1-loop effects of MSSM particles in Higgs productions at the ILC

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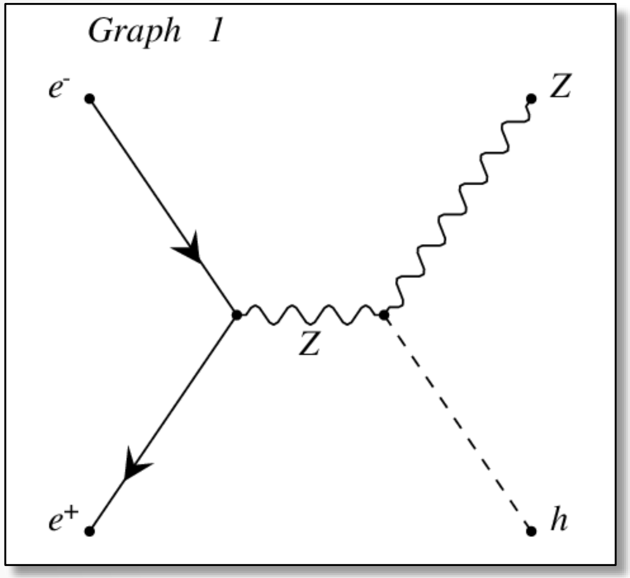
SEIKEI

OUTLINE

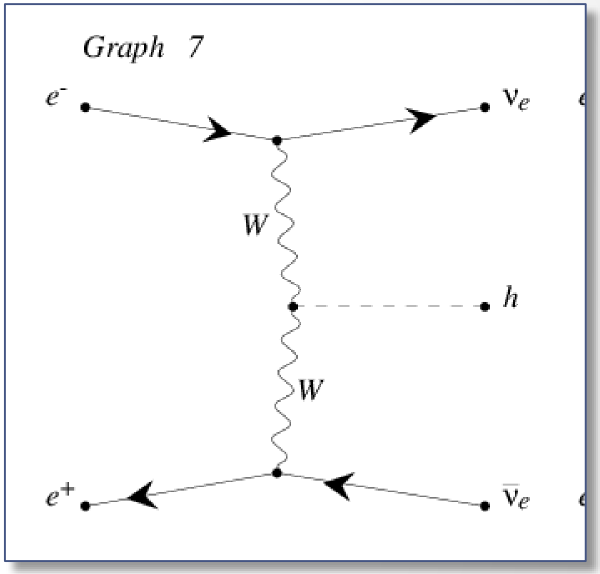
- Introduction(What)
- How(GRACE/SUSY)
- Results
- Summary

Introduction

SUSY indirect detection in Higgs production at the ILC

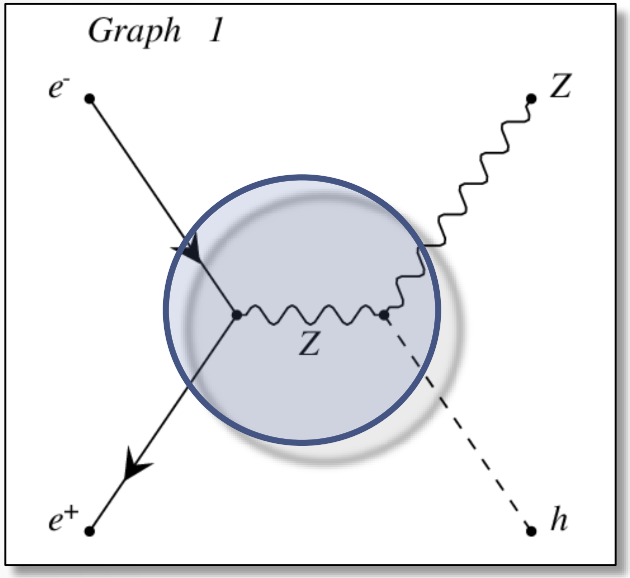


Zh production

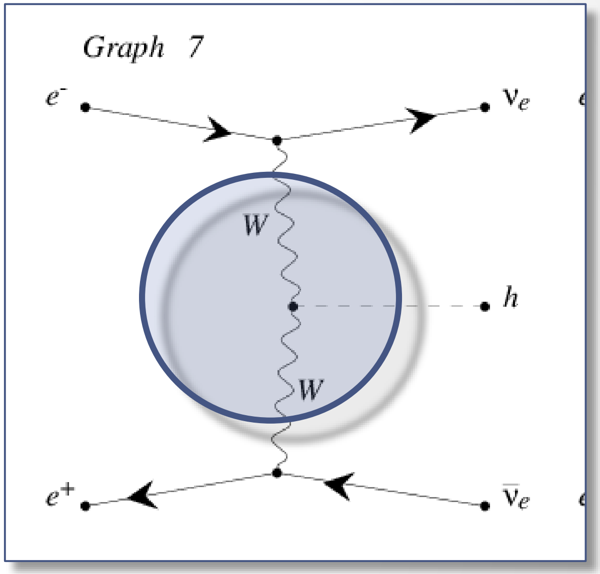


W fusion

SUSY indirect detection in Higgs production at the ILC



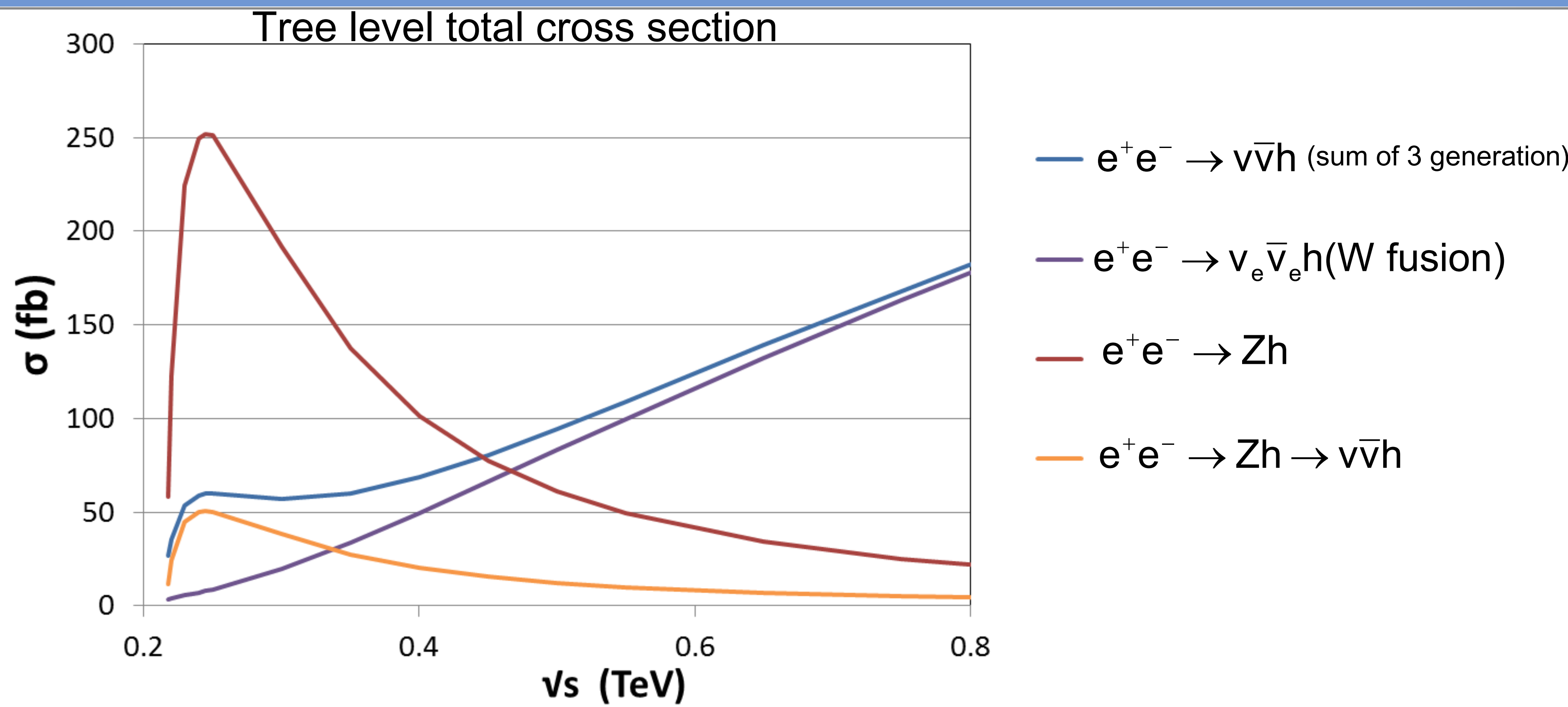
Zh production



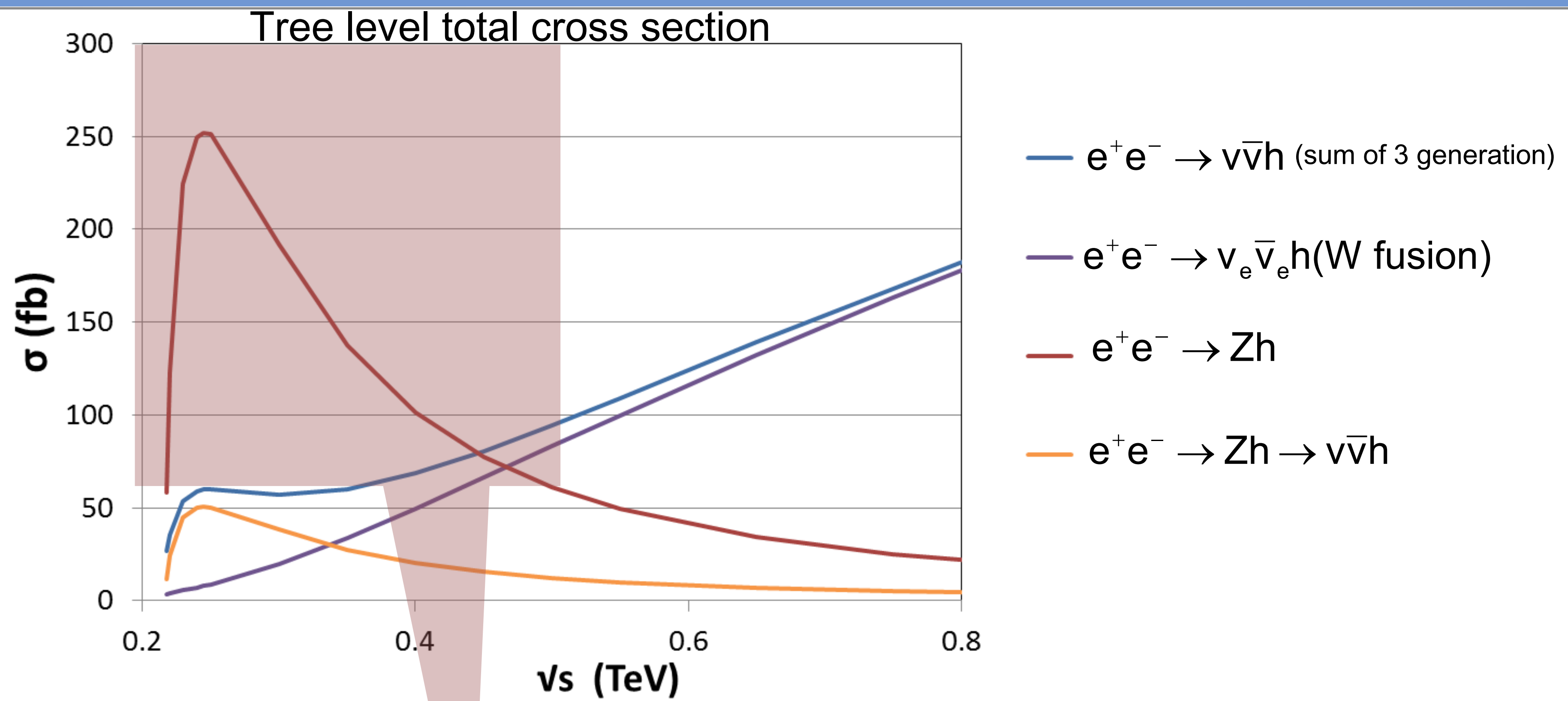
W fusion

Is the 1-loop effect of virtual MSSM particles statistically significant ?

SUSY indirect detection in Higgs production at the ILC

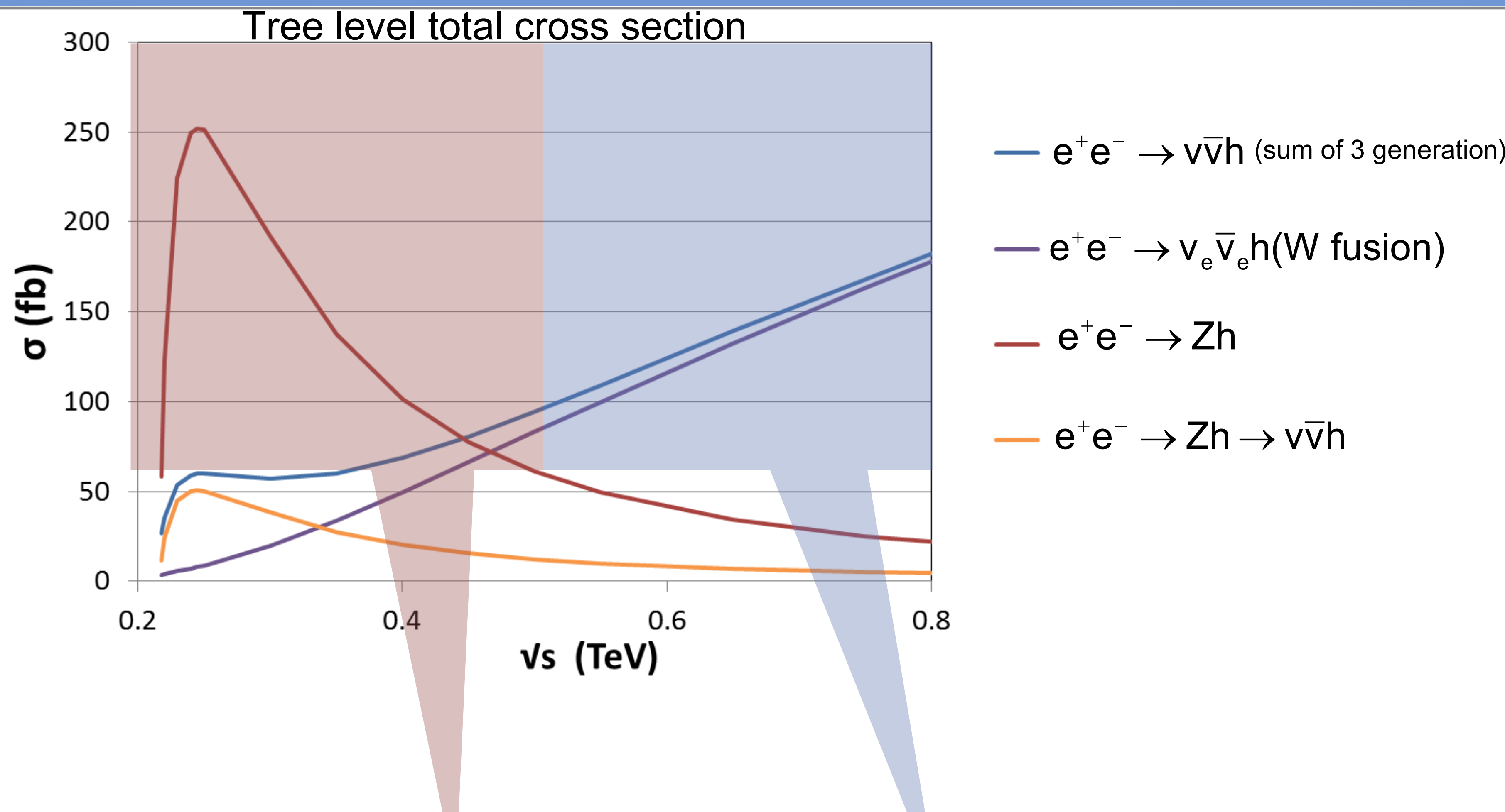


SUSY indirect detection in Higgs production at the ILC



The cross section of Zh
is large at low energy region

SUSY indirect detection in Higgs production at the ILC



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The cross section of $\nu\bar{\nu}h$ is large at high energy region

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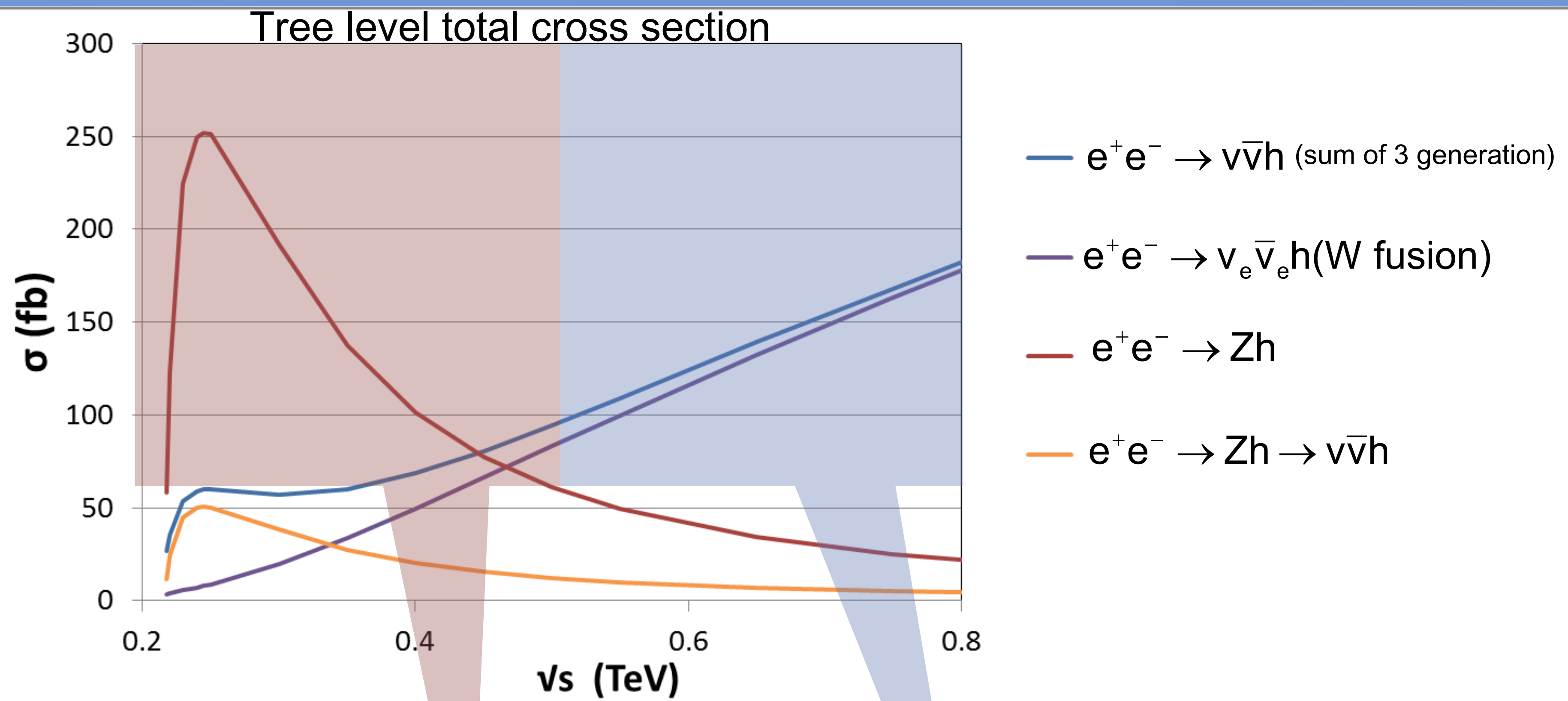

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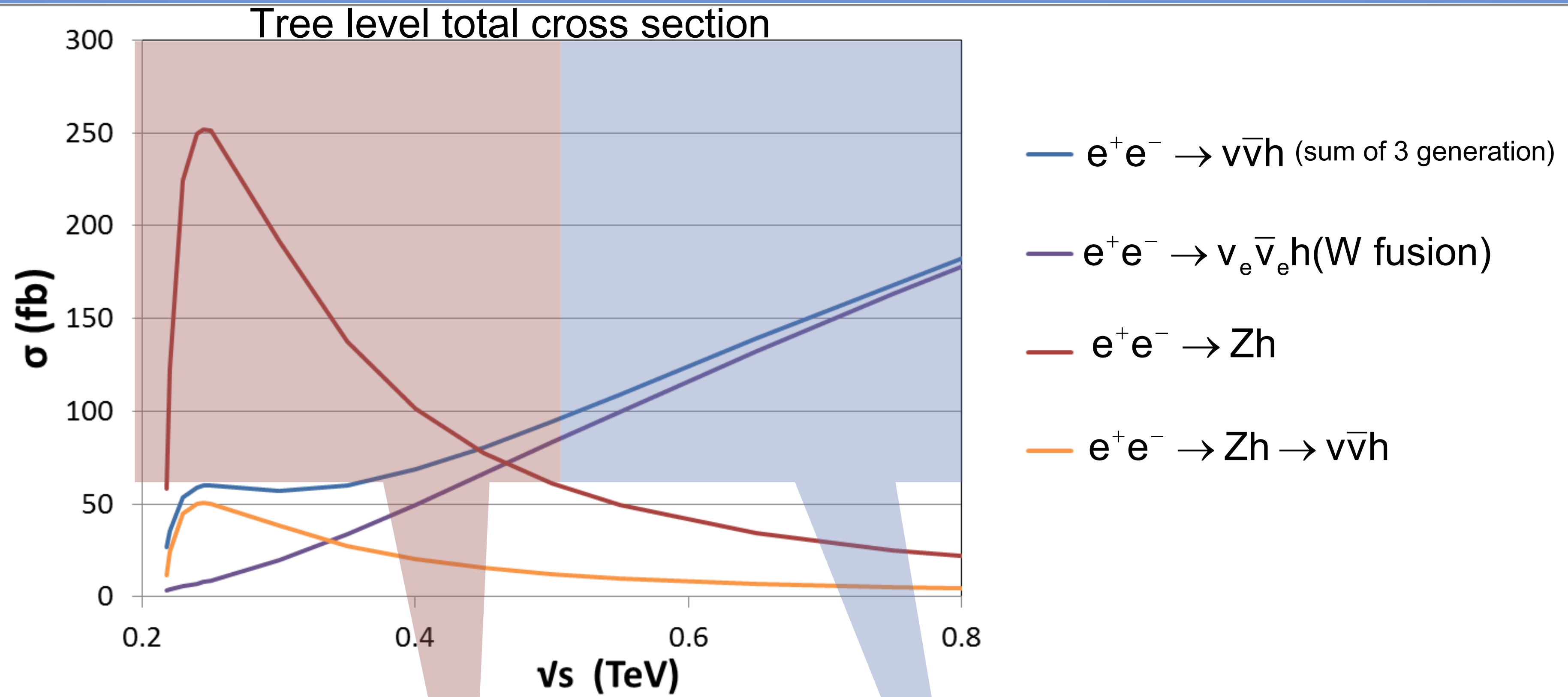
The accurate measurement of SM Higgs is expected

SUSY indirect detection in Higgs production at the ILC



The cross section of Zh is large at low energy region

The cross section of $\nu\bar{\nu}h$ is large at high energy region

The accurate measurement of SM Higgs is expected

At the same time, We want to focus on the effect of MSSM

Selection of sets (Zh)

we have taken into account

- Higgs mass ($m_h(exp)=125.09 \pm 0.24$ GeV)
- B physics constraint ($b \to s\gamma, B_s \to \mu\mu$)
- muon g-2 constraint $a_\mu(exp) - a_\mu(SM) = (25.9 \pm 8.1) \times 10^{-10}$

SuSpect2 (A.Djouadi, J.Kneur and G.Moultaka)

- DM thermal relic density (Planck data of Ωh^2)

micrOMEGAs (G. Belanger, F. Boudjema, A. Pukhov, A. Semenov)

- LHC direct search of sparticles

	light stop $\cong$ 300GeV	heavy stop $\cong$ 1000GeV
The DM abundance is explained by Co-annihilation of stau and LSP	set 1	set 2
The DM abundance is explained by Co-annihilation of stop and LSP	set 3	inconsistent with muon g-2 (LSP is too heavy)

arxiv:1609.07868[hep-ph] Y. Kouda, T. Kon, Y. Kurihara, T. Ishikawa, M. Jimbo, K. Kato and M. Kuroda

Selection of sets (W fusion)

Signal	higgs + missing

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

MSSM $e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 h$

(This study does not focus on this)

We have selected the set neutralino pair is not produced.

$(\tilde{\chi}_1^0 \geq 500\mathrm{GeV})$

We pay attention to the case

"only the effects of virtual MSSM particles are statistical significant"

the set (W fusion)

Higgs (consistent with the observed mass)

ElectroWeak particles
(Only these contribution
don't explain muon g-2)

QCD particles

set 10			
h	H	A	H^+
125.2	2000	2000	2002
$\tilde{\chi}_1^+$	$\tilde{\chi}_2^+$		
583.3	1376		
$\tilde{\chi}_1^0$	$\tilde{\chi}_2^0$	$\tilde{\chi}_3^0$	$\tilde{\chi}_4^0$
552.8	588.2	614.8	1376
$\tilde{\ell}_1$	$\tilde{\ell}_2$	$\tilde{\nu}_\ell$	
601.5	651.7	646.9	
$\tilde{\tau}_1$	$\tilde{\tau}_2$	$\tilde{\nu}_\tau$	
589.5	662.5	646.9	
$\tilde{u}_1$	$\tilde{u}_2$	$\tilde{d}_1$	$\tilde{d}_2$
5000	5000	4800	5000
$\tilde{t}_1$	$\tilde{t}_2$	$\tilde{b}_1$	$\tilde{b}_2$
1798	2508	2200	2501
θ_τ	θ_b	θ_t	
1.164	1.539	1.481	
M_1	M_2	M_3	
585.0	1370	2500	
μ=586, tan β=30			

- How(GRACE/SUSY)

(before and after the discovery of Higgs)

GRACE/SUSY

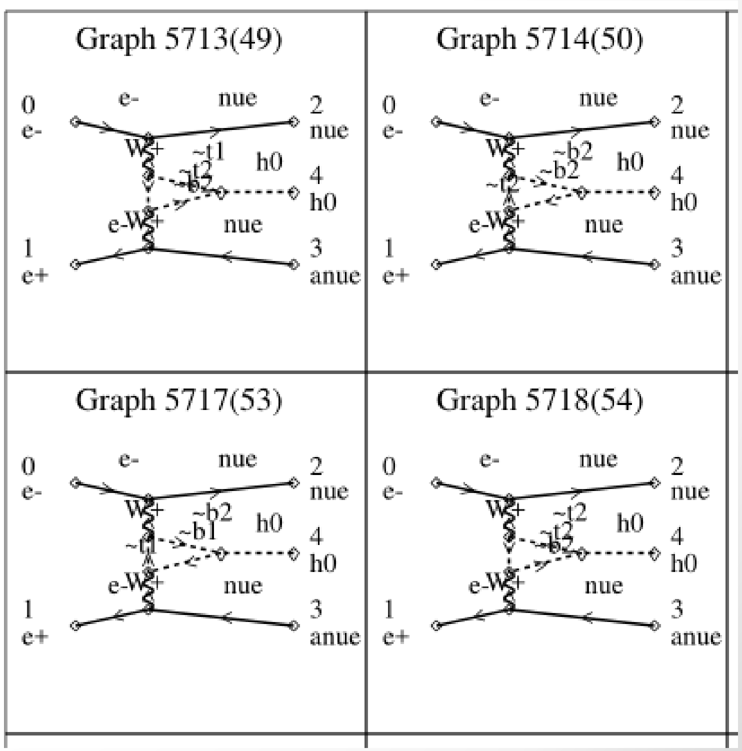
☆The system that can automatically calculate cross sections or decay widths in SM and MSSM

＊GRACE/SUSY [tree version (opened to public)]
Comput.Phys.Commun.153:106-134,2003 **download :** http://minami-home.kek.jp/

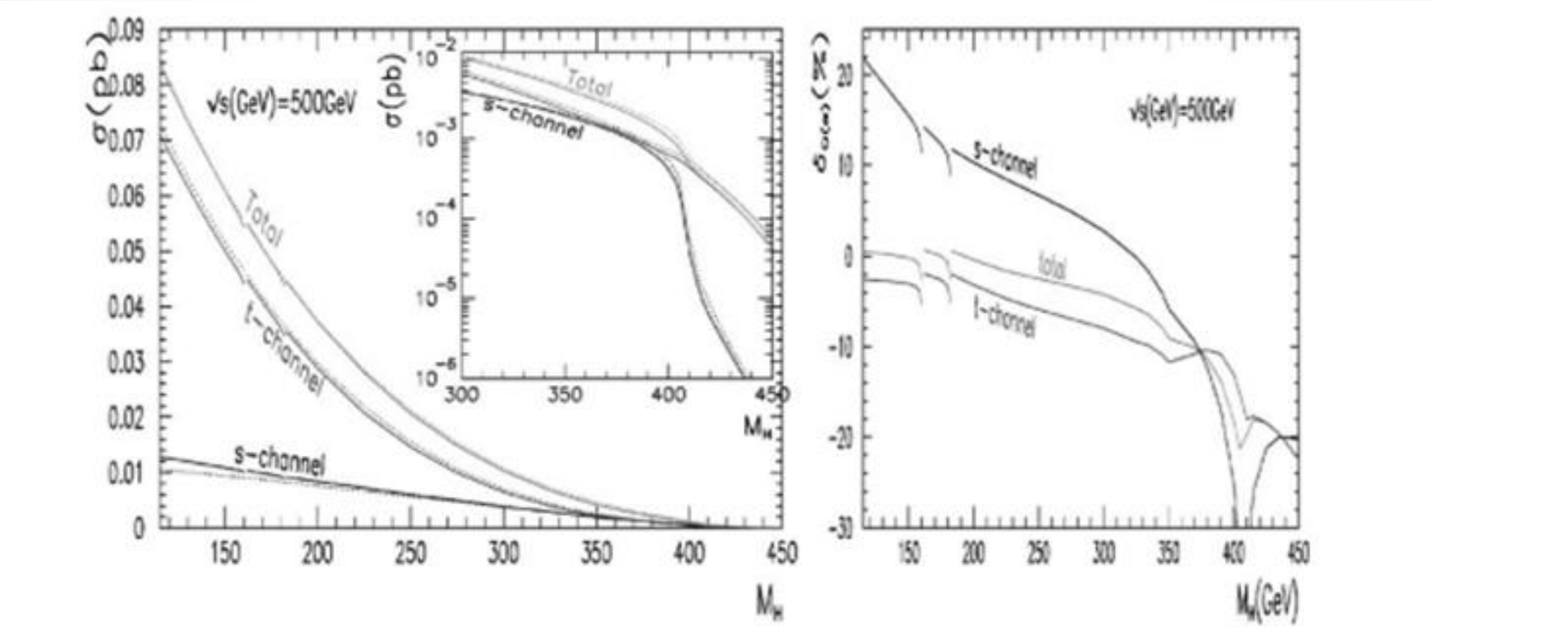
＊GRACE/SUSY-loop [1-loop version(unopened to public)]
Phys.Rev.D75:113002,2007

1. Feynman diagrams
2. Physical amplitudes
3. Phase space Integration
4. Event generation
5. Various Self-checks

We can check the validity of numerical calculation



GRACE (before the discovery of higgs)



SM full 1-loop correction of $e^+e^- \to \nu\bar{\nu}h$ have calculated with using GRACE in 2003

G. Bélanger , F. Boudjema , J. Fujimoto , T. Ishikawa , T. Kaneko, K. Kato, Y. Shimizu, Physics Letters B 559 (2003) 252–262

Denner et al., NPB660(2003)289

Before the discovery of Higgs,
GRACE have been used with Higgs mass as a free parameter.

- Higgs mass was final free parameter in SM.

GRACE (after the discovery of Higgs)

After the discovery of Higgs, GRACE is used with Higgs mass as a fixed parameter
for the search of MSSM that have many free parameters.
For example, in this way,

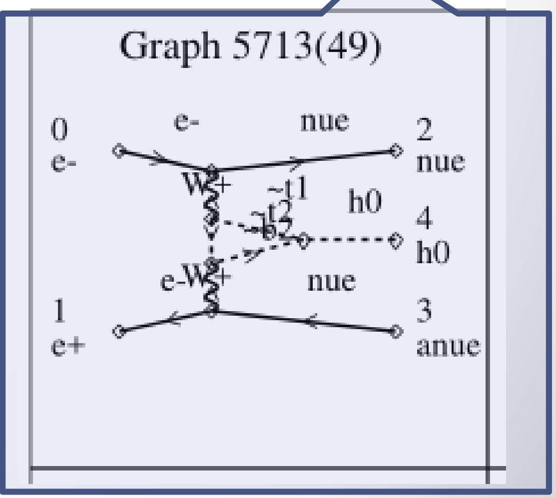
step1, we can generate all diagrams.

$e^+e^- \rightarrow \nu_e \bar{\nu}_e h$ full 1-loop MSSM diagrams・・・13793diagrams

step 2, we can select diagrams.

By selecting diagrams that WW fusion in internal line, they are reduced to 239 diagrams

step 3, we can check whether a renormalization works well.



we have confirmed(self- check)
the cancelation of ultraviolet or infrared divergence

and

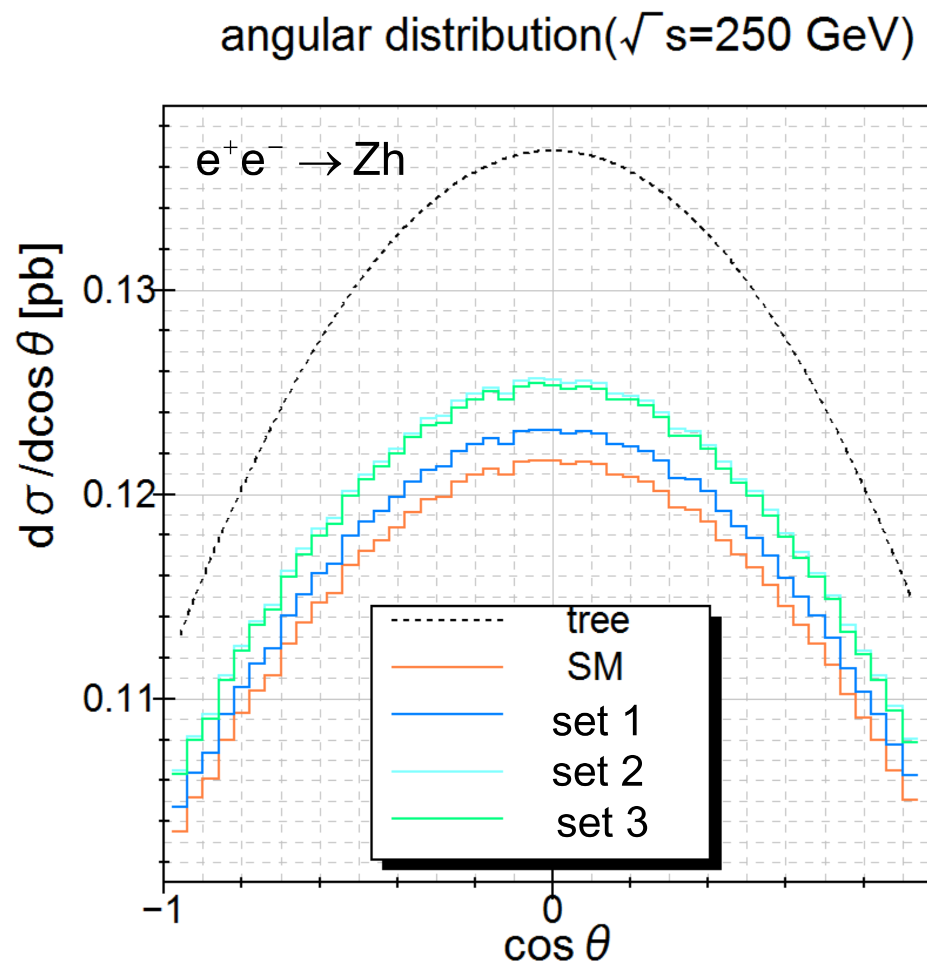
independence on the cut off energy between hard and soft photon

step 4, actual calculations

Results
(ZH,W fusion)

Angular distribution(1-loop level)

- θ is the Z generation angle.
- The 1-loop correction for the tree level is negative.
- The correction of MSSM for SM is positive.



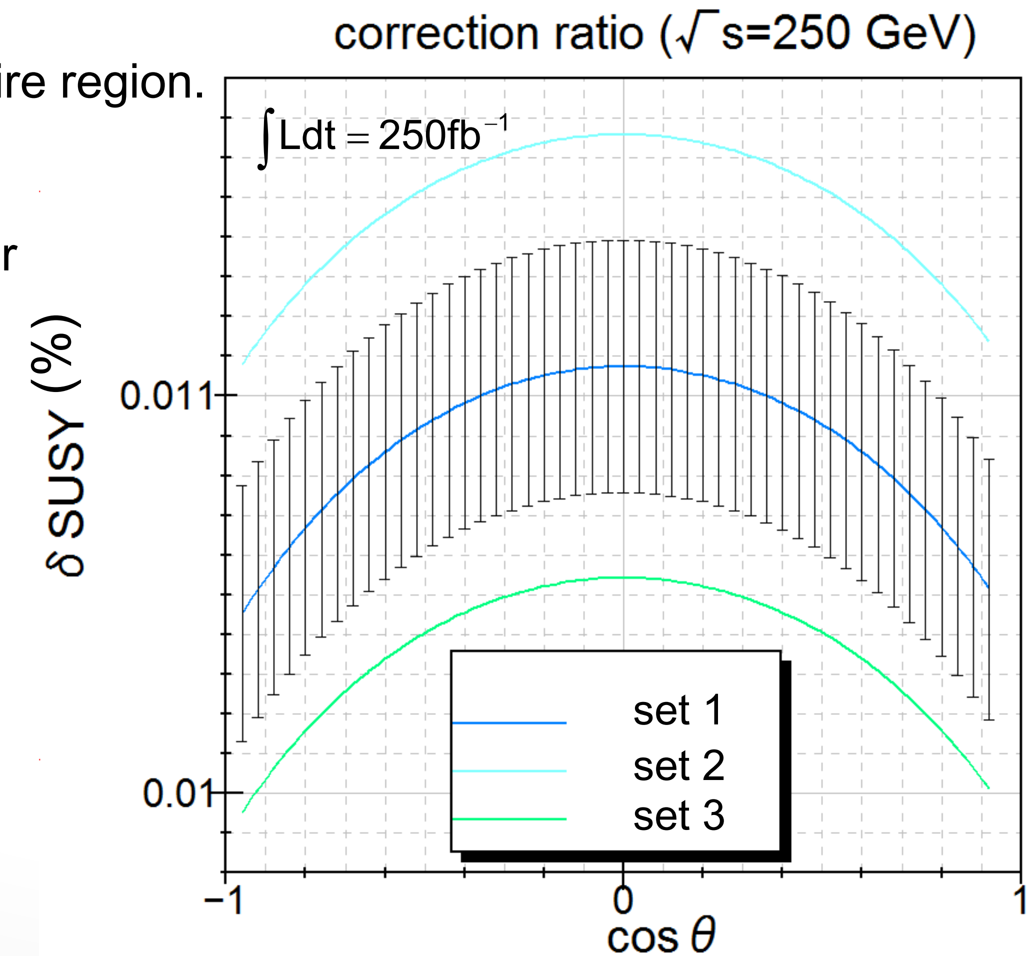
MSSM 1-loop effect

- We have defined the correction ratio δ
- We have compared with the statistical error (assumed the luminosity that planed in the ILC).

H.baer et al,
The International Linear Collider Technical Design Report - Volume 2: Physics (2013)

$$\delta_{SUSY} = \frac{\frac{d\sigma_{SUSY\,1\text{-}loop}}{d\cos\theta} - \frac{d\sigma_{SM}}{d\cos\theta}}{\frac{d\sigma_{tree}}{d\cos\theta}}$$

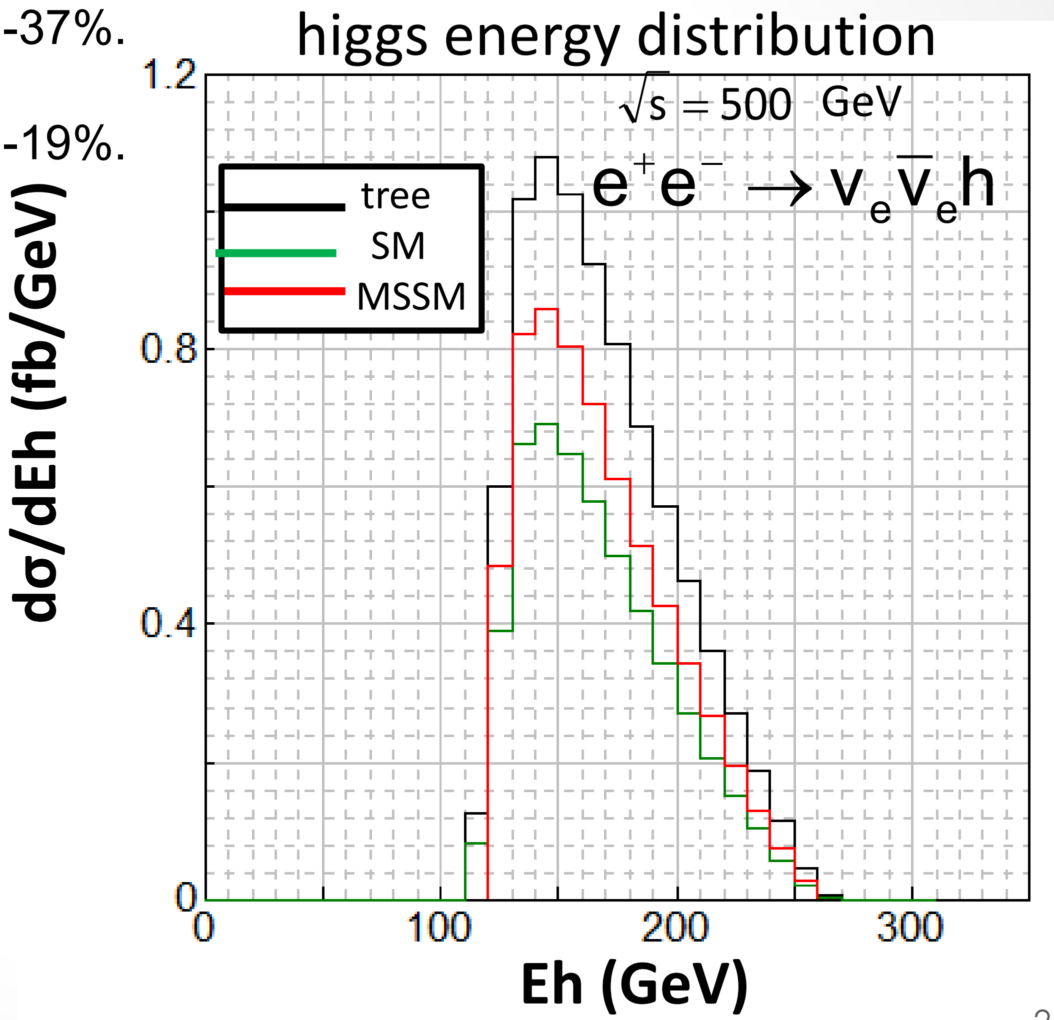
- The 1-loop effect is 11% in the entire region.
- The 1-loop effect for SM is larger than the error.
- The difference among sets is larger than the error.



Energy distribution (1-loop level)

- 1-loop correction for the tree level is negative.
- MSSM correction for SM is positive.
- The correction of SM total cross section for the tree level is -37%.
- The correction of MSSM total cross section for the tree level is -19%.

preliminary

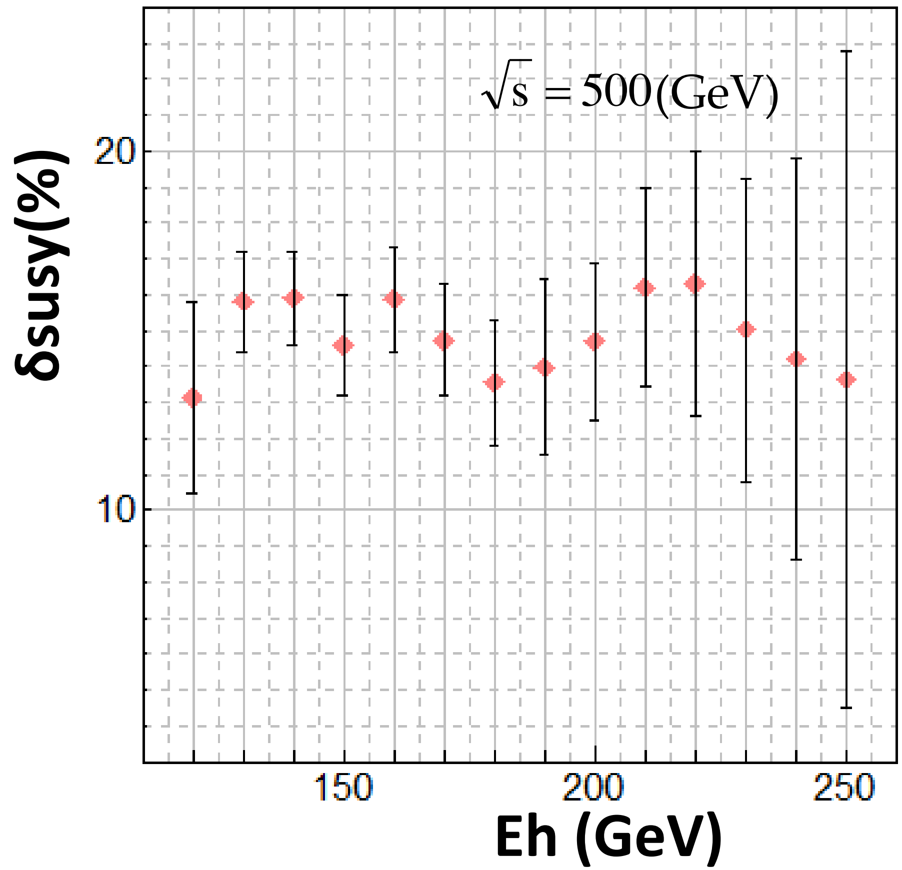


MSSM 1-loop effect

- We have defined the correction ratio δ.
- We have compaired with Monte Carlo integration error.
- The correction ratio is 15% in the entire region.
- The 1 loop effect is larger than the error.

$$\delta_{SUSY} = \frac{\dfrac{d\sigma_{SUSY1-loop}}{dE_h} - \dfrac{d\sigma_{SM}}{dE_h}}{\dfrac{d\sigma_{tree}}{dE_h}}$$

preliminary



summary

summary

- We select sets that consistent with Higgs mass, B physics, DM relic density, LHC direct search of sparticles, and muon g-2(in Zh)
- We have probed statistical significance at the ILC.
- In W fusion calculation, We have considered a set neutralino is not produced, and investigate whether only one loop effect is statistically significant.

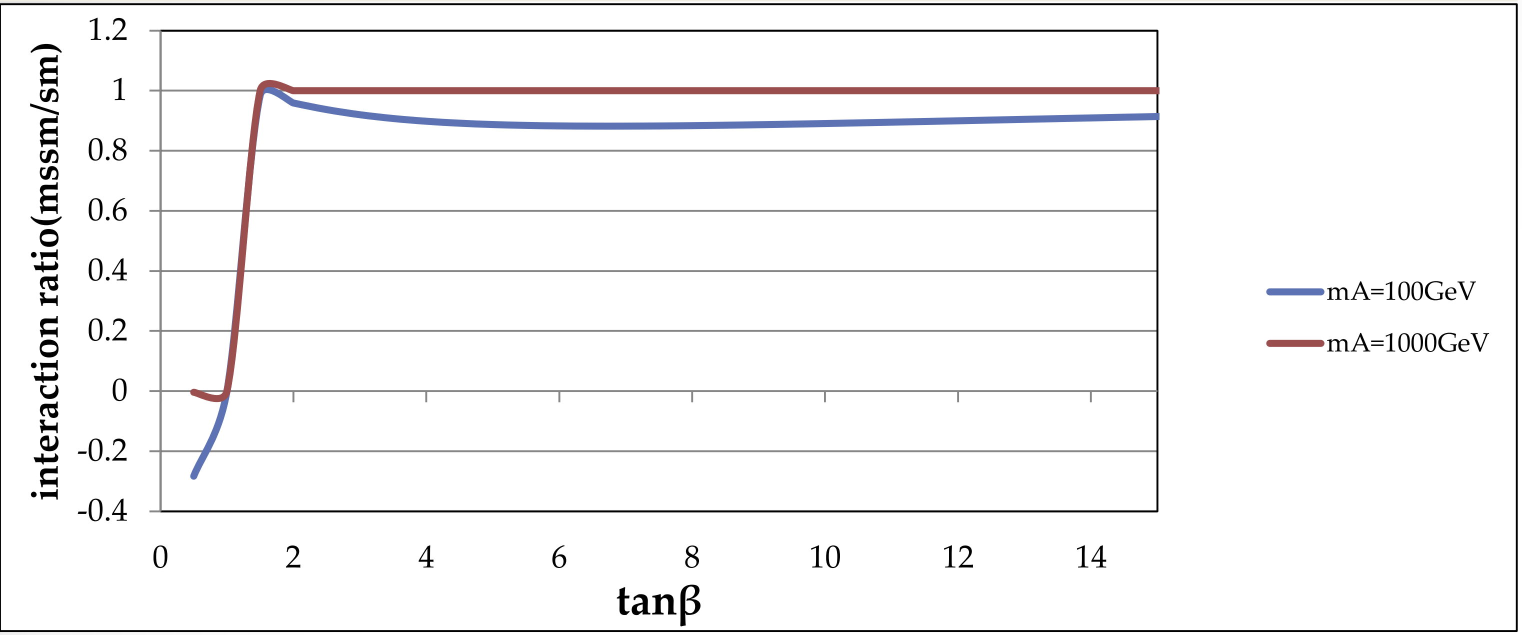
conclusion

GRACE/SUSY is very Useful for the search of MSSM particles!!

back up

Higgs–Gauge-boson–Gauge-boson

$$L = +gM_W[\cos(\alpha-\beta)H^0 - \sin(\alpha-\beta)h^0]W^+_\mu W^{-\mu} + \frac{g_Z}{2}M_Z[\cos(\alpha-\beta)H^0 - \sin(\alpha-\beta)h^0]Z_\mu Z^\mu.$$



$$d\sigma^{M,G}_{L\&S}(k_c) \equiv d\sigma^{M,G}_{virtual} + d\sigma^{G}_{soft}$$

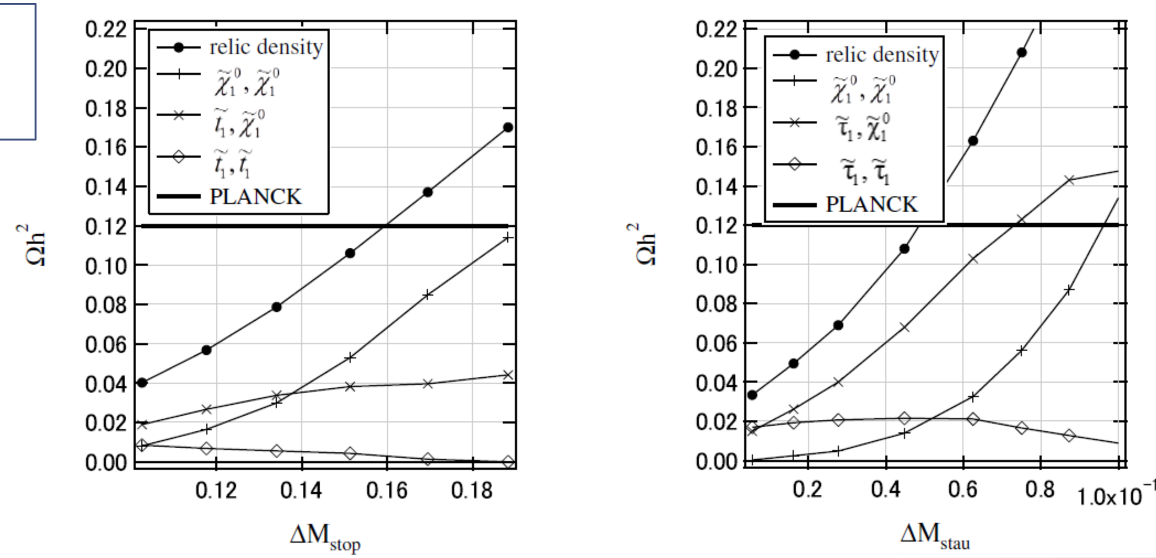
← The part compared in the δsusy

$$d\sigma^{M,G}_{1loop} \equiv d\sigma_{tree} + d\sigma_{L\&S}(k_c)^{M,G} + \int_{k_c} \frac{d\sigma^{G}_{hard}}{dE_\gamma} dE_\gamma$$

canceled each other, because they are common in SM and MSSM

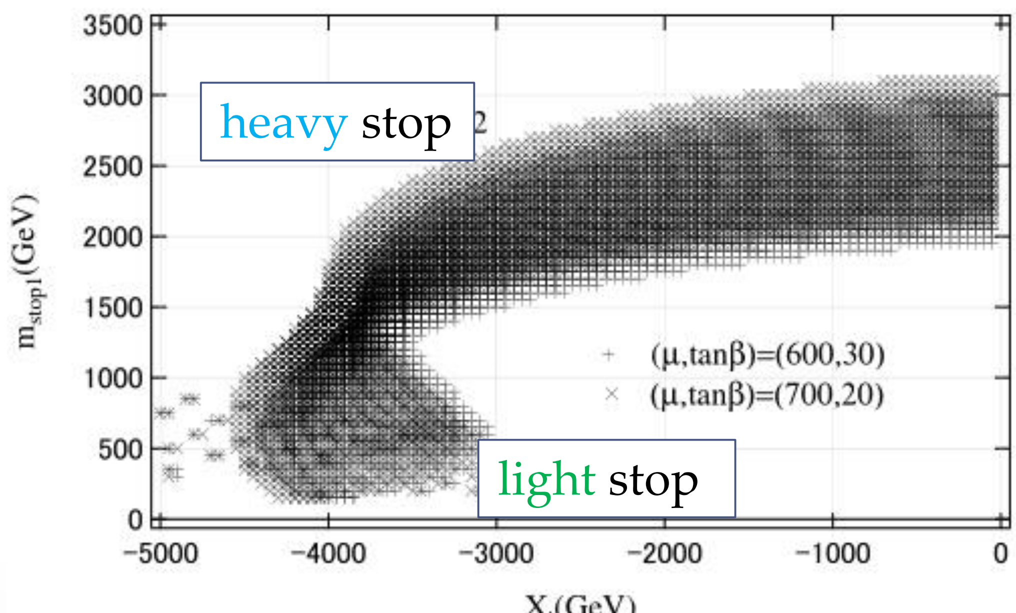
Classification of sets

Sfermion co-annihilation scenario in Bino Dark Matter



micrOMEGAs (G. Belanger, F. Boudjema, A. Pukhov, A. Semenov)

Stop that consistent with Higgs mass



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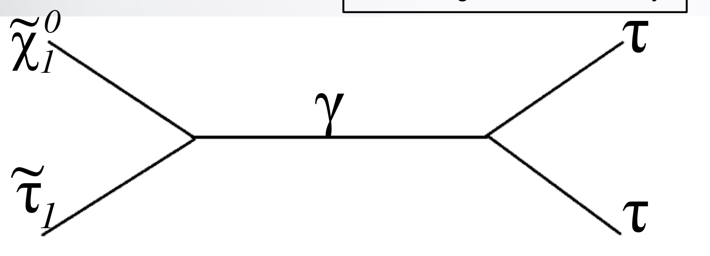
- DM thermal relic density — (Planck data of Ωh^2)
- LHC direct search of sparticles

Our sets have almost pure Bino DM
(No mix with Higgsino or Wino)

Then, the stop1 or the stau1 mass
are constrained
(sfermion co-annihilation scenario)

G. Bélanger LAPTH-Annecy



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