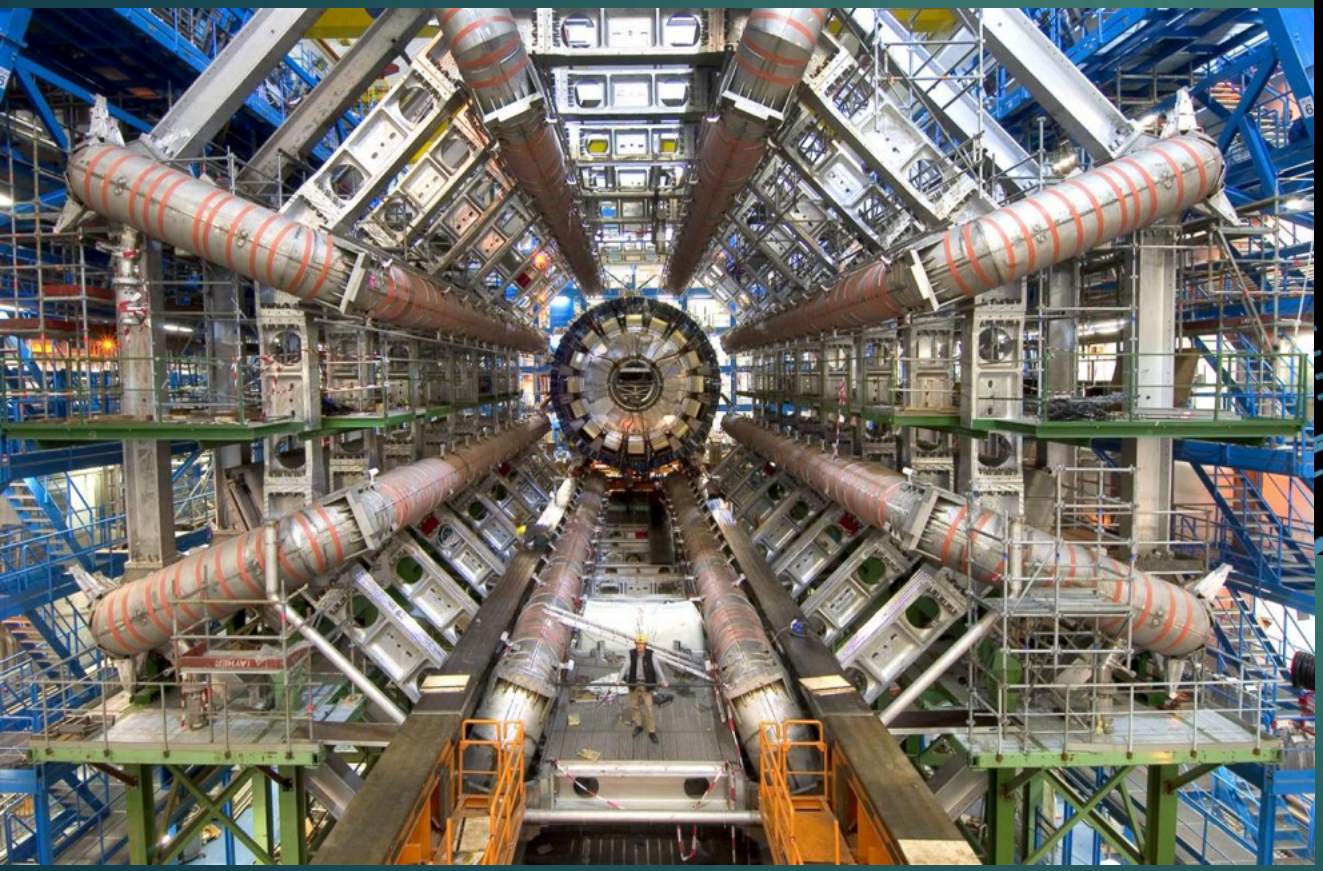
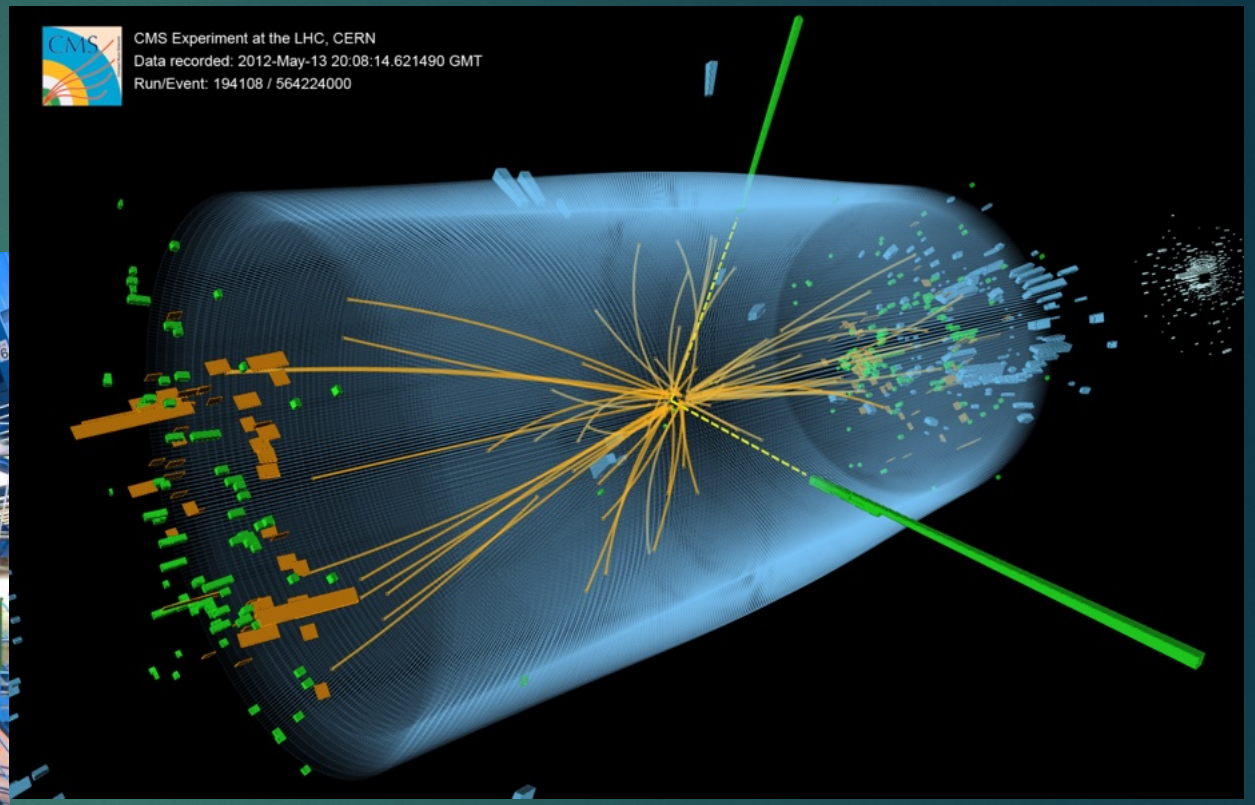
- Braganca (Portogallo)
- Paris (Francia)
- Grenoble (Francia)
- Bologna (Italia)
- Skierniewice (Polonia)

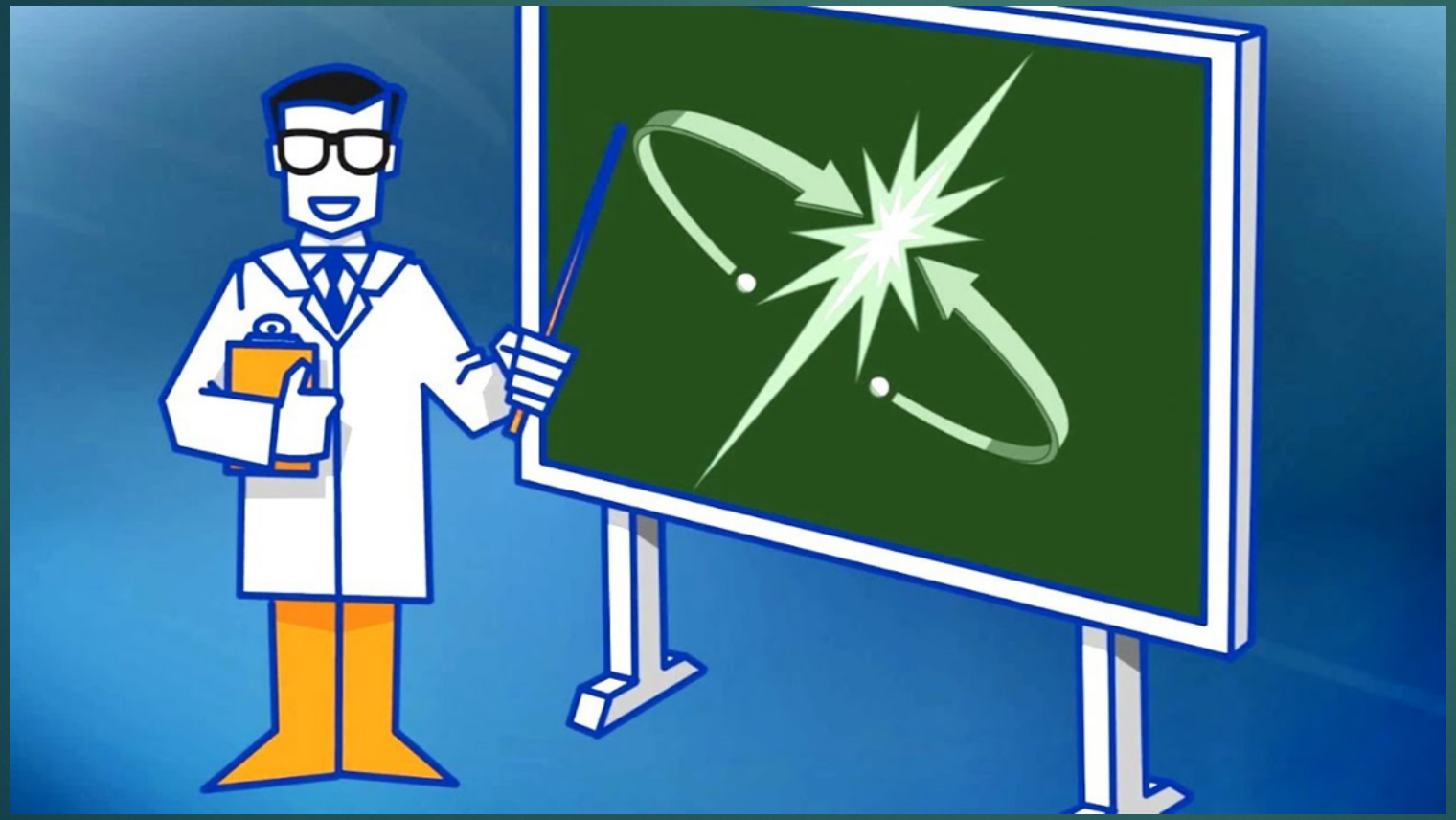
Rivelare le particelle – International Masterclasses 2025

Stefano Marcellini – INFN Sezione di Bologna

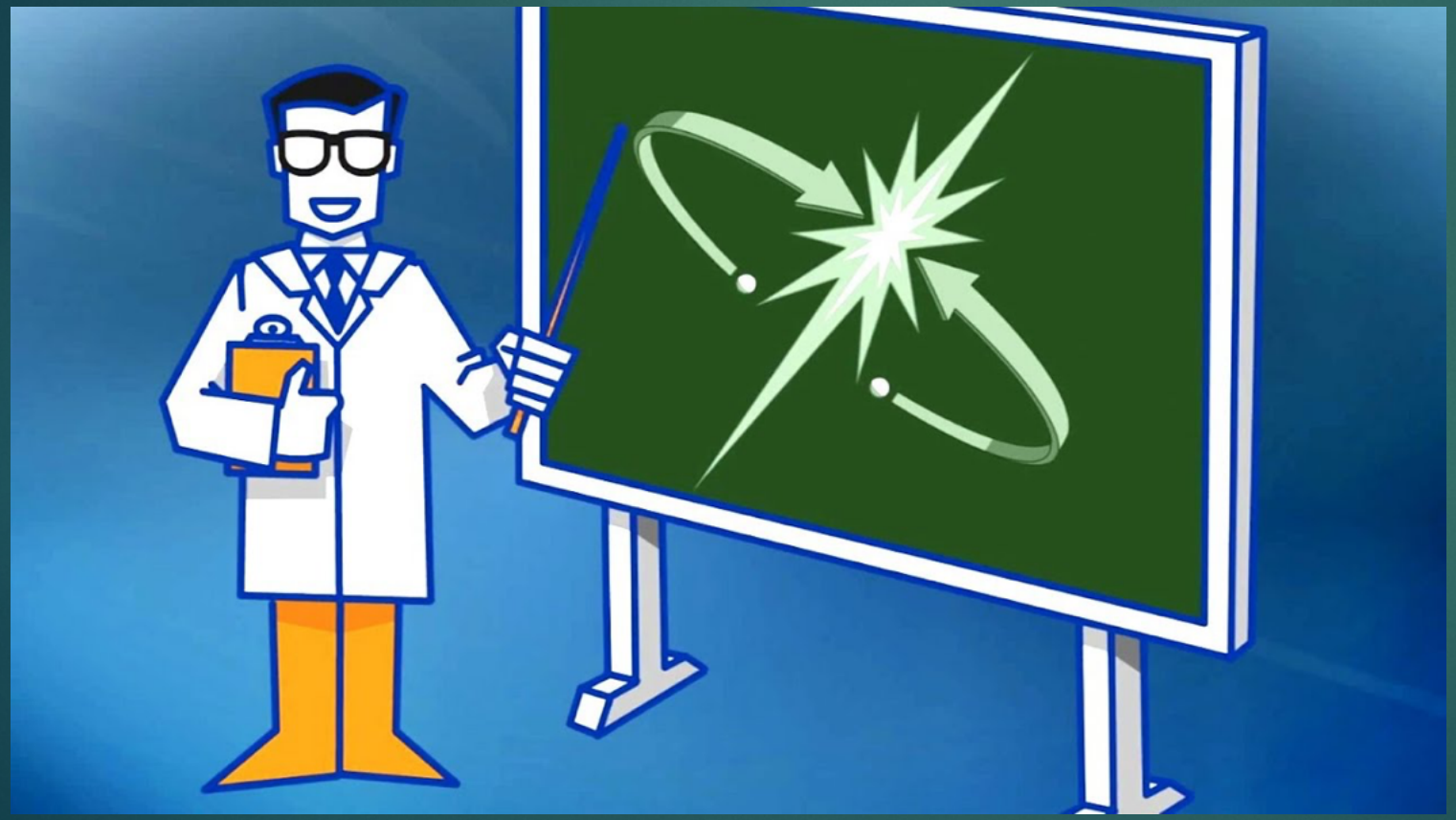




INFN
Istituto Nazionale di Fisica Nucleare

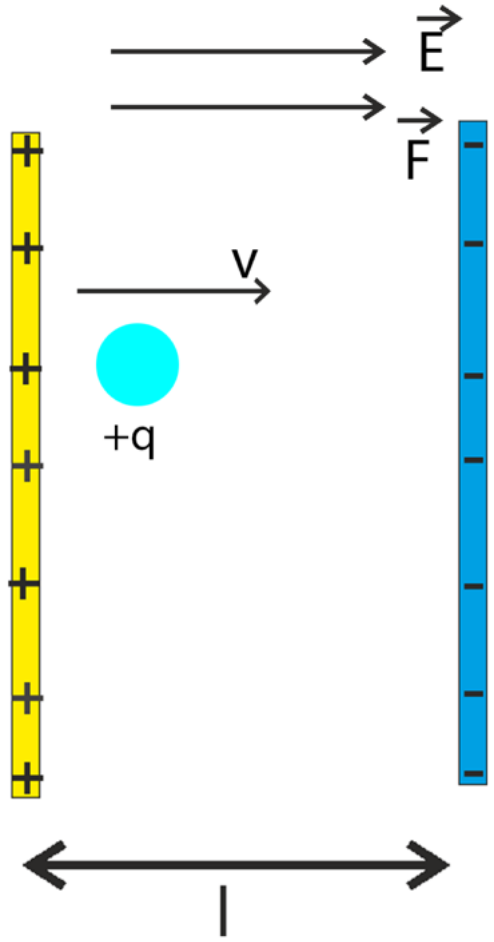


Come funziona un esperimento di fisica delle particelle agli acceleratori?

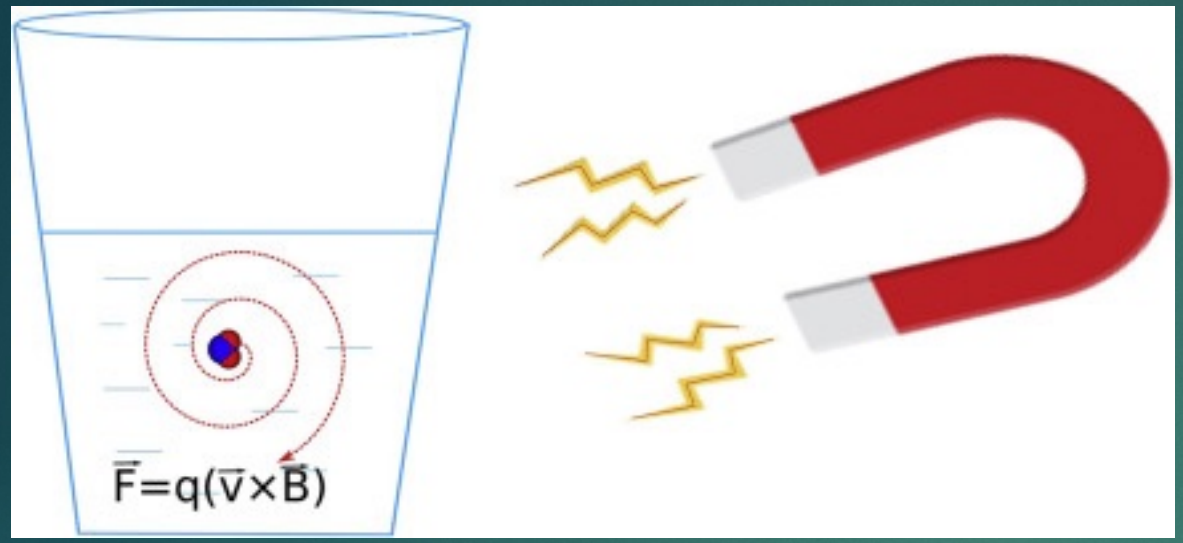


Le particelle vanno:

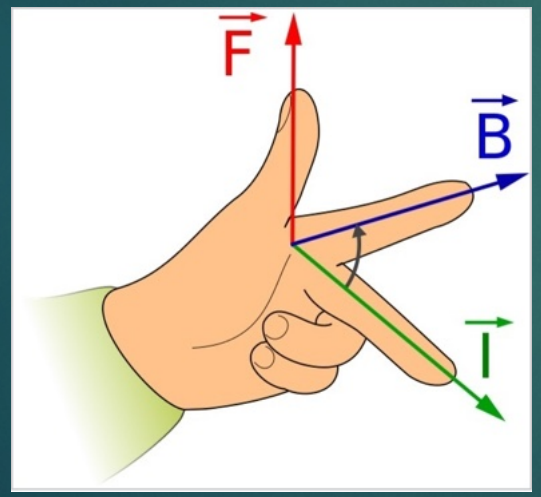
- ACCELERATE
- FATTE SCONTRARE FRA LORO
- SI OSSERVA COSA SUCCEDE DOPO LO L'URTO

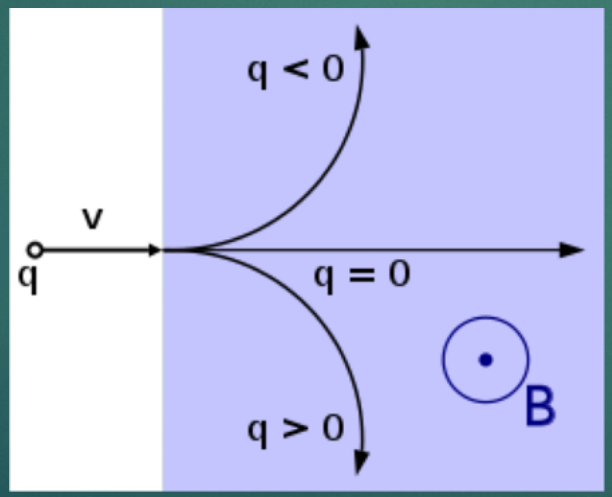


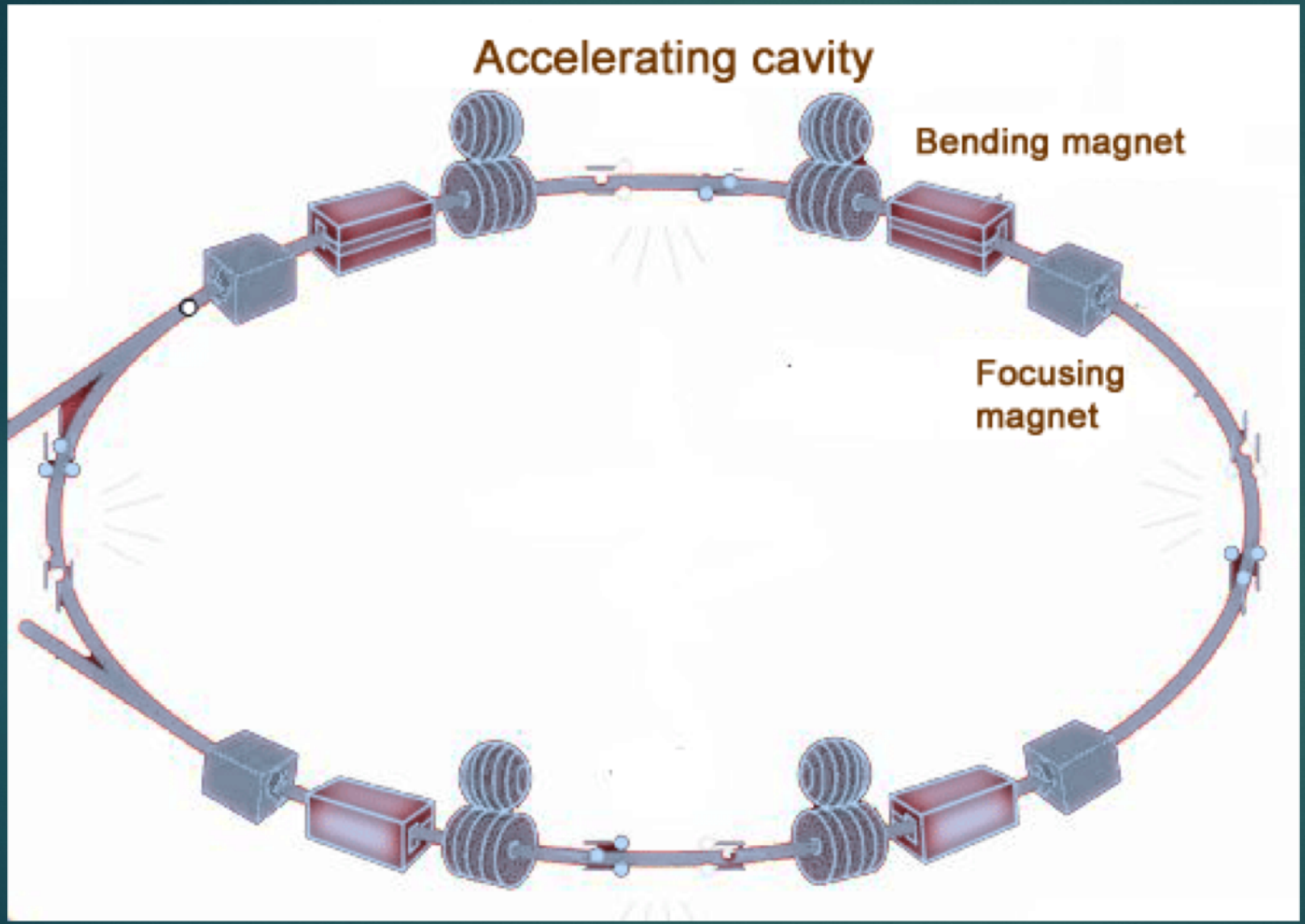
Un campo elettrico accelera una particella carica



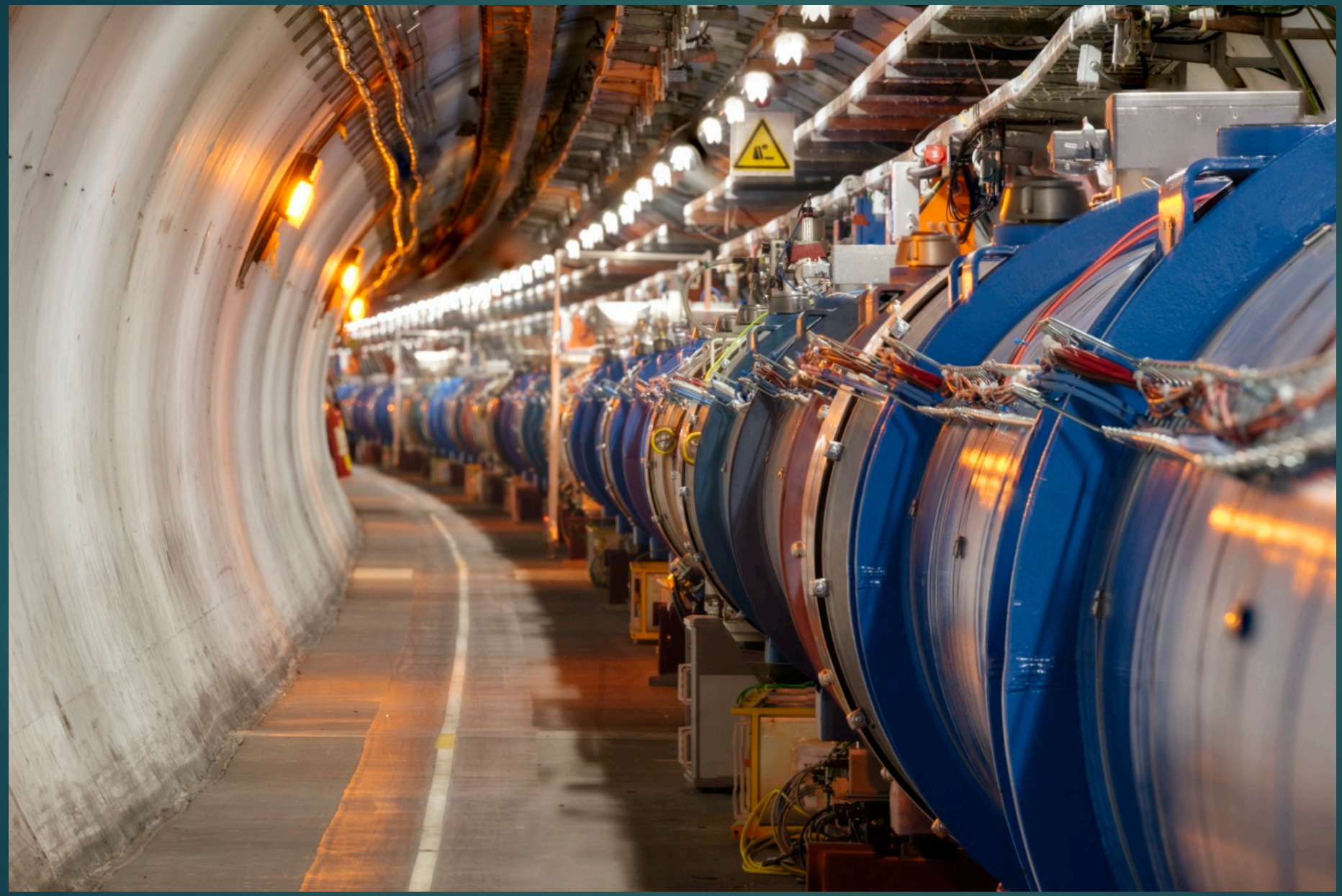
Un campo magnetico curva la traiettoria di una particella carica.

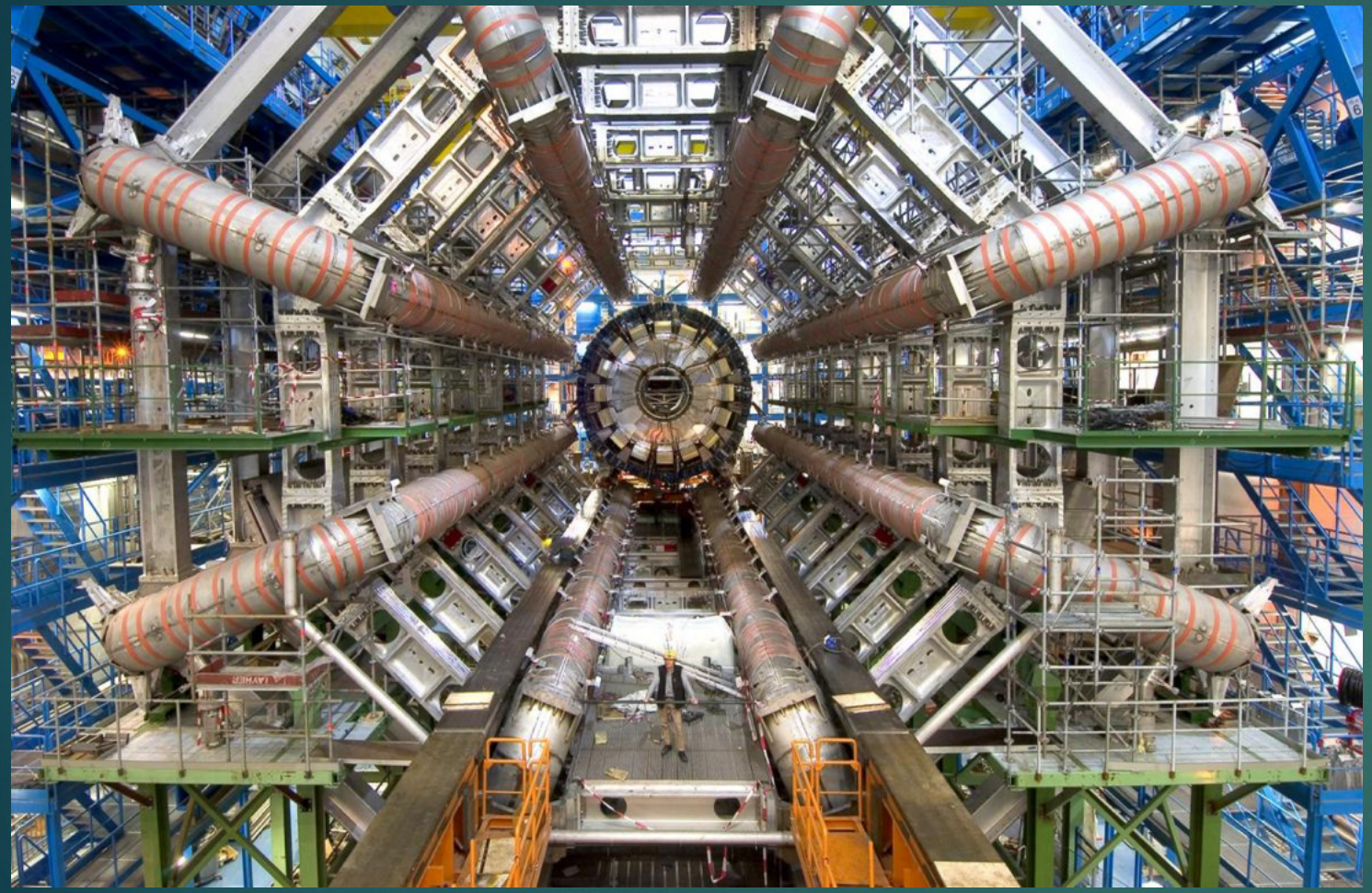




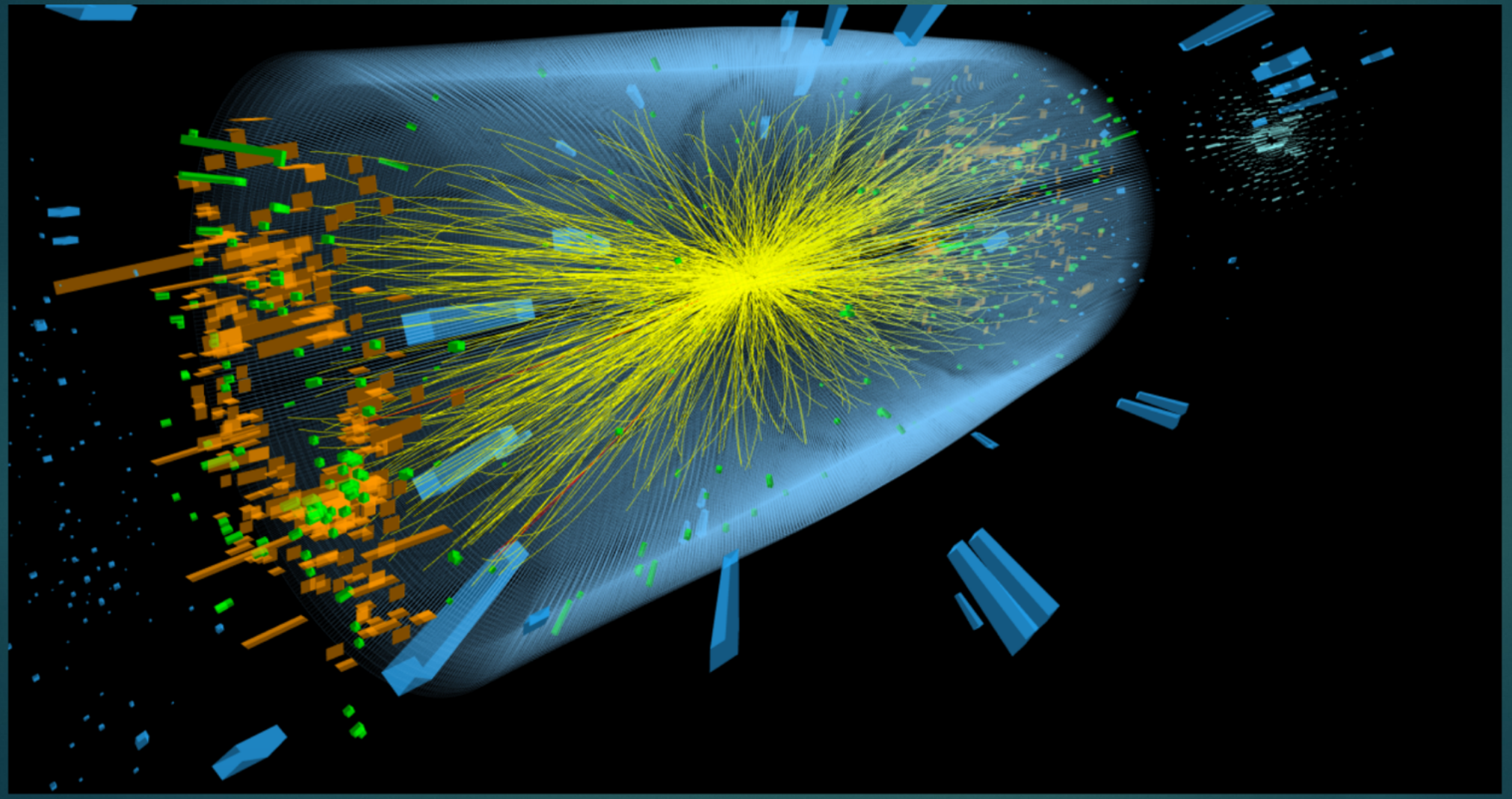

Accelerating cavity
Bending magnet
Focusing
magnet


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km



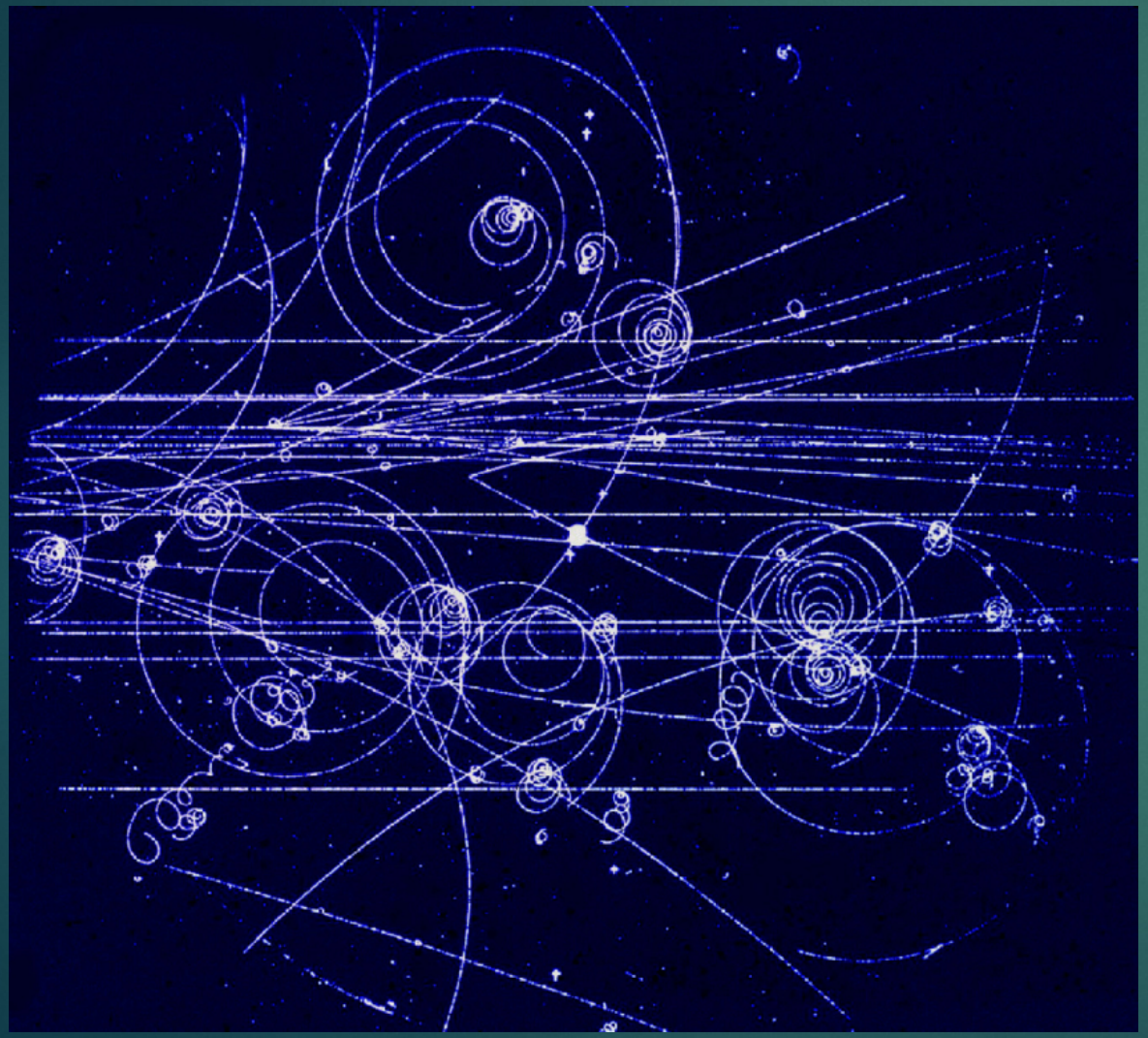


Un rivelatore di particelle «vede» cosa succede negli urti fra le particelle



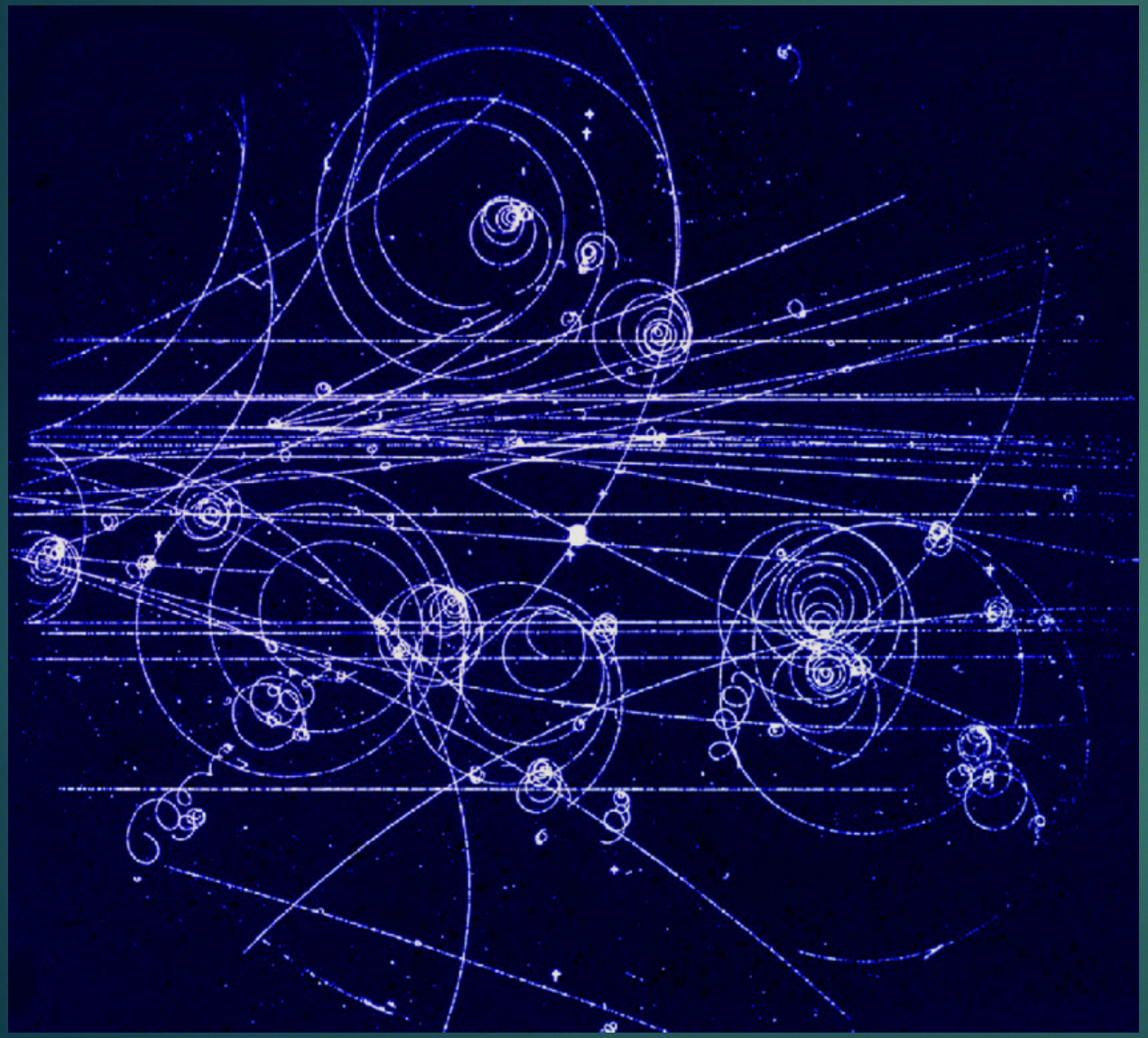
Come possiamo «vedere» le particelle?

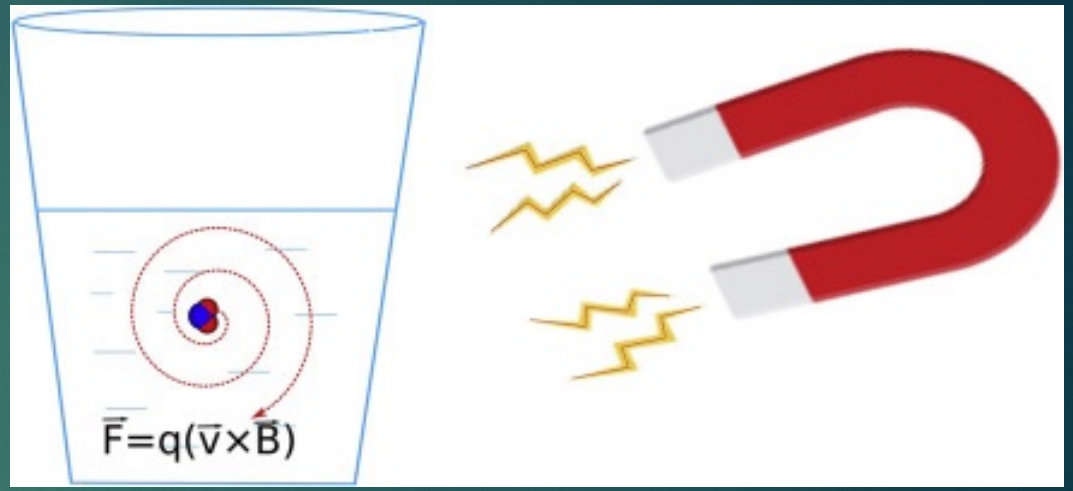
Vedere qualcosa tramite l'interazione con il mezzo circostante

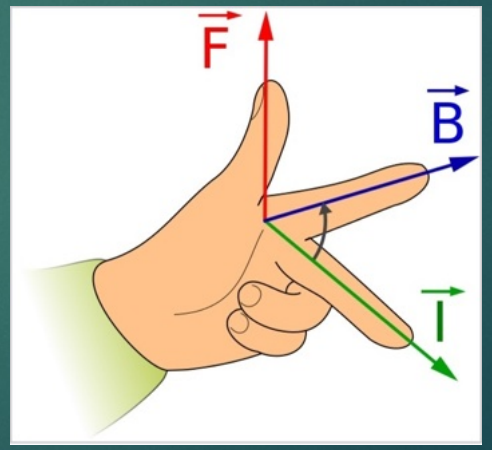


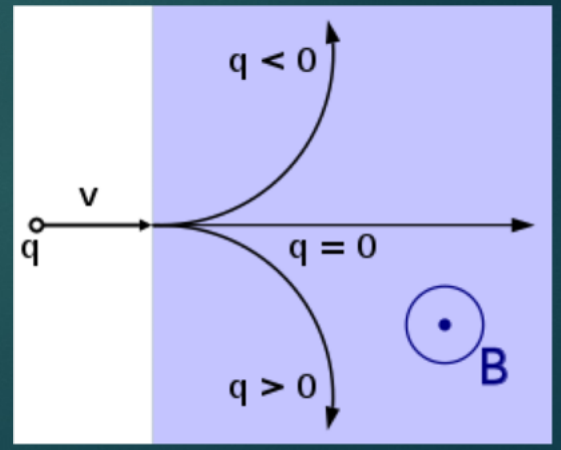
Le particelle cariche ionizzano il mezzo in cui passano

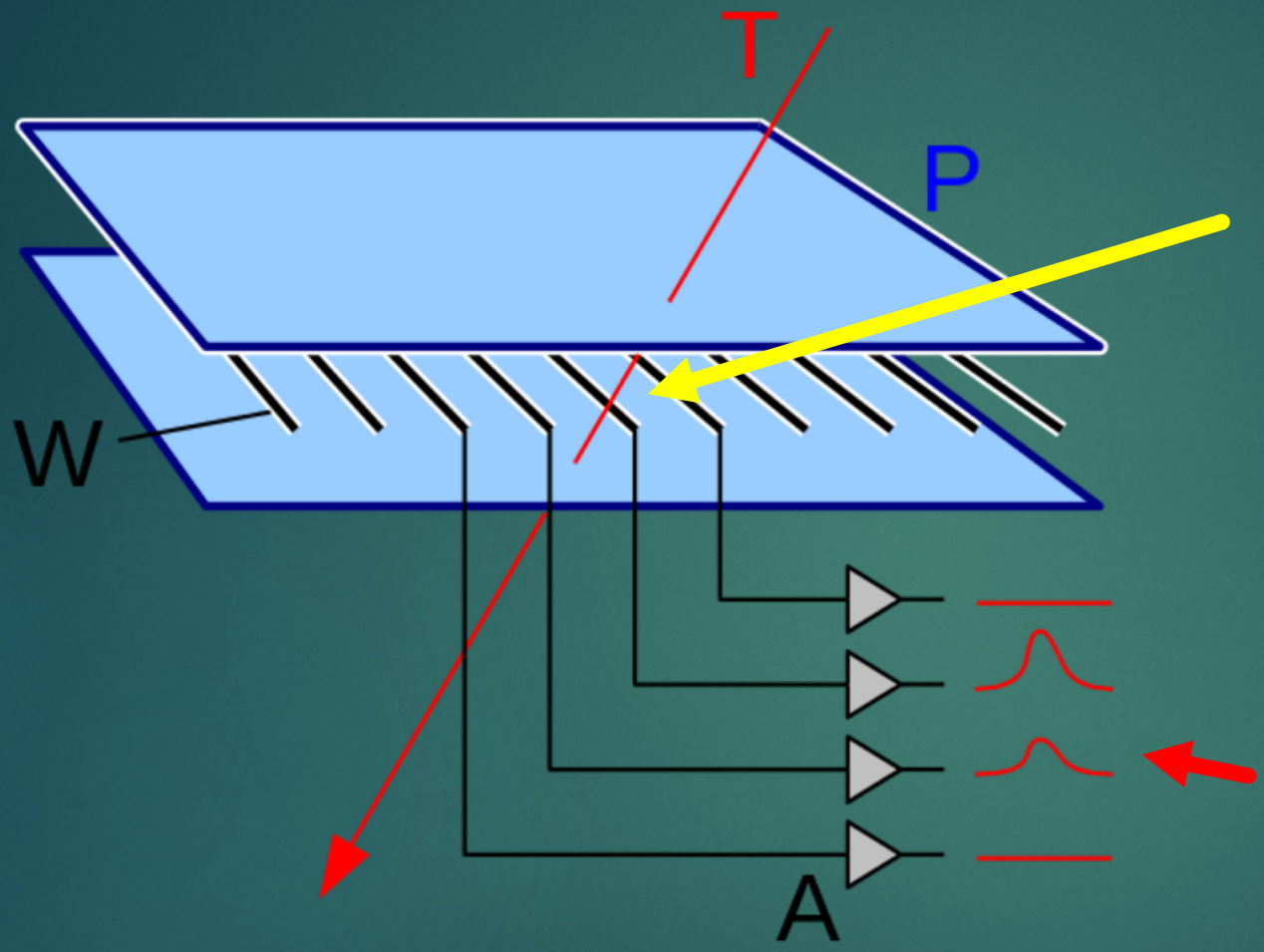
Dalla ricostruzione della ionizzazione prodotta è possibile ricostruire le loro tracce




F=q(v×B)


F
B
I


q < 0
v
q
q = 0
q > 0
B

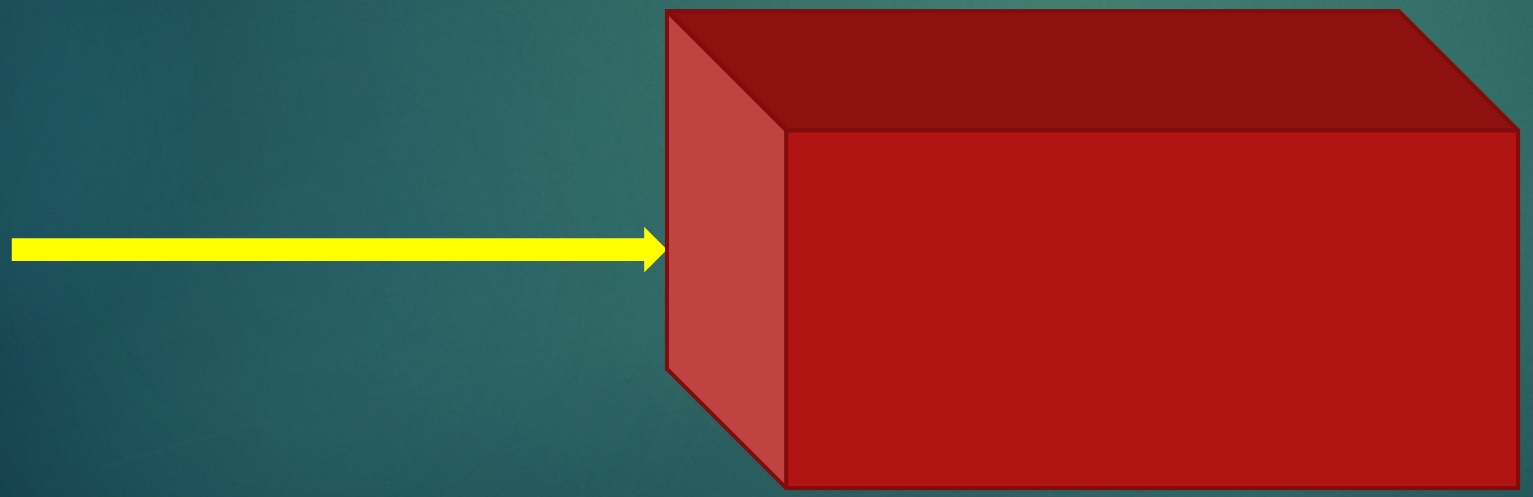


Una particella carica ionizza il mezzo che attraversa producendo cariche elettriche libere di muoversi

Cariche positive e negative viaggiano verso il catodo e i fili anodici.

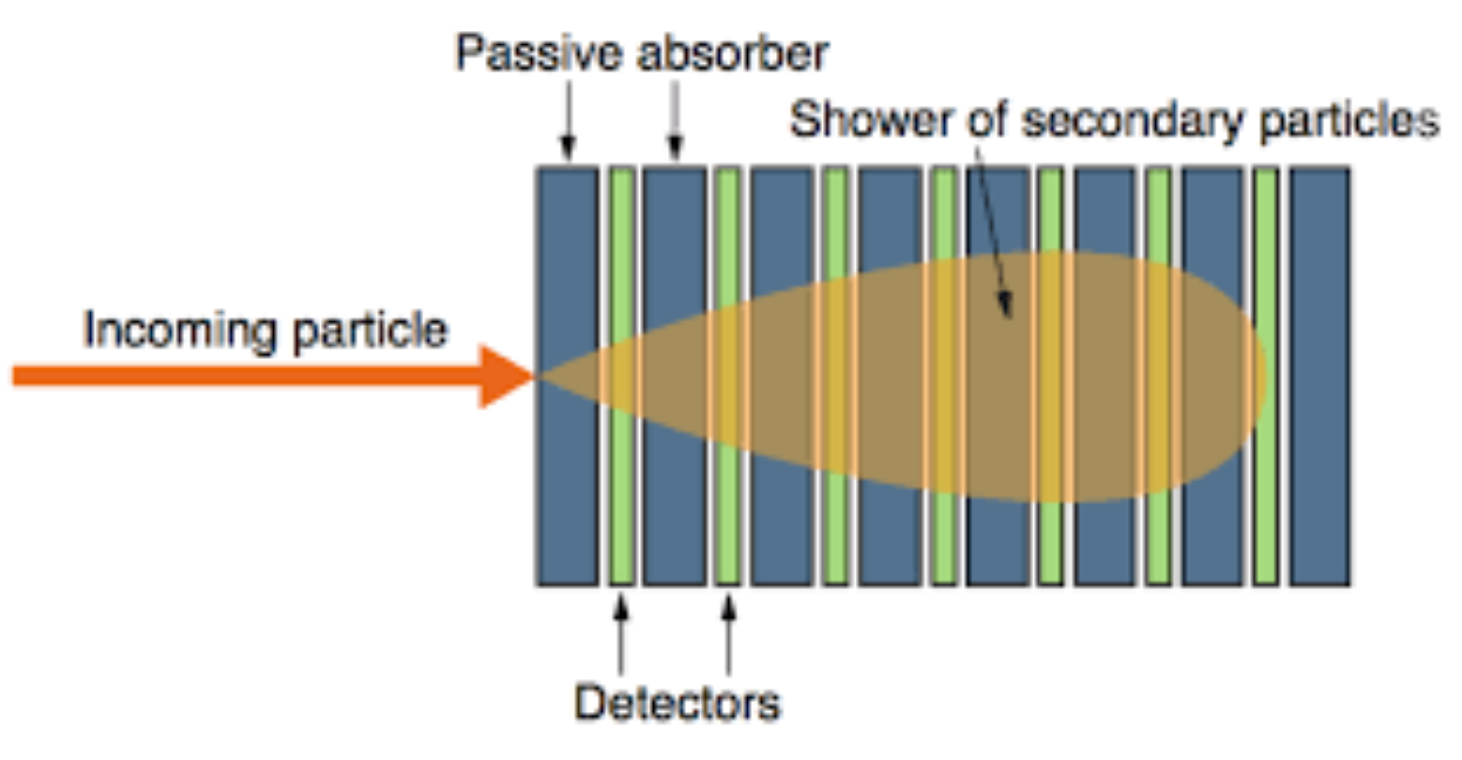
Dall'altezza della carica raccolta si ricava a posizione in cui è passata la particella

Calorimetri: misurare l'energia delle particelle



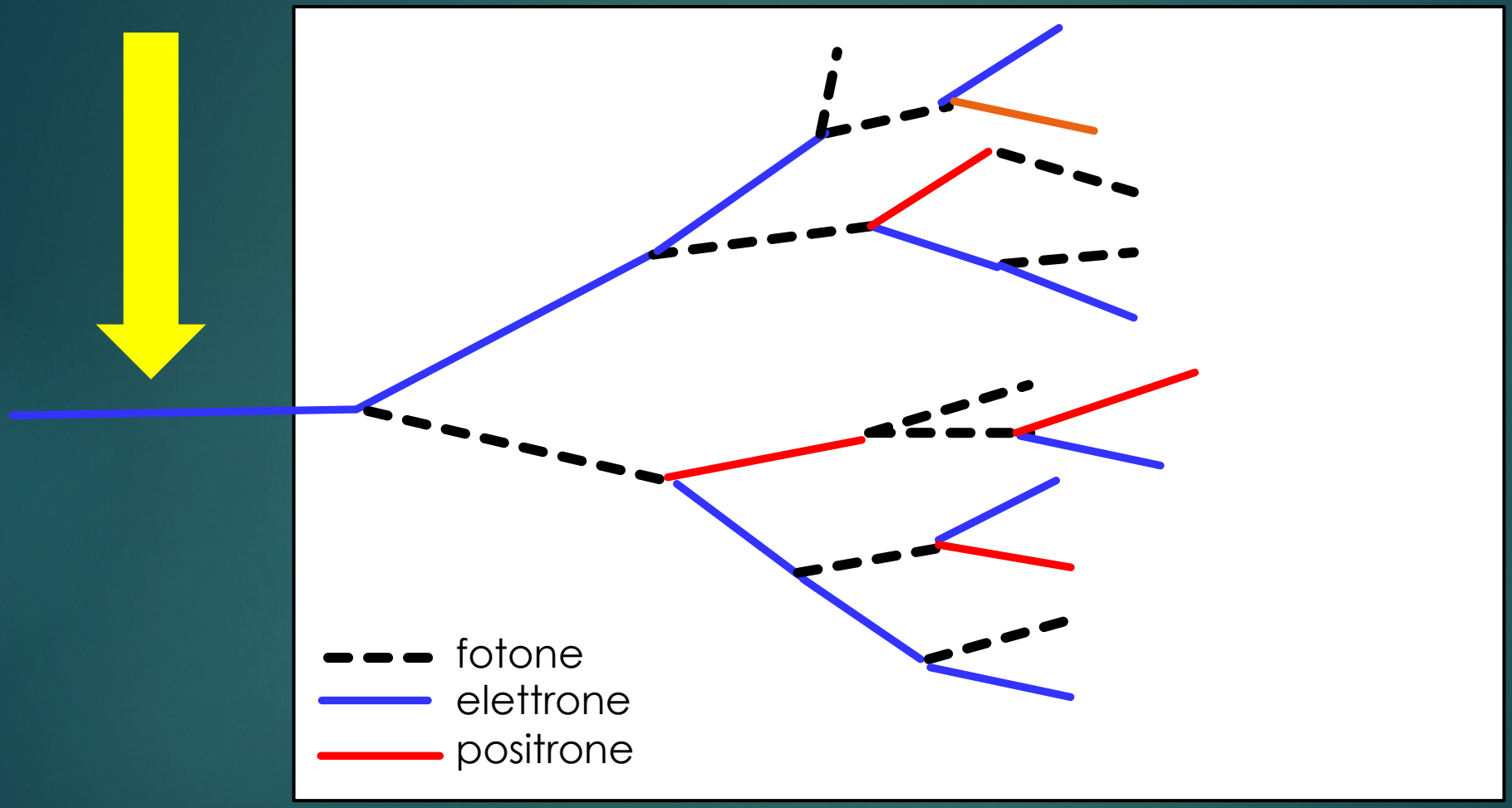
Calorimetri: misurare l'energia delle particelle

«Distrugge» la particella originaria

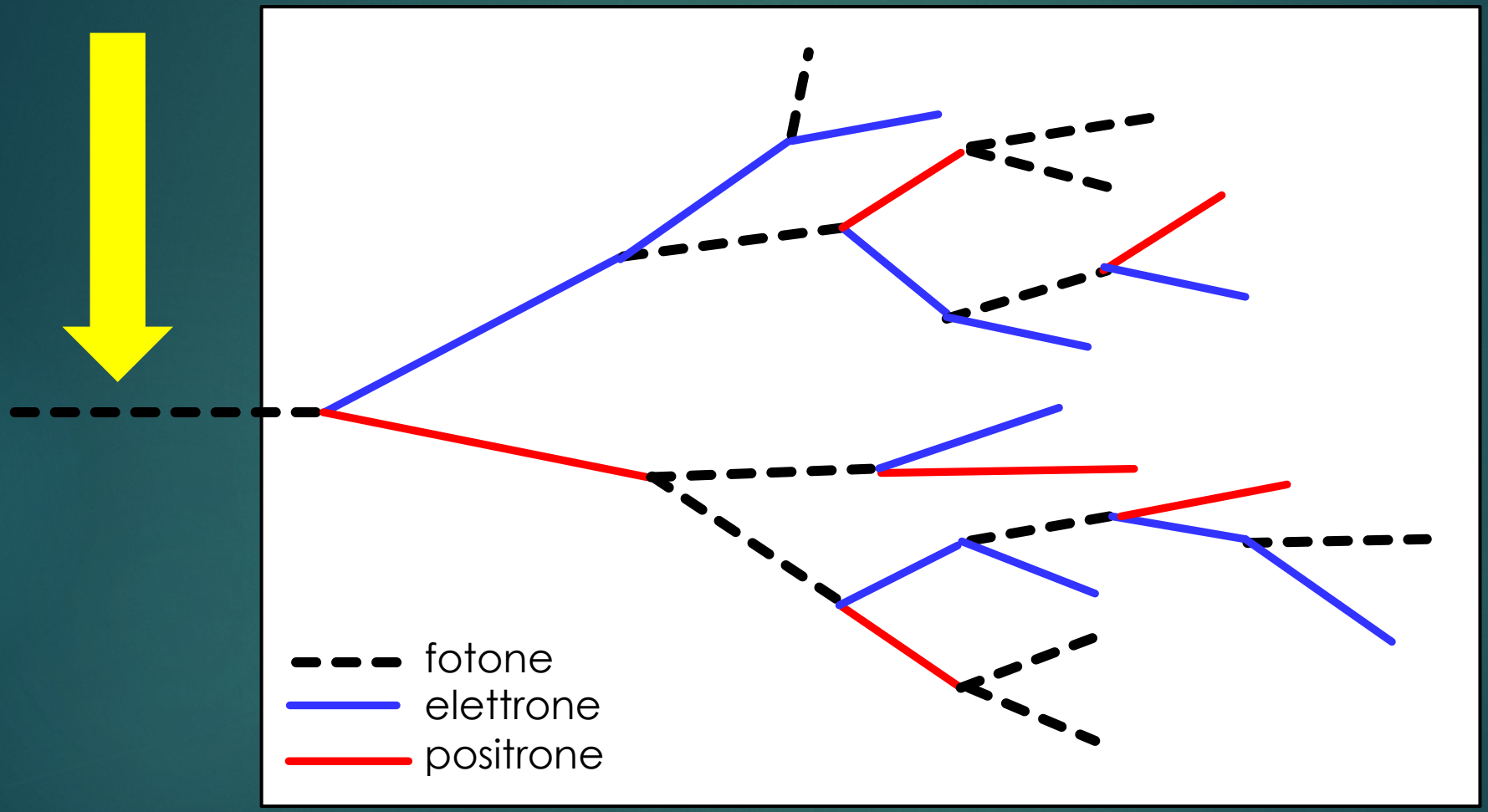


Oltre il calorimetro assorbitore, in linea di principio non esce fuori niente

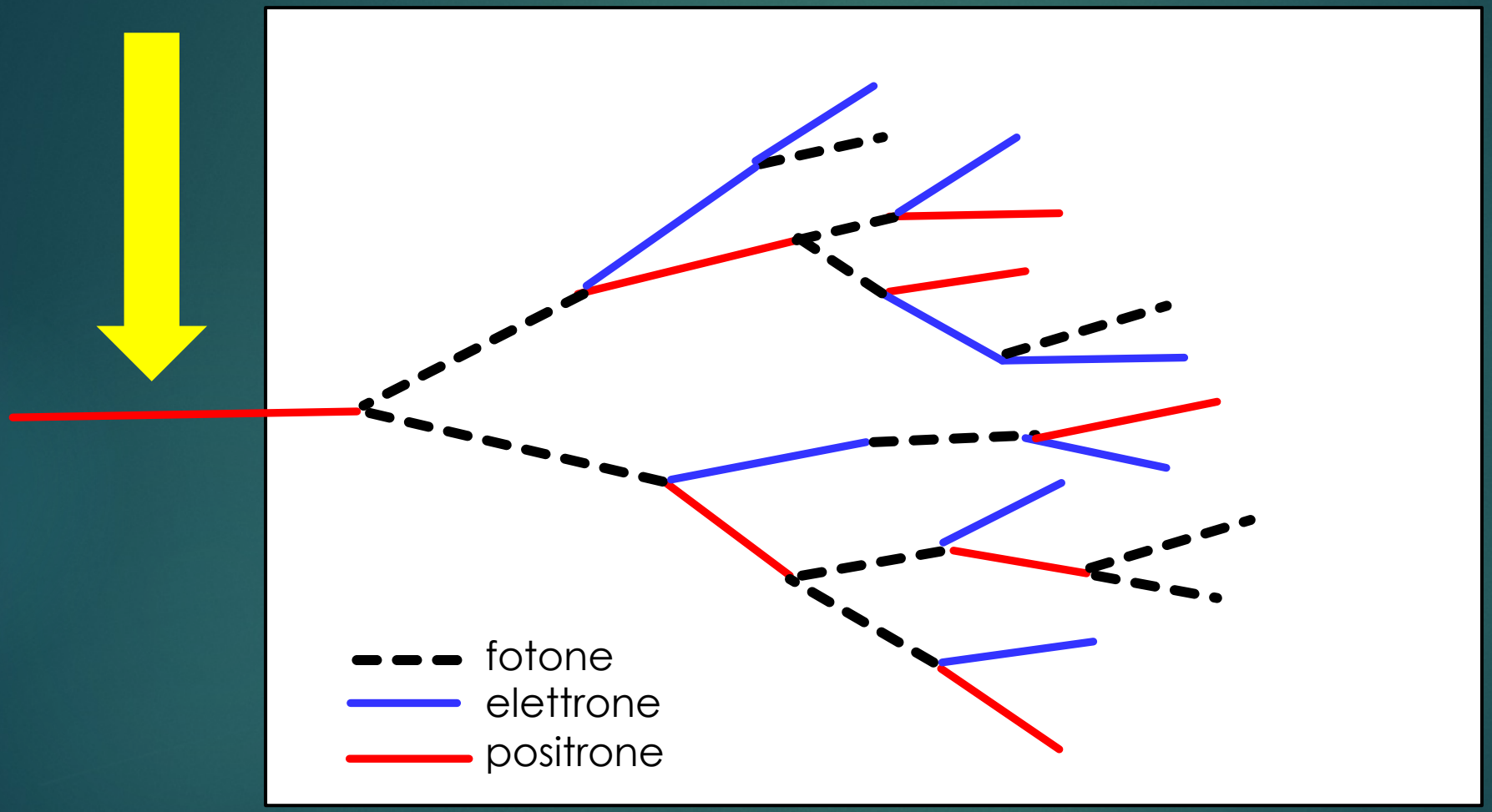
ELETTRONE

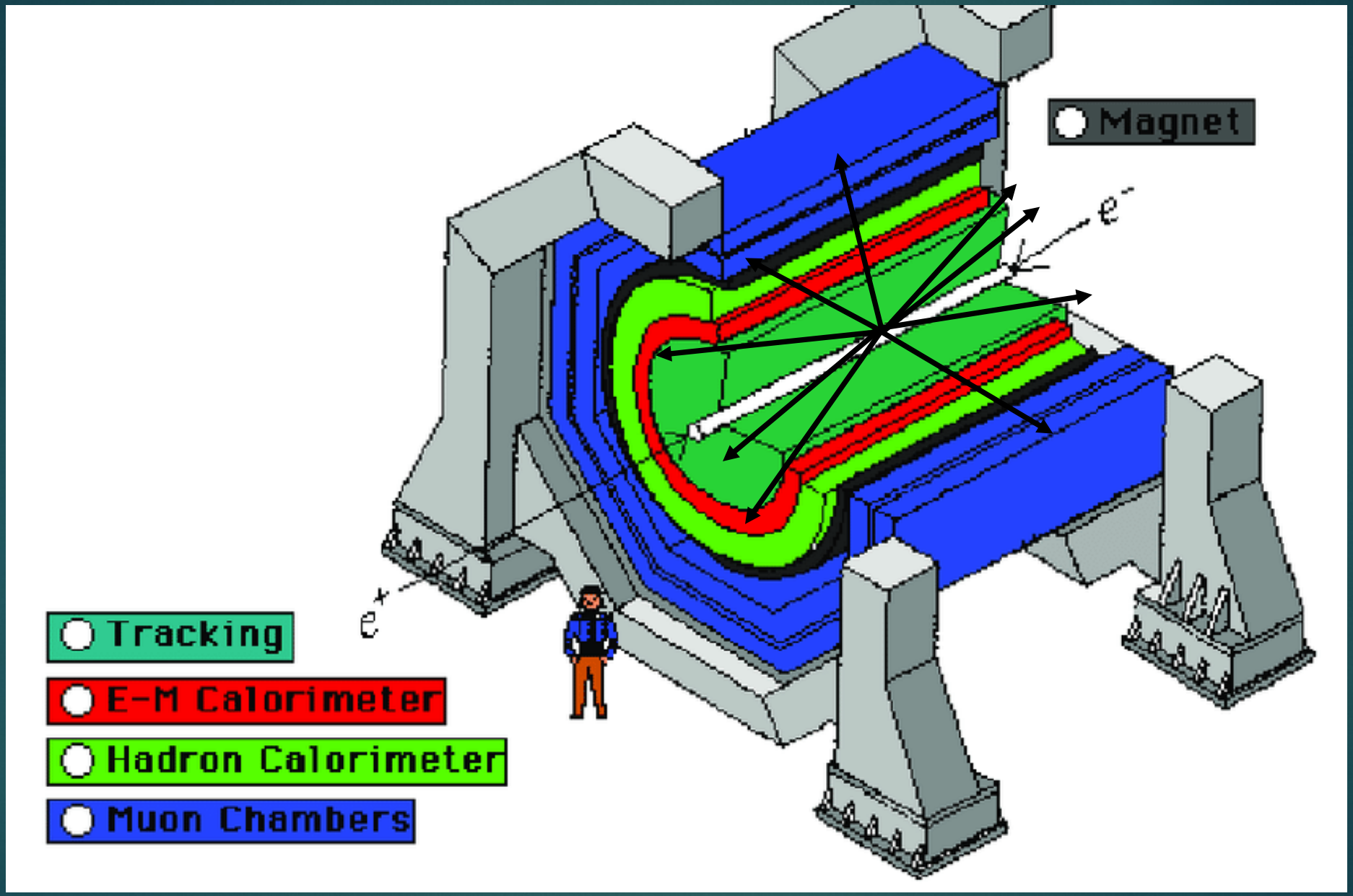


FOTONE

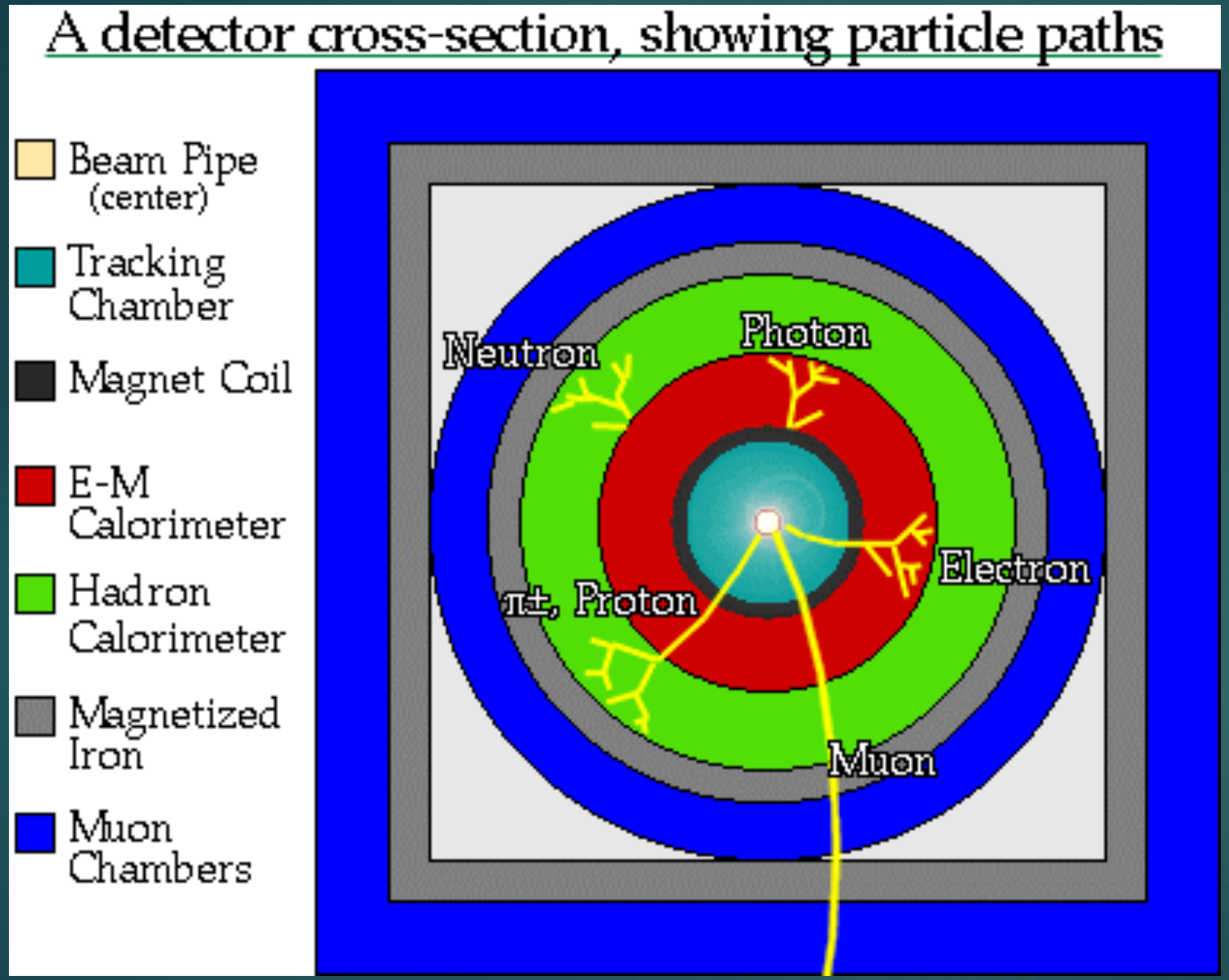


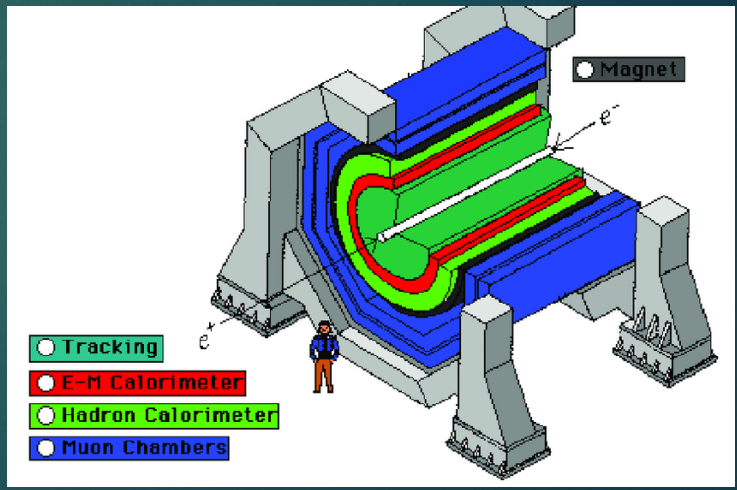
POSITRONE



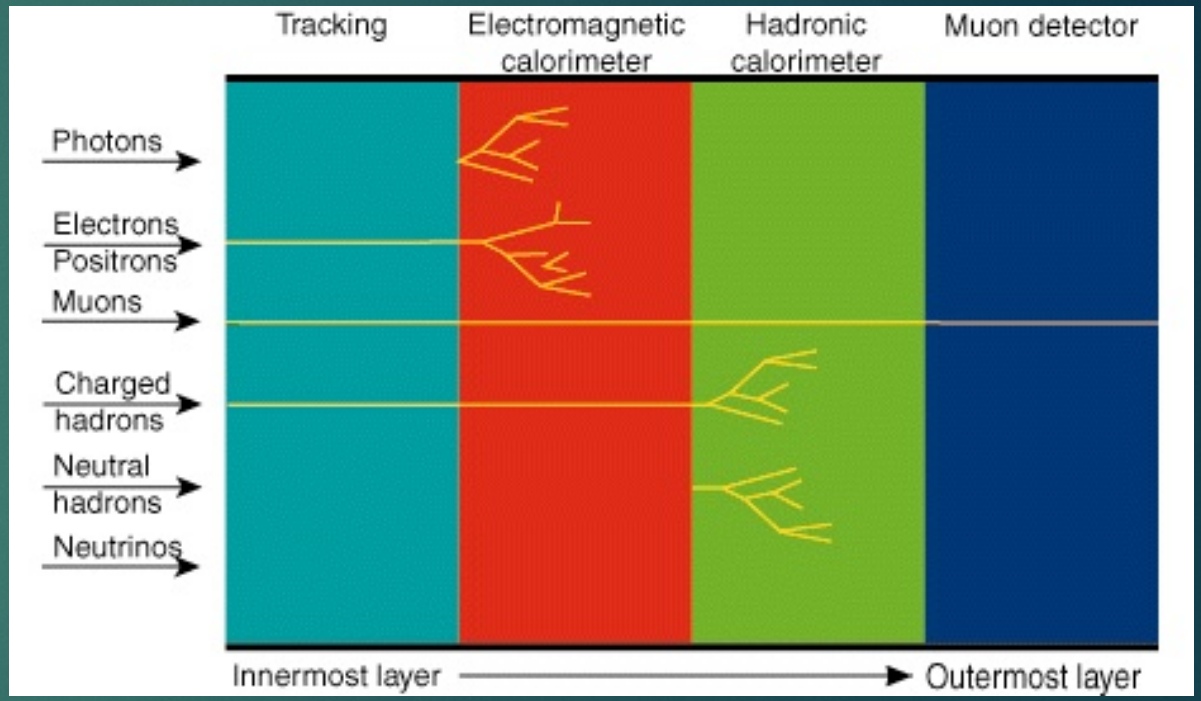

Magnet
e⁻
e⁺
Tracking
E-M Calorimeter
Hadron Calorimeter
Muon Chambers

A detector cross-section, showing particle paths



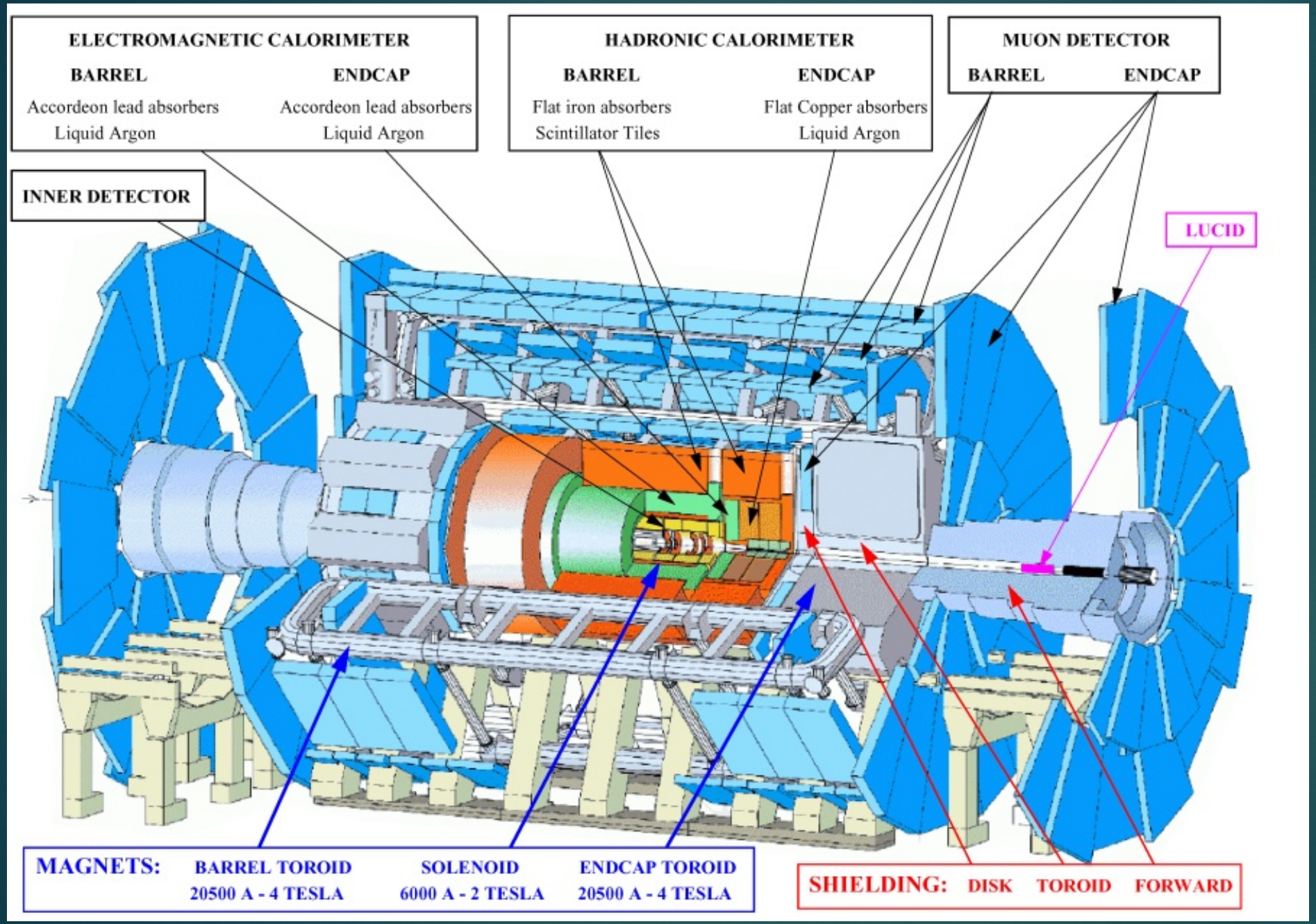


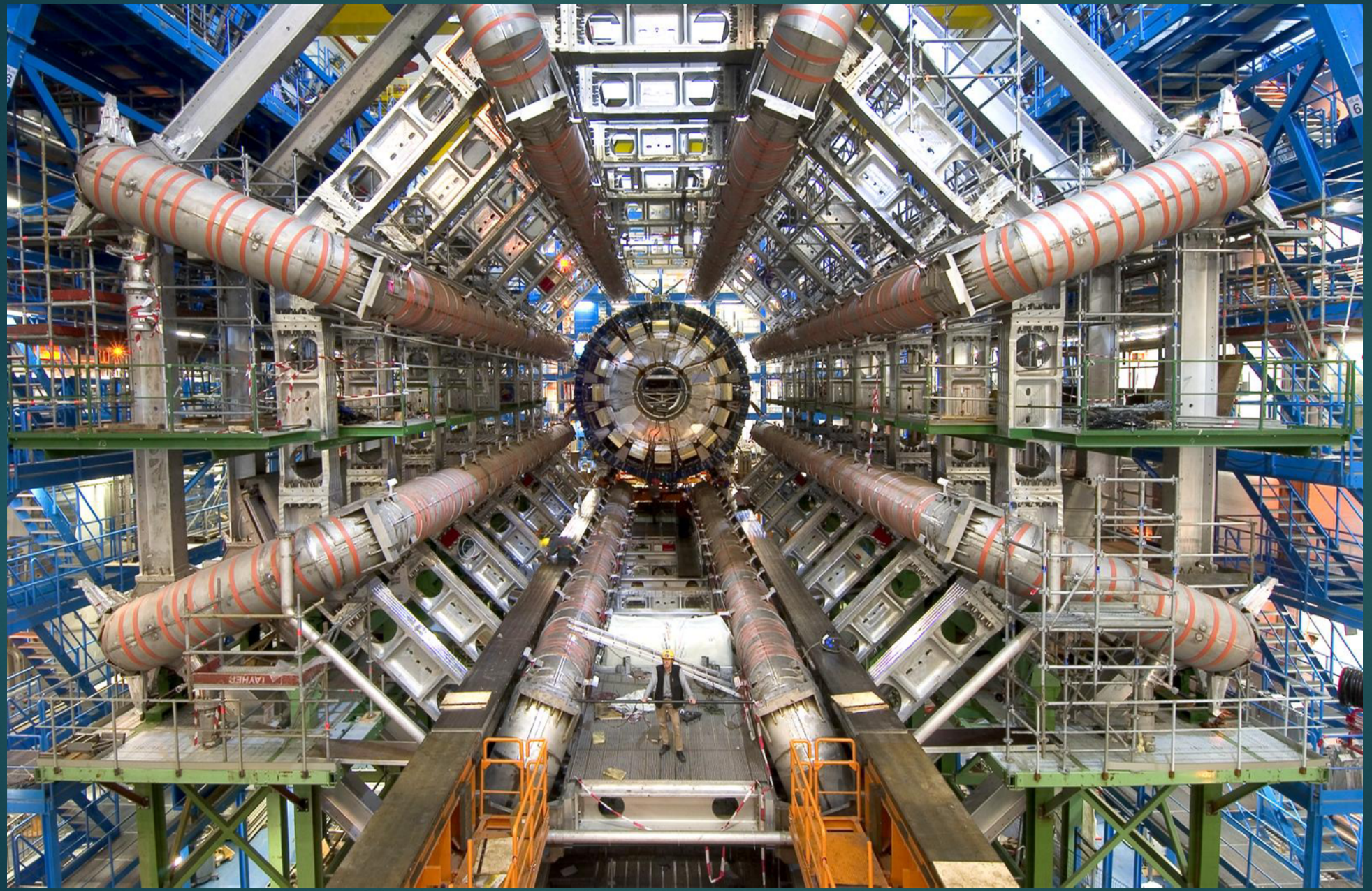
	Traccia	sciame EM	Segnale Muoni
Elettrone	SI	SI	NO
Positrone	SI	SI	NO
Fotone	NO	SI	NO
Muone	SI	NO	SI
Altre particelle cariche	SI	NO	NO
Neutrino	NO	NO	NO

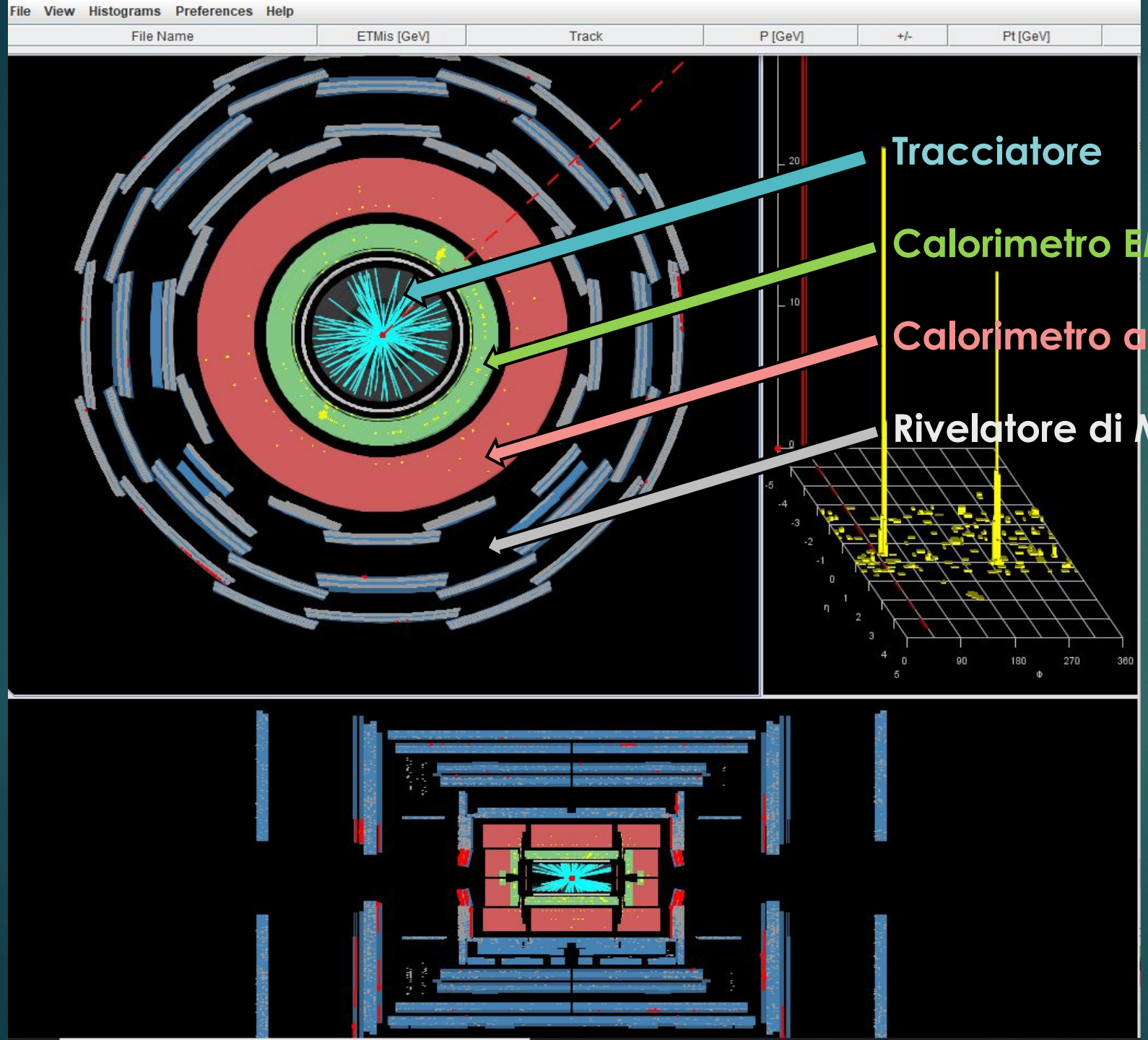


ESPERIMENTO ATLAS

A Toroidal LHC ApparatuS






File View Histograms Preferences Help
File Name
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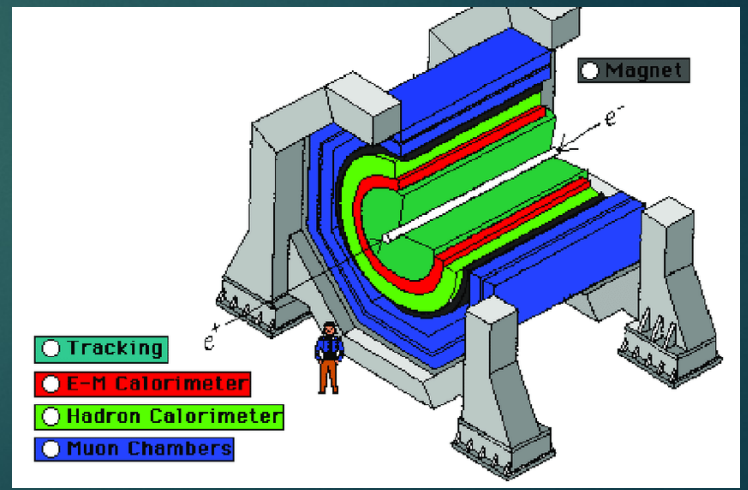
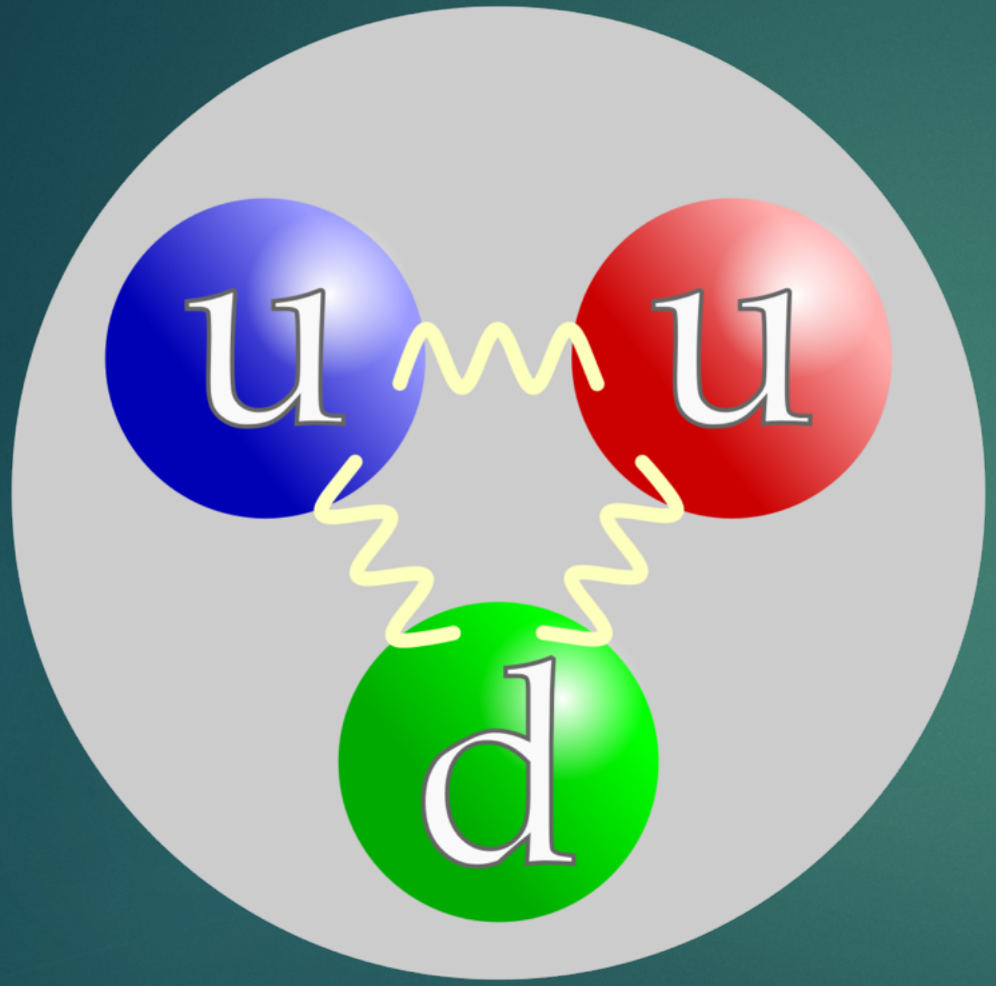
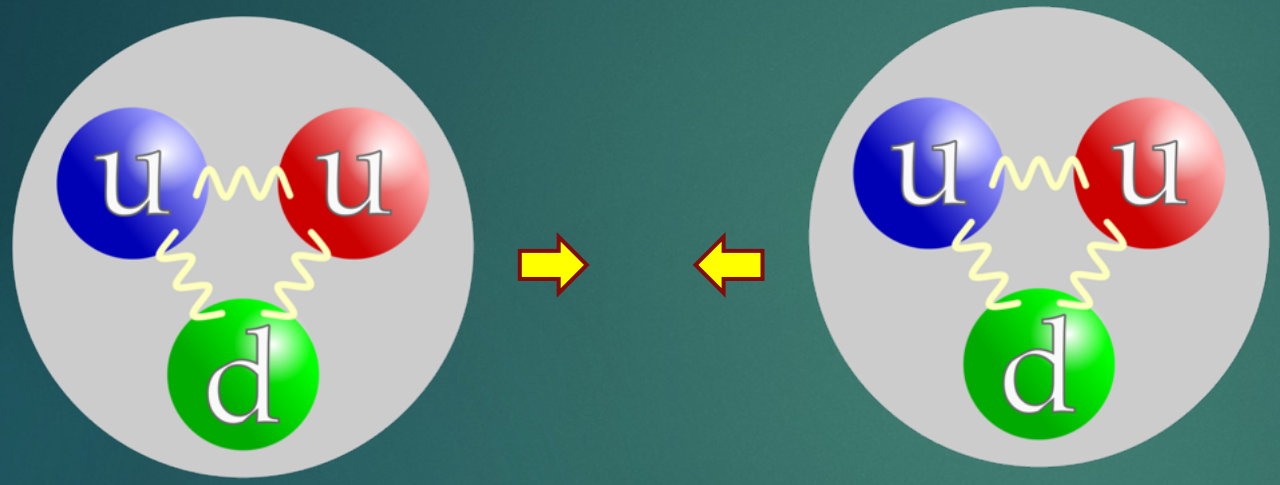
Pt [GeV]
Tracciatore
Calorimetro EM.
Calorimetro adronico
Rivelatore di Muoni

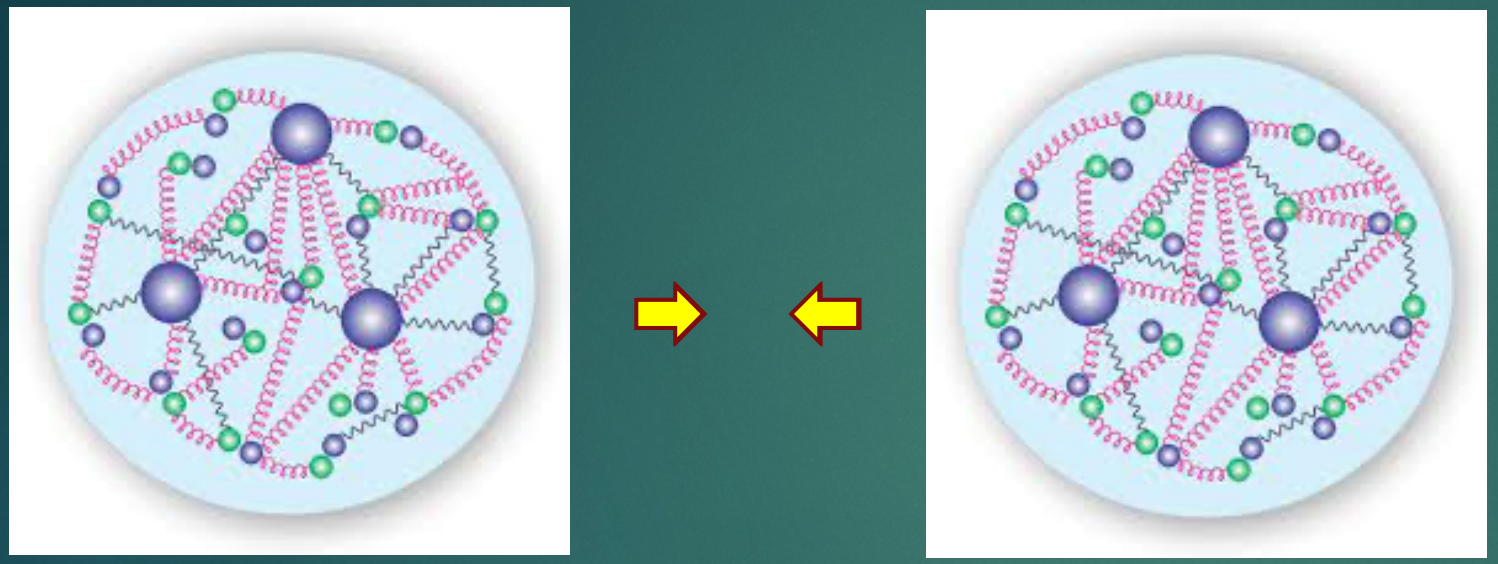

Magnet
Tracking
E-M Calorimeter
Hadron Calorimeter
Muon Chambers



Un protone, a livello «basico», è relativamente semplice

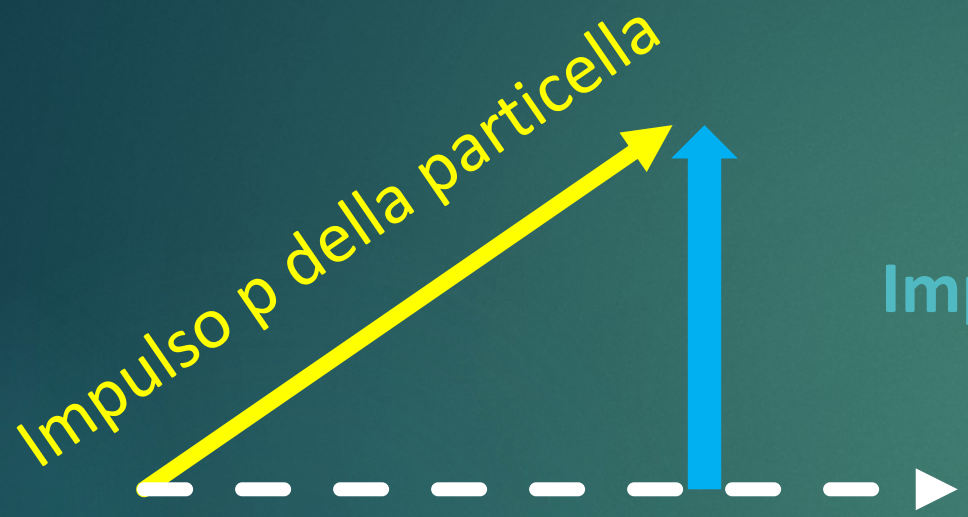


Quando però due protoni si urtano ad alta energia, si «scrutano» reciprocamente in grande dettaglio



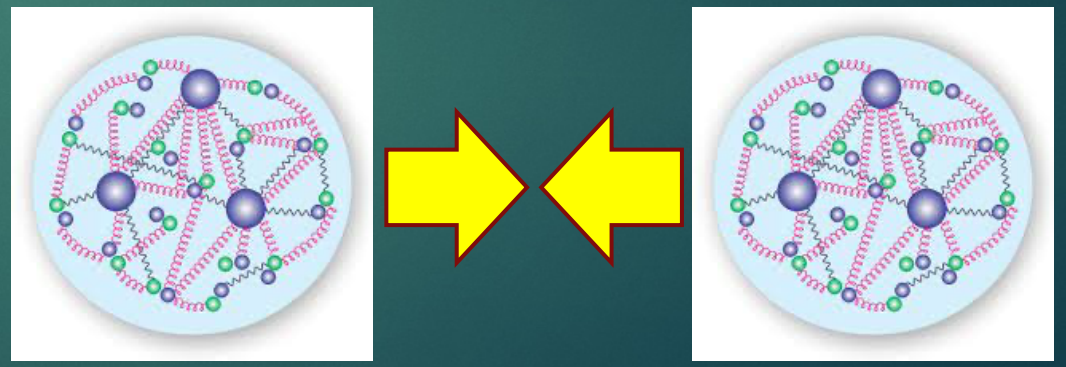
E scoprono di essere molto complessi al loro interno

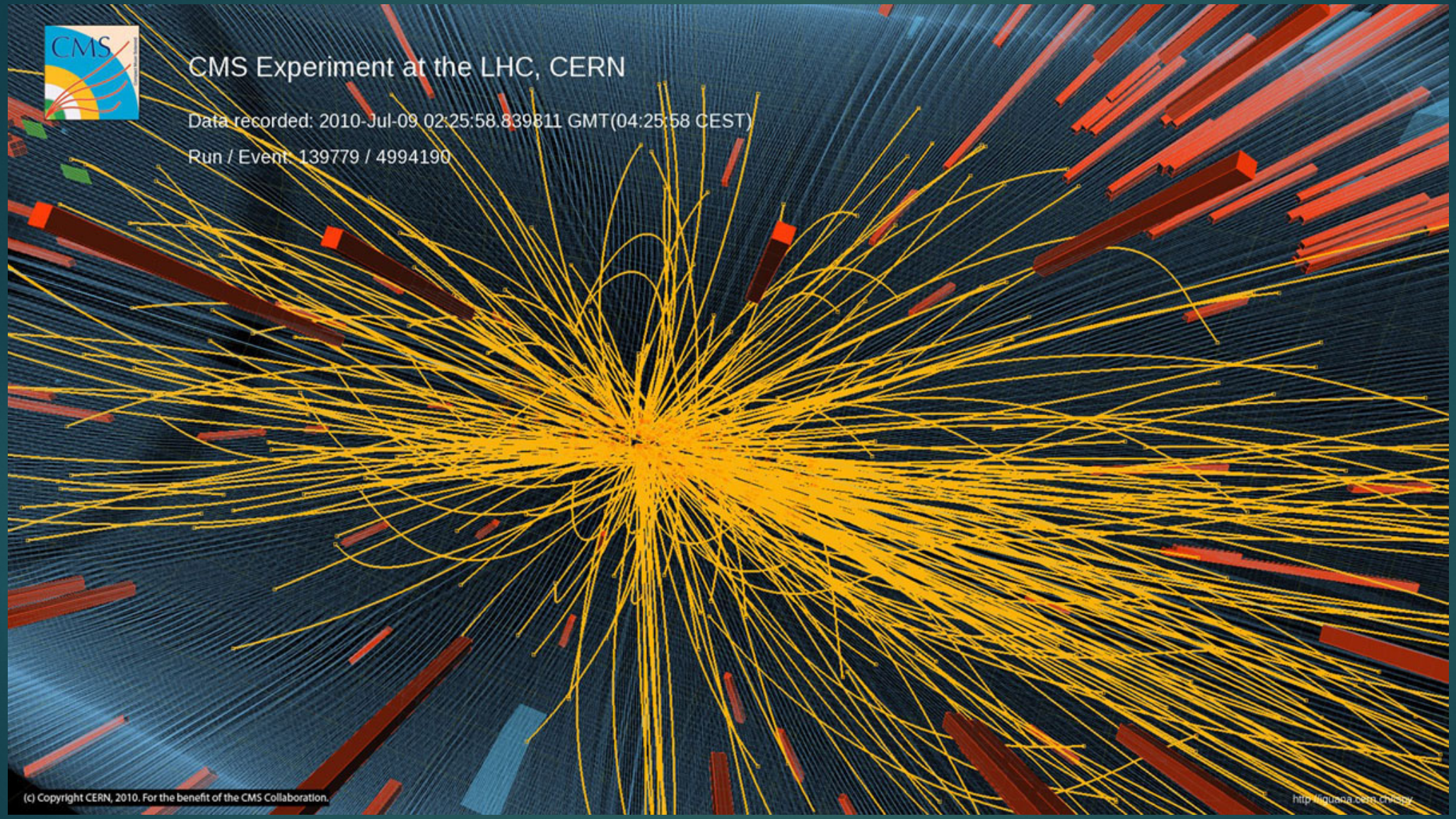
Momento (o impulso) trasverso

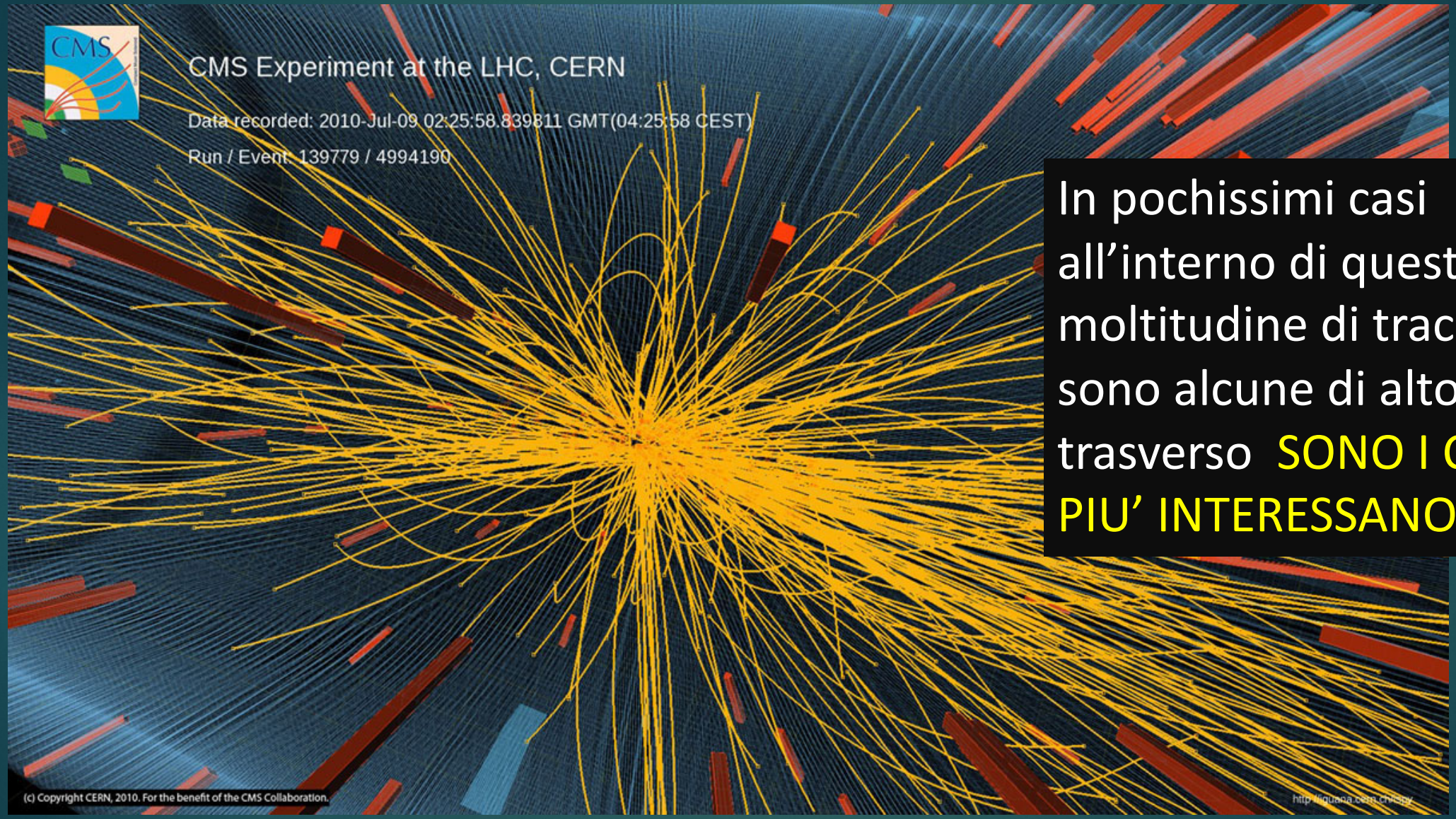


Impulso trasverso p_T della particella

Dierezione del fascio di protoni incidente

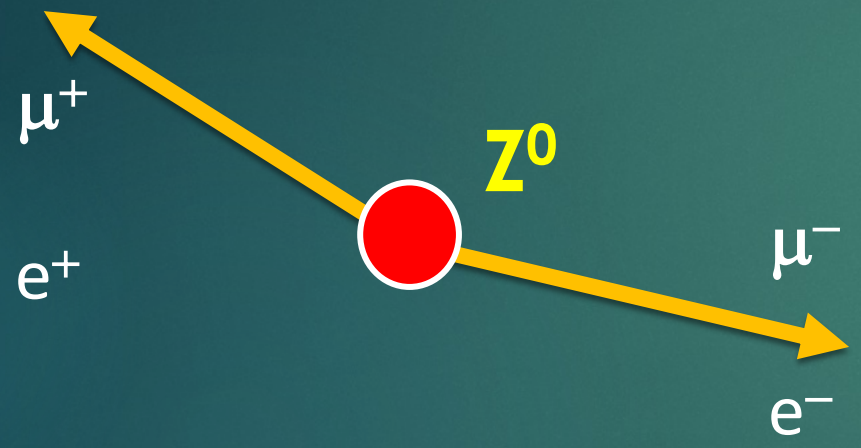



CMS Experiment at the LHC, CERN
Data recorded: 2010-Jul-09 02:25:58.839811 GMT(04:25:58 CEST)
Run / Event: 139779 / 4994190
(c) Copyright CERN, 2010. For the benefit of the CMS Collaboration.



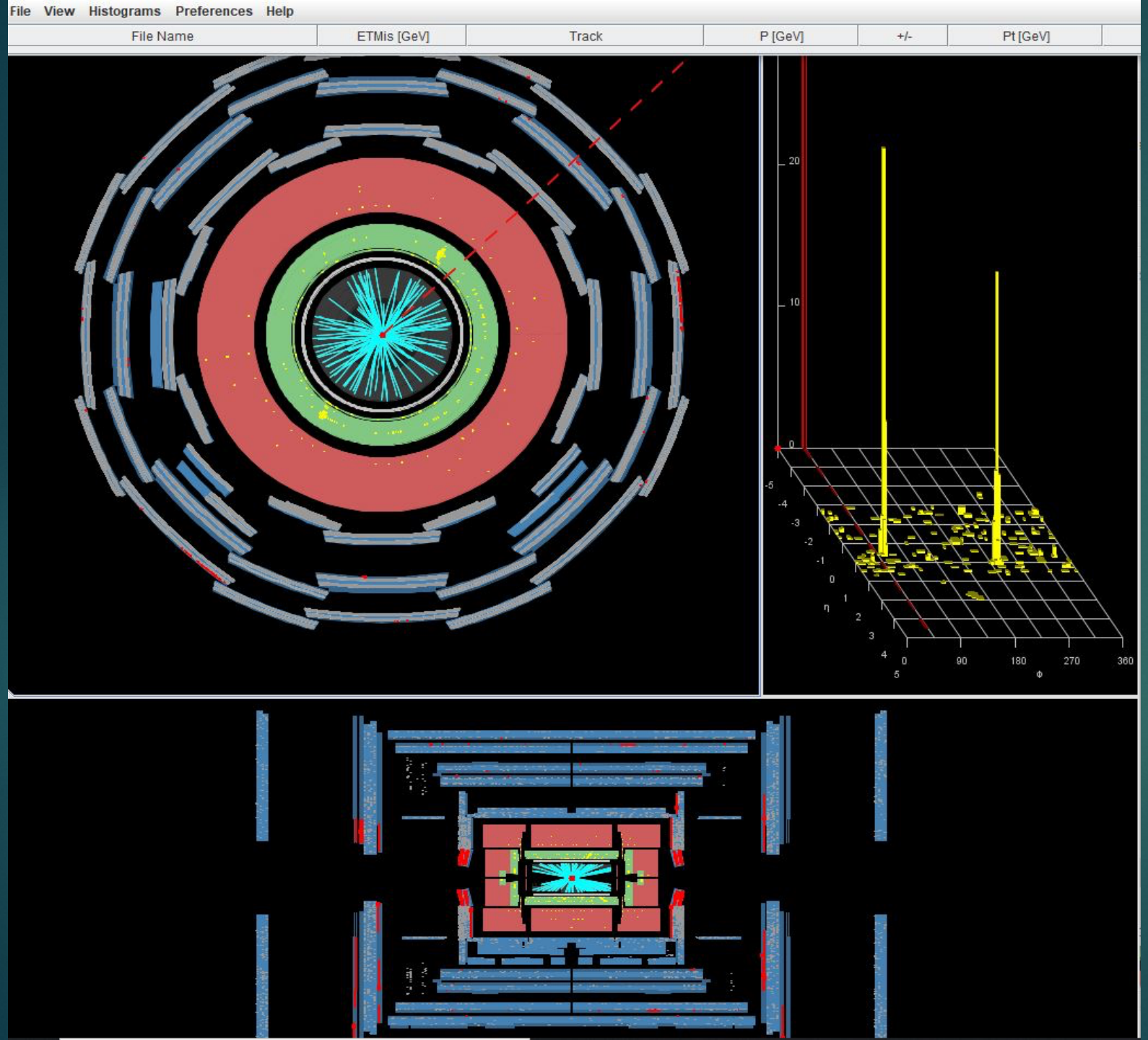
In pochissimi casi all'interno di questa moltitudine di tracce ce ne sono alcune di alto impulso trasverso SONO I CASI CHE PIU' INTERESSANO!

Massa invariante: Ricostruzione della massa di una particella a partire dai suoi prodotti di decadimento



2 muoni segno opposto, oppure
2 elettroni segno opposto

$$M_{Z^0} = \sqrt{\left(\frac{E_{\mu^+}}{c^2} + \frac{E_{\mu^-}}{c^2}\right)^2 - \left(\frac{\vec{p}_{\mu^+}}{c} + \frac{\vec{p}_{\mu^-}}{c}\right)^2}$$


File View Histograms Preferences Help
File Name
ETMis [GeV]
Track
P [GeV]
+/-
Pt [GeV]
20
10
0
-5
-4
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η
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2
3
4
5
0
90
180
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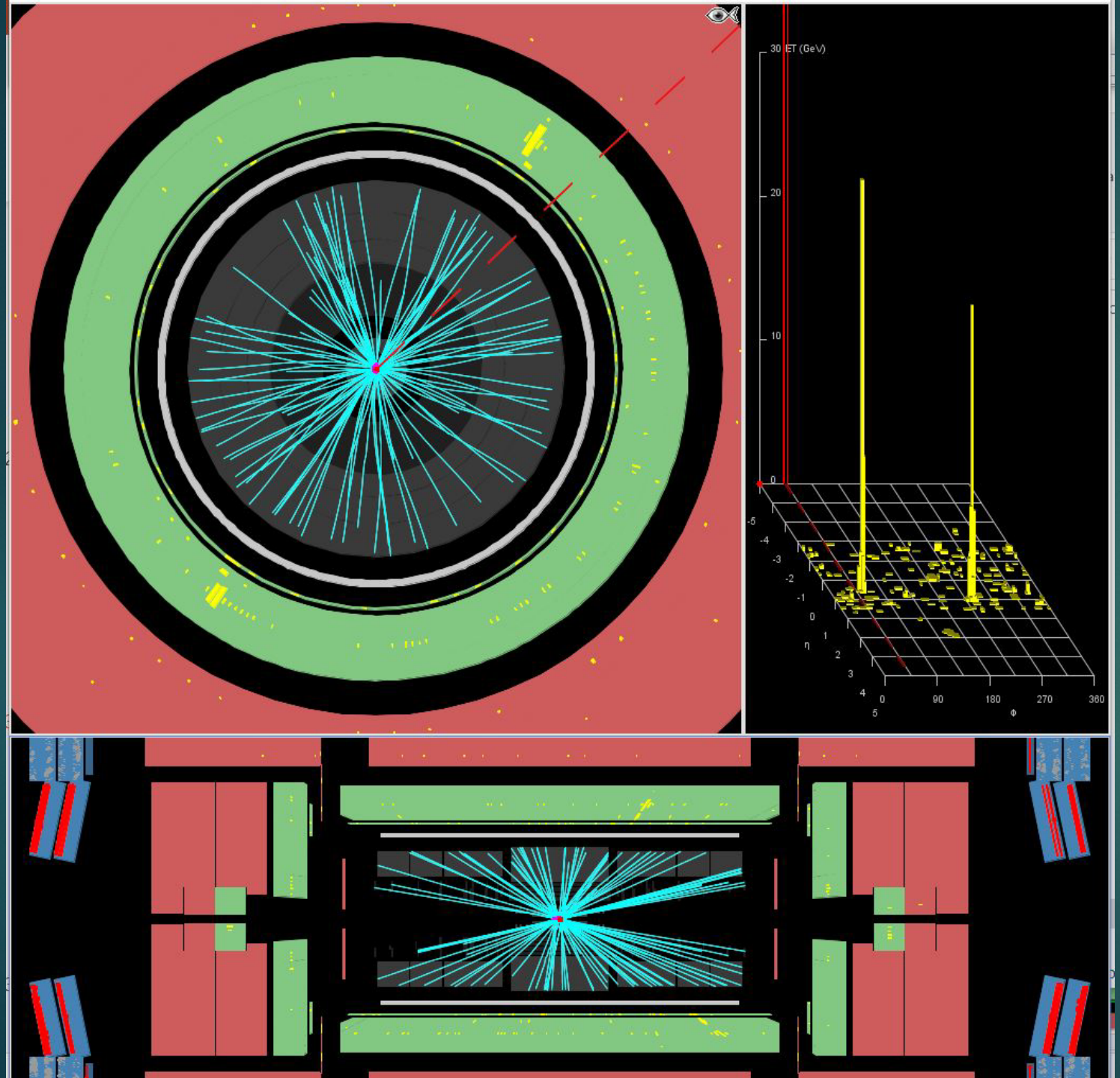
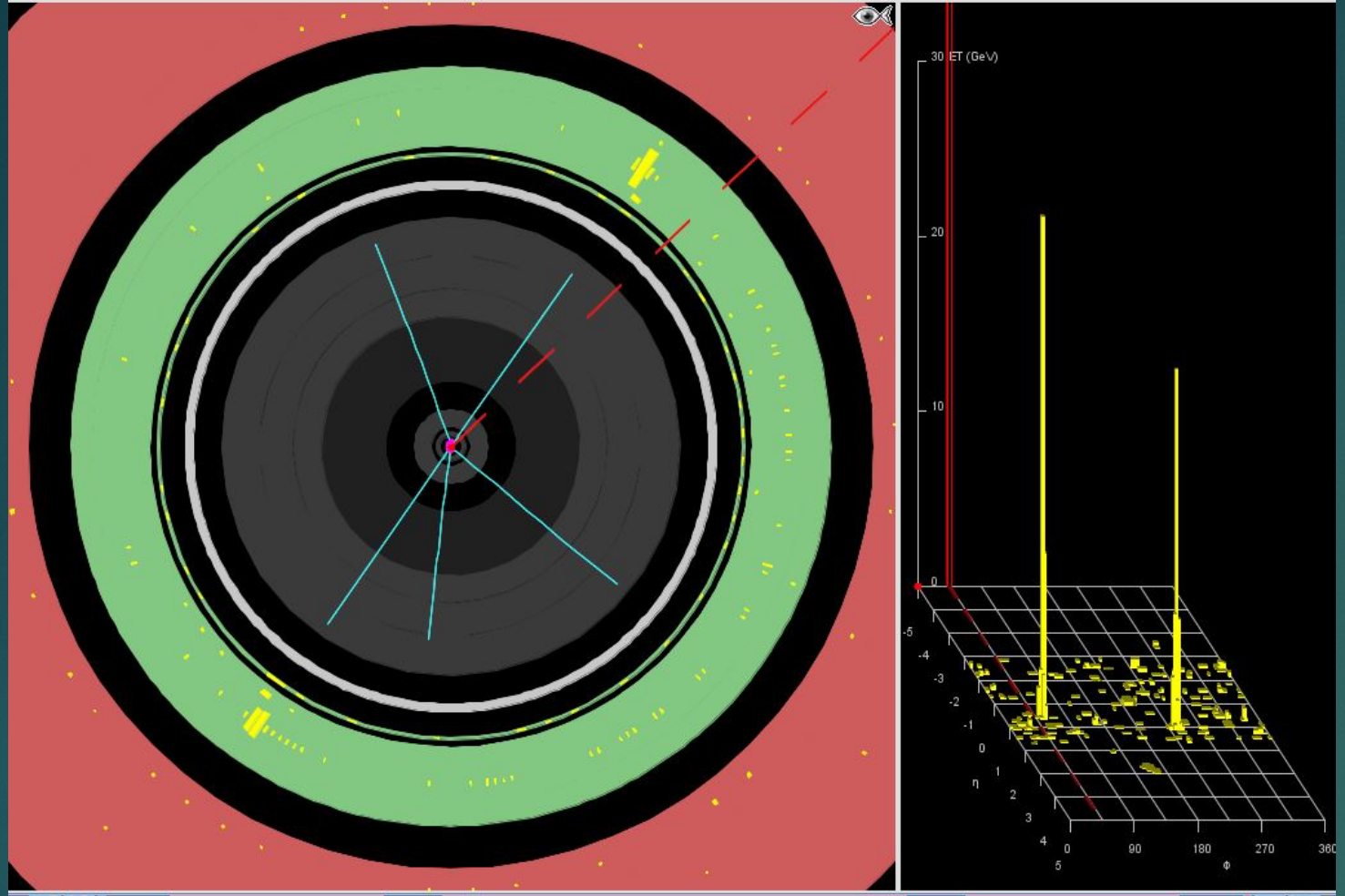
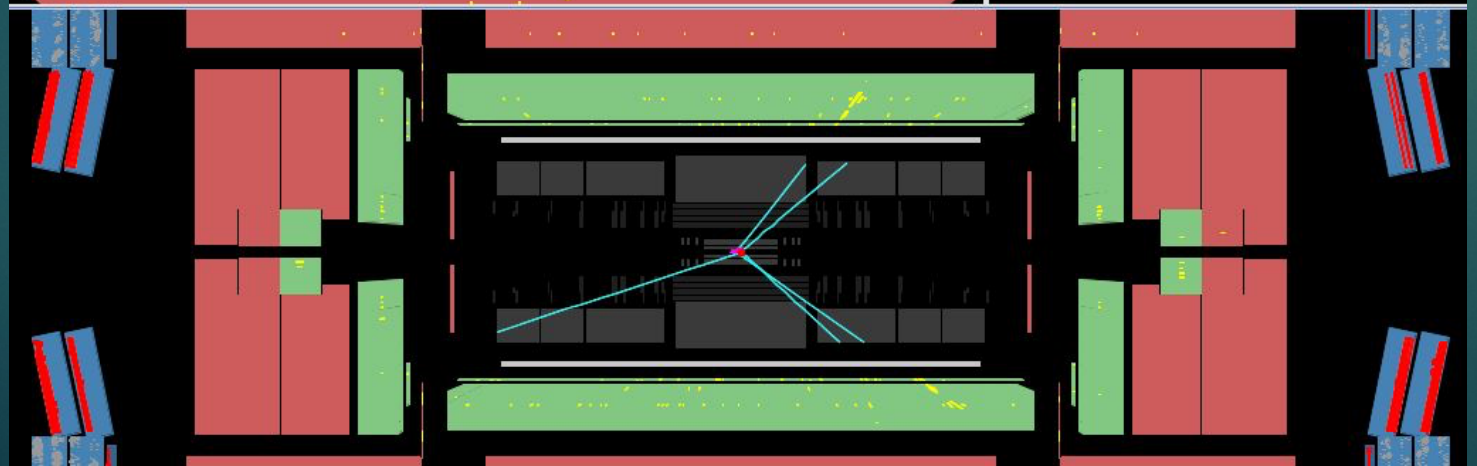
360
φ

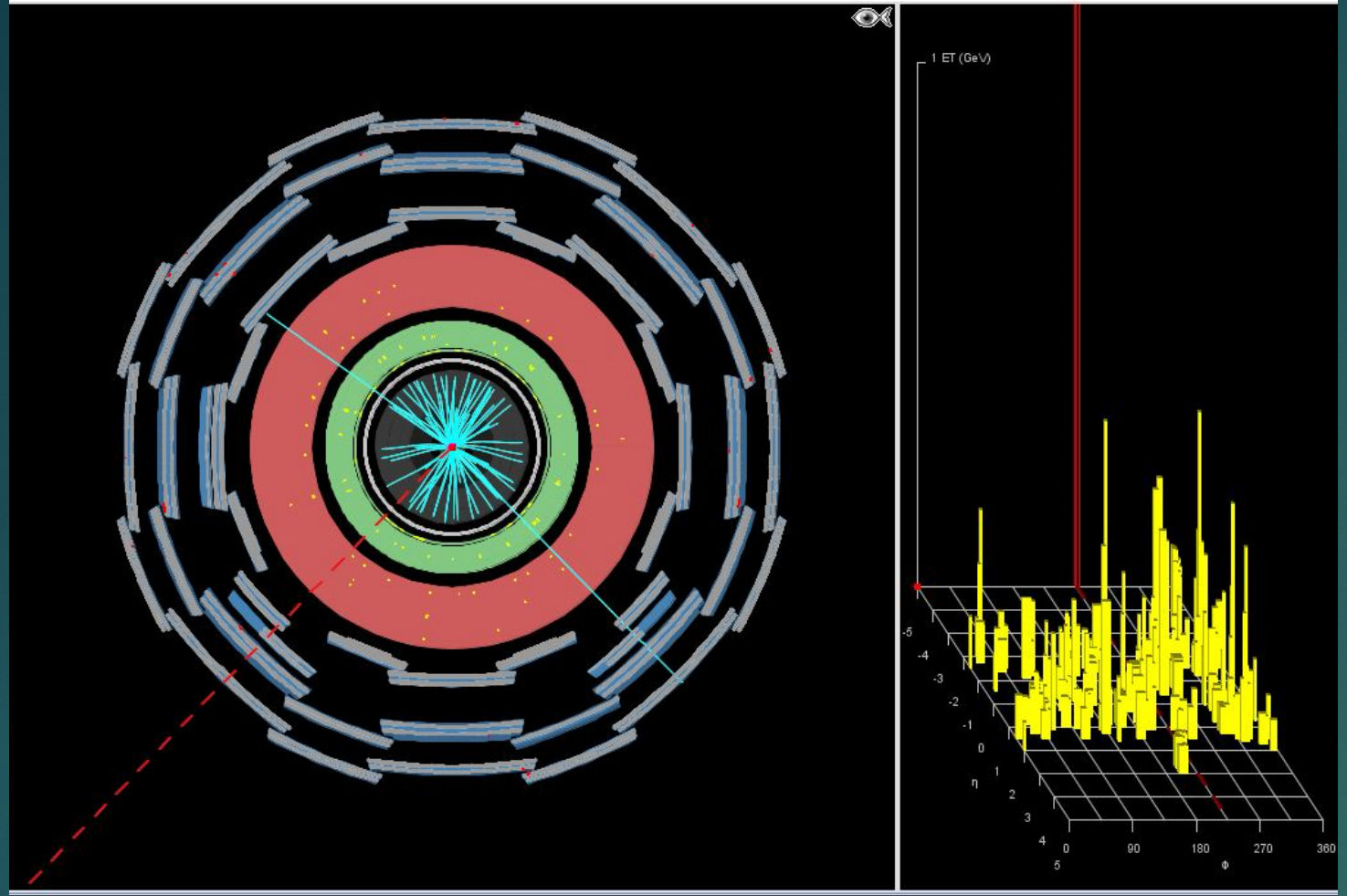


p_T delle tracce > 1 GeV

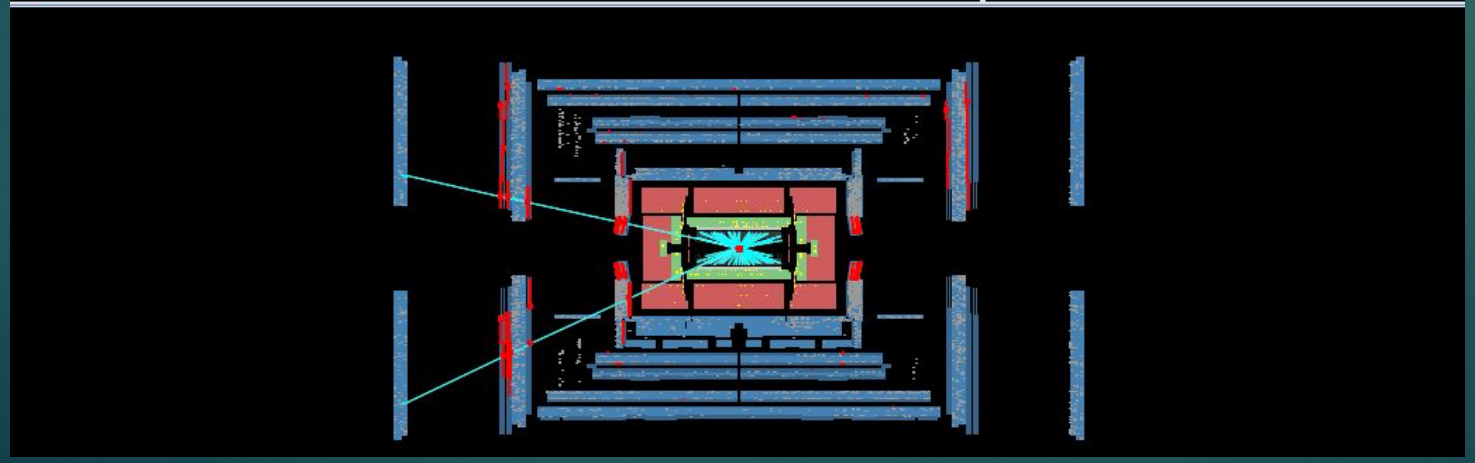


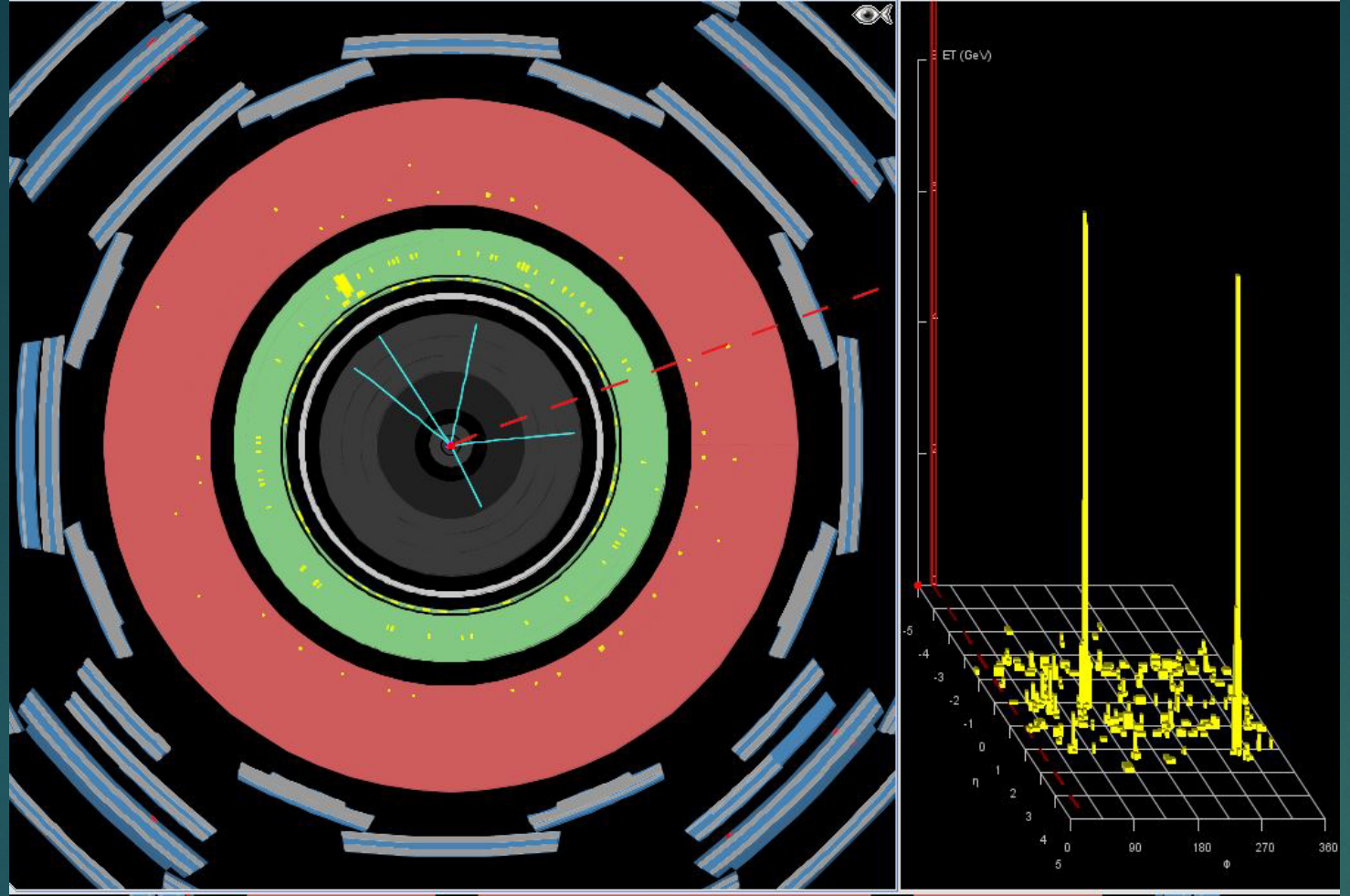


p_T delle tracce > 10 GeV



1 ET (GeV)
-5
-4
-3
-2
-1
0
1
2
3
4
5
η
0
90
180
270
360
Φ




ET (GeV)
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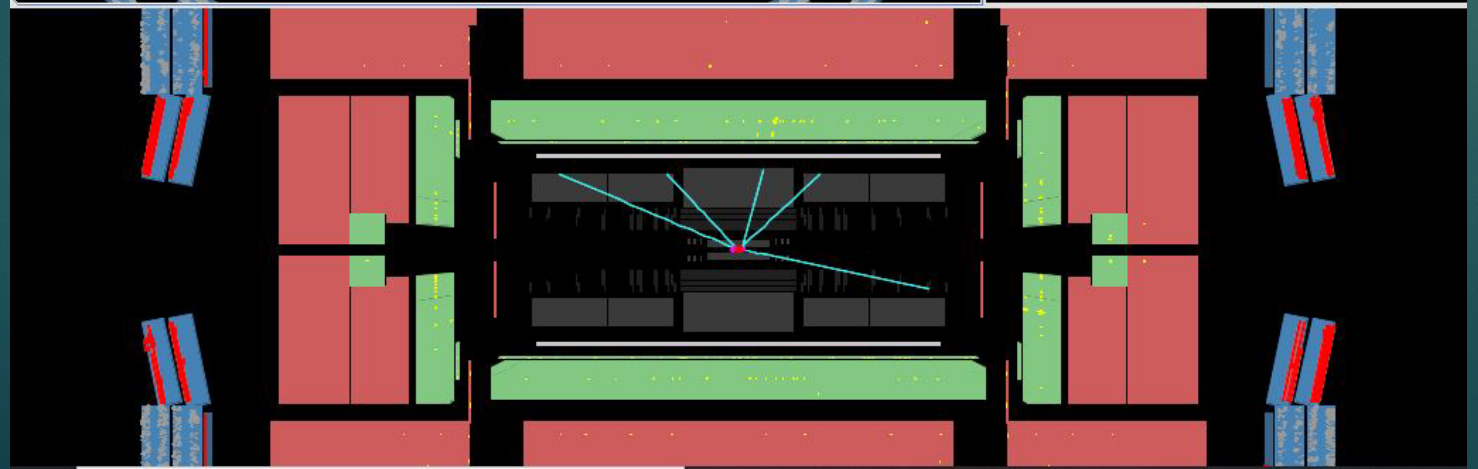
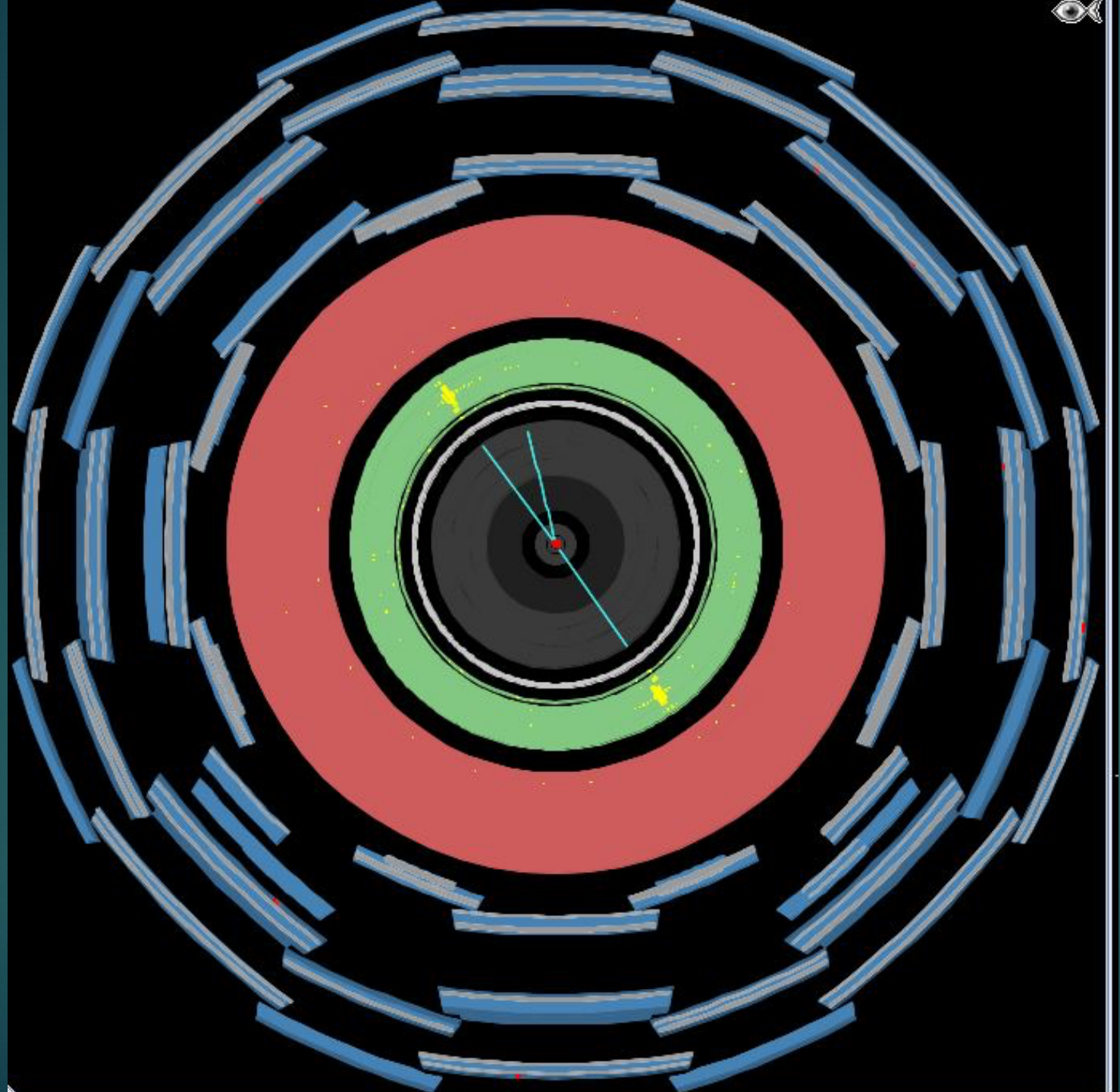
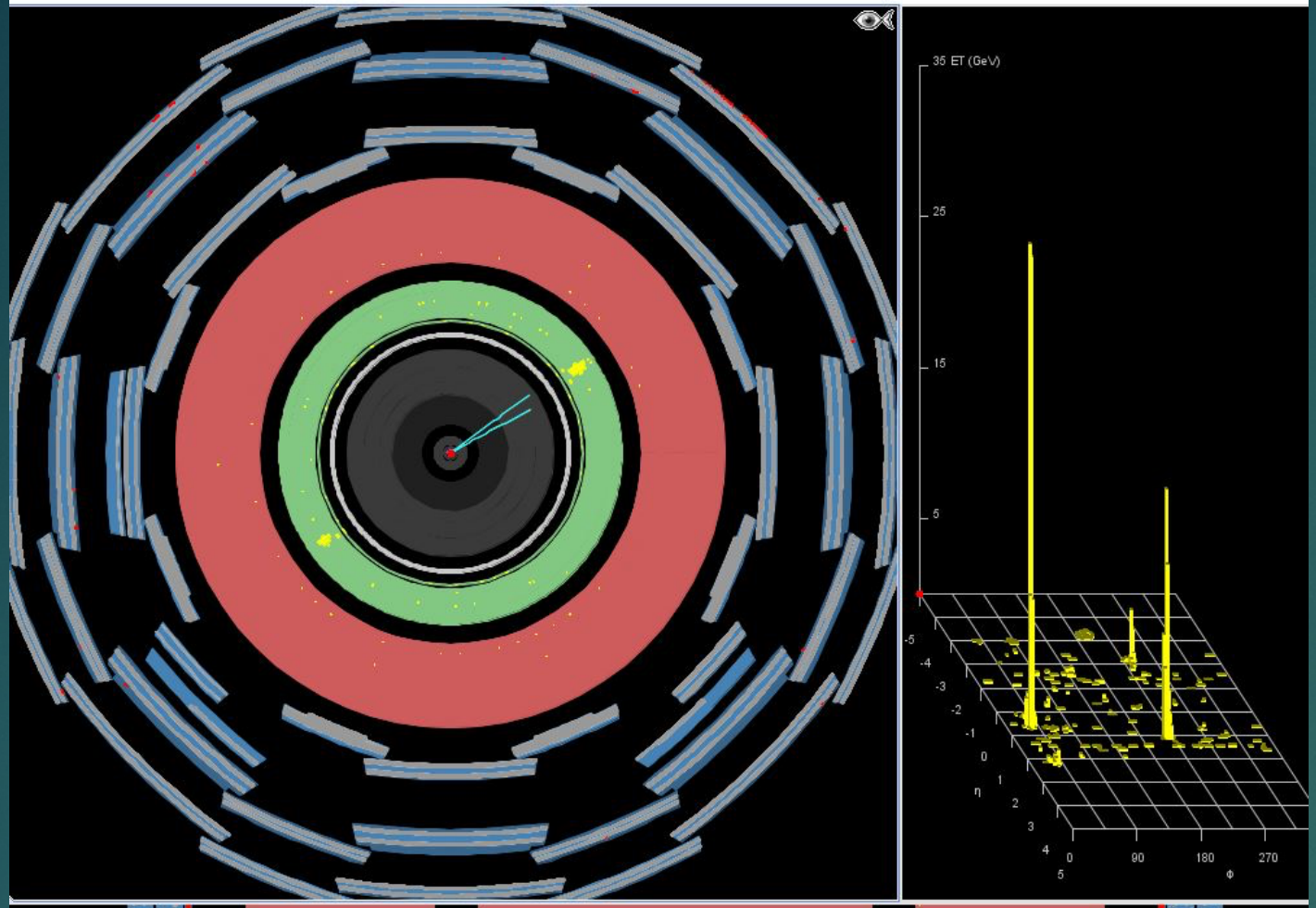
Φ






35 ET (GeV)
25
15
5
-5
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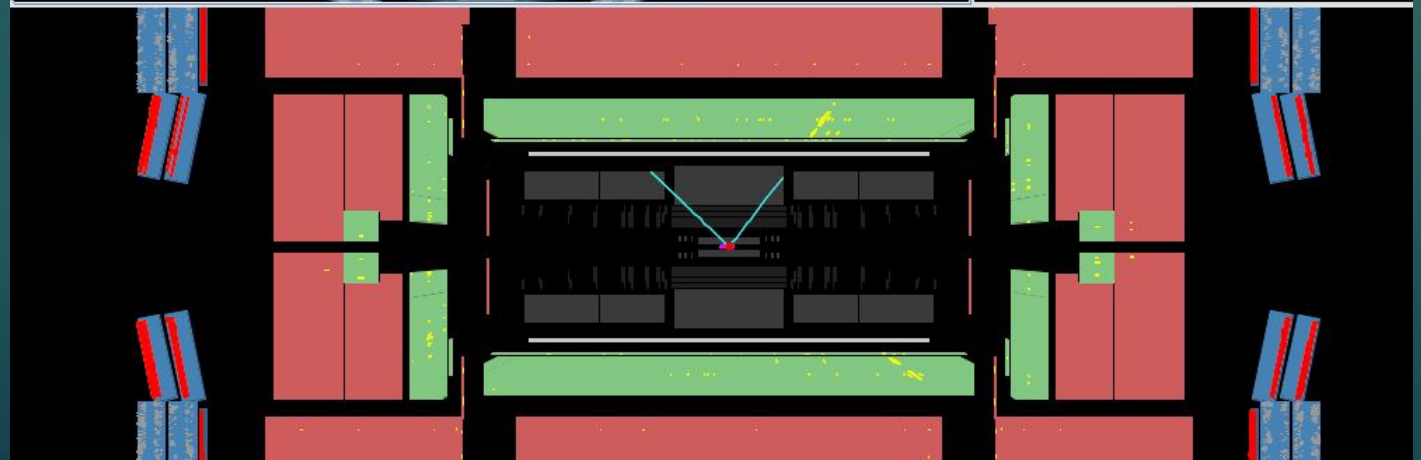
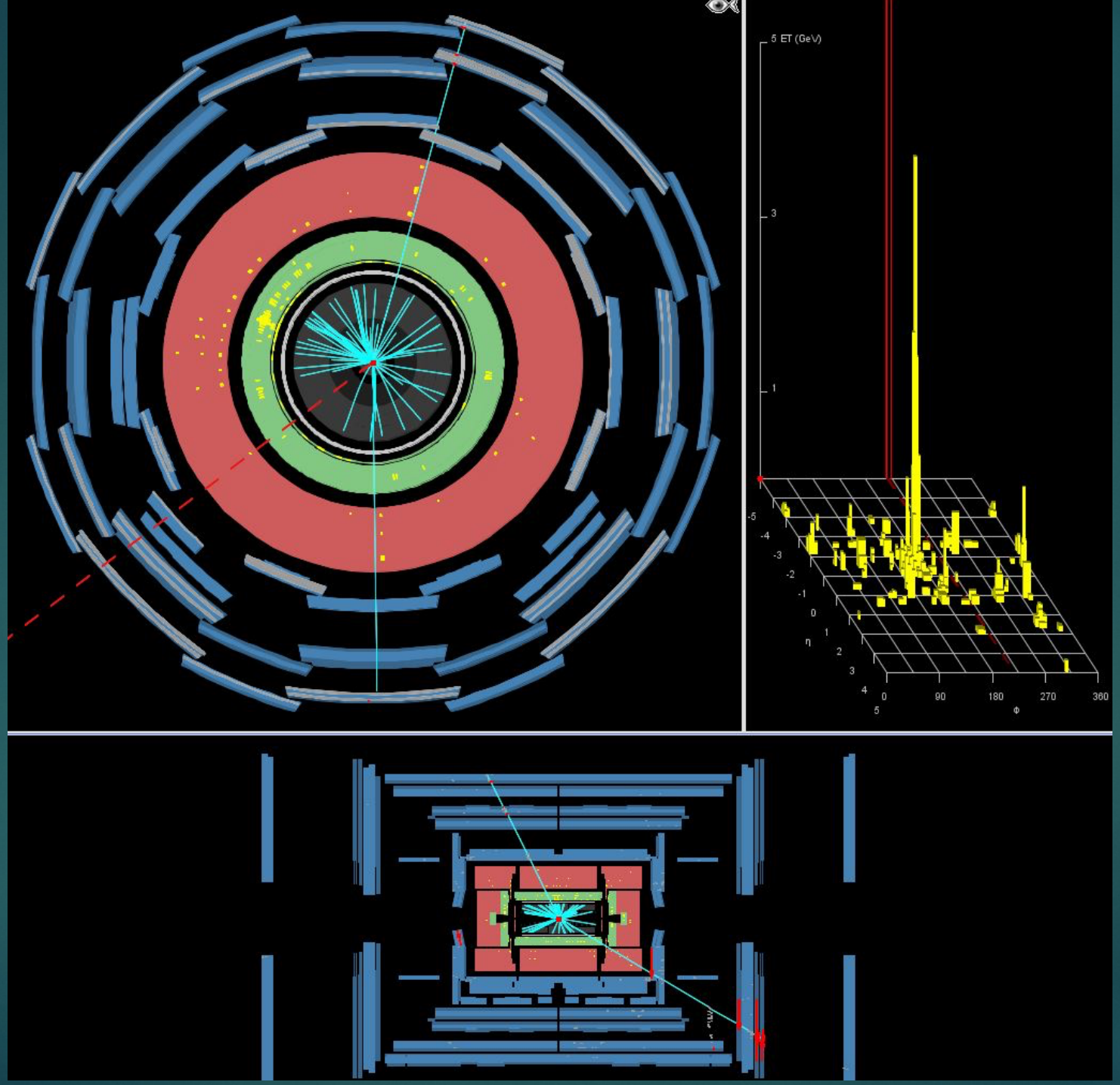
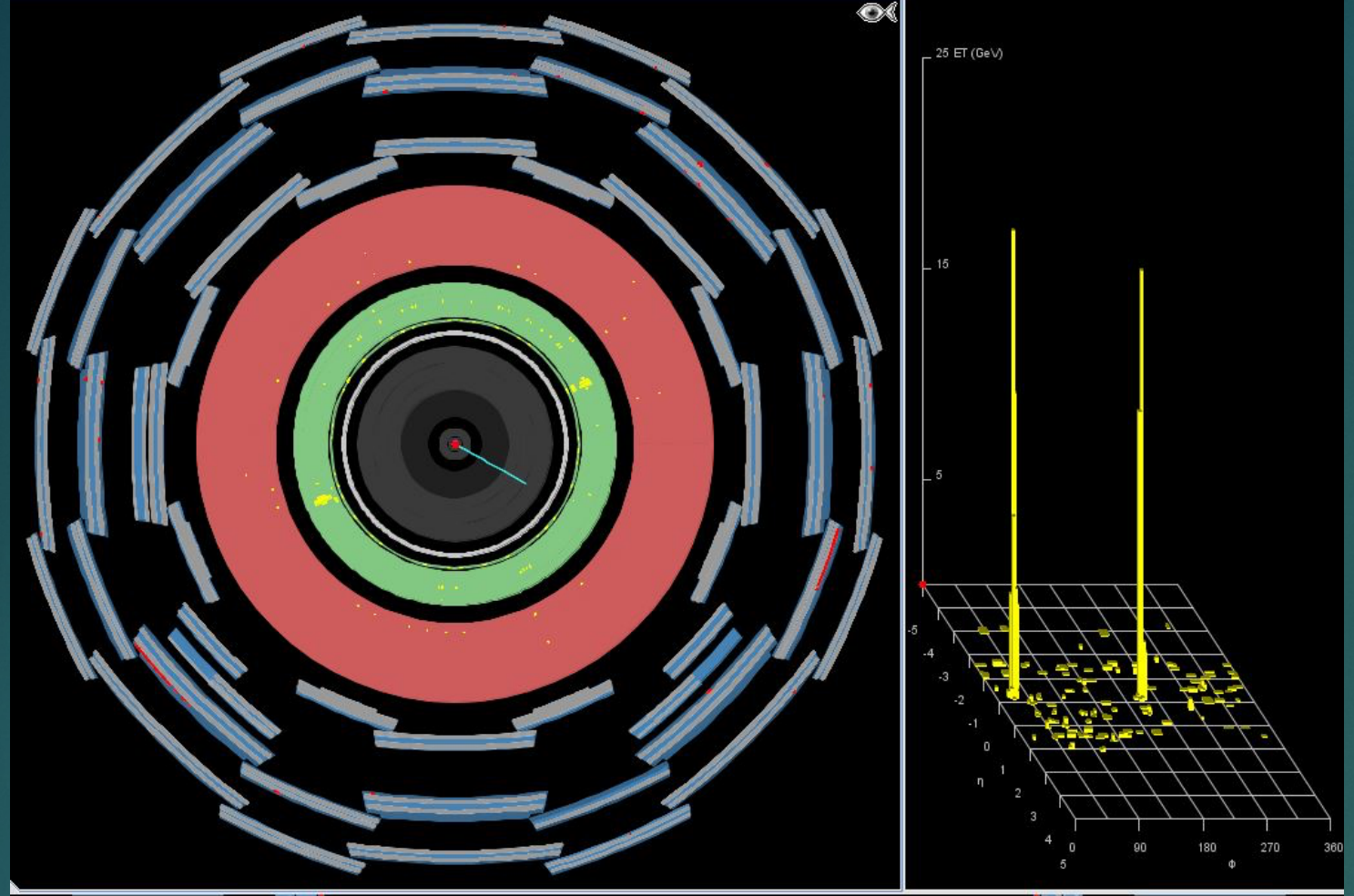
-2
-1
0
1
2
3
4
η
0
90
180
270
5
Φ




5 ET (GeV)
3
1
-5
-4
-3
-2
-1
0
1
2
3
4
η
0
90
180
270
360
5
Φ



25 ET (GeV)
15
5
-5
-4
-3
-2
-1
0
1
2
3
4
η
0
90
180
270
360
Φ