Report of the Study Group for the Measurement of the Total Cross-Section for $e^+e^- \rightarrow$ Hadrons.

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Abstract

A discussion of the critical factors relevant to an accurate measurement of the total cross section for $e^+e^- \rightarrow \gamma^* \rightarrow$ hadrons is presented. Three quite different techniques for this measurement are introduced, and the impact of the non-annihilation process $e^+e^- \rightarrow e^+e^- +$ hadrons is calculated as a background contribution. There does not appear to be any fundamental obstacle to the achievement of an accuracy on the order of ~2%.

The one-photon annihilation reaction, $e^+e^- \rightarrow \gamma^* \rightarrow$ hadrons, is one of the most fundamental processes in the physics of colliding e^+e^- beams. The very surprising results presently available about this reaction from the CEA and SPEAR I not only indicate the naivete of existing notions about the dynamics of this process, but also suggest the possibility of far more spectacular deviations from our original expectations at PEP energies. This would be the situation if the total cross section were to remain constant around 20 nanobarns, the apparent trend up to energies of $S = 4E^2 \simeq 25\ \mathrm{GeV}^2$. In that case, the value of R, the ratio of the total cross-section for one-photon annihilation into hadrons to the total cross-section for one-photon annihilation into muon pairs, would exceed 200. A less violent alternative would be to have R level off around

8, a value compatible with extrapolations of the invariant differential cross-sections measured at SPEAR I. It is also conceivable that R will approach a still smaller asymptotic value, indicating the existence of some resonant structure at present energies. It seems clear that accurate measurements of this cross-section over the SPEAR-PEP energy range should not only provide some of the most exciting experimental results in e^+e^- physics, but should also be an essential element in the unraveling of the dynamics involved in this new q^2 regime.

The experimental problem requires the successful understanding of five basic factors: 1) Normalization, i.e. measurement of the luminosity; 2) trigger - efficiency and biases; 3) backgrounds, such as beam-gas collisions, cosmic ray showers, and 2γ processes-the non-annihilation reactions; 4) detection, identification and reconstruction efficiences; 5) lepton identification.

The committee members generally felt that the Bhabha process provides the best measurement of the luminosity, from both the systematic as well as statistical perspective. No particular effort was invested in a separate detailed design for this monitoring purpose.

A problem more challenging than the luminosity measurement is the construction of triggers which do not systematically reject or introduce losses for particular final state topologies, for example, all-neutrals, or extremely low-energy particles, or low multiplicity. In this connection the results from the present magnetic detector at SPEAR I which covers only about two-thirds of 4π and requires two charged particles above 200 MeV/c for a trigger depend on model-dependent corrections, with attendant systematic uncertainties.

Beam-gas collisions are expected to contribute copious low-energy debris of potentially serious nuisance value for triggers which do not require a large deposited energy. Neither these events nor cosmic ray showers are likely to survive the analysis stage. The 2γ process is expected to be dominated by small invariant masses for the final-state hadron system. Shen has studied the 2γ reaction from the standpoint of background for the 1γ annihilation and concluded that the contribution should be manageably small if the energy of the hadron system is measured. (See sub-report by Shen).

Lepton identification is important for the tagging of 2γ events, muon-pairs and Bhabha events, all of which must be filtered out of the data.

Three complementary and quite different approaches were proposed and evaluated. A non-magnetic modular detector has been studied by Lynch and Schwitters. Weighing in at about just 10 tons, their technique is the simplest one thought capable of reaching the a reasonable accuracy. A massive calorimeter covering essentially 4π has been proposed and studied by Feldman and Hitlin, and should be relatively free from background and trigger biases. Finally, a new technique for the detection and measurement of charged particles over >99% of 4π has been proposed by Nygren, which should be capable of nearly 100% reconstruction efficiency even for very high multiplicity events. Of the three techniques, only calorimetry provides inherent sensitivity to all-neutral final states, which implies a correction of possibly 2 to 5% for the other techniques. All of these studies are described in the subreports.

Finally, it should be emphasized that the rates, approximately 50 R per hour, are sufficiently high even in the more pessimistic range for R, so that statistically adequate results may be obtained in a few days running. It is therefore appropriate to consider simultaneous scheduling of more than one experiment for this basic measurement so that the complementary techniques can provide cross-checks on the systematics.