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FSI EFFECTS IN MESON PRODUCTION IN *NN* COLLISIONS*

V. Baru[a,b], A.M. Gasparian[a,b], J. Haidenbauer[a]
A.E. Kudryavtsev[b], and J. Speth[a]

[a]Institut für Kernphysik, Forschungszentrum Jülich GmbH
D–52425 Jülich, Germany
[b]Institute of Theoretical and Experimental Physics
117258, B. Cheremushkinskaya 25, Moscow, Russia

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Some features of the NN final state interaction (FSI) and its role in near-threshold meson production in NN collisions are investigated using realistic NN potentials. It is shown that the FSI effects should not be factorized from the production amplitude. The issue of the universality of the NN FSI for the production of mesons with different masses is discussed.

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The total amplitude for the meson-production reaction $pp \to ppx$, including a final state interaction (FSI) between the outgoing nucleons, can be determined from the DWBA expression

$$\mathcal{M} = A^{\rm on}_{\rm prod} + A^{\rm off}_{\rm prod} G_0 T_{NN} \ , \tag{1}$$

where the term on the very r.h.s. implies an integration over the off-shell production amplitude A and the off-shell NN T-matrix. Since meson production in NN collisions requires a large momentum transfer between the initial and final nucleons one expects that the range of the production interaction will be much smaller than the characteristic range of the NN interaction in the final state. Goldberger and Watson argued that in such a case the meson can be considered to be produced practically from a point like region

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so that the production amplitude can be factored out of the integral [1], *i.e.*

$$\mathcal{M} = A^{\rm on}_{\rm prod} + A^{\rm off}_{\rm prod} G_0 T_{NN} \;\approx\; A^{\rm on}_{\rm prod}[1 + G_0 T_{NN}] \;=\; A^{\rm on}_{\rm prod}\psi_k^{(-)^*}(0). \quad (2)$$

Here $\psi_k^{(-)}(\vec{r})$ is the NN scattering wave function [1], where $\psi_k^{(-)}(\vec{0})$ is related to the Jost function $\mathcal{J}$ via $\psi_k^{(-)^*}(0) \;=\; \mathcal{J}^{-1}(-k)$ [1]. Obviously Eq. (2) suggests that FSI effects can be reduced to a mere multiplicative factor $\mid \psi_k^{(-)^*}(0) \mid^2$ (commonly referred to as enhancement factor). In particular, it implies that FSI effects are universal, *i.e.* do not depend on the specific meson produced.

We have studied several aspects of NN FSI effects [2] and we want to present some of the results here. Specifically, we want to discuss the validity of the multiplication prescription Eq. (2) that has been utilized by several authors [3–7] in their studies of meson production. We examine the influence of the NN FSI on the absolute value of the reaction amplitude by employing different models of the NN interaction and a simple but realistic one-boson-exchange (OBE) model for the elementary production amplitude. Furthermore we look at the dependence of the FSI effects on the mass of the produced meson.

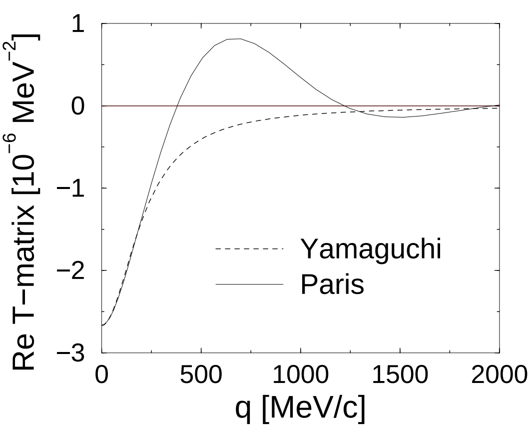

Fig. 1. Real part of the NN $^1S_0$ T-matrix as a function of the off-shell momentum q calculated at the fixed on-shell momentum $k = 10$ MeV$/c$.

For the NN interaction we consider the Paris potential and a simple separable Yamaguchi potential. The latter has been employed in, *e.g.*, Ref. [3] and therefore it is interesting to see how the results based on this model compare with the ones for a realistic interaction model like the Paris potential. Both models yield comparable results for the phase shifts at energies close to the threshold. However, the off-shell behavior of the T-matrix for the Yamaguchi potential is rather different from the one of the Paris NN potential.

This can be seen from Fig. 1 where we compare the off-shell properties of the Paris NN model with the one of the Yamaguchi potential for the ${}^1S_0$ partial wave. The most striking difference is definitely the zero crossing of the T-matrix that occurs for realistic potential models at off-shell momenta $q \approx 350$ MeV/c whereas the one of the Yamaguchi potential never changes sign.

For the calculation of the loop integral on the r.h.s. of Eq. (1) we need to specify a model for the production amplitude. We assume that it has the form

$$A_{\text{prod}} = \frac{g \cdot A_{\mu N \to xN}}{t - m_\mu^2}\,, \tag{3}$$

which corresponds to the exchange of a scalar meson μ of mass m_μ in the t-channel followed by the production of a meson x in a rescattering process. The corresponding diagram is shown in Fig. 2(a). The coupling g at

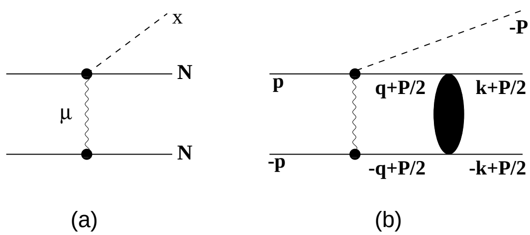

Fig. 2. Diagrammatic representation of the graphs included in our calculation

the $NN\mu$ vertex and the amplitude $A_{\mu N \to xN}$ are assumed to be constants. Furthermore, for simplicity reasons, we use non-relativistic kinematic for the intermediate nucleons. The total reaction amplitude for this production model is then given by the sum of the two diagrams of Fig. 2. For the kinematics at the production threshold we obtain

$$\mathcal{M} = -\frac{g \cdot A_{\mu N \to xN}}{r^2 + \lambda^2} \Psi(\vec{k})\,, \tag{4}$$

where

$$r = \frac{m}{m + \frac{m_x}{2}} \sqrt{m m_x + \frac{m_x^2}{4}}\,, \quad \lambda^2 = \frac{m^2}{(m + \frac{m_x}{2})^2} \frac{m_x^2}{4} + \frac{m}{m + \frac{m_x}{2}} m_\mu^2.$$

$\Psi(\vec{k})$ is given by the expression

$$\Psi(k) = 1 - \frac{m\pi [m m_x + m_\mu^2]}{\sqrt{m m_x + m_x^2/4}} \int_0^\infty \frac{dqq\; T_{NN}(q,k)}{[q^2 - k^2 - i0]}\; \ln\left[\frac{(q+r)^2 + \lambda^2}{(q-r)^2 + \lambda^2}\right]\,. \tag{5}$$

The function $F_{NN} =| \Psi(k) |^2$, shown in Fig. 3 for the two considered NN models and for some typical masses of the emitted meson x, is the equivalent of the FSI enhancement factor that follows from the factorization assumption Eq. (2). We want to emphasize however, that, unlike $\psi_k^{(-)^*}(0)$ in Eq. (2), $\Psi(k)$ includes now also information on the production amplitude. (Note that the Coulomb interaction between the nucleons is included in the presented results, *cf.* Ref. [2].) It can be seen from those figures that the FSI factors F_{NN} resulting for the Yamaguchi potential are strongly at variance with those obtained for a realistic NN interaction. They are much larger and they also make believe that there is only a weak dependence on the mass of the produced meson. These differences are due to the properties of the corresponding off-shell T-matrices (*cf.* Fig. 1) as discussed in detail in Ref. [2].

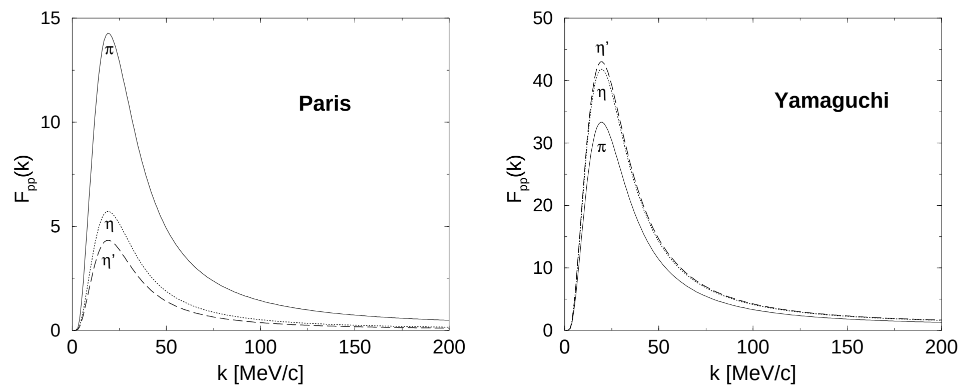

Fig. 3. The FSI factor $F_{pp} =| \Psi(k) |^2$ calculated for different NN potential models and for the production of different mesons as a function of the pp on-shell momentum k.

Thus, it is obvious that the NN FSI can not be factorized from the production amplitude if one wants to obtain reliable quantitative predictons. The absolute value of the FSI factor F_{NN} depends on the momentum transfer, *i.e.* on the mass of the produced meson. It is, in general, not universal! Only for large momentum transfers, *i.e.* for the production of heavy mesons, the FSI factor is getting independent of the mass of the produced meson.

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