SAC Questionnaire - Neutron detectors - Overview

This document contains an overview of the neutron detectors available/under construction/considered. Detailed answers are found in the attached 2-page questionnaires for each of the different systems. Contained are:

- LANA (Large Area Neutron Array and possible upgrade/extension)
- MoNA-LISA (Modular Neutron Array and its upgrade, the Large Area Multi-Institutional Scintillator Array)
- VANDLE (Versatile Array of Neutron Detectors at Low Energy)
- LENDA (Low-Energy Neutron Detector Array)
- DESCANT (DEuterated SCintillator Array for Neutron Tagging)
- 3Hen
- NERO (Neutron Emission Ratio Observer)

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

Detector	Primary physics motivation	Experimental capability	Primary Reaction type
LANA	Nuclear asymmetry energy, equation of state	Liquid scintillator, fast neutron, n-γ separation	HI collision
MoNA-LISA	Structure of neutron-unbound states	Plastic scintillator, Fast neutrons	Knockout, (d,p)
VANDLE	Shell structure, r- and rp-process, weak interactions, stewardship, equation of state	Plastic scintillator, Low energy neutrons (100's keV – 10+ MeV)	(d,n), βn
LENDA	Spin-isospin response of RI, weak transition strengths for astrophysics, isovector giant resonances	Plastic Scintillator, ~100 keV-5 MeV	(p.n)
DESCANT	Nuclear structure, nuclear reactions, β-delayed neutrons	Liquid scintillator, fast neutron ~100's of keV – ~10 MeV range, high-granularity, 70 cells, n-γ discrimination	Neutron evaporation, β-delayed neutrons,
3Hen	absolute Iβn for low energy βn-emitters, discoveries of new βn- and β2n-emitters, T1/2 for new n-rich isotopes, nuclear structure, r-process, processes in nuclear fuels	high granularity and efficiency (77+-2% for ~ kev for 1 MeV neutrons), 74 3He tubes,	decay spectroscopy of beta-delayed neutron emission
NERO	Measurement of beta delayed neutron emission branching for nuclear structure and r-process. Reaction studies with low-energy neutrons	Efficiency of 40% up to 1 MeV, high efficiencies for up to few MeV. No thresholds, insensitive to other radiation	decay spectroscopy of beta-delayed neutron emission

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?*

Detector	Unique Capabilities	(S)tandalone/ (C)onjuction/ (B)oth	NSCL/other lab.
LANA	n-γ separation, fast neutrons	C (AT-TPC, HiRA, other particle detectors)	NSCL
MoNA-LISA	High detection efficiency for fast neutrons	C (e.g. Sweeper/ HRS, Caesar)	NSCL

VANDLE	Adaptable, few 100 keVs-10+ MeV,low threshold (100 keVee), timing resolution fraction of ns	C (external TOF start, recoil separator, gamma detector)	HRIBF (other possible)
LENDA	Adaptable configuration, 100 keV-5 MeV, low threshold (~26 keVee), timing resolution ~500 ps	C (spectrometer e.g. S800/HRS)	NSCL (others possible)
DESCANT	High efficiency, high granularity, digital signal processing, neutron energy information from pulse height and TOF	C, with γ-ray spectrometer, recoil spectrometer, β-detector	TRIUMF, others possible
3Hen	high efficiency and granularity, digital signal processing	C, e.g., with A1900	HRIBF, NSCL,FRIB
NERO	High efficiency, large inner cavity to add additional equipment such as segmented active stopper	C, with implantation and β detection system	NSCL, GSI others possible

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?*

Detector	Description	Alternatives studied?	Design fixed?
LANA	Liquid Scintillator walls, position sensitivity (horizontal: bars with readout at both ends, vertical: segmented), Fast Neutrons. Status: Relatively old (parts will need replacement/ maintenance), difficult to move. Future: Upgrade/Alternative needed	Detector like MoNA could be suitable	Existing LANA is fixed, future upgrade/alternative not yet fixed.
MoNA-LISA	Plastic Scintillator Bars: 200 x 10 x 10 cm^3 (MoNA 144 + LISA 144), position sensitivity, neutron ToF. MoNA is used at NSCL in conjuction with Sweeper. Usually 9 walls of 16 bars each. Optimized for 50–200 MeV neutrons. LISA is under construction. Funded by MRI.		Detector module design is fixed, but the array can be configured.
VANDLE	Plastic scintillator bars: ~100x(5x5x200cm) + ~100x(3x3x60cm), position sensitivity (segmentation and readout at end of each bar), 100's keV -10 MeV neutrons Status: Under construction, initially optimized for (d,n) and βn studies Future: Other configurations easily achieved, could be combined with LENDA to improve low-energy capability	Liquid scintillator studied, lower efficiency and n-γ separation will not work below ~500 keV.	Detector components fixed, but setup is highly adaptable.
LENDA	Plastic scintillator bars: 24x(2.5x4.5x30cm), position sensitivity (segmentation and readout at end of each bar), ~150 keV-5 MeV Neutrons Status: Constructed, optimized for (p,n) experiments in inverse kinematics with fast beams Future: Doubling solid angle is cost effective, could also be combined with VANDLE to achieve higher neutron energies and increase solid angle. Use for (d,n) and βn studies is considered.	Liquid scintillator studied, lower efficiency and n-γ separation will not work below ~500 keV.	Detector components fixed, but setup is highly adaptable.
DESCANT	70 deuterated benzene cells, designed for spherical shell with 50cm TOF to front face. Cells are tapered hexagonal shaped containers ~ 2000 cc in volume. Cells are 15 cm depth, 5" PMTs with anode directly to 1GHz wave form digitizers with on-board processing. Modularity allows for flexible configurations. Cell designed for close packed configuration to cover ~1.1π sr.	Normal scintillator studied, differences in efficiency small over energy range < 10 MeV.	Device funded, prototype delivery imminent. Demonstrated physical properties with

		Limited pulse height information compared with deuterium.	smaller test detectors.
3Hen	74 3He tubes at 10 atm, 2-foot long, efficiency reaching nearly 80% up to 1 MeV, over 50% for 5 MeV neutrons	best in class	design can be modified (e.g., new moderator)
NERO	60 BF_3 and ^{3}He gas counters (multihit) embedded in PE moderator, Efficiency 40% (<1 MeV), >20% (<5 MeV)		Device exists

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

Detector	Status
LANA	Use of neutron arrays for EOS studies at FRIB is being discussed. Preliminary designs for auxiliary neutron arrays are in planning stage.
MoNA-LISA	MoNA has been used for experiments since 2003. LISA is under construction, bars are ordered, electronics modules already purchased. Modules will be built at the individual institutes during summer 2010 and be brought to NSCL for final assembly of the array.
VANDLE	Prototype elements assembled and characterized. Subset of system (~20 bars) will be tested 2010, stage-wise completion of full array 2010-2012
LENDA	Detector constructed, first experiments soon at NSCL
DESCANT	Fully funded; prototype delivery imminent
3Hen	fully funded, commissioning experiments likely in 2010-2011 at HRIBF
NERO	Device exists and ready for use

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

Detector	Costs	Funding source
LANA	For new array: <$500K	Possibly through NSF MRI
MoNA-LISA	already funded	NSF MRI
VANDLE	$700K (hardware only)	NNSA Academic Alliance
LENDA	$250K (hardware & labor)	NSF
DESCANT	$900k detector cells; $150k electronics, frame (TRIUMF) $300k. Dedicated, facility-specific frame for NSCL/FRIB would require separate funding	Canadian Foundation for Innovation, Ontario Research Fund, TRIUMF
3Hen	$ 50 K for adapting to the NSCL/FRIB conditions	funded at HRIBF-ORNL, further costs possibly DOE or other source
NERO		

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

Detector	Collaboration	Contact
LANA	NSCL (B. Tsang, B. Lynch), WMU (M. Famiano), IUCF (R. de Souza, S. Hudan), WUSTL (L. Sobotka, R. Charity), TAMU (S. Yenello)	M. Famiano (WMU) Michael.famiano@wmich.edu
MoNA-LISA	NSCL (Thoennessen, Baumann, Spyrou), Hope (DeYoung, Peaslee), CMU (Finck), IUSB (Hinnefeld), Westmont (Rogers), FSU (Tabor),	M. Thoennessen (NSCL) thoennessen@nscl.msu.edu P. DeYoung (Hope) deyoung@hope.edu

	Concordia (Luther), Wabash (Brown), Gettysburg (Stephenson), Rhodes (Meyers), Ohio Wesleyan (Kaye), Augustana (Frank), WMU (Pancella)	
VANDLE	Rutgers U., ORAU, ORNL, U. Tenn., CO School of Mines, LSU, Tenn. Tech., MSU.	J. Cizewski (Rutgers U.) Cizewski@physics.rutgers.edu W. Peters, ORAU wapeters@nuclearemail.org
LENDA	NSCL Charge-Exchange group	R. Zegers zegers@nscl.msu.edu
DESCANT	Guelph (P. Garrett, C. Svensson), TRIUMF, Colorado School of Mines (Sarazin), Montreal (J.-P. Martin)	P. Garrett (Guelph) pgarrett@physics.uoguelph.ca
3Hen	ORNL, UTK (Grzywacz), Mississippi State (Winger), LSU (Zganjar)	K.P. Rykaczewski rykaczewskik@ornl.gov
NERO	A. Aprahamian (Notre Dame), M. DelSanto(NSCL), K.-L. Kratz (University of Mainz), G. Lorusso (NSCL), F. Montes (NSCL), P. Reeder (formerly at PNNL), J. Pereira (NSCL) B. Pfeiffer (GSI), K. Smith (NSCL), H. Schatz (MSU/NSCL)	Fernando Montes, montes@nscl.msu.edu

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?)*

Detector	Development
LANA	Is part of a larger effort for studies of EOS, collaboration meeting monthly, information disseminated through a website. International collaborators for the full project (i.e. including other experimental devices) from Europe, Japan
MoNA-LISA	Weekly meetings through video conference; annual retreat; four new members were added for the LISA project; http://www.cord.edu/dept/physics/mona/; http://mona-collaboration.blogspot.com/
VANDLE	Monthly meetings via video conference and in person, new collaborators welcome, http://vandle.oit.utk.edu/vandlewiki
LENDA	Weekly meetings, implementation (but not construction & design) for (p,n) experiments involves collaboration from GSI and RIKEN/U. Tokyo. Website: http://groups.nscl.msu.edu/charge_exchange/public/experiments/pn_inverse.htm
DESCANT	Part of the TIGRESS collaboration; bi-annual meetings with TIGRESS collaboration
3Hen	proposal to DOE followed by the funding via the HRIBF capital funds and by UTK contribution via NNSA grant, web page at UTK
NERO	

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

Detector	Alternatives/decision
LANA	Upgrades considered could be like MoNA or existing LANA. MoNA is more portable, but LANA has n-γ discrimination capability, which is important in certain cases.
MoNA-LISA	Smaller module cross section was considered; liquid scintillator was considered
VANDLE	Based on development of other systems, other options were investigated (see 3), but plastic scintillator is superior. Geometry tailored to energy range.
LENDA	Based on development of other systems, other options were investigated (see 3), but plastic

	scintillator is superior. Geometry tailored to energy range.
DESCANT	Normal scintillator considered; different configurations of cells
3Hen	based on the history of earlier 3He detectors developments and collaboration with local ORNL experts, UTK and UNIRIB collaborators (like S. Liddick, now NSCL)
NERO	

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

Detector	Existing equipment with similar capabilities
LANA	MoNA, but it has no n-γ discrimination capability
MoNA-LISA	LANA has lower detection efficiency but n-γ discrimination capability.
VANDLE	LENDA is aimed at lower energy neutrons, MoNA/LANA is aimed at higher energies.
LENDA	VANDLE is aimed at slightly higher energy neutrons, MoNA/LANA at much higher energy neutrons
DESCANT	VANDLE, LENDA, but with n-γ discrimination, neutron energy via pulse height
3Hen	NERO, but its efficiency is lower
NERO	3Hen, it has higher efficiency but smaller cavity.