Two-Pion Production in Proton-Proton Scattering near Threshold

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1 Motivation

The IUCF measurements of the reaction $pp \to pp\pi^0$ [1] enabled to make a substantial progress in the theoretical description of the pion production. Two-pion production is a natural extension of these studies, allowing to gain further information about the reaction mechanism. It can also deliver interesting information about interaction between the reaction products in the final state. For example in the reaction $pp \to nn\pi^+\pi^+$ we expect to observe the influence of the neutron-neutron final state interaction on the energy dependence of the total cross section.

2 Experimental arrangement

In order to study the pion pair production in various isospin states, we propose to measure the following reactions:

$$
\begin{array}{ll}
pp \to pn\pi^+\pi^0 & \text{(threshold: } p_{beam}\text{=1209 } MeV/c\text{),} \\
pp \to pp\pi^+\pi^- & \text{(threshold: } p_{beam}\text{=1219 } MeV/c\text{),} \\
pp \to nn\pi^+\pi^+ & \text{(threshold: } p_{beam}\text{=1226 } MeV/c\text{).}
\end{array}
$$

Measurements can be performed with the use of the COSY-11 experimental facility after extending it with additional drift chambers and a neutron detector. The drift chambers are needed to extend the momentum acceptance towards smaller values, so that besides the proton momenta also the momenta of positively charged pions can be measured. In turn, the neutron detector will allow to register the neutrons produced in the forward direction. This detector will be placed downstream the beam with respect to the target position, at the 0^o direction behind the COSY-11 dipole magnet. It will consist of alternately ordered sheets of scintillator material and of lead, forming a stack with a total thickness of 30 cm. At present, the new drift chambers are ready for installation and the neutron detector is being built and we expect to have it ready in June this year.

3 Counting rate estimation

To the best of our knowledge there exist no experimental cross sections for two pion production in the nucleon-nucleon scattering in the threshold region. Only an upper limit of 10 nb at excess energy of 1.8 MeV has been determined for the reaction $pp \rightarrow pp\pi^+\pi^-$ in the very first COSY-11 beam time [2]. In order to estimate the cross section we extrapolate the $pp \rightarrow pp\pi^+\pi^-$ data measured at higher energies by Shimizu at al. [3] towards threshold. We assume, that the energy dependence of the cross section is given by the phase space and the final state interaction of the two outgoing protons as suggested by C. Wilkin [4]. This estimated energy dependence is shown in fig. 1 and the numerical values of the cross section near threshold are given in table 1 together with the detector acceptance and the expected counting rate.

excess energy [MeV]	cross section[a] [nb]	acceptance[b] [%]	counts[c] [1/day]
1.0	0.07	12	2
2.0	0.62	5	7
3.0	2.10	1.8	8

[a]estimated
[b]for the detection of two protons and the pion π^+
[c]assuming the luminosity of $2.5 \cdot 10^{30} cm^{-2} s^{-1}$

Table 1: Estimated cross sections, detector acceptance and the expected counting rate for measurements of the reaction $pp \rightarrow pp\pi^+\pi^-$ near threshold.

From the above estimations it seems that we are now in a position to measure the cross sections for the two pion production at least as far as the statistics is concerned. Corresponding estimations for the reactions $pp \rightarrow pn\pi^+\pi^0$ and $pp \rightarrow nn\pi^+\pi^+$ are in progress, however, overall we don't expect drastic differences as compared to the reaction $pp \rightarrow pp\pi^+\pi^-$.

4 Proposed measurements

We propose to perform preliminary test measurements which should be regarded as a feasibility study to determine the magnitudes of the cross sections for the two pion production near threshold and to determine the experimental background. We plan to perform them at three beam momenta corresponding to the excess energy of 2 MeV above each of the reaction thresholds (see table 2).

p_{beam} [MeV/c]	Q($pp \to pn\pi^+\pi^0$) [MeV]	Q($pp \to pp\pi^+\pi^-$) [MeV]	Q($pp \to nn\pi^+\pi^+$ [MeV]
1215.0	2.0	-	-
1224.5	5.3	2.0	-
1232.0	7.9	4.6	2.0

Table 2: Proposed beam settings for the preliminary studies of the two pion production.

For each of the beam momentum settings, the event trigger will be adjusted to measure the three reactions simultaneously. For example in the measurement of the reactions $pp \to pp\pi^+\pi^-$ at the excess energy of 2 MeV, the reaction $pp \to pn\pi^+\pi^0$ will be measured at the excess energy of 5.3 MeV and the reaction $pp \to nn\pi^+\pi^+$ will be tested below threshold.

In order to perform these test measurements we would like to ask for one week of the COSY beam time.

References

[1] H. O. Meyer et al., Nucl. Phys. **A 539**(1992)633

[2] A. Khoukaz, PhD thesis, University of Münster

[3] F. Shimizu et al., Nucl. Phys. **A 386**(1982)571

[4] C. Wilkin, private communication (1996)

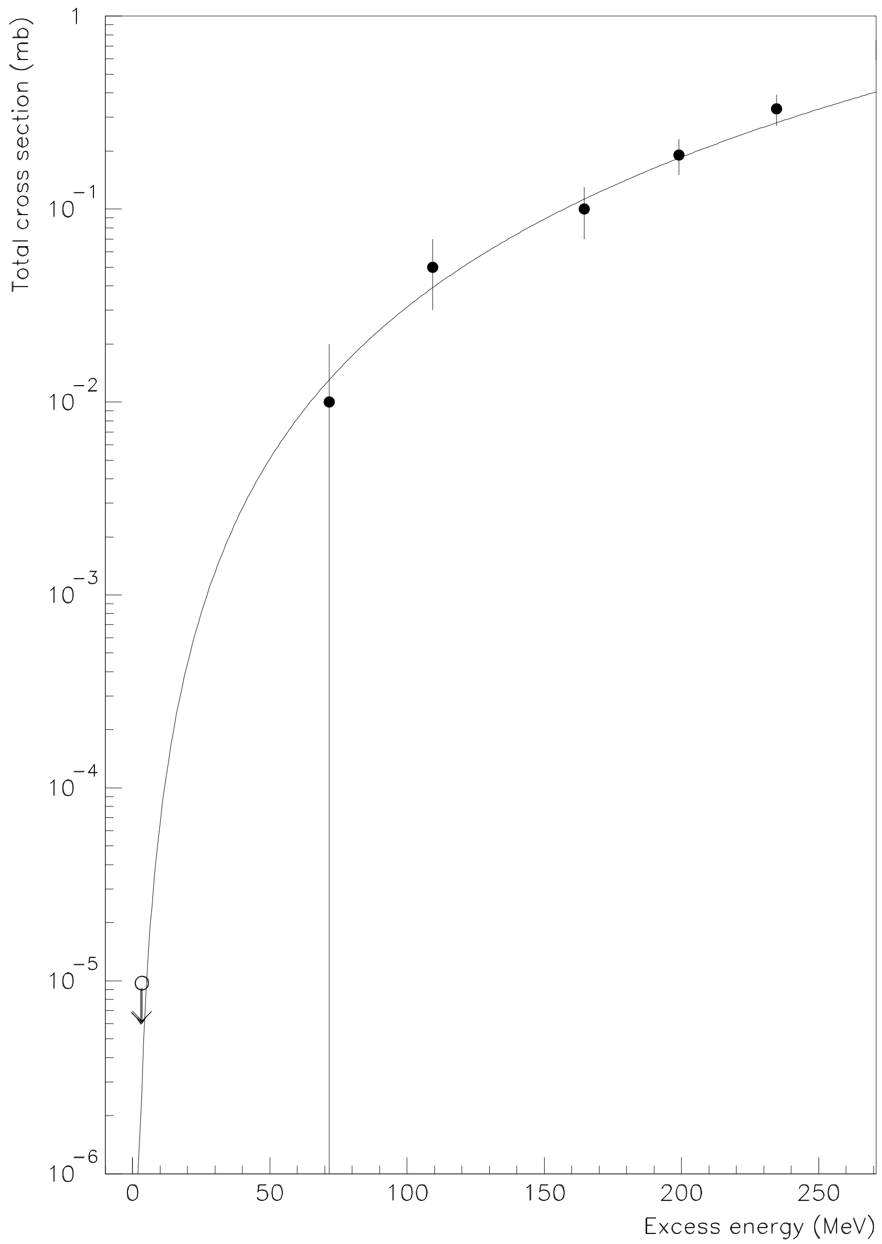

Figure 1: Energy dependence of the cross section for the reaction $pp \to pp\pi^+\pi^-$ as given by the phase space and the final state interaction between the two protons. Shown are also the experimental data points measured by Shimizu et al. [3] which were used to fix the absolute normalization. Indicated is also the upper limit for the cross section at excess energy of 1.8 MeV as determined by the COSY-11 collaboration.