Addenda 2008 to variationsQCD2007

On concise hypotheses for the interpretation of a wide scalar resonance as gauge boson binary in QCD

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Fig 1 : *Tentative* **sketch of the $\pi\pi$, $I = 0$ elastic s-wave from $K\overline{K}$ threshold to ~ 1.8 GeV .** →

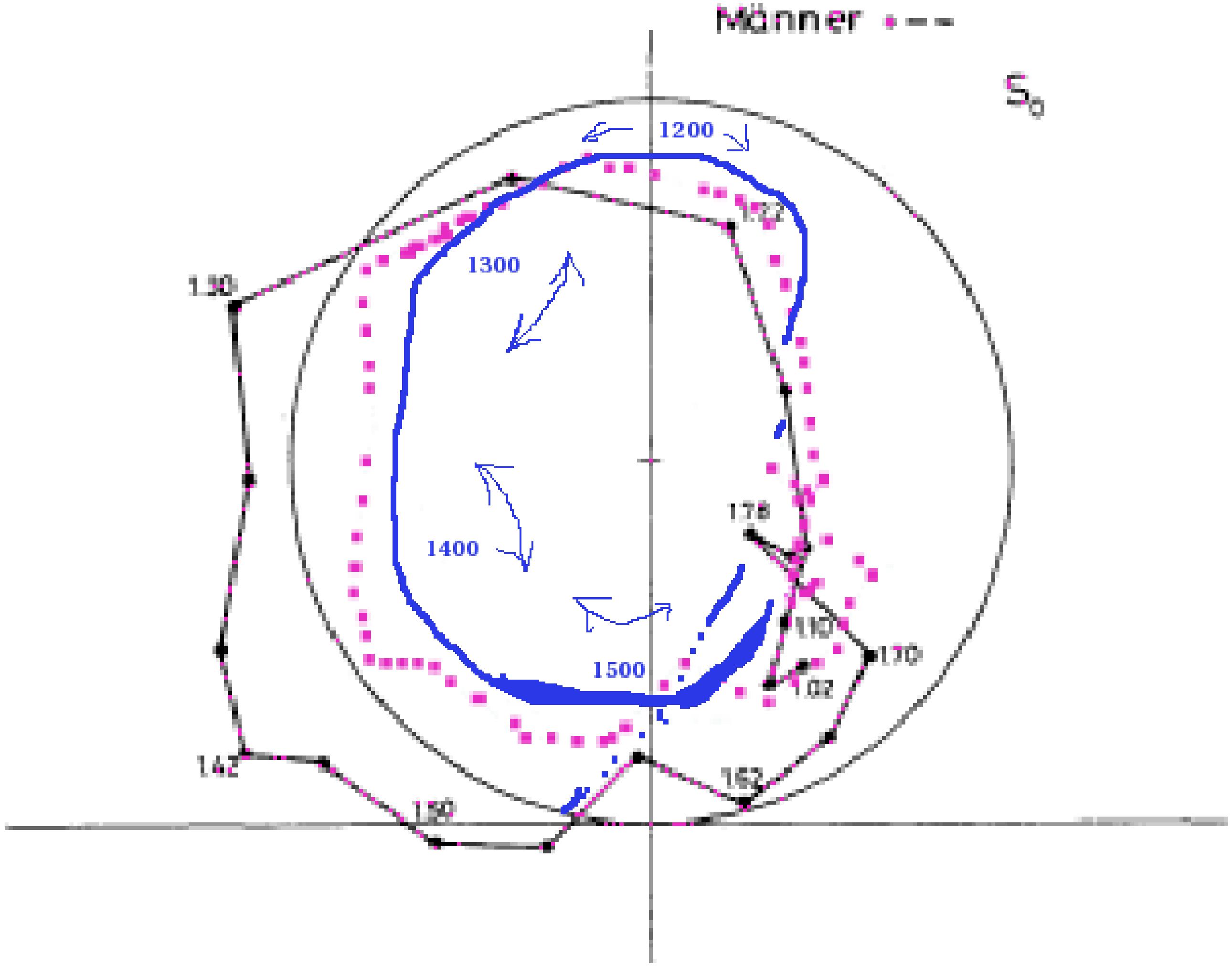

Fig. 2 : *Tentative* reshaping of the $\pi\pi$, $I = 0$ elastic s-wave $+ - -$ according to ref. [1] →

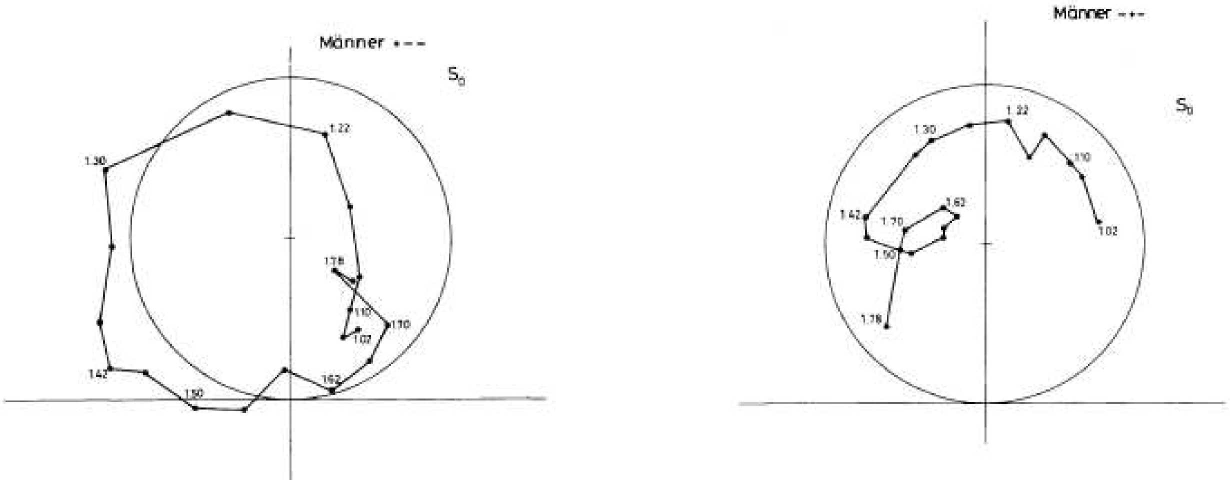

Fig. 3 : Original solutions of ref. [1] for the $\pi\pi$, $I = 0$ elastic s-wave $+--$ and $-+-$

as shown in ref. [2] →

In its Ansatz the solution $+--$ of Männer in ref. [1] is supported by the solution of Kaminski, Pelaez and Yndurain [3] in the region 1300 MeV $\leq \sqrt{s} \leq 1420$ MeV . →

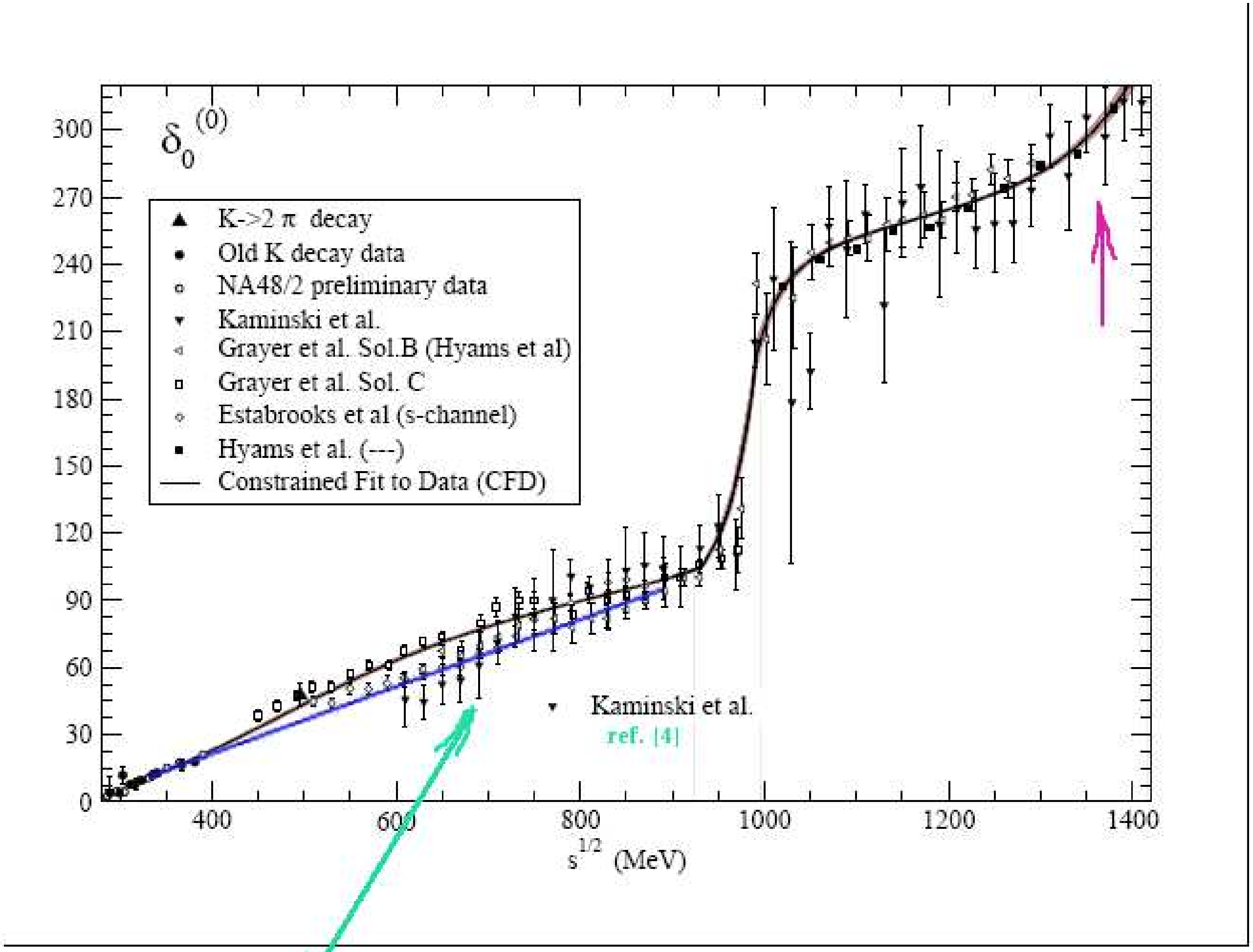

FIGURE 7.1A. S0 wave phase shift (CFD Set). Some data from refs. 4, 6 are also shown. Notice the hump around 700 MeV. **From Kaminski, Pelaez and Yndurain , ref. [3] .**

Fig. 4: Solution of ref. [3] for the $\pi\pi$, $I = 0$ elastic s-wave for $2\, m_{\pi^+} \leq \sqrt{s} \leq 1420$ MeV →

The feature relevant with respect to the difference between the two solutions $+ - -$, $- + -$ of Männer in figure 3 (ref. [1] as shown in ref. [2]) is marked by the purple arrow in figure 4 . The discussion centers around the interpretation of the dip *in (s-wave) cross section* as reported by Becker et al. in ref. [5] the second dip of the red dragon .

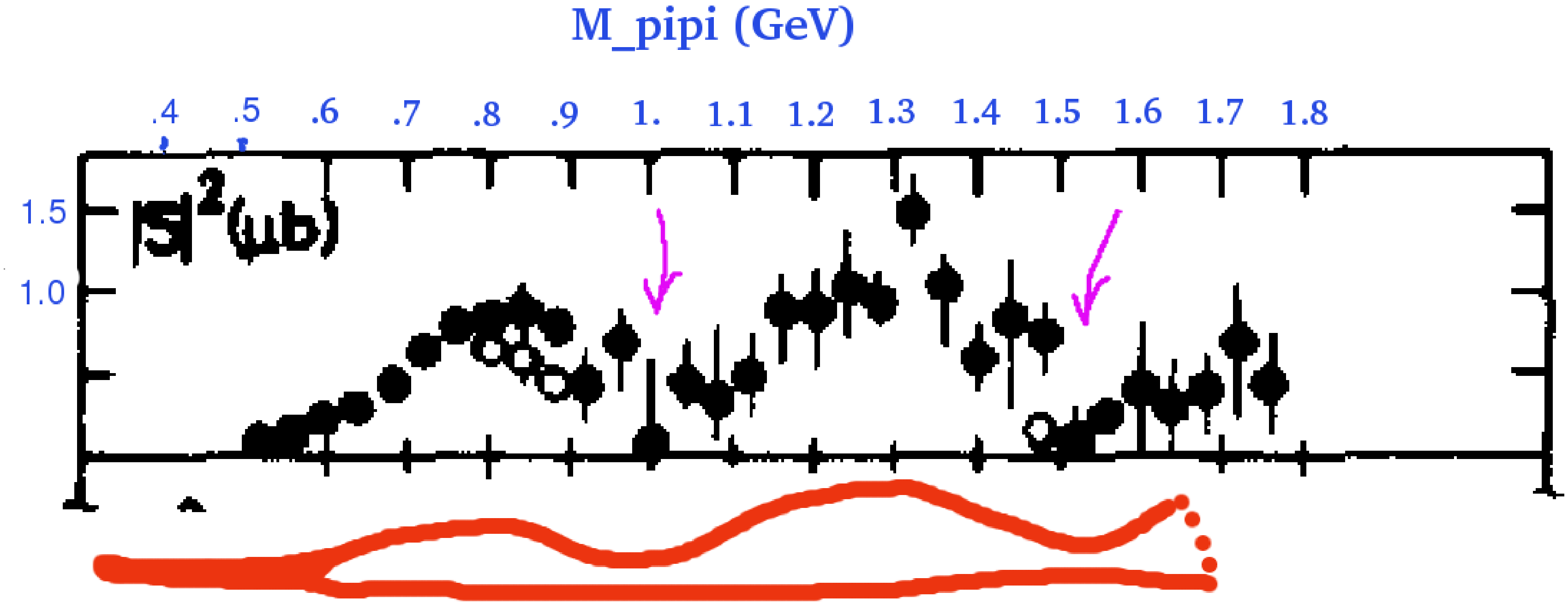

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Fig. 5 : The $\pi\ \pi$, $I = 0 \,\&\, 2$ s-wave ; ref. [5]

It is by reading the text in here figure 4 from Kaminski, Pelaez and Yndurain (op. cit. [3]) mentioning a 'hump' around $\sqrt{s} \sim 700$ MeV ← that something unexpected emerges .
What I mean by the unexpected is not the solution outlined in figure 4 , but rather the appearance of newly evaluated data points starting at $\sqrt{s} \sim 600$ MeV and referring to a paper from 1996 by Kaminski , Lesniak and Rybicki (op. cit. [4]) , based on data by the CERN-Cracow-Munich collaboration on a polarized target, reported around 1978/9 in ref. [5] .

At this point I would like to commemorate Francisco Yndurain – a friend – who died on 5. June and express to his family and near ones my deeply felt condolences.

It is on the errors of the determination of this particular δ_0^0 phase shift through the Chew-Low extrapolation at the lowest possible center of mass energies that he addressed me in e-mail exchanges in spring and summer 2007 . While I deferred his questions to Wolfgang Ochs, abstaining from any definite statement, the above mentioned results do shed light by themselves on this *important* point raised by Francisco .
The clear answer following also from these evaluations mentioned above is that these errors are far bigger than assumed .

The unexpected detour to the region of $\sqrt{s} \ \sim \ 600$ MeV will come into perspective below , but here let me return to the properties of $f_{\,0}\ (\ 1500\ )$ as confronting different s-wave phase shift solutions in the region 1200 MeV $\ \le\ \sqrt{s}\ \le\ 1800$ MeV .
This brings me to the ’first’ concise hypothesis underlying even all interpetations of scalar resonances (at low $m\ \overset{\sim}{<}\ 2$ GeV spectral mass)

1) A successful identification of a gauge boson binary resonance with $J^{\,PC}\ =\ 0^{\,++}$ quantum numbers should be preceded by a clear determination of scalars neighbouring in mass – mainly expected to conform to the valence $q\ \overline{q}$ composition .

[a]

Without great detail the list of scalar resonances as discussed at the meeting in Lisbon , on ’Scalar resonances and related topics’ , February 11 - 16 , serves as guide [6]

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[a] The sad news just arrived that Jan Stern died yesterday, 2. July in Paris. We shall keep this gifted and spirited man and physicist in humble memory .

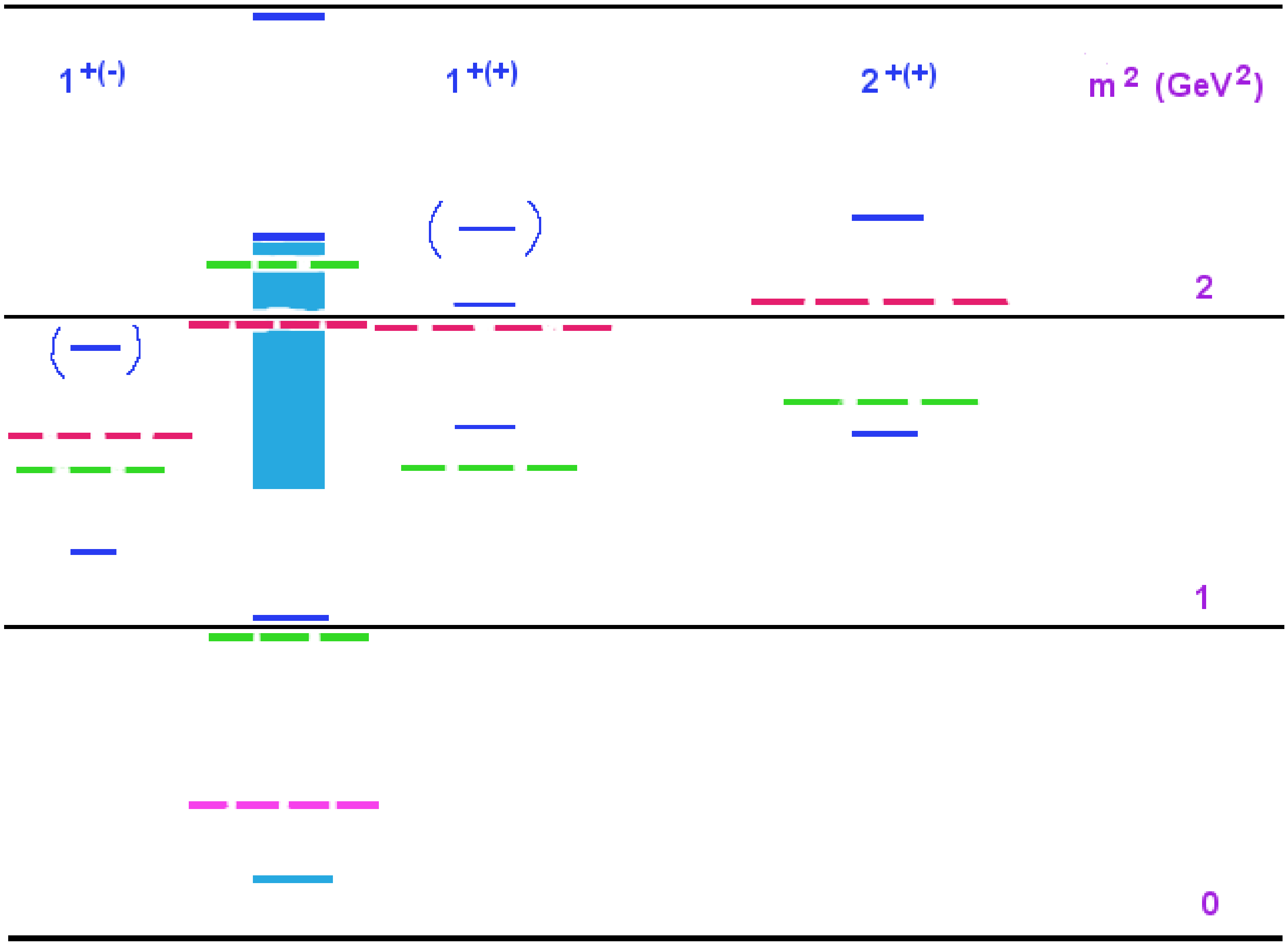

Fig. 6 : $J^{PC}{}_{n} = 0^{++}, 1^{+-}, 1^{++}, 2^{++}$ – **nonets** *adapted* **from refs. [7] , [8] , [9]** (→) .

1 To figure 6 : The set of states displayed in two tables (eqs. 1 and 2) , comprises , using the pole coordinates obtained by Caprini, Colangelo and Leutwyler [8] and name σ as well as those obtained by Descotes-Genon and B. Moussallam [9] and name κ (see the discussion by Meadows in ref. [10]) , while following the PDG otherwise, except the mass value for $f_0(980) \rightarrow m = 1010$ MeV from Hyams et al. [11] , Wolfgang Ochs's thesis [12] and Grayer et al. [13] , see also Protopopescu et al. [14] .

(1)

name	mass [MeV]	width [MeV]	I^G	$\#$
σ	$441 \, {}^{+}_{-} \, {}^{16}_{8}$	$544 \, {}^{+}_{-} \, {}^{18}_{25}$	0^+	1
κ	658 ± 13	557 ± 24	$\frac{1}{2}$	4
$a_0(980)$	984.7 ± 1.2	$50 - 100$	1^-	3
$f_0(980)$	1010 ± 20	$40 - 100$	0^+	1
				9

→

1 to figure 6 continued

(2)

name	mass [MeV]	width [MeV]	$I^{\,G}$	$\#$
$f_{\,0}\,(\,1370\,)$	$1200 - 1500$	$300 - 500$	$0^{\,+}$	1
$K_{\,0}\,(\,1430\,)$	$1414\ \pm\ 6$	$290\ \pm\ 21$	$\frac{1}{2}$	4
$a_{\,0}\,(\,1450\,)$	$1474\ \pm\ 19$	$265\ \pm\ 13$	$1^{\,-}$	3
$f_{\,0}\,(\,1500\,)$	$1505\ \pm\ 6$	$109\ \pm\ 7$	$0^{\,+}$	1
$f_{\,0}\,(\,1710\,)$	$1724\ \pm\ 7$	$137\ \pm\ 8$	$0^{\,+}$	1
				$10\ (19)$

Provided all 19 states listed in eqs. 1 and 2 are retained , hypothesis 1 is simply not fulfilled and thus no further logical consequences can be drawn for a gauge boson binary scalar .

2 **But the discussion about the spectoscopic derivation for the scalars is not from recently and I continue in the following the account of hypotheses and derivations which also were defended (not originally in time) in our common paper with Wolfgang Ochs [15] (1998) .**

→

Thus the 'second' concise hypothesis is

2) The lowest lying nonet with $J^{PC} = 0^{++}$ quantum numbers is interpretable even from an ensemble of not very coherent data, and conforms with a $q \, \overline{q}$ valence-quark composition , within four associated nonets corresponding to $L_{q \, \overline{q}} = 1$.

A major point , *minimally* **extending the discussion here , concerns**

$$K \rightarrow 2 \pi \ \textbf{decays , the} \ \Delta I = 1/2 \ \textbf{rule}$$

$$\left(\ \textbf{the 'story' of} \ \left(\delta_{0}^{0} - \delta_{0}^{2} \right) \ (m_{K}) \sim 60^{\circ} \right)$$

The main 'new' ingredient is to admit $\pi^{0} \leftrightarrow \eta$ mixing – for simplicity induced as only and to lowest mixing order through the ratio of quark masses

(3) $$r = \frac{m_{d} - m_{u}}{m_{s} - \widehat{m}} \sim \tfrac{1}{48} \quad ; \quad \widehat{m} = \tfrac{1}{2} \left(m_{u} + m_{d} \right)$$

→

(4)
$$\mathcal{M}^{\,2}_{\pi\,\eta} = \begin{pmatrix} \frac{4}{3}\,m_{\,s} + \frac{2}{3}\,\widehat{m} & -\frac{1}{\sqrt{3}}\,\Delta\,m \\ -\frac{1}{\sqrt{3}}\,\Delta\,m & 2\,\widehat{m} \end{pmatrix} M_{\,0} + \cdots \qquad \rightarrow$$

$$\vartheta \sim \frac{\sqrt{3}}{4}\,r \sim 0.9\,\% \quad ; \quad \underline{\pi}^{\,0} \sim \pi_{\,0} + \vartheta\,\eta$$

Just considering the charged kaon decay the final state pion pair induces the pure isospin $I = 1$ admixture (using Condon-Shortley phase conventions)

(5)
$$\vartheta \, \langle\, \eta\,\pi^{\,+} \,| \rightarrow - \left\{ \begin{array}{l} I = 1 \\ I_{\,3} = 1 \end{array} \right\}$$

This induces – of course only as a *part* of isospin breaking corrections – the enhanced $\Delta\,I = \frac{1}{2}$ piece of the weak Hamiltonian

(6)
$$\delta\,\langle\,\underline{\pi}^{\,0}\,\underline{\pi}^{\,+}\,|\;T\;|\,\underline{K}^{\,+}\,\rangle = \vartheta\,\langle\,\eta\,\pi^{\,+}\,|\;\mathcal{H}^{\,\Delta\,I\,=\,\frac{1}{2}}_{\,\Delta\,S\,=\,-1}\;|\,K^{\,+}\,\rangle + \cdots$$

The pseudoscalar states – not underlined in eq. 6 – refer to ideal $SU2_{\,fl}$ quantum numbers , but masses inherited from the physical (underlined) pions . →

Hence the first term singled out among all contributions proportional to ϑ reduces with respect to overall isospin

(7) $$\vartheta \, \langle \, \eta \, \pi^{\,+} \, | \, \mathcal{H}^{\,\Delta \, I \, = \, \frac{1}{2}}_{\,\Delta \, S \, = \, -1} \, | \, K^{\,+} \, \rangle \, = \, \vartheta \, \frac{1}{\sqrt{2}} \, \mathcal{B}^{\,(\frac{1}{2})} \, \Big|_{\,\eta\pi}$$

and the full $K^{\,+}$ decay amplitude becomes

(8) $$\begin{aligned} \langle \, \underline{\pi}^{\,0} \, \underline{\pi}^{\,+} \, | \, T \, | \, \underline{K}^{\,+} \, \rangle \, &= \, T^{\,+0} \\ T^{\,+0} \, &= \, \frac{\sqrt{3}}{2} \, \mathcal{A}^{\,(\frac{3}{2})} \, + \, \frac{1}{\sqrt{2}} \, \vartheta \, \mathcal{B}^{\,(\frac{1}{2})} \, \Big|_{\,\eta\pi} \, + \, \cdots \end{aligned}$$

Isospin corrections to $K \, \rightarrow \, 2\pi \, (\gamma)$ decays have been considered in a systematic chiral expansion by Cirigliano, Ecker, Neufeld and Pich [16] , with the result that

(9) $$(\, \delta^{\,0}_{\,0} \, - \, \delta^{\,2}_{\,0} \,) \, (\, m_{\,K} \,) \rightarrow \sim \, 60^{\,\circ} \qquad \text{correcting all isospin breakings}$$

but how the amplitude $\mathcal{B}^{\,(\frac{1}{2})} \, \Big|_{\,\eta\pi}$ outlined in eq. 8 can be reliably calculated is not obvious .

The relative order of the isospin correction particularly to $T^{\,+0}$ can nevertheless be estimate rewriting eq. 8 in the form

→

(10)
$$\begin{aligned} T^{+0} &= \frac{\sqrt{3}}{2} \mathcal{A}^{\left(\frac{3}{2}\right)} \left[1 + \delta_I^{+0} \right] \\ \delta_I^{+0} &= \frac{\sqrt{2}}{\sqrt{3}} \vartheta \, \mathcal{B}^{\left(\frac{1}{2}\right)} \Big|_{\eta\pi} / \mathcal{A}^{\left(\frac{3}{2}\right)} + \cdots = O(\vartheta R) \\ R &= \left| \mathcal{A}^{\left(\frac{1}{2}\right)} / \mathcal{A}^{\left(\frac{3}{2}\right)} \right|_{no\ I\ br.} \sim 22.2 \\ |\vartheta R| &= O(20\,\%) \end{aligned}$$

→

While the change in cosine of the corrected phase shift difference in ref. [16] is indeed of the right order it may well induce a reduction of $\Delta\delta = \left(\delta_0^0 - \delta_0^2\right)(m_K)$

(11)
$$\Delta\delta \to O(41^\circ)$$

→

The present – limited – outline shall conclude exploring the logical possibility

The rise of the $I = 0 \, \pi\pi$ phase shift in the region $m_K \leq \sqrt{s} < \sim 0.8$ GeV could be slower than experimental analyses [11] - [14] have suggested

Lets return to the results in the CERN yellow report by Petersen [2] (1975) , and his analysis of the Roy [17] equations, extending the foundations laid by Basdevant, Froggatt and Petersen ([18] 1974) . In the report (op.cit.) Peterson shows three characteristic curves for the $I = 0 \, \pi\pi$ s-wave phaseshifts $\delta_0^0 (\sqrt{s})$ in figure 3.13 (p. 54) .

The three curves correspond to the scattering lengths $a_0^0 = 0.17 , \, 0.30, 0.50$ iin units of m_π^{-1} respectively , but it is not possible for me to know , which inputs , experimental and theoretical were at the basis of the 3 curves.
In figure 7 below a quadratic interpolation to the value $a_0^0 = 0.22$ is performed with the result

$$\delta_0^0 (0.5 \text{ GeV}) \sim 32^\circ \tag{12}$$

→

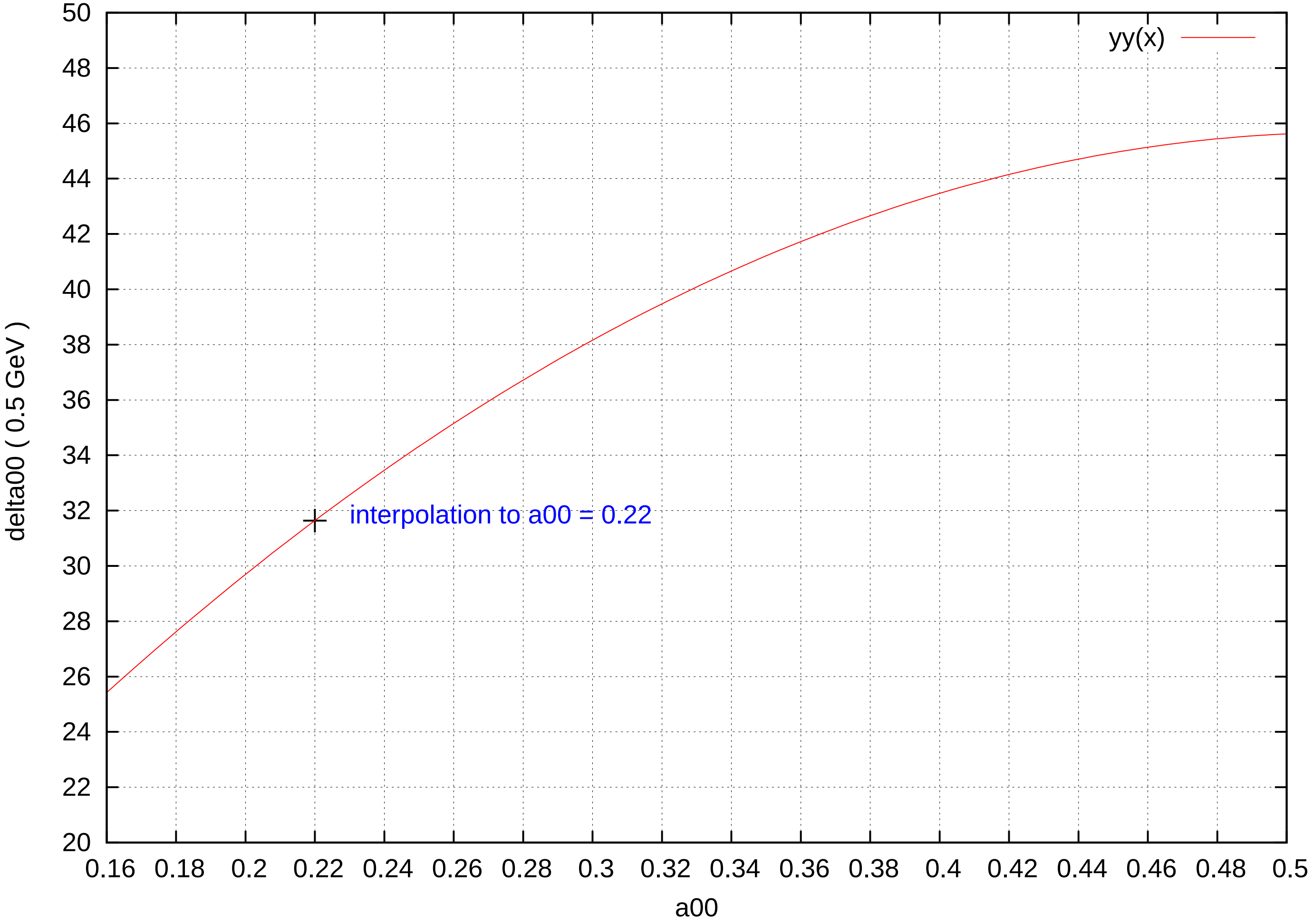

Fig. 7 : The $\pi\ \pi\ ,\ I = 0\ \&\ 2$ s-wave ; as calculated by Petersen for different values of the scattering lengths for $a_0^0 = 0.22\ :\ \delta_0^0\,(0.5$ GeV $) = 31.64^\circ$, ref. [2] →

Choosing a value $\delta_0^2(0.5\ \text{GeV}) \sim -9^\circ$ would correspond to

(13) $$\Delta\delta \sim 41^\circ$$

on the low side of values obtained e.g. in refs. [3] or [8] but comparable with the (low) order of magnitude estimate in eq. 11 .

Finally let me return te figure 4 (p.5) , where the phaseshifts obtained with the polarized proton target by the CERN-Munich-Cracow collaboration [4] also indicate a possible trend towards the lower side of allowed combined experimental error bands.

Conclusions

1) The concise hypotheses outlined do not allow to identify with clarity any candidate gauge boson binary with quantum numbers 0^{++} at present .

2) The derivation from dispersive partial wave analyses of low mass complex poles in scalar meson meson scattering amplitudes has *not* reached a convincing analytical demonstration despite a large number of confirming theoretical approaches .

3) I discussed arguments in support of *maintaining* the logical possibility that the spectroscopic ’embarras de richesse’ of scalar resonances below 2 GeV resolves into an interpretable spectrum .

Thank you

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