Rivelatori di particelle

Nello Bruscino

INFN Roma

Istituto Nazionale di Fisica Nucleare

Ricapitolando…

[The Higgs Boson Simplified Through Animation (on Youtube)]

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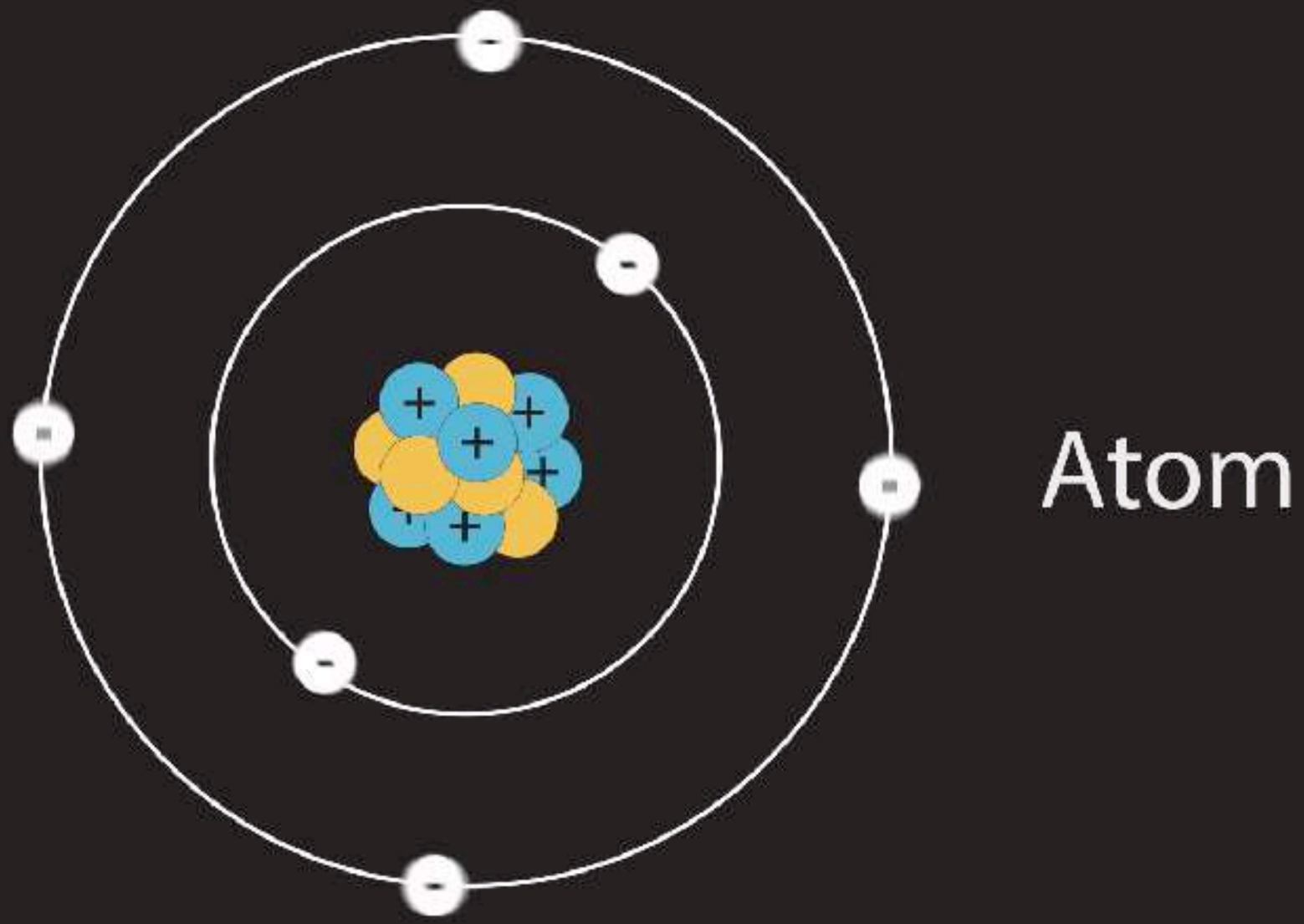

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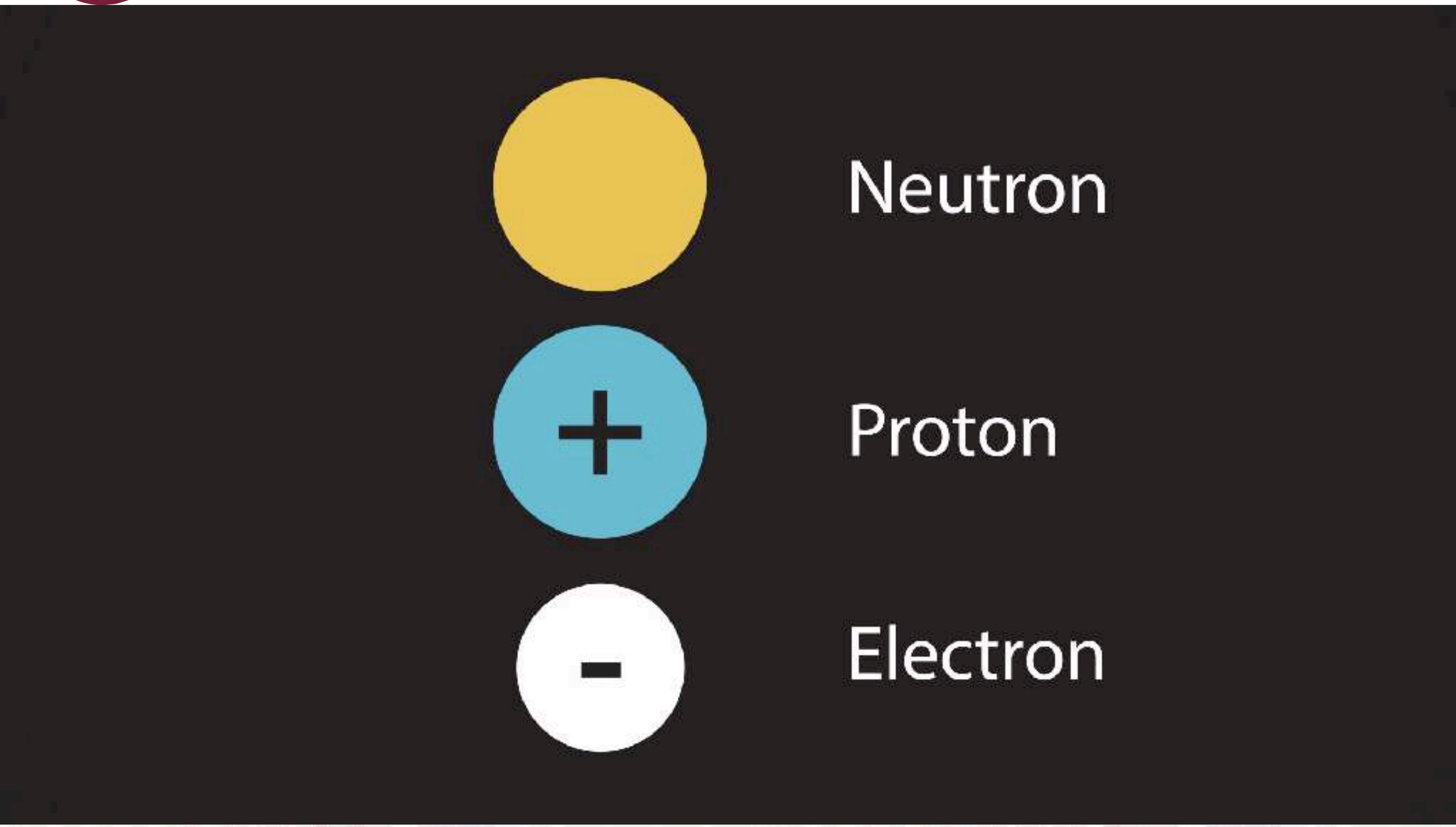

Ricapitolando…

[The Higgs Boson Simplified Through Animation (on Youtube)]

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Quarks

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Ricapitolando…

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Ricapitolando…

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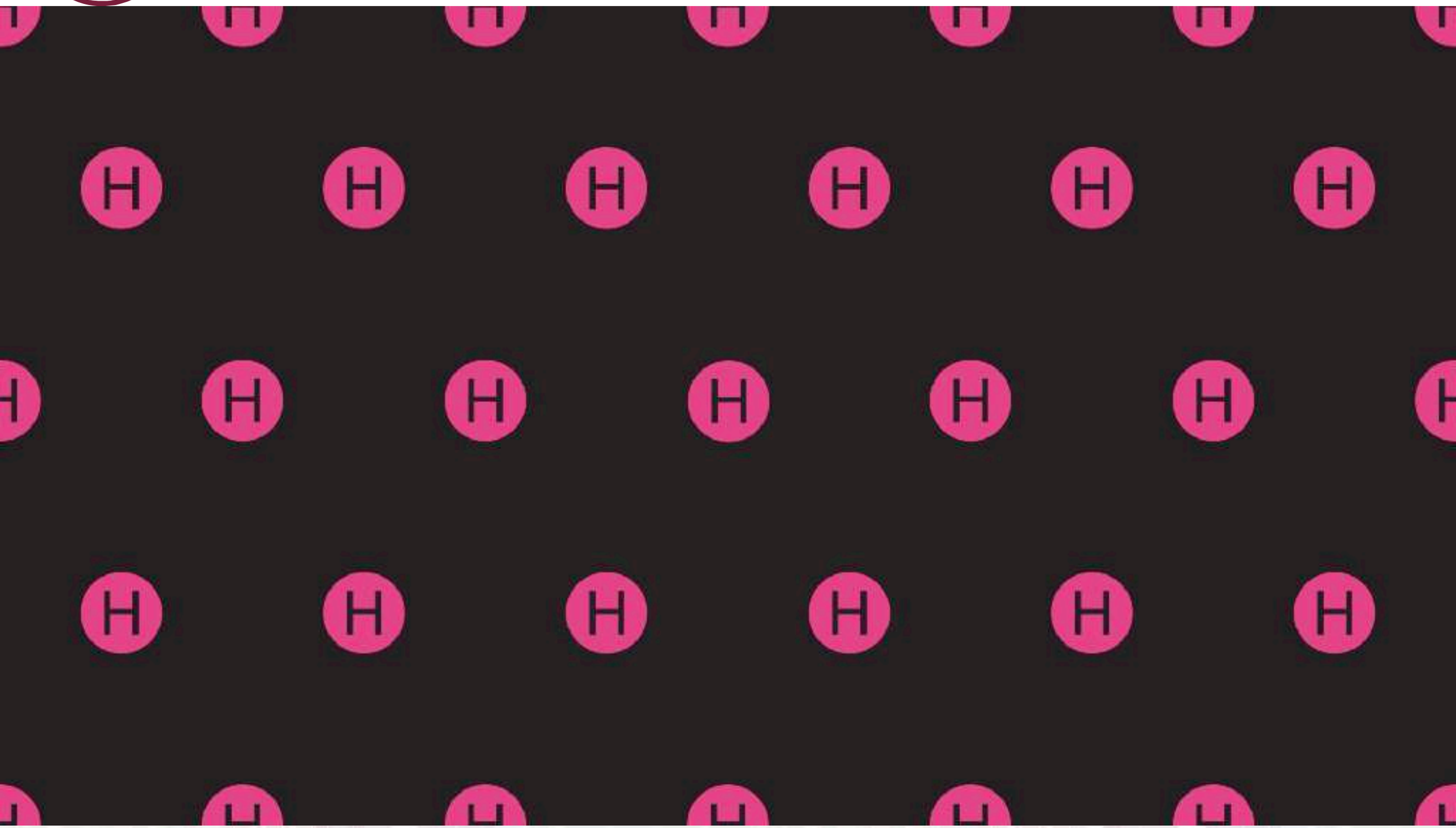

Ricapitolando…

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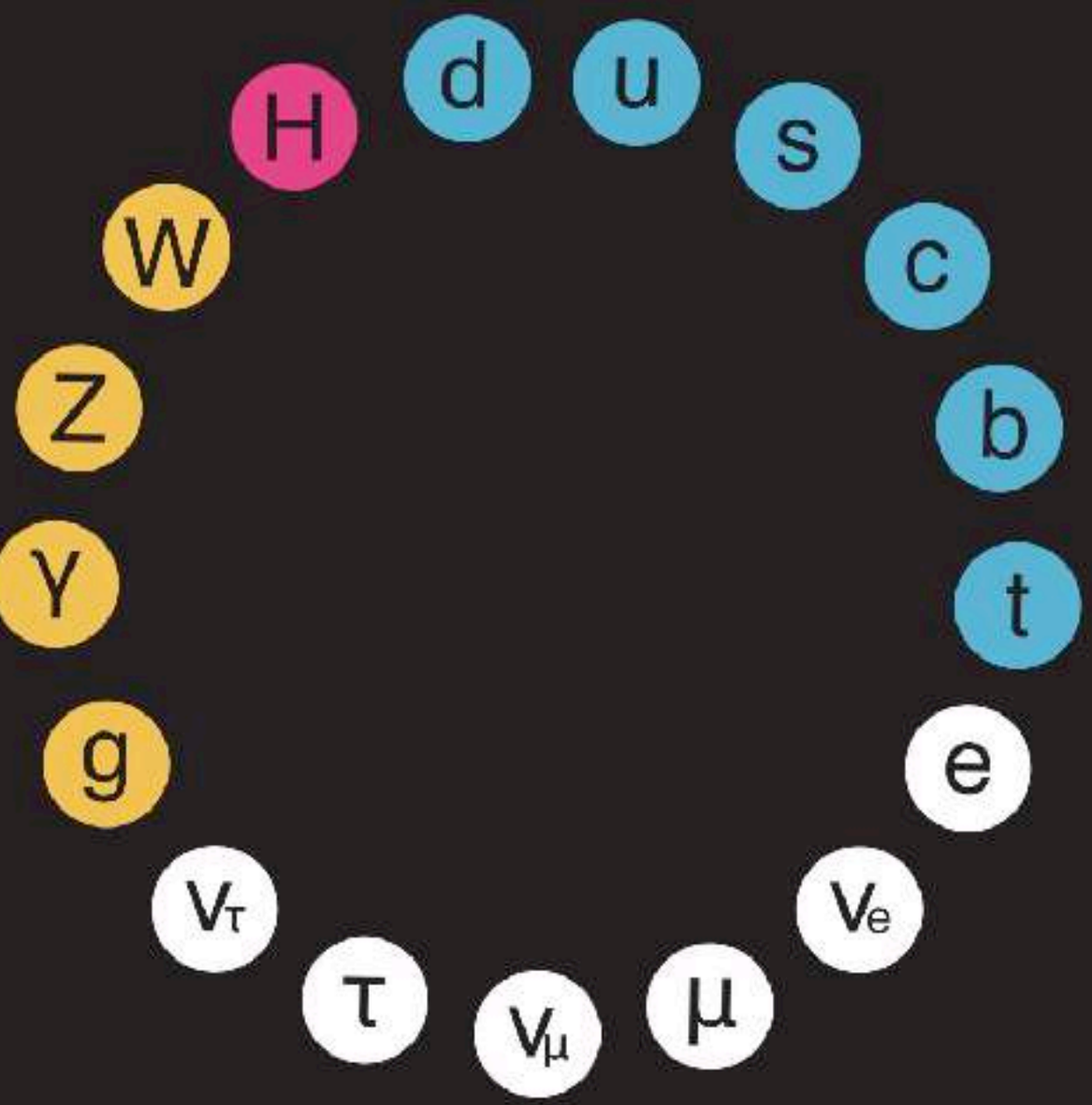

Large
Hadron
Collider

Ricapitolando…

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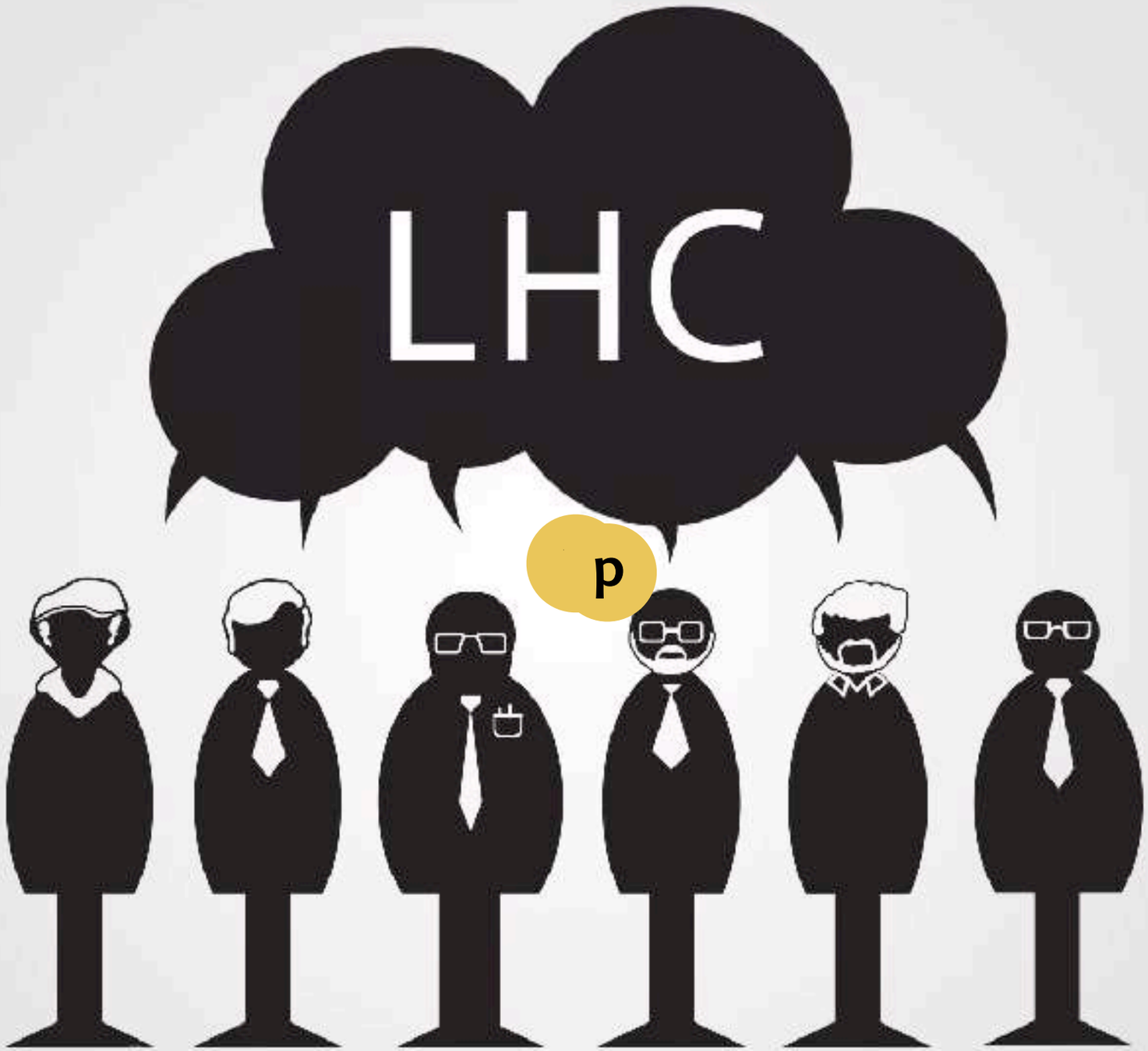
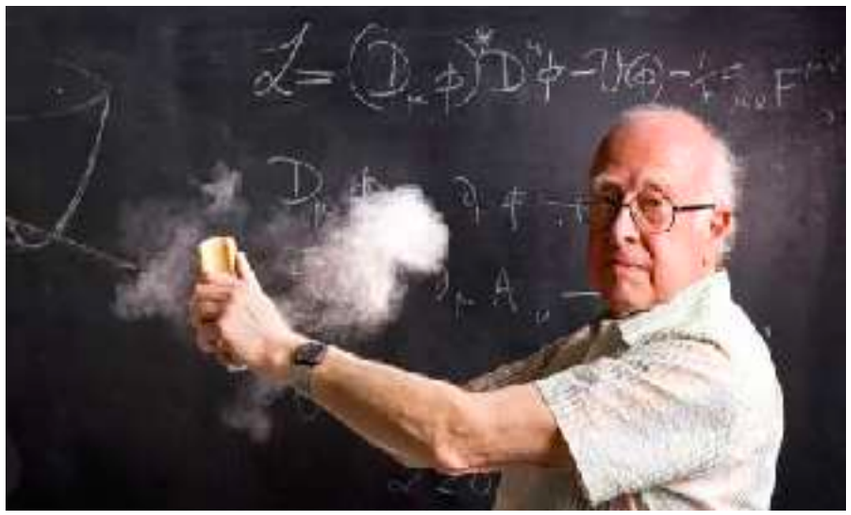


Ricapitolando…

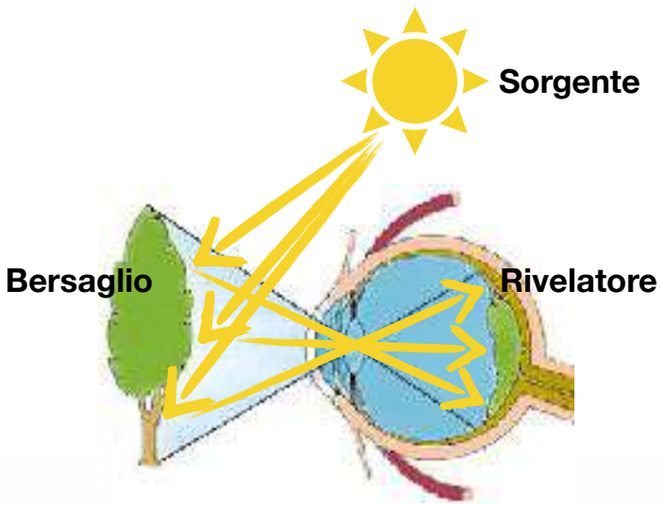
Domanda #1

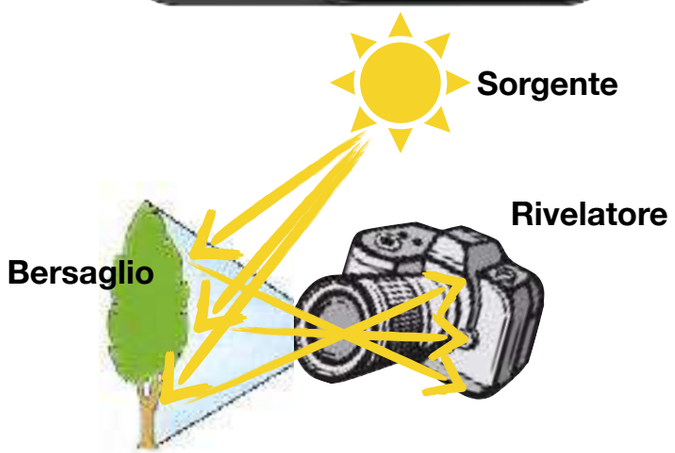
Come si osserva l’∞-mente piccolo?

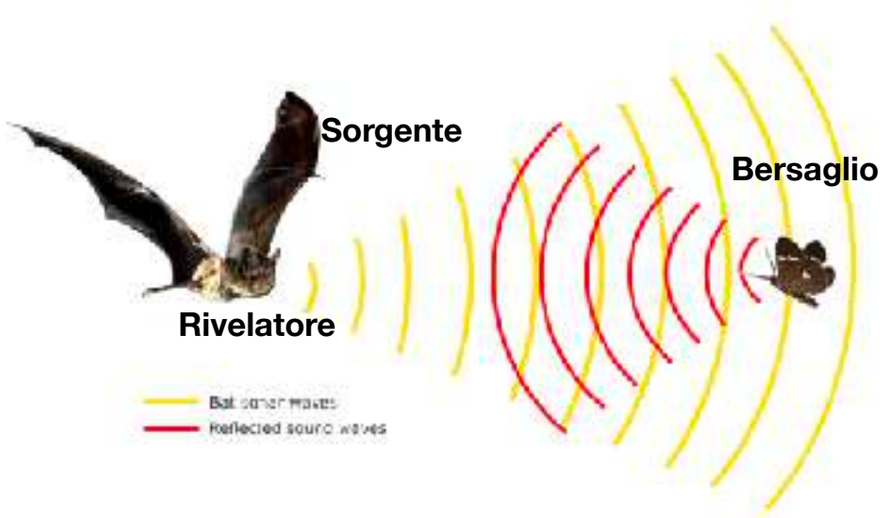


- A. Ad occhio nudo, se si ha una buona vista (12 decimi)
- B. Con un microscopio molto potente
- C. Con un rivelatore di particelle
- D. È Impossibile osservare particelle così piccole con le tecnologie attuali

Rivelatori ovunque





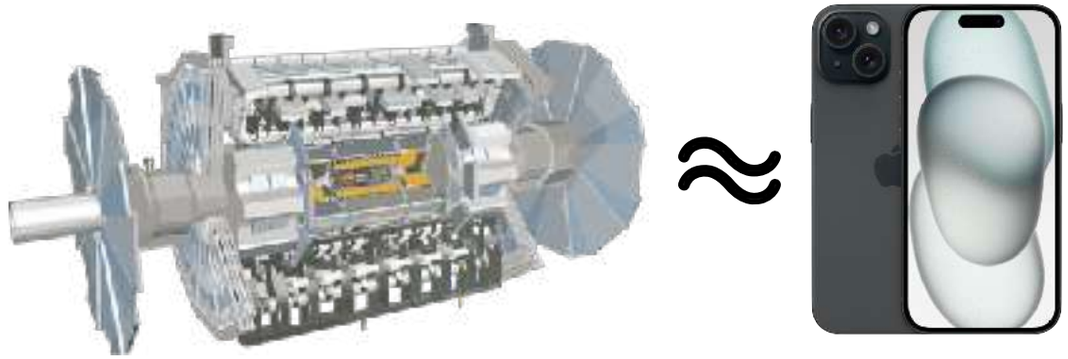


Rivelatore di fotoni

Rivelatore di fotoni

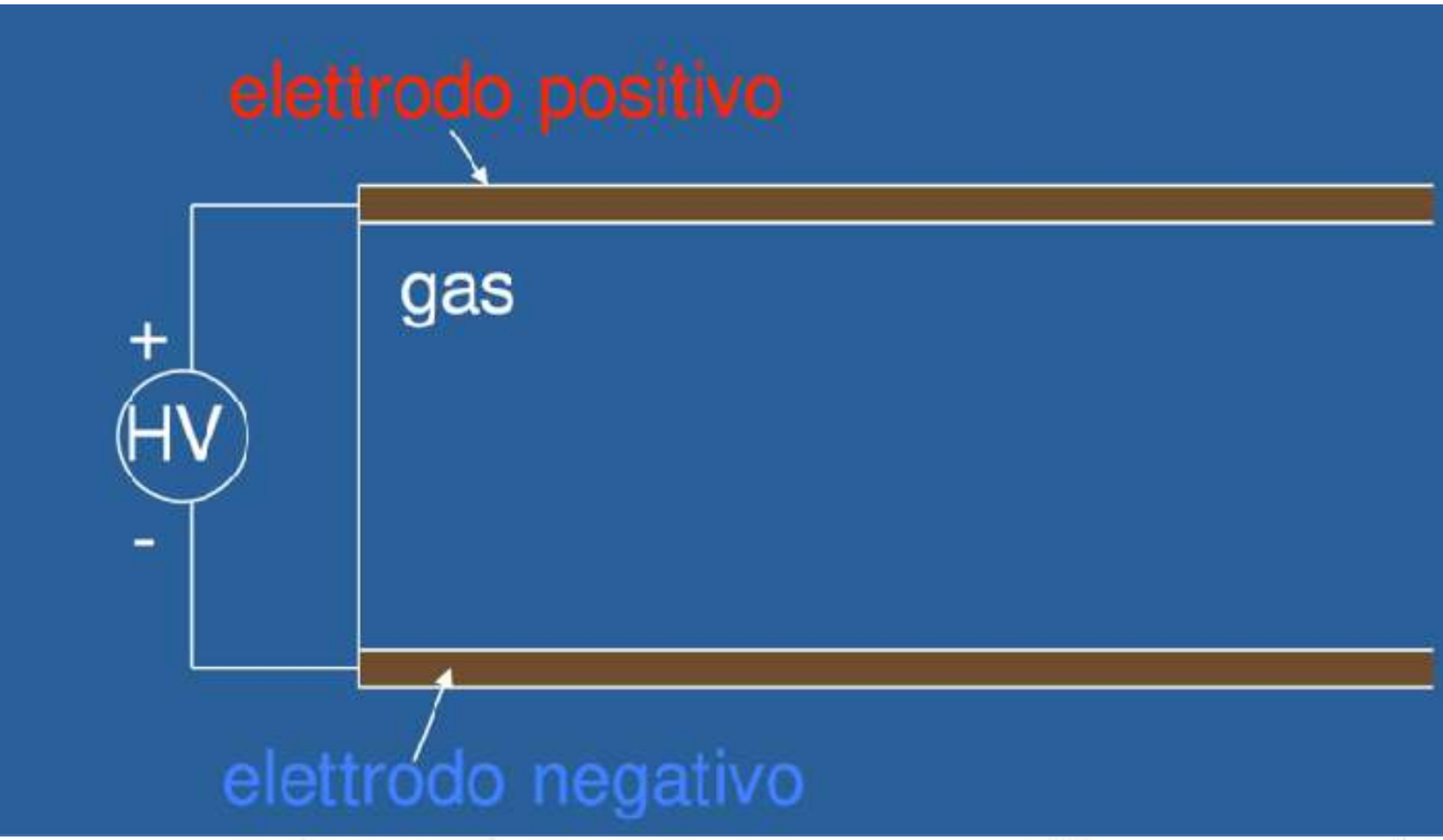
Rivelatore di infrasuoni (bio sonar)

Analogie e numeri



Risoluzione	100 MP	100 MP
Framerate	40 MHz (40 milioni fps)	250 fps
Peso	10 tonnellate	< 1 kg
Dati	1 PB/s (1 milione x ↠)	~5 GB/s
Dimensione	50m x 20m x 20m	pochi cm^3
Costo!	~2 milioni €	1000-6000 €

Esempio di rivelatore di particelle

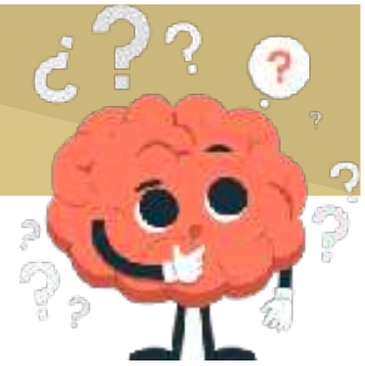


La **particella** carica attraversa il **materiale**, lo **ionizza** e produce un **segnale elettrico**

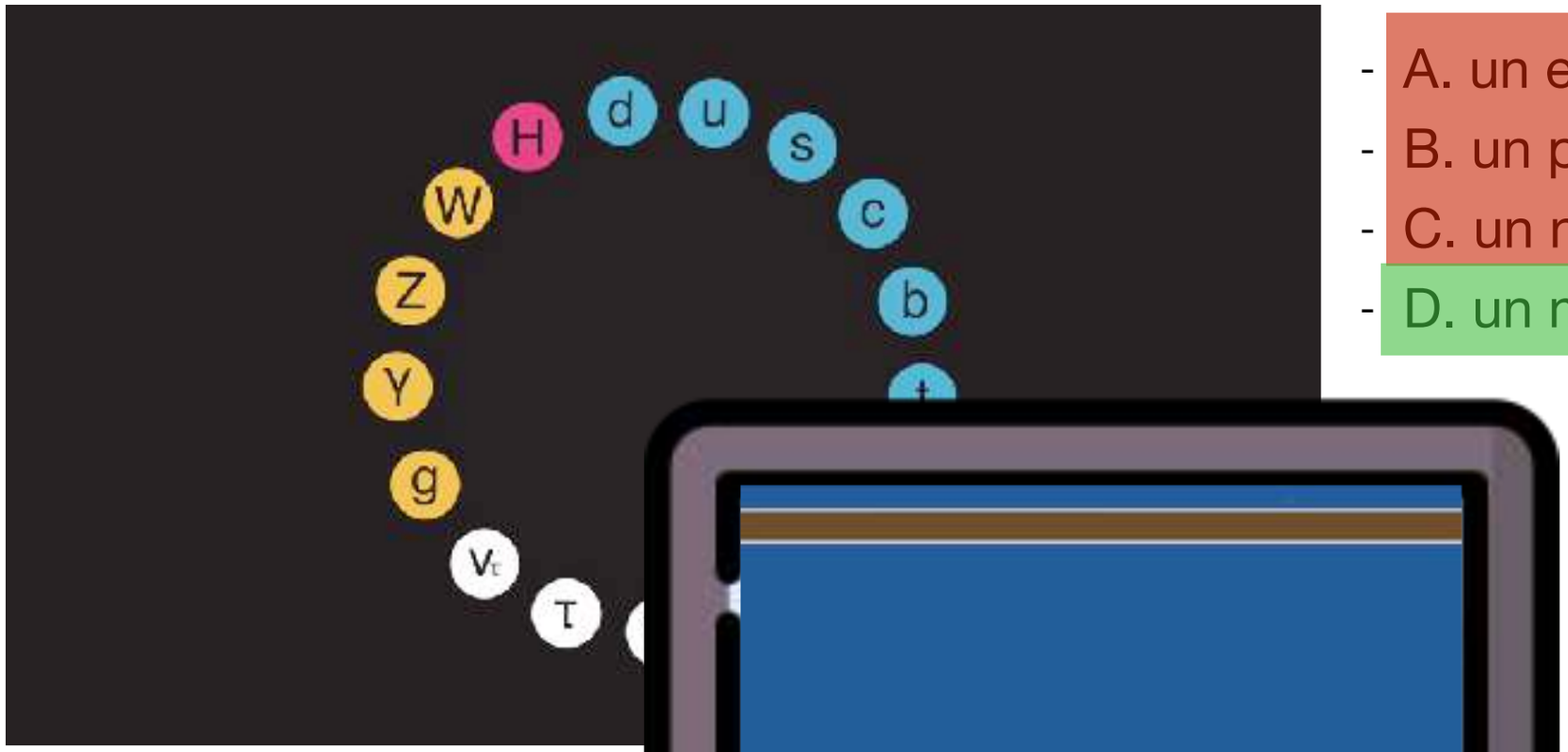
La **luce** riflessa dall'albero viene **assorbita dalla retina** che produce un **segnale elettrico**

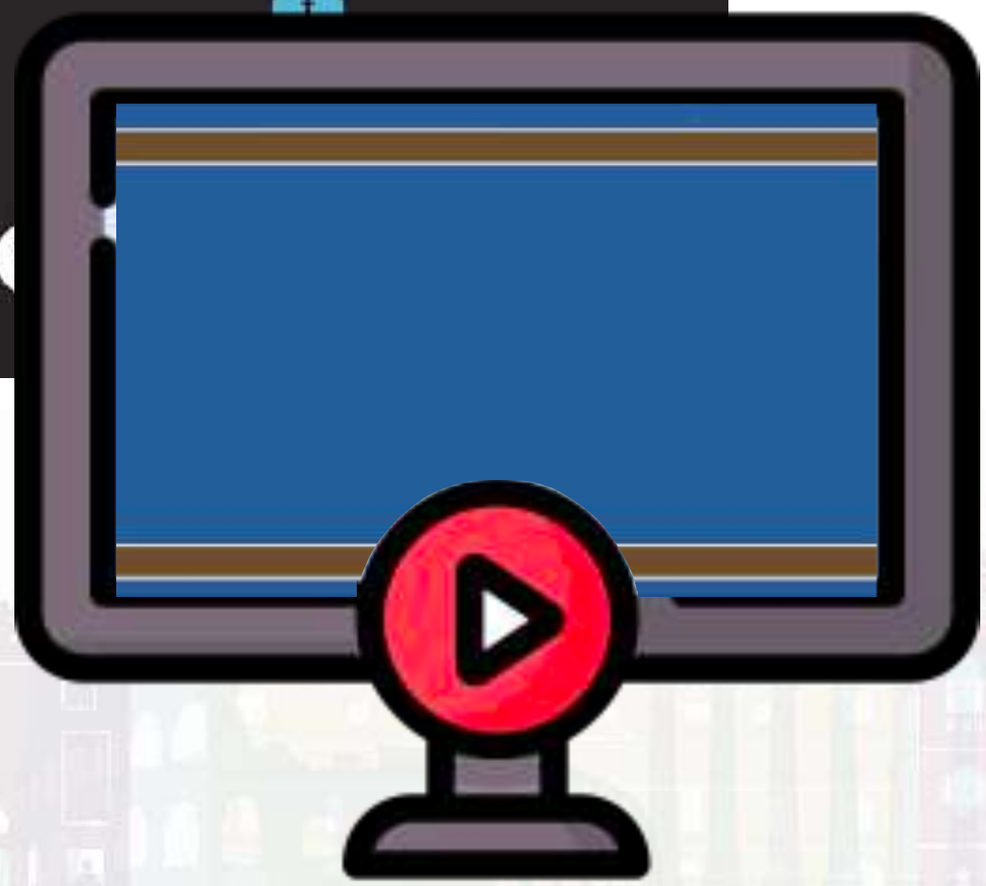
L'**eco** prodotto dall'ostacolo viene **ascoltato** dal cetaceo e processato come **segnale elettrico**

Domanda #2



Quale particella ha attraversato il rivelatore?





- A. un elettrone
- B. un positrone
- C. un neutrone
- D. un muone

Identikit di una particella

UP QUARK
DISCOVERED: 1969

MATTER PARTICLE

Mass:	2 MeV/c^2
Electric Charge:	+2/3
Strong Charges:	blue, red, green
Weak Charge:	+1/2
Lifetime:	unlimited

CHARM QUARK
DISCOVERED: 1974

MATTER PARTICLE

Mass:	1300 MeV/c^2
Electric Charge:	+2/3
Strong Charges:	blue, red, green
Weak Charge:	+1/2
Lifetime:	10^{-12} s

TOP QUARK
DISCOVERED: 1995

MATTER PARTICLE

Mass:	$173 \cdot 10^3$ MeV/c^2
Electric Charge:	+2/3
Strong Charges:	blue, red, green
Weak Charge:	+1/2
Lifetime:	$6 \cdot 10^{-25}$ s

DOWN QUARK
DISCOVERED: 1969

MATTER PARTICLE

Mass:	5 MeV/c^2
Electric Charge:	-1/3
Strong Charges:	blue, red, green
Weak Charge:	-1/2
Lifetime:	900 s

STRANGE QUARK
DISCOVERED: 1969

MATTER PARTICLE

Mass:	100 MeV/c^2
Electric Charge:	-1/3
Strong Charges:	blue, red, green
Weak Charge:	-1/2
Lifetime:	$5 \cdot 10^{-8}$ s

BOTTOM QUARK
DISCOVERED: 1977

MATTER PARTICLE

Mass:	4200 MeV/c^2
Electric Charge:	-1/3
Strong Charges:	blue, red, green
Weak Charge:	-1/2
Lifetime:	$2 \cdot 10^{-12}$ s

ELECTRON NEUTRINO
DISCOVERED: 1956

MATTER PARTICLE

Mass:	$< 2 \cdot 10^{-6}$ MeV/c^2
Electric Charge:	0
Strong Charges:	–
Weak Charge:	+1/2
Lifetime:	undefined

MUON NEUTRINO
DISCOVERED: 1962

MATTER PARTICLE

Mass:	$< 2 \cdot 10^{-6}$ MeV/c^2
Electric Charge:	0
Strong Charges:	–
Weak Charge:	+1/2
Lifetime:	undefined

TAU NEUTRINO
DISCOVERED: 2000

MATTER PARTICLE

Mass:	$< 2 \cdot 10^{-6}$ MeV/c^2
Electric Charge:	0
Strong Charges	–
Weak Charge:	+1/2
Lifetime:	undefined

ELECTRON
DISCOVERED: 1897

MATTER PARTICLE

Mass:	0.511 MeV/c^2
Electric Charge:	-1
Strong Charges:	–
Weak Charge:	-1/2
Lifetime:	unlimited

MUON
DISCOVERED: 1937

MATTER PARTICLE

Mass:	106 MeV/c^2
Electric Charge:	-1
Strong Charges:	–
Weak Charge:	-1/2
Lifetime:	$2.2 \cdot 10^{-6}$ s

TAU
DISCOVERED: 1975

MATTER PARTICLE

Mass:	1777 MeV/c^2
Electric Charge:	-1
Strong Charges:	–
Weak Charge:	-1/2
Lifetime:	$2.9 \cdot 10^{-13}$ s

W^+ BOSON
DISCOVERED: 1983

EXCHANGE PARTICLE

Mass:	$80.4 \cdot 10^3$ MeV/c^2
Electric Charge:	+1
Strong Charges:	–
Weak Charge:	+1
Lifetime:	$3 \cdot 10^{-25}$ s
Range:	10^{-18} m

W^- BOSON
DISCOVERED: 1983

EXCHANGE PARTICLE

Mass:	$80.4 \cdot 10^3$ MeV/c^2
Electric Charge:	-1
Strong Charges:	–
Weak Charge:	-1
Lifetime:	$3 \cdot 10^{-25}$ s
Range:	10^{-18} m

Z BOSON
DISCOVERED: 1983

EXCHANGE PARTICLE

Mass:	$91.2 \cdot 10^3$ MeV/c^2
Electric Charge:	0
Strong Charges:	–
Weak Charge:	0
Lifetime:	$3 \cdot 10^{-25}$ s
Range:	10^{-18} m

PHOTON
DISCOVERED: 1905

EXCHANGE PARTICLE

Mass:	0
Electric Charge:	0
Strong Charges:	–
Weak Charge:	0
Lifetime:	unlimited
Range:	unlimited

GLUON
DISCOVERED: 1979

EXCHANGE PARTICLE

Mass:	0
Electric Charge:	0
Strong Charges:	red, blue, green + antired, antiblue, antigreen
Weak Charge:	0
Lifetime:	unlimited
Range:	10^{-15} m

HIGGS BOSON
DISCOVERED: 2012

Mass:	$125 \cdot 10^3$ MeV/c^2
Electric Charge:	0
Strong Charges:	–
Weak Charge:	-1/2
Lifetime:	$2 \cdot 10^{-22}$ s

ANTI-UP QUARK
DISCOVERED: 1969

ANTIMATTER PARTICLE

Mass:	2 MeV/c^2
Electric Charge:	-2/3
Strong Charges:	antiblue, antired, antigreen
Weak Charge:	-1/2
Lifetime:	unlimited

ANTI-CHARM QUARK
DISCOVERED: 1974

ANTIMATTER PARTICLE

Mass:	1300 MeV/c^2
Electric Charge:	-2/3
Strong Charges:	antiblue, antired, antigreen
Weak Charge:	-1/2
Lifetime:	10^{-12} s

ANTI-TOP QUARK
DISCOVERED: 1995

ANTIMATTER PARTICLE

Mass:	$173 \cdot 10^3$ MeV/c^2
Electric Charge:	-2/3
Strong Charges:	antiblue, antired, antigreen
Weak Charge:	-1/2
Lifetime:	$6 \cdot 10^{-25}$ s

ANTI-DOWN QUARK
DISCOVERED: 1969

ANTIMATTER PARTICLE

Mass:	5 MeV/c^2
Electric Charge:	+1/3
Strong Charges:	antiblue, antired, antigreen
Weak Charge:	+1/2
Lifetime:	900 s

ANTI-STRANGE QUARK
DISCOVERED: 1969

ANTIMATTER PARTICLE

Mass:	100 MeV/c^2
Electric Charge:	+1/3
Strong Charges:	antiblue, antired, antigreen
Weak Charge:	+1/2
Lifetime:	$5 \cdot 10^{-8}$ s

ANTI-BOTTOM QUARK
DISCOVERED: 1977

ANTIMATTER PARTICLE

Mass:	4200 MeV/c^2
Electric Charge:	+1/3
Strong Charges:	antiblue, antired, antigreen
Weak Charge:	+1/2
Lifetime:	$2 \cdot 10^{-12}$ s

ELECTRON ANTI-NEUTRINO
DISCOVERED: 1956

ANTIMATTER PARTICLE

Mass:	$< 2 \cdot 10^{-6}$ MeV/c^2
Electric Charge:	0
Strong Charges:	–
Weak Charge:	-1/2
Lifetime:	undefined

MUON ANTI-NEUTRINO
DISCOVERED: 1962

ANTIMATTER PARTICLE

Mass:	$< 2 \cdot 10^{-6}$ MeV/c^2
Electric Charge:	0
Strong Charges:	–
Weak Charge:	-1/2
Lifetime:	undefined

TAU ANTI-NEUTRINO
DISCOVERED: 2000

ANTIMATTER PARTICLE

Mass:	$< 2 \cdot 10^{-6}$ MeV/c^2
Electric Charge:	0
Strong Charges:	–
Weak Charge:	-1/2
Lifetime:	undefined

POSITRON
DISCOVERED: 1932

ANTIMATTER PARTICLE

Mass:	0.511 MeV/c^2
Electric Charge:	+1
Strong Charges:	–
Weak Charge:	+1/2
Lifetime:	unlimited

ANTI-MUON
DISCOVERED: 1937

ANTIMATTER PARTICLE

Mass:	106 MeV/c^2
Electric Charge:	+1
Strong Charges:	–
Weak Charge:	+1/2
Lifetime:	$2.2 \cdot 10^{-6}$ s

ANTI-TAU
DISCOVERED: 1975

ANTIMATTER PARTICLE

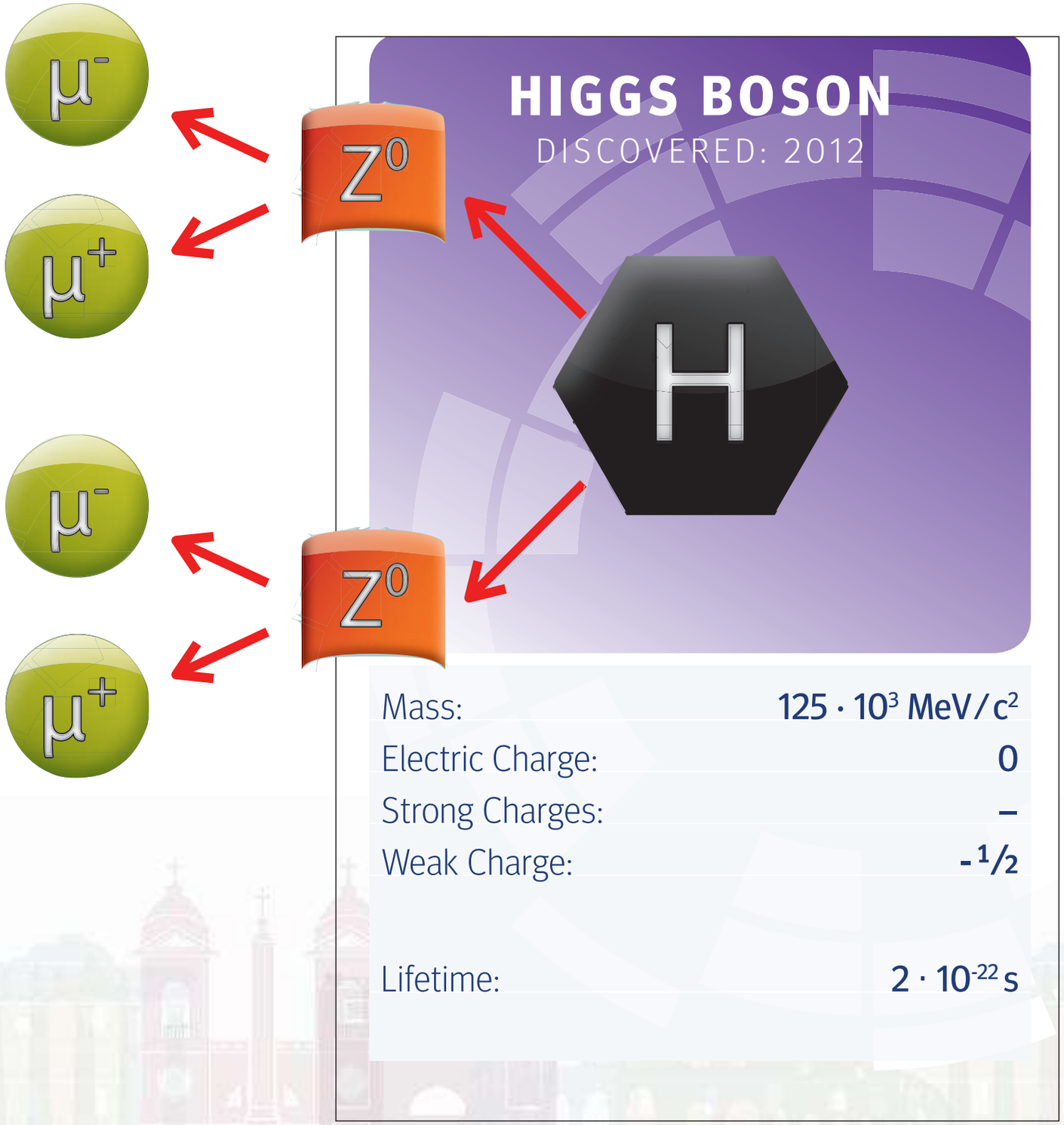
Mass:	1777 MeV/c^2
Electric Charge:	+1
Strong Charges:	–
Weak Charge:	+1/2
Lifetime:	$2.9 \cdot 10^{-13}$ s

Identikit di un muone

SEGNI PARTICOLARI:

- 200x più pesante di un elettrone
- carica elettrica negativa
- carica forte nulla
- **vita media “lunga”**
- Proprietà cinetiche
  - + energia E
  - + momento p
  - + velocità v (β)

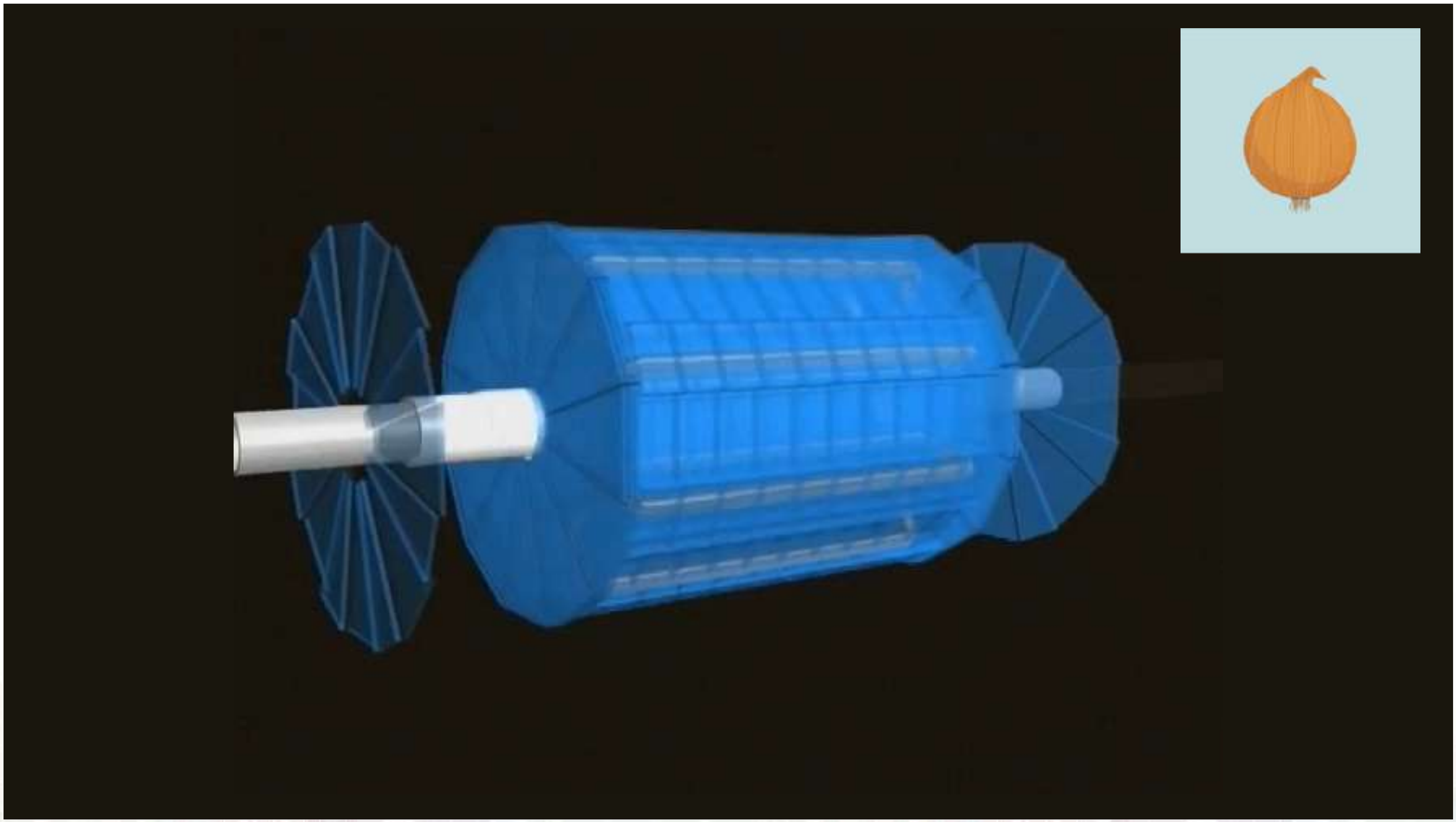
Identikit di un bosone di Higgs



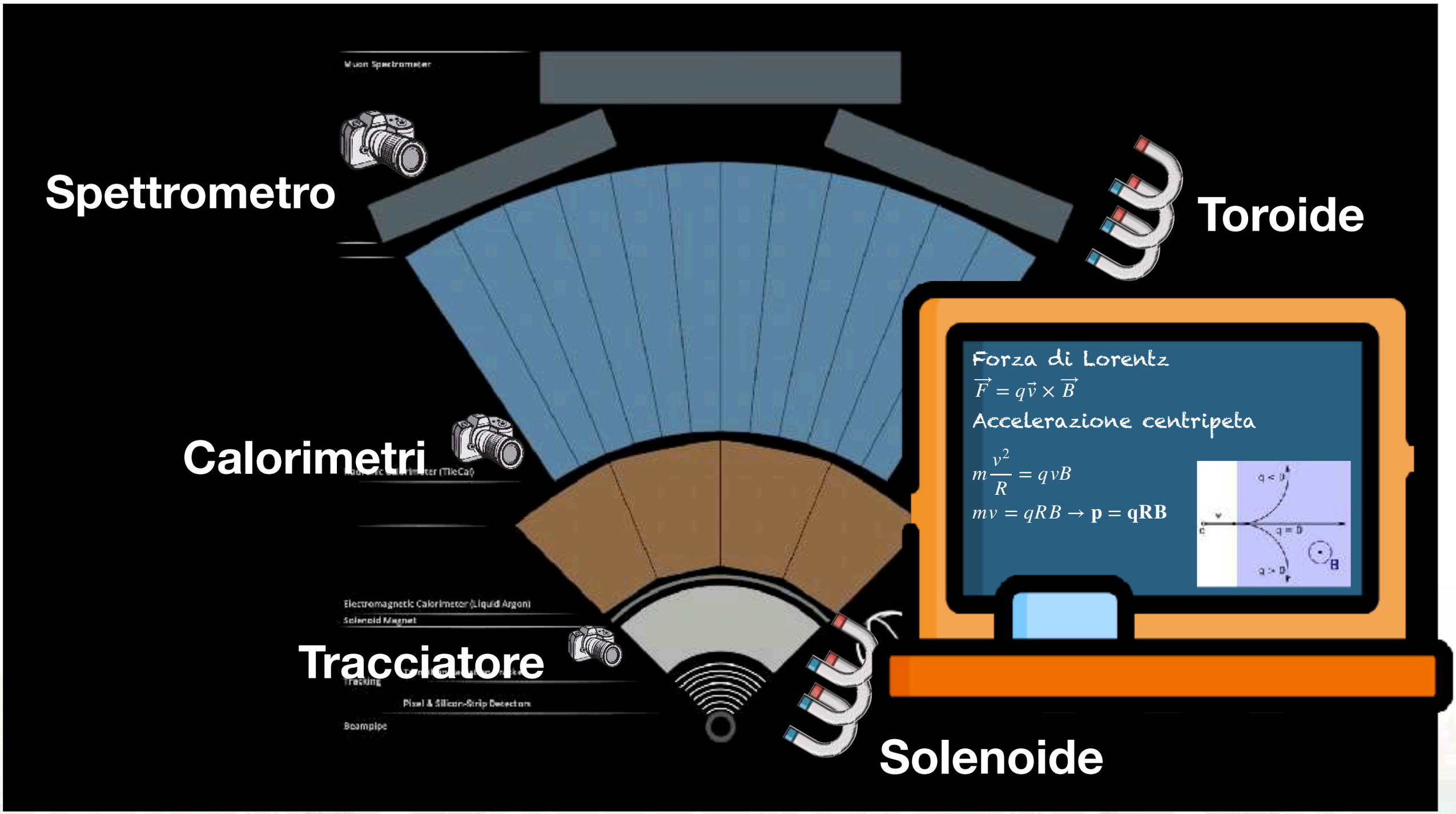
SEGNI PARTICOLARI:

- 2ª particella elementare più pesante dopo il quark top
- carica elettrica e forte nulle
- **vita media brevissima!**
- Proprietà cinetiche (E, p, β)

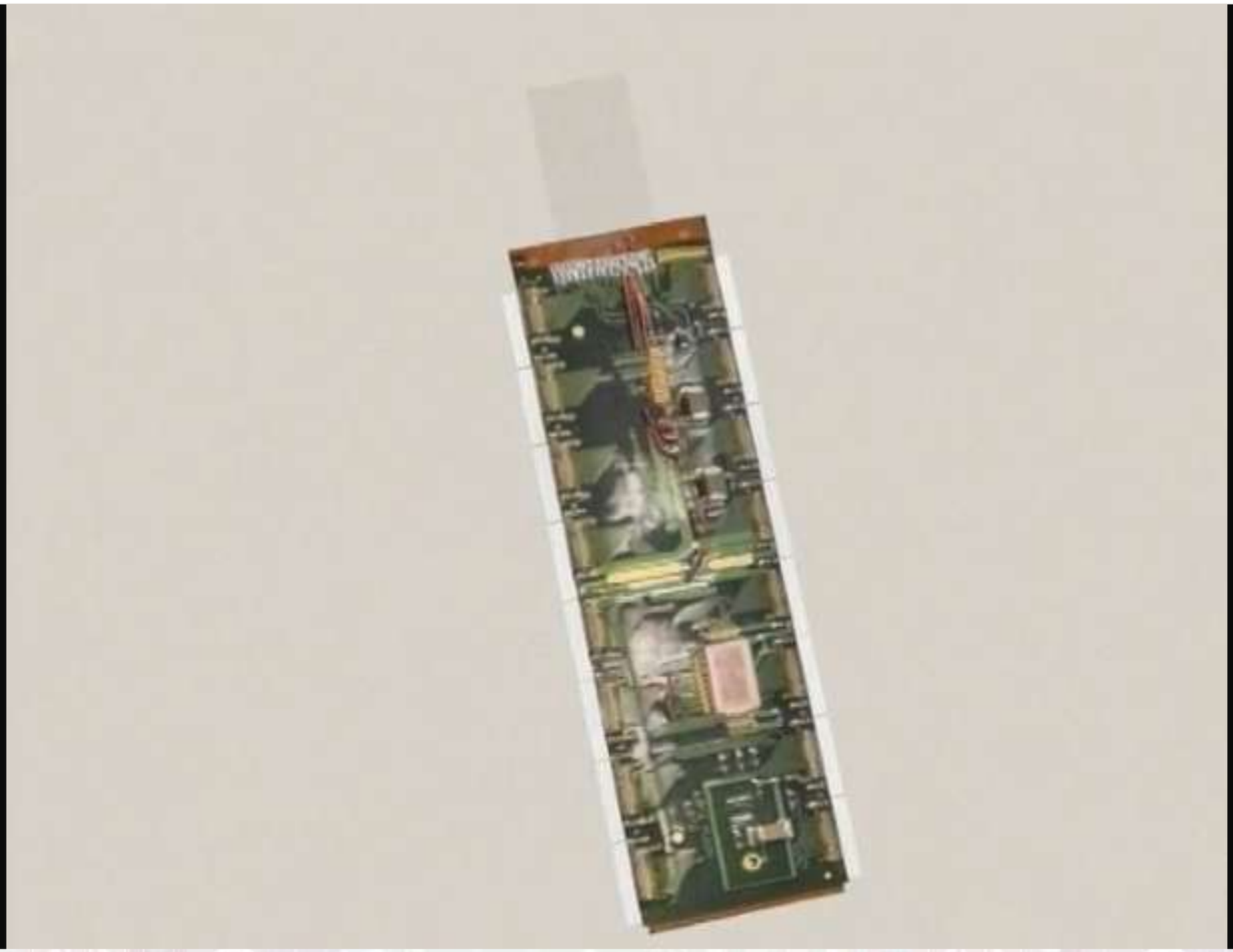
Il rivelatore ATLAS: la macchina fotografica più potente al mondo



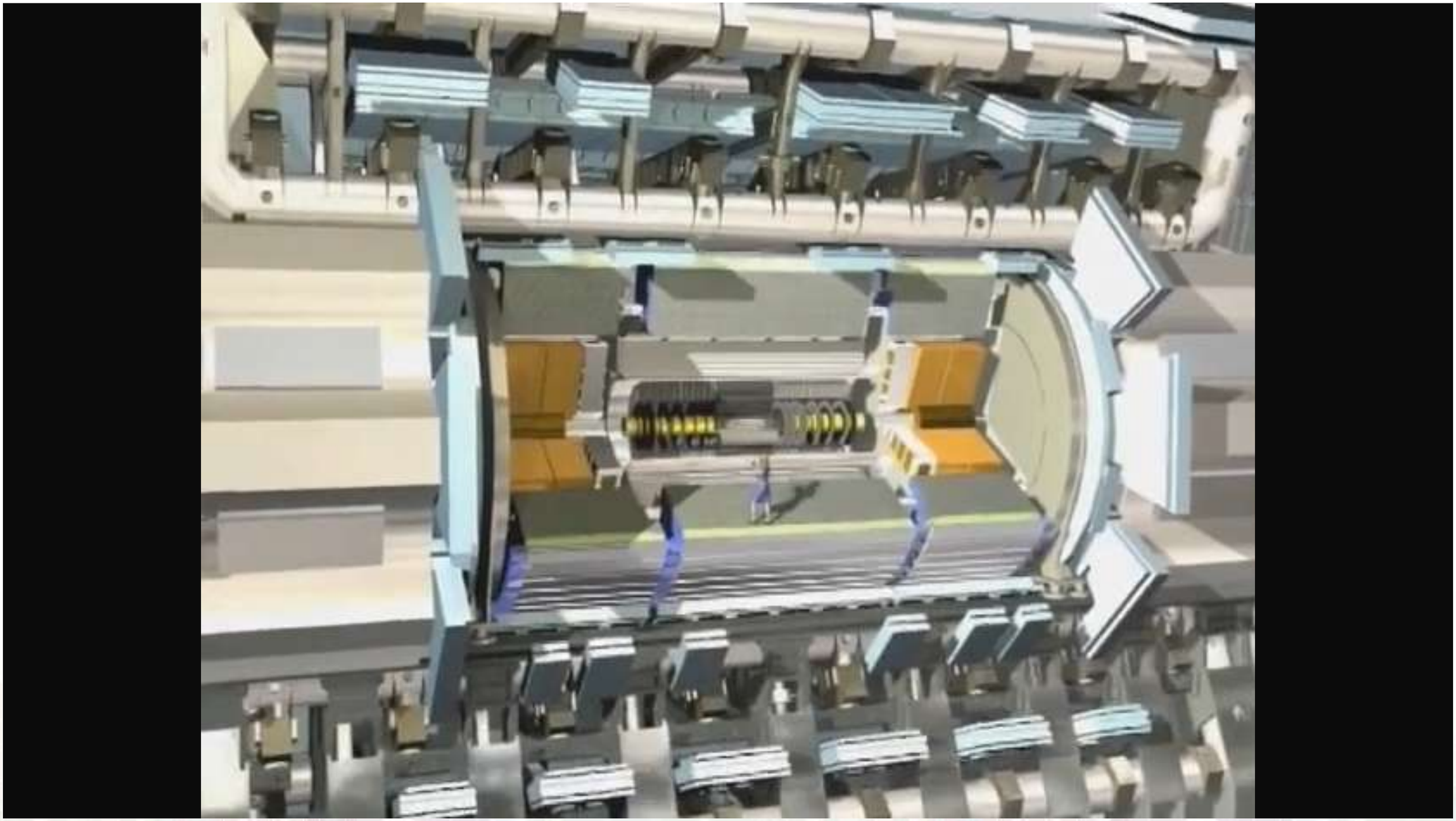
Elementi principali di un rivelatore



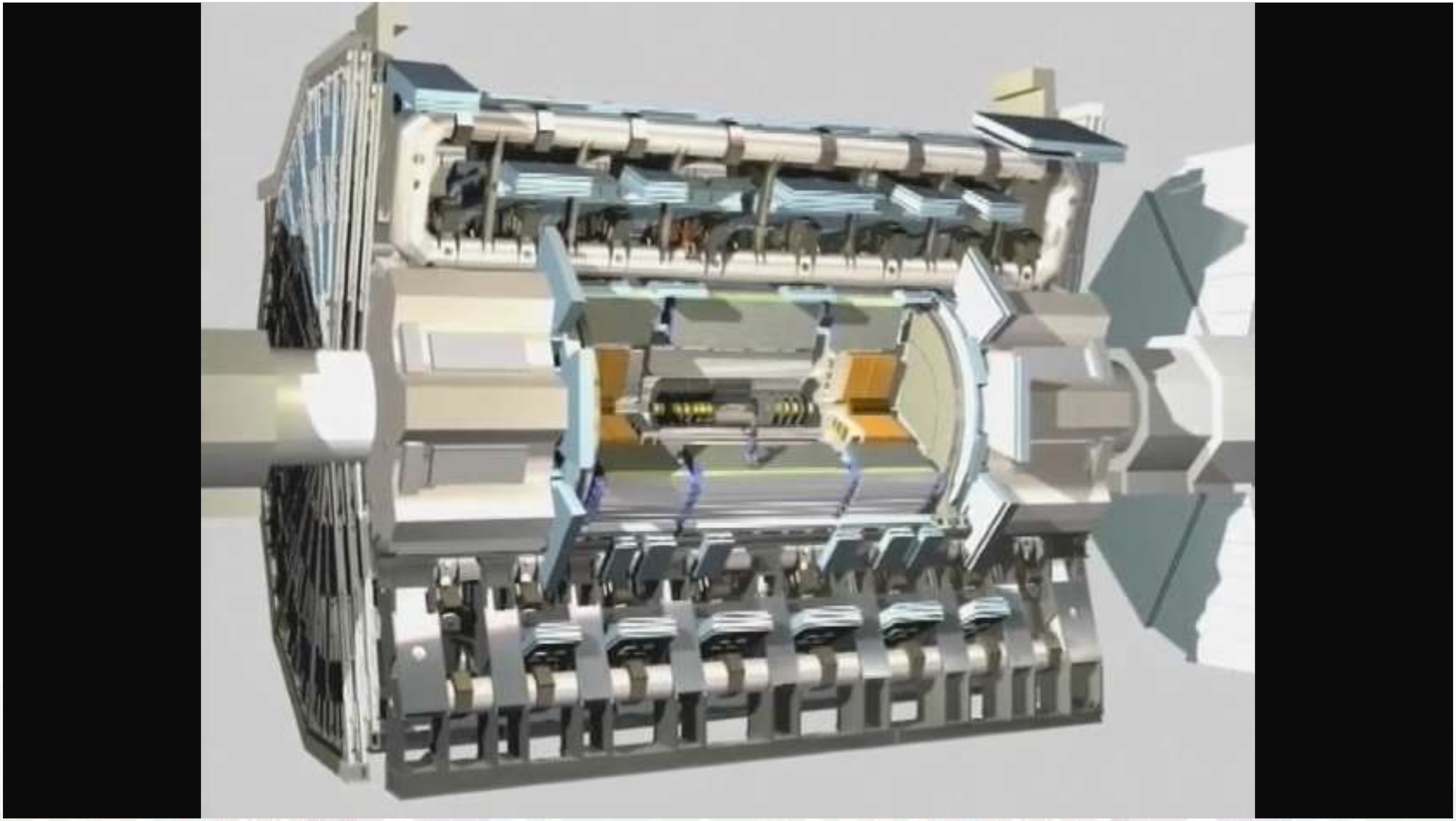
Tracciatori → Carica (q) e momento (p)



Calorimetro → Energia (E)

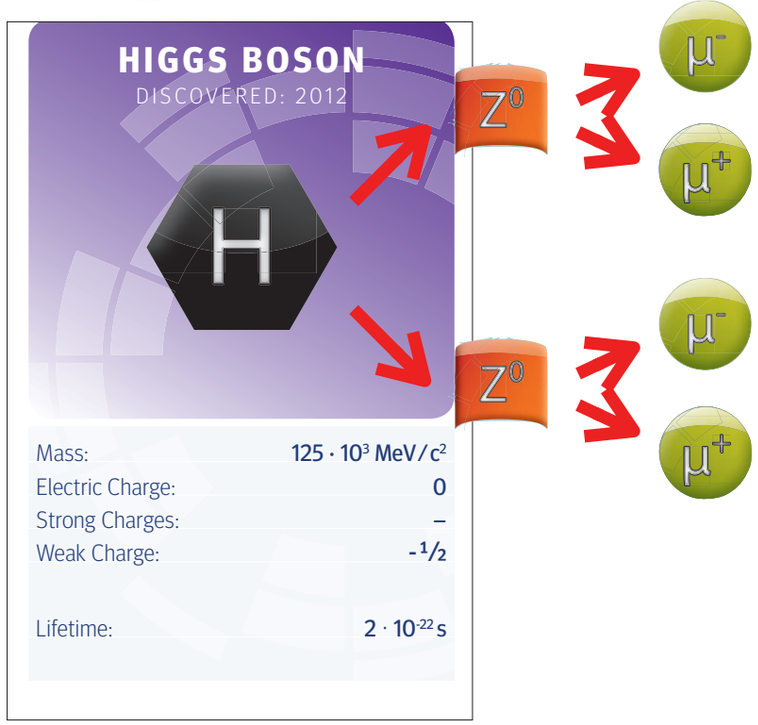


Spettrometro a muoni → q, p



Acquisizione dati

Esempio di analisi dei dati dell'LHC

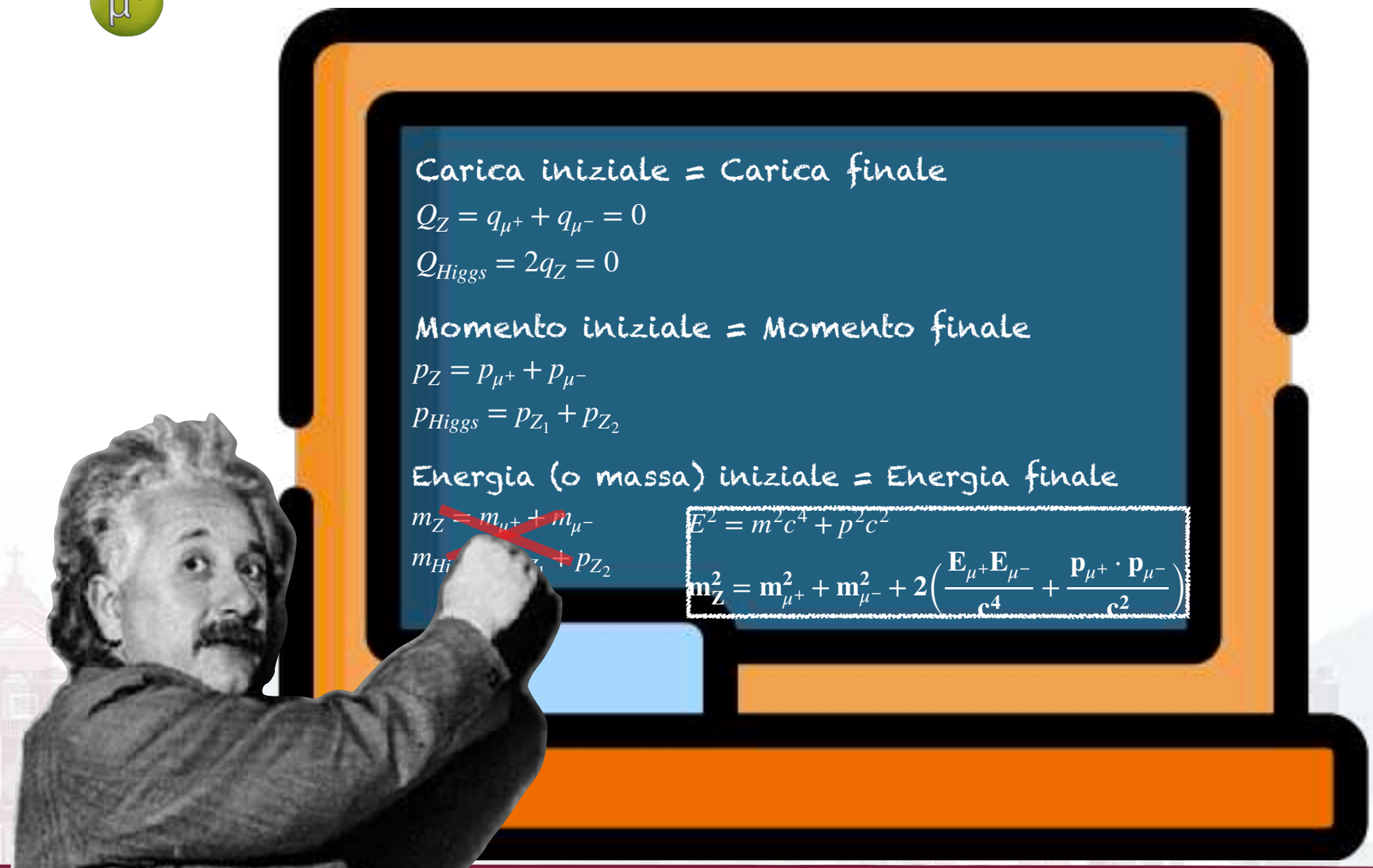


Domanda #3: quando si produce un bosone di Higgs all'LHC, cosa osserviamo nel rivelatore?

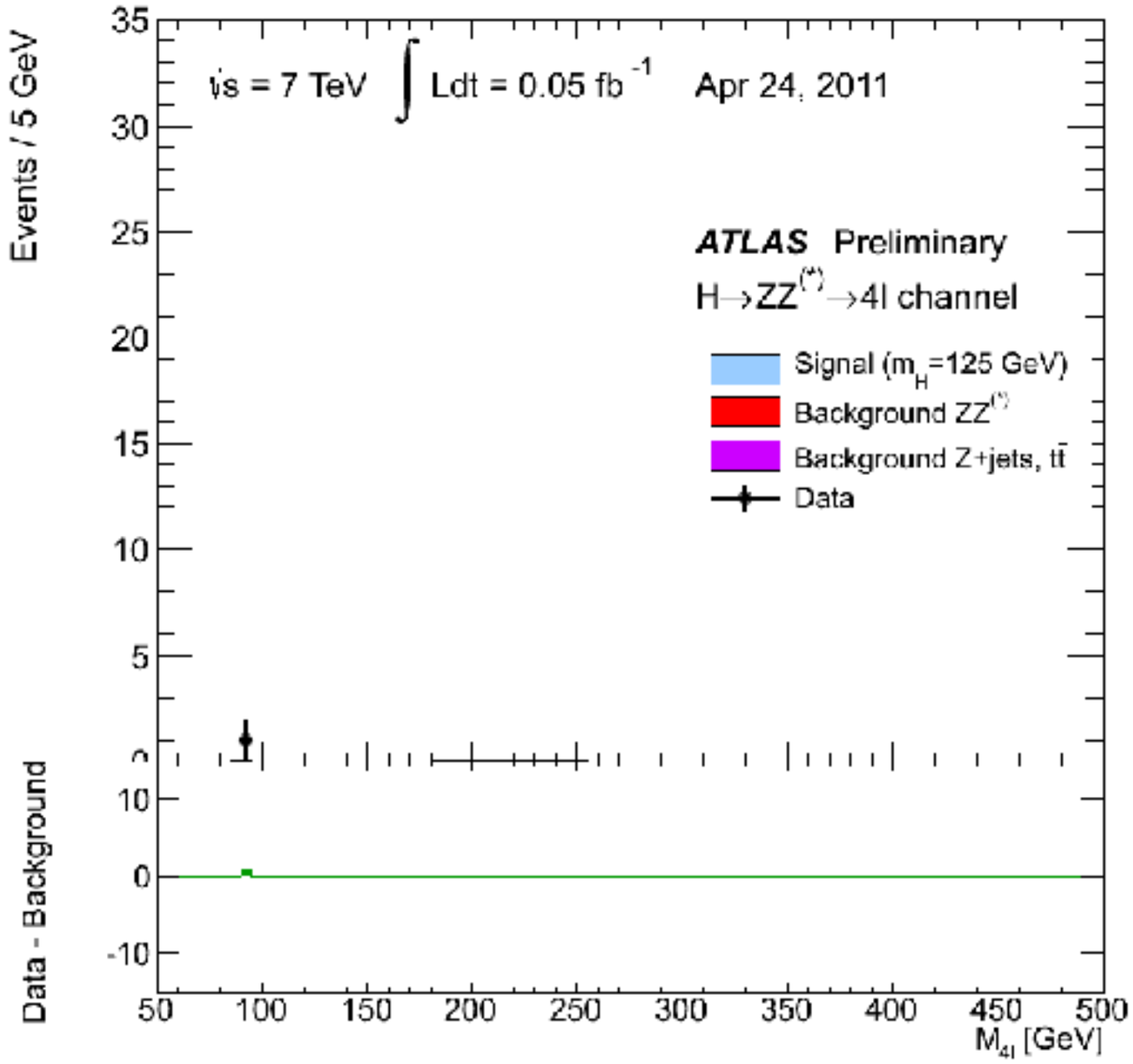
- 4 muoni (in generale, i suoi prodotti di decadimento)

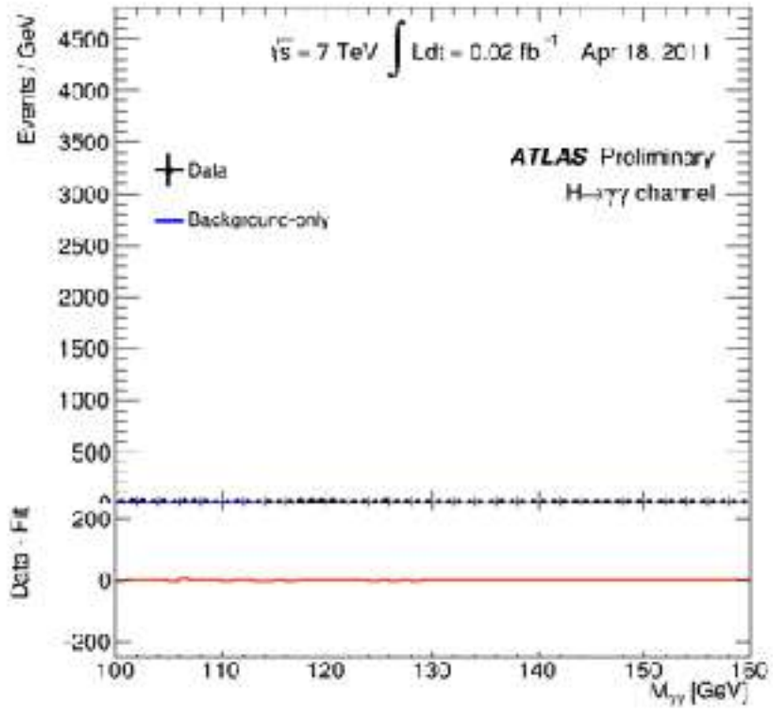
Domanda #4: come facciamo a sapere che sono stati originati da un Higgs?

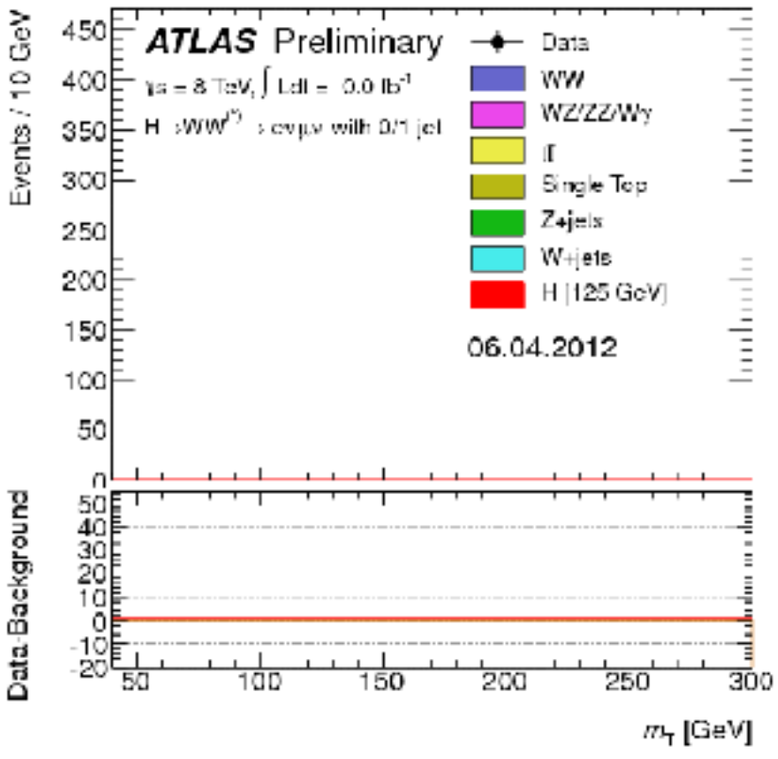
- misuriamo q, p dei muoni (o delle altre particelle ricostruite)
- applichiamo i principi di conservazione



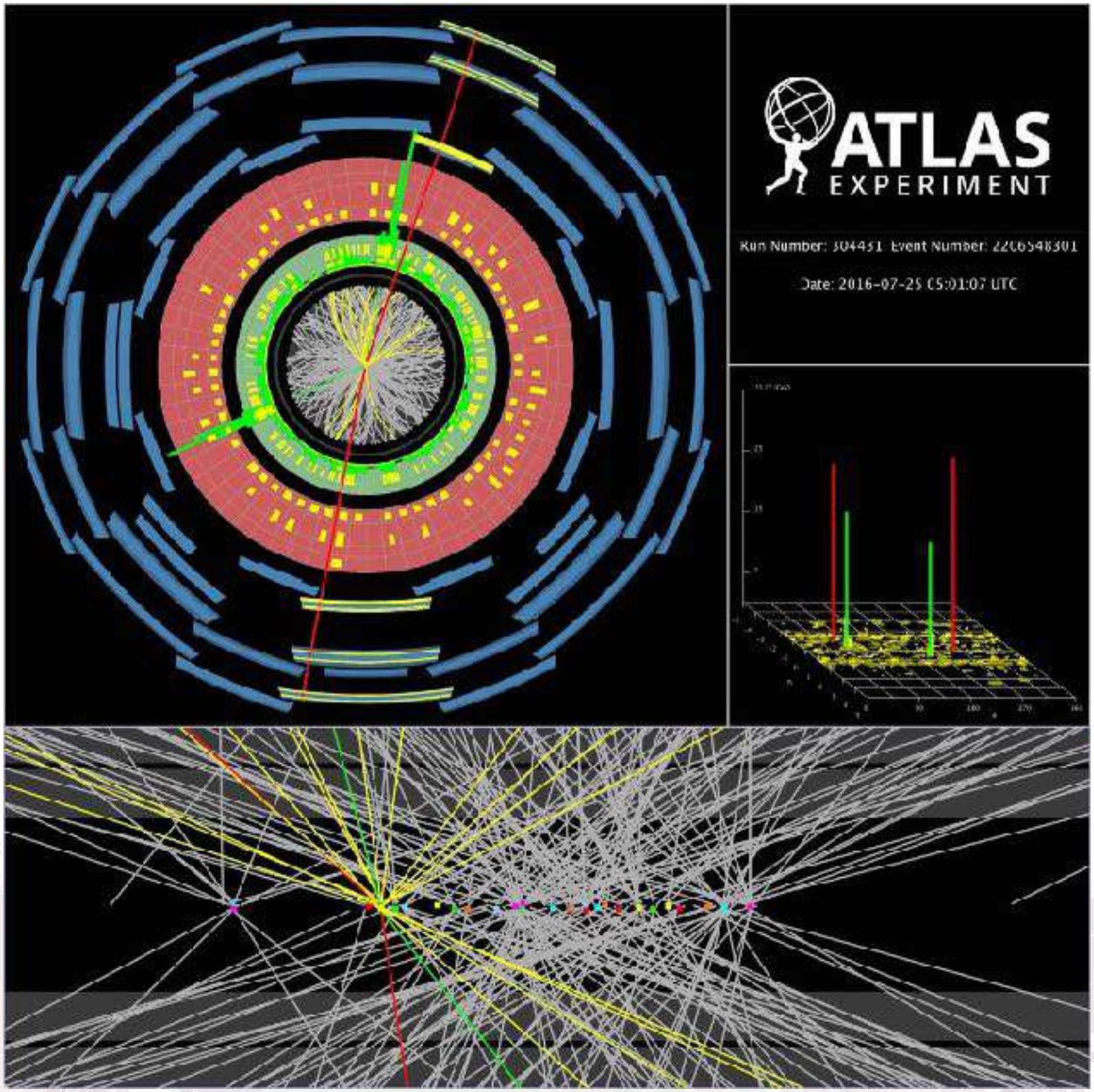
Esempio di analisi dei dati dell'LHC



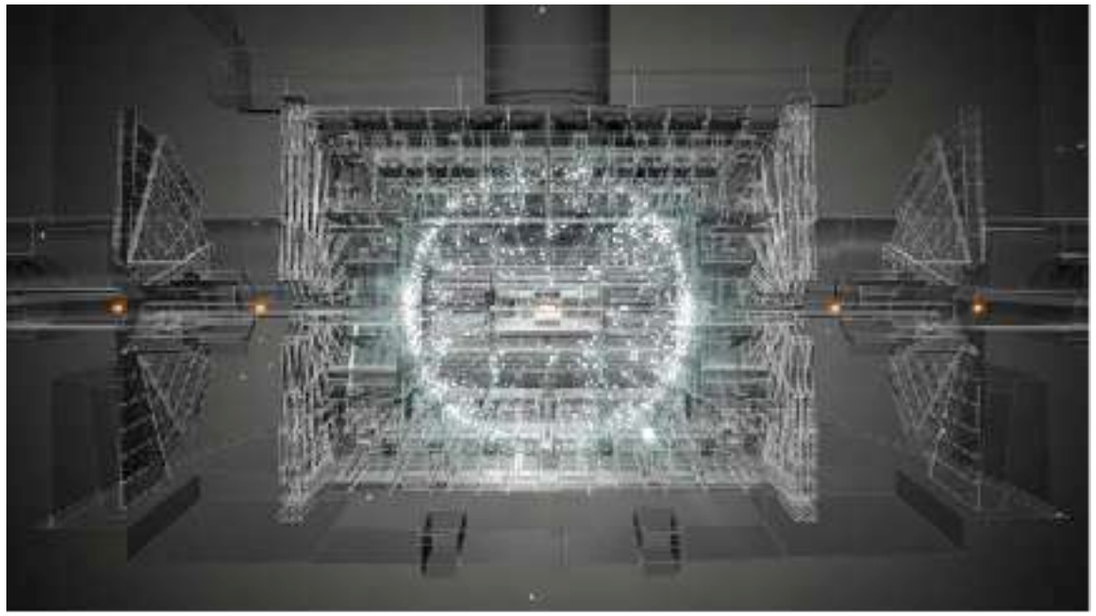




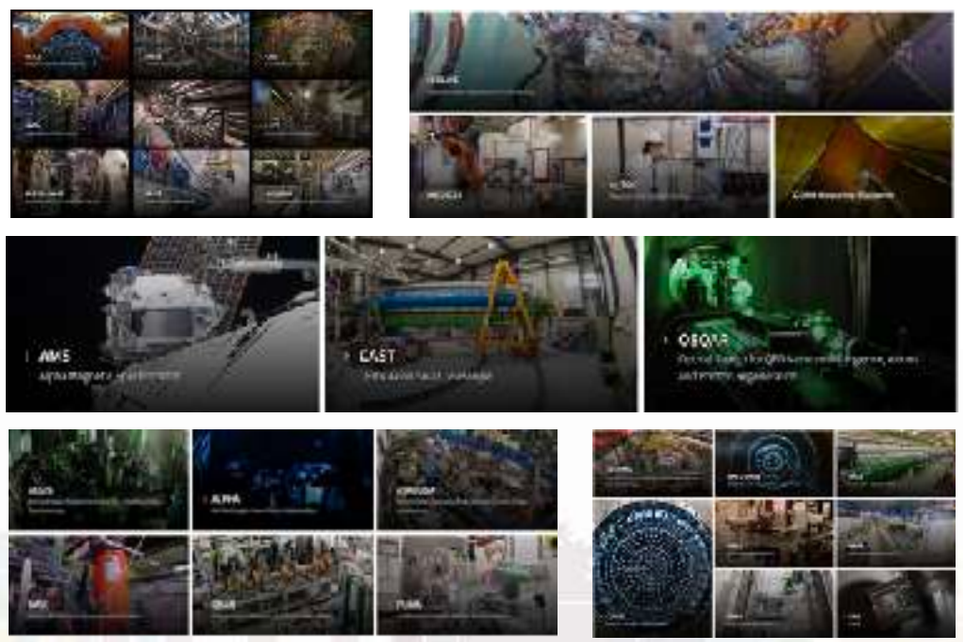
Candidato bosone di Higgs (H → ZZ → eeμμ)



LHC d.H. (dopo Higgs)



Cosa si fa all'LHC da 10 anni?



Grazie!