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Study of $\bar{p}p$ Baryon Exchange Processes

V. L. Korotkikh[1,2]

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abstract

The cross-section of the process $\bar{p} + p \to X^0 + \eta$ is estimated, where the exchange particle is a virtual $N^+(1535)$ and the X^0 can be the exotic meson.

[1] Moscow State University, 119899 Moscow, Russia ; e-mail: vlk@lav1.npi.msu.su
[2] Physics Department, Brookhaven National Laboratory, Upton, NY 11973-5000

It is suggested in reference [1] to study a process with baryon exchange in order to look for the exotic mesons with unnatural quantum numbers $J^{PC} = 1^{-+}$.

The reaction

$$\bar{p} + p \to X^0 + \eta, \quad X^0 \to \pi^\pm \rho^\mp, \quad \rho^\mp \to \pi^\mp + \pi^0 \tag{1}$$

can be described in Regge pole model [2] by diagram in Fig. 1.

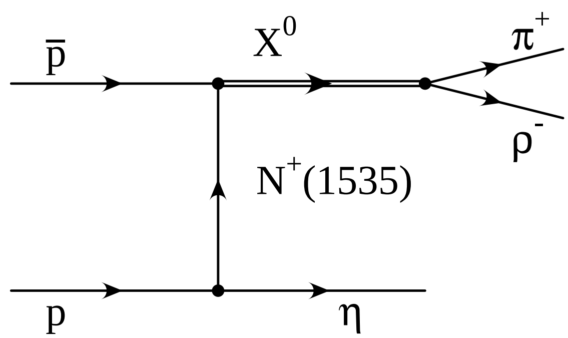

Fig.1. Production of a meson X^0 in a baryon-exchange process from $\bar{p}p$ interactions.

Since the branching ratio for $N^+(1535) \to p + \eta$ is in the 30–55% range, the contribution of $N^+(1535)$ exchange is expected to be substantial.

Because the $\bar{p} + N^+(1535)$ initial state is not an eigenstate of C, J^{PC}-exotic states are now allowed. So, if $\bar{p}$ ($J^P = \frac{1}{2}^-$) and $N^+(1535)$ ($J^P = \frac{1}{2}^-$) are in a relative P-wave and the total intrinsic spin is zero, i.e. $S = 0$, then the state X^0 can be both $J^{PC} = 1^{--}$ and $J^{PC} = 1^{-+}$. The latter of these cannot be a $\bar{q}q$ state, and therefore is an exotic state.

The aim of this note is an estimation of absolute cross-section of reaction (1) in terms of its $u-$ and also $p_{\ lab}-$ dependence.

We use the formulae of Regge model from reference [3], where a detailed study of the backward scattering is presented. The backward meson scattering

$$\pi^- + p \to p + \pi^- \tag{2}$$

is descibed by the diagram in Fig.2. The authors of [3] found the corresponding parameters in order to fit data.

The amplitudes of the annihilation reaction (3), shown in Fig.3

$$\bar{p} + p \to \pi^+ + \pi^- \tag{3}$$

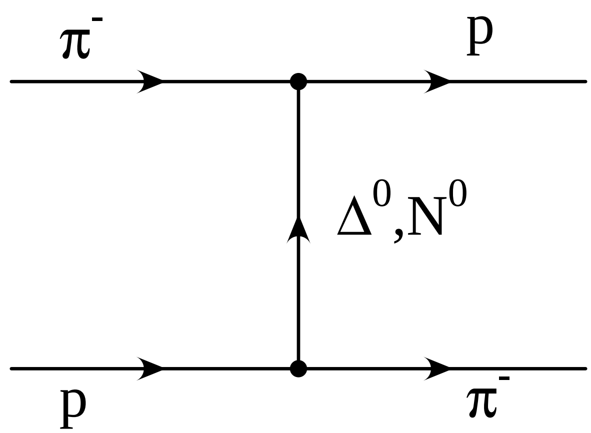

Fig.2. Backward scattering of meson.

are related to the amplitude of reaction (2), and in the limit of large energy, the cross-section is equal to

$$\frac{d\bar{\sigma}}{du}(\bar{p}p \rightarrow \pi^+\pi^-) = \frac{1}{2}\frac{d\sigma}{du}(\pi^- p \rightarrow p\pi^-) \tag{4}$$

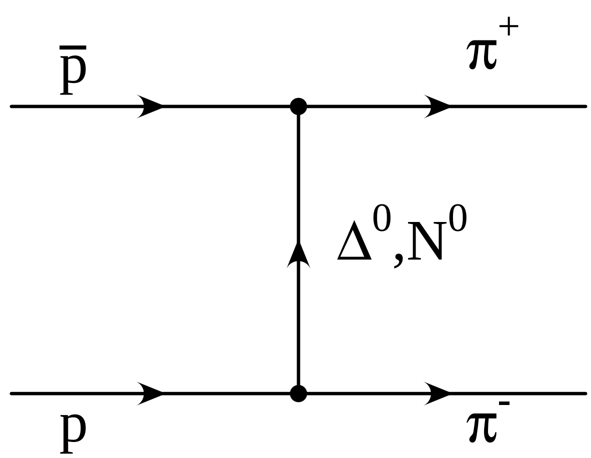

Fig.3. Annihilation reaction $\bar{p} + p \rightarrow \pi^+ + \pi^-$

We repeated Barger and Cline's [3] calculation of reaction (3) and received the same results at 10 GeV with their parameters:

$$\frac{\beta_\Delta}{8\pi} = 0.10\ GeV^{-1},$$
$$s_0 = 2.85\ GeV^2, \tag{5}$$
$$\alpha_\Delta(u) = 0.15 + 0.9\ u.$$

The differential cross-section depends on these parameters as

$$\frac{d\bar{\sigma}}{du} = 389.3\ \mu b\ \frac{\pi}{2\ s}\ \left(\frac{\beta_\Delta}{8\pi}\right)^2\ |R(\alpha, s)|^2,$$
$$R(\alpha, s) = (\alpha + 1/2)\ (\alpha + 3/2)\ \frac{1 + e^{-i\pi(\alpha - 1/2)}}{cos\ \pi\alpha}\ \left(\frac{s}{s_0}\right)^{\alpha - 1/2}, \tag{6}$$

where $\alpha = \alpha(u)$ is the Regge trajectory of given baryon exchange.

The integral cross-section is

$$\sigma(s) = \int \frac{d\sigma}{du} du \tag{7}$$

with $s \approx (2\ m_N\ p_{lab})$.

We assume that a good estimation of cross-section for reaction (1) will be the cross-section of reaction (8), which is shown in Fig.4.

$$\bar{p} + p \to \eta + \eta \tag{8}$$

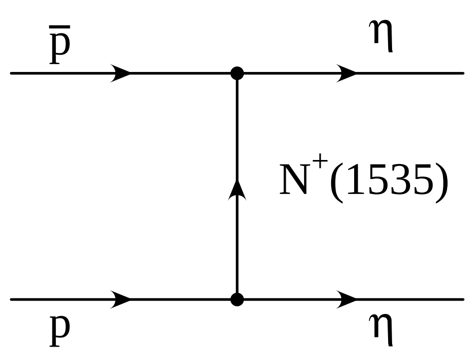

Fig.4. Annihilation reaction $\bar{p} + p \to \eta + \eta$

For this reaction we use the next parameters:

$$
\begin{aligned}
\frac{\beta_N}{8\pi} &= (0.10\ GeV^{-1})\ BR(N(1535) \to p + \eta), \\
s_0 &= 2.85\ GeV^2, \\
\alpha_N(u) &= -1.62 + 0.9\ u, \\
BR(N(1535) \to p + \eta) &= 0.45\ .
\end{aligned}
\tag{9}
$$

Parameters of the Regge trajectory of N(1535) baryon exchange were taken from reference [4] and the branching of $N(1535)$ from reference [5].

The results are presented in Fig.5 and Fig.6.

The integral cross-section is well approximated by

$$
\sigma(p_{lab}) = 75.0 \left(\frac{p_{lab}}{3.0 GeV}\right)^{-5.0}\ \mu b\ . \tag{10}
$$

References

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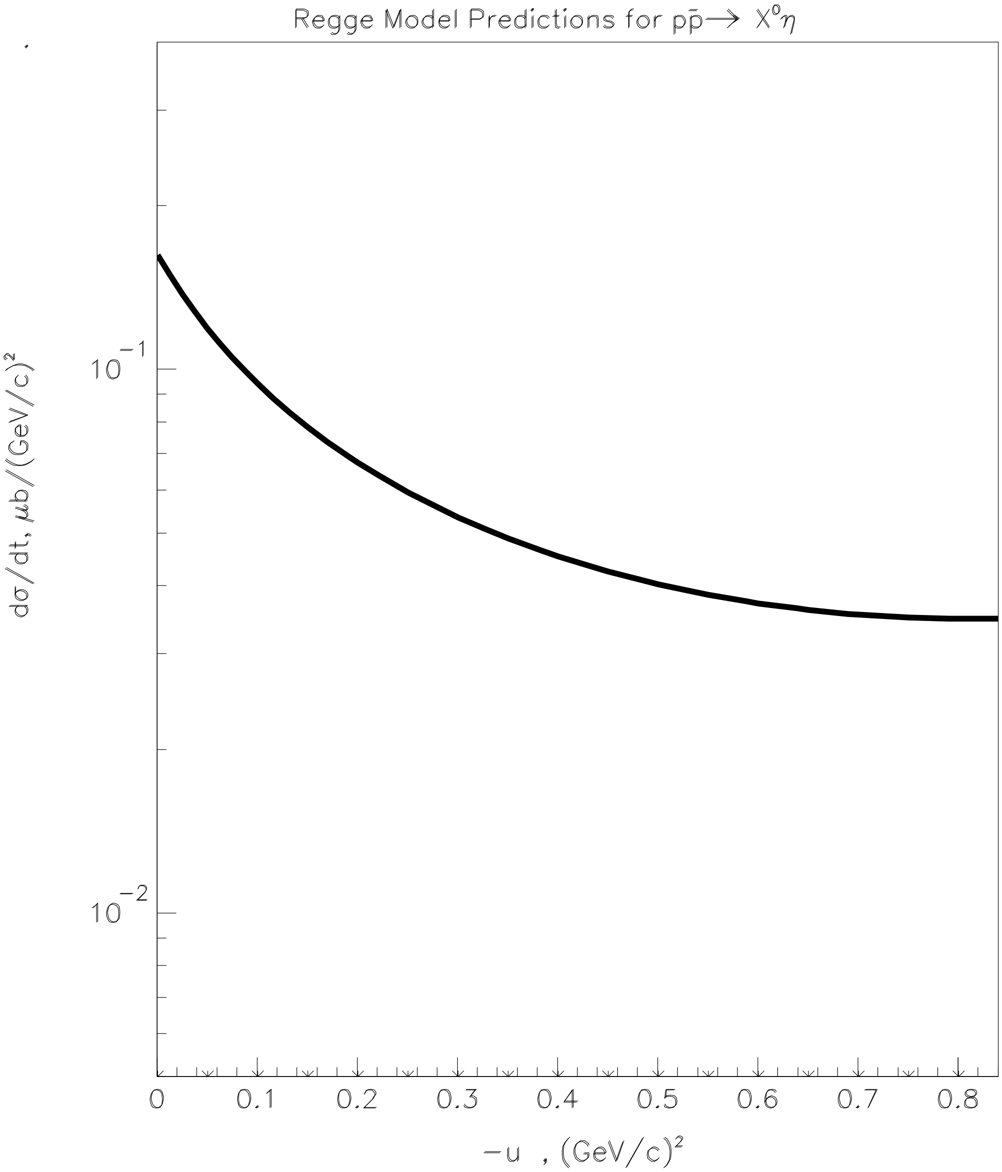

Fig.5. Differential cross-section of reaction $\bar{p} + p \to \eta + \eta$ at 4.0 GeV/c.

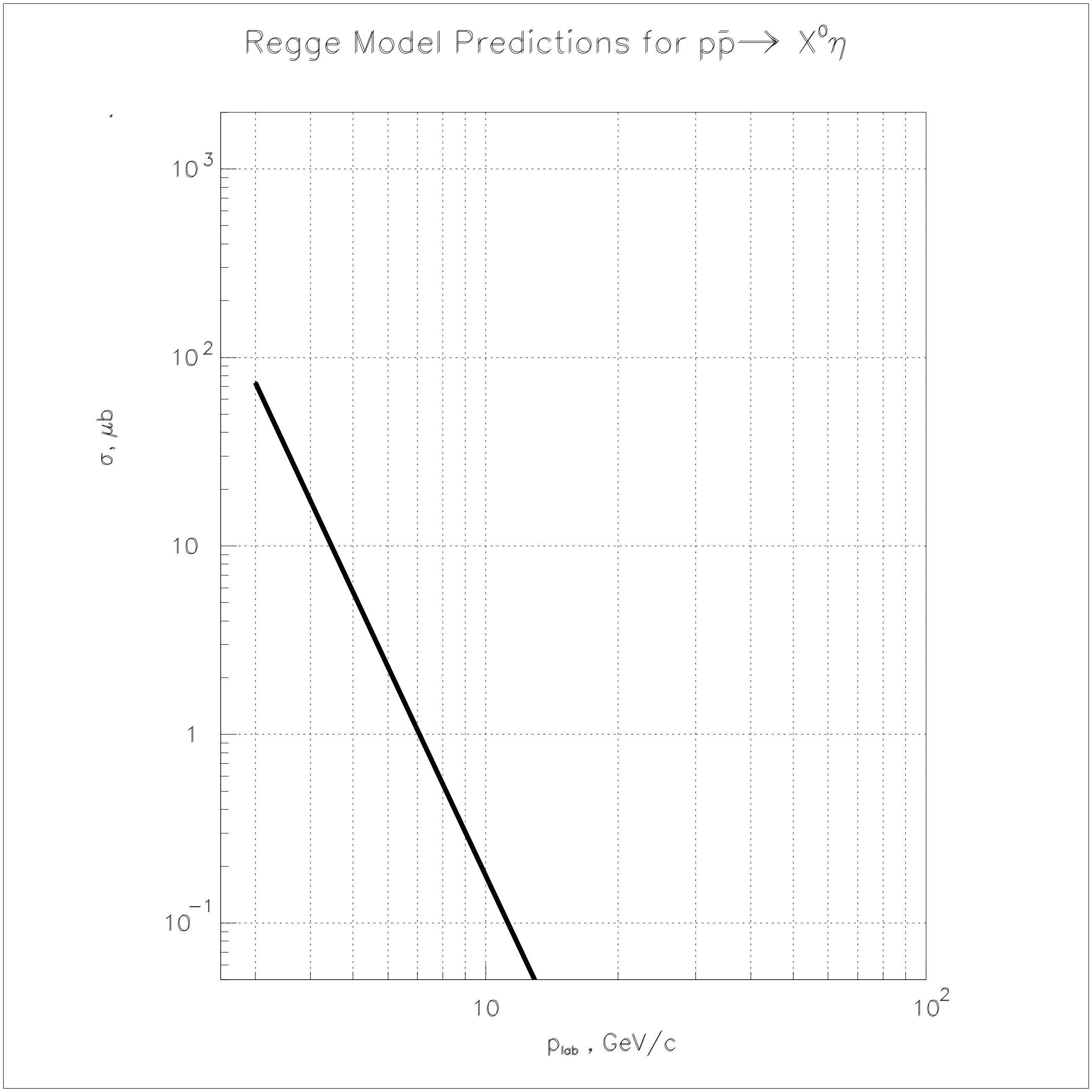

Fig.6. Integral cross-section of reaction $\bar{p} + p \to \eta + \eta$.