Top EW couplings at LCs

Emi Kou (LAL-Orsay)

based on arXive:1307.8102
by Amjad, Boronat, Frisson, Garcia, Poeschl, Ros, Richard, Rouene, Ruiz Femenia, Vos

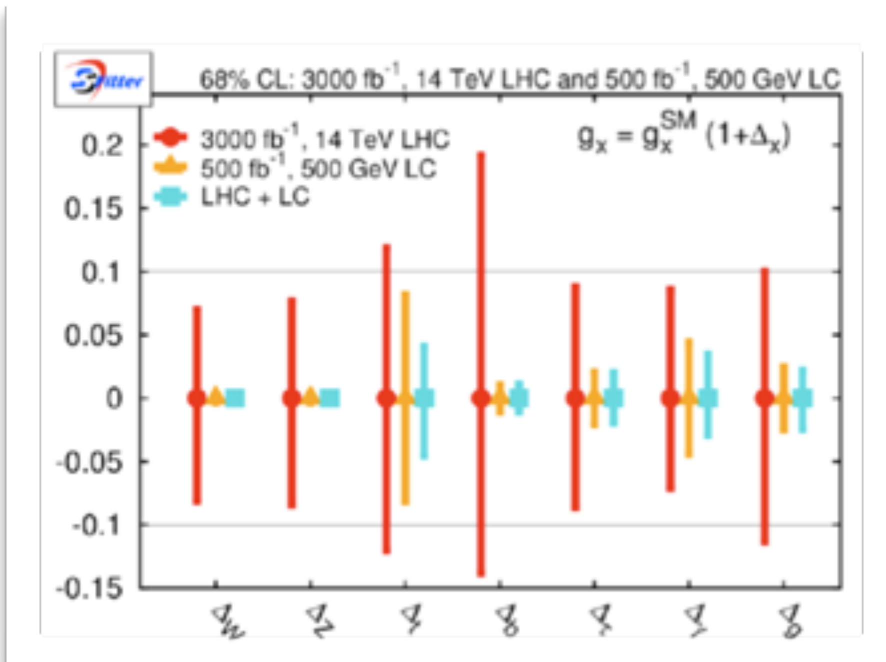
LC 13 @ ECT Trento (16-20 September)*

Linear Colliders

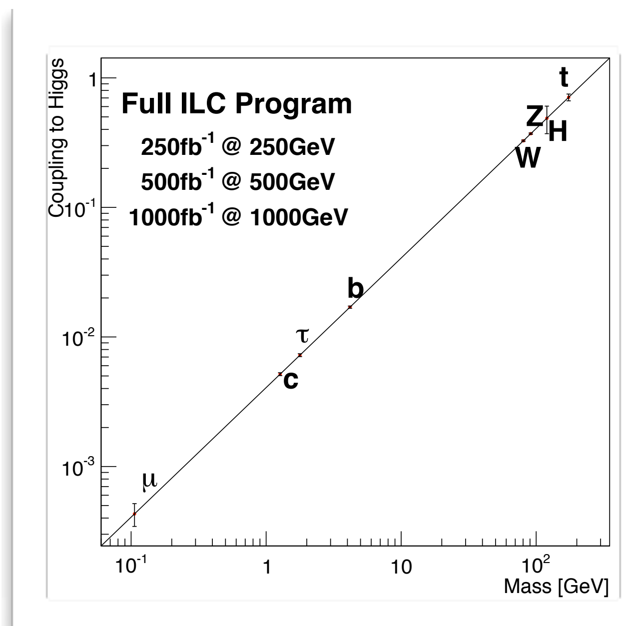
✳ The LHC discovery of Higgs particle completed all the particles needed in SM.

✳ Now we are aiming at precisely measuring the properties of these particles to search for signs of new physics.

✳ Challenges towards precision can adequately be met in a clean environment ➠ e+e- colliders.



Klute et al. 1301.1322



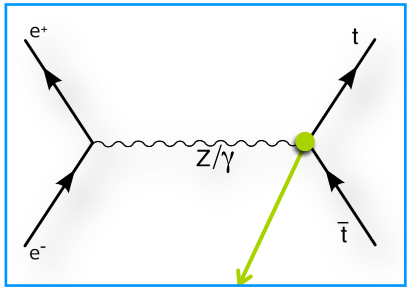
DBD 2012

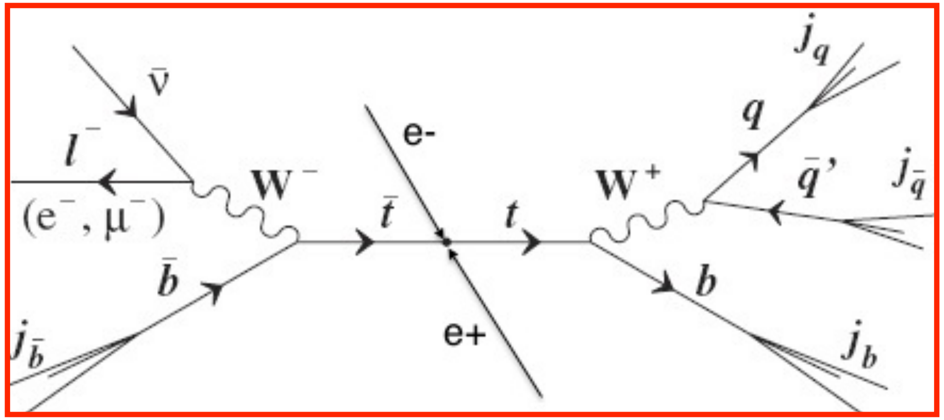
Top Physics at LCs

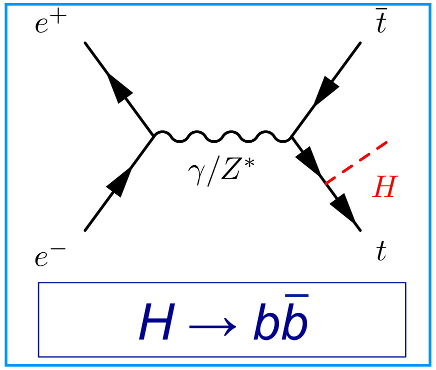
✳ The top physics is one of the three pillars of linear collider physics program.

✳ Current on-going studies in the ILC collaboration include:

- Properties of top: mass, width and cross section
- Coupling of top, namely, top Yukawa coupling
- BSM: anomalous couplings to BSM gauge bosons (Z', W', Extra dimension etc) ➠ Top Electroweak coupling.

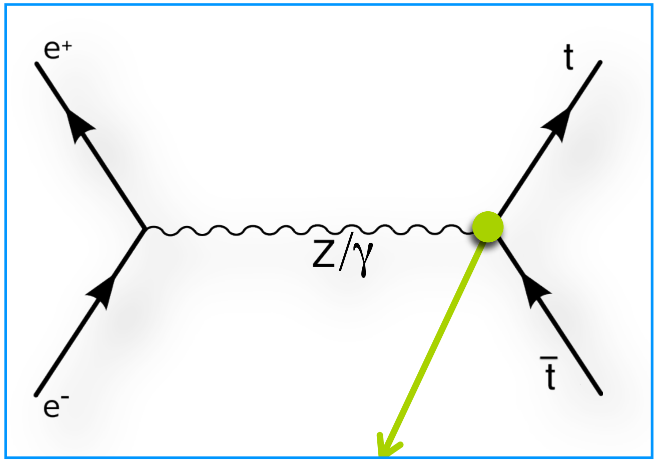






$10^{5\text{-}6}$ ttbar pairs production
at sqrt[s]=500 GeV with 500 fb^{-1}!

Top electroweak couplings



CP violating

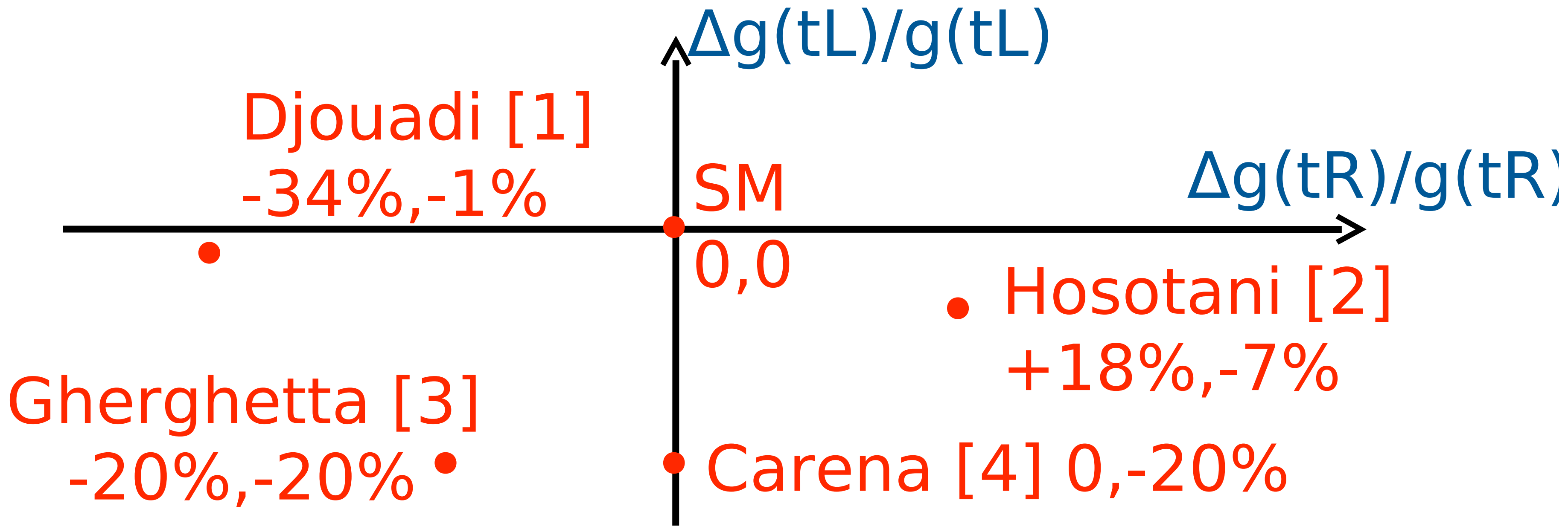
$$\Gamma_\mu^{t\bar{t}X}(k^2,q,\bar{q}) = -ie\left\{\gamma_\mu\left(F_{1V}^X(k^2)+\gamma_5 F_{1A}^X(k^2)\right)+\frac{\sigma_{\mu\nu}}{2m_t}(q+\bar{q})^\mu\left(iF_{2V}^X(k^2)+\gamma_5 F_{2A}^X(k^2)\right)\right\}$$

In SM, X=γ, Z

$$F_{1V}^{\gamma,SM} = -\frac{2}{3},\ F_{1A}^{\gamma,SM} = 0,\ F_{1V}^{Z,SM} = -\frac{1}{4s_w c_w}\left(1-\frac{8}{3}s_w^2\right),\ F_{1A}^{Z,SM} = \frac{1}{4s_w c_w},\quad F_{2V}^{\gamma} = Q_t(g-2)/2$$

➠ new physics models

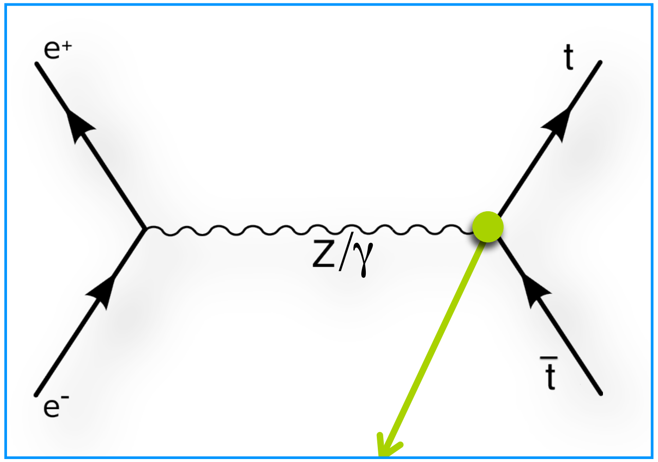
New physics models inducing anomalous coupling



[1] : Djouadi et al.,Nuclear Physics B, Volume 773 (2007)
[2] : Hosotani et al., Prog. Theor. Phys. 123 (2010), 757-790
[3] : Cui, Gherghetta et al., arXiv:1006.3322v1 [hep-ph]
[4] : Carena et al., Nuclear Physics B759 (2006)

From: thesis
Ph. Doublet

Top electroweak couplings



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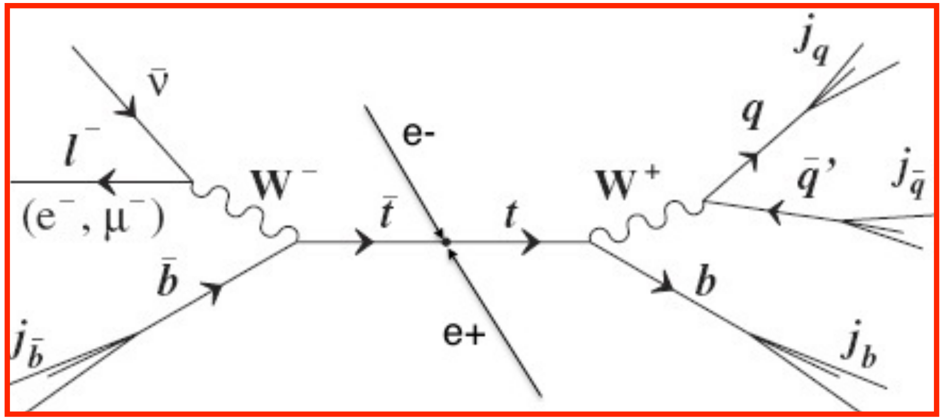
➠ new physics models

In this talk:

ILC sensitivity to the 6 form factors

Observables

Amjad et al, arXive:1307.8102



t tbar
→(bW)(bW)
→(bqq)(blnu)

Observables

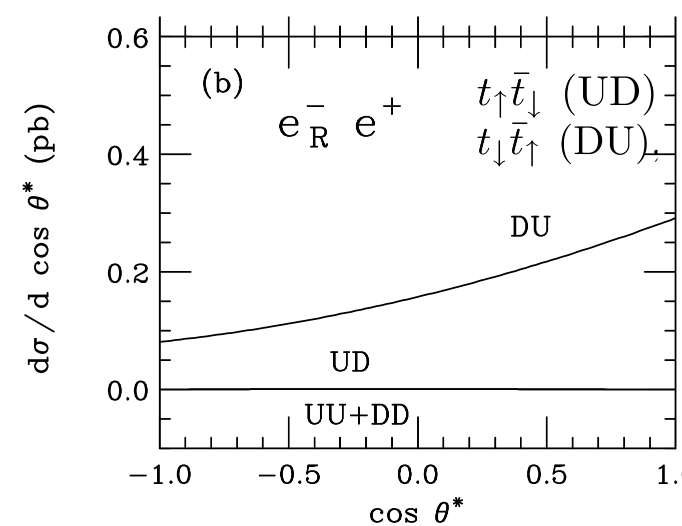
- Cross section of ttbar production
- Forward-Backward asymmetry A_{FB}
- Helicity angle $\theta_{helicity}$
  - $\theta_{helicity}$: lepton direction in t rest frame

Polarized beam useful!

ILC pol. beam option: $(e^-, e^+) = (\pm 0.8, \mp 0.3)$

Parke and Shadmi PLB387 ('96)

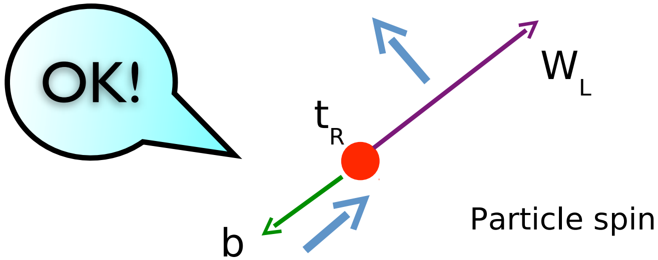
Top production and decays are very different form the other fermions. Many (interesting) angular correlations emerge, which can be used to extract various information.

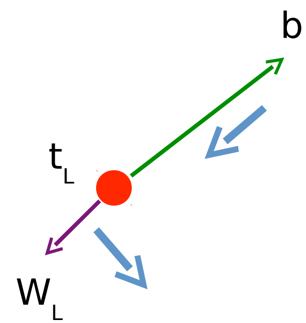


Forward-Backward Asymmetry

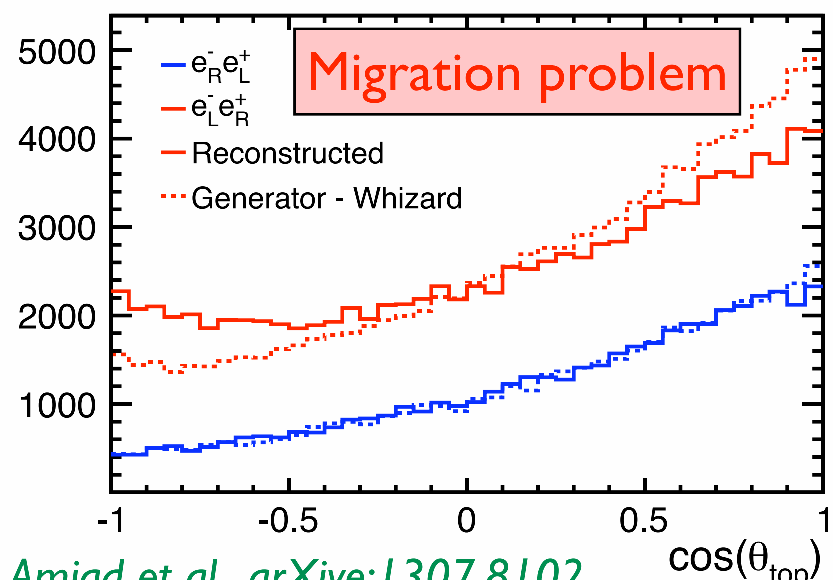
$$A^t_{FB} = \frac{N(\cos\theta > 0) - N(\cos\theta < 0)}{N(\cos\theta > 0) + N(\cos\theta < 0)}.$$

- θ polar angle of t quark
- kinematics are determine by using top hadronic decays
- t(tbar) quark association by b(bbar) quark





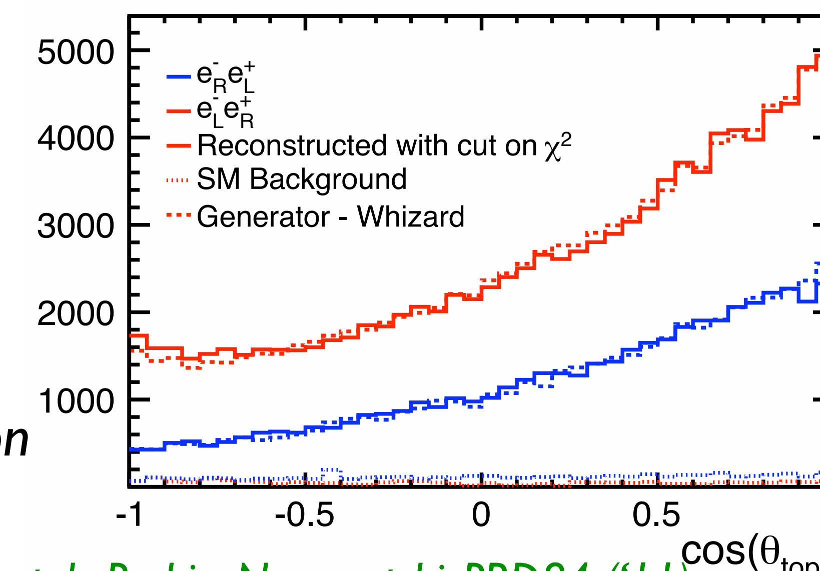
wrong association of W (b) = wrong association of top



Amjad et al, arXive:1307.8102

more sever cut for t_L reconstruction

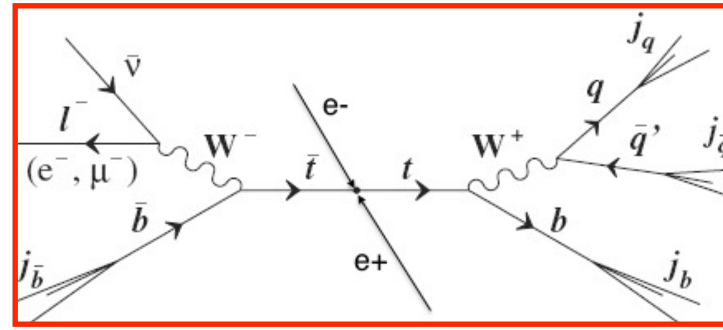
(rec. eff. 28.5%)



Devetak, Peskin, Nomerotski, PRD84 ('11)

New idea for b charge measurement?

Helicity slope

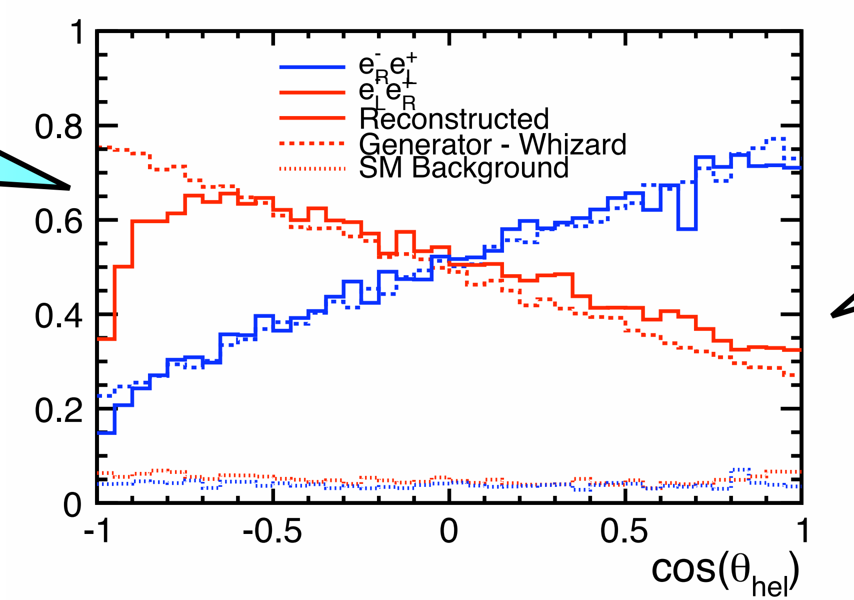


$$\frac{1}{\Gamma}\frac{d\Gamma}{dcos\theta_{hel}} = \frac{1+\lambda_t cos\theta_{hel}}{2} = \frac{1}{2} + (2F_R - 1)\frac{cos\theta_{hel}}{2}$$

$\theta_{helicity}$: lepton direction in t rest frame

$$\lambda_t = 1 \text{ for } t_R \quad \lambda_t = -1 \text{ for } t_L$$

missing leptons with small energy causes a dip



migration less prominent

Amjad et al, arXive:1307.8102

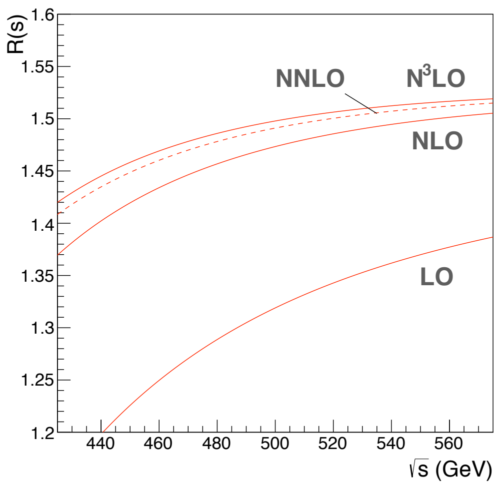
Result : sensitivity of ILC to the form factors

Coupling	SM value	LHC [3] $\mathcal{L} = 300$ fb^{-1}	e^+e^- [8] $\mathcal{L} = 300$ fb^{-1} $\mathcal{P}, \mathcal{P}' = -0.8, 0$	e^+e^-[*ILC DBD*] $\mathcal{L} = 500$ fb^{-1} $\mathcal{P}, \mathcal{P}' = \pm 0.8, \mp 0.3$
$\Delta\widetilde{F}^{\gamma}_{1V}$	0.66	$^{+0.043}_{-0.041}$	$^{-}_{-}$	$^{+0.002}_{-0.002}$
$\Delta\widetilde{F}^{Z}_{1V}$	0.23	$^{+0.240}_{-0.620}$	$^{+0.004}_{-0.004}$	$^{+0.002}_{-0.002}$
$\Delta\widetilde{F}^{Z}_{1A}$	-0.59	$^{+0.052}_{-0.060}$	$^{+0.009}_{-0.013}$	$^{+0.006}_{-0.006}$
$\Delta\widetilde{F}^{\gamma}_{2V}$	0.015	$^{+0.038}_{-0.035}$	$^{+0.004}_{-0.004}$	$^{+0.001}_{-0.001}$
$\Delta\widetilde{F}^{Z}_{2V}$	0.018	$^{+0.270}_{-0.190}$	$^{+0.004}_{-0.004}$	$^{+0.002}_{-0.002}$

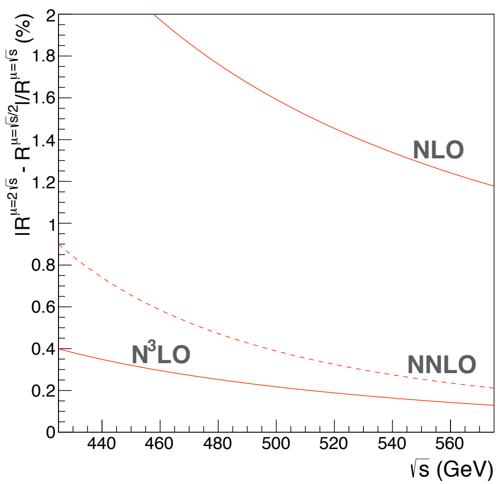
Table 4: *Sensitivities achievable at 68.3% CL for CP conserving form factors $\widetilde{F}^{X}_{1V,A}$ and $\widetilde{F}^{X}_{2V}$ defined in Eq. 1 at the LHC and at linear e^+e^- colliders. The assumed luminosity samples and, for e^+e^- colliders, the beam polarisation, are indicated. In the LHC studies and in earlier studies for a linear e^+e^- collider as published in the TESLA TDR [8] study, only one coupling at a time is allowed to deviate from its Standard Model value. In the present study, denoted as* ILC DBD, *either the four form factors $\widetilde{F}_1$ or the two form factors $\widetilde{F}_2$ are allowed to vary independently. The sensitivities are based on statistical errors only.*

Theoretical uncertainties

✳QCD corrections are known up to N^3LO



(a) Perturbation series

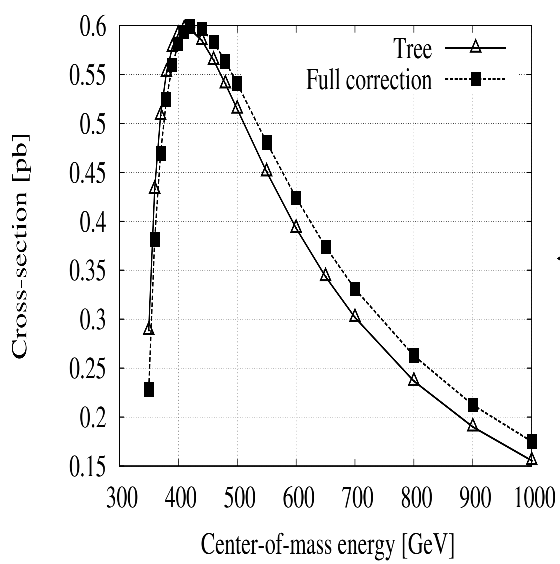


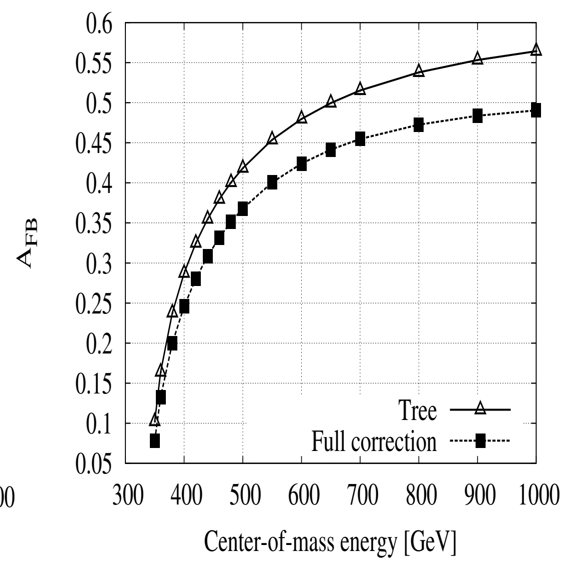
(b) Scale variations

QCD correction (N^3LO) is at the per mil level

Kiyo, Maier, Maierhofer, Marquard, NCP B823 ('09)
Bernreuther, Bonciani, Gehrmann, Heinesch, Leineweber. NPB750 ('06)
Hoang, Mateu, Zebarjad, NPB813 ('09)

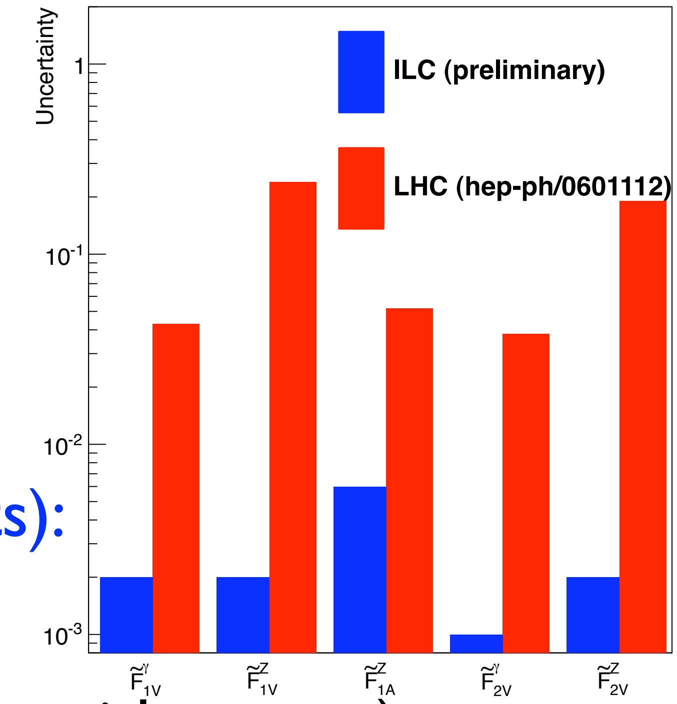
✳Electroweak corrections are known at one-loop level





EW correction at one-loop is
~5% for cross section
~10% for A_{FB}

Fleischer, Leike, Riemann, Werthenbach, EJPC31 ('03)
Kheim, Fujimoto, Ishikawa, Kaneko, Kato, arXive:1211.1112



Outlook

- Experimental issues (some are common with the other top physics measurements):
  - ✓ b-tagging and charge identification
  - ✓ jet algorithm (Durham-algorithm, kt-algorithm etc...)
  - ✓ luminosity measurement
  - ✓ refinement of the current analysis

- Theoretical topics :
  - ✓ theoretical uncertainties (QCD, electroweak corrections)
  - ✓ CP violating observable
  - ✓ new observables, new ideas (e.g. more angular correlation)!

Y. Kiyo, E.K. in preparation

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$\Delta\mathrm{Re}\,\widetilde{F}_{2A}^{\gamma}$	$+0.17$ -0.17	$+0.007$ -0.007
$\Delta\mathrm{Re}\,\widetilde{F}_{2A}^{Z}$	$+0.35$ -0.35	$+0.008$ -0.008
$\Delta\mathrm{Im}\,\widetilde{F}_{2A}^{\gamma}$	$+0.17$ -0.17	$+0.008$ -0.008
$\Delta\mathrm{Im}\,\widetilde{F}_{2A}^{Z}$	$+0.035$ -0.035	$+0.015$ -0.015

Table 5: *Sensitivities achievable at 68.3% CL for the top quark magnetic and electric dipole form factors $\widetilde{F}_{2A}^{V}$ defined in Eq. 1, at the LHC and at for a linear e^+e^- collider as published in the TESLA TDR [8]. The assumed luminosity samples and, for TESLA, beam polarisation, are indicated. In the LHC study and in the TESLA study only one coupling at a time is allowed to deviate from its Standard Model value. The sensitivities are based on statistical errors only*