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Nuclear Physics A639 (1998) 117c–120c

NUCLEAR PHYSICS A

Characteristics of an active chamber target to locate the reaction vertex in the $(K^-_{stopped},\pi^0)$ reaction.

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1. INTRODUCTION

Experiment 907 at the Alternating Gradient Synchrotron (AGS) requires that a kaon beam (p= 682 MeV/c) stops in a carbon target (2.2 g/cm^2). The stopped K^- are subsequently captured on a nucleus and may then react to produce a π^0 and a recoiling hypernucleus. The π^0 immediately decays into two γ rays (BR=100 %) so that to observe the $^{12}C(K^-_{stopped},\pi^0)^{12}_{\Lambda}B$ reaction, one must measure the energy and direction of the two photons.

The Neutral Meson Spectrometer (NMS), originally constructed and operated at the Los Alamos Meson Physics Facility (LAMPF), was used for this purpose. The NMS is a high-resolution, large-acceptance shower spectrometer [1]. It consists of two arms, each containing an array of pure CsI crystals and photon converter planes. The converter planes are equipped with bismuth germanate (BGO) and tracking chambers. The BGO converts the photons while the tracking chambers provide the position of the conversion point. The calorimetry is predominantly measured by the CsI crystal arrays, although the energy deposited in the BGO is also included. However the π^0 energy, ω, is mainly obtained from a measurement of the geometric opening angle, η, between the photons, when the energy is shared equally between them.

In order to properly measure η, three points are required in the production plane of the photons. The conversion points in each arm of the NMS, and one point at the vertex of the π^0 decay, are used. Hence, these positions must be accurately known. The reaction vertex is measured by an Active Chamber Target (ACT) constructed of layers of cathode strip chambers and target planes. This paper discusses the design, construction, and performance of the ACT used for BNL experiment 907 at the AGS.

2. DESIGN AND CONSTRUCTION

There were two predominant design constraints on the construction of the ACT for our experiment. In the first place, the amount of material between the target and the NMS should be minimal. This is necessary to ensure that photons from the target region are

*On behalf of E907 collaboration at Brookhaven National Laboratory

†Supported in part by the United States Department of Energy under grant # DE-FG03-94ER40836

0375-9474/98/$19.00
PII S0375-9474(98)00259-0

not absorbed in the ACT before they reach the NMS. Secondly, the ACT must be large enough to accept as much beam as possible but thin enough to keep the stopping vertices reasonably close together. Other design factors were implemented to facilitate various operational tasks such as changing or removing targets, accessing individual cathode or anode planes, and placing the readout electronics.

Reduction of material in the path of γ rays was achieved by two methods. Firstly, polyethylene, (C_2H_4, radiation length = 48 cm), was used for the detector frames instead of G10 [?] (60 % SiO_2 and 40 % epoxy, radiation length = 19 cm). Electrical connections were made on an etched 0.025 cm thick G10 sheet glued onto the C_2H_4. This decreases the two-photon interaction probability from $\sim$ 20 % to $\sim$ 8 %. Secondly, the geometry of the chamber was trimmed to follow the shape of the target, minimizing excess material, and providing the maximum target exposure to the beam, as shown in Fig. ??.

The cathode strips were etched onto a 9000 nm gold coated 0.0013 cm kapton foil using electric discharge to a pin positioned by a CNC mill. Each cathode plane has 64 strips 0.4 cm wide. Electrical connections between the strips and the G10 sheet were made with conducting epoxy. The average capacitance between two strips was measured to be $\sim$ 12 pF, and the resistance of an individual strip was measured to be $\sim$ 1.10 Ω/cm. The cathode foils were attached to the supporting frames with epoxy. Readout connections were divided equally to each side and routed to pre-amplifiers (32 connections per side).

Anodes wires are 20 μm diameter gold-plated tungsten wire. There are a total of 128 wires spaced 0.254 cm apart. The wires were strung with an average tension of 72 g and attached to the plane with epoxy. Electrical connections were made by soldering the wires to lands on the thin G10 sheet.

The anode to cathode spacing is 0.353 cm and the cathode strips make an angle of 68.34 degrees with the vertical anode wires. The U and V cathode strips are mirror images of each other giving a 2-D readout on each chamber. In order to keep the chamber rigid and all the planes aligned, 0.317 cm diameter steel rods are used as pins. In addition, to keep the chamber planes parallel, the chamber stack is mechanically reinforced by two 1.27 cm thick aluminum end plates. These plates are machined to remove excess material on the face of the plates, reducing the probability of conversion in the ACT.

Targets are inserted between every two chambers, as shown in Fig. ??. Each cathode plane can accommodate targets thinner than 0.2 cm, but for targets thicker than 0.2 cm, a separate polyethylene target holder is used. The ACT is mounted on the beamline with the help of two alignment rods.

3. OPERATION AND PERFORMANCE

Three types of data were taken at $\sim$ 682 MeV/c momentum, 1) pion beam data were taken to study the performance of the ACT to straight through tracks and minimum ionizing particles, 2) positive-kaon beam data were taken to study the behavior of the ACT for stopping kaons, and 3) production K^- beam data were taken to study the reaction, ${}^{12}C(K^-_{stopped},\pi^0){}^{12}_{\Lambda}B$.

The ACT cathode signals were amplified by trans-impedance pre-amplifiers and transmitted through approximately 76 m long twisted-pair cable , acting as a delay, to LeCroy FastBus ADC's. These signals were AC coupled to the ADC's by transformers to reduce

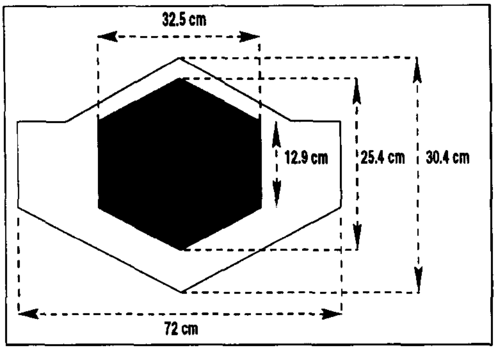

Figure 1. Front view of ACT. The chamber parameters are trimmed to follow the target shape.

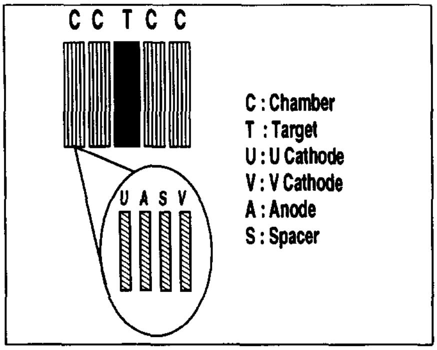

Figure 2. Conceptual design of an ACT segment. Target is inserted between 2 sets of chambers.

low-frequency noise and ground loops. The overall charge gain of the electronics system was $\sim$ 55-60 [3]. The chamber was operated with a humidified gas mixture of argon (60 %) and isobutane (40 %). The nominal high voltage of the anode wires was 2.2 kV and the average current draw of 10 chambers was $\sim$ 28 μA from a typical 1.2 second beam spill of 6 million particles.

Pion data were analyzed to obtain the induced charge profiles, chamber efficiencies, and resolutions. The induced charge distribution on the cathode strips was found to be Gaussian with a FWHM of $\sim$ 5 mm. The center of gravity (COG) method was used to obtain position centroids with the number of strips in the COG calculation always taken to be 5 (cluster). The cluster multiplicity in the pion data was found to be predominantly one. It is very important that the charge gains for the cathode strips are calibrated with respect to each other in order to use the COG method, and these relative calibrations were done by inducing a common charge into the pre-amplifiers.

Chamber efficiencies were obtained by defining a track using two sets of U and V planes, one upstream and the other downstream to the beam, and checking all the planes in between for hits within 1.2 cm of the defined track. The planes used to define the track were then changed to obtain efficiencies for all planes. The average efficiency was found to be $\sim$ 96 %. Similarly, residuals were obtained by fitting a straight line track through all 10 sets of U and V planes and calculating the distance between the true centroid, χ, and the fitted track. The resolution for the U planes, σ_U, was found to be 310 μm and for the V planes, σ_V, to be 333 μm. These resolutions translate into σ_X of 244 μm (vertical), and σ_Y of 616 μm (horizontal).

Positive kaons, stopped in the ACT, sometimes decay into $\pi^+\pi^0$ (BR = 21.16 %). The π^+ leaves with a maximum kinetic energy of 108.5 MeV ($\beta = 0.82$), and the energy loss of a stopping K^+ is significantly larger than the ionization caused by the π^+. In this case, there are at the most 2 tracks in the ACT, and there is a sizable difference in their energy loss. One can identify these by grouping clusters with similar energies. In addition, the stopping point of the K^+ can be identified by its energy loss as a function of distance, i.e, by the range curve (see Fig. ??).

In the case of K^-'s, track identification based upon energy losses is not as efficient as in case of the K^+ data due to nuclear interactions. Reaction products cause energy losses comparable to a stopping K^-, and therefore, a new technique is employed. All possible clusters are individually fit using linear regression. In the case of a single track, the stopping vertex is provided by projecting the track to the center of the target downstream of the point where the energy loss was a maximum. In case of multiple tracks, an incoming K^- track is identified by analyzing the hits in the two most upstream chambers and projecting to the target downstream of the chamber with maximum energy loss. It is also possible to use the intersection of all possible tracks as the stopping point. The probability of identifying the correct stopping target was found to $\sim$ 80 % in the case of K^+ data.

These techniques worked very well and the performance of the ACT was satisfactory. More studies using various other targets are planned in the future.

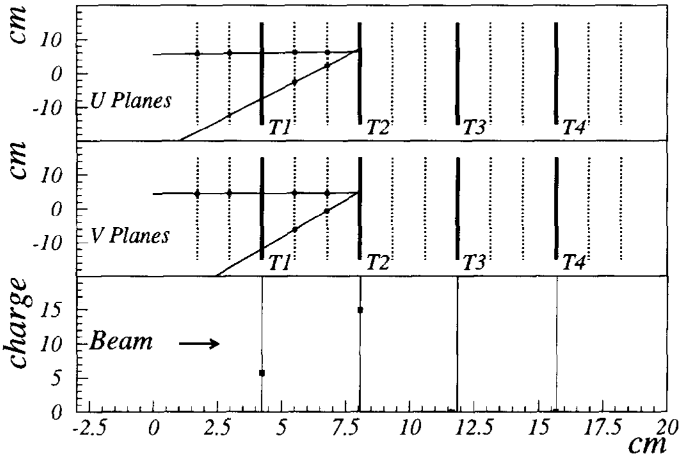

Figure 3. A $K^+ \rightarrow \pi^+\pi^0$ event. Incoming K^+ and outgoing π^+ tracks are seen in both U and V planes. A range curve is also shown with maximum charge deposition at the point of K^+ stop at the second target (T2).

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