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PROPOSAL TO STUDY $\bar{p}d$ INTERACTIONS AT 12 GeV/c

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Summary.-

We propose to take 300,000 pictures with ~ 10 $\bar{p}$ per picture in order to study $\bar{p}d$ interactions at 12 GeV/c. This experiment is intended to complete our previous runs in order to study the incident momentum dependence of $\bar{p}d$ interactions. We will investigate the general features of the $\bar{p}n$ interactions (topological cross sections, multiparticle production, annihilation and non annihilation channels) and we will also search for new resonances. Coherent production will also be studied. A comparison between the $\bar{p}p$ and $\bar{p}n$ data will be carried out.

1. INTRODUCTION

As a continuation of our work done during these last years we are proposing to study the $\bar{p}d$ interactions at 12 GeV/c. Since no $\bar{p}d$ data exist now between 9 and 15 GeV/c our experiment will contribute to a better knowledge of the incident momentum dependence of the $\bar{p}d$ interactions. In fact, the experiment carried out at 15 GeV/c[1] was not very fruitful because of the bad quality of the pictures. Therefore a new data point at ~12 GeV/c obtained with the 2 m bubble chamber will be of great interest for studying exclusive channels and searching for heavy boson resonances. Furthermore another interest of the present experiment is that numerous $\bar{p}p$ data has been taken recently at the same momentum, and also that a pd experiment has been carried out at 11.6 GeV/c[2]. This will allow us to make a meaningfull comparison between $\bar{p}p$ and $\bar{p}n$ interactions as well as between $\bar{p}n$ and pn. In particular the observation of enhancements in $\bar{p}n$ and $\bar{p}p$ reactions will certainly be of great help for identifying resonances.

2. PHYSICS INTEREST

a). General features

The main motivations for studying $\bar{p}d$ interactions has been exposed in a few other proposals which have been presented at the T C C[3]. The subjects which can be studied are the following :

- Annihilation channels (we expect in any case to study the four constraint annihilation reactions)
- Non annihilation channels, (in particular a search for baryonic resonances will be carried out)
- Comparison of the leading particle effect in $\bar{p}N$ and pN interactions[4]
- Diffraction dissociation of the neutron target
- Correlation between the outgoing particles (among other things we will also study the two particle correlations in the transverse plane as proposed in reference (5) and (6)
- Multiparticle production phenomena (in the same manner as made for lower $\bar{p}p$ incident momenta[7] we will search for multivariables sensitive to the production mechanisms[8])
- Single particle distributions and inclusive reactions

— Coherent reactions : it will be interesting in particular to analyse the $\bar{p}d \to \bar{n}d\pi^-$ and $\bar{p}d \to \bar{p}d\pi^+\pi^-$ reactions in the same way as it has been done at 5.5 GeV/c and 15 GeV/c[9,10].

Apart of these general interests let us also stress out below some special features which we intend to study with the proposed experiment.

b). Topological cross sections and statistical moments of the charged multiplicities

It is primarily in the determination of these quantities that the systematic errors will be of importance. Our recent result in the 5.5 — 15 GeV/c region[11] (Fig.1) has shown that systematic errors are rather difficult to estimate. In the framework of the impulse approximation, however, these errors are expected to be nearly independent on the incident momentum. Therefore it seems to us essential to determine the statistical moments and multiplicity distributions by the same experimental methods. Using our previous data (5.5 — 15 GeV/c) we will be able to carry out a meaningfull study of the incident momentum dependence of the $\bar{p}n$ multiplicity distributions.

Among other things we will also see :

- If the dispersion D and the average $\langle n \rangle$ of the charged multiplicity distributions are related through a linear rule as for pp and $\bar{p}p$ interactions (Fig.2)

- If the data still obey the early KNO scaling as shown by the $\bar{p}n$ interactions in the 5.5 — 15 GeV/c region (Fig.3).

- If, as for lower incident momenta, the average $\langle n \rangle$ for $\bar{p}n$ is smaller than for $\bar{p}p$ in contrast to the dispersion D which is greater for $\bar{p}n$ than for $\bar{p}p$ (see Fig.2 and 4).

c). Search for heavy resonances

Previous $\bar{p}N$ experiments[12,13] showed some evidence for the existence of massive narrow-width resonances (see also Fig. 5). These experiments were carried out in the 5.5 GeV/c incident momentum region ($\bar{p}p$ at 5.7 GeV/c and $\bar{p}n$ at 5.5 GeV/c). The proposed experiment will allow to cover a different effective mass region (see Table I). In fact, for searching narrow $\bar{p}p$ resonances the study of $\bar{p}n$ interactions seems to be more favorable than $\bar{p}p$ ones.

Indeed the most simple inelastic reactions in which a $\bar{p}p$ state may appear are the $\bar{p}n \to \bar{p}p\pi^-$ and $\bar{p}p \to \bar{p}p\pi^0$ channels. But the former, being a four constraint reaction, allows a better determination of the $\bar{p}p$ effective mass than the one constraint $\bar{p}p \to \bar{p}p\pi^0$ reaction . The $\bar{p}p \to \bar{p}p\pi^+\pi^-$ reaction also is not very favorable for searching $\bar{p}p$ resonances because of the presence of strong $\bar{\Delta}$ and Δ which are produced in equal amount because of charge conjugation invariance. Therefore, although the $\bar{p}n \to \bar{p}p\pi^+2\pi^-$ is a more complicated reaction it may be more suitable for detecting $\bar{p}p$ resonances than the $\bar{p}p \to \bar{p}p\pi^+\pi^-$ reaction. In any case the study of $\bar{p}d$ interactions at 12 GeV/c will complete those made with $\bar{p}p$ interactions. Thus enhancements observed in both $\bar{p}n$ and $\bar{p}p$ interactions will certainly facilitate the interpretation of enhancements in terms of resonances.

As an additional interest let us still remember that the proposed experiment will allow us to study the exotic $I = 2$ $\bar{p}n\pi^-$ system which is produced in the $\bar{p}n \to \bar{p}n\pi^-\pi^+$ reaction. This reaction is the simplest one in which an $I = 2$ subsystem can appear. Finally we intend also to search for resonance production in annihilation channels.

d). Comparison between $\bar{p}p$ and $\bar{p}n$ interactions

Some recent works(14) stressed out the interest to study at high energy the influence of double scattering or screening effect on topological and inelastic cross sections. This is generally made by using models(14) for analysing the $\bar{p}n$ interactions. At 12 GeV/c we will be able to make a direct comparison between multiplicity distributions and some exclusive reaction obtained with a free and a bound nucleon. This will allow us to see to what extent the cross section calculation made for $\bar{p}n$ inelastic reactions are reliable. Essentially we will calculate correction factors which may have an importance in the determination of the statistical moments derived from the $\bar{p}n$ interactions.

3. NUMBER OF PICTURES AND EVENTS

We estimate the $\bar{p}n$ topological cross sections at 12 GeV/c by interpolating our $\bar{p}d$ data at 9 and 15 GeV/c (see Fig.1). With 300,000 pictures and 10 $\bar{p}$ per pictures we will obtain a reasonable number of events for carrying out the outlined study program. This is shown by Table II which gives for each topology the number of expected events having a visible spectator proton stopping in the chamber. In Table III we give estimates for the number of events obtained for some specific channels in which we are primarly interested. For the study of these reactions we also intend to use odd prong events namely those having a spectator proton below the threshold detection of the chamber. Thus for the $\bar{p}n \rightarrow \bar{p}p\pi^-$ reaction we will dispose of about 11,000 events for searching $\bar{p}p$ resonant system in the mass range of 2 — 3 GeV/c. Assuming that the coherent cross section at 12 GeV/c is nearly the same as that at 15 GeV/c we will obtain about 11,000 and 4,000 events for the $\bar{n}d\pi^-$ and $\bar{p}d\pi^+\pi^-$ final state, respectively, allowing us to carry out a meaningfull study of coherent processes.

Conventional measuring machines and automatical devices will be used to measure the events. The conventional apparatus will serve to treat the events with a visible short recoiling positive track.

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TABLE I – Approximate effective mass ranges (obtained with peripheral phase space) in which there are enough events to search for resonance production at 12 GeV/c in the $\bar{p}N \to \bar{N}Nm\pi$ $(1 \leq m < 2)$ reaction

reaction	particle combination	mass range (GeV/c^2)
$\bar{p}n \to \bar{p}p\pi^-$	$\bar{p}p$	3.8 – 4.7
	$\bar{p}\pi$	1.2 – 2.0
$\bar{p}n \to \bar{N}N\pi\pi$	$\bar{N}N$	3.2 – 4.2
	$\bar{N}N\pi$	3.8 – 4.8
	$\bar{N}\pi\pi$	1.5 – 3.0
	$\pi\pi$	0.4 – 1.2

Table II - Expected number of $\bar{p}n$ events as function of the charged multiplicity n for the events having a visible spectator proton stopping in the chamber (i.e. spectator protons having a momentum greater than 0.1 GeV/c). The numbers were obtained with 300,000 photographs and 10 $\bar{p}$ per picture.

n	number of events
3	54,000
5	36,000
8	18,000
10	5,000
12	750
14	~ 90
annihilation into pions (total)	51,000

TABLE III - Estimation of the number of events for some specific channels. For the reactions with spectator protons we also include the events with invisible spectator proton

reaction	number of events
$\bar{p}d \to p_s \bar{p} p \pi^-$	11,000
$\to p_s \bar{p} n \pi^+ \pi^-$	12,000
$\bar{p}d \to \bar{n} d \pi^-$	11,000
$\to \bar{p} d \pi^+ \pi^-$	4,000

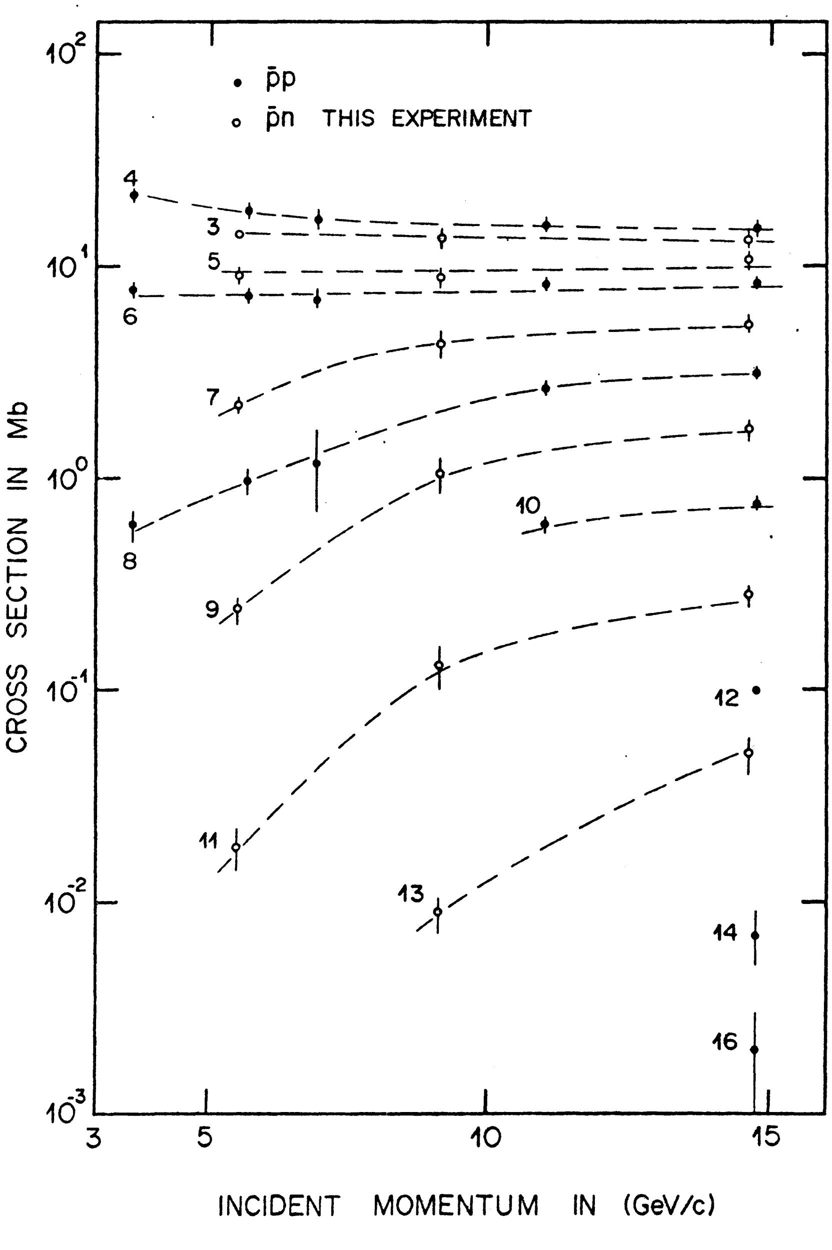

Figure 1

Distributions of the $\bar{p}n$ topological cross sections in the 3 – 15 GeV/c incident momentum region and comparison with $\bar{p}p$ data [taken from reference (11)]

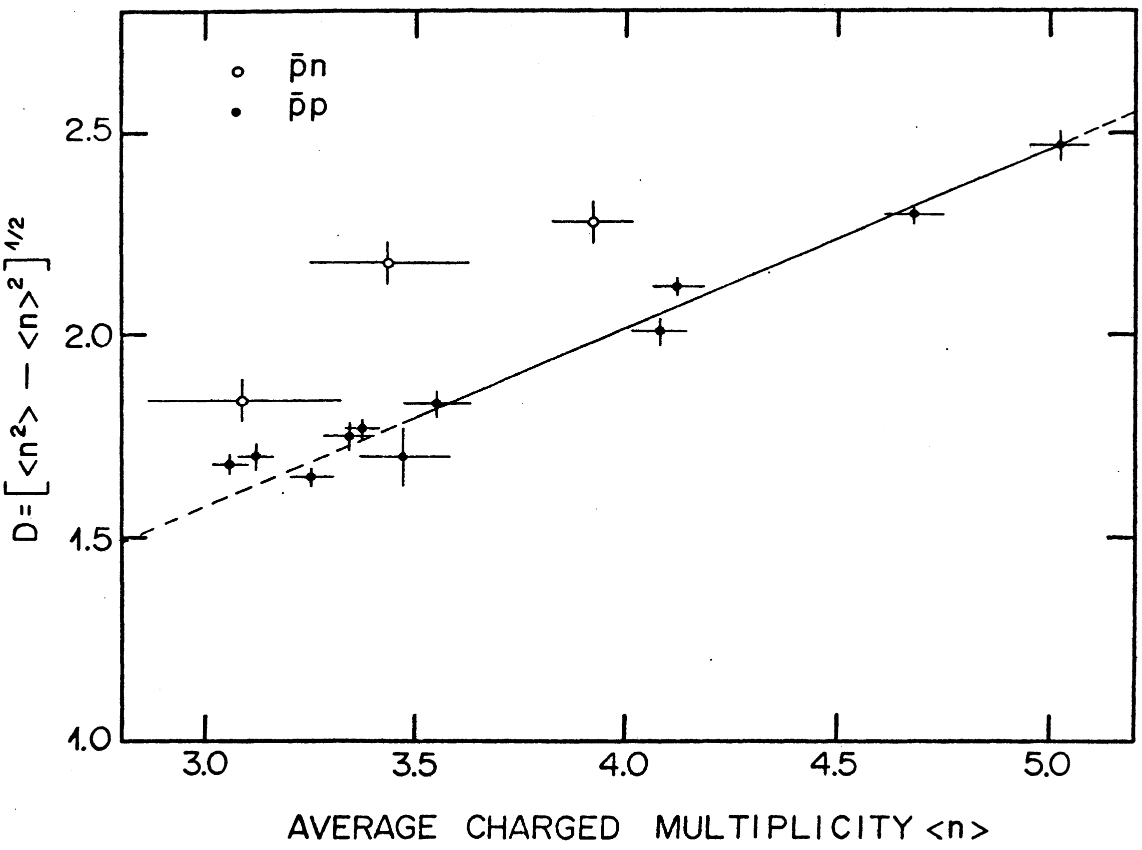

Figure 2

The dispersion D of the charged multiplicity versus its average $\langle n \rangle$ for the $\bar{p}n$ and the $\bar{p}p$ interactions. By fitting the straight line to the $\bar{p}p$ data in the $\langle n \rangle > 3.5$ region we only took into account the errors on the D quantities.

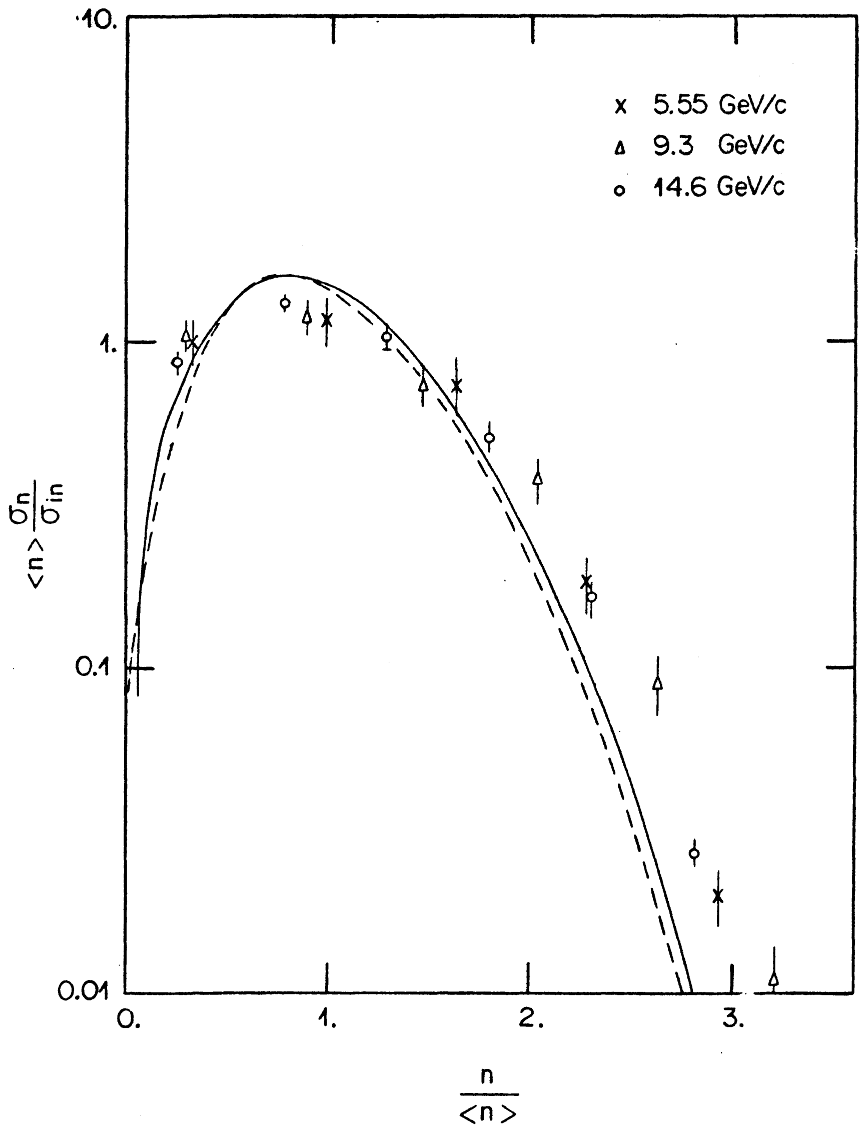

Figure 3

The distribution of $\langle n\rangle\sigma_n/\sigma_{in}$ versus $n/\langle n\rangle$ for the $\bar{p}n$ interactions at 5.55, 9.3 and 14.6 GeV/c. The full and dashed lines are obtained by fitting the pp and $\bar{p}p$ data. Note that the scaling behavior seems to be different for pp, $\bar{p}p$ and $\bar{p}n$ interactions [reference (11)]

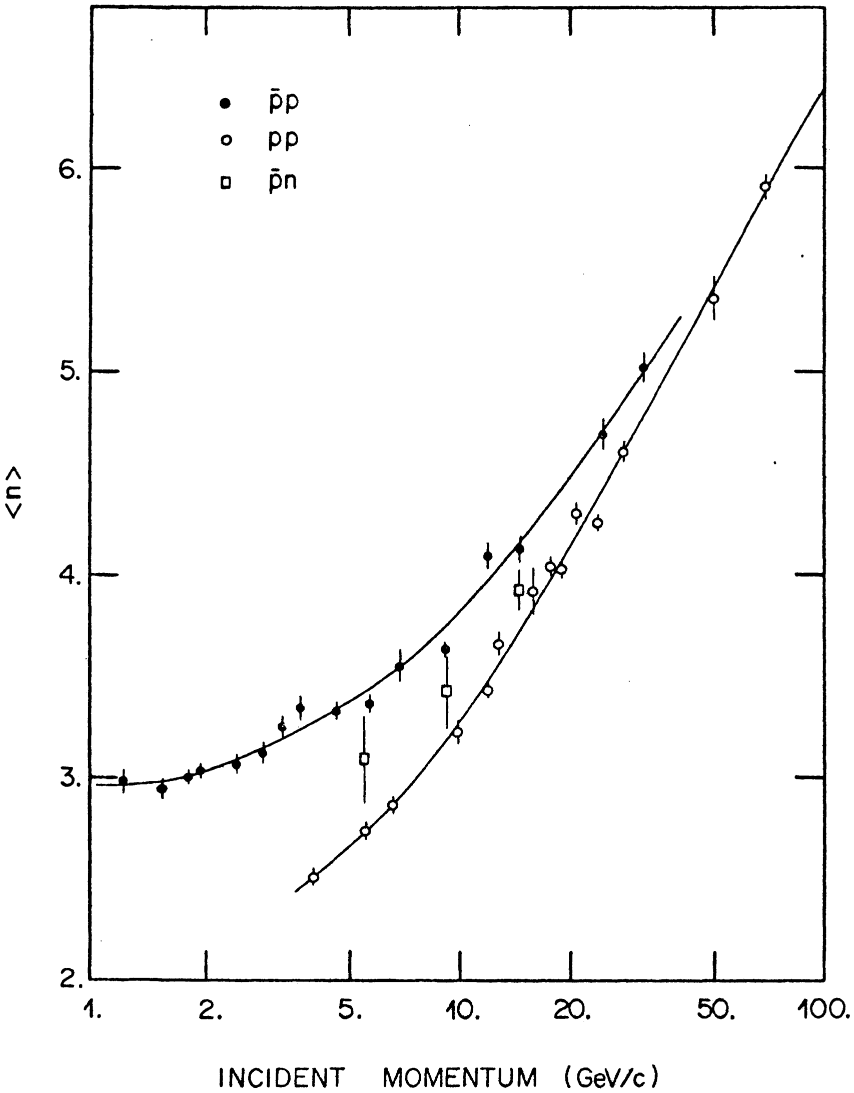

Figure 4

Comparison between the average multiplicity for pp, $\bar{p}p$ and $\bar{p}n$ interactions as a function of the incident momentum. The full curves are drawn to guide the eye.

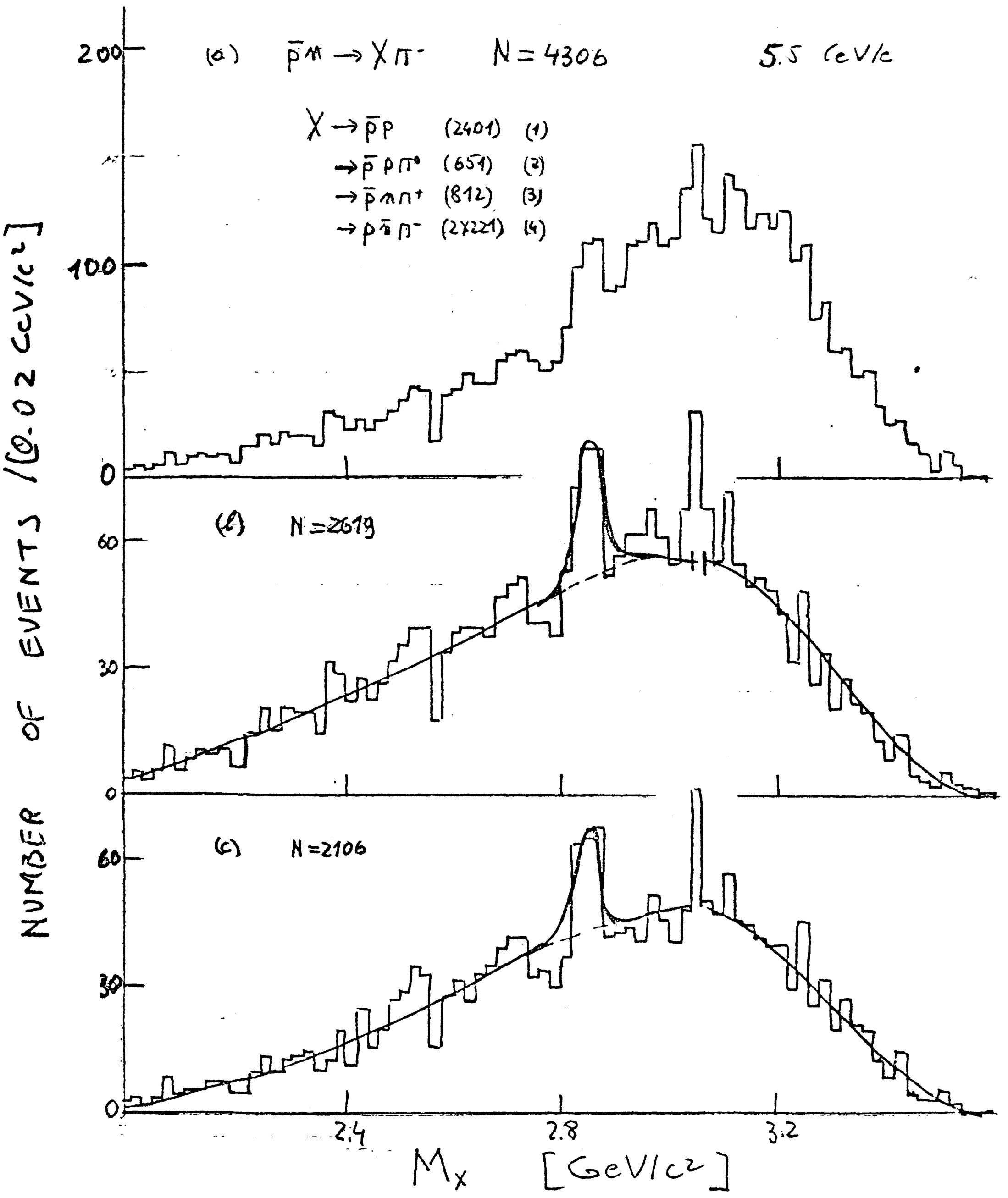

Figure 5

Example of structure observed at 2.8 GeV/c^2 in the $\bar{p}n \to X\pi^-$ reaction (5.5 GeV/c, Strasbourg data) ; a) all our events ; b) excluding the $\bar{\Delta}^{--}$ (1236) events ; c) excluding in addition from channel (1) the $\bar{\Delta}$(1900) and $p\pi^-$ mass combination in the 1,6 GeV/c^2 region