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Results in pion proton scattering near the higher resonances

par

P. FALK-VAIRANT and G. VALLADAS

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Résultats pour la diffusion des mesons pi par les protons dans le domaine des hautes résonances (1962).

Sommaire. — On présente brièvement les données connues concernant la section efficace totale pour la diffusion des mésons pi par les protons dans le domaine d'énergie de 400 MeV à 1,5 GeV. On a également rassemblé tous les résultats concernant les sections efficaces totales pour des canaux particuliers : diffusion élastique, diffusion inélastique et échange de charge. En partant des nouveaux résultats sur la section efficace pour la diffusion élastique et inélastique dans l'état T = 1/2.

CEA 2092 - FALK-VAIRANT P., VALLADAS G.

Results in pion proton scattering near the higher resonances (1961).

Summary. — We present briefly the available information on the total cross sections for pion proton scattering in the energy region from 400 MeV to 1.5 GeV. We also have collected all results on total cross sections for particular channels like elastic scattering, inelastic scattering and charge exchange. Using new results on the total cross section for neutral events, we have plotted separately the cross section for elastic and for inelastic scattering in the T = 1/2 state.

RESULTS IN PION PROTON SCATTERING NEAR THE HIGHER RESONANCES

P. Falk-Vairant and G. Valladas

Centre d'Etudes Nucléaires, Saclay, France

(presented by G. Valladas)

We present briefly the available information on the total cross sections for pion proton scattering in the energy region from 400 MeV to 1.5 GeV. We also have collected all results on total cross sections for particular channels like elastic scattering, inelastic scattering and charge exchange. Using new results on the total cross section for neutral events, we have plotted separately the cross section for elastic and for inelastic scattering in the $T=1/2$ state.

π^+p total cross section

Fig. 1 shows the total cross section for scattering of positive pions on hydrogen. The points are the results of measurements carried out at Saclay in 1959 [1], the dashed line represents the results obtained by a group working at Berkeley [2, 3].

There is a difference of 2 to 3 mb between the Saclay and the Berkeley results, at all energies. This discrepancy is not yet understood.

π^-p total cross section

Fig. 2 shows the total cross section for scattering of negative pions. The points (and the corresponding solid line) represent the measurements of the Saclay group [1]. The dashed line shows, at energies smaller then 0.36 GeV, the results of Konin et al at Dubna [4]. Above this energy, the same line represents the results of Devlin et al at Berkeley [3].

The values for energy and cross section at the maxima, as deduced from the Saclay data, are the following :

$T\pi$ Lab. (MeV)	σ Total (mb)
605 ± 5	45.8 ± 1.8
890 ± 9	58.0 ± 1.8

We can deduce easily the total cross section in the $T = ½$ state from the $\pi^- - p$ and $\pi^+ - p$ total cross sections. For any detailed discussion, one has to know separately the cross sections for elastic and inelastic scattering in this isotopic spin state. We shall make an attempt to deduce these cross sections from the available data.

Data on partial cross sections

In the scattering of positive pions, one distinguishes relatively easily between elastic scattering on one hand, and the sum over all inelastic channels on the other hand. In the case of negative pions, however, the cross sections for the various channels are, for experimental reasons, most easily obtained in the following combinations :

class *(a)* charged elastic $\pi^- + p \to \pi^- + p$

(b) charged inelastic $\pi^- + p \to \pi^+ + \pi^- + n$
$\pi^0 + \pi^- + p$
$3\pi + n$
Strange particles (charged)

(c) neutrals $\pi^- + p \to \pi^0 + n$
$\pi^0 + \pi^0 + n$
$3\,\pi^0 + n$
Strange particles (neutrals)

In order to calculate the $T = \frac{1}{2}$ elastic cross section one has to know the cross section for charge-exchange. It appeared desirable to provide additional measurements of the total cross section for events of class *(c)* and to separate charge exchange events from neutral inelastic events.

These are two objectives of an experiment now in progress at Saclay. A description and preliminary results have been submitted in form of a contributed paper. The experiment is done by counting the number of negative pions which interact in hydrogen without triggering a 4π counter surrounding the target. The experiment is designed in such a way as to yield at the same time a measurement of the total $\pi^{-}p$ cross section, thus providing checks, particularly on the beam energy. Fig. 3 shows preliminary results. On a different scale Fig. 3 also shows the $\pi^{-}p$ total cross-section as measured previously (dashed line) and as obtained in this experiment (circles).

One notices that the total cross section for neutral events presents maxima at energies close to the resonances of the $T = \frac{1}{2}$ total cross section. The second maximum, at about 860 MeV, appears, however, to be shifted by about 30 MeV from the position of the corresponding resonance (890 MeV).

This shift arises probably from the fact that charge exchange scattering results from the interference of

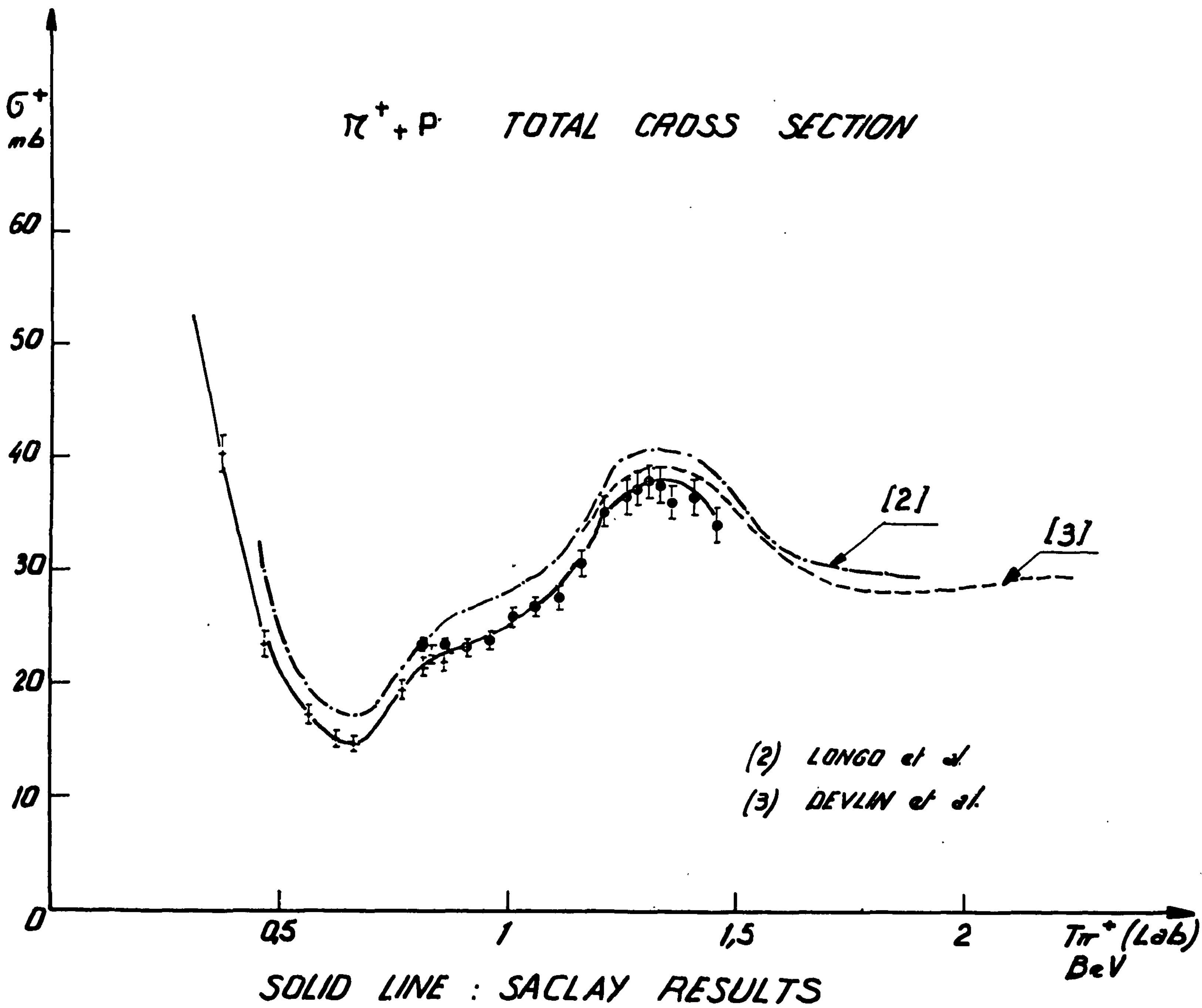

Fig. 1 $\pi^{+}-p$ total scattering cross section.

amplitudes in the $T = {}^1/_2$ and $T = {}^3/_2$ states. Just to understand the effect, let us suppose that the interaction is purely elastic; the charge exchange term would then be given by the expression :

$$\sigma_{ex} \propto \lambda^2 \sin^2 (\delta_{3/2} - \delta_{1/2})$$

A precise measurement of the effect may eventually be useful for the phase shift analysis at the second resonance.

Fig. 4 shows a compilation of all other data on total cross sections in $\pi^- p$ scattering above 450 MeV. The upper graph represents measurements of the charged elastic scattering; the middle one shows total cross sections for neutral events. In most of the cases, all results at a given energy come from the same experiment. The results at 460 MeV, 600 MeV and 770 MeV are propane bubble chamber data by Crittenden et al [5]. The points at 800 MeV, 950 MeV, 960 MeV and 1010 MeV are hydrogen bubble chamber data obtained respectively by McCormick et al [6], Erwin et al [7], Alles-Borelli et al [8] and Derado et al [9]. Data at 1370 MeV come from a diffusion cloud chamber experiment by Eisberg et al [10], those at 900 MeV and at 1500 MeV have been obtained in emulsions by Walker et al [11].

We have used for the three classes of events the branching ratios as published by the authors and we

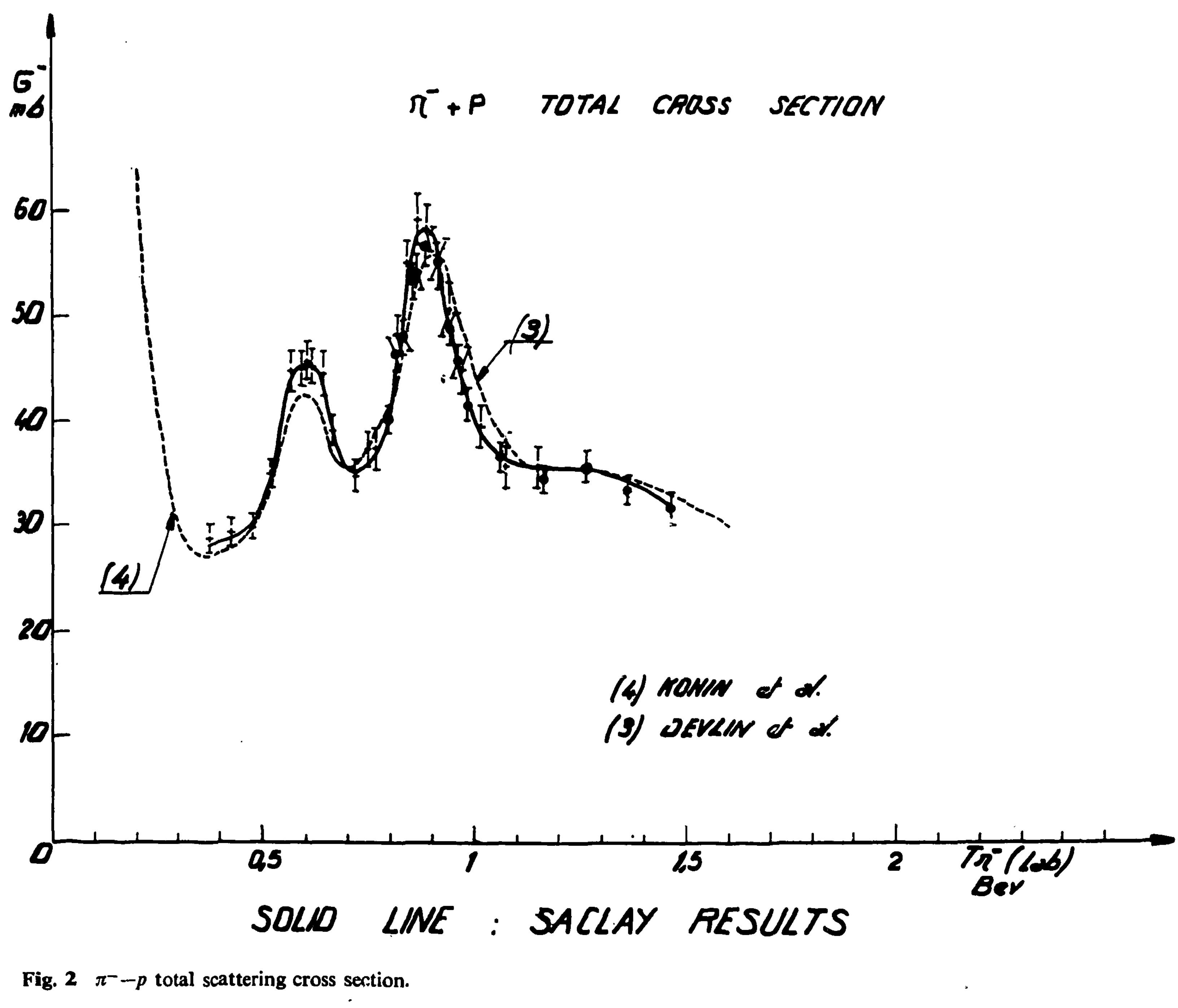

Fig. 2 $\pi^- - p$ total scattering cross section.

have adjusted the cross sections to make their sum equal to the measured π^-p total cross section [1].

In two other propane chamber experiments, one at 915 MeV by Bergia et al[12], the other at 1300 MeV by Chretien et al[12], only the total cross section for charged elastic scattering was obtained by fitting the extrapolated forward cross section to its value as deduced by dispersion relations.

On the graph for neutral events, the dashed line represents the recent Saclay data. These counter results are in agreement with the hydrogen bubble chamber data between 900 MeV and 1000 MeV. At energies where only the elastic cross section was measured (915 MeV and 1300 MeV) we have added the Saclay value for neutral events and deduced the charged inelastic cross section by subtraction (open circles). At 517 MeV and 617 MeV, Meyer et al[14] have measured in a hydrogen bubble chamber the ratio of charged elastic to charged inelastic events. Using our data on neutrals, we obtain the points plotted at these energies.

The upper graph shows that the charged elastic cross section reaches about 25 mb at 900 MeV and decreases again to about 10 mb at 1300 MeV. This is a quite violent variation in the region of the third resonance. The point at 600 MeV seems to prove the presence of another maximum at the second resonance. The charged inelastic cross section does not undergo the same violent changes. As well at 900 MeV as at 1400 MeV this cross section is of the order of 20 mb.

We now want to split the neutral events into charge exchange scatters on one hand and all inelastic events on the other hand. At 600 MeV and at 770 MeV

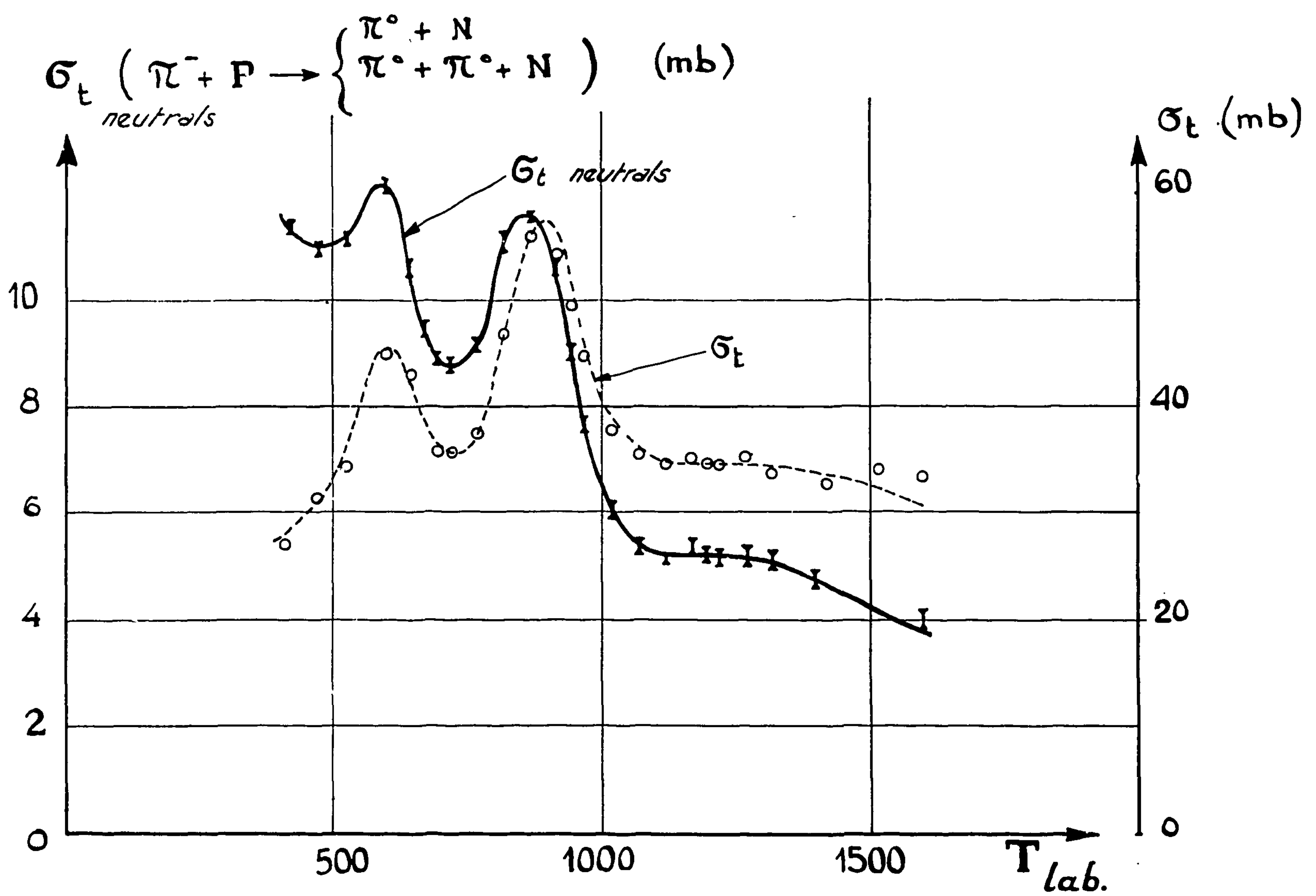

Fig. 3 The solid curve shows the total neutrals cross section, and refers to the left hand abscissa. The dotted curve is the total cross section for π^-—p scattering, and refers to the righthand abscissa.

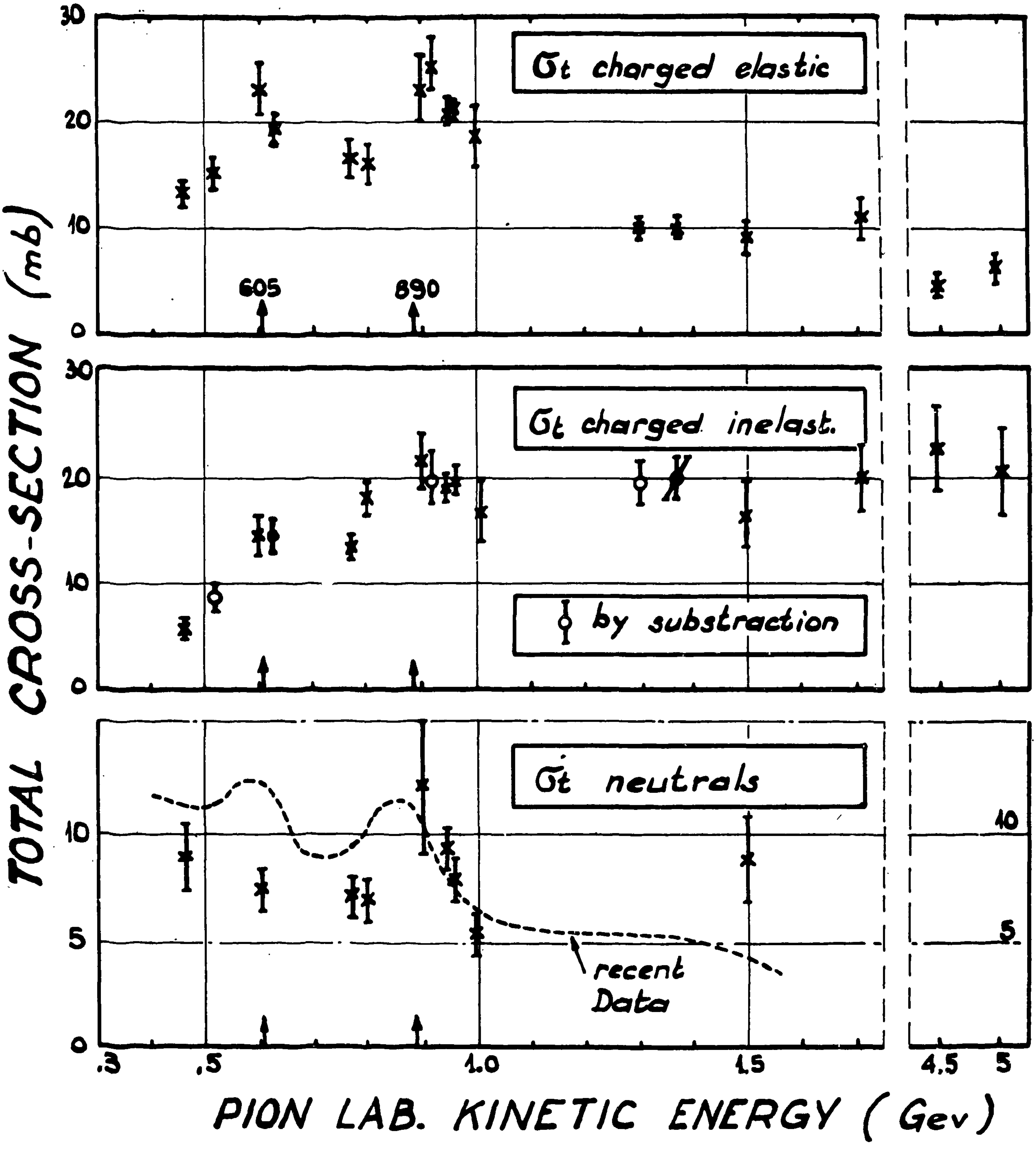

Fig. 4 Compilation of other data on total cross sections, in $\pi^- - p$ scattering above 450 MeV. See text for explanation and references.

Crittendèn et al[5] have counted the number of electron pairs in the vicinity of the stopping track and have deduced a cross section of the order of 3 or 4 mb for neutral inelastic events (more than 2 γ rays). A similar method is used in the Saclay experiment on neutral events: The ratio of the number of counts with and without a lead converter surrounding the target depends upon the ratio of events with one or two neutral pions emitted. Very preliminary results between 600 MeV and 1000 MeV give a cross section of the order of 2mb for events with more than one π^0. We have used these results for calculating the charge exchange cross section.

Elastic and inelastic T = ½ cross sections

Using the charge exchange cross section previously determined, we have calculated the elastic scattering in the T = ½ state from the expression.

$$\sigma_{t\,\mathrm{el}}(T={}^1/_2) = {}^3/_2[\sigma_{t\,\mathrm{exch}}(\pi^- p)+\sigma_{t\,\mathrm{el}}(\pi^- p) - {}^1/_3\sigma_{t\,\mathrm{el}}(\pi^+ p)]$$

The total cross section for elastic scattering of positive pions was obtained by drawing a smooth curve through the experimental points by Willis[15] at 500 MeV, by Erwin and Kopp (private communication) at

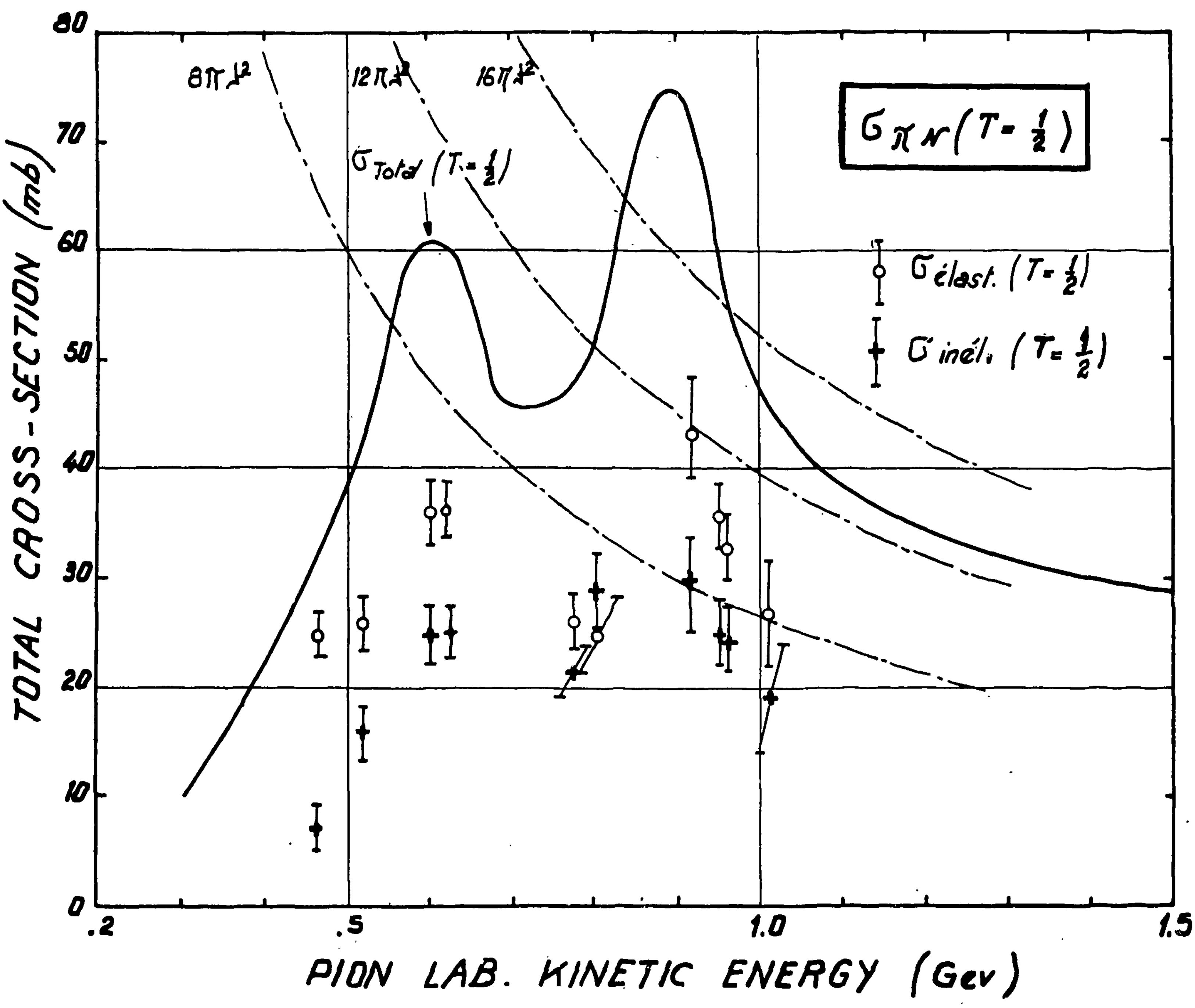

Fig. 5 The solid curve represents the total $T = ½$ cross section. The open circles are the elastic $T = ½$ cross section. The crosses are inelastic $T = ½$ cross section, obtained by subtraction.

990 MeV and by Glaser et al[16] at 1100 MeV. The three experiments give cross sections of 17 mb, 15 mb and 13 mb respectively. The resulting values of $\sigma_{t\ el}(T = ½)$ are plotted in Fig. 5 (circles) together with the $T = ½$ cross section (solid line). The inelastic $T = ½$ cross section (crosses) results by subtraction.

Attribution of angular momentum

Among the various problems concerning the behaviour of the $T = ½$ cross sections we would like, in conclusion, to consider briefly the possibility to assign an angular momentum state to an eventual resonance ($\delta = 90°$) at about 900 MeV from the ratio of elastic to inelastic interaction in the resonant part of the total $T = ½$ cross section.

In Fig. 6 we have drawn very tentatively two curves showing the possible behaviour of the elastic and the inelastic cross sections, only in order to simplify the discussion which follows. In doing so we have assumed that the inelastic $T = ½$ cross section above 1000 MeV is equal to the inelastic $\pi^- p$ cross section at higher energies, 20 mb (Fig. 4)[17].

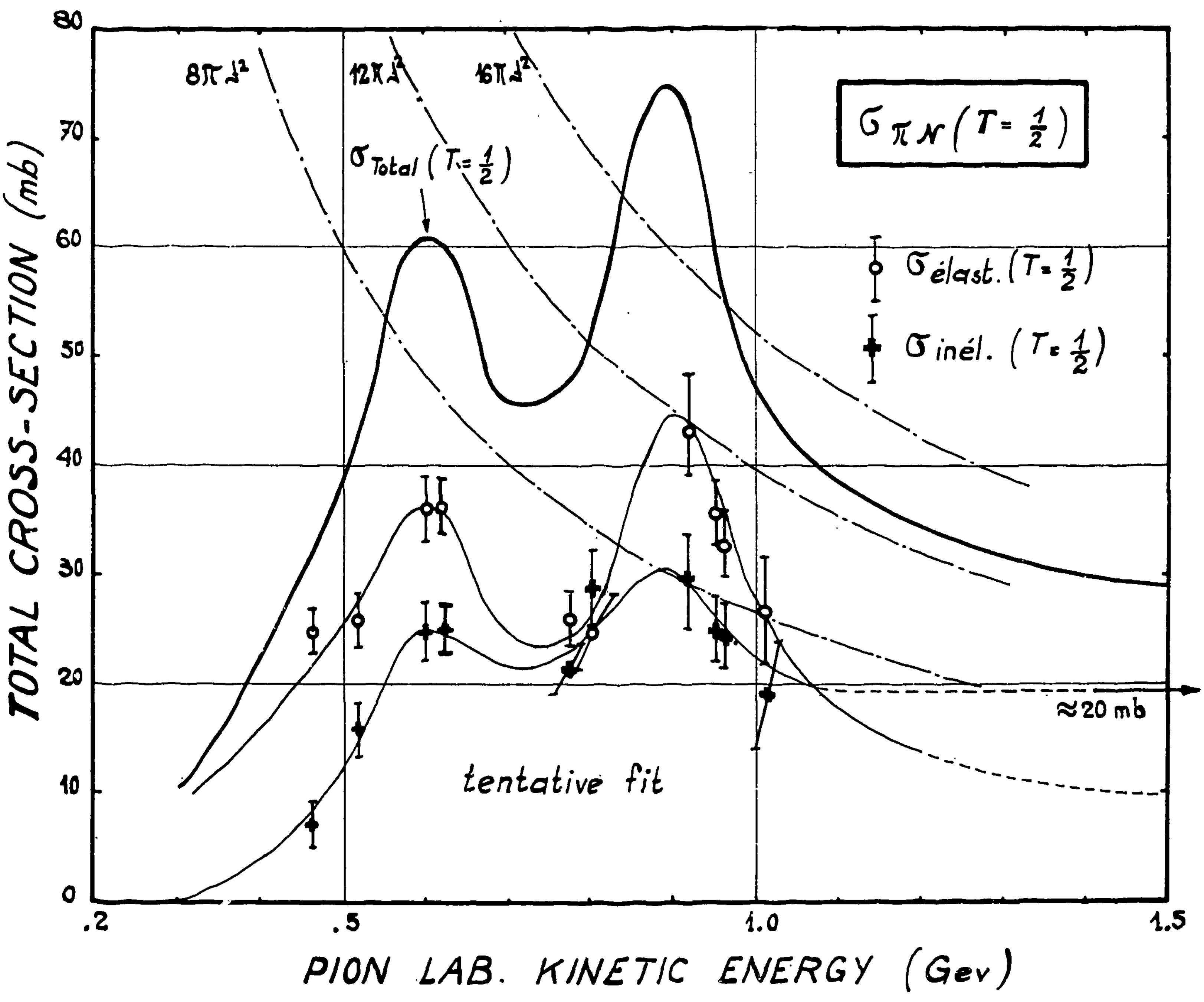

Fig. 6 A tentative fit to the data of Fig. 5.

We analyze this total cross section in the following way :

(a) We subtract a constant background equal to 30 mb from σ_t. The remaining part may be filled by a Breit-Wigner formula in the neighbourhood of the maximum.

(b) From the height of this resonance ≈ 40 mb, one finds that the angular momentum has to be $^5/_2$ or more.

(c) For a given angular momentum the height of the maximum determines the imaginary part of the resonant phase shift and one can deduce the resonant inelastic maximum cross section. We have :

$$\text{for } J = \begin{cases} ^5/_2 \\ ^7/_2 \\ ^9/_2 \end{cases} \sigma_{\text{inel. max.}} \approx \begin{cases} 5 \text{ mb} \\ 13 \text{ mb} \\ 18 \text{ mb} \end{cases}$$

From the present data, we can only estimate that the inelastic contribution to the resonance is probably between 5 and 15 mb. It follows that the two possible values of J are $^5/_2$ and $^7/_2$. More precise measurement of the $\pi^- p$ elastic scattering are needed at the resonance energy.

We have limited the present paper to the results of total cross section measurement only and we have tried to show how these data may complete information drawn from differential measurements on elastic and inelastic scattering.

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DISCUSSION

PICCIONI : Do you find any indication at all, however tentative of the parity of what you call the second resonance in a $T = \frac{1}{2}$ state.

VALLADAS : No. The shift is difficult to interpret if one does not know quite well the value of the phase shifts α_{33} and δ_{33} and the variation of their imaginary part around 600 MeV.

If the imaginary parts of these phase shifts are increasing rapidly with energy and if the real parts are small, the maximum would be shifted toward lower energies for either hypothesis on the orbital momentum (P or D). It seems too early to draw any conclusion from the present data.

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