3π and 4π meson production in np interactions at intermediate energies

A.P. Jerusalimov[1]★, *A.V.* Belyaev[1], *V.P.* Ladygin[1], *V.N.* Pechenov[2], and *Yu.A.* Troyan[1]

[1]*Joint Institute for Nuclear Research, 141980 Dubna, Russia*
[2]*GSI Helmholtzzentrum fur Schwerionenforschung GmbH, 64291 Darmstadt, Germany*

Abstract. The study of 3π and 4π meson production in np interactions was carried out at the momenta of incident neutrons P_0=3.83, 4.42 and 5.20 GeV/c. The characteristics of the reactions were satisfactorily described by OPER model. For the better description of the reaction $np \to pp\pi^+\pi^-\pi^-\pi^0$ it was necessary to take into account the production of η^0 and ω^0 mesons.

1 Introduction

The study of multipion production in NN collisions is one way to obtain information about the NN, πN and $\pi\pi$ states, including:

dibaryons (including I=2 in $pp\pi^+$),
dipions (narrow σ^0 meson, $\pi\pi$ state with I=2),
pentaquarks (I=5/2, S=+1),
missing resonances, etc.

Also the important task is the test of various models of pion production in NN interaction, such as, for example, Valencia model [1], Xu Cao model [2] and OPER model [3, 4].

2 Experiment

The neutron-proton interactions were studied using neutron beam and liquid hydrogen bubble (target) at the JINR Synchrophasotron [5]. The unique in fullness and precision data were obtained. It allowed to carry out the detailed study of inelastic np interactions in in a wide range of energies using the quasimonochromatic neutrons with P_0<2.5% under condition of 4π geometry.

The following reactions with 3 and 4 π mesons in the final states were studied:

$np \to pp\pi^+\pi^-\pi^-$,
$np \to pp\pi^+\pi^-\pi^-\pi^0$,
$np \to np\pi^+\pi^+\pi^-\pi^-$

at the momenta of P_0=3.83, 4.42 and 5.20 GeV/c (see figure 1).

The accuracy of the momentum and scattering angle reconstruction for the secondary charged particles was $\sigma_p/p \sim 2\%$ and $\sigma_\Theta \sim 10$ mrad, respectively. The separation of the reaction channels

★e-mail: jerus@jinr.ru

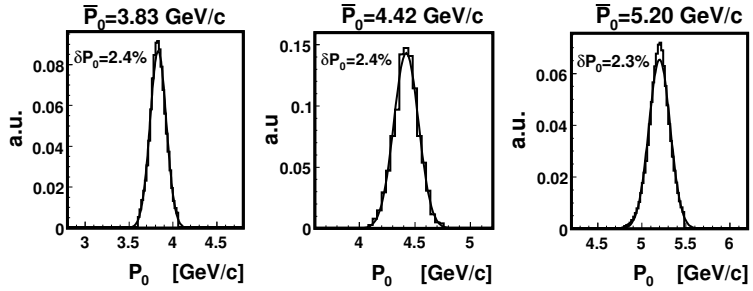

Figure 1. The momentum distributions of the incident neutrons at P_0= 3.83, 4.42 and 5.20 GeV/c

were carried out by the standard χ^2 procedure using corresponding constraint equations [6]. Finally, the numbers of events that were selected for the further study:

	P_0=3.83 GeV/c	P_0=4.42 GeV/c	P_0=5.20 GeV/c
$np \to pp\pi^+\pi^-\pi^-$	390 events	743 events	5790 events
$np \to pp\pi^+\pi^-\pi^-\pi^0$	66 events	215 events	2666 events
$np \to np\pi^+\pi^+\pi^-\pi^-$	83 events	344 events	4530 events

The cross sections of the considered reactions were presented in [7].

3 Data analysis

This reaction is characterized by:
- plentiful production of the Δ resonance, both from direct production and from Δ^* and N^* decays through the mode $\Delta\pi$,
- large peripherality of the secondary nucleons.

The model of reggeized π meson exchange suggested in ITEP [3] was taken to describe the experimental distributions of the considered reactions. The advantages of this model are:

- small number of free parameters (3 in our case),
- wide range of the described energies (2÷200 GeV),
- calculated values are automatically normalized to the reaction cross section.

The following diagrams were taken into account to calculate the characteristics of the reactions $np \to NN\,3\pi$ and $np \to NN\,4\pi$:

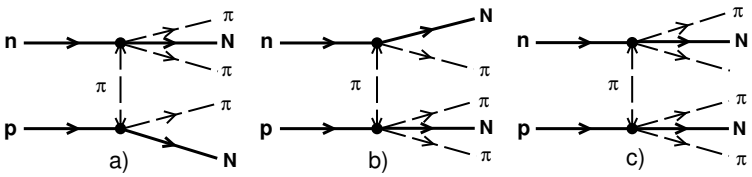

Figure 2. Diagrams of OPER model for the reactions of 3π and 4π meson production in np interactions.

3.1 Reaction $np \to pp\pi^+\pi^-\pi^-$

The results of the calculations using OPER model for the reaction $np \to pp\pi^+\pi^-\pi^-$ are shown in figure 3 for the data at P_0 = 5.2 GeV/c and in figure 4 for the data at P_0 = 4.42 GeV/c and P_0 = 3.83 GeV/c. One can see a good agreement between the experimental data and theoretical calculations.

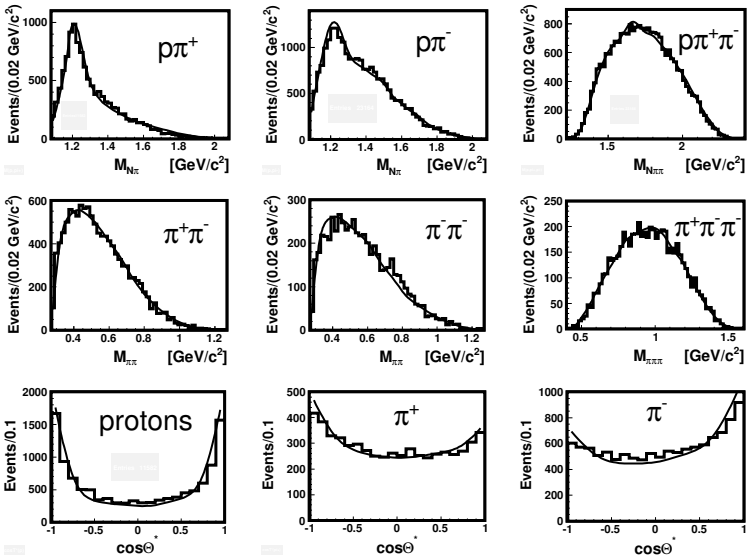

Figure 3. The distributions for the reaction $np \to pp\pi^+\pi^-\pi^-$ at P_0=5.20 GeV/c. Solid line - calculations using OPER model.

3.2 Reaction $np \to pp\pi^+\pi^-\pi^-\pi^0$

The results of the calculations using OPER model for the reaction $np \to pp\pi^+\pi^-\pi^-\pi^0$ are shown in figure 5 for the data at P_0 = 5.20 GeV/c.

One can see a good agreement between the experimental data and theoretical calculations except the region of η^0 and ω^0 mesons at the masses of $\pi^+\pi^-\pi^0$ combinations. As far as it concerned the description of η^0 and ω^0 mesons it is necessary to take into account the diagrams of the type that are showed in figure 6.

The diagrams 6a and 6b describe η^0-meson production through the production of N^*_{1535} resonance in πN interaction with the consequent decay $N^*_{1535} \to N\eta^0$. The "hanged" diagrams 6c and 6d describe η^0 meson production due to a-π or σ-η interaction.

The results at P_0=4.42 GeV/c and P_0=3.83 GeV/c are not presented due to a small statistics. But OPER model also described satisfactorily the experimental distribution and the signal of η^0 and ω^0 mesons production was also observed at these energies.

3.3 Reaction $np \to np\pi^+\pi^+\pi^-\pi^-$

The results of the calculations using OPER model for the reaction $np \to np\pi^+\pi^+\pi^-\pi^-$ are shown in figure 7 for the data at P_0 = 5.2 GeV/c and in figure 8 for the data at P_0 = 4.42 GeV/c and P_0 = 3.83 GeV/c.

One can see a good agreement between the experimental data and theoretical calculations.

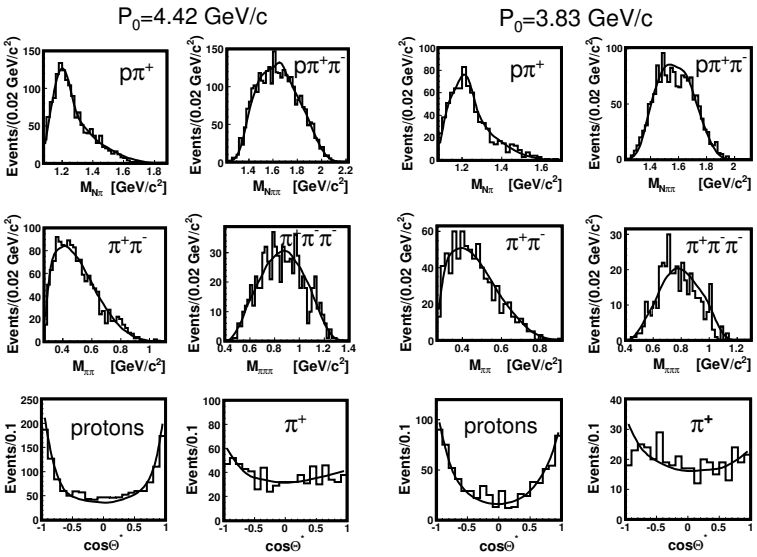

Figure 4. The distributions for the reaction $np \to pp\pi^+\pi^-\pi^-$ at P_0=4.42 GeV/c and P_0=3.83 GeV/c. Solid line - calculations using OPER model.

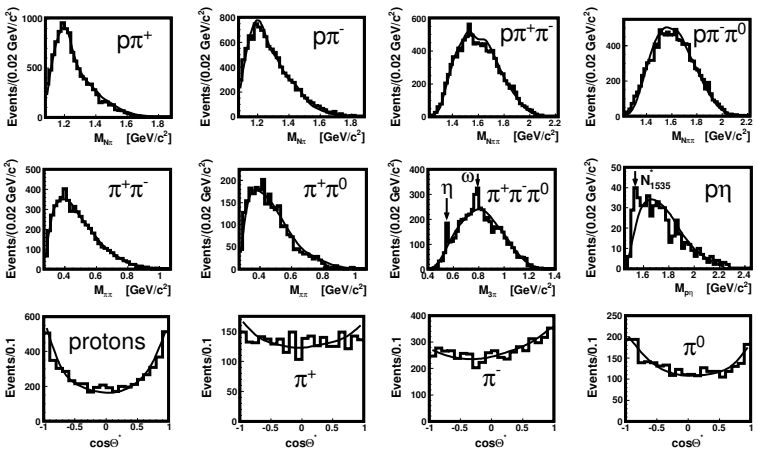

Figure 5. The distributions for the reaction $np \to pp\pi^+\pi^-\pi^-\pi^0$ at P_0=5.20 GeV/c. Solid line - calculations using OPER model.

4 Conclusion

Multi π mesons production in np interaction is provided by the excitation and $N\pi$ and $N\pi\pi$ decays of Δ^* and N^* resonances (taken from PWA and GIM).

The large peripherality of the secondary hadrons leads to the idea to use some exchange models (π, P etc. exchange).

It was shown that there are no noticeable signal of ρ meson production in the considered reactions.

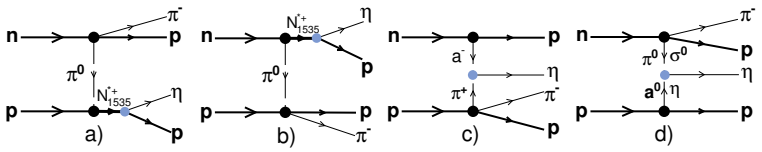

Figure 6. Diagrams of OPER model for the reaction $np \to pp\pi^-\eta^0$.

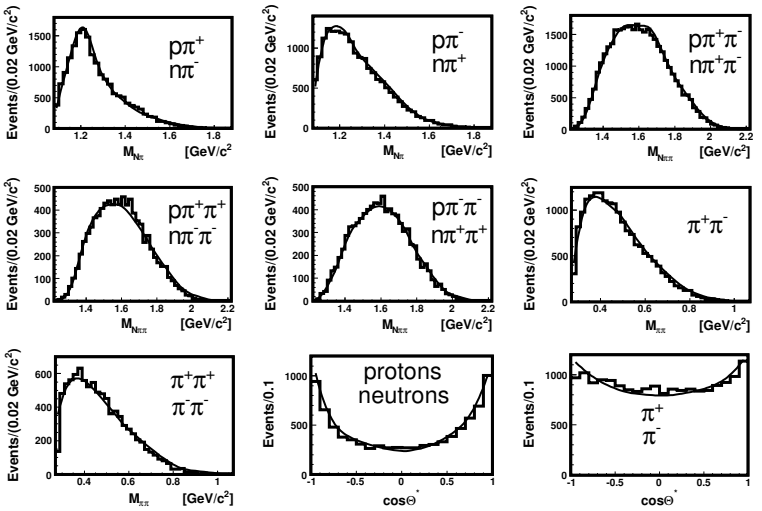

Figure 7. The distributions for the reaction $np \to np\pi^+\pi^+\pi^-\pi^-$ at P_0=5.20 GeV/c. Solid line - calculations using OPER model.

OPER model allows to obtain a good description of the characteristics of 3 and 4 pions production in np interactions.

To get a better description of the reaction $np \to pp\pi^+\pi^-\pi^-\pi^0$ it is necessary take into account η^0 and ω^0 production.

References

[1] L. Alvarez-Ruso, E. Oset, E. Hernandez, NP A **633**, 519 (1998)
[2] Xu Cao, Bing-Song Zou and Hu-Shan Xu, PR C **81**, 065201 (2010)
[3] L. Ponomarev, Part. and Nucl. **7**, 186 (1976) (in Russian)
[4] A.P. Jerusalimov et al., http://arxiv.org/pdf/1203.3330.pdf
[5] A.P. Gasparian et al., Prib.Tekh.Eksp. **2**, 37 (1977) (in Russian)
[6] J.P. Berge, F.T. Solmitz and H.D. Taft, Rev.Sci.Instrum. **32**, 338 (1961)
[7] C. Besliu et al., Sov.J.Nucl.Phys. **43**, 565 (1986)

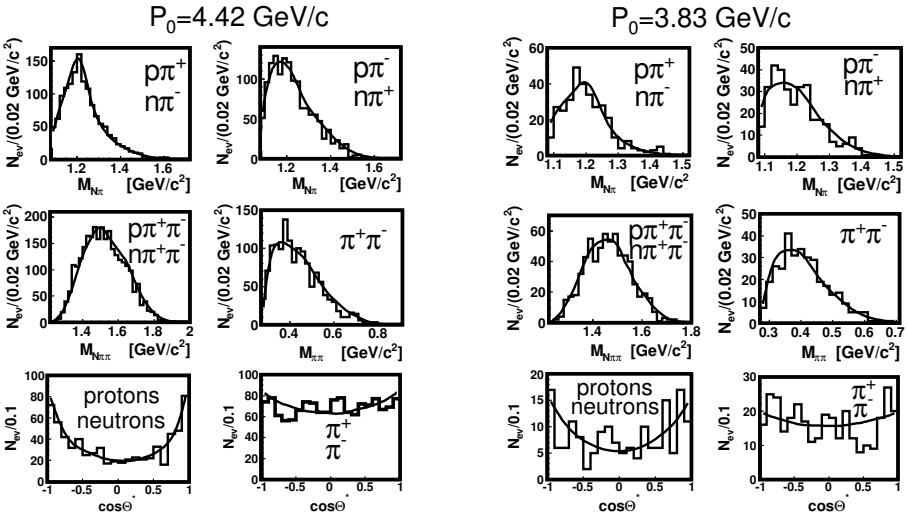

Figure 8. The distributions for the reaction $np \to np\pi^+\pi^+\pi^-\pi^-$ at P_0=4.42 GeV/c and P_0=3.83 GeV/c. Solid line - calculations using OPER model.