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Publication Date
1973-03-01

Reprinted from the Proceedings of the First EPS Conference on "Meson Resonances and Related Electromagnetic Phenomena" Bologna, Italy, April 14-16, 1971, Edited by R. H. Dalitz and A. Zichichi

LBL-1726
c.1

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March 1973

Prepared for the U.S. Atomic Energy Commission
under Contract W-7405-ENG-48

Reprinted from the volume: Proceedings of the First EPS Conference on « Meson Resonances and Related Electromagnetic Phenomena » - Bologna, April 14-16, 1971 - Edited by R. H. DALITZ and A. ZICHICHI - Published by Editrice Compositori, Bologna, Italy

Study of the $\bar{p}n$ partial cross-sections between 1.0 and 1.6 GeV/c (*)

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We shall discuss some results of a $\bar{p}n$ formation experiment in the region of the first enhancement of the total cross section (1) ($E^* \simeq 2190$ MeV) from the Berkeley-Padova-Pisa-Torino collaboration.

With the aim of carefully studying the $\bar{p}n$ partial cross sections in this energy region, we have exposed the 81 cm CERN D.B.C. to a separated beam of antiprotons at seven different momenta between 1.0 and 1.6 GeV/c; the step between two contiguous momenta (100 MeV/c) has been chosen to have, taking into account the Fermi motion, a smooth distribution of the c.m. $\bar{p}n$ energy.

The $\bar{p}n$ c.m. energy interval we can explore ranges from 2.04 to 2.32 GeV, completely enclosing the region of the bump of the total cross section. We have an average of $\frac{1}{2}$ev/μb at each momentum setting.

One of the possible origins of the bump is a threshhold effect due to the $\bar{\Delta}N + \Delta\bar{N}$ channel.

(*) Invited paper presented by A. Bettini

The values of cross section of the reaction:

$$\bar{p}n \to \bar{p}p\pi^- , \qquad (1)$$

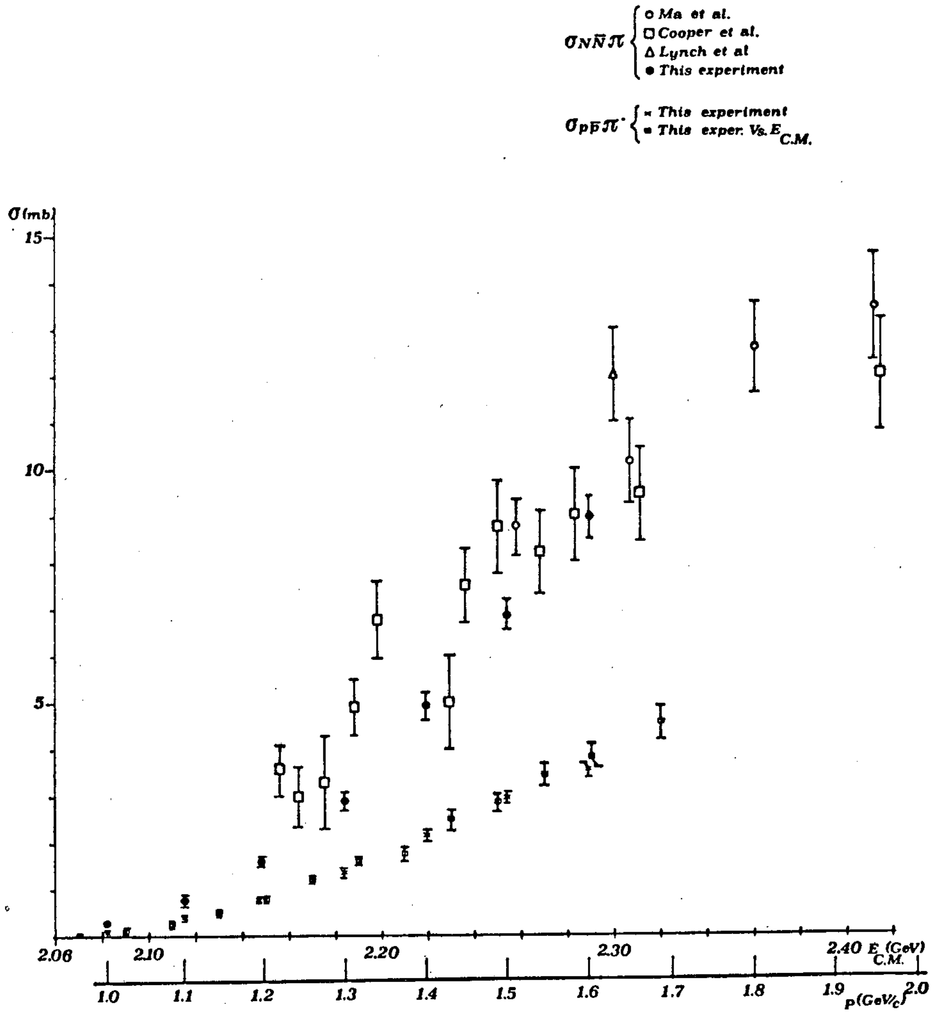

Fig. 1. – Cross-section for the reactions $\bar{p}n \to \bar{p}p\pi^-$ and $\bar{p}n \to \bar{\mathcal{N}}\mathcal{N}\pi$ as measured by this experiment, compared with that for the reaction $\bar{p}p \to \bar{\mathcal{N}}\mathcal{N}\pi$ as measured by other experiments (these last have been multiplied by two to take into account the total isotopic spin).

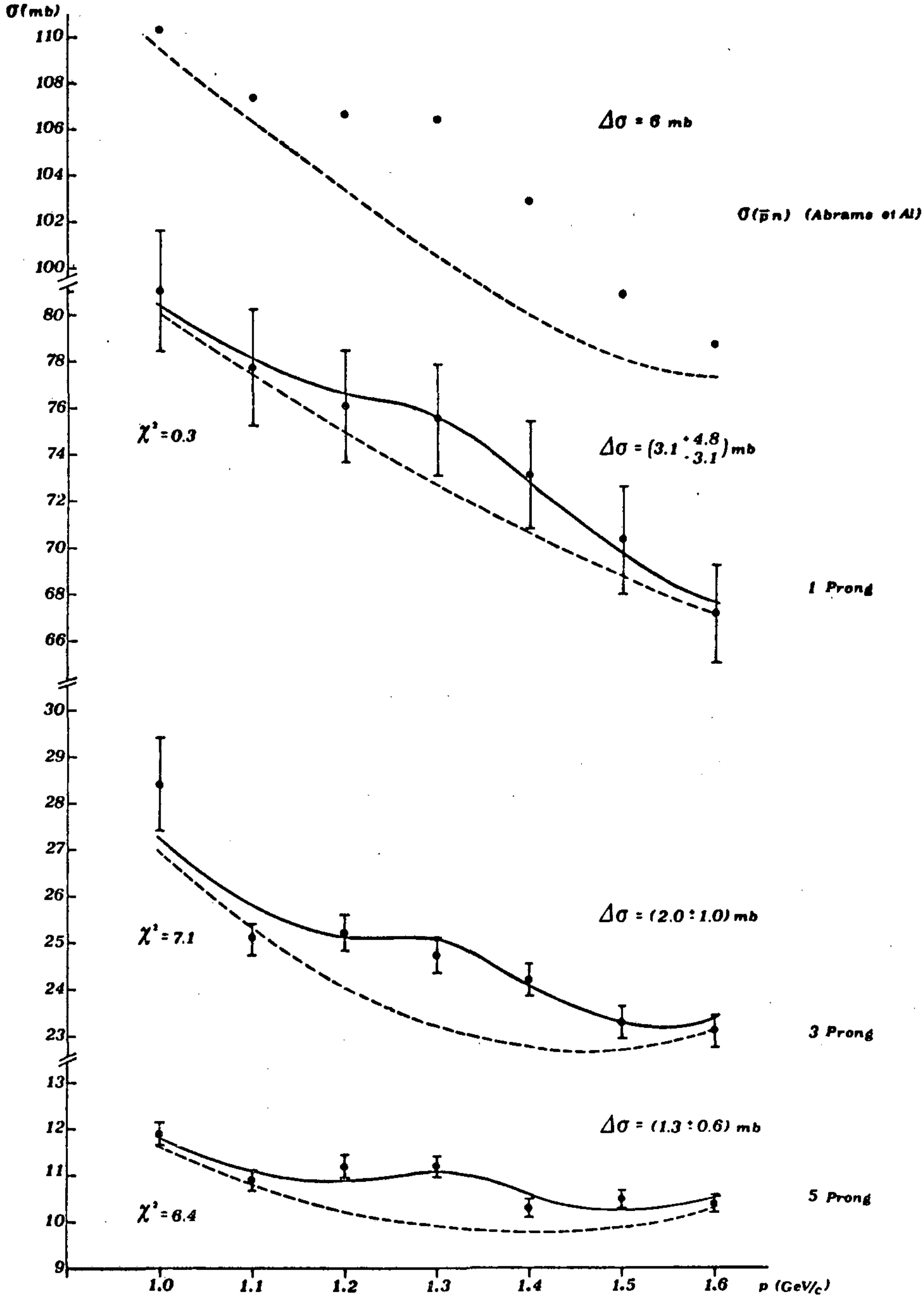

Fig. 2. – Total $\bar{p}n$ cross-section from Abrams *et al.* [1] and topological cross-sections from our experiment.

we have measured are reported in Fig. 1 as a function of incident $\bar{p}$ momentum and c.m. energy. The channel appears to be completely dominated by $\bar{\Delta}^{--}$ production; it is then reliable to apply an isobar model to evaluate the contribution of the unseen channel:

$$\bar{p}n \to \bar{p}n\pi^0 ; \tag{2}$$

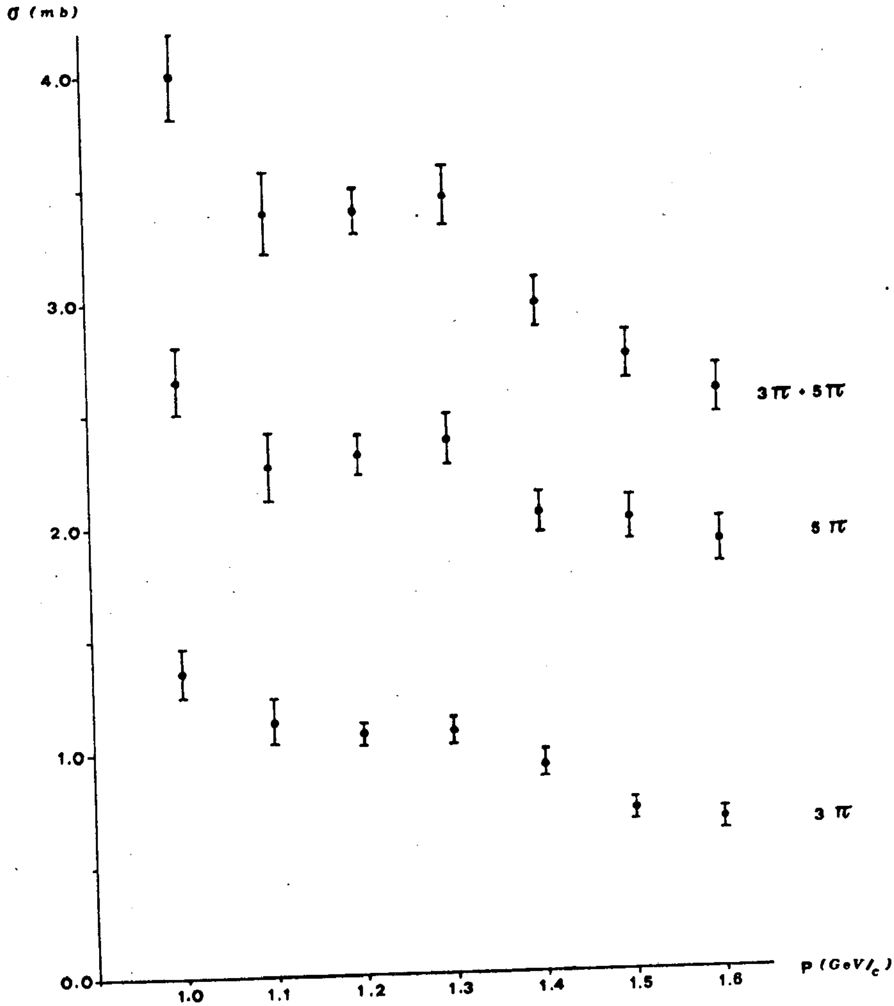

Fig. 3. – Cross-sections for the reactions $\bar{p}n \to 2\pi^-\pi^+$ and $\bar{p}n \to 3\pi^-2\pi^+$ as function of the beam momentum.

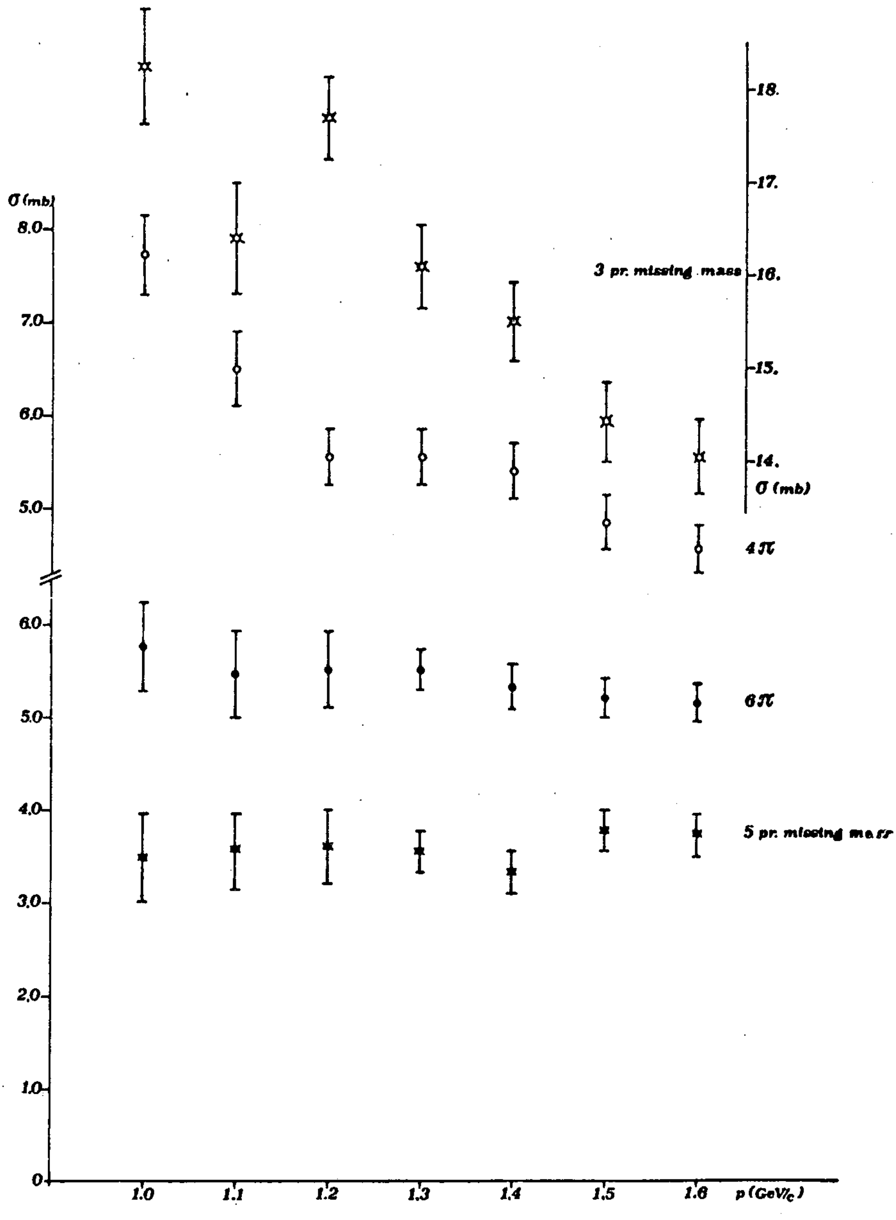

Fig. 4. – Cross-sections for the reactions $\bar{p}n \rightarrow 2\pi^- \pi^+ \pi^0$, $pn \rightarrow 3\pi^- 2\pi^+ \pi^0$, $\bar{p}n \rightarrow 2\pi^- \pi^+ MM$ (see text) and $\bar{p}n \rightarrow 3\pi^- 2\pi^+ MM$ (see text) as function of the beam momentum.

the cross section for the third one:

$$\bar{p}n \rightarrow \bar{n}n\pi^- \tag{3}$$

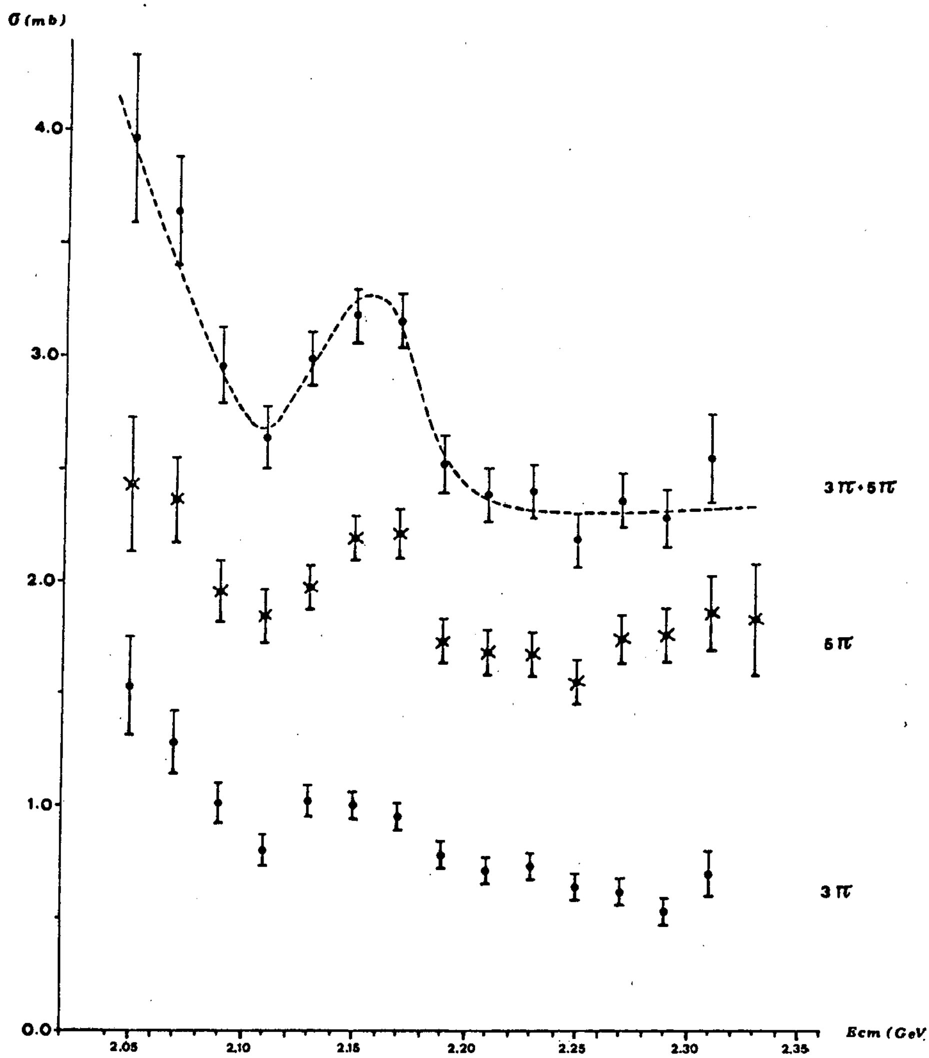

Fig. 5. – Cross-sections for the reactions $\bar{p}n \rightarrow 2\pi^- \pi^+$ and $\bar{p}n \rightarrow 3\pi^- 2\pi^+$ as functions of the c.m. $\bar{p}n$ energy (Preliminary)

is equal to that of reaction (1) due to *G*-parity conservation. The values of the cross section for the reaction $\bar{p}n \to \mathcal{N}\bar{\mathcal{N}}\pi$ evaluated in this way are reported in Fig. 1, compared to the published values of the cross section for the reaction $\bar{p}p \to \mathcal{N}\bar{\mathcal{N}}\pi$, multiplied by two to take into account isotopic spin.

As one can see, the one pion production cross section grows *at a constant rate* through all the region of the bump of the total cross section; from this observation we conclude that this channel cannot be at the origin of the 6 mb (1) bump. To explain the bump this cross section should have reached saturation (or at least its derivative have decreased) inside the region of the bump.

On the other hand we have positive evidence that the annihilation cross sections give contributions to the bump.

Figure 2 shows the values of the Abrams et al. (1) total cross section at our momentum setting (the dotted curve is the background they estimate under the resonance) and the values we measured for the cross sections of the odd-prong topologies (mainly p̄n interactions). The errors are point-to-point errors and do not include a 4% normalization error. The curves are fits of a Breit-Wigner function with mass and width fixed at the Abrams et al. values ($M = 2190$ MeV, $\Gamma = 85$ MeV) plus a parabolic background. Taking into account the big errors due to the ignorance of the background behaviour, we find a one-standard-deviation effect in the one-prong and two-standard-deviation effects both in 3-prong and 5-prong. No similar effect is seen in the even-prong topologies. This observation is in agreement with an assignment of $I = 1$ to the bump.

Let's consider now the physical cross section. In Fig. 3 the cross sections for the reactions:

$$\bar{p}n \to \pi^+\pi^-\pi^- \tag{4}$$

and

$$\bar{p}n \to 2\pi^+3\pi^- \tag{5}$$

are reported versus the incident p̄ momentum. A signal is observed in both processes at the same position and with the same width; it is enhanced by summing the two cross sections. The error bars in these and in the following mentioned cross sections are point-to-point errors. A 10% systematic normalization error is not included.

The cross sections for reactions:

$$\bar{p}n \to \pi^+\pi^-\pi^-\pi^0 \tag{6}$$

and

$$\bar{p}n \to 2\pi^+3\pi^-\pi^0 \tag{7}$$

(1 *c* fits) and:

$$\bar{p}n \rightarrow \pi^+\pi^-\pi^- MM \quad (8)$$

and

$$\bar{p}n \rightarrow 2\pi^+3\pi^- MM \quad (9)$$

(0 *c* fits) are shown in Fig. 4. Reactions (8) and (9) are defined as those with a missing mass greater than $1\pi^0$ and include also events with missing K^0's, *i.e.* some of the charged tracks may be kaons.

These channels have not yet been studied as carefully as reactions (1)-(5); we do not yet know exactly the contamination of different categories present at each energy; this is taken into account in the big error bars given to the data points. We do not observe in these channels any big signal at 1.3 GeV/c, even though more work is needed before a definite conclusion can be reached.

At this point we note that the odd *G*-parity states seem to give the main contribution to the bump. On the other hand we note that at each momentum the datum point receives contribution from c.m. $\bar{p}n$ energies in a range of about 60 MeV due to the Fermi motion; this effect necessarily tends to wash out the variations of the cross sections. The measurement of all the momenta of the final state particles can give on the other hand a highly precise determination of the c.m. energy for each event. We could then (the deuteron wave function being known) easily compute the cross sections as a function of the c.m. $\bar{p}n$ energy. Preliminary results are shown for reaction (4) and (5) in Fig. 5.

As can be seen, both cross sections resonate. The sum of them (the curve is hand-drawn to guide the eye) shows an enhancement of $\Delta\sigma \simeq (0.7 \div 0.8)$ mb, over a guessed background. We have not yet fitted curves to find the values of the parameters of the resonance, but it appears that $M \simeq 2.160$ MeV, $\Gamma \simeq 60$ MeV.

From this observation and taking into account the contribution of the many-π^0's counterparts we can conclude that the bump in the total cross section is mainly due to $G = -1$ pionic annihilations.

The bump we observe shows up nicely, mainly for the good signal to background ratio we have due to the pure $I = 1$ initial state and to the small value of the cross sections. For comparison note that the cross section for $\bar{p}p \rightarrow 2\pi^+2\pi^-\pi^0$ is around 14 mb in this energy region (a factor of 7 bigger than that of reaction (5)); if a bump of the same height were to be present it would certainly be much more difficult to detect.

REFERENCE

1) R. J. Abrams *et al.*: *Phys. Rev. Lett.*, **18**, 1209 (1967).

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