Physics Benchmarks for the DBD

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Keisuke Fujii

The Panel Members

- Keisuke Fujii (KEK)
- Klaus Desch (Bonn)
- Andrei Nomerotski (Oxford)
- Tim Barklow (SLAC)
- Franco Bedeschi (Pisa)
- Aurore Savoy-Navarro (Paris)
- Stewart Boogert (Rutherford)
- Seong Youl Choi (Chonbuk)
- Youanning Gao (Tinghua)
- Michael Peskin (SLAC) : Chair
- Georg Weiglein (Durham)
- Jae Yu (Texas-Arlington)

Previous (=Before Beijing) New Physics Benchmarks

Benchmark Objectives

- To evaluate detector performance at 1 TeV
  --> Category 1 benchmarks:
- To respond early discoveries at the LHC
  --> Category 2 benchmarks:
- to demonstrate ILC capabilities of precision Higgs analysis for mH=120 GeV
  --> Category 3 benchmarks:

1st Category: 1 TeV benchmark reactions for detector evaluation

1. e+e- -> nunubarH with H->bbbar for mH=200GeV: X-section x BR
   --> Stress on endcap region + PFA
2. e+e- -> ttbarH followed by H->WW/ZZ for mh=200GeV: X-section x BR
   --> 10 jets --> jet overlaps and combinatorics + PFA + flavor tagging
3. e+e- -> tau+tau-: A_FB & Pol(tau)
   --> Stress on tracking and calorimeter granularity
4. e+e- -> bbbar, ccbar: X-section & A_FB
   --> Heavy flavor tagging and tracking in a narrow jets
5. e+e- -> nunubar+WW,ZZ: X-section
   --> W/Z separation --> well known benchmark for PFA performance

Notice that 1, 2, 3, and 4 overlap with the 2nd category (Early LHC discovery scenarios) discussed already

2nd Category: Early discovery scenarios at LHC

1.a 200GeV SM Higgs: e+e- -> nunubarH with H->bbbar & ttbarH @ 1TeV
  --> top/bottom Yukawa couplings to the Higgs

2.a 1.5TeV Z': e+e- -> ffbar (f=tau,b,c) @500GeV & @1TeV
  --> A_FB, X-section, Pol(tau) for both Pol(e)

3.a ttbar resonances at 1-1.5TeV: e+e- -> ttbar @ 500GeV
  --> A_FB, X-section
      for both Pol(e)
  --> 4 form factors

$$\delta\mathcal{L} = eA_\mu \bar{t}[\gamma^\mu P_L F_{1AL}(Q^2) + \gamma_m u P_R F_{1AR}(Q^2)t + \frac{e}{c_w s_w} Z_\mu \bar{t}[\gamma^\mu P_L F_{1ZL}(Q^2) + \gamma^\mu P_R F_{1ZR}(Q^2)]t$$

4.a "stable" stau NLSP (GMSB): e+e- -> stau+stau-,se1+se1-,chichi
  --> LHC can learn much in this, What te ILC can add?

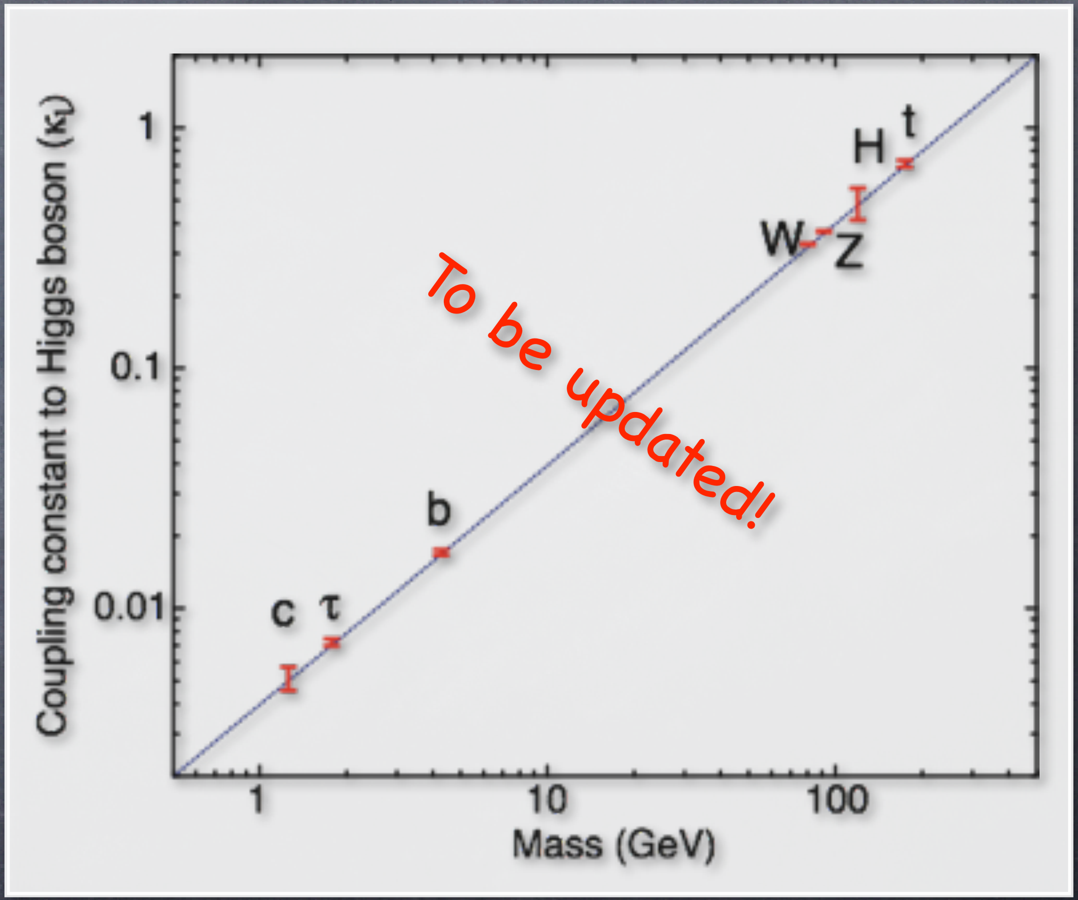
Nicely presented by Michael's Alburqueque talk

Notice that 1 and 2 overlap with the 1st category (1 TeV benchmarks)

3rd Category: precision Higgs analysis

- H coupling measurements for mH=120GeV
  - e+e- -> ZH with H -> ffbar, VV(*) f=b, c, tau; V=g, A, W, Z @ 230GeV:
    --> Estimate the ILC's ultimate precision on these BRs
  - ZHH @ Ecm=500GeV:
    --> triple Higgs self-coupling

Our goal is to update this figure of coupling vs mass measurements



Then came The IDAG's Request

for a short more focused list to demonstrate that the LOI detectors can operate without major modifications at 1 TeV

The IDAG suggested

- e+e- -> t tbar H @ 1 TeV
- e+e- -> W+ W- @ 1 TeV

5th Physics Panel Meeting on Apr. 27, 2010

Discussed how to make the short list

Agreed that
 the list should

- focus on issues which really need full simulation such as b-tagging in complex multi-jet topology, PFA performance, missing E response at 1 TeV
- and at the same be interesting as physics studies

Agreed that
 it is important for the LOI groups

- to look at other processes in fast simulation and cooperate to clarify and bolster the ILC physics case

Revised New Physics Benchmarks

Benchmark Objectives

- To test aspects of the detectors and of the machine parameters that were not addressed in the original LOI studies.
  --> Class 1 benchmarks:
  - to be done individually by the both LOI groups
  - with full simulations
- To consolidate the ILC physics case by demonstrating more precise estimates of the ILC capabilities.
  --> Class 2 benchmarks:
  - to be done collectively by the two groups together
  - with fast simulations informed by the existing full simulation results

Class 1 Benchmarks

to test the detector aspects not yet tested

With full simulation to be done individually by the two LOI groups

1. e+e- -> nu nubar H, H -> b bbar and mu+mu- @ 1TeV with mH=120 GeV
   - to measure X-section x BR(H->bbbar)
   - replaces IDAG's W+W- @ 1TeV to address the forward jets,
2. e+e- -> t tbar H, H -> b bbar @ 1TeV with mH=120 GeV
   - to measure the top Yukawa coupling to the Higgs
   - mH=120 GeV instead of the previous 200GeV (10-jet analysis is overkill)
   - Common BG sample only up to 8 partons
3. e+e- -> Z H, H -> bbbar, ccbar, gg @ 350GeV with mH=120GeV
   - to measure BR(H->bbbar), BR(H->ccbar), BR(H->gg)
   - to assess SB2009

- 1 TeV performance, forward tracking/calorimetry/mu ID; wide rapidity coverage
- b-tag, missing E; complex multi-jet events at 1 TeV
- PFA and heavy quark tagging capabilities in a boosted system

Class 2 Benchmarks

to consolidate the ILC physics case

With fast simulation (tuned to reproduce the currently available full-simulation results) to be done collectively by the two groups to be presented in the ILC TDR

- Precision Higgs Studies
  - to demonstrate the ILC capabilities to assemble the complete phenomenological profile of the Higgs boson in a way that cannot be done at hadron colliders (model-indep. determination of the Higgs coupling)
  - at Mh=120 and 200 GeV
- Particles from Beyond the Standard Model
  - to respond in a timely fashion to possible early discoveries at the LHC running at 7 TeV

Precision Higgs Studies

Model-independent determination of the Higgs couplings

1. e+e- -> Z H, H -> WW/ZZ @ 500 GeV with mH=200 GeV
   - to measure BR
2. e+e- -> Z H @ 230 GeV and @ 350 GeV with mH=120 GeV
   - to measure BRs for H->bbbar, ccbar, gg, WW*, ZZ*, tau+tau-, gamma gamma
3. e+e- -> nu nubar H @ 1 TeV with mH=200 GeV (120 GeV in class 1)
   - to measure BR(H->bbbar)
4. e+e- -> t tbar H @ 1 TeV with mH=200 GeV (120 GeV in class 1)
   - to measure the top Yukawa coupling to the Higgs
5. e+e- -> Z H H, nu nubar H @ 500 GeV and 1 TeV with mH=120 GeV
   - to measure the triple Higgs self-coupling

- to optimize Ecm to do the precision Higgs studies

1. e+e- -> Z H with mH=120 GeV @ 230 - 400 GeV
   - to measure total X-section from observation of the recoil Z
   - to determine the systematic dependence on the machine E & parameters.

Particles from BSM

To respond timely to early discoveries from the LHC at 7TeV

1. a Z' w/ a mass < 2TeV: e+e- -> ffbar (f=tau,b,c) @500GeV & @1TeV
   --> A_FB, X-section, Pol(tau) for both Pol(e) -> Z'couplings to f

2. a ttbar resonances at 1-1.5TeV: e+e- -> ttbar @ 500GeV
   --> A_FB, X-section
   Pol(t)
   for both Pol(e)
   --> 4 form factors
   at Q^2=500GeV

$$\delta\mathcal{L} = eA_\mu \bar{t}[\gamma^\mu P_L F_{1AL}(Q^2) + \gamma_m u P_R F_{1AR}(Q^2)t + \frac{e}{c_w s_w} Z_\mu \bar{t}[\gamma^\mu P_L F_{1ZL}(Q^2) + \gamma^\mu P_R F_{1ZR}(Q^2)]t$$

3. a "stable(life>1sec)" stau NLSP (GMSB): e+e- -> stau+stau-, se1+se1-, chichi
   --> masses, quantum numbers, and couplings
   LHC can learn much in this, What the ILC can add?

My Personal View

It is widely accepted that the ILC can be approved only in the context of a discovery at the LHC. To certain extent I share this opinion, but I think there is no general consensus on what discovery is enough.

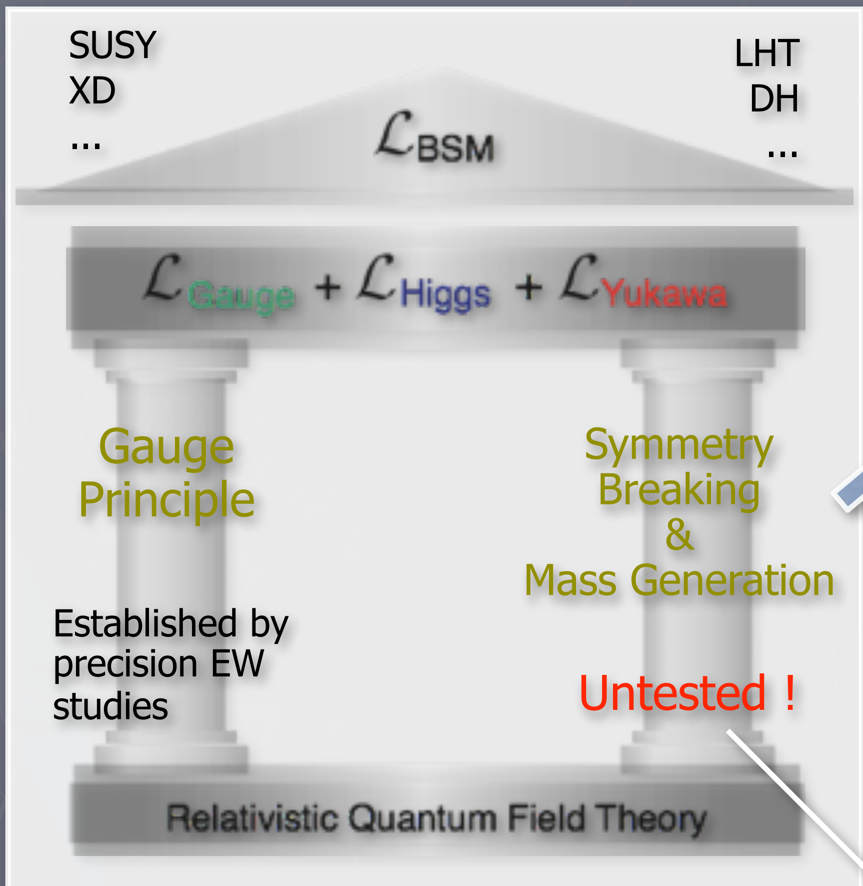
Is the Higgs boson enough or do we need something clearly beyond the standard model?

We may need to start discussing this in terms of the reduction of the initial cost of the ILC with possible staging options

Primary Goal

Discovery of New Fundamental Forces

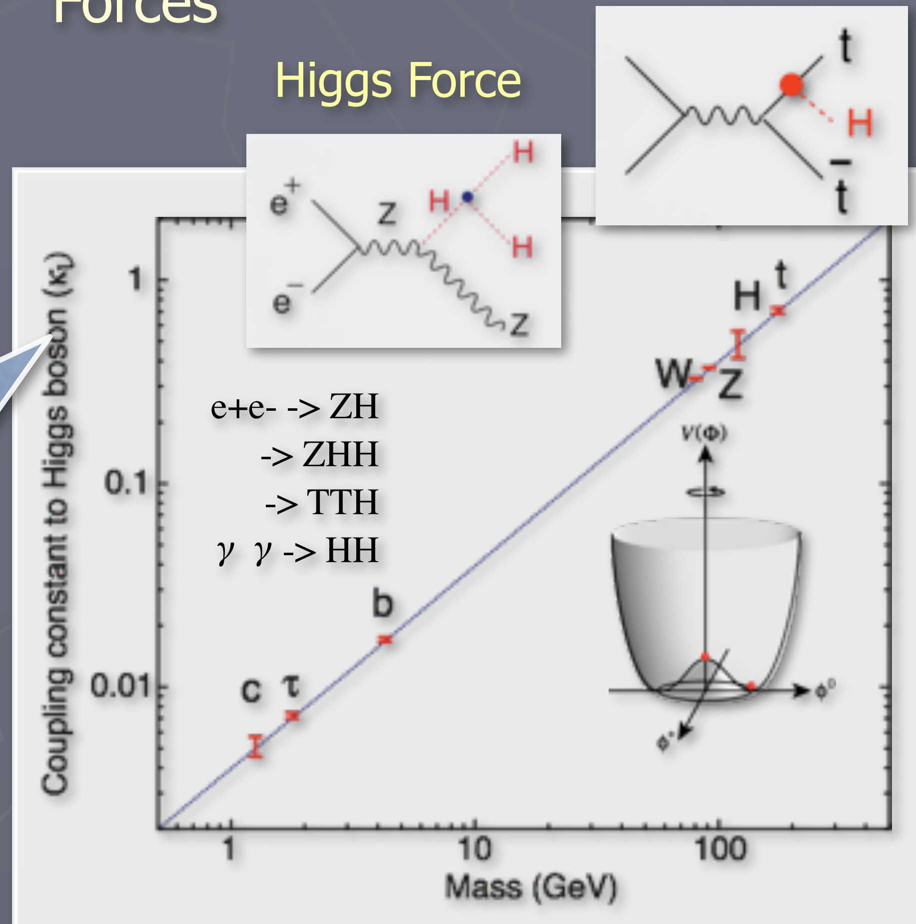
Two Main Pillars of the Standard Model



New Fundamental Forces

Higgs Force

Yukawa Force



We don’t know how firm it is!

First verify the 2nd pillar, then put the BSM roof!

My Answer to the Question

Is the Higgs boson enough or do we need something clearly beyond the standard model?

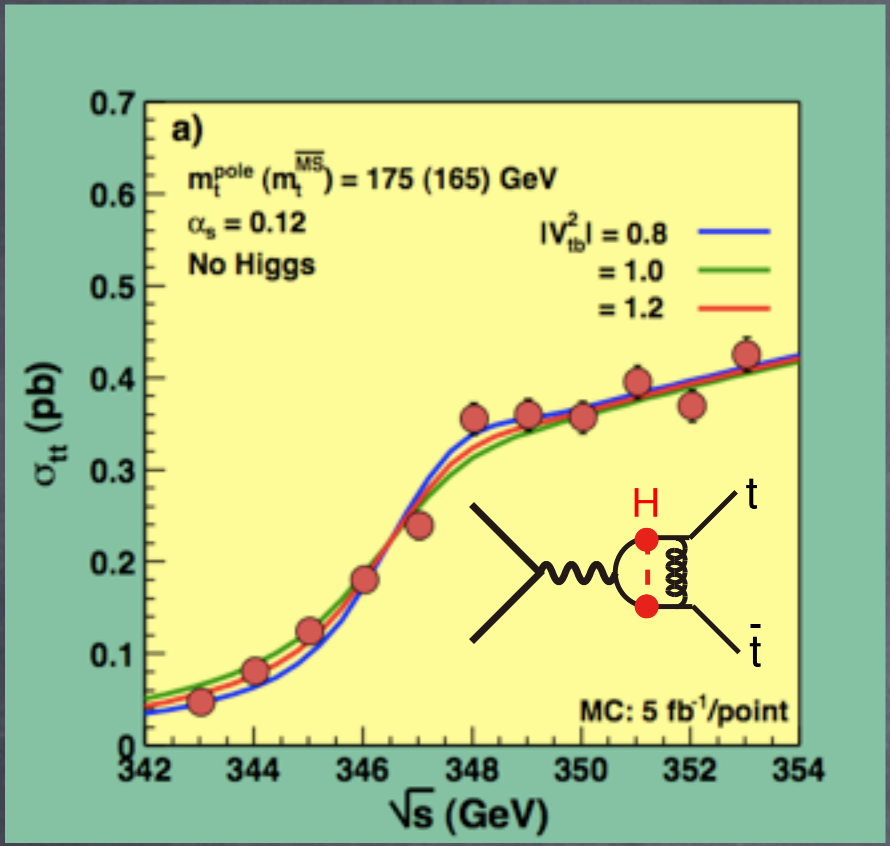
The Higgs boson is enough and, as Rolf said, if a light SUSY signal is discovered at the LHC in the current run we can assume that there is a light Higgs and hence we should start serious negotiations with our funding agencies for the budget to do the precision Higgs studies!

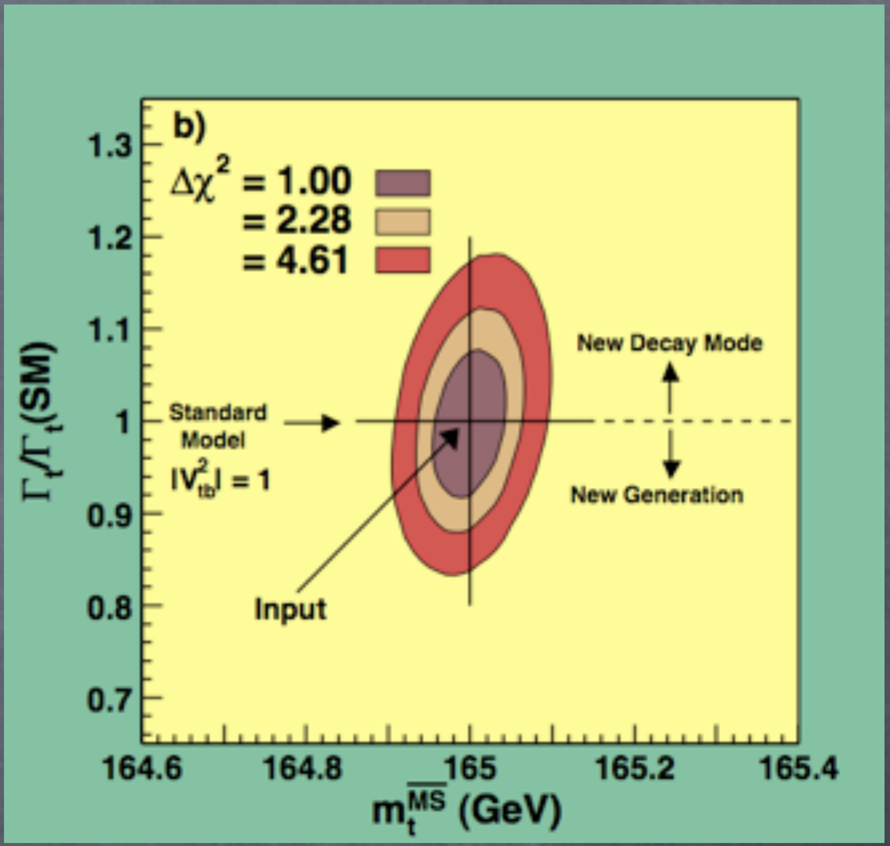
Well Known Thresholds

for ILC 500

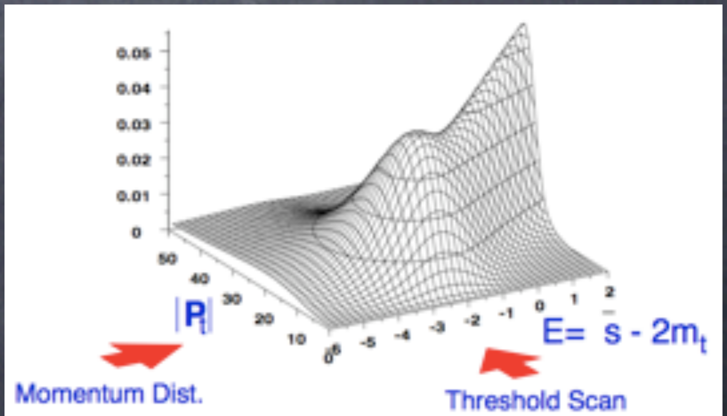
- ZH @ 230 GeV
  - mh, gamma_h, JCP
  - Gauge quantum numbers
  - absolute measurement of ZZH coupling (Recoil mass)
  - BR(h->VV,qq,ll,invisible) : V=W/Z(direct), g,A(loop)
- ttbar @ 340-350GeV <-- Solid Threshold
  - threshold scan
  - AFB, momentum distribution
  - Form factor measurements
- ZHH @ 500GeV
  - cross section peak at around 500GeV
- ttbarH @ 500GeV
  - Optimum at around 700GeV but QCD enhancement allows measurement concurrent to ZHH

TTbar Threshold





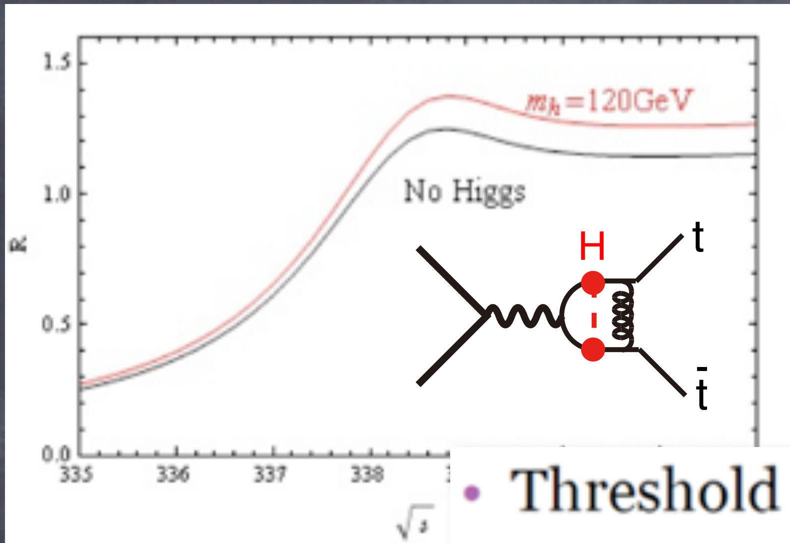
$$\Delta m_t \lesssim 100\,\mathrm{MeV}$$



Theoretical ambiguity of mt could be improved to < 50MeV in the future

Normalization ambiguity could also be significantly reduced in the future

Recent Improvement of Normalization



9% effect on the X-section

Normalization ambiguity due to the QCD enhancement has been an obstacle to do this measurement

Yuichiro Kiyo
@ LCWS10

Use of the RG improved potential can significantly improve the situation!

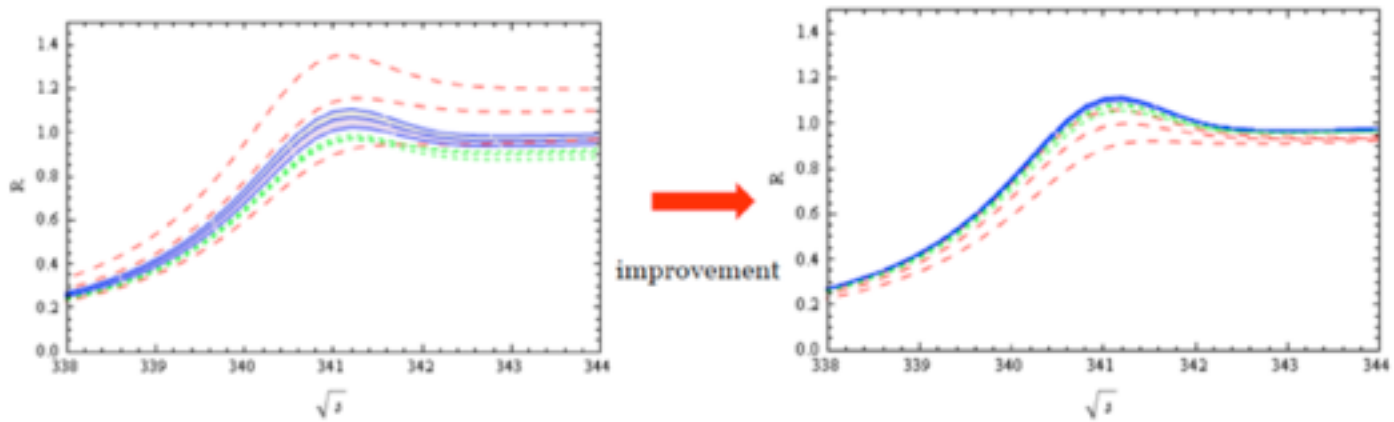
Still preliminary but prospect is bright!

- Threshold enhancement is due to Coulomb resummation

  ↓

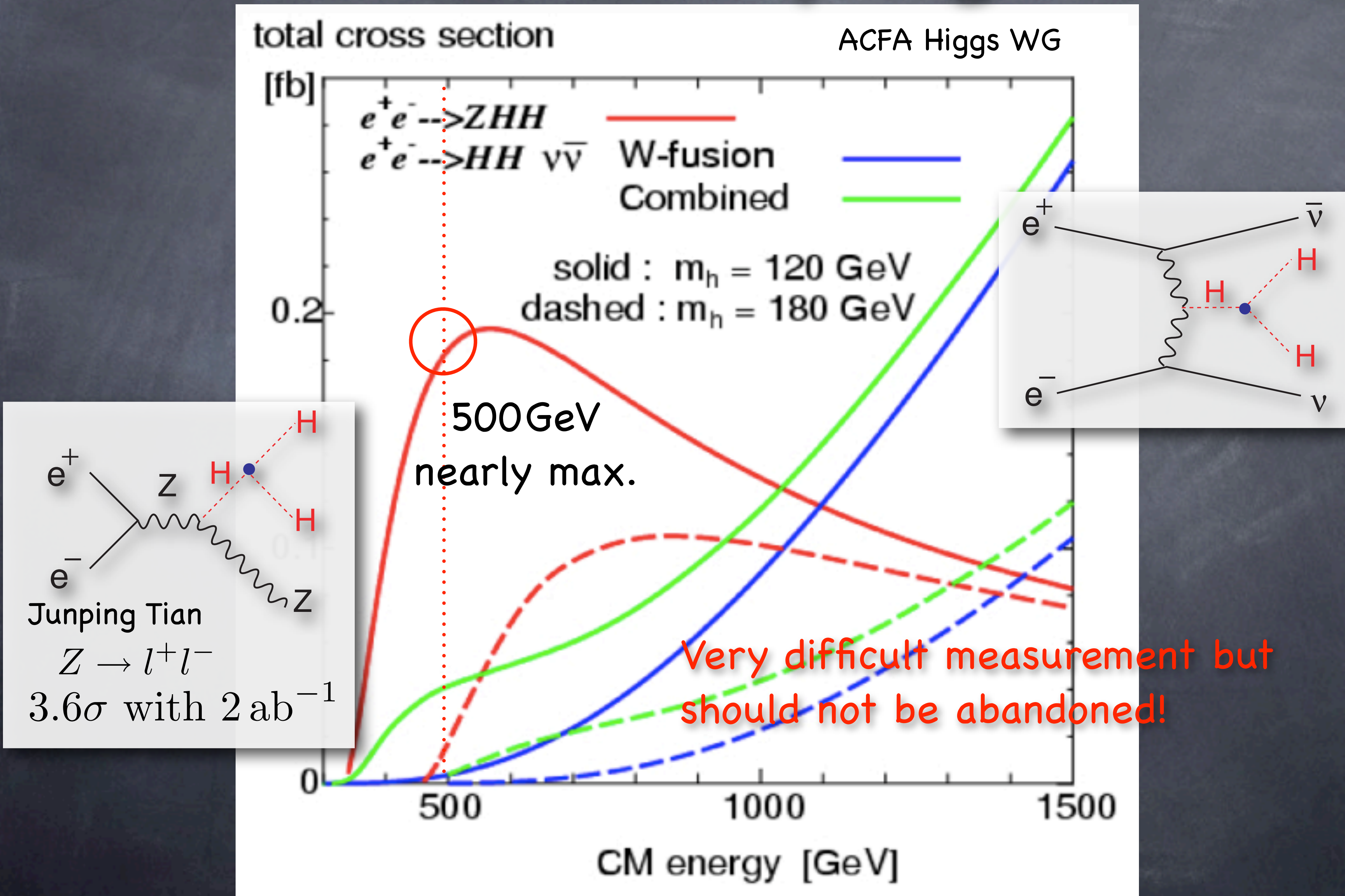
  RG improved potential to reach high accuracy
- Below RG improvement is applied to QCD static potential.

  (In the plots below we neglected other corrections as a first study)



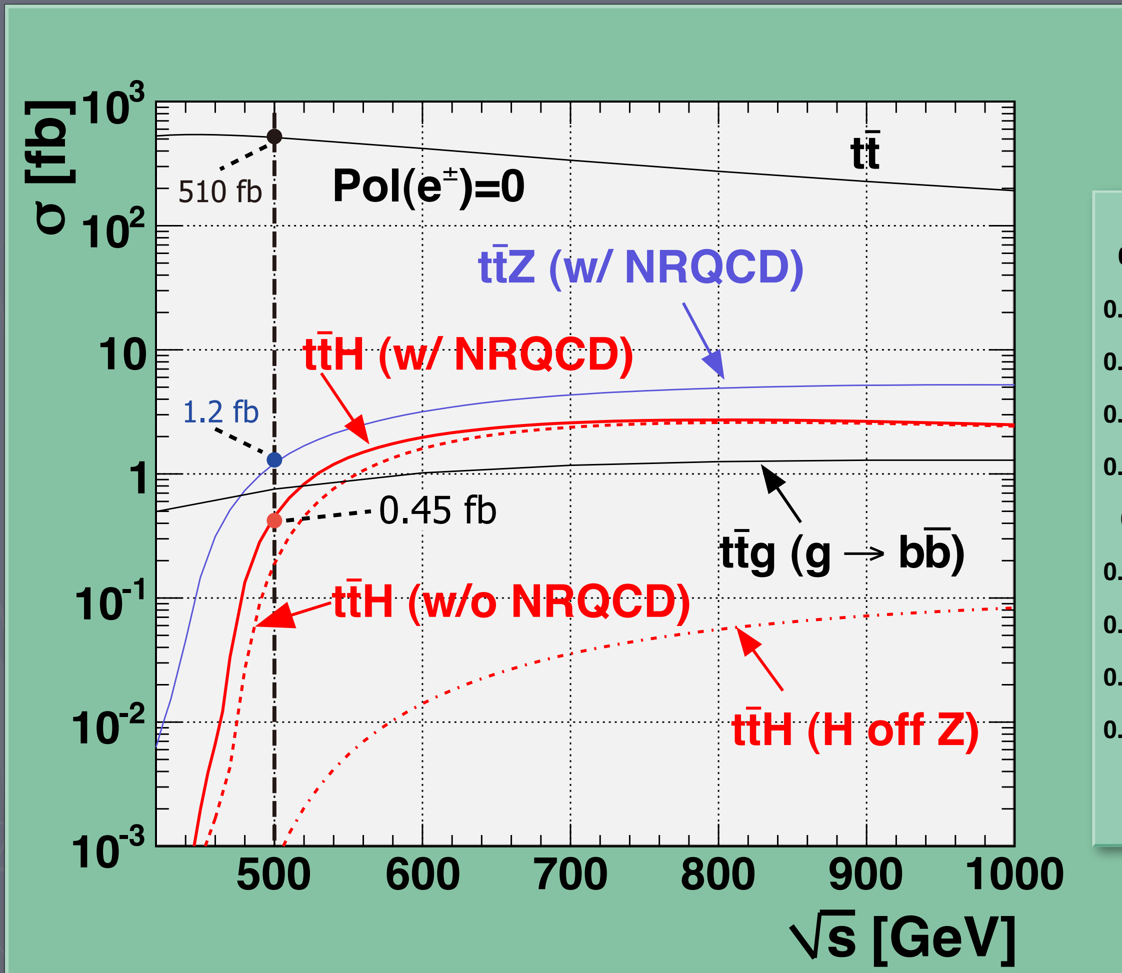
$M_{t,PS}$ =170GeV, LO(Red)/NLO(Green)/NNLO(Blue) for μ=20, 30, 40GeV

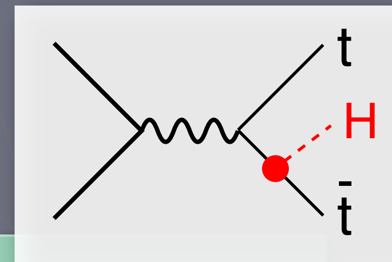
HHH Coupling

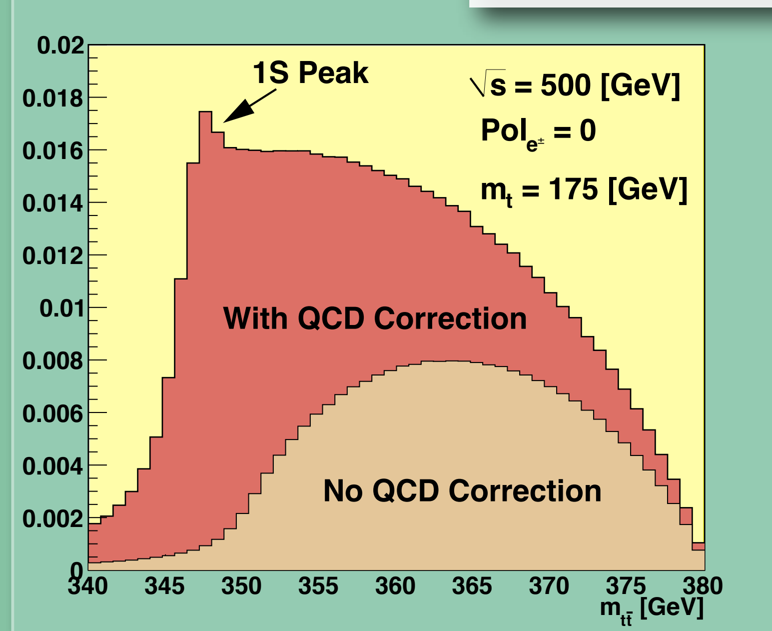


Top Yukawa Couping

The largest among matter fermions







x2 Enhancement by NR QCD correction to the ttbar system

Fast simulation suggests $\Delta g_Y(t)/g_Y(t) \simeq 10\,\%$ with $1\,\mathrm{ab}^{-1}$ @ $500\,\mathrm{GeV}$

Summary

- New list of benchmark reactions prepared and distributed to the LOI groups.
- My personal view:
  The primary goal of the ILC 500 is to establish the 2nd pillar, which means that it has to be self-contained in terms of precision Higgs studies starting from e+e- -> ZH at Ecm = mZ+mH+30GeV, then ttbar at around 340GeV, and then ZHH and ttbarH at the highest energy of 500GeV in order to fully cover the coupling vs mass plot.
- It is very important for us, LOI groups, to cooperate and produce a common physics volume that goes with DBDRs.