



Istituto Nazionale di Fisica Nucleare



UNIVERSITÀ
DI PAVIA



INTERNATIONAL
MASTERCLASSES

The logo consists of several overlapping, semi-circular shapes in dark blue, light blue, and lime green, resembling a stylized particle detector or a series of connected arcs.

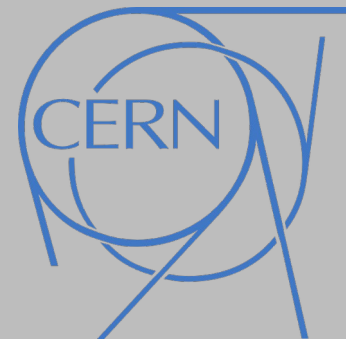
hands on particle physics

ALICE & CMS & ATLAS @ Pavia

1 e 3 Marzo 2023



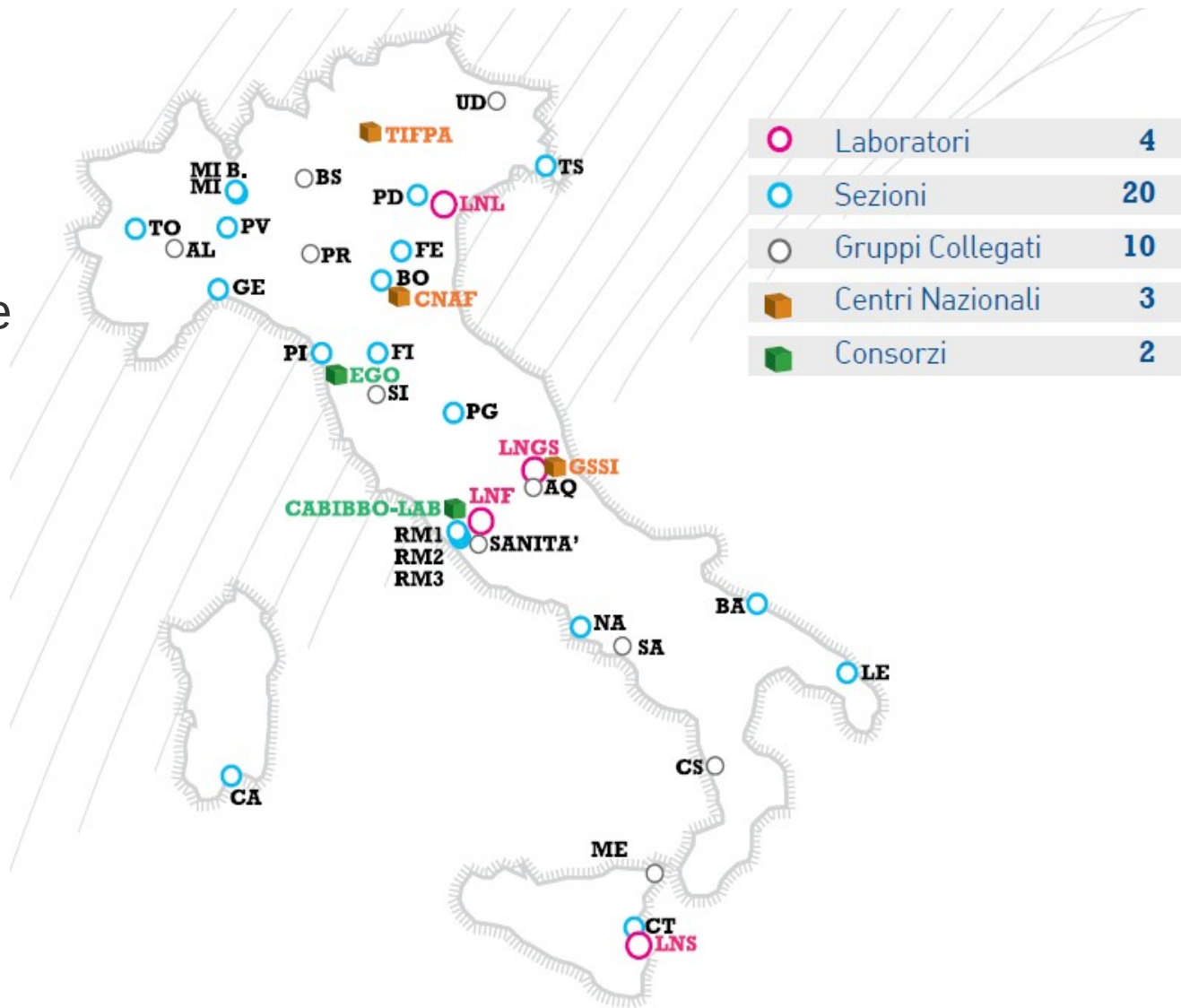
International Particle
Physics Outreach Group



- Istituto Nazionale di Fisica Nucleare
 - fondi per costruzione apparati e per le trasferte di fisici e tecnici



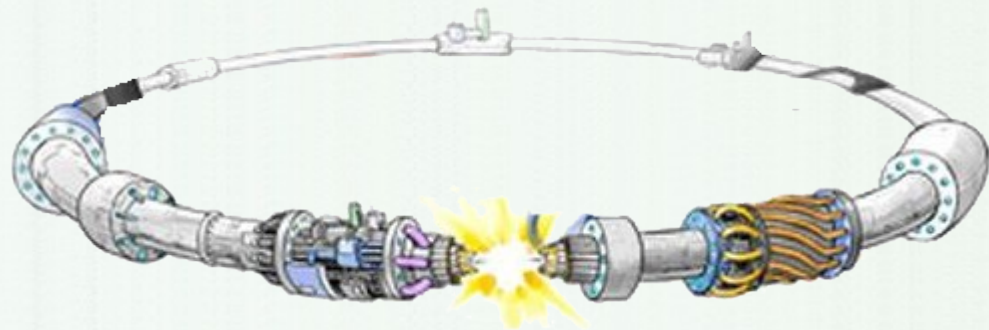
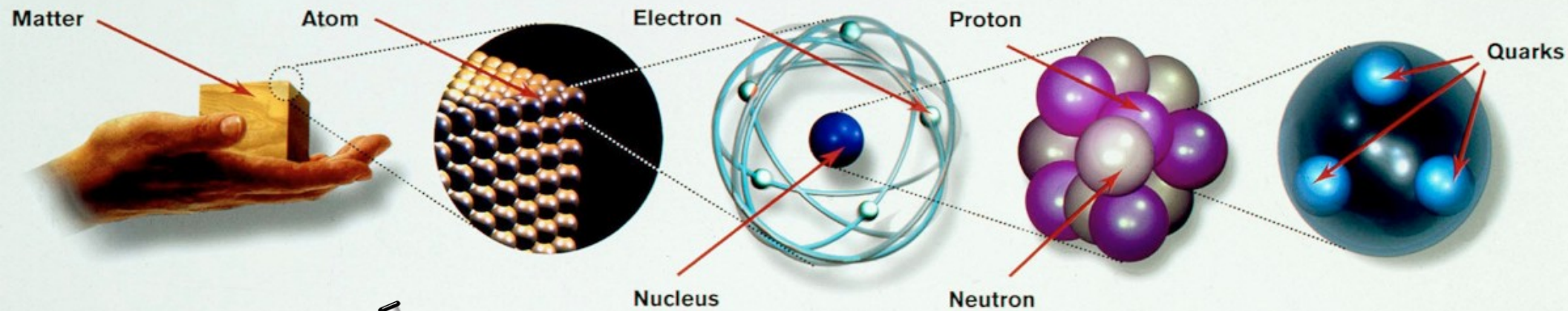
Istituto Nazionale di Fisica Nucleare



CERN



Fisica delle Particelle Elementari





Quale frase contiene il maggior numero di informazioni scientifiche in meno parole?

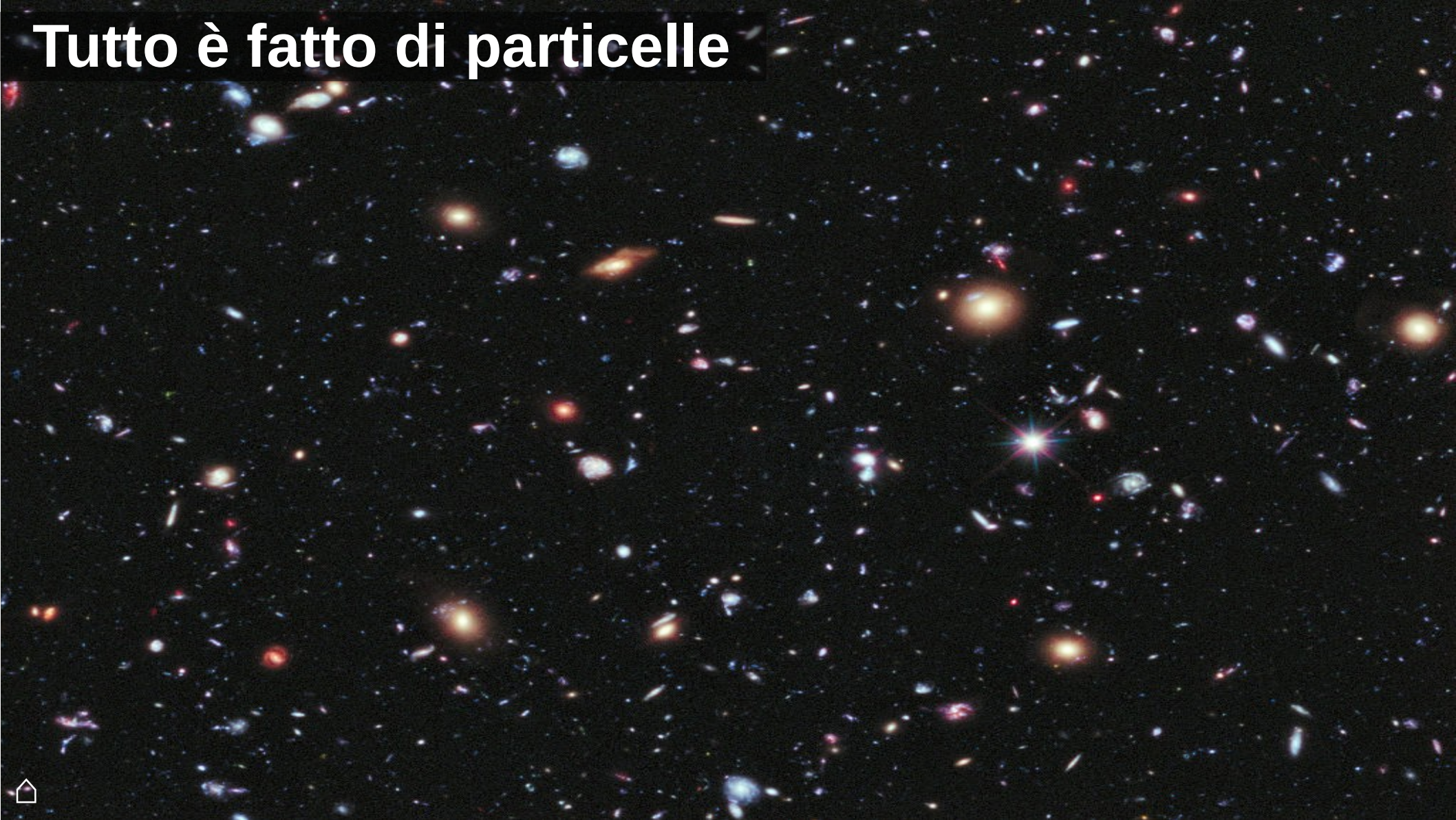
Richard Feynman:



Quale frase contiene il maggior numero di informazioni scientifiche in meno parole?

Richard Feynman:
“... tutto è fatto di particelle ...”

Tutto è fatto di particelle



Tutto è fatto di particelle

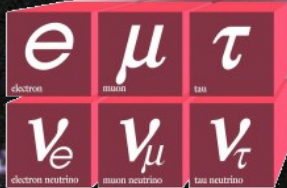
Quarks



Forces

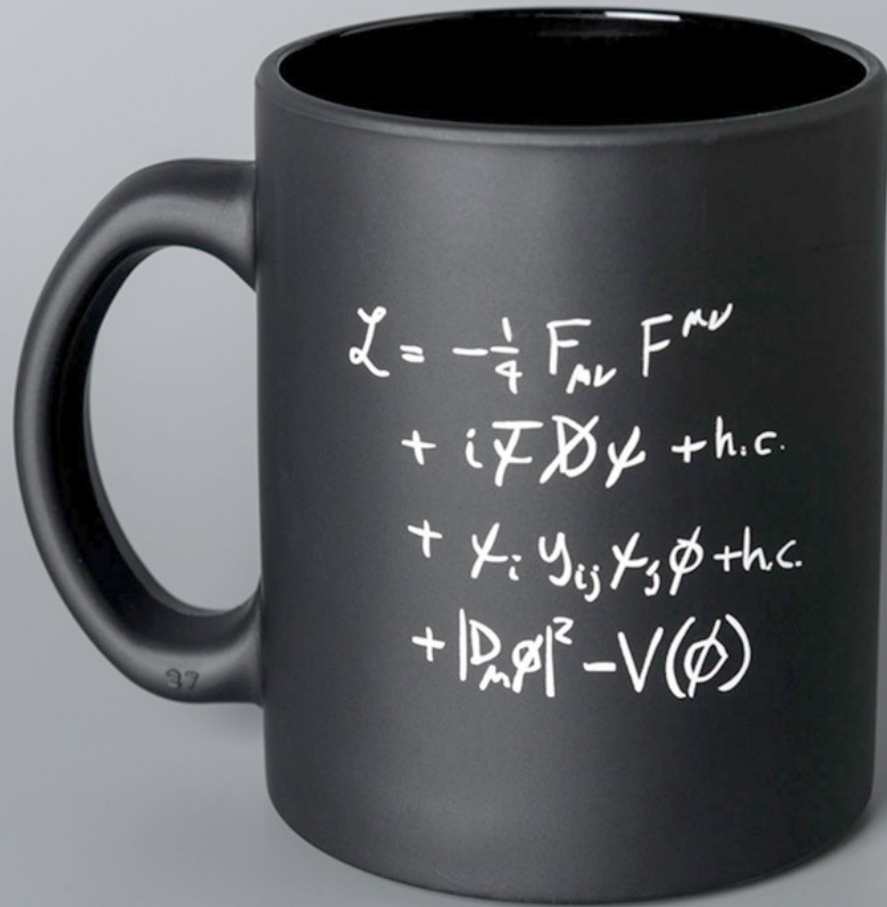


H
Higgs boson



Leptons

Modello Standard



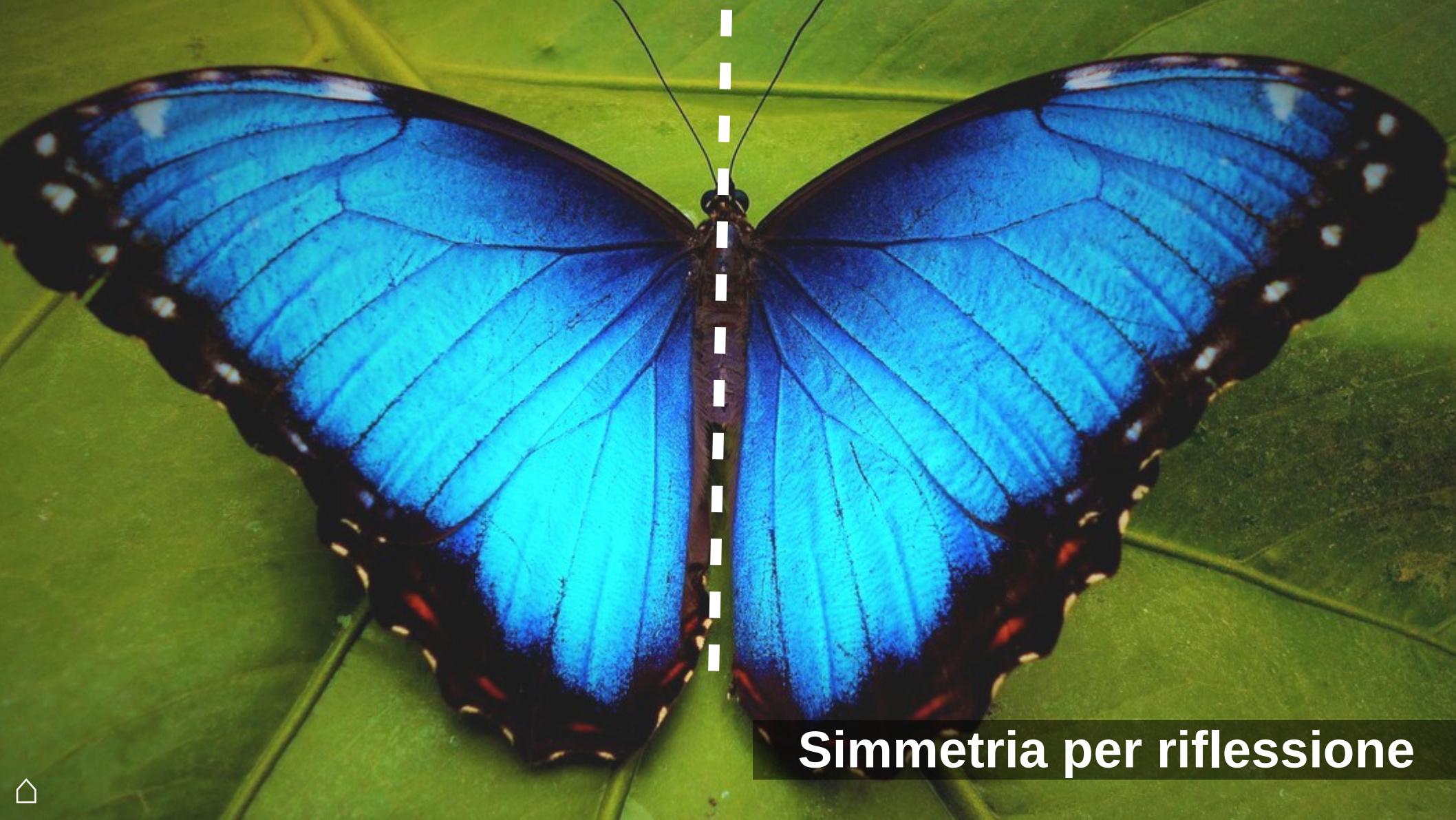
$$\begin{aligned}
L_{SM} = & -\frac{1}{2}\partial_\nu g_\mu^a \partial_\nu g_\mu^a - g_s f^{abc} \partial_\mu g_\nu^a g_\mu^b g_\nu^c - \frac{1}{4}g_s^2 f^{abc} f^{ade} g_\mu^b g_\nu^c g_\mu^d g_\nu^e + \\
& \frac{1}{2}ig_s^2 (\bar{q}_i^\sigma \gamma^\mu q_j^\sigma) g_\mu^a + \bar{G}^a \partial^2 G^a + g_s f^{abc} \partial_\mu \bar{G}^a G^b g_\mu^c - \partial_\nu W_\mu^+ \partial_\nu W_\mu^- - \\
& M^2 W_\mu^+ W_\mu^- - \frac{1}{2}\partial_\nu Z_\mu^0 \partial_\nu Z_\mu^0 - \frac{1}{2c_w^2} M^2 Z_\mu^0 Z_\mu^0 - \frac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - \frac{1}{2}\partial_\mu H \partial_\mu H - \\
& \frac{1}{2}m_h^2 H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - M^2 \phi^+ \phi^- - \frac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \frac{1}{2c_w^2} M \phi^0 \phi^0 - \beta_h \left[\frac{2M^2}{g^2} + \right. \\
& \left. \frac{2M}{g} H + \frac{1}{2}(H^2 + \phi^0 \phi^0 + 2\phi^+ \phi^-) \right] + \frac{2M^4}{g^2} \alpha_h - igc_w [\partial_\nu Z_\mu^0 (W_\mu^+ W_\nu^- - \\
& W_\nu^+ W_\mu^-) - Z_\nu^0 (W_\mu^+ \partial_\nu W_\mu^- - W_\mu^- \partial_\nu W_\mu^+) + Z_\mu^0 (W_\nu^+ \partial_\nu W_\mu^- - \\
& W_\nu^- \partial_\nu W_\mu^+)] - igs_w [\partial_\nu A_\mu (W_\mu^+ W_\nu^- - W_\nu^+ W_\mu^-) - A_\nu (W_\mu^+ \partial_\nu W_\mu^- - \\
& W_\mu^- \partial_\nu W_\mu^+) + A_\mu (W_\nu^+ \partial_\nu W_\mu^- - W_\nu^- \partial_\nu W_\mu^+)] - \frac{1}{2}g^2 W_\mu^+ W_\mu^- W_\nu^+ W_\nu^- + \\
& \frac{1}{2}g^2 W_\mu^+ W_\nu^- W_\mu^+ W_\nu^- + g^2 c_w^2 (Z_\mu^0 W_\mu^+ Z_\nu^0 W_\nu^- - Z_\mu^0 Z_\mu^0 W_\nu^+ W_\nu^-) + \\
& g^2 s_w^2 (A_\mu W_\mu^+ A_\nu W_\nu^- - A_\mu A_\mu W_\nu^+ W_\nu^-) + g^2 s_w c_w [A_\mu Z_\nu^0 (W_\mu^+ W_\nu^- - \\
& W_\nu^+ W_\mu^-) - 2A_\mu Z_\mu^0 W_\nu^+ W_\nu^-] - g\alpha [H^3 + H\phi^0 \phi^0 + 2H\phi^+ \phi^-] - \\
& \frac{1}{8}g^2 \alpha_h [H^4 + (\phi^0)^4 + 4(\phi^+ \phi^-)^2 + 4(\phi^0)^2 \phi^+ \phi^- + 4H^2 \phi^+ \phi^- + 2(\phi^0)^2 H^2] - \\
& gMW_\mu^+ W_\mu^- H - \frac{1}{2}g \frac{M}{c_w^2} Z_\mu^0 Z_\mu^0 H - \frac{1}{2}ig [W_\mu^+ (\phi^0 \partial_\mu \phi^- - \phi^- \partial_\mu \phi^0) - \\
& W_\mu^- (\phi^0 \partial_\mu \phi^+ - \phi^+ \partial_\mu \phi^0)] + \frac{1}{2}g [W_\mu^+ (H \partial_\mu \phi^- - \phi^- \partial_\mu H) - W_\mu^- (H \partial_\mu \phi^+ - \\
& \phi^+ \partial_\mu H)] + \frac{1}{2}g \frac{1}{c_w} (Z_\mu^0 (H \partial_\mu \phi^0 - \phi^0 \partial_\mu H) - ig \frac{s_w^2}{c_w} M Z_\mu^0 (W_\mu^+ \phi^- - W_\mu^- \phi^+) + \\
& igs_w M A_\mu (W_\mu^+ \phi^- - W_\mu^- \phi^+) - ig \frac{1-2c_w^2}{2c_w} Z_\mu^0 (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) + \\
& igs_w A_\mu (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) - \frac{1}{4}g^2 W_\mu^+ W_\mu^- [H^2 + (\phi^0)^2 + 2\phi^+ \phi^-] - \\
& \frac{1}{4}g^2 \frac{1}{c_w^2} Z_\mu^0 Z_\mu^0 [H^2 + (\phi^0)^2 + 2(2s_w^2 - 1)^2 \phi^+ \phi^-] - \frac{1}{2}g^2 \frac{s_w^2}{c_w} Z_\mu^0 \phi^0 (W_\mu^+ \phi^- + \\
& W_\mu^- \phi^+) - \frac{1}{2}ig^2 \frac{s_w^2}{c_w} Z_\mu^0 H (W_\mu^+ \phi^- - W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu \phi^0 (W_\mu^+ \phi^- +
\end{aligned}$$

ecc...

Alla base della fisica: **simmetria**



Trasformazione che lascia invariato un oggetto



Simmetria per riflessione

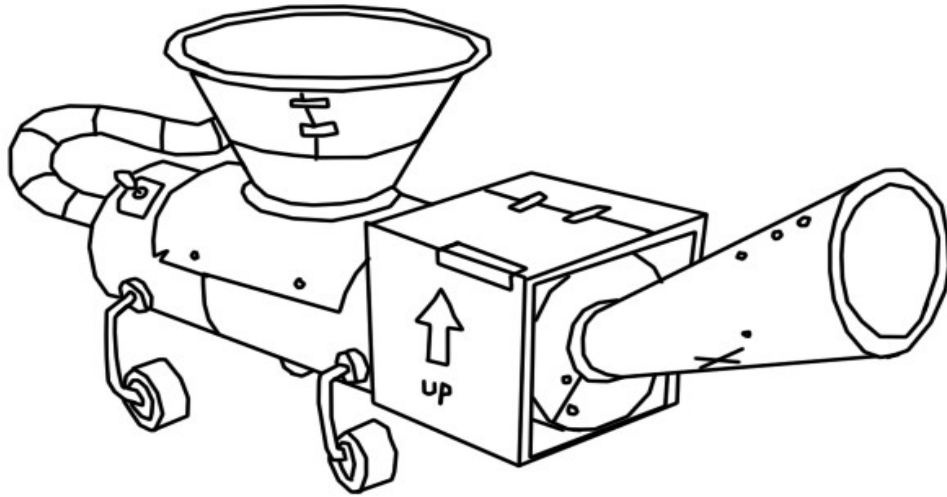




Simmetria per rotazioni

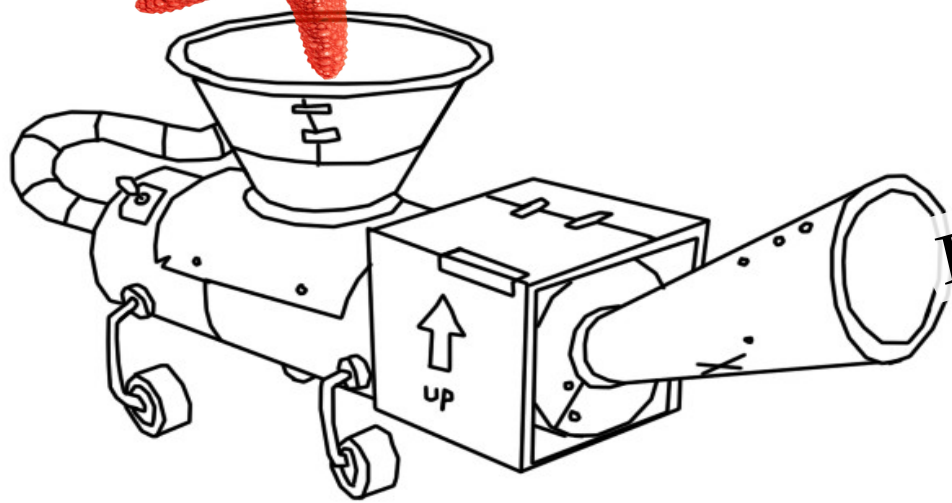
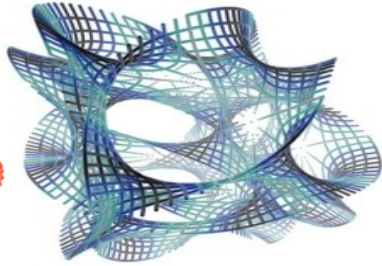
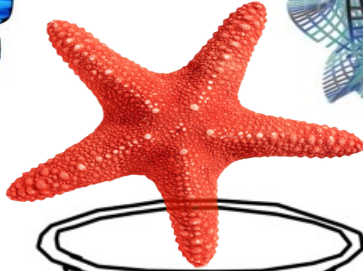
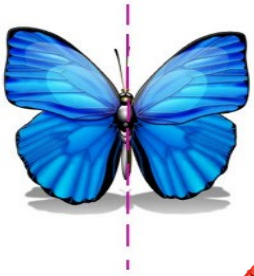
Macchina per teorie

Simmetrie



Equazioni

Simmetrie



$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 8\pi G T_{\mu\nu}$$
$$E = mc^2$$
$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\bar{\psi}\not{\partial}\psi + h.c. + \psi_i \gamma_{ij} \psi_j \phi + h.c. + |D_\mu \phi|^2 - V(\phi)$$
$$dU = \delta Q - \delta L$$

Equazioni



Ad ogni **simmetria** di un sistema fisico è associata una legge di **conservazione**

Emmy Noether, 2015

Teorema di Noether

Invarianza per
traslazioni temporali



$$dU = \delta Q - \delta L$$

Teorema di Noether

Invarianza per
traslazioni temporali



$$dU = \delta Q - \delta L$$

Invarianza per
traslazioni spaziali



$$\frac{d \sum \vec{p}_i}{dt} = 0$$

Teorema di Noether

Invarianza per
traslazioni temporali



$$dU = \delta Q - \delta L$$

Invarianza per
traslazioni spaziali



$$\frac{d \sum \vec{p}_i}{dt} = 0$$

Invarianza della
velocità della luce



$$E = mc^2$$

Teorema di Noether

Invarianza per
traslazioni temporali



$$dU = \delta Q - \delta L$$

Invarianza per
traslazioni spaziali



$$\frac{d \sum \vec{p}_i}{dt} = 0$$

Invarianza della
velocità della luce



$$E = mc^2$$

Principio di equivalenza

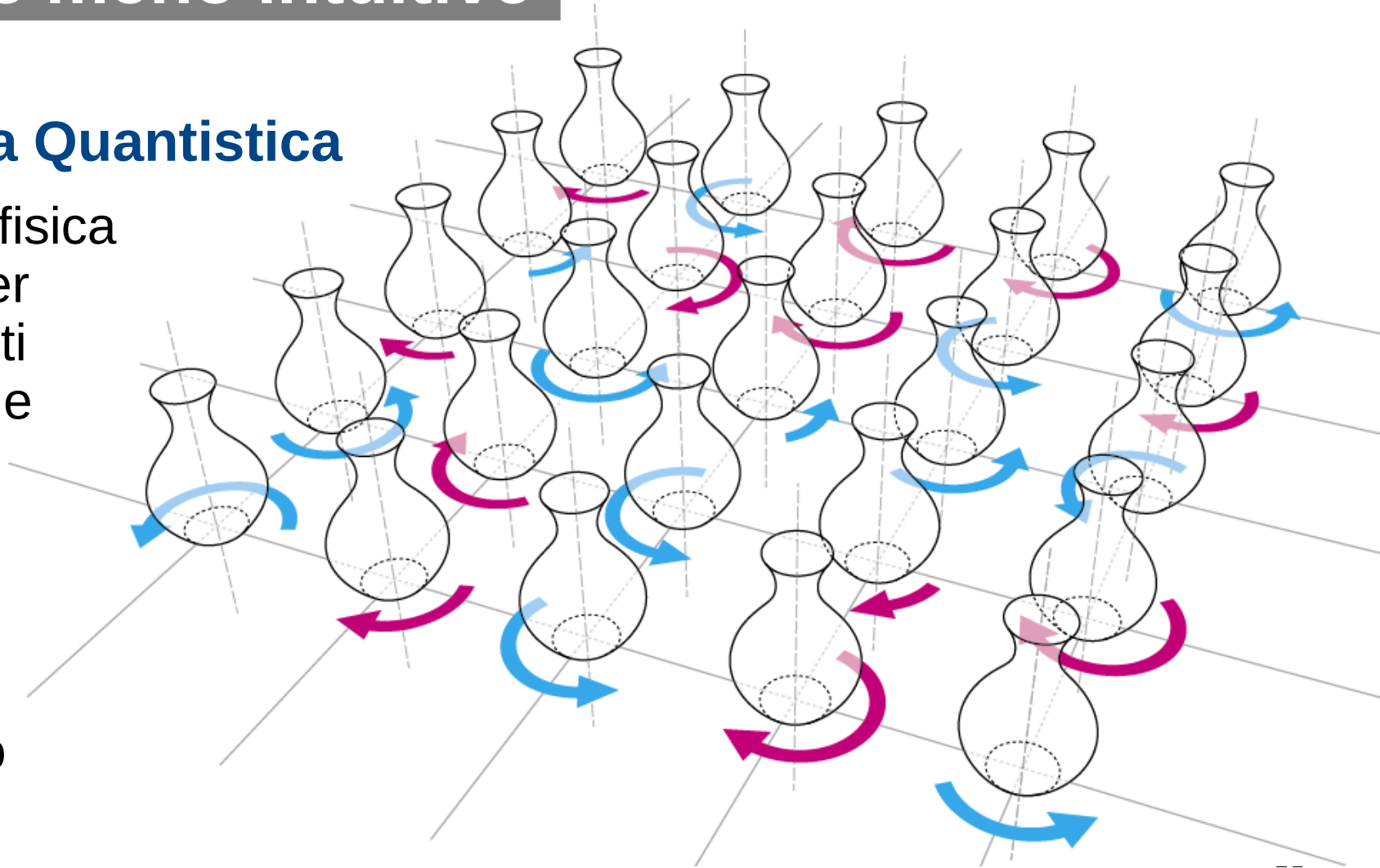


$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 8\pi G T_{\mu\nu}$$

Simmetrie meno intuitive

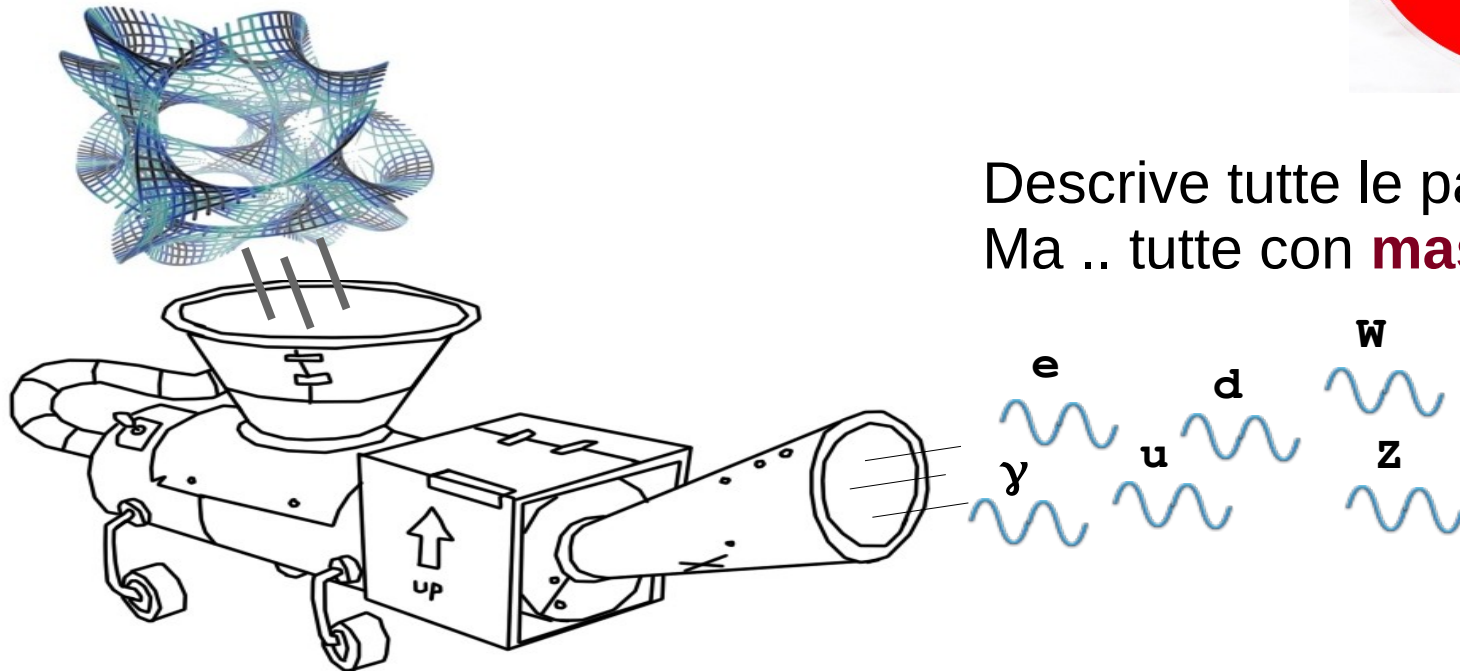
Meccanica Quantistica

Leggi della fisica
invarianti per
cambiamenti
arbitrari delle
fasi della
funzione
d'onda del
sistema in
ogni punto
dello spazio



Modello standard delle particelle

Simmetria $SU(2)_L \times U(1)$



E se la simmetria fosse **rotta**?



$$\mathcal{L} = (D_\mu \phi)^\dagger D^\mu \phi - \mathcal{V}(\phi) - \frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

$$D_\mu \phi = \partial_\mu \phi - i e A_\mu \phi$$

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$$

$$\mathcal{V}(\phi) = \alpha \phi^\dagger \phi + \beta (\phi^\dagger \phi)^2$$

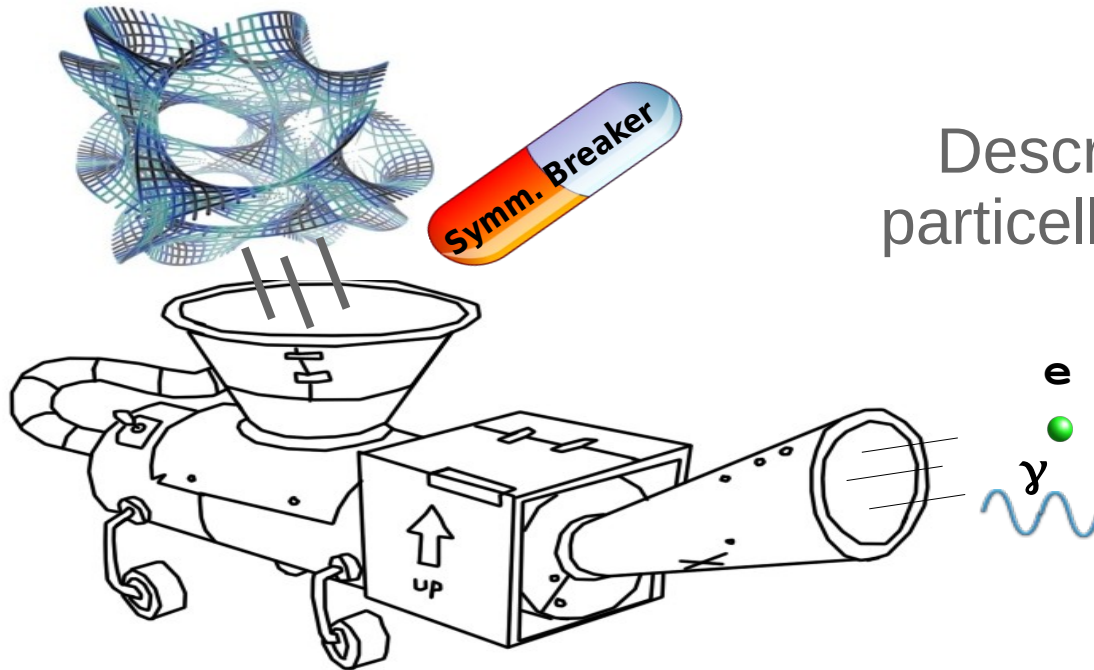
$$\alpha < 0, \beta > 0$$

Peter Higgs

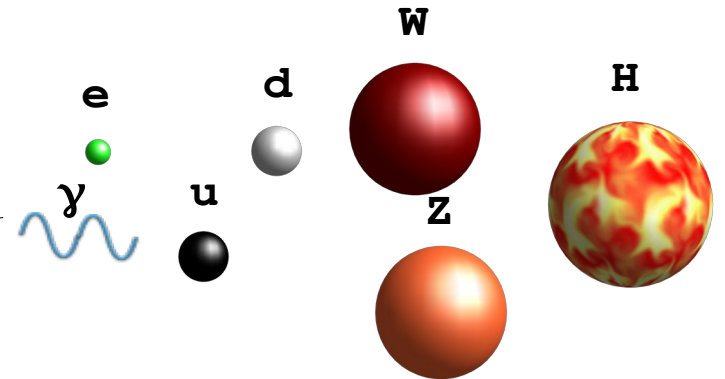
Modello standard delle particelle

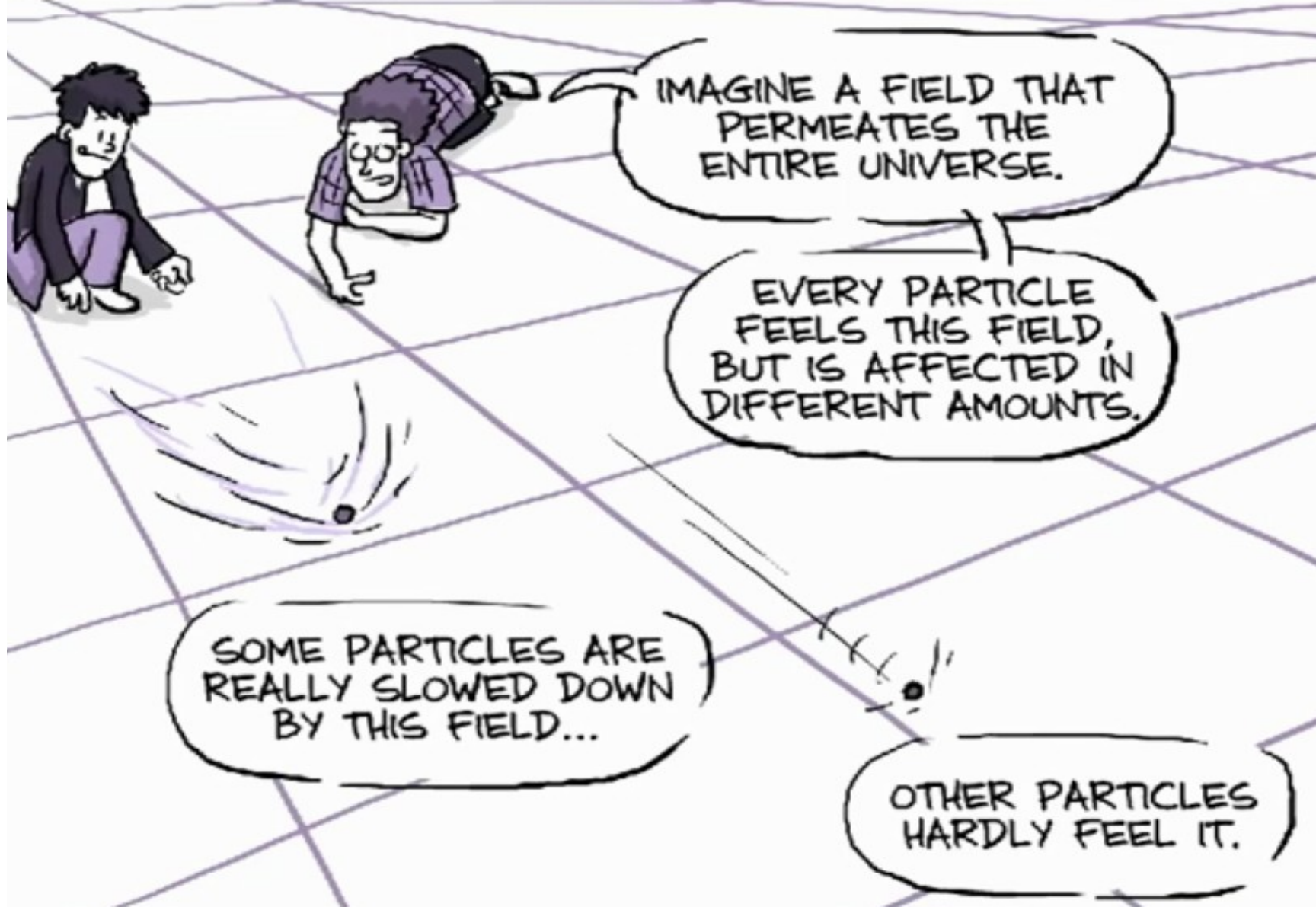
Simmetria $SU(2)_L \times U(1)$

- Meccanismo di **Higgs**:
in natura la simmetria è “**rotta**”



Descrizione corretta delle
particelle note + ... una nuova



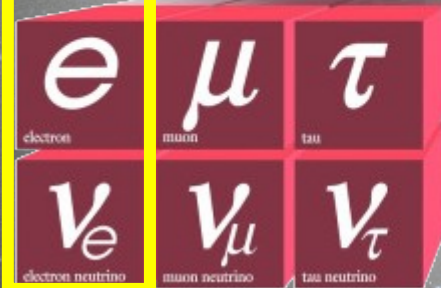


Tutto è fatto di particelle



Tutto è fatto di particelle

Quarks



Leptons

Forces



Tutto è fatto di particelle

Quarks



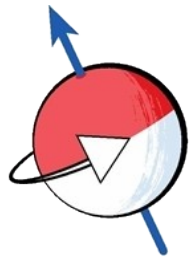
Forces



H
Higgs boson



Leptons



Spin 1/2

I fermioni La materia

Quarks



Leptons



Forces



I bosoni Le forze



Spin 1

Interazioni mediate da bosoni



Interazioni mediate da bosoni

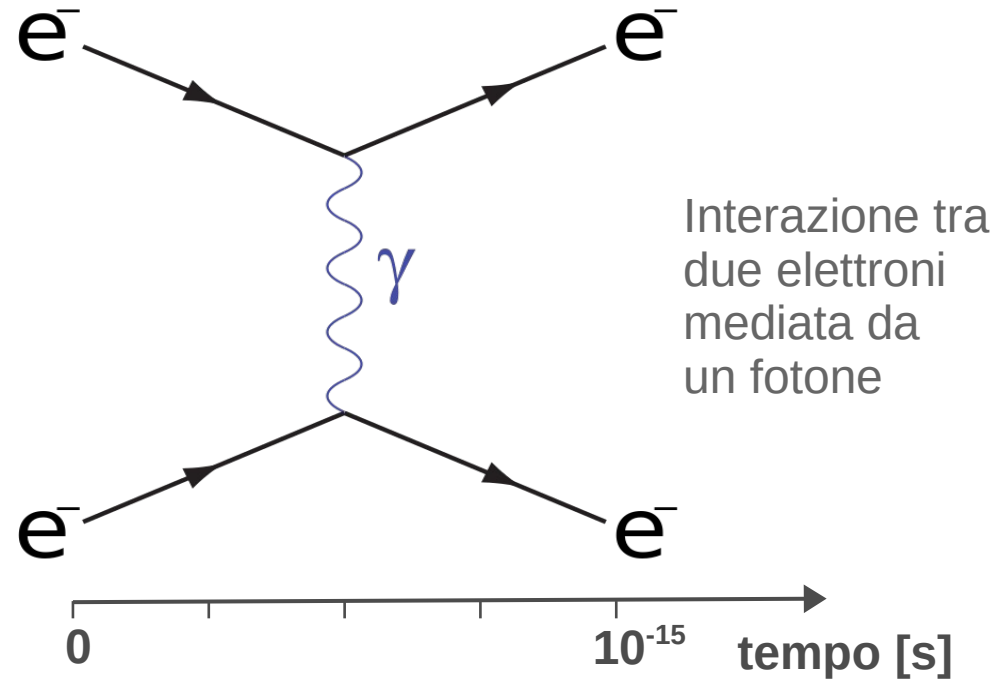


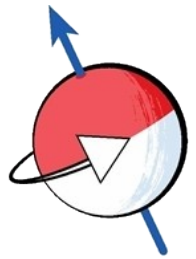
A volte la particella emittente si trasforma



Diagrammi di Feynman

- Ogni elemento è un pezzo dell'equazione
- Ad ogni vertice si conserva: carica, energia, impulso





Spin 1/2

I fermioni La materia

Quarks



Leptons



Forces

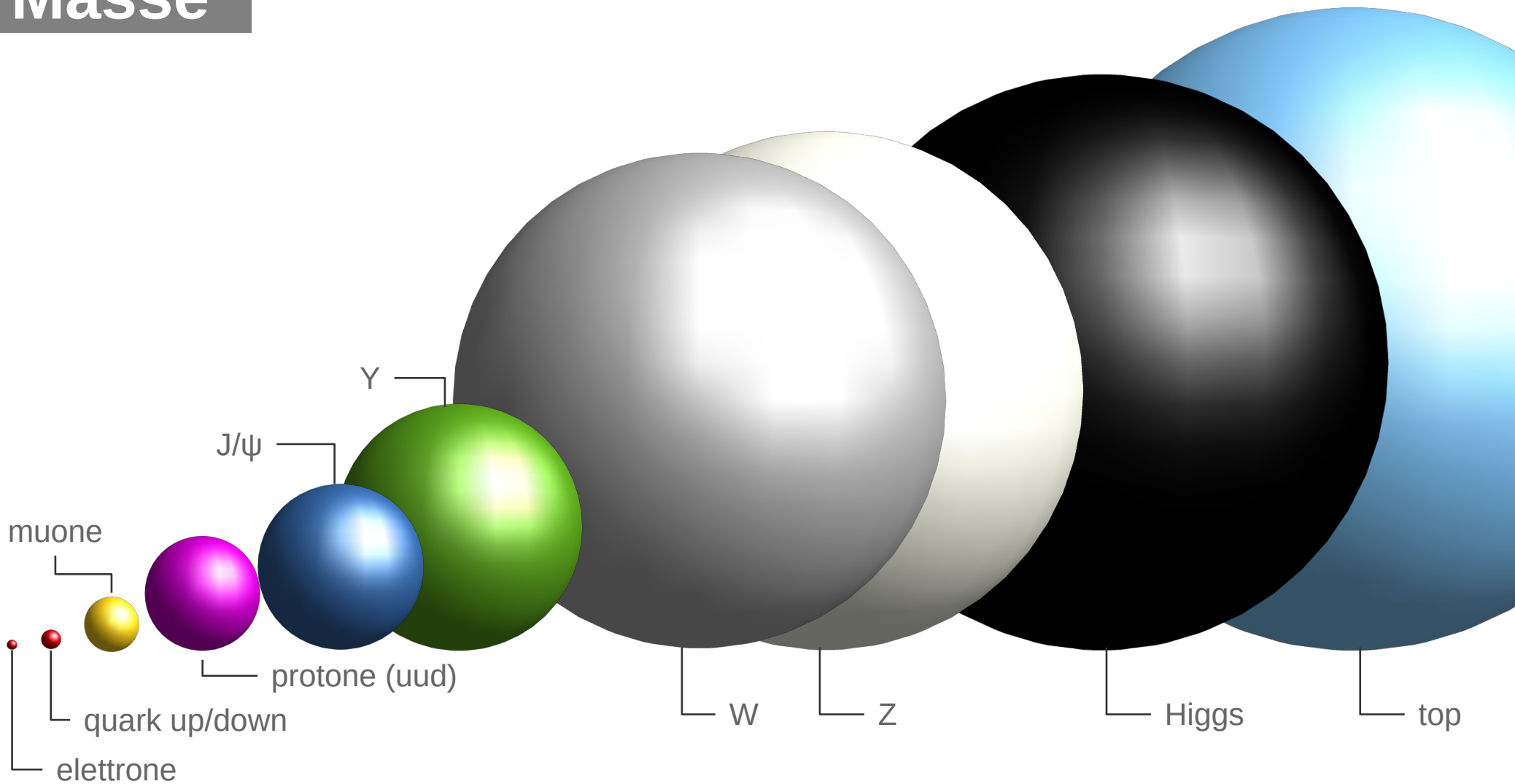


I bosoni Le forze



Spin 1

Masse



Masse



Masse

- Unità di misura di energia
 - $E=mc^2$
- **ElectronVolt**
 - 1 **eV** = $1.6 \cdot 10^{-19}$ J
 - 1 **GeV** = 10^9 eV
 - 1 **TeV** = 10^{12} eV
- **Protone = 1 GeV**

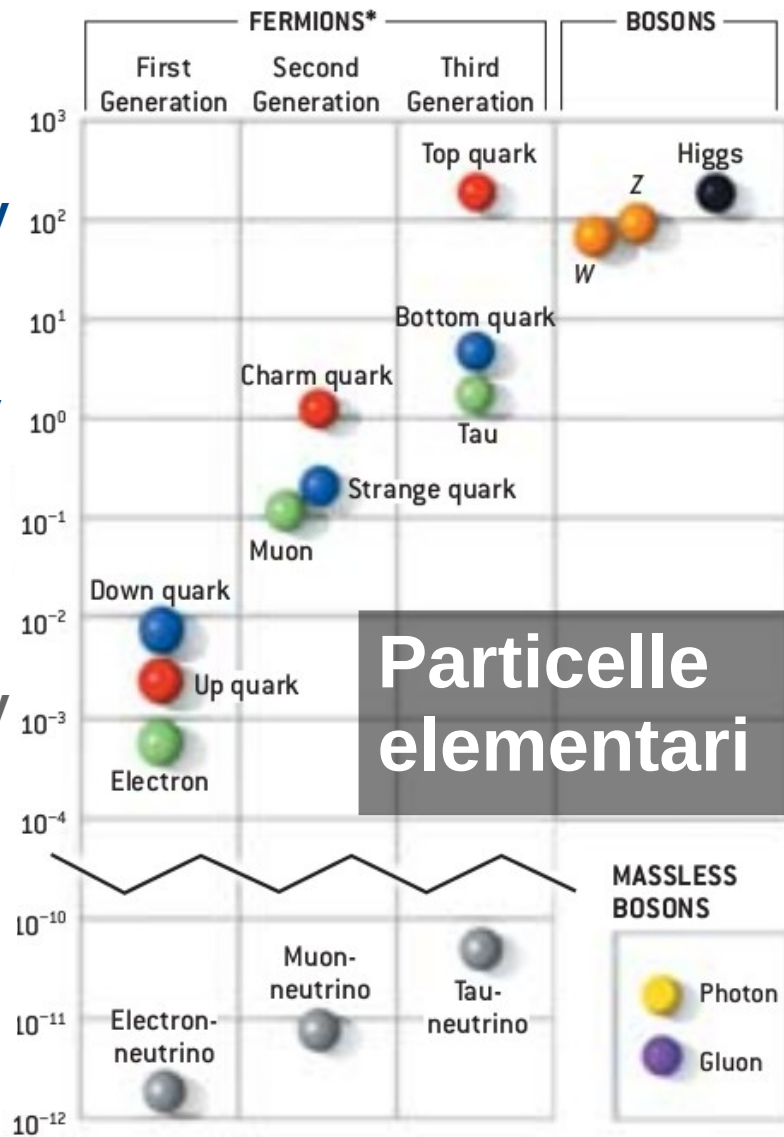


Masse

100 GeV

1 GeV

1 MeV

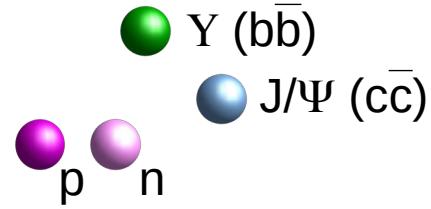
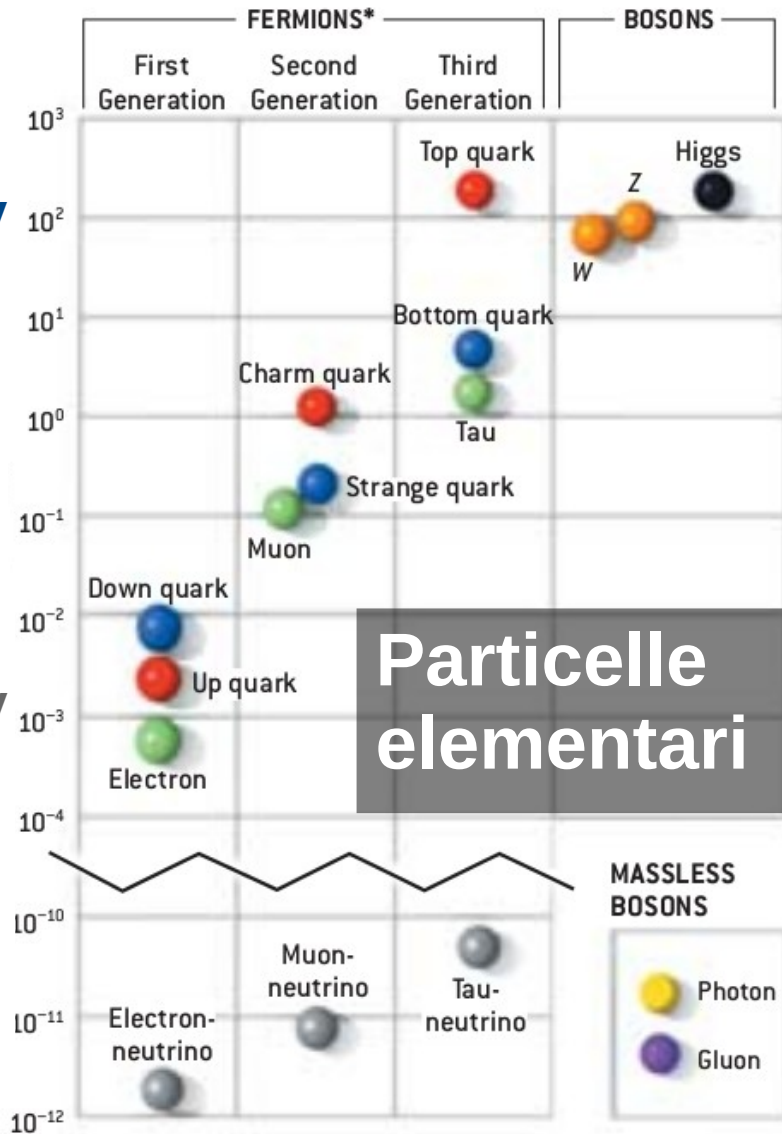


Masse

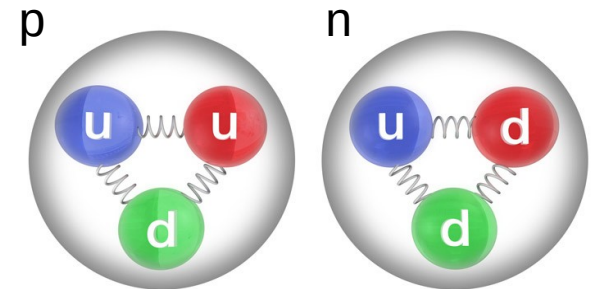
100 GeV

1 GeV

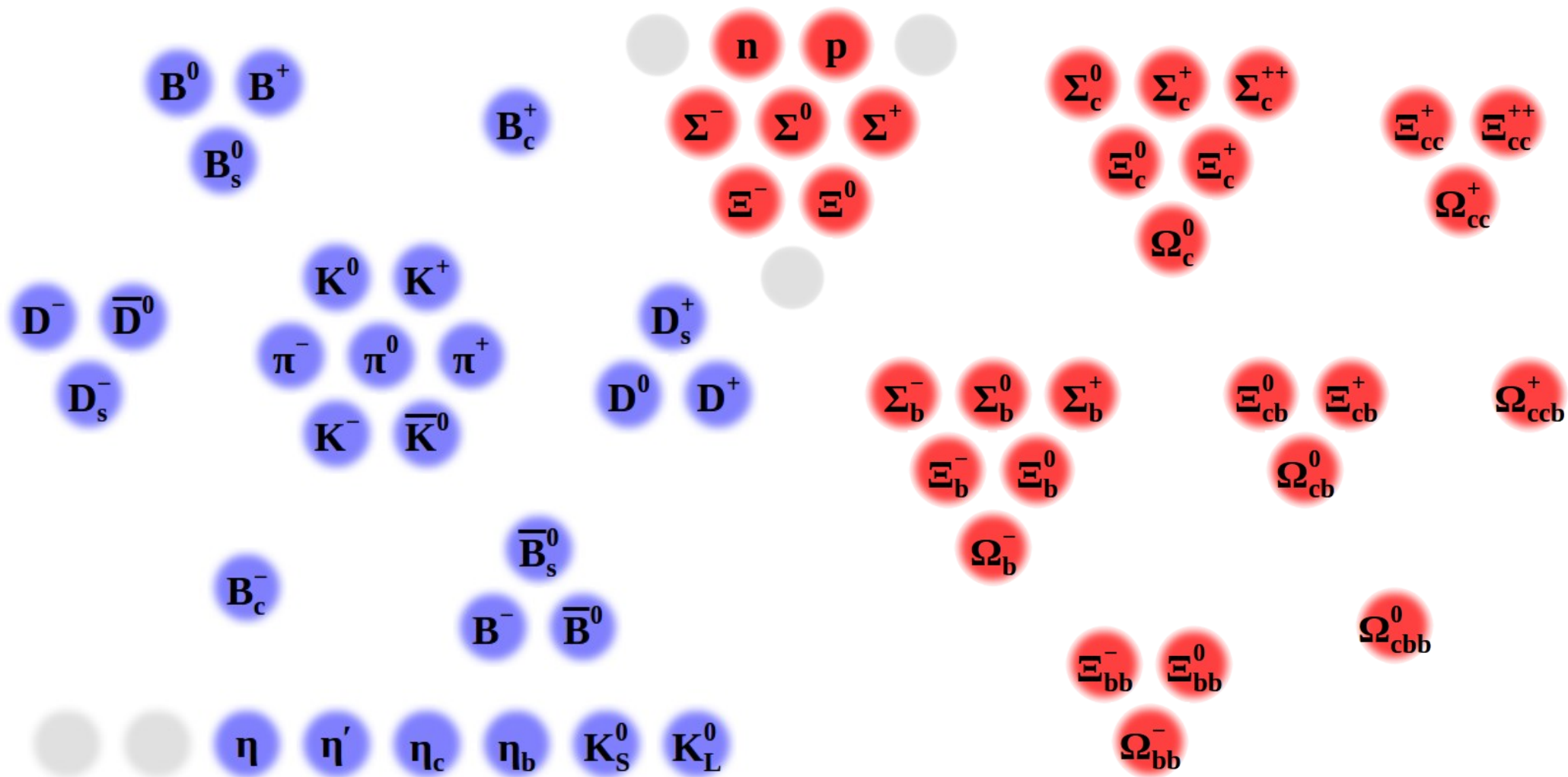
1 MeV

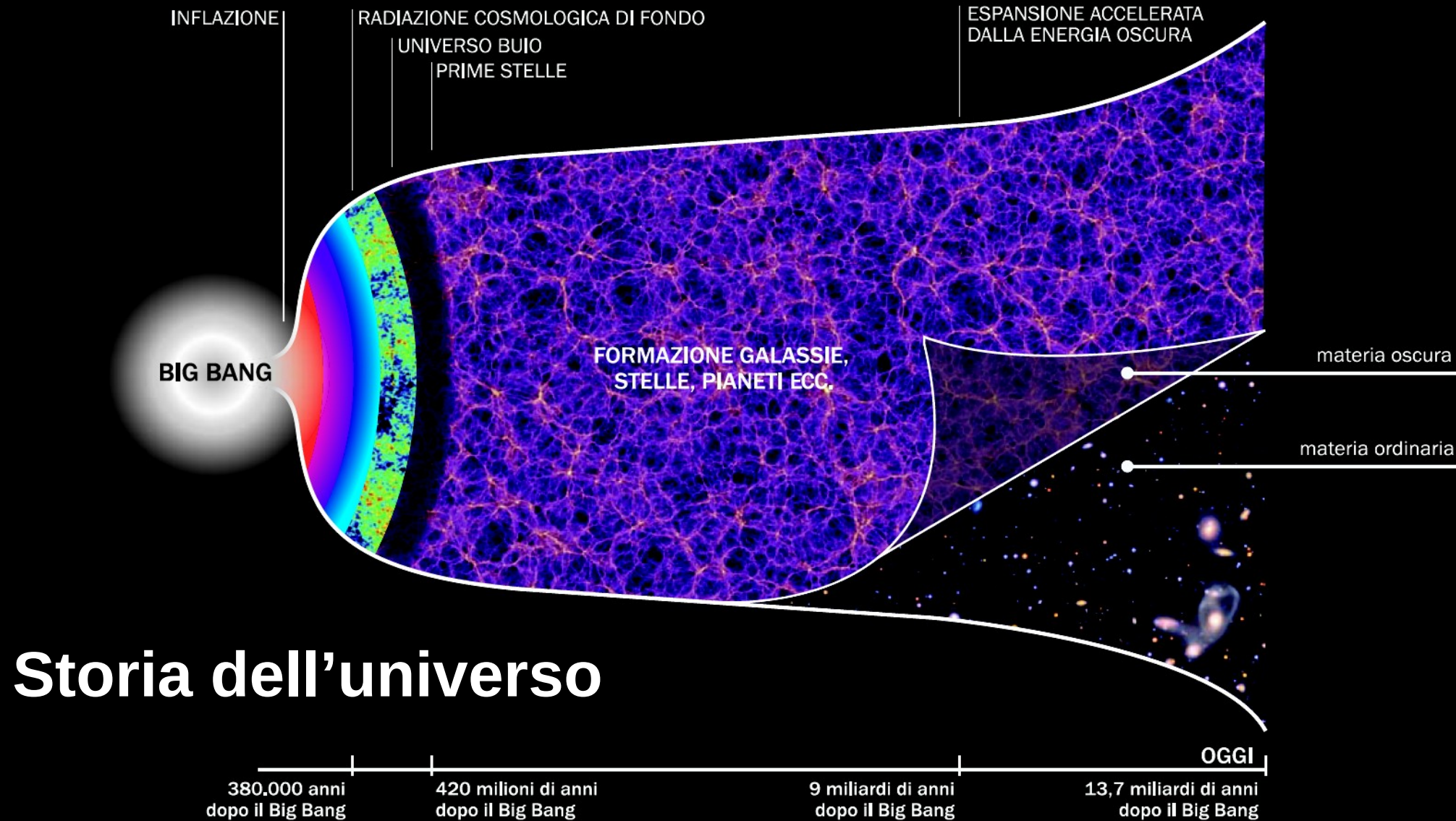


Particelle composte



Lo zoo





Storia dell'universo

Da ricordare



- La natura è **matematica**
- Formule da principi di **simmetria**
- **Tutto** è fatto di **particelle**
- **Masse** misurate in GeV
 - Protone 1 GeV
 - Bosone Z 90 GeV
 - Bosone Higgs 125 GeV

Chi fornisce la massa alle particelle elementari?

- A) I grassi saturi
- B) Il bosone di Higgs
- C) $E=mc^2$

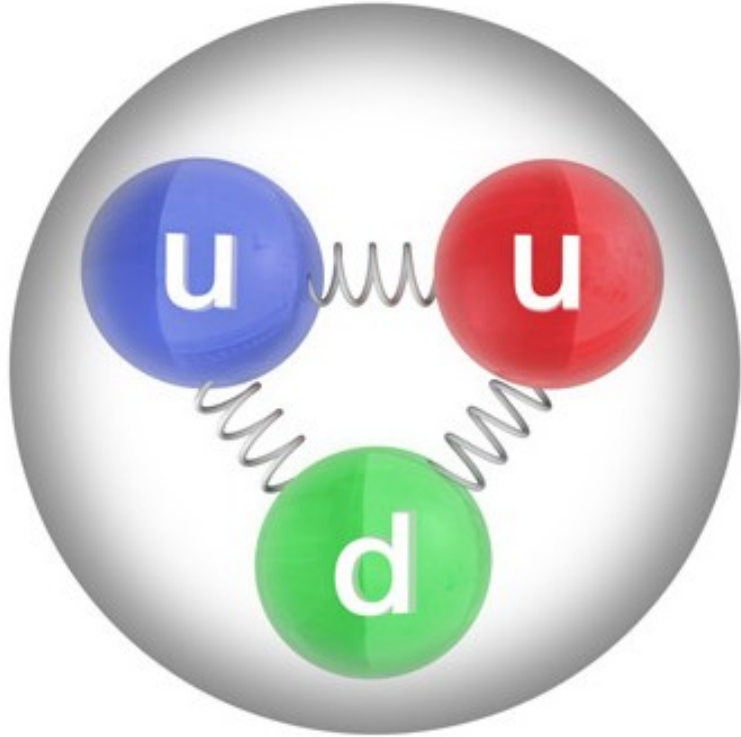


Chi è responsabile della massa del pinguino?

- A) Il bosone di Higgs
- B) I pesci
- C) $E=mc^2$



Massa del protone

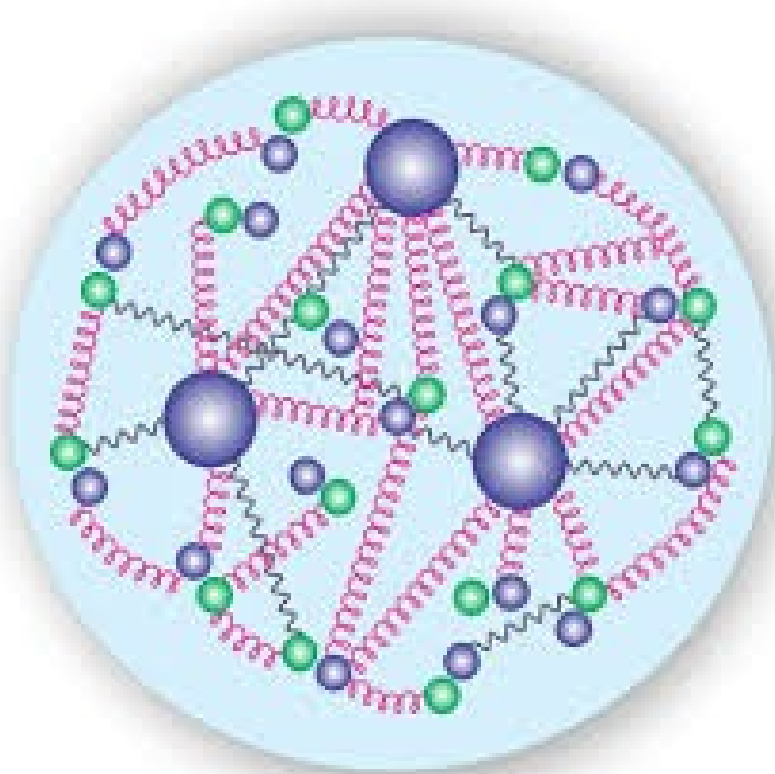


Massa **protone** ~ **1000** MeV

Massa quark **up** ~ **3** MeV

Massa quark **down** ~ **5** MeV

Massa del protone



Per 99% è

energia di legame ($E=mc^2$)
della forza nucleare forte

Massa **protone** ~ **1000** MeV

Massa quark **up** ~ **3** MeV

Massa quark **down** ~ **5** MeV

Decadimenti



Decadimenti

- Poche particelle sono stabili
 - Elettrone, protone e neutrini
- Le altre **decadono** in quelle più stabili
 - Con un tempo caratteristico
- Oggi vedremo
 - $Z \rightarrow e^+e^-, \rightarrow \mu^+\mu^-, \dots$
 - $J/\Psi(c\bar{c}) \rightarrow e^+e^-, \rightarrow \mu^+\mu^-, \dots$
 - $Y(b\bar{b}) \rightarrow e^+e^-, \rightarrow \mu^+\mu^-, \dots$



Decadimenti

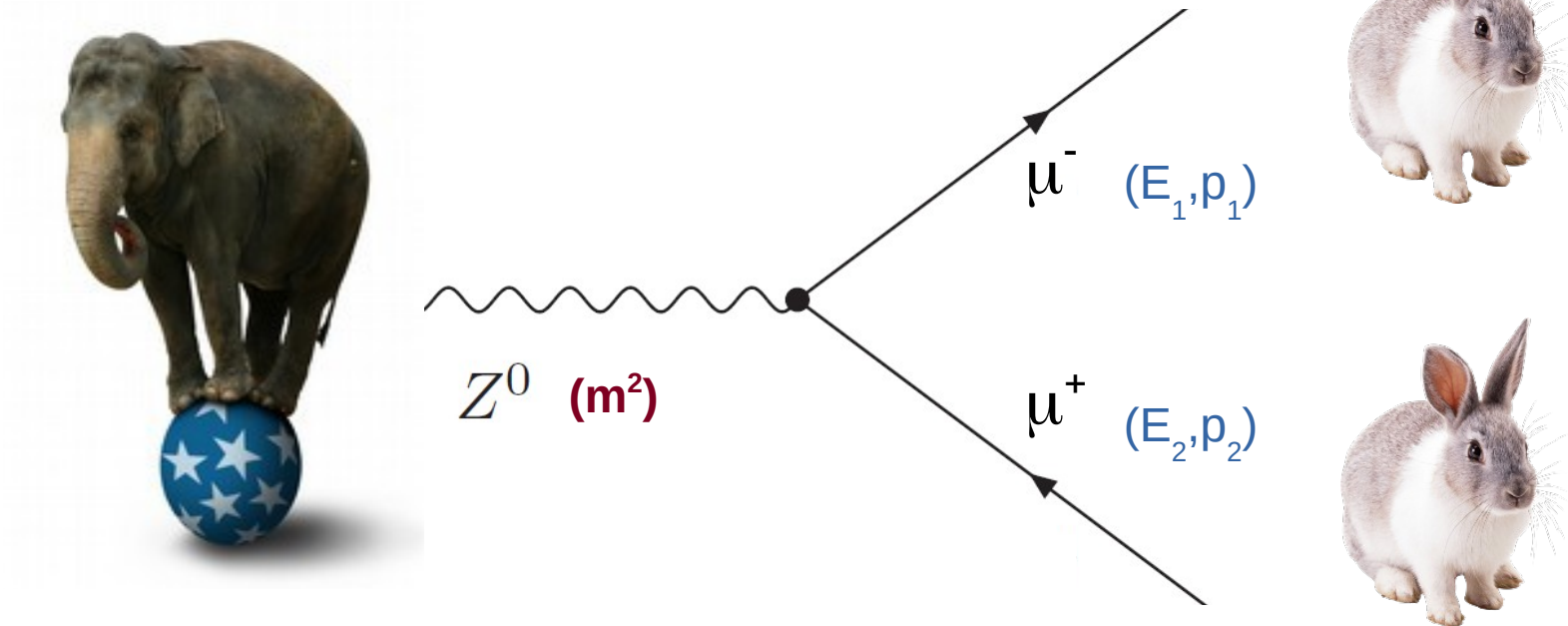
- Poche particelle sono stabili
 - Elettrone, protone e neutrini
- Le altre **decadono** in quelle più stabili
 - Con un tempo caratteristico
- Oggi vedremo
 - **Z** $\rightarrow e^+e^-$, $\rightarrow \mu^+\mu^-$, ...
 - **J/ Ψ** ($c\bar{c}$) $\rightarrow e^+e^-$, $\rightarrow \mu^+\mu^-$, ...
 - **Y** ($b\bar{b}$) $\rightarrow e^+e^-$, $\rightarrow \mu^+\mu^-$, ...



Conservazione energia e impulso

Misurando **energia** e **impulso** dei prodotti di decadimento
→ si può risalire alla **massa** della particella iniziale

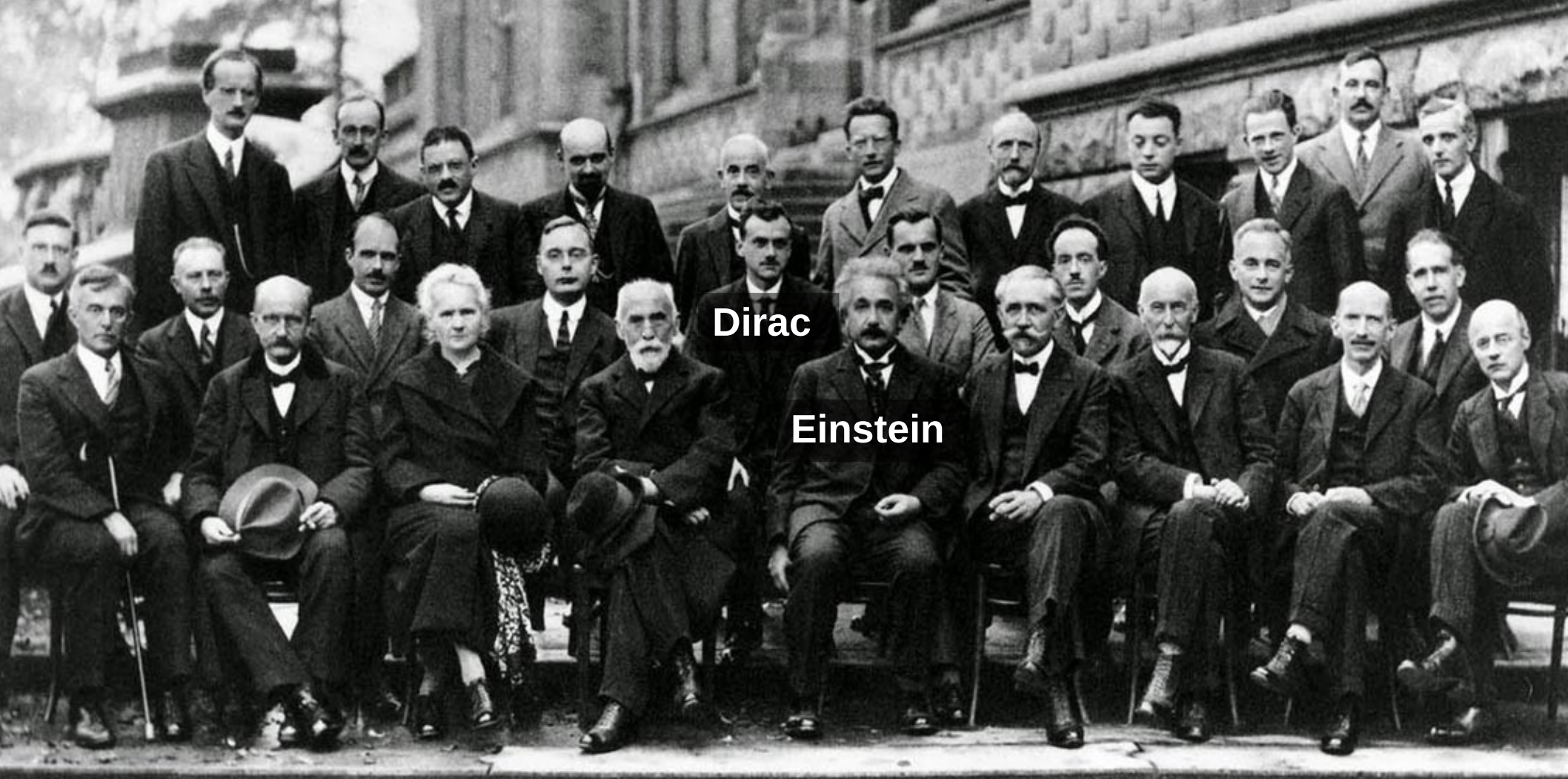
$$m^2 = (E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2$$



Come produrre nuove particelle?



Congresso di Solvay 1927



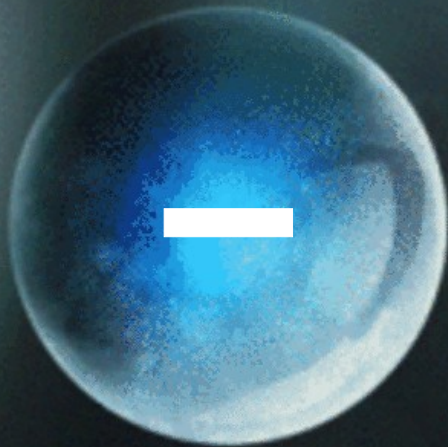
Dirac

Einstein

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

Dirac (1928)

Antimateria



Ogni particella → antiparticella
stessa massa ma carica opposta

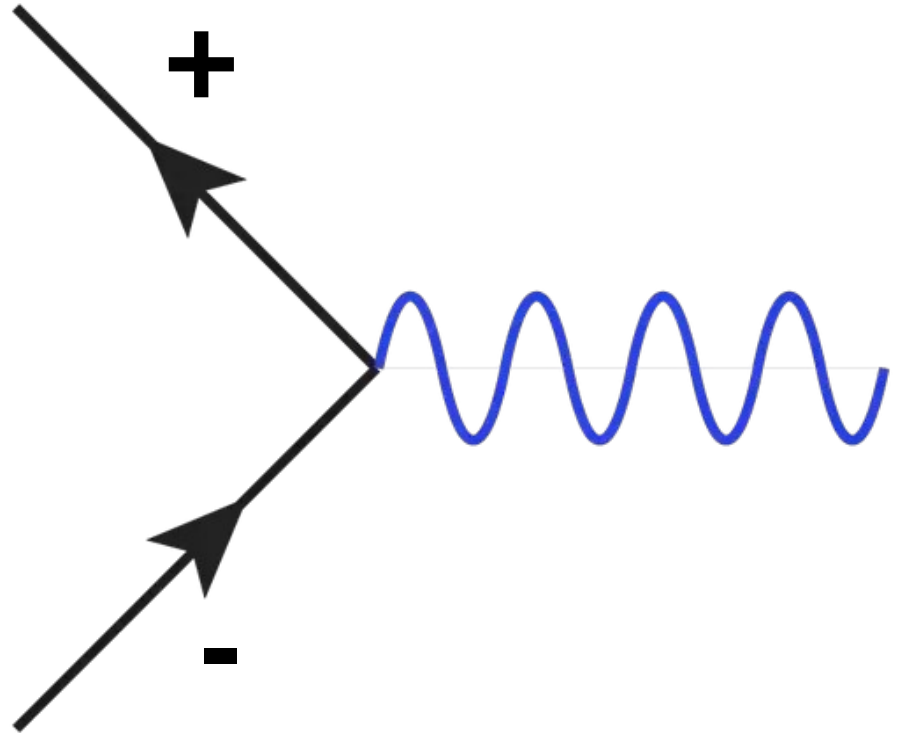
Antimateria

Se una **particella** incontra
la sua **anti-particella**
si **annichilano**

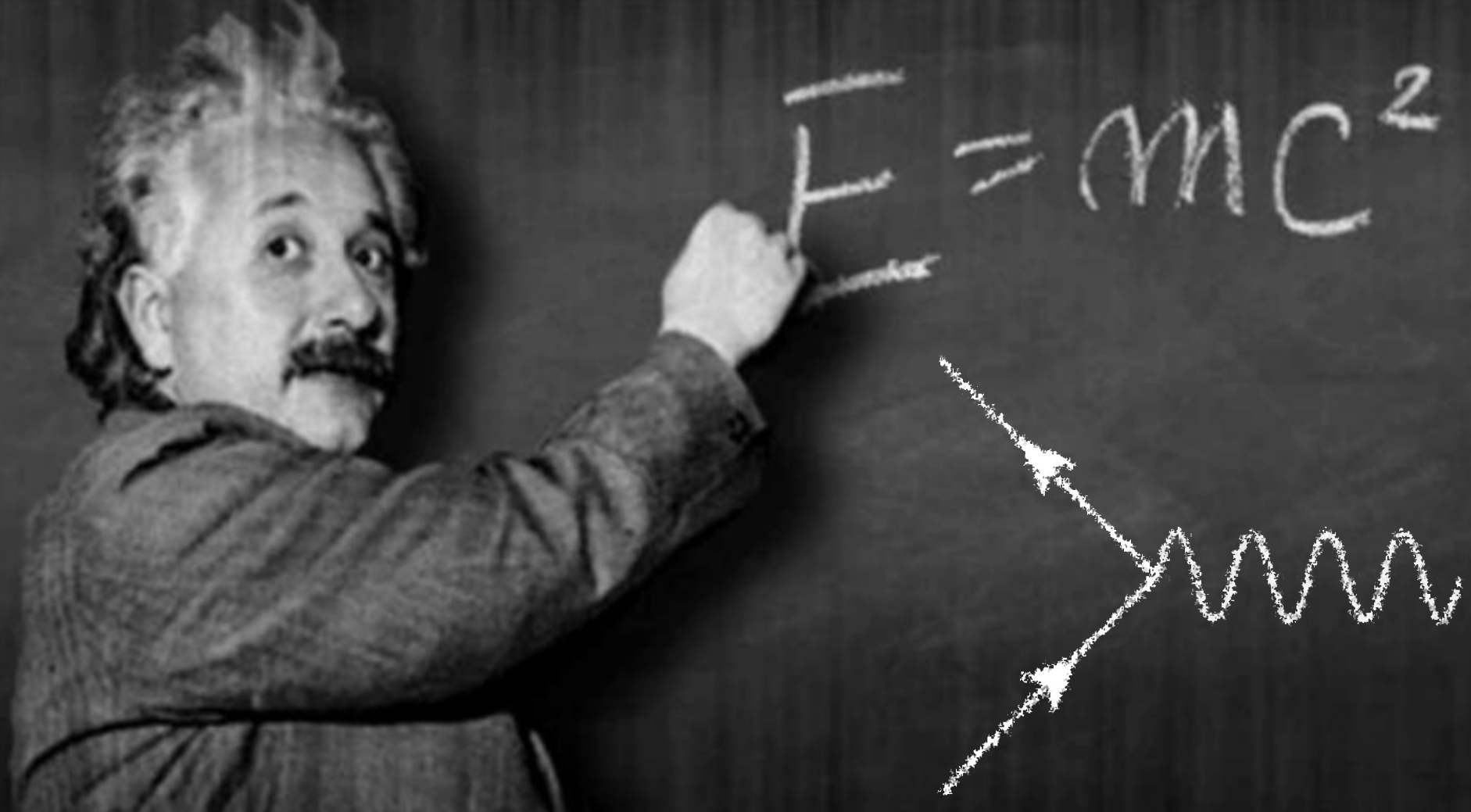
- La **massa** diventa **energia**

$$E=mc^2$$

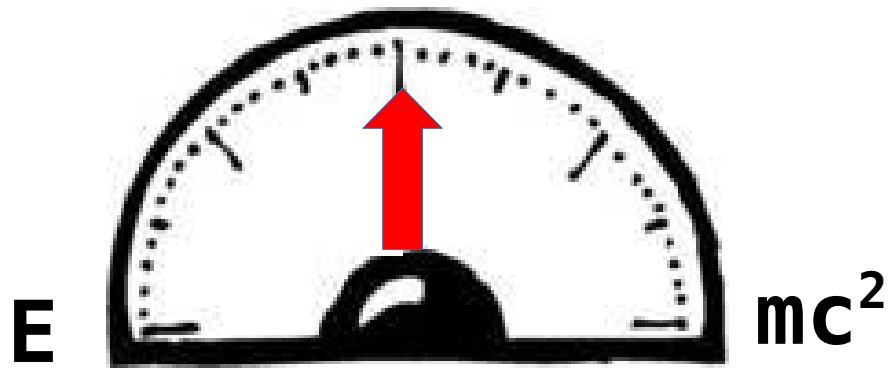
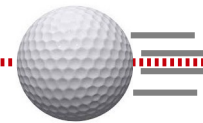
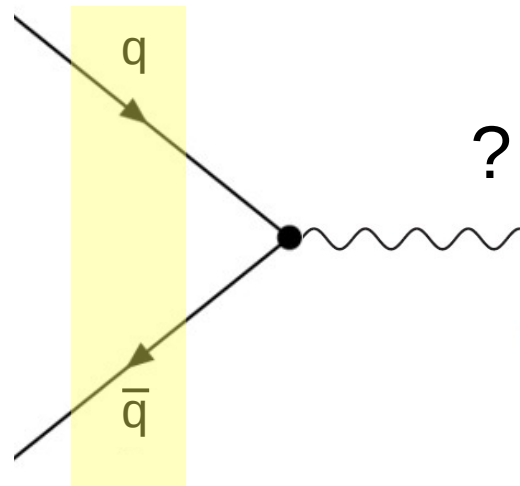
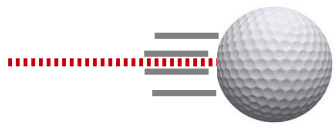
- Particelle a carica neutra:
fotoni, gluoni o il bosone Z



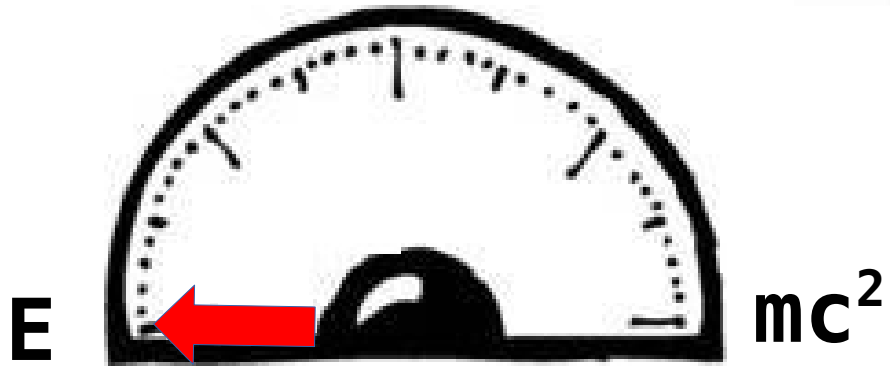
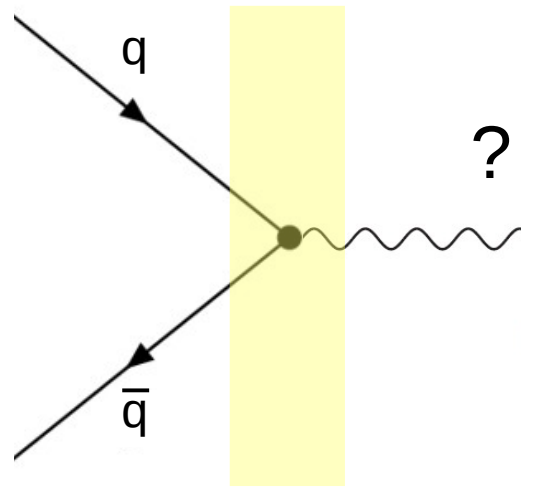
Come produrre nuove particelle?



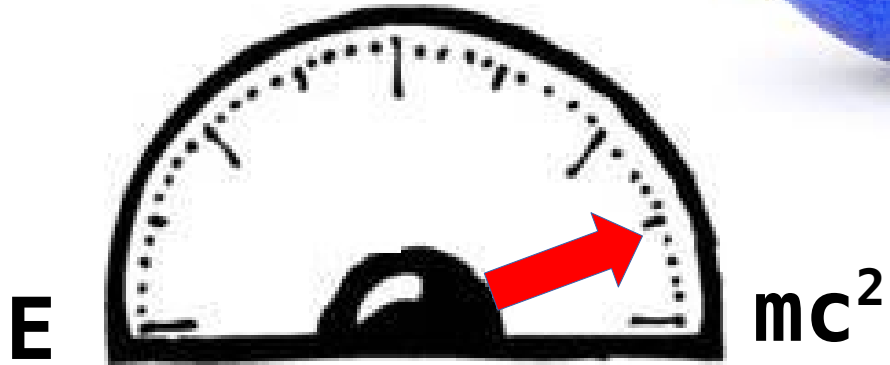
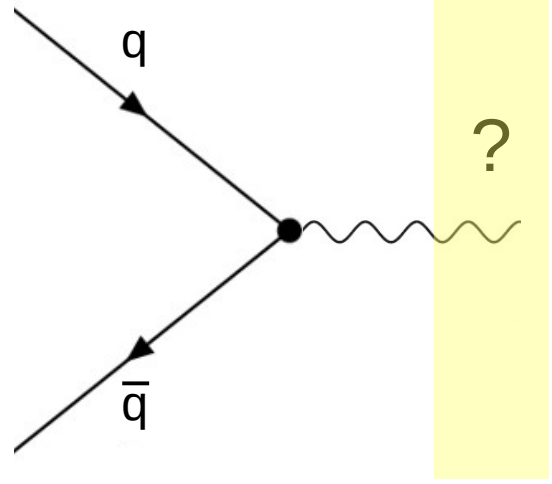
Collider



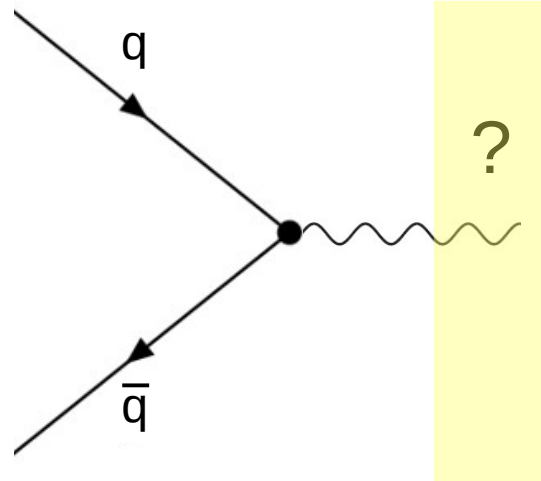
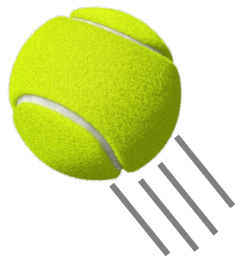
Collider



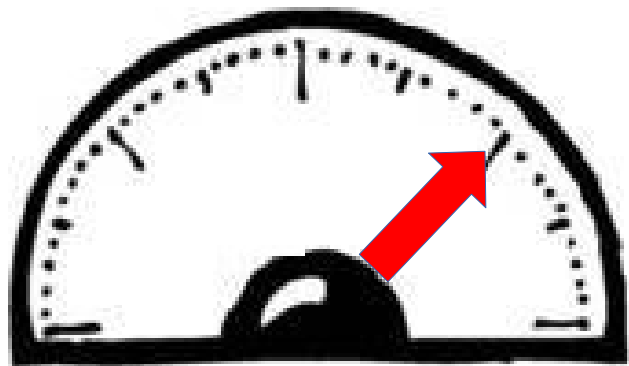
Collider



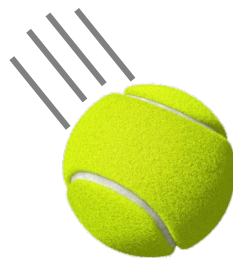
Collider



E



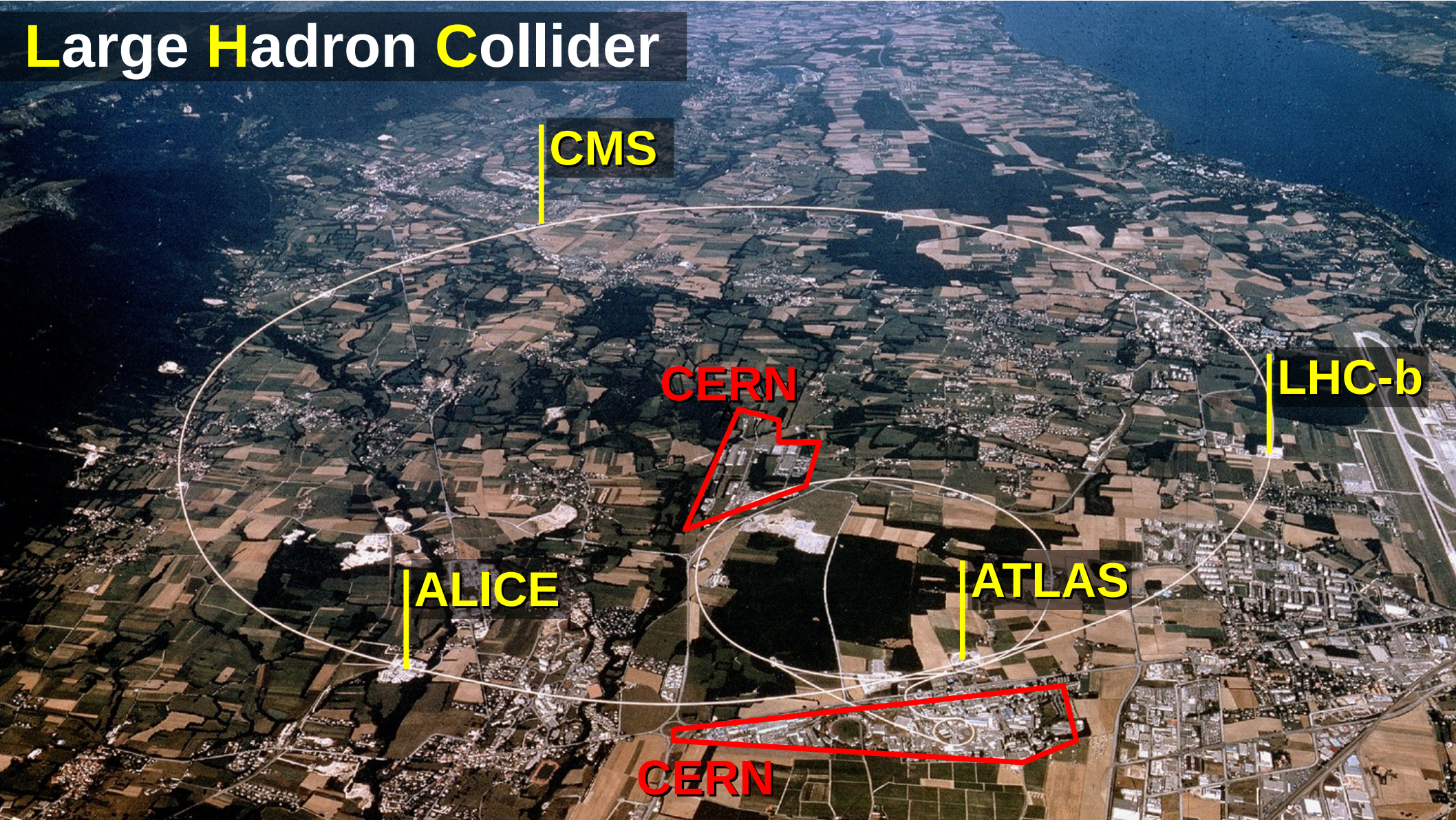
mc^2



Large Hadron Collider



Large Hadron Collider



CMS

CERN

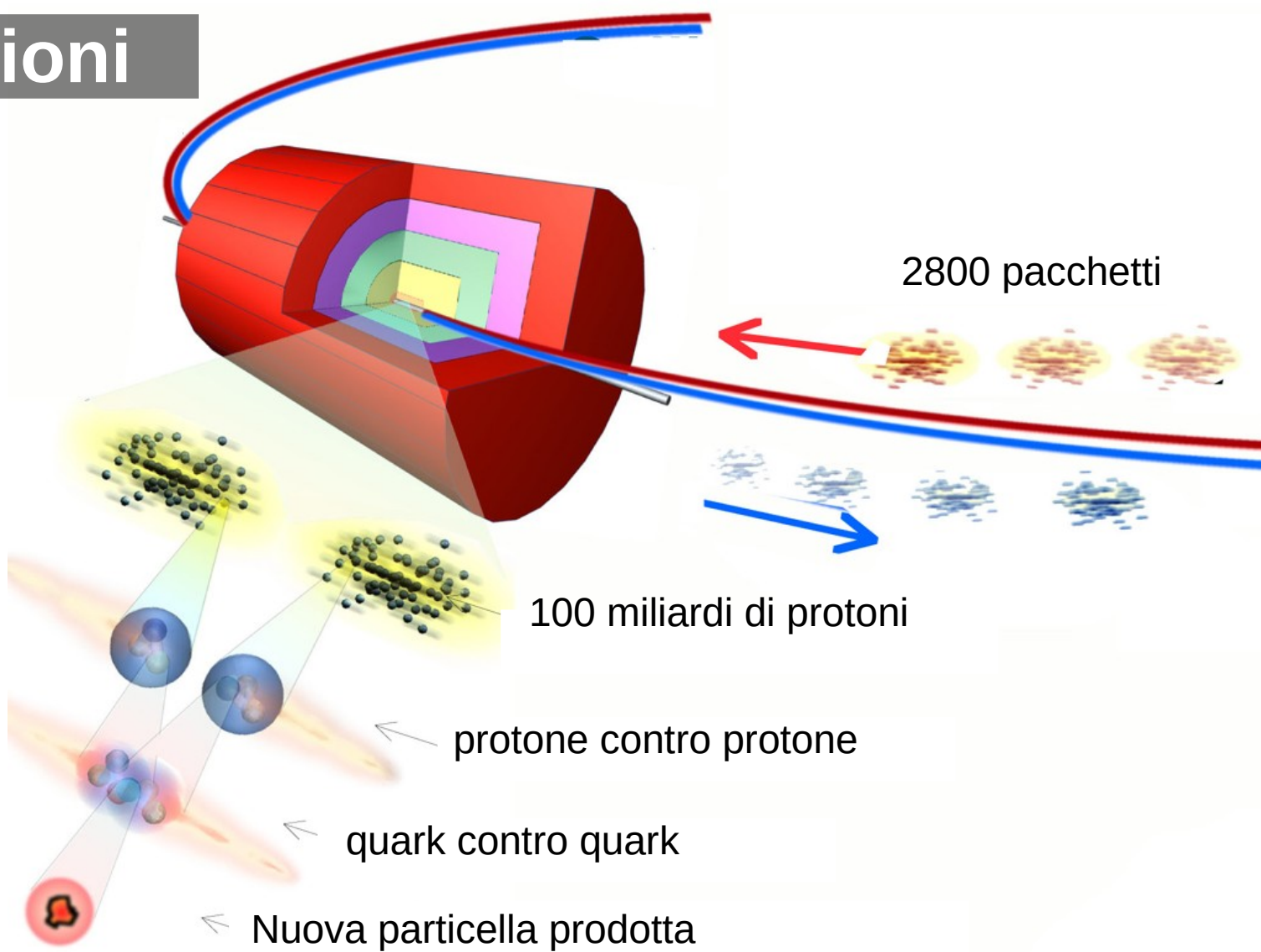
LHC-b

ALICE

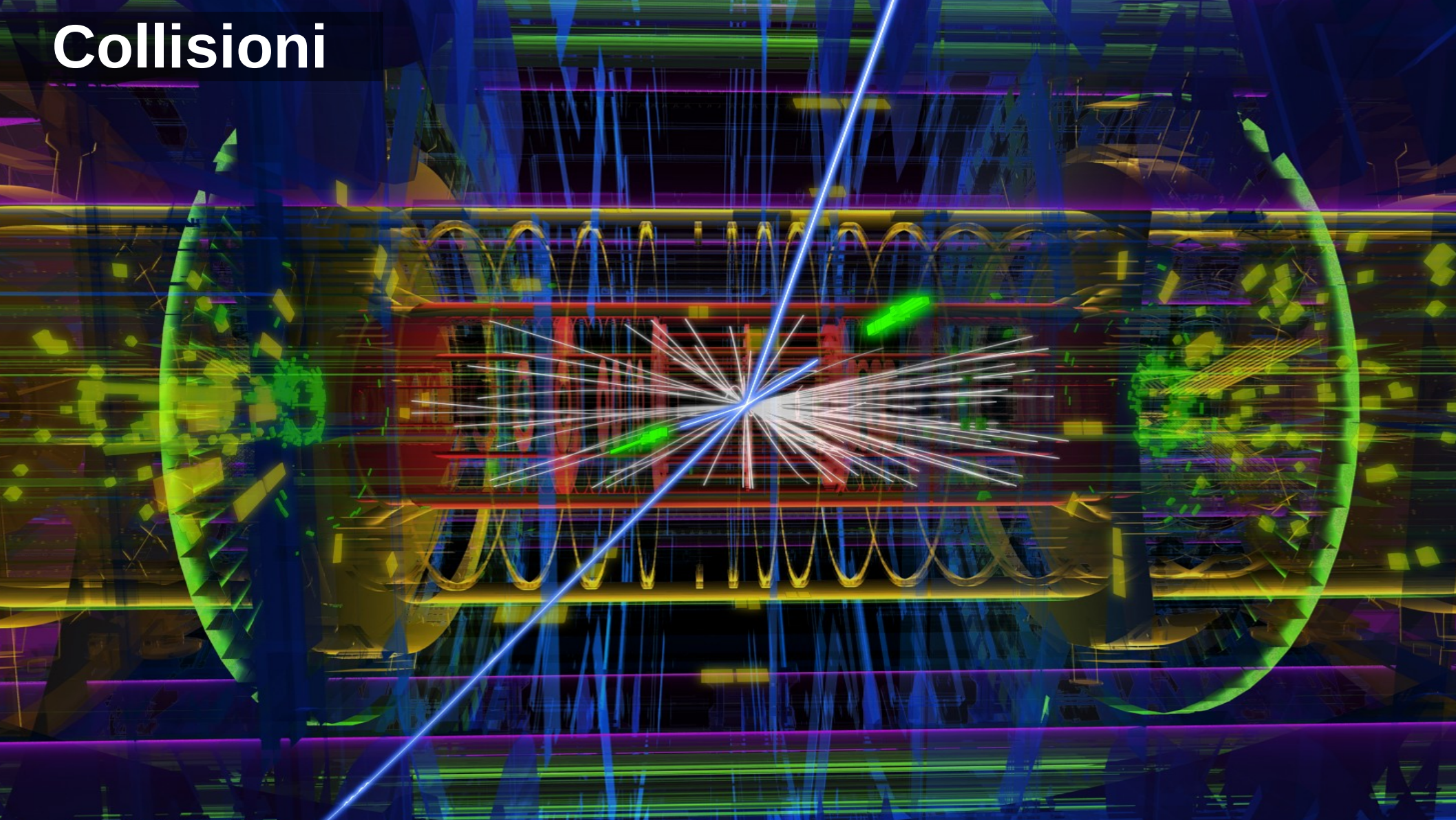
ATLAS

CERN

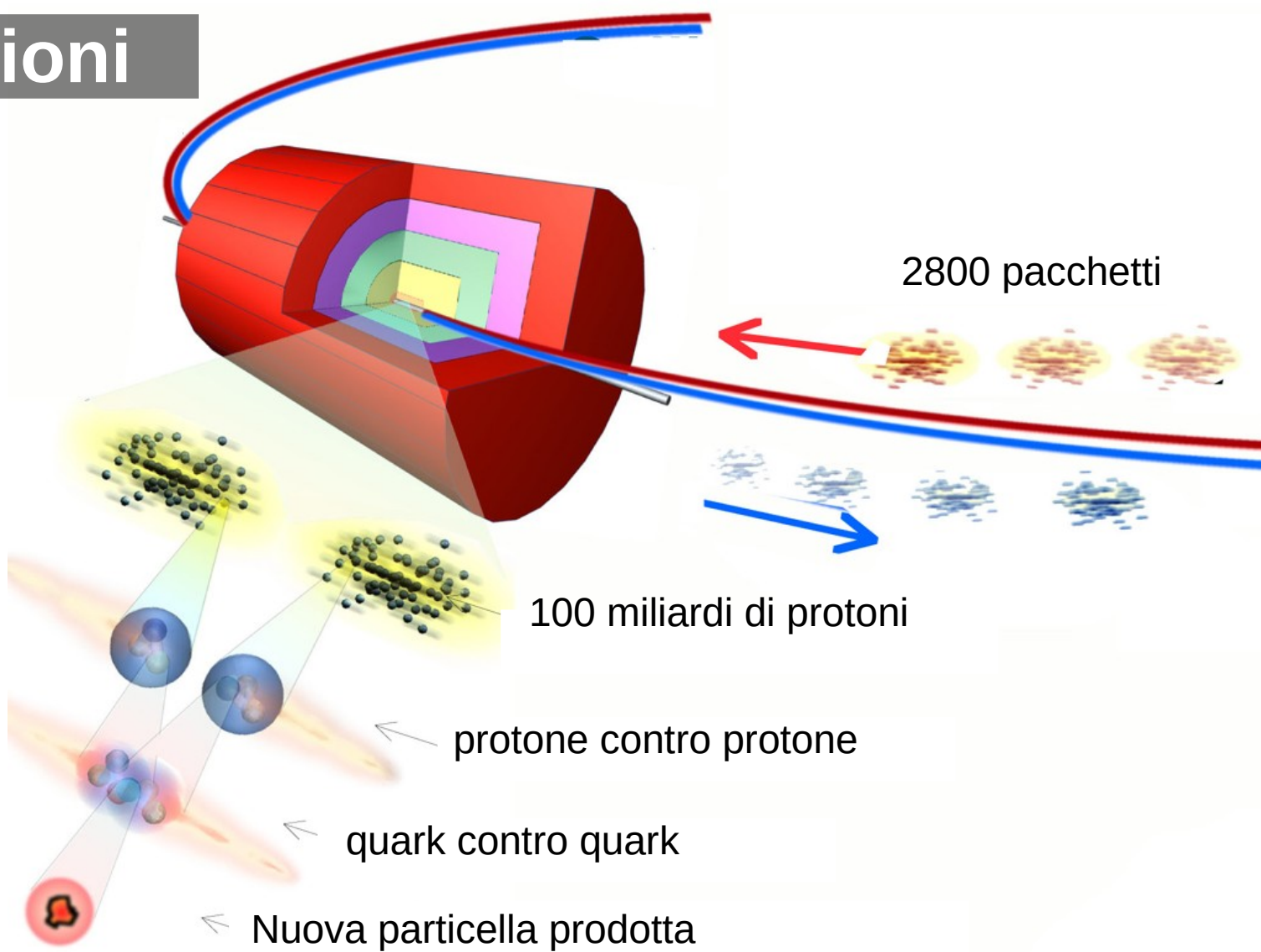
Collisioni



Collisioni



Collisioni



Forza bruta



Eventi rari

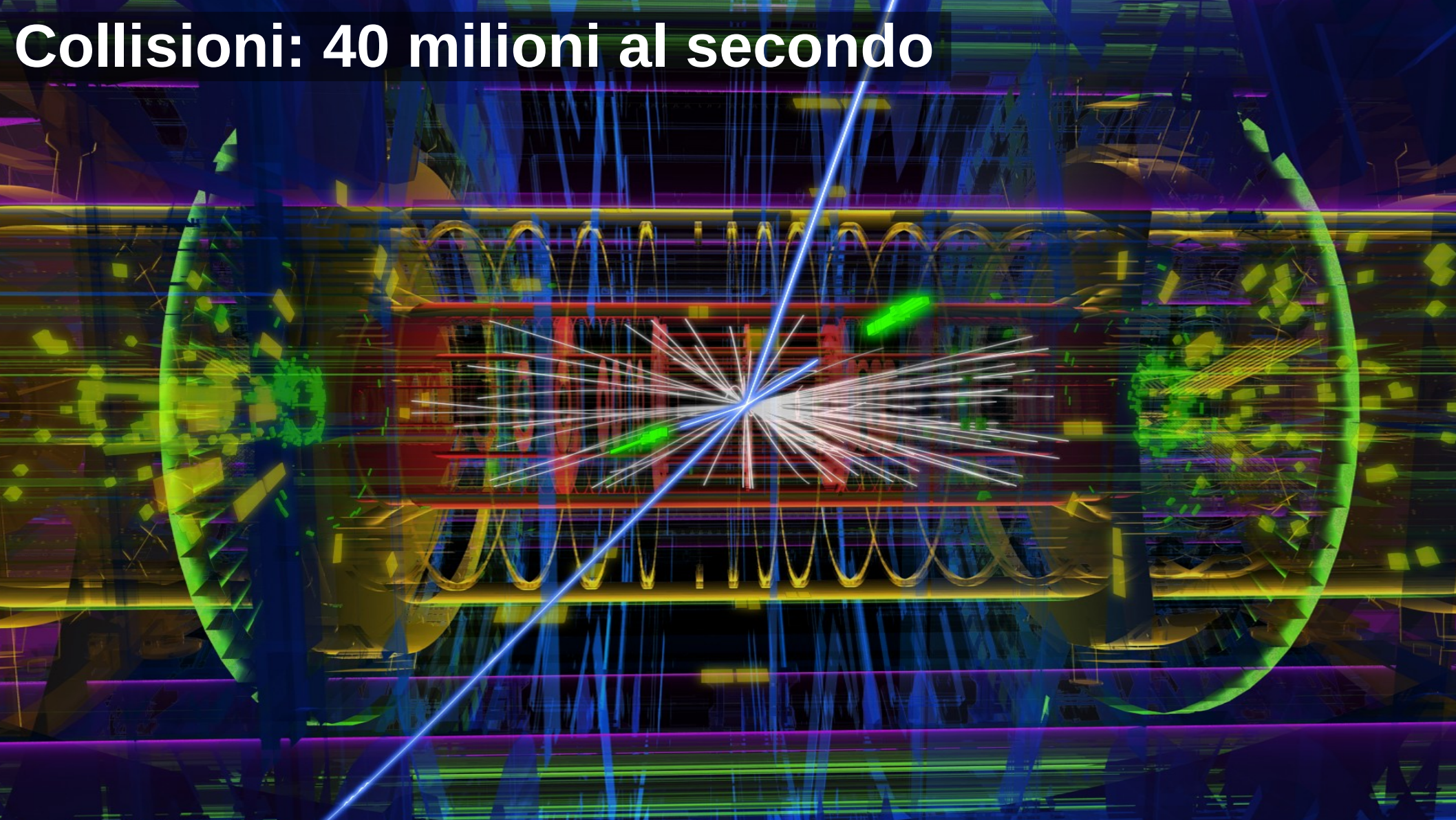
Segnale/fondo:

$1/10^{10}$

- 1 granello ogni 400 secchielli



Collisioni: 40 milioni al secondo



Da ricordare



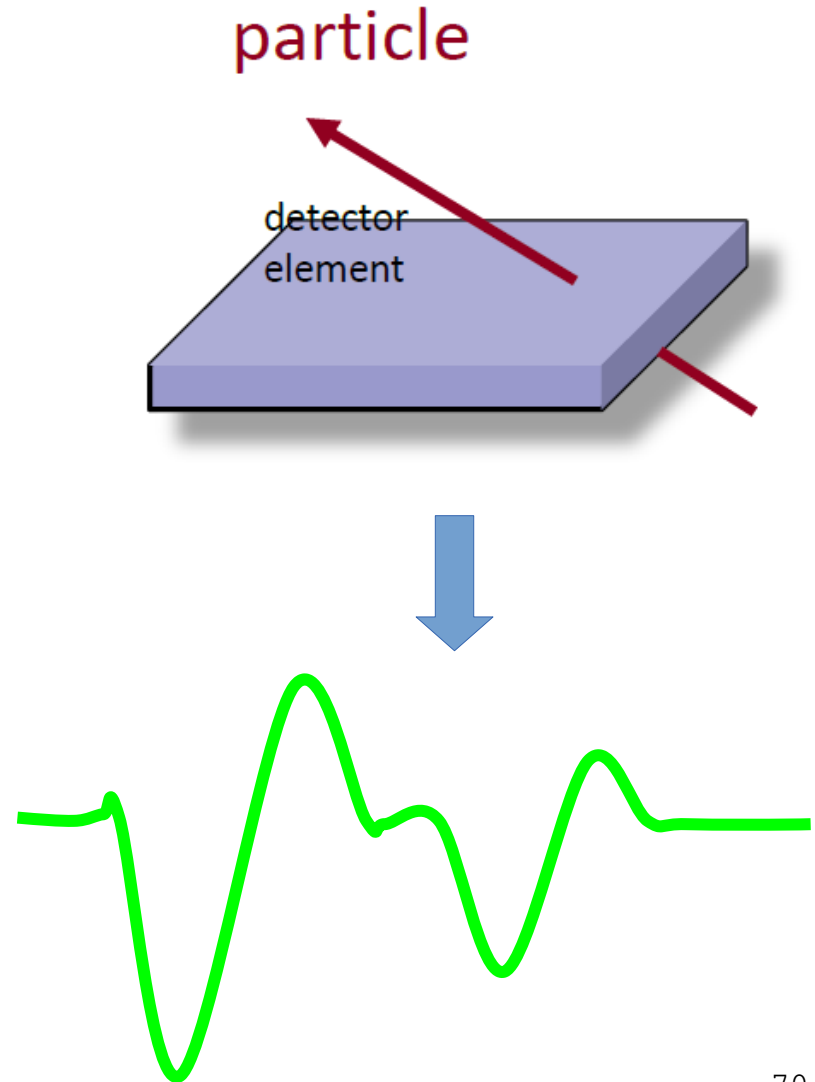
- Acceleratore da **27 km**
 - Per far collidere ad alta energia particelle leggere
- Per produrre **particelle massive**
 - $E=mc^2$ e annichilazione
- Le particelle massive **decadono** in quelle stabili, che riveliamo
- **Eventi rari**, necessari milioni di scontri al secondo

Rivelatori di particelle



Rivelatori di particelle

- **Interazione** delle particelle con la materia
- Liberazione di elettroni, ioni, fotoni
- Raccolta di **segnali elettrici**

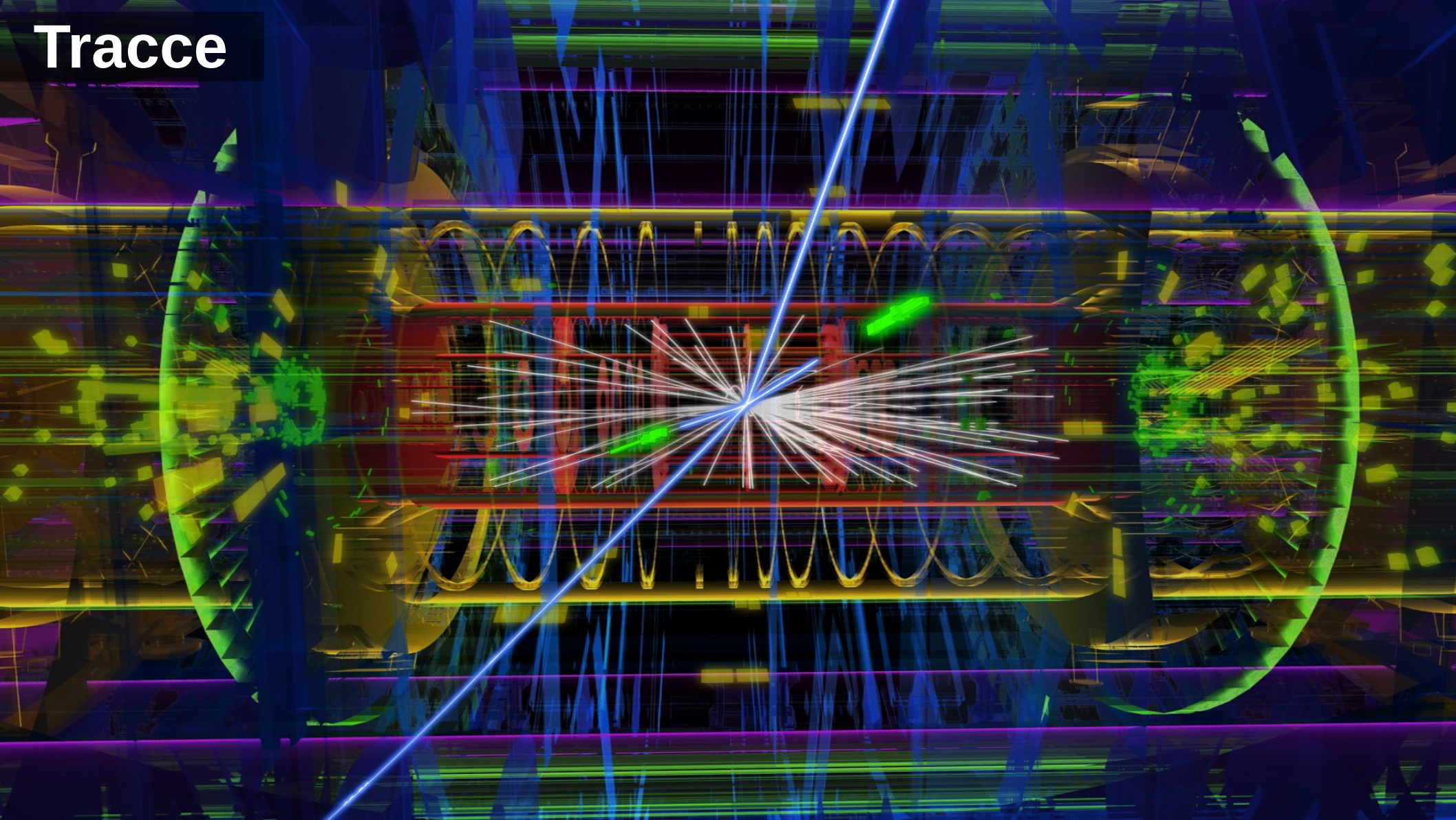


Rivelatori di particelle

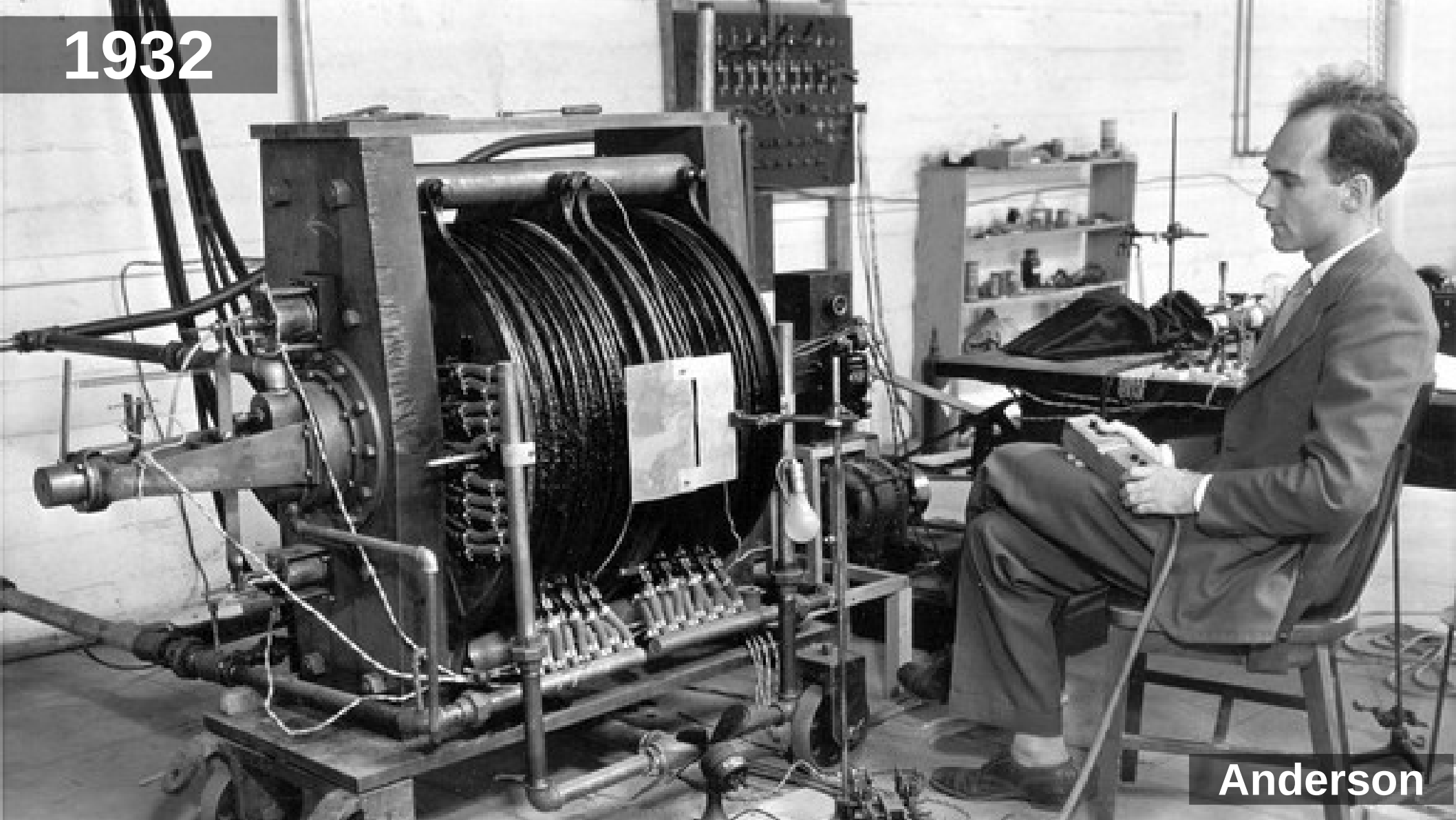
The image displays a dense and intricate pattern of white, glowing tracks against a dark blue, almost black, background. These tracks, which represent particle paths, are of varying lengths and thicknesses, some appearing as thin, sharp lines while others are thicker and more diffuse. They crisscross the frame in multiple directions, creating a complex web of intersections and loops. The overall effect is that of a high-energy particle detector's output, where the tracks are the result of ionizing particles passing through a sensitive medium.

Seguire le scie

Tracce

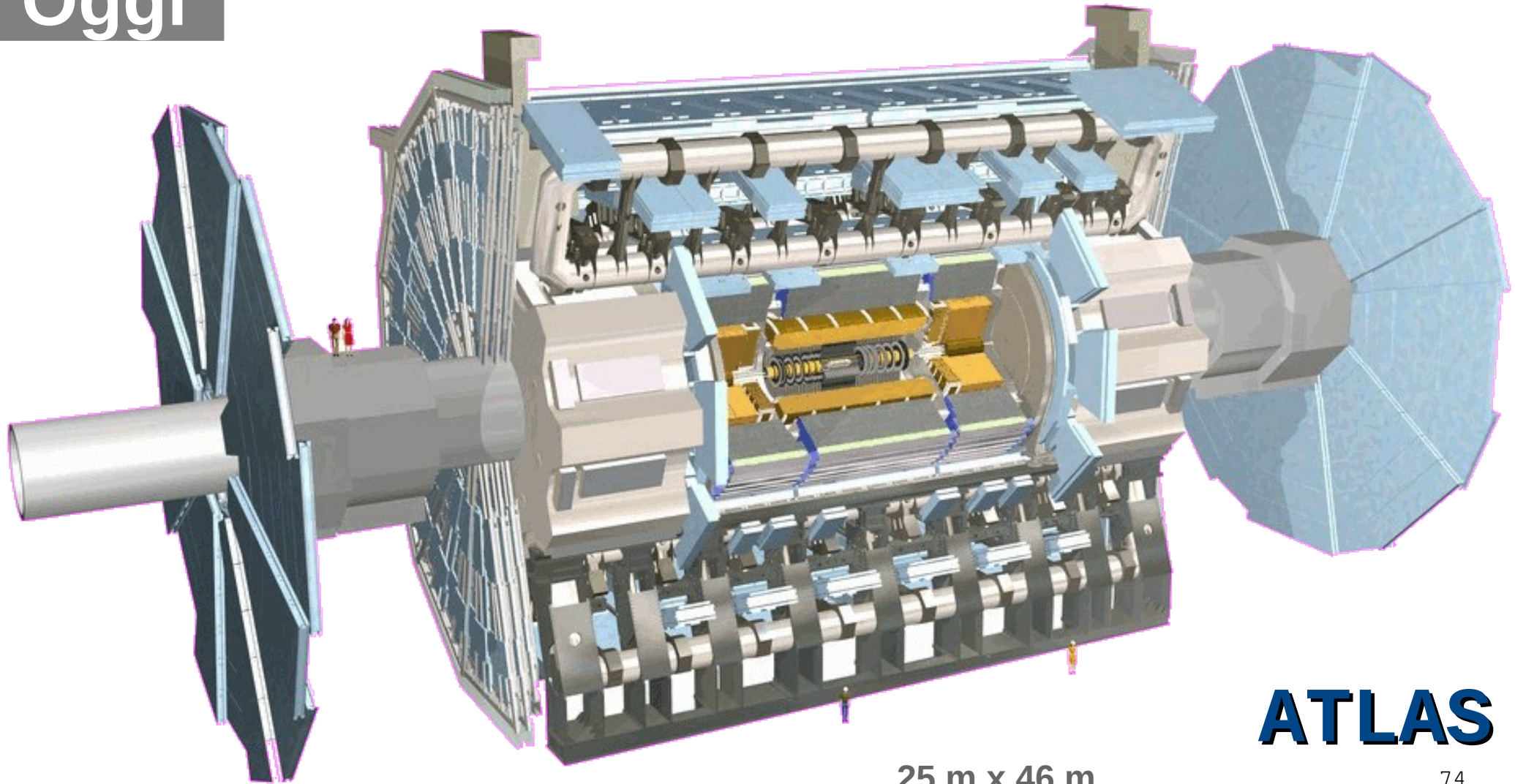


1932



Anderson

Oggi



25 m x 46 m

ATLAS

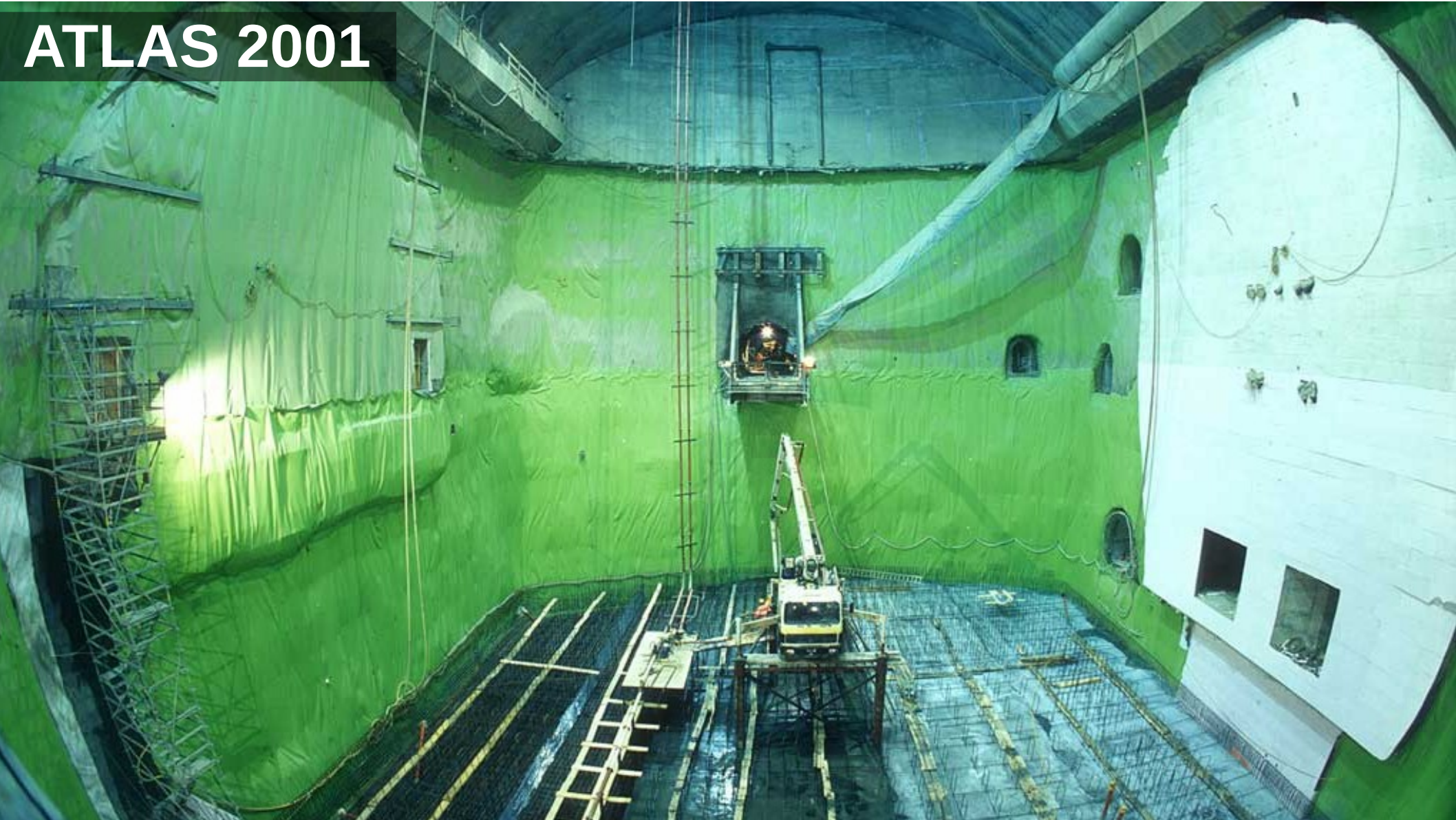
Home made



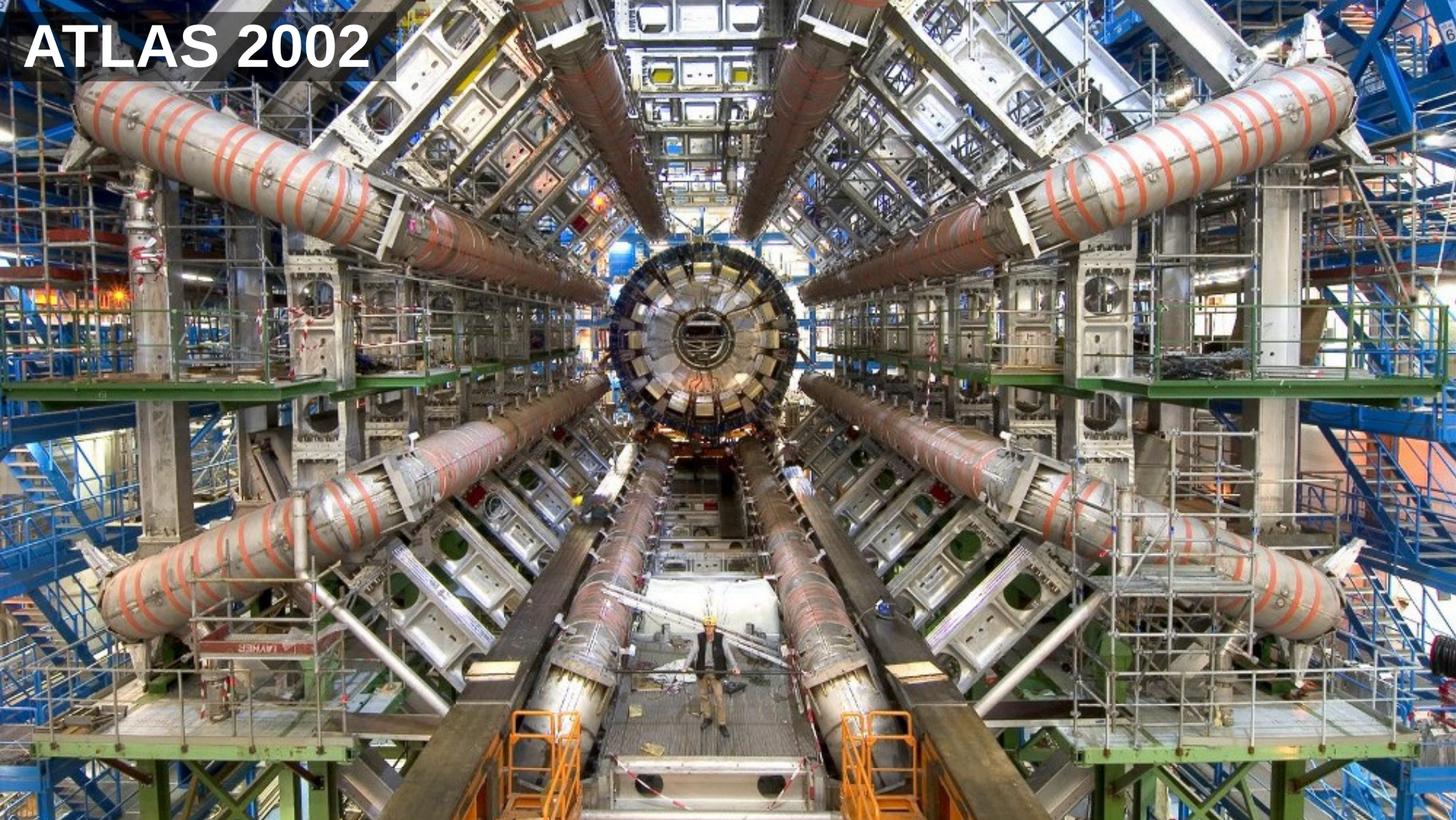
Home made



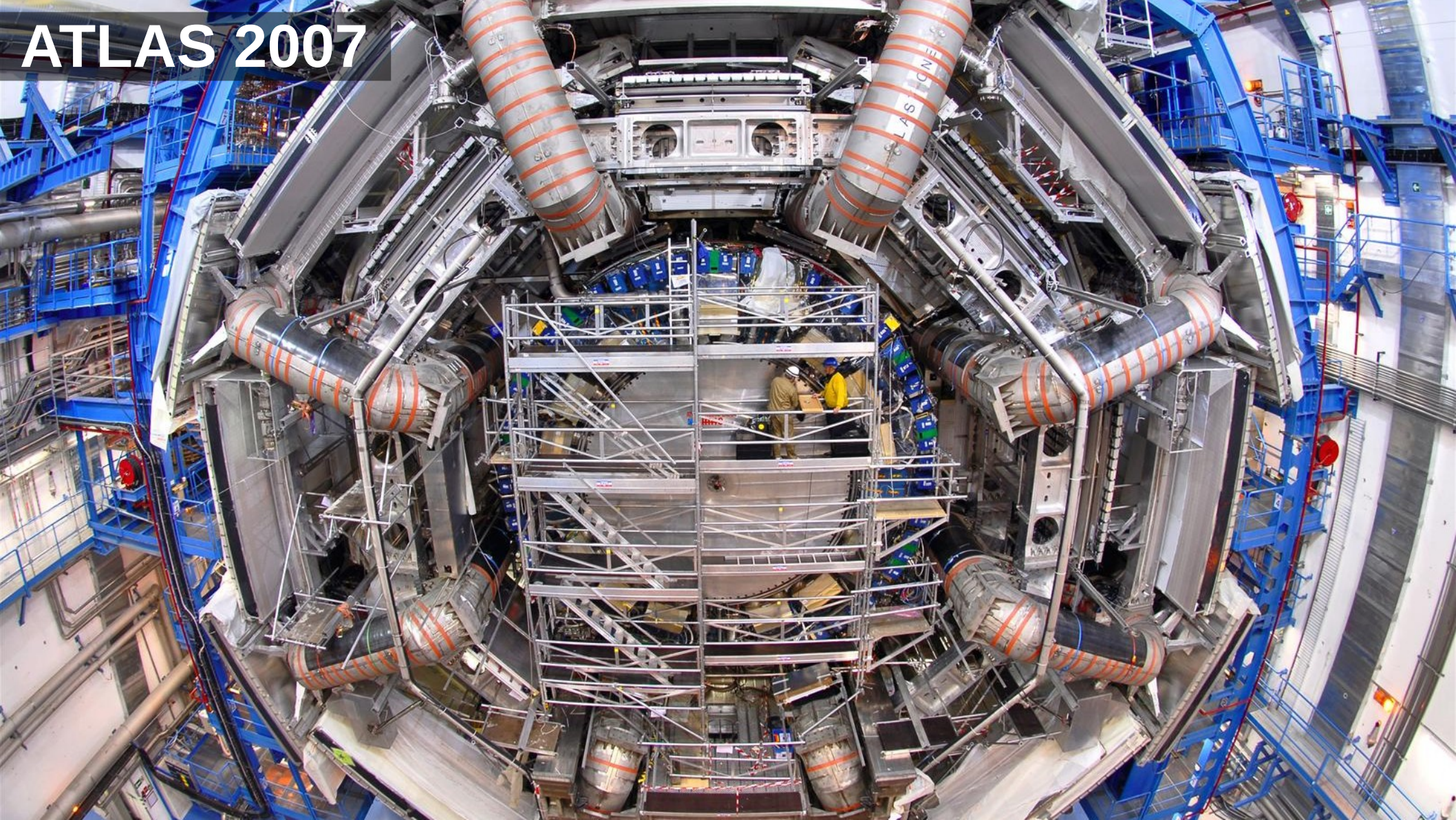
ATLAS 2001



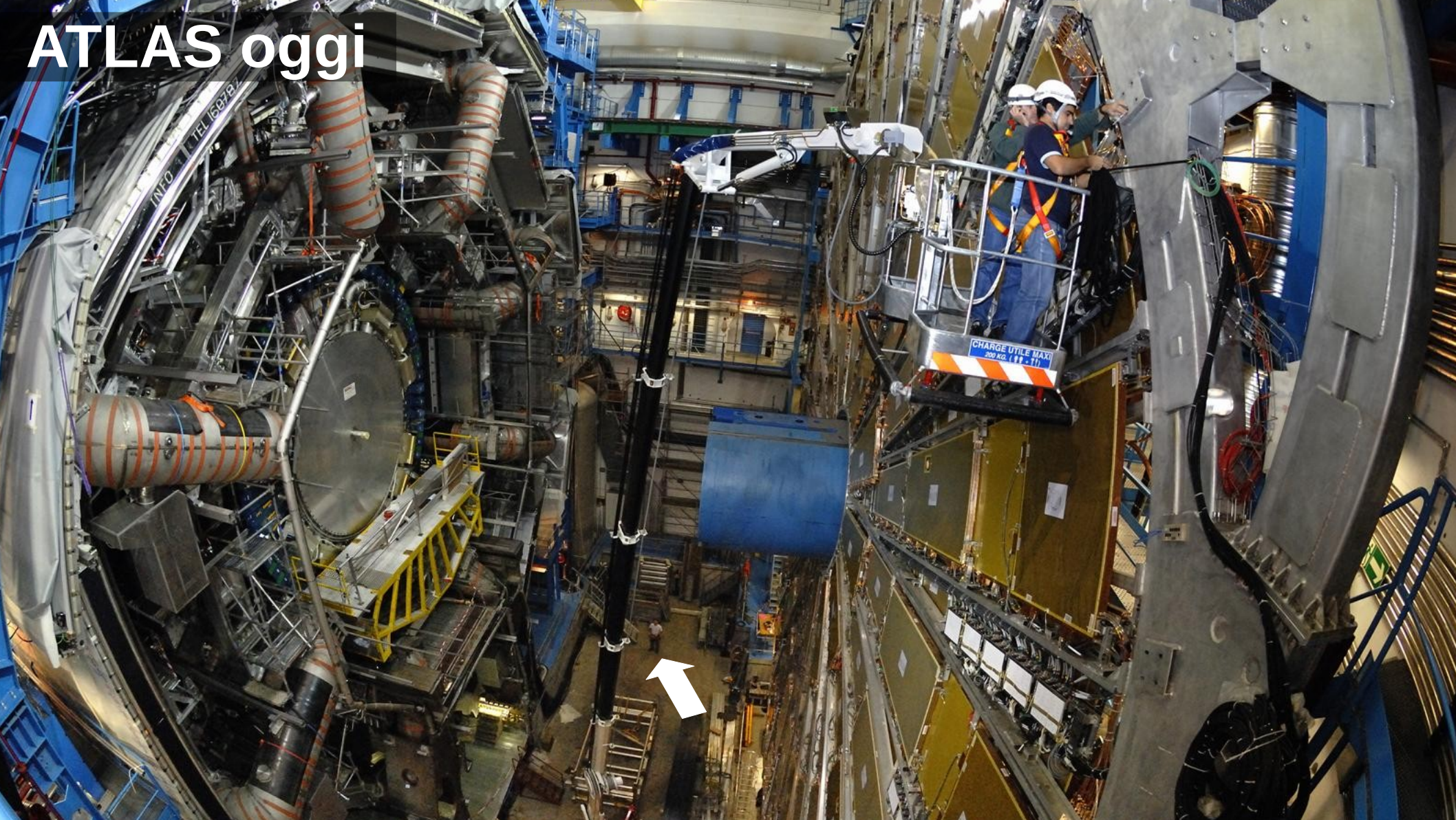
ATLAS 2002



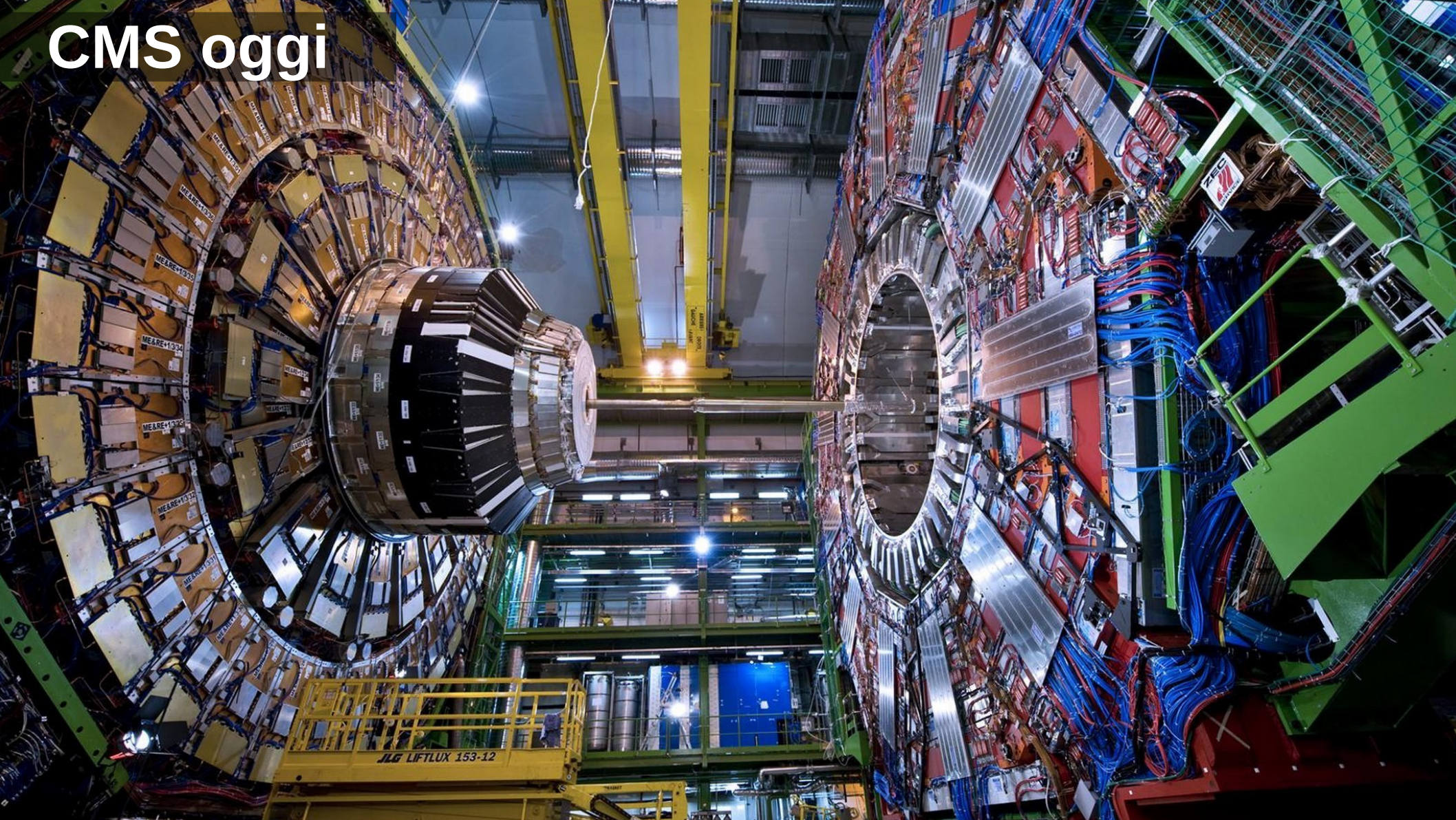
ATLAS 2007



ATLAS oggi



CMS oggi



Alice oggi





Presa dati: 2010-12, 2015-18, 2022-2025 ... 2034

Big data

A photograph of a large sand dune under a clear blue sky. The dune is a smooth, golden-yellow slope that curves from the left towards the right. A dark shadow is cast on the right side of the dune, indicating the sun is low in the sky. The sky is a deep, clear blue with a few wispy white clouds on the left side.

~10 PB/anno

Analisi dati





CERN
Ginevra

CHE COS'È

È una rete planetaria che unisce e utilizza contemporaneamente la potenza di calcolo e la memoria di decine di migliaia di differenti computer sparsi nel mondo

Nodi di I livello

- CNAF - Bologna, ITA
- In2p3 - Lione, FRA
- SARA - Amsterdam, OLA
- Ral - Oxford, GBR
- GridKa, Karlsruhe - Stoccarda, GER
- Fermilab - Chicago, USA
- Triumf - Vancouver, CAN
- Brookhaven - Long Island, USA
- Nordic - SVE-FIN-NOR
- Pic - Barcellona, SPA
- Ascc - Taiwan, CIN

Fibra ottica
dedicata
per i nodi
di I livello



L'utente può collegarsi alla Grid dal proprio pc e usare le risorse di calcolo che gli servono



140 centri
di calcolo
in 33 Paesi



Oltre 10.000
gli utenti che
utilizzano Grid

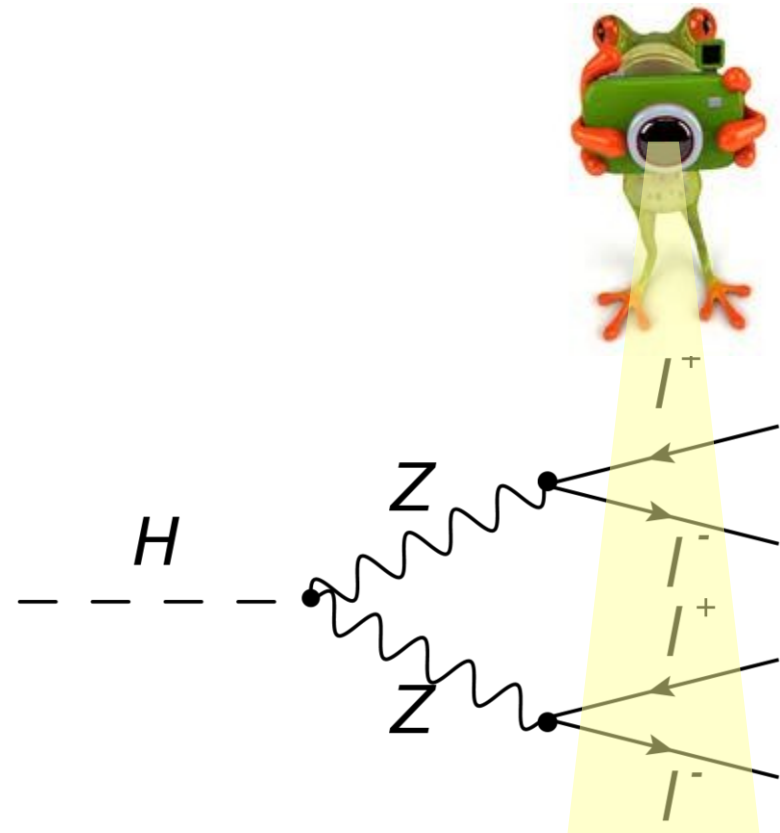
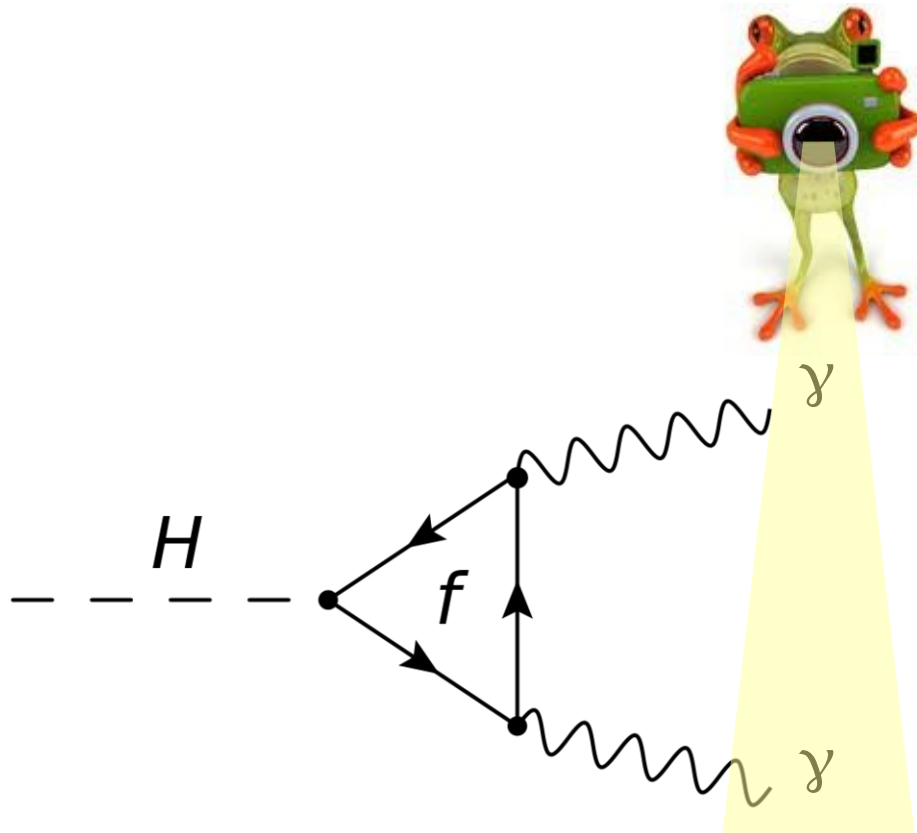


La potenza
di calcolo prodotta
è pari a quella di 100.000 computer

Ricerca bosone di Higgs

L'Higgs non è stabile, **decade** in fotoni o leptoni

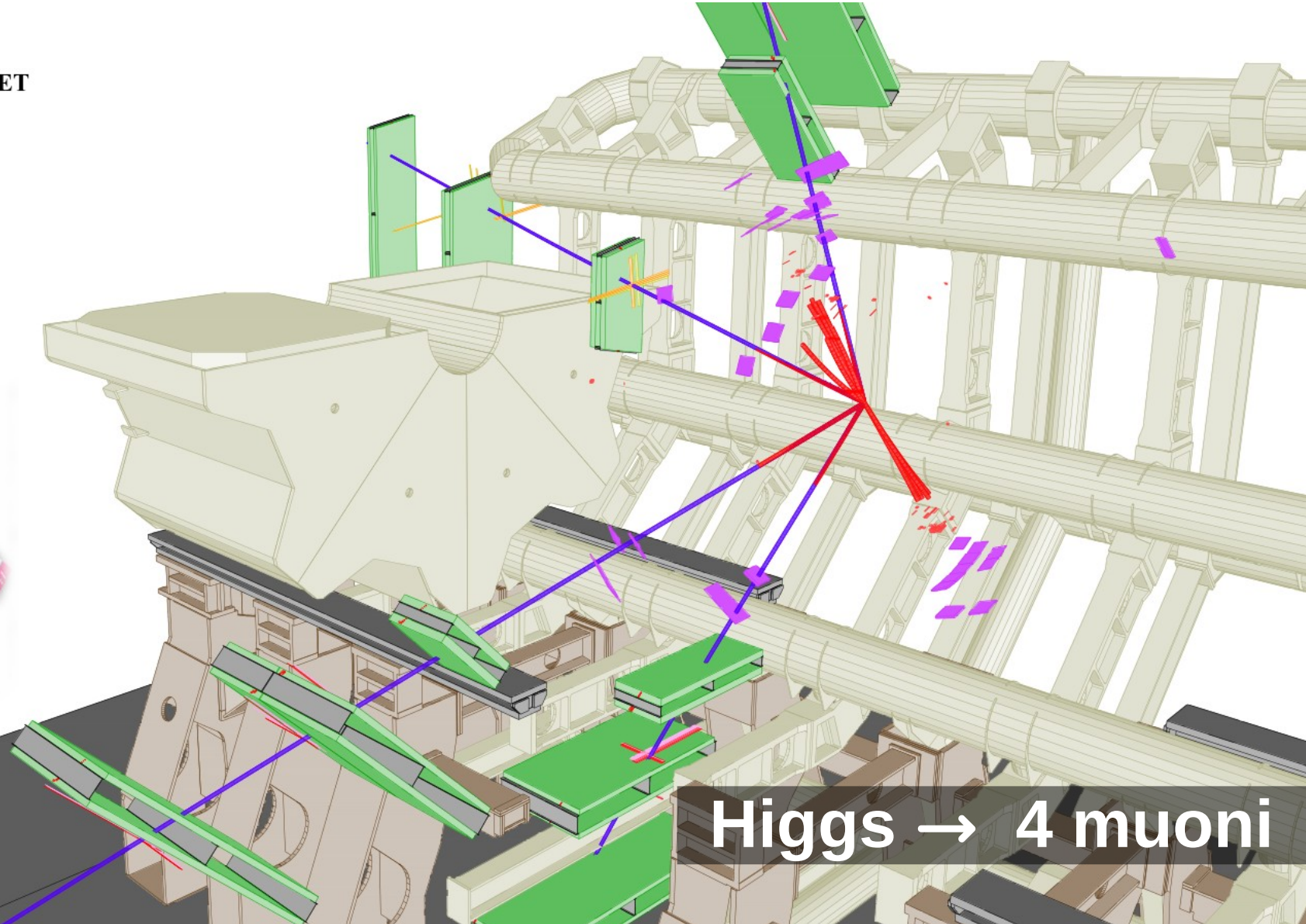
- Identificato partendo dai prodotti del suo decadimento



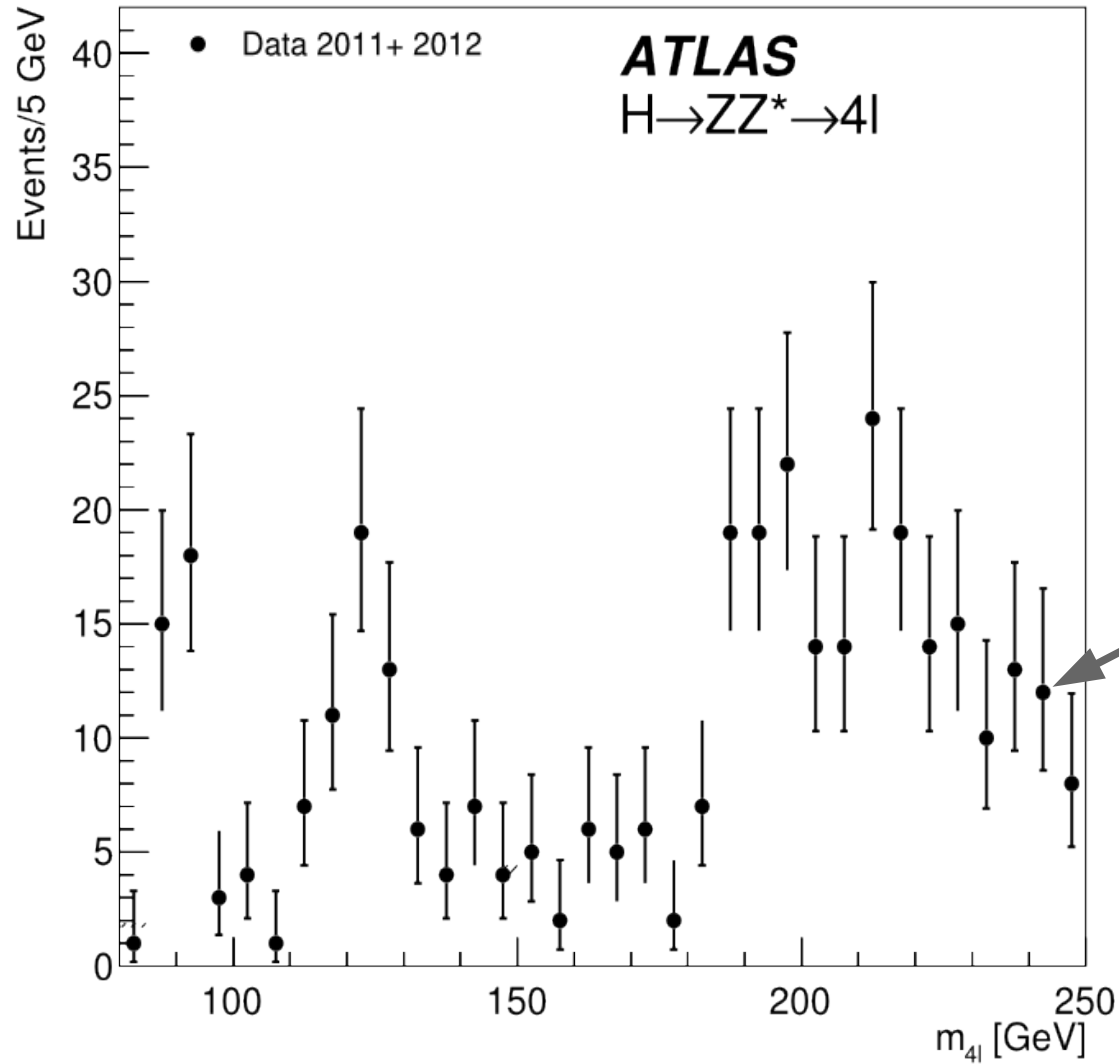
Run Number: 189280,
Event Number: 143576946
Date: 2011-09-14, 11:37:11 CET

EtCut > 0.3 GeV
PtCut > 3.0 GeV
Vertex Cuts:
Z direction < 1cm
Rphi < 1cm

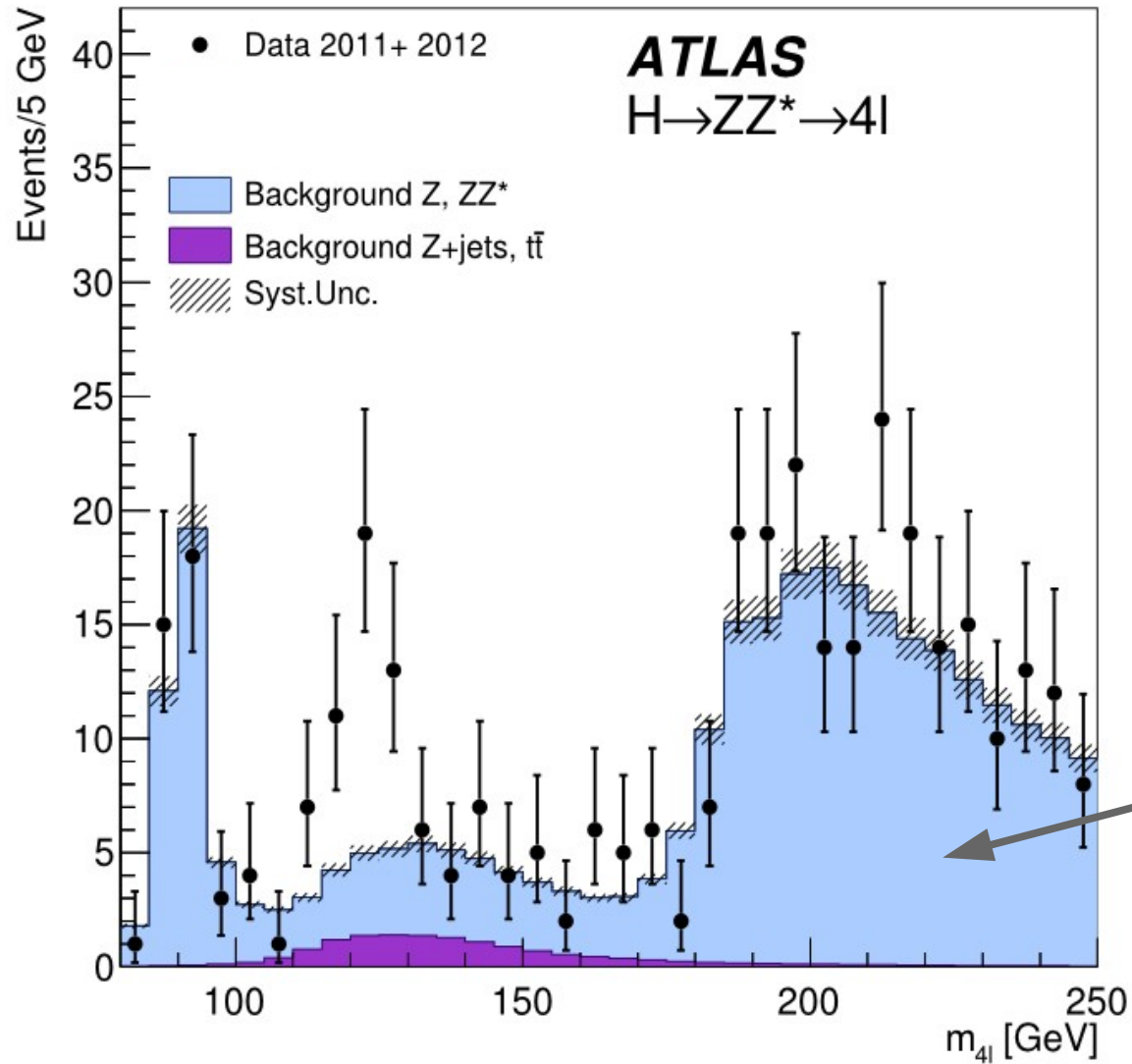
Muon: blue
Cells: Tiles, EMC



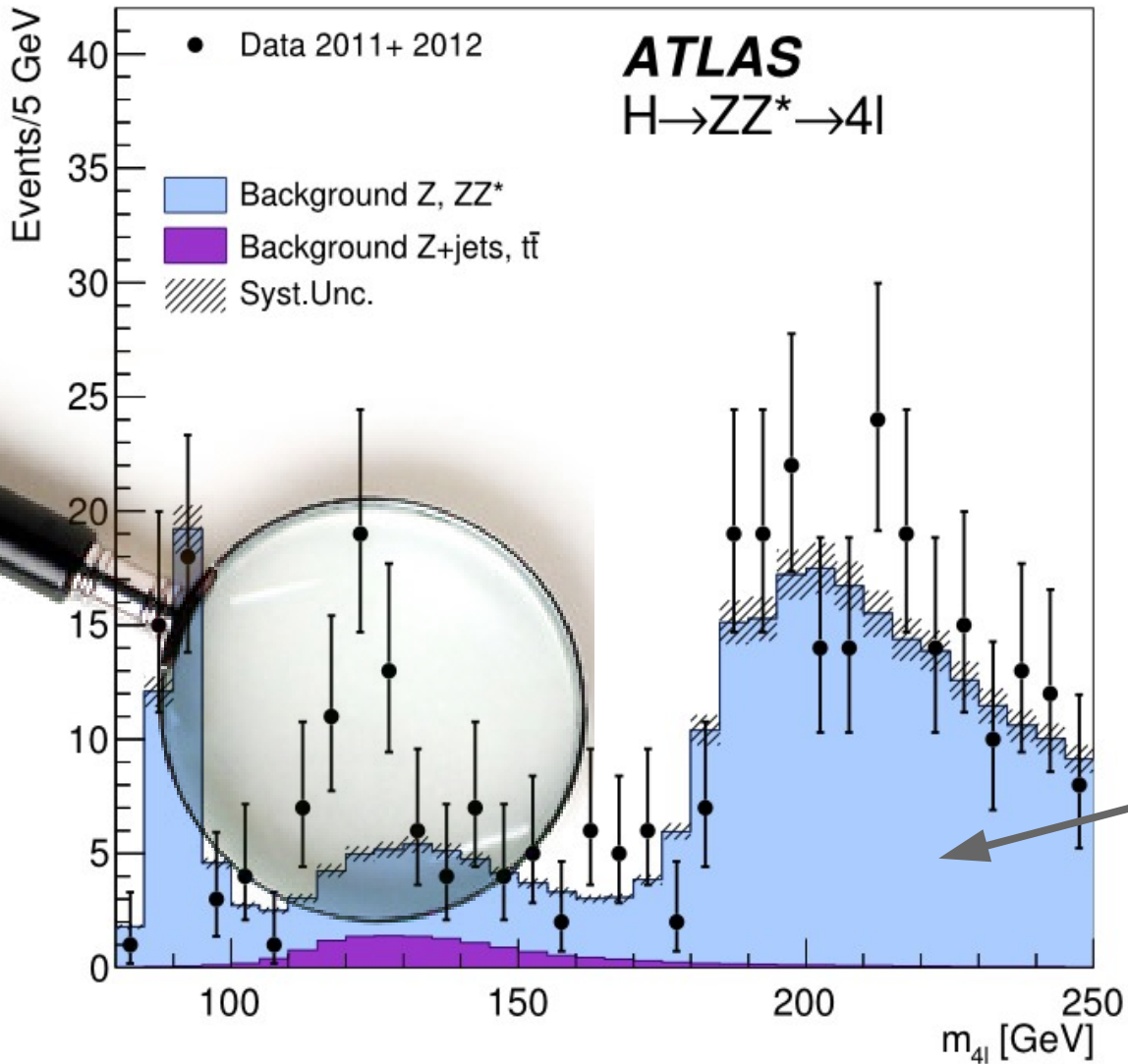
Higgs → 4 muoni



**Dati
sperimentali**

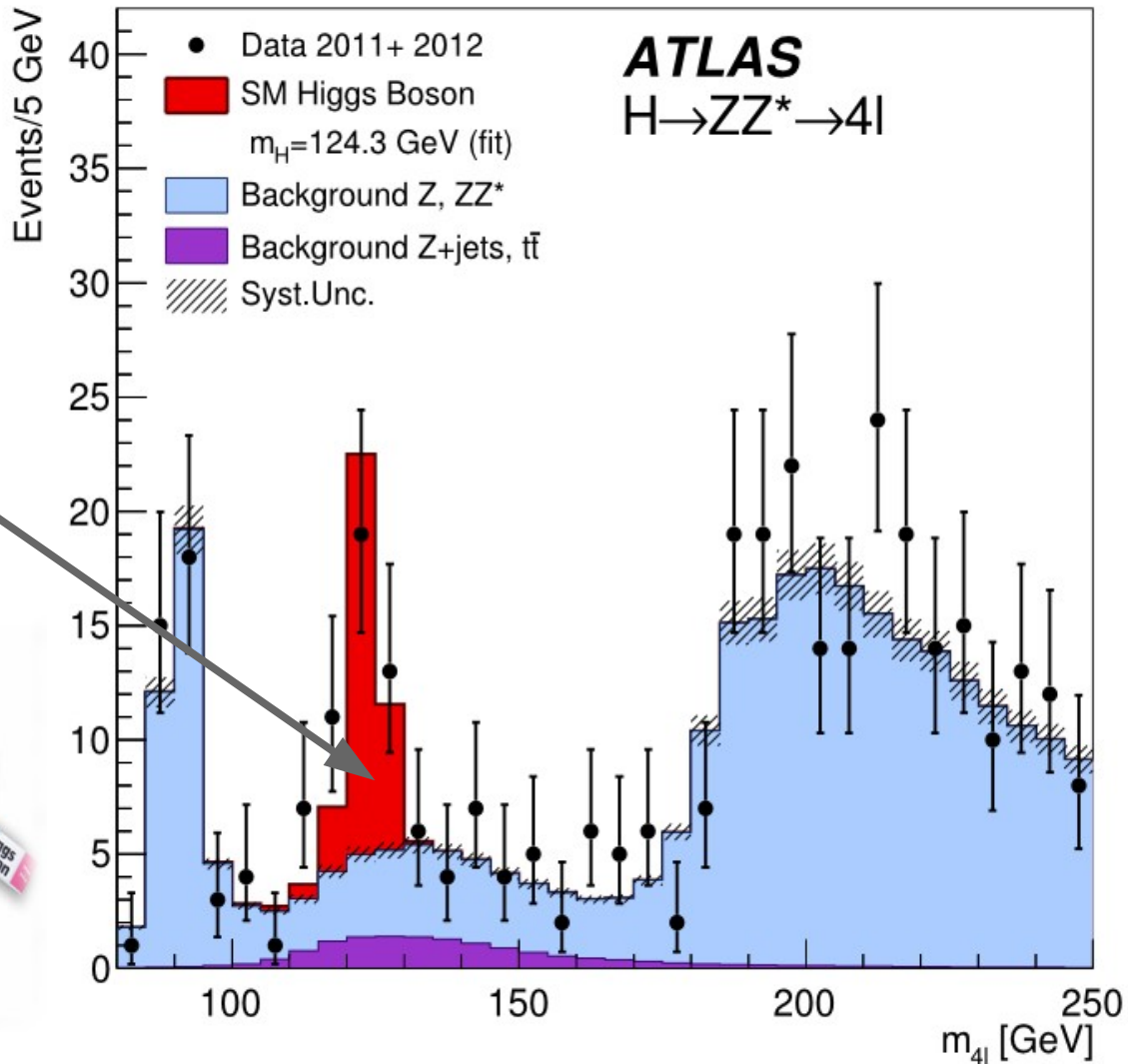


**Fondo
atteso**



Fondo atteso

Segnale
atteso di
Higgs



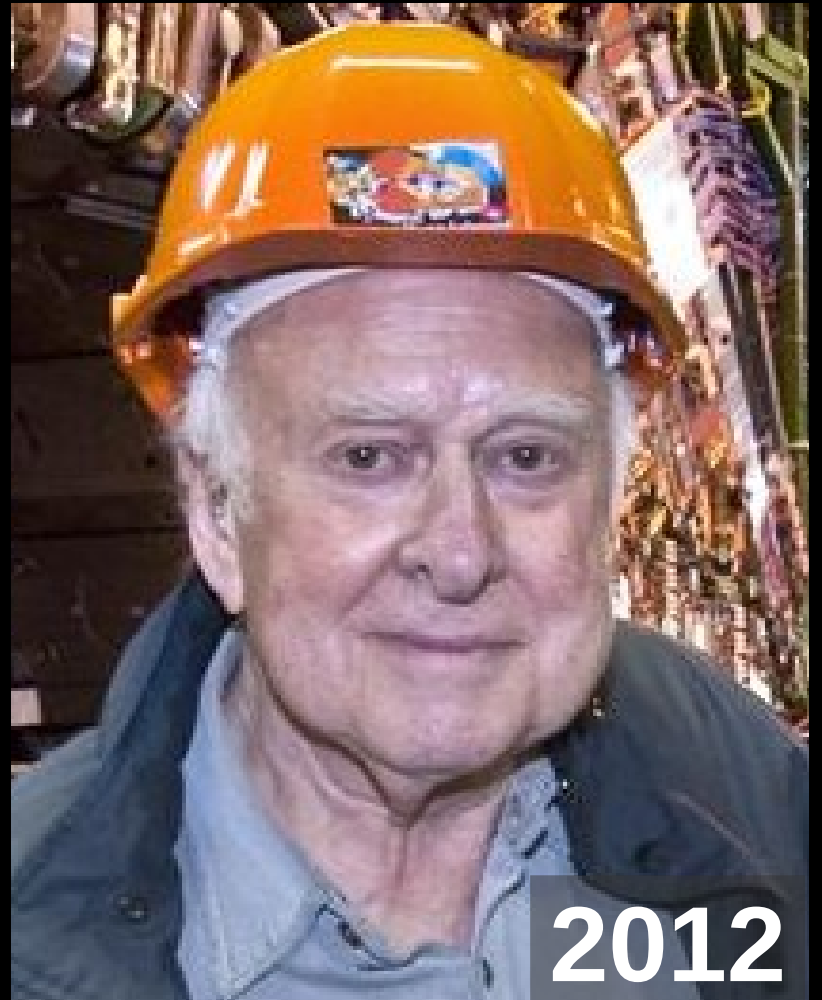
Bosone di Higgs



Prof. Peter Higgs



1964



2012



Premio Nobel 2013



8 October 2013

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”

Prossimi passi



u	c	t	γ	g	g
d	s	b	Z^0	g	g
ν_e	ν_μ	ν_τ	W^+	g	g
e	μ	τ	W^-	g	

Higgs

u c t γ g g

d s b Z^0 g g

ν_e ν_μ ν_τ W^+ g g

e μ τ W^- g h

Cosa sappiamo?



Cosa sappiamo? Poco

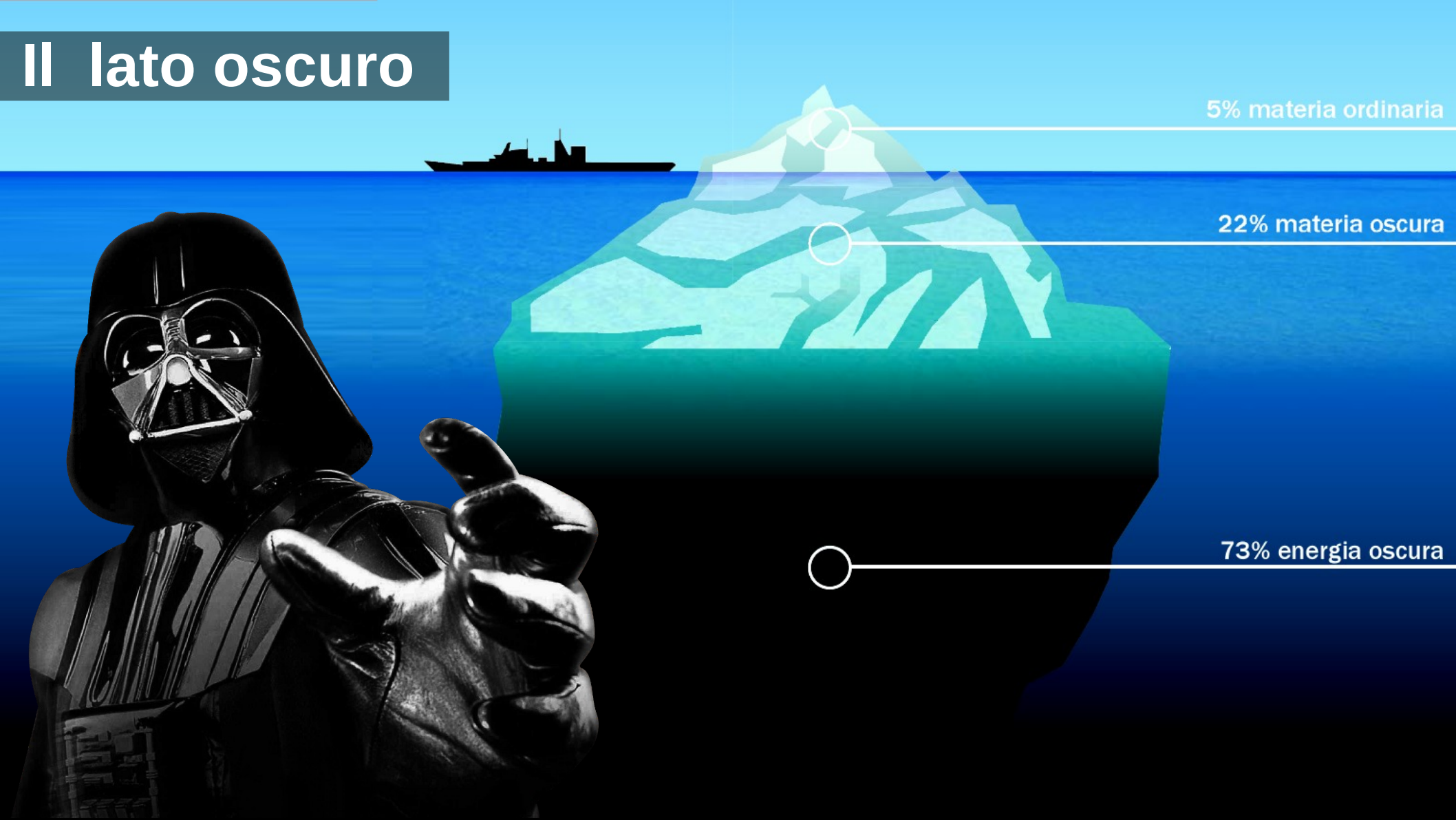
- I quark sono **indivisibili**?
- Dov'è finita l'antimateria?
- Esistono altre **dimensioni**?
- Esiste una teoria che unisca tutte le forze fondamentali?
- Cos'è la **materia oscura** ?
- Cos'è l' **energia oscura** ?



Il dubbio è conoscenza



Il lato oscuro



5% materia ordinaria

22% materia oscura

73% energia oscura

La massa mancante

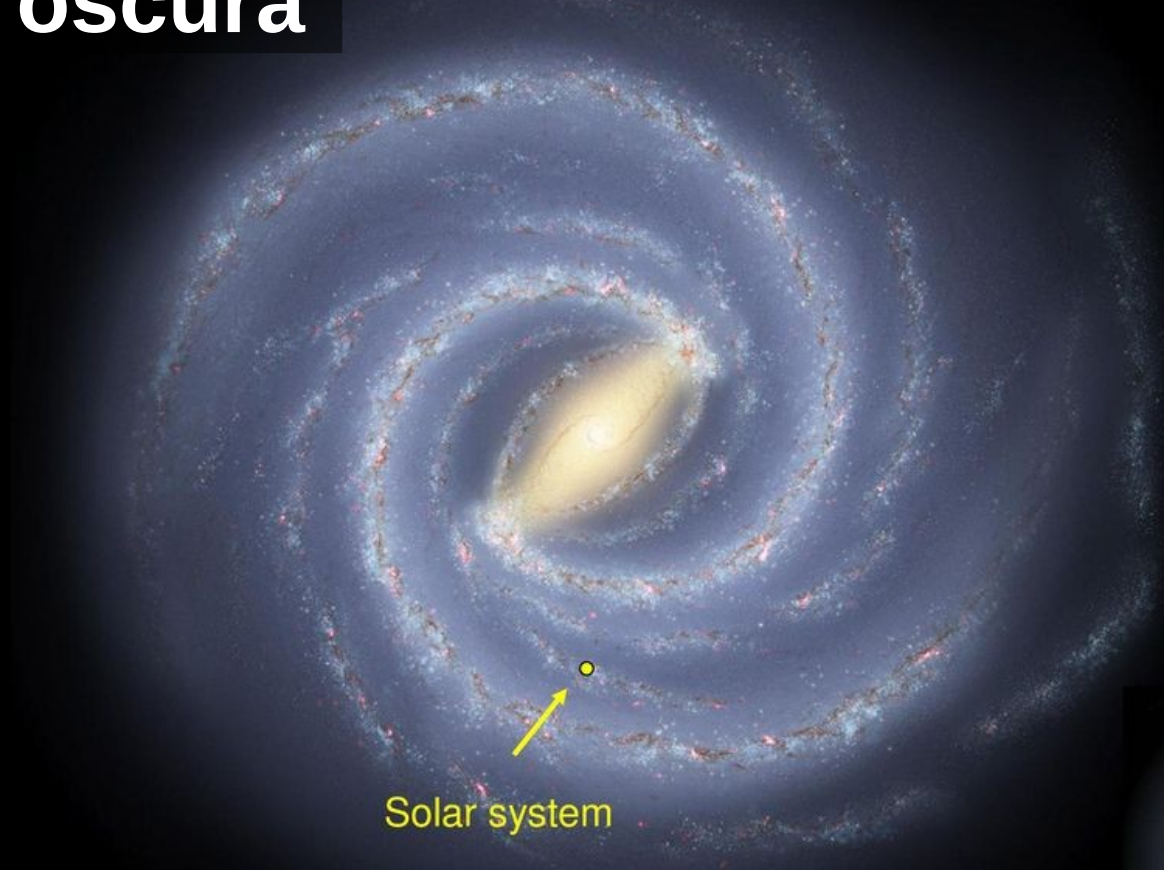


'30: Ian Ort, Fritz Zwicky

'60: Vera Rubin

← 100,000 light years →

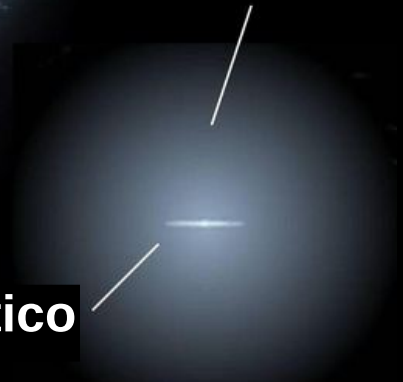
Materia oscura

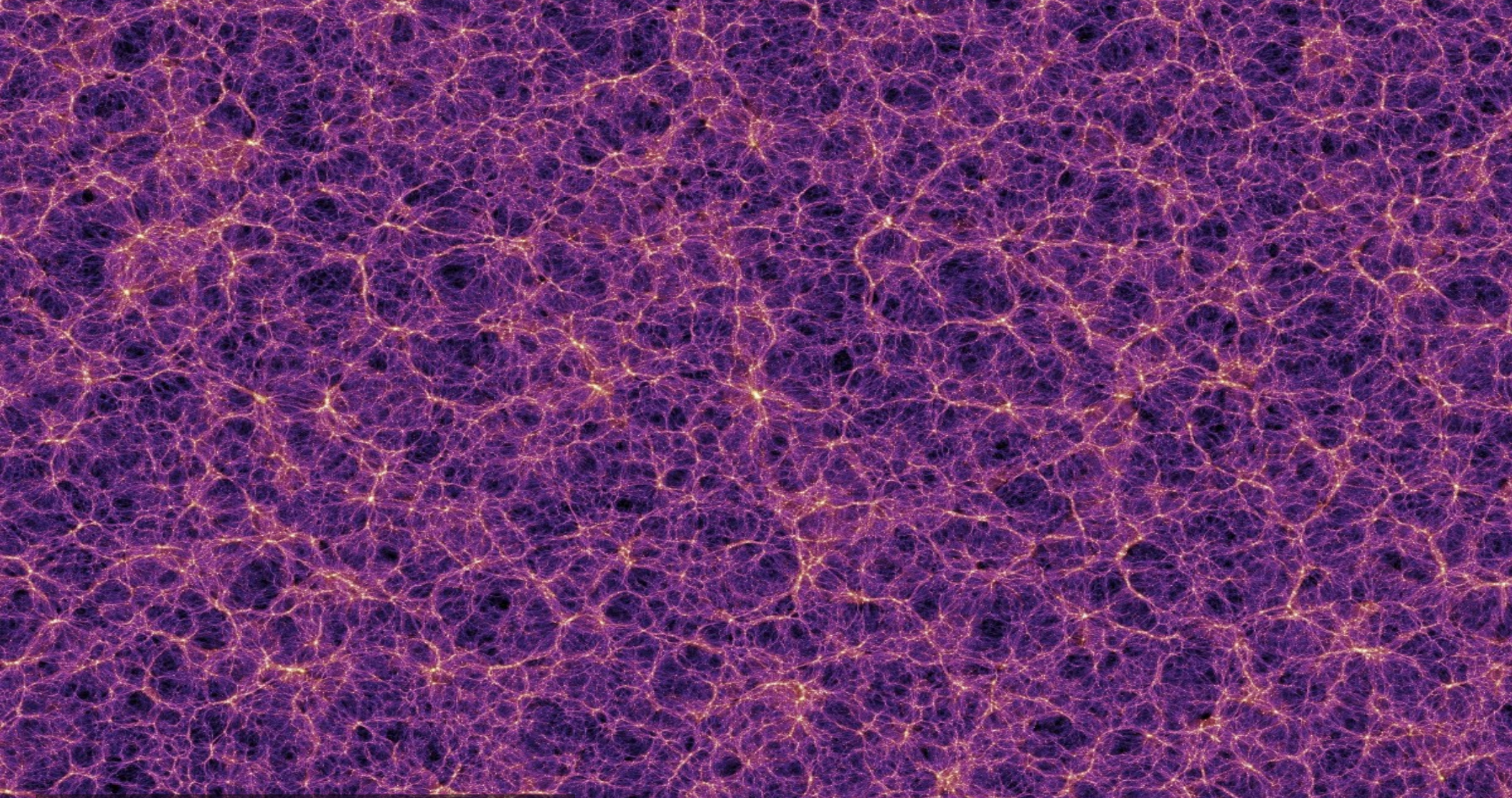


Solar system

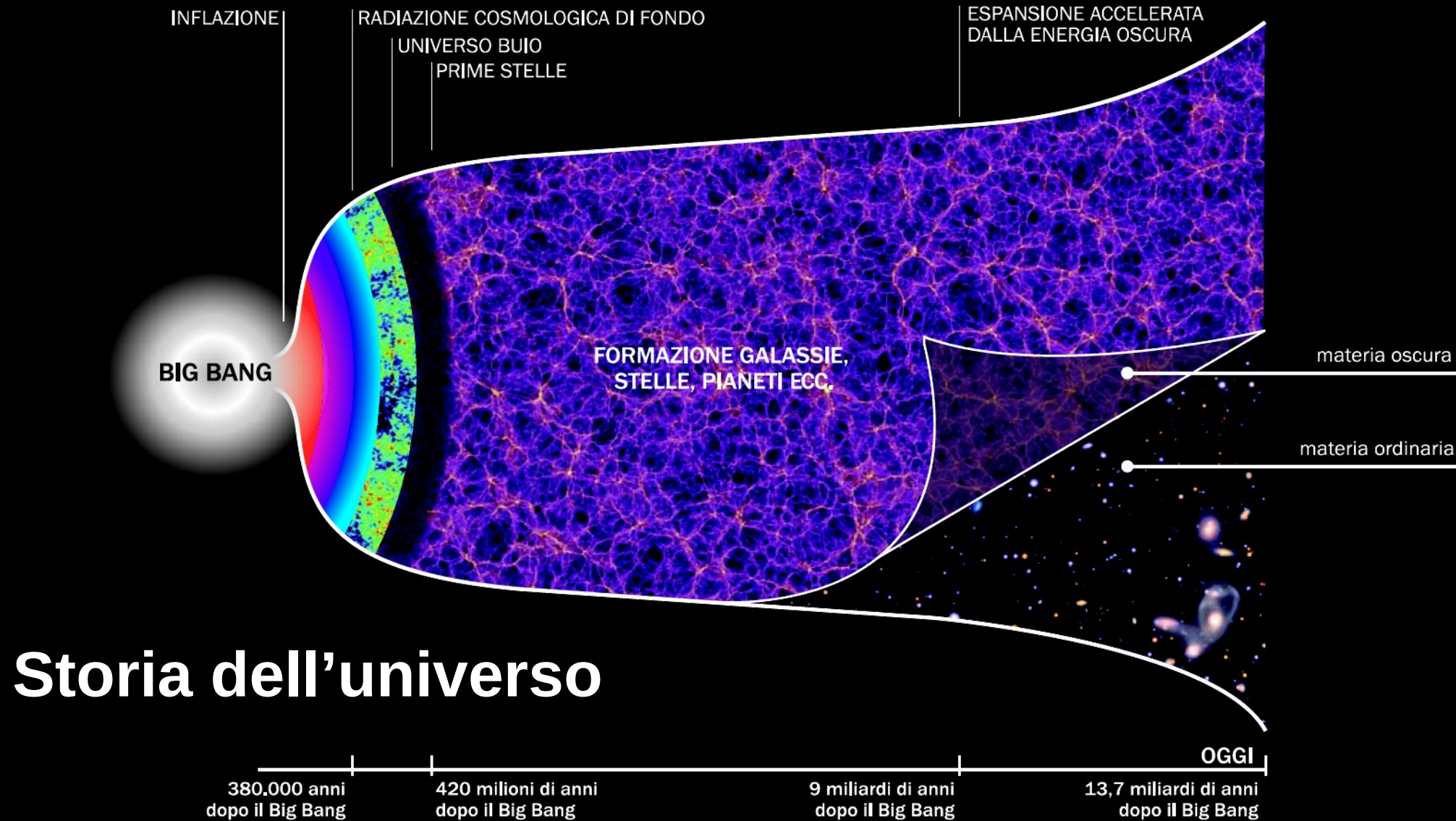
Materia oscura

Disco galattico



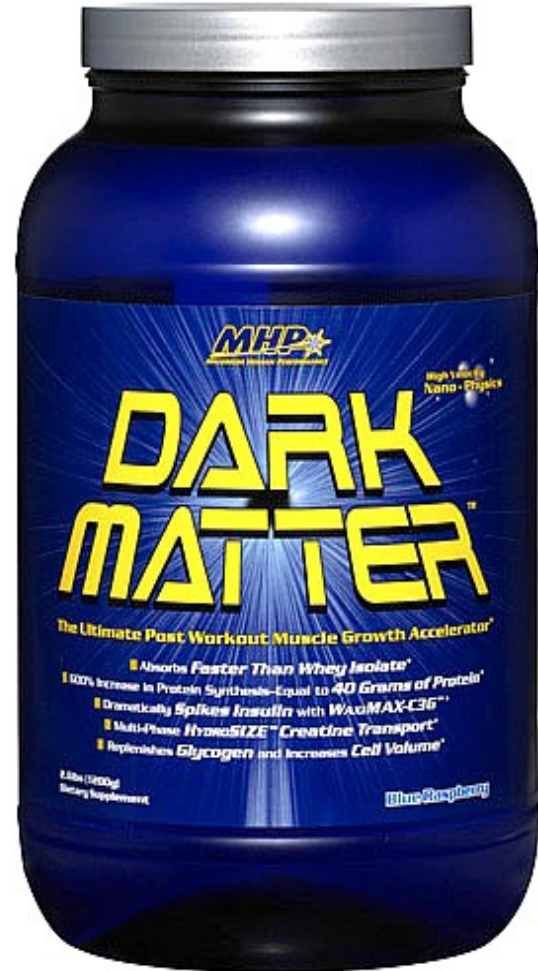


Millenium simulation © Max Plank

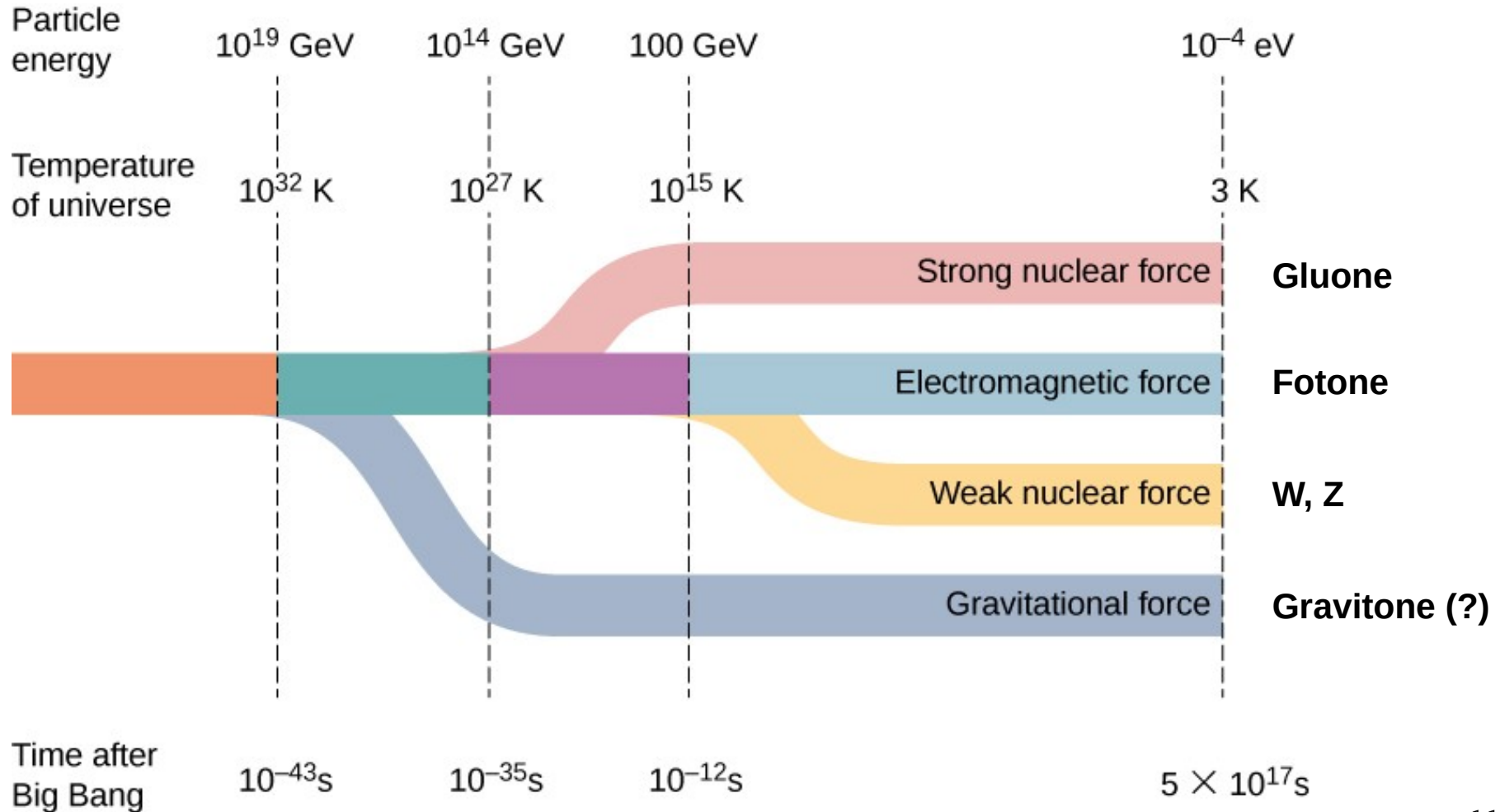


Materia oscura

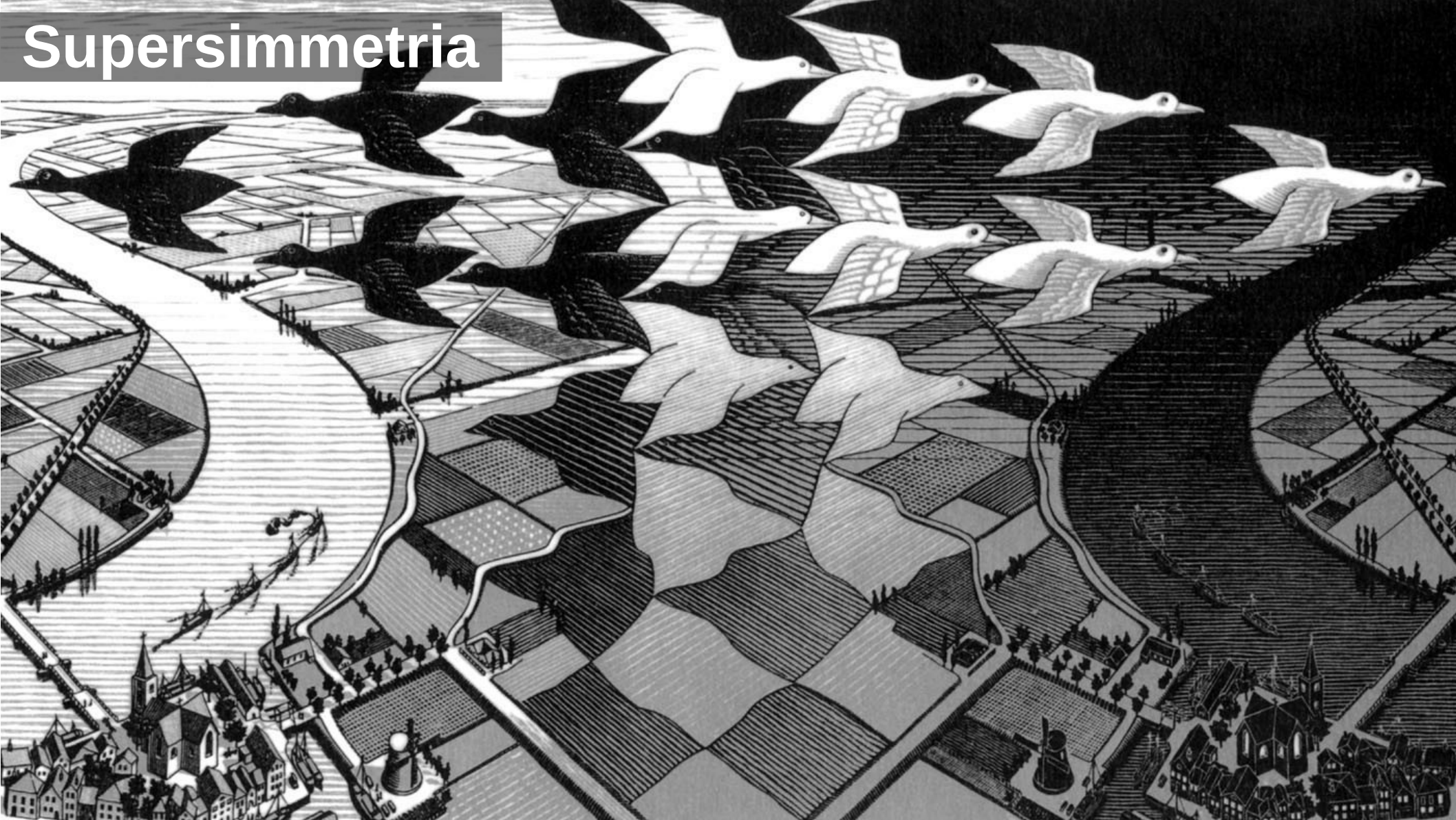
- **Permea** lo spazio
- Interagisce solo **gravitazionalmente**
- Seme per formazione **galassie**
- **Non compatibile** con il modello standard delle particelle elementari
 - Possibili spiegazioni nelle teorie di unificazione delle forze



Teorie di unificazione

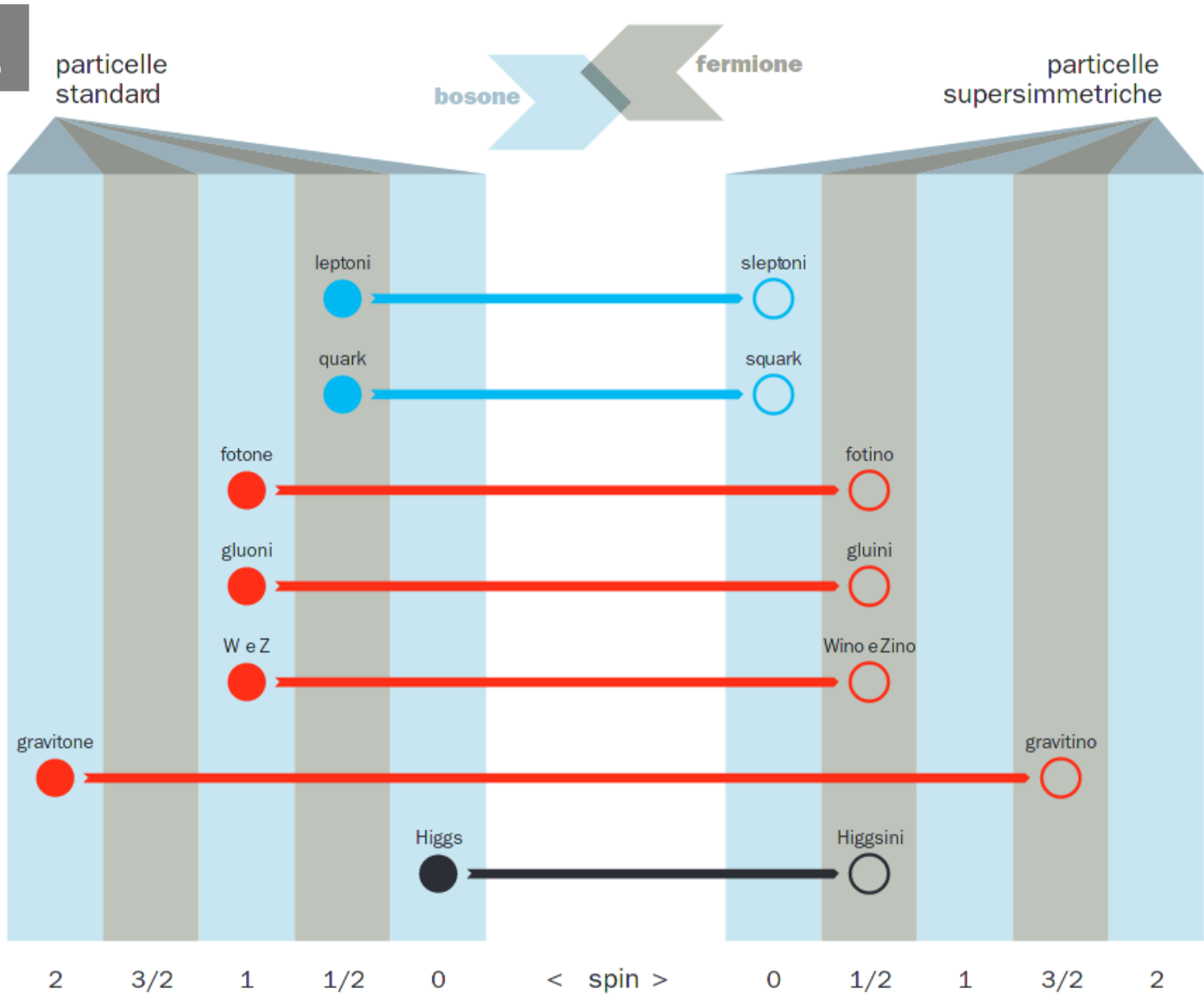


Supersimmetria



Supersimmetria

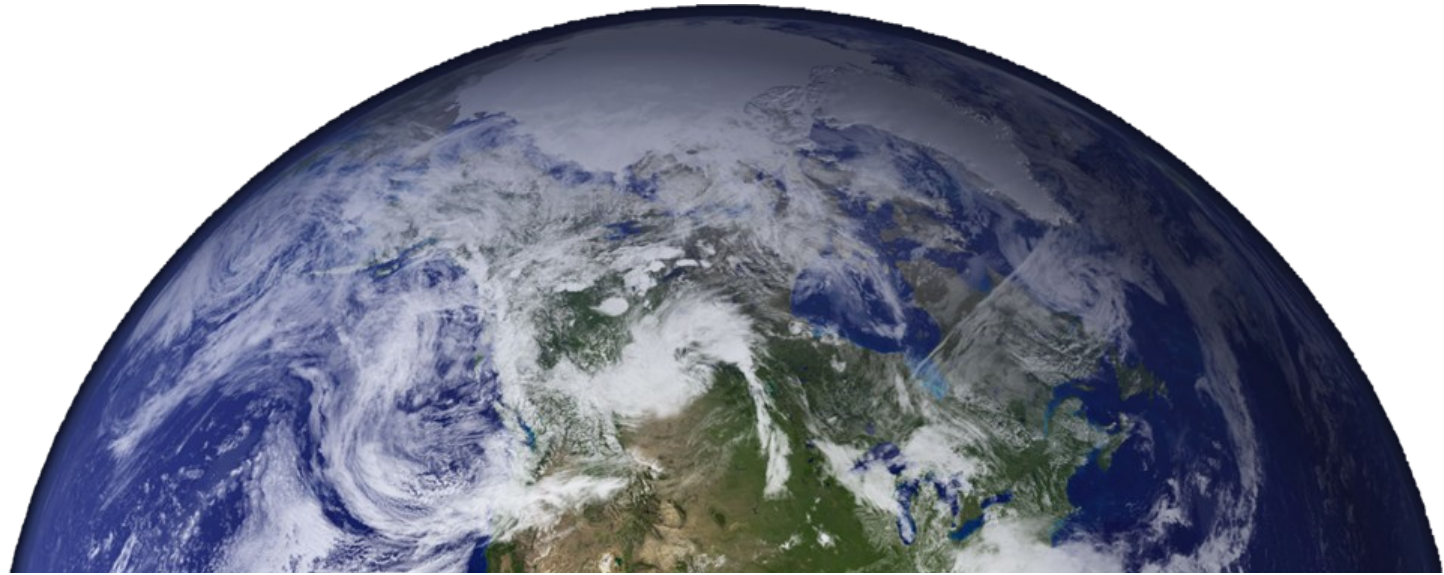
- materia
- mediatori
- massa



La gravità è ?



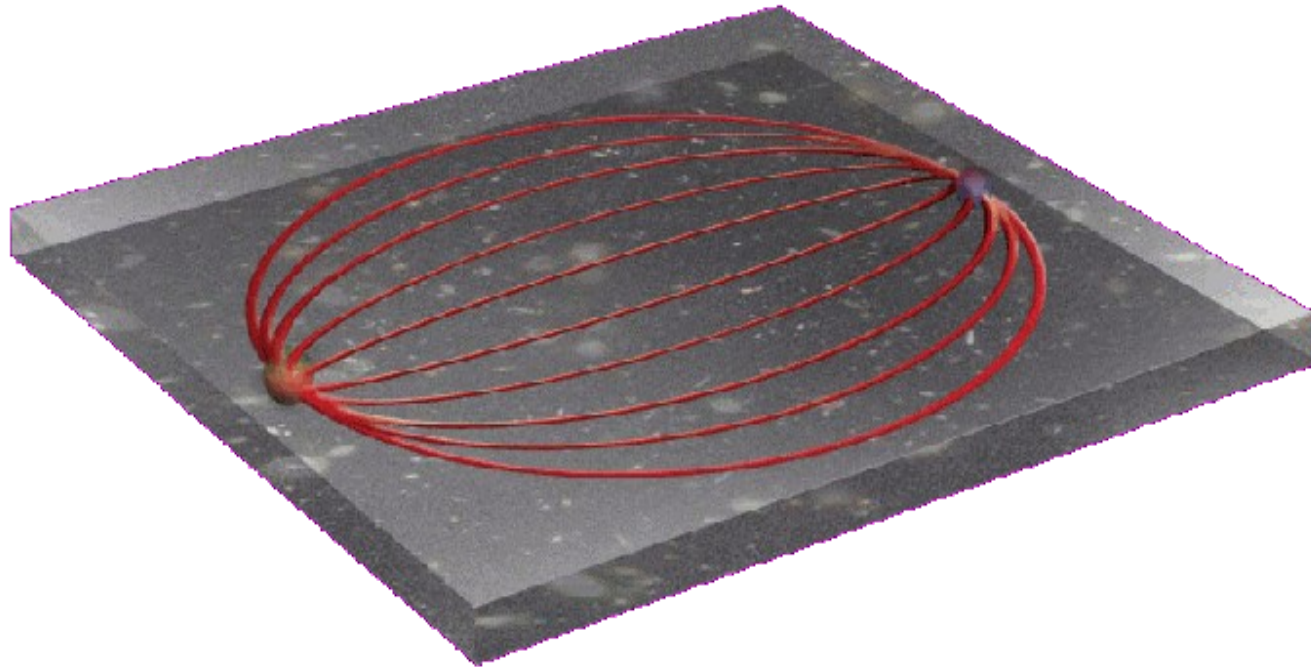
La gravità è **debole!**



Dimensioni aggiuntive?

Potrebbero spiegare debolezza forza gravitazionale

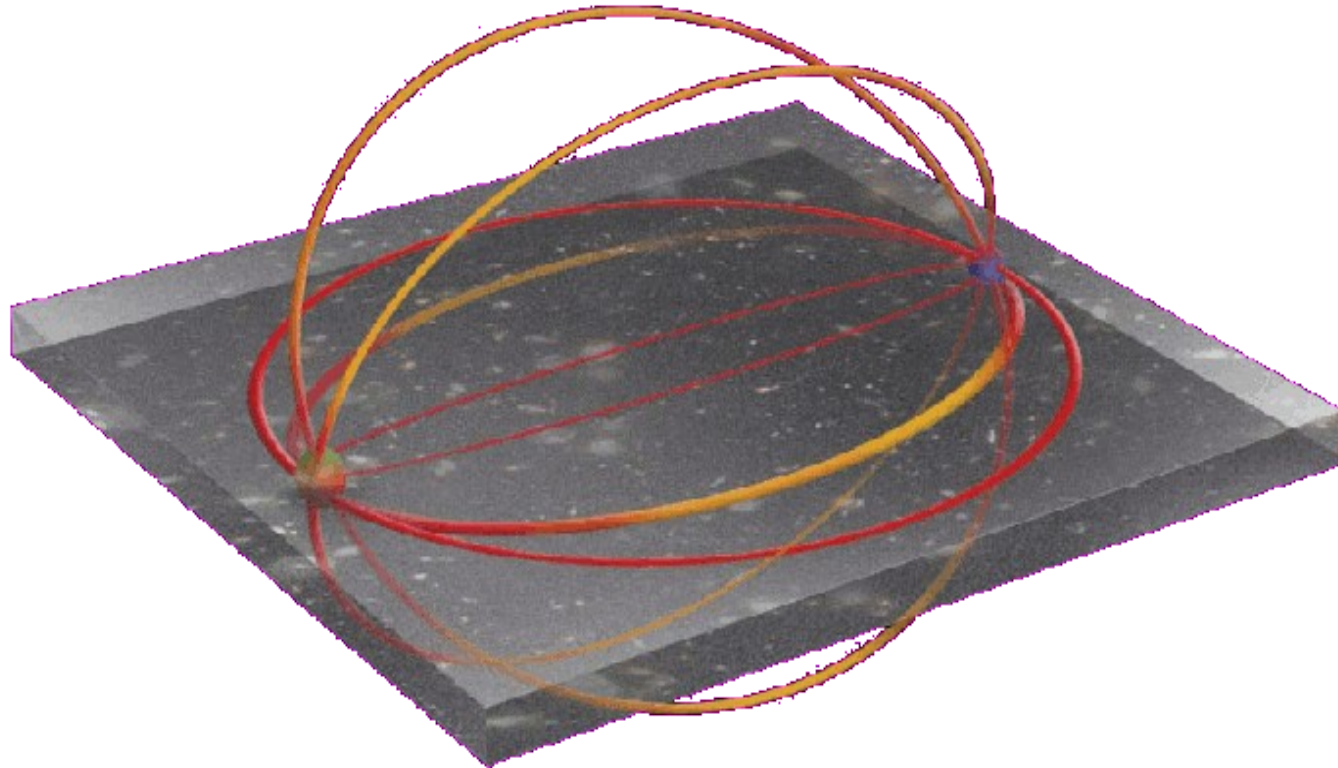
- Le altre forze sono **confinata** in 3D



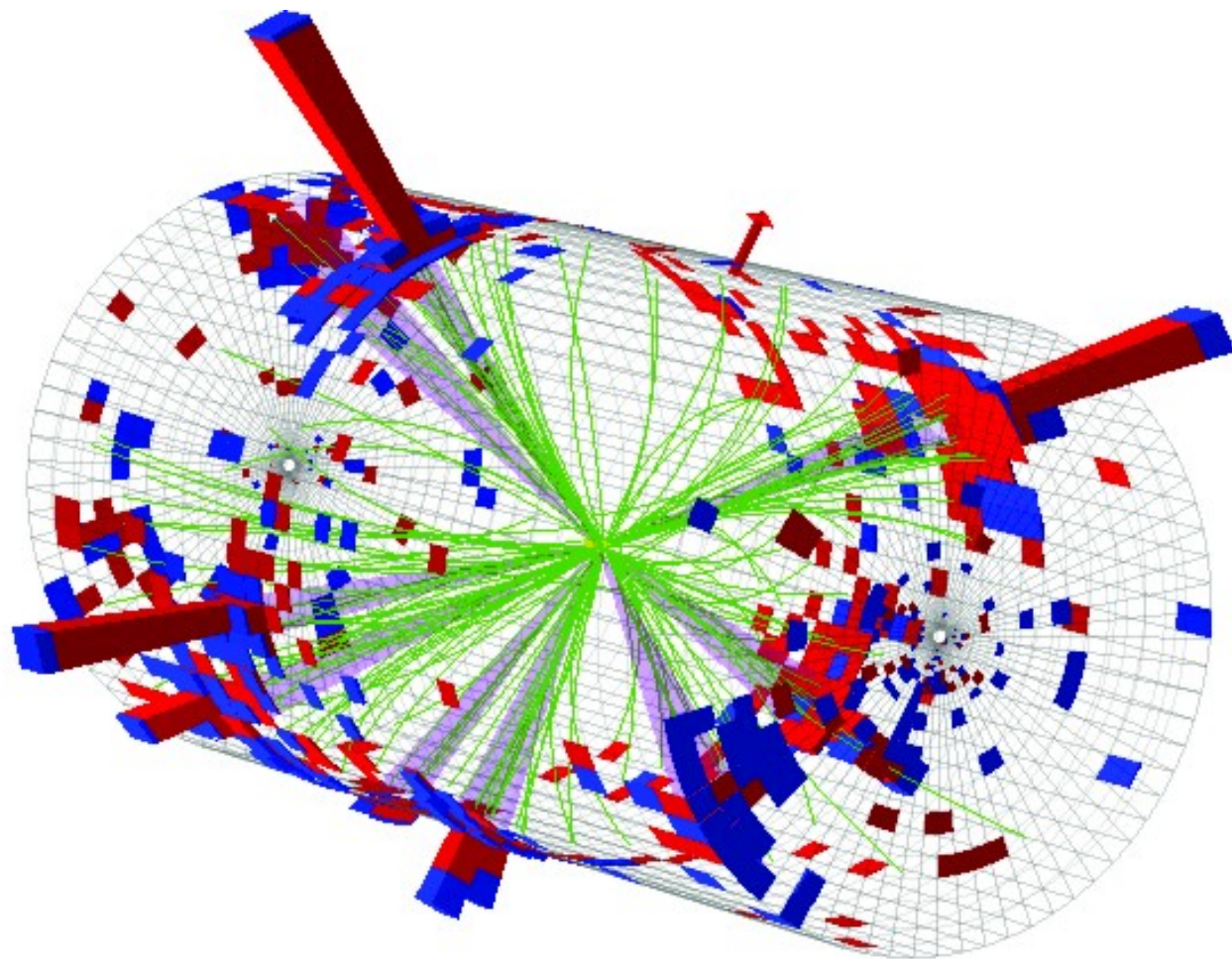
Dimensioni aggiuntive?

Potrebbero spiegare debolezza forza gravitazionale

- Le altre forze sono **confinata** in 3D
- La gravità si **distribuisce** invece in tutte le dimensioni



Micro buchi neri



A close-up photograph of a document. A green pushpin is pinned to a line graph. The graph consists of a black line with several circular nodes. The background of the document features large, stylized numbers in a cursive font, including '2020', '2030', and '2040'. A silver pushpin is also visible in the upper right corner, slightly out of focus. In the bottom left corner, there is a dark grey rectangular box containing white text.

LHC fino a **2038**

Futuri acceleratori



SWITZERLAND

FRANCE

FCC



100 km Circumference



Al lavoro



UNIVERSITÀ
DI PAVIA



Al lavoro



Al lavoro



Al lavoro



Al lavoro



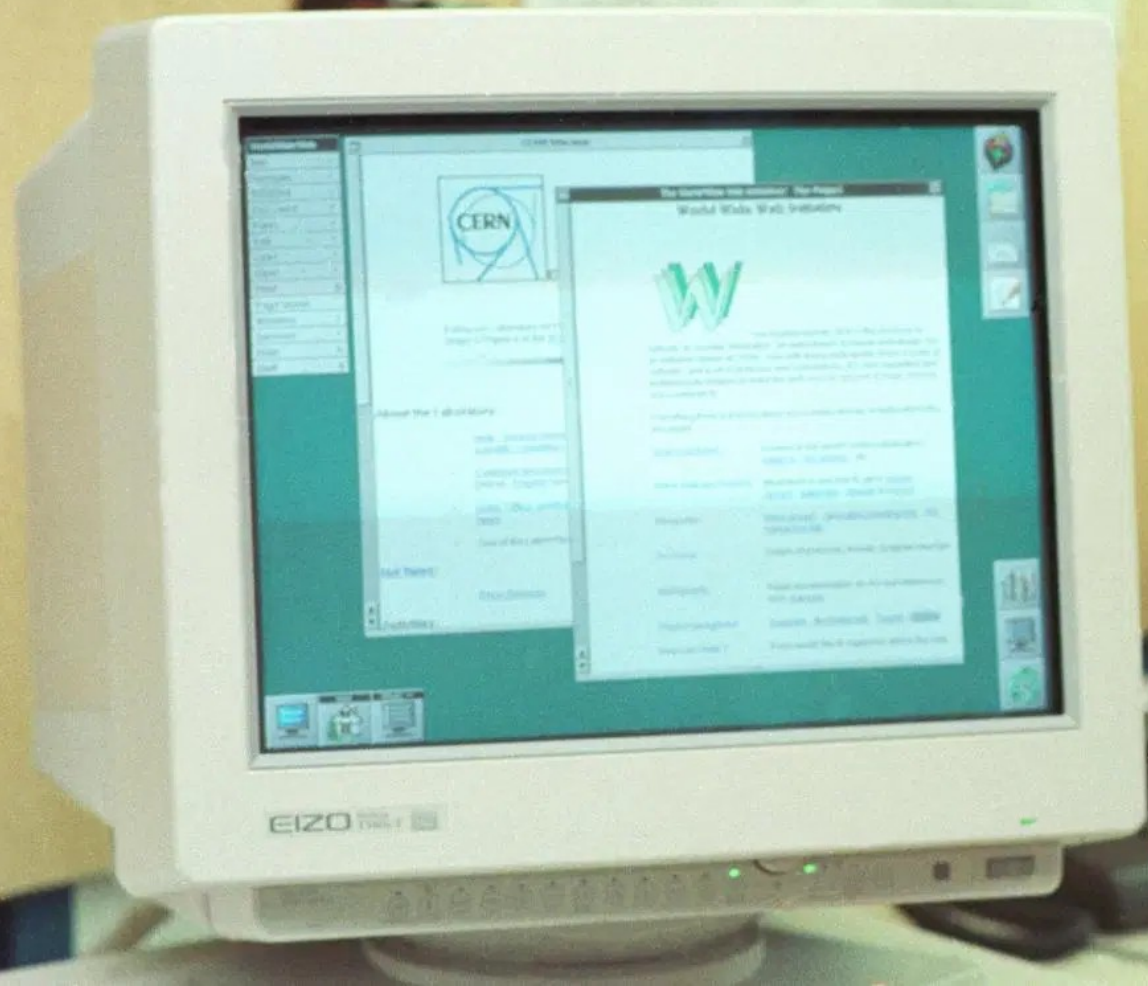
Ricadute sulla società



Disegnare il futuro



WWW



WWW

Vague but exciting ...

Tim Berners-Lee, CERN/DD

March 1989

Information Management: A Proposal

Abstract



Centro Nazionale Adroterapia Oncologica





Ricerca di base

Non un frutto pronto

A low-angle shot of a massive, ancient tree trunk covered in vibrant green moss. The tree's thick, gnarled branches spread out across the top of the frame, creating a dense canopy of bright green leaves. Sunlight filters through the foliage, creating a soft, ethereal glow and long, vertical rays of light that illuminate the forest floor. In the background, numerous slender tree trunks rise vertically, creating a sense of depth and a lush, verdant atmosphere. The overall scene is one of natural beauty and tranquility.

Ricerca di base

Ma un **seme** che produrrà un
albero con frutti inimmaginabili

Backup

Nessuna gerarchia

- La maggior parte del lavoro svolto dai **giovani**



MEMBER STATES**7889**

Austria	117
Belgium	120
Bulgaria	96
Czech Republic	244
Denmark	67
Finland	111
France	868
Germany	1342
Greece	237
Hungary	76
Israel	65
Italy	2045
Netherlands	168
Norway	67
Poland	350
Portugal	127
Romania	134
Slovakia	124
Spain	447
Sweden	85
Switzerland	228
United Kingdom	771

OBSERVERS 2718

Japan	314
Russia	1187
USA	1217

Budget: ~1.2 GCHF
Italia: 11.2%
Pro capite: 2 CHF/anno

**ASSOCIATE MEMBERS**

India	357	745
Lithuania	35	
Pakistan	65	
Turkey	173	
Ukraine	115	

ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP 118

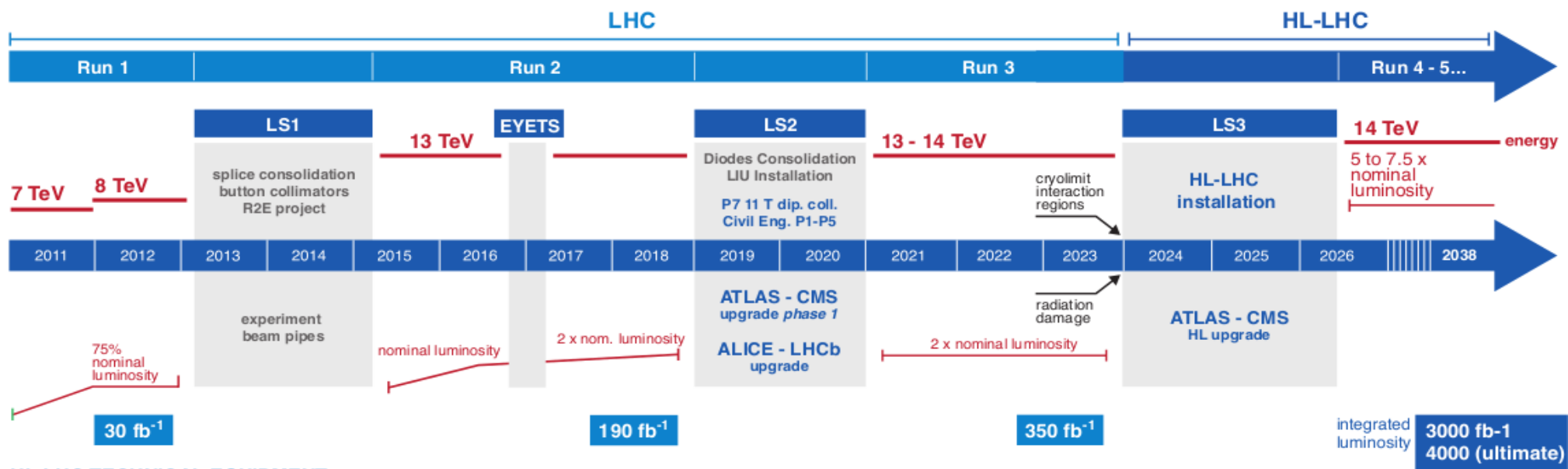
Cyprus	26
Serbia	57
Slovenia	35

OTHERS 1872

Afghanistan	1	Bolivia	4	Egypt	31	Kazakhstan	5	Mongolia	2	Philippines	3	Thailand	22
Albania	3	Bosnia & Herzegovina	2	El Salvador	1	Kenya	3	Montenegro	11	Saint Kitts and Nevis	1	T.F.Y.R.O.M.	2
Algeria	14	Brazil	135	Estonia	15	Korea Rep.	185	Morocco	20	Saudi Arabia	2	Tunisia	5
Argentina	27	Burundi	1	Georgia	46	Kyrgyzstan	1	Myanmar	1	Senegal	1	Uruguay	1
Armenia	19	Cameroon	1	Ghana	1	Latvia	2	Nepal	10	Singapore	4	Uzbekistan	4
Australia	31	Canada	161	Hong Kong	1	Lebanon	23	New Zealand	5	Singapore	4	Venezuela	10
Azerbaijan	10	Chile	20	Iceland	3	Luxembourg	2	Nigeria	3	South Africa	56	Viet Nam	13
Bangladesh	11	China	510	Indonesia	11	Madagascar	4	North Korea	1	Sri Lanka	6	Zambia	1
Belarus	48	Colombia	45	Iran	51	Malaysia	15	Oman	3	Sudan	1	Zimbabwe	2
Benin	1	Croatia	41	Iraq	1	Malta	9	Palestine (O.T.)	7	Swaziland	1		
		Cuba	12	Ireland	16	Mauritius	1	Paraguay	2	Syria	1		
		Ecuador	6	Jordan	1	Mexico	82	Peru	7	Taiwan	51		

LHC: 2010 → 2038

LHC / HL-LHC Plan



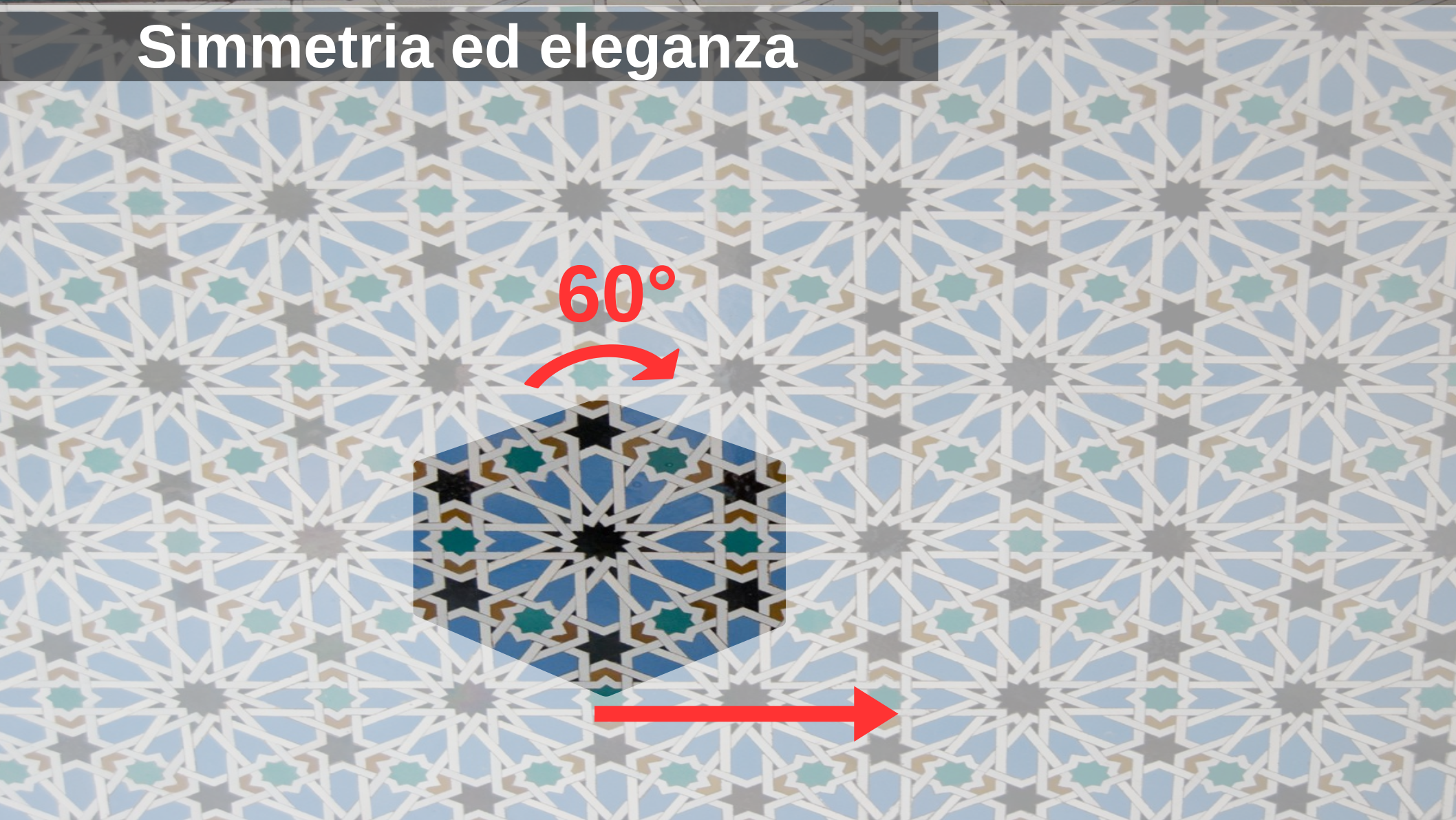
Alhambra, Granada



Simmetria ed eleganza

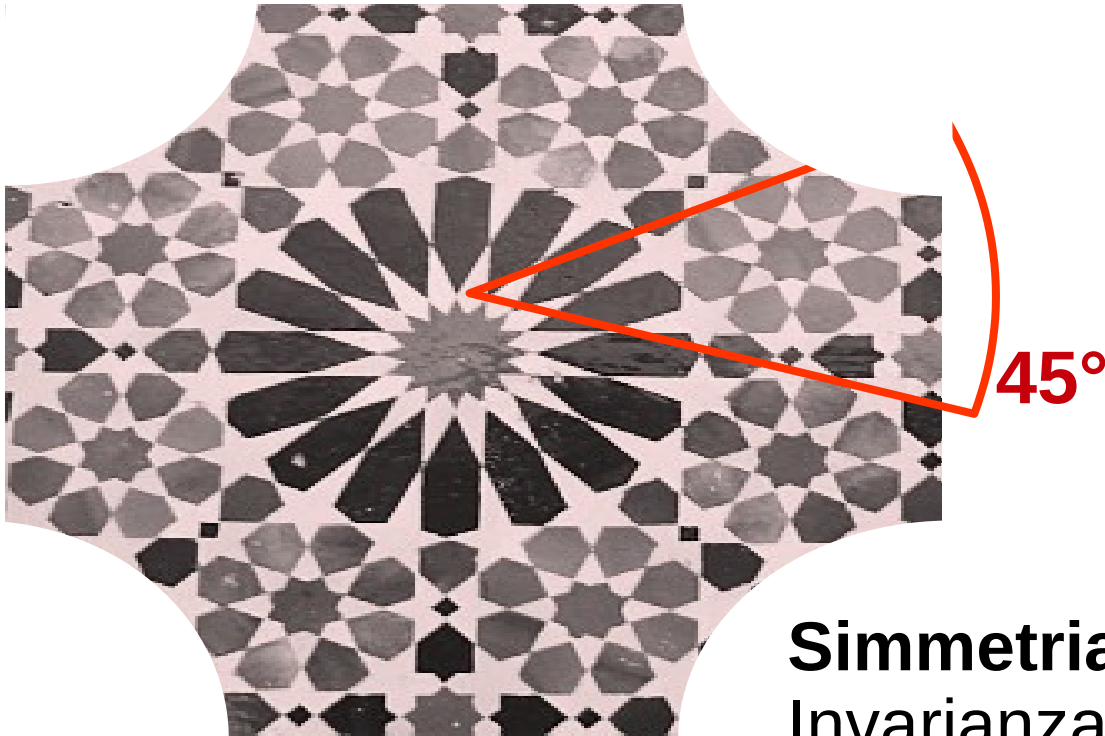


Simmetria ed eleganza



Rottura spontanea di simmetria

- Forse in natura la simmetria non è **perfetta**

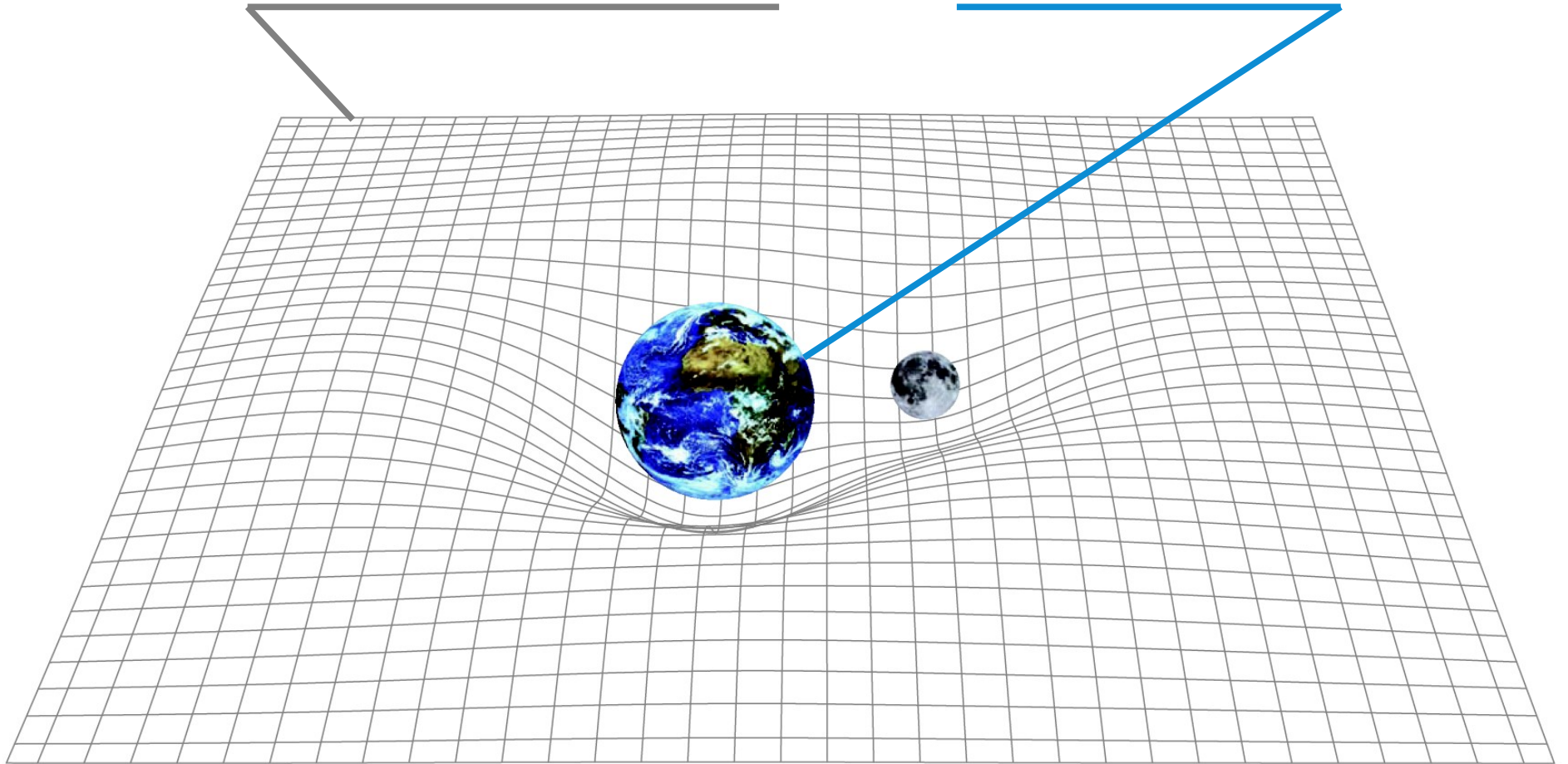


Simmetria 45° “perfetta”
Invarianza per rotazioni di 45°

Relatività generale

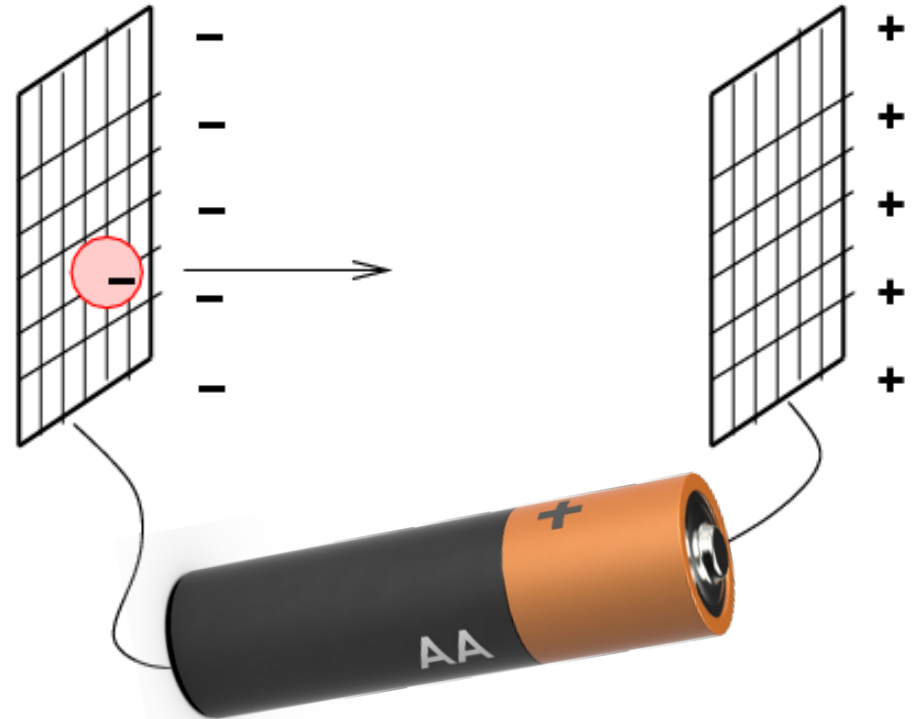


$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 8\pi G T_{\mu\nu}$$



Electronvolt (eV)

- Unità di misura di energia e massa
 - Energia cinetica di un **e** in un campo di un **Volt**
- Multipli
 - **MeV** = 10^6 eV
 - **GeV** = 10^9 eV
 - **TeV** = 10^{12} eV
- Protone = 1 GeV
 - $E=mc^2$



Cognome **Bosone**

Nome **Higgs**

nato il $\sim 10^{-30}$ s dopo il BigBang

(atto n..... P..... S.....)

a **Ovunque** (.....)

Cittadinanza **Nostro universo**

Residenza **Ovunque**

Via.....

Stato civile **Assai poligamo**

Professione **Spacciatore di massa**

CONNOTATI E CONTRASSEGNI SALIENTI

Statura **Da 100 a 1000 GeV**

Spin **0**

Parità **+1**

Segni particolari **Sfuggente**

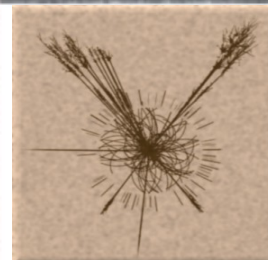
Accoppiamento con particelle

proporzionale alla loro massa



Firma del titolare **Decado in $\gamma\gamma$, WW ,
 ZZ , bb , cc , $\tau\tau$, ecc**

Impronta del dito
indice sinistro



IL SINDAGO

Peter Higgs



100 milioni di canali di elettronica

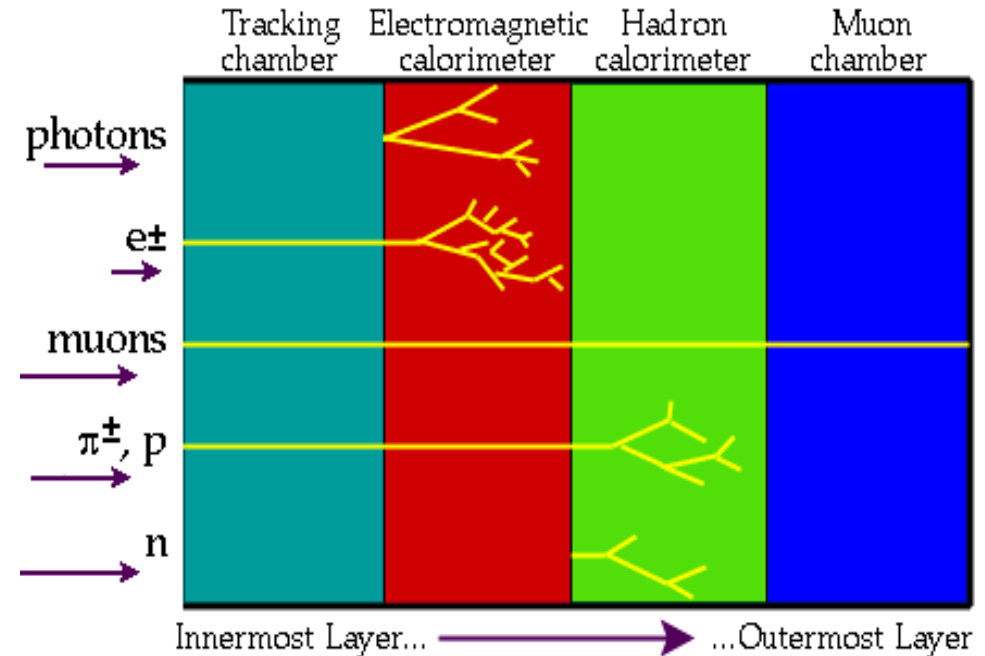
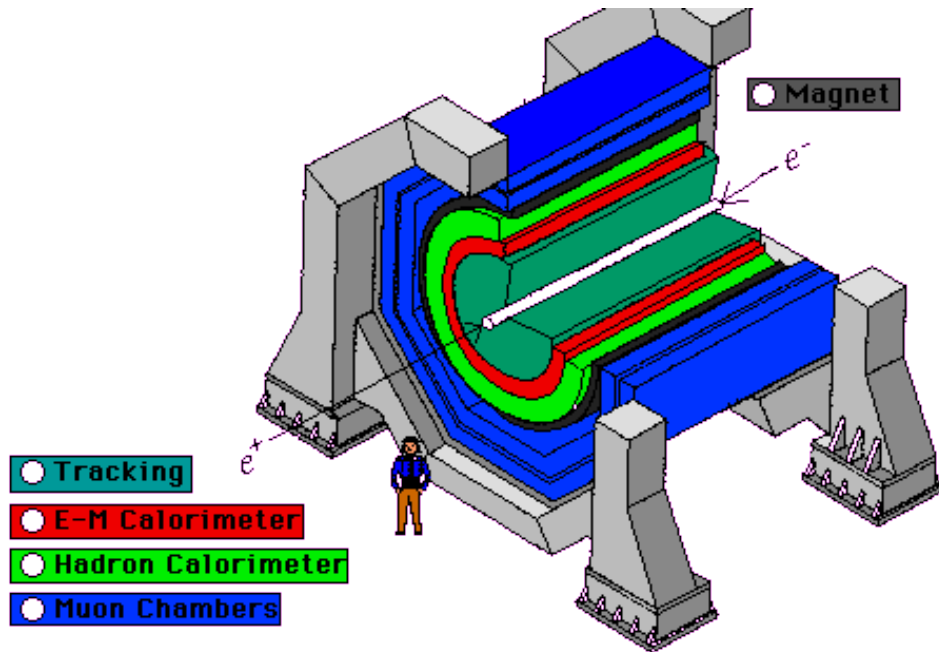


10^8 canali @40 MHz : ~60 TB/s

~500 milioni di film in
streaming (in contemporanea)

Rivelatori

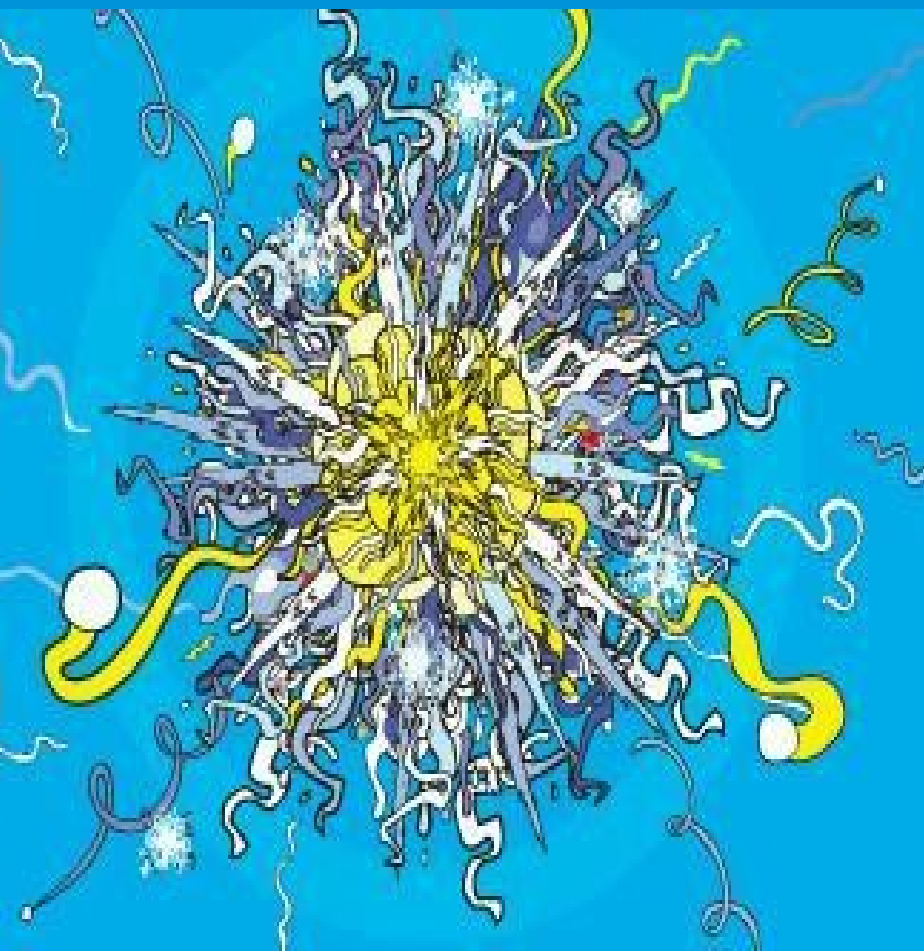
- Struttura a cipolla
 - Sotto-rivelatori basati su tecnologie diverse
 - +/- adatte a rivelare uno specifico tipo di particella



Dov'è finita l'antimateria?

Celebrating the world's largest physics experiment

BIG
BANG!



1 000 000 000

1 000 000 000

Materia Anti-Materia

100

Materia

100

Anti-Materia



1 000 000 000

1 000 000 000

Materia **Anti-Materia**

1 000 000 001

999 999 999

Materia Anti-Materia

101

99

Materia

Anti-Materia






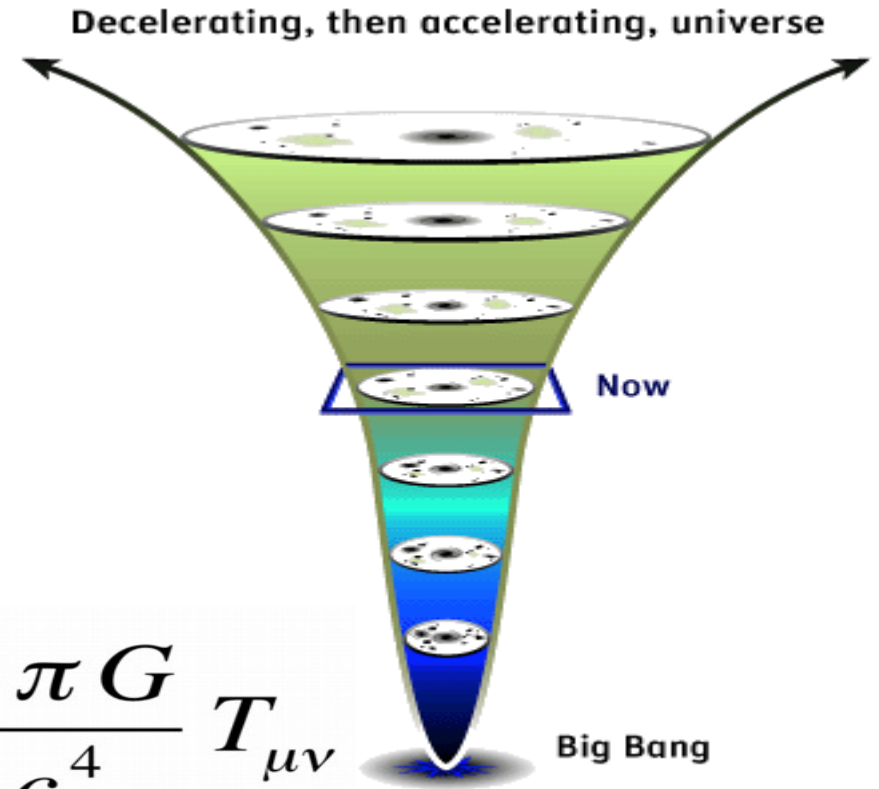


Il più grande “abbaglio” di Einstein

Costante cosmologica Λ

- Introdotta per compatibilità con universo statico
- **Permea** lo spazio generando una pressione negativa che **estende la trama** dello spazio tempo

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$




Quanto ne sappiamo di Λ ?

Teoria



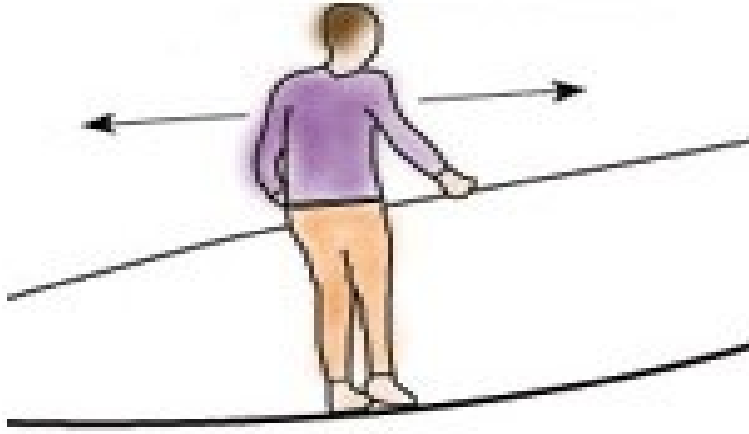
$$\Lambda \approx 1$$

Esperimento

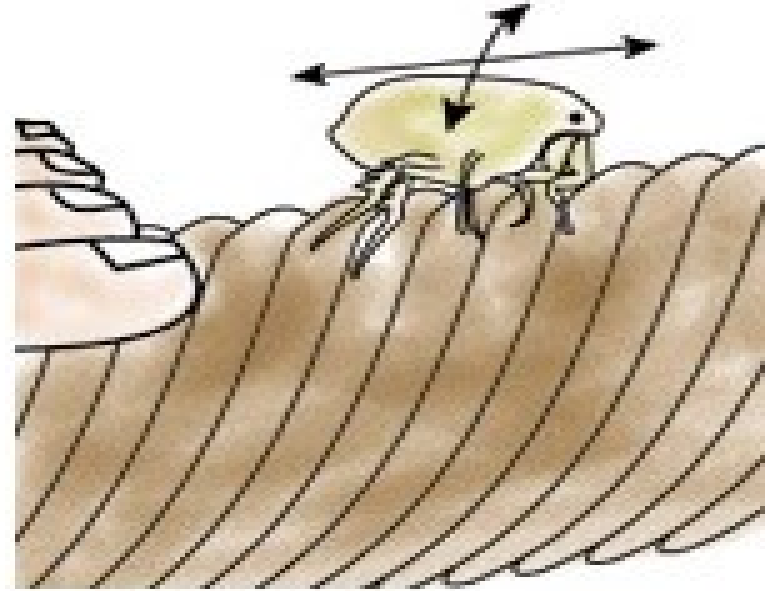


$$\Lambda =$$

- Dove sono queste dimensioni aggiuzionali?
 - Sono **avvolte** su loro stesse e noi non possiamo avvertirle



An acrobat can only move in one dimension along a rope..



...but a flea can move in two dimensions.