Exploring gluonic aspects of hadron structure in the 1-3 GeV/c^2 mass region

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Workshop on LEPS new beamline

Purpose

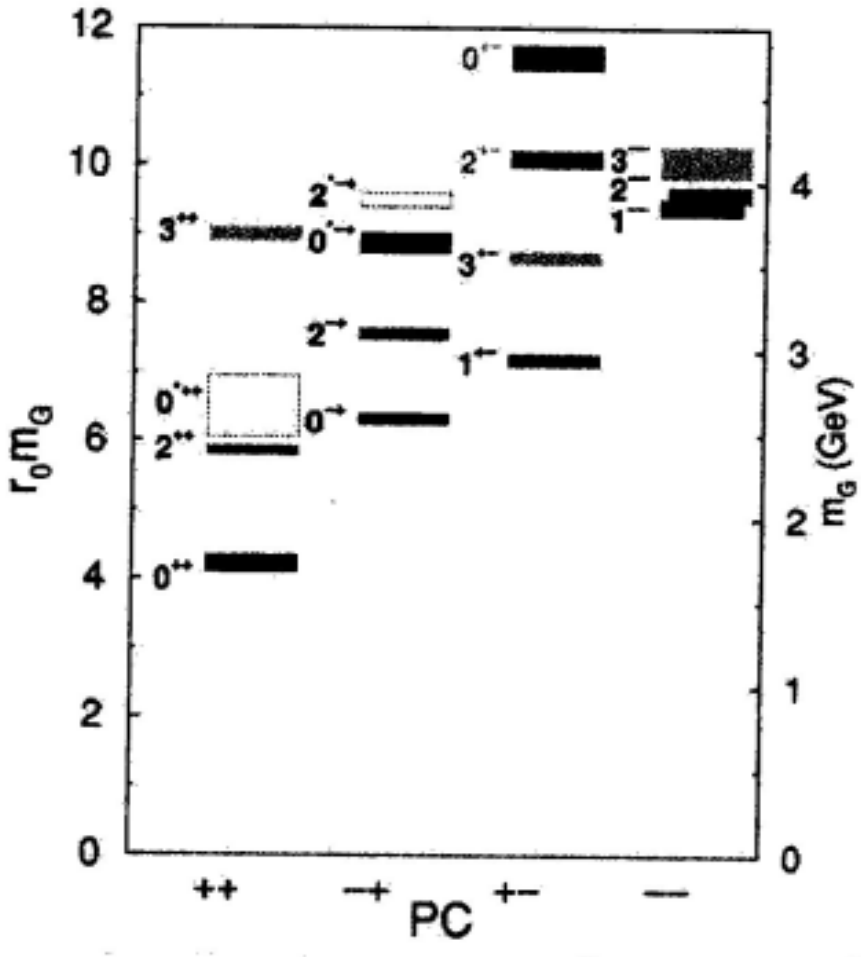
Understanding quark and gluon confinement inside hadron at non-perturbative QCD region

Motivation is simple, but experimental signatures to clarify it is NOT simple.

Self-coupling of gluon

- Glueball (mainly 2 vector meson decay)
- Hybrids (just shortly commented)

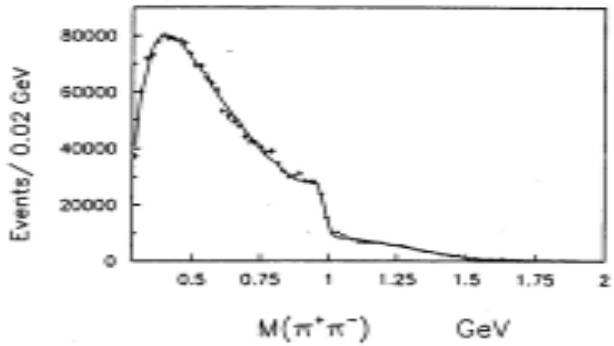
Prediction of Glueball mass in Lattice QCD

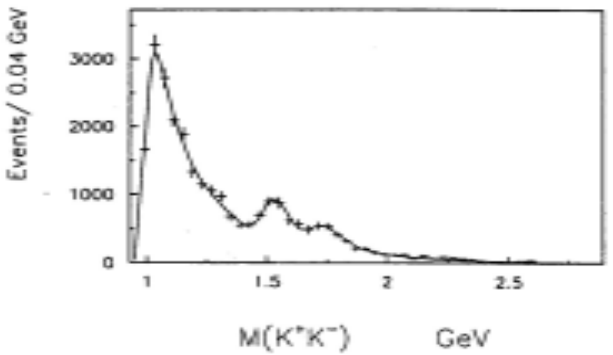


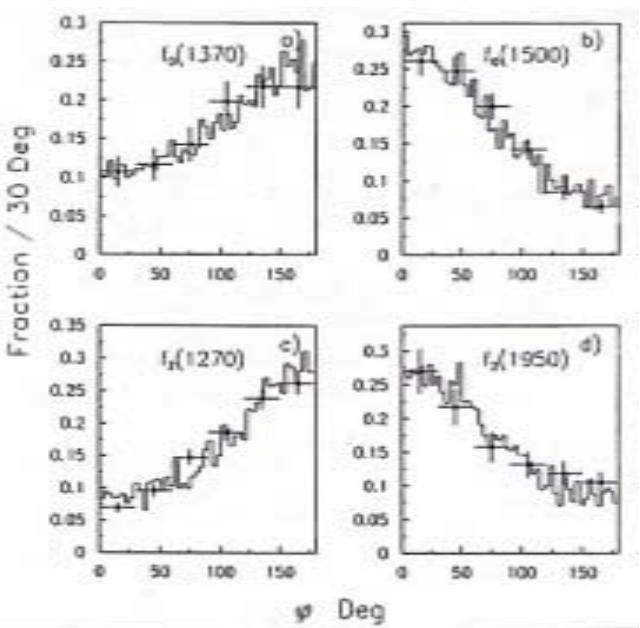
C.J. Morningstar and M. Peardon, Phys. Rev. D60 (1999) 034509

M_0++ ~1.6 GeV/c2

M_2++ ~2.3 GeV/c2







KK/ππ decay

WA102 Collaboration results
D. Barberis et al., Phys. Lett.
B462 (1999) 462
F.E. Close, A. Kirk and G. Schuler,
Phys. Lett. B477 (2000) 13

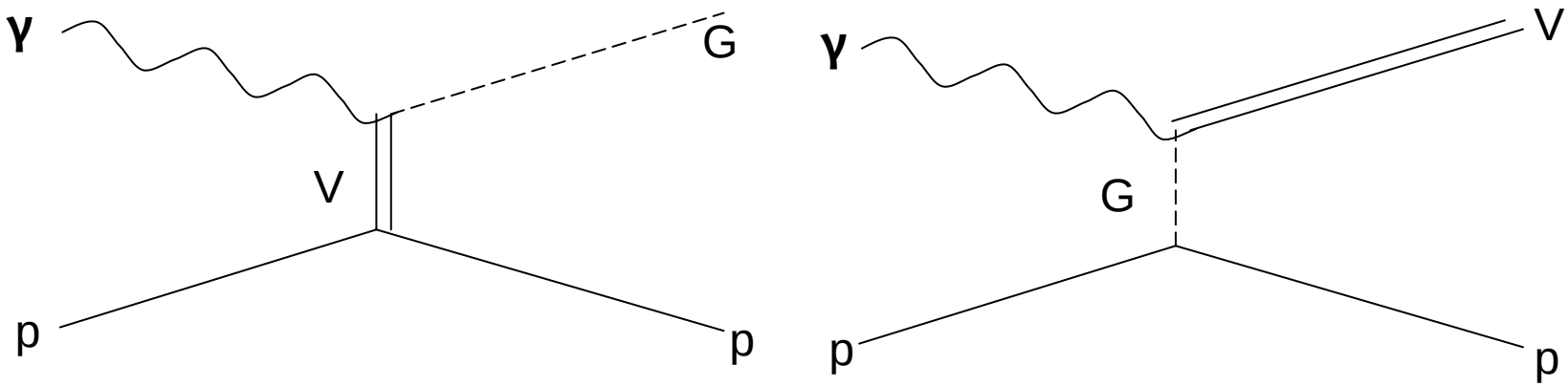
PWA	M(MeV)	Γ (MeV)
f0(980)	987± 6± 6	48±12± 8
f0(1370)	1312±25±10	109±22±15
f0(1500)	1502±12±10	49± 9± 8
f0(1710)	1727±12±11	63± 8± 9

f0(1500),f0(1710) flavor blindness?
Glueball filter by **Φ** dependence?

PDG suggesting f0(1500) as glueball candidate but f0(1710) as ss state.

Glueball photoproduction in t-channel

S.R. Cotanch and R.A. Williams, nucl-th/0505074
S.R. Cotanch and R.A. Williams, Phys. Rev. C70 (2004) 055201



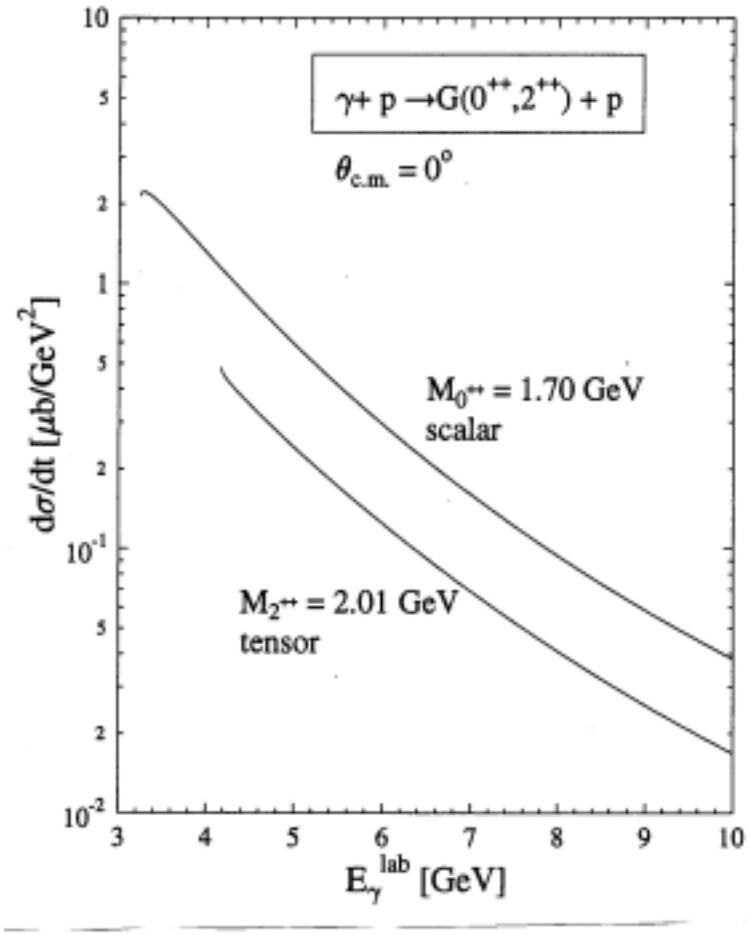
- t-channel dominates for $\theta_{cm}<65°$
- Dominated by ρ meson contribution
- No pseudoscalar exchange for C=+ glueball

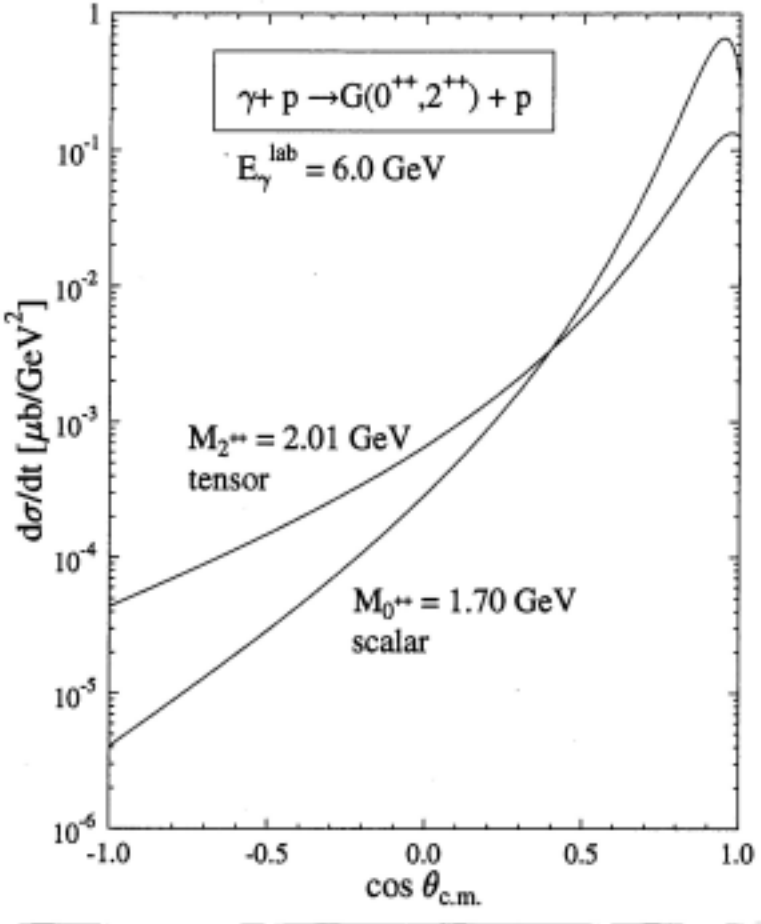
$$\frac{d\sigma^{G_0}}{dt} = \frac{\pi}{4\omega_{cm}^2}\sum_{\sigma'\sigma}[|H^1_{\sigma'\sigma}|^2 + |H^2_{\sigma'\sigma}|^2]$$

$$\frac{d\sigma^{G_2}}{dt} = \frac{\pi}{4\omega_{cm}^2}\sum_{\sigma'\sigma}[a(|H^1_{\sigma'\sigma}|^2 + |H^2_{\sigma'\sigma}|^2) + b\,|H^0_{\sigma'\sigma} + \tfrac{1+y}{1-y}H^3_{\sigma'\sigma}|^2]$$

$$H^{\mu}_{\sigma'\sigma} = \sum_{V=\rho,\omega,\phi}\frac{eg_{GJV\gamma}}{M_J}g_{VNN}F_t(t)\Pi_V(t)\bar{u}(p',\sigma')[\gamma^{\mu} + i\tfrac{\kappa_V^T}{M_0}\sigma^{\mu\alpha}k'_{\alpha}]u(p,\sigma)$$

Cross section





Glueball at new beam line

Optimistic yield estimation

~1 μb/GeV^2 x #photons x Targe Thickness

x 6.022x10^{23} (Avo. #) x 0.0708 g/cm^3 (LH_2 dens.)

$\Rightarrow$ 0.4 x 10^{-7} x #photons x Thickness /GeV^2

Production Thresholds in γ N $\rightarrow$ XN

M_x = 1.5 GeV	E_γ=2.7 GeV
2.0 GeV	4.1 GeV
2.5 GeV	5.8 GeV

2 vector meson decay

- 2 vector meson decay width

$$\Gamma_{G_2 \to VV} = \frac{g^2_{G_2 VV}}{20\pi} M_{G_2} (1-4x)^{1/2} [1-3x+6x^2]$$

VV'	$\rho^0\rho^0$	$\omega\omega$	$\phi\phi$	$\omega\phi$
Γ [$G_2(2010) \to VV'$]	26.2	25.8	10.3	33.0 MeV
Γ [$G_2(2300) \to VV'$]	37.2	36.8	20.3	44.7 MeV

- Flavor blindness suggests comparable widths.
- Strong mixing with quarkonium could be a problem.

Radiative decay

- Radiative decay width with VMD

$$\Gamma_{f_0 \to V\gamma} = \frac{1}{8}\alpha_e g^2_{f_0 V\gamma} \frac{M^3_{f_0}}{M^2_0}(1-x)^3$$

$$\Gamma_{f_2 \to V\gamma} = \frac{2}{5}\alpha_e g^2_{f_2 V\gamma} M_{f_2}(1-x)^3\left[1+\frac{x}{2}+\frac{x^2}{6}\right]$$

$$g_{f_2\rho\gamma} = \frac{g_{f_2\rho\rho}}{f_\rho}$$

$$g_{f_2\omega\gamma} = \frac{g_{f_2\omega\omega}}{f_\omega} + \frac{g_{f_2\omega\phi}}{f_\phi}$$

$$g_{f_2\phi\gamma} = \frac{g_{f_2\phi\phi}}{f_\phi} + \frac{g_{f_2\phi\omega}}{f_\omega}$$

- Flavor blindness

$$R_{\omega/\rho} = \left(\frac{g_{f_2\omega\gamma}}{g_{f_2\rho\gamma}}\right)^2 \Rightarrow \left(\frac{f_\rho}{f_\omega}\right)^2\left(1+\frac{f_\omega}{f_\phi}\right)^2$$

- $|f_{\rho}|$=4.965, $|f_{\omega}|$=17.06, $|f_{\phi}|$=13.38 $R_{\omega/\rho}$=0.44

V γ	ρ	ω	ϕ	γ	
Γ [$G_0(1700) \rightarrow V\gamma$]	1950	844	453	15.1	keV
Γ [$G_2(2010) \rightarrow V\gamma$]	298	129	91.6	1.72	keV
Γ [$G_2(2300) \rightarrow V\gamma$]	377	164	128	1.96	keV

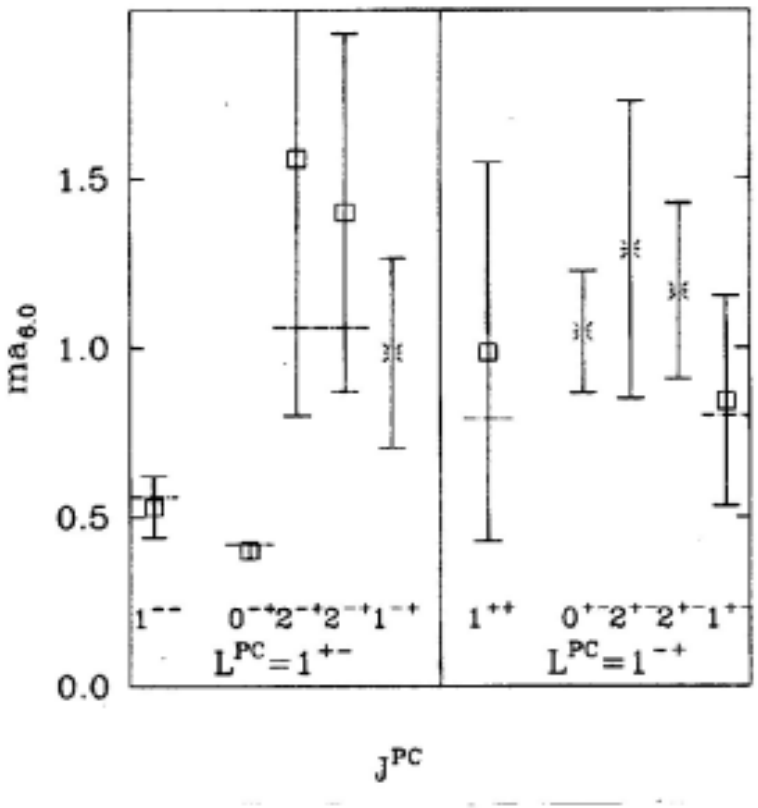
- No ω/ρ suppression is expected in usual meson radiative decay

Hybrids mass in Lattice QCD

P. Lacock et al., Phys. Rev. D54 (1996) 6997

ma=0.54 ⇒ physical mass 1 GeV/c^2

predicted masses ~2 GeV/c^2 or higher



$J=L+S$, $P=(-1)^L$, $C=(-1)^{L+S}$

↓

Exotic quantum number

J^{PC} =0--, 0+-, 1-+, 2+-,…

Additional selection rule is necessary for non-exotic quantum number

Hybrids search

- Light exotic hadron : $\pi_1(1400)$ in $\eta\,\pi$

  $J^{PC}=1^{-+}$ M=1376±17 MeV Γ=300±40 MeV

  E852 $\pi^- p \rightarrow \eta\,\pi^- p$

  Phys. Rev. Lett. 79 (1997) 1630

  Crystal Barrel p_bar d → $\pi^-\pi^0\eta\,p$

  Phys. Lett. B423 (1998) 175

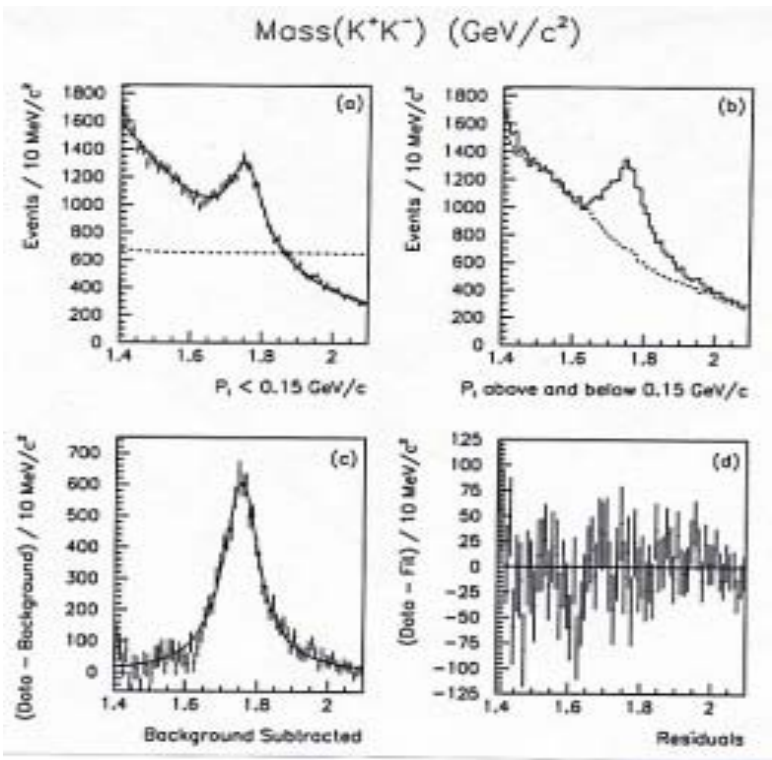
- Confirmation of $\pi_1(1400)$ and other hybrids search in higher mass region would be possible.

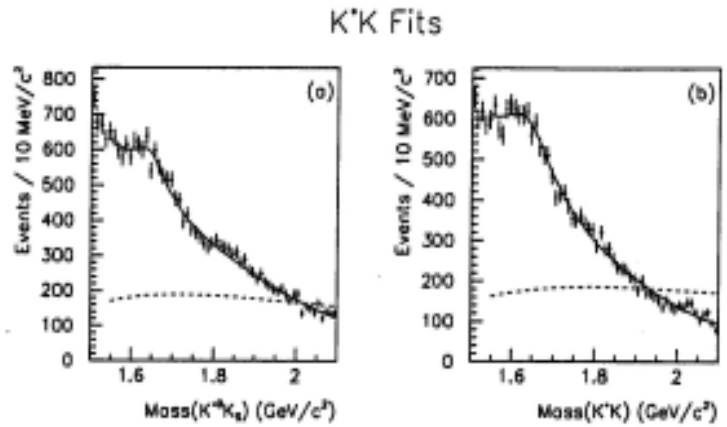
Quark-antiquark spectroscopy

Maybe not so interesting, but mapping out non-exotic qq states helps glueball and hybrids search.

ex. X(1750) from FOCUS

J.M. Link et al., Phys. Lett. B545 (2002) 50





Φ(1680) decaying to K*K

Another vector meson decaying to K+K-

Could it be tested by linearly polarized photon beam?

Summary

- Photoproduction cross section of glueball suggests that new beamline with higher photon energy is a good candidate to hunt it including 2 vector meson decay of tensor glueball.
- Hybrids search including $\pi_1(1400)$ would be possible.