Mixing of pseudoscalar-baryon and vector-baryon in the $J^P = 1/2^-$ sector and the N*(1535) and N*(1650) resonances

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Outlook

Section 1

Introduction

- $N^*(1535)$ and $N^*(1650)$ are both well established 4-star resonances of the $J^P = 1/2^-$ sector.

[1] N. Kaiser, P. B. Siegel and W. Weise, Phys. Lett. B **362**, 23 (1995)
[2] T. Inoue, E. Oset and M. J. Vicente Vacas, Phys.Rev.C**65**, 035204(2002)

Approach to the nature of $N^*(1535)$ and $N^*(1650)$

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- The introduction of the chiral unitary techniques [1] lead to the dynamically generation of the $N^*(1535)$.

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- The introduction of the chiral unitary techniques [1] lead to the dynamically generation of the $N^*(1535)$.
- However, in this case of the $N^*(1535)$, different cut offs or different subtraction constants[2] for different channels must be used.
- This was considered as a manifestation a nonnegligible component of a genuine state of $N^*(1535)$.

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[2] T. Inoue, E. Oset and M. J. Vicente Vacas, Phys.Rev.C**65**, 035204(2002)

- In one work[3] $N^*(1535)$ and $N^*(1650)$ are obtained with only pseudoscalar - baryon states using an offshell approach, which is in principle equivalent to having different subtraction constants in different channels.
- The $N^*(1650)$ is dinamically generated with the vector meson-baryon interaction, including the ρN channel.
- The mixture of the pseudoscalar-baryon and vector-baryon channels can remove the pathology observed by the need of different subtraction constants in different channels.

[3] J. Nieves and E. Ruiz Arriola, Phys. Rev. D **64**, 116008 (2001)

Section 2

Framework

Coupled channels with $J^P = 1/2^-$

The coupled channels of $N^*(1535)$ and $N^*(1650)$ used in this work are

πN, ηN, $K\Lambda$, $K\Sigma$, ρN and $\pi\Delta$ (d-wave).

$PB \to PB$ transition mediated by a vector meson exchange[4]. The potential of this transition is given by

$$V_{ij} = -C_{ij}\,\frac{1}{4f^2}\,\left(k^0 + k'^0\right) \qquad (1)$$

with the PB transition coefficients

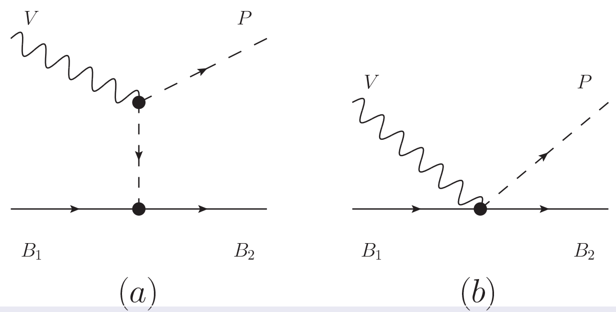
	πN	ηN	$k\Lambda$	$k\Sigma$
πN	2	0	$\frac{3}{2}$	$-\frac{1}{2}$
ηN		0	$-\frac{3}{2}$	$-\frac{3}{2}$
$K\Lambda$			0	0
$K\Sigma$				2

Table : Coefficients of PB transition with $I = 1/2$

[4] T. Inoue, E. Oset and M. J. Vicente Vacas, Phys.Rev.C**65**, 035204(2002)

Vertices of the transition diagrams

Vertices for the transition of $\rho N \to PB$ for (a) meson exchange and (b) the Kroll-Ruderman term



Vertices of the transition diagrams

Vertices for the transition of $\rho N \to PB$ with the Kroll-Ruderman term included

$$t_{\rho N(s)\to\pi N(s)} = -2\sqrt{6}g\frac{D+F}{2f}\left\{\frac{\frac{2}{3}\vec{q}^{\,2}_{\pi N}}{(P_V+q_{\pi N})^2-m_\pi^2}+1\right\} \quad (2)$$

$$t_{\rho N(s)\to\eta N(s)} = 0 \quad (3)$$

$$t_{\rho N(s)\to K\Lambda(s)} = -\frac{1}{2}\sqrt{6}g\frac{D+3F}{2f}\left\{\frac{\frac{2}{3}\vec{q}^{\,2}_{K\Lambda}}{(P_V+q_{K\Lambda})^2-m_K^2}+1\right\} \quad (4)$$

$$t_{\rho N(s)\to K\Sigma(s)} = -\frac{1}{2}\sqrt{6}g\frac{D-F}{2f}\left\{\frac{\frac{2}{3}\vec{q}^{\,2}_{K\Sigma}}{(P_V+q_{K\Sigma})^2-m_K^2}+1\right\} \quad (5)$$

$\pi\Delta$ transition potentials

The transition of $\rho N \to \pi\Delta(d)$ is introduced with

$$t_{\rho N(s)\to\pi\Delta(d)} = g\frac{2}{\sqrt{3}}\frac{f_{\pi N\Delta}}{m_\pi}\left\{\frac{\frac{2}{3}\vec{q}^{\,2}}{(P_V+q)^2-m_\pi^2}\right\} \quad (6)$$

The transitions involving d wave are introduced with a parameter[5] γ for $\pi\Delta(d) \to \pi\Delta(d)$ and $\pi\Delta(d) \to \pi N(s)$.

$$t_{\pi\Delta(d)\to\pi\Delta(d)} = -\frac{\gamma_0}{m_\pi^5}q_{\pi\Delta}^4 \quad (7)$$

$$t_{\pi\Delta(d)\to\pi N(s)} = -\frac{\gamma_1}{m_\pi^3}q_{\pi\Delta}^2 \quad (8)$$

[5] As done in L. Roca, S. Sarkar, V. K. Magas, and E. Oset, Phys. Rev. C 73, 045208 (2006).

Section 3

Fitting the data

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We fit eight parameters to the data[6] of the πN scattering in S_{11}.

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We fit eight parameters to the data[6] of the πN scattering in S_{11}.

- Six subtraction constants of the G function, one for each channel ($\pi N(s)$, $\eta N(s)$, $K\Lambda(s)$, $K\Sigma(s)$, $\rho N(s)$, $\pi\Delta(d)$).
- Two parameters of the L=2 transitions, γ_i

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μ[MeV]	$a_{N\pi}$	$a_{N\eta}$	$a_{\Lambda K}$	$a_{\Sigma K}$	$a_{N\rho}$	$a_{\Delta\pi}$	γ_0	γ_1
M_B	-1.203	-2.208	-1.985	-0.528	-0.493	-1.379	0.595	1.47
630	-2.001	-3.006	-3.128	-1.799	-1.291	-2.720	0.595	1.47

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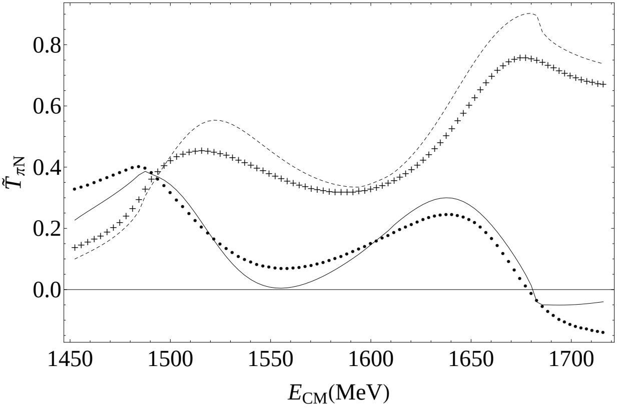
- Where now, all the subtraction constants are of the natural size.

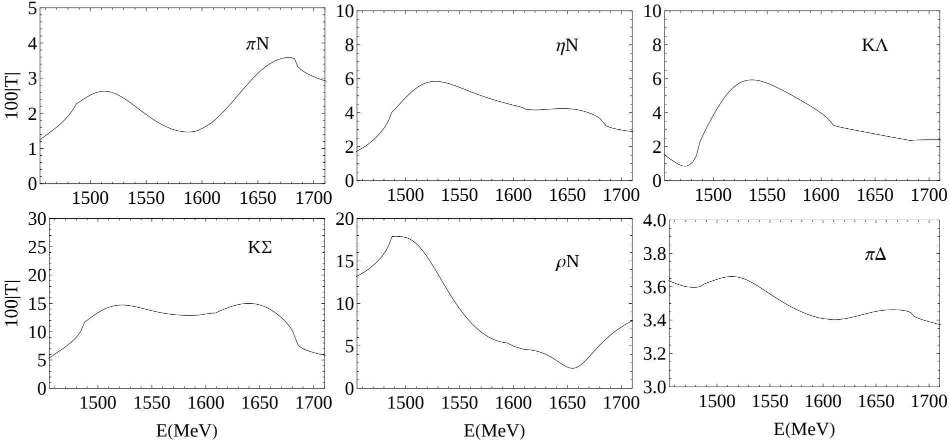
[6] R. A. Arndt, W. J. Briscoe, I. I. Strakovsky and R. L. Workman, Phys. Rev. C **74**, 045205 (2006)

Fitting the data



We show the real part (circles) and imaginary part (cross) of the data and the result of our fit of $\tilde{T}_{\pi N}$ for real (solid) and imaginary (dashed) parts.

Results of the $|T|^2$ matrix for the diagonal channels



Branching ratios for the $N^*(1535)$ $J^P = 1/2^-$

$N^*(1535)$ $J^P = 1/2^-$						
	Theory	PDG	Cutkosky [7]	Anisovich [8]	Vrana [9]	Thoma [10]
Re	1508.1	1490 – 1530	1510 ± 50	1501 ± 4	1525	$1508 {}^{+10}_{-30}$
2Im	90.3	90 – 250	260 ± 80	134 ± 11	102	165 ± 15
Channel	Branching Ratio $[\Gamma_i/\Gamma(\%)]$					
$N\pi$	58.6	35 – 55	50 ± 10	54 ± 5	35 ± 8	37 ± 9
$N\eta$	37.0	42 ± 10		33 ± 5	51 ± 5	40 ± 10
ΛK	0.0	-				
ΣK	0.0	-				
$N\rho$	1.0	2 ± 1			2 ± 1	
$\Delta\pi$	3.3	0 – 4		2.5 ± 1.5	1 ± 1	23 ± 8

[7] R. E. Cutkosky *et al.*, Phys. Rev. D **20**, 2839 (1979).
[8] A. V. Anisovich *et al.*, Eur. Phys. J. A **48**, 15 (2012)
[9] T. P. Vrana *et al.*, Phys. Rept. **328**, 181 (2000)
[10] U. Thoma *et al.*, Phys. Lett. B **659**, 87 (2008)

Branching ratios for the $N^*(1650)$ $J^P = 1/2^-$

$N^*(1650)$ $J^P = 1/2^-$						
	Theory	PDG	Cutkosky [11]	Anisovich [12]	Vrana [13]	Thoma [14]
Re	1672.3	1640 – 1670	1640 ± 20	1647 ± 6	1663	1645 ± 15
2Im	158.2	100 – 170	150 ± 30	103 ± 8	240	187 ± 20
Channel	Branching Ratio $[\Gamma_i/\Gamma(\%)]$					
$N\pi$	58.9	50 – 90	65 ± 10	51 ± 4	74 ± 2	70 ± 15
$N\eta$	27.6	5 – 15		18 ± 4	6 ± 1	15 ± 6
ΛK	5.7	-		10 ± 5		
ΣK	0.0	-				
$N\rho$	5.6	1 ± 1			1 ± 1	
$\Delta\pi$	2.2	0 – 25		19 ± 9	2 ± 1	10 ± 5

[11] R. E. Cutkosky *et al.*, Phys. Rev. D **20**, 2839 (1979).
[12] A. V. Anisovich *et al.*, Eur. Phys. J. A **48**, 15 (2012)
[13] T. P. Vrana *et al.*, Phys. Rept. **328**, 181 (2000)
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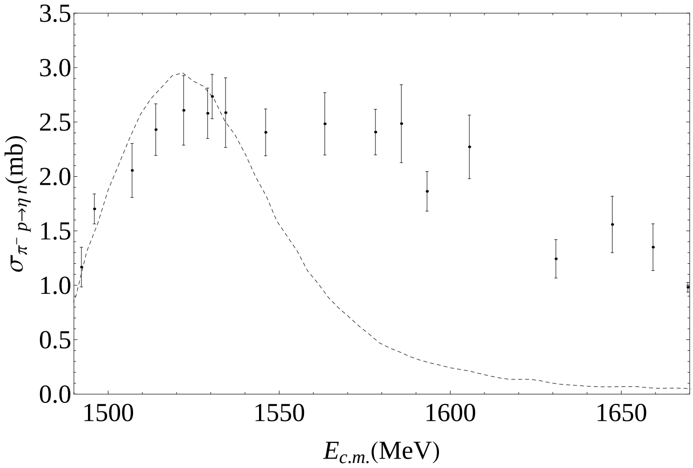

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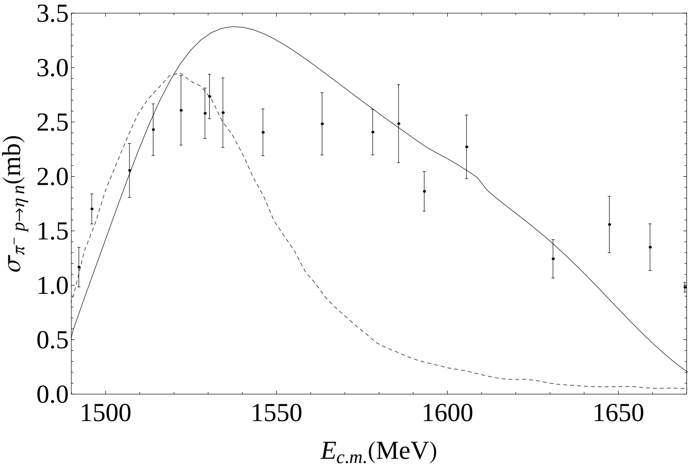

T. Inoue, E. Oset and M. J. Vicente Vacas, Phys.Rev.C**65**

Conclusions

- We have used the πN, ηN, $K\Lambda$, $K\Sigma$, ρN and $\pi\Delta$ (d-wave) in coupled channels to fit the experimental data of the S_{11} πN scattering.
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- We are able to generate both the $N^*(1535)$ and the $N^*(1650)$ resonances considering the ρN and $\pi\Delta$ channels which is an important success of the mixing of pseudoscalar and vector mesons.
- The important component of a genuine state in the wave function of the $N^*(1535)$ claimed in other works, can be translated now by stating that the missing components can be filled up by the ρN and $\pi\Delta$ channels.