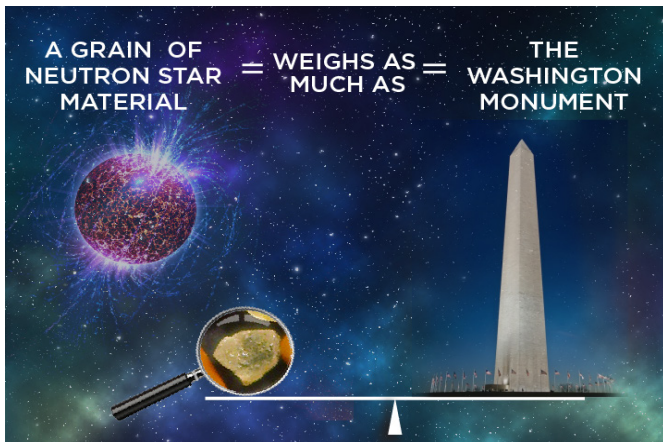


WHAT KEEPS THE NEUTRON STAR FROM COLLAPSING?

Contributed by Betty Tsang

The matter inside neutron stars is so dense that the weight of neutron star matter the size of a grain of sand* is similar to that of the Washington Monument (81,000 tons). To survive the gravitational pull from its own weight and to prevent it from collapsing into a black hole, a neutron star relies strongly on the pressure generated from the nuclear force, which is repulsive at high density. A major part of this force comes from the nuclear symmetry energy. The symmetry energy describes how much more repulsive the nuclear forces in pure neutron matter are, than the forces inside stable nuclei with comparable numbers of protons and neutrons.

To understand the sizes of neutron stars and the stability of neutron stars from gravitational collapse, one needs to know more about how the symmetry energy varies with density. We can study this by colliding nuclei with different numbers of neutrons and protons and seeing how the pressures attained differ. However, the effect is much smaller in nuclei than in neutron stars because most nuclei have similar numbers of neutrons and protons. Past studies at NSCL have provided experimental constraints on the symmetry energy at densities below those typically found in the centers of most heavy nuclei.



A grain made of a neutron star matter weighs as much as the Washington Monument. *Computations assume a 2 solar mass neutron star with 24 km diameter and a 0.64mm diameter spherical grain.

At NSCL, we have compared the emission of neutrons to that of protons, taking advantage of the fact that the symmetry energy repels neutrons from a neutron rich system while attracting protons. We further enhance this repulsion or diminish the attraction by changing the relative numbers of neutrons and protons in the system. The combination of these two strategies provides the sensitivity to the symmetry energy that we seek.

In high-energy collisions at NSCL and even more so in FRIB, one can create densities of nuclear matter that approach twice the saturation density (corresponding to twice the central density of a lead nucleus). This is the density that most strongly influences the radii of neutron stars. Such radii have been deduced by studying x-rays emitted from neutron stars using satellite X-ray observatories. The radii thus obtained range from 9 to 14 km.

To design experiments to study the symmetry energy at twice saturation density, we have simulated collisions of different Sn isotopes. For example, we have compared neutron-rich collisions using a ^{132}Sn (rare isotope beam) on a ^{124}Sn (stable target) to neutron "poor" collisions using a ^{108}Sn (rare isotope beam) on a ^{112}Sn (stable target) using a Boltzmann-Uehling-Uhlenbeck transport code developed by Pawel Danielewicz and modified by Jun Hong. We examined several observables that we can measure experimentally, including the ratios of neutron to proton energy spectra, ratios of triton to ^3He spectra and, in high energy collisions, the ratios of the spectra of negative and positive pions (the pion is the lightest particle that interacts via the strong force). We find that ratios of the center of mass spectra of negative pions divided by corresponding spectra of positive pions provide the most sensitive observable to probe this density dependence at twice saturation density.

To address this scientific opportunity, we need a time projection chamber inside a strong magnet to measure pions. Dr. Zbigniew Chajcki and his colleagues at Western Michigan University, together with members of the HiRA and AT-TPC groups, have proposed to build a portable time projection chamber that could be used to measure pion spectra and other observables on the fast beam lines at NSCL and FRIB.

NSCL RETIREES OFF TO NEW ADVENTURES

Christine O'Conner is retiring after working at MSU for 32 years, almost 29 of those at the Lab. Her hire date here was 8/28/86. Her favorite part of working here has always been the interesting people; the staff, the faculty and visitors from all over the globe. One of her favorite memories is the day she got to make the announcement over the intercom that MSU had been awarded the FRIB project and hearing voices loudly cheering up and down the hallways. Chris said that "there was a lot of joy and pride in the Lab that day!"

When Chris retires, she plans to do some traveling to see friends and family, and to spend a lot of time tending her garden which has been sorely neglected that last few years.

Gene Battin, Accelerator Engineer/Physicist II, will be retiring May 1st after 16 years with the NSCL. He began his career in

operations with the Indiana University Cyclotron Facility in August of 1978 and joined the lab in 1999. His knowledge-in-depth of accelerator systems served the lab well, especially on the night shifts and in the training of new operators. Upon retirement, Gene will be moving back to southern Indiana both to be closer to his children and to pursue his astronomical interests (with a lessened risk of frostbite).

Laura Gonzales has worked at the Lab for 21 years. She always enjoyed interacting with people, and meeting scientists from all over the world. She said the best part of working at the front desk was the variety, she always had something new to do each day. She was so glad to help out everybody here and meet new friends.

Laura is currently in her third semester studying to become a Minister. After she retires she looks forward to a lot more time to study! During the winter Laura will live in Texas where she will get to spend time with her extended family. She will miss being here with the people in the lab, but is looking forward to volunteering in her community and enjoying her family even more. Laura's last day at the Lab will be April 31, and we will have a celebration in her honor.

JINA-CEE IAC MEETING AT MSU

The [Joint Institute for Nuclear Astrophysics, Center for the Evolution of the Elements](#) (JINA-CEE) International Advisory Committee will hold its first meeting on May 4-5 at MSU. The Committee is chaired by Bob Tribble (BNL) and consists of nine experts from the international nuclear astrophysics community: Ani Aprahamian (Notre Dame, JINA-CEE), Jolie Cizewski (Rutgers), Brian Fields (Illinois), and Reiner Kruecken (TRIUMF) will be at MSU for this year's meeting. Wick Haxton (UC Berkeley), Jim Lattimer, (SUNY Stony Brook), and Verne Smith (NOAO) will join remotely.

From JINA-CEE, non-MSU participants will be Timothy Beers (Notre Dame), Jason Clark (ANL), Alexander Heger (Monash), Falk Herwig (Victoria), Micha Kilburn (Notre Dame), Gail McLaughlin (North Carolina State), Sanjay Reddy (Washington), Frank Timmes (Arizona State), and Michael Wiescher (Notre Dame).

The committee will meet at the Kellogg Center to evaluate JINA-CEE's scientific progress at the intersection of nuclear physics and astrophysics, and to provide external advice on long-term program developments.

HANDS-ON FIRE EXTINGUISHER TRAINING - HERE AT FRIB/NSCL

A typical fire extinguisher contains 10 seconds of extinguishing power. Always read the instructions that come with the fire extinguisher beforehand and become familiarized with its parts. If your line manager requested fire

extinguisher training for you, hands-on training is required before operating a fire extinguisher.

Hands-on fire extinguisher training will be available to all employees next week. Anyone who would like the opportunity to extinguish a fire can stop by during the scheduled times. No registration is required. Contact Carol Lentz, x184 if you have questions.

- Wednesday April 29, 2:00-3:00 pm
- Thursday April 30, 9:00-10:00 am

East Parking Area (Outside ReA12 High Bay by the Theory trailer)

CCF UPDATE

This week, the cyclotrons continue a long run of Ge-76, which is produced by an inductively heated high-temperature oven in the SuSI ion source. This beam is serving a beta-decay experiment in the S2 vault.

LABORATORY GOLF LEAGUE

The NSCL/FRIB Golf League is looking for new members. We play on Tuesdays after work at [Timber Ridge Golf Club](#) - if you are interested in more information, please contact [Gary Westfall](#) or [Don Lawton](#).

SEMINARS

- **WEDNESDAY, APR 29 AT 4:10 PM**
NSCL Lecture Hall
Chris Ruiz, TRIUMF
'Radiative Capture for Astrophysics using Radioactive Ion Beams'
- **THURSDAY, APR 30 AT 11:00 AM**
Theory Trailer Conference Room
Michael Kruse, Lawrence Livermore National Laboratory
'The photonuclear cross section of the Boron-10 nucleus'
- **FRIDAY, MAY 1 AT 11:00 AM**
Nuclear Conference Room
Special Seminar- Post Doc Candidate
Kasey Lund, Washington State University

PEOPLE AT THE LAB

- Adam Powers joined CCF Operations this week as a Student Labor Assistant. His line manager is John Bonofiglio.
- Yassid Ayyad Limonge joined the lab this week as a Research Associate. Wolfi Mittig is his line manager.

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