Two meson cloud of the baryon antidecuplet

Pentaquark'05,
Jefferson Laboratory 20/10/2005

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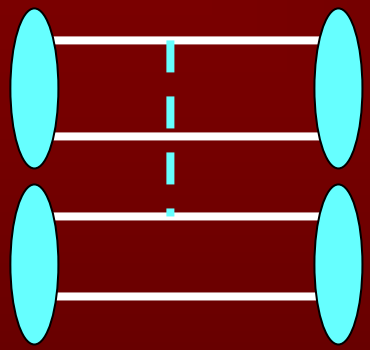
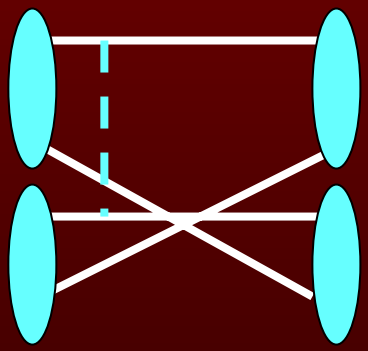
Outline:

- Resonating Group Method and hadron molecules
- Θ^+ not a molecule
- No N K π resonance above threshold (Z^*) $\bar{10}$
- Two meson cloud of 10

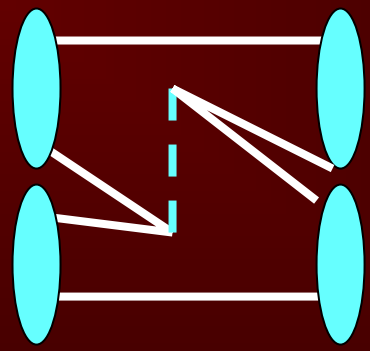
Exotic SU(3) channels are repulsive
(E. Ribeiro 1980)



= 0 (color factor)



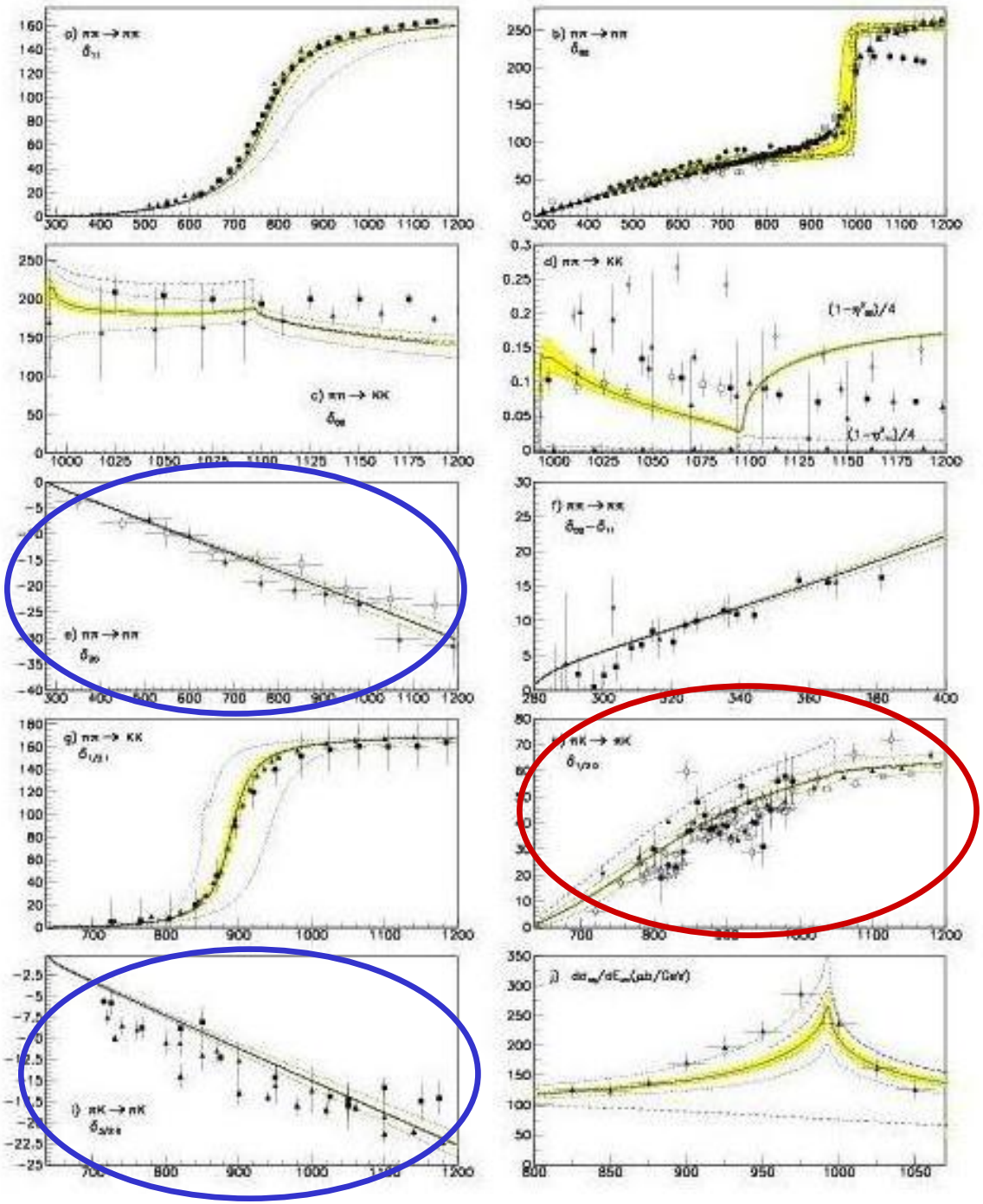
repulsive



attractive

In exotic scattering the second diagram can't contribute

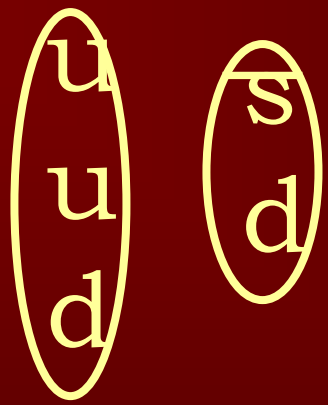
for example $\pi+\pi+$ (I=2) $u\bar{d}\,u\bar{d}$ no annihilation



Gomez Nicola Pelaez (2001)

Exotic Kaon Nucleon molecule?

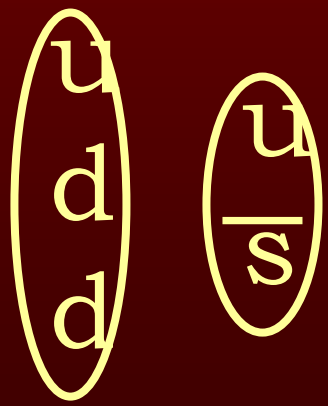
pK^0



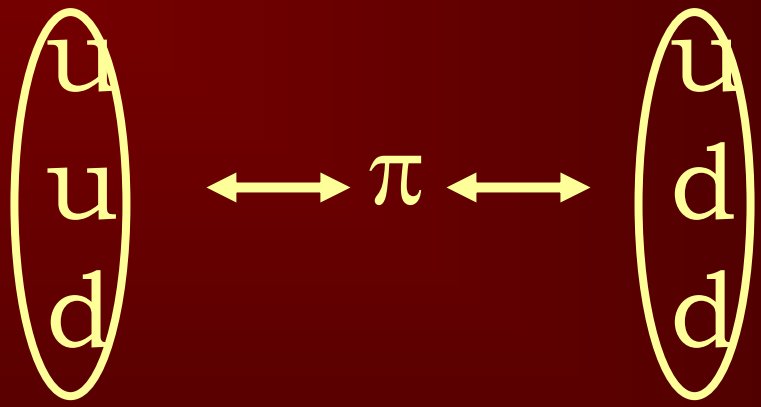
Pauli exclusion principle at work

No resonance

nK^+

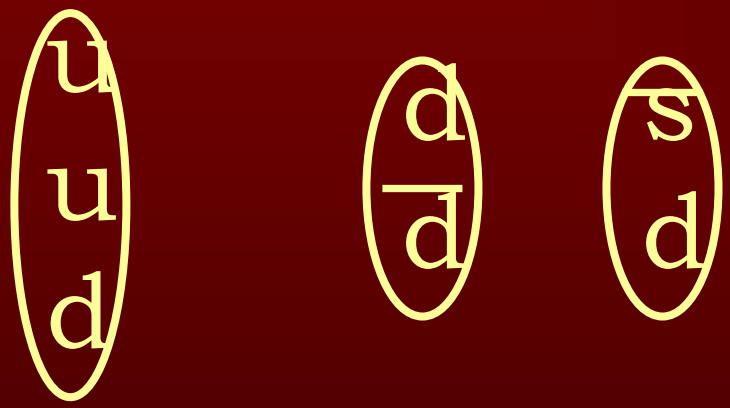


A famous exotic molecule



The deuteron

Θ^+ as heptaquark molecule (Bicudo and Marques, 2003)



P π K

Use a pion in the valence wavefuncti

for a parity + stat

M=1573 MeV

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Make use of Kπ correlation: κ

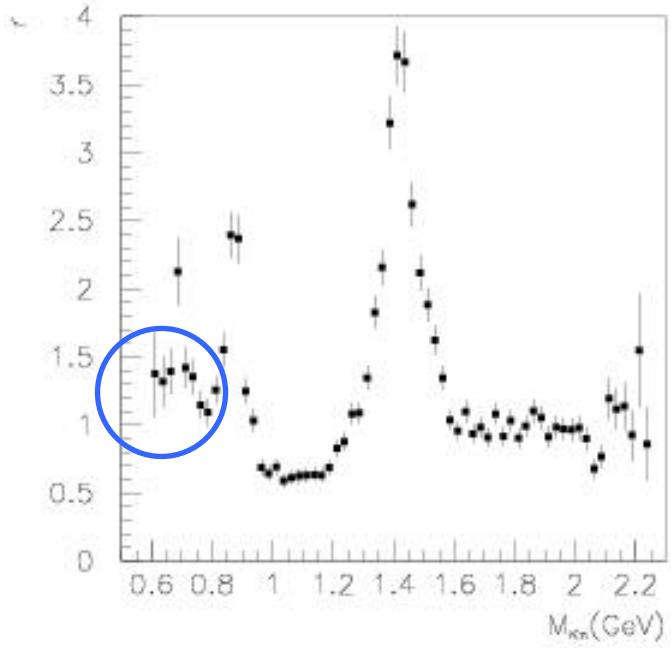
Experimental evidence: BES&L

$J/\psi \to (K\pi)(K\pi)$

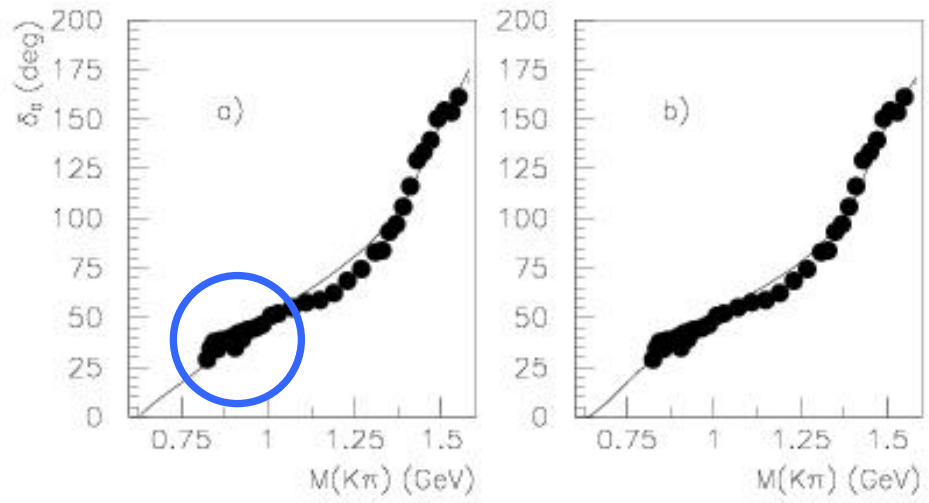
Analysis by D. V. Bugg

hep-ex/0510026

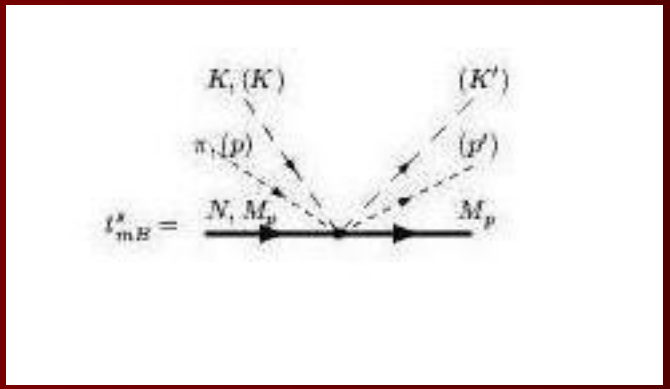
Mass spectrum recoiling against a K*



Phase shift



Mass 700-800 M
Width 400 MeV
(Gomez Nicola ar
Pelaez, 270 MeV)



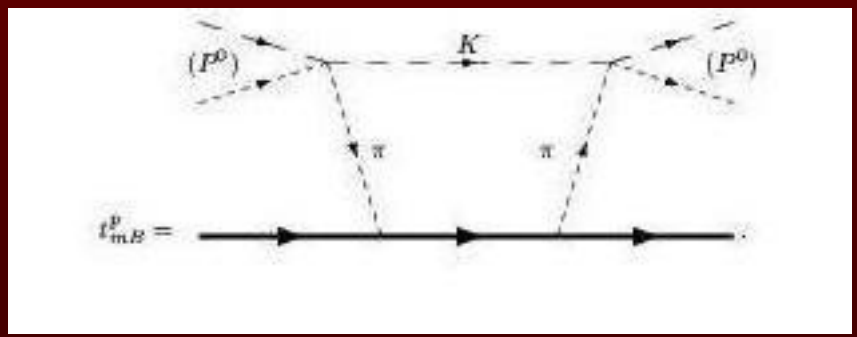
Two meson-nucleon vertex (approximate on-shell factorizati

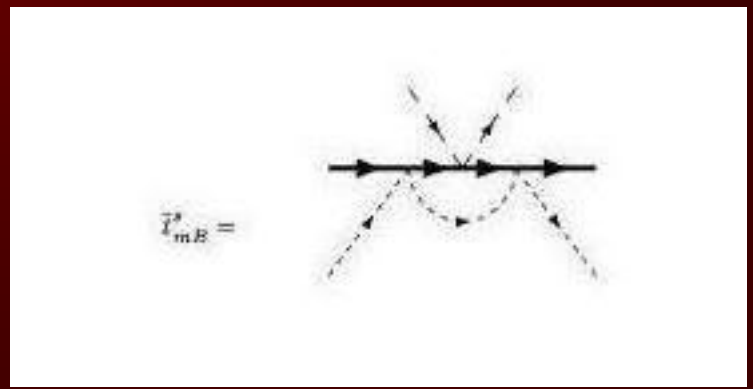
$$\langle \Theta^1 | t^s_{mB} | \Theta^1 \rangle = -\frac{1}{144 f^4} \left(-4(\not{K} + \not{K}') - 11(\not{p} + \not{p}') \right)$$

$$\langle \Theta^0 | t^s_{mB} | \Theta^0 \rangle = -\frac{21}{144 f^4} \left((\not{K} + \not{K}') - (\not{p} + \not{p}') \right)$$

KπN scattering matrix with Lippman-Schwinger equation

Need to examine other vertices

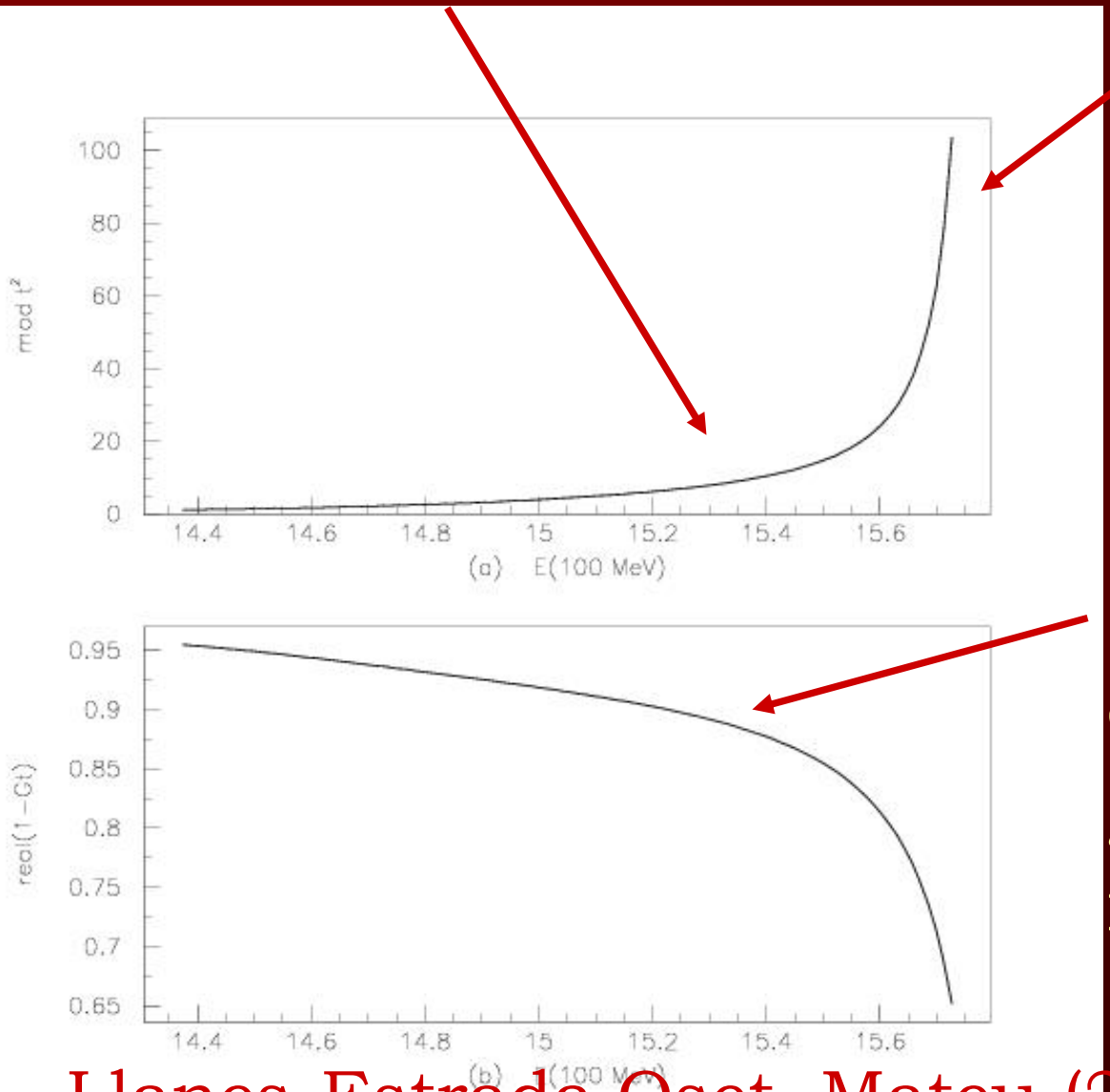




t_{mb}^{p}

t_{mb}^{s2}

$|t|^2$: no resonance



KπN thresho
effect

1-GV (denomina
of Lippman-Schwing
geometric series:
no zero.

Llanes-Estrada,Oset, Mateu (2003)

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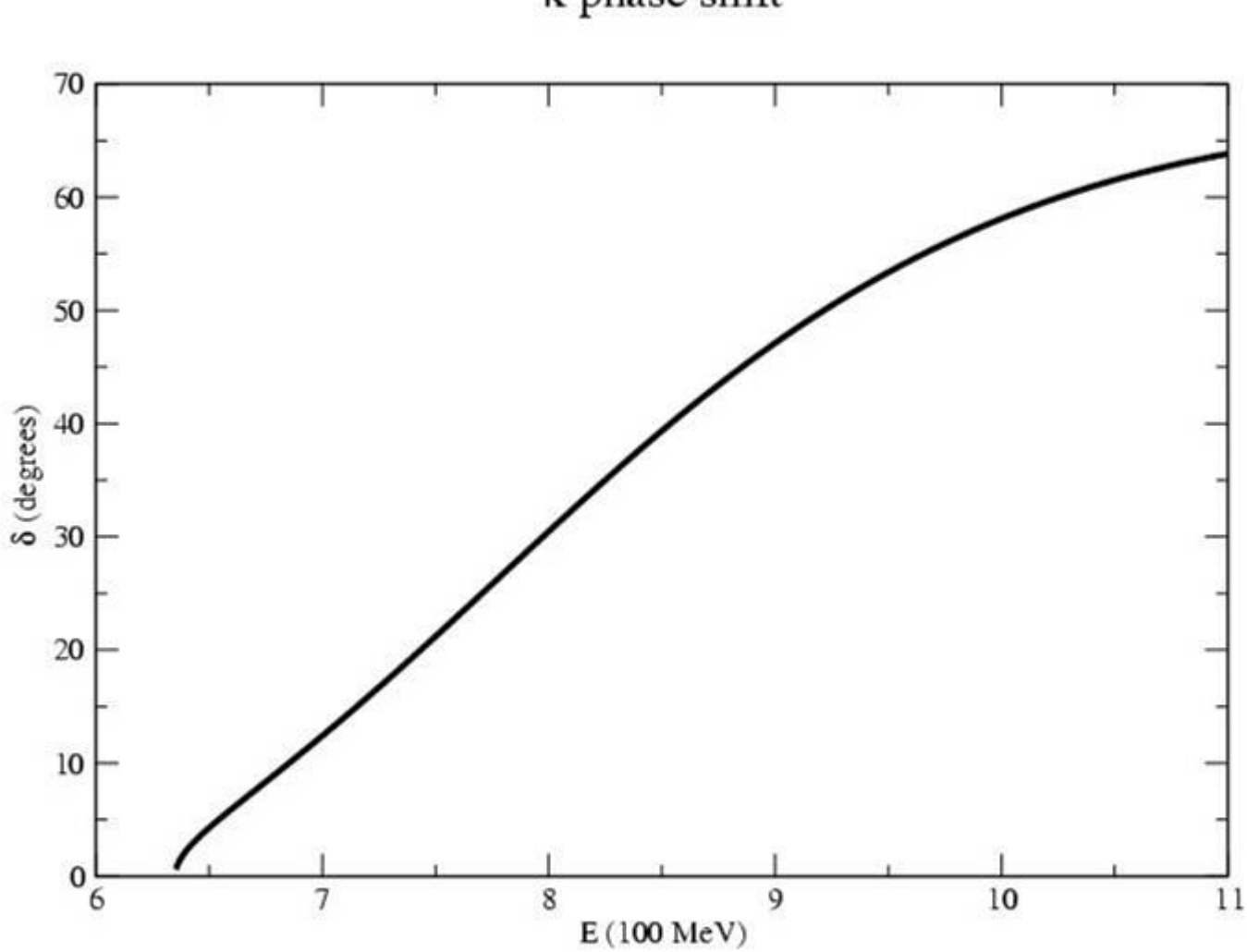
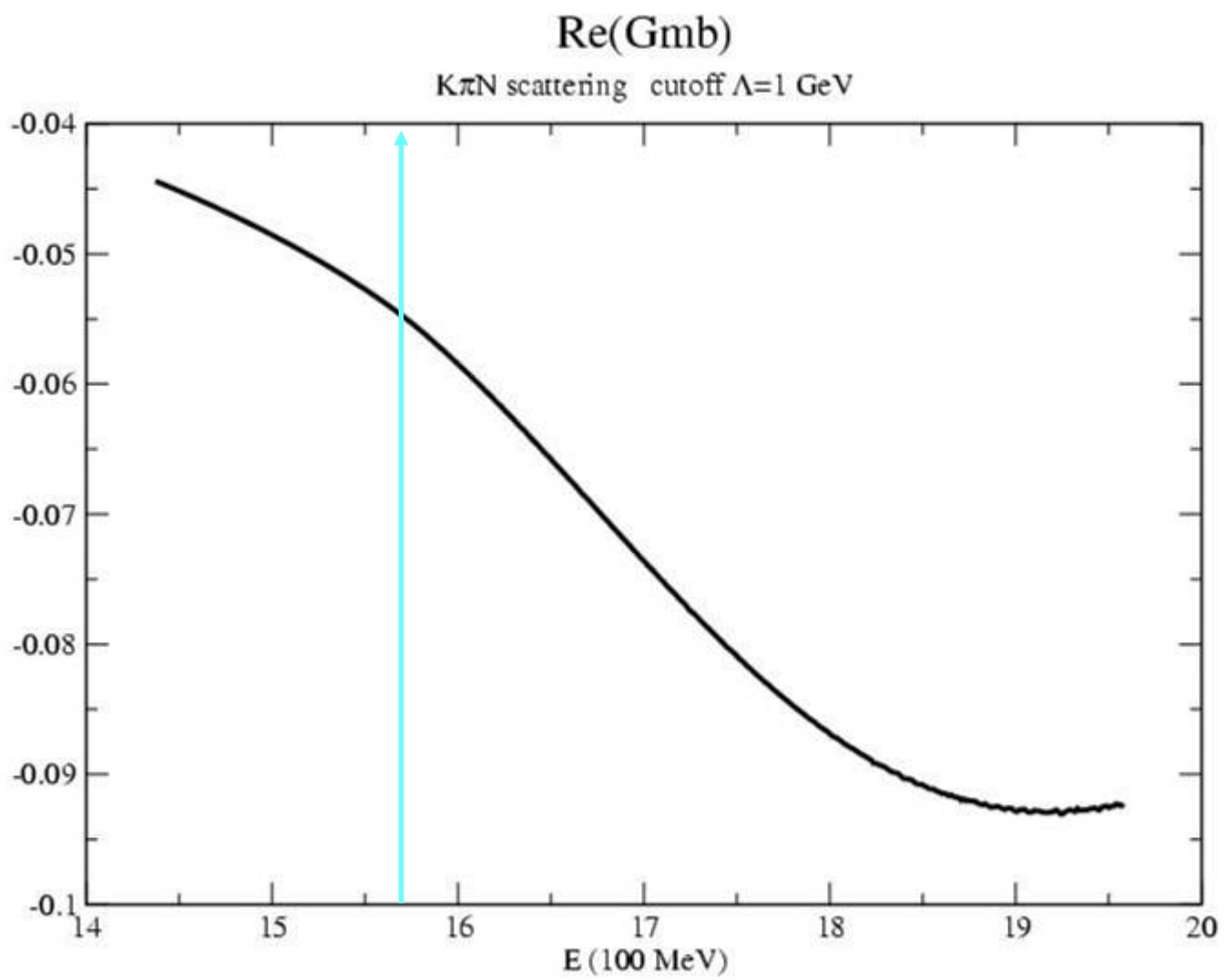
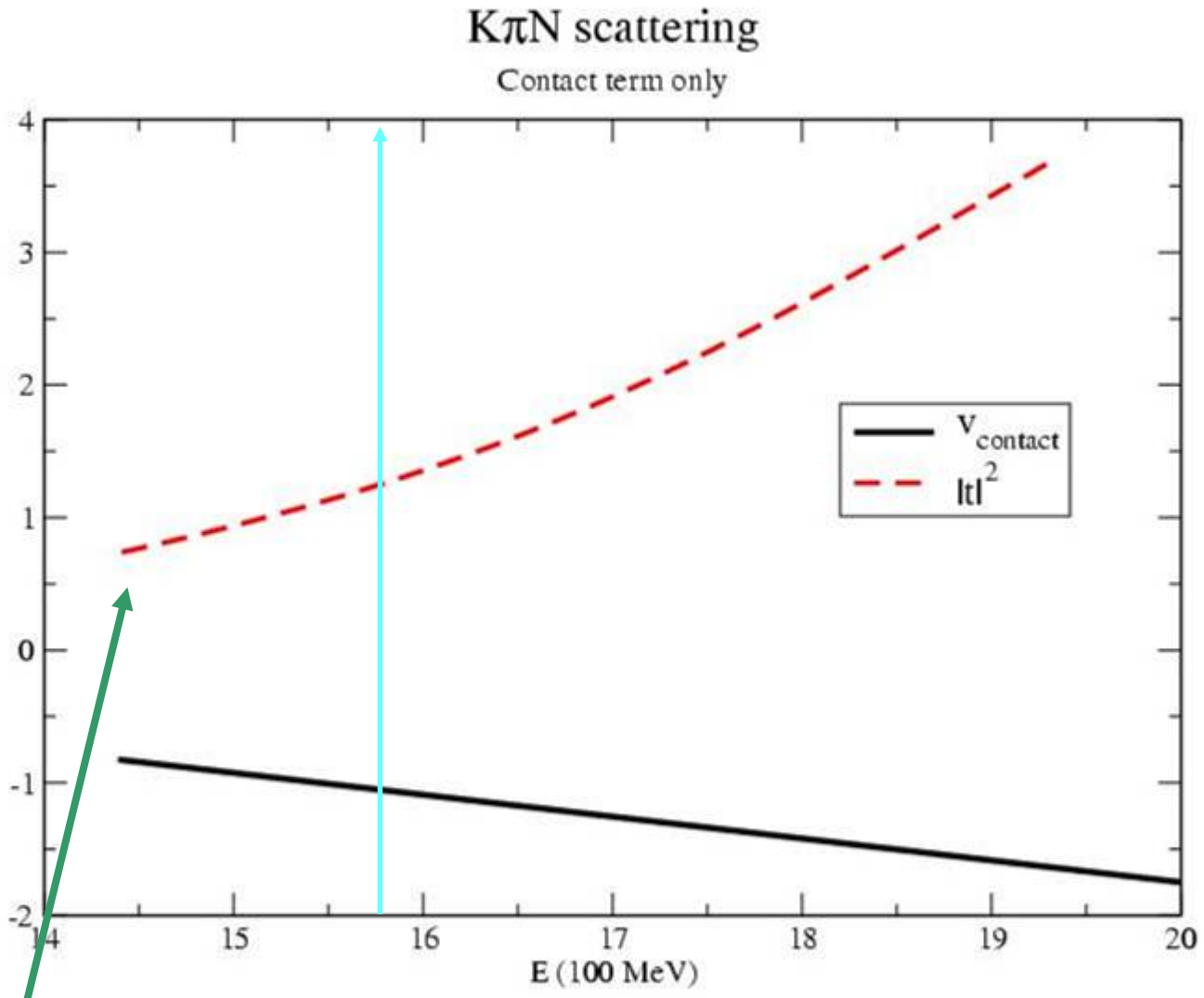
Old predictions (compiled by Nowakowski et al. 2003)

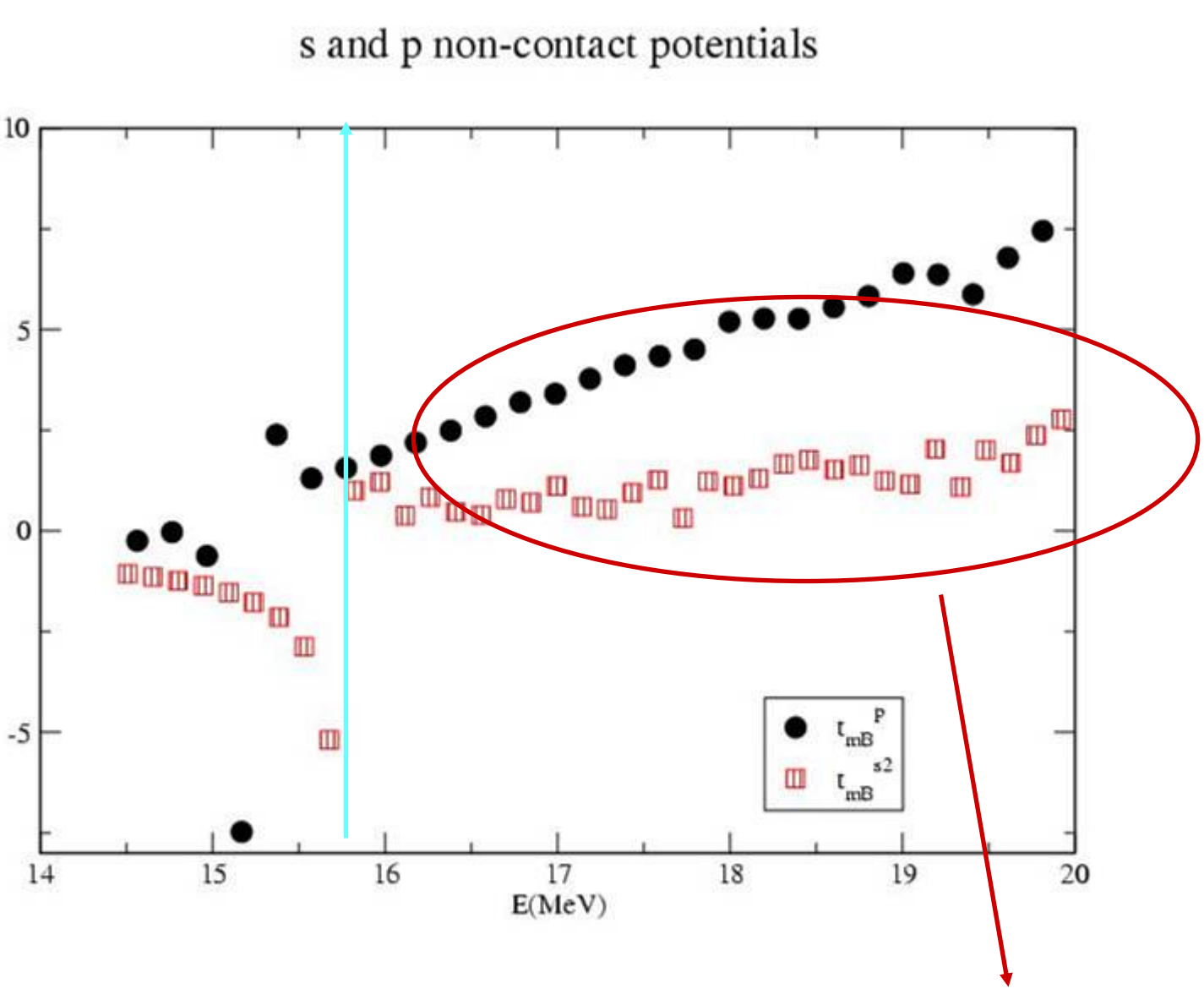
- $P_{01}(1831)$, $P_{13}(1811)$, $D_{03}(1788)$, $D_{15}(2074)$ (Hyslop et al 1992)
- K*N resonance around 1830 MeV (Aaron et al 1970)
- $S_{01}(1710)$ (Roiesnol 1979)
- 1530, 1570 (notice this second is at the KπN threshold)


κ phase shift
70
60
50
40
30
20
10
0
δ (degrees)
6
7
8
9
10
11
E (100 MeV)


Re(Gmb)
KπN scattering cutoff Λ=1 GeV
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.1
14
15
16
17
18
19
20
E (100 MeV)



Contact term only: no resonance



Non-contact terms clearly positive

Above threshold: no resonance expec

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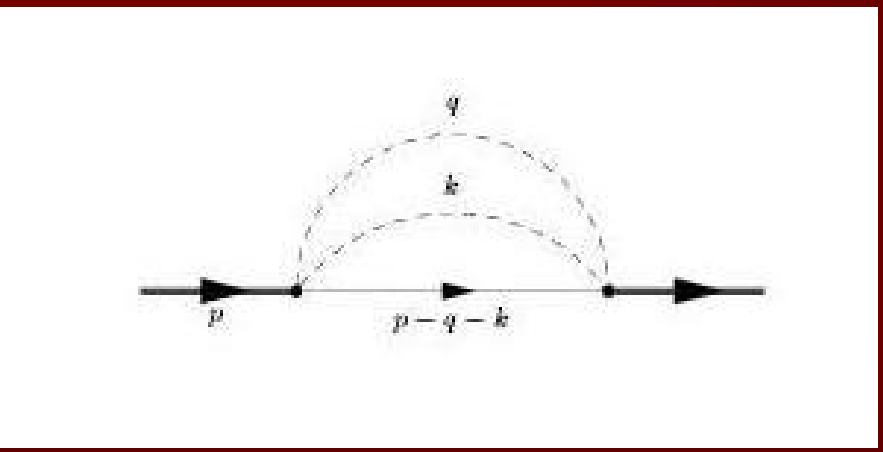
Antidecuplet members (inspired by Diakonov, Petrov, Polyak

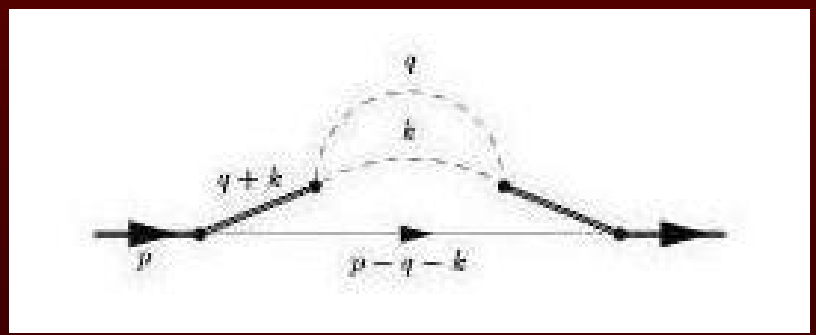
Θ(1540)
N(1710)
Σ(1770)
Ξ(1860)

Solutions:
Problems:
Mass splitting breaks SU
Mass splitting breaks SU
N(1710) seen in πN
N(1710) > Nπ
Θ(1540) > NK
Θ(1540) > NK
(Arndt et al., Nov 03
(Arndt et al., Nov 03

Decays of N*(1710)



Scalar vertices
Nππ s-wave
Γ=25 MeV from PD



Vector: intermediat
ρ or K* resonance
Nππ p-wave
Γ=15 MeV

$$\phi = \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & \pi^+ & K^+ \\ \pi^- & -\frac{1}{\sqrt{2}}\pi^0 + \frac{1}{\sqrt{6}}\eta & K^0 \\ K^- & \bar{K}^0 & -\frac{2}{\sqrt{6}}\eta \end{pmatrix}$$

$$B = \begin{pmatrix} \frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & \Sigma^+ & p \\ \Sigma^- & -\frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda & n \\ \Xi^- & \Xi^0 & -\frac{2}{\sqrt{6}}\Lambda \end{pmatrix}$$

$$P^{333} = \sqrt{6}\Theta^+_{\overline{10}}, P^{133} = \sqrt{2}\,N^0_{\overline{10}},$$
$$P^{233} = -\sqrt{2}\,N^+_{\overline{10}}, P^{113} = \sqrt{2}\,\Sigma^-_{\overline{10}},$$
$$P^{123} = -\Sigma^0_{\overline{10}}, P^{223} = -\sqrt{2}\,\Sigma^+_{\overline{10}}, \quad (1)$$
$$P^{111} = \sqrt{6}\Xi^{--}_{\overline{10}}, P^{112} = -\sqrt{2}\,\Xi^-_{\overline{10}},$$
$$P^{122} = \sqrt{2}\,\Xi^0_{\overline{10}}, P^{222} = -\sqrt{6}\Xi^+_{\overline{10}},$$

SU(3)
field defs.
8x8x$\overline{10}$

Construction of effective lagrangian
derivative expansion and respecting

$$\mathsf{L}^{8s} = \frac{g^{8s}}{2f}\bar{P}_{ijk}\epsilon^{lmk}\phi_l{}^a\phi_a{}^i B_m{}^j + \text{h.c.}$$

$$\mathsf{L}^{8a} = i\frac{g^{8a}}{4f^2}\bar{P}_{ijk}\epsilon^{lmk}\gamma^\mu(\partial_\mu\phi_l{}^a\phi_a{}^i - \phi_l{}^a\partial_\mu\phi_a{}^i)B_m{}^j + \text{h.c.}$$

$$\mathsf{L}^{27} = \frac{g^{27}}{2f}[4\bar{P}_{ijk}\epsilon^{lbk}\phi_l{}^i\phi_a{}^j B_b{}^a - \frac{4}{5}\bar{P}_{ijk}\epsilon^{lbk}\phi_l{}^a\phi_a{}^j B_b{}^i] + \text{h.c.}$$

What does chiral symmetry have to

$$\mathcal{L}^{\chi} = \frac{g^{\chi}}{2f}\bar{P}_{ijk}\epsilon^{lmk}(A_\mu)_l{}^a(A^\mu)_a{}^i B_m{}^j + \text{h.c.}$$

$$A_\mu = \frac{i}{2}\left(\xi^\dagger\partial_\mu\xi - \xi\partial_\mu\xi^\dagger\right)$$

$$\xi = e^{i\phi/\sqrt{2}f}$$

$$S = \xi M\xi + \xi^\dagger M\xi^\dagger$$

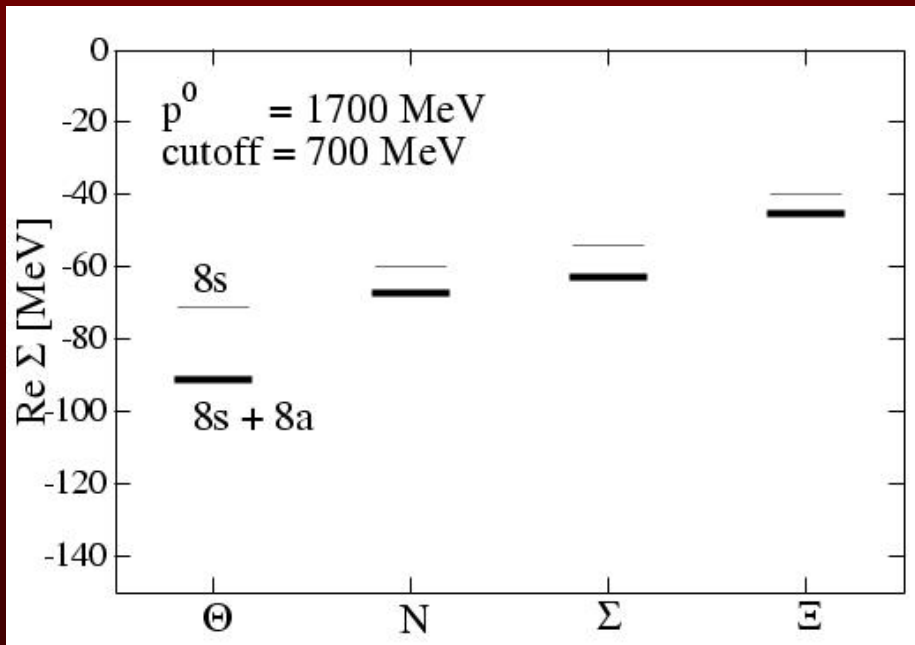
$$M = \begin{pmatrix} m_\pi^2 & & \\ & m_\pi^2 & \\ & & 2m_K^2 - m_\pi^2 \end{pmatrix}$$

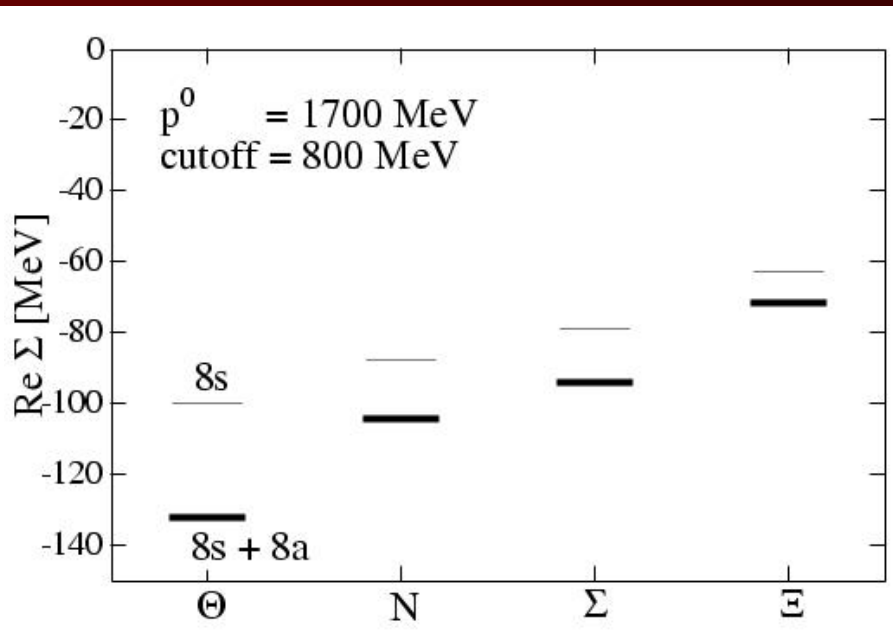
$$\mathcal{L}^{M} = \frac{g^{M}}{2f}\bar{P}_{ijk}\epsilon^{lmk}S_l{}^i B_m{}^j + \text{h.c.}$$

Chirally sym.
two derivative

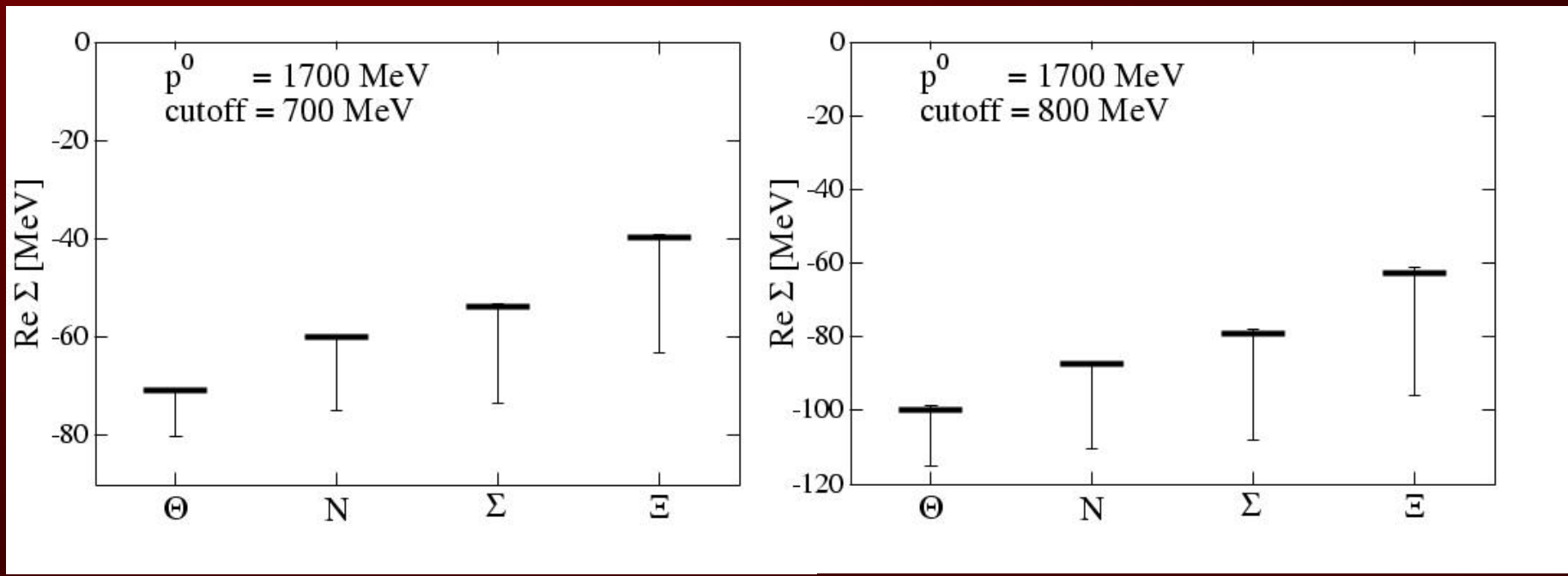
Mass terms
break SU(3)
directly

$L^8_s + L^8_a$

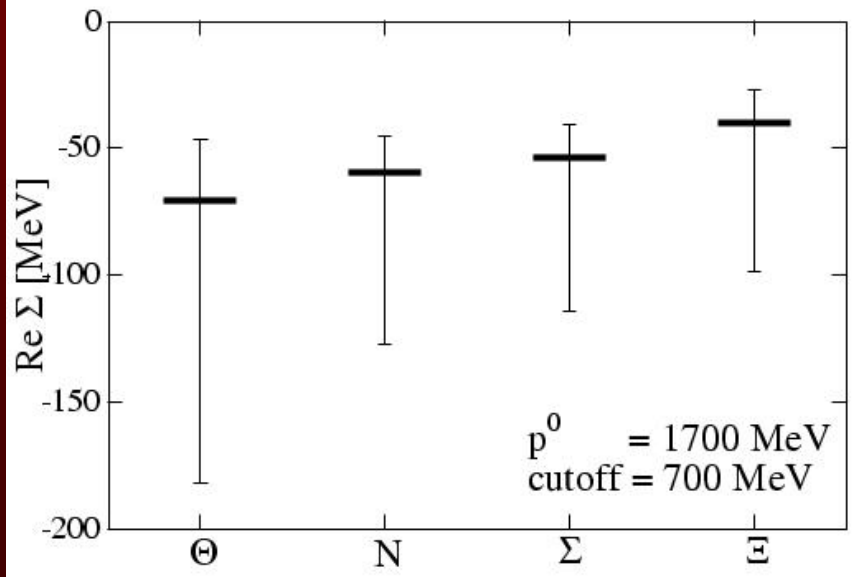

0
-20
-40
-60
-80
-100
-120
-140
Re Σ [MeV]
p0 = 1700 MeV
cutoff = 700 MeV
8s
8s + 8a
Θ
N
Σ
Ξ

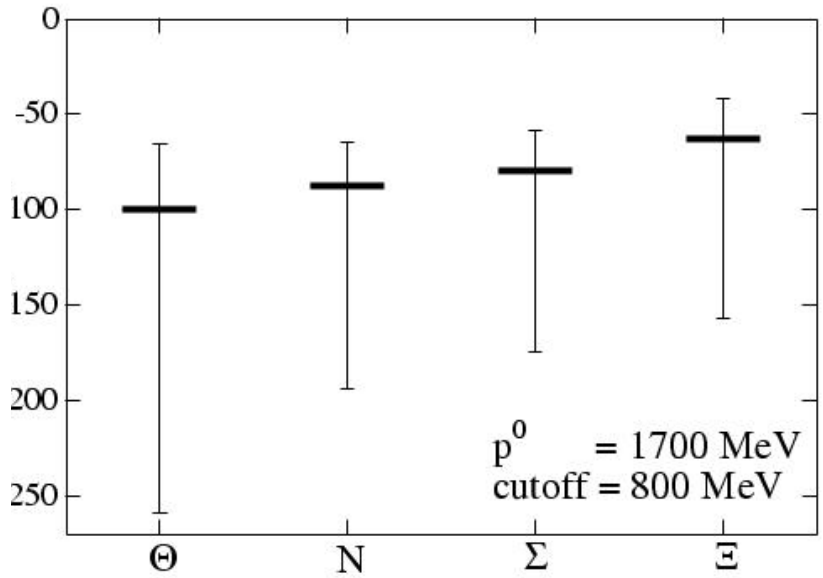

0
-20
-40
-60
-80
-100
-120
-140
Re Σ [MeV]
p0 = 1700 MeV
cutoff = 800 MeV
8s
8s + 8a
Θ
N
Σ
Ξ

$L^{8}_{s} + L^{27}$


p⁰ = 1700 MeV
cutoff = 700 MeV
Re Σ [MeV]
0
-20
-40
-60
-80
Θ
N
Σ
Ξ
p⁰ = 1700 MeV
cutoff = 800 MeV
Re Σ [MeV]
0
-20
-40
-60
-80
-100
-120
Θ
N
Σ
Ξ

$L^{8}_{s} + L^{M}$


0
-50
-100
-150
-200
Re Σ [MeV]
Θ
N
Σ
Ξ
p0 = 1700 MeV
cutoff = 700 MeV


0
-50
100
150
200
250
Θ
N
Σ
Ξ
p0 = 1700 MeV
cutoff = 800 MeV

Three body decays of pentaquark p

Decay widths [MeV]	$\Gamma^{(8s)}$	$\Gamma^{(\chi)}$
$N(1710) \to N\pi\pi$ (input)	25	25
$N(1710) \to N\eta\pi$	0.58	0.32
$\Sigma(1770) \to N\bar{K}\pi$	4.7	4.5
$\Sigma(1770) \to \Sigma\pi\pi$	10	3.6
$\Xi(1860) \to \Sigma\bar{K}\pi$	0.57	0.40

Three body decays of pentaquark p

Decay Γ(MeV)	$\Gamma^{(8s)}$	$\Gamma^{(8a)}$	Γ^{tot}_{BMM}
$N(1710) \to N\pi\pi$	25	15	40
$N(1710) \to N\eta\pi$	0.58	-	
$\Sigma(1770) \to N\bar{K}\pi$	4.7	6.0	24
$\Sigma(1770) \to \Sigma\pi\pi$	10	0.62	
$\Sigma(1770) \to \Lambda\pi\pi$	-	2.9	
$\Xi(1860) \to \Sigma\bar{K}\pi$	0.57	0.46	2.1
$\Xi(1860) \to \Xi\pi\pi$	-	1.1	

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Thanks to my collaborators A. Hosaka, T. Hyodo, M. Vicente-Vacas, V. Mateu, E. Oset, J. Pelaez

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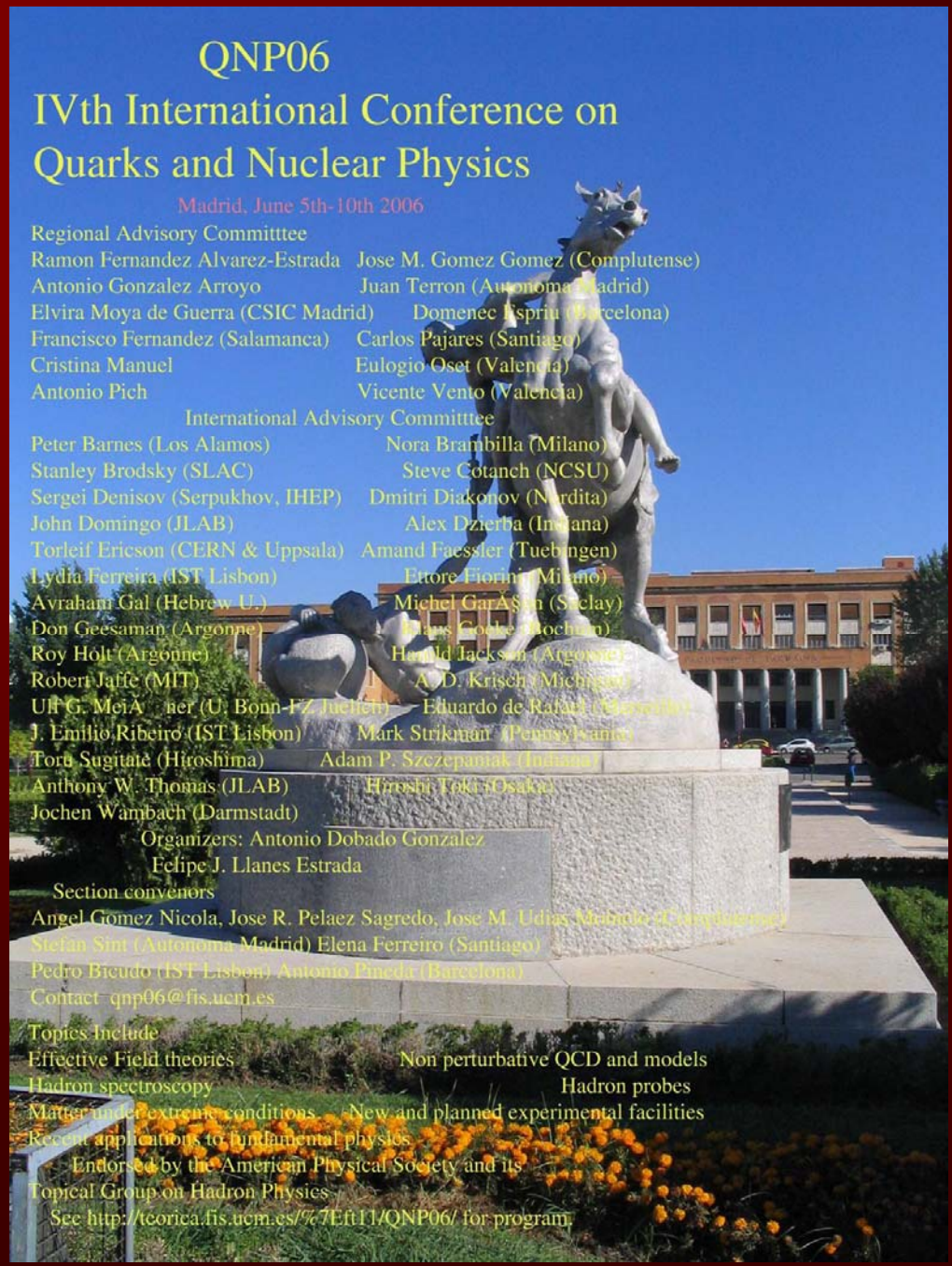

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IVth International Conference on Quarks and Nuclear Physics

Madrid, June 5th-10th 2006

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