Relativistic Nuclear Collisions

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The Relativistic Nuclear Collisions (RNC) program in the Nuclear Science Division at LBNL carries out experimental research in Nuclear Physics, with participation in STAR experiment at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, and in the ALICE experiment at the Large Hadron Collider (LHC) at CERN. Our interests focus mainly on two areas of Quantum Chromo-dynamics (QCD): the nature of strongly interacting matter and exploration of the QCD phase diagram; and the spin structure of the nucleon.

High Energy Heavy Ion Collisions

Numerical QCD calculations on the lattice indicate that, above a temperature of about 170 MeV, strongly interacting nuclear matter dissolves into a plasma of quarks and gluons, called the Quark-Gluon Plasma (QGP). The QGP filled the universe 10 microseconds after the Big Bang, and may exist today in the cores of neutron stars. However, the QGP can only be studied experimentally via the collision of heavy atomic nuclear at very high energy, and both RHIC and the LHC have vigorous, ongoing programs in this area. The picture of the QGP that has emerged from these experimental studies is quite different from initial theoretical expectations of a rather featureless gas of non-interacting quarks and gluons at high temperature. Rather, the QGP displays complex and fascinating collective behavior, whose basic constituents (“quasi-particles”) are quite different from undressed quarks and gluons and appear to interact with the lowest specific viscosity allowed by nature. Experimental study of the QGP has attracted attention from neighboring fields of physics, including condensed matter, plasma physics, and even string theory.

The RNC has played a central role in the STAR experiment at RHIC throughout its history, constructing the STAR central detector (the Time Projection Chamber, or TPC), and leading fundamental discoveries by STAR about the QGP, in particular the collective dynamical behavior of the QGP and the interaction and modification of hard QCD jets in the QGP. The latter effect, known as “jet quenching”, was predicted by our theory colleagues in the NSD. More recently, members of the RNC STAR group have turned their attention to questions about the behavior of heavy quarks in the QGP, as well as to an experimental search for the QGP critical point via a beam energy scan (BES), utilizing the tremendous flexibility of the RHIC collider complex to provide collisions of heavy nuclei at center of mass energy per nucleon pair from 5 to 200 GeV.

The RNC also plays a key role in the ALICE experiment at the LHC. The RNC, together with collaborators at other US institutions, led the construction and commissioning of the ALICE EMCal, a large electromagnetic calorimeter that enables ALICE to carry out unique measurements of jets and other hard probes in nuclear collisions. To date there have been two successful heavy ion running periods at the LHC. Members of the RNC are focusing on the analysis with ALICE data of jets (shown in the picture above), photons, and high momentum light meson and heavy flavor production which together will provide deep insight into the nature of jet quenching at the LHC.

Spin of the Nucleon

A profound, long-standing problem in QCD is the nature of the spin of the nucleon. The quark and anti-quark spins are known to carry only a small fraction of the proton spin, whereas the distribution of the remaining fraction amongst gluon spin and orbital angular momenta is not well understood. RHIC is not only the world’s first and most flexible heavy ion collider, but is also the world’s only polarized proton collider, enabling unique studies of proton spin structure. Members of the RNC are focusing on world-leading measurements of nucleon spin structure and spin in QCD, through measurements with STAR of jets and other probes.

Computing

Analyzing the large amount of data accumulated by the STAR and ALICE detectors is a formidable challenge. RNC provides significant computing capabilities for both experiments, primarily through the PDSF analysis center at NERSC, and is the Host Institution for the ALICE-USA computing project. Grid technologies for highly distributed computing play a key role in efficient usage of these resources, as does the high capacity HPSS mass storage system at NERSC. RNC is collaborating with NERSC to develop the next generation of computing facility for large collider detectors, through exploratory usage of massively interconnected computing facilities at NERSC.

Looking Ahead

Looking to the future, the RNC is playing a central role in the Heavy Flavor Tracker (HFT) upgrade for STAR. The HFT, an ultra-high precision silicon vertex detector for heavy flavor measurements, is based on next-generation MAPS sensors together with a revolutionary mechanical support structure that was developed by RNC. Upgrades to the ALICE detector, for the period 2017 and beyond, are currently under active discussion. The RNC also has strong interest and is an active participant in the development of the Electron-Ion Collider project.

• RNC Home Page
• STAR Collaboration
• ALICE