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Determination of the Higgs boson spin with a linear e^+e^- collider

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Abstract. The energy dependence of the production cross section of a light Higgs boson is studied at threshold and compared to the expectations of several spin assumptions. Cross section measurements at three centre-of-mass energies with an integrated luminosity of 20 fb^{-1} allow the confirmation of the scalar nature of the Higgs Boson.

INTRODUCTION

Spontaneous symmetry breaking in the Standard Model leads to one remnant scalar particle, the Higgs boson [1]. A light Higgs boson is expected to be produced at an e^+e^- collider of a few hundred GeV via the Higgs-strahlung process, $e^+e^- \to$ Z H. However, if a particle produced in association with the Z is detected, the confirmation of its scalar nature will be essential to its identification with the Higgs boson. Here we study the production of a Standard Model Higgs boson with a mass $m_H = 120$ GeV near the kinematic threshold and compare the cross section to predictions for bosons of spin 0, 1 and 2 produced in association with the Z [2].

EXPERIMENTAL CONDITIONS AND DETECTOR SIMULATION

The study is performed for a linear collider operated at a centre-of-mass energies of 215, 222 and 240 GeV. The simulated data statistics corresponds to an integrated luminosity of 20 fb^{-1} at each energy point. The detector used in the simulation follows the proposal presented in the TESLA Technical Design Report [3]. The simulation of the detector is done using SIMDET [4].

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SIGNAL AND BACKGROUND PROCESSES

Events of the signal, $e^+e^- \to Z\,H$, are generated using PYTHIA [5]. Only Z decays into electrons and muons are considered. For the Higgs boson all decay modes are simulated as expected in the Standard Model. The values of the cross section in the Standard Model and the expected numbers of events corresponding to a luminosity of 20 fb^{-1} are given in Table 1 at centre-of-mass energies of 215, 222 and 240 GeV. The following background processes are considered: $e^+e^- \to$

$\sqrt{s}$(GeV)	215	222	240
$\sigma(ZH \to \ell^+\ell^- X)$	7.2	12.6	16.8
events	144	252	336

TABLE 1. The cross sections and numbers of events expected in the Standard Model for the production of a Higgs boson of $m_H = 120$ GeV at centre-of-mass energies of 215, 222 and 240 GeV and a luminosity of 20 fb^{-1}

$(\gamma\gamma) \to e^+e^- f\bar{f}$, $e^+e^- \to q\bar{q}(\gamma)$, $e^+e^- \to W^+W^-$ and $e^+e^- \to ZZ$. Initial state Bremsstrahlung is simulated by PYTHIA. Beamstrahlung is taken into account using the CIRCE program [6].

CROSS SECTION MEASUREMENT

The cross section determination is based on the $e^+e^- \to Z\,H \to \ell^+\ell^- +$ 2-jet final state, where ℓ is an electron or muon. The signature is two isolated energetic electrons or muons and two jets. The identification of electrons and muons and the formation of jets are performed as described in Reference [7]. The selection efficiencies for the processes $e^+e^- \to Z\,H \to e^+e^-$ 2-jet and $e^+e^- \to Z\,H \to \mu^+\mu^-$2-jet are about 50%. Each event is subject of a kinematic fit imposing energy and momentum conservation [8]. The distributions of the two jet invariant mass are shown in Figure 1 for centre-of-mass energies of 215, 222 and 240 GeV. The dijet mass spectra are fitted with the superposition of signal and background distributions. The signal is parametrised with a gaussian and the background is fixed to the Monte Carlo expectation.

RESULTS

The cross sections obtained for the process $e^+e^- \to Z\,H \to \ell^+\ell^- +$2-jet at centre-of-mass energies of 215, 222 and 240 GeV are shown in Figure 2. The results of fits using the predictions from models with s=0, 1 and 2 [2] with the normalisation as free parameter are also shown. The s=0 case is clearly distinguished from the s=1 and 2 cases. The fit with the s=0 prediction has a good χ^2 probability and

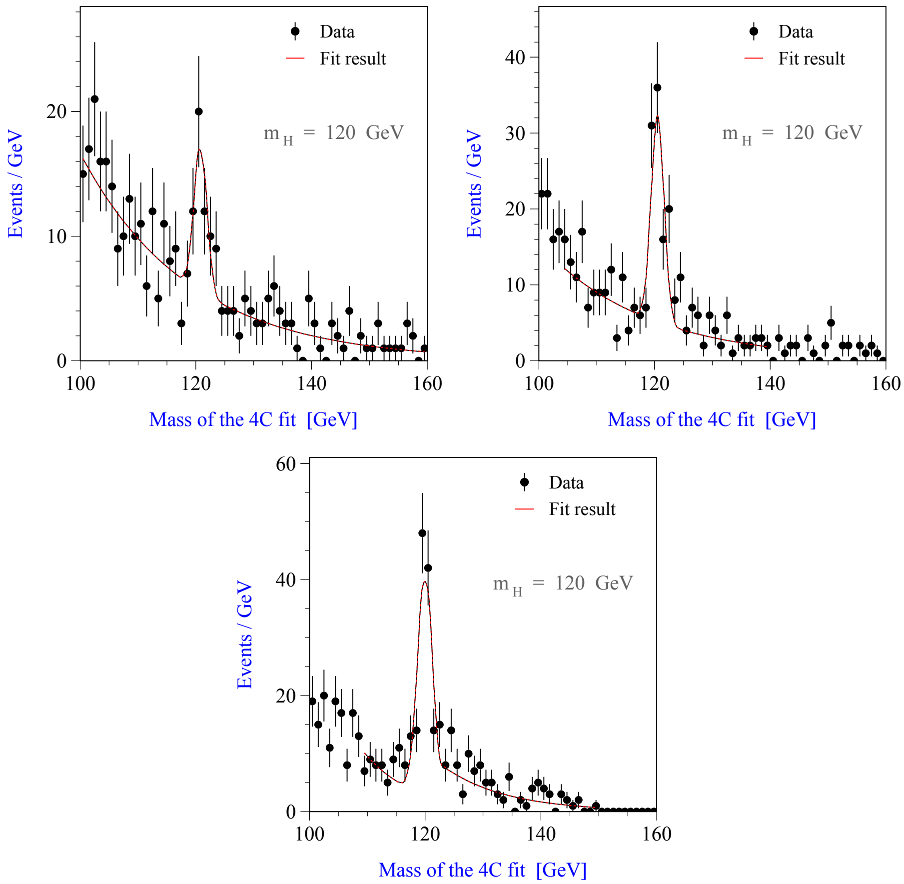

FIGURE 1. The dijet invariant mass from the ZH $\rightarrow \ell^+\ell^-\mathrm{q}\overline{\mathrm{q}}$ final state after a 4C kinematic fit for $\sqrt{s} = 215$ (top left), 222 (top right) and 240 GeV (bottom).

its normalisation factor equals to unity. The other fits have a χ^2 probability of less than 10^{-5}. The study of the Higgs boson production just above the kinematic threshold shows that the measurement of the cross section at three centre-of-mass energy points using a luminosity of 20 fb^{-1} allows confirmation of the scalar nature of the Higgs boson. Bosons with other spins can be disfavoured[2].

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[2] There are particular scenarios for s=1 and 2 [2], which show a threshold behaviour similar in shape to the s=0 one. This can be disentangled using angular information in addition.

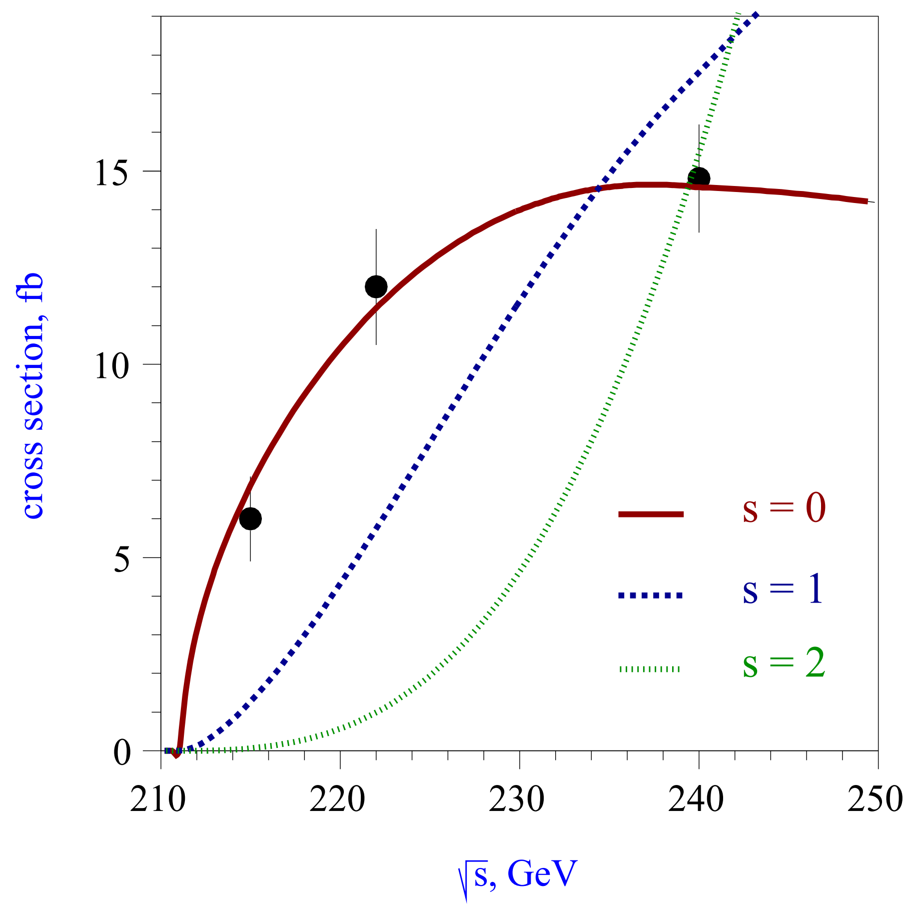

FIGURE 2. The cross sections determined at $\sqrt{s}$ = 215, 222 and 240 GeV (dots) and the predictions for s=0 (full line), s=1 (dashed line) and s=2 (dotted line).

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