Vol. 29 (1998) ACTA PHYSICA POLONICA B No 11

TWO-PION PRODUCTION IN PROTON–PROTON COLLISIONS NEAR THRESHOLD AT CELSIUS*

R. Bilger[i], W. Brodowski[i], H. Calen[h], H. Clement[i], J. Dyring[e], C. EkstrÖM[h], K. Fransson[e], J. Greiff[j], L. Gustafsson[e], S. Häggström[e], B. Höistad[e], J. Johanson[e], A. Johansson[5], T. Johansson[e], A. Khoukaz[e], K. Kilian[g], I. Koch[e], S. Kullander[e], A. Kupsc[b], P. Marciniewski[b], B. Morosov[f], A. Mörtsell[e], W. Oelert[g], R. Ruber[e], U. Schubert[e], B. Shwartz[d], J. Stepaniak[b], A. Sukhanov[d,f,e], P. Sundberg[e], A. Turowiecki[a], G. Wagner[i], Z. Wilhelmi[a], J. Zabierowski[c], A. Zernov[f], J. Zlomanczuk[e]

[a]Inst. of Exp. Phys., Warsaw Univ., 00-681 Warszawa, Poland
[b]Institute of Nuclear Studies, 00-681 Warszawa, Poland
[c]Institute of Nuclear Studies, 90-137 Łódź, Poland
[d]Budker Institute of Nuclear Physics, 630 090 Novosibirsk, Russia
[e]ISV, University of Uppsala, S-751 21 Uppsala, Sweden
[f]Joint Institute for Nuclear Research, Dubna, 101000 Moskow, Russia
[g]IKP, KFA, D-52425 Jülich, Germany
[h]TSL, University of Uppsala, S-75121 Uppsala, Sweden
[i]Tübingen University., D-72076 Tübingen, Germany
[j]Inst. of Exp. Phys., Hamburg University, D-2000 Hamburg, Germany

(Received June 18, 1998)

Two-pion production reactions in proton-proton collisions near threshold are measured using an internal cluster-jet hydrogen target and the WASA/PROMICE detector at the CELSIUS storage ring. Four out of the five possible two-pion production reactions are measured simultaneously.

PACS numbers: 13.75.–n, 25.10.+s, 25.40.Ve

1. Introduction

Two-pion production in the near threshold region is an important tool to study the fundamental nucleon-nucleon, pion-nucleon and pion-pion interaction. The theoretical understanding of the contributing processes is

* Presented at the MESON '98 and Conference on the Structure of Meson, Baryon and Nuclei, Cracow, Poland, May 26–June 2, 1998.

improving, but more data, especially close to threshold ($\sim$ 0.6 GeV, are needed. Recent calculations for all reaction channels can be found in [1].

Within the WASA/PROMICE collaboration data on $\pi\pi$ production in proton-proton collisions have been collected at 650, 680, 725, 750 and 775 MeV. All possible two-pion reaction channels except $pp \to nn\pi^+\pi^+$ are measured simultaneously.

The WASA/PROMICE detector (Fig. 1) is well suited to measure meson production reactions close to threshold. The charged outgoing particles are measured in the forward part (FD) of the detector. The neutral mesons are measured by their decay into two γ's in the central part (CD) of the detector.

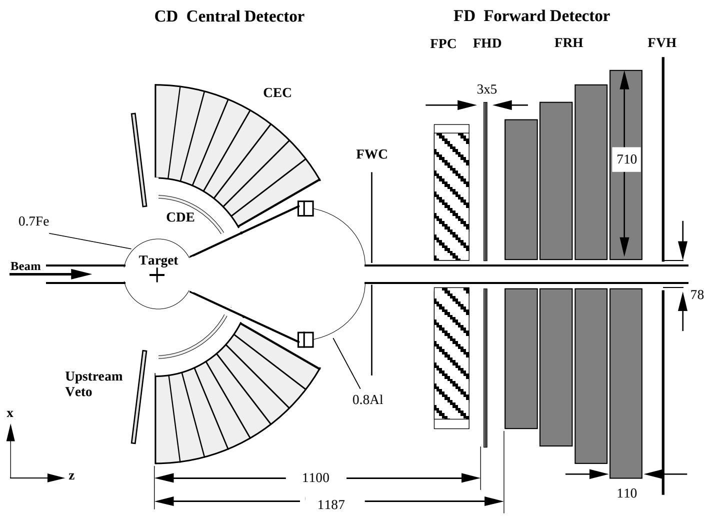

Fig. 1. The WASA/PROMICE detector at CELSIUS storage ring, TSL in Uppsala.

2. The experiment

The $pp \to pp\pi^+\pi^-$ events are selected by detecting two protons and at least one pion in the FD. The protons are identified using the ΔE/E information from the different layers of the FD. The pions are also identified using the ΔE/E information from the FD. In addition, the positive pions can be identified by detecting the delayed pulse from the decay of the π^+, $\pi^+ \to \mu^+\nu_\mu \to e^+\nu_e\overline{\nu}_\mu$, with an efficiency of about 60 percent [2].

The dominating background comes from single neutral pion production. The γ's from the decay of the π^0 can convert into e^+e^- pairs in the material surrounding the target region. If an electron ends up in the FD together with two protons, a $pp \to pp\pi^0$ event can be misidentified as a $pp \to pp\pi^+\pi^-$

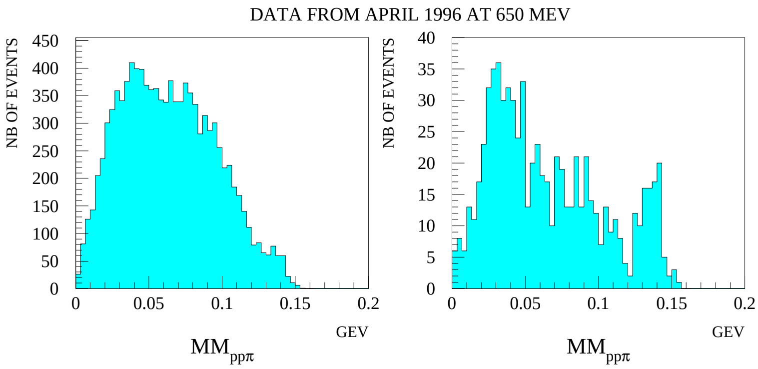

Fig. 2. The missing mass of the two protons plus the pion when the pion is identified using only the $\Delta E/E$ information (left) and when a delayed pulse from the pion is requested in addition (right).

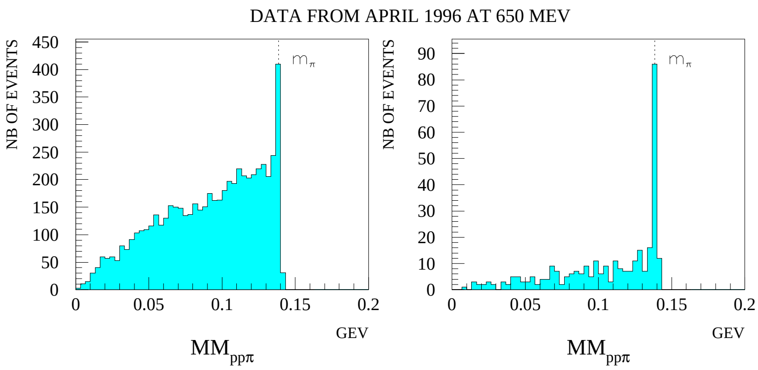

Fig. 3. The result of the kinematical fitting. The missing mass of the two protons plus the pion when the pion is identified using only the $\Delta E/E$ information (left) and when a delayed pulse from the pion is requested in addition (right).

event. The background from single pion production is seen clearly as a broad bump to the left of the pion peak in Fig. 2 (left), where the missing mass of the two protons plus the pion is plotted. In Fig. 2 (right) the condition that the pion causes a delayed pulse is added, which leads to a great reduction in the background from single pion production events.

An alternative way to select the $pp \to pp\pi^+\pi^-$ events is to use kinematical fitting. Several hypothesis are fitted to the data and the reaction which gives the highest fit probability is selected. The result of the fit can be seen in Fig. 3, where the missing mass of the two protons and the pion is plotted without (left) and with (right) the requirement of a delayed pulse from the pion decay. In addition of giving higher statistics, the use of kinematical fitting also improves the missing mass resolution.

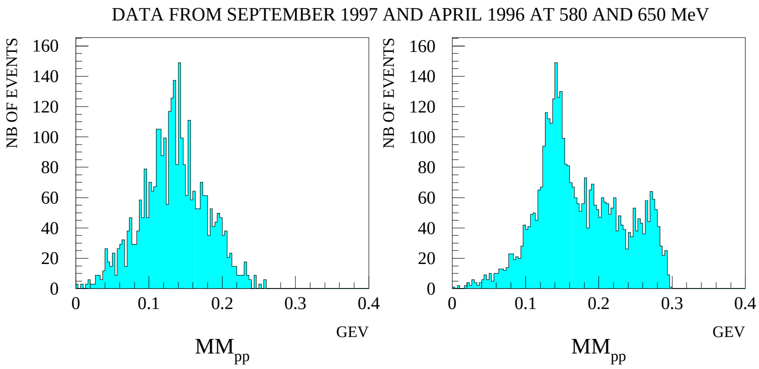

Fig. 4. The missing mass of the two protons when at least two γ's are identified in the CD, below the two-pion production threshold (left) and at 70 MeV above the threshold (right).

The $pp \to pp\pi^0\pi^0$ events are selected by identifying two protons in the FD and at least two γ's in the CD. In Fig. 4 (right) the missing mass of the two protons is plotted. In Fig. 4 (left), data recorded below the threshold for two-pion production but analysed using the same routines as for data recorded above the threshold are plotted. As can be seen, the dominating background comes from single neutral pion production, also for this reaction channel.

The luminosity is determined from data on elastically scattered protons recorded in parallel. One proton is detected in the FD and one proton in the CD. Using the the relation $\tan(\theta_1) * \tan(\theta_2) = 1/\gamma^2$, where θ_1 and θ_2 are the scattering angles for the two protons, it is possible to select a clean sample of elastically scattered protons.

3. Summary

All but one of the possible two-pion production reactions in proton-proton collisions at several energies close to threshold are presently being analysed within the WASA/PROMICE collaboration. The cross sections for the the $pp \to pp\pi^+\pi^-$ reaction at 650 and 680 MeV as well as the cross section for the reaction $pp \to pp\pi^0\pi^0$ at 650 MeV will be presented in [3]. When all data have been analysed, the statistics should be good enough to study various event distributions, even at the lowest energy, 650 MeV.

The cross sections for the $pp \to pp\pi^+\pi^-$ reaction at 725, 750 and 775 MeV will be presented in [4]. In addition to the analysis of the $\pi^+\pi^-$ and $\pi^0\pi^0$ reaction channels, the $\pi^+\pi^0$ reaction channels are also being investigated and a status report of that analysis can be found in [5].

REFERENCES

[1] E. Oset *et al.*, *Nucl. Phys.* **A633**, 519 (1998).

[2] G.R. Kurtz, π^+/π^--Identifikation in Szintillationszählern, Diploma thesis, University of Tübingen.

[3] J. Johanson, Ph.D. Thesis, Uppsala university, in preparation.

[4] W. Brodowski, Ph.D. Thesis, University of Tübingen, in preparation.

[5] A. Khoukaz, Progress Report, University of Münster.