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AN IDENTIFYING, MOMENTUM-SENSITIVE DETECTOR SYSTEM FOR NEGATIVE PIONS

by

Hans O. Meyer[†] and Klaus Springer[‡]

ABSTRACT

We describe a detector arrangement for identifying negative pions by detecting star events. The initial pion momentum can be determined from a range measurement. The described system compares favorably with devices described earlier with respect to its high efficiency and its geometrical uniformity. Preliminary data have been taken which demonstrate the usefulness of the system.

I. INTRODUCTION

The detector system described in this paper is designed to be used with contaminated π^- beams of some large momentum spread. Its task is to identify the negative pions in the beam and to pass only pions with an initial momentum within a fixed, narrow range. The principle of operation is to slow the π^- down to rest with an absorber, to use the star formation at the end of the π^- range for identification and the absorber thickness as a range measurement, which then gives the momentum information.

In arrangements described elsewhere,^{1,2} which were built for the same purpose, the star events were detected by large pulses from a thin scintillator in the stopping region. In order to achieve good rejection against non-star events, one has to use a high discrimination level. This decreases the efficiency of the detector drastically, since it is geometricaly improbable that a star-decay deposits most of its energy within the thin scintillator where it took place. Also, it is difficult to collect the light from the scintillator equally well from different places in the scintillator. Therefore, the effective

discrimination level is dependent on geometry which gives rise to disturbing non-uniformities of the detector efficiency. The above two disadvantages are overcome by the arrangement described in this paper. The identification of the π^- is achieved by detecting decay protons from a star event in coincidence with the incident stopped π^- . Because of the peculiar structure of the detector which is to optimize the available solid angle, we will call it "sandwich-counter."

II. DESCRIPTION OF DETECTOR ARRANGEMENT

The detector system ("sandwich-counter") which is used to identify star events produced by stopped negative pions is shown in Fig. 1. It consists of a stack of thin scintillator sheets³ (item 1 in Fig. 1). Neighboring sheets are optically decoupled from each other by a layer of 1-mg/cm² aluminized Mylar. Light guides (items 2, 3 in Fig. 1) are connecting every other scintillator sheet to one of two photomultipliers. We will label the signals from these two photomultipliers by B and C, respectively. If a π^- stops in one of the scintillator sheets, giving rise to a signal "B", the decay products from the star event may then lead to a simultaneous signal "C" from an adjacent sheet. The signature of a star event in the detector will then be a coincidence B·C. The thickness d of the scintillator sheets has been chosen to d = 3.2 mm in

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Fig. 1. Sandwich-counter configuration. (1) Scintillator stack; (2), (3), light guides leading to photomultipliers B and C, respectively. The letters refer to geometrical dimensions mentioned in the text.

order to optimize the performance of the system with respect to protons emitted from stars, as discussed in the next section. The thickness c of the stack on one hand determines the efficiency of the detector, on the other hand c is responsible for the accuracy to which the range of a stopping π^- is known. We chose $c = 10$ mm, which by the range measurement technique enables us to determine the initial energy of a stopped 100 MeV-pion to ± 1.6 MeV. (The effect of range straggling has been included in this figure.)

In order to suppress false B-C coincidences, such as generated e.g., by neutron-induced recoil protons, a beam defining scintillator "A" of 3-mm thickness has been placed upstream from the sandwich-counter (Fig. 2) and a veto-detector "D" of 50-mm thickness downstream from it. The signature of a stopped negative pion in the sandwich-counter thus becomes $A \cdot B \cdot C \cdot D$.

III. CALCULATED PULSE HEIGHT DISTRIBUTIONS

In order to gain some insight in the performance of the sandwich-counter, we calculated the expected pulse height distribution in a given sheet from protons emitted by a star event, taking place in one of the adjacent sheets. The energy distribution of the star protons from π^- capture in ^{12}C (which stands for scintillator materials) has been taken from Ref. 4 (upper curve in Fig. 3). The

Fig. 2. Experimental arrangement. B, C are the photomultipliers for the sandwich-counter and A, D are beam defining detectors as described in the text.

location of the star within the primary sheet and the angles of proton emission were the random parameters in a Monte Carlo calculation. The star-protons were assumed to be emitted isotropically. The geometrical parameters of the sandwich-counter were fixed to $c = 10$ mm, $d = 3.2$ mm (Fig. 1) and a, b infinite as compared to any proton ranges of reasonable frequency. The calculated number of detected protons as a function of the energy, deposited in the sheet adjacent to the sheet with the star event, are shown by the lower curve in Fig. 3. It is remarkable that this curve decreases towards low energies. This is due to the fact that it is improbable for a proton with low energy (and short range) to reach the neighboring sheet in the scintillator stack. This latter point applies even more for star fragments with higher masses, which led us to the assumption that such particles are not contributing significantly to the coincidence rate discussed here.

By integrating the lower curve in Fig. 3 for all energies, we determined the theoretical efficiency ϵ_{th} of the sandwich-counter to $\epsilon_{th} = 0.25$.

The pulse height distribution from the primary sheet, essentially given by the stopping pions, can also be calculated. Assuming a uniform density of stops throughout the detector, this pulse height distribution decreases towards low energies, due to the non-linearity of the range-energy relationship. It exhibits a peak at 14 MeV, and 97% of its area lies above 2 MeV.

Fig. 3. The upper curve shows the energy distribution of protons from π^- capture in ^{12}C as calculated in Ref. 4. The calculated energy distribution of the fraction of these protons which is detected by the sandwich-counter is shown by the lower curve.

This leads to the following conclusion. If the threshold of the sandwich-counters B, C is set to about 2 MeV, almost all the coincidence events cause pulses above this level in both the primary and the adjacent, secondary sheet; and the detector efficiency is not seriously affected by variations in light collection efficiency, i.e., the detector efficiency is expected to be uniform throughout the sensitive area of the sandwich-counter.

IV. MEASUREMENTS

The object of the preliminary experimental data presented in this section is twofold. Firstly, we want to prove that the sandwich-counter is behaving as expected, i.e., that it is sensitive to stopping negative pions. This is achieved by measuring a range-curve of the signal $A \cdot B \cdot C \cdot \bar{D}$ for a negative and a positive pion beam, respectively. Secondly, an experimental value for the detection efficiency of a π^- stop will be deduced.

The experimental setup has been described above and corresponds to the arrangement displayed in Fig. 2. The discriminator levels for the detectors B and C have been set with a ^{207}Bi source to a value corresponding to an energy deposition of 1 to 2 MeV. The measurements have been conducted parasitically

at the low-energy pion channel of the Los Alamos Meson Factory.

The upper half of Fig. 4 shows the rate $A \cdot B \cdot C \cdot \bar{D}$ as a function of the absorber thickness between the output of the secondary pion beam line and detector A for incident negative pions of two different initial energies. Pronounced peaks are observed at absorber thicknesses corresponding to the range of the incident pions. The width of the peak is larger for the higher incident energy due to the effect of range straggling.

A similar range curve has been obtained with a beam of positive pions, which is displayed in the lower half of Fig. 4. In this case, no peak is observed at a range which corresponds to π^+ stopping in the sandwich-counter.

The measured detector efficiency ϵ_m is given by $\epsilon_m = f \cdot N_{\pi\text{stop}}/N_\pi$. Here N_π is the number of incident pions, $N_{\pi\text{stop}}$ the number $A \cdot B \cdot C \cdot \bar{D}$ of detected pions; and the factor f ($f > 1$) takes into account that the stop peak is wider than the detector thickness, and only a part of the potentially detectable events are seen for a given absorber setting. The number of incident pions N_π has been determined from the drop of an integral range curve near the pion range. In this manner we obtain an experimental value of $\epsilon_m = 30\% \pm 10\%$ for the detector efficiency. The quoted error is caused by counting statistics in both N_π and $N_{\pi\text{stop}}$. The measured efficiency ϵ_m is in agreement with the calculated value ϵ_{th} .

Two more features of the experimental data in Fig. 4 should be discussed. The first one is the fact that the π^- stop peaks are superimposed on background. This means that not all non-star events are rejected. We have shown that this rejection ratio can be substantially improved by raising the discriminator level on B and C. This, however, would affect the detector efficiency and its uniformity. The second feature of the measurements we would like to point out is the monotonous rise of the rate $A \cdot B \cdot C \cdot \bar{D}$ for increasing pion energy (decreasing absorber thickness). It is not yet understood which events cause this behavior, and more investigation should be devoted to this point.

Fig. 4. Range curves of the coincidence rate A·B·C·D for negative pions of 30 MeV and 100 MeV (upper half) and positive pions of 90 MeV (lower half). The rates are normalized to the incident pion flux. The dashed line is to guide the eye.

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