A SEARCH FOR NARROW STATES PRODUCED IN THE REACTION $\pi^- p \rightarrow n + \gamma$'s AT 13 GeV/c*

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ABSTRACT

Using a double arm lead-glass lead-scintillator calorimeter system we have searched for narrow states, such as the η_c, produced in the exclusive reactions $\pi^- p \rightarrow \gamma\gamma n$, $\pi^- p \rightarrow \pi^0 \gamma n$, and $\pi^- p \rightarrow \pi^0 \pi^0 n$ at 13 GeV/c. We find a 90% c.l. upper limit $\sigma \cdot BR < 260$ pb for $\gamma\gamma$ states with masses from 2.6 to 3.1 GeV/c^2. Corresponding limits on narrow $\pi^0\gamma$ and $\pi^0\pi^0$ states are also given.

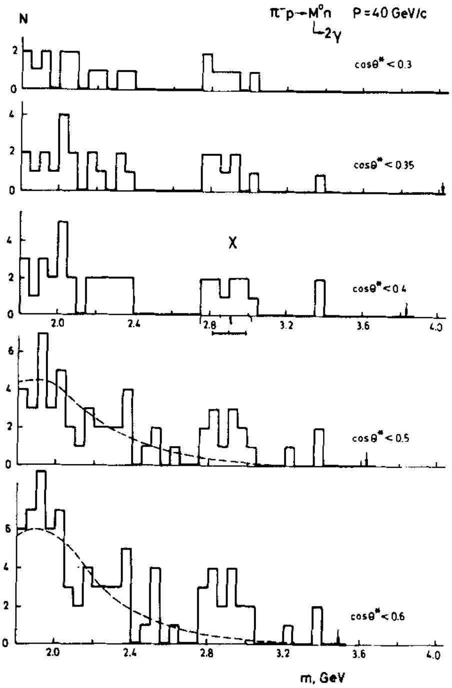

Fig. 1. $\gamma\gamma$ mass spectra from Ref. 2.

This is a brief status report on AGS Experiment 732 which is a search for narrow states produced in the exclusive reaction $\pi^- p \rightarrow n + \gamma$'s at 13 GeV. Our primary motivation was the unsatisfactory state of the $^1S_0$ charmonia, at the time of our proposal. One had hyperfine splittings apparently larger than fine splittings, M1 radiative rates too low by orders of magnitude, etc.[1] We hoped to find the real η_c and η_c' in hadronic production. There was also a tantalizing Russian result in 40 GeV $\pi^- p \rightarrow \gamma\gamma n$. Apel et al.,[2] claimed to see a $\gamma\gamma$ peak at 2.88 GeV/c^2 (consistent in mass with the DESY η_c candidate). The cross section × branching ratios was $\sim$ 200 picobarns. Fig. 1 shows their data. After a number of cuts were imposed on the data, a signal was

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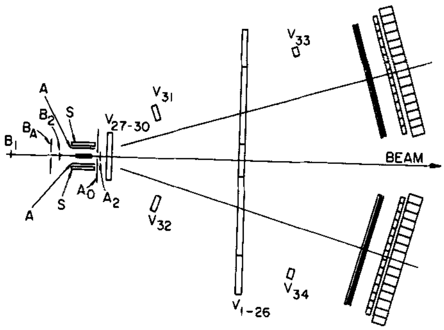

Fig. 2(a). Experimental layout. S and V counters are lead-scintillator shower counters. A are charged particle veto counters which surround the scintillator target.

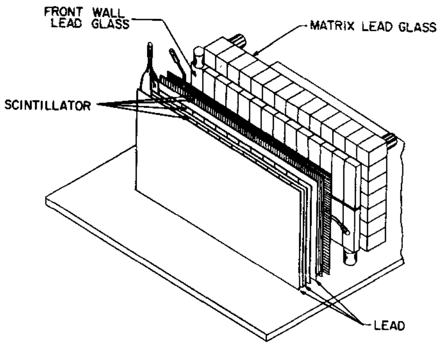

Fig. 2(b). Details of one photon calorimeter. Components of the converter section are shown in an exploded view for clarity.

apparent but not really compelling.

Our apparatus is shown schematically in Fig. 2(a). Briefly, there is a 13 GeV/c beam incident on a live scintillator target, there are two calorimeters at ± 16° and the rest of 4π sr is filled with lead-scintillator shower counters set in veto. The calorimeter shown in Fig. 2(b) is 16 radiation lengths in all, 4 r.l. of lead scintillator followed by 12 r.l. of lead glass in 2 layers. At the end of the lead scintillator section are two crossed fine grain hodoscopes. These serve to identify π^0's which appear as two clusters in each projection. π^0 rejection is really the key to this experiment, and that worked quite well.

Photon energy resolution was $\sigma_E/E \sim 15\%/\sqrt{E}$ which would imply a $\gamma\gamma$ mass resolution of about 120 MeV/c at 2.8 GeV/c^2. However, the fact that we have an exclusive process works in our favor here because we can make use of constrained fitting. This reduces $\sigma_{M_{\gamma\gamma}}$ by more than a factor of 2 to around 45 MeV/c^2.

We took a number of test runs at 6 GeV/c in order to see some common garden variety resonances. In Fig. 3(a) we see a large f^0 in the $\pi^0\pi^0$ spectrum. In the $\gamma\gamma$ spectrum of Fig. 3(b) we see both an η and an η' in the right places. We also see two other peaks which are due to $\pi^0 \to \gamma$ feed-down, in one case from $\omega \to \pi^0\gamma$ and in the other case from the f^0, which show how π^0 misidentification can be a problem. It turns out that at the sensitivity we have reached, this is not yet the limiting factor.

We triggered on neutral energy of more than 9 GeV, at least one GeV in each arm, and no vetos. After 10 days running at about 10^7 π^-/burst, not much more than a test run, we collected approximately 3 million triggers, mainly $\pi^0\pi^0$. With the trigger in force

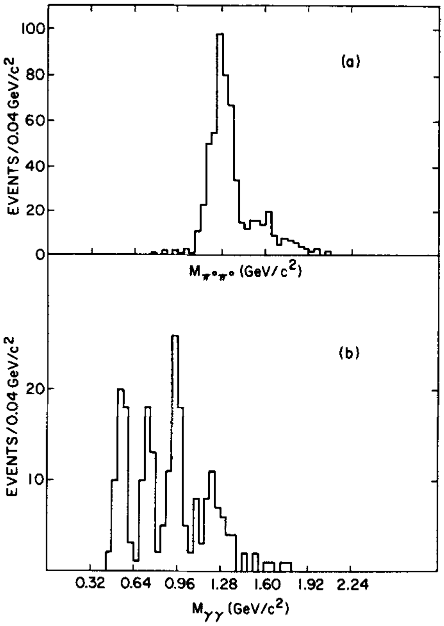

Fig. 3.
a) $M_{\pi^0\pi^0}$ from $\pi^- p \to n + 4\gamma$ at 6 GeV/c.
b) $M_{\gamma\gamma}$ from the same runs.

one can look at the energy distribution of say the $\pi^0\pi^0$ sample (shown in Fig. 4) and see that the events are not all piled up against the cut at 9 GeV but fall into a clean, full energy peak. This indicates that the trigger was successful. The 10 day run allowed us to reach about 10 events per nanobarn for $\gamma\gamma$.

Fig. 5 shows the results in the three modes that we have analyzed thus far: $\pi\pi$, $\pi\gamma$, and $\gamma\gamma$. One doesn't really expect narrow resonances in the $\pi\pi$ spectrum and none are seen. The solid curve is the shape of the acceptance. In the $\pi\gamma$ spec- there are fewer events and again there is no apparent structure. The dashed curve

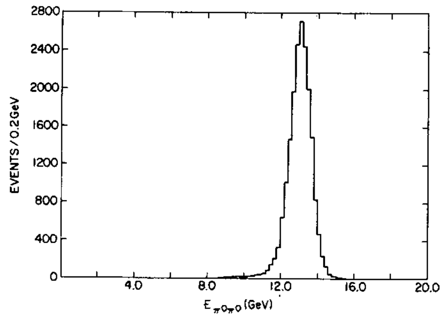

Fig. 4. $E_{\pi^0\pi^0}$ spectrum from 13 GeV/c running.

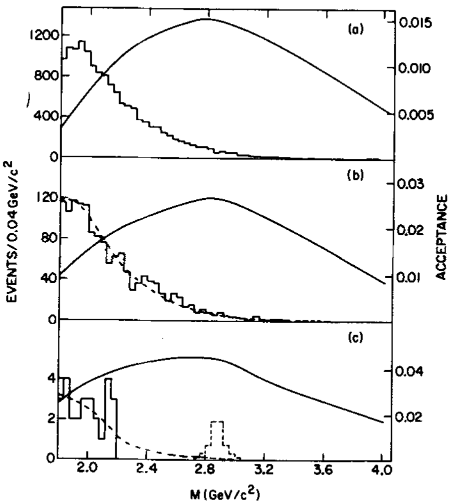

Fig. 5. Histogram of effective mass from 13 GeV/c runs. Solid lines indicate the acceptance. Dashed lines in (b) and (c) indicate the calculated $\pi^0\pi^0$ feed-down.
a) $\pi^0\pi^0$
b) $\pi^0\gamma$
c) $\gamma\gamma$. The dotted peak shows the predicted contribution of the X^0.(2)

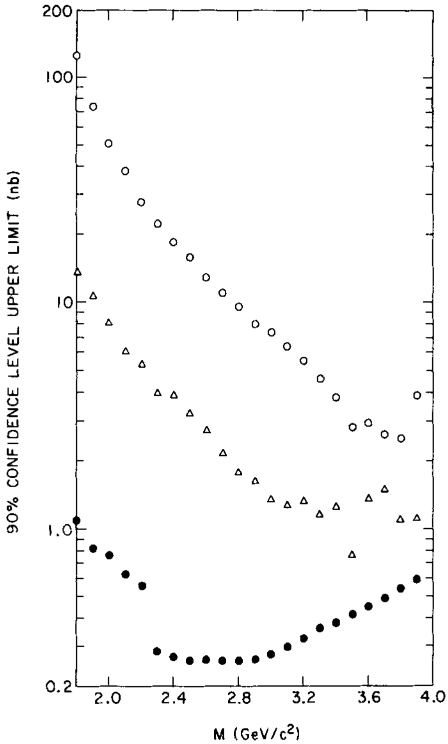

Fig. 6. 90% confidence level upper limits for narrow resonance production in $\pi^0\pi^0(\circ)$, $\pi^0\gamma(\triangle)$, and $\gamma\gamma(\bullet)$.

here is the expectation of the Monte Carlo calculation of the $\pi\pi$ feed-down and it accounts for the $\pi\gamma$ that we see quite nicely. In the most interesting process, $\gamma\gamma$, there are very few events, nothing above 2.2 GeV, and again the feed-down from $\pi\pi$ explains what we do see. This translates into a limit on $\sigma\cdot$BR of $\sim$ 260 picobarns at 2.88 GeV/c^2. This is higher than the $\sigma\cdot$BR claimed by Apel et al.,[2] but in an exclusive reaction one would expect the cross section at 13 GeV/c to be much larger than the cross section at 40 GeV/c. In fact one would expect the η_c to scale like η's which go something like $p^{-1.5}$ or at least like p^{-1}. If the cross-section scales like p^{-1}, this would imply 600 picobarns at 13 GeV/c, which would give 5½ events for our run. The dotted curve in Fig. 5(c) is such a peak, smeared with our resolution, superimposed upon our spectrum. I don't think it could have been missed. After this experiment was proposed the theorists decided that the X(2880) makes a poor η_c candidate because the $\sigma\cdot$BR claimed by Apel et al.,[2] is too high; it implies a very large $\Gamma(\eta_c \rightarrow \pi A_2)$.[3,4] There was speculation that the X might be a 4-quark object à la Jaffe in which case one expects a momentum scaling even faster than for an η-like object, i.e., $\sigma \propto p^{-2.5}$. This would predict 33 events which certainly could not have been missed.

Fig. 6 shows the 90% confidence level upper limits for all three modes as a function of mass from 1.8 to 3.8 GeV/c^2.

Finally, we are currently proceeding with our run with an improved apparatus. Our aim is to improve the sensitivity by a factor of 20-down to about the 10 picobarn level where the η_c is expected to show up.

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