ILC Parameters & Physics goals

First considerations
by Physics & Detector Working Group

presented by Jim Brau (4/1/2014)

ILC Physics & Detectors (Machine) Parameters Working Group

- Hitoshi created an ILC parameters working group:
  - T. Barklow, J. Brau (convener), K. Fujii, J. List
- Hitoshi asked us to consider the physics and detectors impact of ILC machine parameters
- First review - very tentative identification of important physics issues - starting point for discussion in broader community

Summary of Considerations

- Phases of energy operation from 250 GeV to maximum baseline energy
- Maximum reach baseline energy (we argue one should seriously consider 550 GeV)
- Operation at energies below 250 GeV
- Safety margin in energy reach

Preliminary Comments

1. Physics considerations suggest following evolution

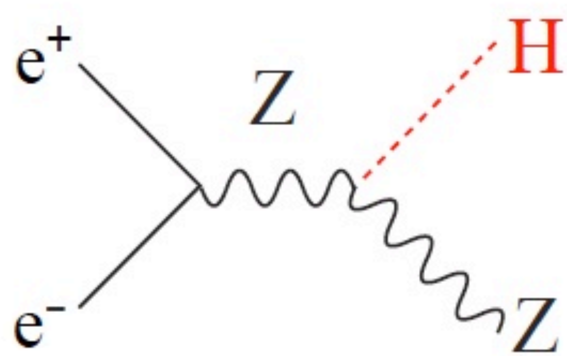
- operate at 250 GeV until capability (sufficient number of cryomodules produced) to upgrade to 350 is reached (say 1+2.5 years)
- pause to upgrade to 350 GeV
- operate at 350 GeV while capability to upgrade to maximum baseline energy is fabricated (say 3 years)
- pause for final upgrade to maximum baseline energy
- continue operations at maximum baseline energy or other energy points

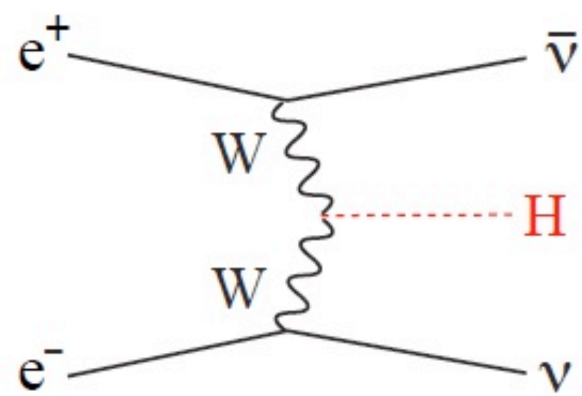
Preliminary Comments

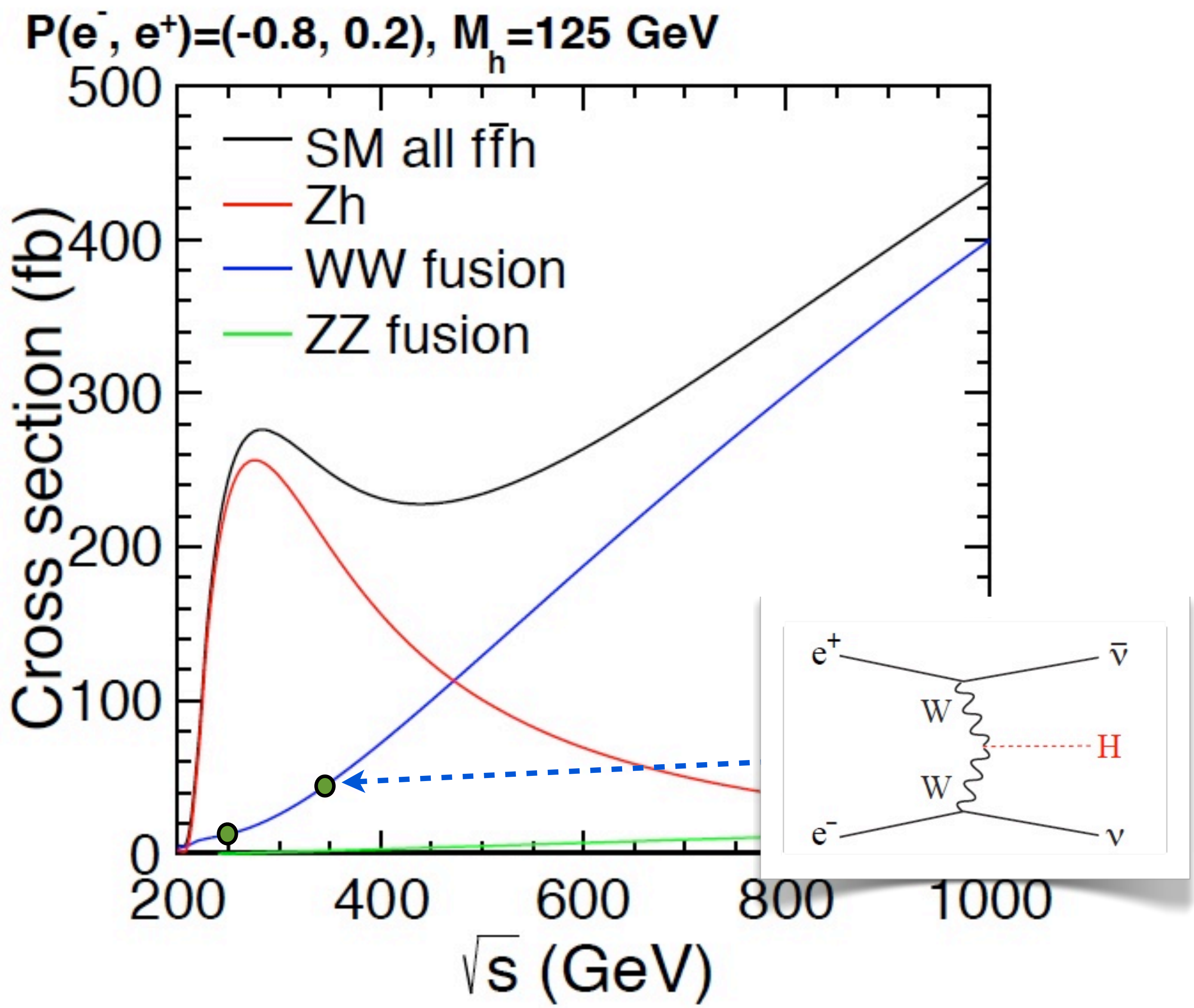
2. Set maximum baseline energy reach to 550 GeV
   - motivated by tth threshold
3. All three energies (250, 350, 550) are thresholds of important physics channels (ZH, $t\bar{t}$, $t\bar{t}h$), where the cross-sections rise steeply. Thus a sufficient <u>safety margin</u> in needed to ensure that these energies are actually reached.
4. Consider strategies for operation at lower E
   - Z-pole (for physics, with positron polarization)
   - WW threshold (with positron polarization)
   - Higgs threshold scan

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.





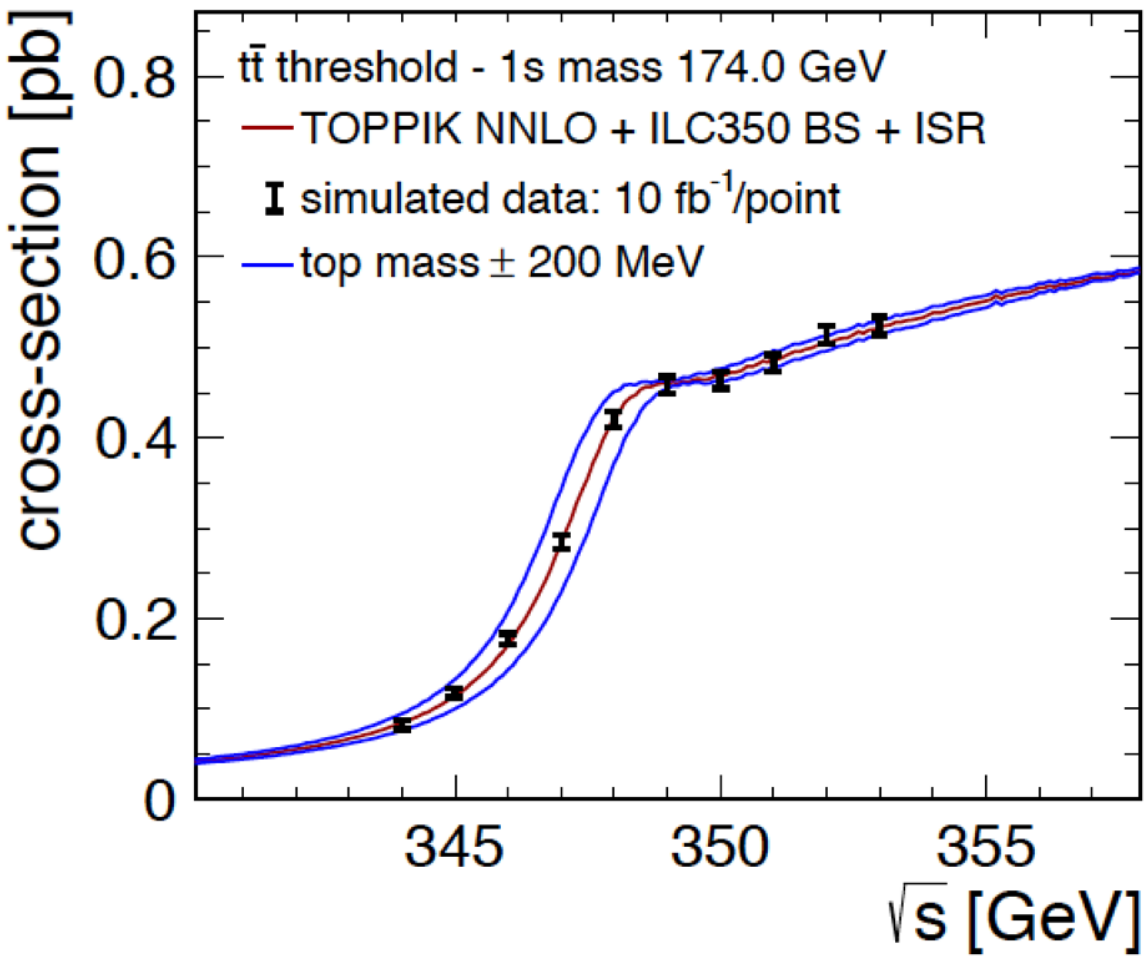


P(e-, e+)=(-0.8, 0.2), Mh=125 GeV
SM all ff̄h
Zh
WW fusion
ZZ fusion
Cross section (fb)
500
400
300
200
100
0
200
400
600
800
1000
√s (GeV)
e+
ν̄
W
H
W
e-
ν

Energy Phasing (2) - Top threshold

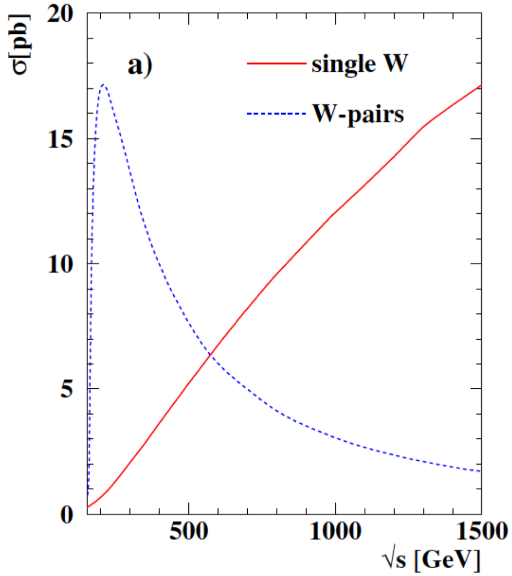
- There is a prominent rise in the cross section associated with the threshold for top quark pair production.
    - There are no stable top bound states, but the threshold structure is precisely predicted by perturbative QCD.
    - The top quark mass can be accurately measured with a precision of 100 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.

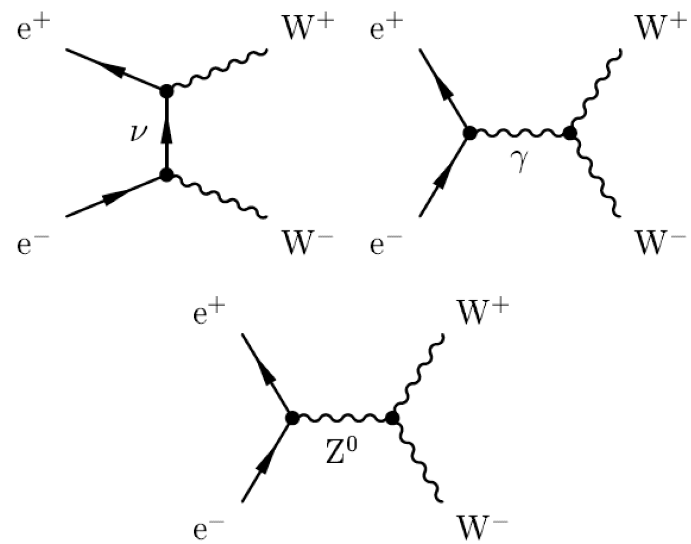
tt threshold cross section



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

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





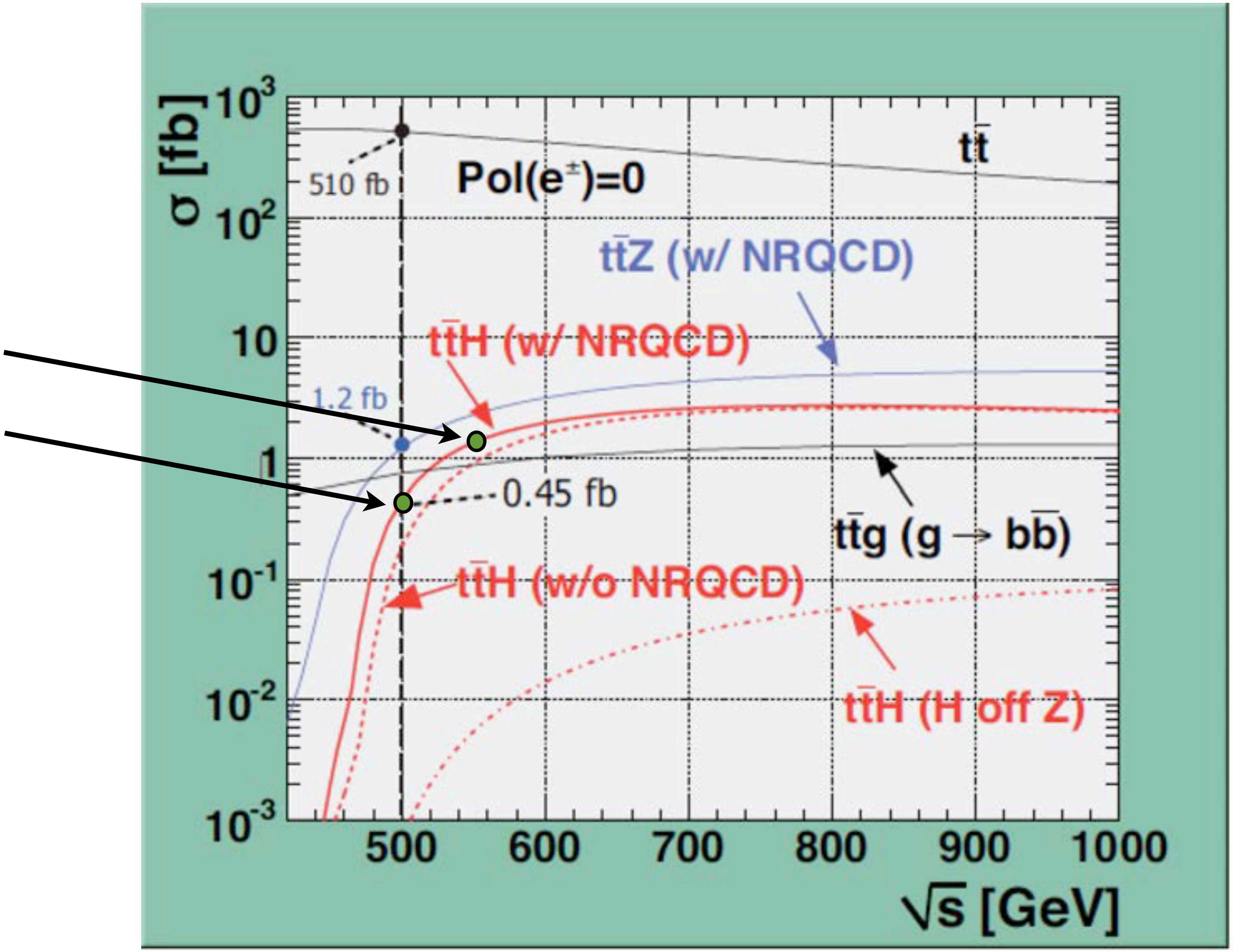
- This is another important measurement that is improved at 350 GeV relative to 250 GeV.

Comments on 350 GeV

- The main weakness at 350 GeV relative to 250 GeV is the mass resolution sensitivity, which is about two times more precise at 250 GeV.
    - The precision at 350 GeV, however, is sufficient to reach the theoretically interesting limit of 100 MeV.
- Given above considerations and others (which require more detailed study) a mix of 250 and 350 running would probably be optimal, and moving from 250 GeV to 350 GeV as soon as cryomodule production and machine operation allows seems desirable.

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 energy dependence of the cross section (next slide) shows a sharp rise, arguing for increasing that upper baseline energy to 550 GeV or so where the cross section for this important channel is significantly larger than at 500 GeV.



σ [fb]
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
510 fb
Pol(e±)=0
$t\bar{t}$
$t\bar{t}Z$ (w/ NRQCD)
$t\bar{t}H$ (w/ NRQCD)
1.2 fb
0.45 fb
$t\bar{t}g$ ($g \to b\bar{b}$)
$t\bar{t}H$ (w/o NRQCD)
$t\bar{t}H$ (H off Z)
500
600
700
800
900
1000
√s [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 understood.

Summary of Preliminary Comments

1. Physics considerations suggest following evolution
   - operate at 250 GeV until capability to upgrade to 350 GeV is reached, then upgrade to 350 GeV for a few years of operation before moving to maximum energy
2. Strong motivation for baseline energy reach of 550 GeV
3. Energies (250, 350, 550) are thresholds for physics requiring a safety margin of operation.
4. Consider strategies for operation at lower E
   - Z-pole, WW threshold, Higgs threshold

<u>SPECIFIC STUDIES NEEDED</u>

- 350 GeV detailed performance studies
- PERFORMANCE vs. INTEGRATED LUM.