

Disentangling effects from the initial stage and the  
evolution stage in heavy ion collisions using EPOS and  
PHSD

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**Flash talk for Hard Probes 2023**

with:  
**Klaus Werner & Elena Bratkovskaya & Vadym Voronyuk**

March 31, 2023



## Theoretical models to study HIC:

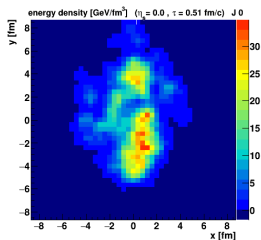
**EPOSi+PHSDe** : Initial distribution of matter  
 (partons/hadrons) from EPOS (**EPOSi**) + Evolution of matter  
 in PHSD (**PHSDe**)

<i>Models Steps</i>	<b>EPOS</b>	<b>PHSD</b>
<b>Initial Conditions</b> (i)	<b>Parton-Based Gribov-Regge Theory</b>	PYTHIA
<b>Evolutions</b> (e)	Core-Corona Separation Viscous Hydrodynamic Expansion Statistical Hadronization Final State Hadronic Cascade	<div style="border: 1px solid green; border-radius: 15px; padding: 5px;">                     QGP formation                      Microscopic description of sQGP phase                      Non-equilibrium off-shell parton/hadron evolution                      Final state hadronic interaction                 </div>

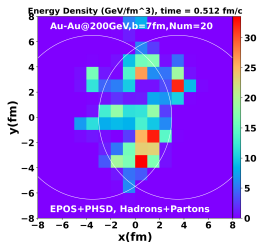
Purpose: Separate "initial" and "evolution" effects,  
 Study the influence of the initial conditions on observables

# Energy density evolution in the three models

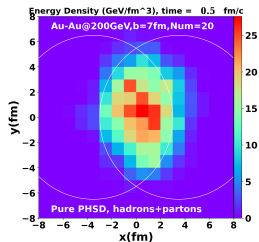
$t = 0.5 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

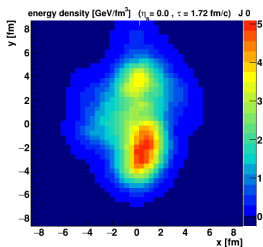


(c) PHSD

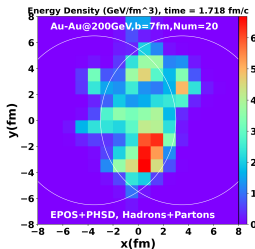
Au-Au at 200A GeV, b=7 fm, Num=20

# Energy density evolution in the three models

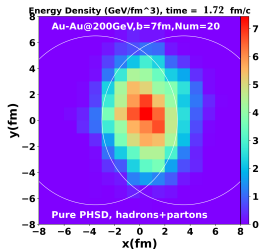
$t = 1.7 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

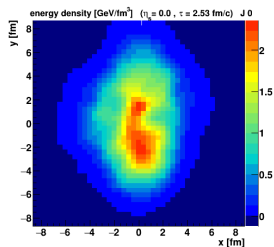


(c) PHSD

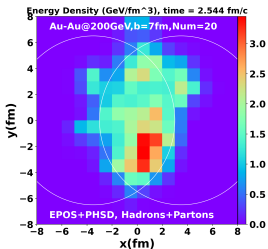
Au-Au at 200A GeV,  $b=7 \text{ fm}$ , Num=20

# Energy density evolution in the three models

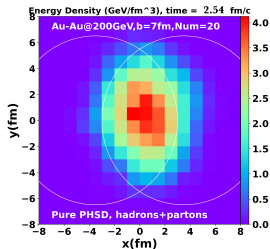
$t = 2.5 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

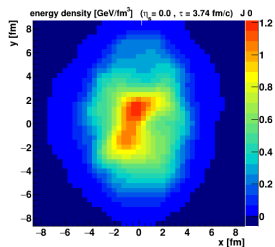


(c) PHSD

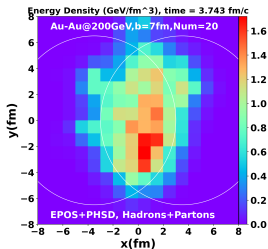
Au-Au at 200A GeV,  $b=7 \text{ fm}$ , Num=20

# Energy density evolution in the three models

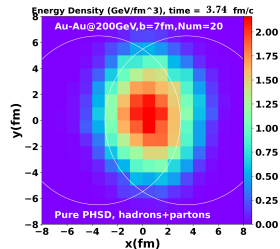
$t = 3.7 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

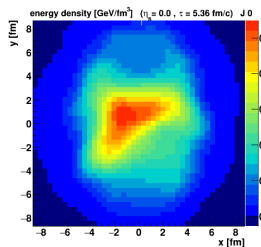


(c) PHSD

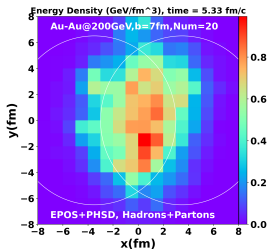
Au-Au at 200A GeV, b=7 fm, Num=20

# Energy density evolution in the three models

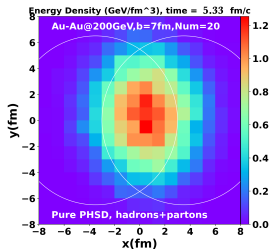
$t = 5.3 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

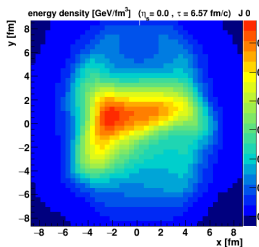


(c) PHSD

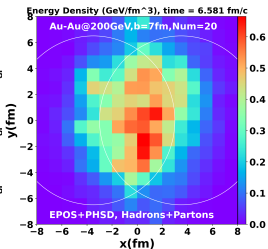
Au-Au at 200A GeV, b=7 fm, Num=20

# Energy density evolution in the three models

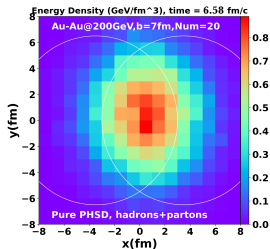
$t = 6.5 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe



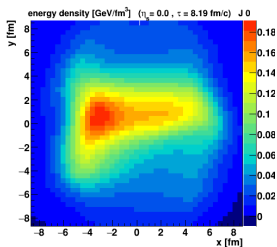
(c) PHSD

Au-Au at 200A GeV,  $b=7 \text{ fm}$ , Num=20

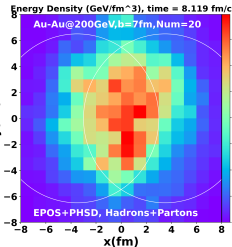


# Energy density evolution in the three models

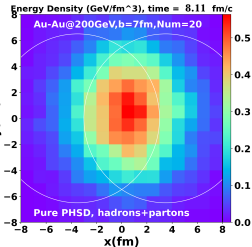
$t = 8.1 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

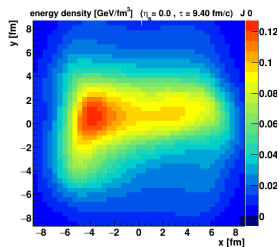


(c) PHSD

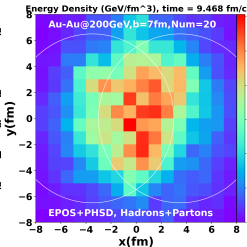
Au-Au at 200A GeV,  $b=7 \text{ fm}$ , Num=20

# Energy density evolution in the three models

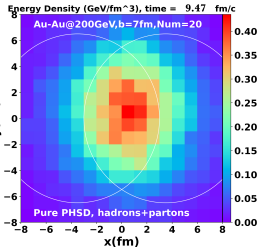
$t = 9.4 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

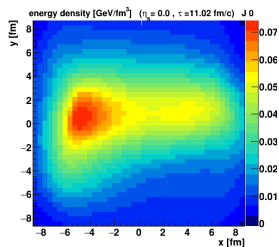


(c) PHSD

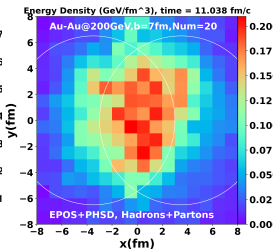
Au-Au at 200A GeV,  $b=7 \text{ fm}$ , Num=20

# Energy density evolution in the three models

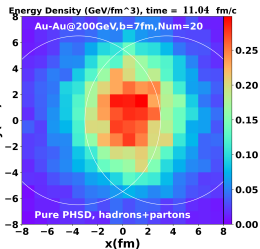
$t = 11 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

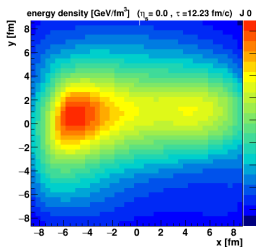


(c) PHSD

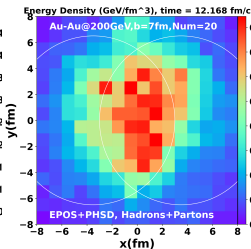
Au-Au at 200A GeV, b=7 fm, Num=20

# Energy density evolution in the three models

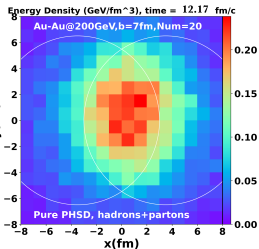
$t = 12.2 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

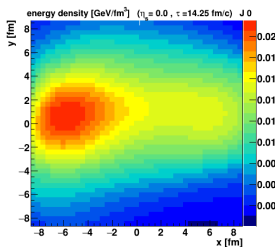


(c) PHSD

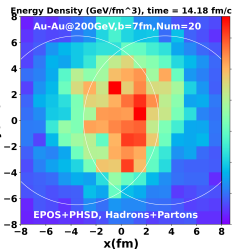
Au-Au at 200A GeV, b=7 fm, Num=20

# Energy density evolution in the three models

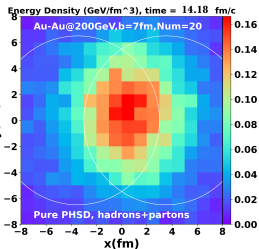
$t = 14.2 \text{ fm}/c$



(a) EPOS



(b) EPOSi+PHSDe

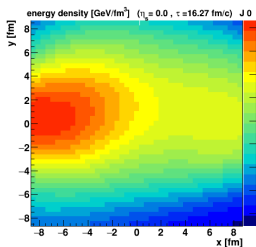


(c) PHSD

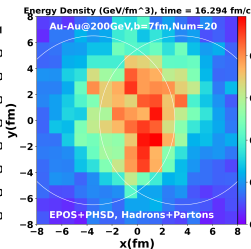
Au-Au at 200A GeV, b=7 fm, Num=20

# Energy density evolution in the three models

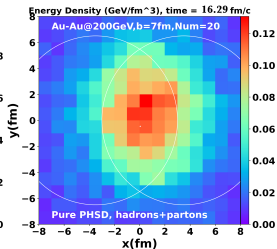
$t = 16.2 \text{ fm}/c$



(a) EPOS



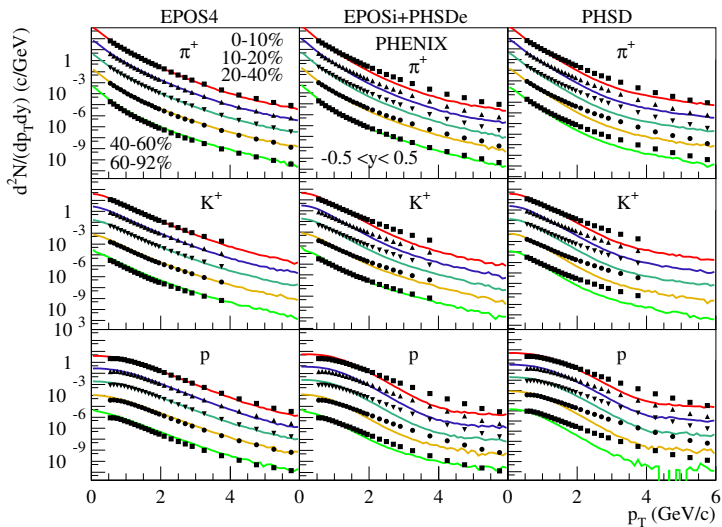
(b) EPOSi+PHSDe



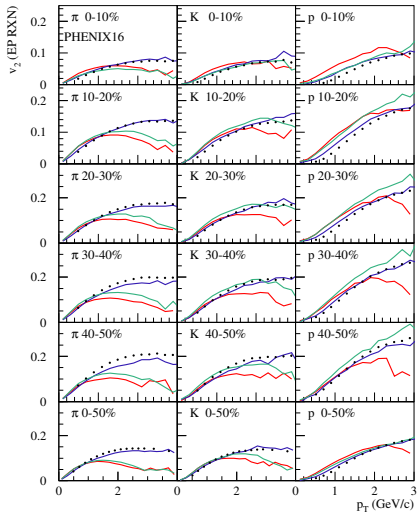
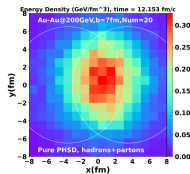
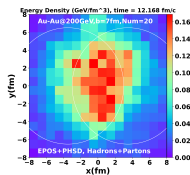
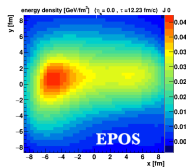
(c) PHSD

Au-Au at 200A GeV, b=7 fm, Num=20

# Transverse momentum spectra for Au-Au at 200A GeV



# Elliptic flow for Au-Au at 200A GeV



EPOS, EPOS+PHSD, PHSD



- Combining two separate HIC models successfully.
- EPOSi+PHSDe: initial phase state from EPOS + matter evolution from PHSD
- The main distinctions between EPOS and PHSD are related to their "evolutions", while an "initial condition" has a minor role.
- The initial conditions from pure EPOS (and similar in EPOSi+PHSDe), based on Parton Based Gribov Regge Theory (PBGRT), show more asymmetric energy density profile in coordinate space than the profile based on PYTHIA strings initial conditions in the PHSD.
- Hydrodynamic expansion in EPOS converts the initial asymmetric shape of energy density to a larger transverse flow more effectively (especially for larger  $p_T$ ) than the microscopic partonic interactions based on DQPM as used in pure PHSD and EPOSi+PHSDe.

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**from electron-positron annihilation up to heavy ion collisions**

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Thank you for selecting me :-)

