Neutron Wall Upgrade -- Instrumentation for FRIB

To get firmer ideas about instrument packages that will be proposed at the FRIB Workshop, Feb, 20-22, 2010, we request that each collaboration to fill in the following questionnaire. These should be e-mailed to Kim Lister (Lister@anl.gov) and copied to Brad Sherrill at (Sherrill@frib.msu.edu) and Rick Casten (Rick@riviera.physics.yale.edu) no later than Feb 12, 2010. The recommended ***length*** *is* ***2 pages****, plus two additional figures. One figure should present the instrument and the other should indicate its location, size, etc on the floor at FRIB by using the attached floor plan template.*

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1) What is the primary physics motivation and experimental capability of the proposed instrument and why is this important for FRIB science?

The density dependence of the nuclear asymmetry energy is of great importance. It is directly relevant to the nearly every macroscopic property of neutron stars. Calculations predict that comparisons of neutron to proton emission can provide sensitivity to the symmetry energy over a range of densities. This requires impact parameter selected measurements of neutrons and protons emission probabilities and flows for a set of reactions with varying asymmetry. The relevant neutron data are largely impact parameter gated continuum spectra. At the lower portions of the neutron energy spectra, they are prone to contamination from 's originating from (n,n') reactions caused by neutrons scattering on the materials in the experimental vaults.

To obtain high statistics neutron data for such studies, which must be free from contamination from -ray emission, large area liquid scintillator detector arrays can be used. The Large-Area Neutron Array (LANA) consists of two large walls of NE213 liquid scintillator, which allows clean separation of the interesting neutrons from photons. For this reason, the Large Area Neutron Array remains a viable and useful option in studies relevant to the nuclear EOS.

Additionally, as an auxiliary detector to e.g., the AT-TPC, it can be a powerful tool for reactions of astrophysical interest such as (,n) reactions at astrophyisically interesting energies or for any other reaction where removal of 's originating from (n,n') reactions can be important.

2) What are the unique capabilities of this device that are not available in existing equipment? Is this instrument stand alone or is it to be used (solely or partially) in conjunction with other instruments. Could it be used at NSCL or other laboratories before FRIB?

The LANA in particular is currently the only large area neutron array with n-gamma discrimination available at the NSCL. The array can be moved to different locations within the NSCL and FRIB facilities, but would require a major effort to transport outside the lab as the glass cells that contain the scintillator are somewhat delicate. The array is currently fully

functional, but it does require maintenance and will require replacement of components and modern electronics over time.

The proposed studies also require the use of a large charged particle array to gate the data on centrality. This requires the installation of a large thin-walled scattering chamber in a neutron time of flight area.

3) Describe the instrument in some detail – how does it meet the scientific requirements and what are the (estimated) performance specifications? Be brief but as detailed as you can. Is the design fixed or are multiple options still being discussed and encouraged?

The detector in question is not new and is described extensively in the literature (cf. Zecher et al. Nucl. Instr. & Meth. Phys. Res. A 401, 329 (1997)). It consists of two separate banks of detectors, each 2×2 meters2 in area and containing 250 liters of liquid scintillator, which makes it one of the largest such arrays in the world.

- Neutron-gamma discrimination obtained via the use of NE-213 scintillator liquid.
- For neutron time-of-flight measurements, the time resolution of the detector has been demonstrated to be about 1 ns.
- Position sensitivity obtained via laterally spaced bars with PMT detectors on each end. Each cell is position sensitive to better than 10 cm, with a typical efficiency of about 11% for neutrons of 20-40 MeV.
- Higher efficiency: Generally efficiency higher than LANA would be nice. This could be achieved without loss of resolution by doubling the number of walls covering the relevant angular domain. Efficiencies exceeding 20% could be achieved this way and would be desirable. If design effort for a new auxiliary neutron detector is undertaken, multiple design options would be discussed.
- Large solid angle coverage. In a single experiment, it is generally desirable to cover all angles between 0 and 60o and possibly more. This requires a vault suitable for neutron detection of a large range of scattering angles. Such capabilities currently exist in the S2 and N2-3 vaults.

4) What is the current stage of development of your project ?

The use of neutron-detector arrays in the future EOS program at FRIB is being planned, using the LANA and MONA-LISA arrays, and experiments will be proposed. Preliminary designs for an improved neutron array with n-gamma is still in the discussion phase.

5) What is the approximate cost of the project: discuss possible sources of funding.

Very likely, the cost of a large array neutron detector for these purposes will not exceed $500K. Doubling the number of LANA elements would cost approximately $250k. Funding for an

addition device at the FRIB facility will likely come from NSF MRI funding if construction of an additional device is thought to be necessary.

6) Please provide a brief list of collaborators and institutions, and spokesperson(s) contact info.

WMU - Michael Famiano, michael.famiano@wmich.edu

NSCL - William Lynch, Betty Tsang

IUCF - Romualdo de Souza, Sylvie Hudan

WUSTL - Lee Sobotka, Robert Charity

TAMU - Sherry Yenello

7) Please can you outline how your collaboration has been developing your project and how you are growing your collaboration (How many meetings? Participants? Circular mailings? Have you a web-site?)

The Symmetry Energy Project collaboration has seen tremendous progress in the past year with a major DOE grant. Currently, the collaboration spans several institutes in Europe, Japan, and the USA and a International Symposium on Nuclear Symmetry Energy will be held at RIKEN from 7/26-28/2010. Informally, the US collaborators have been meeting roughly monthly, and a collaboration meeting with our Japanese and Western European collaborators will take place on Feb 19, 2009. In addition, information is disseminated via an updated web page (http://groups.nscl.msu.edu/hira/sep.htm).

8) Did you consider alternative designs? What alternatives were considered? How did you arrive at a final design?

The major designs considered for this include both MoNA and LANA. Both designs can work well for various applications. While MoNA has higher efficiency than LANA, the neutron-gamma discrimination of LANA is extremely important in some cases. It presents the most compact type of design for its purpose. (Mike, what about copying the LAND design?)

9) What existing equipment exists in the US Community that has similar goals and characteristics, even if inferior in performance?

MoNA-LISA will be a larger array, but does not provide pulse shape discrimination between neutrons and photons. Discrete arrays of neutron detectors exist, at a variety of laboratories, but have much, much lower detection efficiencies than LANA.