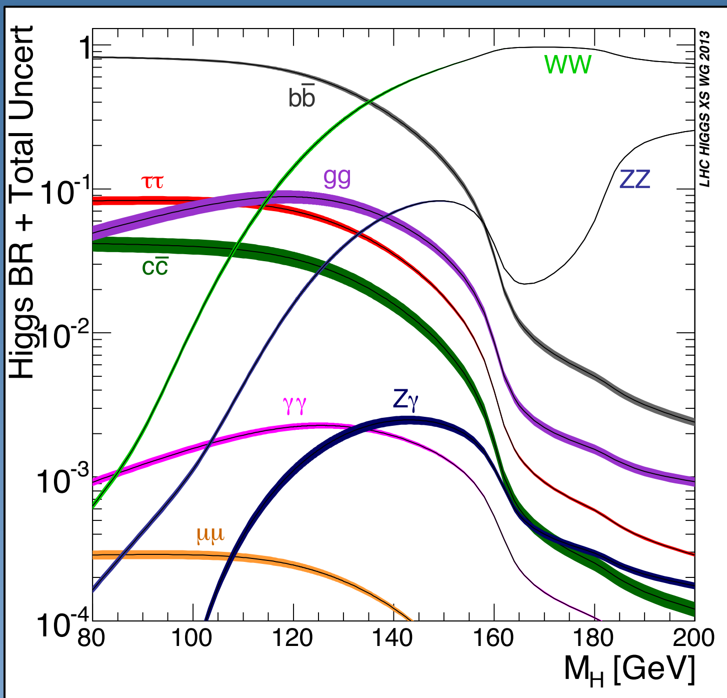
http://www.nikhef.nl/~ivov/BND2014/

Higgs physics
- exercises -

Question 1: Higgs branching fractions



$$\Gamma(h \rightarrow f\bar{f}) \propto N_C m_f^2$$

Predicted (I)

$$\frac{\Gamma(h \rightarrow c\bar{c})}{\Gamma(h \rightarrow \tau^+\tau^-)} = \frac{3 \times (1.275)^2}{(1.777)^2} = 1.55$$

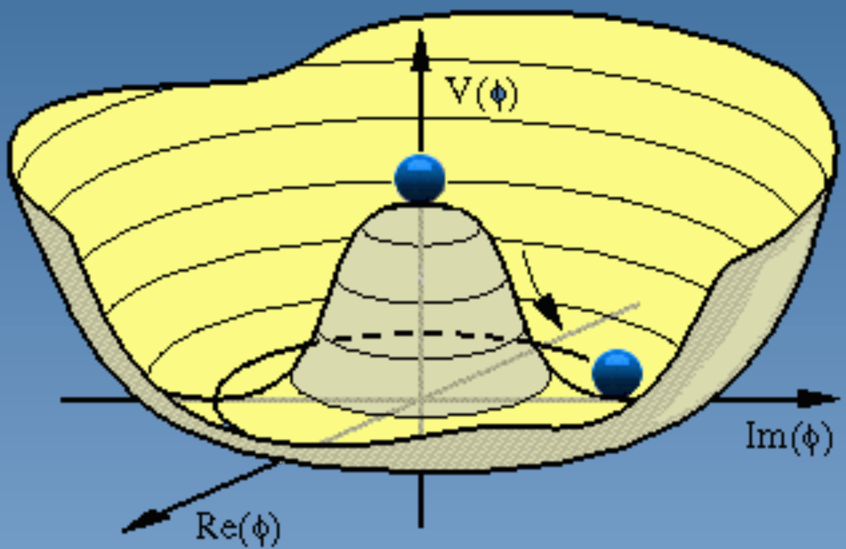
Predicted (II)

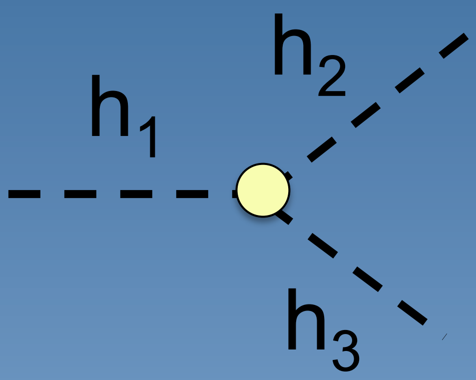
$$\frac{\Gamma(h \rightarrow c\bar{c})}{\Gamma(h \rightarrow \tau^+\tau^-)} = \frac{2.91\%}{6.32\%} = 0.46$$

Q1: Why does (I) not work ?
Note: can also study bb/tau's

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageBR3

Question 2: Higgs self-coupling





In the lecture we talked about the hhh vertex and the kinematic suppression because Γ_h= 4 MeV

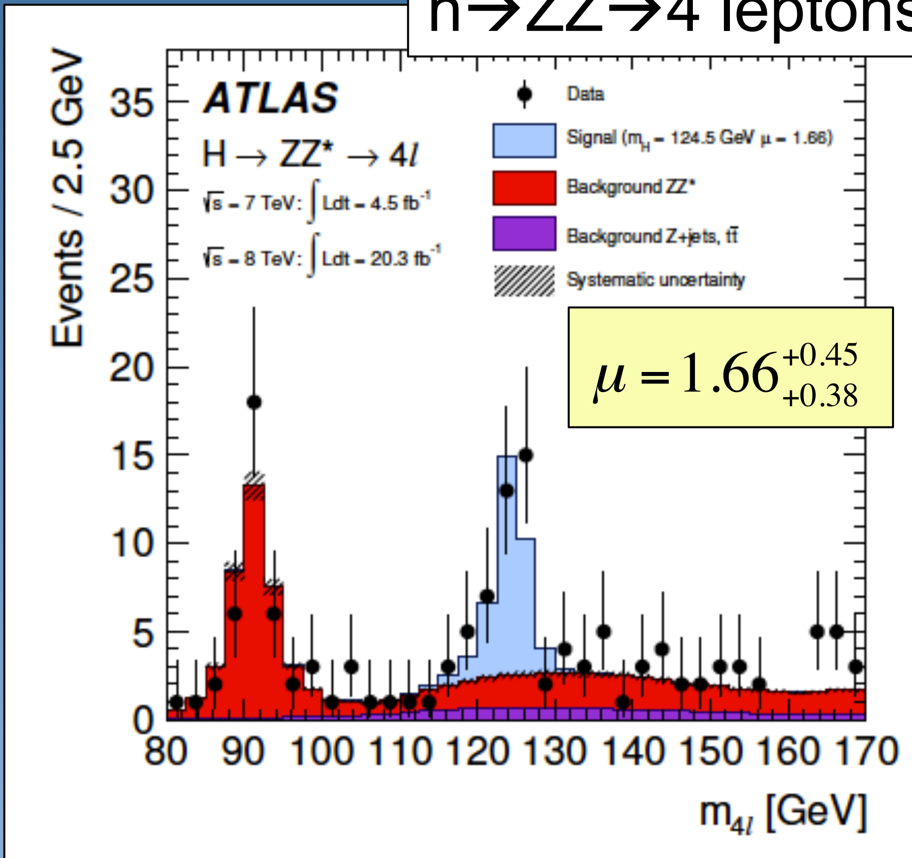
What is most 'economical' :

- h1 off-shell, h_1 an/ord h_2 a bit off-shell, …

→ what is the most optimal configuration ?

Question 4: significance

h→ZZ→4 leptons



$$\mu = 1.66^{+0.45}_{+0.38}$$

Look in region $120<m_h<130$ and do a counting experiment

A) What is the significance of the observed excess ?

B) Given μ=1.66, what was the expected significance ?

Question 3: Hypercharge of the vacuum

Mixing between W_3 and B fields
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$$(-gW_3 + g'Y_{\phi_0}B_\mu)^2 = (W_3, B_\mu)\begin{pmatrix} g^2 & -gg'Y_{\phi_0} \\ -gg'Y_{\phi_0} & g'^2 \end{pmatrix}\begin{pmatrix} W_3 \\ B_\mu \end{pmatrix}$$

c) **bonus:** Imagine that we would have chosen $Y_{\phi_0'} = -1$. What, in that scenario, would be the (mass-)eigenvectors A'_μ and Z'_μ, the 'photon' and 'Z-boson' ? In such a model, what would be their masses ? Compare them to those in the Standard Model.

Exercise [4]: A closer look at the covariant derivative
The covariant derivative in the electroweak theory is given by:

$$D_\mu = \partial_\mu + ig'\frac{Y}{2}B_\mu + ig\vec{T}\cdot\vec{W}_\mu$$

Looking only at the part involving W_μ^3 and B_μ show that:

$$D_\mu = \partial_\mu + i\mathrm{A}_\mu\frac{gg'}{\sqrt{g'^2+g^2}}\left(T_3 + \frac{Y}{2}\right) + i\mathrm{Z}_\mu\frac{1}{\sqrt{g'^2+g^2}}\left(g^2T_3 - g'^2\frac{Y}{2}\right)$$

Make also a final interpretation step for the A_μ part and show that:

$$\frac{gg'}{\sqrt{g'^2+g^2}} = e \quad \text{and} \quad T_3 + \frac{Y}{2} = Q, \text{ the electric charge.}$$

c) **bonus:** Imagine that we would have chosen $Y_{\phi_0'} = -1$. Show explicitly that in that case the photon does not couple to the electric charge.

Question 5: alternative Standard Model

Exercise [5] Gauge bosons in a model with an $SU(2)_L$ symmetry

Imagine a system described by a local $SU(2)_L$ gauge symmetry (iso-spin only) in which all gauge bosons are be massive. Note that this is different from the $SU(2)_L \times U(1)_Y$ symmetry of the SM involving also hypercharge. In this alternative model:

a) Explain why the Higgs field ϕ needs to be an $SU(2)_L$ doublet.
b) How many gauge bosons are there and how many degrees of freedom does ϕ have ?
c) Determine the masses of the gauge bosons in this model.
d) What property of the particles do the gauge bosons couple to and what defines the 'charge' of the gauge bosons themselves ?