Collaboration Questionnaire -- Instrumentation for FRIB

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To get firmer ideas about instrument packages that will be proposed at the FRIB Workshop, Feb, 20-22, 2010, we request 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 floorplan 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. I in that it is directly relevant to the nearly every macroscopic property of neutron stars. Several observables are proposed to study this energy. The observables of interest may gain or lose sensitivity with the density studied. Calculations predict that cAt higher densities (thus higher beam energies), sensitivity to pion production in nuclear reactions may be most relevant, though isotopic observables are relevant at all energies. Incomparisons of particular, 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 widely is thought to be the most sensitive isotopic observable. For this reason, high sensitivity to neutrons in reactions of 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 γ's originating from (n,n'γ) 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 γ-ray emission, l Large area liquid scintillator detector arrays can be used. s, despite their low efficiency aThe Large Area Neutron Array (LANA) consists of two large walls of NE213 liquid scintillator, which allows clean separation re most useful in distinguishing of emitted the interesting neutrons and from photons and protons. For this reason, the Large Area Neutron Array (http://groups.nscl.msu.edu/hira/sep/08a%20eq%20neutron%20walls.pdf) (LANA) remains a viable and useful option in studies relevant to the nuclear EOS.

Additionally, as an auxiliary detector to e.g., the AT-TPC (http://groups.nscl.msu.edu/hira/sep/08.5%20eq%20active%20target%20time.pdf), it is can be a powerful tool for reactions of astrophysical interest such as (α,n) reactions at astrophyisically interesting energies or for any other reaction where removal of γ's originating from (n,n'γ) 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?

~~2)~~

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The LANA in particular is currently the only large area neutron array with n-γ ~~d~~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. ~~, and thus extremely useful in studies in which photon scattering may contaminate high-resolution neutron measurements. A major drawback of this array is that its portability is somewhat prohibitive. Thus, its ability to be used in conjunction with other detectors (such as the AT-TPC) is also limited.~~ 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. ~~For this reason, additional neutron detection capabilities at the NSCL/FRIB would be desirable. Position sensitivity to within 10 mrad is important and quite technically feasible, as is a large solid angle coverage.~~

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~~While the currently available device is acceptable, its major drawbacks include its relative permanence in location and its age. Many of the components will very soon require replacement or maintenance.~~

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 ~~A detector of similar proportions to the existing LANA or the MoNA array would be extremely useful. Of particular importance are the following:~~consists of two separate banks of detectors, each 2×2 meters[2] in area and containing 250 liters of liquid scintillator, which makes it one of the largest such arrays in the world.

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- 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.

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- ~~Position sensitivity obtained via laterally spaced bars with PMT detectors on each end.~~
- ~~Neutron-gamma discrimination obtained via the use of scintillator liquid.~~
- Large solid angle coverage. In a single experiment, it is generally desirable to cover all angles between 0 and 60^o 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.
- ~~Portability: Ideally, moving the detector from one part of the laboratory to another with little effort is desirable.~~
- ~~Higher efficiency: Generally higher than LANA would be nice, but this would be achieved either through multiple elements or larger elements in the existing liquid design. Efficiencies exceeding 25% would be desired.~~

~~If a new auxiliary neutron detector is constructed, multiple design options would be discussed.~~

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

The use of neutron detector arrays in the ~~existing~~ future EOS program at FRIB is ~~still~~ being ~~discussed~~ planned, using the LANA and MONA-LISA arrays, and experiments will be proposed. Pand ~~p~~reliminary designs for ~~auxiliary~~ an improved neutron array with n-γ ~~s~~ is still in the ~~planning~~ discussion phase~~s~~. ~~Currently, much of the focus within the collaboration is toward the AT-TPC. However, the use of neutron detectors in future experiments is still being discussed.~~

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. Spokesperson(s) provide contact info.

- WMU Michael Famiano, michael.famiano@wmich.edu
- NSCL -
- William Lynch,
- Betty Tsang
- ~~WMU~~
- ~~Michael Famiano, michael.famiano@wmich.edu~~
- IUCF -
- Romualdo de Souza,
- Sylvie Hudan
- WUSTL -
  - Lee Sobotka,
  - Robert Charity

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- 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 ~~may be more portable~~ 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 ~~is currently the most similar~~will be a larger array, ~~though~~ but does not provide pulse shape ~~it suffers from the fact that it cannot produce~~ discriminatioe between neutrons and photons. Discrete arrays of neutron detectors exist, at a variety of laboratories, but have much, much lower detection efficiencies than LANA. ~~would also provide similar results at a much larger cost.~~

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