Z. Phys. C - Particles and Fields 31, 181-184 (1986)

Zeitschrift für Physik C Particles and Fields

An Upper Limit for Two-Jet Production in Direct $\Upsilon(1S)$ Decays

ARGUS Collaboration

H. Albrecht, U. Binder, G. Harder, I. Lembke-Koppitz, A. Philipp, W. Schmidt-Parzefall,
H. Schröder, H.D. Schulz, R. Wurth
DESY, D-2000 Hamburg, Federal Republic of Germany

J.P. Donker, A. Drescher, U. Matthiesen, H. Scheck, B. Spaan, J. Spengler, D. Wegener
Institut für Physik, Universität, D-4600 Dortmund[1], Federal Republic of Germany

J.C. Gabriel, K.R. Schubert, J. Stiewe, R. Waldi, S. Weseler
Institut für Hochenergiephysik, Universität, D-6900 Heidelberg[1], Federal Republic of Germany

K.W. Edwards[3], W.R. Frisken[4], Ch. Fukunaga[4], D.J. Gilkinson[5], D.M. Gingrich[5], M. Goddard[4],
H. Kapitza[3], P.C.H. Kim[5], R. Kutschke[5], D.B. MacFarlane[5], J.A. McKenna[5], K. McLean[2], A.W. Nilsson[2],
R.S. Orr[5], P. Padley[5], P.M. Patel[2], J.D. Prentice[5], H.C.J. Seywerd[5], B.J. Stacey[5], T.-S. Yoon[5], J.C. Yun[3]
Institute of Particle Physics[6], Canada

R. Ammar, D. Coppage, R. Davis, S. Kanekal, N. Kwak
University of Kansas[7], Lawrence, KA 66044, USA

G. Kernel, M. Pleško
J. Stefan Institute and Department of Physics, University, YU-61000 Ljubljana[8], Yugoslavia

L. Jönsson, Y. Oku
Institute of Physics, University, S-22362 Lund[9], Sweden

A. Babaev, M. Danilov, A. Golutvin, V. Lubimov, V. Matveev, V. Nagovitsin, V. Ryltsov, A. Semenov,
V. Shevchenko, V. Soloshenko, V. Sopov, I. Tichomirov, Yu. Zaitsev
Institute of Theoretical and Experimental Physics, SU-117259 Moscow, USSR

R. Childers, C.W. Darden, H. Gennow[10]
University of South Carolina[11], Columbia, SC 29208, USA

Received 24 February 1986

Abstract. Using the ARGUS detector at the e^+e^- storage ring DORIS II at DESY, we have studied the distribution of various topological quantities on the $\Upsilon(1S)$ resonance and in the nearby continuum. With the help of the second Fox-Wolfram moment we determine the two-jet contribution to direct $\Upsilon(1S)$ decays to be less than 5.3% with 95% confidence.

---

[1] Supported by the Bundesministerium für Forschung und Technologie, FRG

[2] McGill University, Montreal, Canada

[3] Carleton University, Ottawa, Canada

[4] York University, Downsview, Canada

[5] University of Toronto, Toronto, Canada

[6] Supported by the Natural Sciences and Engineering Research Council, Canada

[7] Supported by the U.S. National Science Foundation and a University of Kansas Faculty Improvement award

[8] Supported in part by the Internationales Büro KfA, Jülich and DESY, Hamburg, FRG

[9] Supported by the Swedish Research Council, Sweden

[10] Now at the University of Stockholm, Sweden

[11] Supported by the U.S. Department of Energy, under contract DE-A809-80ER10690

Quantum chromodynamics predicts that the $\Upsilon(1S)$ resonance decays predominantly into three gluons [1]. This has been confirmed earlier by comparing the topology of $\Upsilon(1S)$ decays to that of events in the nearby continuum [2]. There exist, however, alternative models which predict a sizeable branching fraction of the $\Upsilon(1S)$ into two light quarks leading to two jets. The 'mixed model' of Donnachie and Landshoff [3] explains the observed topology of direct $\Upsilon(1S)$ decays by mixing $q\bar{q}$ decays with decay modes of isotropic structure, estimating a two-jet contribution of about 50%. More recently, a supersymmetric model was proposed by Shifman and Voloshin [4] in order to explain an observed narrow peak in the $\Upsilon(1S)$ inclusive gamma spectrum at $E_\gamma = 1.1$ GeV [5]. In this model, the exchange of a squark between b and $\bar{b}$ in the $\Upsilon(1S)$ would lead approximately to a 25% contribution of two-jet events in direct $\Upsilon(1S)$ decays.

A direct observation of three jets in $\Upsilon(1S)$ decays is not possible, since the low energies of the gluons lead to wide and overlapping jets. But with good statistics and the use of adequate topological observables one should be able to draw more precise conclusions about the two and three jet composition in $\Upsilon(1S)$ decays than those obtained so far.

We report here on a new high statistics investigation of event topologies on the $\Upsilon(1S)$ resonance and in the nearby continuum. The results have been obtained from data collected with the ARGUS detector at the DORIS II electron positron storage ring during 1983. The detector and its trigger are described in [6]. The data used in this analysis comprise 2.18/pb in the continuum at 9.98 GeV cms energy and 3.07/pb on the $\Upsilon(1S)$ resonance.

Multihadron events are selected by requiring at least 6 charged particles originating from the interaction region and a total energy deposition of more than 1.7 GeV in the shower counters. Two additional event cuts are applied: First, we require less than 2 charged particles with momentum greater than 2.5 GeV/c and shower energy greater than 2.0 GeV, in order to reduce the background from radiative Bhabha events. Second, we require a missing momentum less than 3.0 GeV/c, in order to eliminate asymmetrical or wrongly reconstructed events. The missing momentum is evaluated by forming the vector sum of all observed charged particles and all neutrals with an energy deposited in the shower counters of greater than 100 MeV. After these cuts we are left with 5,175 events in the continuum and 28,259 on the $\Upsilon(1S)$ resonance.

For each accepted event, we determine the topological quantities sphericity, S [7], thrust, T [8], and the second Fox-Wolfram moment, H_2 [9], which is defined as

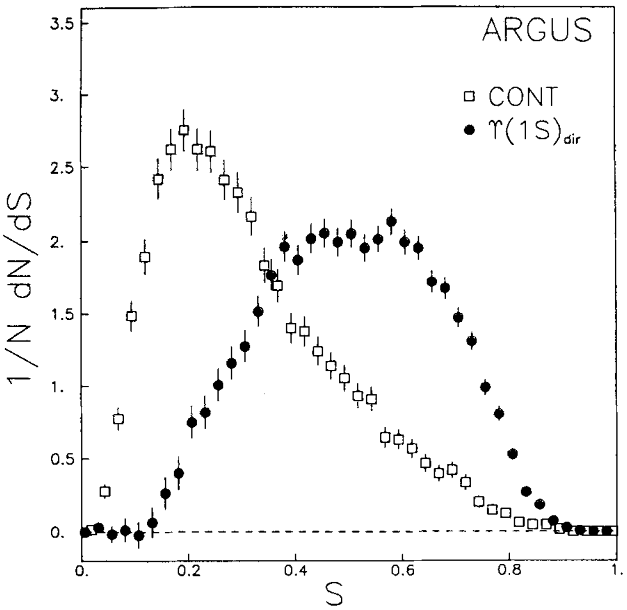

Fig. 1. Sphericity distributions (from charged and neutral particles) of direct $\Upsilon(1S)$ decays and continuum events at 9.98 GeV CMS-energy

$$H_2 = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} \{|p_i| \cdot |p_j| \cdot (3\cos^2\alpha_{ij} - 1)\}}{2\left(\sum_{k=1}^{N} |p_k|\right)^2}. \tag{1}$$

where the sums run over all particles in the event and α_{ij} is the angle between the two particles, i.e. zero for $i=j$.

The distributions for the continuum events and for direct $\Upsilon(1S)$ decays are shown in Figs. 1, 2, and 3. The distributions differ only slightly if we use charged particles alone or charged particles and photons in the evaluation of S, T, and H_2. The distributions shown are those for charged and neutral particles.

The data for direct $\Upsilon(1S)$ decays (N_{dir}) are obtained from the data at the resonance energy (N_{on}) and the data in the nearby continuum (N_{off}) by the following subtraction:

$$(1-r) \cdot \frac{dN_{\text{dir}}}{N_{\text{dir}}} = \frac{dN_{\text{on}}}{N_{\text{on}}} - r \cdot \frac{dN_{\text{off}}}{N_{\text{off}}} \tag{2}$$

with

$$r = \frac{N_{\text{off}} \cdot L_{\text{on}} \cdot s_{\text{off}}}{N_{\text{on}} \cdot L_{\text{off}} \cdot s_{\text{on}}} \cdot \left(1 + \frac{\sigma(\Upsilon \to \mu\mu)}{\sigma(\mu\mu, \text{off})}\right). \tag{3}$$

L_{on} (L_{off}) and s_{on} (s_{off}) are the integrated luminosities and squared centre-of-mass energies on and off resonance respectively. The correction $\sigma(\Upsilon \to \mu\mu)/\sigma(ee \to \mu\mu,$

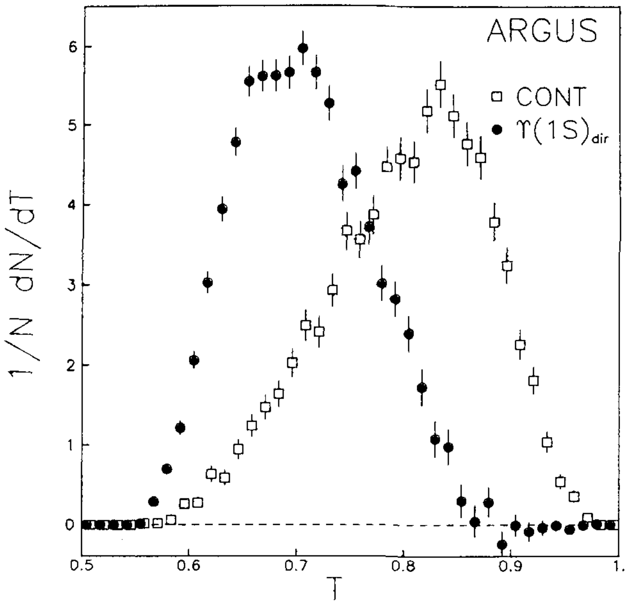

Fig. 2. Thrust distributions (from charged and neutral particles) of direct $\Upsilon(1S)$ decays and continuum events at 9.98 GeV CMS-energy

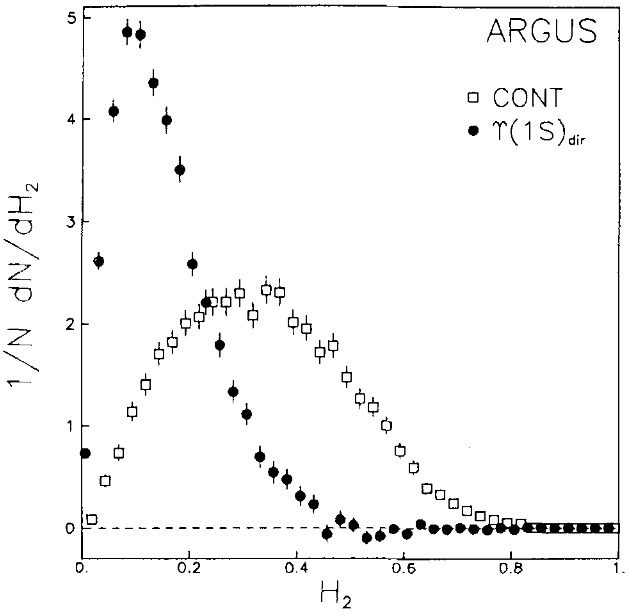

Fig. 3. Distributions of the second Fox-Wolfram moment (from charged and neutral particles) of direct $\Upsilon(1S)$ decays and continuum events at 9.98 GeV CMS-energy

off resonance) takes care of hadronic $\Upsilon(1S)$ decays through a virtual photon (vacuum polarisation). Using $\sigma(\Upsilon\to\mu\mu)=(0.28\pm0.03)$ nb, calculated from the visible hadronic cross section, the total hadronic acceptance, the fraction of τ pairs which simulate hadronic events and the muon pair branching ratio, and $\sigma(\mu\mu$, off resonance$)=0.872$ nb, we get $\sigma(\Upsilon\to\mu\mu)/\sigma(ee\to\mu\mu$, off$)=0.32\pm0.04$ and $r=0.375\pm0.014$. The direct distribution so defined contains no contribution from the continuum at the resonance energy or from the electromagnetic decay of the $\Upsilon(1S)$.

The distributions show marked differences between continuum events and direct $\Upsilon(1S)$ decays as reported previously [2]. One sees that H_2 allows the best discrimination of two-jet events. In a wide region above $H_2=0.45$, there are almost no events from direct $\Upsilon(1S)$ decays. Therefore it is possible to give an upper limit for additional $q\bar{q}$ contributions on the $\Upsilon(1S)$, by investigating the residual distribution, obtained by subtracting a variable amount of two-jet data from the resonance data:

$$(1-r')\cdot\frac{dN_{\text{res}}}{N_{\text{res}}}=\frac{dN_{\text{on}}}{N_{\text{on}}}-r'\cdot\frac{dN_{\text{off}}}{N_{\text{off}}}. \tag{4}$$

It is not necessary to assume any detail about the shape of the residual distribution; it could be any mixture of three gluons and an unknown mechanism. The only restriction placed on the following analysis is that every bin in $dN_{\text{res}}/N_{\text{res}}$ has a positive expectation value. A negative bin content can only be the result of a statistical fluctuation. Instead of performing a statistical analysis on all 40 bins of the dN/dH_2 distribution, we divide the distribution into only two bins: one below and one above $H_2=0.45$. In the upper bin, the observed fractions are $\Delta N_{\text{on}}/N_{\text{on}}=0.0704\pm0.0016$ and $\Delta N_{\text{off}}/N_{\text{off}}=0.193\pm0.006$. Using (4) and the positivity condition $\Delta N_{\text{res}}/N_{\text{res}}\geqq 0$, we derive

$$r'\leqq 0.365\pm0.014.$$

i.e. at most $(36.5\pm1.4)\%$ of all observed events at the resonance energy are two-jet events. Subtracting the expected fraction r of continuum events and electromagnetic resonance decays, we obtain

$$r'-r\leqq -0.010\pm0.020$$
$$<0.034 \text{ with } 95\% \text{ confidence,}$$

i.e. at most 3.4% of all observed events at the resonance energy are two-jet decays of the $\Upsilon(1S)$ in excess of electromagnetic decays. A likelihood analysis leads to the same result. The limit can be converted to an upper limit for the $\Upsilon(1S)$ branching ratio:

$$\text{BR}(\Upsilon(1S)\to 2\,\text{Jets, NE})<$$
$$\eta\cdot 0.034/(1-N_{\text{off}}L_{\text{on}}s_{\text{off}}/N_{\text{on}}L_{\text{off}}s_{\text{on}})=0.053.$$

where η, the acceptance ratio of resonance and continuum events with six or more charged particles, is estimated to be 1.12 by a Monte Carlo calculation.

We find that less than 5.3% of all $\Upsilon(1S)$ decays are non-electromagnetic (NE) two-jet events of the topology as observed in e^+e^- annihilation at $\sqrt{s} = 10\,\mathrm{GeV}$.

In conclusion, we see no evidence for $\Upsilon(1S)$ decays into two jets, in excess of those expected from the electromagnetic decay $\Upsilon(1S) \to \gamma \to q\bar{q}$. The upper limit for this branching ratio is 5.3% with 95% confidence. This limit is inconsistent with the Donnachie-Landshoff 'mixed model' and the Shifman-Voloshin model with a squark-antisquark component in the $\Upsilon(1S)$ meson.

Acknowledgements. It is a pleasure to thank E. Michel, W. Reinsch, Mrs. U. Djunda and Mrs. E. Konrad for their competent technical help in running the experiment and processing the data. We thank Dr. H. Nesemann and his group for the good operation of the storage ring. The visiting groups wish to thank the DESY directorate for the support and kind hospitality extended to them.

References

1. T. Appelquist, H.D. Politzer: Phys. Rev. Lett. **34**, 43 (1975); K. Koller, H. Krasemann, T.F. Walsh: Z. Phys. C – Particles and Fields **1**, 71 (1979)
2. DASP-2 Coll. W. Schmidt-Parzefall: Proc. of the XIX Int. Conf. in HEP, p. 260.Tokyo 1978; PLUTO Coll. Ch. Berger et al.: Phys. Lett. **82B**, 449 (1979); PLUTO Coll. Ch. Berger et al.: Z. Phys. C – Particles and Fields **8**, 101 (1981); DHHM Coll. F.H. Heimlich et al.: Phys. Lett. **86B**, 399 (1979); LENA Coll. B. Niczyporuk et al.: Z. Phys. C – Particles and Fields **9**, 1 (1981); CLEO Coll. D. Andrews et al.: CLNS 81/513; DASP-2 Results R. Waldi: Ph. D. Thesis, IHEP-HD/83-1
3. A. Donnachie, P.V. Landshoff: Z. Phys. C – Particles and Fields **4**, 231 (1980)
4. M.A. Shifman, M.B. Voloshin: '$\zeta(8.3)$ as a Bound State of Coloured Scalars', preprint ITEP-156 (1984)
5. Crystal-Ball Coll.: DESY 84/064, SLAC-PUB-3380
6. H. Albrecht et al.: Phys. Lett. **134B**, 137 (1984)
7. J.D. Bjorken, S.D. Brodsky: Phys. Rev. **D1**, 1416 (1970)
8. E. Farhi: Phys. Rev. Lett. **39**, 1587 (1977)
9. G.C. Fox, S. Wolfram: Phys. Rev. Lett. **41**, 1581 (1978)