Neutron background rates in Hall D

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(Dated: December 3, 2021)

We document the low energy neutron ($\leq$ 15 MeV) background rates in Hall D for the various targets used in its experimental program. Normalized by target thickness, the neutron background coming from the target material is the essentially the same for all targets.

Tables I and II provide the Hall D neutron radiation levels as measured in stable running conditions during the SRC-CT run (Nov.-Dec. 2021, targets used: LD_2, L^4He and ^{12}C-multifoil targets) and during the summer 2020 GlueX-II run (Jul.-Sept. 2020, target used: LH_2). Both runs used the same diamond: JD70-105 (47 μm, 3.9×10^{-4} Radiation Length), so the fluxes should be nearly the same for the same beam current (they may still differ due to different beam tune leading to different interception by the collimator and different diamond tuning). All rates are normalized to 150nA.

The rates are for low energy neutrons, in the range of 2.5×10^{-8}MeV to 15MeV, as detected by the 508-p2 CARM radiation monitor attached to the back of the solenoid (looking downstream). The specifications form the company from which the neutron probe 508-p2 was bought are shown in Fig. 1.

The rates are averaged over a time of a few hours (the dispersion for the neutron rates is large due to the low radiation levels, but we have EPICS data coming every few seconds, so the average is precise). However, since the neutron rates are very low, the signal binning is coarse (0.03 mrem/h) which results e.g. in the same average rate values for L^4He and ^{12}C.

The target thicknesses are only the target material (i.e. no window, etc) and are courtesy of C. Keith. In "empty" target condition, neutrons can still be generated at the target location from the residual gas in the cell and the various windows and insulating material around the cell.

Run	Target type	neutron rate for 150nA	Target thickness
GlueX-II (2020)	LH_2	0.30 mrem/h	2.09 g/cm^2
SRC-CT (2021)	LD_2	0.63 mrem/h	5.00 g/cm^2
SRC-CT (2021)	L^4He	0.50 mrem/h	3.53 g/cm^2
SRC-CT (2021)	^{12}C	0.50 mrem/h	3.39 g/cm^2
GlueX-II (2020)	Empty(H_2 gas)	0.15 mrem/h	neglected
SRC-CT (2021)	Empty(D_2 gas)	0.15 mrem/h	neglected
SRC-CT (2021)	Empty(^{4}He gas)	0.10 mrem/h	neglected

TABLE I: Neutron radiation levels for a 150nA electron beam current on a 3.9×10^{-4} Radiation Length diamond.

To obtain the rates coming solely from the target material, Table I's rates should be reduced by 0.02 mrem/h from neutrons not produced at the target location (as determined in https://logbooks.jlab.org/entry/3934854, with correction for 150 nA). Furthermore, visually, roughly half of the "empty" target rate comes from the windows, so correcting the rates (except that of ^{12}C) by 0.04 mrem/h and normalizing by the thickness, we obtain the rates given in Tables II. For the ^{12}C, instead of using the 0.04 mrem/h empty target correction (relevant only for the liquid targets), we assumed about 10% of non-Carbon events (cursory estimated by looking at the vertex reconstruction plot).

Target type	neutron rate for 150nA
LH_2	0.115 mrem/h/(g/cm^2)
LD_2	0.114 mrem/h/(g/cm^2)
L^4He	0.125 mrem/h/(g/cm^2)
^{12}C	0.127 mrem/h/(g/cm^2)

TABLE II: Rates from the target primary material only and normalized by target thickness.

This analysis is rudimentary as there is presently no need to be more precise. From the binning of the neutron rate and the cursory treatment of the background, the numbers in Tables I and II may be accurate within 10-20%. If more precise values are needed, an analysis of the rates from the empty target runs should be done.

APANTEC

APANTEC NB1X / NH1X

Neutron Detector Smart Probe

BF_3 or He-3 Proportional Counter | **'Smart' Detector Operation**

The Apantec NB1/NH1 Neutron Probe is based on the design by I. O. Anderson and J. Braun and provides dose response corresponding to the human body. It directly measures the biological dose rate of neutrons in energy from thermal (0.025 eV) to 15 MeV.

The Neutron Probe contains a proportional counter, which produces pulses resulting from neutron interactions occurring within it. The proportional counter is essentially a thermal neutron detector, but the probe is designed to respond to thermal, epithermal and fast neutrons.

The probe includes a high hydrogen content polyethylene moderator, which moderates and attenuates neutrons so that the net incident flux at the proportional counter is a thermal and low epithermal flux representative of the tissue equivalent dose rate due the neutron field. In addition, the proportional counter is enclosed with a tissue equivalent boron impregnated sleeve, which provides the interaction between the neutrons and the counter.

The detector provides a pulse output to an associated RM1 series display unit for display and control. The RM1 series display unit provides serial RS485 and Ethernet communications for networking to a central computer using Apantec's DORIS software. The neutron detector is available in two configurations. The NB1X uses a BF_3 proportional counter, while the NH1X is provided with a He-3 proportional counter.

Detector Type

NB1X	BF_3 counter with Boron impregnated sleeve and polyethylene moderator
NH1X	He-3 counter with Boron impregnated sleeve and polyethylene moderator

Measurement Range	0.1 µSv/h to 100 mSv/h
Energy Range	0.025 eV to 15 MeV
Energy Response	± 20%, 0.025 keV to 15 MeV
Accuracy	±15% over entire range
Linearity	±5%
Response Time	4 s
Environmental	-31 °F to 140 °F 0-95% RH, non-condensing
Operating Voltage	+12 VDC
Dimensions	12 in. L x 8 in. Dia
Weight	20 lb nominal

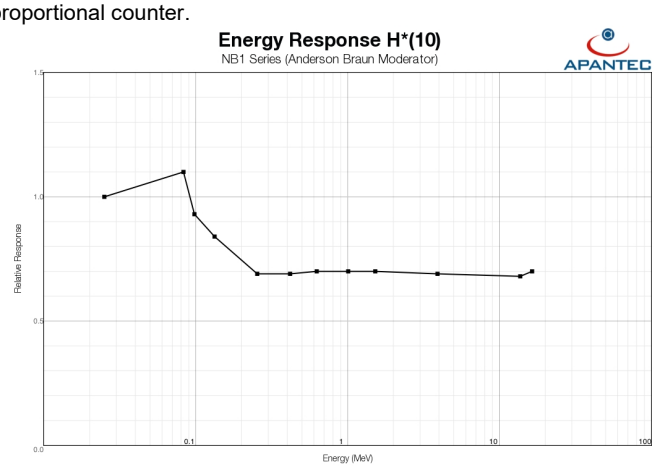

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FIG. 1: Specifications from APANTEC, LCC for the neutron probe 508-p2 (NB1X type).