EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Date: 16 February, 1967

Letter of Intention

To : Members of EEC

From: J.K. Bienlein, A. Citron, J. König, H. Schopper (Karlsruhe, CERN)

Re : n-p scattering above 6 GeV/c

It is proposed to measure the angular dependence of the n-p elastic scattering above 6 GeV/c in the forward and backward (charge-exchange scattering) direction. In order to separate the elastic from the inelastic events, the directions of the two outgoing particles and the momentum of the less energetic particle will be determined. The last can be done either by a time-of-flight measurement or a magnetic analysis. From these observations the momentum of the incident neutron is also obtained. The forward diffraction peak could be investigated in the momentum range from 6 to 12 GeV/c with a beam from target 1 at an angle of about 50 mrad. In order to perform measurements at higher momenta, a neutron beam produced at 0° would be necessary at a later stage of the experiment.

1) Previous measurements and aim of the experiment

An impressive amount of information has been obtained during the last years on the angular and energy dependence of p-p scattering[1]. However, very little is known so far about the n-p scattering. Since the two isospin amplitudes might behave differently, an investigation of the n-p scattering seems very important. An additional attractive feature is that this scattering can be observed for angles larger than 90° c.m., a region not accessible to p-p scattering.

The forward diffraction peak in n-p scattering has been investigated in one experiment only[2]. The slope has about the same value as for p-p scattering. Since this experiment covered the momentum range from 1 to 6 GeV/c only, a shrinkage of the diffraction peak could not be established.

In the same experiment, the energy dependence of the cross-section near 90° c.m. was measured. The data can be fitted by a decrease which is either exponential or a power of the energy.

The data on charge exchange scattering are more copious, but the highest incident momentum used so far is 8 GeV/c[3]. A sharply peaked angular distribution was found with about half the width of the p-p diffraction peak.

Some information on the n-p scattering has been obtained from p-d scattering[4]. This is especially true for the total cross-section.

This being the present experimental situation, the investigation of the following problems seems to be most interesting:

- Does the forward diffraction peak shrink for momenta above 6 GeV/c and is there a secondary peak?
- What is the behaviour of the backward peak above 8 GeV/c?
- What is the s and t dependence of the cross-section near 90°?
- Relative values of the total cross-section are well known from p-d scattering. The absolute value is known with less accuracy because of screening corrections. Therefore an absolute measurement of the n-p total cross-section at least at one energy would be important.

In the first stage of the experiment, it is proposed to measure the n-p scattering in the momentum range from 6 to 12 GeV/c. For this purpose, a beam at 3° originating from target 1 could be used which would interfere with no other experiments. With the experimental set-up described below, it seems to be possible to measure both the forward and backward scattering. It might even be feasible to get some information for the angular region around 90° c.m. In a later stage of the experiment (after the 1968 shut-down) these measurements could be extended to higher energies.

2) The neutron beam

If target 1 is chosen as the production target a 0° neutron beam is not possible at present since it interferes with the shielding of the h_3 beam. However, if the area between h_3 and the PS, which is not used, is considered as a possible location of the experiment, a neutral beam from target 1 can be set up under a production angle of about 3° without disturbing other experiments.

The neutron fluxes have been estimated by using the cross-sections for proton production from Be at primary momenta of about 20 GeV/c[5]. On a target 3×3 cm^2 at a distance of 60 m from the production target, one obtains the following neutron fluxes if 3×10^{11} protons/burst hit target 1 (2 cm Be)

Neutron momentum	Neutrons/(GeV/c) per burst	
production angle	0°	3°
6	5×10^3	3.6×10^3
8	9×10^3	4.6×10^3
10	12×10^3	4.3×10^3
12	20×10^3	3.2×10^3
14	$\sim 24 \times 10^3$	$\sim 1.6 \times 10^3$
16	$\sim 30 \times 10^3$	$\sim 0.9 \times 10^3$

As will be shown below, the fluxes for a production angle of 3° give reasonable counting rates up to momenta of about 12 GeV/c.

For higher momenta a 0°-neutron beam would be required. The neutron fluxes which could then be obtained are also shown in the above table.

With the target size and distance as indicated above, the neutron direction is known with an accuracy of about ± 0.02°.

To set up such a neutral beam it would be required to provide a hole through the shielding wall, to install a collimator, a γ-ray filter and a cleaning magnet with a bending force of about 20 kG·metre and a gap height of about 3 cm. The installation of the beam should be performed during the PS shut-down.

3) Experimental method

In order to separate the elastic from the inelastic events, it is intended to measure precisely the directions of the two outgoing particles. Since the direction of the incoming particle is also known, one obtains one constraint which corresponds essentially to the complanarity of the elastic scattering. From the observed directions the momentum of the incident neutron can be calculated.

In order to suppress further the inelastic background, a crude momentum determination of the particle emitted at a large angle is foreseen. In case of forward scattering this will be the recoil proton, whereas for backward scattering the neutron momentum will be measured. Since in both cases the momentum is not higher than about 1 GeV/c, a time-of-flight method seems most adequate to measure this momentum. The achievable resolution is satisfactory and a large solid angle can be obtained.

The experimental set-up as conceived by now is shown in the figure. The hydrogen target has the dimensions $3 \times 3 \times 50$ cm^3. Except for the geometrical arrangement and the size, the two arms for the detection of the two outgoing particles are very similar. First the particles pass through a spark chamber and a scintillation counter close to the target. At a distance of about 3 m is placed a sandwich of scintillation counters and thick-plate spark chambers.

For forward scattering the trigger is $1,2,3,\bar{4},\bar{5},6$. The direction of the neutron is detected with the spark chambers D, whereas that of the proton by A and B. The time-of-flight of the proton is measured between 1 and 2.

For backward scattering the trigger would be $\bar{1},\bar{2},3,4,5,6$. Now the direction of the proton is determined by C and D, and the time-of-flight of the neutron by 4 and 2.

The detection efficiency of the spark chambers for neutrons is about 60% at 6 GeV/c and rises with increasing energy[2)]. The time-of-flight counters would be similar to those used by H. Müller. They would also permit one to select electronically events which are approximatively coplanar. The counter-spark chamber sandwich could also be used to determine the range of the proton. If the counter array for the particle emitted at a large angle has a size of 1×1 m^2, a solid angle of $\Omega \approx 0.1$ sr is obtained.

With counters of this size, a time resolution of 0.7 nsec is possible giving a momentum resolution of 4% at 0.5 GeV/c and of 10% at 1 GeV/c.

In the first stage of the experiment, existing optical spark chambers (chambers from the neutrino or from the Müller-Zavattini experiment) would be used. They should later be replaced by wire chambers with ferrite core read-out.

A detailed description and possible changes of the detection system will be described after a more detailed study in the final proposal. The major part of the detectors could be built at Karlsruhe.

4) Expected counting rates

Assuming a neutron beam as described in part 2), one expects the following counting rates for the set-up of part 3:

Incident momentum 6 GeV/c (accepted interval 1 GeV/c)

$\lvert t \rvert$ (GeV/c)^2	0.1	0.5	1	3	6	9
$\Theta_{c.m.}$	11°	26°	37°	68°	104°	151°
events/week	3.1×10^5	5.7×10^4	6800	680	500	4700

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Incident momentum 12 GeV/c (interval 1 GeV/c)

$\lvert t \rvert$ $(GeV/c)^2$	0.1	0.5	1
$\Theta_{c.m.}$	8°	18°	25°
events/week	2.7×10^5	5.1×10^4	6.1×10^3

In calculating these figures it has been assumed that 10^5 bursts/week can be obtained, which seems rather realistic. For 12 GeV/c, the cross-sections measured at 6 GeV/c have been used, which implies that the shrinking of the diffraction peak is neglected.

Since all incident momenta are measured at the same time, the data-taking would require only about 4 weeks.

5) Time schedule

The neutral beam should, if possible, be installed during the shut-down in April 1967, since otherwise a very long delay might result.

Some beam testing would be started in late summer or autumn of this year. The beam geometry and contaminations should be established by these measurements.

The measurements proper could be taken up by the beginning of 1968, and the first stage of the experiment (3° neutron beam) would be determined at the time of the 1968 shut-down.

The group would consist of physicists and technicians from Karlsruhe. However, it would be greatly appreciated if some CERN physicists would join the group in order to establish a mixed group.

We should like to thank Dr. H. Müller for his help in preparing this letter.

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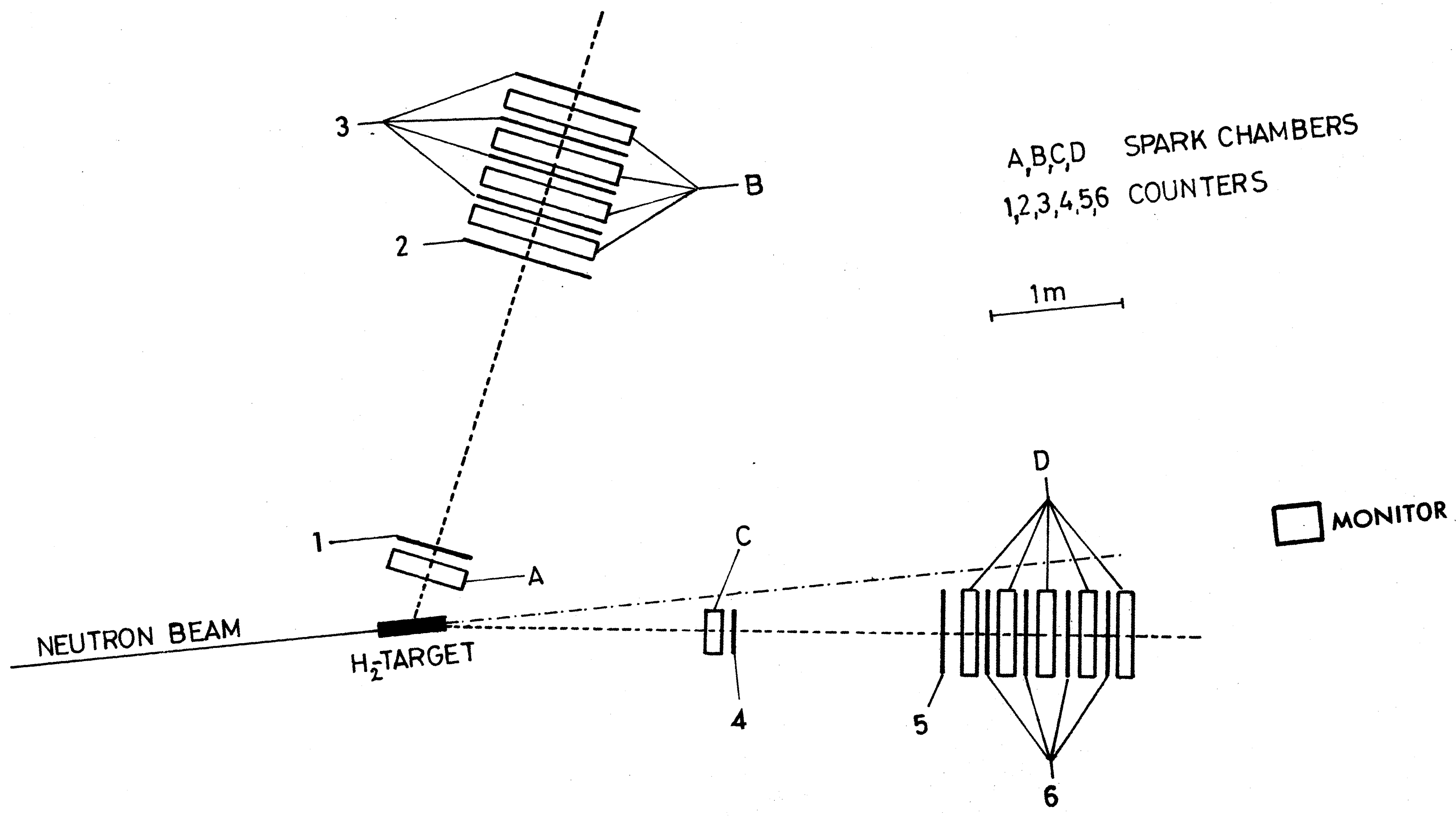

N-P SCATTERING EXPERIMENTAL SET UP