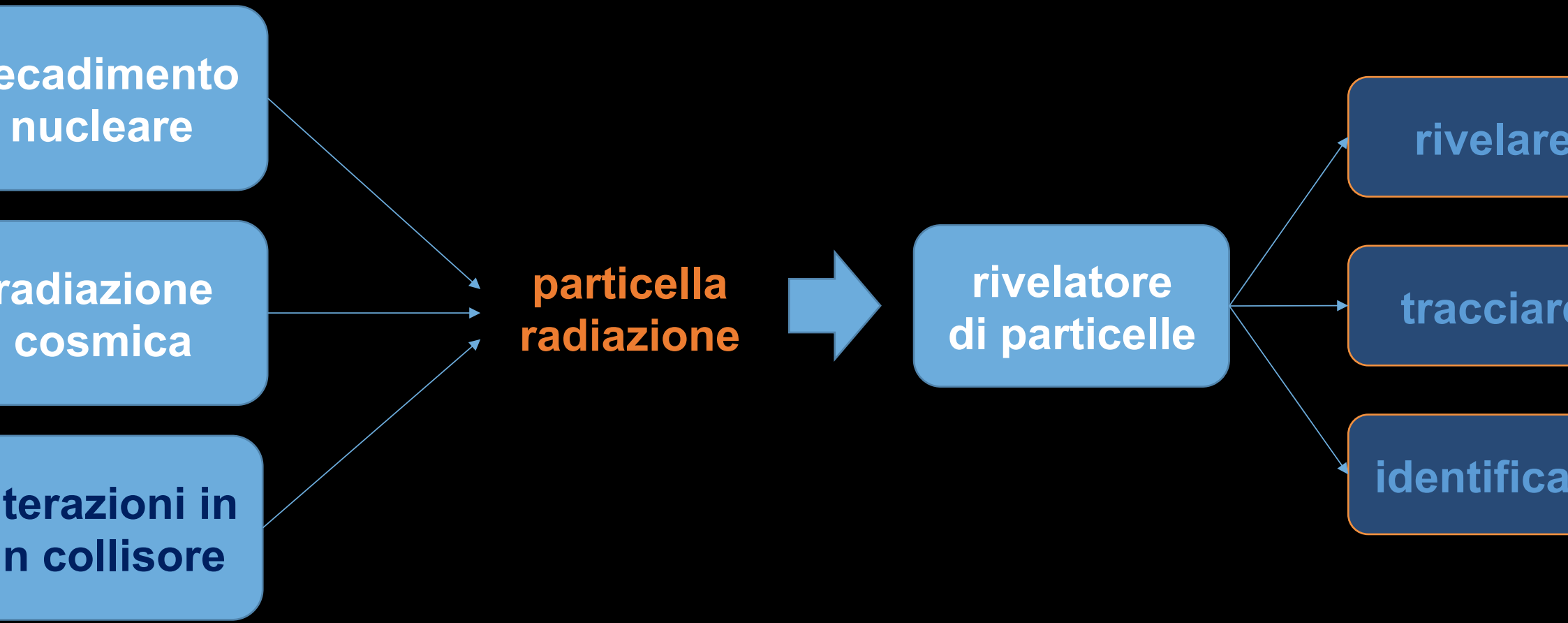
Rivelatori di Particelle

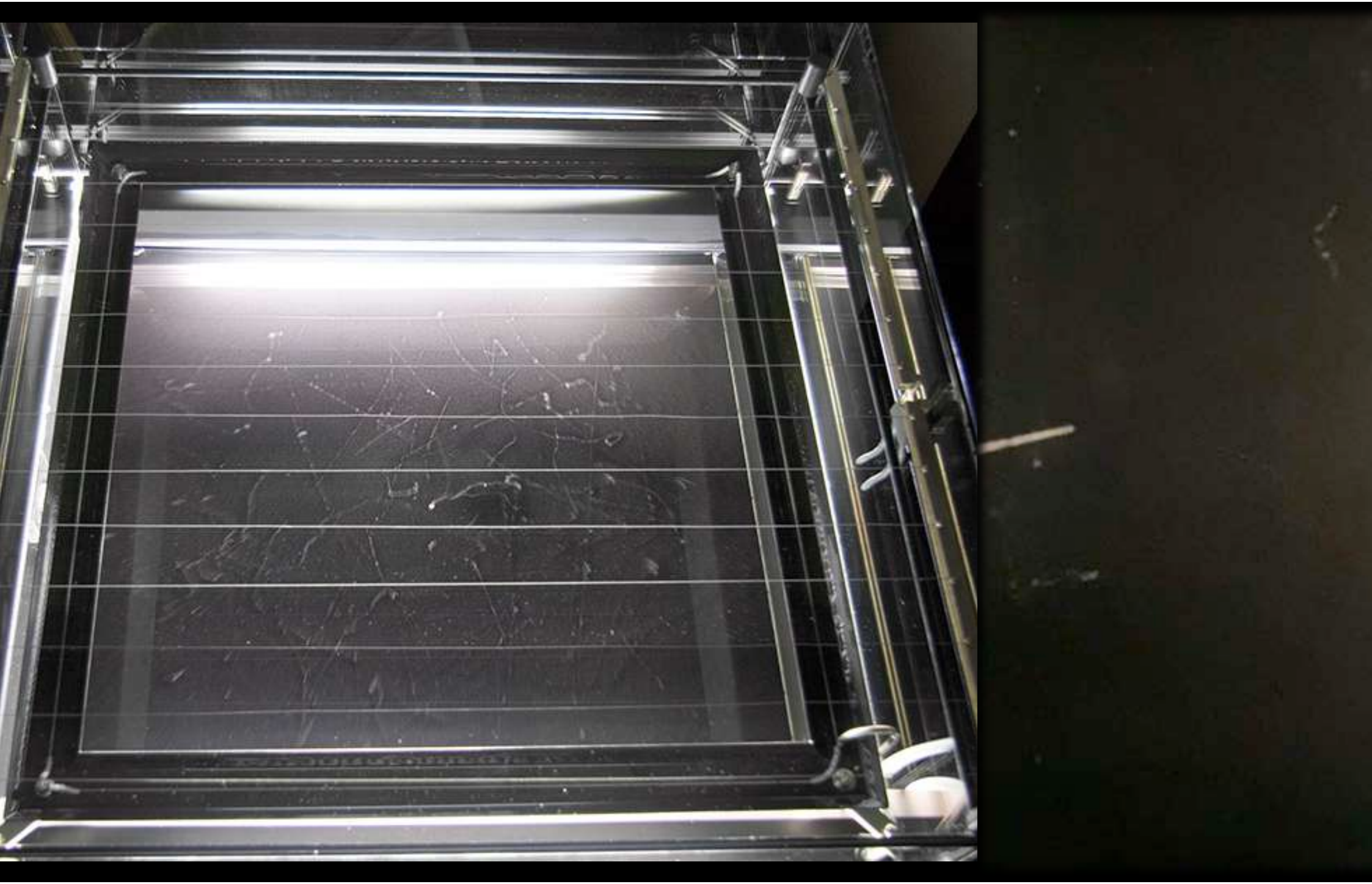
Danilo Domenici

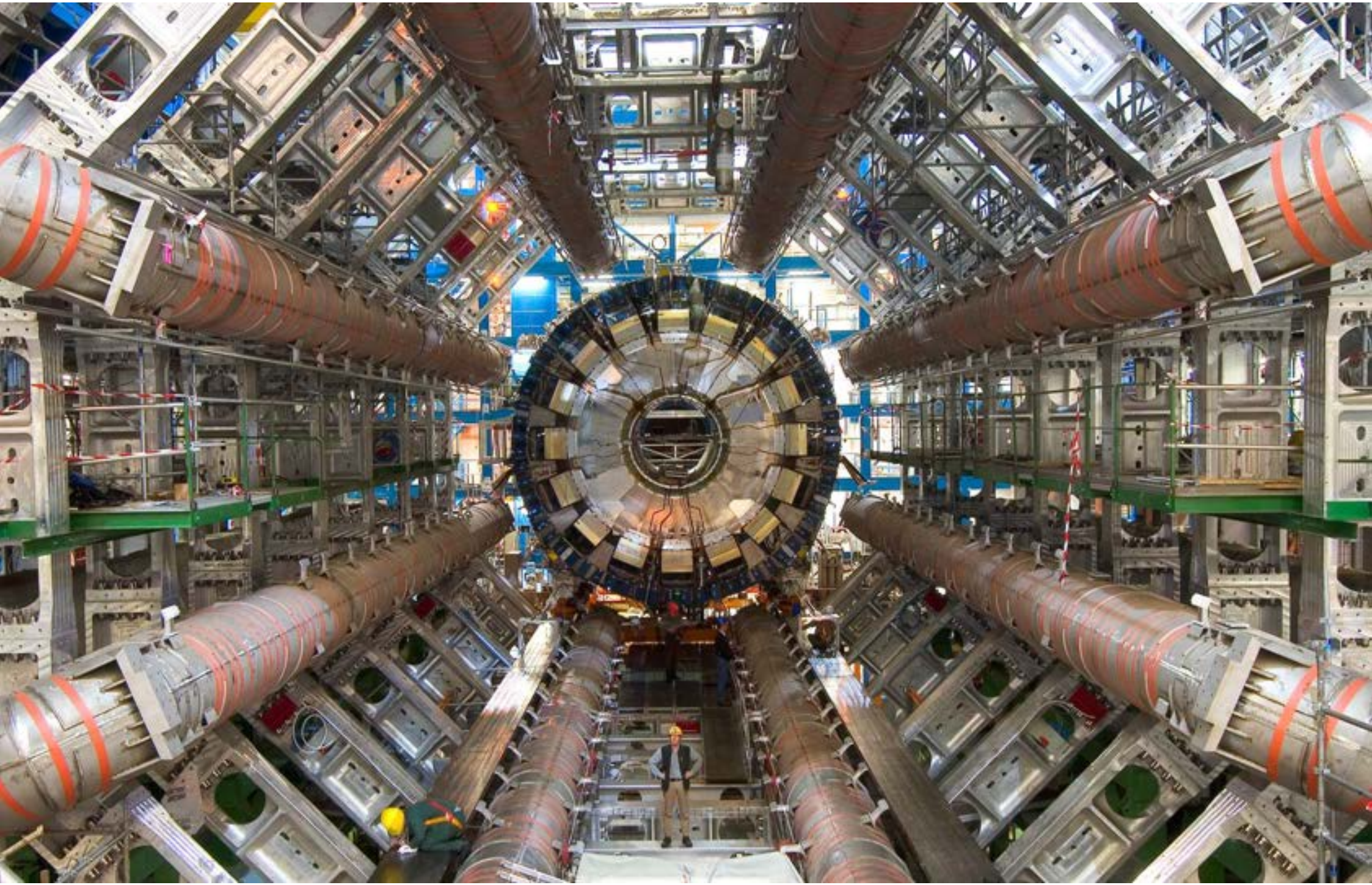
mappa concettuale

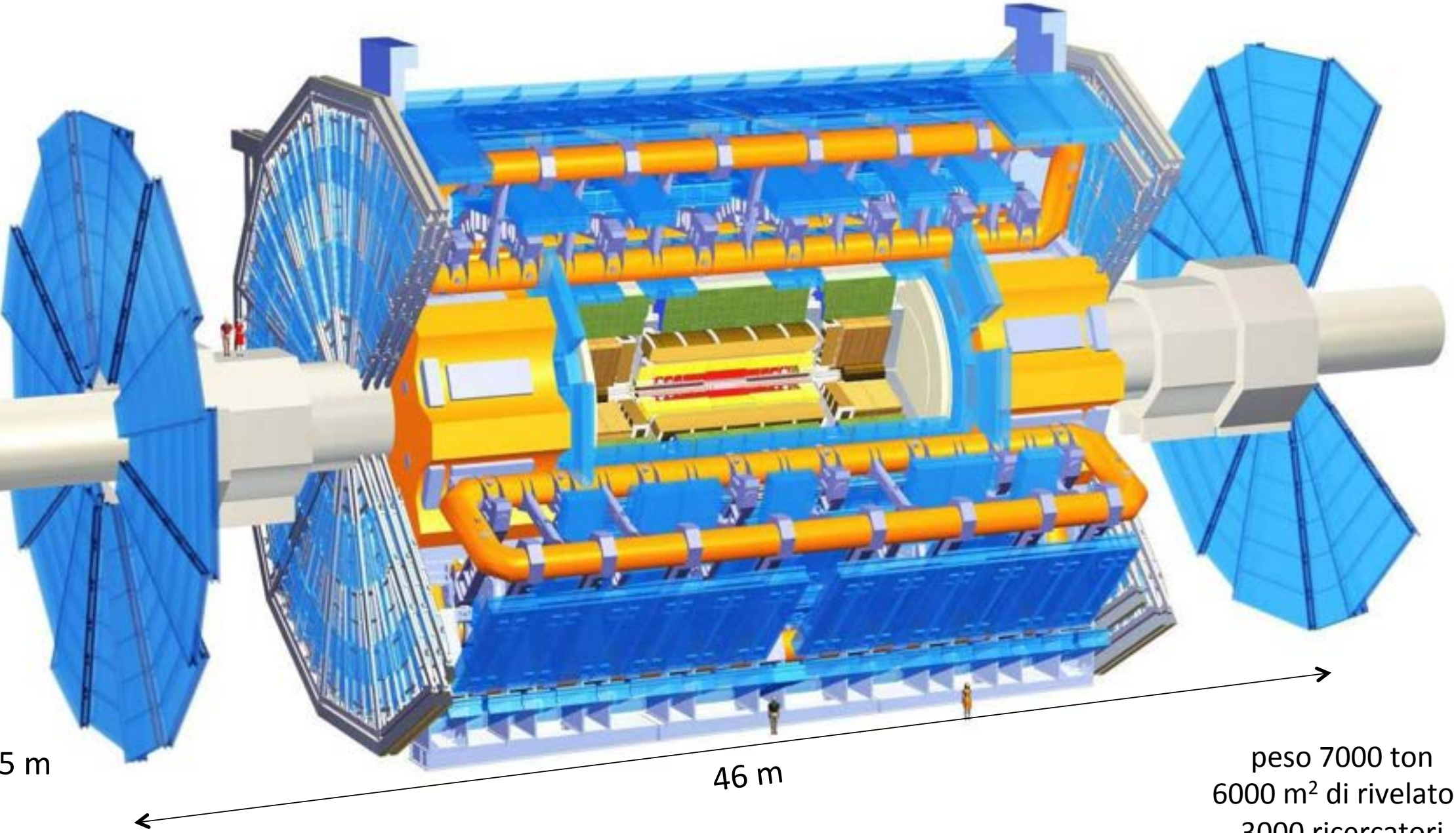



ТЕРРА-П
4.95 μSv/h
ЕКОТЕСТ

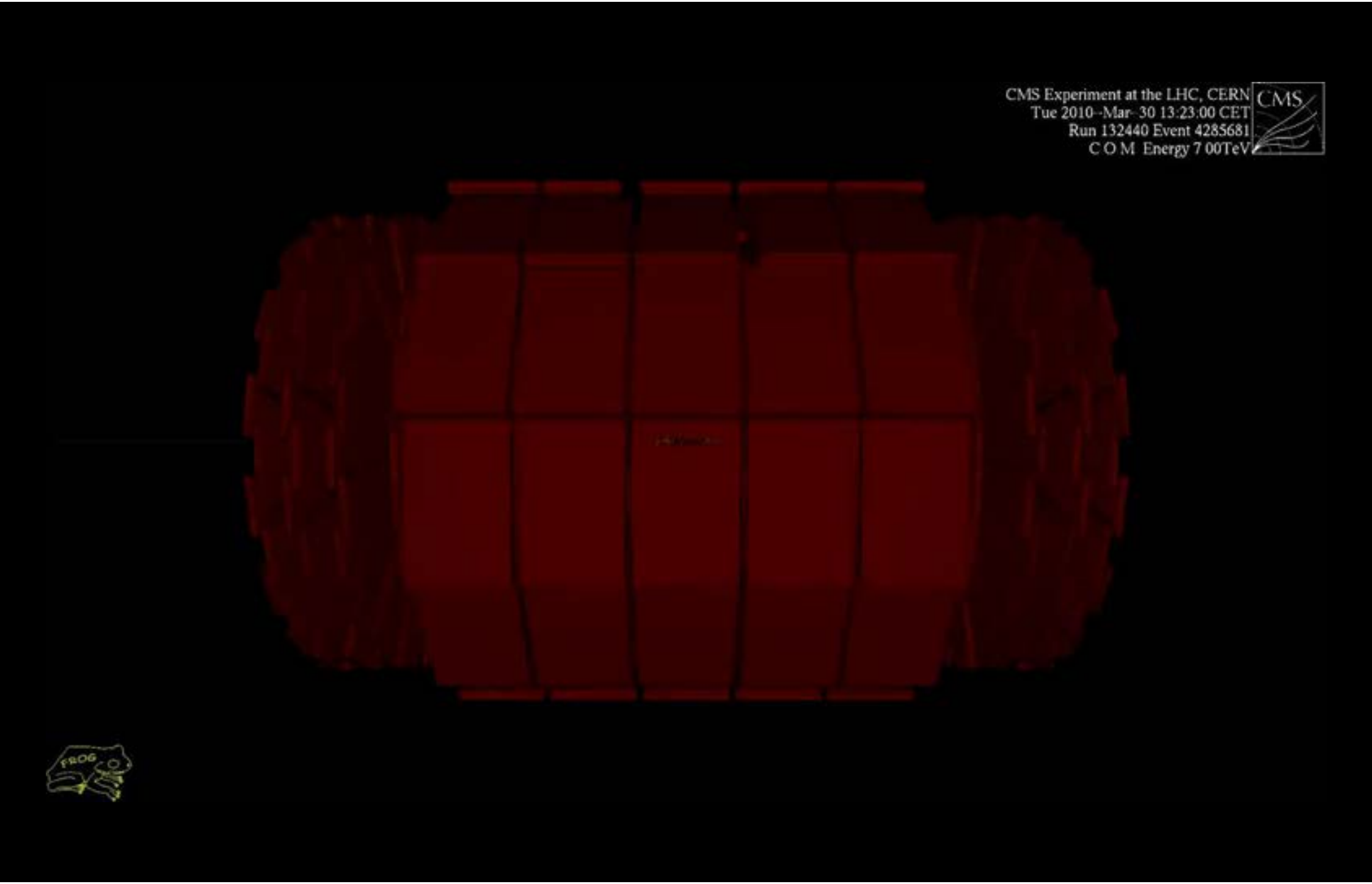

KRUSTY
BRAND
GEIGER
COUNTER



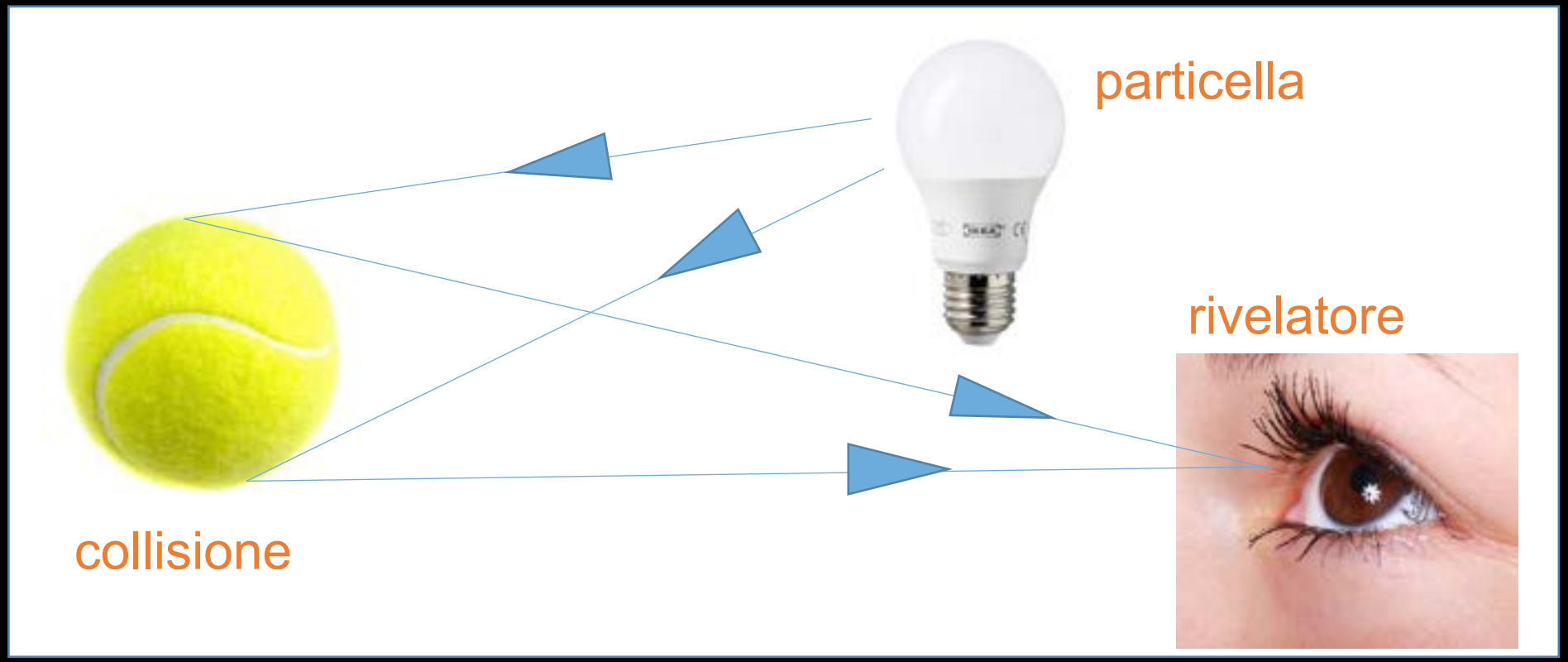




peso 7000 ton
6000 m^2 di rivelatori
3000 ricercatori
38 paesi del mondo

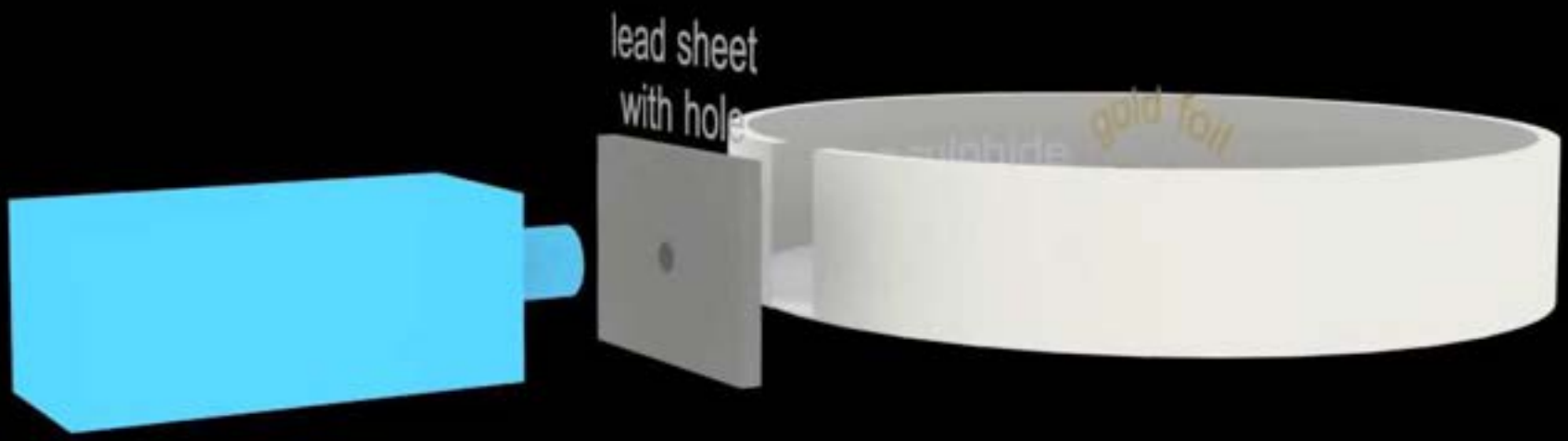

CMS Experiment at the LHC, CERN
Tue 2010--Mar--30 13:23:00 CET
Run 132440 Event 4285681
C O M Energy 7 00TeV
CMS
FROG

perchE’ facciamo collidere le particelle?

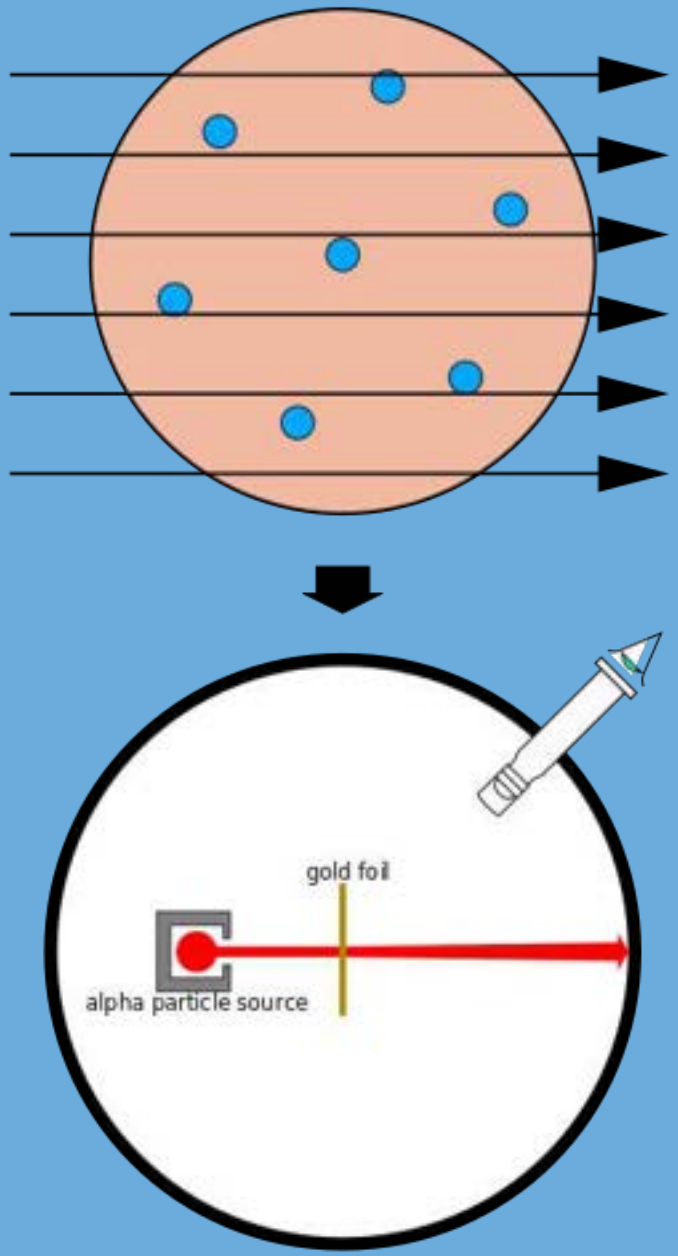


per capire come è fatta la materia

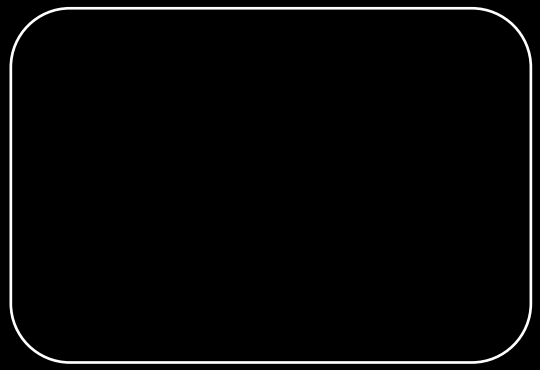
esperimento di rutherford



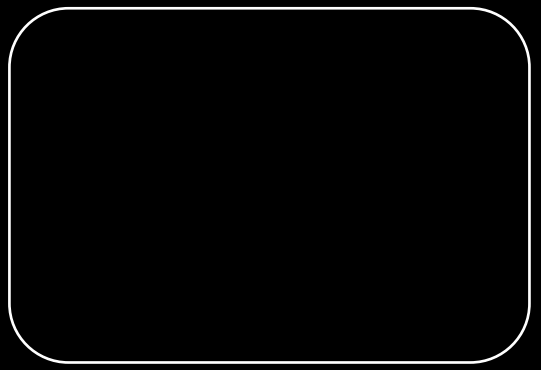
THOMSON MODEL



perchE’ le facciamo collidere a energia sempre piu’ alta?

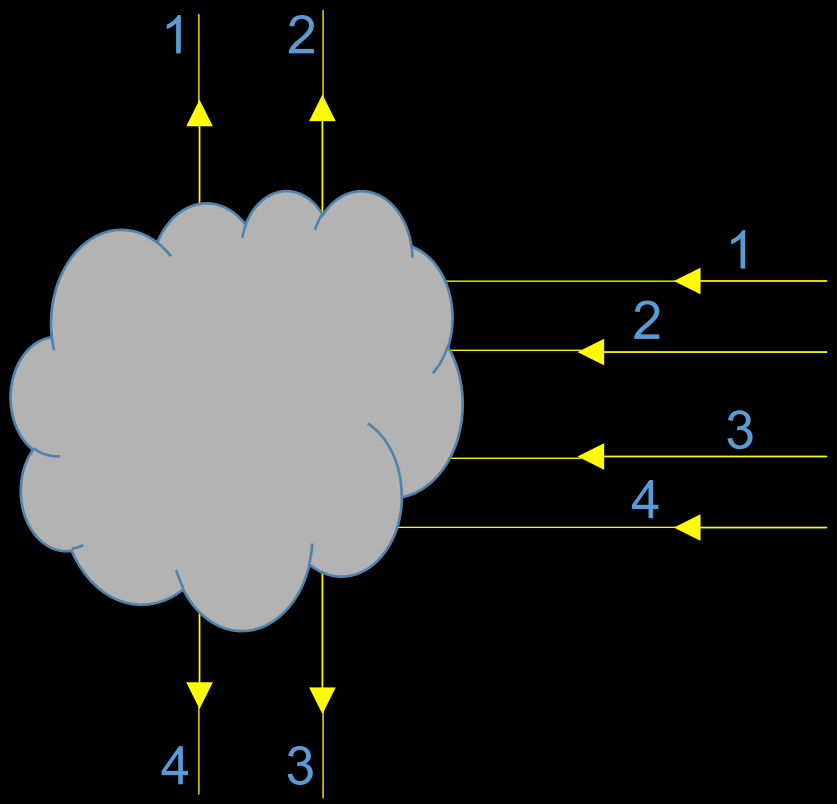


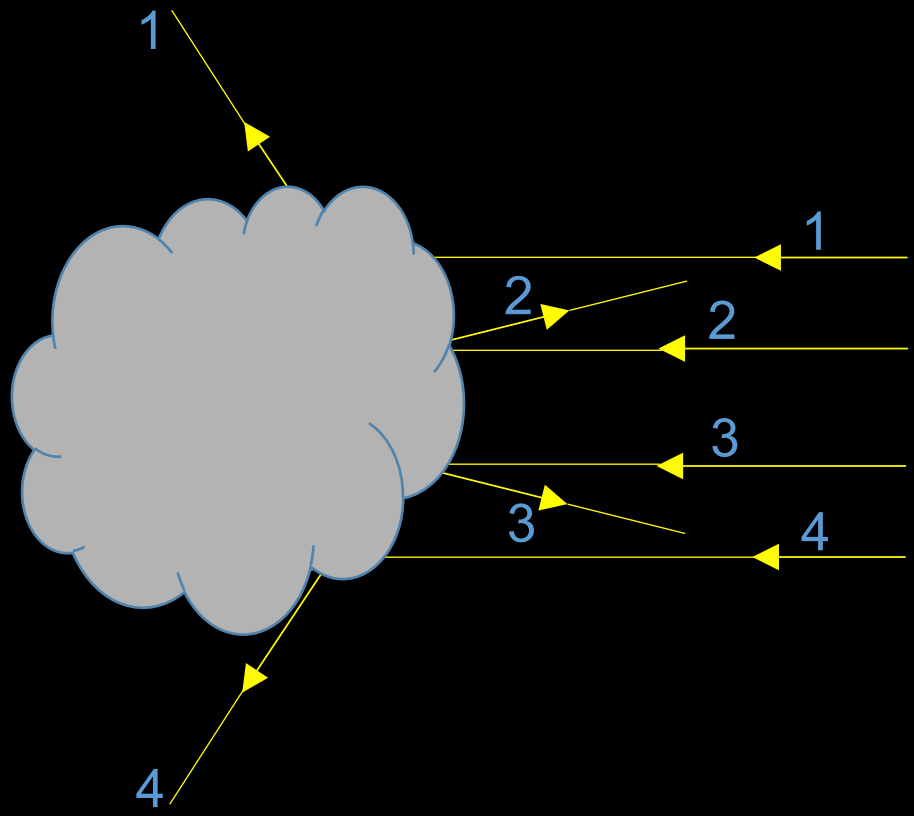
diminuisce la lunghezza
che posso studiare

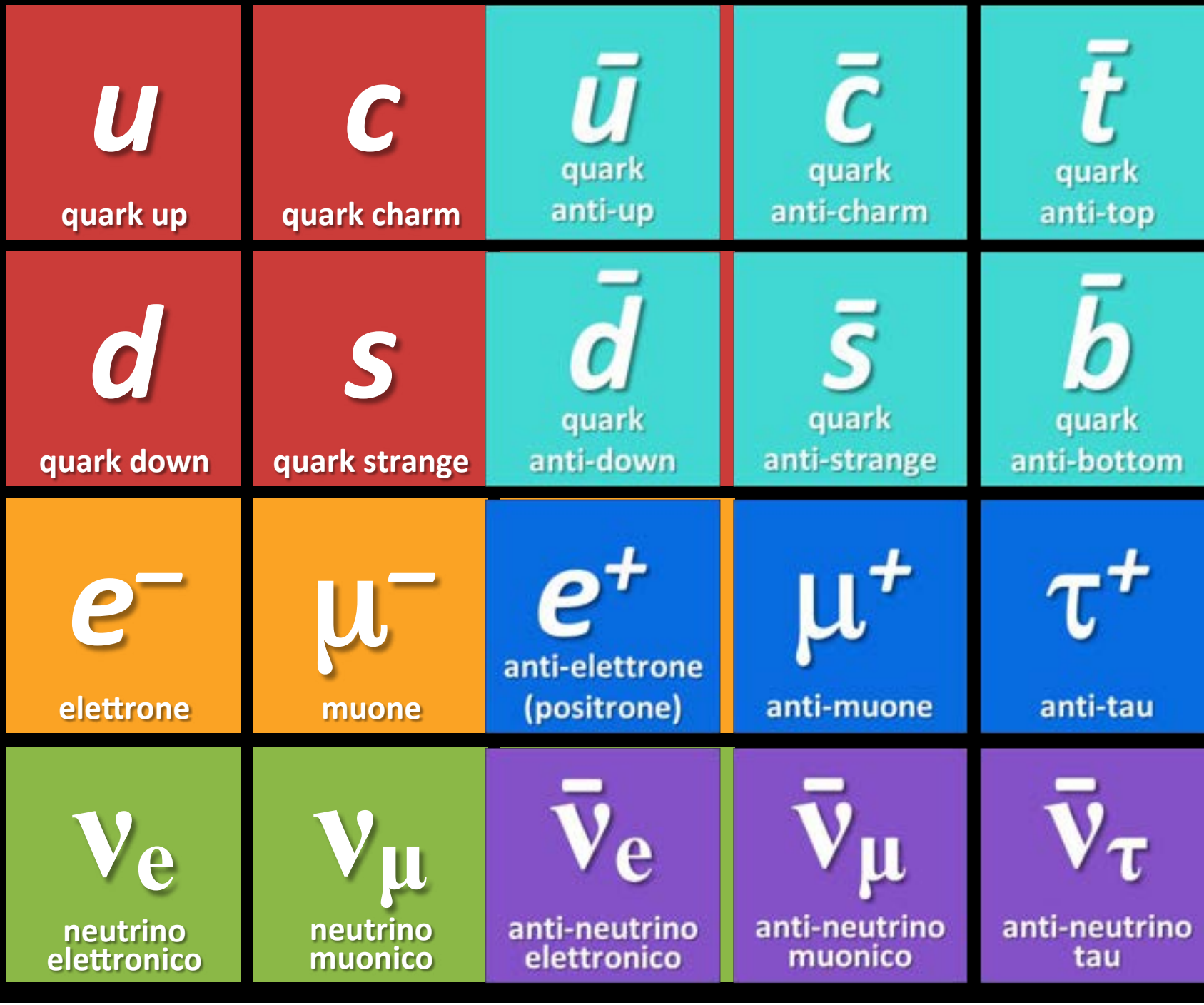


aumenta la nuova materia
che posso creare

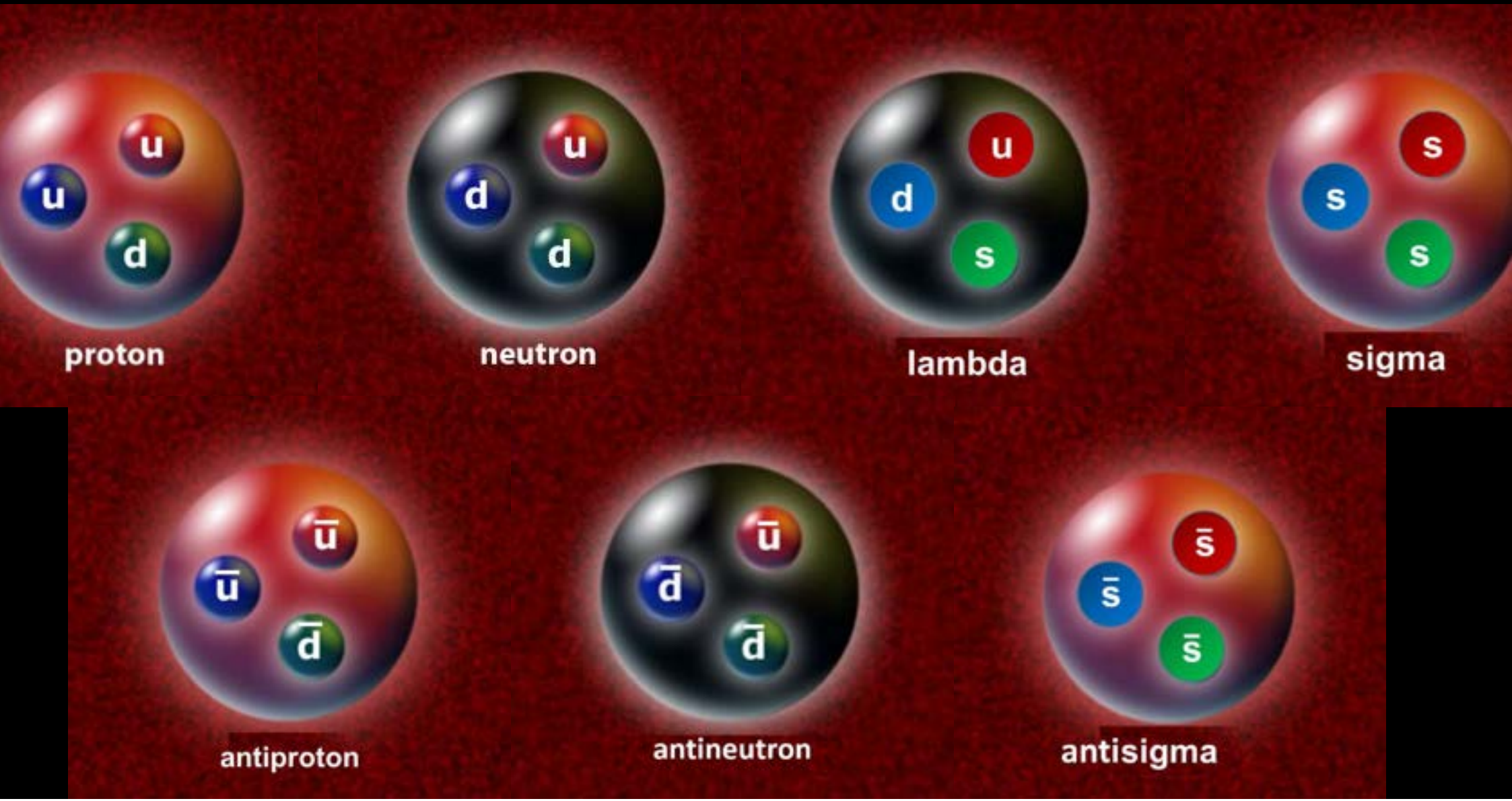
come vediamo l’invisibile



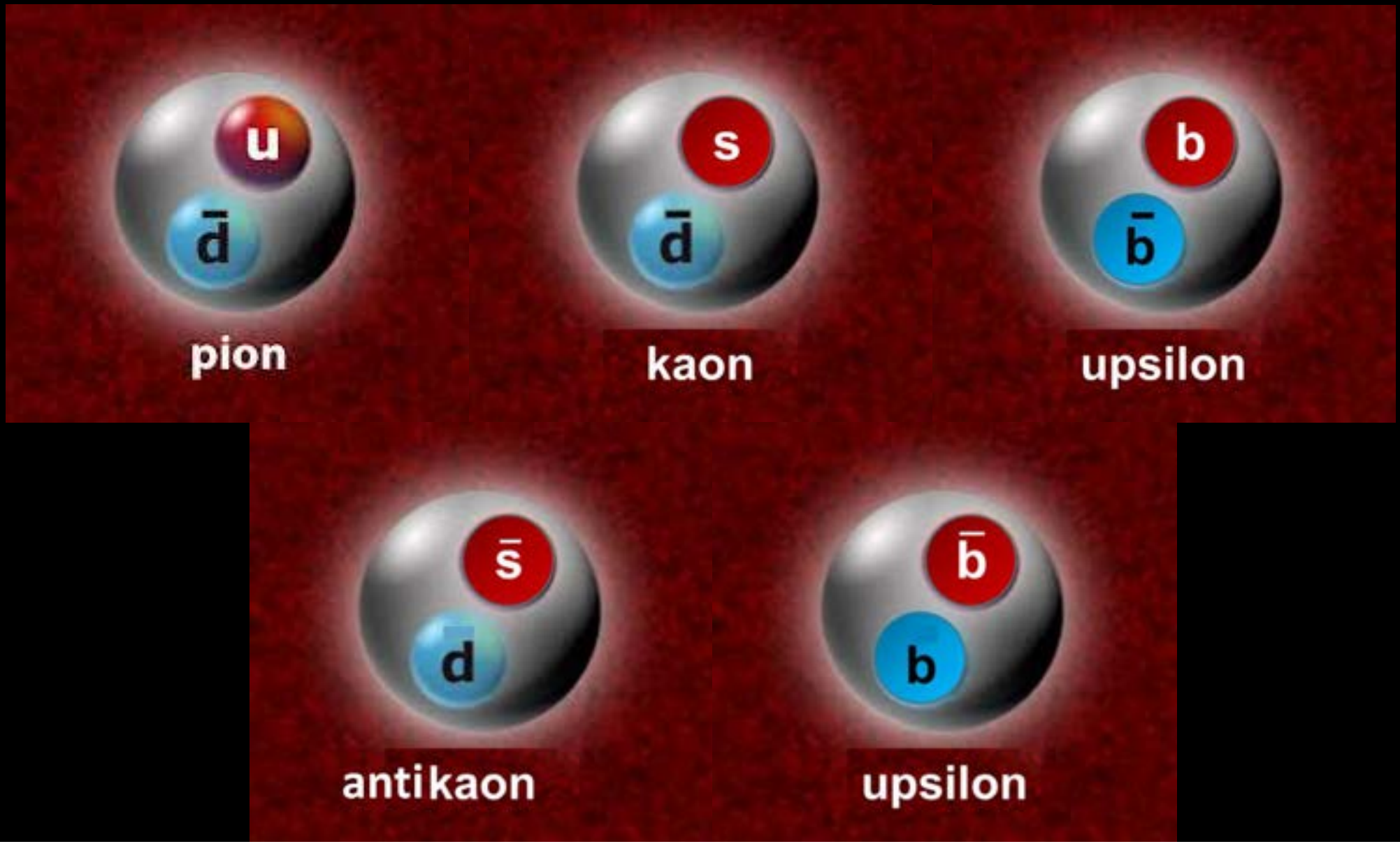



u
quark up
c
quark charm
$\bar{u}$
quark anti-up
$\bar{c}$
quark anti-charm
$\bar{t}$
quark anti-top
d
quark down
s
quark strange
$\bar{d}$
quark anti-down
$\bar{s}$
quark anti-strange
$\bar{b}$
quark anti-bottom
e^-
elettrone
μ^-
muone
e^+
anti-elettrone (positrone)
μ^+
anti-muone
τ^+
anti-tau
ν_e
neutrino elettronico
ν_μ
neutrino muonico
$\bar{\nu}_e$
anti-neutrino elettronico
$\bar{\nu}_\mu$
anti-neutrino muonico
$\bar{\nu}_\tau$
anti-neutrino tau

Barioni - 3 quark

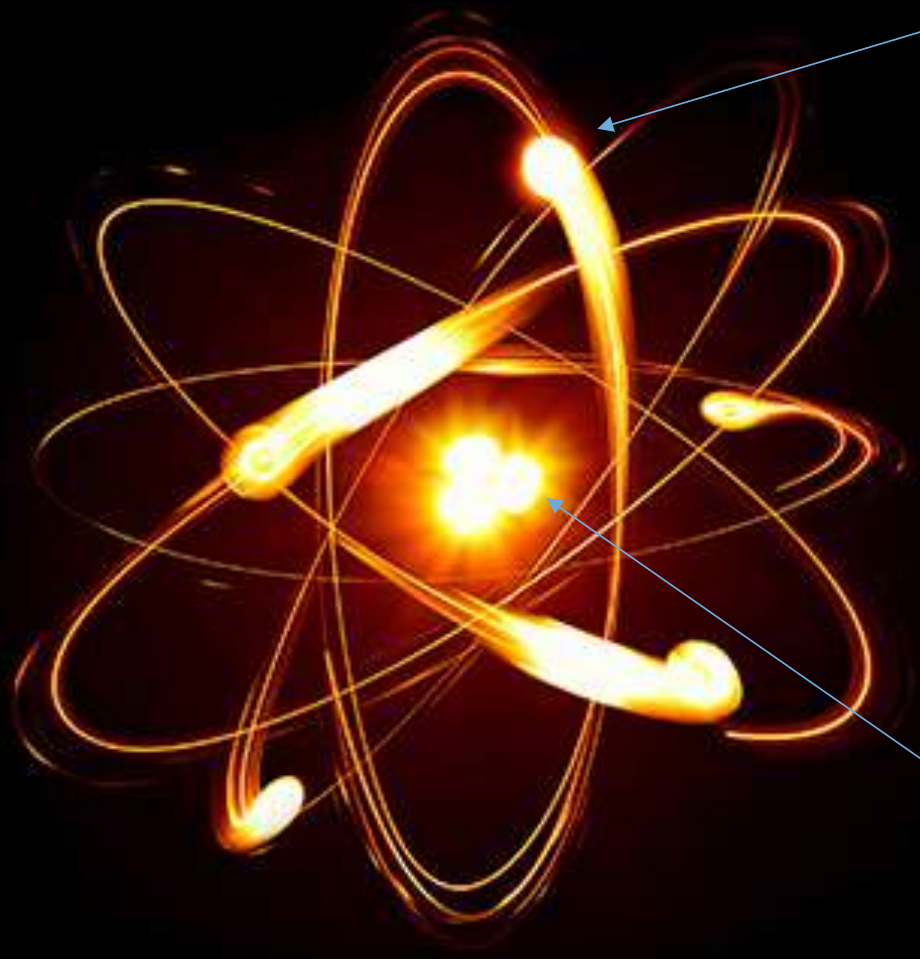


Mesoni - 1 quark 1 antiquark



interazione radiazione-materia

tipi diversi
di particelle
possono interagire
con gli elettroni
o con il nucleo



elettroni
carica elettrica negativ

nucleo
carica elettrica positi
carica forte

interazione radiazione-materia

particelle direttamente rivelabili

e	p	n	γ
elettrone	protone	neutrone	fotone

particelle stabili

μ	π	K
muone	pione	kaone

particelle con vita media > 10^{-10} s

tutte le particelle con vita media < 10^{-10} s
si identificano attraverso i loro prodotti di decadimento

interazione radiazione-materia

particelle e antiparticelle direttamente rivelabili

interazione radiazione-materia

urti con gli elettroni – forza elettromagnetica

e	μ	p	π	K
elettrone	muone	protone	pione	kaone

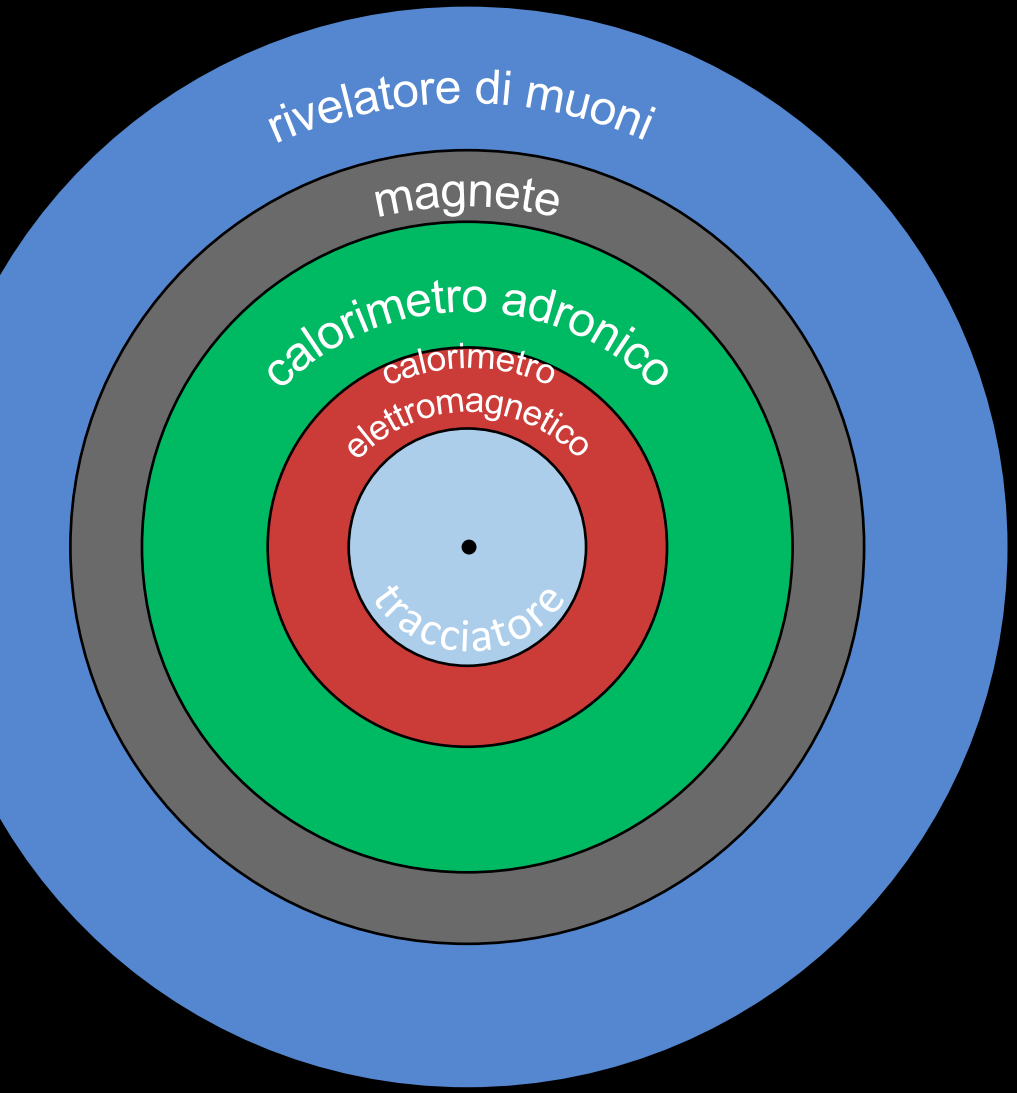
urti con il nucleo – forza forte

p	π	K	n
protone	pione	kaone	neutrone

produzione di coppie e^+e^-

γ	e
fotone	elettrone

apparato di rivelazione ermetico



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

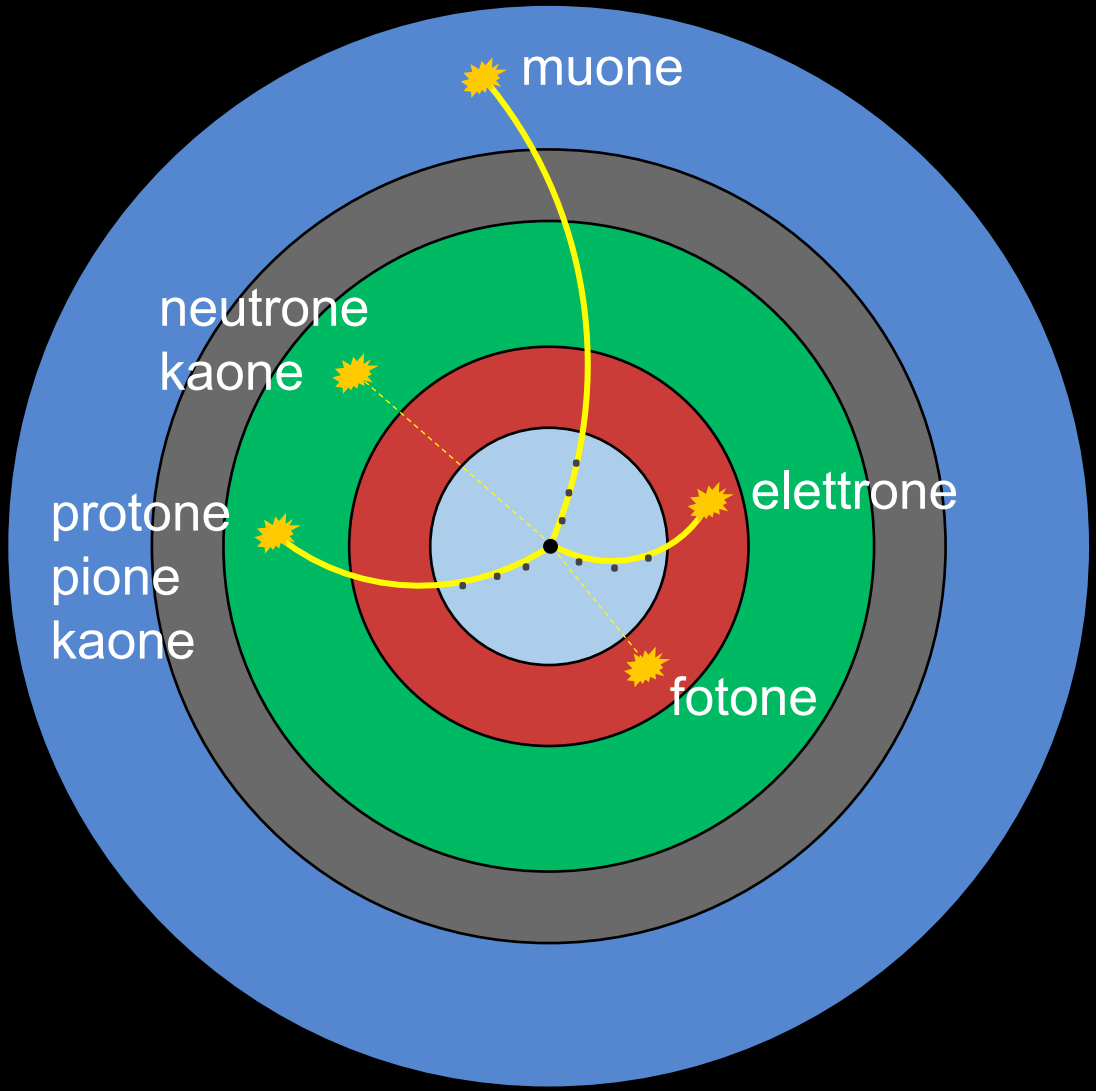
Calorimetro Elettromagnetico
rivela elettroni e fotoni
e ne misura l'energia

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

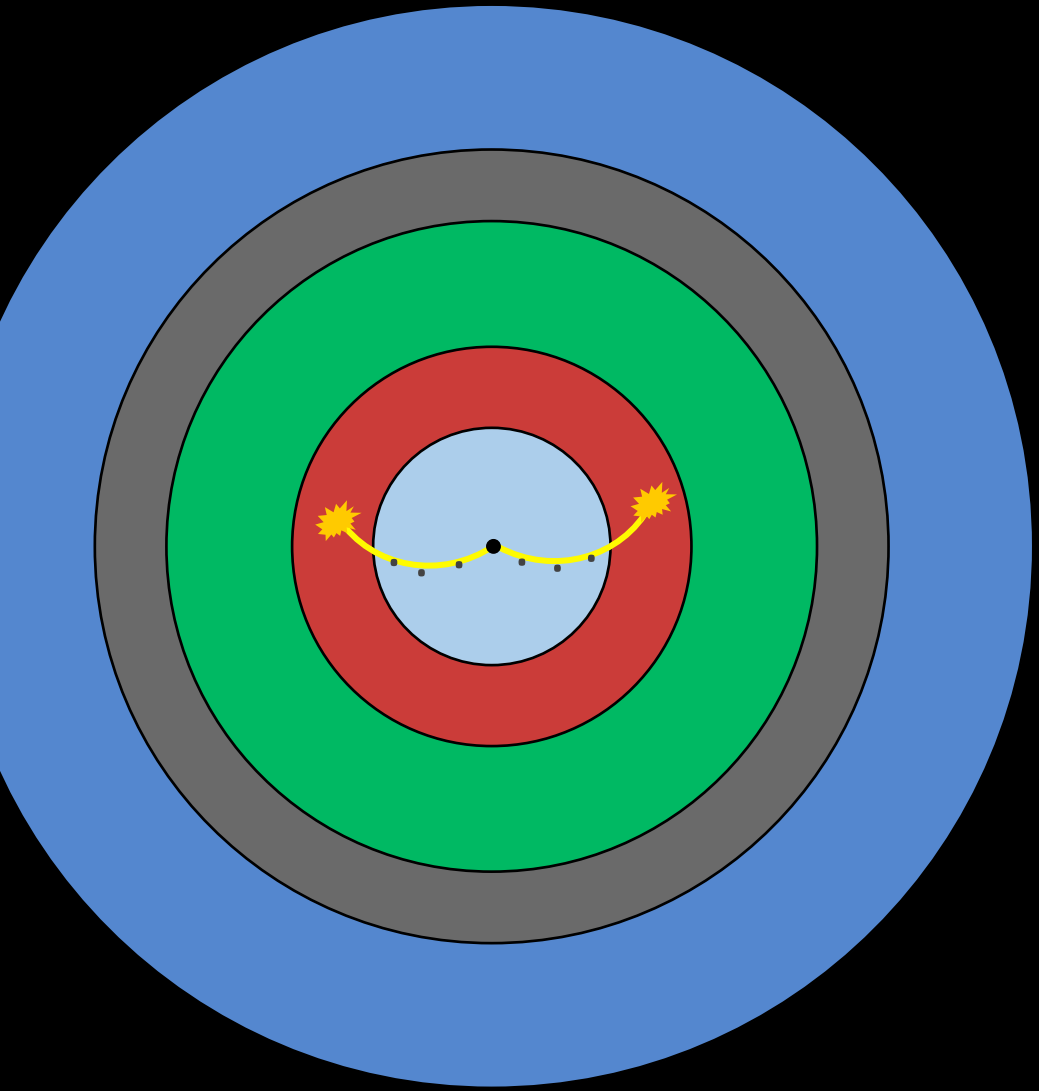
Magnete
curva le particelle cariche
e ne permette la misura della quantità di moto

Rivelatore di Muoni
rivela i muoni

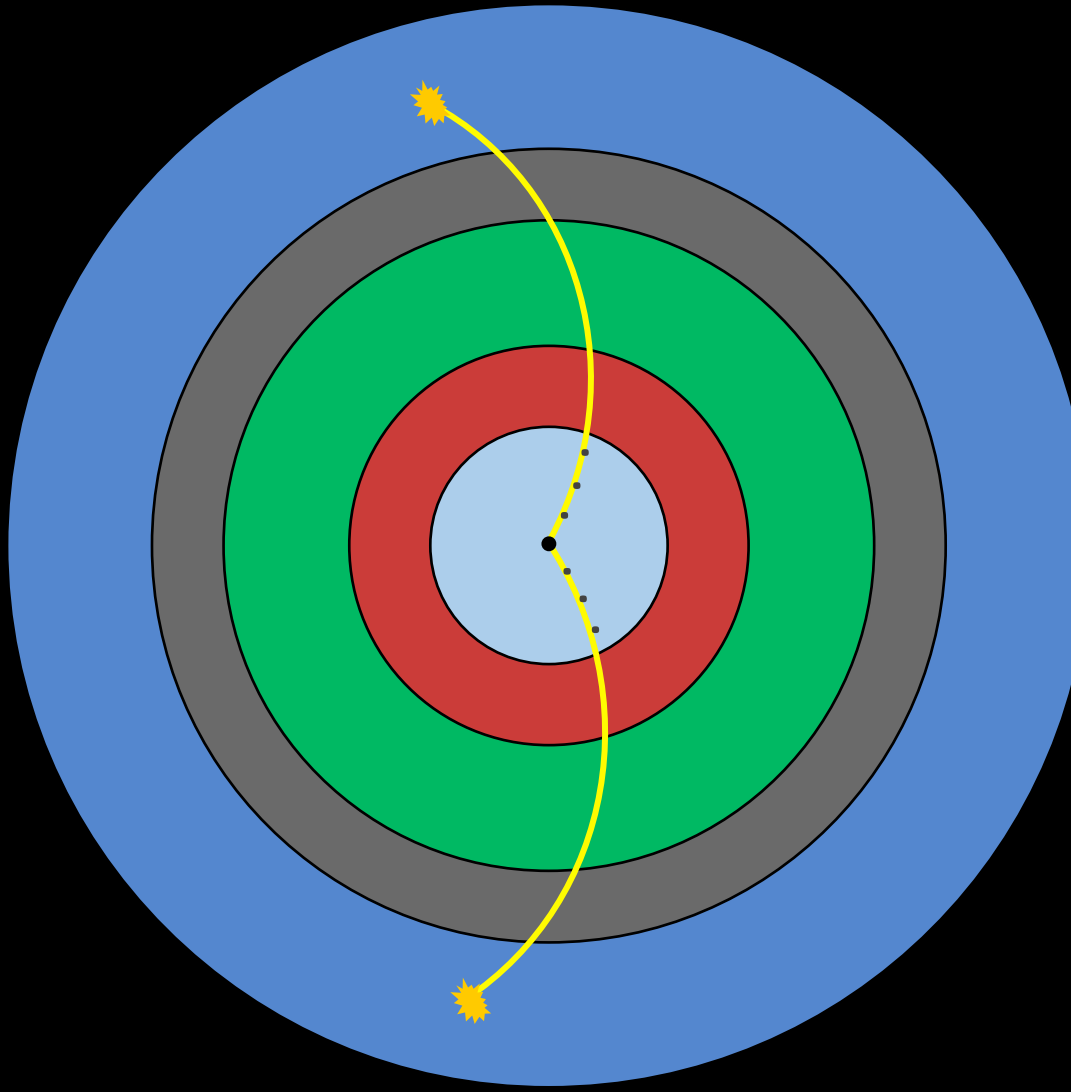
identificazione delle particelle

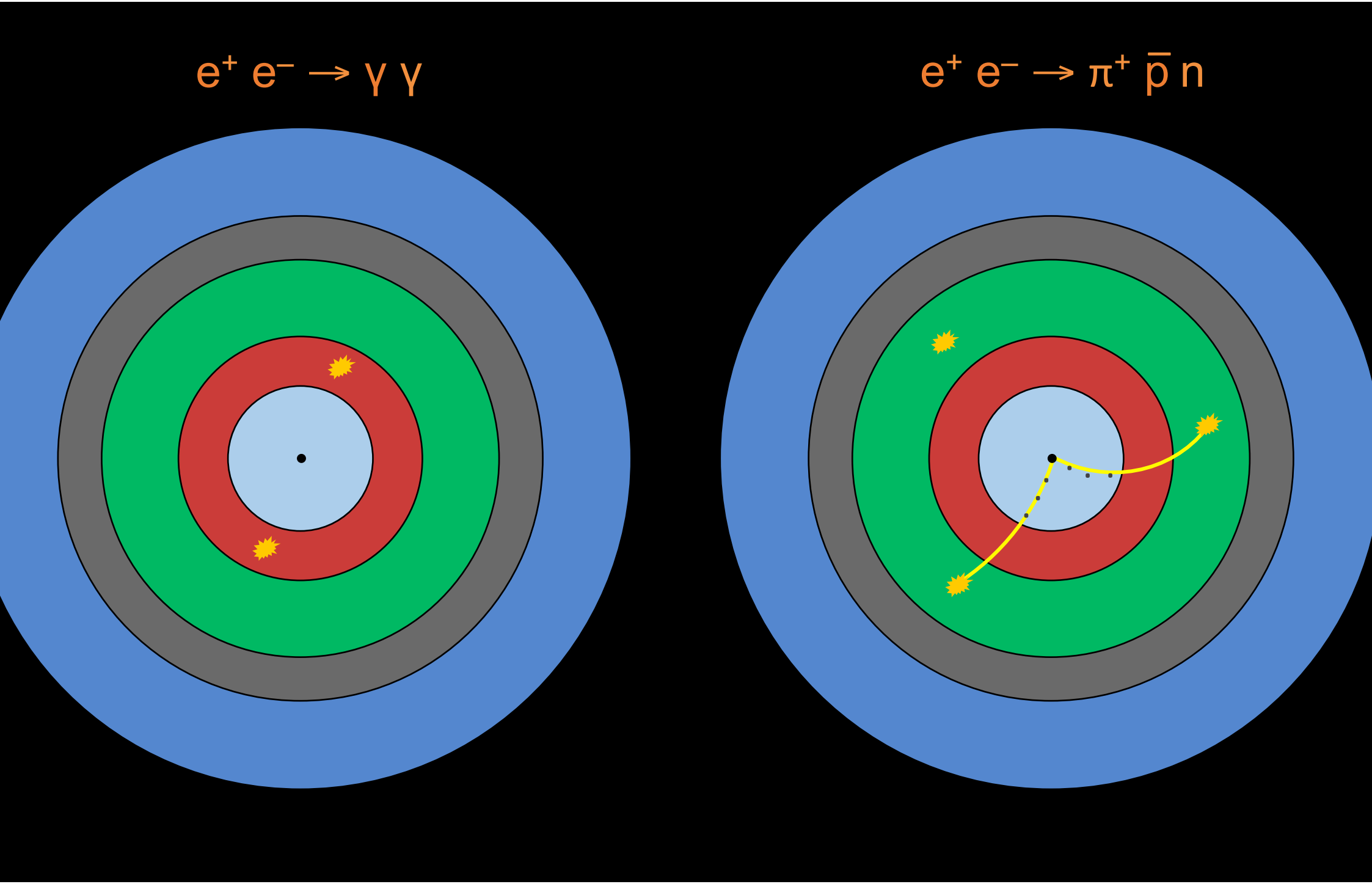


$e^+ e^- \rightarrow e^+ e^-$

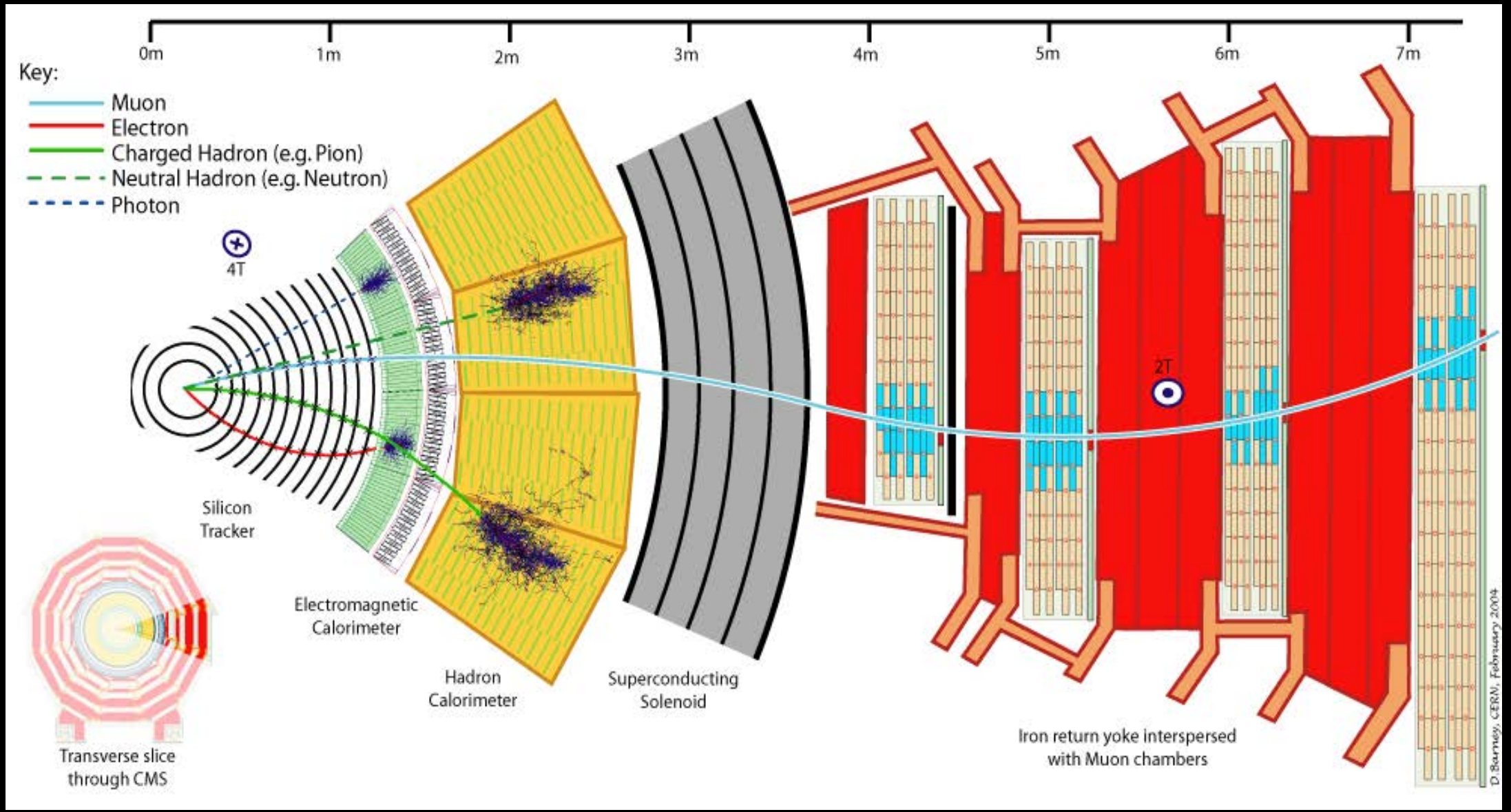


$e^+ e^- \rightarrow \mu^+ \mu^-$

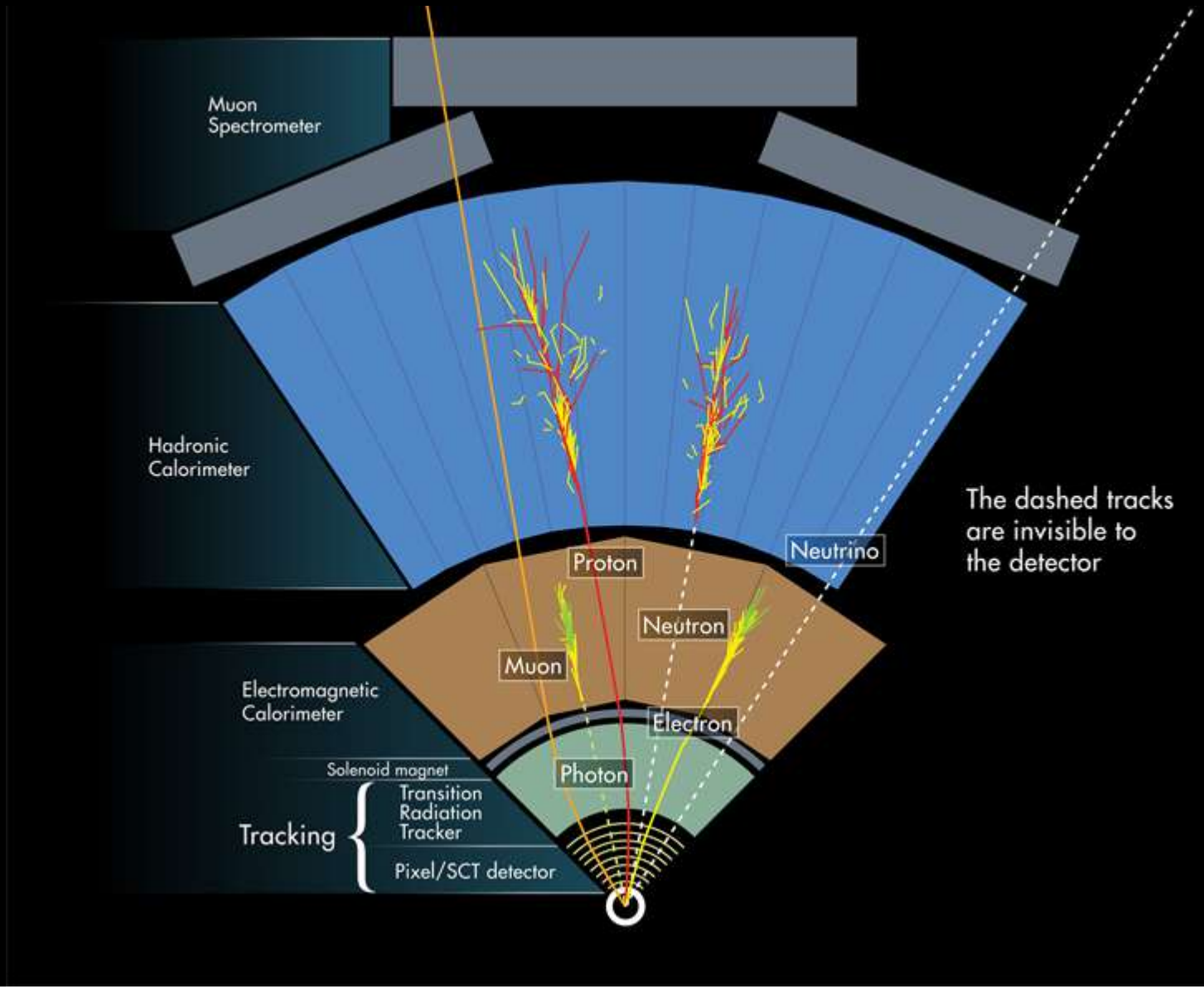


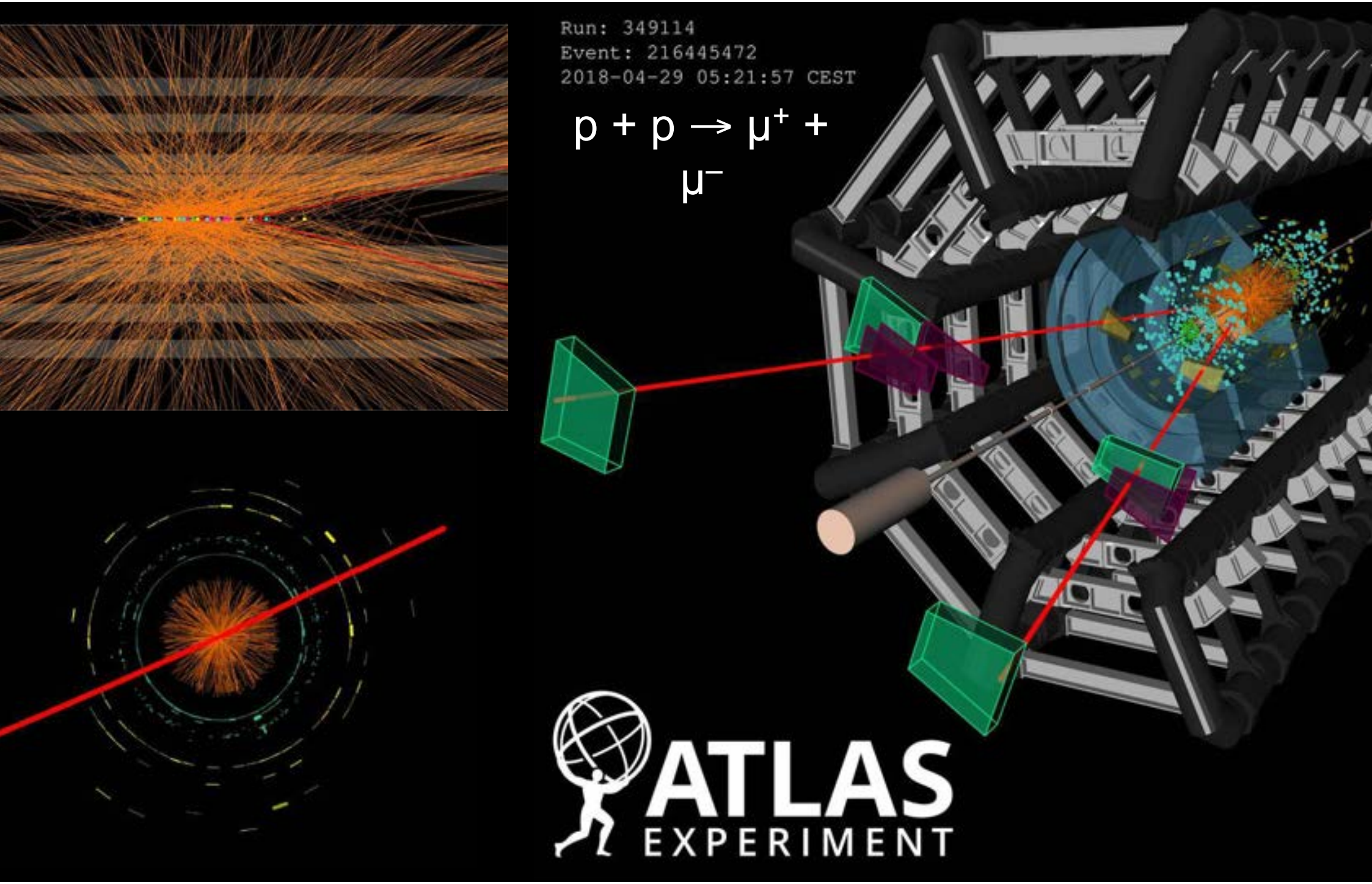

$e^+ e^- \rightarrow \gamma\,\gamma$
$e^+ e^- \rightarrow \pi^+ \bar{p}\, n$

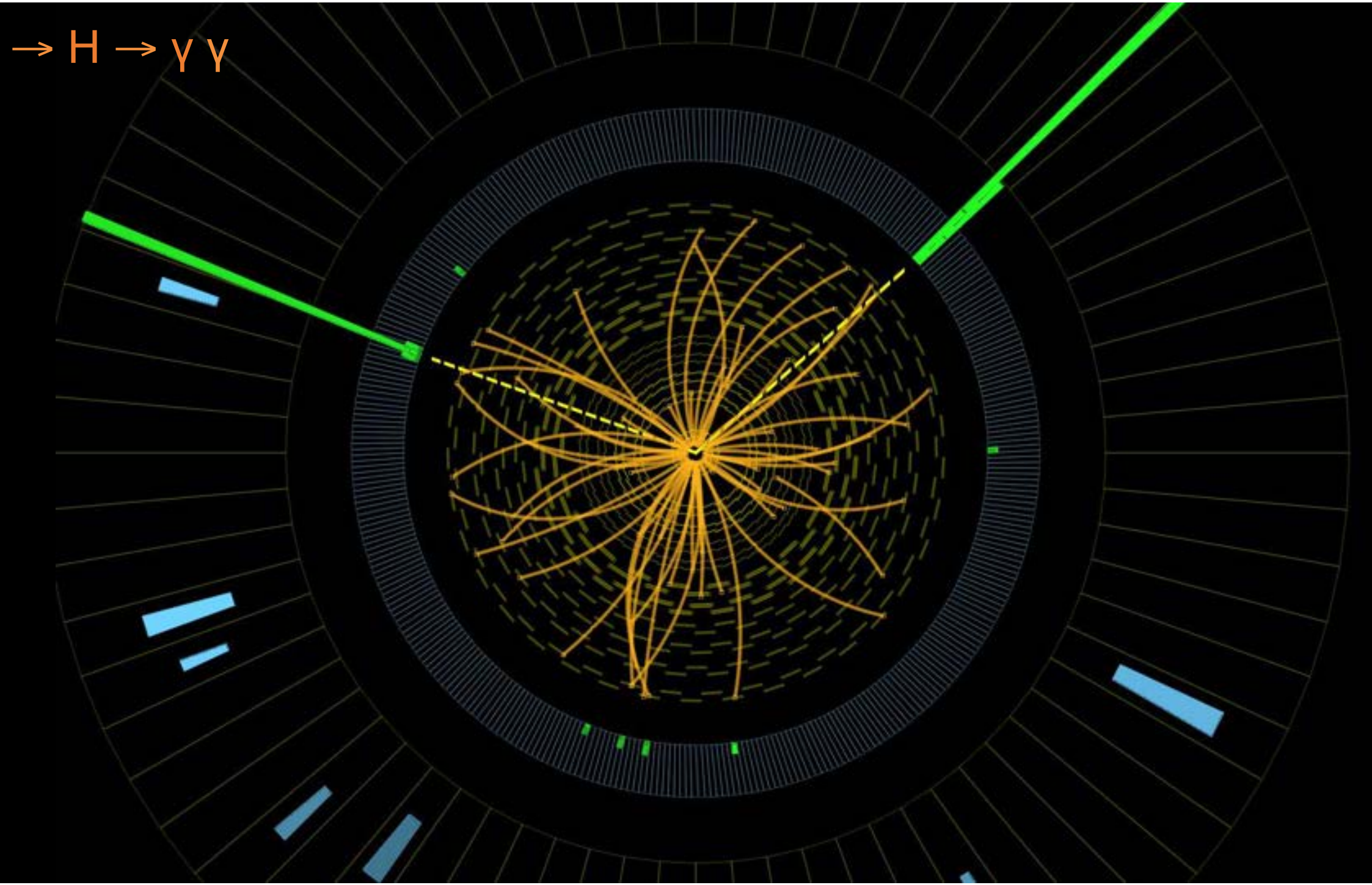
il rivelatore cms a lhc

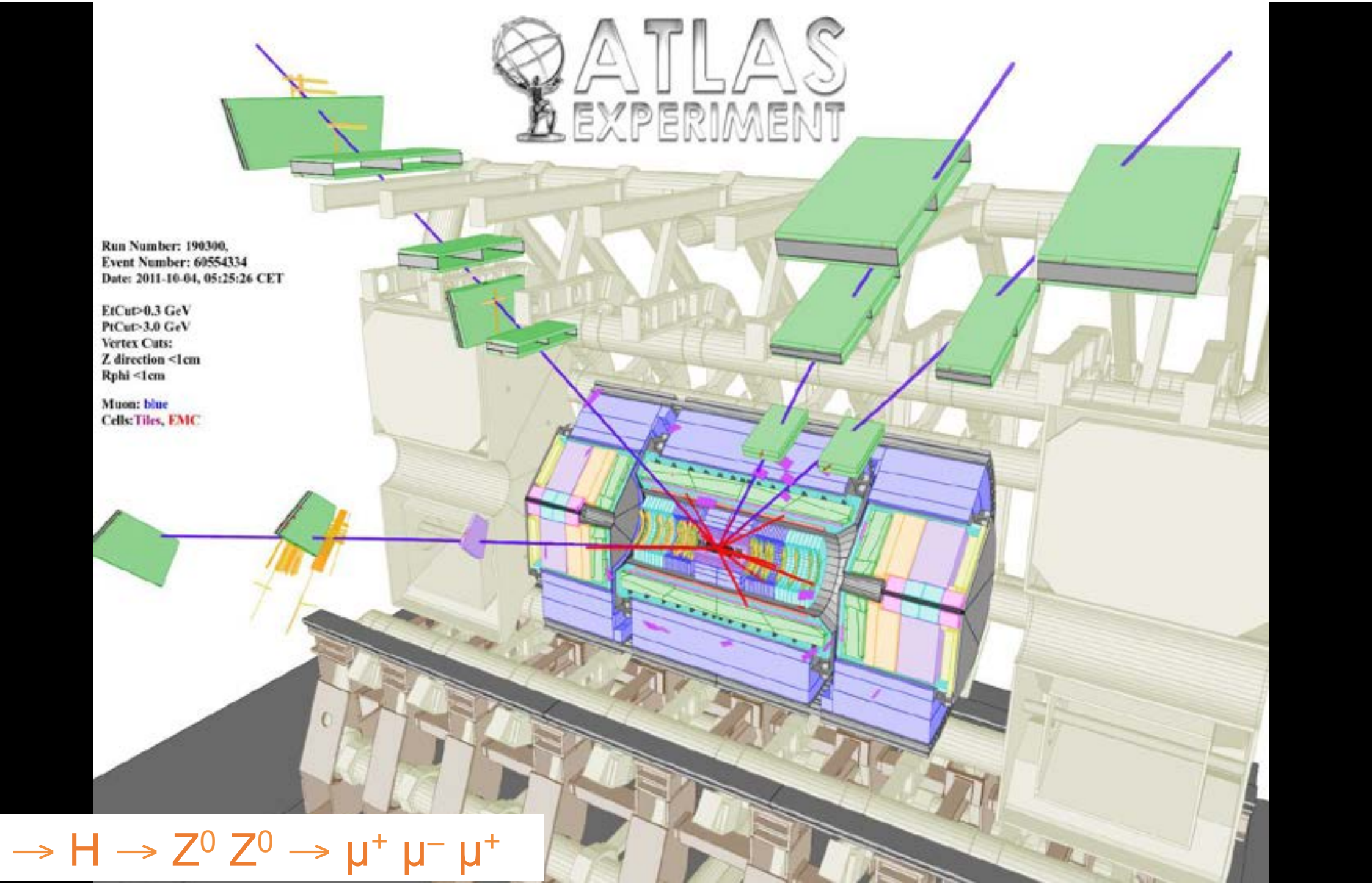


il rivelatore atlas a lhc



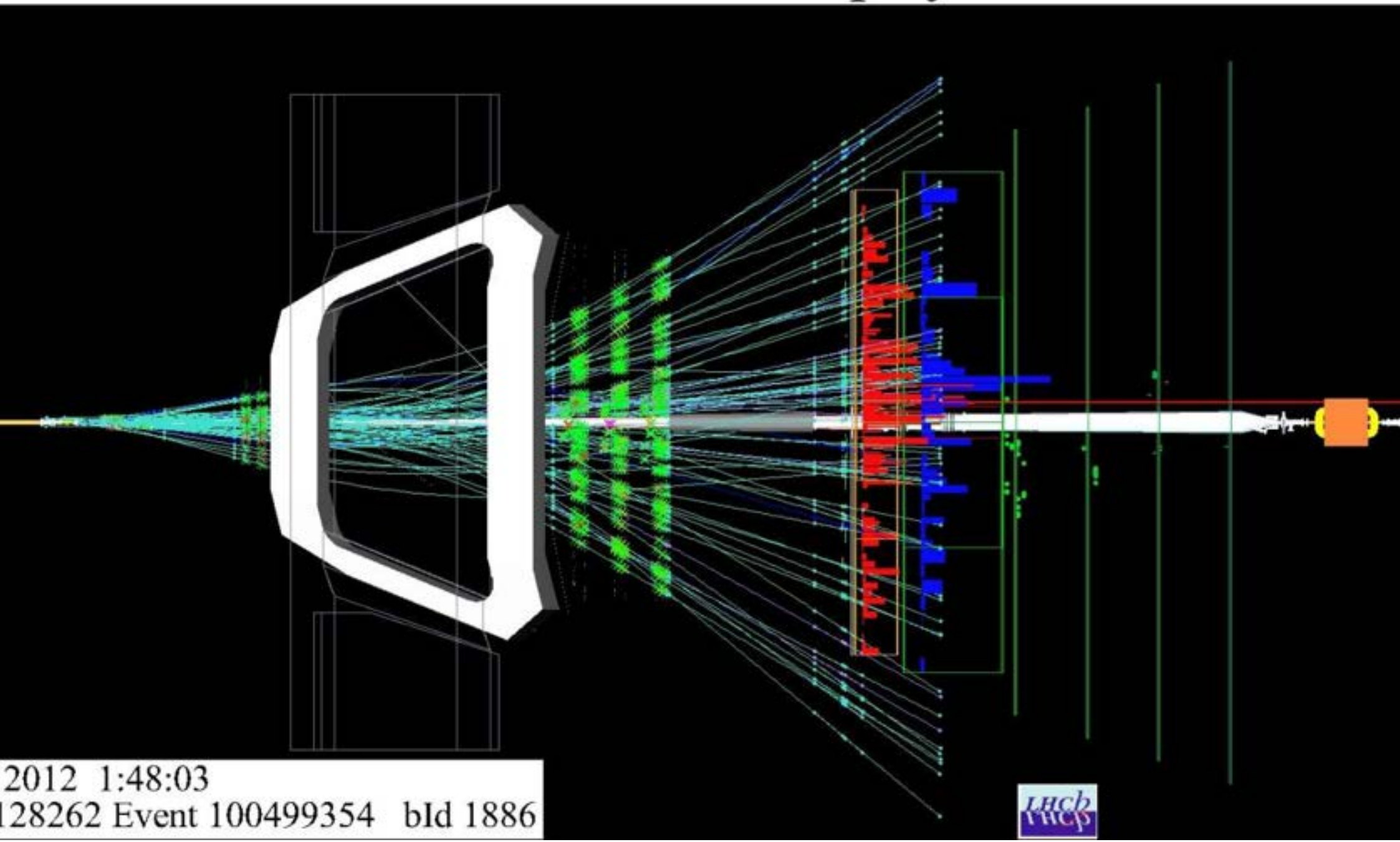

Run: 349114
Event: 216445472
2018-04-29 05:21:57 CEST
p + p → μ+ + μ−
ATLAS
EXPERIMENT

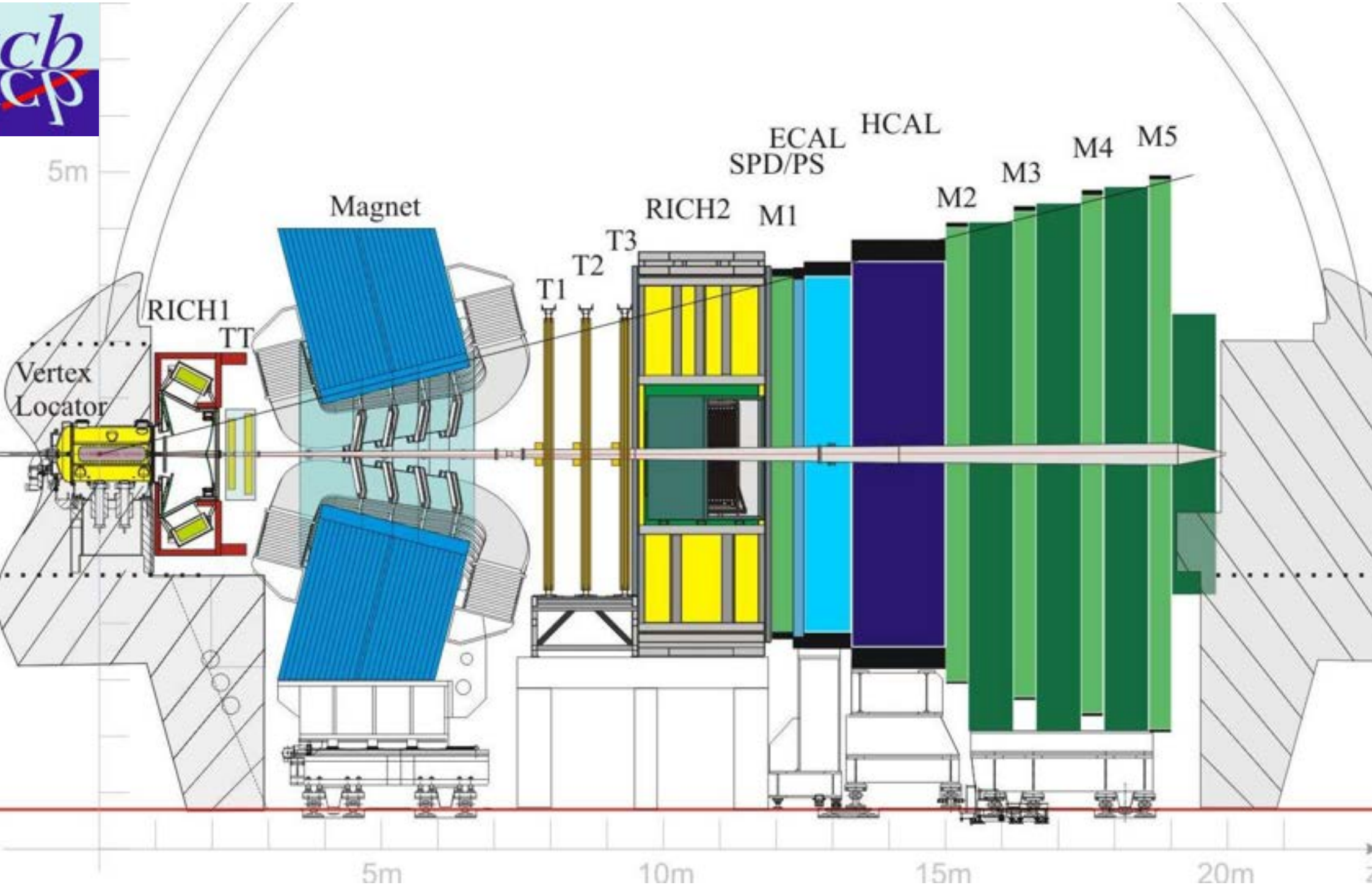

→ H → γ γ

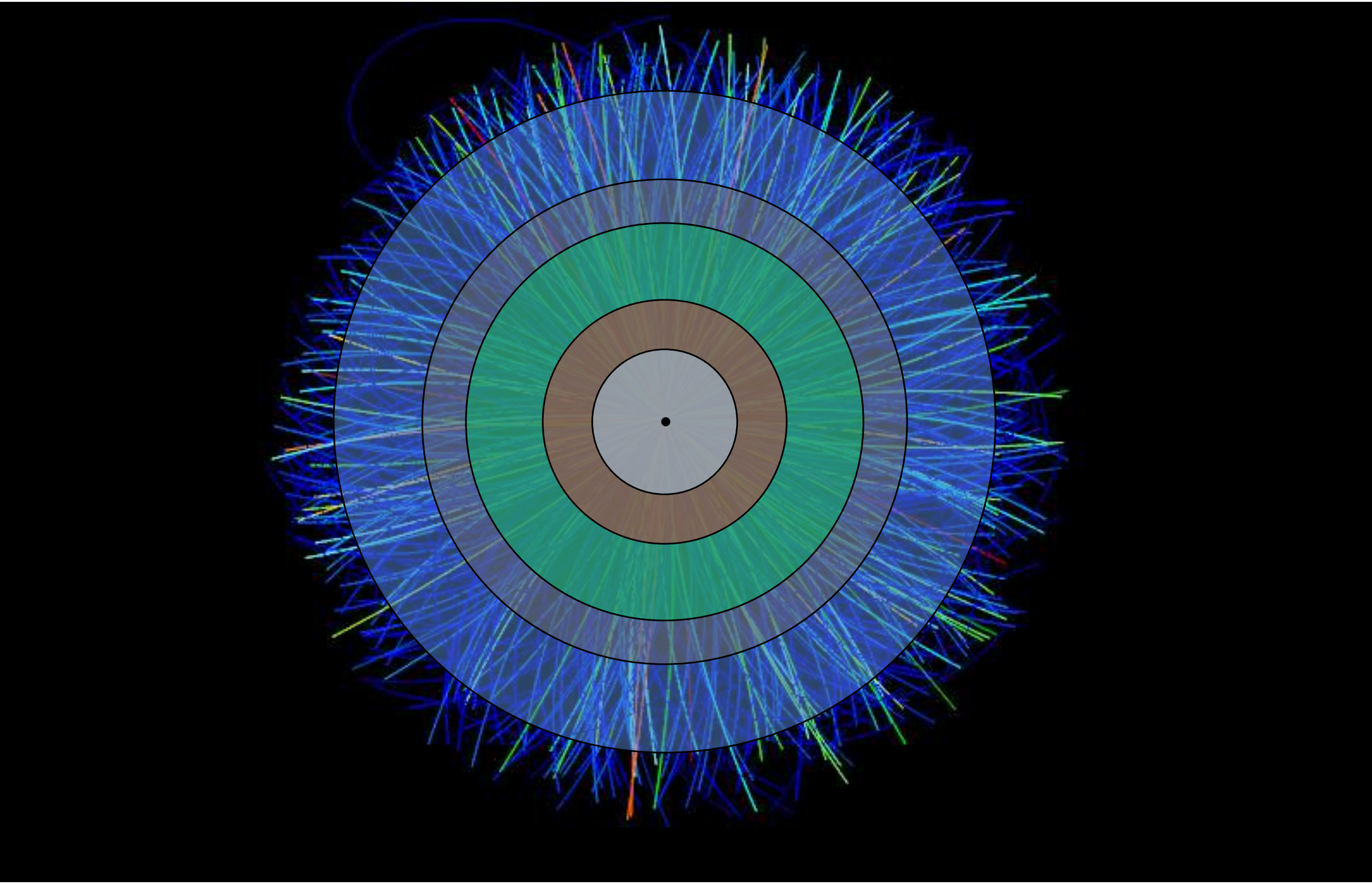


$\rightarrow H \rightarrow Z^0 Z^0 \rightarrow \mu^+ \mu^- \mu^+$

LHCb Event Display

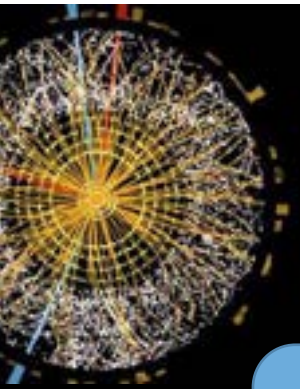



5m
Magnet
RICH1
TT
Vertex
Locator
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5
5m
10m
15m
20m



LHC computing

LHC big data



40 M/s x 100 MB
4 PB/s

Trigger
Livello1

100 k/s x 1 MB
100 GB/s

Trigger
Livello2

300/s x 1 MB
100 PB/y

Lhc computing grid

WLCG
Worldwide LHC Computing Grid

170 centri di calcolo
in 42 paesi del mondo
collegati a 10Gb/s

caratteristiche dei rivelatori

Sensibilità

capacità di produrre un segnale per un certo tipo di radiazione e di energia

Risoluzione

capacità di distinguere tra due misure vicine di una grandezza fisica misurata (es. posizione o tempo)

Efficienza

frazione di particelle rivelate rispetto a quelle incidenti

Tempo morto

tempo necessario per essere di nuovo attivo dopo la rivelazione di una particella

tipi di rivelatori

Funzione

Tracciatori

Calorimetri

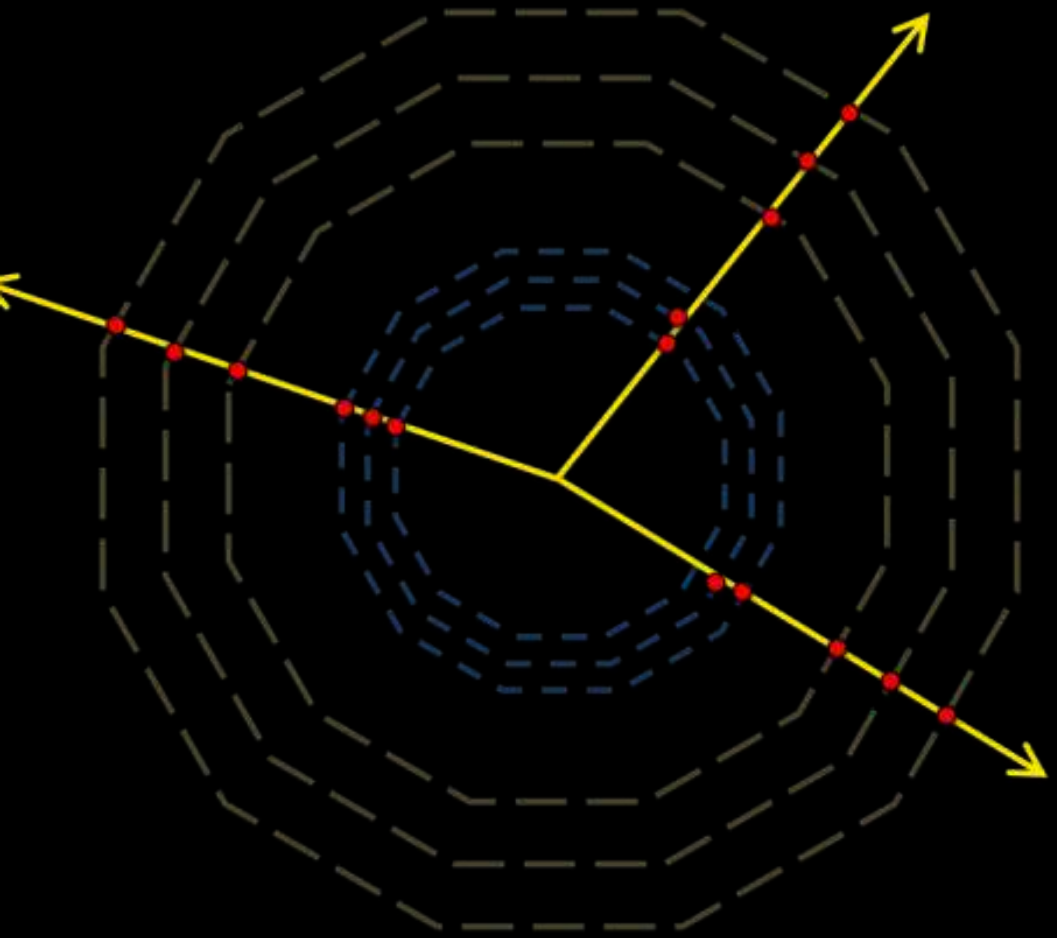
Rivelatori Cherenkov

Materiale

Rivelatori a gas

Rivelatori a stato solido

tracciatori

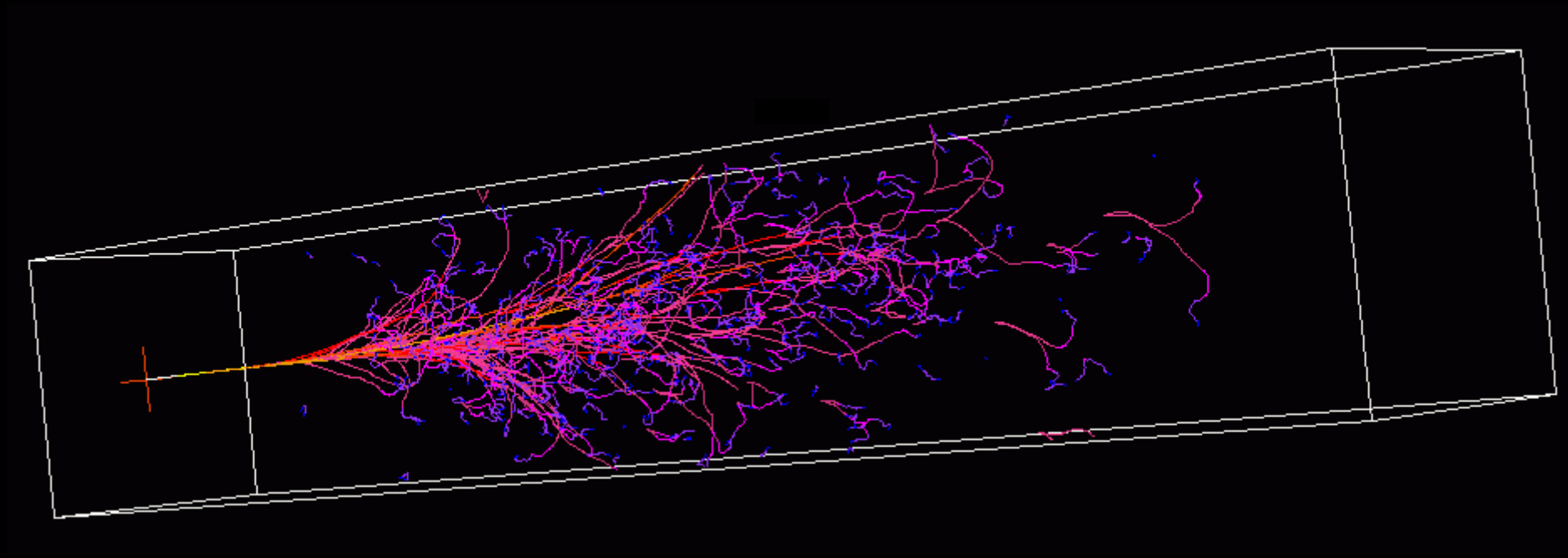


Sensibilità
tutte le particelle cariche

p = eBr
immersi in campo magnetico
misurano la quantità di moto

Materiali leggeri
la particella deve perdere
poca energia

calorimetri



Sensibilità
Ecal: elettroni e fotoni
al: protoni, neutroni, pioni, kaoni

Energia
misurano l'energia
(senza campo magnetico)

Materiali pesanti
la particella deve perde
tutta la sua energia

calorimetri

Sciame Elettromagnetico

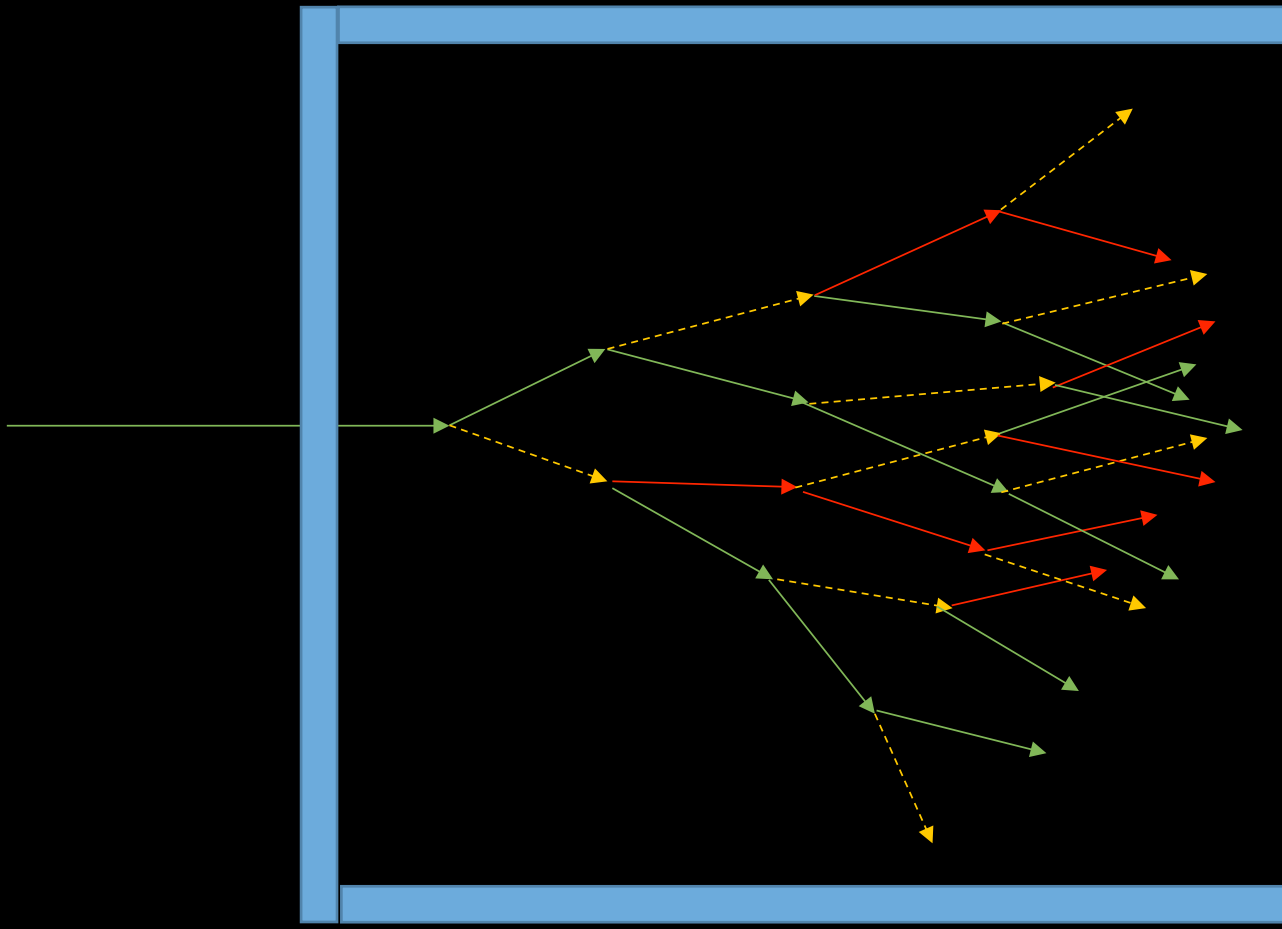
Radiazione da Frenamento
(elettroni e positroni)

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

$e^+ + N \rightarrow e^+ + N + \gamma$

Produzione di Coppie
(fotoni)

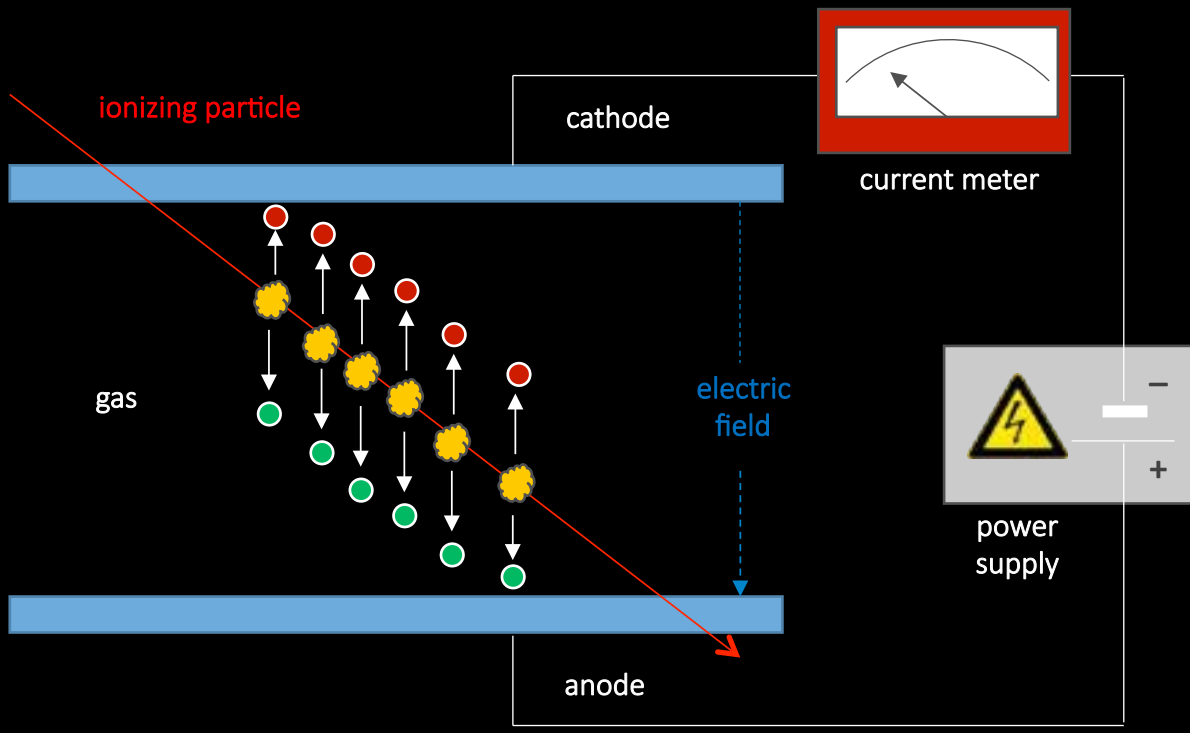
$\gamma + N \rightarrow N + e^- + e^+$



rivelatori a gas

Ionizzazione Atomica

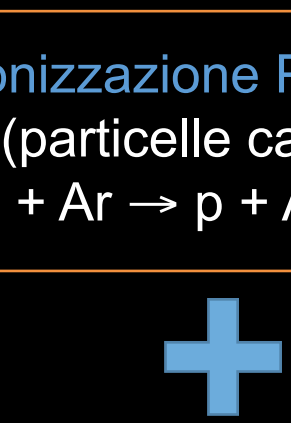
particelle cariche
$p + Ar \rightarrow p + Ar^{+} + e^{-}$



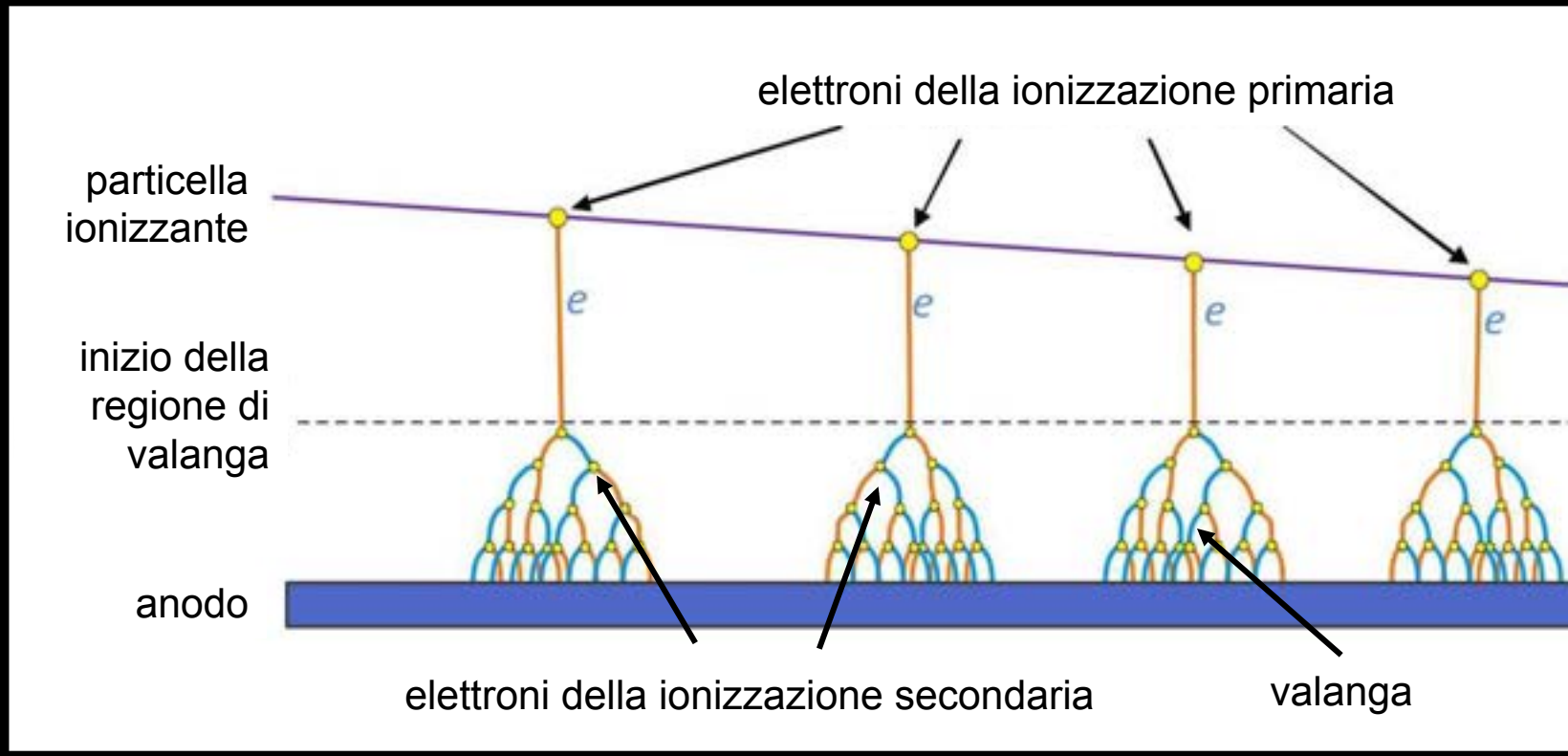
Punti di Forza
grandi volumi con poca spesa
segnale grande

Moltiplicazione a valanga

onizzazione Primaria
(particelle cariche)
$+ Ar \rightarrow p + Ar^{+} + e^{-}$

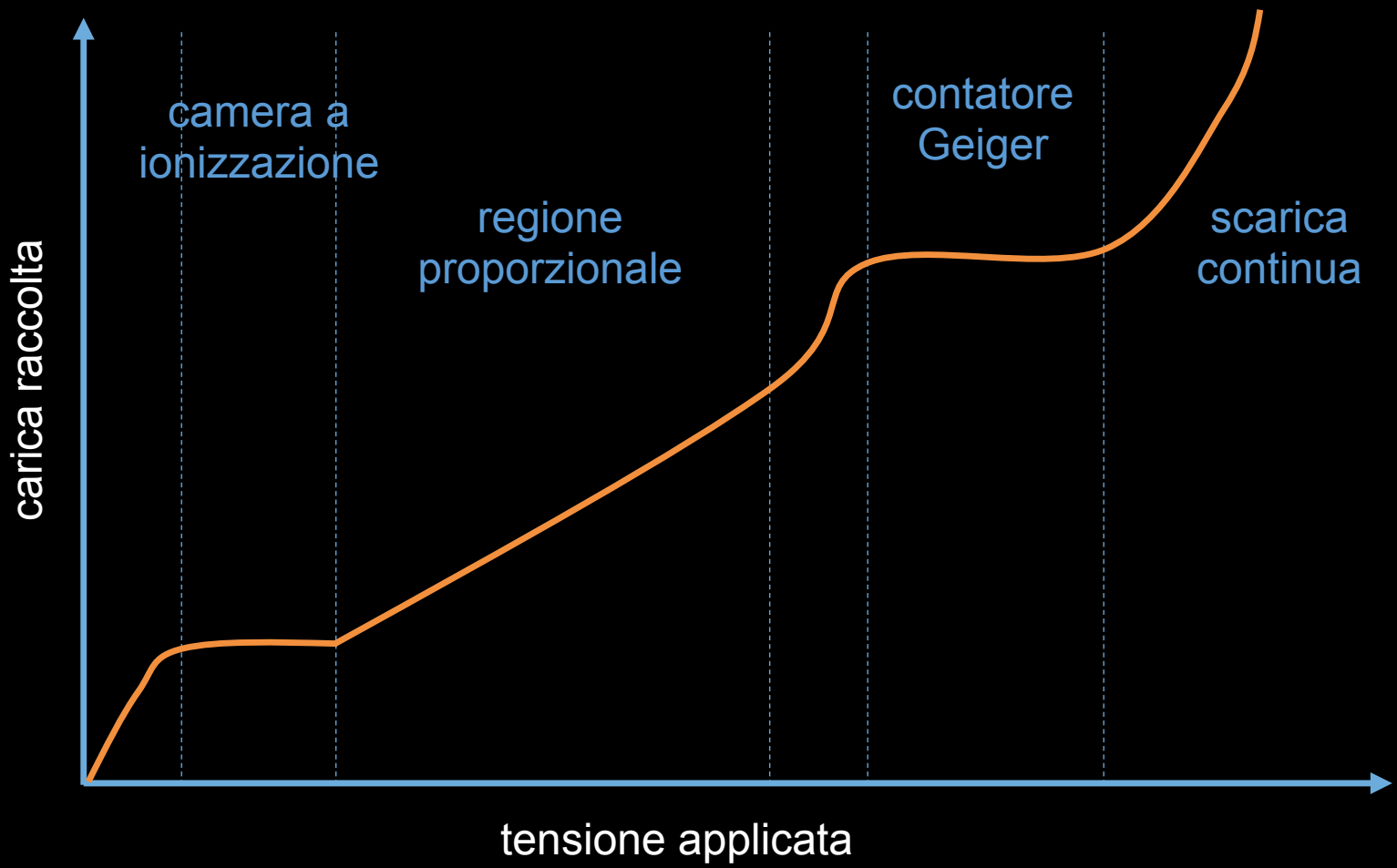


izzazione Secondaria
(elettroni)
$+ Ar \rightarrow e^{-} + Ar^{+} + e^{-}$

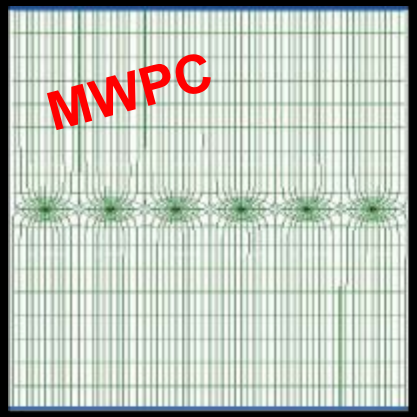


i elettroni primari vengono moltiplicati dal gas
con un guadagno G

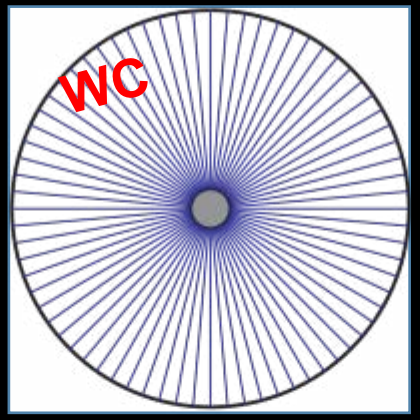
regioni operative dei rivelatori a gas



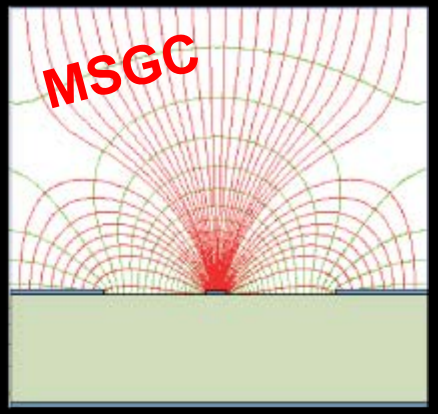
configurazioni di elettrodi



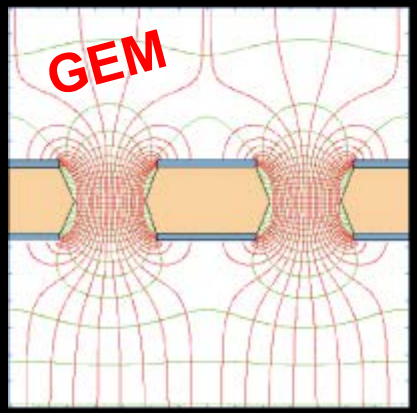
multi-filo



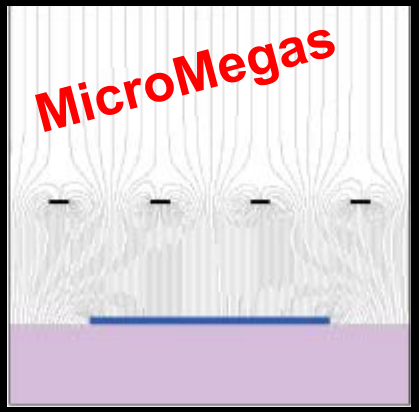
filo singolo



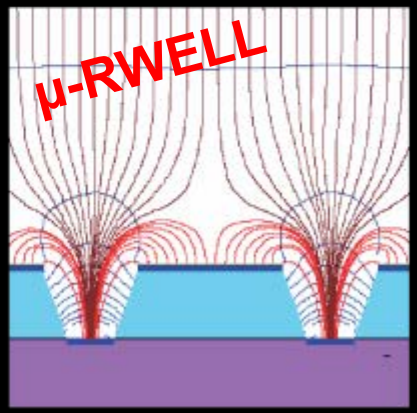
strisce



fori

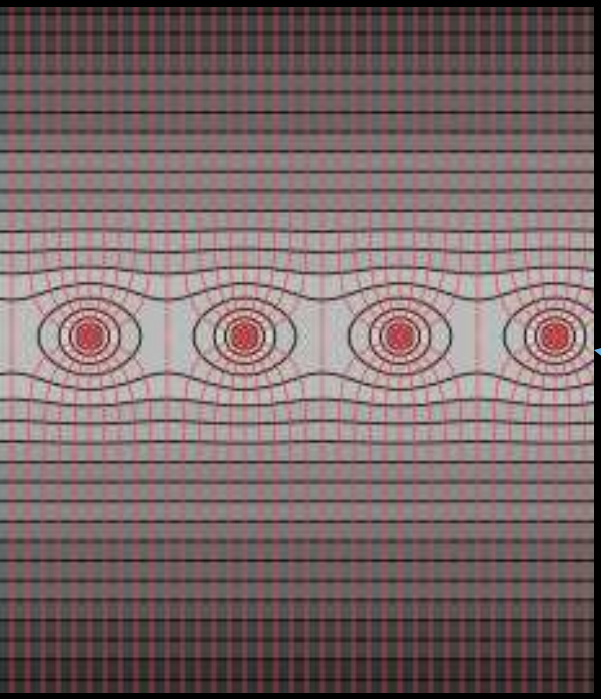


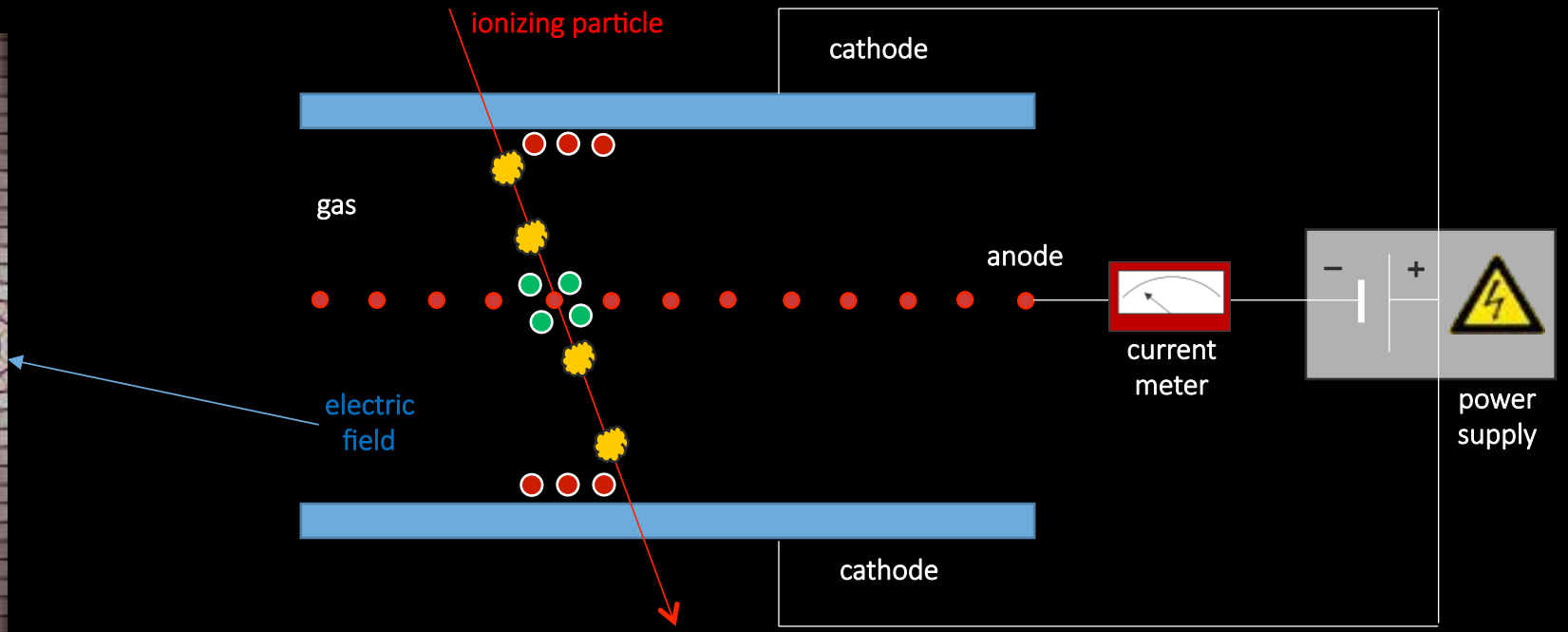
griglia



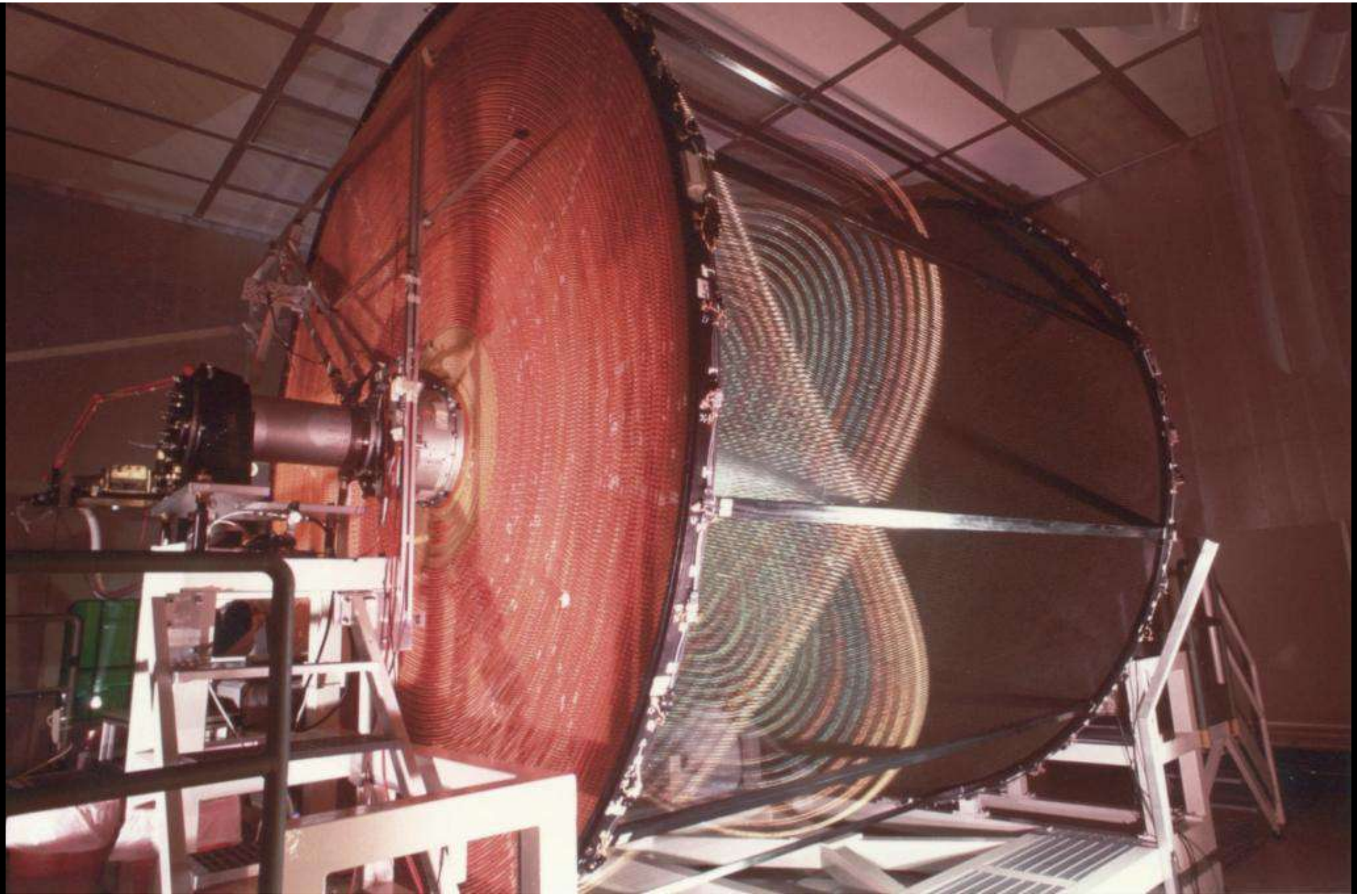
pozzi

Multiwire proportional chamber

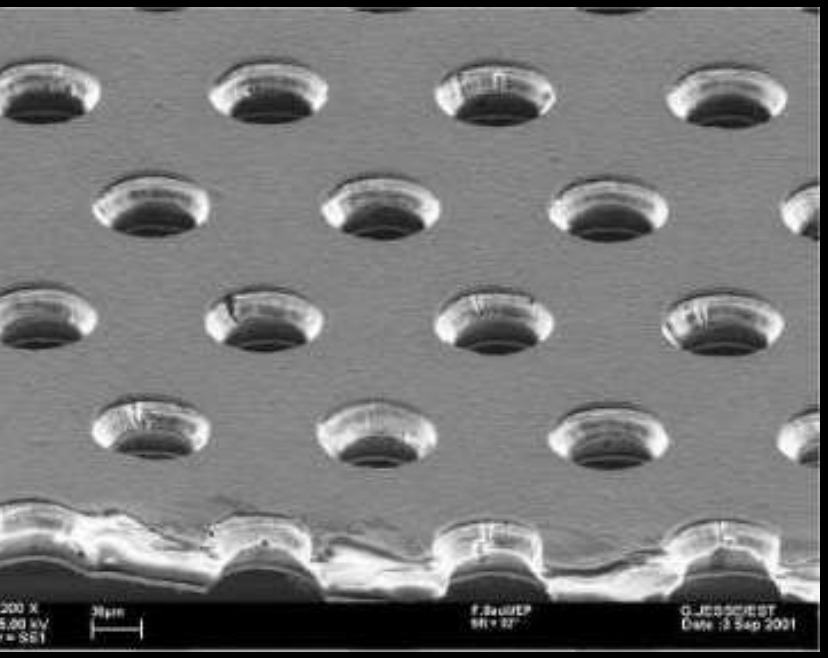




il segnale del filo fornisce la posizione della particella
il campo elettrico vicino al filo (1/r) moltiplica gli elettroni

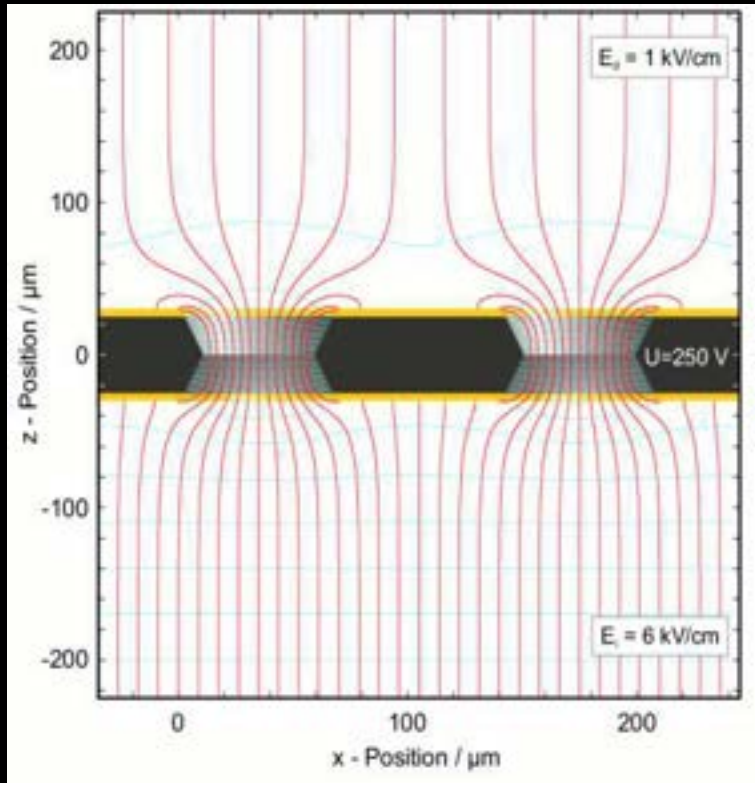


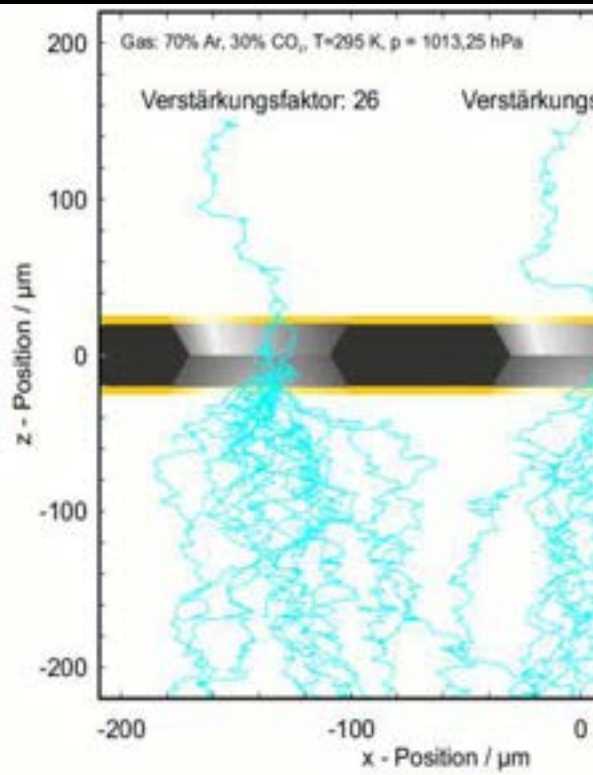
GEM - gas electron multiplier



un foglio di kapton metallizzato e micro-forato
moltiplica gli elettroni

Punti di forza
piccolo tempo morto



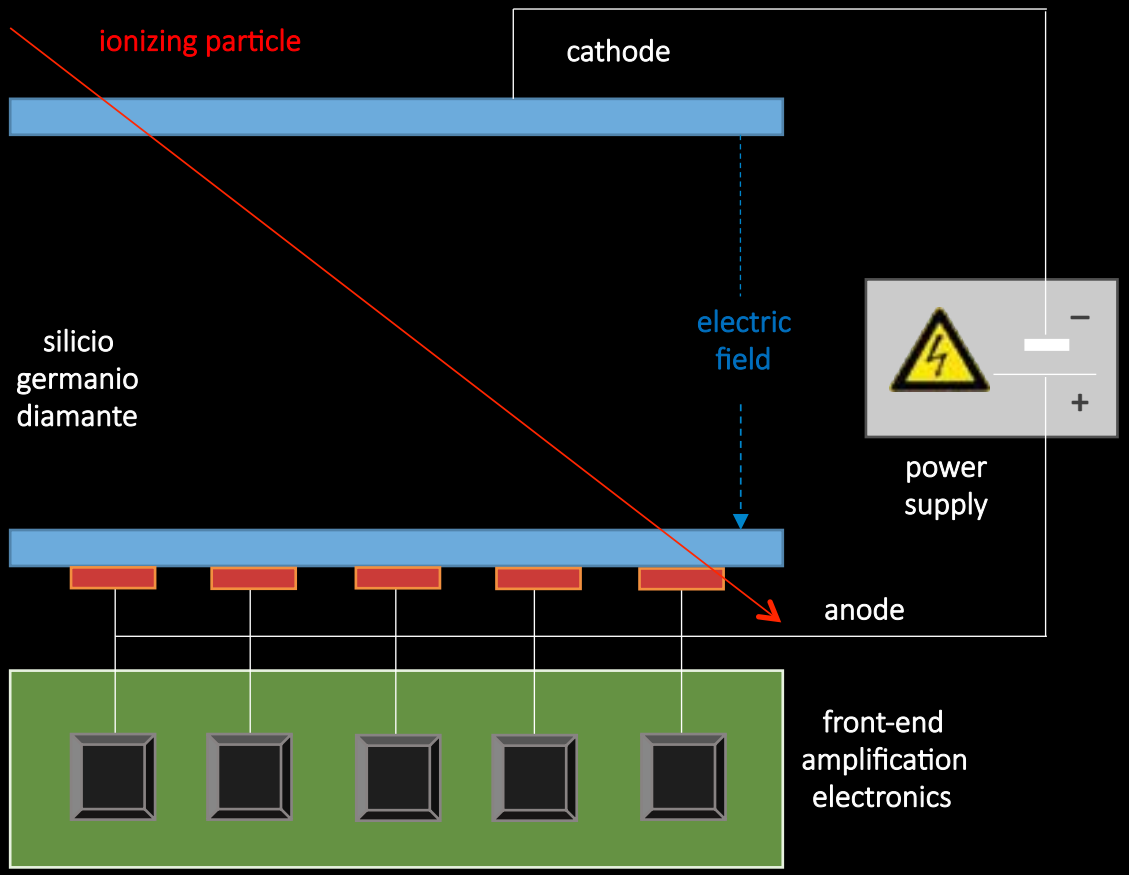


GEM cilindrica

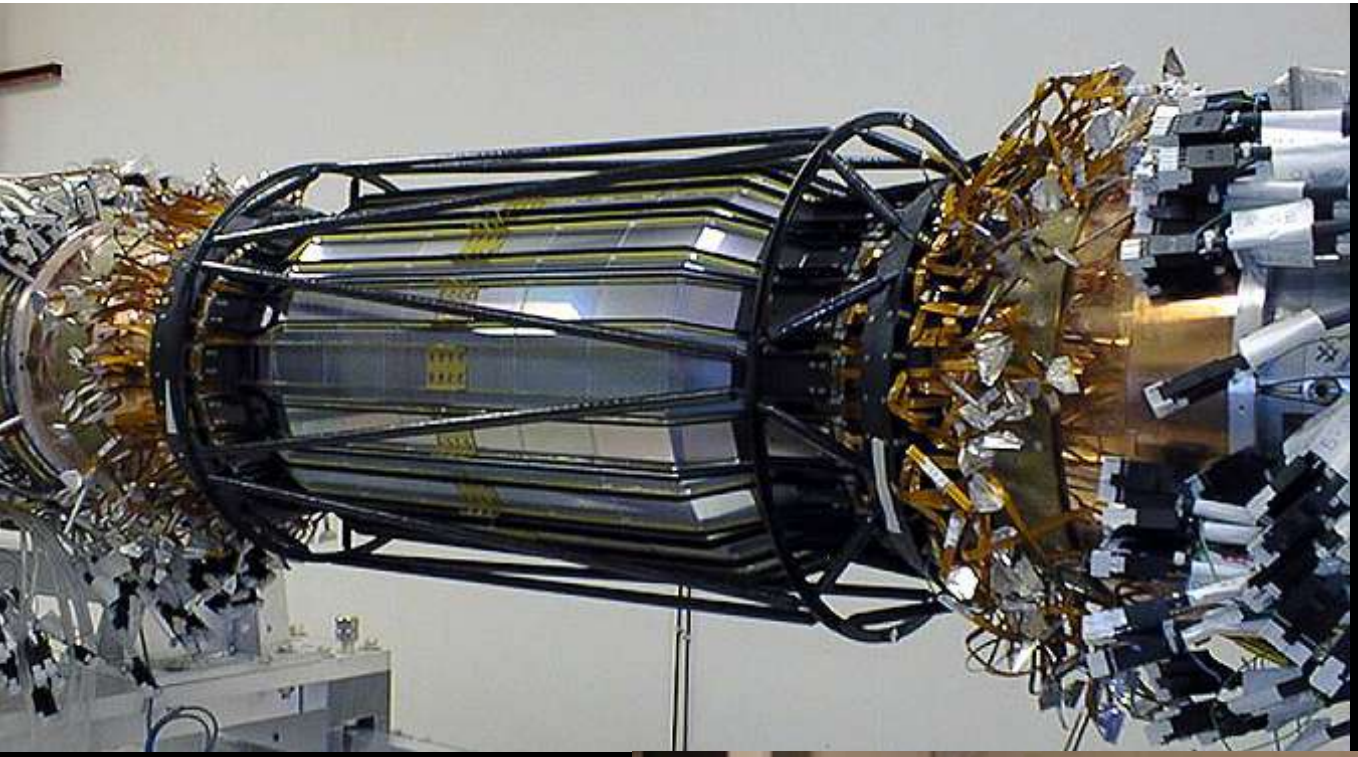
rivelatori a stato solido

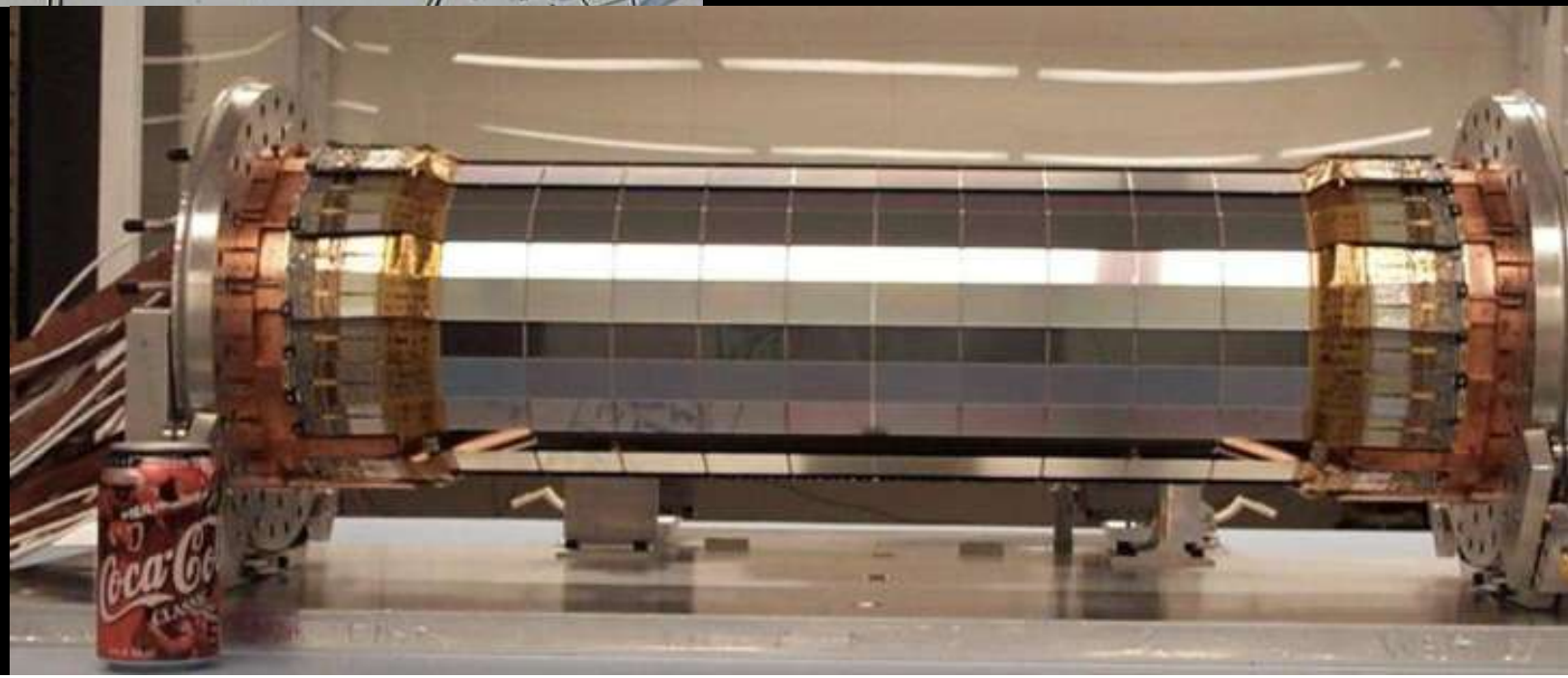
Produzione di Coppie Elettrone - Lacuna

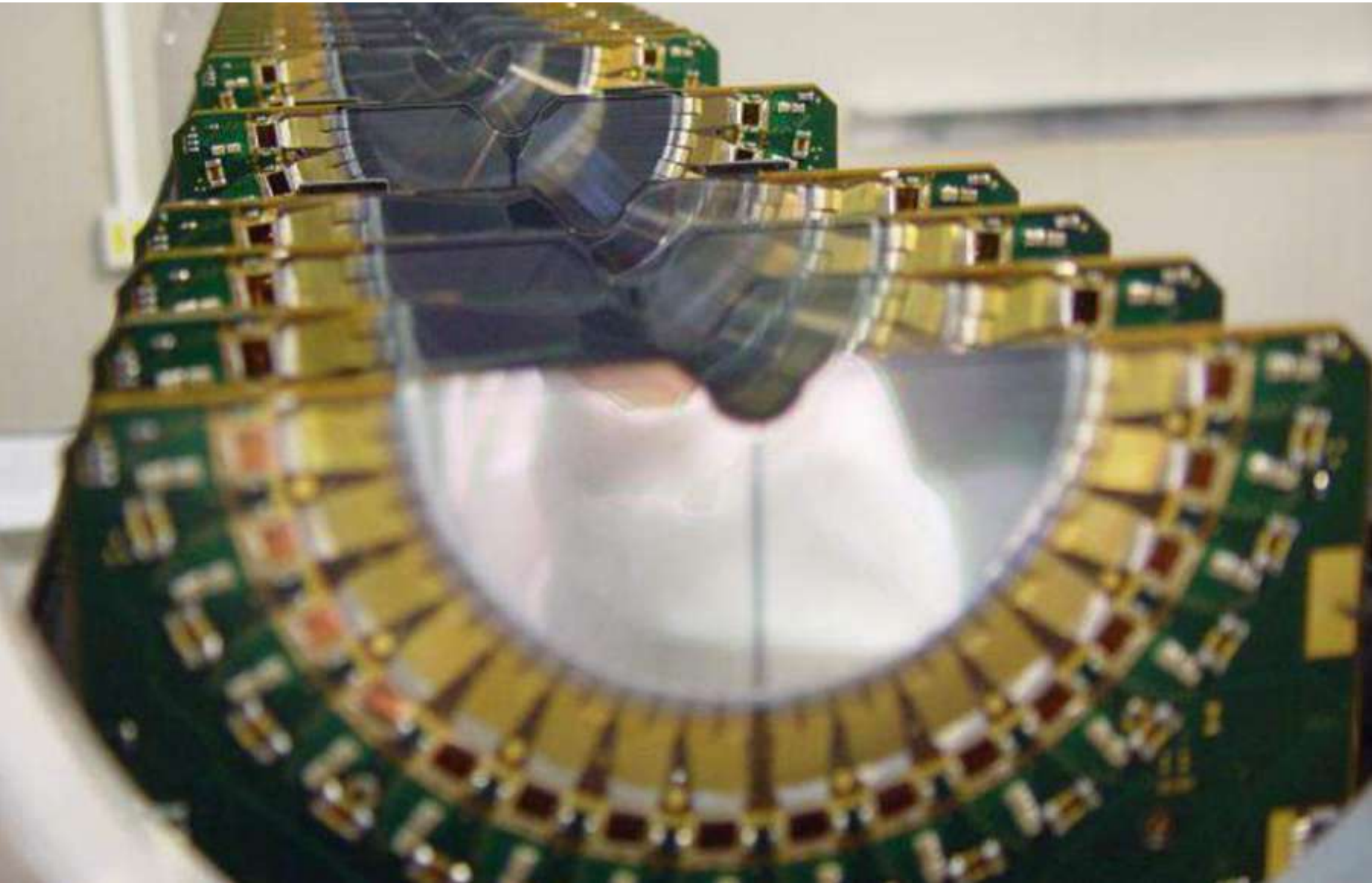
particelle cariche
$p + Si \rightarrow p + e^- + h$

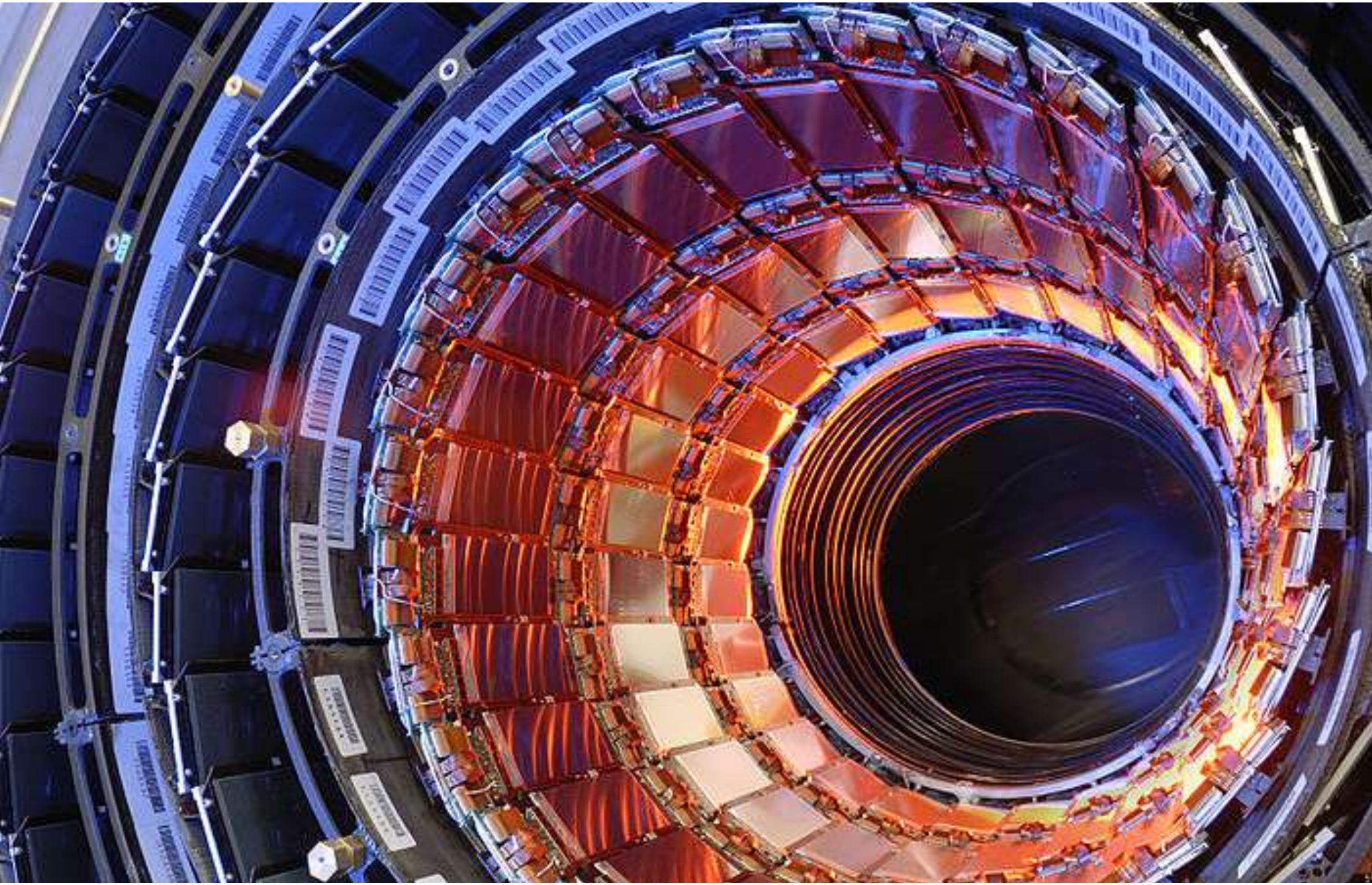


Punti di Forza
risoluzione spaziale e temporale

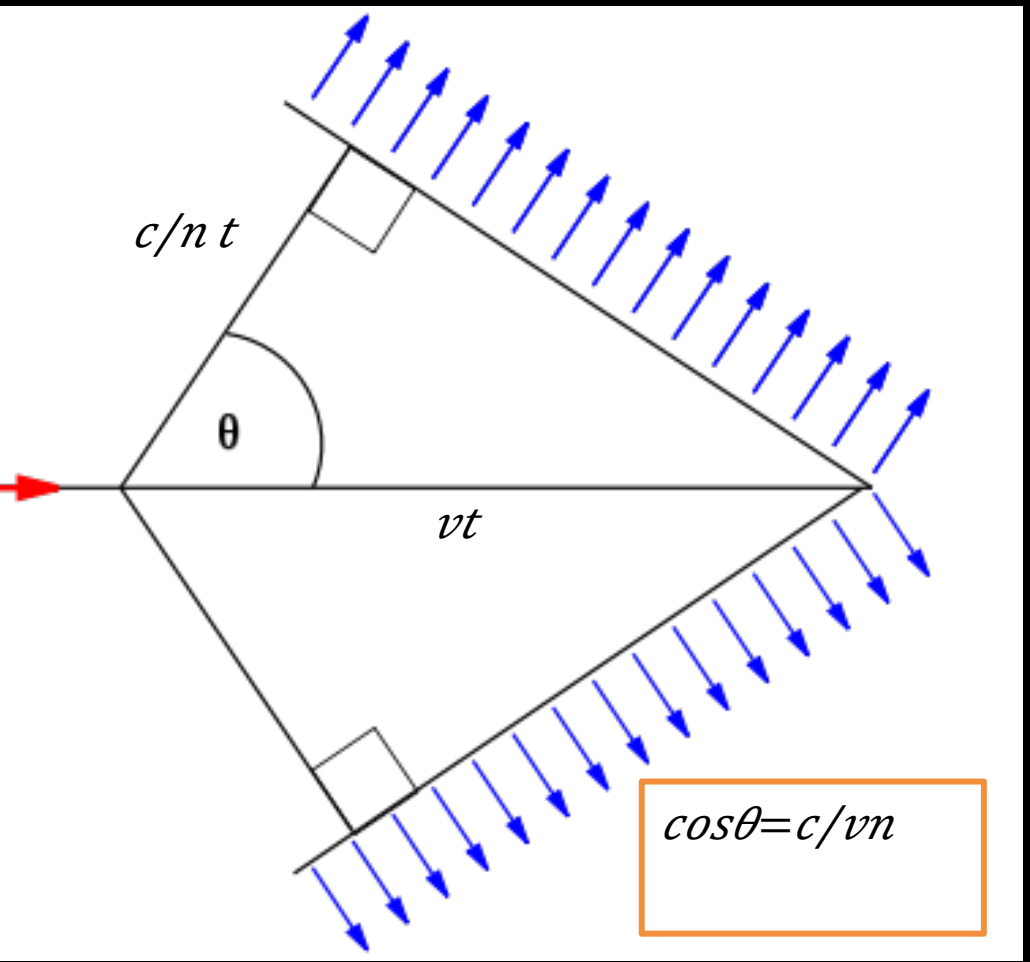




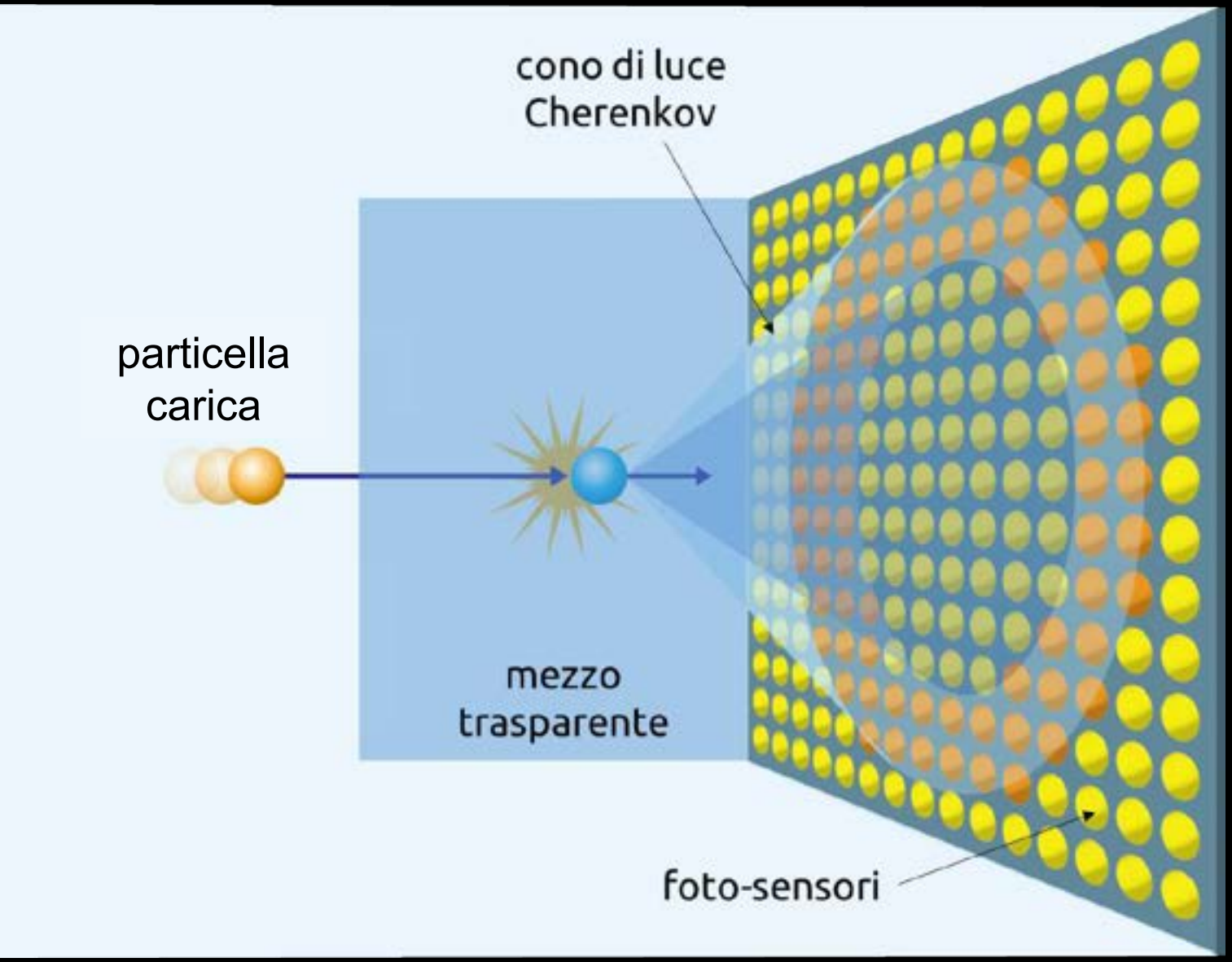


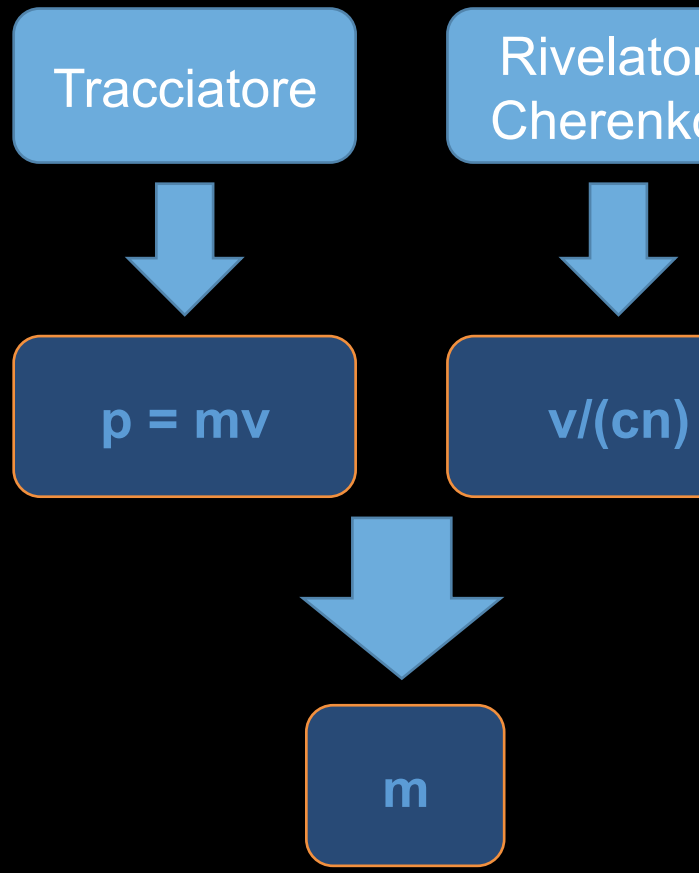


effetto cherenkov



rivelatori cherenkov

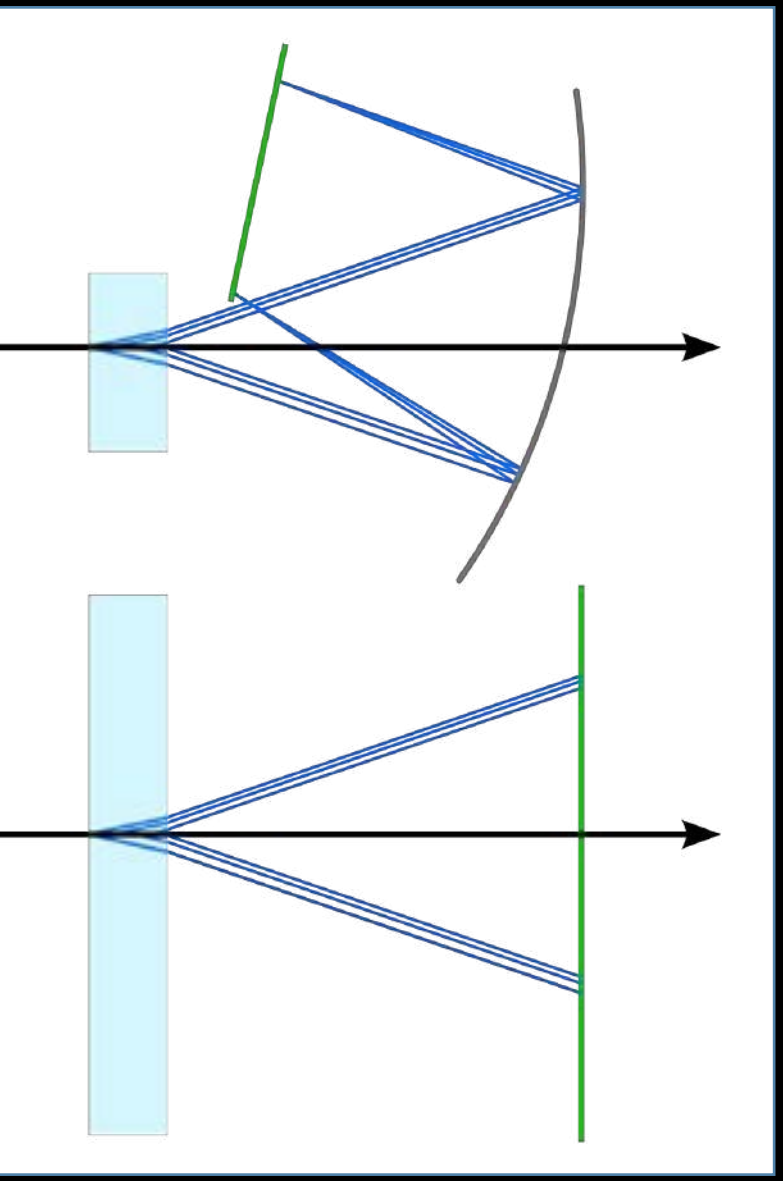


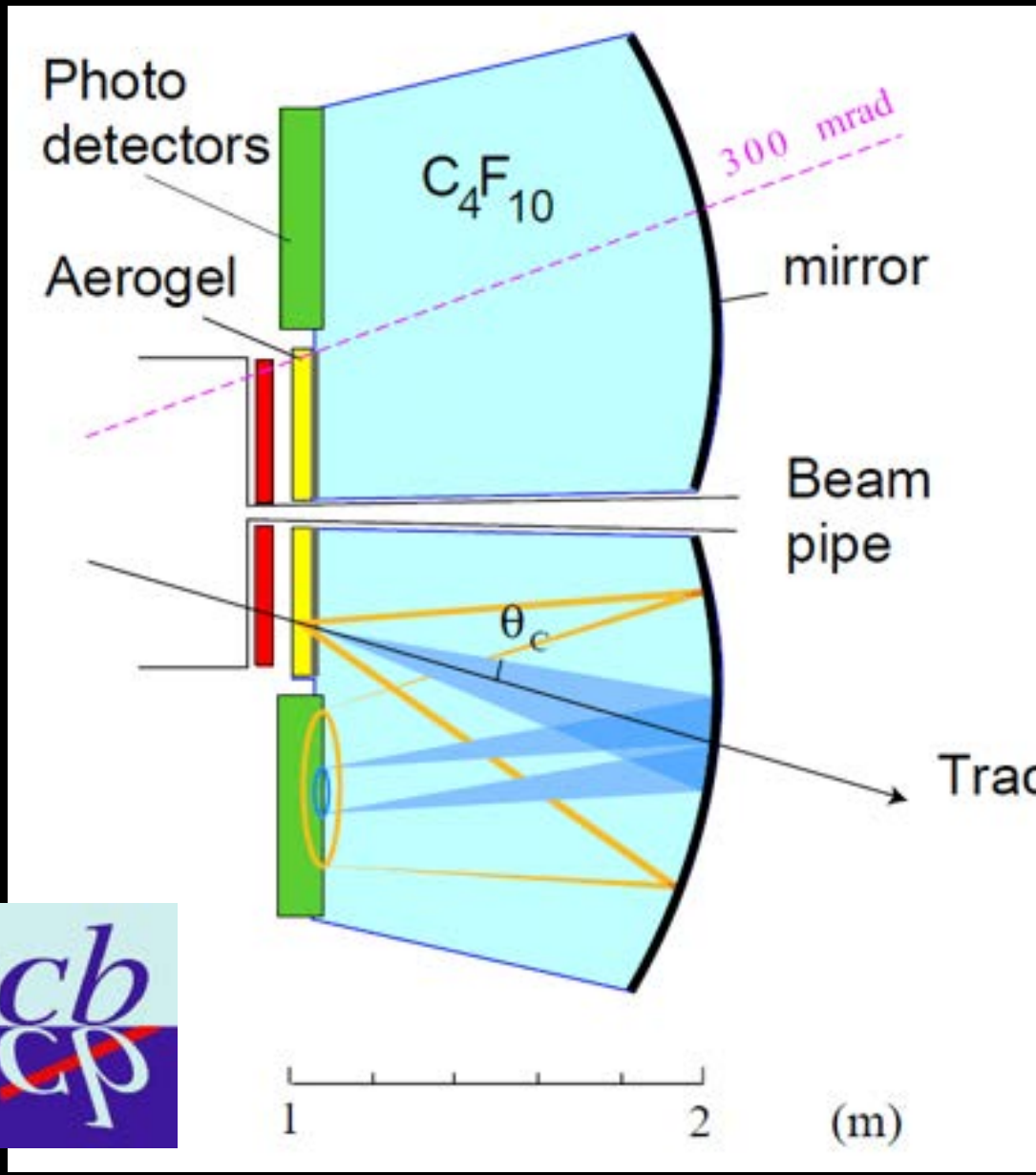


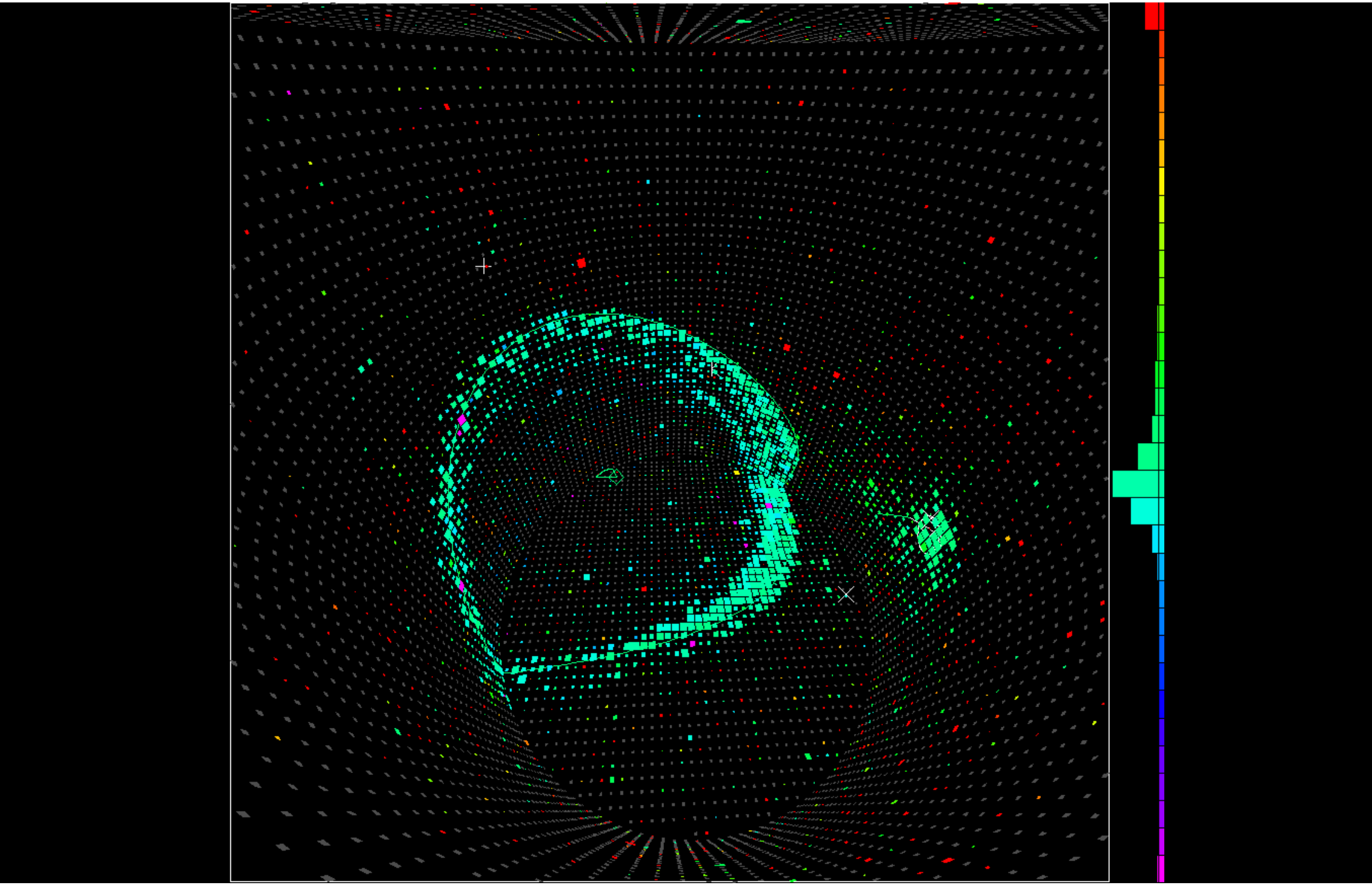
identificazione della partice

pione 140 MeV
kaone 500 MeV
protone 940 MeV

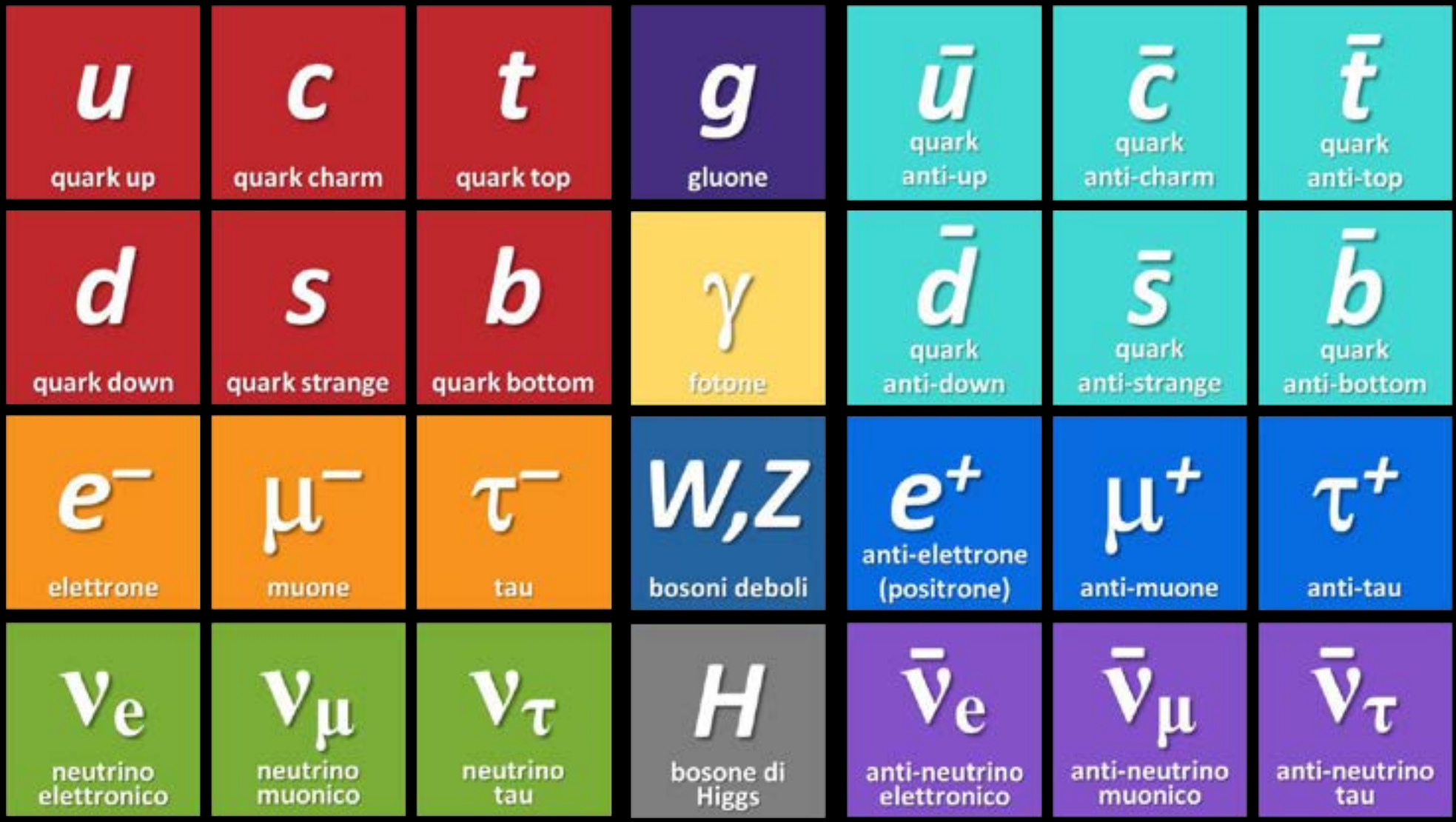
rich – ring imaging cherenkov





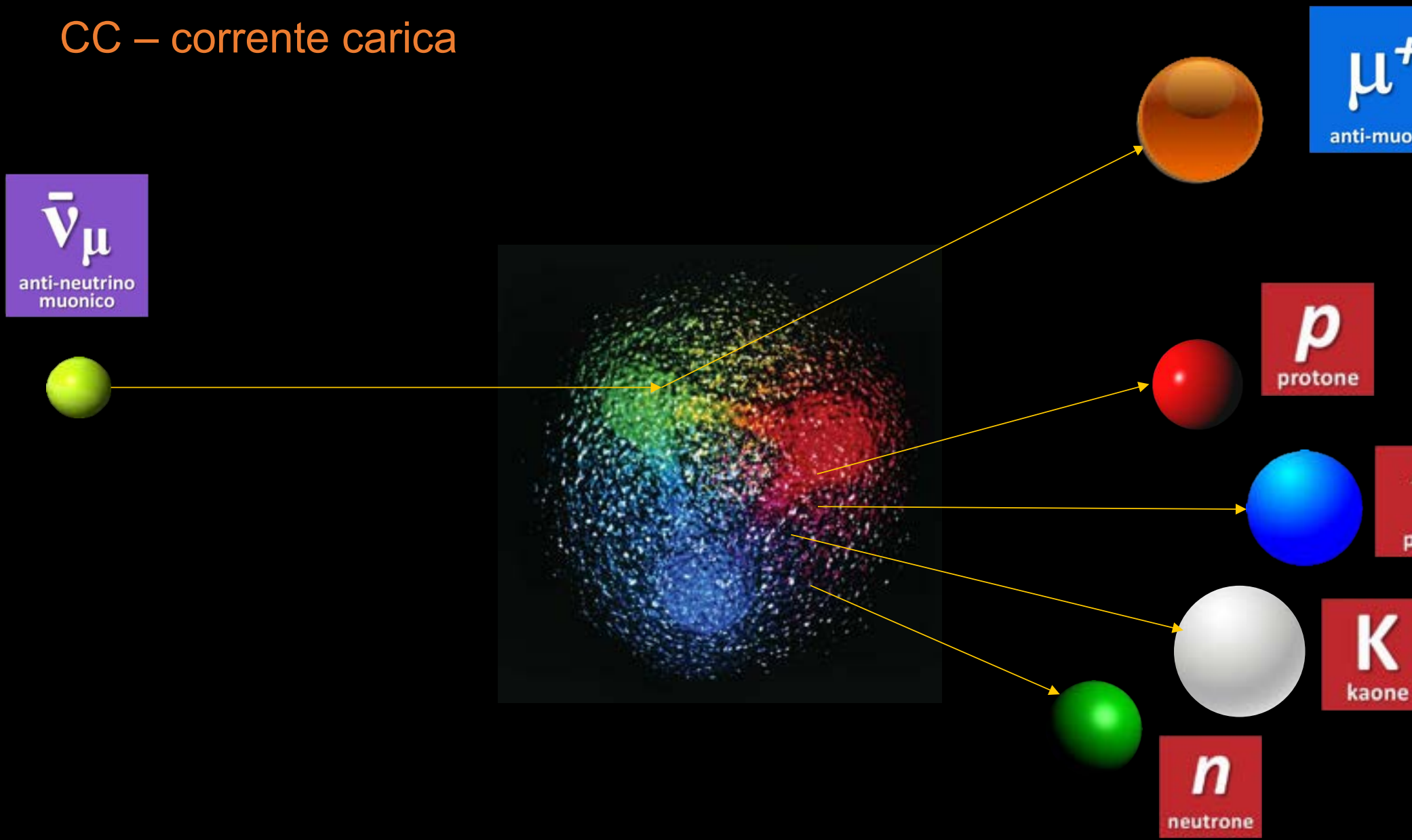


modello standard delle particelle e delle interazioni



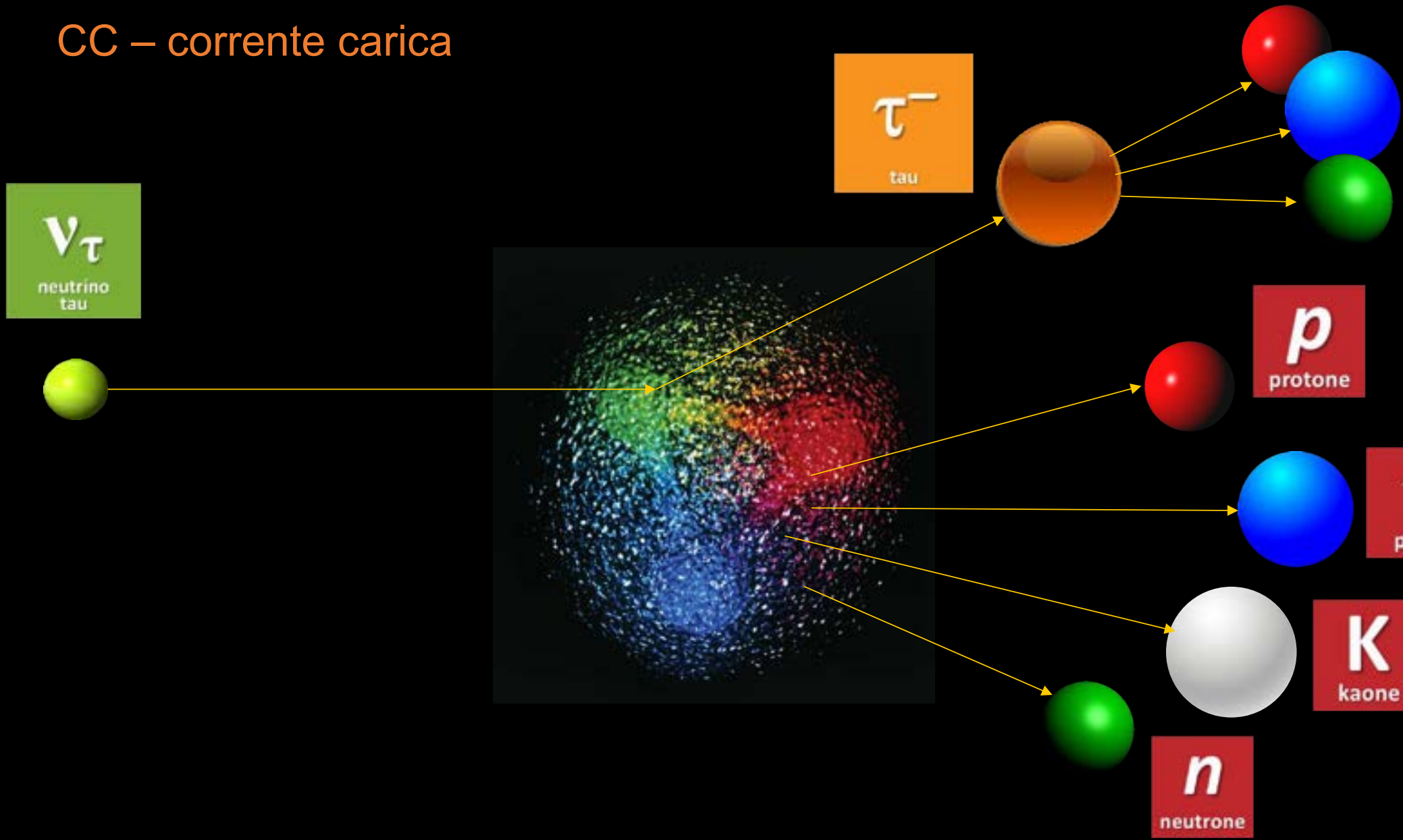
interazione dei neutrini

CC – corrente carica



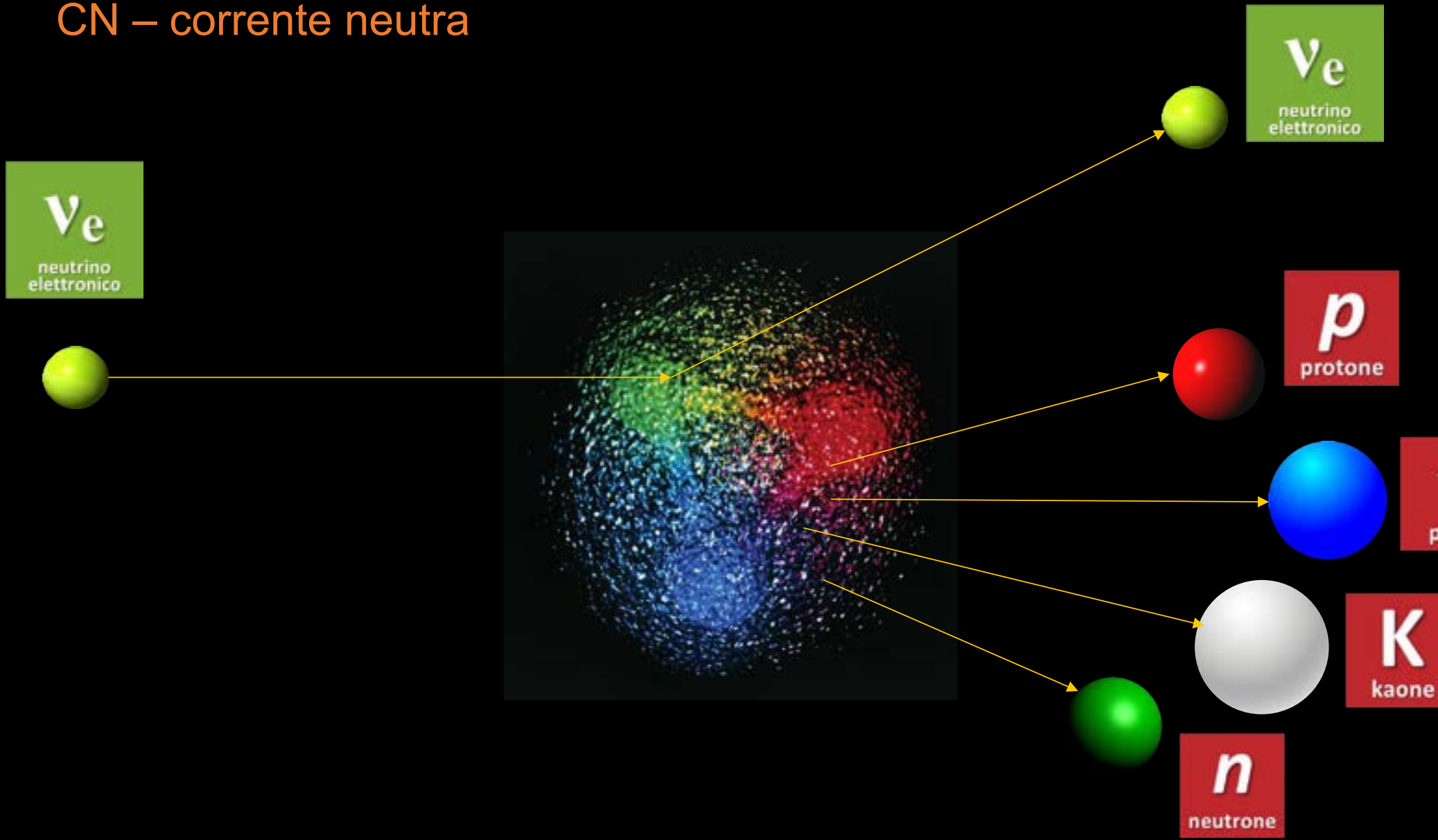
interazione dei neutrini

CC – corrente carica



interazione dei neutrini

CN – corrente neutra

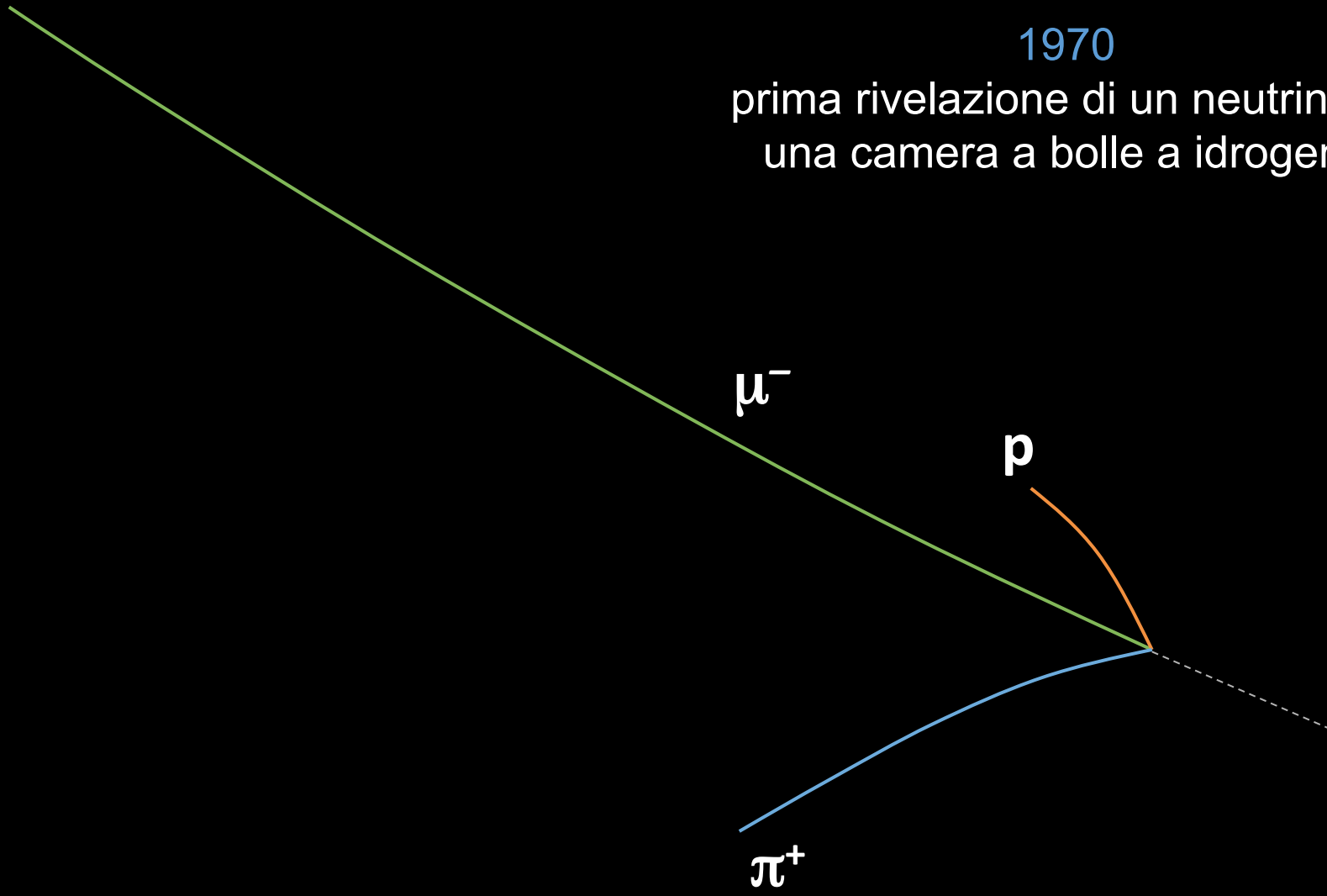


rivelare i neutrini

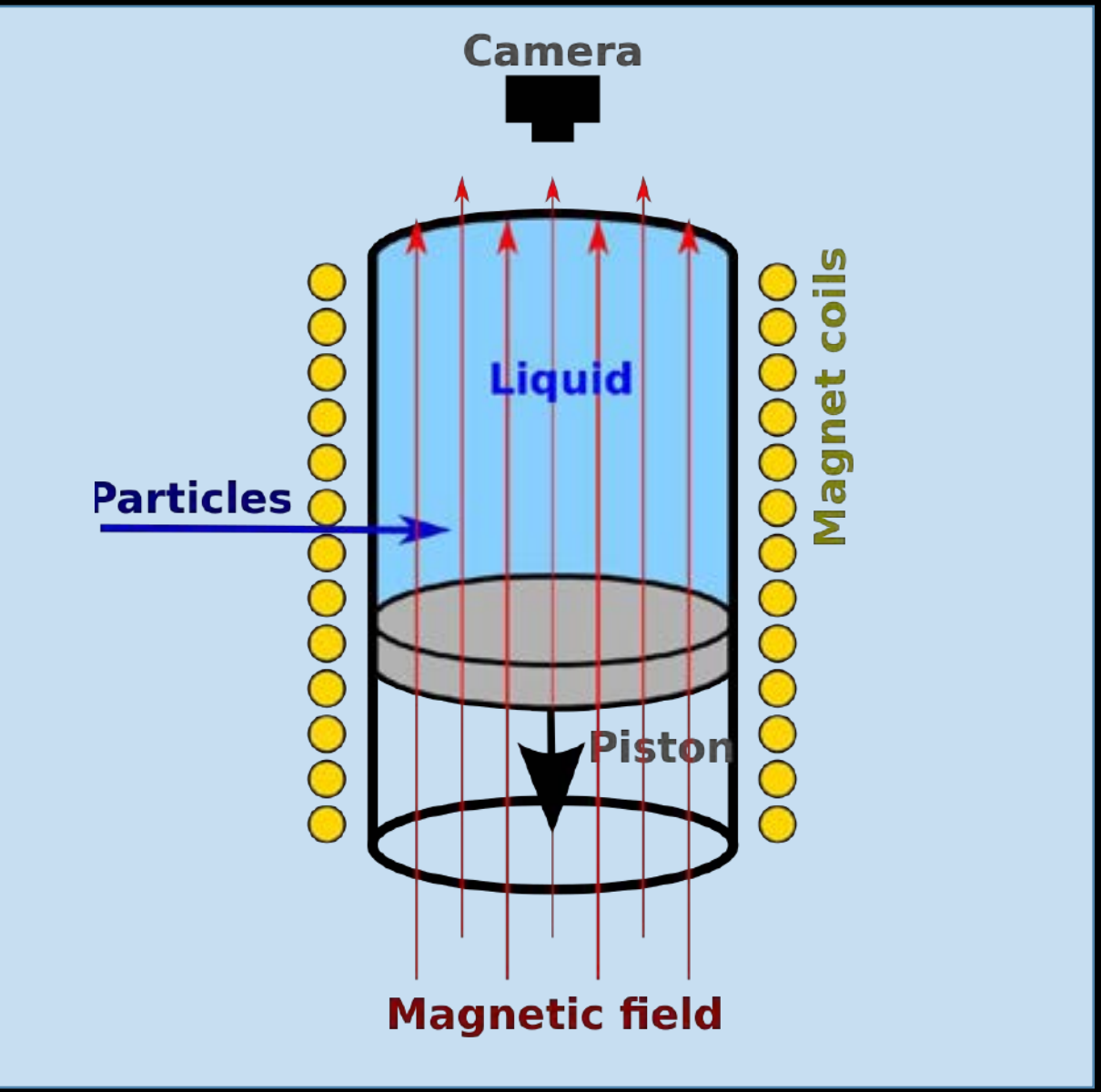
1970

prima rivelazione di un neutrin

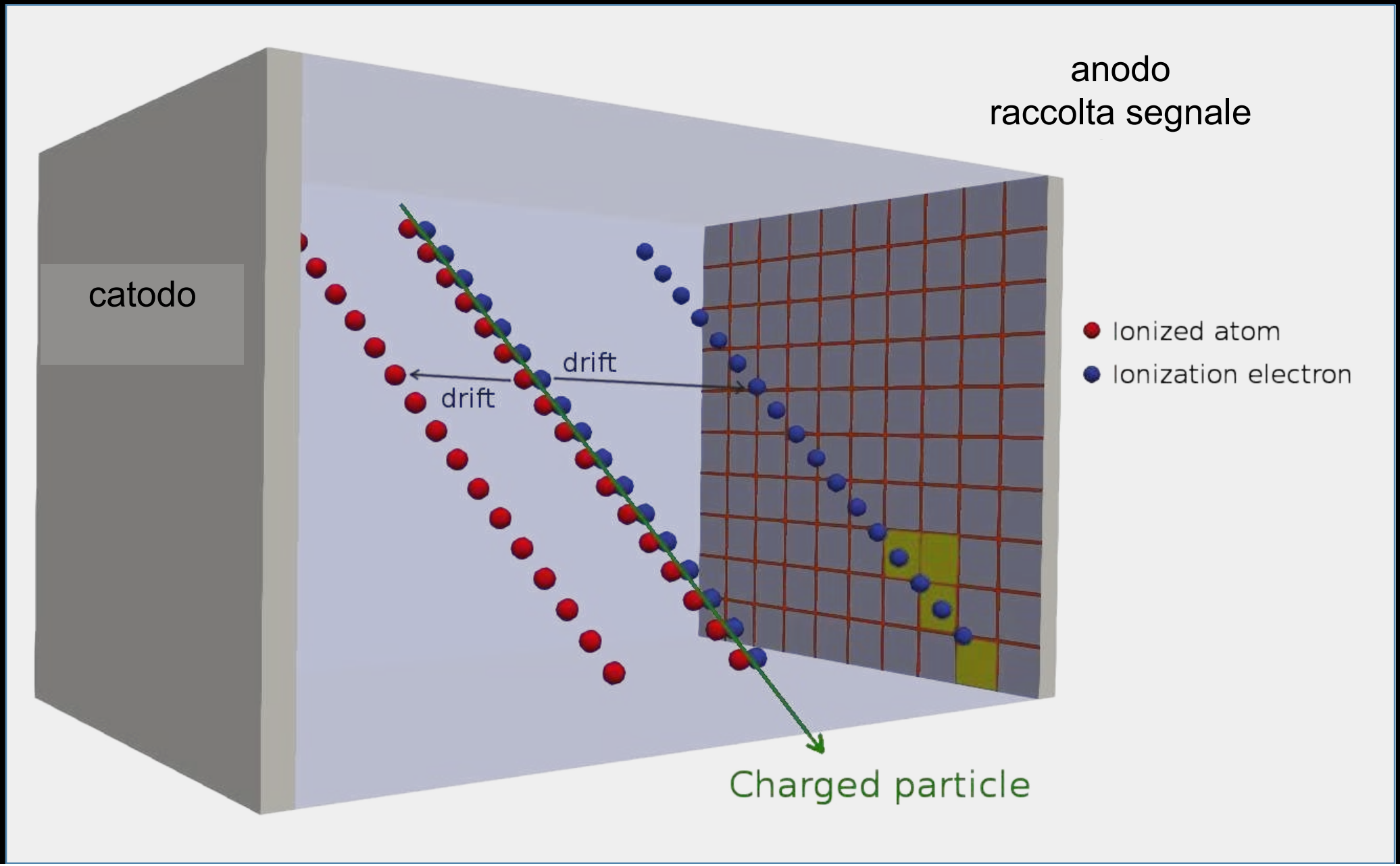
una camera a bolle a idroge



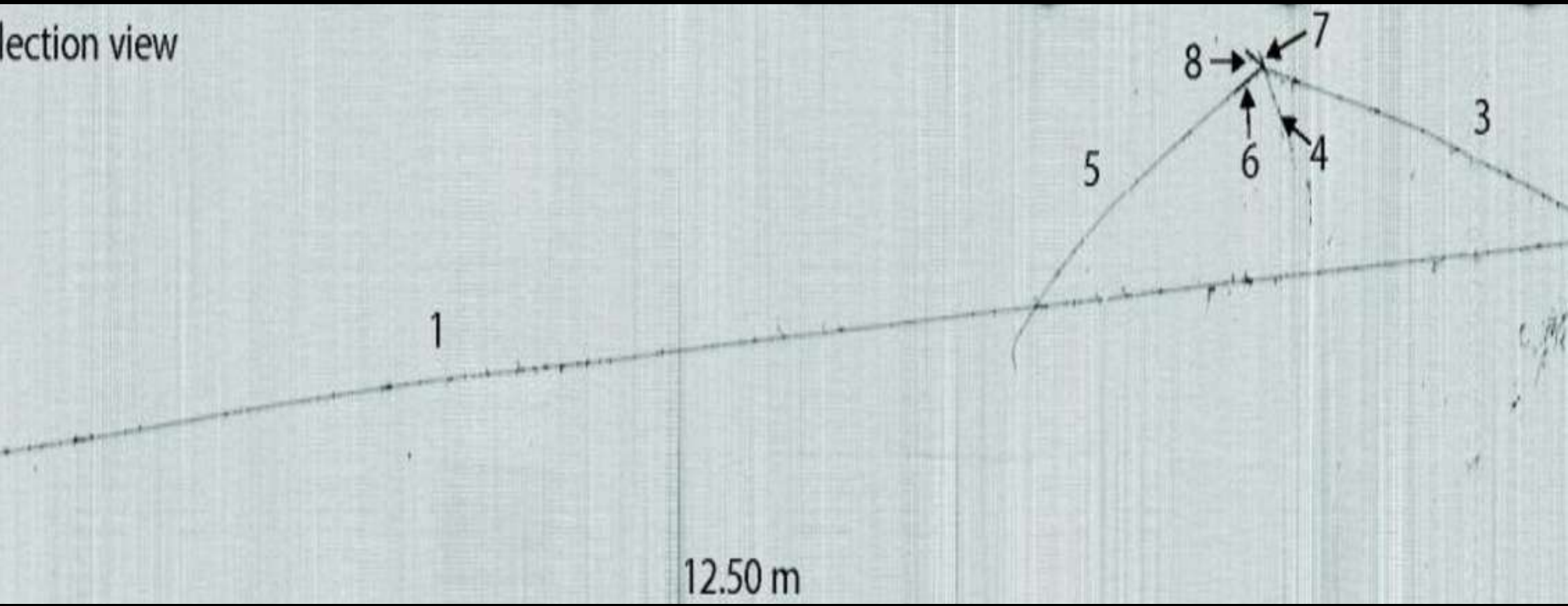
camera a bolle



time projection chamber

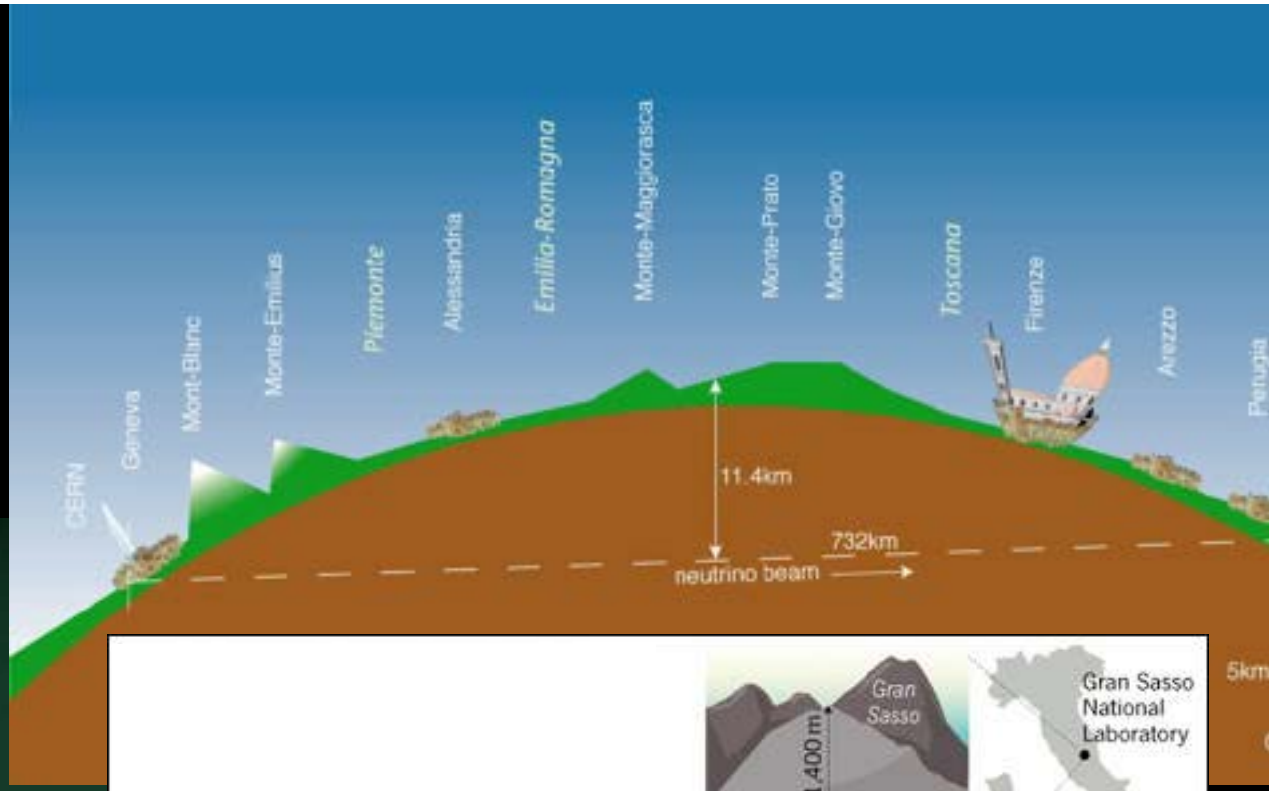


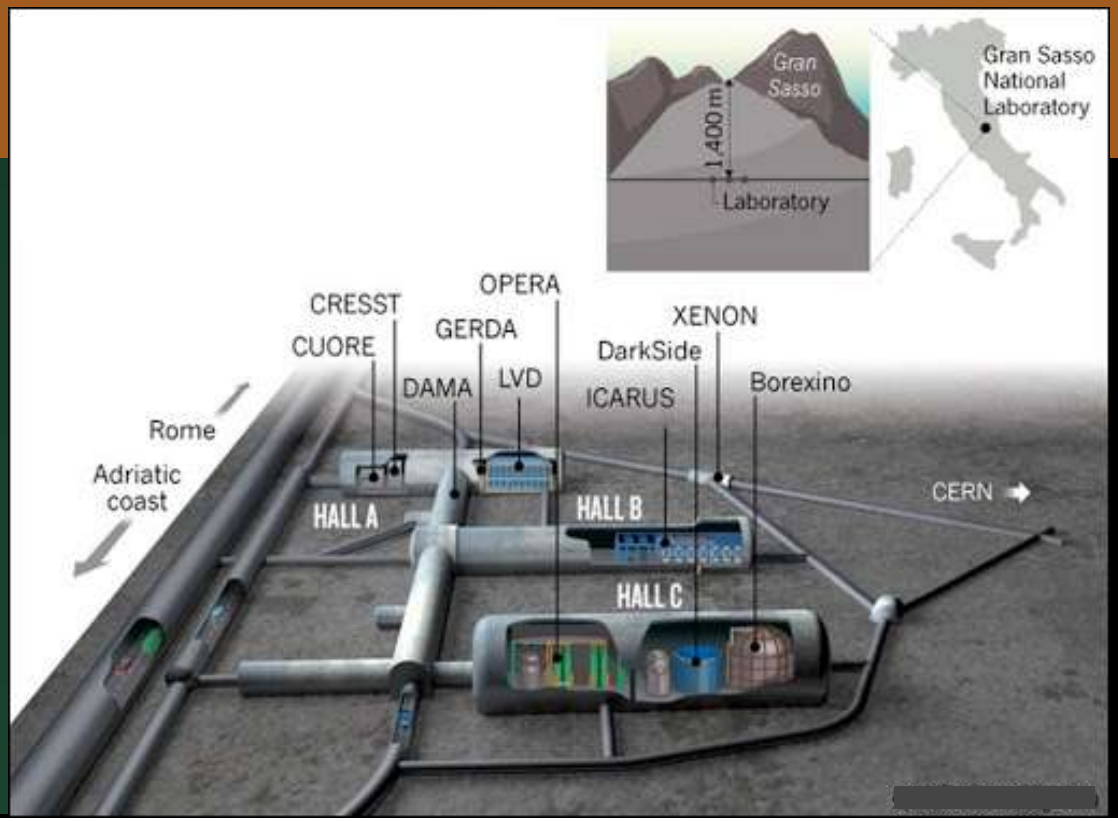
ICARUS a CNGS



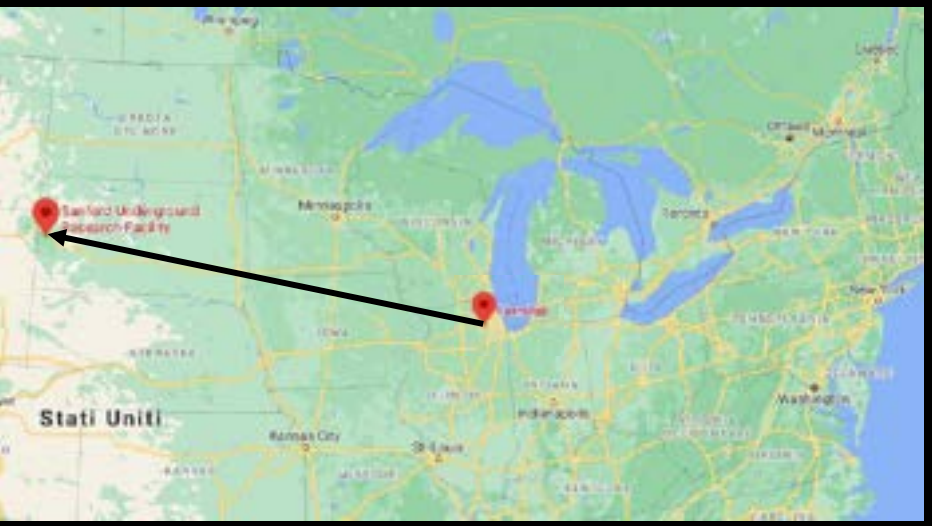
Cern neutrinos to gran sasso

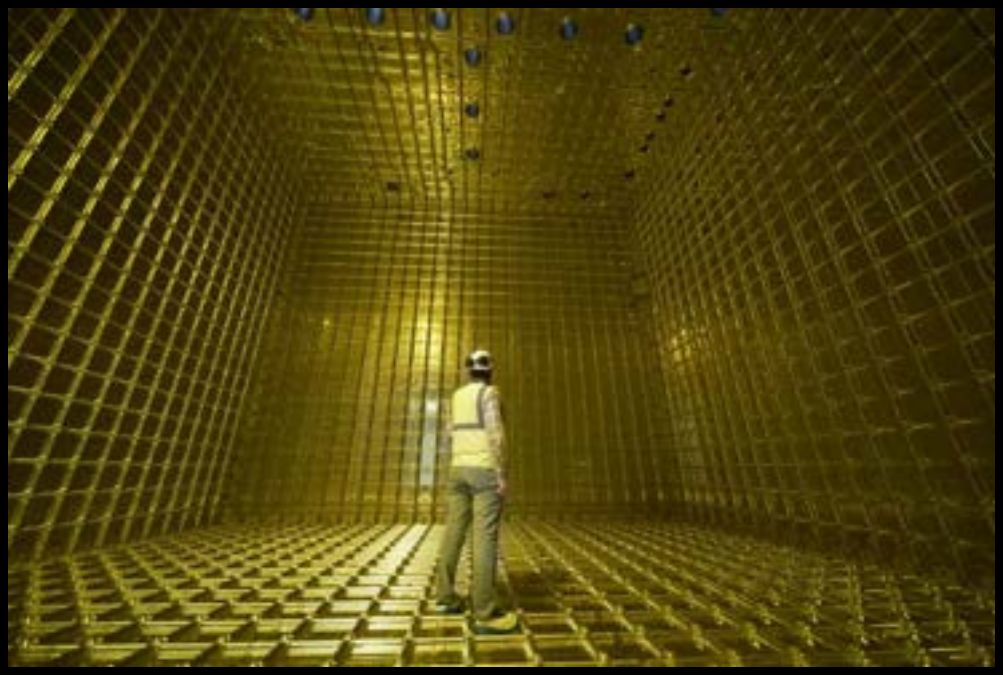
2008 – 2012
OPERA - ICARUS

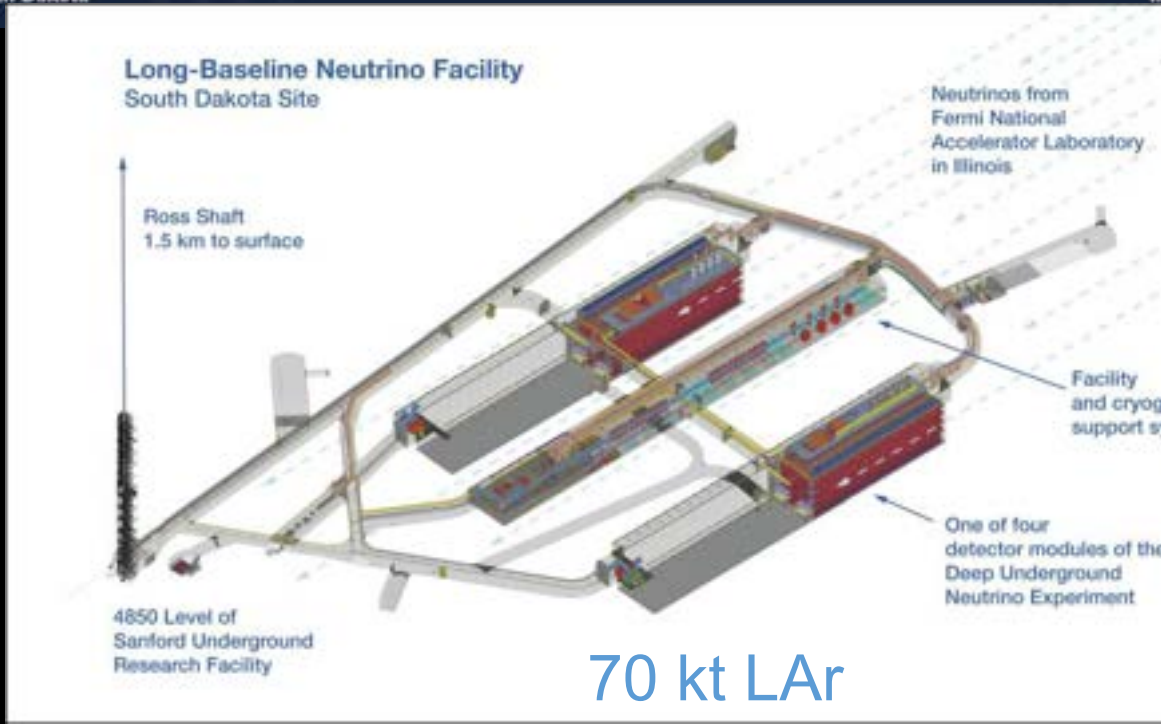




DUNE
deep underground neutrino experiment







positron emission tomography