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ELECTRONICS EXPERIMENTS COMMITTEE

PROPOSAL

TO STUDY THE "EXOTIC EXCHANGE" REACTIONS $\pi^- p \rightarrow K^+ \Sigma^-$ and $\pi^- p \rightarrow d\bar{p}$

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INTRODUCTION

We propose an experiment to study the two reactions

$$\pi^- p \to K^+ \Sigma^- \qquad (K^+ \text{ forward}) \qquad (1)$$

$$\pi^- p \to d\bar{p} \qquad (\text{deuteron forward}) \qquad (2)$$

which present an "exotic" t-channel, at 5 and 8 GeV/c incident pion momentum. In the first part of our proposal we will briefly recall the physical aim and the experimental knowledge we have about these reactions. The second part presents the experimental method and apparatus we intend to use, and the background problem is discussed. The third part puts forward our needs at CERN and a proposed time-table.

PART I

1. PHYSICAL INTEREST

The effects of cut contributions, in hadron collisions, have become more and more important$^{1)}$ since the measurement$^{2)}$ of a non-zero polarization in the charge exchange process $\pi^- p \to \pi^0 n$ at high energy, which cannot be explained by the Regge-pole contribution alone. The experiments which have been performed up to now with good accuracy are studies of reactions where the cut contribution appears as a competitive phenomenon between cuts and usual trajectories; this situation has two disadvantages:

i) the cut contribution, in order to be understood, has to be separated from others and appears as a perturbation;

ii) the cuts introduced in reactions where usual trajectories are allowed, are of the type "Pomeron × Regge", which is not very satisfactory since one does not know precisely what the Pomeron is.

As Phillips pointed out, as early as 1967 $^{3)}$, a direct way to investigate cuts of the type "Regge × Regge" is to study processes which proceed through an exchange of "exotic" quantum numbers.

Berger$^{4)}$ has noted that when there are more than two bodies in the final state, it is difficult to select the true "exotic" exchange owing to the possible kinematic reflections. Therefore, the simplest way to study exotic exchanges is to look at real two-body processes.

We have chosen two reactions induced by pions [reactions (1) and (2)] because the high flux one can get with pion beams gives the possibility of observing the expected small cross-sections with good statistics.

2. OUR OBJECTIVE

We propose to measure the behaviour of the forward differential cross-section at 5 and 8 GeV/c incoming pion momentum.

The momentum transfer range covered will be:

$t_{min} > -t > 0.3$ $(GeV/c)^2$ for reaction (1) at 5 GeV/c

$t_{min} > -t > 0.35$ $(GeV/c)^2$ for reaction (1) at 8 GeV/c

$t_{min} > -t > 0.85$ $(GeV/c)^2$ for reaction (2) at 5 GeV/c

$t_{min} > -t > 0.9$ $(GeV/c)^2$ for reaction (2) at 8 GeV/c

This will answer the questions regarding:

a) the presence of a forward peak;

b) the energy dependence of $(d\sigma/dt)_{t=0}$;

c) the presence of a forward dip, as in the πp or Kp charge exchange processes; and

d) if the shape of the differential cross-section is e^{at}, the value of "a".

Michael^5) has remarked that, if the reaction is described by the exchange of a still undiscovered "exotic" particle, this particle should be heavy (if not it should have been seen). Therefore, if its trajectory is parallel to the other known trajectories, the intercept with zero will be very low. In the case of reaction (1), the "exotic" particle will be a K^* $(I = 3/2)$. If one assumes that the spin-0 state has a mass of 1700 MeV, one obtains $\alpha(0) = -3$, while if the reaction is governed by a cut exchange, one will expect^5,6) an intercept

$$\alpha(0) \approx \alpha(0)_1 + \alpha(0)_2 - 1 \ ,$$

where α_1 and α_2 are the two trajectories involved in the double exchange. In the case of reaction (1), which can be described by a "$\rho \times K^*$" cut (see Fig. 1)

$$\alpha(0)_1 = \alpha_\rho(0) \simeq 0.5$$

$$\alpha(0)_2 = \alpha_{K*}(0) \simeq 0.2$$

and we obtain $\alpha(0) \approx -0.3$.

In case of "exotic particle exchange", one then gets the prediction

$$\left(\frac{d\sigma}{dt}\right)_{t=0} \propto \left(\frac{s}{s_0}\right)^{-8} ,$$

while in the case of a cut one gets$^{6)}$

$$\left(\frac{d\sigma}{dt}\right)_{t=0} \simeq \frac{\left(\frac{s}{s_0}\right)^{2[\alpha_1(0)+\alpha_2(0)]-4}}{\log\left(\frac{s}{s_0}\right)^2} = \frac{\left(\frac{s}{s_0}\right)^{-2.6}}{\log\left(\frac{s}{s_0}\right)^2} .$$

Figure 2, where we have normalized the two predictions at 5 GeV/c, shows that they differ by a factor of five between 5 and 8 GeV/c.

An interesting prediction has been found by Dean$^{7)}$ in the frame of a simple quark model. Assuming that the two elementary reactions involved in the double exchange are of the form

$$\frac{d\sigma}{dt} = A\,e^{at} \quad \text{and} \quad \frac{d\sigma}{dt} = B\,e^{bt} ,$$

he obtains for the double exchange

$$\frac{d\sigma}{dt} = \frac{AB}{(A+B)^2}\,e^{(ab/a+b)t} .$$

Reaction (1) (cf. Fig. 1) involves the π^-p charge exchange, for which $a \approx 11$ $^{8)}$, and the associated production reaction

$$\pi^0 n \to K^+\Sigma^- .$$

Assuming that the slope of $\pi^-p \to K^0\Sigma^0$ is identical to $\pi^0 n \to K^+\Sigma^-$, one has $b \simeq 7$ $^{9)}$ and consequently a slope of about 4 $(\mathrm{GeV/c})^{-2}$ for the double exchange. Our experiment will be a good check of these simple hypotheses of Dean and Michael.

3. OUR EXPERIMENTAL KNOWLEDGE ABOUT TWO-BODY EXOTIC EXCHANGES

Up to now our knowledge is quite poor and is based on very low statistics$^{10)}$. The only observed forbidden peaks are in the reaction

$$\bar{p}p \to \overline{\Sigma^-}\,\Sigma^- \qquad (K^* I = {}^3\!/_2 \text{ exchange})$$

for which the CERN fast $\bar{p}$ group$^{11)}$ observed 12 well-identified events, corresponding to a cross-section of 1.3 ± 0.4 μb at 5.7 GeV/c incident $\bar{p}$ momentum (see Fig. 3). A second forbidden peak has been reported by Lehmann$^{12)}$ in the K^-p backward elastic scattering at 5 GeV/c K^- incident momentum:

$$K^-p \to pK^- \qquad (Z^* \text{ exchange}) .$$

This peak was a preliminary result of a spark chamber experiment, and corresponds to a cross-section of 0.1 μb (integrated over the peak) based on 30 observed events.

4. WHAT CAN WE EXPECT?

4.1 Reaction (1)

The reaction $\pi^-p \to K^+\Sigma^-$ has been studied with bubble chamber techniques$^{13)}$ at momenta up to 4 GeV/c.

This experiment shows that the Σ^- is strongly emitted forward, and that the total cross-section falls as $p_{\text{lab}}^{-3.8}$ as for a baryon exchange mechanism. Figure 4 shows the behaviour of the total $\pi^-p \to K^+\Sigma^-$ cross-section found in this experiment. This figure shows the same result, but limited to the forward hemisphere (i.e. for $0 < \cos\theta_{K^+} < 1$ in the c.m.s.). From these plots one sees that it is difficult to get a prediction just by extrapolating the results, therefore we propose two estimates:

Hypothesis 1: The last three points indicate a cut effect, and then the cross-section (K^+ forward) for $p_{\pi^-} > 4$ GeV/c is decreasing slowly with energy. We call this estimate "optimistic"; this leads us to

$$\sigma\ (K^+ \text{ forward})\ \text{optimistic} \approx 0.35\ \mu\text{b at 5 GeV/c}$$
$$\sigma\ (K^+ \text{ forward})\ \text{optimistic} \approx 0.1\ \mu\text{b at 8 GeV/c}$$

Hypothesis 2: The last three points indicate nothing and are just statistical fluctuations; the cross-section falls with the same slope. We call this estimate "pessimistic"; it gives

$$\sigma\ (K^+ \text{ forward})\ \text{pessimistic} \approx 0.04\ \mu\text{b at 5 GeV/c}$$
$$\sigma\ (K^+ \text{ forward})\ \text{pessimistic} \approx 0.003\ \mu\text{b at 8 GeV/c.}$$

4.2 Reaction (2): $\pi^- p \rightarrow d\bar{p}$

To our knowledge, this reaction has only been studied by one group, in 1963 14). The cross-section has been found to be 16 ± 10 μb at 4.13 GeV/c and 8^{+12}_{-8} μb at 4.95 GeV/c. These momenta are not far from threshold, which is 3.74 GeV/c, so one can expect considerable fluctuations with energy. Another point is that no angular distribution has been obtained, therefore we cannot predict what we will observe when the deuteron is emitted forward. Our experiment will therefore be an exploration of this reaction.

PART II

1. EXPERIMENTAL METHOD

1.1 The apparatus

The experimental set-up we intend to use is shown schematically on Fig. 5.

The π^- beam, with a flux of 10^6 π^- per PS cycle enters the 60 cm long 4 cm diameter H_2 target. The direction of the incoming π^- is recorded by two sets of proportional chambers.

The H_2 target is surrounded by two 12-element cylindrical hodoscopes, the inner being sensitive to charged particles and the outer one, made of a lead-scintillator sandwich, to γ-rays. We have calculated on the assumption that they are 70% efficient for γ-ray detection and 5% efficient for neutron detection. A second set of γ detectors (80% efficiency) is placed in front of the bending magnet, covering the whole solid angle where γ-rays may escape, except the forward region where the beam and the forward accepted K^+ and d go through. The charged particles emitted forward are analysed in momentum and direction by a standard CERN 2 m bending magnet placed between two sets of proportional chambers
The magnet bends positive particles towards three telescopes, and the hot π^- beam on the other side. The three telescopes are identical and consist of three threshold Čerenkov counters each (one detecting the kaons and two set on pions) providing a rejection against pions of 10^{-4}.

The acceptance of this apparatus has been calculated by the Monte Carlo method and is shown as a function of the momentum transfer in Fig. 6.

1.2 The electronic decision

The decision to record an event will be made at two levels:

- by a counter logic
- by a correlation between two wire planes.

1.2.1 Counter logic

Let us define some logic signals:

P : one pion entering the target;

C_0 : no charged particle in the inner cylindrical hodoscope;

C_1 : one and only one charged particle in the inner cylindrical hodoscope;

C_B : one or more charged in backward direction, outside of the inner cylindrical hodoscope;

T : one charged in one and only one telescope;

Γ : one or more γ-rays detected around the target by the outer hodoscope or by the γ detector in front of the magnet;

K : a kaon signal from one and only one telescope;

π : a pion signal comes from one or more telescopes.

Thus the counter logic conditions for reaction (1) will be:

$$R_1 = (P) \times (C_1) \times (\bar{\Gamma}) \times (K) \times (\bar{\pi}) \times (T)$$

and for reaction (2)

$$R_2 = (P) \times (C_1 \text{ or } C_0) \times (\bar{\Gamma}) \times (\overline{C_B}) \times (\bar{K}) \times (\bar{\pi}) \times (T) ,$$

where (A) × (B) means condition A and condition B true, $\bar{A}$ meaning condition A false. We discuss below the background induced in such trigger conditions by reactions other than reactions (1) and (2).

1.2.2 The correlation

Let us define y_1 and y_2, the ordinate before and after the magnet, of the forward K^+ or d, in the direction perpendicular to the beam axis in the horizontal plane.

A given y_1 corresponds to an angle θ of emission with respect to the beam line with a certain uncertainty $\Delta\theta$ ($\Delta\theta$ depending on beam size and divergence, target size, and gap height of the magnet). For a simple two-body reaction, a fixed θ corresponds to a defined momentum, so a particle emitted in such a collision and entering the magnet at an ordinate y_1 emerges at a point $y_2 \pm \Delta y_2$.

Figure 7 is an illustration of this correlation effect in the two-body case of reaction (1) $\pi^- p \to K^+\Sigma^-$ at 5 GeV/c and in the case of the reaction

$$\pi^- p \to \phi n \qquad (K^+ \text{ detected by the telescopes}) .$$
$$\hookrightarrow K^+K^-$$

This figure is the result of a Monte Carlo calculation, taking into account all the resolution effects.

Measuring y_1 and y_2 with two wire planes of Charpak-type chambers and a diode matrix, we will know if the correlation condition is fulfilled within less than 1 μsec. We intend to use this condition as a precaution to reduce the number of triggers and thus the beam time lost in reading out the chambers. The effects of this correlation condition on the trigger rates is discussed below.

1.3 The background problem

In Part I we have seen that the cross-sections we are looking for are of the order of several per cent of a microbarn. At this level the background induced by all the dominant allowed reactions has to be carefully taken into account.

1.3.1 Background in the $K^+\Sigma^-$ final state

a) Induced by two-body reactions

If one considers the associated production reaction

$$\pi^- p \to K^0 \Lambda^0 \ (\Sigma^0) \ ,$$

where the K^0 is strongly emitted forward[9], it produces a K^0 beam in the target which, by the reaction

$$K^0 p \to K^+ n \ ,$$

produces K^+ with the same kinematical properties as K^+ of reaction (1). For a 60 cm long H_2 target, one gets an "apparent" cross-section for this double process of 0.09 μb at 5 GeV/c. This is the most dangerous reaction, since it has the same order of magnitude as expected for the $K^+\Sigma^-$ final state and the same reconstructed invariant mass.

As shown in Table 1, our two cylindrical hodoscopes suppress this contribution strongly.

b) Induced by a K^+ associated with two or more bodies

We have mainly used the work of Dahl et al.[15], which is a systematic study of strange particle production in $\pi^- p$ collisions at momenta up to 4 GeV/c, as an input to our calculation.

Selecting all their observed final states where a K^+ is present, we have simulated with a Monte Carlo program 20 different multi-body final states representing the different configurations in a pessimistic way$^{16)}$. The corresponding contamination is summarized in Table 1.

c) Induced by pions and protons

Assuming that a proton has a 1% chance to give a signal in the kaon Čerenkov counter, we have simulated through our apparatus the elastic $\pi^- p$ backward scattering and the backward production of ρ^- and A_2^-. The contamination due to π^+ emitted forward has been estimated, assuming that it comes mainly from the reactions

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

and

$$\pi^- p \to \pi^+ \pi^- \; N^*(1236) \; (N^* \to \pi^0 n)$$

taking into account the rejection of 10^{-4} against pions of our telescopes. Table 1 summarizes all these contaminations.

1.3.2 Background in the $d\bar{p}$ final state

We ensure with our trigger that the positive particle detected in the telescope is heavier than a kaon; therefore it can be either a proton or a deuteron. The reaction of the type

$$\pi^- p \to p + X^- \qquad \text{(p emitted forward)}$$

will then be a background. This background is a problem if the X^- mass is such that, when reconstructed assuming that the forward proton is a deuteron, it falls into the range of the proton mass. This ambiguity appears at 5 GeV/c when X^- has a mass around the A_2 mass. Nevertheless, the final state is then a multipion system which is strongly rejected by our target hodoscope counters.

We have estimated the background we will obtain due to the reactions

$$\pi^- p \to p\pi^- \qquad \text{(proton forward)}$$

$$\pi^- p \to p\rho^- \qquad \text{(proton forward)}$$

$$\pi^- p \to pA_2^- \qquad \text{(proton forward)}$$

The results are presented in Table 2.

1.4 Conclusion of the background problem, the trigger rate

Tables 1 and 2 show the number of counts expected during 5 PS days with a safety factor of π, i.e. for 5×10^{10} incident pions. These results have been obtained with the following hypothesis:

- Precision on incident momentum $\Delta p/p = \pm 0.7\%$.
- Precision $\Delta p/p = \pm 1\%$ in momentum analysis in the spectrometer.
- At 8 GeV/c the cross-sections of all background processes can be deduced from lower energies using the Morrison law[17)] $\sigma \propto p^{-n}$, where

  $n = 1.5$ for non-strange meson exchange
  $n = 2$ for strange meson exchange
  $n = 4$ for baryon exchange.

- The shape of the differential cross-section for our two reactions is of the form:

  $$\frac{d\sigma}{dt} \propto e^{4t} ,$$

  which is Dean's prediction[7)] for reaction (1) (t being the momentum transfer between the incident pion and the forward-emitted particle K^+ or deuteron).

- For reaction (1) we have taken into account the possible presence of a forward dip in the cross-section by reducing it by an arbitrary factor of 40%. The cross-section is then:

  σ_{opt} = 0.21 μb at 5 GeV/c
  " = 0.06 μb at 8 GeV/c
  σ_{pess} = 0.023 μb at 5 GeV/c
  " = 0.0018 μb at 8 GeV/c

- For reaction (2) the cross-section was assumed[*)] to be:

  optimistic = $\sigma(\pi^- p$ elastic backward$) \times 0.1$
  pessimistic = $\sigma(\pi^- p$ elastic backward$) \times 0.01$
  at 5 and 8 GeV/c.

We then reach the following conclusions:

The background events are rejected at three different levels:

[*)] Optimistic and pessimistic refer to the possibility of our apparatus.

i) The counter logic around the target has a very strong effect on the highly dangerous background reactions, and reduces the over-all background trigger rate by a factor of 7 at 5 GeV/c and a factor of 12 at 8 GeV/c.

ii) The correlation y_1/y_2 acts only on the over-all background trigger rate, reducing it by a factor of 3 at 5 GeV/c and a factor of 2 at 8 GeV/c.

iii) The analysis will reject events that show, in the chambers placed between the target and the spectrometer magnet, more tracks than would correspond to the event. This third level acts on the dangerous background reactions and reduces the number of candidates by a factor of 1.4 at 5 GeV/c and a factor of 2 at 8 GeV/c.

Figures 8, 9, 10, and 11 show the over-all missing-mass spectrum expected, after these three levels of rejection, in the optimistic cases defined above for reactions (1) and (2) at 5 and 8 GeV/c. The normalization is for 5×10^{10} incident pions.

2. CONCLUSION

In 20 days running at 5 GeV/c and 30 days at 8 GeV/c, we expect to reach the following numbers of events:

Reaction (1): $\pi^- p \to K^+ \Sigma^-$

optimistic: 5 GeV/c, ≃ 20,000 good events + 15% contamination
pessimistic: 5 GeV/c, ≃ 800 good events + 17% contamination
optimistic: 8 GeV/c, ≃ 10,000 good events + 15% contamination
pessimistic: 8 GeV/c, ≃ 300 good events + 85% contamination

Reaction (2): $\pi^- p \to d\bar{p}$

optimistic: 5 GeV/c, 35,000 good events + 7% contamination
pessimistic: 5 GeV/c, 3,500 good events + 40% contamination
optimistic: 8 GeV/c, 30,000 good events + 4% contamination
pessimistic: 8 GeV/c, 2,500 good events + 20% contamination

By contamination we mean background/(good events + background), background being the unwanted events surviving all cuts.

We will then be able to obtain the differential cross-sections, except for reaction (1) at 8 GeV/c in the pessimistic case ($\sigma = 1.8 \times 10^{-3}$ μb) where the background contribution will be too high.

PART III

1. OUR NEEDS FROM CERN

In order to perform this experiment, we will request from CERN:

i) a standard 2 m magnet;

ii) a $\pi^{\pm}$ beam of 10^6 π^- per PS cycle, working in the energy range 5-8 GeV/c. The π^+ will be used during a short period in order to calibrate the apparatus with the well-measured reaction $\pi^+ p \rightarrow K^+ \Sigma^+$.

2. BEAM REQUEST AND TIME-TABLE

Our beam request will be:

i) 3 weeks for testing the whole apparatus;

ii) 7 weeks for data taking.

If a positive decision is taken by the EEC before February 1971, we will be ready to install the whole apparatus and start the tests at Easter 1972.

Table 1a

Expected signals for 5 × 10^{10} incident pions as calculated
including all the background contributions for reaction (1) at 5 GeV/c

	K^+ signal in telescope alone	Counter logic counts	Counter logic + correlation	Events after selection(*)	Events with(**) MM = $M(\Sigma^-) \pm 20$ MeV	Events with(**) MM = $M(\Sigma^-) \pm 80$ MeV	Events with(**) MM = $M(\Sigma^-) \pm 120$ MeV
Background from cascades of "two-body"	1400	150	150	70	10	40	50
Background from K^+ + multibody	34×10^5	5×10^5	1.4×10^5	8.5×10^4	22	700	2100
Background from π^+ and p in telescope	5000	1700	1250	1250	8	50	70
Sum of background	35×10^5	5×10^5	1.4×10^5	8.6×10^4	40	790	2220
Trigger rate per PS cycle	∿ 70	∿ 10	∿ 2.8				
Optimistic				Good events	1730	4750	5100
				$\frac{\text{Background}}{\text{All events}}$	2%	14%	30%
Pessimistic				Good events	200	530	570
				$\frac{\text{Background}}{\text{All events}}$	17%	60%	80%

*) By selection we mean rejection, at the level of the analysis, of the events presenting an unwanted number of tracks in the chambers placed between the target and the spectrometer magnet.

**) By MM (missing mass) we mean the reconstructed missing mass assuming the forward particle is a kaon.

Table 1b

Expected signals for 5×10^{10} incident pions as calculated including all the background contributions for reaction (1) at 8 GeV/c

	K^+ signal in telescope alone	Counter logic counts	Counter logic + correlation	Events after selection(*)	Events with(**) $MM = M(\Sigma^-) \pm 20$ MeV	Events with(**) $MM = M(\Sigma^-) \pm 80$ MeV	Events with(**) $MM = M(\Sigma^-) \pm 120$ MeV
Background from cascades of "two-body"	485	50	50	25	4	15	20
Background from K^+ + multibody	40×10^5	3×10^5	1.5×10^5	4×10^4	49	200	350
Background from π^+ and p in telescope	3650	1400	1100	1100	4	30	45
Sum of background	40×10^5	3×10^5	1.5×10^5	4×10^4	57	245	415
Trigger rate per PS cycle	~ 80	~ 6	~ 3				
Optimistic				Good events	445	1530	1895
				$\frac{\text{Background}}{\text{All events}}$	12%	14%	18%
Pessimistic				Good events	13	46	57
				$\frac{\text{Background}}{\text{All events}}$	82%	84%	88%

*) By selection we mean rejection, at the level of the analysis, of the events presenting an unwanted number of tracks in the chambers placed between the target and the spectrometer magnet.

**) By MM (missing mass) we mean the reconstructed missing mass assuming the forward particle is a kaon.

Table 2a

Expected signals for 5×10^{10} incident pions as calculated including all the background contributions for reaction (2) at 5 GeV/c

	Deuteron or proton signal in telescope alone	Counter logic counts	Counter logic + correlation	Events after selection(*)	Events with(**) MM = $M(\bar{p}) \pm 20$ MeV	Events with(**) MM = $M(\bar{p}) \pm 80$ MeV	Events with(**) MM = $M(\bar{p}) \pm 120$ MeV
All background	5×10^5	8.5×10^4	8×10^4	7.4×10^4	245	610	880
Trigger rate per PS cycle	∿ 10	∿ 1.7	∿ 1.6				
Optimistic				Good events	4460	8850	8950
				$\frac{\text{Background}}{\text{All events}}$	5.2%	6.5%	9%
Pessimistic				Good events	446	885	895
				$\frac{\text{Background}}{\text{All events}}$	35%	41%	50%

*) By selection we mean rejection, at the level of the analysis, of the events presenting an unwanted number of tracks in the chambers placed between the target and the spectrometer magnet.

**) By MM (missing mass) we mean the missing mass reconstructed assuming the forward particle is a deuteron.

Table 2b

Expected signals for 5×10^{10} incident pions as calculated including all the background contributions for reaction (2) at 8 GeV/c

	Deuteron or proton signal in telescope (no target or γ hod)	Counter logic counts	Counter logic + correlation	Events after selection$^{(*)}$	Events with$^{(**)}$ MM = M($\bar{p}$) ± 20 MeV	Events with$^{(**)}$ MM = M($\bar{p}$) ± 80 MeV	Events with$^{(**)}$ MM = M($\bar{p}$) ± 120 MeV
All background	3×10^5	5×10^4	4.85×10^4	4.8×10^4	15	105	215
Trigger rate per PS cycle	∿ 6	∿ 1	∿ 1				
Optimistic				Good events	1300	4380	5330
				$\frac{\text{Background}}{\text{All events}}$	1.14%	2.35%	3.88%
Pessimistic				Good events	130	438	533
				$\frac{\text{Background}}{\text{All events}}$	10.4%	19.4%	28.8%

*) By selection we mean rejection, at the level of the analysis, of the events presenting an unwanted number of tracks in the chambers placed between the target and the spectrometer magnet.

**) By MM (missing mass) we mean the missing mass reconstructed assuming the forward particle is a deuteron.

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Figure captions

Fig. 1 : Feynman graph describing the reaction $\pi^- p \rightarrow K^+\Sigma^-$ as two simple exchanges "$\rho \times K^*$" used, for example, by Michael[5].

Fig. 2 : Prediction for the behaviour of $(d\sigma/dt)_{t=0}$ as a function of P_{π^-} for $\pi^- p \rightarrow K^+\Sigma^-$:

- with the hypothesis of a cut exchange;
- with the hypothesis of the exchange of a heavy yet unknown "exotic" K* 3/2 state.

The two predictions are normalized at 5 GeV/c.

Fig. 3 : Differential cross-section for $\bar{p}p \rightarrow \overline{\Sigma^-}\Sigma^-$. This figure is from Sonderegger's report[10].

Fig. 4 : Cross-section for $\pi^- p \rightarrow K^+\Sigma^-$ from Dahl et al.[13]:

a) total cross-section

b) cross-section for $0 < \cos\theta_{K^+}$ (c.m.s.) < 1.

Fig. 5 : Schema of the proposed experimental set-up.

Fig. 6 : Acceptance, as a function of t, of our apparatus at 5 and 8 GeV/c.

Fig. 7 : Correlation effect y_1/y_2, the points are from reaction $\pi^- p \rightarrow \phi n(\phi \rightarrow K^+K^-)$ and the limits from the $\pi^- p \rightarrow K^+\Sigma^-$ reaction.

Fig. 8 : Missing-mass spectrum expected for reaction (1) in the "optimistic" case at 5 GeV/c. This histogram is a Monte Carlo calculation including all background contributions. Each reaction is weighted according to its cross-section, and the number of events corresponds to 5×10^{10} incident pions. The shaded area corresponds to good events; the remaining spectrum is the background contribution.

Fig. 9 : Missing-mass spectrum expected for reaction (1) in the "optimistic" case at 8 GeV/c, with the same conditions as for Fig. 8, except for the weighting of the background contribution which has been taken as an extrapolation from 5 GeV/c according to Morrison's law$^{17)}$.

Fig. 10 : Missing-mass spectrum expected for reaction (2) in the "optimistic" case at 5 GeV/c, with the same weighting factors as for Fig. 8.

Fig. 11 : Missing-mass spectrum expected for reaction (2) in the "optimistic" case at 8 GeV/c, with the same weighting factors as for Fig. 9.

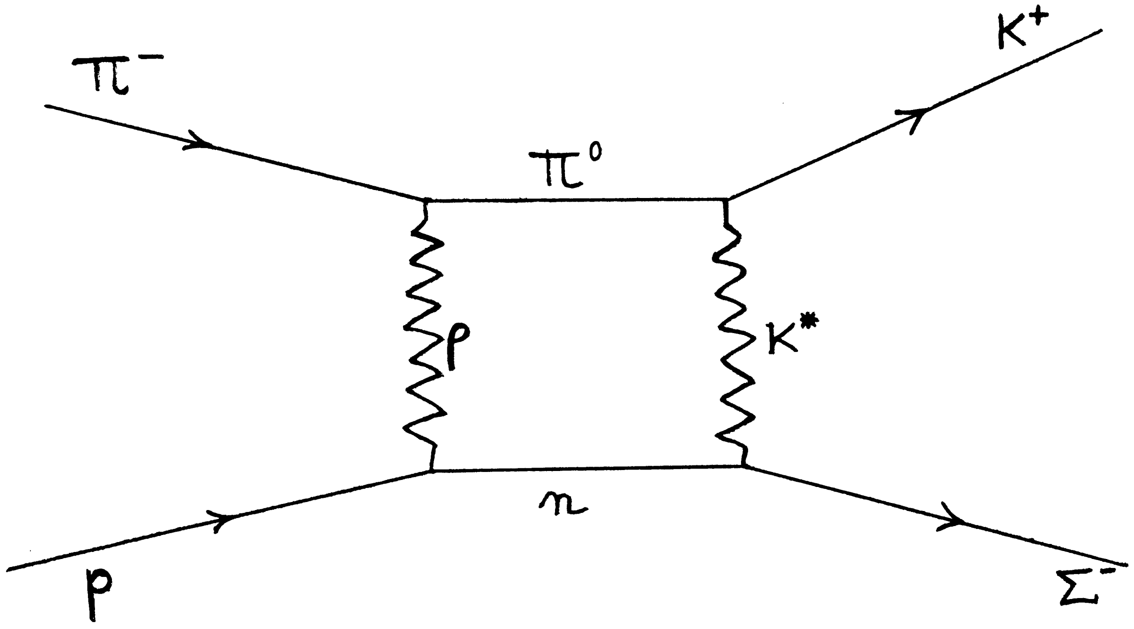


Fig. 1

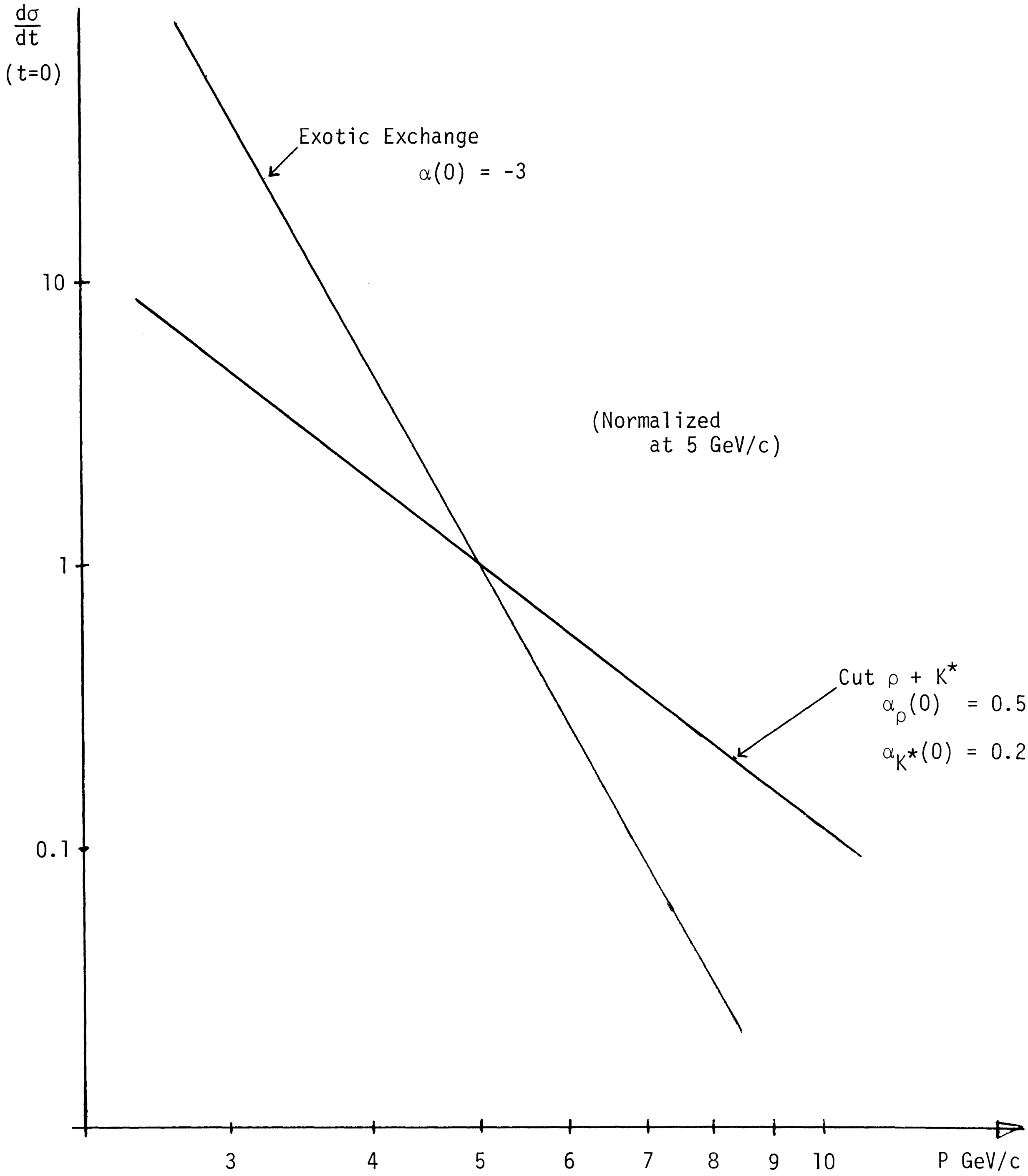

$\frac{d\sigma}{dt}$
(t=0)
10
1
0.1
Exotic Exchange
$\alpha(0) = -3$
(Normalized at 5 GeV/c)
Cut $\rho + K^*$
$\alpha_\rho(0) = 0.5$
$\alpha_{K^*}(0) = 0.2$
3
4
5
6
7
8
9
10
P GeV/c

Fig. 2

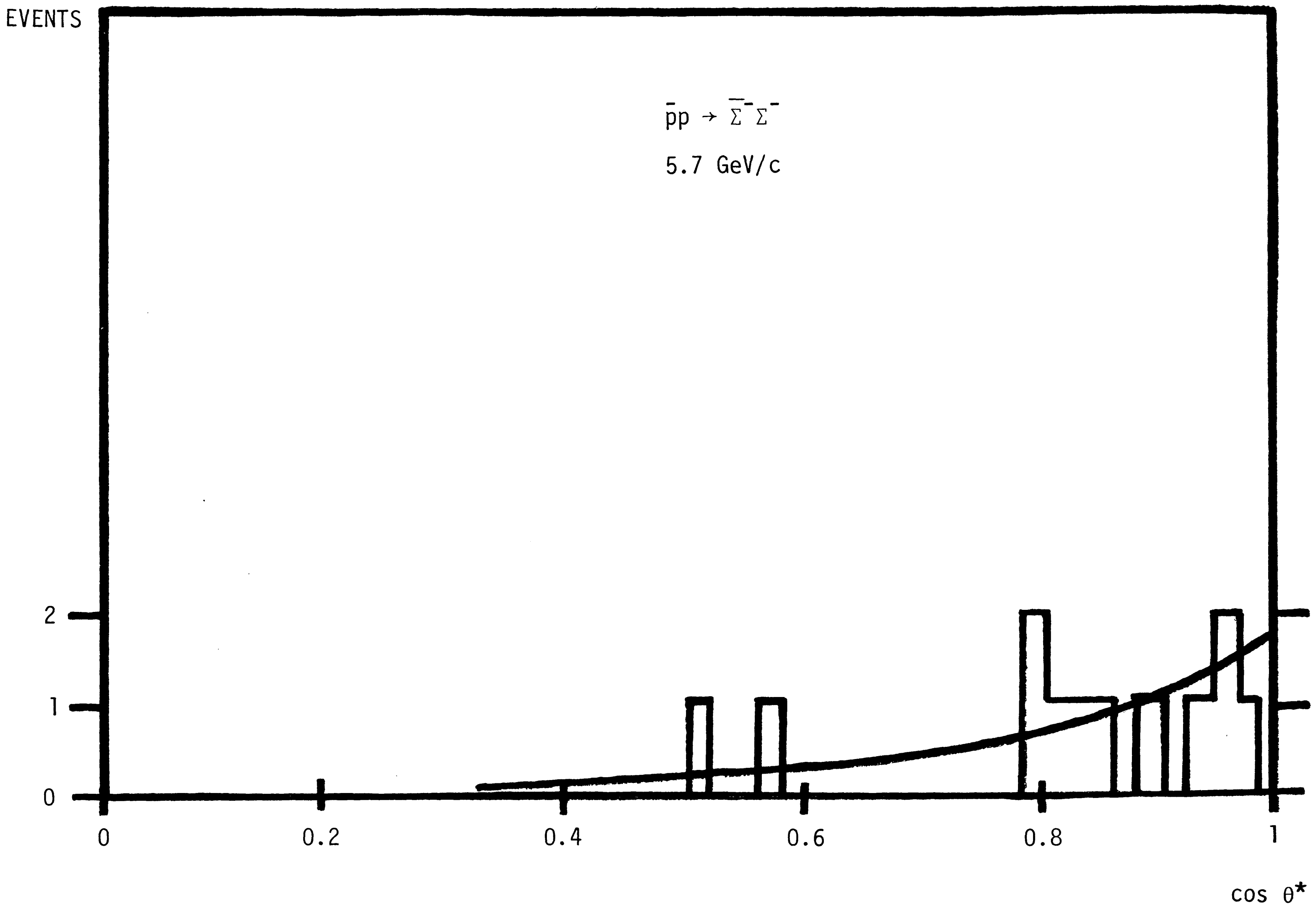


Fig. 3

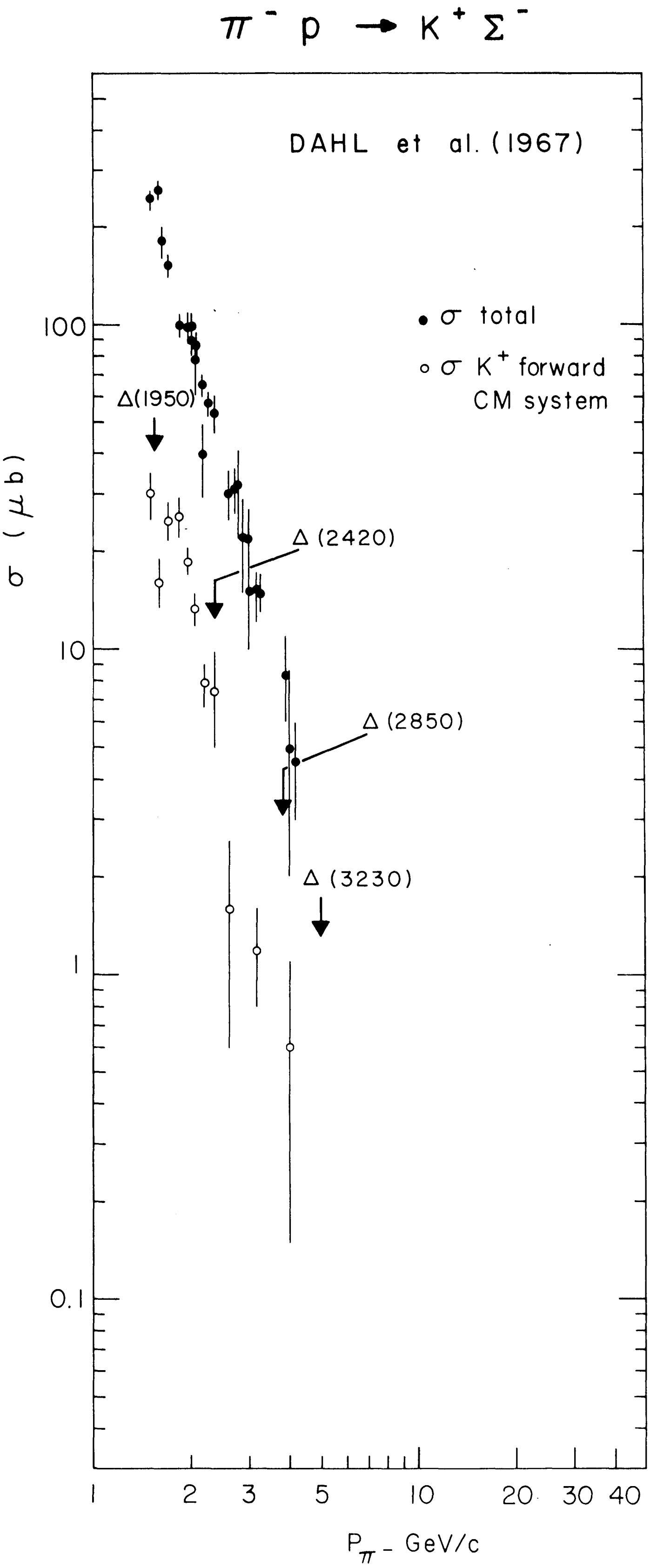
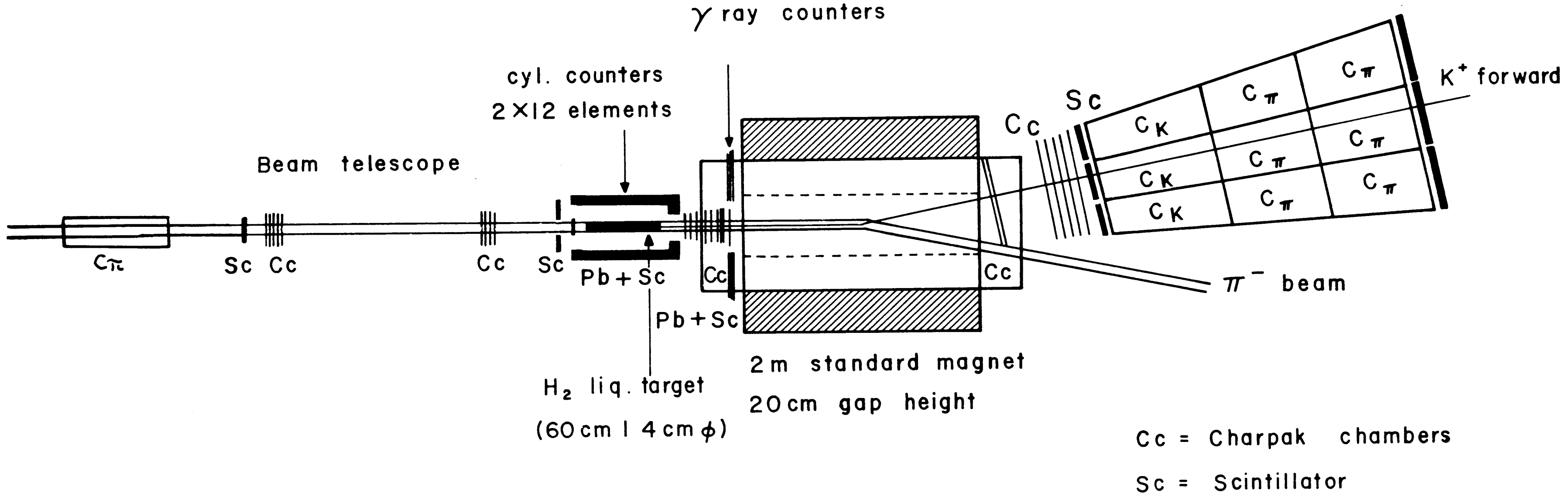

$\pi^- p \rightarrow K^+ \Sigma^-$
DAHL et al. (1967)
● σ total
○ σ K⁺ forward CM system
Δ(1950)
Δ (2420)
Δ (2850)
Δ (3230)
σ (μb)
100
10
1
0.1
1
2
3
5
10
20
30
40
P_{π^-} GeV/c

Fig. 4



Experimental Layout

Fig. 5

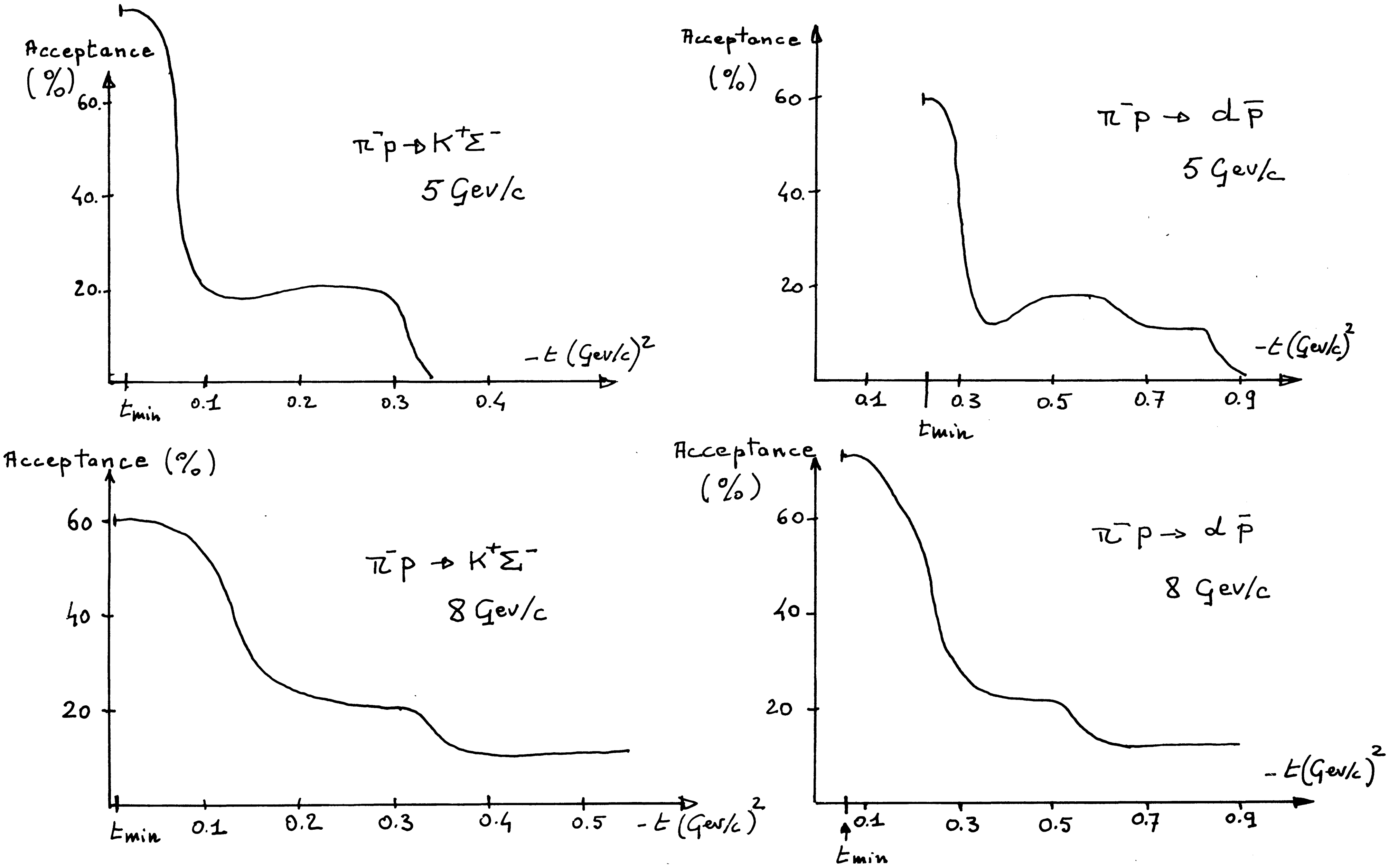

Acceptance (%)
60.
40.
20.
$\pi^- p \to K^+ \Sigma^-$
5 Gev/c
$-t$ (Gev/c)^2
t_{min}
0.1
0.2
0.3
0.4
Acceptance (%)
60
40.
20
$\pi^- p \to d \bar{p}$
5 Gev/c
$-t$ (Gev/c)^2
0.1
t_{min}
0.3
0.5
0.7
0.9
Acceptance (%)
60
40
20
$\pi^- p \to K^+ \Sigma^-$
8 Gev/c
t_{min}
0.1
0.2
0.3
0.4
0.5
$-t$ (Gev/c)^2
Acceptance (%)
60
40
20
$\pi^- p \to d \bar{p}$
8 Gev/c
$-t$ (Gev/c)^2
0.1
t_{min}
0.3
0.5
0.7
0.9

Fig. 6

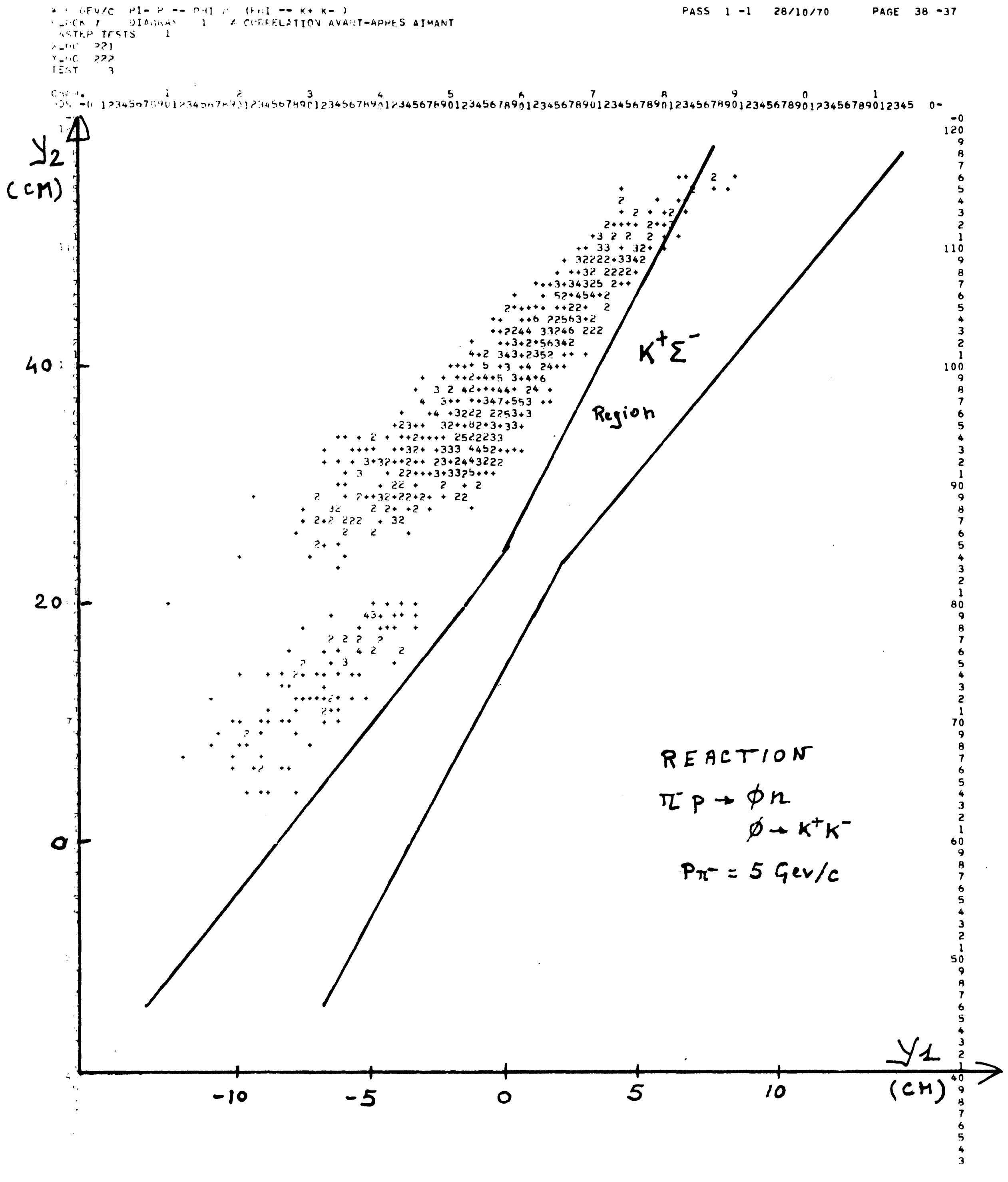

5 GEV/C PI- P -- PHI N (PHI -- K+ K-)
PASS 1 -1 28/10/70 PAGE 38 -37
BLOCK 7 DIAGRAM 1 CORRELATION AVANT-APRES AIMANT
ASTEP TESTS 1
XLOC 221
YLOC 222
TEST 3
y_2 (cm)
40
20
0
-10
-5
0
5
10
y_1 (cm)
$K^+\Sigma^-$
Region
REACTION
$\pi^- p \to \phi n$
$\phi \to K^+K^-$
$P_{\pi^-} = 5$ Gev/c

Fig. 7

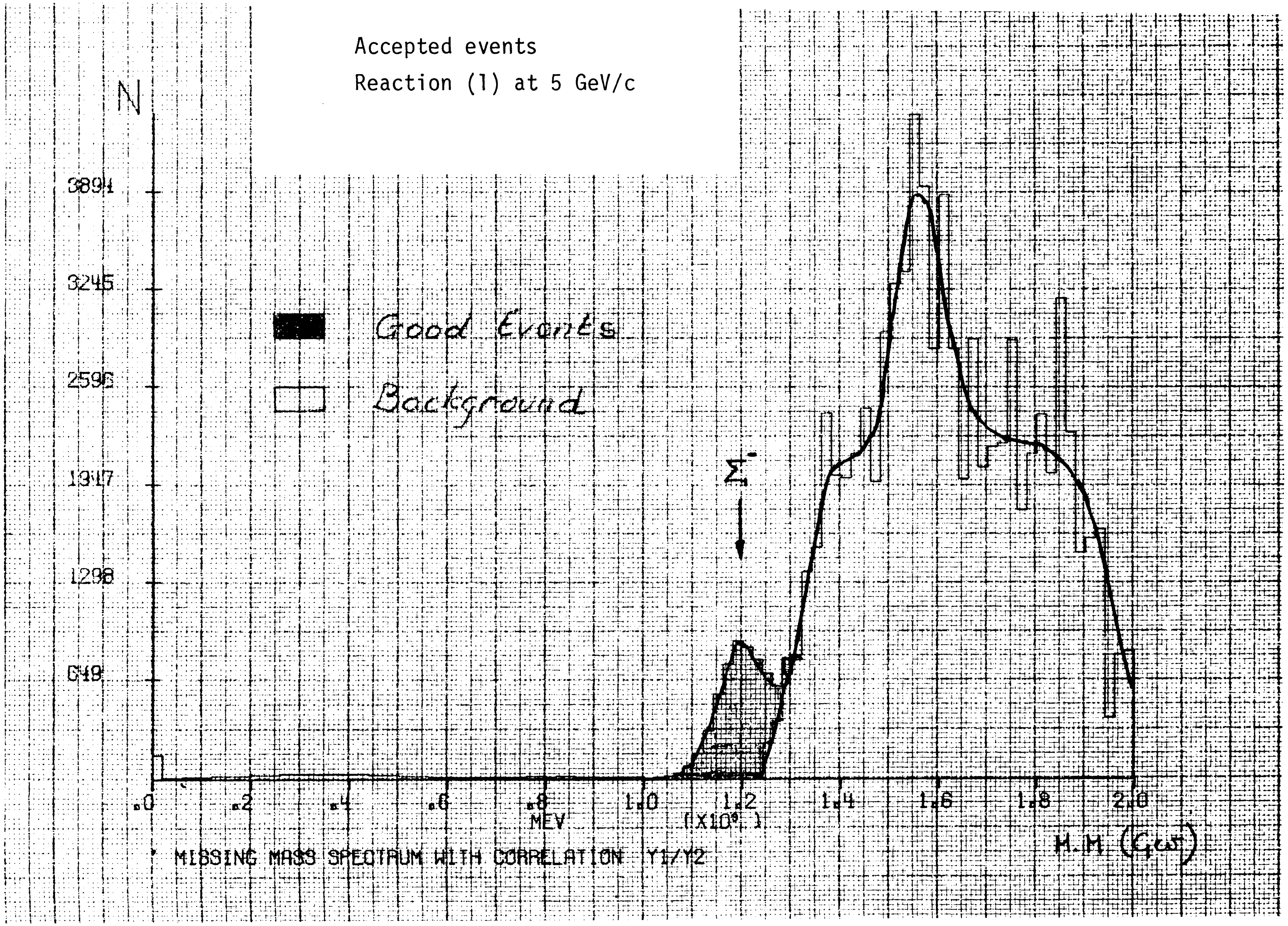
Accepted events
Reaction (1) at 5 GeV/c
N
3894
3245
2596
1947
1298
649
Good Events
Background
Σ⁻
.0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
MEV
(X10³)
MISSING MASS SPECTRUM WITH CORRELATION Y1/Y2
M.M. (GeV)

Fig. 8

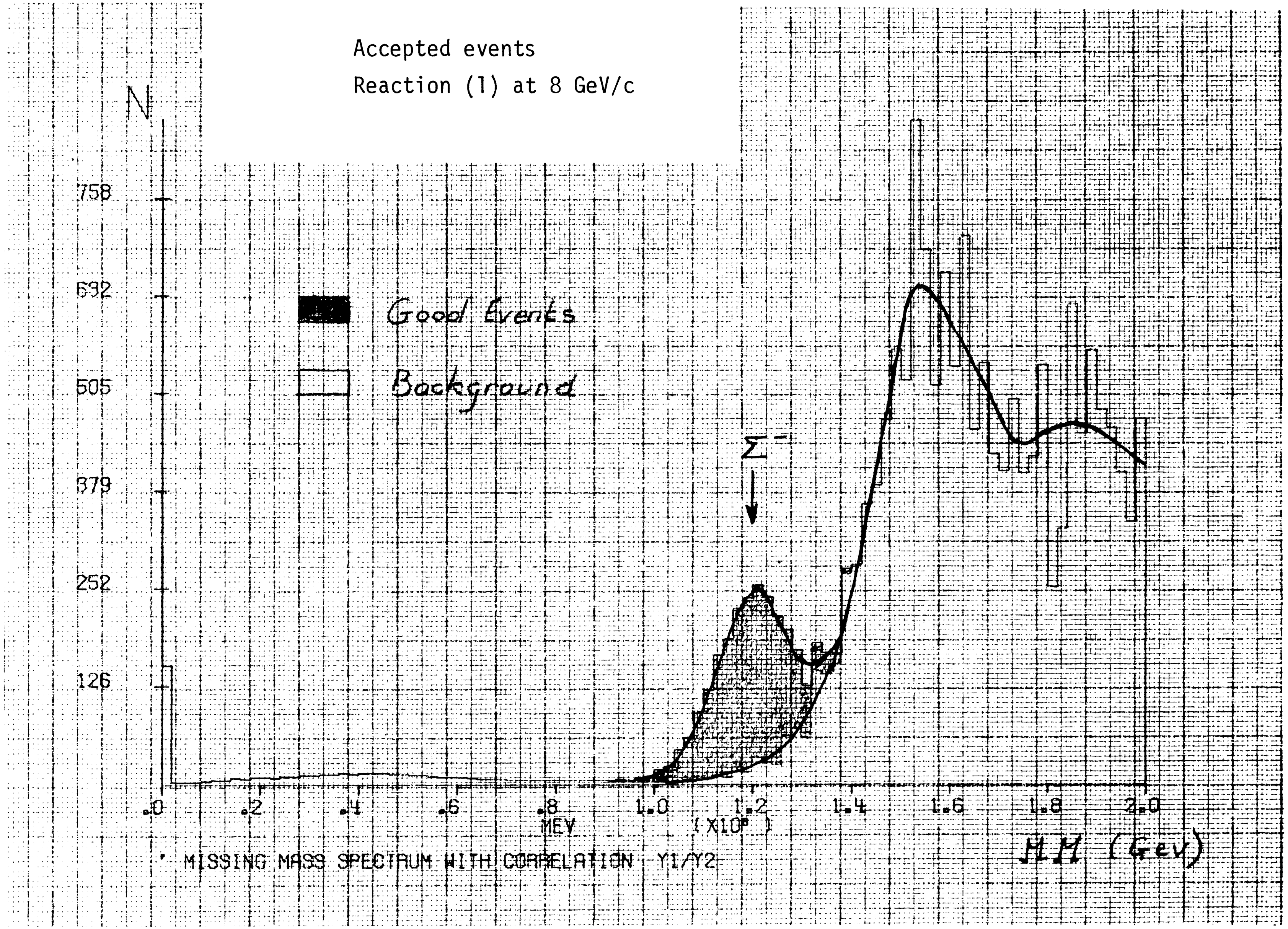
Accepted events
Reaction (1) at 8 GeV/c
N
758
632
505
379
252
126
Good Events
Background
Σ⁻
.0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
MEV
(X10^{3})
MISSING MASS SPECTRUM WITH CORRELATION Y1/Y2
MM (Gev)

Fig. 9

Accepted events
Reaction (2) at 5 GeV/c

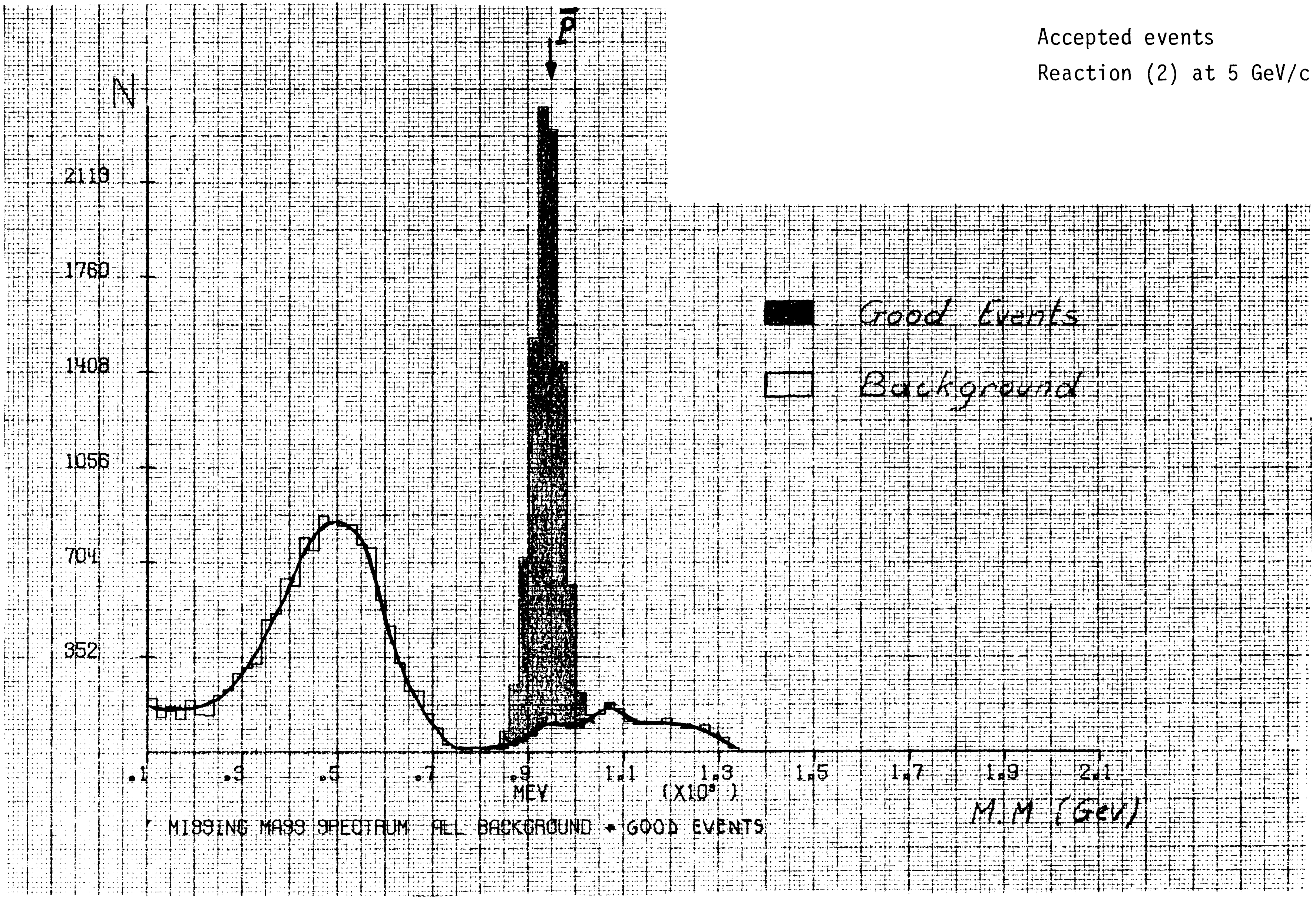


Fig. 10

Accepted events

Reaction (2) at 8 GeV/c

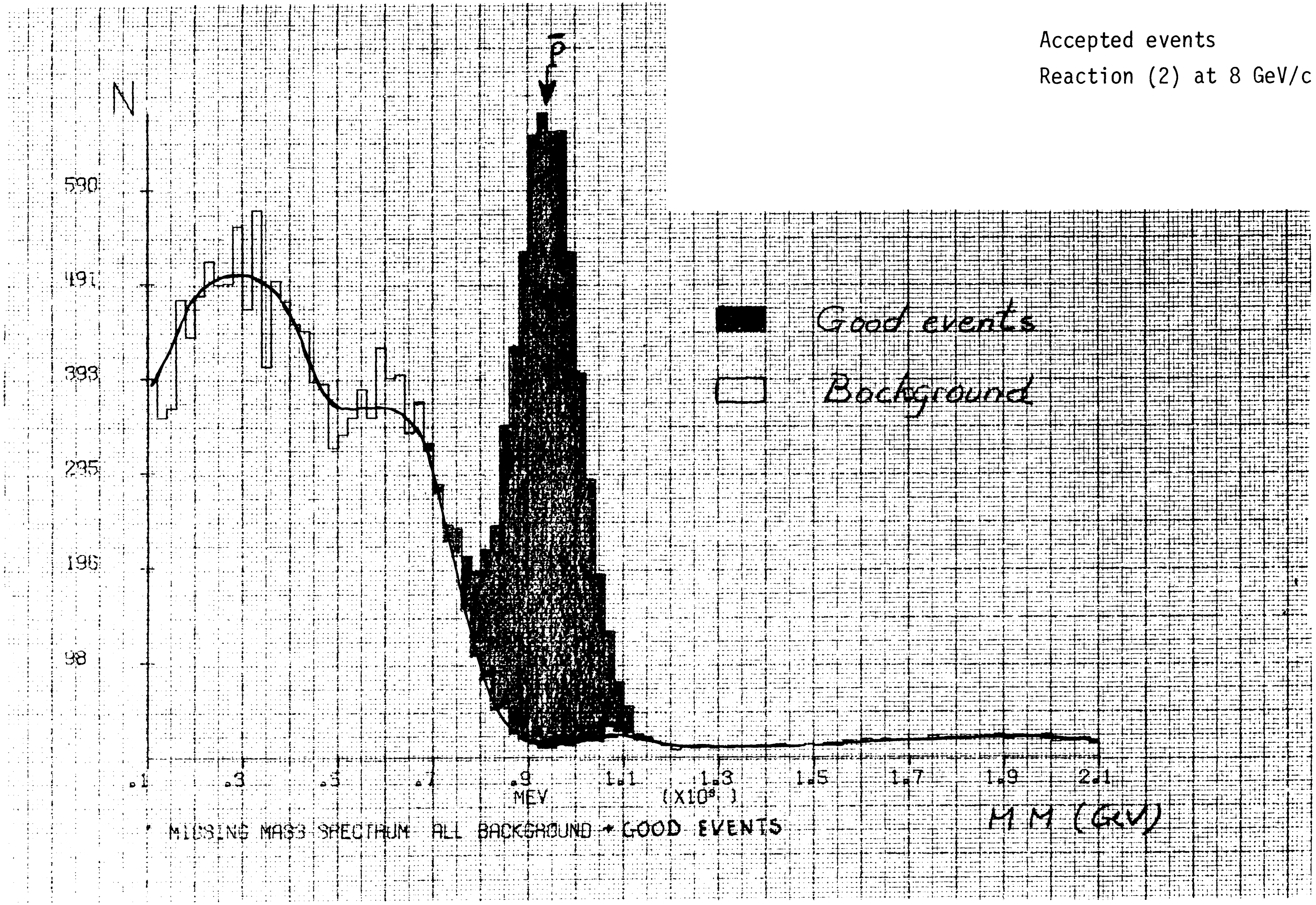


Fig. 11