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A Search for Structure in the γ-Ray Spectra from $\bar{p}d$ and $\bar{p}p$ Annihilations at Rest*

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We report here the results of an experiment to observe discrete energy γ-rays from $\bar{p}p$ annihilations at rest. In a recent publication by an Athens-Syracuse group,[1] it was reported that in the annihilation of antiprotons in deuterium, an excess number of γ-rays, ($\approx$ 25%) above those from neutral pions assuming charge independence, are produced and in addition, the data suggested the existence of several narrow lines between 100 and 300 MeV. Approximately 1000 γ rays from annihilations were observed in the BNL 30" bubble chamber. The authors interpreted these data as preliminary evidence for the radiative transition of a bound state of the proton-antiproton system.

We have therefore undertaken an experiment to measure the γ spectra with high efficiency and good statistics (10^6 events). The beam used was a 750 MeV/c separated antiproton beam from the BNL AGS. The antiprotons were then degraded so as to stop in a target of liquid hydrogen or deuterium (6" diameter x 19" length.) 300 stopped antiprotons were obtained every AGS pulse. Figure 1 is a section view of the apparatus as seen by the antiproton. The technique used was to observe the γ rays with a NaI(Tℓ) crystal (10" x 10") which was oriented 90° to the target. The target was surrounded on four sides by eight scintillation counters in order to determine the approximate charged pion multiplicity of each event. Upon the recognition of a stopping $\bar{p}$ in the target, the signal pulse height from the NaI(Tℓ) crystal was routed to a pulse-height analyzer (4 MeV threshold). The data in the pulse-height analyzer was arranged into 32 separate 128 channel spectra of $\approx$ 4 MeV/channel, depending on the charged particle multiplicity, the charge of the particle entering the crystal and the energy leakage into the surrounding scintillator shield counter. Complete details of the apparatus are presented elsewhere.[2]

Checks of the energy calibration and detector resolution were regularly made. The minimum ionizing peak ($\approx$ 130 MeV) from charged particles was continously monitored in order to calibrate the energy scale. The detector resolution was measured by stopping π^- and measuring the width of the 129.4 MeV γ line from $\pi^- p \rightarrow n\gamma$ and $\pi^- d \rightarrow nn\gamma$. We obtained an energy resolution of 15% FWHM for the lowest two energy leakage levels.[3]

We collected a total of 475,000 γ ray events from hydrogen and 573,000 events from deuterium. Figures 2 and 3 show the γ ray spectra for all 4 energy leakage levels, summed over all charged particle multiplicities for

hydrogen and deuterium respectively.[3] A detailed discussion of background contributions energy leakage effects, etc. is presented elsewhere.[4]

We conclude that to 1% of the continuum for discrete γ lines between 50 and 200 MeV and with a 15% energy resolution, we observe no structure in the γ spectra of antiproton annihilations in hydrogen or deuterium. We do observe that spectra associated with certain multiplicities exhibit structure at a few tenths per cent intensity.[5] These are believed due to secondary processes such as the 129.4 MeV γ from π^- from the annihilations that stop in the target ($\pi^- p \rightarrow n\gamma$).

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References

1. T.E. Kalogeropoulos, A. Vayaki, G. Grammatikakis, T. Tsilimigras, and E. Simopoulou, Phys. Rev. Let. 33, 1635 (1974).

2. D.N. Michael, Proceedings of IV International Symposium on Antinucleon-Nucleon Interactions, Syracuse, N.Y. (1975)
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3.

Shield Level, Y	Minimum Pulse (MeV)	Maximum Pulse (MeV)
0	-	1.1
1	1.1	4.4
2	4.4	7.6
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5. Ibid.

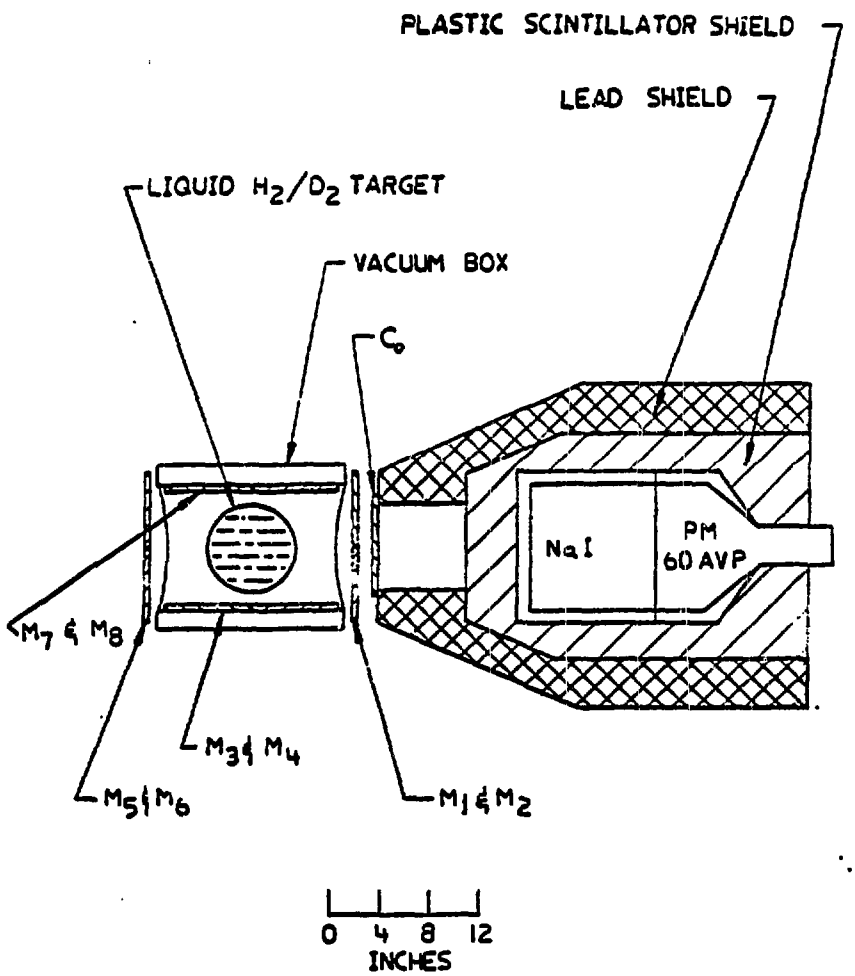

Fig. 1. Section view of apparatus as seen by an incoming antiproton.

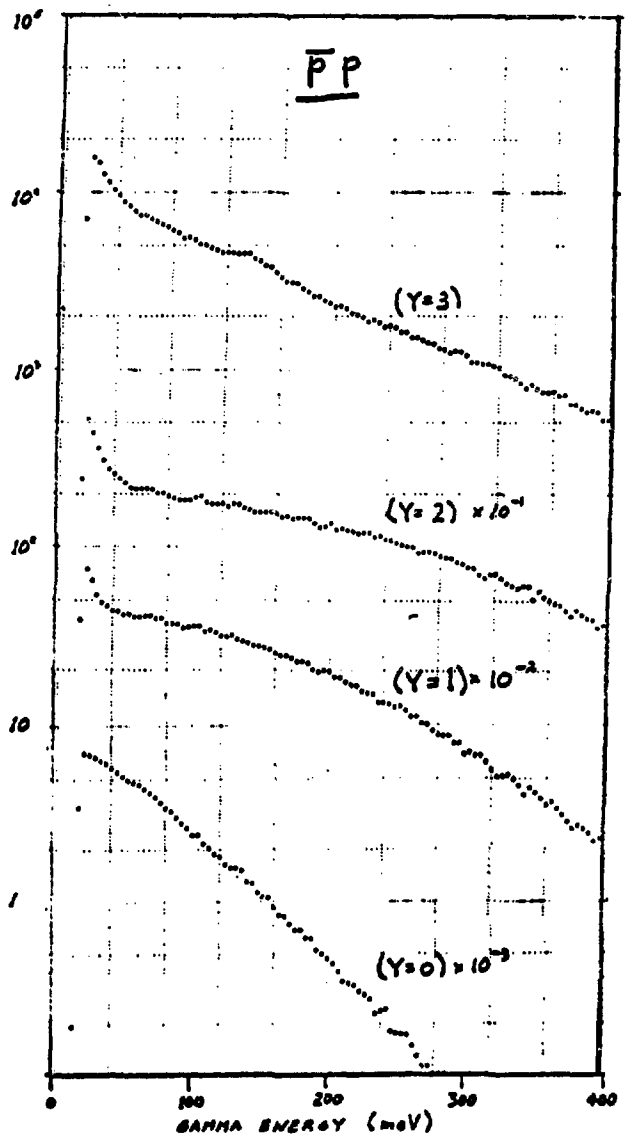

Fig. 2. Gamma spectra obtained in the experiment from hydrogen. Spectra obtained with the four different shield-level requirements, Y, are shown. Absolute scales of the four spectra have been displaced relative to each other by factors of ten.

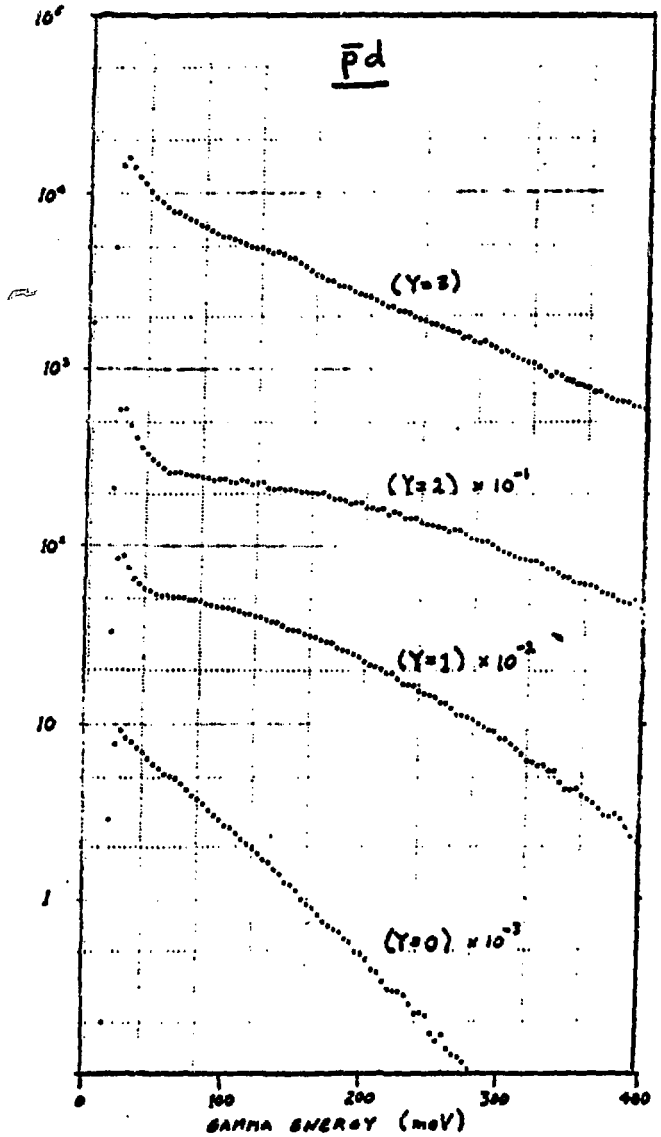

Fig. 3. Gamma spectra obtained in the experiment from deuterium.

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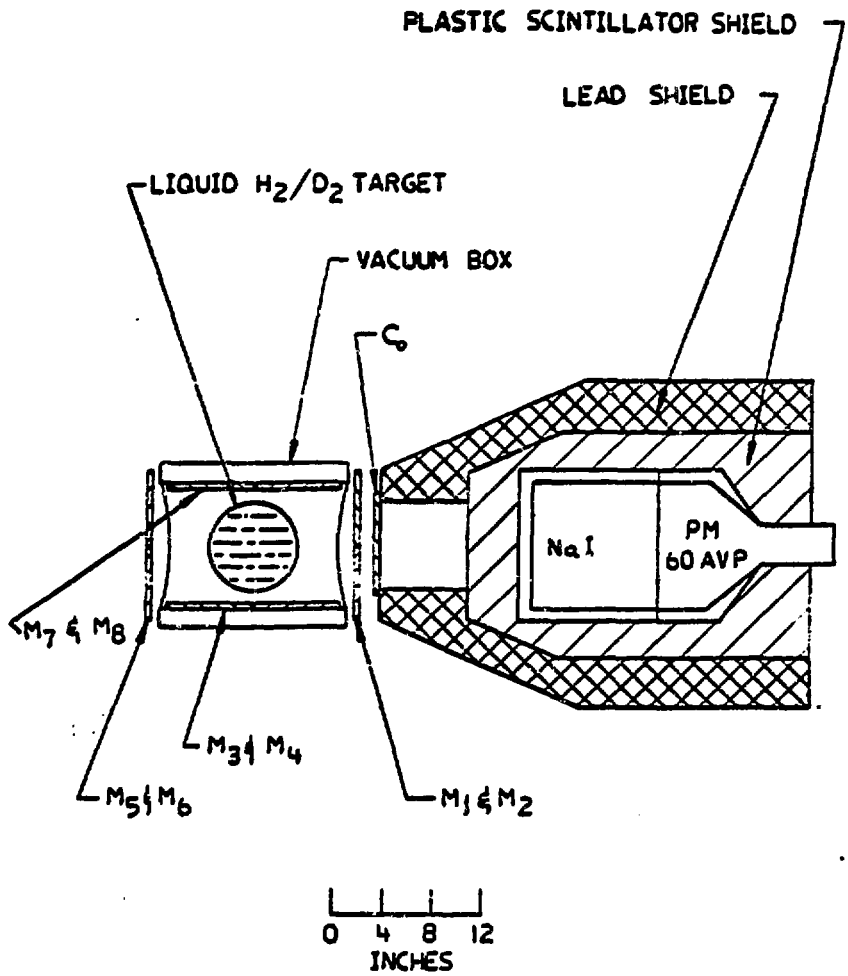

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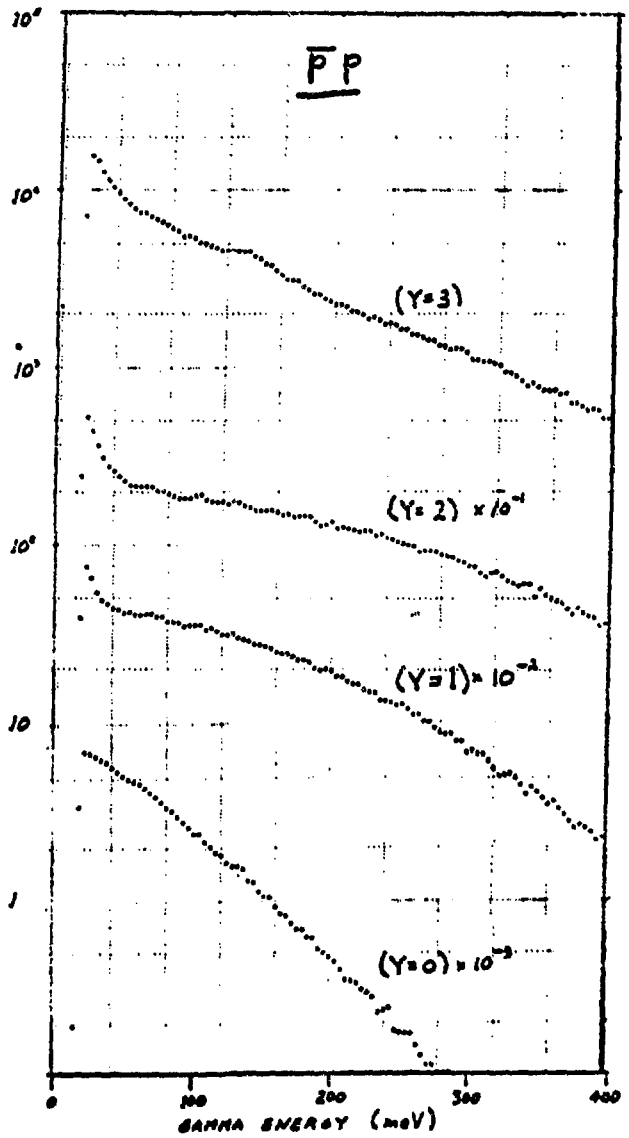

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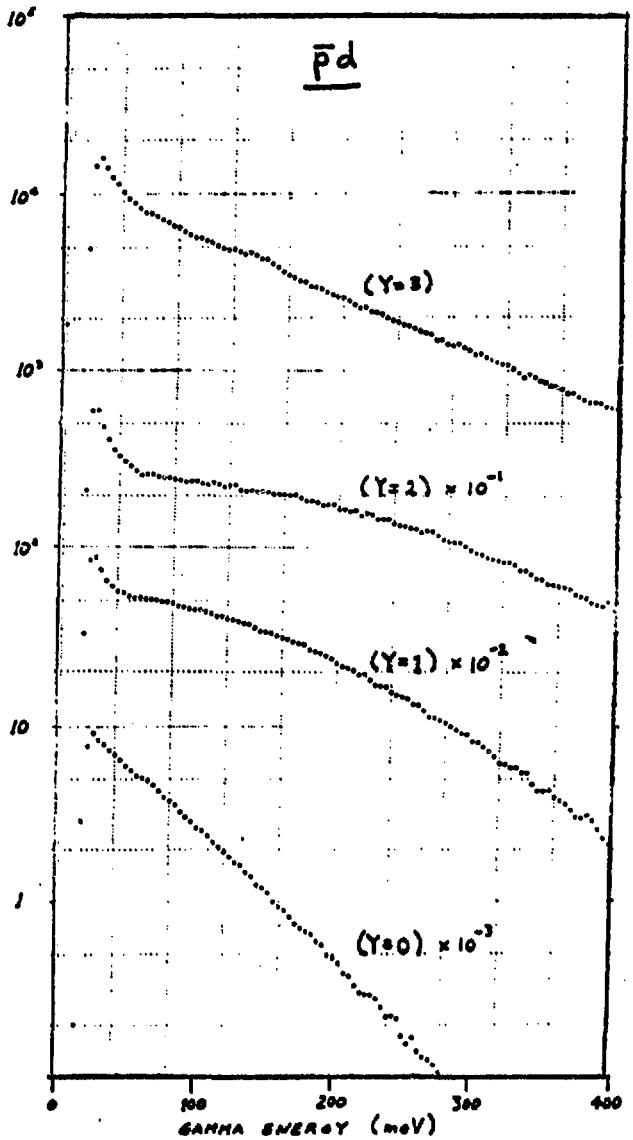

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