Excitation of $d^*(2380)$ dibaryon in the coherent $pd \to pd\pi\pi$ channel

and other dibaryon studies at ANKE

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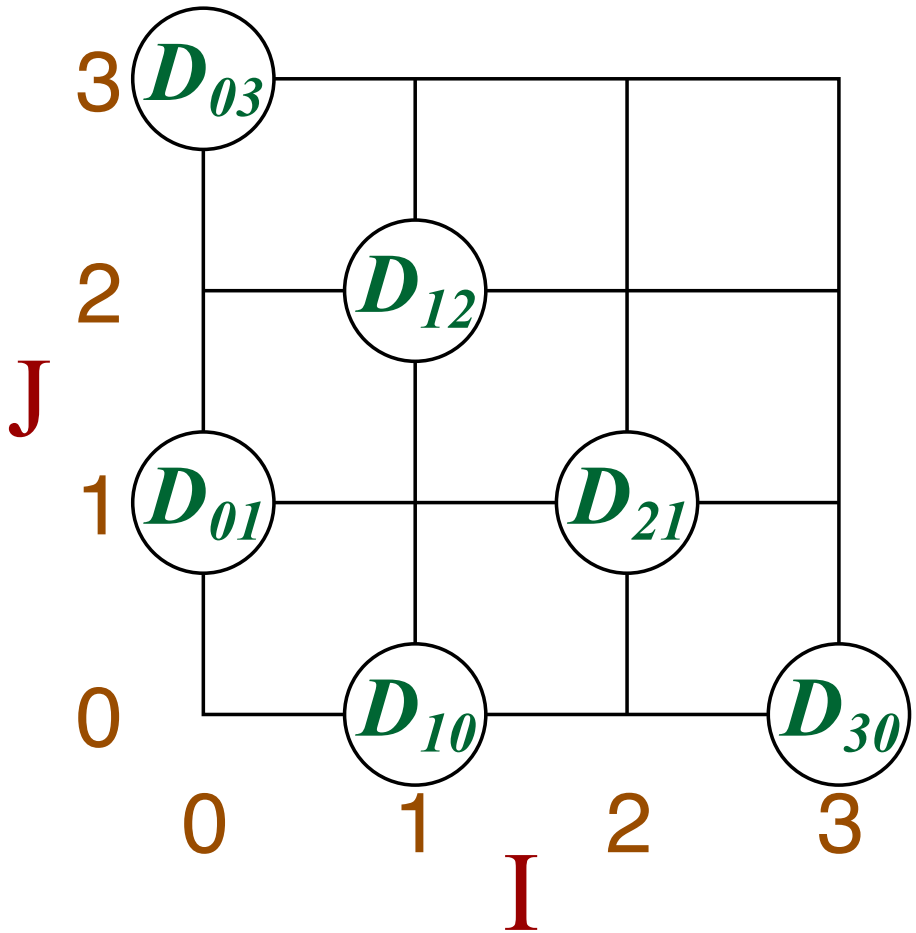
First predictions of dibaryon resonances

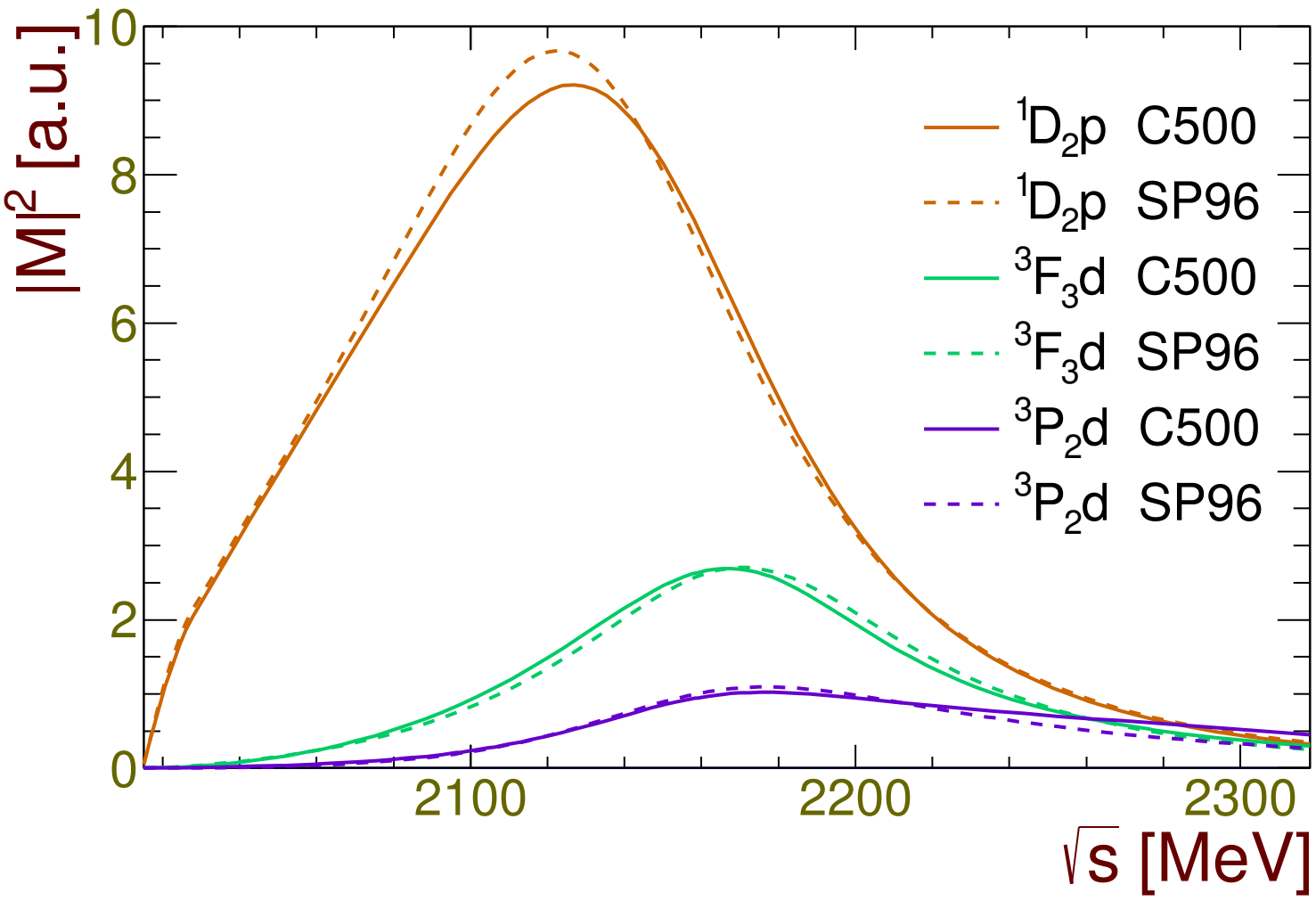


First classification based on SU(6) symmetry

D_{IJ}, where
I is isospin
J is ang. momentum

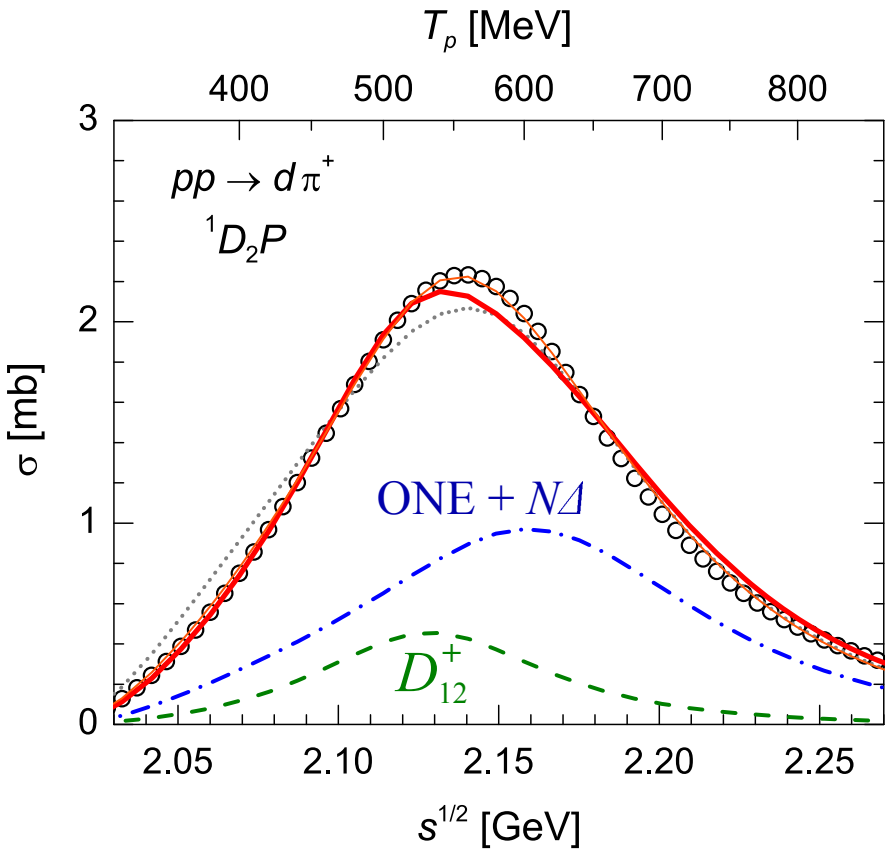
R.J. Oakes, Phys. Rev. **131**, 2239 (1963)
F.J. Dyson and N.H. Xuong, Phys. Rev. Lett. **13**, 815 (1964)

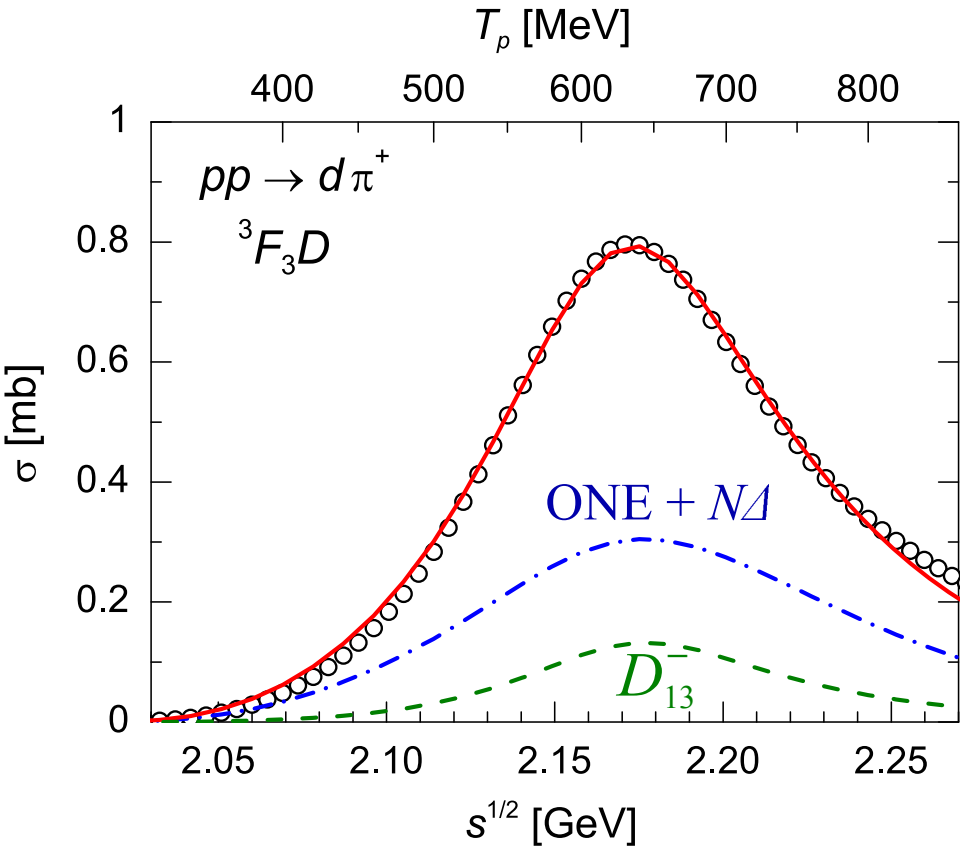
Dibaryon resonances in $pp \to d\pi^+$



$^1D_2 - D_{12}^+$ $^3F_3 - D_{13}^-$ $^3P_2 - D_{12}^-$

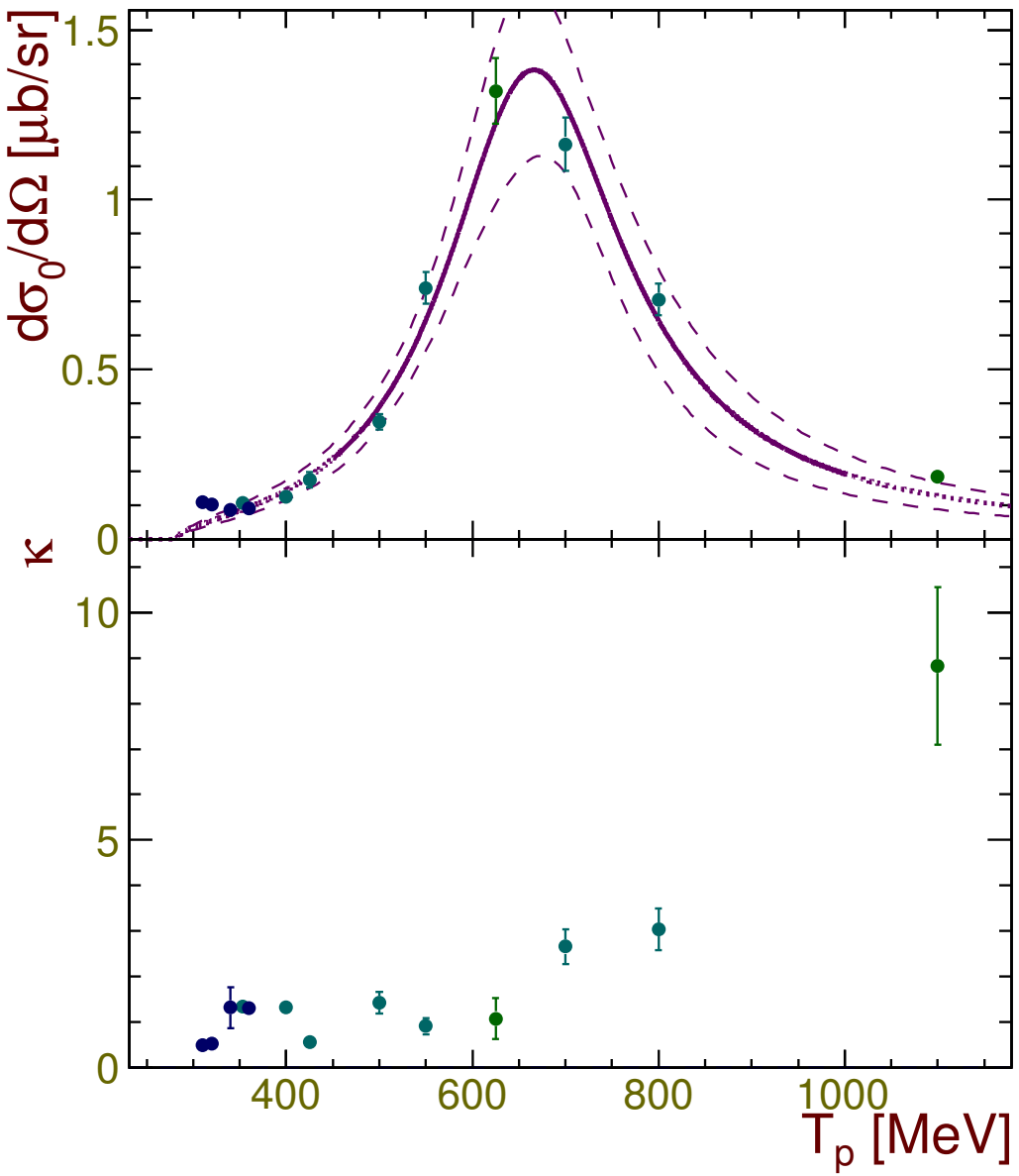
Dibaryon contributions into $^1D_2$ and $^3F_3$

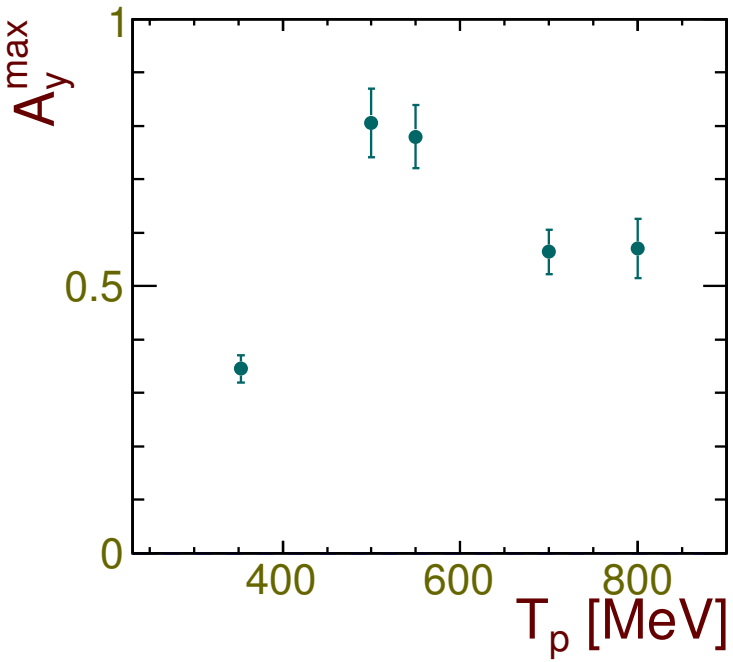




M.N. Platonova, V.I. Kukulin, Nucl. Phys. A **946**, 117 (2016)

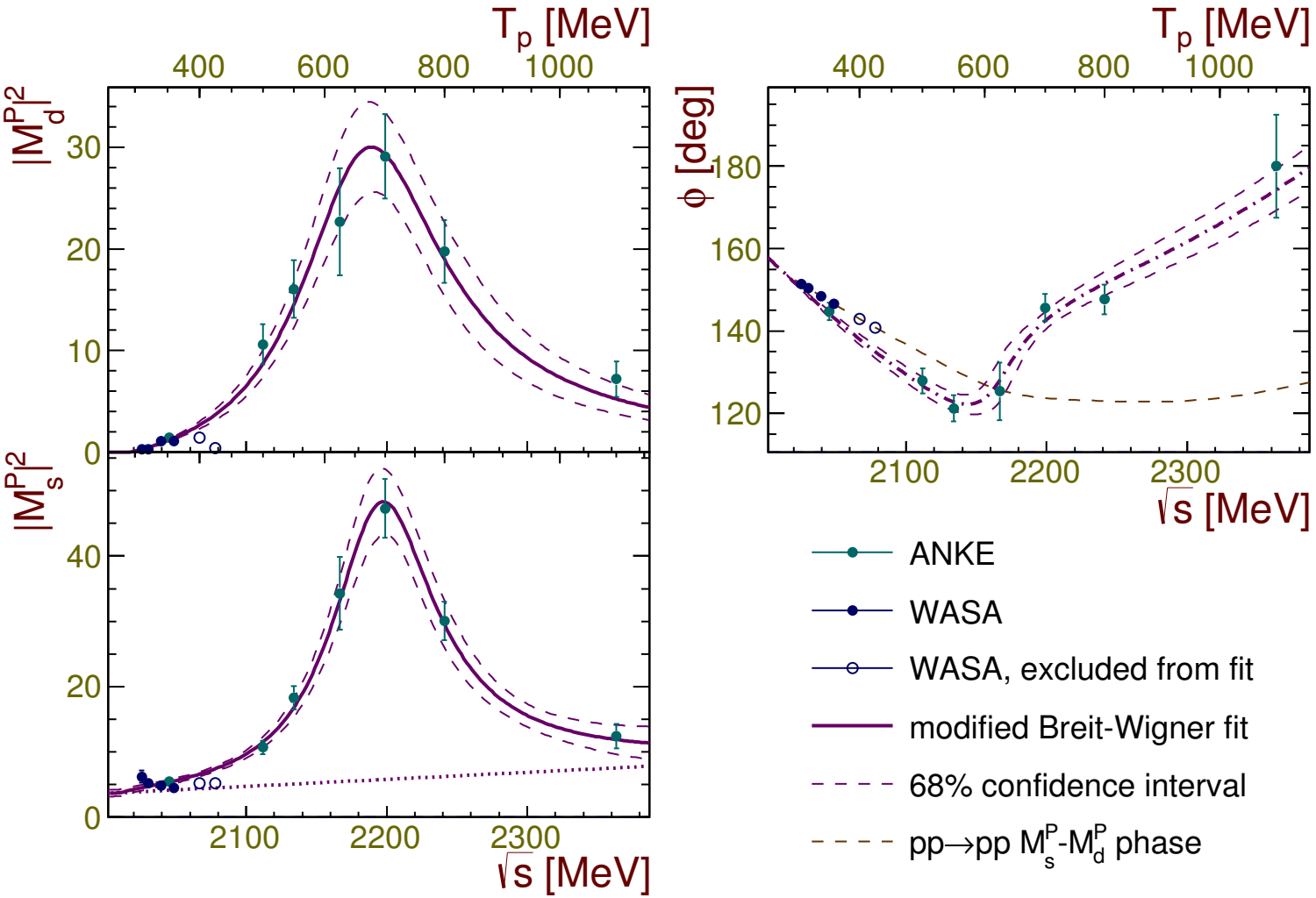
Dibaryon resonances in $pp \to \{pp\}_s\pi^0$





new ANKE data
published ANKE data
published WASA data
Breit-Wigner fit
68% confidence interval

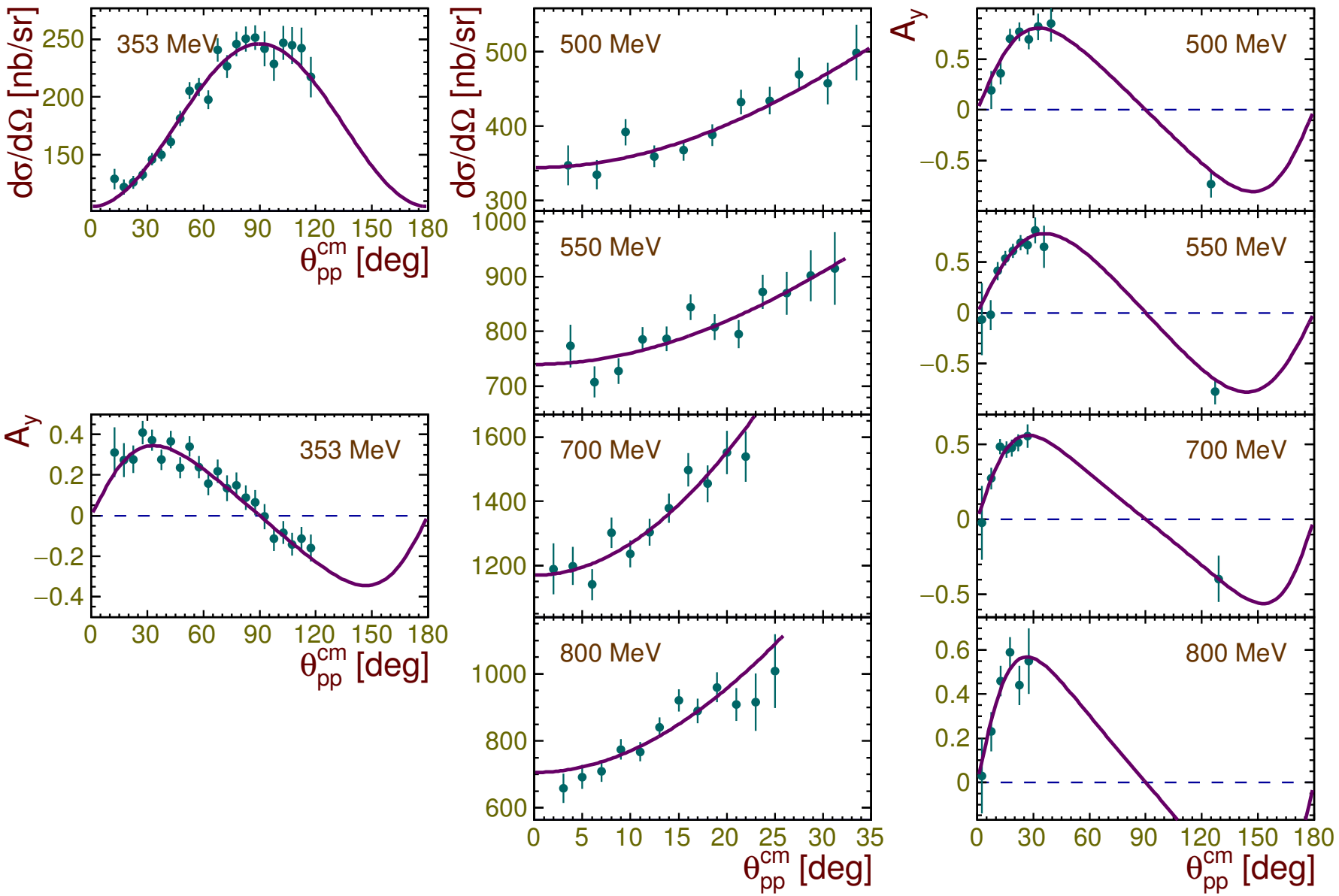
Dibaryon resonances in $pp \to \{pp\}_s\pi^0$



$^3P_2 - D_{12}^-$

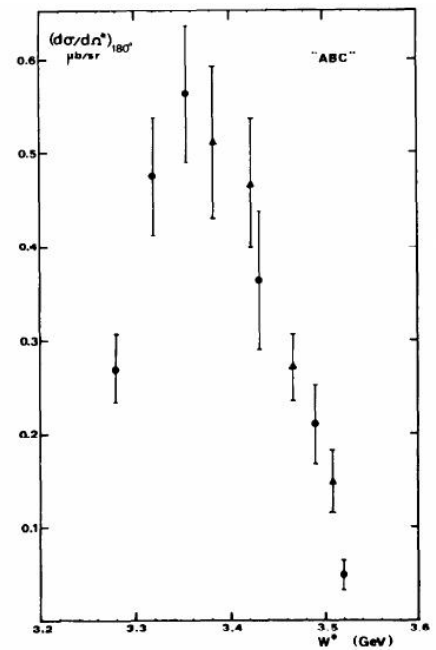
$^3P_0 - D_{10}^-$

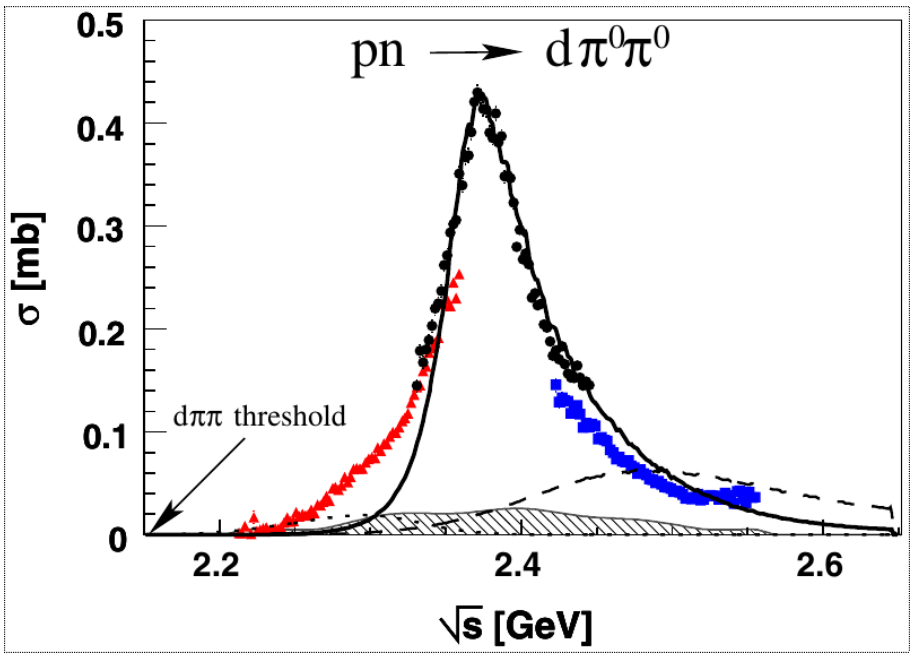
Measured cross section $d\sigma/d\Omega$ and analyzing power A_y



$d^*(2380)$ dibaryon resonance

For the first time a cross section peak associated with the ABC effect was observed at Saturne [Nucl. Phys. B 67, 1 (1973)], but didn't draw particular attention.



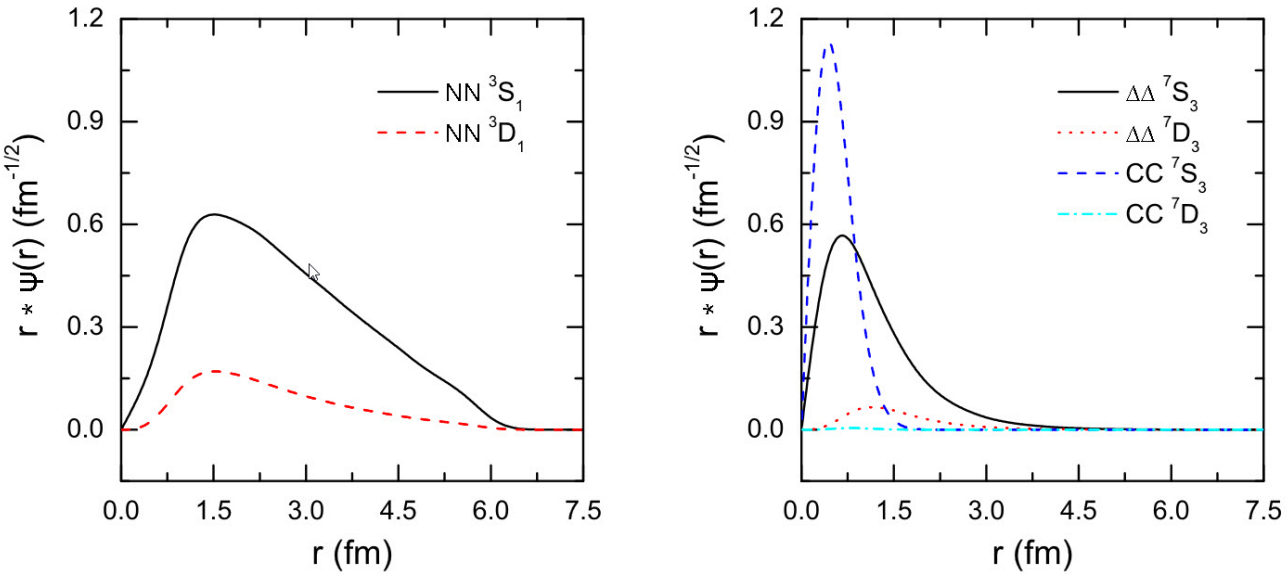


WASA studies have found that it is a manifestation of the $d^*(2380)$ dibaryon resonance D_{03}^{+}, a candidate for the true dibaryon.

Contribution of "true" dibaryons into $d^*(2380)$

Chiral constituent-quark models: $\approx 2/3$ hidden-color contribution

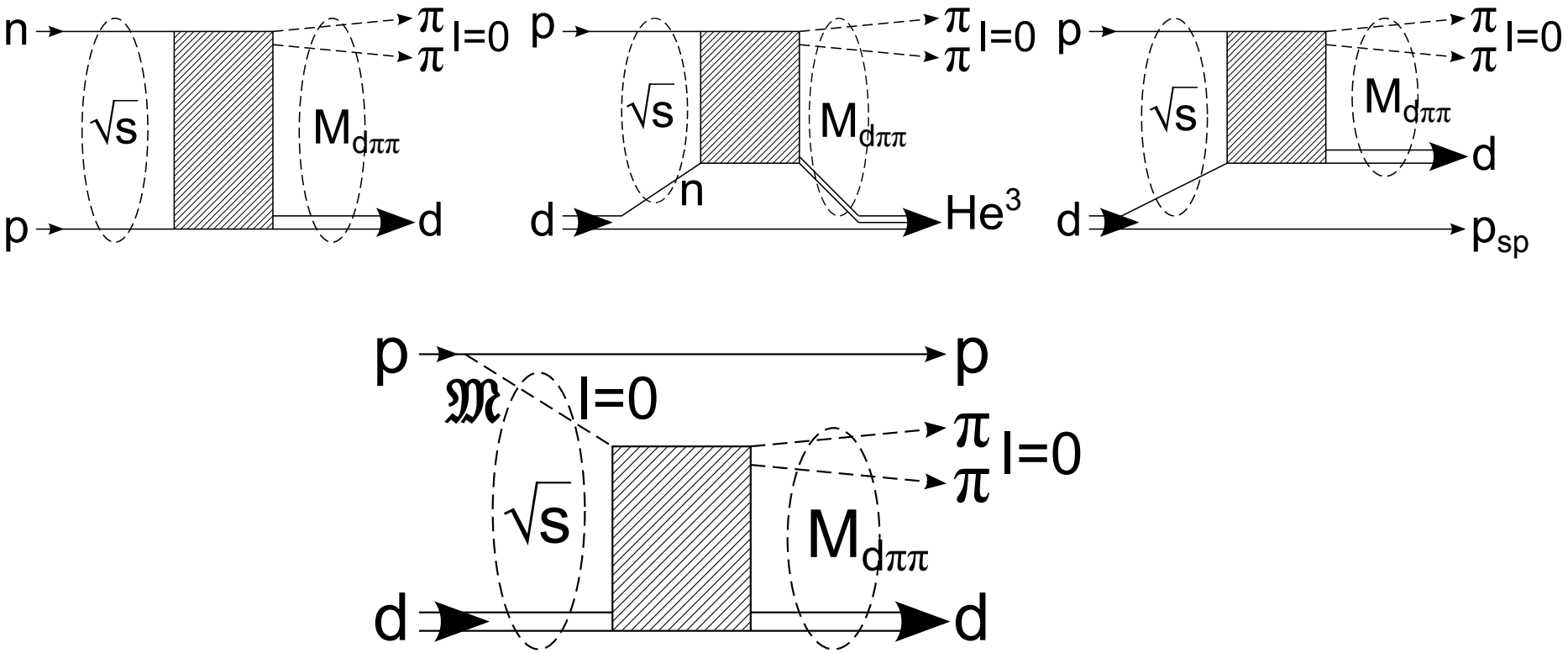
Y. Dong et al., Phys. Rev. C **94**, 014003 (2016);
Qi-F. Lu et al., Phys. Rev. D **96**, 014036 (2017).



Traditional meson-baryon interpretation

J.A. Niskanen, Phys. Rev. C **95**, 054002 (2017);
A. Gal, Phys. Lett. B **769**, 436 (2017);
A. Gal, arXiv:1803.08788 [nucl-th] (2018).

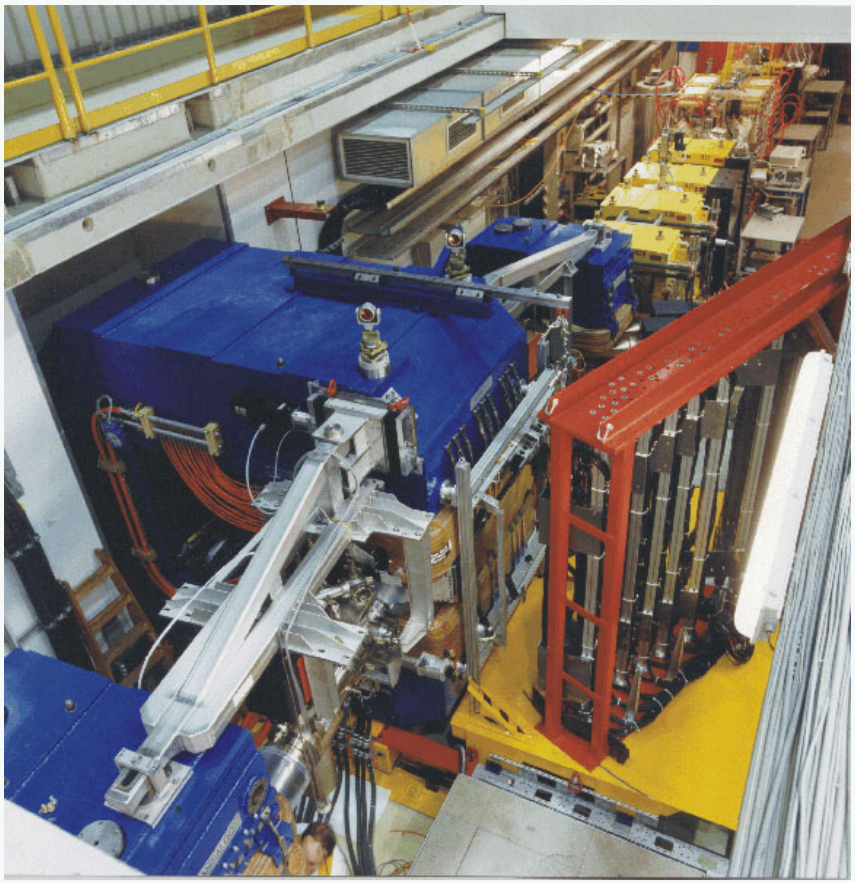
Reaction mechanisms with $d^*(2380)$ excitation



Experimental setup

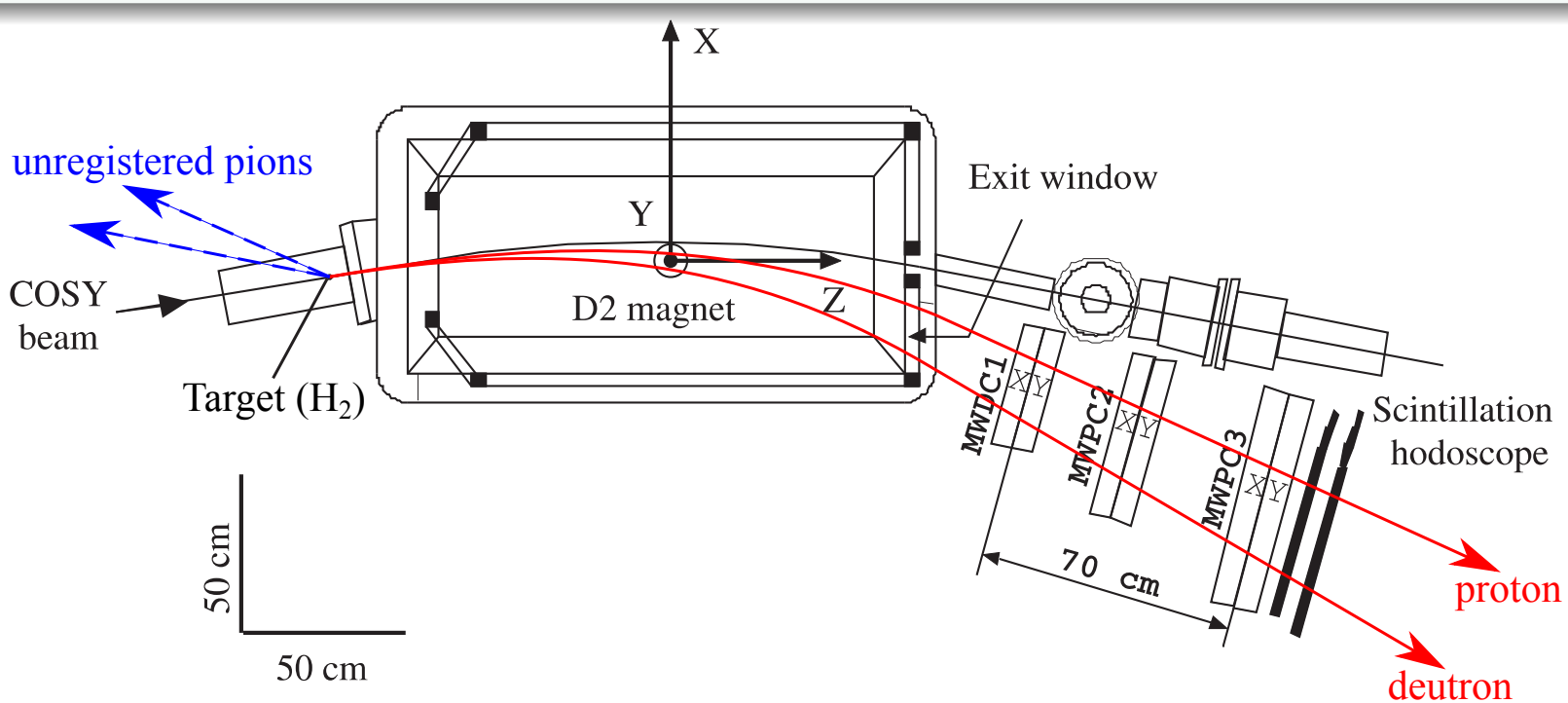
COSY synchrotron

ANKE spectrometer



Experimental setup

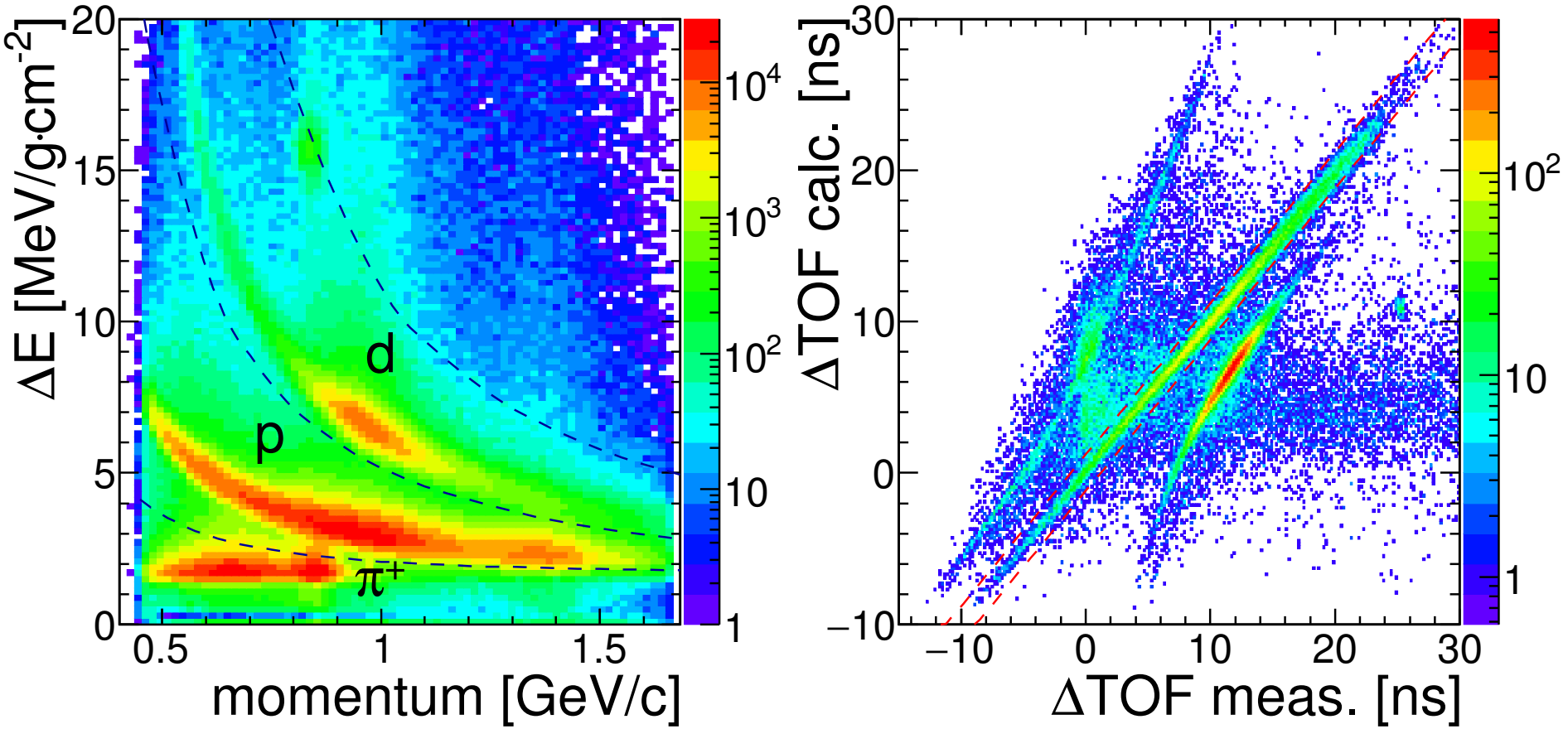
- Forward detector of the ANKE spectrometer at the synchrotron COSY–Jülich
- Proton beam, deuterium target



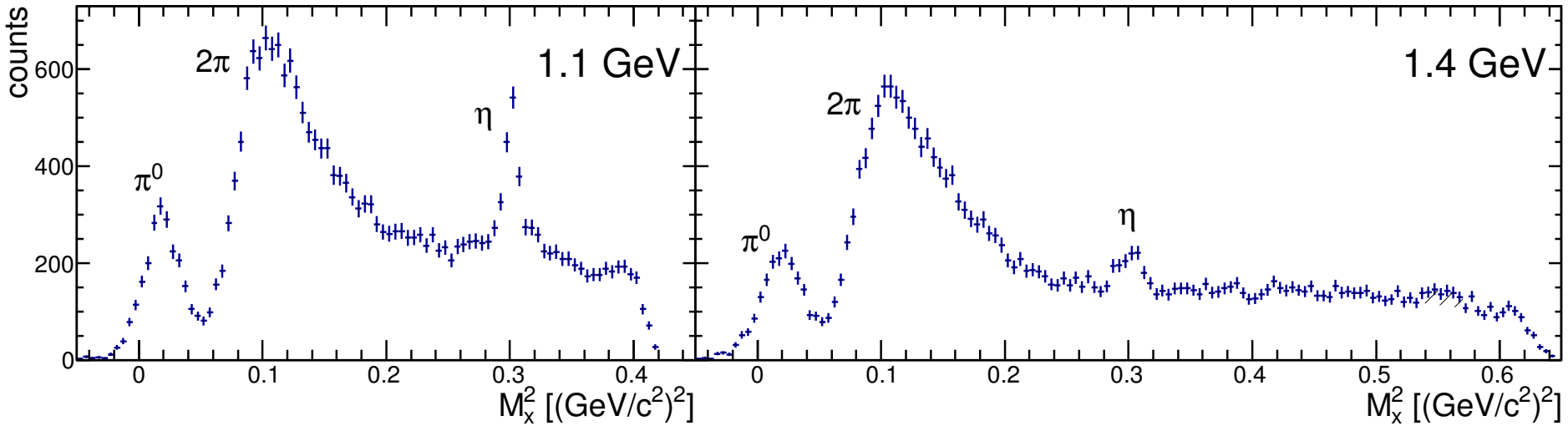
Allows measuring

- Differential cross section $d\sigma/d\Omega$

Selecting pd pairs



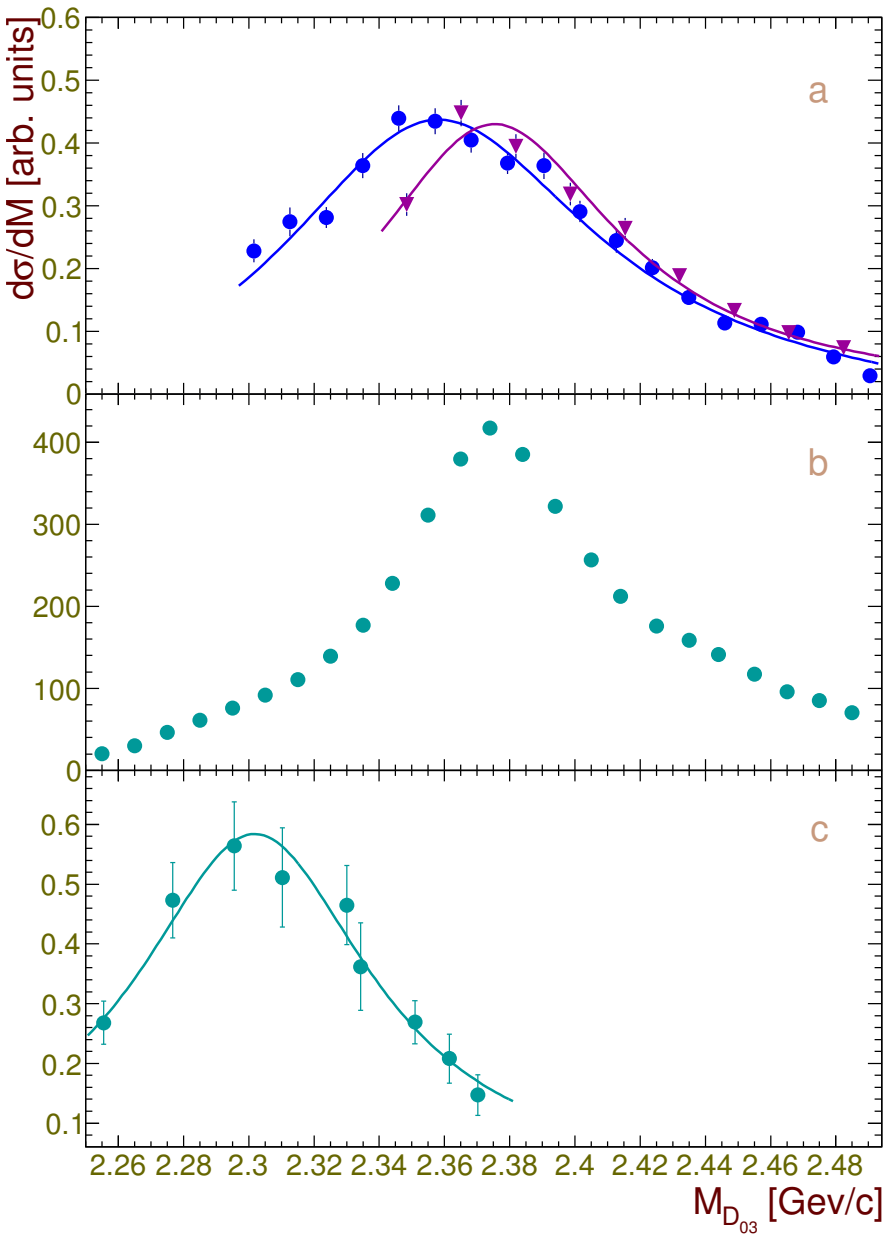
Missing mass distributions



Missing mass cuts

$$
\begin{aligned}
0.073\ (\mathrm{GeV}/c^2)^2 < \quad M^2_{\pi\pi} \quad &< 0.17\ (\mathrm{GeV}/c^2)^2, \\
0.982 < \ \cos\theta^{\mathrm{cm}}_{p} \ &< 1, \\
-1 < \cos\theta^{d\pi\pi}_{d} \ &< -0.98.
\end{aligned}
$$

Spectra of the invariant mass $M_{d\pi\pi}$



Spectra of invariant mass $M_{d\pi\pi}$

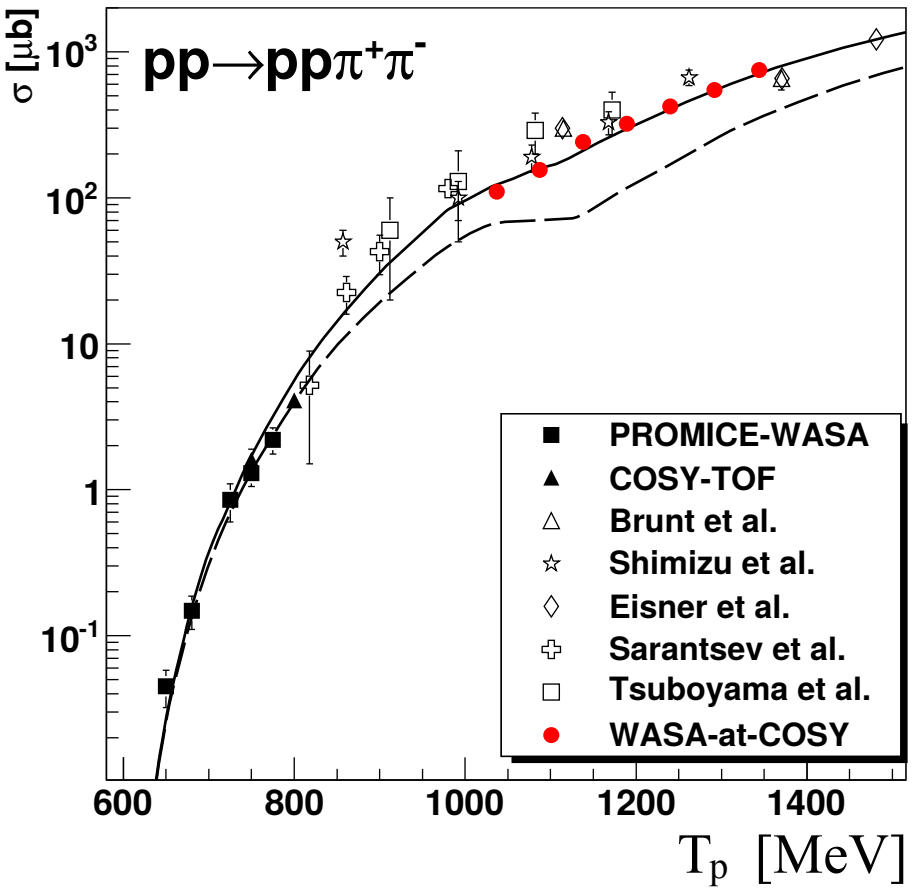
(a) via meson exchange (ANKE)
- ● at 1.1 GeV
- ▼ at 1.4 GeV

(b) in a quasi-free np collision (WASA)

(c) for the reaction $dp \to \mathrm{He}^3 + \pi^0\pi^0$ (Saturne)

T_p [MeV]	$\langle M_{d\pi\pi} \rangle$ [MeV/c^2]	Γ [MeV/c^2]
1.1	2357	115
1.4	2372	92
WASA	2380	70
Saturne	2301	89

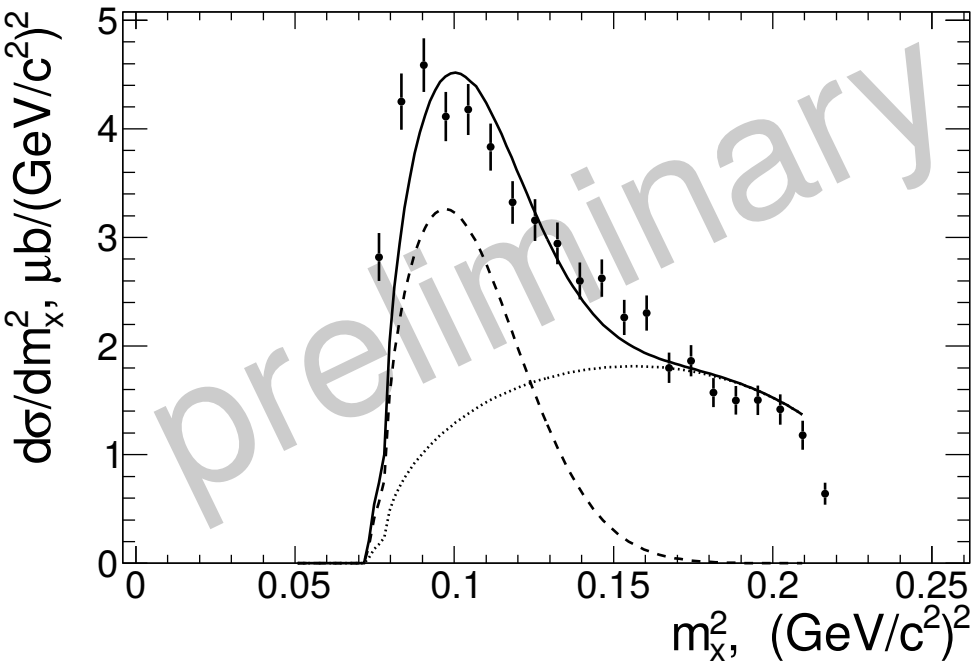
Charge-3 D_{21}^{+} dibaryon resonance

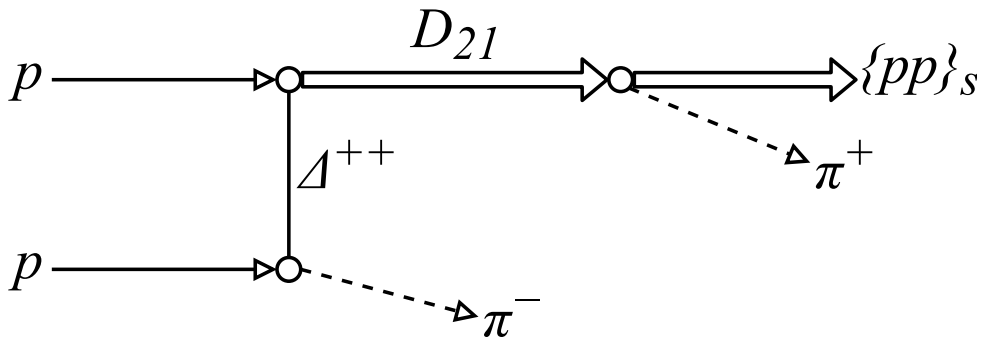


P. Adlarson et al., WASA@COSY, "An isotensor dibaryon in the $pp \to pp\pi^+\pi^-$ reaction?", arXiv:1803.03193 [nucl-ex] (March 2018)

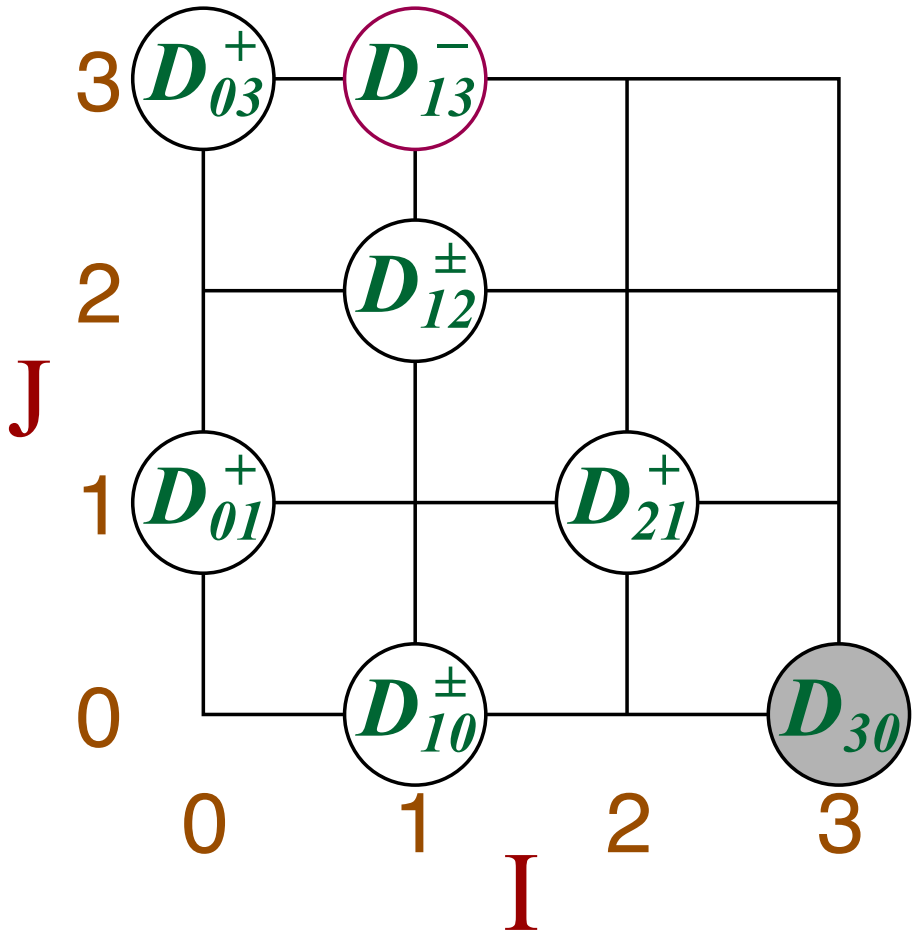
Charge-3 D_{21}^{+} dibaryon resonance at ANKE?

Possible indication on observation of D_{21} dibaryon in $pp \to D_{21}\pi^- \to \{pp\}_s\pi^+\pi^-$ channel





Known dibaryons



D_{01}^{+} deuteron

D_{10}^{+} ${}^1S_0$ diproton, ${}^1S_0$ $\{pn\}_s$

D_{10}^{-} ${}^3P_0$ $(pp \to \{pp\}_s\pi^0)$

D_{03}^{+} $d^*(2380)$ $(pd \to pd\pi\pi)$

D_{12}^{+} ${}^1D_2$ $(pp \to d\pi^+)$

D_{12}^{-} ${}^3P_2$ $(pp \to d\pi^+/\{pp\}_s\pi^0)$

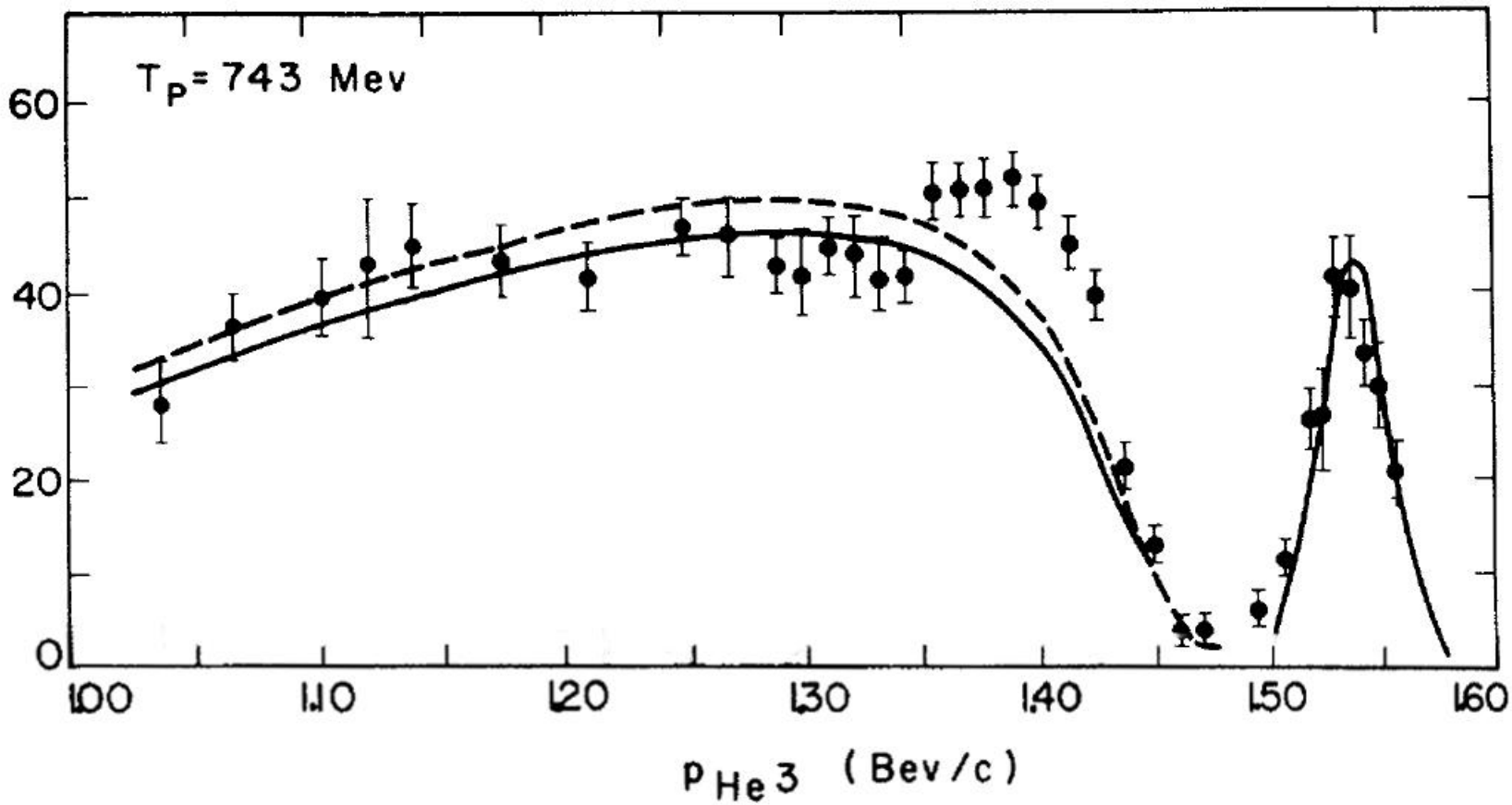
D_{21}^{+} charge-3 $(pp \to pp\pi^+\pi^-)$

D_{13}^{-} ${}^3F_3$ $(pp \to d\pi^+)$

D_{30} charge-4 (???)

ABC effect

The ABC effect is the narrow enhancement in the $M_{\pi\pi}$ invariant mass spectra of $\pi\pi$ pairs near the threshold; it's named after [A. Abashian, N.E. Booth and K.M. Crowe, Phys. Rev. Lett. 5, 258 (1960)].

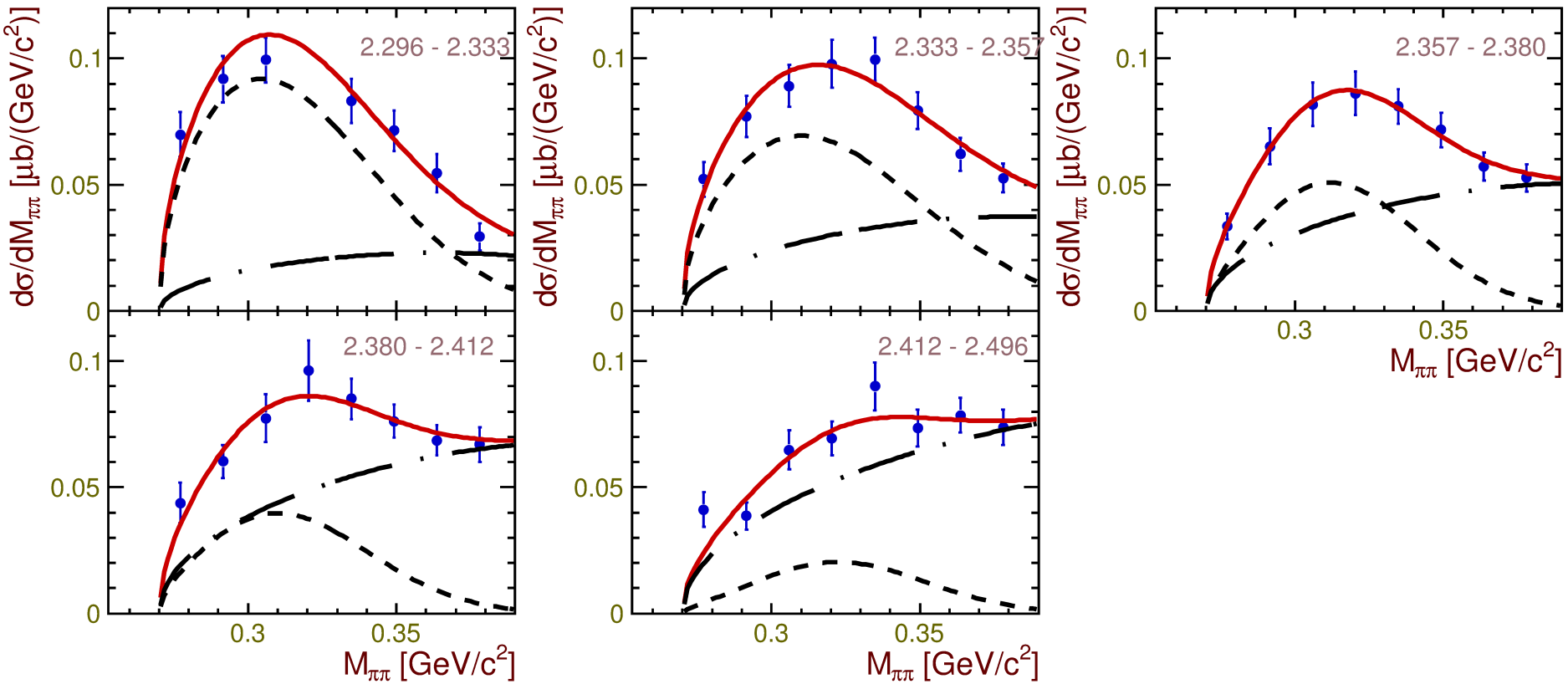


ABC effect

Main features

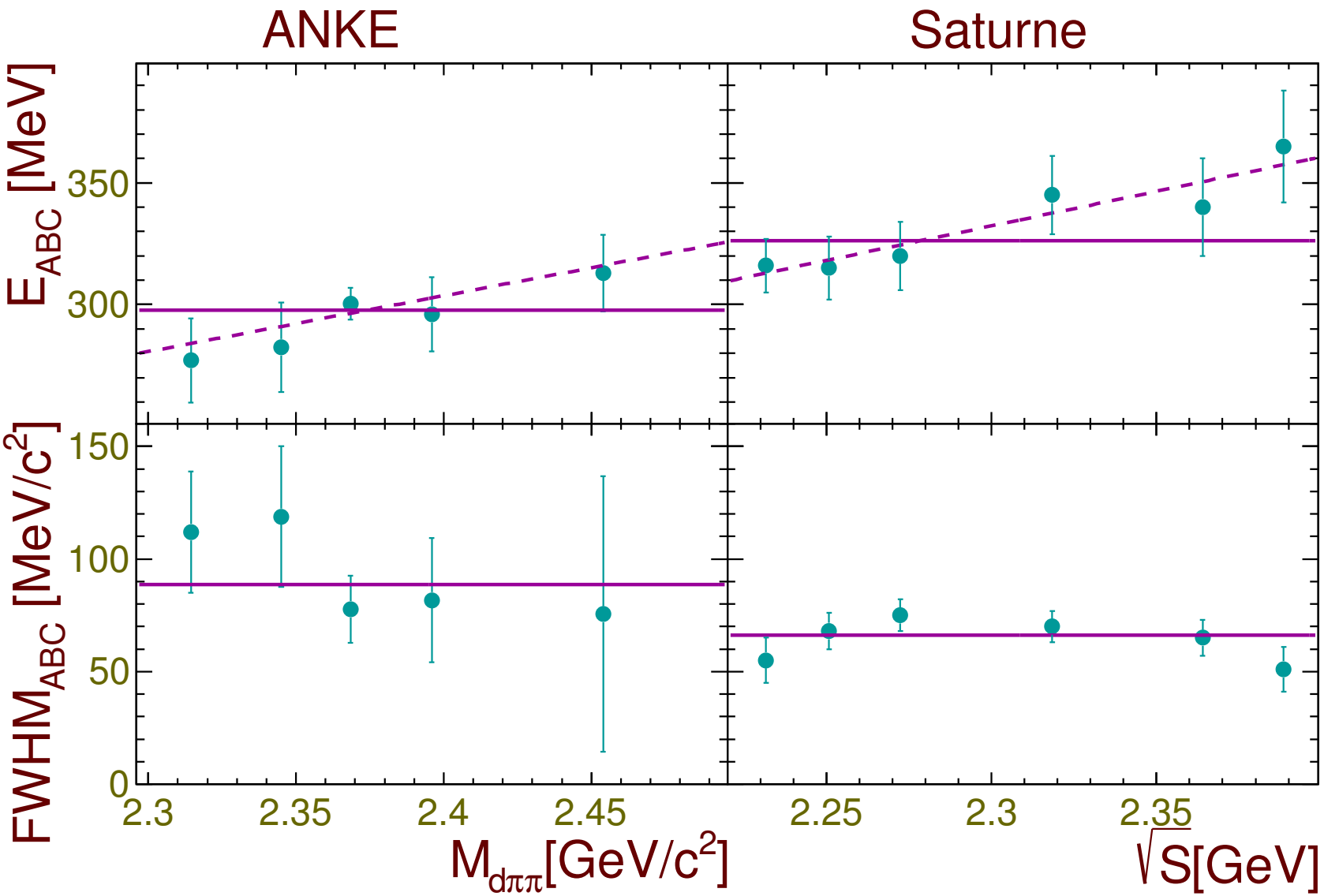
- complicated structure of the $\pi\pi$ invariant mass spectra
- isoscalar nature of the $\pi\pi$ pair
- presence of the effect only in reactions accompanied by production of the bound light nucleus: d, ^{3}He, ^{4}He
- strong peaking of angular distribution in the forward and backward direction
- resonance behavior of the cross section in dependence on the initial energy

ABC effect at ANKE



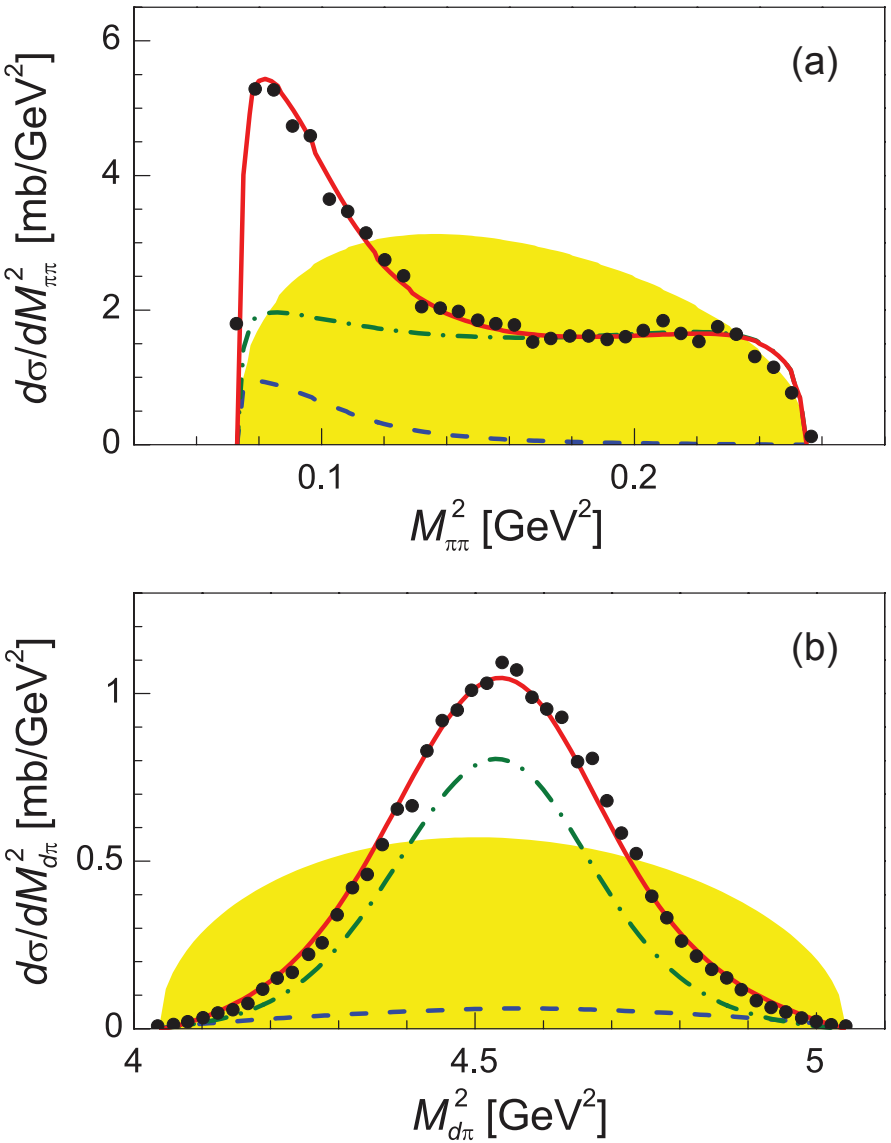
Spectra of invariant mass $M_{\pi\pi}$ at 1.1 GeV in different $M_{d\pi\pi}$ intervals. The curves show decomposition of the spectra into the Gaussian and phase space contributions.

Parameters of the ABC peak in different $M_{d\pi\pi}$ intervals



Possible origin of the ABC peak

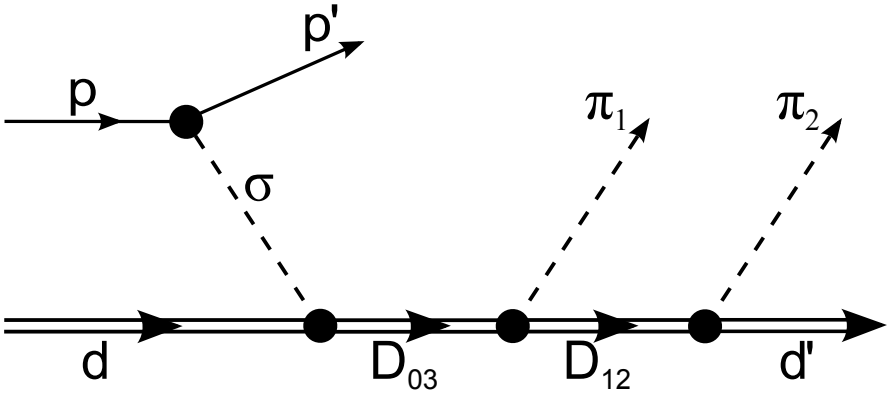
M.N. Platonova, V.I. Kukulin, Phys. Rev. C **87**, 025202 (2013)

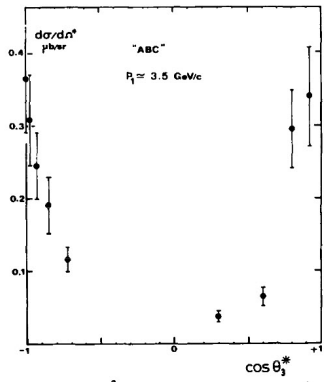


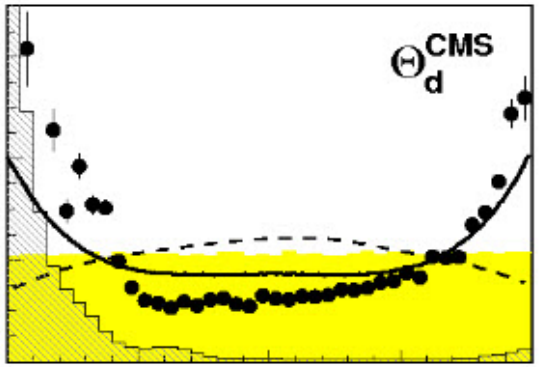
$$D_{03} \to N + N$$
$$\to \dots$$
$$\to D_{12} + \pi \to N + N + \pi$$
$$\to D_{12} + \pi \to \dots$$
$$\to D_{12} + \pi \to d + (\pi + \pi)_{I=0}$$
$$\to d + \sigma \to d + (\pi + \pi)_{I=0}$$

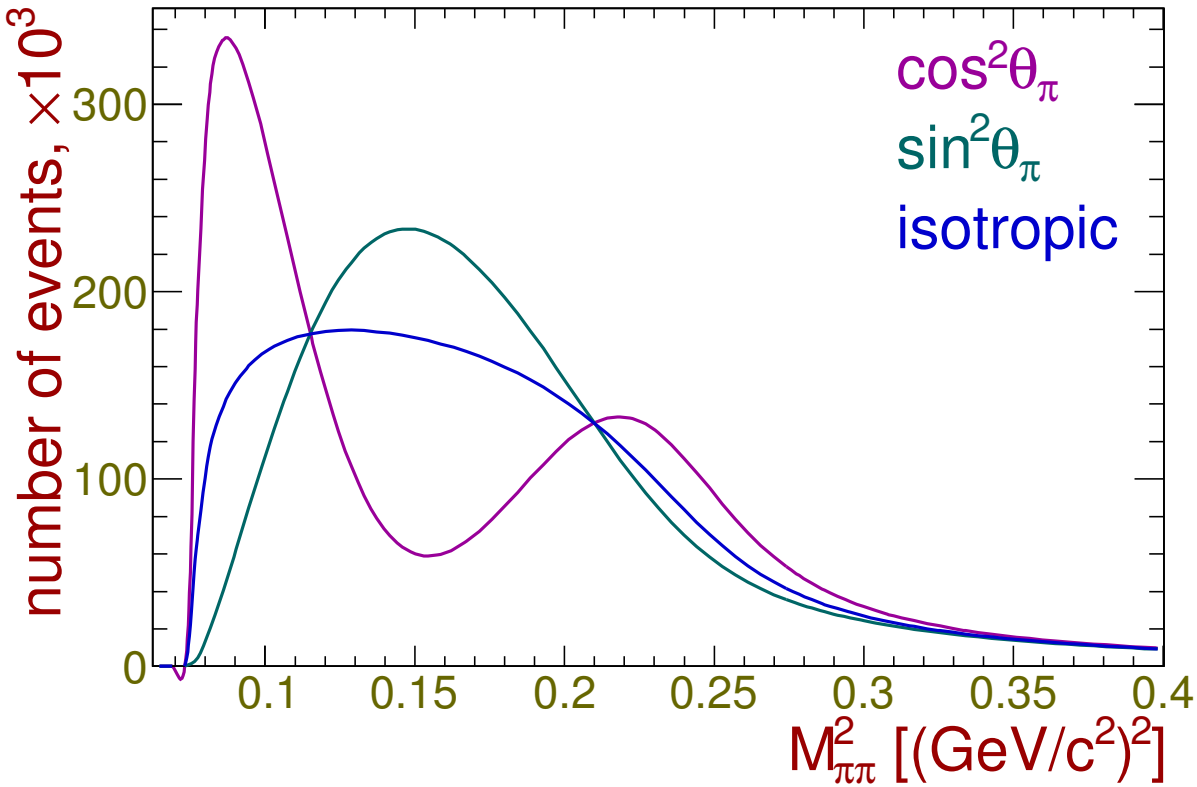
Here:
$m_\sigma \approx 300$ MeV,
$\Gamma_\sigma \approx 100$ MeV
PDG:
$m_\sigma \approx 400$–550 MeV,
$\Gamma_\sigma \approx 400$–$700$ MeV

Possible origin of the ABC peak





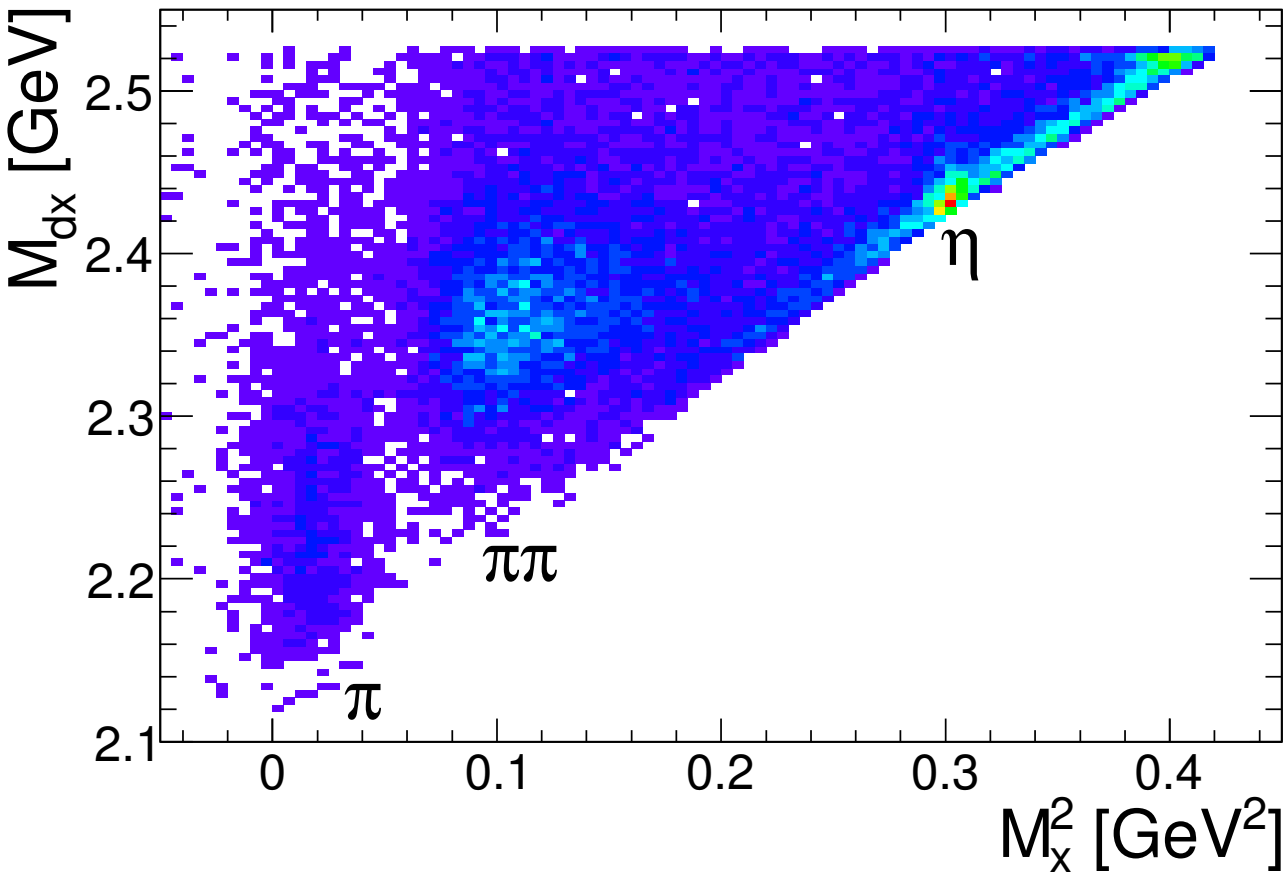




Peak: 275 MeV
FWHM: 130 MeV

Outlook

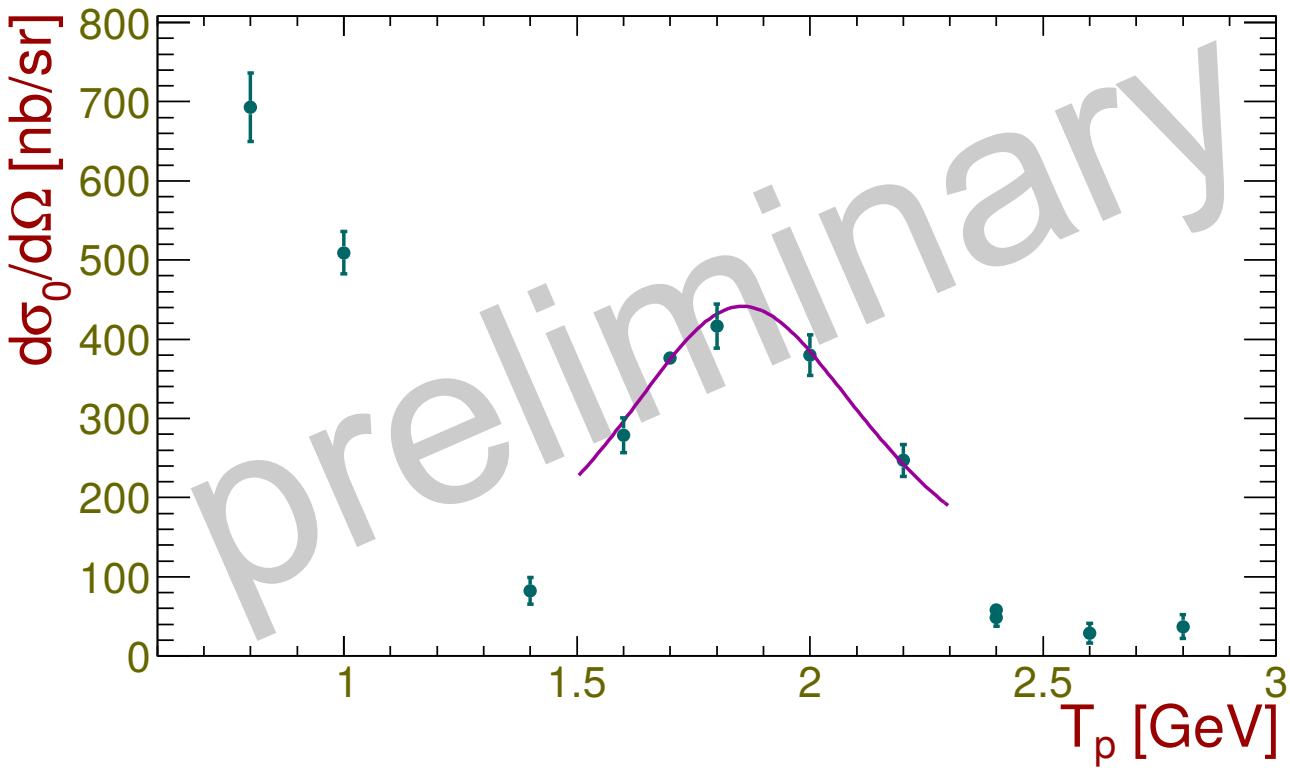
Possible observation of $N^*(1535)N$ dibaryon in $pd \to p\{N^*(1535)N\} \to pd\eta$ channel



$M_{d\eta}$ peak position close to $N^*(1535)N$ mass

Outlook

A second peak in the energy spectrum of the $pp \to \{pp\}_s\pi^0$ forward cross section.



$$M = 2646 \pm 5 \text{ MeV}, \Gamma = 132 \pm 14 \text{ MeV}$$

$\{N\Delta(1700)\}$? $\{\Delta(1232)N^*(1440)\}$? Or something else?

Summary

- Dibaryon resonances are a well established experimental fact. The data on their spectroscopy are being accumulated;
- The ANKE@COSY experiments made an noticeable contribution to the emerging spectroscopy of dibaryon resonances:
  - Parameters of ${}^3P_2$ (D_{13}^-) resonance were specified;
  - An earlier unobserved ${}^3P_0$ (D_{10}^-) resonance was detected;
  - A new method for excitation of the ${}^3D_3$ (D_{03}^+) resonance was studied;
- A new interpretation of the ABC effect was proposed: the manifestation of the successive production of two pions in quasi-collinear kinematics and the presence of a dibaryon resonance between them;
- Further studies on dibaryon resonances are in progress.

Thank you
for you attention!

Any questions?