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$3\pi^\circ$ FINAL STATES WITH WASA AT CELSIUS AND COSY

C. Pauly [1], *P. Vlasov for the CELSIUS/WASA and WASA-at-COSY coll.*
Institut fuer Kernphysik, Forschunszentrum Juelich
52425 Juelich
Germany

Abstract

High statistic samples of $3\pi^0$ final states in pp scattering at different energies have been measured using the WASA detector. Cross sections for prompt $3\pi^0$ production were determined, η–production dynamics are studied by means of pp and pη invariant mass distributions, and the $\eta \to 3\pi^0$ Dalitz plot density distribution was measured.

1 Introduction

Hadronic $3\pi^0$ production in pp scattering opens up a wide and interesting field of research and allows to study multi pion production mechanisms, η–production dynamics, and gives the possibility of precise tests of QCD model calculations and predictions. In this text, we summarize on measurements which were done using the WASA 4Π detector installed at the CELSIUS accelerator in Sweden. The analysed data were measured during several production beam periods in 2002 and 2003 using a proton beam with kinetic energy of 1300 MeV to 1450 MeV (Q=17 MeV to Q=74 MeV above the η-threshold), impinging on frozen hydrogen pellets from the unique WASA pellet target system.

In this energy range, two basic mechanisms for $3\pi^0$ production seem to be important: Direct, *prompt* production ($pp \to pp3\pi^0$, here also including possible excitation of intermediate N^* or Δ resonances) and the *resonant* process via production and decay of an η–meson, $pp \to pp(\eta \to 3\pi^0)$. The cross section for prompt 3pi0 production in this energy range has never been measured before, and the obtained results provide first hints on the reaction dynamics in the production mechanism. Further more, the prompt multi-pion production is an important background channel in the analysis of other, rare η decay channels as proposed with WASA-at-COSY, thus a precise knowledge of the

[1] c.pauly@fz-juelich.de

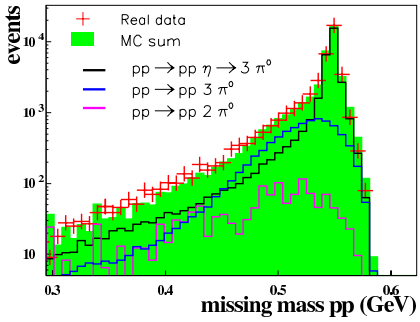

Figure 1: Experimental pp missing mass distribution for $pp\pi^0\pi^0\pi^0$ final states at beam energy T=1360 MeV with fit of the Monte Carlo distributions for $2\pi^0$, $3\pi^0$ and η production.

cross section is essential for their analysis.
Analysis of the resonant process allows to study η–production dynamics in the range from Q=17 MeV to Q=74 MeV above production threshold by means of invariant mass distributions and Dalitz plots of particle subsystems. A precise measurement of the $3\pi^0$ Dalitz plot density distribution for the $\eta \to 3\pi^0$ decay poses an important test of QCD calculations.

2 Event reconstruction

The analysis is based only on completely reconstructed events with both protons measured in the WASA Forward detector(3° to 17°), and all 6 gammas being detected in the CsI(Na) calorimeter (20°0 to 140°). Additional cuts on energy thresholds (20 MeV for gammas), overall energy and momentum conservation, and time cuts are used to further suppress background and event overlap. The most probable combinations of the 6 gammas to form 3 pions are selected and used in a final kinematical fit of the full event, based on 8 overconstraints. Separation between prompt and resonant contribution is obtained by applying a narrow cut on the pp missing mass distribution, the remaining prompt background below the η peak is in the order of 5-10 %. The good agreement between Monte Carlo and real data is demonstrated in fig. 1 showing a fit of Monte Carlo simulated distributions for prompt and resonant 3pi0 production to data.

3 Cross section for prompt $3\pi^0$ production

The ratio of prompt and resonant contribution obtained by the fit of the pp missing mass distribution can be directly converted into cross sections for prompt 3pi0 production by using the well known $pp \to pp(\eta \to 3\pi^0)$ cross section for normalization. As a cross check, the resonant η–production cross sections were calculated using the luminosity obtained from pp elastic

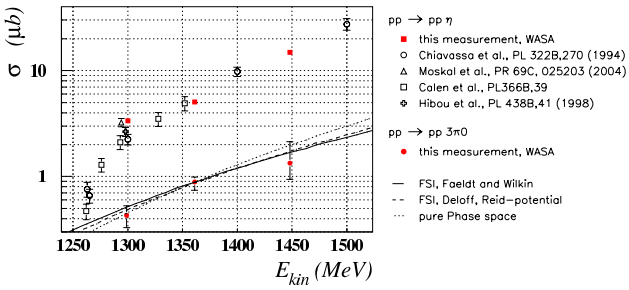

Figure 2: Cross section overview for η production $pp \rightarrow pp\eta$ and prompt 3 pion production, $pp \rightarrow pp3\pi^0$ as function of beam energy.

scattering and applying a complete acceptance correction. The results are summarized in fig. 2. The deduced $pp \rightarrow pp3\pi^0$ excitation function is consistent with the increase of phase space volume, which allows for a first rough extrapolation also to higher energies available now with WASA-at-COSY. The obtained η production cross sections are in good agreement with results form other experiments. Further discussion of the results can be found in [2].

4 Eta production dynamics

In Fig. 3 the obtained invariant mass distributions for the pp and pη subsystems are shown. The obtained results nicely combine with results from previous measurements by COSY11 [4] and COSY-TOF [5], and expand these studies to a higher energy range. One can clearly see how the spectra at lowest excess energy, Q=17 MeV, are dominated by pp final state interaction leading to an enhancement for low pp invariant mass. The pp FSI effect fades our for the higher excess energies and is replaced by a prominent dip in the pη invariant mass distribution, which is the dominant deviation from phase space at Q=74 MeV. This dip lacks a theoretical description yet, a possible explanation might be higher partial wave contributions.

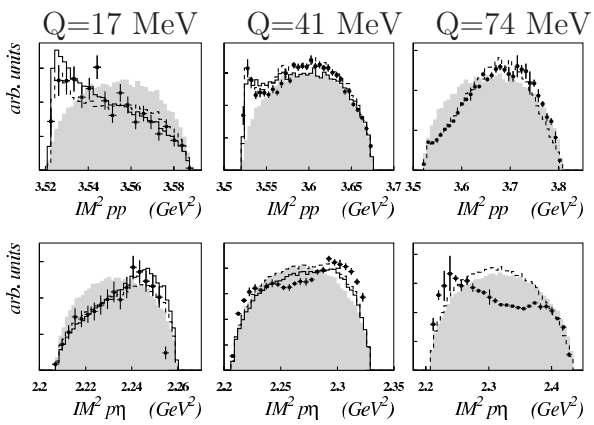

Figure 3: Invariant mass of the pp and pη system for events of type $pp \rightarrow pp\ \eta$ from Q=17 MeV to Q=74 MeV above the η production threshold.
Solid line shows the calculation from [?]

5 $\eta \to 3\pi^0$ Dalitz plot density distribution

The distribution of events in a symmetrized Dalitz plot of the 3 pions in the $\eta \to 3\pi^0$ decay is a sensitive probe for the interaction of pions in the final state. Without any pion rescattering, the Dalitz plot population would be flat due to the three identical final state particles. A linear fit to the one dimensional density distribution (expressed as function of the radial parameter z) yields the slope parameter α. Different approaches on the theory side exist to include this pion rescattering, a precise measurement of α is a crucial test of these QCD calculations. Two high precision measurements of α were performed by KLOE [6] and Crystal Ball [7], each based on $> 10^6$ events in the Dalitz plot. The CELSIUS/WASA result for α, shown in fig 4, is based on 75000 events and in agreement within stated errors but limited by statistics. More details can be found in [3].
These studies are now continued with WASA-at-COSY, data taken during a first production run in April 2007 will significantly increase the present statistic and hopefully allow for a more accurate determination of α.

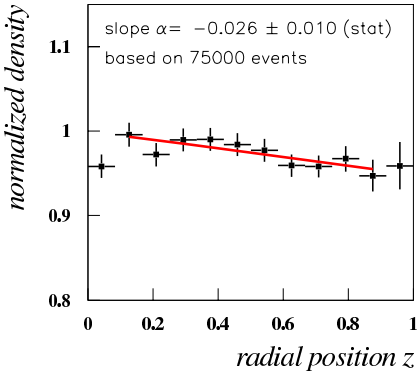

Figure 4: Efficiency corrected Dalitz plot density distribution as function of radial variable z, together with the fitted result for slope α. Only statistical errors are shown.

References

[1] A. Deloff, *Phys. Rev. C69*, 035206 (2004).

[2] C. Pauly et al., *Phys. Lett. B649*, 122 (2007).

[3] M. Bashkanov et al., *Phys. Rev. C76*, 048201 (2007)

[4] P. Moskal et al., *Phys. Rev. C69*, 025203 (2004).

[5] M. Abdel-Bary et al., *Eur. Phys. J. A16*, 127 (2003).

[6] F. Ambrosino et al., *arXiv:0707.4137[hep-ex]*.

[7] W. B. Tippens et al., *Phys. Rev. Lett. 87*, 192001 (2001).