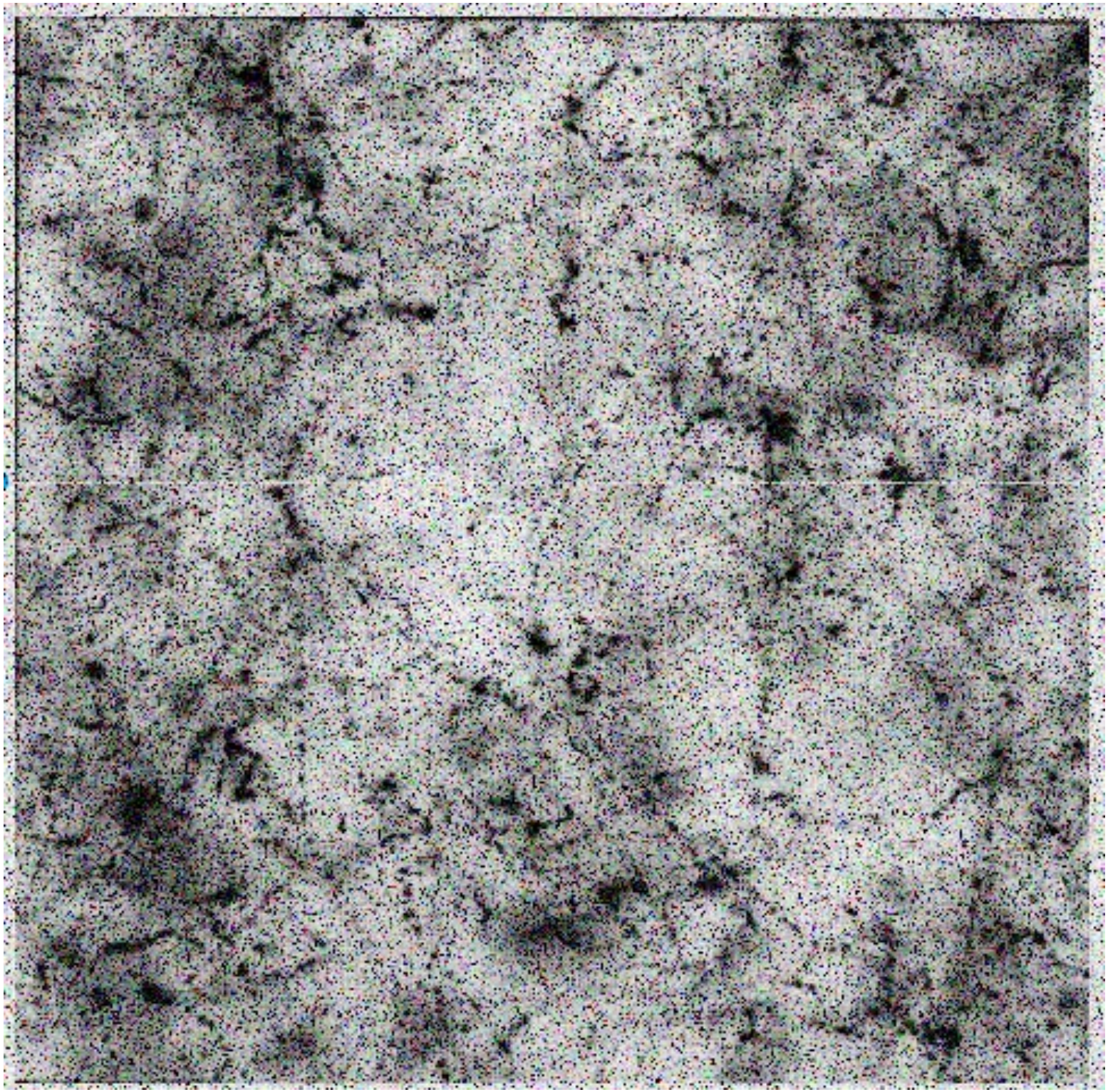
Uno sguardo all'infinitamente piccolo

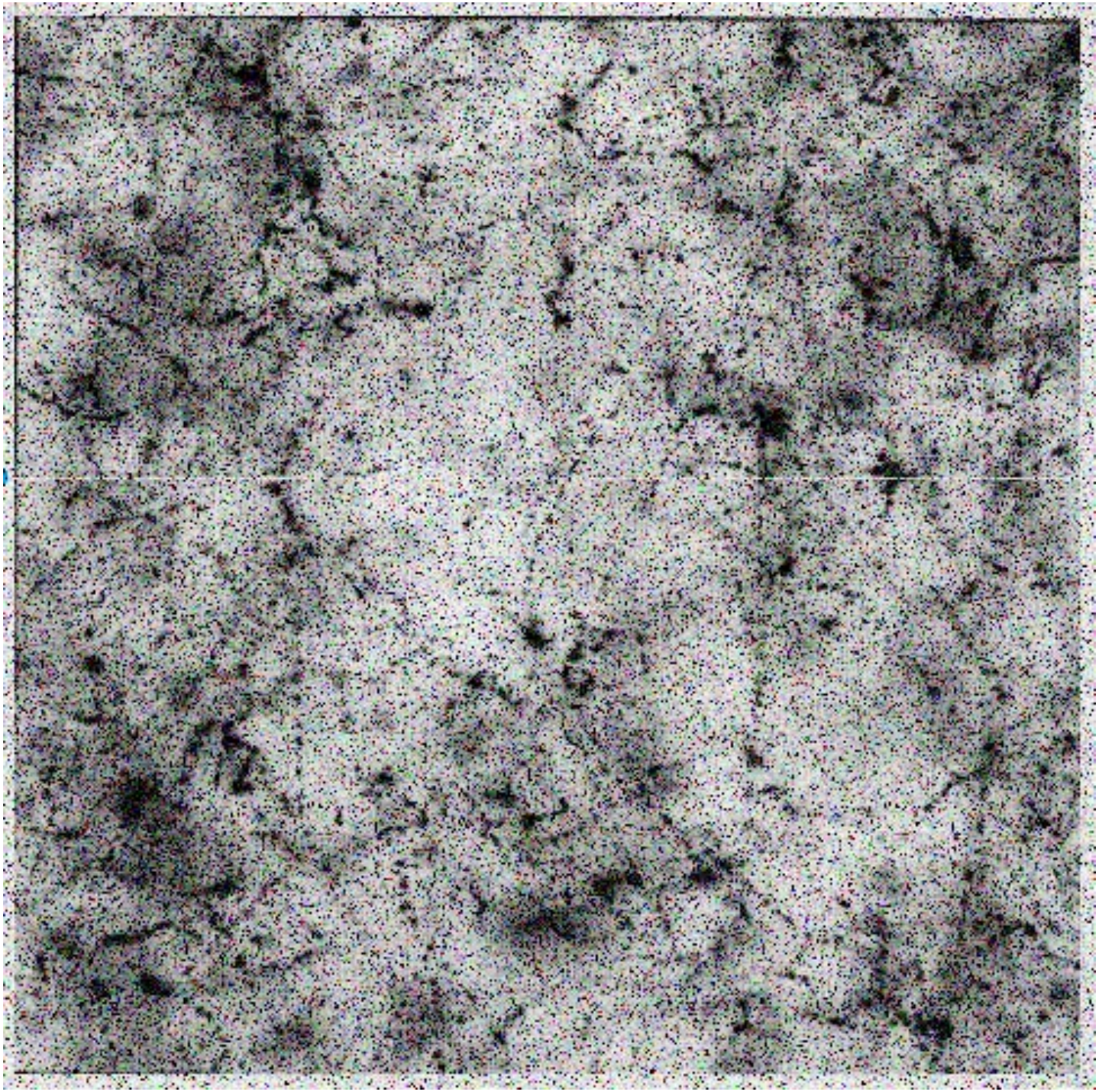
Immagini e immaginazione nella fisica delle particelle (elementari)

Rosamaria Venditti

Università di Bari e INFN

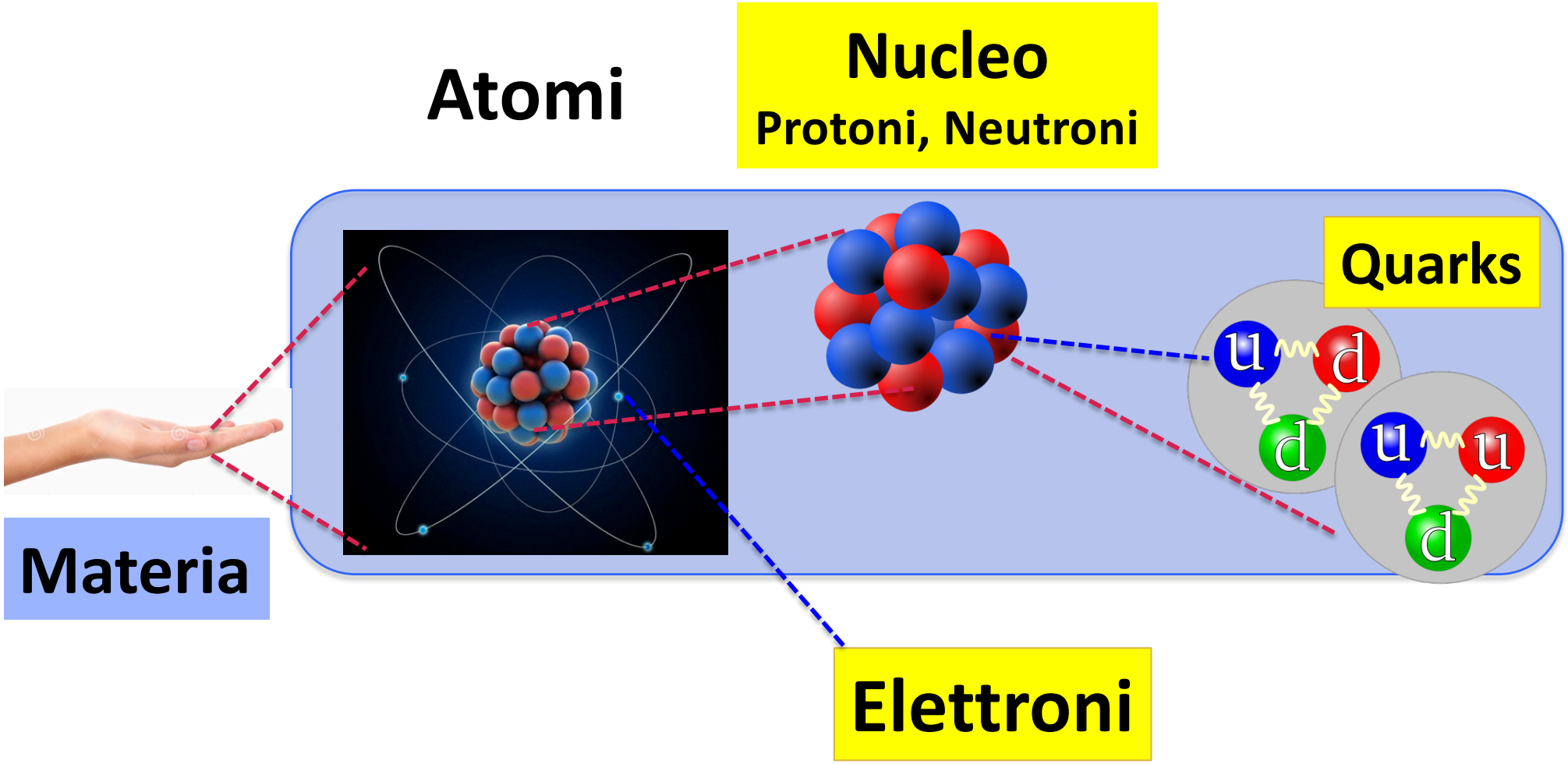
Jackson Pollock, numero 32



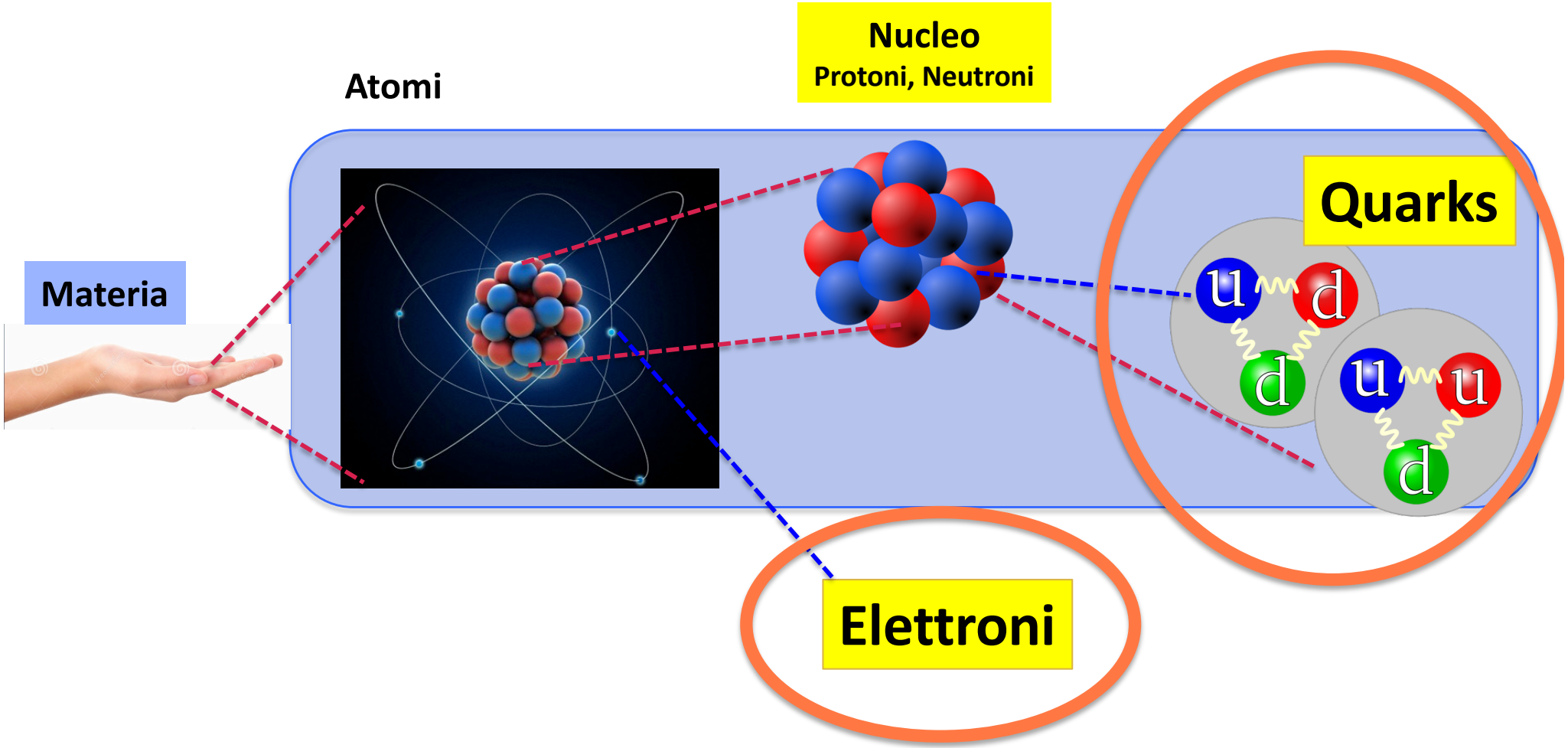


Emulsione nucleare con tracce di raggi cosmici

I componenti fondamentali della materia



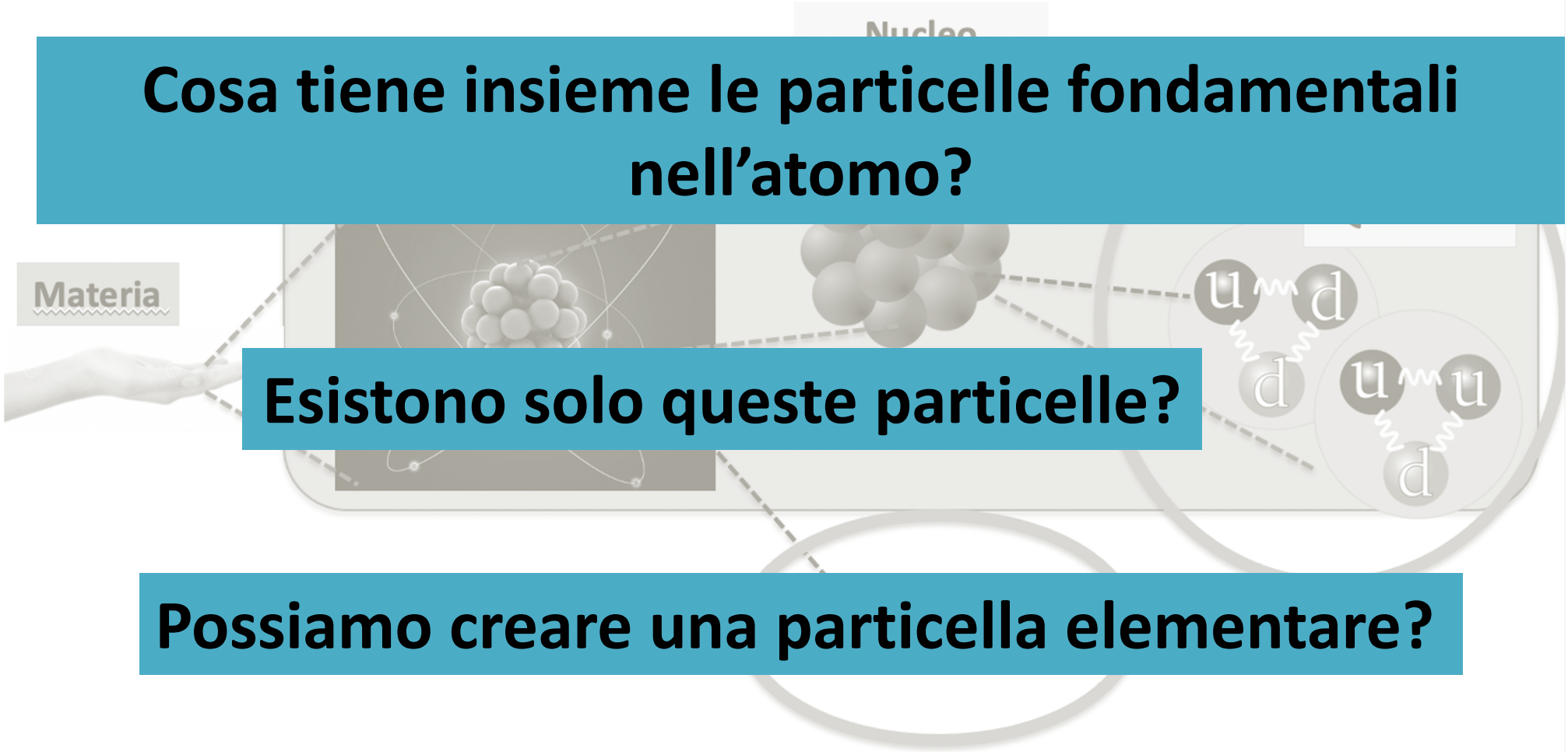
I componenti fondamentali della materia



Elementari=prive di struttura e quindi stabili!!

I componenti fondamentali della materia

Cosa tiene insieme le particelle fondamentali nell'atomo?

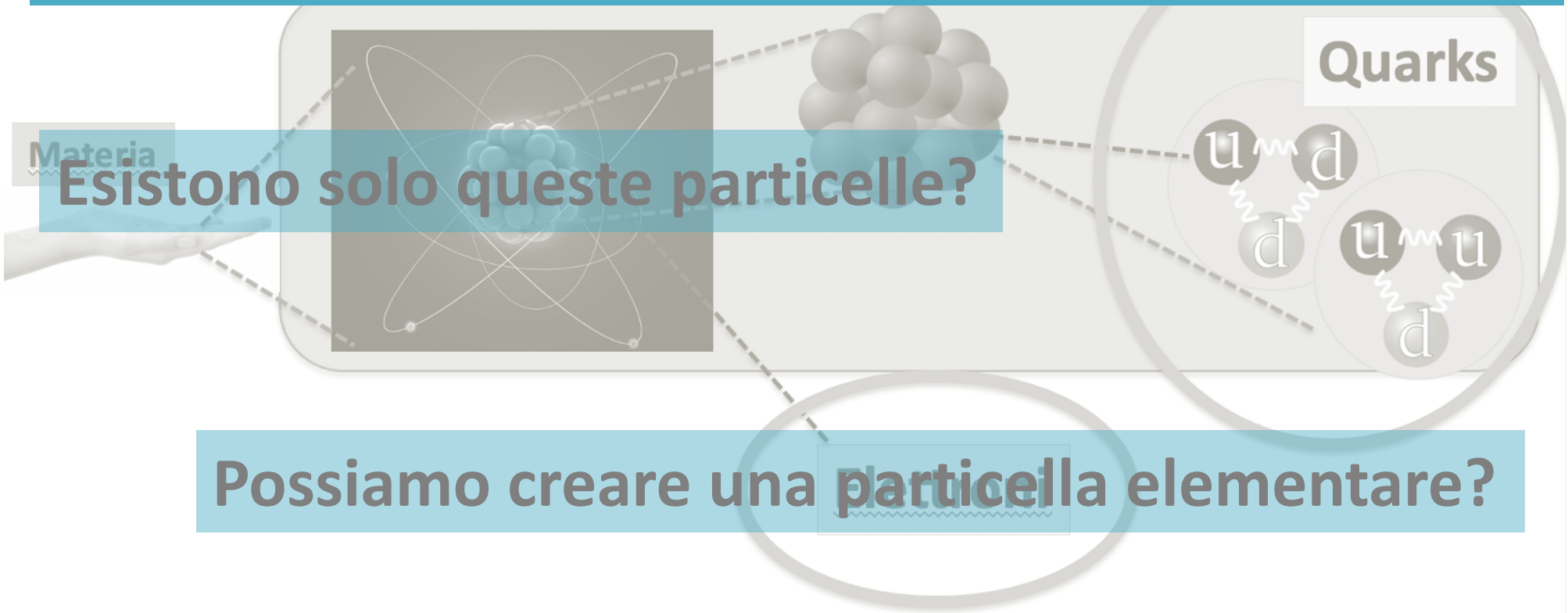


Esistono solo queste particelle?

Possiamo creare una particella elementare?

I componenti fondamentali della materia

Cosa tiene insieme le particelle fondamentali nell'atomo?

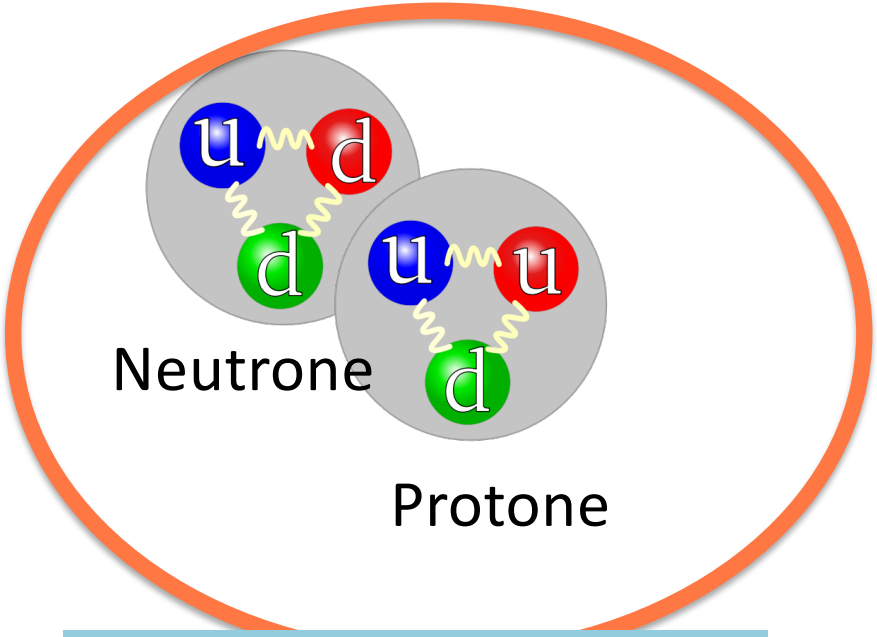


Esistono solo queste particelle?

Possiamo creare una particella elementare?

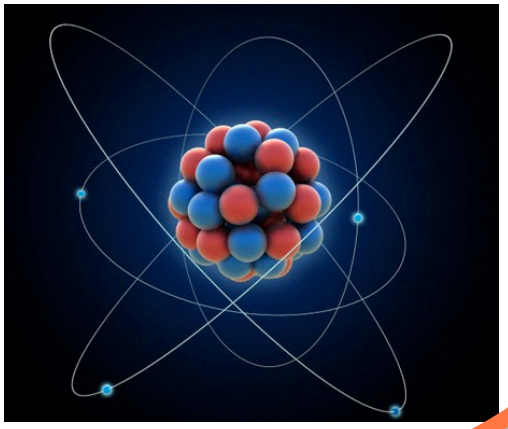
Le forze agiscono sulle particelle

Confinamento dei Quarks



Forza nucleare forte

Formazione atomi



Forza elettromagnetica

Le interazioni fondamentali

1. Elettromagnetica
2. Forte
3. Debole
4. Gravitazionale

Le interazioni fondamentali

Paticella mediatrice

1. Elettromagnetica

Fotone

2. Forte

Gluone

3. Debole

Bosoni
W,Z

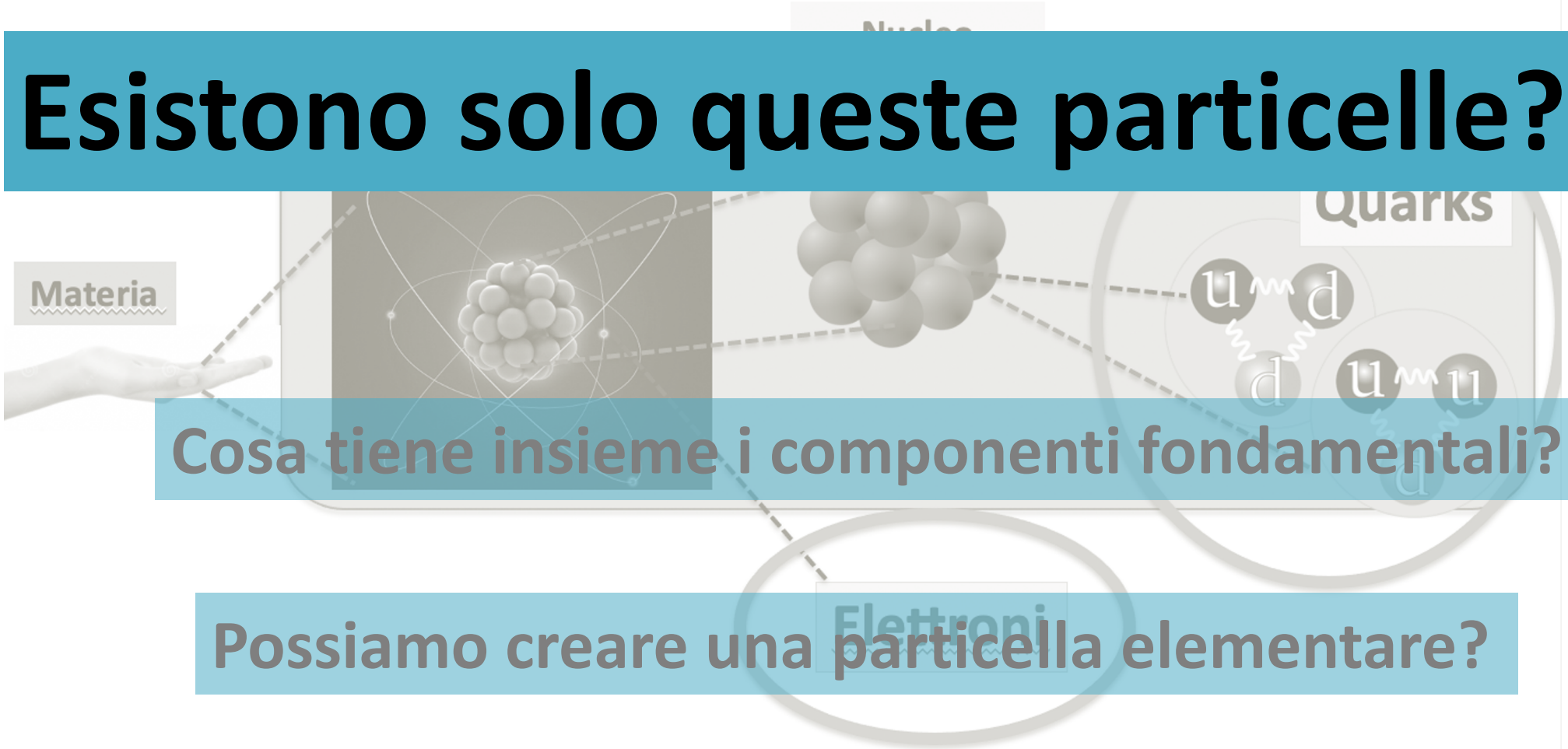
4. Gravitazionale

?

Gravitone?

I componenti fondamentali della materia

Esistono solo queste particelle?



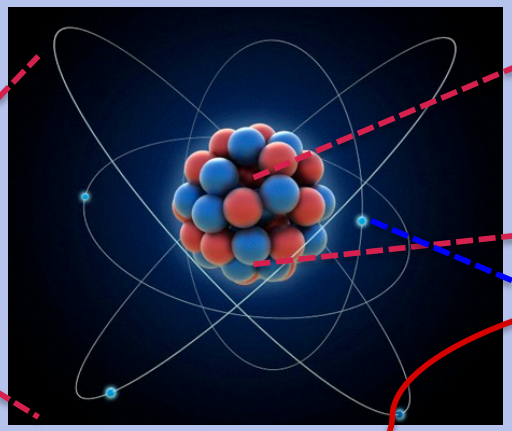
Cosa tiene insieme i componenti fondamentali?

Possiamo creare una particella elementare?

Quark e leptoni:i componenti fondamentali

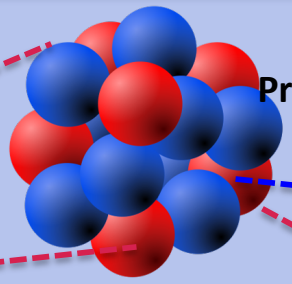
Materia

Atomi



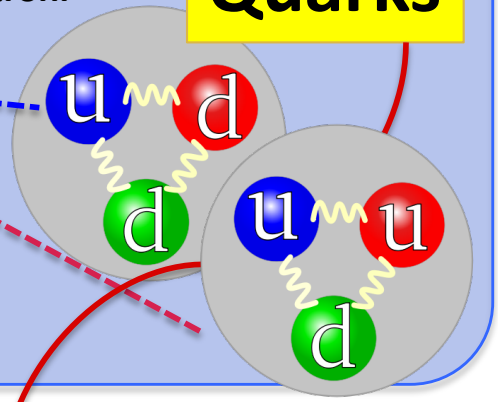
Nucleo

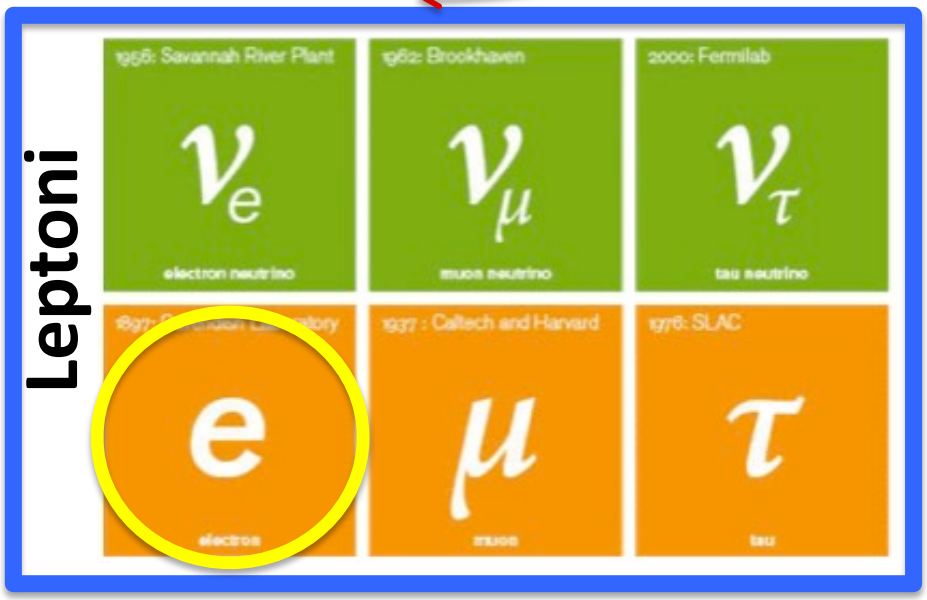
Protoni, Neutroni

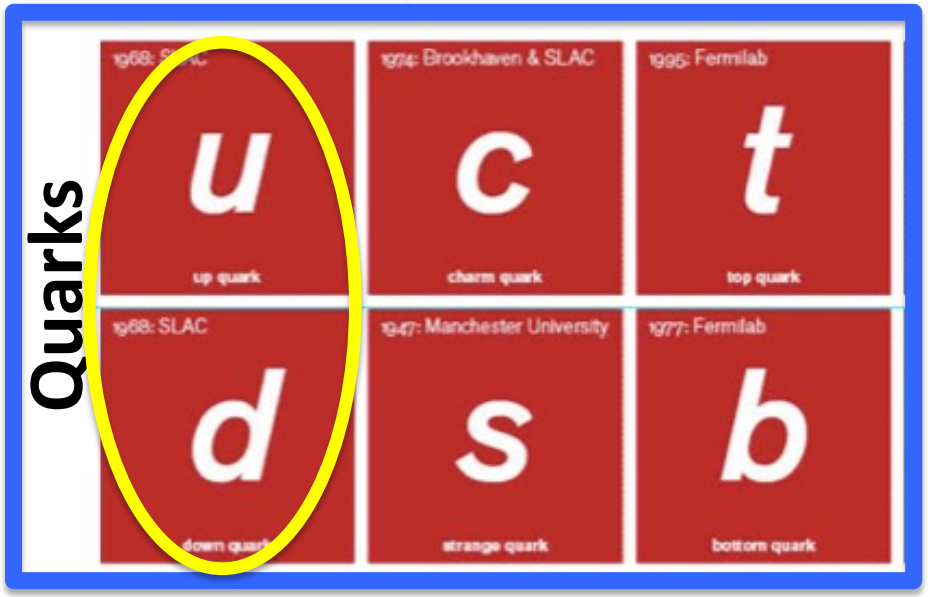


Elettroni

Quarks





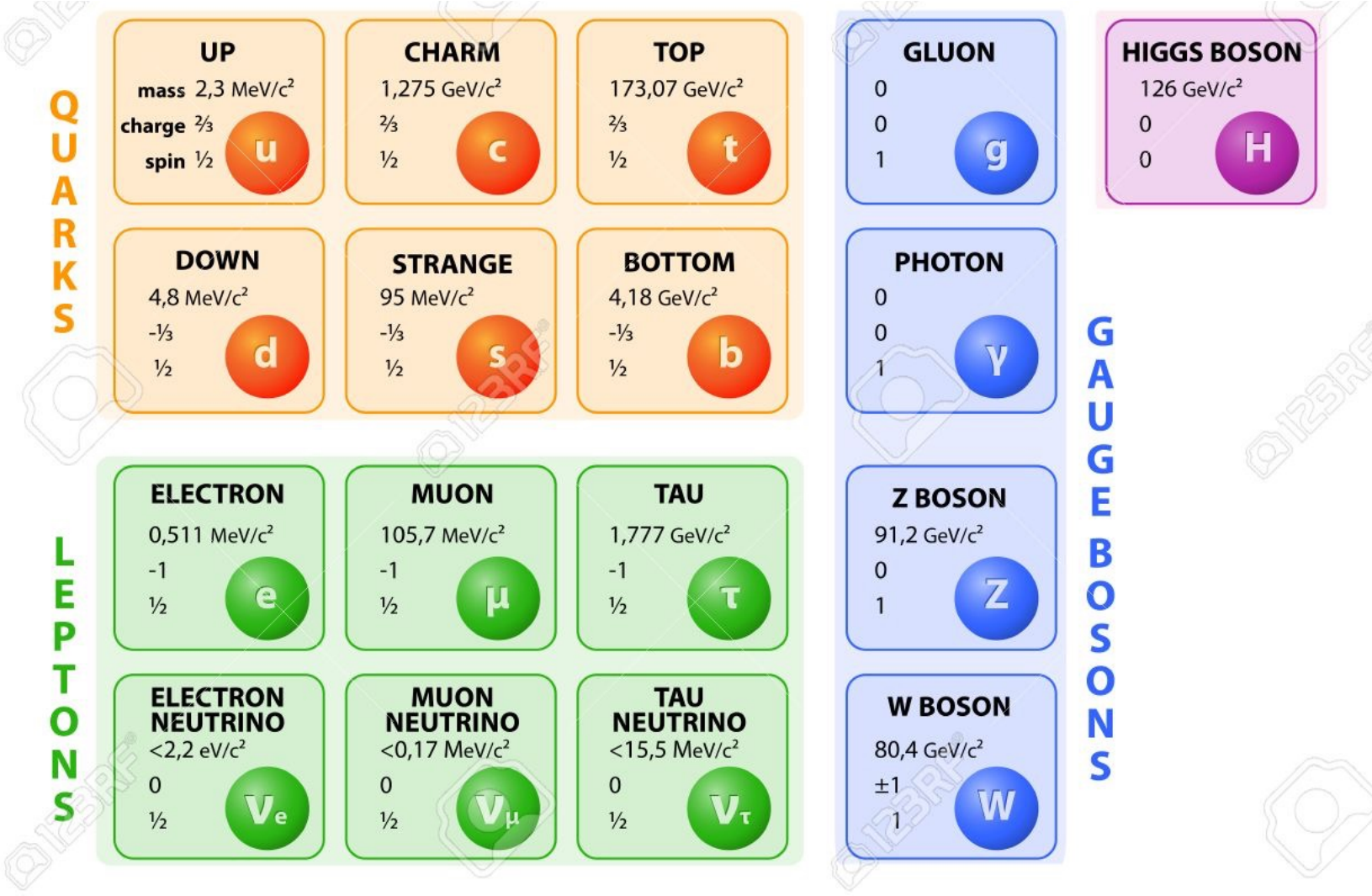


Mettendo insieme forze e particelle fondamentali…

Particelle+interazioni fondamentali

=

Modello Standard

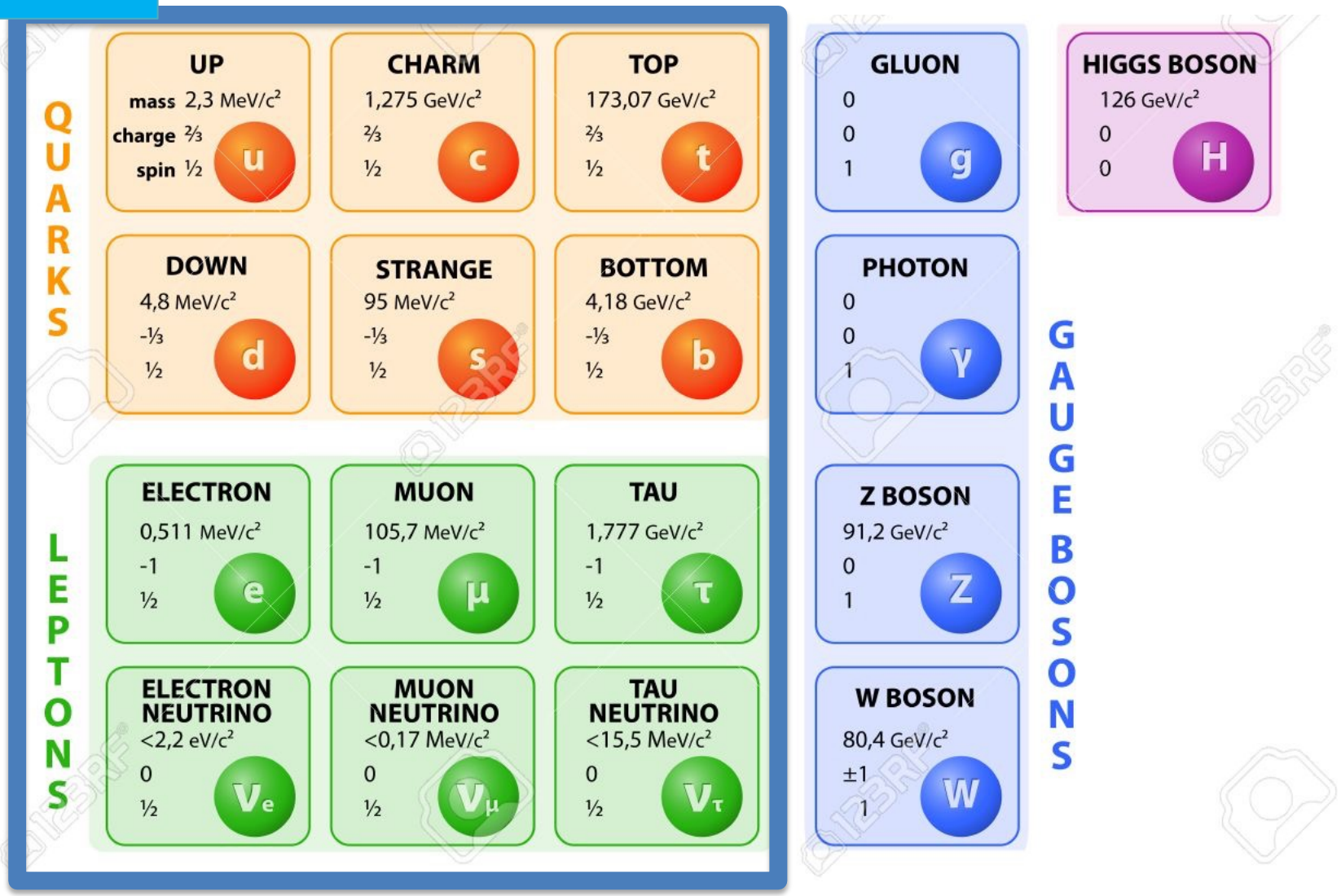


Particelle+interazioni fondamentali

=

Materia

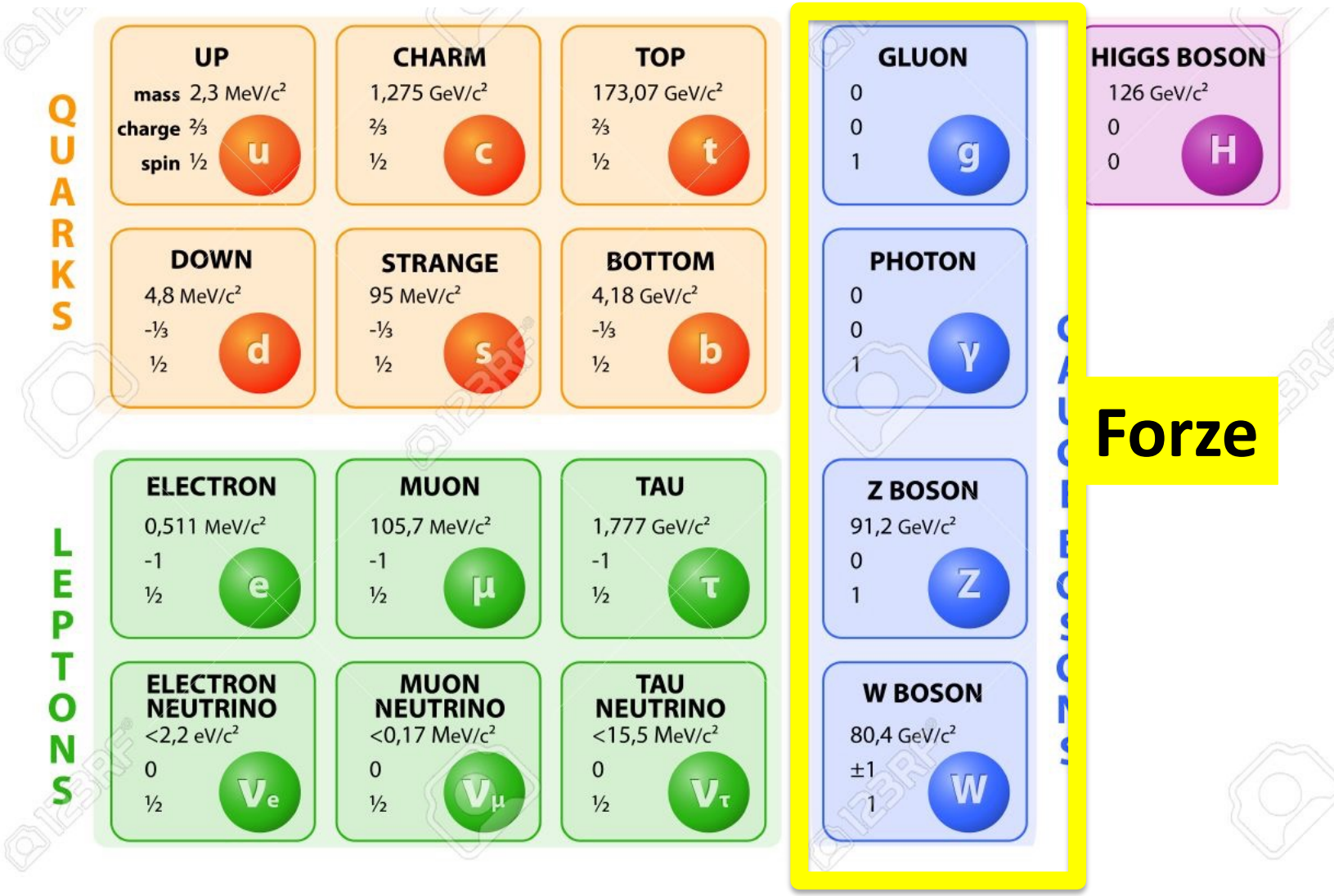
Modello Standard



Particelle+interazioni fondamentali

=

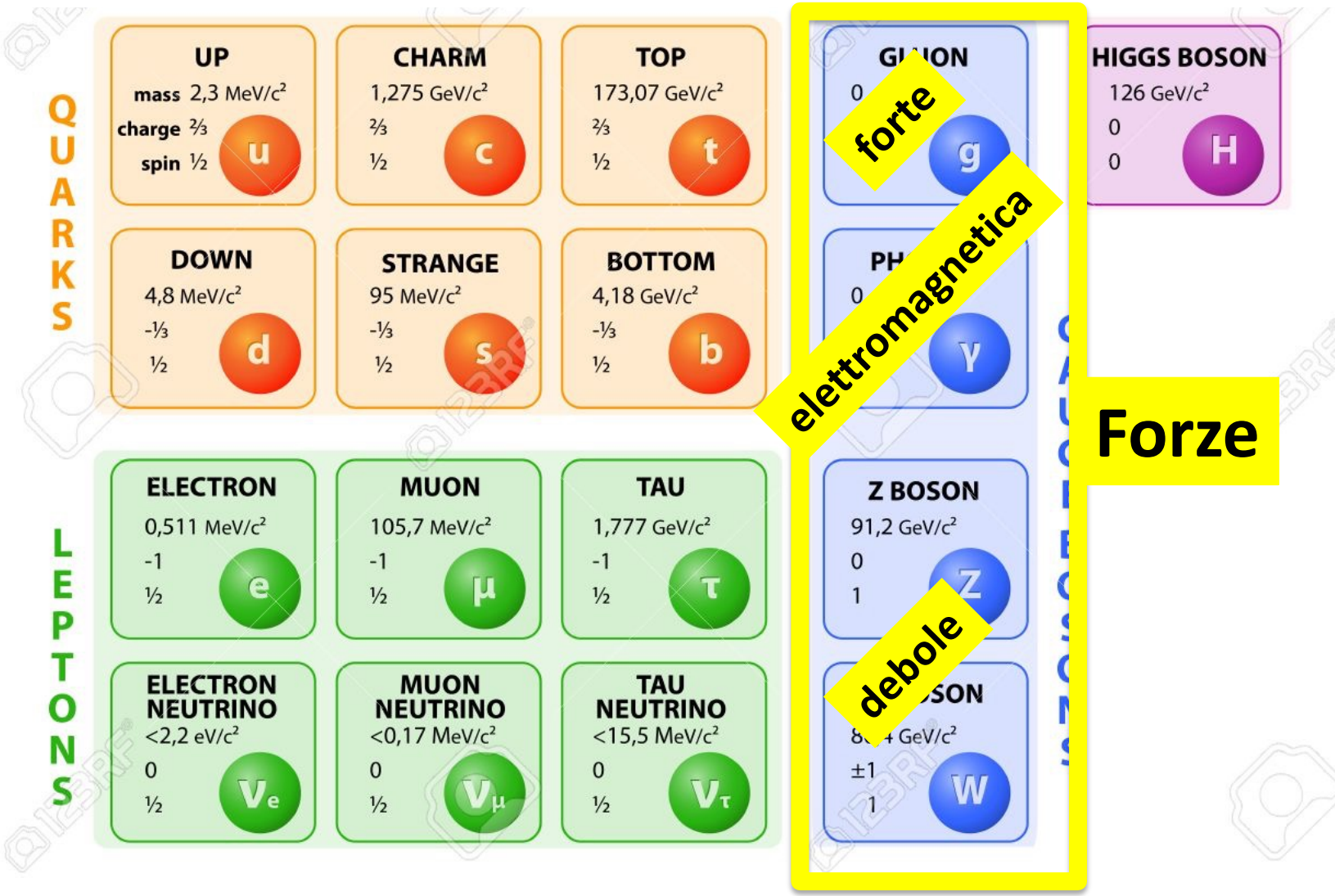
Modello Standard



Particelle+interazioni fondamentali

=

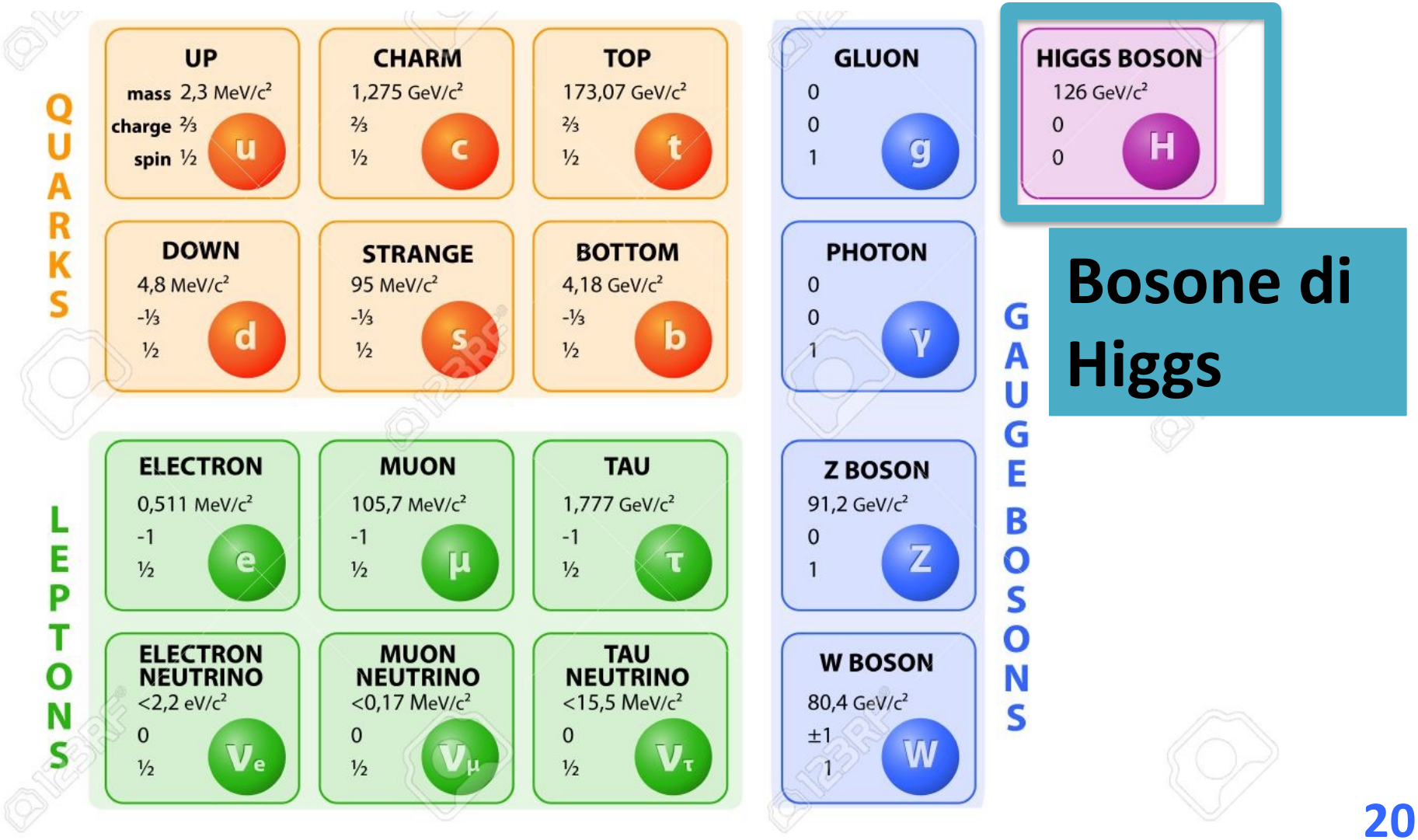
Modello Standard



Particelle+interazioni fondamentali

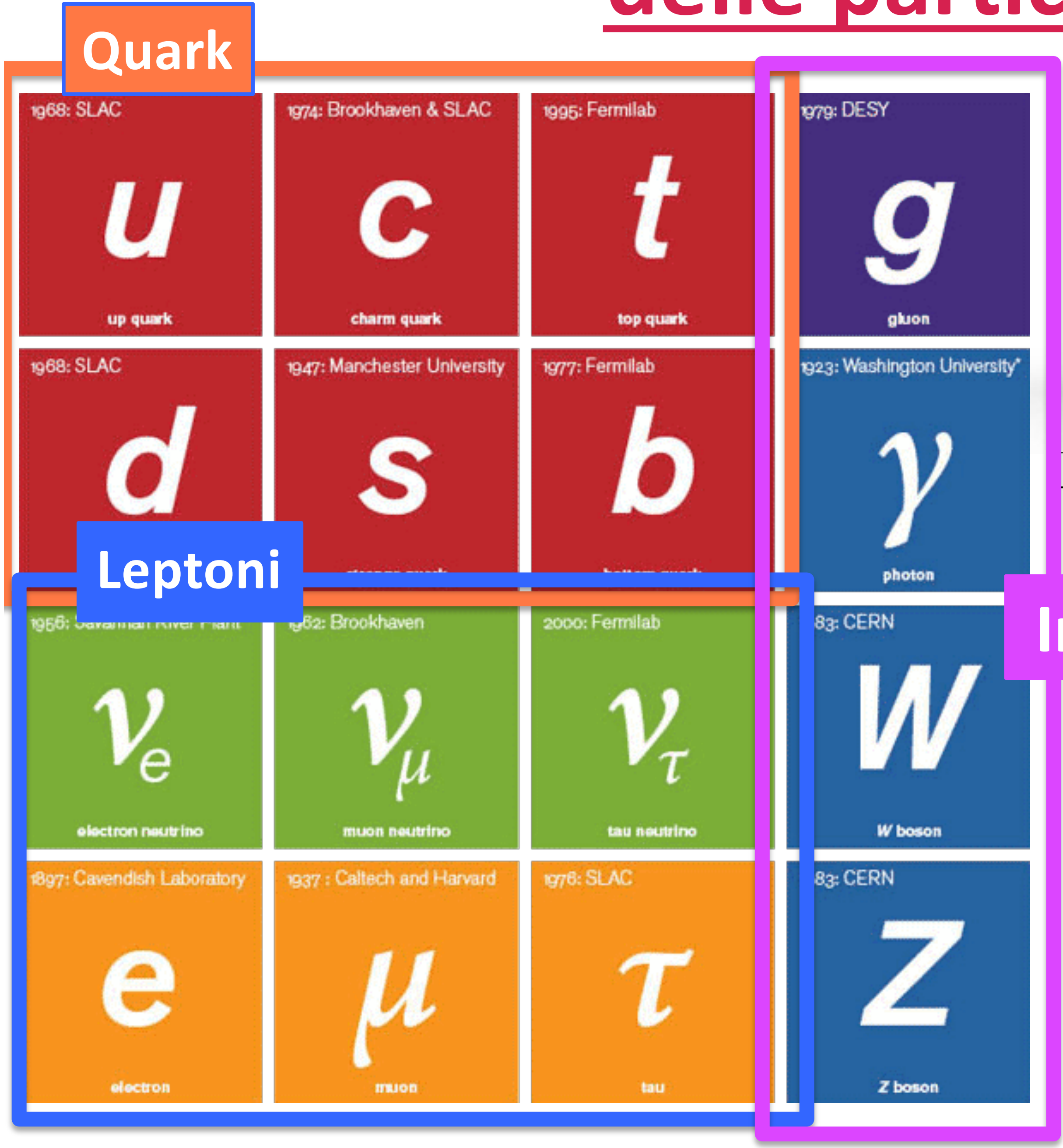
=

Modello Standard



Bosone di Higgs

Il Modello Standard della Fisica delle particelle



Perchè le particelle hanno queste masse?

Riassumendo

Nel 1964 Higgs, Brout, Englert suggeriscono di introdurre un'altra particella, che da' massa a tutte le altre

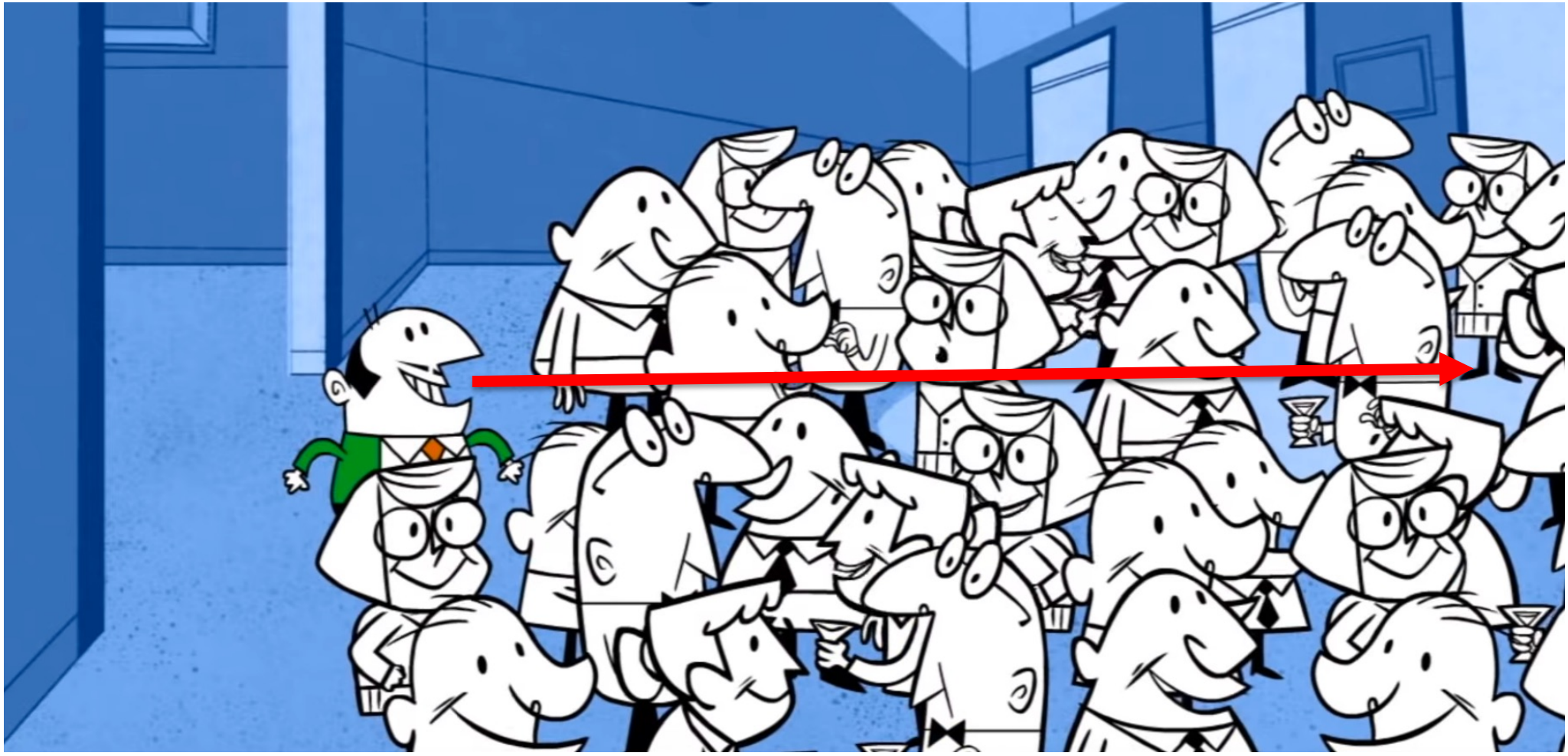
Perche’ le particelle hanno massa?

By Don Lincoln & David Miller

https://www.youtube.com/watch?v=joTKd5j3mzk

https://ed.ted.com/lessons/the-higgs-field-explained-don-lincoln

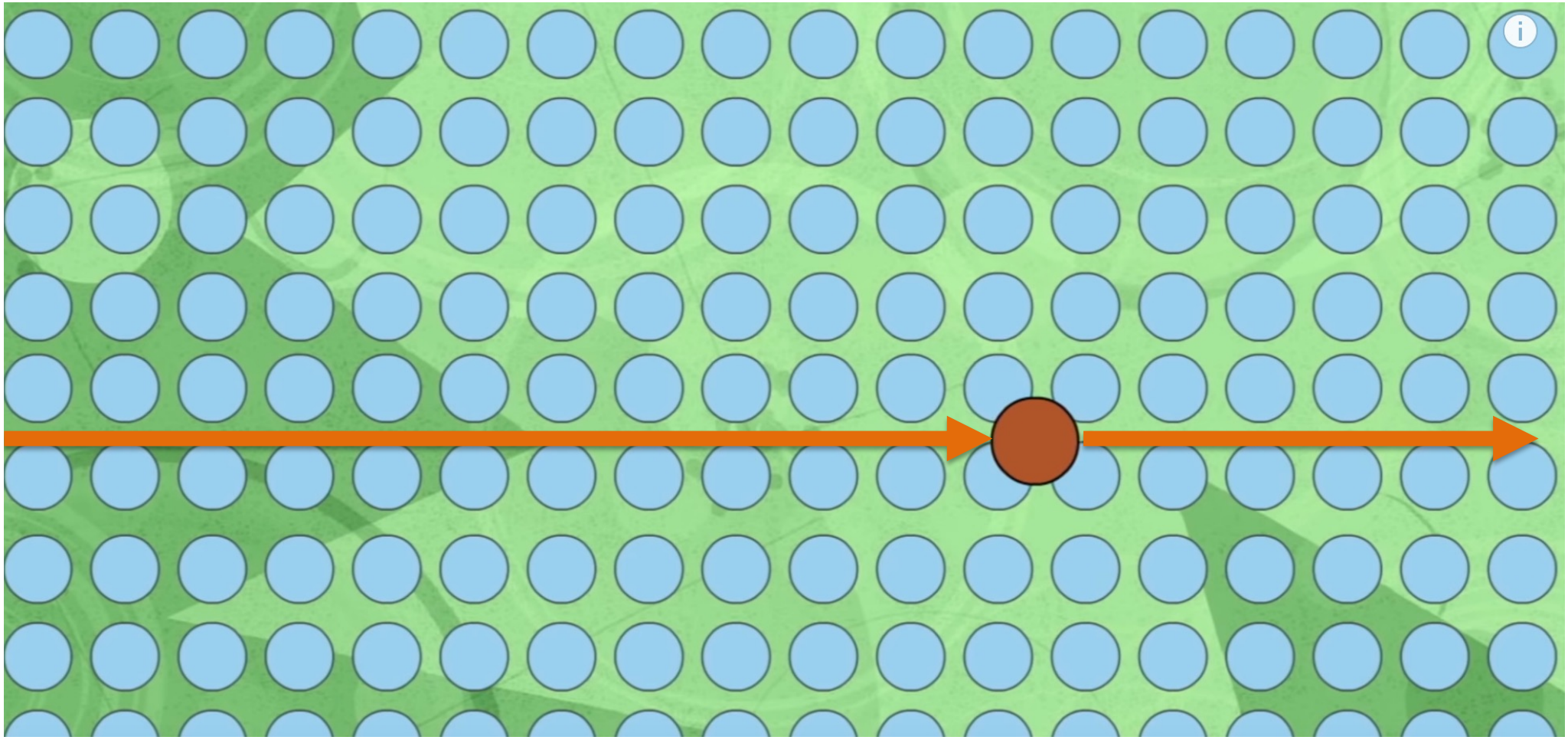
Perche’ le particelle hanno massa?



Perche’ le particelle hanno massa?

Perche’ le particelle hanno massa?

Campo di Higgs



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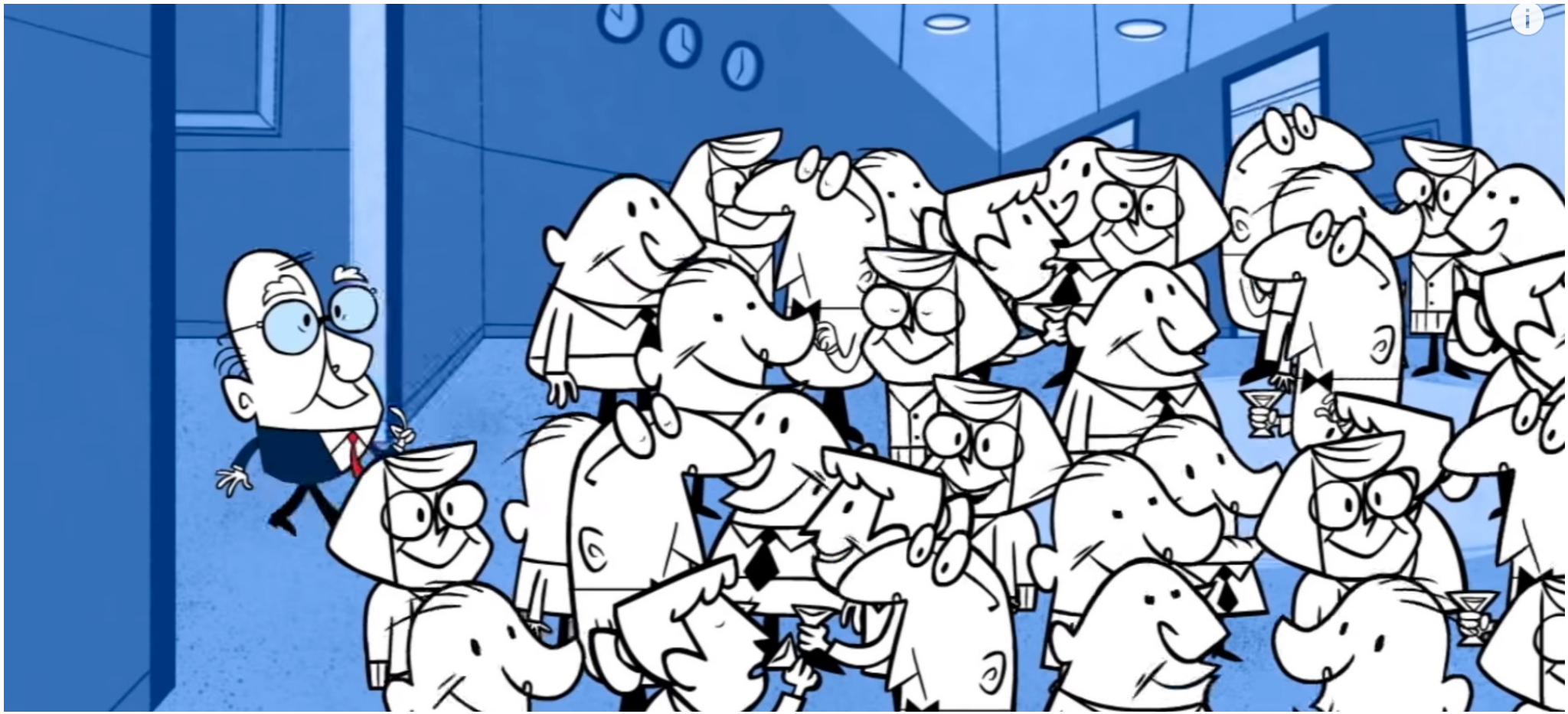

Perche’ le particelle hanno massa?

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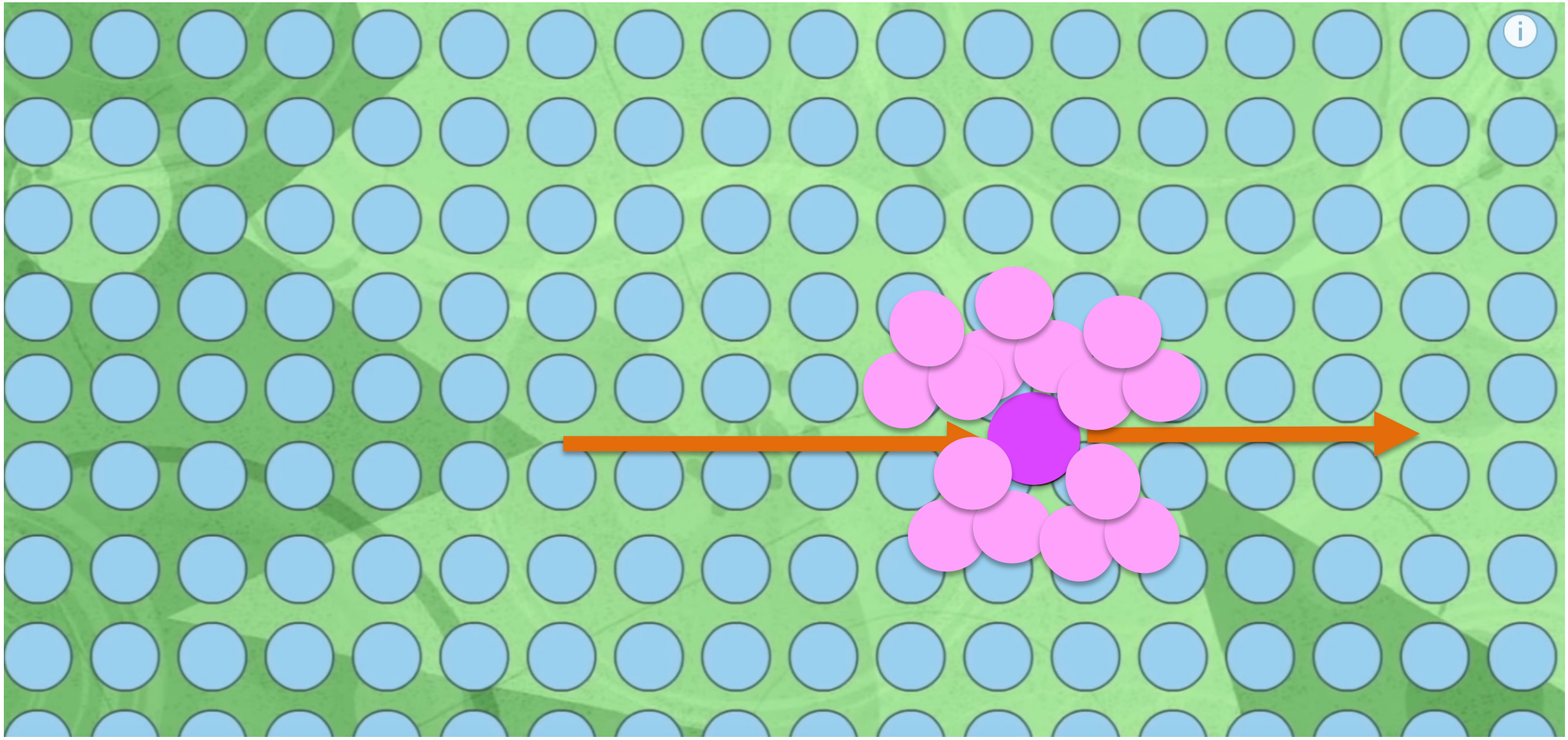
Campo di Higgs



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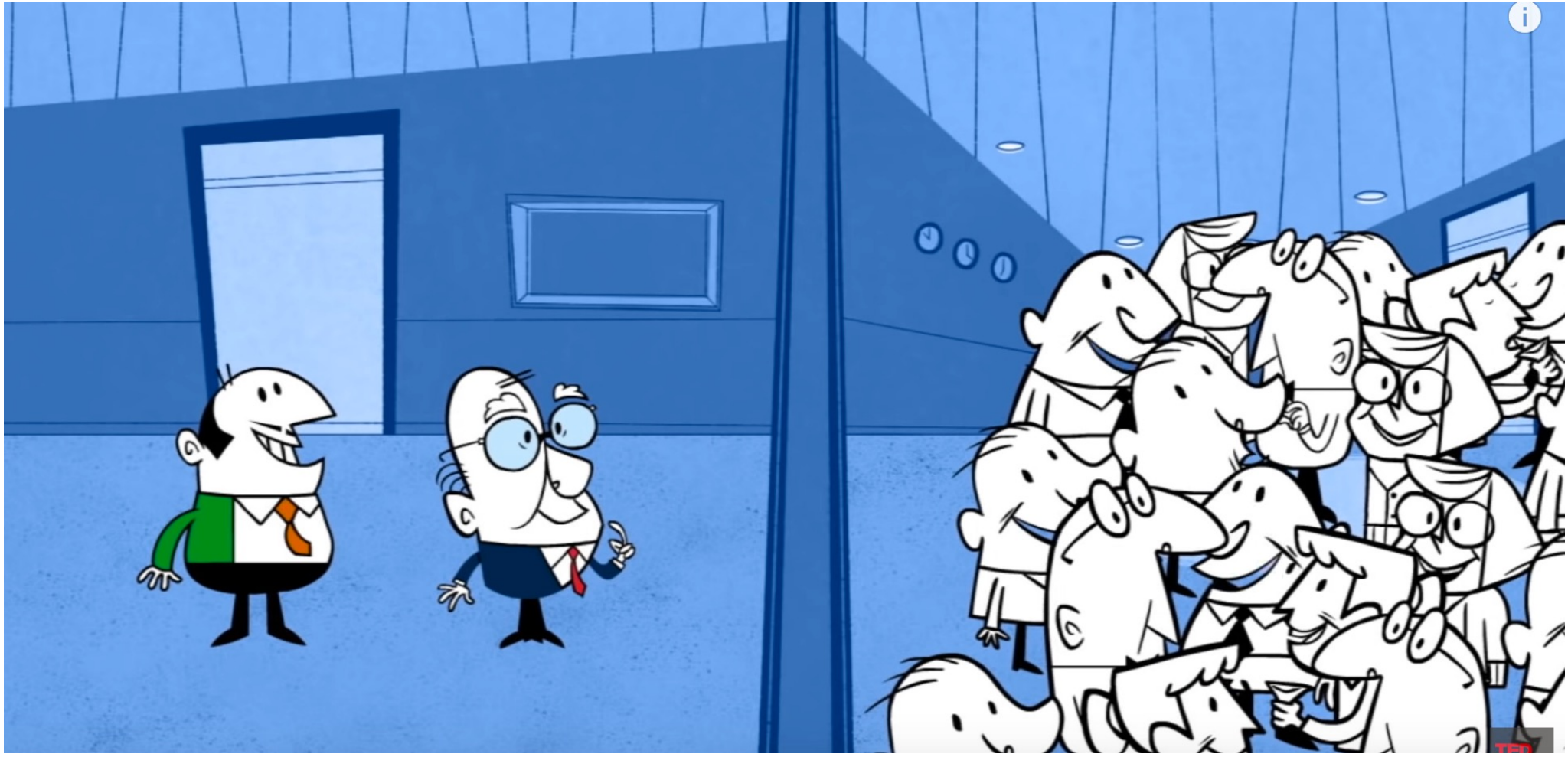

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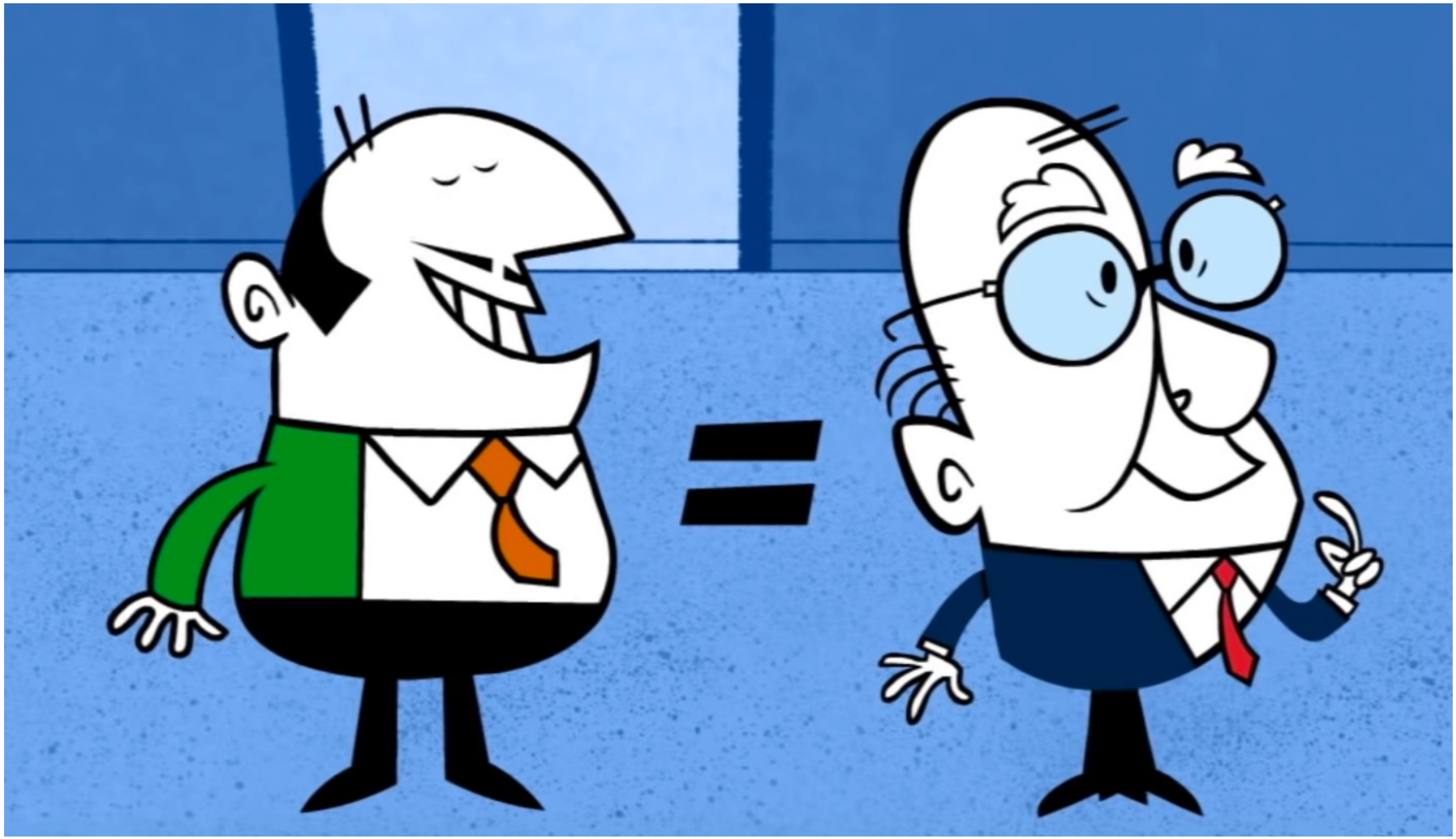

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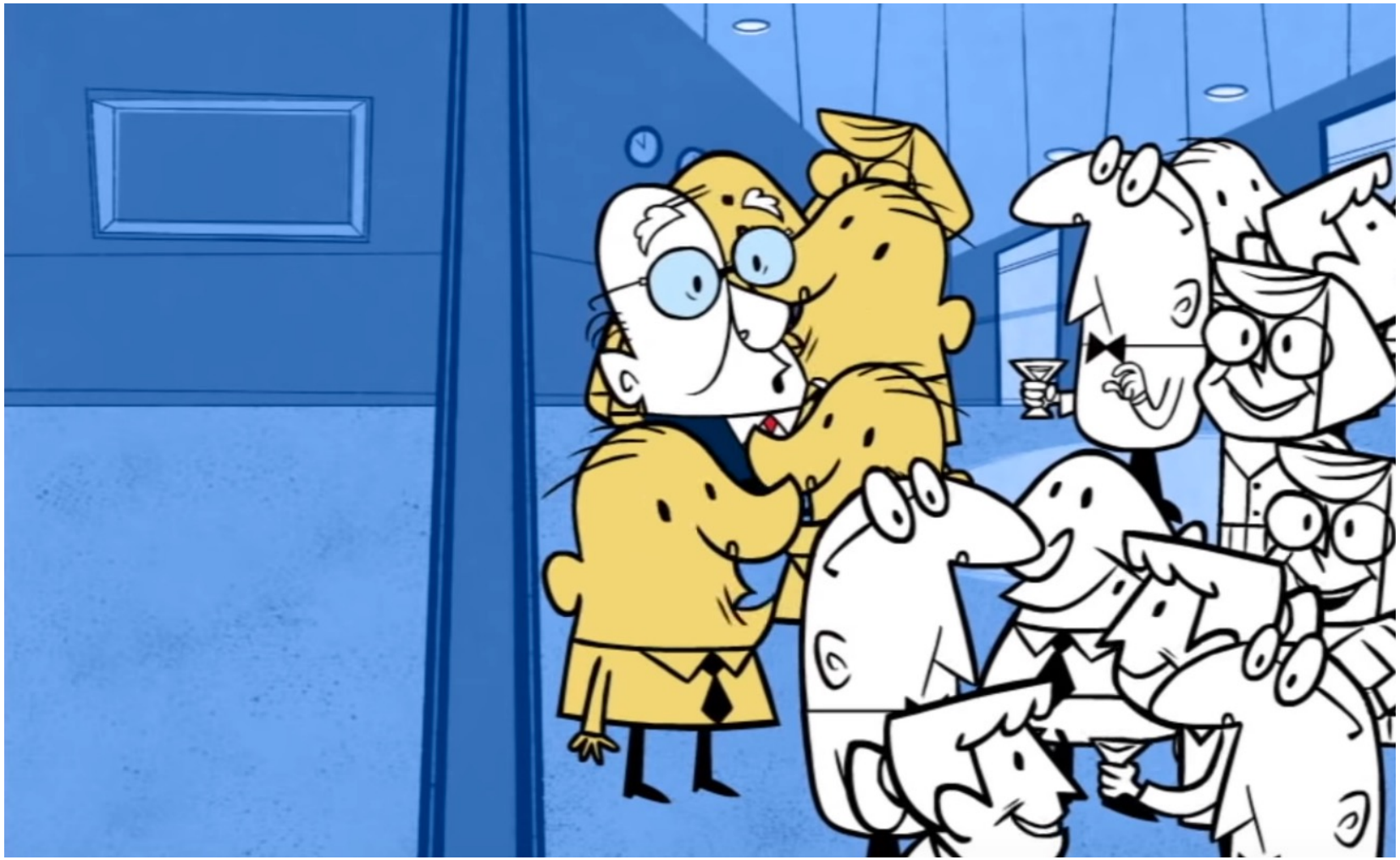


Cosa studiamo al CERN

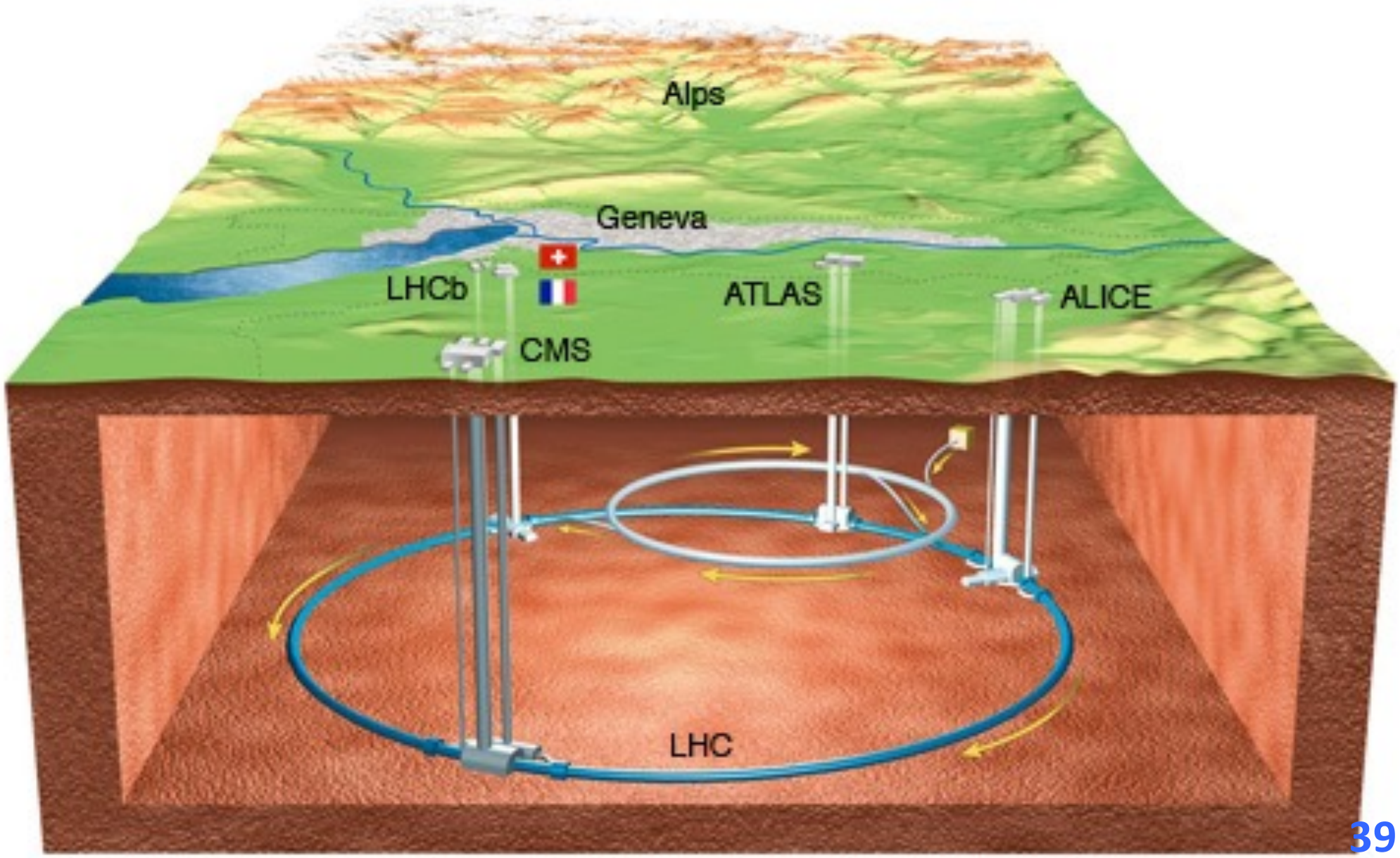
Si ma questo bosone che crea massa…. Esiste?

Benvenuti al CERN!

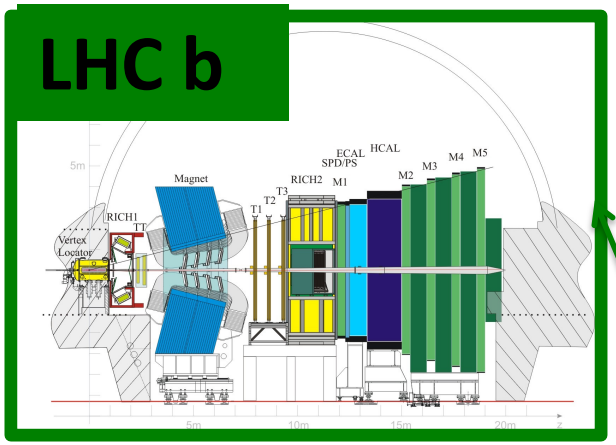

CERN

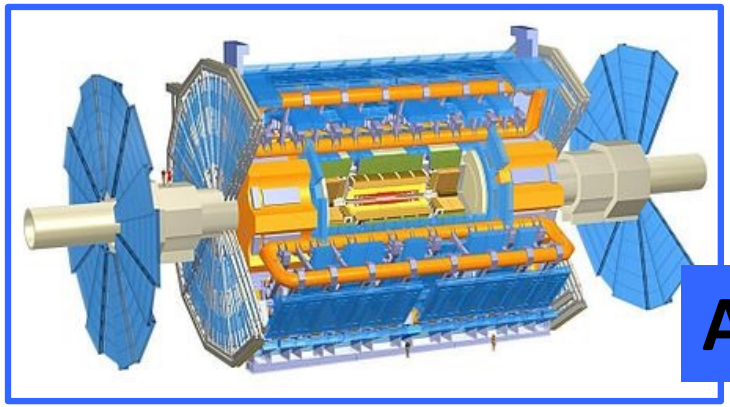
Un enorme laboratorio…

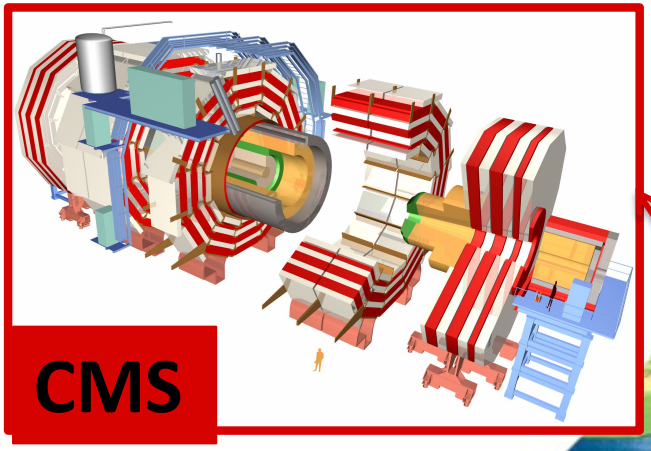
Una fabbrica di Higgs: LHC

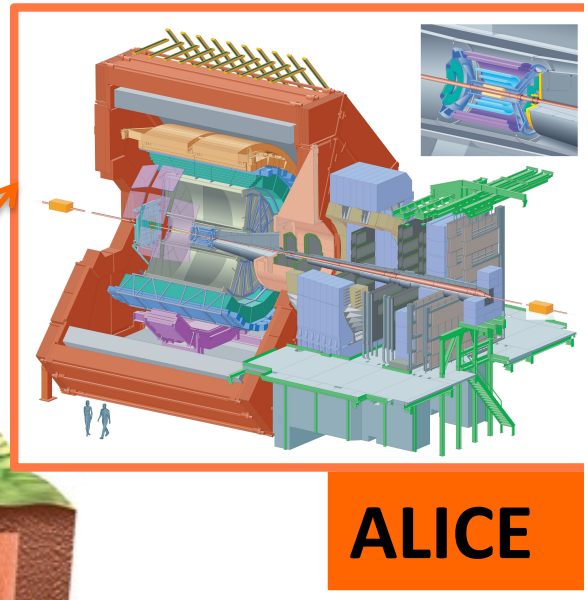


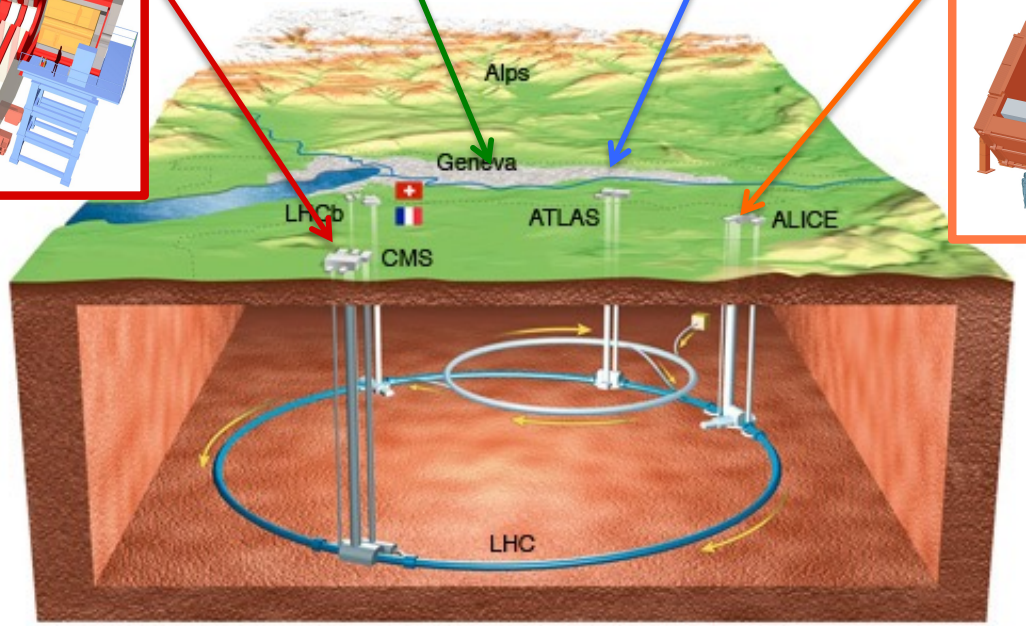
4 punti di impatto, 4 esperimenti

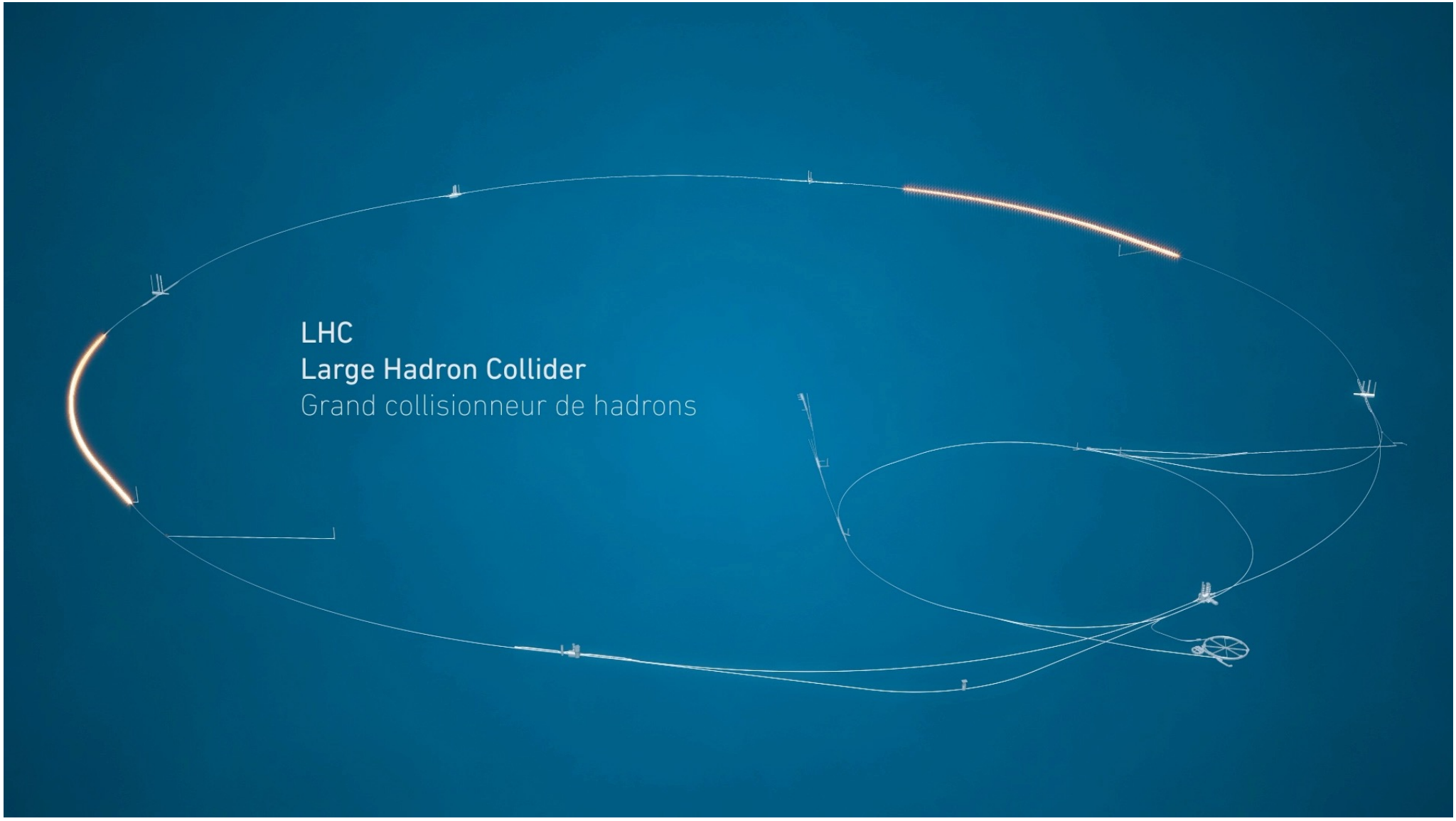






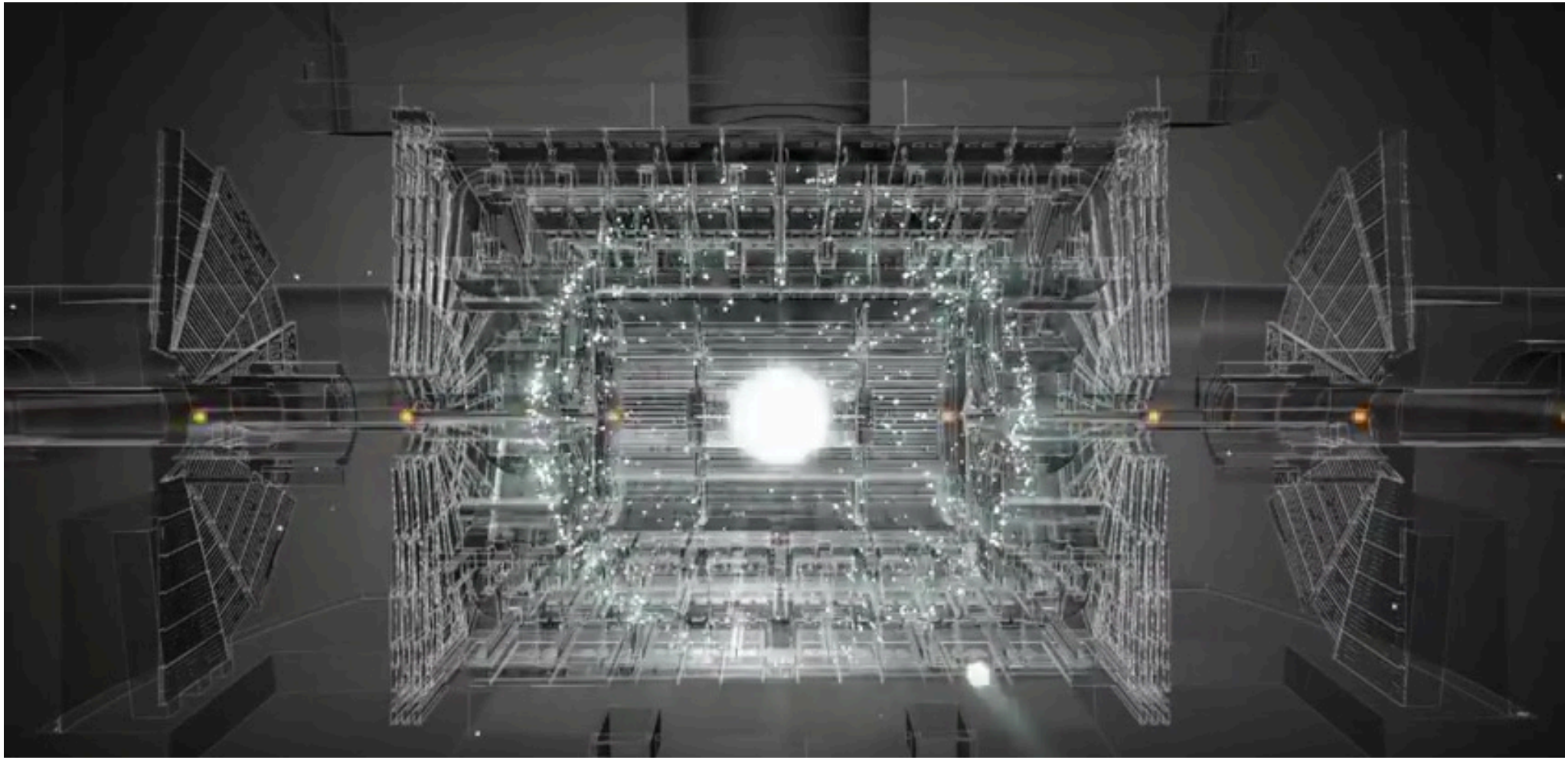






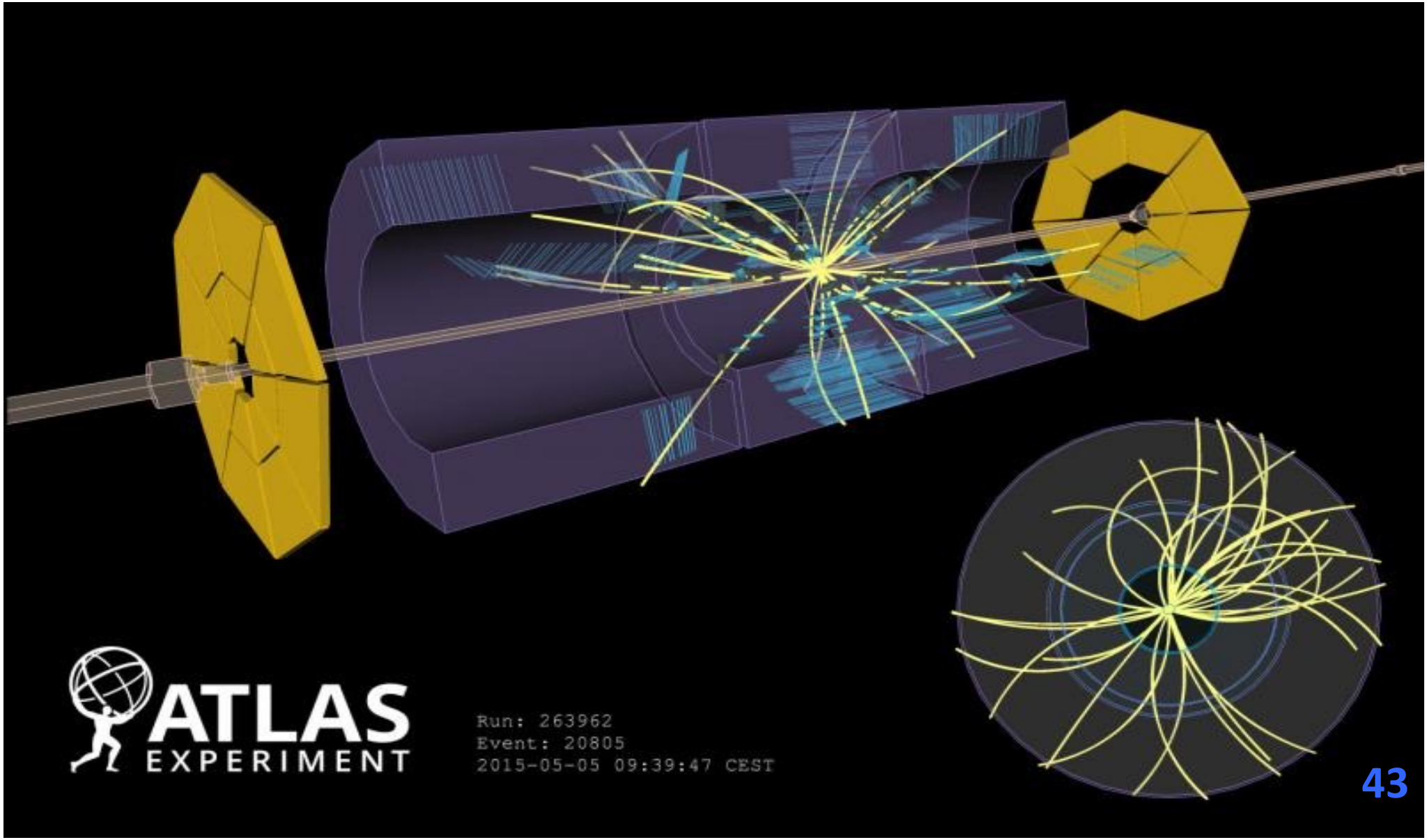
- https://videos.cern.ch/record/2021097

Impatto tra i fasci

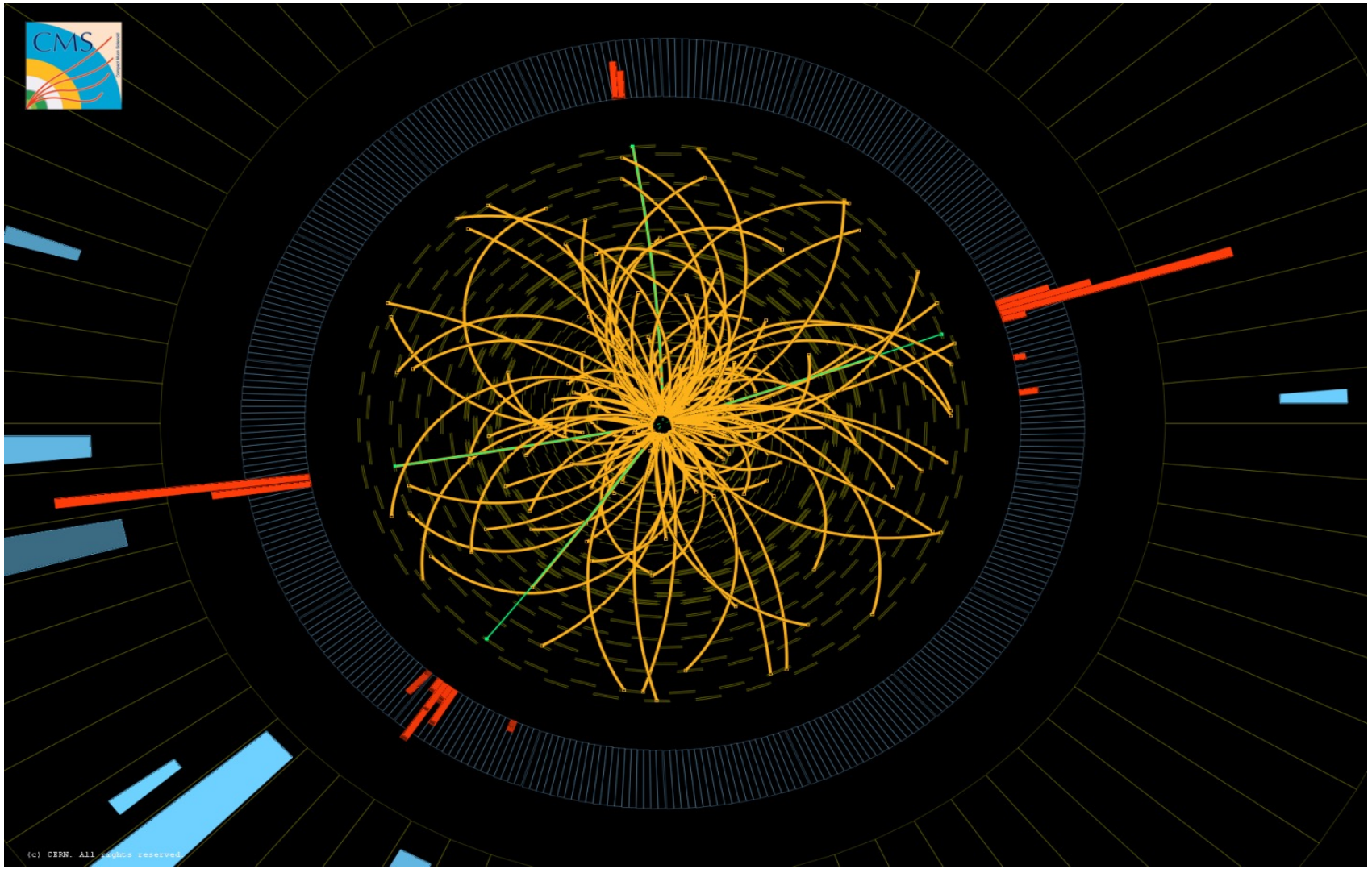


Dopo l’impatto

Dopo l’impatto, le nuove particelle iniziano a propagarsi



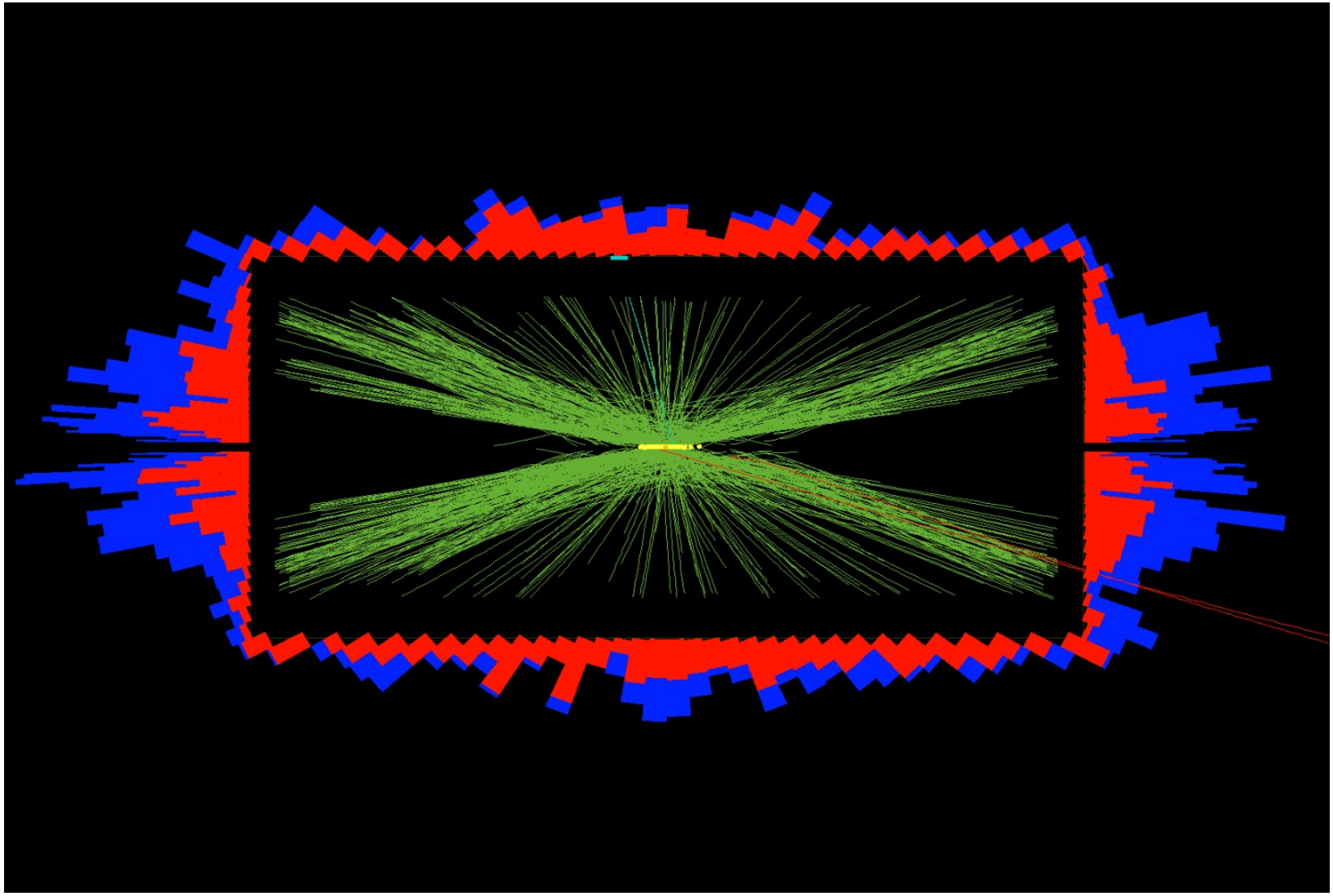
Dopo una collisione…
La vita può essere difficile



Tracce che emergono dopo la collisione di due protoni

Tra queste c'è un bosone di Higgs

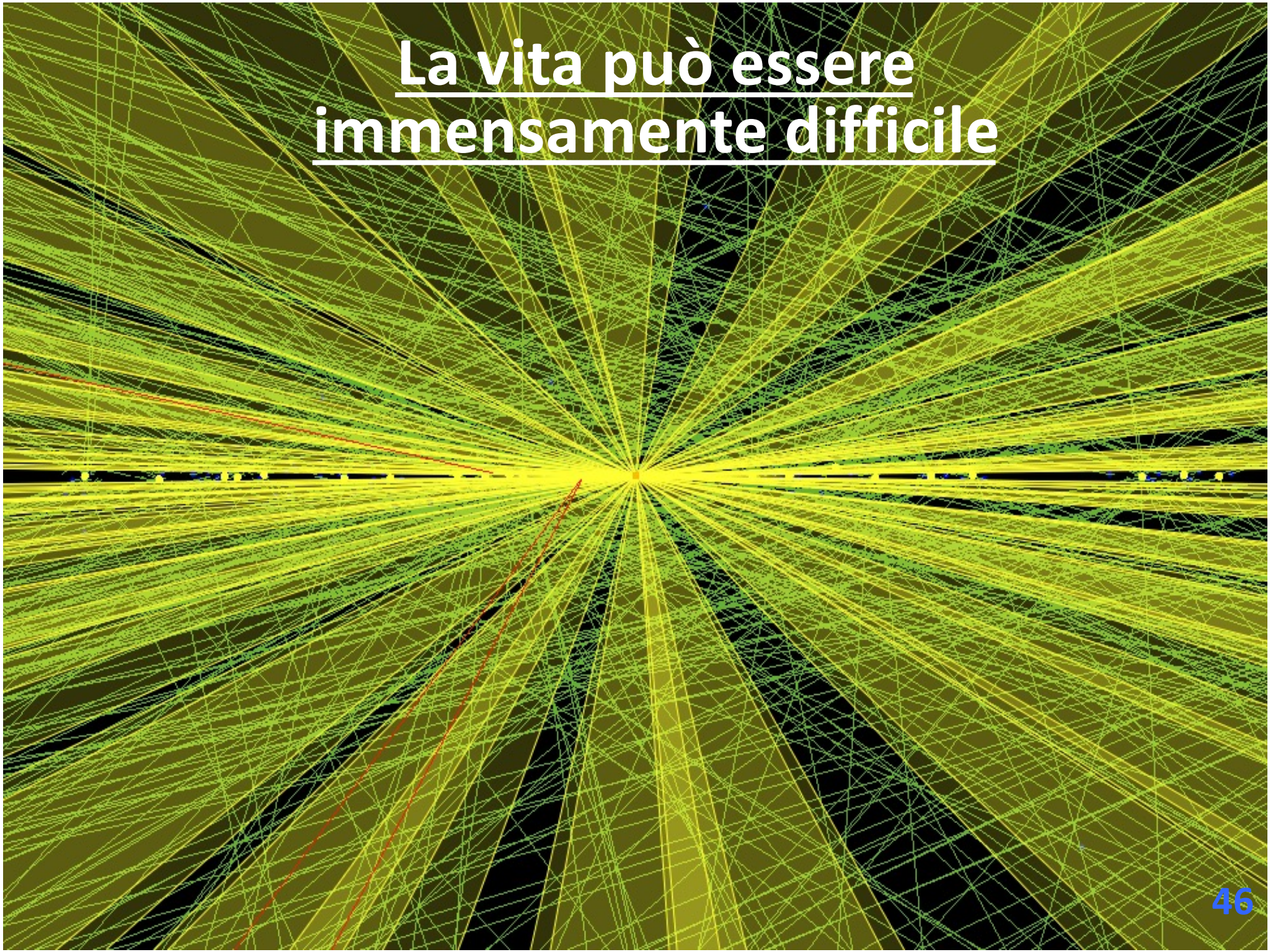
La vita può essere molto difficile



100 vertici+ Migliaia di Tracce + Energia che emergono dopo la collisione di due protoni

Tra queste tracce, si nasconde un bosone di Higgs

La vita può essere immensamente difficile



HIGGS BOSON

H

The **HIGGS BOSON** is the theoretical particle of the Higgs mechanism, which physicists believe will reveal how all matter in the universe get its mass. Many scientists hope that the Large Hadron Collider in Geneva, Switzerland will detect the elusive Higgs Boson when it begins colliding particles at 99.99% the speed of light.

Wool felt with gravel fill for maximum mass.

LIGHT HEAVY

$9.75 PLUS SHIPPING

GLUON PHOTON NEUTRINO TACHYON ELECTRON UP QUARK DOWN QUARK TAU NEUTRINO MUON UP QUARK
NEUTRON DOWN QUARK TAU GLUON **HIGGS BOSON** NEUTRINO TACHYON ELECTRON UP QUARK DOWN
NEUTRINO MUON UP QUARK PROTON NEUTRON DOWN QUARK TAU GLUON PHOTON NEUTRINO TACHY
PROTON NEUTRON DOWN QUARK TAU GLU
TAU NEUTRINO MUON UP QUARK PROTON N
ELECTRON UP QUARK DOWN QUARK TAU NEU

The PARTICLE ZOO

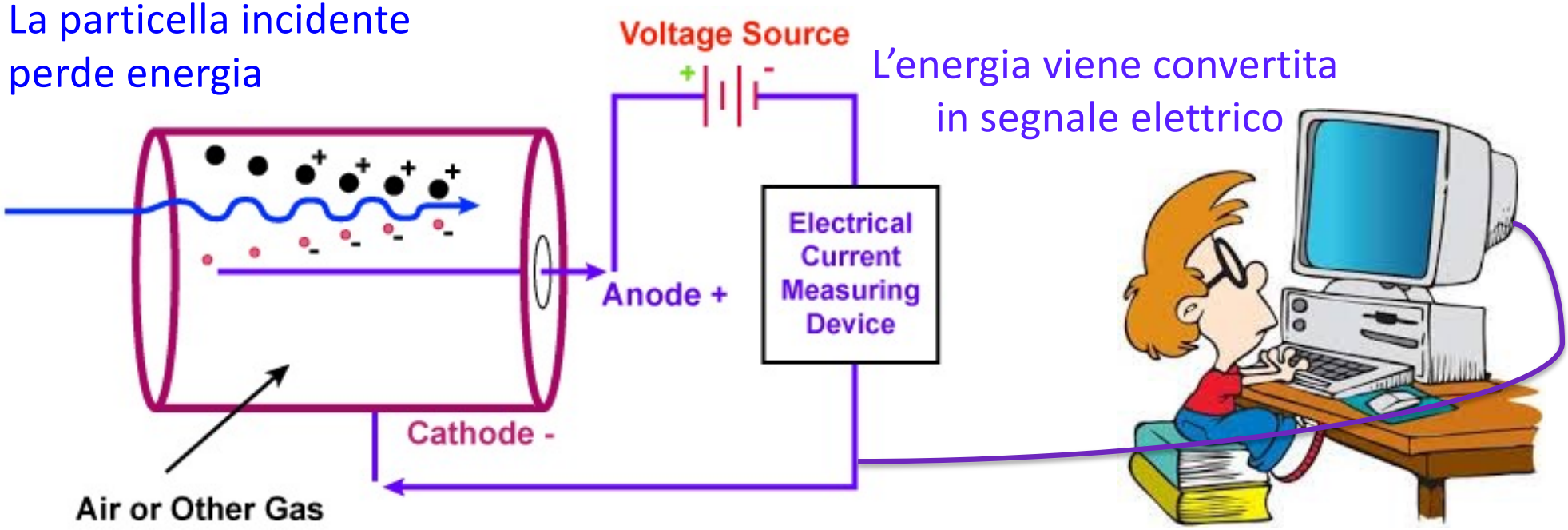
Come funziona un esperimento a LHC

Identificare particelle

Problema:
ricostruire e identificare migliaia di particelle con altissima precisione

Suggerimento:
ogni tipo di particella interagisce in modo diverso con la materia

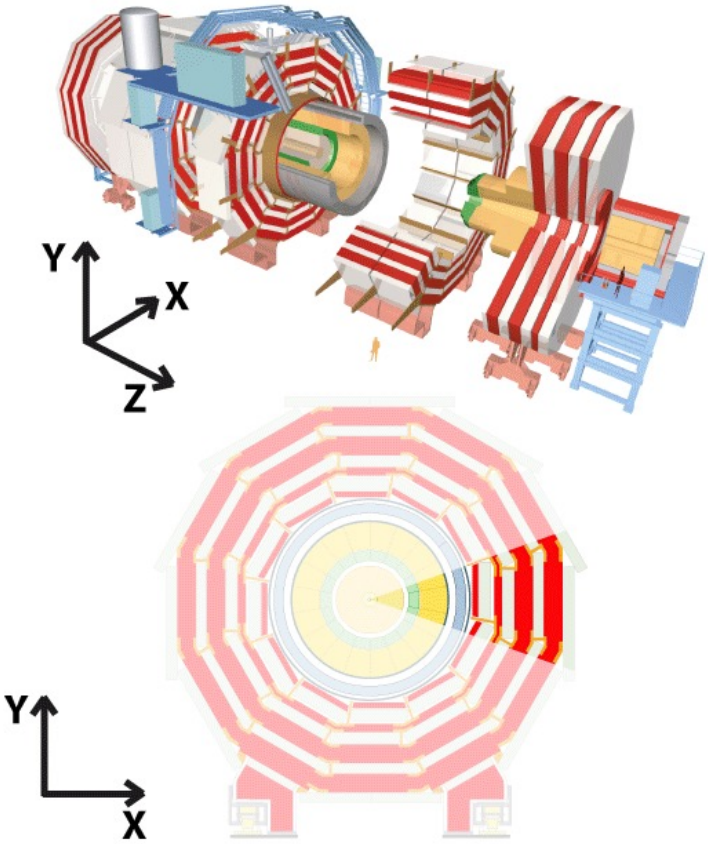
La particella incidente perde energia

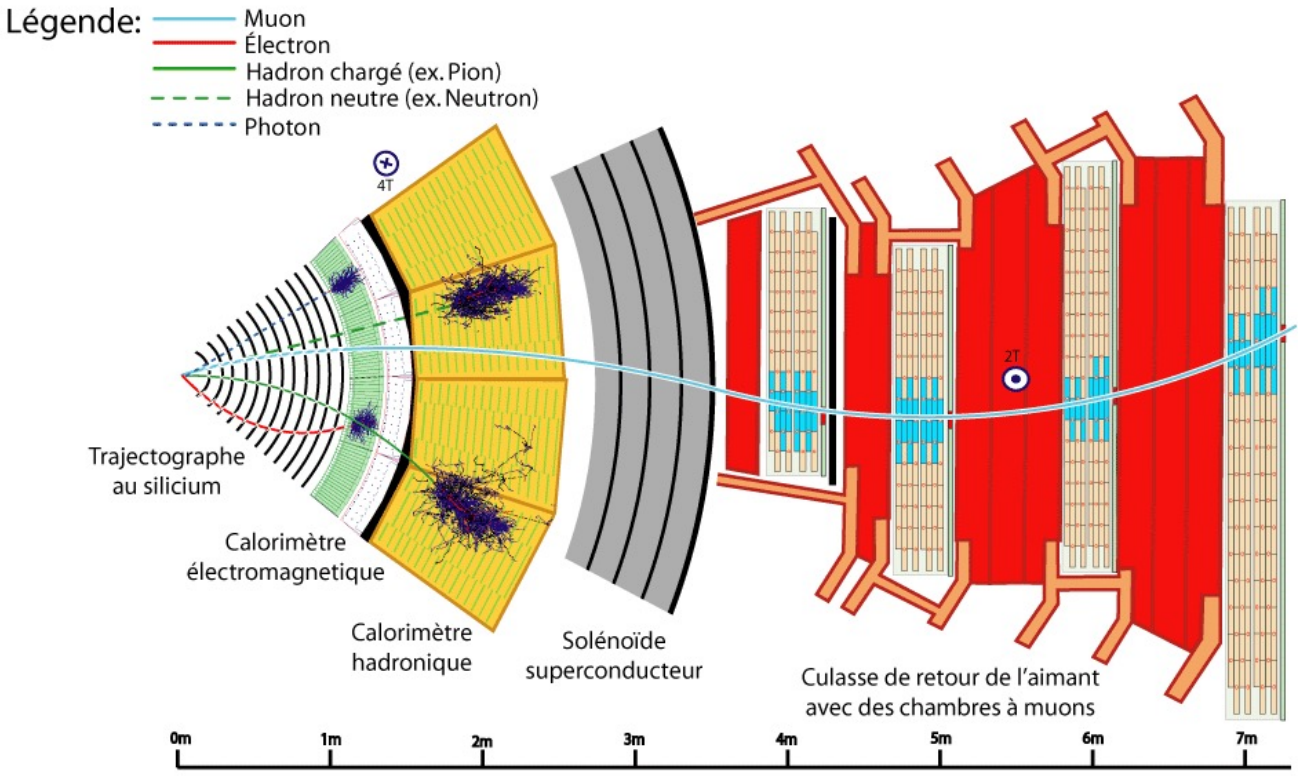


L'energia viene convertita in segnale elettrico

Il segnale elettrico viene convertito in grandezze fisiche che possiamo analizzare (posizione, energia, carica elettrica…)

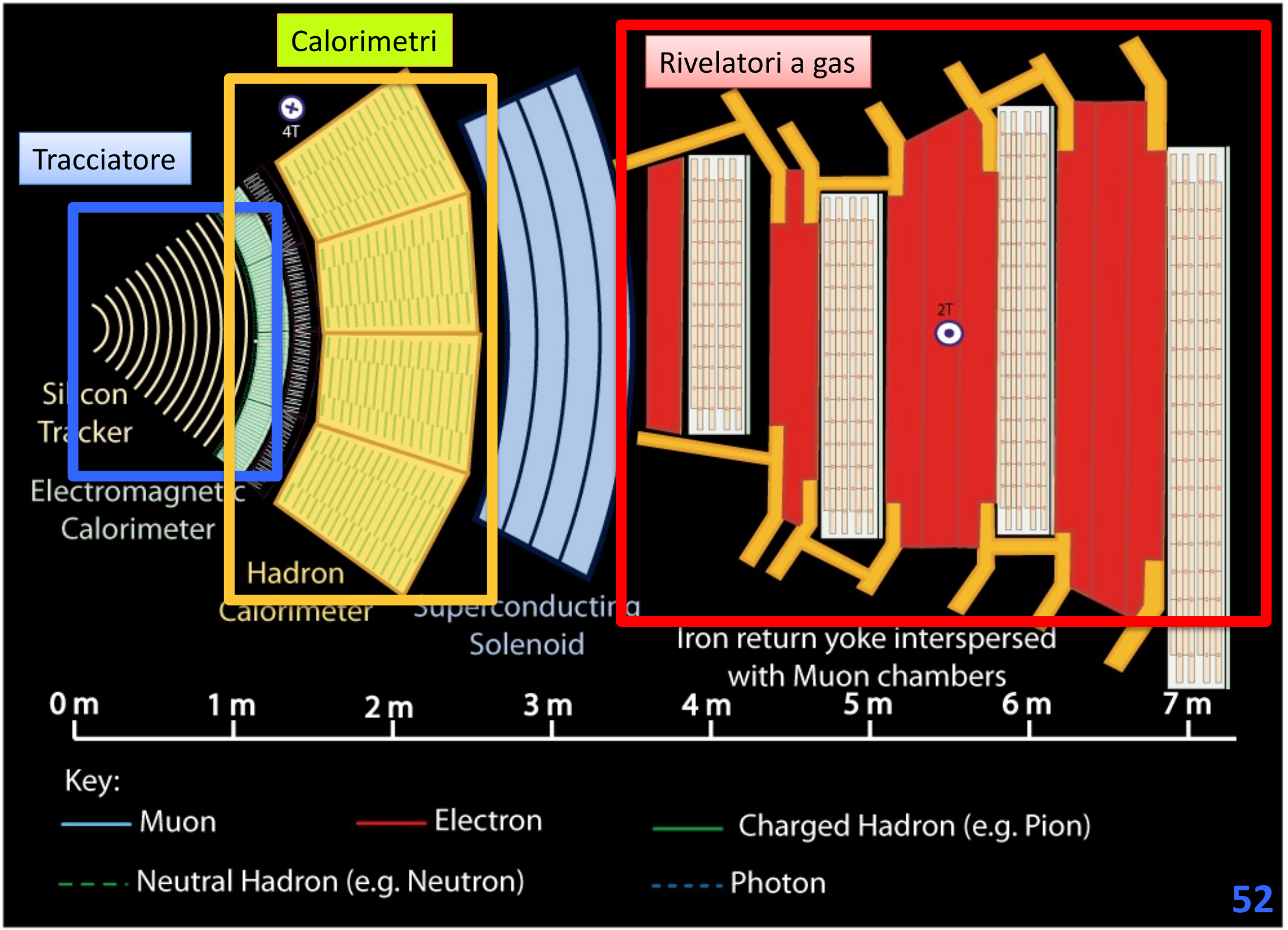
Soluzione: i rivelatori, una gigantesca macchina fotografica

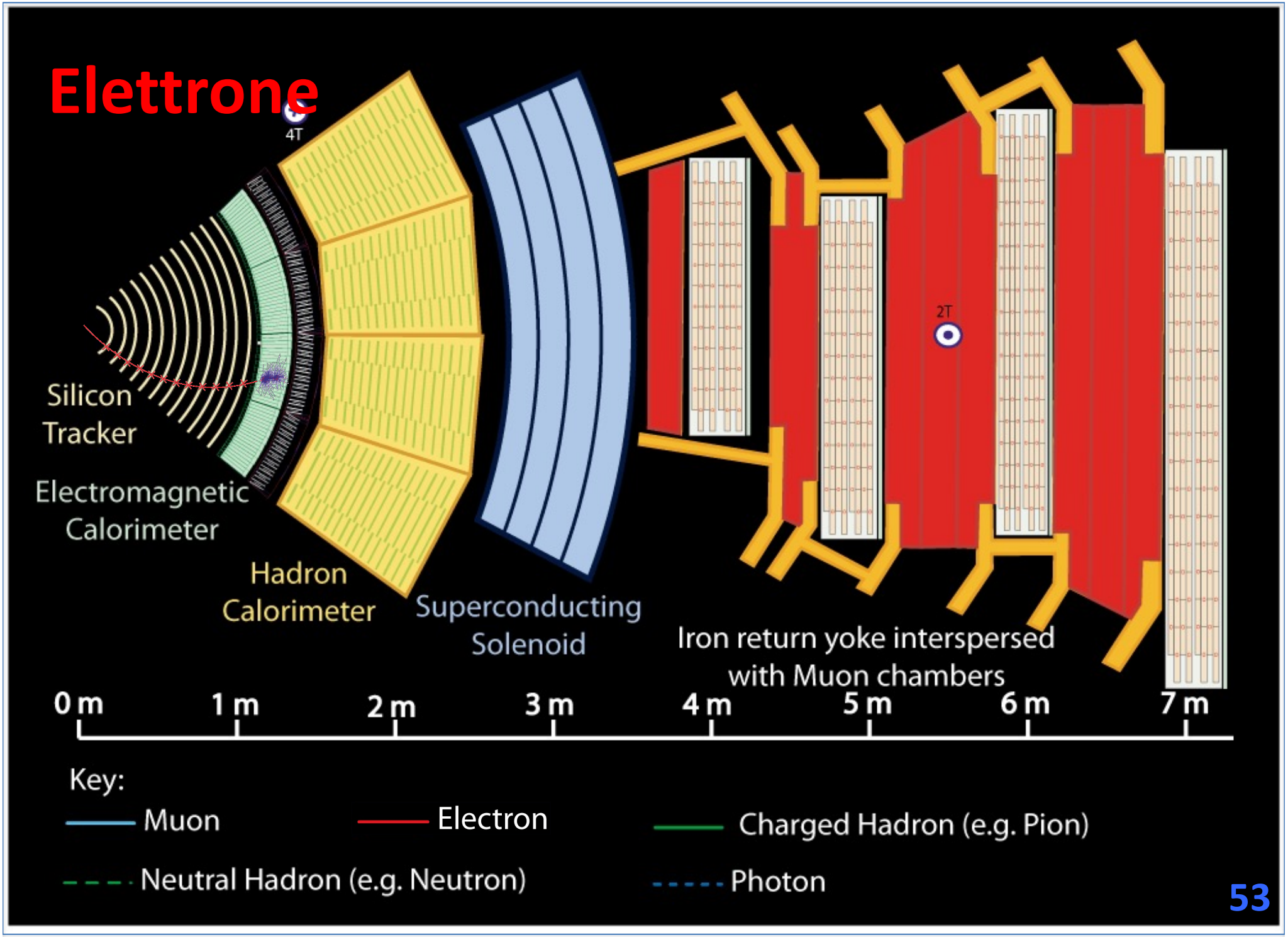




Composto da diversi apparati, ciascuno dedicato all'identificazione di un tipo di particella

Soluzione: i rivelatori, una gigantesca macchina fotografica


Calorimetri
Rivelatori a gas
Tracciatore
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon


Elettrone
4T
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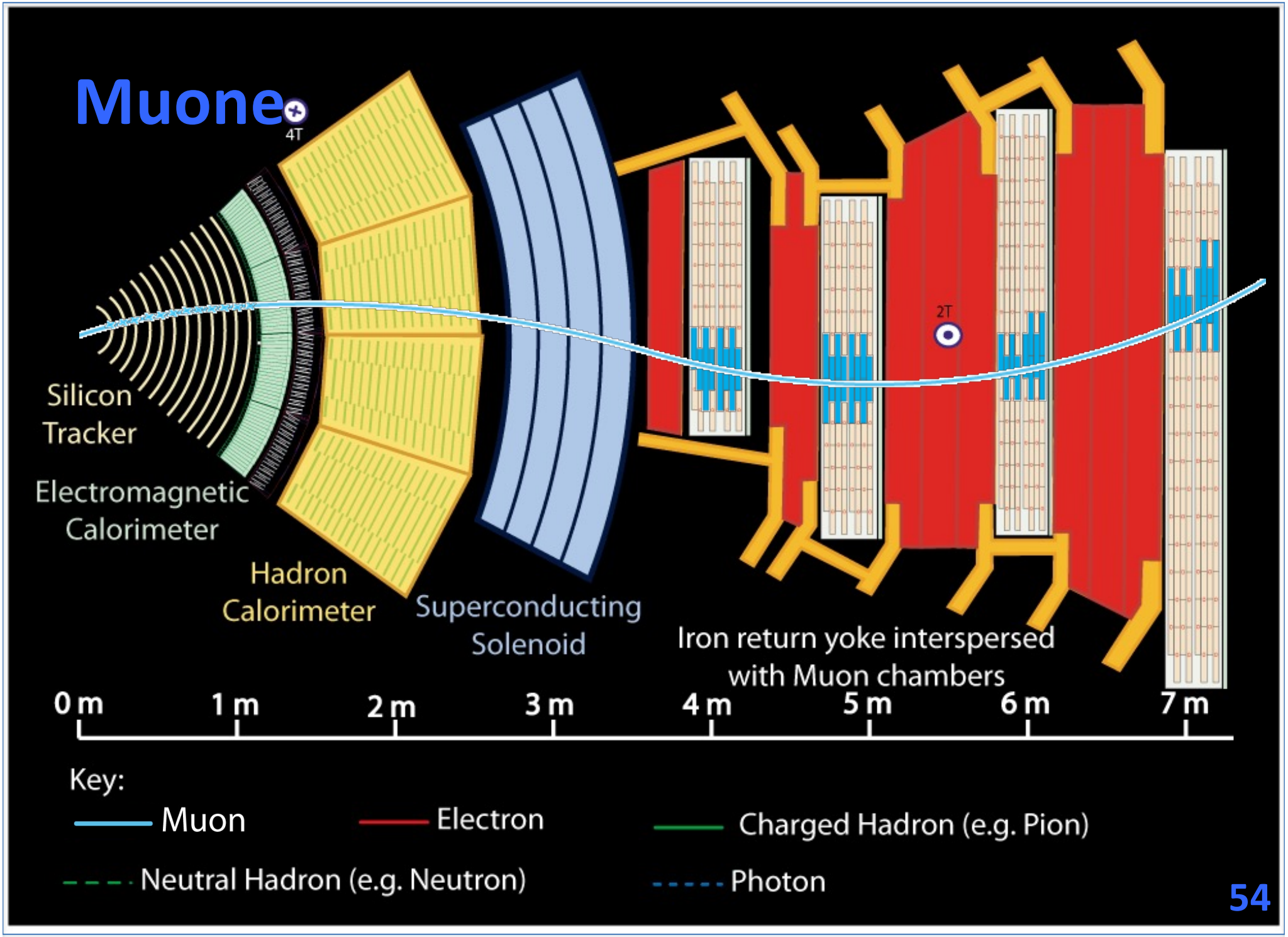
Muone
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Silicon Tracker
Electromagnetic Calorimeter
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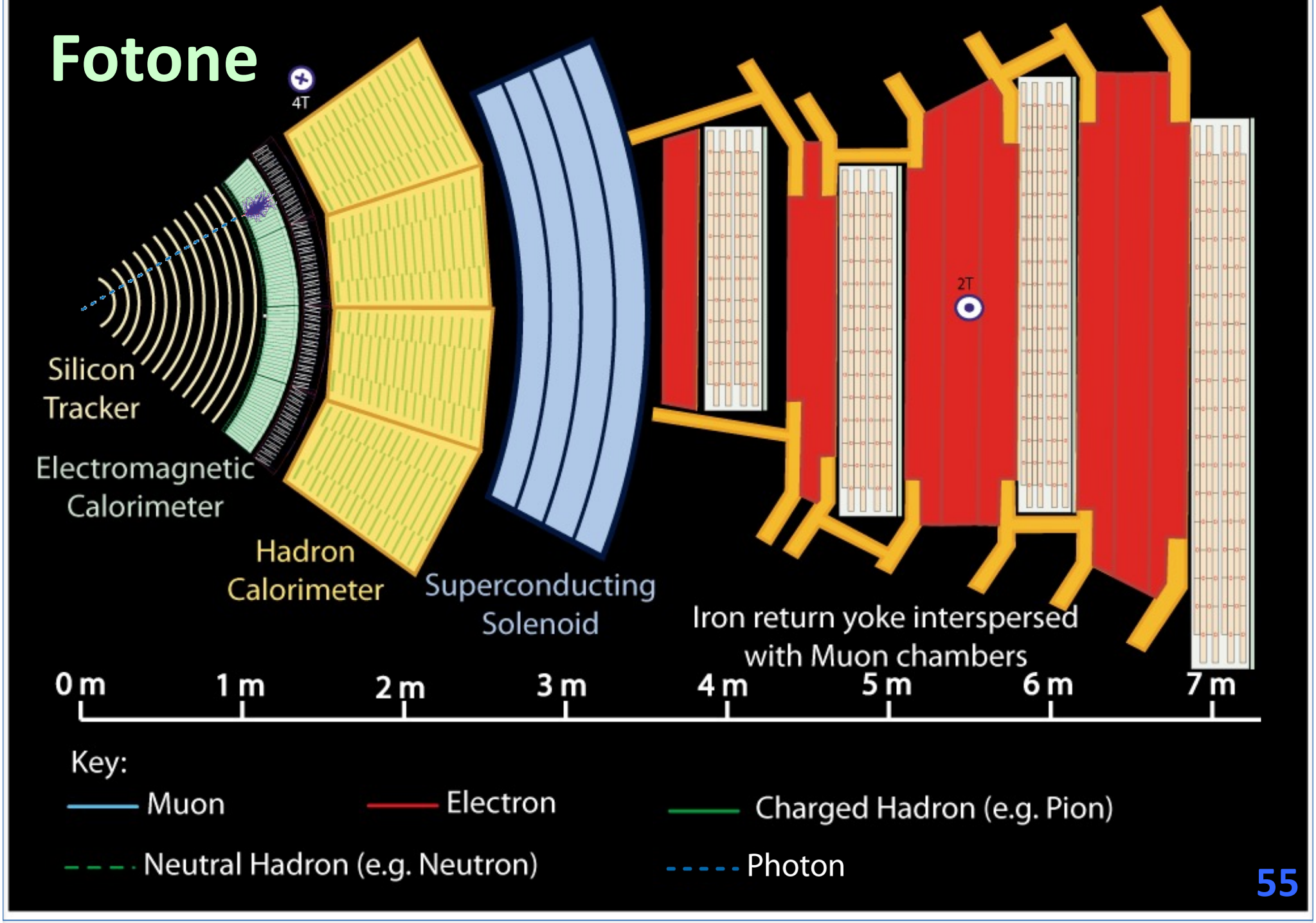
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon

Fotone


4T
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0 m
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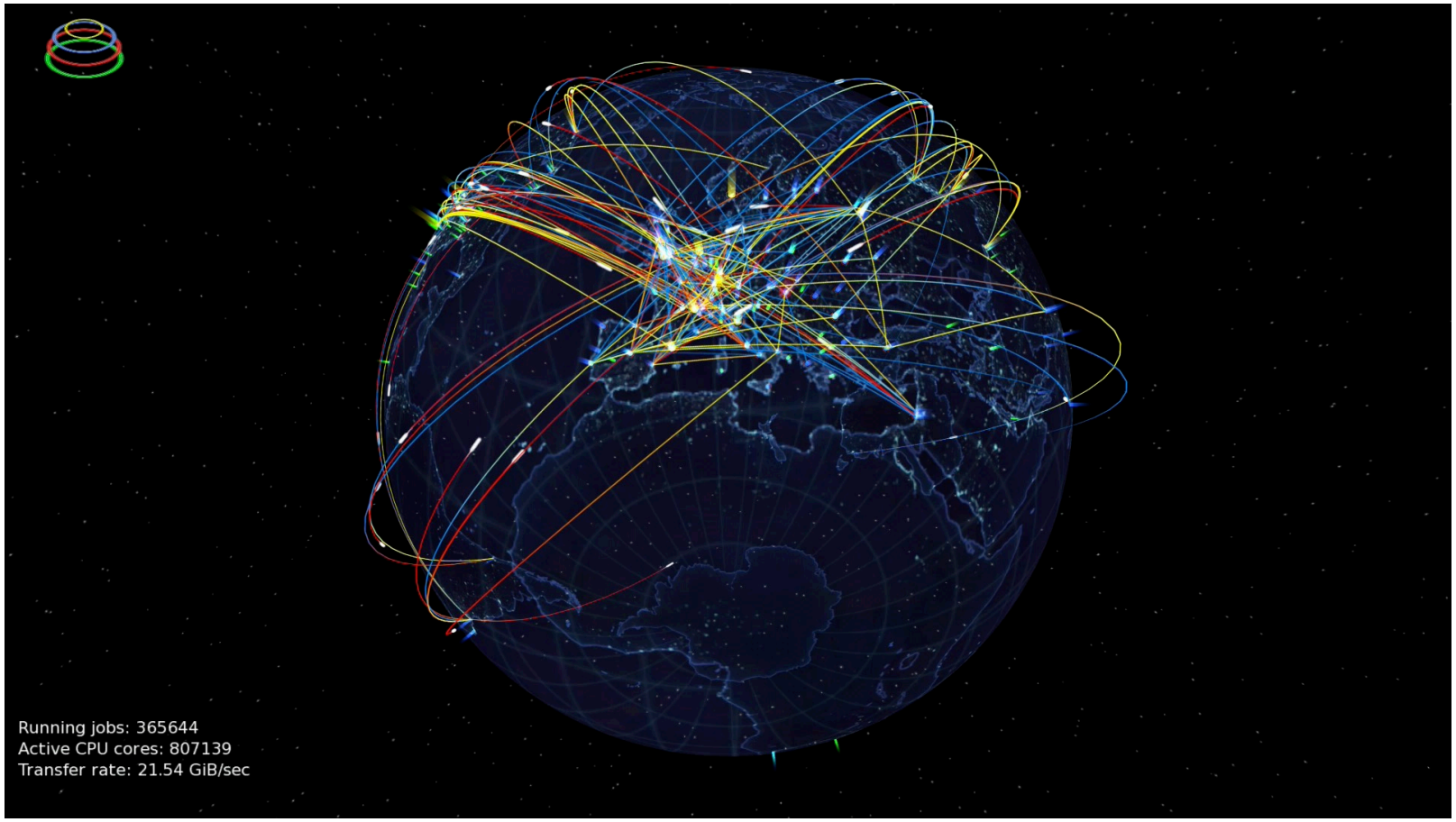
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon

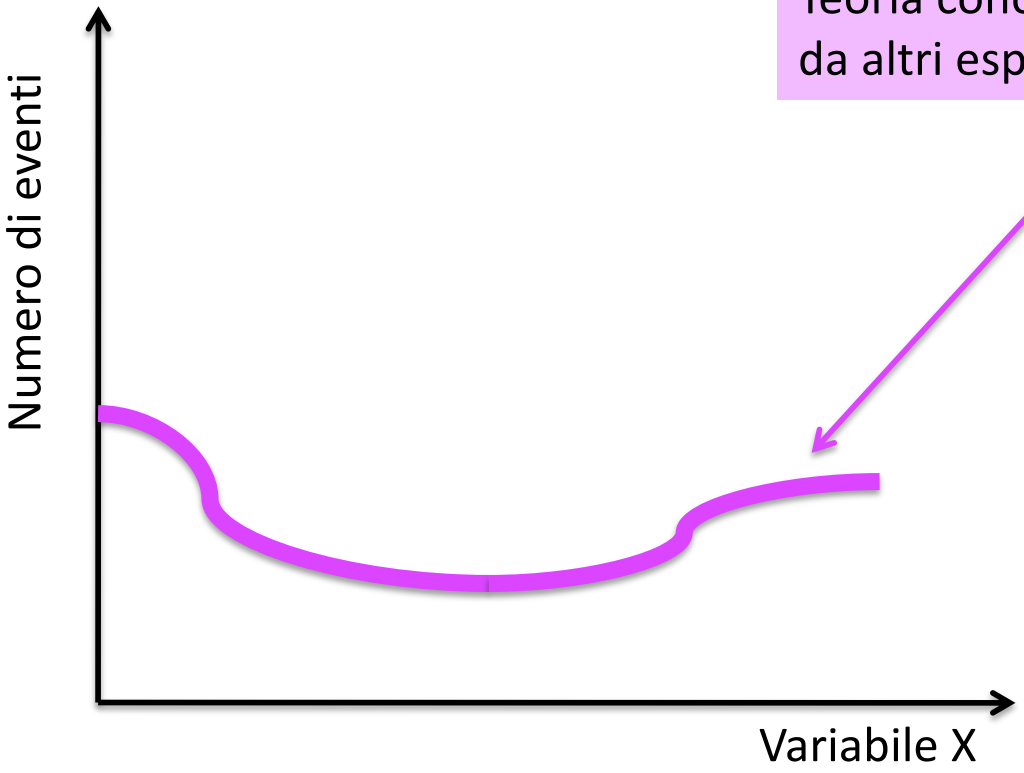
I dati

Gestione dei dati

- La mole di dati prodotti da LHC: ~200 Petabytes /anno
- **Worldwide LHC Computing Grid (WLCG)**
  - 170 centri di calcolo
  - 42 paesi (>1M processori)
- **Bari è uno dei centri di calcolo attivi!!**



In pratica …

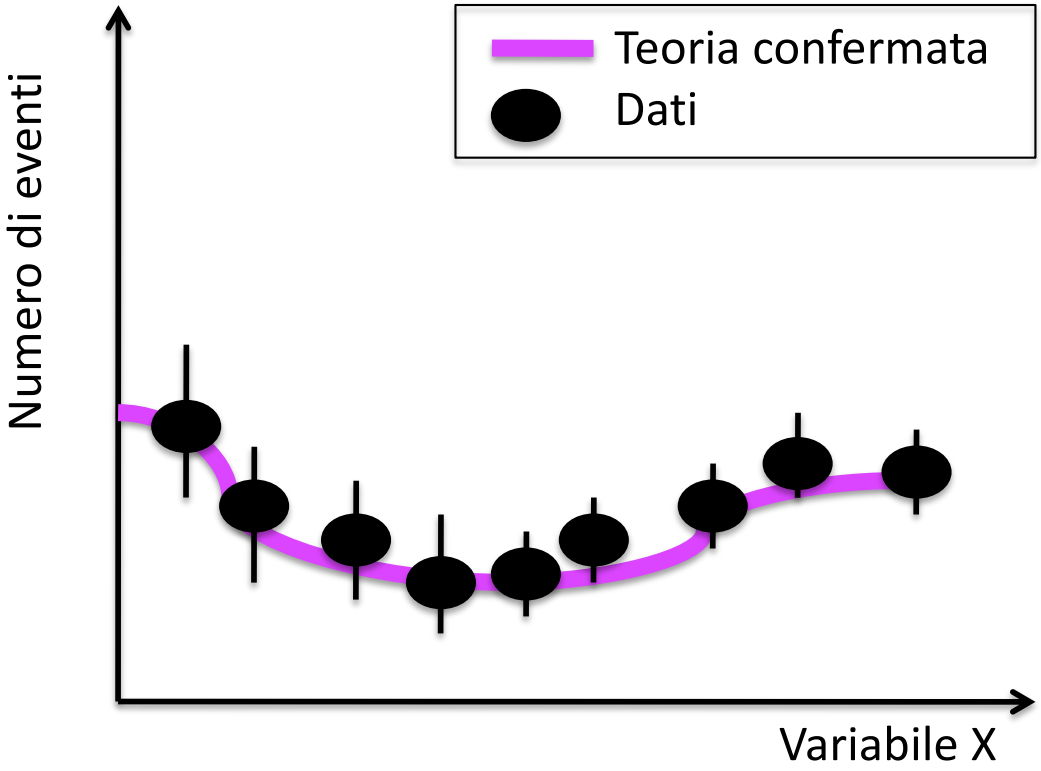


Teoria conosciuta confermata
da altri esperimenti

Facciamo il nostro esperimento
E raccogliamo dati…

"I'll be right back—can you watch my Large Hadron Collider?"

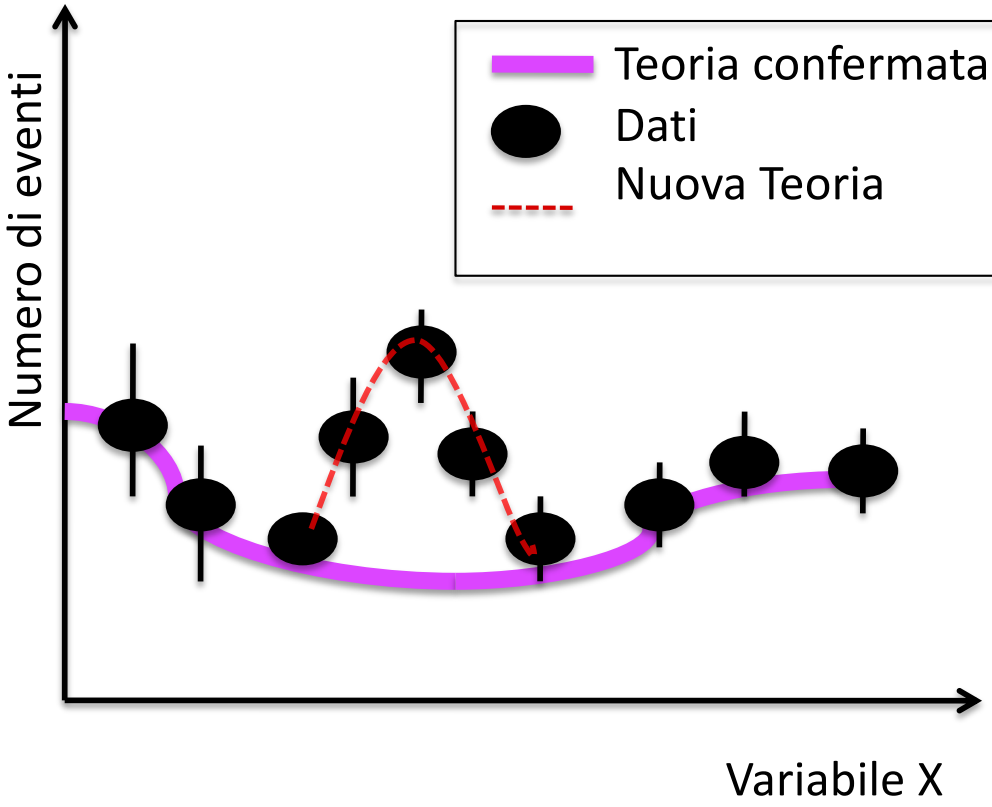
Caso 1



Anche i dati raccolti al nostro esperimento verificano la teoria

I fisici solitamente sono molto delusi

Caso 2



I dati raccolti al nostro esperimento si discostano dalla teoria confermata e sono compatibili con una nuova teoria

La scoperta del bosone di Higgs

Identikit del bosone di Higgs

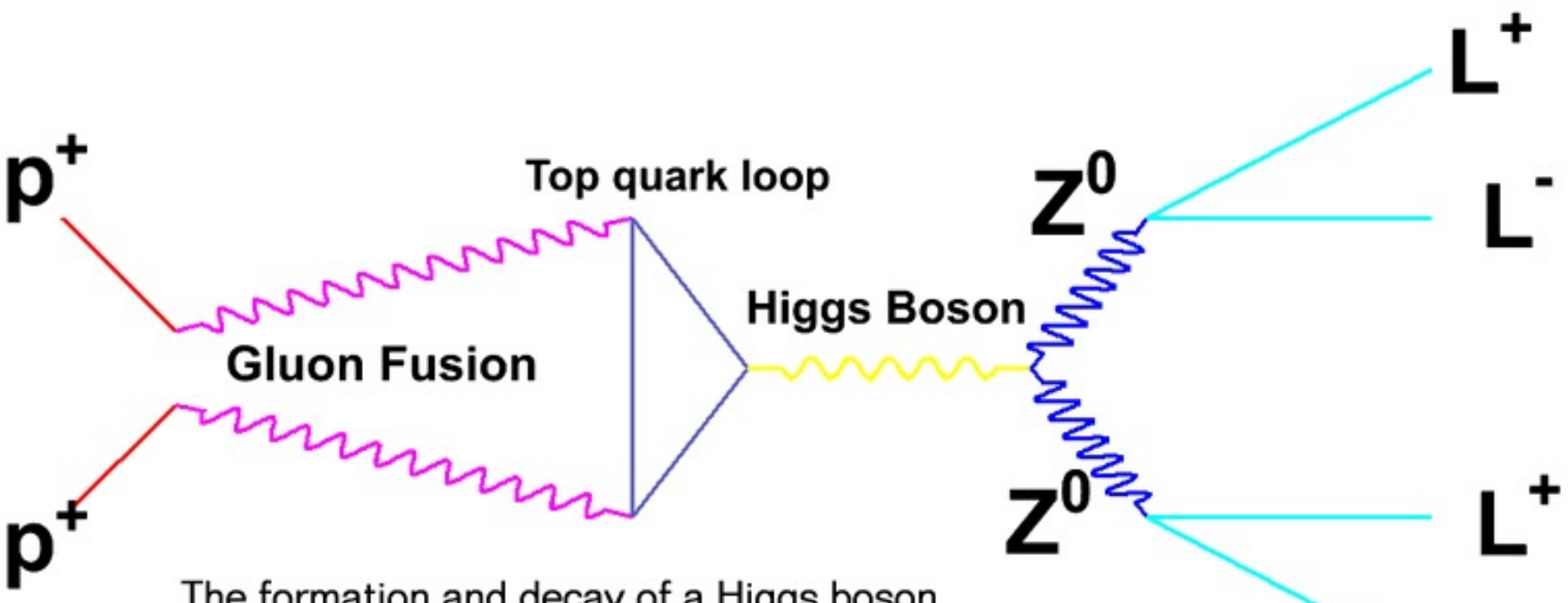
Massa: ~$2.5*10^{-22}$ g

Vita media: 10^{-22} secondi

Predetto: 1964 da P. Higgs, F. Englert, R. Brout, T. Kibble, Guralnik, Hagen

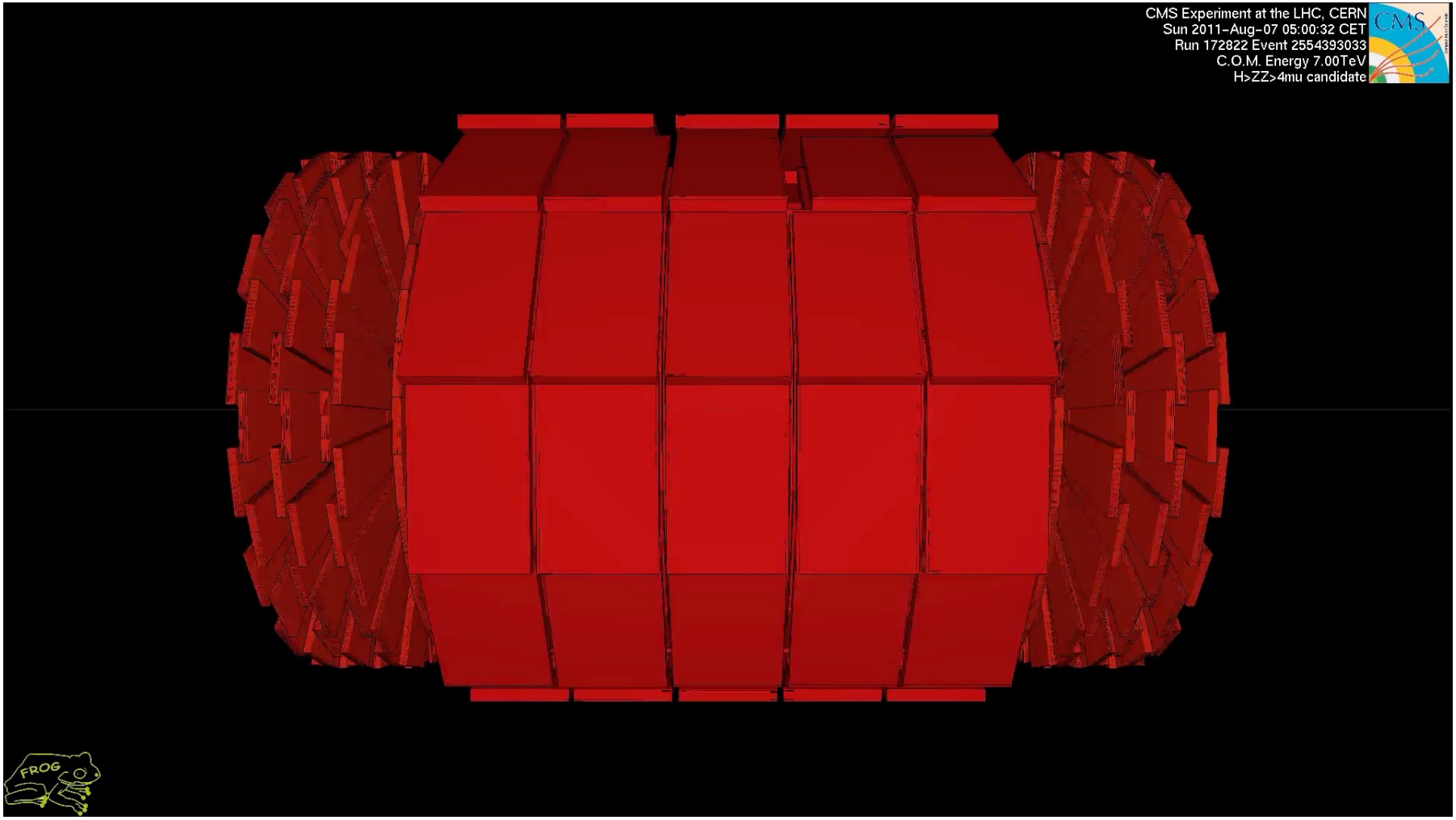
Vita da Higgs in teoria

Decadimento del bosone di Higgs in 4 elettroni

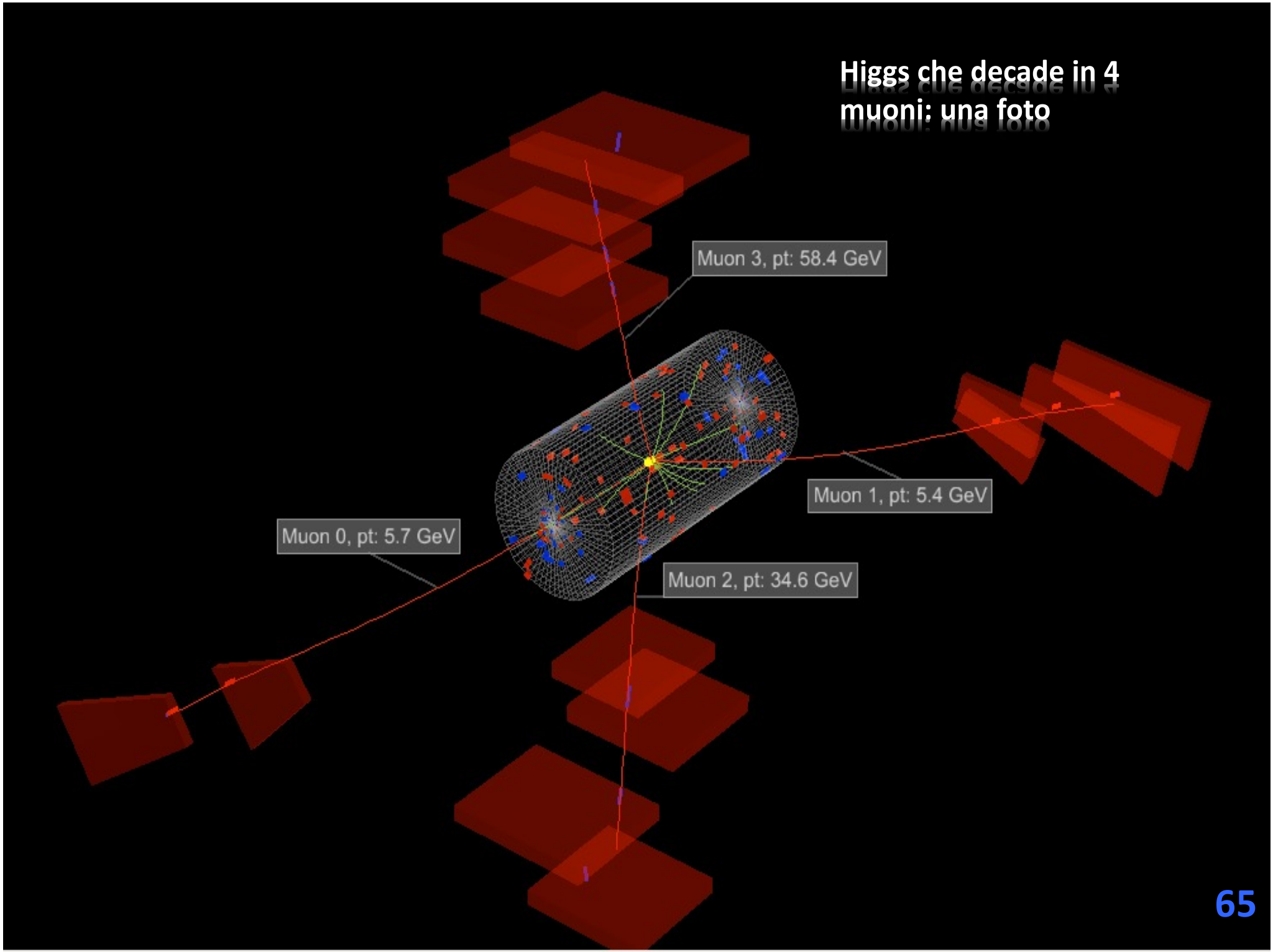


The formation and decay of a Higgs boson after a proton-proton collision. The decay would produce Z° hadrons and L leptons.

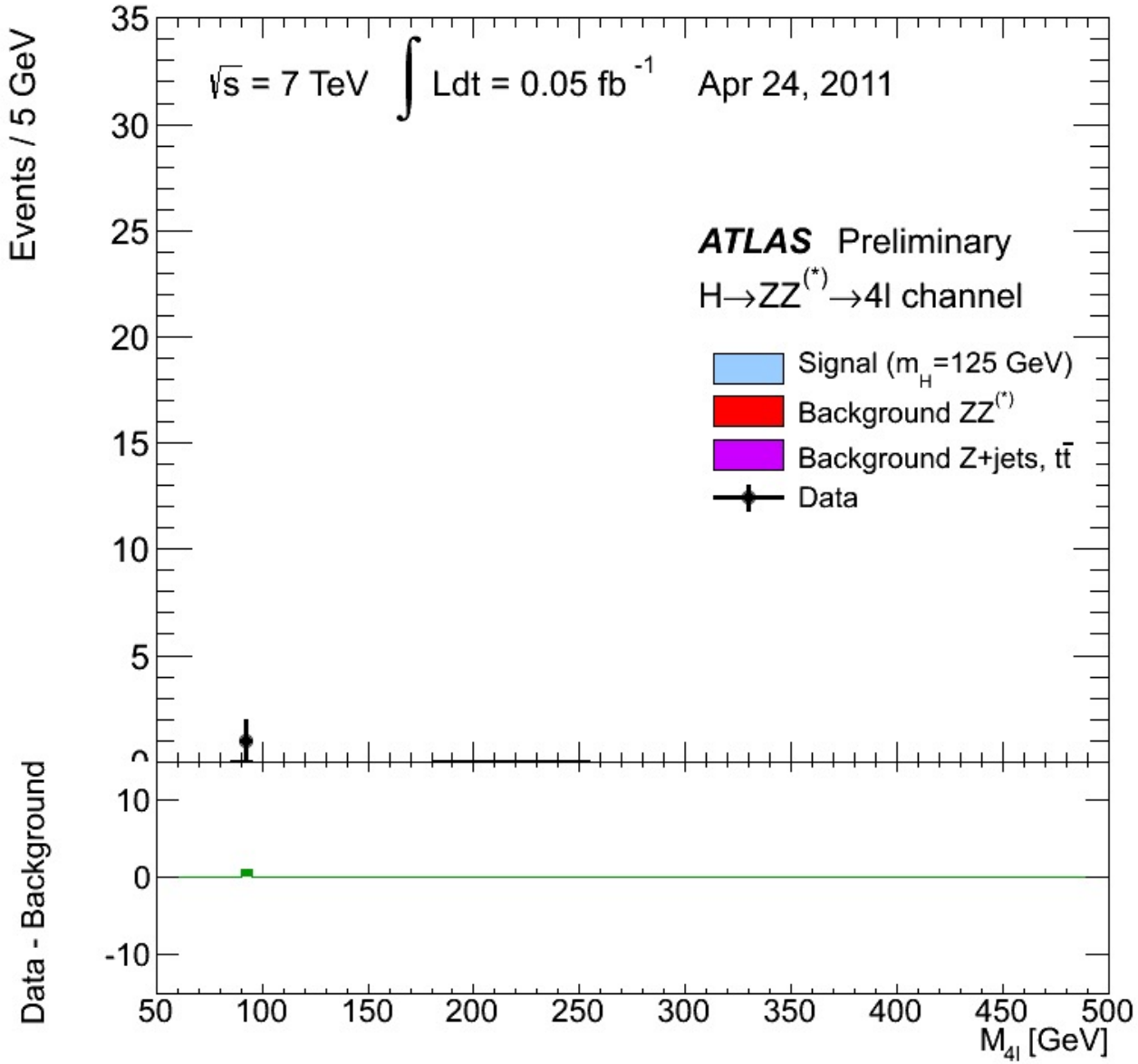
Higgs che decade in 4 muoni: documentario



Higgs che decade in 4 muoni: una foto

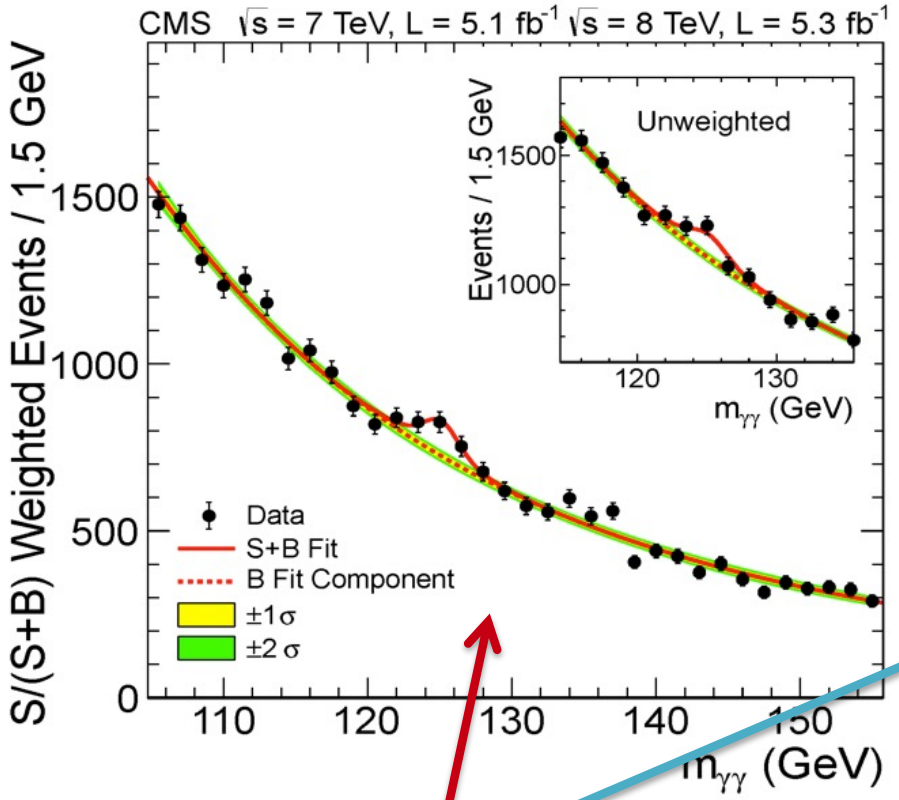


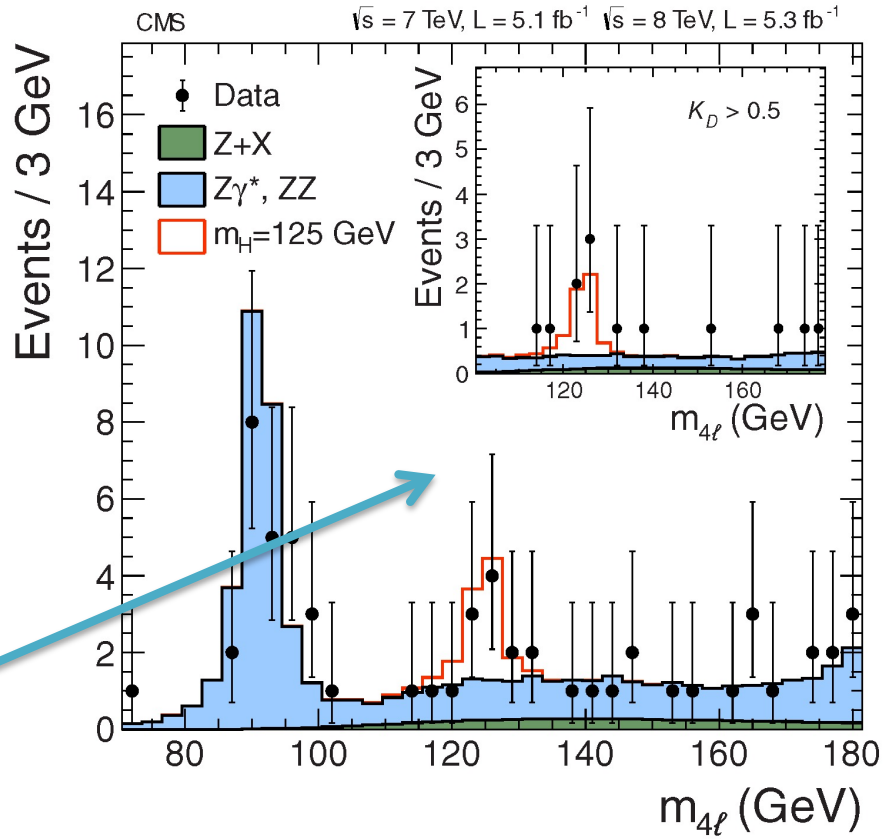
Basta una sola foto?



Rappresentazione di eventi di Higgs che decade in 4 muoni in un istogramma

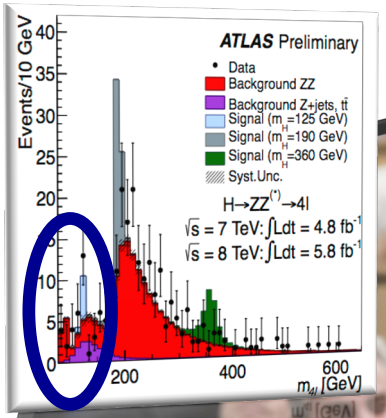
La scoperta

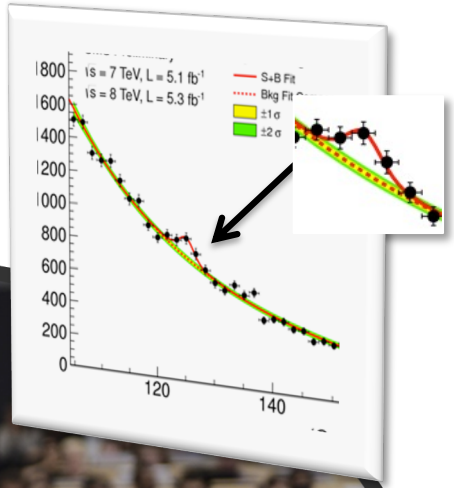




I “bump” nei dati implicano la presenza di una nuova particella: il bosone di Higgs!

CERN, 4 Luglio 2012

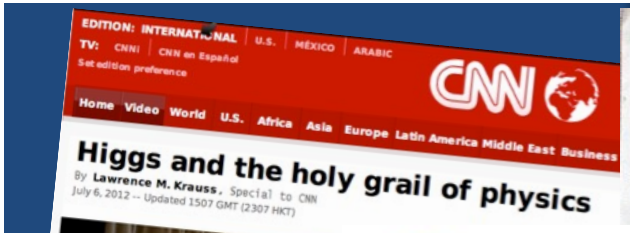




Fabiola Gianotti
ATLAS Spokesperson 2010-2012

Joe Incandela
CMS Spokesperson 2012-2013

Eureka!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Higgs and the holy grail of physics
By Lawrence M. Krauss, Special to CNN
July 6, 2012 -- Updated 1507 GMT (2307 HKT)

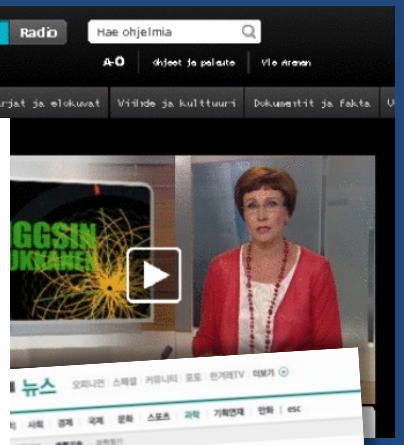

THE AUSTRALIAN
Carbon dealing not over for Labor
After 50 years – and billions of dollars – the God particle is no longer a theory
Asylum calls 'use navy like NRMA'


NewScientist


CERN
Higgs search update 04.07.2012
Searching for the


il manifesto
Rai, guerra s
Il Cda lo dec
Materiali storico


The Nobel Prize in Physics 2013
François Englert, Peter Higgs
The Nobel Prize in Physics 2013
Photo: A. Mahmoud
François Englert
Prize share: 1/2
Photo: A. Mahmoud
Peter W. Higgs
Prize share: 1/2


REENA
TV
Radio
Hae ohjelmia


뉴스
'힉스 입자'에 이름 붙인 건
'무궁화 꽃...' 실제 모델 이휘소 박사


ВЕСТИ RU
Открытие "частицы Бога" сдел
премию Нобеля


La masse est dite
l'ancien patron mis en examen
A nos lecteurs


CERN researcher Albert de Roeck explains the Higgs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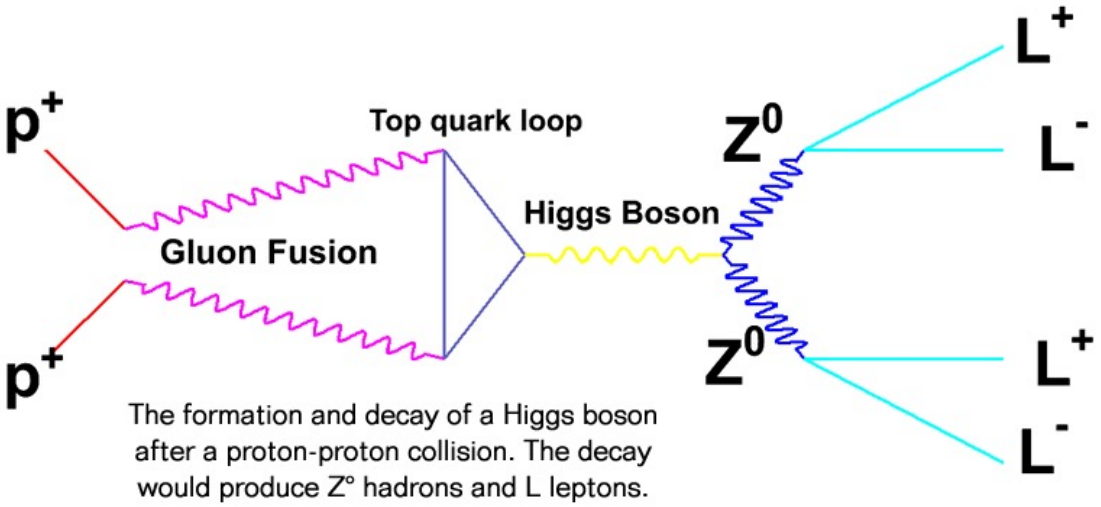
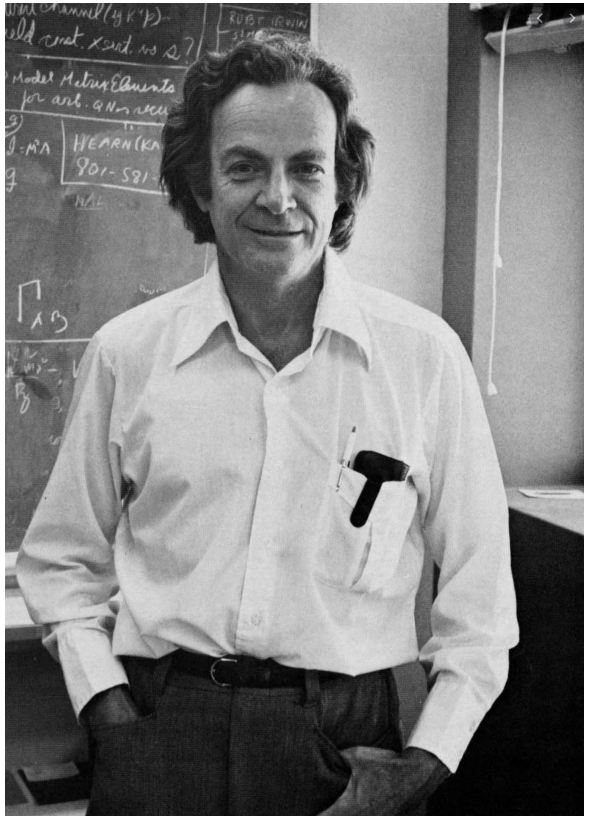
Immagini e immaginazione: I diagrammi di Feynman

La teoria: i diagrammi di Feynman



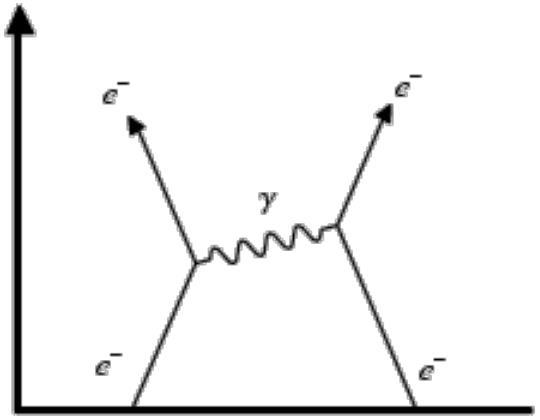
The formation and decay of a Higgs boson after a proton-proton collision. The decay would produce Z° hadrons and L leptons.



Richard Feynman, 1918-1988

Il linguaggio matematico del Modello Standard: diagrammi di Feynman

Name	Graph Element	Mathematical Equivalent	Physical Interpretation
Outgoing N line	x	$\bar{\psi}^{+}(x)$	N emitted (creation)
Outgoing $\bar{N}$ line	x	$\psi^{+}(x)$	$\bar{N}$ emitted (creation)
Incoming N line	x	$\psi^{-}(x)$	N absorbed (annihilation)
Incoming $\bar{N}$ line	x	$\bar{\psi}^{-}(x)$	$\bar{N}$ absorbed (annihilation)
Outgoing π line	x	$\varphi^{+}(x)$	π emitted (creation)
Incoming π line	x	$\varphi^{-}(x)$	π absorbed (annihilation)
Internal N line	x y	$iS_F(x-y)$	Virtual N
Internal $\bar{N}$ line	x y	$-iS_F(y-x)$	Virtual $\bar{N}$
Internal π line	x y	$i\Delta_F(x-y)$	Virtual π
Vertex	$\dot{x}$	$-g_0\gamma_5$ and $\int dx$	Interaction
Closed N loop		Precede with $-\mathrm{Tr}$	—

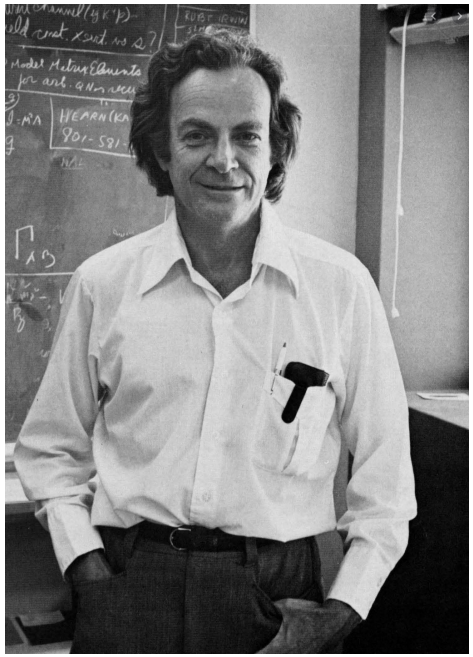


Leptoni, quark

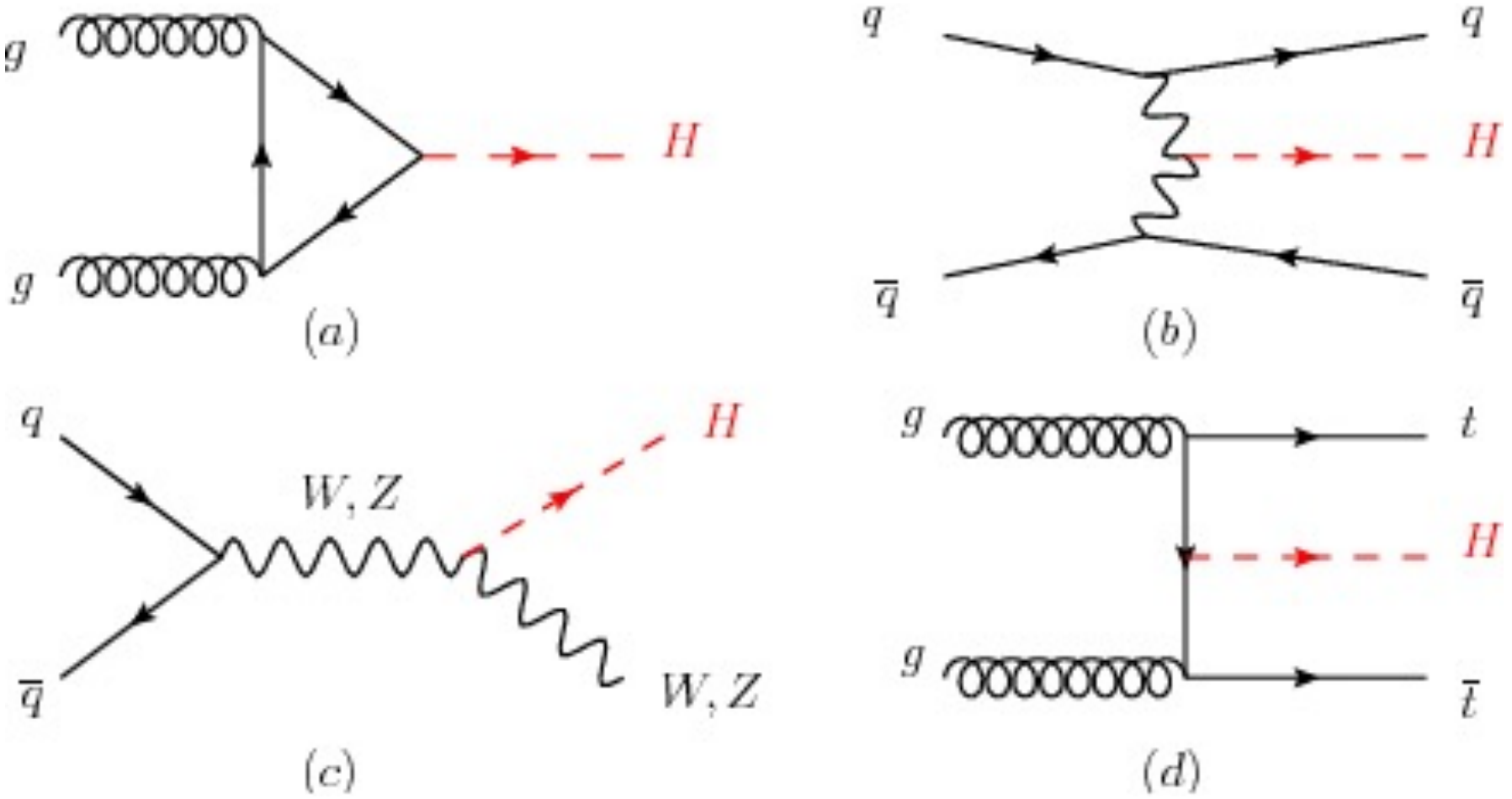
Fotoni, W, Z

gluoni

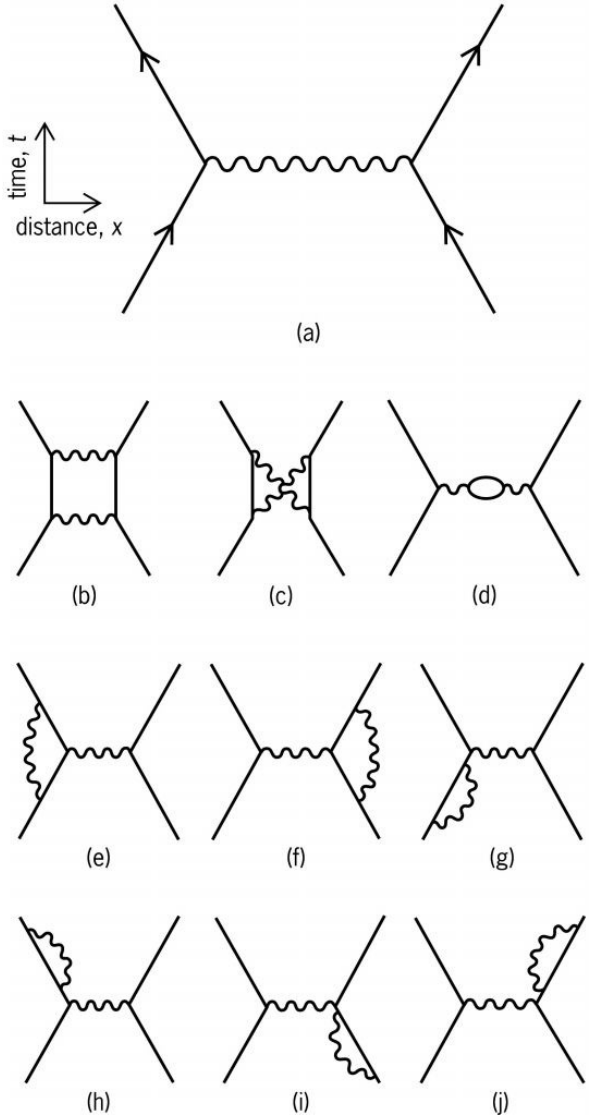
Bosone di Higgs

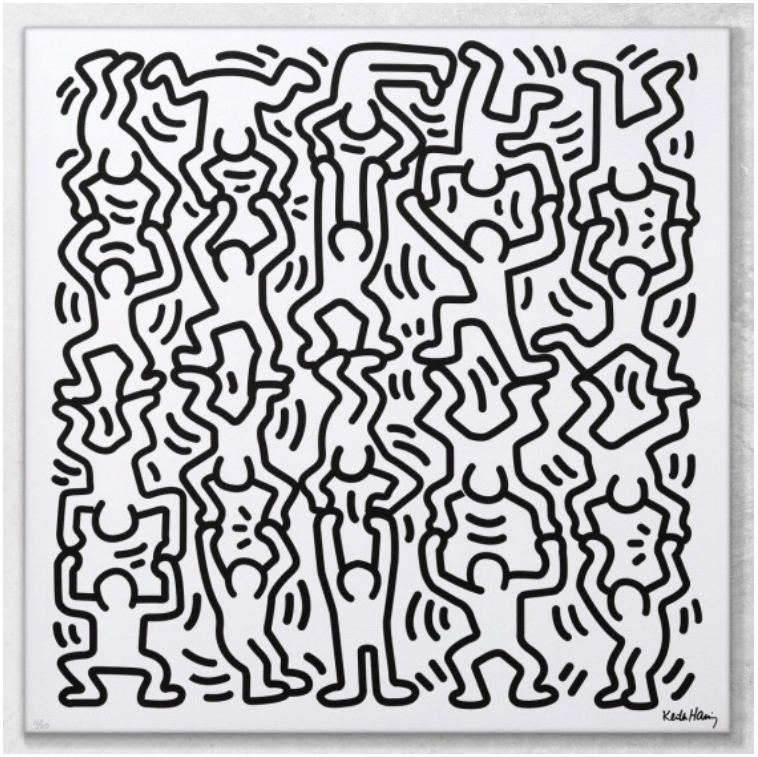


Diagrammi di Feynmann per la produzione di un bosone di Higgs?

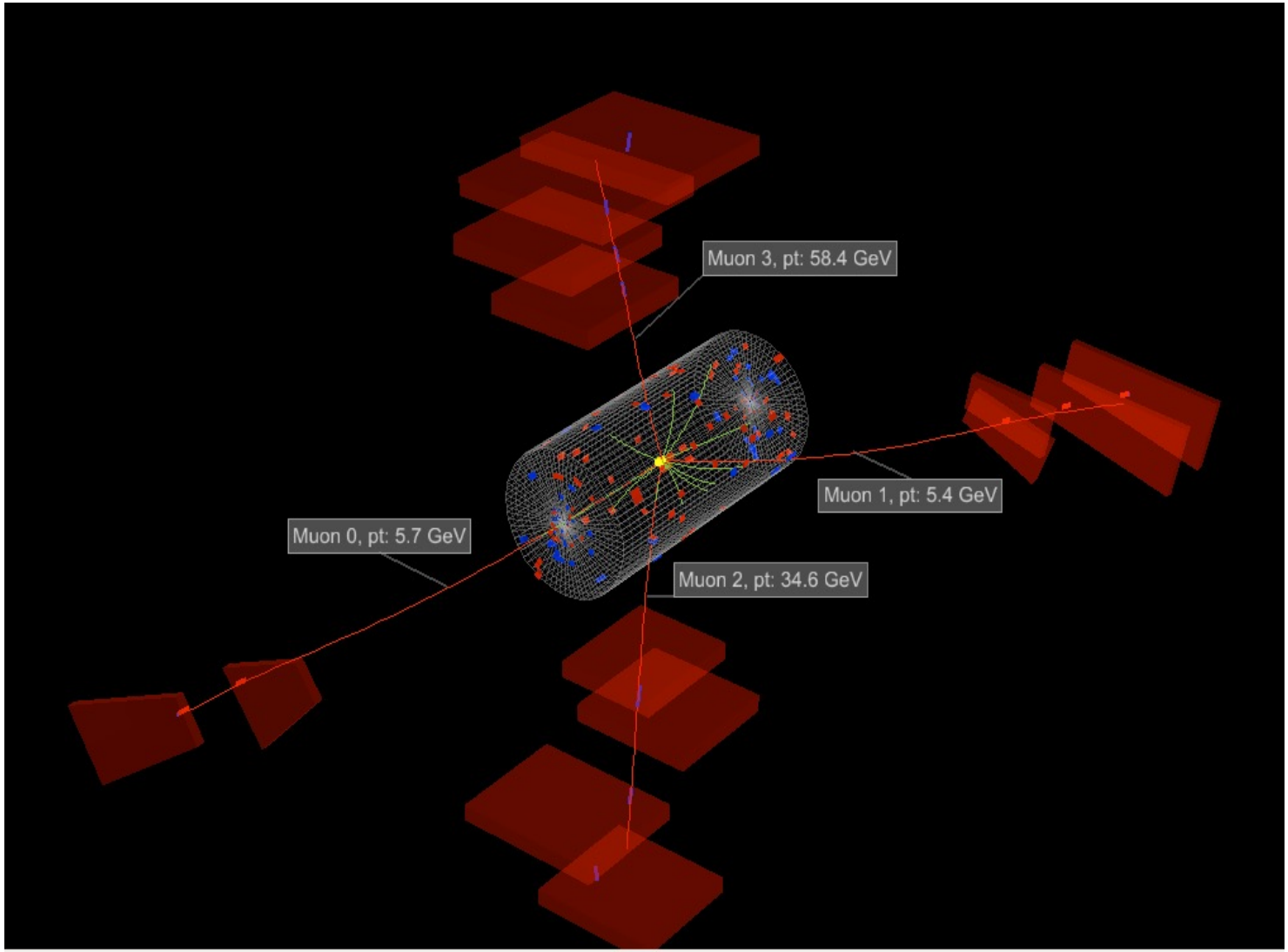


Diagrammi di Feynman o opera d'arte?





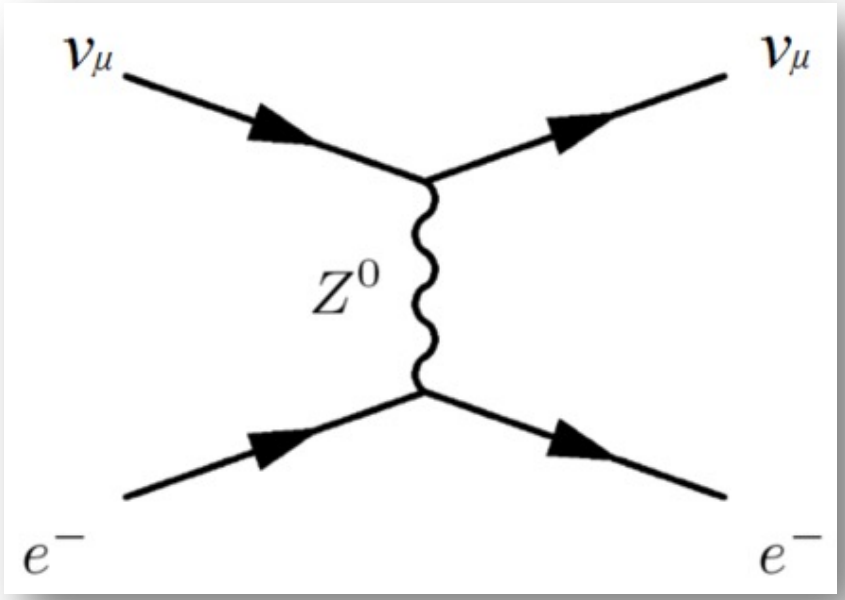
Immagini e immaginazione: gli event display



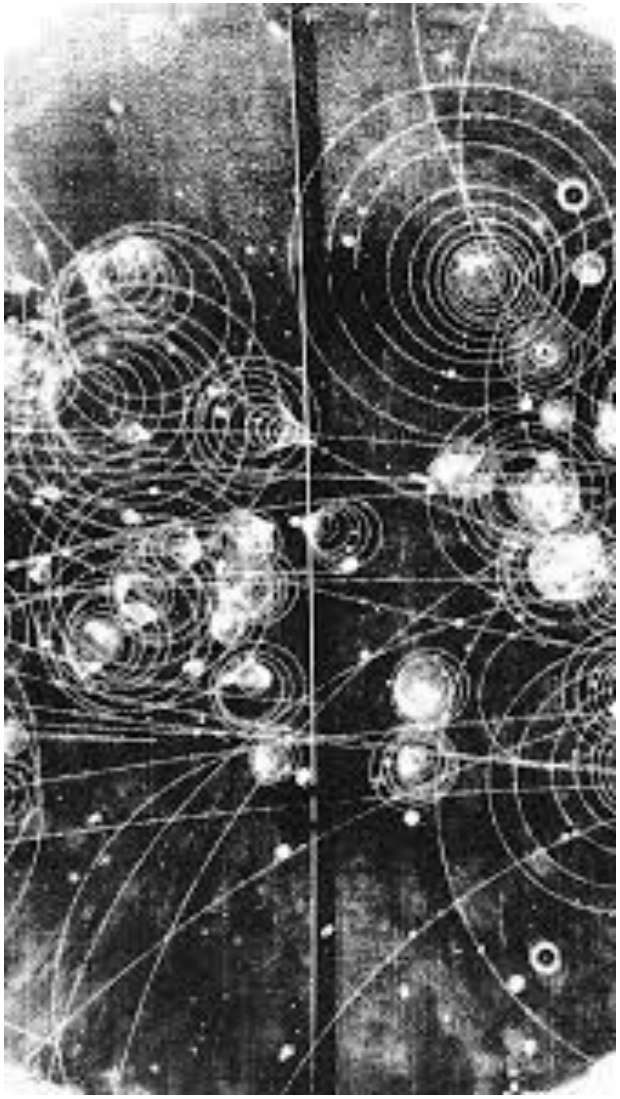
Evento Higgs →4muoni visto dall'esperimento CMS

Immagini prodotte da un esperimento più "antico"

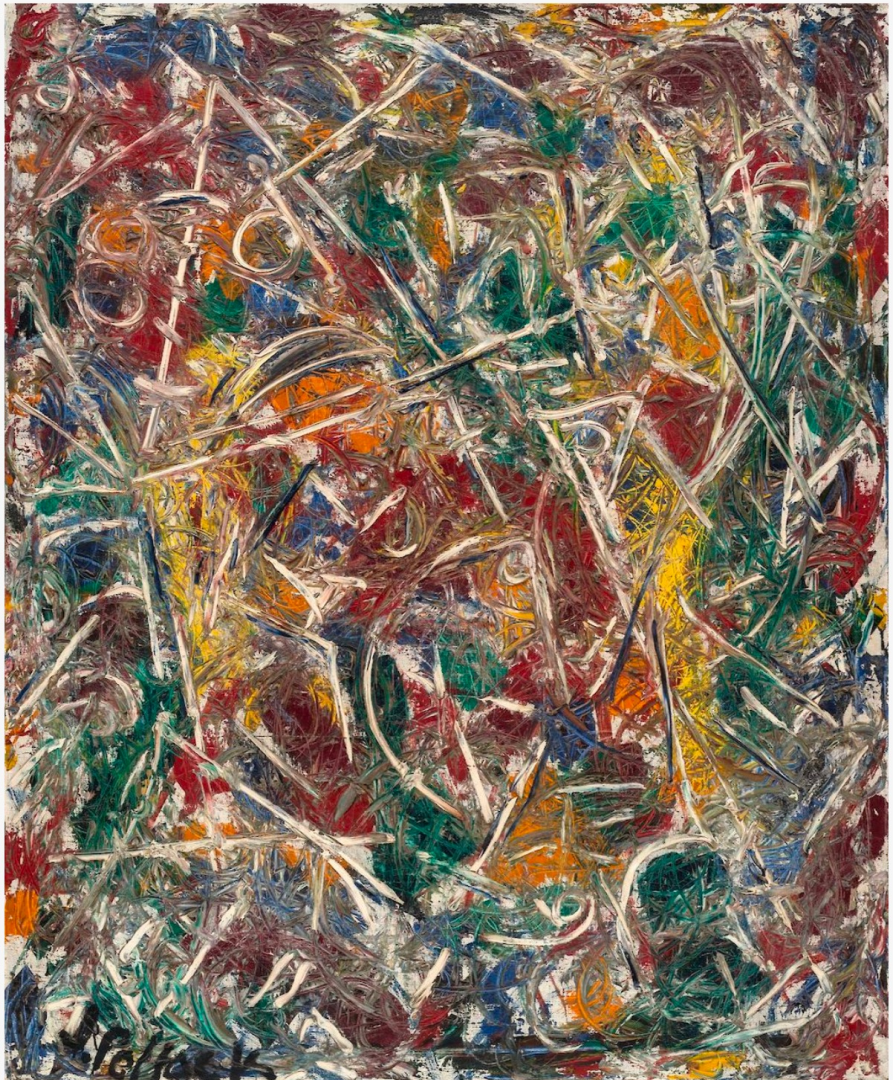
Gargamelle:a heavy liquid bubble chamber detector in operation at CERN between 1970 and 1979.



Event display e immaginazione

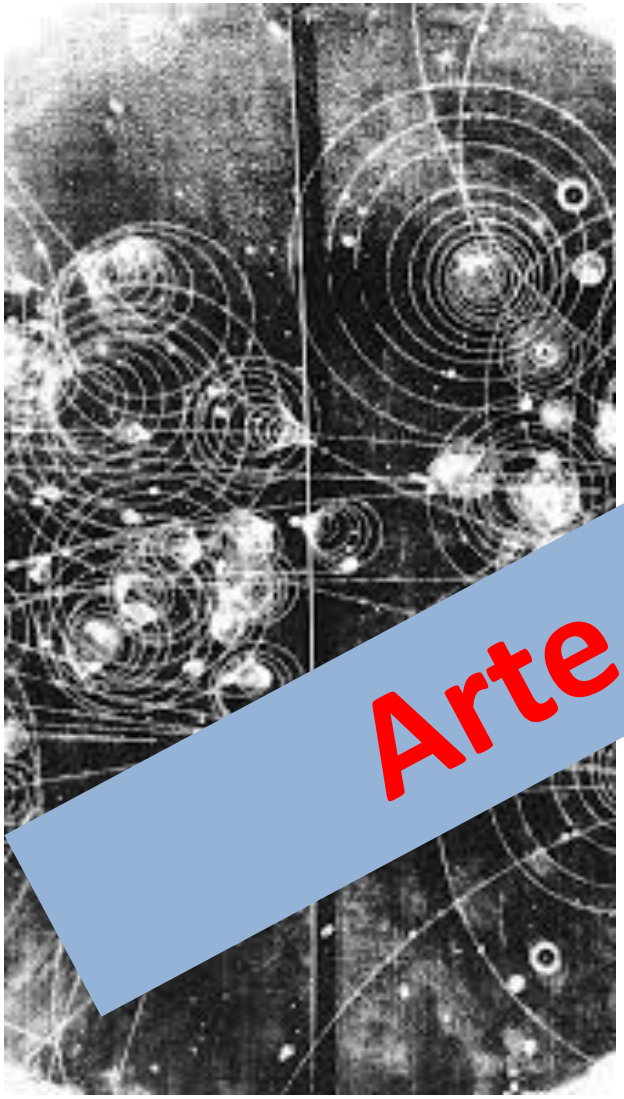


Event display di una camera a bolle



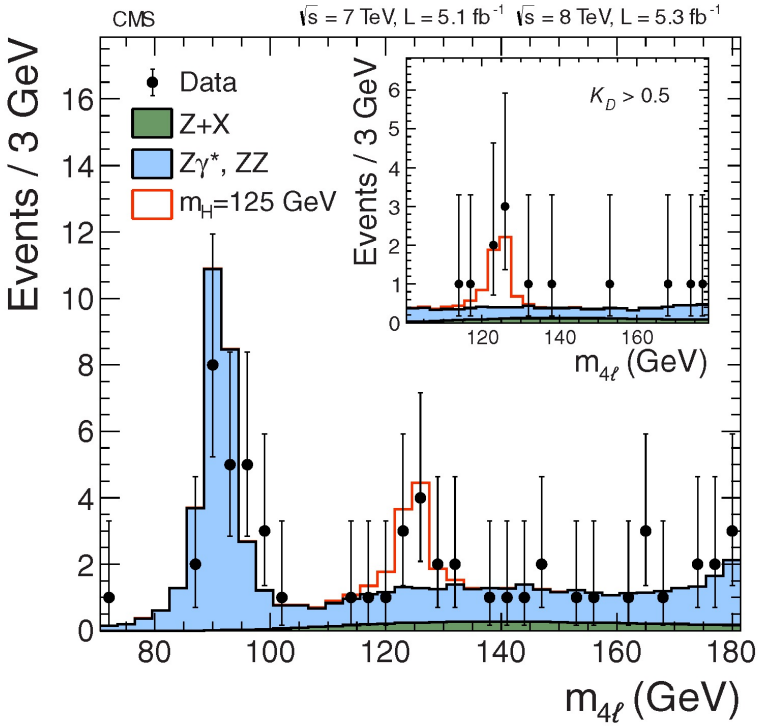
Una tela di Pollock

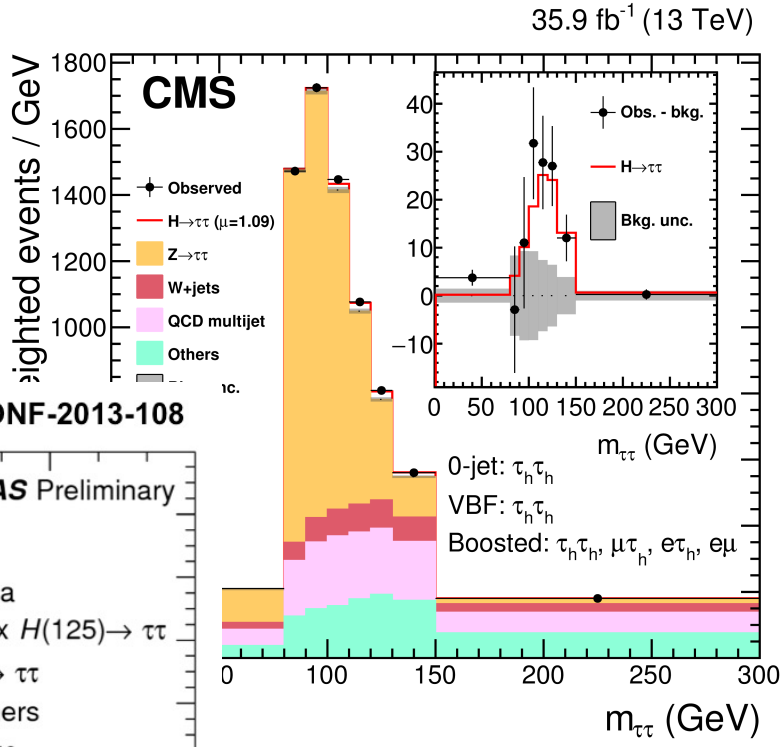
Event display e immaginazione

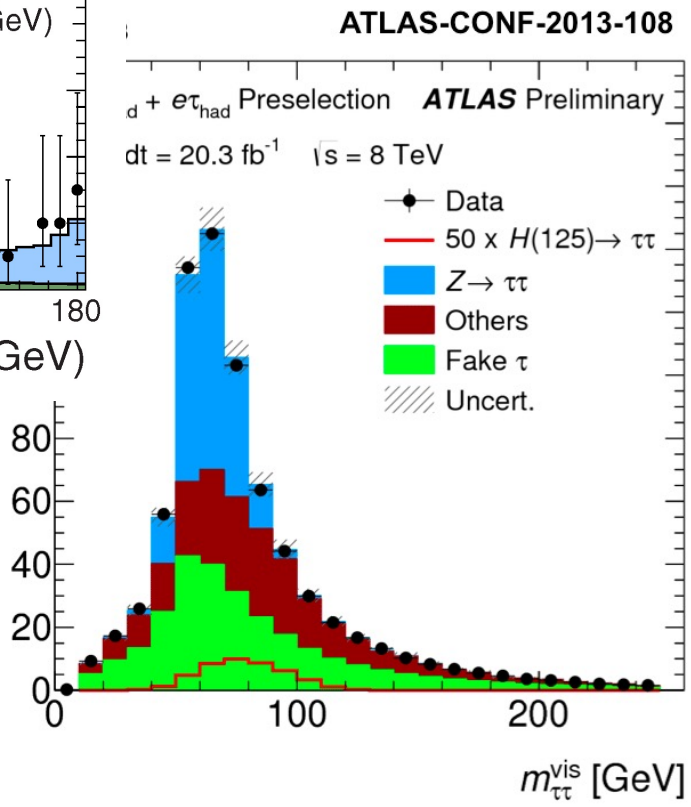


Arte o scienza?

Immagini e immaginazione: gli istogrammi

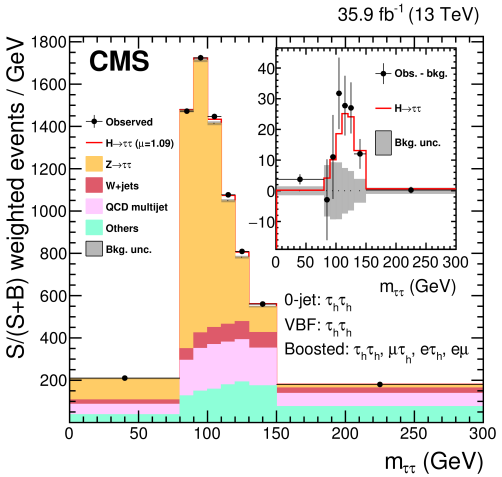


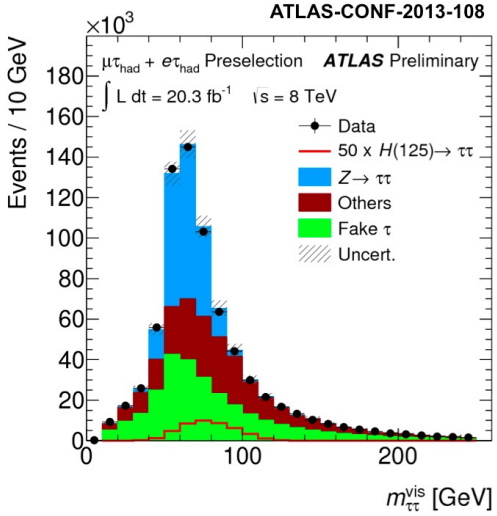


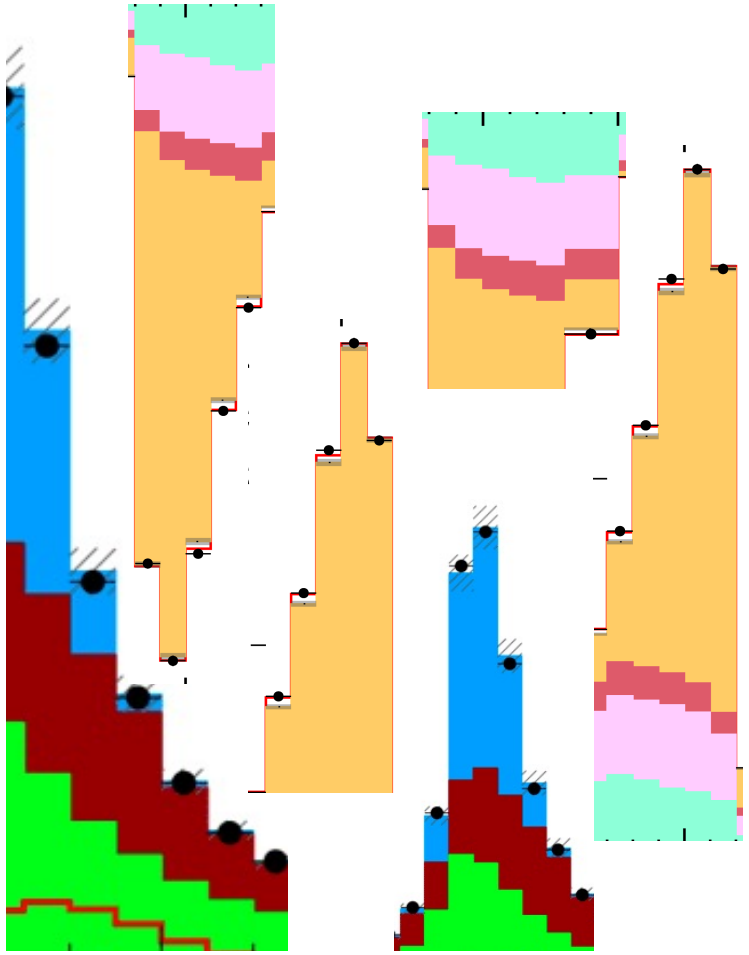


Istogrammi da cui si evince l'esistenza del bosone di Higgs

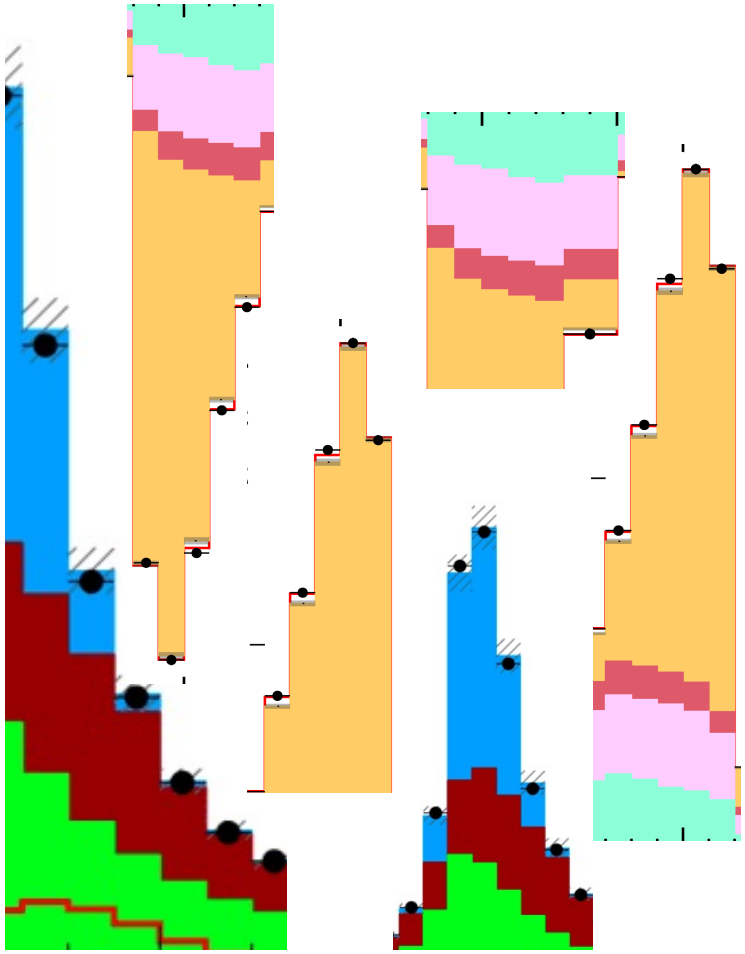
Immagini e immaginazione: gli istogrammi

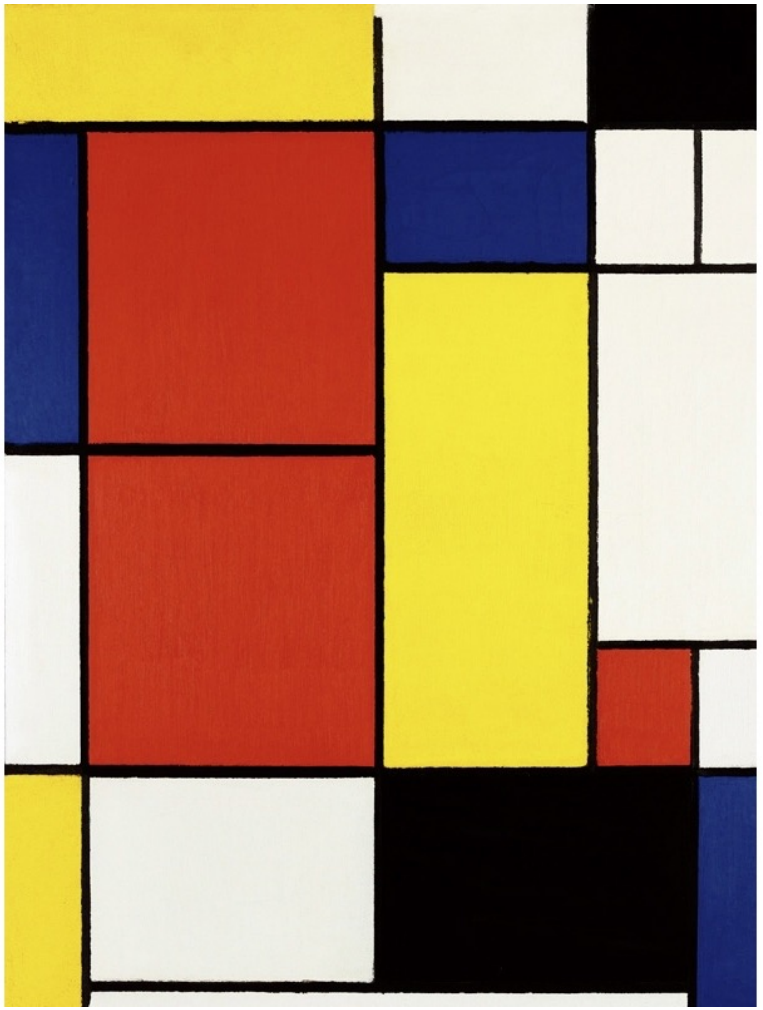






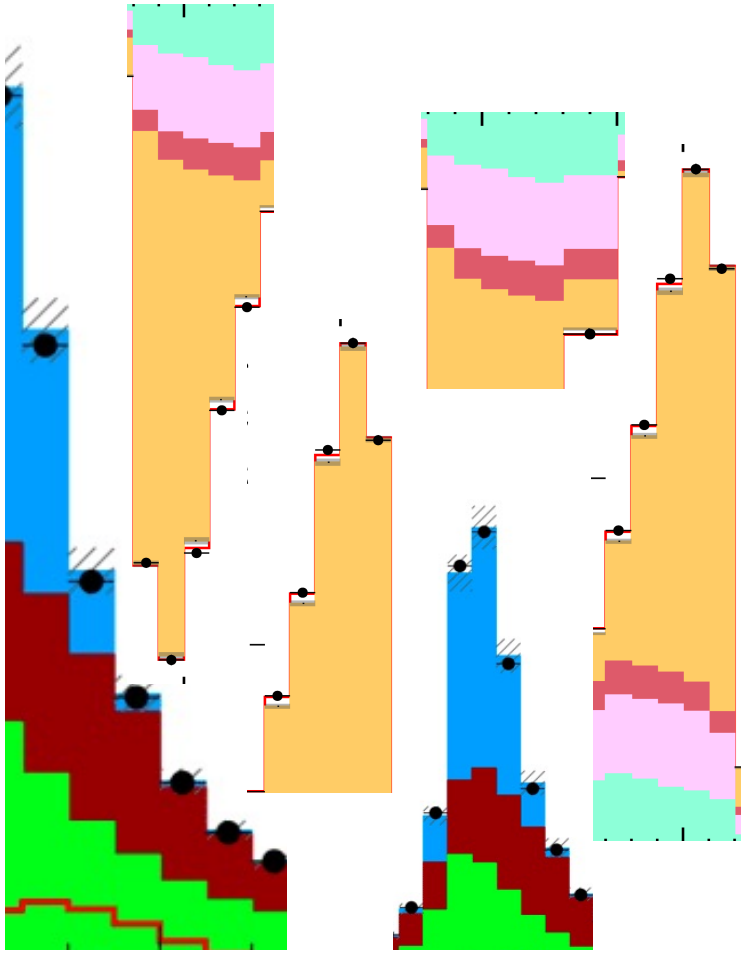
Immagini e immaginazione: gli istogrammi





Piet Mondrian, Composition II

Immagini e immaginazione: gli istogrammi



Paul Klee, Ponte Rosso

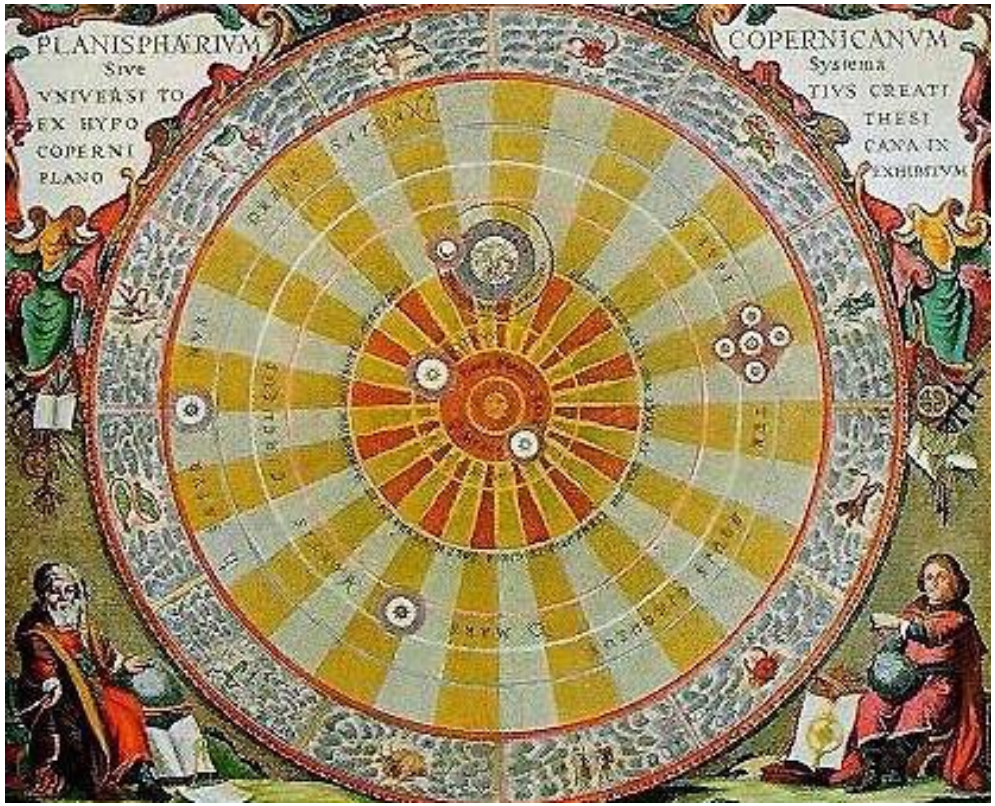
Immagini (artistiche):
un modo per comunicare la conoscenza

Pittura rupestre, Paleolitico

Un primo approccio alla comprensione della natura

Rappresentazioni della conoscenza della natura nell'arte

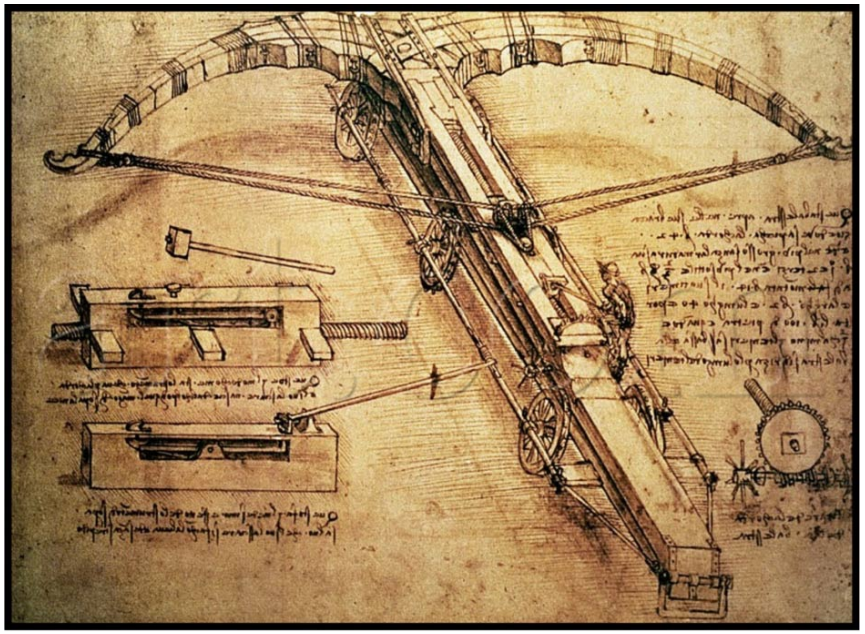
Giudizio Universale, Michelangelo, 1536-1541

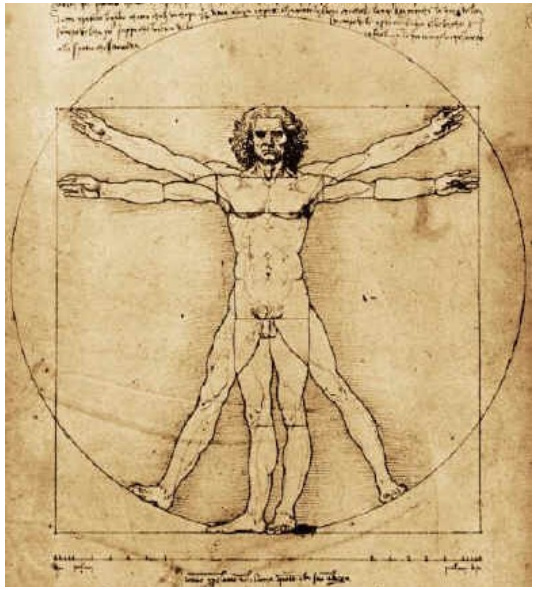


Struttura eliocentrica del Sistema solare

Rappresentazione del Sistema solare?

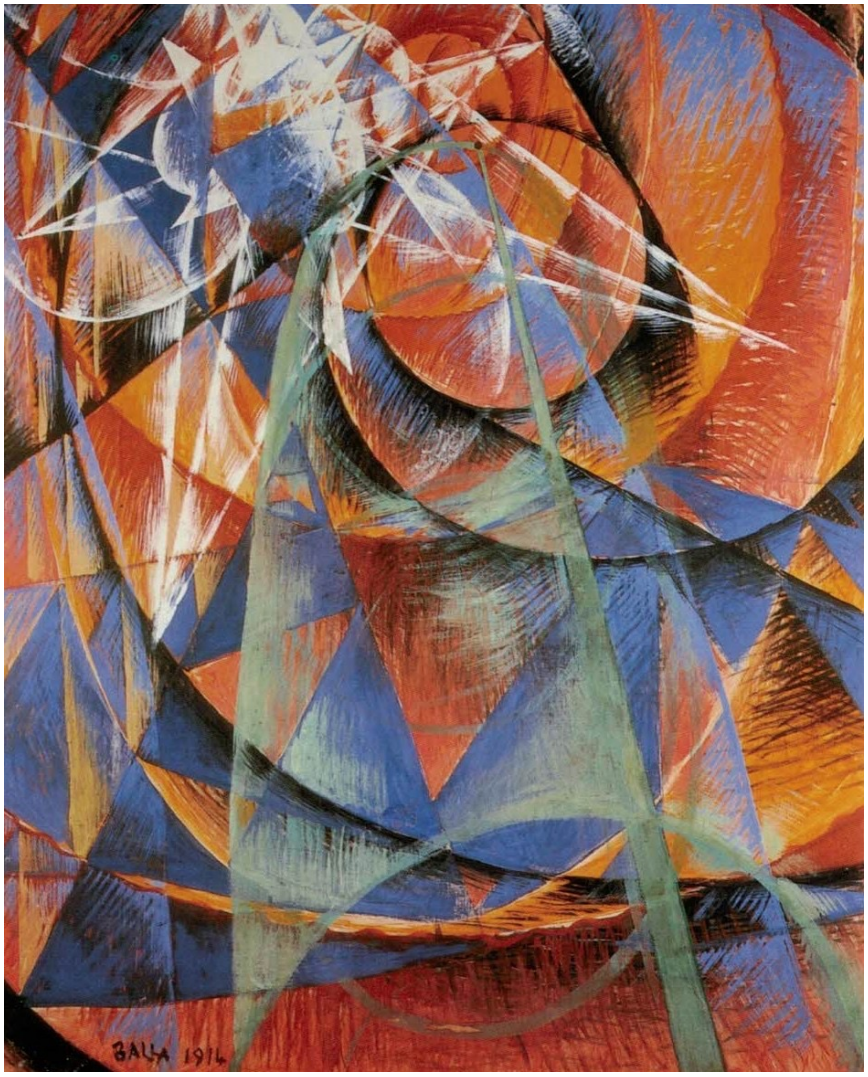
Rappresentazioni della conoscenza della natura nell'arte





Studi di Leonardo da Vinci su anatomia, proporzioni, e progetti per le macchine da Guerra … diventati poi opera d'arte.

Rappresentazioni della conoscenza della natura nell'arte

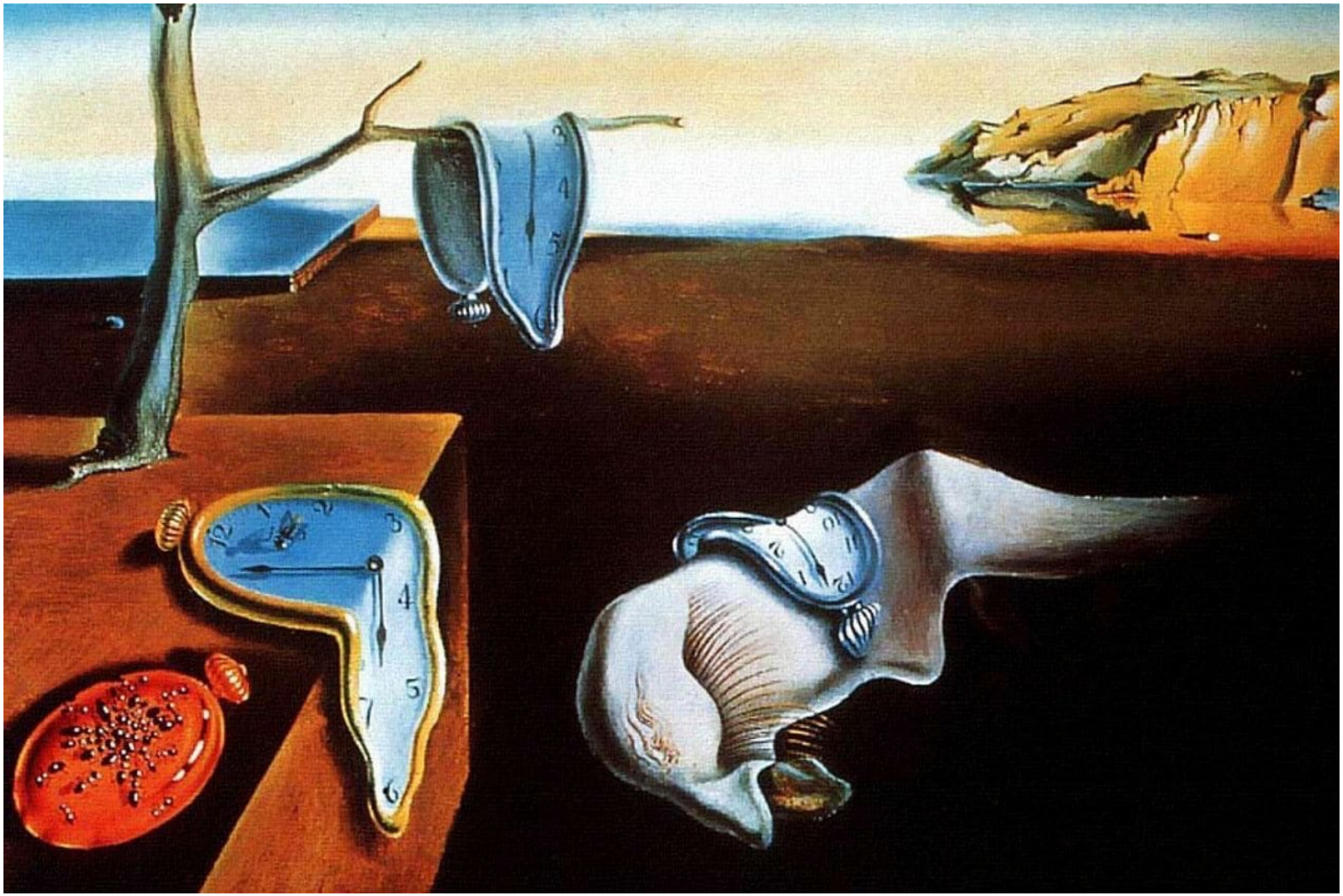


Mercurio passa davanti il Sole, Giacomo Balla, 1914

Notte stellata, Vincent van Gogh, 1889

Rappresentazione fenomeni astronomici

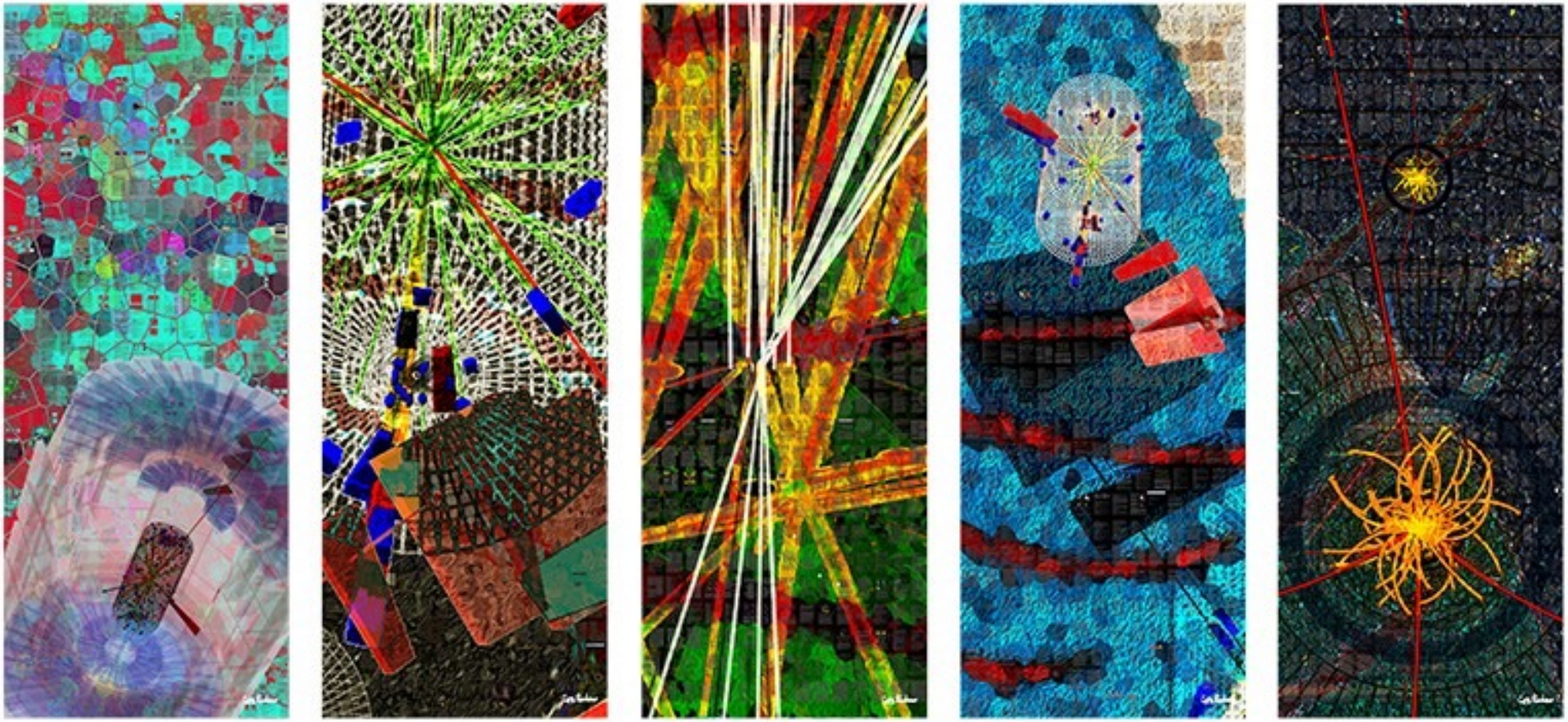
Rappresentazioni della conoscenza della natura nell'arte



La persistenza della memoria (1931), Salvador Dalí.

Rappresentazione della teoria della relatività di Einstein?

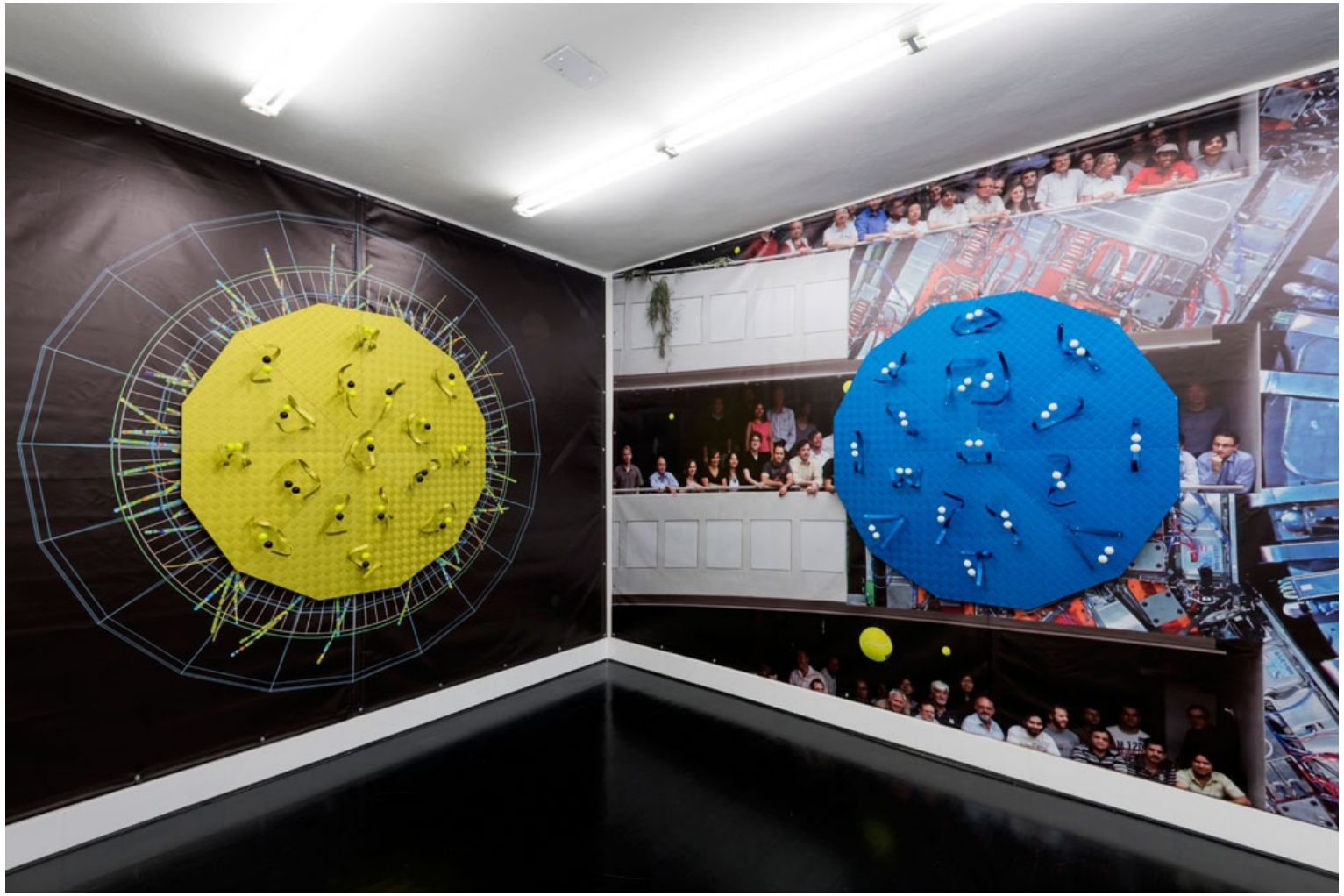
Rappresentazioni della conoscenza della natura nell'arte



Xavier Cortada - Alla ricerca del bosone di Higgs, 2013

Rappresentazione dei decadimenti del bosone di Higgs registrati dall'esperimento CMS

- La natura e la sua comprensione (teoria scientifiche), sono sempre state fonte di ispirazione per gli artisti.
- La conoscenza attuale della Natura (ma anche quello che ancora non conosciamo e stiamo tentando di capire), è un potenziale campo di ispirazione poco esplorato…



Luca Pozzi, “Detectors”

We have only just started to understand the Higgs boson and the symmetry the rules Nature…

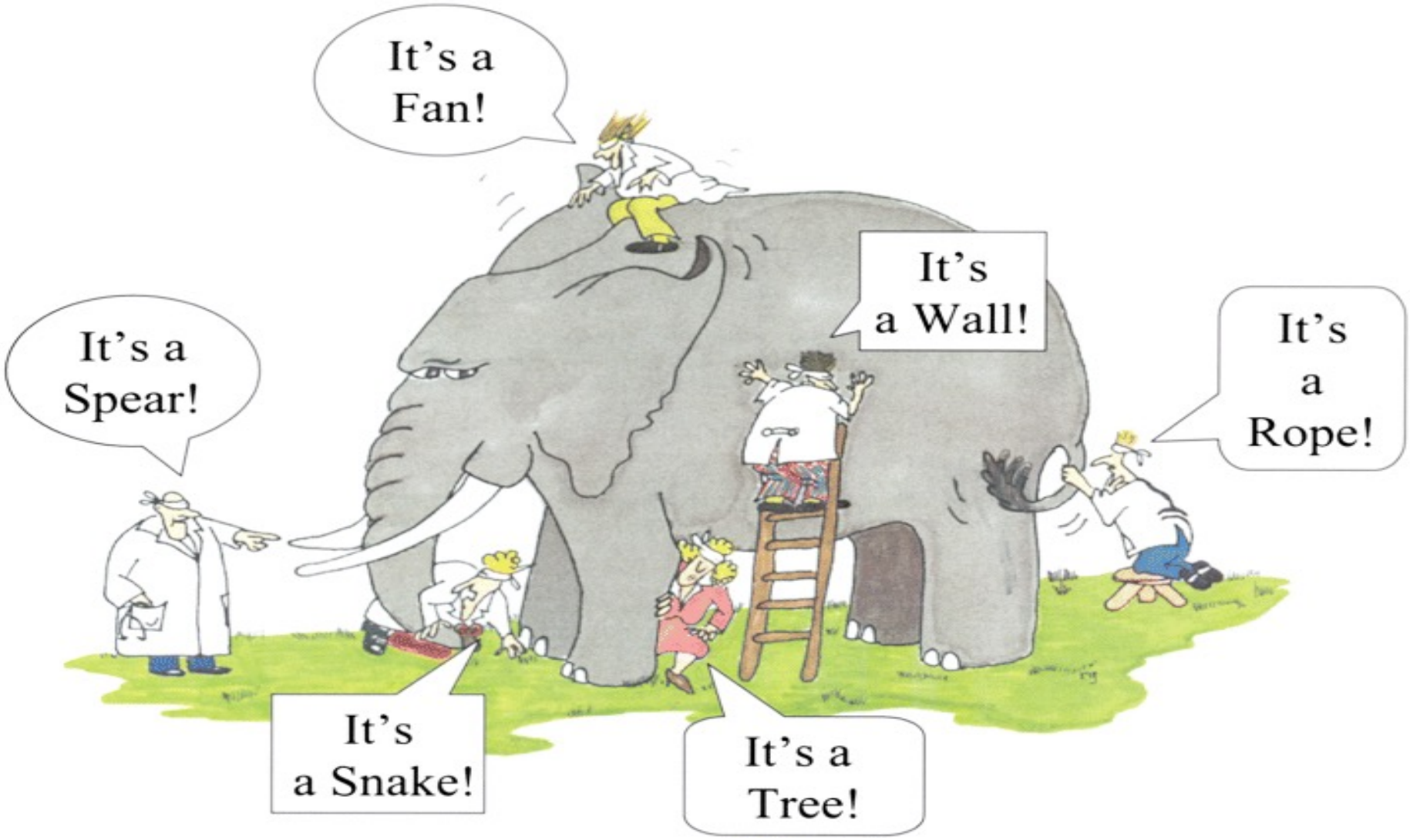
…and we need to look from every angle


It's
a
Rope!


It’s a
Spear!


It's
a Wall!

But we have only just started to understand the Higgs boson…and we need to look from every angle

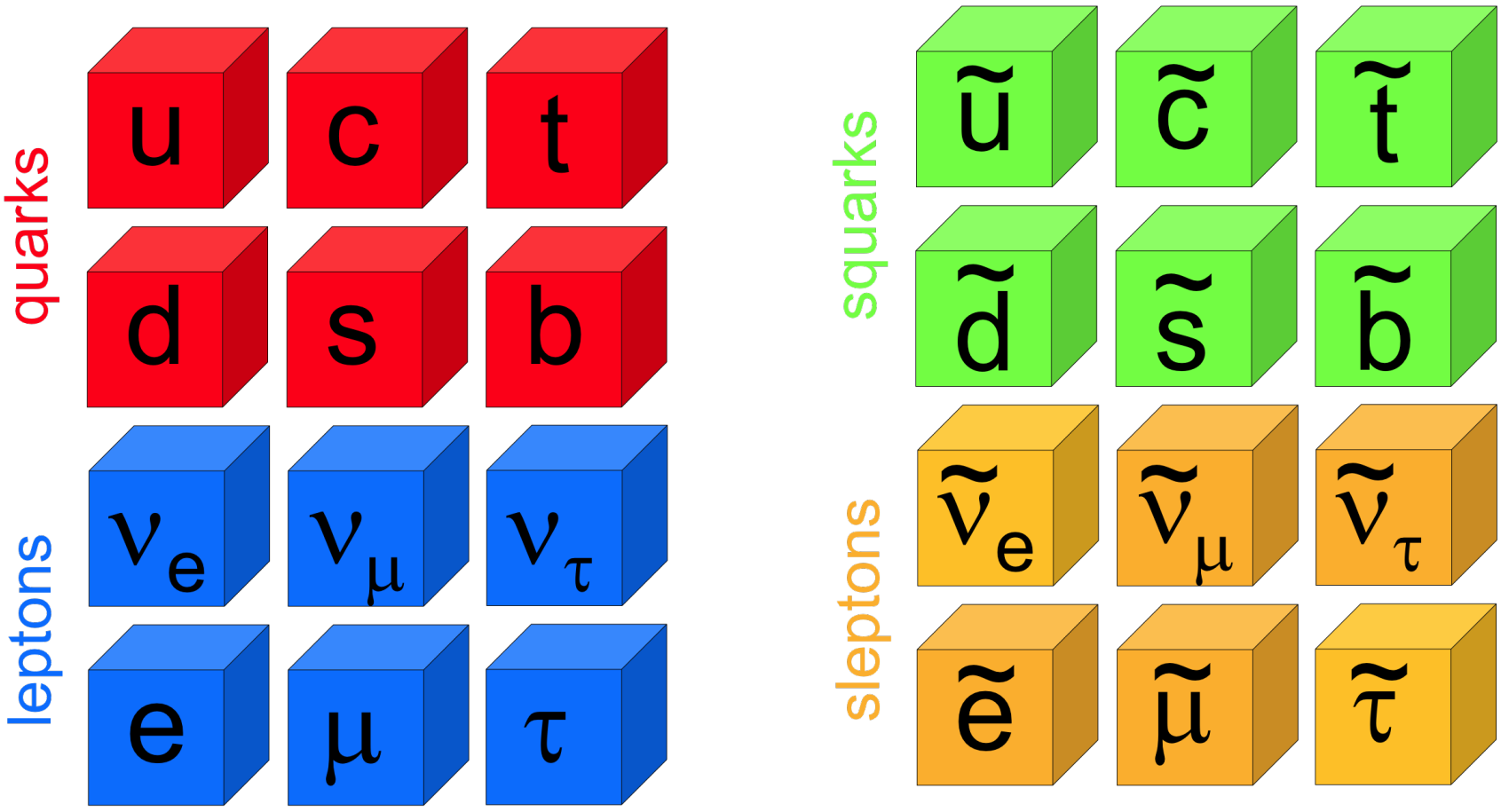


E adesso?

Asimmetria Materia-Antimateria

Materia Oscura

Supersimmetria:
un nuovo tipo di materia?

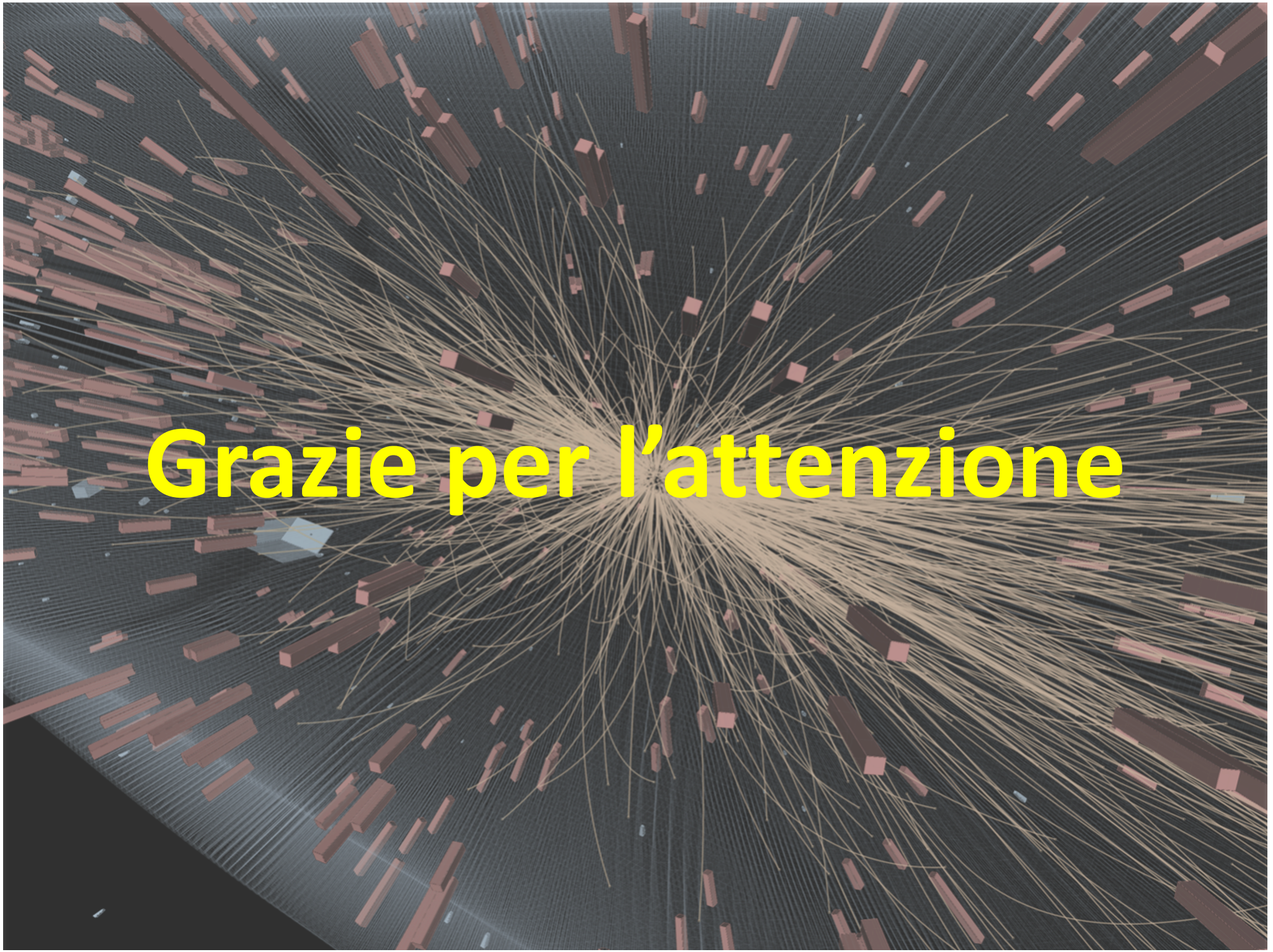



KEEP
CALM
AND
INSERT COIN
TO CONTINUE

Ci stiamo lavorando …

Large Hadron Collider al CERN

il protagonista della fisica delle particelle dei prossimi 10 anni


Grazie per l’attenzione