# REACTION OF TWO PION PRODUCTION $pd \to pd\pi\pi$ IN RESONANCE REGION

N.T. Tursunbayev[1,2]
Adviser: Yu.N. Uzikov[1,2]

[1] Joint Institute for Nuclear Researches, Dubna, Russia

[2] Dubna State University, Dubna, Russia

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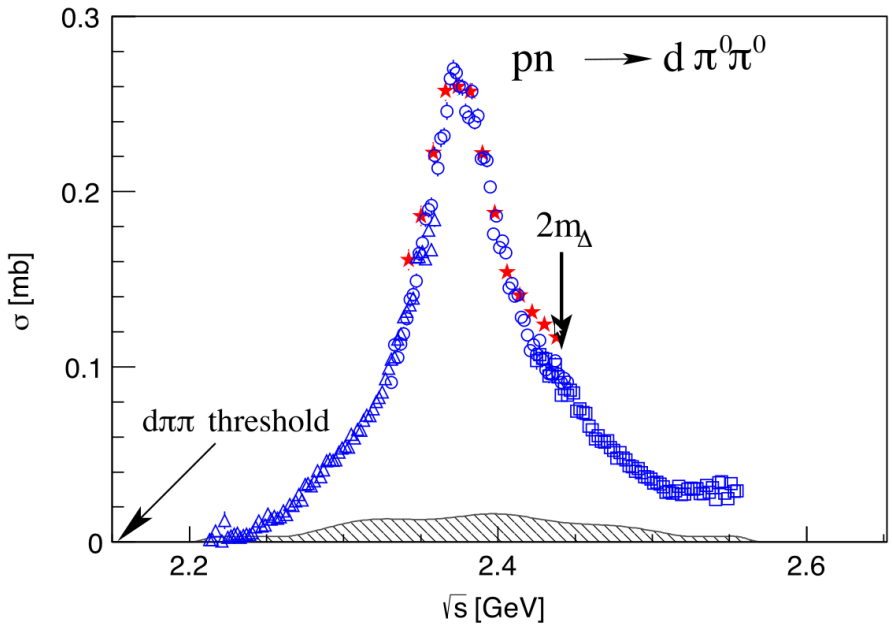
# Motivation

Search for dibaryon resonances in two-nucleon systems has a long history (1). At present as one of the most realistic candidate to dibaryon is considered the resonance $D_{IJ} = D_{03}$ observed by WASA@COSY (2) in the total cross section of the reaction of two-pion production

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

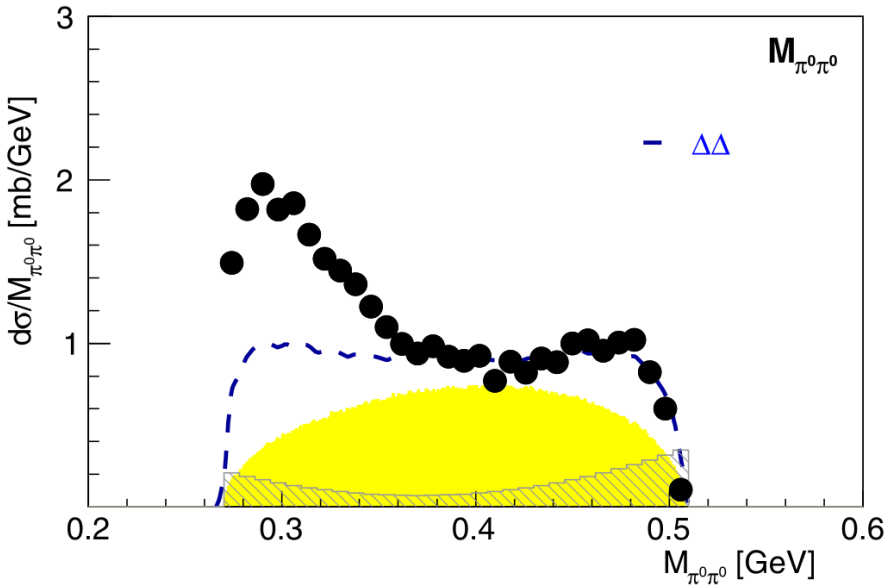
*H. Clement / Progress in Particle and Nuclear Physics 93 (2017) 195–242*



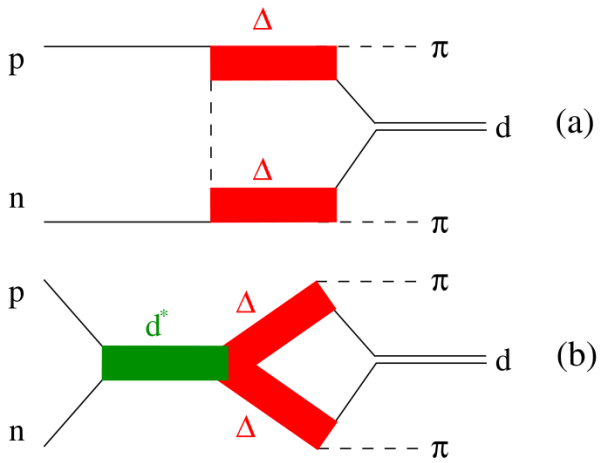

(i) 6q-models, – Y.-B. Dong, et al. (2016) (hidden colour);
(ii) hadron picture, $\pi N\Delta$ system – A.Gal, H.Garcilazo, PRL 111 (2013) 172301;
$\Delta\Delta$ system – J. Niskanen, PRC 95 (2017) 054002 A. Gal PLB 769 (2017) 436

1. H. Clement, Prog. Part. Nucl. Phys. 93, 195 (2017).
2. P. Adlarson *et al.*, (WASA@COSY Collab.), Phys. Rev. Lett. 106, 242302 (2011).

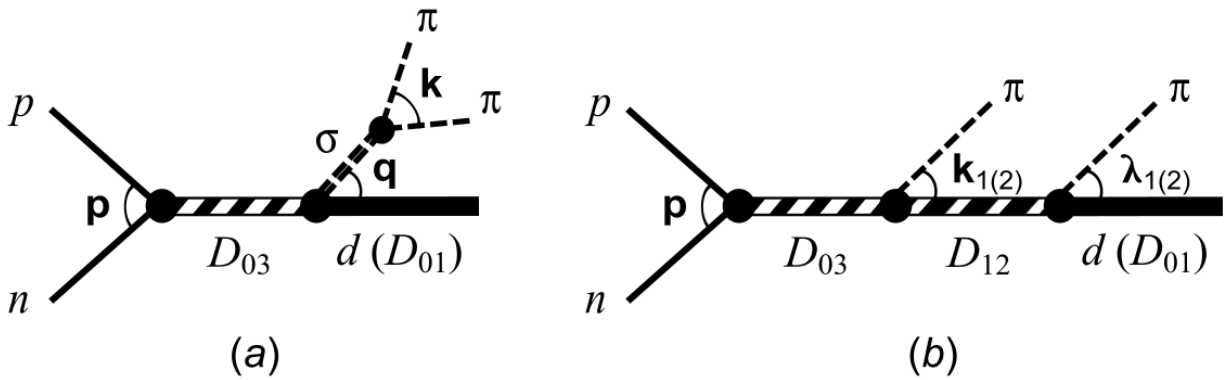
*M. Bashkanov et al. / Nuclear Physics A 958 (2017) 129–146*

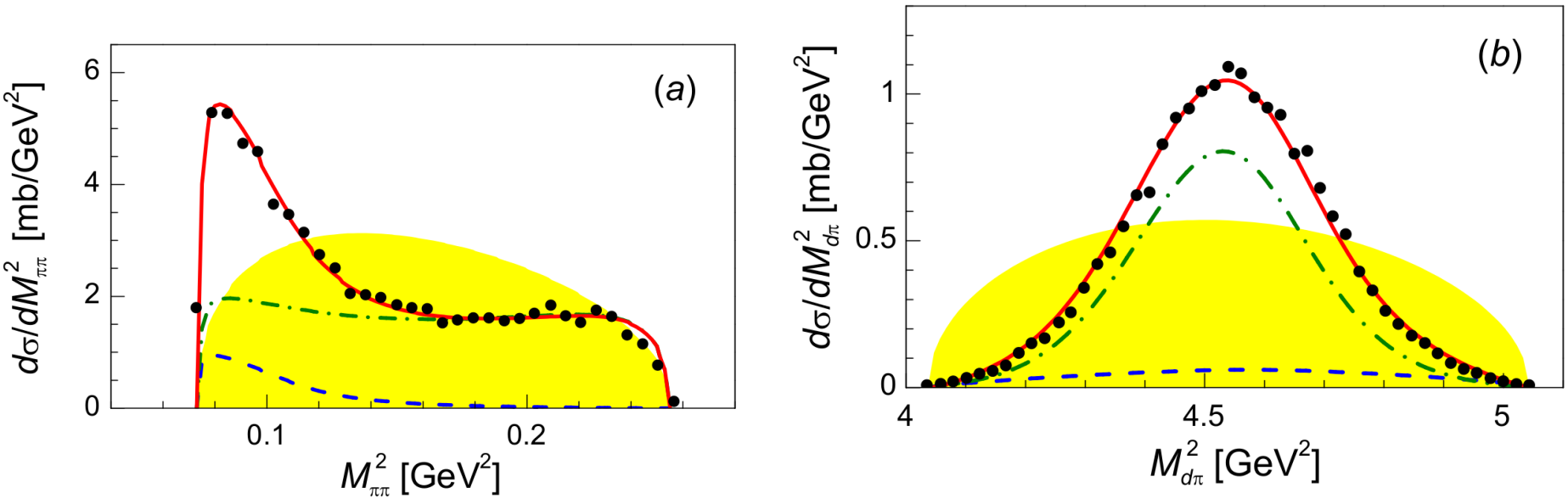



*M. Bashkanov et al. / Nuclear Physics A 958 (2017) 129–146*



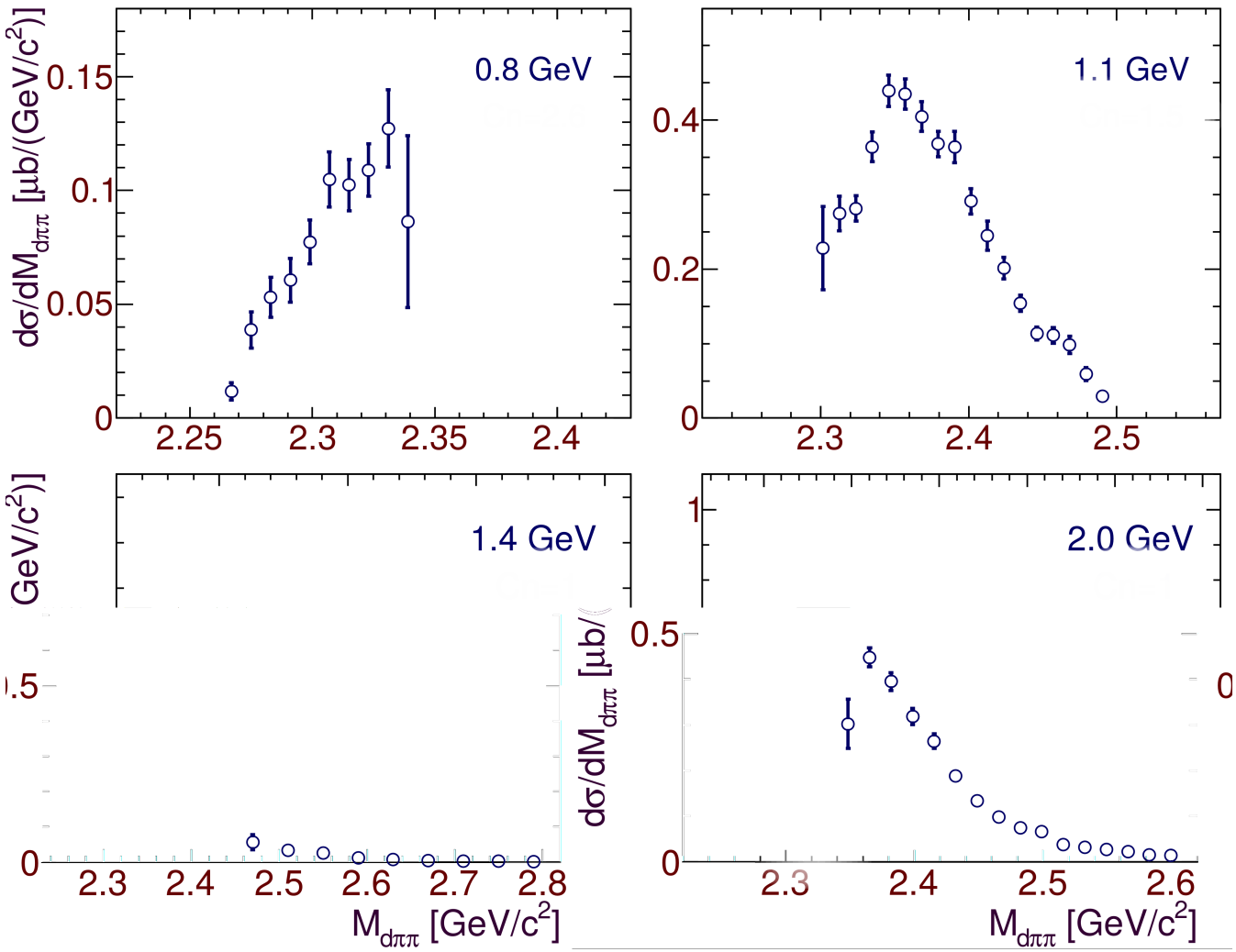

The enhancement took place near the threshold of the spectrum, $M_{\pi\pi} \sim 300$ MeV/$c^2$, with a surprisingly small width of about 40 MeV/$c^2$. This phenomenon got the name of the Abashian-Booth-Crowe (ABC) effect (1961).



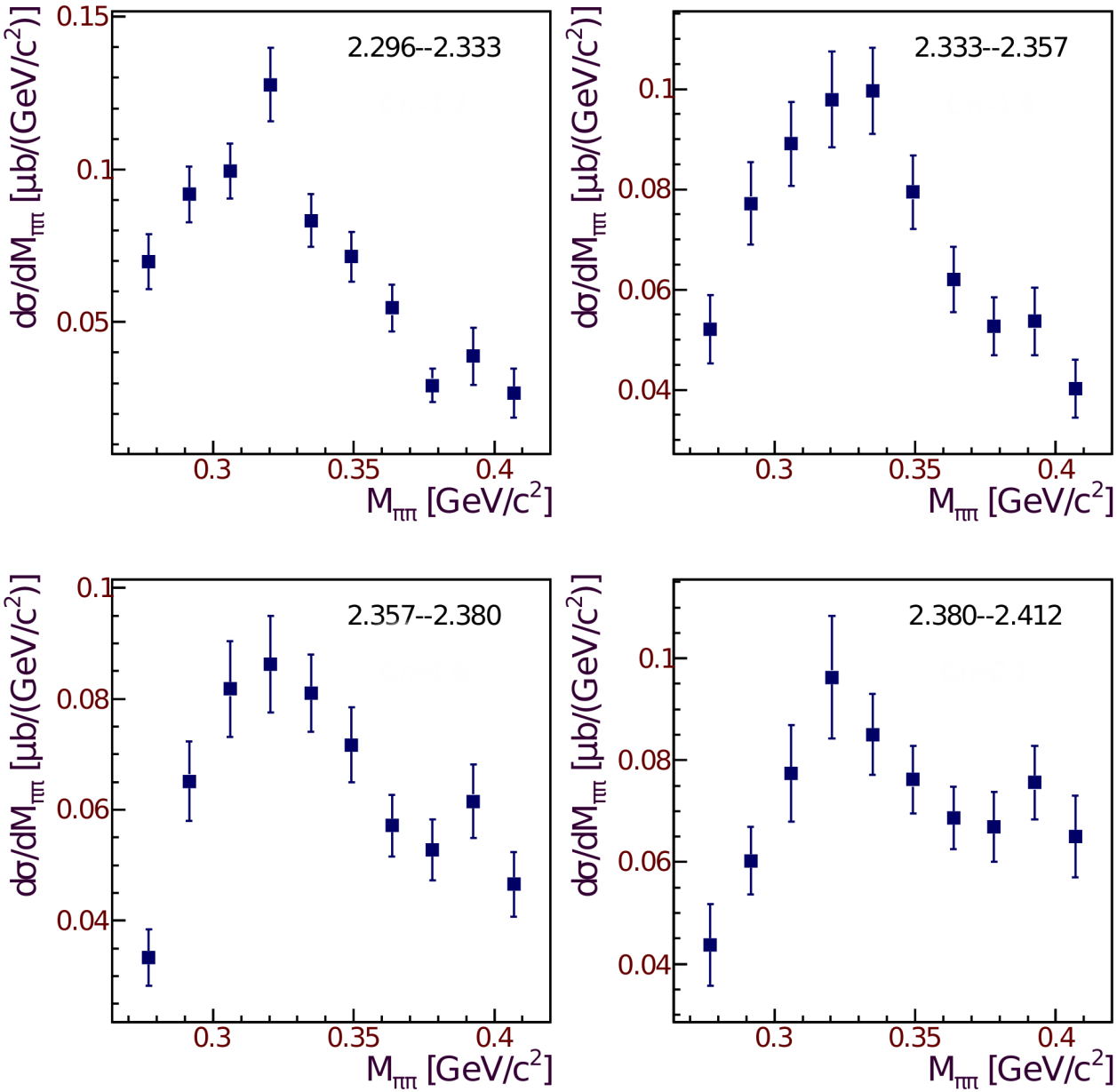



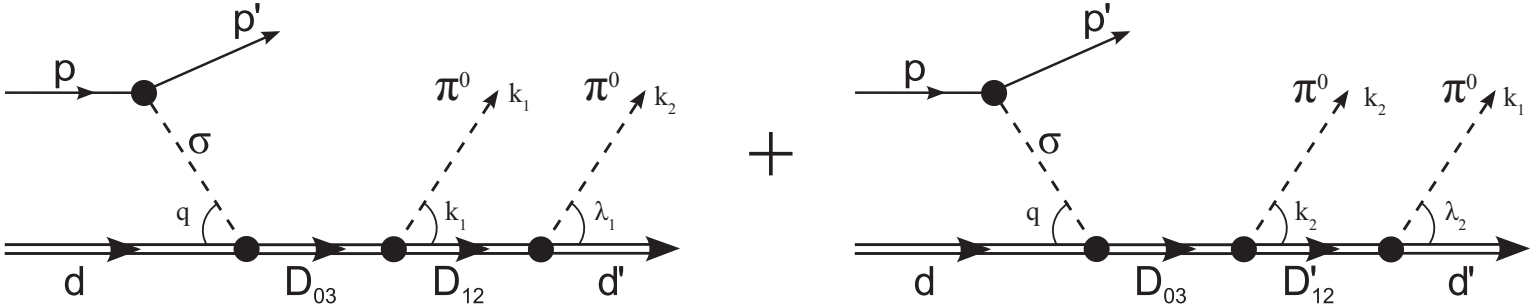

The contribution of the $\sigma$-production mechanism is shown by dashed lines while the contribution of the mechanism going through the intermediate dibaryon $D_{12}$ is shown by dash-dotted lines. The solid lines correspond to the summed cross sections.

# $pd \to pd\pi\pi$ 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.


2.296--2.333
2.333--2.357
2.357--2.380
2.380--2.412
dσ/dM$_{ππ}$ [μb/(GeV/c$^2$)]
M$_{ππ}$ [GeV/c$^2$]




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

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

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

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

The vertex factors $F$ in eq. (3) are defined as in (3)

$$F_{D_{03}\to d\sigma}(q) = M_{D_{03}}(q)\sqrt{\frac{8\pi\Gamma^{(l=2)}_{D_{03}\to d\sigma}(q)}{q^5}}$$

$$\Gamma^{(l=2)}_{D_{03}\to d\sigma}(q) = \Gamma^{(l=2)}_{D_{03}\to d\sigma}\left(\frac{q}{q_0}\right)^5\left(\frac{q_0^2+\lambda_{d\sigma}^2}{q^2+\lambda_{d\sigma}}\right)^3$$

$$F_{D_{03}\to D_{12}\pi_1}(k_1) = M_{D_{12}\pi}(q)\sqrt{\frac{8\pi\Gamma^{(l=1)}_{D_{03}\to D_{12}\pi}(k_1)}{k_1^3}}$$

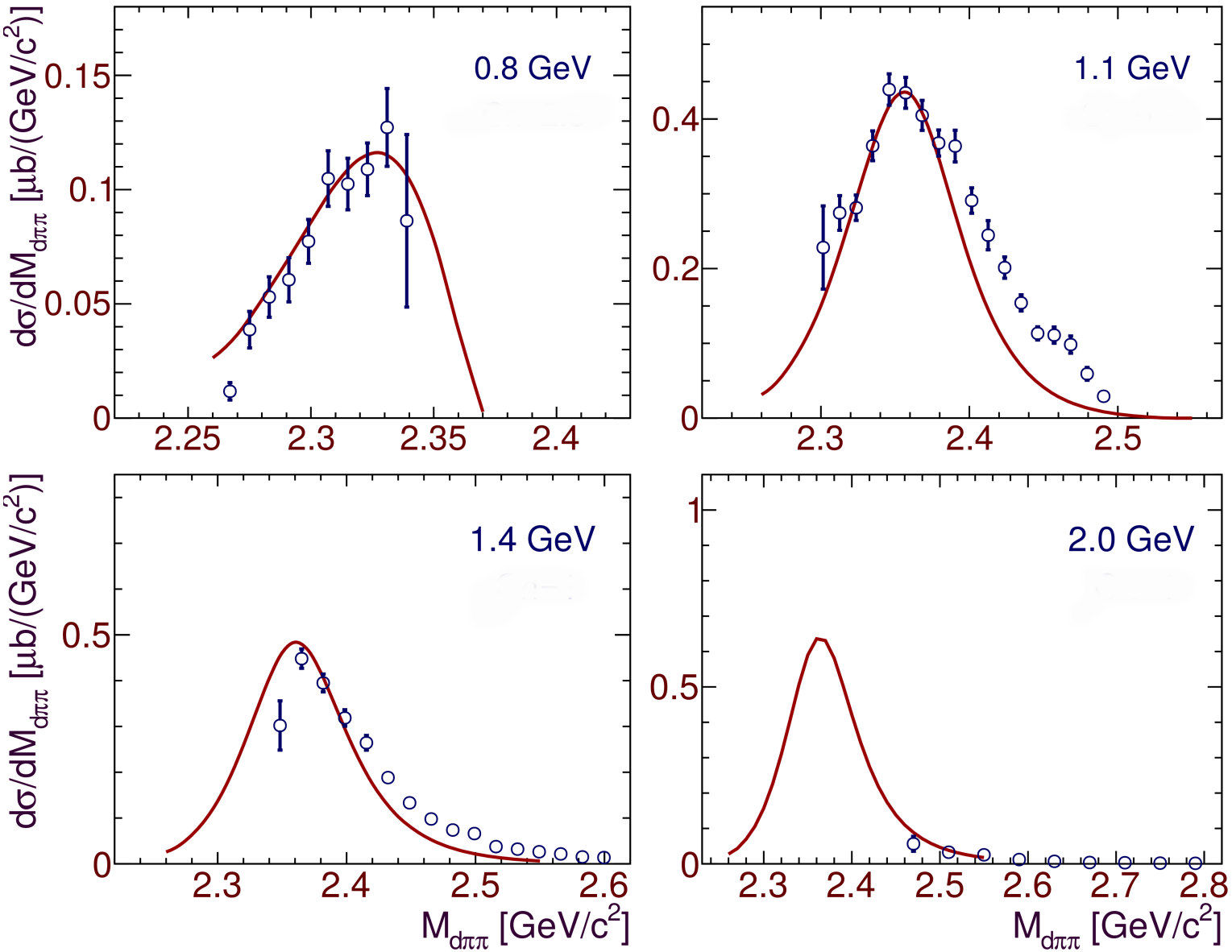
$$\Gamma^{(l=1)}_{D_{03}\to D_{12}\pi}(k_1) = \Gamma^{(l=1)}_{D_{03}\to D_{12}\pi}\left(\frac{k_1}{k_{10}}\right)^3\left(\frac{k_{10}^2+\lambda^2_{D_{12}\pi}}{k_1^2+\lambda_{D_{12}\pi}}\right)^2$$

$$F_{D_{12}\to d\pi_2}(\lambda_1) = M_{d\pi_2}(\lambda_1)\sqrt{\frac{8\pi\Gamma^{(l=1)}_{D_{12}\to d\pi}(\lambda_1)}{\lambda_1^3}}$$

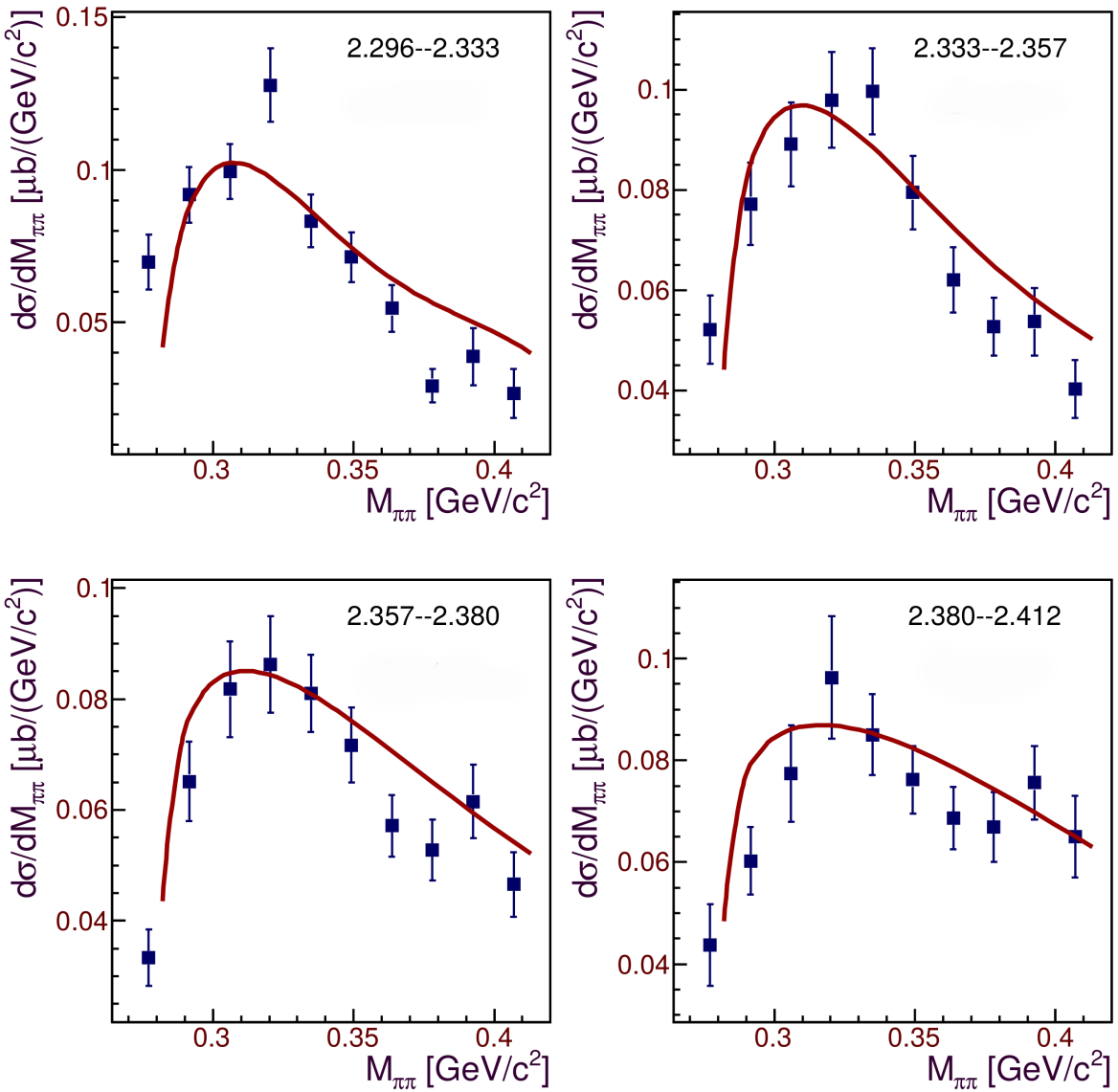
$$\Gamma^{(l=1)}_{D_{12}\to d\pi}(\lambda_1) = \Gamma^{(l=1)}_{D_{12}\to d\pi}\left(\frac{\lambda_1}{\lambda_{10}}\right)^3\left(\frac{\lambda_{10}^2+\lambda^2_{d\pi}}{\lambda_1^2+\lambda_{d\pi}}\right)^2 \quad (4)$$

$$M_{D_{03}} = 2.36\ GeV\ \ \Gamma_{D_{03}} = 110\ MeV$$
$$M_{D_{12}} = 2.15\ GeV\ \ \Gamma_{D_{12}} = 110\ MeV$$
$$M_\sigma = 0.4\ GeV\ \ \Gamma_\sigma = 0.4\ GeV$$
$$f_\sigma = 2.2$$
$$\Gamma^{(l=2)}_{D_{03}\to d\sigma} = 23\ MeV$$
$$\Gamma^{(l=1)}_{D_{03}\to D_{12}\pi} = 6.5\ MeV$$
$$\Gamma^{(l=1)}_{D_{12}\to d\pi} = 8.4\ MeV$$
$$k_{10} = 0.177\ GeV\ \ \lambda_{D_{12}\pi} = 0.12\ GeV$$
$$\lambda_{10} = 0.224\ GeV\ \ \lambda_{d\pi} = 0.25\ GeV$$
$$q_0 = 0.362\ GeV\ \ \lambda_{d\sigma} = 0.18\ GeV \quad (5)$$

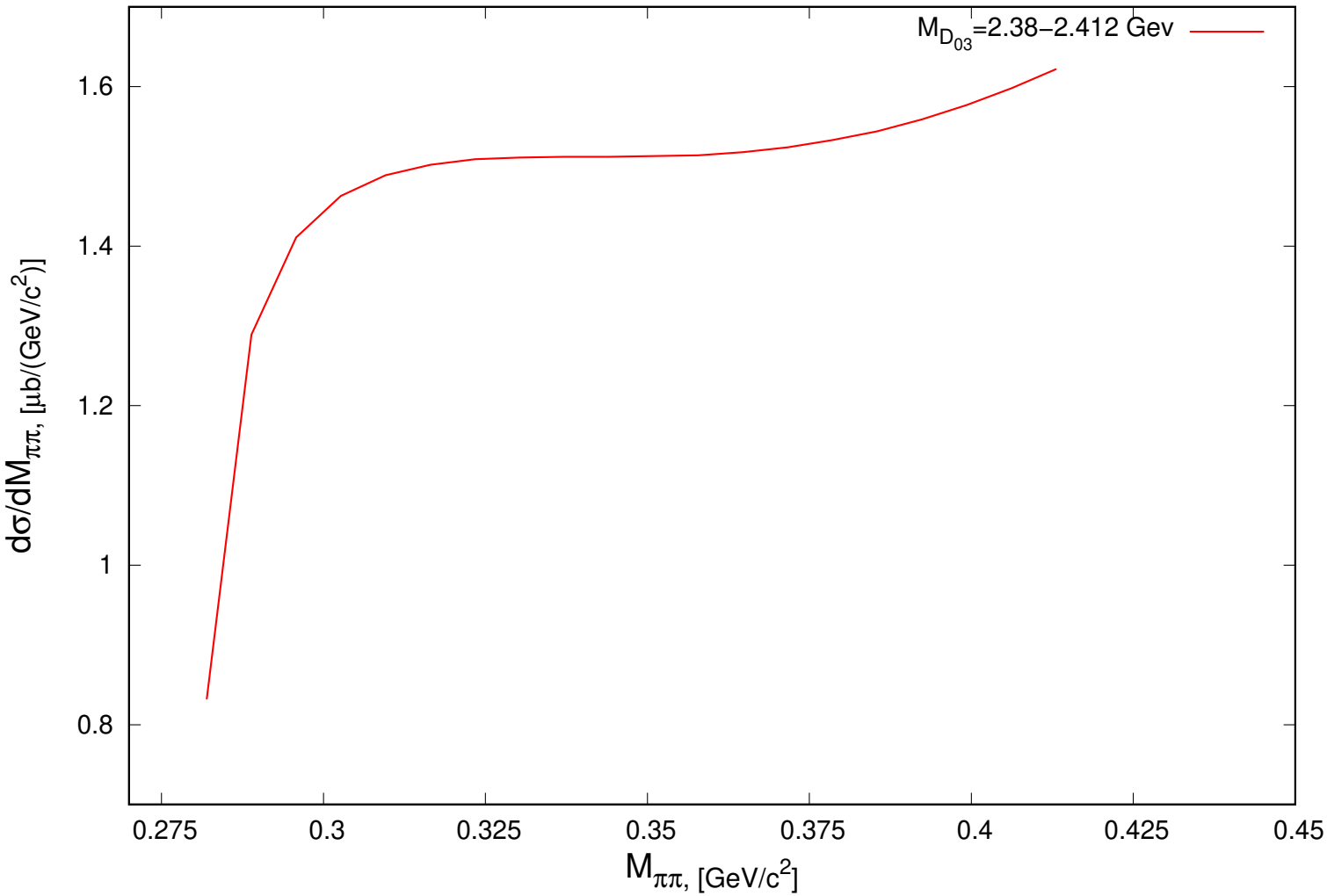
# $pd \to pd\pi\pi$ reaction. ANKE@COSY data and two-resonance model



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




squared dashes-V.Komarov et al.(for ANKE collab.) arxiv:1805.01493 (nucl-exp) full lines – two-resonance model.


$M_{D_{03}}$=2.38–2.412 Gev
1.6
1.4
1.2
1
0.8
dσ/dM$_{ππ}$, [μb/(GeV/c$^2$)]
0.275
0.3
0.325
0.35
0.375
0.4
0.425
0.45
M$_{ππ}$, [GeV/c$^2$]

# 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 $\sigma$-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 (ABC effect). Absolute value is yet determined because magnitude of some partial width not known.