Use machine learning to identify the equation of state of quark-gluon plasma

With the support in part from the National Natural Science Foundation of China, Prof. Wang XinNian (王新年) from the Central China Normal University (CCNU), Dr. Pang LongGang (庞龙刚), a former postdoctoral fellow at CCNU and now postdoctoral fellow at the University of California Berkeley, and their collaborators have recently applied the machine learning technique to the field of relativistic heavy-ion physics and succeeded in identifying the type of equation of state (EOS) of the quark-gluon plasmas encoded in the final hadron spectra from viscous relativistic hydrodynamics simulations. Their pioneering work, "An equation-of-state-meter of quantum chromodynamics transition from deep learning", was published in the 2018 January 15th issue of *Nature Communications* (https://www.nature.com/articles/s41467-017-02726-3)

One of the fundamental problems in modern physics is the phase transition from quark-gluon plasma to hadronic gas in strong interaction and the physical properties of quark-gluon plasma in high-energy heavy-ion collisions. This problem is closely related to the equation of state of matter in the early universe shortly after the Big Bang. Determination of EoS is therefore the Holy Grail in high-energy heavy-ion physics. So far there is no direct way to measure EoS experimental. It is also challenging to extract EoS from comparing experimental data and theoretical simulations since the final hadron spectra are also influenced by the initial condition and medium transport properties.

Prof. Wang, Dr. Pang and their collaborators have developed a deep convolutional neutral network to identify the EoS that is encoded in the final hadron spectra. Much like using deep machine learning for image recognition, they feed the final hadron spectra as 2-dimentional images from hydrodynamic simulations with known EoS to the computer to train the neutral network. The network then is tested against another set of events from hydrodynamic simulations for EoS identification. They found that after learning the characteristics from 22000 events (images), the network can identify the EoS in the test events with 95% successful rate. They also found the region of phase space that is the most sensitive to EoS (Figure). Their next stage of study is to apply the deep machine learning technique to extract EoS from real experimental data.

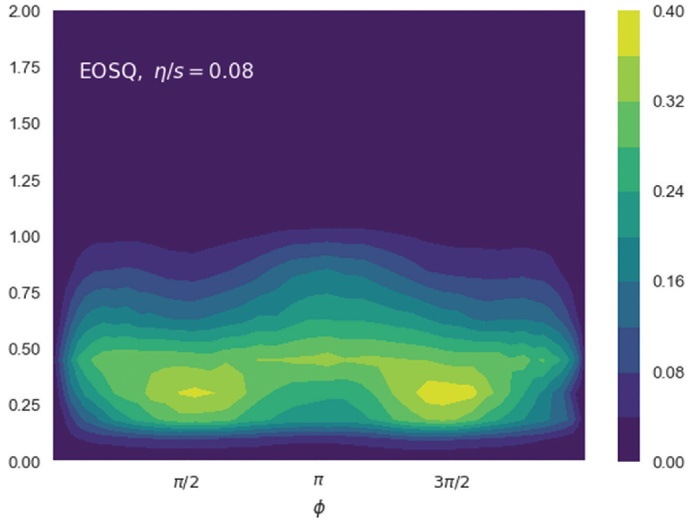

Figure The distribution of sensitivity of the trained network to EoS in the transverse momentum and azimuthal angle.