A dynamically initialized hybrid approach with varying equations of state

Renan Hirayama[1,2], Zuzana Paulínyová[2,3], and Hannah Elfner[1,2,4]

[1]Helmholtz Research Academy Hesse (HFHF), GSI Helmholtz Center, Max-von-Laue-Str. 12, 60438 Frankfurt am Main
[2]Frankfurt Institute for Advanced Studies (FIAS), Ruth-Moufang-Straße 1, 60438 Frankfurt am Main
[3]Faculty of Science, P. J. Šafárik University, Košice, Slovakia
[4]GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt

2023 IS INITIAL STAGES

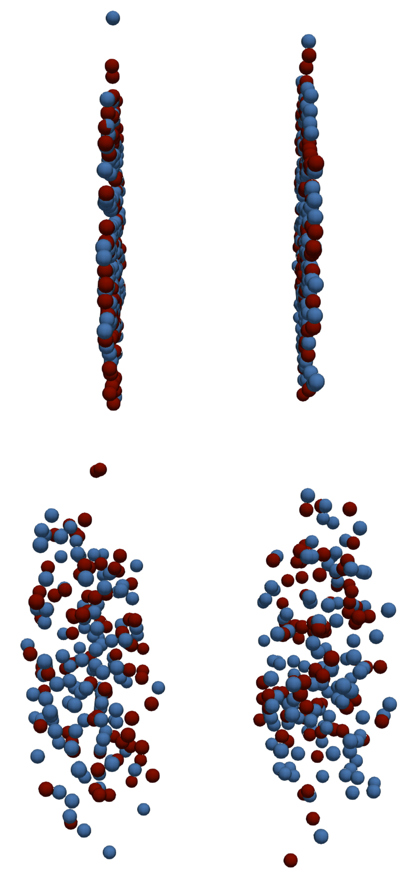
smash

Initialization of hybrid models

- In high beam energy heavy ion collisions, the traditional initialization for hydrodynamics is at the crossing of iso-τ hypersurface. A common choice is the passing time

$$\tau_0 = 2m_N \frac{R_{\text{proj}} + R_{\text{targ}}}{\sqrt{s_{\text{NN}} - 4m_N^2}}$$

- Centrality determination makes core-corona (dense-dilute) separation necessary
- Low energies $\rightarrow$ nonequilibrium, secondary interactions, larger nuclei passing time
- Goal: dynamical condition for fluidization based on local energy density



SMASH

Simulating **Ma**ny **S**trongly-interacting **H**adrons

- Evolve hadrons according to the Boltzmann equation [1]

$$p^\mu \partial_\mu f_i + m_i F^\alpha \partial^p_\alpha f_i = C_i^{\text{coll}}$$

- Particle in energetic enough region $\rightarrow$ fluidization
- Following [2], only hadronic or string decay products ❓
- Threshold condition determined at production, but fluidization happens at formation time
- Background from fluid T^{00} not included yet ❗

vHLLE

viscous **H**arten-**L**ax-van **Le**er-**E**infeldt algorithm

- Israel-Stewart equations of motion with viscosity [3]
- Matching time steps with transport requires Cartesian coordinates
- Fluidized particles enter as *smeared* sources (Z. Paulínyová's poster)

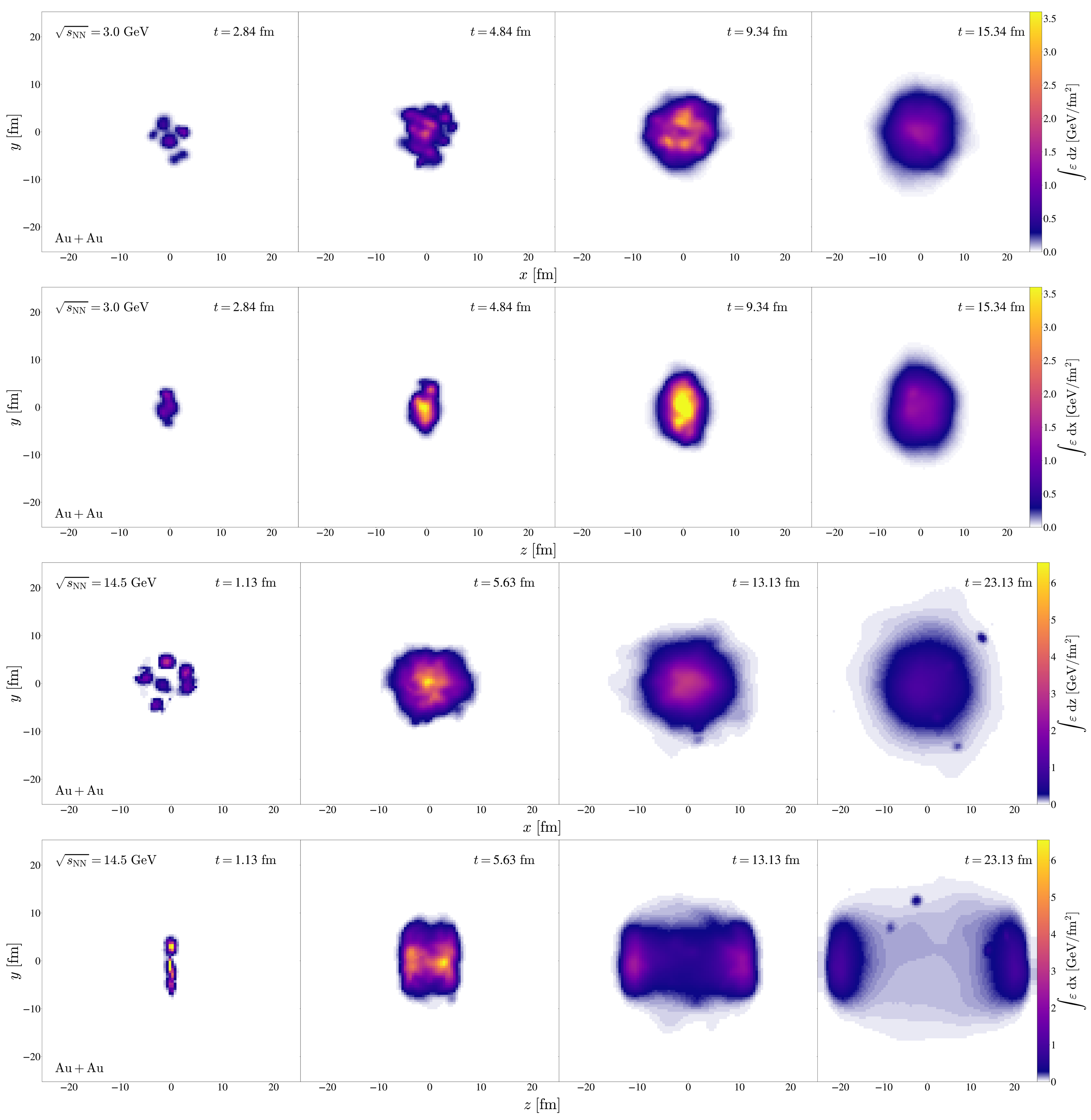
$$J^\mu(\mathbf{r}) = \frac{1}{\Delta t}\sum_i p_i^\mu K(\mathbf{r} - \mathbf{r}_i)$$

$$T^{\mu\nu}(\mathbf{r}) = \sum_i \frac{p_i^\mu p_i^\nu}{p_i^0} K(\mathbf{r} - \mathbf{r}_i)$$

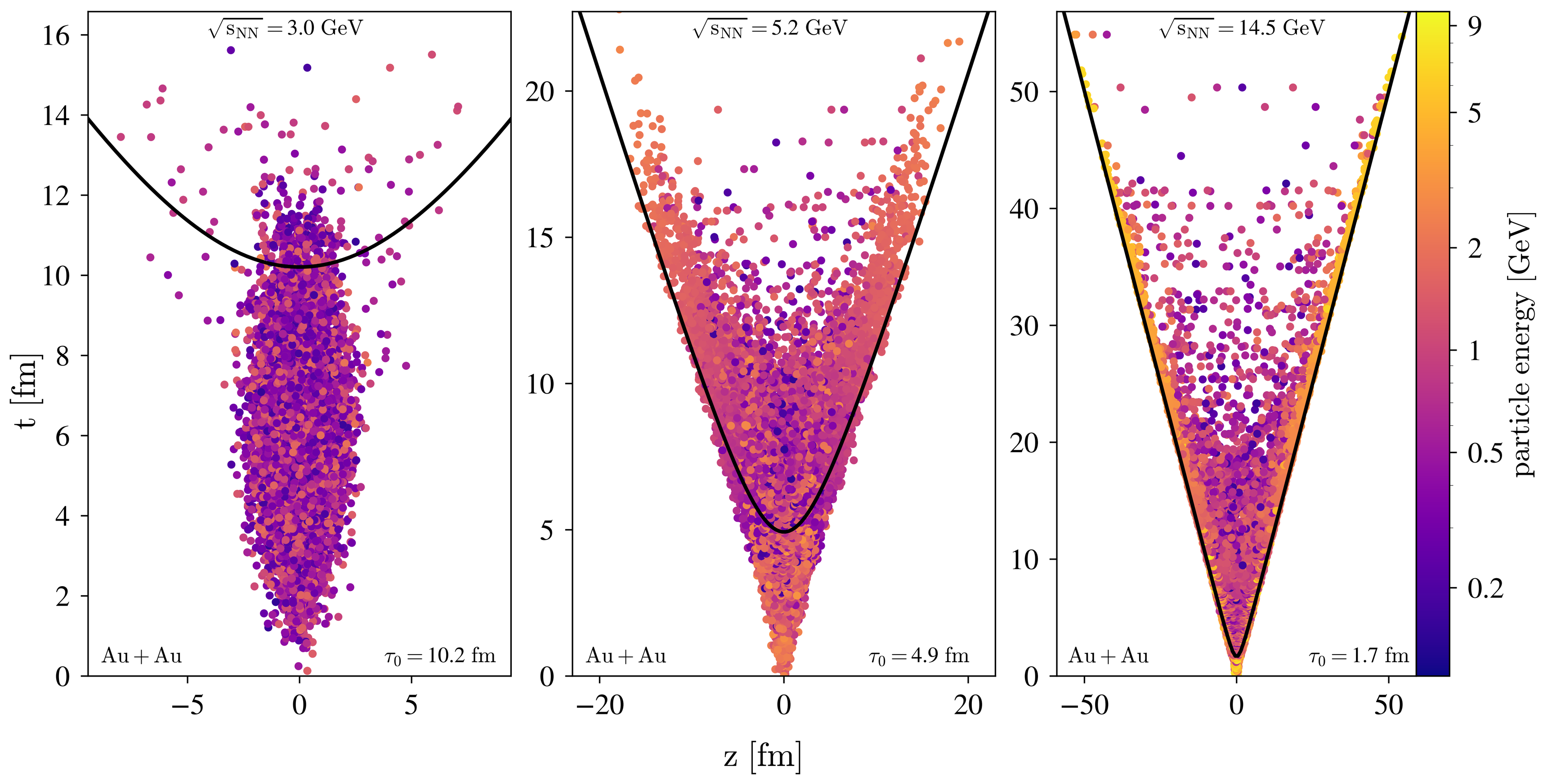
- No particlization yet ❗

Energy density profiles

- Au+Au collisions with $b = 0$
- Threshold $\epsilon_f = 0.5\ \text{GeV/fm}^3$
- Viscosity $\eta/s = 0.2,\ \zeta/s = 0$
- Smearing parameter $\sigma = 1$ fm

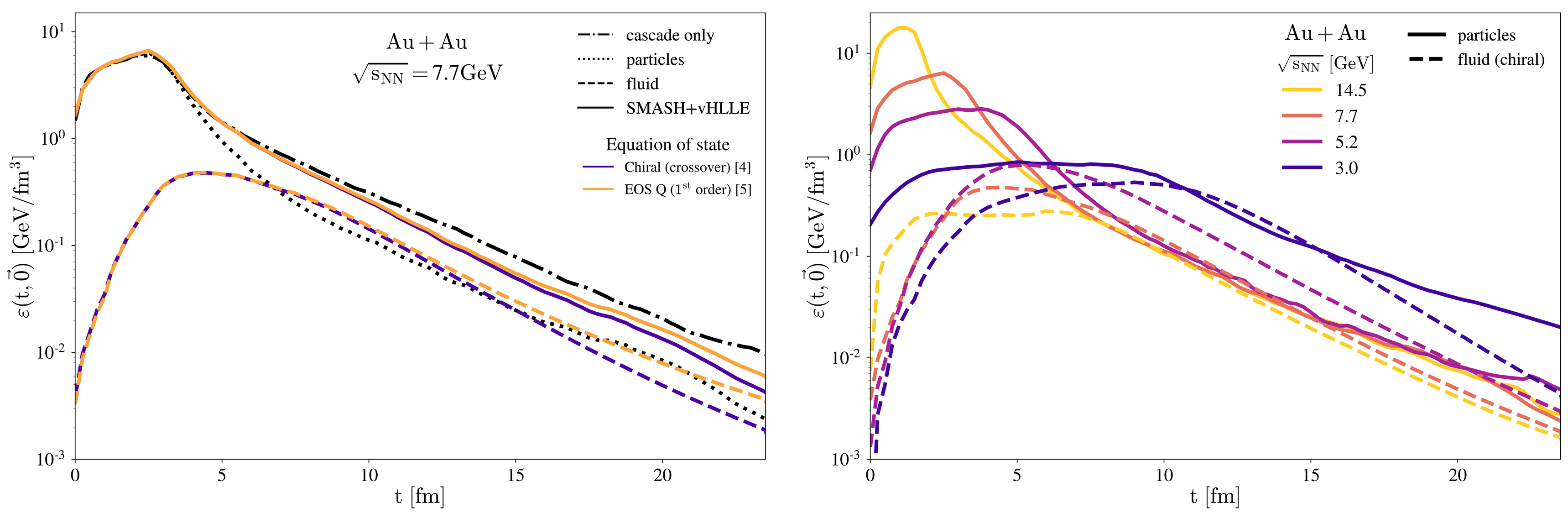


Dynamic fluidization



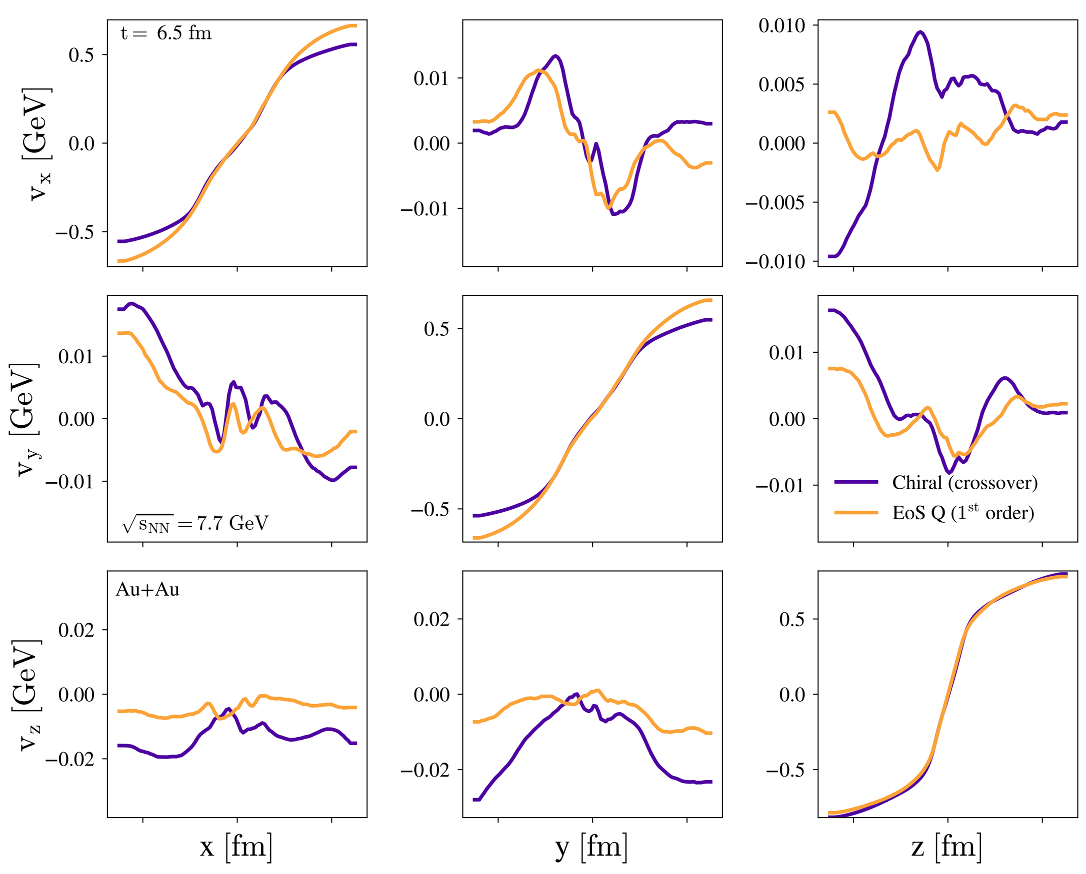
- At lower energies, fluidization happens way before τ_0 👍
- As the beam energy increases, so does the energy of particles entering hydro; more important sources are closer to the iso-τ_0 hypersurface 👍
- Spread depends on threshold energy and formation time 🤔

Central cell evolution



- Less ε at center than cascade mode ↳ faster expansion?
- Small difference between EoS: ε includes compression energy
- Higher $\sqrt{s_{NN}} \Rightarrow$ faster fluidization
- Fast beams expand away quickly
- Contribution depends on which particles are chosen to fluidize

Fluid velocities



- Larger $v_x(x), v_y(y)$ for stiffer EoS with phase transition
- Off-diagonal larger for softer chiral EoS
- Longitudinal flow $v_z(z)$ is indifferent to EoS
- Asymmetric transverse plane: fluctuations ❓
- Relatively small statistic (25 events), but same ICs

Outlook

- Allow different particles to fluidize
- Vary threshold energy and formation time
- Communication between energy density backgrounds for concurrent evolution
- Particle sampling to compute observables
- Radial and anisotropic flow may be sensitive to EoS and phase transition

References

[1] J. Weil, et al., PRC 94.5 (2016) 054905.
[2] Y. Akamatsu, et al., PRC 98.2 (2018) 024909.
[3] Iu. Karpenko, P. Huovinen, and M. Bleicher, Comput. Phys. Commun. 185.11 (2014) 3016-3027.
[4] J. Steinheimer, S. Schramm, and H. Stöcker. J. Phys. G 38.3 (2011) 035001.
[5] P.F. Kolb, J. Sollfrank, and U. Heinz, PRC 62.5 (2000) 054909.

HFHF · CRC-TR 211 Strong-interaction matter under extreme conditions · GOETHE UNIVERSITÄT FRANKFURT AM MAIN · GSI · FIAS Frankfurt Institute for Advanced Studies · PAVOL JOZEF ŠAFÁRIK UNIVERSITY IN KOŠICE

LaTeX TikZposter