THE $D_{03}(2380)$ DIBARYON RESONANCE EXCITATION IN *pd* COLLISION IN THE GEV REGION

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The 24th European Conference on Few-Body Problems in Physics,
2-6 September 2019

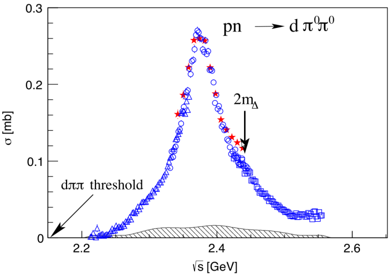
CONTENT

MOTIVATION

Search for dibaryon resonances in two-nucleon systems has a long history *(H. Clement, Prog. Part. Nucl. Phys. 93, 195 (2017))*. At present as one of the most realistic candidate to dibaryon is considered the resonance $D_{IJ} = D_{03}$ observed by WASA@COSY in the total cross section of the reaction of two-pion production (*P. Adlarson et al., Phys. Rev. Lett. 106, 242302 (2011)*)

$$M_{D_{03}} = 2.38\ GeV\ \Gamma_{D_{03}} = 70\ MeV\ I = 0\ J = 3\ J^P = 0^+$$

H. Clement / Progress in Particle and Nuclear Physics 93 (2017) 195–242

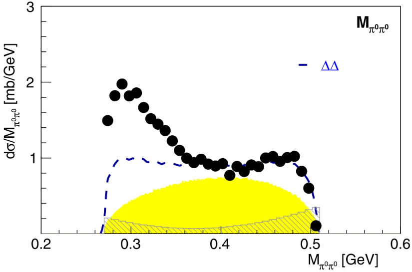


(i) 6q-models , – Y.-B. Dong, et al. (2016) (hidden colour);
(ii) hadron picture, $\pi N\Delta$ system – A.Gal, H.Garcilazo, PRL 111 (2013) 172301;
$\Delta\Delta$ **system** – J. Niskanen, PRC 95 (2017) 054002 A. Gal PLB 769 (2017) 436

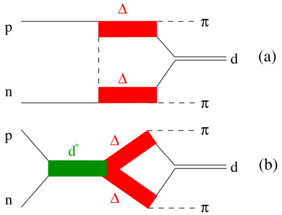
04.09.2019
d^*(2380) hexaquark: from Photoproduction to Neutron Stars - **Dr Mikhail Bashkanov** (University of York)
Dibaryon resonances and NN interaction - **Dr Olga Rubtsova** (Skobeltsyn Institute of Nuclear Physics, Moscow State University)

ABC EFFECT

M. Bashkanov et al. / Nuclear Physics A 958 (2017) 129–146

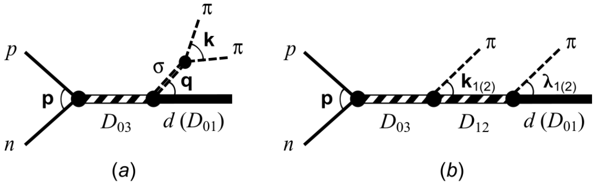


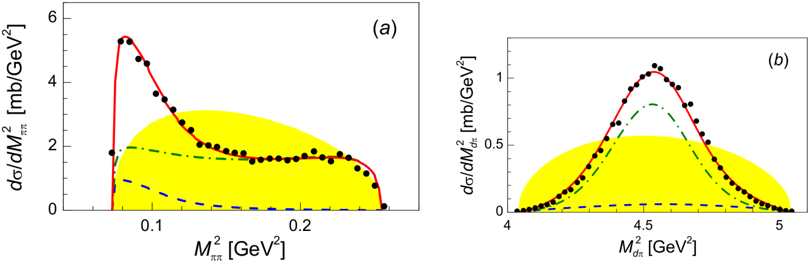
M. Bashkanov et al. / Nuclear Physics A 958 (2017) 129–146



The enhancement took place near the threshold of the spectrum, $M_{\pi\pi} \sim 300$ MeV/c^2, with a surprisingly small width of about 40 MeV/c^2. This phenomenon got the name of the Abashian-Booth-Crowe (ABC) effect (1961).

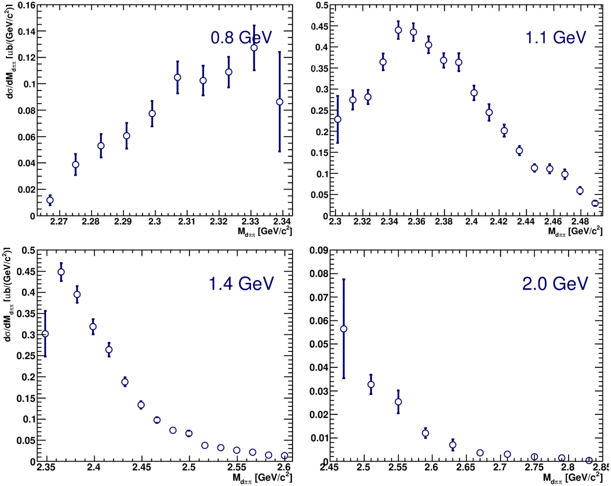
PLATONOVA AND KUKULINS MODEL





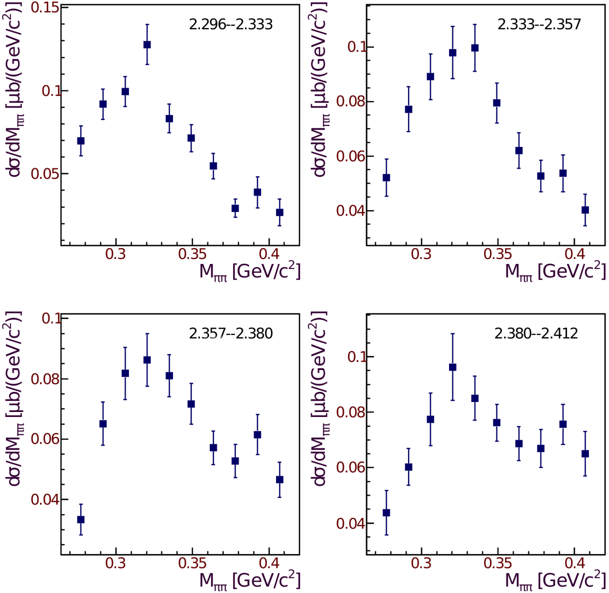
The contribution of the σ-production mechanism is shown by dashed lines while the contribution of the mechanism going through the intermediate dibaryon D_{12} is shown by dash-dotted lines. The solid lines correspond to the summed cross sections.

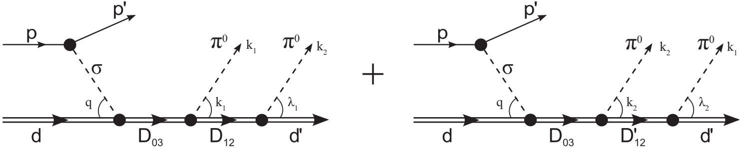
$pd \to pd\pi\pi$ REACTION. ANKE@COSY DATA



The experiment was performed at the proton beam energies $T_p = 0.8, 1.1, 1.4$, and 1.97 GeV with the spectrometer ANKE installed at the storage ring of the synchrotron COSY. V.Komarov et al.(for ANKE collab.) EPJ. A (2018) 54: 206

$pd \to pd\pi\pi$ REACTION. ANKE@COSY DATA





The two-step decay mechanism of the reaction $pd \to pd\pi\pi$:
$p + d \to p + D_{03} \to p + D_{12} + \pi_1 \to pd + \pi_1 + \pi_2$

$$d\sigma = \frac{(2\pi)^4}{4I}\int \overline{|M_{fi}|^2}\,\delta^{(4)}(P_i - P_f)\frac{d^3p_1}{(2\pi)^3 2E_1}\frac{d^3p_2}{(2\pi)^3 2E_2}\frac{d^3p_3}{(2\pi)^3 2E_3}\frac{d^3p_4}{(2\pi)^3 2E_4} \qquad (1)$$

$$M^{\lambda'_p\lambda'_d}_{\lambda_p\lambda_d}(pd \to pd\pi\pi) = M^{\lambda'_p}_{\lambda_p}(p \to p'\sigma)\frac{1}{{p_\sigma}^2 - {m_\sigma}^2 + i m_\sigma \Gamma_\sigma}M^{\lambda'_d}_{\lambda_d}(\sigma d \to d\pi\pi) \qquad (2)$$

$$\begin{aligned} M^{\lambda'_d}_{\lambda_d}(\sigma d \to d\pi\pi) = &\sum_{\lambda_2,\lambda_3,\mu,m_1,m_2} \frac{F_{D_{03}\to d\sigma}(q)F_{D_{03}\to D_{12}\pi_1(k_1)}}{P^2_{D_{03}} - M^2_{D_{03}} + iM_{D_{03}}\Gamma_{D_{03}}}\frac{F_{D_{12}\to d\pi_2(\lambda_1)}}{P^2_{D_{12}} - M^2_{D_{12}} + iM_{D_{12}}\Gamma_{D_{12}}} \\ &\times (1\lambda_d L\mu|3\lambda_3)\mathcal{Y}_{L\mu}(\hat{\mathbf{q}})(2\lambda_2 l_1 m_1|3\lambda_3)\mathcal{Y}_{l_1 m_1}(\hat{\mathbf{k}}_1)(1\lambda'_d l_2 m_2|2\lambda_2)\mathcal{Y}_{l_2 m_2}(\hat{\lambda}_1) + \\ &\frac{F_{D_{03}\to d\sigma(q)}F_{D_{03}\to D_{12}\pi_2(k_2)}}{P^2_{D_{03}} - M^2_{D_{03}} + iM_{D_{03}}\Gamma_{D_{03}}}\frac{F_{D_{12}\to d\pi_1}(\lambda_2)}{P^2_{D_{12}} - M^2_{D_{12}} + iM_{D_{12}}\Gamma_{D_{12}}} \\ &\times (1\lambda_d L\mu|3\lambda_3)\mathcal{Y}_{L\mu}(\hat{\mathbf{q}})(2\lambda_2 l_1 m_1|3\lambda_3)\mathcal{Y}_{l_1 m_1}(\hat{\mathbf{k}}_2)(1\lambda'_d l_2 m_2|2\lambda_2)\mathcal{Y}_{l_2 m_2}(\hat{\lambda}_2) \end{aligned} \qquad (3)$$

The vertex factors F in eq. (3) are defined as in Platonova, M.N., Kukulin, V.I.: Phys. Rev. C 87, 025202 (2013).

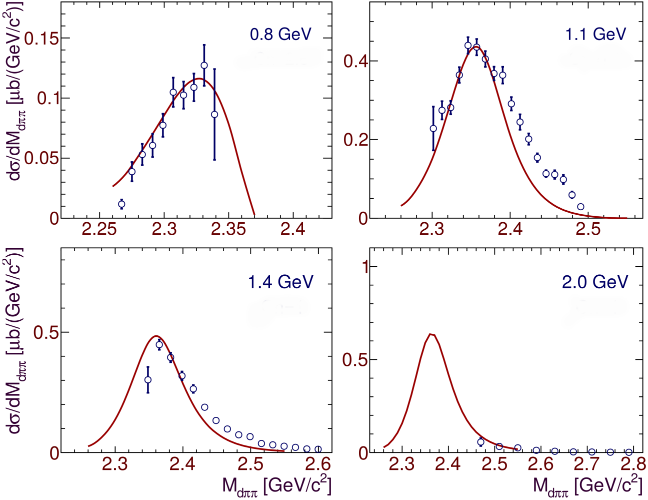
$$\begin{aligned} F_{R\to ab}(q) &= M_{ab}(q)\sqrt{\frac{8\pi\Gamma^{(l)}_{R\to ab}(q_{ab})}{q_{ab}^{2l+1}}} \\ \Gamma^{(l)}_{R\to ab}(q_{ab}) &= \Gamma^{(l)}_{R\to ab}\left(\frac{q_{ab}}{q_0}\right)^{2l+1}\left(\frac{q_0^2+\lambda_{ab}^2}{q_{ab}^2+\lambda_{ab}}\right)^{l+1} \end{aligned} \tag{4}$$

$$\begin{aligned} M_{D_{03}} = 2.38\ GeV\ \ \Gamma_{D_{03}} = 70\ MeV \qquad M_{D_{12}} = 2.15\ GeV\ \ \Gamma_{D_{12}} = 110\ MeV \\ M_\sigma = 0.55\ GeV\ \ \Gamma_\sigma = 0.5\ GeV\ \ f_\sigma = 2.2\quad \Gamma^{(L)}_{D_{03}\to d\sigma} = 8.5\ MeV \\ \Gamma^{(l_1)}_{D_{03}\to D_{12}\pi} = 6.5\ MeV \qquad \Gamma^{(l_2)}_{D_{12}\to d\pi} = 10\ MeV \\ k_{10} = 0.177\ GeV\ \ \lambda_{D_{12}\pi} = 0.12\ GeV \\ \lambda_{10} = 0.224\ GeV\ \ \lambda_{d\pi} = 0.25\ GeV \\ q_0 = 0.362\ GeV\ \ \lambda_{d\sigma} = 0.18\ GeV \end{aligned} \tag{5}$$

(Platonova-Kukulin, NPA 946, 117(2016))

$pd \to pd\pi\pi$ REACTION. ANKE@COSY DATA AND TWO-RESONANCE MODEL

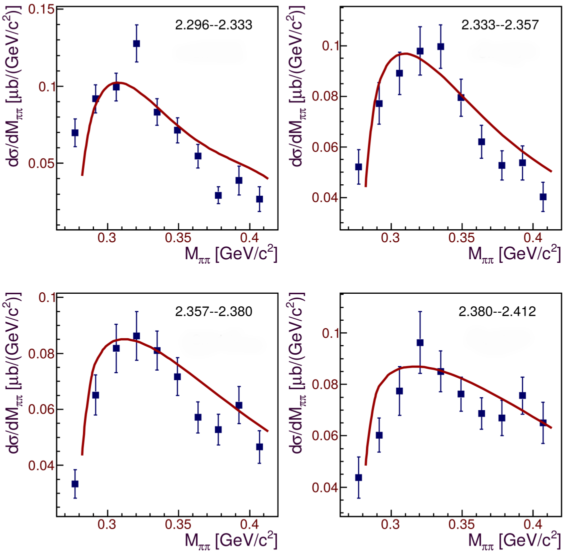
All curves normalized to the experiment!!!



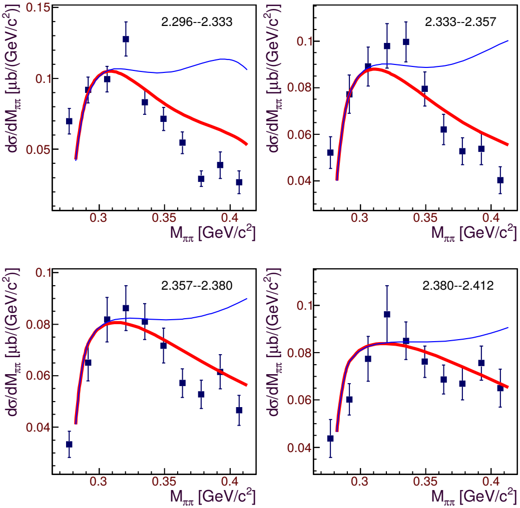
Yu.Uzikov, N. Tursunbayev, EPJ Web of Conf., 204, 08010 (2019)

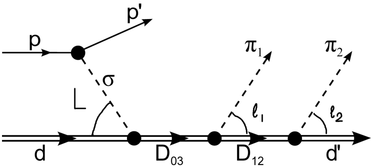
$pd \to pd\pi\pi$ REACTION. $M_{\pi\pi}$ SPECTRA AT $T_p = 1.1 GeV$.

All curves normalized to the experiment!!!



squared dashes-V.Komarov et al.(for ANKE collab.) EPJ. A (2018) 54: 206
full lines – two-resonance model.



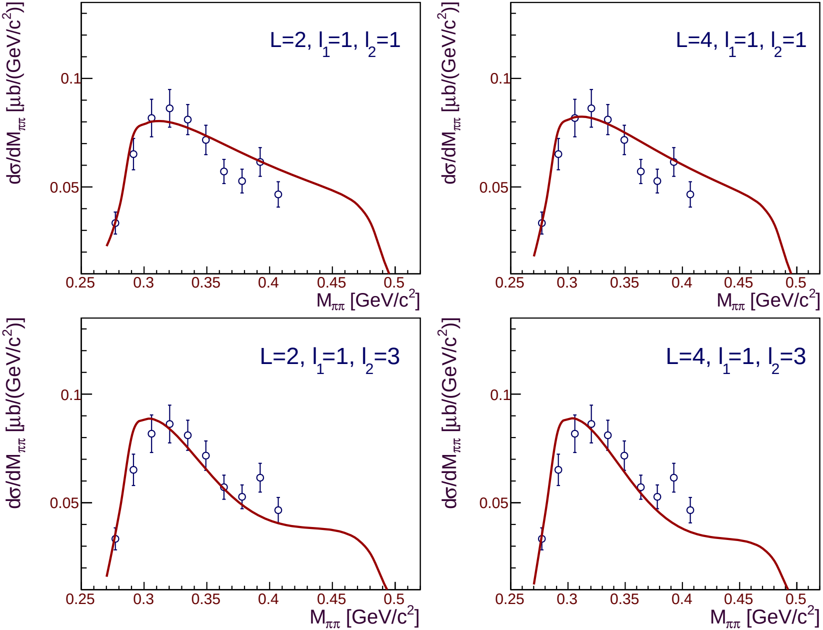


$L = 2,4$ $l_1 = 1,3,5$ $l_2 = 1,3$

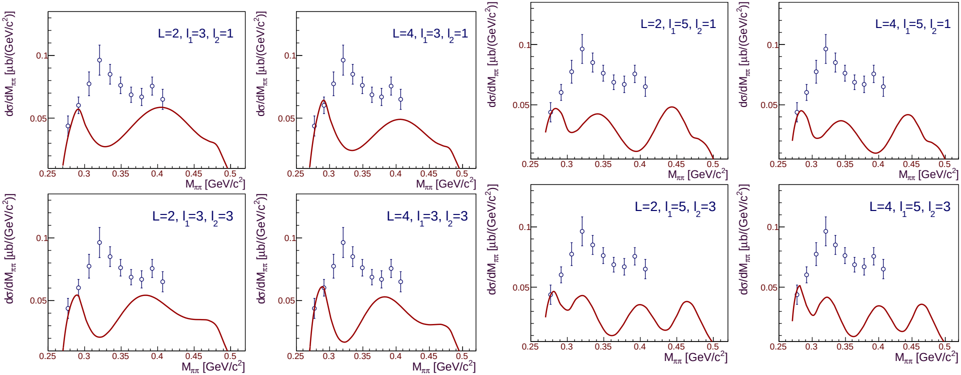
12 combination of orbital momentum

Yu.Uzikov, N. Tursunbayev, Springer Proceedings in Physics, (2019)

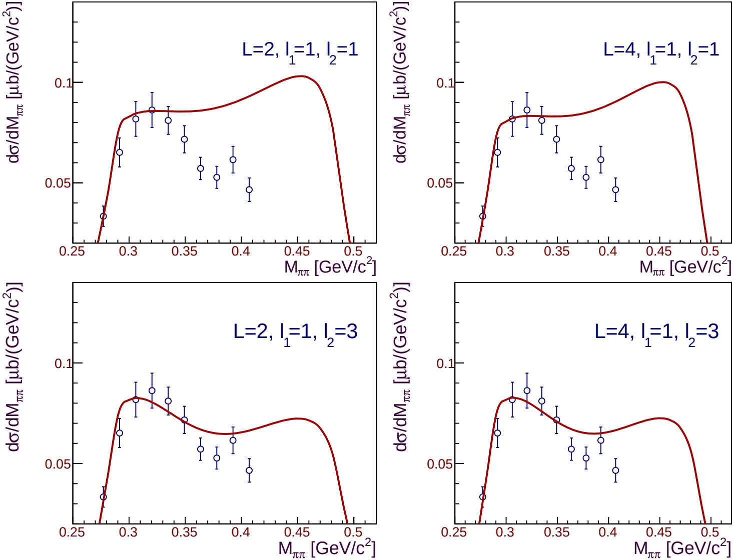
$0^\circ < \theta_d^{cms} < 11^\circ \quad M_{D03} = 2.357 - 2.38\ GeV \quad T_p = 1.1\ GeV$



$$0^\circ < \theta_d^{cms} < 11^\circ \quad M_{D03} = 2.357 - 2.38\ GeV \quad T_p = 1.1\ GeV$$



$0 < \theta_d^{cms} < \pi \;\; M_{D03} = 2.357 - 2.38\ GeV \;\; T_p = 1.1\ GeV$



NUMERICAL RESULTS

$\Gamma^{exp}_{D_{03}\to d\pi\pi} = 10\ MeV$ (M. Baskanov, H. Clement, T. Skorodko, Eur. Phys. J. A 51, 87 (2015)). If we assume that this width is completely determined by the decay $D_{03} \to D_{12}\pi \to d\pi\pi$, which is the basis of the model in question, then in order to get agreement with data in absolute value we should put $\Gamma_{D_{03}\to d\sigma} = 8.5\ MeV$ and $\Gamma_{D_{03}\to \pi^0 NN} = 15\ MeV$.

$at\ \ l_1 = 1, l_2 = 1\ \ \Gamma^{theor}_{D_{03}\to d\pi\pi} = 0.468\ MeV$

$at\ \ l_1 = 1, l_2 = 3\ \Gamma^{theor}_{D_{03}\to d\pi\pi} = 0.146\ MeV$

$at\ \ l_1 = 3, l_2 = 1\ \ \Gamma^{theor}_{D_{03}\to d\pi\pi} = 0.131\ MeV$

$at\ \ l_1 = 3, l_2 = 3\ \ \Gamma^{theor}_{D_{03}\to d\pi\pi} = 0.043\ MeV$

$at\ \ l_1 = 5, l_2 = 1\ \ \Gamma^{theor}_{D_{03}\to d\pi\pi} = 0.32\ MeV$

$at\ \ l_1 = 5, l_2 = 3\ \ \Gamma^{theor}_{D_{03}\to d\pi\pi} = 0.26\ MeV$.

In order to get this results, we use next parameters: $\Gamma_{D_{03}\to D_{12}\pi} = 6.5\ MeV$ and $\Gamma_{D_{12}\to d\pi} = 10\ MeV$ (M.N. Platonova, V.I. Kukulin. NPA 946 (2016))

Also using two resonance model we calculated partial width of decay $\Gamma_{D_{03}\to \pi^0 NN}$ at three combinations of orbital momentum of relative motion D_{12} and π^0

$at\ \ l_1 = 1\ \Gamma^{theor}_{D_{03}\to \pi^0 NN} = 0.433\ MeV$

$at\ \ l_1 = 3\ \ \Gamma^{theor}_{D_{03}\to \pi^0 NN} = 0.5\ MeV$

$at\ \ l_1 = 5\ \ \Gamma^{theor}_{D_{03}\to \pi^0 NN} = 0.625\ MeV$

Upper limit to $\Gamma^{exp}_{D_{03}\to \pi^0 NN} = 6.3\ MeV$ (WASA@COSY Collaborations, PLB774 (2017), 599-607))

SUMMARY

- The model calculations using the mechanism of the coherent pion pair production in the $pd \to pd\pi\pi$ reaction with the t-channel σ-meson exchange and two dibaryon resonances D_{03} and D_{12} qualitatively reproduce the experimentally obtained mass distribution dependence of the differential cross section of the final $d\pi\pi$ system and also $\pi\pi$ system.
- Since the orbital momenta L, l_1, l_2 in vertices are not known, we considered all possible combinations of these momenta separately. On this way we found that for lowest momenta the observed in the reaction $pd \to pd\pi\pi$ enhancement at low M_{pipi} is not related to the true ABC effect, but rather to specific kinematic conditions of ANKE experiment (almost collinear kinematics) and this enhancement disappears for the full interval of the deuteron scattering angles.
- For higher orbital momenta ($L = 2, l_1 = 1, l_2 = 3, L = 4, l_1 = 1, l_2 = 3$) the enhancement effect in $M_{\pi\pi}$ distribution takes the place even for full interval of the deuteron scatterig angles $\theta = 0 - \pi$.
- The model allows one to reproduce the shape of the distributions $M_{d\pi\pi}$ and for certain orbital momentum - $M_{\pi\pi}$. However, the question of the absolute value of the calculated cross section remains open. Other mechanisms need to be researched.

Thank you for your attention!