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# ROPER RESONANCE EXCITATION IN NN-COLLISIONS WITH SINGLE- AND DOUBLE-PION PRODUCTION

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**Abstract**

Whereas in most investigations the Roper resonance is sensed only very indirectly via complex partial wave analyses, we find indications for its excitation in the $pp \to np\pi^+$ reaction, where some resonance-like structure is observed in the invariant $n\pi^+$ mass spectrum at $M \approx 1360$ MeV with a width of 150 MeV. The values fit very favorably to the most recent phase shift results as well as to the observations at BES. In near-threshold two-pion production $pp \to pp\pi^0\pi^0$, where the Roper excitation and its subsequent decay into $N\pi\pi$ is the only dominant process, we find its decay into the $N\sigma$ channel as the prevailing decay process - in favor of Roper's nature as a monopole excitation

# 1 Introduction

The Roper resonance has been a puzzle ever since its detection in $\pi N$ phase shifts [1]. In most investigations no apparent resonance signatures could be found in the observables. Not only its nature has been a matter of permanent debate, also its resonance parameters show a big scatter in their values [2].

New phase shift evaluations [3, 4] of $\pi N$ and $\gamma N$ data show the pole of the Roper resonance to be nearly 100 MeV below its canonical value of 1440 MeV with a width not much different from that of neighboring baryon states. After the pioneering $\alpha p$ scattering experiment at Saclay [5], where for the first time direct evidence for the Roper resonance has been found in the missing mass spectrum, also new BES data [6] on $J/\Psi \to \overline{N}N^*$ show a clear structure in the $M_{p\pi^-}$ invariant mass spectrum at $M \approx 1358$ MeV and a width of $\Gamma \approx 179$ MeV. Note that with the pole position being roughly 80 MeV below the previously adopted value of the N*(1440), also its decay branchings (taken at the pole position) change dramatically.

# 2 Experiment and Results

In order to shed more light on this issue exclusive measurements of the reactions $pp \to NN\pi$ and $pp \to NN\pi\pi$ have been carried out at several energies from 650 - 1450 MeV at the CELSIUS storage ring using the $4\pi$ WASA detector setup including the pellet target system.

The $pp \to np\pi^+$ measurement at $T_p = 1.3$ GeV shows in the $M_{p\pi^+}$ spectrum the expected strong $\Delta^{++}$ excitation. The $M_{n\pi^+}$ spectrum, however, exhibits only a small structure around the position of the $\Delta^+$ due to the isospin suppression of the latter. Towards higher $M_{n\pi^+}$ masses we find a

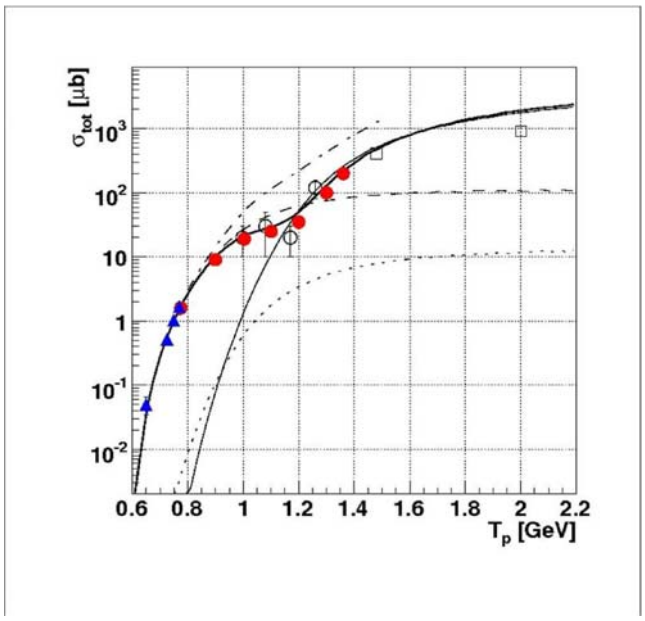


Figure 1: Energy dependence of the $pp \to pp\pi^0\pi^0$ reaction (thick solid line) together with calculations for the Roper excitation with successive decay into $N\sigma$ (dashed) and $\Delta\pi$ (dotted) channels as well as for $\Delta\Delta$ excitation (thin solid). The prediction of Ref. [9] is indicated by the dash-dotted curve. Solid dots denote results of this work, solid triangles are PROMICE/WASA results [10]. Open circles and squares show bubble chamber results of Refs. [11–13].

structure around 1360 MeV with a width of about 150 MeV, which we associate with the Roper excitation. At present the details of this structure still have to be worked out.

In Fig. 1 the energy dependence of the $pp \to pp\pi^0\pi^0$ reaction is shown, which separates into a clear Roper excitation region near threshold and a high-energy region governed by $\Delta\Delta$ excitation.

In the analysis of near-threshold $\pi^+\pi^-$ production the unique sensitivity of this reaction to the two-pion decay of the Roper resonance has been demonstrated [7, 8]. The $\pi^0\pi^0$ channel selects specifically only the isoscalar part of the Roper decay into the $\pi\pi$ channel. Analysis of these data provides a ratio of approximately 4:1 for the decay branching into $N\sigma$ and $\Delta\pi$ channels at a pole mass of 1360 MeV - in favor of a monopole mode interpretation of the Roper excitation. Note that though the branching ratios at the pole position reflect the physics of the decay of a resonance, in the PDG convention the branching ratios are quoted at the Breit-Wigner mass. Usually this

distinction is not very significant, however, the Roper resonance is one of the big exceptions, since its Breit-Wigner mass of 1440 MeV is as far as 80 MeV above the pole position. In the PDG convention our branching ratio reads 1:1 in very good agreement with the values quoted in Ref. [4]. Note that this branching ratio is a factor of 4 smaller than the one quoted in PDG [2].

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