HYPERON TOTAL CROSS SECTION MEASUREMENTS

We feel that our new charged hyperon beam in Proton Center and our spectrometer have matured sufficiently to measure hyperon total cross sections. As part of our program of hyperon physics we plan to measure Σ^-, Σ^+ and Ξ^- total cross sections on hydrogen and deuterium. This will extend the Σ^- and Ξ^- measurements to the highest available energy and be the first Σ^+ total cross section measurement. We ask for accelerator time and an appropriate cryogenic target.

The understanding of the baryon octet total cross sections at high energies is of fundamental importance. The recent measurements at CERN of the Σ^- and Ξ^- cross sections* up to 137 GeV/c only serve to emphasize this. As the first precise measurement of these cross sections at high energies they have shown most of the existing phenomenological models to be inadequate. Precise measurements of total cross sections at the highest available energies and with the greatest variety of nucleon projectiles will provide a firm experimental foundation for theories describing the octet structure of high energy interactions.

* S. F. Biagi et al, CERN-EP/80-172, Sept. 1980

Experimental Configuration

The total cross section measurement is performed using straightforward modifications of the present flux measurement apparatus shown in figure 1. Figure 1 insert shows the modifications in more detail. The essential features are:

1. A target assembly consisting of three identical flasks, each 2m long, which could be cycled into the beam between accelerator pulses. The flasks would contain liquid hydrogen, liquid deuterium, and vacuum, so that both the hyperon-proton and hyperon-neutron cross sections could be measured. This is the only new piece of equipment we are requesting.
2. A pair of high resolution proportional chambers before and after the target. Each chamber is an X, Y, U module with 65 μm resolution and separated by 1m to give an angular resolution of about 0.1 mrad. The measurement of the hyperon direction downstream of the target allows a correction to be made for small angle elastic (and inelastic) interactions.
3. Hyperons which survive into the decay region would be identified in the existing hyperon decay spectrometer. Figure 2 shows the Σ^+ and Σ^- mass resolution as measured in our spring 1980 test run. Note the expected $\Sigma^+ - \Sigma^-$ mass shift.

Rates

Table 1 shows the $\Sigma^\pm$ and Ξ^- trigger rates which we have measured in our spring 1980 run. These rates are limited entirely by backgrounds in our drift chamber spectrometer (probably muons). Additional shielding planned for our winter 1980 run should help this substantially, but we will use these for our estimates. The $\Sigma^\pm$ rates are sufficient to saturate our

data collection system (∿500 events/pulse) at all momenta. The same is true for Ξ^- at the lowest momentum in Table I.

From our spring 1980 run we know that 40% of the Σ trigger events will be reconstructed with a vertex in our decay fiducial volume and have the hyperon trajectory extrapolate upstream to the hyperon production target. Upstream hyperon decays in the region of the PWC's or in the last part of the hyperon channel are the major components of the other triggers.

The Ξ trigger requires the reconstruction of three charged tracks ($\Xi^- \to \pi^- \Lambda \to \pi^- p$) and since our full complement of drift chambers was not in place for the spring 1980 run, we do not have a good estimate of the reconstruction efficiency. All chambers will be ready for the winter 1980 run, and for the present we estimate that the reconstruction efficiency will be 20%.

The number of events (for LH_2 and target empty subtraction) needed to measure the total cross section to a given precision $\Delta\sigma/\sigma$ is

$$N = \left(\frac{2\sigma}{\Delta\sigma I_f}\right)^2$$

where I_f is the fraction of the beam that interacts in the target. For* a 2m LH_2 target, I_f = 0.29 for Σ and 0.25 for Ξ^-. Thus, for a $\Delta\sigma/\sigma$ = 1% measurement we require $0.48 \times 10^6 \Sigma$ events and $0.65 \times 10^6 \Xi$

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* For these estimates we use the recently measured $\Sigma^- p$ total cross section of 34.14 mb at 136.9 GeV/c and $\Xi^- p$ cross section of 29.35 mb at 133.8 GeV/c measured by Biagi et al, CERN EP/80-172. We assume the $\Sigma^+ p$ cross section is the same as $\Sigma^- p$.

events. With 5 pulses per minute and with sufficient flux to saturate our data collection system, a measurement at one energy could be done for $\Sigma^{\pm}$ in 0.33 days and for Ξ^- in 0.81 days. These times need be extended by a factor of $\sim$1.5 to include the deuterium running.

The Ξ^- fluxes at the higher momenta are not sufficient with the present shielding to saturate our data collection system. We expect the shielding to be installed for our winter run to improve this substantially. If this does not turn out to be the case we would measure the Ξ cross section in the energy region flux is adequate.

We plan to measure the Σ^+ and Ξ^- total cross sections on protons and neutrons at five energies from 125 to 350 GeV/c and with Ξ^- at three energies in that same range. This will extend by a factor of 2.5 the energy of the previous Σ^- and Ξ^- total cross sections. It will be the first measurement of the Σ^+ total cross sections. This will require about 400 hours of beam time. A machine energy of 400 GeV is requested with as long a beam spill as practical.

Table I

Trigger rates measured in Spring 1980 run. These numbers are for forward production and are scaled to a rate of $\sim 10^6$ per pulse in the drift chambers. They are limited entirely by muon backgrounds. For this run the accelerator operated at 350 GeV with 1.5sec beam spill.

Momentum	$\bar{\Sigma}$	Ξ	Total Secondary Beam Rate	Incident Protons
+200	2.7K		590K	0.38×10^{10}
-200	12	.75	220	3.2
-250	7.8	.23	51	3.7
-300	8.1	.12	21	5.5
-320	.9		2	6.3

Figure 1

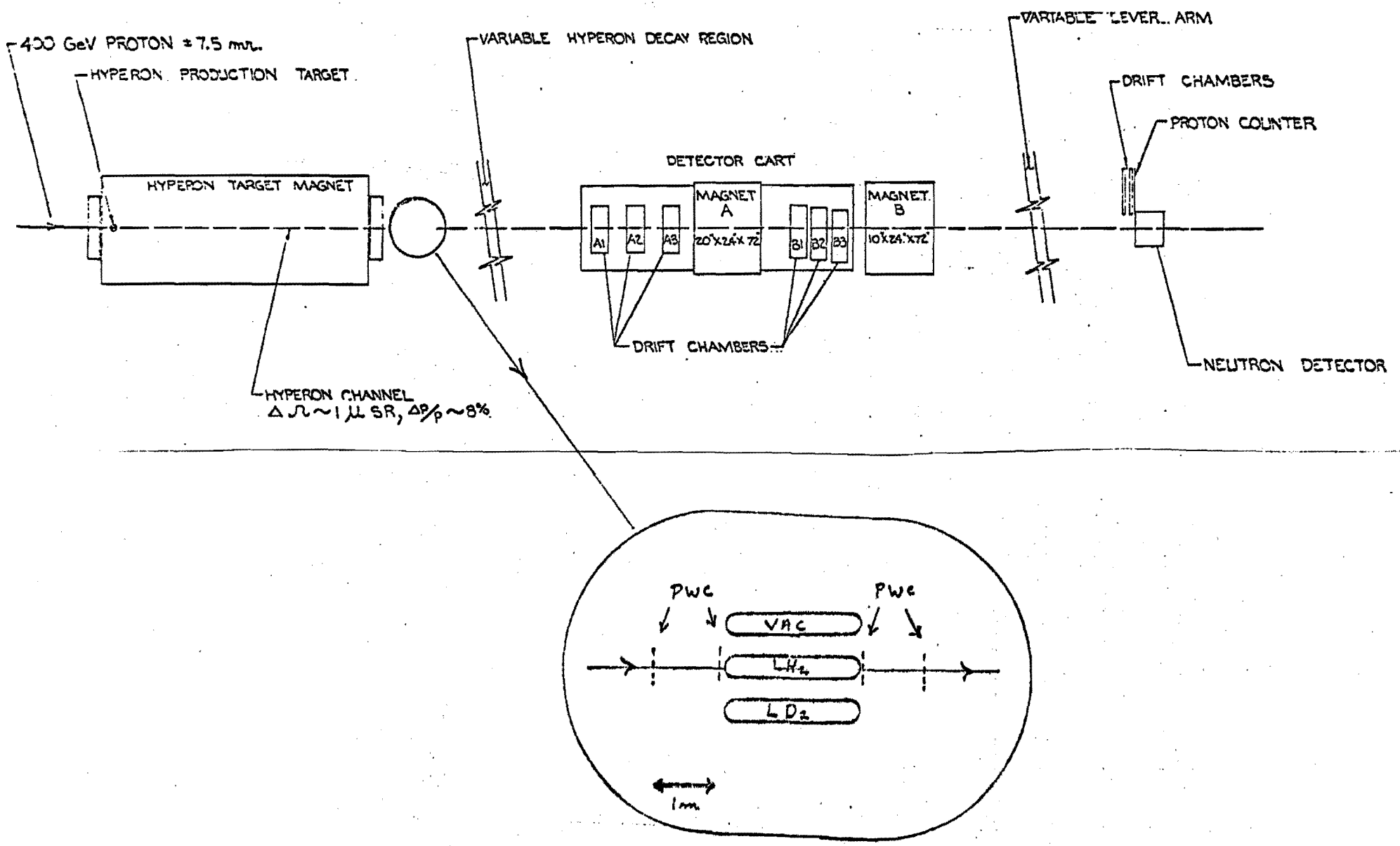
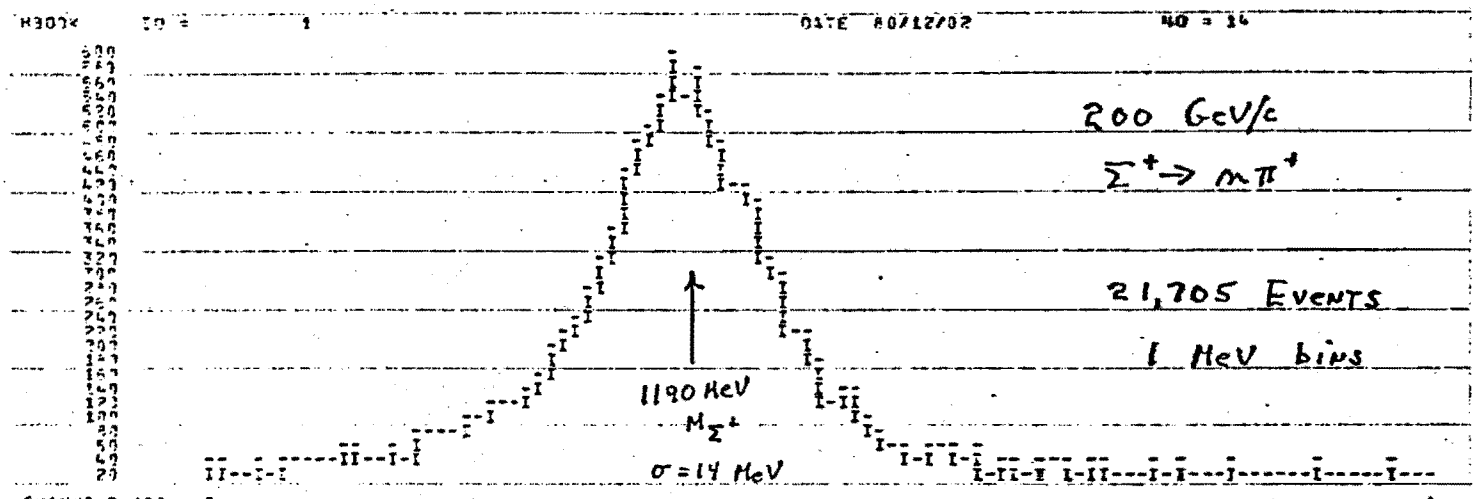
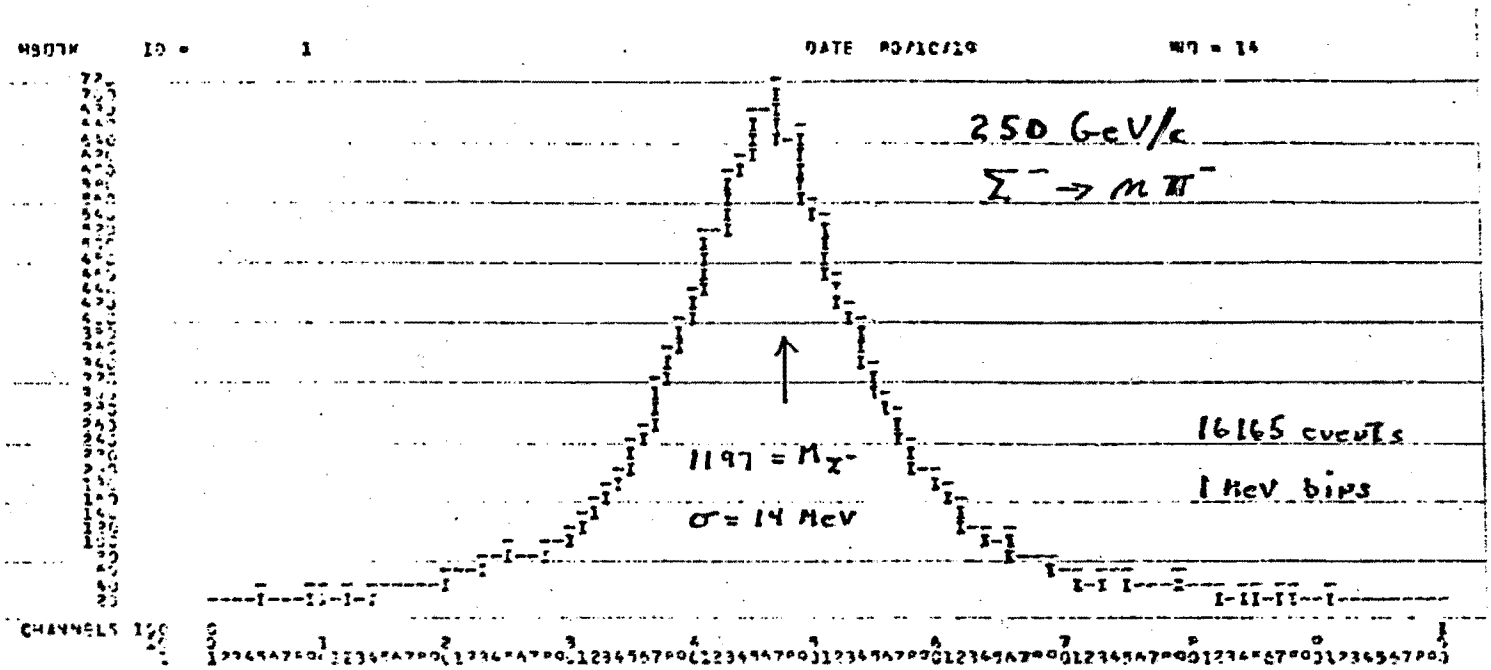

400 GeV PROTON ± 7.5 mr.
HYPERON PRODUCTION TARGET
HYPERON TARGET MAGNET
HYPERON CHANNEL
ΔΩ ~ 1 μ SR, Δp/p ~ 8%
VARIABLE HYPERON DECAY REGION
DETECTOR CART
A1
A2
A3
MAGNET A
20"x24"x72"
B1
B2
B3
MAGNET B
10"x24"x72"
DRIFT CHAMBERS
VARIABLE LEVER ARM
DRIFT CHAMBERS
PROTON COUNTER
NEUTRON DETECTOR
PWC
PWC
VAC
LH2
LD2
1m

Figure 2


200 GeV/c
$\Sigma^+ \to n\pi^+$
21,705 Events
1 MeV bins
1190 MeV
M_{Σ^+}
$\sigma = 14$ MeV


250 GeV/c
$\Sigma^- \to n\pi^-$
16165 events
1 MeV bins
$1197 = M_{\Sigma^-}$
$\sigma = 14$ MeV

Elastic Scattering of the Hyperons

A major component of the original E-497 proposal was to study the energy and hypercharge dependence of the forward slope in elastic hyperon proton scattering. The questions that proposal sought to provide answers to remain. There has been little change in the experimental situation since the results of the BNL experiment at 28 GeV performed by members of our group in the early seventies. (Ref. 1)

The discovery that hyperons are produced with substantial polarizations adds significantly to the physics which can be extracted from a study of elastic hyperon scattering. As an example, the production polarization of X=0.5 (P=200 GeV/c for 400 GeV/c protons on target) sigma+ at a production angle of 5mr is measured to be 22%. (Ref. 2) Recall that the decay mode sigma+ --> P + PIO has an analyzing power of 100%. This will allow us to measure the differential cross section, left-right asymmetry (equivalent to a polarized target experiment), final state polarization of the scattered hyperon, and total cross section (via the optical theorem). Thus we can make four of the nine possible measurements in sigma+ + P --> sigma+ + P from the same data sample. The other hyperons (sigma-, cascade-, omega-) are not as favorable in this regard, lacking either analyzing power, polarization or both. However, some spin dependent measurements should be possible with reduced precision for cascade- + P --> cascade- + P.

Experimental Configuration

The experimental configuration for the hyperon elastic scattering experiment is a variant of the configuration for the total cross section measurement. The differences are listed below.

1. 50cm LH_2 target (the existing E-69 target) in place of the three flask target for the total cross section measurement.
2. A recoil detector (described below) surrounding the LH_2 target to detect the recoil proton and reject inelastic events.
3. A hardware scatter detector (HSD) used in the trigger to detect scattered hyperons (described below).

The balance of the experiment remains unchanged from the total cross section configuration. The trigger, identification, and reconstruction of hyperons is the same as for the E-497 flux measurements, save for the scattering requirements of the recoil detector and HSD in the trigger.

New Apparatus Required

In order to trigger on elastically scattered hyperons we must be able to separate, at the trigger level, scattered from unscattered beam particles and elastic from inealstic scattering events.

The method we propose to use to reject unscattered beam tracks is shown schematically in Figure 1. The basic idea is to use a fast memory lookup to reject events for which the hits in high resolution multi wire proportional chambers (PWC's) are consistent with a straight line trajectory through the target. The current PWC read-out has latched wire data available 20nsec after a strobe is applied.

Using these signals as inputs the HSD first calculates the wire number of a cluster of two or three adjacent wire hits in each of the two PWC's upstream of the target. The resulting 12 bit number uniquely determines the point in phase space of the incident hyperon to within the resolution of the PWC's. This number is used as an address in a 4K x 128 bit fast memory. Stored in each memory location is a bit mask which determines the acceptance for each possible input phase space point. This mask is compared to the wire hit pattern in the last PWC downstream of the target to determine whether the beam particle scattered. Three identical systems (one each for x, y, and u) will detect all scatters with high efficiency and some redundency to allow for occasional extra hits in the PWC's. Such a system has been designed at Yale and a prototype is currently under construction. The current design has a maximum cycle time of 300nsec.

To distinguish elastic from inelastic scattering events we propose to build a recoil detector to completely surround the target. A conceptual schematic is shown in Figure 2. A detailed design is currently underway. The detector consists of a double layered phi hodoscope constructed of 0.5 inch x 60cm scintillators and 0.5 inch phototubes. Surrounding the phi hodoscope detects the recoil proton and allows us to reject events with more than one charged recoil particles at the trigger level and to use coplanarity as an elastic scattering constraint offline. The lead glass array serves to reject events with neutral recoil particles which decay electromagnetically. The rejection of inelastic events becomes rapidly more difficult with increasing $|t|$ since the elastic cross section goes as exp(bt) with B = 9 (GeV/c)**-2 and the inelastic

production increases with increasing |t|. For elastic scattering events with |t| > 0.44 (GeV/c)**2 the recoil proton is above Cerenkov threshold in lead glass. The number of Cerenkov photoelectrons produced varies from about 100 at |t| = 0.5 to about 400 at |t| = 1.0. Thus a measurement of the pulse height in the lead glass block through which the recoil proton passes gives both a fast trigger for high |t| events and, offline, a second |t| measurement which adds a extra constraint to the elastic scattering hypothesis.

The recoil detector will substantially reduce the background from inelastic events produced by target fragmentation. Beam fragmentation inelastic events will be rejected by the hyperon decay spectrometer downstream. A quantitative analysis of the rejections attainable with the above techniques is currently in progress.

Rates

Using the hyperon fluxes measured in our spring 1980 run (Table 1) and assuming 50% reconstruction efficiency for one track decays (sigma --> N + Pi) and 20% for three track decays (cascade --> Lambda + Pi --> P + Pi + Pi) we get the following rates of good reconducted elastic scattering events per day of running (5 pulses/min. 20 hours/day):

Sigma+	6.0E4/day
Sigma-	2.6E5/day
Cascade-	6.6E3/day
Omega-	10/day (?)

In the above table we have assumed that a tmin cut of 0.075 (GeV/c)**2 is applied by the HSD. This corresponds to half the elastic scattering cross section.

The lower limit of our |t| acceptance is determined by the angular resolution of the PWC's. For the geometry shown in Figure 1 the angular resolution is 200 micro radians. Requiring a scattering angle of at least three standard deviations gives a tmin = (3.6E-7) *P(GeV/c)**2 where P is the incident hyperon momentum in GeV/c. The |tmin| for which the HSD will generate good triggers can be made larger than the above minimum, but not smaller. The effective |tmax| acceptance is determined by the lack of cross section rather than geometrical acceptance. Assuming we take no more than 1.0E6 events at a given kinematical point the effective |tmax| is about 1.8 (GeV/c)**2 assuming that B = 9.0 (GeV/c)**-2.

Summary

We propose to measure the energy and hypercharge dependence of the forward slope in elastic hyperon proton scattering in the energy range 100 - 350 GeV. We will also study the left-right asymmetry and final state polarization for sigma+ + P --> sigma+ + P and cascade- + P --> cascade- + P for at least one incident momentum.

Requests

In order to carry out the measurements described above we will require the following:

1. The E-69 50cm LH_2 target refurbished and installed in the P-Center pit.
2. A recoil detector, as described above, including electronics (descriminators and latches for all PMT's, ADC's for Pb glass)
3. Three HSD systems, as described above.
4. 400 hours of beam in P-Center at intensities 2-10E10.

References

1. For a summary of the current experimental situation and references see "Hyperon Beam Physics", by J. Lach and L. Pondrom in annual reviews of nuclear and Particle Science, Vol. 29 (1979).

2. "Polarization of sigma+ hyperons produced by 400 GeV Protons" C. Wilkinson, et al., (submitted to PRL).

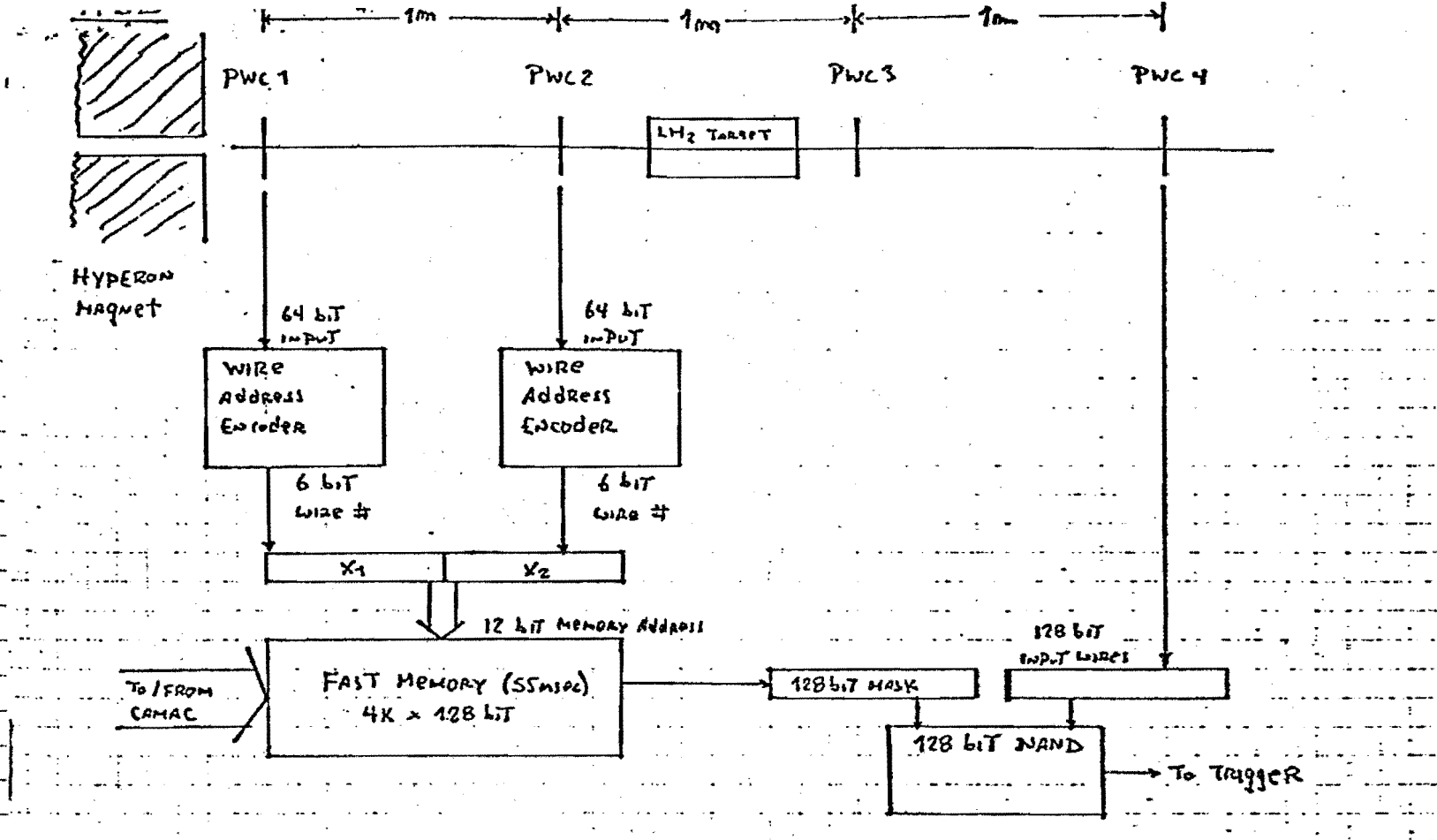
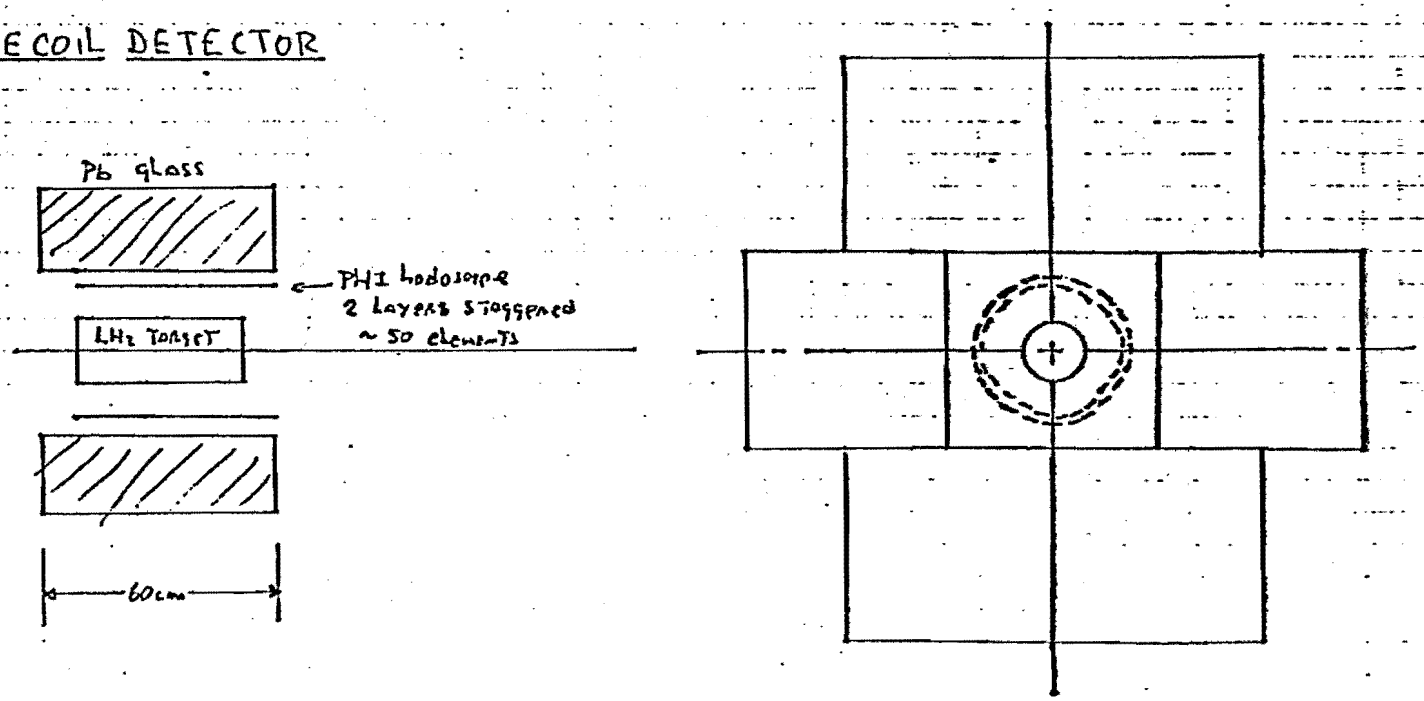


FIGURE 1

RECOIL DETECTOR



SCINTILLATORS 1/2" x 1/4" x 24"

PHOTOTUBES 1/2" HAMMAMATSU PMTs

Pb GLASS 12 blocks 6" x 6" x 14"

FIGURE 2.