Contribution ID: **1106** Type: **Poster**

Exploring the QCD EoS with AI: Constraints from Current Data and tools for Future Experiments

Various approaches to exploring QCD Equation of State (EoS) using modern machine learning/deep learning techniques are presented. In the first part, various existing experimental measurements are used in a Bayesian framework [1] to constrain the density dependent potentials in UrQMD [2] for densities from 2 to 6 times saturation densities (n_0). It is shown that while the observables used in the study tightly constrain the EoS from 2- 4.5 n_0, the constraints on the EoS beyond 3 n_0 are highly sensitive to the choice of observations, highlighting the importance of future experiments.
The second part discusses novel AI based analysis techniques for next generation experiments. We show that DL based models can accurately identify different types of QCD transitions, directly using experimental information such as hits/tracks of particles in the detectors [3]. These methods outperform conventional methods and can be used in experiments for online event characterisation or analysis. We also present a more robust approach using generative models. A point cloud diffusion model capable of ultra fast generation of event-by-event collision output is presented [4]. The model is able to generate realistic collision events with 26 distinct hadron types. The model can be used as a versatile alternative to conventional surrogate models such as the Gaussian process, for a comprehensive Bayesian inference. By being differentiable, such methods can also be directly used for various inverse problems or parameter estimation tasks in experiments. The point cloud representation also makes the model easily adaptable not only to other model calculations or for detector simulations but also in other fields such as cosmic ray air shower simulations.

[1] Omana Kuttan, M., Steinheimer, J., Zhou, K., & Stoecker, H., QCD Equation of State of Dense Nuclear Matter from a Bayesian Analysis of Heavy-Ion Collision Data. Physical Review Letters, 131(20), 202303.
[2] Omana Kuttan, M., Motornenko, A., Steinheimer, J., Stoecker, H., Nara, Y., & Bleicher, M., A chiral mean-field equation-of-state in UrQMD: effects on the heavy ion compression stage. The European Physical Journal C, 82(5), 1-12.
[3] Omana Kuttan, M., Zhou, K., Steinheimer, J., Redelbach, A., & Stoecker, H., An equation-of-state-meter for CBM using PointNet. JHEP 21 (2020), 184.
[4] Under Preparation: Omana Kuttan, M., Zhou, K., Steinheimer, J., & Stoecker, H., Towards a foundational AI model for heavy-ion collisions through point cloud diffusion.

Category

Theory

Collaboration (if applicable)

Primary authors: STOECKER, Horst (FIAS); Dr STEINHEIMER, Jan (Frankfurt Institute for Advanced Studies); Prof. ZHOU, Kai (Chinese University of Hong Kong - Shenzhen (CUHK-Shenzhen)); OMANA KUTTAN, Manjunath (Frankfurt Institute for Advanced Studies)

Presenter: OMANA KUTTAN, Manjunath (Frankfurt Institute for Advanced Studies)

Track Classification: New theoretical developments