Collaboration Questionnaire -- Instrumentation for FRIB

Working Group Super Scintillator Arrays (Group 7)

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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?

A new-scintillator-material versatile detector shell or 4π array is being discussed for γ-spectroscopic measurements. No decisions have yet been made, either for a detector material or for a principal geometry. A lanthanum halide is preferred (see Q.2). A "modular" concept is desirable, to allow for a setup at a target position and a decay-station position either way, and facilitate use with other detectors.

Principal applications include:
I. Intermediate-energy projectile Coulomb excitation with a thick target for nuclear structure studies very far from stability (transition matrix elements, evolution of shell structure). The intrinsic energy resolution is adequate since Doppler broadening due to target thickness is significant.
II. Electronic-timing lifetime measurements, particularly with re-accelerated and stopped beams, for bound states, to obtain transition strengths between low-lying collective states in deformed nuclei, or lifetimes of sub-nanosecond intrinsic states. Electronic-timing lifetime measurements for bound states are capable of covering the range $\tau \geq 20$ ps (Mach et al. J. Phys G 31, S1421, 2005). They are an important complement to other methods for determining lifetimes and transition matrix elements viz. Recoil Distance Doppler Shift and Coulomb Excitation. With respect to the former, the Electronic-Timing method does not only overlap in range, it also provides the only means to determine lifetimes in cases of very slow or stopped γ emitters.
III. Giant-resonances, where γ decay provides key information for this collective mode. Of interest are states at high energy and angular momentum in neutron-rich nuclei only accessible via fusion-evaporation with rare-isotope beams (e.g. Maj et al. Acta Phys. Pol. B 40, 565 , 2009).
IV. Calorimetric measurements based on total γ absorption to determine e.g. β-decay strength functions. Method has been used to obtain "β feed" (Duke et al. Nucl. Phys. A 151, 609, 1970) and to determine n-capture cross sections (e.g. Couture et al., Proc. International Conference on Nuclear Data for Science and Technology 2007, http://nd2007.edpsciences .org). Particularly in the context of β-decay work, this technique seems to be important for experiments at FRIB.

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?

At this point, the uniqueness of the device is in the detector material. The emerging scintillators are characterized, in their photon response, by a better energy resolution (compared to NaI:Tl or CsI:Na) and a time resolution comparable to BaF2 (the energy resolution of BaF2 is inferior to that of NaI). Examples of new scintillators under consideration are LaBr3:Ce, LaCl3:Ce and CLYC (Cs2LiYCl6). The lanthanum halides have the additional advantage over CLYC of a somewhat higher energy resolution and higher density. The lanthanum halides, being denser than BaF2, can, in principle, be more compact than a BaF2 shell, while CLYC has gamma-neutron separation capabilities through pulse shape discrimination. It seems that lanthanum-halide detectors are predestined for a decay-station setup and at least equally good for a target-position setup as CLYC (or BaF2). If a choice pro-lanthanum-halide is made, the neutron background (relevant at the target position) has then to be reduced by time-of-flight discrimination.

With respect to item I in Q. 1, Weisshaar et al. (NIM A 594, 56, 2008) have demonstrated that the high time resolution helps via narrow gating to reduce background. With respect to all items in Q. 1, the relatively high energy resolution of the new materials is crucial. In case of item III in Q. 1, the "add-back" mode (imperative for high-energy γ rays) could be improved due to a higher gain of the nearest-neighbor detectors (compared to BaF2). The combination of improved time and energy resolution is essential for item II: the former helps to observe small (< 100 ps) centroid shifts of time peaks, while the latter allows to gate on photo peaks to reduce randoms.

A new-scintillator shell/array is not necessarily a stand-alone device. As a target-position device, it would benefit from additional particle detectors for reaction-channel selection and Doppler-broadening correction. As a decay-station device, it would be obviously combined with particle detectors. The new shell/array should be moveable with portable electronics. Hence it could be used at other locations before FRIB.

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?

N/A (no design has been proposed yet – see Q. 1).

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

The project, since it just started, is in the discussion stage (see Q. 6).

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

N/A (see Q. 3).

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

A group of interested people/potential collaborators has been formed based on subscription to the workshop. They represent following institutions: ANL, LANL, MSU, ORNL, UMass. Lowell, Washington U., Yale, and IFJ Cracow/Poland. We have contacted Radiation Monitoring Devices, Inc.

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 group of potential collaborators has communicated by e-mail and Skype conference.

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

N/A (see Q. 3).

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

Existing equipment: BaF2 array/ORNL and Yale, Dance/LANL, CAESAR array/MSU.