

Particelle alla frontiera dell'energia

Incontro di orientamento sull'attività di ricerca dell'INFN

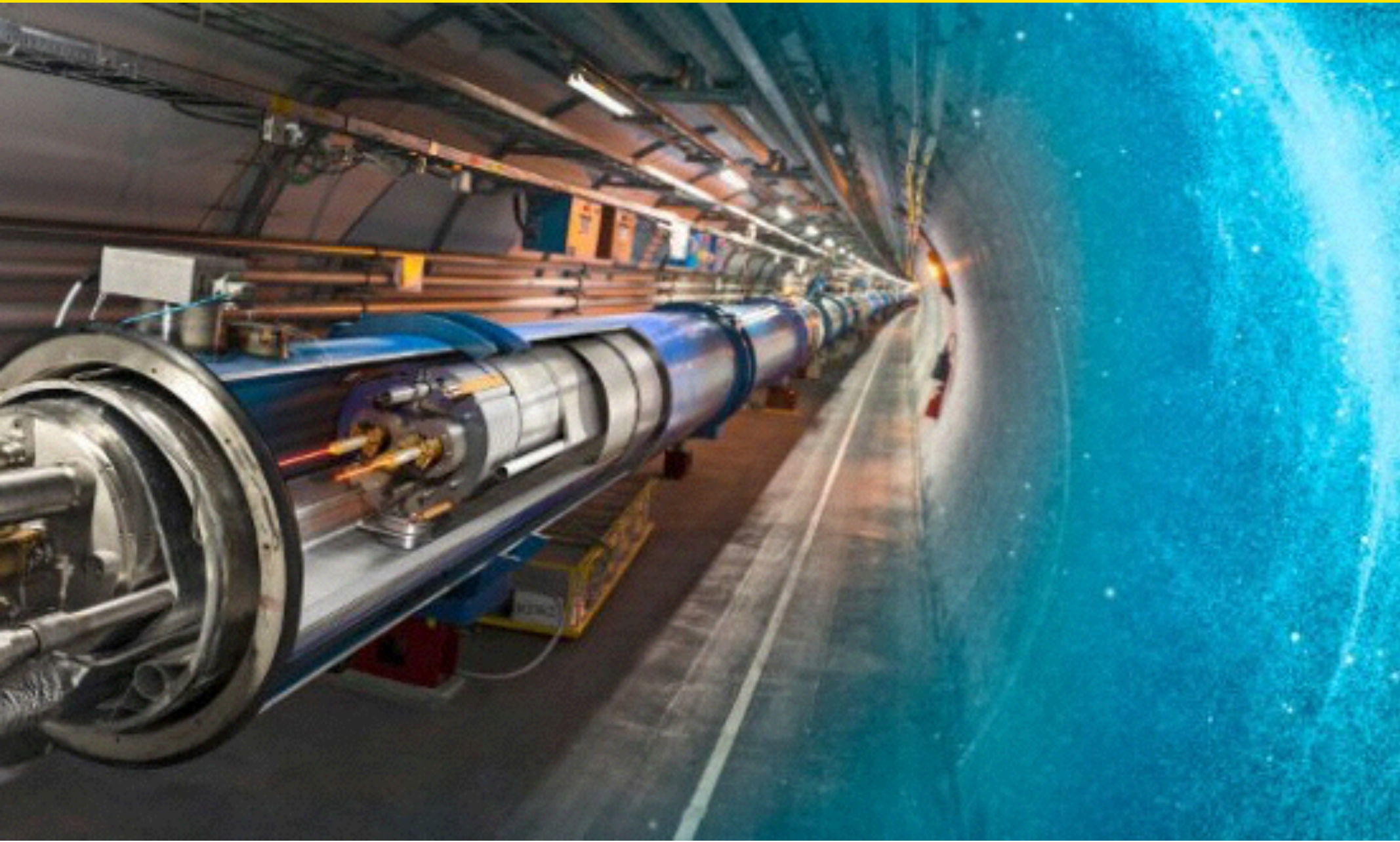


SAPIENZA
UNIVERSITÀ DI ROMA

Andrea Messina — 14 Giugno 2016



fisica delle particelle



fisica delle particelle



La fisica delle particelle ha come obiettivo la comprensione delle leggi della natura attraverso lo studio della materia e delle forze a livello fondamentale

le particelle elementari e le loro interazioni

Quarks



Forces



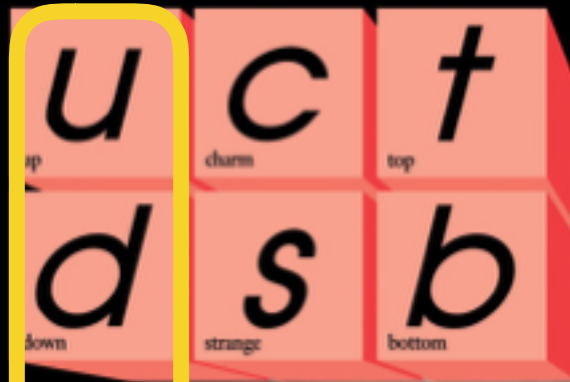
H
Higgs
boson



Leptons

le particelle elementari e le loro interazioni

Quarks



Leptons

Materia ordinaria

Forces



H
Higgs boson

le particelle elementari e le loro interazioni

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

campi di forze



$$+ i\bar{\psi} \not{D} \psi + h.c$$



interazione
campi e particelle

$$+ \bar{\psi}_i \gamma_{ij} \psi_j \phi + h.c$$



interazione
particelle e higgs

$$+ |D_\mu \phi|^2 - V(\phi)$$



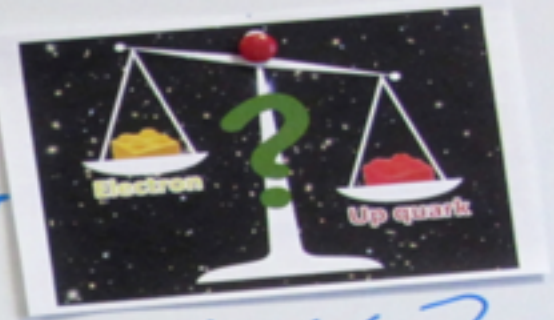
higgs

fisica delle particelle: alcune delle domande fondamentali

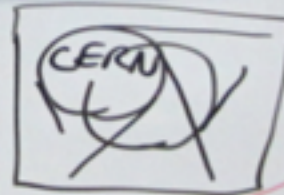


Anti-matter?

What else??



Mass?



Dark Matter?



Dark Energy?

acceleratori: una fabbrica di particelle

$E = mc^2 / \sqrt{1 - v^2/c^2}$

$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$

$E^2 = m^2 c^4 + p^2 c^2$

$t = \frac{t' + vx'}{\sqrt{1 - v^2/c^2}}$ $x = \frac{x' + vt'}{\sqrt{1 - v^2/c^2}}$ $y = y'$ $z = z'$

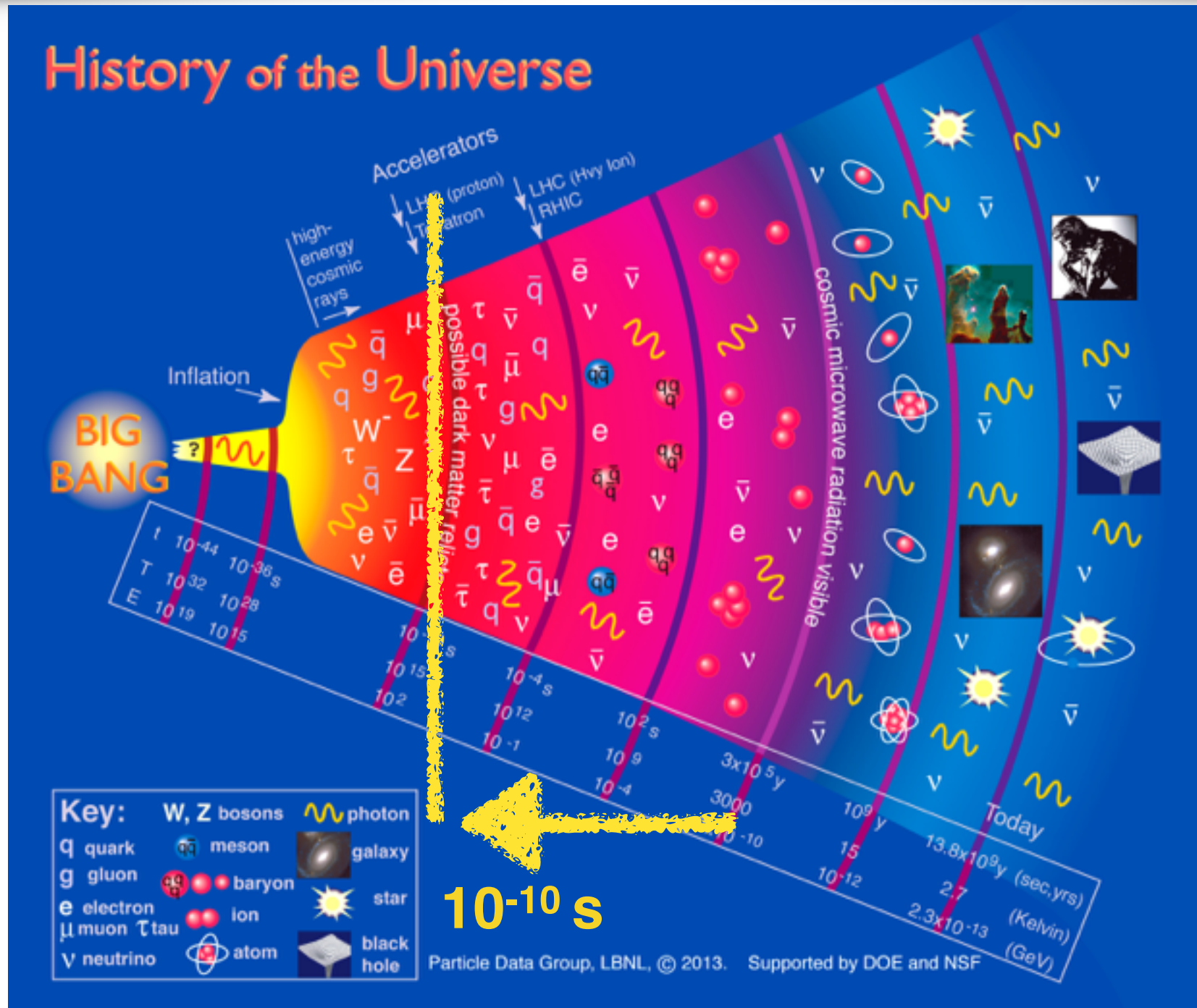
Before

After

t

\bar{t}

acceleratori: una macchina del tempo



LHC: la frontiera dell'energia

13 TeV

13'000'000'000'000 eV = 0.000002 Joule



LHC: la frontiera dell'energia

362 MJ

An aerial photograph of the USS Zumwalt (DDG 1000) sailing on the open ocean. The ship's deck is visible, with several fighter jets parked. The number '75' is visible on the superstructure. Large, bold, orange text '362 MJ' is superimposed over the center of the image.

filmino su LHC



LHC
Large Hadron Collider
Grand collisionneur à hadrons

filmino su LHC



LHC
Large Hadron Collider
Grand collisionneur à hadrons

Collisioni

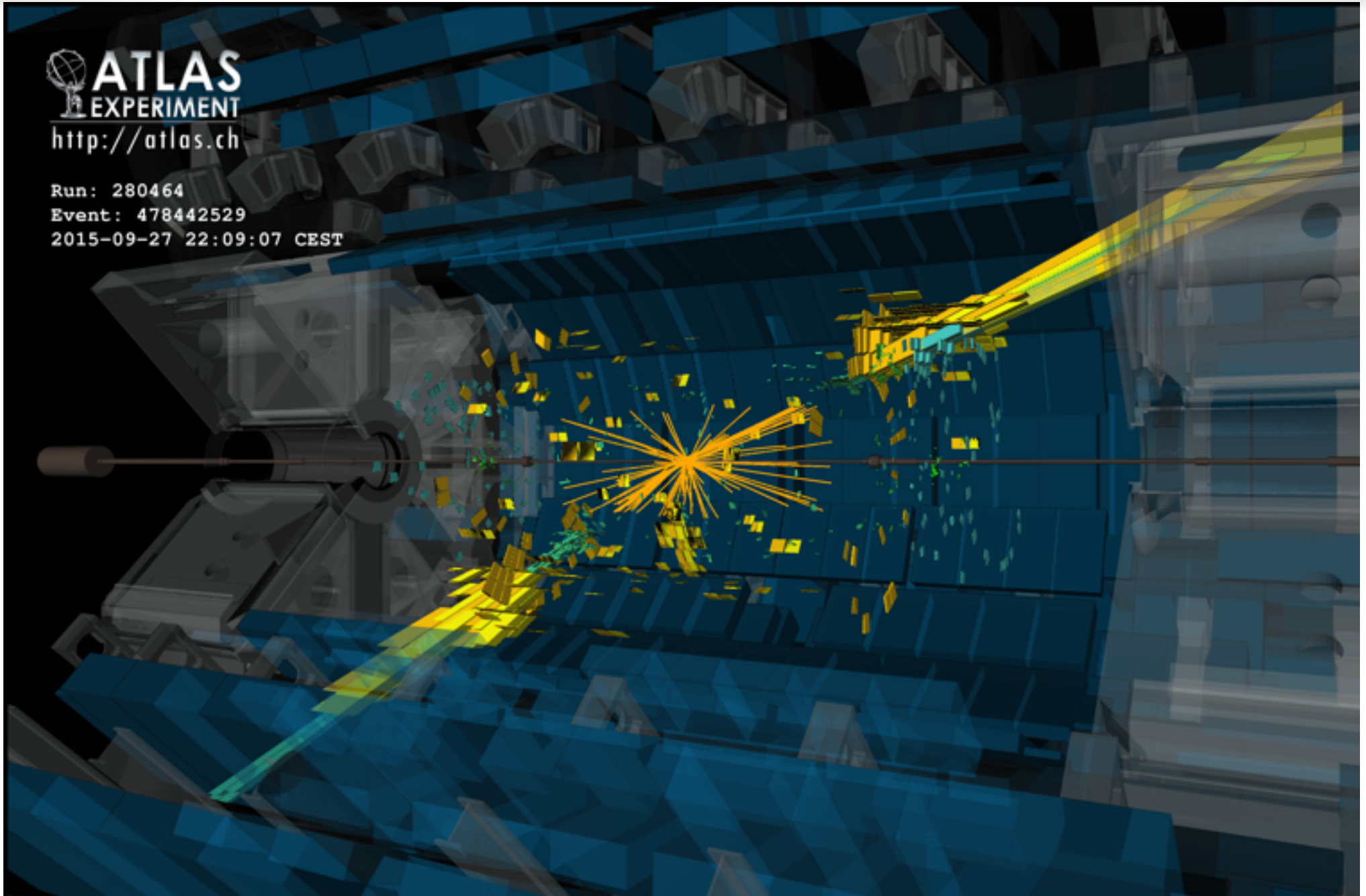
 **ATLAS**
EXPERIMENT

<http://atlas.ch>

Run: 280464

Event: 478442529

2015-09-27 22:09:07 CEST



Collisioni

 **ATLAS**
EXPERIMENT

<http://atlas.ch>

Run: 280464

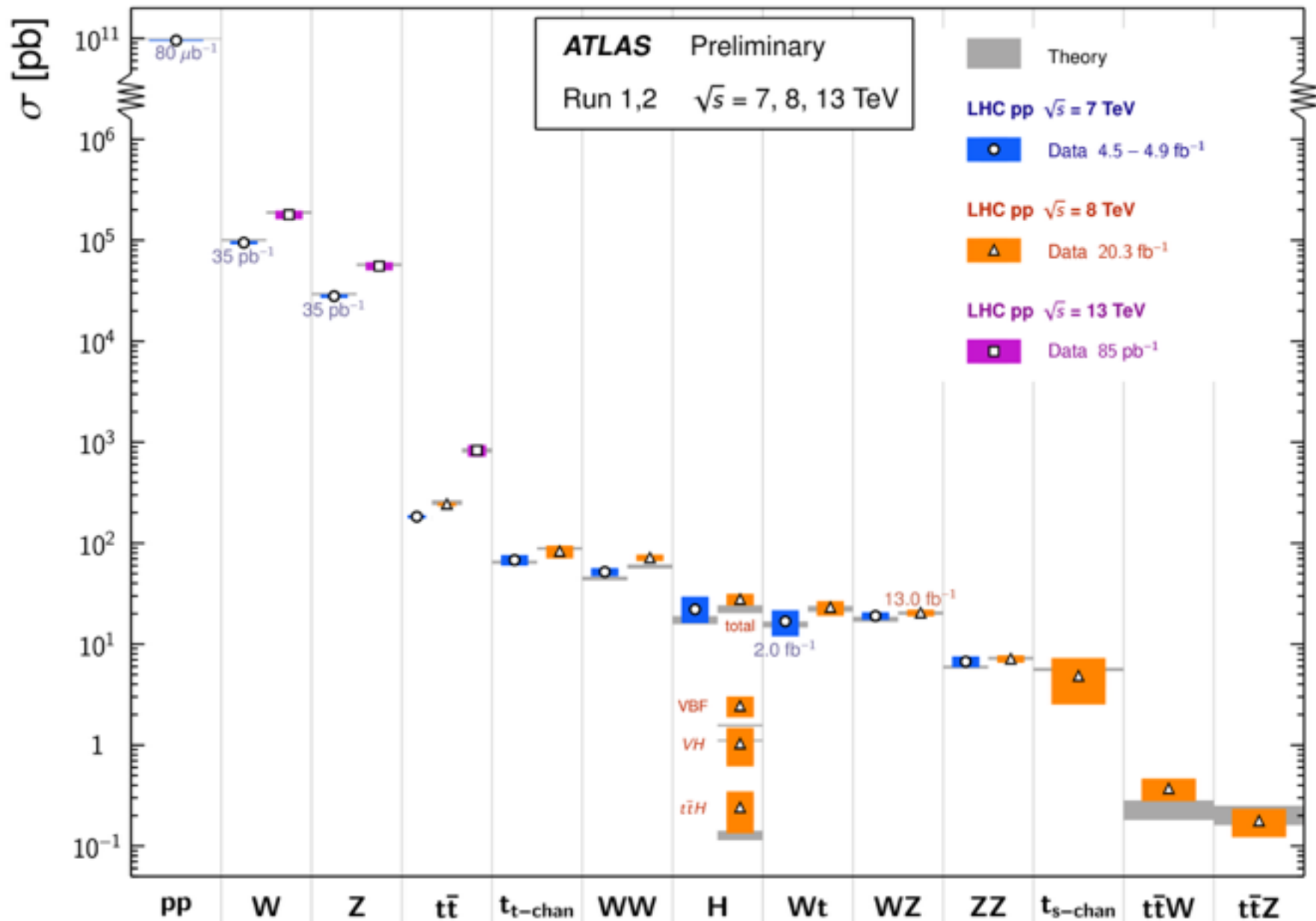
Event: 478442529

2015-09-27 22:09:07 CEST

40 milioni di incroci al secondo
25 collisioni ad incrocio

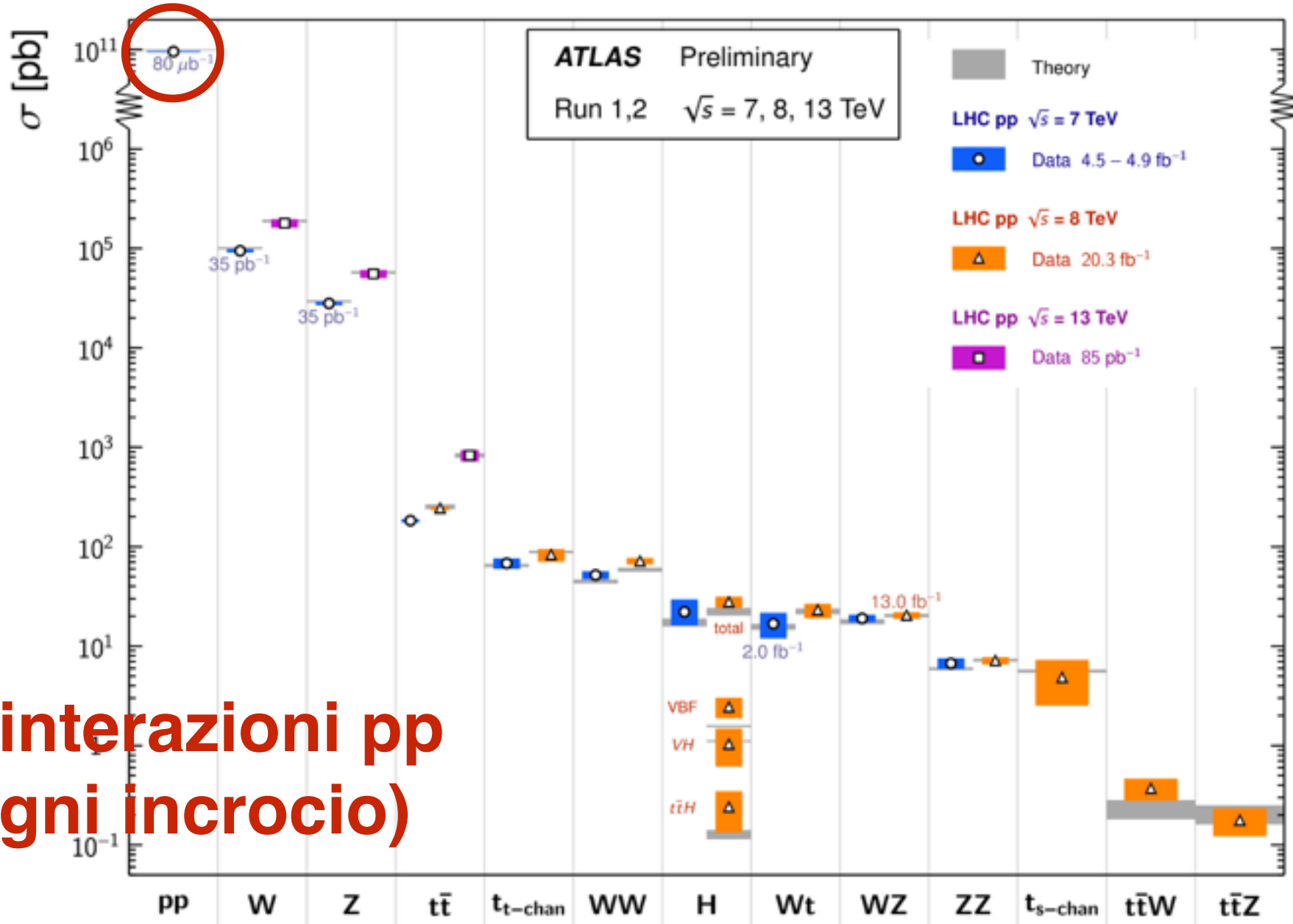
cosa si produce nelle collisioni

Standard Model Total Production Cross Section Measurements Status: Nov 2015



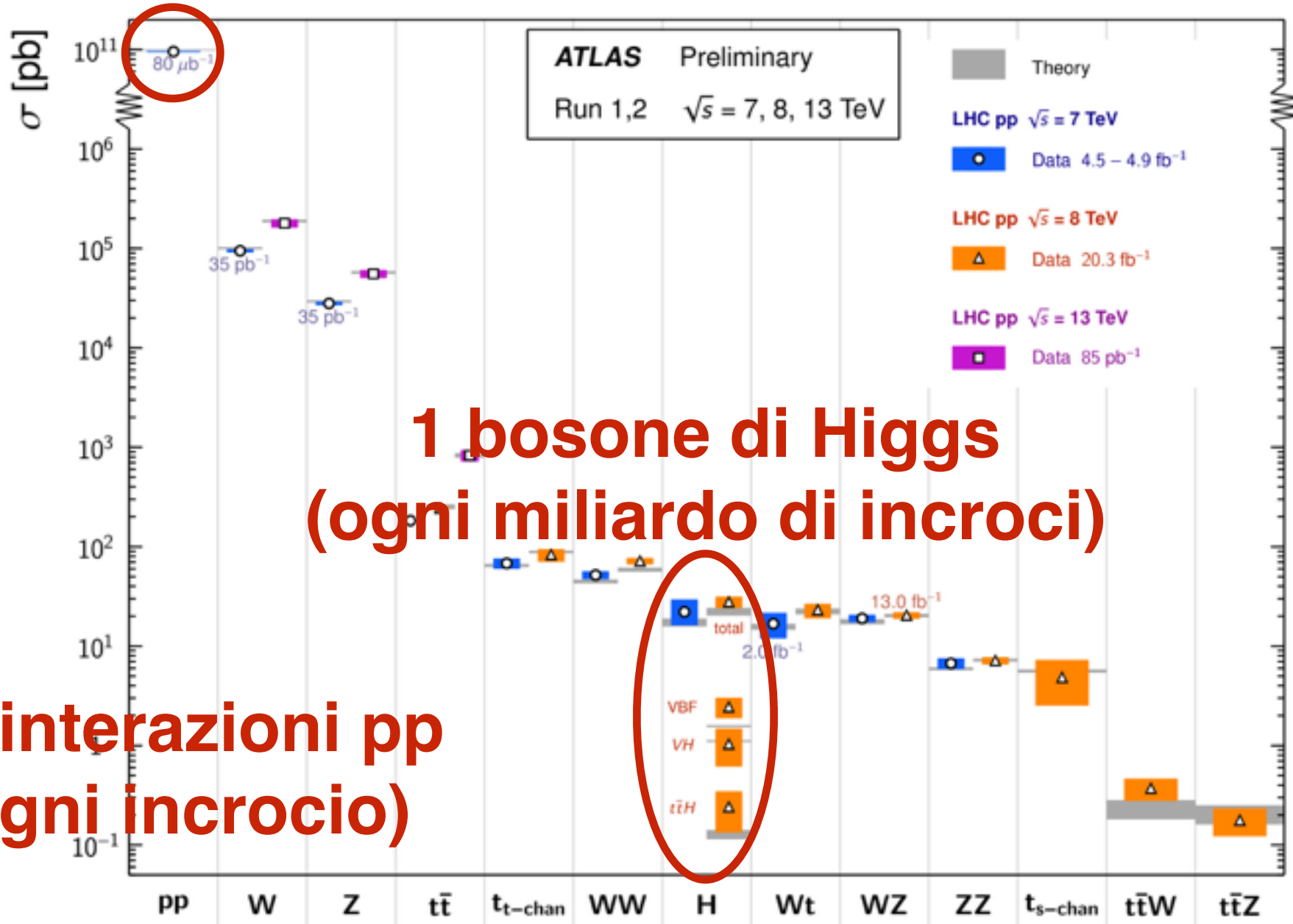
cosa si produce nelle collisioni

Standard Model Total Production Cross Section Measurements Status: Nov 2015

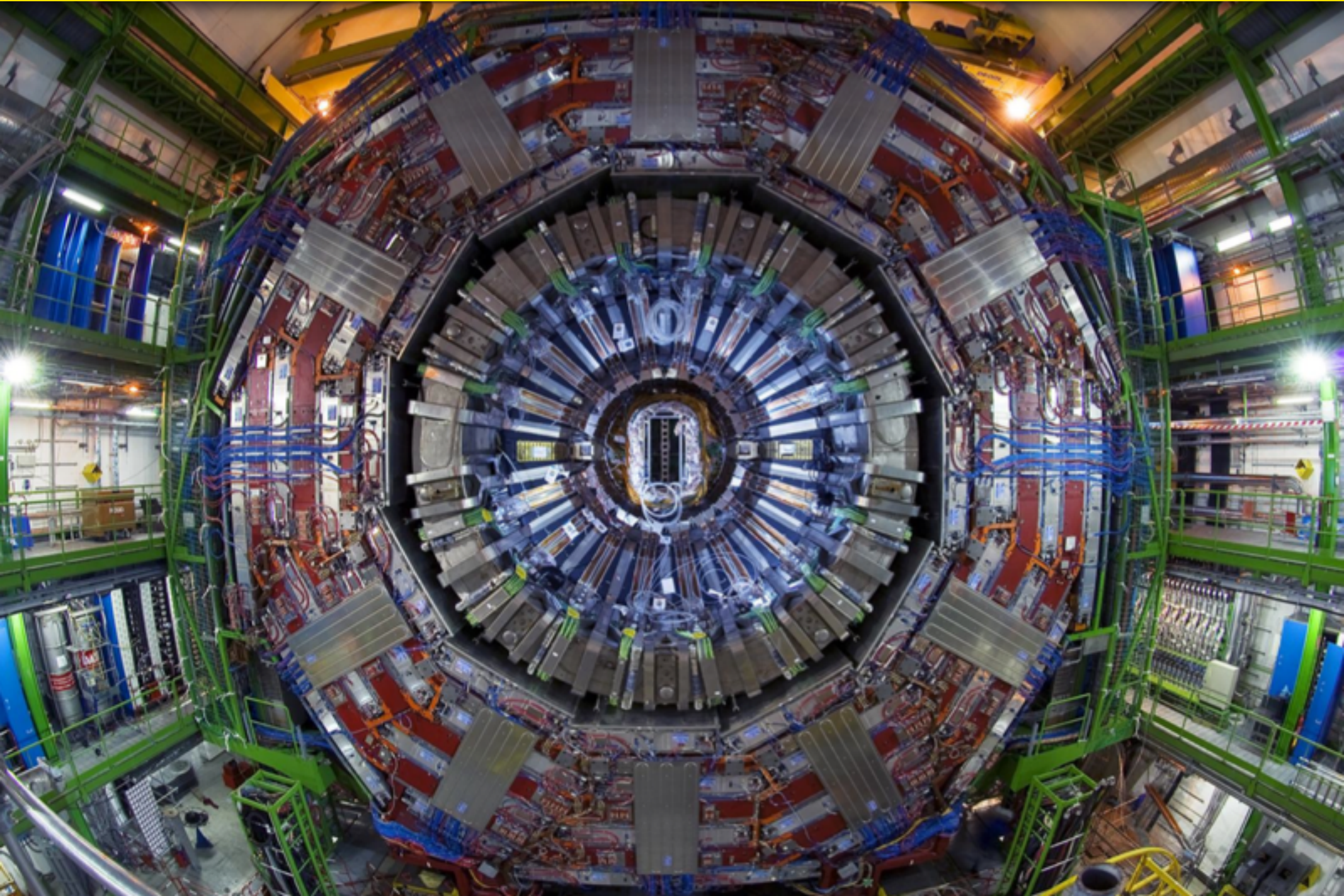


cosa si produce nelle collisioni

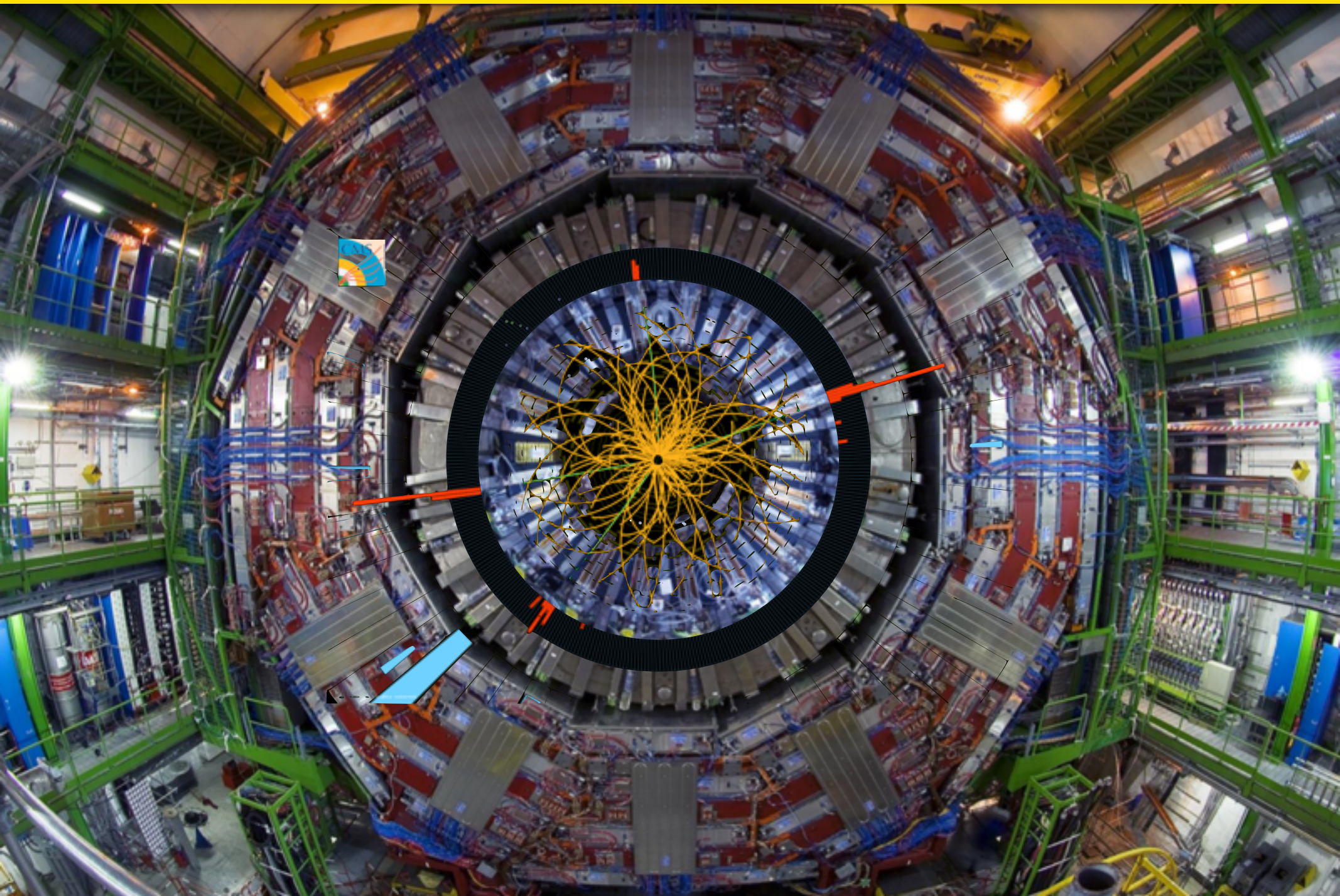
Standard Model Total Production Cross Section Measurements Status: Nov 2015



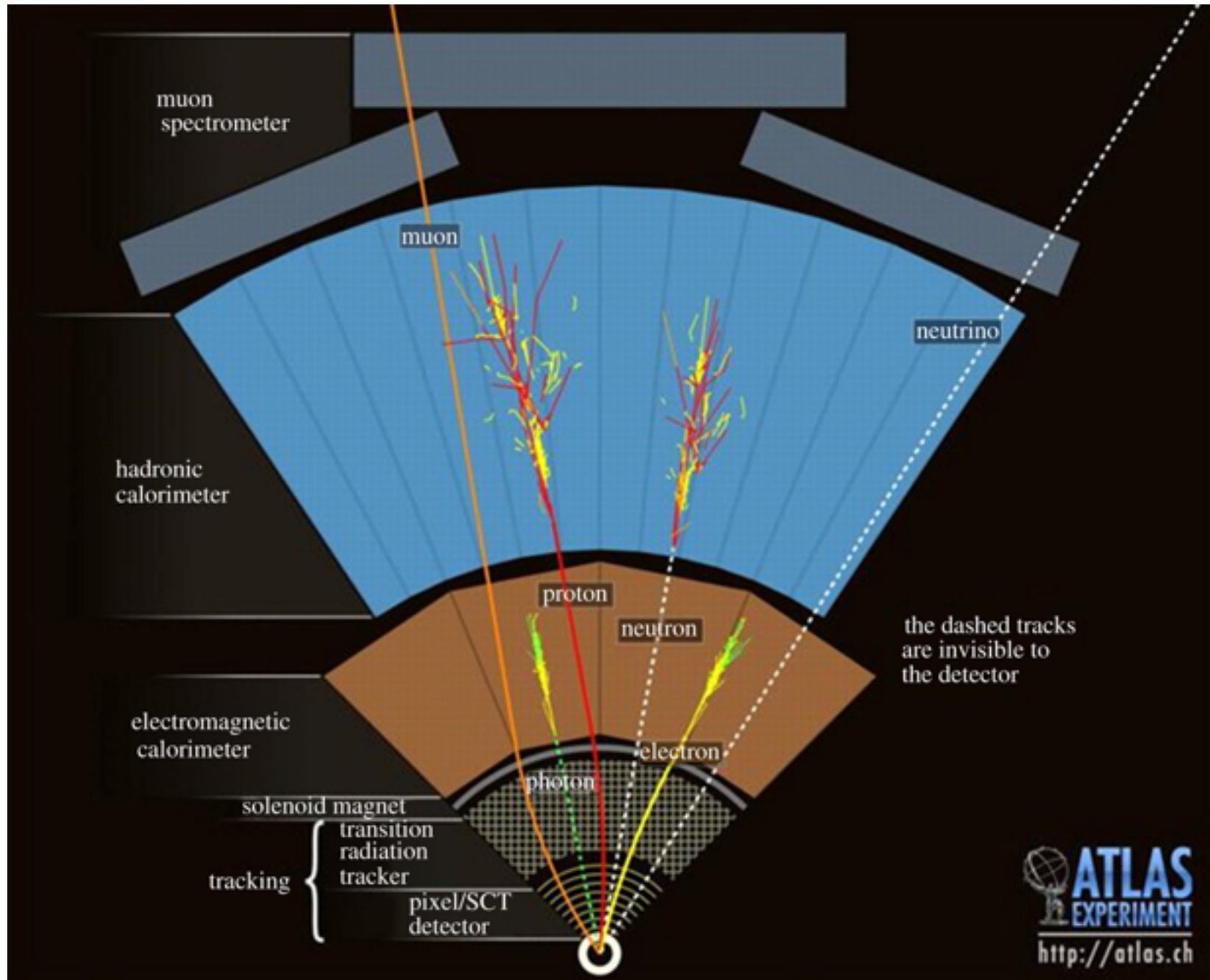
rivelatori di particelle



rivelatori di particelle



rivelatori di particelle



scoperta del bosone di higgs (2012)



8 October 2013

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2013 to

François Englert and Peter Higgs

“for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN’s Large Hadron Collider”

scoperta del bosone di higgs (2012)



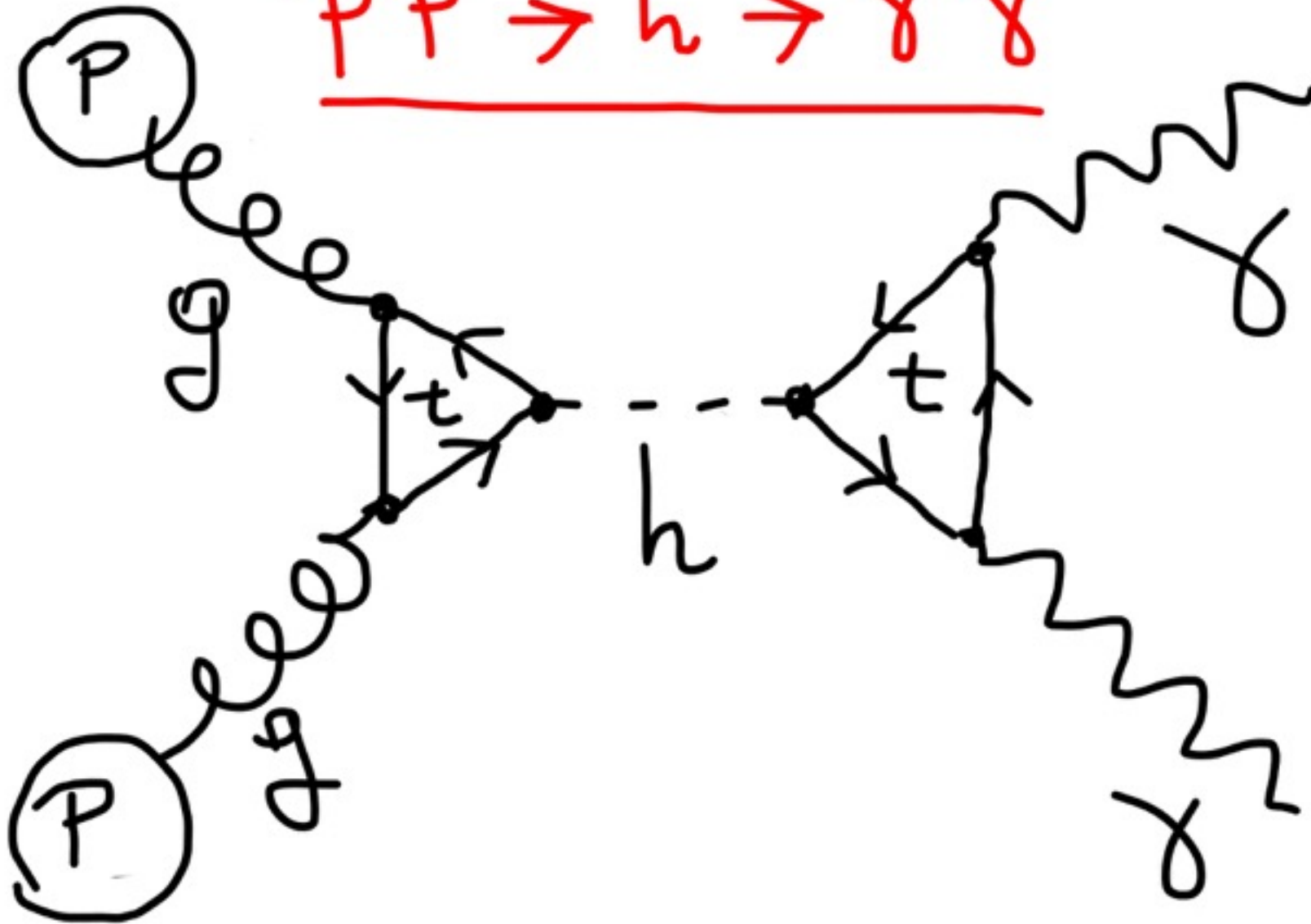
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higgs in 2 fotoni

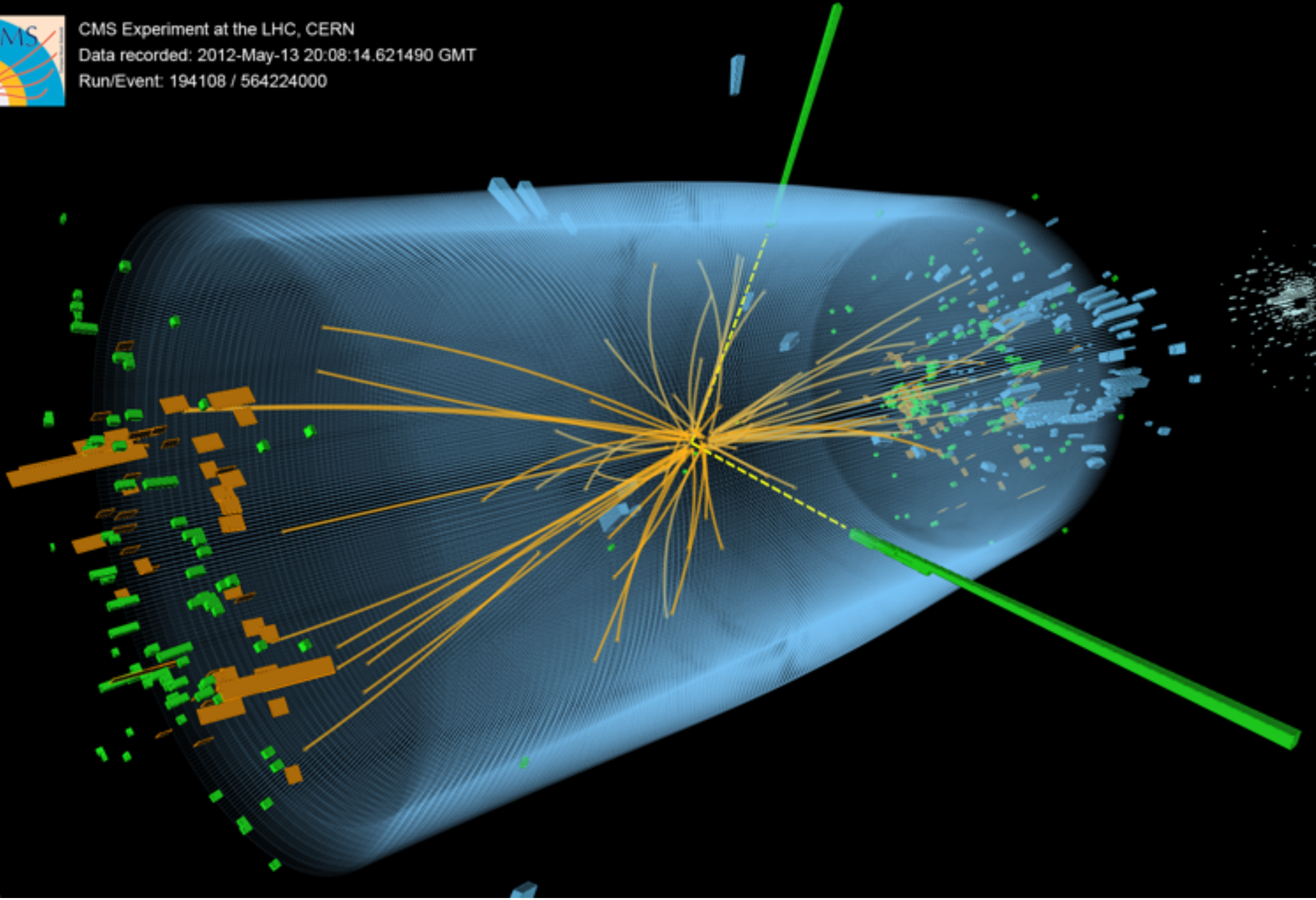
$$\underline{PP \rightarrow h \rightarrow \gamma\gamma}$$



higgs in 2 fotoni

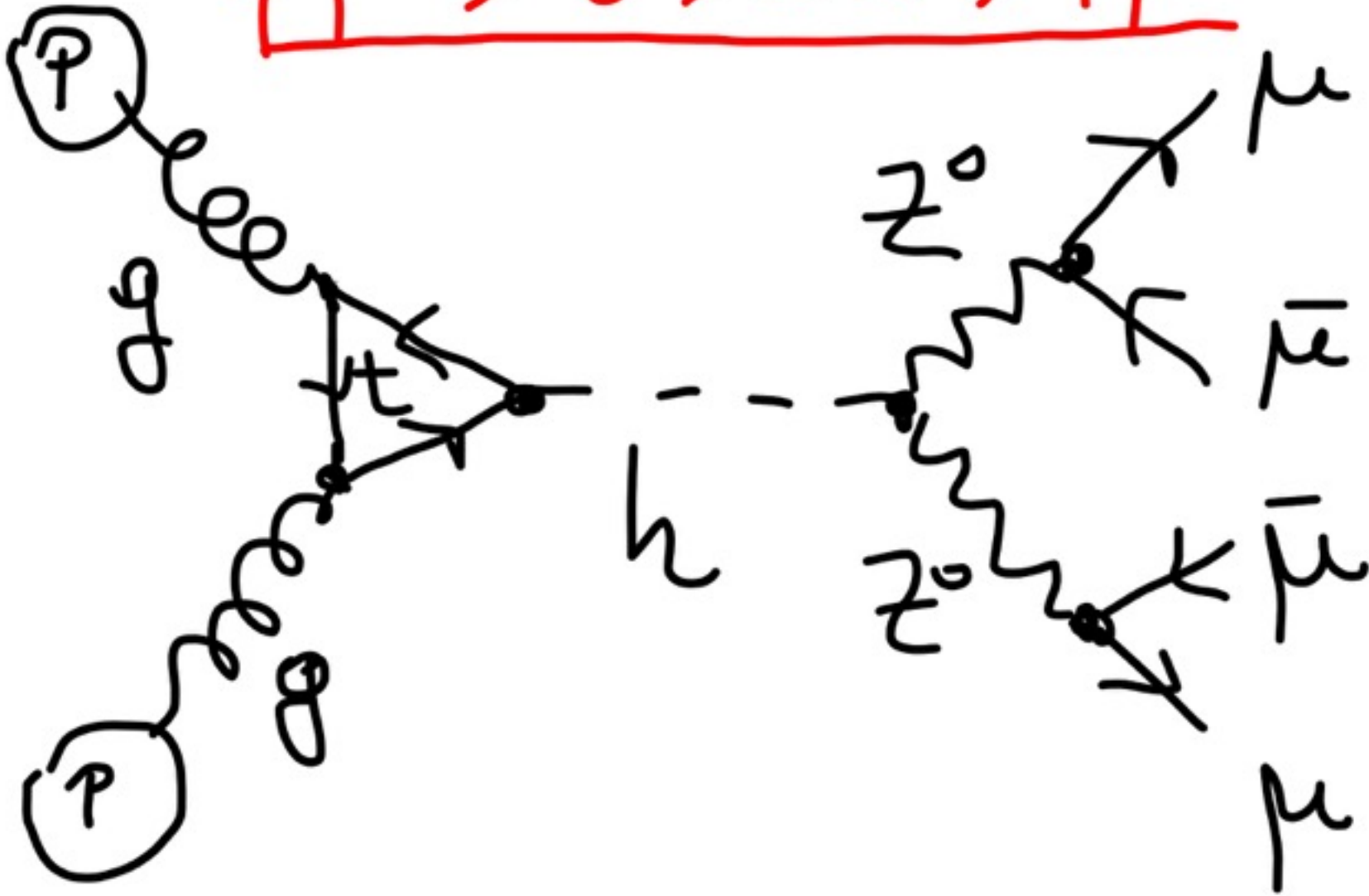


CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000



higgs in 4 mu

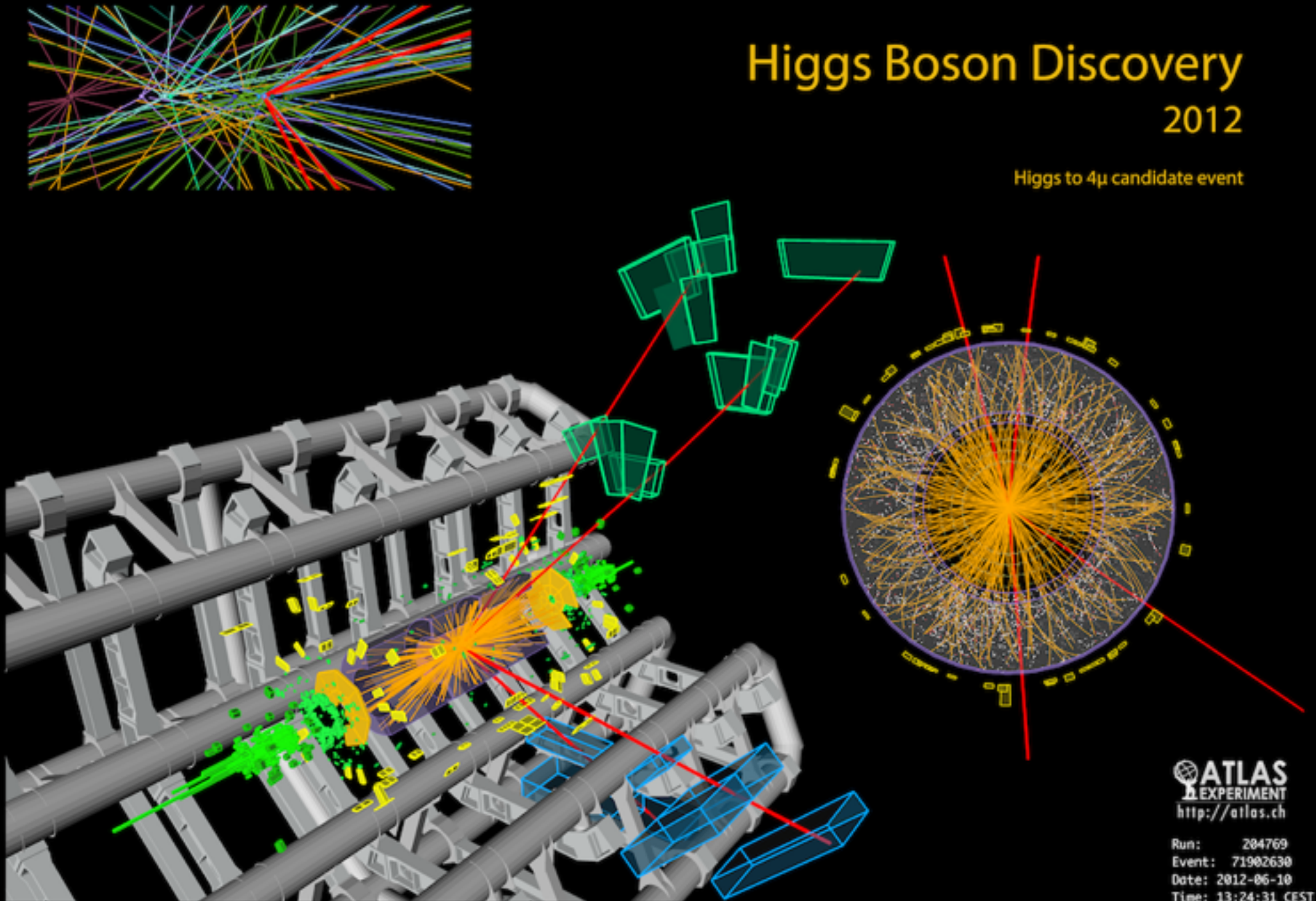
$$pp \rightarrow h \rightarrow Z^0 Z^0 \rightarrow 4\mu$$



higgs in 4 mu

Higgs Boson Discovery 2012

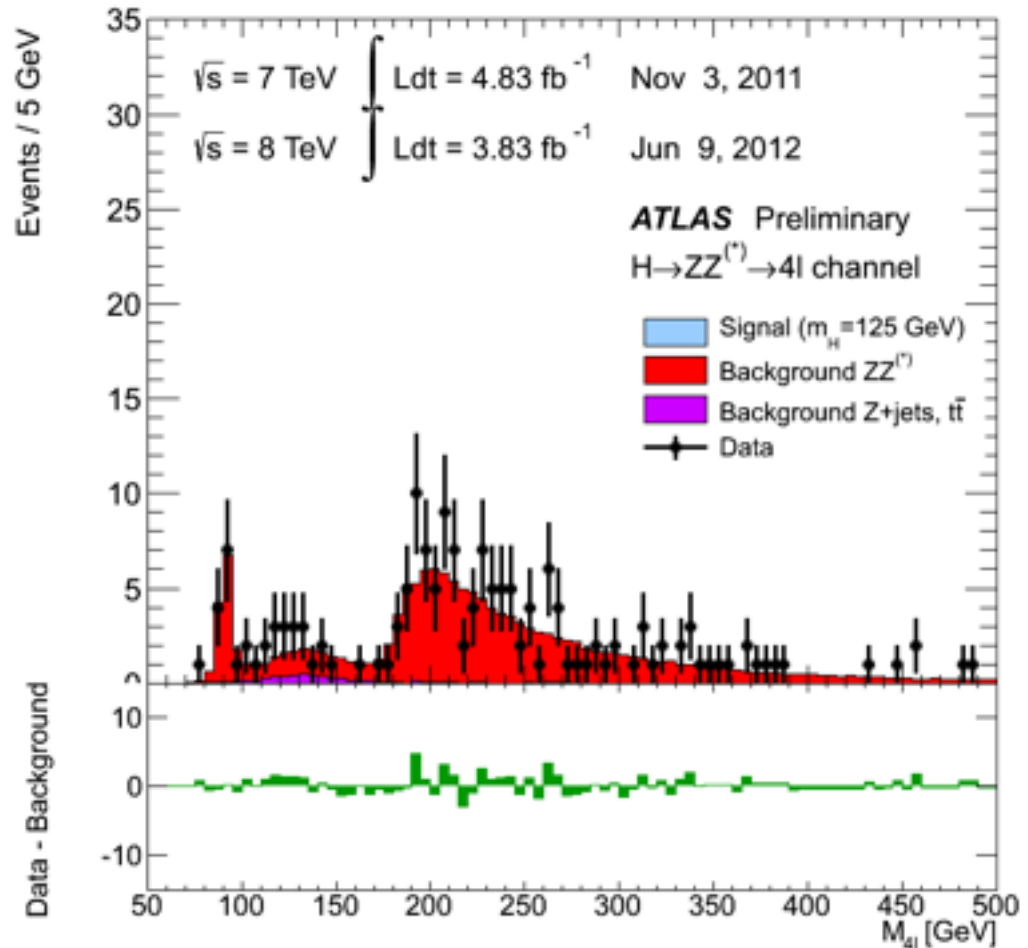
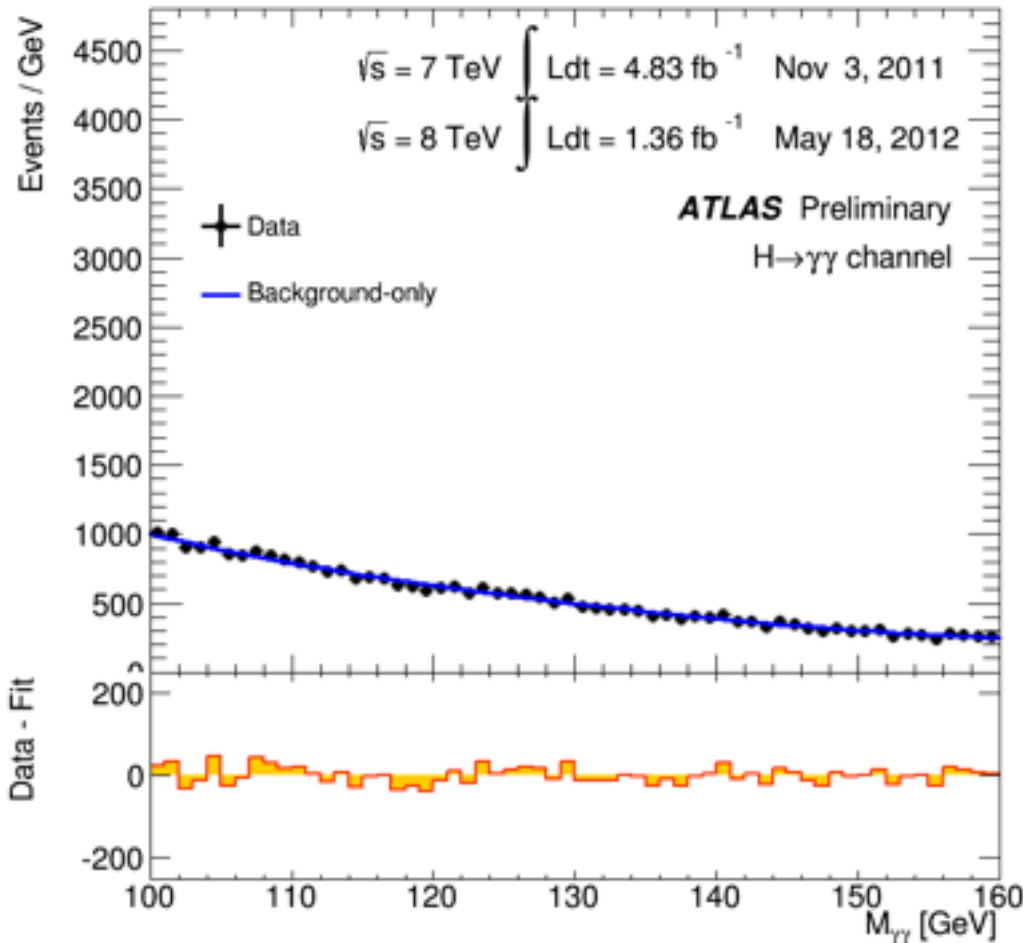
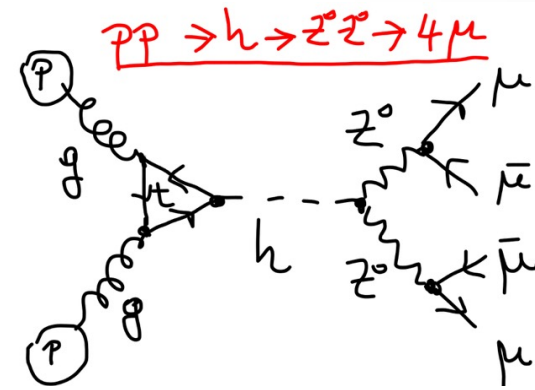
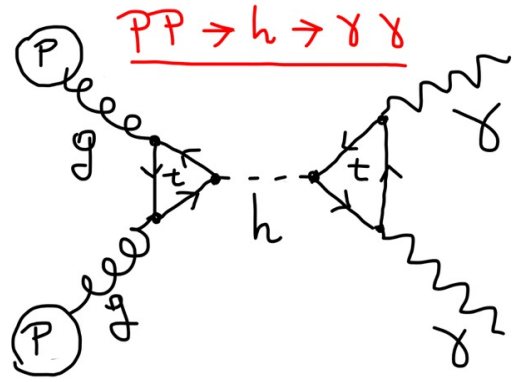
Higgs to 4 μ candidate event



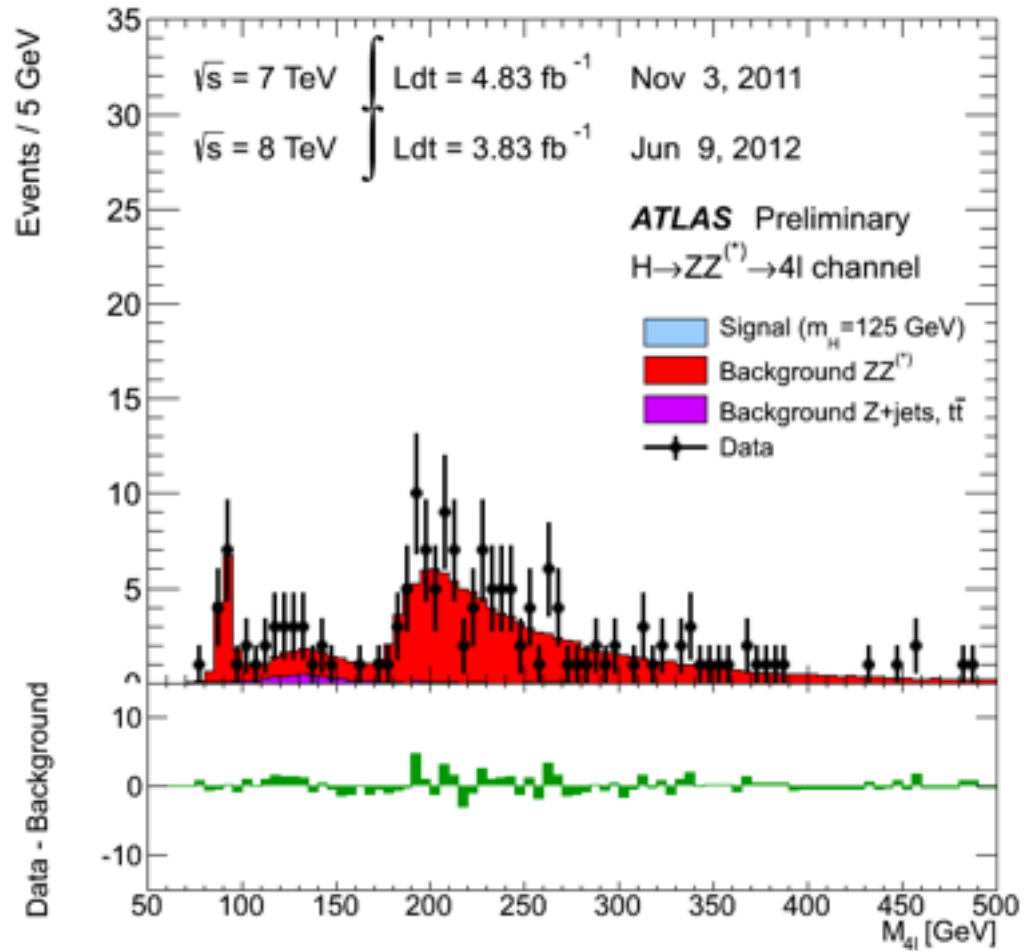
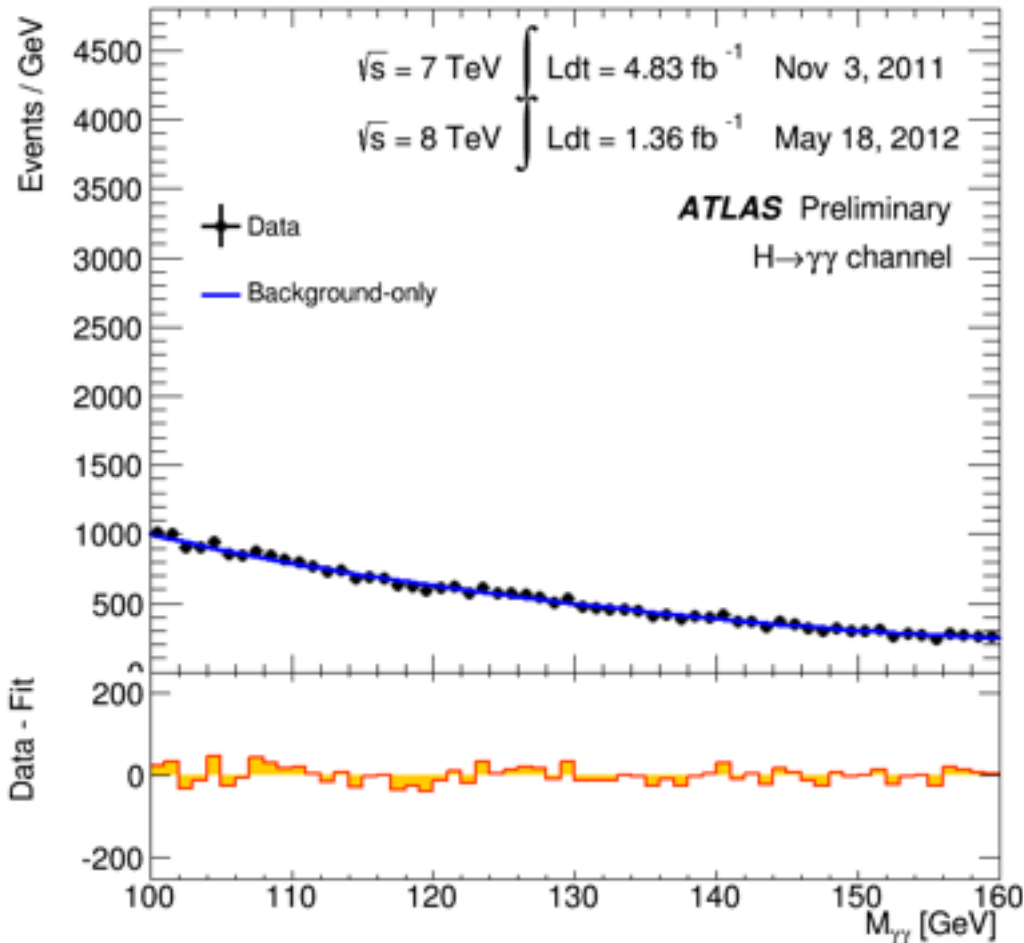
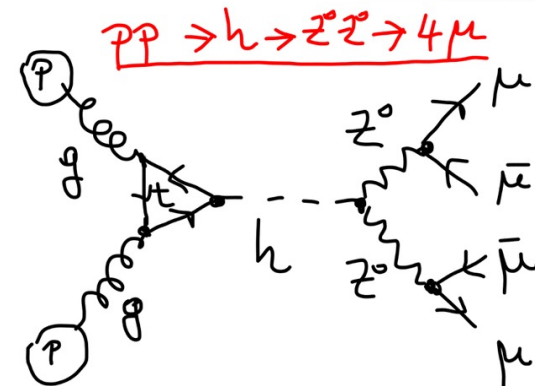
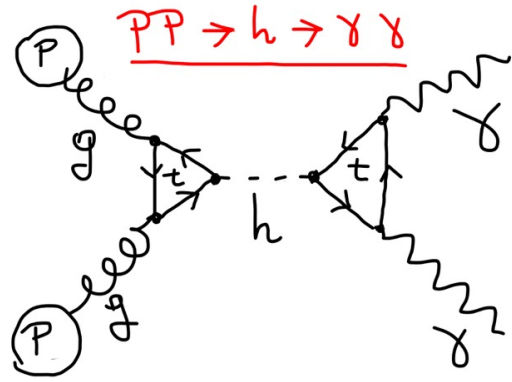
ATLAS
EXPERIMENT
<http://atlas.ch>

Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

scoperta del bosone di higgs

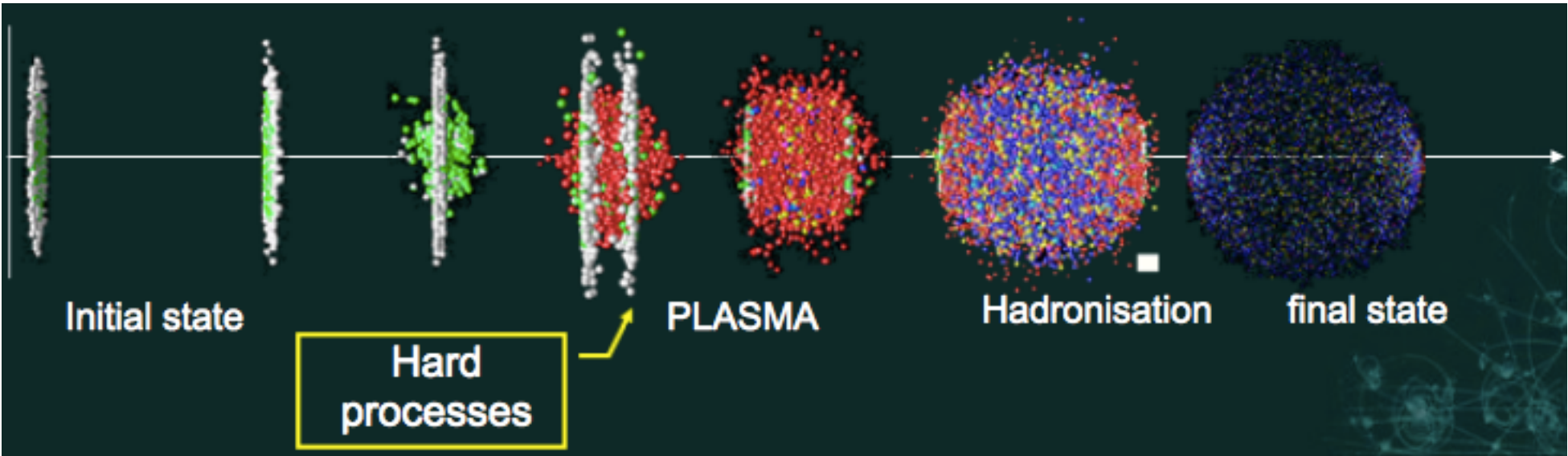
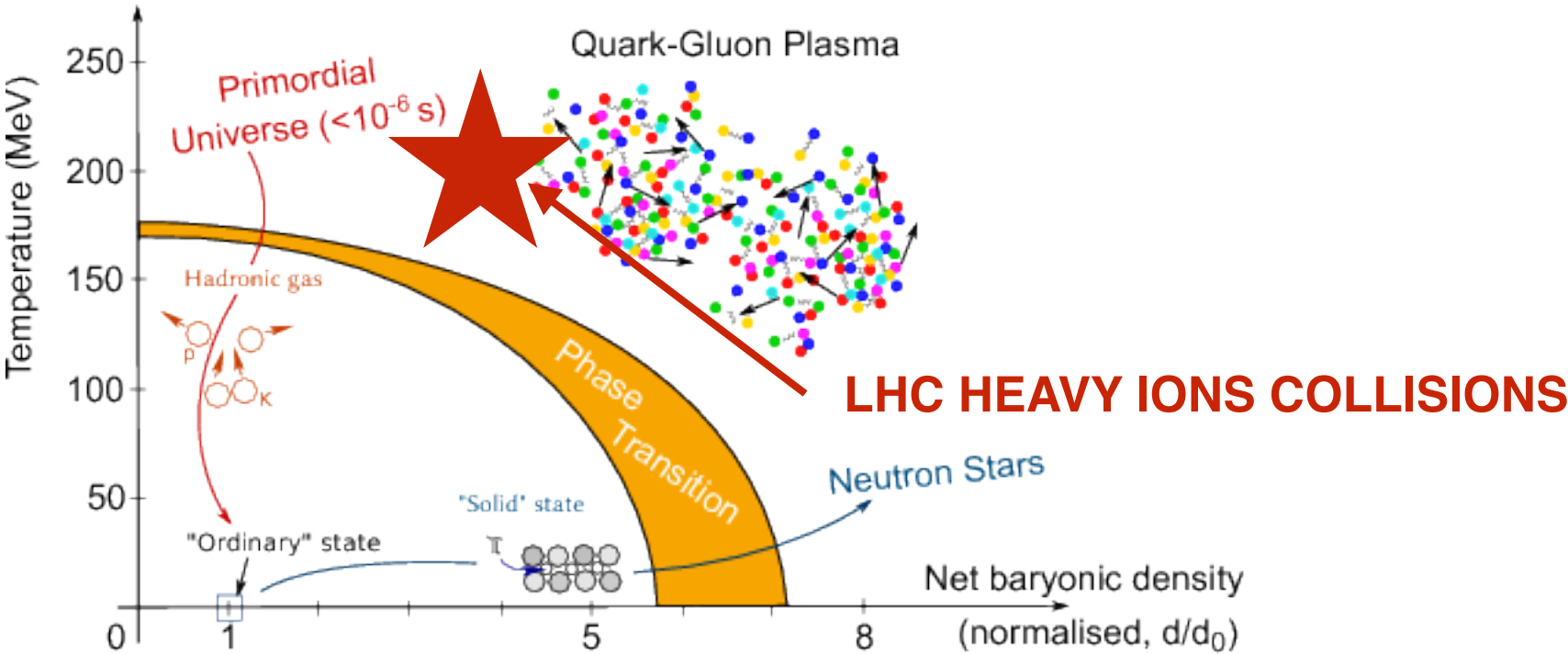


scoperta del bosone di higgs



altre sfide ad LHC

quark-gluon plasma



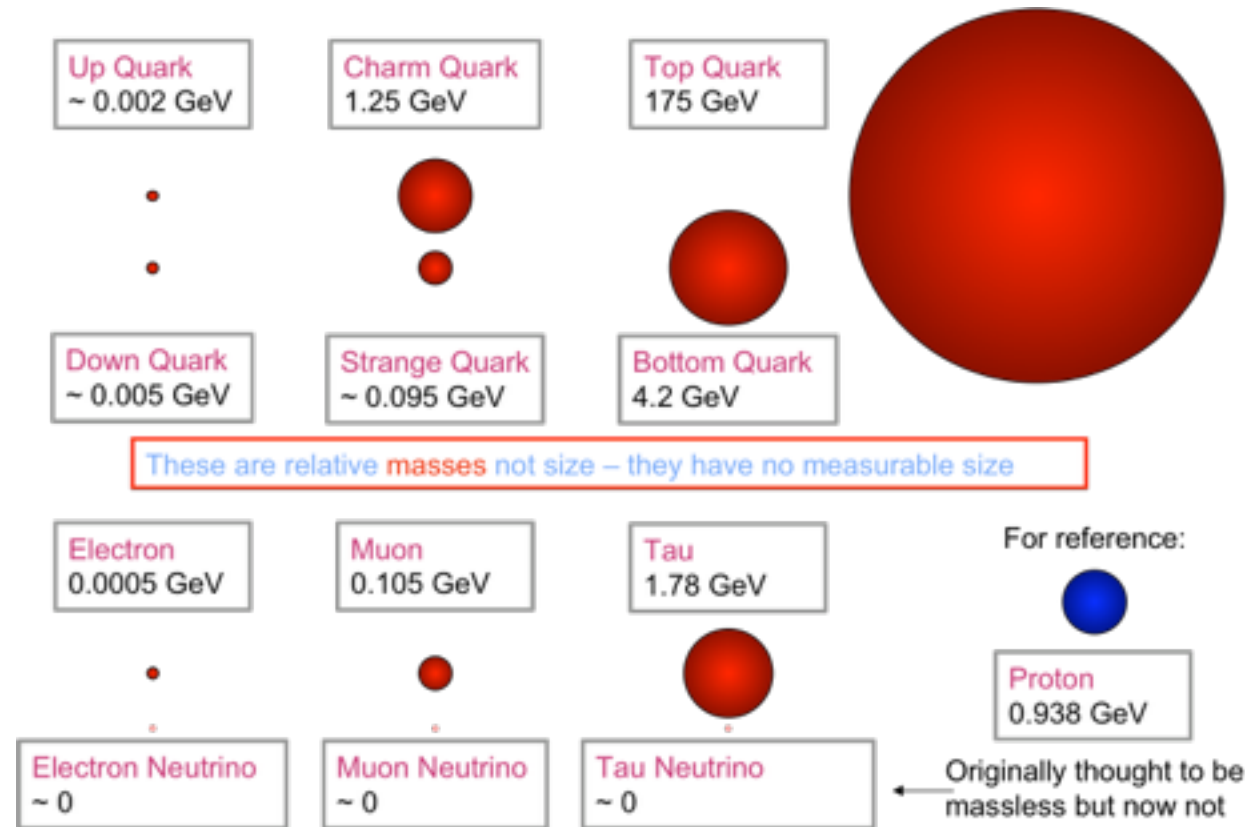
problema del flavour

problema del flavour

- **Perché esistono più famiglie di leptoni e quarks?**

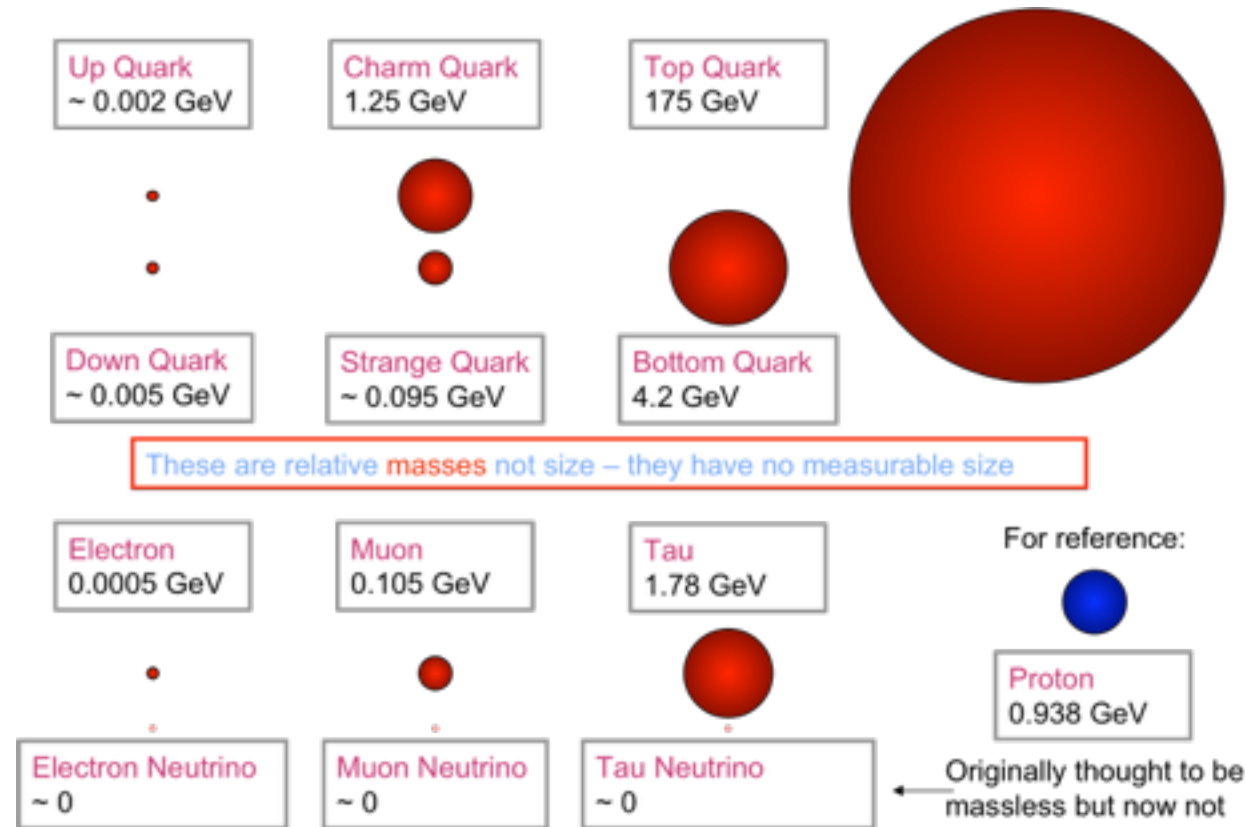
problema del flavour

- Perché esistono più famiglie di leptoni e quarks?
- Perché hanno masse così diverse tra loro dalla scala EW?

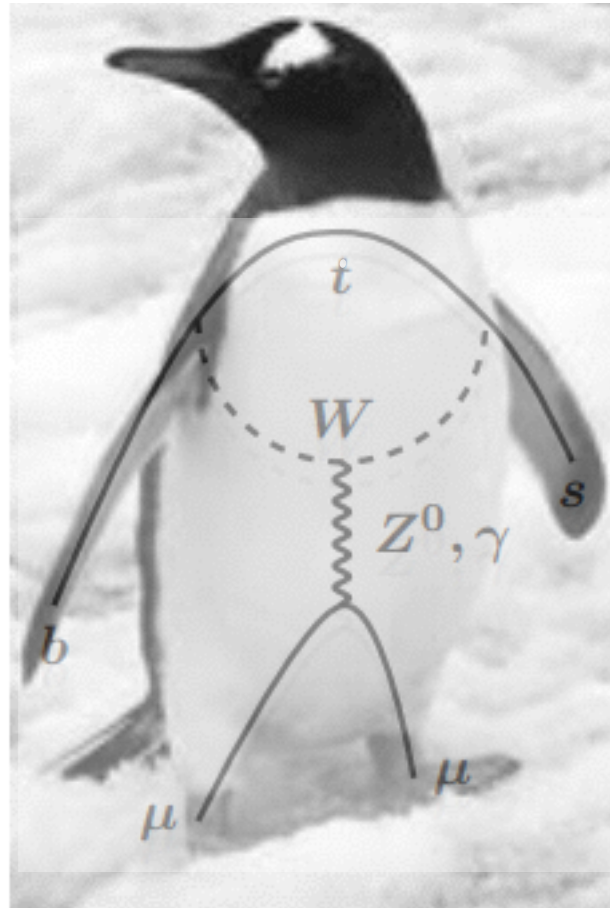


problema del flavour

- Perché esistono più famiglie di leptoni e quarks?
- Perché hanno masse così diverse tra loro dalla scala EW?
- Perché c'è asimmetria materia antimateria?

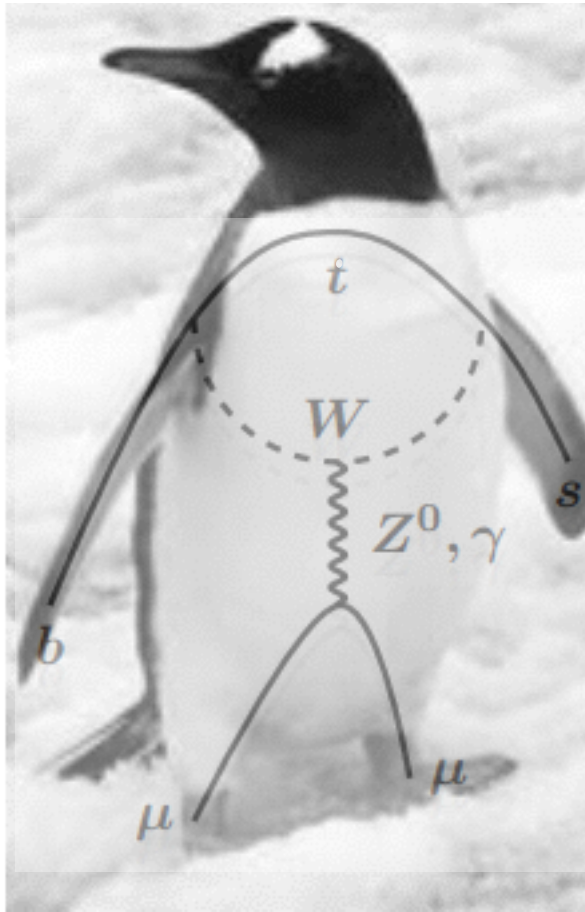


LHCb e fisica del flavour

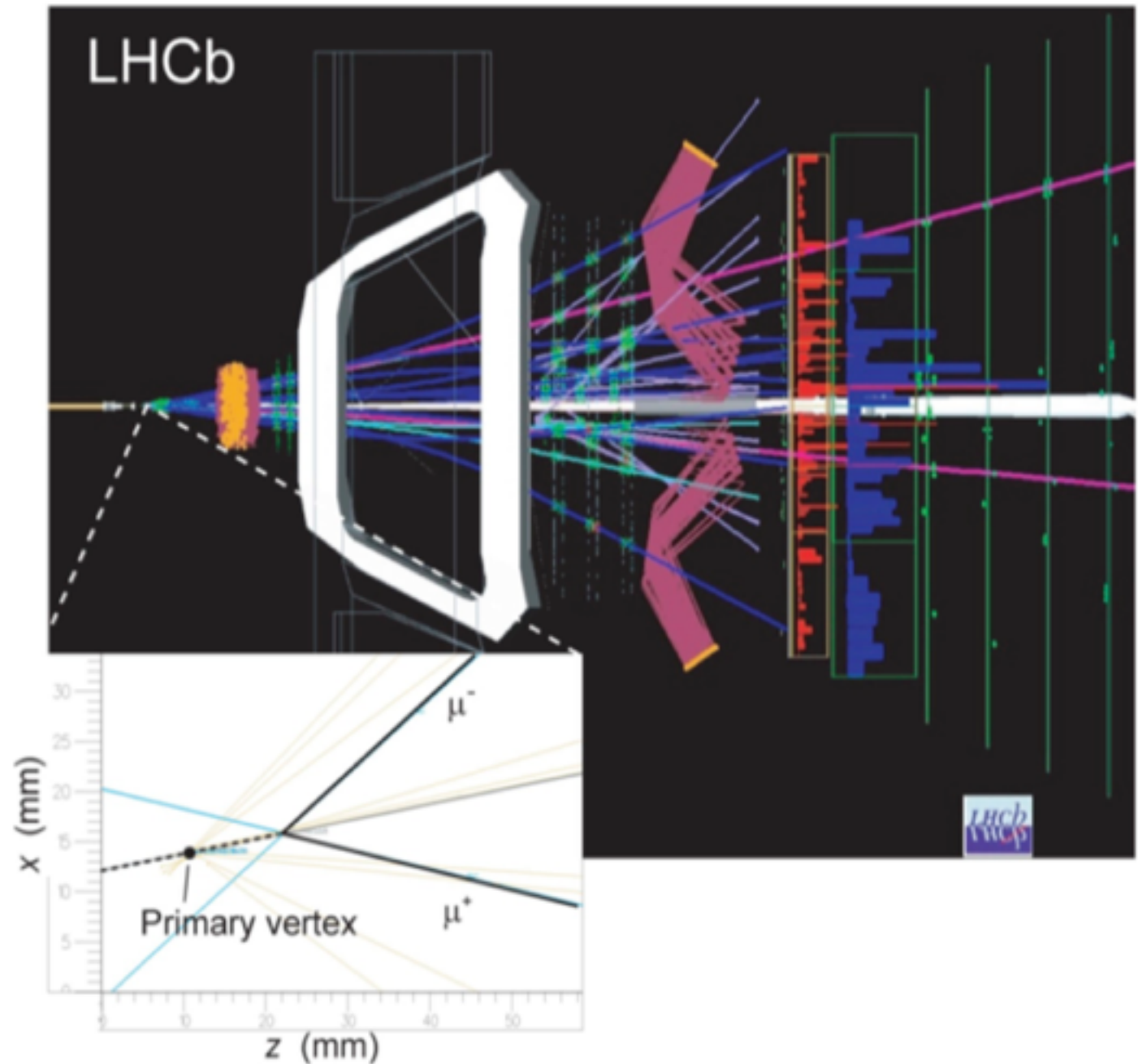


**processo molto
raro nel SM
BR $\sim 3 \cdot 10^{-9}$**

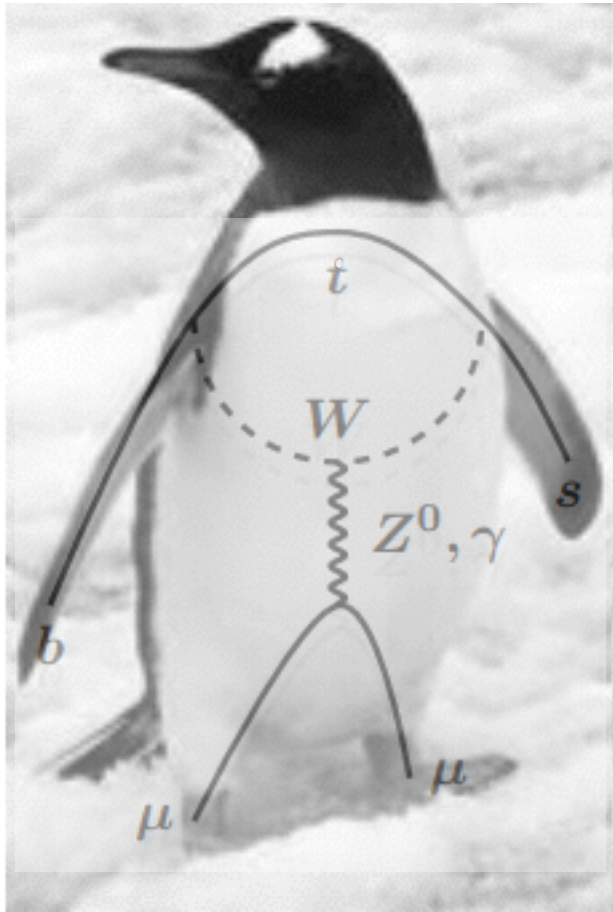
LHCb e fisica del flavour



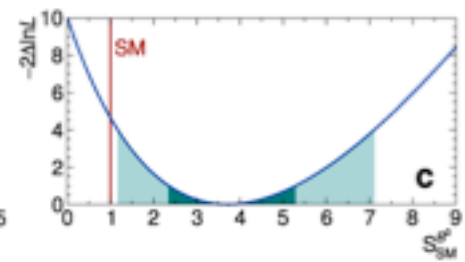
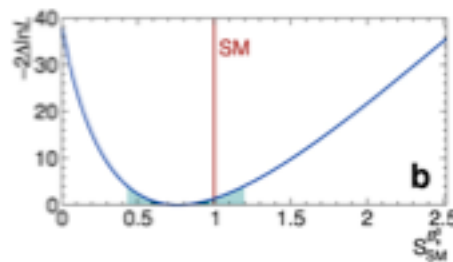
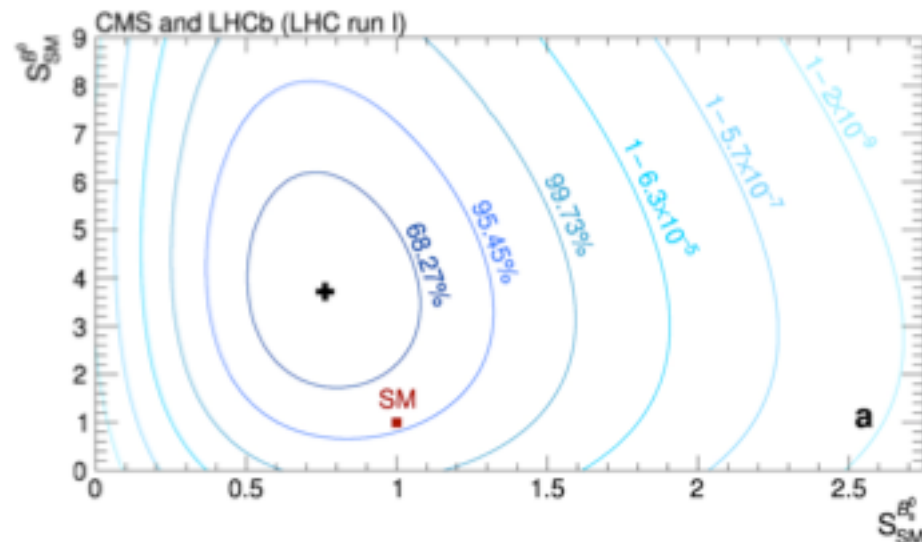
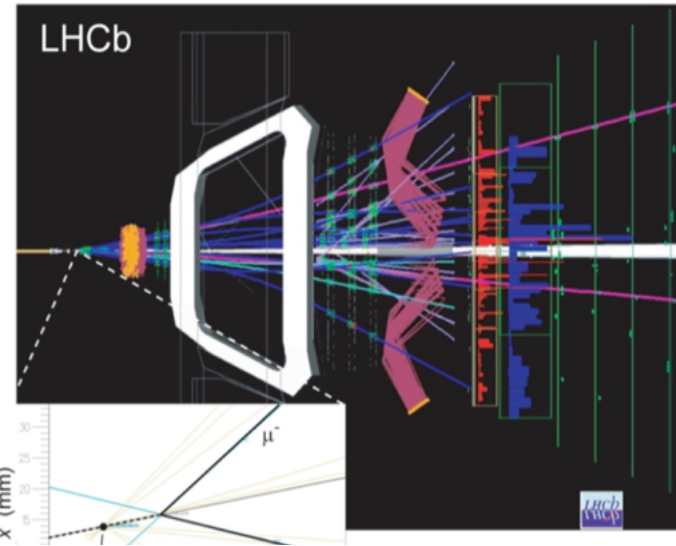
processo molto raro nel SM
 $BR \sim 3 \cdot 10^{-9}$



LHCb e fisica del flavour



processo molto raro nel SM
BR $\sim 3 \cdot 10^{-9}$



chi è veramente il bosone di Higgs?

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★ Il bosone di higgs è uno scalare fondamentale?

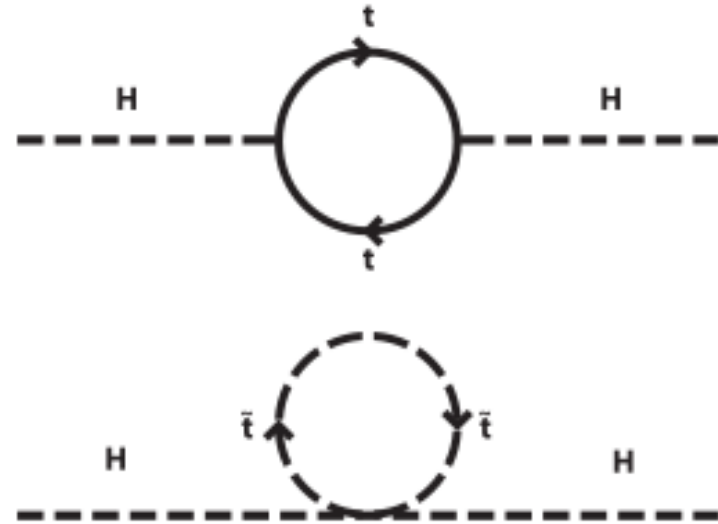
chi è veramente il bosone di Higgs?

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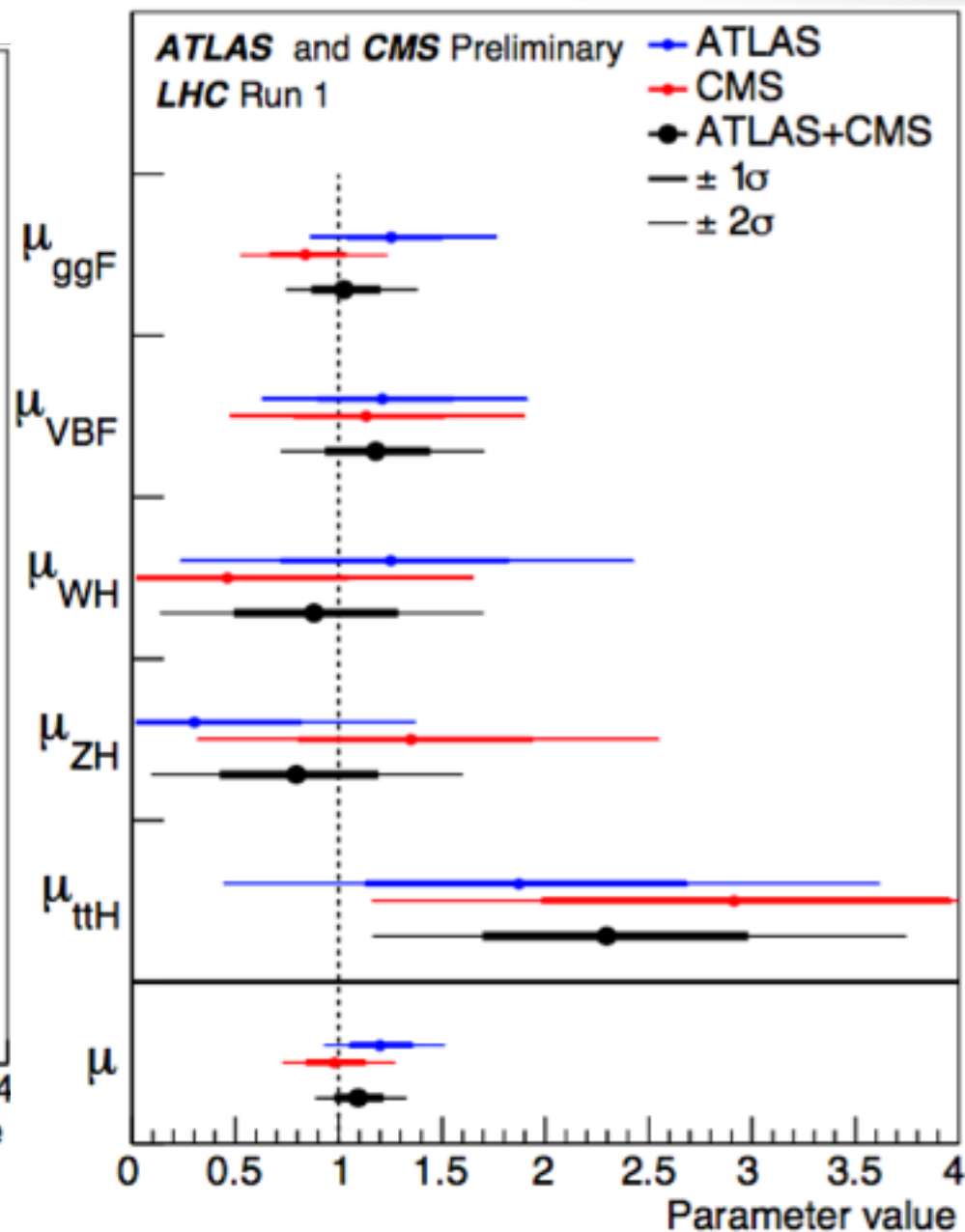
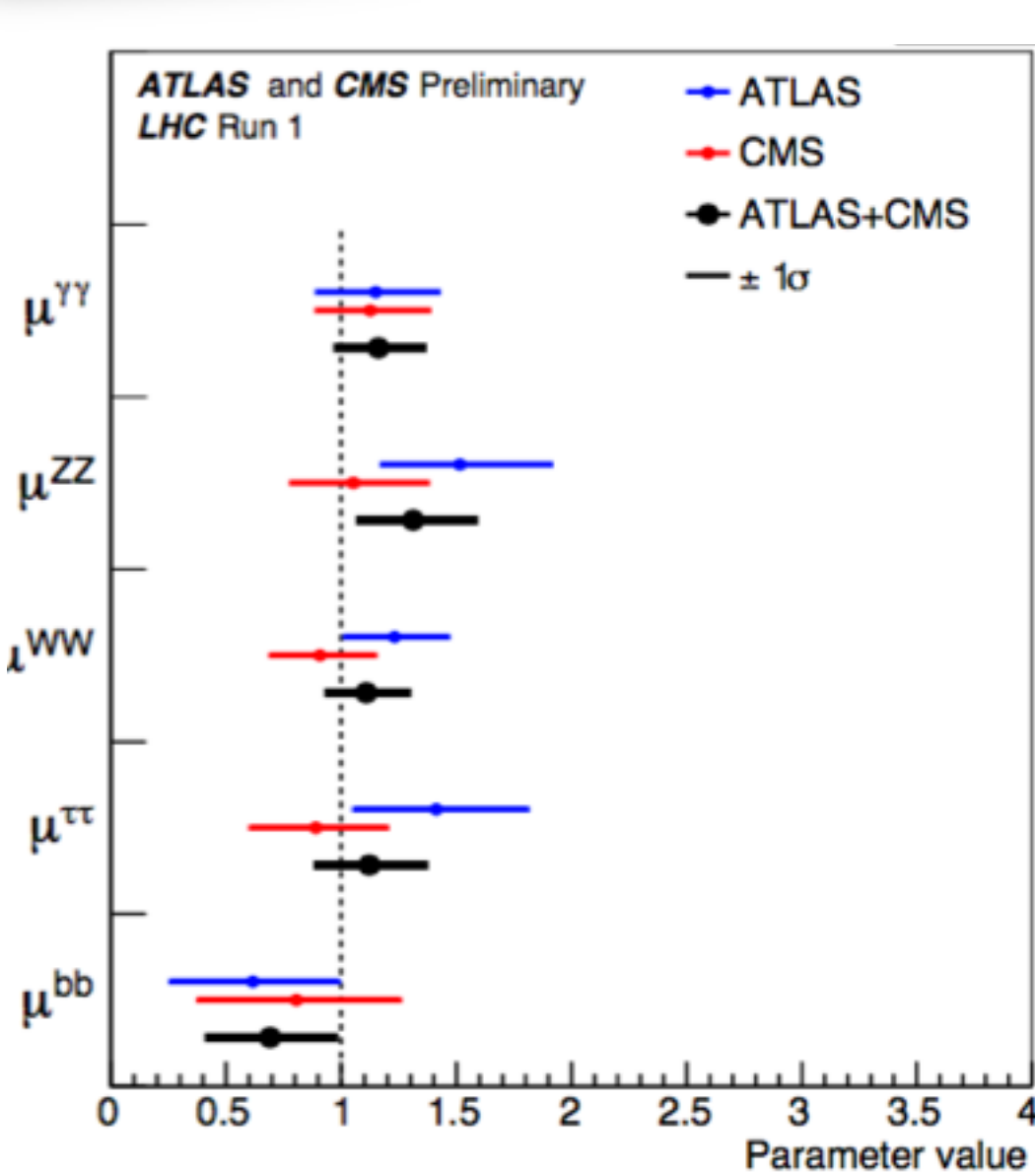
★ E' solo o ha dei partner?

chi è veramente il bosone di Higgs?

- ★ Il bosone di higgs è uno scalare fondamentale?
- ★ E' solo o ha dei partner?
- ★ Qual è il meccanismo che protegge la sua massa da grandi correzioni quantistiche?
- ★ non è elementare
- ★ esiste una simmetria che lo protegge (SUSY)

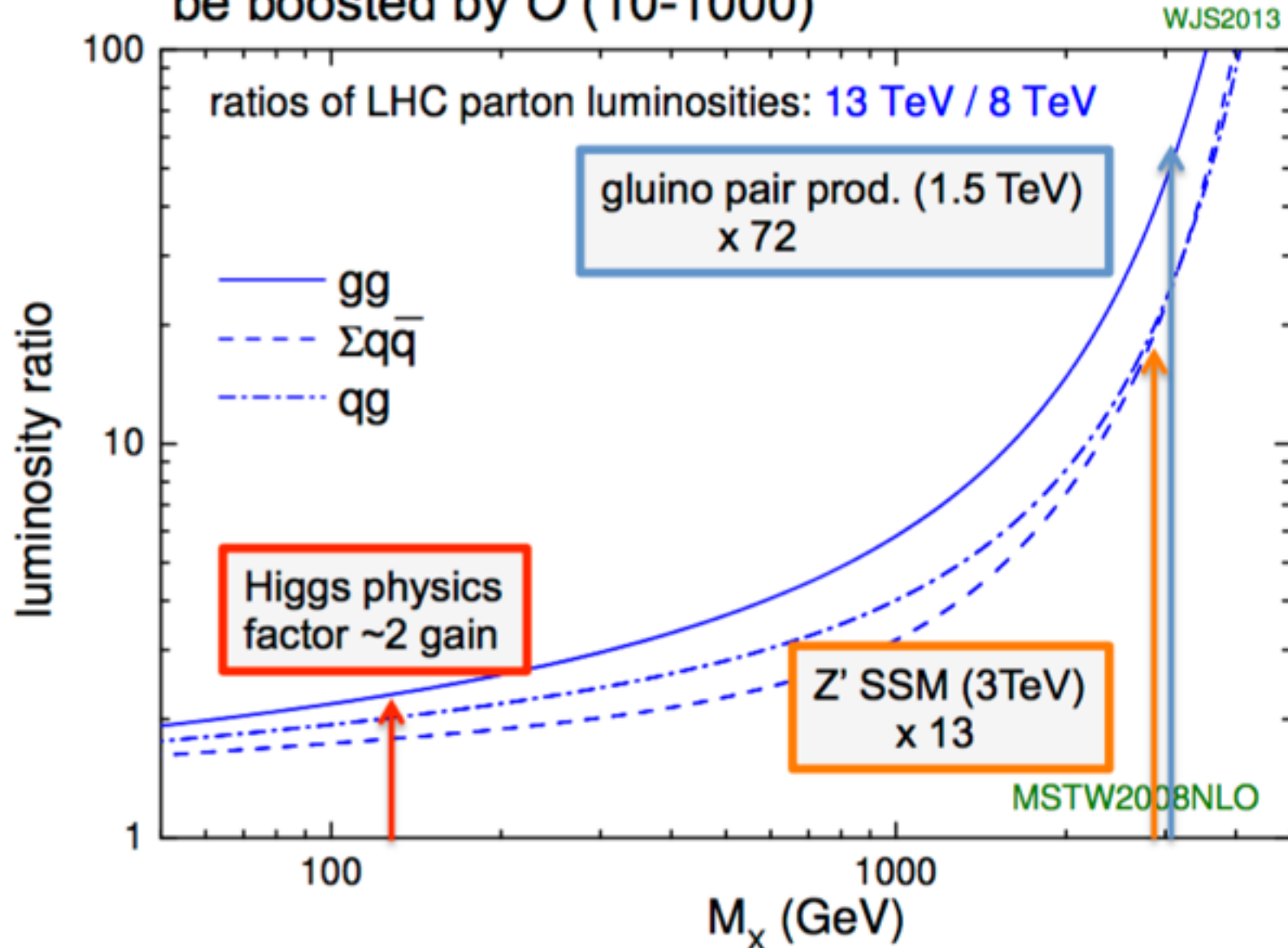


chi è veramente il bosone di Higgs?



ricerca di nuova fisica

Sensitivity for High scale BSM will be boosted by $O(10-1000)$



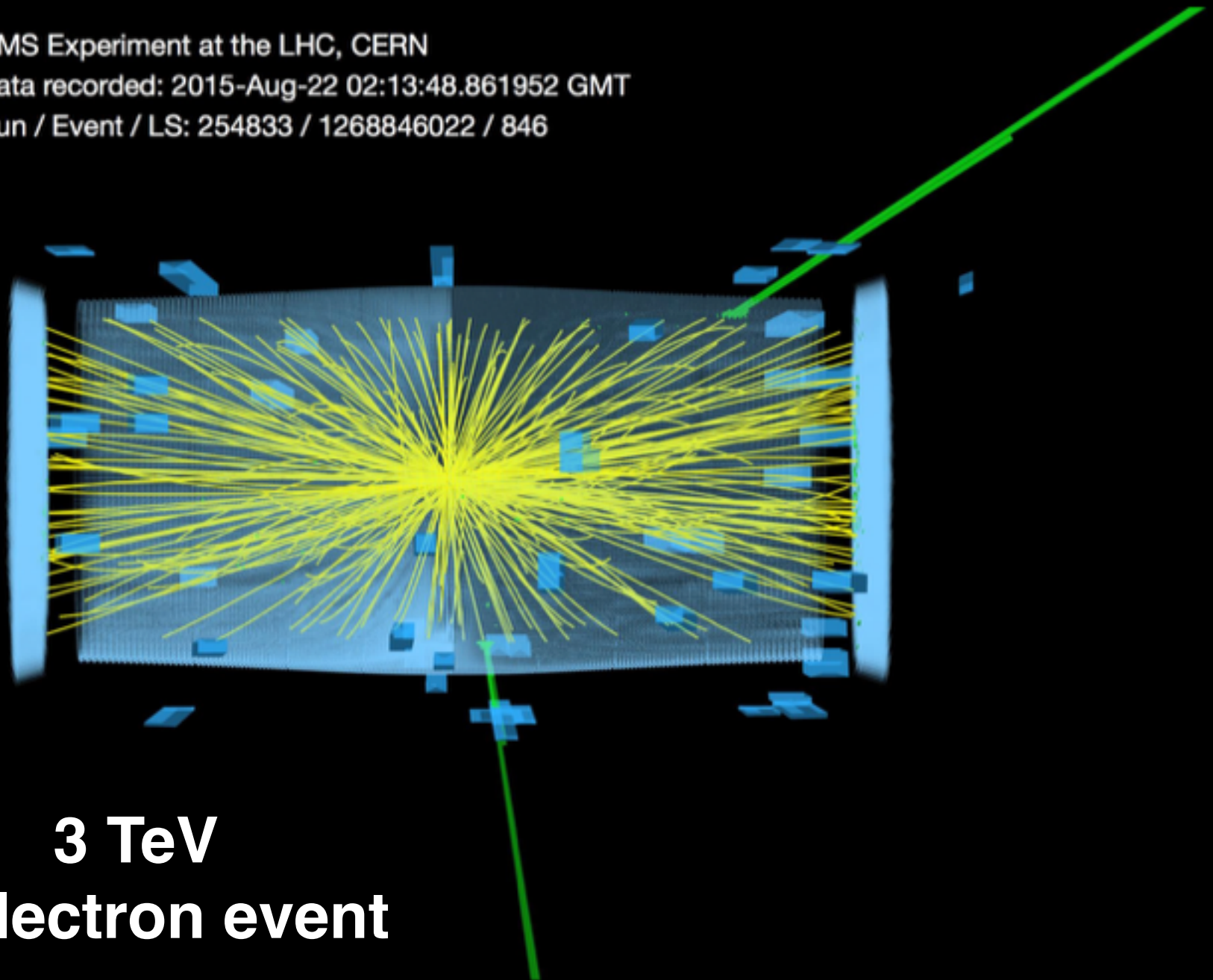
ricerca di nuova fisica



CMS Experiment at the LHC, CERN

Data recorded: 2015-Aug-22 02:13:48.861952 GMT

Run / Event / LS: 254833 / 1268846022 / 846



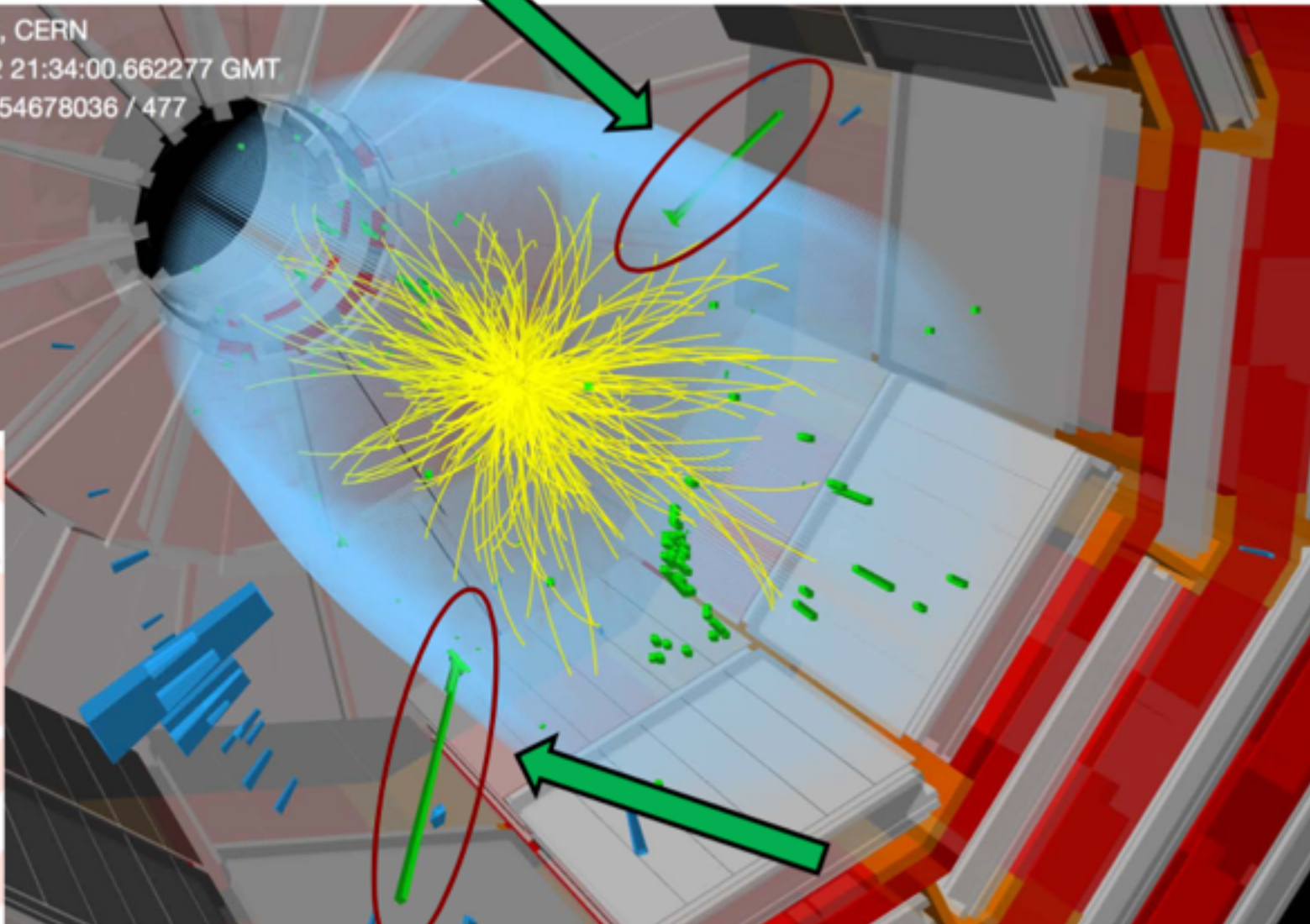
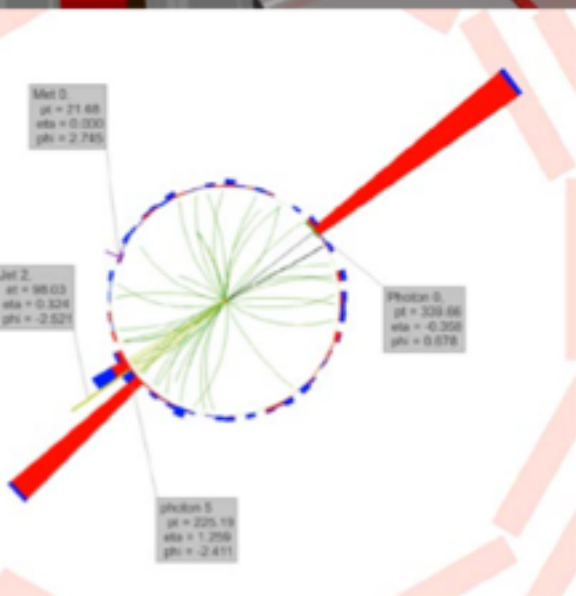
**3 TeV
di-electron event**

ricerca di nuova fisica

$m(\gamma\gamma) = 745 \text{ GeV}$

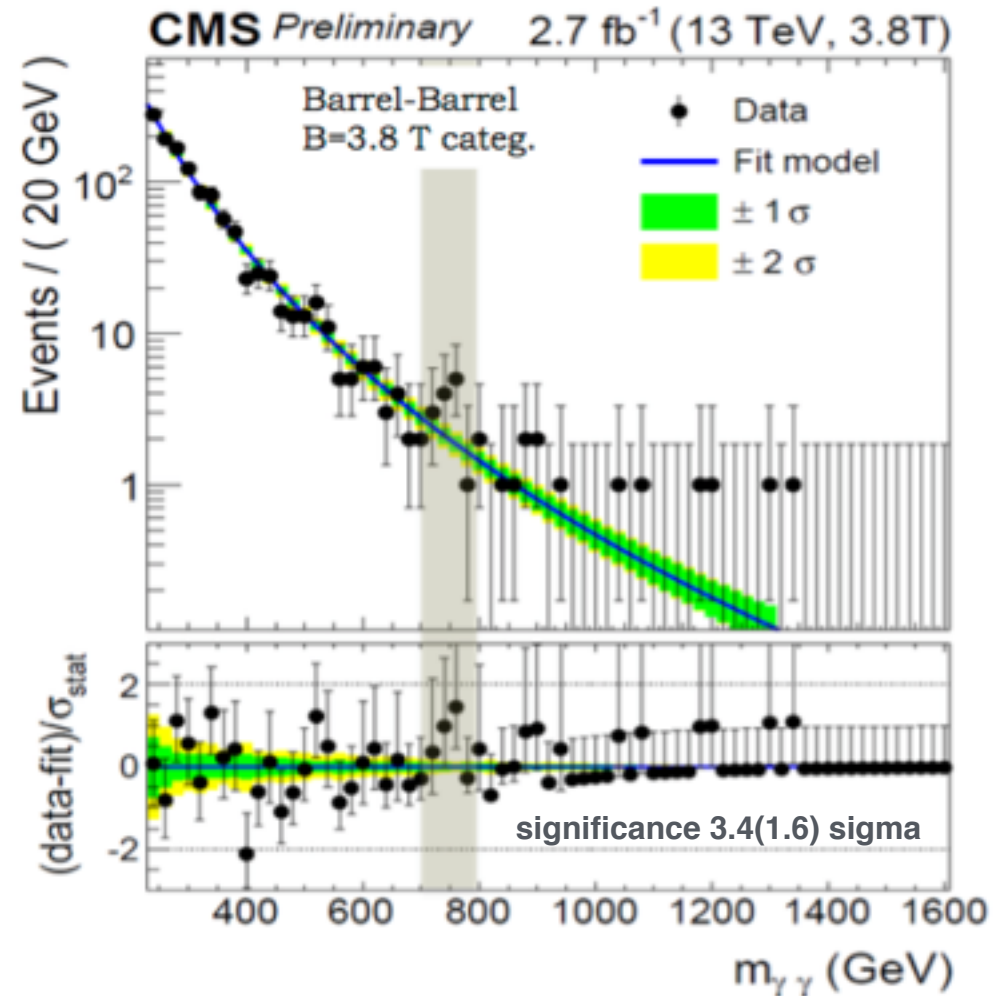
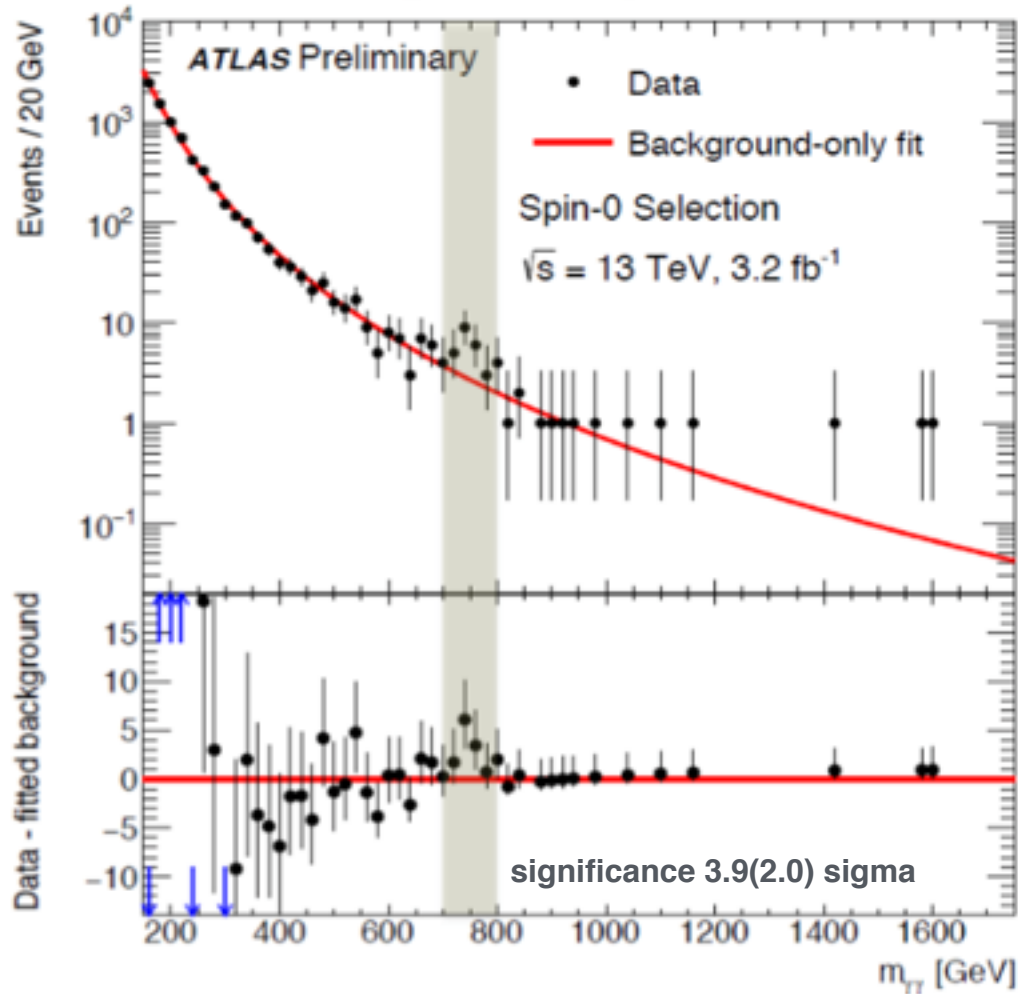


CMS Experiment at the LHC, CERN
Data recorded: 2015-Nov-02 21:34:00.662277 GMT
Run / Event / LS: 260627 / 854678036 / 477

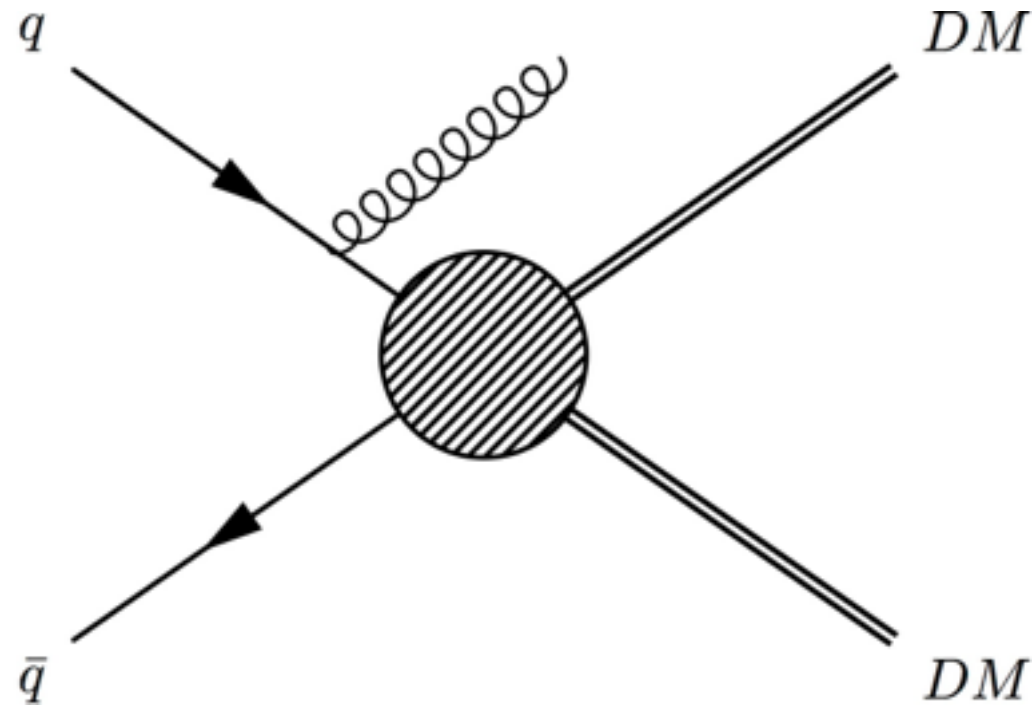


ricerca di nuova fisica

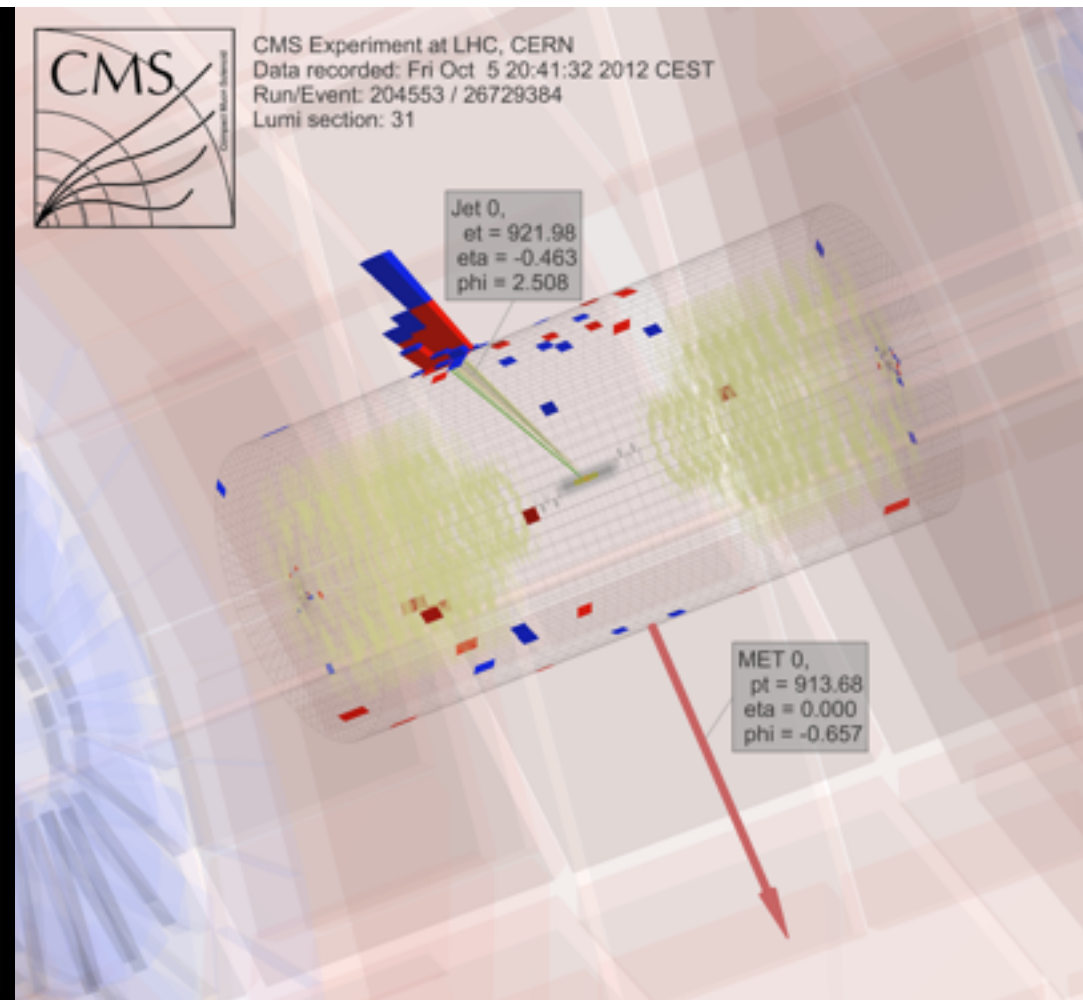
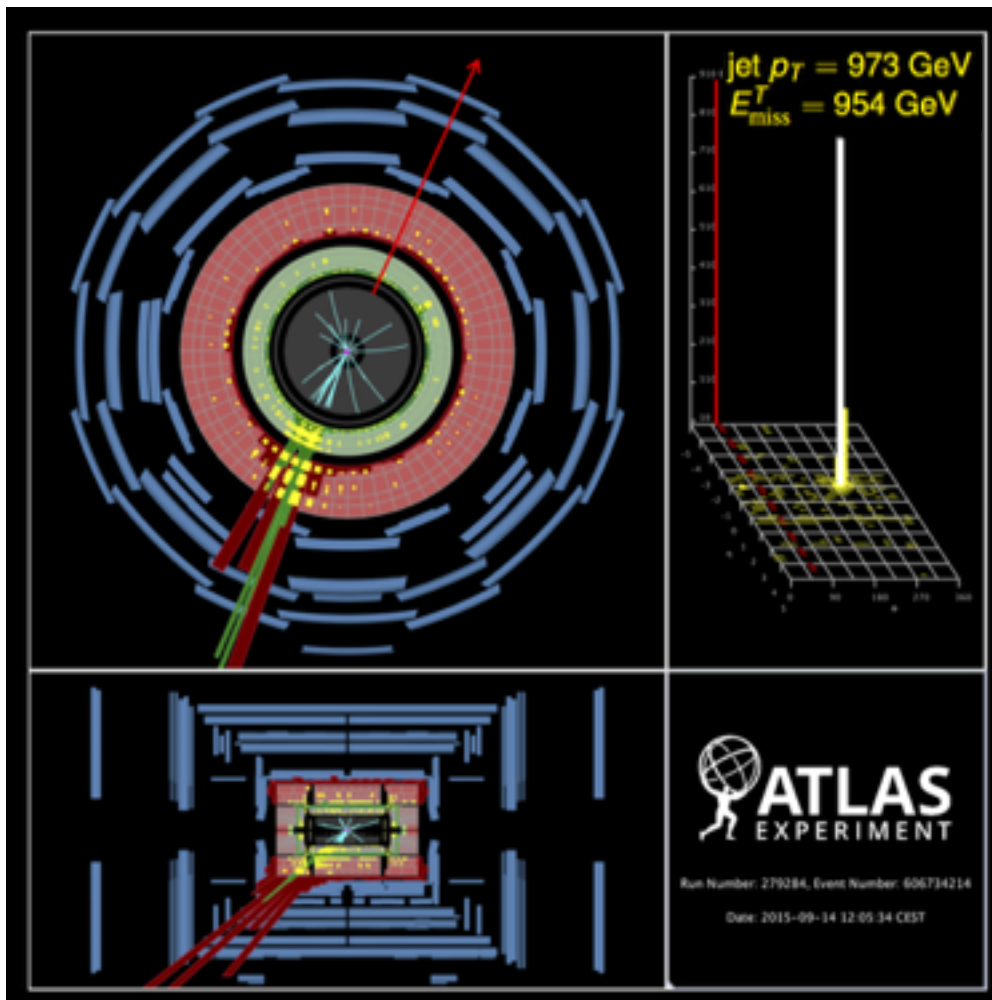
$m_{\gamma\gamma}$ distribution @ 13 TeV - Moriond updates



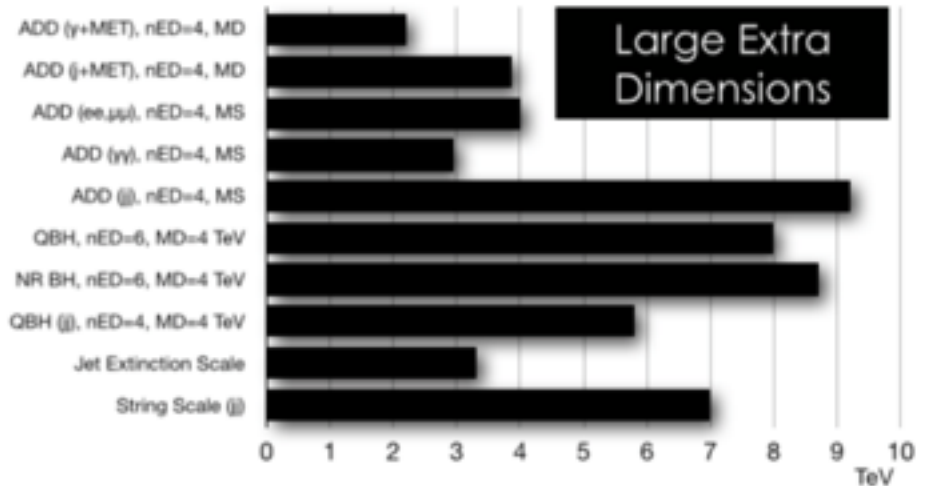
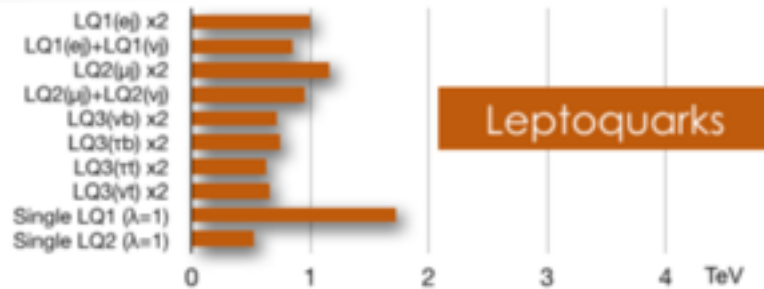
ricerca diretta della materia oscura



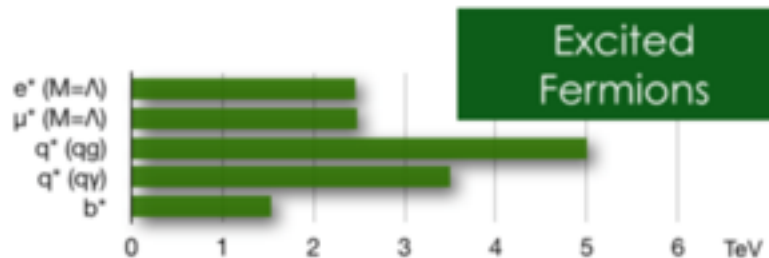
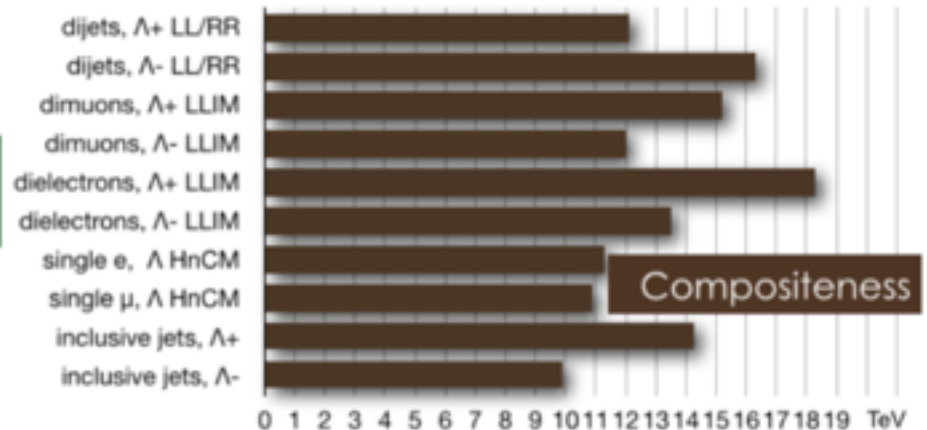
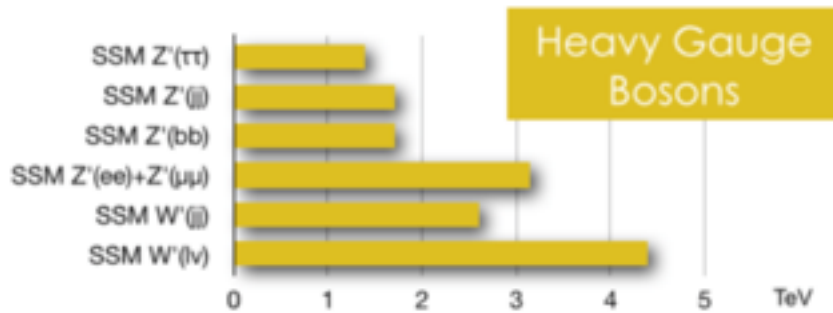
ricerca diretta della materia oscura



ricerche di particelle esotiche ($M \sim 1-10$ TeV)



CMS Preliminary



conclusioni

An iceberg floating in the ocean. The tip of the iceberg is visible above the water surface, while the much larger, submerged part is visible below. The water is a deep blue, and the sky is a lighter blue with some clouds. The iceberg is white and jagged.

**LHC sta esplorando la fisica
fondamentale alla frontiera
dell'energia prodotta in
laboratorio**

siamo nel pieno del RUN 2 di LHC

**tra oggi ed il 2018 ~ fattore 30 in
statistica rispetto al 2015**

**il programma di scoperta di fisica è
ricchissimo**

**la nuova fisica potrebbe essere
dietro l'angolo, e qualcuno di voi
potrebbe contribuire a scoprirla!**