The LHC and the Higgs boson

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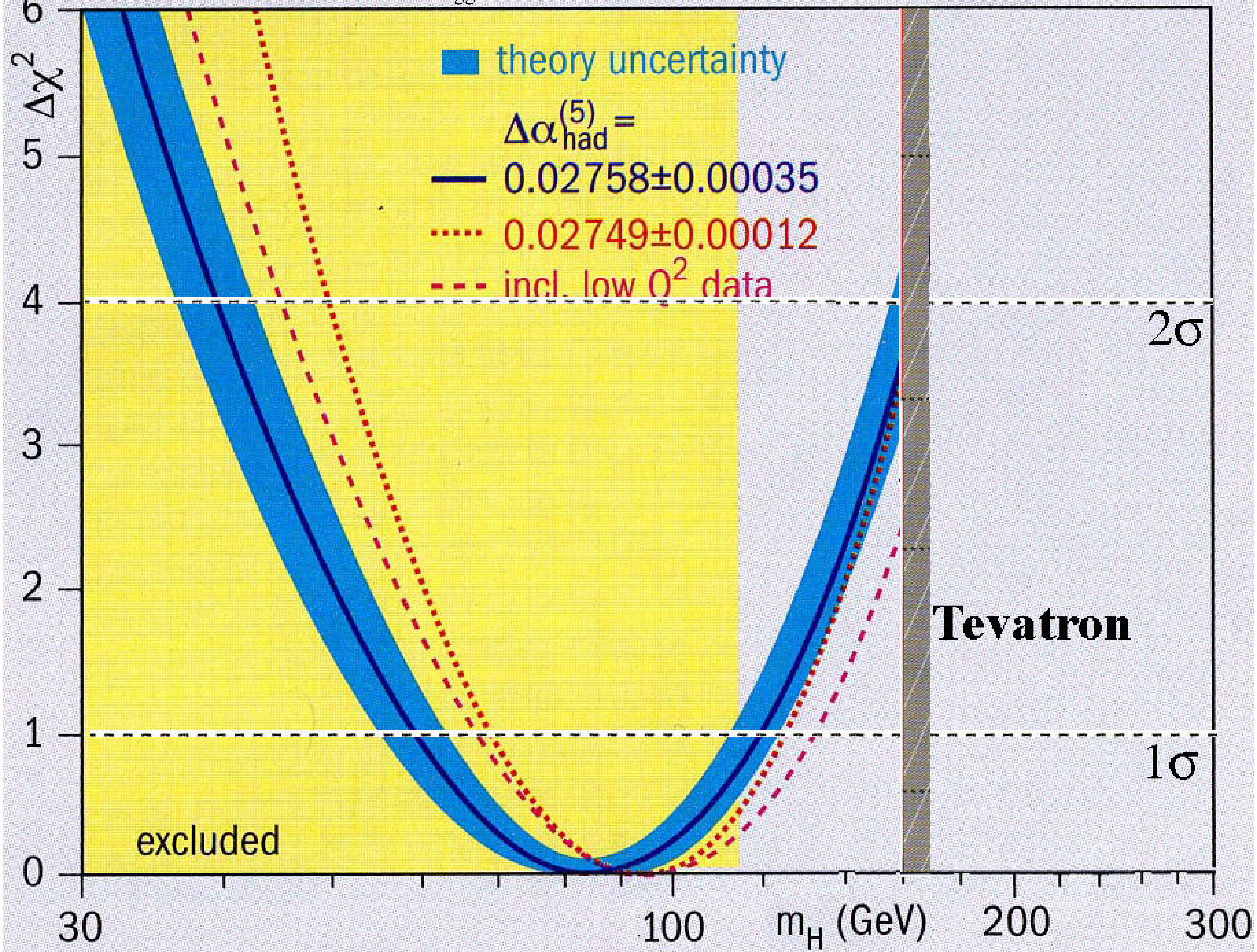
Higgs search



Higgs hunting

In 1974 I asked myself: if the Higgs is all around us in the vacuum we should really be able to see it. Since the Higgs field in the vacuum is an energy distribution at least gravity should see it.

The answer to that is that the Higgs field generates a curvature of the universe, corresponding to some value for the cosmological constant (Linde, MV).

This can be calculated from the expectation value of the Higgs field in the vacuum according to the Standard Model.

The result is about 45 orders of magnitude different from the observed rather small value.

I then stopped believing in a Higgs. Of course one may also question the cosmological part of Einstein's theory of gravity.

Naturally the next question is where Higgs mass dependent terms could be observed experimentally. This required investigation of the radiative corrections in the Standard Model.

SPC (1976-1980)

At that time I was asked to become a member of CERN’s Scientific Policy Committee (SPC).

There existed some studies (Richter; Bennett et al, CERN 77-14) on the construction of a 100-200 GeV electron-positron machine.

After reflecting on that I decided to accept the invitation and start pushing for an electron-positron collider.

Thus I started searching for Higgs mass dependent radiative corrections that could be observed with such a machine.

The first objects were the radiative corrections (rc) to the W and Z masses. First I introduced the ρ parameter (involving the ratio of the W and Z mass). For the simplest Higgs system ρ = 1 + rc, and I started investigating these radiative corrections.

Unexpectedly, a correction proportional to the top mass **squared** turned up. That correction was experimentally observed and led to a prediction for the top mass, as later found at Fermilab.

Higgs mass dependent corrections

In principle there could also be corrections proportional to the square of the Higgs mass. However as fate has it they are zero in the case of the simplest Higgs system. The next term was very small ($\rho = 1 +$ C(top)+ 0.000815 ln m/M) and it seemed to be too small to be measurable.

However, the precision measurements at LEP etc. exceeded the wildest expectations. The figure on slide one represents essentially the measurement of the Higgs mass dependent term through a precision determination of the ρ parameter.

Another observable Higgs mass dependent radiative correction occurs in WW (or WZ or ZZ) production.

This correction is energy dependent and becomes of the order of a percent at an energy of 250 - 300 GeV.

The fact that there are only these small (i.e. logarithmic) corrections goes under the name of "screening theorem".

Note: even without a Higgs one expects the ρ parameter to be one as then the quadratic divergencies cancel (they drive ρ to 1).

LEP energy decision (1979)

On the basis of the arguments given I started pushing in the SPC
for 300 GeV. No luck. I lowered to 250 GeV.

Simultaneously other people pushed for a 150 GeV (??) machine.

Then there was that fateful SPC meeting.

One of CERN's director generals got up and stated: let us take the average.

Thus the 200 GeV LEP machine was born.

What would a 250 GeV machine have meant ?

It is really a sad story. It would have meant that the excluded region would be extended upwards by 50 GeV. If no Higgs observed that would put the limit to 164 GeV. We would know by now if a Higgs existed…..

Mind you, I myself am not going scot-free. I had no idea that the precision measurements would produce an upper limit of 170 GeV. Else I might have fought harder.

Heavy Higgs

As a model of a theory without a Higgs the Standard Model in the limit of a very large Higgs mass can be used. What happens ?

The radiative corrections due to the Higgs become large, so much so that perturbation theory breaks down (strong interaction).

The Higgs sector in the limit of a heavy Higgs looks like the σ model.
One speaks of the equivalence theorem (Gaillard, H. Veltman ao).

That σ model was already employed succesfully for the system of pion-pion scattering at low energy. The idea was then to scale up to the GeV level (from 100 MeV to 250 GeV).

In the π π system there occurs a strong resonance, the ρ meson.

Could there be a strong WW resonance at about 2 TeV ?

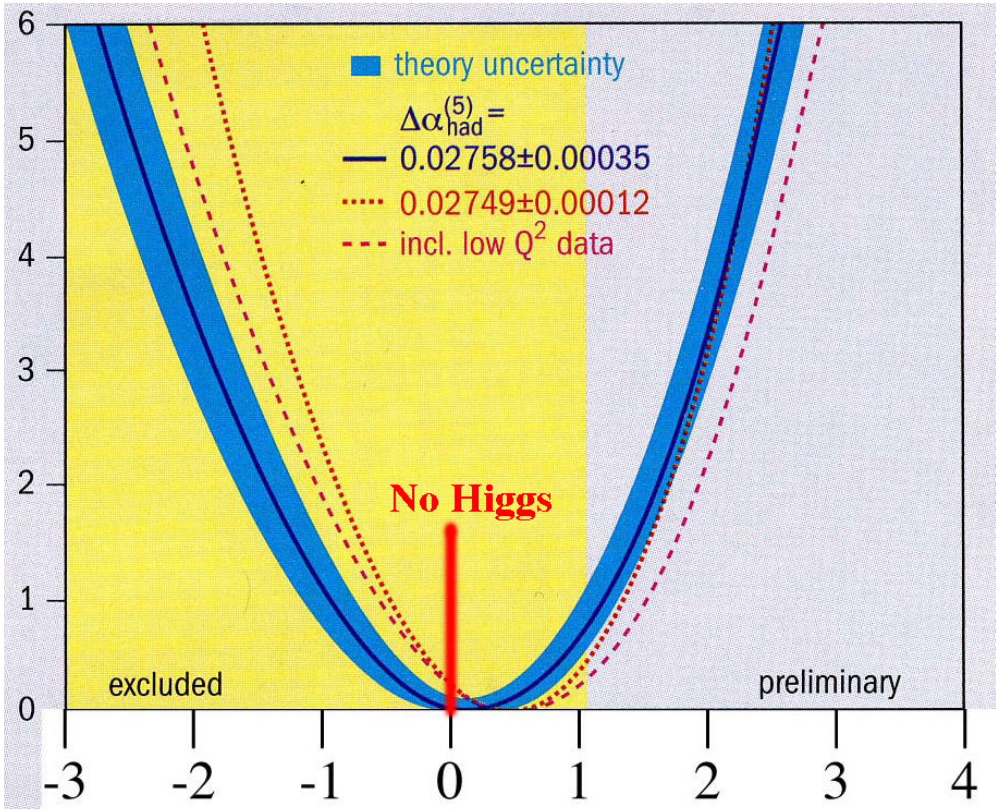
Following Lehmann, the result of an analysis (H + M Veltman 1991) was : very likely not.

If we now apply that knowledge to the ρ parameter, what is the result ?

ρ parameter for a heavy Higgs

It is very hard to come to a precise conclusion. But, on the basis of the results from the above analysis it appears that a neglible correction to the ρ parameter would result.

Thus it seems reasonable that the No-Higgs model corresponds to no correction to the ρ parameter, which is the red line in the figure.



Correction to the ρ parameter apart from some factor.

Invisible Higgs

Another solution to the possibility that no Higgs is found is to make the Higgs invisible or at least less visible (van der Bij, Hill).

One way to do this is by introducing a scalar particle (U-particle) that couples to the Higgs but to no other particle of the SM.

However, one can have other particles with their own system to which the U particle couples. The Higgs might thus decay in them.

For example, imagine another SM (SM'), with its own photons and vector bosons, and its own quarks and QCD interactions. Now assume that SM' couples to the U particle as well.

That is perfectly possible, but there is no escape of the gravitational interactions. The U-particle must couple to gravity (because it carries energy), and per force then also all the other particles that the U particle couples to must couple to gravitons.

Astrophysicist will undoubtedly have no problem with the idea that the SM' particles constitute dark matter and thus consider the idea proven.

Conclusion

Thus if no Higgs is seen in the near future then either there is no Higgs or it is less visible. At this time the No-Higgs possibility seems preferable because of the excellent fit to the ρ parameter.

The above two options are of course not the same thing. Investigating carefully WW production at very high energies (> 250 GeV) may clarify the issue.

Therefore it seems that the LHC should be used to explore WW pair production as precisely as possible. Else we must wait for the next linear collider….

But then, who knows what will happen ?

Der Mohr hat seine Arbeit getan,
der Mohr kann gehen.

Schiller 1783