THEORY

T.D. Lee: "50% of Theoretical Physics is emotion"

ASSUME That $\sigma(500)$, $\kappa(800)$ ACTUALLY exist.
What are our options?

1. An USUAL $(q\bar{q})$ $L=1$, Scalar Nonet $[\sigma, \kappa, a_0(980), f_0(980)]$ below 1 GeV.

Seems reasonable at first sight building on $(q\bar{q})$ $L=0$. $[\pi, \rho$ etc.$]$

Problems

Joe Schechter (Kyoto, 2000)

- $a_0(980)$ and $\sigma(500)$ — Same # Non-strange quarks NOT degenerate.
- As P-wave States, why not in > 1 GeV energy region of other P-wave States.

- cannot explain $f_0(980) \sim s\bar{s}$, and $a_0^+(980) \sim u\bar{d}$ degeneracy. Kolia Achasov [Nucl. Phys. A675, 279c (2000)] regard explanation of observed $\phi \rightarrow \gamma f_0(s\bar{s})$ detached from $a_0(980)$ as "Awful" from theoretical viewpoint.

- No denying that Scadron (Kyoto, 2000) Produced in $q\bar{q}$ approach not only Nambu relation $m_\sigma \approx 2m_q$ but also treasured Sakurai Vector Meson dominance Universality Condition. However $q\bar{q}$ for vector meson Not challenged (in isolated environment, remote from background) — quote N. Achasov (Private Communication 1/29/02)

QCD Sum Rules agree very well

Linear σ – model (Scadron), effective lagrangians, obtained in Nambu – Jona Lasinio NJL type model are valid, strictly speaking, only for 'virtualities' much less than threshold for creation of $q\bar{q}$ pair, i.e. light (better for massless) particles. Sometimes work, e.g. vector channel.

However Bjorken (2/7/02 Communication) on $m_\sigma = 2m_q$

"Sorry, but I don't have anything useful to say about σ – mass. It is pushing the limits of what NJL can do In My humble Opinion."

- Van Beveren, Scadron et al. [Modern Phys. Lett. A, Vol. 17, No. 225 (2002) 1673 – 1684] argued strongly against $q\bar{q}$ approach of Shakin – Wang. Perhaps 'two $q\bar{q}$ birds are being killed with one stone?'

2. What if σ – exists $\lesssim$ 1 GeV, but K (800) does not exist — Cherry & Pennington [Nucl. Phys. A688 (2001) 823]

In S. Narison's words (19/9/01)

" In addition to the glueball of mass 1.5 GeV found e.g. on the lattice in the quenched approx. as well as from sum rule, a light glueball is needed for simultaneous saturation of the subtracted and unsubtracted sum rules where the stablization scale occurs.... this light glueball couples strongly to pi-pi (OZI violation) and is Not found from quenched lattice simulation — Need to include quark loops [c.f. S. Narison, hep-ph/0208081] believe Ochs & Minkowski [hep-ph/0209223 and hep-ph/0209225] endorses this approach since $f_0(980)/a_0(980)$ can be returned to $q\bar{q}$ assignment together with above 1 GeV $f_0(1500)$ and $\kappa(1430)$.

3. $(qq)(\bar{q}\bar{q})$ – States: Structure allows two configurations in Color Space: $\{\bar{3}3\}$ and $\{6\bar{6}\}$, may mix/rearrange to form $(q\bar{q})(q\bar{q})$ with Color Configuration. Difficult to distinguish a tetraquark state from a mesonic molecule. Isgur and Weinstein (1983) observed that four quarks in Confining Potential are mainly arranged as two Colour Singlets at large (1.5 fm) distance and give birth to <u>MESONIC MOLECULES</u>

Such a loose bound structure appears consistent with Rosner's 2^c worth statement: –

"A low-mass (~ 600 MeV) scalar (as a dynamically induced $\pi-\pi$ interaction) is consistent both with theory (current algebra, crossing symmetry and unitarity) and with experiment. A similar enhancement appears to be occurring in the $I = \frac{1}{2}$ S-wave $K-\pi$ system"

May even be relevant to electroweak scale if the Higgs boson turns out to be a broad, dynamically generated object rather than the narrow state everyone is hoping for at 115+ GeV.

Adler [c.f. hep-ph/0109191] supportive of Rosner
Namely PCAC Consistency Condition → need low energy broad $\pi - \pi$ Scattering resonance.

<u>CAVEAT</u>! Building in of Analyticity, unitarity, crossing in dispersion theoretic, Roy Equations Procedures [Kaminski, Keiji Igi, Bugg/Zou, Josef Speth, Ted Barnes] either <u>for</u> σ - meson existence or <u>against</u> σ - meson existence

MUST CONFRONT the <u>left - hand Cut Problem</u>
Volodya Anisovich Says:-

"... The $\pi - \pi$ amplitude has the left-hand cut affected by interaction forces, so constraints coming from left-hand cut are important, our knowledge is rather vague (mostly to test <u>individual</u> hypothesis e.g. ρ - exchange etc.).

The left-hand cut is highly unstable near threshold s. A comparatively small change of partial wave amplitudes affect the left hand cut considerably. The reason being the contribution from different (t and u) channels and different resonances <u>Cancel each other to a great extent</u>"

Fitting data within rigid constraints on $\pi\pi$ amplitudes for $s < 4m_\pi^2$ can lead to incorrect amplitude representations in mass region of σ searched for!

<u>CONCLUSION</u>: Theory method here cannot be definitive on existence / Non existent of σ - meson!

4. Ishida Model of Chiral Particles / Covariant Level Classification

[Kyoto, 2000; this Symposium]

Nils Tornqvist: relativistic S-wave $q\bar{q}$ bound states with $J^{PC} = 0^{++}$ quantum numbers, "chiralons", would appear only at low masses, include $(\sigma, \kappa, a_0, f_0)$, very speculative, but would open up a new approach.

WHERE is the 'Smoking Gun' test of Model?

Believe it is the Scalar B_0^χ of the B-meson system.

$$B_0^\chi \longrightarrow B + \pi \quad (S\text{-wave})$$

Possible evidence for Production of B_0^χ [Mass 5530 – 5570 MeV; $\Gamma \sim$ 10 – 40 MeV] as analysed by Ishida et al. hep-ph/0208245 from the data of L3 and Aleph.

Update: I. Yamauchi, this Symposium, $\Gamma \sim$ 20 MeV

IMPORTANT TO HAVE independent affirmation of B_0^χ by an experimental group, e.g. at CLEO where much fine features of B-Physics is done. Pushed my CLEO friend Sheldon STONE very hard on this since July, 2002.

Sheldon Stone replied on December 4, 2002

" I don't have much to add. The new CLEO $\Upsilon(3S)$ data shows the same double peak structure as before (relevant to B_0^χ interpretation of Ishida model). I don't think we are going to be able to say much about B_0^χ. Have fun in Tokyo"

Sheldon

5. Mesonic Molecules Revisited

Inspired by Weinstein – Isgur (1983), $(qq)(\bar{q}\bar{q})$ case, but considering only mesonic degrees of freedom (i.e. Color singlets) — e.g. ρ – exchange between $K\bar{K} \longleftrightarrow f_0(980)$ — A very Compact molecule. Reason: Radiative ϕ decays exclude the extended loosely bound Weinstein – Isgur molecule while giving strong evidence for compact $K\bar{K}$ – state or a Compact four-quark state

[N. N. Achasov, hep-ph/0201299, Also talk at this Tokyo Symposium. "Radiative decays of ϕ meson ......"]

Think the Adler – Jaffe – Achasov [hep-ph/0109191] approach Could be a mix of 3. above and 5. here. Need broad σ: $\pi-\pi$ resonance at low mass and would like to accomodate $f_0(980)$ as a Compact four-quark state — to form below 1 GeV Scalar Nonet.

N.B. V. Anisovich (9/24/02) argued that classification of Kaon states on (J, M^2) – plane (hep-ph/0208123, Fig. 11) points out that a κ (~ 900 MeV) (Much under discussion at this Symposium, does not belong to (J, M^2) trajectories related to $q\bar{q}$ states. Strong argument against κ as $q\bar{q}$ — all other $q\bar{q}$ states lie on these linear trajectories well.

Turn this argument around. A κ (800 – 900 MeV) cannot be glueball (isospin); implausible to be a hybrid (believed to be significantly higher than 1 GeV mass). What else can it be if existence established? Reductio Ad Absurdum reasoning :—

$\boxed{\kappa \text{ is a multi-quark state!}}$

<u>IMPORTANT POINT</u>: Quark content of (σ, $f_0(980)$, $a_0(980)$, κ) "virtuality" dependent in Bogolinbov sense. Adler calls it Coherent states which is worth following up in future.

T. Kunihiro, Progr. Theor. Phys. Suppl. 120 (1994), 75

Since hep-ph/0109191, Tornquist (5/17/2002) no longer troubled that pion could end up as a 4q state. In new thinking [hep-ph/0204215 v3 6 Jun 2002]. These low lying scalars are <u>emerging</u> Goldstone Higgs nonet (of strong nonperturbative interactions when a hidden local symmetry is spontaneously broken) and is a superposition of $q\bar{q}$, $qq\bar{q}\bar{q}$, $qqq\bar{q}\bar{q}\bar{q}$ ... Emerging coined from Bjorken [hep-th/0111196] where Jaffe's natural nonlinear realization in hep-ph/0109191 $\zeta = \sqrt{f^2 - \vec{\pi}^2} = f - \frac{\vec{\pi}^2}{2f} + \ldots$ is reproduced in bj's Eq. (12) — Convergence of views!

<u>Observations</u>:

- If scalar nonet predominantly of 4q-form of Jaffe $(3, \bar{3})$, 4q system coupled in color — inverted equally spaced spectrum follows [Tornqvist, hep-ph/0204215] $a_0(980)/f_0(980)$, $\kappa(\sim 800)$, $\sigma(600)$ — Not bad at all!
- How about instanton effects that Narison emphasize for the η' problem. Could it cause trouble for the multi-quark Adler-Jaffe-Achasov approach hep-ph/0109191? N. Kochelev [9/22/02] says "From his point of view, a multi-quark interaction, induced by instantons, could be <u>reason</u> for the observed enhancements in 0^{++} channels."
- M. Iwasaki: 'Meson Bound-State Search Experiments' [Kyoto, 2000] say σ below 280 MeV (two pion threshold) would become stable (hence very narrow width).

Seems to resonate with Zahed et al. [hep-ph/0209249] which discusses scalar - isoscalar excitation in dense quark matter. Here σ- meson in this phase appears as 4q state (diquark and anti-diquark) with a well-defined mass and extremely small width, as a consequence of its small coupling to two pions. Question: In A-J-A inspired paper [hep-ph/0109191], it was argued that when Bogoliubov virtuality of σ- states ~ m_π mass as $q\bar{q}$ states, chiral partner of π, but when virtualities of $\sigma \lesssim 1$ GeV, exhibit 4q state characteristics. Is Zahed et al. saying that even below 2π threshold (closer to m_π than 1 GeV), σ retains 4q characteristic?

[Perhaps experimental work of Dirac Collaboration, πN Newslett. 16 (2002) 352. http://dirac.web.cern.ch/Dirac on Pionium, Kaonium will clarify this issue?]

THE FUTURE

Beyond light scalars < 1 GeV, lies the U(3) × U(3) linear σ - model. This model does not exist in the tree level approximation (unfortunately!). This model is renormalizable and strategically (my favorite word) its study on the lattice is very intriguing, above 1 GeV say. $\boxed{\text{BuT Existence of } \kappa(800) \text{ Critical to theory}}$

[N. Achasov (12/10/02), N. Achasov and G.N. Shestakov, Phys. Rev. D49, 5779 (1994); N. Tornqvist mentioned in Kyoto, 2000, p. E227 that Joe Schechter was one of the originators of the U(3) × U(3) linear sigma model (LσM).]

M. Ishida (hep-ph/0212383, and this Symposium)

Makes an <u>important</u> critique of Conventional analysis

$$\mathcal{F}_{\pi\pi} = \alpha(s)\, T_{\pi\pi}\,; \quad \alpha(s): \text{slowly varying real function}$$

Production Amplitude — Scattering Amplitude

$\Longrightarrow$ $\mathcal{F}$ and T have the same phases and same structure

(<u>Common Positions of Poles</u>, if they exist)

Often argued amplitude of $J/\psi \to \omega\pi\pi$ (or $D^+ \to \pi^-\pi^+\pi^+$) (for $\pi\pi$ Production) <u>must take same phase</u> as the $\pi\pi$ scattering phase, since in this energy range $m_{\omega\pi}$ ($\sim M_\psi$) is large, and $\pi\pi$ decouples from ω in final channel. Phase constraint is argued to come from $\pi\pi$ elastic unitarity condition [Fermi - Watson - Migdal Theorem]

However according to the excellent work of Suzuki - Achasov [references given in hep-ph/0109187] large relative strong phase needed for $J/\psi \to \omega\pi^0, \rho\pi$, $K^*\bar{K}$ for the famous puzzle here, likewise for $J/\psi \to 0^-0^-$. Long distance effect and <u>Non</u> Perturbative QCD regime.

Suzuki (1/04/03): In $J/\psi \to \omega\pi\pi$, invariant $m_{\omega\pi} \lesssim 1.6$ GeV. There are "overlapping resonant phases" — many non strange resonances up to 2 GeV in PDG to contribute.

For $D \to K\pi$, K and π back to back at 1.87 GeV. Experimentally [CLEO, Phys. Rev. Lett. <u>78</u> (1997) 3261] final state $K-\pi$ interaction very large ($\sim 90°$) in interaction phase difference $\delta_{3/2} - \delta_{1/2}$ at m_D. Hence $K-\pi$ scattering at 1.87 GeV definitely <u>not</u> in perturbative QCD regime. SAME for $K^*-\pi$ at 1.87 GeV.

$B \to D\pi, D\rho, D^*\pi$ situation discussed by Rosner - Chiang [hep-ph/0212274 v.3 8 Jan 2003]

If $\mathcal{F} = \alpha(s)\, T$ not true for say $J/\psi \to \omega\pi\pi$, $J/\psi \to \pi K \pi K$, $D \to \pi\pi\pi$, $D \to K\pi\pi$, even though the question of rescattering and its importance remains debatable. Need to <u>separate</u> analysis involving $(n \geq 3)$ multi-hadron final states as listed above from the clean $n = 2$ case. To wit following M. Ishida

Take FOCUS Experiment $D^+ \to (K^-\pi^+)\mu^+\nu$

isolated in strong interaction level $\Rightarrow$ Fermi-Watson-Migdal Theorem applicable $\to$ $\mathcal{F}$ and T have common phase

FOCUS: $D^+ \to \bar{K}^{*0}\mu^+\nu$ dominant, with small S-wave $(K^-\pi^+)$ - component, <u>and constant phase $\delta = \pi/4$</u> in region of κ with $m_{K\pi} \sim 0.8$ GeV. This δ is suggested by Ochs - Minkowski [hep-ph/0209225] to be the same as K-π scattering phase shift by the extensive LASS (1988) data. Fermi-Watson-Migdal Theorem is respected.

Shabalin (1988) on $K_{\ell 4}$ decay, using SU(3)/LσM $K^+ \to \pi^+\pi^- e^+\nu$, considered as $K^+ \to \sigma e^+\nu$ $(\sigma \to \pi^+\pi^-)$ explains large width (twice as large as soft pion prediction)

Watson ~~teem~~ Thm here amplitude has same phase as $\pi\pi$ scattering phase shift, σ Breit-Wigner phase motion not observed, but large width suggests σ production! Analogue of FOCUS.

Take Now E791 Experiment $D^+ \to (K^-\pi^+)\pi^+$ — Not isolated
(large phase motion / Breit Wigner in κ region) $\to \bar{K}^0\pi^+$
Rescattering or other mechanism

$\Longrightarrow$ $\mathcal{F}_{K\pi}$ has different phase from $T_{K\pi}$ of scattering. — Watson Thm questionable

<u>Conclusion</u>: No contradiction between E791 and FOCUS

Brian Meadows [22/10/02]

"E791 did an excellent job in showing that a "NR" (contact)
amplitude with magnitude and phase independent of position
on the Dalitz plot simply did not work as it had for earlier
data. The next simplest assumption, <u>an S-wave Breit
Wigner</u>, did however give an excellent description of the
data, <u>both magnitude and phase</u> — in both $K\pi$ and
$\pi\pi$ systems. Really that is all." My applause as a
most sensible way to proceed — <u>the next simplest assumption</u>

Urge CLEO [Phys. Rev. Lett. <u>89</u>, 251802 (2002)]
from $D^0 \rightarrow K_S^0 \pi^+\pi^-$, currently <u>NULL</u> result on $\kappa^-(800) \rightarrow K_S^0\pi^-$, and Babar [hep-ex/0207089], <u>NULL</u> result
on $\kappa^+(800)K^-$ in $D^0 \rightarrow K^0 K^- \pi^+$ Dalitz plot analysis,
to follow the next simplest assumption to verify or
refute E791. Breit Wigner and phase motion should
be same in CLEO/Babar according to Ishida/Suzuki

<u>Remark</u>: D. Bugg (10/31/02): "Particles are to be
identified as poles. If you allow the pole position
to be different in different processes, you are
allowing the particles to have different mass and
width in different processes (VMW procedure?). This
is <u>Not</u> true for $\rho(770)$ and $f_2(1270)$ in different
processes ......"

Achasov { However $\rho(770)$ and $f_2(1270)$ could again be a case
of 'isolated environment, remote from background'

<u>Rosner</u> (9/24/02): Our experience with reactions
$\gamma\gamma \rightarrow \pi\pi$ indicates that the way in which a <u>broad</u> resonance
(e.g. σ, κ) <u>manifests itself can differ significantly from
process to process, particularly elastic vs inelastic channels</u>
(Comparison)

Compilation of σ, κ Poles [Van Beveren - Rupp] hep-ph/0201006

If "σ" exists at low mass, it should be deployed to solve other outstanding puzzles [remember 50% of theoretical physics is 'emotion']

Ishida's work exciting to me. [Phys. Lett. B518, 31, 47 (2001); hep-ph/0110357, hep-ph/0110358, and hep-ph/0212383]

Remember multipole expansion of QCD has more or less successfully treated suppression of spectra near $\pi\pi$ threshold [resulting amplitude has Adler zero around $s \sim 0$]

in

$\psi(2S) \to \psi(1S)\pi\pi$ $\quad \Delta E = 589$ MeV $\quad ka \sim 0.7$

$\Upsilon(2S) \to \Upsilon(1S)\pi\pi$ $\quad \Delta E = 563$ MeV $\quad ka \sim 0.3$

$\Upsilon(3S) \to \Upsilon(2S)\pi\pi$ $\quad \Delta E = 332$ MeV $\quad ka \sim 0.18$

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here k is typical momentum of emitted gluons

$$k \sim \tfrac{1}{2}(m_{\Phi'} - m_{\Phi}), \quad \Phi = \psi, \Upsilon \text{ for two gluon emission.}$$

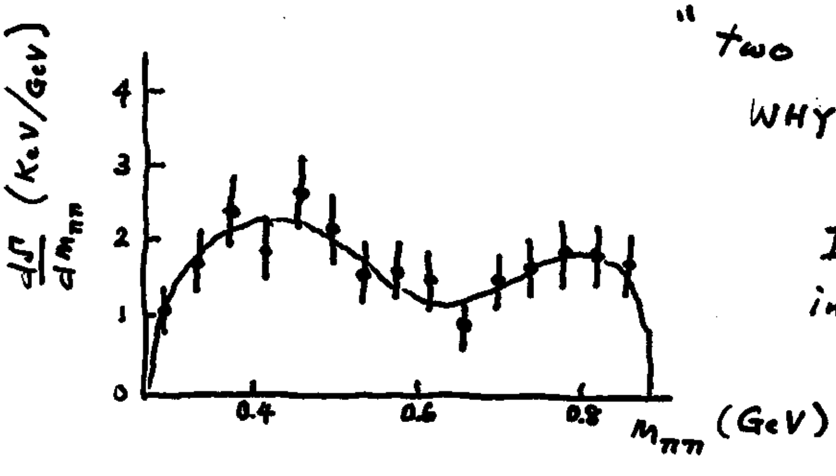
[Similar results if choose $1/k \sim 1$ fm, typical size of light hadrons]

a : Size of $Q\bar{Q}$ system, estimated from potential models.

Also known from Nuclear Physics that the classification of multipole orders is valid even for $\boxed{ka \sim 1}$

Fly in ointment

$\Upsilon(3S) \to \Upsilon(1S)\pi\pi$ $\quad \Delta E = 895$ MeV $\quad ka \sim 0.48$



"two Peak Anomaly"

WHY is Multipole failing for reasonable?

Ishida proposes tantalizing intervention of "σ" for mass range

$0 < m_{\pi\pi} \lesssim 900$ MeV

Actually they introduce Production amplitude $\mathcal{F}^G_{2\pi}$ (where G is ground-state tensor and Scalar glueballs intermediary, straightforward extension of two gluon intermediary of multipole / QCD work)

$\mathcal{F}^G_{2\pi} \approx -2\xi^G p_{10} p_{20}$, vanishes when $p_{1\mu} \to 0_\mu$. Thus, it has Adler zero, Satisfy general constraint from chiral symmetry, does not vanish at $s = m_\pi^2$. In relevant Process, Adler limit $p_{1\mu} \to 0_{1\mu} \Longrightarrow$ Neglect ΔE in comparison with m_π. At $s = 4m_\pi^2$, $p_{1\mu} \hat{=} p_{2\mu} \longrightarrow p_{10} = p_{20} \approx \Delta E/2 = 450$ MeV $\gg m_\pi$ in $\Upsilon(3S) \to \Upsilon(1S)\pi\pi$ transition. $F^G_{2\pi}$ almost s-independent in Physical region here, has No zero close to threshold.

Hence No Suppression Near threshold. $\pi\pi$ Spectrum can Show Steep increase from threshold!

$$\mathcal{F}^{Phen} \equiv \mathcal{F}^{Phen}_{\sigma+2\pi} + \tilde{F}^G_{2\pi}$$

σ Breit-Wigner   direct 2π amplitude

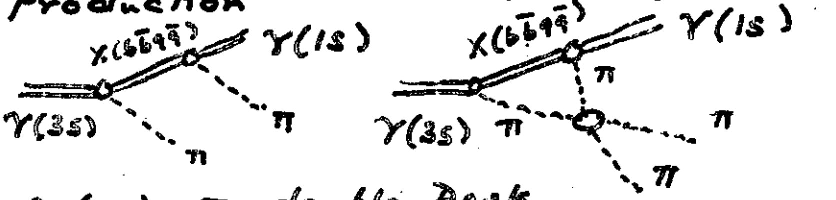
<u>Remarks</u>:

- Constraints of chiral symmetry the $\mathcal{F}_\sigma$ amplitude Must be strongly cancelled by Non-resonant <u>repulsive</u> $\pi-\pi$ amplitude in $\pi\pi$ Scattering — destructive interference between $\mathcal{F}_\sigma$ and $\mathcal{F}_{2\pi}$ explains suppression of threshold spectra for $\Upsilon(2S) \to \Upsilon(1S)\pi\pi$, and $\psi(2S) \to \psi(1S)\pi\pi$. For $\Upsilon(3S) \to \Upsilon(1S)\pi\pi$ amplitudes interfere <u>constructively</u>. These behaviors of Production amplitudes Consistent with chiral Symmetry Constraint. Especially interesting that double Peak structure, bottom around σ-Peak Position. $\Upsilon(3S) \longrightarrow \Upsilon(1S)\pi\pi$ spectra reproduced well by interference between direct $\mathcal{F}_{2\pi}$ with zero phase and $\mathcal{F}_\sigma$ with moving Phase. <u>We are observing very Phase motion of σ-Breit Wigner via double Peak anomaly Puzzle!</u>

• D.V. Bugg (1/5/03): Ishida background phase shift δ_{BG} is <u>repulsive</u>, because take for orientation σ: $M - i\Gamma/2 \sim 550 - 250$ MeV
$\Rightarrow$ Scattering length $\sim 1/m_\pi$. But K_{e4} data demand Scattering length $\sim 0.22/m_\pi$. Hence repulsion needed to balance σ resonance contribution. Repulsive short range interaction required. <u>Question</u>: Mechanism for short-range repulsion?
(ANS: Model independent Chiral cancellation mechanism)

• M. Ishida (7/22/02): The $\mathcal{F}^G_{2\pi}$ derivative type interaction
May have other origin: All sequential two-pion production
gives this type of amplitude according to Adler Self-
consistency condition. The $\Upsilon(1S)-\pi$ resonance amplitude

V. Anisovich et al. [Phys. Rev. <u>D51</u>, R4619 (1995)] deployed such $X(b\bar{b}q\bar{q})$ state in 10.4 – 10.8 GeV region with $J^P = 1^+$ and hence decay in S-wave to $\Upsilon(1S)-\pi$, including both Sequential two-pion Production and triangle singularity rescattering graphs



to explain $\Upsilon(3S) \to \Upsilon(1S)\pi\pi$ double Peak anomaly

$X(b\bar{b}q\bar{q})$ difficult to establish experimentally.
Need $\Upsilon(nS) \longrightarrow \underbrace{\pi + \Upsilon(1S)} + \pi$, $n \geq 6$ to do a mass distribution plot.

in this sense is Consistent with Ishida's analysis "σ" double Peak explanation.
of $\Upsilon(3S) \longrightarrow \Upsilon(1S)\pi\pi$

• V. Anisovich (1/25/03), maintains possible existence of logarithmic (triangle) singularities near ππ threshold should be attributed to search of σ meson in three particle process. Influence of such singularities on ππ spectra are important for low ππ mass (e.g. at $f_0(980)$)
More so at σ – mass.

<u>QUESTION</u>: Is there Convergence to a unified viewpoint on $\Upsilon(3S) \to \Upsilon(1S)\pi\pi$ anomaly?

Selected Meson Topics of Symposium beyond low mass Scalars

$J^{PC} = 1^{-+}$: Situation at Protvino (Hadron 2001). Ted Barnes summarized [hep-ph/0202157] that VES Collaboration (V. Dorofeev, Hadron 2001): No clear preference for a $\pi_1(1400)$ (the M(1405) of Gams in 1988) with $I=1$, $J^{PC} = 1^{-+}$) resonance interpretation. Fit of similar quality from a Non resonant signal. Hence critique of Dalitz et al. [Phys. Lett. B213 (1988), 537] about P-wave interfering background of Gams (1988) remains valid?

E 852 / Brookhaven (A. Popov, Hadron 2001 Proceedings) favors C-exotic $\pi_1(1600) \longrightarrow \eta'-\pi$, $\rho-\pi$, and $b_1(1235)-\pi$.

Nevertheless for a hybrid $q\bar{q}g$ state, theory [Flux tubes, Confining field theory of M. Cornwall/SFT (1984)] continues to maintain Mass prediction for 1^{-+} between 1.9 - 2.1 GeV!

Given my comfort with multi-quark Scalars below 1 GeV, why not treat $\pi_1(1600)$ as the lightest (?) C-exotic from multi-quark (e.g. 4q) Configuration?

T. Tsuru, Indication of 1^{-+} Meson in GAMS (this Symposium)

Historical Review of Search for $J^{PC} = 1^{-+}$ States since 1988.

A. Zaitsev, Exotic Meson Searches in VES, other experiments (this Symposium) $\pi^- A \longrightarrow (b_1(1235)\pi)A$, supports four quark interpretation for $\pi_1(1600)$ in $\pi p \longrightarrow \eta\pi n$, $\eta'\pi n$ Charge exchange.

Existence of $\pi_1(1800)$ in $J^{PC} = 0^{-+}$

$\pi_1(1800) \longrightarrow f_0(980)\pi$, $\varepsilon\pi$, $a_0\eta$, $f_0(1500)\pi$ [unitary singlet + Octet?]

$\not\longrightarrow \rho\pi$ [Octet + Octet] Crypto-exotic hybrid $q\bar{q}g$ (longitudinal fluctuation of flux tube)

S. Olsen, $p\bar{p}$ radiative decay (this Symposium)

$J/\psi \to \gamma p\bar{p}$ using 58 million data sample at BES.

Result: Resonance at $M = 1859 \pm 3^{+5}_{-25}$ MeV

$\Gamma < 30$ MeV (90% C.L.)

NOTE $M_{p\bar{p}}$ (threshold) = 1876.54 MeV

Not yet seen in $J/\psi \to \pi^0 p\bar{p}$, $J/\psi \to \eta^0 p\bar{p}$

Could Ishida's argument that in $J/\psi \to \gamma (p\bar{p})$ isolated in strong interaction level

v.s. $J/\psi \to \pi^0 (p\bar{p})$, $\eta^0 (p\bar{p})$ not isolated in strong interaction

be a consideration?

NOTE AT BELLE $B \to (p\bar{\Lambda})\pi$ → threshold enhancement (resonance?)

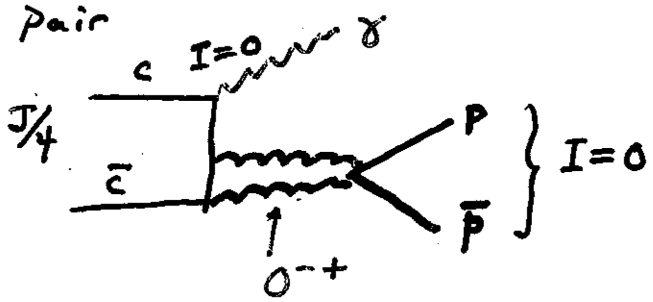
here π from phase space may have moved significantly away from $(p\bar{\Lambda})$ environment | also seen (above / below $p\bar{\Lambda}$ threshold not yet established)

M. Suzuki (1/20/03): Historically these $J^{PC} = 0^{-+}$ octet Mesons in SU(3) were predicted (before Gell-Mann) by Ikeda, Ogawa, and Ohnuki, [Progr. Theor. Phys. 22, 715 '59]

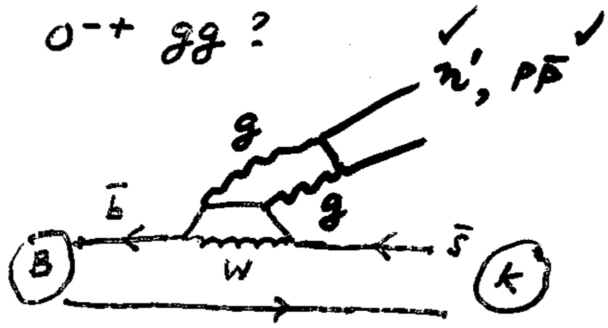
- The S-wave mesonic states near $B\bar{B}$ (baryon) thresholds are "six-quark ($qqq\,\bar{q}\bar{q}\bar{q}$) molecular states". The (qqq) and ($\bar{q}\bar{q}\bar{q}$) are pulled together by gluon equivalent of the molecular Van der Waals force (analogous to suspected $D\bar{D}$ molecular state mode of $cc\bar{c}\bar{c}$). Emphasize deuteron analogy, not Fermi/Yang or Sakata model dynamics.
- If these states are bound states, they should show up as Breit–Wigner resonances in meson channels (check our PDG 2002 resonance table!)
- Near $p\bar{p}$ threshold, Coulombic enhancement important $|\vec{P}|/m_N$ small compared with $\alpha = 1/137$. Enhancement here not present for $p\bar{\Lambda}$ ($\bar{\Lambda}$ has only magnetic moment). Strength of BELLE $p\bar{\Lambda}$ 'enhancement' vs $p\bar{p}$ at BES?

Rosner (2/19/03)

Comment on $\bar{p}p$: could be produced from gluon pair



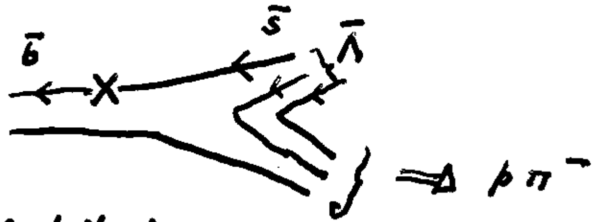
Possible enhancement in 0^{-+} gg ?



ANY Relation to $B \to \underbrace{(gg)}_{\to \eta' ?} K$

We do see $B \longrightarrow p\bar{p}K$!

Certainly in $B^0 \longrightarrow \bar{\Lambda} p \pi^-$,* the mechanism is probably



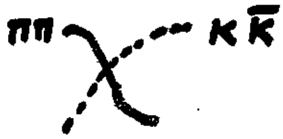
and not so related to $J/\psi \longrightarrow \gamma p \bar{p}$ (check here for 4π, $\pi\pi K\bar{K}$ enhancement)

*[BELLE Collaboration: hep-ex/0302024, 2/18/03]
Fig. 2 especially

Correlate $p\bar{p}\gamma$ with dip in $e^+e^- \longrightarrow$ hadrons
[R. Calabrese PEP-N, workshop Proceedings]

Steve Olsen (this Symposium), dip in $J^{PC} = 1^{--}$ $p\bar{p}$ system near $M_{p\bar{p}} = 2m_p$ [$M = 1870 \pm 10$ MeV, $\Gamma = 10 \pm 5$ MeV]

Note enhancement / dip Correlation like S-wave $\pi\pi$ at $K\bar{K}$ threshold



| 0^+

M. Suzuki says that my Russian friend Kolia will be interested here! } work in generalized vector dominance