Radiative Corrections to the Higgs Production at the ILC

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Outline

- Higgs production at the ILC
- Determination of the Higgs properties at the ILC
- Associated production with a pair of top-quarks
  - EW corrections to $e^+e^- \to t\bar{t}h$ in SM
  - EW corrections to $e^+e^- \to t\bar{t}h^0$ in MSSM
- EW corrections to $e^+e^- \to hhZ$
- Associated production with a pair of Z-bosons

$$e^+e^- \to ZZh$$

- Summary

Higgs production at LC

- The main Higgs production mechanisms at LC
  - Higgs-strahlung $e^+e^- \to Z^* \to Zh$
  - Gauge boson fusion

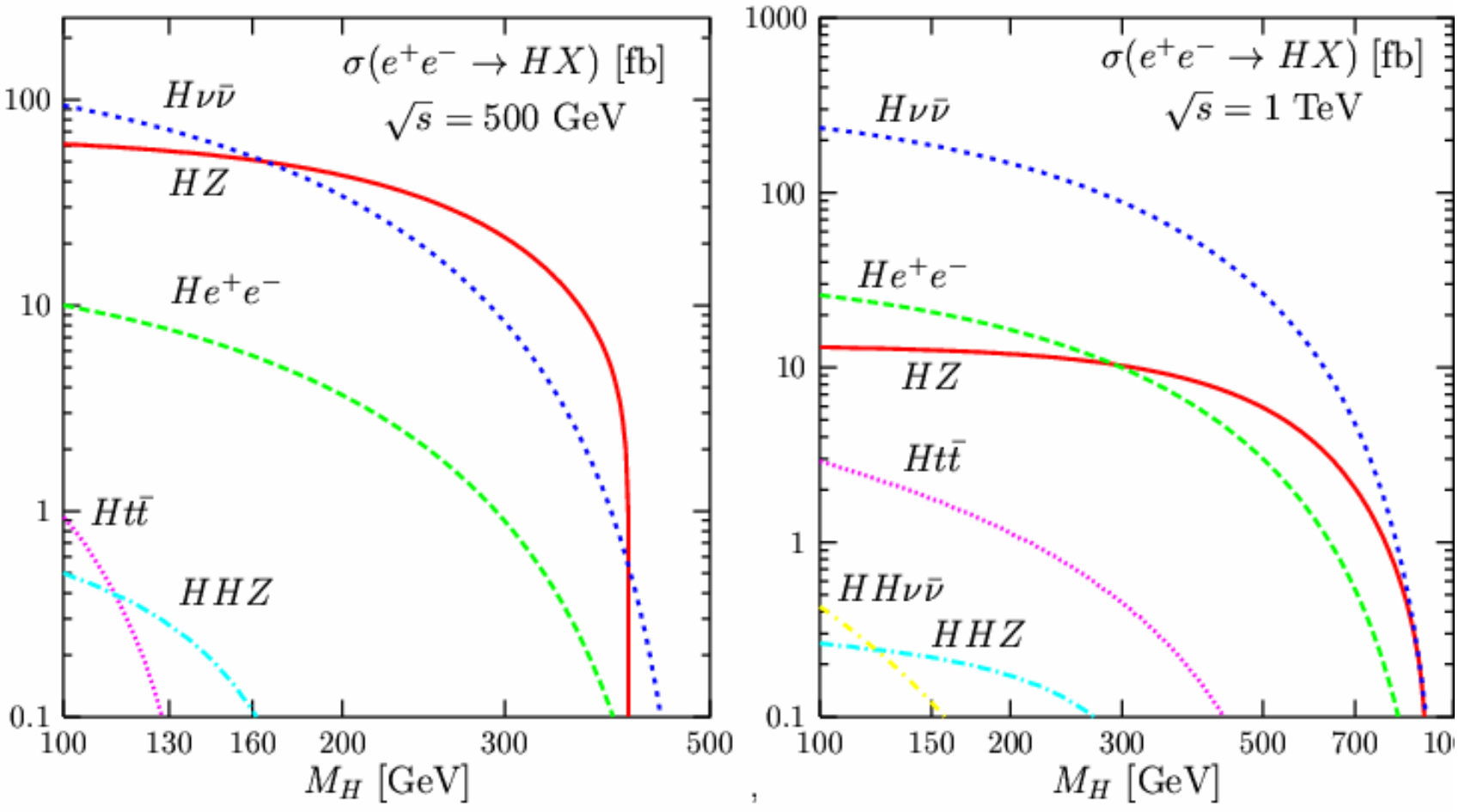
$$e^+e^- \to \nu\bar{\nu}W^*W^* \to \nu\bar{\nu} + h$$

$$e^+e^- \to e^+e^-Z^*Z^* \to e^+e^- + h$$

  - Radiation off top quarks $e^+e^- \to t\bar{t}h$
  - Double Higgs-strahlung

$$e^+e^- \to Z^* \to Z + hh$$

Higgs production at LC



- From A. Djouadi hep-ph/0604109

Determination of Higgs properties

- Higgs Mass
- Higgs Spin-parity
- Higgs couplings to gauge bosons
- Higgs width and branching ratios
- Higgs couplings to top quarks
- Tri-linear Higgs self-coupling

  Reach to a precision of several %

  Theoretical predictions within percent level are necessary.

  Radiative corrections to the Higgs production are important!

EW corrections to $e^+e^- \to t\bar{t}h$

- Motivation: this process is used to determine the top quark Yukawa coupling
- QCD corrections were well know

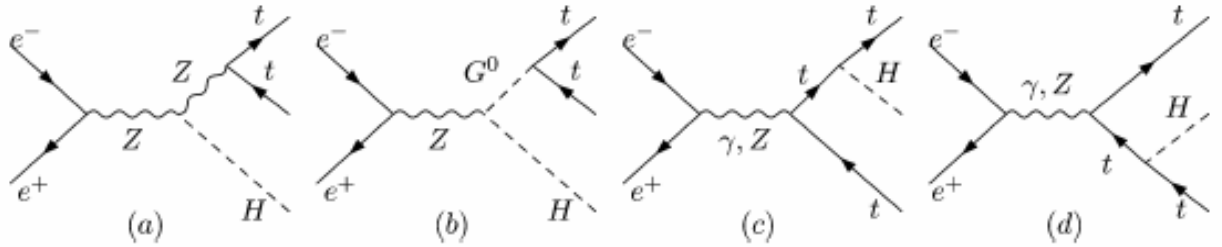
  hep-ph/9808433,9808443
- EW corrections have been presented by three groups

  Y. You, *et. al*, hep-ph/0306036

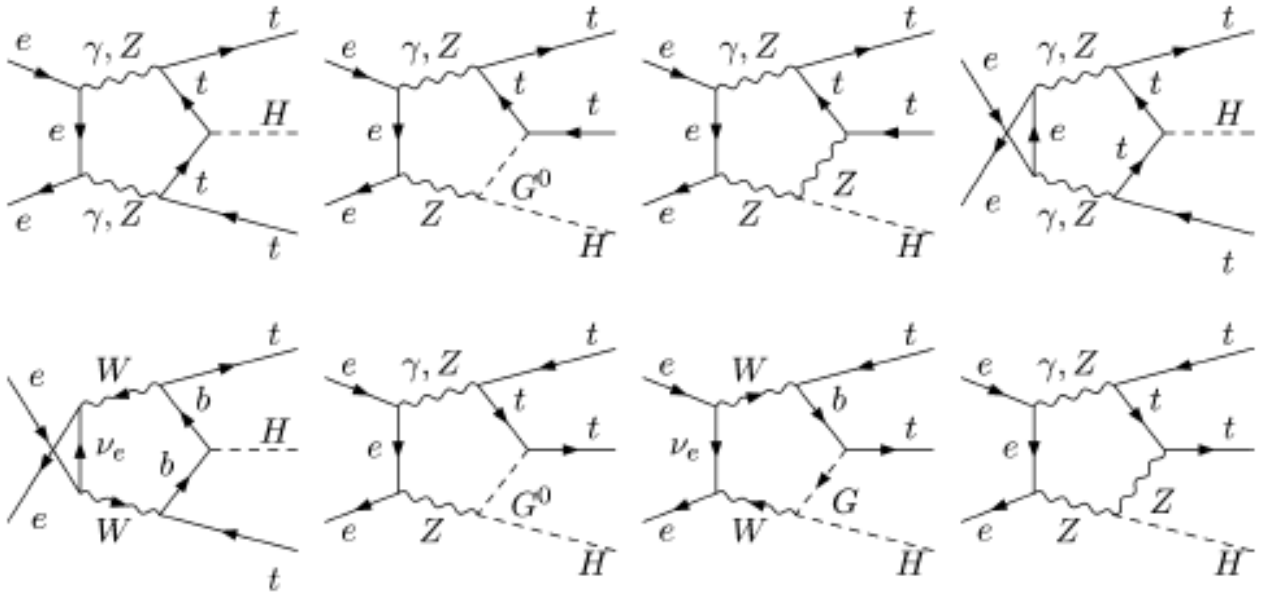
  G. Belanger, *et. al*, hep-ph/0307029

  A. Denner, *et. al*, hep-ph/03070193

Tree level Feynman diagrams

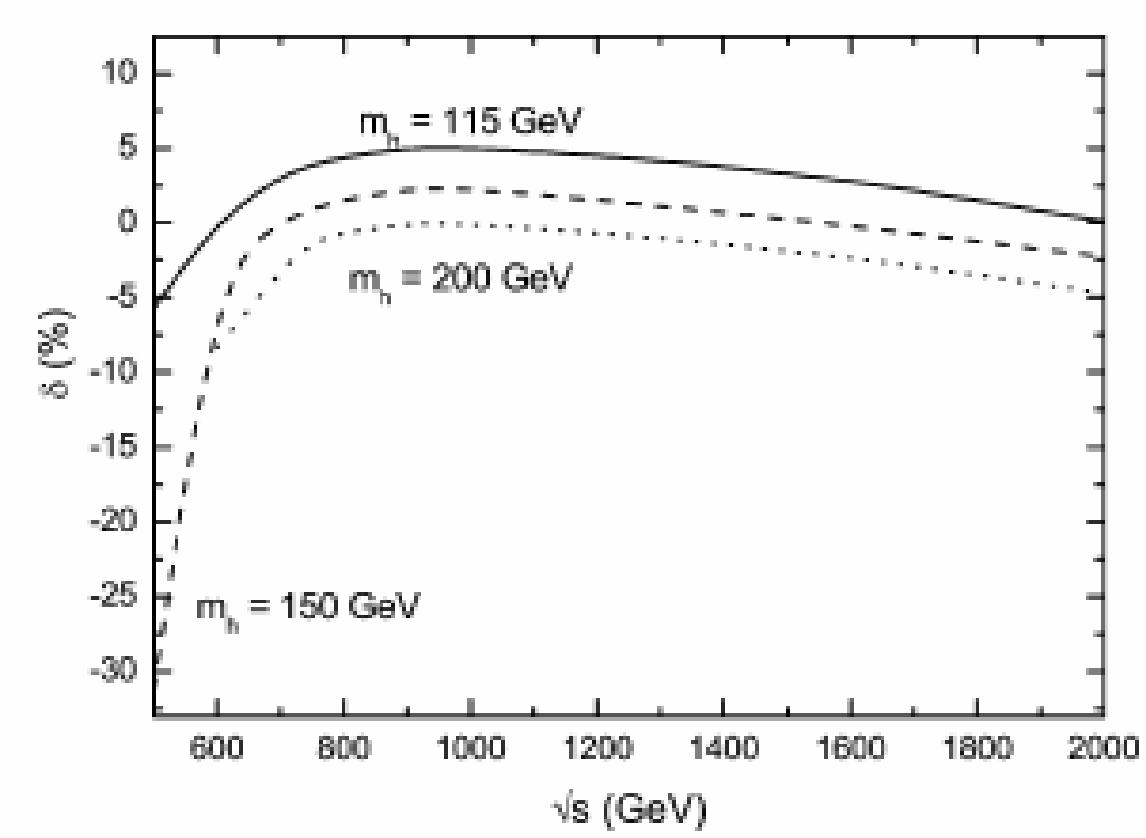


Sample one-loop diagrams

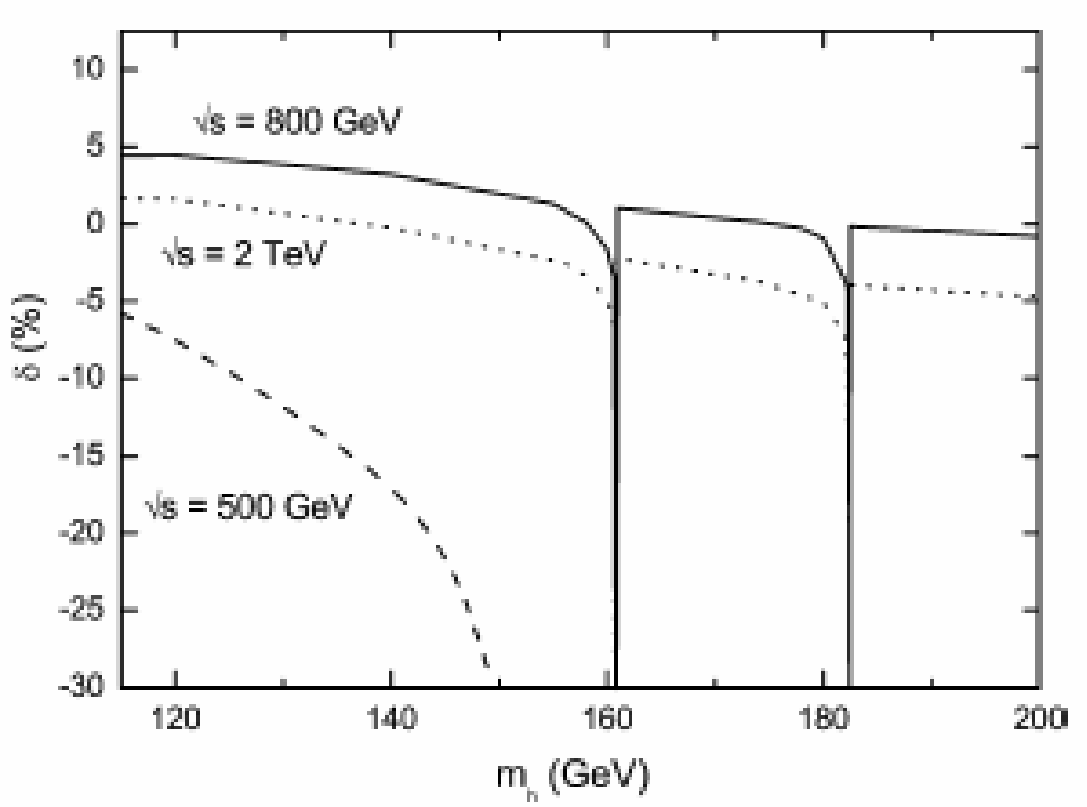


Use FeynArts, FormCalc, LoopTools to Calculate the virtual correction. Use CompHep and Grace to calculate the photon emission.

Typical results $e^+e^- \to t\bar{t}h$



Results(continue)



EW corrections to $e^+e^- \to t\bar{t}h^0$ in MSSM

J.J. Liu hep-ph/0507293

- Higgs sector in MSSM
  - Enlarged Two-Higgs-Doublets: H_1, H_2
  - Five physical states: $h^0, H^0, A^0, H^\pm$
  - Input parameters: $\tan\beta = v_2 / v_1, \quad m_{A^0}$
  - Other parameters at tree-level

$$M^2_{H^\pm} = M^2_W + M^2_{A^0},$$

$$M^{2,\mathrm{tree}}_{H^0,h^0} = \frac{1}{2}\left(M^2_{A^0} + M^2_Z \pm \sqrt{(M^2_{A^0} + M^2_Z)^2 - 4M^2_{A^0} M^2_Z \cos^2 2\beta}\right),$$

$$\cos 2\alpha = \cos 2\beta \frac{M^2_Z - M^2_{A^0}}{M^2_{H^0} - M^2_{h^0}}, \qquad \sin 2\alpha = -\sin 2\beta \frac{M^2_Z + M^2_{A^0}}{M^2_{H^0} - M^2_{h^0}}.$$

- Parameters in other sectors in MSSM
  - Sfermion sector:

    $M_{\tilde{Q}}, M_{\tilde{U}}, M_{\tilde{D}}, M_{\tilde{E}}, M_{\tilde{L}}$ are assumed to be degenerated as M_{susy}

    The soft trilinear couplings are $A_q = A_l = A_f$
  - Chargino-neutralino sector:

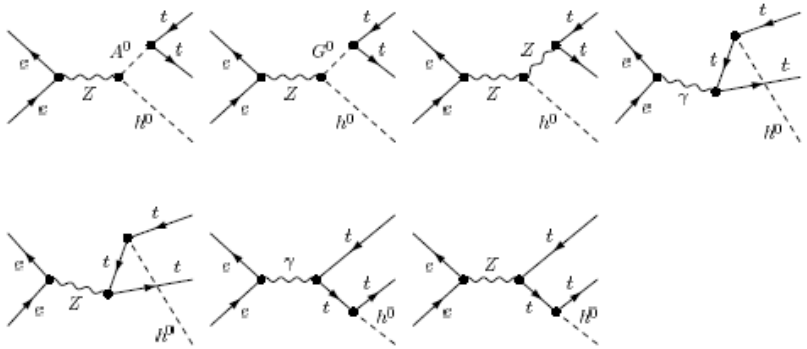
    soft-breaking gaugino mass parameters

    M_1, M_2 with GUT relation $M_1 = (5/3)\tan^2\theta_W M_2$

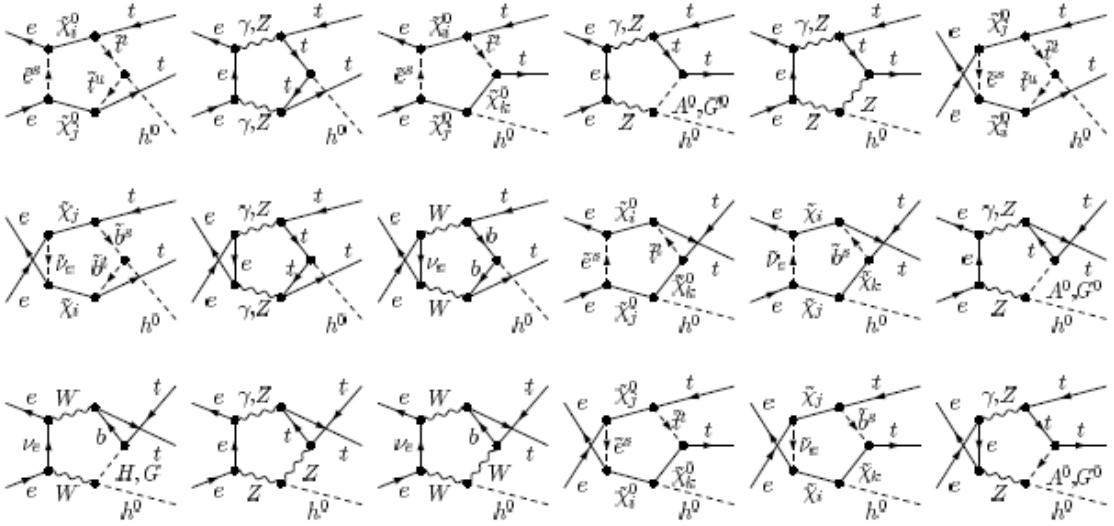
    Higgsino-mass parameter μ

EW corrections to $e^+e^- \to t\bar{t}h^0$ in MSSM

Tree-level Feynman diagrams



Sample one-loop diagrams



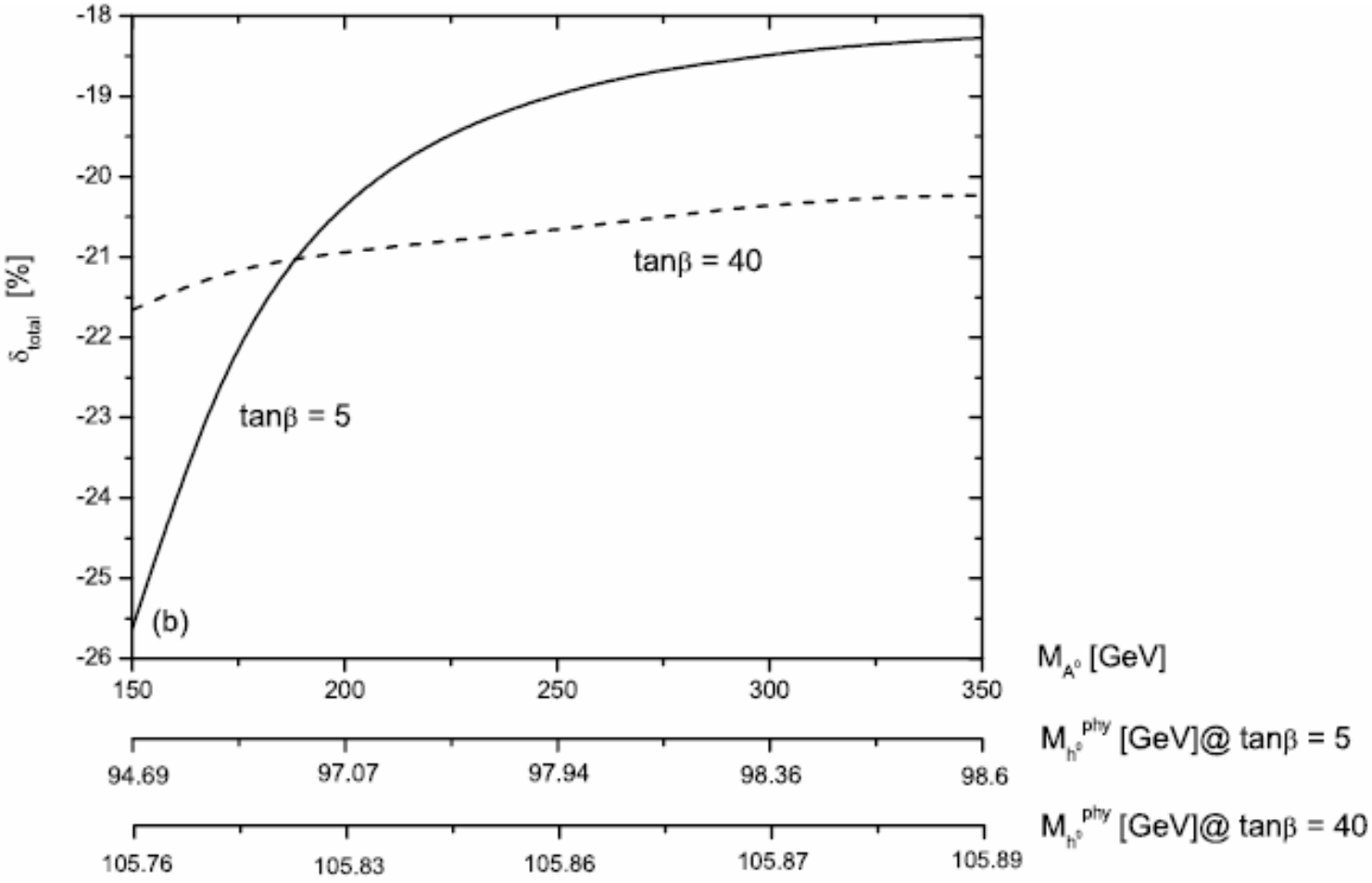
Results

TABLE I. Taking $M_{A^0} = 300$ GeV, the Born cross section σ_{tree} and the corrected cross section σ_{total} as well as the corresponding relative corrections δ_{total} for different values of $\tan\beta$ and c.m.s. energy $\sqrt{s}$.

$\sqrt{s}$[GeV]	$tan\beta$	M_{h^0}[GeV]	σ_{tree}[fb]	σ_{total}[fb]	δ_{total}[%]
500	5	98.36	1.070746(1)	0.761(1)	−28.97(9)
	40	105.87	0.7086974(7)	0.4938(6)	−30.33(8)
800	5	98.36	3.808457(3)	3.105(5)	−18.5(1)
	40	105.87	3.515246(3)	2.800(4)	−20.4(1)
1000	5	98.36	3.065664(3)	2.568(4)	−16.2(1)
	40	105.87	2.889250(3)	2.362(4)	−18.2(1)
2000	5	98.36	1.073347(1)	0.924(2)	−13.9(2)
	40	105.87	1.041033(1)	0.874(2)	−16.1(2)

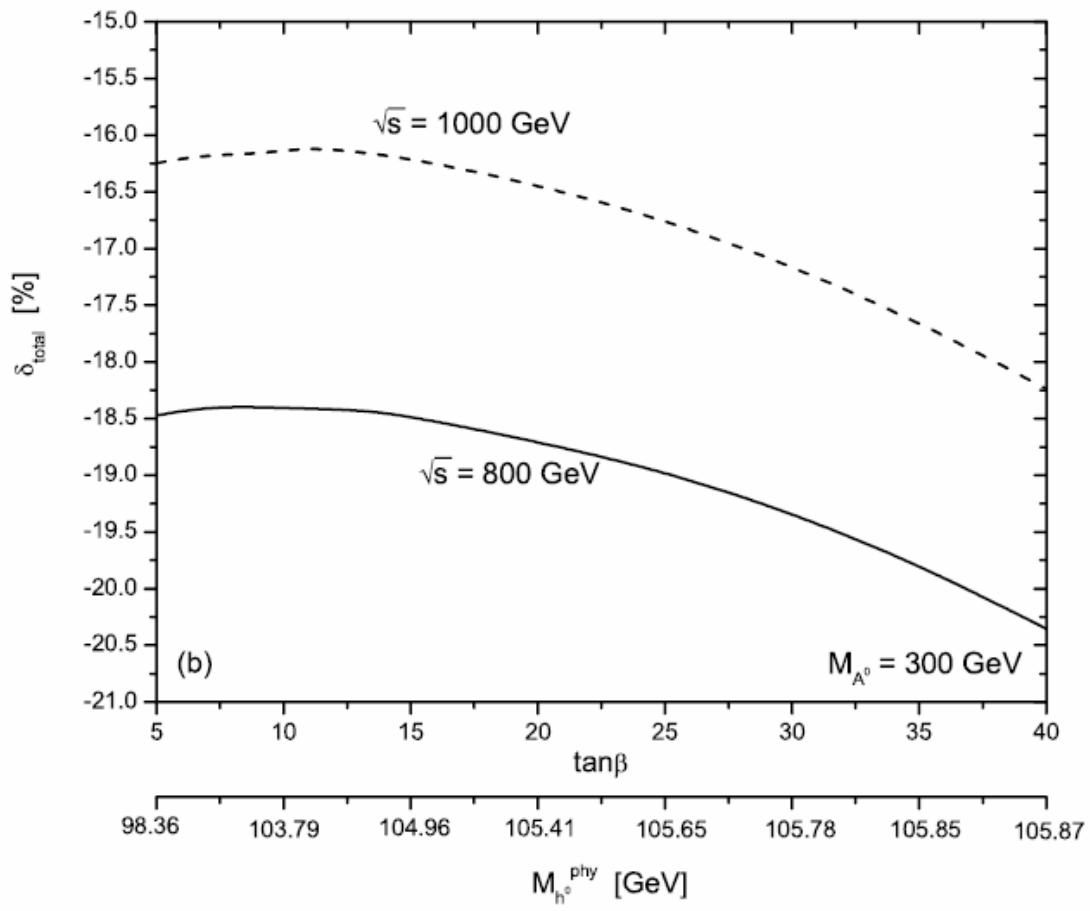
Results (continue)

- Dependence of the relative corrections on M_A with $\sqrt{s} = 800GeV$



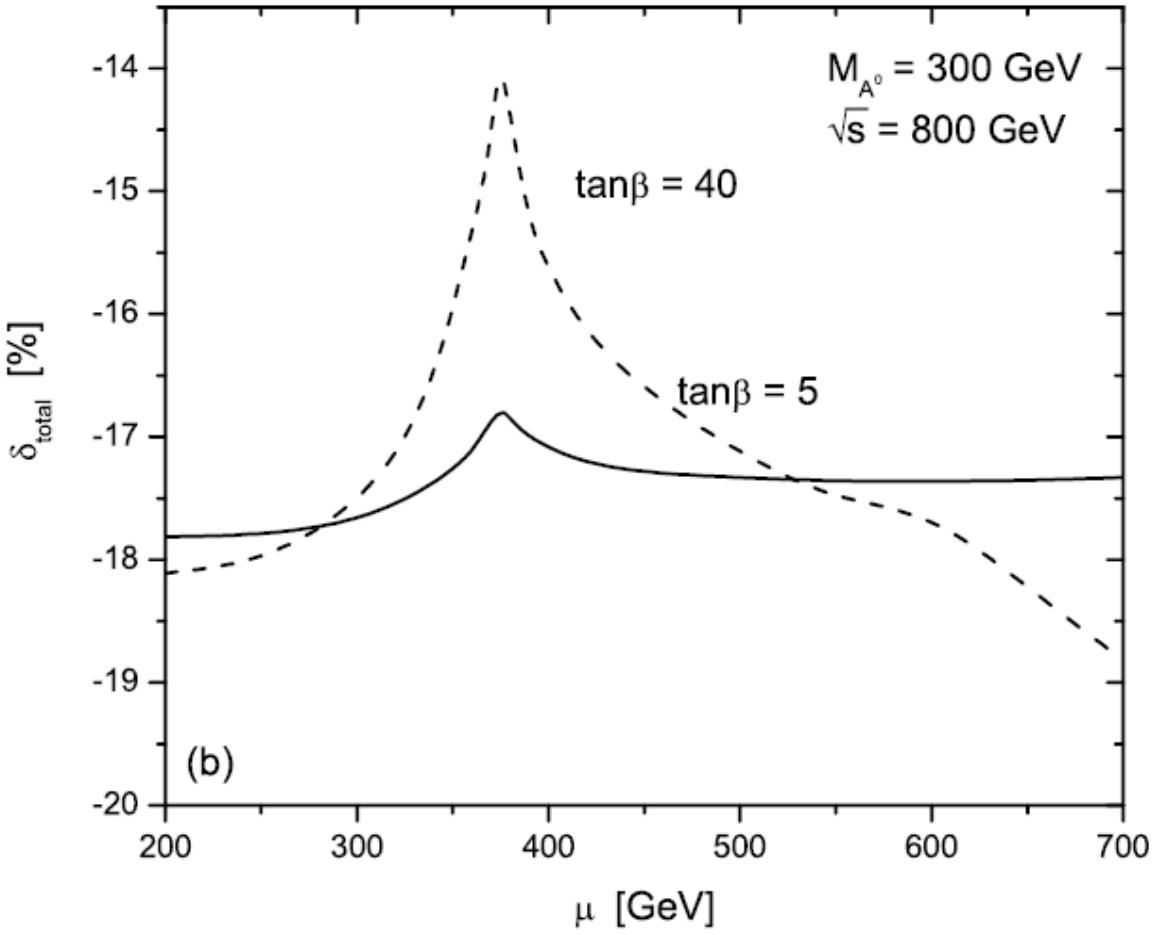
Results (continue)

- Dependence of the relative corrections on $\tan\beta$



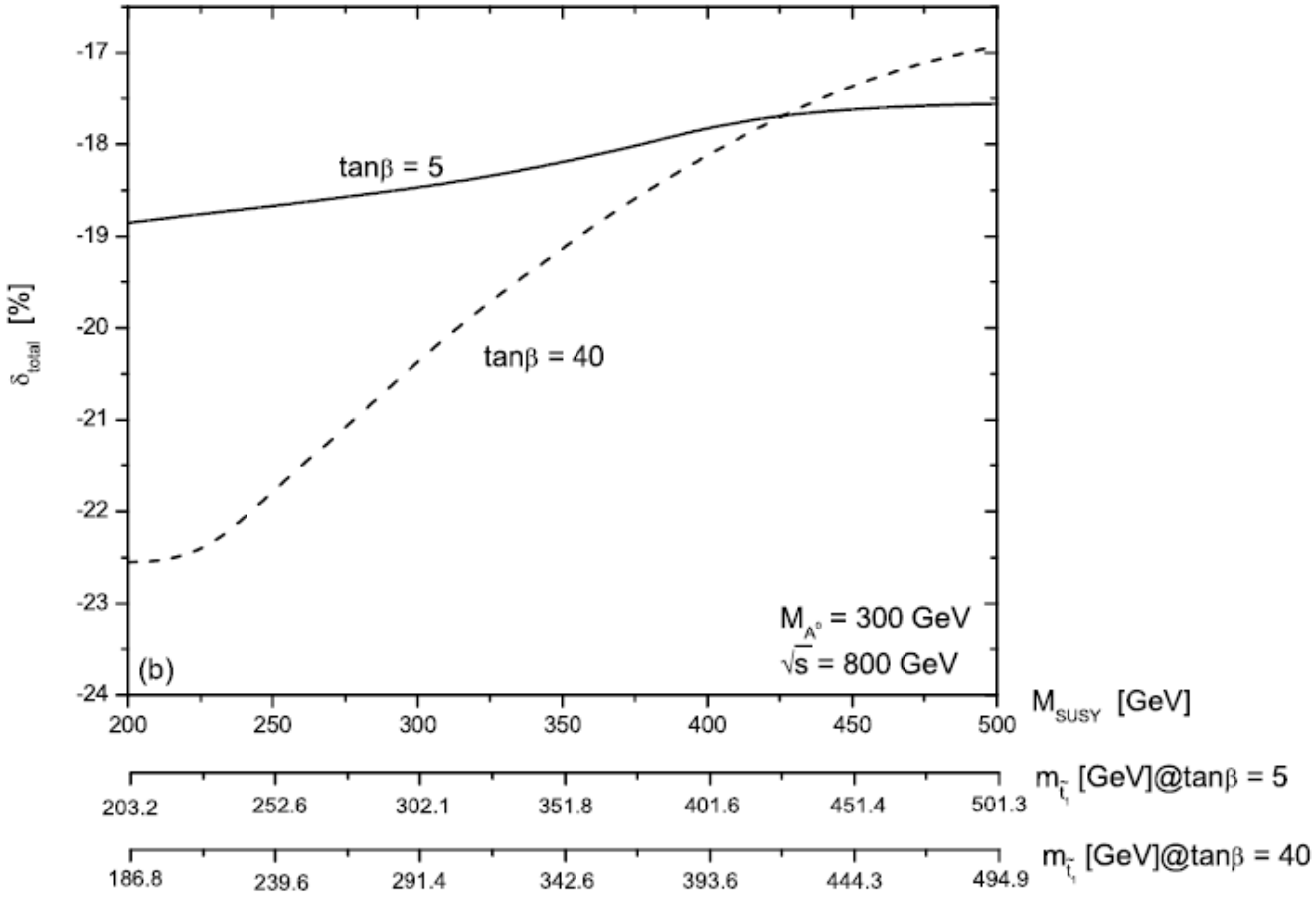
Results (continue)

- Dependence of the relative corrections on μ



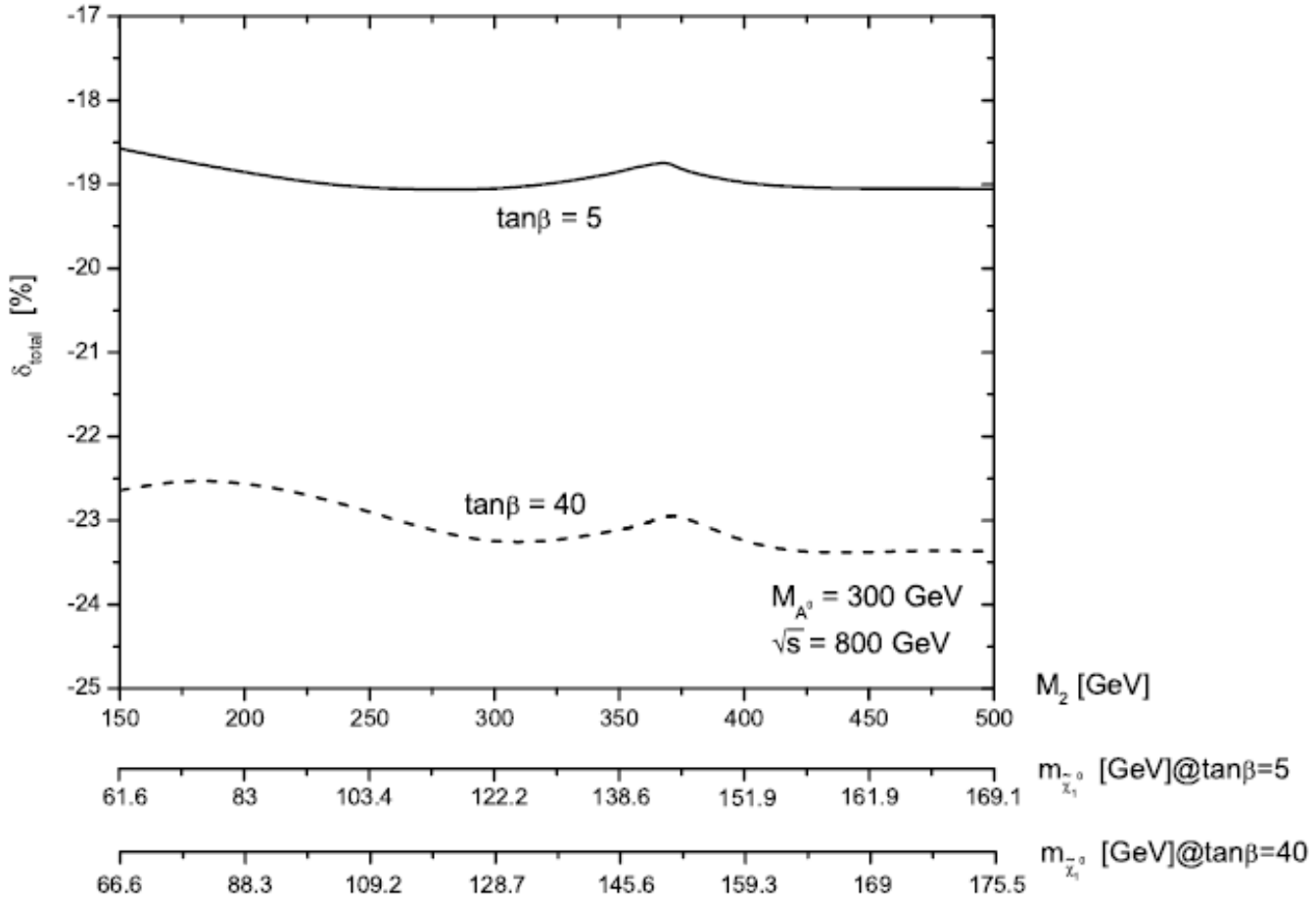
Results (continue)

- Dependence of the relative corrections on M_{SUSY}



Results (continue)

- Dependence of the relative corrections on M_2

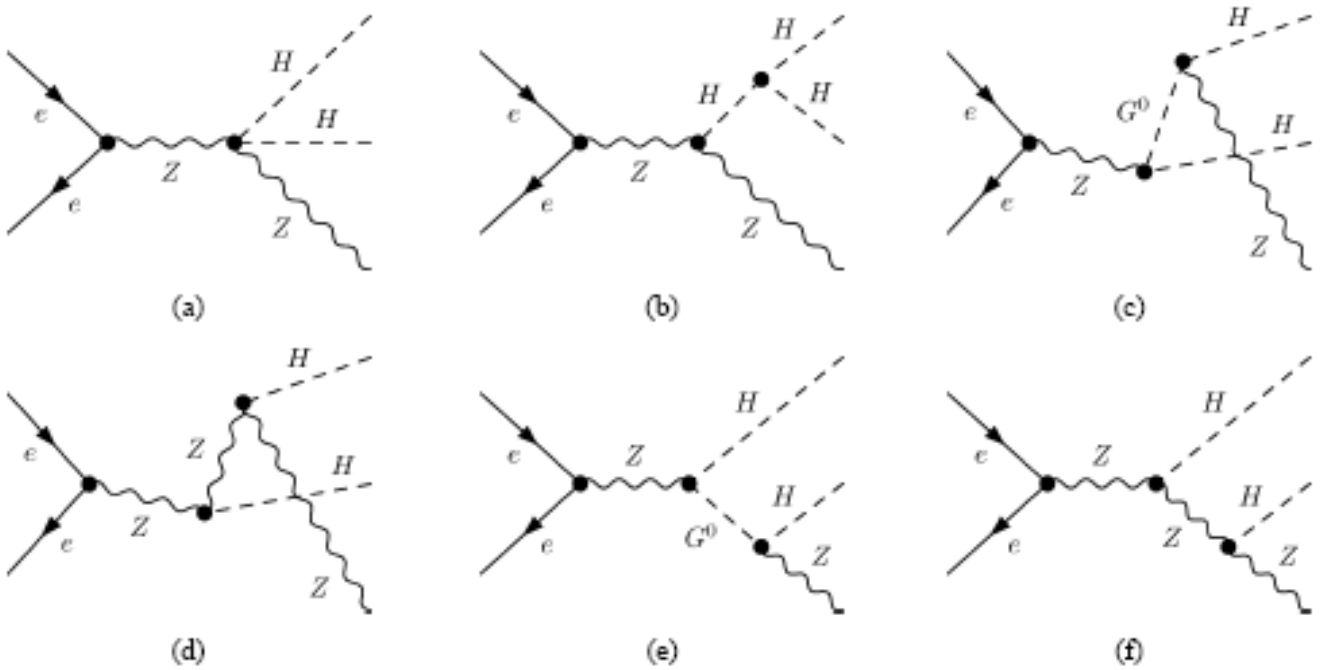


EW corrections to $e^+e^- \to hhZ$

- This process is used to determine Higgs self-couplings and reconstruct the Higgs potential.
- Simulation showed a precision of about 10% on the total cross section can be reached with high integrated luminosity $\int \lambda = 2ab^{-1}$:

  hep-ex/0101028
- EW corrections to this process have been presented by two groups
  - R. Y. Zhang, *et. al*, hep-ph/0308203
  - G. Belanger, *et. al*, hep-ph/0309010

Tree level diagrams



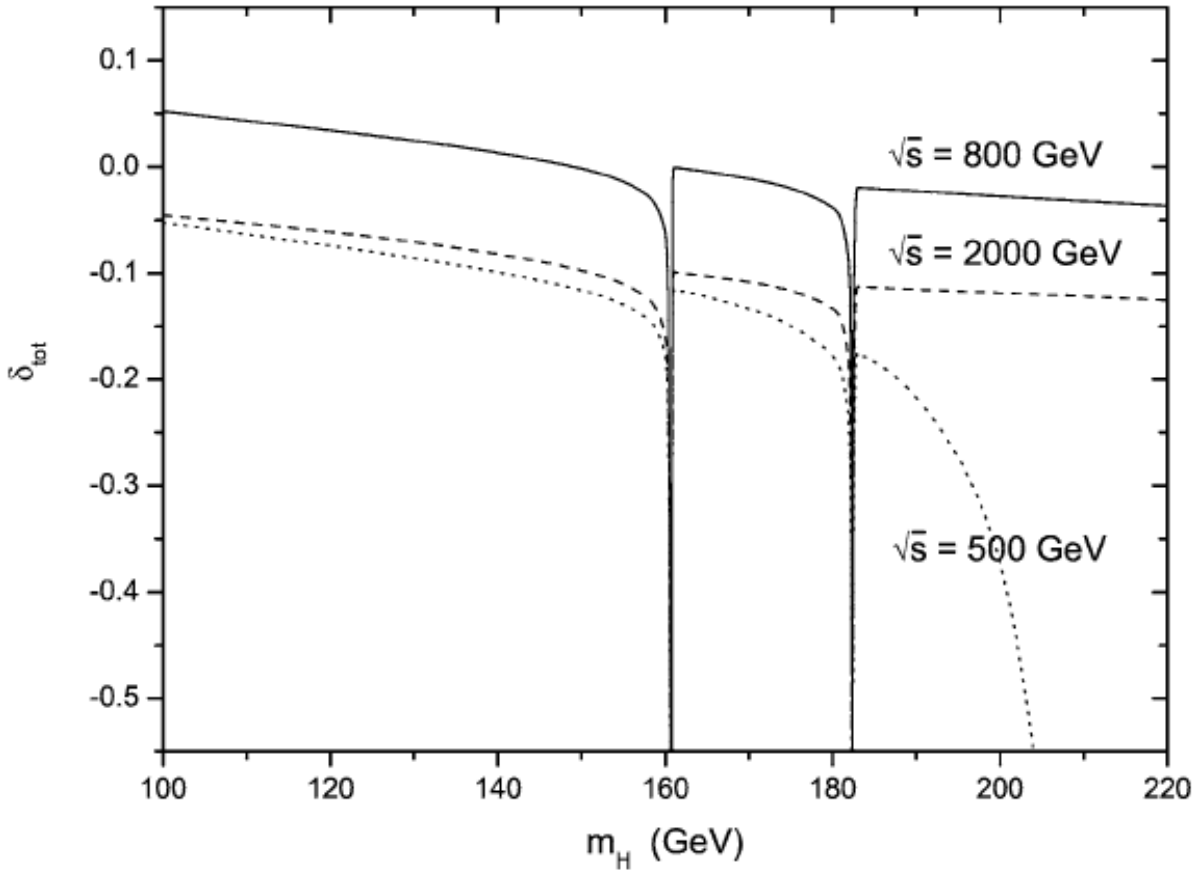
Results to $e^+e^- \to hhZ$

The Born cross section σ_{tree}, the corrected cross section σ_{tot} and the full $\mathcal{O}(\alpha_{\text{ew}})$ electroweak relative correction δ_{tot} for various Higgs boson mass and c.m. energy values

$\sqrt{s}$ [GeV]	m_H [GeV]	σ_{tree} [fb]	σ_{tot} [fb]	δ_{tot} [%]
500	115	0.17493(2)	0.1629(2)	−6.9(1)
	150	0.071834(6)	0.06357(6)	−11.50(7)
	200	$0.49611(3) \times 10^{-3}$	$0.3329(2) \times 10^{-3}$	−32.90(4)
600	115	0.17428(2)	0.1740(3)	−0.2(1)
	150	0.10840(1)	0.1041(1)	−4.0(1)
	200	0.031802(3)	0.02935(2)	−7.71(7)
700	115	0.15868(3)	0.1632(3)	2.8(2)
	150	0.11665(2)	0.1155(2)	−1.0(1)
	200	0.058846(7)	0.05665(7)	−3.7(1)
800	115	0.14156(3)	0.1471(3)	3.9(2)
	150	0.11363(2)	0.1135(2)	−0.1(2)
	200	0.07246(1)	0.0705(1)	−2.7(1)
1000	115	0.11293(2)	0.1168(3)	3.4(3)
	150	0.09890(2)	0.0983(3)	−0.6(2)
	200	0.07790(1)	0.0753(2)	−3.3(2)
1500	115	0.07119(2)	0.0704(3)	−1.1(4)
	150	0.06684(2)	0.0634(2)	−5.1(3)
	200	0.06165(1)	0.0569(2)	−7.7(3)
2000	115	0.05021(1)	0.0473(2)	−5.8(4)
	150	0.04812(1)	0.0435(2)	−9.6(4)
	200	0.04630(1)	0.0408(2)	−11.9(4)

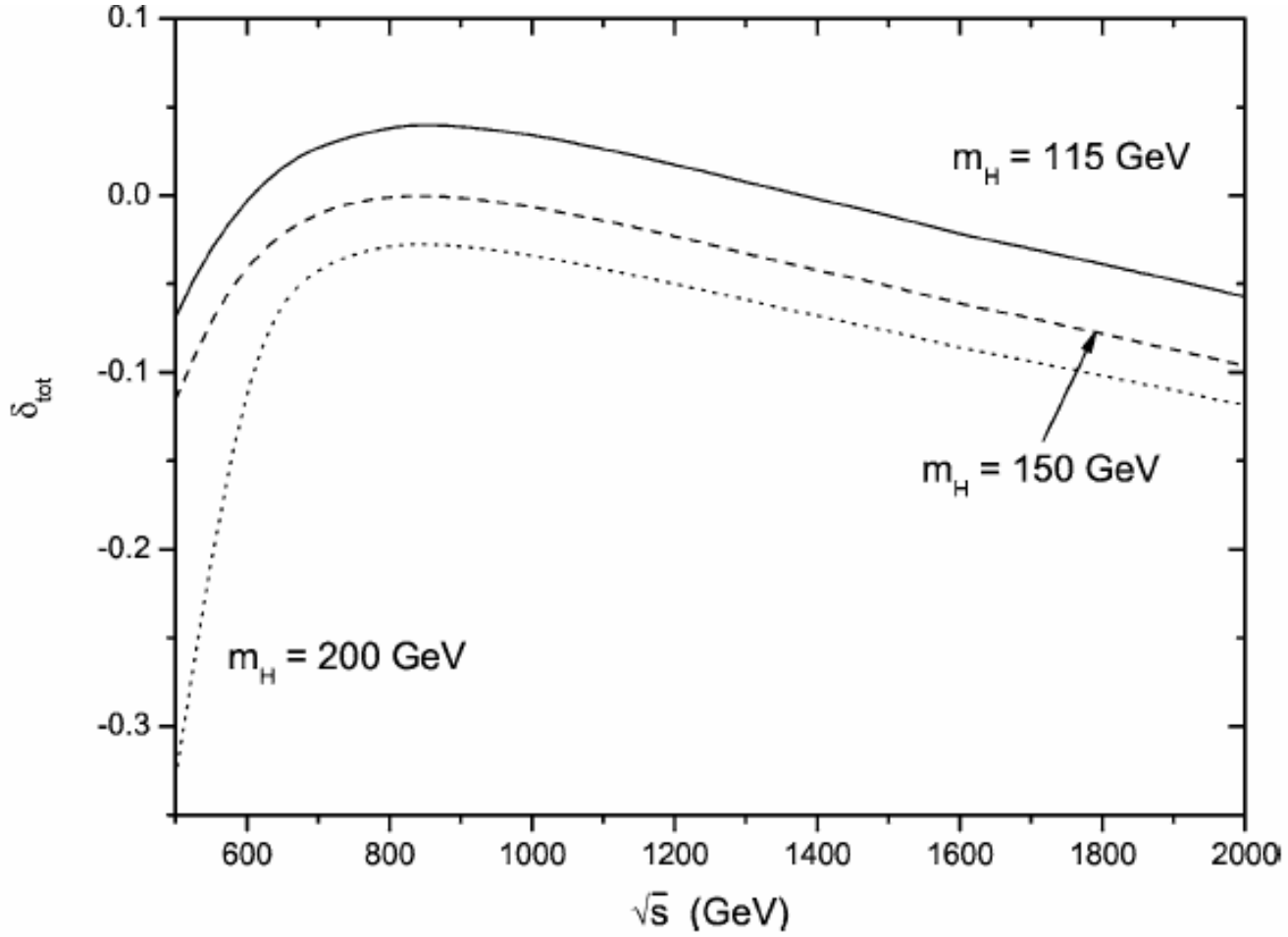
Results (continue)

- Dependence of the relative corrections on Higgs mass



Results (continue)

- Dependence of the relative corrections on collide energy



Results: compare with hep-ph/0309010

from hep-ph/0309010

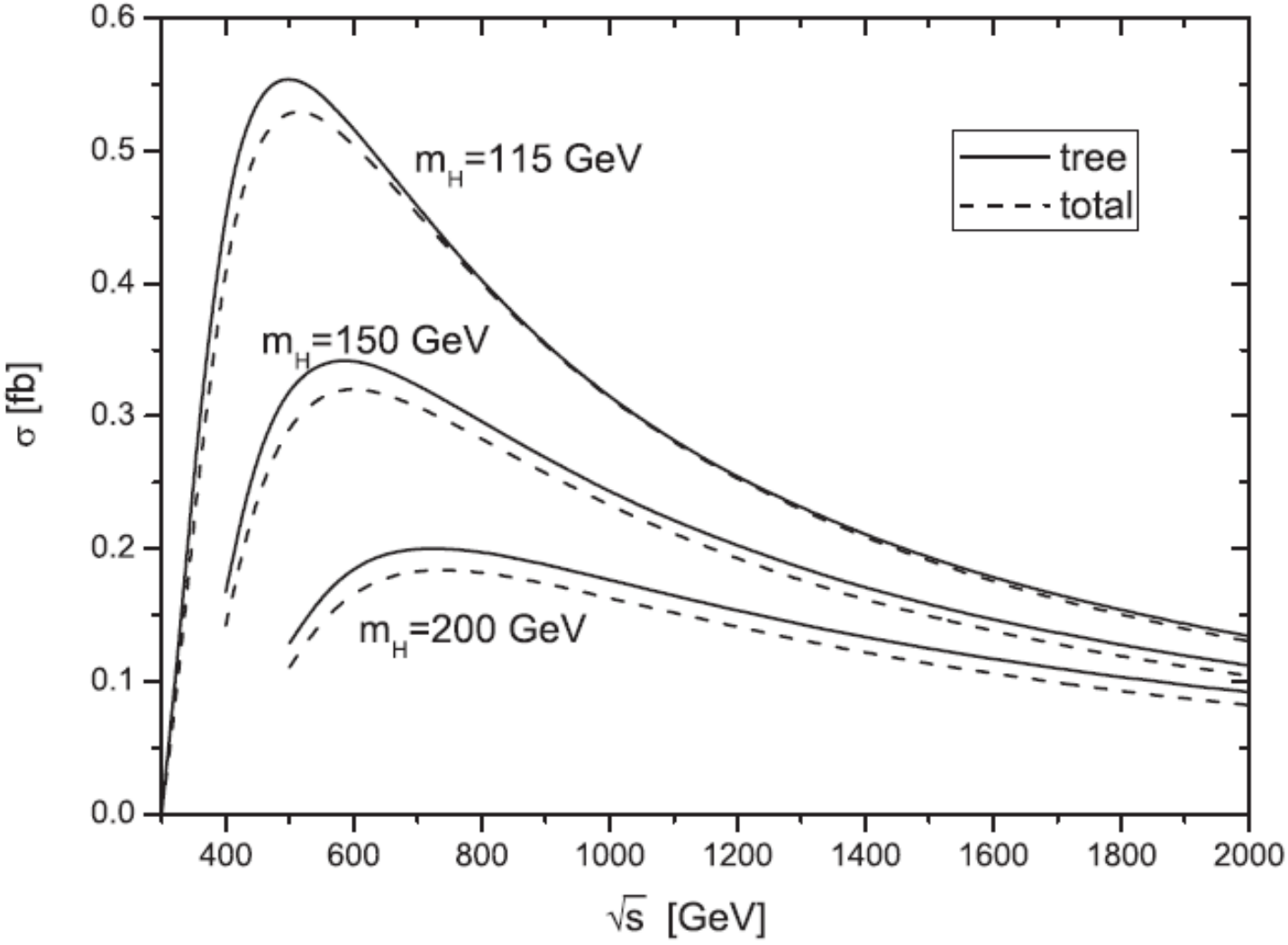
$\sqrt{s}$ (GeV)	M_H (GeV)	$\sigma_{\rm tree}$ (fb)	$\sigma_{\mathcal{O}(\alpha)}$ (fb)	$\delta_{\mathcal{O}(\alpha)}$ [%]
	115	*0.17493(2)*	*0.1629(2)*	*−6.9(1)*
		0.17491(2)	0.16282(2)	−6.91(1)
500	150	*0.071834(6)*	*0.06357(6)*	*−11.50(7)*
		0.071830(5)	0.063529(9)	−11.59(9)
	200	$0.49611(3)\cdot 10^{-3}$	$0.3329(2)\cdot 10^{-3}$	*−32.90(4)*
		$0.49606(4)\cdot 10^{-3}$	$0.332(3)\cdot 10^{-3}$	−33.0(6)
	115	*0.14156(3)*	*0.1471(3)*	*+3.9(2)*
		0.14155(1)	0.14705(2)	+3.89(1)
800	150	*0.11363(2)*	*0.1135(2)*	*−0.1(2)*
		0.11362(1)	0.11353(1)	−0.08(7)
	200	*0.07246(1)*	*0.0705(1)*	*−2.7(1)*
		0.072454(7)	0.07044(1)	−2.78(1)
	115	*0.07119(2)*	*0.0704(3)*	*−1.1(4)*
		0.07118(1)	0.07058(2)	−0.85(3)
1500	150	*0.06684(2)*	*0.0634(2)*	*−5.1(3)*
		0.06683(1)	0.06359(2)	−4.86(3)
	200	*0.06165(1)*	*0.0569(2)*	*−7.7(3)*
		0.061644(6)	0.05707(2)	−7.42(3)
	115	*0.05021(1)*	*0.0473(2)*	*−5.8(4)*
		0.05021(1)	0.04773(2)	−4.95(4)
2000	150	*0.04812(1)*	*0.0435(2)*	*−9.6(4)*
		0.048119(5)	0.04387(3)	−8.83(7)
	200	*0.04630(1)*	*0.0408(2)*	*−11.9(4)*
		0.046300(4)	0.04115(3)	−11.13(6)

EW corrections to $e^+e^- \to ZZH$

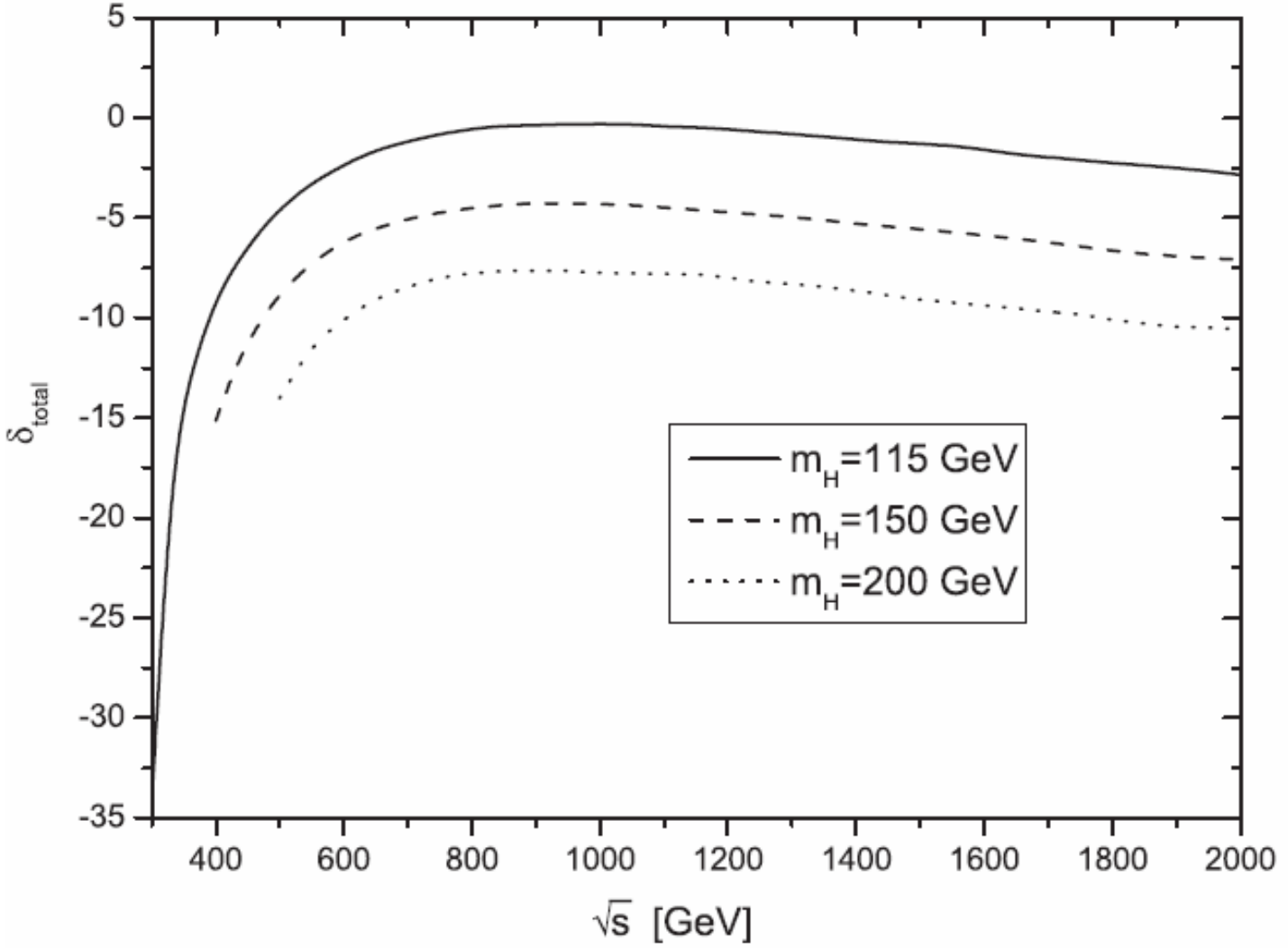
hep-ph/0604127

- Be useful to probe Higgs coupling to Z bosons
- Test the quadri-linear couplings (such as g_{HZZZ} $g_{H\gamma ZZ}$) which do not exist at tree-level in SM
- Could be potential backgrounds for new physics

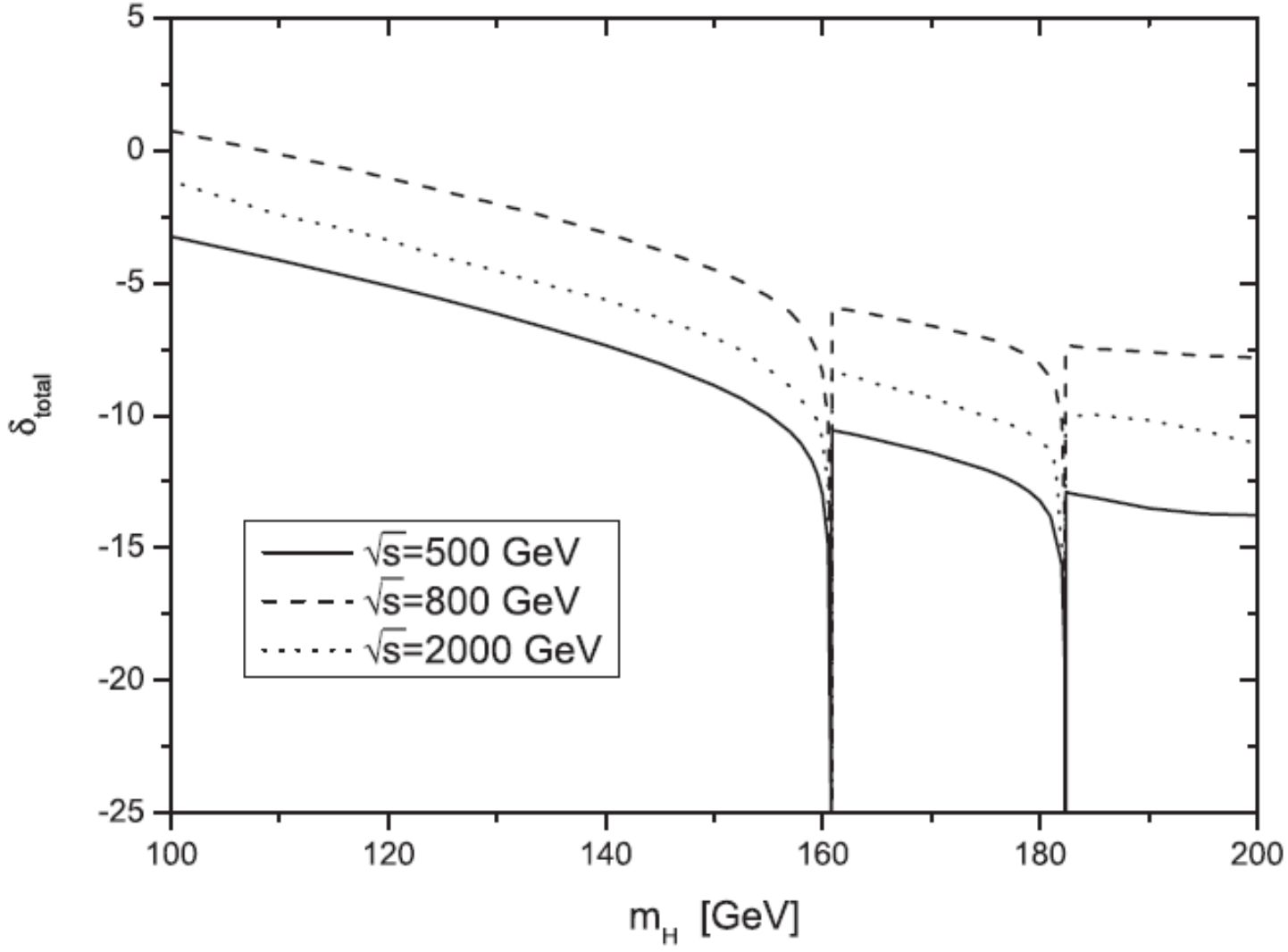
Results to $e^+e^- \to ZZH$



Results (continue)



Results (continue)



Summary

- Higgs properties can be determined with high accuracy at the ILC
- Theoretical predictions of the cross sections for Higgs production at the ILC within per-cent accuracy are necessary
- We calculated the NLO EW corrections to the cross sections for $e^+e^- \to t\bar{t}h^0, HHZ, ZZH$
- The relative corrections are significant: from several % to a few 10% depending on collide energy, Higgs mass and other parameters

Thank you!