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Proposal for an experiment using the CERN Omega magnet

STUDY OF THE REACTION $\pi^+ p \to n + \geq 2$ CHARGED PARTICLES USING A SLOW NEUTRON TRIGGER

by

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1. INTRODUCTION

Here we propose to study the reaction $\pi^+p \rightarrow n + \geq 2$ charged particles at 12 GeV/c as a natural continuation of the present $\pi^-p \rightarrow n + \geq 2$ charged particles experiment (S112). The acceptance range and efficiency of the mass recoiling against the neutron of the proposed experiment is shown in fig. 1 The proposed experiment will utilize essentially the same set-up as that of the π^-p experiment, and no additional software development will be required.

The physics interests in the proposed experiment are mainly the following :

a) Study of Q=2 (I=2) non-strange meson systems and their comparison with the corresponding Q=0 (I=0, 1, 2) non-strange meson systems produced in the π^-p experiment.

b) Study of the elastic I=2 $\pi\pi$ scattering and its comparison with $\pi^+\pi^-$ elastic scattering obtained in the π^-p experiment.

c) Search for exotic meson states ($qq\bar{q}\bar{q}$).

2. PHYSICS INTERESTS

a) The proposed $\pi^+p \rightarrow n + \geq 2$ charged particles affords the possibility of studying meson systems of a pure isospin state (I=2). In this respect it complements the $\pi^-p \rightarrow n + \geq 2$ charged particles experiment where the meson system is a priori in an isospin mixture (I=0, 1, 2). In particular since it is expected that resonant meson states of isospin 2 have a relatively small, if any, cross section, this I=2 meson system may assist the analysis of the corresponding π^-p experiment, in differentiating between kinematical enhancements and genuine resonant states.

Such a comparative study, for instance, has been employed in the investigation of the A_1 effect seen in the $\pi^- \rho^0$ system [1]. In that study, the two reactions $\pi^+ p \to \pi^+ \rho^0 p$ and $\pi^- n \to \pi^- \rho^- p$ at similar beam momenta, have been compared by using double Regge diagrams (fig. 2a). The proposed experiment, together with the $\pi^- p$ study will allow us to carry out an analysis for similar cases with the same beam momentum and apparatus. For example in the case of the $\rho\pi$ enhancement (A_1) the double Regge diagrams involved (fig. 2b) are identical through charge conjugation of the upper (beam) vertex. This fact greatly simplifies the comparison of the two reactions, allowing greater model independence than the previous study [1] since no Pomeron contribution is present.

This type of comparative study is envisaged to be useful also for other possible mesons states such as those in the "σ" region.

b) The study of I=2 elastic scattering has so far been carried out in the following reactions :

$$\pi^+ p \to \pi^+ \pi^+ n \qquad (2),(3)$$
$$\pi^- n \to \pi^- \pi^- p \qquad (2),(4)$$
$$\pi^- p \to \pi^- \pi^- \Delta^{++} \qquad (5)$$

The first reaction ($\pi^+ p$) has been recently studied by Hoogland et al. [3] in a wire chamber experiment at 12.5 GeV/c. That analysis covered the $\pi\pi$ mass range only up to 1.5 GeV, due to geometrical restrictions. Furthermore the neutron was not recorded and consequently one-constraint events were used. All other reported experiments covered lower mass regions (due to low beam momentum) and were based on limited statistics.

In the proposed experiment, the 4-constraint events $\pi^+ p \to \pi^+ \pi^+ n$ will cover an extended $M(\pi\pi)$ region up to about ~2.1 GeV (see fig. 1).

Information on this reaction will also be useful for the interpretation of the $\pi^-\pi^+$ study from the $\pi^-p \to \pi^+\pi^-n$ reaction.

c) The possible existence of exotic resonances has been recently investigated by several authors. Using duality quarks diagrams it has been argued that if exotic mesons exist they should be strongly coupled to baryon-antibaryon systems [6] as is illustrated in fig. 3a. Thus the search for exotic mesons would be more promising if the production as well as the decay are coupled to $\bar{B}B$ systems.

An obvious place to look for exotic non-strange mesons states is in the non-annihilation $\bar{p}p$ and $\bar{p}d$ formation experiments. The presence of formation resonant states in these experiments is so far rather limited and inconclusive.

It has been further suggested [7] that πp reactions mediated by a baryon exchange should also be utilised for the search of exotic meson production. This is illustrated in fig. 2b in which one observes that the meson exotic state is produced in a diagram where both the s and t channels consist of non exotic baryons. The similarity of this last reaction with the backward production of non exotic mesons which is also mediated by a baryon exchange (fig. 3) leads to the educated guess that exotic mesons may have a similar cross section i.e. 1 to 10 μb [8]. Here it is worthwhile to mention that exotic strange mesons are expected to have smaller production cross sections.

Very little data exists at present on the reaction $\pi^-p \to p(\bar{p}n)$ [9] and $\pi^+p \to p(p\bar{n})$ [10] where the particles in the brackets emerge in the backward direction. These bubble chamber experiments suffered large difficulties in the identification of the events and their separation from other final states channels. For these two reactions cross sections have been reported as

$$\sigma|\pi^- p \to p(n\bar{p})| = 97 \pm 26 \ \mu b \text{ at } 8 \text{ GeV/c}$$

and $$\sigma|\pi^+ p \to p(\bar{n}p)| = 39 \pm 5 \ \mu b \text{ at } 13 \text{ GeV/c.}$$

The proposed experiment affords a favourable set-up to search for non strange exotic mesons in the reaction $\pi^+ p \to p\ (p\bar{n})$ since all outgoing particles may be detected. The $\pi^+ p$ and $\pi^- p$ interactions leading to final states $\bar{N}NN$ are shown in fig. 4 where the $\bar{N}N$ system is on the target vertex. Note that the systems $\bar{n}p$ and $n\bar{p}$ may be detected both in the $\pi^- p$ and the $\pi^+ p$ slow neutron counter experiments. The only difference is that in the $\pi^- p$ reaction only Δ can be exchanged in the t-channel whereas in the $\pi^+ p$ experiment both N and Δ are allowed. The $\pi^- p \to n(\bar{p}p)$ reaction (fig. 4c) can be studied with the slow proton trigger experiment in the one constraint two prong events. The mass region to be covered by the proposed experiment is illustrated in fig. 5, where a t dependence of $\exp(-8|t|)$ was assumed.

We estimate from the existing $\bar{N}$ cross section data that the slow neutron counters should have about 50% anti-neutron detection efficiency. At the same time it is expected that almost always the $\bar{n}$ annihilation products will trigger the charged particles veto counters situated in front of the neutron counters. We therefore propose to use these charged particles counters just to flag the interactions. From tests carried out in the $\pi^- p \to n + \ldots$ run this modification should add about 25% to the recorded triggers.

3. EXPERIMENTAL SET-UP

The experimental set-up will be identical to that of the $\pi^- p$ slow neutron experiment (S112) except for the following changes :

1) Incident positive beam
2) Veto on incident protons
3) Reverse of magnetic field polarity
4) Veto counter used as flag counters.

4. TRIGGER RATE

For the estimation of the expected trigger rate we have used the $\pi^- p \to n$ ... slow neutron experiment, taking into account the following factors :

1) Values of cross sections (given in table 1 [11]),
2) Beam intensities ratio (see table 2)
3) Dead time losses.

In this way we estimate the ratio of π^+ triggers to that of the π^- to be approximately 1/3. Numbers of events per day for several $\pi^+ p$ reactions in the proposed experiment are shown in table 1, allowing data taking efficiency of 70% which was achieved in the $\pi^- p$ run.

5. RUNNING TIME REQUESTED

The total running time requested is 10 days which corresponds to $\simeq$ 45 events/μb. We estimate that this requested running time will enable us to carry out the physics programme underlined in this proposal. Specifically, we thus expect to collect ~21000 $\pi^+ p \to n\pi^+\pi^+$ events i.e. about 3000 events per 50 MeV $\pi\pi$ mass interval.

Since the antineutron detection efficiency is expected to be more than twice that of the neutron detection, we expect for a 5 μb exotic meson production cross section to collect more than 900 events.

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Reaction	Cross section mb	Expected rate 10^3 ev/day
$\pi^- p \rightarrow$ 2 prong	10	115
$\rightarrow \pi^+\pi^- n$	0.7	8
$\rightarrow$ 4 prong	9.5	110
$\rightarrow \pi^+\pi^-\pi^+\pi^{'} n$	0.7	8
$\pi^+ p \rightarrow$ 2 prong	9	40
$\rightarrow \pi^+\pi^+ n$	0.5	2.1
$\rightarrow$ 4 prong	9	40
$\rightarrow \pi^+\pi^+\pi^+\pi^- n$	0.6	2.6

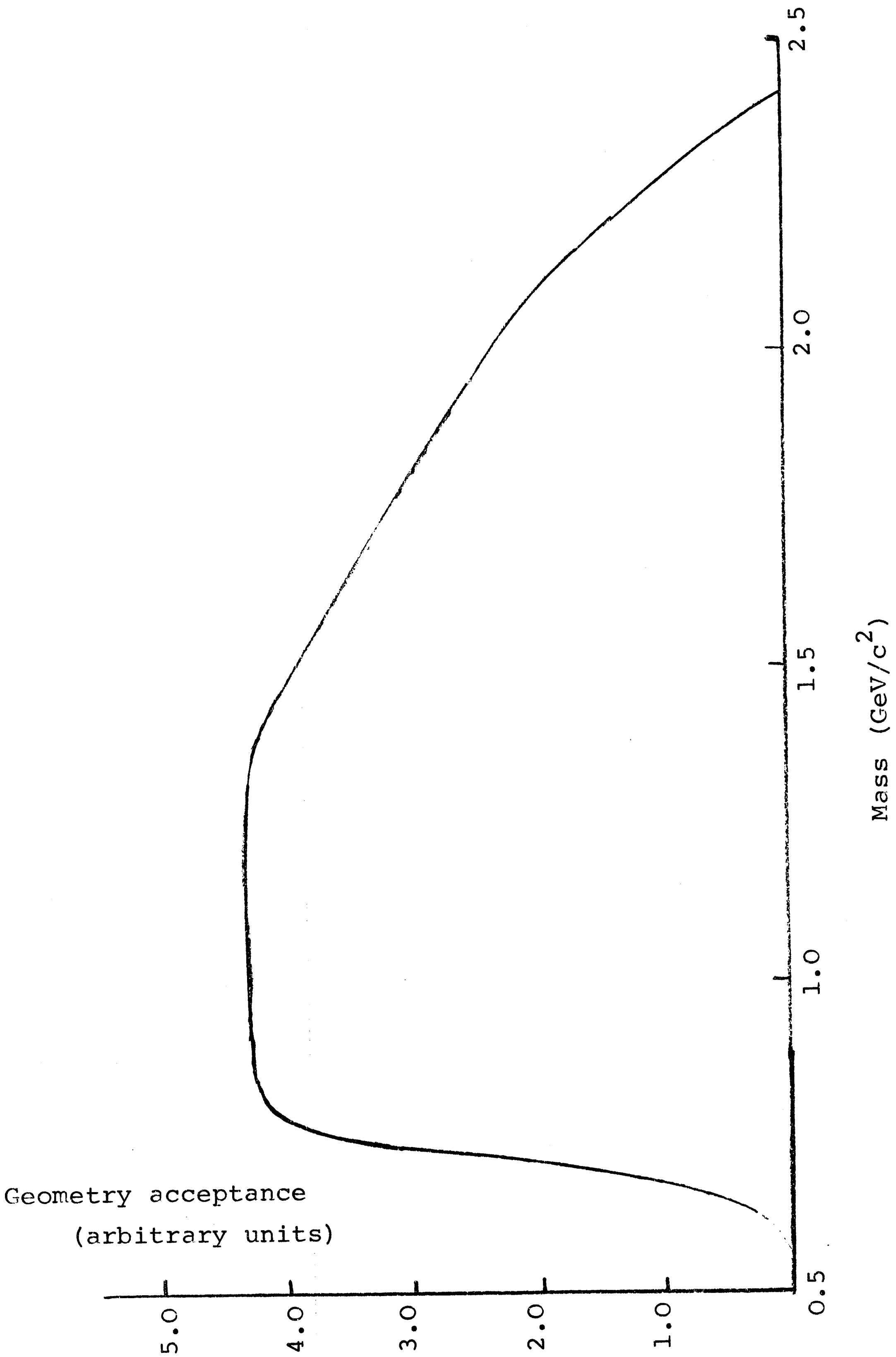
Table 1

Trigger rate for the $\pi^+ p$ slow neutron experiment as estimated from the rate obtained in the $\pi^- p$ experiment.

Beam flux per burst	Constituents of beam	Trigger rate	Trigger rate including dead time of 20 ms
Negative 10^5	98.6 % π^- 1.0 K^-	22 (measured)	11
Positive 2×10^5	11% π^+ .85% K^+ 88% p	4.6 (using σ values of table 1)	3.8 (4.8 if veto counters removed)

Table 2

Comparison of neutron trigger rates with π^- and π^+ beams at the Omega.



<u>Figure 1</u>

Recoiling Mass Acceptance of the Neutron Counters in the Reaction $\pi^+ p \rightarrow n + MM^{++}$ at 12 GeV/c assuming $d\sigma/dt \propto e^{8t}$.

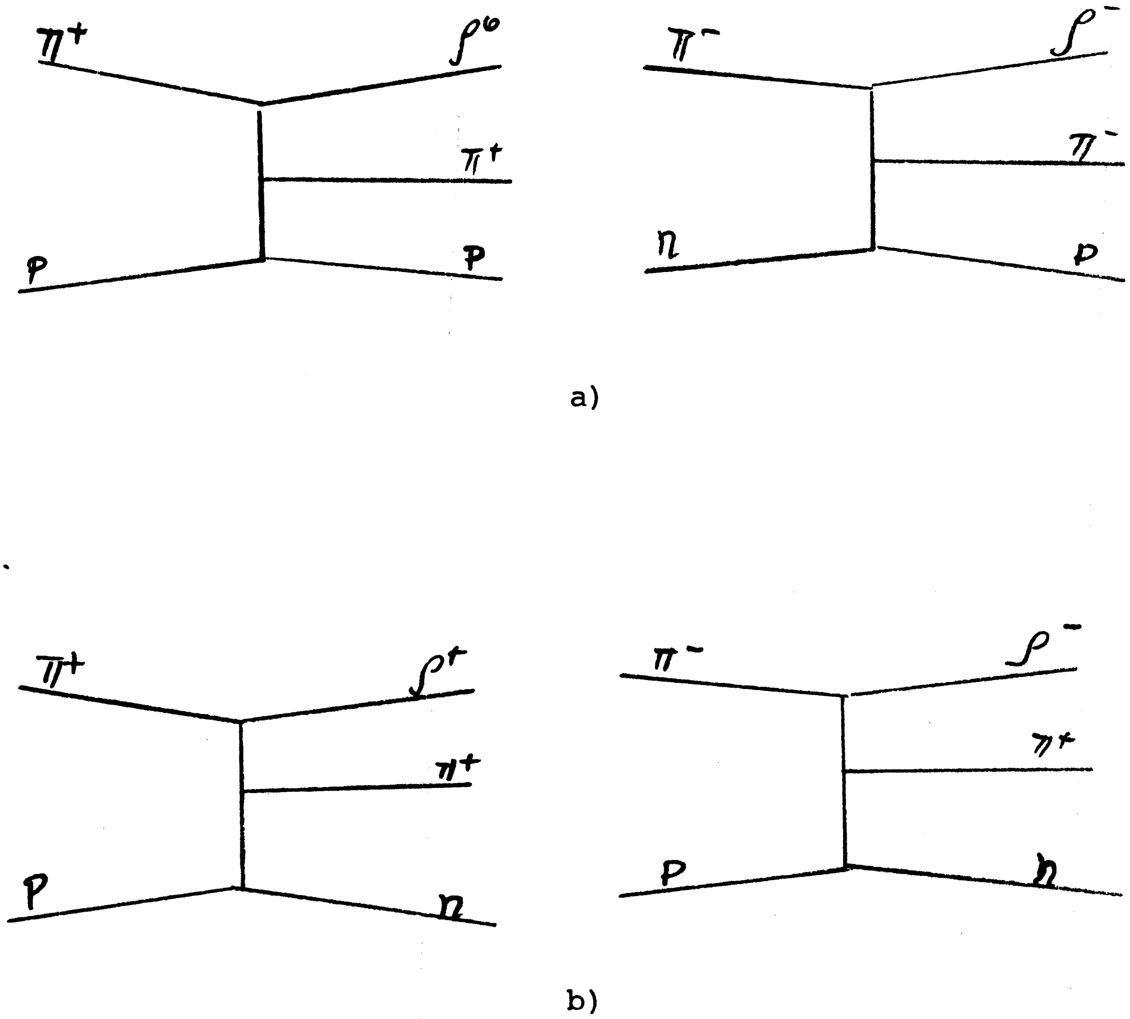


Figure 2

Double Regge Diagrams for A_1 ($\rho\pi$) Study.

a) Diagrams compared in reference

b) Diagrams to be utilised in the proposed experiment.

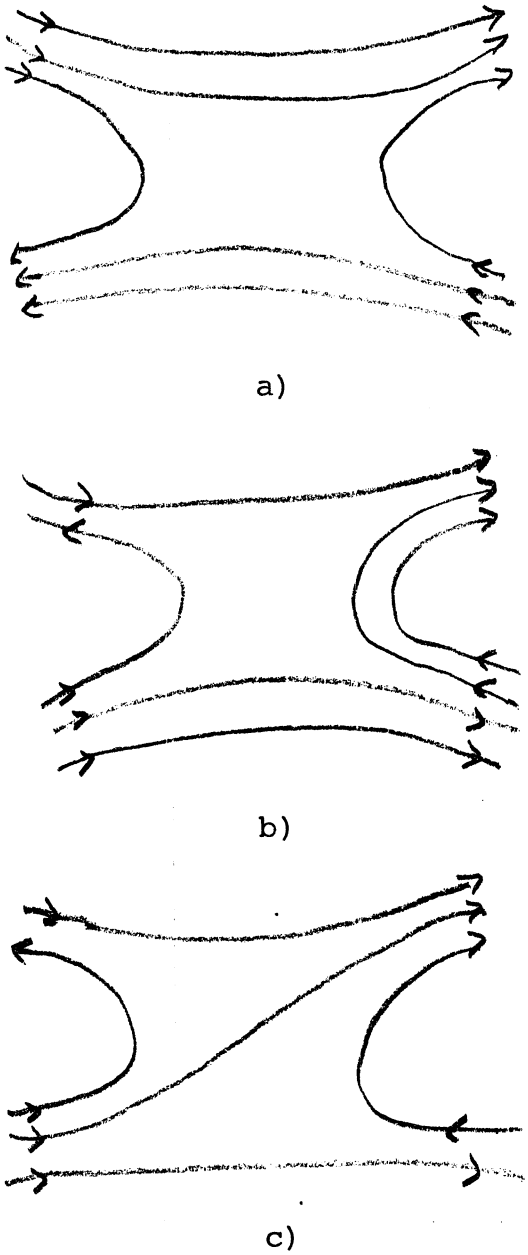


Figure 3

Duality Quark Diagrams for Meson Production

a) BB coupling of exotic mesons.

b) Backward production of exotic mesons having non exotic s and t channels.

c) Backward non-exotic meson production.

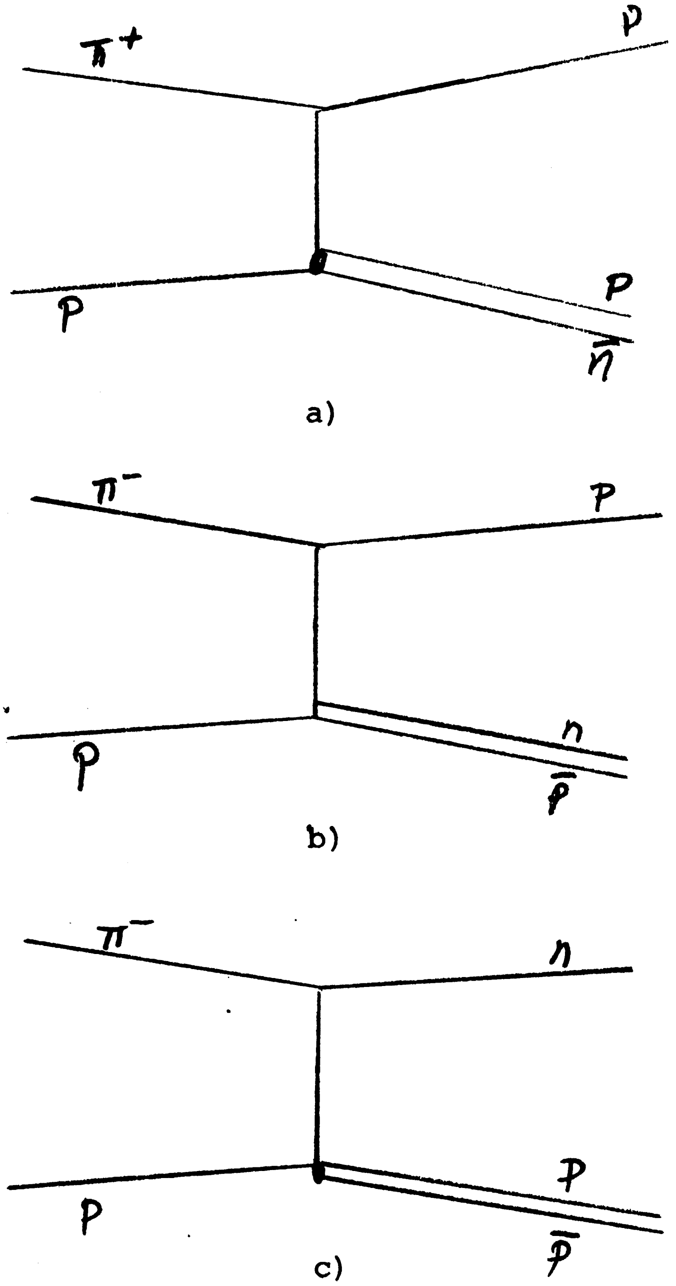


Figure 4

Production of Backward ($N\bar{N}$) System in $\pi p \rightarrow N + (N\bar{N})$ Reactions.

a) Configuration accessible in the proposed experiment.

b) Configuration accessible in the $\pi^- p \rightarrow n + \geqslant 2$ charged particles.

c) Configuration accessible in the slow proton trigger experiment.

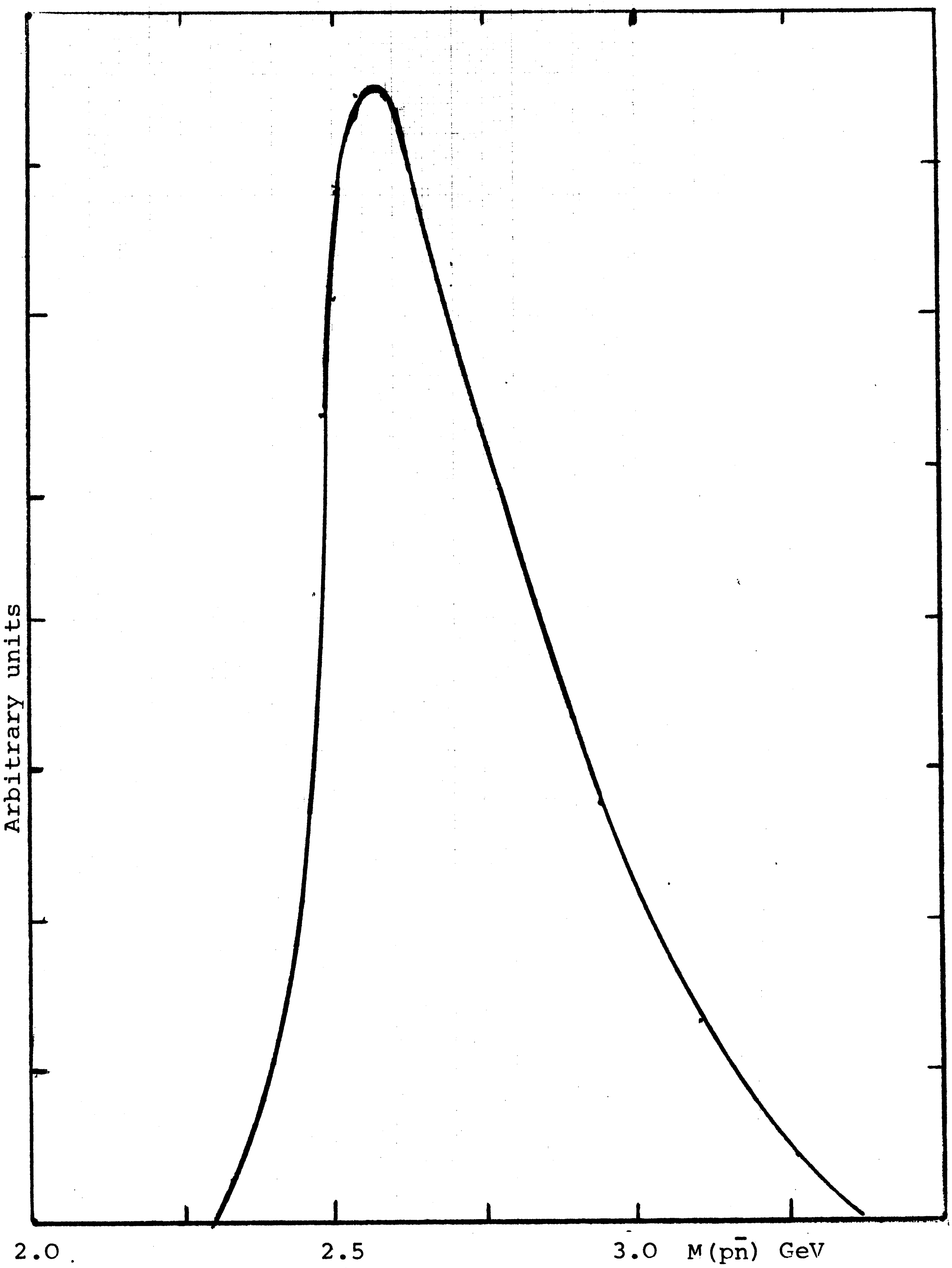


Figure 5

Calculated mass acceptance of the p$\bar{n}$ system in the reaction $\pi^+p \rightarrow p(p\bar{n})$ at 12 GeV/c using the slow neutron counters.