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$K^- p(n)$ interaction in the region 900 - 1200 MeV/c

1. Generalities

It has been known for quite some time that the $K^- p$ total cross section is dominated in this region by a broad bump peaking at 1050 MeV/c.[1,2] This behaviour was attributed by Cook et al[1] to the existence of a I = o resonant state, Y_o^* (1815), on the basis of the absence of a corresponding bump in the $K^- n$ total cross section.

Both the size of the resonance, and the complexity of the angular distributions suggested that the spin J of Y_o^* (1815) should be greater than 3/2, possibly 5/2. (J = 5/2 would be required if Y_o^* (1815) were a Regge recurrence of the Λ) Recent evidence by Barbaro-Galtieri et al[3] suggests that the situation in the region of the Y_o^* (1815) bump is actually much more complicated. The $K^- p$ invariant mass, in $K^- n \rightarrow K^- p \pi^-$ at 1.51 GeV/c showed in fact a resonance at 1765 MeV, in addition to a shoulder corresponding to Y_o^* (1815). This new resonance corresponds to $P_k \sim 940$ MeV/c. Various arguments have been given to show that it is unlikely that Y^* (1765) be in fact a shifted Y_o^* (1815). Arguments based on the behaviour of the angular distributions for $K^- p$ elastic and charge exchange processes suggest that an I = 1 component be present in the region, and induced the above authors to attribute Y^* (1765) to an I = 1 resonance.

Let us now review the situation in more detail. For this purpose it is useful to recall the reaction amplitudes and important relations about cross sections for $K^- p$ and $K^- n$ processes, which follow from the assumption of charge independence. The first relation of interest is that which holds for the total cross sections:

$\sigma (K^- n) = \sigma_1 (\bar{K} N)$; pure I = 1

$\sigma (K^- p) = \frac{1}{2} (\sigma_o (\bar{K} N) + \sigma_1 (\bar{K} N))$; I = 0,1

$\sigma_o (\bar{K} N) = 2 \sigma (K^- p) - \sigma (K^- n)$, thus when only the I = 1 amplitude is present

$$\sigma (K^- n) = 2 \sigma (K^- p) \qquad (1)$$

For the various channels in K^- p and K^- d we have

a) K^- p

$$\sigma(K^- p) = \frac{1}{4}\left|T_o + T_1\right|^2 \quad \text{elastic}$$

$$\sigma(\overline{K^o} n) = \frac{1}{4}\left|T_o - T_1\right|^2 \quad \text{charge exchange}$$

subfixes 0,1 refers to I = 0,1 amplitudes

$$\sigma(\Sigma^+ \pi^-) = \left|\frac{1}{\sqrt{6}} M_o - \frac{1}{2} M_1\right|^2$$

$$\sigma(\Sigma^- \pi^+) = \left|\frac{1}{\sqrt{6}} M_o + \frac{1}{2} M_1\right|^2$$

$$\sigma(\Sigma^o \pi^o) = \left|\frac{-1}{\sqrt{6}} M_o\right|^2$$

$$\sigma(\Lambda \pi^o) = \left|\frac{1}{\sqrt{2}} N_1\right|^2$$

$$\sigma(\Lambda \pi^+ \pi^-) = \left|\frac{1}{\sqrt{6}} R_o - \frac{1}{2} R_1\right|^2$$

$$\sigma(\Lambda \pi^- \pi^+) = \left|\frac{1}{\sqrt{6}} R_o + \frac{1}{2} R_1\right|^2$$

$$\sigma(\Lambda \pi^o \pi^o) = \left|\frac{-1}{\sqrt{6}} R_o\right|^2$$

From these follow

$$\sigma_o(\Sigma \pi + \Lambda \pi \pi) = 6\left[\sigma(\Sigma^o \pi^o) + \sigma(\Lambda \pi^o \pi^o)\right] \qquad (2)$$

$$\sigma_1(\Sigma \pi + \Lambda \pi + \Lambda \pi \pi) = 2\sigma(\Sigma^+ \pi^-) + 2\sigma(\Sigma^- \pi^+) - 4\sigma(\Sigma^o \pi^o) \qquad (3)$$

$$+ 2\sigma(\Lambda \pi^o) + 4\sigma(\Lambda \pi^\pm \pi^\mp) - 4\sigma(\Lambda \pi^o \pi^o)$$

b) K^- d

$$\sigma(\Sigma^+ \pi^- n) = \frac{1}{4}\left|\frac{M_1}{\sqrt{2}} - \frac{M_o}{\sqrt{3}}\right|^2$$

$$\sigma(\Sigma^- \pi^+ n) = \frac{1}{4}\left|\frac{M_1}{\sqrt{2}} + \frac{M_o}{\sqrt{3}}\right|^2$$

$$\sigma(\Sigma^- \pi^o p) = \frac{1}{4}\left|M_1\right|^2$$

$$\sigma(\Sigma^o \pi^- p) = \frac{1}{4}\left|M_1\right|^2$$

$$\sigma(\Sigma^o \pi^o n) = \frac{1}{12}\left|M_o\right|^2$$

$$\sigma(\Lambda \pi^o n) = \frac{1}{4}\left|N_1\right|^2$$

$$\sigma(\Lambda \pi^- p) = \frac{1}{2}\left|N_1\right|^2$$

Note that the amplitudes for $\Lambda \pi \pi N$ processes are identical to those for $\Sigma \pi N$ above.

Signifioant relations follow:

$$\sigma(\Lambda \pi^- p) = 2\sigma(\Lambda \pi^o n) \text{ or } \frac{K^- n \longrightarrow \Lambda \pi^-}{K^- p \longrightarrow \Lambda \pi^o} = \frac{2}{1} \qquad (4)$$

if the I = 1 amplitude is $\neq 0$. Also if this is the case

$$\sigma\ (\Sigma^{0}\ \pi^{-}\ p) = \sigma\ (\Sigma^{-}\ \pi^{0}\ p) \qquad (5)$$

We also have

$$\frac{\sigma\ (K^{-}\ n \longrightarrow \Lambda\ \pi^{0}\ \pi^{\bar{0}})}{\sigma\ (K^{-}\ p \longrightarrow \Lambda\ \pi^{\pm}\ \pi^{\mp})} = \frac{2\ |R_1|^2}{|R_1|^2 + |R_0|^2} = \frac{2}{1} \text{ for } R_0 = 0 \qquad (6)$$

Relations (1) - (6) provide various possible tests to detect the presence of an enhancement in the I = 1 amplitude in the region of the 1815 bump.

2. Total and partial cross sections

Relation (1) is the basis for the assignement I = 0 to Y_0^* (1815). As to the possibilities of a nearby I = 1 resonance we can (fig. 1) note that the well known bump in K^- p total is asymmetric, with a steeper slope on the high momentum side, and some indication of a shoulder in the region 900 - 1000 MeV/c.

If there is a Y_1^* in this region, the K^- n total cross section should have a bump twice as high. First, the two points at ~ 980 MeV/c are in disagreement so that a bump in K^- n here is not excluded. Second, there is a gap between 810 and 980 MeV/c where a bump could well have escaped detection, considering that such a bump, as pointed out by Barbaro-Galtieri et al[3], will be smeared by the Fermi motion in deuterium. Clearly the data are not in contradiction with a possible I = 1 resonances in the region and measurements of K^- n cross sections in the region 800 - 1000 MeV/c are urgently needed.

The data on K^- p elastic (fig. 2) are very contradictory in the region 700 - 1200 MeV/c. In fact, the points of Bastien and Berge[4] at 762 and 850 MeV/c and of Graziano and Wojcicki[5] at 1.15 GeV/c are consistently higher than the set of cross sections in the region given by Beall et al[6]. The general trend is that of a bump around 1 GeV/c, however, and the bubble chamber data are suggestive perhaps of a rise beyond 850 MeV/c, more rapid than indicated by the spark chamber results. Here in particular, closely spaced points taken with the same detector are necessary. Aside from the disagreement with the B.C. data, the set of spark chamber points is again not inconsistent with a structure between 900 and 1100 MeV/c.

The K^- p charge exchange data are meager and interesting. (Fig. 3). A definite rise is observed in B.C. data from 600 to 850 MeV/c; with a possible levelling off. At 1 GeV/c, a counter point would suggest a very rapid enhancement, also confirmed by a B.C. point at 1.15 GeV/c. Of course, this would be quite consistent with a large I = 0 amplitude. Unfortunately no data are available between 850 and 1000 MeV/c, where a possible I = 1 resonance may produce a drastic drop in the cross section, since $\sigma (K^- p \longrightarrow \overline{K^o} n) = \frac{1}{4} |T_o - T_1|^2$. This is of course a rather sensitive channel, and no B.C. points have as yet been published between 850 and 1150 MeV/c.

For the $\Sigma \pi$ cross sections (fig. 4) the usual gap exists between 850 and 1150 MeV/c. The $\Lambda \pi^o$ cross section on the other hand (fig. 5) indicates a possible rise beyond 750 MeV/c, and thus of course can only be due to the I = 1 component. At 850 MeV/c, for two body final states ($\Sigma \pi$ and $\Lambda \pi$), $\sigma_o \sim 5$ mb, $\sigma_1 \sim 9$ mb. The $K^- n \longrightarrow \Lambda \pi^-$ is an extremely good channel to detect an I = 1 resonance here, because of relation (1.4).

The $\Lambda \pi^+ \pi^-$ cross section may be interesting as well (fig. 6). Comparison with $K^- n \longrightarrow \Lambda \pi^- \pi^o$, aside from the slightly larger difficulties would also be worthwhile (1.6).

3. Angular distributions

The following is the expression for the differential cross section obtained from expansion through $g_{7/2}$ partial waves.
It is expressed in the form

$$k^2 \frac{d\sigma}{d\Omega} = \sum_n A_n \mu^n, \text{ when } \mu = \cos\theta$$

$$\frac{d\sigma}{d\Omega} = \left\{ |s_1|^2 + |p_1|^2 + |p_3|^2 + |d_3|^2 + \frac{9}{4}\left(|d_5|^2 + |f_5|^2 + |f_7|^2 + |g_7|^2 \right) \right\}$$

$$+ 2\,\mathrm{Re}\Big\{ -(s_1^* d_3 + p_1^* p_3) - \frac{3}{2}(s_1^* d_5 + p_1^* f_5 + p_3^* g_7) + \frac{3}{2}(d_3^* d_5 + p_3^* f_5 + s_1^* g_7 + p_1^* f_7) - \frac{9}{4}(d_5^* g_7 + f_5^* f_7) \Big\}$$

$$+ \mu \,.\, 2\,\mathrm{Re}\Big\{ s_1^* p_1 + 2(s_1^* p_3 + p_1^* d_3) - 5 p_3^3 d_3 - \frac{9}{2}(s_1^* f_5 + p_1^* d_5) + \frac{9}{2}(d_5^* f_7 + f_3^* g_7) - 6(s_1^* f_7 + p_1^* g_7) + \frac{21}{2}(d_3^* f_7 + p_3^* g_7) + \frac{45}{4} d_5^* f_5 - \frac{81}{4} f_7^* g_7 \Big\}$$

$$+ \mu^2 \Big\{ 3(|p_3|^2 + |d_3|^2) - \frac{9}{2}(|d_5|^2 + |f_5|^2) + \frac{45}{4}(|f_7|^2 + |g_7|^2) + 2\,\mathrm{Re}\Big[3(p_1^* p_3 + s_1^* d_3) - 3(p_3^* f_7 + d_3^* g_7) + \frac{9}{2}(s_1^* d_5 + p_1^* f_5) - 18(d_3^* d_5 + p_3^* f_5) - 15(s_1^* g_7 + p_1^* f_7) + \frac{207}{4}(d_5^* g_7 + f_5^* f_7) \Big] \Big\} \qquad (7)$$

$$+ \mu^3 \,.\, 2\,\mathrm{Re}\Big\{ \frac{15}{2}(s_1^* f_5 + f_1^* d_5 + p_1^* g_7) + 6(p_3^* d_5 + d_3^* f_5) + 9 p_3^* d_3 - 10 s_1^* f_7 - 15(d_5^* f_7 + f_5^* g_7) - 55(p_3^* g_7 + d_3^* f_7) - \frac{117}{2} d_5^* f_5 + \frac{795}{2} f_7^* g_7 \Big\}$$

$$+ \mu^4 \Big\{ \frac{45}{4}(|d_5|^2 + |f_5|^2) - \frac{165}{4}(|f_7|^2 + |g_7|^2) + 2\,\mathrm{Re}\Big\{ \frac{45}{2}(p_3^* f_5 + d_3^* d_5) + \frac{35}{2}(s_1^* g_7 + p_1^* f_7) + \frac{25}{2}(d_3 g_7 + p_3 f_7) - \frac{675}{4}(d_5^* g_7 + f_5^* f_7) \Big] \Big\}$$

$$+ \mu^5 \,.\, \mathrm{Re}\Big\{ \frac{105}{2}(p_3^* g_7 + d_3^* f_7) + \frac{225}{4} d_5^* f_5 + \frac{45}{2}(d_5^* f_7 + f_5^* g_7) - \frac{1875}{4} f_7^* g_7 \Big\}$$

$$+ \mu^6 \Big\{ \frac{175}{4}(|f_7|^2 + |g_7|^2) + 2\,\mathrm{Re}\Big[\frac{525}{4}(d_5^* g_7 + f_5^* f_7) \Big] \Big\}$$

$$+ \mu^7 \,.\, 2\,\mathrm{Re}\Big[\frac{1225}{4} f_7^* g_7 \Big]$$

For the polarizations we have:

$$k^2 \frac{d\sigma}{d\Omega} p(\theta) =$$

$$(1-\mu^2)^{1/2} \times 2\,\mathrm{Im.}$$

$$\begin{aligned}
1 \Big\{ & s_1^* p_1 + (p_1^* d_3 - s_1^* p_3) + \tfrac{3}{2}(p_1^* d_5 - s_1^* f_5) + \tfrac{3}{2}(d_3^* f_5 - p_3^* d_5) \\
& + d_3^* p_3 + \tfrac{3}{2}(s_1^* f_7 - p_1^* g_7) + \tfrac{3}{2}(p_3^* g_7 - d_3^* f_7) + \tfrac{9}{4}(f_5^* g_7 - d_5^* f_7) \\
& + \tfrac{9}{4}(d_5^* f_5 - f_7^* g_7) \Big\} \\
+ \mu \Big\{ & 3(s_1^* d_3 - p_1^* p_3) + 3(p_1^* f_5 - s_1^* d_5) + \tfrac{15}{2}(d_3^* d_5 - p_3^* f_5) \\
& + \tfrac{15}{2}(p_1^* f_7 - s_1^* g_7) + 3(d_3^* g_7 - p_3^* f_7) + \tfrac{63}{4}(d_5^* g_7 - f_5^* f_7) \Big\} \\
+ \mu^2 \Big\{ & \tfrac{15}{2}(s_1^* f_5 - p_1^* d_5) + \tfrac{15}{2}(p_1^* g_7 - s_1^* f_7) + \tfrac{3}{2}(d_3^* f_5 - p_3^* d_5) \\
& + 30(d_3^* f_7 - p_3^* g_7) + 9\, p_3^* d_3 - \tfrac{63}{2} d_5^* f_5 + \tfrac{315}{4} f_7^* g_7 \Big\} \\
+ \mu^3 \Big\{ & \tfrac{45}{2}(p_3^* f_5 - d_3^* d_5) + \tfrac{35}{2}(s_1^* g_7 - p_1^* f_7) + 5(d_3^* g_7 - p_3 f_7) \\
& + 105(f_5^* f_7 - d_5^* g_7) \Big\} \\
+ \mu^4 \Big\{ & \tfrac{225}{4} d_5^* f_5 + \tfrac{105}{2}(p_3^* g_7 - d_3^* f_7) + \tfrac{15}{4}(f_5^* g_7 - d_5^* f_7) \\
& - \tfrac{1315}{4} f_7^* g_7 \Big\} \\
+ \mu^5 \Big\{ & \tfrac{525}{4}(d_5^* g_7 - f_5^* f_7) \Big\} \\
+ \mu^6 \Big\{ & \tfrac{1225}{4} f_7^* g_7 \Big\}
\end{aligned} \qquad (8)$$

The angular distributions for $K^- p \longrightarrow K^- p$ reported by Beall et al[6] in the region 800 - 1400 MeV/c show as more prominent features a peak around 1000 MeV/c in both A_4 and A_5. A peak in A_5, neglecting f_7 and g_7 waves, can only be due to $d_5 - f_5$ interference as seen in expression (7). Recently Barbaro-Galtieri et al[3] have elaborated on this point by analyzing the variation of A_5 in the region 800 - 1400 on the basis of the above data, inclusive of the data of Sodickson et al[7], Graziano and Wojcicki[5] and Bastien[4]. Chosing the following parameters for Y^* (1765) and Y^* (1815) :

M_1 = 1765 MeV, Γ, = 60 MeV, $\Gamma e/\Gamma$ = 0.6; M_2 = 1815 MeV, Γ_2 = 70 MeV, $\Gamma e/\Gamma$ = 0.6, the calculated variation of A_5 versus P_K is not inconsistent with the data (fig. 7).

Characteristic of the A_5 behaviour would be the presence of two peaks, corresponding to the two resonances, tentatively assigned to d $_{5/2}$ (1765) and f $_{5/2}$ (1815) respectively. Barbaro-Galtieri et al also point out that in the momentum region between the two resonances at ~ 1000 MeV/c, A_5 should decrease since the two resonating amplitudes are nearly orthogonal. This situation on the other hand should generate a large polarization term in $\sin\theta \cos^4\theta$ which is proportional to Im $d_5^* f_5$. A measurement of the sign of this polarization would solve the $d_{5/2} - f_{5/2}$ ambiguity.

On the other hand recent results of Wenzel et al[8] while confirming the bump in A_5, also require $A_6 \neq 0$ at 990, 1032 and 1181 MeV/c. This agrees with the data of Ferro-Luzzi et al[9] at 1.22 GeV/c, which for $K^- p \rightarrow \bar{K}^o n$ show a significant A_6 coefficient. It is then quite important to find out if A_6 is just due to background or if it shows a resonant behaviour. If this were the case, $J > 5/2$ would be required for either of the two resonances.

Finally, the basis for the I = 1 assignement for Y^* (1765) rests on the observation that A_5 for $K^- p \rightarrow \bar{K}^o n$ shows the same behaviour as for $K^- p \rightarrow K^- p$ but has opposite sign. The data of Wohl et al[10] and Graziano and Wojcicki[5] in the region 1000 - 1150 MeV/c were used for this purpose. Since each of the amplitudes in (7) must be expressed in terms of I = 0 and I = 1 amplitudes:

$$T\,(K^- p \rightarrow K^- p = \frac{1}{2}\left|T_o + T_1\right| \;;\; T\,(K^- p \rightarrow \bar{K}^o n) = \frac{1}{2}\left|T_o - T_1\right|$$

it follows that A_5 $(K^- p \rightarrow K^- p)$ and A_5 $(K^- p \rightarrow \bar{K}^o n)$ will have opposite sign only as a result of interference between the I = 0 and I = 1 d and f amplitudes. It is clear however that one would like perhaps independent evidence on this ispin assignement.

4. Experimental program

a) choice of beam momenta

It would be desirable to explore the region 900 - 1200 MeV/c at intervals of 30 MeV/c, both in H_2 and D_2.

As to the choice of actual momenta, the following table of relevant momenta may be of help

TABLE I

Reaction	E^*	P_K Resonance MeV/c	P_K Threshold MeV/c
$K^- p \rightarrow Y^*(1660)$	1660	715	–
$K^*(725)\ p$	1663	–	720
$\Lambda\ \eta$	1663	–	720
$N^*(1238)\ K$	1732	–	870
$\Sigma\ \eta$	1741	–	890
$Y^*(1765)$	1765	940	–
$\Xi\ K$	1815	–	1045
$Y^*(1815)$	1815	1045	–
$K^*(888)\ p$	1826	–	1070
$\Lambda\ \rho$	1865	–	1155
$\Lambda\ \omega$	1897	–	1225

A suitable sequence of momenta of interest would then be, for example (850), 880, 910, 940, 970, 1000, 1030, 1070, 1100, 1130, (1660), 1190; (850) and (1160) stand to indicate that a considerable amount of data is already available at this momenta. The above sequence corresponds approximately, and can be made to coincide exactly, with equal c.m. energy intervals of 15 MeV.

b) What to do where

The preceding discussion already indicates several of the points where new information is required. Aside from the systematic exploration of cross sections, angular distributions etc. for the various channels, in particular in the regions where the data are either missing or contradictory, particular emphasis may be placed on some of the more sensitive aspect. The main questions are:

1) Isospin content in the region 900 - 1200

If indeed Y_1^* (1765) and Y_0^* (1815) do exist with the correct ispin assignement, one would like to see some distinguishing feature of such a situation. Relevant information may be sought in the K^- n total cross section between 900 and 1000 MeV/c, where an enhancement due to Y_1^* (1765) should be present. Rapid variations in the $K^- p \rightarrow \bar{K}^0 n$ cross section may be expected, in particular between the I = 0 and I = 1 resonances, as well as in the sign of the coefficients in the angular distribution. On this latter point, one would like for example observe the momentum dependence of the ratio Y_1^* (1765) A_5 (K^- p ⟶ K^- p) / A_5 (K^- p ⟶ $\bar{K}^o$ n) in the region 940 - 1070 MeV/c, where the I = 0,1 interference should be maximal.

Furthermore the ratio $\frac{K^- n \longrightarrow \Lambda \pi^-}{K^- p \longrightarrow \Lambda \pi^o}$ should be rather sensitive indicator of Y_1^*, while $\frac{K^- p \longrightarrow \Lambda \pi^{\pm} \pi^{\mp}}{K^- p \longrightarrow \Lambda \pi^o \pi^o}$ may be sensitive in the region of Y_o^*.

Minami(11) recently suggested that also the reaction K^- n ⟶ N^* (1238) $\bar{K}^o$ may be sensitive for the detection of the Y_1^* (1765) excitation.

2) Spin-parity of Y_1^* (1765) and Y_o^* (1815)

Since $d_{5/2}$ $f_{5/2}$ interference is required, a critical test, as suggested by Barbaro-Galtieri et al, will be the determination of the sign of the polarization contributed by the sin θ $\cos^4$ θ term in σ(θ) P (θ), which depends only on such interference, (if partial waves higher than 5/2 do not show resonant behaviour). This test will be more sensitive in the region between 940 and 1070 MeV/c, where the $d_{5/2}$ and $f_{5/2}$ amplitudes should be nearly orthogonal.

Minami(11) further suggests that the angular distribution in

$$K^- p \longrightarrow Y_1^* (1385) \pi \longrightarrow \Lambda \pi^+ \pi^-$$

may discriminate against the $d_{5/2}$ $f_{5/2}$ anbiguity for the two resonances respectively.

3) Excitation of K^* (725)

As can be seen from Table I, the threshold of K^- p ⟶ K^* (725) p corresponds to the c.m. energy of Y_1^* (1660) while that of K^- p ⟶ K^* (888) p corresponds roughly to the excitation of Y_o^* (1815). The region between ∼800 and 1000 MeV/c should be a very good region to excite the K^* (725) without, or with diminished effect of the otherwise dominating K^* (888).

The excitation function of K^* (725) in K^- p ⟶ K p seem to increase with decreasing K^- momentum, with a cross section of ∼100 μb at ∼1050 MeV/c(12), with reasonable extrapolation one may expect a further rise, before the drop at threshold. The advantages of this situation are two fold. On one side K^* (888) should not take up all of the phase space, on the other close enough to threshold the K^* (725) should still be produced as an s-state relative to the nucleon, so that an Adair analysis will be possible using essentially all the events. The reactions of interest will be then

$$K^- p \longrightarrow \bar{K}^o \pi^- p \quad a)$$
$$\longrightarrow K^- \pi^o p \quad b)$$

where a/b = 2/1 if $I = \frac{1}{2}$ for K^* (725).

4) Study of the K^o - and Λ - nucleon interaction

A very substantial number of K^o's and Λ's will interact in the chamber yielding as a by product the material for,essentially another experimental program.

5. Exposure requirements

In order to determine the coefficients of an angular distributions up to A_6, $\sim$600 events are required.

What determines the exposure requirements is obviously the smallest cross section which one wants to study. In the region of interest this corresponds to $\sim$1 mb. Taking the figures of 236 meters/mb for the collision length in liquid H_2 and a useful track length of 50 cm, in the 81 cm H.B.C., 600 events of $\sim$1 mb require

$$600 \times 236 \times 2 = 2.84 \times 10^5 \text{ tracks or}$$

$\sim$25.000 frames at $\sim$12 tracks/frame.

For 10 momenta in liquid H_2, this then corresponds to $\sim$250.000 frames. For liquid D_2, if the density is twice that of liquid H_2, then the collision length/mb is the same as for H_2. In only $\sim$80 o/o of the collisions with a neutron, the proton is a spectator in the sense of the impulse model, at these momenta. This fraction includes recoil momenta below $\sim$280 MeV/c.

Since, however the limit of $\sim$1 mb for the rarest channel of interest is a rather conservative one, for liquid D_2 as well, approximately 250.000 frames may be required.

The actual allocation of numbers of frames to particular momenta may of course vary, accordingly to the emphasis one may wish to place on some of the items previously discussed.

If in the average 5 channels are explored with 600 events each, at each momentum, the experiment requires the measurement of $\sim$60.000 events.

REFERENCES

1) V. Cook, B. Cork, T.F. Hoang, D. Keefe, L.T. Kerth, W.A. Wenzel and T.F. Zipf, Phys. Rev. 123, 320 (1961).

2) O. Chamberlain, K.M. Crowe, D. Keefe, L.T. Kerth, A. Lemowich, Tin Maung and T.F. Zipf, Phys. Rev. 125, 1696 (1962).

3) A. Barbaro-Galtieri, A. Hussain and R.D. Tripp, Physics Letters, 6, 296 (1963).

4) P.L. Bastien and J.P. Berge, Phys. Rev. Letters 10, 188 (1963).

5) W. Graziano and S.G. Wojcicki, Phys. Rev. 128, 1868 (1962).

6) E.F. Beall, W. Holley, D. Keefe, L.T. Kerth, J.J. Thresher, C.L. Wang and W.A. Wenzel, Proc. 1962 Int. Conf. High Energy Physics CERN, p. 368.

7) L.A. Sodickson, I. Manelli, M. Wahlig and D. Frisch, Phys. Rev. To be published.

8) J.J. Thresher, private communication to R. Armenteros.

9) M. Ferro-Luzzi, F.T. Solmitz and M.L. Stevenson, Proc. 1962 Int. Conf. High Energy Physics CERN p. 376.

10) C. Wohl et al. B.A.P.S. 8, 340 (1963).

11) S. Minami, Preprint Oct. 18, 1963.

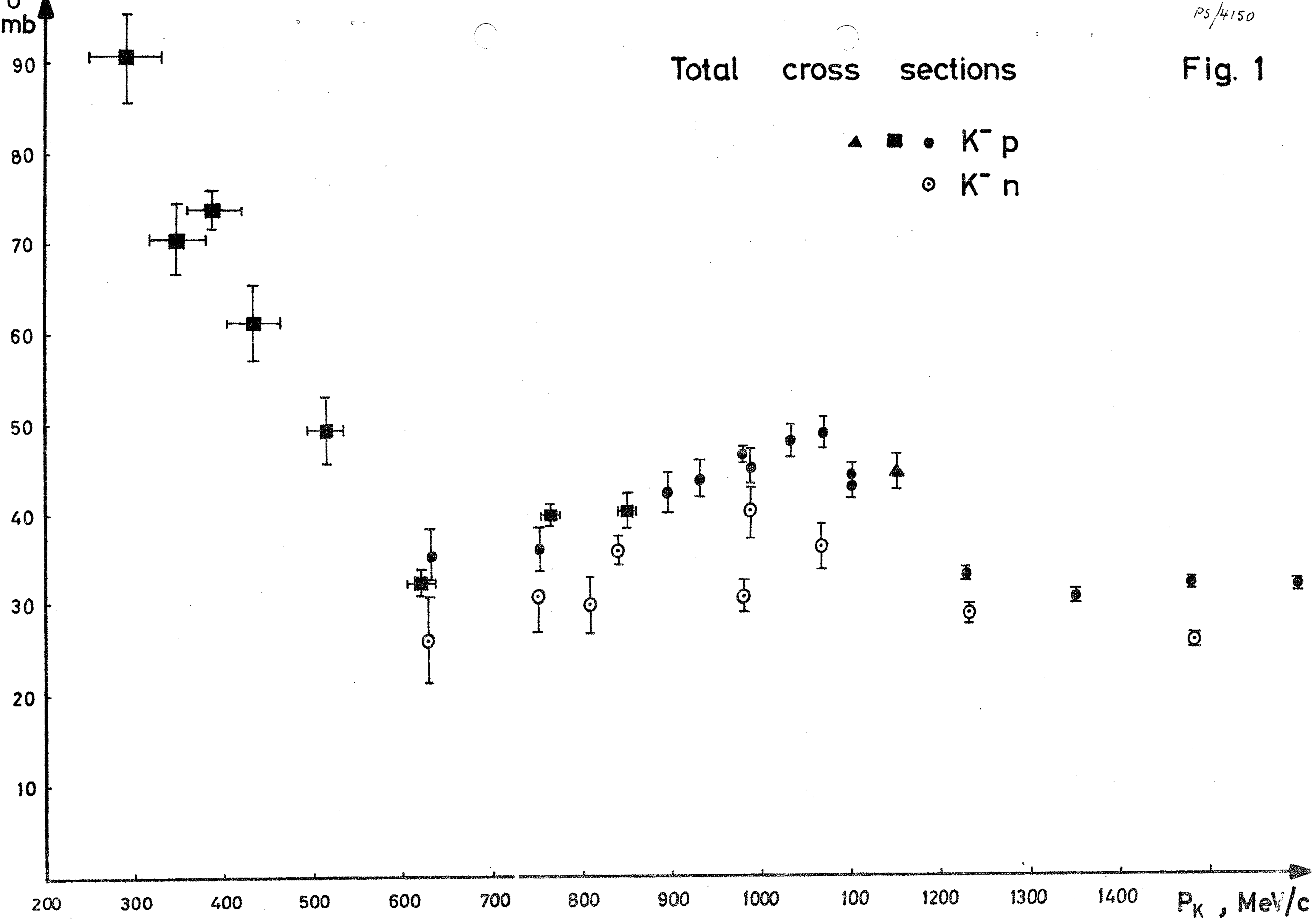
12) S.G. Wojcicki et al. Physics Letters 5, 283 (1963).

Appendix

TABLE II

CM ENERGY	KIN ENERGY	K MOMENTUM
1660.0	375.6	715.6
1675.0	402.2	747.7
1690.0	429.1	779.8
1705.0	456.3	811.7
1720.0	483.6	843.6
1735.0	511.3	875.4
1750.0	539.1	907.3
1765.0	567.2	939.2
1780.0	595.5	971.1
1795.0	624.1	1003.0
1810.0	652.9	1035.0
1825.0	682.0	1067.2
1840.0	711.3	1099.4
1855.0	740.8	1131.7
1870.0	770.6	1164.1
1885.0	800.6	1196.6
1900.0	830.9	1229.3
1915.0	861.4	1262.1
1930.0	892.1	1295.0
1945.0	923.1	1328.1
1960.0	954.3	1361.4

PS/4150



Total cross sections

Fig. 1

PS/4150

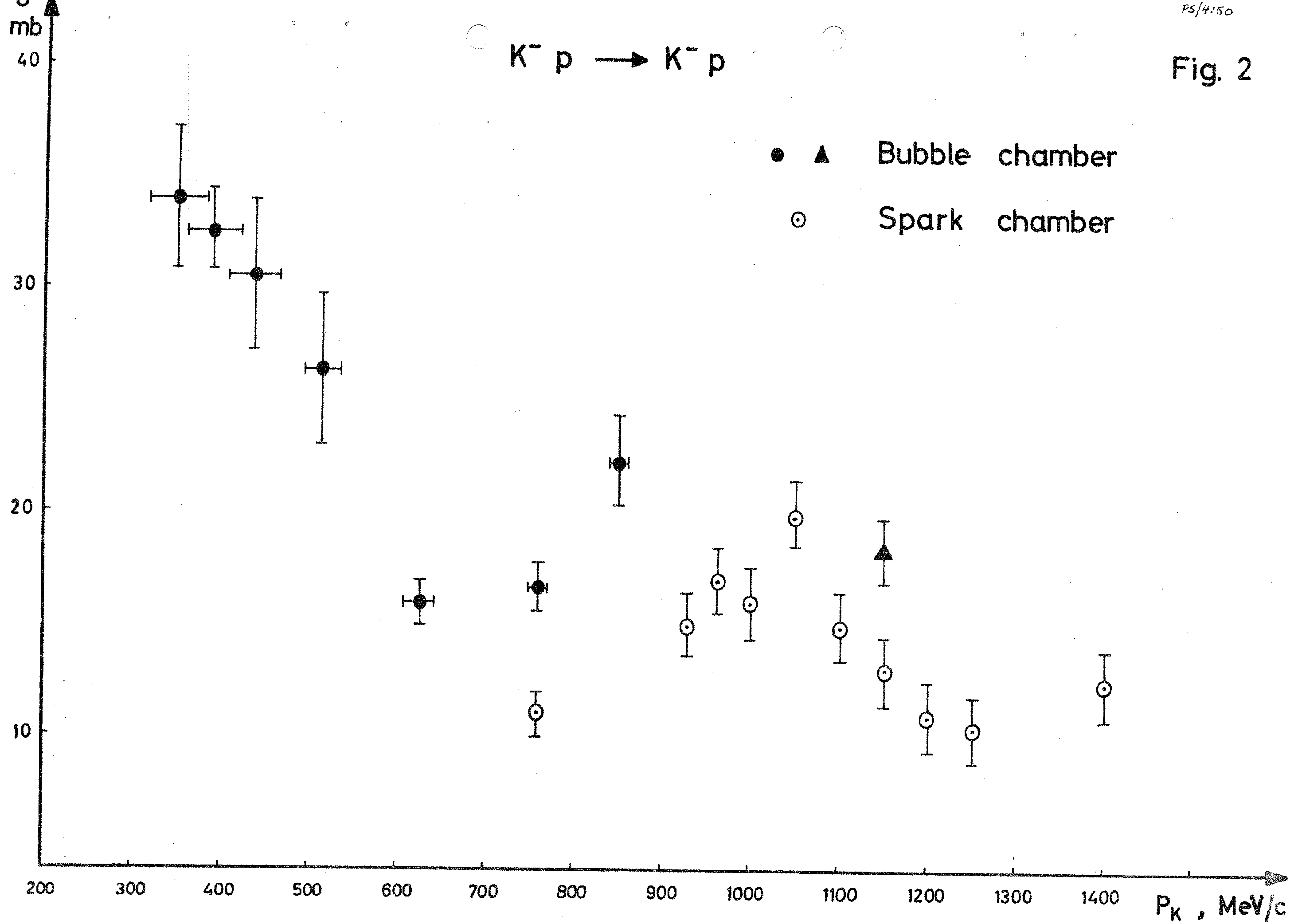
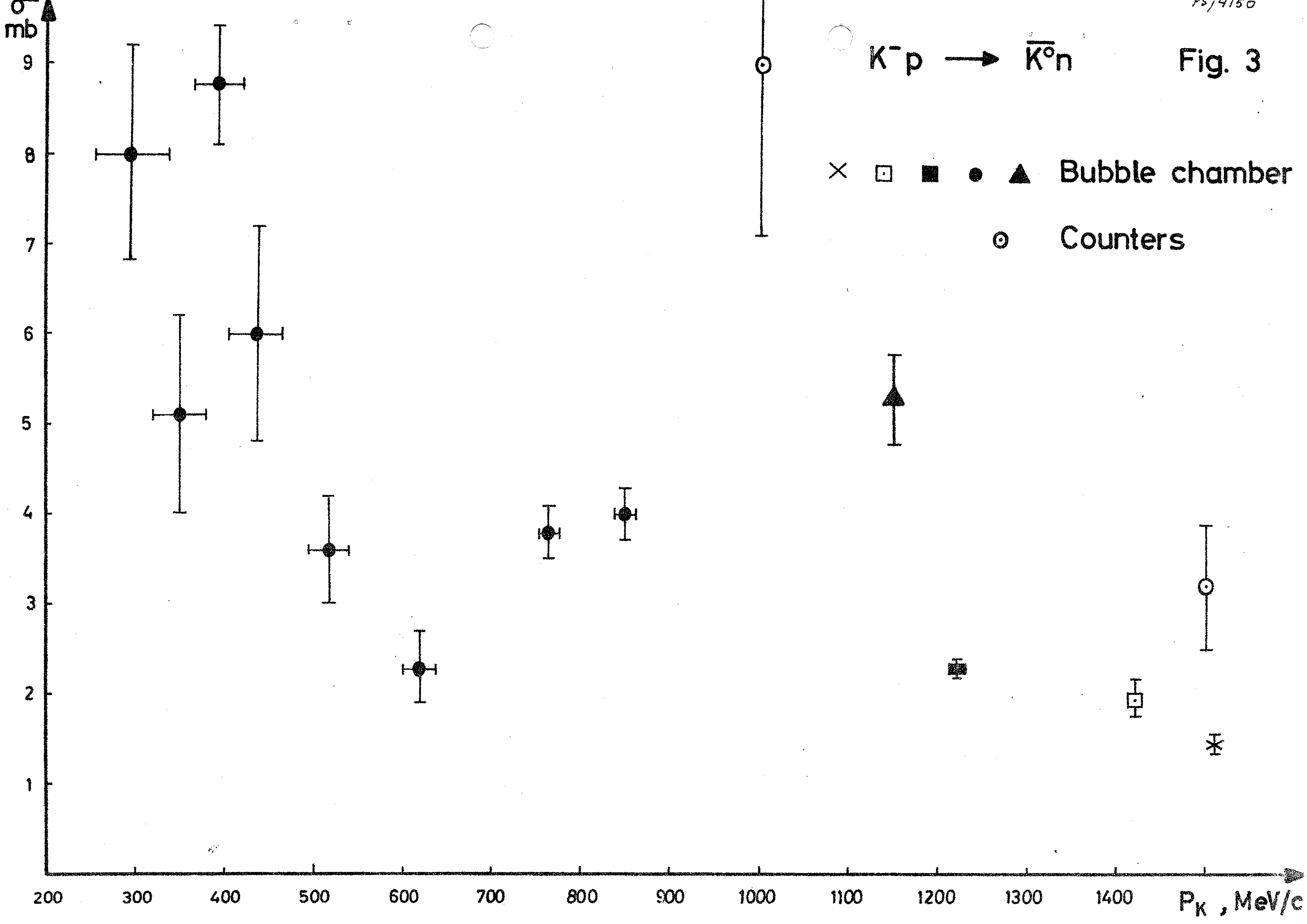
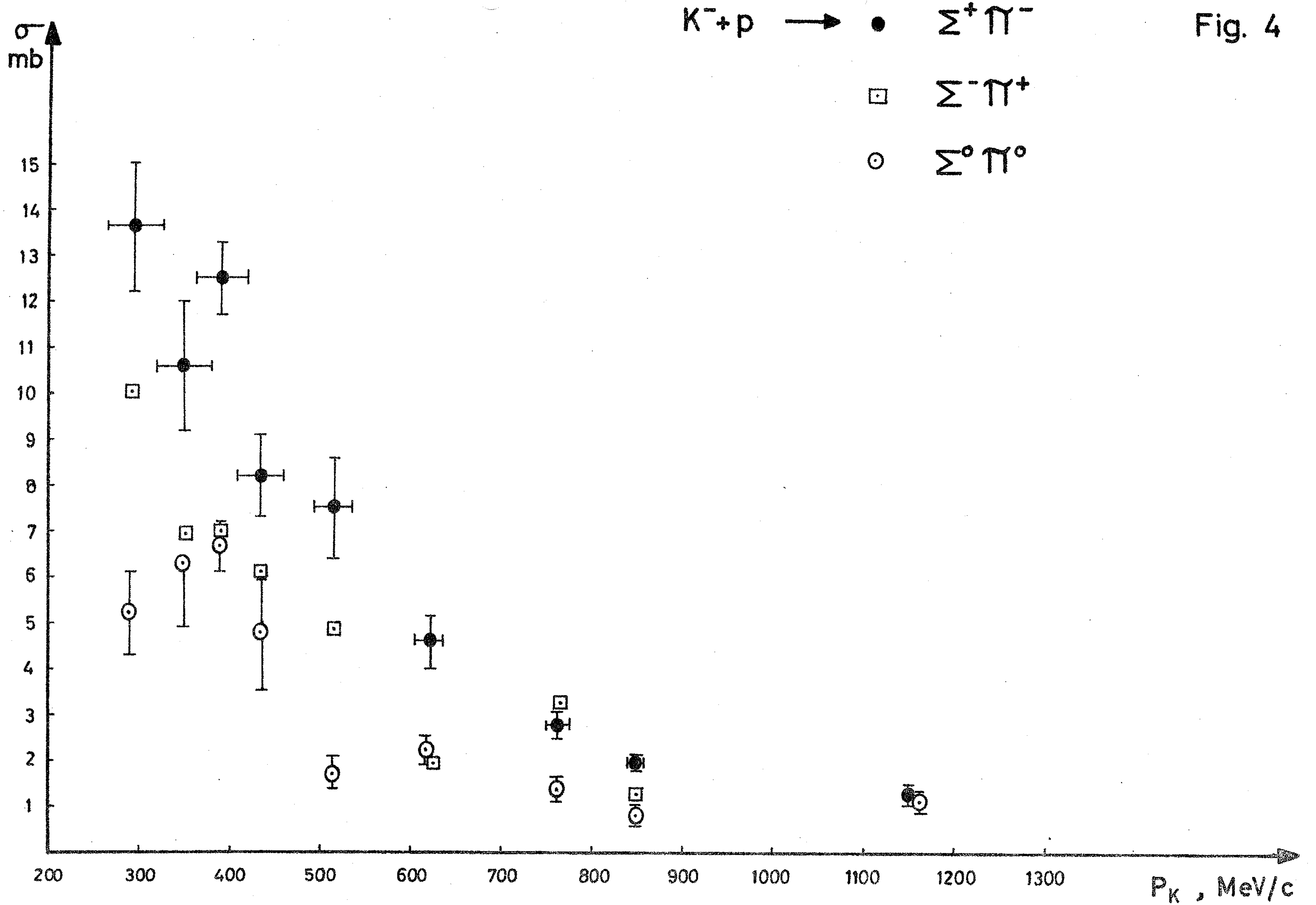

$K^- p \longrightarrow K^- p$
σ
mb
40
30
20
10
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
P_K , MeV/c
● ▲ Bubble chamber
⊙ Spark chamber

Fig. 2


$K^-p \longrightarrow \overline{K^o}n$
Fig. 3
× □ ■ ● ▲ Bubble chamber
⊙ Counters
σ mb
1
2
3
4
5
6
7
8
9
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
P_K , MeV/c

PS/4150

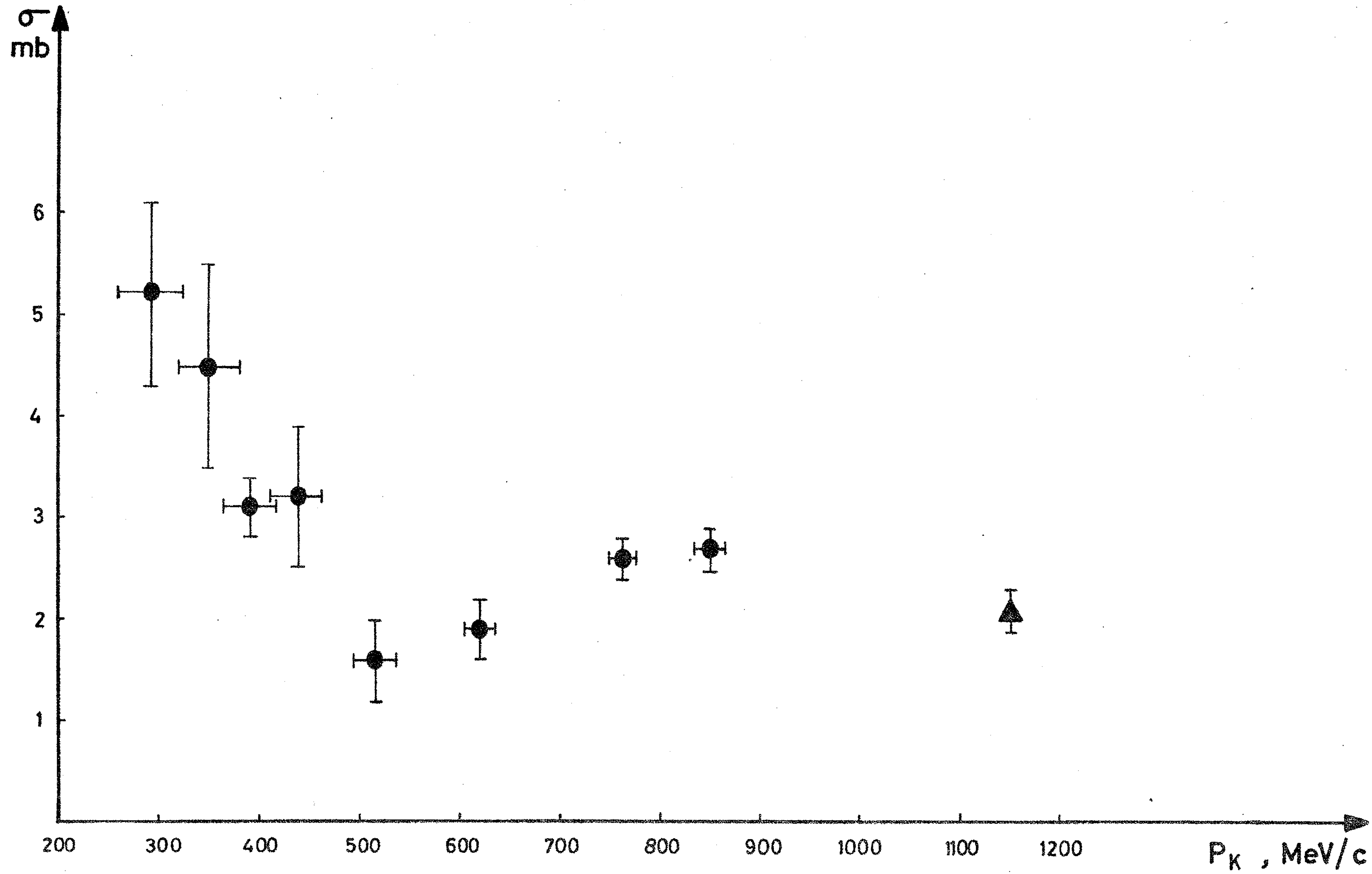
Fig. 4



$K^- + p \longrightarrow$ ● $\Sigma^+\pi^-$
□ $\Sigma^-\pi^+$
⊙ $\Sigma^0\pi^0$
σ mb
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
200
300
400
500
600
700
800
900
1000
1100
1200
1300
P_K , MeV/c

Fig. 5

$K^- p \rightarrow \Lambda \pi^0$



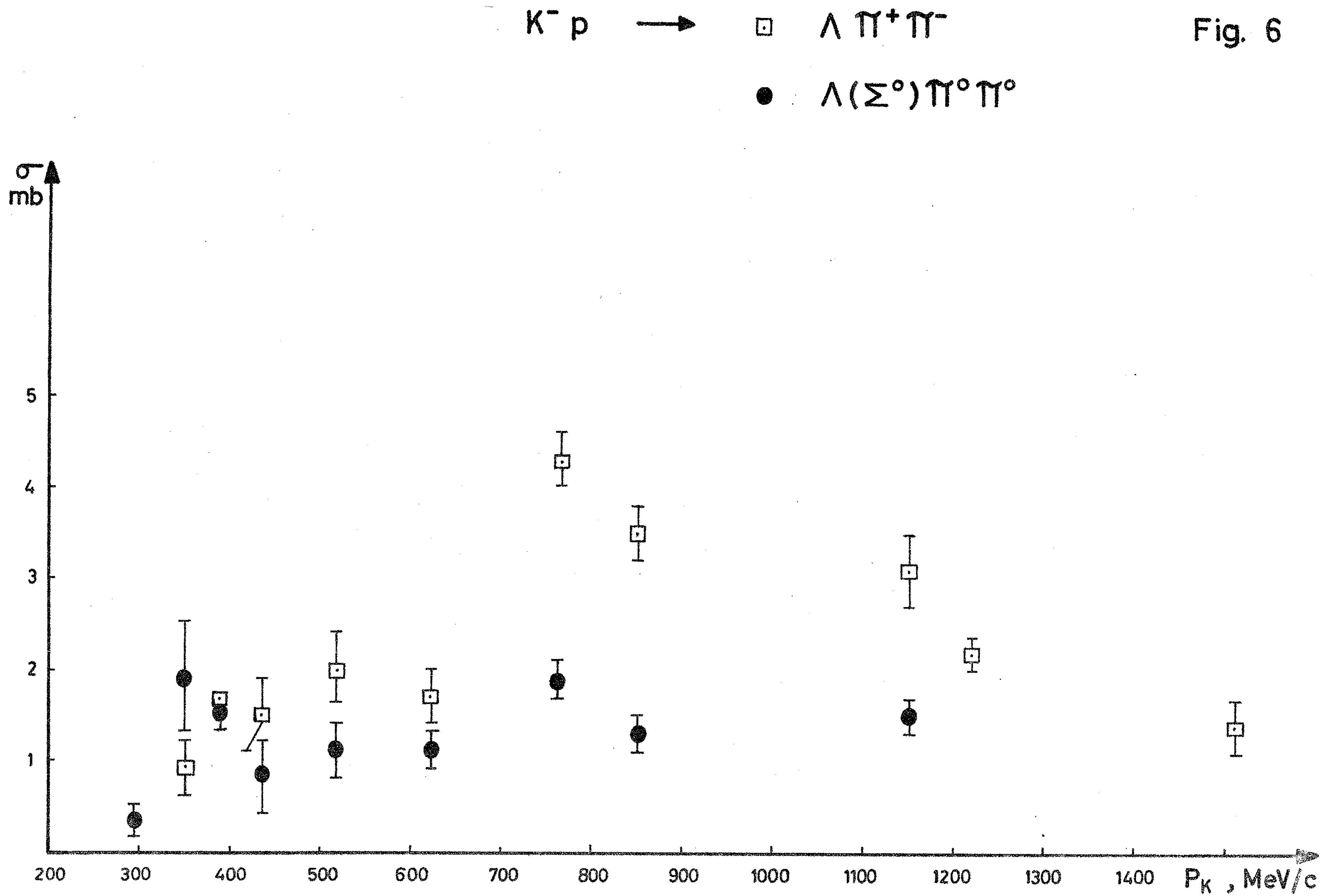

K⁻ p → Λ π⁺ π⁻
Λ(Σ°) π° π°
σ mb
1
2
3
4
5
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
P_K , MeV/c

Fig. 6

PS/4150

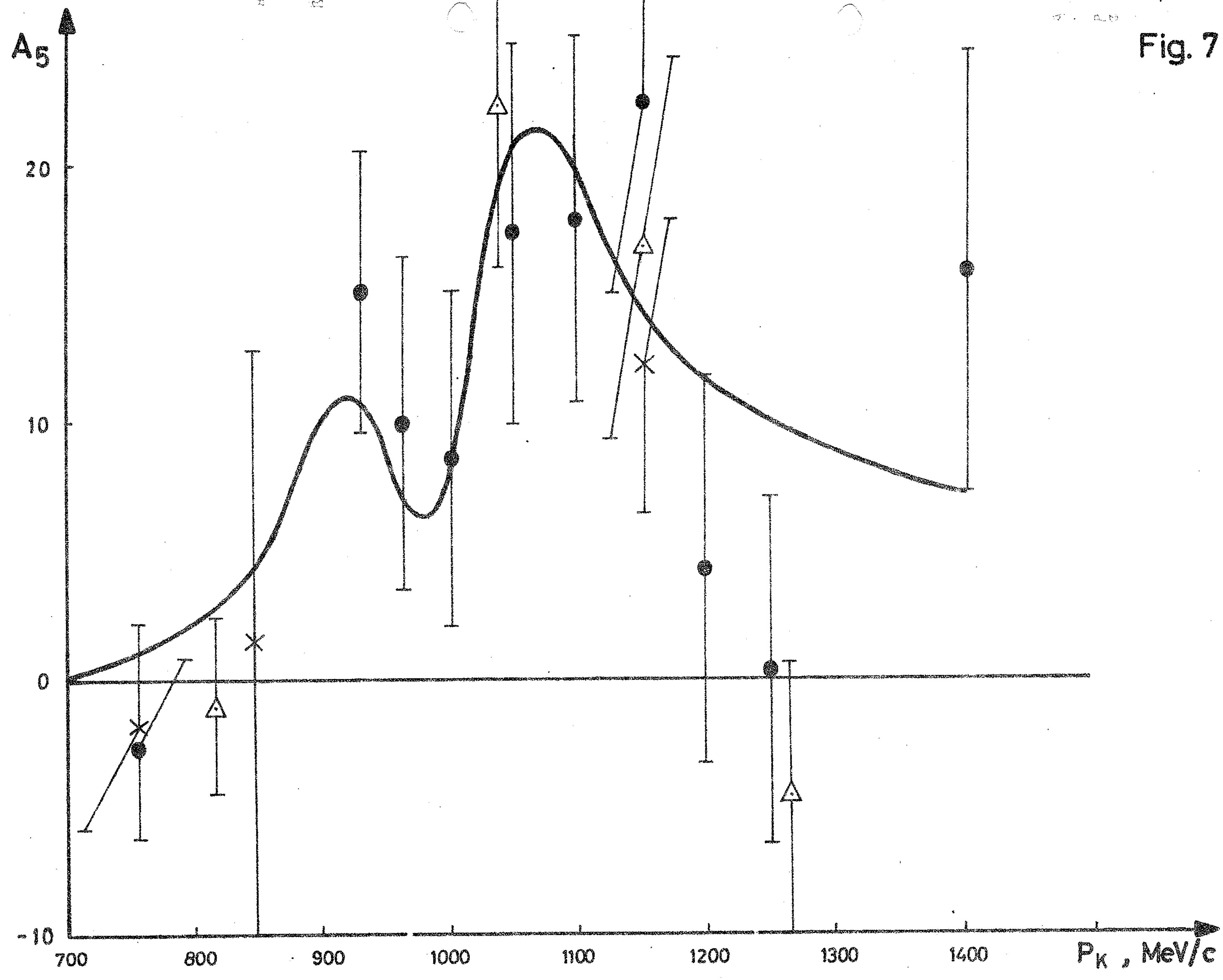


Fig. 7