TWO COMMENTS CONCERNING π-e ELASTIC SCATTERING (PROPOSALS 49 AND 71)

Michael Goitein
Lawrence Radiation Laboratory

ABSTRACT

A calculation of knock-on probabilities indicates severe problems in surrounding a long target with veto counters more forward than about 25°. This question is relevant to all experiments with veto counters.

A second comment suggests that shower counters be used in both the electron and π^- detectors of Proposal 71.

I. KNOCK-ON ELECTRONS

It is proposed in both experiments (and, indeed, in many similar experiments involving elastic or two-body scattering) to place a veto counter close to the hydrogen target--with a small opening in the forward direction through which elastic scattering takes place--typically within a few milliradians.

Our observation is that there is a substantial probability that a knock-on electron will be produced in the course of an elastic scatter. Indeed, in 50-cm hydrogen liquid, the probability that the incident or scattered pion will produce a knock-on electron of energy greater than or equal to T (MeV) is

$$p(\geq T) \approx \frac{0.5}{T}\,(\text{MeV}).$$

The probability of the scattered electron producing a knock-on is, it turns out, just half of this (since, on the average, the electron only traverses half the target). The angular distribution of these knock-on electrons is quite broad:

$$\theta = \tan^{-1}\sqrt{\frac{2\,me}{T}}\,.$$

So, we find:

T (MeV)	Probability of Knock-On of Energy ≥ T in 50 cm H_2	Angle at Which Electron of T Emerges (Degrees)
5	15%	24°
20	3.75%	12.6°
100	0.75%	5.7°

Clearly, one cannot put up bare veto counters up to a few milliradians since one will then anti-out 15% or so of the good events (the very low energy electrons stop in the target). Assuming that one can range out electrons up to 5 MeV, one then has to place 5 MeV of absorbers in front of the veto counter and leave a large hole (semi angle of 25° or so) in the forward direction (see Fig. 1).

These observations are independent of incident (or scattered) π (or e) energy provided it be >> 100 MeV or so. The reason that this knock-on process is more aggravating at high energies (such as NAL will provide) is that the inelastic or multi-body processes that one is trying to veto are thrown more and more forward in the laboratory system as energies rise. Hence there is an increasingly large chance of failing to veto them.

So far we have addressed ourselves to the trigger--that is, the immediate consequence of a forward hole is that spurious triggers are possible. Neither proposal makes clear how bad this would be--it clearly warrants calculation. There are, however, two further considerations relating to the analysis.

1. Energy Balance:

Knock-on electrons can also carry away energy. Indeed, even if one had perfect momentum resolution on the incident π and final-state π and e (high energy), one would observe an energy imbalance (Fig. 2) and, outside 100 MeV, say, there would be 0.75% of "good" elastic events. Happily (or unhappily), since the energy resolution is unlikely to allow a tighter energy balance cutoff, this will not be a major problem. But, it will be a small correction.

2. Counting Stray Extra Particles:

If one were to attempt to reduce inelastic contamination by rejecting all events with more than two tracks emerging from the target, one could be in bad trouble from knock-on events. One must require (forward going) spurious tracks to have more than 100 MeV/c or so before rejecting an event on this basis.

II. PARTICLE IDENTIFICATION

When an event satisfies an energy balance requirement, there remains the problem of identifying which of the two final trajectories is the recoil electron and which the pion (or kaon). For a particle of mass m_x there is a critical incident momentum

$$p_x \simeq \frac{m_x^2}{2m_e} \qquad (m_e = \text{electron mass}),$$

(p_x = 19 GeV for π's and 240 GeV for K's). When the momentum of the incident particle (pion, say) is below this critical value, the lower momentum particle is always the electron. Above that momentum there is an ambiguity. In principle it can be resolved by comparing the scattered particle angles, but in practice, at high energies, these are both very small and not easily distinguished. So, clearly, one incorporates a shower counter for electron identification--as in Proposal 71.

Parenthetically, we note that, at AGS energies of ~20-25 GeV π beam, the highest momentum transfers correspond to approximately equipartition of energy between the π and electron. There is then the possibility of spatial overlap in the scattered particle detectors. At higher energies (50 GeV and up) the situation in which equipartition of energy is possible corresponds to fairly low momentum transfer compared to the maximum achievable--and hence is relatively uninteresting. So the overlap problem goes away.

The purpose of this comment is to suggest that shower counters be placed in both the π^- and electron detectors. One would require that the higher momentum particle have a shower process and that the lower momentum particle not have a shower. The reason for this is easily seen in the example illustrated in Fig. 3. Consider two cases: Process (b) is low momentum transfer and not desired, but it is about ten times more prolific than desirable case (a). Assume for argument's sake the following performance characteristics of a shower counter: 99% efficient for electrons and 1% efficient for π^-. If one only has a shower counter on the momentum side, then (a) will be 99% efficiently detected, but (b) will be 1% efficient and, due to its higher cross section, will be a 10% contamination.

If one has shower counters on both particles, then (a) is detected with 99%-1% = 98% efficiency and (b) is detected with 1% × 1% = 0.01% efficiency leading to a 0.1% background. Thus, one has traded a large background for a small and easily measured detector inefficiency. Presumably it could be measured by turning the incident beam energy and intensity down and running the π^- beam directly into the shower counters.

This comment, of course, applies only to the case of negatively charged incident particles.

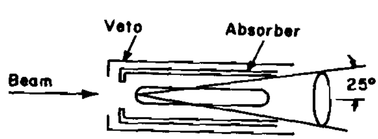

Fig. 1. Veto counter configuration necessary to avoid rejecting good elastic events accompanied by knock-on electrons.

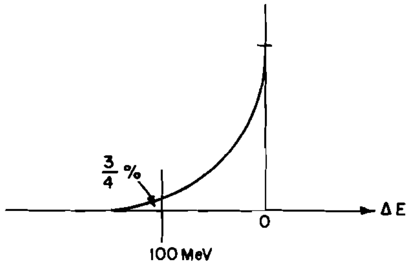

Fig. 2. Energy balance spectrum from knock-on electron effects (50 cm H_2 target).

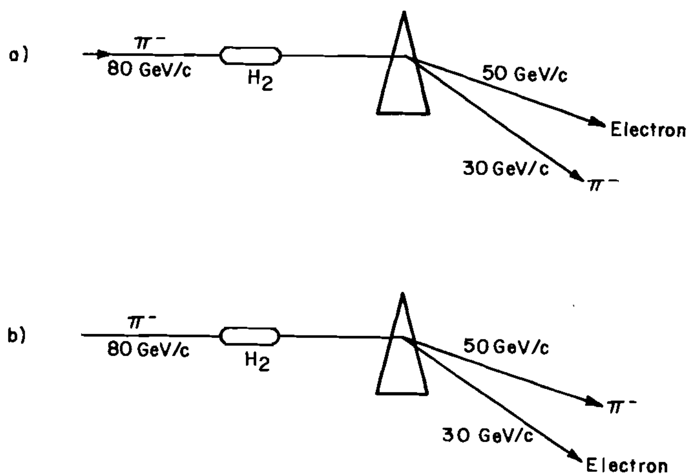

Fig. 3. Two types of event with similar kinematics in the absence of particle identification.