Wasa-at-COSY

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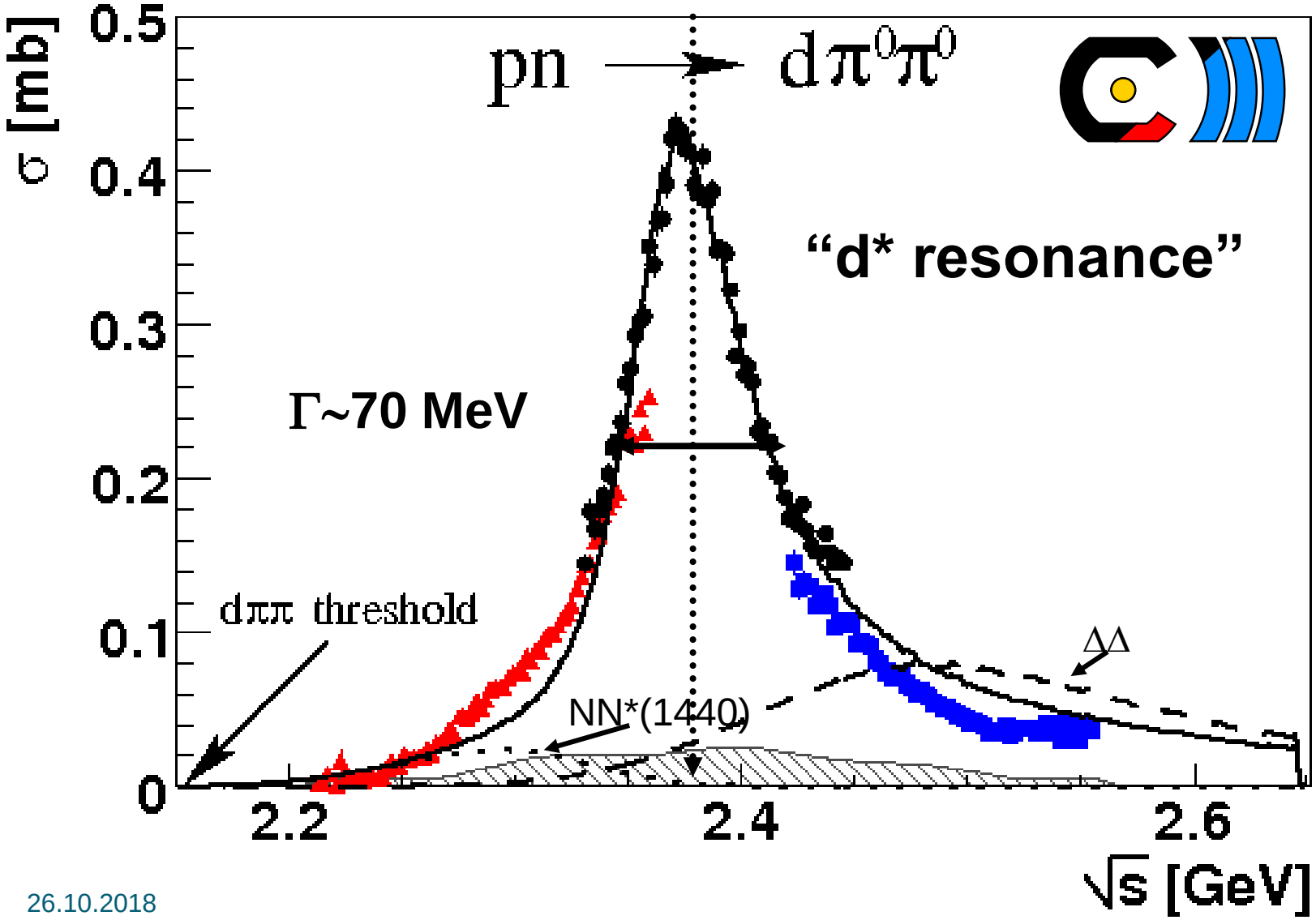
for WASA-at-COSY Collaboration

The Dibaryon resonance d*(2380)

and other higher isospin states

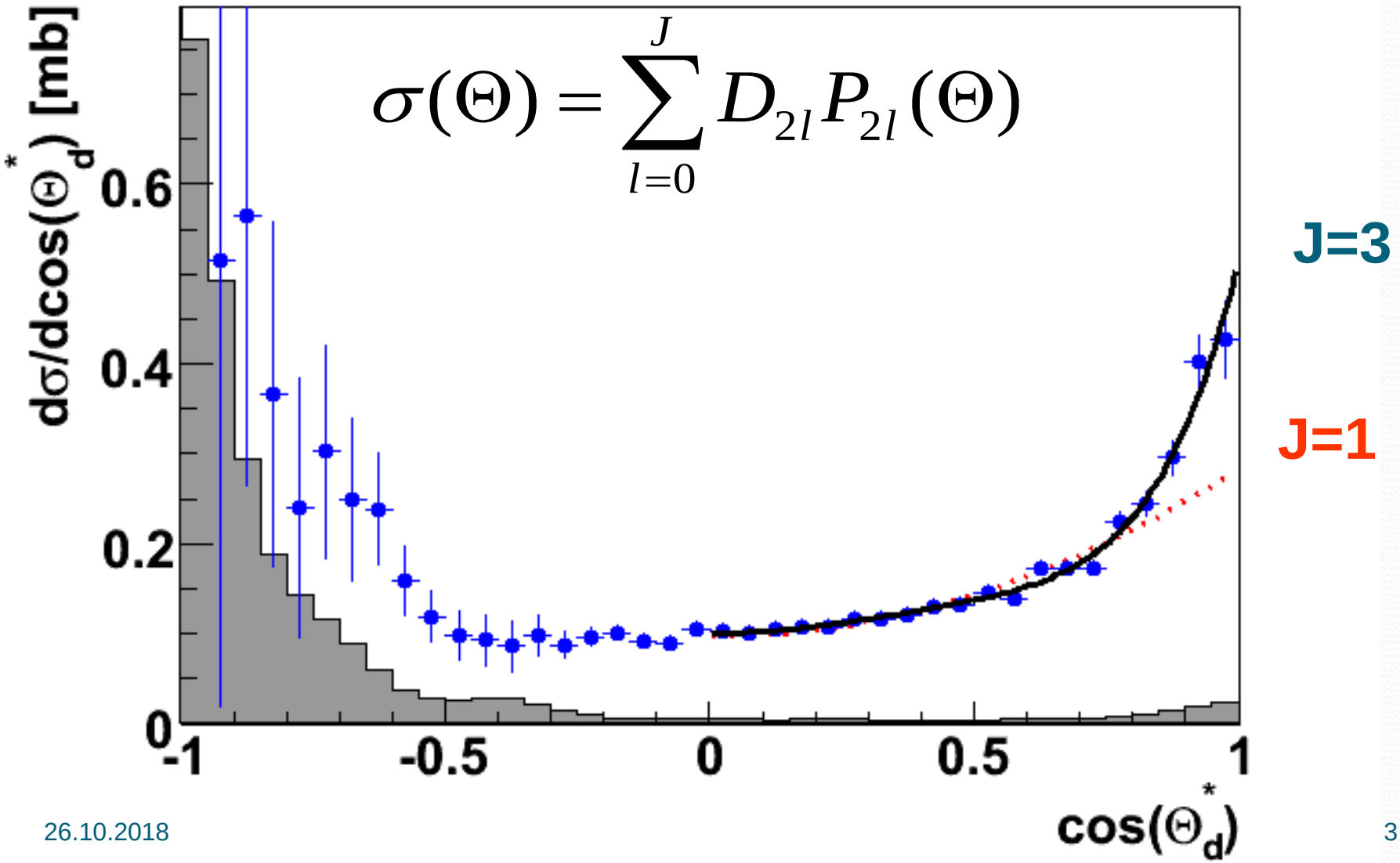
Total cross section $pn \rightarrow d\pi^0\pi^0$

P. Adlarson et. al Phys. Rev. Lett. 106:242302, 2011



Angular distribution in the peak

P. Adlarson et. al Phys. Rev. Lett. 106:242302, 2011



Quantum numbers of the structure

$pn \rightarrow d^* \rightarrow \Delta\Delta \rightarrow d\ \pi^0\pi^0$

Antisymmetrization: $J^P=1^+$ or 3^+ : if $L_{\Delta\Delta}=0$

$$\sigma(\cos\Theta_d^*) = \underbrace{\underbrace{D_0P_0 + D_2P_2}_{1^+} + D_4P_4 + D_6P_6}_{3^+}$$

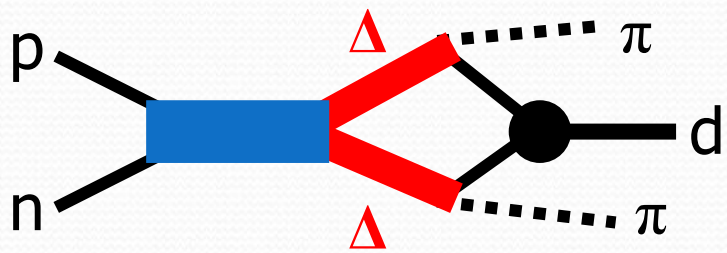
1^+ excluded by $\sigma(\Theta)$.
3^+ assigned

$$\underbrace{pn}_{I=0,1} \rightarrow \underbrace{d}_{I=0}\ \underbrace{\pi^0\pi^0}_{I=0,2} \Bigg\} \Rightarrow I=0$$

The extracted properties of the new particle

$$d^*(2380)$$

$$pn \rightarrow \textbf{dibaryon} \rightarrow \Delta\Delta \rightarrow d\pi^0\pi^0$$



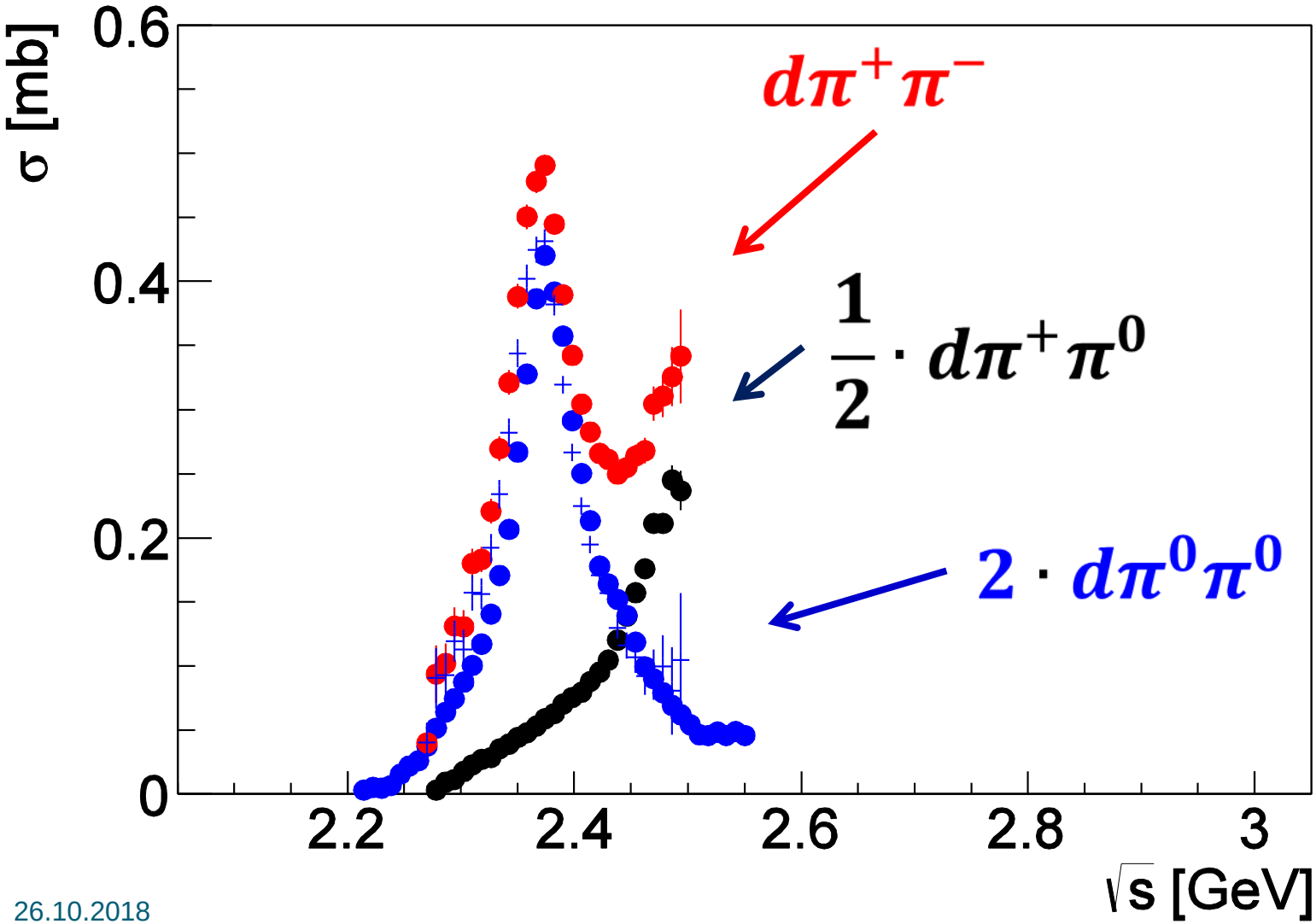
$$I(J^p) = 0(3^+)$$

$$M_{d^*} = 2.38\ GeV \approx 2M_\Delta - 90\ MeV$$

$$\Gamma_{d^*} = 70\ \mathrm{MeV} \ll \Gamma_{\Delta\Delta} = 240\ MeV$$

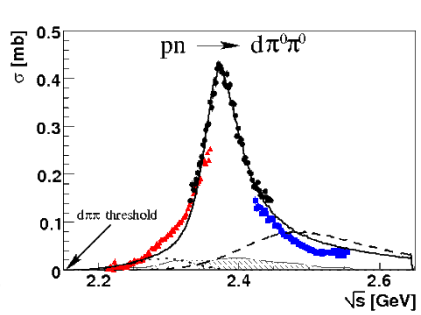
Total cross section pN → dππ

P. Adlarson et. al Phys. Lett. B721 (2013) 229

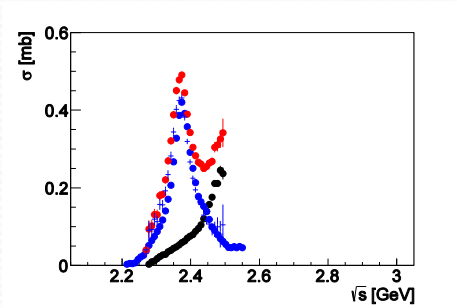


Dibaryon hadronic decays

PRL 106 (2011) 242302

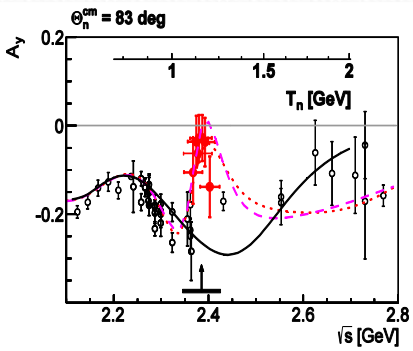


WASA data

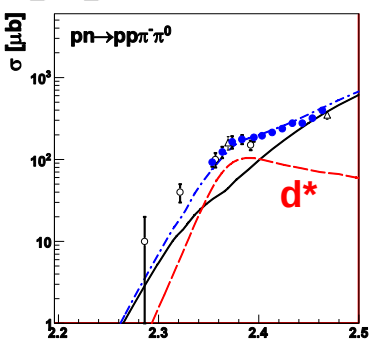


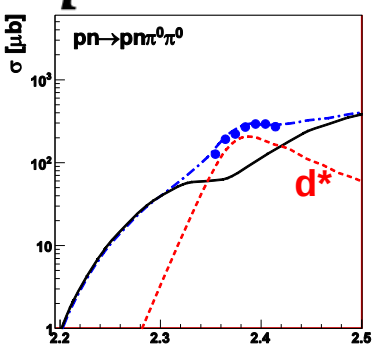
PLB 721 (2013) 229

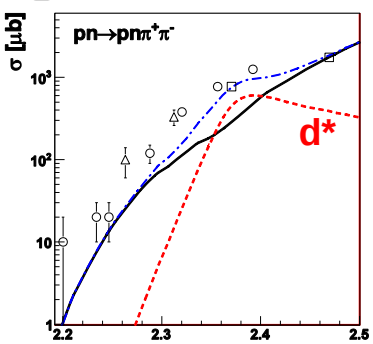
$$pn \rightarrow d^*(2380) \rightarrow d\pi^0\pi^0,\ d\pi^+\pi^-,\ pn,\ pp\pi^-\pi^0,\ pn\pi^0\pi^0,\ pn\pi^+\pi^-$$



PRL 112 (2014) 202301 arXiv:1408.4928







PRC 88 (2013) 055208 arXiv:1409.2659

Total cross section

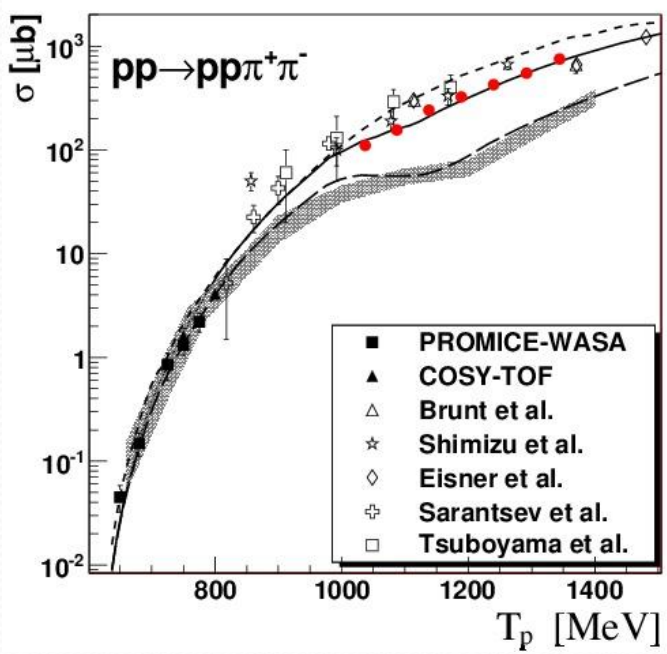
$pp \rightarrow pp\pi^+\pi^-$

Isotensor final state

Predictions • **F. J. Dyson, N-H Xuong PRL. 13(1964) 815**

Reaction was measured by use of the quasifree process in pd collisions

the energy region Tp = 1.08−1.36 GeV corresponding to √s = 2.35 - 2.46 GeV



● - data WASA@COSY

original Valencia calculations
t-channel meson exchange

"modified Valencia" calculations

model with the process
$pp \rightarrow D_{21}\pi^- \rightarrow pp\pi^+\pi^-$

isospin based prediction

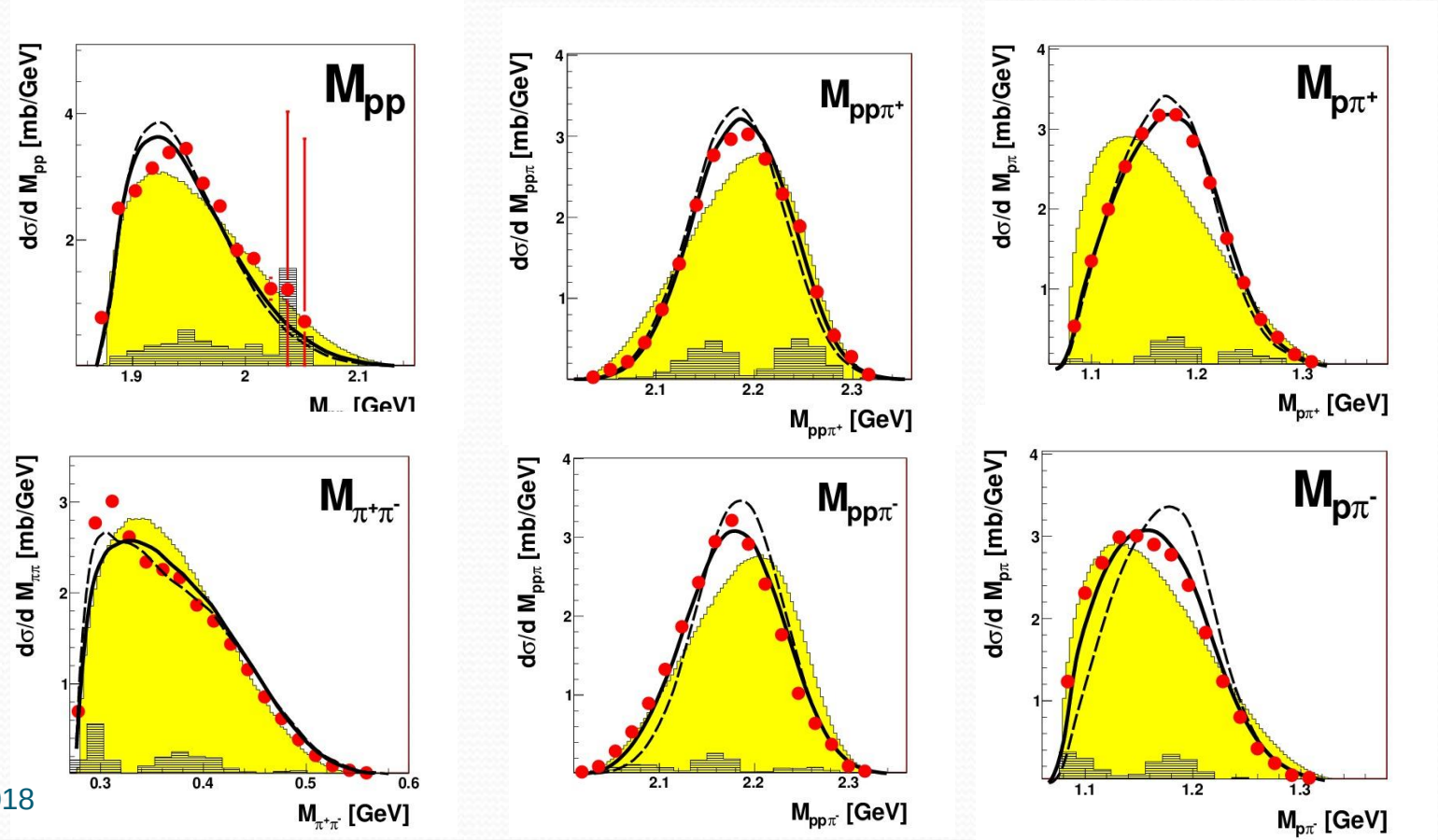
arXiv:1803.03193[nucl-ex]2018

Differential cross sections

- Phase Space
- data
- systematic uncertainties

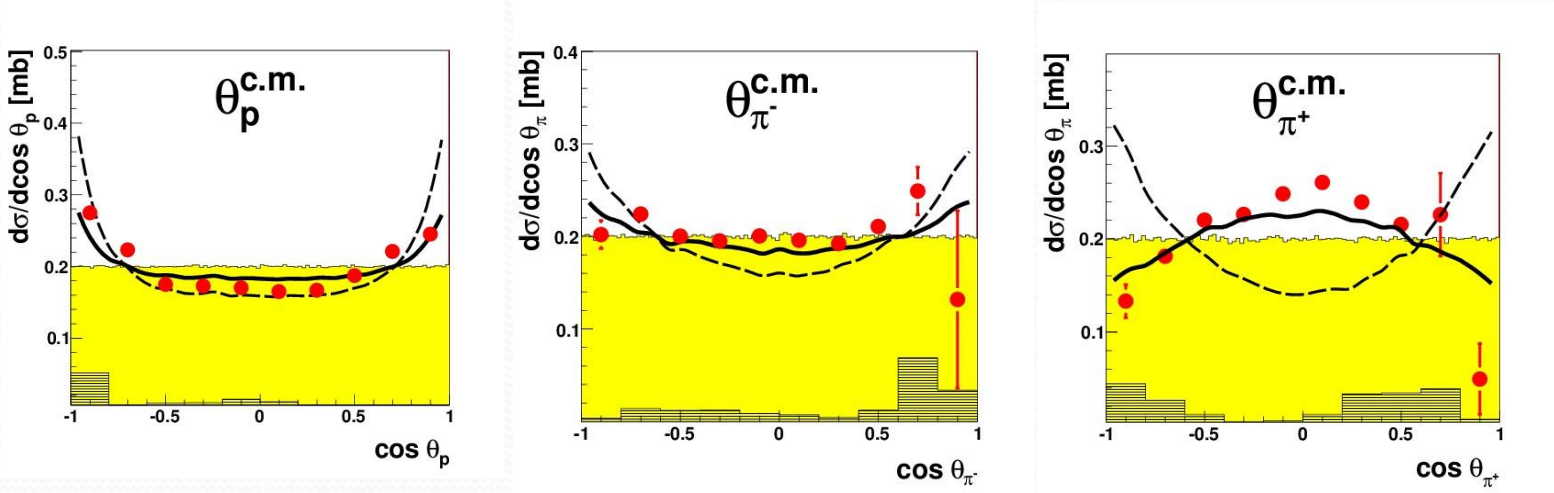
"modified Valencia" calculations

model with the process
$pp \rightarrow D_{21}\pi^- \rightarrow pp\pi^+\pi^-$



Angular distributions

- Phase Space
- data
"modified Valencia" calculations
- systematic uncertainties
model with the process
$pp \rightarrow D_{21}\pi- \rightarrow pp\pi+\pi-$



Conclusion

- Status of the d* Resonance

decay channel	branching	status
d $\pi^0\pi^0$	15 %	observed
d $\pi^+\pi^-$	25 %	observed
pp$\pi^0\pi^-$	7 %	observed
np$\pi^0\pi^0$	(12 %, predicted*)	observed
np$\pi^+\pi^-$	(31 %, predicted*)	HADES
np	(10 %, predicted)	observed

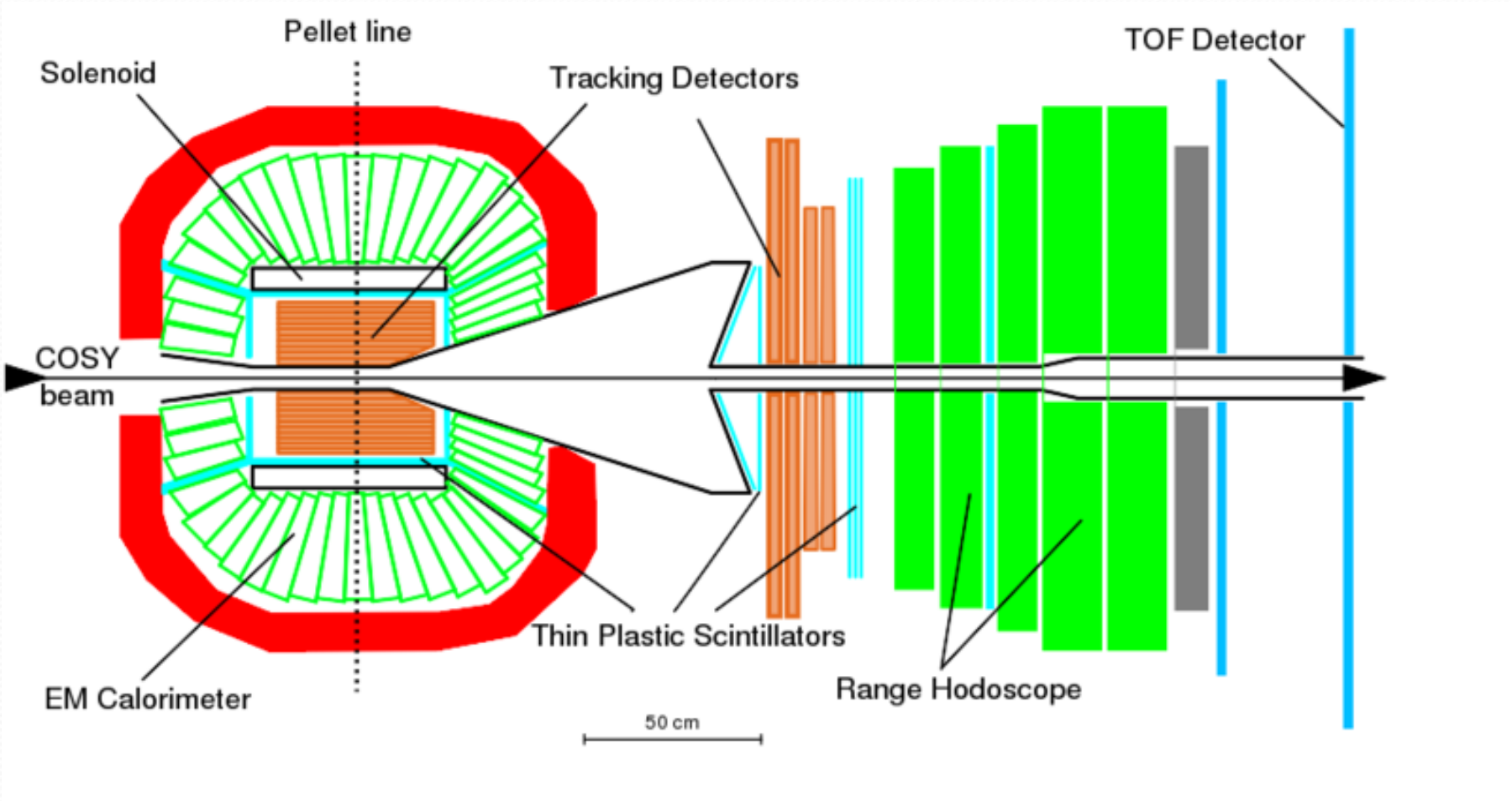
- Dibaryon d*: M=2380 MeV, Γ=70 MeV, $I(J^p)=0(3^+)$

- ppπ+π− channel is the associated production of the theoretically predicted isotensor ΔN state D_{21} M=2140 MeV, Γ=110 MeV

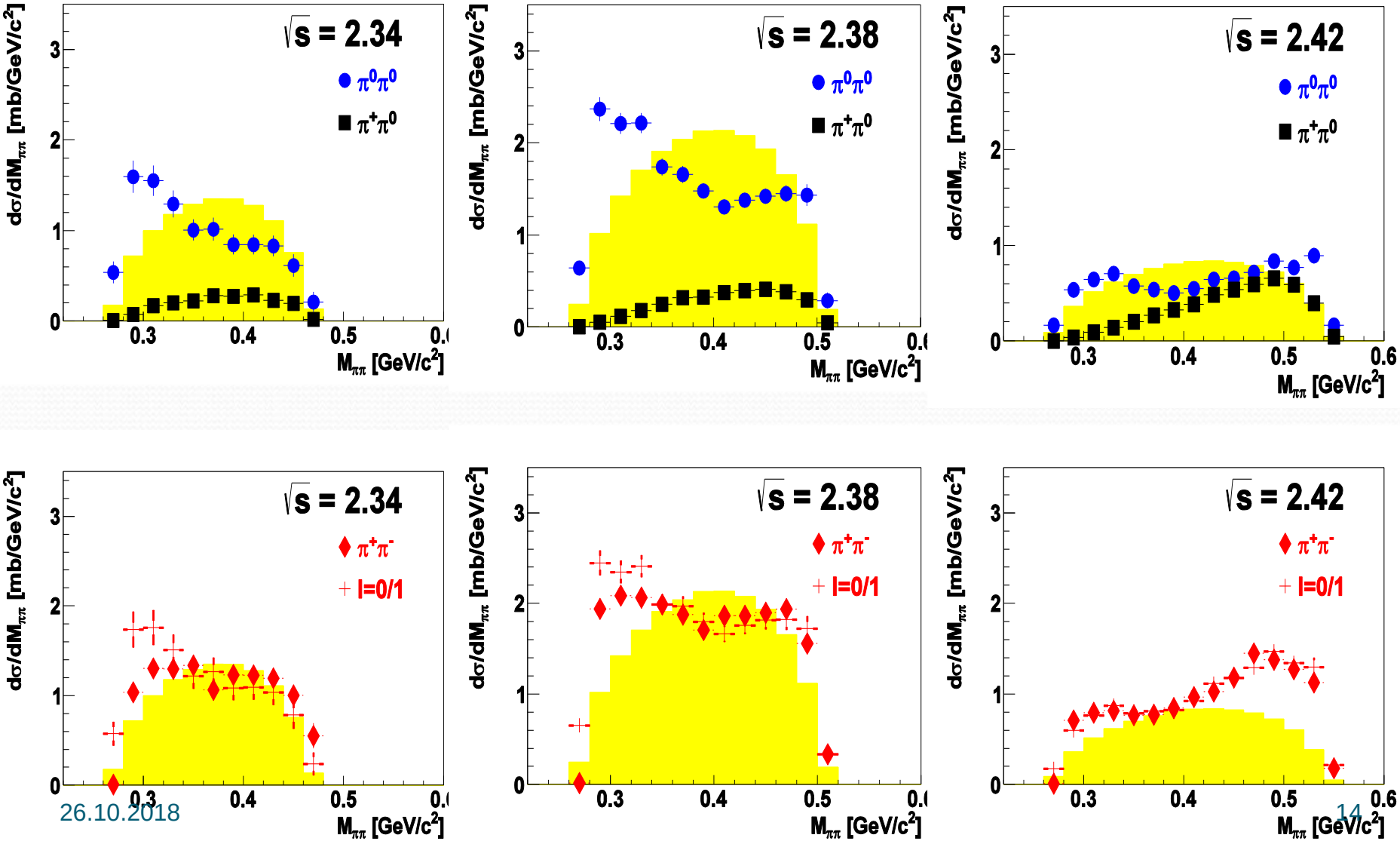
with specific signatures in invariant mass spectra and in the π+ angular distribution

Thank you

WASA detector at COSY



ABC-effect in Mππ for pN → dππ



Isospin relations

$$\sigma[pn \to d\pi^+\pi^-] = \overbrace{\frac{1}{2}\sigma[pp \to d\pi^+\pi^0]}^{I=1}$$
$$\underbrace{+2\sigma[pn \to d\pi^0\pi^0]}_{I=0}$$

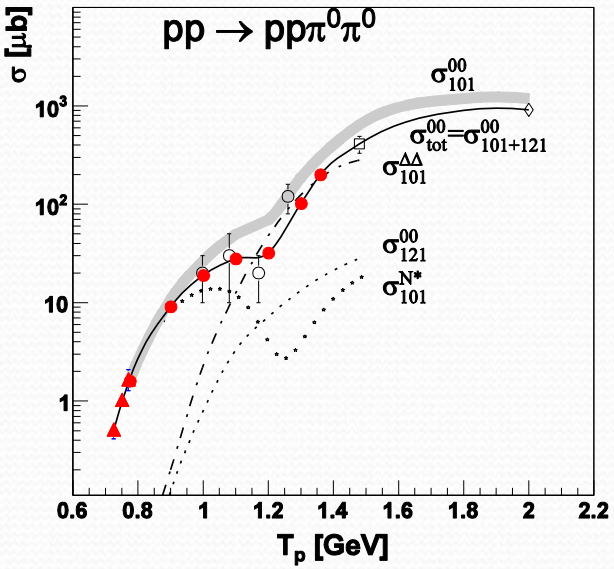
The decay modes of the dibaryon

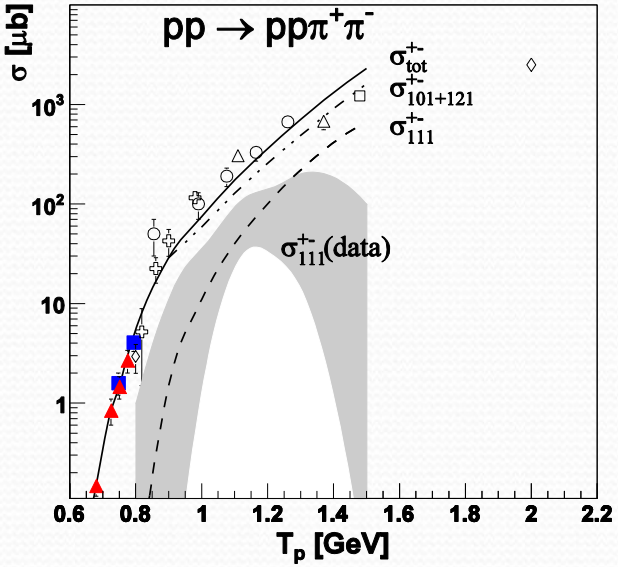
Channel	Publications
d $\pi^0\pi^0$	M. Bashkanov et. al Phys.Rev.Lett. 102 (2009) 052301 P. Adlarson et. al Phys. Rev. Lett. 106:242302, 2011 P. Adlarson et. al Phys.Lett. B721 (2013) 229-236
d $\pi^+\pi^-$	P. Adlarson et. al Phys.Lett. B721 (2013) 229-236
pp$\pi^0\pi^-$	P. Adlarson et. al Phys. Rev. C 88, 055208
np$\pi^0\pi^0$	arXiv:1409.2659
np	A. Pricking, M. Bashkanov, H. Clement. arXiv:1310.5532 P. Adlarson et al. Phys. Rev. Lett. **112**, 202301, (2014) P. Adlarson et al. Phys. Rev. C **90**, 035204 , (2014)
pn e^+e^-	M. Bashkanov, H. Clement, Eur.Phys.J. A50 (2014) 107
^{3}He $\pi\pi$	M. Bashkanov et. al Phys.Lett. B637 (2006) 223-228 arXiv:1408.5744
^{4}He $\pi\pi$	P. Adlarson et. al Phys.Rev. C86 (2012) 032201
	+ activities from other groups

M. Bashkanov, Stanley J. Brodsky, H. Clement Phys.Lett. B727 (2013) 438-442

Non-fusion channels

Isospin Decomposition

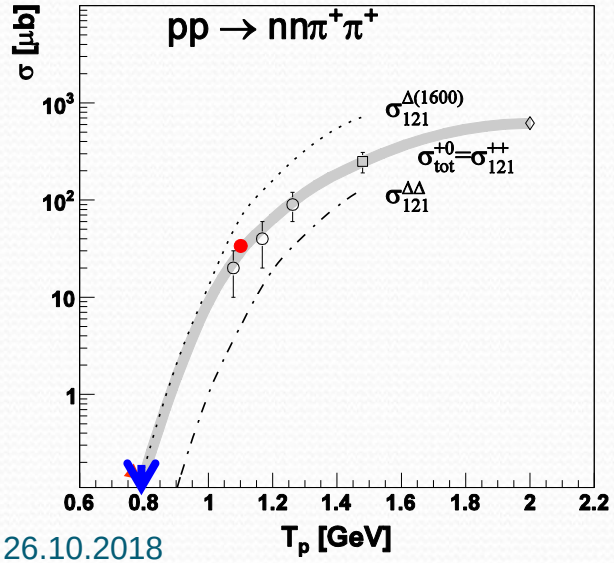




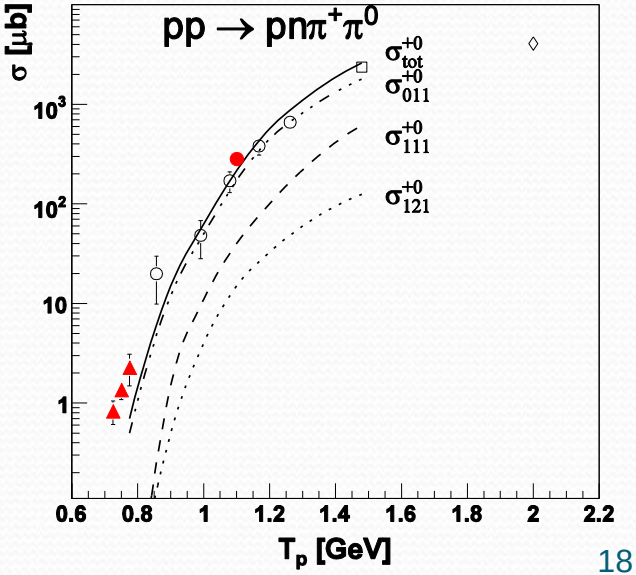
N*(1440)

ΔΔ

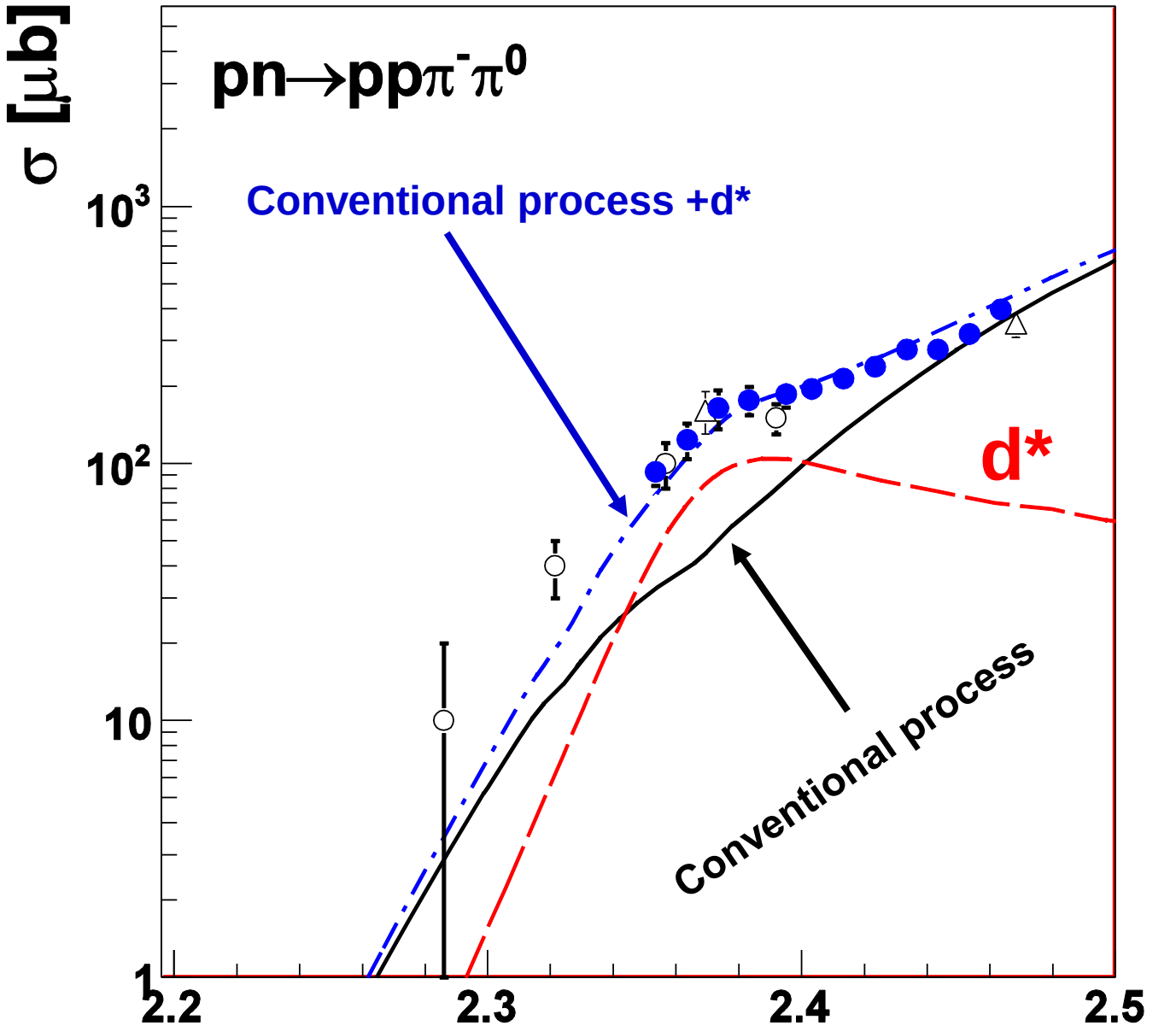
Δ(1600)



T. Skorodko et al.,
PLB 679 (2009) 30

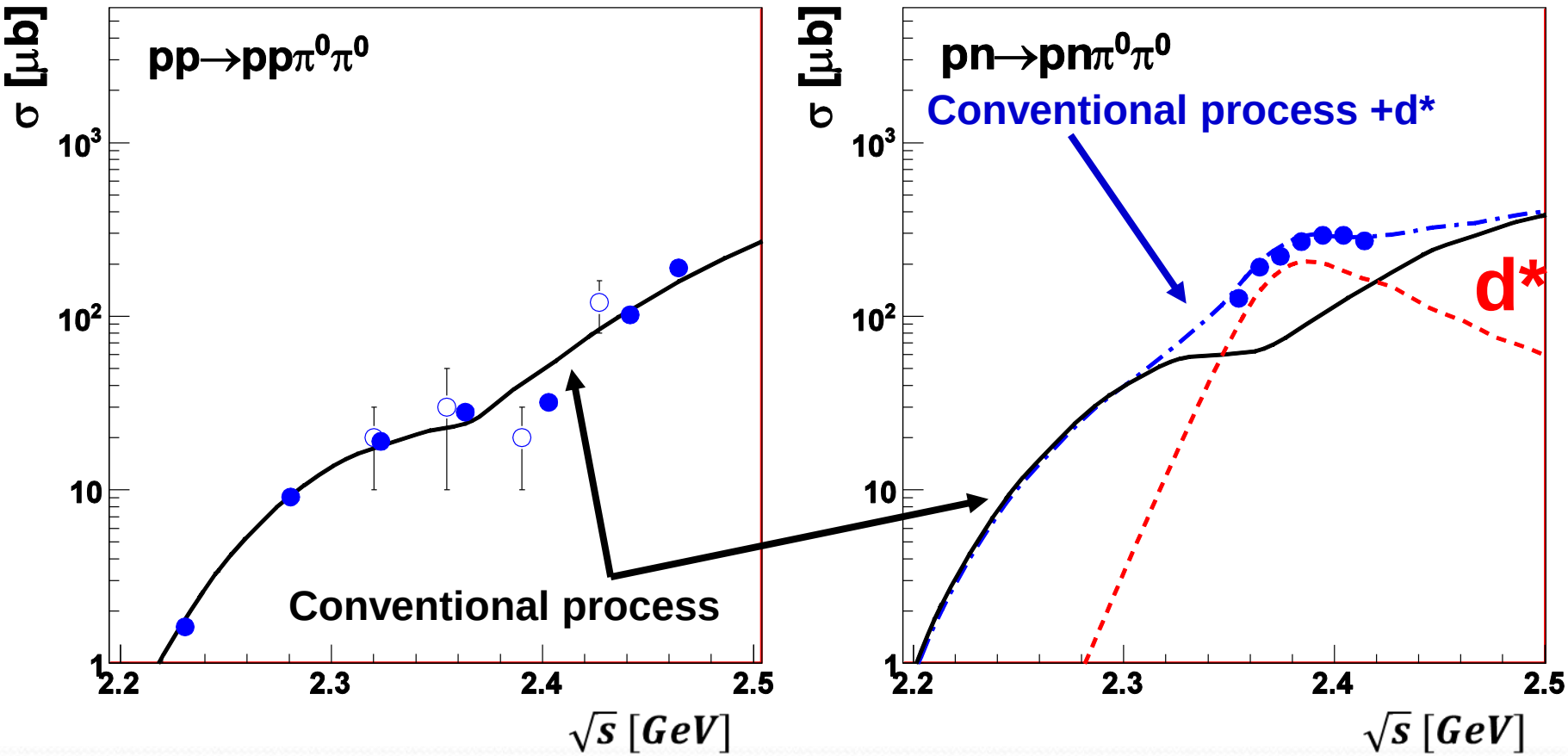


$pn \rightarrow pp\pi^-\pi^0$



P. Adlarson et al., Phys. Rev. C 88, 055208 (2013).

$pn \rightarrow pn\pi^0\pi^0$



P. Adlarson et al., arXiv:1409.2659

The family of dibaryons

Predictions of $I(J^p) = 0(3^+)$ state

- F. J. Dyson, N-H Xuong PRL. 13(1964) 815
  - first prediction
- T. Goldman, *et* al, PRC 39, 1889 (1989)
  - "d*", "inevitable dibaryon"
- T. Kamae and T. Fujita, PRL 38, 471 (1977)
  - deuteron photodisintegration
- A. Gal, H. Garcilazo PRL 111 (2013) 172301
  - Faddeev-Yakubovsky calculations
- H. Huang, J. Ping, F. Wang, PRC 89, 034001 (2014)
  - Quark model
- F. Huang, Z.Y. Zhang, P.N. Shen, W.L. Wang arXiv:1408.0458
  - RGM, "hexaquark-dominated exotic state"

$pd \to {}^3He\pi\pi$, T_p=0.89 GeV

$M_{\pi\pi}$ $M_{^3He\pi}$

$^3He\pi^+$

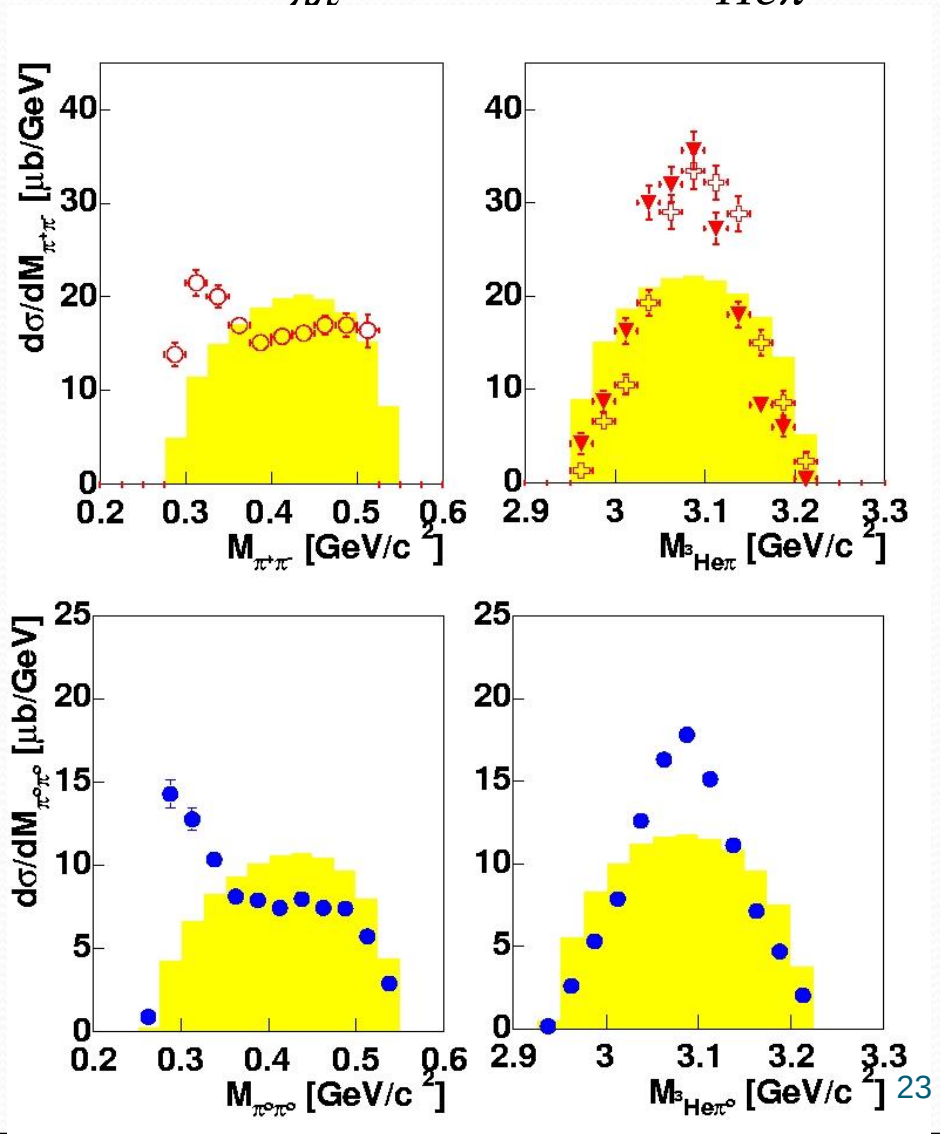
$^3He\pi^-$

$\pi^+\pi^-$

(I=0,1)

$\pi^0\pi^0$

(I=0)



M.Bashkanov *et*. al,
Phys. Lett. **B637** (2006) 223-228

Kinematics

$$\vec{d}p \rightarrow np + p_{sp}$$