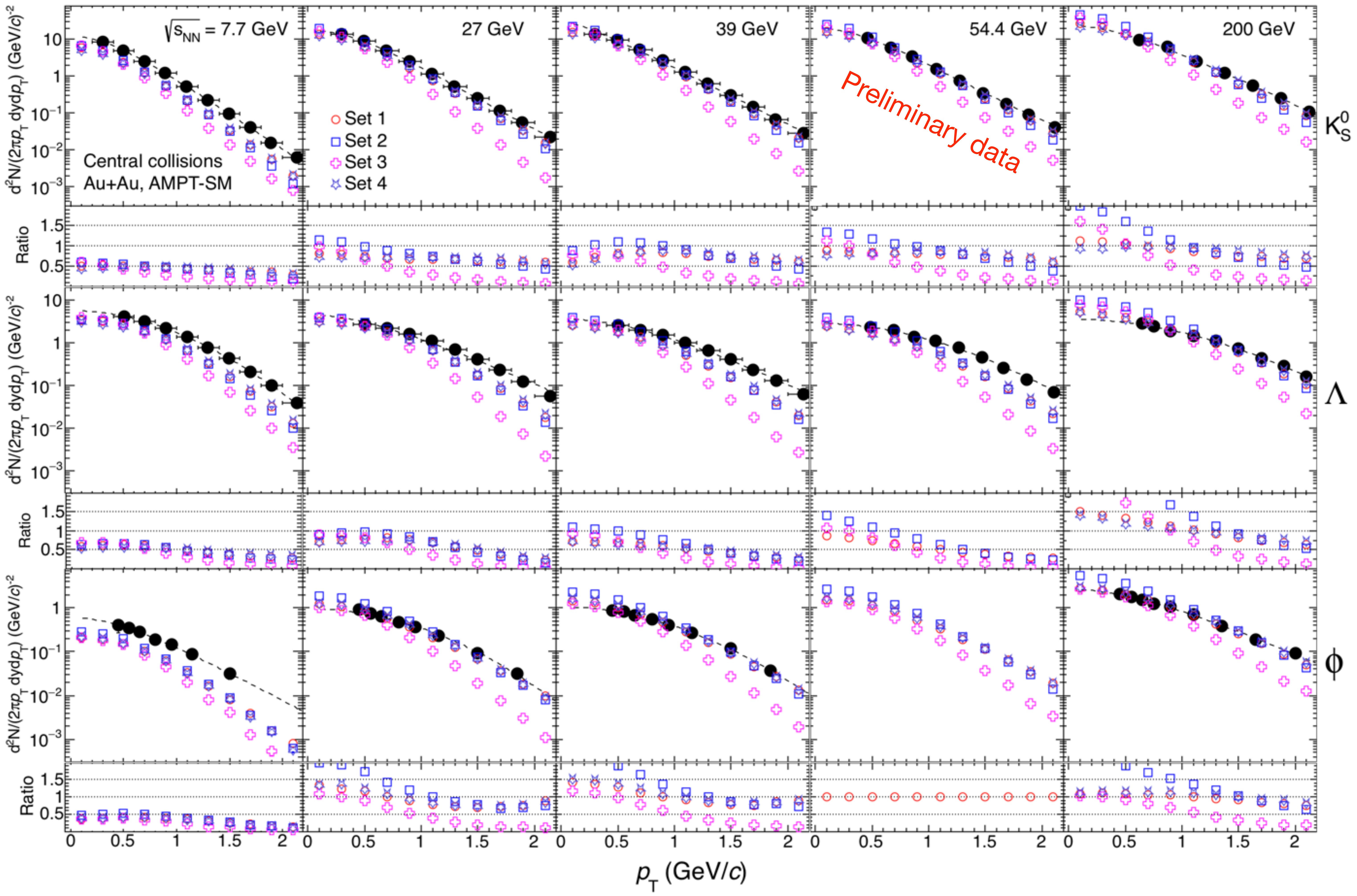
Invariant yield of strange hadrons: AMPT-Default



✓ Set 2 (σ = 3 mb, a = 2.2, and b = 0.15) of AMPT-Def describes the strange particle spectra better at low energies

Phys.Rev.C 93, 021903 (2016)

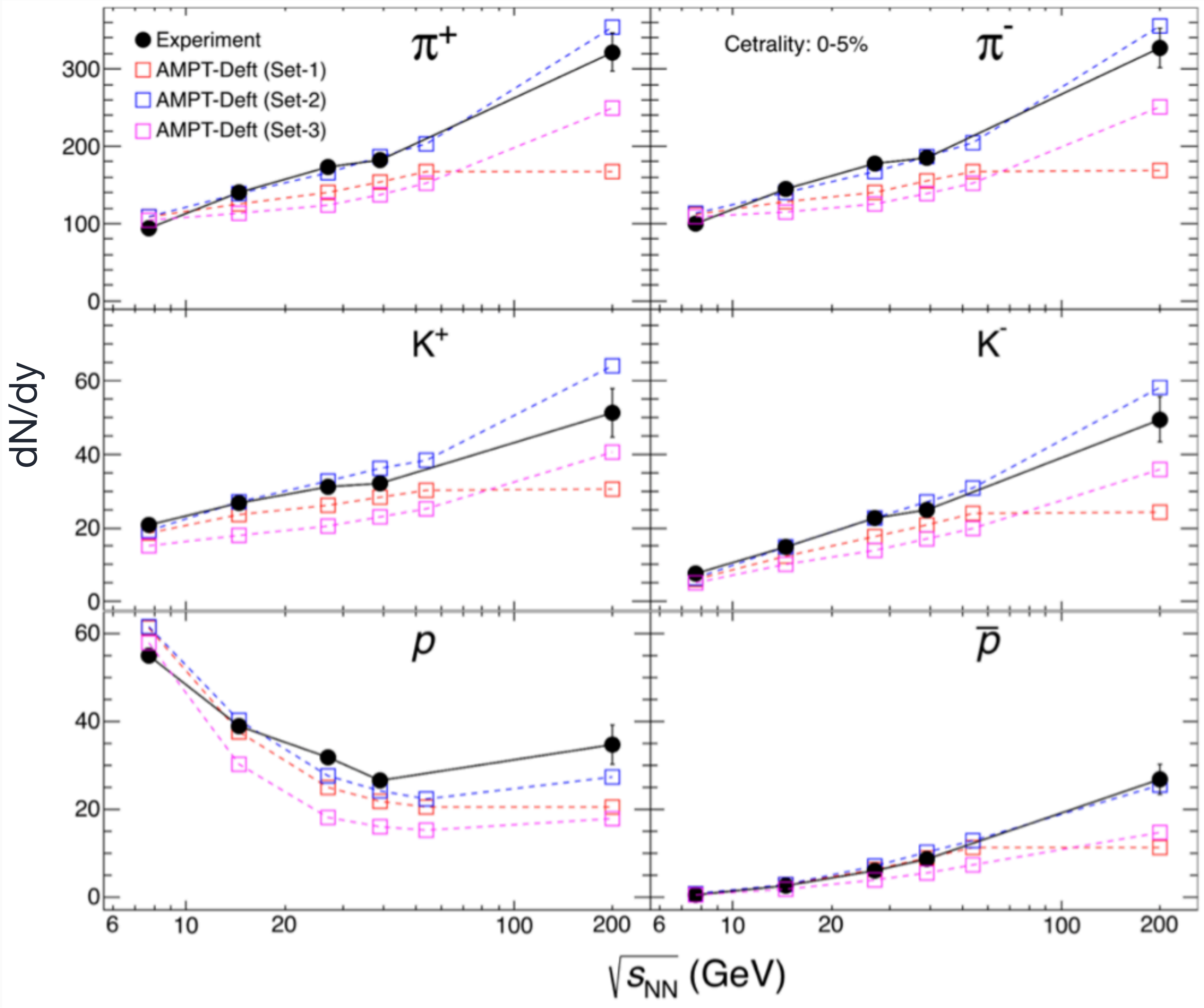
Invariant yield of strange hadrons: AMPT-SM

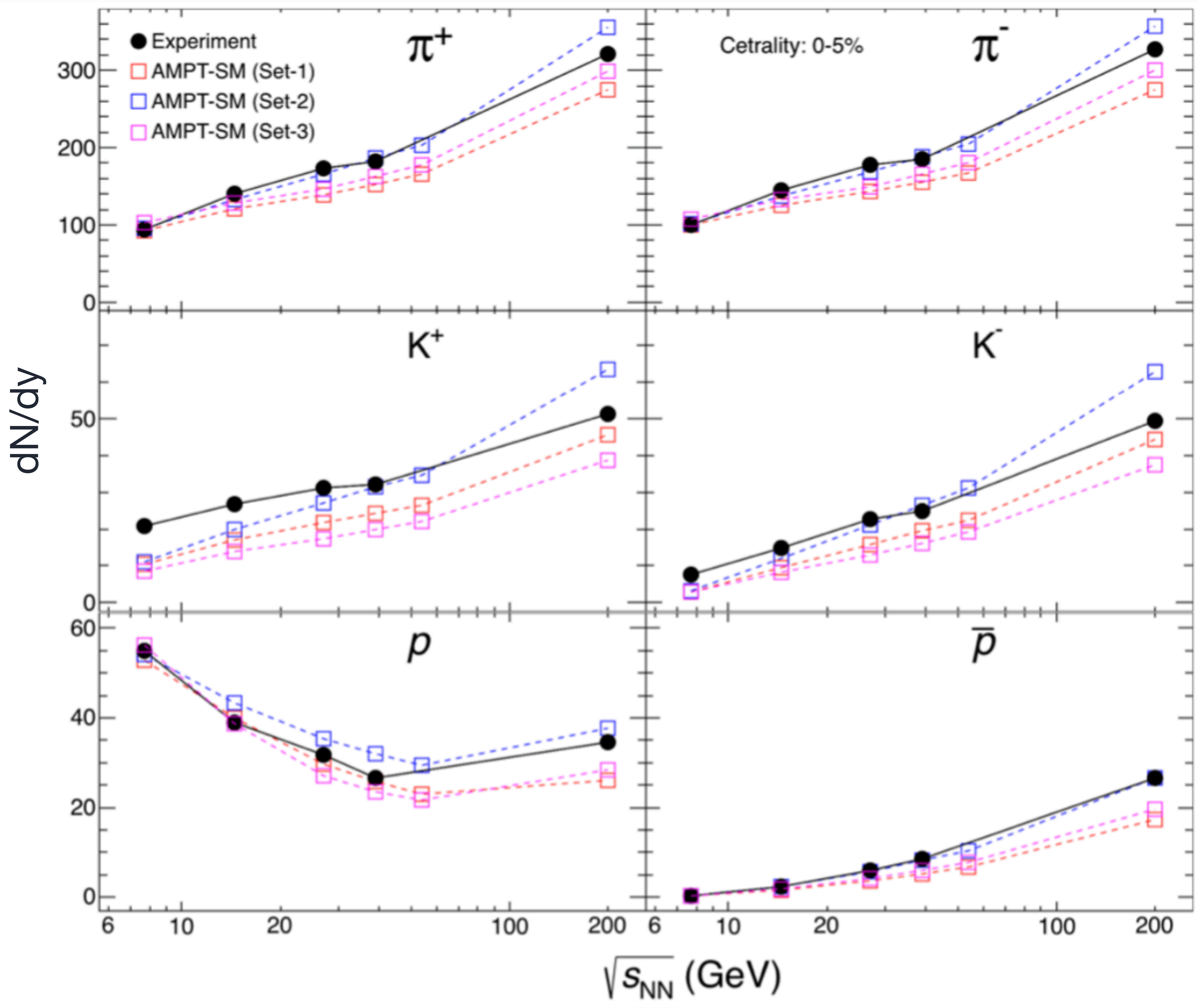


✓ Set 2 (σ = 3 mb, a = 2.2, and b = 0.15) of AMPT-SM describes the strange particle spectra better at higher energies

Phys.Rev.Lett. 98, 062301 (2007)

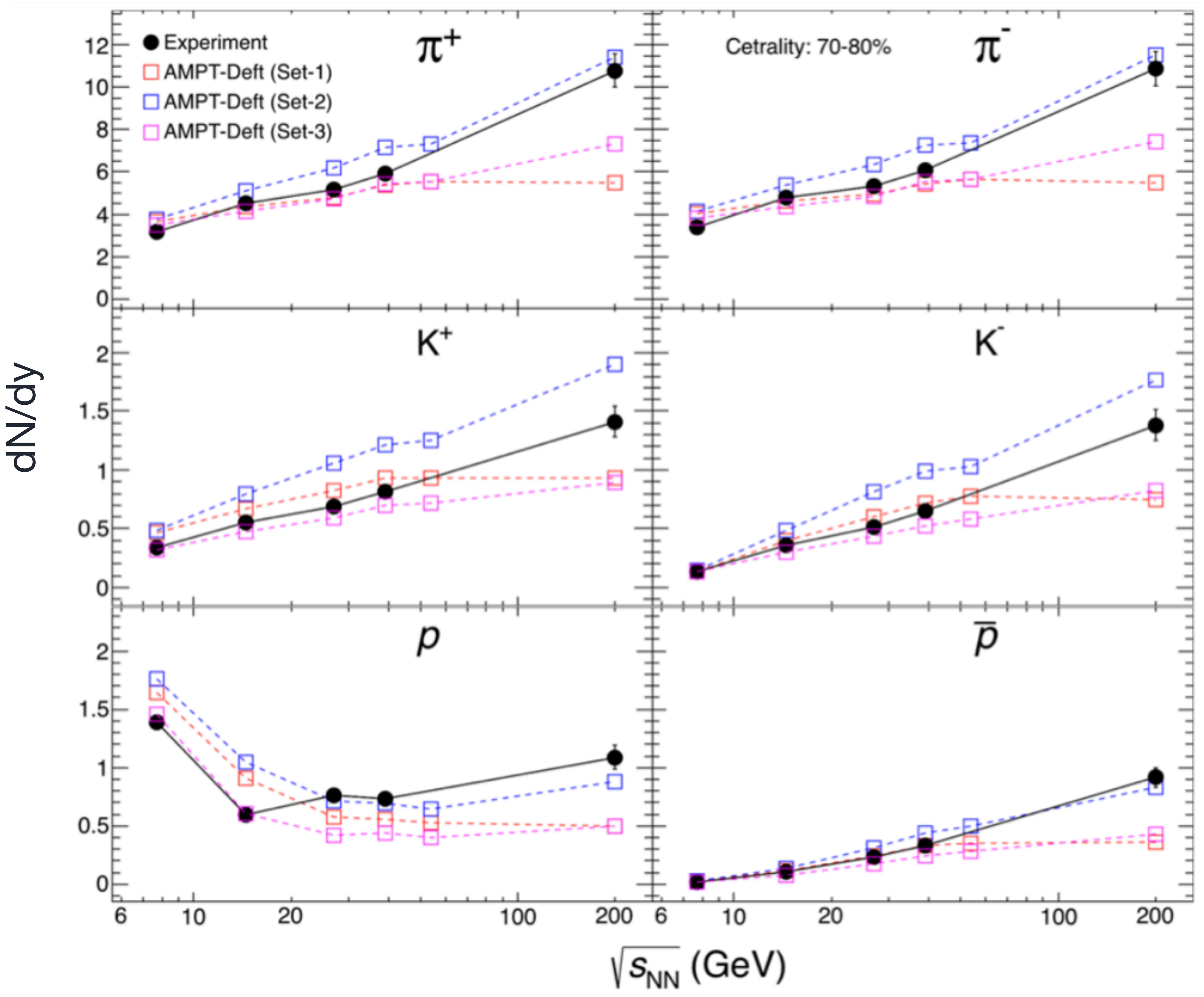
dN/dy vs $\sqrt{s_{NN}}$: Most central

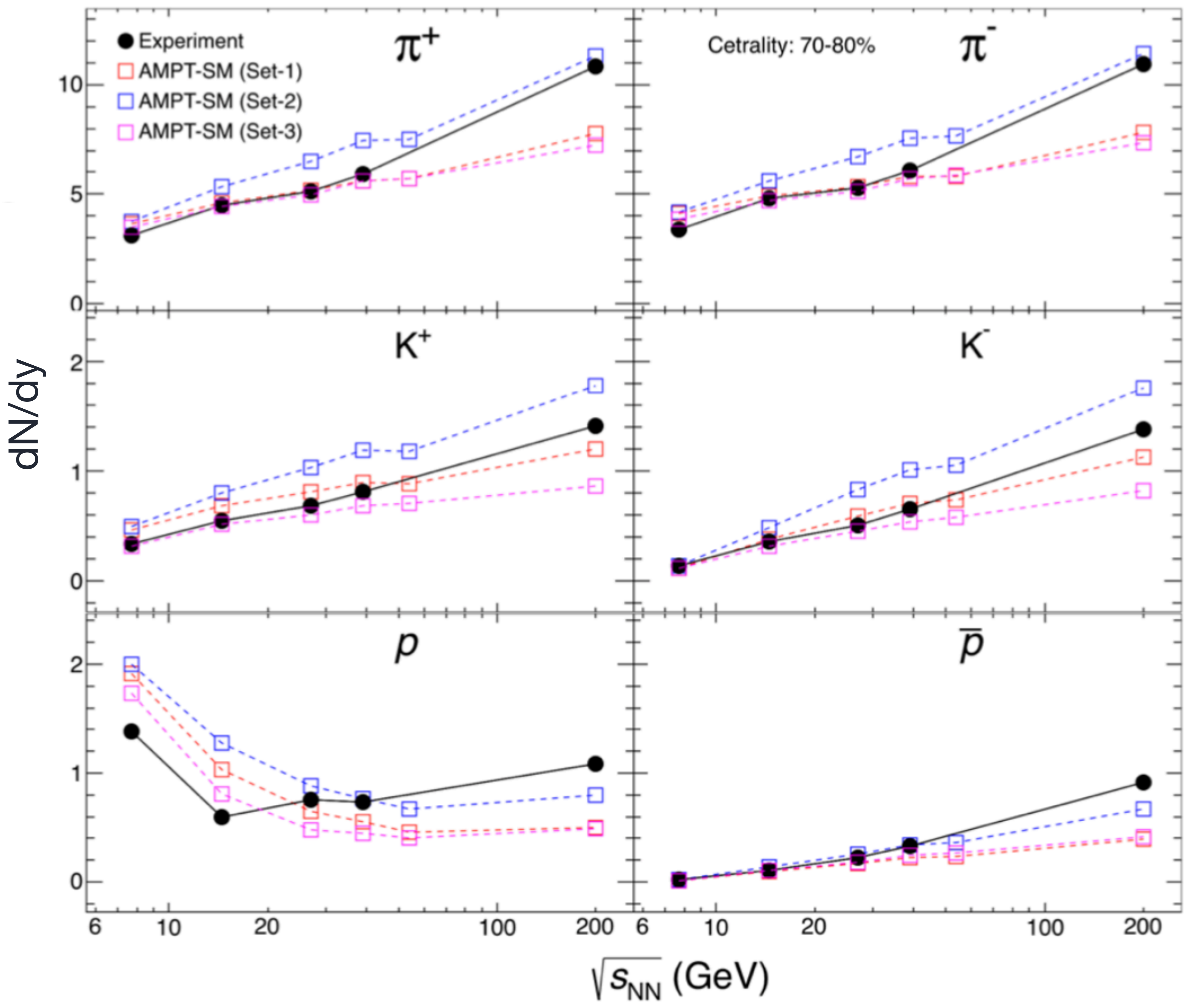




✓ Set 2 (σ = 3 mb, a = 2.2, and b = 0.15) describes p_T integrated yields better at high energy

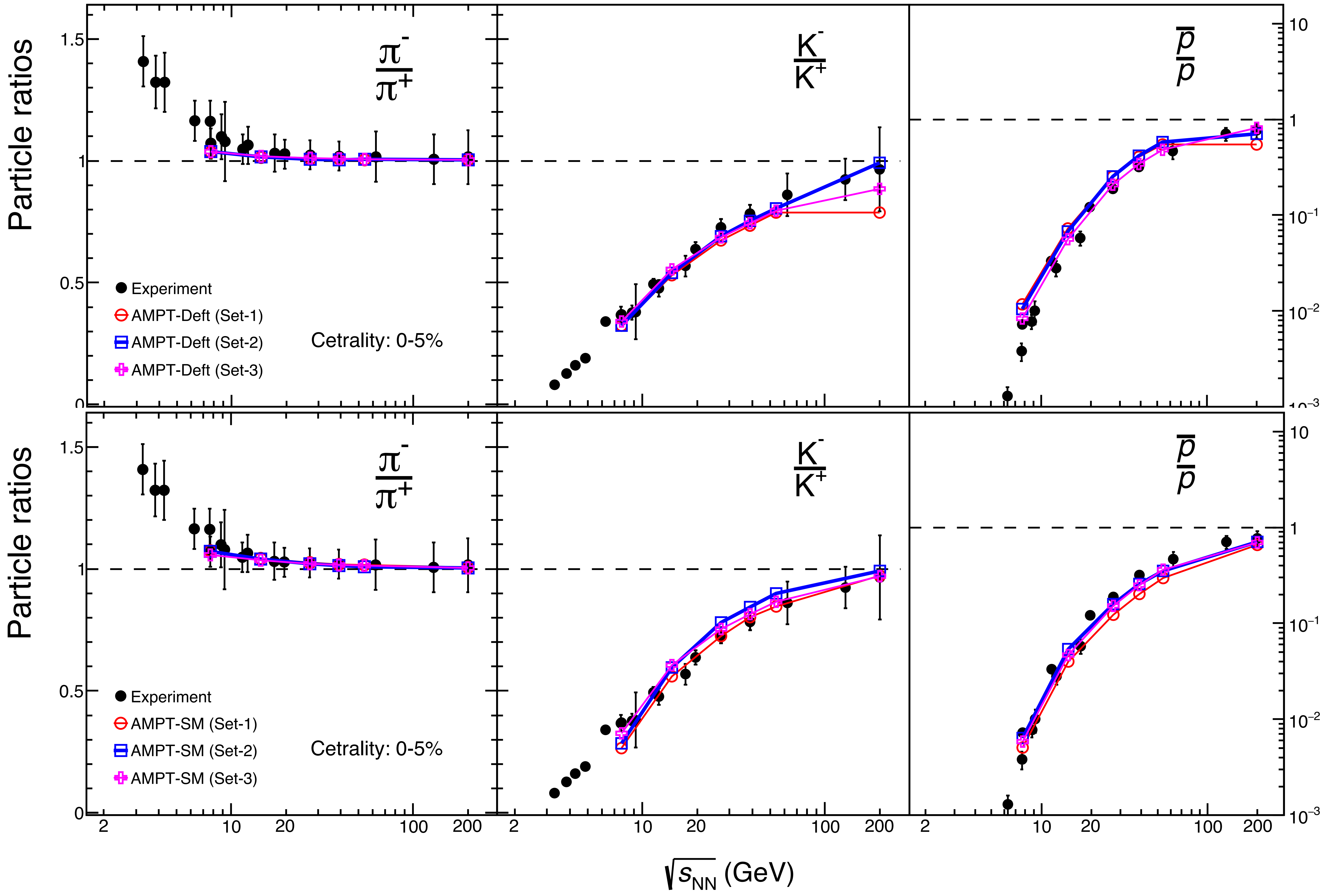
dN/dy vs $\sqrt{s_{NN}}$: Peripheral





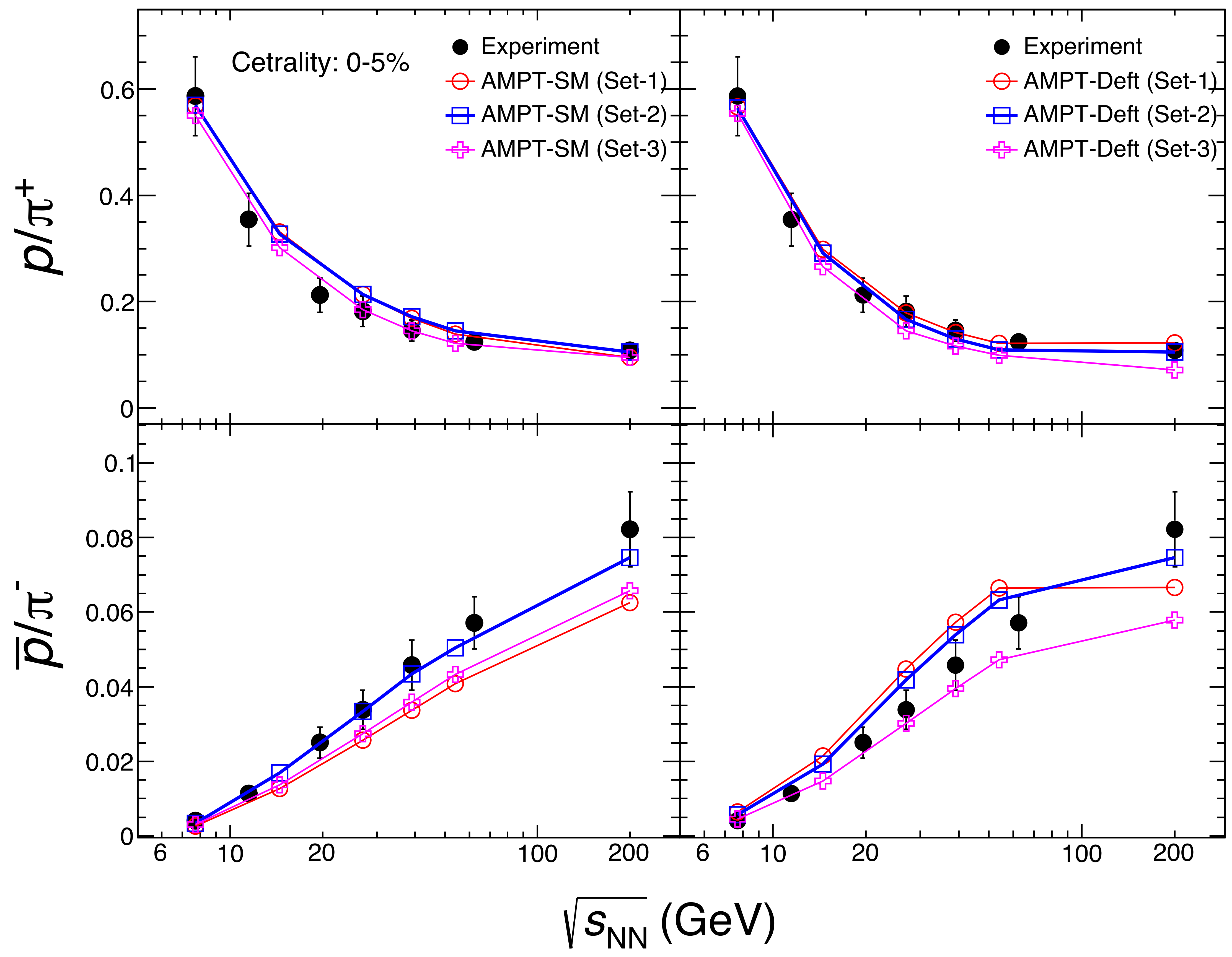
- ✓ Set 2 (σ = 3 mb, a = 2.2, and b = 0.15) describes p_T integrated yields better at high energy

Particle ratios vs $\sqrt{s_{NN}}$: AMPT-SM



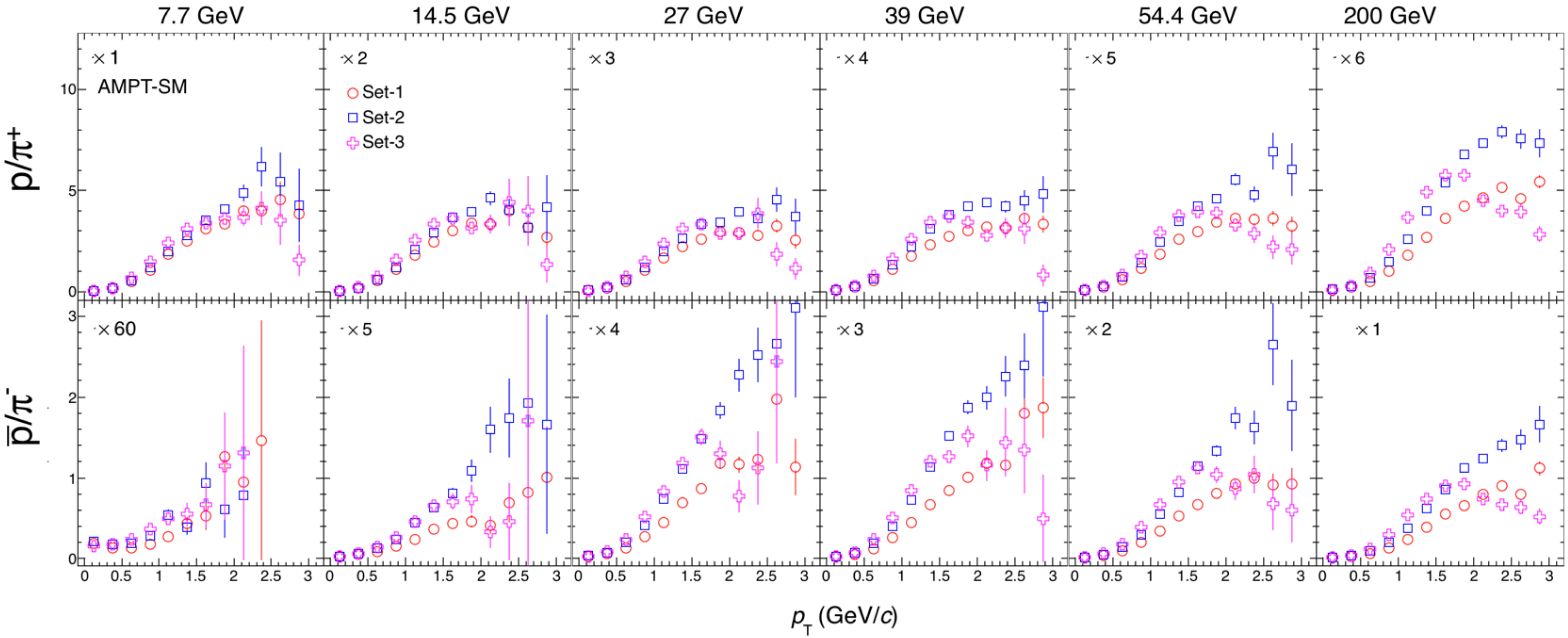
- ✓ All the anti-particle to particle ratios are well described by the three set of parameters
- ✓ Systematic effects of model parameters cancel on particle ratios

Ratios vs $\sqrt{s_{NN}}$



- ✓ p/π^+ ratio increases with decreasing energy due to baryon stopping
- ✓ $\bar{p}/\pi^-$ ratio increases as we go to higher energy
- ✓ No strong dependence on model parameters

Baryon to meson ratio: AMPT-SM



✓ p_T dependent ratios show preference for model parameters

Kinetic properties

Blast Wave Model: Hydrodynamic inspired model

$$\frac{1}{p_T}\frac{dN}{dp_T} \propto \int_0^R r dr m_T I_0\left(\frac{p_T \sinh\rho}{T_{\text{kin}}}\right) K_1\left(\frac{m_T \cosh\rho}{T_{\text{kin}}}\right)$$

I_0, K_1 : Bessel function

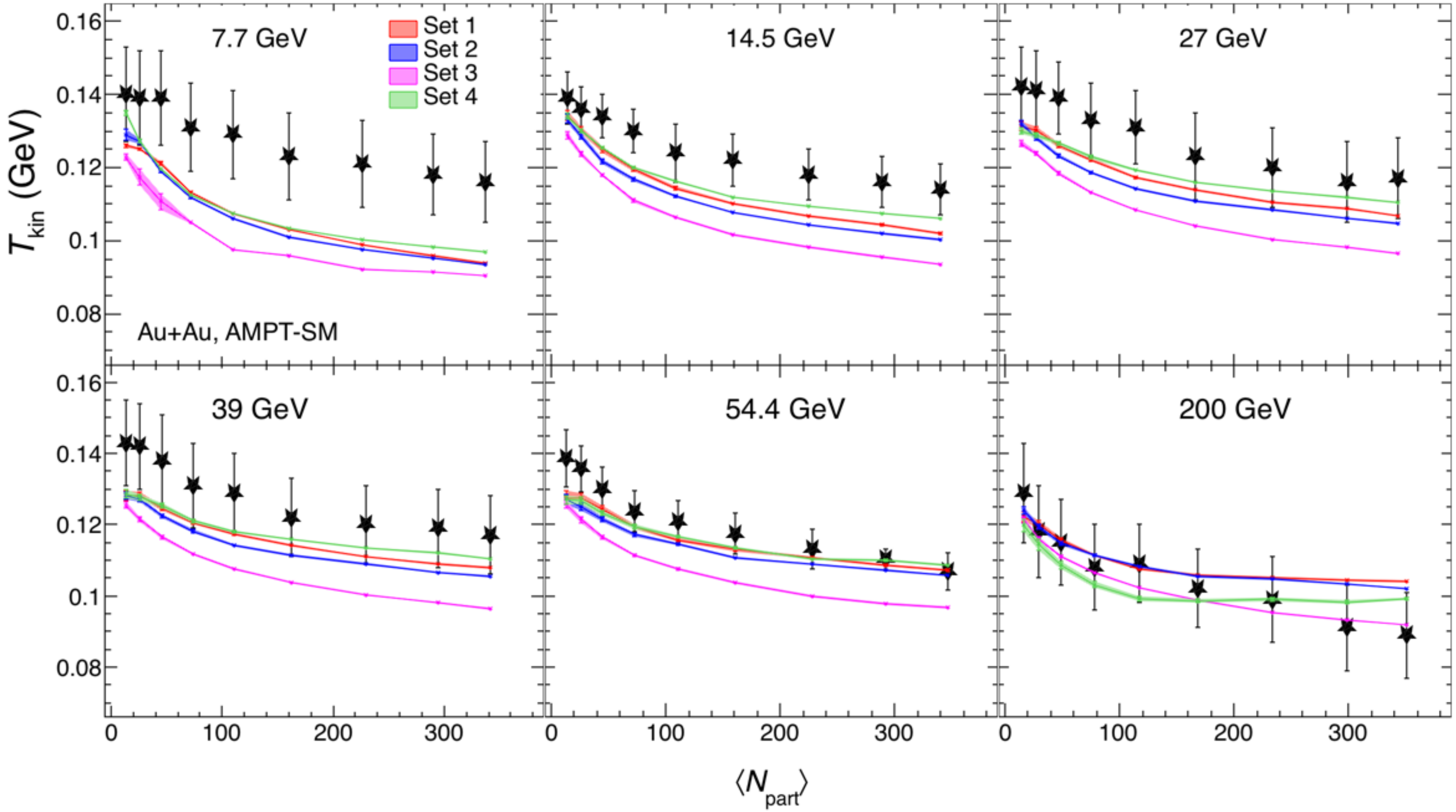
$\rho(r) = tanh^{-1}\beta$

$\beta =$ Radial flow

T_{kin} : Kinetic freeze-out temperature

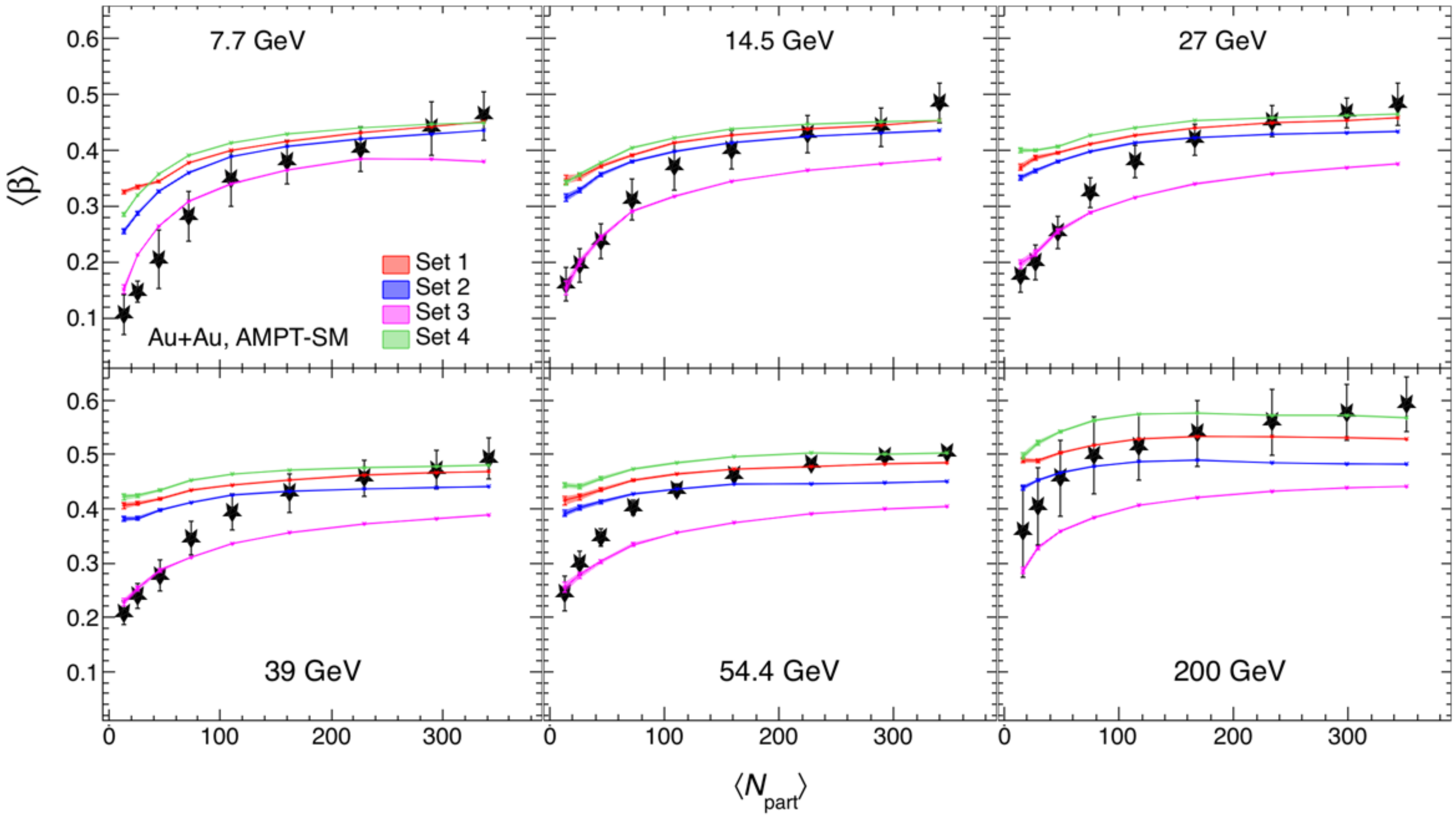
Momentum distributions are fitted simultaneously with blast wave to extract the kinetic freeze-out temperature (KFO) and average radial flow velocity (<β>)

Centrality dependence of KFO



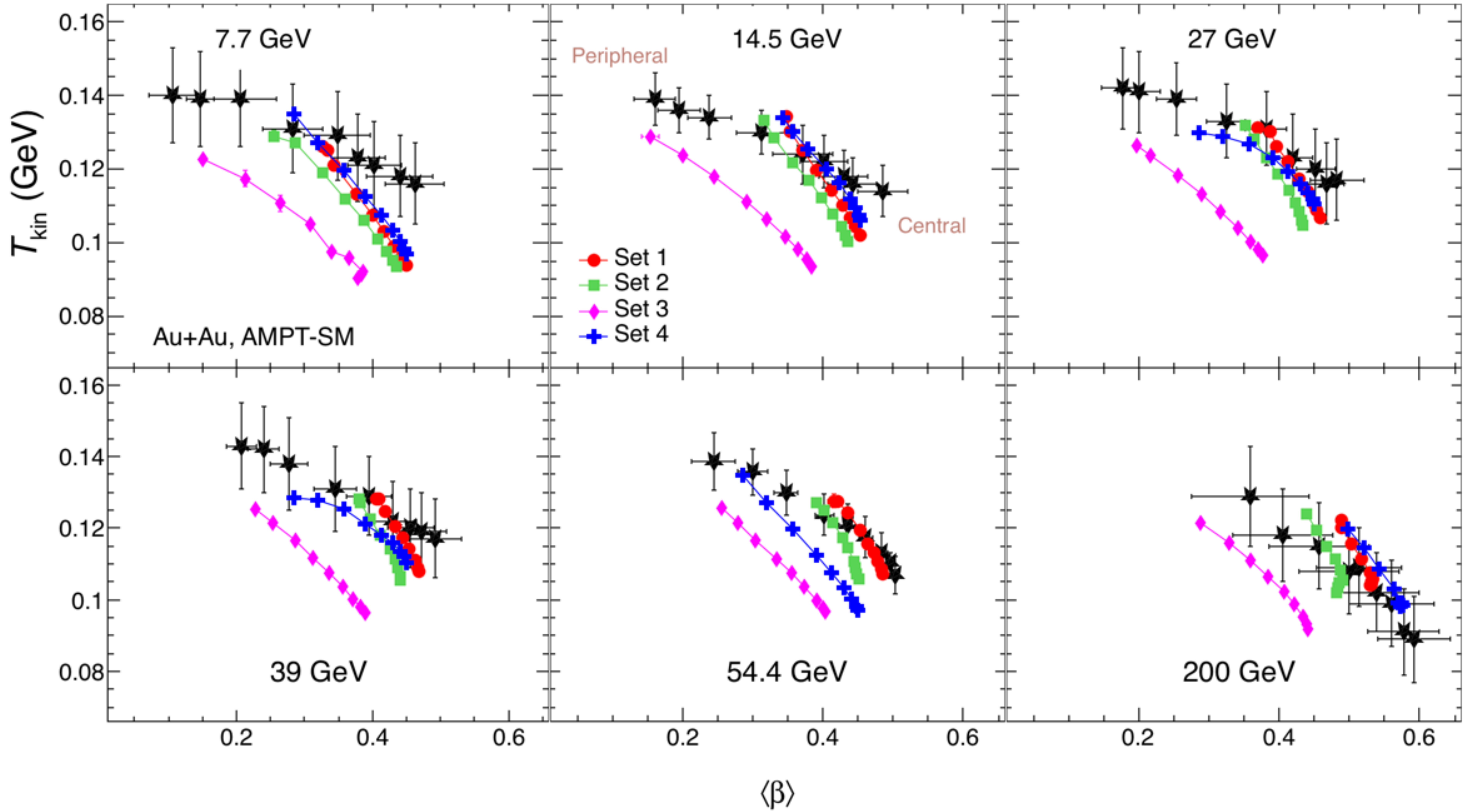
✓ Sets 1, 2, and 4 show similar behavior whereas Set 3 shows large deviation from data

Centrality dependence of <β>



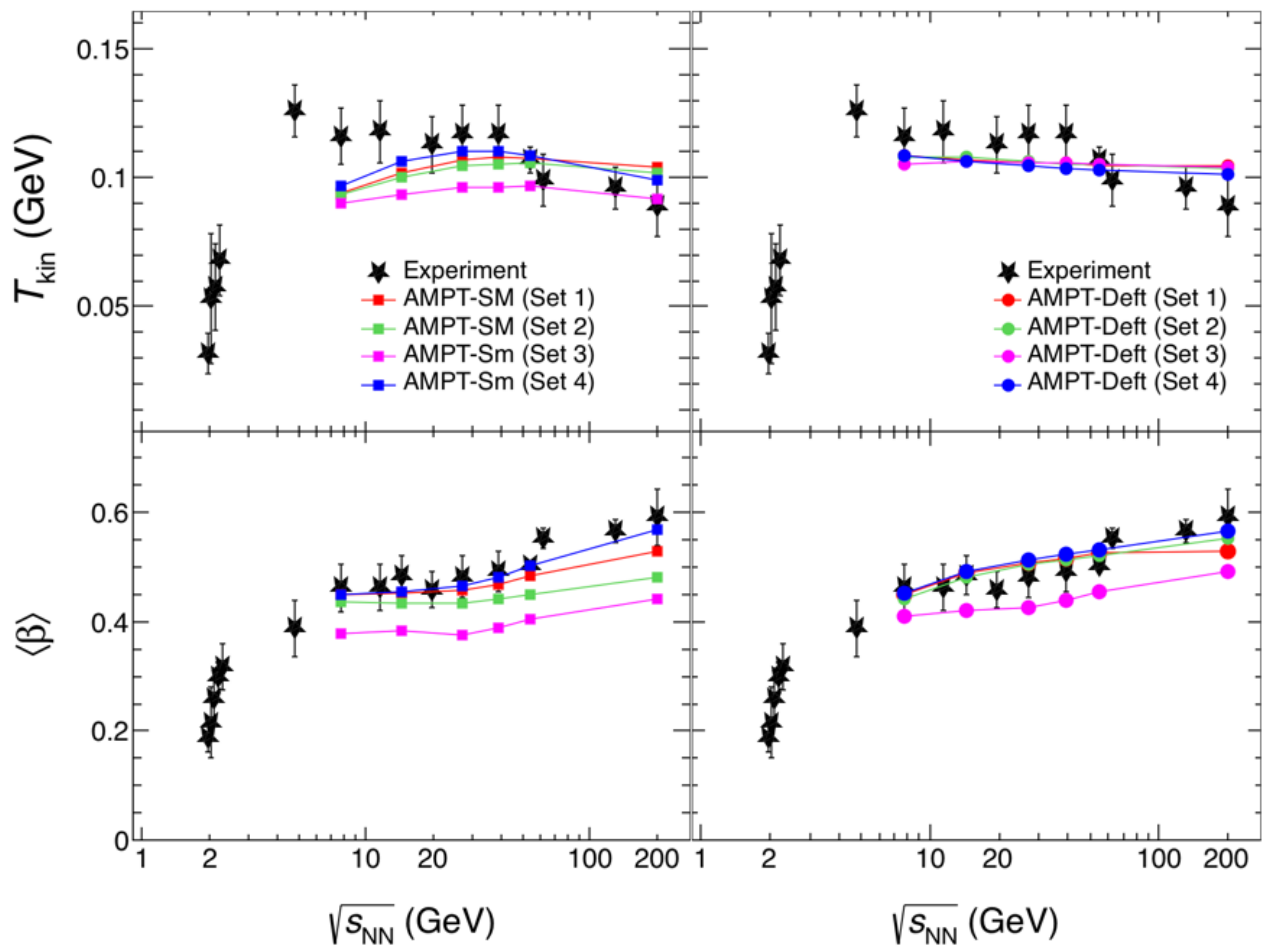
✓ Sets 1, 2, and 4 almost show similar behavior and describe the data at higher energies whereas Set 3 describe the data better at low energies

T_{kin} vs <β>



✓ Sets 1, 2, and 4 show similar behavior whereas Set 3 shows a significant deviation from the experimental results

Energy dependence of T_{kin} and <β>



✓ Sets 1, 2, and 4 of AMPT-SM describe the data better whereas Set 3 shows a deviation for average transverse flow velocity

Summary

- A comprehensive study of p_T spectra for identified hadrons ($\pi^{\pm}$, $K^{\pm}$, p($\bar{p}$),K_s^0, ϕ and Λ) are performed using AMPT Model
- p_T spectra for $\pi^{\pm}$, $K^{\pm}$ and p($\bar{p}$), K_s^0, ϕ and Λ for various energies are compared with the STAR data
- p_T dependent particle ratios show preference on model parameters
- p_T integrated particle ratios don't show strong dependence on model parameters
- At low energy, the Default Set2 (a = 2.2, b = 0.15) describes the data reasonably well whereas at higher energy the String Melting Set 2 (a = 2.2, b = 0.15) describes data better
- All sets also show that T_{kin} and $<\beta>$ are anti-correlated. Sets 1, 2, and 4 show similar behavior whereas Set 3 shows a significant deviation from the experimental results.

Thank you for your attention!!