

NOUVELLE PHYSIQUE AU L.H.C.

École de Gif

Clermont-Ferrand, Septembre 2010

Les mesures de précision à une échelle d'énergie permettent de deviner la présence d'une nouvelle Physique à l'échelle supérieure

Exemple : La prédition de l'existence du méson π par Yukawa en 1934

La portée des forces nucléaires est de l'ordre de 1 fermi
 $(\sim 10^{-13}\text{cm})$.

La Physique était correcte, les détails non !

Exemple : La prédiction de l'existence des particules charmées en 1969

L'absence des certaines désintégrations faibles

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- ▶ Une théorie phénoménologique pour les interactions faibles : La théorie de Fermi

$$\mathcal{L}_W = \frac{G}{\sqrt{2}}J_{(w)}^\mu(x)J_{(w)\mu}^\dagger(x)$$

Une théorie non-renormalisable.

$$\begin{aligned} A \sim & C_0^1(G_F\Lambda^2) + C_1^1 G_F M^2 \\ & + C_0^2(G_F\Lambda^2)^2 + C_1^2 G_F M^2(G_F\Lambda^2) + C_2^2(G_F M^2)^2 \\ & + \dots \\ & + C_0^n(G_F\Lambda^2)^n + C_1^n G_F M^2(G_F\Lambda^2)^{n-1} + \dots \\ & + \dots \end{aligned}$$

Constante effective : $G_F\Lambda^2$

La "théorie" est valable jusqu'à une énergie $\sim \Lambda$

In the same way New Physics is predicted for LHC

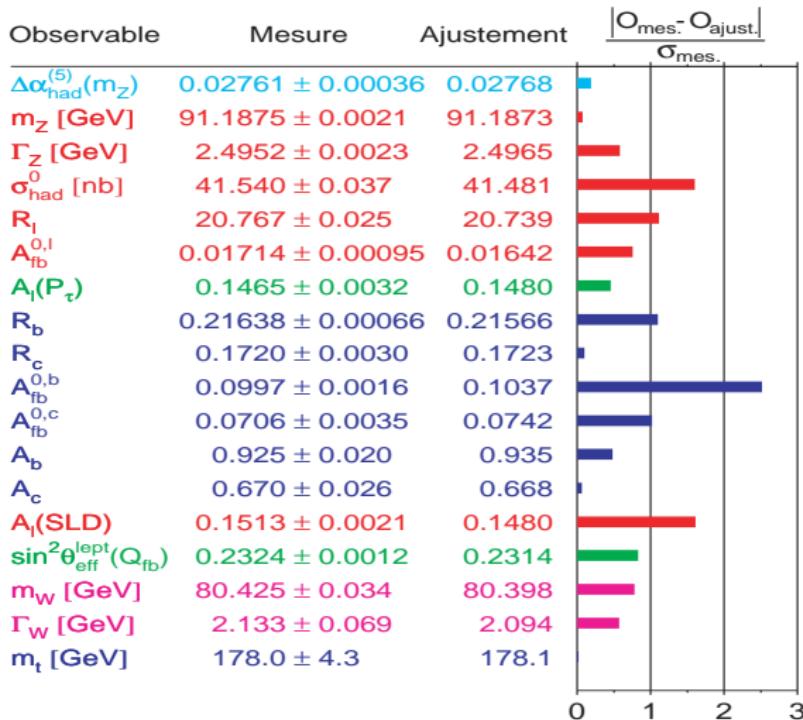
THE STANDARD MODEL

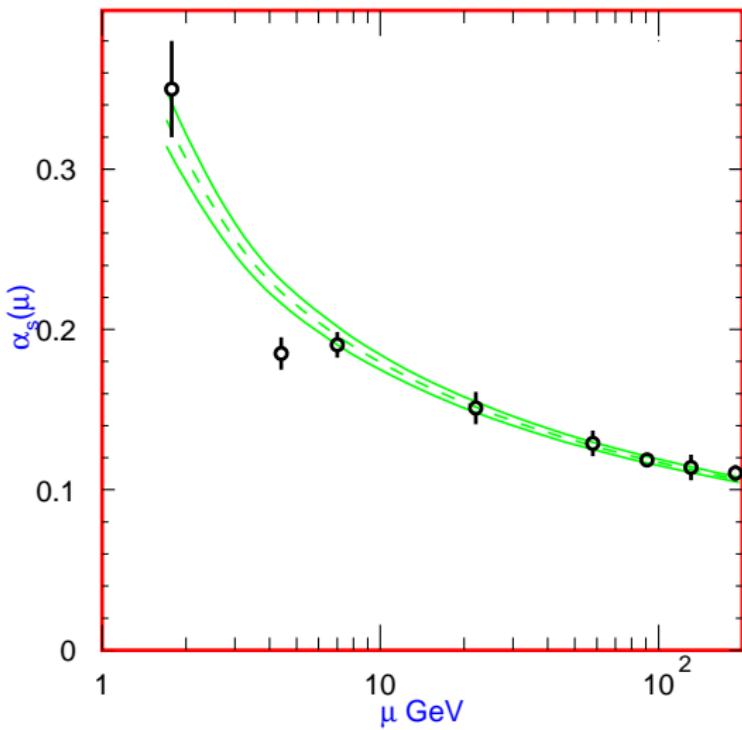
$$U(1) \times SU(2) \times SU(3)$$

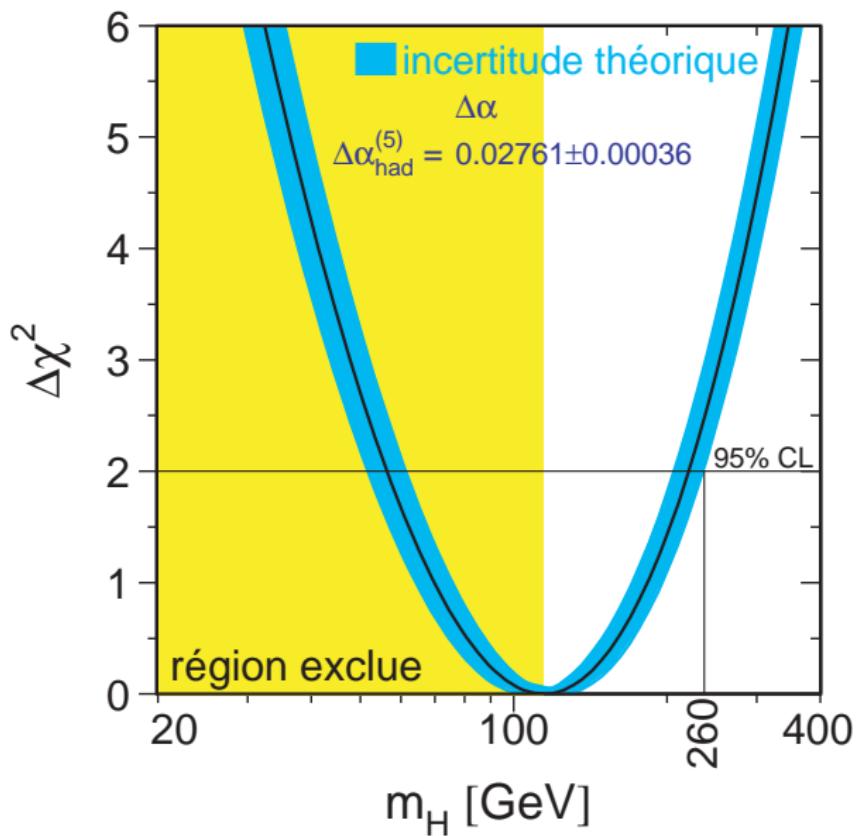
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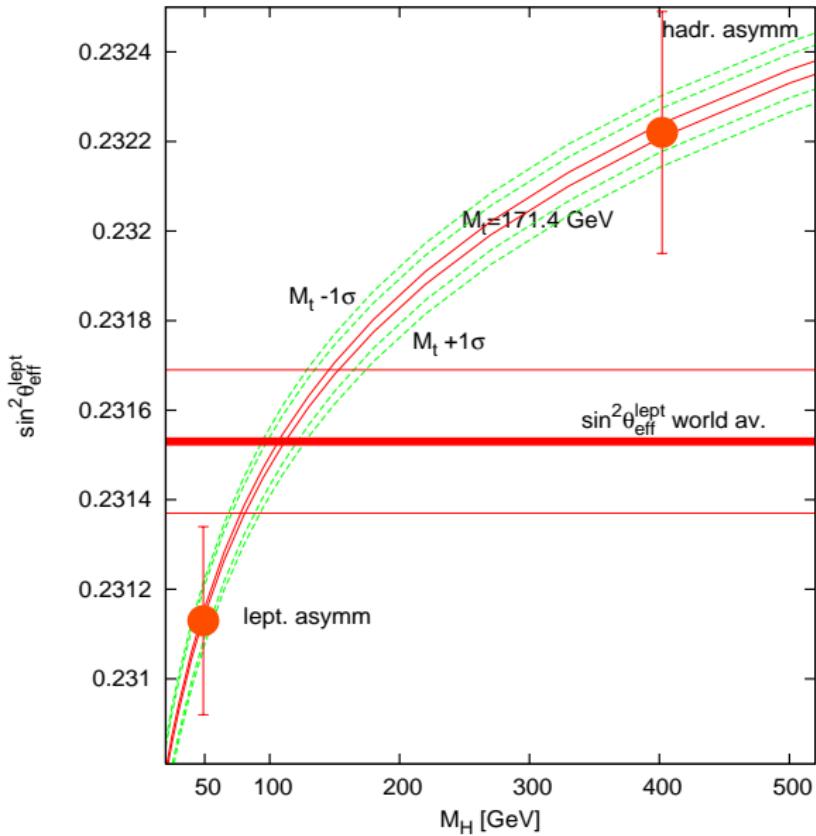
$$\begin{array}{c} U(1) \times SU(2) \times SU(3) \\ \Downarrow \\ U(1)_{em} \times SU(3) \end{array}$$

**THE STANDARD MODEL
HAS BEEN ENORMOUSLY SUCCESSFUL**









What we have learnt

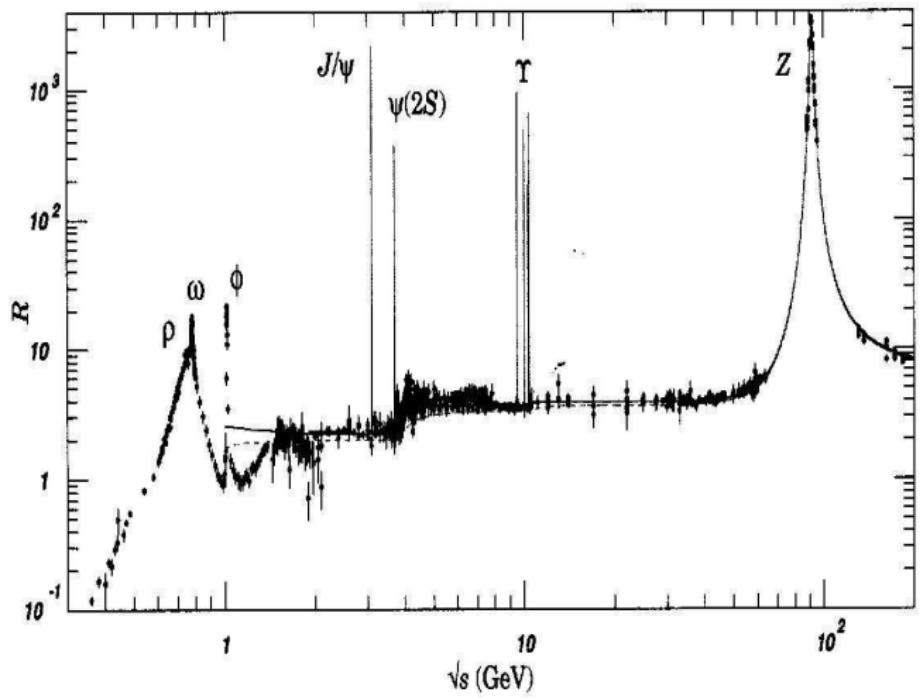
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Outside the region of strong interactions



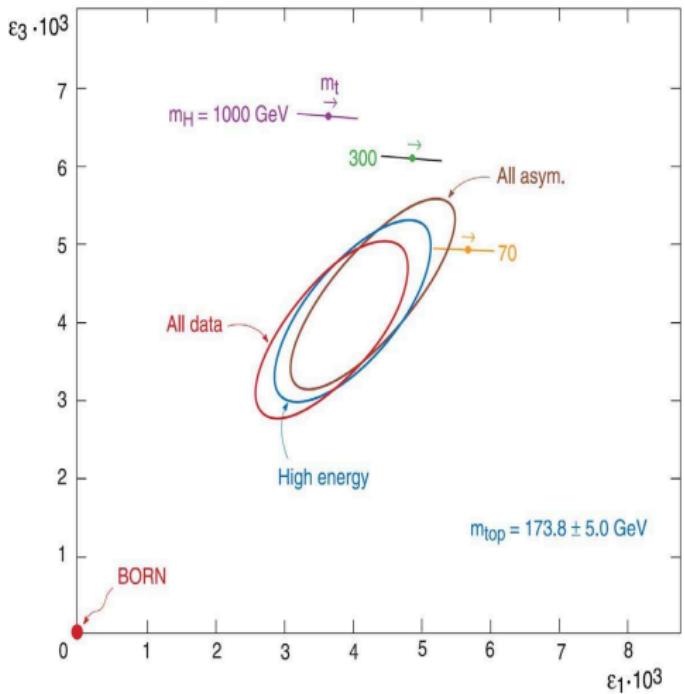


Figure 6: Data vs theory in the ϵ_3 - ϵ_1 plane (notations as in fig.5)

$$\epsilon_1 = \frac{3G_F m_t^2}{8\sqrt{2}\pi^2} - \frac{3G_F m_W^2}{4\sqrt{2}\pi^2} \tan^2 \theta_W \ln \frac{m_H}{m_Z} + \dots \quad (1)$$

$$\epsilon_3 = \frac{G_F m_W^2}{12\sqrt{2}\pi^2} \ln \frac{m_H}{m_Z} - \frac{G_F m_W^2}{6\sqrt{2}\pi^2} \ln \frac{m_t}{m_Z} + \dots \quad (2)$$

Why ?

-We do not really understand why.

Why ?

Dyson's argument :

$$A_n \sim \alpha^n (2n - 1)!!$$

Perturbation theory breaks down when $A_n \sim A_{n+1}$

$$2n + 1 \sim \alpha^{-1}$$

For QED $n \gg 1$; For QCD ???

I want to exploit this experimental fact and argue that the available precision tests of the Standard Model allow us to claim with confidence that new physics will be unravelled at the LHC.

The argument assumes the validity of perturbation theory and it will fail if the latter fails. But, as we just saw, perturbation theory breaks down only when strong interactions become important. But new strong interactions imply new physics.

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Limits on the Standard Model Higgs mass :

- 1) $m_H \geq 114$ GeV (Exp.)
- 2) $m_H = 85^{+39}_{-28}$ GeV (From global fit)
- 3) $m_H \leq \mathcal{O}(1\text{TeV})$ (Validity of perturbation)
- 4) $m_H \geq \mathcal{O}(130\text{GeV})$ (Vacuum stability)

$$\mathbf{m}_H^2 \sim \lambda$$

$$\frac{d\lambda}{dt} = \frac{3}{4\pi^2} [\lambda^2 + 3\lambda h_t^2 - 9h_t^4 + \dots]$$

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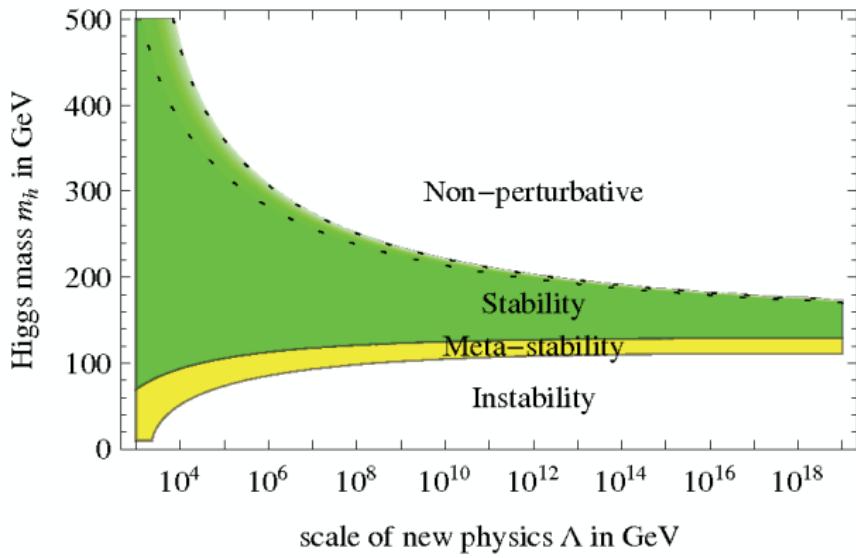
$$\Lambda \sim 10^{16} \text{ GeV} \rightarrow m_H \leq 180 \text{ GeV}$$

Vacuum stability

$$\lambda > 0$$

for $\Lambda \sim 10^{16} \text{ GeV}$

$$m_H \geq 130 \text{ GeV}$$



Can we “predict” the value of the Higgs mass?

$$m_Z/m_H = C \quad (3)$$

$$C = \frac{m_Z}{m_H} = \frac{\sqrt{g_1^2 + g_2^2}}{\sqrt{8\lambda}} \quad (4)$$

$$\begin{aligned} 16\pi^2 \beta_{g_1} &= g_1^3 \frac{1}{10} \\ 16\pi^2 \beta_{g_2} &= -g_2^3 \frac{43}{6} \\ 16\pi^2 \beta_\lambda &= 12\lambda^2 - \frac{9}{5}g_1^2\lambda - 9g_2^2\lambda + \frac{27}{100}g_1^4 + \frac{9}{10}g_1^2g_2^2 + \frac{9}{4}g_2^4 \end{aligned} \tag{5}$$

$$\begin{aligned}
\beta_z &= \beta_{\eta_1} + \beta_{\eta_2} = \\
&= \frac{-\lambda w}{16\pi^2\rho z} \left[\left(\frac{27}{100}\rho^2 + \frac{9}{10}\rho + \frac{9}{4} \right) z^2 - \left(2\rho^2 + \frac{54}{5}\rho - \frac{16}{3} \right) z \right. \\
&\quad \left. + 12(\rho + 1)^2 \right] \tag{6}
\end{aligned}$$

$$\eta_1 = \frac{g_1^2}{\lambda} \quad ; \quad \eta_2 = \frac{g_2^2}{\lambda} \quad ; \quad z = \eta_1 + \eta_2 \quad ; \quad \rho = \frac{\eta_1}{\eta_2} \quad ; \quad w = \eta_1 \eta_2 \tag{7}$$

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No new Strong Interactions \Rightarrow

Perturbation theory is reliable \Rightarrow

$$m_H^2 \sim \alpha M^2$$

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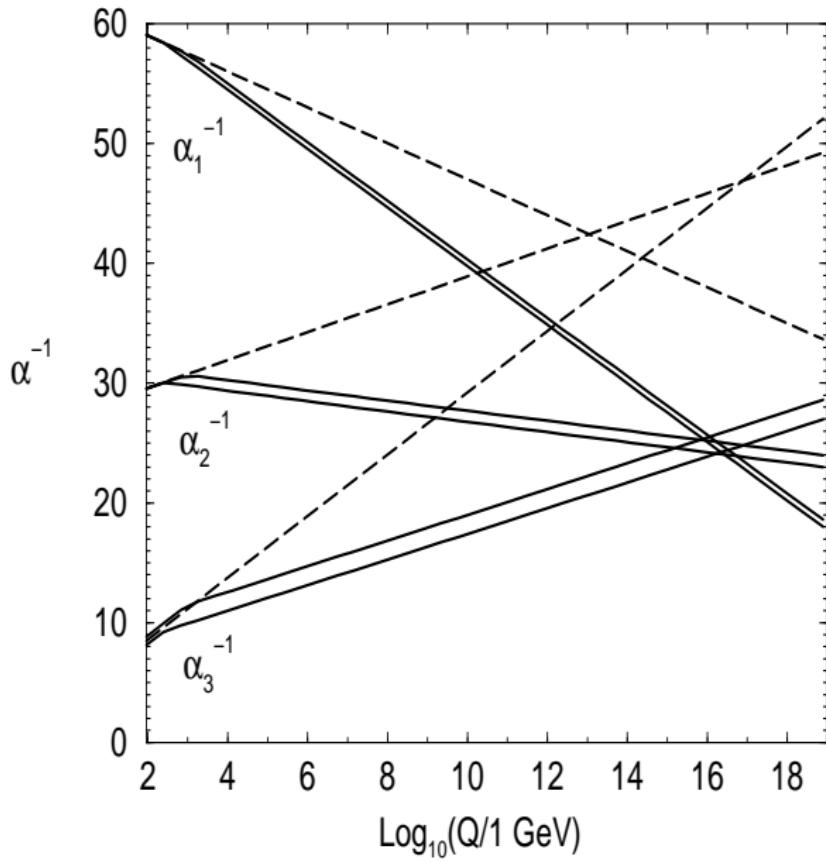
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Possible solution of the dark matter problem

Possible (Predictable) LHC Results

- 1) A Light Higgs is found

Hierarchy

⇒ -Large extra dimensions

Possible (Predictable) LHC Results

- 2) No Light Higgs is found

New Strong Interactions

Possible (Predictable) LHC Results

2) No Light Higgs is found

New Strong Interactions

1) Technicolor

The Higgs boson is a bound state of new, heavy fermions

Possible (Predictable) LHC Results

2) No Light Higgs is found

New Strong Interactions

2) Little Higgs

The Higgs boson is a pseudo-Goldstone boson of a new symmetry

Possible (Predictable) LHC Results

**THE ABSENCE OF A LIGHT HIGGS
IMPLIES NEW PHYSICS**

**BUT A LIGHT HIGGS IS UNSTABLE
WITHOUT NEW PHYSICS**

CONCLUSIONS

THE TIME FOR SPECULATIONS WILL BE SOON OVER!

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NEVER BEFORE AN EXPERIMENTAL FACILITY WAS LOADED
WITH SO GREAT EXPECTATIONS