Threshold Measurements of the Reaction $pp \rightarrow pp\pi^+\pi^-$ at the COSY-11 Installation

COSY-11 Collaboration

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1 Physical Motivation

The production of mesons in fundamental reactions like the p-p scattering near threshold is an important tool to study reaction mechanism and particle interaction. The low relative momenta of the outgoing particles near threshold result in a large interaction time, which provides a sensible probe to examine final state interactions. Measurements of the π^0-production near threshold [1] led to theories of the nucleon-nucleon interaction which have been extended by additional short range interaction terms, being in good agreement to data [2], [3].
In the case of the two pion production similar unexpected results might be observed, but no realistic data exist near threshold. In addition to the nucleon-nucleon and the nucleon-pion interaction the two pion production near threshold allows to study the pion-pion interaction. Therefore, threshold measurements to the two pion production are desirable.

2 Experimental Arrangement

The basic experimental setup of the internal COSY-11 installation (Fig. 1) consists of a hydrogen cluster target at the internal COSY target place TP3, installed in front of a regular COSY dipole, which is used to separate reaction products from the circulating beam and to analyze their momenta. The exit windows of a specially developed vacuum chamber, mounted inside the dipole gap, link the COSY vacuum and the detection system, which is operated in normal atmosphere.
Including the knowledge of the magnetic field, the information obtained from two drift chamber systems (D1 and D2) in combination with a particle identification based on a time–of–flight measurement and the dE/dx–information of two scintillation hodoscopes (S1 and S2) and a large area scintillation wall allow a complete determination of the four–momentum vectors of both baryons in the exit channel. Apart from positively charged pions being detected by a set of new drift chambers and scintillators (D3, S8 in Fig. 1), a detection of negatively charged pions is provided by an array of silicon pad detectors and an additional scintillation counter mounted inside the dipole gap. Due to the narrow opening of the dipole gap the geometrical acceptance of the detection system is limited especially in the vertical direction. For a more detailed coverage of the COSY–11 detection system see [4].

3 Status

Data of cross section for the reaction $pp \rightarrow pp\pi^+\pi^-$ (threshold: $p_{beam} = 1.2187\,GeV/c$) are available above $1.38\,GeV/c$ [5-8], thus experimental data for the first $160\,MeV/c$ above threshold are still missing. Therefore, this reaction was examined close to threshold in first studies [9] at COSY-11 with the standard experimental set-up for the two reaction protons. For the detection of the π^+ additional scintillation detectors were added, which allowed charged particle detection but no momentum reconstruction. The reaction should be selectable by the detection of four charged ejectiles. The detection of the outgoing pions is necessary to distinguish this reaction from the reaction $pp \to pp\pi^0\pi^0$ (threshold: $p_{beam} = 1.1921\,GeV/c$). Data were taken at beam momenta of $1.224\,GeV/c$ and $1.222\,GeV/c$, i.e. $5.3\,MeV/c$ and $3.3\,MeV/c$ above threshold and at beam momenta of $1.205\,GeV/c$ and $1.190\,GeV/c$, i.e. $13.7\,MeV/c$ and $28.7\,MeV/c$ below threshold. In all cases no events with the postulated criterion, i.e. detection of all four ejectiles, could be found, thus the evaluation of the data resulted in the estimation of upper limits for the cross section, which are listed in Table 1. Also listed are the integrated luminosity $L \cdot T$, the efficiency of the detection system ϵ and the upper limit of detected events (confidence level 90%) in the case of no observed events.

beam momentum	[GeV/c]	1.222	1.224
$N_{pp\pi^+\pi^-}$		< 2.30, CL=90%	< 2.30, CL=90%
$L \cdot T$	$[10^{34} cm^{-2}]$	> 0.34, CL=99.9%	> 2.33, CL=99.9%
efficiency ϵ	[%]	$5.1^{+7.3}_{-2.8}$	$1.7^{+1.3}_{-0.7}$
$\sigma < \frac{N_{pp\pi^+\pi^-}}{L \cdot T \cdot \epsilon}$	[nb]	29.4, CL=90%	9.9, CL=90%

Table 1: Upper limits for the $\pi^+\pi^-$ production in the pp-scattering near threshold.

Due to the higher integrated luminosity at $1.224\,GeV/c$ the upper limit at this beam momentum is much smaller than the corresponding value at $1.222\,GeV/c$ and is therefore more significant. In Fig. 2 this value and the up to now existing data close to threshold are shown. Measurements at the threshold region have been done by the MOMO collaboration at COSY and by the WASA/PROMICE collaboration at Uppsala.

a) At COSY in the $pd \to {}^3He\,\pi^+\pi^-$ reaction MOMO [10] registers a strong depletion of cross section for low $\pi^+\pi^-$ relative momenta compared to phase space. This effect can not be explained up to now by standard mechanism and will be further investigated.

b) In the $pp \to pp\pi^+\pi^-$ reaction studies at Uppsala using beam momenta of $1.250\,GeV/c$ and $1.404\,GeV/c$ very preliminary results seem to indicate again a much lower cross section than reported in the literature for $1.404\,GeV/c$ and no events could be extracted at $1.250\,GeV/c$ [11].

4 Proposed Measurements and Beam Request

We propose to repeat and extend the measurements of the two pion production at threshold with considerable increased luminosity. Due to an increased target density and a higher COSY beam current in combination with an optimized target/beam overlap the luminosity has been increased to $L \geq 2.5 \cdot 10^{30}\,cm^{-2}s^{-1}$ compared to previous numbers ($L = 1.2 \cdot 10^{29}\,cm^{-2}s^{-1}$). Additionally, compared to the earlier arrangement the detection system was improved by a further drift chamber for the detection of the π^+ track. The $\pi^+\pi^-$-production can be selected by measuring the four momenta vectors of both outgoing protons and the positively charged pion. Due to this fact the efficiency is increased by a factor of ≈ 3 compared to the detection of all four ejectiles. Both, the improved luminosity and the higher efficiency lead to an expected counting rate of a factor of ≈ 60 higher than in earlier measurements.
During the previous COSY-11 measurements data have been taken for 2.5 days at a beam momentum of $1.224\,GeV/c$. To make use of the above mentioned improvements the following beam time is requested:

- 4 days at 1.190 GeV/c (below two charged and neutral pion threshold)
- 10 days at 1.224 GeV/c

$\Rightarrow$ **14 days**

Due to the four times higher measuring time and the mentioned increased counting rate by a factor of ~ 60, an improvement of a factor of $\sim$ **240** compared to our last measurement is expected. This will result in a sensitivity of cross section measurements of up to $\sim 40\,pb$ depending on the possible background suppression.

References:

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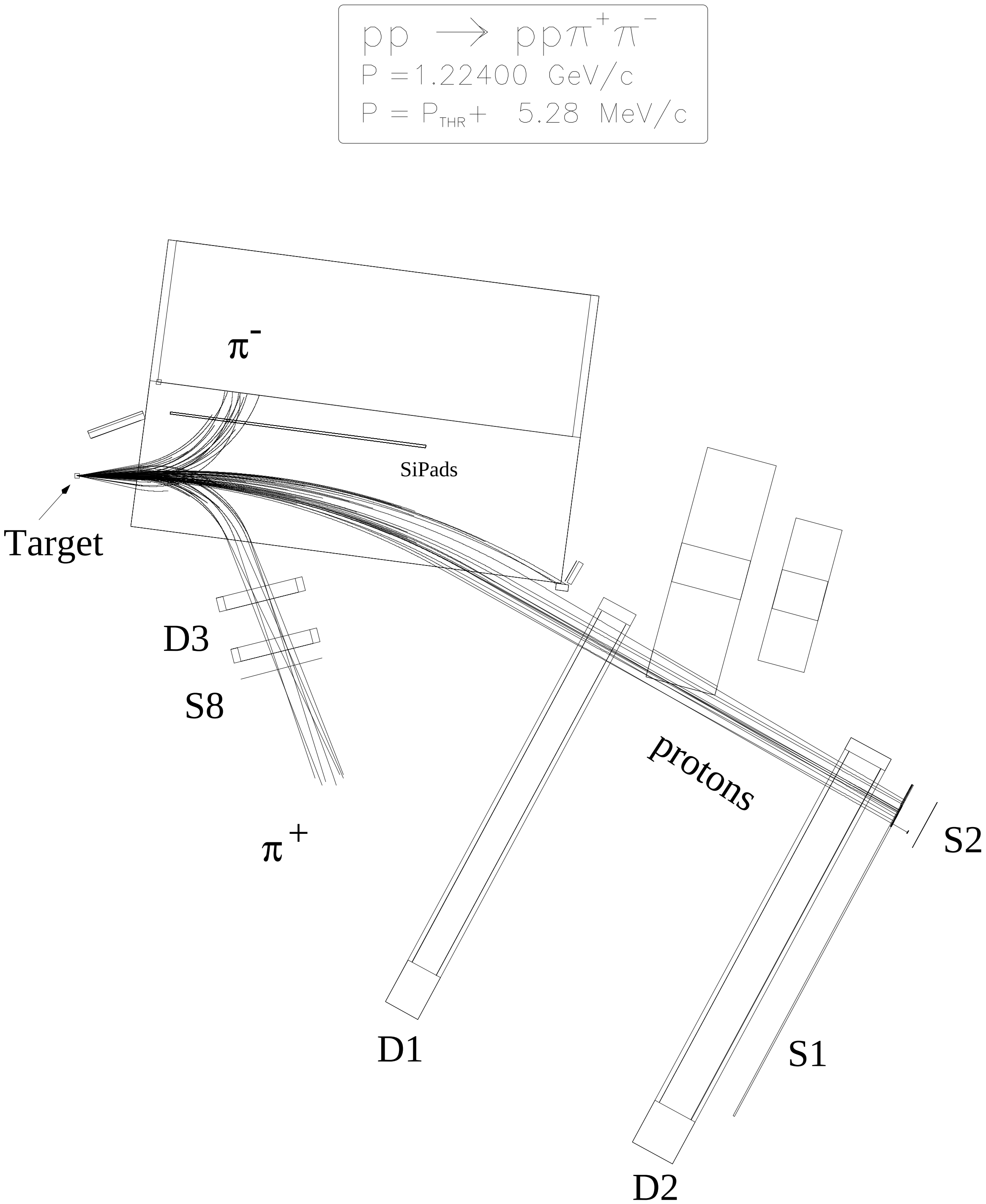

Figure 1: Target region of the COSY-11 installation and typical tracks of the reaction $pp \to pp\pi^+\pi^-$ close to threshold.

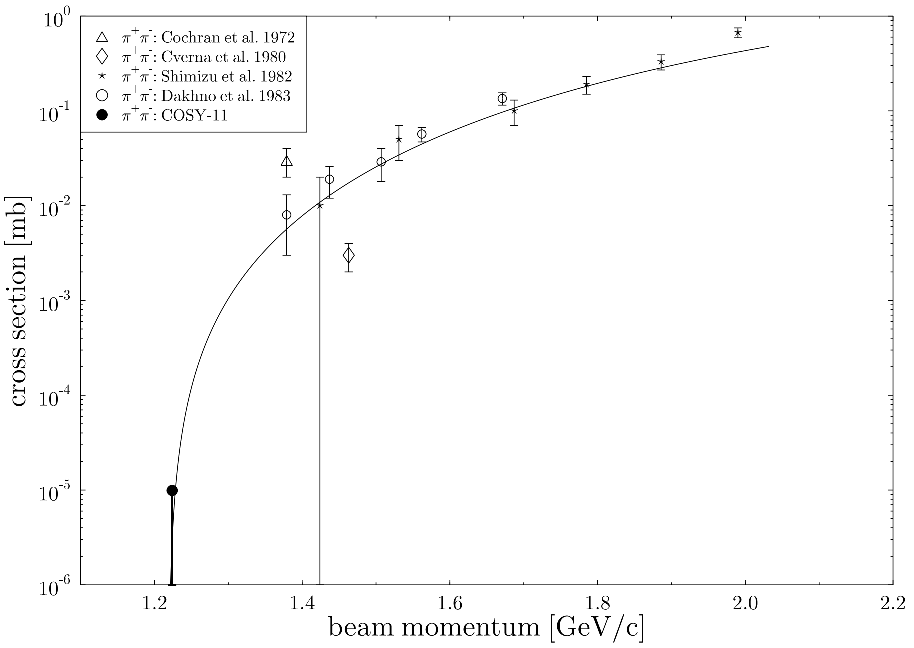

Figure 2: Available cross section for the reaction $pp \to pp\pi^+\pi^-$ near the threshold.