The Physics Case for TESLA

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- Electroweak Symmetry Breaking: The Higgs
- Standard Model Physics
- Physics beyond the Standard Model

TESLA Parameters

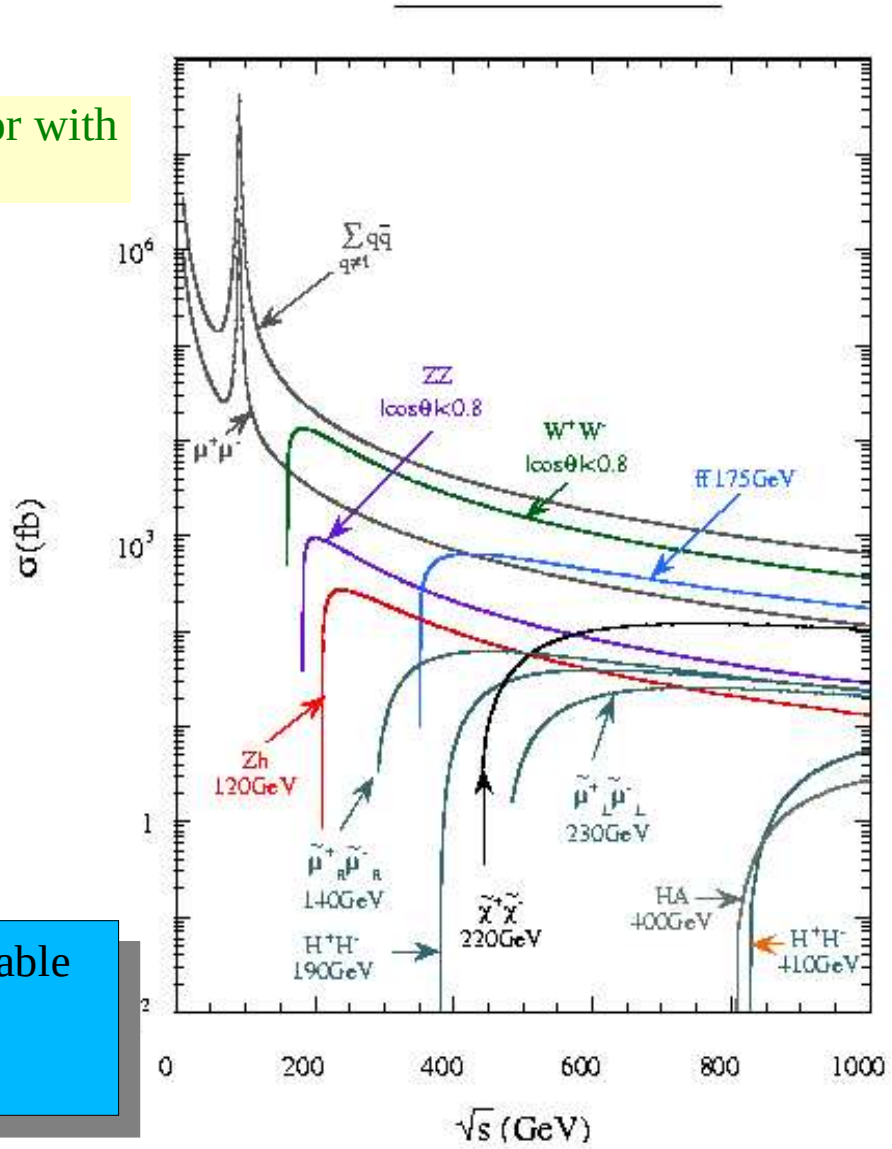
TESLA: electron positron linear accelerator with an integrated X−Ray laser

luminosity: 5×10^{34} cm^{-2} s^{-1}

bunch trains of 2820 bunches
time between bunches 337 ns

integrated luminosity/year 500 fb^{-1}

100000 Higgs/year
300000 tt / year
1000000 WW/year



enormous quantities of data will be available at the highest energies!
Precision physics will be possible

EW Symmetry Breaking

- central question for the next generation of colliders:
  - understand the nature of the electroweak symmetry breaking mechanism (EWSB)

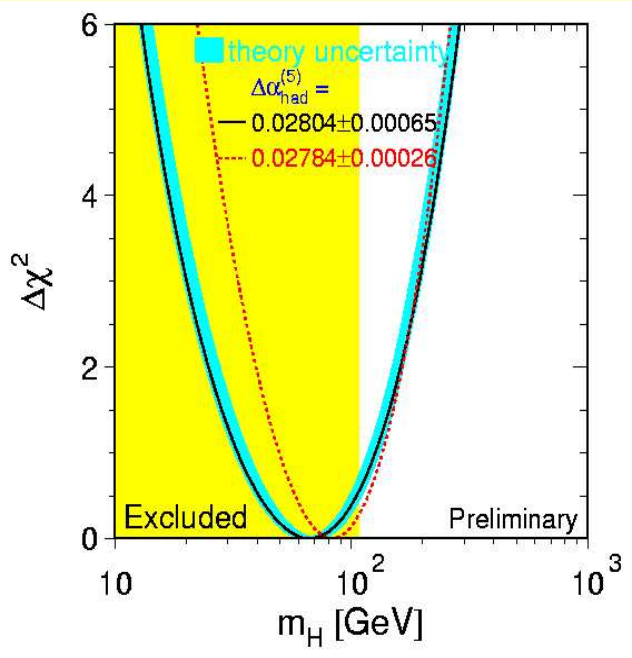
- currently three main routes to EWSB are discussed:

1. an elementary Higgs boson exists → search for the Higgs boson
2. the Higgs boson is composite → search for the substructure
3. there is no Higgs boson → new strong force must exist at some scale

The Case for an Elementary Higgs

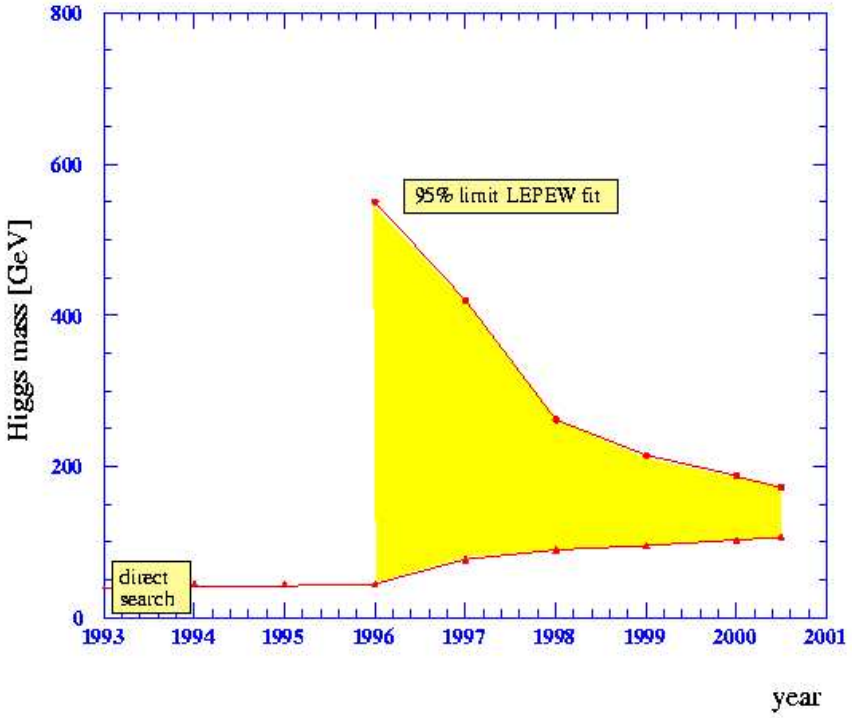
If the Higgs is elementary:

indirect limits from LEP



M < 188 GeV@95% CL

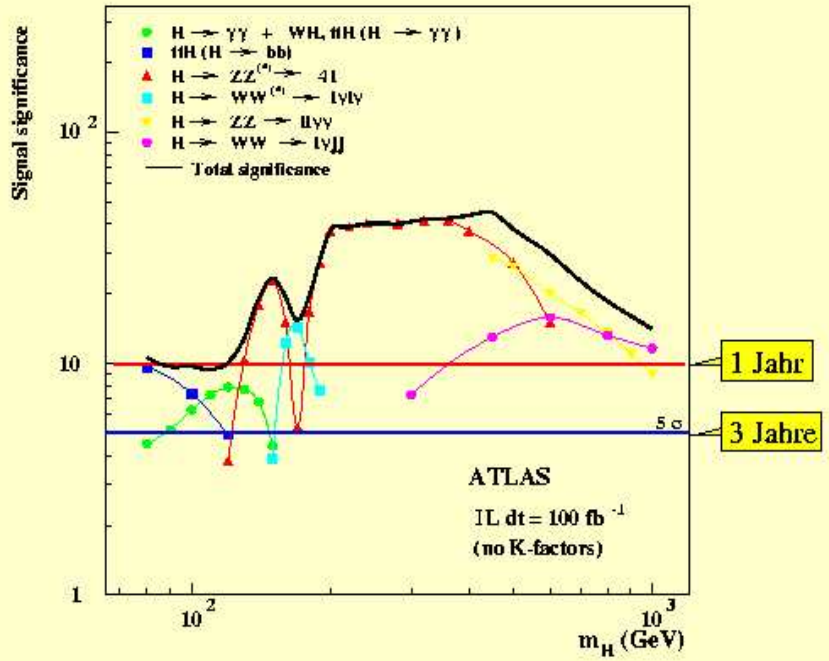
development of limits over time:



- light elementary Higgs very much favoured
- other (theoretical) constraints

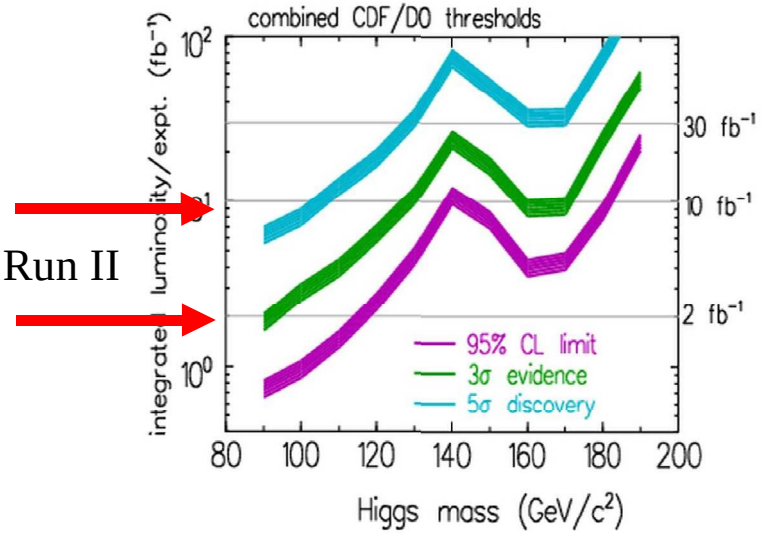
validity of perturbation theory:	< 500 GeV
GUT constraints (naive)	< 180 GeV
SUSY models	< 205 GeV

Possible Discovery of the Higgs



LHC: convincing signals after approx. 3 years
if the Higgs is light
faster, if the Higgs is heavy

Tevatron reach for run II:



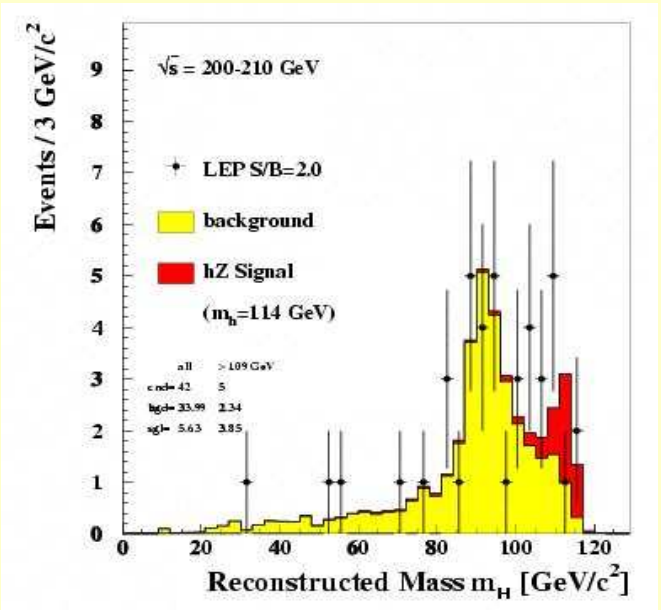
Either Tevatron or LHC will likely find the Higgs if it is there,
and if LEP has not already found it

Higgs Properties

"Is it or is it not?"

Once "signals" are found:

- determine mass and width
- measure quantum numbers J^{PC}
- determine the couplings to fermions (mass)
- measure Higgs self−coupling, determine the potential
- separate SM Higgs from SUSY Higgs or other models



LEP data from September 2000:
some excess observed (< 3 sigma)
at M(higgs) = 115 GeV

Need whole series of measurement to fully establish nature of Higgs mechanism

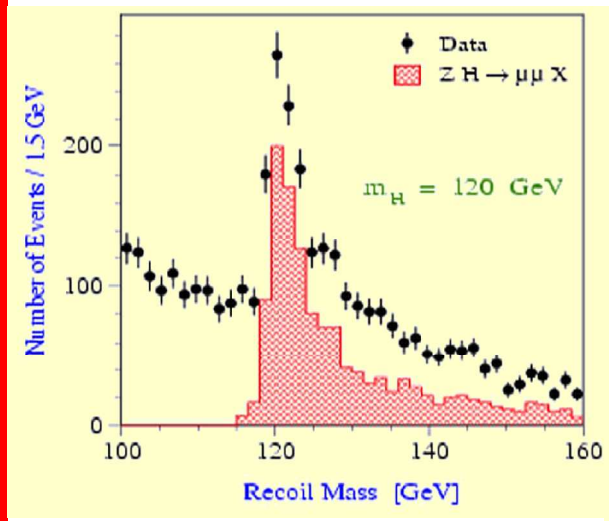
Higgs Parameters: Mass, Width

determination of mass of Higgs:

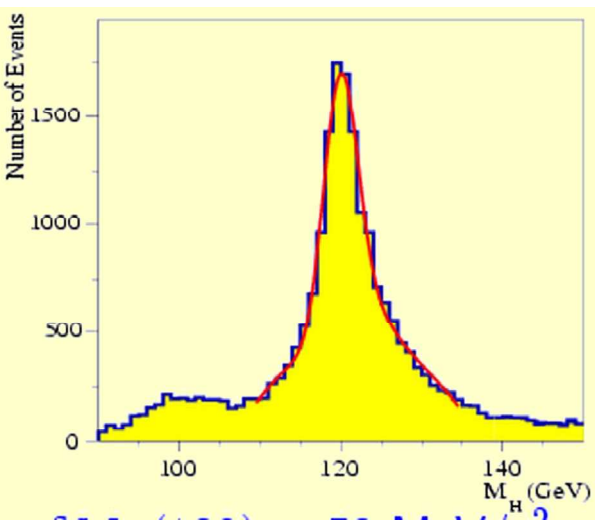
direct reconstruction of Higgs in a number of decay channels possible,

most favourable ee → Z → HZ

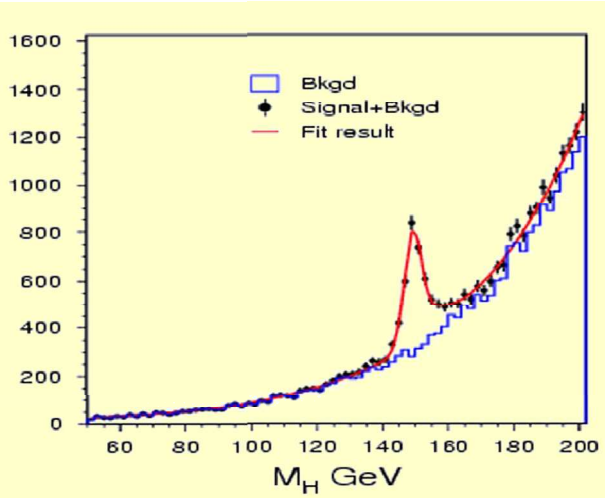
ZH → mmX



ZH → qqbb



ZH → WW qq

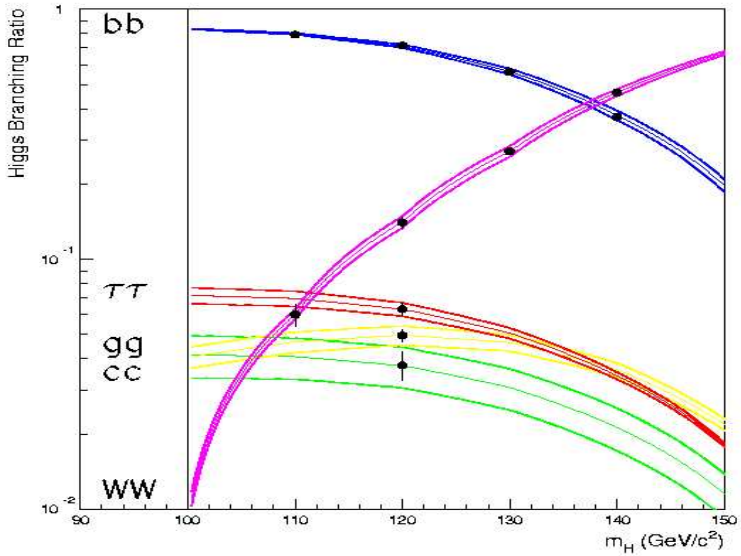


Clear signals in many channels:

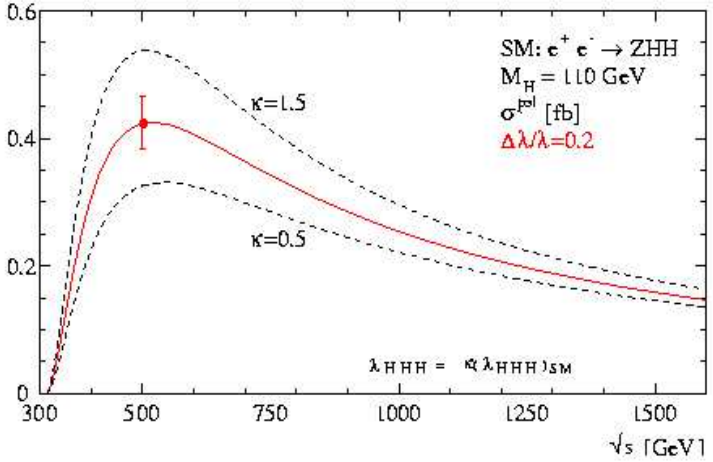
mass		width:
M(Higgs)	dM	
120 GeV	40 MeV	to 5−10%
150 GeV	70 MeV	
180 GeV	90 MeV	

Beyond a Discovery

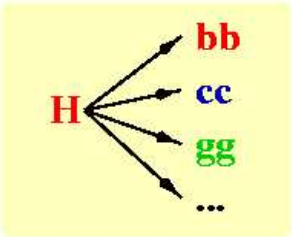
couplings to fermions:



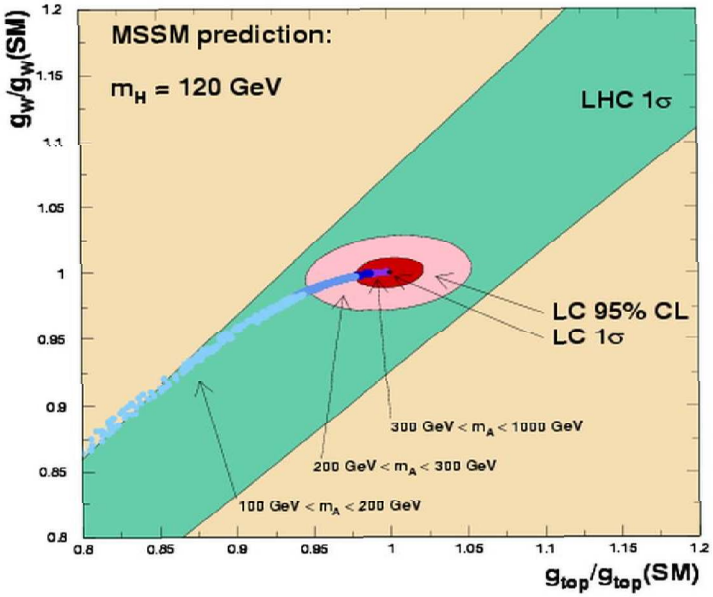
Higgs self couplings: Higgs Potential



- complete test of our understanding of mass
  - can the Higgs explain the Z−mass?
    is the existence of the Higgs enough?



comparison to LHC:

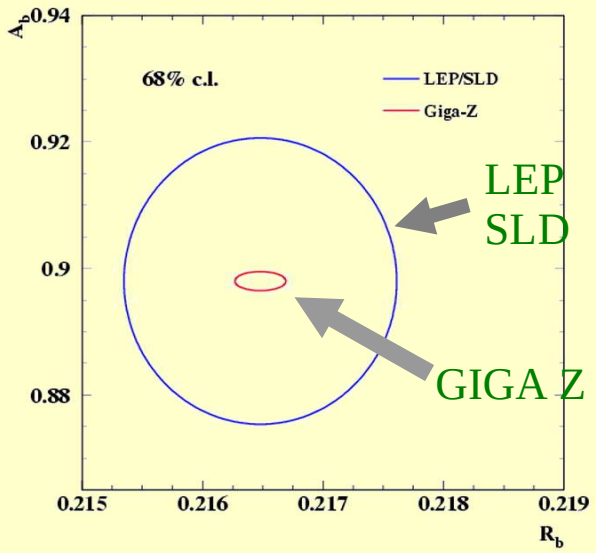


"GIGA Z"

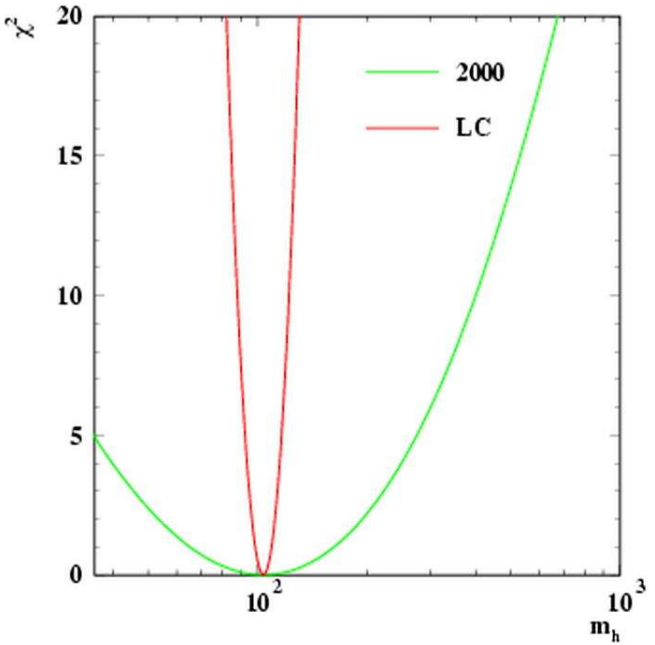
• if light Higgs is not found: return to lower energies as a first step!

GIGA Z:
operate TESLA at 91 GeV
very high luminosity
1 billion Z bosons possible

improve the precision electroweak measurement from LEP



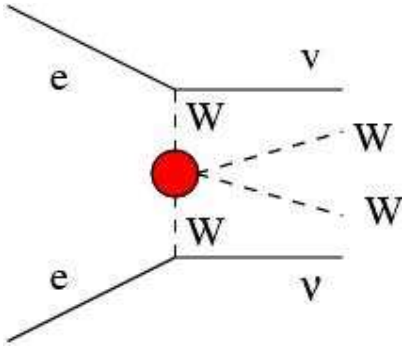
• redo the indirect Higgs "limits" using GIGA Z:
  • get much more stringent information
  • if there is an inconsistency somewhere, it will show up here

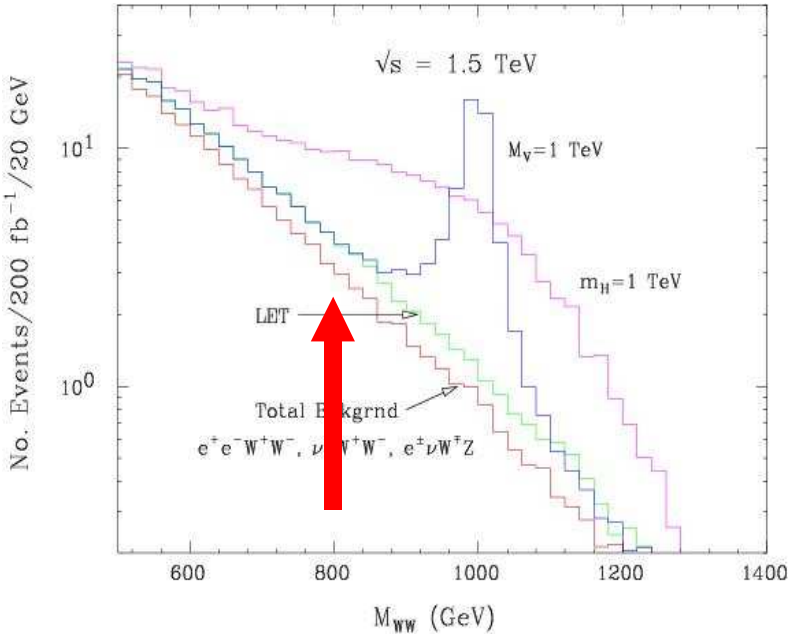


try to look see indications of where to go for new physics before going there!

The Higgs does not exist...

- if no Higgs is found at LEP, Tevatron, LHC, LC:
  - very fundamental arguments require: something must happen on the TeV scale
  - one possibility: a new strong interaction (WW rescattering) plays the role of the Higgs
    there are no fundamental scalars in nature, "fermioncentric" world,
    either no Higgs exists, or the Higgs is composite





- main access: study of WW scattering
- effects already visible at "low" energies

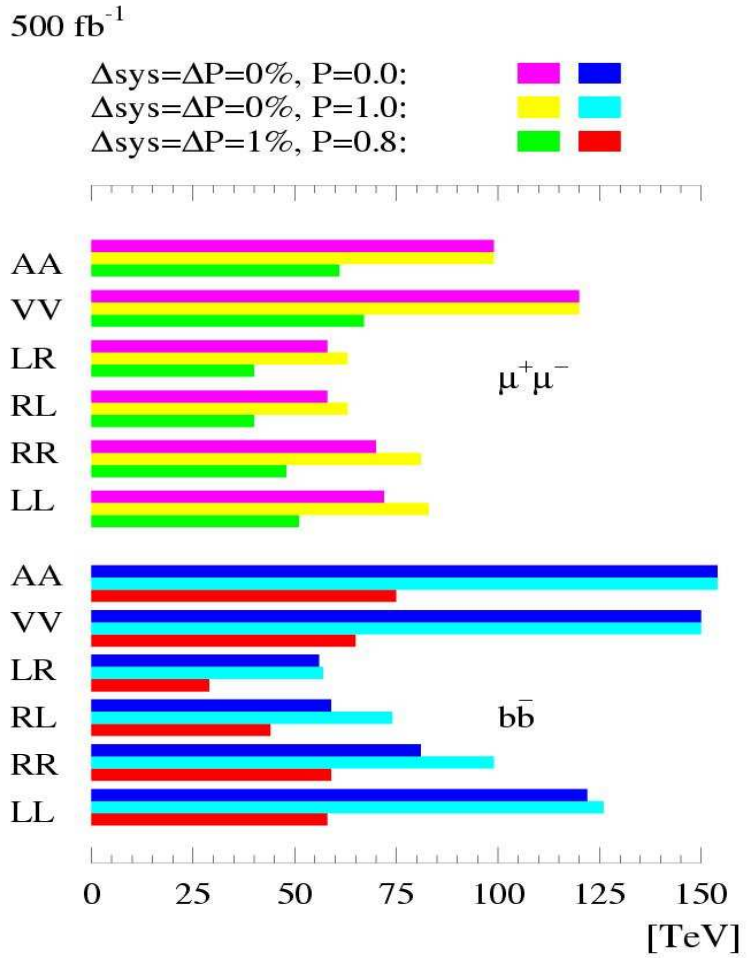
consistent models for this type are difficult

Substructure

- is there a structure below the known one
  - new heavy Z−like bosons
  - Leptoquarks?
  - exotic spin 2 exchange particles?
  - ...

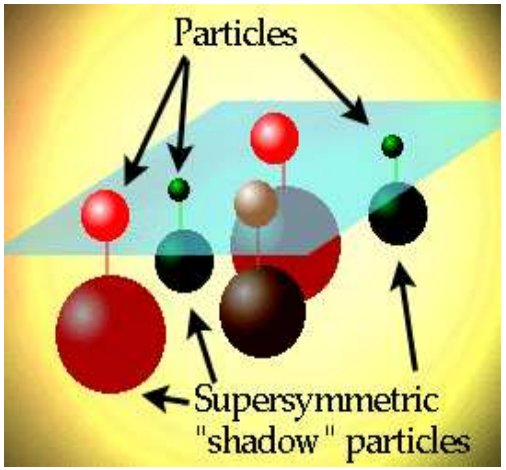
- best studied in the reaction: $e^+e^- \to f\bar{f}$

the scale of substructure can be probed well beyond the energy of the collider



Physics beyond the Standard Model

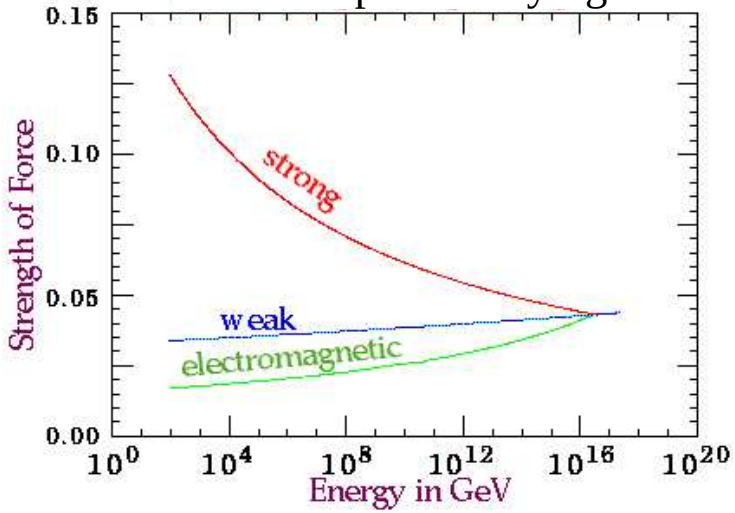
- "there must be something more than just the Standard Model..."
  SUPERSYMMETRY?



just one possible model of many
but experimental signatures are
similar

SUSY: fundamental symmetry between fermions and bosons
doubles number of particles
particles must be heavy, since no observation so far
SUSY must be "broken"

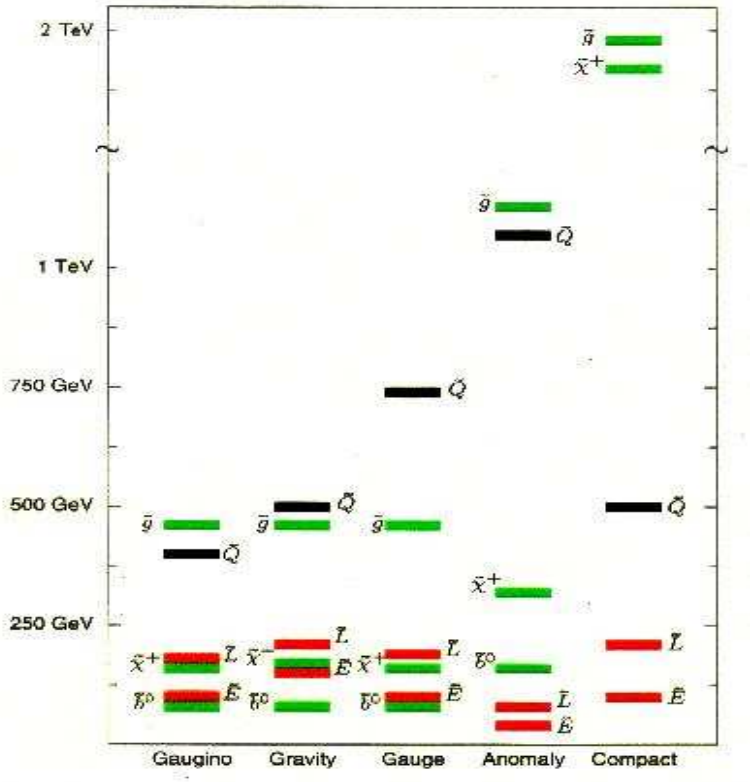
SUSY helps in unifying forces at large energies



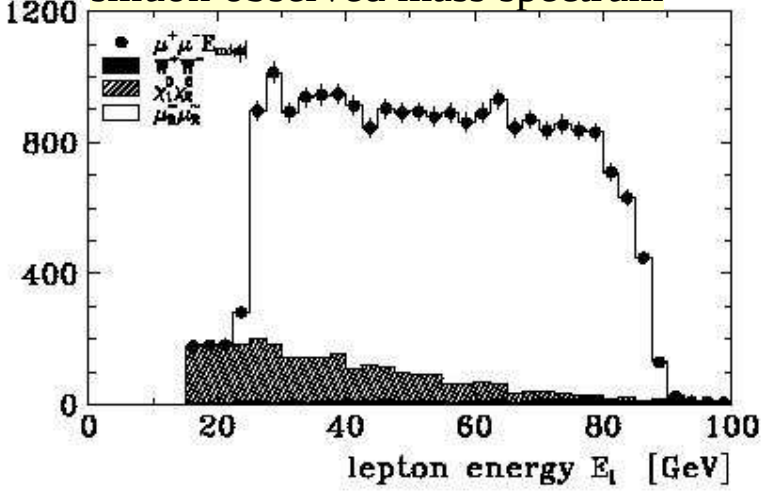
- Supersymmetry extends the SM,
  does not replace it
  (example: quantum mechanics
  extends classical
  mechanics, does not replace it)
- so far no experimental evidence for SUSY

Supersymmetry

- key to Supersymmetry:
  - discovery
  - spectroscopy to select the correct model
- in "all" models: expect at least some of the SUSY partners at few 100 GeV ("no loose theorem", nearly model−independent)



smuon observed mass spectrum

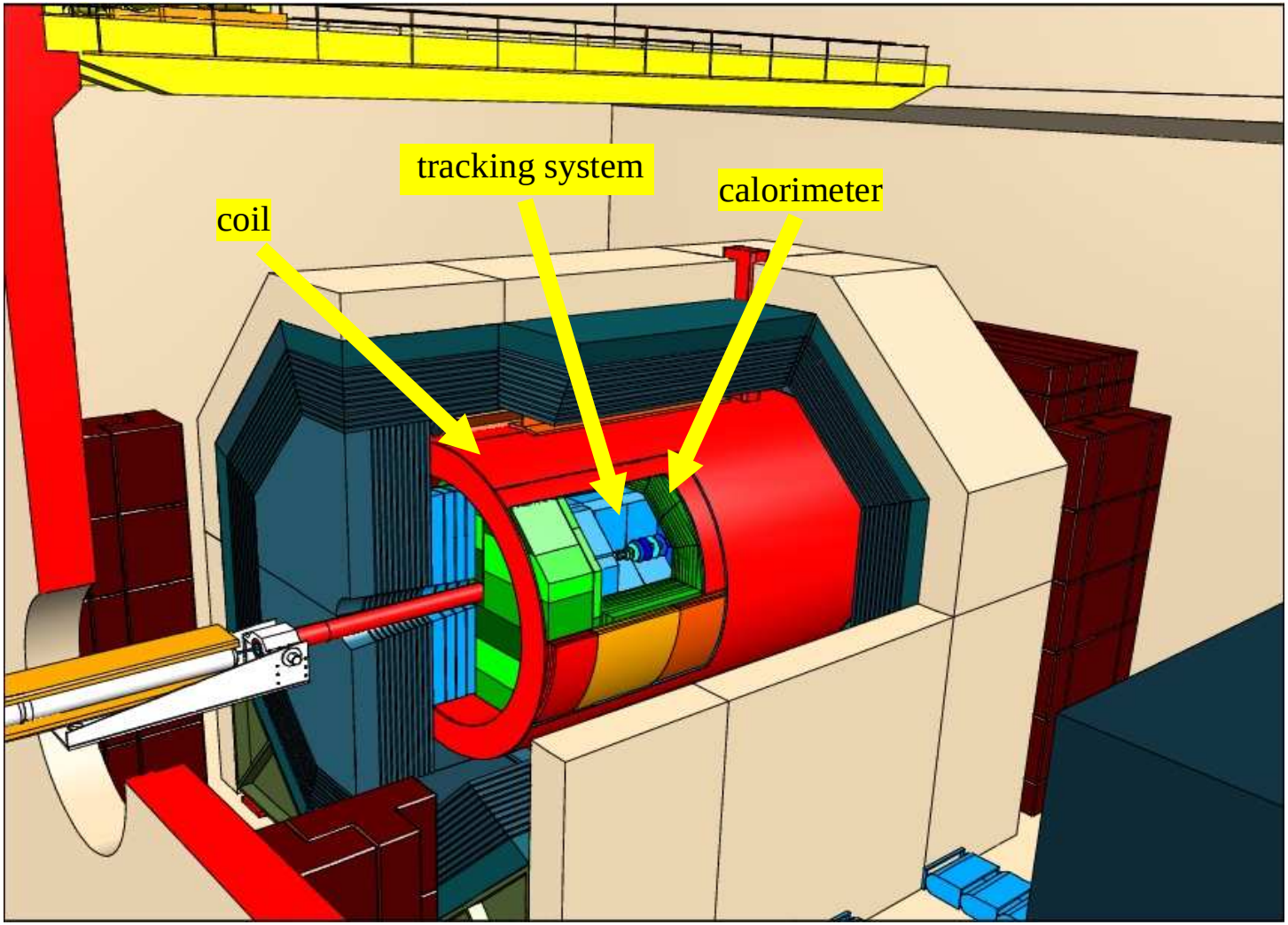


spectacular signals for SUSY partners if in the kinematic reach at LC

TESLA will be able to contribute significantly to the knowledge about SUSY, if SUSY exists

A Detector for TESLA

view of a proposed detector for TESLA

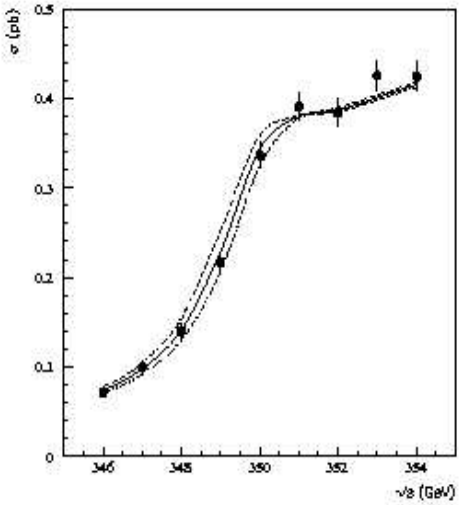


ECFA−DESY linear collider study

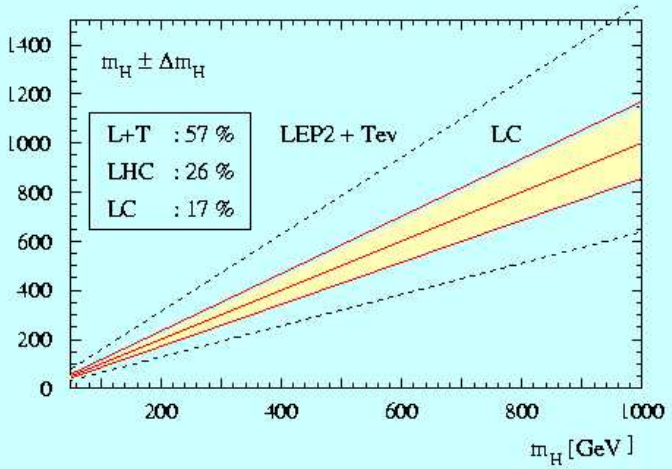
TOP Physics

- A linear collider with E>350 GeV is a top factory
- allows precision studies of the top system
  - top is the heaviest known fermion
  - top−Higgs coupling is very interesting if it exists (Higgs couples to mass)

top threshold scan



based on 500 fb^{-1} of integrated luminosity (1 year)
error: m =±100±(100−200) MeV



- allows stringent consistency checks of the Standard Model

Precision Tests of the Standard Model

Physics Summary

- a linear collider with E= 500 to 800 GeV offers many possibilities

- EWSB: major insights expected
  - Higgs precision measurements
  - SUSY (or similar) precision study
  - model independent search for alternative scenarios

very strong hints for physics at a few 100 GeV!

- many precision measurements to significantly extend our present knowledge
  - electroweak precision measurements
  - W mass measurement
  - top mass and properties
  - QCD physics
  - ....

results feed back into EWSB understanding

- a linear collider will also search for the totally unexpected
  - substructure?
  - completely new physics: extra dimensions?
  - ...

- the linear collider will complement the physics program of the LHC. Only together can we hope to understand the fundamental problem of electroweak symmetry breaking!