Introduction to Physics Considerations on ILC Parameters

Joint ILC Parameters Working Group

presented by Jim Brau (5/14/2014)

ILC Parameter Joint Working Group

- Membership appointed by Hitoshi Yamamoto and Mike Harrison
    - T. Barklow, J. Brau (co-convener), K. Fujii, Jie Gao, J. List, N. Walker (co-convener), K. Yokoya
- Charge (next slide)

ILC Parameter Joint Working Group – Charge

March 19, 2014

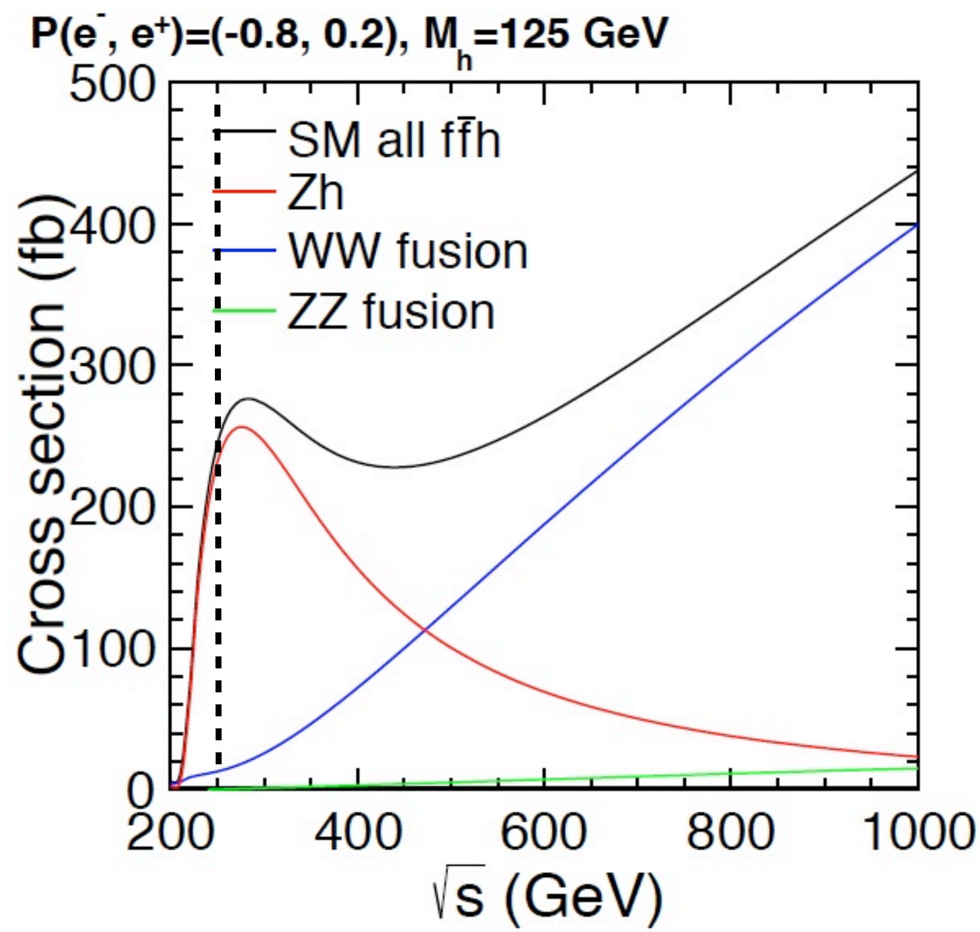
- The ILC parameter working group reports to the LCC Directorate. It consists of members from both the ILC accelerator and the physics & detector groups where each team selects a co-convener for this working group.
- This working group prepares information on ILC machine parameters and staging scenarios as well as potential upgrade paths in a form readily usable by the LCC. In doing so, the WG will take into account technical machine constraints and physics and detector needs regarding the fundamental ILC machine parameters such as energy, luminosity, crossing angles, etc.
- The first task for the working group is to prepare multiple scenarios for staging up to about 500 GeV. The report should contain the pros and cons of each scenario as well as luminosities needed at each energy to produce corresponding physics results.

List of Physics Considerations

- Phases of energy operation from 250 GeV to maximum baseline energy (eg. 350 GeV, etc.)
  - including required and available int. lumi.
- Maximum reach baseline energy (we find physics motivation for 550 GeV based on tth)
- Operation at energies below 250 GeV
- Safety margin in energy reach
- Polarization

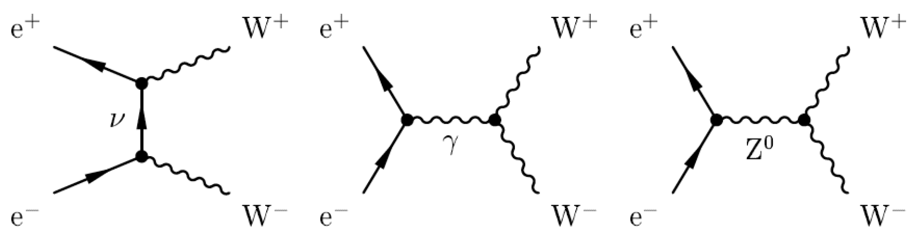
250 GeV operation

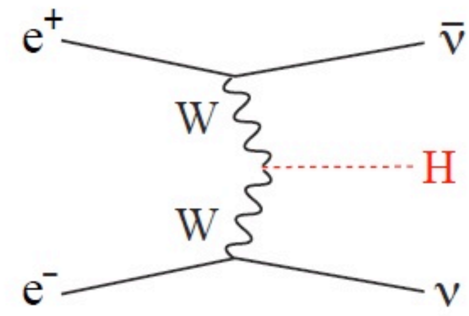
- Enables precision measurements of Higgs properties

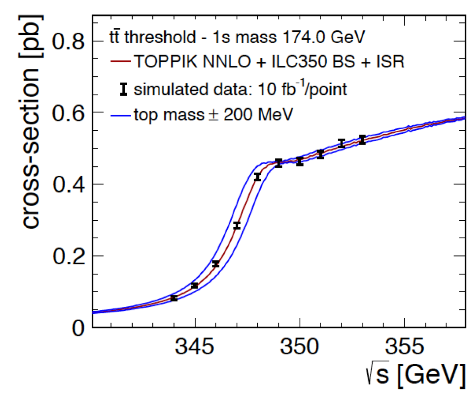


Physics at 350 GeV

- 350 GeV opens important physics
  - WW fusion strengthens significantly, improving precision of hWW coupling
  - Top cross section rise yields top mass measurement to 100 MeV
  - Sensitivity (~E^2) to BSM in $e^+ e^- \rightarrow W^+ W^-$



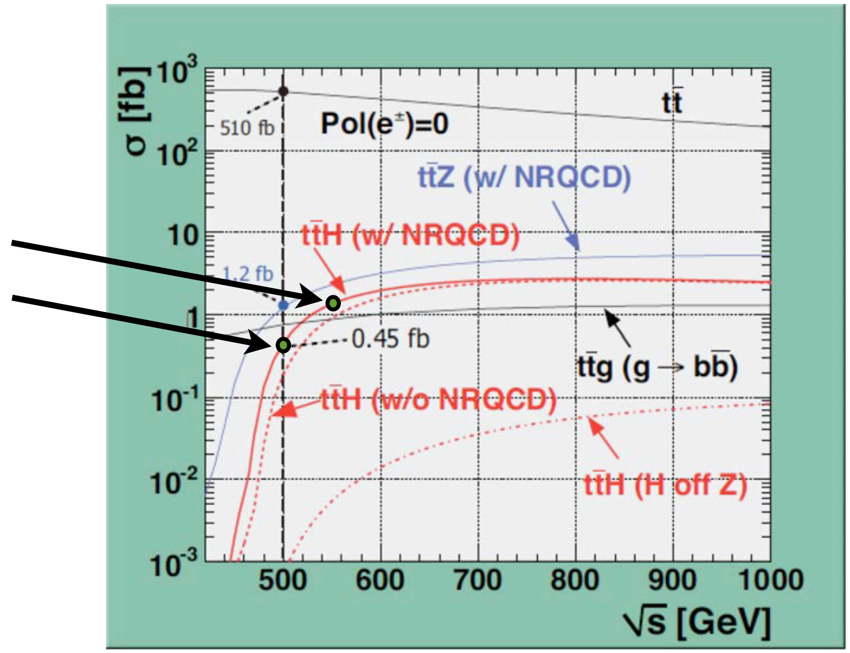




- Weakness – Limits Higgs mass precision
  - ~100 MeV vs. ~40 MeV at 250 GeV

Maximal Baseline Energy

- 500 GeV is an arbitrary maximum baseline energy.
- However, it is within reach of an important channel, namely ***tth***, where the top Yukawa coupling can be measured.
- The cross section rises sharply at ~500 GeV, suggesting an upper baseline energy of **550 GeV or so,** where the cross section for this important channel is significantly larger than at 500 GeV.



Lower Energy Operation

There is interest in lower energy operation

- *Z*-pole
- *WW* threshold
- Higgs threshold scan

for a number of physics motivations.

- This interest will increase even more as long as no signs of New Physics appear at the LHC.
- Each of these energies raises its own issues on the machine and detector side which should be considered and must be understood.

Staging Scenarios

- Designed to explore impact of different sequences of operation on evolution of Higgs precision

a. 250 inv.fb @ 250, 500 inv.fb @ 500

b. 250 inv.fb @ 250, 500 inv.fb @ 550

c. 250 inv.fb @ 250, 1000 inv.fb @ 500
(for comparison with scenario b)

d. 100 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 500

e. 100 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 550

f. 25 inv.fb @ 250, 350 inv.fb @ 350, 500 inv.fb @ 500

g. 500 inv.fb @ 250, 500 inv.fb @ 500

a.* 350 inv.fb @ 350, 500 inv.fb @ 500

h. 50 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 500, 1 inv.ab @ 250

i. 50 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 550, 1 inv.ab @ 250

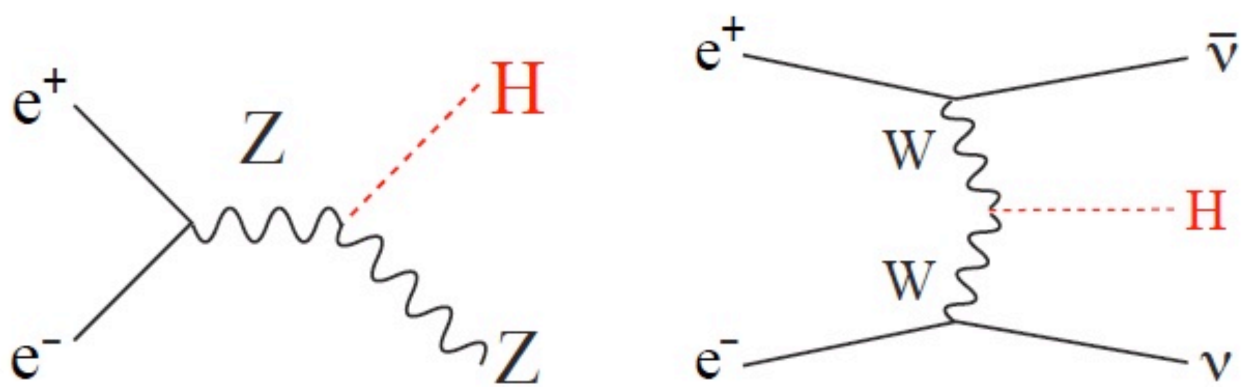
Working Group Timeline

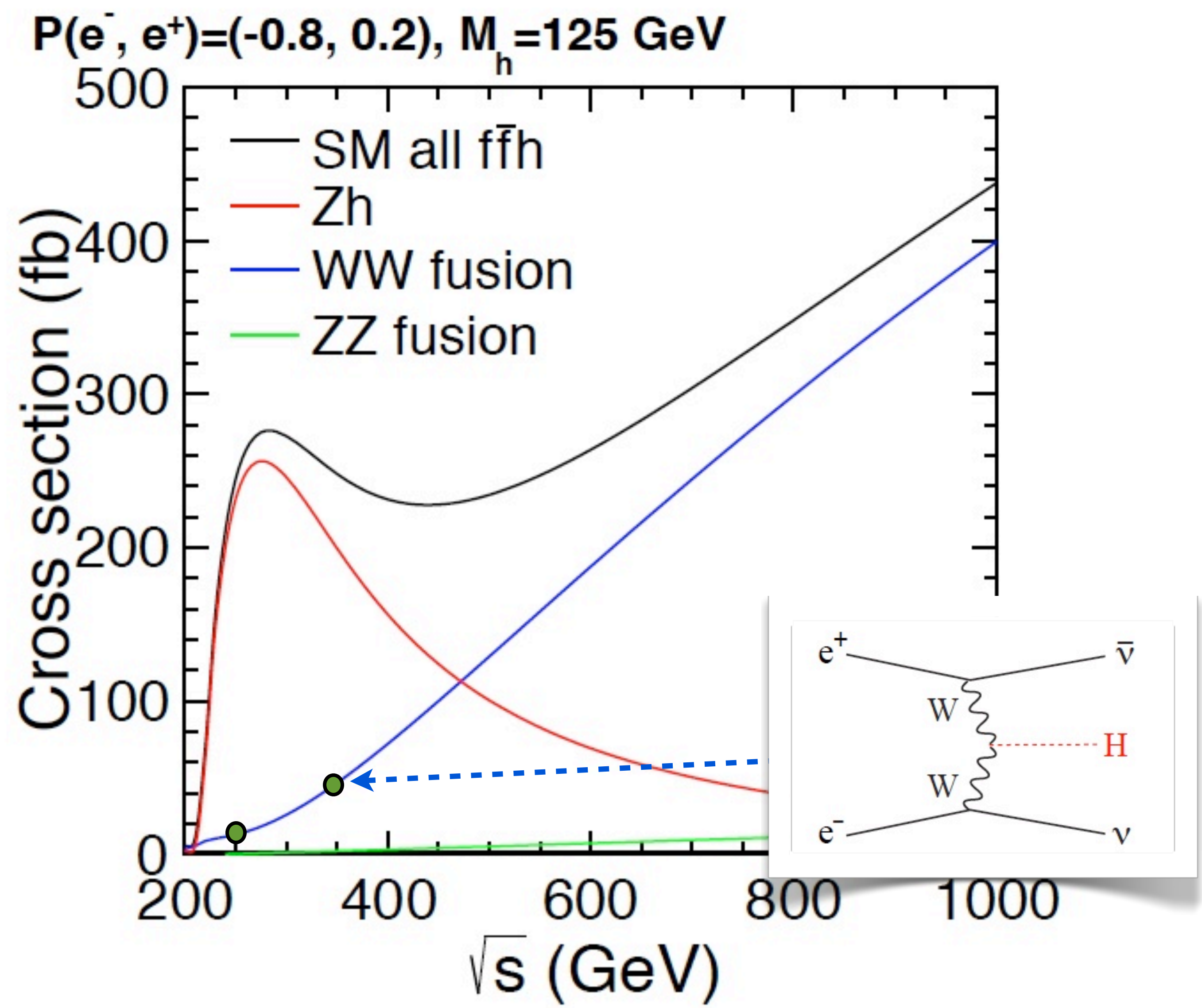
- February - Machine perspective on Energy-phased approach (G. Dugan, M. Harrison, B. List, N. Walker)
- First physics response discussed at the LCB meeting - DESY Feb 20, 2014
- Joint Working Group established
- Telecons - ~ every 2-3 weeks
- Plenary discussion at AWLC14
- Draft report fall 2014 - presented at LCWS14

EXTRAS

Energy Phasing (1) - WW

- 350 GeV opens important physics channels
  - Higgs production through WW fusion becomes important, giving much improved precision on the hWW coupling - this significantly improves precision of total Higgs width, which in turn leads to significant improvements in the errors on all Higgs couplings obtained from σ x BR measurements at 250 or 350 GeV.

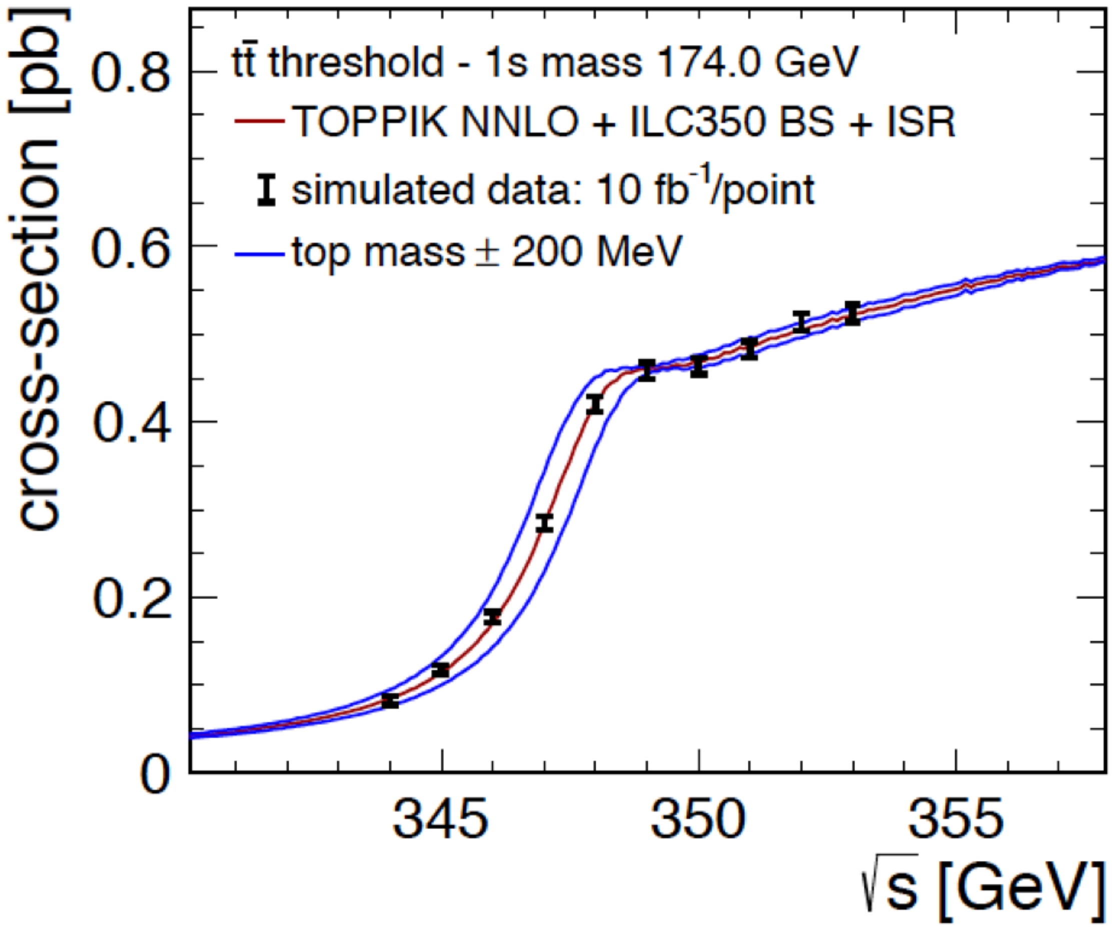



P(e-, e+)=(-0.8, 0.2), Mh=125 GeV
500
400
300
200
100
0
200
400
600
800
1000
Cross section (fb)
√s (GeV)
SM all ff̄h
Zh
WW fusion
ZZ fusion
e+
ν̄
W
H
W
e-
ν

Energy Phasing (2) - Top threshold

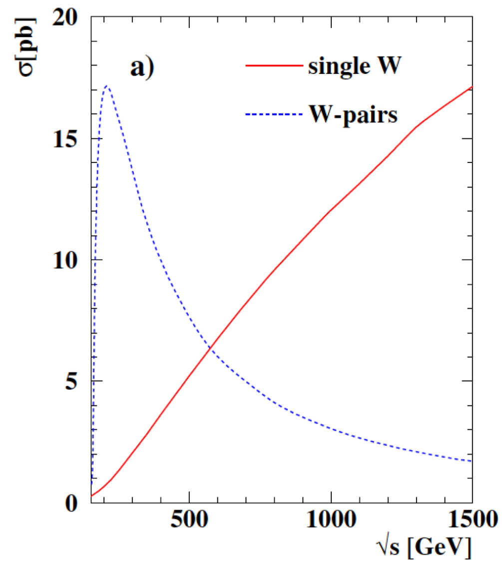
- There is a prominent rise in the cross section associated with the threshold for top quark pair production.
  - There are no stable top bound states, but the threshold structure is precisely predicted by perturbative QCD.
  - The top quark mass can be accurately measured with a precision of 100 MeV.
    - This accuracy would be a valuable input to grand unification, as well as other fundamental physics predictions.
- The top pair production threshold measurements reduces the uncertainty in the cross section for **tth**, an important uncertainty in the top Yukawa coupling measurement at 550 GeV.

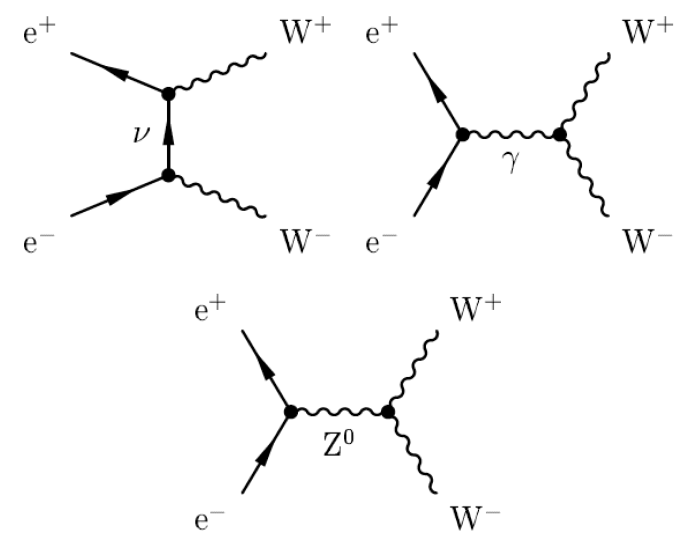
tt threshold cross section



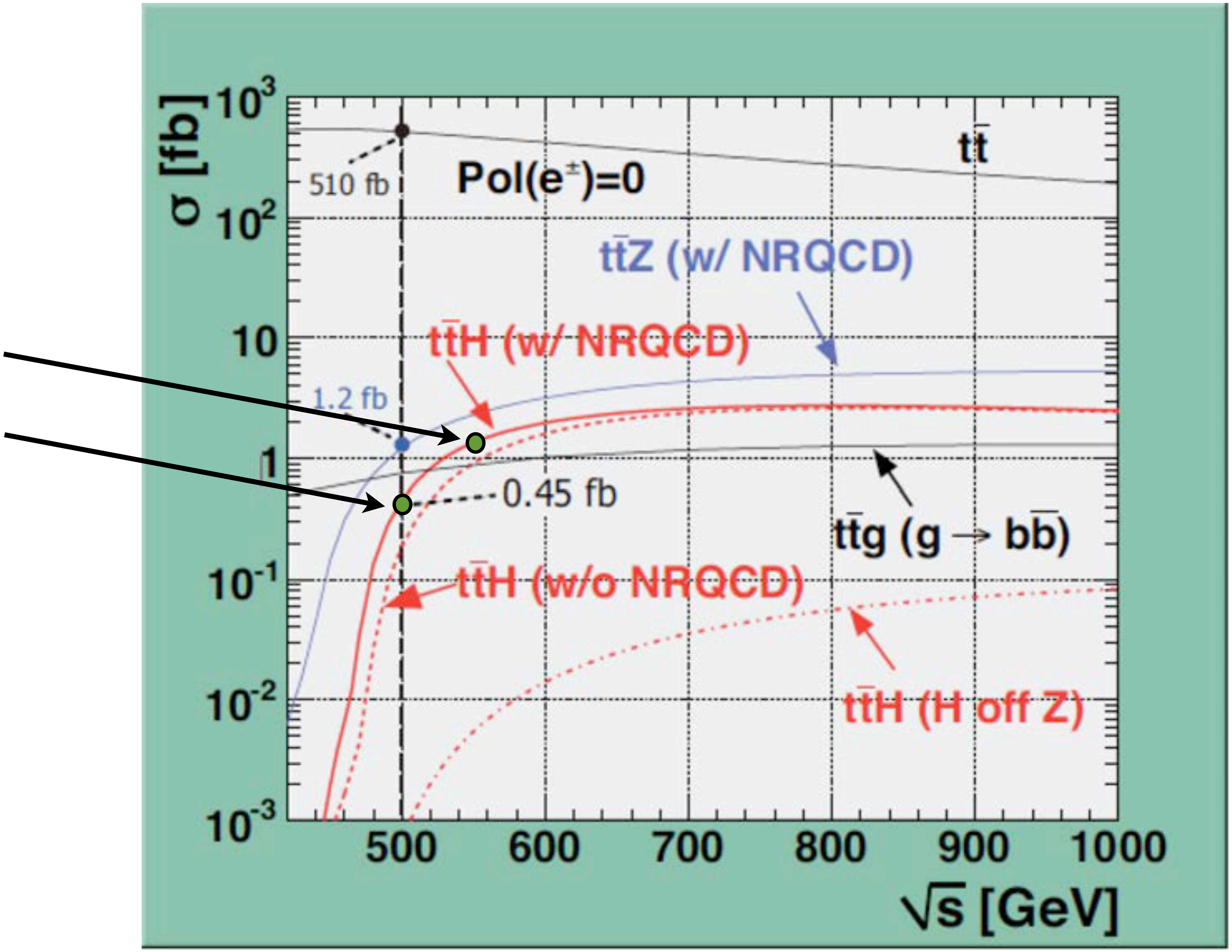
Energy phasing (3) - $e^+ e^- \rightarrow W^+ W^-$

- The $e^+ e^- \rightarrow W^+ W^-$ reaction is exceptionally sensitive to possible modifications of Standard Model couplings at high energy, with a sensitivity growing as E^2.





- This is another important measurement that is improved at 350 GeV relative to 250 GeV.



σ [fb]
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
500
600
700
800
900
1000
√s [GeV]
510 fb
Pol(e±)=0
tt̄
tt̄Z (w/ NRQCD)
tt̄H (w/ NRQCD)
1.2 fb
0.45 fb
tt̄g (g → bb̄)
tt̄H (w/o NRQCD)
tt̄H (H off Z)