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EXCITED ELECTRON SEARCHES IN RADIATIVE WIDE ANGLE BHABHA EVENTS*

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Status of wide angle Bhabha Monte Carlo generators is reviewed, referring to experimental searches for excited electrons in e^+e^- collisions at LEP2.

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1. Introduction

The process $e^+e^- \to e^+e^-$ (Bhabha scattering), is one of the major processes in e^+e^- collisions. Reliable calculation of cross-section and kinematical distributions is important to understand the efficiency for measuring the e^+e^- final state itself, and also for measurements of (or searches for) other processes, in which case the Bhabha event is a background. Bhabha scattering is also an essential tool for the luminosity measurements. For the measurements of Z° lineshape at LEP, the statistical error is less than 0.1 % for counting the hadronic events. In order to fully exploit this potential precision, an accuracy of better than 0.1 % is desired for luminosity determination. To this end, there have been impressive progress on the accurate calculation of the small angle Bhabha scattering, and implemented in Monte Carlo generators and semi-analytical programs. Currently the theory error in luminosity measurement is estimated to be 0.11%, and it is foreseen that an accuracy of 0.04% may eventually be achieved [1].

Monte Carlo generators for wide (large) angle Bhabha scattering are less under control. There are number of programs currently available: a classical $\mathcal{O}(\alpha)$ program BABAMC [2], more modern programs are BHAGEN95, BHAGENE3, BHWIDE, SABSPV, UNIBAB [3]. None of them is

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regarded as a 'standard' program. This may be compared to the case of μ and τ pair generator, where KORALZ [4] is the 'standard'. According to the studies in [1], these modern generators agree with each other and with semi-analytical programs at a level of 0.5-1.0% at the Z° peak and 3-5% at the LEP2 [1] energies for cross-sections with simple kinematical cuts. These are in practice not particularly bad figures for the physics at the Z° energies. The main physics interest for large angle Bhabha event at $\sqrt{s} \approx M_Z$ is the measurements of Z° decays into e^+e^- and determination of parameters like Γ_{ee} and $A_{\rm FB}(e^+e^-)$. Bhabha Monte Carlo is used to evaluate the experimental efficiency. If the scattering angle is restricted to large angle (typically $|\cos\theta| < 0.7$) the e^+e^- production is largely dominated by $Z^\circ \to e^+e^-$. Efficiency for selecting such electron pairs is rather high, nearly 100% for the sample of e^+e^- within the imposed kinematical acceptance. Therefore, quality of the Bhabha Monte Carlo generator is in general not a dominant factor to determine the overall accuracy of the measurements[2].

However, when Bhabha event is considered as a background source for other processes, different criteria must be considered. Behaviour in the corners of phase space will become important. This would be the case for new particle searches at LEP2. As a relevant example of such cases, we consider in the following, search for excited electrons at LEP2.

2. Excited leptons

If the known leptons are composite particles and are bond states of new elementary particles, excited leptons, ℓ^*, should exist. Excited leptons have been searched for at e^+e^- colliders [5,6] and at the HERA ep collider.

Excited leptons can be pair produced in e^+e^- collisions, like ordinary leptons, through an exchange of γ or Z°. In this mode, search can be made for ℓ^* with its mass less than $\sqrt{s}/2$. A charged ℓ^* is expected to decay into $\ell\gamma$ with a 100% branching ratio when the mass of ℓ^* is less than M_W. If the mass is larger the decays modes $\ell^* \to W\nu$ and $Z^\circ\ell$ become important, and the branching ratio to $\ell\gamma$ depends on the mass of ℓ^*. The single ℓ^* production $e^+e^- \to \ell^*\ell$, and also the decay of ℓ^*, are governed by $\ell^*\ell V$ coupling, and described by a ratio f/Λ of unknown parameter f and compositeness scale Λ. The ℓ^* of its mass close to $\sqrt{s}$ can be searched in the single production mode, but the cross-section is a function of the mass and the unknown parameter f/Λ.

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[1] LEP has recently been upgraded to provide centre-of-mass energies well above the Z° and above the production threshold of W pair. This high energy version of LEP is commonly referred to as LEP2.

[2] This simply means it is less sensitive compared to the luminosity measurement. High quality generators are always desirable for high precision Z° measurements.

The main signatures of ℓ^* production are $\ell^*\ell^* \to \ell\ell\gamma\gamma$ (pair production) or $\ell^*\ell \to \ell\ell\gamma$ (single production). In case of e^* (excited electron) production, single production from t-channel γ exchange is also possible. In this case, the electron in the final state tends to be close to the beam direction, which leads to a final state where only $e\gamma$ from the e^* decay is visible ($e\gamma$ topology). At the LEP e^+e^- collider, direct searches have been carried out at $\sqrt{s} \approx M_Z$ and at higher energies ($\sqrt{s}$ =130-140 and 161 GeV) [5, 6], and ruled out excited leptons with masses less than about 80 GeV, and for ℓ^* with larger masses, lower limits on f/Λ have been set at $\mathcal{O}(1\ \mathrm{TeV}^{-1})$. Most stringent limit is usually on the excited electrons, due to its large production cross-section.

3. e^* searches and radiative Bhabha

Main background for the expected e^* signals is due to radiative Bhabha events. In the analyses of the OPAL experiment at $\sqrt{s}$=130–140 GeV and 161 GeV [5], the Bhabha background was evaluated using two Monte Carlo generators. Program BHWIDE [3, 7] was used to generate events with both e^+ and e^- at large angle ($12.5° < \theta < 167.5°$), to simulate $e^+e^-\gamma\gamma$ and $e^+e^-\gamma$ topologies. BHWIDE is a new generation of Monte Carlo program based on $\mathcal{O}(\alpha)$ YFS exponentiation, and generates multiple photons in the final state. Remaining phase space was complimented by using TEEGG generator [8], which generated events with one electron restricted in small angle region, and the other electron or photons in large angle. Such a topology is not calculated by ordinary Bhabha generators, since this involves one electron of the scattering angle $\theta = 0°$. This was necessary to simulate the $e\gamma$ topology. Combination of these two generators covers the whole phase space except for small corners where both of the electrons in small angle region, in which the cross-section is huge and is only relevant for luminosity measurements.

Comparisons of data and Monte Carlo distributions are shown in figure 1 for the energy of electrons and photons in the $e^+e^-\gamma$ topology. Here the high energy region is dominated by radiative Bhabha events generated by BHWIDE.

Distributions of e-γ invariant masses are plotted in figure 2 for the sample at $\sqrt{s}$ = 161 GeV. Though the statistics of the data sample is limited, we see that the observed energy distributions are described by Bhabha Monte Carlos reasonably well.

In case of $e^+e^-\gamma\gamma$ topology there are very few events observed, which are compatible with the expectation of radiative Bhabha Monte Carlos. More detailed comparisons of data and Monte Carlo at LEP2 are not yet available.

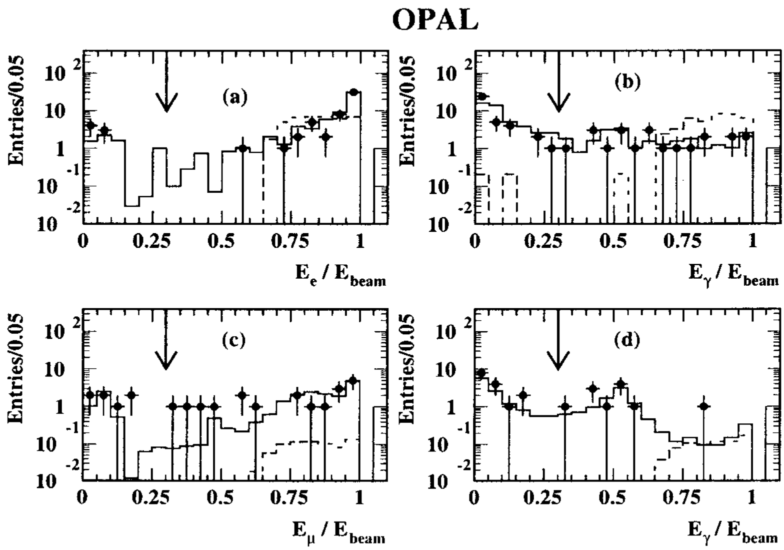

Fig. 1. Energy distribution of electron (a) and photon (b) in $e^+e^-\gamma$ events at $\sqrt{s}$=130–140 GeV. Solid histograms are Standard Model Monte Carlos and points are data. Dashed histograms indicate predictions for single production of e^* of mass 110 GeV. For comparison, similar distributions for $\mu^+\mu^-\gamma$ are shown in (c) and (d).

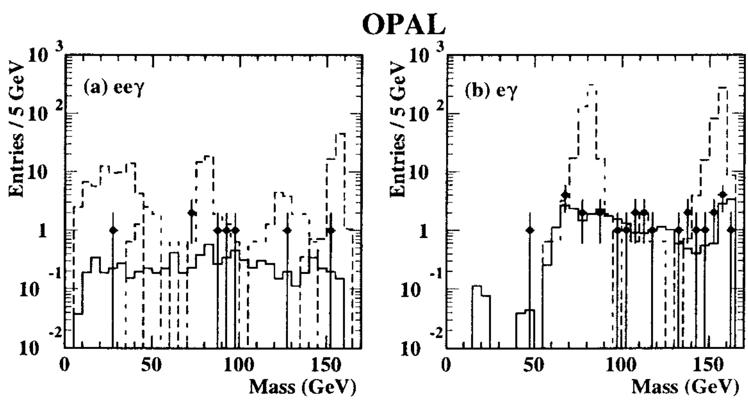

Fig. 2. $e-\gamma$ mass distribution in the search for single production of e^*. (a) is for $e^+e^-\gamma$ topology and (b) for $e\gamma$ topology. Solid histograms are Standard Model Monte Carlos and points are data. Dashed histograms indicate predictions for e^* production with masses of 80 and 155 GeV, respectively.

4. Outlook

Comparisons at LEP2 of data and Monte Carlo programs for radiative Bhabha event showed reasonable agreements, though with limited statistics. With coming larger data sample, more precise test of the Monte Carlo generators will become possible. It is important to understand the quality of the generators for large angle Bhabha events, which is a (background) process of large cross-section at LEP2, where some new particle/phenomena might eventually show up. Systematic comparisons among different programs and with the existing large data sample at Z° should also be useful (was not included in the presentation at this workshop).

REFERENCES

[1] Physics at LEP 2, editors G. Altarelli, T. Sjöstrand and F. Zwirner, CERN 96-01, vol. 2, p.229.

[2] M. Böhm, A. Denner, W. Hollik, *Nucl. Phys.* **B304**, 687 (1988); F.A. Berends, R. Kleiss, W. Hollik, *Nucl. Phys.* **B304**, 712 (1988).

[3] Brief summaries are in Physics at LEP 2, editors G. Altarelli, T. Sjöstrand and F. Zwirner, CERN 96-01, vol. 2, p.274.

[4] S. Jadach, B.F.L. Ward, Z. Was, *Comput. Phys. Commun.* **79**, 503 (1994).

[5] OPAL Collaboration, G. Alexander *et al.*, CERN-96/094 to be published in *Phys. Lett.* **B**; OPAL Collaboration, K. Ackerstaff *et al.*, CERN-96/138 (to be published in *Phys. Lett.* **B**).

[6] L3 Collaboration, M. Acciarri *et al.*, *Phys. Lett.* **B370**, 211 (1996); DELPHI Collaboration, P. Abreu *et al.*, *Phys. Lett.* **B380**, 480 (1996); ALEPH Collaboration, D. Buskulic *et al.*, *Phys. Lett.* **B385**, 445 (1996).

[7] S. Jadach, W. Placzek, B.F.L. Ward, UTHEP-95-1001, October 1995.

[8] D. Karlen, *Nucl. Phys.* **B289**, 23 (1987).