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PROPOSAL TO STUDY Σ^-p AND Σ^-d INTERACTIONS AT 20 GeV/c WITH THE 2m BUBBLE CHAMBER

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Abstract.-

It is proposed to carry out a general study on Σ^-p and Σ^-n interactions at 20 GeV/c. Informations about diffraction dissociation, topological cross sections and statistical momenta of the charged multiplicities will be obtained and compared with other types of high energy reactions. It is also planned to study the inclusive, semi-inclusive and some of the exclusive reactions obtained from the Σ^-N interactions. As a by-product of the experiment, we will be able to study the elastic Σ^-p, Σ^-n and Σ^-d scattering and also the coherent production of Σ^- on deuteron.

A.- INTRODUCTION

In contrast to the large amount of data accumulated in non - strange baryon - baryon interactions, there is only a limited amount of information on ΣN reactions. We propose therefore to carry out a general study on ΣN interactions at 20 GeV/c using the 2m bubble chamber. As Σ^+ beams are more difficult to handle than Σ^- ones, we propose to study $\Sigma^- p$ and $\Sigma^- d$ interactions. To this end we would like to collect about 100,000 multiprong events (i.e., events having more than two charged outgoing particle for studying the $\Sigma^- p$ interactions. A similar amount of events is also requested for the study of the $\Sigma^- n$ interactions. The utilization of deuteron targets will also allow the study of $\Sigma^- d$ coherent production phenomena. As will be pointed out below this experiment would allow us to bring a significant contribution to the study of $\Sigma^- N$ interactions.

B.- SOME TECHNICAL ASPECTS CONCERNING THE EXPERIMENT

From previous investigations[1,2] it appears that an enriched Σ^- beam at 20 GeV/c can be provided although such a beam will be contamined mainly by π^-. This is not a great inconvenience for calculating the incident Σ^- flux which will be determined from the number of Σ^- decaying in the chamber (at 20 GeV/c the mean decay free path is about 75 cm). The π^- contamination of the beam due to the $\Sigma^- \rightarrow n\pi^-$ decays in front of the chamber will not really complicate the analysis of the data because these π^- are of low momentum (see Fig.1) and are hence easily recognizable in the bubble chamber. In any case the problems due to the beam contamination will be solved primarly at the scanning level. This is because we intend to record only events in which the observation of strange particles decay in the chamber. Further kinematical fitting of the events will then help in obtaining the final sample of $\Sigma^- N$ interactions.

In order to achieve the fitting of events we would like to have a beam with a momentum resolution of about 1% which appears to be feasible[2]. Such a resolution will allow us to handle easily the four constraint events, as shown by previous high energy experiments performed in the incident momentum range of 15 — 20 GeV/c. Furthermore it is also expected that some information about one constraint events will be obtained, at least when the neutral particle is a π^o. Indeed in this case the missing mass $[M_m^2(\pi^o)]$ of these reactions will also populate the $M_m^2(\pi^o) < 0$ region. The events in this region whenever they do no fit any other hypothesis can be considered as good candidates for studying the event category having a π^o in the final state. Such an event selection will of course complicate the cross section determination. Nevertheless some production features of these one constraint events can be studied.

C.- PHYSICS INTEREST

As already stated above the aim of the proposed experiment consists in making a general study or $\Sigma^- p$ and $\Sigma^- n$ interactions. As similar experiments[4] are planned at the SPS and at NAL the data at 20 GeV/c will be of great importance for studying the incident momentum dependence of the $\Sigma^- N$ interactions. In the following we will briefly discuss some aspects of the physics we intend to study.

1. Topological cross sections and multiplicities

The proposed experiment will offer us the possibility to measure topological cross sections and also the statistical momenta of the charged multiplicities. Comparisons between ΣN and pp or $\bar{p}p$ data will allow to evaluate the importance of the s - channel quantum numbers on the quantities mentioned above. In particular it will also be of interest to see whether or not $\Sigma^- N$ interactions at 20 GeV/c obey the KNO scaling property[5].

2. Inclusive reactions

Because of the size of the bubble chamber an important fraction of the produced strange particles will decay in the chamber. This will allow us to study in particular the inclusive reactions :

$$\begin{aligned} \Sigma^- N &\to \Sigma^{\pm} X \\ &\to \Lambda X \end{aligned}$$

(where X means anything). The comparison of the inclusive reactions obtained from the $\Sigma^- N$ with the pp data will be carried out. This will permit among other things to check the factorization properties of the inclusive reactions (i.e., by comparing for instance $pp \rightarrow pX$ with $\Sigma N \rightarrow pX$ or $\Sigma p \rightarrow \Sigma X$).

3. Diffraction dissociation

We also intend to study the diffraction dissociation of the incoming Σ^- and N particles which appears to play an important role in high energy production processes. Similarly to the dissociation of the $p \rightarrow N^*$ seen in pp interactions, it is expected that the $\Sigma^- \rightarrow Y_1^*$ will be produced abundantly. This will offer us the possibility of studying the production of resonances having the same isospin as the incoming Σ^- and to search for the SU(3) partner of the $N^*(1470)$. In fact, it has been predicted by Lipkin in a recent work[(6)] that there should be Y_1^* resonances not discovered as yet, which are primarly produced in the diffraction dissociation processes. As the incoming $\Sigma^- N$ system is exotic (in the sens that the baryonic number $B = 2$) the contribution of the leading exchange degenerate Regge trajectories are expected to cancel and the interactions will be dominated by Pomeron exchange. Then if the Pomeron is a pure SU(3) singlet the transition octet $\rightarrow$ decuplet will not be allowed by diffractive dissociation. Thus the study of $\Sigma^- N$ interaction may bring some additional information about the SU(3) nature of the Pomeron. Finally let us also point out that the proposed experiment will also allow us to see if helicity is conserved in the s or t channel. Furthermore as Λ will be present in some of the final states, polarization measurements of the Λ will lead to further information about diffraction dissociation mechanisms.

4. Correlation

The two particle correlation features are often used in high energy reactions for analysing the production process. Such a study will also be made here for inclusive, semi - inclusive and exclusive reactions. A comparison with other reactions may lead to a better understanding of high energy production phenomena.

5. Exclusive reactions

As stated above the momentum resolution we requested will allow us to handle the four constraint reactions. Some of the reactions which can be studied from this experiment are listed below ($m \geq 0$)

$\Sigma^- p \to \Sigma^- p (m+1)\pi^+ (m+1)\pi^-$

$\to \Sigma^+ p 2\pi^- m\pi^+ m\pi^-$

$\to \Sigma^- \Lambda K^+ m\pi^+ m\pi^-$

$\to \Lambda p \pi^- m\pi^+ m\pi^-$

$\to pp K^- \pi^- m\pi^+ m\pi^-$

$\to \Xi^- p K^+ \pi^- m\pi^+ m\pi^-$

$\Sigma^- n \to \Sigma^- p\pi^- m\pi^+ m\pi^-$

$\to \Sigma^+ p 3\pi^- m\pi^+ m\pi^-$

$\to \Sigma^- \Lambda K^o m\pi^+ m\pi^-$

$\to \Lambda p 2\pi^- m\pi^+ m\pi^-$

$\to pp K^- 2\pi^- m\pi^+ m\pi^-$

$\to \Xi^- \Lambda K^o m\pi^+ m\pi^-$

Any information on these channels will be of interest in itself because of the scarcity of existing data. Among other things a study of Y^* and Ξ^* production is anticipated. The Y^* resonances are expected to be abundant in the final state since in $\Sigma^- N$ interactions Y^* can be produced without strangeness exchange. In addition a search for Λp and $\Lambda\Lambda$ resonances, for which some evidence for their existence has been reported(7), will be made (such resonances may for instance populate the $\overline{10}$ SU(3) multiplet).

Although exotic resonances are predicted to be primarly coupled to the $\bar{N}N$ system(8) the proposed experiment is particularly suitable for searching exotic $\Sigma^-\pi^-$ resonant systems(9). For this one can for example use the simplest channel $\Sigma^- p \to \Sigma^- p\pi^+\pi^-$ (or even the subchannel $\Sigma^- p \to \Sigma^-\pi^-\Delta^{++}$) in which an outgoing $\Sigma^-\pi^-$ system appears. Furthermore a search for exotic t-channel exchange is particularly suitable in reactions having Σ^+ in the final state.

As an additional physics interest we can also mention that the reaction $\Sigma^- n \to \Sigma^- p\pi^-$ will permit obtaining information about $\pi\Sigma \to \pi\Sigma$ scattering if π exchange contributes to the $\Sigma^- p\pi^-$ production. Finally we also expect to study some of the production features of the one constraint events.

6. Utilization of the Fermi-motion in the $\Sigma^- n$ reactions

In the study of the $\Sigma^- n$ part of the experiment, the Fermi-motion of the neutron target will lead to a rather important c.m. energy spread (see Fig. 2). Thus for certain high cross section channels, some information about then c.m. energy dependence can be obtained.

7. Coherent production

A fraction of Σ^-d interactions will lead to reactions coherently produced on deuterium. The study of coherent production phenomena, will allow us to analyse the systems emitted in a pure isospin $I = 1$ state : i.e., those recoiling against the deuteron. An estimation of the cross sections can be made assuming that coherent production phenomena are nearly independent of the type of the incident particle and incident momentum. This in any case appears to be verified by the $pd \to pd\pi^+\pi^-$ and $\bar{p}d \to \bar{p}d\pi^+\pi^-$ reactions in the 5.5 — 15 GeV/c incident momentum region[10]. Using then the $\bar{p}d \to \bar{p}d\pi^+\pi^-$ cross section at 15 GeV/c, we will have available of about 2000 $\Sigma^-d \to \Sigma^-d\pi^+\pi^-$ events. This number is obtained by the same method as that described in Section D.

7. Miscellaneous

As a by - product of the proposed experiment, we will also measure the Σ^-p and Σ^-d elastic scattering from which some information about the ΣN isospin amplitudes will be gained. Some knowledge about backward elastic ΣN scattering and total Σ^-N and Σ^-d cross section will also be obtained.

D.- NUMBER OF EVENTS AND SCHEDULE OF THE ANALYSIS

The total Σ^-N cross section $[\sigma_t(\Sigma^-N)]$ can be estimated from the relations

$$\sigma_t(pn) - \sigma_t(\Sigma^-p) = \sigma_t(\pi^+p) - \sigma_t(K^-n)$$

$$\sigma_t(pn) - \sigma_t(\Sigma^-n) = \sigma_t(\pi^-p) - \sigma_t(K^-p)$$

deduced from the quark model[11]. One obtains thus that $\sigma_t(\Sigma^-p) \simeq \sigma_t(\Sigma^-n) \simeq 35$ mb. If one assumes that the fraction of the two pronged events in Σ^-p interactions is equal to that observed in pp interactions at 20 GeV/c, we will have a cross section of about 18mb for the reactions having more than two outgoing particles. Based on this cross section one can estimate the number of photographs necessary to obtain 100,000 multiprong Σ^-p interactions. For this purpose we will chose a fiducial volume as shown in Fig.3. This ensures that the direction of the incomong Σ^- track as well as the momenta of the charged decay tracks can still be measured. We can obtain in this fashion 100,000 events with 500,000 photographs and 12 Σ^- entering in the chamber for each burst. These values are obtained by taking into account the corrections due to the path length attenuation of the incident Σ^- decaying in the chamber and also that introduced by our scanning criteria. This last correction was estimated from the $\Sigma^- p \to \Sigma^- p\pi^+\pi^-$ reaction simulated by generating events peripherally by a Monte Carlo method[12]. The number thus obtained is some kind of average because the outgoing Σ^- are expected to have a smaller laboratory momentum for high multiplicity events whereas the produced Λ have a longer life time than the Σ^-. For the $\Sigma^- d$ part of the experiment we also require 500,000 photographs. Only 1/3 of the $\Sigma^- n$ interactions will have a visible spectator proton stopping in the chamber. This is not a great inconvenience for the study of the four constraint events which is one of the most interesting aspect of the $\Sigma^- d$-part of the proposed experiment. Assuming that $\Sigma^- p$ and $\Sigma^- n$ interactions have nearly equal cross sections we also expect to obtain 100,000 $\Sigma^- n$ events having at least 3 particles in the final state (we neglects here the $\Sigma^- d \to \Sigma^- pn$ breackup reaction). The statistics which would be obtained by this experiment can be easily handled by the collaborating laboratories. All the three groups have a scanning capacity sufficient for treating 10^6 pictures. Moreover part of the CERN spiral reader and the Strasbourg HPD in addition to conventional measuring machines will be devoted to this experiment. The most interesting physical aspects of the experiment are expected to be obtained within 18 months after the realization of the experiment.

References

1). CERN/TCC 70 - 37 Report

2). The construction of Σ^- beam for a bubble chamber experiment does not seems to need a big investment. Furthermore it appears that a beam of 20 GeV/c with about 1% momentum resolution can be provided although some further investigation is necessary. Lazeyras, Private communication

3). Such an 1% resolution is for instance used for analysing the $\bar{p}d$ interactions at 15 GeV/c (Rutgers - Stevens - Strasbourg collaboration).

4). At the SPS there is a proposal (SPC/P 73 - 2) for studying the $\Sigma^- p$ interactions in the 75 - 150 GeV/c range while at NAL (proposal N°214) a similar experiment is planned at 50, 100 and 200 GeV/c.

5). Z. Koba, H.B. Nielsen and P. Olesen, Nucl. Phys., B40, 317 (1972)

6). H.J. Lipkin, Phys. Rev., D7, 846 (1973)

7). R.D. Tripp, Proceedings of the Int. Conf. on High Energy Physics, Vienna, 1968, p. 173
P. Beilliere et al., Phys. Letters, 39B, 671 (1972)
G. Alexander, O. Benary, Amsterdam Conference, 1971

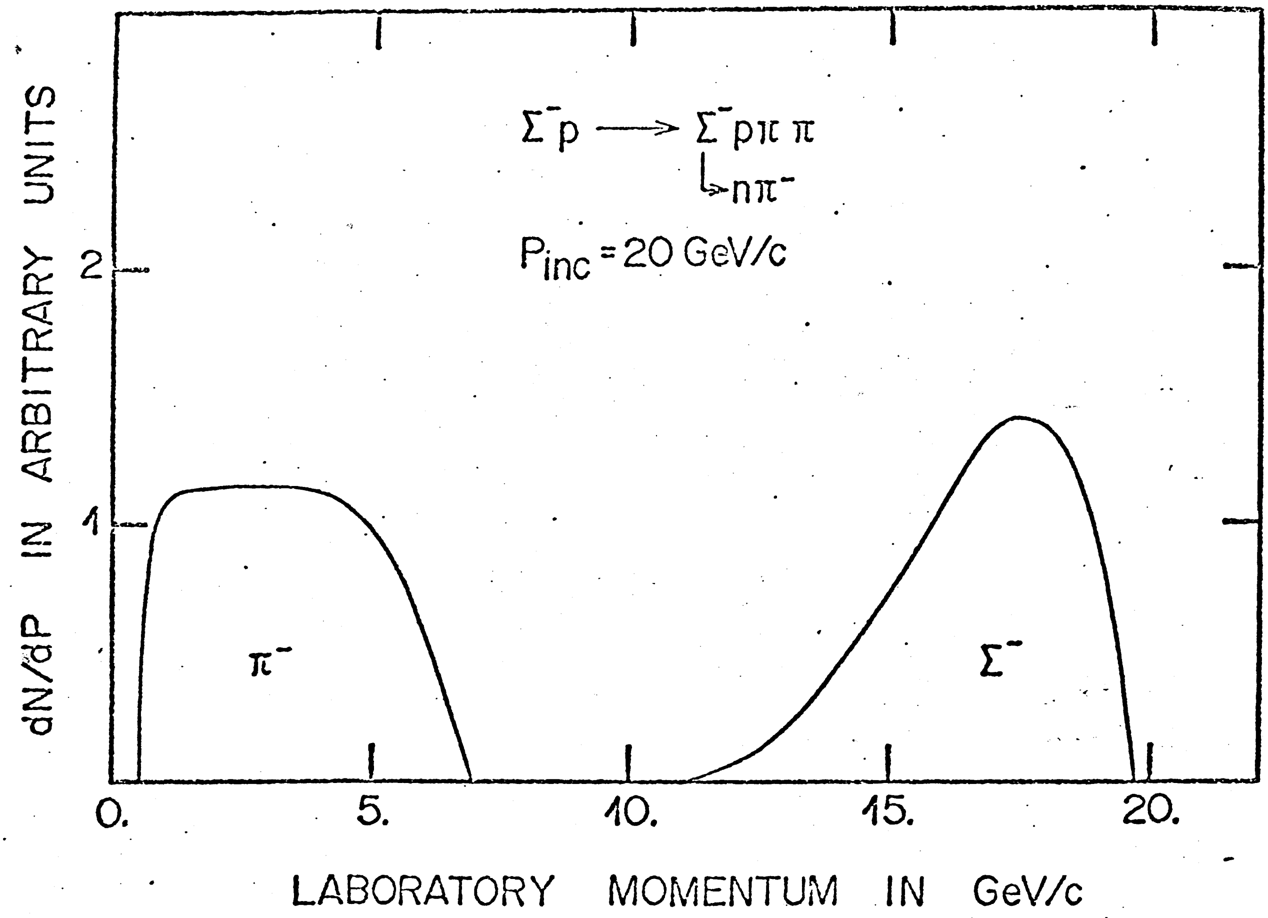
8). J. Rosner, Phys. Rev. Letters, 21, 950 (1968)

9). Some evidence for a $\Sigma^-\pi^-$ system have been reported by Y.L. Pan and R.P. Ely, Phys. Rev. Letters, 13, 277 (1964)

10). The $\bar{p}d\pi^+\pi^-$ final state coherently produced by 14.6 GeV/c antiprotons, Rutgers - Stevens - Strasbourg collaboration, D. Brick et al., to be published in Il Nuovo Cimento, 1974.

11). H.J. Lipkin, Phys. Rev., 174, 2151 (1968)

12). This means that each generated event was weighted by a peripheral $e^{bt_1} \times e^{bt_2}$ factor where $b = 8 (\mathrm{GeV/c})^{-2}$ is taken from pp data at 20 GeV/c. Here t_1 (t_2) is the four momentum transfer between the incoming and outgoing Σ^- (p).



<u>Figure 1</u>

Momentum distributions (dN/dP) of the outgoing Σ^- and the π^- coming from the $\Sigma^- \rightarrow n\pi^-$ decay. The $\Sigma^- p \rightarrow \Sigma^- p\pi\pi$ reaction was simulated by generating Monte Carlo events weigthed each by a peripheral $e^{bt_1} \times e^{bt_2}$ factor with $b = 8(\mathrm{GeV/c})^{-2}$. Here t_1 (t_2) is the four momentum transfer between the incoming and outgoing Σ^- (p).

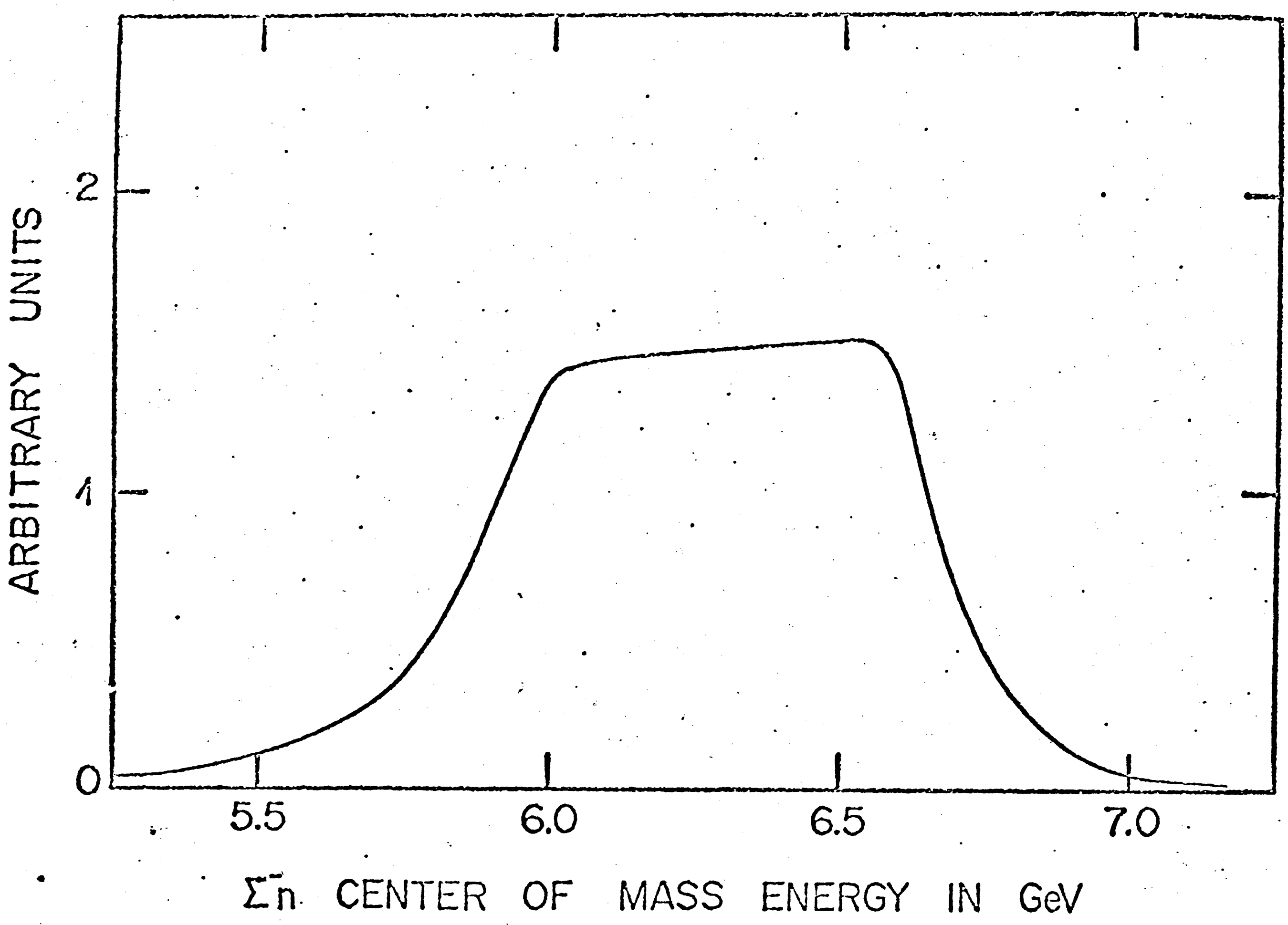
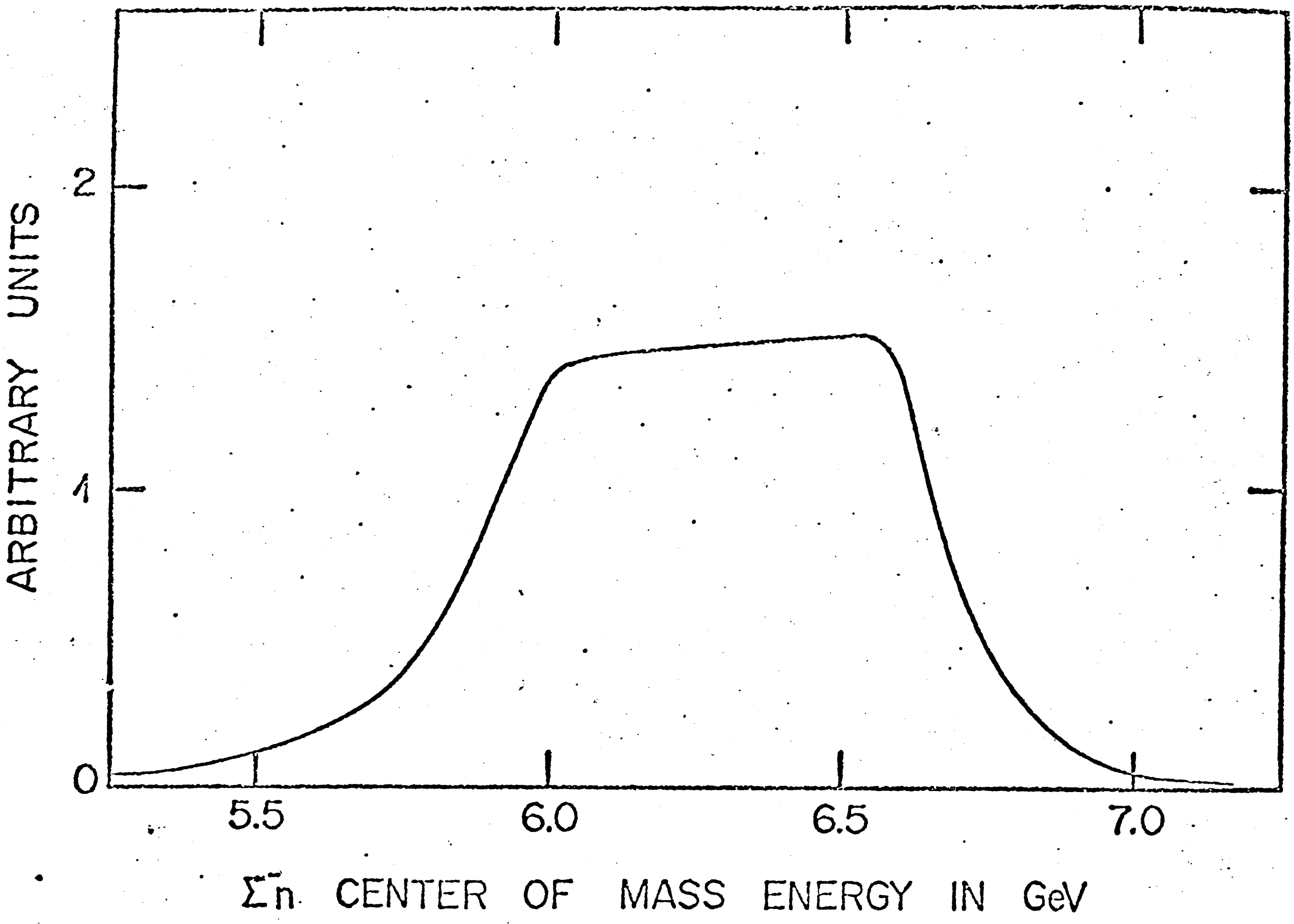


Figure 2

The $\Sigma^- n$ c.m. energy distribution for the events having, a visible proton spectator stopping in the chamber. In order to cover such a c.m. energy interval with a nucleon at rest in the laboratory system one needs a Σ beam having a momentum in the range of 17 – 23 GeV/c



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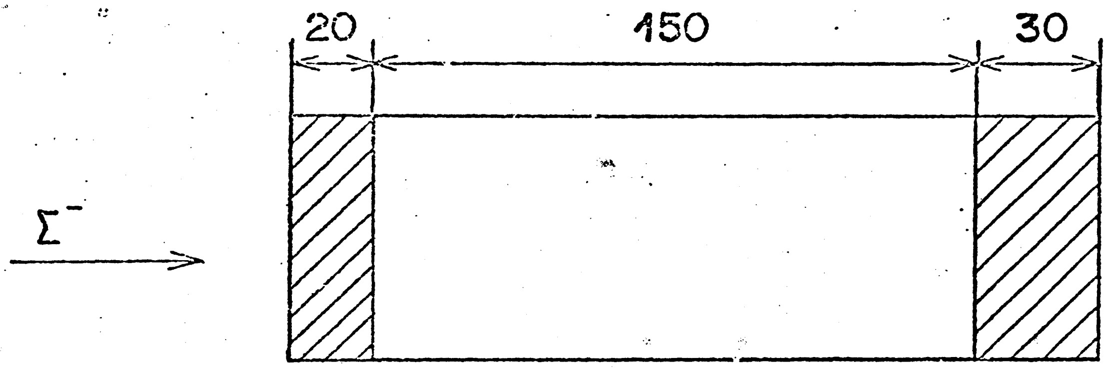

Figure 3

The unshaded area represents the chosen fiducial region in which the interaction and the decay of the outgoing strange particle have to take place. This choice will allow us to measure the incoming Σ^- track as well as the momentum of the outgoing decay tracks.