Di-lepton Width of Upsilon(1S, 2S, 3S)

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Note for Paper Committee

The $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$ di-lepton widths (Γ_{ee}) are being calculated on the lattice by Christine Davies's group at the University of Glasgow, likely to be presented at HEP2005 Europhysics. (That's why I'm aiming for the same conference.) My goal is to provide a precise experimental measurement for comparison. Currently, the experimental precisions on Γ_{ee} are 2.2% (1S), 4.2% (2S), and 9.4% (3S): the expected theoretical accuracy is 2–5%. My precisions are likely to be about 2% for each resonance, so my measurements will confirm or refute lattice predictions on the $\Upsilon(2S)$ and $\Upsilon(3S)$. In this paper, you will find most of the argument for that precision. (A checklist of what has been done and what will be done by the time of the conference will follow.)

The experimental method is to fit lineshape scans for a total Υ cross-section (integrated over beam energy). From this Γ_{ee} can be derived:

$$\Gamma_{ee} = \frac{{M_\Upsilon}^2}{6\pi^2} \int \sigma(e^+e^- \to \Upsilon)\, dE. \tag{1}$$

(See the big PDG, page 837 (orange 2004), or Peskin and Schroeder, page 151.) Unlike most partial width measurements, the coupling of Υ to e^+e^- which is used is in the production cross-section, not the decay. The total cross-section will be determined by counting all Υ decays except for $\Upsilon \to e^+e^-$, $\mu^+\mu^-$, and cascades that end with a lower Υ resonance decaying to e^+e^- or $\mu^+\mu^-$, and then adding these back in using their known branching fractions. (The easiest anti-bhabha cut excludes anything with a high-momentum track, such as these signal modes.) It is customary to quote the total *hadronic* cross-section, in which $\Upsilon \to e^+e^-$, $\mu^+\mu^-$, and $\tau^+\tau^-$ are all left out, and only the missing cascades are added back in. This is because $\Gamma_{ee}\Gamma_{\mathrm{had}}/\Gamma_{\mathrm{tot}}$ can be quoted with higher precision and can avoid the assumption of lepton universality. I will do both.

Seeing that my ultimate goal is to have accurate fits, my goal for this paper is to precisely measure the hadronic cross-section of *every* run in the Υ energy region. This means that I need to know the number of Υs very well (but not the number of continuum events; I will be effectively subtracting them off with the lineshape fits), the $e^+e^- \to \gamma\gamma$ ("gamgam") luminosity, and how these two might be affected by backgrounds and instrumental glitches that can have a different dependence than integrated luminosity.

In this paper, I have completed arguments for the following:

- I know the Υ hadronic efficiency very well: $98.7 \pm 1.1\%$, $96.7 \pm 1.3\%$, and $97.0 \pm 1.3\%$ for the three resonances.

- I've searched for (and sometimes found) pathological runs by several general criteria, and can guarantee that the remaining runs are free of these issues.

- With my current set of gamgam cuts, there are no luminosity trigger issues. I can't think of anything else that would vary run-by-run.

While you read this (and we have meetings, and you ask me questions about it, and all that), I will continue to study the following issues:

- Fitting lineshape scans with Karl's fit function (includes Breit-Wigner $\otimes$ radiative corrections $\otimes$ beam energy spread Gaussian, where $\otimes$ is a convolution, with continuum interference in the Breit-Wigner). I will vary all the lineshape distortions by their uncertainties and get more systematic errors for Γ_{ee}. (Yes, I did this before, but with new hadron cuts and gamgam cuts, I want to be sure that the results don't change.) Also, I want to check the beam energy calibration by artificially inserting miscalibrations, to see how much variation in Γ_{ee} is possible before the fit χ^2 becomes unbelievable. I've never done this with real data or a real fit function.

- Translating gamgam counts into a luminosity measurement. This will set the overall scale for Γ_{ee} as a multiplicative factor that I can apply after all fitting. Note that this doesn't need to be a gamgam luminosity measurement (in which I'd have to be sure I understand conversion probability and the effect of individual CC crystals biasing shower θ measurements). I can simply compare my number of gamgams to a bhabha/mupair luminosity measurement (in which track-finding efficiency becomes the major issue).

Nothing in these last two studies will change what has been established in this paper.