Exotics lead the way to glueballs --- through anomalies

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Avec le support de l'IISN, Belgique.

Glueballs are the most direct prediction of QCD since, at the difference of photons, the non-abelian gluons carry a colour charge.

Yet, despite many searches **we have no undisputable evidence** pinpointing a particular state as a glueball, and they remain elusive.

They have certainly been produced abundantly, but …

MAYBE THEY ARE "ANOTHER KIND OF FISH"

MAYBE THEY ARE “ANOTHER KIND OF FISH”

Their quantum numbers of course include no Isospin, charge, or flavour, leaving only their mass (various calculations), spin , parity, and of course decay modes (into other glue states or ordinary mesons) as criteria

A typical expected glueball would be, say a J^{PC} =0^{++} state between 1 and 2 GeV…the prototype colourless, smell-less, flavour-less compound: **something perfectly mimetic** with the background (vacuum).

MAYBE THEY ARE “ANOTHER KIND OF FISH”, perfectly mimetic, …or NO FISH at all.

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An OCTOPUS surrounded by "many ordinary fish", probably waiting for left-overs
a common way for fishermen to locate the mimetic octopus. Corfu, 2022)

(or : ordinary mesons as the decay products of a glueball)

Most of the time, the search proceeds through a partial wave analysis of the decay products.

This is practically limited to few bodies final states, typically 2 ordinary mesons (π, ρ, K…) , although some candidates have been seen in more complex finals states for instance in 4 π .

Concentrating for now on 2-meson finals states, can we be more specific?
What about be the branching ratios?

The starting point would be to remark that glue states are

- **flavour blind,**

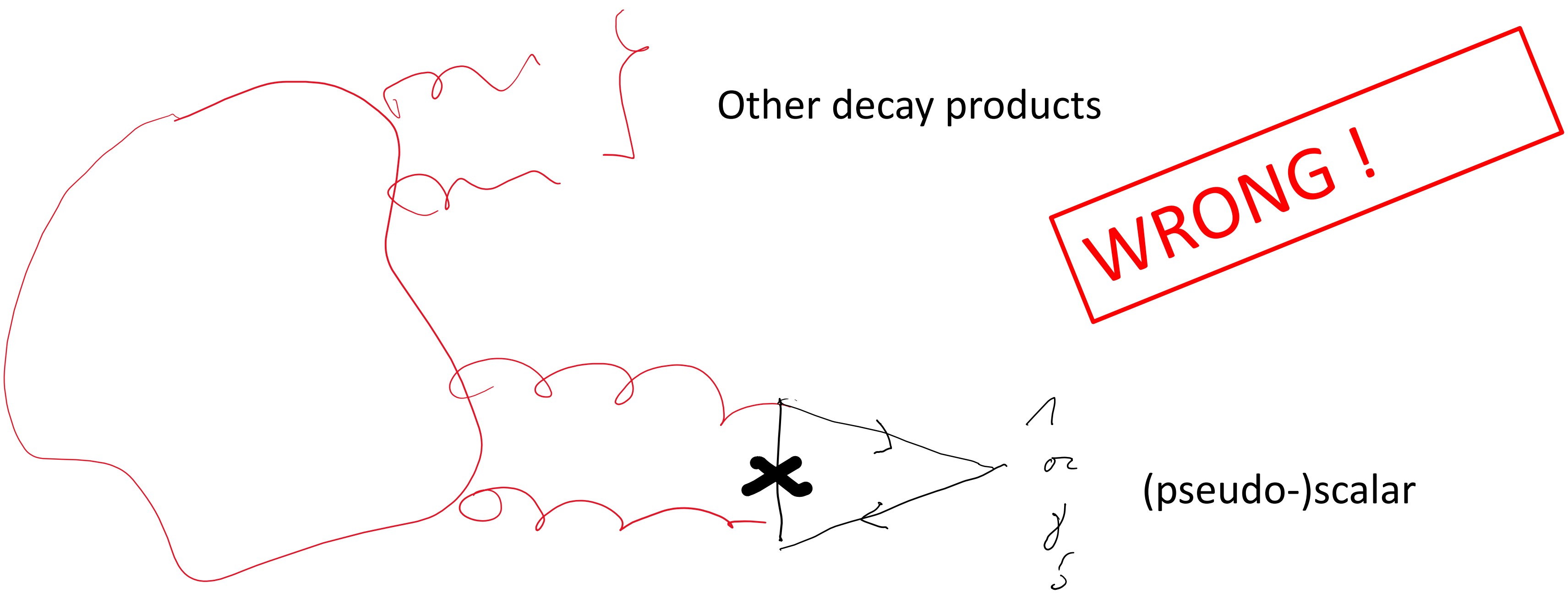
and should thus not distinguish according to isospin or hypercharge, more precis $\pi^+\pi^-$ $K\bar{K}$ for instance should be produced equally (up to phase space).

- **could favour the heavy states.**

even discounting phase space, one could assume that the "overlap of the wave functions" between the glueball and final particles

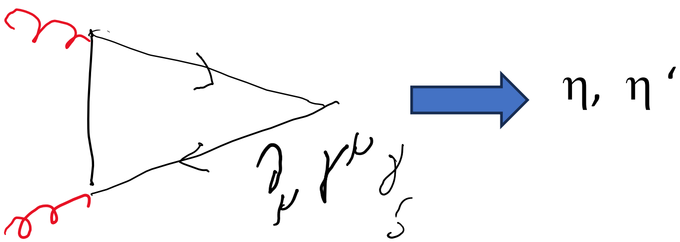
Moving from Wave function to **Chiral Suppression**,

Another prejudice is that gluons **would not couple significantly to light** quark pseudoscalars.



Expect a suppression $(m/M)^2$ for light (m) versus heavy quarks (M) ....an argument used against η π (η') □

✖ **Mass insertion**



This suppression is WRONG for the singlet channel !
Instead, the chiral anomaly gives a direct path to η η'

$$\partial^\mu A^8_\mu = \frac{2}{\sqrt{6}}(m_u \bar{u} i\gamma_5 u + m_d \bar{d} i\gamma_5 d - 2m_s \bar{s} i\gamma_5 s) \ ,$$

$$\partial^\mu A^0_\mu = \frac{2}{\sqrt{3}}(m_u \bar{u} i\gamma_5 u + m_d \bar{d} i\gamma_5 d + m_s \bar{s} i\gamma_5 s) + \boxed{\frac{1}{\sqrt{3}} \frac{3\alpha_s}{4\pi} G^a_{\mu\nu} \tilde{G}^{a,\mu\nu}}$$

$$\frac{< G^{\mu\nu} \widetilde{G}_{\mu\nu} \mid \eta' >}{< G^{\mu\nu} \widetilde{G}_{\mu\nu} \mid \eta >} \approx 3$$

More generally, could states **with quantum numbers similar to those contructed from pure gluon constructions:**

Think for instance of the 0^{++}

$$G^{\mu\nu}G_{\mu\nu}$$

and the 0^{-+}

$$G^{\mu\nu}\widetilde{G}_{\mu\nu}$$

The 0^{++} mode corresponds to the " σ " meson, the scalar and isospin 0 partner of the pion, a strange and very wide structure seen in partial wave analysis, (notably through interference)

decaying at least in to 2 π. It is now listed as f_0 (500) , but with a mass estimate of 400 to 800 MeV, and a width 100 to 800…

The 0^{-+} mode on the other hand corresponds to the quantum numbers of the η or η' , or more precisely to their Isospin = 0 component.

Exotics

Maybe turning to exotics would make things easier?

What are exotics?

We mainly mean meson states which cannot be realized with quarks alone.
In particular, their P and C properties may be incompatible with Spin/Isospin.

For instance, the π_1 I=1, J= 1^{-+} (previously called $\widetilde{\rho}$)
could correspond to the interpolating current

$$\phi^{\mu}_{\tilde{\rho}0} = g_s G^{\mu\nu}_a \, \tfrac{1}{2}(\bar{\mathrm{u}}\gamma_\nu\gamma_5\lambda^a \mathrm{u} - \bar{\mathrm{d}}\gamma_\nu\gamma_5\lambda^a \mathrm{d}) / f_{\tilde{\rho}} m^3_{\tilde{\rho}}$$

The Parity of a q-antiqark system is given by $(-)^{l+1}$ with l the angular momentum, while the Charge conjugation is given by $(-)^{l+s}$, so the 1^{-+} state is forbidden in a strict 2-quark state.

Does the existence of the (PDG listed) π_1 prove the presence of exotics involving "valence gluons"?
Not really : a "gluon" could be replaced by a quark bilinear
This means that we would need to distinguish between a valence gluon and a 4quark state.

To identify an exotic, we are thus confronted with the same problem: can we predict from first principles the preferred decay channels of valence-gluon exotic?

Common prejudice from QCD sum rules in 1984

(de Viron et al, Latorre, Narison et al **the ρ π mode would dominate while the η π modes would be suppressed .**

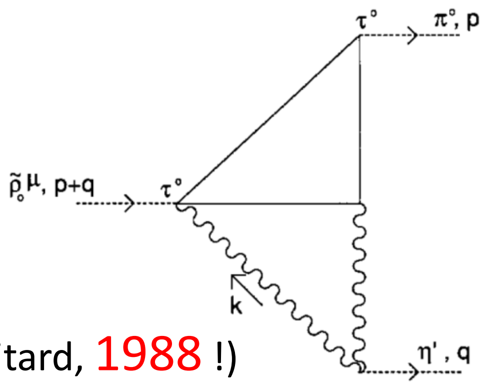
Other approaches based on bag, flux tube models were giving analogous predictions , for instance the order (Barnes, Swanson, Close ….

More recently: C. A. Meyer and Y. Van Haarlem arXiv:1004.5516v2

$$\pi b_1 : \pi f_1 : \pi\rho : \eta\pi : \pi\eta'$$

Once again none of these studies take into account quantum anomalies!!

A coïncidence : our study of anomalies (including in the CP context), and a challenging η' signal from the GAMS collaboration brought us to study alternate decay modes

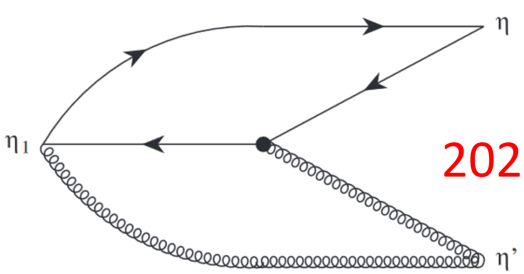


Jmf + S Titard, 1988 !)

A tentative evaluation (difficult due to need of a cut-off) indicates that **the η (') π mode could dominate !**

Rem. The Gams group collaborated with Gherstein, who advocated similar gluon based decays (without ref to anomaly)

This work was largely ingored.. but re-discovered independently in the case of the η_1



(b)

2022

$$\frac{< G^{\mu\nu}\widetilde{G}_{\mu\nu} \mid \eta' >}{< G^{\mu\nu}\widetilde{G}_{\mu\nu} \mid \eta >} \approx 3$$

QCD axial anomaly enhances the $\eta\eta'$ decay of the hybrid candidate $\eta_1(1855)$

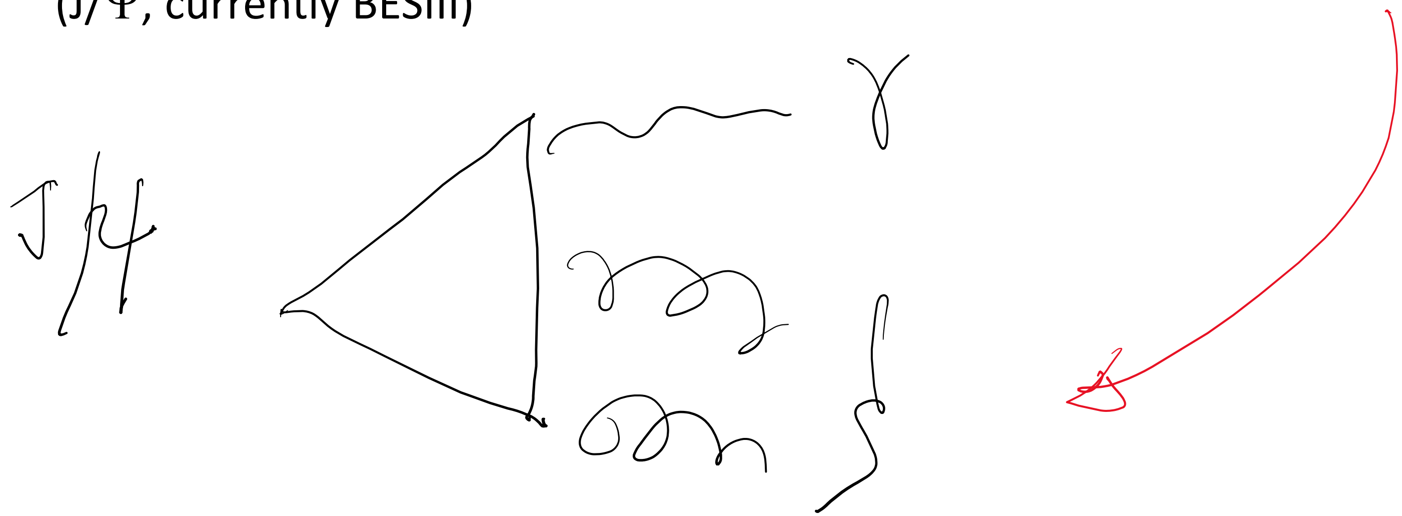
Hua-Xing Chen[1,*] Niu Su[1,†] and Shi-Lin Zhu[2‡]

The experimental Scene

Production schemes

- Collision experiments (for instance pions on fixed target)
  - A special case of “glue rich” suspected channels, like central low x) production, proton antiproton collisions (LEAR)

- Gluon-rich states in the (radiative) decay of heavy flavour mesons (J/Ψ, currently BESIII)



HOW it started (for me) , and WHY it returns

From the **mid-80's** the **GAMS expt** (and the associated NA12, WA102 report several new mesons (first in 38 GeV pion- proton, then in central production) **presence of η(')** mesons, and compatible with scalar glueballs first, with exotics a bit later.

Possible glueballs G(1590) → f0 (1500)
X(1750),
X(1920) (eta eta prime mostly) f0 (1770 ?) (see however Sarantsev 2021)
Possible hybrids

M(1405) → π_1 (1400-1600)
X(1740) X(1910) → $\eta_1(1855)$
The following years saw partial confirmations, but also difference on the mass, width, and decay modes. Yet, despite the a-priori, the link to η(') persisted.

What was missing : a clear production context.

Searches in **J/Y radiative decays** …SLAC did not have enough photon resolution, but now …**BESIII** produces impressive output in a clean context

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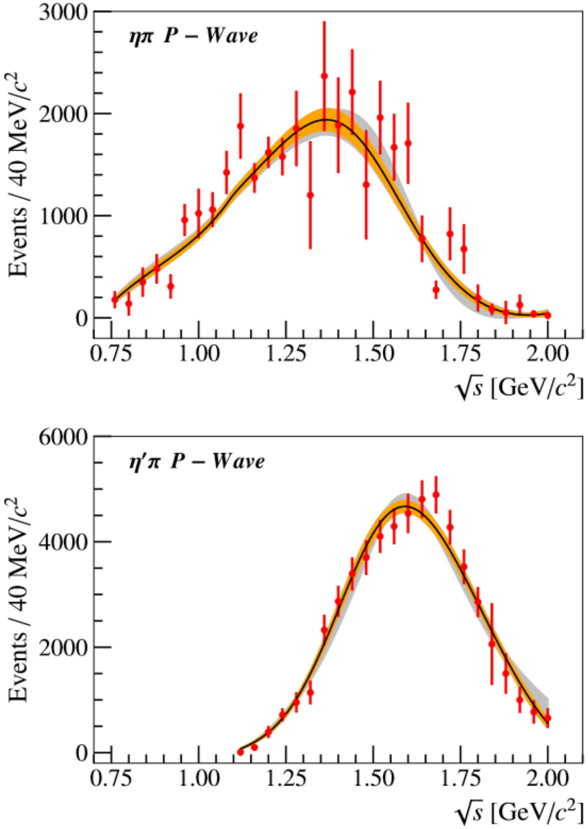
X(1750),
X(1920) ($\eta\ \eta$ 'mostly) f0 (1770 ?) (see however Sarantsev 2021)
Possible hybrids
M(1405) → π_1 (1400-1600)
X(1740) X(1910) → $\eta_1(1855)$

Why the shifts in masses ?

Line shapes are heavily distorted by phase space (in particular for η')
according to decay channel
and interferences …recent analysis (see later) even suggest that the
same
peaik may appear under multiple names

The π_1

$\pi_1(1400) + \pi_1(1600)$



Partial wave analysis of COMPASS data (Kopf et al.)

PDG now lists 2 states, but a recent coupled analysis (Kopf et al.) shows it could be one single state (around 1600) (see however also C. A. Meyer and Y. Van Haarlem)

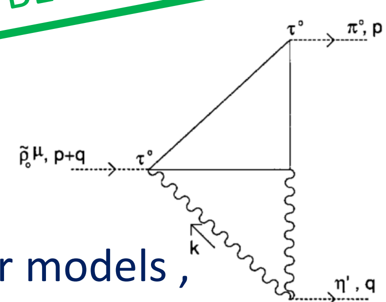
Consistently seen in $\eta(')\,\pi$ modes,

sometimes in $\rho\,\pi$ or b_1 p,...

Complex situation: various production channels, other resonances, ….

NEED the « clean channel » , but not yet searched for in BESIII

$$\frac{< G^{\mu\nu}\widetilde{G}_{\mu\nu} \mid \eta' >}{< G^{\mu\nu}\widetilde{G}_{\mu\nu} \mid \eta >} \approx 3$$



Not favored by older models , but by anomaly contribution

$\pi_1(1400)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\eta\pi^0$	seen
Γ_2	$\eta\pi^-$	seen
Γ_3	$\eta'\pi$	
Γ_4	$\rho(770)\pi$	not seen

$\Gamma(\eta'\pi)/\Gamma(\eta\pi^0)$ **Γ_3/Γ_1**

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.80	95	BOUTEMEUR	90	GAM4	100 $\pi^- p \to 4\gamma n$

$\Gamma(\rho(770)\pi)/\Gamma_{total}$ **Γ_4/Γ**

VALUE	DOCUMENT ID		TECN	COMMENT
not seen	AGHASYAN	18B	COMP	190 $\pi^- p \to \pi^-\pi^+\pi^- p$

$\pi_1(1600)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\pi\pi\pi$	seen
Γ_2	$\rho^0\pi^-$	seen
Γ_3	$f_2(1270)\pi^-$	not seen
Γ_4	$b_1(1235)\pi$	seen
Γ_5	$\eta'(958)\pi^-$	seen
Γ_6	$\eta\pi$	seen
Γ_7	$f_1(1285)\pi$	seen

$\Gamma(\eta'(958)\pi^-)/\Gamma(\eta\pi)$ **Γ_5/Γ_6**

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$5.54\pm1.1^{+1.8}_{-0.27}$	[1] KOPF	21	RVUE	0.9 $p\overline{p}\to\pi^0\pi^0\eta$, $\pi^0\eta\eta$, $\pi^0K^+K^-$ and 191 $\pi^-p\to\pi^-\pi^-\pi^+p$

Despite smaller phase space

[1] From T-matrix pole based on combined fit of Crystal Barrel and $\pi\pi$ scattering data (ALBRECHT 20), and COMPASS data (ADOLPH 15), using a coupled-channel model of $\eta\pi$, $\eta'\pi$ and $K\overline{K}$ systems.

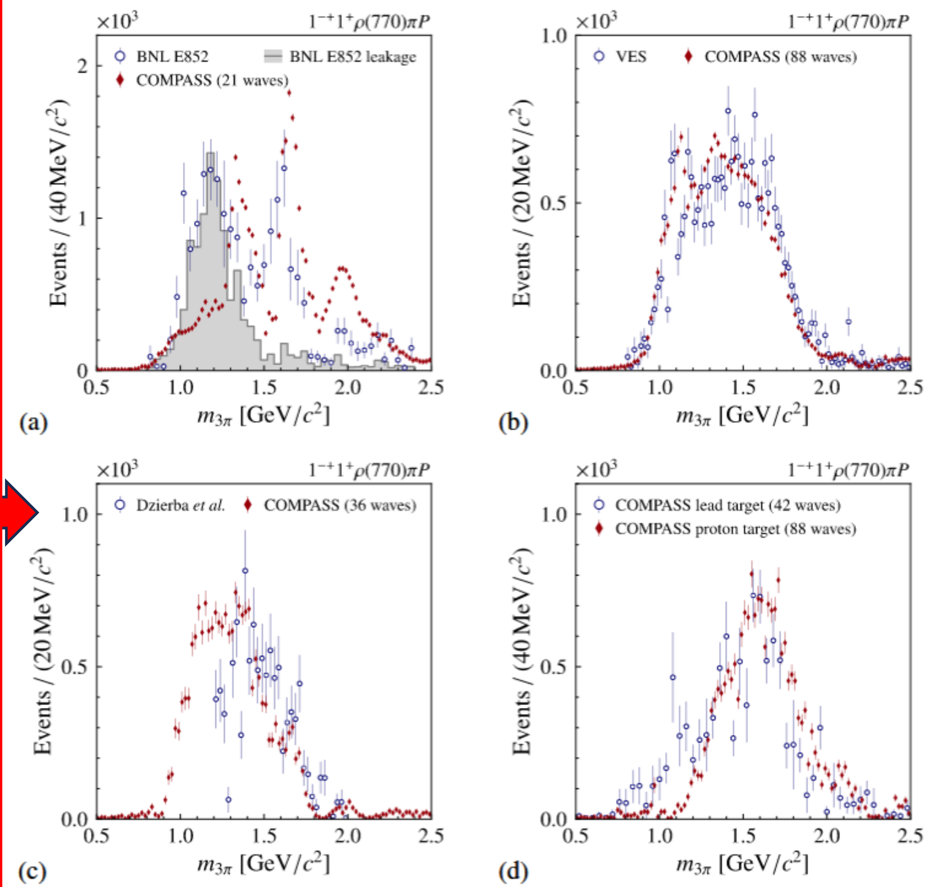
A remaining puzzle is that in $\gamma + \pi^{\pm} \rightarrow \pi^{\pm}\pi^{-}\pi^{+}$ reactions the production of the $\pi_1(1600)$ seems to be much less prominent than expected considering vector-meson dominance and the observation of the $\rho(770)\pi$ decay.[7] The CLAS experiment [62,63] and the COMPASS Primakoff experiment [64,65] find nearly vanishing intensities of the 1^{-+} wave in the 1.6 GeV/c^2 mass region. This, however, could in principle be due to destructive interference of a $\pi_1(1600)$ with a nonresonant component—a

Looking for the ρ π channel in COMPAS is no easy business!

Various partial waves analysis (up to 88 waves!)

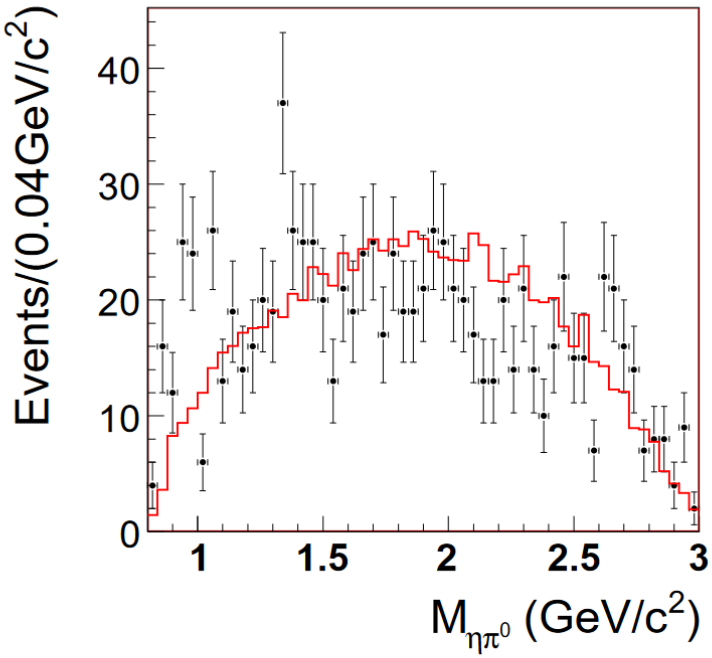
PHYSICAL REVIEW D **105,** 012005 (2022)

Exotic meson $\pi_1(1600)$ with $J^{PC} = 1^{-+}$ and its decay into $\rho(770)\pi$



search for π_1 in BESIII… this could clear the slate! …some day

BESIII daa from 2016 PRD …but no partial wave analysis (red is phase space, NOT background)
Prominent a2 ane a0 ,



Wait for η’ π data ?

The π_1 status summary

For now, we retain that

- Seen consistently in $\pi\,\eta(')$ modes,
- Large η' despite small phase space as expected (predicted) from anomaly diagram
- « seen » in $\rho\,\pi$ modes, but analysis difficult
- Are the 1400 and 1600 entries the same wide partial wave?

- Not really searched for in J/Ψ radiative decays, in particular into η'
- The last analysis would be interesting in the context of the $\eta 1$

The η_1

Seen by GAMS,
and now by BESIII
decay modes : $\eta\ \eta'$

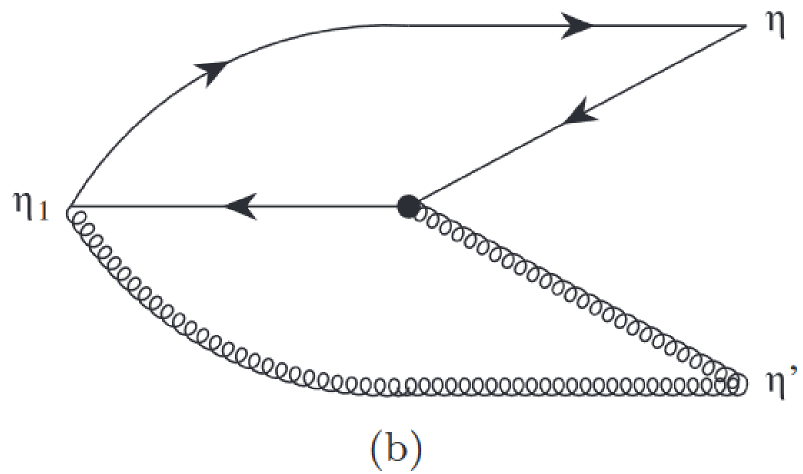
$\eta_1(1855)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\eta\eta'$	seen

$\Gamma(\eta\eta')/\Gamma_{total}$ Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	ABLIKIM	22AI	BES3	$J/\psi \to \gamma\eta\eta'$
seen	BARBERIS	00A		450 $pp \to p_f\eta\eta' p_s$
seen	ALDE	91B	GAM2	38 $\pi^- p \to \eta\eta' n$

We find that the QCD axial anomaly enhances the decay width of the ηη′ channel although this mode is strongly suppressed by the small P -wave phase space. Our results support
the interpretation of the η1(1855) recently observed by BESIII as the ¯ssg hybrid meson of IGJP C =
0+1−+. The QCD axial anomaly ensures the ηη′ decay mode to be a characteristic signal of the hybrid nature of the $\eta_1(1855)$ (Chen, Su and Zhu)



Conclusion from Exotics

At least 2 states of spin $J^{PC} = 1^{-+}$ seen clearly,

In all cases, the η' decay primes as expected from anomalies, but not from standard treatment.

Back to glueballs, the situation is more complex, as the quantum numbers are generic and more states can interfere.

At least 3 candidates

$f_0(1370)$	1350 ± 150	350 ± 150
$f_0(1500)$	1505 ± 6	109 ± 7
$f_0(1710)$	1722 ± 6	135 ± 7
η	547.86 ± 0.02	$(1.31 \pm 0.05) \times 10^{-3}$
η'	957.78 ± 0.06	0.23 ± 0.02

f0 (1500) : seen by many expts : GAMS …crystal barrel, BES …

$f_0(1500)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor
Γ_1	$\pi\pi$	(34.5 ± 2.2) %	1.2
Γ_2	$\pi^+\pi^-$	seen	
Γ_3	$2\pi^0$	seen	
Γ_4	4π	(48.9 ± 3.3) %	1.2
Γ_5	$4\pi^0$	seen	
Γ_6	$2\pi^+2\pi^-$	seen	
Γ_7	$2(\pi\pi)_{S\text{-wave}}$	seen	
Γ_8	$\rho\rho$	seen	
Γ_9	$\pi(1300)\pi$	seen	
Γ_{10}	$a_1(1260)\pi$	seen	
Γ_{11}	$\eta\eta$	(6.0 ± 0.9) %	1.1
Γ_{12}	$\eta\eta'(958)$	(2.2 ± 0.8) %	1.4
Γ_{13}	$K\overline{K}$	(8.5 ± 1.0) %	1.1
Γ_{14}	$\gamma\gamma$	not seen	

A strange beast indeed (in fact large despite at threshold in η’ η

Although at the edge of phase space, the η η' is enhanced ---- see work by Gherstein, Prokoshkin et al, following Novikov, Shifman Vaiinshtein,Zakharov. , and our later work on the nature of η'

Missing in most quark model analysis

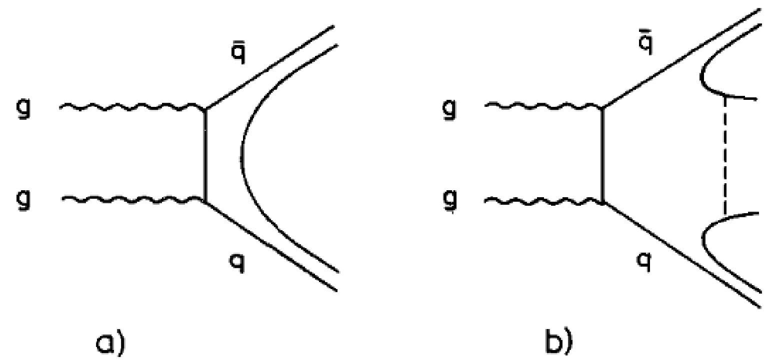


Fig. 1a and b. (See text)

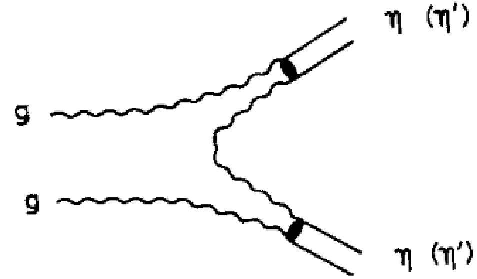


Fig. 2. (See Text)

4 π is larger than 2 π , (could be 2 σ)

KK is less than 2 π, $\eta\eta'$ with respect to $\eta\eta$ is significant , despite being « at threshold »

Are we missing modes?
For instance, we could be missing 3 or 4 σ as they are not searched for (or searchable for) in BESIII

Probably not possible to determine from inclusive, due to clutter of states!

$J/\Psi \rightarrow \gamma X$

… the ones that got away!

see however: Scalar isoscalar mesons and the scalar glueball from radiative J /ψ decays Plys Lett B 2021A.V. Sarantsev, I. Denisenko , U. Thoma , E. Klempt,

A.V. Sarantsev, I. Denisenko, U. Thoma et al. *Physics Letters B 816 (2021) 136227*

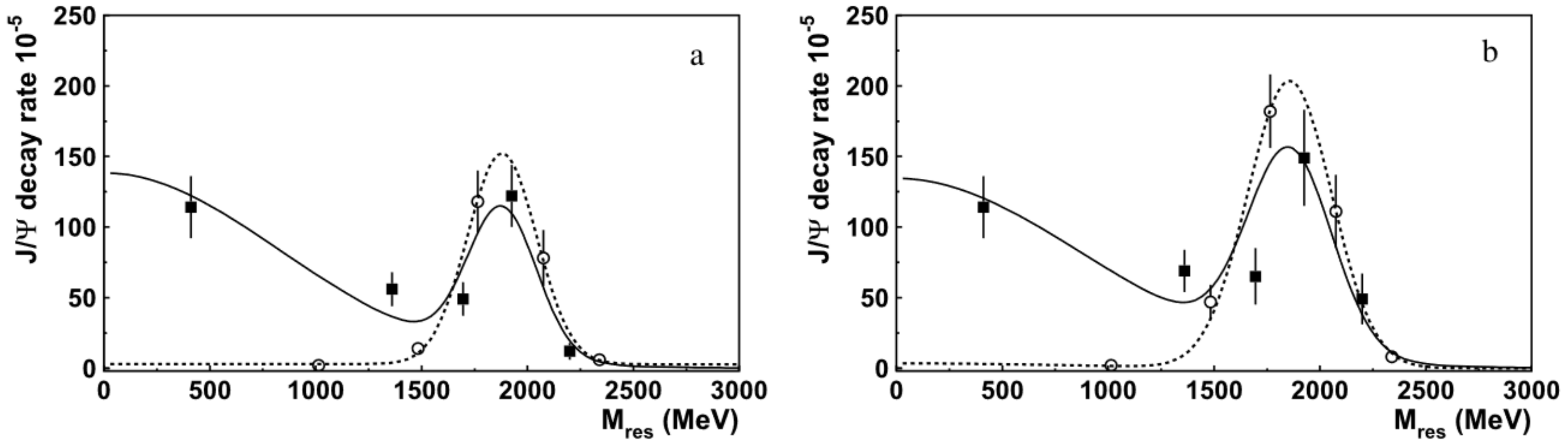


Fig. 4. Yield of radiatively produced scalar isoscalar octet mesons (open circles) and singlet (full squares) mesons. a) Yield for $\pi\pi$, $K\bar{K}$, $\eta\eta$, $\eta\eta'$, and $\phi\omega$ decays. b) Yield when 4π decavs and $\omega\omega$ are included.

“in the 1500-2100 MeV mass region. Singlet scalar mesons are
produced over a wide mass range but their yield peaks in the same mass region.”

“ The peak is interpreted as scalar glueball. Its mass and width are determined to M = 1865””

Caveat : they don’t include η’ η , some extra

In a previous study , which tried to include « anomaly –like contributions » in a more classical pheno fit based on rough graph structures,
we had concluded that the 1710 would be the major glueball bearer,, but our expectations for BESIII were not met …(not seen in $\eta\ \eta'$)

Another approach is provided directly by experimenters !

Another approach is provided directly by experimenters !

Combine measure of « glue production » and glue-like decay

$J/\Psi \to \gamma X \to \gamma \eta \eta'$

Resonance	M (MeV/c^2)	Γ (MeV)	M_{PDG} (MeV/c^2)	Γ_{PDG} (MeV)	B.F. ($\times 10^{-5}$)	Sig.
$f_0(1500)$	1506	112	1506	112	3.05 ± 0.07	$\gg 30\sigma$
$f_0(1810)$	1795	95	1795	95	0.07 ± 0.01	7.6σ
$f_0(2020)$	1935 ± 5	266 ± 9	1992	442	1.67 ± 0.07	11.0σ
$f_0(2100)$	2109 ± 11	253 ± 21	2086	284	0.33 ± 0.03	5.2σ
$f_0(2330)$	2327 ± 4	44 ± 5	2314	144	0.07 ± 0.01	8.5σ

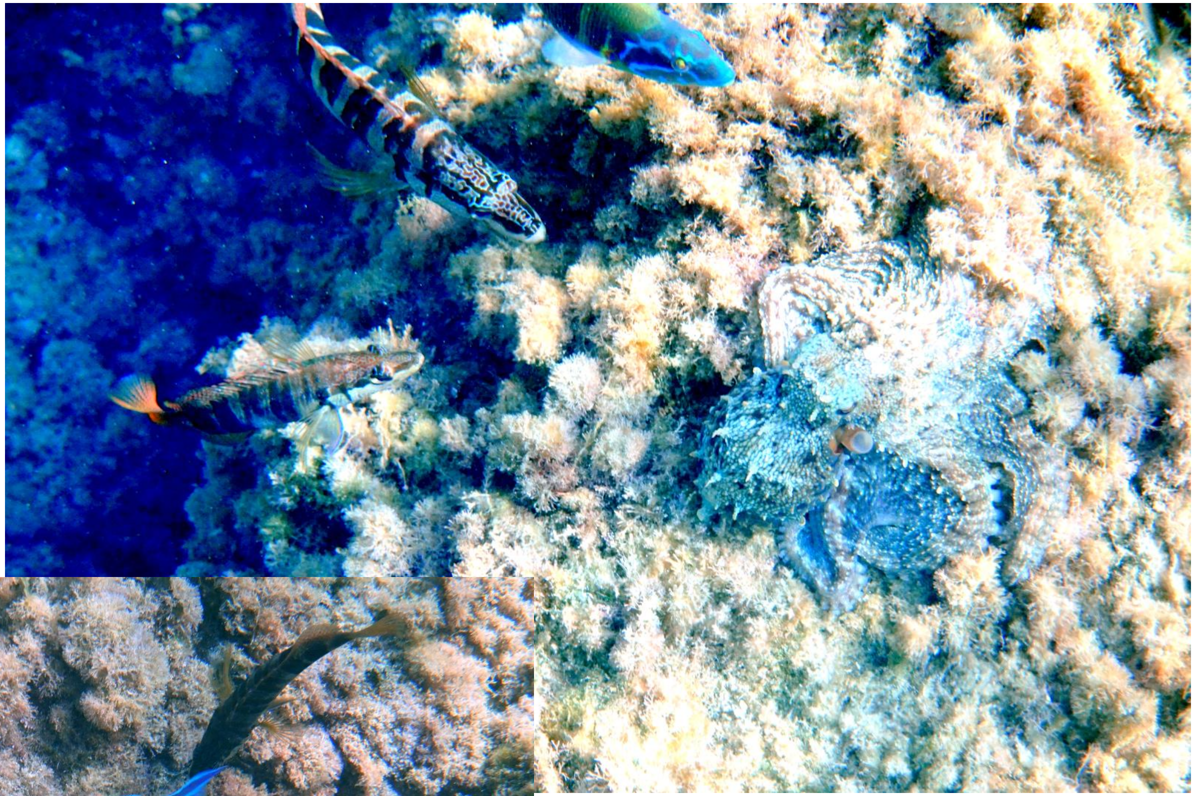
Seems the good old f0(1500) remains a favorite (but is not alone)
(that it was previously named G(1590) results from the phase space distortion near threshold in eta etaprime mode)

The Future ?

- More data coming from BESIII radiative decays

- Intepretation ; probably not by « quark models » linking individual peaks (distorted by phase space) ,
- Rather, extensive partial wave analysis (tens of waves) to give a full picture of the energy range → there is progress there.

- Eta and Etaprime could still be unique guides (with a relatively cleaner background) to point out Glueballs and Exotic states



Back up slides (PDG values)

$\eta_1(1855)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\eta\eta'$	seen

$\Gamma(\eta\eta')/\Gamma_{total}$ $\qquad$ Γ_1/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
seen	ABLIKIM	22AI	BES3	$J/\psi \rightarrow \gamma\eta\eta'$
seen	BARBERIS	00A		450 $pp \rightarrow p_f\eta\eta' p_s$
seen	ALDE	91B	GAM2	38 $\pi^- p \rightarrow \eta\eta' n$

$\pi_1(1400)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\eta\pi^0$	seen
Γ_2	$\eta\pi^-$	seen
Γ_3	$\eta'\pi$	
Γ_4	$\rho(770)\pi$	not seen

$\Gamma(\eta'\pi)/\Gamma(\eta\pi^0)$ **Γ_3/Γ_1**

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.80	95	BOUTEMEUR	90	GAM4	100 $\pi^- p \to 4\gamma n$

$\Gamma(\rho(770)\pi)/\Gamma_{total}$ **Γ_4/Γ**

VALUE	DOCUMENT ID		TECN	COMMENT
not seen	AGHASYAN	18B	COMP	190 $\pi^- p \to \pi^-\pi^+\pi^- p$

$\pi_1(1600)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\pi\pi\pi$	seen
Γ_2	$\rho^0\pi^-$	seen
Γ_3	$f_2(1270)\pi^-$	not seen
Γ_4	$b_1(1235)\pi$	seen
Γ_5	$\eta'(958)\pi^-$	seen
Γ_6	$\eta\pi$	seen
Γ_7	$f_1(1285)\pi$	seen

$\Gamma(\eta'(958)\pi^-)/\Gamma_{total}$ Γ_5/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
seen	IVANOV	01	B852	18 $\pi^- p \to \eta' \pi^- p$

$\Gamma(\eta'(958)\pi^-)/\Gamma(\eta\pi)$ Γ_5/Γ_6

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$5.54 \pm 1.1 ^{+1.8}_{-0.27}$	[1] KOPF	21	RVUE	0.9 $p\overline{p} \to \pi^0\pi^0\eta$, $\pi^0\eta\eta$, $\pi^0 K^+ K^-$ and 191 $\pi^- p \to \pi^-\pi^-\pi^+ p$

$\eta_1(1855)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\eta\eta'$	seen

$\Gamma(\eta\eta')/\Gamma_{total}$ Γ_1/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
seen	ABLIKIM	22AI	BES3	$J/\psi \to \gamma\eta\eta'$
seen	BARBERIS	00A		450 $pp \to p_f \eta\eta' p_s$
seen	ALDE	91B	GAM2	38 $\pi^- p \to \eta\eta' n$

$f_0(1710)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$K\overline{K}$	seen
Γ_2	$\eta\eta$	seen
Γ_3	$\eta\eta'$	
Γ_4	$\pi\pi$	seen
Γ_5	$\gamma\gamma$	seen
Γ_6	$\omega\omega$	seen

$\Gamma(\eta\eta)/\Gamma(K\overline{K})$ — Γ_2/Γ_1

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
0.48±0.15		BARBERIS	00E		450 $pp \to p_f \eta\eta p_s$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.46^{+0.70}_{-0.38}$		[1] ANISOVICH	02D	SPEC	Combined fit
<0.02	90	[2] PROKOSHKIN	91	GA24	300 $\pi^- p \to \pi^- p \eta\eta$

[1] From a combined K-matrix analysis of Crystal Barrel (0. $p\overline{p} \to \pi^0\pi^0\pi^0$, $\pi^0\eta\eta$, $\pi^0\pi^0\eta$), GAMS ($\pi p \to \pi^0\pi^0 n$, $\eta\eta n$, $\eta\eta' n$), and BNL ($\pi p \to K\overline{K} n$) data.

[2] Combining results of GAM4 with those of ARMSTRONG 89D.

$\Gamma(\eta\eta')/\Gamma(\pi\pi)$ — Γ_3/Γ_4

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<2.87 × 10^{-3}	90	[1] ABLIKIM	22AS	BES3	$J/\psi(1S) \to \gamma\eta\eta'$

$f_0(2020)$ BRANCHING RATIOS

$\Gamma(\rho\rho)/\Gamma(\omega\omega)$ — Γ_3/Γ_4

VALUE	DOCUMENT ID		COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •			
~ 3	BARBERIS	00F	450 $pp \to p_f \omega\omega p_s$

$\Gamma(\eta\eta)/\Gamma_{total}$ — Γ_5/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	UMAN	06	E835	5.2 $\overline{p}p \to \eta\eta\pi^0$

$\Gamma(\eta'\eta')/\Gamma_{total}$ — Γ_6/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
seen	[1] ABLIKIM	22C	BES3	$J/\psi \to \gamma\eta'\eta' \to 4/5\gamma 2(\pi^+\pi^-)$

[1] From a partial wave analysis of the systems (γX), with $X \to \eta'\eta'$, and $(\eta' X)$, with $X \to \gamma\eta'$ in the decay $J/\psi \to \gamma\eta'\eta'$. The intermediate resonance X is parametrized by a constant-width, relativistic Breit-Wigner.

$n^{2s+1}\ell_J$	J^{PC}	I $= 1$ $u\bar{d}$, $\bar{u}d$, $\frac{1}{\sqrt{2}}(d\bar{d} - u\bar{u})$	I $= \frac{1}{2}$ $u\bar{s}$, $d\bar{s}$; $\bar{d}s$, $\bar{u}s$	I $= 0$ f'	I $= 0$ f
1^1S_0	0^{-+}	π	K	η	$\eta'(958)$
1^3S_1	1^{--}	$\rho(770)$	$K^*(892)$	$\phi(1020)$	$\omega(782)$
1^1P_1	1^{+-}	$b_1(1235)$	K_{1B}[a]	$h_1(1415)$	$h_1(1170)$
1^3P_0	0^{++}	$a_0(1450)$	$K_0^*(1430)$	$f_0(1710)$	$f_0(1370)$
1^3P_1	1^{++}	$a_1(1260)$	K_{1A}[a]	$f_1(1420)$	$f_1(1285)$
1^3P_2	2^{++}	$a_2(1320)$	$K_2^*(1430)$	$f_2'(1525)$	$f_2(1270)$
1^1D_2	2^{-+}	$\pi_2(1670)$	$K_2(1770)$[a]	$\eta_2(1870)$	$\eta_2(1645)$
1^3D_1	1^{--}	$\rho(1700)$	$K^*(1680)$[b]	$\phi(2170)$[d]	$\omega(1650)$
1^3D_2	2^{--}		$K_2(1820)$[a]		

Γ_{275}	$\gamma f_0(1500) \to \gamma\pi\pi$	$(1.09 \pm 0.24) \times 10^{-4}$
Γ_{276}	$\gamma f_0(1500) \to \gamma\eta\eta$	$(1.7 \, {}^{+0.6}_{-1.4}) \times 10^{-5}$
Γ_{277}	$\gamma f_0(1500) \to \gamma K^0_S K^0_S$	$(1.59 \, {}^{+0.24}_{-0.60}) \times 10^{-5}$
Γ_{278}	$\gamma f_0(1500) \to \gamma\eta\eta'$	

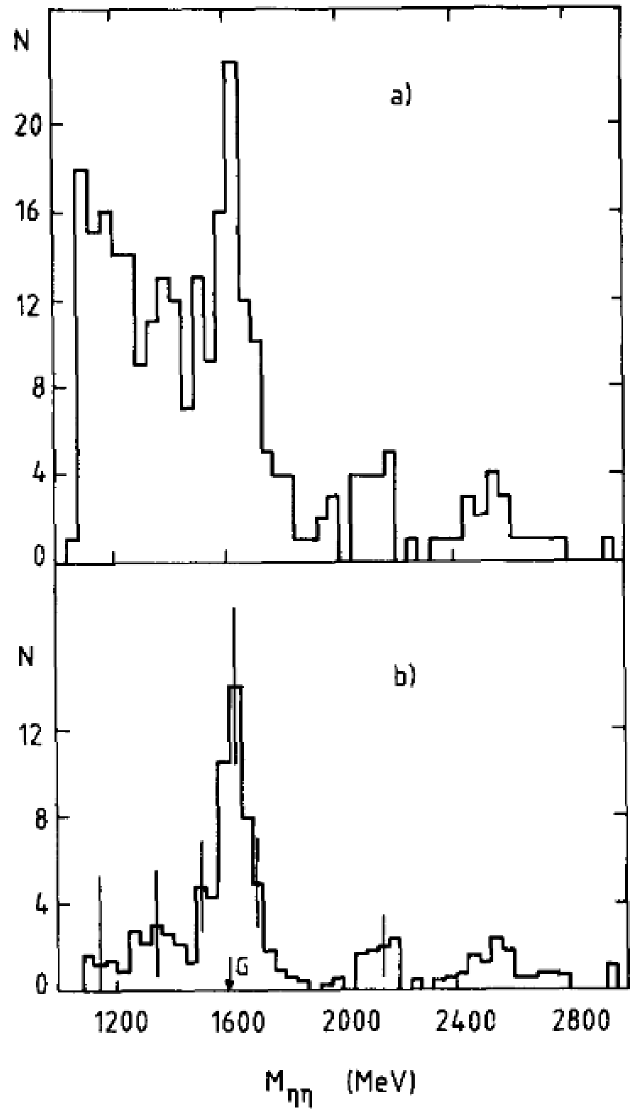


Fig. 3. Invariant mass of ηη-systems (40 MeV mass bins) before (a) and after (b) background subtraction showing clearly the production of G(1590) in reaction (1). The arrow points to the tabulated value of the G mass.

[3] S.S. Gershtein and A.A. Logunov, Yad. Fiz. 39 (1984) 1514; 44 (1986) 1253.

[4] S.S. Gershtein, A.K. Likhoded and Yu.D. Prokoshkin, Z. Phys. C 24 (1984) 305; Yad. Fiz. 39 (1984) 251.

Abstract

The scalar meson$G$(1590) is considered as a possible glueball. The decay mechanism, characteristic of a glueball, is proposed (the discolouring of gluons by gluons) which allows one to understand the increase of$G \to \eta\eta$ decay rate, as compared to the decays$G \to \pi\pi$ and$G \to K \bar{K}$ observed in the experiment. It is proposed to measure the ratio of branching ratios$R = BR(G \to \eta\eta')/BR(G \to \eta\eta)$, which is sensitive to the gluon content of$G$(1590). In the one-pion exchange model the predicted$R$ values are within the range:$2 \lesssim R \lesssim 3.7$.