Physics Panel Report

2010/03/26

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)

Plan of the Talk

1. Brief review of the panel activities:

   New benchmark reactions

   The panel's response to SB2009

2. Personal view on precision Higgs analysis

The Panel Activities

The charge from RD is to think about possible physics scenarios for ILC

We had 4 (phone) meetings since Nov.8, 2008

1st Meeting on Nov. 8, 2008

Discussed the goals of the panel and agreed to start with scenarios with early LHC discovery (--> new benchmarks)

Then came a request from ILCSC to study the physics case for a PLC for resonant Higgs production --> a PLC report

2nd Meeting on Feb. 12, 2009

Discussed the PLC report but no time to reach consensus.

--> agreed to the importance of considering staging options.

--> Precision Higgs study program (--> new benchmarks)

--> agreed to general policy for controversial subjects

General Policy for Controversial Subjects

Agreed to

1. Every document from the group, whether authored by the whole group or by a few members, be discussed by the Panel in a phone meeting before it is sent out. The panel should make a collective decision on how this document should be released.

2. The importance of coming to a consensus if possible on basic numbers to be presented, which should be the default mode of operation. The interpretation of these numbers -- in particular, the question of what physics results justify what cost -- is subjective and beyond the scope of the panel.

3rd Meeting on Sep. 16, 2009

Discussed the Early Discovery Scenarios at LHC

Agreed to

the following scenarios and ILC Responses to them

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

RD's request for a new benchmark list just after this

Then active SB2009 discussions followed

4th Meeting on Nov. 6, 2009

Discussed

new benchmark reactions (draft)

physics panel response to SB2009 (draft), and

the process of writing up physics of possible staging options

New benchmark reactions for DBDR

- Demonstrate the ILC's physics capabilities w.r.t. other proposed accelerators
  - ILC's reaction to early LHC discovery
  - Precision Higgs analysis
- Evaluate the capabilities of the LOI detectors for physics at 1TeV

3 categories

- 1 TeV benchmarks mostly for detector performance evaluation
- In response to possible early LHC discoveries (previous page)
- Precision Higgs analysis for mH=120GeV

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

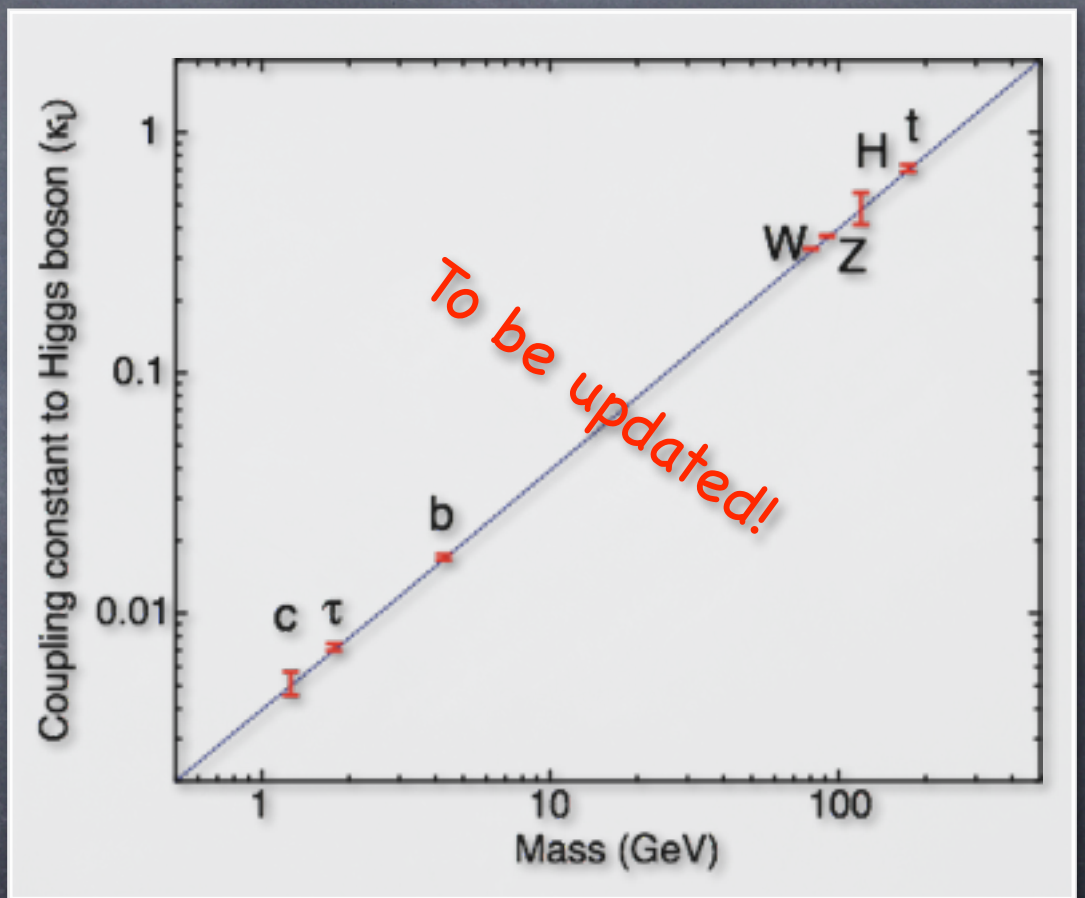
Notice that 1, 2, 3, and 4 overlap with the 2nd category (Early LHC discovery scenarios) discussed already

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

I will return to this later



Response to SB2009

Agreed to give

1. the luminosity samples required by the physics at the ZH X-section peak (230GeV for mH=120GeV) and the ttbar threshold (~340GeV)
2. a short list of quantities whose parametric dependence on machine parameters the LOI groups should try to determine

Remarks on the SB2009 Machine Design

ILC LOI Common Task Groups Physics Panel

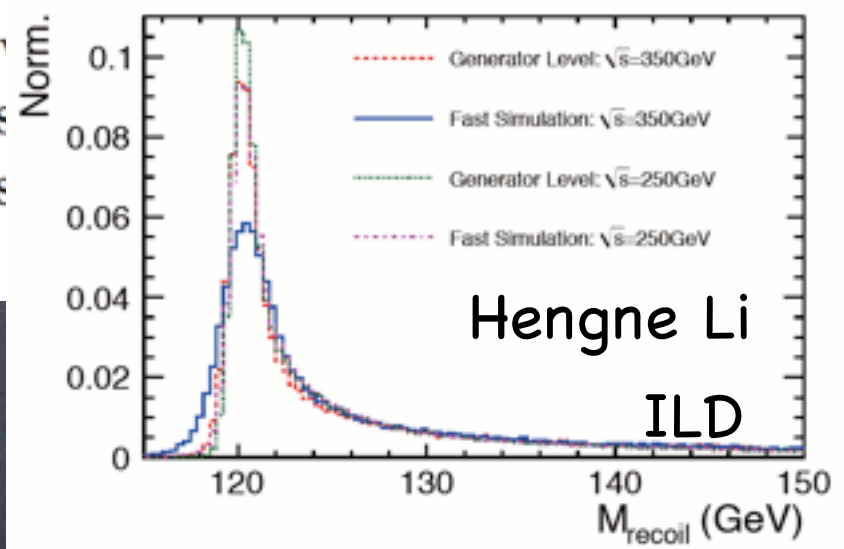
It seems to us important to specify the amounts of running that would be needed at these lower energies. We estimate these as follows: To achieve the accuracy in Higgs couplings of a few percent, which should be a goal of the ILC, a luminosity sample of about 250 fb^{-1} at the Higgs cross section peak would be required. With this data sample, the measurements are still statistics-limited. They would profit from increased running up to 400 fb^{-1}. If the running is done at higher energy, these luminosity estimates should be increased to obtain the same total number of Higgs events. The main goals of the $t\bar{t}$ threshold program would achieve their theoretical systematics limits at about 100 fb^{-1}. We hope that the LOI groups will refine these estimates of needed luminosity in the light of more detailed studies.

2. a short list of quantities whose parametric dependence on machine parameters the LOI groups should try to determine

These studies can be performed as parametric analyses and do not require full detector simulation. Here are the studies that are, in our opinion, the most important:

1. Dependence of the Higgs coupling measurement accuracies on E_{CM} and $P(e^+)$ for an assumed fixed $\mathcal{L} \cdot \sigma(e^+e^- \to Zh)$
2. Dependence of the Higgs recoil mass on δE_{bm} and Ecm
3. Dependence of BR$(h \to c\bar{c})$ on R_{vtx}
4. Dependence of the top quark mass on the machine stability parameters

The ability of the ILC to measure b and c for
GeV, a study that is proposed in the new s
affected by R_{vtx}; and the dependence on this
a part of this study.



Recoil mass resolution quickly deteriorates with energy

Restoring the process of writing up physics of possible staging options

Our project of a handbook of staging options is dormant for the moment

The paper above is related to another paper that it would be very useful for us to produce -- a comprehensive survey of the capabilities of the ILC to measure the Higgs boson couplings, including the levels of accuracy that result from the LOI studies. Some of the numbers needed for this survey are still not known, and are requested in the 2009-10 benchmarks document.

KF promised to find some collaborators at KEK to produce a first draft in the next couple of months. The Panel can hopefully improve this draft while we wait for the next round of benchmark studies to be completed. Michael hopes that we can bring this document into final form toward the end of 2010.

The promise was not yet fulfilled and all I can do today is to give my very personal view and plan

My Very Personal View

which has not been discussed at the panel at all and talking about it here might be a violation of rule 1 on slide 5.

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.

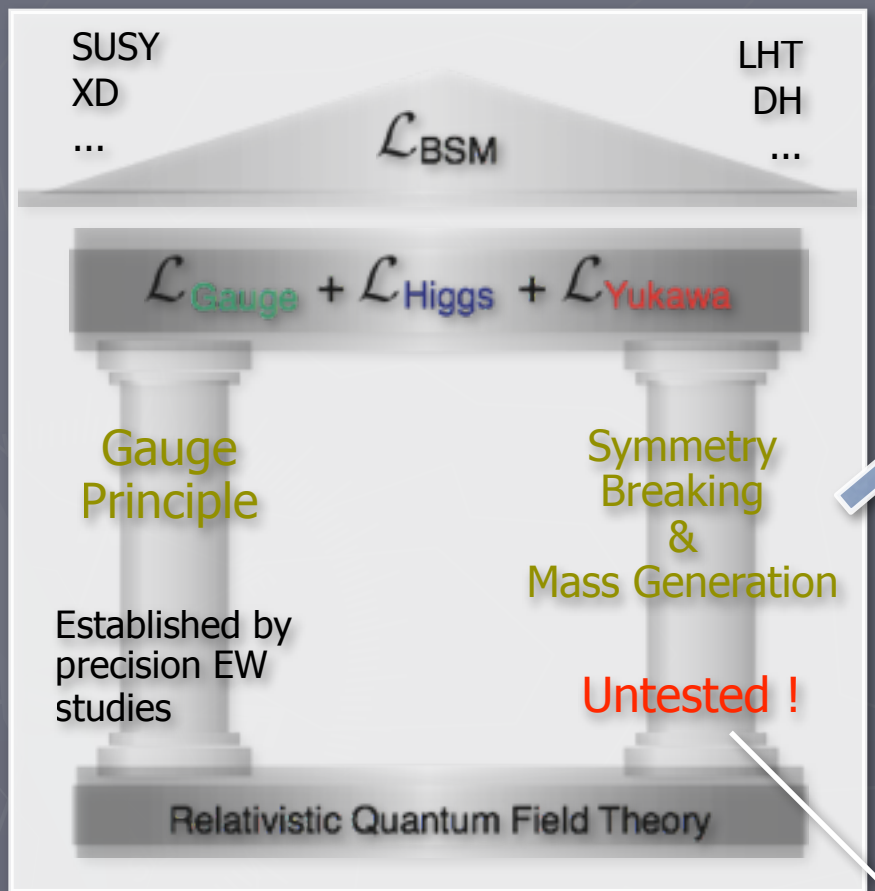
Is the Higgs boson enough or do we need something clearly beyond the standard model? Talking about this here is a violation of rule 2 on slide 5.

So, don't take what I am going to say as from the panel.

Primary Goal

Discovery of New Fundamental Forces

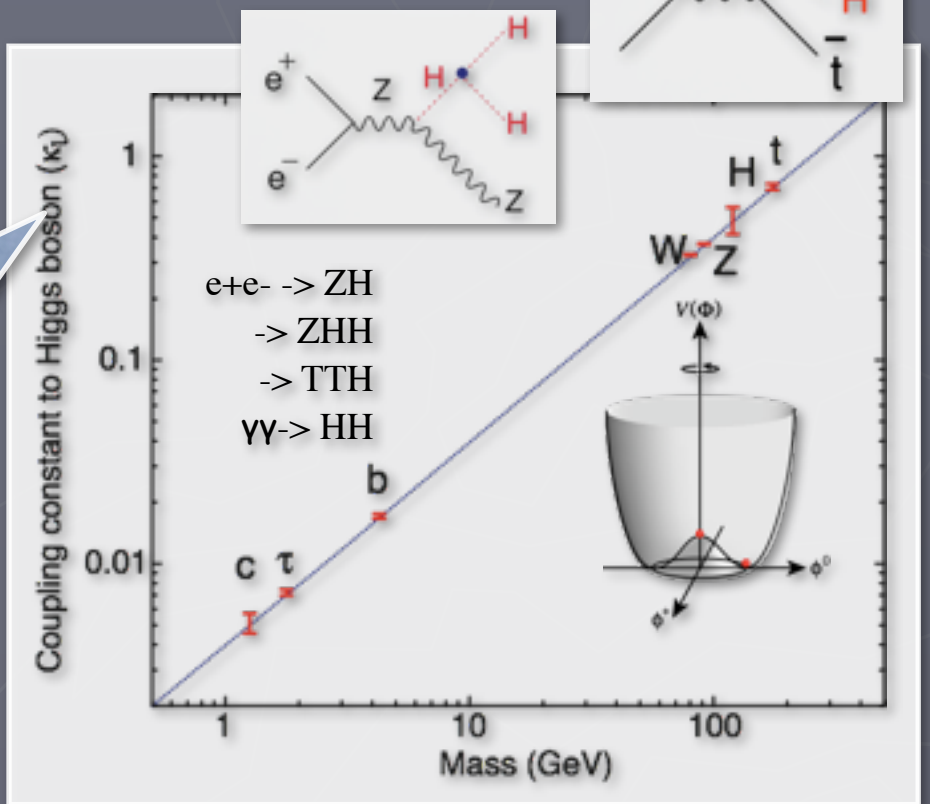
Two Main Pillars of the Standard Model



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!

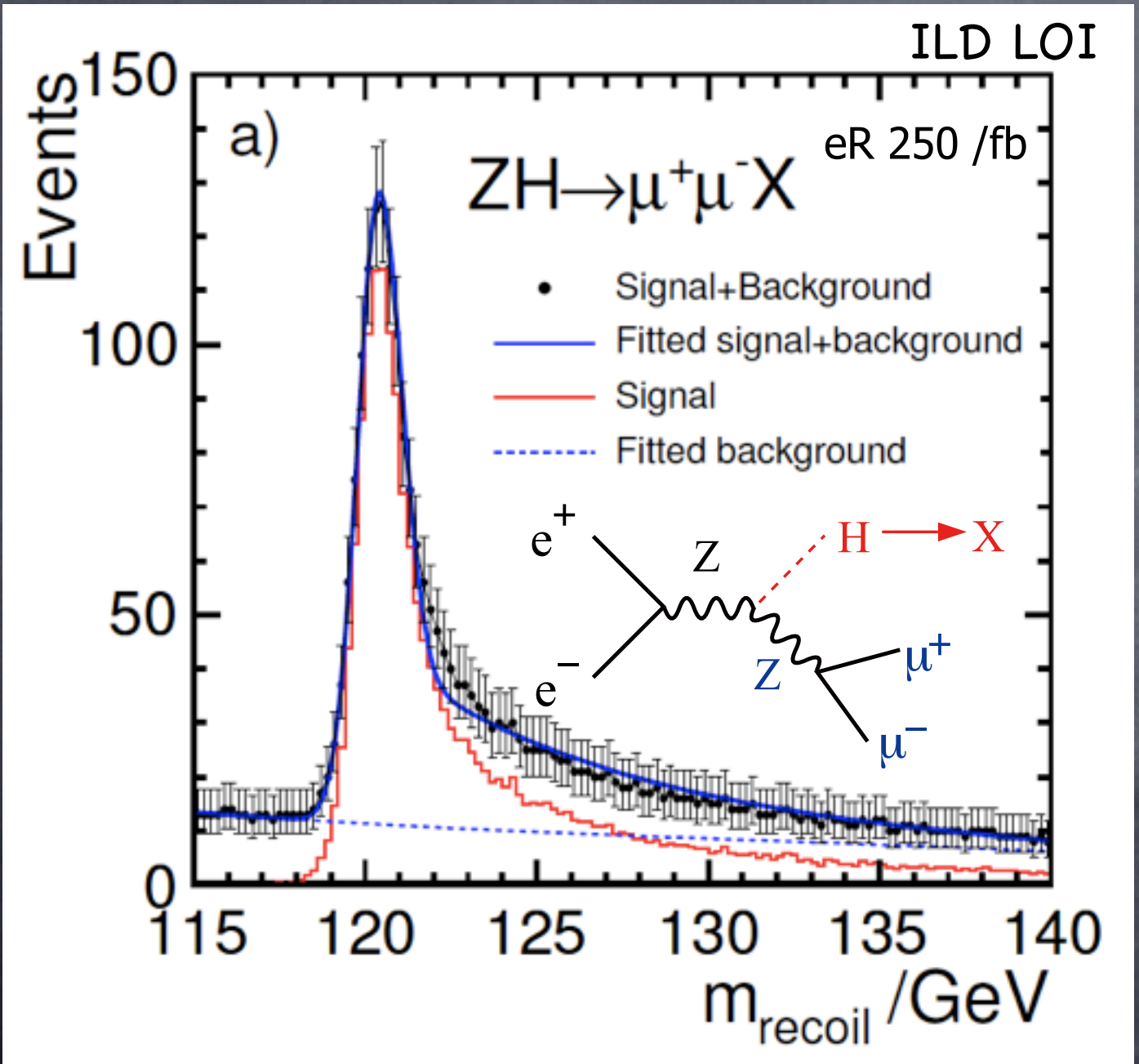
Can we do this
with the ILC 500?

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

Recoil Mass Measurement



Absolute measurement of the ZZH coupling

$$\Delta\sigma_H/\sigma_H \lesssim 4\%$$

$$\Delta m_H \lesssim 40\,\mathrm{MeV}$$

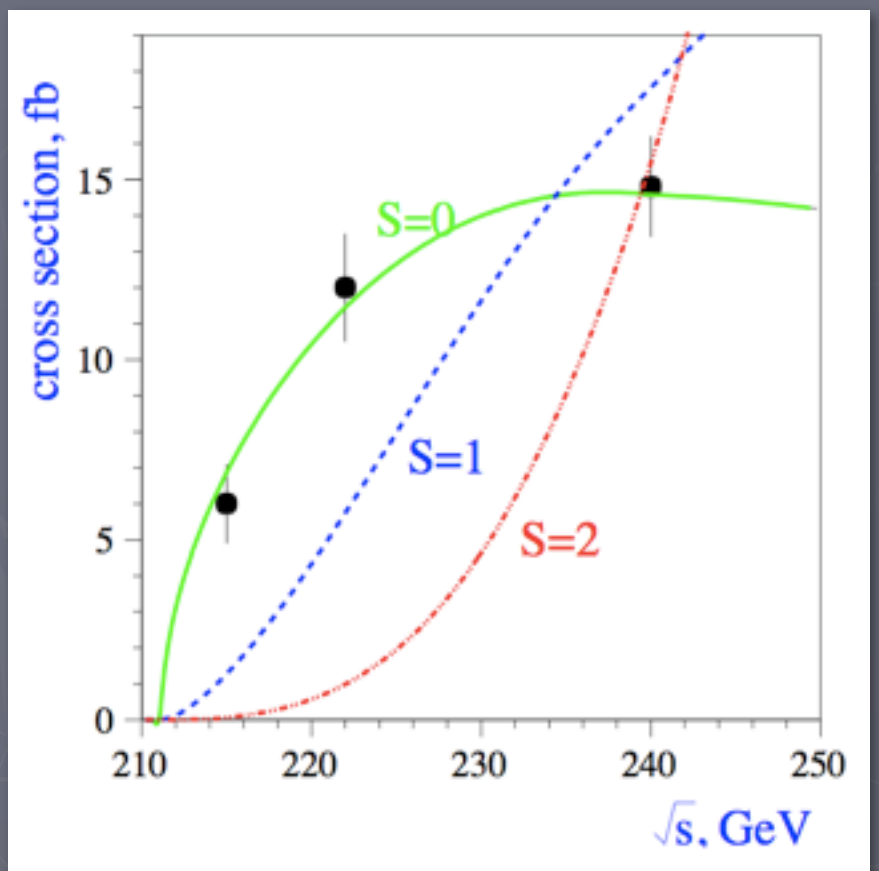
with Z->mu+mu- alone

In order to measure a (finite) invisible width, the resolution matters!

J-CP

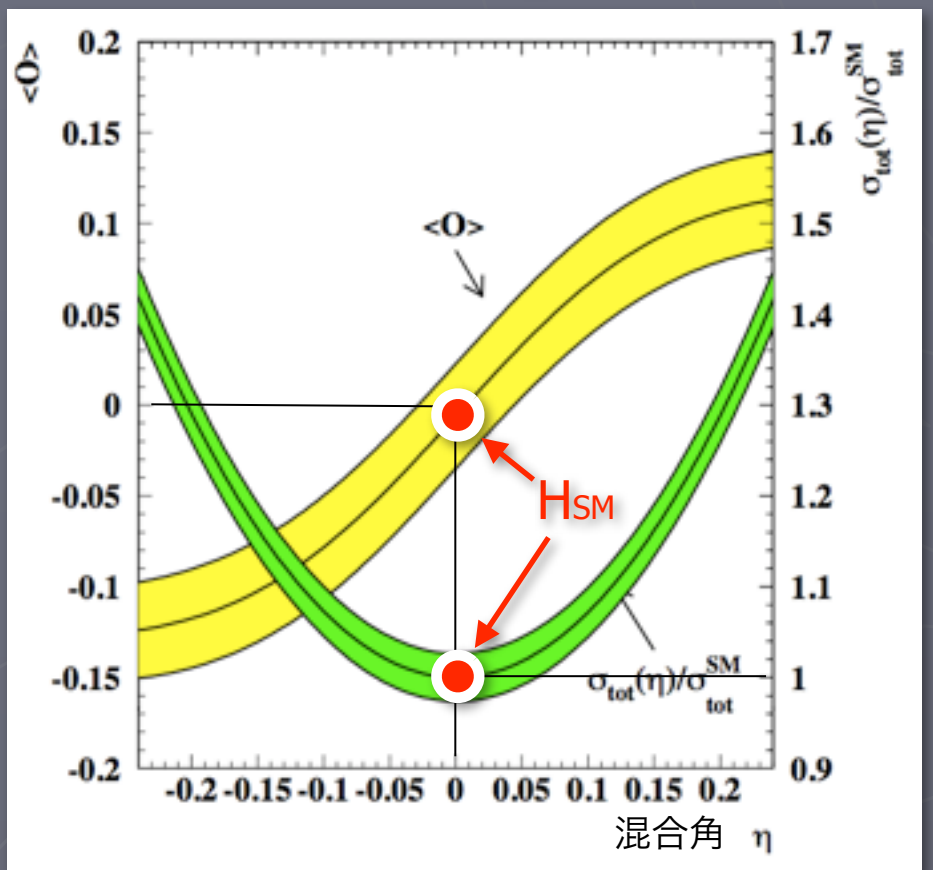
Is this really a scalar?

Determination of Spin



Threshold Scan

CP-mixing?



Total X-section + Z decay

18

Branching Ratios

Example: ILD LOI (not yet optimized)

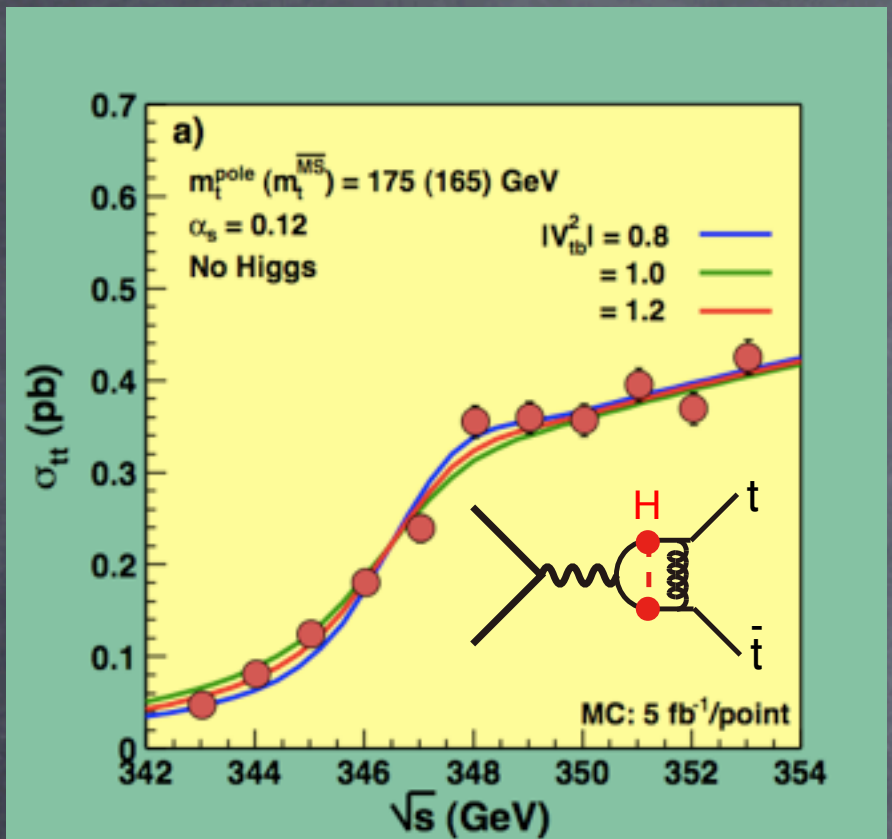
Analysis	$\sqrt{s}$	Observable	Precision	Comments
Higgs recoil mass	250 GeV	$\sigma(e^+e^- \to ZH)$	± 0.30 fb (2.5 %)	Model Independent
		m_H	32 MeV	Model Independent
		m_H	27 MeV	Model Dependent
Higgs Decay	250 GeV	$Br(H \to b\bar{b})$	2.7 %	includes 2.5 %
		$Br(H \to c\bar{c})$	12 %	from
		$Br(H \to gg)$	29 %	$\sigma(e^+e^- \to ZH)$

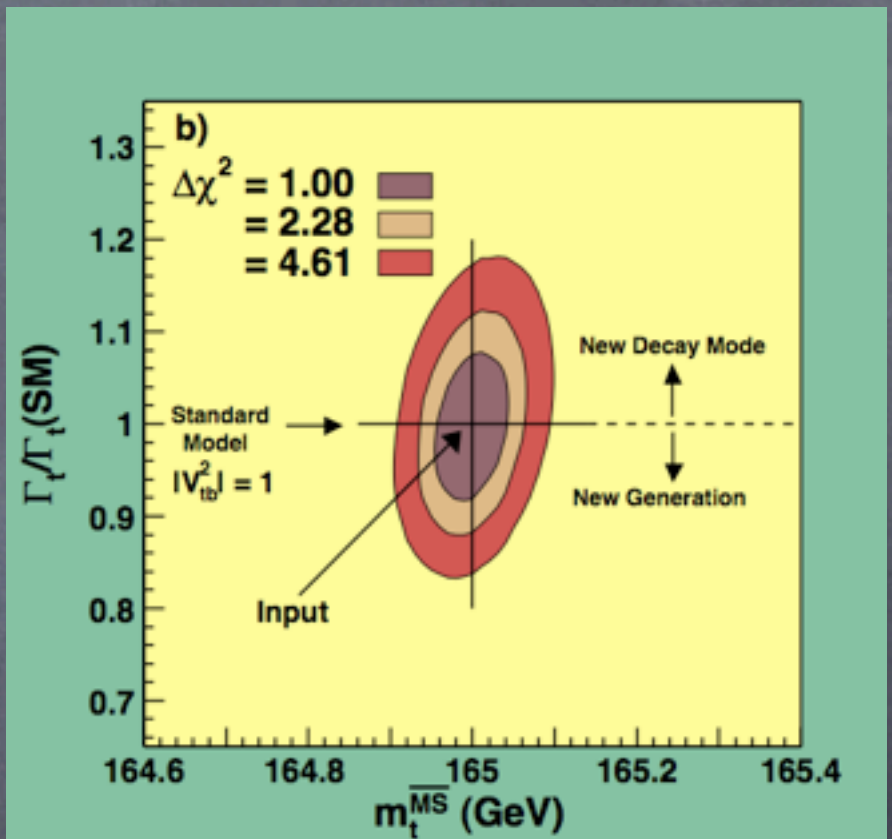
To be updated!

Further studies

- H -> ffbar (f=tau, mu?)
- H -> VV(*) (V=gamma, Z, W)

TTbar Threshold

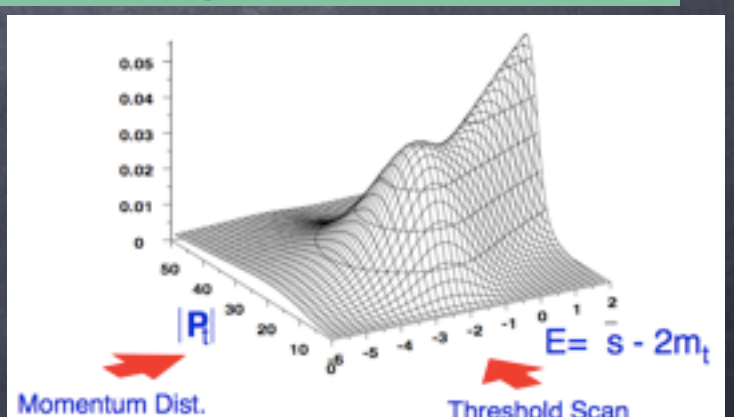




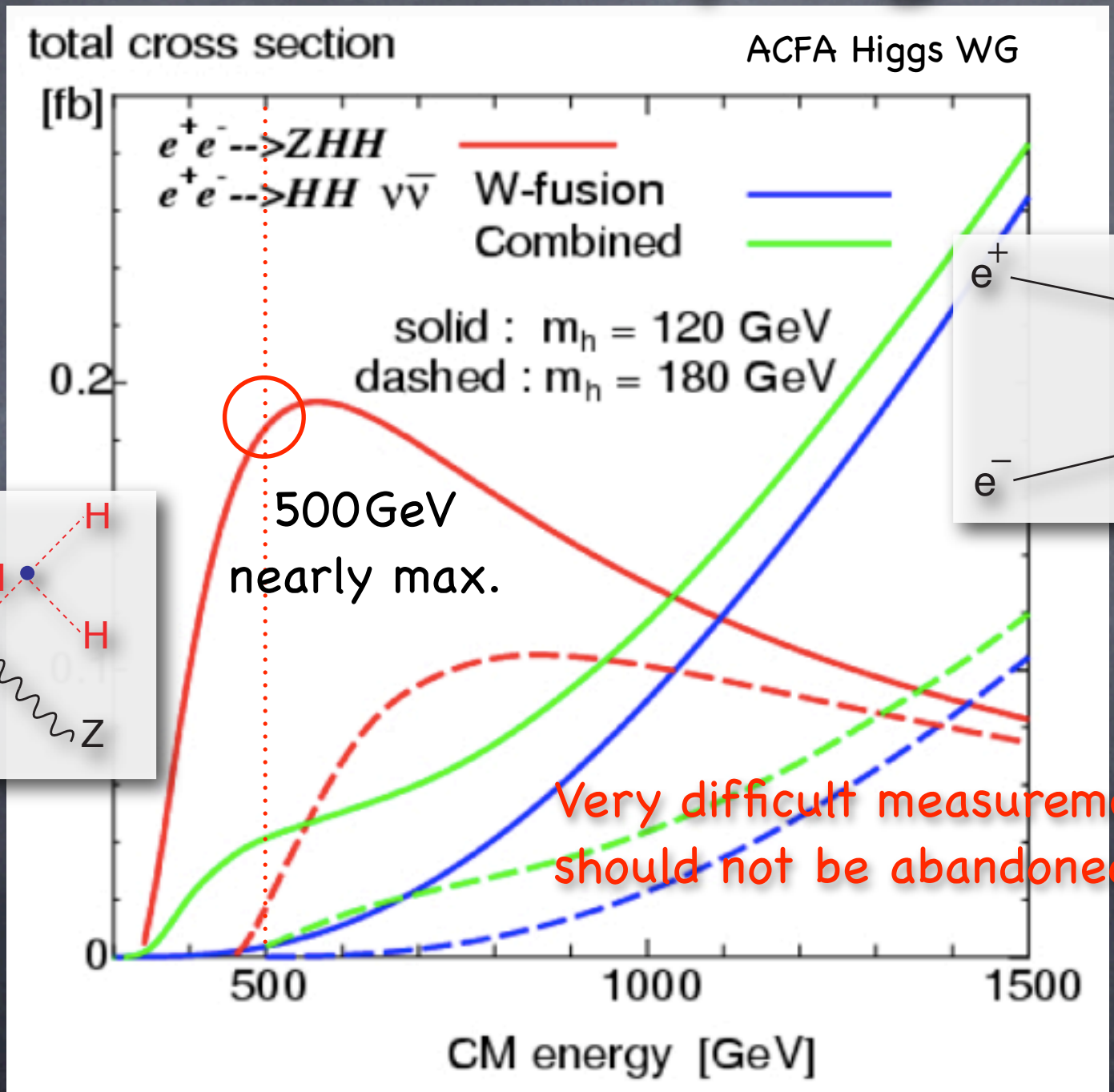
$$\Delta m_t \lesssim 100\,\mathrm{MeV}$$

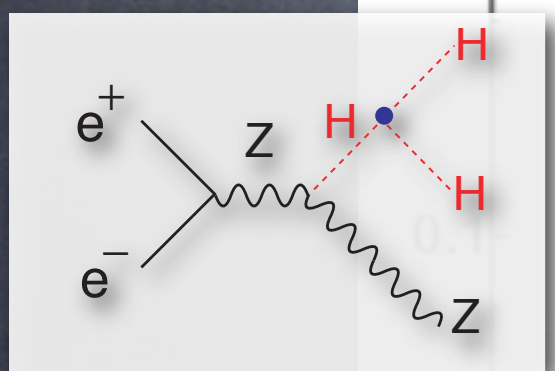
Theoretical ambiguity of mt could be improved to < 50MeV in the future

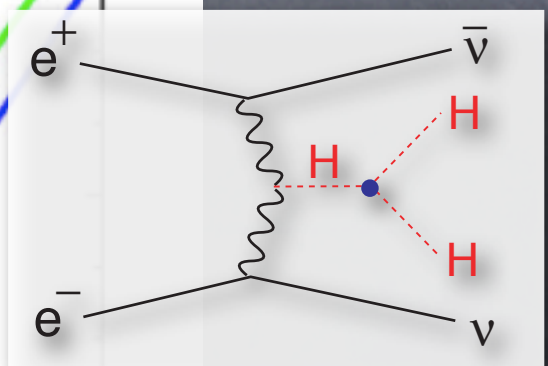
Normalization ambiguity could also be significantly reduced in the future



HHH Coupling

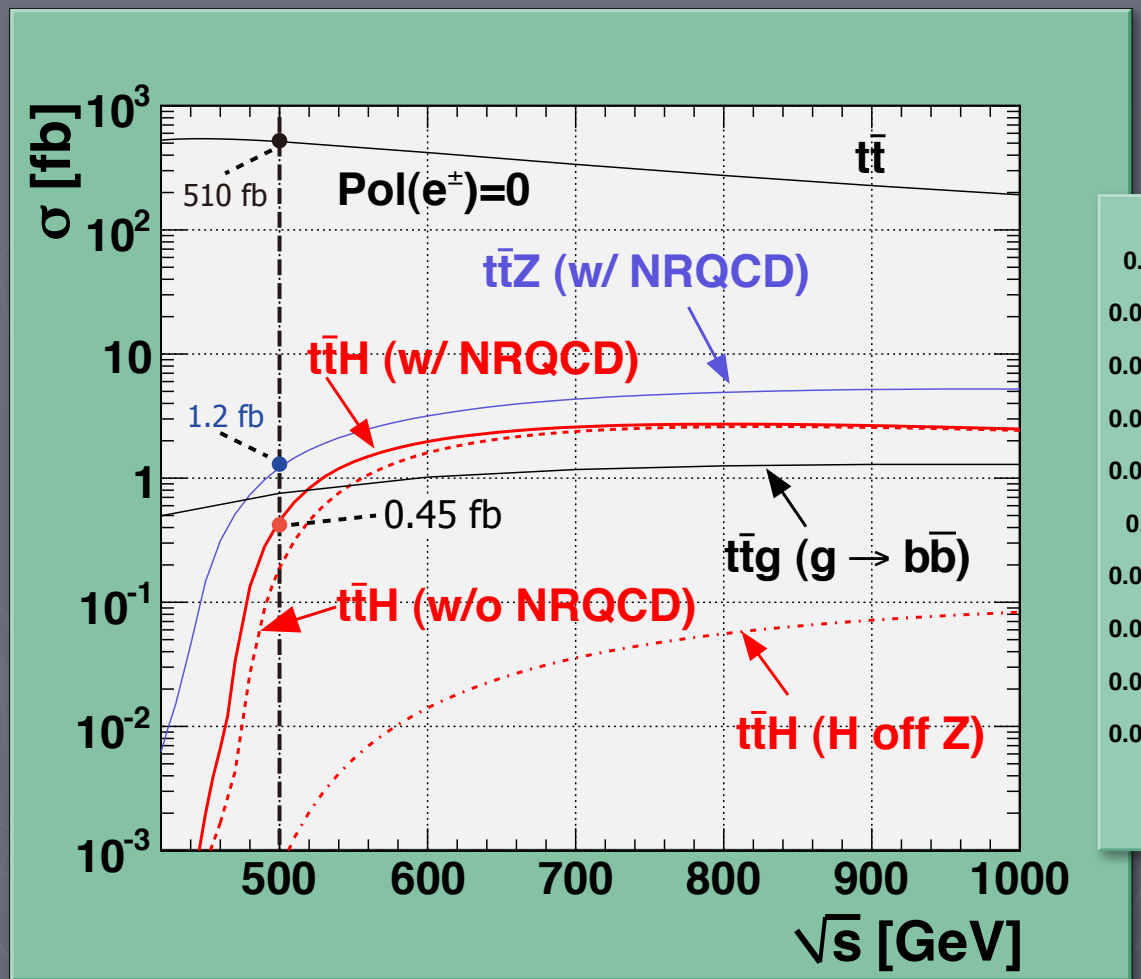


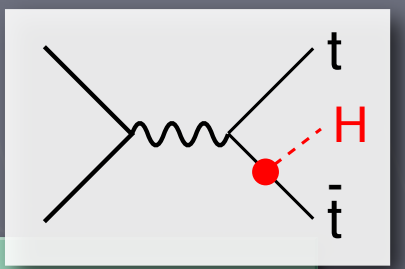


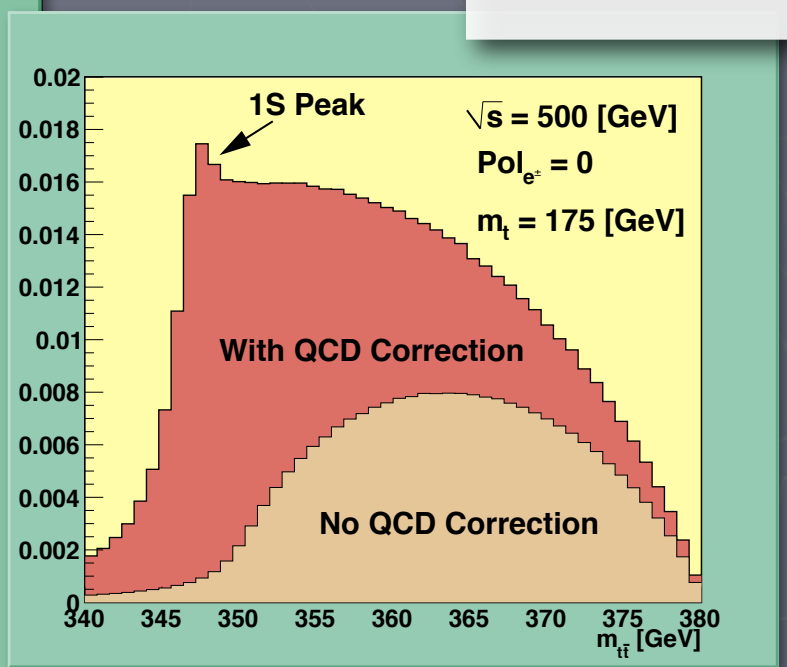


Top Yukawa Couping

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 handed to the RD. (which is not yet officially circulated to the LOI group?)
- The physics panel responded to SB2009 with an initial estimate of the required luminosity samples at the ZH X-section peak and at the ttbar threshold. It also suggested possible study items 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. The running at the ZH X-section maximum is an essential part of this program to make the ILC unique and attractive.