FOLLOWING THE ROAD OF CHARM :

New Physics at the L.H.C.

EPS-HEP

Grenoble, July 2011

Precision measurements at a given energy scale allow to guess new Physics at the next energy scale

Example : Yukawa's prediction of the π meson in 1934

The range of nuclear forces is of order 1 fermi ($\sim 10^{-13}$cm).

The Physics was correct, the details were not!!

Example : The prediction for charmed particles in 1969

The absence, with very high accuracy, of certain weak decays

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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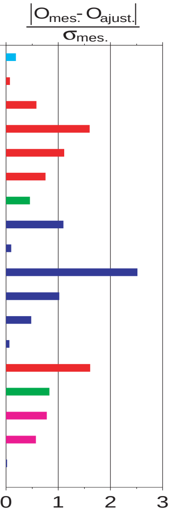
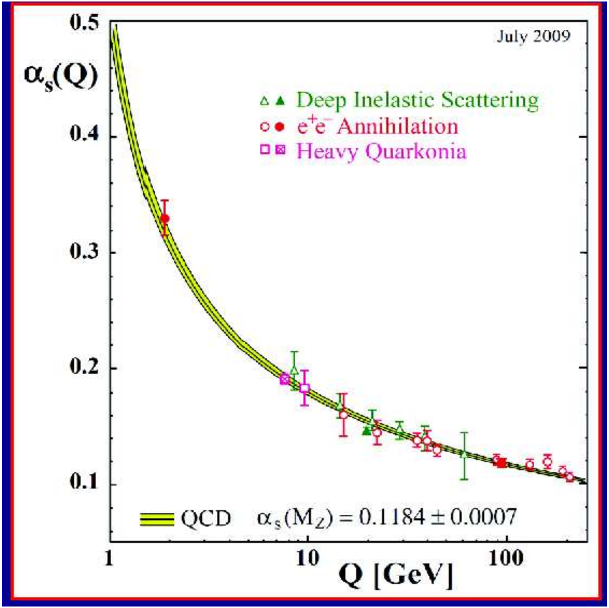
$$U(1) \times SU(2) \times SU(3)$$
$$\Downarrow$$
$$U(1)_{em} \times SU(3)$$

THE STANDARD MODEL

HAS BEEN ENORMOUSLY SUCCESSFUL

Observable	Mesure	Ajustement
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02761 ± 0.00036	0.02768
m_Z [GeV]	91.1875 ± 0.0021	91.1873
Γ_Z [GeV]	2.4952 ± 0.0023	2.4965
σ^0_{had} [nb]	41.540 ± 0.037	41.481
R_l	20.767 ± 0.025	20.739
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01642
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21638 ± 0.00066	0.21566
R_c	0.1720 ± 0.0030	0.1723
$A^{0,b}_{fb}$	0.0997 ± 0.0016	0.1037
$A^{0,c}_{fb}$	0.0706 ± 0.0035	0.0742
A_b	0.925 ± 0.020	0.935
A_c	0.670 ± 0.026	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.425 ± 0.034	80.398
Γ_W [GeV]	2.133 ± 0.069	2.094
m_t [GeV]	178.0 ± 4.3	178.1




July 2009
$\alpha_s(Q)$
0.5
0.4
0.3
0.2
0.1
Deep Inelastic Scattering
e^+e^- Annihilation
Heavy Quarkonia
QCD $\alpha_s(M_Z) = 0.1184 \pm 0.0007$
1
10
100
Q [GeV]

What we have learnt

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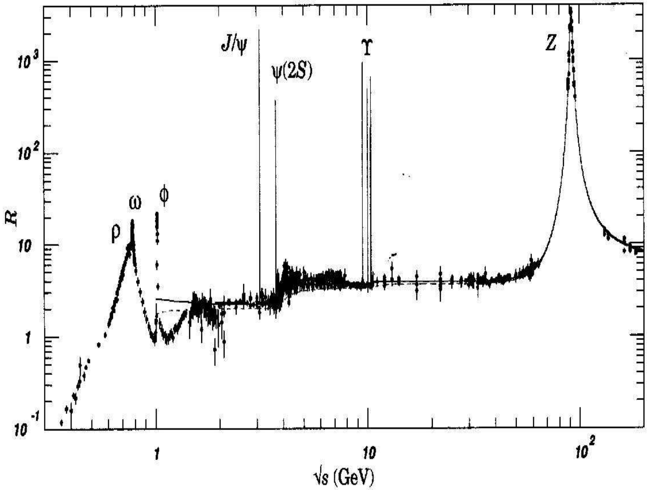
Outside the region of strong interactions



J/ψ
ψ(2S)
ϒ
Z
ρ
ω
ϕ
R
10^3
10^2
10
1
10^-1
1
10
10^2
√s (GeV)

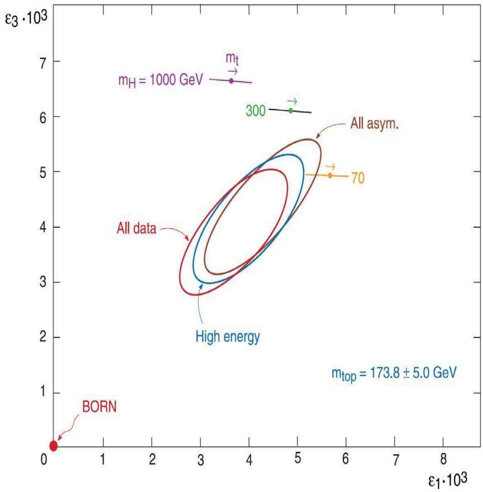


Figure 6: Data vs theory in the ϵ_3-ϵ_1 plane (notations as in fig.5)

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

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

Why ?

-We do not really understand why.

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 is present at the TeV scale and the LHC can, probably, discover it.
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.

First task of LHC

Study the Higgs sector of the theory.

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Possible (Predictable) LHC Results

- 1) A Light Higgs is found
- The Standard Model is **complete**
- No new Strong Interactions $\Rightarrow$

  Perturbation theory is reliable $\Rightarrow$

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

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Hierarchy

- Supersymmetry

  -Gauge coupling unification

  -Possible solution of the dark matter problem

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Possible (Predictable) LHC Results

1) A Light Higgs is found

Hierarchy

- Supersymmetry

  -Gauge coupling unification

  -Possible solution of the dark matter problem

- Large extra dimensions
- Other

Possible (Predictable) LHC Results
2) No Light Higgs is found

New Strong Interactions

Possible (Predictable) LHC Results

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

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 IS OVER !

L.H.C. IS WORKING

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NEVER BEFORE AN EXPERIMENTAL FACILITY WAS LOADED WITH SO GREAT EXPECTATIONS