PHYSICAL REVIEW D VOLUME 33, NUMBER 1 1 JANUARY 1986

Search for monoenergetic photons from $\Upsilon(1S) \rightarrow \gamma + X$

D. Besson, J. Green, R. Namjoshi, F. Sannes, P. Skubic,* and R. Stone
Rutgers University, New Brunswick, New Jersey 08854

M. S. Alam, N. Katayama, I. J. Kim, C. R. Sun, and V. Tanikella
State University of New York at Albany, Albany, New York 12222

D. Bortoletto, A. Chen, L. Garren, M. Goldberg, N. Horwitz, A. Jawahery, P. Lubrano, G. C. Moneti, C. G. Trahern, and H. van Hecke
Syracuse University, Syracuse, New York 13210

S. E. Csorna, M. D. Mestayer, R. S. Panvini, G. B. Word, and Xia Yi
Vanderbilt University, Nashville, Tennessee 37235

A. Bean and T. Ferguson
Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213

P. Avery, C. Bebek, K. Berkelman, E. Blucher, D. G. Cassel, T. Copie, R. DeSalvo, J. W. DeWire, R. Ehrlich, R. S. Galik, M. G. D. Gilchriese, B. Gittelman, S. W. Gray, A. M. Halling, D. L. Hartill, B. K. Heltsley, S. Holzner, M. Ito, J. Kandaswamy, R. Kowalewski, D. L. Kreinick, Y. Kubota, N. B. Mistry, J. Mueller, E. Nordberg, M. Ogg, D. Peterson, D. Perticone, M. Pisharody, K. Read, D. Riley, A. Silverman, P. C. Stein, and S. Stone
Cornell University, Ithaca, New York 14853

A. J. Sadoff
Ithaca College, Ithaca, New York 14850

T. Bowcock, R. T. Giles, J. Hassard, K. Kinoshita, F. M. Pipkin, and Richard Wilson
Harvard University, Cambridge, Massachusetts 02138

P. Haas, M. Hempstead, T. Jensen, H. Kagan, and R. Kass
Ohio State University, Columbus, Ohio 43210

S. Behrends, T. Gentile, Jan M. Guida, Joan A. Guida, F. Morrow, R. Poling, C. Rosenfeld,† E. H. Thorndike, and P. Tipton
University of Rochester, Rochester, New York 14627

(Received 14 August 1985)

We present the results of a search for monoenergetic photons from the process $\Upsilon(1S) \rightarrow \gamma + X$. Upper limits at 90% confidence level for the branching ratio $B(\Upsilon(1S) \rightarrow \gamma + X)$ range from 0.1% to 1.4% for photon energies between 150 and 2000 MeV.

The radiative decay $\Upsilon(1S) \rightarrow \gamma + X$ is a potentially fruitful way to search for new particles X. Of particular interest is the possibility of radiative decays to a Higgs particle, first suggested by Wilczek.[1] The presence of such a particle would be indicated by a monoenergetic photon. This paper presents the results of a search for monoenergetic photons from $\Upsilon(1S)$ decay.

The results were obtained with the CLEO detector[2] from a sample of approximately 263 000 $\Upsilon(1S)$ decays. Photons were converted in a 0.1-radiation-length-thick cylindrical lead converter. Inside the converter was a ten-layer cylindrical drift chamber, the vertex detector, which we used to veto charged tracks. The combined thickness of the beam pipe and the vertex detector was 0.013 radiation lengths. Immediately outside the converter was a 17-layer drift chamber. Photon candidates were recognized in this chamber as pairs of oppositely charged tracks forming a secondary vertex near the radius of the lead converter. We also required that the vertex detector show no tracks pointing to the secondary vertex. Photon energies were calculated by refitting the two tracks to the hits in the drift chamber under the supposition that they were due to a converted photon. The supposition imposes four constraints on the fit: in the longitudinal view the tracks must be identical and extrapolate to the event vertex, and in the transverse view the tracks must intersect at the converter. The opening angle in the transverse view was not constrained, allowing an apparent mass for the photon. This analysis procedure differs from that described in a previous publication[3] only in that the magnetic field was increased to 1.0 T to improve

RAPID COMMUNICATIONS

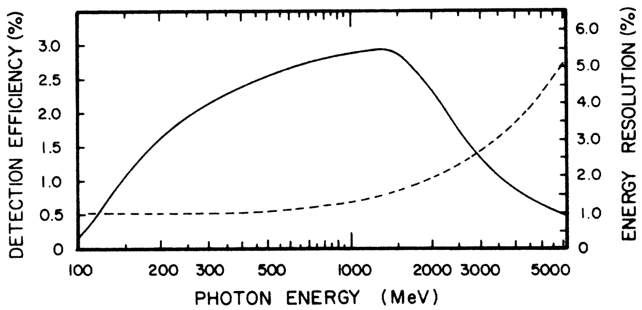

FIG. 1. The total photon detection efficiency (solid curve and left-hand scale) and the rms energy resolution (dashed curve and right-hand scale).

the resolution and the vertex detector was used as a charged-track veto.

The photon detection efficiency depends strongly on the photon energy and less strongly on event topology and multiplicity. The efficiency for detecting a narrow photon line was estimated using the efficiency for single charged tracks, including effects such as energy loss in the converter, accidental vetoes in the vertex detector, and multiple scattering. The photon efficiency is shown in Fig. 1 as the solid line. The poor photon efficiency at low energy reflects the difficulty of reconstructing charged tracks below about 50 MeV/c. At high energies the electron and positron tracks merge and are not recognized as converted photons. We verified the photon-efficiency calculation by comparing the observed photon spectrum with that predicted to come from π^0 decays, using the charged-pion spectrum to estimate the π^0 spectrum.

The root-mean-square photon-energy resolution σ_E was estimated as a function of energy from the known charged-track momentum resolution. Bremsstrahlung radiation of the pair-produced particles in the converter causes a long radiative tail. Particles which radiate a large amount of energy are excluded in the efficiency calculation because the photon they reconstruct to will be shifted in energy off the narrow peak we seek and be lost in the background. Multiple scattering of the electrons in the lead converter and the drift chamber degrades the resolution, but tracks that have suffered large scatters will be eliminated by cuts on the quality of the constrained fit to the photon hypothesis and the apparent mass of the photon. The photon-energy resolution for acceptable track combinations is shown as a dashed curve in Fig. 1. The same calculation done with 0.3-T magnetic field agrees with the observed width of photon lines from $\Upsilon(2S) \to \gamma + (P\ \text{state})$ decays.[3]

The observed photon spectrum for all $\Upsilon(1S)$ decays is plotted in Fig. 2(a). The bin width corresponds approximately to $2\sigma_E$. No outstanding structure is observed. The 90%-confidence-level upper limits shown in Fig. 3 for $B(\Upsilon(1S) \to \gamma + X)$ were determined as a function of the photon energy taking into account uncertainties in the acceptance and resolution estimates. The largest excursion from a smooth photon spectrum is a 4σ deviation at 520 MeV.

Higgs-type particles are expected to couple primarily to the heaviest fermion pairs available, $c\bar{c}$ and $\tau^+\tau^-$ pairs in this case. The Higgs-particle decay would therefore preferentially produce jetlike topologies or low-multiplicity decays. In Fig. 2(b) we show the photon spectrum for events

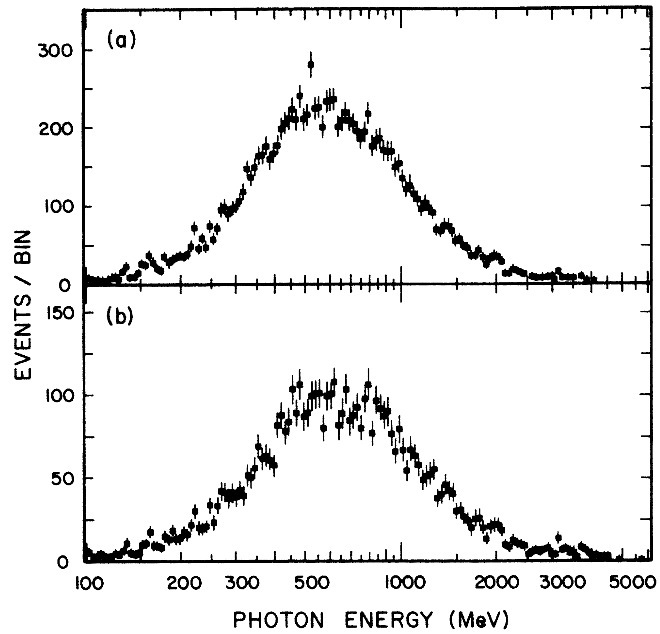

FIG. 2. (a) The photon-energy spectrum from all $\Upsilon(1S)$ decays. (b) The photon-energy spectrum from $\Upsilon(1S)$ decays with $R_2 > 0.22$ or charged-particle multiplicity five or less. In both cases the bin's size is chosen to be approximately twice the rms energy resolution.

whose Fox-Wolfram event shape parameter R_2 is greater than 0.22 or whose charged-particle multiplicity is five or less (excluding the photon related tracks). With these criteria the event topology would be consistent with $c\bar{c}$ or $\tau^+\tau^-$ decays of a Higgs-type particle. Again no significant structure is observed. An analysis of low-multiplicity events or jetlike events alone also yields no evidence for monoenergetic photons.

In summary, we have found no evidence for monoenergetic photons in $\Upsilon(1S) \to \gamma + X$ in the photon-energy range from 150–2000 MeV. Previously published results from the CUSB[4] and ARGUS[5] collaborations and unpublished results from CUSB[6] and the Crystal Ball Group[7] are in agreement with this conclusion in the mutually overlapping photon-energy region. The results presented here are more restrictive than previous studies for photon energies below about 500 MeV. Future searches for new particles produced in ra-

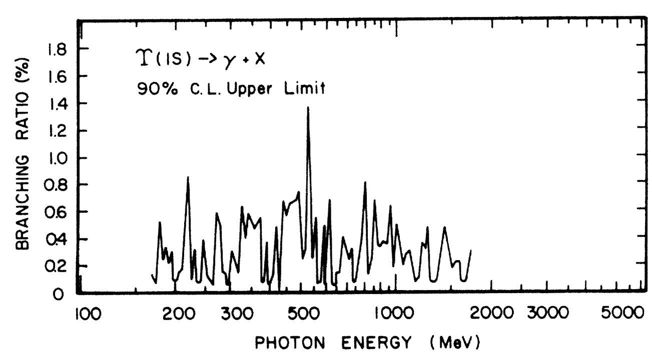

FIG. 3. The 90%-confidence-level upper limits to the branching ratio $B(\Upsilon(1S) \to \gamma + X)$ as a function of photon energy.

diative $\Upsilon(1S)$ decays will require larger data samples and/or improved detectors.

It is a pleasure to thank the members of the Cornell Electron Storage Ring operating staff for their efforts. This work was supported by the National Science Foundation and the United States Department of Energy. One of us (M.G.D.G.) would like to thank the Alfred P. Sloan Foundation for support. One of us (H.K.) would like to acknowledge the Department of Energy for support.

---

*Present address: Department of Physics, University of Oklahoma, Norman, OK 73019.

†Present address: Physics Department, Louisiana State University, Baton Rouge, LA 70803.

[1]F. Wilczek, Phys. Rev. Lett. **39**, 1304 (1977).

[2]D. Andrews *et al.*, Nucl. Instrum. Methods **211**, 47 (1983).

[3]P. Haas *et al.*, Phys. Rev. Lett. **52**, 799 (1984).

[4]S. Youssef *et al.*, Phys. Lett. **139B**, 332 (1984).

[5]H. Albrecht *et al.*, Phys. Lett. **154B**, 452 (1985).

[6]J. Lee-Franzini, 20th Rencontre de Moriond Conference, 1985 (unpublished).

[7]S. Lowe, 20th Rencontre de Moriond Conference, 1985 (unpublished).