Reactions dd->dd $\pi\pi$ and pd->pd$\pi\pi$ and isoscalar dibaryons

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NUCLEUS-2025, 1-6 July 2025, Sankt-Peterburg

CONTENT

- WASA dibaryon d*(2380) in the reactions pn-> d$\pi^0\pi^0$ and pn->pn. Experimental data and theoretical models.
- ANKE@COSY data on pd->pd$\pi\pi$ and t-channel excitation of d*(2380).
- Indication to isoscalar resonances in γ+d->d$\pi^0\pi^0$ (ELPH and BGOOD data).
- Possible search for isoscalar dibaryons in **dd->dd $\pi\pi$** and **pd->pd$\pi\pi$** reactions in dd-collision at SPD NICA .
- Summary

F.J. Dyson, N.-H. Xuang, PRL 13, № 26 (1964) 815

VOLUME 13, NUMBER 26 PHYSICAL REVIEW LETTERS 28 DECEMBER 1964

Table I. $Y = 2$ states with zero strangeness predicted by the $\underline{490}$ multiplet.

Particle	T	J	SU(3) multiplet	Comment	Predicted mass
D_{01}	0	1	$\underline{10}^*$	Deuteron	A
D_{10}	1	0	$\underline{27}$	Deuteron singlet state	A
D_{12}	1	2	$\underline{27}$	S-wave N-N^* resonance	$A + 6B$
D_{21}	2	1	$\underline{35}$	Charge-3 resonance	$A + 6B$
D_{03}	0	3	$\underline{10}^*$	S-wave N^*-N^* resonance	$A + 10B$
D_{30}	3	0	$\underline{28}$	Charge-4 resonance	$A + 10B$

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УСПЕХИ ФИЗИЧЕСКИХ НАУК

ДИБАРИОННЫЕ РЕЗОНАНСЫ

М. М. Макаров

Reference to PRL 42, №20 (1979) 1321; γd→np

Angular Dependence of Proton Polarization in the Reaction $\gamma d \to pn$ and a Partial-Wave Analysis of Possible Dibaryon Resonances

H. Ikeda,[a] I. Arai, H. Fujii, T. Fujii, H. Iwasaki, N. Kajiura,[a] T. Kamae
K. Nakamura, T. Sumiyoshi, and H. Takeda[b]
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and

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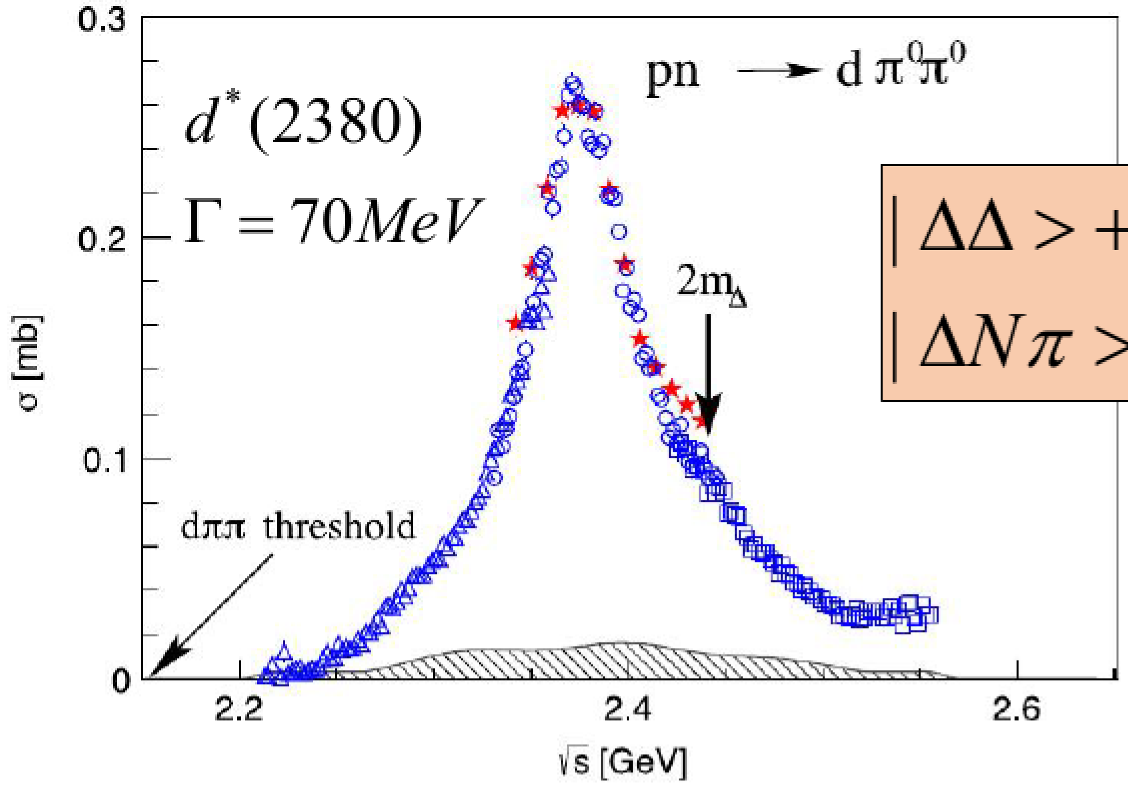
(Received 22 March 1979)

The angular dependence of proton polarization in $\gamma d \to pn$ has been measured at photon energies between 400 and 650 MeV. The polarization and differential-cross-section data are consistently explained by introducing a dibaryon resonance $I(J^P) = 0(3^+)$ or $0(1^+)$ at ≈ 2360 MeV.

DIBARYON RESONANCES

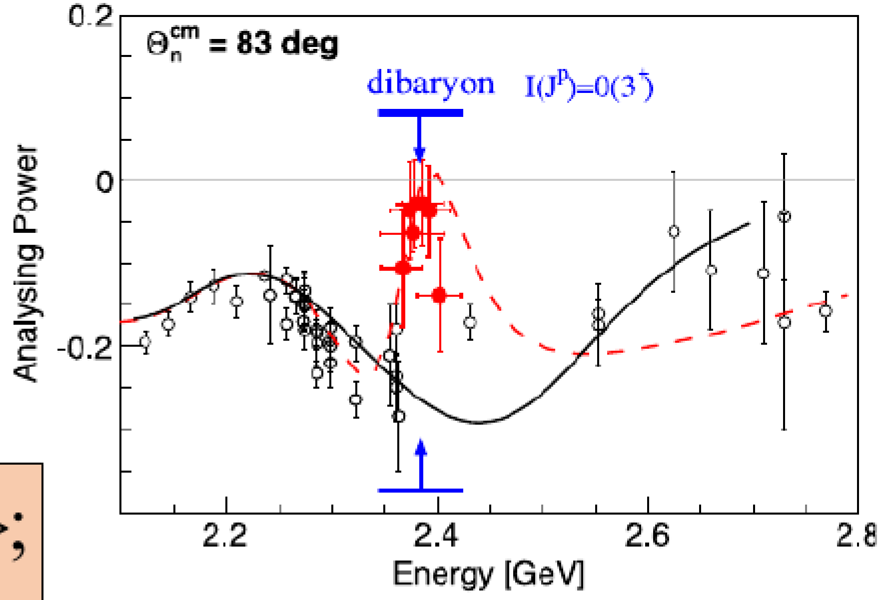
P. Adlarson et al. PRL 106(2011) 242302;
PRC 90 (2014) 035204

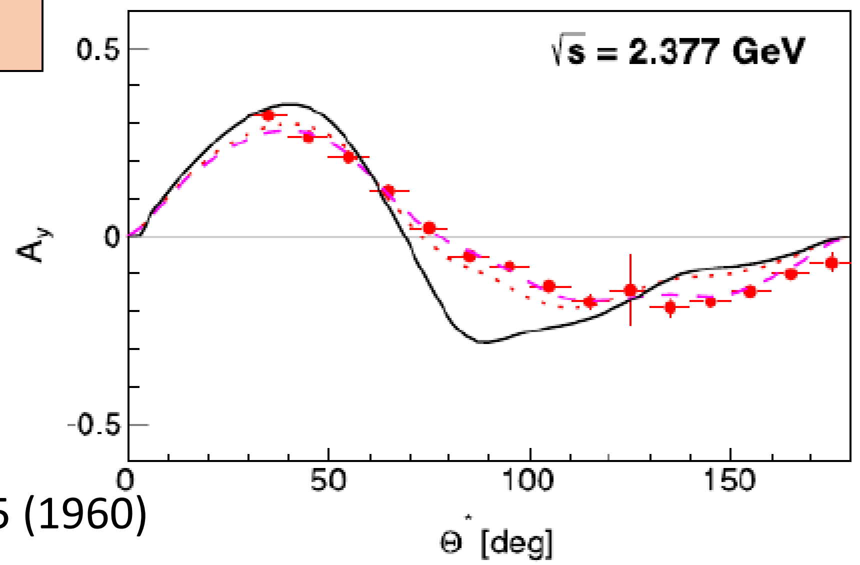
H. Clement / Progress in Particle and Nuclear Physics 93 (2017) 195–242



$$|\Delta\Delta> + |C\bar{C}>;$$
$$|\Delta N\pi>$$

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





ABC – effect , A. Abashian, N. Booth, K. Crowe, PRL 5 (1960)

H. Clement, Prog. Part. Nucl. Phys. 93 (2017) 195-242
H. Clement, T. Skorodko. Chin. Phys. C 45 , № 2 (2021) 022001

Y. Dong et al. "d*(2380) in chiral constituent quark model"
Prog. Part. Nucl. Phys. 131 (2023) 104045:
Compact hexaquark system, hidden color component dominates.

Eur. Phys. J. C (2023) 83:645
https://doi.org/10.1140/epjc/s10052-023-11814-2

Regular Article - Theoretical Physics

Is d^*(2380) a compact hexaquark state?

Manying Pan[1,a], Xinmei Zhu[2,b], Jialun Ping[1,c]

However,
A.Gal, H. Garcilazo, Phys.Rev.Lett. 111 (2013) 172301; d* (2380) is the $\pi\Delta N$

See talk by E. Doroshkevich, on 3 July, Nucleus-2025: NN*(1440), M=2315,Gamma=150 MeV

ANKE@COSY data on pd->pd$\pi\pi$ and t-channel excitation of d*(2380).

V.I. Komarov et al., Eur. Phys. Jour. A 54 (2018) 206

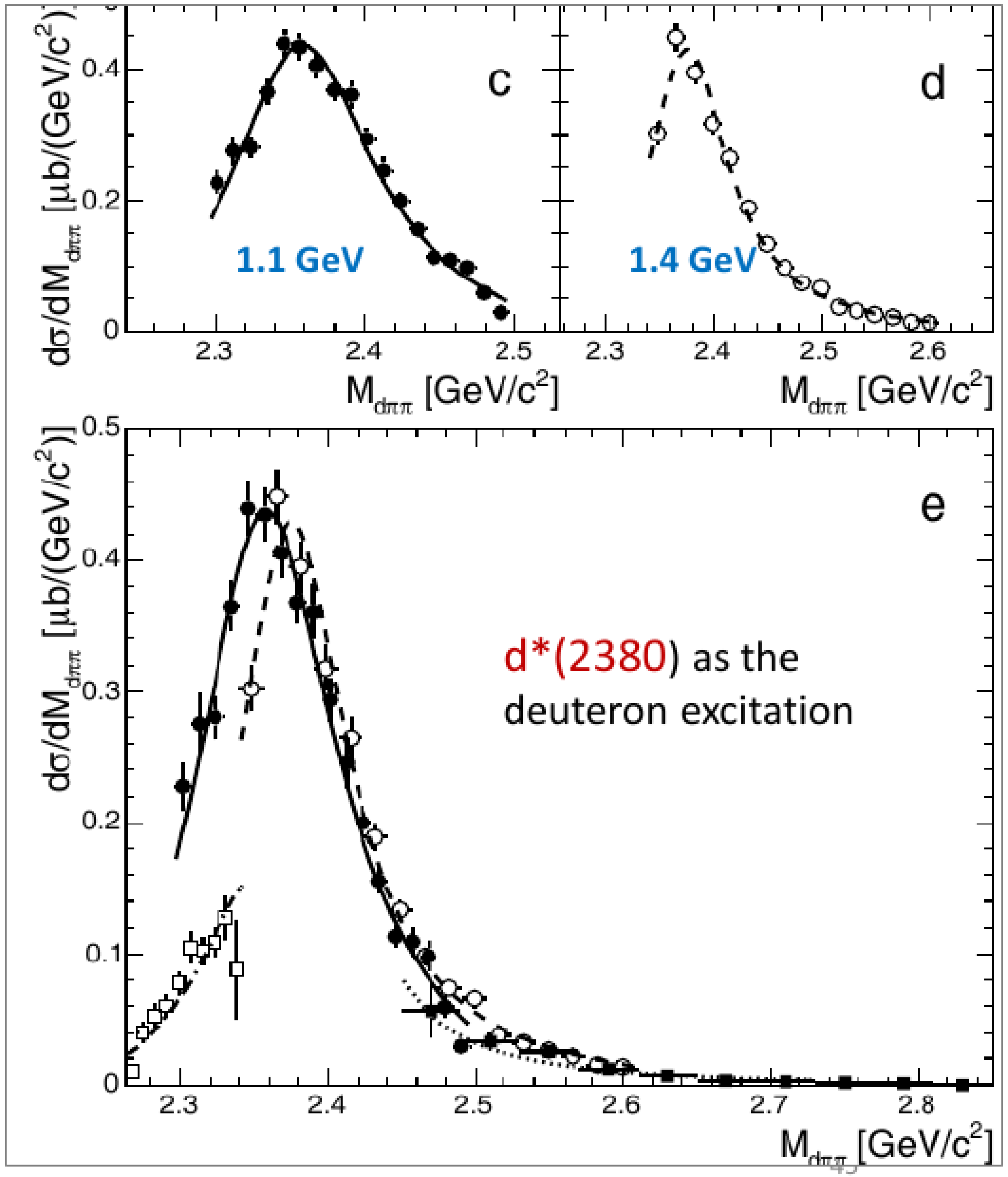
Eur. Phys. J. A (2018) 54: 206
DOI 10.1140/epja/i2018-12641-0

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Experimental Physics

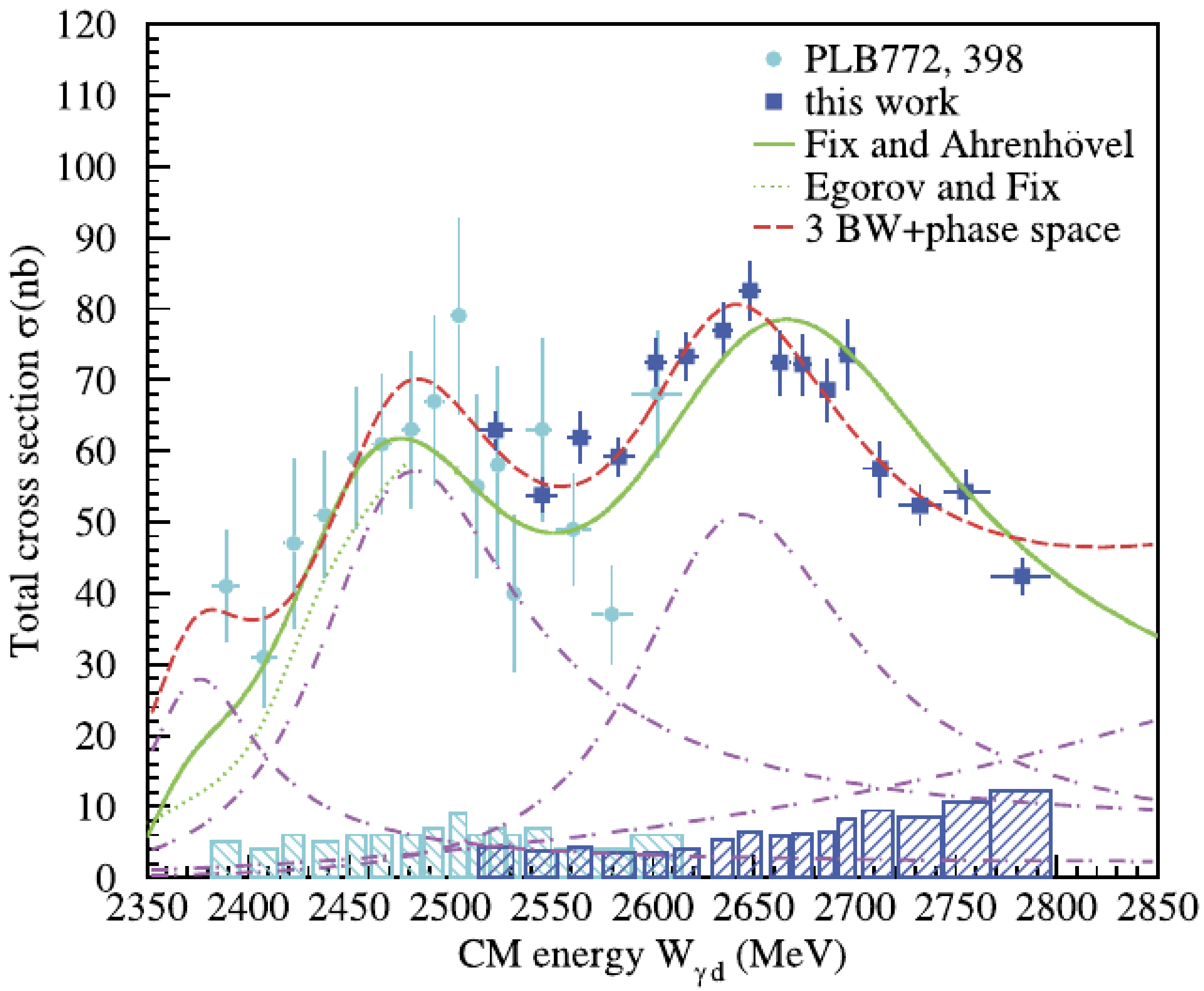
Resonance-like coherent production of a pion pair in the reaction pd → pd$\pi\pi$ in the GeV region

V.I. Komarov[1], D. Tsirkov[1,a], T. Azaryan[1], Z. Bagdasarian[2,3], B. Baimurzinova[4,5], S. Barsov[6], S. Dymov[1,2], R. Gebel[2], M. Hartmann[2], A. Kacharava[2], A. Khoukaz[7], A. Kulikov[1], A. Kunsafina[1,4,5], V. Kurbatov[1], Zh. Kurmanaliyev[1,4,5], B. Lorentz[2], G. Macharashvili[3], D. Mchedlishvili[2,3], S. Merzliakov[2], S. Mikirtytchiants[2,6], M. Nioradze[3], H. Ohm[2], F. Rathmann[2], V. Serdyuk[2], V. Shmakova[1], H. Ströher[2], S. Trusov[2,8], Yu. Uzikov[1,9,10], Yu. Valdau[2,6], and C. Wilkin[11]



T. Ishikawa et al., (ELPH Coll) PLB 798 (2019) 413:
M_D= 2380, 2470, 2630 MeV

γ+d -> $d\pi^0\pi^0$



T.C. Jude, S. Alef, R. Beck et al.

T.C. Jude, S. Alef, R. Beck et al.
(BGOOD at ELSA Coll.) PLB 8328 (2022) 137277

γ+d -> $d\pi^0\pi^0$

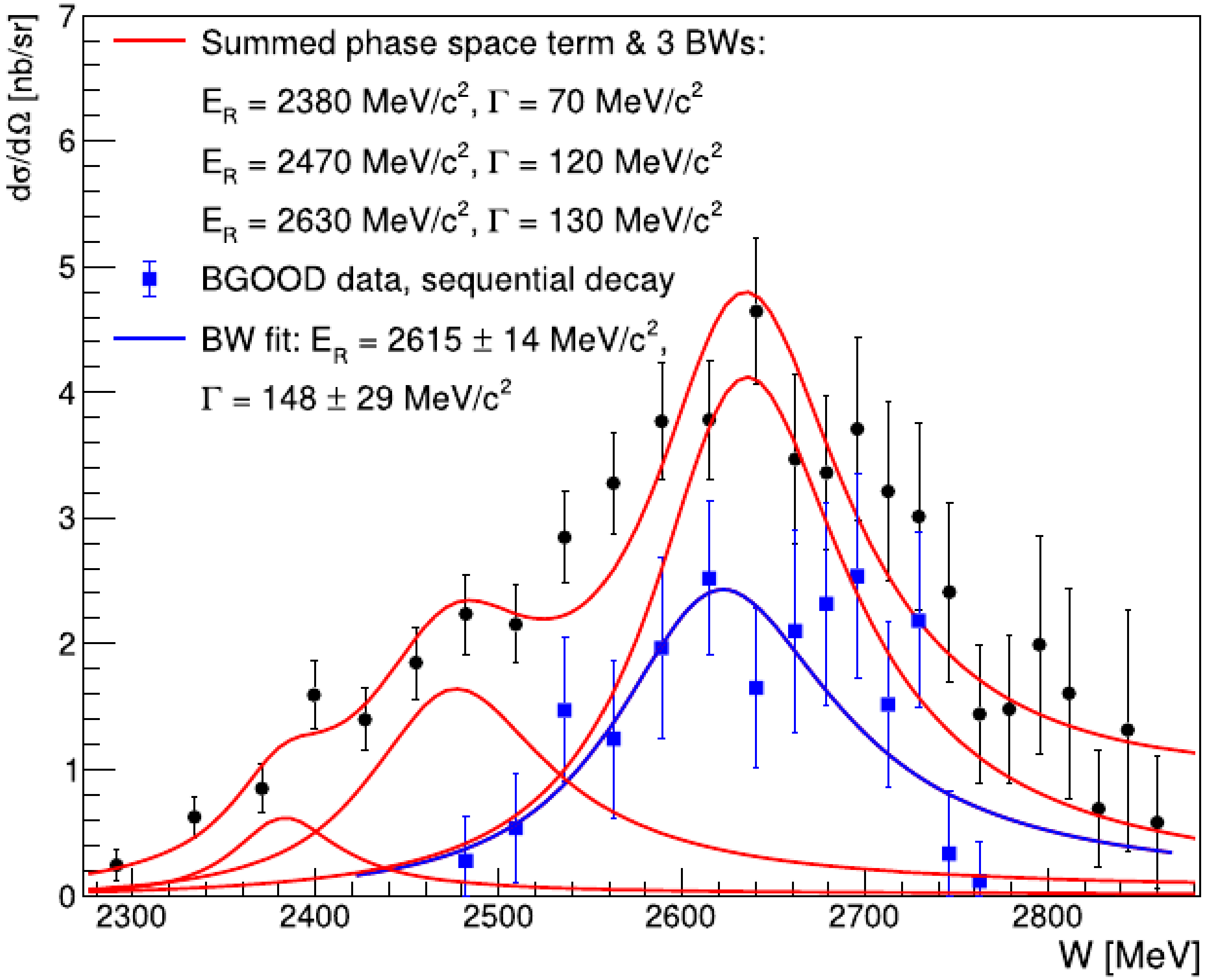


Fig. 7. $\gamma d \rightarrow \pi^0\pi^0 d$ differential cross section for $\cos\theta^d_{CM} > 0.8$ (the same as in Fig. 5). A fit including three Breit-Wigner functions (BW) are shown as the red lines, with the fixed masses and widths labelled inset. The additional small centre-

PHYSICAL REVIEW D **103,** 114025 (2021)

Isospin symmetry breaking in double-pion production in the region of $d^*(2380)$ and the scalar σ meson

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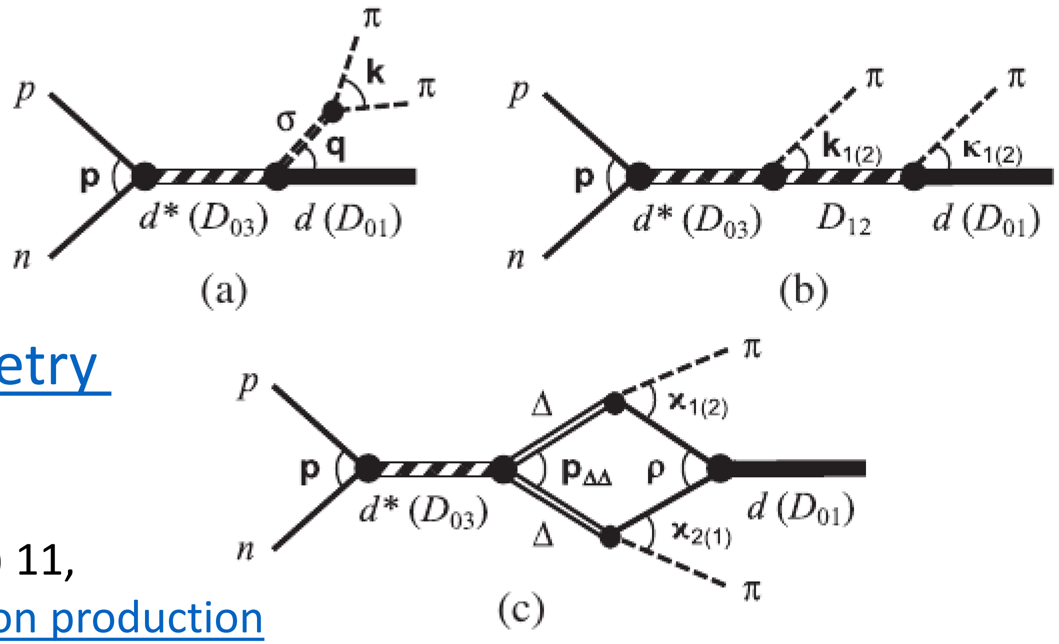
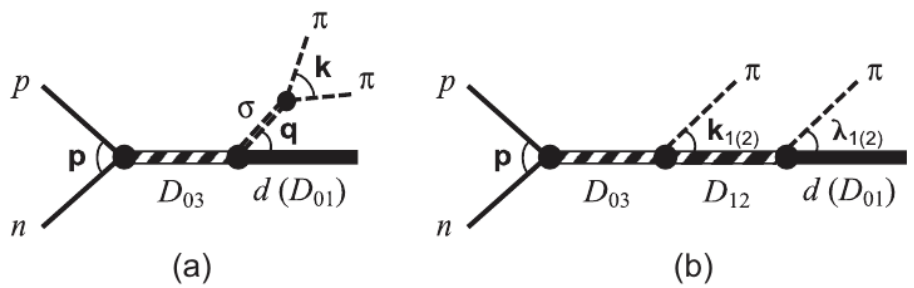
Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow 119991, Russia

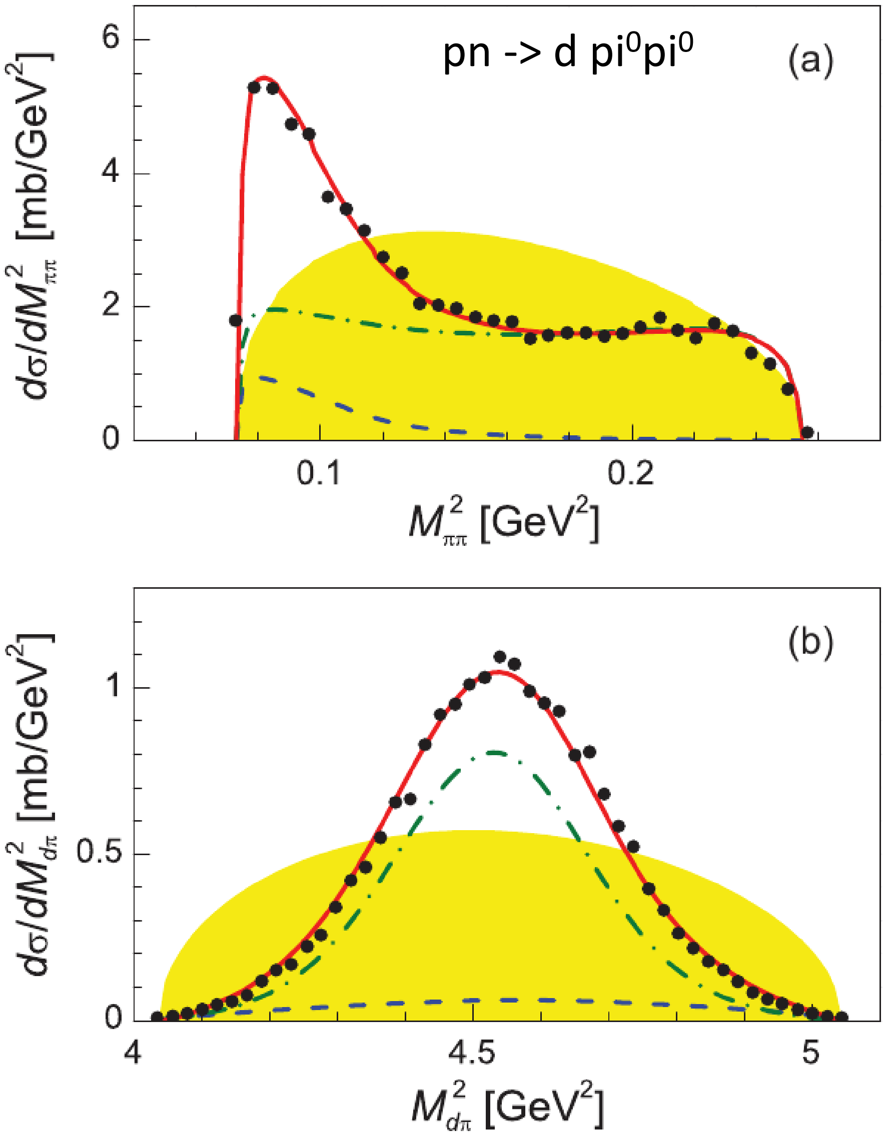


M.P. Platonova, V.I. Kukulin,
PRC 87 (2013) 2, 025202
[ABC-effect as a signal of chiral symmetry restoration in hadronic collisions]

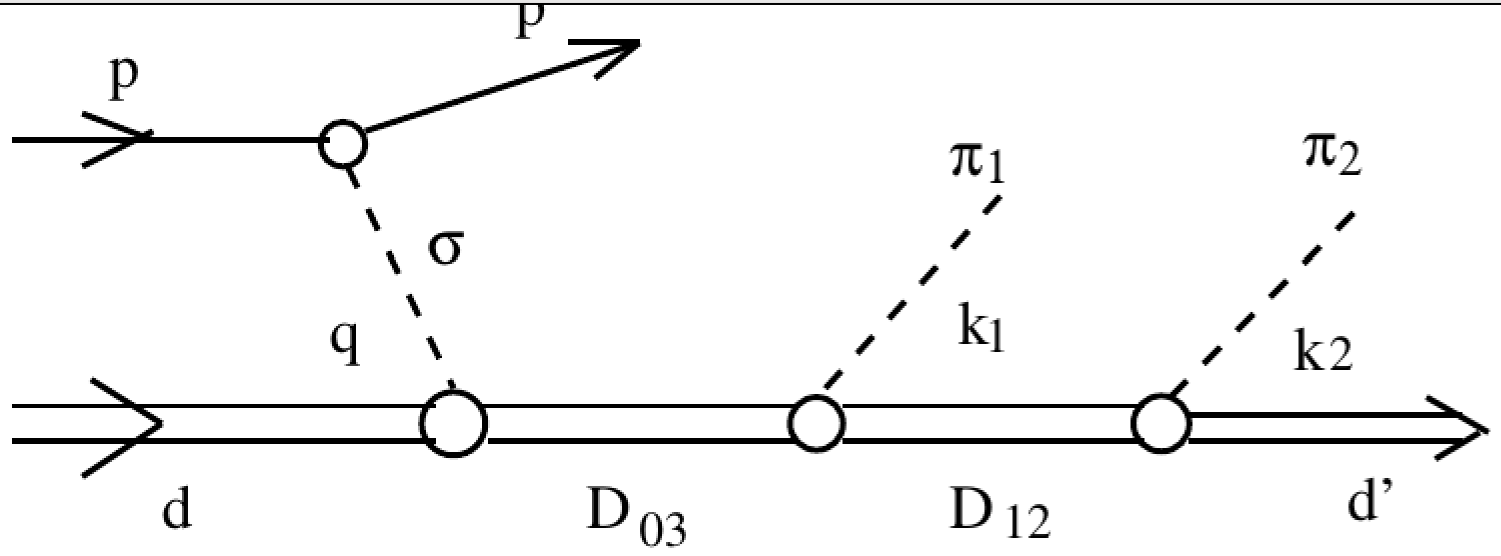
M.P. Platonova, V.I. Kukulin, *Phys.Rev.D* 103 (2021) 11, 1140250, [Isospin symmetry breaking in double-pion production in the region of d*(2380) and the scalar σ meson]



M.N. Platonova,V. I. Kukulin, PRC 87 (2013) 250202



Our Model of the reaction pd->pd$\pi\pi$: PK + σ-exchange in t-channel



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

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

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

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

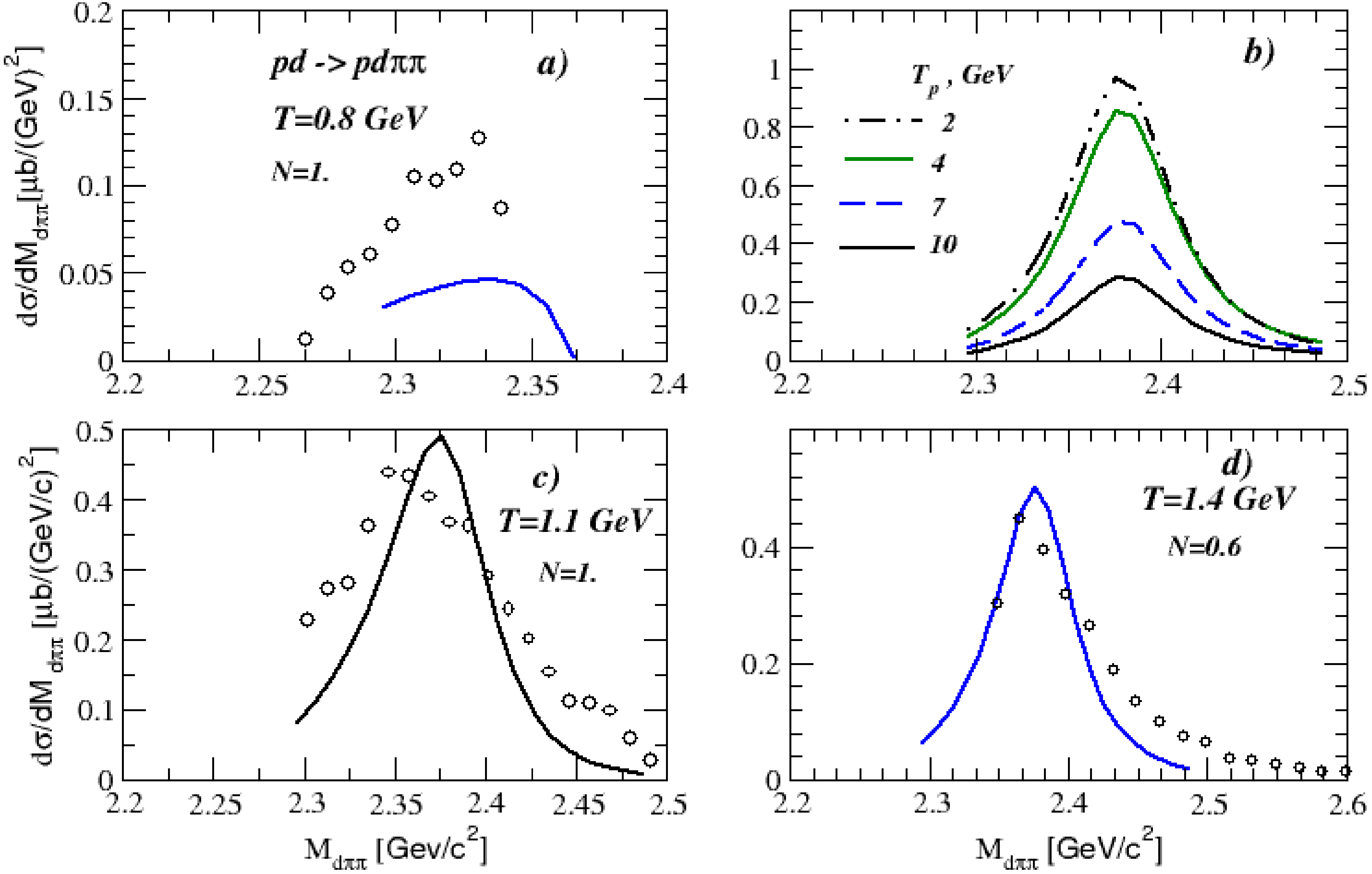
$$\frac{F_{D_{03}\to d\sigma}(q)}{M_{D_{03}}(q)} = \sqrt{\frac{8\pi\Gamma^{(l=2)}_{D_{03}\to d\sigma}(q)}{q^5}}, \quad \Gamma^{(l=2)}_{D_{03}\to d\sigma}(q) = \Gamma^{(l=2)}_{D_{03}\to d\sigma}\Big(\frac{q}{q_0}\Big)^5\Big(\frac{q_0^2 + \lambda^2_{d\sigma}}{q^2 + \lambda_{d\sigma}}\Big)^3,$$

$$\frac{F_{D_{03}\to D_{12}\pi_1}(k_1)}{M_{D_{12}\pi}(k_1)} = \sqrt{\frac{8\pi\Gamma^{(l=1)}_{D_{03}\to D_{12}\pi}(k_1)}{k_1^3}}, \quad \Gamma^{(l=1)}_{D_{03}\to D_{12}\pi}(k_1) = \Gamma^{(l=1)}_{D_{03}\to D_{12}\pi}\Big(\frac{k_1}{k_{10}}\Big)^3\Big(\frac{k_{10}^2 + \lambda^2_{D_{12}\pi}}{k_1^2 + \lambda_{D_{12}\pi}}\Big)^2$$

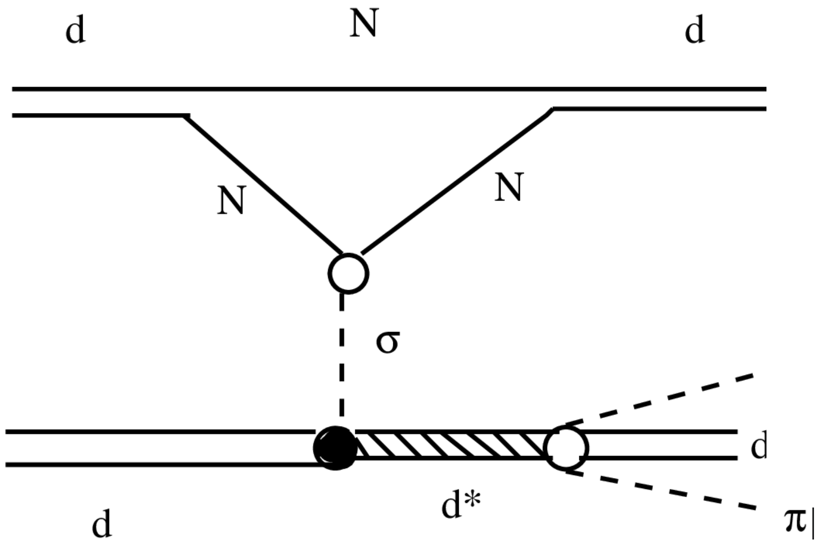
$$\frac{F_{D_{12}\to d\pi_2}(k_2)}{M_{d\pi_2}(k_2)} = \sqrt{\frac{8\pi\Gamma^{(l=1)}_{D_{12}\to d\pi}(k_2)}{k_2^3}}, \quad \Gamma^{(l=1)}_{D_{12}\to d\pi}(k_1) = \Gamma^{(l=1)}_{D_{12}\to d\pi}\Big(\frac{k_2}{k_{20}}\Big)^3\Big(\frac{k_{20}^2 + \lambda^2_{d\pi}}{k_2^2 + \lambda_{d\pi}}\Big)^2.$$

The following numbers were used in our calculations for the D_{03} and D_{12} resonances and the vertices parameters: $M_{D_{03}} = 2.380$ GeV, $\Gamma_{D_{03}} = 70$ MeV, $M_{D_{12}} = 2.15$ GeV, $\Gamma_{D_{12}} = 0.11$ GeV, $m_\sigma = 0.5$ GeV, $\Gamma_\sigma = 0.55$ GeV, $q_0 = 0.362$ Gev/c, $k_{10} = 0.177$ GeV/c, $k_{20} = 0.224$ GeV/c, $\lambda_{\pi D_{12}} = 0.12$ GeV. The values $\Gamma^{(l=1)}_{D_{12}\to d\pi} = 10$ MeV, $\lambda_{d\sigma} = 0.18$ GeV and $\lambda_{d\pi} = 0.25$ GeV were pd->pd$\pi\pi$: data - ANKE@COSY, theory - PK model+ sigma in t-exchange

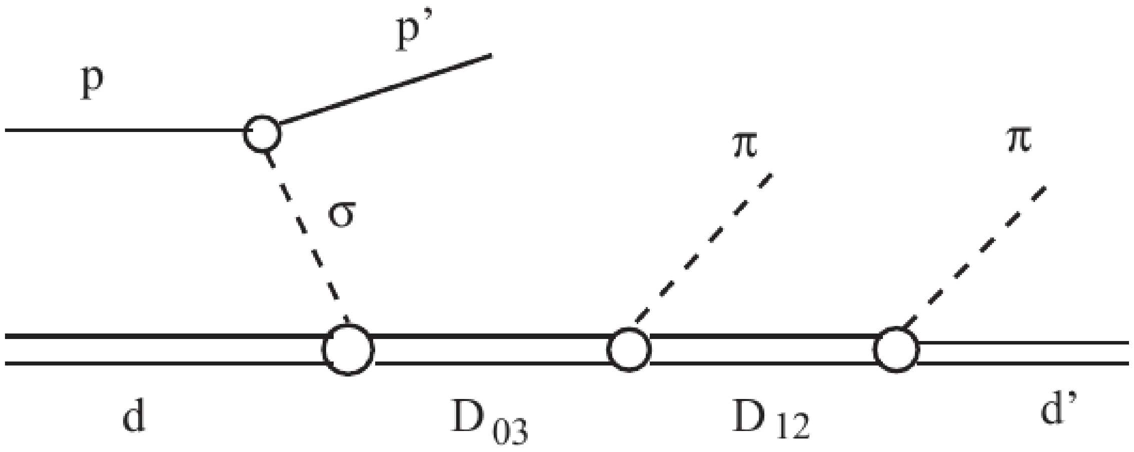
Θ^{p}_{cm}=7°-13°



Model of the reaction dd->dd$\pi\pi$ based on the pd->pd$\pi\pi$ model



a)

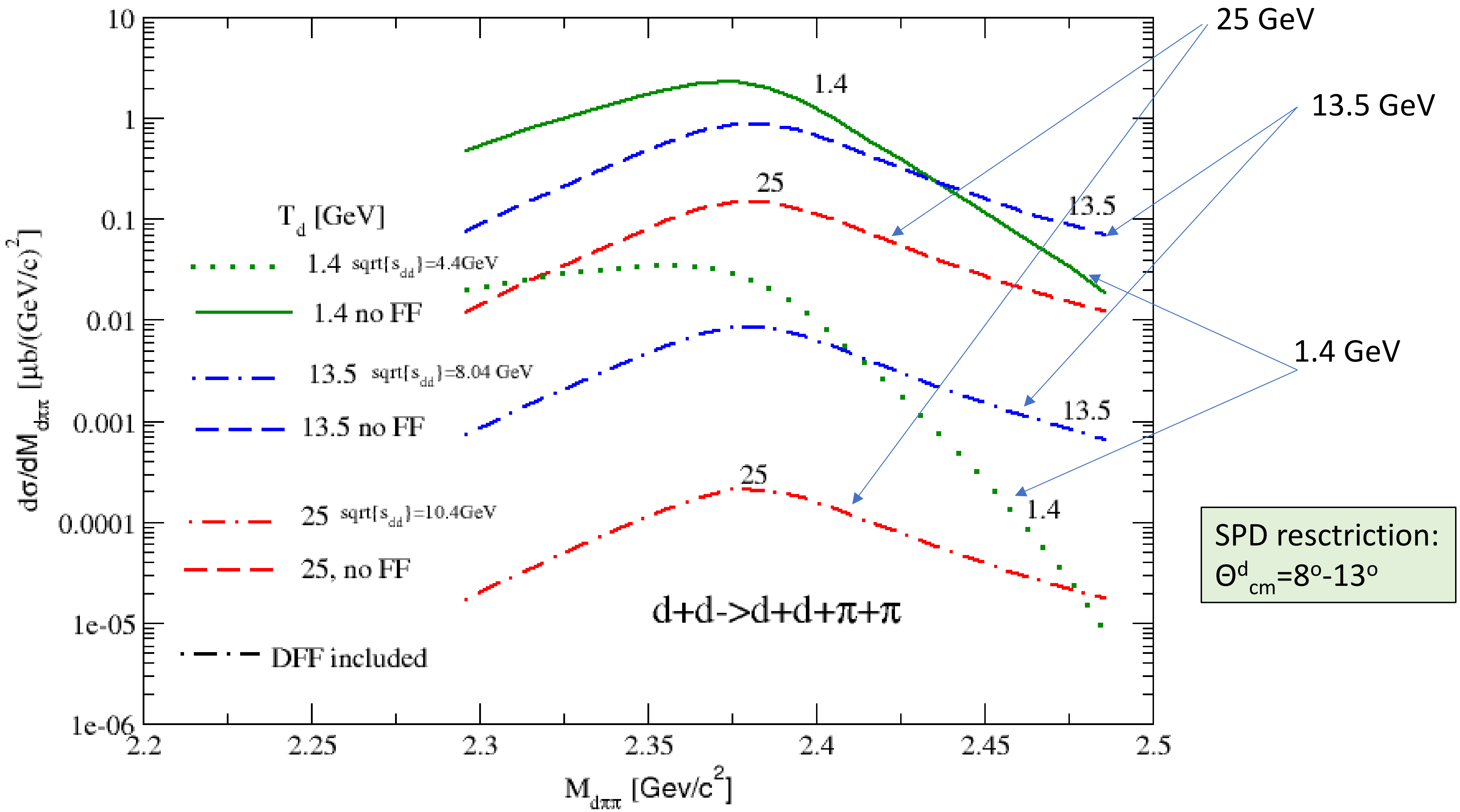


b)

$$S(\Delta/2) = \int_0^\infty [u^2(r) + w^2(r)] j_0(\Delta r/2) r^2 dr$$

Deuteron elastic form factor

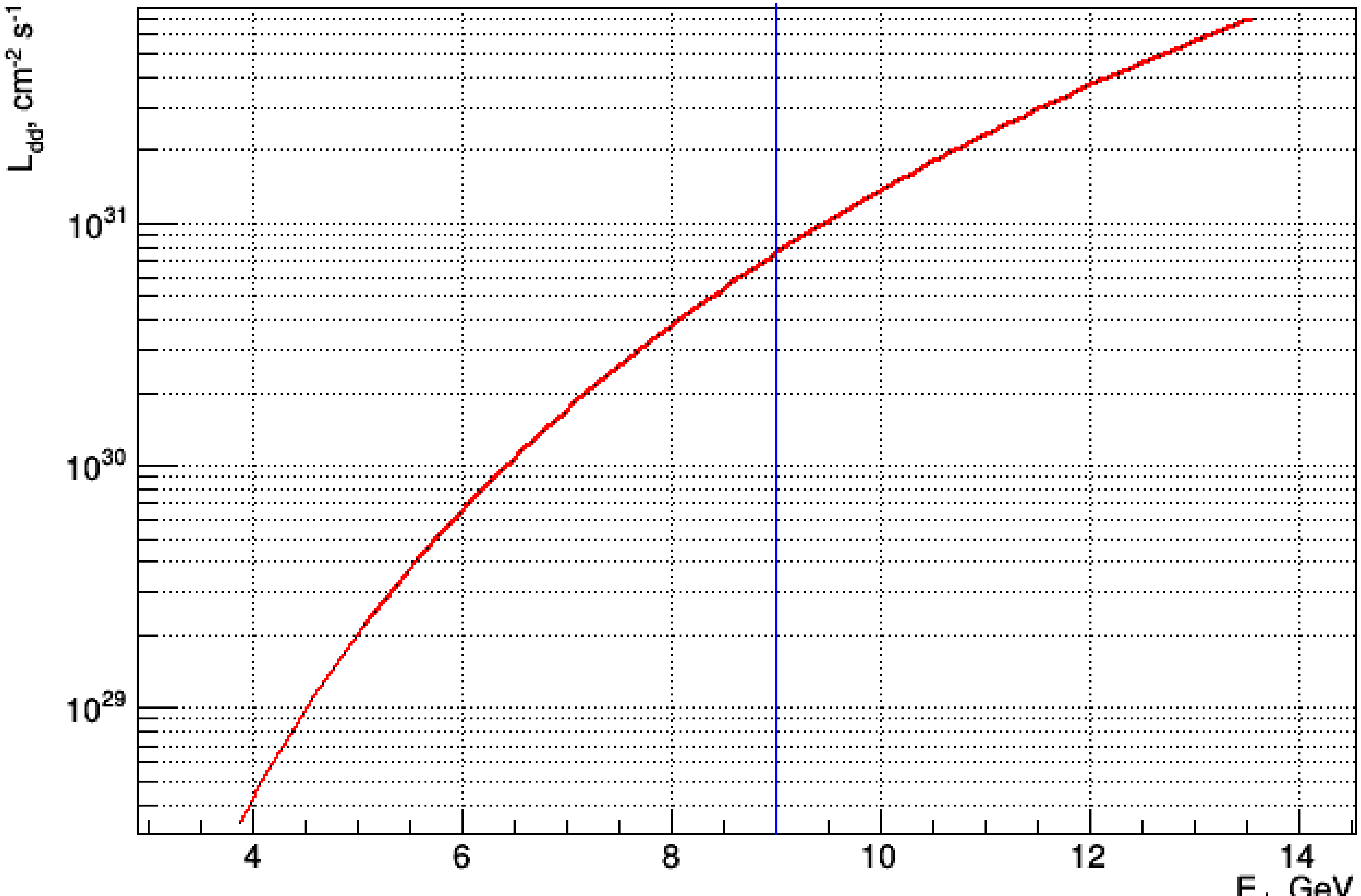
dd->d d-> ddππ



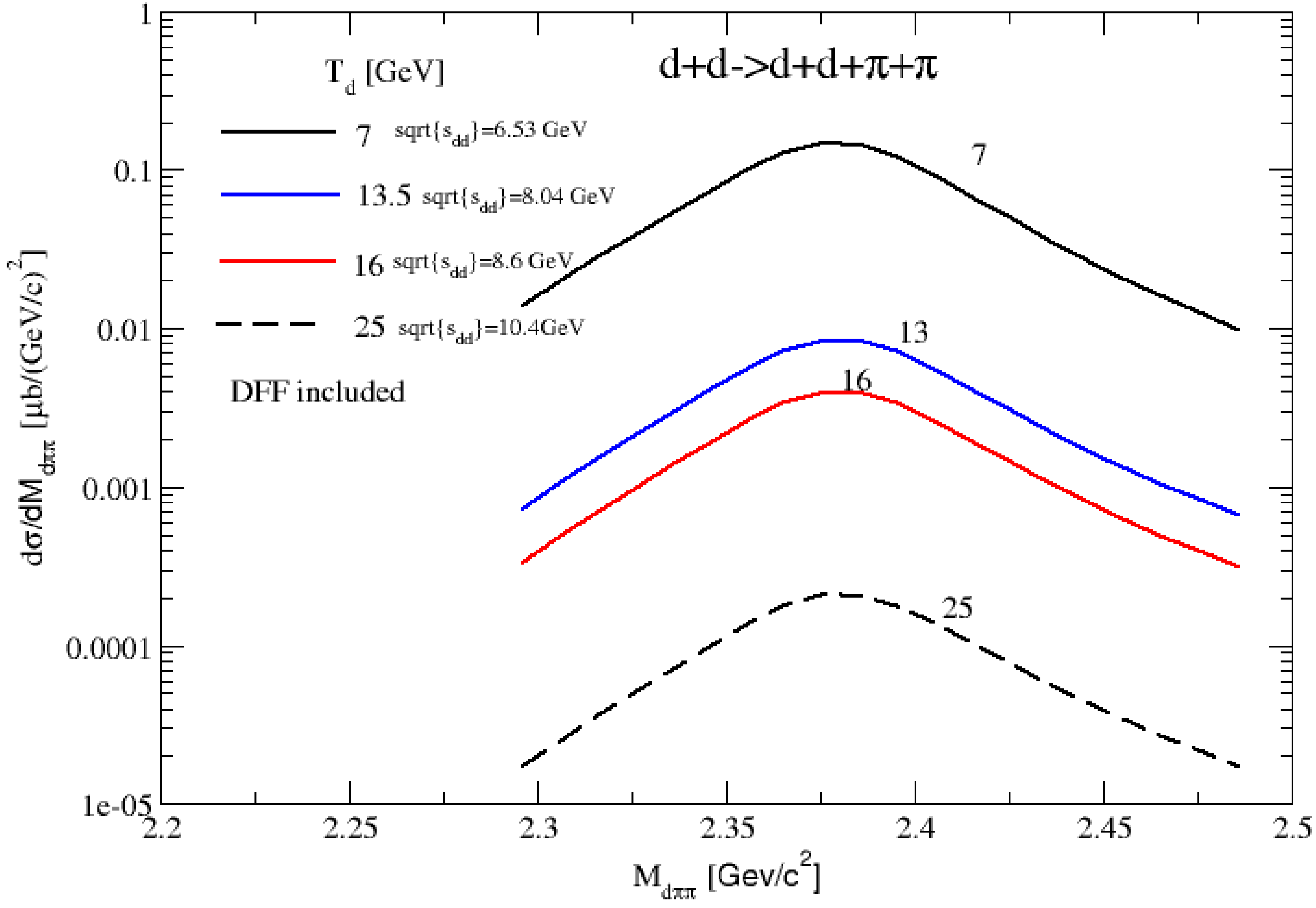
SPD resctriction:
Θ^d_{cm}=8°-13°

Inclusion of the deuteron form factor diminishes the cross section by ~ 2 orders of magnitude

Luminosity at SPD NICA for dd-collisons



Minimal energy of the deuteron in c.m.s. = 4GeV



Deuteron elastic form-factor is included

N- counting rate at maximum cross. sec.

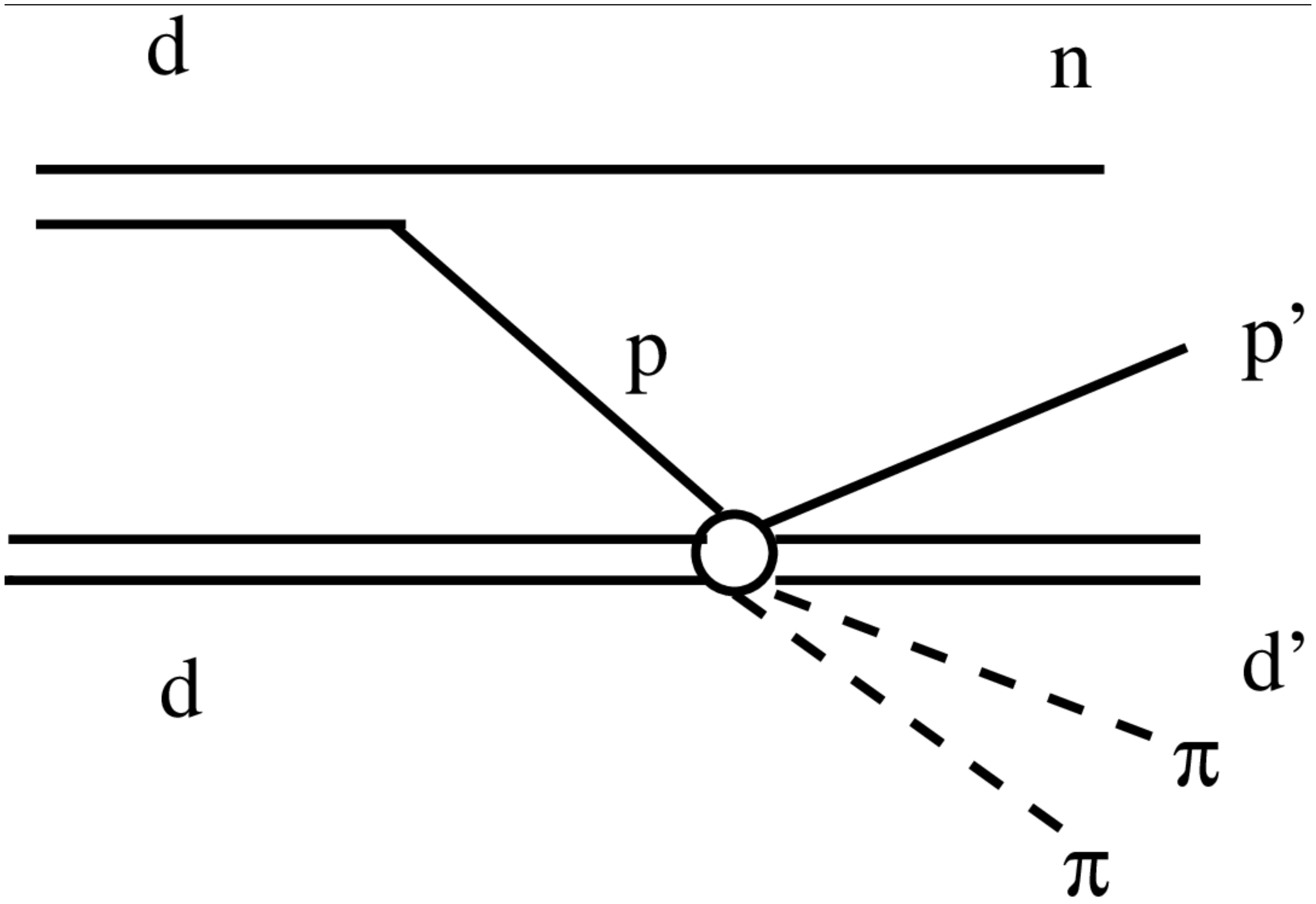
E_d= 4 GeV, L_{dd}=4.1 $10^{28}$$cm^{-2}$ s^{-1}

N=0.14/h

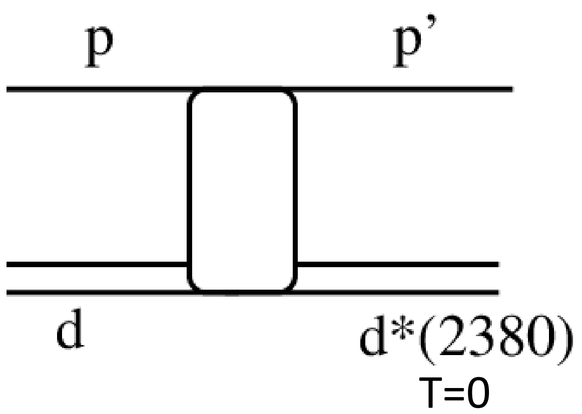
E_d= 5.2 GeV, L_{dd}=2.1 $10^{29}$$cm^{-2}$ s^{-1}

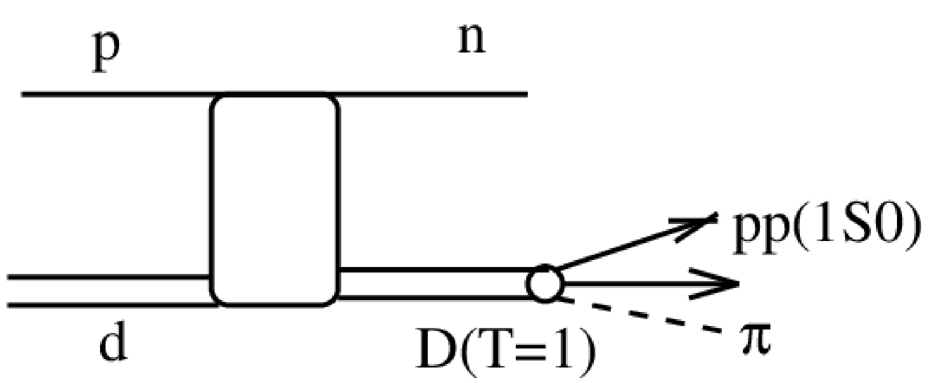
N=0.007/h

Another variant: The pd-> pd $\pi\pi$ subprocess in the dd-> npd $\pi\pi$ reaction

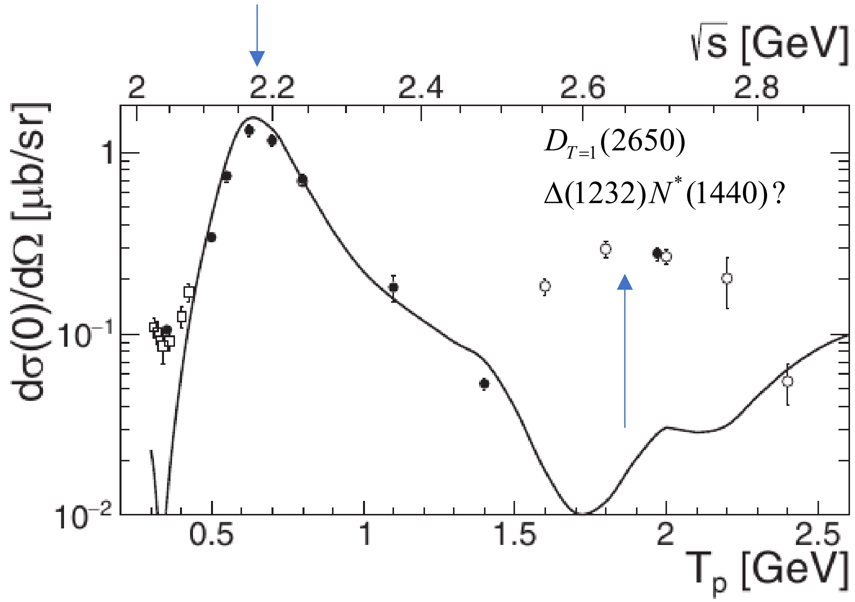


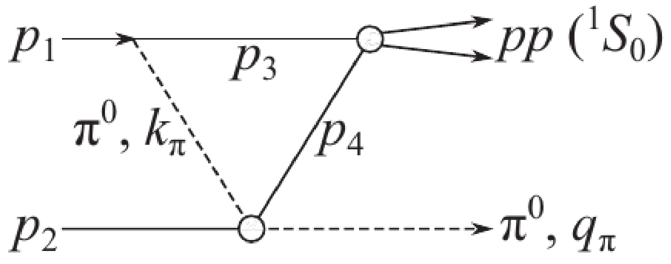
ISOVECTOR DIBARYON RESONANCES: to search at SPD(?)





PHYSICAL REVIEW C **107**, 015202 (2023)





PHYSICAL REVIEW C **107**, 015202 (2023)

Resonant behavior of the $pp \to \{pp\}_s\pi^0$ reaction at the energy $\sqrt{s} = 2.65$ GeV

D. Tsirkov,[1] B. Baimurzinova,[1,2,3,*] V. Komarov,[1] A. Kulikov,[1] A. Kunsafina,[1,2,3] V. Kurbatov,[1] Zh. Kurmanalyiev,[1,2,3] and Yu. Uzikov[1,4,5]

SUMMARY

- Properties of non-strange dibaryons are important for understanding (short-range) NN- dynamics. Compact objects or quasi-molecules?

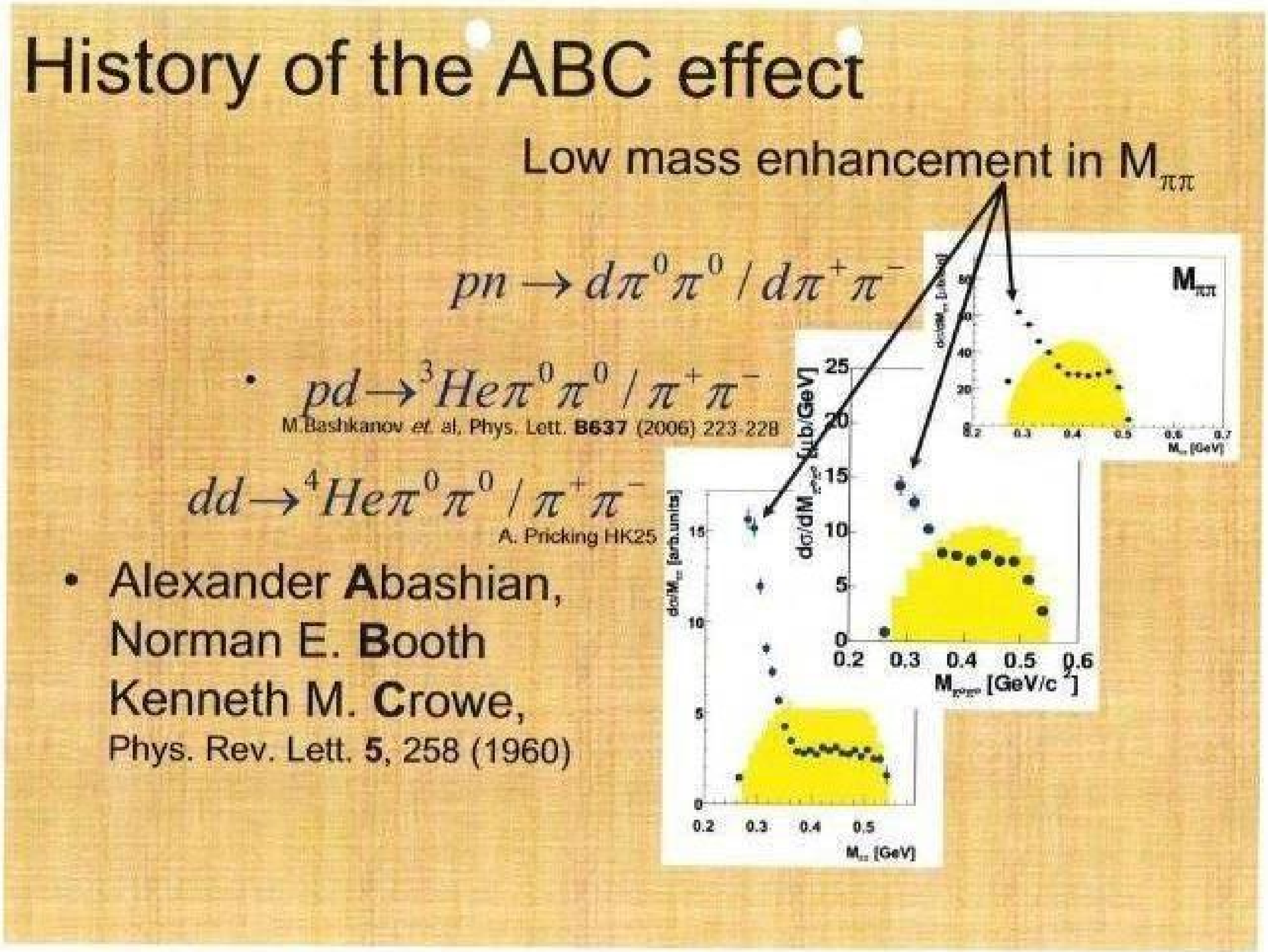
- Isoscalar dibaryons d* with M=2380 and 2470, 2630 MeV can be searched at the first phase of the SPD NICA, in dd-mode at sqrt{s_{dd}} =4-5 GeV.

- The cross section of **dd->d*d->dd $\pi\pi$ is strongly suppressed by the DFF.**

- **The pd->pd$\pi\pi$ is more preferable, but has to be extracted from the dd->n+pd$\pi\pi$ (in the region of dominance of the IA)**

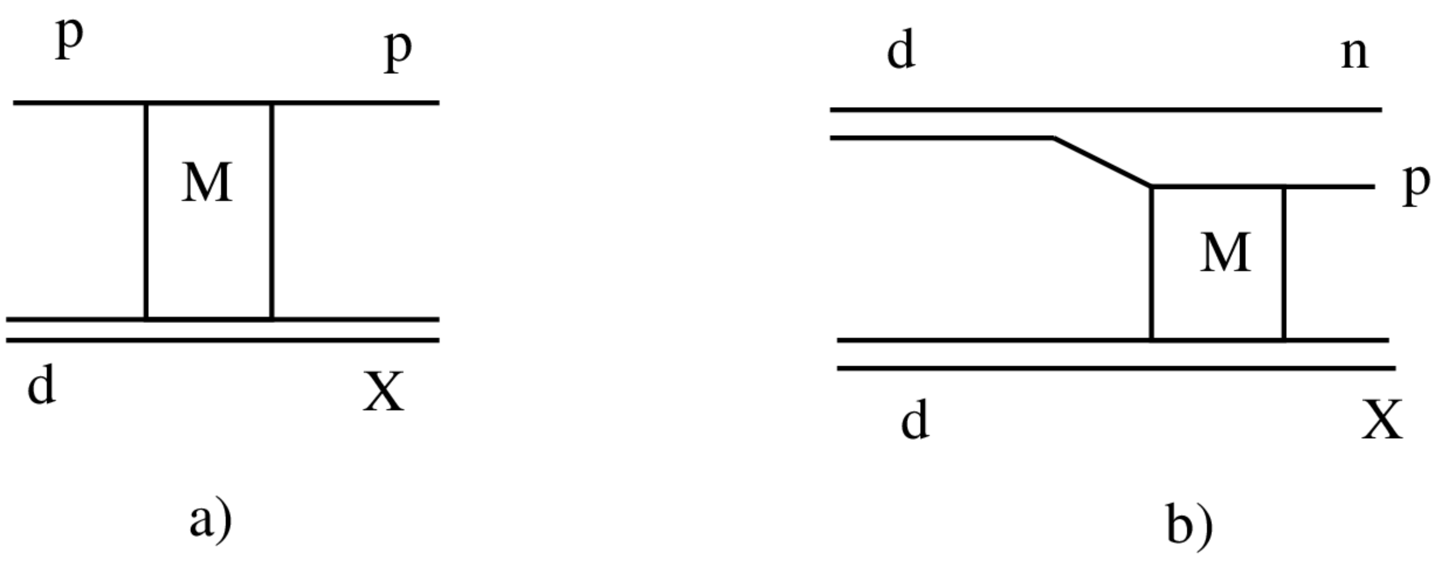
THANK YOU FOR ATTENTION!

ABC effect (puzzle)



from talk by M. Bashkanov, DFG -meeting (Bonn,2010); $I_{\pi\pi} = 0 \Longrightarrow$ ABC
http://wasasrv.ikp.kfa-juelich.de/WasaWiki/index.php/File:MB100716-ABC-meson10.pdf

in Impulse approximation



$$T(dd \to n + pX) = \Sigma_{\sigma'} < \sigma_n, \sigma_{p'} \,|\, \psi_d^{\lambda}(\vec{q}) > T_{\lambda\sigma'}^{M_X \sigma_p}(pd \to pX)$$

'hen the final neutron takes one half (

-wave dominance, suppressed p_T mo

e pd->pd amplitude can be extracted

$$\vec{p}_n = \vec{p}_d / 2$$

TABLE I. Parameters of resonances R and their decay channels $R \to a + b$ relevant for the $pp \to d(\pi\pi)_0$ reactions. For the parameter p_0, the given interval corresponds to all possible isospin channels.

R	M_R (MeV)	$\Gamma_R^{(0)}$ (MeV)	ab	l	p_0 (MeV)	$\Gamma_{R\to ab}^{(0)}$ (MeV)	Λ_{ab} (GeV)
			np	2	730	9	0.35
$\mathcal{D}_{03}$	2376	77	σd	2	350	2	0.18
			$\pi\mathcal{D}_{12}$	1	173–176	31	0.12
$\mathcal{D}_{12}$	2150	110	πd	1	221–223	33	0.15
Δ	1232	117	πN	1	226–229	117	0.16
σ	303	126	$\pi\pi$	0	72–80	126	0.09

M.P. Platonova, V.I. Kukulin, *Phys.Rev.D* 103 (2021) 11, 1140250, Isospin symmetry breaking in double-pion production in the region of d*(2380) and the scalar σ meson

$$\Gamma_{R\to ab}(p) = \Gamma_{R\to ab}^{(0)} \left(\frac{p}{p_0}\right)^{2l+1} \left(\frac{p_0^2 + \Lambda_{ab}^2}{p^2 + \Lambda_{ab}^2}\right)^{l+1},$$

PHYSICAL REVIEW C **107**, 015202 (2023)

Resonant behavior of the $pp \to \{pp\}_s\pi^0$ reaction at the energy $\sqrt{s} = 2.65$ GeV

D. Tsirkov,[1] B. Baimurzinova,[1,2,3,*] V. Komarov,[1] A. Kulikov,[1] A. Kunsafina,[1,2,3] V. Kurbatov,[1]
Zh. Kurmanalyiev,[1,2,3] and Yu. Uzikov[1,4,5]

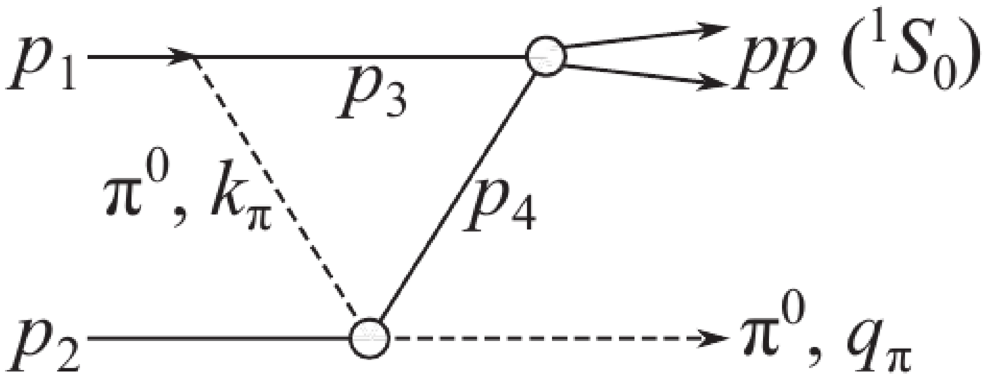


FIG. 6. The OPE mechanism of the reaction $pp \to \{pp\}_s\pi^0$.

shown. Note that the slope changes its sign in the region of the observed peak.

V. DISCUSSION