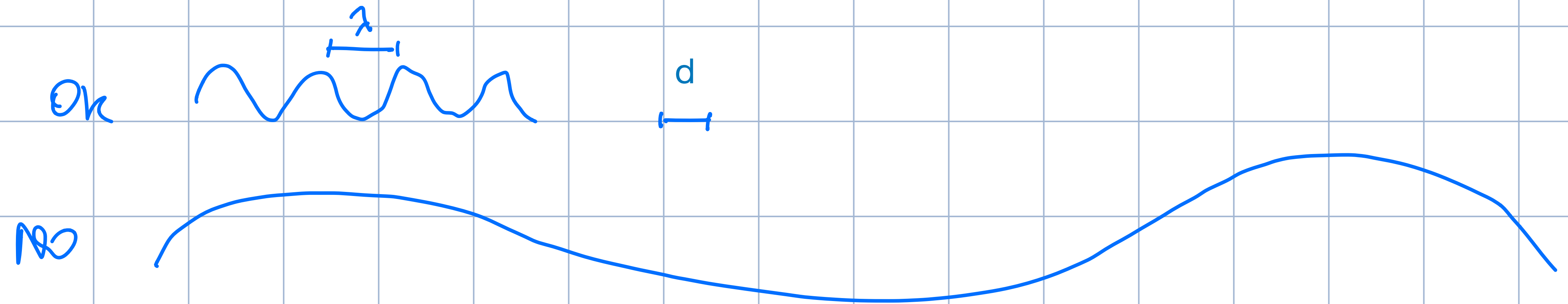


Una squadra esperimenti: LHC

M. Pietsch (UNIPR e INFN)

Vedere cose piccole: lunghezza d'onda $\lambda \sim d$



Microscopi $\rightarrow$ luce

RAGGI X $\lambda \ll \lambda_{\text{visibile}}$

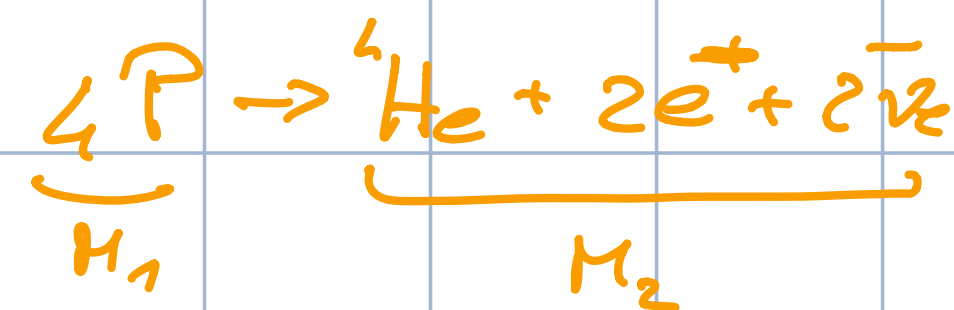
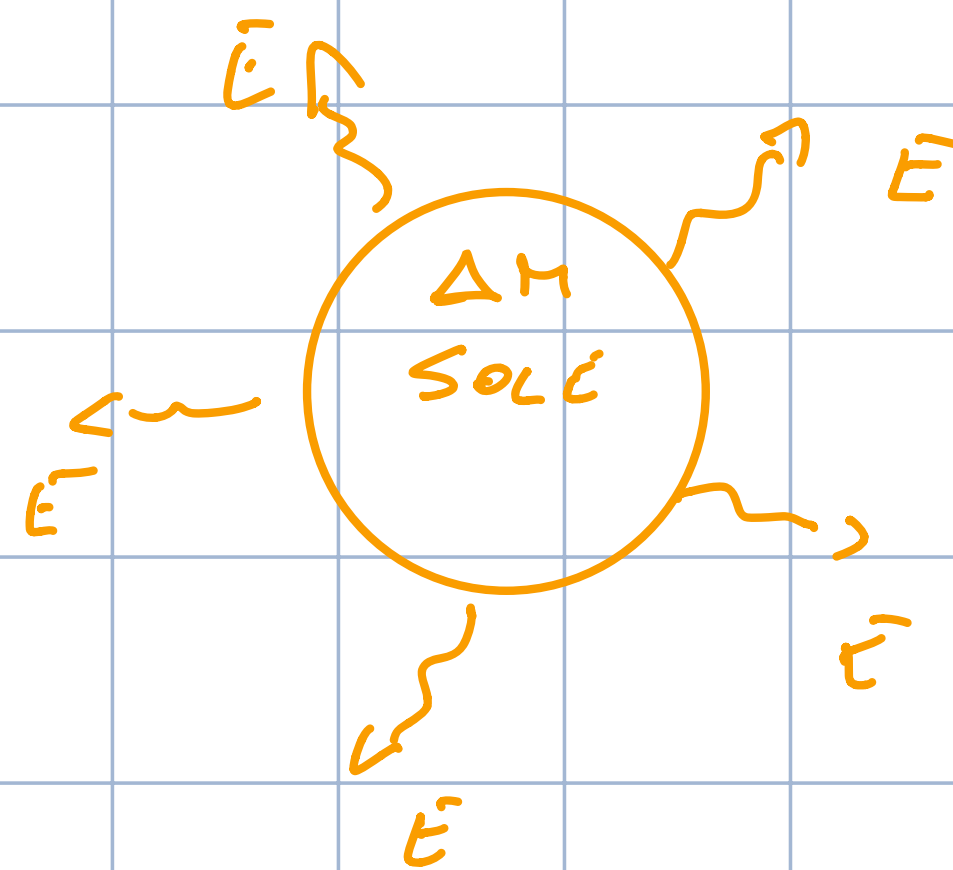
Meccanica Quantistica : $\rightarrow$ le particelle hanno una
lunghezza d'onda

de Broglie $\lambda = \frac{h}{m_e v}$ $\rightarrow$ MICROSCOPIO ELETTRONICO!!

grande impulso $p \rightarrow$ piccole distanze!

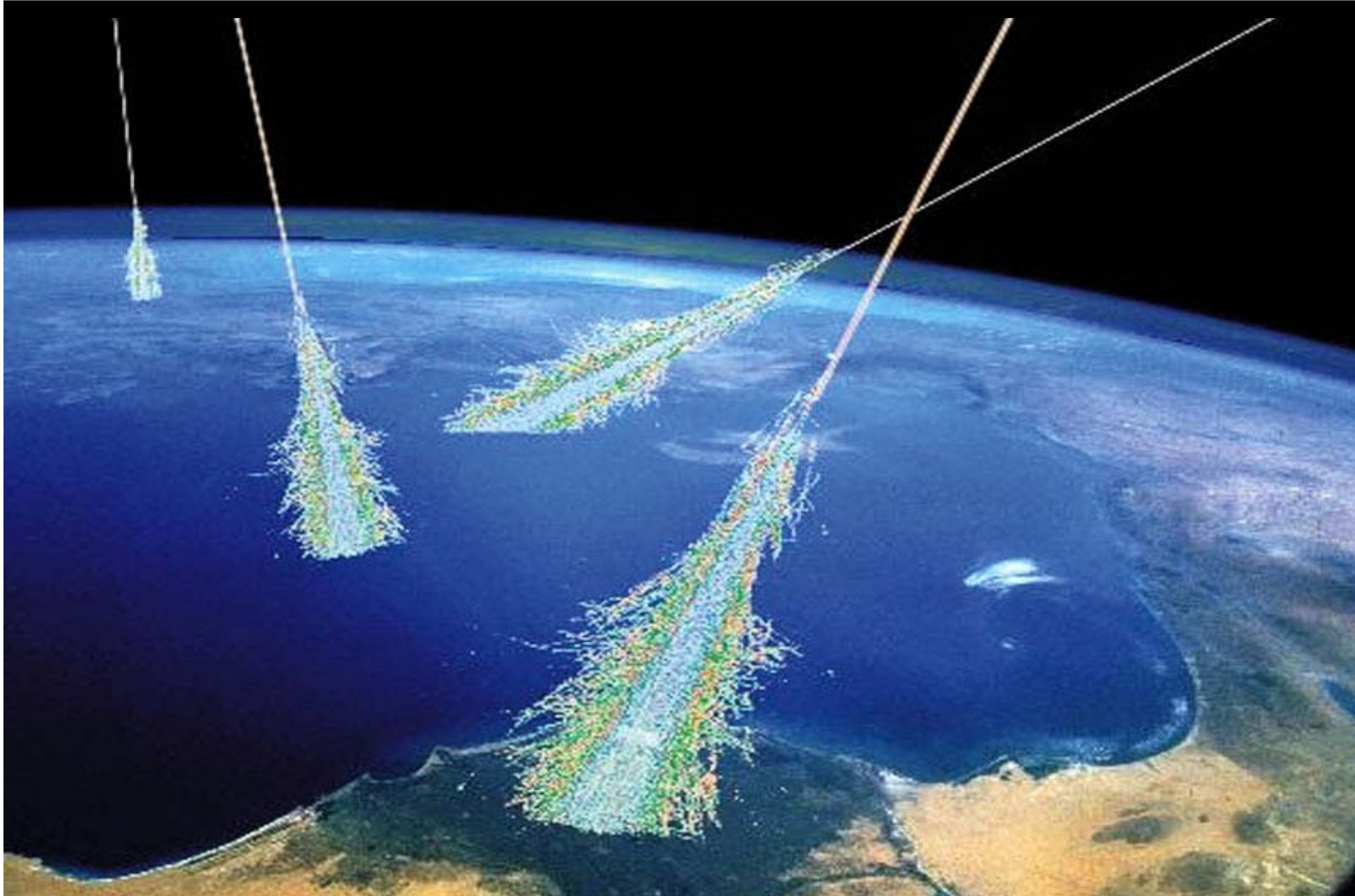
Relatività Speciale (Einstein 1905)

$$E = mc^2$$



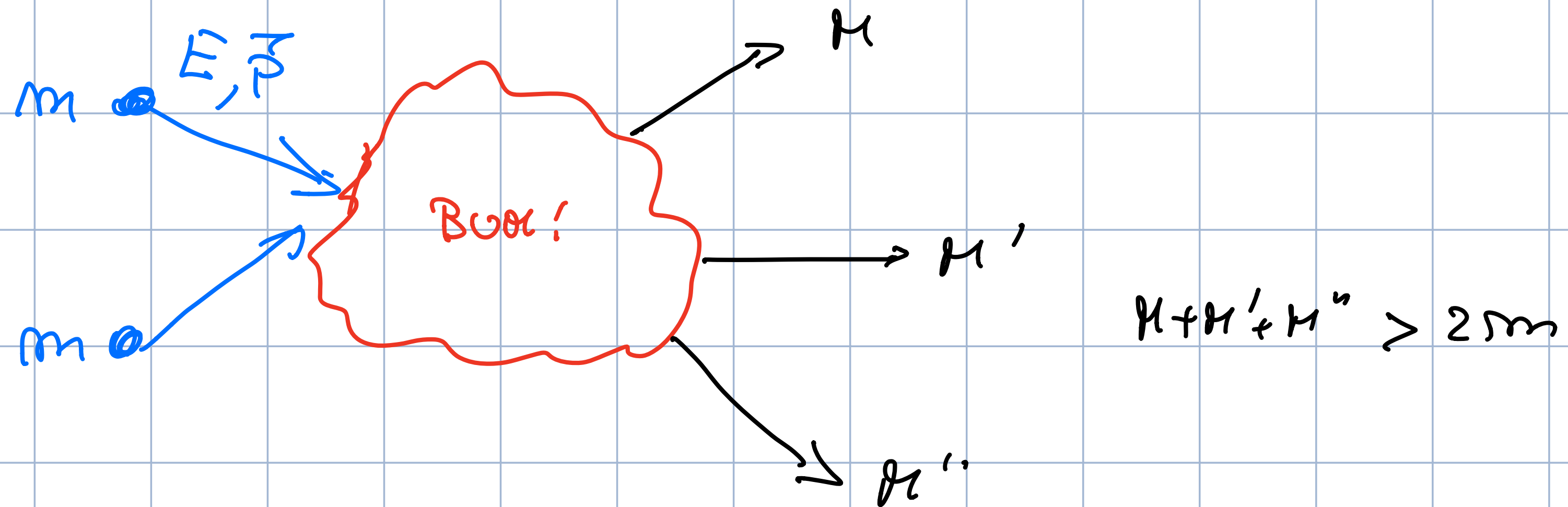
$M_2 < M_1 \rightarrow$ ENERGIA!

SCIAME ELETTROMAGNETICO



Ma anche $E \rightarrow H$ Nuove particelle create
obl nulla!

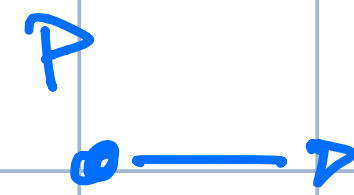
(ES: SCIAMÈ)



ALTE ENERGIE $\Rightarrow$
 $\nearrow$ PICCOLE DIMENSIONI
 (STRUTTURA MICROSCOPICA)
 $\searrow$ NUOVE PARTICELLE

LHC = Large Hadron Collider

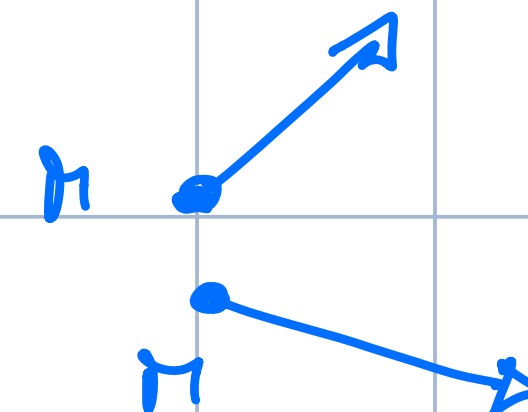
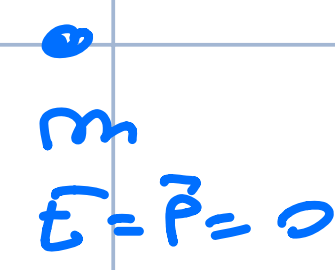
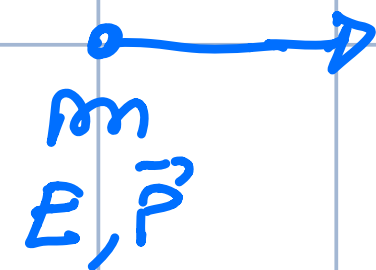
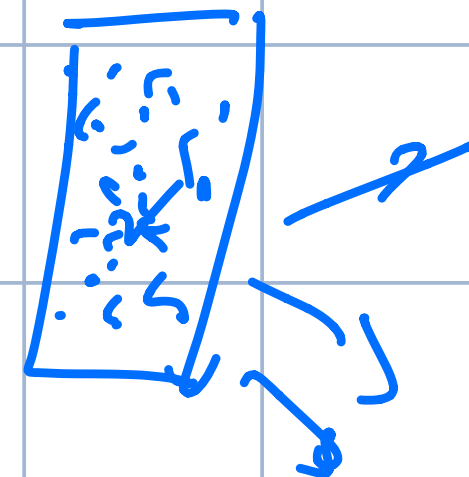
Perche' Collider?



$$r_p \sim 10^{-15} \text{ m}!$$

probabilità di
impatto ~ 0 !

Bersaglio fisso:



$$\vec{p}_1 + \vec{p}_2 = \vec{p}$$

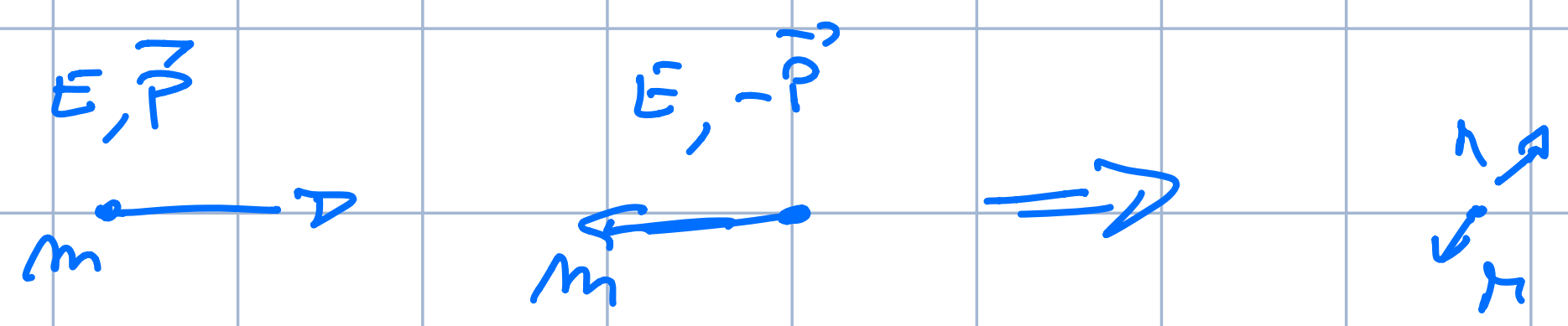
per produrre 2 particelle di massa m

$$\Rightarrow E > \frac{2M^2 - m^2}{m}$$

es: $M = 100 m_p$

$$E_F \gtrsim 2 \cdot 10^4 m_p$$

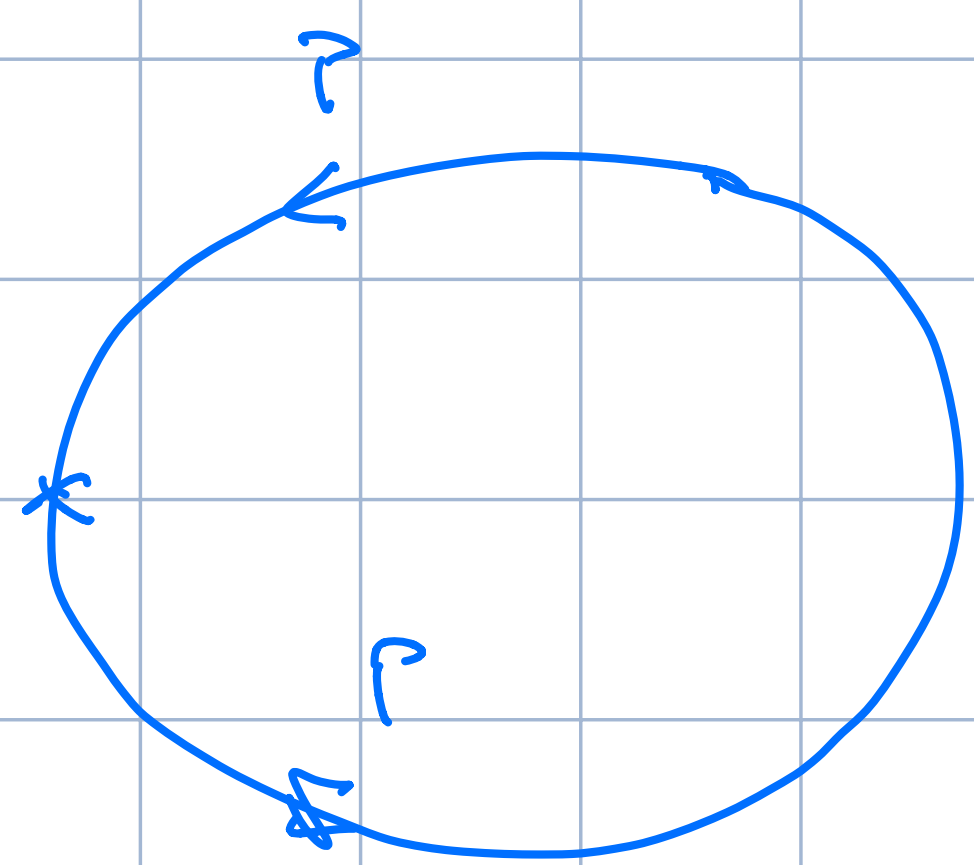
Collider:



$$E_c > M$$

$$\frac{E_c}{E_F} \sim \frac{m}{2M} \ll 1 !!$$

Richiede molto meno energia!



"Pacchetti" di particelle
 Tanti γ $\rightarrow$ Tanti
 interazioni

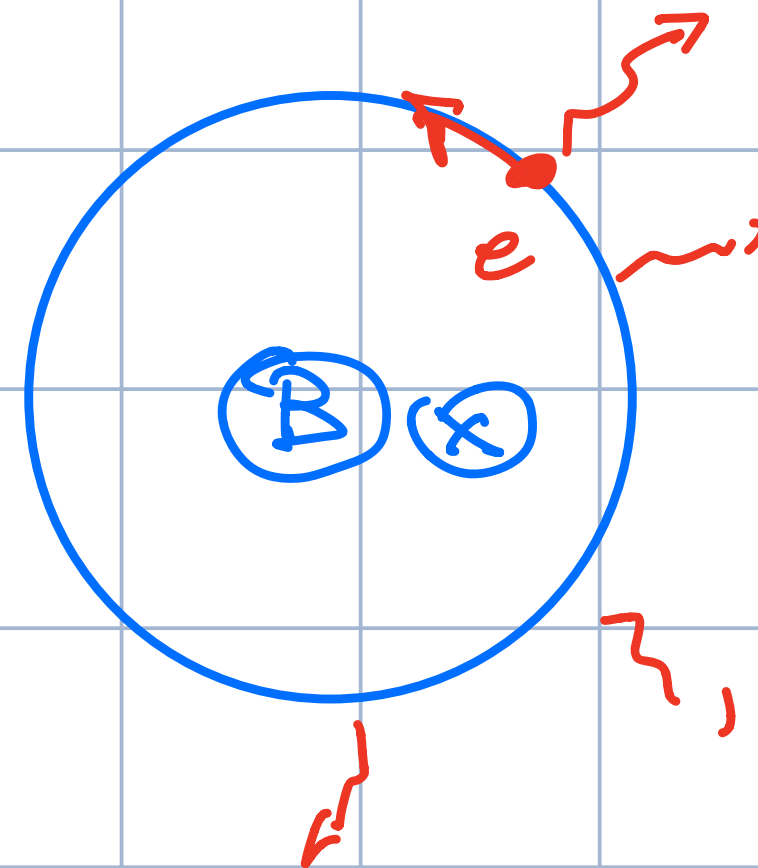
Perche Hadron?

Hadron = contiene
quark e gluoni

Hadron $\rightarrow$ protone $m_p \sim 1 \text{ GeV}$

Lepton $\rightarrow$ elettrone $m_e \sim 0.5 \text{ MeV}$

$$m_p \sim 2000 m_e$$



$$\frac{P_p}{P_e} \sim \left(\frac{m_e}{m_p} \right)^4 \sim 10^{-12}$$

Energie risparmiata

$\rightarrow$ Meggiore E finale!

Perche Lorge?

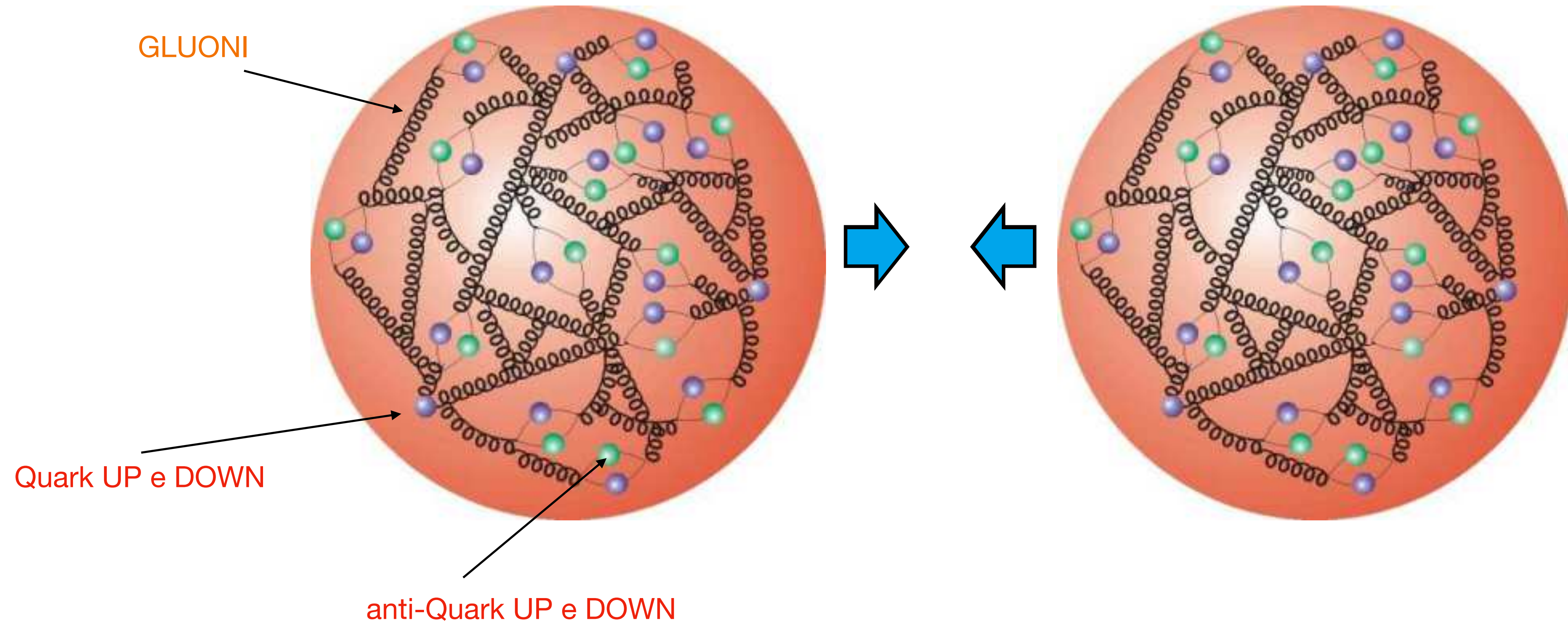
$$\text{Lorentz: } e v B = m_p \frac{v^2}{r}$$

$$\Rightarrow P = m_p v = e B r$$

$B_{\text{max}} \sim 8 \text{ TeV}$ Lorge $P \rightarrow$ Lorge $r \rightarrow r \sim 4.3 \text{ km}$

LHC (hadron collider)

proton $\longrightarrow$ $\longleftarrow$ proton



ALTE ENERGIE: interagiscono GLUONI, QUARK e ANTI-QUARK singolarmente, non tutto il PROTONE

DENTRO LHC

<https://videos.cern.ch/record/2020780>

Il nostro microscopio (il rivelatore ATLAS)

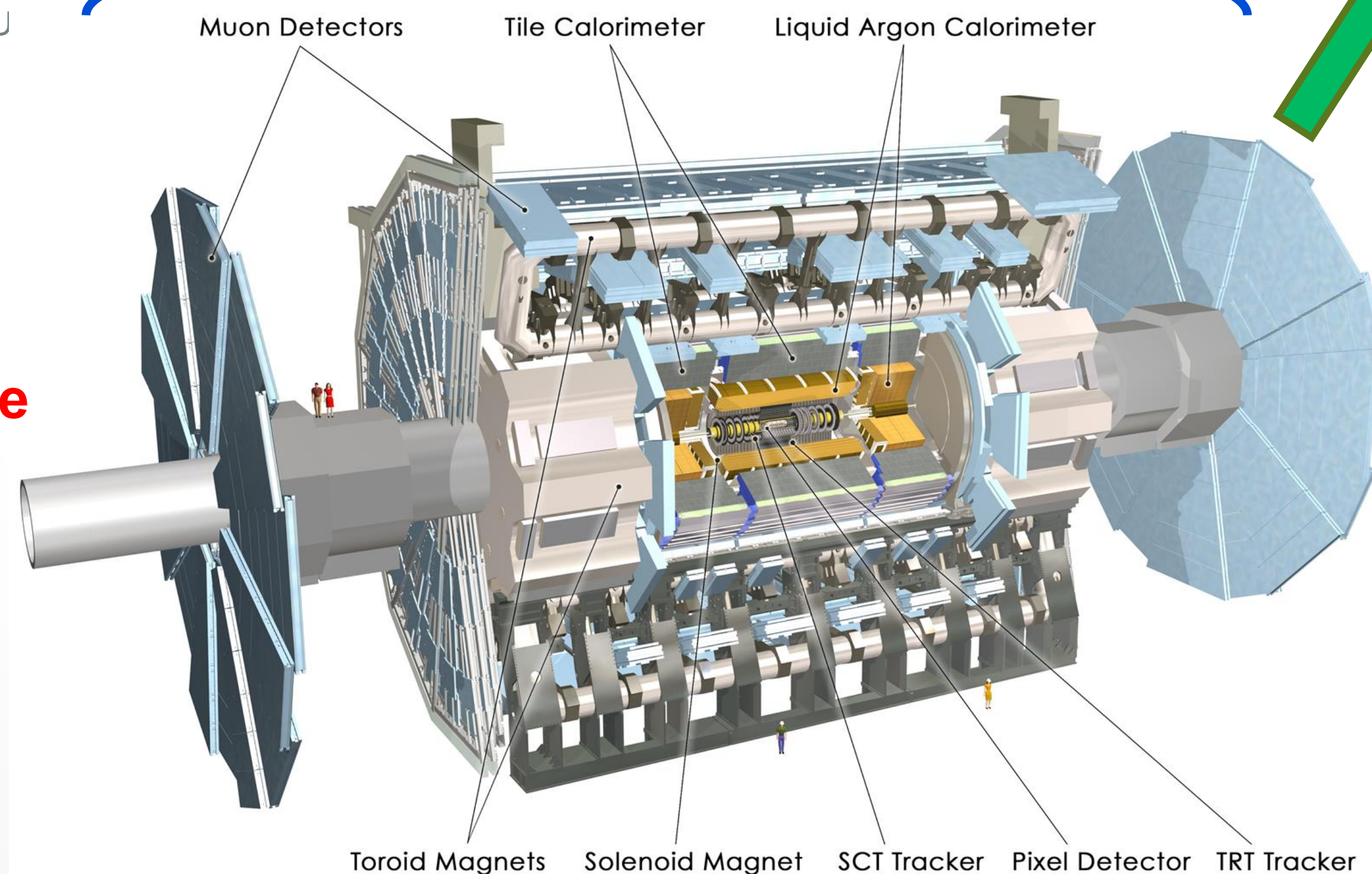


ATLAS vicino ad un edificio
di 5 piani: 15 anni per
progettarlo e costru



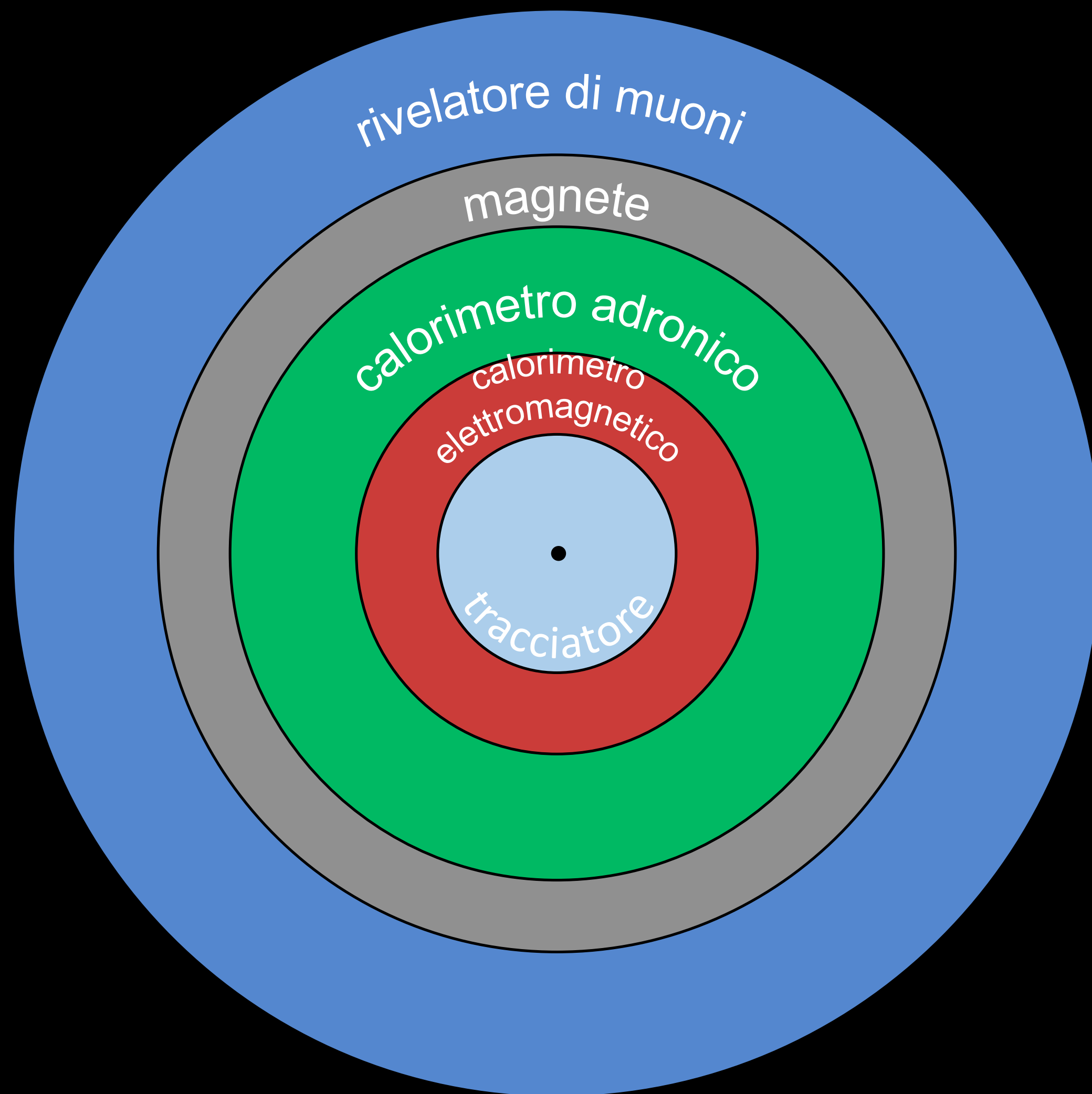
45 m

7000 Tonnellate



24 m

apparato di rivelazione ermetico



Rivelatore di Vertice o Tracciatore Interno
rivela le particelle cariche
e ne misura la quantità di moto

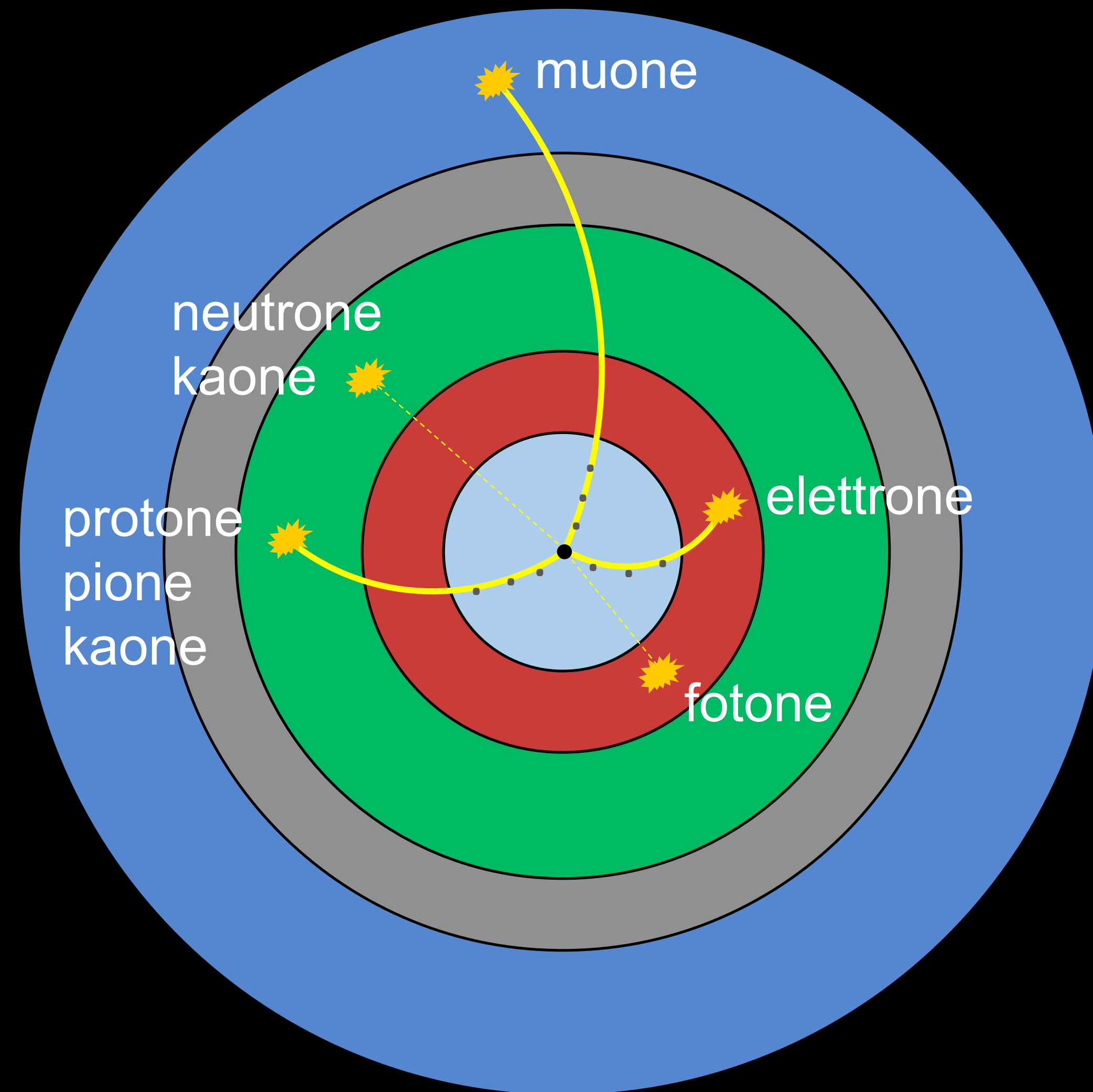
Calorimetro Elettromagnetico
rivela elettroni e fotoni
e ne misura l'energia

Calorimetro Adronico
rivela protoni, neutroni, pioni, kaoni
e ne misura l'energia

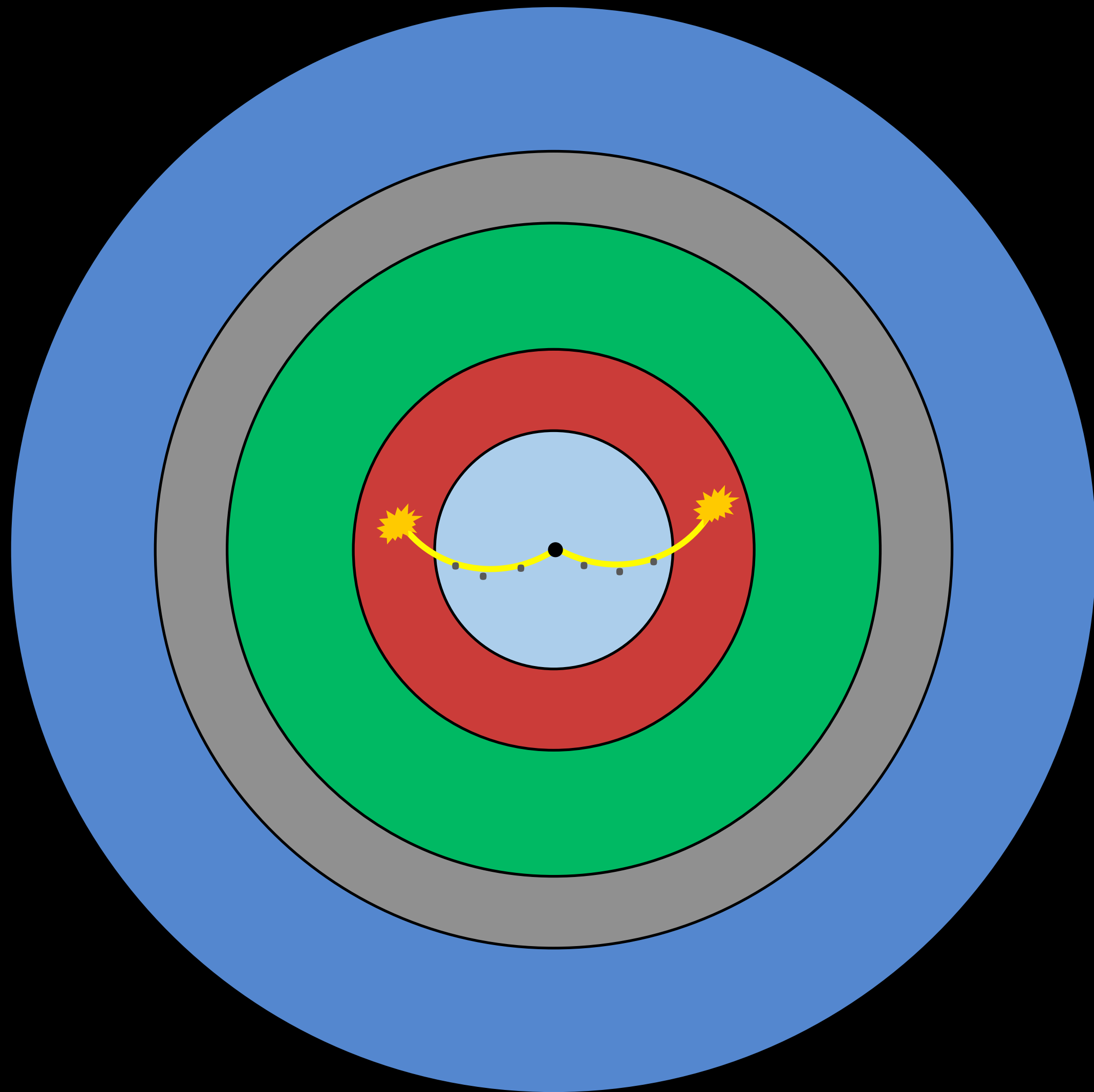
Magnete
curva le particelle cariche
e ne permette la misura della quantità di moto

Rivelatore di Muoni
rivela i muoni

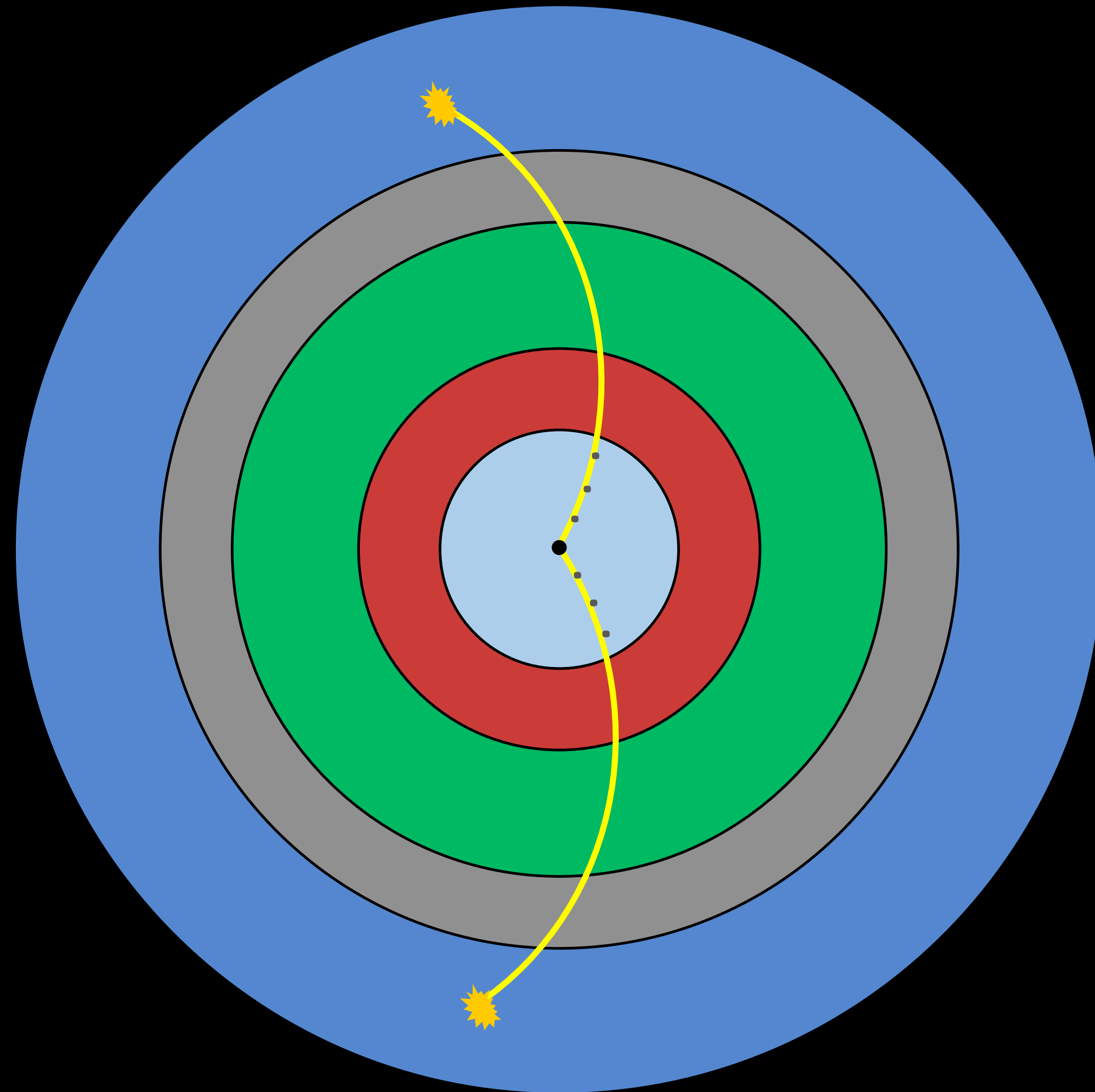
identificazione delle particelle



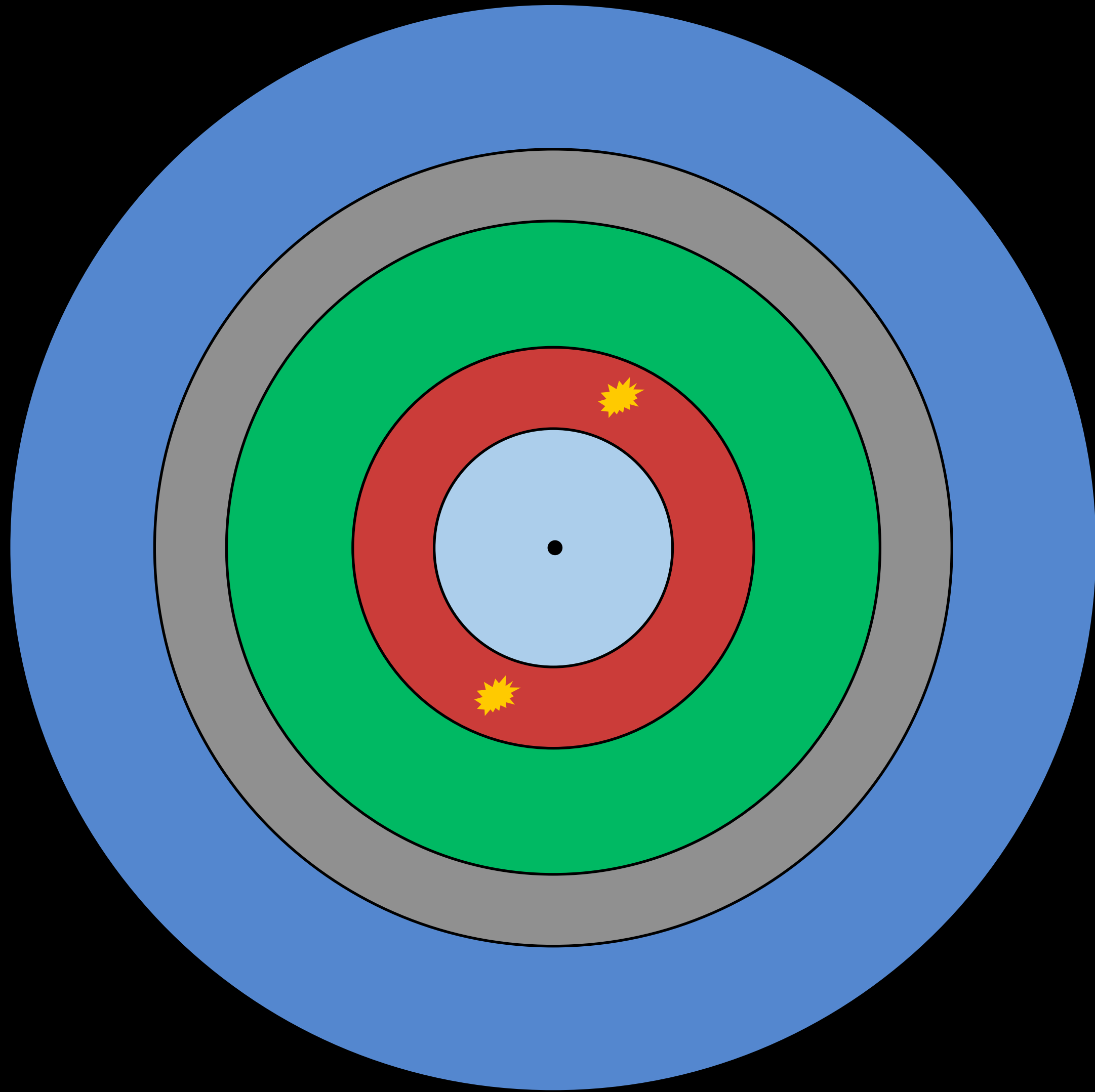
$$e^+ e^- \rightarrow e^+ e^-$$



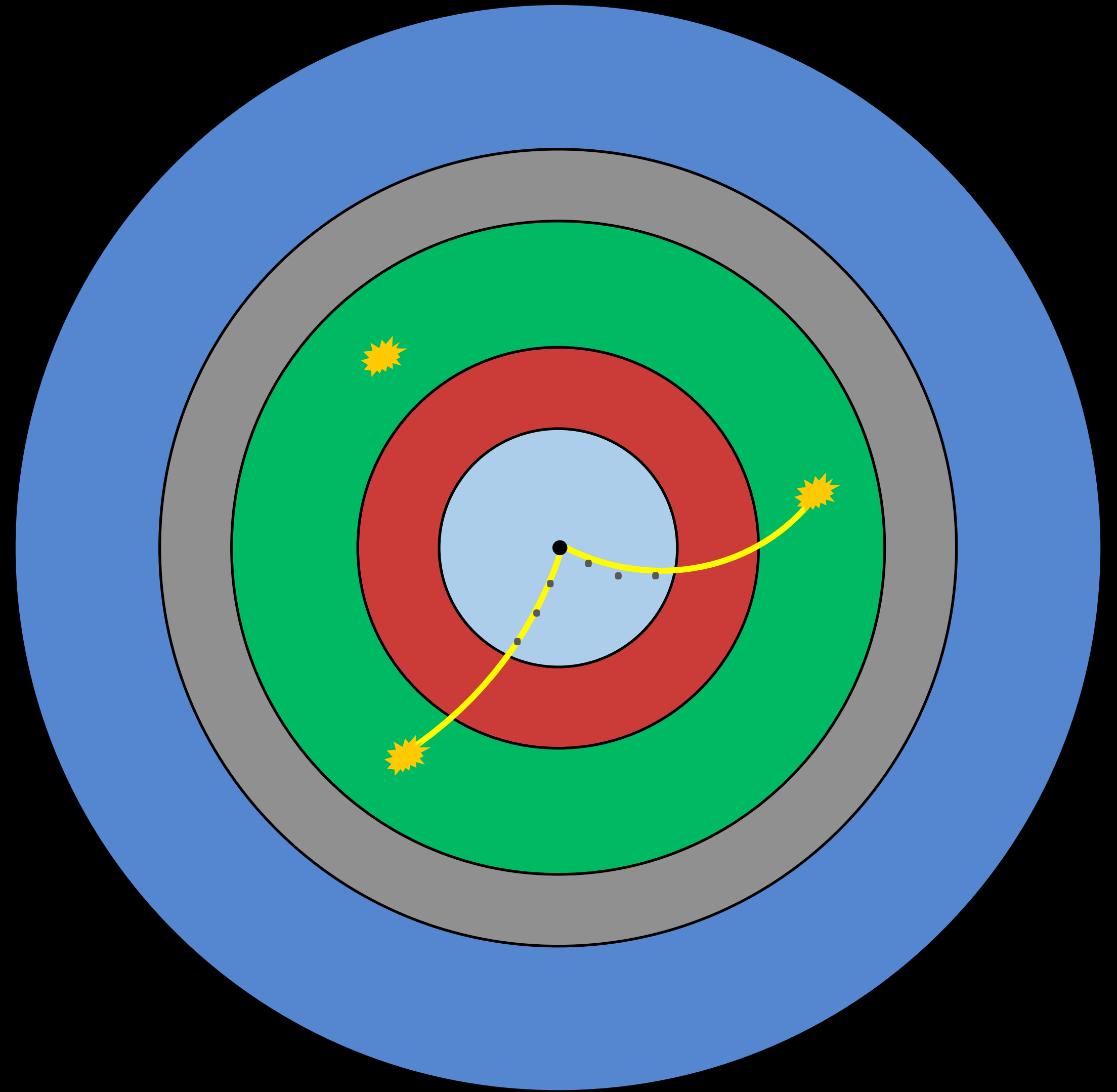
$$e^+ e^- \rightarrow \mu^+ \mu^-$$



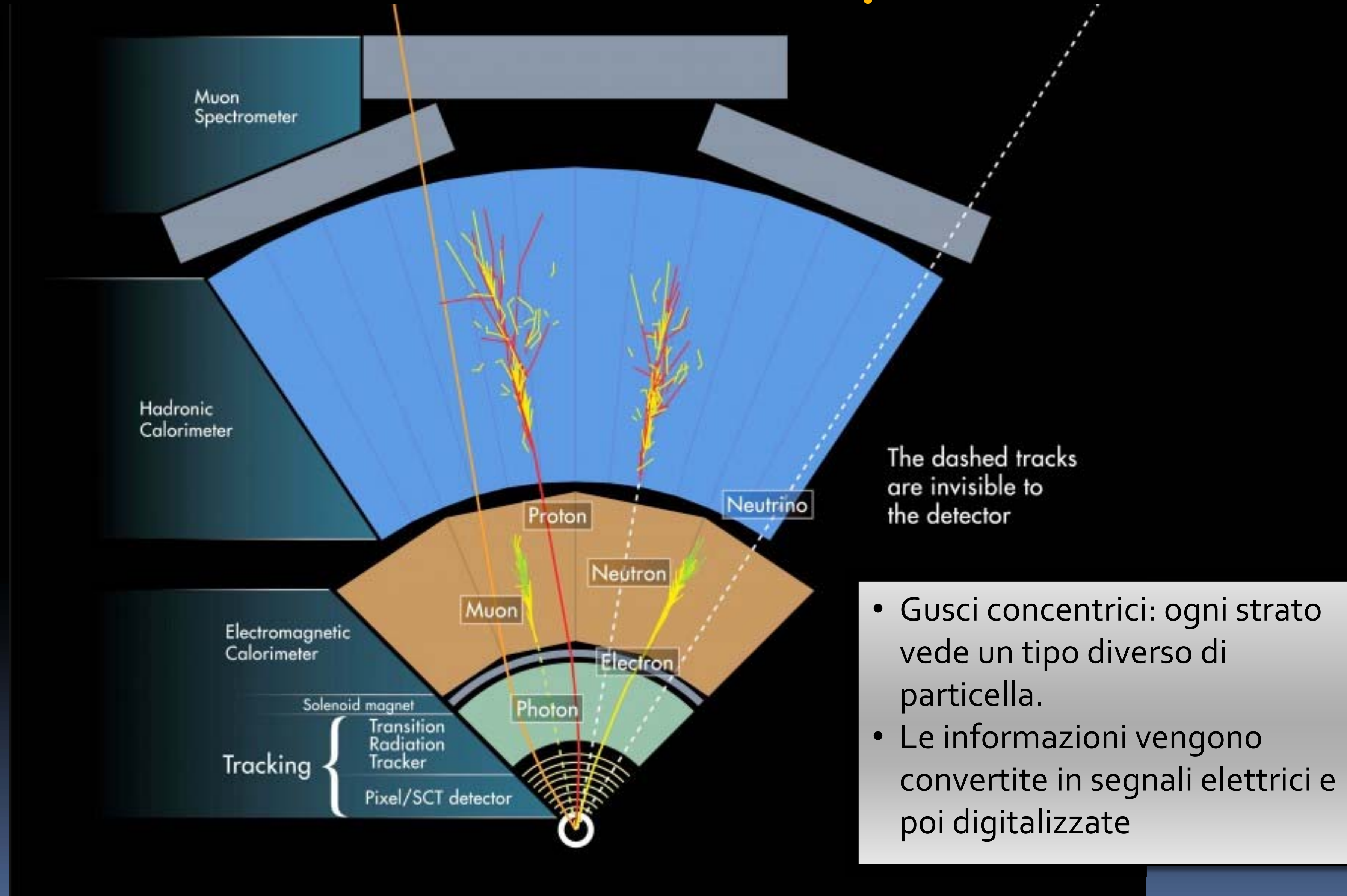
$$e^+ e^- \rightarrow \gamma \gamma$$



$$e^+ e^- \rightarrow \pi^+ \bar{p} n$$

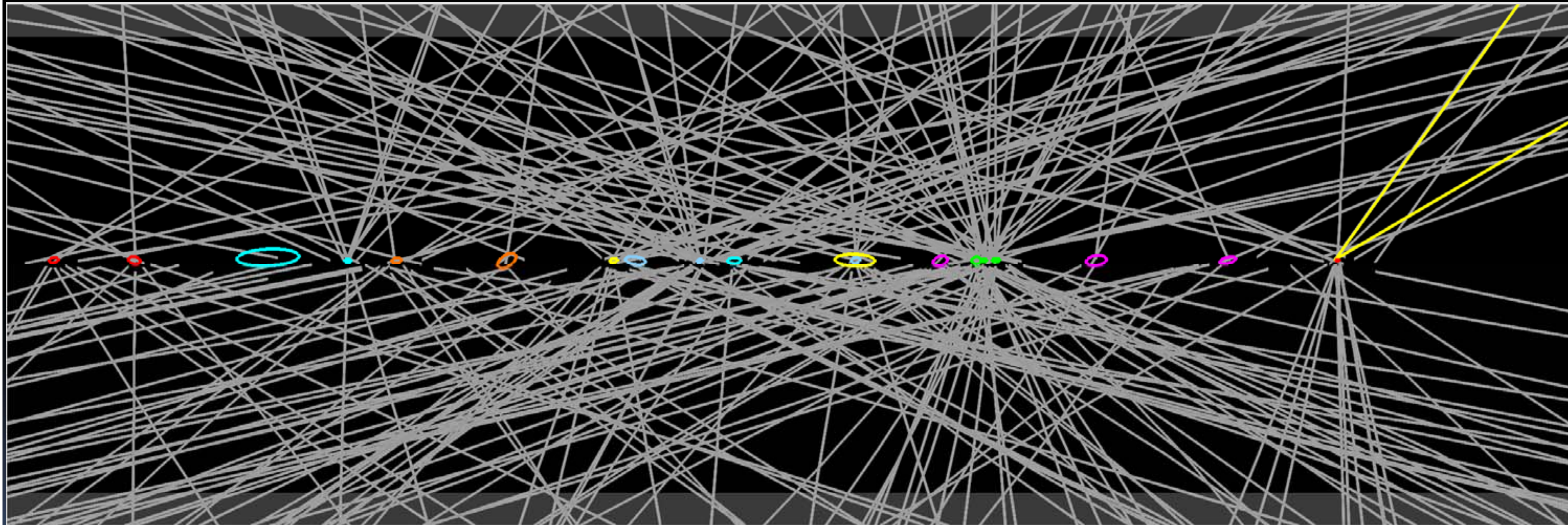


Come si fa a «vedere» una particella?



Quasi fatto...

Però i dati che escono dai rivelatori sono grezzi, difficili da decifrare ad occhio. In più se ne producono **milioni al secondo...**



Elaborazione dei dati di LHC



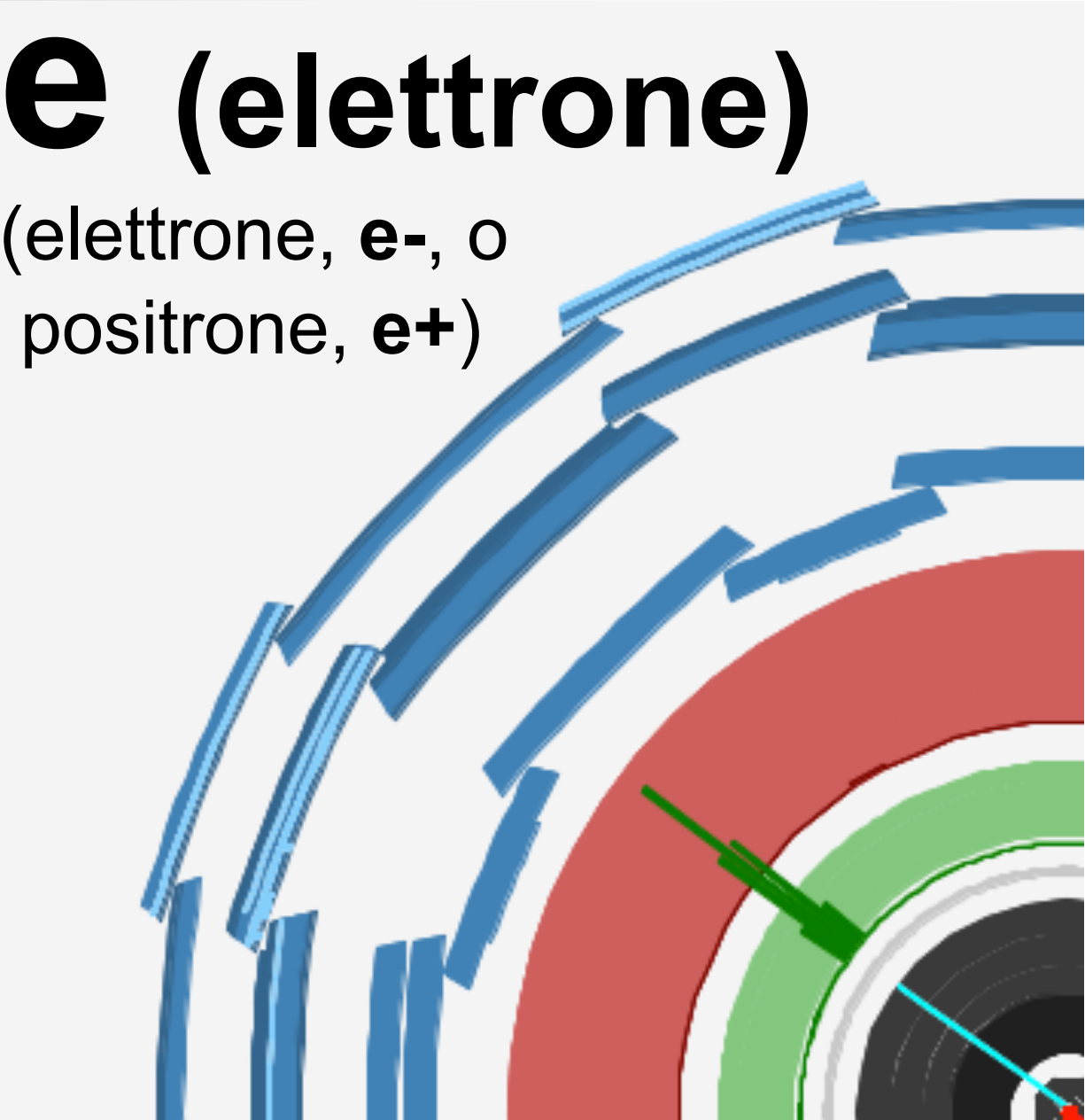
Risultato della ricostruzione

ATLAS
EXPERIMENT
<http://atlas.ch>

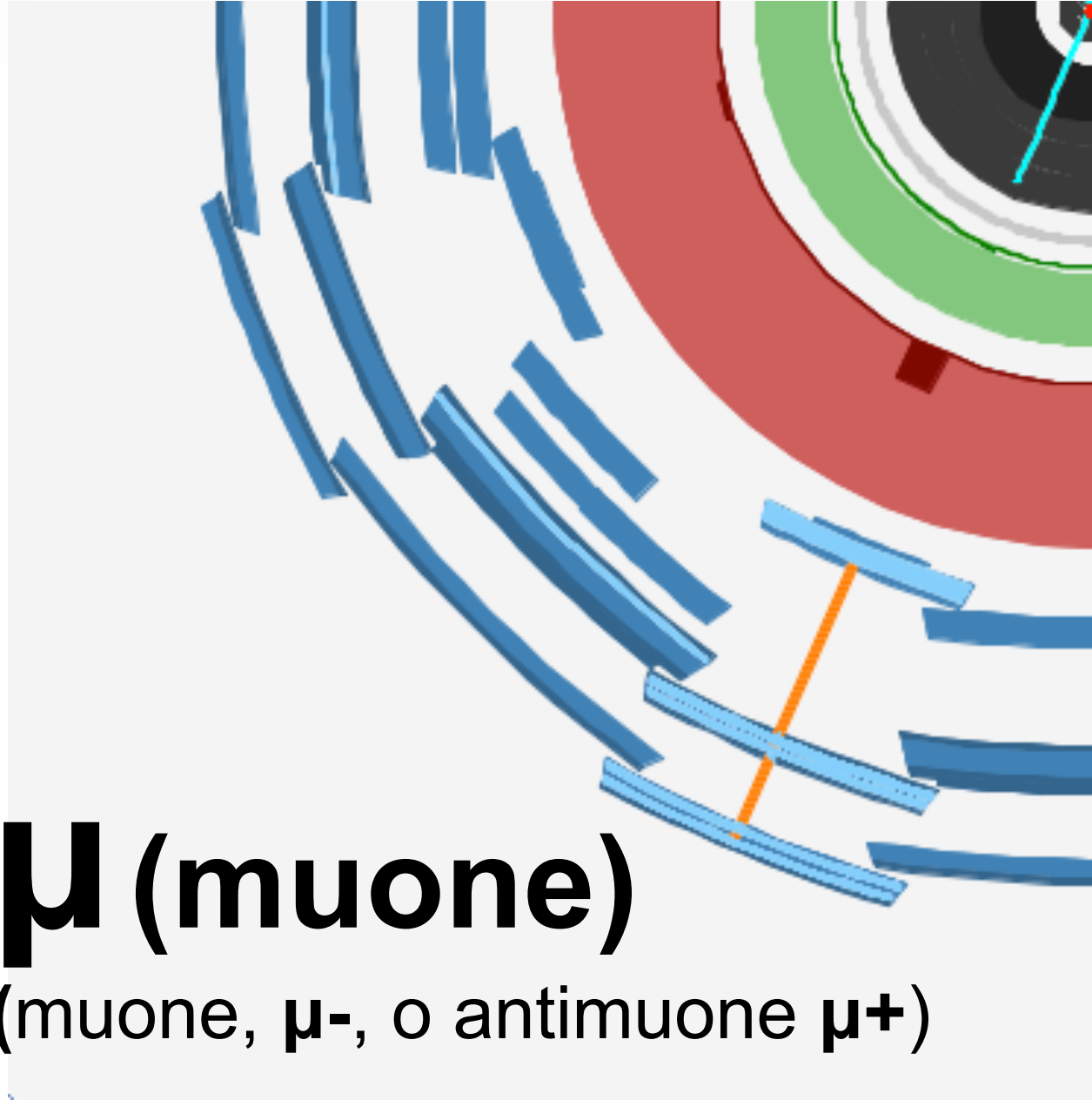
Proprietà fisiche
delle particelle

Run: 204153
Event: 35369265
2012-05-30 20:31:28 CEST

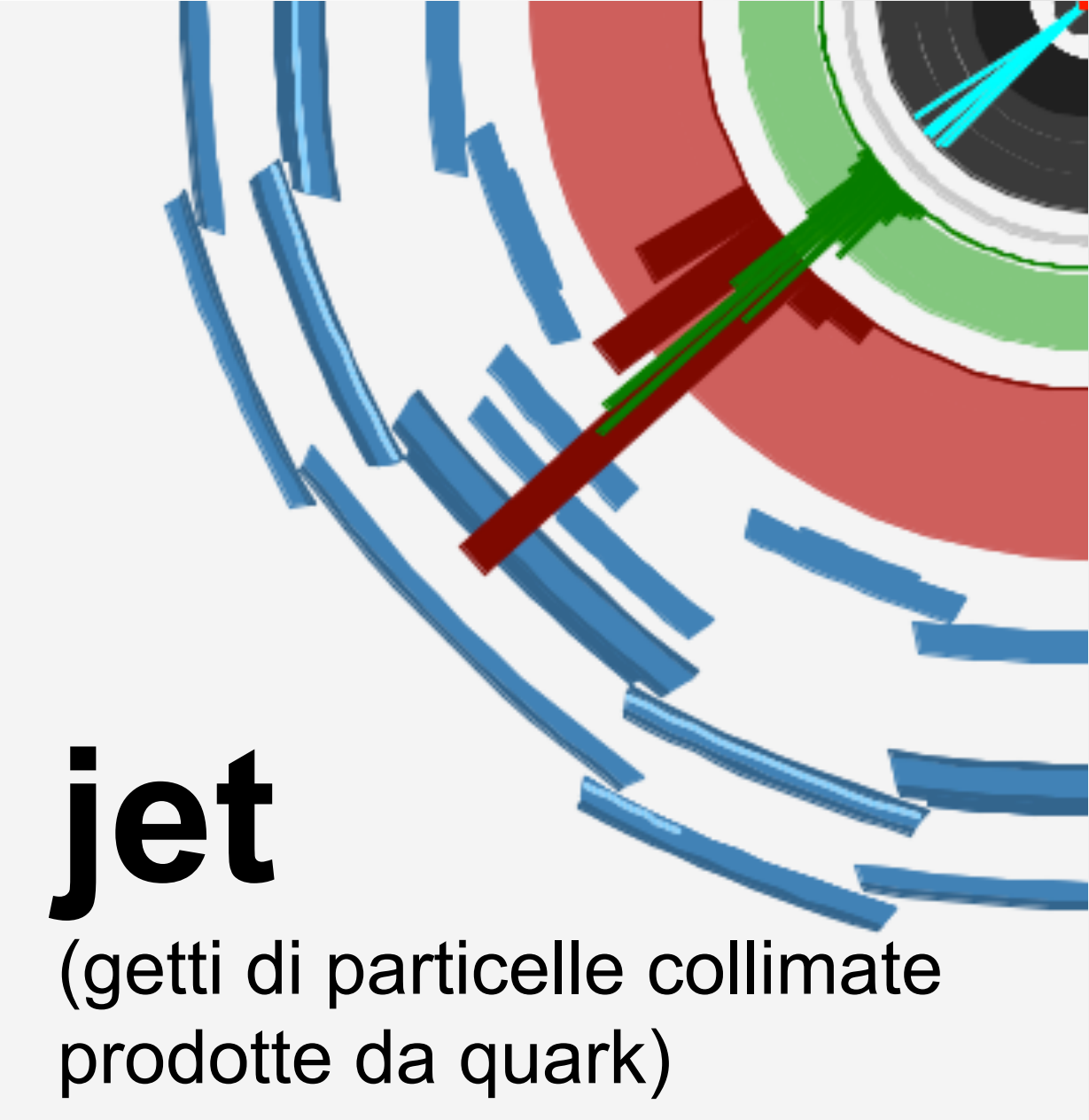
“Orme” da cercare



e (elettrone)
(elettrone, e^- , o
positrone, e^+)



μ (muone)
(muone, μ^- , o antimuone μ^+)



jet
(getti di particelle collimate
prodotte da quark)

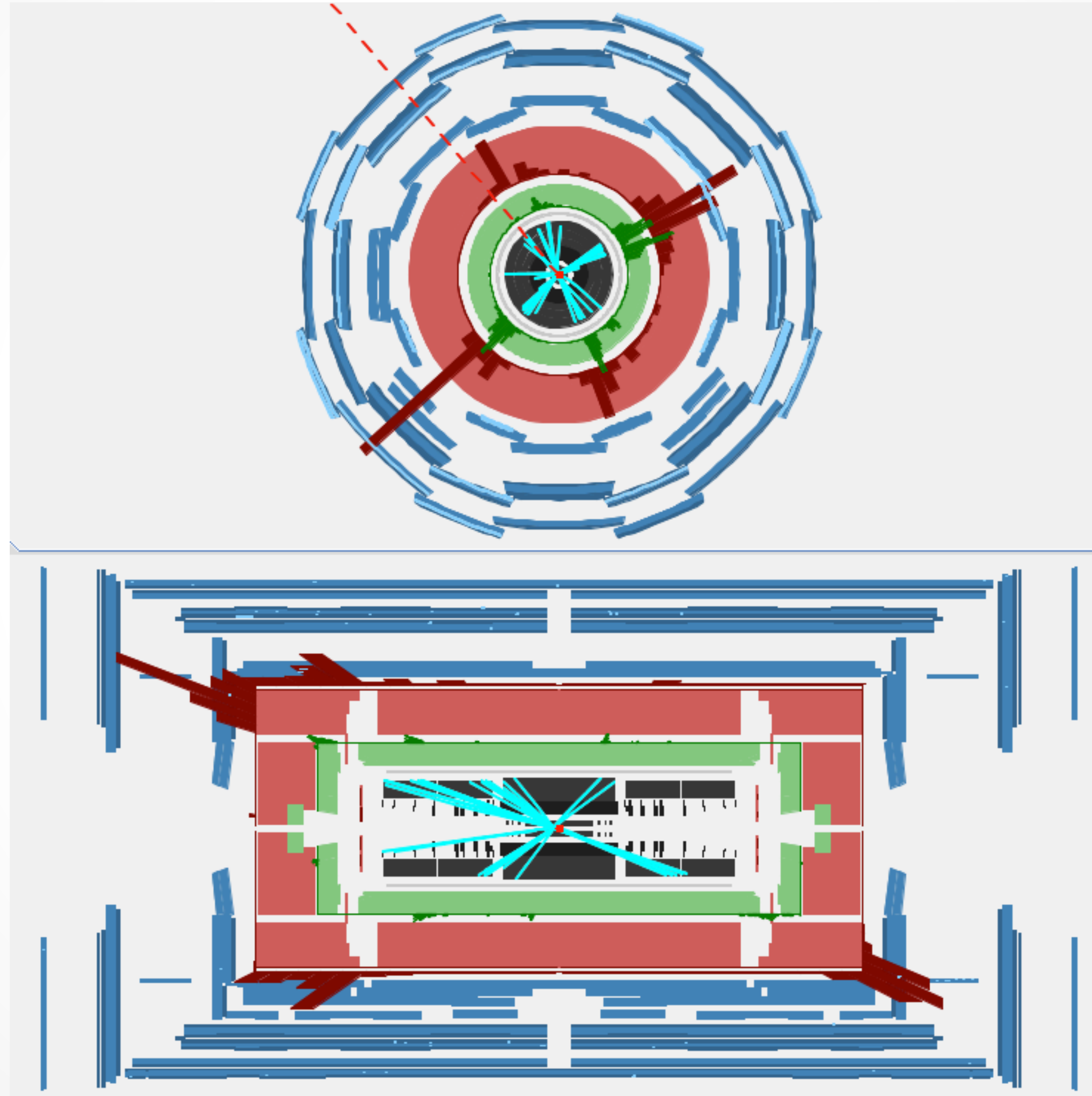
	e	μ	jet	v (neutrino)
Rivelatori Traccianti				
Calorimetro elettromagnetico				
Calorimetro adronico				
Rivelatore di muoni				
Energia “mancante”				   

Come nell’esercizio precedente cerchiamo (stavolta senza differenziare per carica):

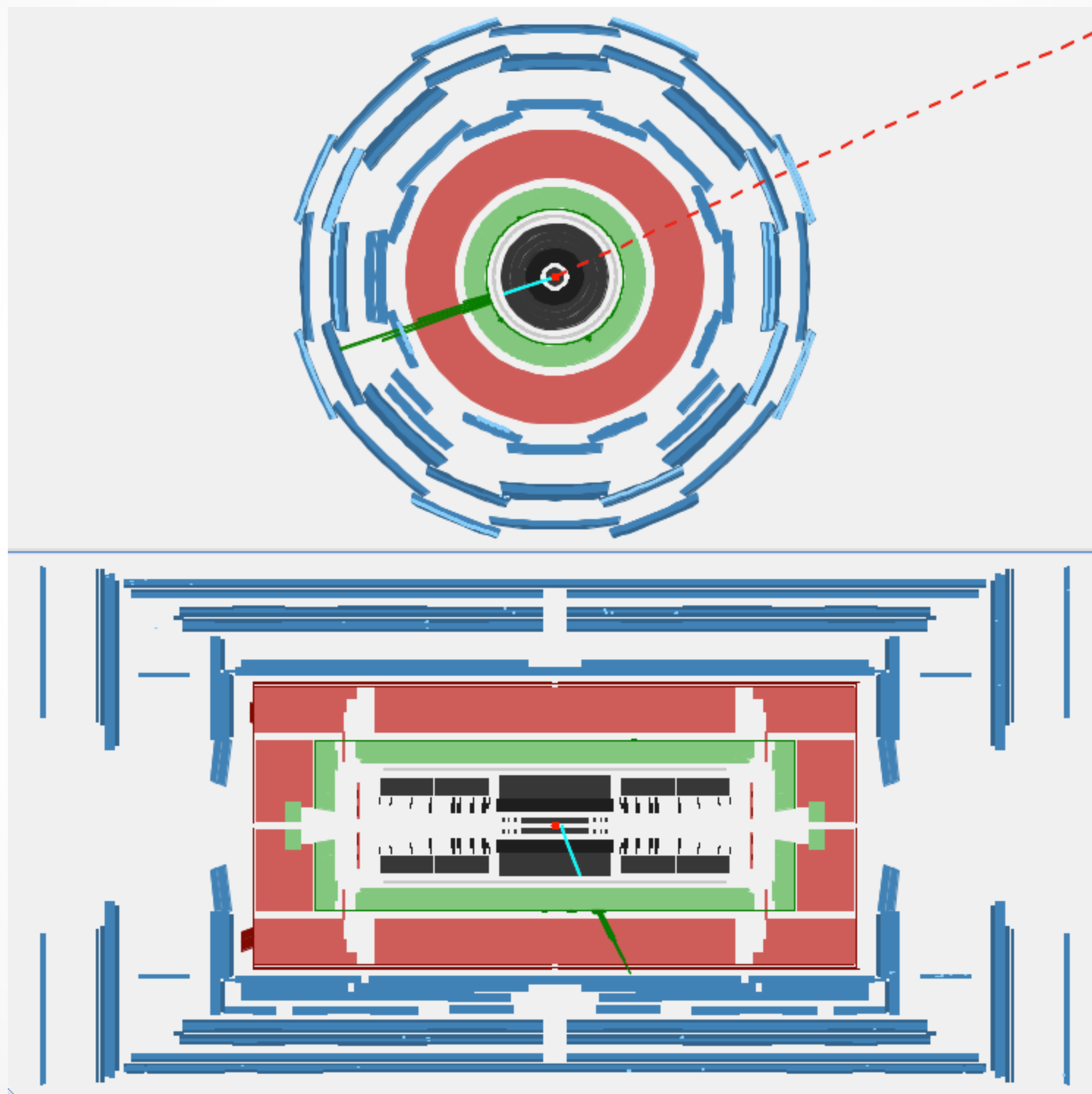
$Z \rightarrow \mu\mu$ $Z \rightarrow ee$ $W \rightarrow ev$ $W \rightarrow \mu\nu$

• $H \rightarrow ZZ \rightarrow \mu\mu\mu\mu$ / $eeee$ / $ee\mu\mu$

Rappresentazione grafica di una collisione registrata dal rivelatore



$$W \rightarrow e \nu$$



$Z \rightarrow \mu\mu$

