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A Measurement of C_{NN} in Neutron-Proton Scattering at 23 MeV *

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In this paper we describe the first results of an experiment to measure the neutron-proton correlation function, C_{NN}, at 180° c.m. and E_n = 23 MeV. The objective of this, as well as our previous measurements, is to contribute to the determination of the n-p, T = 0, phase parameters, of which only four are important at our energy, namely those for the $^3S_1$, $^3D_1$, $^1P_0$ states, and the S-D coupling parameter. The relationship between C_{NN} and the elements of the nucleon-nucleon scattering matrix is given in a recent review article.(1)

The experiment consists in measuring differences in the intensity of scattered particles when a polarized beam of neutrons is incident on a polarized proton target. The scattered intensity is proportional to

$$I(\theta) = I_o(\theta)\left[1 + (p_1 + p_2)P_{np}(\theta) + p_1 p_2 C_{NN}(\theta)\right]$$

where $I_o(\theta)$ is the unpolarized differential cross section, $P_{np}(\theta)$ is

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the polarization function in n-p scattering, p_1 is the beam polarization, p_2 is the proton polarization, and C_{NN} is the quantity of interest. By reversing cyclically the direction of target polarization, a measured asymmetry is obtained, which is

$$e = \left[p_2 P_{np}(\theta) + p_1 p_2 C_{NN}(\theta)\right] \Big/ \left[1 + p_1 P_{np}(\theta)\right]$$

At $\theta = 180°$ c.m., $P_{np} = 0$, which simplifies the interpretation.

The geometry for measuring $C_{NN}(\theta)$ is shown in Fig. 1. The 7-MeV deuteron beam from the Van de Graaff accelerator produces neutrons by the $T(d,n)He^4$ reaction in the 60-psig tritium gas target, which is 3-cm long. Neutrons leaving this target at 30° laboratory angle have 23 MeV energy and polarization + .49 ± .06.[2] Protons scattered by the incident neutrons at the angle θ_p (lab) are detected in a ΔE and E counter telescope. The ΔE,E coincidence system discriminates against all particles except protons. With a 5-microampere deuteron beam, the neutron flux is 10^6 (sr-sec)$^{-1}$, and the counting rate, for $\theta_p = 0$, is 7 counts/sec, of which about 1 count/sec is background.

Protons in the LMN crystal were polarized to an average value of .27 ± .05 by the "solid effect."[3] The crystal was 1.7-mm thick, and had 1.9 cm^2 area. Neodymium-143 was substituted for ~ 0.2% of the lanthanum in the crystal. The crystal was placed in a rectangular microwave cavity, next to a 7.6-micron thick Havar window, through which the protons passed after leaving the crystal. The vacuum-tight cavity was filled with liquid helium at 1.2°K, and also contained a four-turn NMR coil. The coil did not surround the crystal, but was located on the back side of a copper vane mounted in the center of the cavity, and oriented parallel to the plane of the crystal. The purpose of this configuration was to obtain a uniform sampling of the proton spin system by the NMR radio-frequency field. Microwaves were generated by a Varian-Canada reflex klystron VC-104. Thin wall stainless steel wave guide was used to reduce the heat leak to the helium bath. 150 to 200 milliwatts of microwave power at 54 Gc/sec were delivered to the helium bath. Polarization was measured by comparing the enhanced proton NMR signal with the thermal equilibrium signal, as measured by a Q-meter type NMR detector. The approximate 14 kOe magnetic field was modulated with a few tenths oersted at 37 cps, and the rf frequency was swept slowly through the NMR. The largest sources of fractional error in the polarization measurement are believed to arise from the measurement of the thermal equilibrium signal (10%), and from uncertainty in the electronic amplification when comparing signals enhanced about 250 times with the thermal equilibrium signals (5%).

Shortly before the conference opened, we made our first runs with polarized beam and target. Numerous other runs had been made with an unpolarized beam with the aim of investigating possible sources of systematic error. The measurement we give below was made at θ c.m. = 180° (θ_p lab = 0°), where detection of the recoil proton alone can be made in a clean way, and with good intensity. The value of beam polarization was taken to be $p_1 = .49 \pm .06$. The weighted average of two runs gave a result close to zero, namely $C_{NN}(180°) = -.006 \pm .015$. The result is nontrivial since C_{NN} is not constrained to be zero at 180°. The value given above is close to the prediction of the Hamada-Johnston potential model[4] which gives $C_{NN}(180°) = -.008$. Further measurements of $C_{NN}(\theta)$, including other angles, are in progress.

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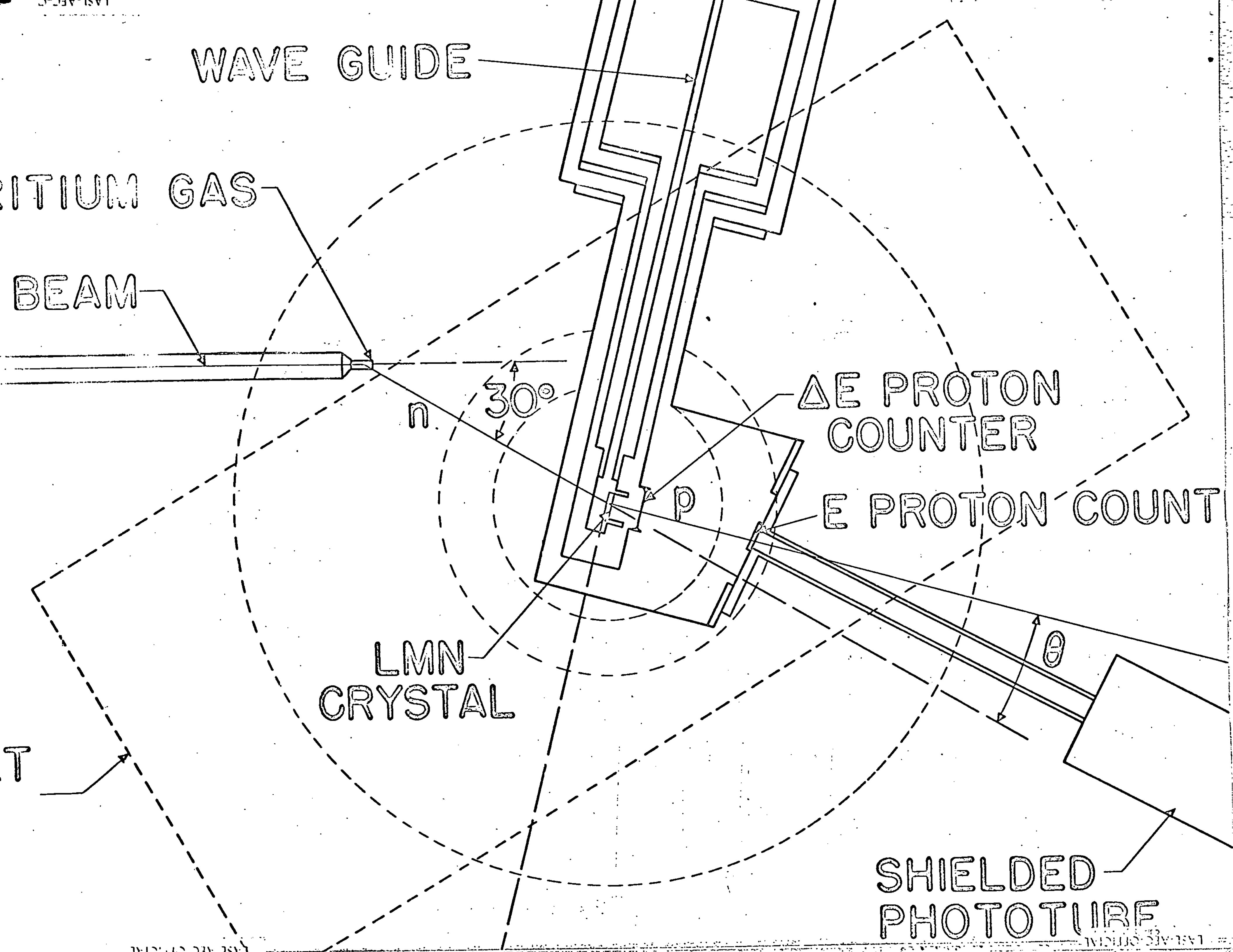
Figure Caption

Fig. 1. Geometry for measurement of $C_{NN}(\theta)$ in n-p scattering at 23 MeV. The scattering plane is vertical.



WAVE GUIDE
RITIUM GAS
BEAM
30°
n
p
ΔE PROTON COUNTER
E PROTON COUNT
θ
LMN CRYSTAL
SHIELDED PHOTOTUBE