Nuclear Science Division Newsletter

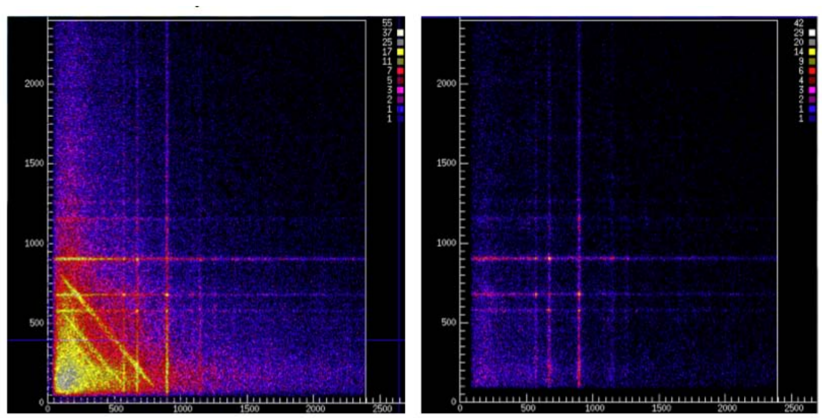
In this issue: **September, 2012**

GRETINA takes data at Michigan State

In July 2012 GRETINA began a campaign of twenty-two experiments at Michigan State University's National Superconducting Cyclotron Laboratory (NSCL), marking a major milestone and a new phase for GRETINA as an operating gamma-ray energy tracking array for nuclear science experiments. A photo of GRETINA installed at the target position of the S800 spectrograph is shown to the right.

Over the 9-month campaign, GRETINA will study a broad range of topics in nuclear structure and astrophysics. These include investigating weakly-bound (halo) nuclei close to the drip-line, providing data relevant to x-ray burst light curves in the rp process, mapping changes to shell structure with increasing neutron/proton ratio, and determining transition strengths important for elemental synthesis in stellar environments.

Five experiments have been completed so far. Data analysis is ongoing, but all indications are that GRETINA is performing superbly. Figure 2 shows some data from an experiment performed in August. The gamma rays are from the decay of ^{64}Ge produced from a fast moving ^{65}Ge beam hitting a ^{9}Be target. The left panel shows gamma ray coincidence data when the 28 Germanium crystals are treated as individual detectors – i.e. the standard approach with no tracking; the right panel shows the same data when gamma-ray tracking is turned on. The clear and significant reduction in the background due to tracking is key to obtaining the best experimental sensitivity possible.

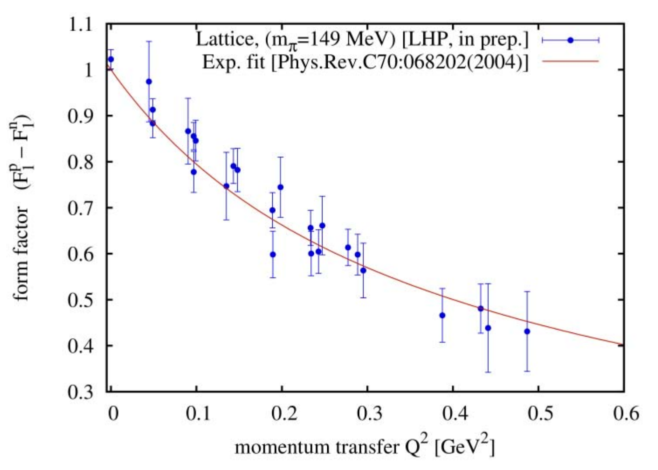


GRETINA uses digital pulse processing, signal analysis, and tracking algorithms to provide the location of a gamma ray's first interaction, as well as reconstruct its energy and reject events with incomplete energy collection. When combined these properties ensure accurate Doppler-shift energy corrections for gamma rays emitted in-flight and provide high efficiency and good peak-to-background.

Computing nuclear QCD from first principles

Critical aspects of modern theoretical research in nuclear physics depend on high performance computing. A significant effort of the NSD Theory group is the interface between low-energy nuclear effective theory and lattice QCD. A principal goal of this effort is to quantitatively connect our understanding of nuclear physics with QCD, the fundamental theory of strong interactions.

Recently, Sergey Syritsyn, with a joint LBNL-MIT lattice theory group has successfully calculated the electromagnetic form factors of the nucleon. Several key characteristics of nucleon structure are very sensitive to the light quark masses, including the electric and magnetic radii and the magnetic moment of the nucleon. For the first time, it was possible to calculate these quantities correctly and reproduce the experimental values (arXiv:1209.1687). While the uncertainties are still large compared to experiment, the precision of the charge radius determination, for example, will soon be sufficient to resolve the recent proton radius controversy (a recent measurement of the proton radius using muonic hydrogen yielded a value 5σ smaller than previous determinations [R. Pohl *et al.,* Nature 466, 213 (2010)]). This achievement is an important step in our ability to derive proton and neutron properties from underlying theory of strongly interacting particles.

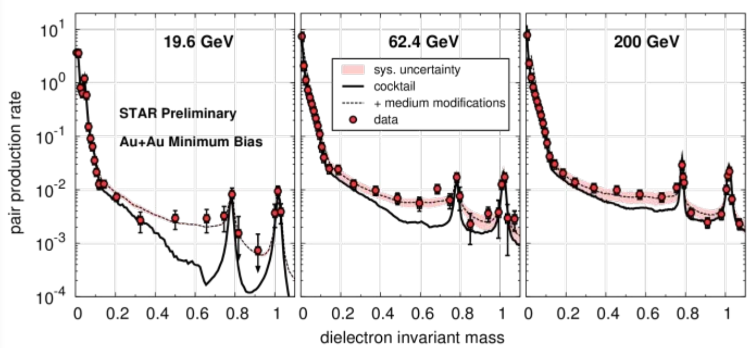


The next major challenge is to understand the formation of nuclei from QCD. Performing lattice QCD (LQCD) calculations of multiple nucleons in a finite volume allows for a direct probe of their interactions. The lightest nucleus, deuterium, is a finely tuned system with an unnaturally large scattering length. This challenges LQCD calculations. The fine tuning also presents new opportunities; by matching low-energy effective theories onto the LQCD calculations, we can study the nature of these fine tunings as a function of the quark masses. In turn, we will ascertain how they are manifested in tritium, helium and other light nuclei, and ultimately, how finely tuned our universe is. Wick Haxton (PI), Sergey Syritsyn and André Walker-Loud are members of a newly funded SciDAC grant, bringing together physicists, applied mathematicians and computer scientists at LBNL and LLNL, the California Lattice (CalLat) Collaboration. In addition to making this connection between QCD and nuclear physics, a principle goal of CalLat is to understand how fundamental symmetry (breaking) manifests itself in nuclear physics, such as parity violation and electric dipole moments. The complex nature of these calculations and the current generation of supercomputers require such a cross-disciplinary collaboration.

NSD speaks out at Quark Matter

The Nuclear Science Division was well represented at Quark Matter (QM) 2012, the major largest international conference in heavy ion physics. Quark Matter takes place every 18 months or so; this edition was in Washington D.C. on August 12-18th. There were 50 plenary and 160 parallel presentations spread over the 6 days.

Xin Dong from RNC gave the STAR plenary highlight talk, presenting the latest results of high statistics measurements at RHIC top energy, as well as results from the Beam Energy Scan, which is aimed at mapping out the structure of the QCD phase diagram. The figure shows one of the STAR highlights generated by the RNC group: the "invariant mass" distribution of electron pairs in Au+Au collisions, for three widely different collision energies. Another RNC-led STAR highlight which generated much interest and discussion was the measurement of high moments of the net proton distribution, which is sensitive to the presence of a critical point.



Shingo Sakai from RNC presented ALICE measurements of single electrons produced by heavy flavor decays in both pp and PbPb collisions at the LHC, showing that heavy quark production is suppressed in PbPb compared to expectations from pp collisions, and that heavy quarks "flow" with the medium, over a broad range of quark momentum. This analysis employs a wide range of electron measurement techniques from ALICE, including the US-led EMCal, which was essential to achieve the very high momentum reach of the measurements

The NSD theory group presented results on the factorization of Di-jet correlations in pA collisions (a talk by F. Yuan), effects of longitudinal fluctuations on the hydrodynamics evolution (a talk by L. Pang, X.N. Wang), as well as the effects of baryon stopping on the difference of proton and anti-proton elliptic flow (a poster by J. Steinheimer and V. Koch). Furthermore, corrections to the kurtosis of the proton number distribution resulting from baryon number conservation as well as from finite acceptance effects were discussed in a talk by A. Bzdak (now at BNL) and V. Koch.

LBNL was also represented on the International Organizing Committee by Xin-Nian Wang and Nu Xu.

NSD Fragments

NSD project scientist **Jason Detwiler** has moved to a faculty position at the University of Washington, where he will be an Assistant Professor. Jason contributed to many of the neutrino projects at LBNL, most notably Majorana Demonstrator. Fortunately, he will continue to with Majorana in Washington.

Newsletter Notes

Please send any comments, including story suggestions to Spencer Klein at srklein@lbl.gov.

Previous issues of the newsletter are available at:
https://commons.lbl.gov/display/nsd/NSD+Newsletter