

O Bosão de Higgs

Descoberta e Futuro

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INVESTIGADOR
FCT



QUALIFICAR 3 CRESCER.



UNI3O EUROPEIA
Fundo Social Europeu



QUADRO
DE REFER3NCIA
ESTRAT3GICO
NACIONAL
PORTUGAL 2007-2013

Escolher
Ci3ncia



Quarks

u up	c charm	t top
d down	s strange	b bottom

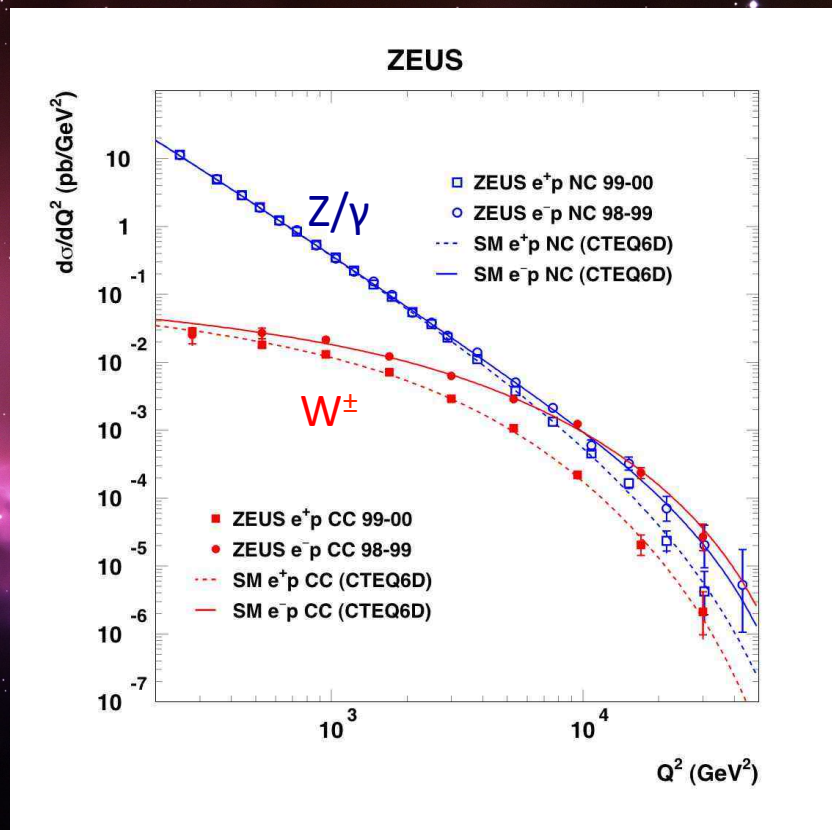
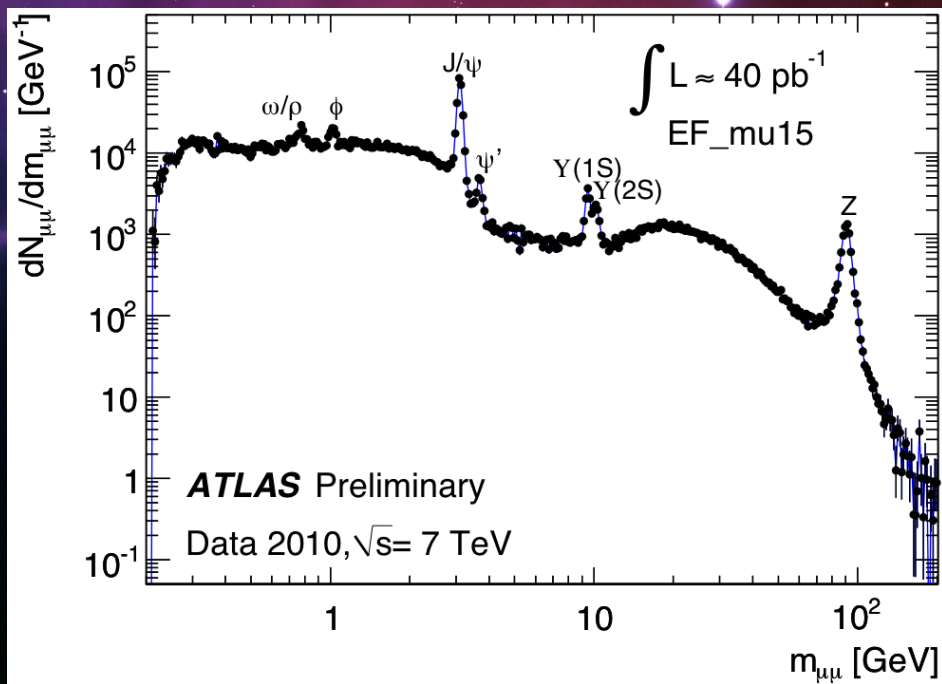
Forces

Z Z boson	γ photon
W W boson	g gluon

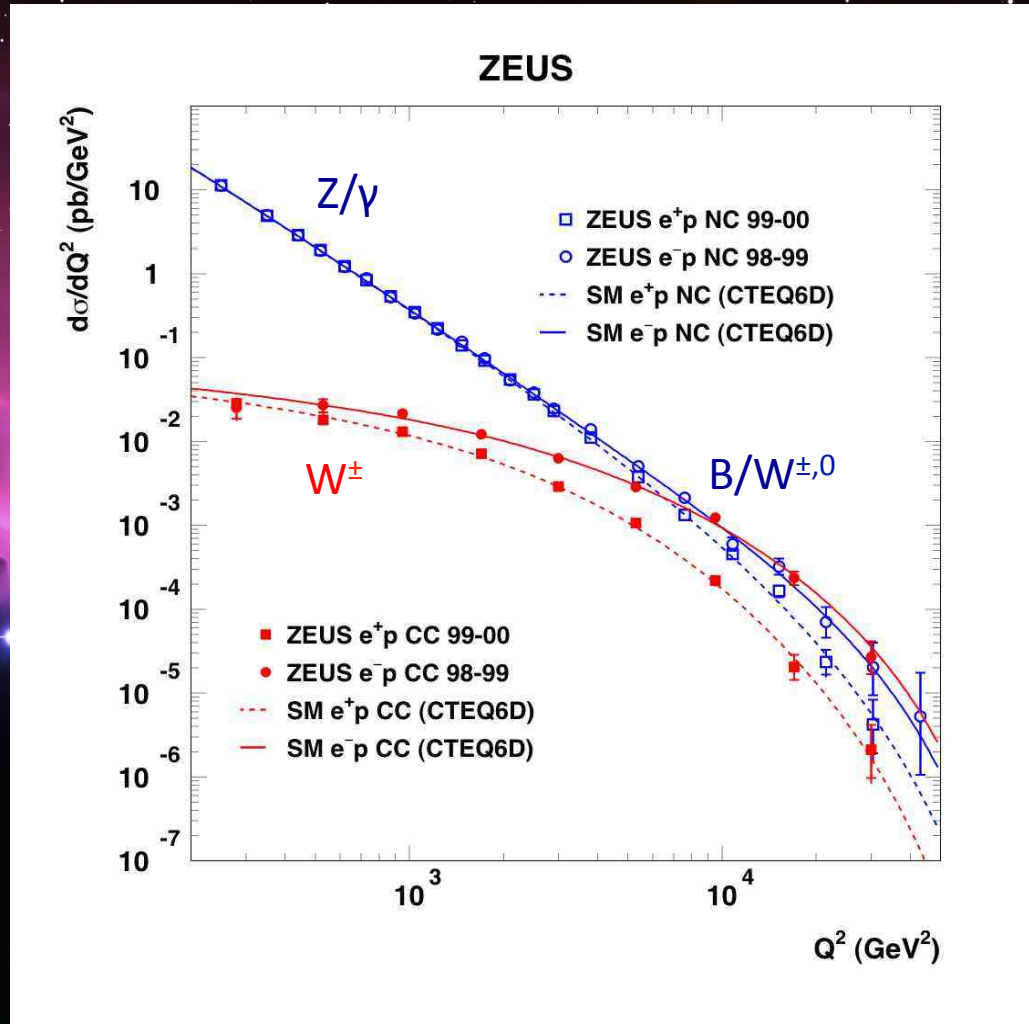


e electron	μ muon	τ tau
ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino

Leptons



γ
 Z^0
 W^+
 W^-
 $+$



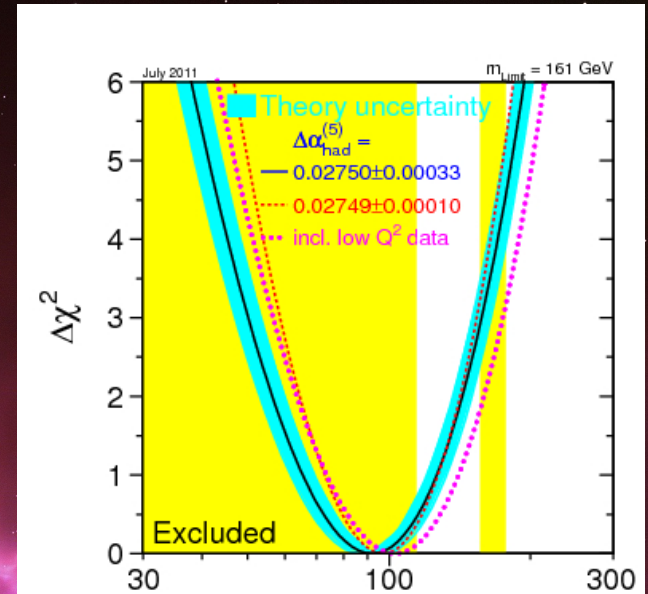
B
 W^+
 W^-
 W^0

Hoje

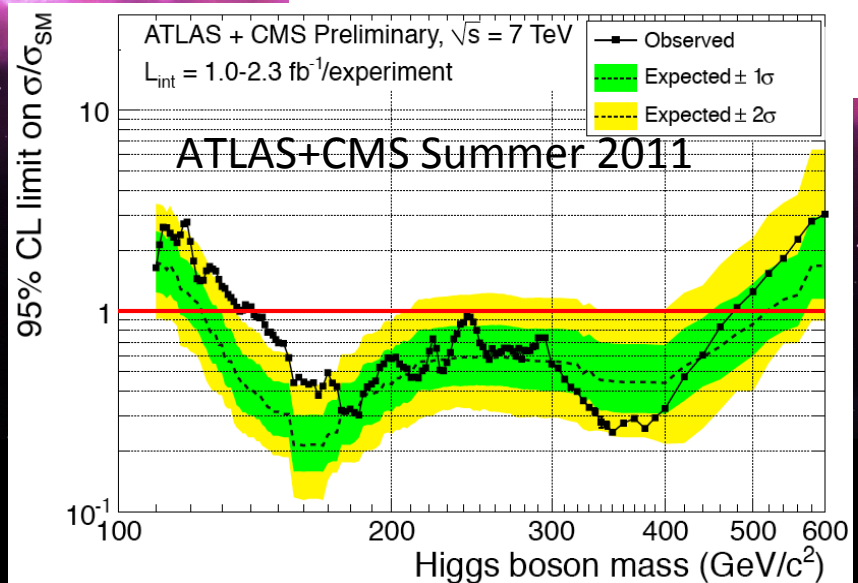
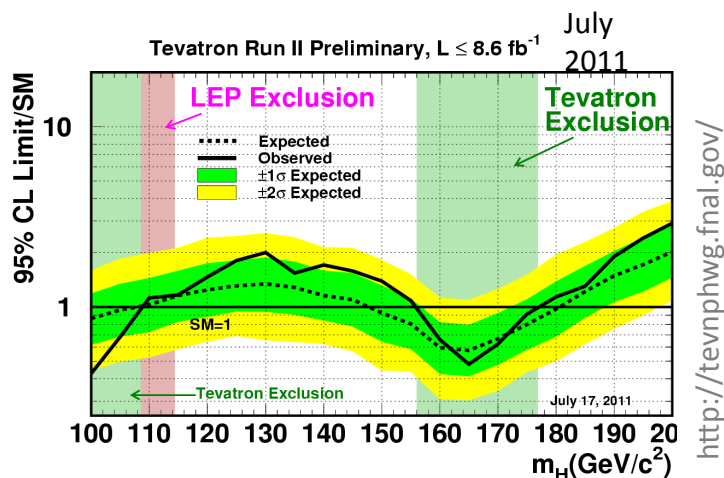
Big Bang

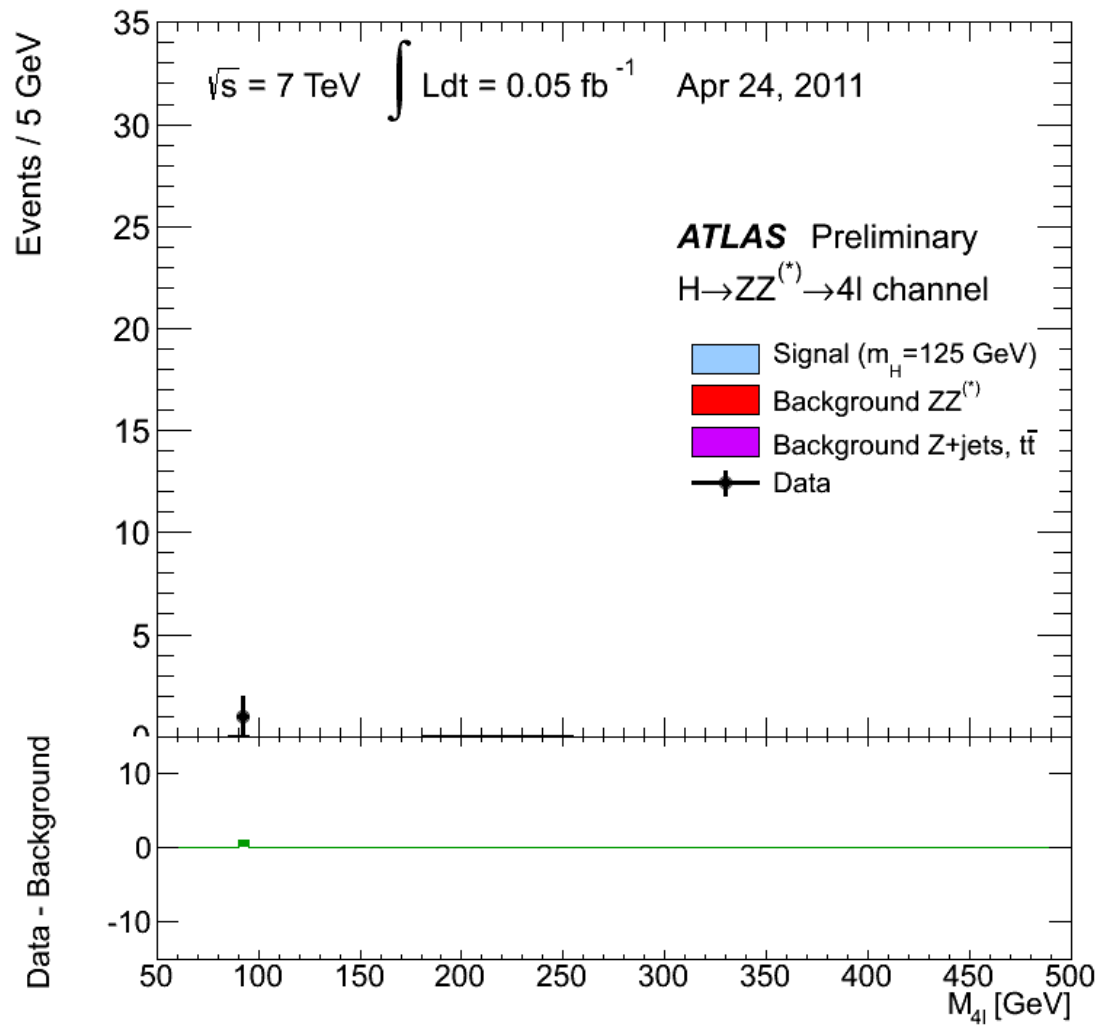
No princípio de 2011

- Mass do bóson de Higgs era o único parâmetro desconhecido!
 - LEP excluiu $m_H < 114.4 \text{ GeV}/c^2$
 - Fit de medidas electrofracas dava $\approx 100 \text{ GeV}/c^2$!!
 - Tevatron excluiu $100 - 108 \text{ GeV}/c^2$ e $156 - 177 \text{ GeV}/c^2$



<http://lepewwg.web.cern.ch/LEPEWWG/>



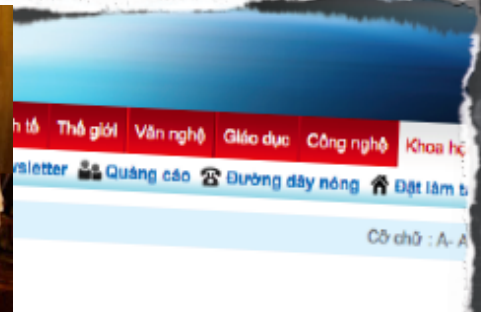


News on
04/07/2012

la Repubblica.it

Cern, scoperta la "particella di Dio"

Higgs boson-like particle discovery
claimed at LHC



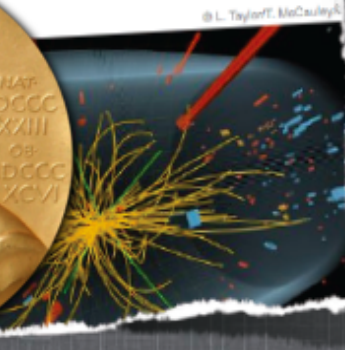
ZEITUNG ONLINE

WISSEN

Scoperto il Bosone di Higgs la particella di Dio esiste davvero

Haarscharf am gottverdamnten Teilchen vorbei

Die Belege scheinen überwältigend: Forscher könnten ein neues Teilchen gefunden haben. Unklar ist, ob es das Higgs-Boson ist, der letzte Baustein im Weltbild der Physik.



Physicists Find Elusive Particle Seen at CERN



The Higgs boson discovery is another giant leap for humankind

The Cern discovery of the Higgs particle is up there with putting man on the moon – something all humanity can be proud of

Scientists in Geneva on Wednesday applauded the discovery of a particle that could be the Higgs boson.

SAY GOD PARTICLE



ONE MORE
GODDAMN TIME



Há muito
mais por
investigar!

Muitas medidas desde a descoberta!

Higgs no Modelo Padrão e Propriedades

- **Mass and couplings ($ZZ+WW+\gamma\gamma$):**
 - Phys. Lett. B 726 (2013), pp. 88-119
- **(Updated Mass):** arXiv:1406.3827
- **(Updated Coupling $\gamma\gamma$):** arXiv:1408.3827
- **(Updated Coupling ZZ):** arXiv:1408.5191
- **Spin and parity ($ZZ+WW+\gamma\gamma$):**
- **$H \rightarrow \gamma\gamma$:** ATLAS-CONF-2013-012
- **$H \rightarrow WW$:** ATLAS-CONF-2013-030
- **$H \rightarrow Z\gamma$:** ATLAS-CONF-2013-009
- **$H \rightarrow b\bar{b}$:** ATLAS-CONF-2013-079
- **$H \rightarrow \tau\tau$:** ATLAS-CONF-2013-108
- **$H \rightarrow \mu\mu$:** ATLAS-HIGG-2013-07
- **$H \rightarrow \text{invisible}$:**
Phys. Rev. Lett. 112, 201802 (2014)
- **$t\bar{t}H(\gamma\gamma)$:** ATLAS-CONF-2014-043
- **$VH(WW)$:** ATLAS-CONF-2013-075
Phys. Lett. B 726 (2013), pp. 120-14
- **$H \rightarrow ZZ$ (on-shell cross-section and pT):** ATLAS-CONF-2014-044 **(off-shell cross-section)** ATLAS-CONF-2014-042

Procuras de novos Bosões de Higgs

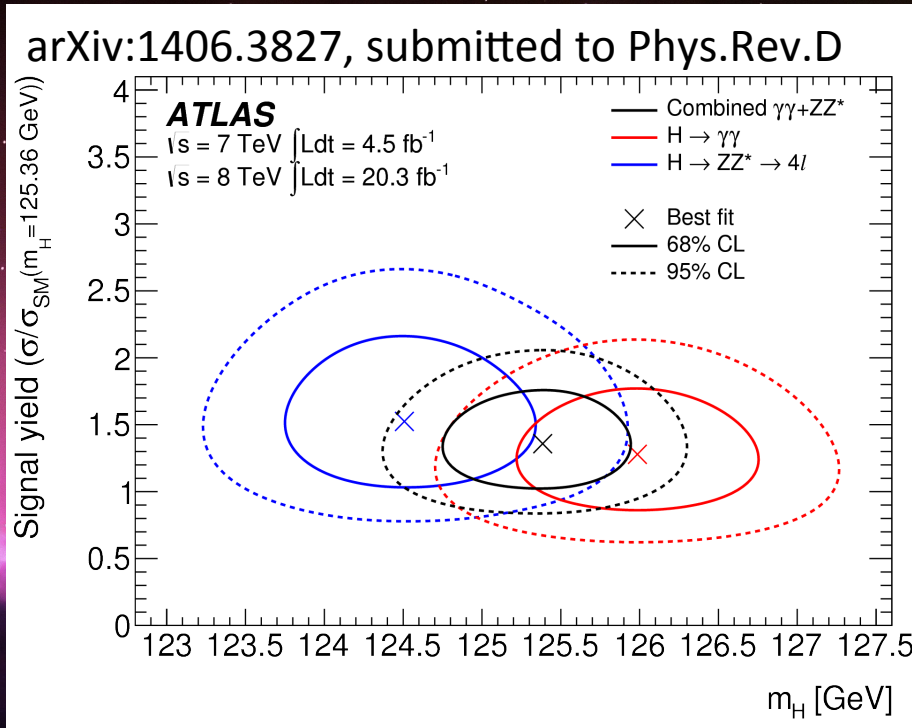
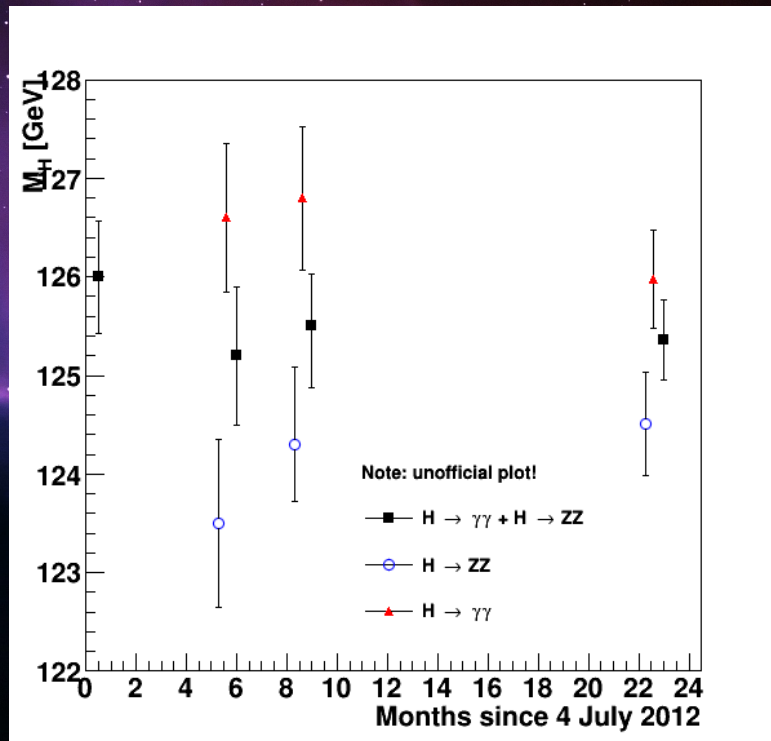
- **$H/h/A \rightarrow \tau\tau$:**
ATLAS-CONF-2014-049 **ATLAS-CONF-2014-005**
- **$X \rightarrow hh \rightarrow 4b$:**
- **$H^\pm \rightarrow \tau \nu$:** ATLAS-CONF-2013-090,
JHEP03(2013)076
- **$H^\pm \rightarrow c s\bar{s}$:**
Eur. Phys. J. C, 73 6 (2013) 2465
- **$H \rightarrow WW$ (2HDM):** ATLAS-CONF-2013-027
- **$X \rightarrow hh \rightarrow \gamma\gamma b\bar{b}$:** ATLAS-HIGG-2013-29
- **Multi-higgs cascade:**
Phys. Rev. D 89, 032002 (2014)
- **SM Higgs Couplings and New Phenomena:**
ATLAS-CONF-2014-010

It is an old maxim of mine that when you have excluded the impossible, whatever remains, however improbable, must be the truth.'

Sherlock Holmes
-The Beryl Coronet



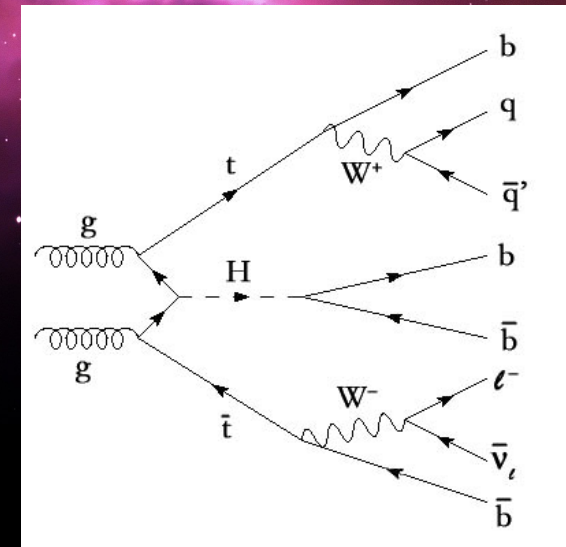
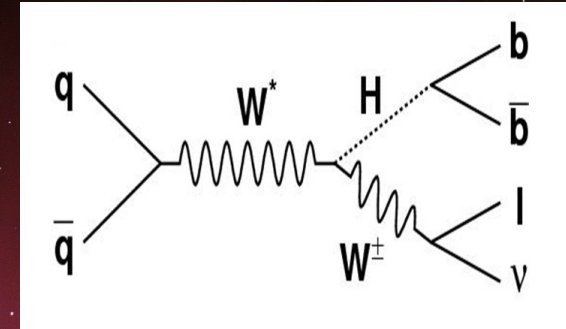
Massa do bóson de Higgs



- Últimos resultados: $m_H = 125.36 \pm 0.37 \text{ (stat.)} \pm 0.18 \text{ (syst.) GeV}$
- $m_{\gamma\gamma} = 125.98 \pm 0.42 \text{ (stat.)} \pm 0.28 \text{ (syst.) GeV}$
- $m_{ZZ} = 124.51 \pm 0.52 \text{ (stat.)} \pm 0.06 \text{ (syst.) GeV}$

O Bosão de Higgs no LIP

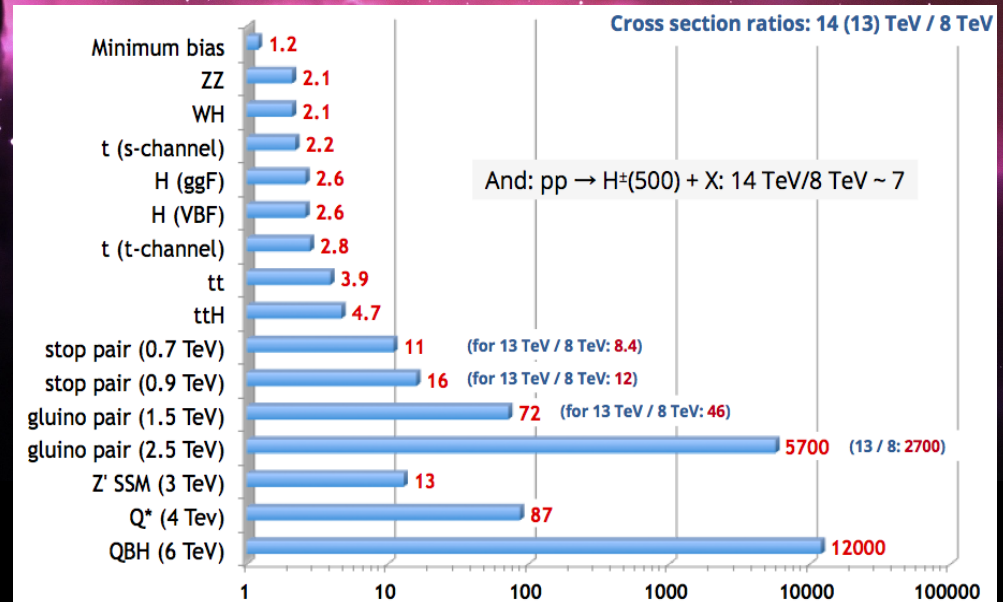
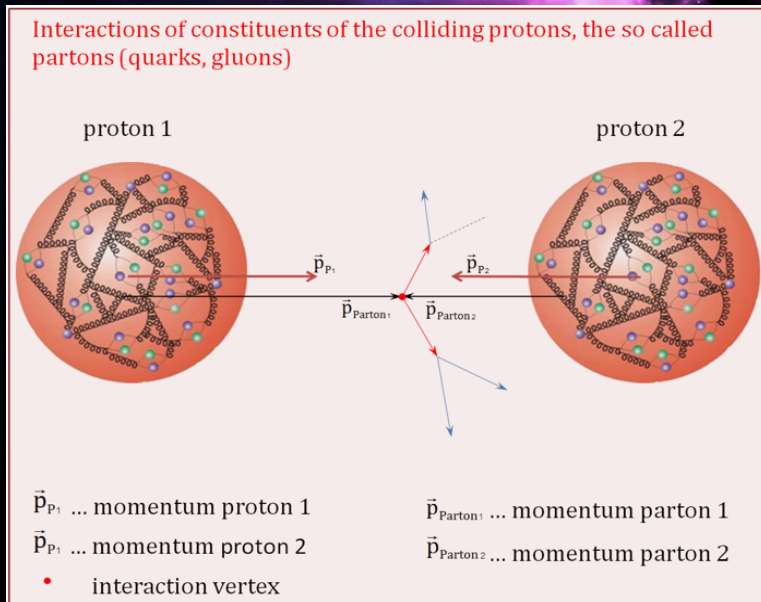
- Colaboramos na descoberta!
 - Estudos nos canais de $H \rightarrow WW$ e $H \rightarrow bb$
- Os nossos interesses actuais: $H \rightarrow bb$
 - Canais de produção: WH , ZH , ttH
 - Queremos medir o acoplamento entre o Higgs e os quarks b e do quark top
 - Queremos medir os números quânticos de CP e outros do bosão de Higgs
 - A longo prazo: acoplamentos do Higgs a si próprio



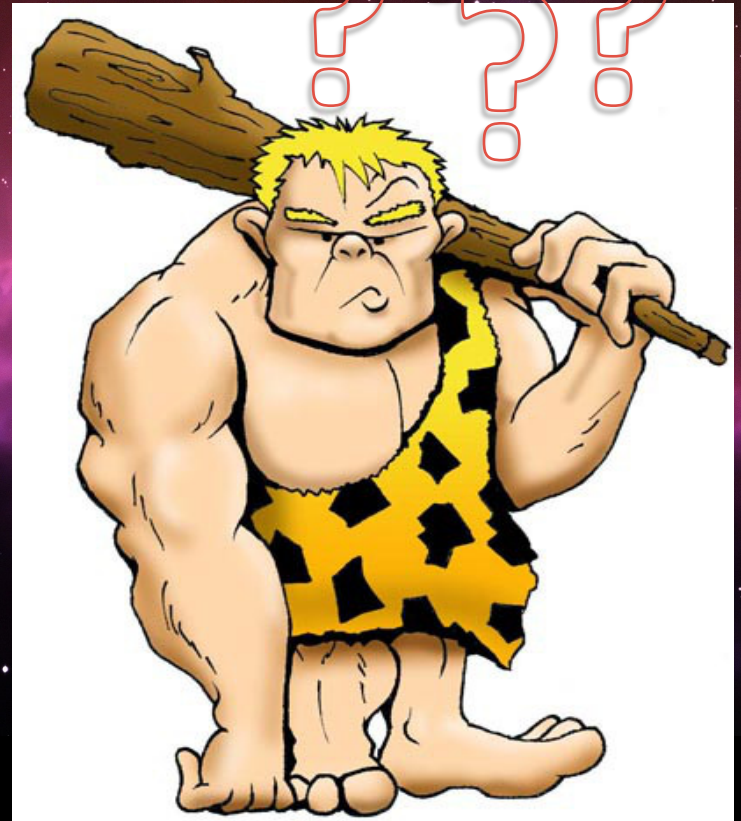
O Futuro do Higgs no LHC

- Energia do centro de massa das colisões mais alta
 - Aumenta muito a capacidade de descobrir partículas muito pesadas
 - Aumenta a taxa de contagem dos canais de produção do Higgs
 - Nalguns casos aumenta muito mais do que o ruído de fundo, como o $t\bar{t}H$

Temos muitas descobertas à nossa espera!



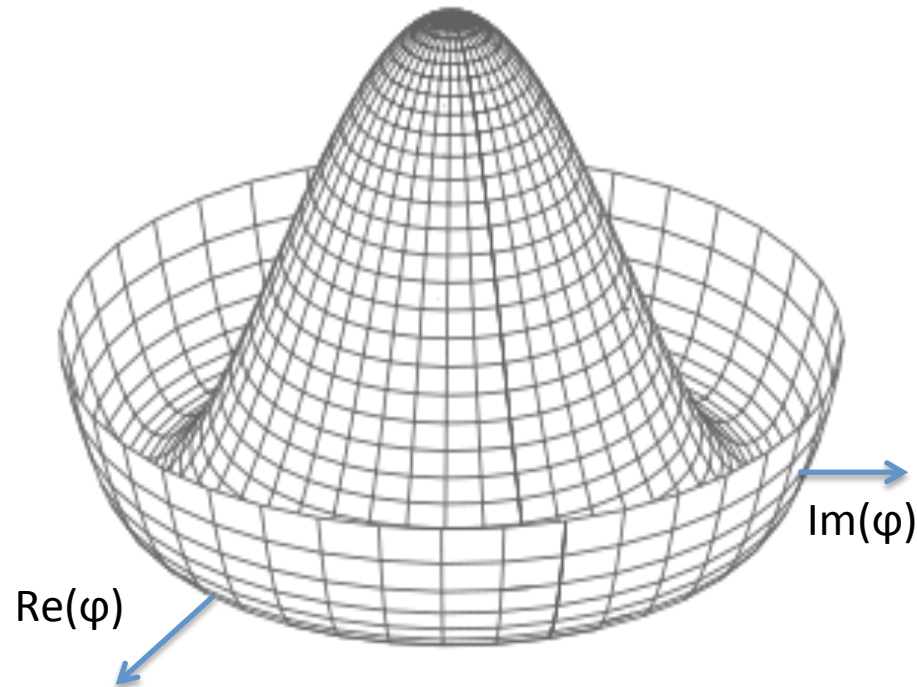
Perguntas?



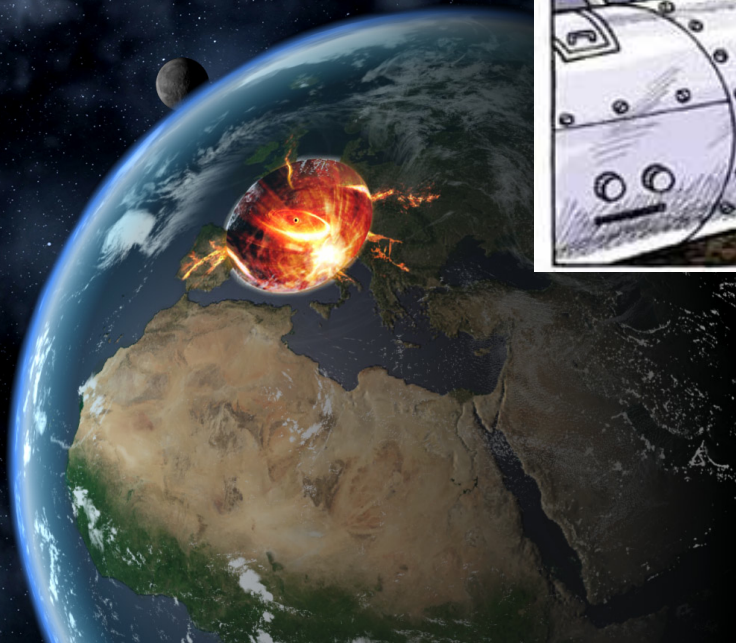
10^{-11} segundos depois do Big Bang...



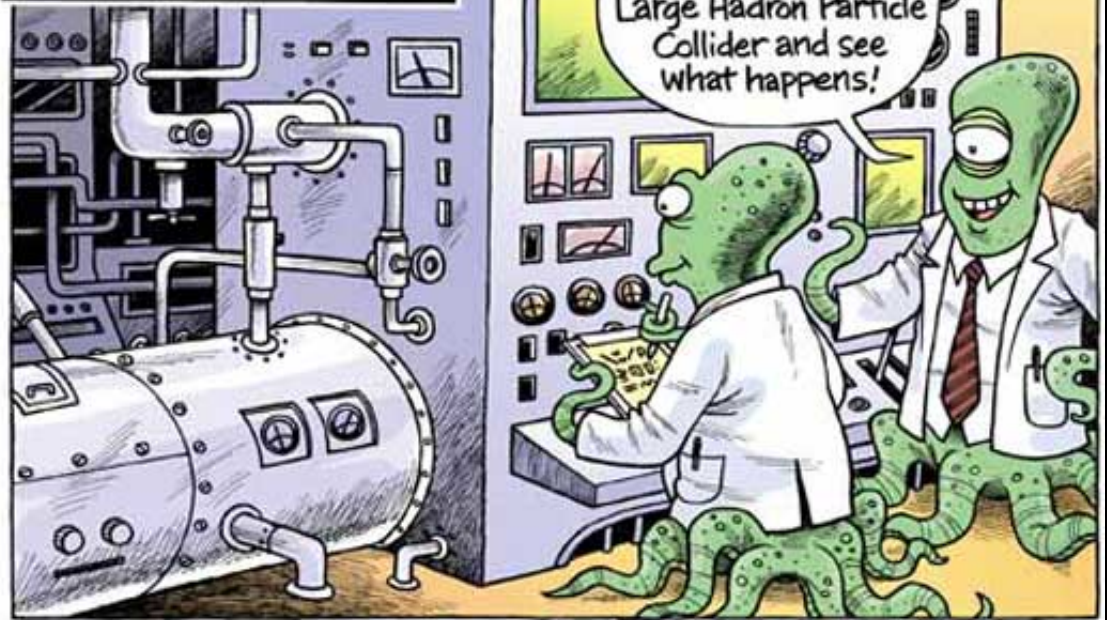
$$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$$



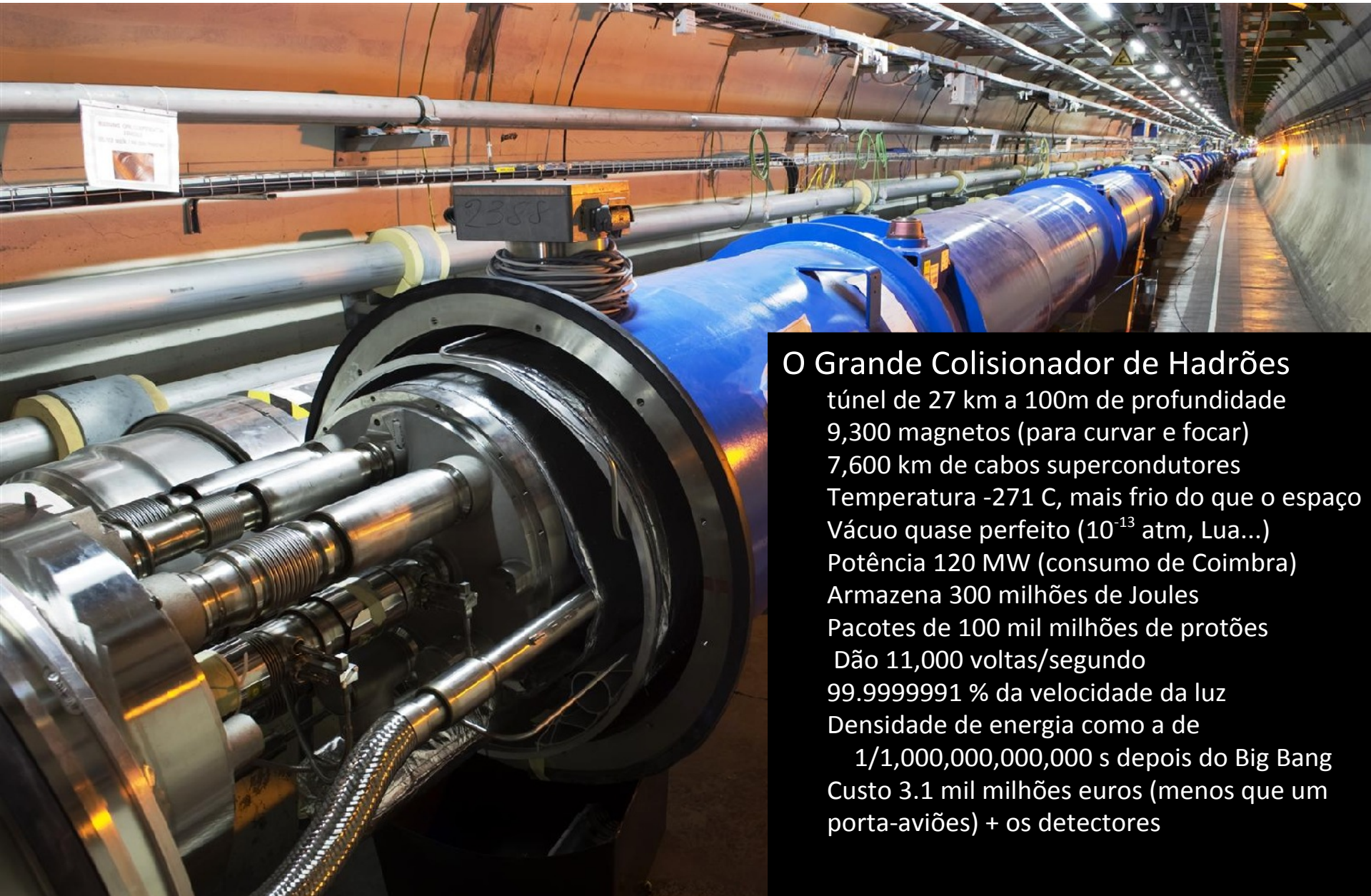
QUI A PEUR
DU
TROU NOIR



13,8 BILLION YEARS AGO,
A FEW SECONDS BEFORE THE
CREATION OF OUR UNIVERSE...

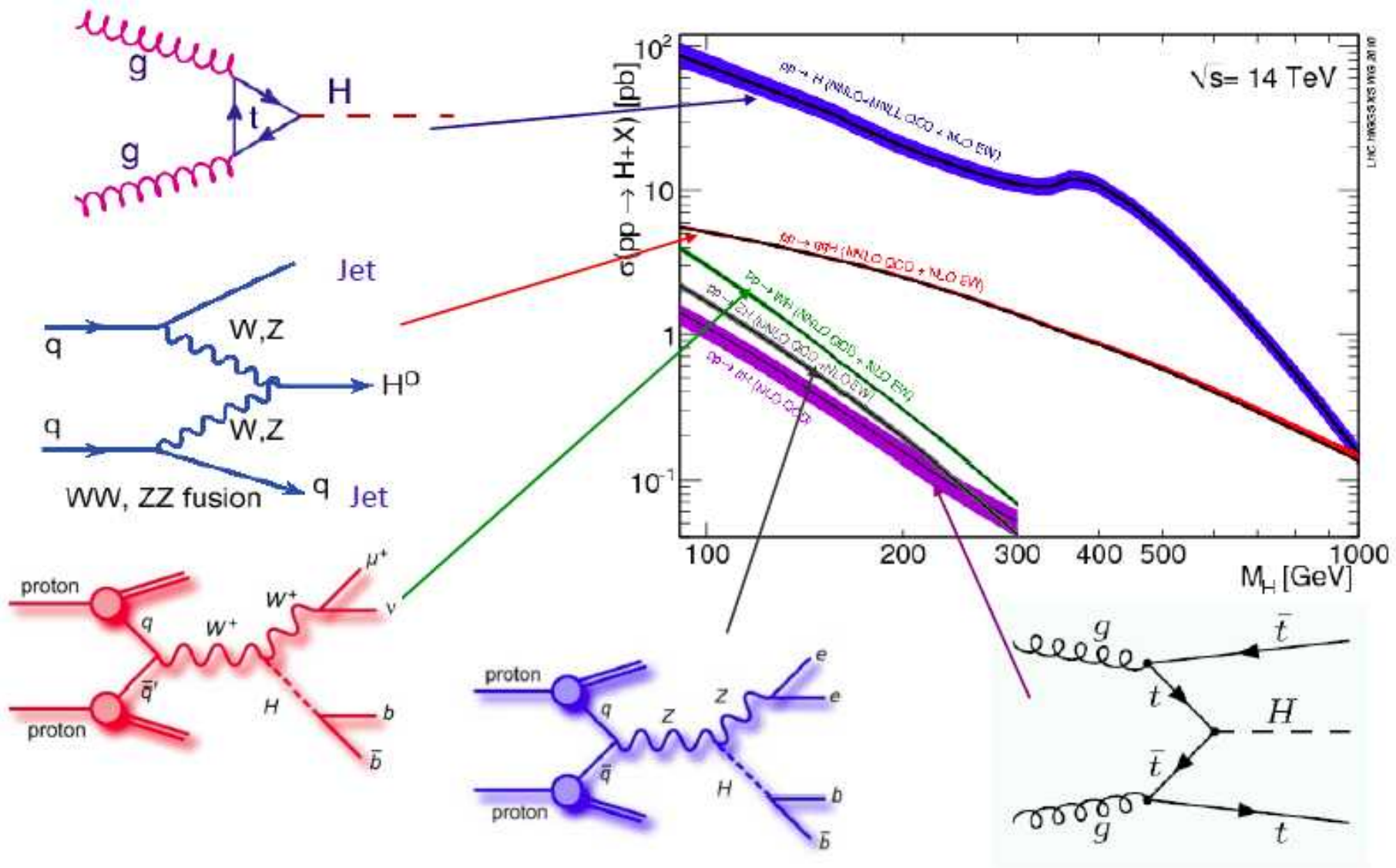


Large Hadron Collider



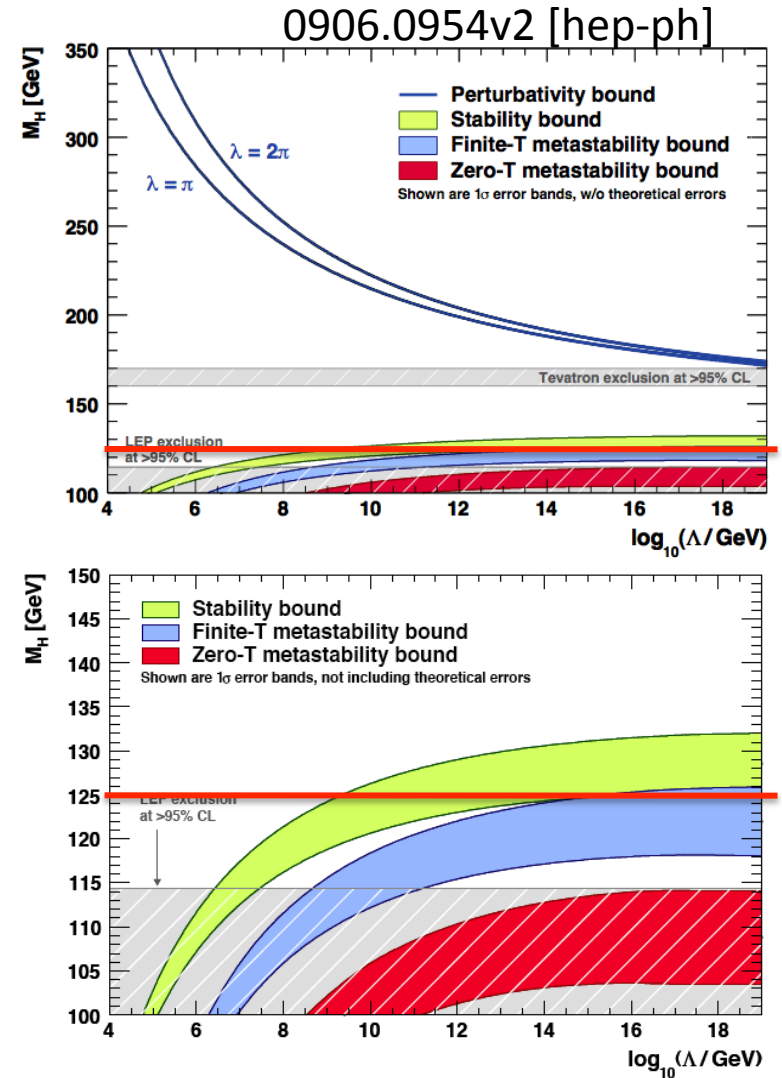
O Grande Colisionador de Hadrões
túnel de 27 km a 100m de profundidade
9,300 magnetos (para curvar e focar)
7,600 km de cabos supercondutores
Temperatura -271 C, mais frio do que o espaço
Vácuo quase perfeito (10^{-13} atm, Lua...)
Potência 120 MW (consumo de Coimbra)
Armazena 300 milhões de Joules
Pacotes de 100 mil milhões de prótons
Dão 11,000 voltas/segundo
99.9999991 % da velocidade da luz
Densidade de energia como a de
1/1,000,000,000,000 s depois do Big Bang
Custo 3.1 mil milhões euros (menos que um porta-aviões) + os detectores

Modos de produção do bóson de Higgs



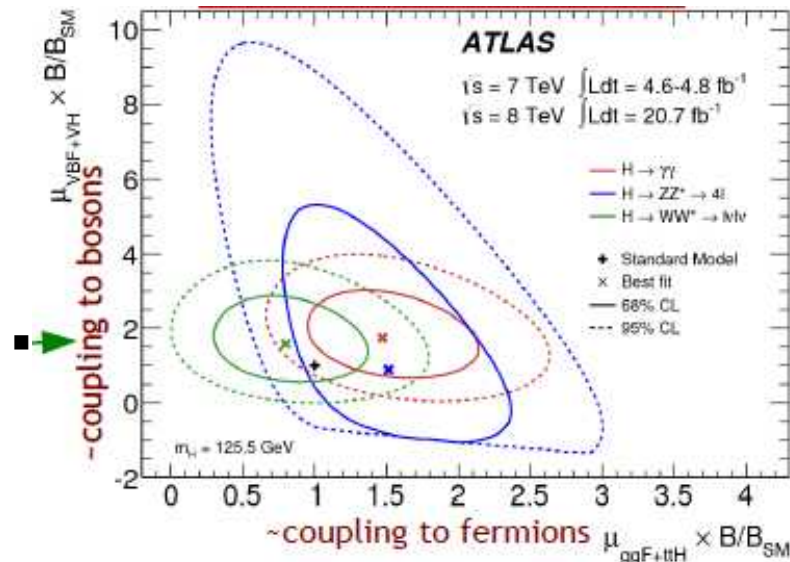
But there is more...

- We know the SM is incomplete
- For a low Higgs mass relative to the top quark mass, the quartic Higgs self-coupling runs at high energy towards lower values.
- At some point it would turn negative indicating that the vacuum is unstable.
- The universe could decay into a more stable lower energy vacuum state.
- Unless new physics appears at some energy scale
- The Higgs sector can give important clues to constrain new physics beyond the SM
- It is a great way to search for new physics!

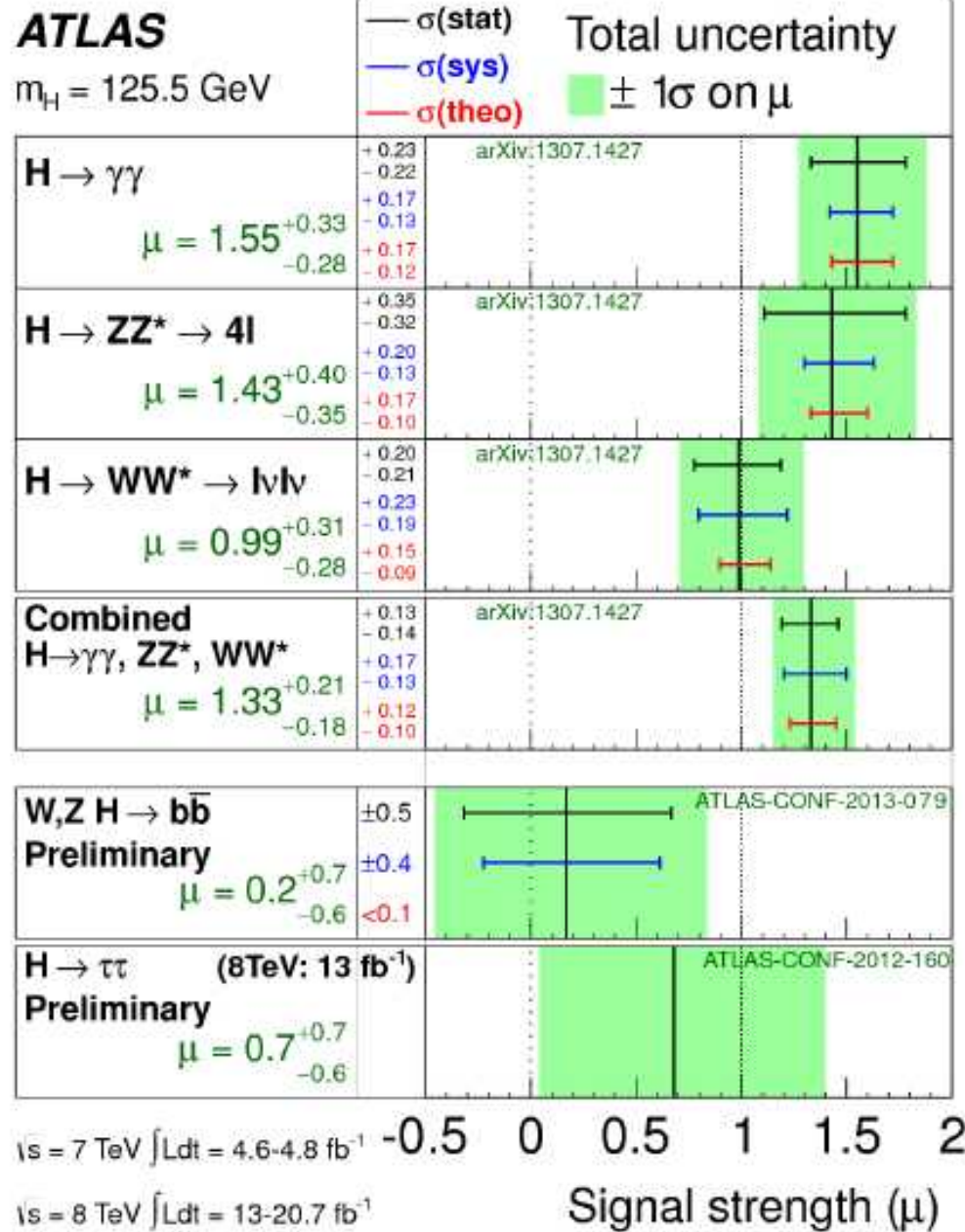


É o Higgs !

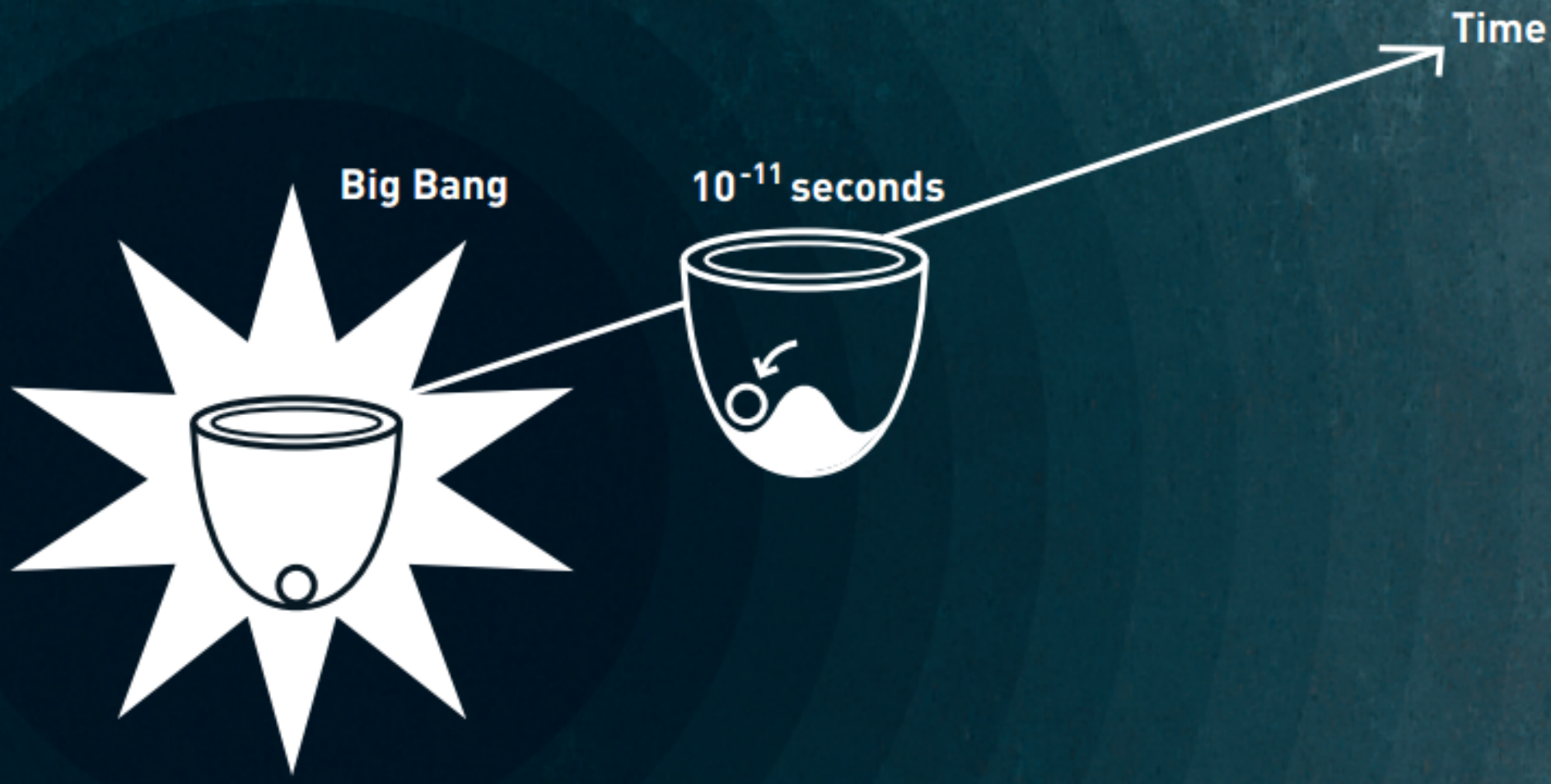
- Quais as propriedades ?
 - spin 0+
 - massa 125.5 GeV
 - acoplamentos previstos pelo Modelo l



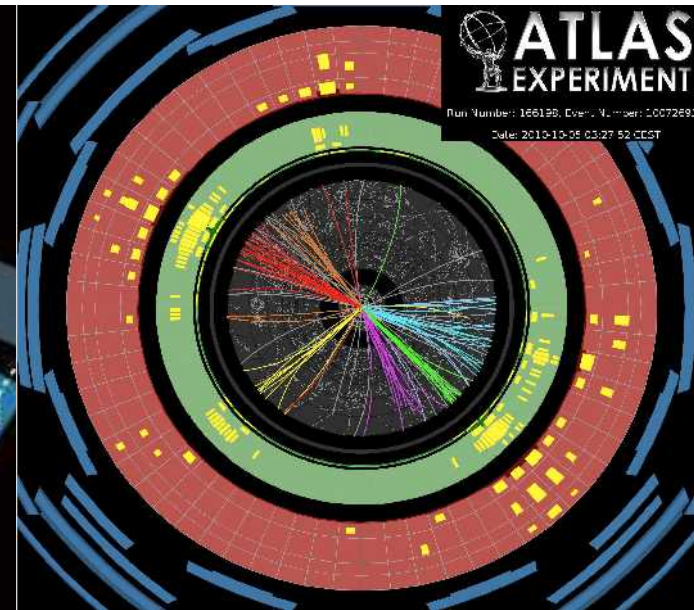
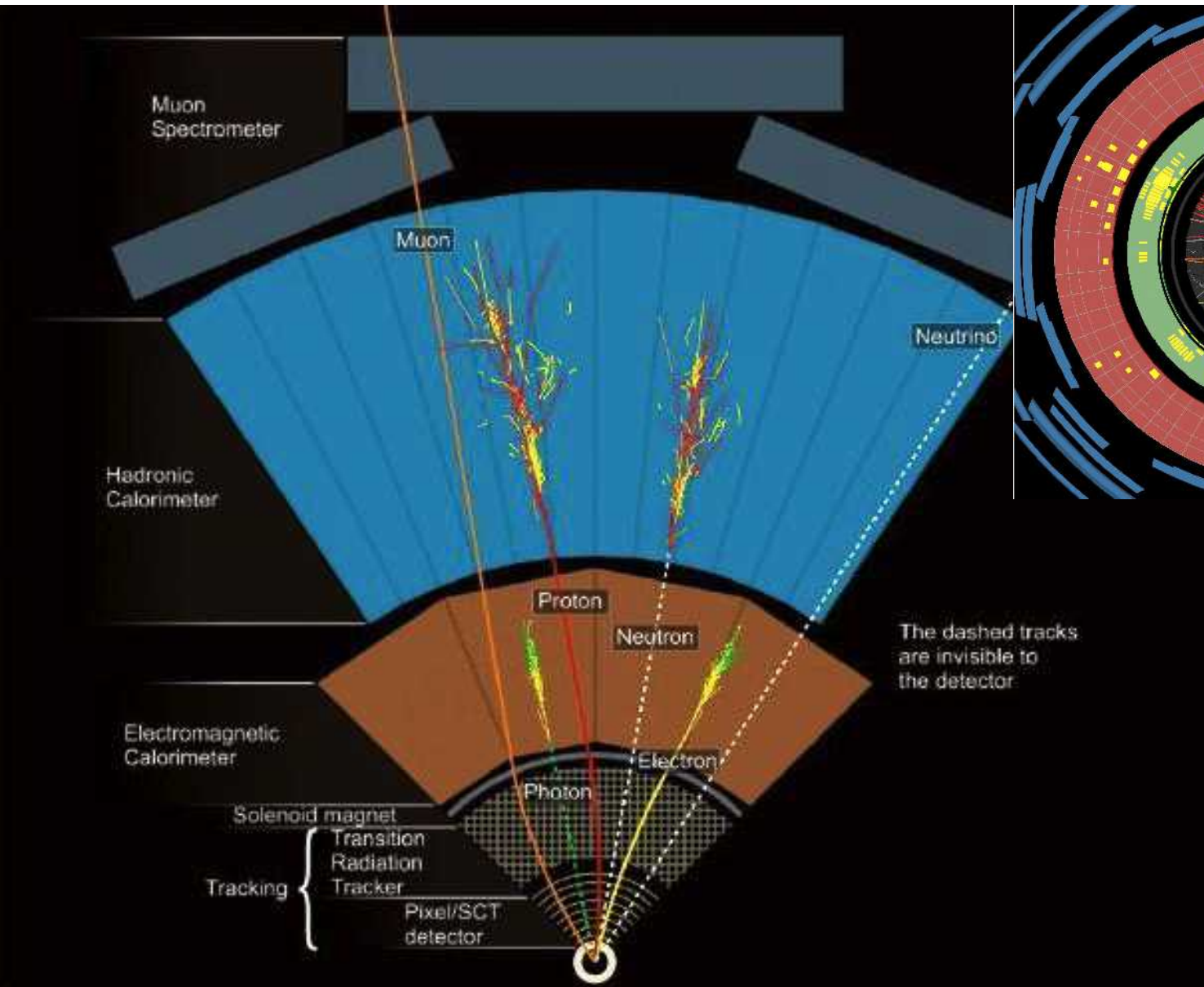
3S



- Razão $\mu = \text{dados} / \text{teoria}$

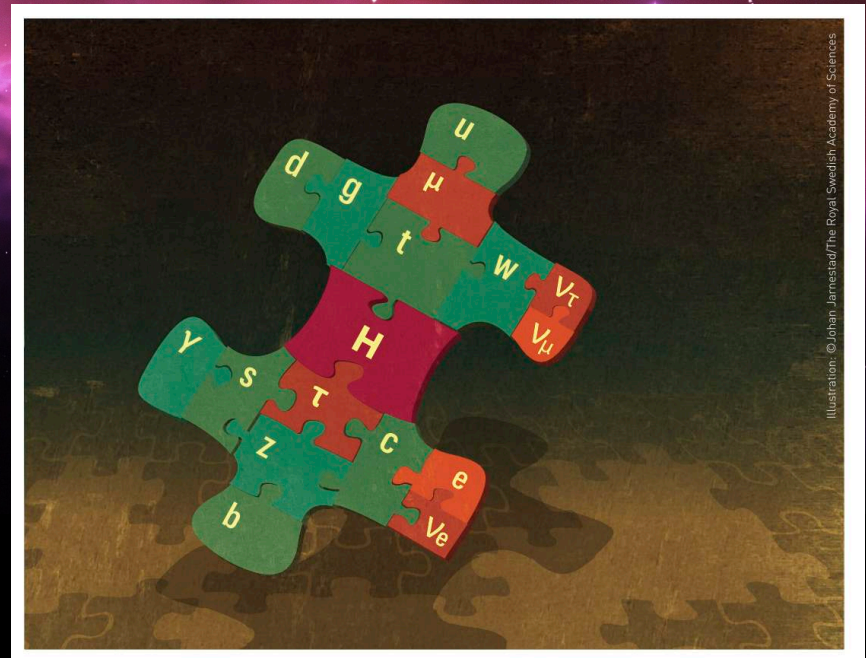


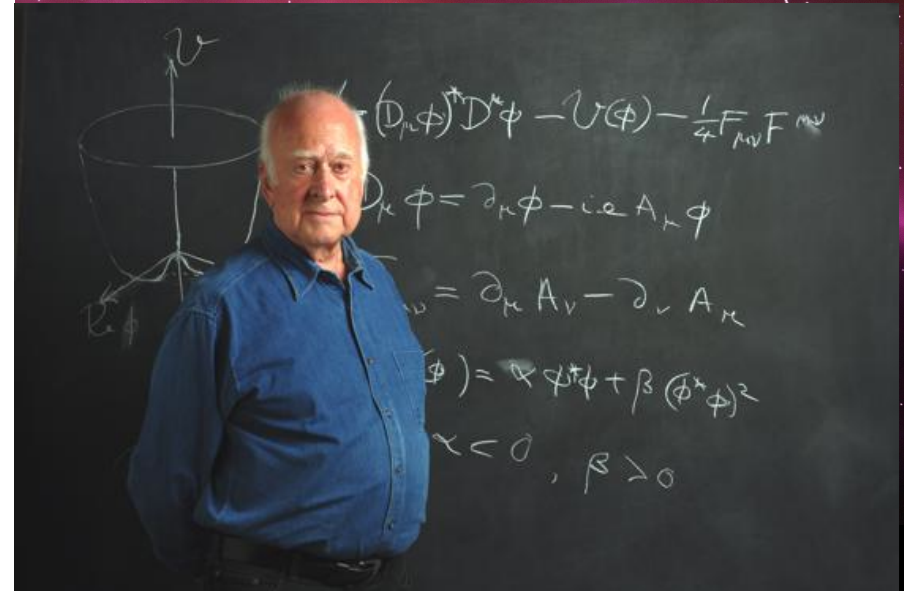
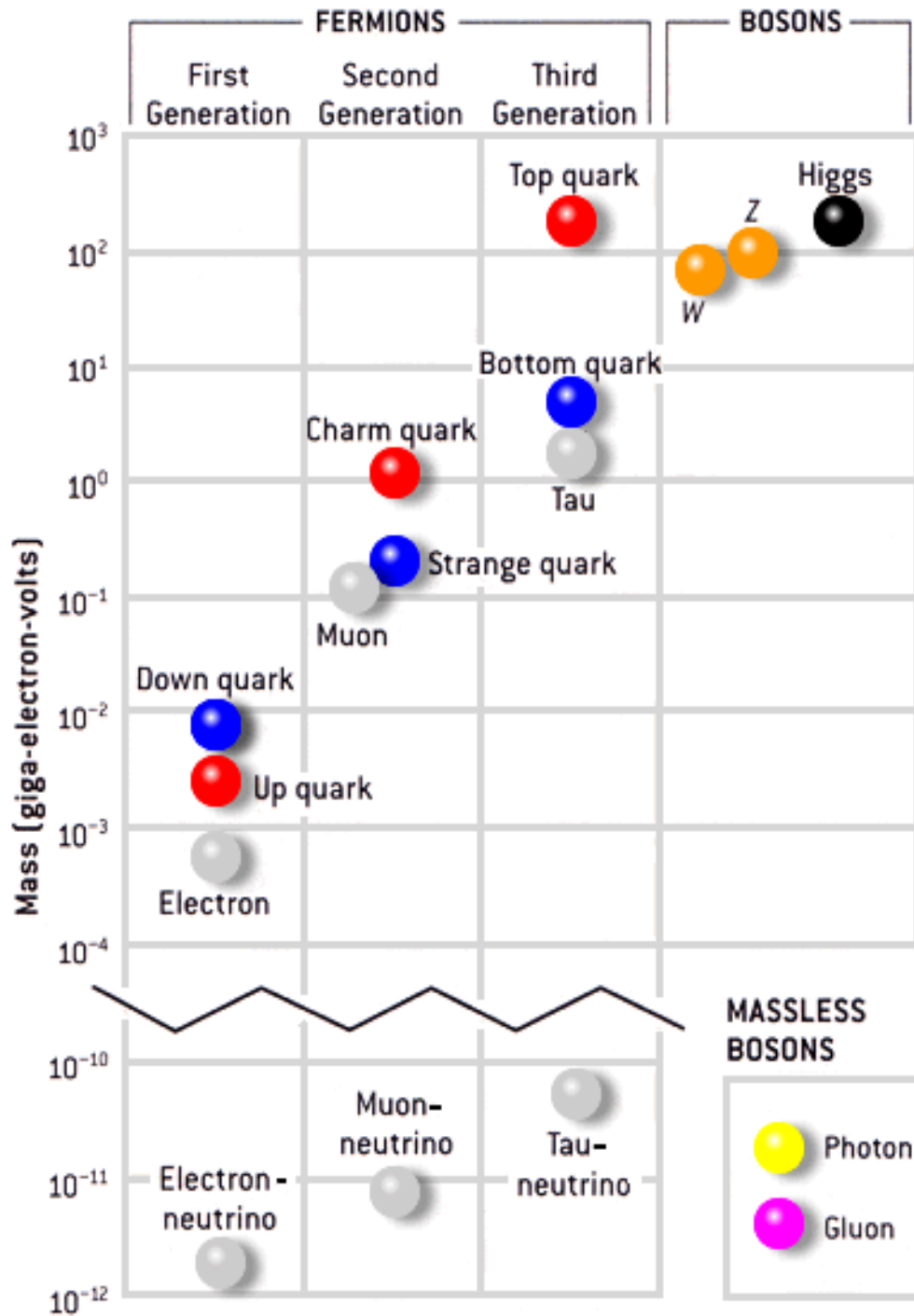
Como se detectam partículas



E agora?...

- O Modelo Standard NÃO pode ser o puzzle completo!
- Há uma dinâmica subjacente ao mecanismo de Higgs?
- Porque é que a força das interações e as massas das partículas são tão diferentes?
- E porque é que a expansão do universo é acelerada? Energia escura!
- União das forças a alta energia?
- Para onde foi a antimatéria?
- O que é a matéria escura?



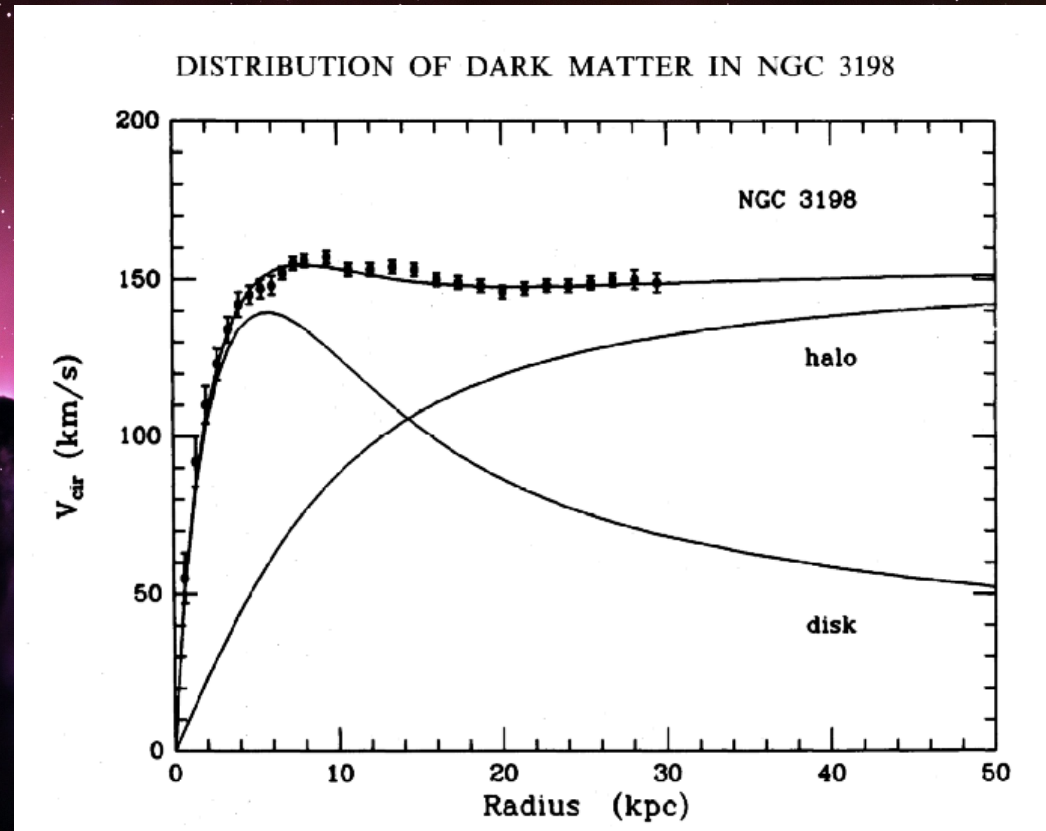


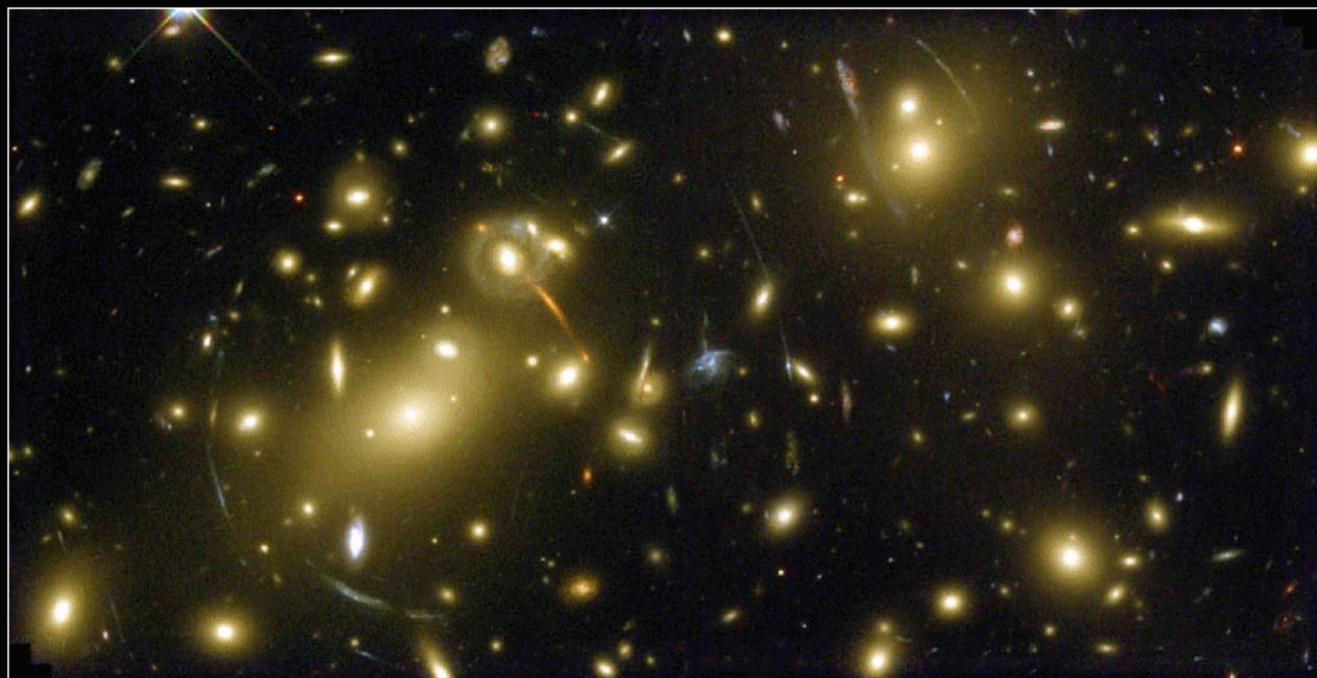
$$\begin{aligned}
 & \mathcal{L} = (D_\mu \phi)^\dagger D^\mu \phi - V(\phi) - \frac{1}{4} F_{\mu\nu} F^{\mu\nu} \\
 & D_\mu \phi = \partial_\mu \phi - ie A_\mu \phi \\
 & F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu \\
 & V(\phi) = \alpha \phi^\dagger \phi + \beta (\phi^\dagger \phi)^2 \\
 & \alpha < 0, \beta > 0
 \end{aligned}$$



Matéria Escura

- Sabemos que existe:
 - Rotação de galáxias
 - Radiação de fundo
 - Microlensing
- Mas **não sabemos o que é!**

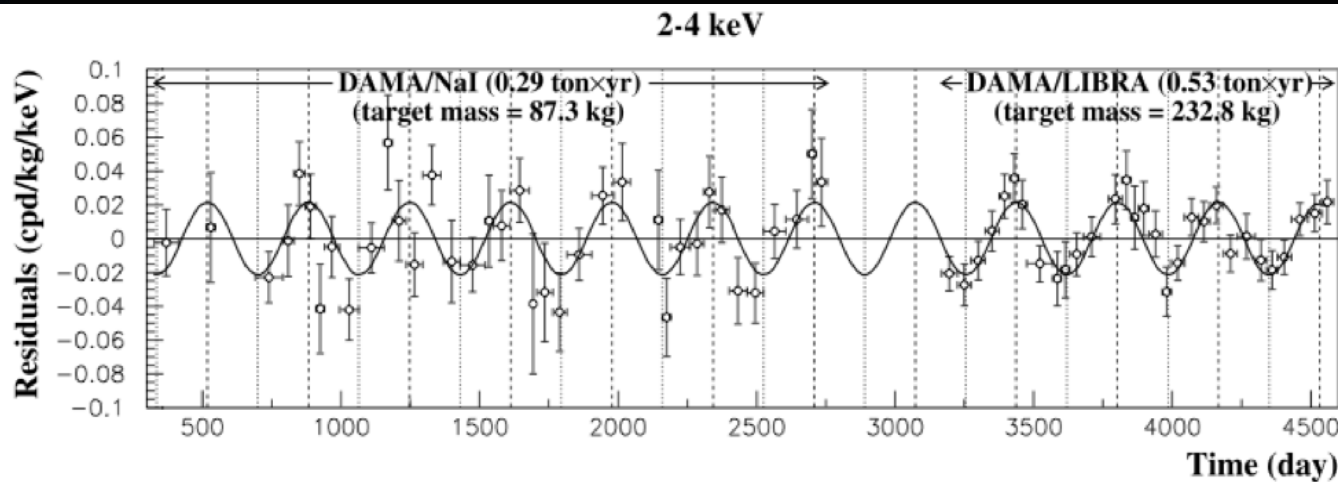




Galaxy Cluster Abell 2218

HST • WFPC2

NASA, A. Fruchter and the ERO Team (STScI, ST-ECF) • STScI-PRC00-08



Unificação das interações?

