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A HIGH RESOLUTION SEARCH FOR THE TENSOR GLUEBALL

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Abstract

A report of the preliminary results of a high resolution search for the $\xi(2230)$, the putative candidate for the 2^{++} glueball, made by the Crystal Barrel at LEAR is presented. No evidence for the formation of $\xi(2230)$ is found in the $\bar{p}p \to \eta\eta$ or $\bar{p}p \to \pi^0\pi^0$ reactions anywhere in the search region, $\sqrt{s} = 2222$ to 2240 MeV.

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One of the most unique predictions of the non-Abelian field theory of QCD is that gluons bind. Therefore, glueballs (gg,ggg,...) must exist if QCD is indeed true.

The search for glueballs is best made in those reactions that must proceed through intermediate states which are rich in glue. Thus J/ψ radiative decay and $\bar{p}p$ annihilation are favorite reactions. Indeed, J/ψ radiative decay studies at SLAC (Mark III) advanced some of the earliest candidates for glueballs. Among these was an extremely narrow ($\Gamma \approx 20$ MeV) resonance, called ξ, with a mass of ~ 2230 MeV, and $J^{PC} =$ (even)$^{++}$.[1)] It is the subject of this report.

Glueball masses have been calculated in many QCD-based models. Perhaps the most reliable calculations are the two most recent lattice-gauge calculations,[2,3)] which predict that the scalar (0^{++}) glueball should have a mass of 1.63 ± 0.08 GeV, and the tensor (2^{++}) glueball should have a mass of 2.31 ± 0.10 GeV. Two good candidates have been advanced for the scalar glueball, the $f_0(1500)$ discovered by the Crystal Barrel, and the $f_J(1710)$ (previously called θ). The search for the tensor glueball is just warming up, and $\xi(2230)$ is the hot candidate, perhaps because of the proximity of its mass to the lattice predictions, and its unusually small reported width.

The original Mark III observation of ξ decay into $K^0_S\,K^0_S$ and $K^+\,K^-$ was not confirmed by DM2[4)] in a J/ψ radiative decay study with comparable resolution and better statistics. Neither was it observed in several $\bar{p}p$ annihilation experiments done at Brookhaven and CERN.[5)] It is fair to state that $\xi(2230)$ became dormant, if not dead, as a result of these failures to find it. However, $\xi(2230)$ was recently resurrected. The BES group at the Beijing Electron Positron Collider studied the radiative decay of 8.8 million J/ψ and reported that they observe its decay not only in the $K^0_S\,K^0_S$ and $K^+\,K^-$ channels, but also in the $\pi^+\,\pi^-$ and $\bar{p}p$ channels, with branching ratios, which, when corrected for phase space, appear to be nearly flavour-blind.[6)] In a more recent communication,[7)] BES has also reported the observation of $\xi(2230)$ decay into neutral channels $\pi^0\,\pi^0$, $\eta\eta$ and $\eta\eta'$. The evidence for $\xi(2230)$ certainly "appears" to be getting stronger.

The BES report of the $\bar{p}p$ decay of $\xi(2230)$ has naturally catalyzed renewed interest in the inverse reaction, i.e. formation of ξ in $\bar{p}p$ annihilation. Indeed, the JETSET experiment (PS202) at the LEAR facility at CERN has reported evidence for ξ formation in the preliminary analysis[8)] of the reaction $\bar{p}p \to \xi(2230) \to \eta\eta$.

In this report, we present preliminary results of the search for ξ formation in $\bar{p}p$ annihilation made by the Crystal Barrel experiment (PS197) at LEAR. Annihilations into several all-neutral channels were measured. Here we present results only for the reactions

$$\bar{p}p \to \eta\eta \qquad \text{and} \qquad \bar{p}p \to \pi^0\,\pi^0. \tag{1}$$

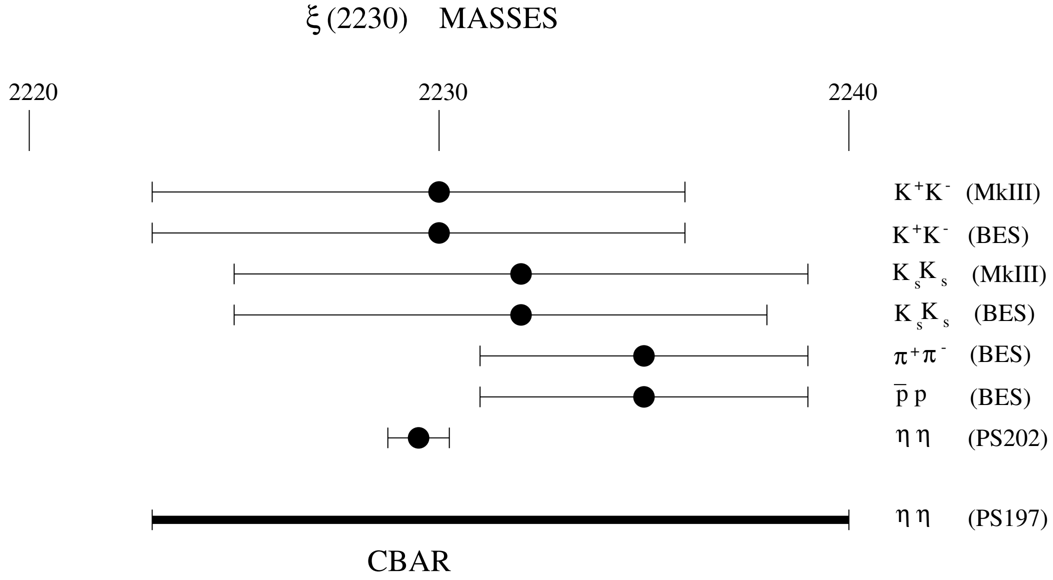

Figure 1: Reported masses of $\xi(2230)$ and the range of our (CBAR) measurements.

The Crystal Barrel detector at the LEAR antiproton facility has been described in detail elsewhere.[9)] In brief it consists of a near hermetic 4π detector for photons and charged particles produced in $\bar{p}$ intereactions with a 4 cm long target of liquid hydrogen. For the present measurements an all neutral trigger was used and the antiproton flux was kept at 300,000 - 500,000 $\bar{p}$/s. Beam momenta were varied between 1412 MeV/c to 1461 MeV/c in steps of approximately 6 MeV/c, which corresponds to energy steps of approximately 2 MeV in the range $\sqrt{s}$ = 2222 to 2240 MeV. As Fig. 1 illustrates this spans the entire mass range in which positive observation of $\xi(2230)$ has been reported by any experiment. The LH_2 target thickness corresponds to $\Delta\sqrt{s} = \pm 0.65$ MeV with straggling which was negligibly small in comparison. The absolute value of energy at the center of the target is expected to be accurate to within ± 0.1 MeV. Relative efficiency and acceptance were determined by Monte Carlo calculations. They were found to be constant to better than $\pm 5\%$ over the entire range of measurements.

Data were analyzed for $\bar{p}p \rightarrow \eta\eta$ and $\bar{p}p \rightarrow \pi^0\pi^0$ with each η and π^0 decaying into two photons. At each incident $\bar{p}$ momentum between 0.5 to 1.3 million all neutral triggers were recorded, yielding between 300 and 700 good $\eta\eta$ events and about 30 times more $\pi^0\pi^0$ events. Typical spectra at various stages of analysis are shown in Fig 2. It may be noticed that the $\eta\eta$, $\pi^0\pi^0$, and $\pi^0\eta$ signals are all very clean, with essentially no background. The absolute cross sections corresponding to our relative measurements were obtained by normalizing our $\pi^0\pi^0$ results to a two parameter fit [$\sigma = Ae^{Bp}$] to the absolute cross section measurements of Dulude et al.[10)] for $\bar{p}p \rightarrow \pi^0\pi^0$. Fig. 3 shows the resulting cross sections. The preliminary

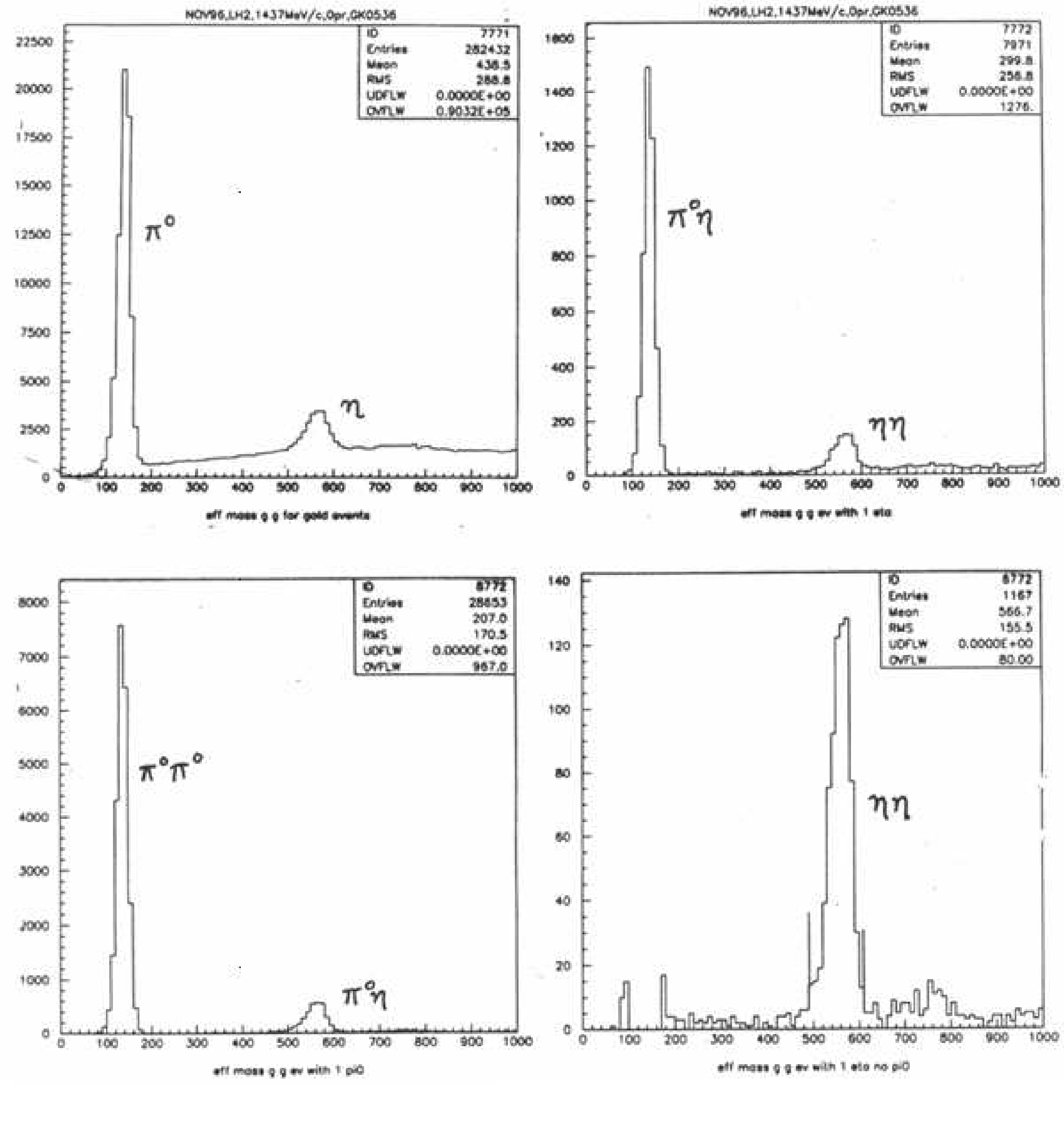

Figure 2: Successive steps of analysis for $\bar{p}p \to \eta\eta$ for $\sqrt{s}$ = 2230.5 MeV.

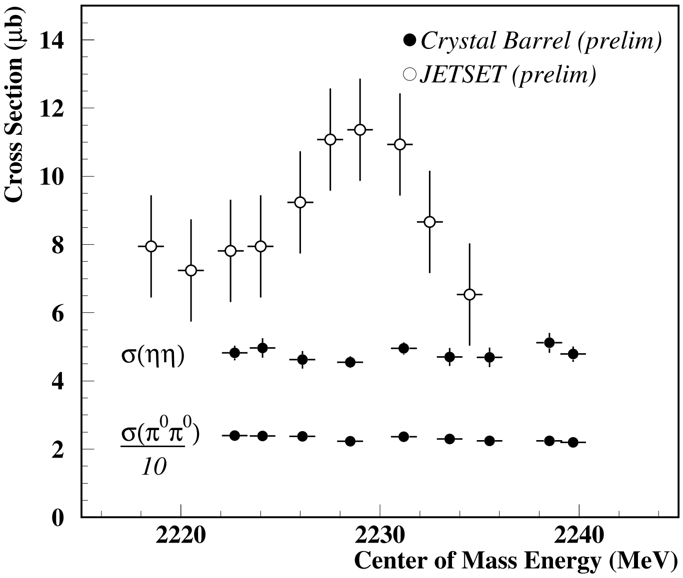

Figure 3: Cross sections for $\bar{p}p \to \eta\eta$ and $\bar{p}p \to \pi^0\pi^0$ from the present measurements (only statistical errors are shown). The open points show the preliminary results for $\bar{p}p \to \eta\eta$ from Ref. 8.

results presented by PS202 for $\bar{p}p \to \eta\eta$ are also shown for comparison.*

It is clear from Fig. 3 that there is no identifiable resonance enhancement in the region $\sqrt{s} = 2222 \to 2240$ MeV.

In order to obtain a quantitative measure of what the data imply for a possible Breit Wigner resonance of the form

$$\sigma = \frac{(2J+1)\pi}{4k^2}\frac{B_{in}B_{out}}{(\sqrt{s}-M)^2+(\Gamma^2/4)} \tag{2}$$

$$B_{in} = \Gamma(p\bar{p} \to \xi)/\Gamma, B_{out} = \Gamma(\xi \to \eta\eta)/\Gamma \tag{3}$$

we have made the following calculations. For an assumed width of the resonance, we determine upper limits for the value of $B_{in}B_{out}$ for a resonance (appropriately resolution broadened) if its center is placed at the given energy. In Fig 4 we show the results obtained for assumed full widths of 5, 10 and 20 MeV. To summarize, the normalization of our data to Dulude et al. leads to an upper limit

$$B(\bar{p}p \to \xi)B(\xi \to \eta\eta) \leq 6 \times 10^{-5} \tag{4}$$

*In a subsequent reanalysis of their data PS202 also finds a relatively flat distribution of their $\eta\eta$ cross sections. (J. Ritter, *priv. comm.*)

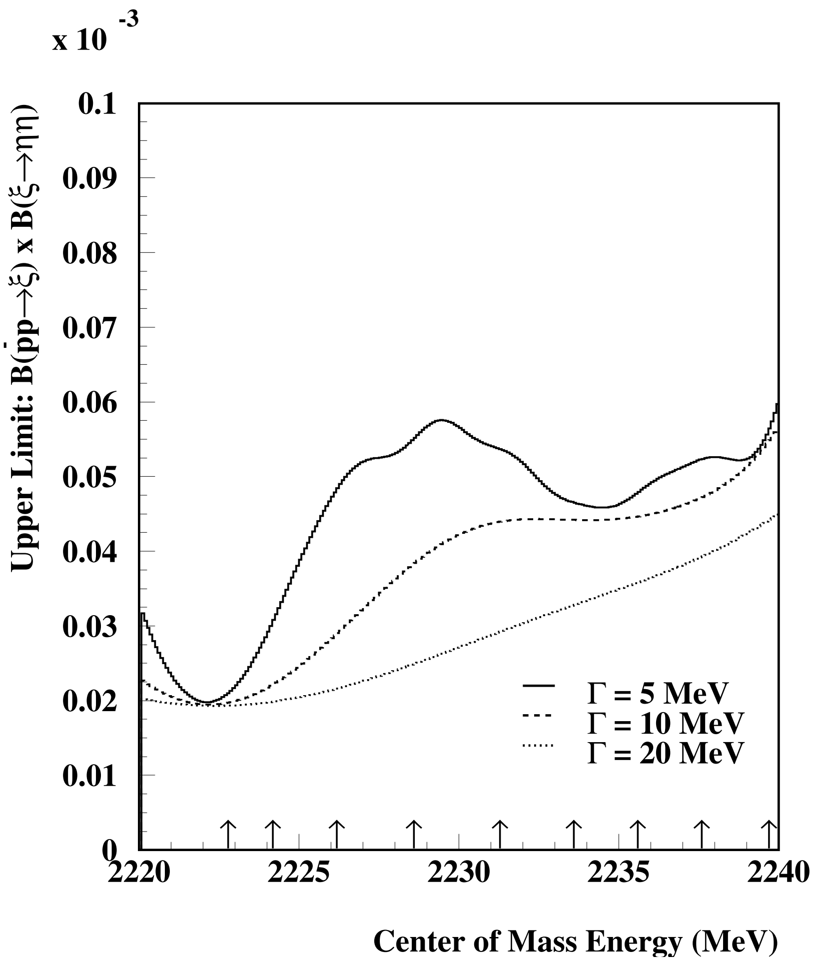

Figure 4: Upper limits for the product branching ratio $B(p\bar{p} \to \xi) \times B(\xi \to \eta\eta)$ as a function of assumed mass for three different values of ξ width.

for a resonance of full width between 5 and 20 MeV anywhere in the mass range 2222 to 2240 MeV.

Our non-observation of $\xi(2230)$ has strong implications for the results from BES. If we combine the BES results, $B(J/\psi \to \gamma\xi)B(\xi \to \bar{p}p\,) = (1.5^{+0.6}_{-0.5} \pm 0.5) \times 10^{-5}$ and $B(J/\psi \to \gamma\xi)B(\xi \to \eta\eta) = (27 \pm 11 \pm 8) \times 10^{-5}$,[7] with our upper limit (Eq. 4), we obtain the following limits:

$$B(J/\psi \to \gamma\xi) \;\geq\; 1.0 \times 10^{-2}, \tag{5}$$

$$B(\xi \to \bar{p}p\,) \;\leq\; 1.4 \times 10^{-3}, \tag{6}$$

$$B(\xi \to \eta\eta) \;\leq\; 27 \times 10^{-3}. \tag{7}$$

The $\geq 1\%$ branching ratio for radiative decay of J/ψ to $\xi(2230)$ is difficult to reconcile with PQCD predictions and the existing data on J/ψ radiative decays.

According to PQCD

$$R = \frac{B(J/\psi \to \gamma gg)}{B(J/\psi \to ggg)} = \frac{16}{5}\frac{\alpha}{\alpha_s}[\frac{1-6.7\alpha_s/\pi}{1-3.7\alpha_s/\pi}]. \quad (8)$$

For $\alpha_s = 0.3$, and the experimental result $B(J/\psi \to ggg) = 0.61 \pm 0.02$,[11] this leads to $B(J/\psi \to \gamma gg) = 4.7\%$ without radiative corrections, or 2.6$\%$ with first order radiative corrections given in square brackets in Eq. 8. The 28 known radiative decays of J/ψ total to $(5.2 \pm 0.5)\%$ already and have an average branching ratio of $\sim 0.2\%$.[11] It seems highly improbable that radiative decay to $\xi(2230)$ alone could have a branching ratio as large as 1%. This casts serious doubt on at least one of the two ingredients $B(J/\psi \to \gamma\xi)(\xi \to \bar{p}p\,)$, and $B(J/\psi \to \gamma\xi)(\xi \to \eta\eta)$ from BES which we have used in obtaining the branching ratio limits (Eq. 5-7) above.

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