

Dependence of observables on the hadronic equation of state.

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Introduction

The **Parton-Hadron-Quantum-Molecular-Dynamics** extends the established **PHSD** [1] transport approach by replacing the mean-field propagation by density dependent two body interactions in a similar way as in the **Quantum Molecular Dynamics** [2] models – this allows for a dynamical description of cluster and hypernuclei formation. The clusters are identified with the **Minimum Spanning Tree** or the **Simulated Annealing Clusterization Algorithm** [3] which generates the most bound configuration of nucleons and clusters. The PHQMD approach can be used in different modes for the hadron propagation: the mean-field based PHSD mode and the QMD mode with different equations-of-state (EoS). **This allows to study the sensitivity of observables on the different descriptions of the potential interactions among nucleons.**

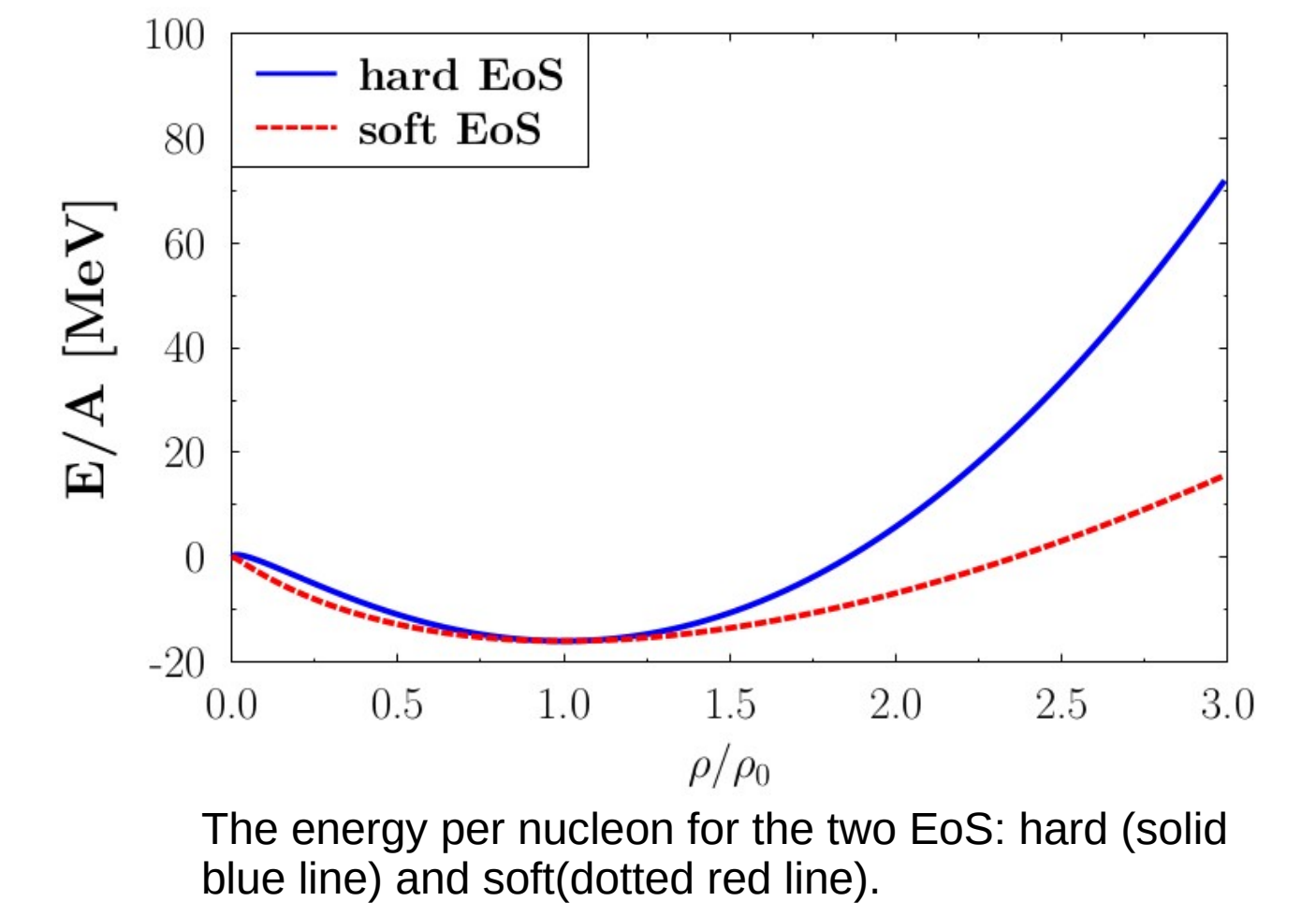
The interaction between the nucleons has two parts, a local Skyrme type interaction and a Coulomb interaction:

$$V_{i,j} = V(\mathbf{r}_i, \mathbf{r}_j, \mathbf{r}_{i0}, \mathbf{r}_{j0}, t) = V_{\text{Skyrme}} + V_{\text{Coul}} = \frac{1}{2} t_1 \delta(\mathbf{r}_i - \mathbf{r}_j) + \frac{1}{\gamma + 1} t_2 \delta(\mathbf{r}_i - \mathbf{r}_j) \rho^{\gamma-1}(\mathbf{r}_i, \mathbf{r}_j, \mathbf{r}_{i0}, \mathbf{r}_{j0}, t) + \frac{1}{2} \frac{Z_i Z_j e^2}{|\mathbf{r}_i - \mathbf{r}_j|} \quad (1)$$

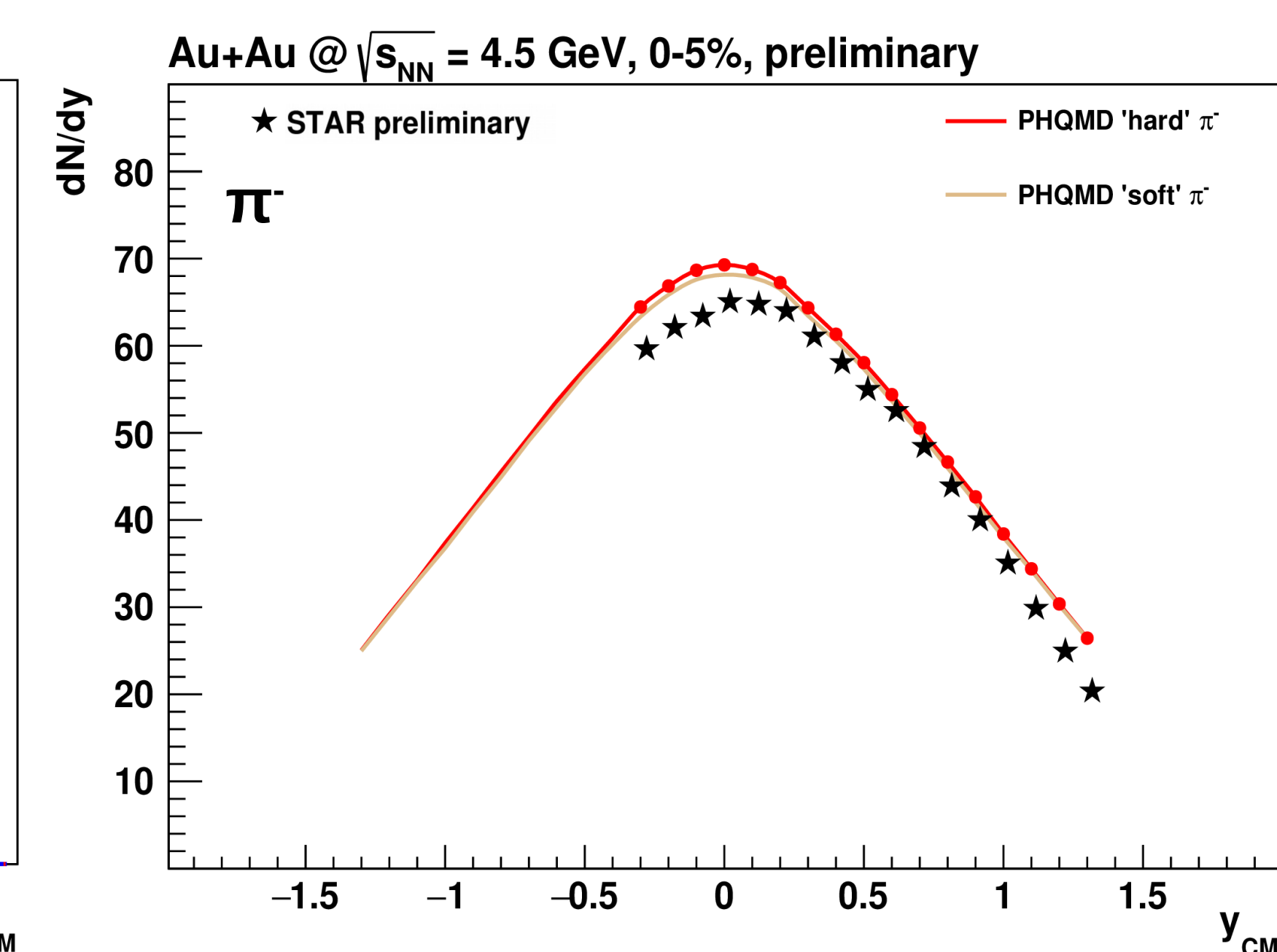
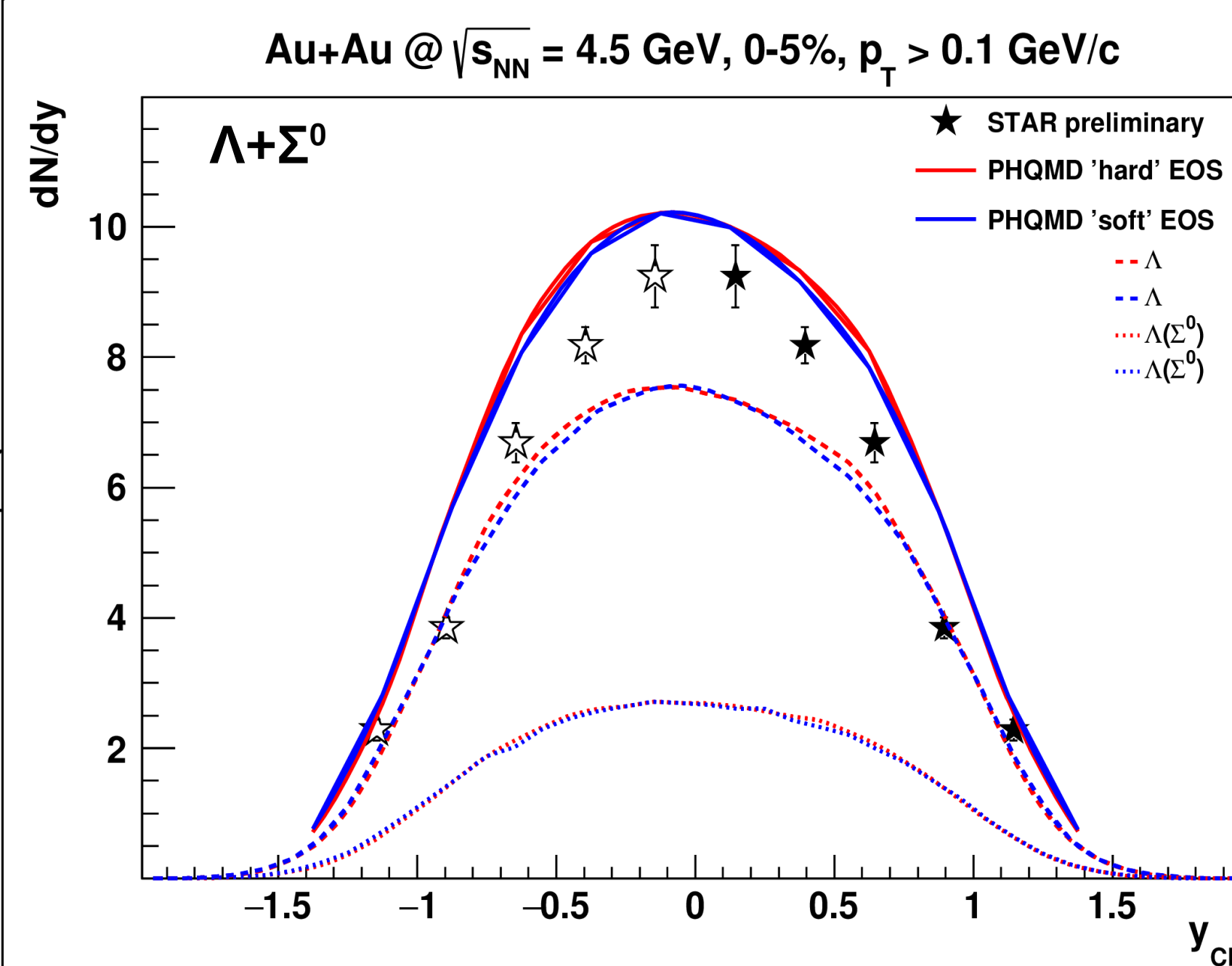
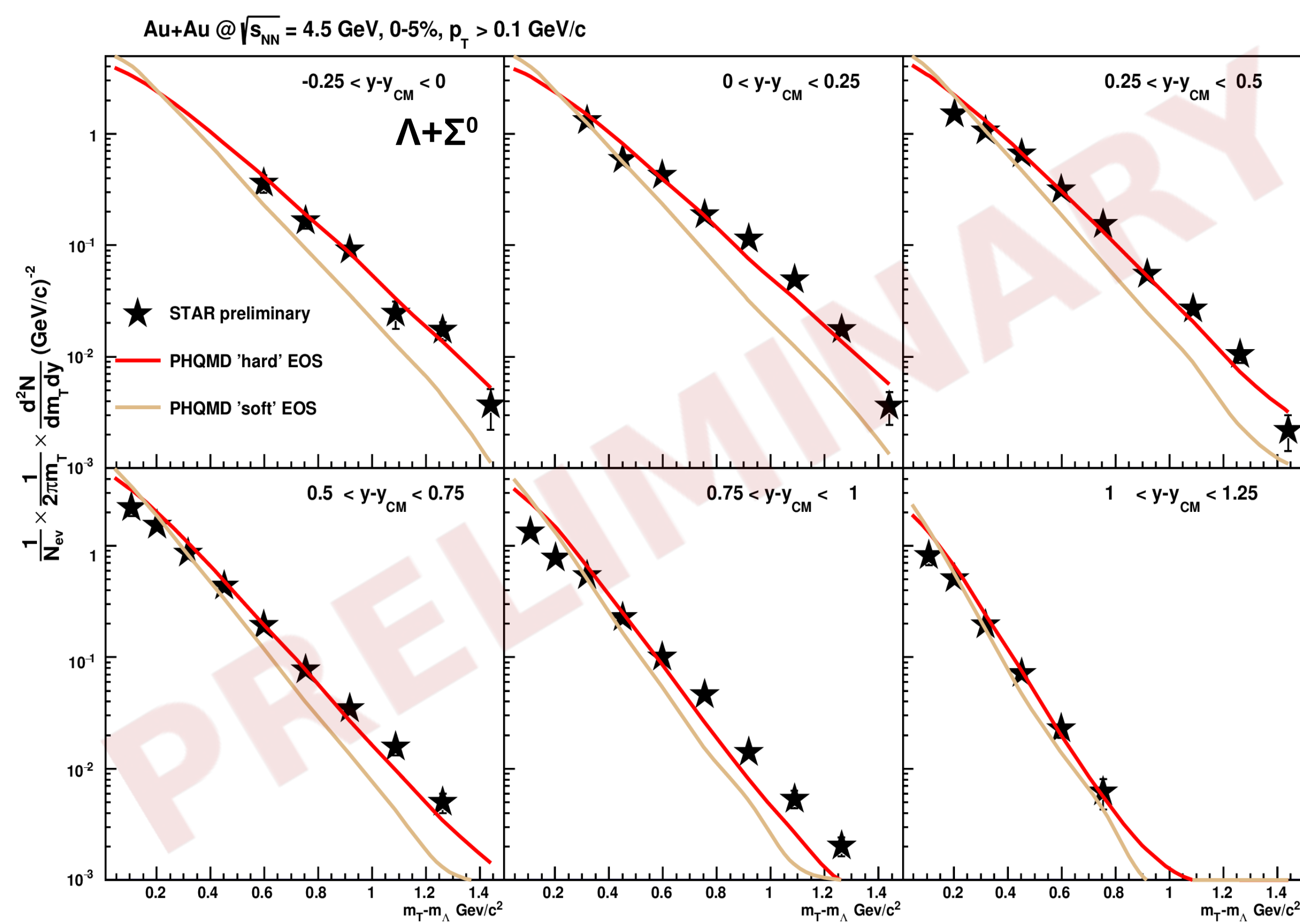
For the Skyrme potential the analytical form is used: $\langle V_{\text{Skyrme}}(\mathbf{r}_{i0}, t) \rangle = \alpha \left(\frac{\rho_{\text{int}}(\mathbf{r}_{i0}, t)}{\rho_0} \right) + \beta \left(\frac{\rho_{\text{int}}(\mathbf{r}_{i0}, t)}{\rho_0} \right)^\gamma \quad (2)$

For a given value of γ the parameters t_1, t_2 in Eq. (1) are uniquely related to the coefficients α, β of the EoS, Eq. (2).

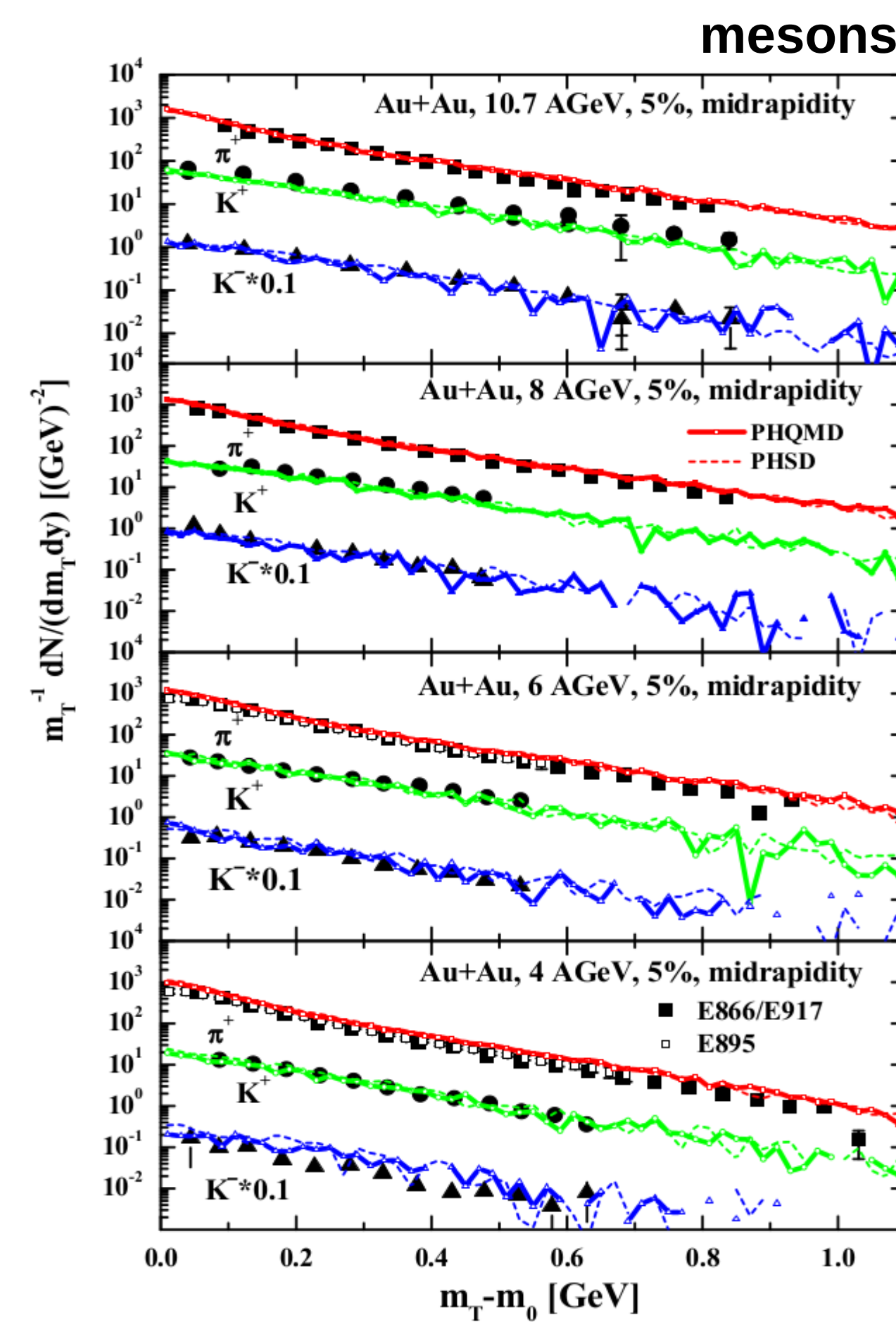
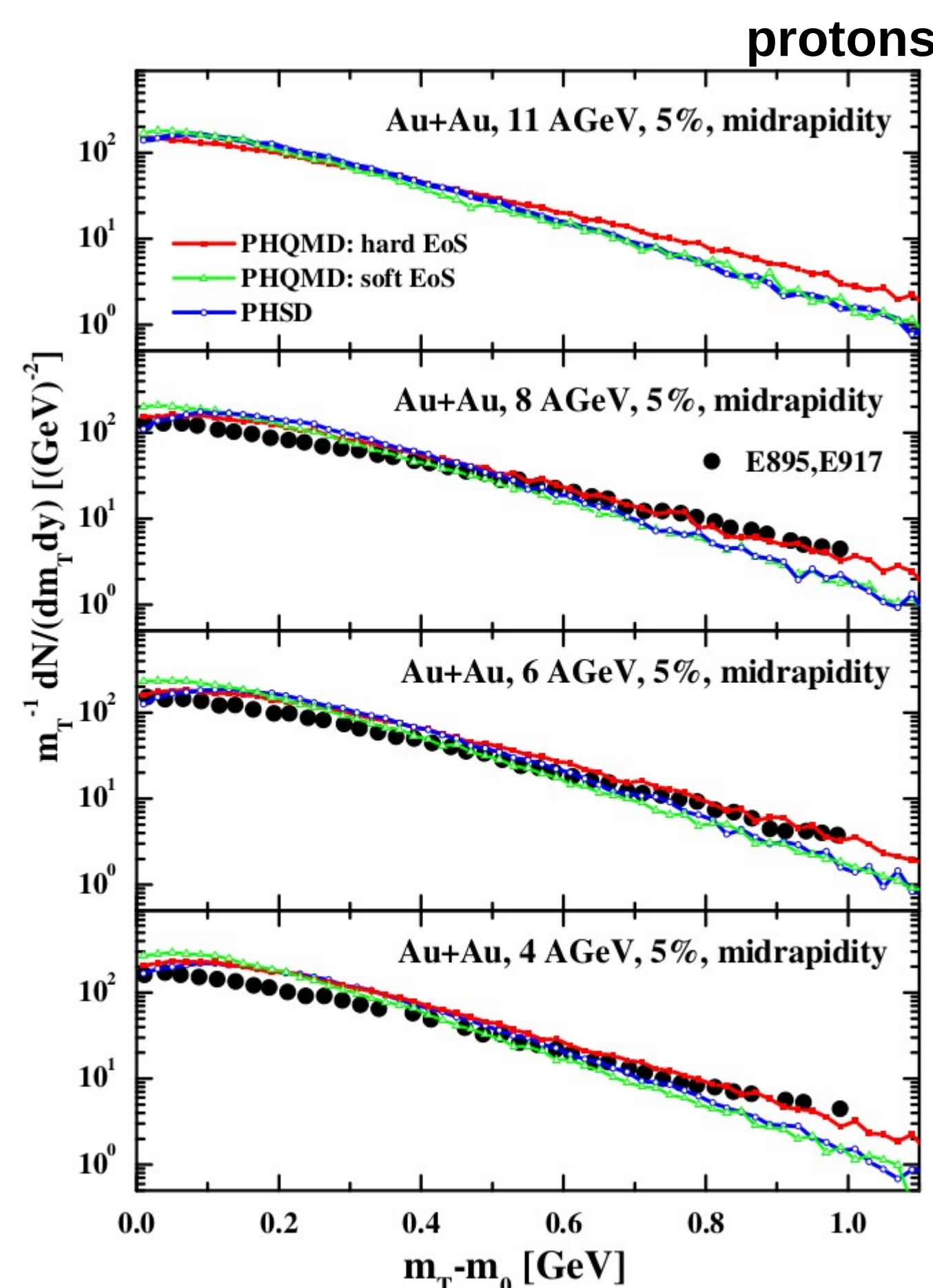
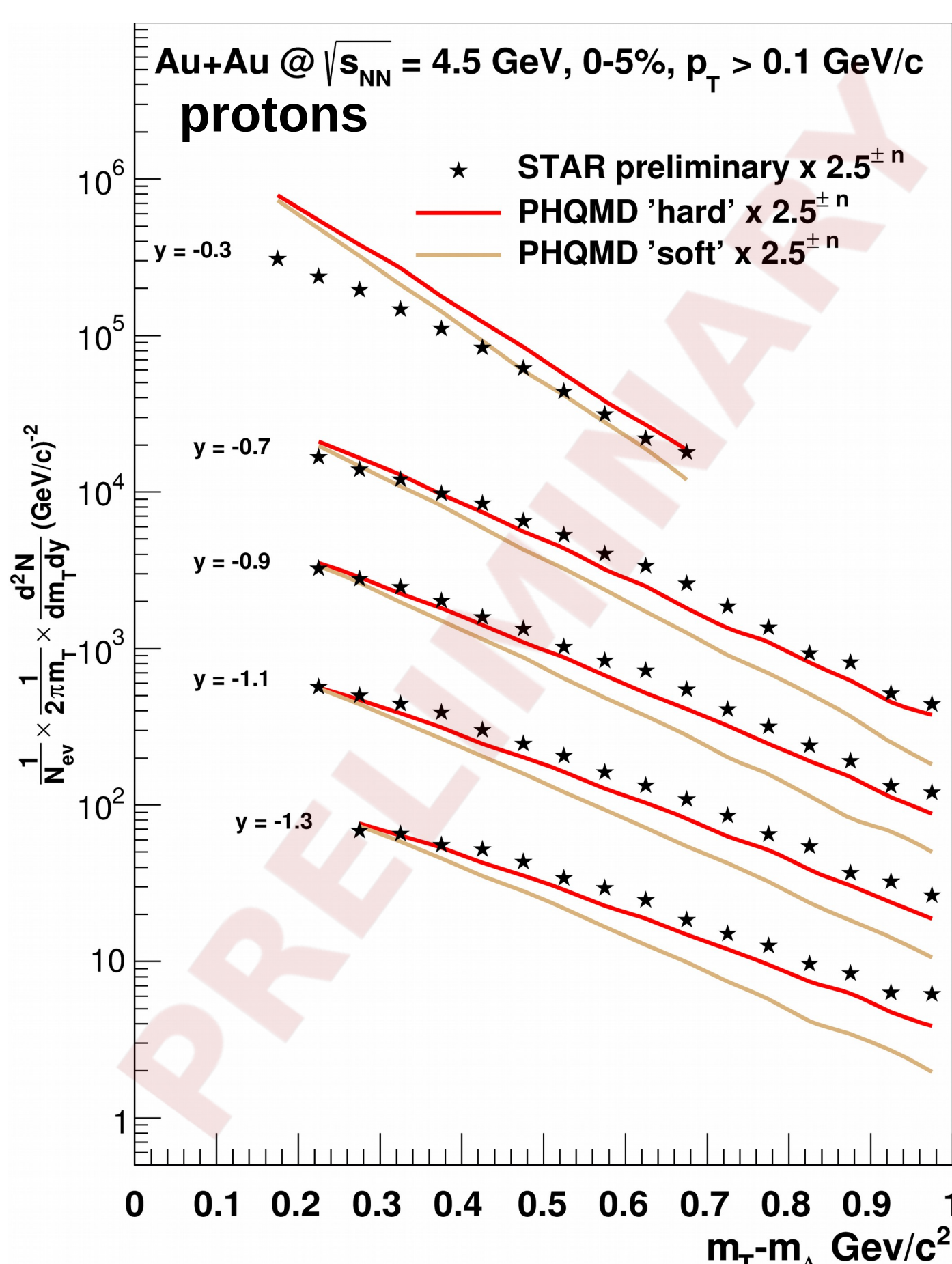
Parameter sets for the nuclear equation of state used in the PHQMD model:	α (MeV)	β (MeV)	γ	K [MeV]
S	-390	320	1.14	200
H	-130	59	2.09	380



Results

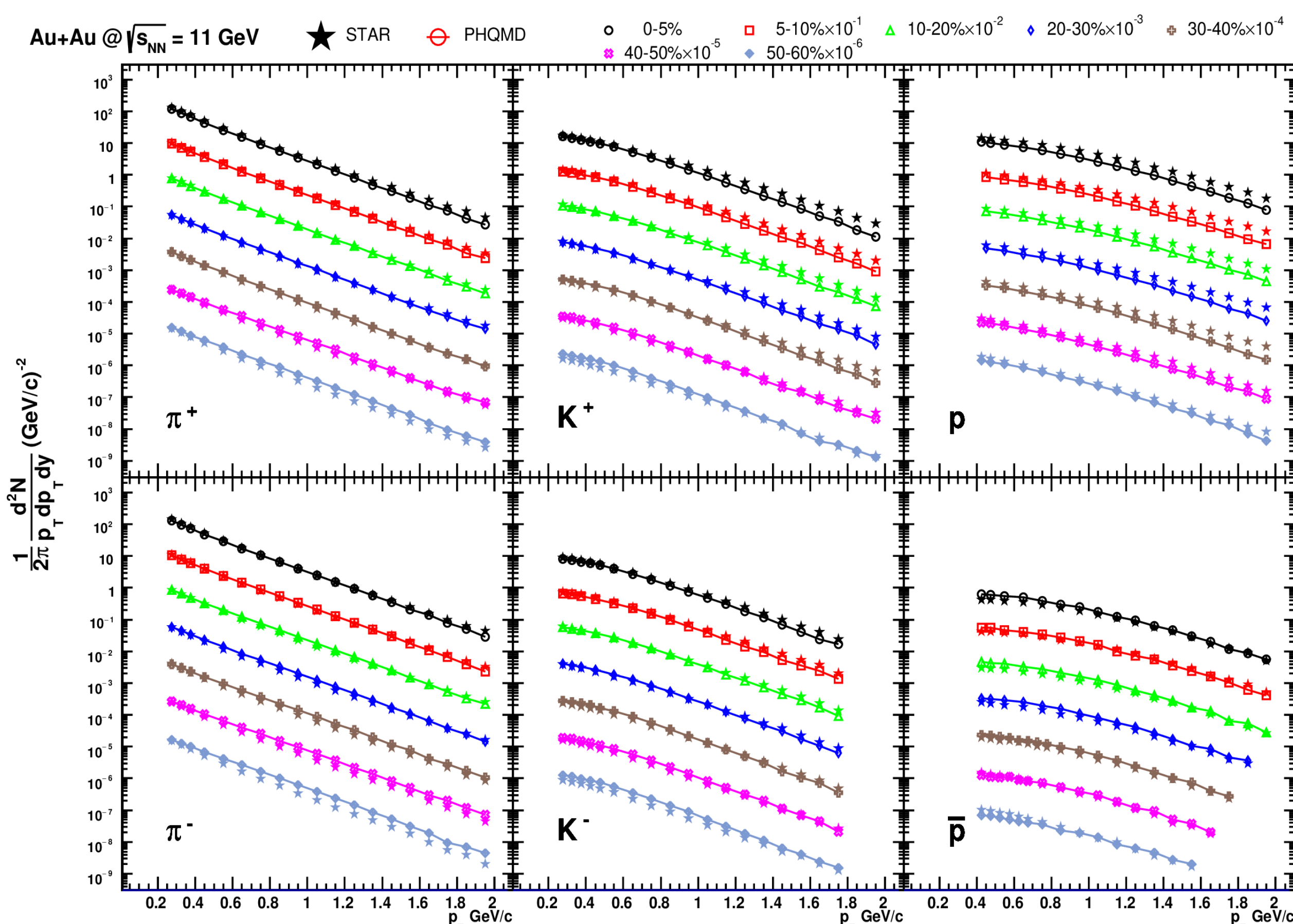


STAR preliminary dN/dy data: Nuclear Physics A, 967 (2017) 808-811

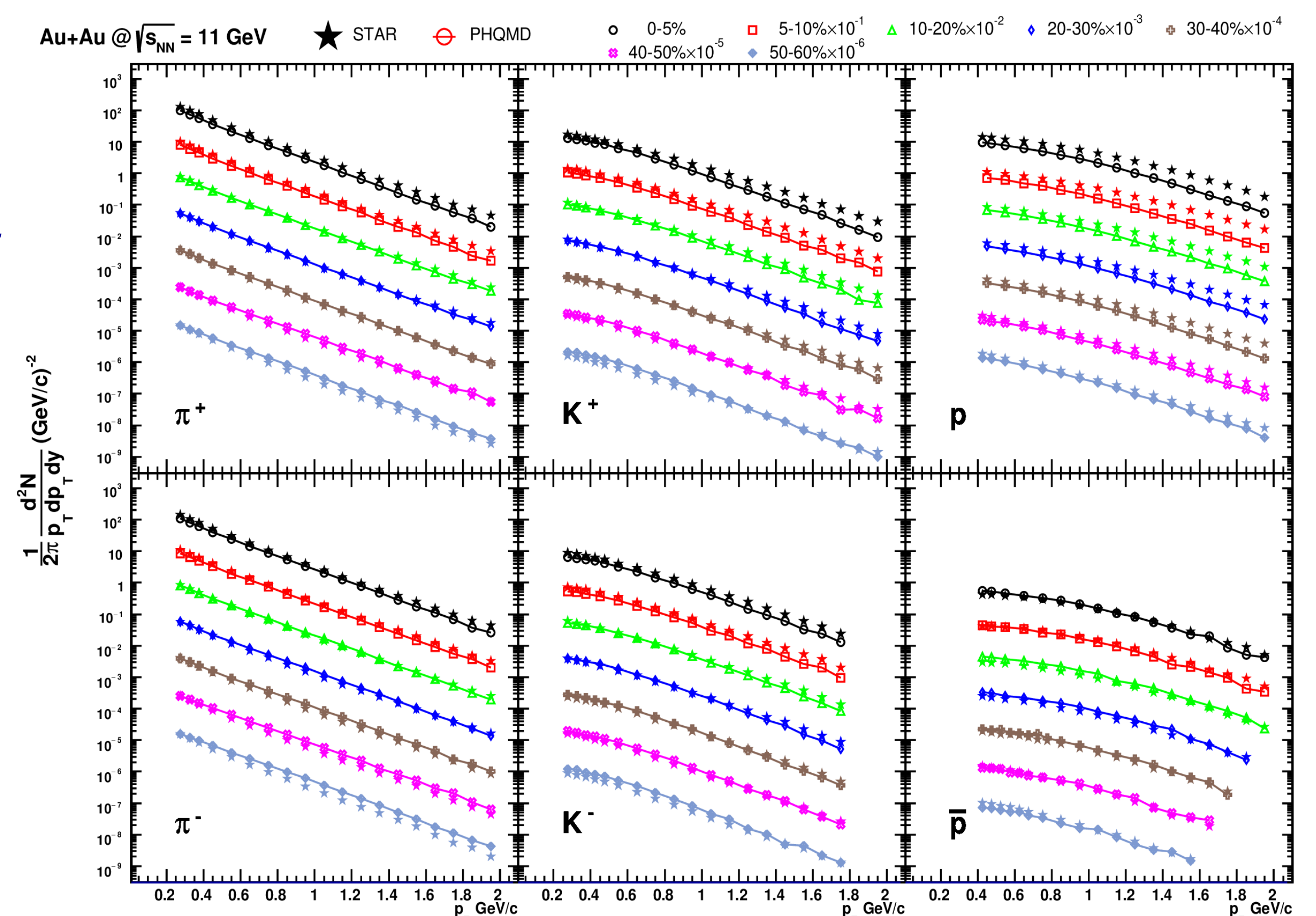


- The transverse mass spectra of protons and $\Lambda + \Sigma^0$ show a sensitivity to the EOS.
- A *hard* EOS increases the slope of the spectra at large m_T and lowers the yield at low m_T as compared to a *soft* EoS.
- PHQMD with soft EoS agrees well with the PHSD (default – soft EoS).
- The newly produced hadronic spectra (π^+ , K^\pm) indicate only a very mild dependence on the nucleon potential – all cases are rather similar to each other.

'HARD' EoS



STAR 'bulk' data: Phys. Rev. C 96, 044904 (2017)



'SOFT' EoS

Summary

PHQMD model is under active development. 'Bulk' hadronic observables like p_T or m_T spectra show sensitivity to the EoS for protons and hyperons, while it's not so visible for π^+ , K^\pm . Dependence on EoS is not very expressed for the dN/dy yields.

1. E.L. Bratkovskaya, W. Cassing, Nucl.Phys. A856 (2011) 162-182.
2. J. Aichelin, Phys Rep. 202 (1991) 233
3. R. K. Puri, J. Aichelin, J.Comput.Phys. 162 (2000) 245-266

