



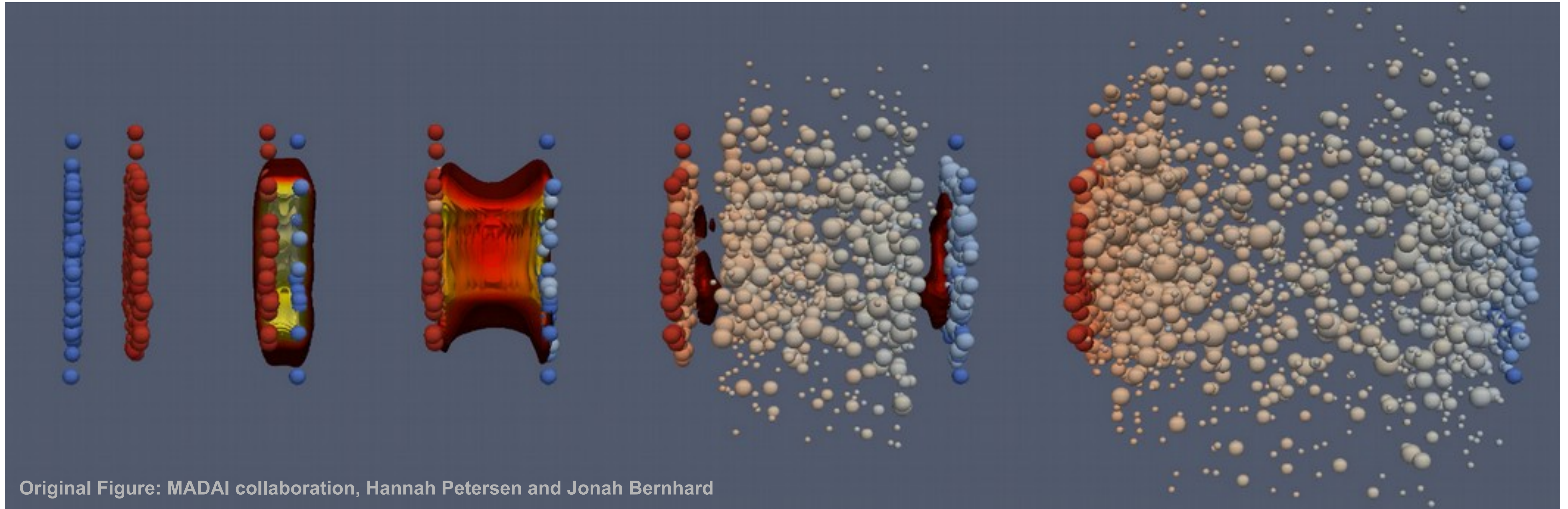
T. NUNES - UNIVERSIDADE FEDERAL DE SANTA CATARINA (UFSC)

IN COLLABORATION WITH D.D. CHINELLATO, G. DENICOL, M. HIPPERT, M. LUZUM, J. NORONHA, W. SERENONE, AND J. TAKAHASHI (THE EXTREME COLLABORATION)

PRE-HYDRODYNAMIC EVOLUTION AND CONFORMAL SYMMETRY IN SMALL SYSTEMS

(BASED ON ARXIV:2006.02324)

HOW DO WE UNDERSTAND HEAVY-ION COLLISIONS?



Pre-Equilibrium
Dynamics

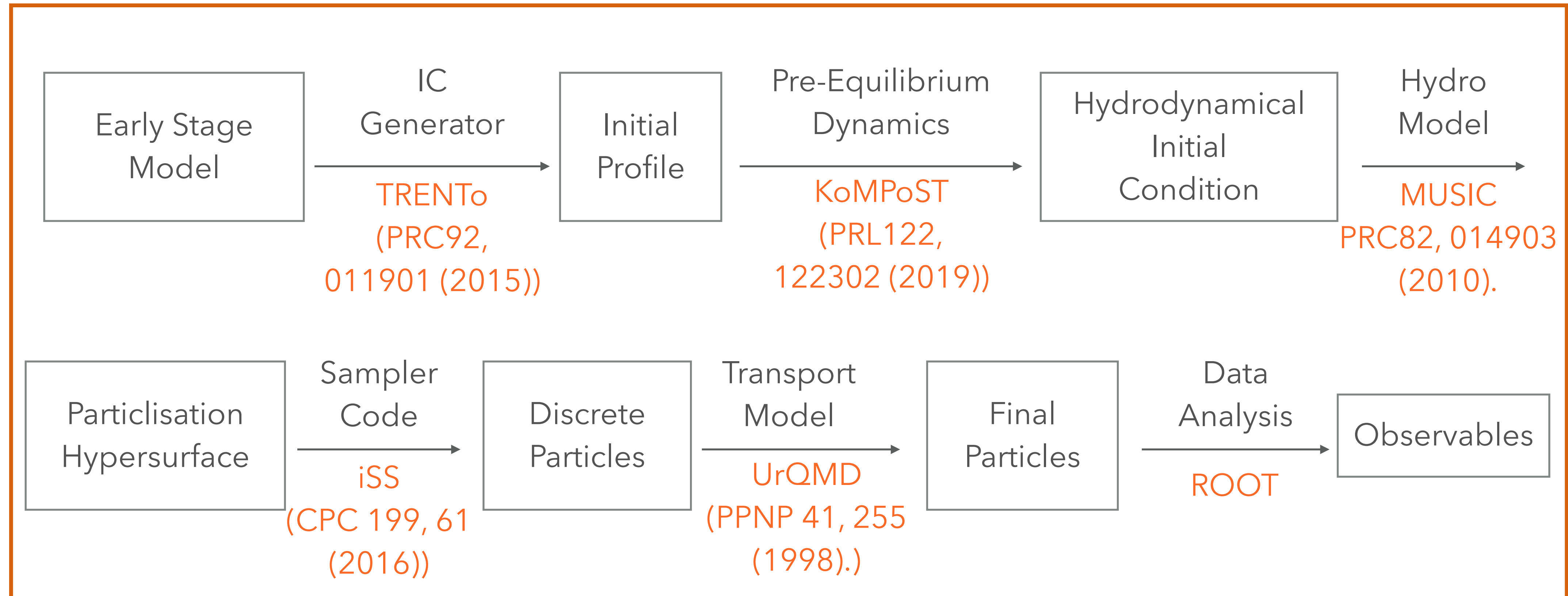
Hydrodynamical
Evolution

Hadronization

Hadronic
Cascade

HOW DO WE SIMULATE HEAVY ION COLLISIONS?

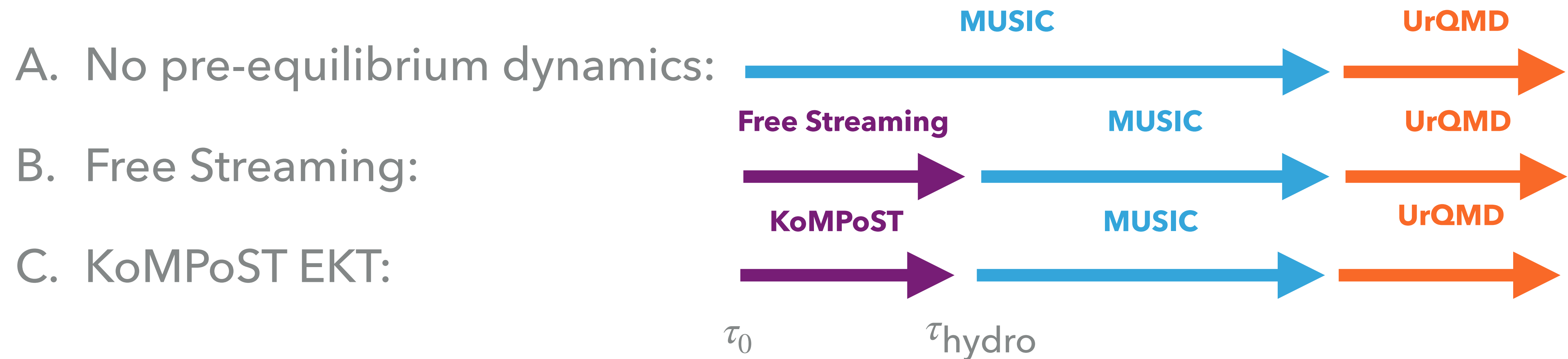
ExTrEMe Hybrid Model



See talks by J.F. Paquet and G. Denicol, Mon

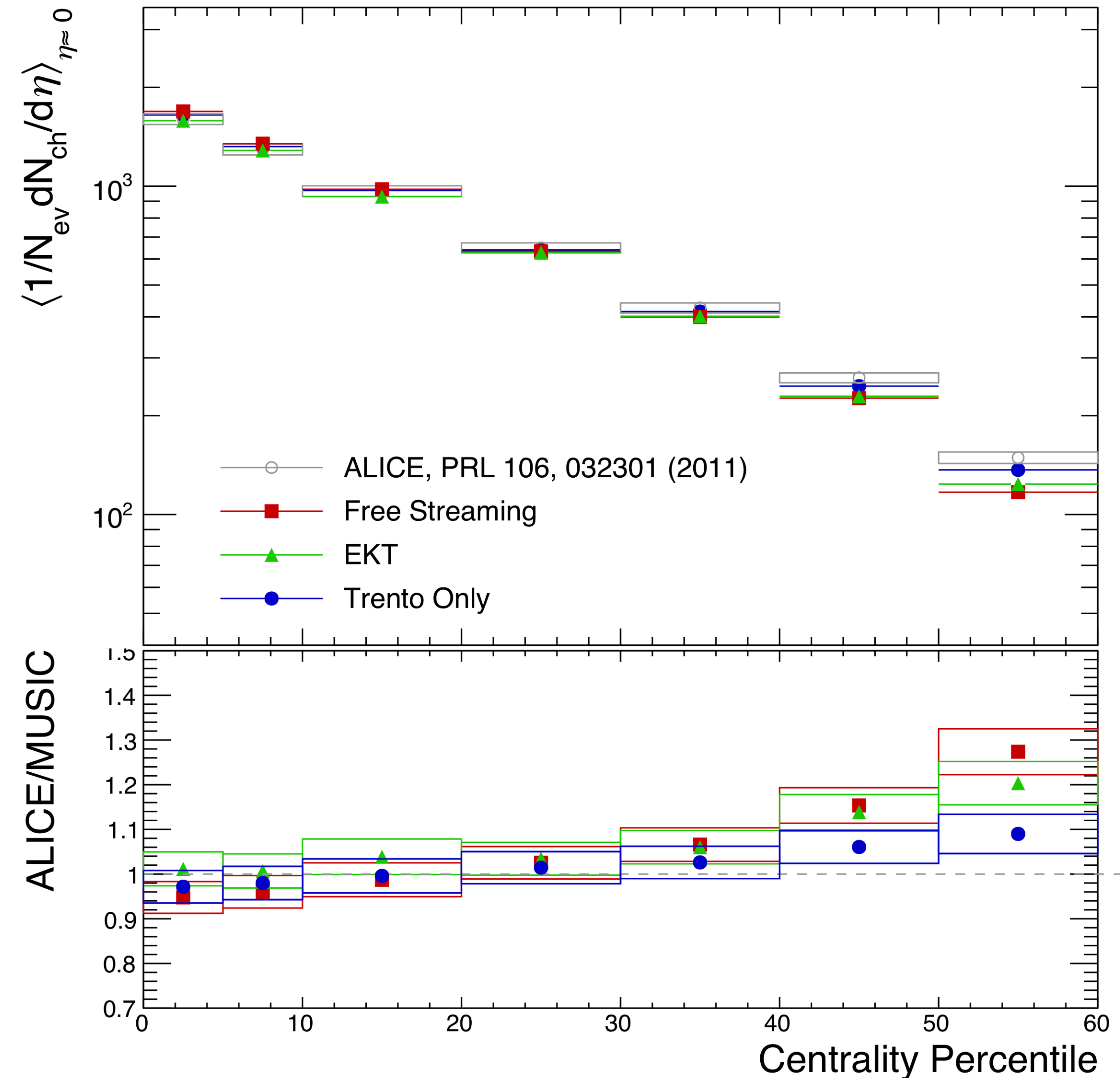
EFFECTS OF PRE-EQUILIBRIUM DYNAMICS

- ▶ Systematic study of how different pre-equilibrium scenarios affect final state observables;
- ▶ Three different scenarios for two different systems: Pb-Pb and p-Pb;



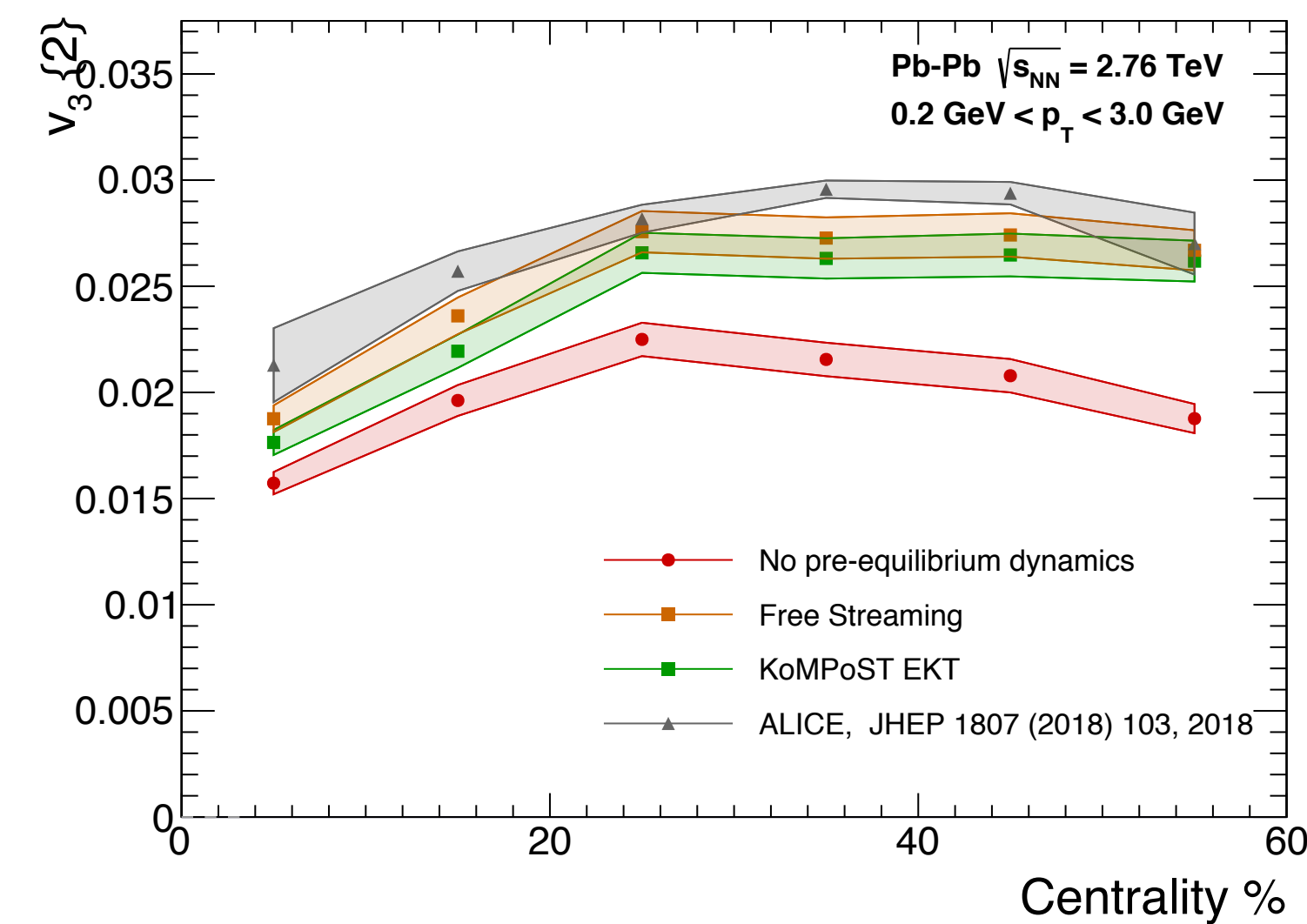
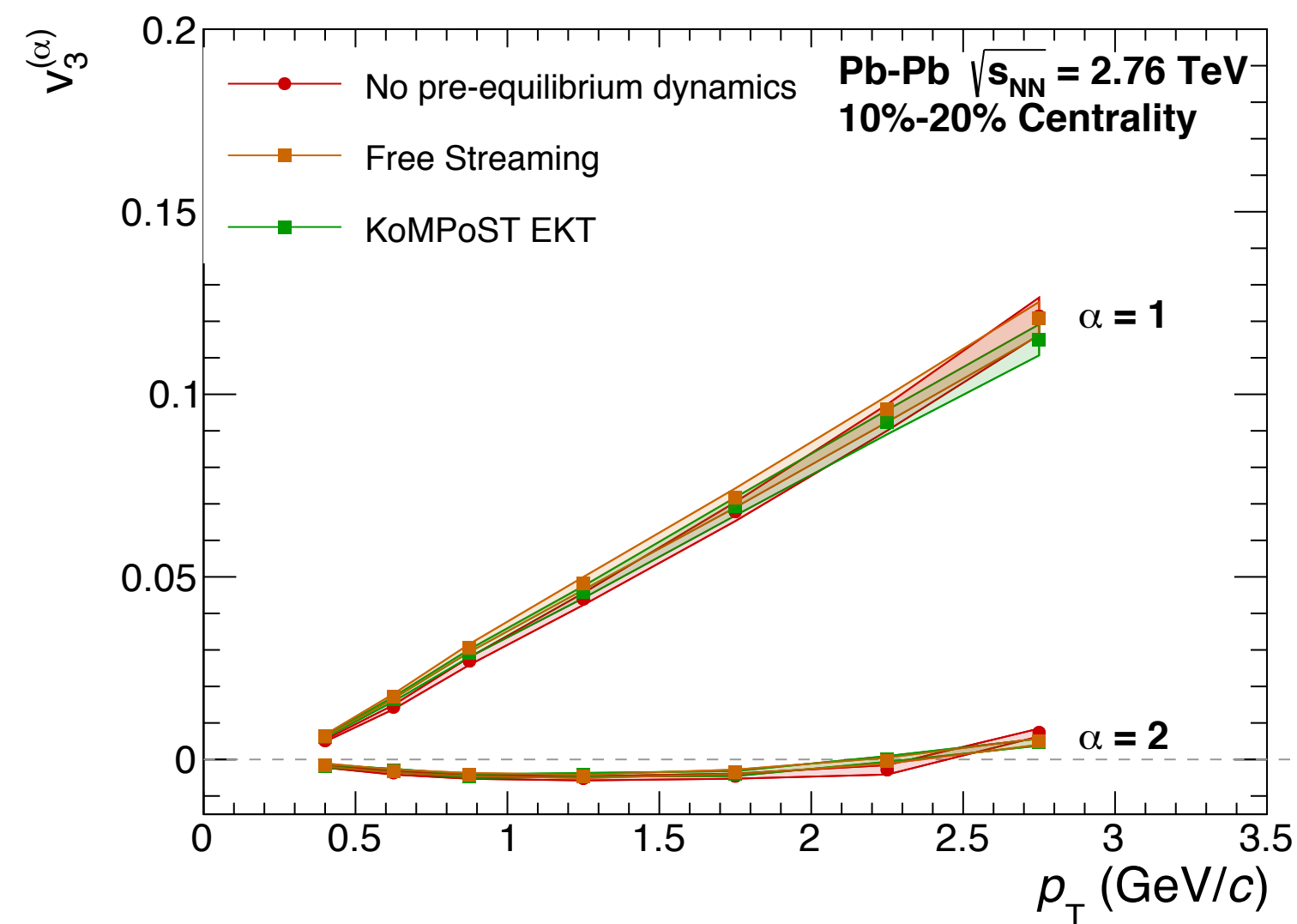
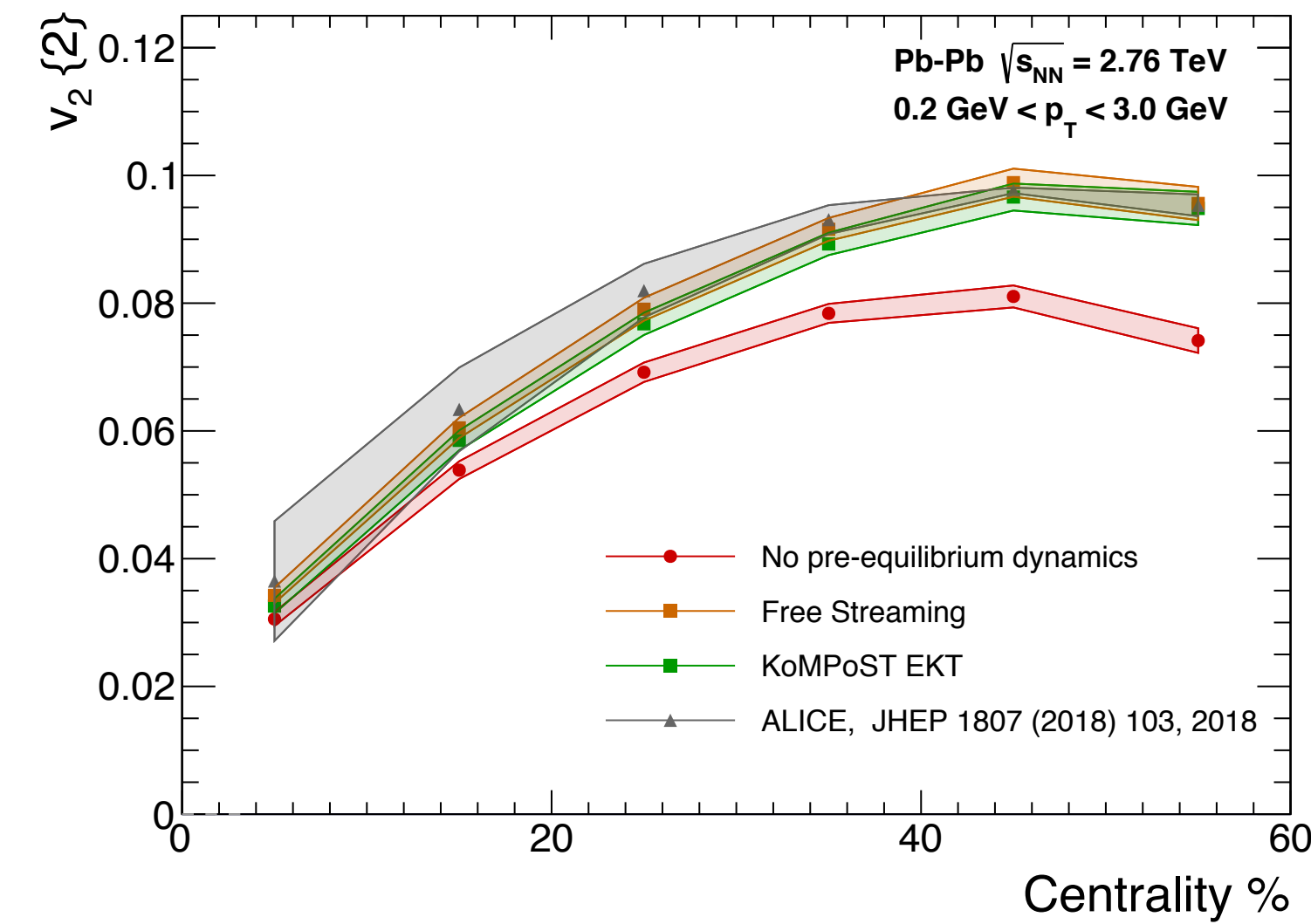
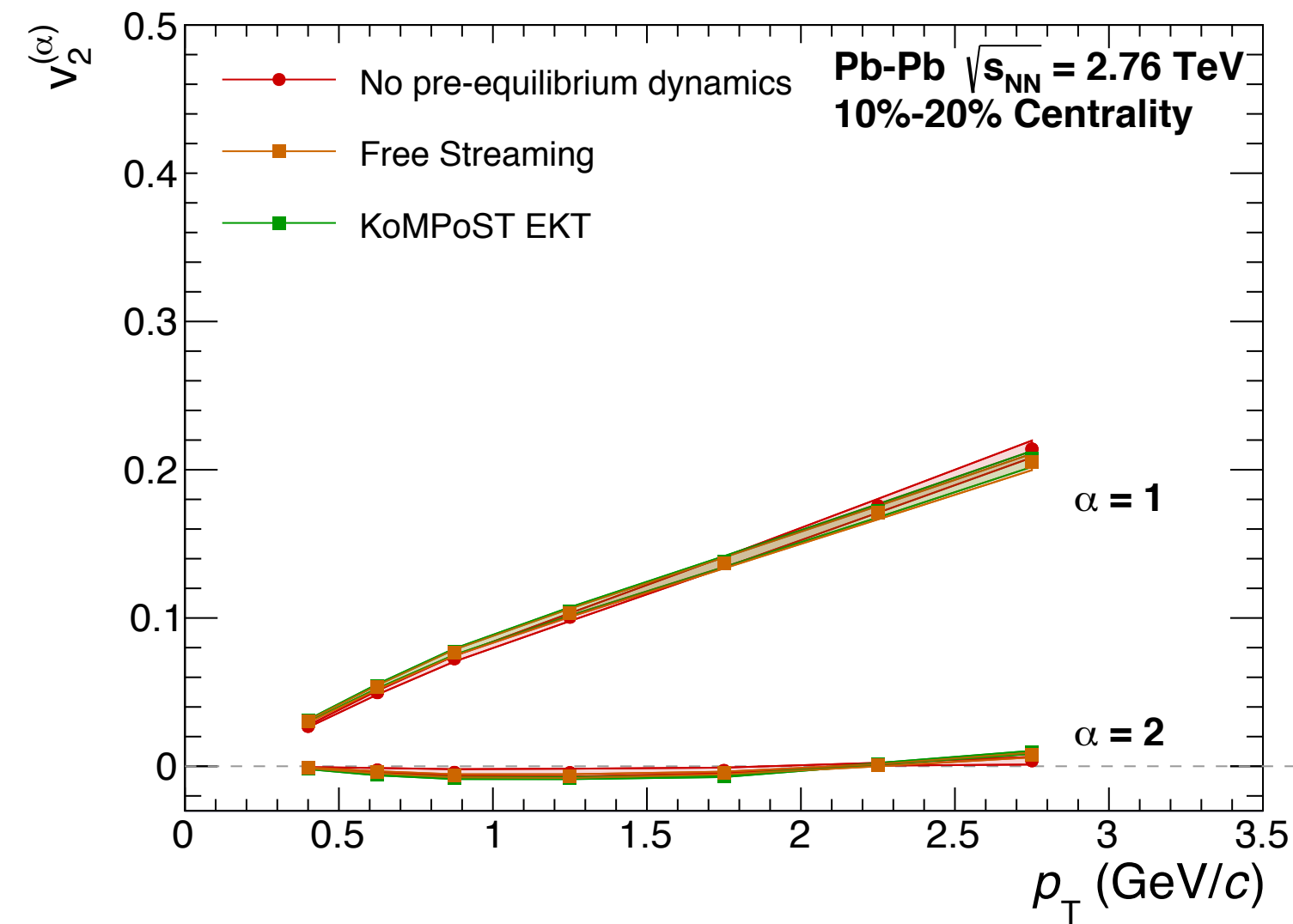
LARGE SYSTEM

- ▶ Simulations of Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV;
- ▶ Simulation parameters inspired by Bayesian results (Bernhard et al. Phys. Rev. C 94, 024907 (2016) and arXiv:1804.06469)
- ▶ $\tau_0 = 0.2$ fm/c and $\tau_{\text{hydro}} = 1.2$ fm/c.
- ▶ Overall normalisation chosen to match ALICE data.



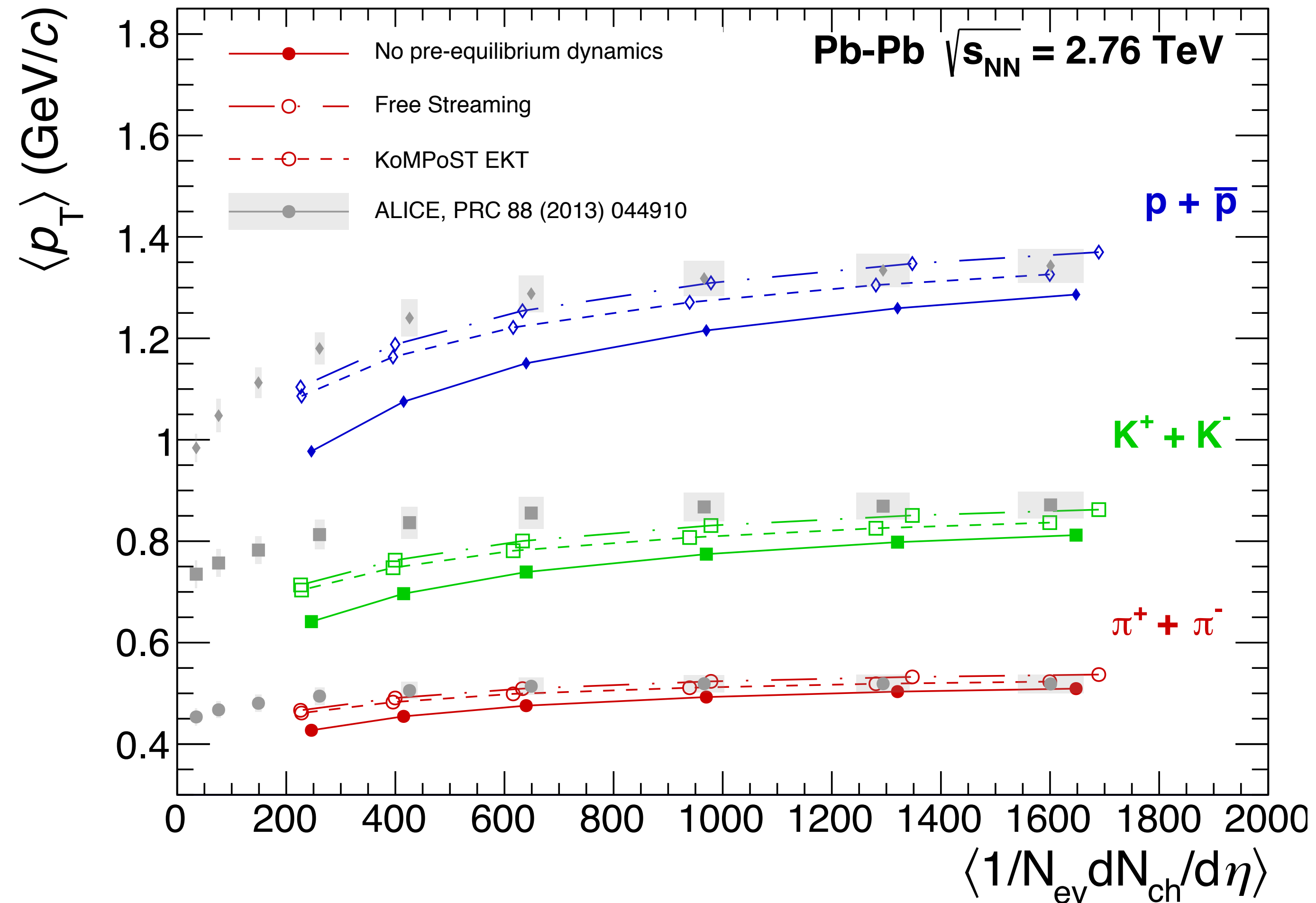
FLOW COEFFICIENTS

- ▶ Increased integrated flow when pre-equilibrium dynamics is included;
- ▶ Mild effect on differential flow;
- ▶ Particle spectra?



MEAN- p_T

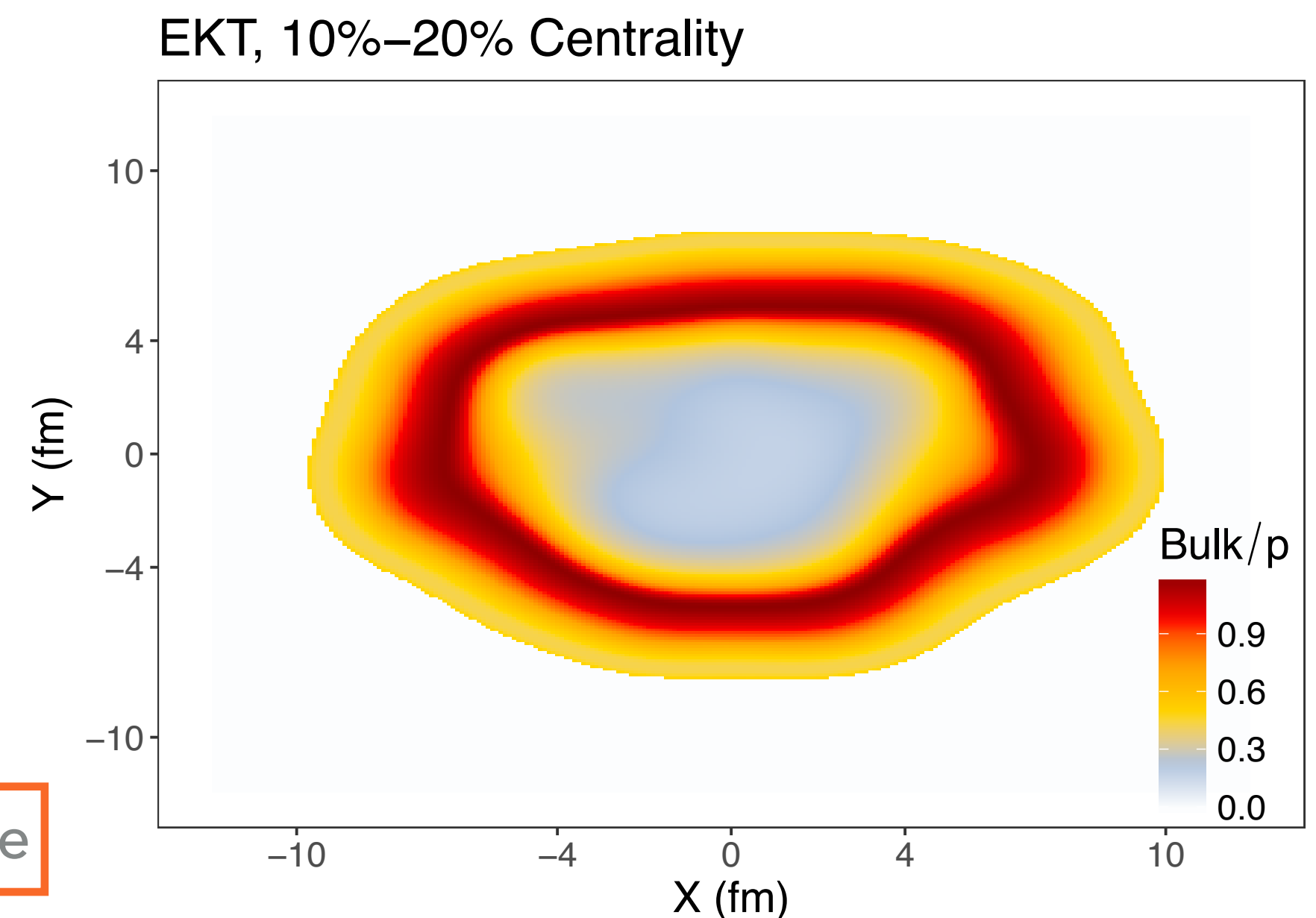
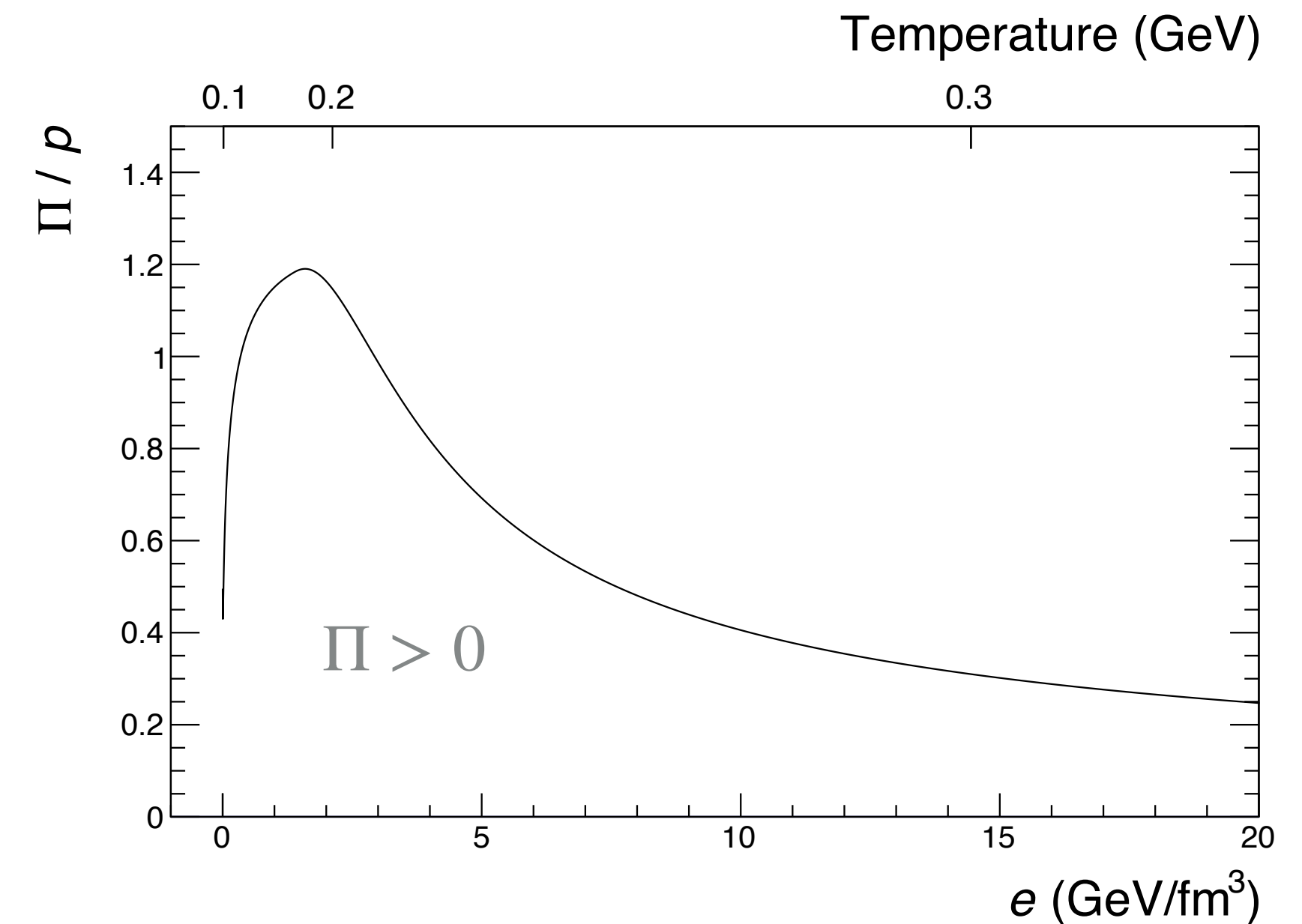
- ▶ mean- p_T is increased when either an EKT or free streaming phase is included;
- ▶ Where is this extra momentum coming from?
- ▶ May it be due to some common feature?



BULK

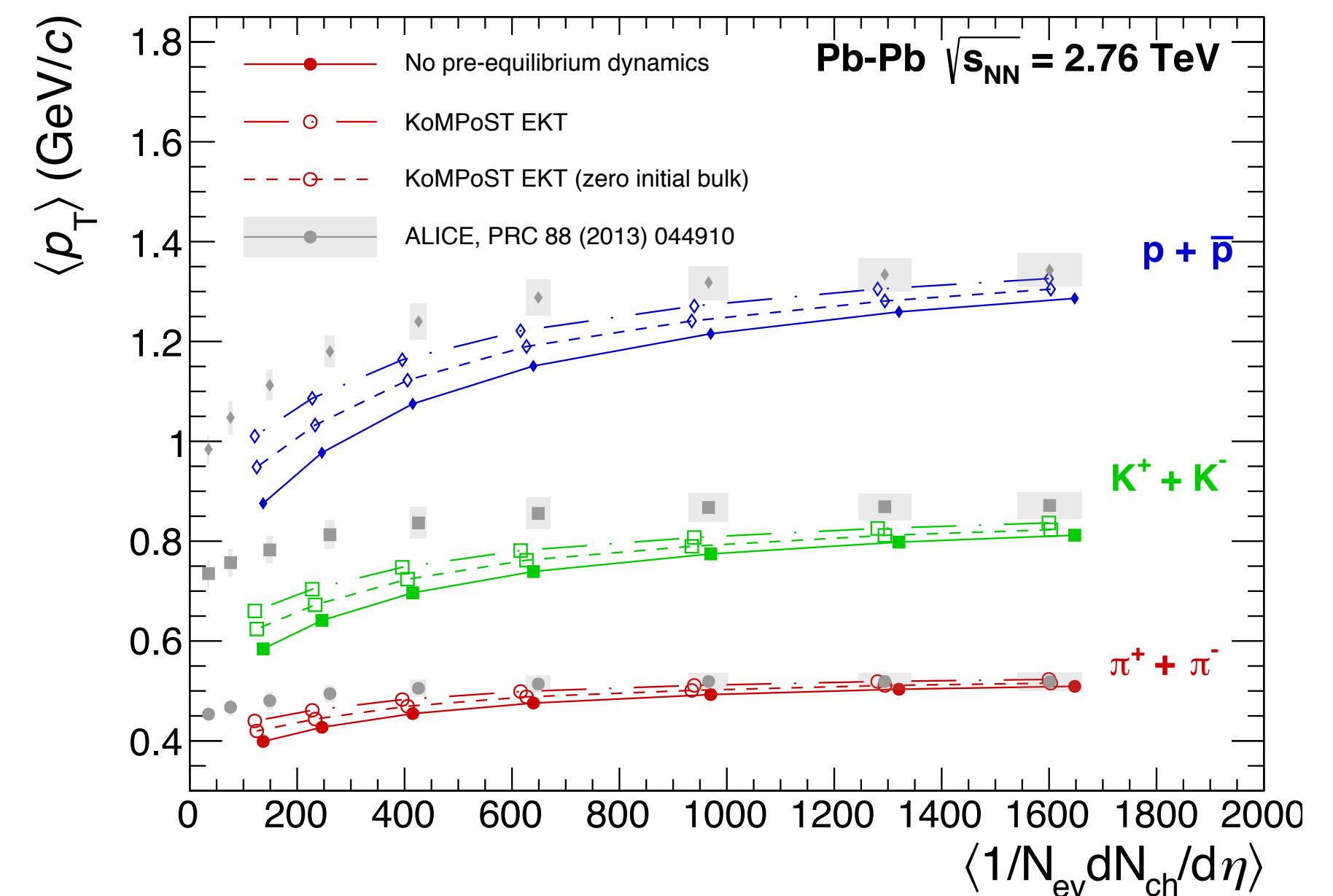
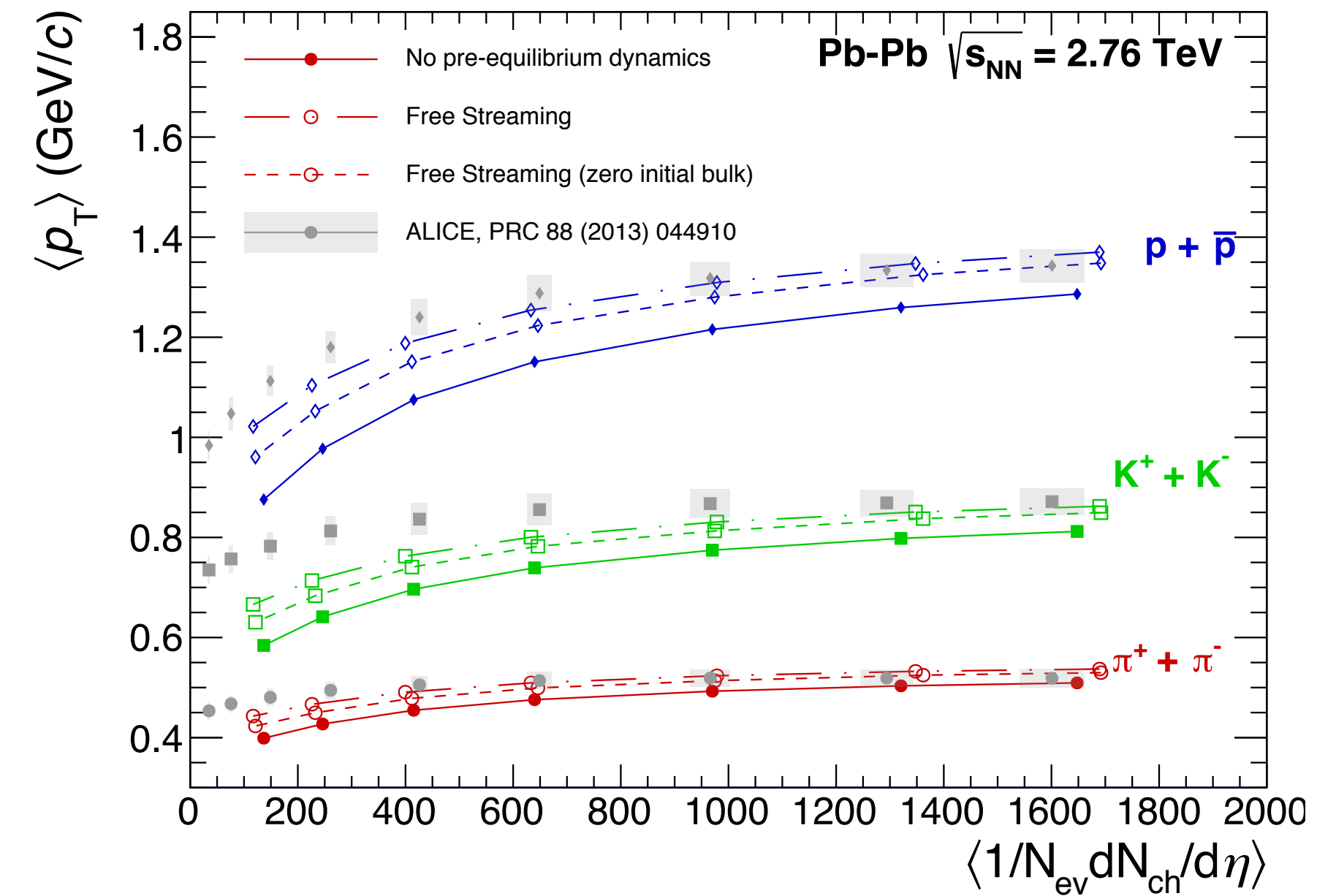
- ▶ Both scenarios model conformal systems with massless particles;
- ▶ This implies $T^\mu{}_\mu = 0$, $\Pi = 0$ and $p_{kinetic} = e/3$;
- ▶ At kinetic to hydro matching, QCD is not conformal \Rightarrow artificial discontinuity in bulk pressure: $\Pi + p(e) = e/3$
- ▶ $\Pi/p(e) \approx \mathcal{O}(1)$ around T_{switch}
- ▶ Is this extra bulk pressure responsible for the added mean- p_T ?

See talk by B. Schenke, Tue



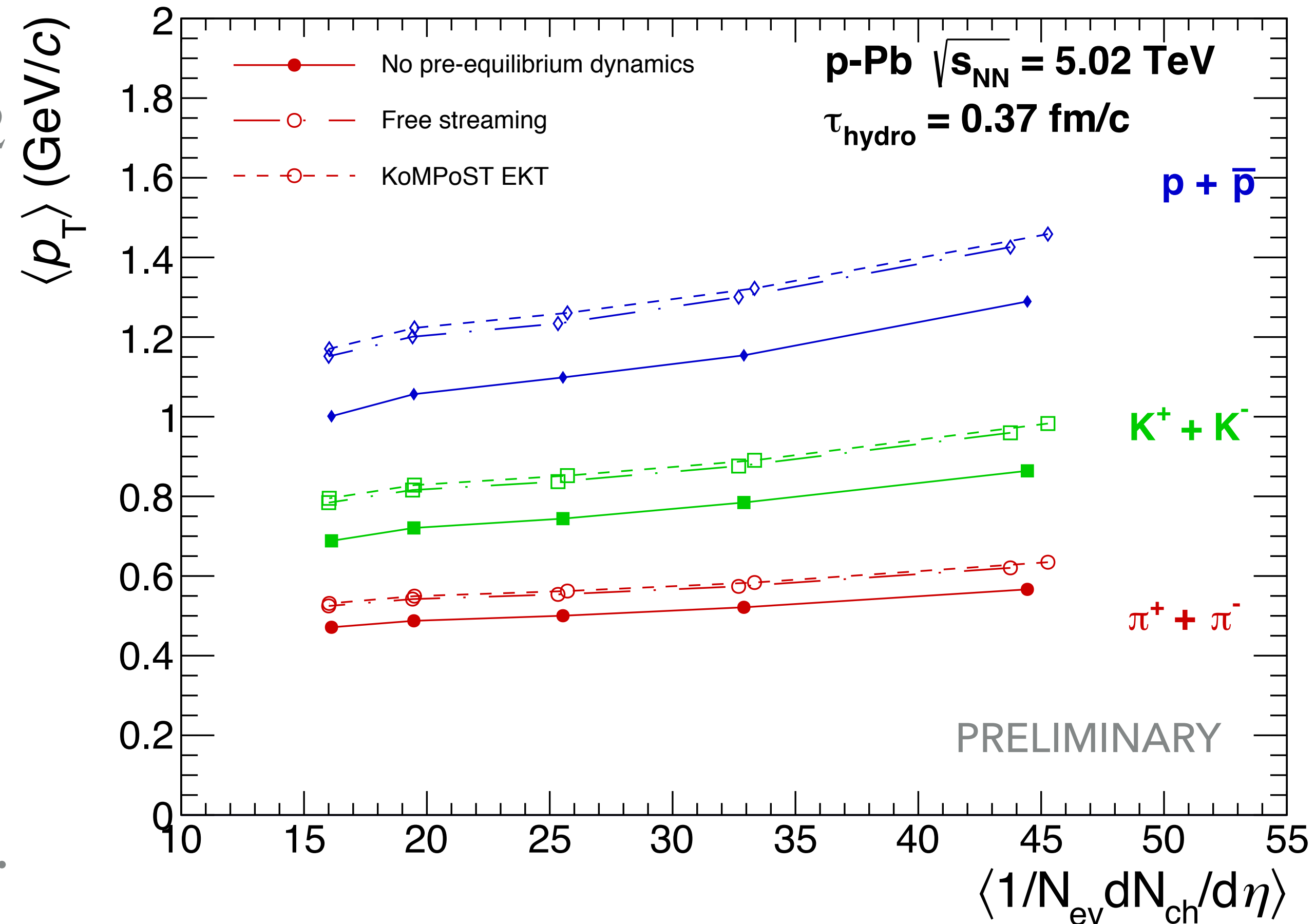
REMOVING THE INITIAL BULK

- ▶ New simulations, with initial bulk for hydro set to zero;
- ▶ A significant portion of the increase in mean- p_T seems to be related to the artificially large bulk at switch time
- ▶ This increase will also be reflected in integrated observables;



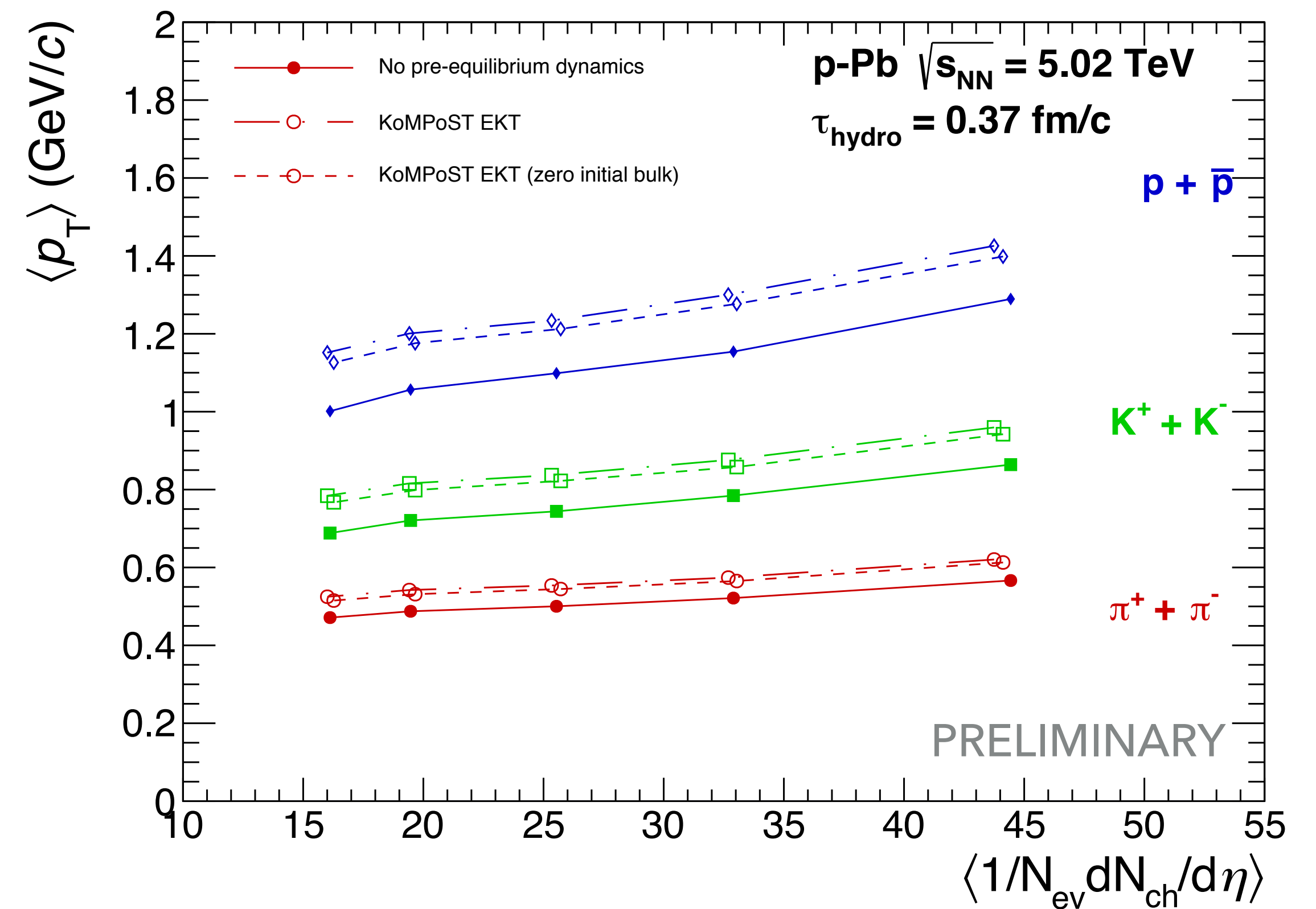
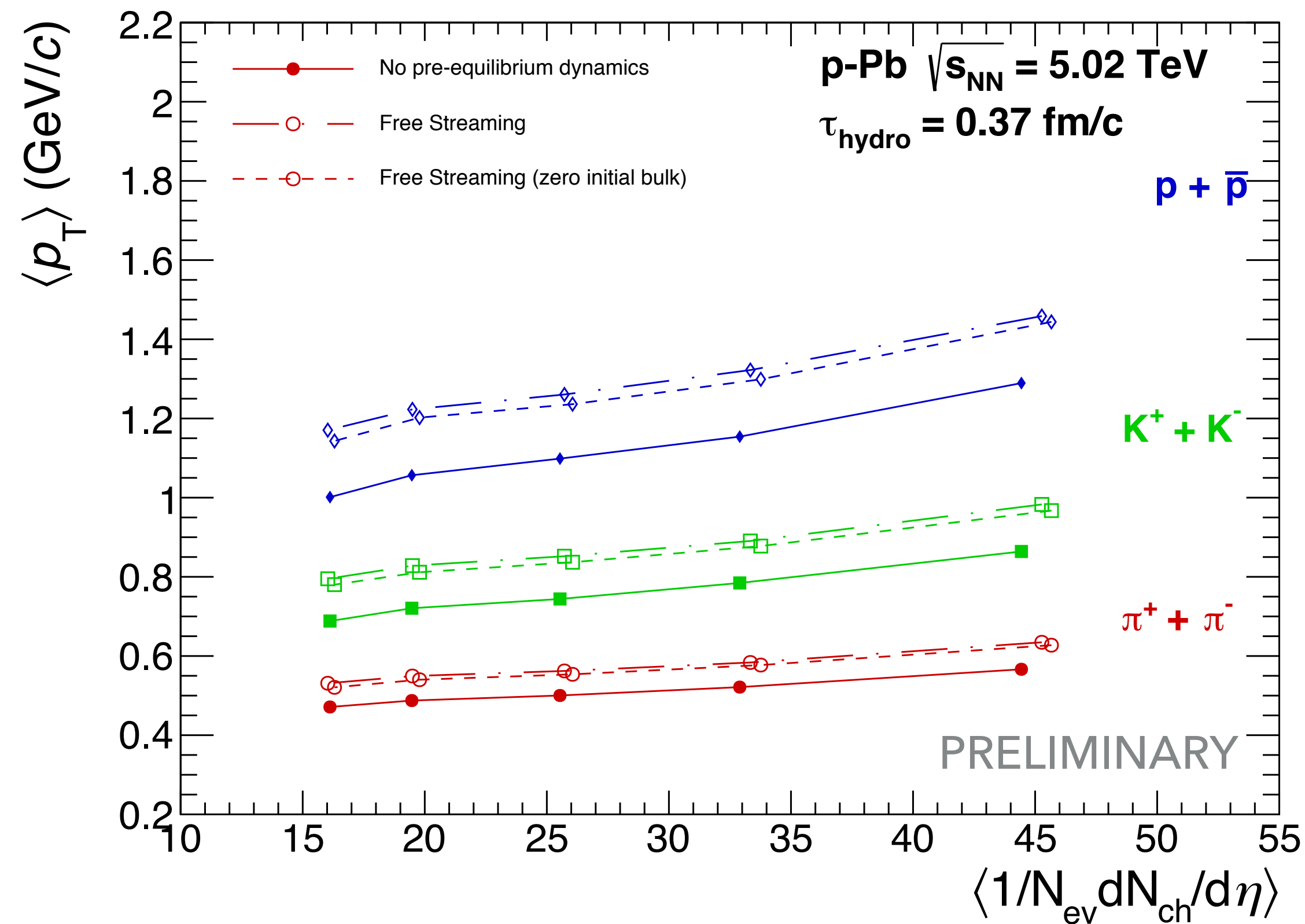
PUSHING THE SETUP TO SMALL SYSTEMS

- ▶ Same numerical setup employed in the simulation of p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV;
- ▶ Simulation parameters inspired by Bayesian results (Bernhard et al., Phys. Rev. C 101, 024911 (2020))
- ▶ $\tau_0 = 0^+$ and $\tau_{\text{hydro}} = 0.37$
- ▶ Increase in mean-pT is again observed when pre-equilibrium dynamics is included.



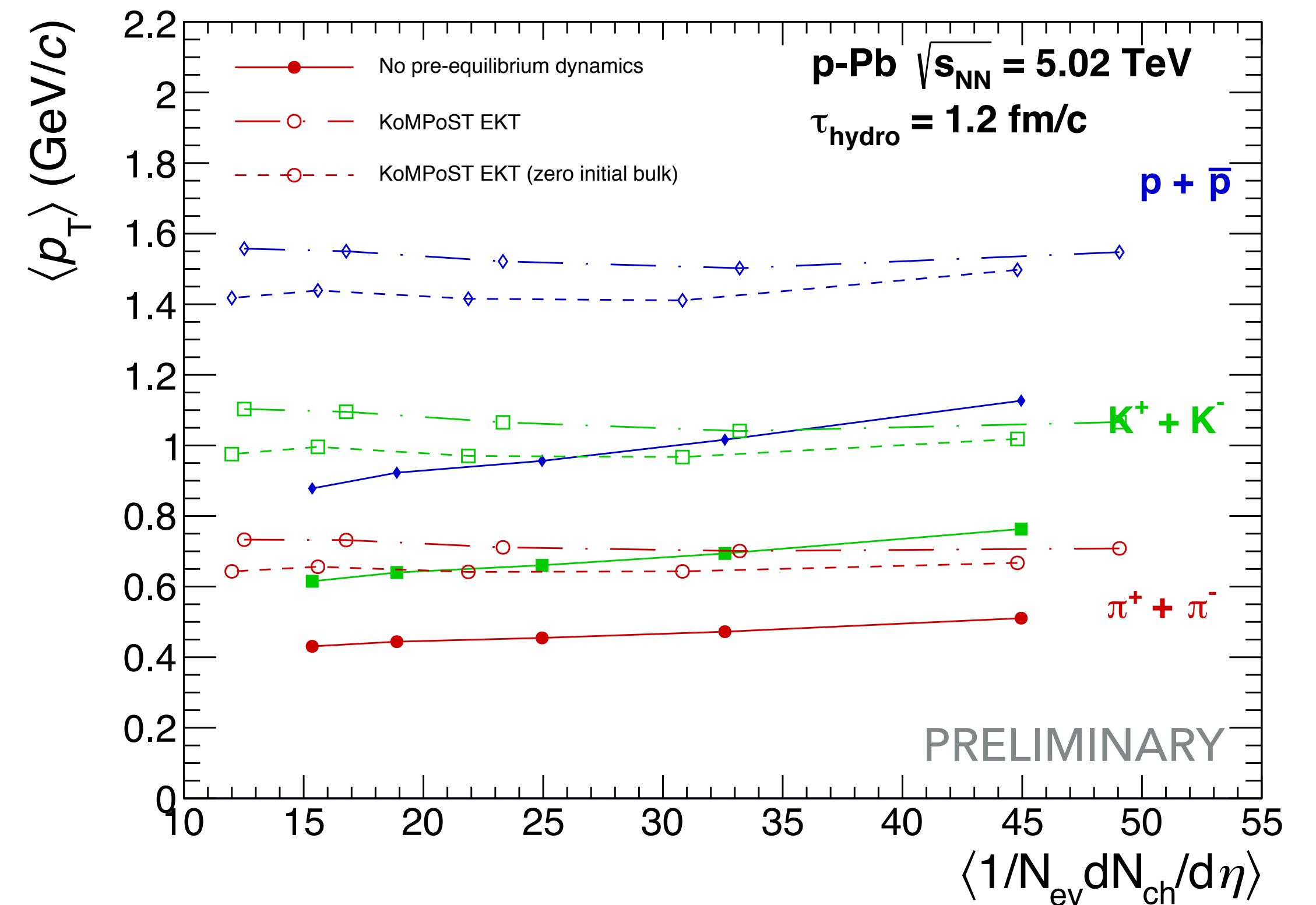
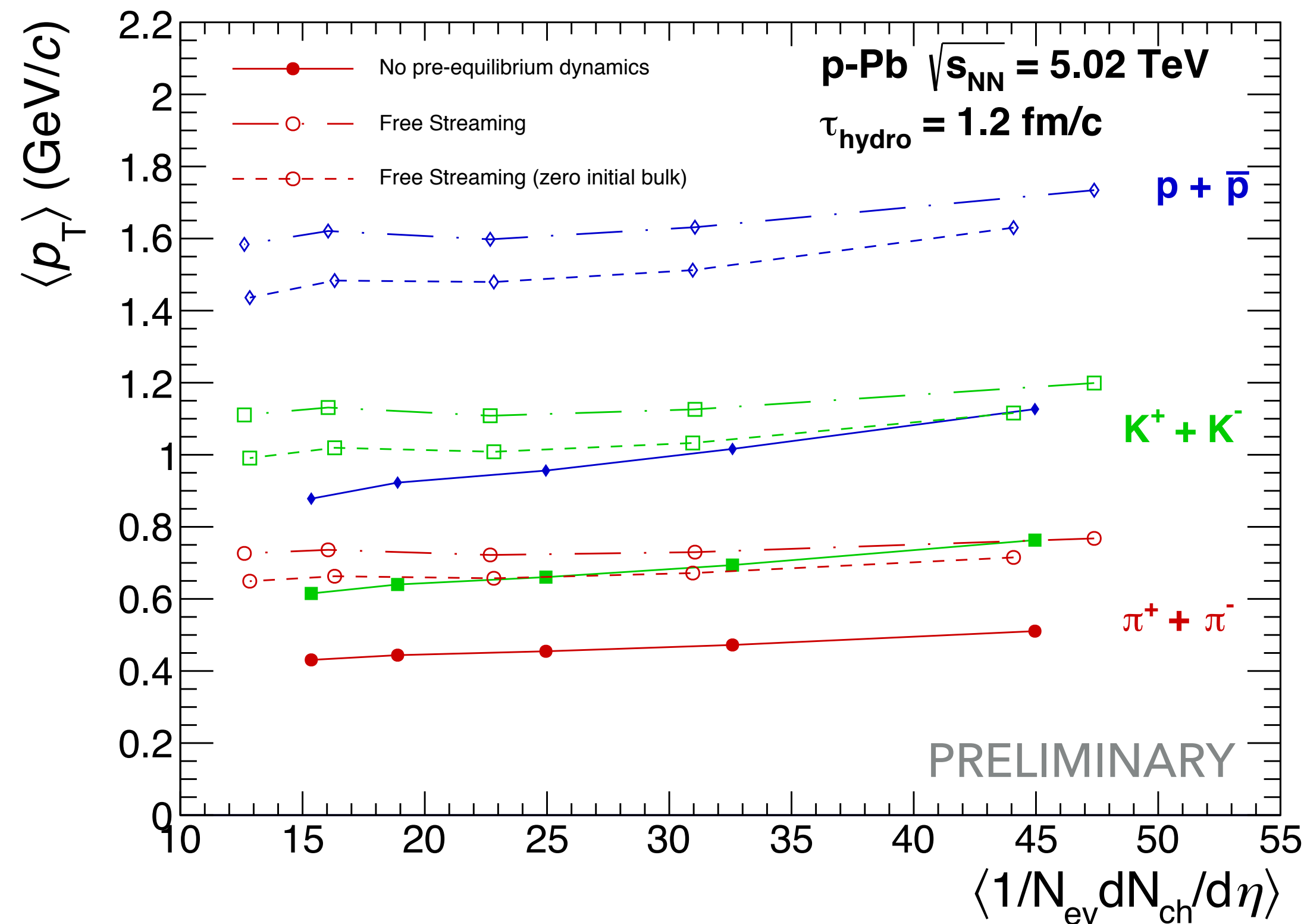
EFFECT OF BULK DISCONTINUITY

- ▶ Again, part of this effect seems to be related to the bulk discontinuity at switch to hydrodynamics. But the effect is smaller than expected.



TIME DEPENDENCE

- Magnitude of the effect seems to be related to duration of pre-equilibrium dynamics.



CONCLUSIONS AND OUTLOOK

We investigated the effects of pre-equilibrium dynamics in large and small systems:

- ▶ Differential flow observables seem largely insensitive to this phase; observables such as the p_T spectrum, however, are sensitive;
- ▶ A potentially large fraction of the effects may be an artifact related to the underlying assumption of conformal invariance;
- ▶ Ultimately, we will need to relax this assumption when building models of pre-equilibrium dynamics.