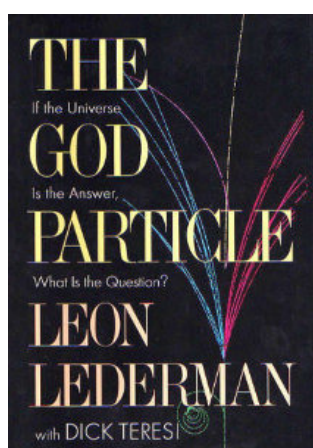
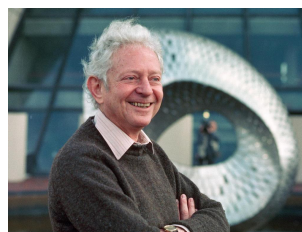




God(damn) – Leon Ledermann (1993)



- *The God Particle:*
- *If the Universe Is the Answer, What Is the Question?*



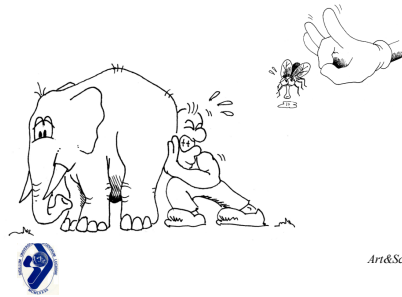
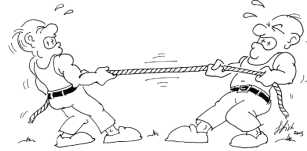
Premio Nobel 1988 per studi sui neutrini



Due concetti base

- Minore è la **massa** di un oggetto, più facile è cambiare il suo movimento.
- La materia interagisce attraverso le **interazioni** (forze).

$$\text{massa} = \frac{\text{forza}}{\text{accelerazione}} \quad (\vec{F} = m\vec{a})$$

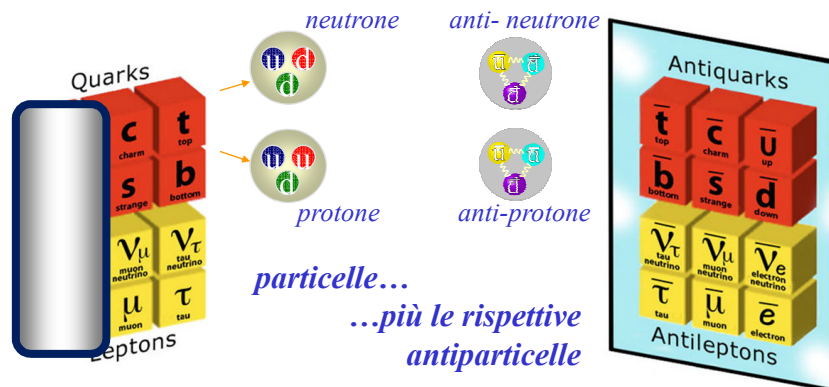
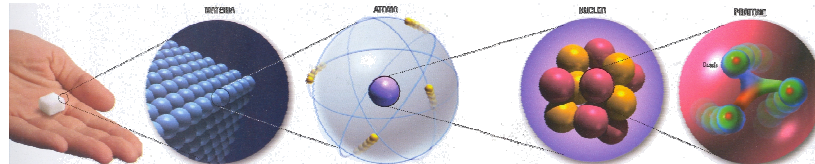


- Applicando una forza a un oggetto questo accelera.

Art&Science across Italy

4

Particelle elementari



Art&Science across Italy

5

Adroni

QUARK E ANTIQUARK FORMANO LE PARTICELLE COMPOSTE CHIAMATE:

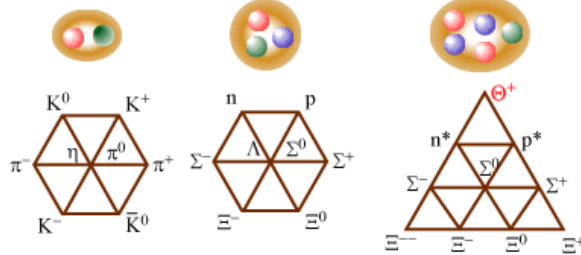
ADRONI

A seconda del numero di quark e antiquark che intervengono gli ADRONI si dividono in:

Meson

Baryon

Pentaquark

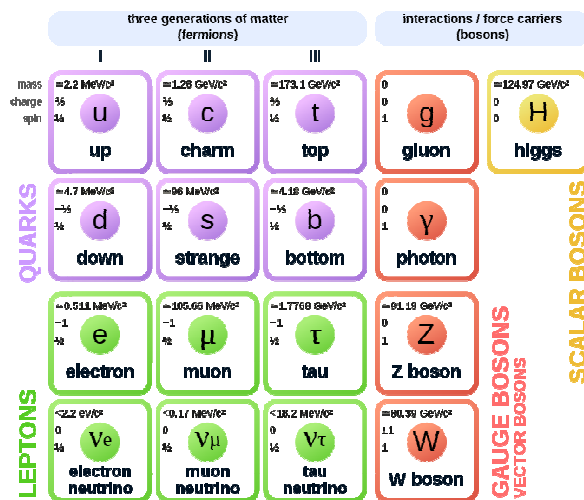


Art&Science across Italy

9

Il problema delle masse

Standard Model of Elementary Particles

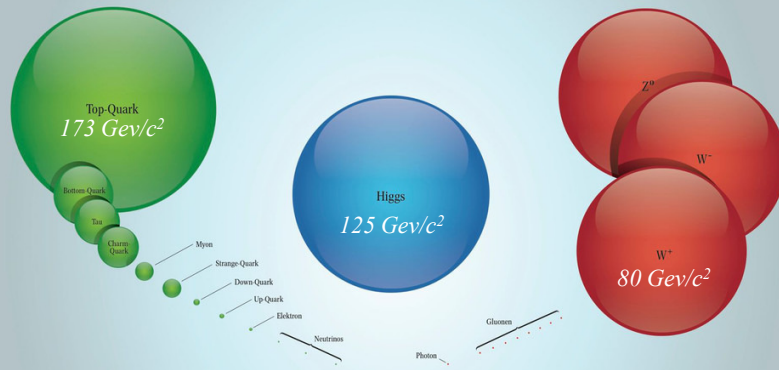


Art&Science across Italy

12

Il problema delle masse

Le particelle elementari hanno **masse molto diverse** tra di loro, anche se sono tutte “**puntiformi**”!



Art&Science across Italy

13

Da dove veniamo?



John Paul Gauguin - *Da dove veniamo? Che siamo? Dove andiamo?*
1897



Art&Science across Italy

14

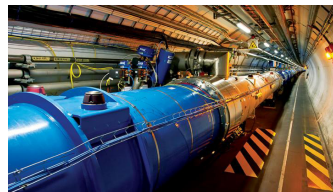
Due strade divergevano in un bosco

*Two roads diverged in a wood, and I
I took the one less traveled by,
And that has made all the difference.
[Robert Frost]*

Infinitamente grande
(osservazione a ritroso nel tempo)



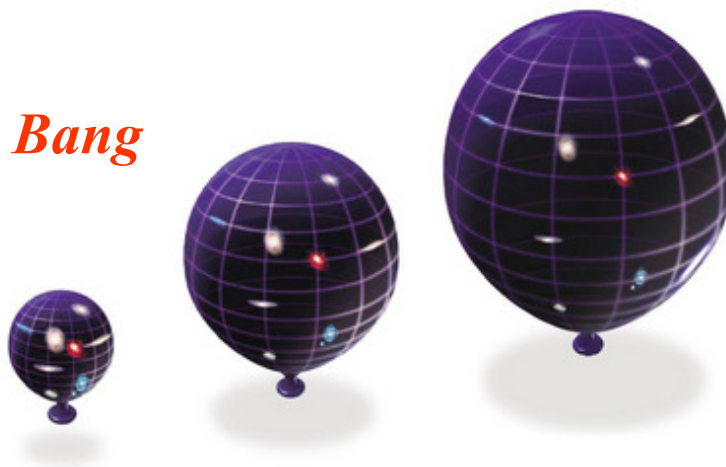
Infinitamente piccolo
(laboratorio sperimentale)



Art&Science across Italy

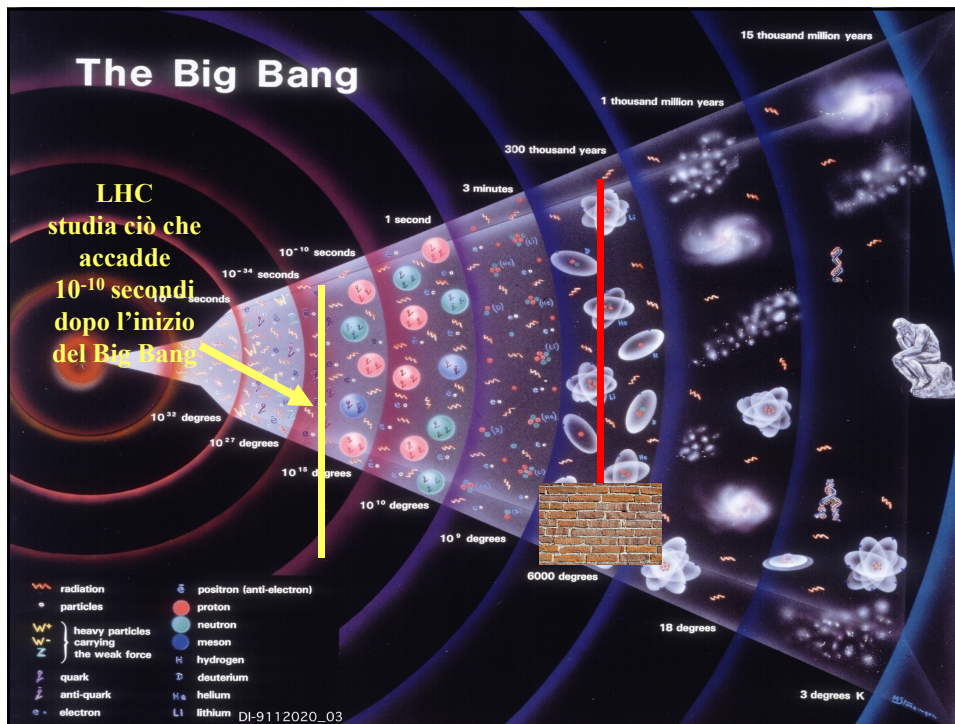
15

Big Bang



Art&Science across Italy

16



Il problema della massa

cos'è?

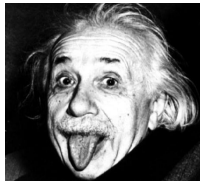


Cosa ricordate della massa



$$\vec{F}_{NET}(x, y, z) = m\vec{a}(x, y, z)$$

La scienza ha descritto (finora!)
come si comporta la massa (qual è il suo effetto)
 prima di capire il perché



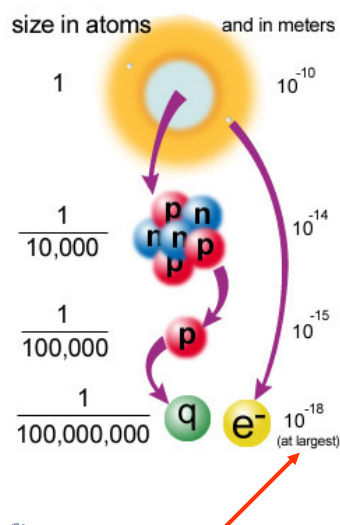
$$E = mc^2$$



Art&Science across Italy

22

La struttura e le dimensioni della materia



- Per quanto ne sappiamo sia gli *elettroni* che i *quarks* sono “puntiformi”

- Ma se sono puntiformi perché hanno una massa?*

- Non dobbiamo pensare come uomini...



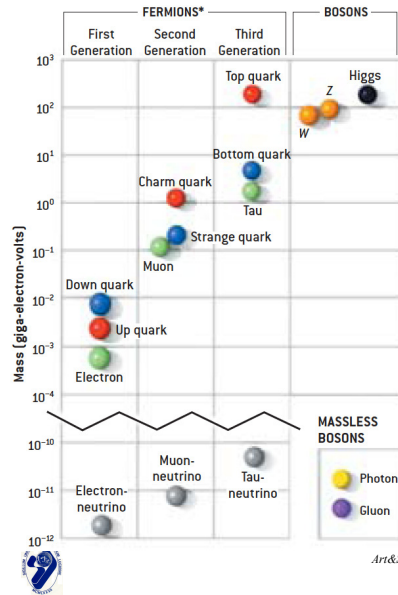
- In Meccanica Quantistica *non necessariamente* una massa corrisponde ad un concetto di dimensione.



Art&Science across Italy

23

La massa delle particelle ricopre 11 ordini di grandezza - Perché ?



• Perché la massa delle particelle elementari copre oltre 14 ordini di grandezza?

• Non c'è nessuna regolarità:

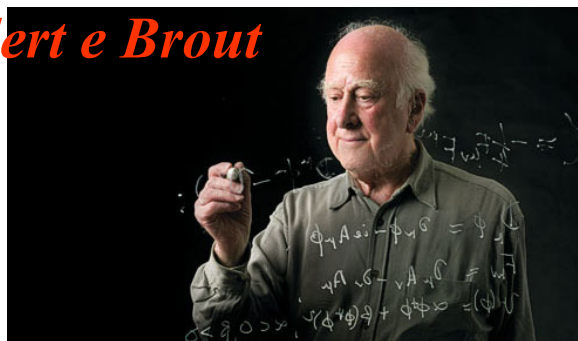
- I **neutrini** sono molto leggeri
- L'**elettone** è 350.000 volte più leggero del quark più pesante



- Il **fotone** è privo di massa
- ma bosoni **W** (80 GeV) e **Z** (91 GeV) pesano circa come un atomo di argento

24

Interviene il meccanismo di Higgs, Englert e Brout



Art&Science across Italy

25

Una sala piena di fisici che chiacchierano: lo spazio vuoto permeato dal campo di Higgs.



Uno scienziato famoso attraversa la stanza e suscita l'interesse e l'attenzione dei fisici presenti che si avvicinano.



*L'interazione aumenta la resistenza al suo moto,
quanto più il personaggio è famoso: acquisisce
"massa" come una particella nel campo di Higgs.*



Meccanismo di Higgs: le particelle acquistano massa

Anche un pettegolezzo può attraversare la sala.



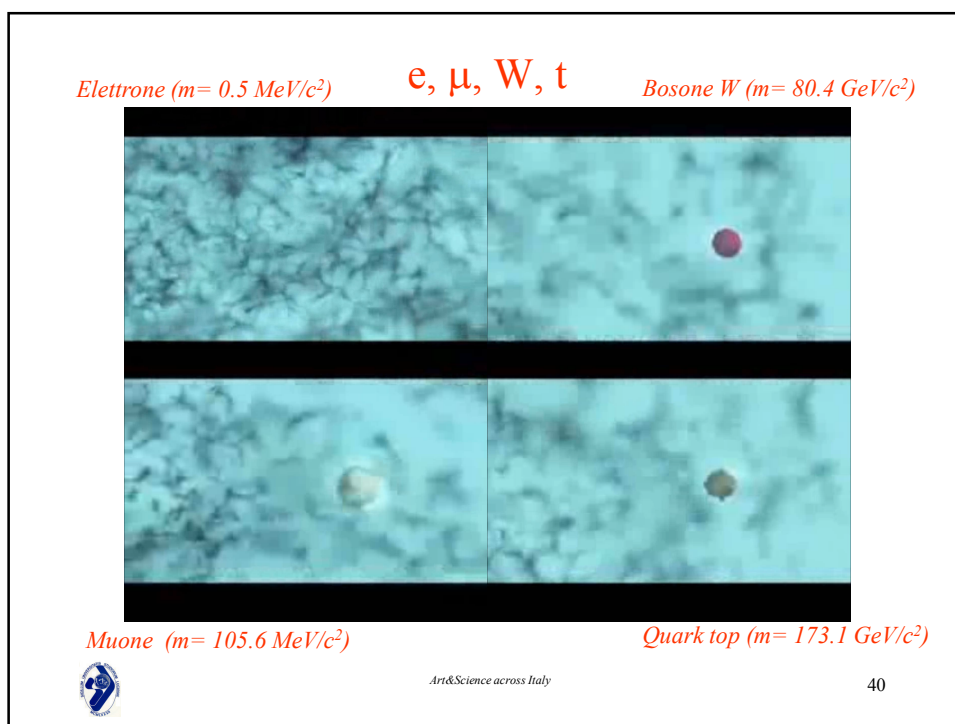


Foto con dedica ...



Art&Science across Italy

41

La caccia
cosa serve?



Art&Science across Italy

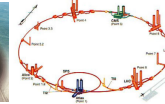
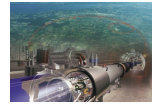
42

Si apre la caccia – Cosa serve



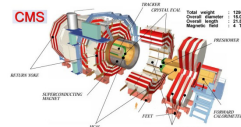
- **Acceleratore:**

- una macchina potente per accelerare i protoni e farli scontrare



- **Rivelatori :**

- Strumenti giganteschi che registrano le particelle prodotte quando emergono dal punto della collisione



- **Supercomputing :**

- Per raccogliere, conservare, distribuire ed analizzare l'enorme quantità di dati prodotti dai rivelatori



- **Scienza collaborativa su scala mondiale:**

- migliaia di scienziati ed ingegneri per progettare, costruire ed operare queste macchine molto complesse

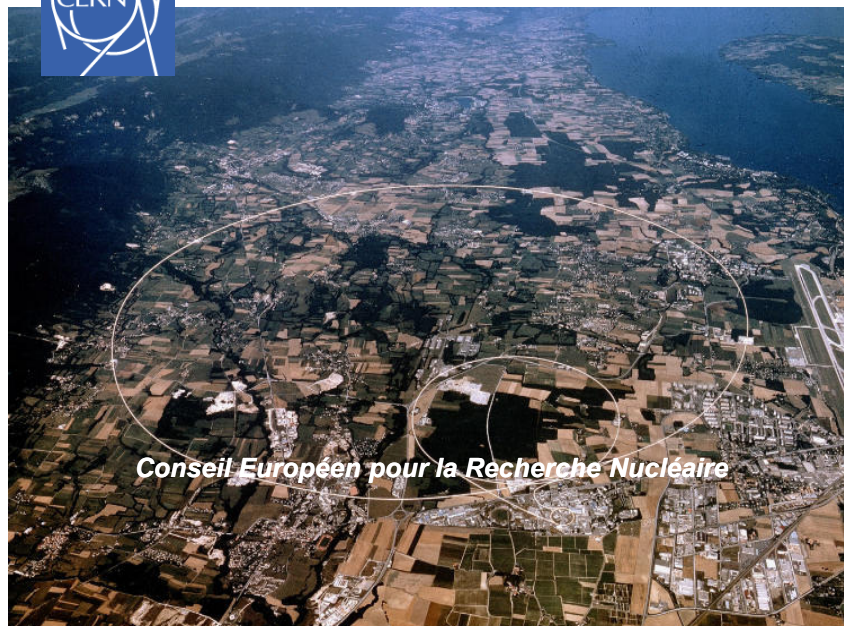


Art&Science across Italy

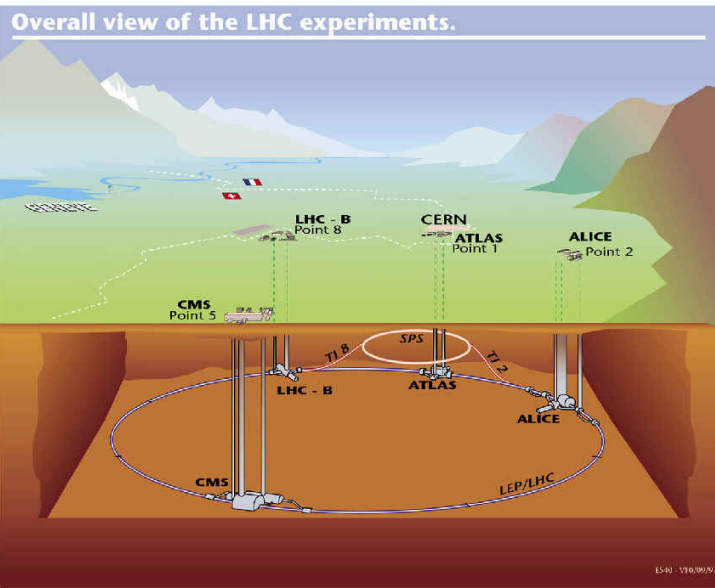
43



Il sito del CERN

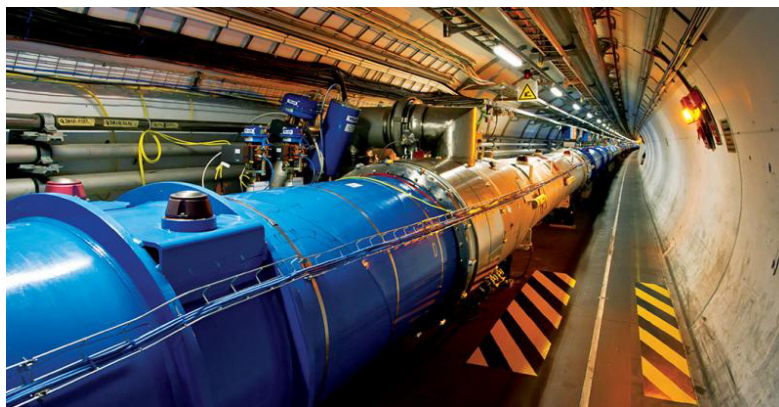


Spaccato del sottosuolo franco-svizzero



5

LHC



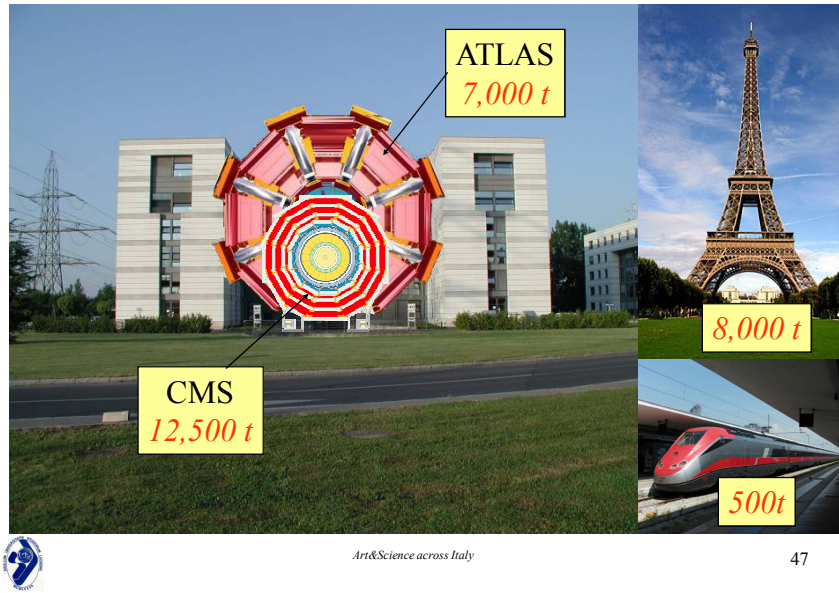
27 km di circonferenza (38,000 tonnellate)
Oltre duemila magneti superconduttori



Art&Science across Italy

46

Due rivelatori giganti

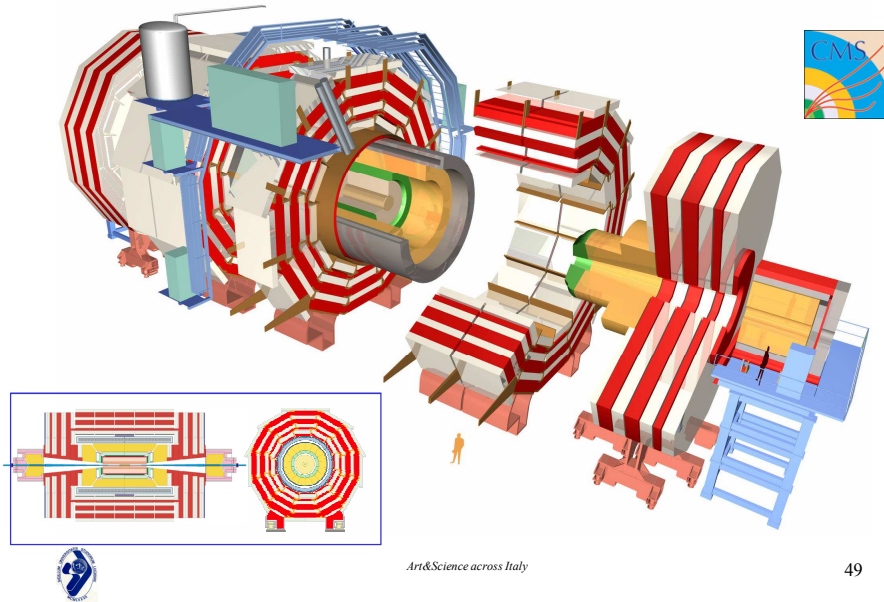


Numerologia “spicciola” di LHC

- Ogni protone effettuerà ogni secondo, ben 11.000 giri completi dell'anello di
27 chilometri
- I fasci di protoni si incrociano
40 milioni di volte al secondo.
- Numero di collisioni a regime: fino a 25 collisioni tra protoni ogni 25 nanosecondi (miliardesimi di secondo), cioè circa
1 miliardo di collisioni al secondo.



L'apparato sperimentale CMS



Raccolta dati

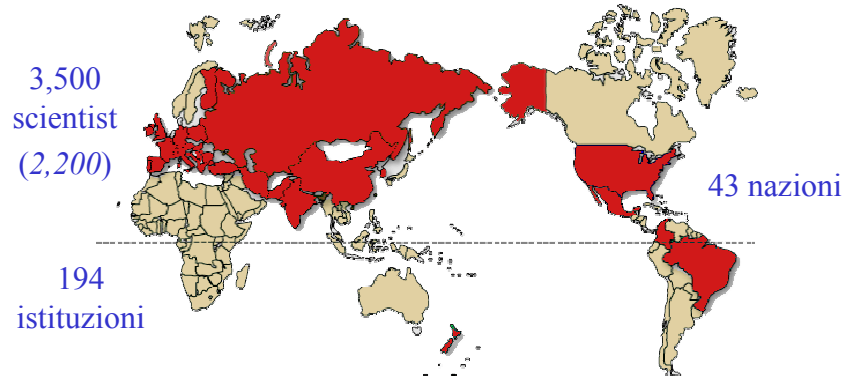
- Apparato sperimentale
 - **100 milioni** di canali di acquisizione dati
 - **40 milioni** di foto al secondo (25 soggetti/immagine)
 - In pochi secondi se le guarda e seleziona le **500** dove i protoni sorridono (...non sempre):
- GRID di computer (worldwide)
 - **500,000** computer in rete
 - **170** centri di calcolo
 - **42** paesi
- Traffico DATI
 - circa 500 Gbit/sec, pari al traffico mondiale istantaneo di telefonia



Art&Science across Italy

50

La Comunità di CMS



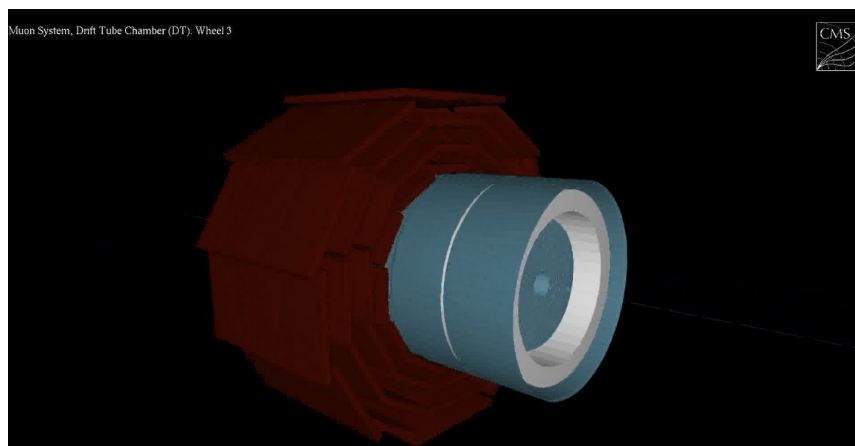
- È l'unico posto al mondo dove riescono a lavorare assieme:
 - Pakistani ed Indiani
 - Americani ed Iraniani
 - Palestinesi ed Israeliani
 - *Italiani ed ...Italiani*



Art&Science across Italy

51

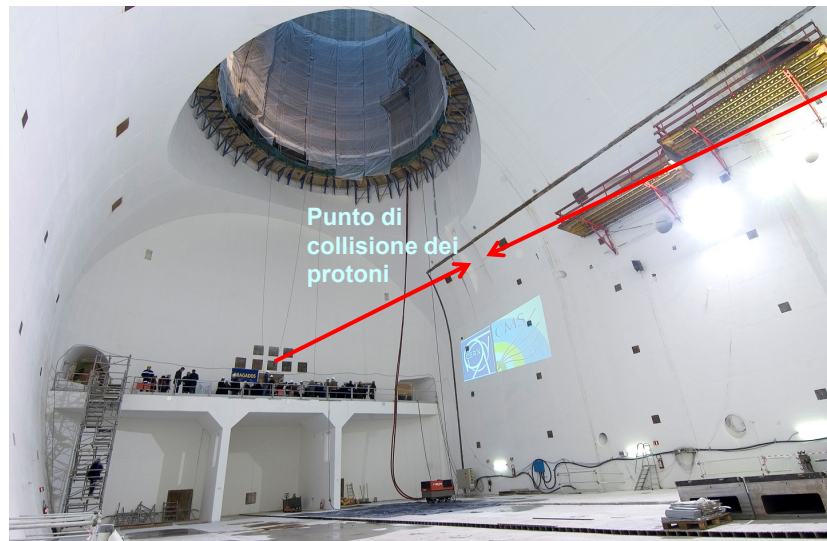
Struttura rivelatori di CMS



Art&Science across Italy

52

CMS – Compact Muon Solenoid



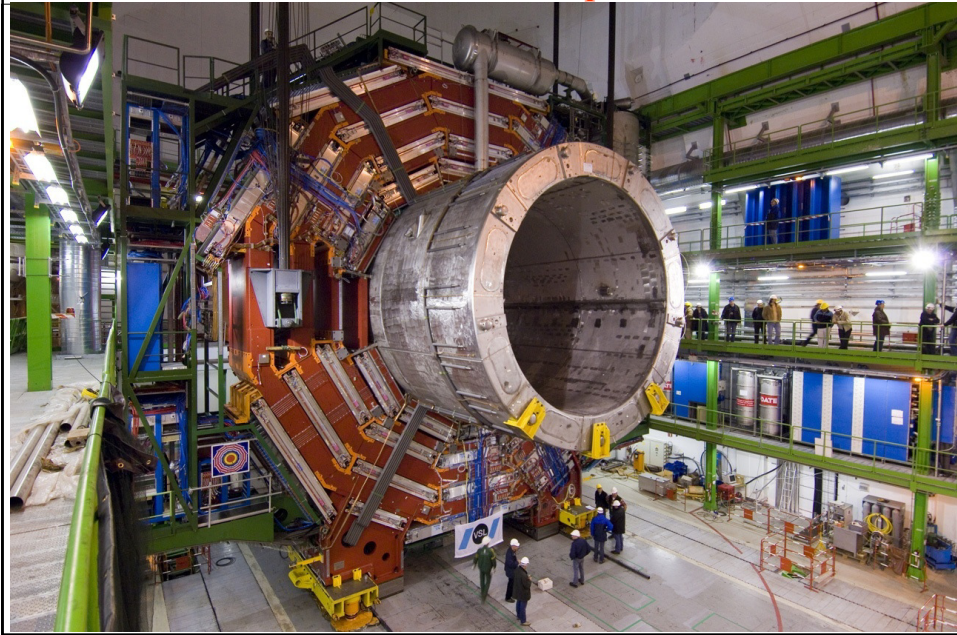
Art&Science across Italy

54

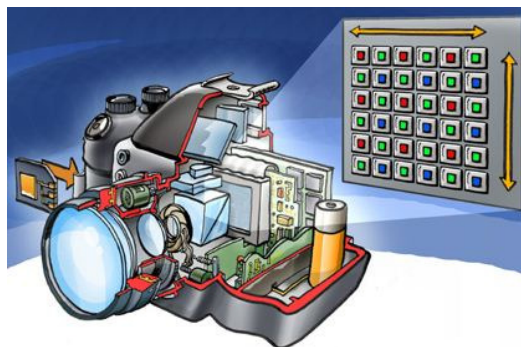
CMS: discesa nel pozzo



CMS: discesa nel pozzo



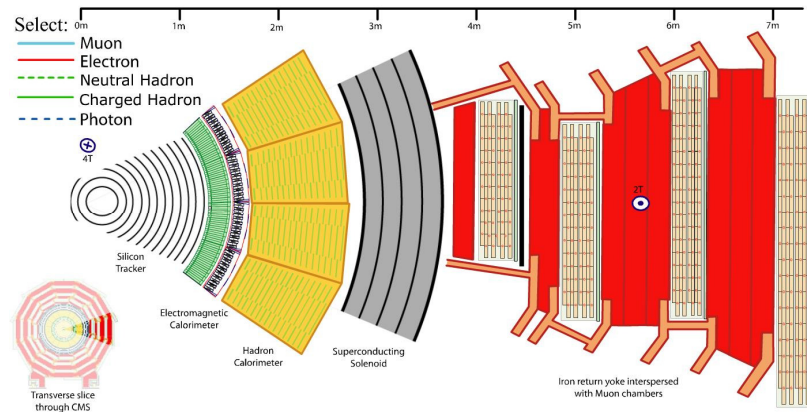
Rivelare



Art&Science across Italy

57

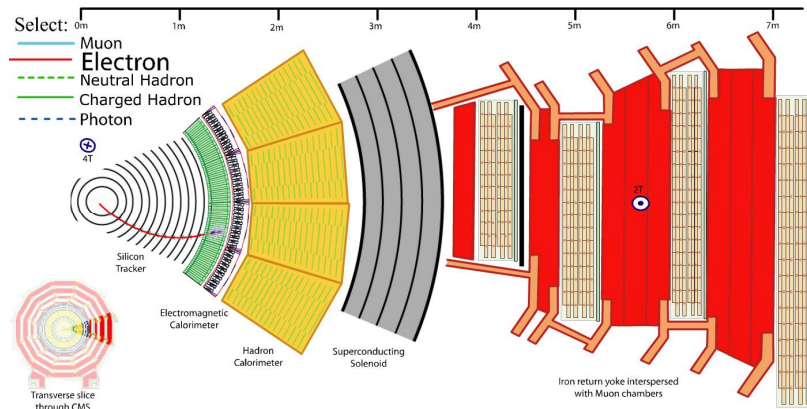
Rivelazione delle particelle in CMS



Art&Science across Italy

59

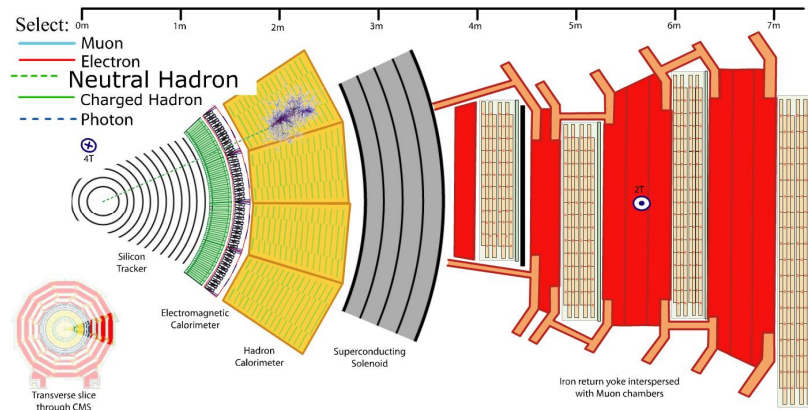
Rivelazione delle particelle in CMS: elettrone



Art&Science across Italy

60

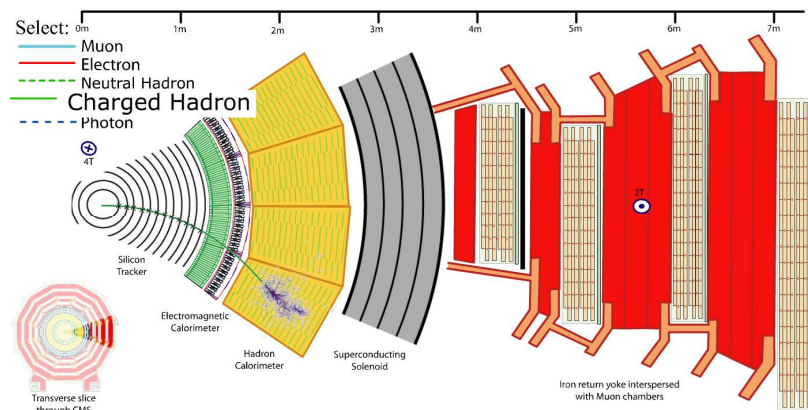
Rivelazione delle particelle in CMS: adrone neutro



Art&Science across Italy

61

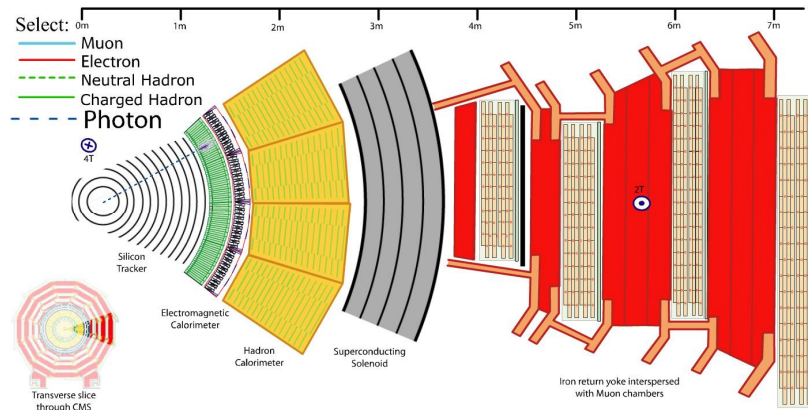
Rivelazione delle particelle in CMS: adrone carico



Art&Science across Italy

62

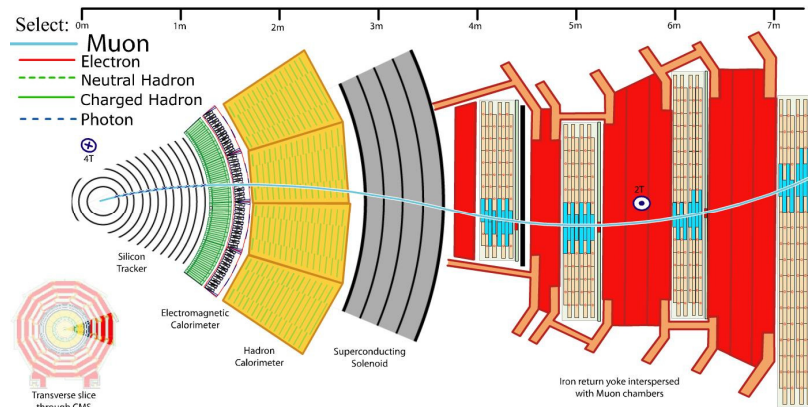
Rivelazione delle particelle in CMS: fotone



Art&Science across Italy

63

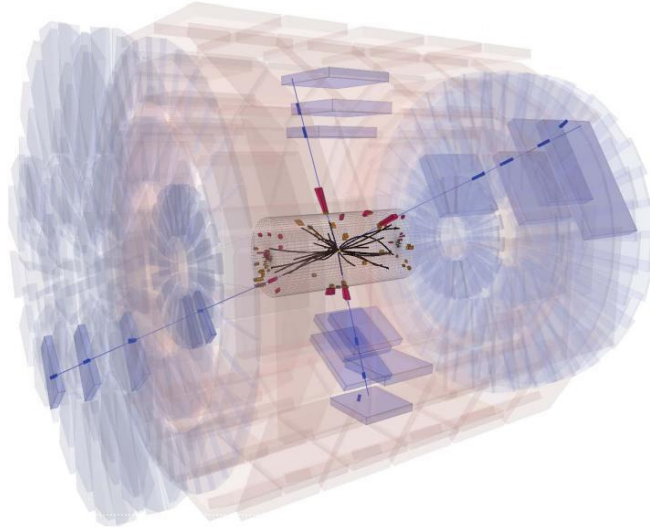
Rivelazione delle particelle in CMS: muone



Art&Science across Italy

64

2011.09.24 - Primo evento $pp \rightarrow \mu\mu\mu\mu$



Art&Science across Italy

65

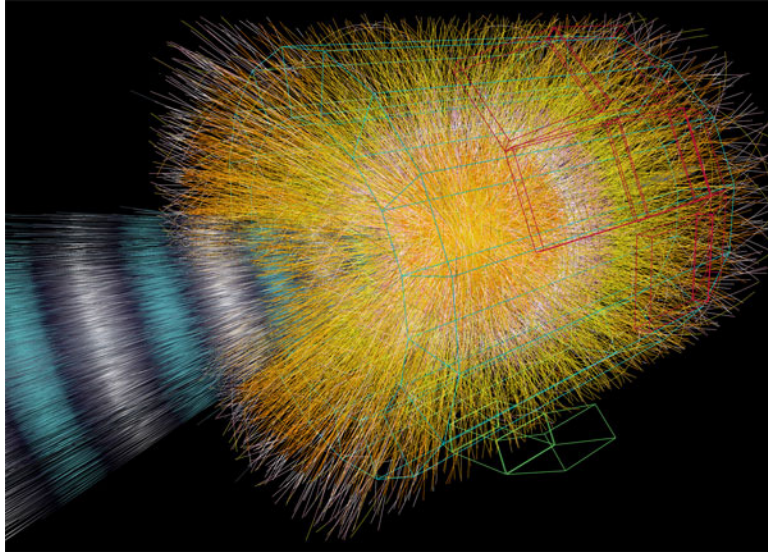
*L'ago nei ...
nei pagliai*



Art&Science across Italy

66

Pile up



Art&Science across Italy

67

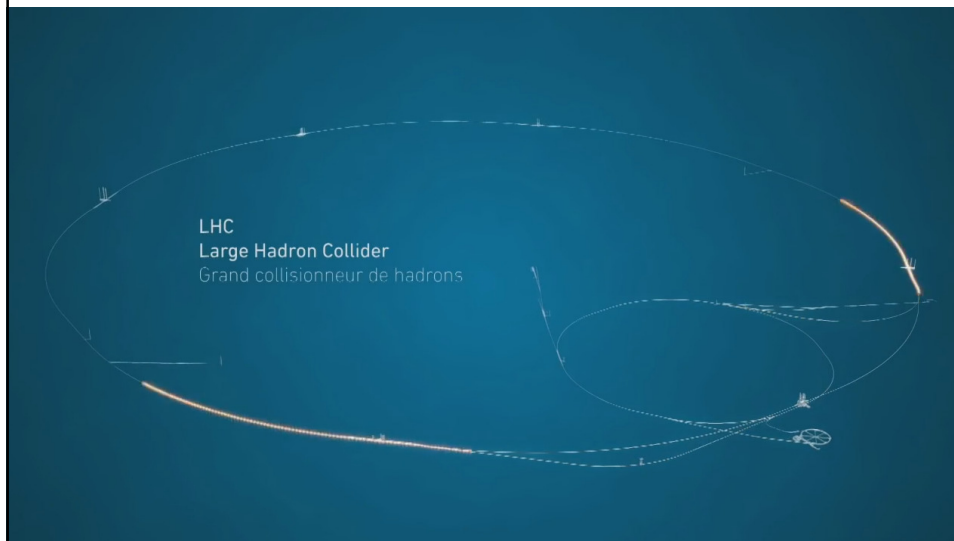
Eventi



Art&Science across Italy

68

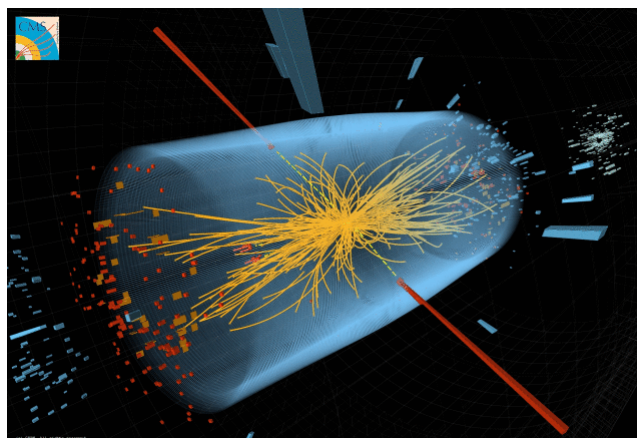
Acceleratore + Rivelatore



Art&Science across Italy

69

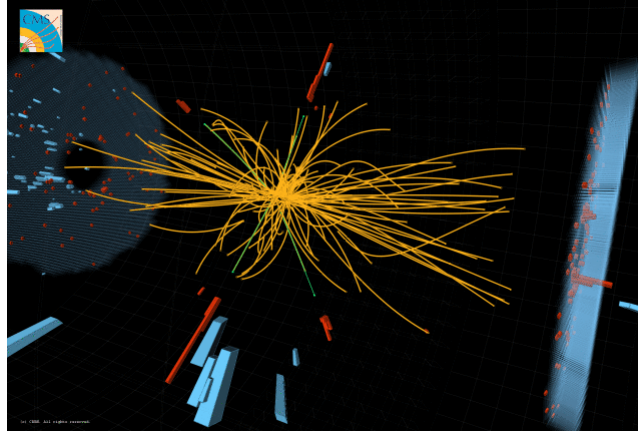
$H \rightarrow \gamma\gamma$ (real)



Art&Science across Italy

70

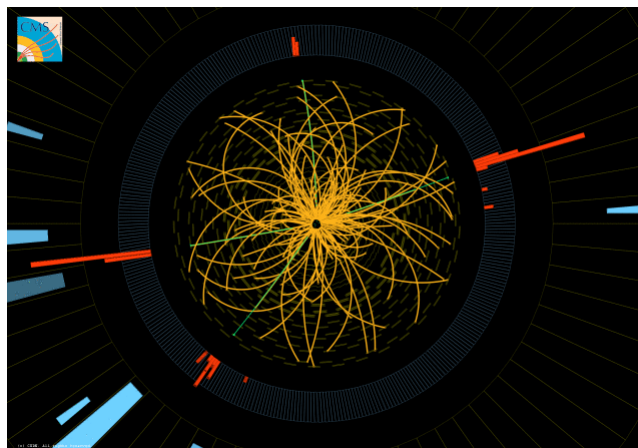
$H \rightarrow eeee$ (real)



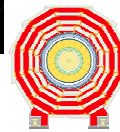
Art&Science across Italy

71

$H \rightarrow eeee$ (real)

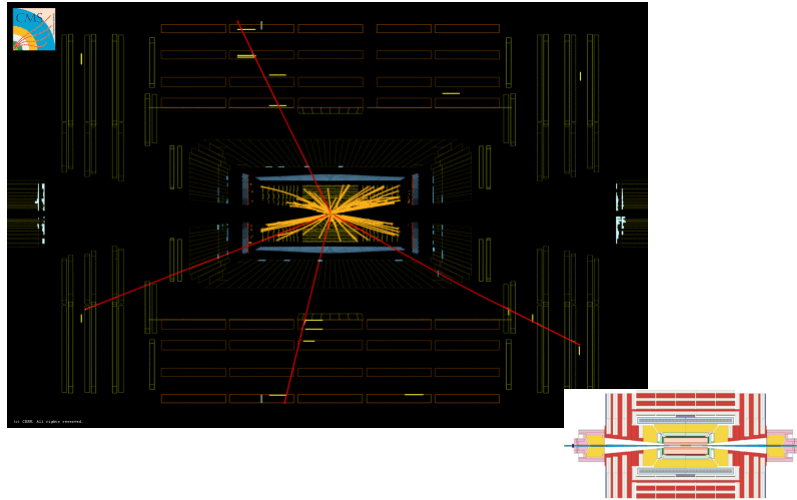


Art&Science across Italy



72

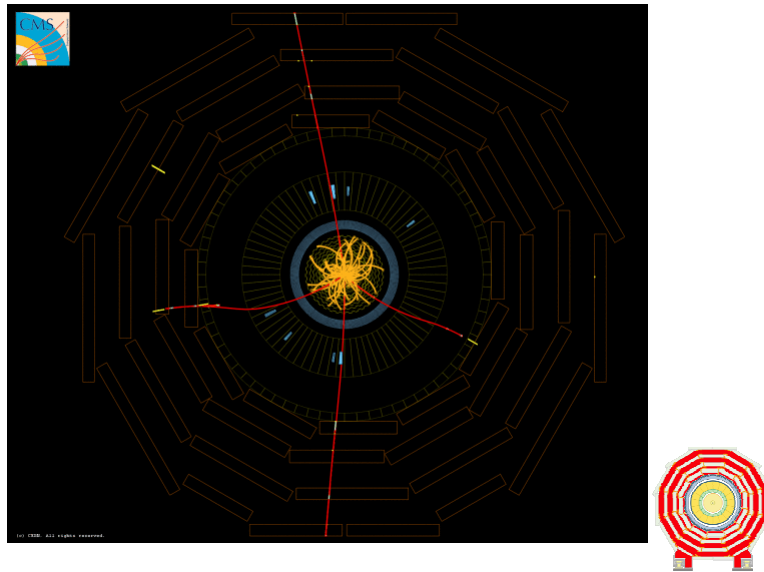
$H \rightarrow \mu\mu\mu\mu$ (real)



Art&Science across Italy

73

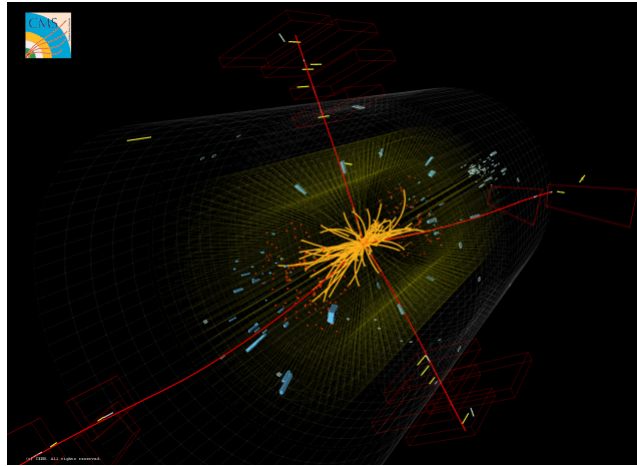
$H \rightarrow \gamma\gamma \mu\mu\mu\mu$ (real)



Art&Science across Italy

74

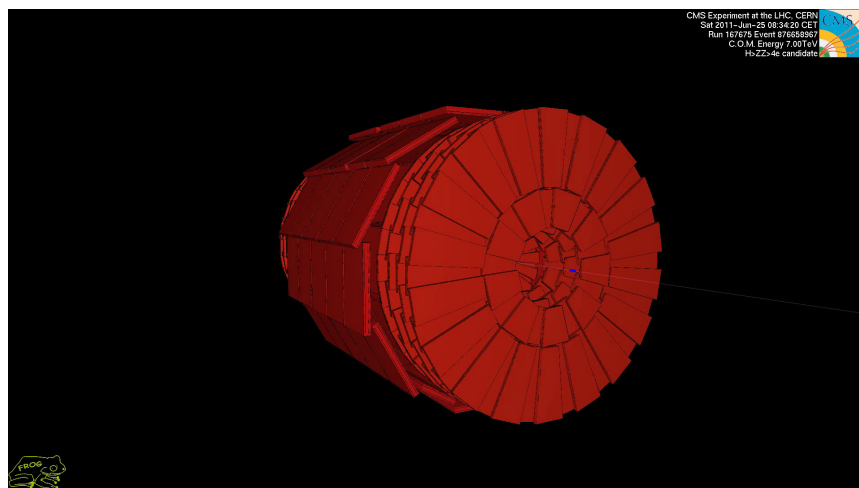
$H \rightarrow \mu\mu\mu\mu$ (real)



Art&Science across Italy

75

Candidato $H \rightarrow Z \rightarrow eeee$



Art&Science across Italy

76

We got it!



"I think I've found the Higgs boson!"



Art&Science across Italy

77

2012.07.04 – Independence Day

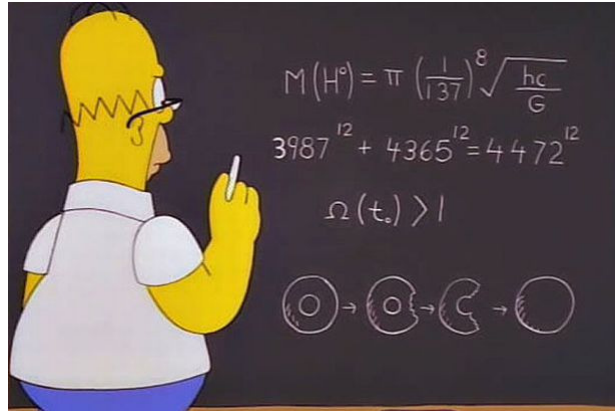


Art&Science across Italy

78

Chi ha veramente scoperto il bosone di Higgs

- Homer Simpson

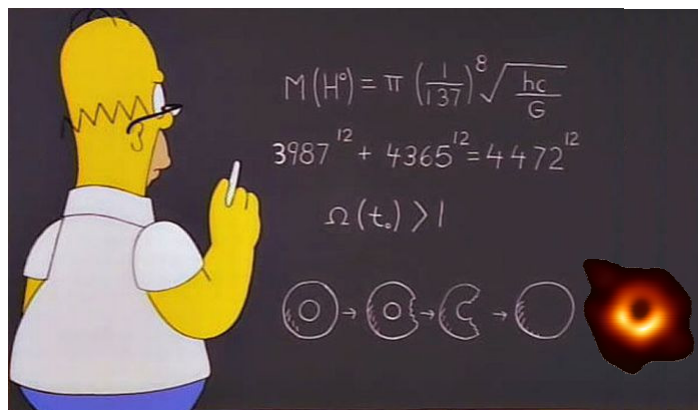


Art&Science across Italy

79

Chi ha veramente modellizzato il buco nero

- Homer Simpson



Art&Science across Italy

80

The 2013 Nobel Prize in Physics



The Nobel Prize in Physics 2013

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

François Englert
Université Libre de Bruxelles, Brussels, Belgium

Peter W. Higgs
University of Edinburgh, UK

"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"

Here, at last!

François Englert and Peter W. Higgs are jointly awarded the Nobel Prize in Physics 2013 for the theory of how particles acquire mass. In 1964, they proposed the theory independently of each other. Englert together with his now deceased colleague Robert Brout, in 1964, their ideas were confirmed by the discovery of a so-called Higgs particle at CERN's laboratory outside Geneva in 2012.

Hadron Collider, is probably the largest and the most complex machine ever constructed by humans. Two research groups of some 3,000 scientists each, ATLAS and CMS, managed to smash the Higgs particle from billions of particle collisions in the LHC.

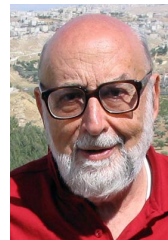
Even though it is a great achievement to have found the Higgs particle – the missing piece in the Standard Model puzzle – the Standard Model is not the final piece in the cosmic puzzle. One of the reasons for this is that the Standard Model cannot explain, for example, why matter is more abundant than antimatter, or how recent

"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"

Peter W. Higgs



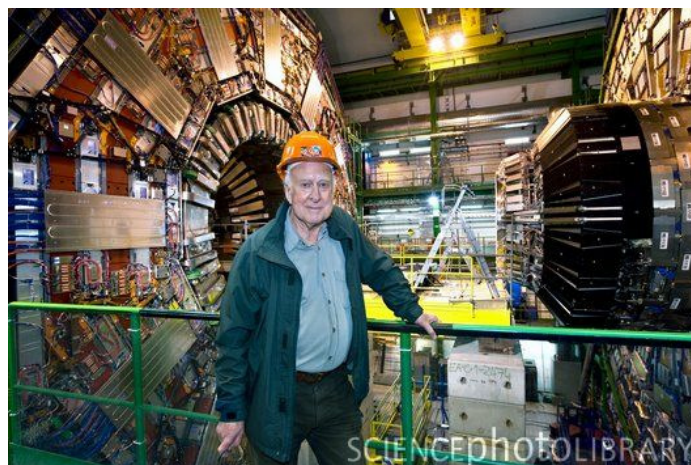
François Englert



Art&Science across Italy

81

Peter Higgs in visita a CMS



Art&Science across Italy

82