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PROPOSAL

STUDY OF THE $(\bar{K}^0\pi^+\pi^-)$-SYSTEM PRODUCED IN THE REACTION $K^-p \rightarrow \bar{K}^0\pi^+\pi^-n$ AT 13 GeV/c USING THE OMEGA PRIME SPECTROMETER AND THE RF-SEPARATED S1 BEAM

III. Physikalisches Institut der RWTH, Aachen

P. Girtler, G. Otter, G. Ransoné, H. Schlütter and E. Wosch

1. PHYSICS MOTIVATION

This experiment is to be regarded as the high statistics continuation of experiment S116 which used the Ω-spectrometer and a PS beam. The statistics can be increased by almost two orders of magnitude by the use of the more intense SPS beam, the RF-separator and the MWPC's of the Ω prime-detector.

These last years the main interest in the physics of hadrons has been the discovery of new quarks and their mesonic bound states. New theoretical ideas, like QCD, have some promise of predictive power. In this situation we feel that a detailed study of "old" mesons, formed by the u-, d- and s-quarks, can be extremely useful. In fact, the properties of many mesons, which are required to exist in quark-models, are not well established. Any meson with well established properties, or even the definite non-existence of such a particle, can be a severe test of theoretical models.

The proposed experiment

$$K^- p \rightarrow \bar{K}^0 \pi^+ \pi^- n \qquad (1)$$

at 13 GeV/c is able to see all low mass K^*-resonances decaying into $K\pi\pi$. It is free of complications due to diffractive production. A detailed partial wave analysis (PWA) of the three-meson-system will give a precise determination of spin-parity J^P of these resonances. This is necessary since only the J^P of the 2^+-state $K^*(1440)$ is well established. All the other states, predicted by the quark model, have either not yet been observed or their resonance character and their quantum numbers are not well known up to now.

We believe that this experiment can answer all these questions for the $K\pi\pi$-mass region below 2 GeV, if it contains a sample of more than 10^5 events. Apart from surprises, which are always possible in experiments that have a new sensitivity an order of magnitude higher, we intend to study the following subjects:

a) From a study of diffractive ($K\pi\pi$)-systems, various groups find good evidence for the production of the two Q-resonances with $J^P = 1^+$ at 1290 and 1400 MeV |1|. However, due to the diffractive Deck background below the resonances the interpretation of the results is complicated. To establish these two resonances without any doubt, a study of the Q's in non-diffractive channels is necessary. Figs. 1 and 2 show the results of a PWA of reaction (1) from the S116 experiment |2|. It is seen, that Q_2 and probably also Q_1 are produced in reaction (1) and therefore can be well studied in a high statistics experiment.

b) Several groups report evidence for structure in the ($K\pi$)- and ($K\pi\pi$)-system in the mass region 1600 - 2000 MeV. The situation concerning this structure is still confused since the results differ in the values of mass and width of this enhancement (for a review see |3|) and it might be possible that more than one K^*-enhancement is responsible for this complex situation. In our PWA of reaction (1) we find one clear peak in the 3^- state (with $M = 1812 \pm 28$ MeV, $\Gamma = 181 \pm 24$ MeV) which was interpreted as $K^*(1780)$.

A high statistics experiment of reaction (1) could clarify the situation concerning several K^*-resonances in this high ($K\pi\pi$) mass region. In addition a reliable measurement of the relative phase of this state should be possible in order to establish the resonance nature of the peak.

c) Meson resonances belonging to the natural spin-parity series (0^+, 1^-, 2^+, ...) can decay into two pseudoscalar particles and are therefore relatively easy to detect and to study. Resonances of the unnatural series (0^-, 1^+, ...) can only be found in a system of at least three pseudoscalar mesons and are much harder to investigate. This explains the fact that 1^-, 2^+, 3^- and partly also 0^+ and 4^+ resonances, predicted by the quark model, are already well known while only some of the states of the unnatural series have been observed. Some of the 1^+ states were found recently, but none of the 2^- resonances are clearly established.

According to the quark model we expect the 2^- states in the $(K\pi\pi)$-system to be in the region 1600 - 1800 MeV. As seen from fig. 1, they are certainly not produced with large cross-section. Therefore only high statistics at high energy can solve the problem. An experiment at low energy is less well suited to find these states since overlaps with other reaction mechanisms complicate the study of these small effects.

d) A spectrometer experiment at SLAC investigated the $(K\pi)$-system and found evidence (in two out of four possible partial wave solutions) for a broad $J^P = 1^-$ resonant-like structure at 1650 MeV |4|. This resonance, if it exists at all, is rather inelastic (elasticity of 0.3) and should therefore be found in reaction (1). Indeed a broad enhancement can be seen in fig. 1 for the 1^--wave around 1600 MeV which is compatible with the SLAC result. However, with the limited statistics of this experiment, no conclusive answer concerning the existence of $K^*(1650)$ can be given.

Another interesting question concerning this $K^*(1650)$ is, how to classify this resonance within the quark model. One possibility is that it is a radial excitation of $K^*(890)$ (that means the S-wave $(q\bar{q})$-triplet) and the other possibility is that $K^*(1650)$ is a D-wave $(q\bar{q})$-triplet. From the interference between the $J^P = 3^-$ $K^*(1780)$ and $K^*(1650)$, it should be possible to solve this problem |5|.

e) In fig. 3 we show the $(K\pi\pi)$-system of reaction (1) produced by unnatural spin-parity exchange, decomposed in natural and unnatural spin-parity states. It is seen that it occurs mainly in the natural series $(1^-, 2^+, 3^-)$ which points strongly to a π-exchange production mechanism. Reaction (1) is therefore well suited for a study of inelastic $K\pi$-scattering: $K^-\pi^+ \to \bar{K}^0\pi^+\pi^-$ +). It is complementary to elastic $K\pi$-scattering and should help to solve the ambiguity problem in the elastic $K\pi$-scattering. In addition good determination of the branching ratios of $K^*(1440)$ and $K^*(1780)$

+) We would like to remind, that elastic $(\pi\pi)$ and $(K\pi)$ scattering were investigated in reactions similar to reaction (1), i.e. $\pi p \to (\pi\pi)n$ resp. $Kp \to (K\pi)n$ |4,6|.

into $K^{*}\pi$ and $K\rho$ should be possible.

In conclusion, a high statistics experiment of reaction (1) could bring much progress in the K^{*}-spectroscopy and could solve many of the waiting problems in this field.

2. APPARATUS AND TRIGGER

We propose to study reaction (1) in the CERN-Ω prime spectrometer, which will be equiped with wire chambers instead of the optical spark chambers used in the Ω-detector |7|. A version of Ω prime with only forward chambers is envisaged, which is expected to be available by early 1979.

The trigger will be a (2prong + V^{o})-trigger, similar to the one used in the previous S116 experiment. It will consist of two multiwire proportional chambers, one of which has an active surface in form of a circle with 22 cm diameter, one horizontal and one vertical plane with a wire spacing of 1 mm (MWPC1). This chamber will be placed about 5 cm downstream of the H_2-target. The second chamber (MWPC2) consisting of 3 planes has a sensitive surface of 96 x 147 cm^2, a wire spacing of 2 mm, and it will be placed about 83 cm downstream of the target. Both chambers exist and will be available from the current Ω-equipment. The trigger condition will be: 2 charged tracks in MWPC1 and 4 charged tracks in MWPC2.

In addition to this topology trigger a cylindrical veto counter (TS) surrounding the target will be used to further eliminate events not belonging to the (2prong + V^{o})-topology. This target hodoscope is especially important to veto events from the 4 prong channels, which give the most serious background to reaction (1). We emphasize that the TS affects the (2prong + V^{o})-events such that only events with the V^{o} decaying before MWPC1 are rejected, which should not fulfill the topology trigger condition anyway. As discussed below, a π^{o}-veto-system surrounding the target would be useful.

The set up of the experiment is schematically drawn in fig. 4. In order to obtain a good V^0 reconstruction efficiency we use a dense packing of all the 6 type B-chambers and one type A-chamber between the trigger chambers MWPC1 and MWPC2 (see ref. |7|). The remaining type A-chambers will be placed downstream of MWPC2. From simulation we know that this set up should give a good event reconstruction by the off-line program TRIDENT.

3. BEAM AND TARGET

We plan to use the RF-separated S1 beam with a flux of $\sim 4 \times 10^5$ K^-/burst which means a total flux of $\sim 1 \times 10^6$ particles/burst at the Ω prime target. The beam momentum should be fixed at 13 GeV, where one has good K^- enrichment. The target will be a 30 cm long cylindrical H_2-target.

4. ACCEPTANCE AND RATES

For the above described trigger set up we have calculated the geometrical acceptance for reaction (1) as well as for the most important background channels which also fulfill the trigger condition. This was done by subjecting events from K^-p bubble chamber experiments to the simulated trigger system |8|. Table 1 shows the results for geometrical acceptance and the expected trigger rates assuming a beam flux of 4×10^5 K^-/burst and the use of i) the (2prong + V^0)-topology trigger only, ii) the topology trigger and the TS veto counter *). In addition a π^0-veto system covering the target region

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*) We would like to remark that the low acceptance for reaction (1), i.e. 17%, is mainly due to the fact that the K^0 has to decay between the 2 trigger MWPC's

would be useful. This was found from model calculations based on bubble chamber data. As for multi-neutral-particle-events we do not know the number and momenta of these particles, we made the assumption that every event had only two neutral particles. The event was rejected when at least one single photon from a π^0 decay hits the π^0-veto system. It was found that the background was further suppressed by a factor of 2 using such a system. Therefore we plan to use such a π^0-veto-system and urge its construction for Ω'.

For the following calculations we assume that a trigger rate of $\lesssim 80$ triggers/burst will be realistic, which should be well manageable by the Ω prime detector.

Assuming 9×10^3 good bursts/day, a Ω prime running efficiency of 75% and 9 days of running time, we shall record $\sim 4{,}9 \times 10^6$ triggers (in case of a π^0-veto system $\sim 2{,}4 \times 10^6$ triggers respectively), out of which $\sim 3{,}0 \times 10^5$ events belong to reaction (1). This corresponds to a sensitivity of ~ 1250 events/μb for this channel.

Assuming a data reconstruction efficiency of 70%, we shall obtain ~ 210.000 good $n\bar{K}^0\pi^+\pi^-$ events after geometrical reconstruction. About 135.000 of these events will have a $(K\pi\pi)$-mass between 1.0 and 2.0 GeV and therefore will be useful for a partial wave analysis.

5. COMPUTING LOAD

The whole statistics will be analysed at the PDP10 computer at Aachen. However, testing and calibration runs will be necessary to be done at CERN, for which we request ~ 20 hours of CDC 7600 C.P. time.

Assuming a total statistics of $4{,}9 \times 10^6$ ($2{,}4 \times 10^6$ resp.) triggers, the estimated requirement for pattern recognition and geometrical reconstruction is the equivalent of ~ 220 days (~ 110 days resp.) of PDP10 computer time. The time available at this machine is such that data reconstruction can be performed within 90 weeks (45 weeks resp.).

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Table I: Acceptance and trigger rates

	i) topology trigger only		ii) total trigger	
	acceptance	trigger/burst	acceptance	trigger/burst
$K^-p \to \bar{K}^0\pi^+\pi^-n$ $\hookrightarrow \pi^+\pi^-$	∿17%	∿6	∿17%	∿5
→ 2 prong + V^0 ($\bar{K}^0\pi^+\pi^-n$ excluded)	∿9%	∿60	∿ 9%	∿50 *)
→ 4 prong	∿0.9%	∿66		≤ 25 *)
→ 4 prong + V^0	∿4,6%	∿39		
→ 6 prong	∿1,1%	∿21		
→ rest		∿13		
total		∿205		≤80

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*) These numbers can be reduced by a factor of 2 by using a π^0-veto counting system (see text, chapter 4).

FIGURE CAPTIONS

Fig. 1 Results of a PWA from experiment S116. The intensities of the various J^P-states as function of the $(\bar{K}^0\pi^+\pi^-)$-mass are given.

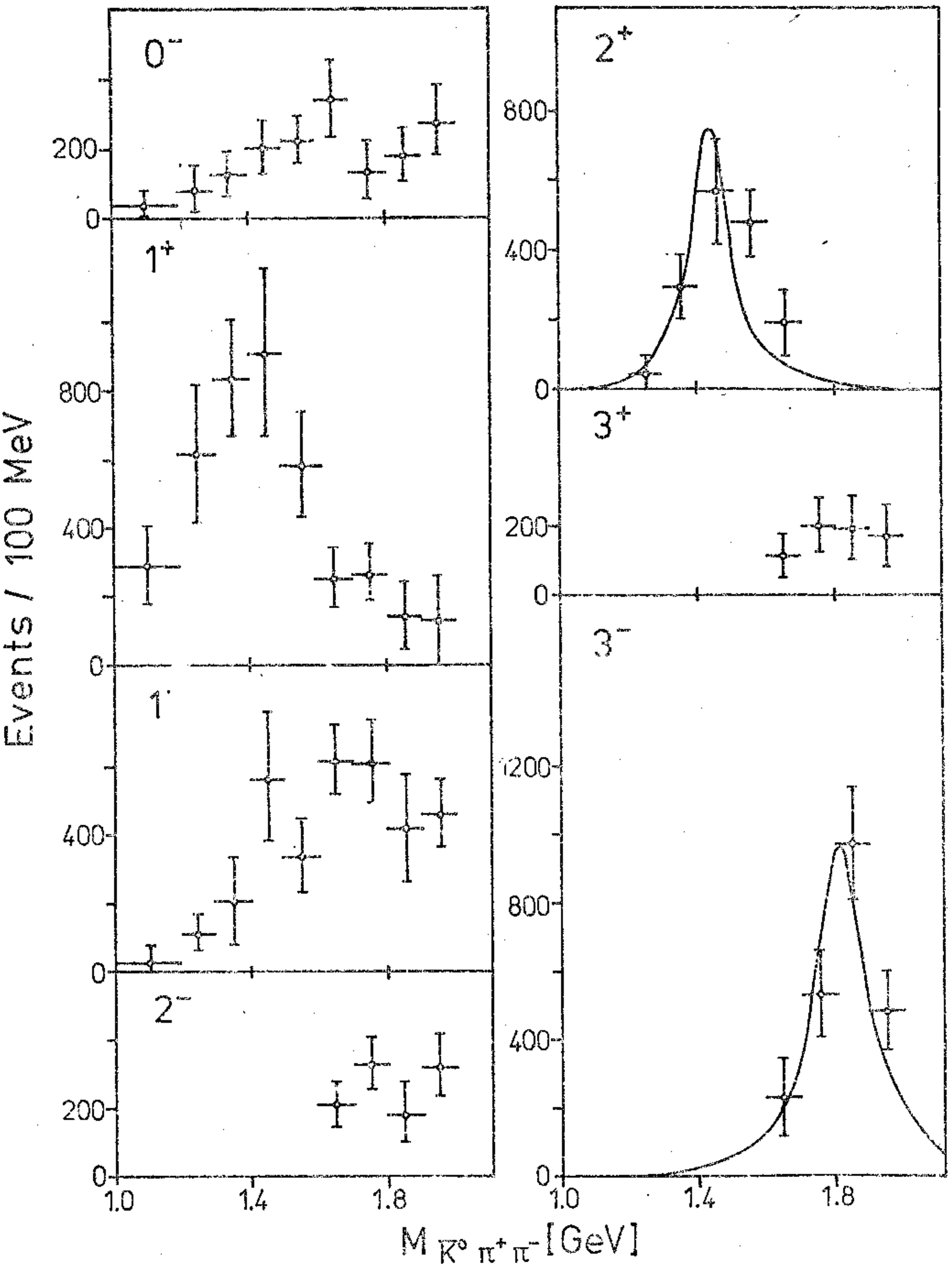
Fig. 2 Intensities of the $J^P = 1^+$ wave, taken from experiment S116.

Fig. 3 Contribution of the natural J^P-series $(1^-, 2^+, 3^-)$ and of the unnatural J^P-series $(0^-, 1^+, 2^-, 3^+)$ produced by unnatural spin-parity exchange.

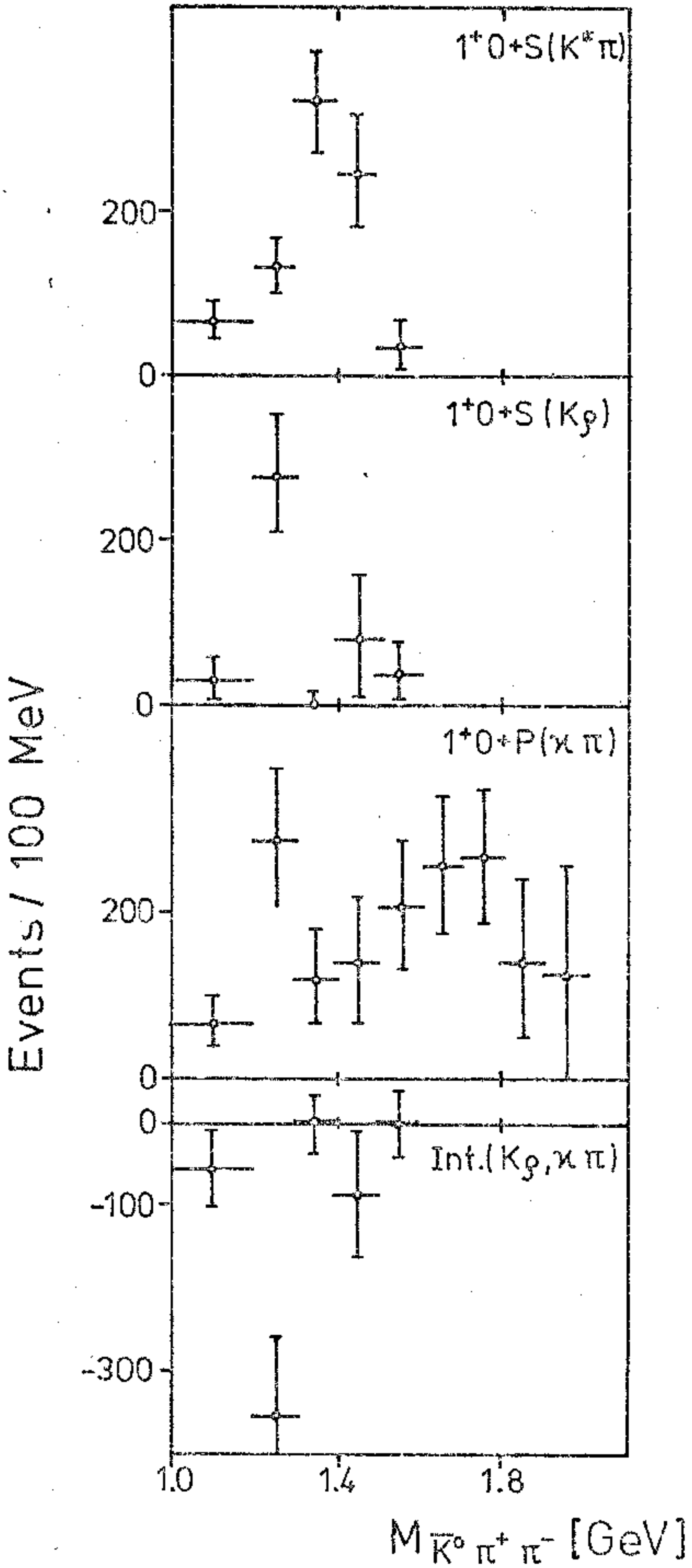
Fig. 4 Experimental set-up. A forward version of the Ω prime detector with A- and B-type chambers is envisaged.

TABLE CAPTION

Geometrical acceptance and trigger rates (position of MWPC1 at x = -100 and MWPC2 at x = -22). The efficiency (single hit efficiency for each plane of the two MWPC's and for the TS are assumed to be 0.95) and the resolution effects (experimental resolution of 2 mm) are taken into account.



J^P -Jntensities



$J^P \Lambda \eta$ l(jn)-Jntensities

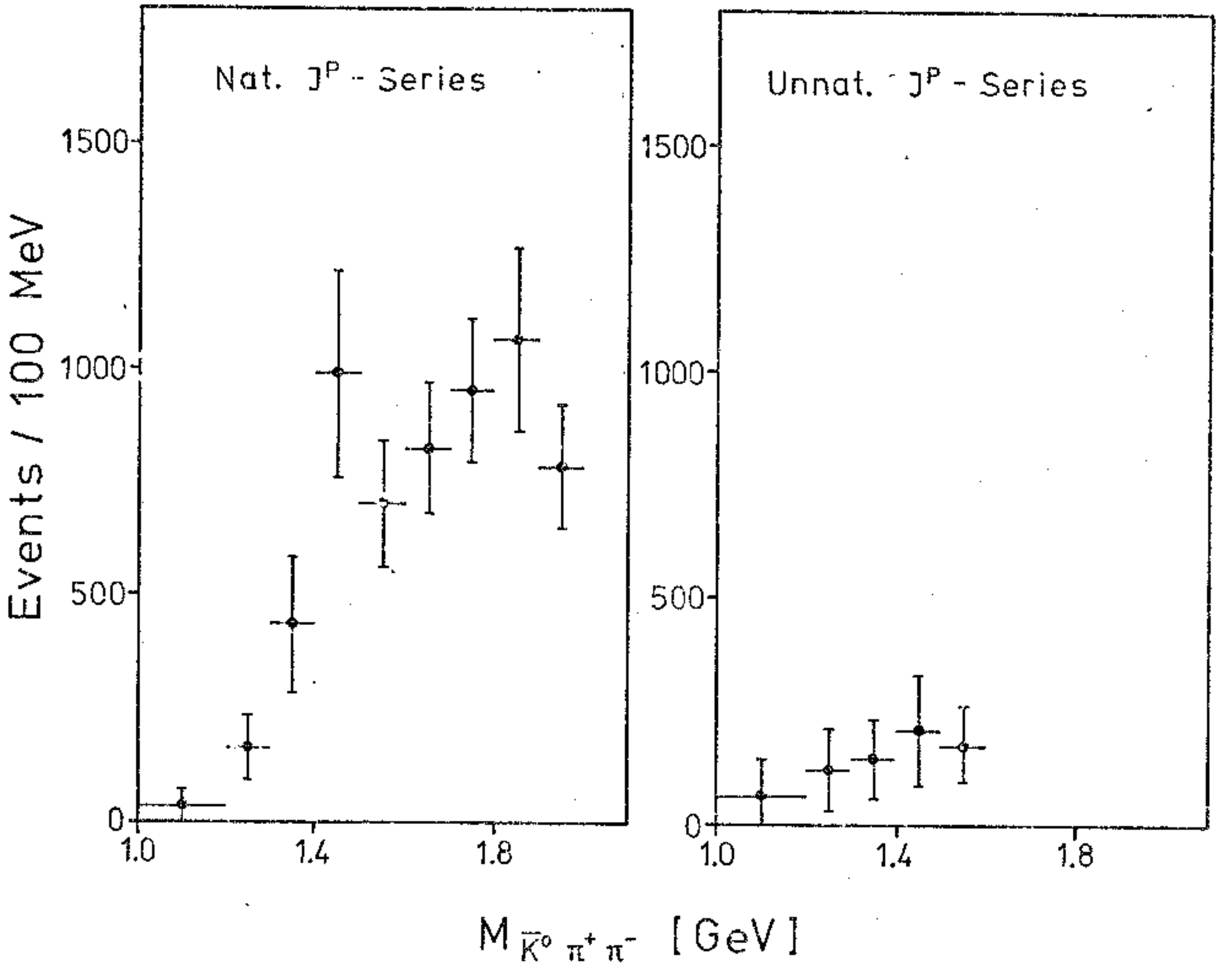


Fig. 3 Unnatural Spin-Parity Exchange

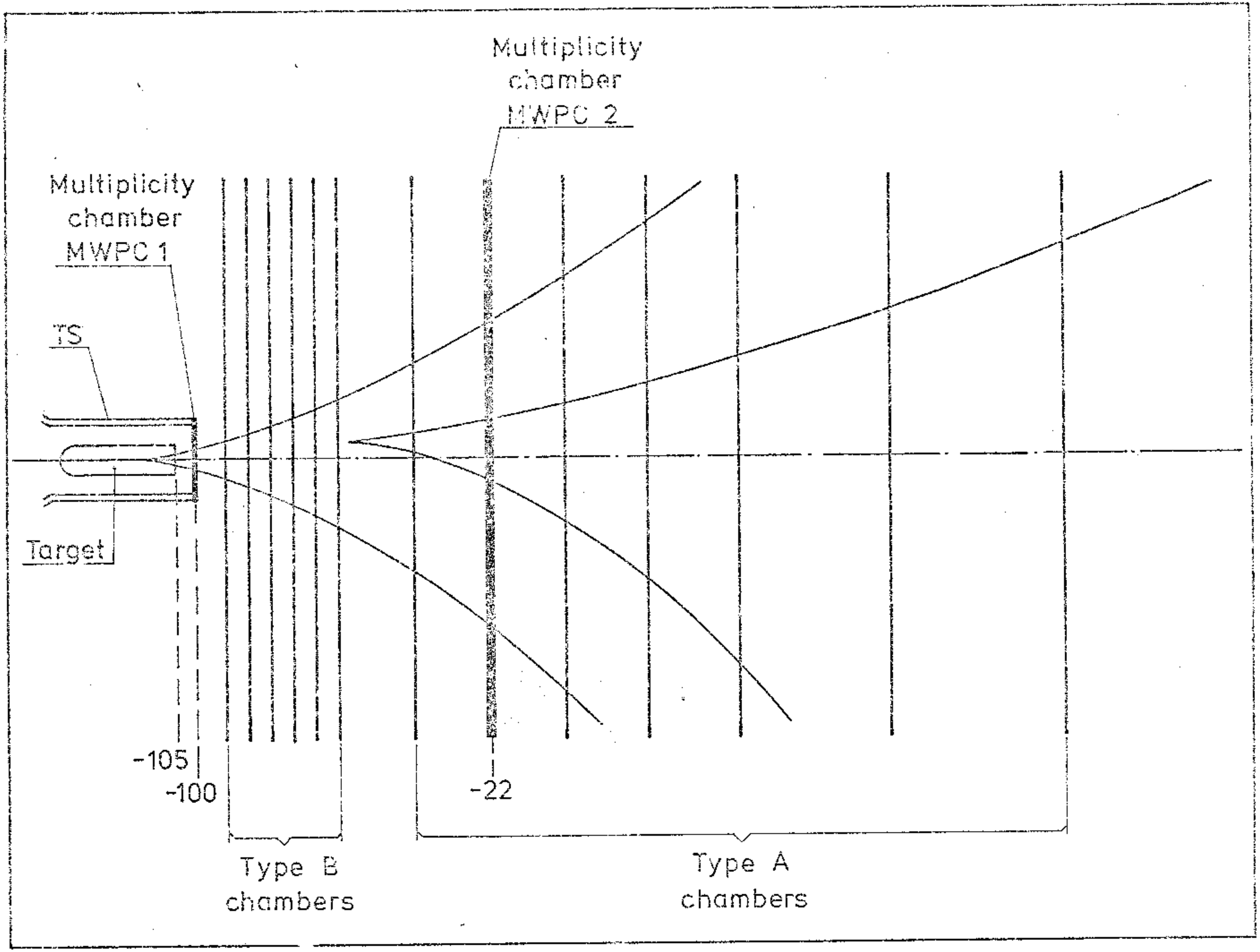


Fig. 4 Trigger set up