P-438

Experimental Proposal

Inelastic Cross Sections of Neutrons on Nuclei

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SUMMARY

We propose to study inelastic cross sections of neutrons on complex nuclei over the FNAL energy range using the M3 neutral beam in the Meson area. Target nuclei would include Be, C, Al, Fe, Cu, Cd, W, Pb, and U. Determinations would be accurate to at least 1%.

This experiment, using the calorimeter of E4 and other existing Michigan equipment, could be set up without interference with other M3 beam users at the end of the M3 beam line and tuned parasitically.

About 500 hours of beam control would be required for final data collection.

Data from E4 has definitively determined the total cross sections of neutrons on nuclei between 30 and 300 GeV with accuracies of 0.5 - 1.0%.[1] A significant consequence of this experiment was the study of the inelastic screening correction to simpler Glauber theory and its necessary inclusion in comparison with data. While general agreement and understanding of this problem is good, other data are ultimately desired in rounding out the interpretation of the physics; specifically the differential elastic scattering and the inelastic cross section. Experimentally both are straight forward using the M-3 beam, although the latter is much simpler and probably of most direct interest.*

Inelastic cross sections of neutrons are trivially accessible experimentally as a single scintillation counter behind a target is all that is required to detect a high-energy neutron interaction; that data plus an absolute measure of the neutron flux is sufficient for a cross section determination. The continuous neutron spectrum is only a modest complication.

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*The elastic scattering of neutrons on nuclei and on hydrogen at very small $|t|$ was proposed by us in P 235 and is discussed in a Letter of Intent to CERN by the CERN-Karlsruhe group; CERN/SPSC/75-47/169, 27 August, 1975).

The total cross section in nuclei contains as one component diffraction scattering leading to excitation or dissociation of the target nucleus without meson production. This process would generally result in protons or neutrons of a few MeV or nuclear β decays; the proposed experiment would not be sensitive to this process and it would be interpreted as part of the elastic scattering.

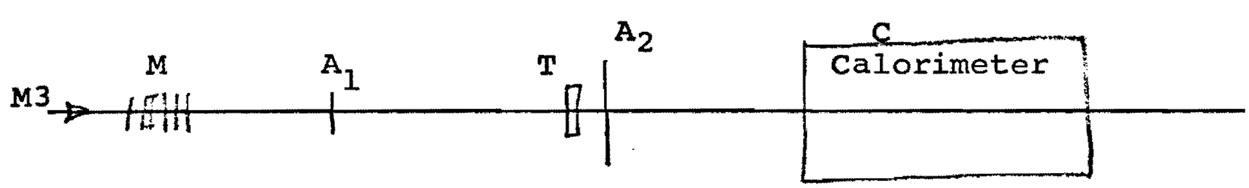
The inelastic cross section of neutrons on light nuclei is expected to reflect the rise seen in the nucleon-nucleon cross section whereas little or no rise is seen in the total cross section as the onset of the inelastic screening effect largely offsets the rise resulting from the N-N increase.

There are very pragmatic reasons for acquiring these data; this is the cross section relevant to interaction mean free paths of protons and neutrons in various elements; numbers estimated and used widely at these energies but as yet unmeasured. At energies beyond the ISR, cosmic ray measurements of proton attenuation in air or other targets may lend insight into the behavior of the N-N cross section, but <u>only</u> if the corresponding data are thoroughly known and understood at accelerator energies.

Inclusive particle production on heavy nuclei may be interpreted using $\bar{\nu}_A = A \frac{\sigma_{NN}}{\sigma_{NA}}$ as a relevant parameter, where $\bar{\nu}_A$ is the average number of collisions of the incident particle within the nucleus, the σ's are inelastic cross sections.

Measurements of inelastic neutron cross sections on nuclear targets below 60 GeV exist from Serpukov and represent the only available data.[2]

The experiment would use the last 50 feet of the M3 neutral beam in the Meson Area, and could operate compatibly with other current users of that beam for all but final data collection. The central element in the experiment is the calorimeter detector from E4,[3] which has a known energy resolution (FWHM ~ 13%) and other properties. The required components in the beam are, as illustrated below, a monitor telescope M, an anticoincidence counter A_1, a target T capable of remote cycling into and out of the beam, a subsequent anticoincidence counter (or counter pair) A_2, and the calorimeter.



The experiment consists simply in recording the calorimeter counts normalized to the beam monitor with and without the target in the beam, scaled into several energy bins, and recorded both with A_2 in coincidence (target interactions, $A_2 + C$) and A_2 in anticoincidence (transmitted or elastically scattered neutrons, $\bar{A}_2C$). A neutron which interacts in a thin target will send virtually all its energetic reaction products forward so that the calorimeter pulse height is substantially independent of whether the neutron interacts ahead of or within the calorimeter. However, the data is redundant; the values of $\bar{A}_2C$ with targets in and out of the beam may be used to determine cross sections independent of values of $A_2 + C$. (See p. 6).

The components need not be widely separated (as in many high energy measurements); it is only sufficient that spacings be sufficient to permit back-scattered particles to be timed out. Targets would be cycled, as in E4, about once per minute. Statistics come quickly; at $\sim 10^5$ neutrons per pulse 1% cross section data are readily collected with a target of 10% attenuation in 5 energy bins in about an hour. Study of systematic effects of beam rate, target thickness, anticoincidence counter solid angles subtended, etc. will require the greatest fraction of time to understand, although much of this study should be possible on a parasitic basis.

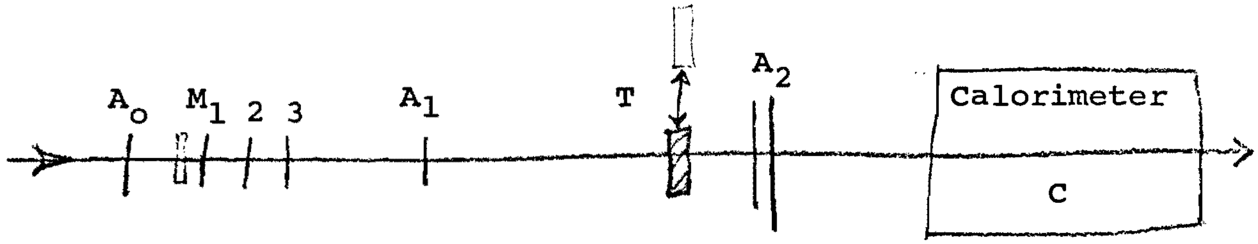
About one month, or 500 hours of beam control should be sufficient for completion of this experiment, following initial parasitic setup and testing.

This experiment would qualify under the earlier "nook and cranny" category, and perhaps could be done without Program Committee approval parasitic to the operation of E248 by our group. However, it seems prudent to draw the proposal to the attention of the Program Committee for critical review.

1. P.V.R. Murthy, C.A. Ayre, H.R. Gustafson, L.W. Jones, M.J. Longo, "Neutron Total Cross Sections on Nuclei at Fermilab Energies", Nuclear Physics B92, 269 (1975).

2. S.P. Denisov et al., Nuclear Physics B61, 62 (1973).

3. L.W. Jones et al., Nuclear Instruments 118, 431 (1974).



Target out: o

Target in: i

Monitor M means $M_1 + M_2 + M_3\ \bar{A}_o$

A_2 may be two thin counters separated by ~ 1/4" Pb coincidence

Neutrons incident on target: N

Neutrons transmitted: N_T

Neutrons interacting in target: N_A

Avagordro's Number: N_a

$$N_T + N_A = N$$

(a) $N_T = Ne^{-\rho N_a \sigma x}$

(b) $N_A = N(1 - e^{-\rho N_a \sigma x})$

N_T: $(\bar{A}_1\ \bar{A}_2\ C)_i$

N_A: $\bar{A}_1(A_2 + C)_i - \bar{A}_1(A_2 + C)_o$

N: $(\bar{A}_1 \bar{A}_2 C)_o$

By normalizing N_T, N_A, and N to M with target in and out, sorting each of 4 sets of data into energy bins, and substituting into (a) and (b) σ may be found in 2 separate ways.