LABORATÓRIO ABERTO DE FÍSICA NUCLEAR

PAC 2023

Proposal	N°
Title: Tests of the LAFN "Neutron Wall" using the 30B beam line	
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Number of days for experiment:	4
Period planned for the experiment (is the setup ready for beam time?): September 2023 (no)	

Technical information

Ion source			Accelerator			Experimental Area	
Beam	Cathode	$I_{mín}$	V_{min}	V_{max}	Bunched beam?	Beam line	Target
$^{7}Li(3+)$		50 nA	6	7	no	30B	^{120}Sn
$^{7}Li(3+)$		50 nA	4.0	5.0	no	30B	p (polypropylene)

Other relevant/needed information:

Tests of the LAFN “Neutron Wall” on the 30B beam line

The objective of this project is to test the “Neutron Wall” detector array under in-beam experimental conditions, and assess its performance for the measurement of fast neutrons both, from a direct reaction and from a fusion-evaporation reaction, in separate measurements.

The “Neutron Wall” (n-Wall, Fig. 1) is a 2m × 2m position sensitive neutron detector array with n/γ discrimination. It consists of 24 stacked square-tube liquid scintillators (BC501A) with photo-multiplier tubes (PMT) on both extremities. It is based on the NSCL/MSU neutron wall array [1], and has been mounted at LAFN more than 15 years ago. The detection of neutrons could be very useful for the investigation of nuclear reactions, particularly those with radioactive beams. The installation of this equipment downstream the 45B beam line of the RIBRAS system for radioactive beam production was decided as a part of the FAPESP Thematic Project entitled “NUCLEAR REACTIONS WITH WEAKLY-BOUND or CLUSTER STRUCTURED RADIOACTIVE AND STABLE NUCLEI”, coordinated by Prof. Alinka Lépine. A post-doc researcher (S. Olorunfunmi) was hired to help with this task.


Figure 1: The n-Wall detector system of LAFN with the door open (left) and closed (right).

Preliminary tests of the new CAEN digitizer electronics (10 units of the V1725 250MS/s module with 16 channels, each, 5 of them running the pulse shape discrimination (PSD) *firmware*) with a portable 2” × 2” liquid scintillator (BC501A) have shown that it is possible to adequately perform the n/γ discrimination by plotting the PSD vs ADC bi-parametric spectrum from an Am/Be radioactive source, which produces fast neutrons as well as high energy gamma rays (Fig. 2). The PSD parameter is obtained as a difference between a long (Energy) and a short (EnergyShort) time integration range of the PMT pulse, divided by the long one: PSD=(Energy-EnergyShort)/Energy, while ADC is the short on itself, in channels.

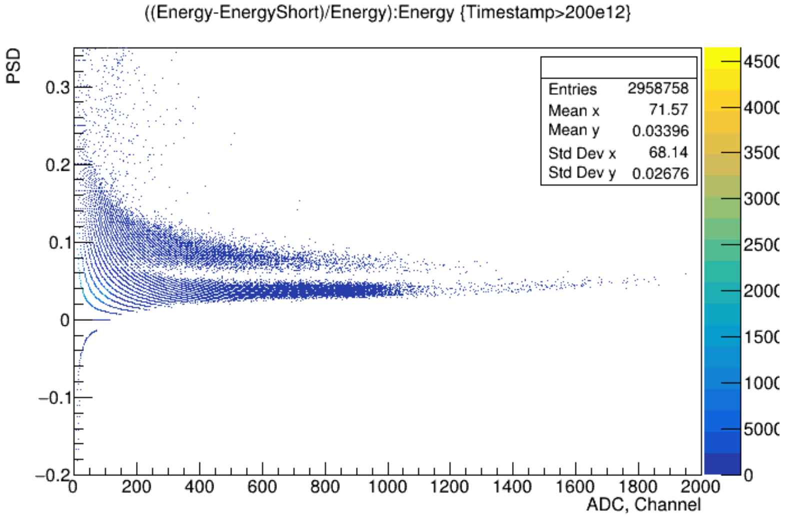

Figure 2: PSD vs ADC histogram spectrum from an Am/Be radioactive source recently measured at LAFN with the new CAEN digitizer system. The discrimination is very good Above ADC ≈ 200. Neutron events are those above PSD=0.06, while gamma rays are those below that. This has been a preliminary measurement, and the parameters of the data acquisition are still to be optimized.

Unfortunately, for safety reasons it is not possible to bias the n-Wall detector or open its door for maintenance, presently. The primary chemical composite of the liquid scintillator (Xilene), besides being toxic, is extremely flammable. In order to inspect it, before use, we are waiting for the visit of a safety specialist which will evaluate its condition. The sensor of the leakage alarm will have to be removed to be tested and calibrated by a private company. We do not foresee any problems since there is no evidence of a significant leak, and after re-installation of the alarm system it should be again ready for use. The HV power supply (CAEN model SY527) which provides about 2kV for each one of the 48 PMTs has already been tested and is operational.

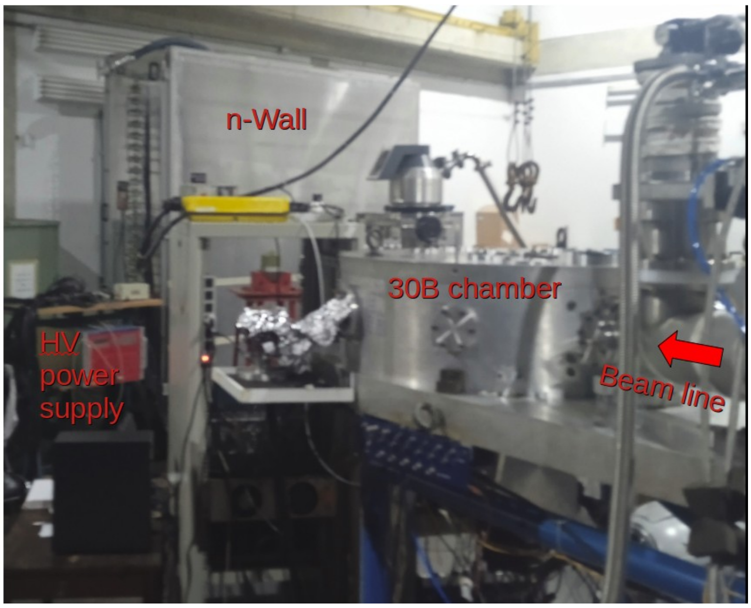

Figura 3: View of the 30B beam line and the n-Wall at the Pelletron experimental hall. At 4 m distance from target it covers a total range of 27^o.

The first tests of the n-Wall should be performed with stable beams in order to provide high statistics spectra in a reasonably short time. The 30B beam line is directed toward the center-left side of the n-Wall (Fig. 3). For the measurements, the n-Wall will be slightly rotated toward the beam line so as to increase its solid angle. A couple of gamma-ray detectors from the "Nossa Caixa" system will be mounted inside the 30B scattering chamber, close to the target. The coincidence with gamma rays will be used in order to produce a start signal for the time of flight (TOF) neutron spectra measurements. Timing resolution tests have been performed between these gamma detectors and a plastic scintillator, with the CAEN digitizer electronics, and were quite satisfactory (a few ns, FWHM). Similar or better timing resolutions are expected with the very fast liquid scintillators.

We propose to measure the well known [2] $p(^7Li,^7Be)n$ at 18.5 MeV inverse reaction which produces known neutron energies as a function of the angle, from the direct reaction kinematics. A polypropylene target (~10μm) will be used, as in ref. [2]. The beam energy is chosen to be above the threshold (16.5 MeV) for the excitation of the ^7Be 429 keV $1/2^-$ state, while below the next open channel threshold in order to: 1) produce the 429 keV ($t_{½}$ =133 fs) gamma ray transition to the ^7Be ground state in temporal coincidence with the neutron, 2) keep the TOF spectrum simple, with the presence of only the two n-energy peak solutions of the inverse kinematics, and 3) allow for detection of the full angular range (0^o-19^o) of the neutron scattering angle (with the wall about 0.5 m off center). The TOF ranges from 150-170 for the fast solution and 260-320 ns for the slow solution. The scattered ^7Be angle (<4.5^o) is too small to allow for its measurement with a charged particle detector, so we plan to detect only gamma rays for the start time signal. Fusion with ^{12}C of the target produces mostly α particles.

A second test would consist in a fusion-evaporation reaction measurement with a relatively heavy target so as to produce mostly the neutron evaporation continuum. We propose to use the $^7Li+^{120}Sn$ reaction at 24 and 28 MeV beam energies. A 1.7 mg/cm² enriched ^{120}Sn target, available at LAFN, should be used. The reason for this choice is that previous measurements of direct reactions and break up have been made at the LAFN of this system at these energies, and it could be interesting to attempt to extract information about the fusion cross section from the neutron gamma coincidence measurements. The compound nucleus (CN) is ^{127}I, and the main evaporation residues are ^{124}I (3n) and ^{125}I (2n) (60% and 33%, respectively, at 24MeV, and 87% and 5%, respectively, at 28MeV), according to PACE4 calculations. The gamma multiplicity (estimated from the angular momentum of the CN) should be around 5 and 8 for the lowest and highest energy, respectively, therefore providing for a large chance of detection of at least one gamma ray in coincidence with the neutrons. It will also be possible to detect multiple neutrons in the same event. The proton from the ^{124}Te (p2n evaporation channel) with 3.5% probability at 28 MeV beam energy (according to the statistical model calculations) might be detected with the use of a Si surface barrier detector, in coincidence with n (also from the ^7Be gs reaction channel).

With these different type measurements it is expected that a good characterization of the n-Wall performance for in-beam experiments will be obtained.

References

[1] P.D. Zecher et al., Nuclear Instruments and Methods in Physics Research A 401 (1997) 329.

[2] M. Lebois et al., Nuclear Instruments and Methods in Physics Research A 735 (2014) 145