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SPIN CORRELATIONS IN WW PAIR PRODUCTION AND DECAY* **

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We discuss spin effects for W-pair production and decay at LEP2 and higher energies. As an example we use observables in the $s\bar{s}c\bar{c}$ decay channel: the two-quark/jet invariant-mass distribution and cross section, in the case when the other two may escape detection. We show, the strong interplay of spin correlations and detector cut-offs resulting in narrowly peaked distributions.

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In the summer of 1996 LEP started to collect data in the new centre-of-mass energy zone corresponding to the W-pair production threshold and above. Physics of the W-pair production and decay constitutes exciting topic in itself see *e.g.* [1].

Among important goals of any experiment at highest centre-of-mass energies it is always to search for new, so far undiscovered particles. In such a program, background from the Standard Models, in particular W-pair production and decay, must be carefully calculated, especially if it varies strongly over available phase space.

In the following, we will report results from Ref. [2] where we have used our Monte Carlo program KORALW [3, 4] as well as grc4f [5] to obtain predictions for cross sections within different phase space regions selected with strong cut-offs for $c\bar{c}s\bar{s}$ final state (CC-43 type process). We will look at the invariant-mass distribution $M_{s\bar{s}}$ of $s\bar{s}$-quark/jet pair, in the case where $c\bar{c}$ quarks/jets are escaping detection. We will call a fermion "visible" if its

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transverse momentum is above 10 GeV and $|\cos\theta_{beam}| < 0.96$. Otherwise we call it "escaping detection".

Our motivation for such a choice is the following: *(i)* it can be realized in practice by most detectors, *(ii)* it excludes jet-like activity in the initial state, such as off-mass-shell initial-state photon bremsstrahlung (or initial-state jet activity in the framework of the phenomenology of *pp* colliders). For complete list of input parameters we refer the reader to Ref. [2].

First we will present numerical results from the Monte Carlo simmulation for $M_{s\bar{s}}$ with the complete matrix element. It will be followed with subsequent simplification to explain better the nature of the physical effects.

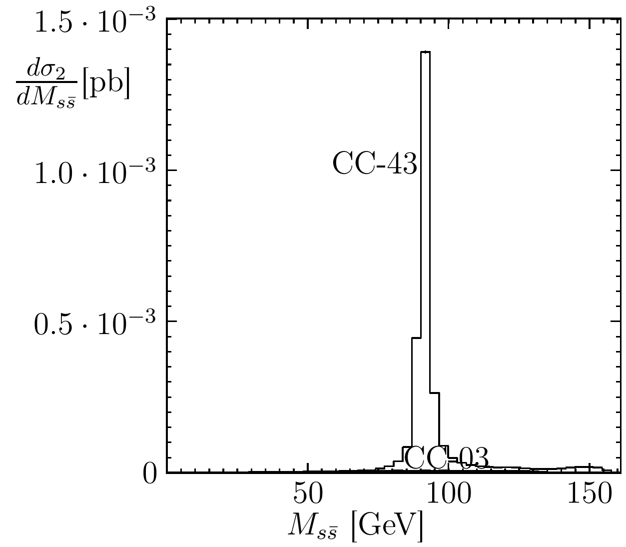

Fig. 1. The $\frac{d\sigma}{dM_{s\bar{s}}}$ differential distribution of the "visible" $s\bar{s}$ jets where $c\bar{c}$ jets escape detection. The centre-of-mass energy is 161 GeV. CC-03 (thick line); CC-43 (thin line).

In Figs 1–3, corresponding respectively to the centre of mass energy of 161, 195 and 350 GeV, thin line corrsponds to such complete Born-level (CC-43) matrix element. Let us point to the spectacular peak in $M_{s\bar{s}}$ distribution, which becomes more and more profound for centre-of-mass energies above the WW threshold. It looks as indeed troublesome background for the new narrow resonances searches. In fact its shape and size is quite similar to the physical peak of the Standard Model Z resonance (selected out from our $s\bar{s}c\bar{c}$ sample).

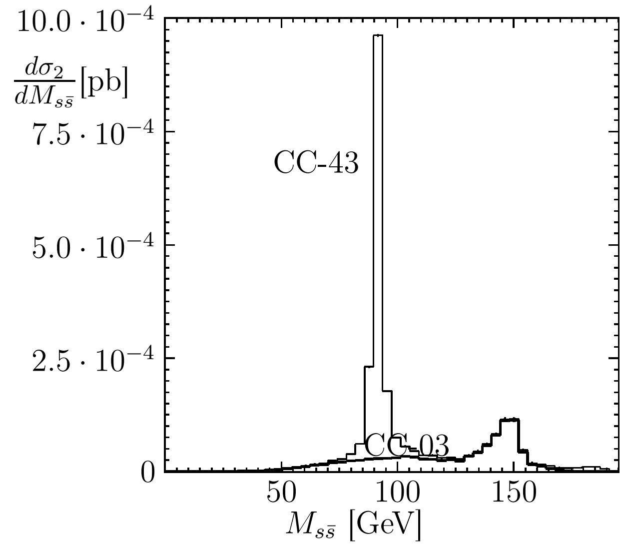

Fig. 2. The $\frac{d\sigma}{dM_{s\bar{s}}}$ differential distribution of the "visible" $s\bar{s}$ jets where $c\bar{c}$ jets escape detection. The centre-of-mass energy is 195 GeV. CC-03 (thick line); CC-43 (thin line).

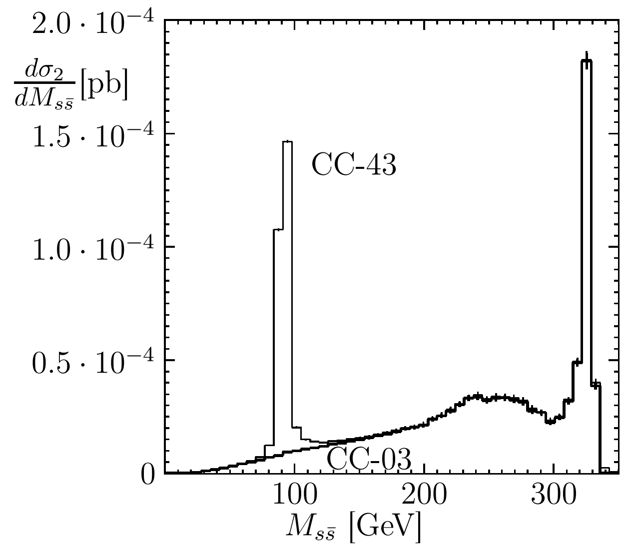

Fig. 3. The $\frac{d\sigma}{dM_{s\bar{s}}}$ differential distribution of the "visible" $s\bar{s}$ jets where $c\bar{c}$ jets escape detection. The centre-of-mass energy is 350 GeV. CC-03 (thick line); CC-43 (thin line).

In the first step of our simplifications, we switch off most of the Born level diagrams for $e^+e^- \to s\bar{s}c\bar{c}$. We will leave only those formed by the intermediate state of W-pair (so called CC-03 diagrams). As we can see the peak of the Z resonance disappeared, but the peak at higher end of the energy spectrum remained intact.

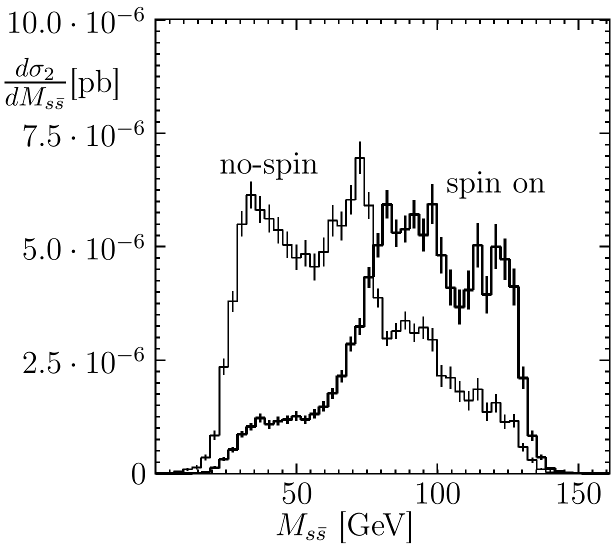

Fig. 4. The $\frac{d\sigma}{dM_{s\bar{s}}}$ differential distribution of the "visible" $s\bar{s}$ jets where $c\bar{c}$ jets escape detection. The centre-of-mass energy is 161 GeV. CC-03 no spin correlation (thin line); CC-03 spin correlations switched on (thick line).

In the second step, we show the importance of spin correlations. To this end in Figs 4–6 (again for CMS energies of 161, 195 and 350 GeV) we confront the same reslults of CC03 calculation (thick line) as from Figs 1–3, with even simpler calculation, where the transverse spin correlations of intermediate W-states (thin line) are neglected. The effect is big, the narrow peak nearly disappears. More precisely it is getting reduced by the factor of four. At lower $M_{s\bar{s}}$ the distribution is incresed substantially.

This exercise proves that any kind of 'on-shell' approximation with simplified spin treatment may lead not only to *quantitative* few or several per cent inaccuracies, but, upon applying cut-offs, to misleading *qualitative* changes in the overall picture. That could lead to the substantial misinterpretation of the background if instead of the full spin treatment, approximation was used.

The cross section for our faked 'object' is of the order of 0.0015 pb for the $c\bar{c}s\bar{s}$ final state alone. This translates to *e.g.* 2 or 3 such events per LEP

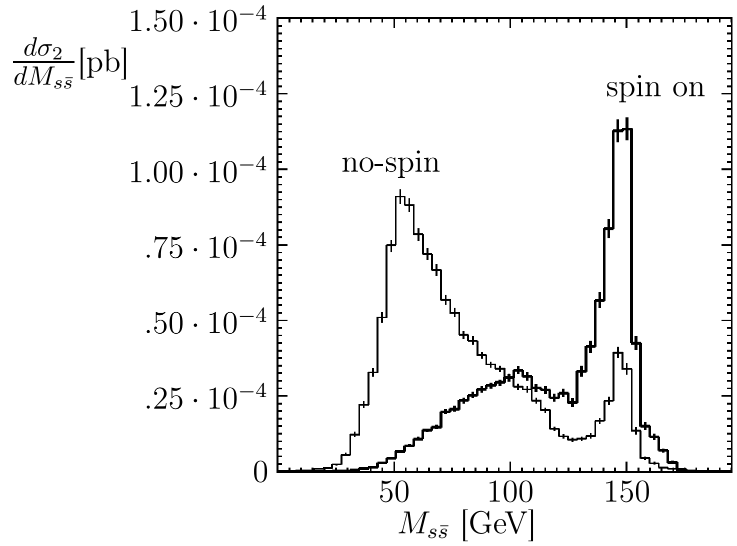

Fig. 5. The $\frac{d\sigma}{dM_{s\bar{s}}}$ differential distribution of the "visible" $s\bar{s}$ jets where $c\bar{c}$ jets escape detection. The centre-of-mass energy is 195 GeV. CC-03 no spin correlation (thin line); CC-03 spin correlations switched on (thick line).

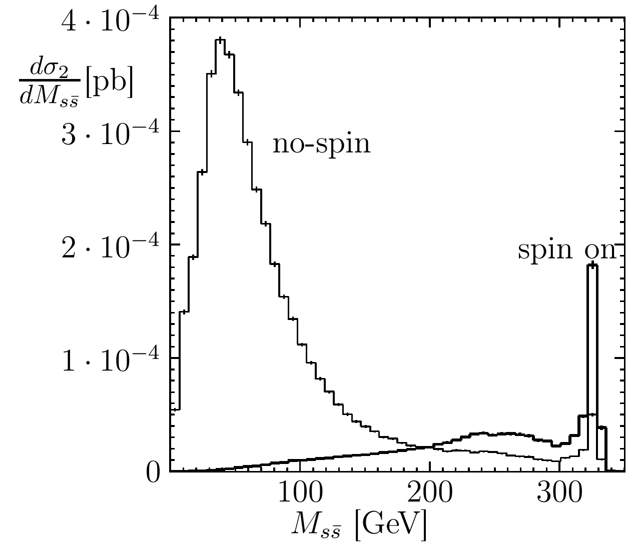

Fig. 6. The $\frac{d\sigma}{dM_{s\bar{s}}}$ differential distribution of the "visible" $s\bar{s}$ jets where $c\bar{c}$ jets escape detection. The centre-of-mass energy is 350 GeV. CC-03 no spin correlation (thin line); CC-03 spin correlations switched on (thick line).

collaboration if all hadronic final states are taken into account. That is the sample specially difficult to estimate the background from the data alone.

The essential in formation of the peak is the veto cut-off on c ($\bar{c}$) quarks transverse momentum. As the consequence it is favorable for c-quarks to have rather small energies and to follow the beam direction. That, together with the constraint of the W mass on $s\bar{c}$ and $\bar{s}c$ pairs forces s and $\bar{s}$ to be back to back. Spin correlation favor such planar configurations also. The four-fermion final state is produced from e^+e^- annihilation. Total angular momentim of the system is thus parallel to the beam direction. This enhances by the factor of four the size of the peak.

We can conclude that in case of processes at centre-of-mass energies higher than W-pair production threshold inclusion of the spin effects may be essential for realistic estimation of background for new particle searches.

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