STUDIES OF A POSSIBLE TRIGGER FOR STUDYING
E⁻ PRODUCTION IN THE STREAMER CHAMBER

by

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Studies of a Possible Trigger for Studying Ξ^- Production in the Streamer Chamber

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Introduction

The following is a brief summary of studies of how one might trigger the streamer chamber for the purpose of studying production of Ξ^- hyperons in K^-p interactions. The study involves investigating the trajectories of particles in the streamer chamber; the events used are real events from experiment E6 (K^-p at 5.5 GeV/c) in the reactions

a.	$K^-p \rightarrow \Xi^- + \dots$	587 events, 350 visible Λ 's	143 μb
b.	$K^-p \rightarrow K^-p\pi^+\pi^-$	3945 events	1.0 mb
c.	$K^-p \rightarrow K^-p\pi^+\pi^-\pi^0$	4364 events	1.1 mb

Interactions (a) are the desired ones, (b) and (c) were used for investigating background.

Components of Trigger

- Threshold Cerenkov counter hodoscope to anti-out particles with $\beta > \beta_{\text{critical}}$
- Hodoscopes immediately before and after the Cerenkov counters to define the angle acceptance and to detect particles with $\beta < \beta_{\text{critical}}$ going

through the Cerenkov counters.

- c. Hodoscopes above, below and at the end of the chamber to count multiplicity.
- d. The usual Cerenkov counters and hodoscopes in the beam. We will not discuss these here.

Assumptions

- a. The trajectories were calculated using, as a model of the magnetic field, a uniform field of 15 kG and a radius of 1 meter. (The actual $\int \mathbf{B} \cdot d\mathbf{l}$ may be $\sim 10\%$ lower.)
- b. The Cerenkov counter is 100% efficient in rejecting particles with $\beta > 0.98$ which was chosen as the critical β , since all protons from $\Xi^- \rightarrow \Lambda \rightarrow p$ have β less than 0.98. (Clearly, the efficiency of the counters will depend on the design.)
- c. The Cerenkov counters fill the downstream exit hole in the magnet. (It may be possible to build a Cerenkov counter hodoscope that fills 80% or more of the hole, which is 85 cm wide by 138 cm high.)
- d. The angle defining hodoscope defines angles in such a way that only particles with the trajectories of protons are counted; the Cerenkov counters will veto the π^+ 's. (With assumptions a, b and c above, it appears that defining an angle to within $\pm 6^\circ$ to 7° will be sufficient to identify and tag protons while vetoing π^+ 's.)
- e. The multiplicity hodoscope counts only charged particles; photon

conversions in the hodoscope have not been considered. Neither have multiple traversals been considered.

Events and Particle Trajectories

The production vertex for all events were placed at a point ~ 25 cm upstream of the center of the chamber (which is also the center of the field) and in the median plane. For this position, a beam angle of 8° with respect to the horizontal gives maximum transmission of protons from $\Xi^- \rightarrow \Lambda + p$ (247 out of 350 or 71%) through the magnet exit hole. The sign of the field was chosen so that the beam is bent downwards and protons upward. Charged particles were swum through the uniform field to the edge and from the edge had a straight trajectory.

The sketch of the chamber and magnet iron shows the coordinate system axes which may help in understanding the discussion of the Cerenkov counters and hodoscope. See Fig. 1.

Discussion of the Proposed Trigger

a. We first consider the effect of the Cerenkov hodoscope (or a segmented Cerenkov counter) and a counter hodoscope immediately before and after the Cerenkov counters. The Cerenkov counters and hodoscopes are placed in the exit hole of the magnet and identify fast protons. The segmenting of the Cerenkov counter will decrease the chance that a pion from the same $\Xi^- \rightarrow \Lambda + p$ event could veto the event.

For a given y coordinate at the upstream face of the Cerenkov counter, only protons with a certain range of angles will make it through the Cerenkov counter. For instance, at $y = -10$ cm, all protons from $\Xi^- \rightarrow \Lambda \rightarrow p$ enter the Cerenkov counters with an angle between -3° and $+10^\circ$ with respect to the horizontal. At $y = +20$ cm, the range is $+9^\circ$ to $+22^\circ$. However, no $\pi^\pm$ or K^- with $\beta < 0.98$ from the background reactions has such a trajectory. Many π^+ 's with $\beta > 0.98$ do, as well as many protons from background reactions. Fig. 2 shows a possible arrangement.

The Cerenkov counter plus angle defining hodoscope then will identify high momentum protons. The acceptance for protons from $\Xi^- \rightarrow \Lambda \rightarrow p$ can be quite good. There were 350 $\Xi^- \rightarrow \Lambda \rightarrow p$ events and 247 or 70% passed through the counters plus hodoscopes. This corresponds to $66 \mu\text{b}$ out of a cross section of $92 \mu\text{b}$ for $\Xi^- \rightarrow \Lambda \rightarrow p$.

The two background reactions have a combined cross section of about 2.1 mb. Other reactions of the type $p\bar{K} + \pi$'s are estimated to have a cross section of about 10 mb and the Λ/Σ reactions which can have protons from decays may contribute another 5 - 10 mb. The counters plus hodoscopes will accept only about 1 mb of the $p\bar{K}\pi$ type reactions, and we estimate a similar value for the Λ/Σ reactions.

So, if only the Cerenkov counters plus angle defining hodoscopes are used as a trigger, we will trigger on about 2 mb of which only 1/30 will be $\Xi^- \rightarrow \Lambda \rightarrow p$.

b. In order to reduce the background, we have investigated the effect of a multiplicity requirement as part of the trigger. We assumed the top, bottom and downstream end of the chamber were covered by some sort of detectors as in Fig. 3, which shows five large detectors. By requiring two other particles to be detected in addition to a proton through the chamber Cerenkov counters, the $\Xi^- \rightarrow \Lambda \rightarrow p$ trigger cross section is $41 \mu\text{b}$ (reduced from $66 \mu\text{b}$ of the proton requirement only), while the two background reactions contribute $190 \mu\text{b}$ together (down from 2.1 mb). Including the Λ/Σ (plus other $p\bar{K}\pi$) may make the total trigger cross section for this arrangement ~ 0.4 or 0.5 mb . Thus, we could get one $\Xi^- \rightarrow \Lambda \rightarrow p$ per 10 or 12 triggers.

Study of the two background reactions shows that $\sim 1/2$ of the events have a K^- contributing to the multiplicity and almost all of them hit the lower $1/3$ of the detector M_3 of Fig. 3, while only a small fraction of $\Xi^- \rightarrow \Lambda \rightarrow p$ have a particle (other than the proton) hitting that part of M_3 .

Therefore, we next investigated the effect of not including the lower $1/3$ of M_3 in the multiplicity requirement. The trigger cross section of $\Xi^- \rightarrow \Lambda \rightarrow p$ was reduced from $41 \mu\text{b}$ to $36 \mu\text{b}$ and the two background reactions from $190 \mu\text{b}$ to $90 \mu\text{b}$. It is difficult to estimate the effect on the Λ/Σ events, but we assume it will be the same as for the $p\bar{K}\pi$ type events. Thus, the estimated trigger cross section for this arrangement is about $250 \mu\text{b}$ of which $\sim 1/8$ is $\Xi^- \rightarrow \Lambda \rightarrow p$.

By using more detectors for the multiplicity requirement (while still

excluding the lower $1/3$ of M_3 in Fig. 3), it is possible to increase the efficiency for $\Xi^- \rightarrow \Lambda \rightarrow p$ so that the ratio $\Xi^- \rightarrow \Lambda \rightarrow p$ /background is increased to $\sim 1/6$. Fig. 4 shows such an arrangement.

Table I summarizes the effectiveness of the above trigger schemes.

Further Discussion

In the above, no mention was made of decay losses. Because the target and its surrounding insulation are dead areas as far as the streamer mechanism is concerned, those Ξ^- 's and Λ 's which decay in the target will not be visible. Analysis of the $\Xi^- \rightarrow \Lambda \rightarrow p$ events shows that for a 6-inch long LH_2 target with $3/4$ " foam insulation, $\sim 40\%$ of the Λ 's and $\sim 70\%$ of Ξ^- 's decay inside the target structure. It is not clear yet whether these events could be recovered in a systematic, efficient way. This indicates that with the best of the above trigger arrangements, $\sim 1/20$ of the triggers would provide both Ξ^- and Λ decay vertices.

Assuming one $\Xi^- \rightarrow \Lambda \rightarrow p$ with both decay vertices visible per 20 triggers is acceptable, what requirements are there for the Cerenkov counter and the angle defining hodoscope? A length of 27" was used in the above studies although half that should be sufficient. For Cerenkov counters of 27" length, the vertical dimension of the hodoscope elements could be 3". This is a reasonable size for scintillation counters and for this size, the number of vertical elements would be 12 for the hodoscope H_{A1} and 18 for H_{A2} (see Fig. 2).

The angle of the proton would then be defined by taking the proper elements of H_{A2} in coincidence with an element of H_{A1} . The elements of H_{A1} could also be used in the multiplicity part of the trigger.

Another possibility for each hodoscope is an array of MWPC with a number of wires tied together. The wires would have to be ~ 70 cm long and in an array ~ 100 cm high. For wire spacing of $1/2$ cm, this would be ~ 200 wires, but if ~ 10 wires are tied together, only 20 amplifiers would be needed for H_{A1} . Similarly for H_{A2} , only 30 amplifiers would be needed. The advantages of MWPC arrays over scintillation counters are (i) less mass for conversion of γ rays, and (ii) no light pipes to act as Cerenkov counters for charged particles (both of these problems seemed to have affected the SLAC-LBL run). Furthermore, the costs may be comparable. Of course, the multiplicity detectors could also be MWPC arrays.

Currently, the beam to the streamer chamber, beam 22, is an unseparated beam. Measurements of the beam give a K^-/π^- ratio of 0.007 at the LH_2 target at 5.5 GeV/c. It is easy to run the chamber with a memory time of 4 - 5 μ sec.

During a recent tuning run for E297, some pictures were taken with $\sim 200,000$ π^- 's per burst on the target with the chamber having a memory time of ~ 5 μ sec or slightly more. This would imply one beam particle/memory time for a uniformly distributed beam.

Although the picture quality was poor due to bad chamber operating

conditions, there were ~ 5 or more beam tracks per picture, and the scanning was quite difficult. This suggests the beam is not uniformly spread in time, but has some structure. Assuming control over chamber conditions improves (as it appears to be), we may be able to take 200,000 particles per ZGS pulse. This appears to be an upper limit to the flux that can be tolerated and will result in $\sim 1500 \text{ K}^-/\text{burst}$ at 5.5 GeV/c. Defining $10^3 \text{ events}/\mu\text{b}$ as equivalent to 10^9 feet of path length in LH_2 , we would require ~ 200 or more shifts of data taking and would get 250,000 K^- pictures with the 'proton plus two other particles' as a trigger. Approximately 14,000 of these would be $\Xi^- \rightarrow \Lambda \rightarrow p$ with both decays visible.

(It may be useful to point out that E297 typically takes pictures with only 20,000 to 25,000 particles per pulse. With a memory time of $\sim 5 - 7 \mu\text{sec}$, they get an extra beam track about $1/3$ to $1/2$ of the time. No physics pictures have been taken with large flux although Notre Dame is considering $\sim 200,000 \pi^-/\text{burst}$ for their experiment.)

From the above, it appears that the experiment is feasible as far as the current study of the trigger is concerned. However, with the current beam, beam 22, we would be taking data for many calendar months. It appears that an enriched beam capable of providing between 5,000 and 10,000 K^- per pulse at 5.5 GeV/c with K^-/π^- ratio of better than $\sim 1/15$ is highly desirable.

Table I
Trigger Effectiveness

Trigger	Trigger Cross Sections						No. of Triggers/ 10 ⁹ Ft. of K ⁻
	$\Xi^- \rightarrow \Lambda \rightarrow p$	$K^- p \rightarrow K^- p \pi^+ \pi^-$ $K^- p \pi^+ \pi^- \pi^0$	Other pK + π 's (Estimated)	Λ/Σ With Proton (Estimated)	Total	Ξ^- /Total	
Total Cross Section	92 μ b	2.1 mb	~ 8 mb	24.3 mb	24.3 mb	.0004	
Proton Only C + Angle	66 μ b	.4 mb	~ .6 mb	2 mb	2 mb	.033	2×10^6
Proton + 2 Others	41 μ b	190 μ b	~ 50 μ b	500 μ b	500 μ b	.125	5×10^5
Proton + 2 Others (restricted)	36 μ b	90 μ b	~ 20 μ b	250 μ b	250 μ b	.18	2.5×10^5

Fig. 1

H_{A1}, H_{A2} angle defining hodoscope
 $\checkmark$ Segmented Cherenkov counter

Fig 2:

$M_1, \dots, M_5$ Multiplicity Detectors

Fig. 3

Fig 4