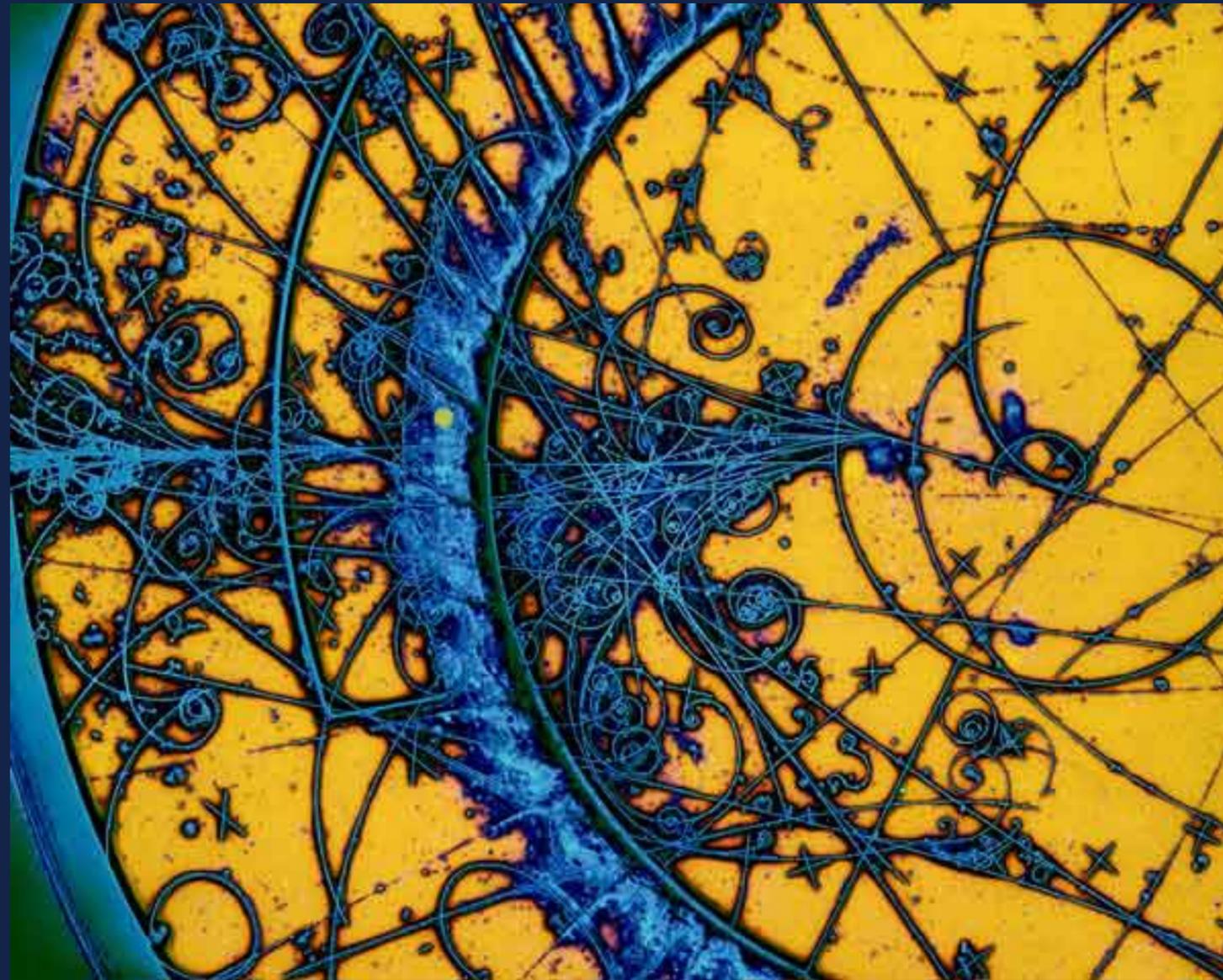


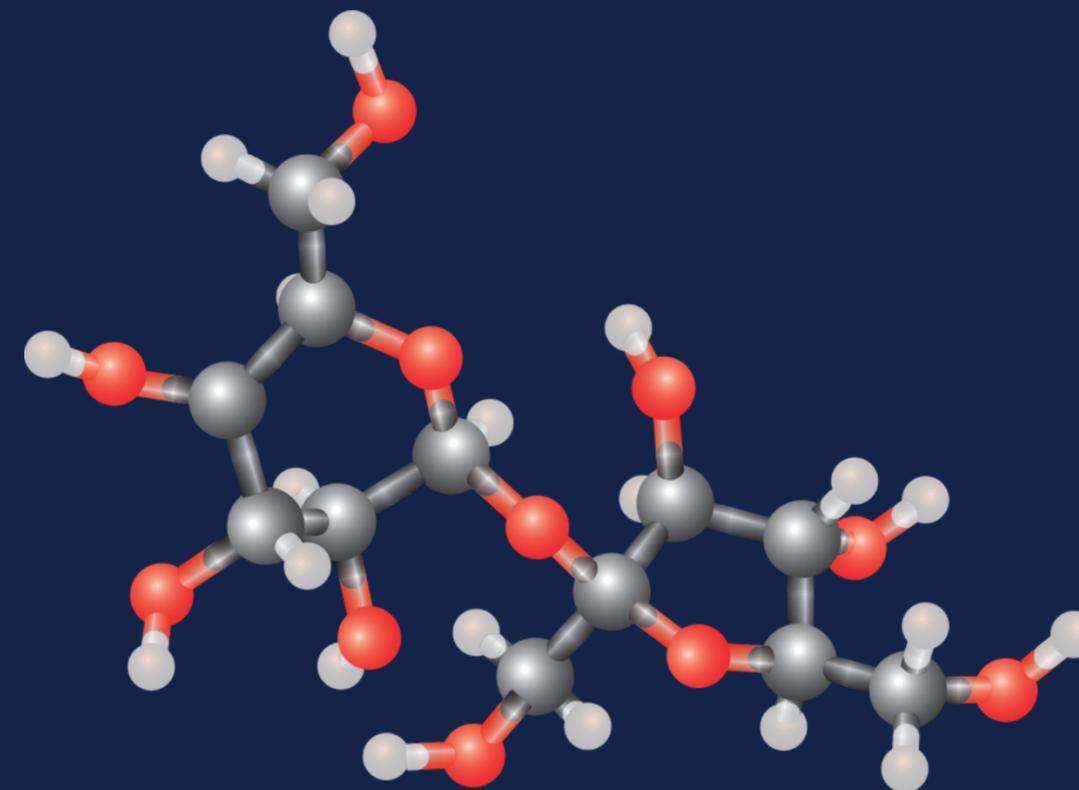
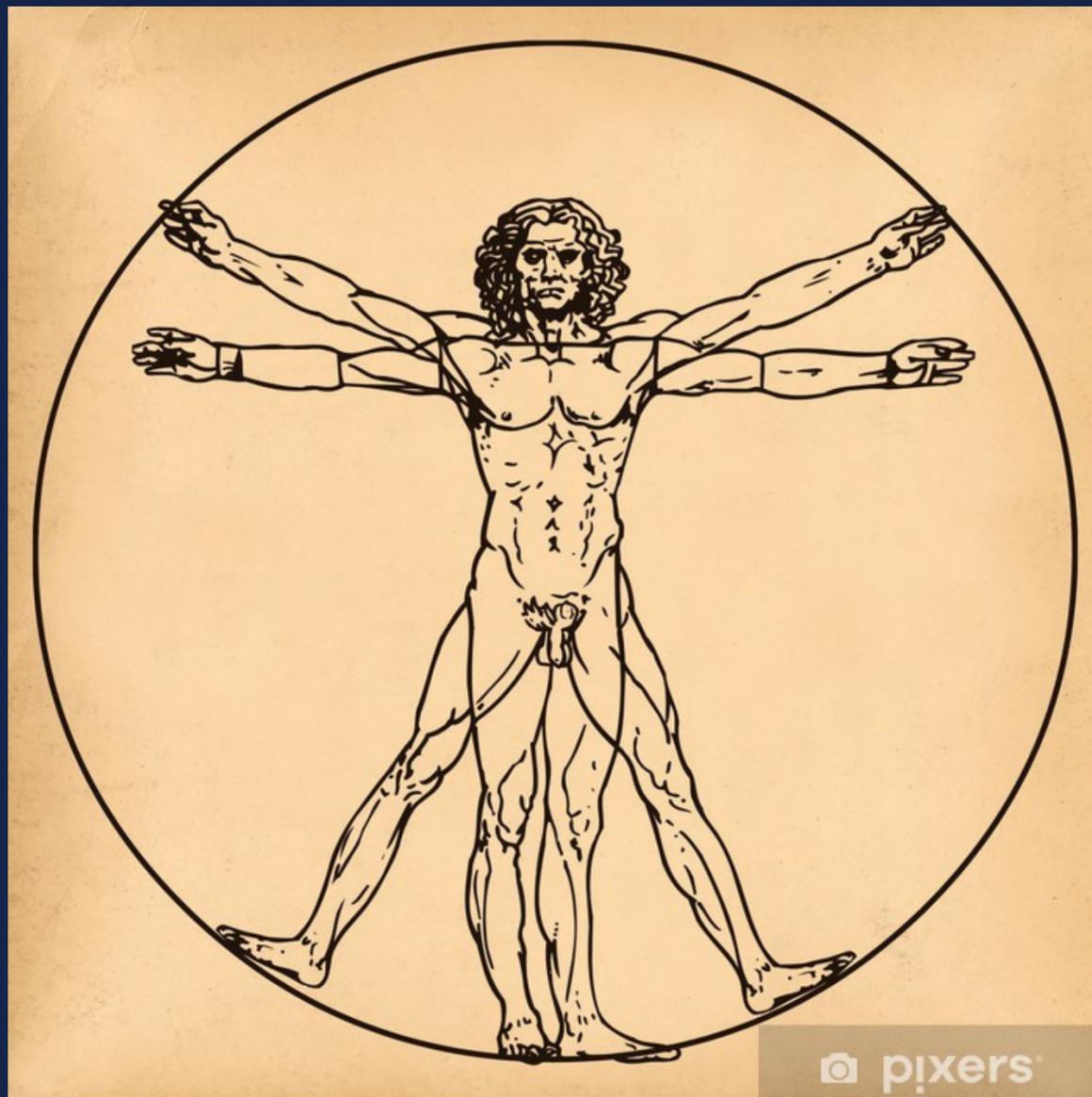
# Particelle Colorate



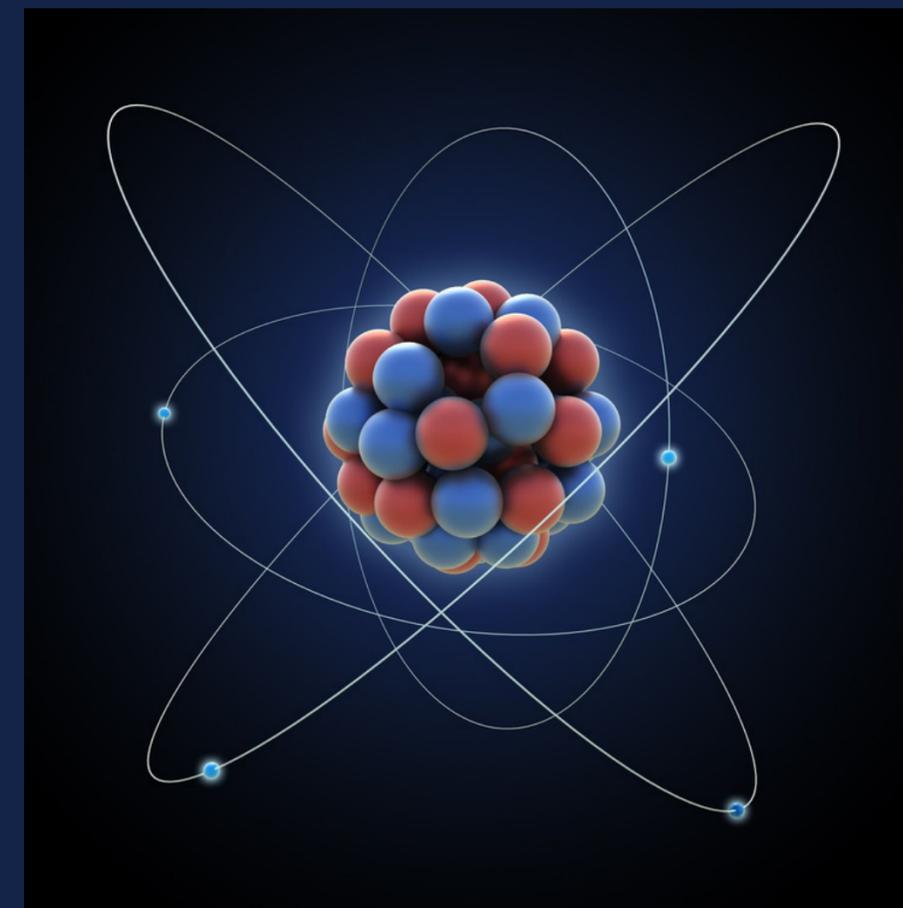
**I. Balossino**  
**I. Garzia**  
**G. Mezzadri**



**per un mondo in bianco e nero**



**Dal macro al micro:  
15 ordini di grandezza**

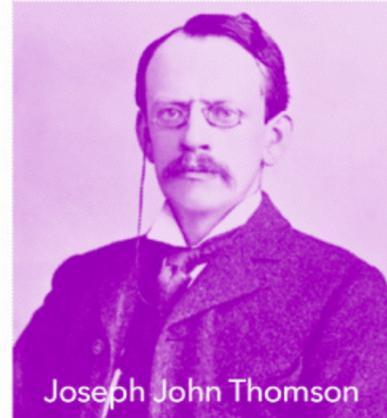


# La lunga storia dell'atomo



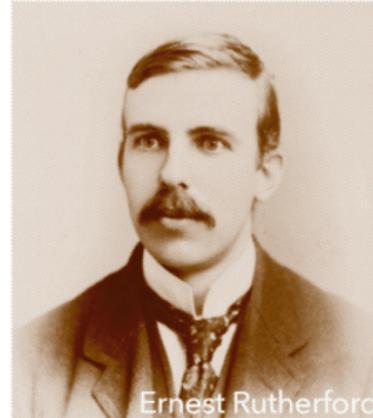
Democrito

DEMOCRITO  
460 A.C.



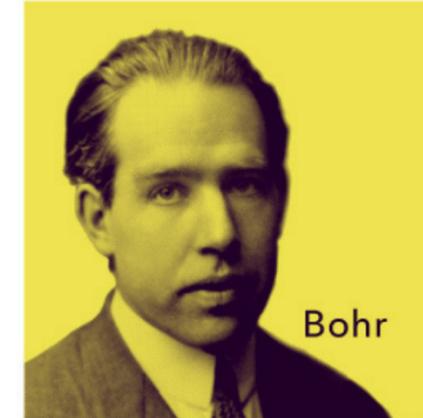
Joseph John Thomson

THOMPSON  
1897



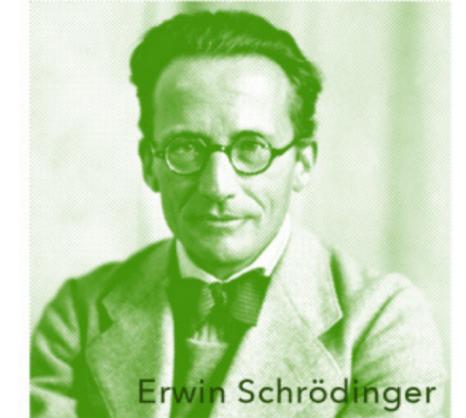
Ernest Rutherford

RUTHERFORD  
1912



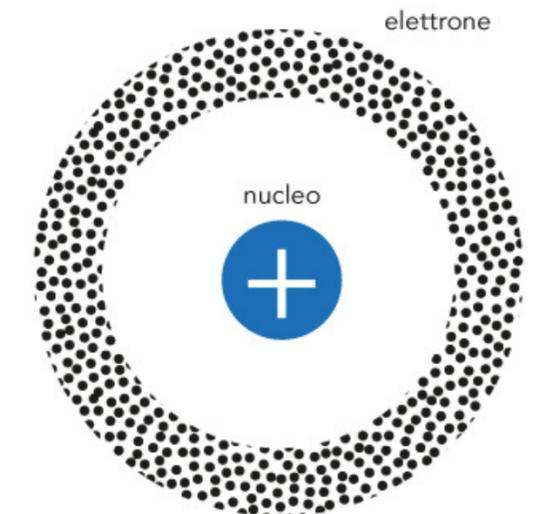
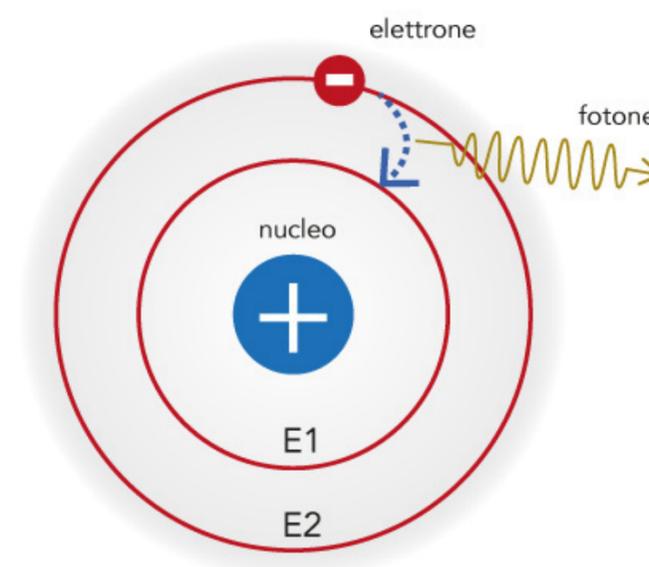
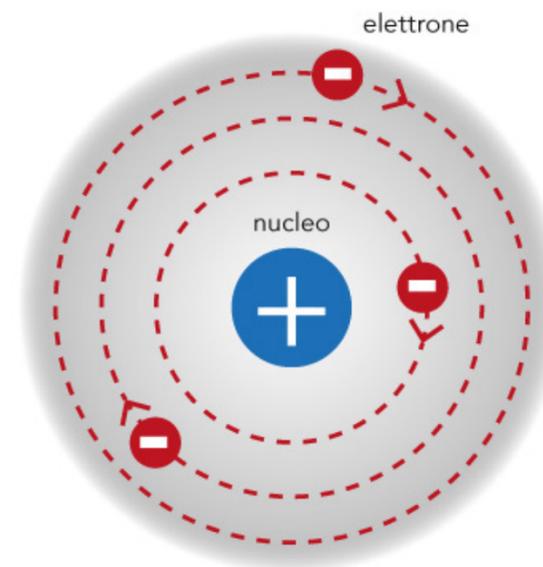
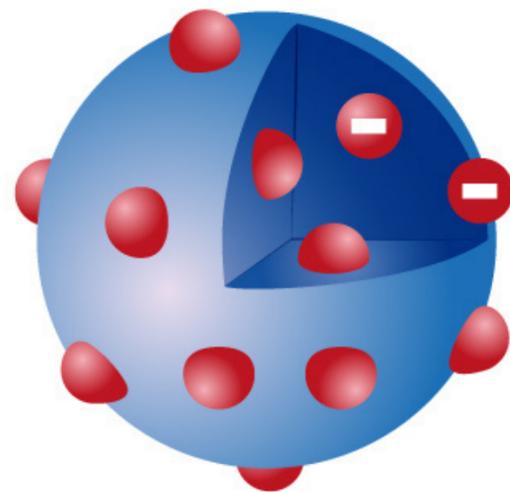
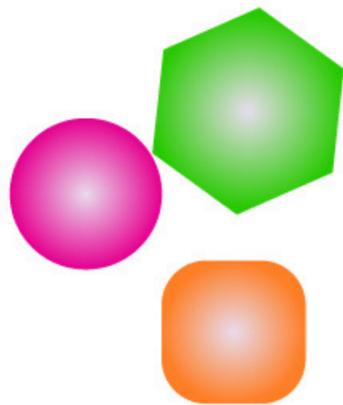
Bohr

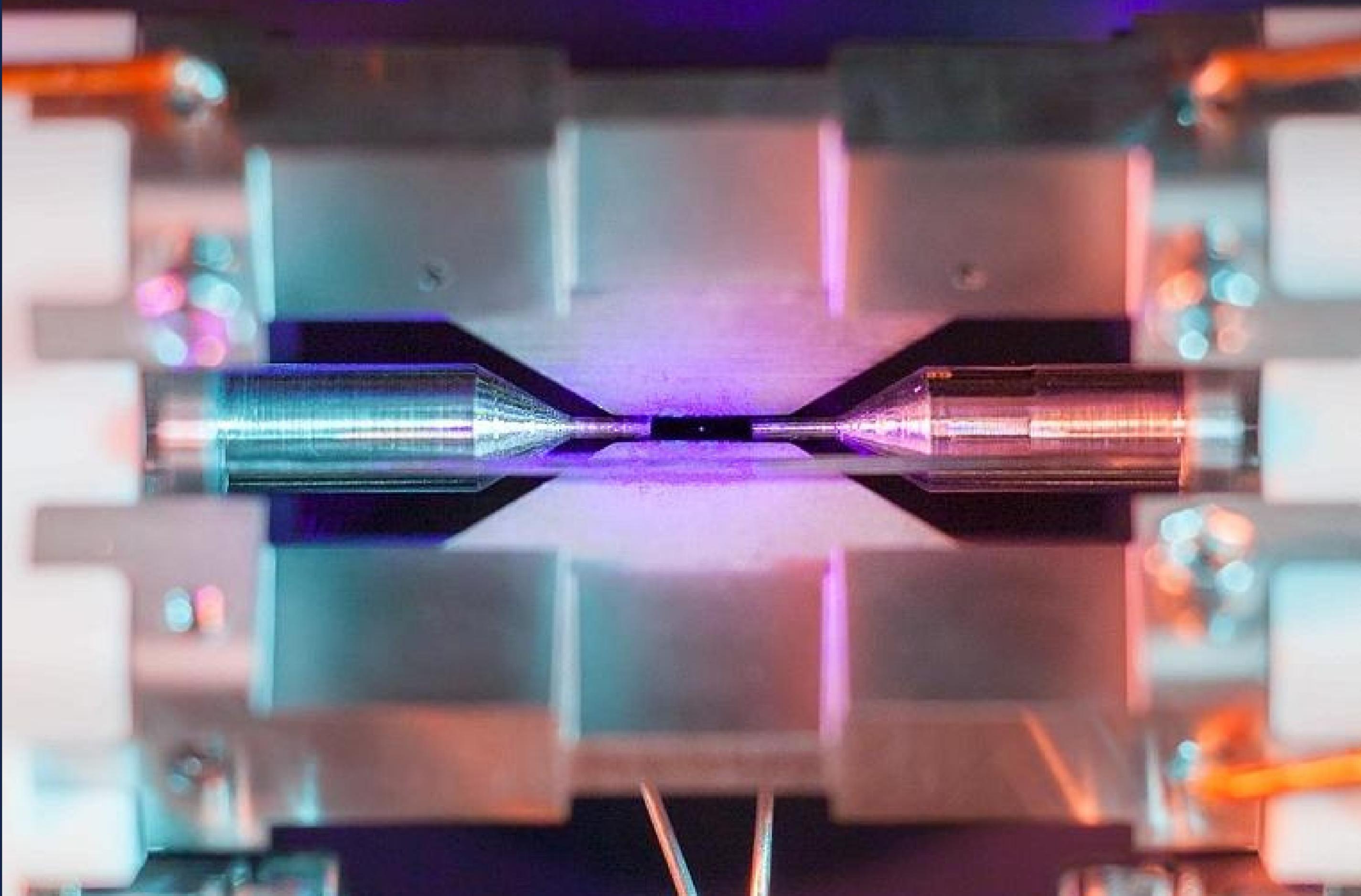
BOHR  
1913



Erwin Schrödinger

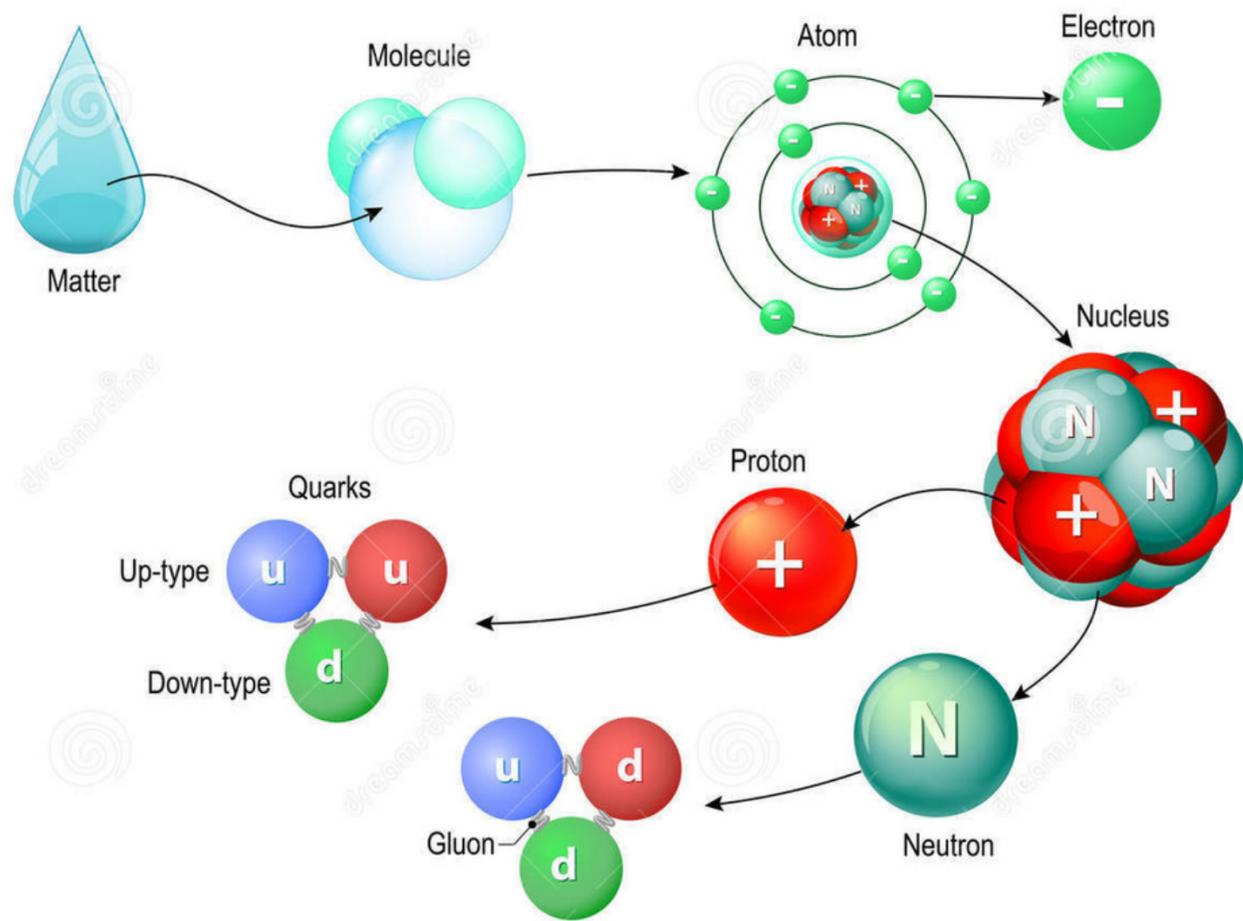
SCHRÖDINGER  
1930





# MATTER

from molecule to quark



Marco Delmastro  
Particelle familiari

## MATERIA

## INTERAZIONI

### LEPTONI

### QUARK

$e$   
 $\nu_e$

$\mu$   
 $\nu_\mu$

$\tau$   
 $\nu_\tau$

$u$

$c$

$t$

$d$

$s$

$b$

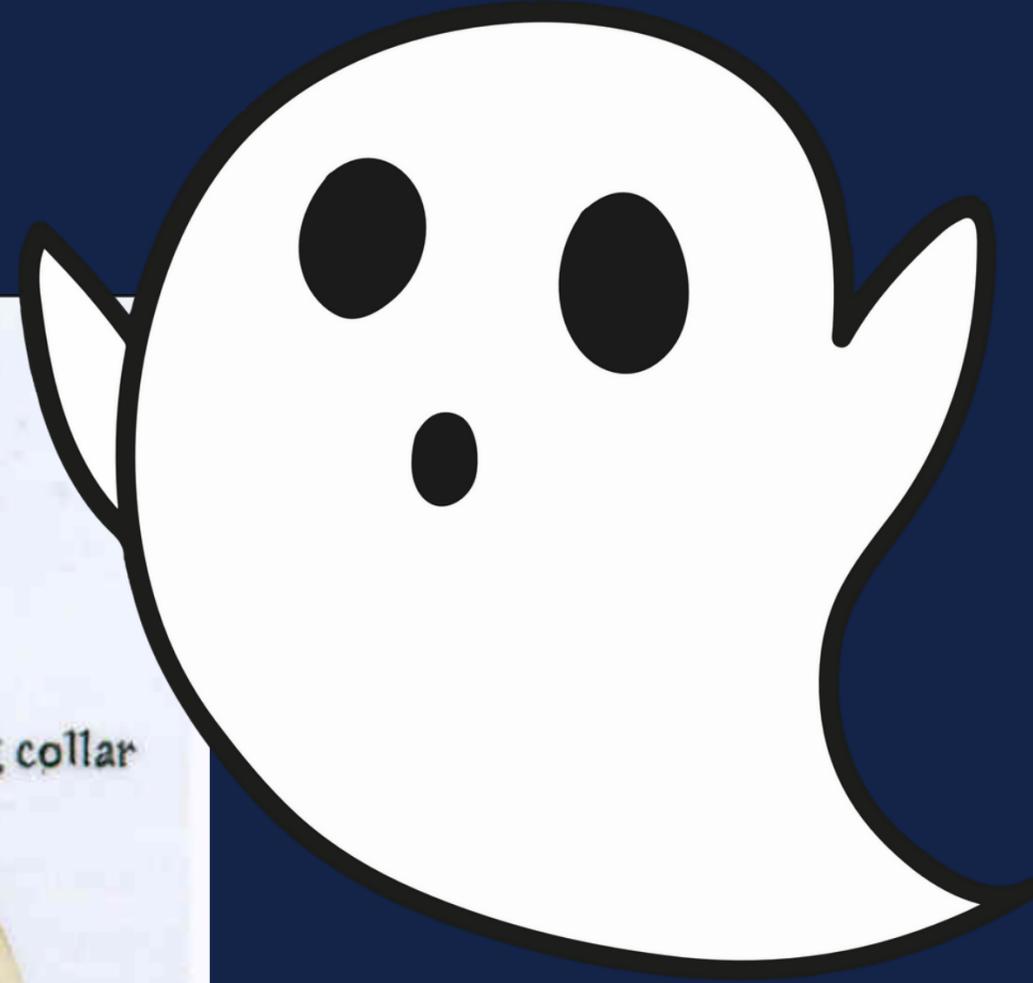
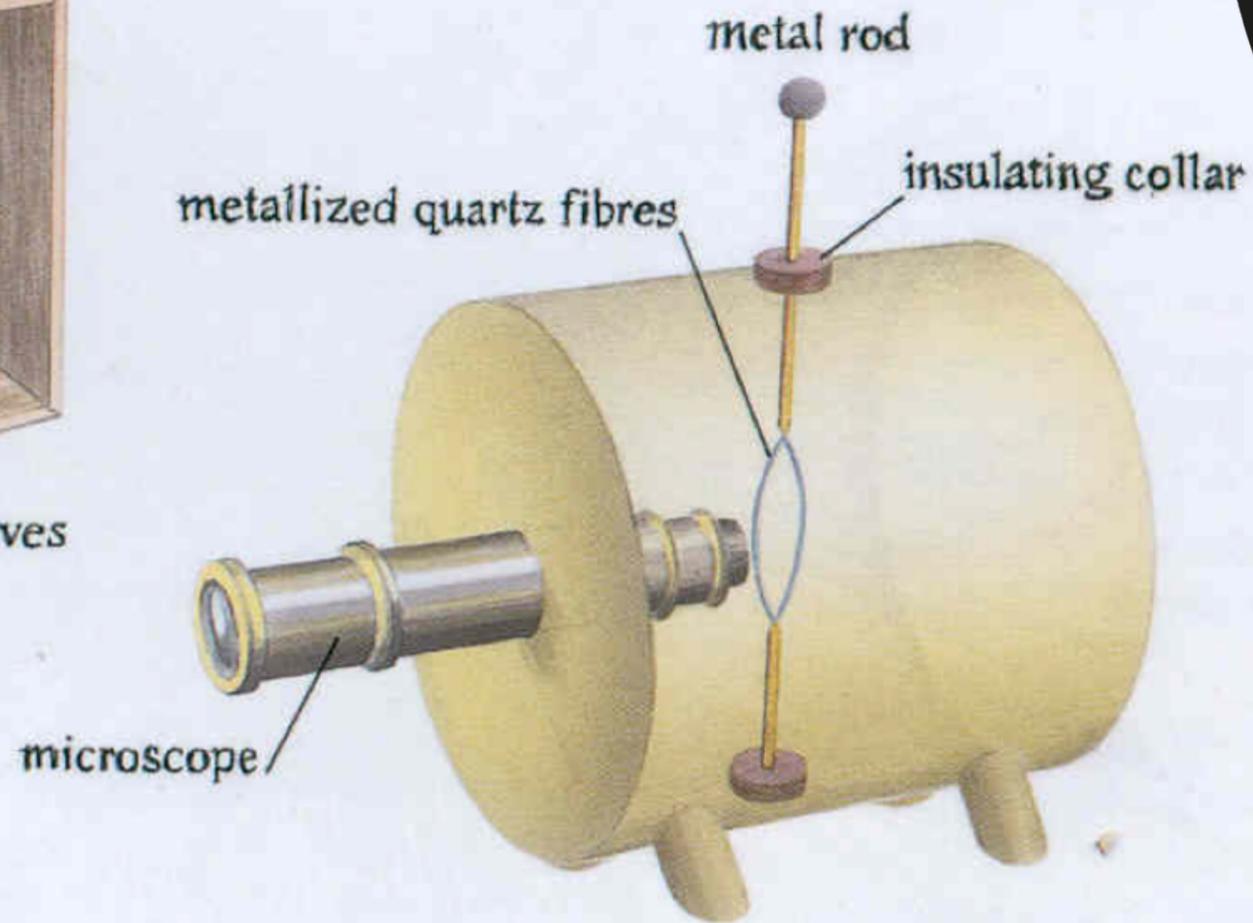
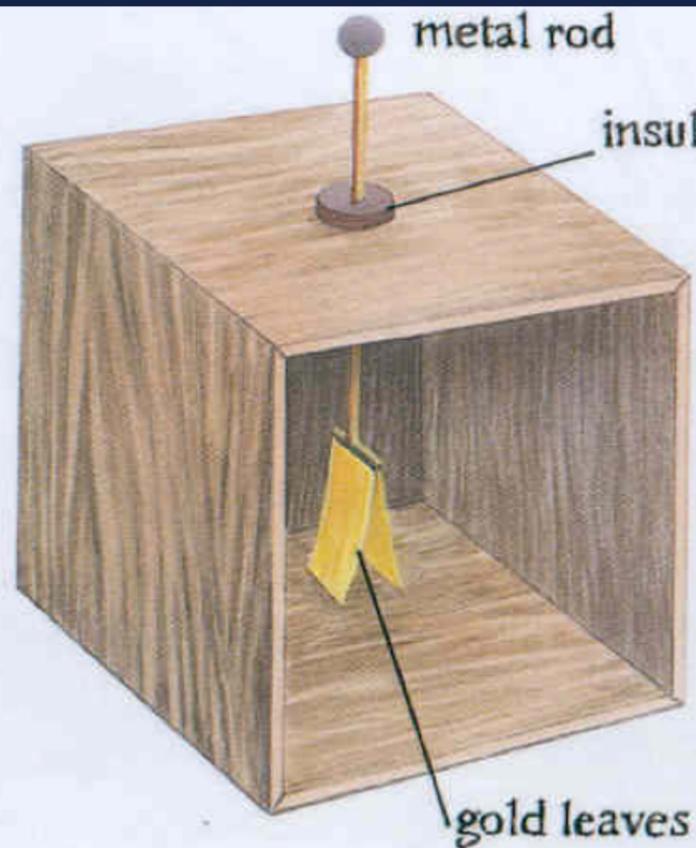
$Z$

$W$

$\gamma$

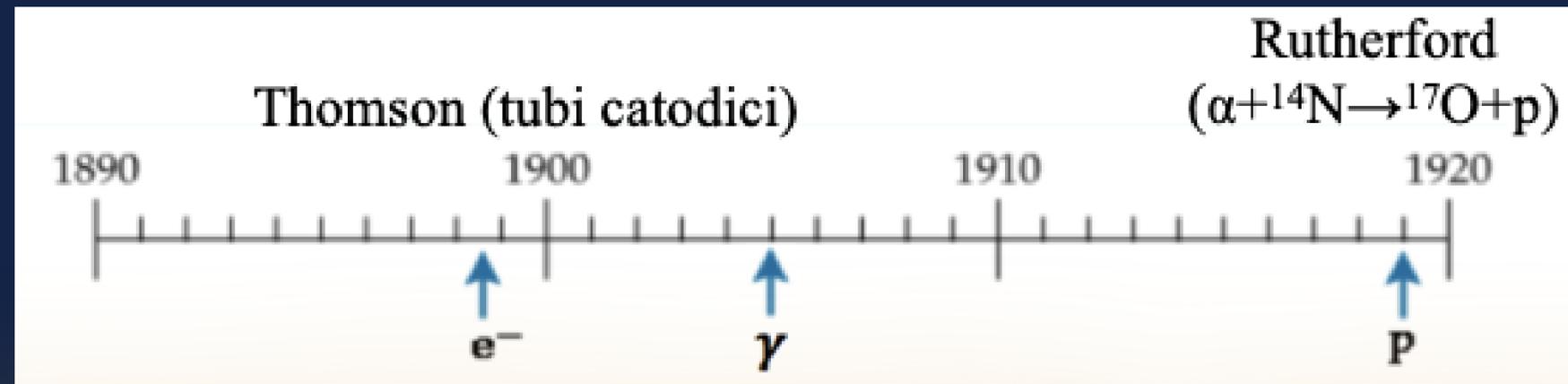
$g$

**Dentro un punto cosa c'è?**



**1785: Coulomb osserva  
elettroscopio che si  
scarica senza contatto  
con l'esterno**

**Radiazione ionizzante?**



# RADIOATTIVITÀ NATURALE



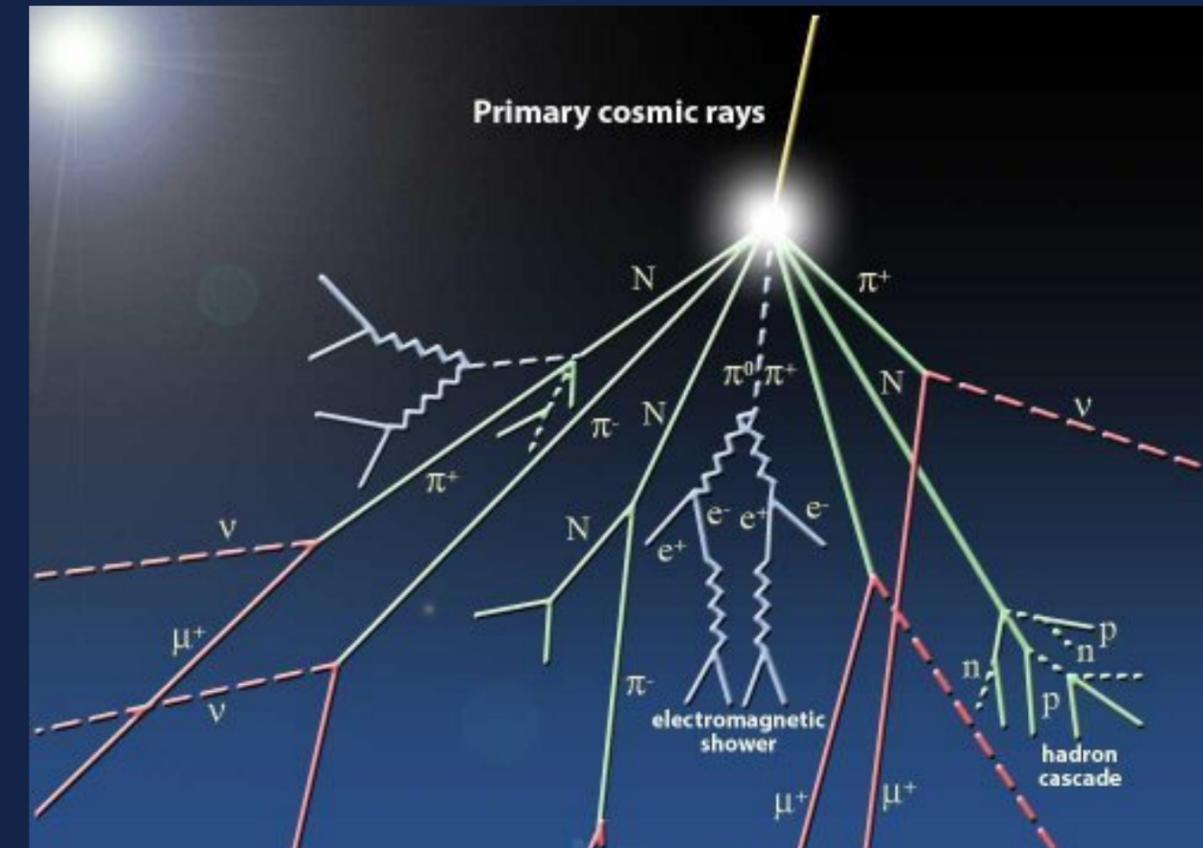
**L'italiano Domenico Pacini propone una teoria alternativa: non dal terreno, ma dal cielo proviene questa radioattività**

# A caccia di particelle



V. Hesse in mongolfiera, 1912

## Elettroscopio portatile

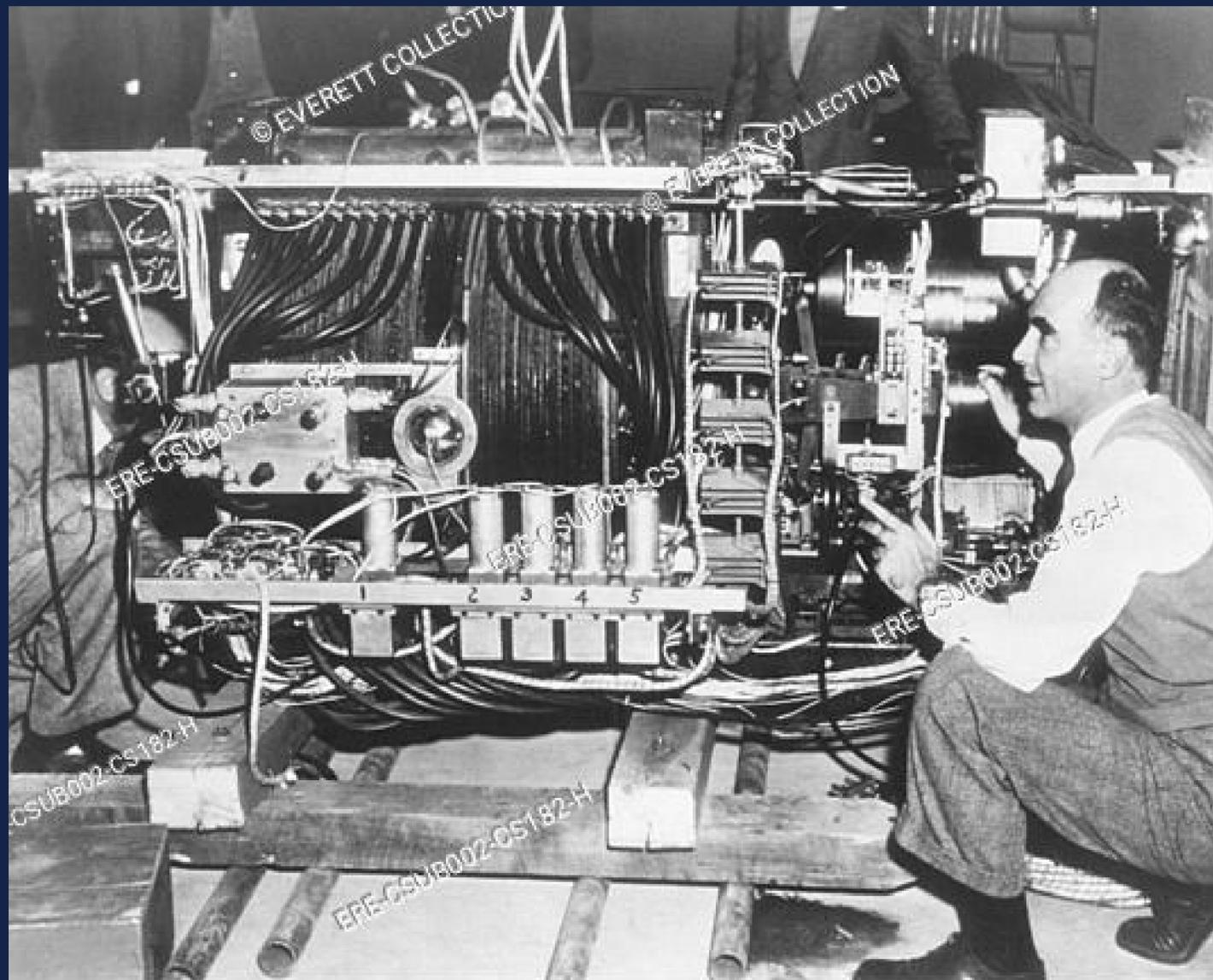


Raggi cosmici

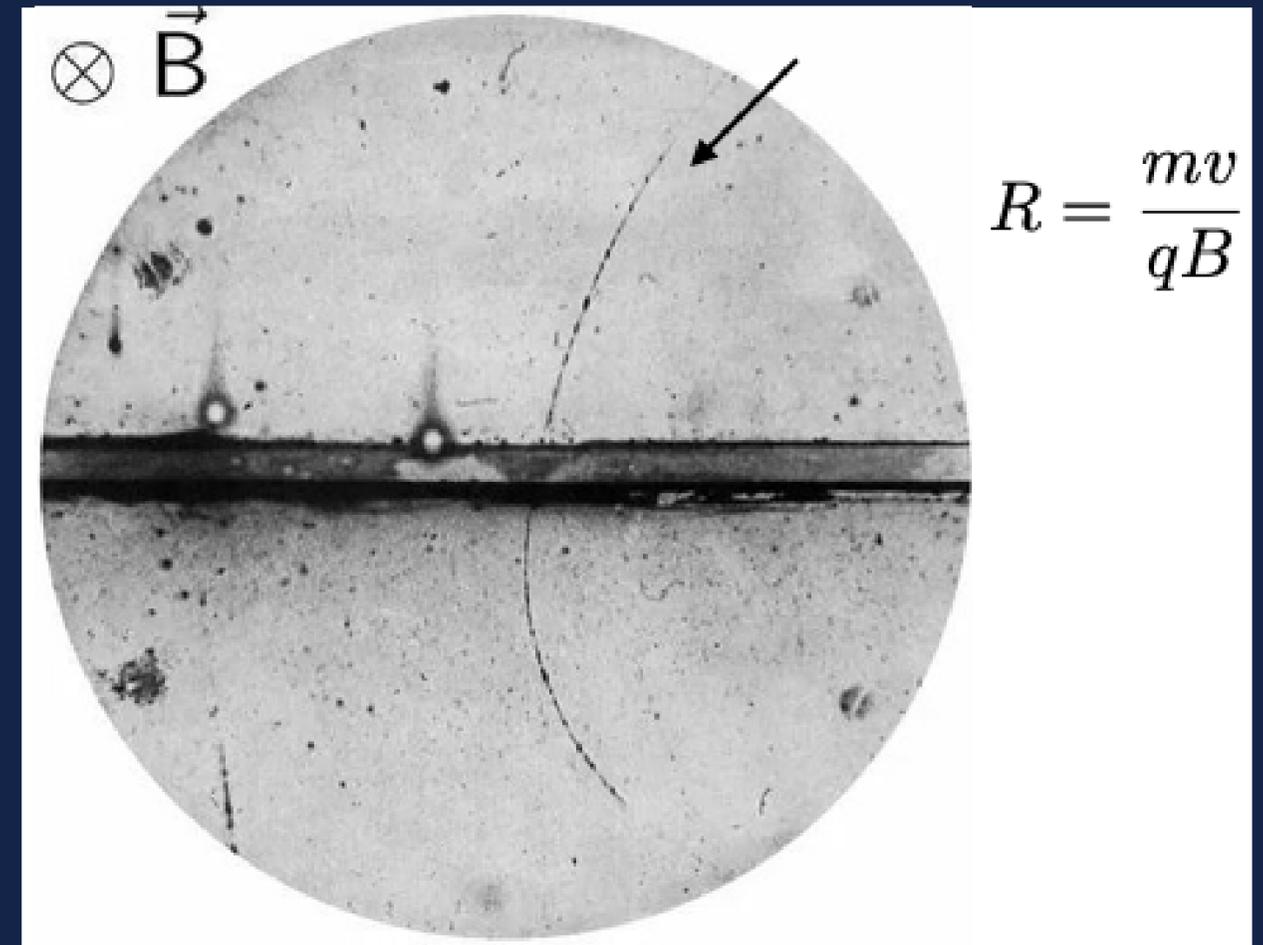
<https://cerncourier.com/a/a-discovery-of-cosmic-proportions/>

# Materia allo specchio

1932: La camera a Nebbia permette di osservare le tracce delle particelle



© EVERETT COLLECTION  
ERE-CSUB002-CS182-H - agefotostock



$$\vec{F} = q\vec{v} \times \vec{B}$$

$\otimes \vec{B}$



q negativa: senso orario  
dal basso

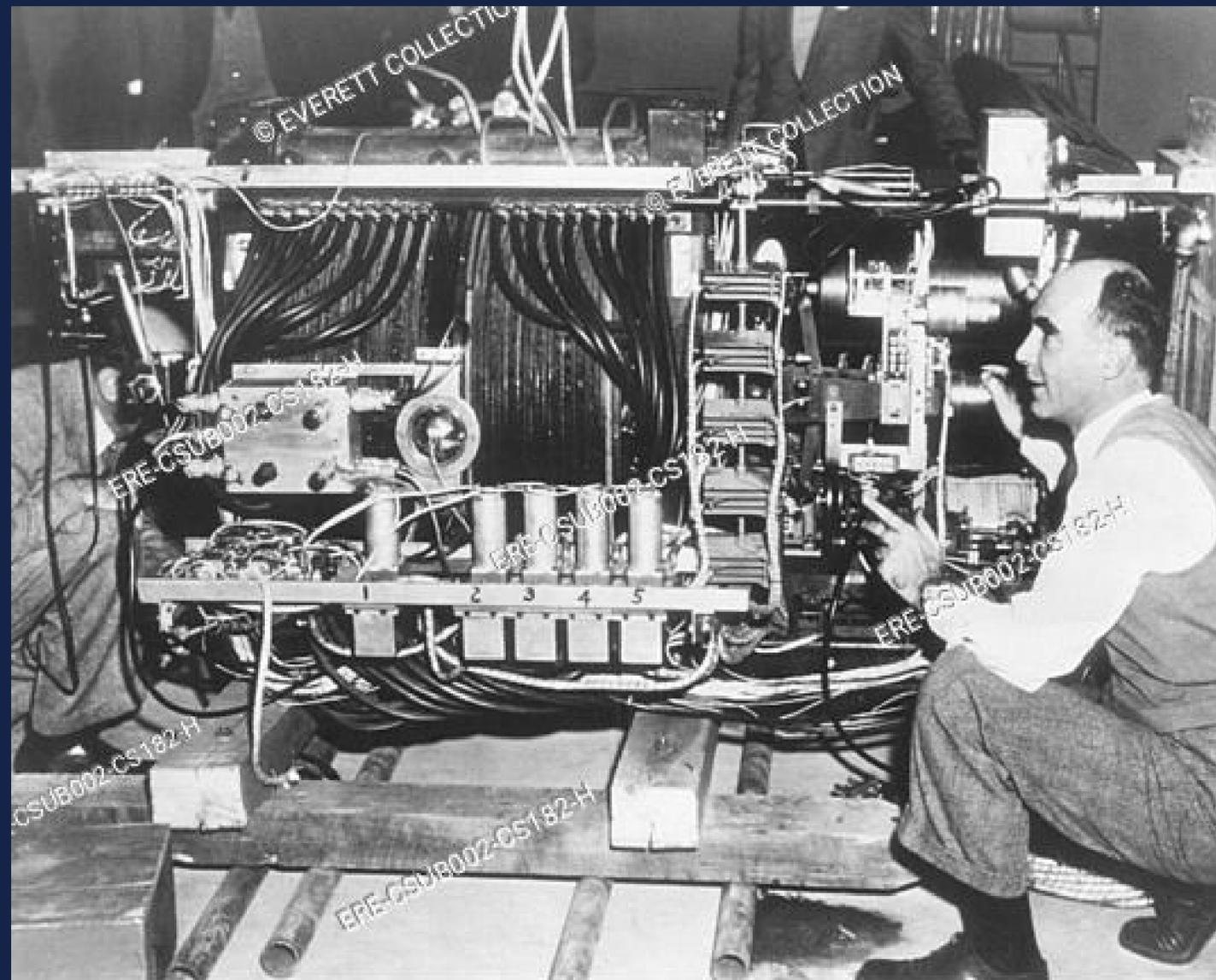
$\otimes \vec{B}$



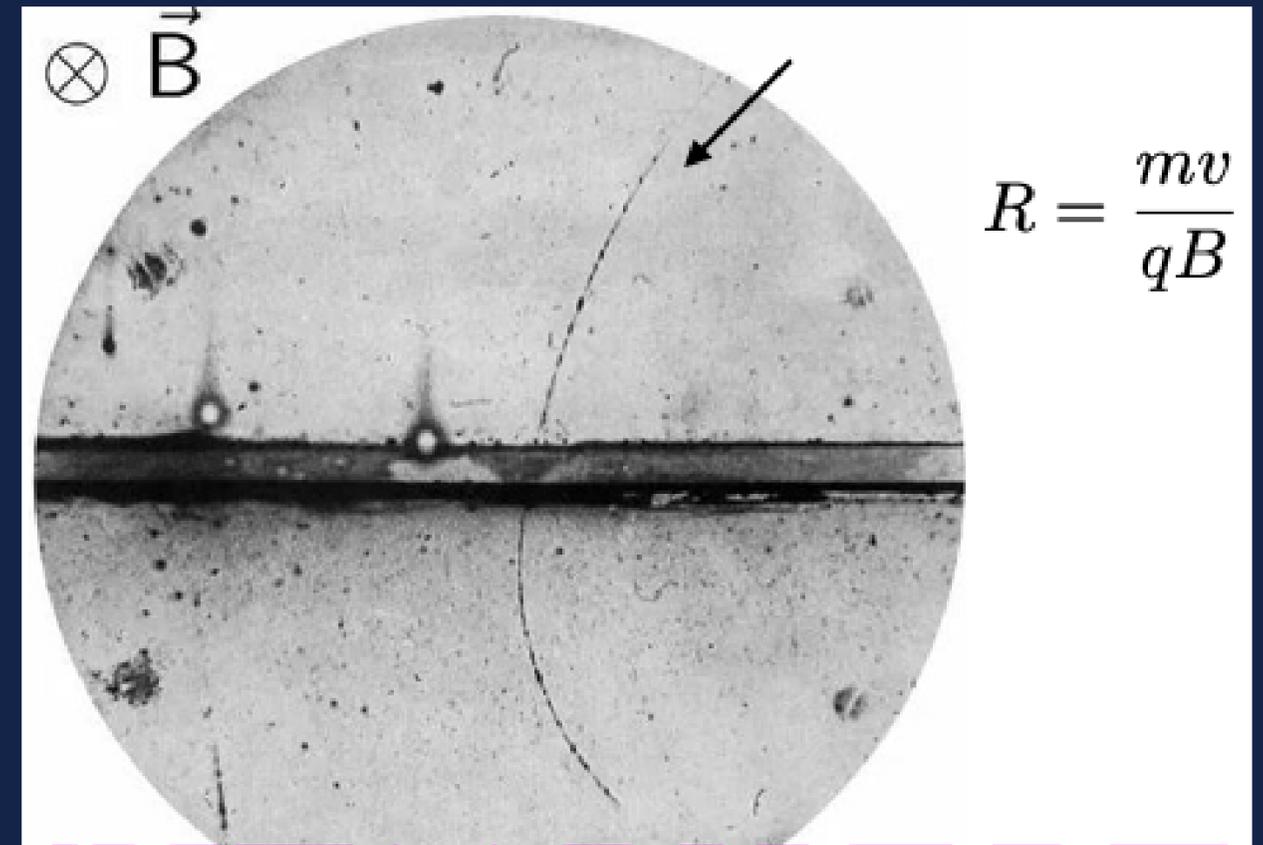
q positiva: senso anti-orario  
dall'alto

# Materia allo specchio

1932: La camera a Nebbia permette di osservare le tracce delle particelle



© EVERETT COLLECTION  
ERE-CSUB002-CS182-H - agefotostock



$$R = \frac{mv}{qB}$$

ANTIMATERIA

$$\vec{F} = q\vec{v} \times \vec{B}$$

$\otimes \vec{B}$



q negativa: senso orario  
dal basso

$\otimes \vec{B}$

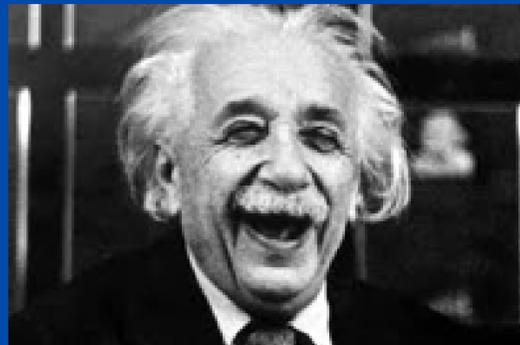


q positiva: senso anti-orario  
dall'alto

# Meccanica Quantistica

1905: Relatività

A. Einstein

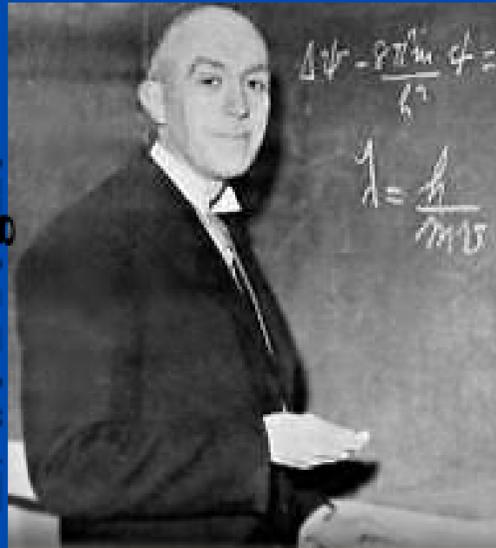


Equivalenza  
massa-energia

$$E=mc^2$$

1924: Proprietà  
ondulatorie della materia

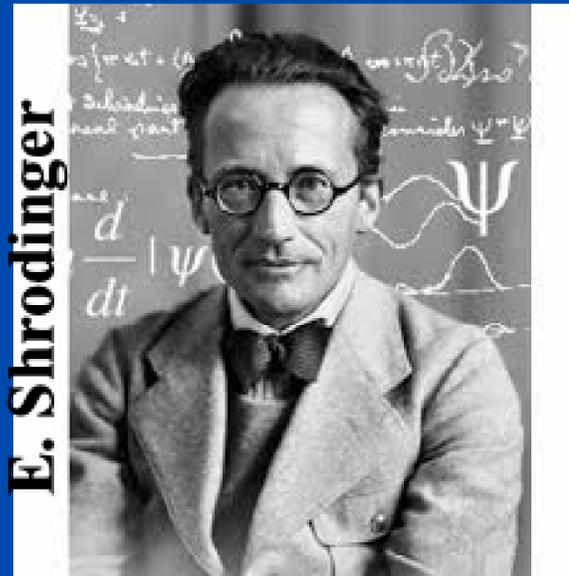
L. de Broglie



$$\lambda = \frac{h}{p}$$

1925: Evoluzione temporale dello  
stato di una particella sub-atomica  
descritto dalla funzione d'onda  $\Psi$

E. Shrodinger



$$i\hbar \frac{\partial}{\partial t} \Psi(x,t) = \left[ \frac{-\hbar}{2m} \frac{\partial}{\partial x^2} + V(x,t) \right] \Psi(x,t)$$

1927: Principio di  
indeterminazione

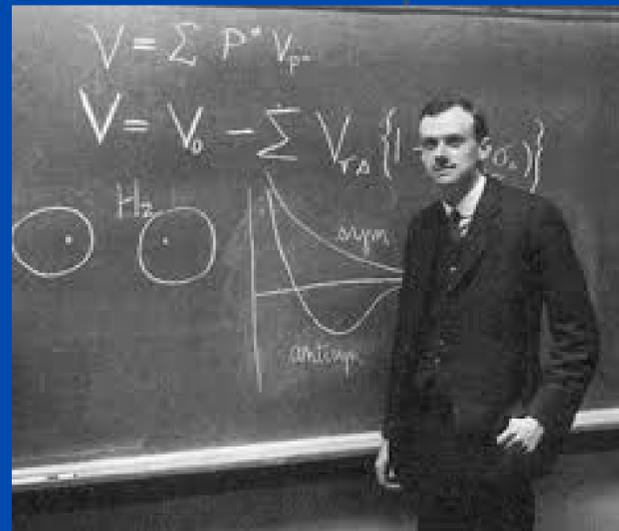
W. Heisenberg



$$\Delta x \cdot \Delta p > \frac{\hbar}{2}$$

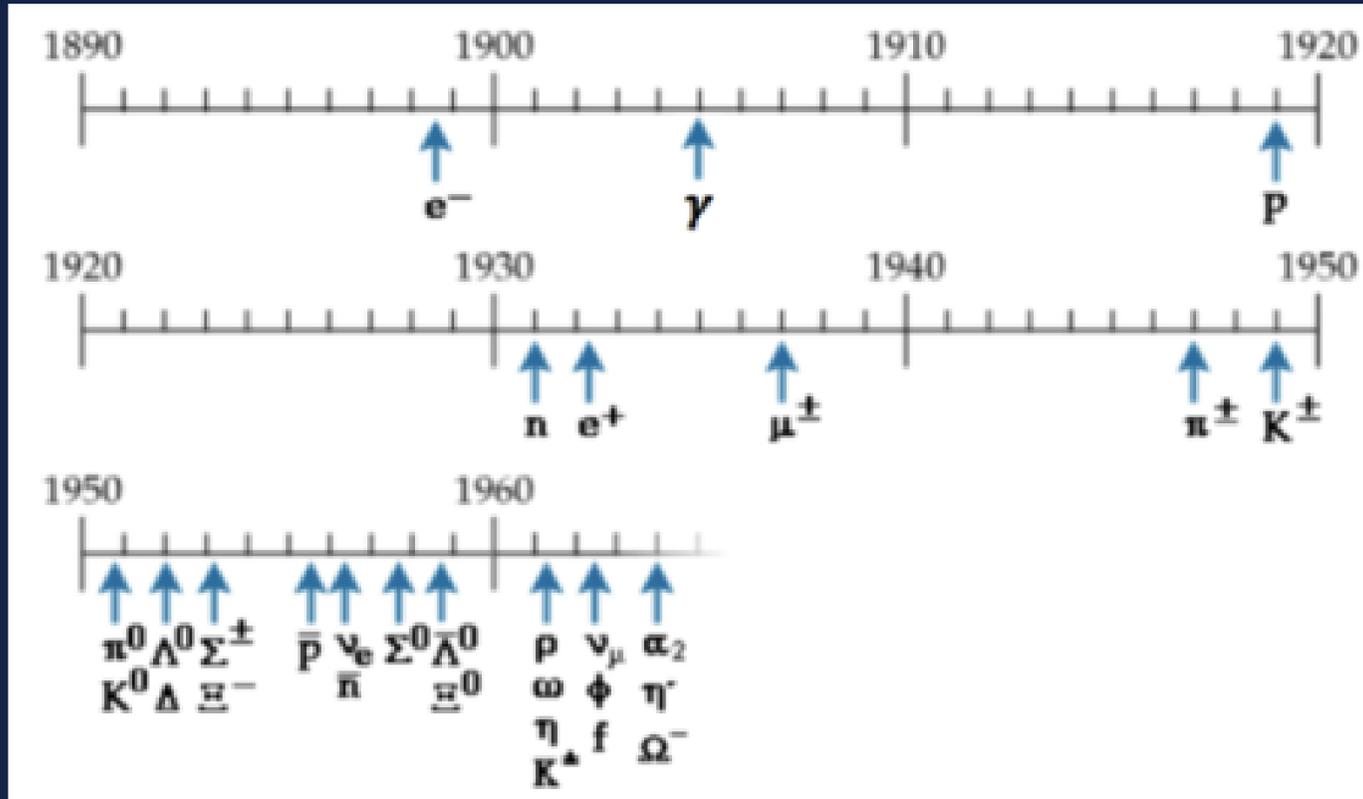
$$\Delta E \cdot \Delta t > \frac{\hbar}{2}$$

P. Dirac



$$(i\gamma^\mu \partial_\mu - m)\psi = 0$$

- 1928: estensione relativistica dell'equazione di Shroedinger
- Unificazione meccanica quantistica e relatività ristretta
- **Prevede l'esistenza dell'antimateria: ad ogni particella corrisponde un'antiparticella**

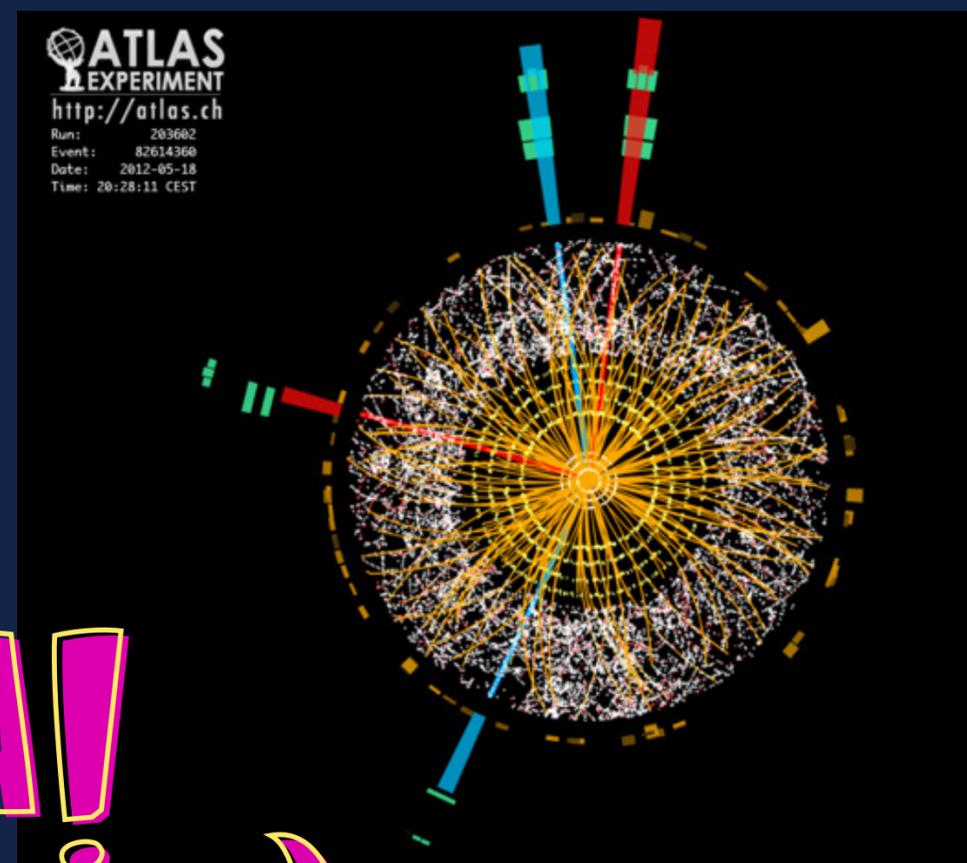


# PARTICELLE

**NON CE N'È MAI ABBASTANZA**

Qual è la tua preferita?

**Anni 50: Nasce la fisica delle particelle in laboratorio**



**ENERGIA È MASSA!  
(PER E AL QUADRATO)**

# Da AdA a LHC

**10 m di circonferenza**



**AdA, la nonna di tutti i  
collisori di particelle (1961)**



**Bruno Touschek  
è stata una  
personalità  
incredibile**



MAGNETIC DISCUSSION

*Bruno Touschek*

# Da AdA a LHC



**LHC, il più potente acceleratore mai prodotto (2008)**

**27 km (!) di circonferenza**

# Cercare le tracce

**Vedere particelle piccolissime che viaggiano alla velocità della luce**



# Cercare le tracce

**Vedere particelle piccolissime che viaggiano alla velocità della luce**

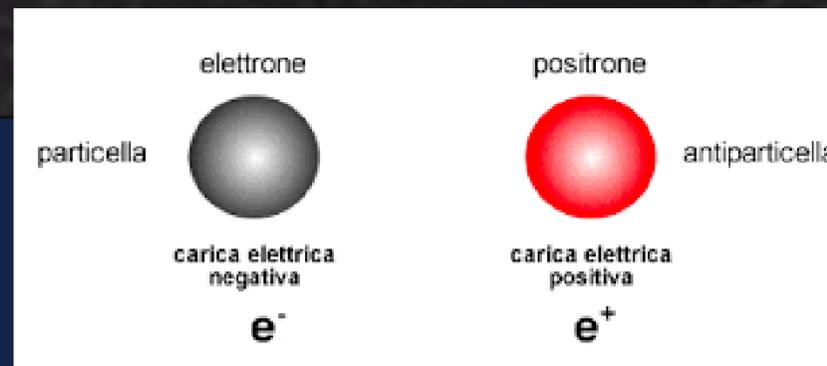


# Cercare le tracce

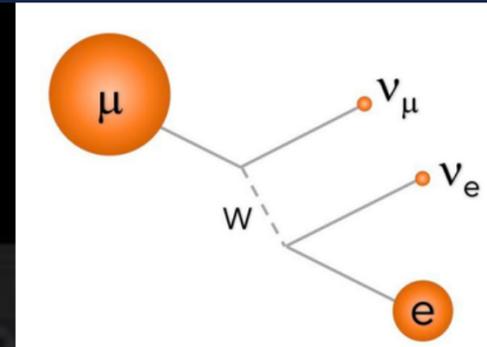
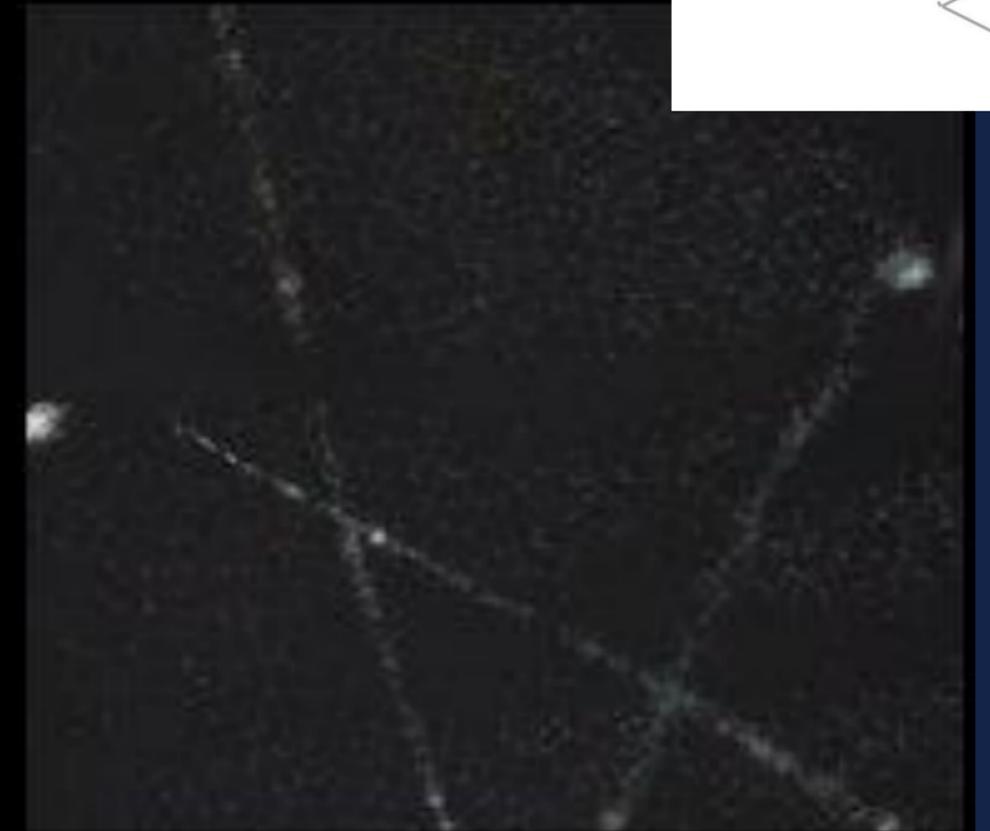
Particelle alfa

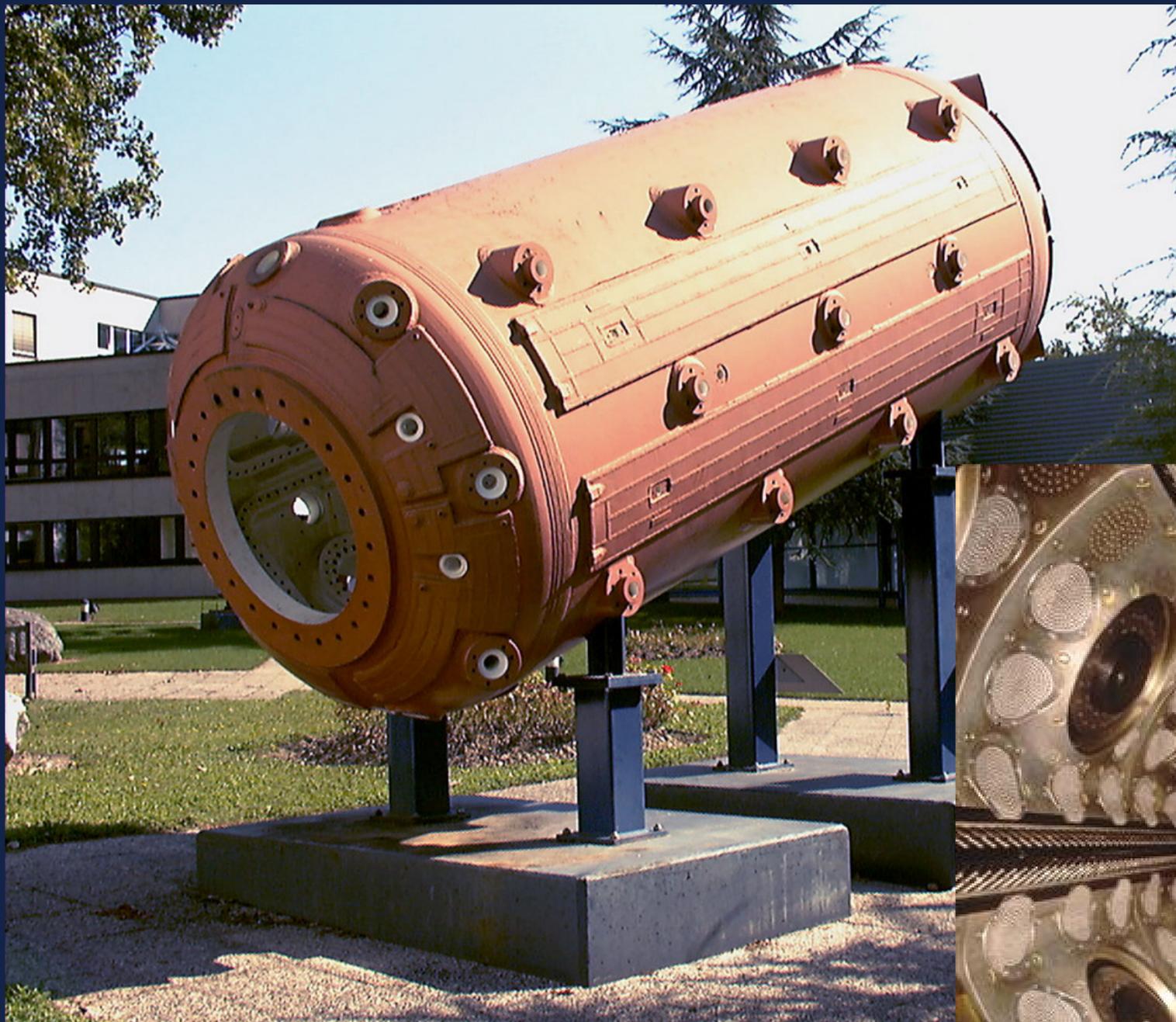


Particelle beta (elettroni)



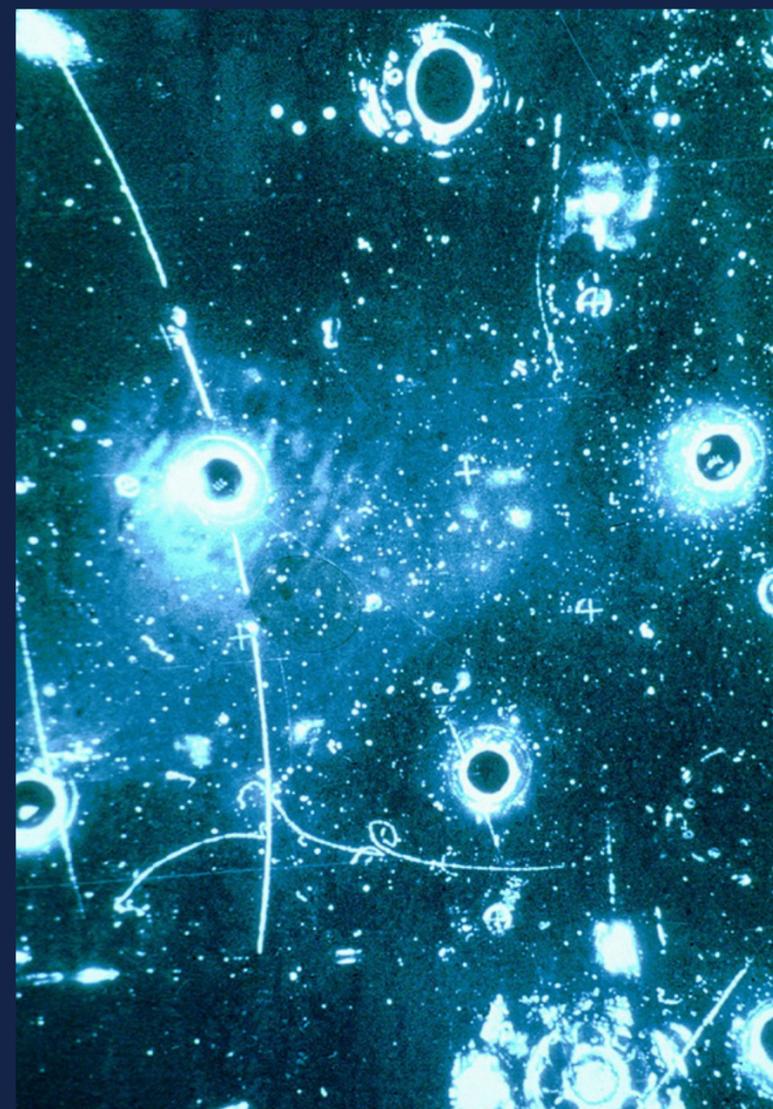
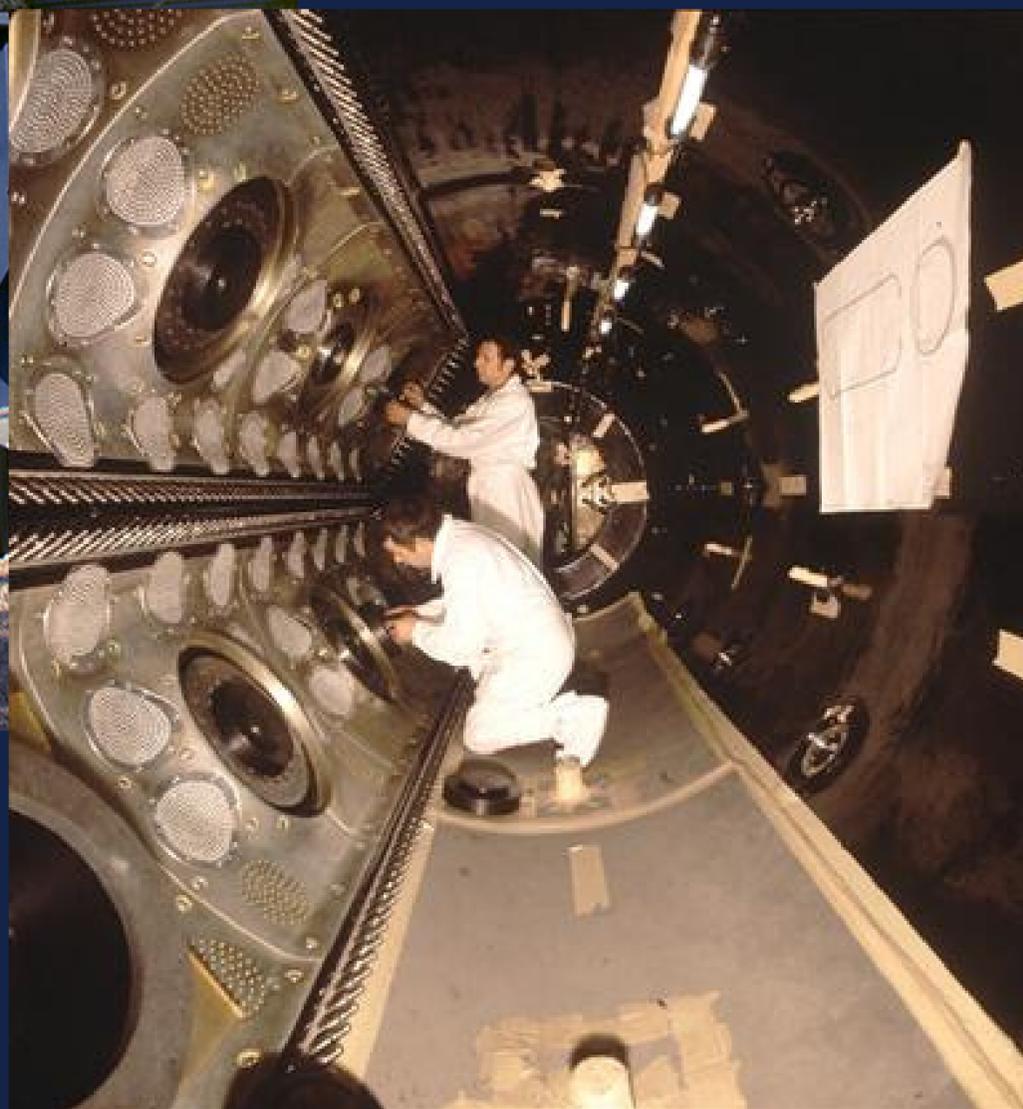
Muoni



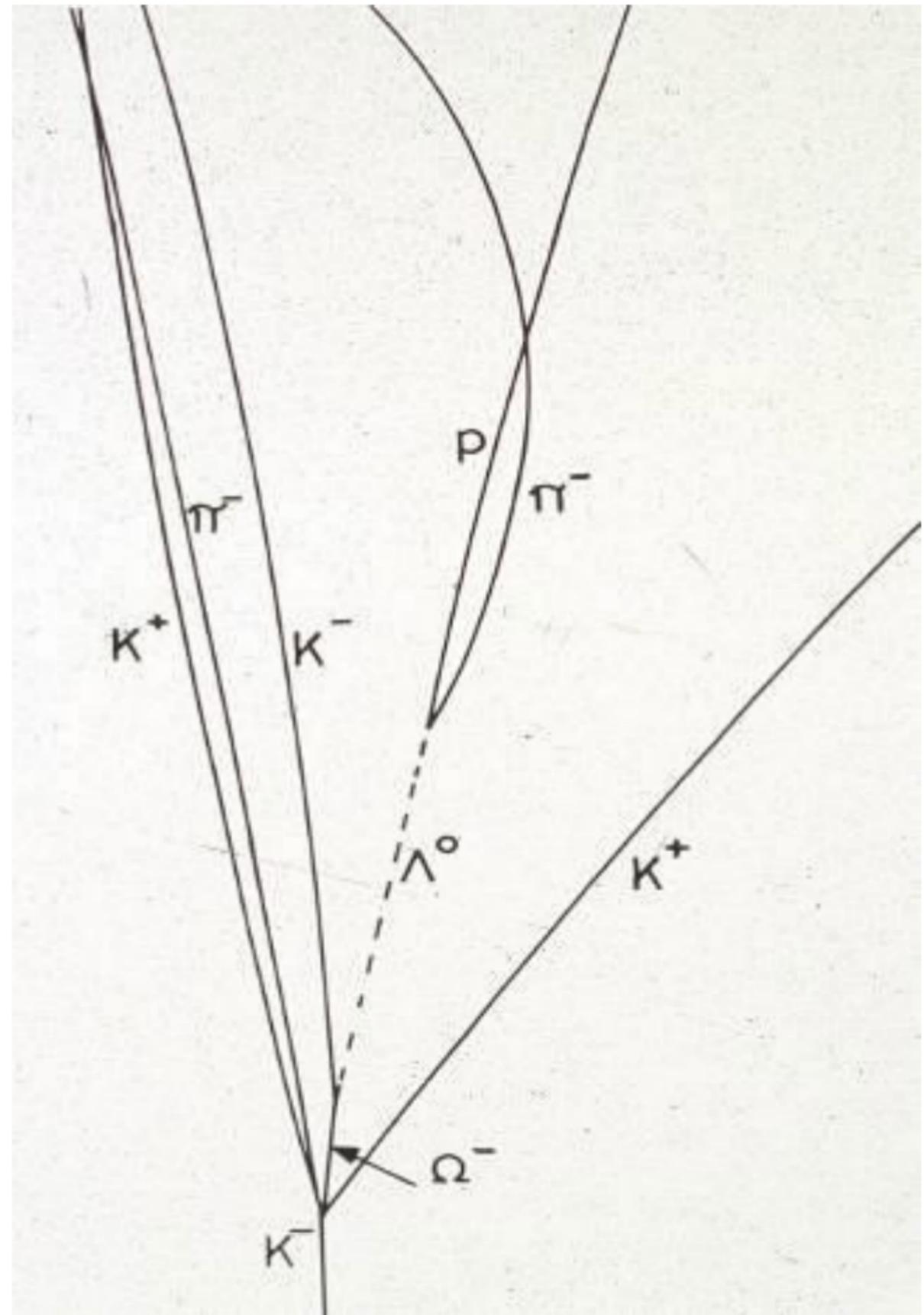
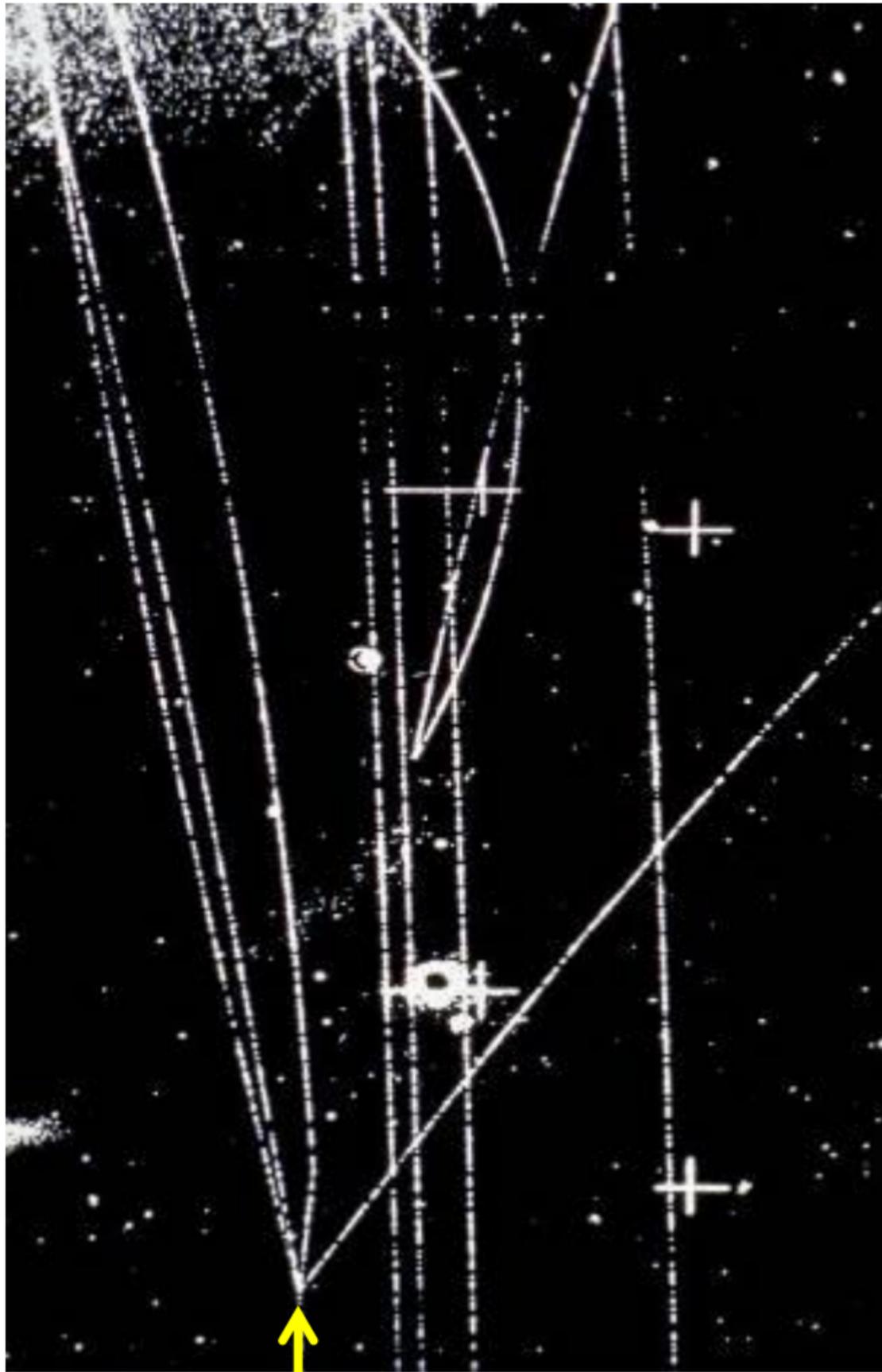


# ARGONNE

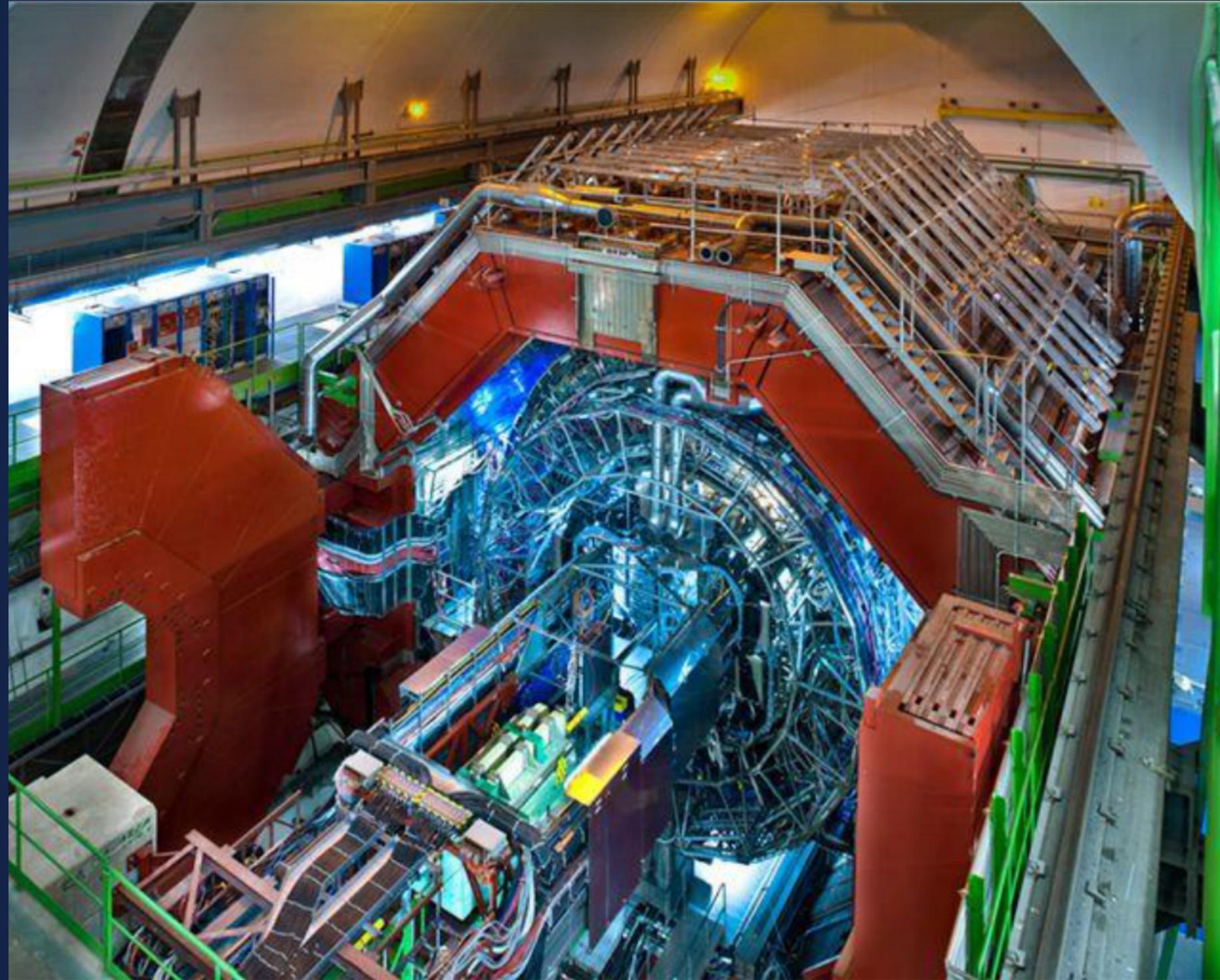
il nonno di tutti i rivelatori di particelle



**Premio Nobel  
C. Rubbia**



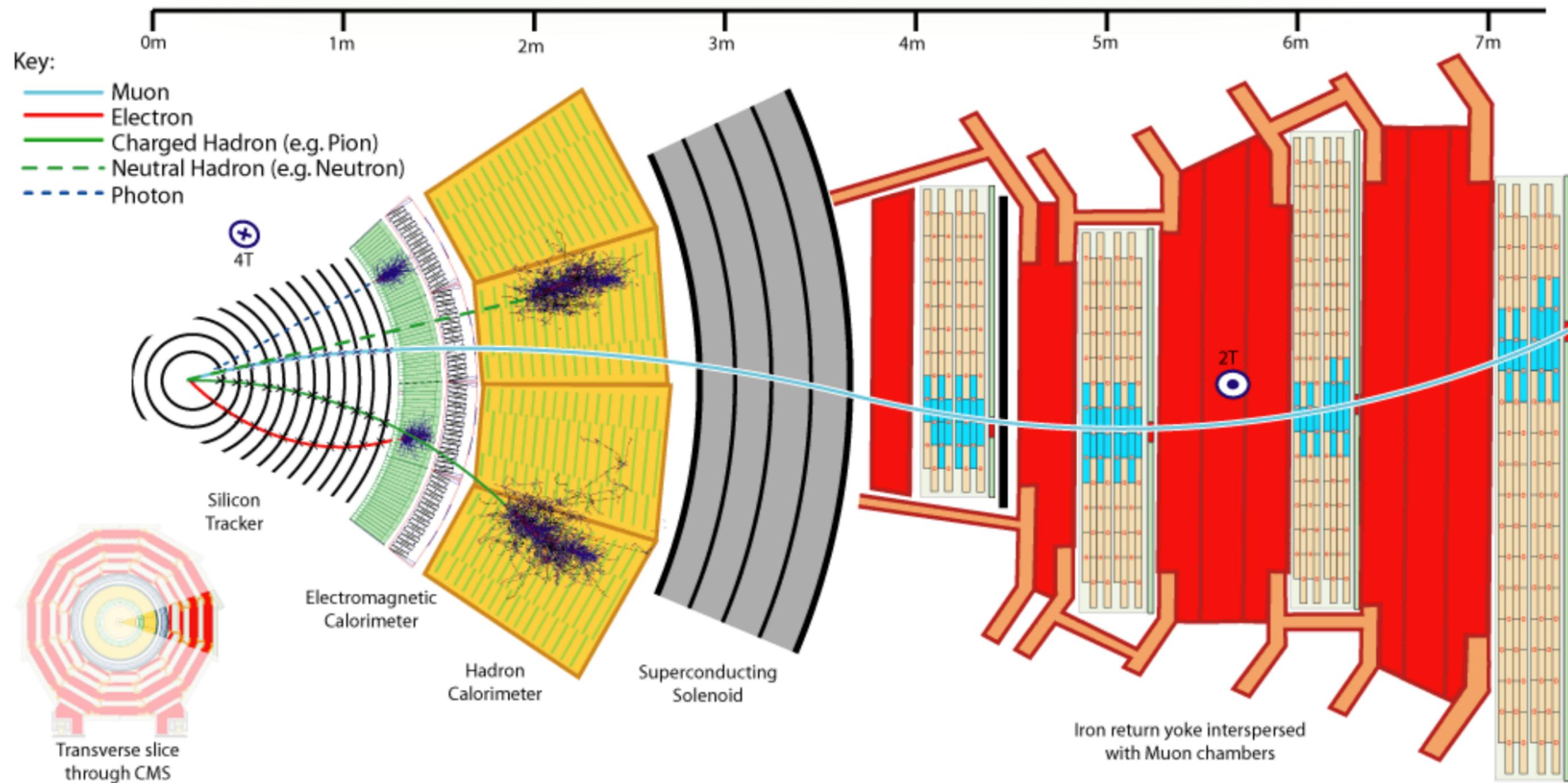
# RIVELATORI MODERNI

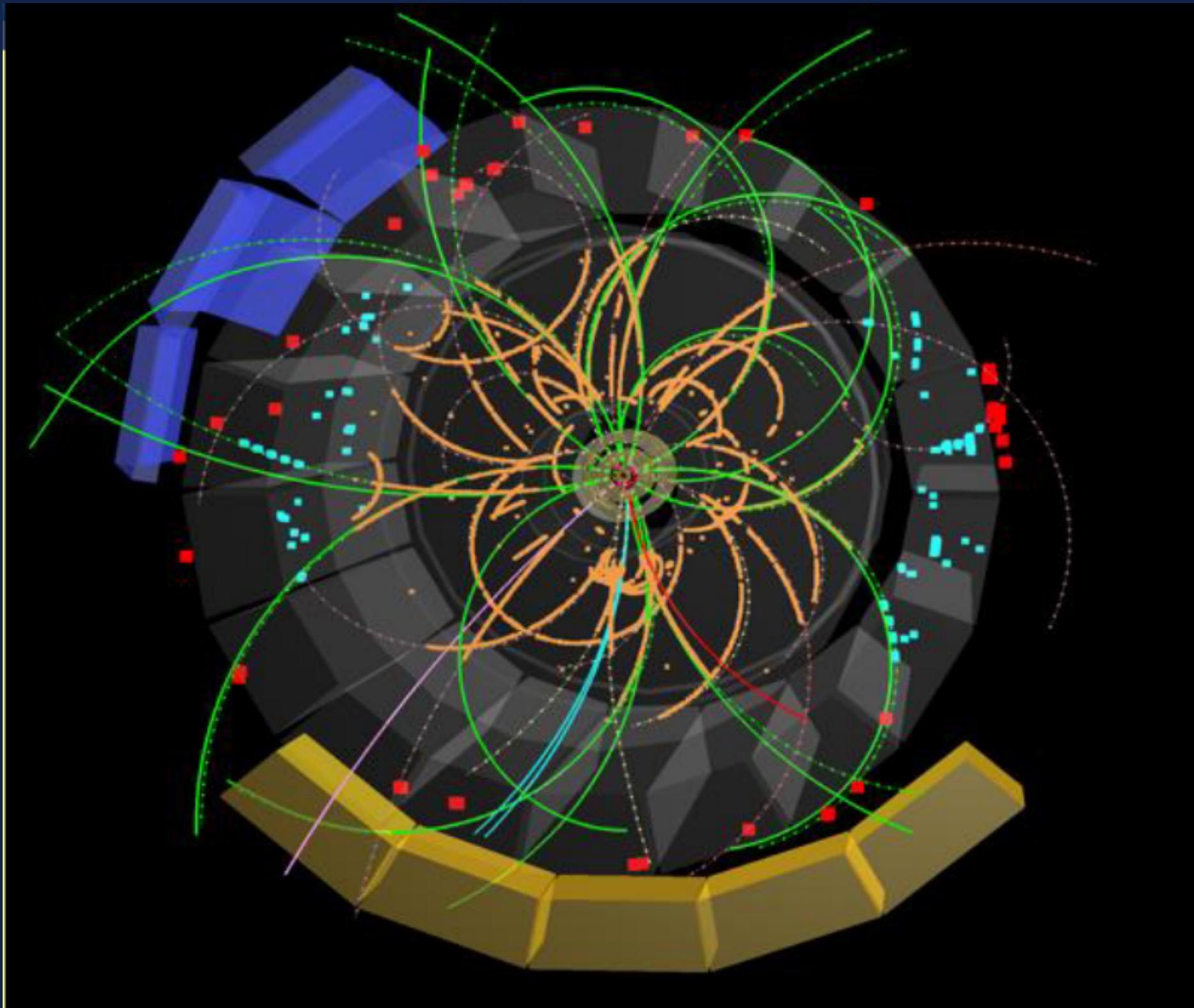


ALICE @  
CERN

# RIVELATORI MODERNI

CMS @  
CERN

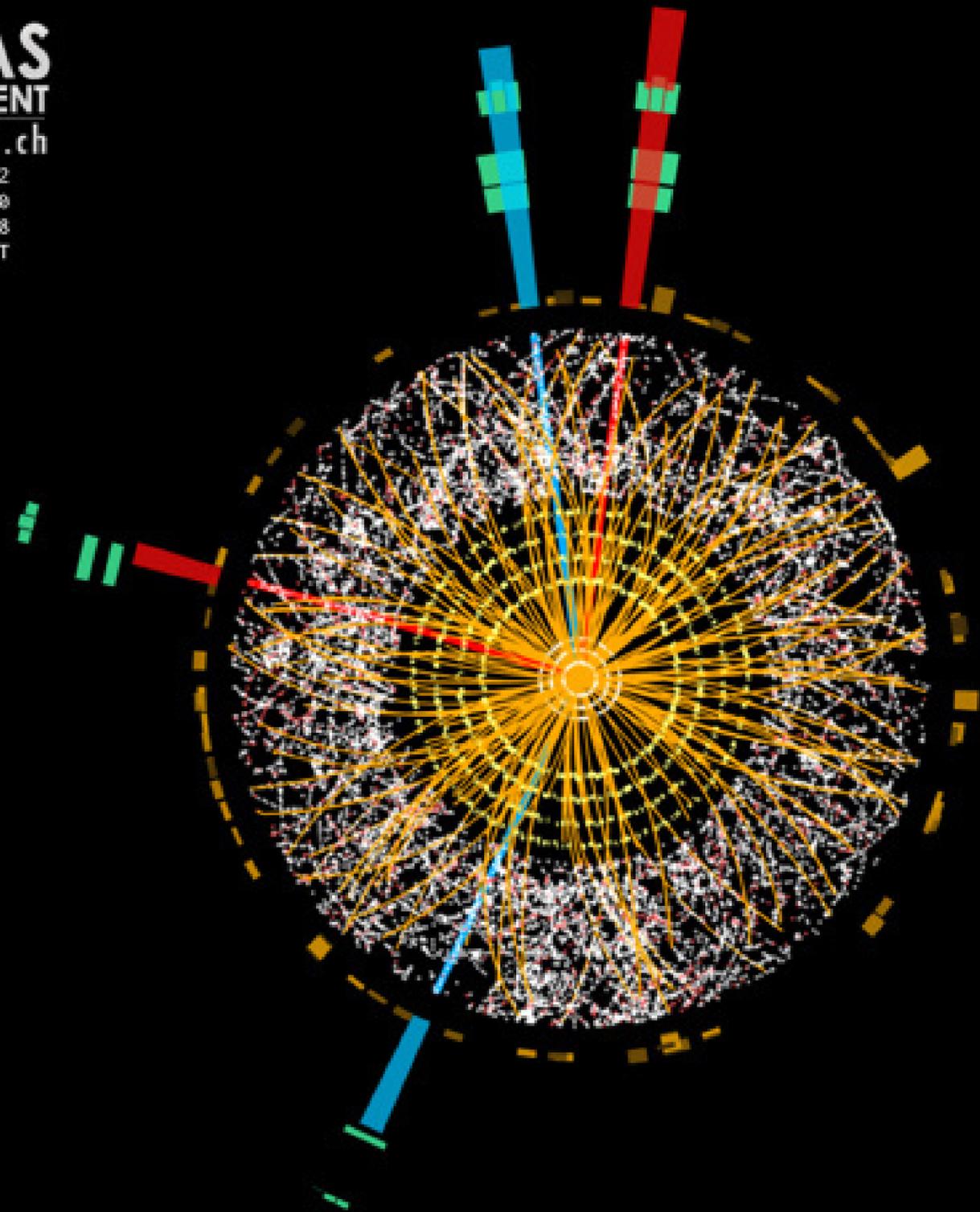
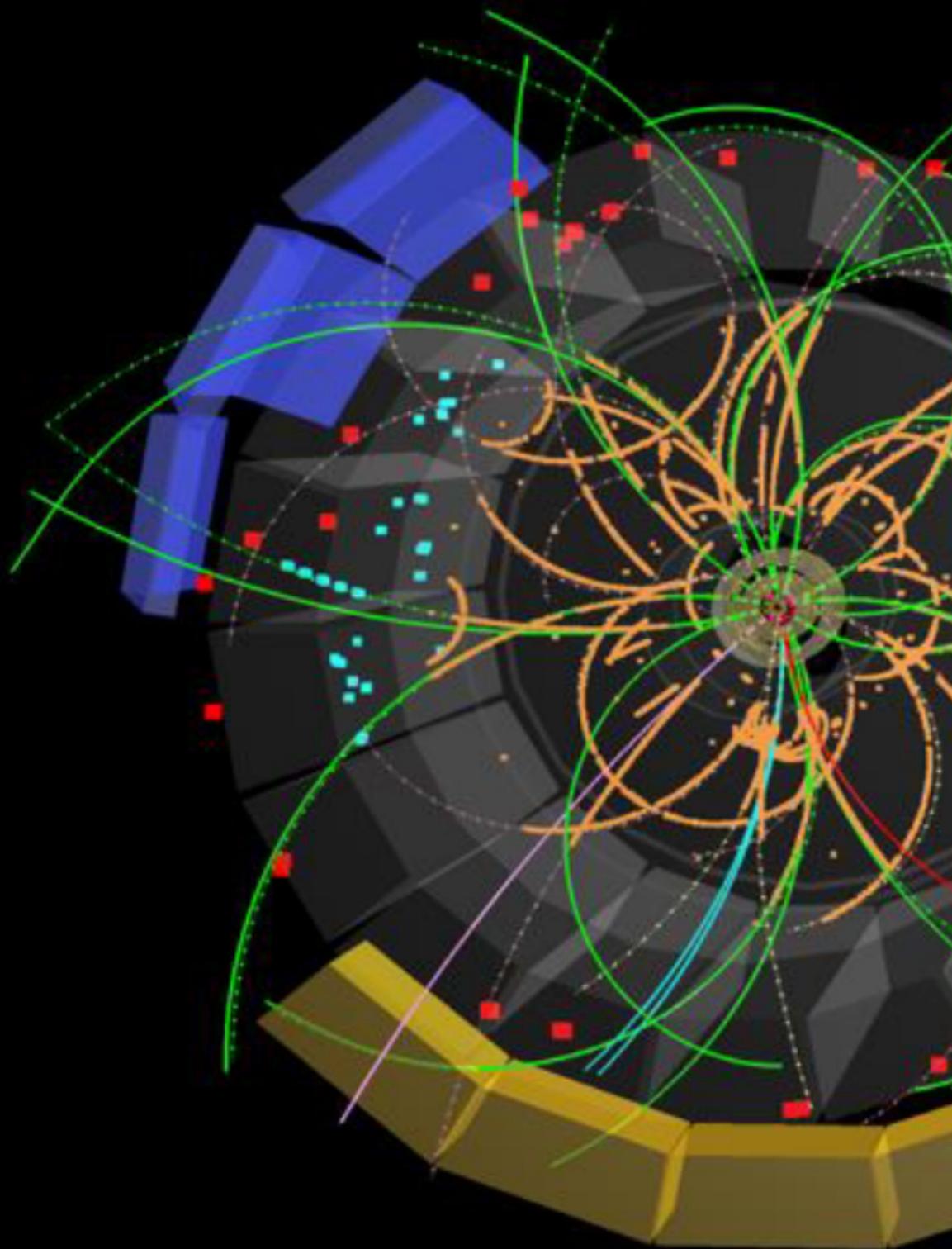




 **ATLAS**  
EXPERIMENT

<http://atlas.ch>

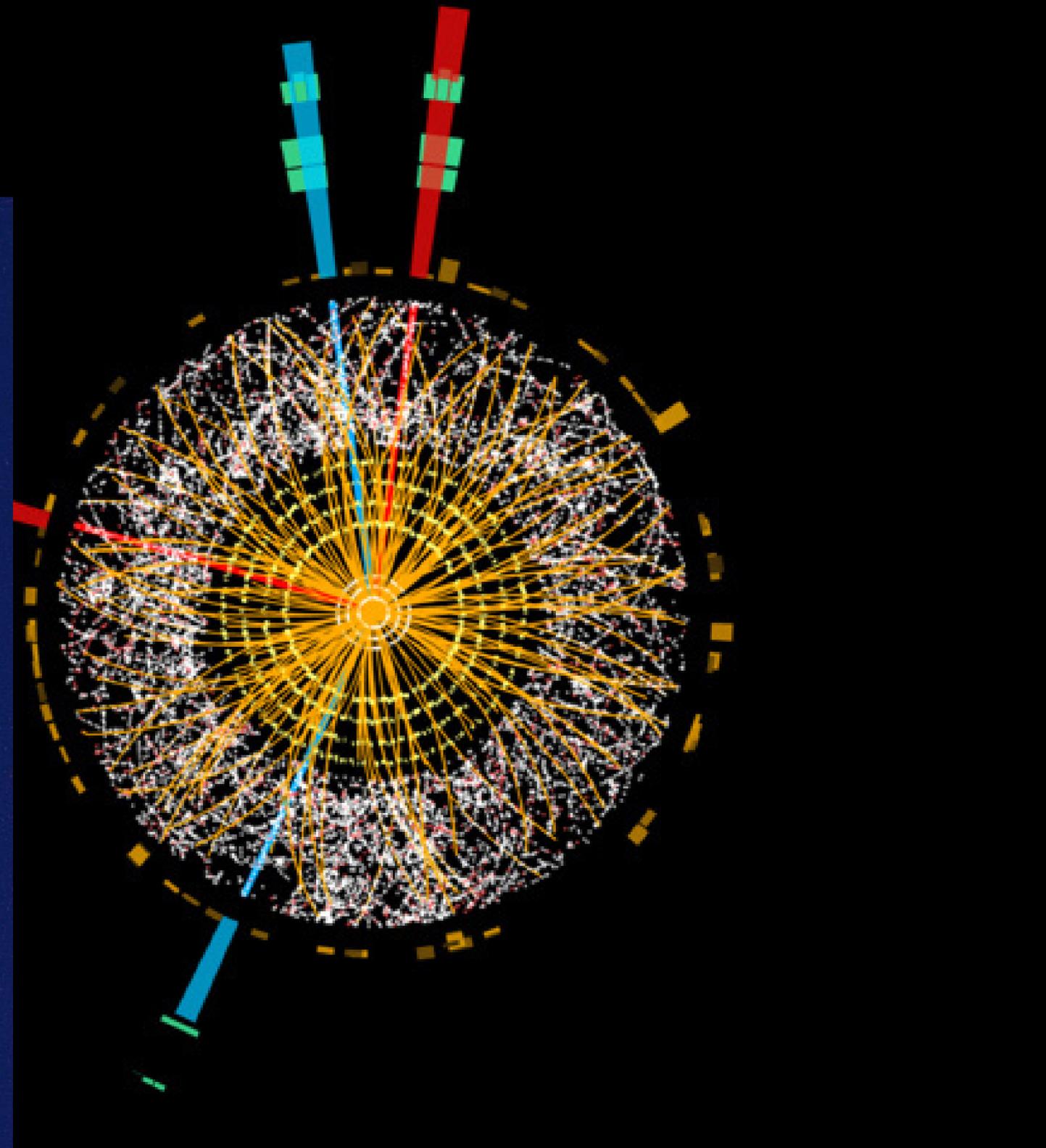
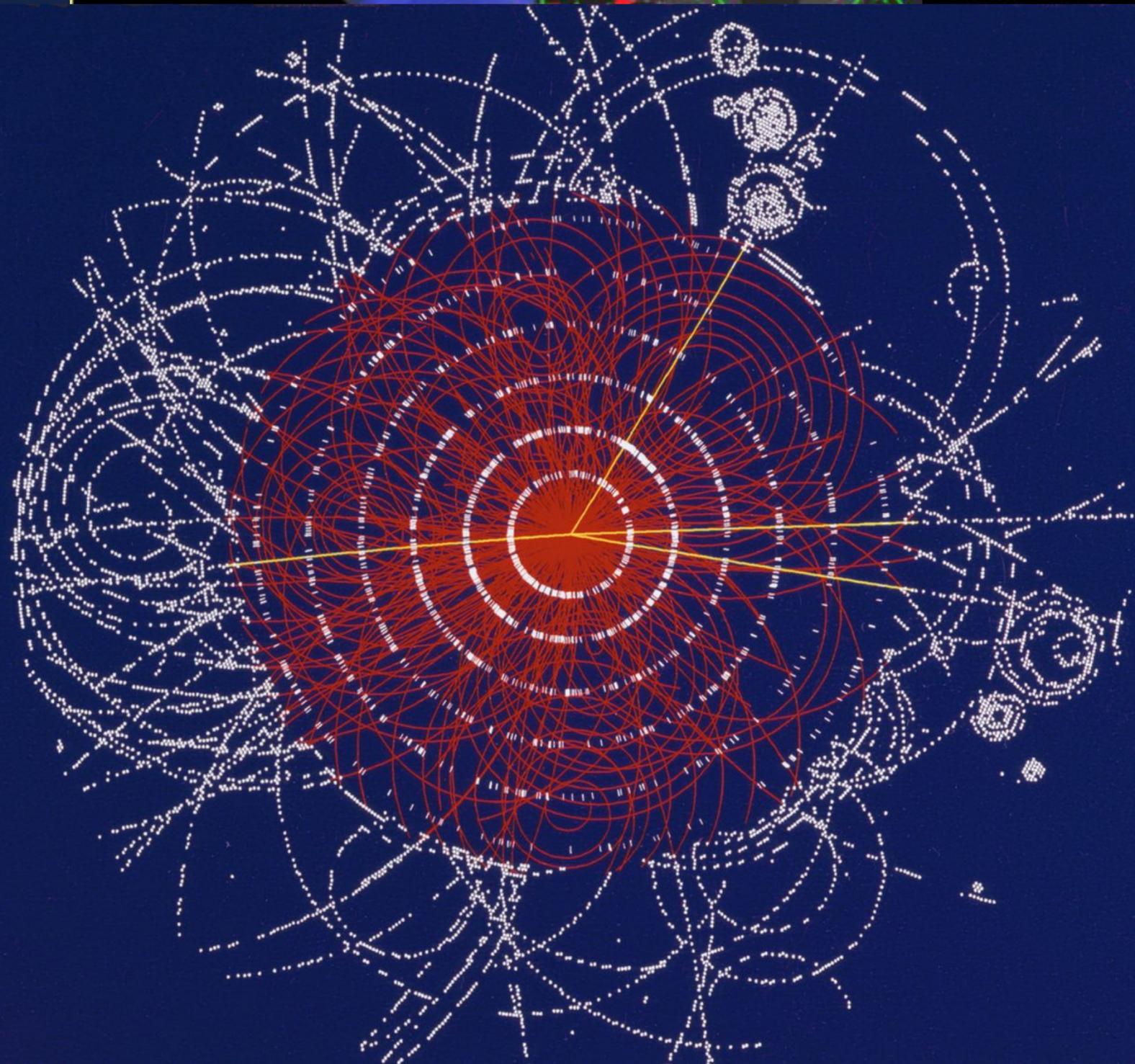
Run: 203602  
Event: 82614360  
Date: 2012-05-18  
Time: 20:28:11 CEST



 **ATLAS**  
EXPERIMENT

<http://atlas.ch>

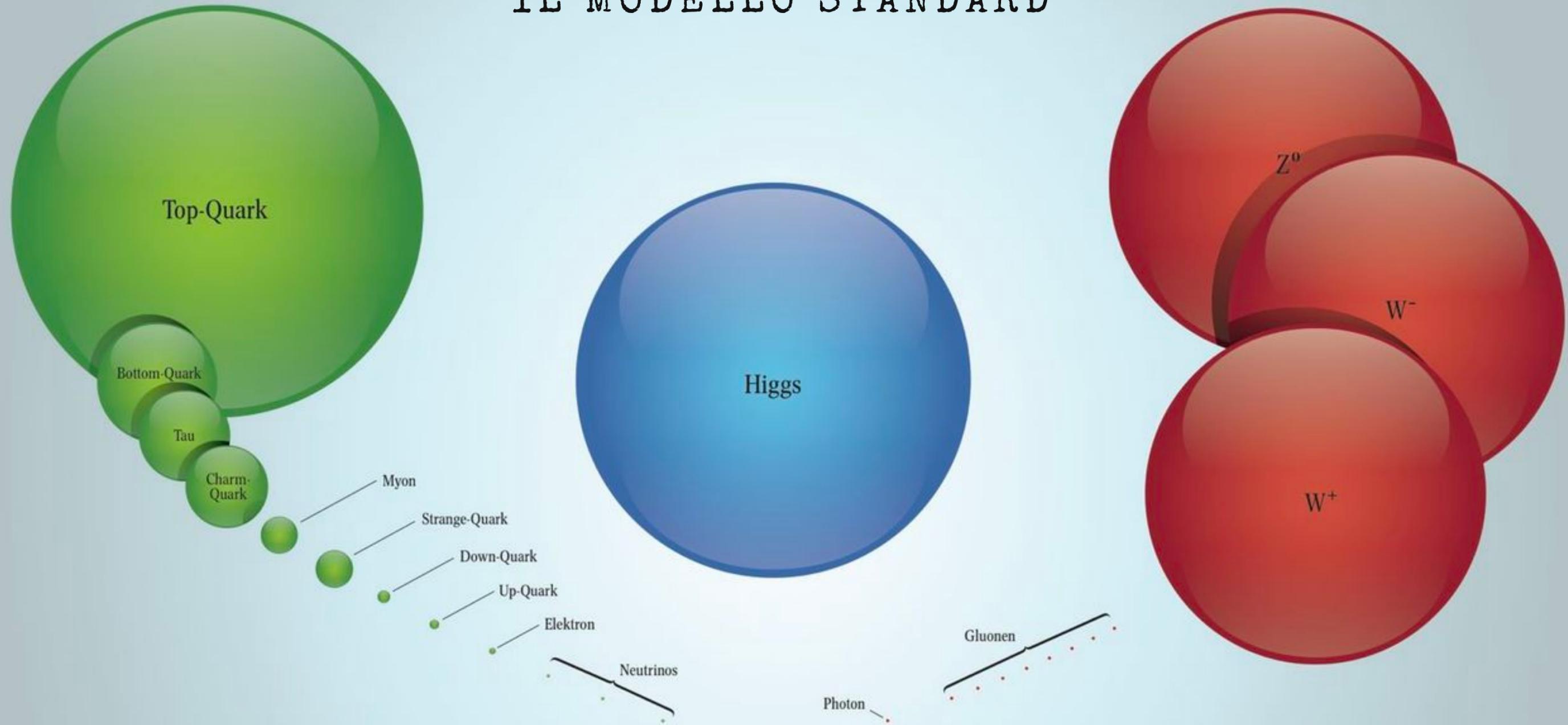
Run: 203602  
Event: 82614360





# Particelle elementari

## IL MODELLO STANDARD



# STANDARD MODEL OF ELEMENTARY PARTICLES

QUARKS

<b>UP</b> mass $2,3 \text{ MeV}/c^2$ charge $\frac{2}{3}$ spin $\frac{1}{2}$ 	<b>CHARM</b> mass $1,275 \text{ GeV}/c^2$ charge $\frac{2}{3}$ spin $\frac{1}{2}$ 	<b>TOP</b> mass $173,07 \text{ GeV}/c^2$ charge $\frac{2}{3}$ spin $\frac{1}{2}$ 
<b>DOWN</b> mass $4,8 \text{ MeV}/c^2$ charge $-\frac{1}{3}$ spin $\frac{1}{2}$ 	<b>STRANGE</b> mass $95 \text{ MeV}/c^2$ charge $-\frac{1}{3}$ spin $\frac{1}{2}$ 	<b>BOTTOM</b> mass $4,18 \text{ GeV}/c^2$ charge $-\frac{1}{3}$ spin $\frac{1}{2}$ 

LEPTONS

<b>ELECTRON</b> mass $0,511 \text{ MeV}/c^2$ charge $-1$ spin $\frac{1}{2}$ 	<b>MUON</b> mass $105,7 \text{ MeV}/c^2$ charge $-1$ spin $\frac{1}{2}$ 	<b>TAU</b> mass $1,777 \text{ GeV}/c^2$ charge $-1$ spin $\frac{1}{2}$ 
<b>ELECTRON NEUTRINO</b> mass $<2,2 \text{ eV}/c^2$ charge $0$ spin $\frac{1}{2}$ 	<b>MUON NEUTRINO</b> mass $<0,17 \text{ MeV}/c^2$ charge $0$ spin $\frac{1}{2}$ 	<b>TAU NEUTRINO</b> mass $<15,5 \text{ MeV}/c^2$ charge $0$ spin $\frac{1}{2}$ 

**GLUON**  
 mass  $0$   
 charge  $0$   
 spin  $1$   

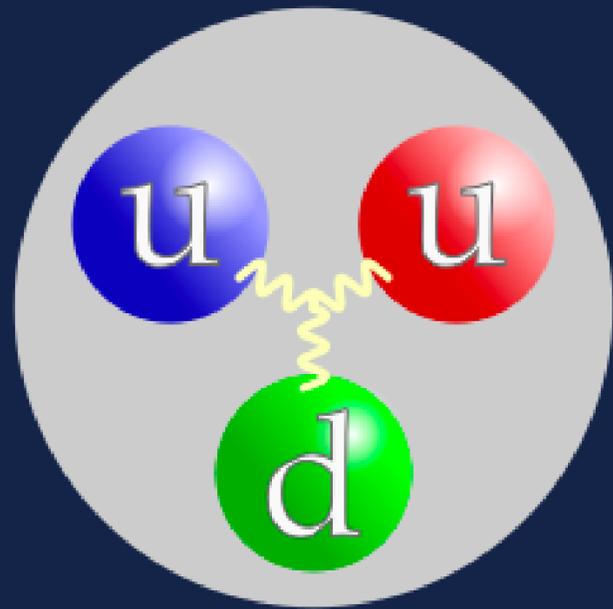

**HIGGS BOSON**  
 mass  $126 \text{ GeV}/c^2$   
 charge  $0$   
 spin  $0$   


**PHOTON**  
 mass  $0$   
 charge  $0$   
 spin  $1$   

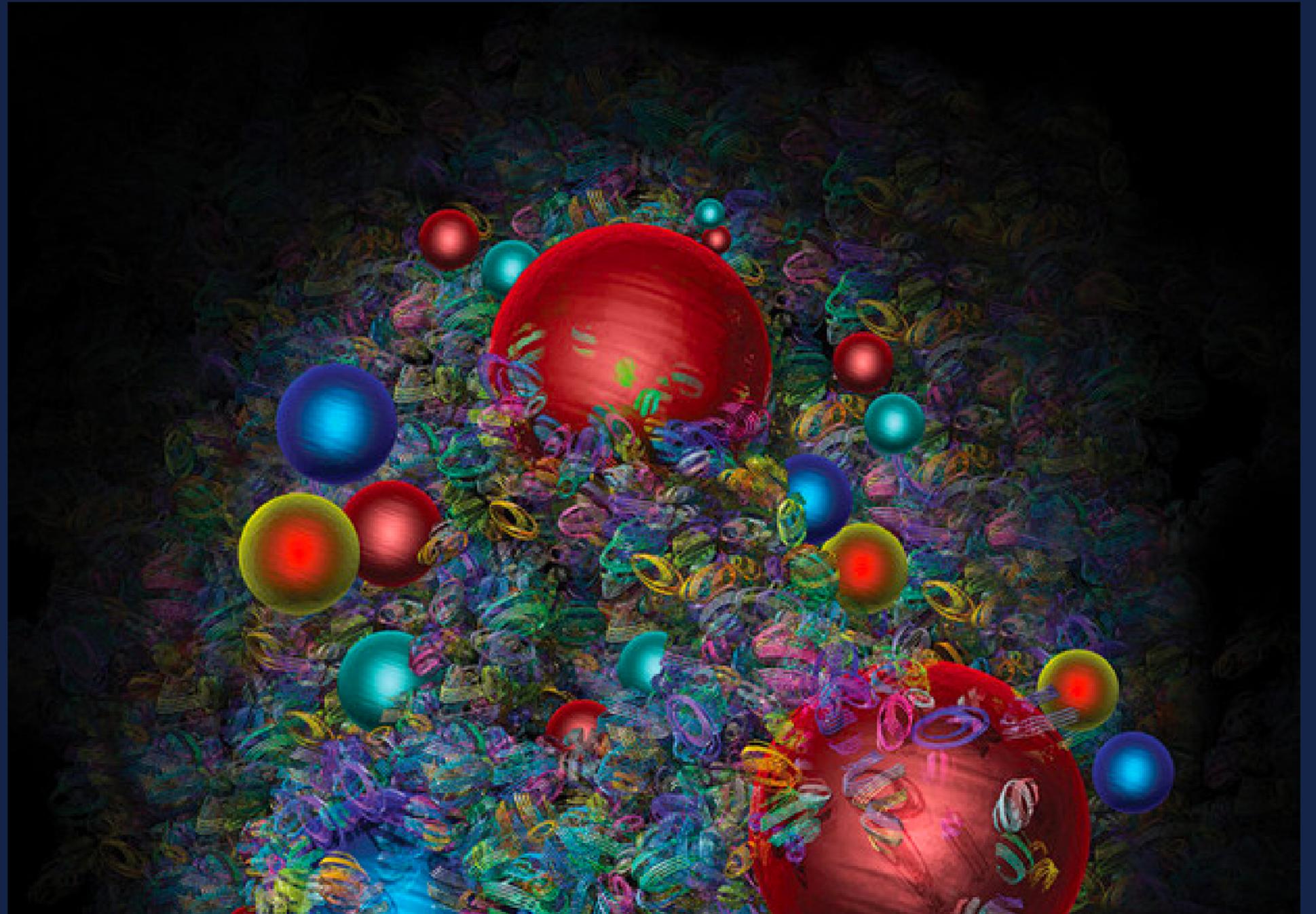

**Z BOSON**  
 mass  $91,2 \text{ GeV}/c^2$   
 charge  $0$   
 spin  $1$   

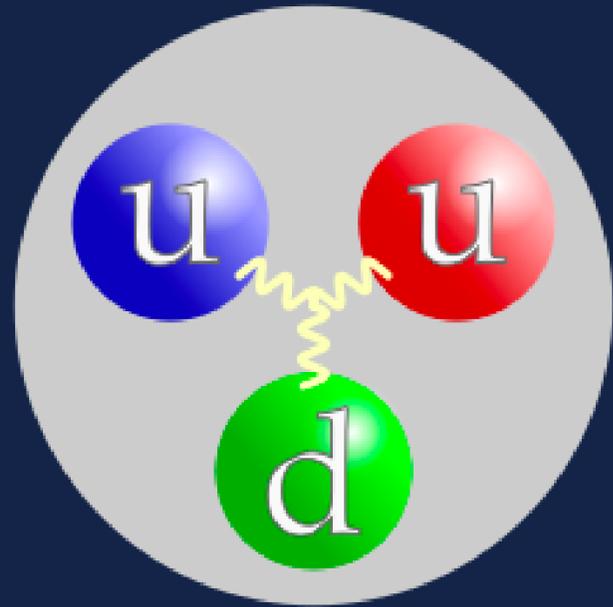

**W BOSON**  
 mass  $80,4 \text{ GeV}/c^2$   
 charge  $\pm 1$   
 spin  $1$   


GAUGE BOSONS

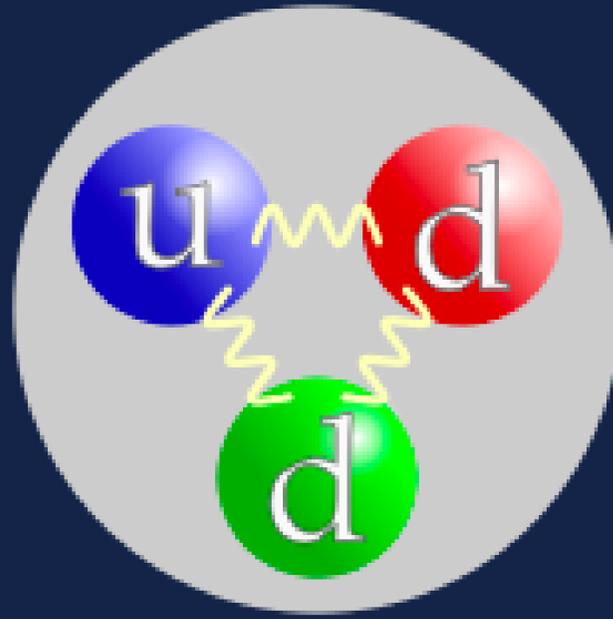


**Protone**

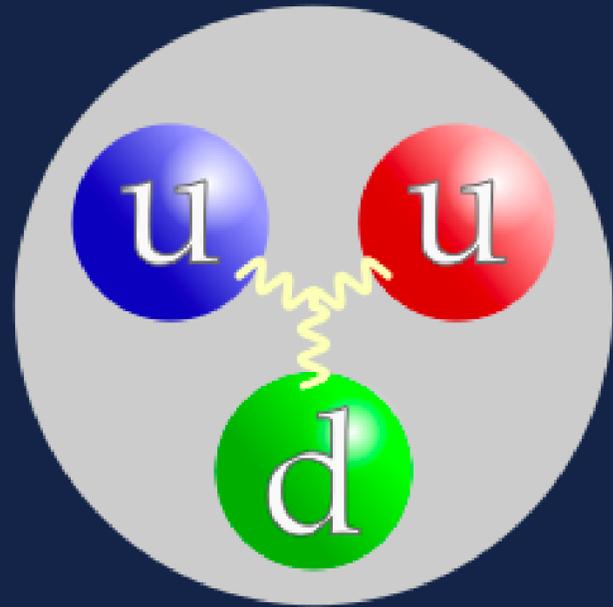




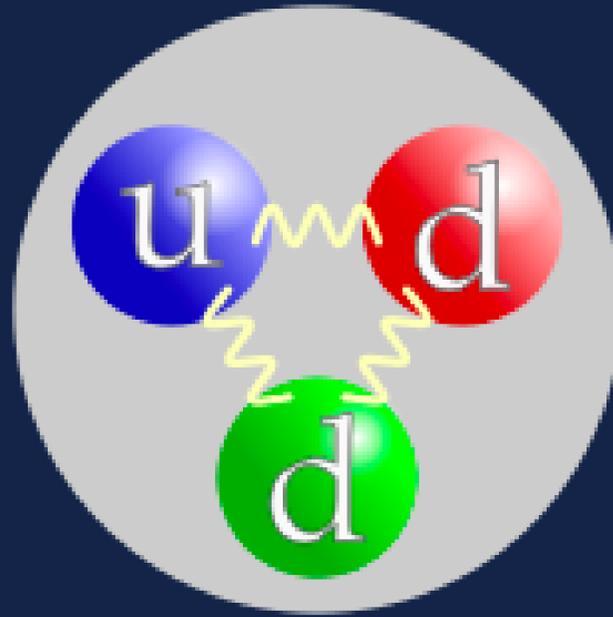
**Protone**



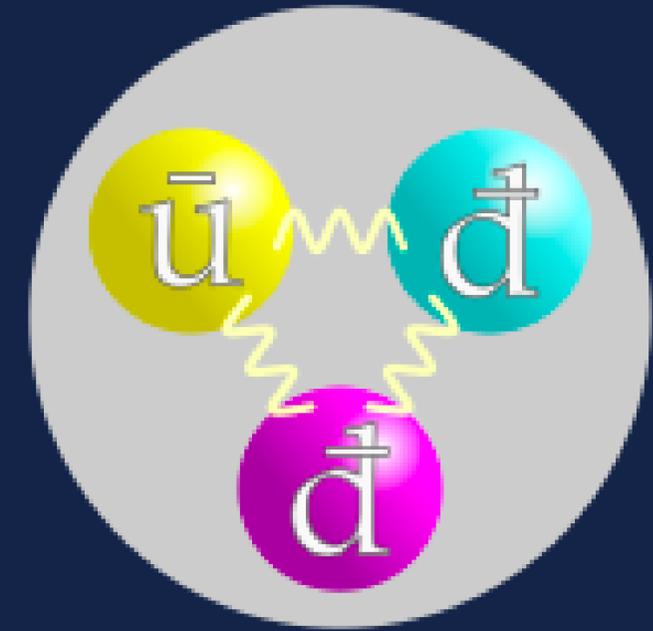
**Neutrone**



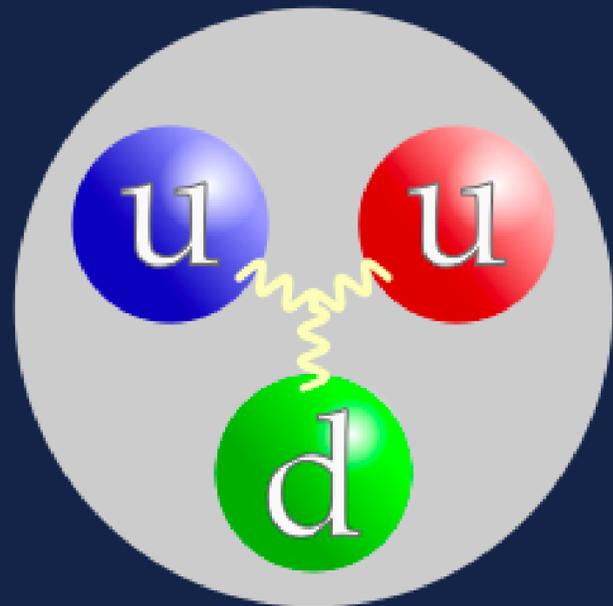
**Protone**



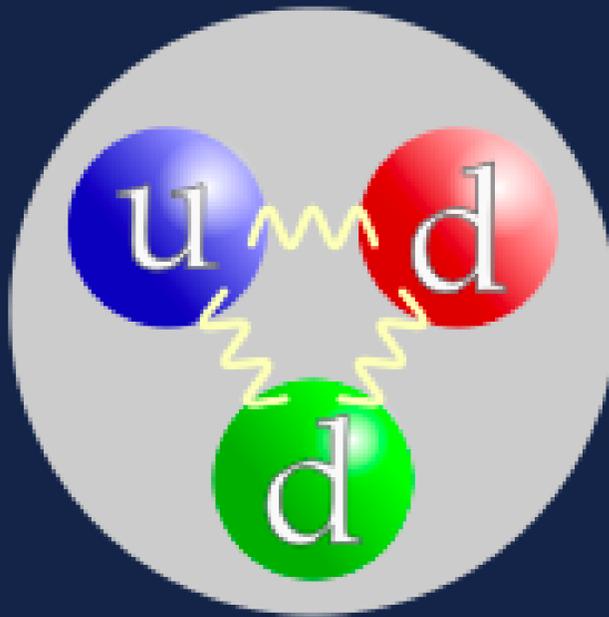
**Neutrone**



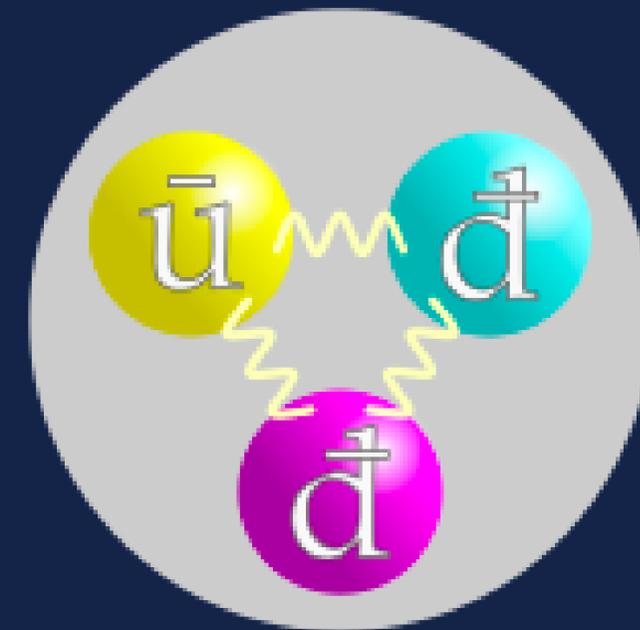
**Anti-protone**



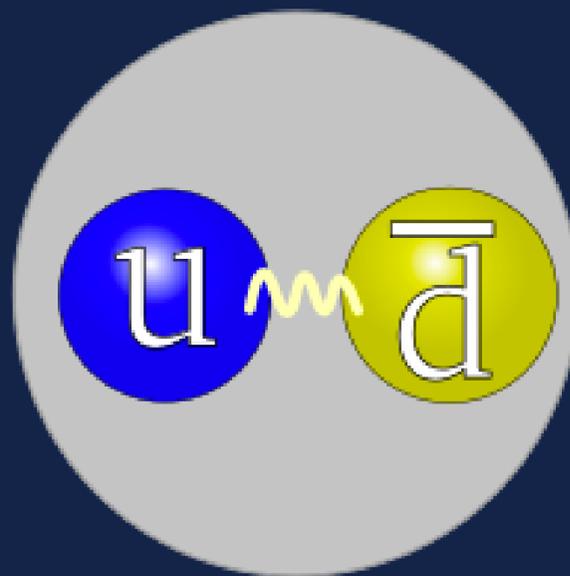
**Protone**



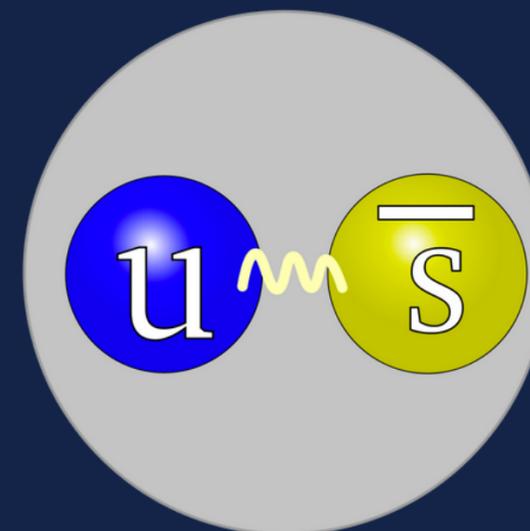
**Neutrone**



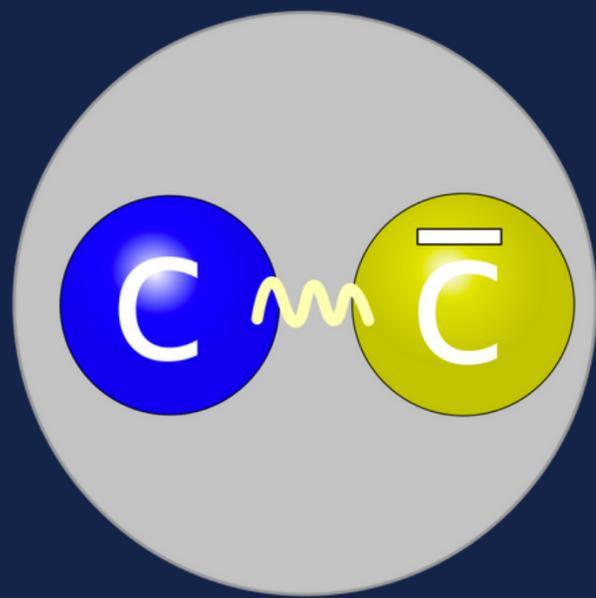
**Anti-protone**



**Pione +**



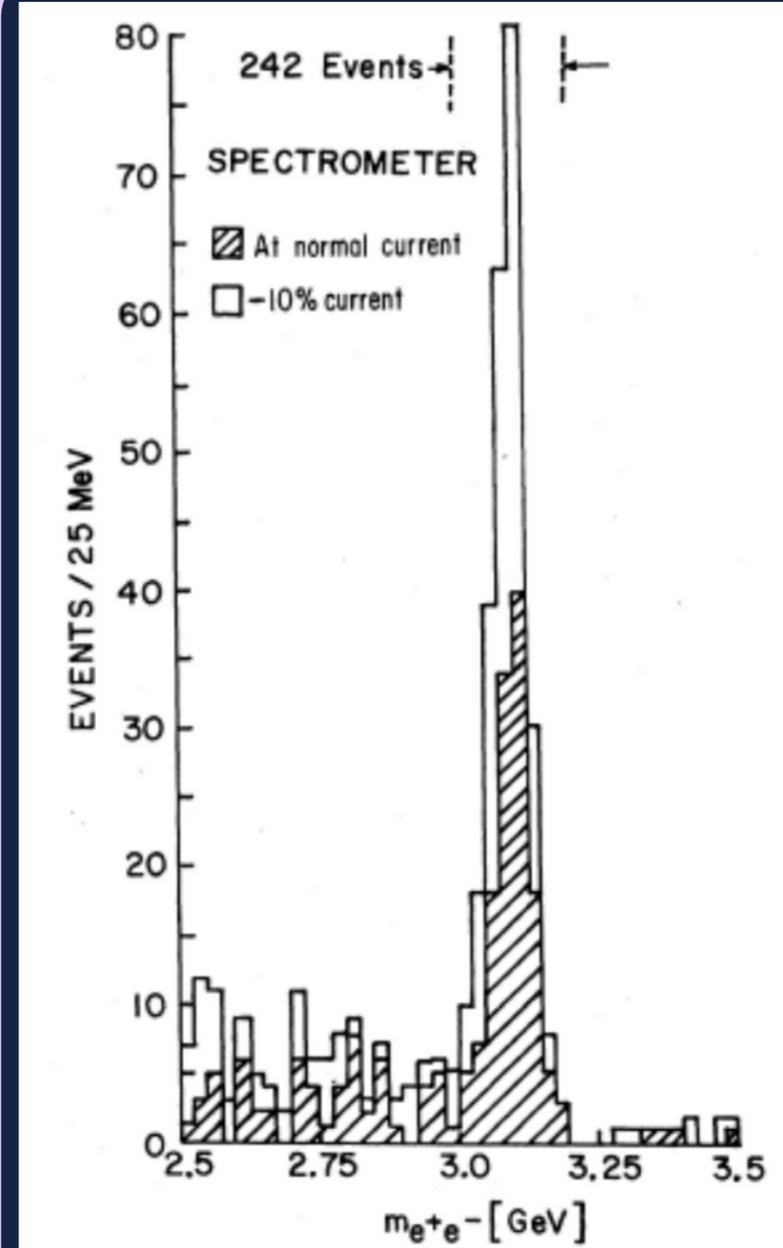
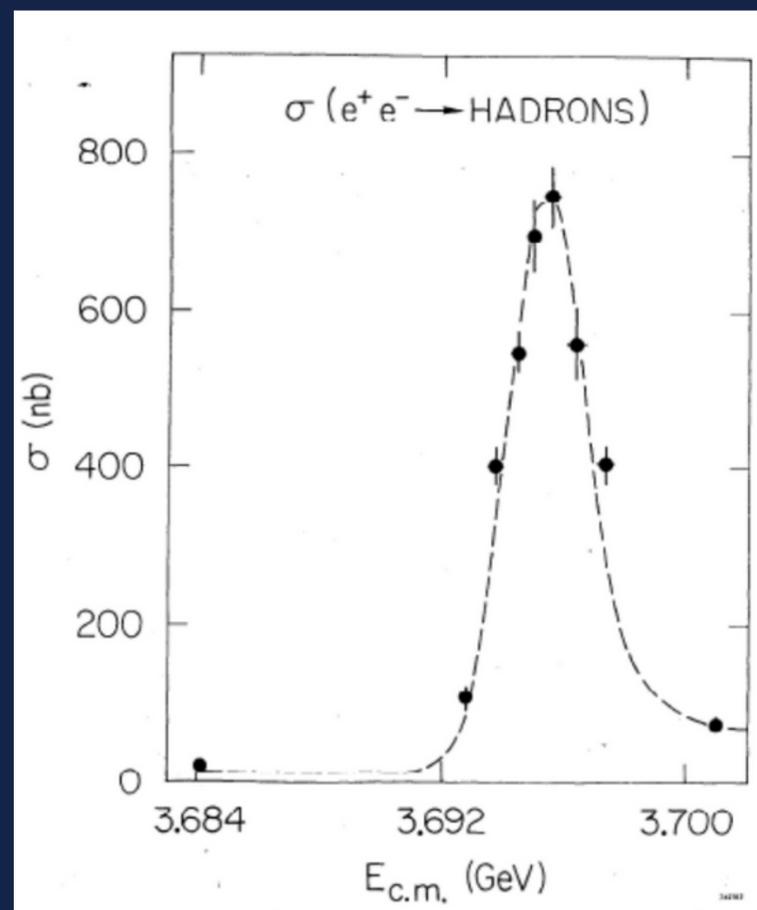
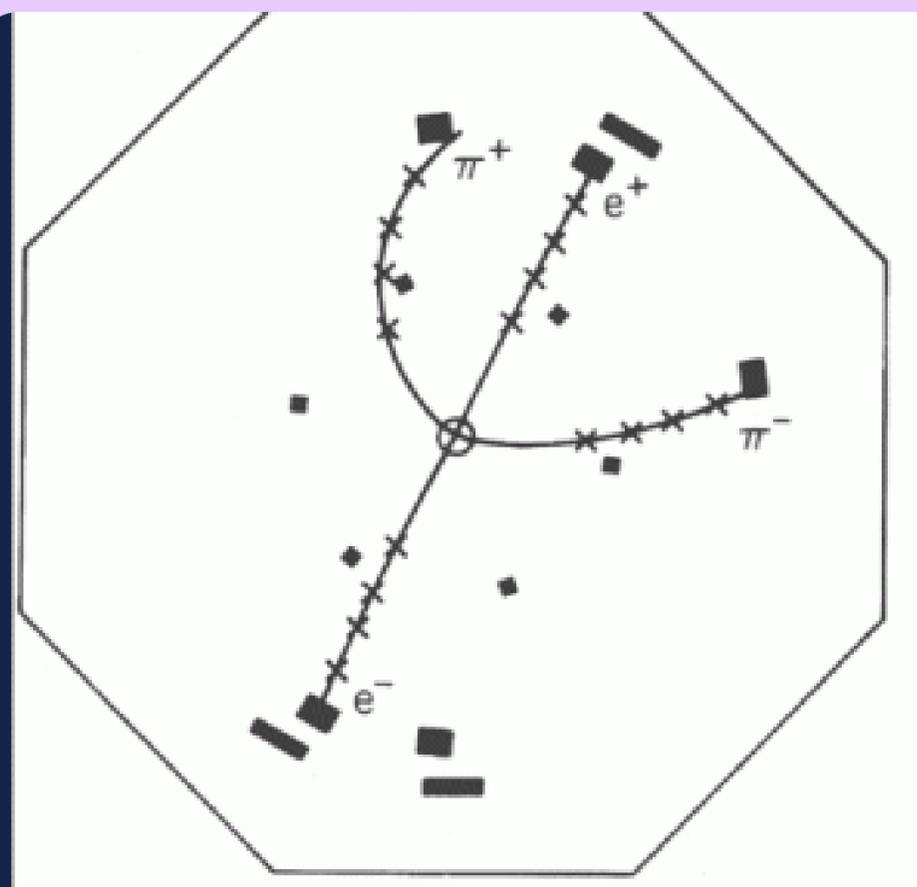
**Kaone +**



$J/\psi$

Scoperta: 1974

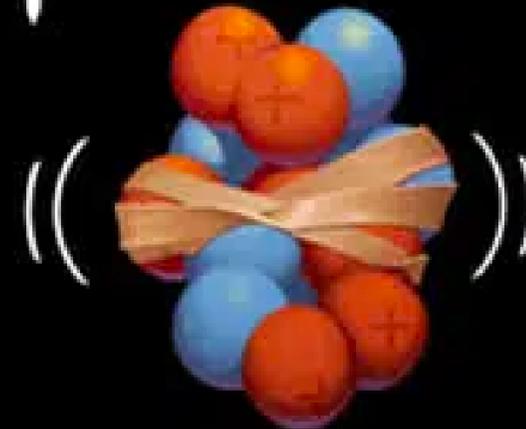
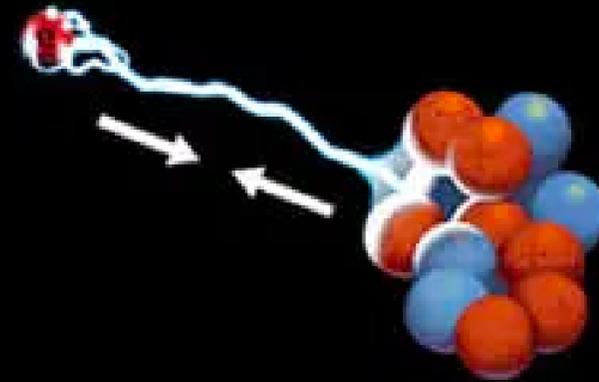
ADONE @ Frascati qualche giorno  
dopo la scoperta



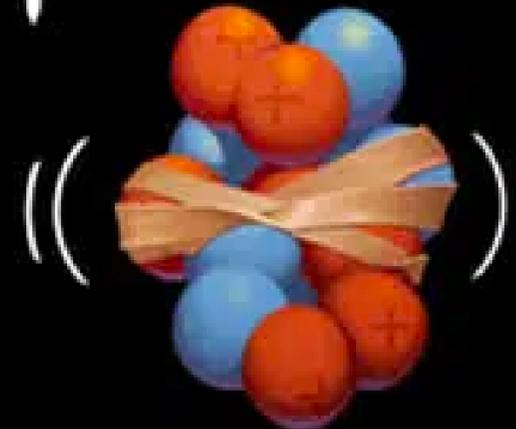
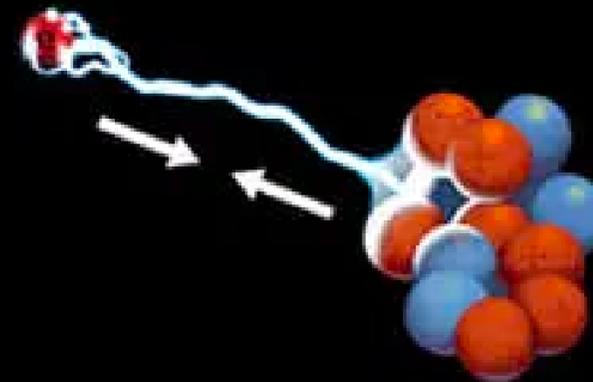
@ Brookhaven Lab

@ SLAC Lab

# Le interazioni Fondamentali



# Le interazioni Fondamentali



- La più antica, la meno nota
- Onde gravitazionali: 2015
- Gravitone?
- Trascurabile su scala atomica e sub-atomica

- Raggio azione  $\infty$
- Carica elettrica
- Equazioni di Maxwell: unificazione
- Coesione atomica e molecolare

- Raggio azione  $\sim 10^{-18}m$
- Fusione termonucleare nelle stelle
- Asimmetria materia-antimateria

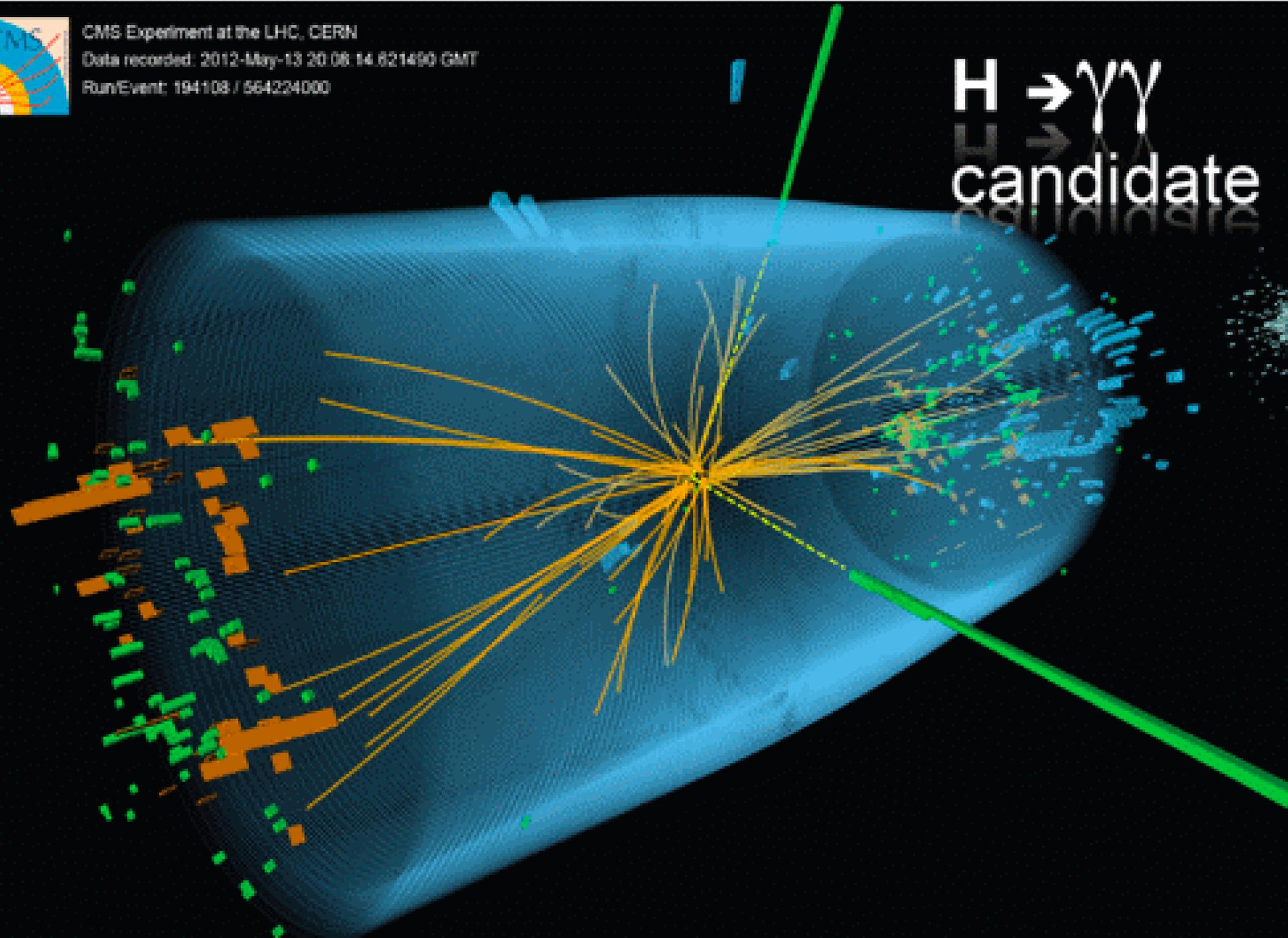
- Raggio azione  $\sim 10^{-15}m$
- Stabilità del nucleo
- Carica forte di colore (8 colori à 8 gluoni)
- Sono "stabili" solo combinazioni neutre di colore

# Il bosone di HIGGS



CMS Experiment at the LHC, CERN  
Data recorded: 2012-May-13 20:08:14.621490 GMT  
Run/Event: 194108 / 564234000

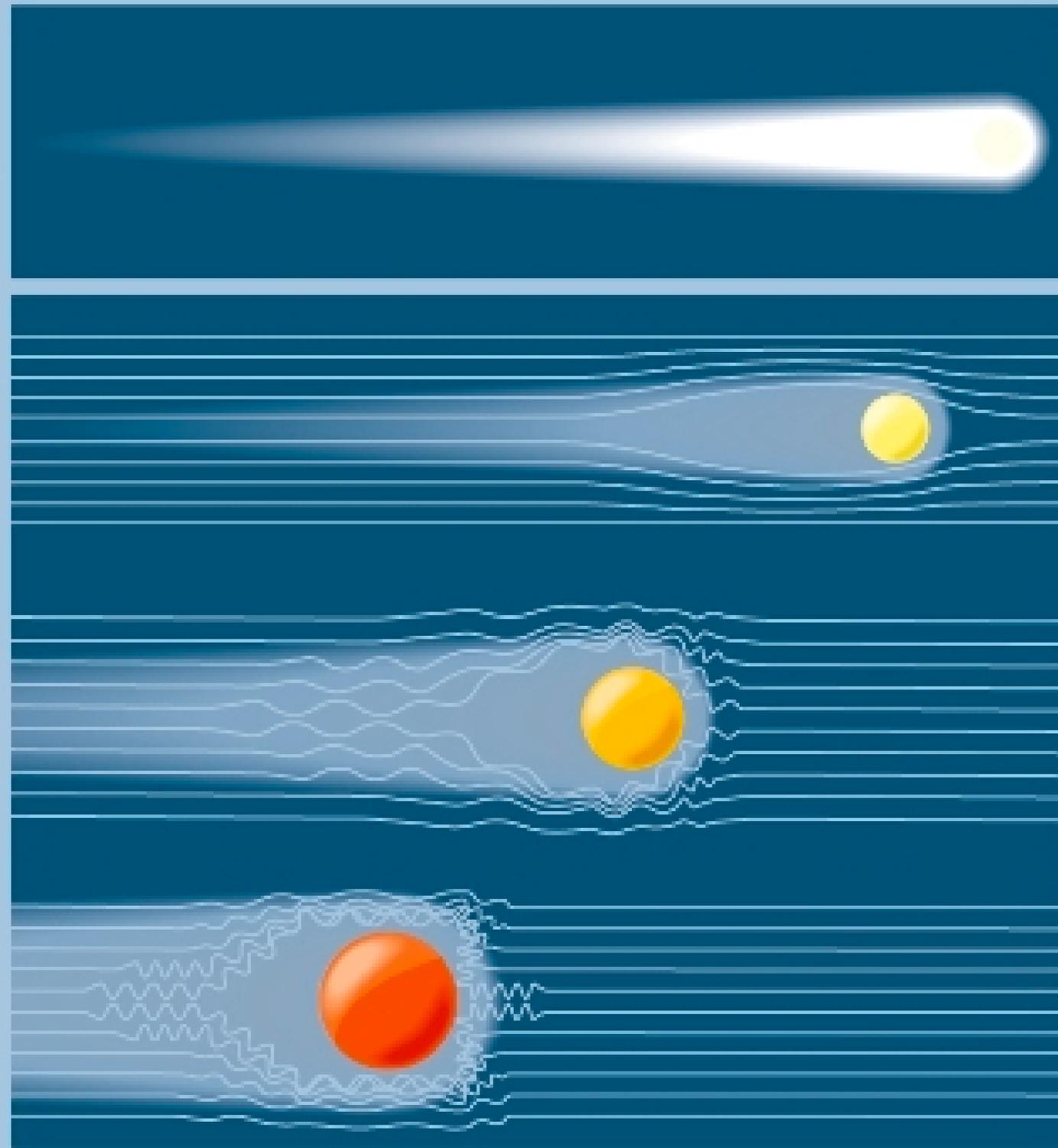
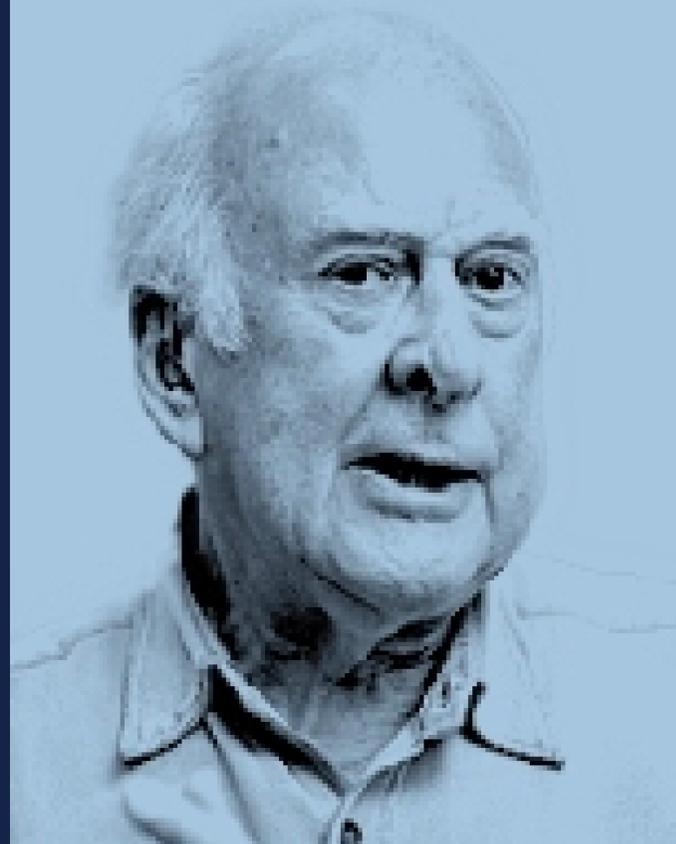
$H \rightarrow \gamma\gamma$   
candidate



**Ginevra - CERN**  
**12 Luglio 2012**



La massa è acquisita dalle particelle quando queste si trovano immerse e interagiscono con il campo di Higgs prodotto dai bosoni di cui è permeato l'universo



● In assenza di campo le particelle viaggerebbero alla velocità della luce

Attraversando il campo le particelle avvertono ognuna una resistenza diversa che è chiamata massa

- Particelle di massa piccolissima o zero (fotoni, elettroni, ecc.)
- Particelle di massa media (muoni, ecc.)
- Particelle di grande massa (quark top, ecc.)

*Grazie di tutto!*

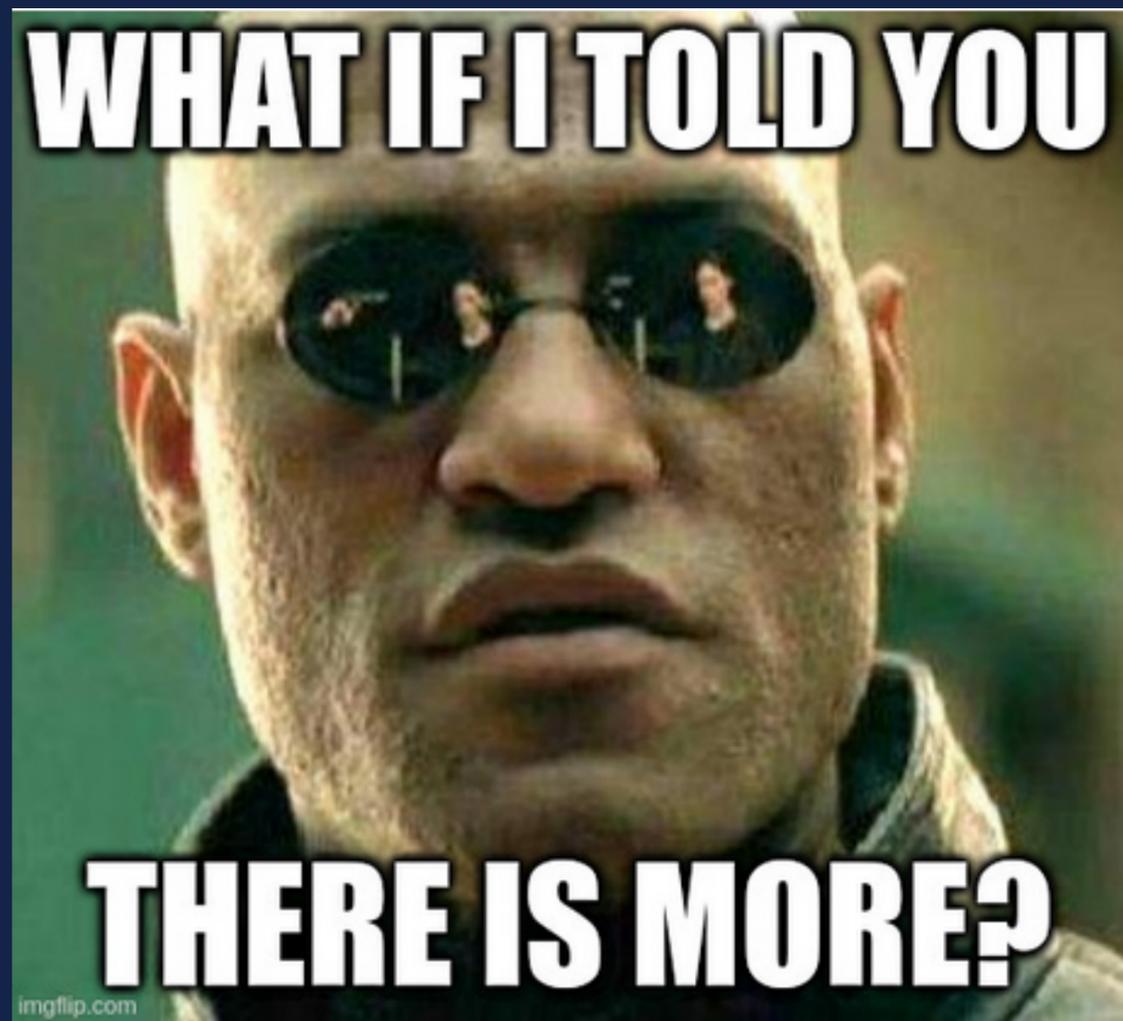
Questa è la nostra storia, abbiamo capito tutto!

**MODELLO STANDARD**

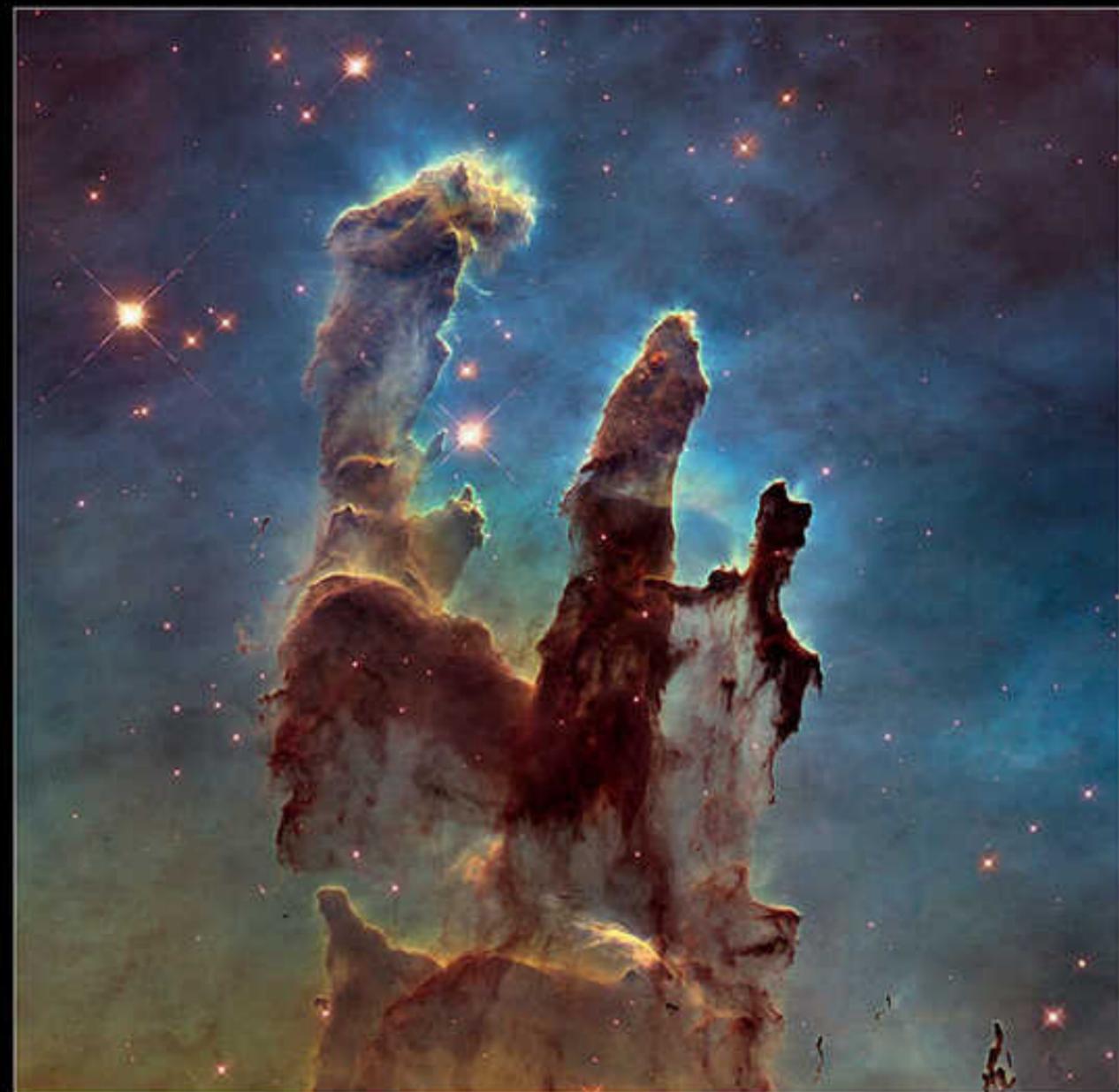
*Grazie di tutto!*

Questa è la nostra storia, abbiamo capito tutto!

MODELLO STANDARD



# COME ESPLORATORI NELLA NOTTE

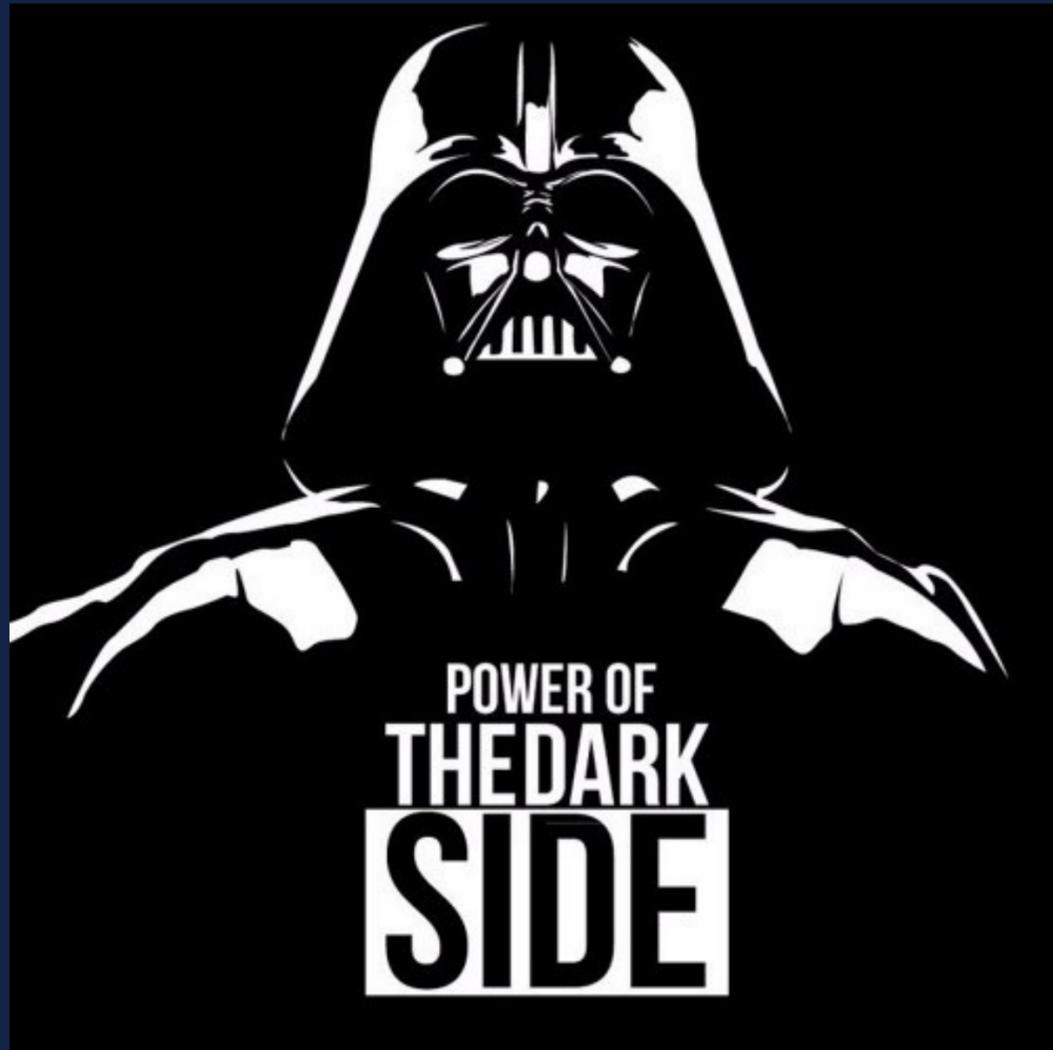


Visible . WFC3 . 2015

# 5%

La materia ordinaria  
del nostro universo

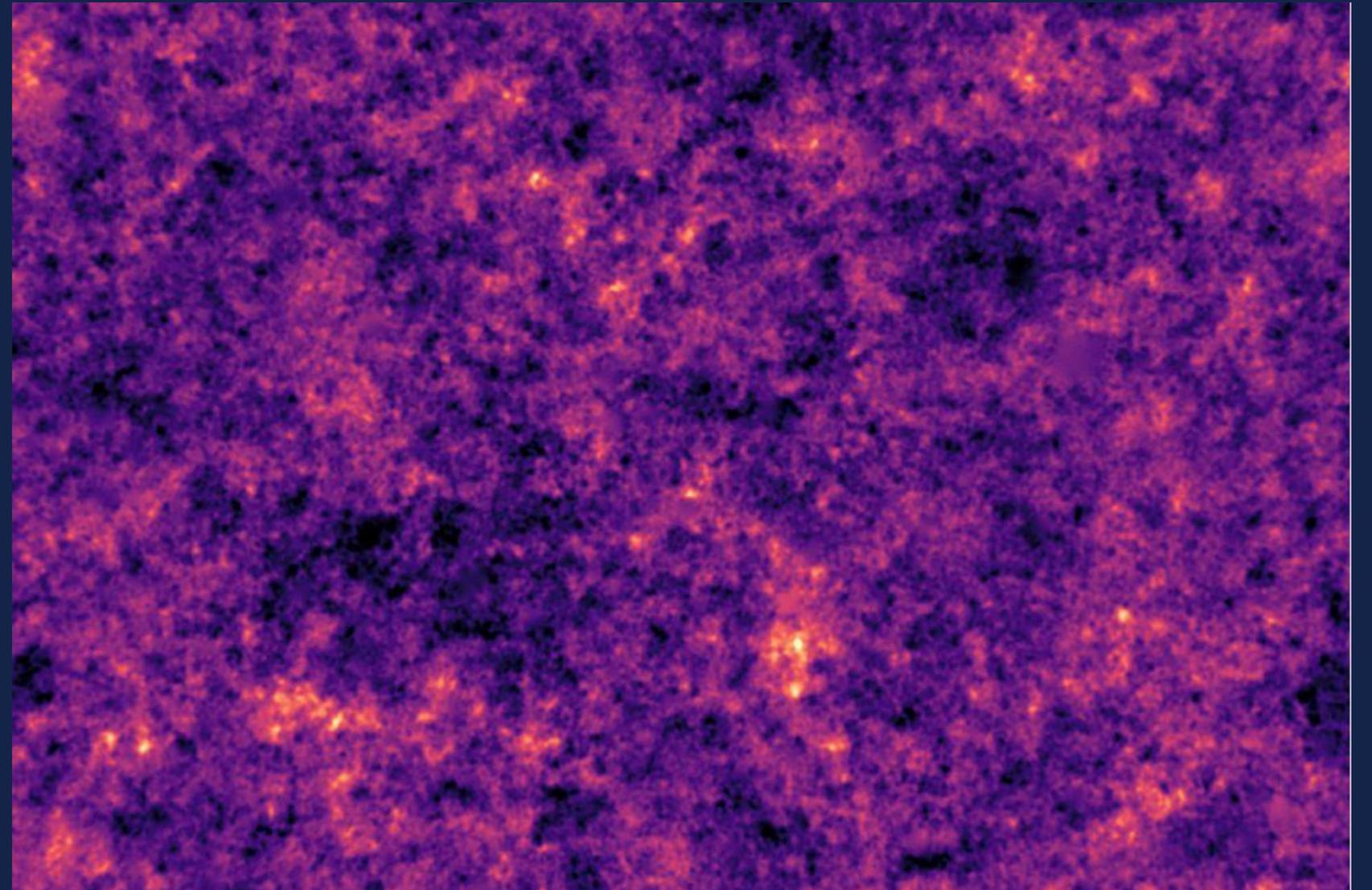




## MATERIA OSCURA

25%

Materia che non interagisce con interazione elettromagnetica



## ENERGIA OSCURA

70%

Energia responsabile dell'espansione delle galassie



CHE FINE HA  
FATTO  
L'ANTIMATERIA?

**Asimmetria tra la presenza di materia e  
antimateria nel nostro universo**

THE END

THE END?

THE END?

**Ci sono  
domande?**

GRAZIE!