Measurement of the top Yukawa coupling near ttbar threshold

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Aim of this talk

- Set up a goal of theory calculations to measure top Yukawa coupling near top threshold
  - SM case
  - Susy case(SPS scenarios)
- Review of current theory status, and further improvement for y_t measurement

Plan of talk

- Motivation
- M_t and y_t measurement near tt-threshold
- Corrections; QCD /EW/ Susy
- Toward y_t measurement
  - Theory accuracy and y_t measurement
  - Renormalization group improvement
- Summary

Motivation

- Top quark is the heaviest fundamental, but still not well-studied.
- Measurement of top quark mass and its coupling with Higgs boson(s) are very important step to reveal EWSB.

$$m_t \doteq 170[\mathrm{GeV}] \sim M_W, M_Z \sim \langle \varphi \rangle_{EWSB}$$

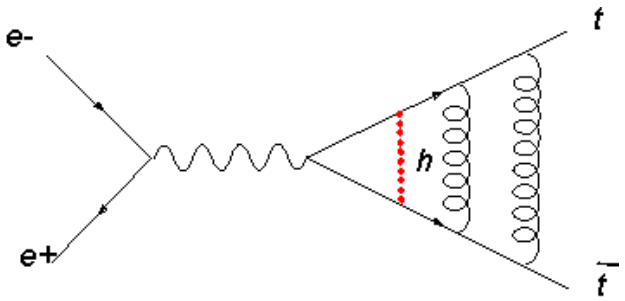
- Top threshold (~ 350GeV) is one of important programs at ILC for both of m_t and y_t measurements.

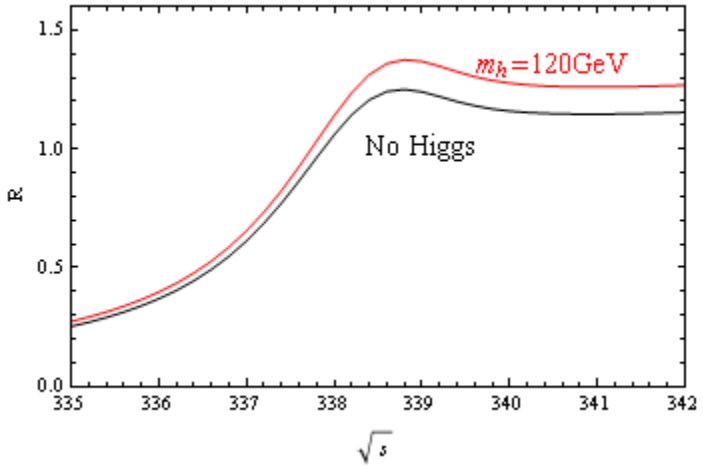
⟷ y_t from ttH@500GeV

m_t ,y_t measurements near top threshold

- Threshold scan around tt-resonance

Fadin-Khoze, Strassler-Peskin(1991), Fujii-Matsui-Sumino(1994), ...





- SM Higgs contribution with m_h =120(200)GeV
  - 1-loop: +6(3)% to |R| Grzadkowski-Kuhn-Krawczyk-Stuart(1992)
  - h+QCD: +3(1)% to |R| (δE=-50(20)MeV) Eiras-Steinhauser(2006)

- SM Higgs contribution to $|R_{tt}|$ is 9 (4) % for m_h =120(200)GeV.

Our theory precision should be better that this!

If we can achieve 4(2)% accuracy for R_{tt} we will have a possibility to see the effect!

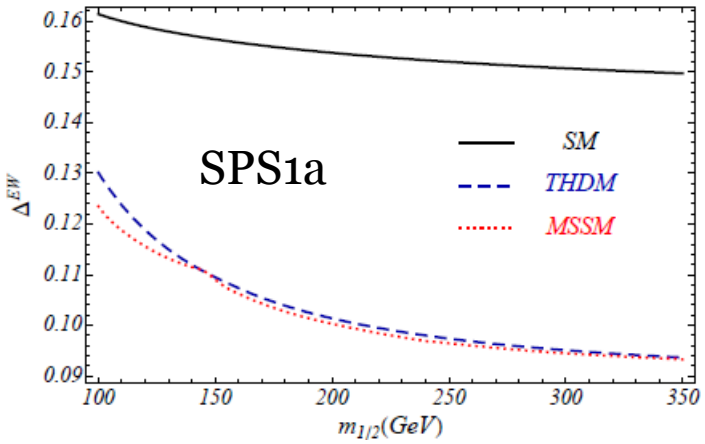
Corr to R_{tt} in SUSY SPS scenarios

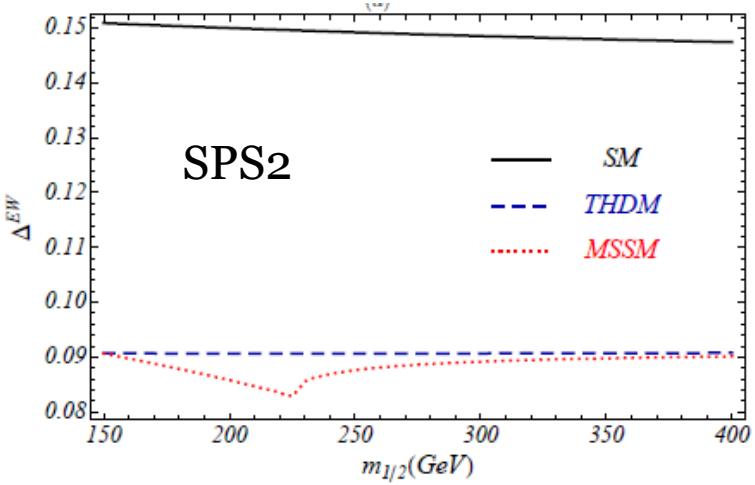
	SPS1a	SPS1a'	SPS1b	SPS2	SPS3	SPS4	SPS5
$\Delta^{\text{SM EW}}$	0.152	0.151	0.149	0.149	0.149	0.150	0.149
$\Delta^{\text{THDM EW}}$	0.097	0.096	0.093	0.091	0.093	0.099	0.094
$\Delta^{\text{MSSM EW}}$	0.096	0.096	0.093	0.089	0.093	0.101	0.094

$$\Delta \equiv \delta R_{tt} \; / \; R_{tt}^{LO}$$

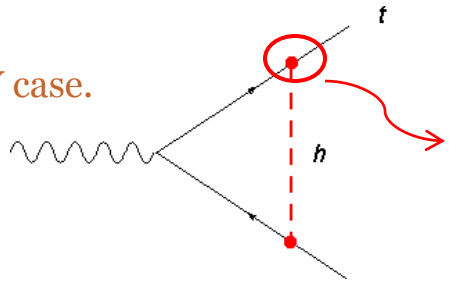
YK-Steinhauser-Zerf(2009)

For SM/THDM(typeII) mass and coupling parameters are taken to be same with corresponding case of MSSM(SPS scenearios) to make a comparison.





- Top yukawa coupling get reduced in SUSY case.
- Sparticle contributions are small.



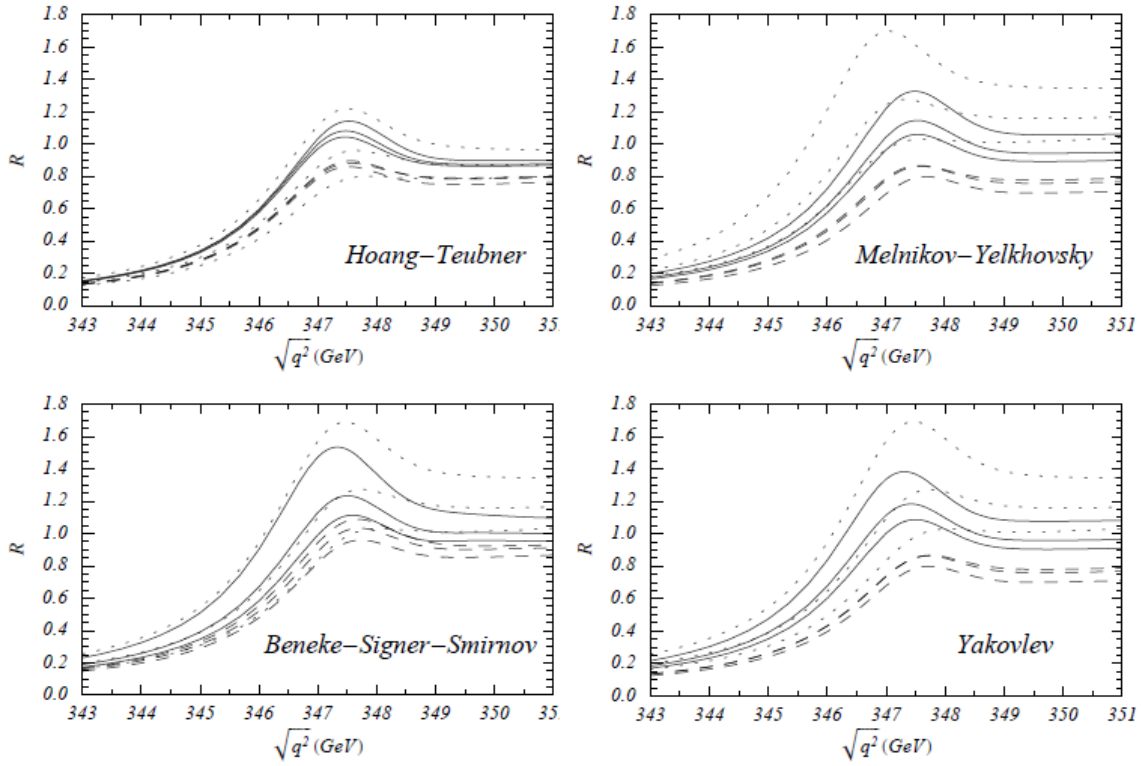
$$\left(\frac{em_t}{2s_W M_W}\right)\frac{\cos\alpha}{\sin\beta}$$

- In case of SPS SUSY scenarios the Higgs exchange contribution to $|R_{tt}|$ get reduced by 5% at one-loop (2-loop 2%?) compared to SM

Almost complete screening of higgs effect.

Nevertheless, it is important to check theory consistency!

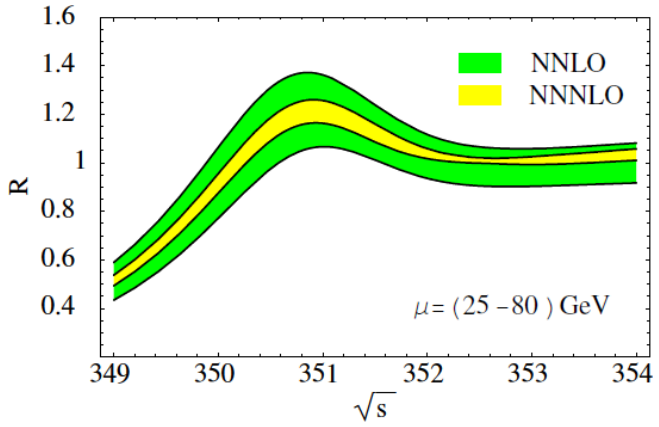
Top threshold in 2000



Can we still have a hope for y_t measurement ?

Toward 4% theory calculation for y_t measurement

- We want to go a 4% accuracy (at least) in loop calculations.
  - 1-loop (xQCD) is probably enough for EW and new physics
  - QCD is currently NNNLO'/NNLL' , for which theory accuracy does not meet our goal yet.



Beneke-YK-Schuller(2008)

•NNNLO result still miss c3, a three-loop matching coefficient.
•We can still improve the NNNLO' with RG-method

List of Known Corrections

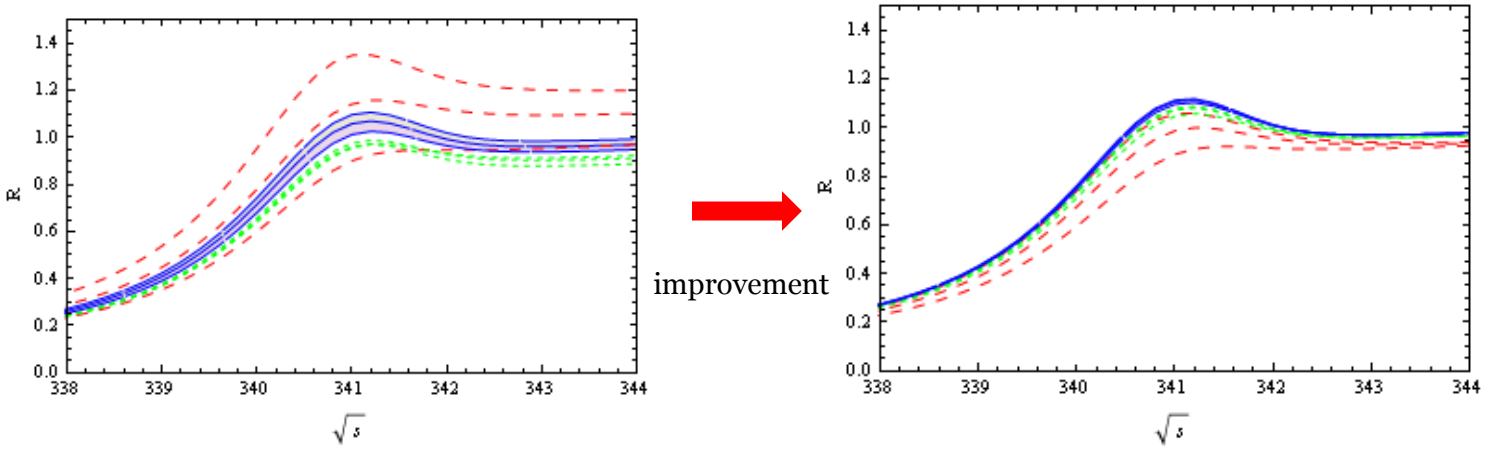
- QCD Source of large theory uncertainty even today(NNNLO)
  - NNLO TopWGR(2000); Hoang-Teubner, Melnikov-Yelkhovsky, Penin-Pipovarov, Beneke-Signer-Smirnov, Yakovlev, Nagano-Ota-Sumino
  - NNNLO'/NNLL' Beneke-YK-Penin-Schuller(2008), Maquard-Piclum-Seidel-Steinhauser(2006)/Hoang-Manohar-Stewart-Teubner(2001), Pineda-Signer(2006)
- EW
  - EW 1-loop Grzadkowski-Kuhn-Krawczyk-Stuart(1987), Hoang-Reisser(2006)
  - Higgs/Z-gluon 2-loop Eiras-Steinhauser(2006)
  - W-gluon 2-loop vertex YK-Seidel-Steinhauser(2008)
  - unstable top effect(t -> bW) Hoang-Reisser-Femenia(2010)
- Susy/THDM
  - 1-loop Hollik-Schappacher(1999), Su-Wise(2001), YK-Steinhauser-Zerf(2009) /Denner-Guth-Kuhn(1992)

RG improvement for threshold XSection

- Threshold enhancement is due to Coulomb resummation

RG improved potential to reach high accuracy

- Below RG improvement is applied to QCD static potential.
  (In the plots below we neglected other corrections as a first study)



$M_{t,PS}$ =170GeV, LO(Red)/NLO(Green)/NNLO(Blue) for μ=20, 30, 40GeV

Summary

- SM case Higgs contribution is $6_{\text{tree}} + 3_{\text{1-loop}} = 9\%$
  (known from '80 at 1-loop and 2-loop by Eiras-Steinhauser 2006)
- We observed almost complete screening of Higgs contribution in SPS SUSY scenarios

Achieve (at least) 4% theory precision! Thus current NNNLO'/NNLL' calculations still needs improvements.

- As a first step we applied RG improvement to QCD static potential and obtained significant reduction of scale uncertainty as well as better convergence in perturbation series. (Still need studies and efforts to apply RG to all the corrections)

Hope a possibility of y_t measument near ttbar threshold!

Short cut

- Subscript : press two keys (ctr, +)
- Superscript: press three keys (ctr, shift, +)
- Go back to normal: (Shift, space)