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Status of Electroweak Corrections to Top Pair Production *†

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Abstract

We review the status of electroweak radiative corrections to top-pair production at a Linear Collider well above the production threshold. We describe the Fortran package `topfit` and present numerical results at $\sqrt{s} = 500$ GeV, 1 TeV, and 3 TeV.

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1 Introduction

Not too much is known about top quarks, and what is known is not as accurate as desired [1]. At a Linear Collider, top-pair production will be one of the dominant and most interesting processes. Very precise measurements are expected. Therefore, the cross-sections have to be predicted with a precision of few per mil [2, 3]. Two quite different experimental set-ups are of interest. One is the top-pair production threshold region, where one expects to get precise values of mass and width. The other one is continuum production at high energy with the hope to get access to some anomalous behavior, potentially manifested in abnormal couplings and/or new final state signatures. Here, we calculate the electroweak Standard Model expectations with one-loop corrections. Earlier series of studies are [4, 5] and [6, 7], and a recent one is [8, 9]. With our study, detailed comparisons of the diverse results were undertaken for the first time [10, 11]. We used the package `DIANA` [12, 13] for automatic generation of the diagrams and `FORM` [14] for the further symbolic calculations, and for the numerics the Fortran packages `FF` [15] and `LoopTools` [16].

2 The Fortran Package `topfit`

The package `topfit` [17, 18] was written in order to have a tool for the numerical estimation of the electroweak corrections to top-pair production. We wanted also to have some flexibility for an easy comparison with other codes. As a result, the user of our program may switch on and off several options and may adjust input parameters. The list in Table 1 is by far not complete. Of course, the usual standard model parameters in the on-mass-shell scheme (particle masses and $\alpha_{em}(0)$) may be chosen. The numerical input is as in [10]. Three different options may be chosen for the output:

- Differential and integrated cross-sections and asymmetries in the Standard Model
- Cross-sections and asymmetries with photonic corrections only, at fixed Born couplings
- Six weak form factors, with/without running α_{em}

Flag	Description
`IFINAL`	choice of final state particle
`IQED`	inclusion of photonic corrections
`CNINI`	initial state corrections
`CNFIN`	final state corrections
`CNINT`	interference corrections
`IWEAK`	Born or use `LoopTools` or use `FF`
`GAMS`	choice of Z width
`IQEDAA`	running of α_{em}
`IPHOTM`	finite photon mass or dimensional regularisation of the IR divergency
`IDCOST`	top quark angular distribution
`ICOSTI`	integrated cross-section and asymmetry
`IHARD`	inclusion of hard bremsstrahlung
`SPRCUT`	photonic phase space cut

Table 1: A collection of flags of `topfit`; more details may be found in [17].

The latter output might be useful for a Monte Carlo approach to QED and QCD corrections, but also for an estimate of the weak corrections.

3 Numerical Results and Conclusions

For comparisons with the results of other groups, with very satisfactory numerical agreements, we refer to [10, 11]. Of course, one has to bear in mind that these comparisons control not more than what is called 'technical precision'. In Figure 1 we show the order of magnitude of the cross-sections, and in Table 2 purely weak form factors at $\sqrt{s} = 3$ TeV. To define the normalizations of F_3^{11} and F_3^{51}, we mention that $d\sigma \sim Re[(u^2 + t^2 + 2m_t^2 s)|F_1^{11}|^2 + 2m_t(ut - m_t^4)(F_1^{11*}F_3^{11} + F_1^{51*}F_3^{51})] + \ldots$, and $t = s(1 - \beta_t \cos\theta)/2$.

The treatment of the one-loop electroweak corrections to top-pair production is well under control up to $\sqrt{s} = 3$ TeV. Of course, there is much Standard Model physics to be included in addition: higher orders, notably in the photonic part, but also numerically large QCD corrections, and finally also phenomena like top-quark

f.f.	Born	Born + weak corrections
F_1^{11}	–3.4822175 E–09, 0	–2.4672033 E–09, +5.6471323 E–12
F_1^{15}	+2.0992410 E–10, 0	–4.6533609 E–10, –3.4235887 E–10
F_1^{51}	+7.5582979 E–10, 0	+1.4831421 E–10, –2.6754148 E–10
F_1^{55}	–1.8476412 E–09, 0	–1.4913239 E–09, +3.4972393 E–10
$m_tF_3^{11}$	0, 0	+2.9895163 E–12, –6.6708986 E–13
$m_tF_3^{51}$	0, 0	–2.4939160 E–12, +9.1292861 E–13

Table 2: *Weak form factors for $d\sigma/d\cos\theta$ at $\sqrt{s}$=3 TeV, $\cos\theta$=0.7. They yield σ_B=0.0762660014 pb and σ_{weak}=0.012482585 pb, correspondingly. The normalization corresponds to $F^{11,\gamma}_{1,Born} = e^2 Q_e Q_t/s$ (see also [10]); some flags chosen:* `IWEAK` *= 1,* `GAMS` *= –1,* `IQED` *=* `IQEDAA` *= 0.*

decays, other background reactions (of different signatures like $e^+e^- \to tWb, tbl_1l_2$, $6f$), or beamstrahlung.

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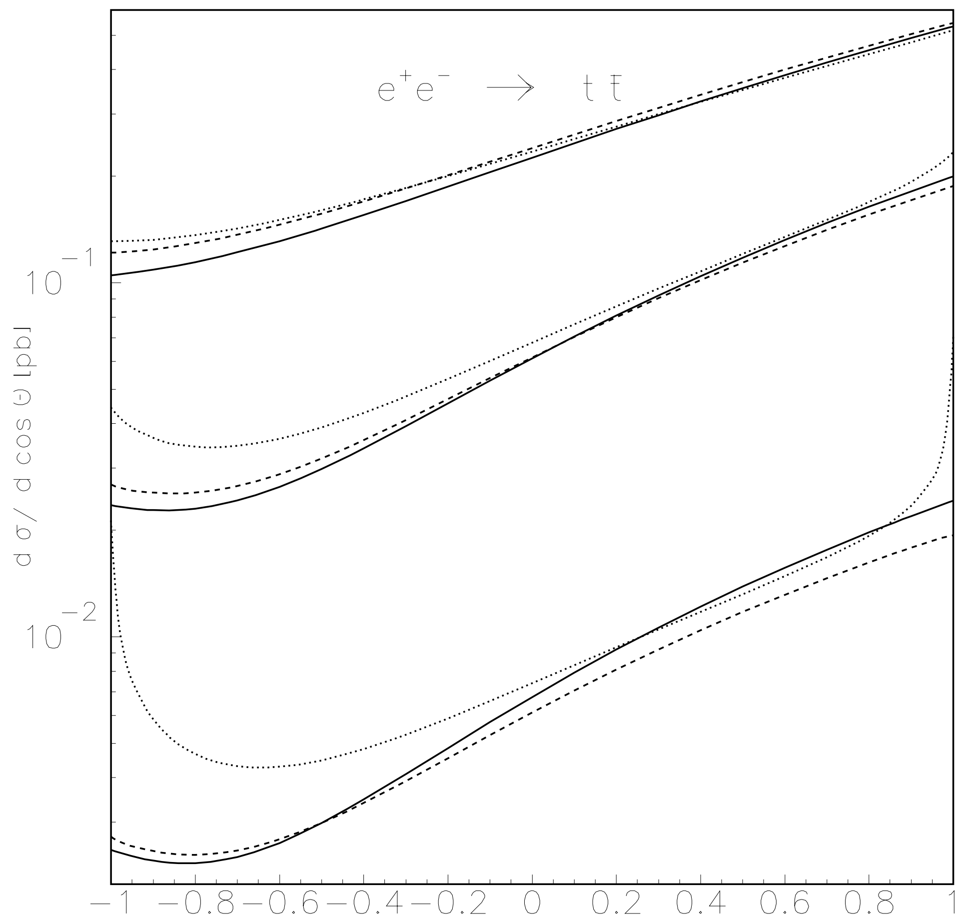

Figure 1: *Differential cross-sections in Born approximation (solid lines), with weak corrections (dashed), and with full electroweak corrections (no cut; dotted). From above:* $\sqrt{s}$ *= 0.5, 1, 3 (in TeV).*