Physics requests to a LC
Do we need LHC and a LC at the same time ?

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Preamble/Disclaimer

- No doubt that (sooner or later, at lower or higher $\sqrt{s}$) an e^+e^- LC will be needed to complement the LHC
- Detailed studies exist worldwide:
  -http://blueox.uoregon.edu/ lc/wwstudy/
  - http://www.desy.de/conferences/ecfa-lc-study.html
  - http://acfahep.kek.jp
  - http://deroeck.home.cern.ch/deroeck/clic/spin2.html
- More recently, LHC/LC Study Group:
  - http://www.ippp.dur.ac.uk/ georg/lhclc/

Impressive amount of detailed, dedicated work

Here just some personal comments 'with the detachment of the outsider' strongly interested in the physics but not personally involved in any of the current LC study groups

The case for a LIGHT HIGGS BOSON

After almost 20 years of EW precision tests

most likely option for EW breaking sector:

LIGHT HIGGS BOSON ($m_H <$ 200-250 GeV)

$\oplus$

no other physics below $\Lambda \sim$ few TeV

unless weakly coupled to SM particles (e.g. SUSY)

if it can escape direct searches and
indirect constraints from flavor physics

Rather SOLID CASE but still some CAVEATS . . .

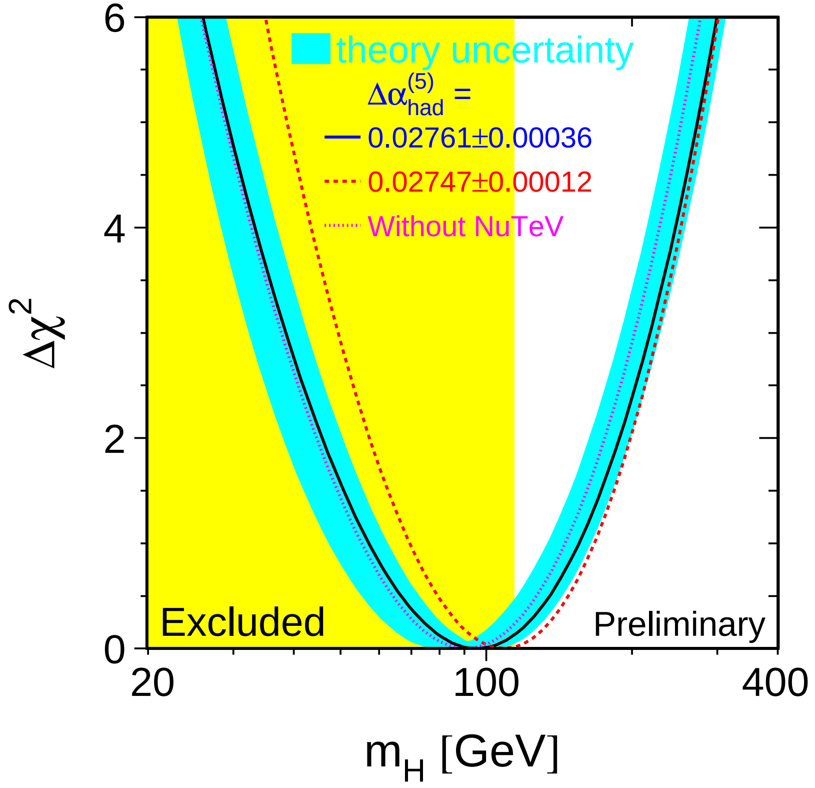
THE CAVEATS:

- no SM-like Higgs found up to $m_H \sim 114$ GeV
- light Higgs may be evaded with
  new physics below $\sim$ 1 TeV
  and a little tuning of more parameters
  (but no predictive model on the market)
- m_H bound from SM fit not crystal-clear
  (precise measurement of m_t will help)
- LITTLE HIERARCHY PROBLEM:

  naturalness + light Higgs $\Rightarrow$
  why no evidence yet for new physics?

  $$(\Delta m_H^2)_t \sim \frac{3G_F}{\sqrt{2}\pi^2}\, m_t^2\, \Lambda^2 \sim\ (0.3\ \Lambda)^2 < \mathcal{O}(m_H^2)$$

SM fit to m_H from EW precision data

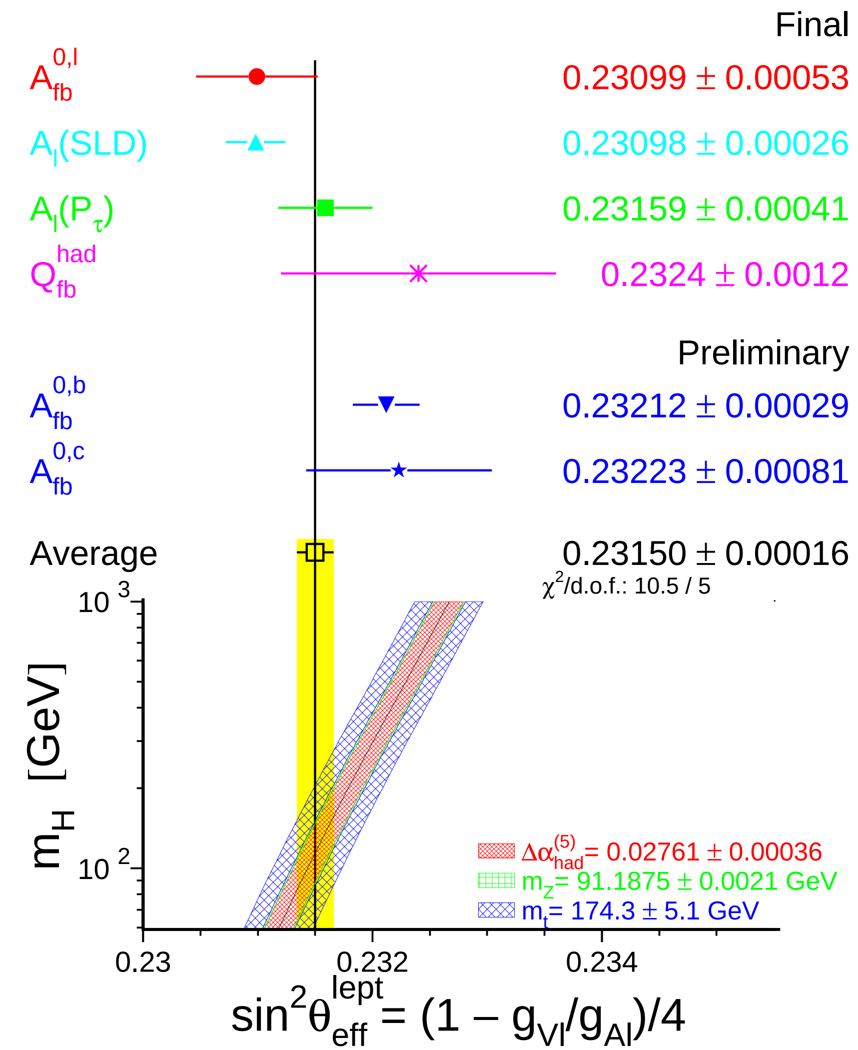


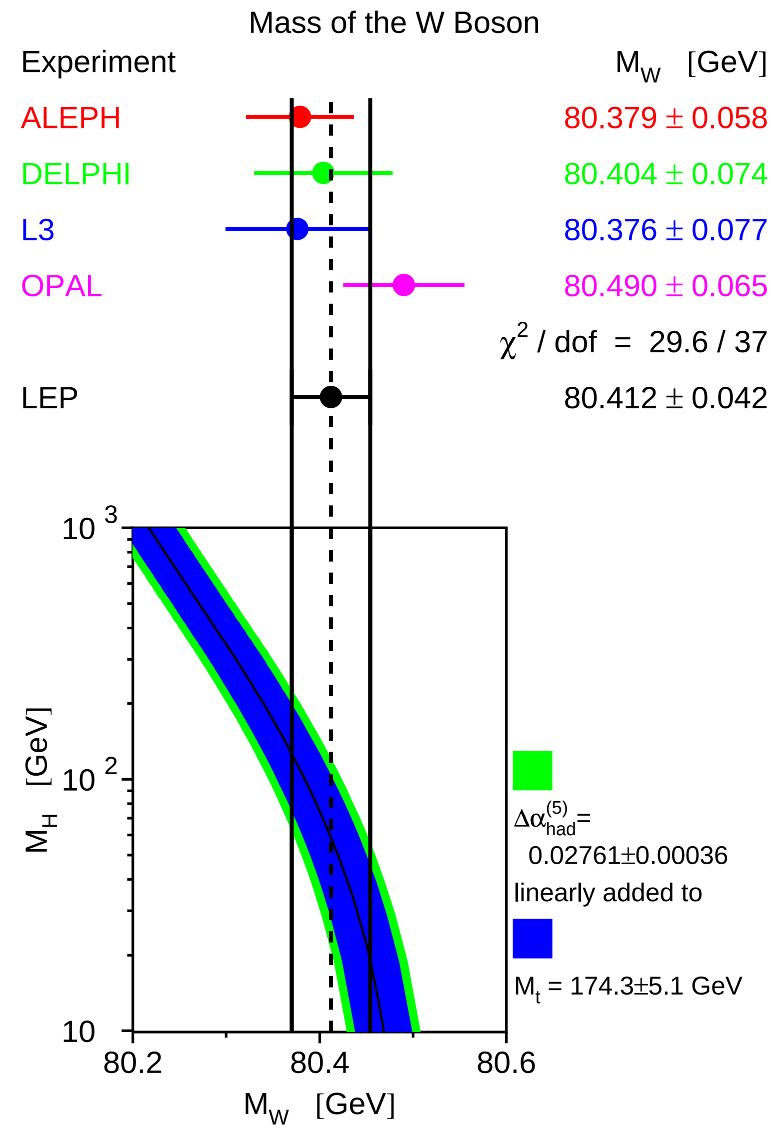
LEPEWWG, Summer 2003:

(without NuTeV)

- $m_H = 91^{+55}_{-36}$ GeV
- $m_H < 202$ GeV (95% c.l.)
- $\chi^2/dof = 16.7/14$ (27.5%)

But how does the preference for a light Higgs arise?



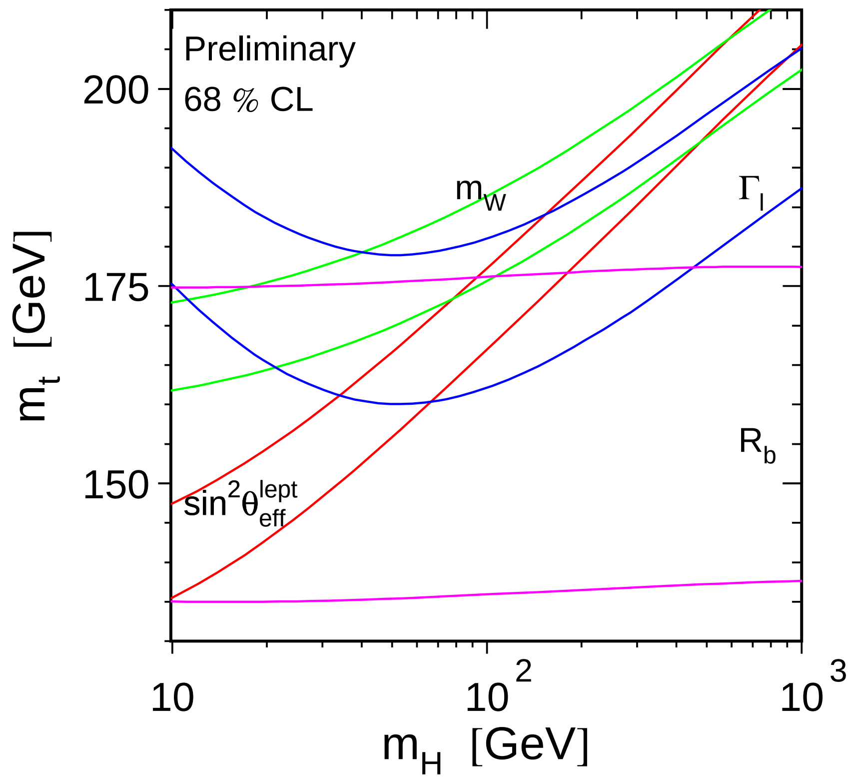


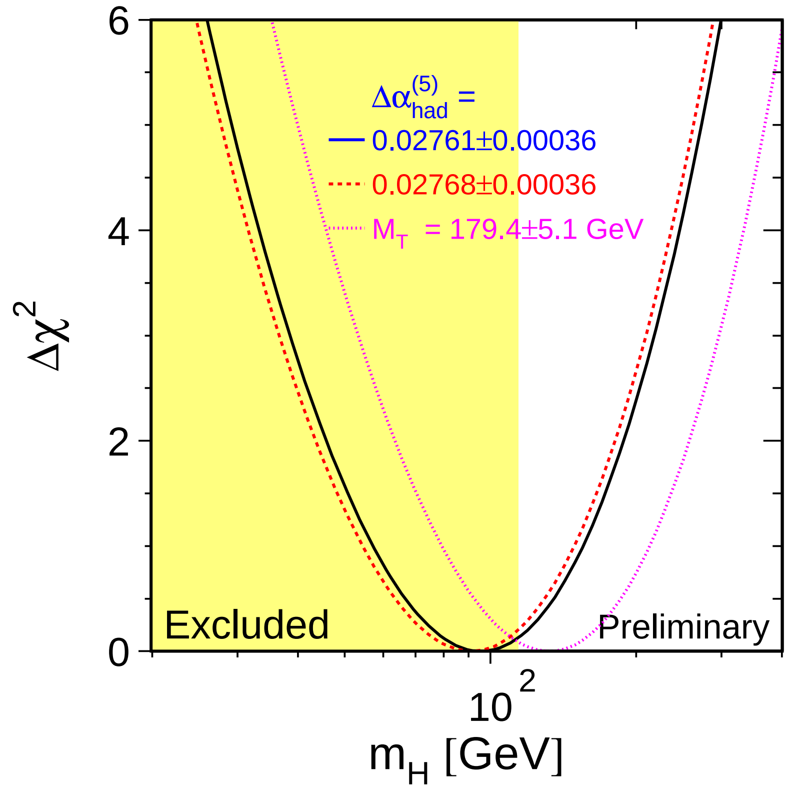
2.9σ between A_l and $A_{FB}^{0,b}$

$\chi^2/dof = 10.5/5$ $(P = 6.2\%)$

$p\overline{p}$-colliders: 80.454 ± 0.059

Average: 80.426 ± 0.034





$+1\sigma$ shift in m_t

m_t–m_H sensitivity

$\Rightarrow m_H < 283$ GeV

The case for (LIGHT) SUPERSYMMETRY

motivated well-defined model(s)
for new physics at the Fermi scale

- can solve the 'big' hierarchy problem ($\Lambda_{SM} \sim \tilde{m}$) and be extrapolated to $\Lambda_{MSSM} \sim \mathcal{O}(M_{GUT}, M_P)$
- fits nicely with gauge coupling unification and unification with gravity (superstrings)
- can provide good dark matter candidates

Also SUPERSYMMETRY, however, has its CAVEATS . . .

THE CAVEATS:

- no SUSY particle found at LEP and Tevatron

  $\oplus \quad (m_h^2)_{MSSM} < m_Z^2 + \frac{3m_t^2}{2\pi v^2} \log \frac{\tilde{m}^2}{m_t^2}$

  $\oplus$ indirect bounds from flavor physics

  ask for a HEAVY SUSY SPECTRUM

- naturalness bound particularly restrictive

  $v^2 = \frac{\tilde{m}^2}{\lambda}$ & $\lambda_{MSSM} < \frac{1}{15} \Rightarrow \; v^2 > \mathcal{O}(15\,\tilde{m}^2)$

  would ask for a LIGHT SUSY SPECTRUM

$\mathcal{O}(1\%)$ fine-tuning required today

light SUSY spectrum for (LHC and) a LC not obvious
(even assuming that supersymmetry is realized)

need further theory input to judge better

Other possibilities?

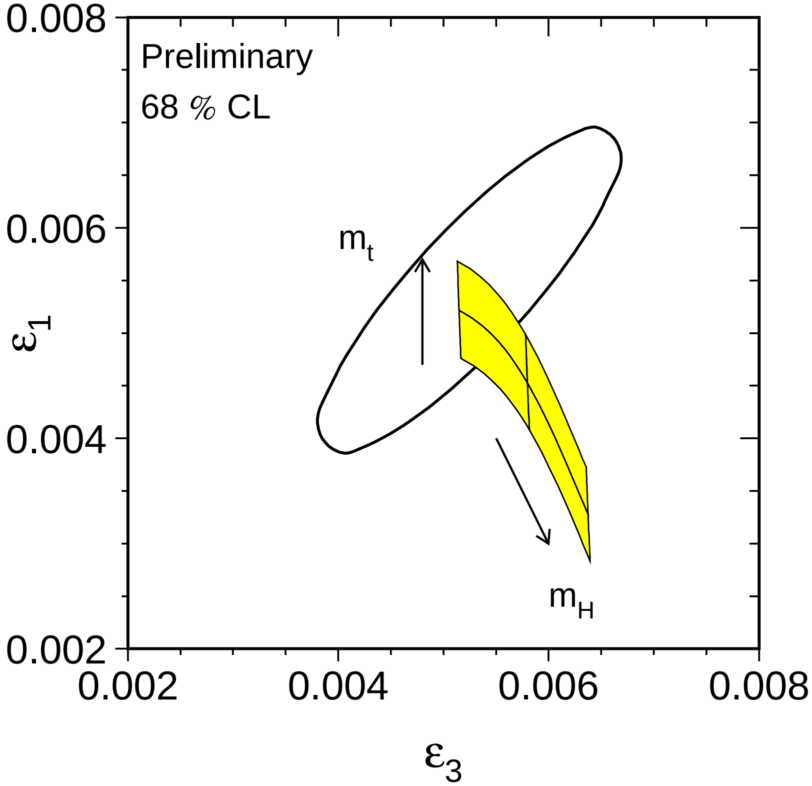
STRONG EW BREAKING SECTOR (heavy Higgs, TC, . . .)
strongly disfavoured by EW precision tests ($\epsilon_{1,2,3}$, S-T-U)
could be allowed by a 'conspiracy', no good model

WEAKLY COUPLED NEW PHYSICS

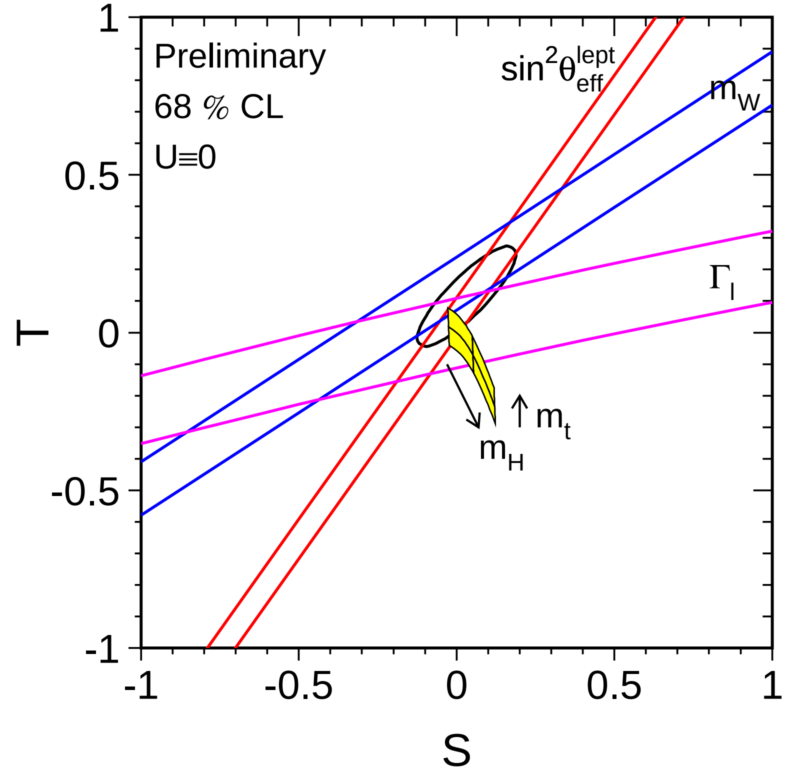
- $\odot$ extra dimensions without 4D susy
- $\odot$ little Higgs models (Higgs $\equiv$ PGB)
- $\odot$ . . .

need UV completion before $\mathcal{O}(10)$ TeV
none of them better than SUSY (thus far)
again: naturalness $\Leftrightarrow$ precision tests

light new physics for a LC possible but not guaranteed



ε_1–ε_3 fit



S–T fit

Complementarity:

COMPLEMENTARITY of LHC/LC is EVIDENT
in all conceivable scenarios of EW breaking

in all scenarios $\sqrt{s} \gg 500$ GeV can help
in some cases $\sqrt{s} \gg 500$ GeV may be needed

many detailed studies already exist

Simultaneity (time overlap):

LHC $\sim$ 2007-20   LC $>$ 2014 (?)

distinct from above, more complicated to judge

not fully studied yet, can learn from LEP/Tevatron

Pro's:

- LC input into ongoing LHC analyses: expertise may disperse after, more flexibility during than after LHC
- LC input into possible LHC upgrades: machine energy vs. luminosity; polarization; detector optimization for specific searches; new trigger options; . . .
- a healthy competitive atmosphere

Con (non-negligible):

- LHC input into LC machine and detectors

Is any compromise possible ?