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NEUTRON-PROTON BREMSSTRAHLUNG EXPERIMENTS

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It is well known that charged particles emit bremsstrahlung radiation when they are accelerated. Classical electron bremsstrahlung occurs when a photon is emitted by an electron accelerated in the field of a nucleus. The bremsstrahlung process also occurs in the scattering of nucleons, for which it is the lowest energy inelastic process that can occur. Like electron bremsstrahlung, nucleon nucleon bremsstrahlung also requires the exchange of a virtual particle to conserve energy and momentum. In electron bremsstrahlung a virtual photon is exchanged but with two nucleons a meson can be exchanged. Unlike electron bremsstrahlung, in nucleon nucleon bremsstrahlung the photon can originate from the exchanged meson. This exchange contribution has been shown in calculations to be a significant fraction of bremsstrahlung events. Thus bremsstrahlung serves as a probe of exchange currents in the nucleon nucleon interaction. Because of a lack of a free neutron target or an intense neutron beam, few measurements of neutron proton bremsstrahlung exist, each having poor statistical accuracy and poor energy resolution. The white neutron source at the Weapons Neutron Research (WNR) target area at the Los Alamos Meson Physics Facility (LAMPF) produces neutrons with energies from below 50 to above 100 MeV. Using time of flight techniques and a liquid hydrogen target, we are measuring the outgoing photons of energies up to 250 MeV at gamma ray angles of around 90° relative to the incident beam. Protons scattered at very forward angles are also detected in coincidence with the gamma rays.

1. INTRODUCTION

Nucleon nucleon bremsstrahlung is a fundamental process that involves the emission of a gamma ray during the nucleon nucleon strong interaction. In an inelastic collision of two nucleons, a photon is the only particle which can be produced at the lowest incident energies. The photon may originate from the accelerated proton. It can also originate from the meson exchanged between the nucleons particularly if the meson is charged. Neutron proton bremsstrahlung (NPB) is more probable than proton proton bremsstrahlung (PPB). PPB in lowest order does not allow $E1$ radiation and the contribution from meson exchange is small. NPB is predominantly dipole, and meson exchange is calculated to contribute significantly to

Scattered protons are detected in an array of 16 phoswich detectors [8] in the plane of the gamma-ray telescopes. The detectors are arranged in 2 rows of 4 on either side of the beam, spanning angles from 8° to 40° degrees. Each is 60 *cm* from the target and subtends an angle of 8°. Each phoswich detector is an $E - \Delta E$ telescope: a 3 *mm* thick ΔE scintillator optically coupled to a 26.7 *cm* thick scintillator with a photomultiplier tube mounted on the back side. The thin plastic has a fast response while the thick scintillator has a large decay constant. Short and long gates are set on the output signal to permit particle identification.

A hardware event trigger consists of simultaneous signals from a BaF_2, a plastic scintillator, and a NaI element in a gamma ray telescope. These must occur within a resolving time of 100 nsec and within a 225 nsec gate after the beam burst. Sharp coincidences (< 10 nsec) between elements are determined in off-line analysis. The time of flight and pulse height signals from all proton and gamma ray elements are stored in memories and read into the VAX computer only after each macropulse. Deadtime is approximately 3%.

3. RESULTS

At present we are still taking data and the results presented here must be considered preliminary. Relative gamma ray production rates for neutrons of incident energies 138, 203, 274, 331, and 401 MeV are plotted as a function of gamma ray energy in figure 3. These rates are for just one of the telescopes at 90° and represent 24 hours of running, including target in and target out, and are less than 5% of the total inclusive data taken. Time independent background has been subtracted, as well as empty target data. Target out rates are in general 50% of the target-in rates. The resulting statistical errors are approximately 8% for the neutron bins and gamma-ray energy bins. Count rates have been normalized to the same number of incident neutrons per neutron bin.

These count rates can be converted to NPB cross sections using the measured neutron flux, target thickness, and detector efficiency and solid angle. We have calculated the efficiency of the gamma ray telescopes using the code *EGS4* [10] but plan to measure it for confirmation.

The rate of gamma ray production clearly rises for neutrons above the π^0 production threshold due to both π^0 decay into two photons and the high ratio of π^0 production to NPB cross section.

Measurements of differential cross sections for outgoing photons and protons in coincidence will provide more stringent tests of NPB calculations than will inclusive cross sections. These measurements will also reduce background due to π^0 production at the higher incident energies, because for a given proton energy only a certain gamma ray energy is kinematically permissible for NPB. We have only a few days of preliminary data on $\gamma - p$ coincidences. These results will be treated in a subsequent paper.

ACKNOWLEDGEMENT

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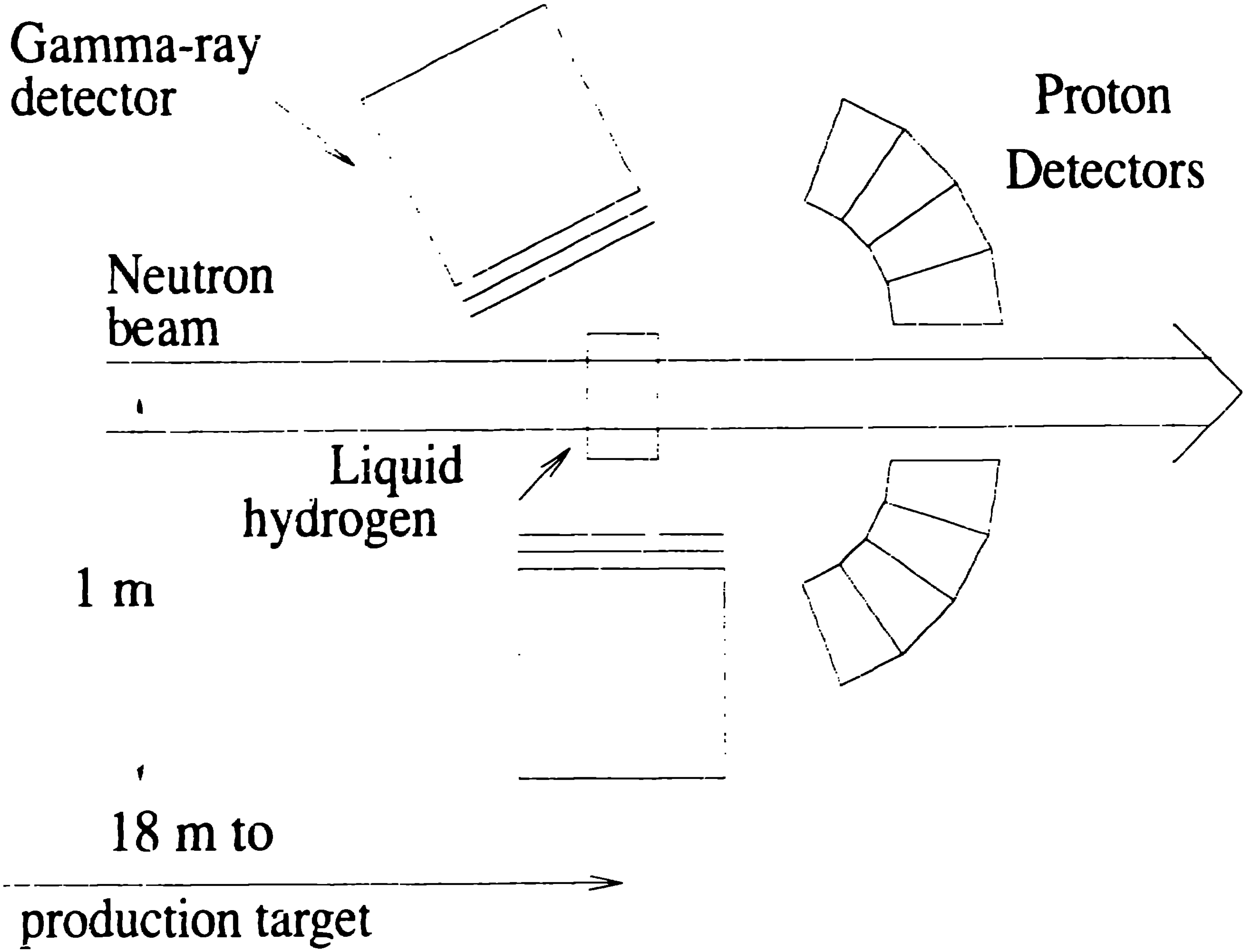
Figure 1. Neutron proton bremsstrahlung experimental apparatus.

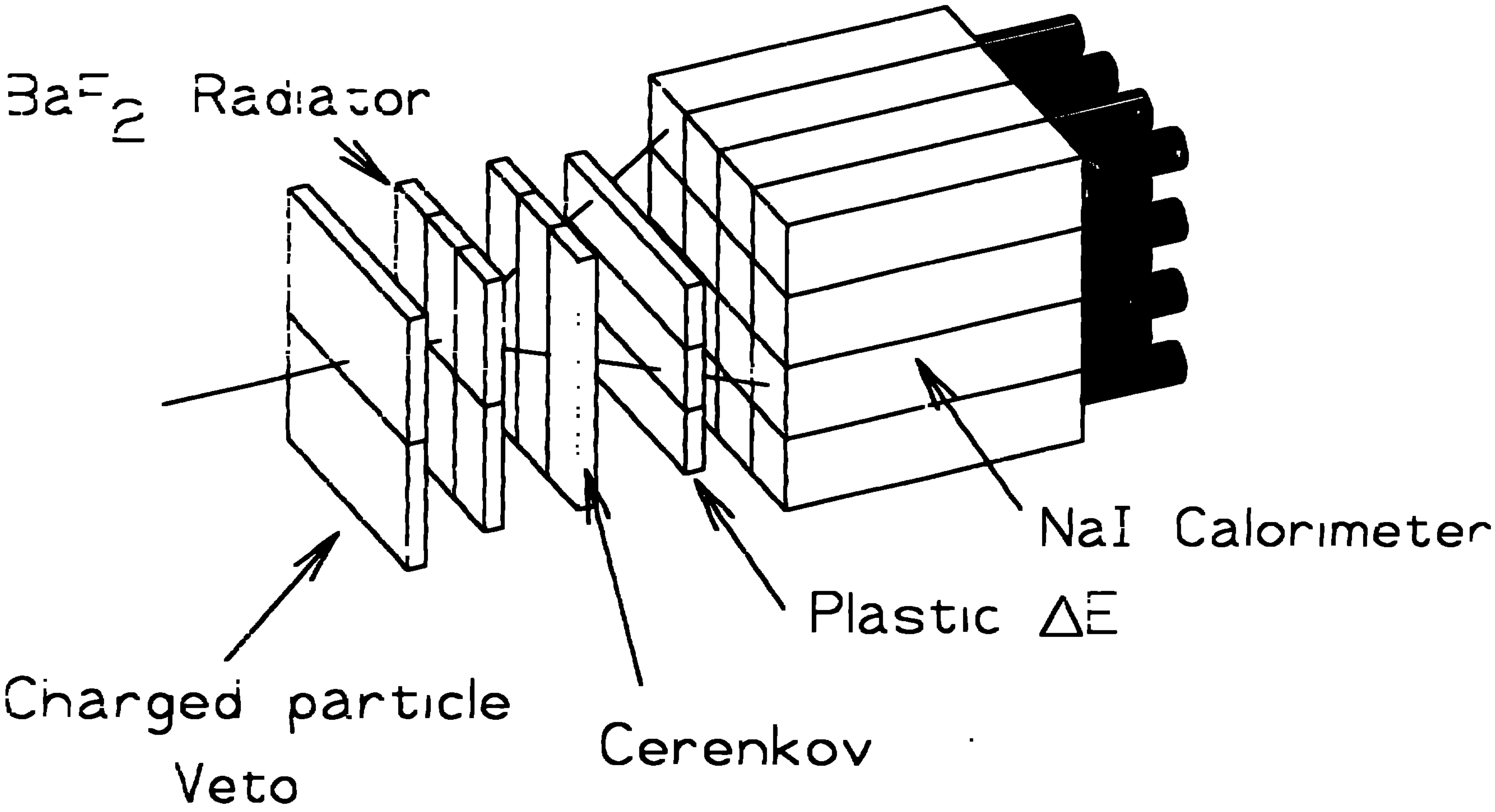
Figure 2. An NPB gamma-ray telescope.

Figure 3. Count rate of gamma rays at 90° as a function of gamma ray and incident neutron energy. Counts per neutron bin are normalized to $2.5 \cdot 10^{30}$ incident neutrons. The logarithm of the resulting number is plotted.

NPB Experimental Apparatus



NEUTRON-PROTON BREMSSTRAHLUNG DETECTOR



Gamma ray production at 90 degrees