# Analyse de données

Masterclasses 2017

IPNL

Gael Touquet

iSpy WebGL

https://www.i2u2.org/elab/cms/ispy-webgl/#

iSpy WebGL masterclass_1.ig:Events/Run_1/Event_13 [13 of 100]

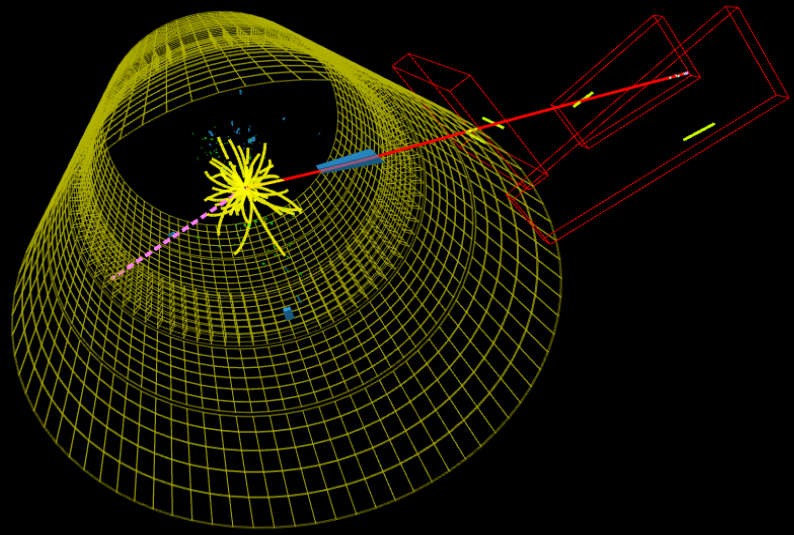
CSC Segments
CSC Rec. Hits (2D)
RPC Rec. Hits
DT Rec. Segments (4D)
DT Rec. Hits
Physics
Vertices (reco)
Tracker Muons (Reco)
Stand-alone Muons (Reco)
Global Muons (Reco)
Jets (PF)
Jets (Reco)
Missing Et (Reco)

CMS Experiment at the LHC, CERN
Data recorded: 2010-Sep-30 02:28:32.502232 GMT
Run / Event / LS: 146944 / 528540707 / 486

vraies données de CMS

Plan:

- la collision
- reconnaitre les particules
- découverte de l'outil d'affichage



Click on a name under "Provenance", "Tracking", "ECAL", "HCAL", "Muon", and "Physics" to view contents in table

# But: découvrir les bosons Z, W, H!

# Intro

- Notre but : tester nos connaissances ( = modèle standard)
- Comment faire ?
  - Produire des particules grâce au LHC (collisionneur)
  - Déterminer les particules produites grâce a CMS (détecteur)
  - Déterminer ce qu'il c'est passe au moment de la collision (vous)

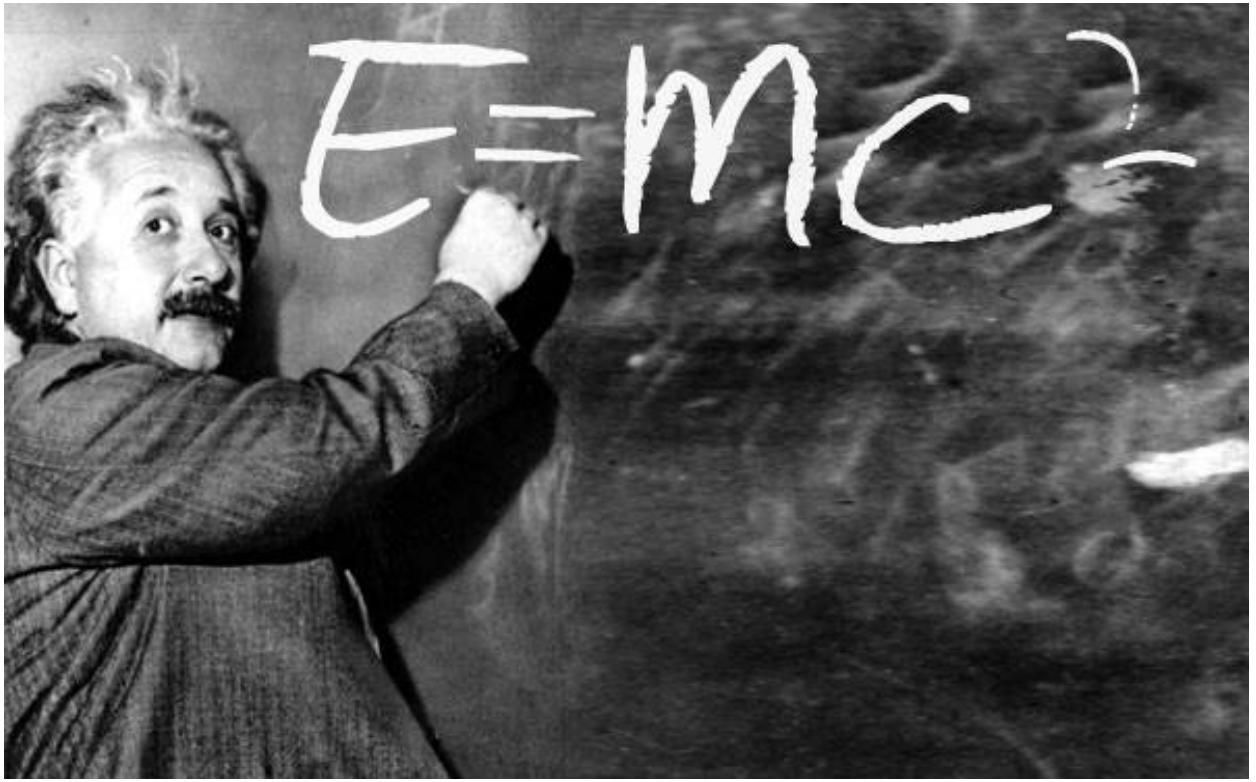
# LA COLLISION

# Fabriquer des particules

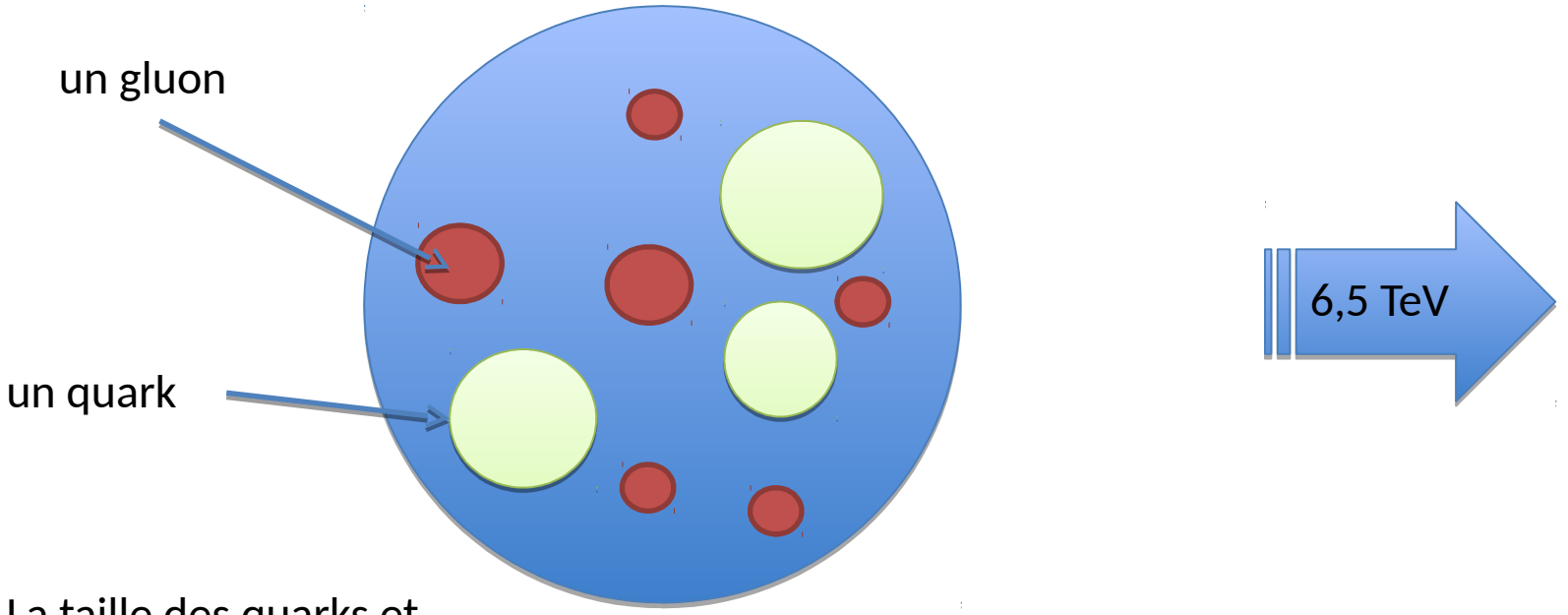
Les particules ont:

- une énergie cinétique ( = 0 quand la particule est au repos)
- une énergie de masse ( = 0 quand la particule est de masse nulle)

énergie de masse = masse x (vitesse lumière)$^2$



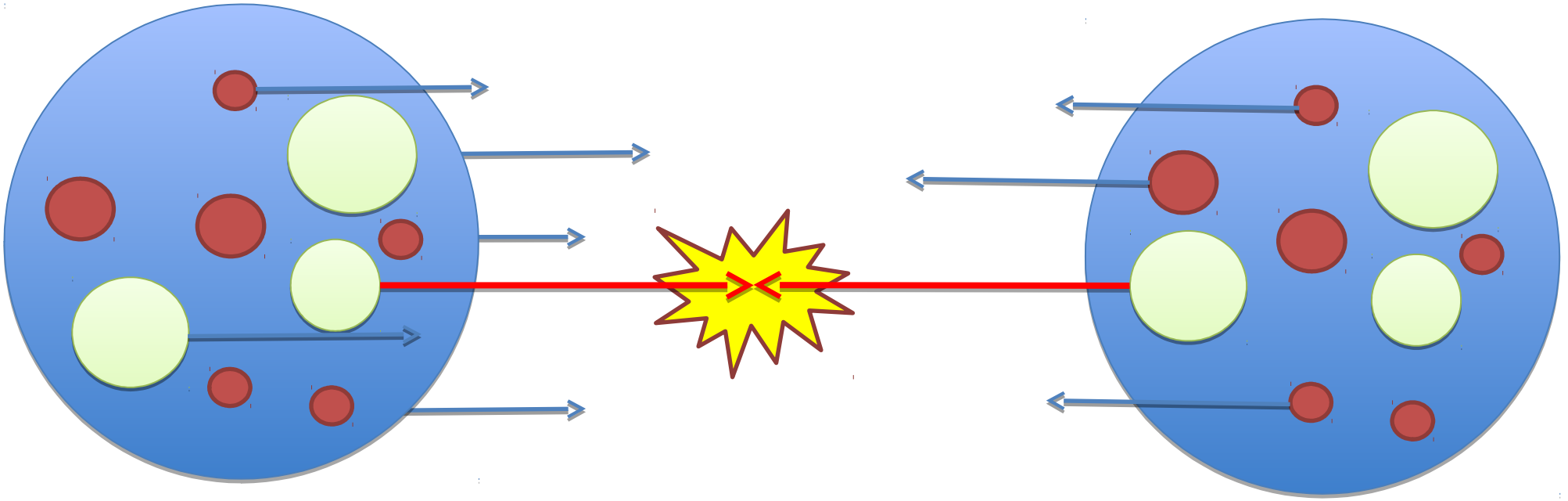
# Un proton dans le LHC




La taille des quarks et des gluons représente leur énergie.

$$E_{\text{proton}} = \sum_{\text{quarks}} E_{\text{quark}} + \sum_{\text{gluons}} E_{\text{gluon}} = 6{,}5 \ \text{TeV}$$

# Une collision proton-proton



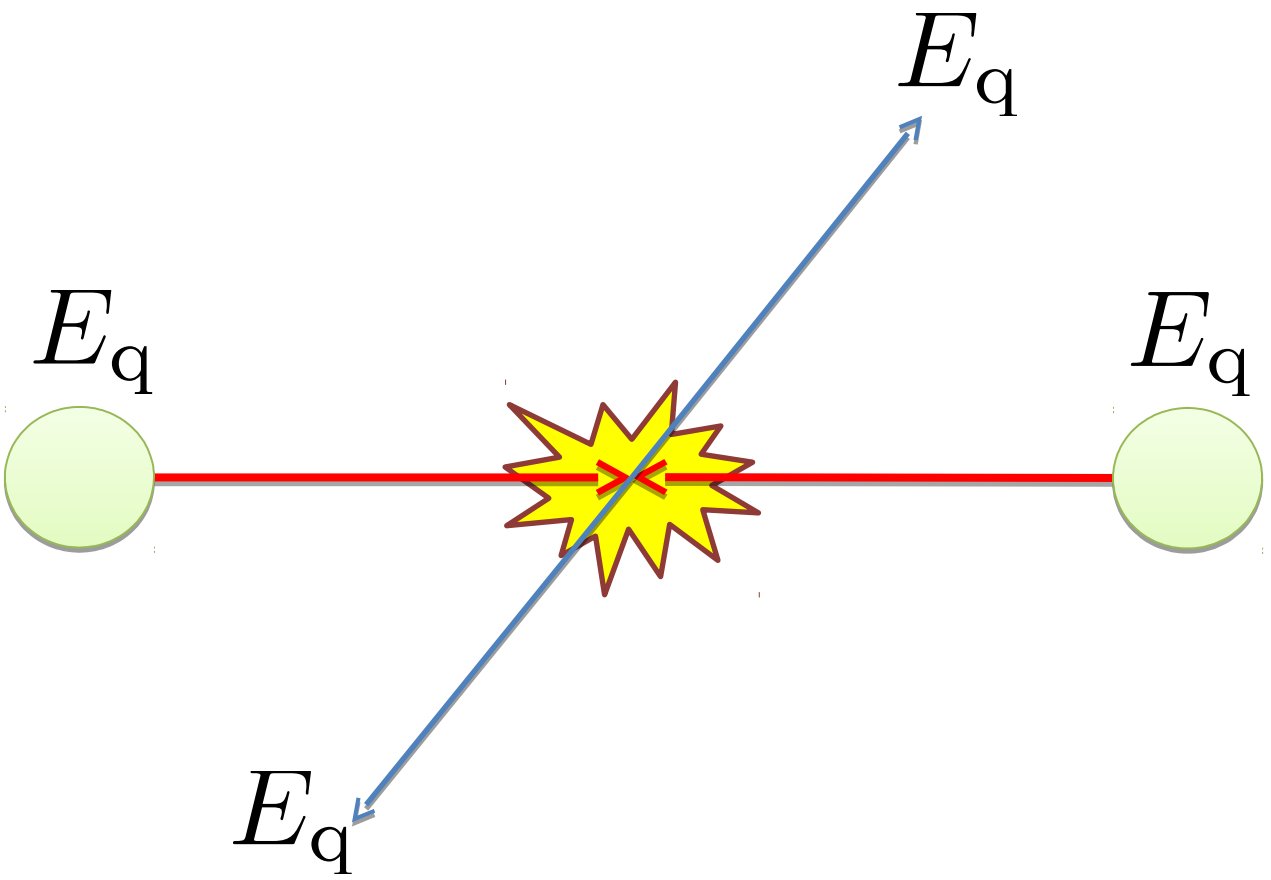
6,5 TeV

6,5 TeV

Seuls deux quarks entrent en collision,
le reste continue tout droit.

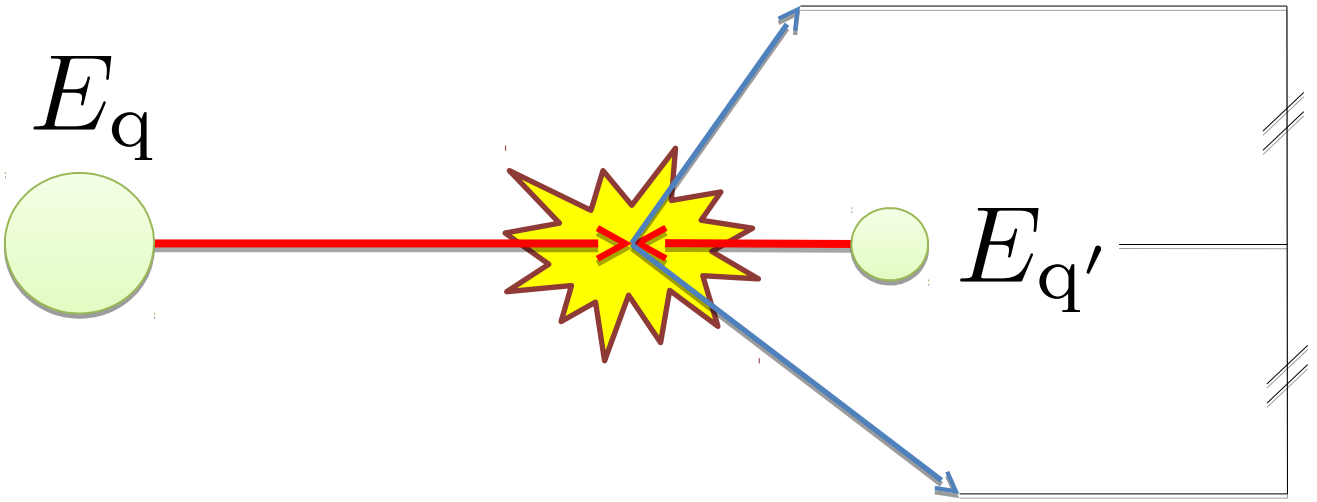
$$E_{\text{collision}} \ll 2E_{\text{proton}} = 13\ \text{TeV}$$

# Production de nouvelles particules



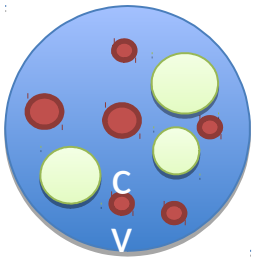

Production de deux particules de masse nulle.
Les deux quarks ont la même énergie.
Conservation impulsion: les particules sont produites dos à dos

# Production de nouvelles particules

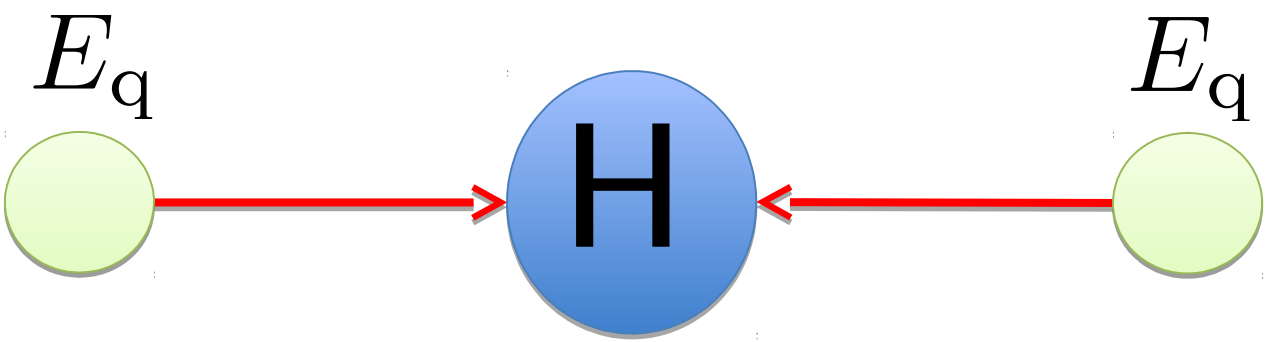



Production de deux particules de masse nulle.
L'un des quarks a plus d'énergie
Conservation impulsion:

- les particules finales sont poussées vers la droite.
- même impulsion dans la direction verticale



# Production d'un boson de Higgs
# Création



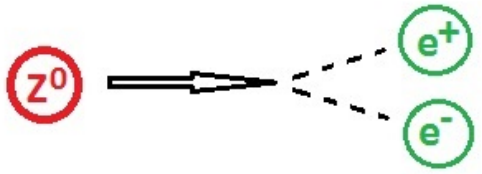

boson de Higgs **au repos**

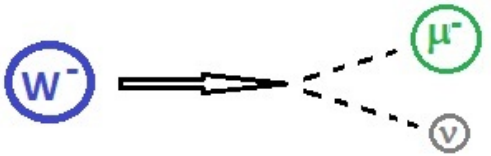
Conservation de l'énergie:

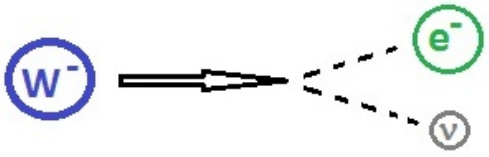
$$2E_\mathrm{q} = m_\mathrm{H}$$

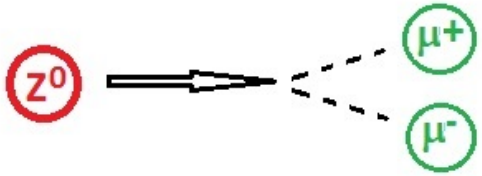
$$E_\mathrm{q} = 125\,\mathrm{GeV}/2 = 62.5\,\mathrm{GeV}$$

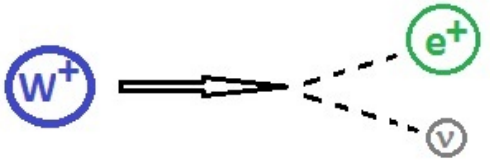
# Les bosons Z, W et H se desintegrent

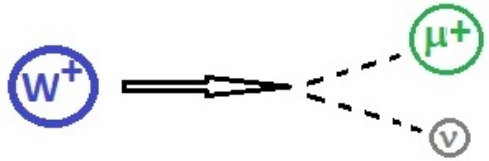


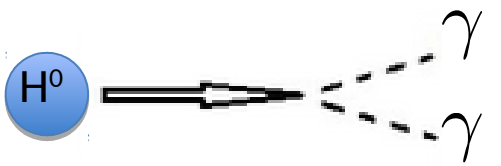



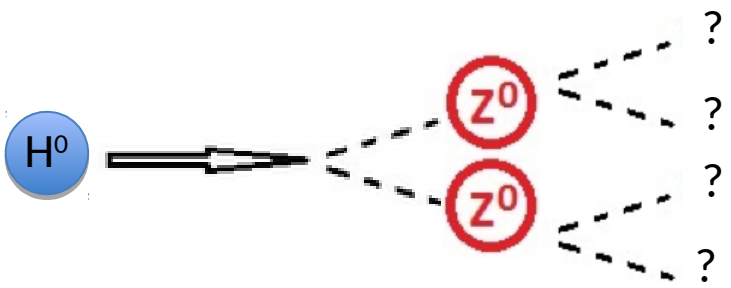



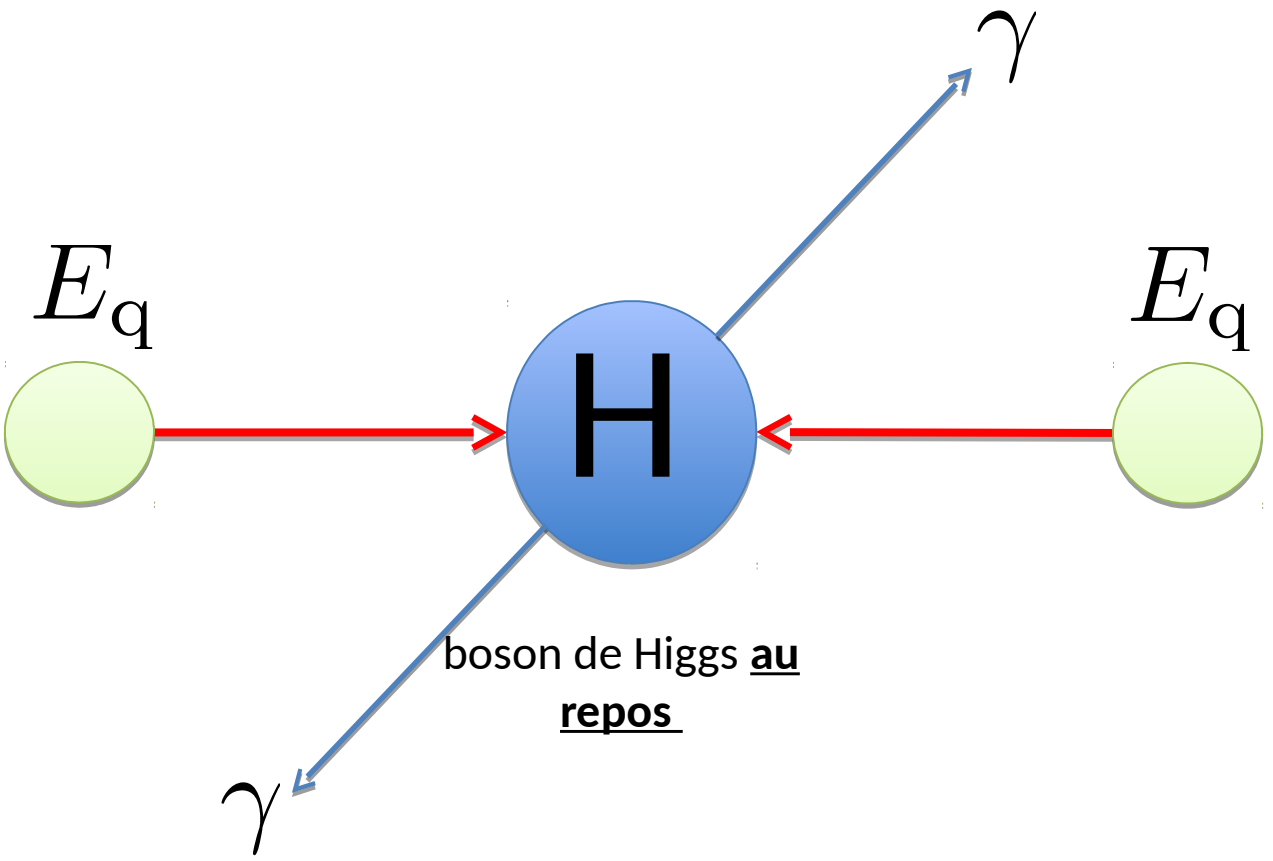




Lois de conservation
- énergie / impulsion
- saveur (e+e- ou mu+mu-, mais pas e+mu-)
- charge

Les Z, W, H se désintègrent très rapidement
Que voit-on dans le détecteur?

# Production d'un boson de Higgs
# Désintégration immédiate

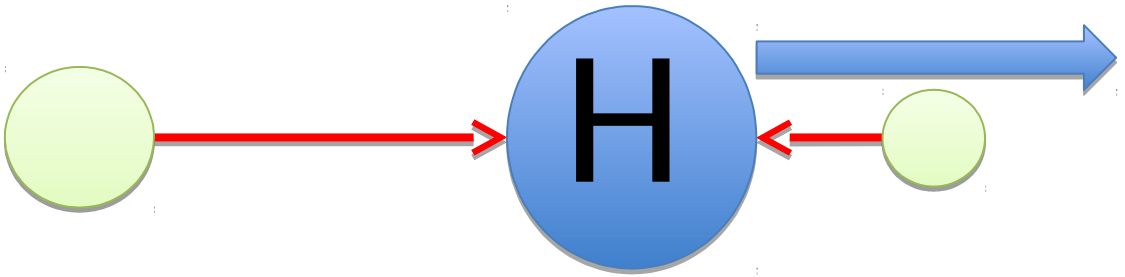



Conservation de l'énergie:

$$2E_\gamma = m_H$$

$$E_\gamma = 125\,\mathrm{GeV}/2 = 62.5\,\mathrm{GeV}$$

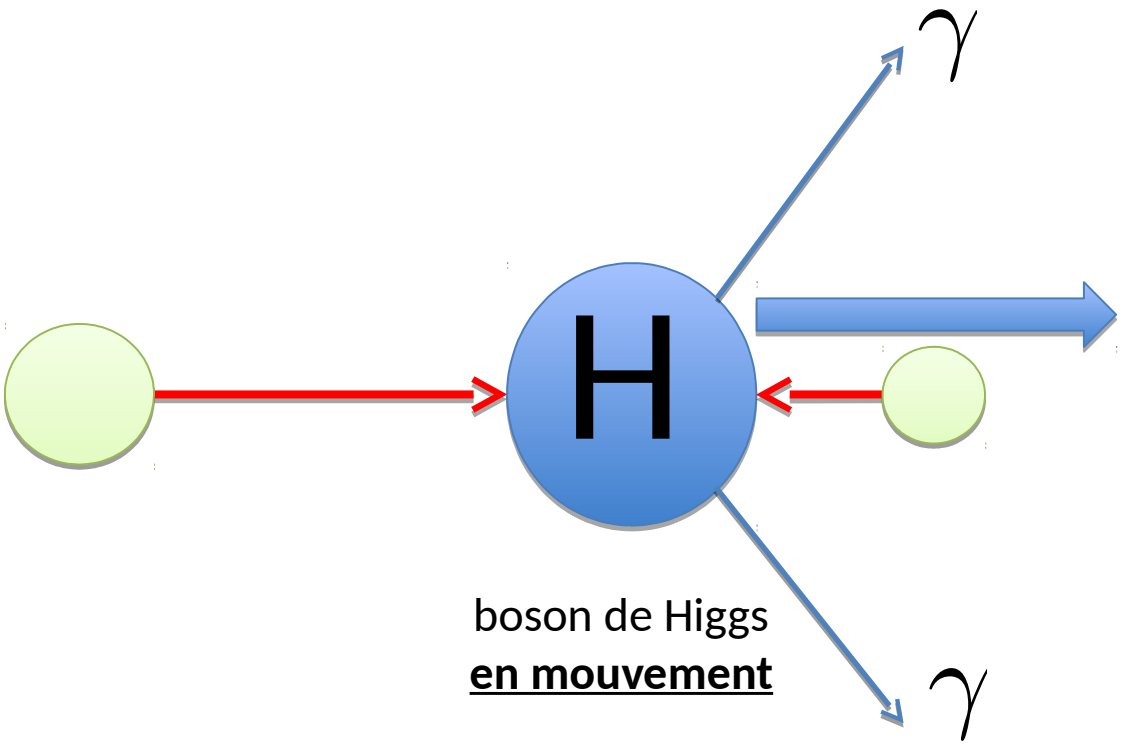
# Production d'un boson de Higgs
# Création




boson de Higgs
**en mouvement**

Conservation de l'impulsion:
Le boson de Higgs part vers la droite.

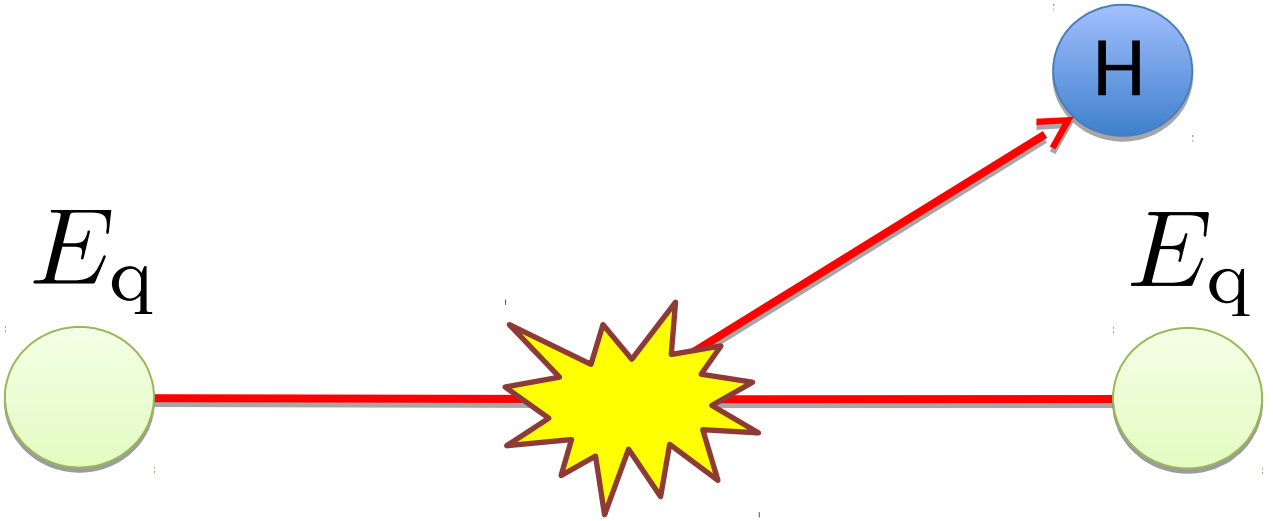
# Production d'un boson de Higgs
# Désintégration immédiate




boson de Higgs
**en mouvement**

Conservation de l'impulsion
L'angle entre les deux photons est
< π

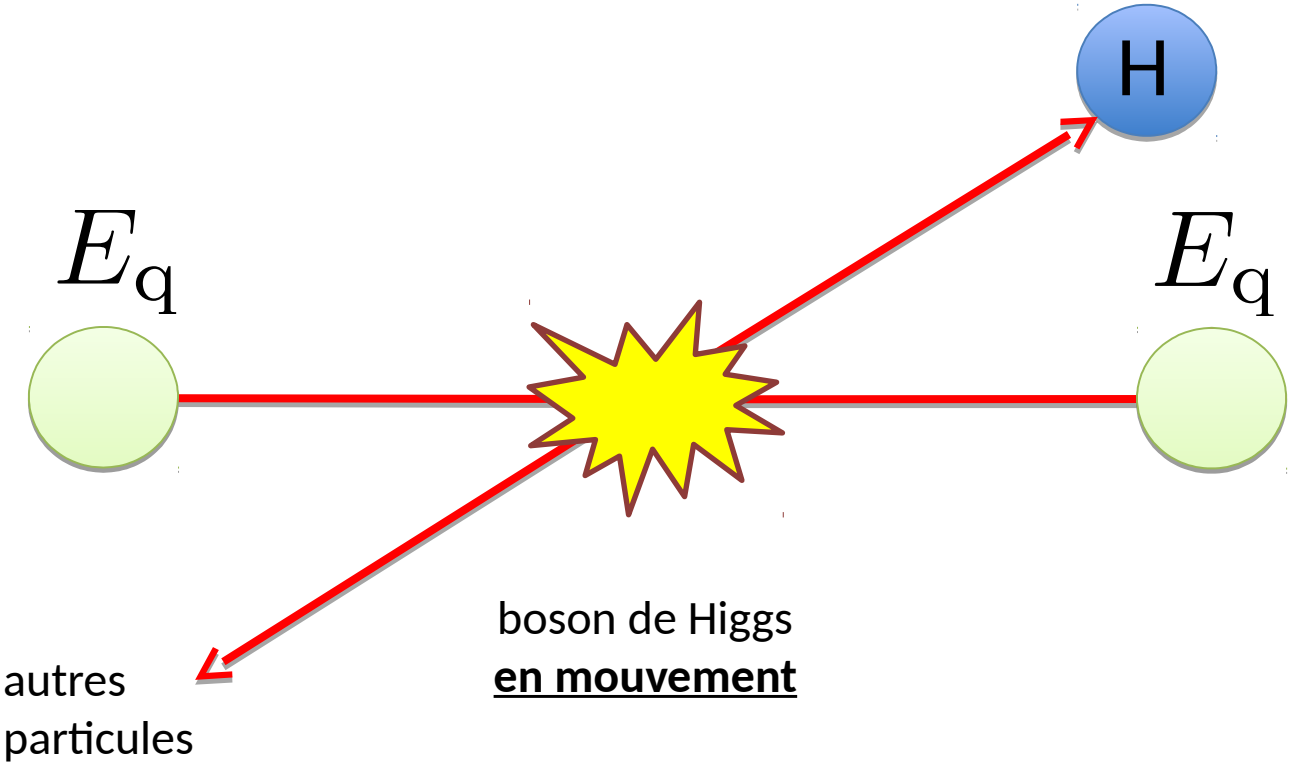
# Production d'un boson de Higgs
# Création




boson de Higgs
**en mouvement**

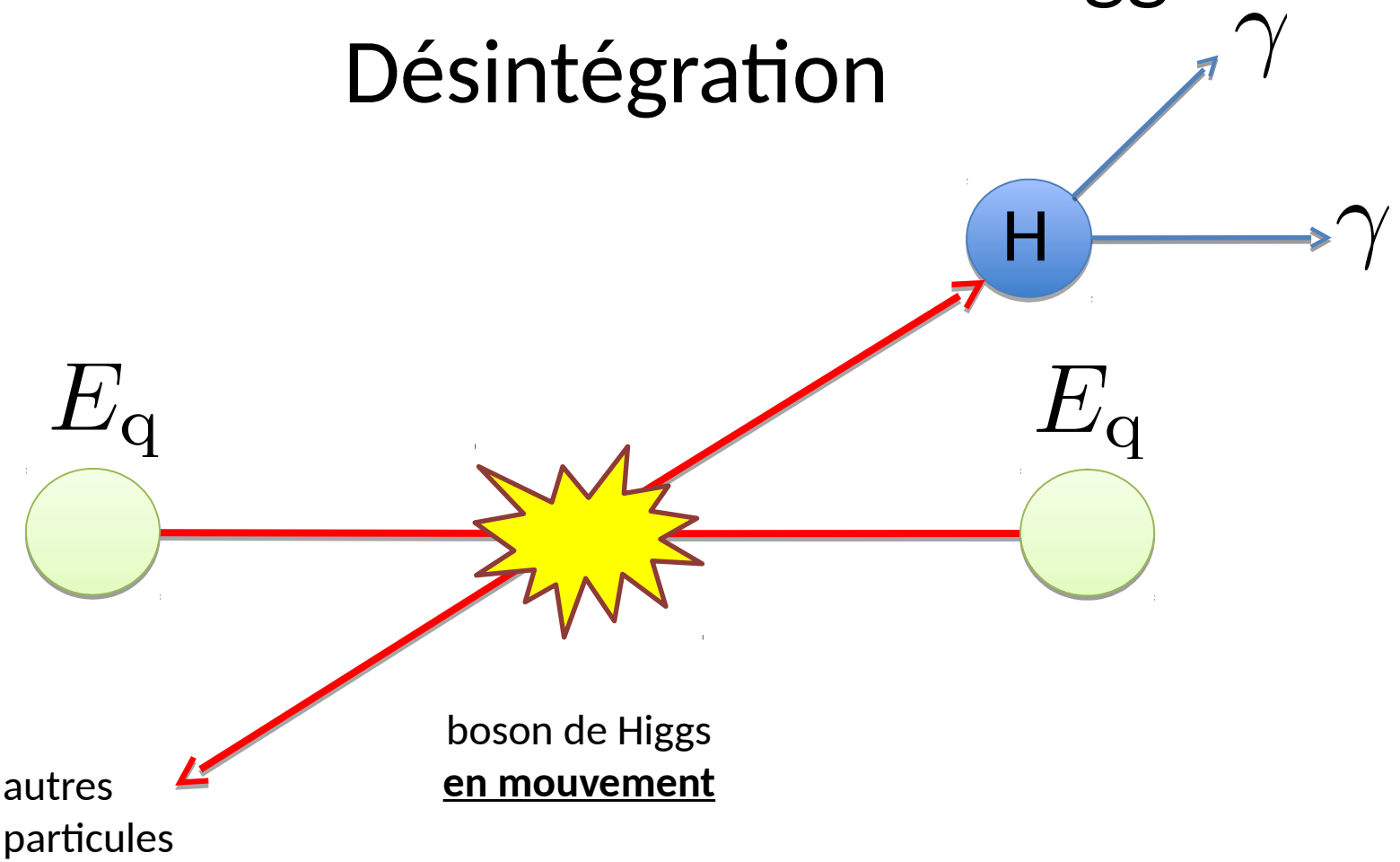
Conservation de l'impulsion:
IMPOSSIBLE

# Production d'un boson de Higgs
# Création




Conservation de l'impulsion:
Ok! il suffit d'avoir d'autres particules de l'autre côté

# Production d'un boson de Higgs
# Désintégration

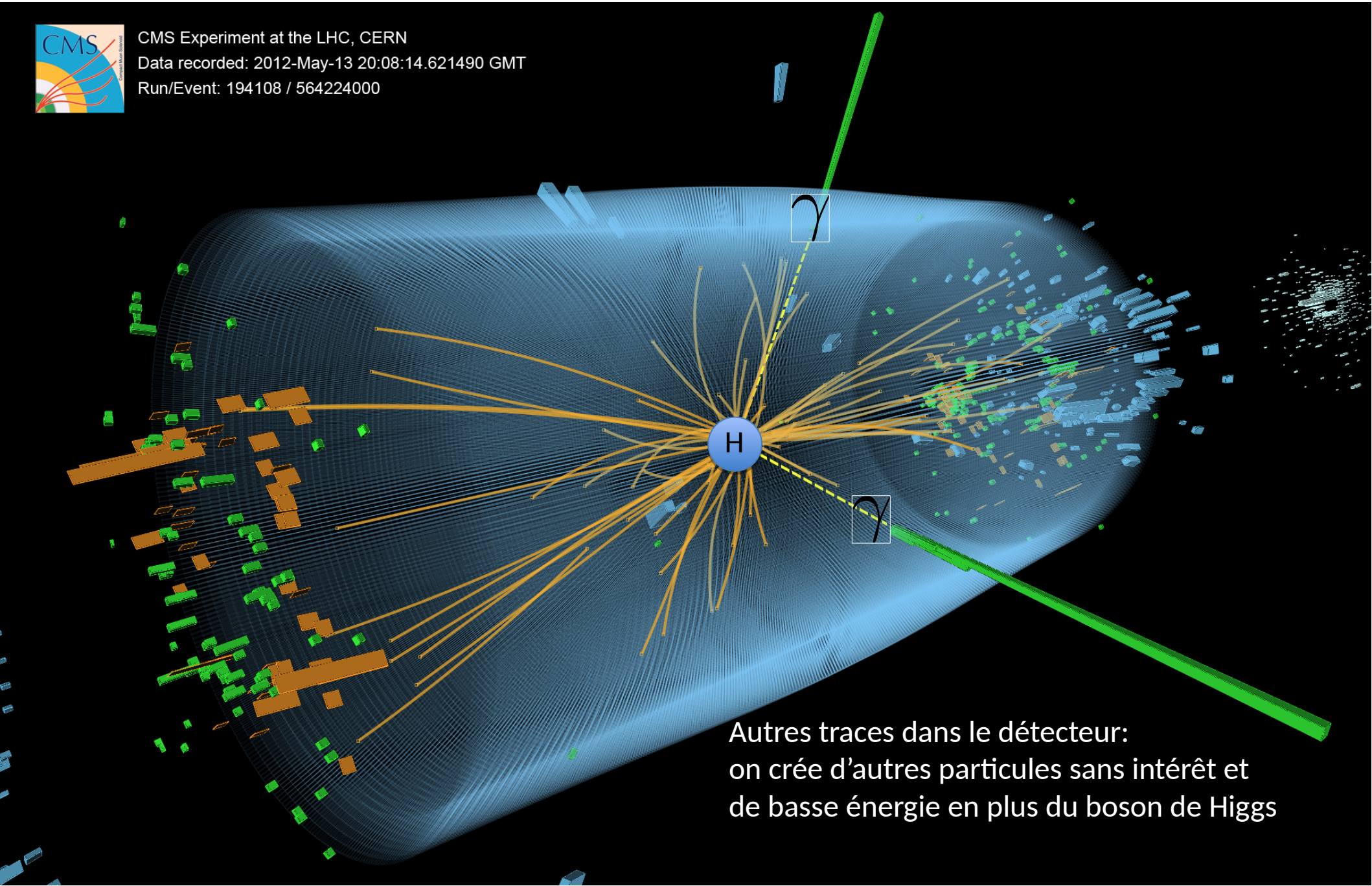



Conservation de l'impulsion:
Ok! il suffit d'avoir d'autres particules de l'autre côté

$$2E_q > m_{\mathrm{H}}$$

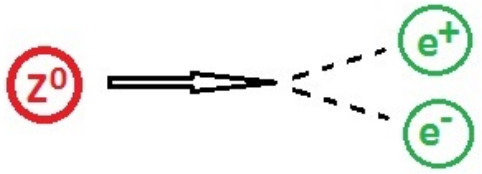
$$E_\gamma > 125\,\mathrm{GeV}/2 = 62.5\,\mathrm{GeV}$$

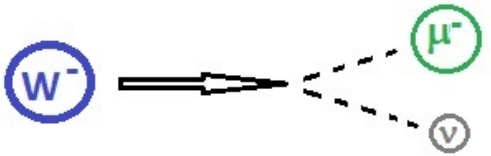
# Tout se passe immédiatement au centre du détecteur

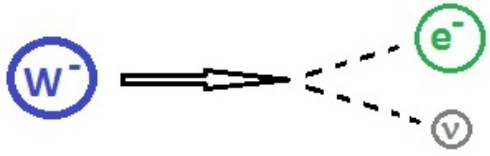


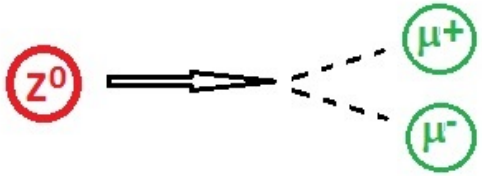
# RECONNAÎTRE LES PARTICULES

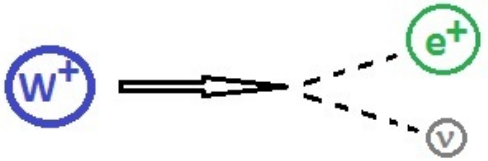
# Les bosons Z, W et H

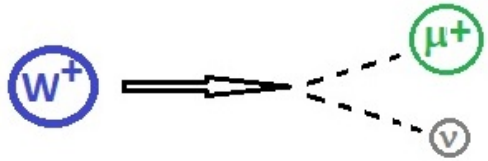


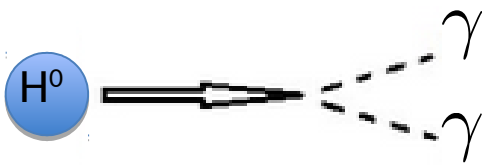



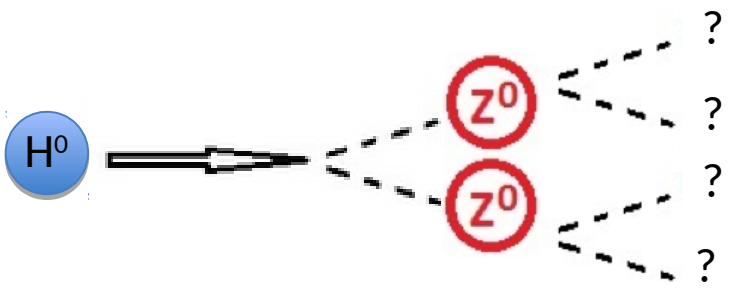



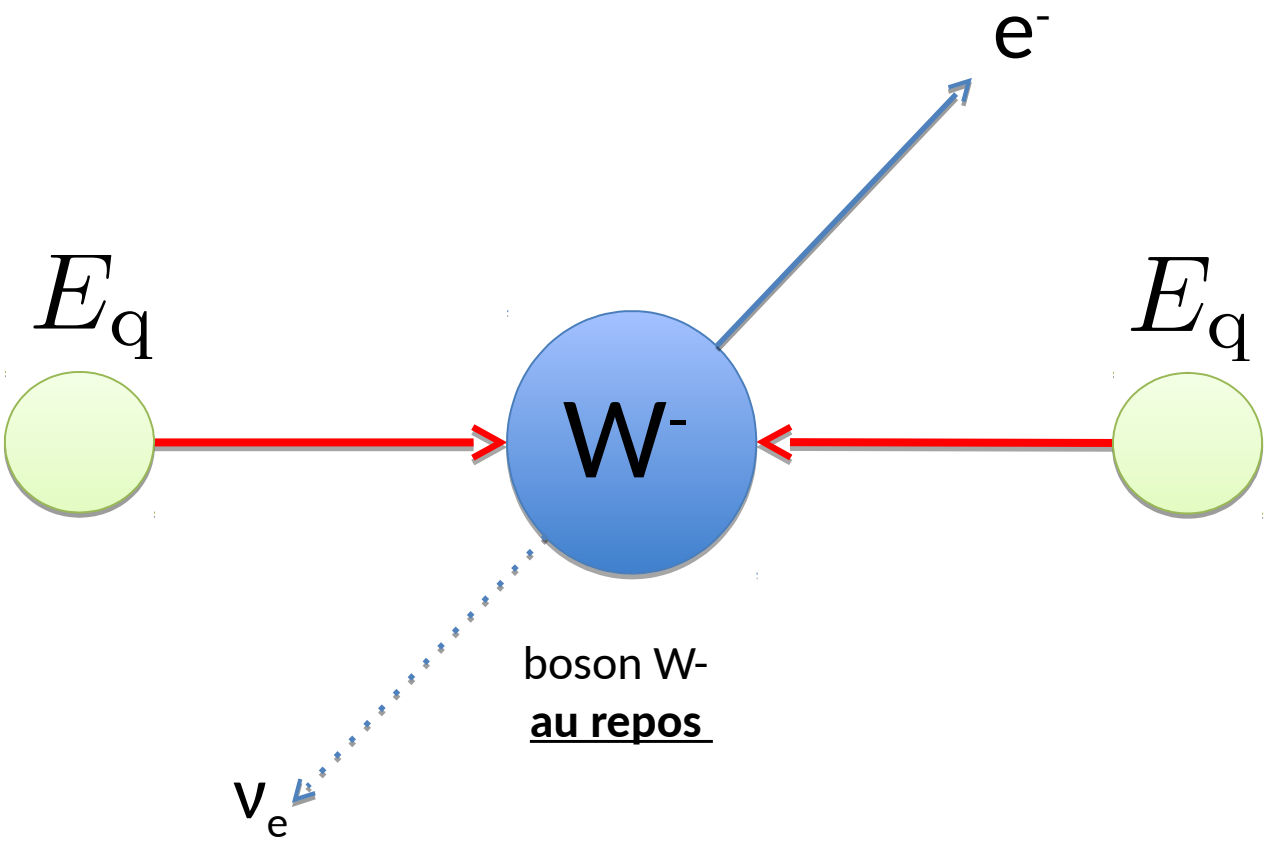




Lois de conservation
- énergie / impulsion
- saveur (e+e- ou mu+mu-, mais pas e+mu-)
- charge

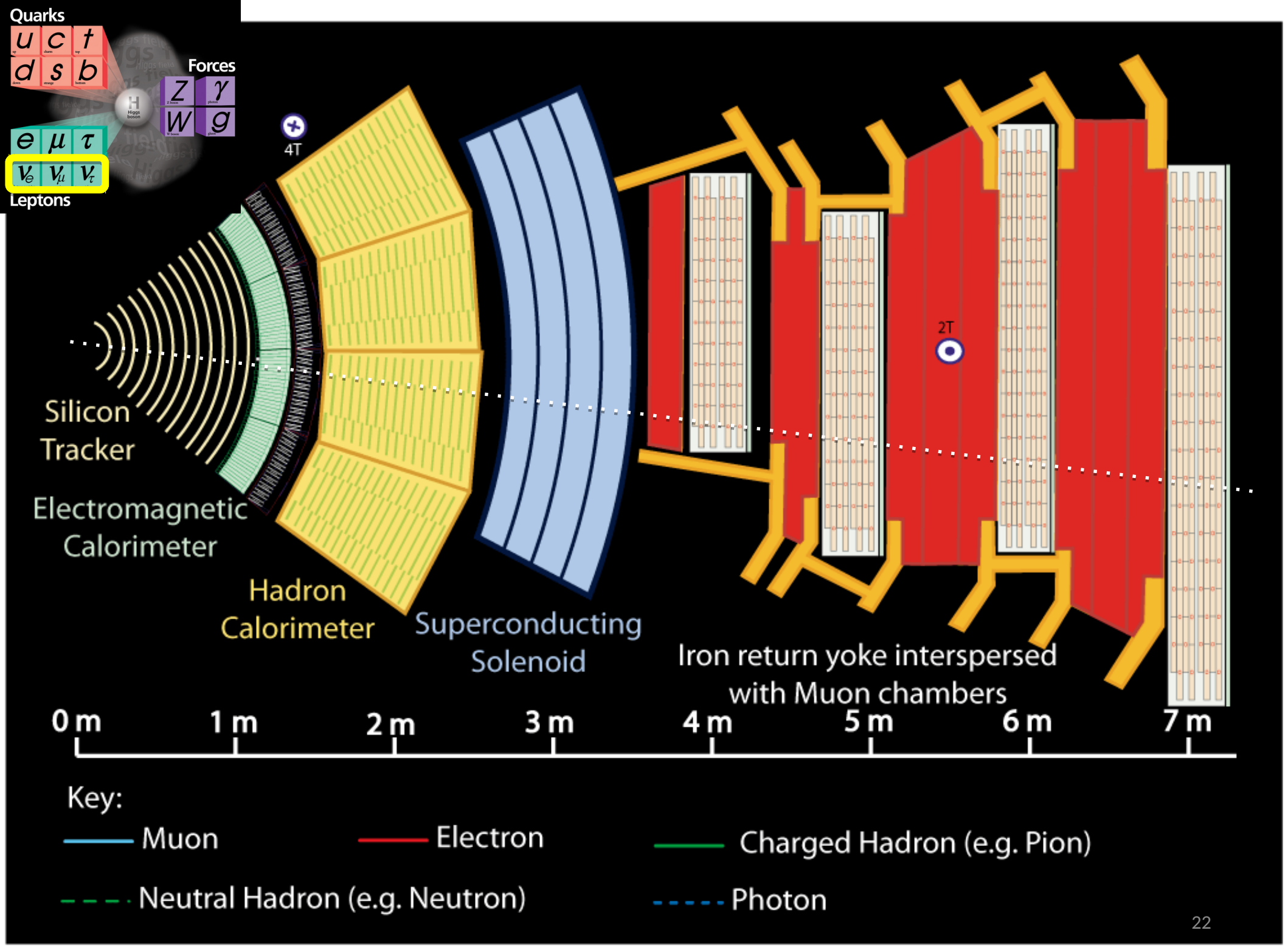
Les Z, W, H se désintègrent très rapidement
Que voit-on dans le détecteur?

# Neutrinos = énergie manquante (MET)




Traverse le détecteur sans intéragir! => invisible

Mais on peut calculer l'énergie manquante à partir des particules visibles.


Quarks
u c t
d s b
Forces
Z γ
W g
H
Higgs boson
e μ τ
νe νμ ντ
Leptons
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
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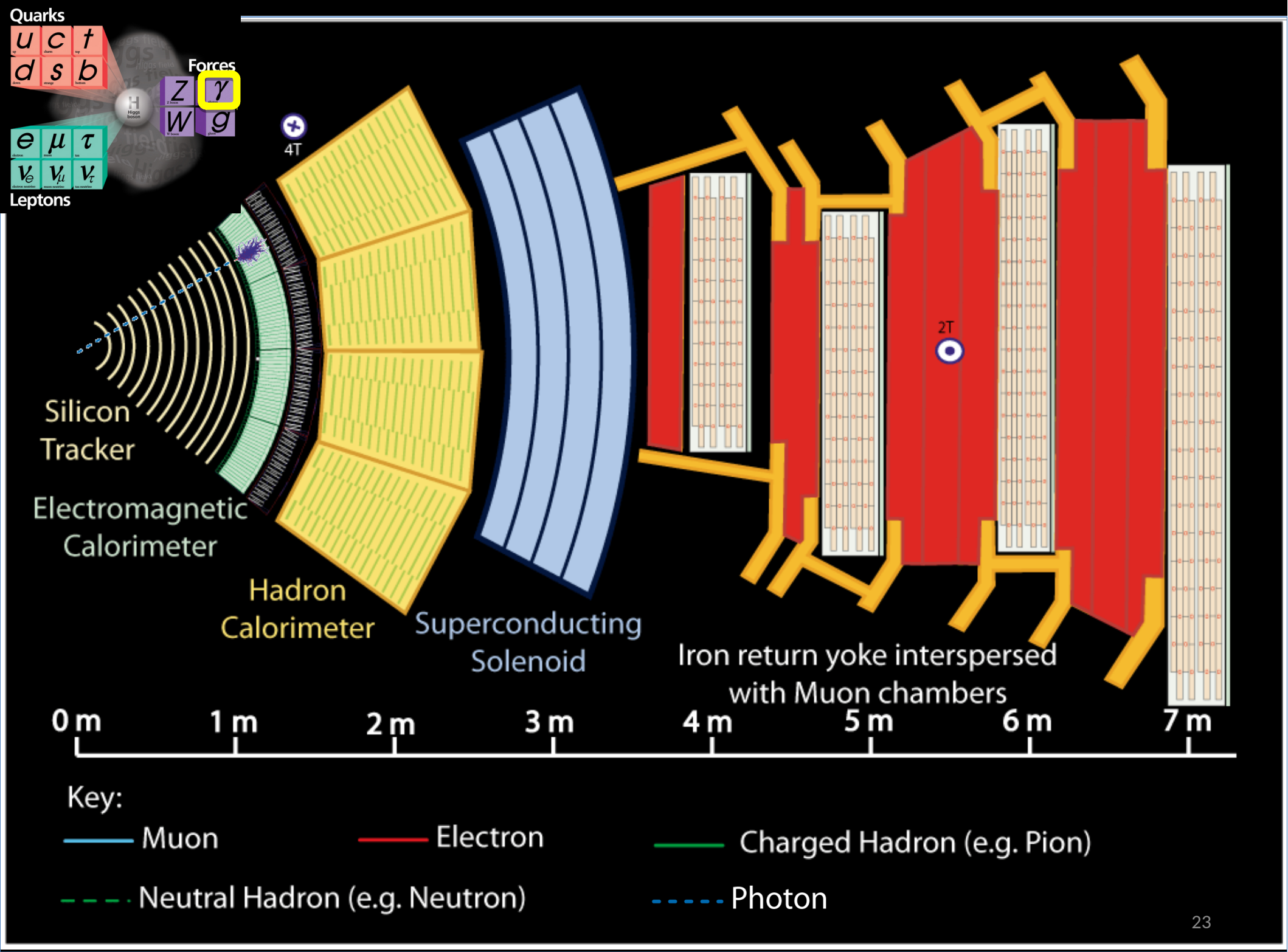
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon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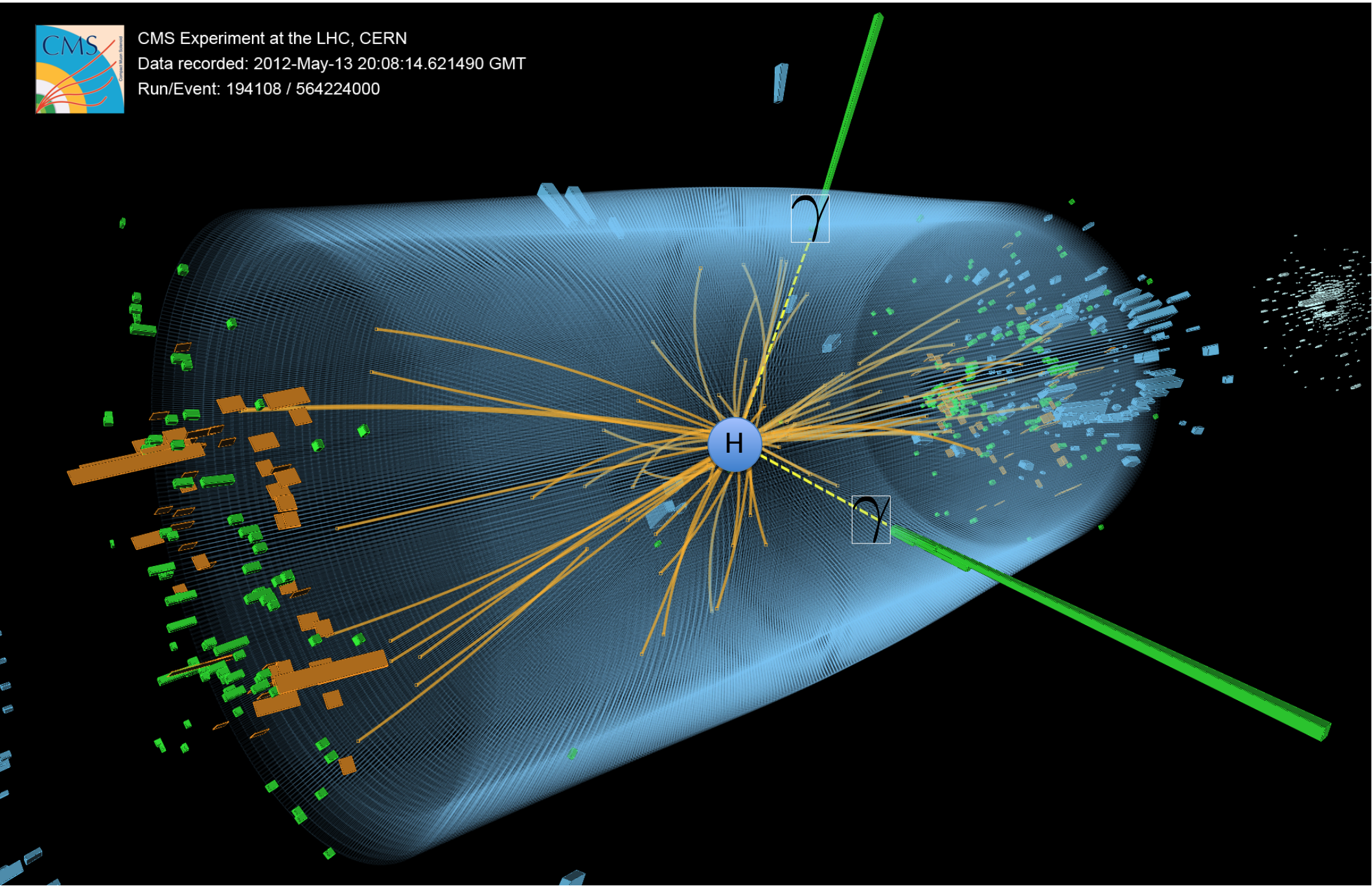
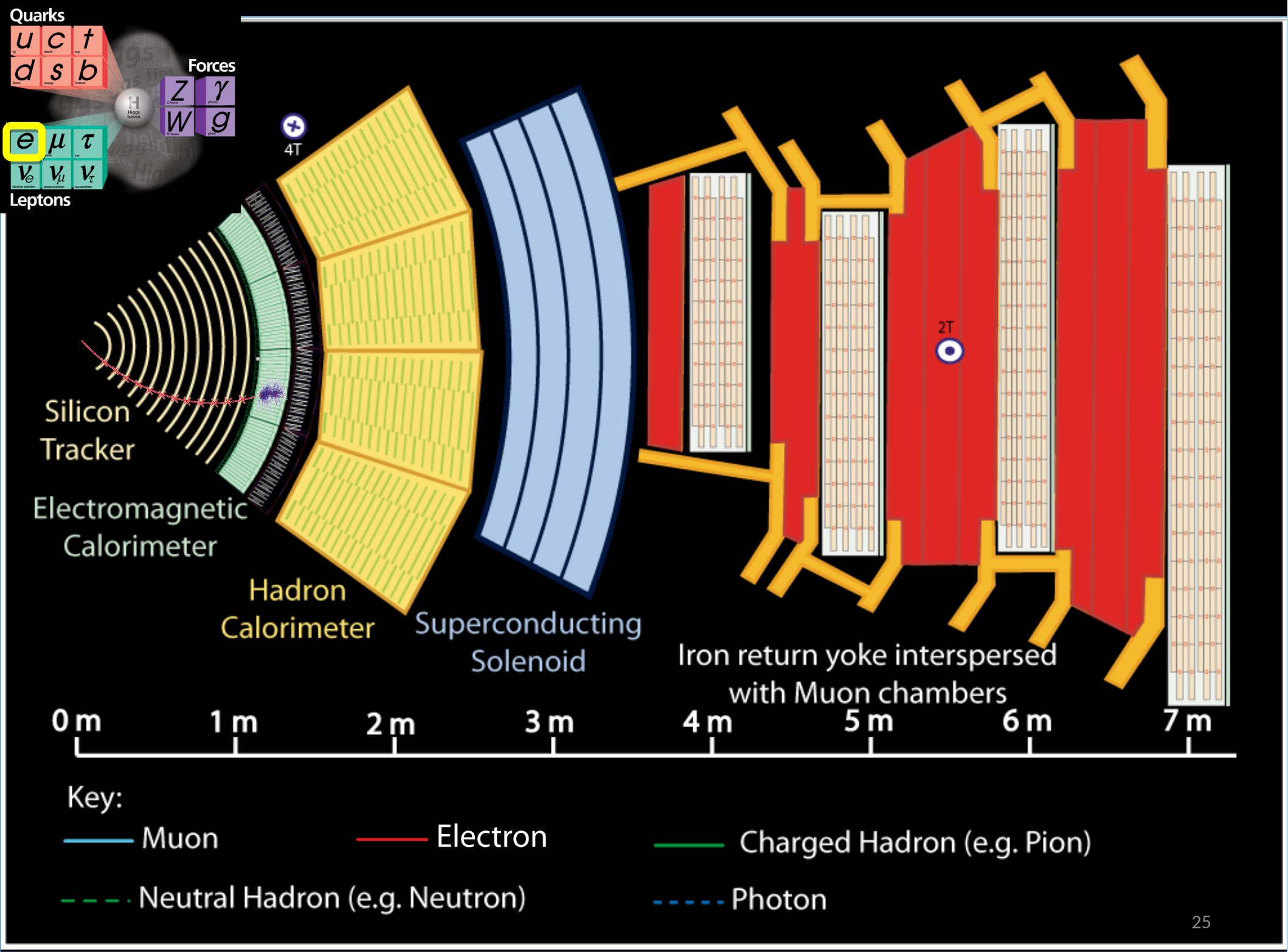
# 2 photons: boson de Higgs?

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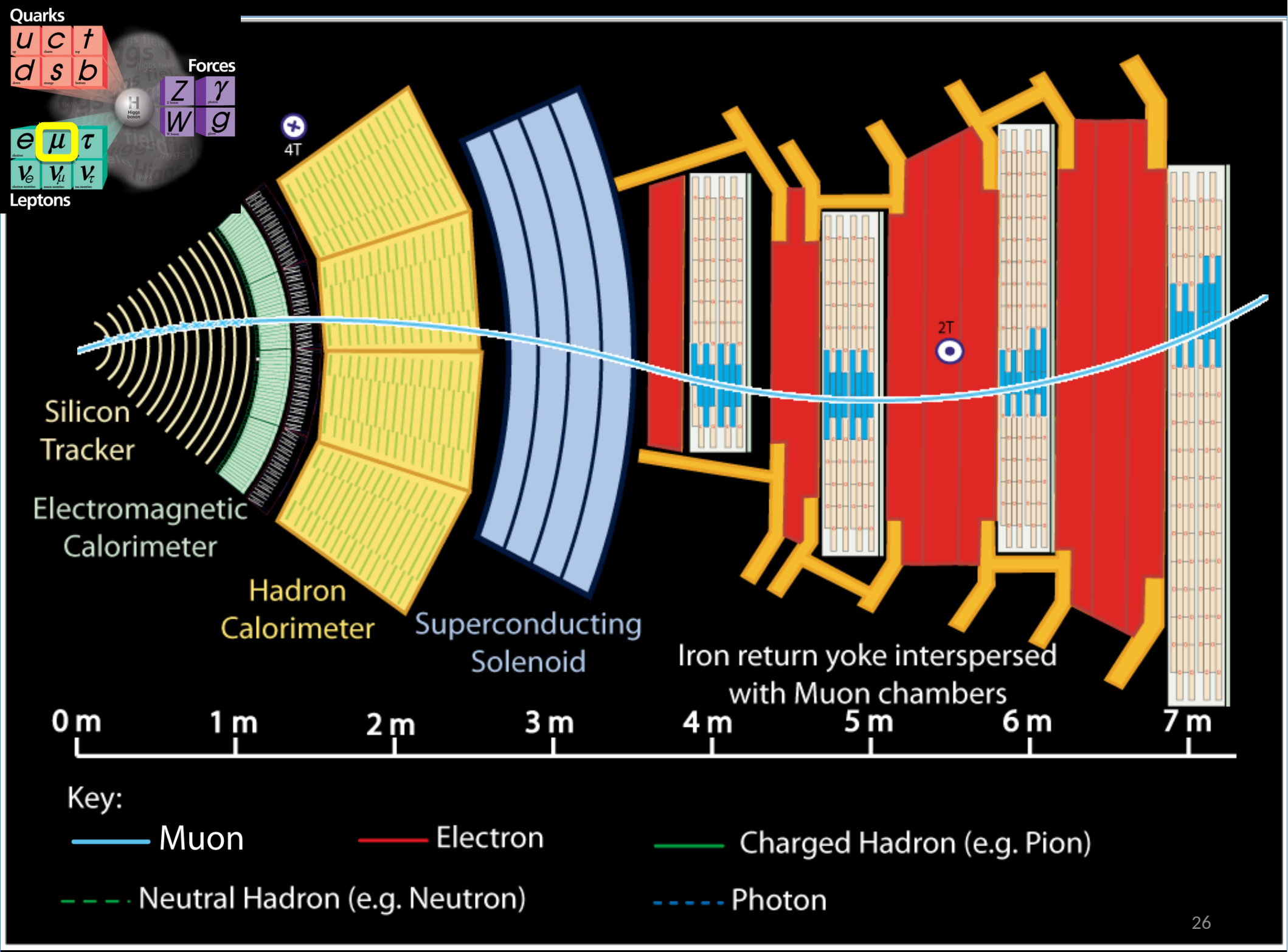
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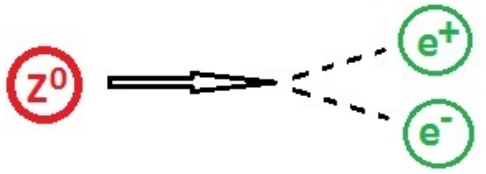
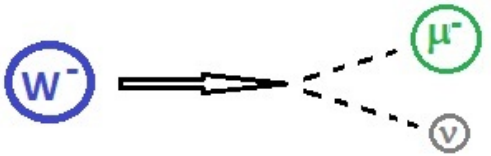
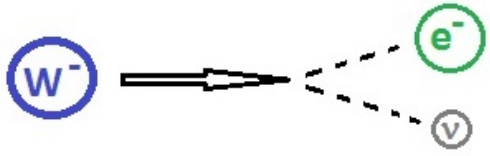
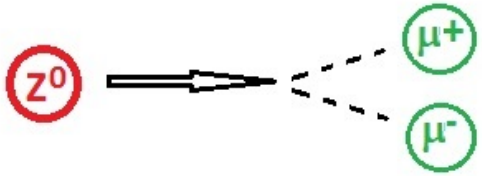
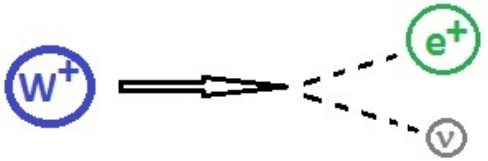
# Les bosons Z, W et H

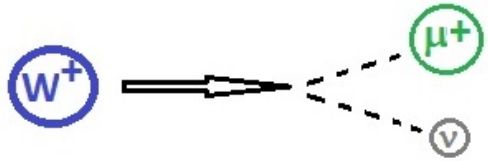


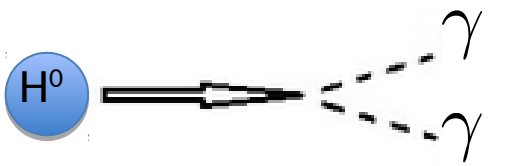



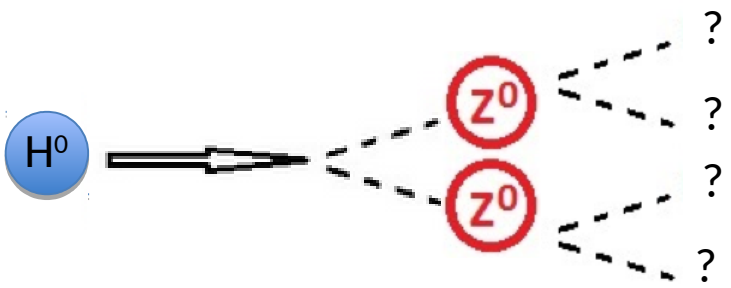

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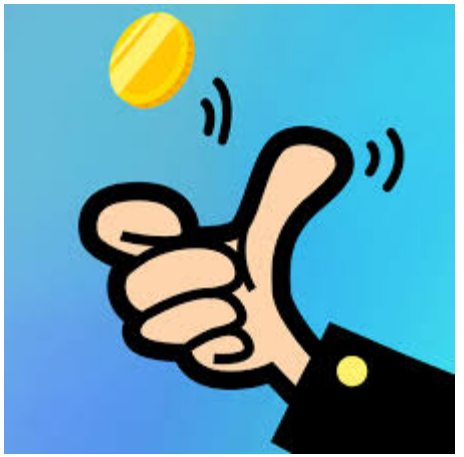
- charge

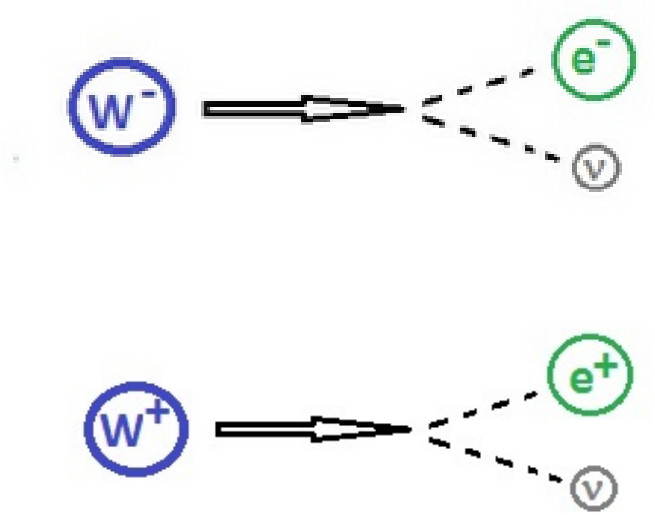
Quelles sont les probabilités ?

# Les incertitudes statistiques : le lancer de pièce

- Comment vérifier que les probabilités sont 50/50 ?
- On lance la pièce et on compte :
  - 2 lancer ne suffit pas !
  - On veut un maximum de lancer pour diminuer l'incertitude statistique



# Les incertitudes statistiques exemple: rapport W+ / W-

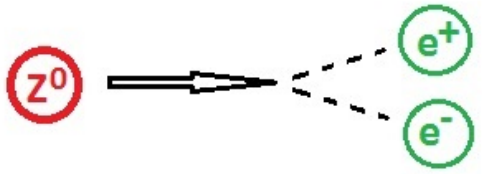


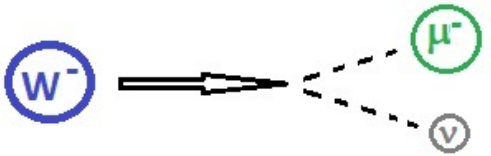

- Signature:
  - un électron
  - énergie manquante (MET)
- Supposons R = W+/W- = 2
- On voit:
  - 21 événements e+ et MET
  - 9 événements e- et MET
- Rapport R = W+/W-?
  - R = 21/9 = 2.3
  - Plus on a d'événements, plus notre mesure s'affine

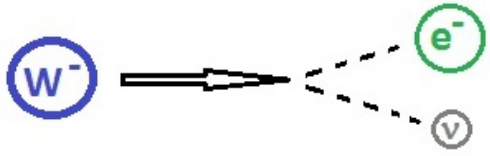
on va combiner les résultats de tous les groupes masterclasses !

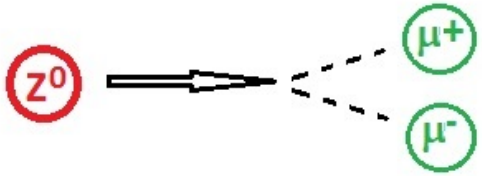
# QU’ALLONS-NOUS FAIRE?

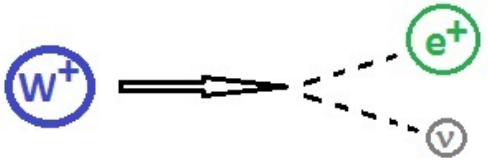
# Les bosons Z, W et H

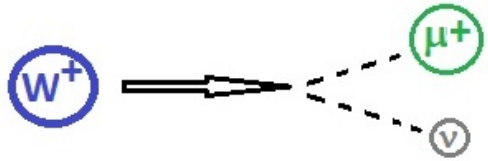


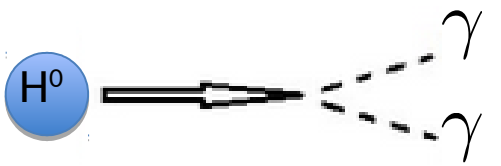



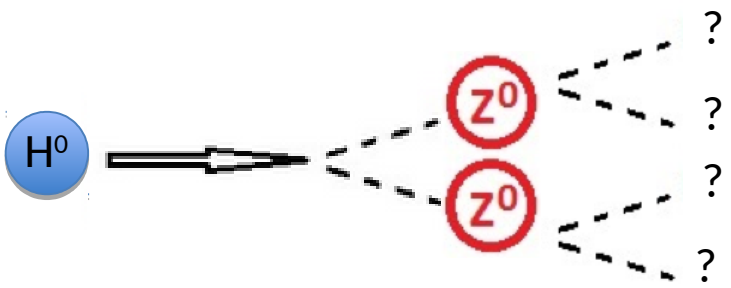



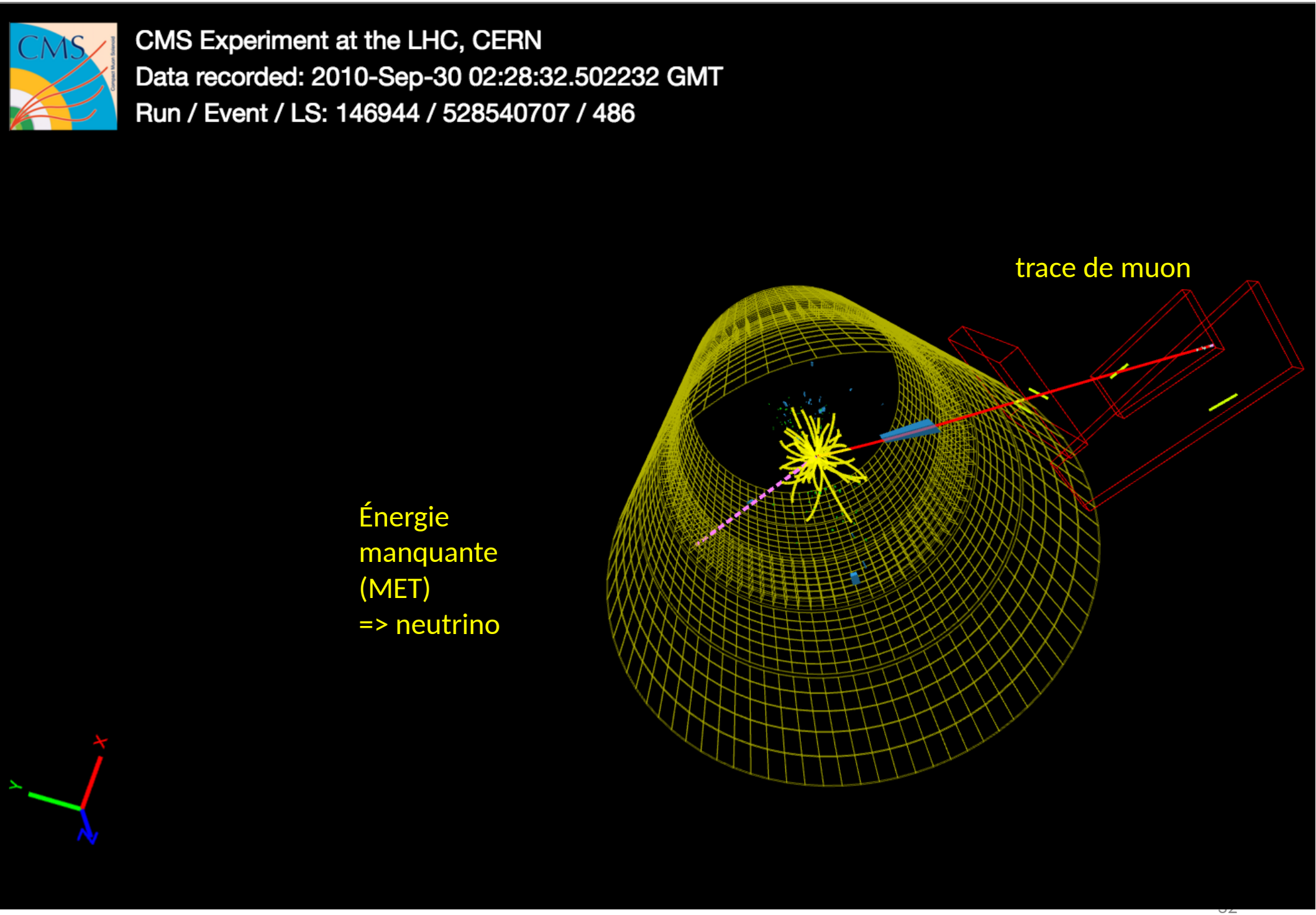



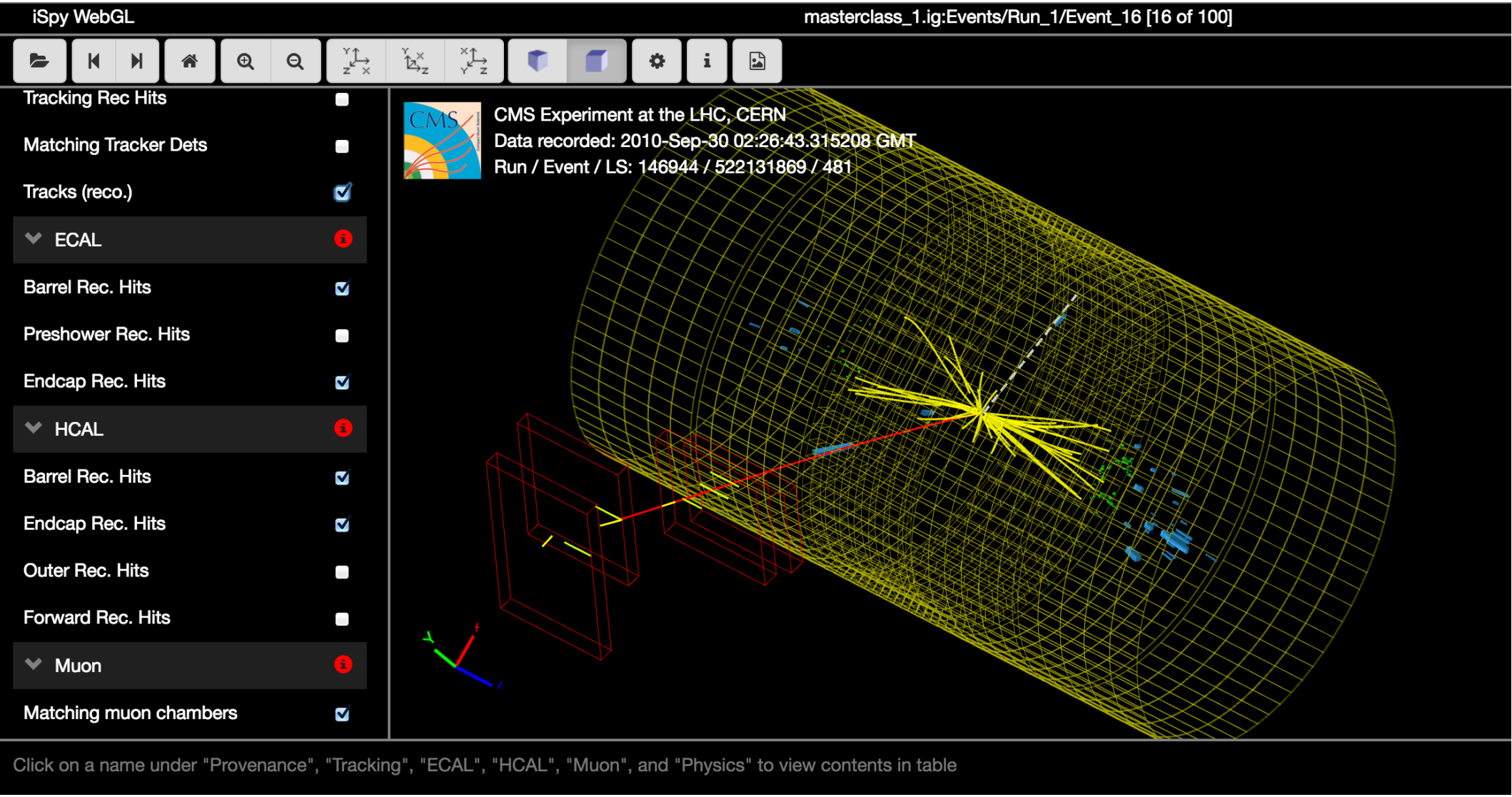




Lois de conservation
- énergie / impulsion
- saveur (e+e- ou mu+mu-, mais pas e+mu-)
- charge

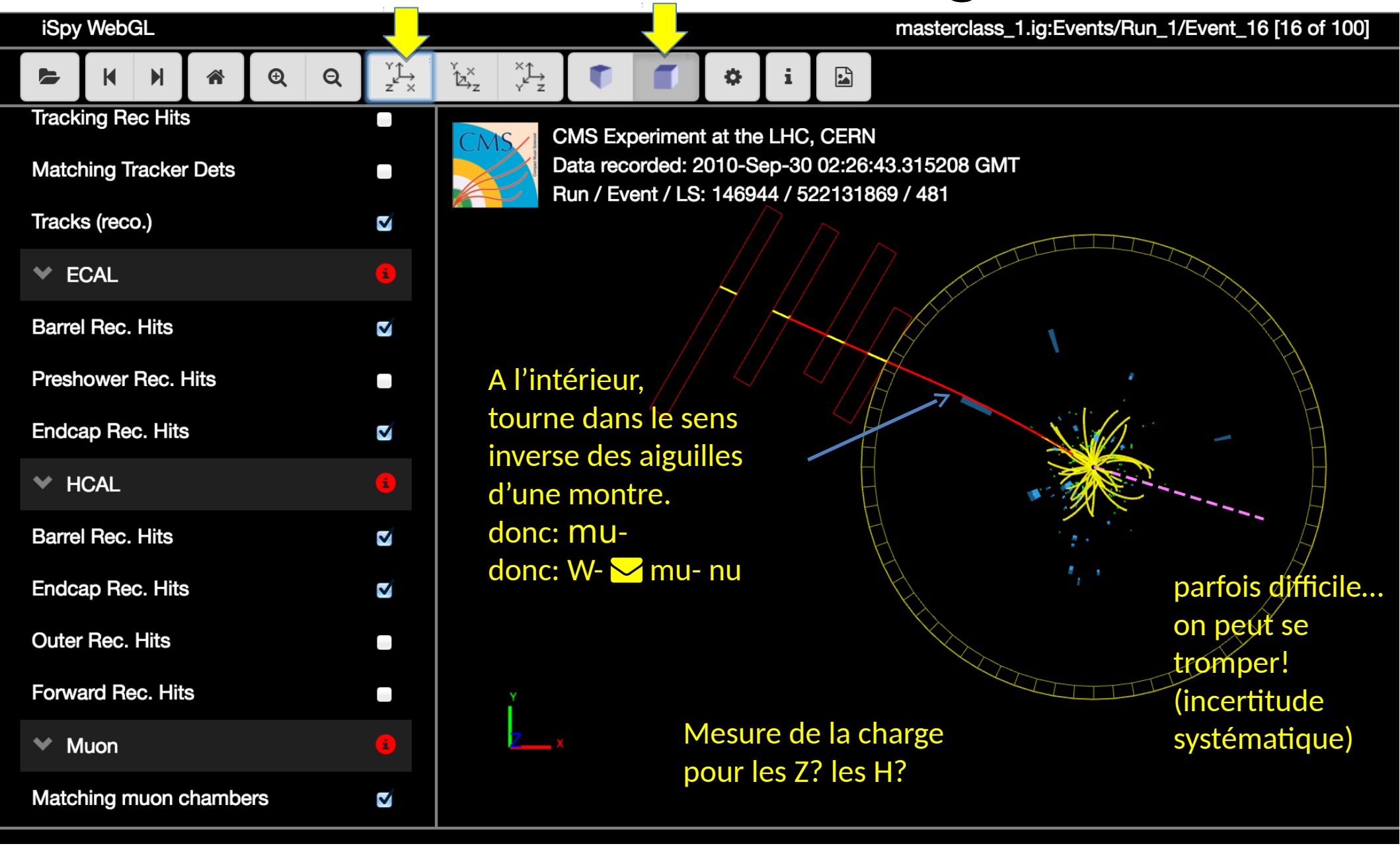
Les Z, W, H se désintègrent très rapidement
Que voit-on dans le détecteur?

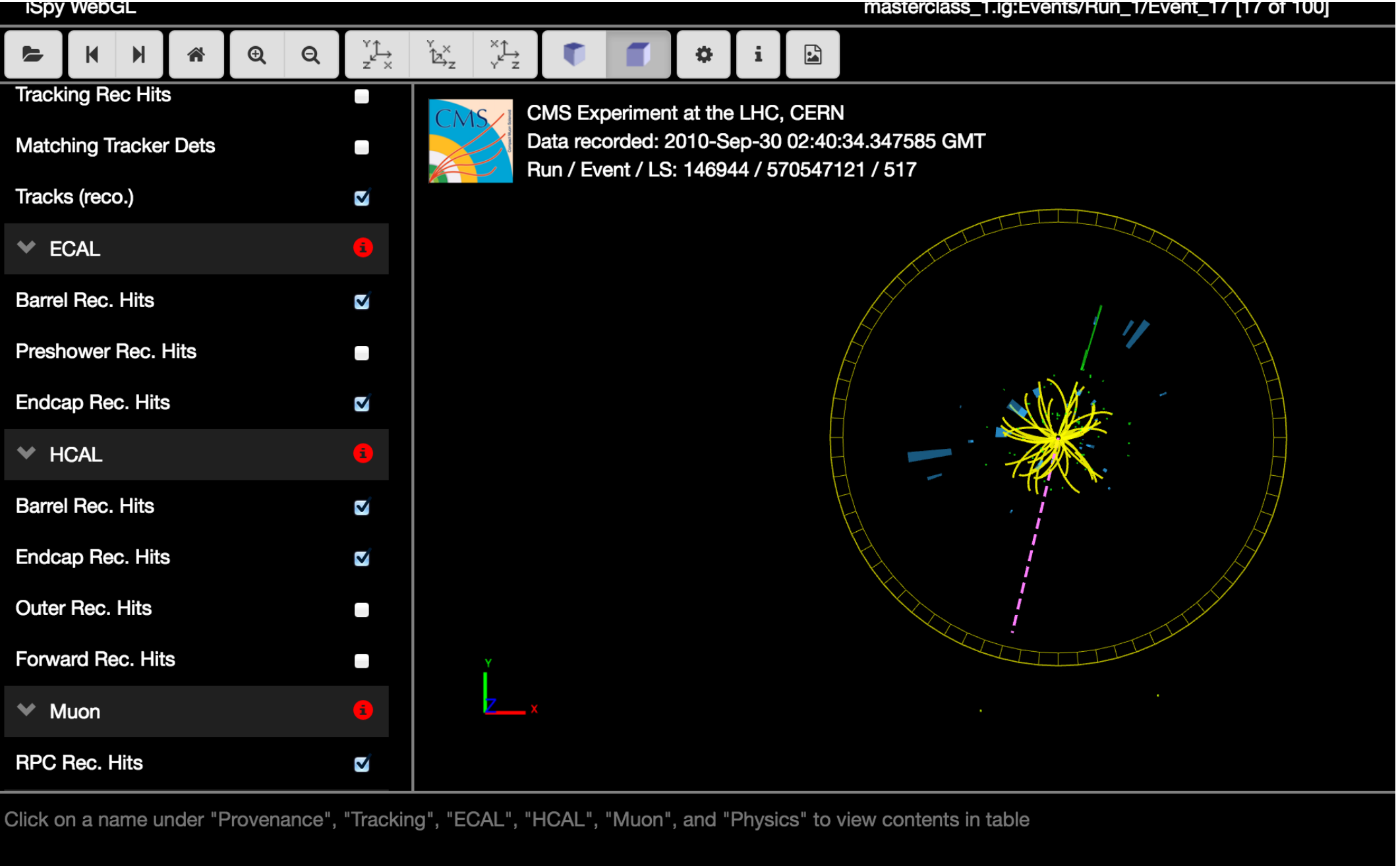

CMS Experiment at the LHC, CERN
Data recorded: 2010-Sep-30 02:28:32.502232 GMT
Run / Event / LS: 146944 / 528540707 / 486
trace de muon
Énergie
manquante
(MET)
=> neutrino
X
Y
Z

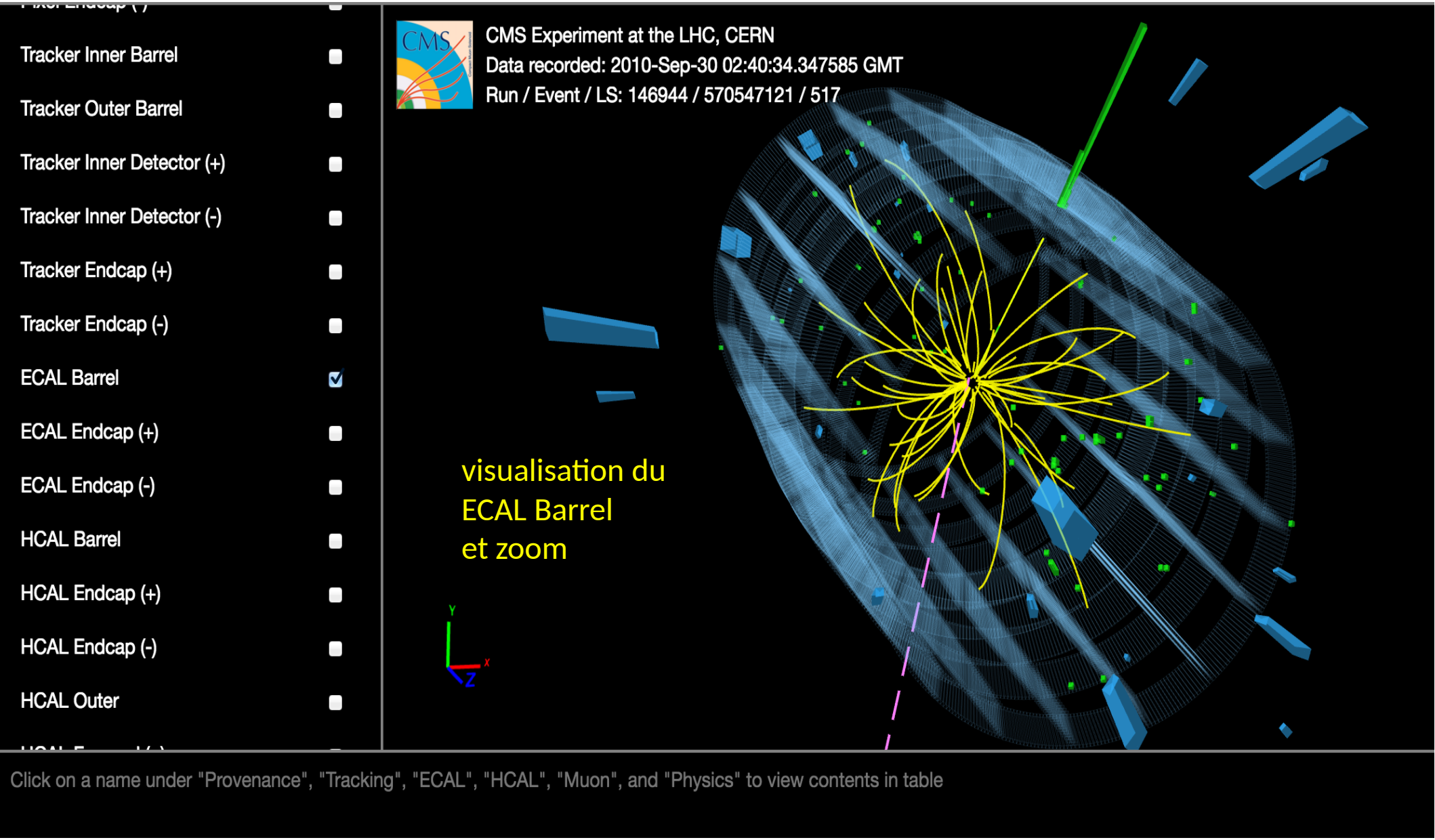
# Mesure de la charge



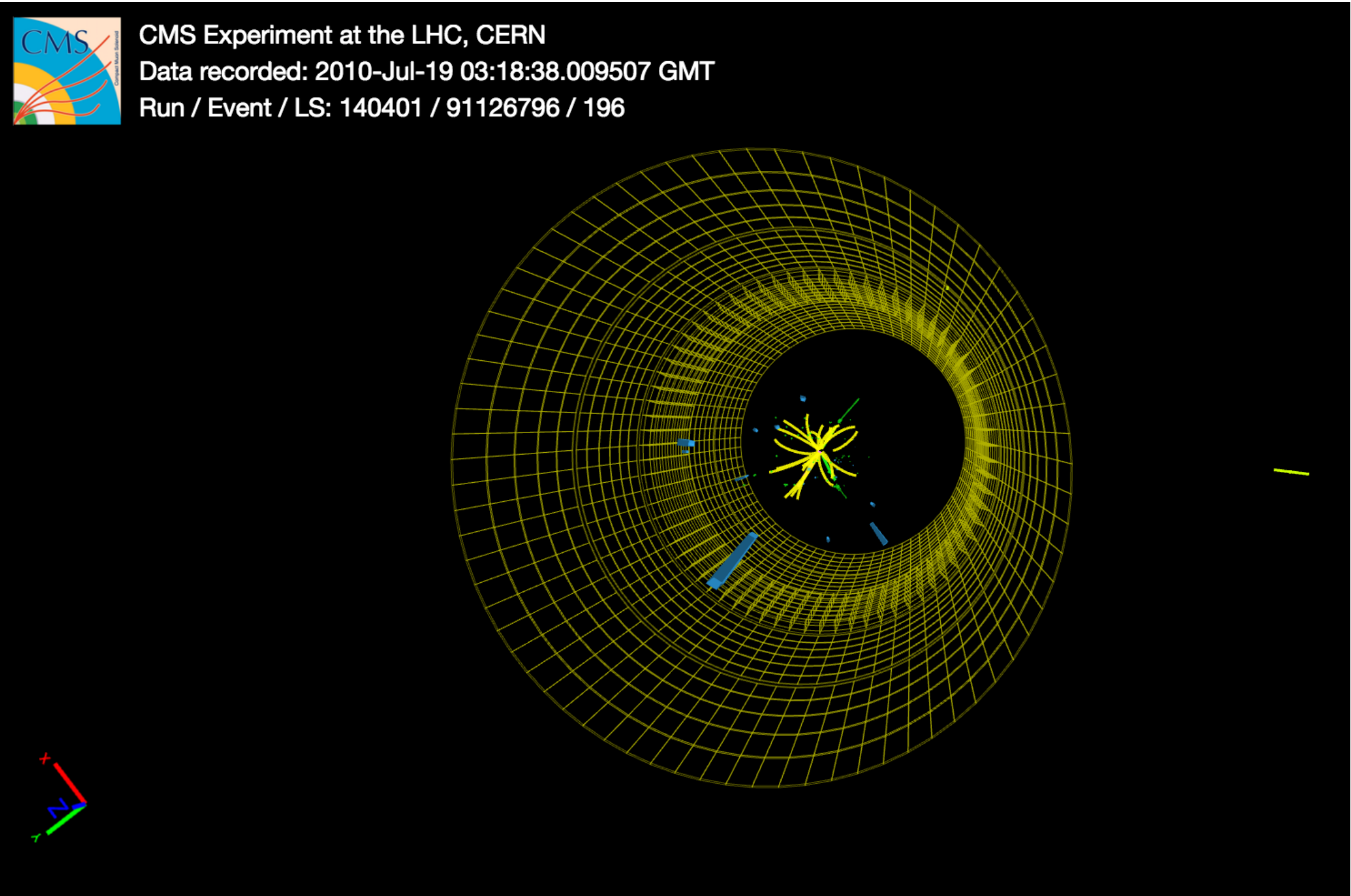
# Mesure de la charge



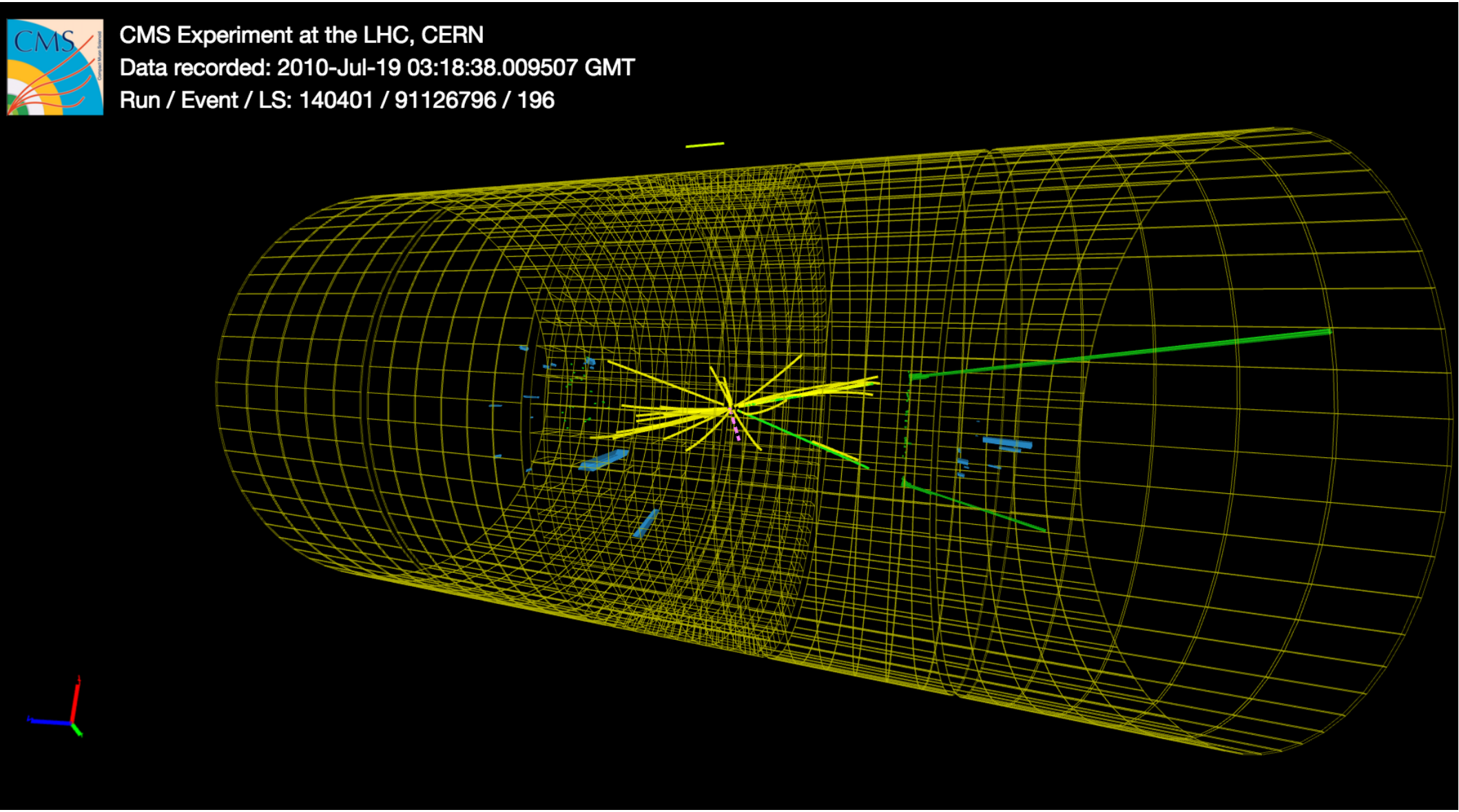

iSpy WebGL
masterclass_1.ig:Events/Run_1/Event_17 [17 of 100]
Tracking Rec Hits
Matching Tracker Dets
Tracks (reco.)
ECAL
Barrel Rec. Hits
Preshower Rec. Hits
Endcap Rec. Hits
HCAL
Barrel Rec. Hits
Endcap Rec. Hits
Outer Rec. Hits
Forward Rec. Hits
Muon
RPC Rec. Hits
CMS Experiment at the LHC, CERN
Data recorded: 2010-Sep-30 02:40:34.347585 GMT
Run / Event / LS: 146944 / 570547121 / 517
Y
Z
x
Click on a name under "Provenance", "Tracking", "ECAL", "HCAL", "Muon", and "Physics" to view contents in table


Tracker Inner Barrel
Tracker Outer Barrel
Tracker Inner Detector (+)
Tracker Inner Detector (-)
Tracker Endcap (+)
Tracker Endcap (-)
ECAL Barrel
ECAL Endcap (+)
ECAL Endcap (-)
HCAL Barrel
HCAL Endcap (+)
HCAL Endcap (-)
HCAL Outer
CMS Experiment at the LHC, CERN
Data recorded: 2010-Sep-30 02:40:34.347585 GMT
Run / Event / LS: 146944 / 570547121 / 517
visualisation du
ECAL Barrel
et zoom
Y
X
Z
Click on a name under "Provenance", "Tracking", "ECAL", "HCAL", "Muon", and "Physics" to view contents in table

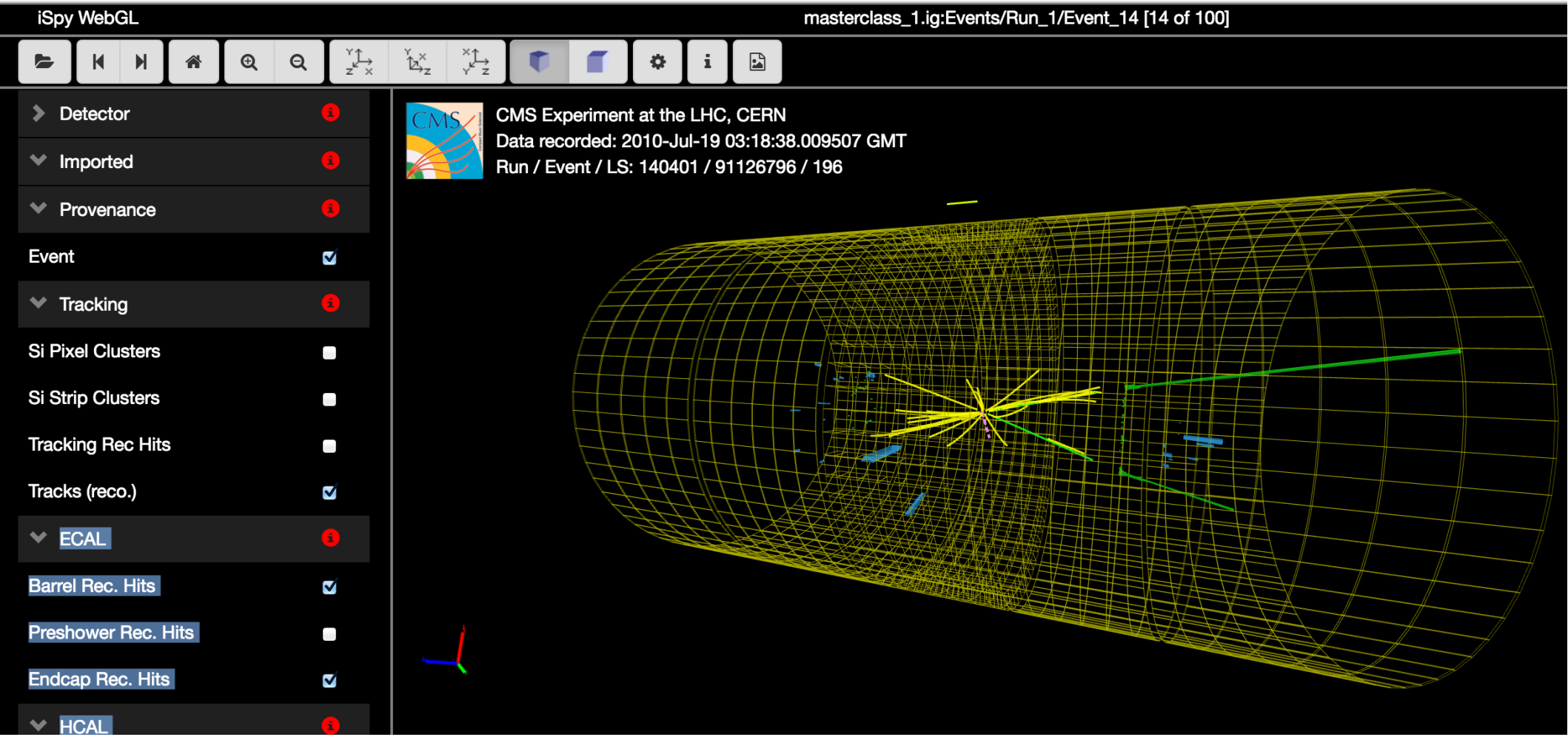
# Difficile à dire...



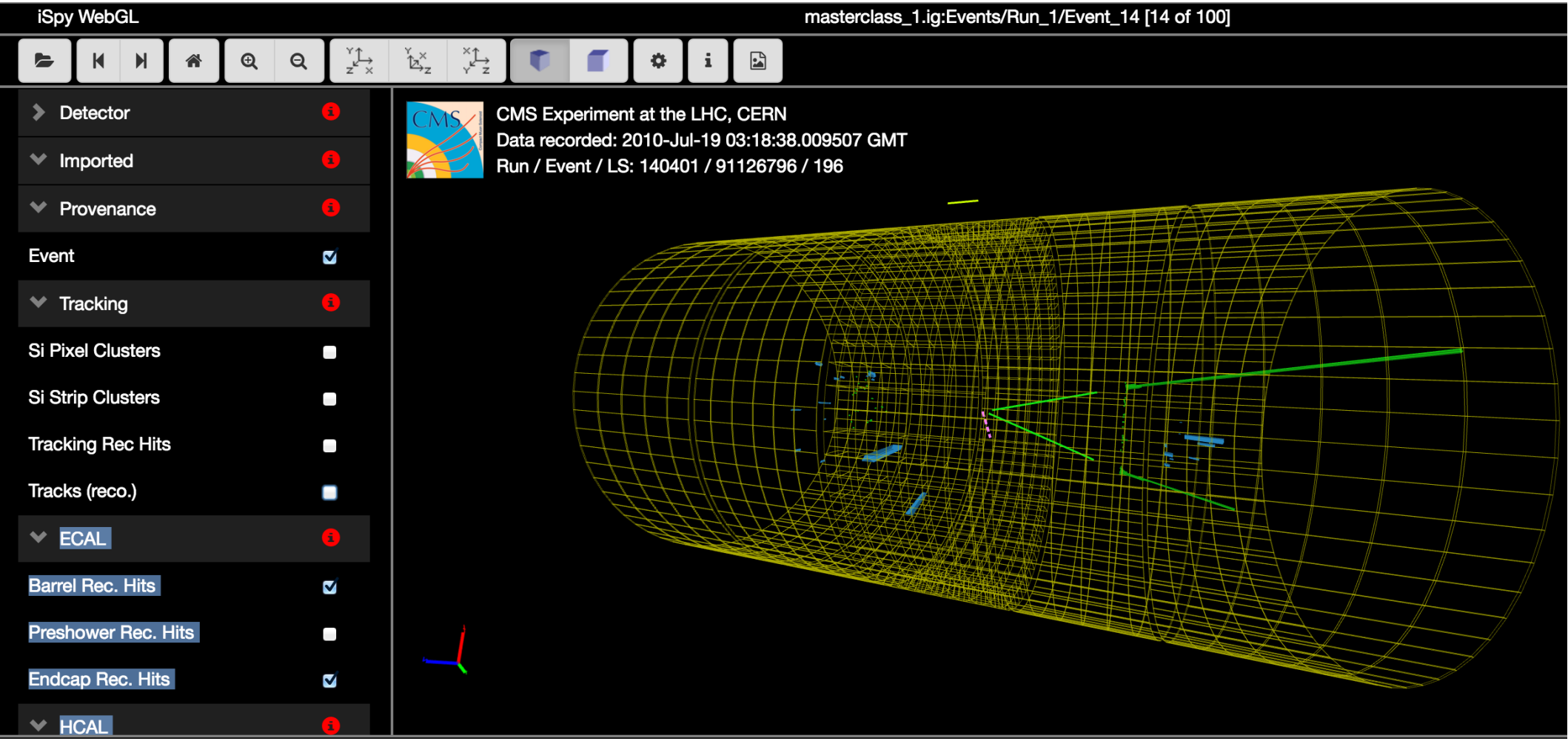
# On fait tourner la vue



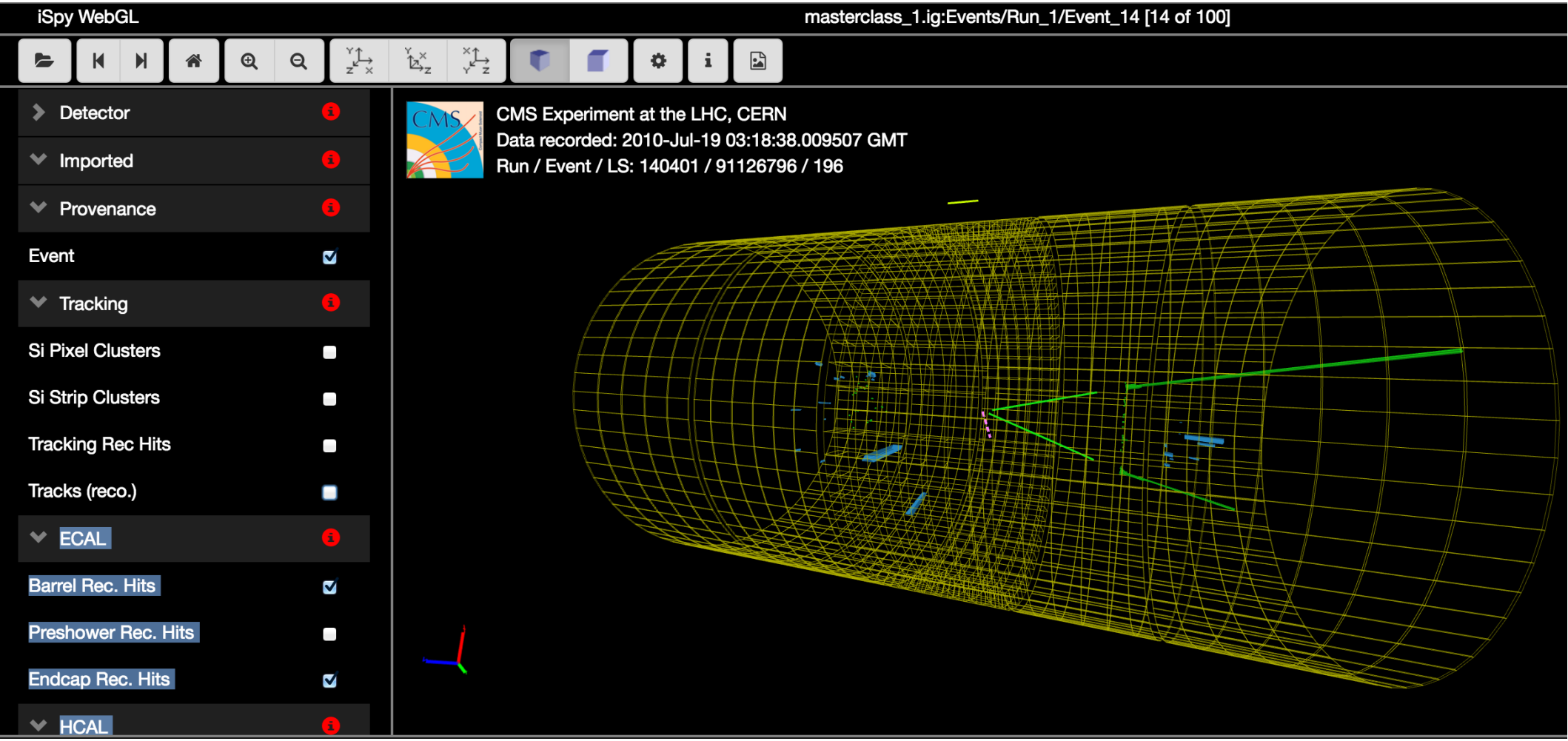
# On enlève les traces



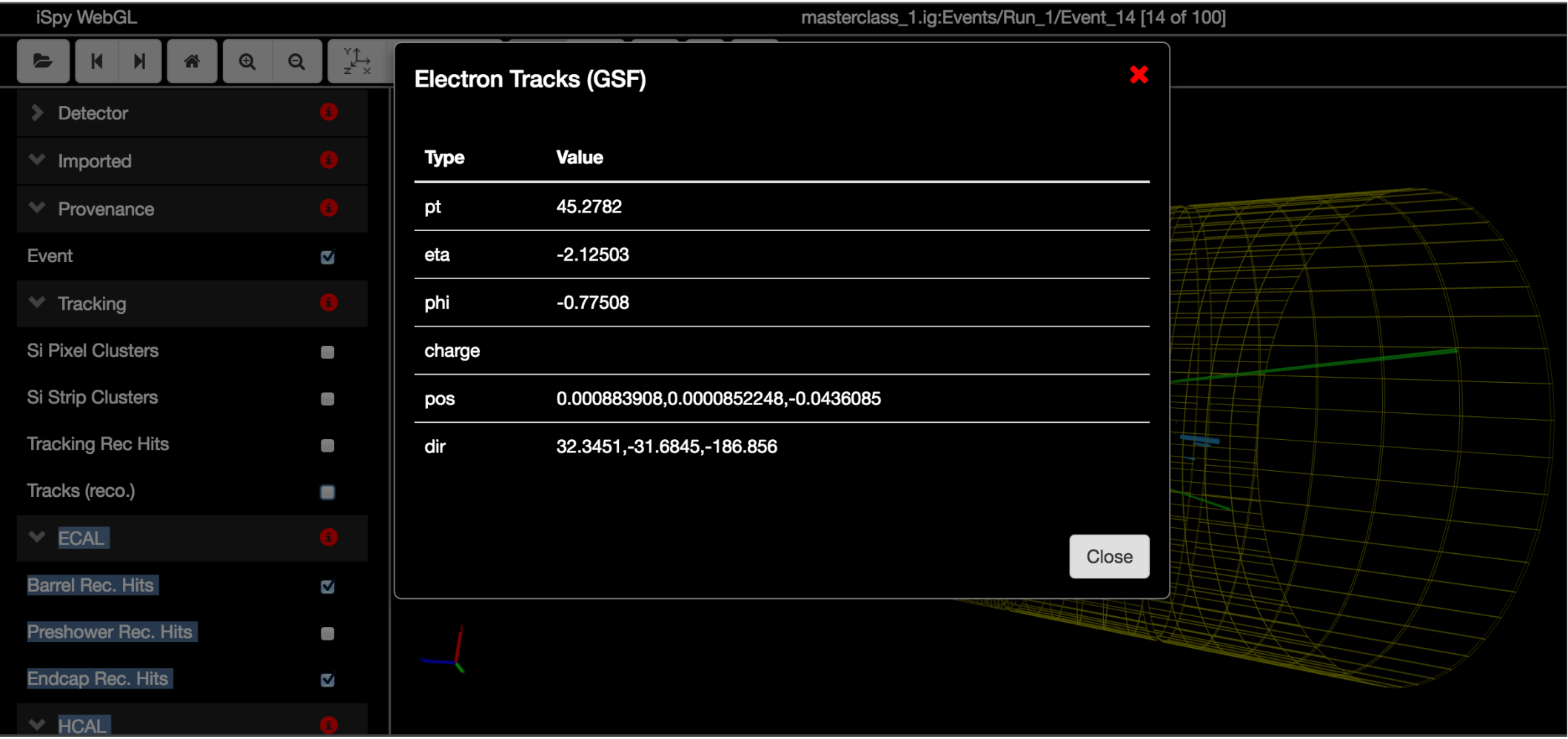
# On enlève les traces

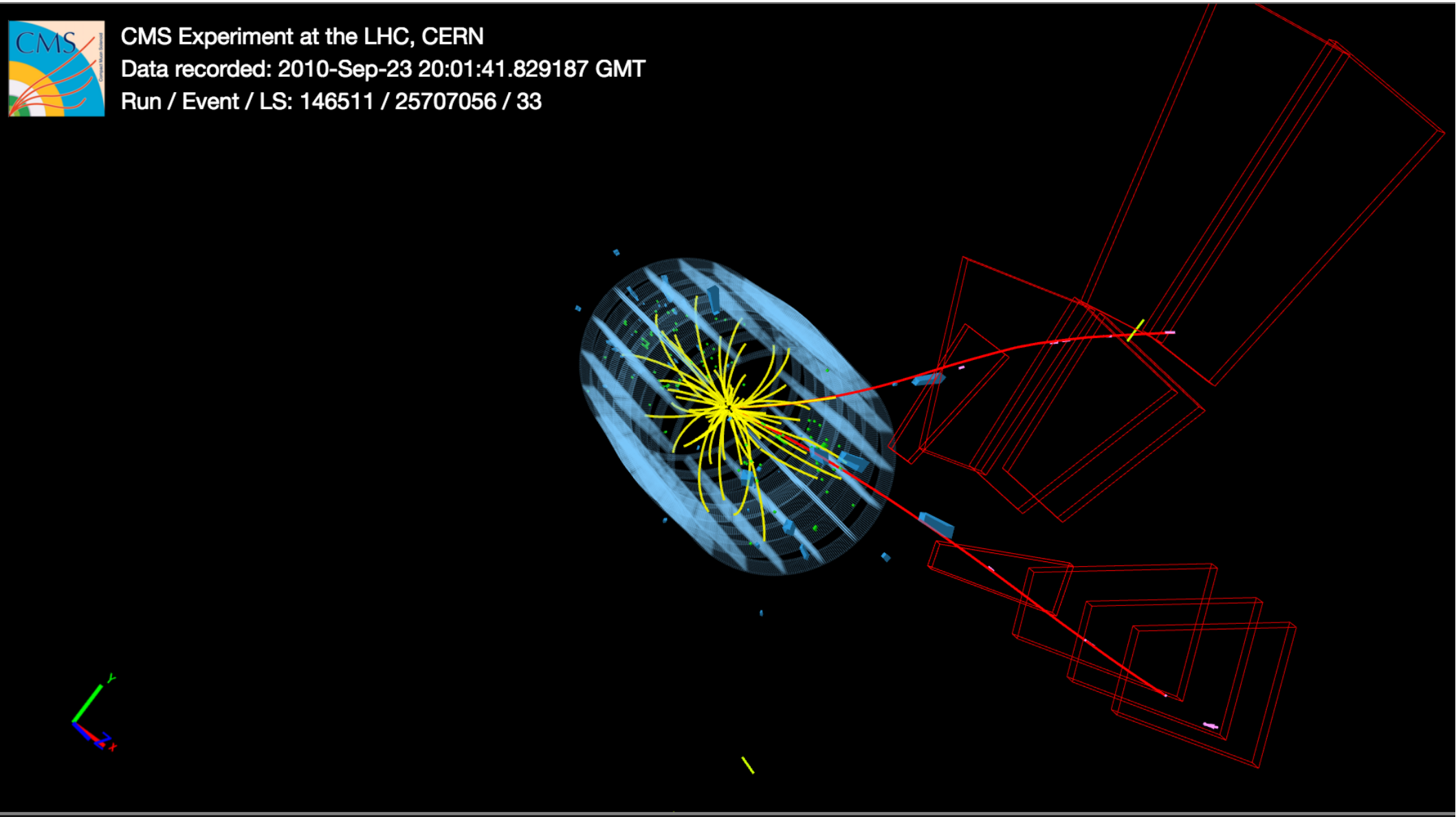


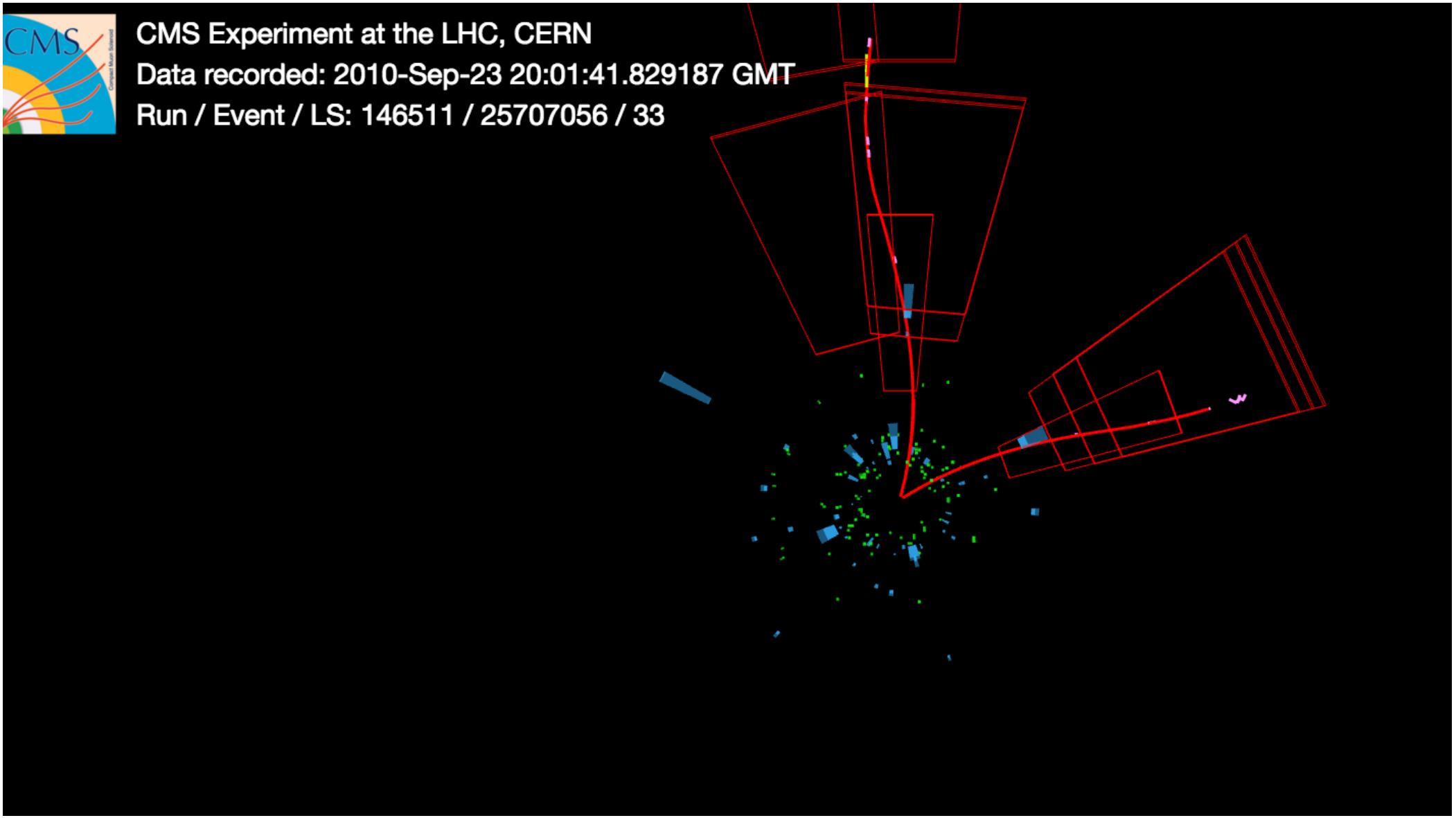
# 2 x (trace+dépôt ECAL)



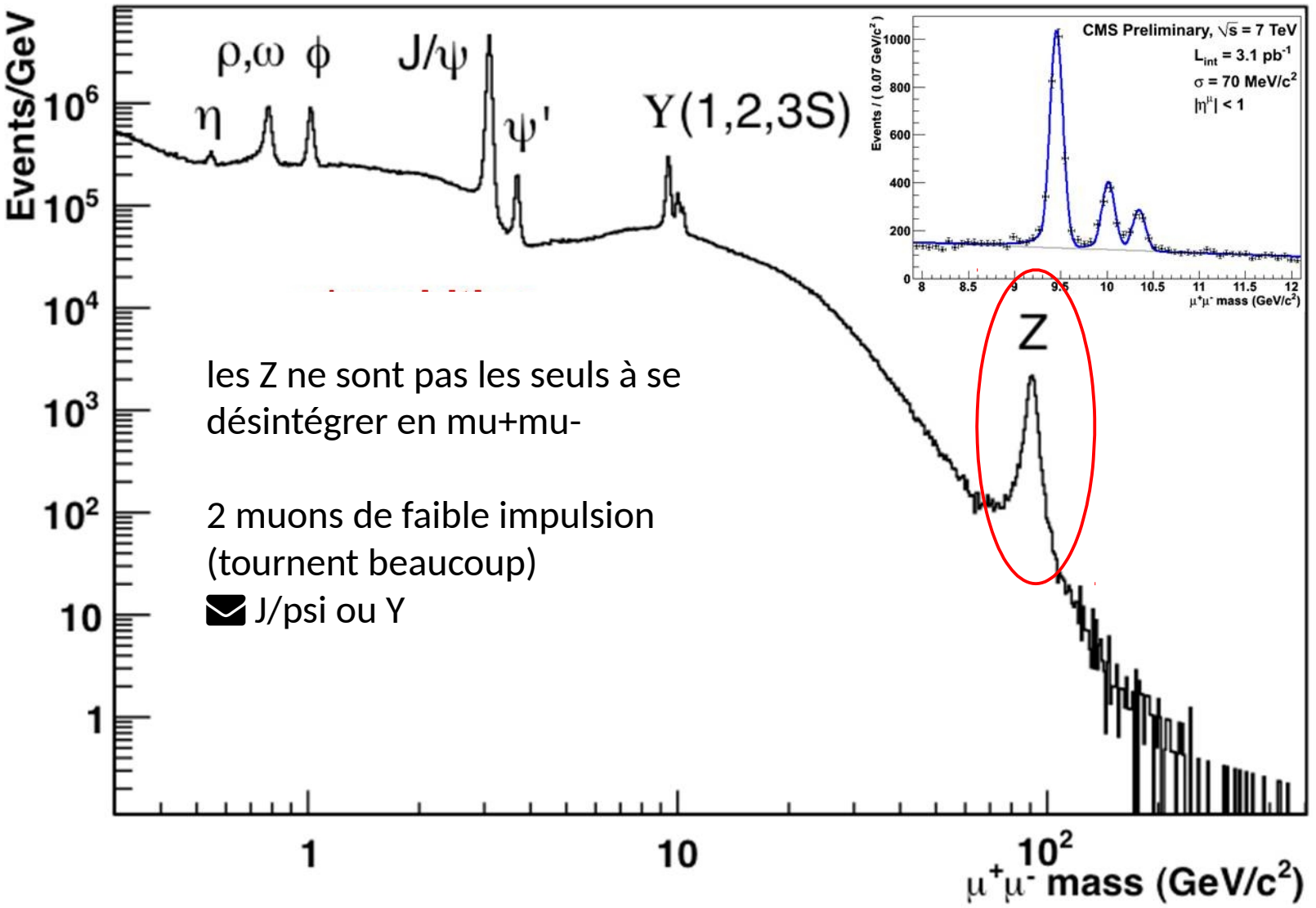
# Cliquer sur les objets pour info




CMS Experiment at the LHC, CERN
Data recorded: 2010-Sep-23 20:01:41.829187 GMT
Run / Event / LS: 146511 / 25707056 / 33


CMS Experiment at the LHC, CERN
Data recorded: 2010-Sep-23 20:01:41.829187 GMT
Run / Event / LS: 146511 / 25707056 / 33

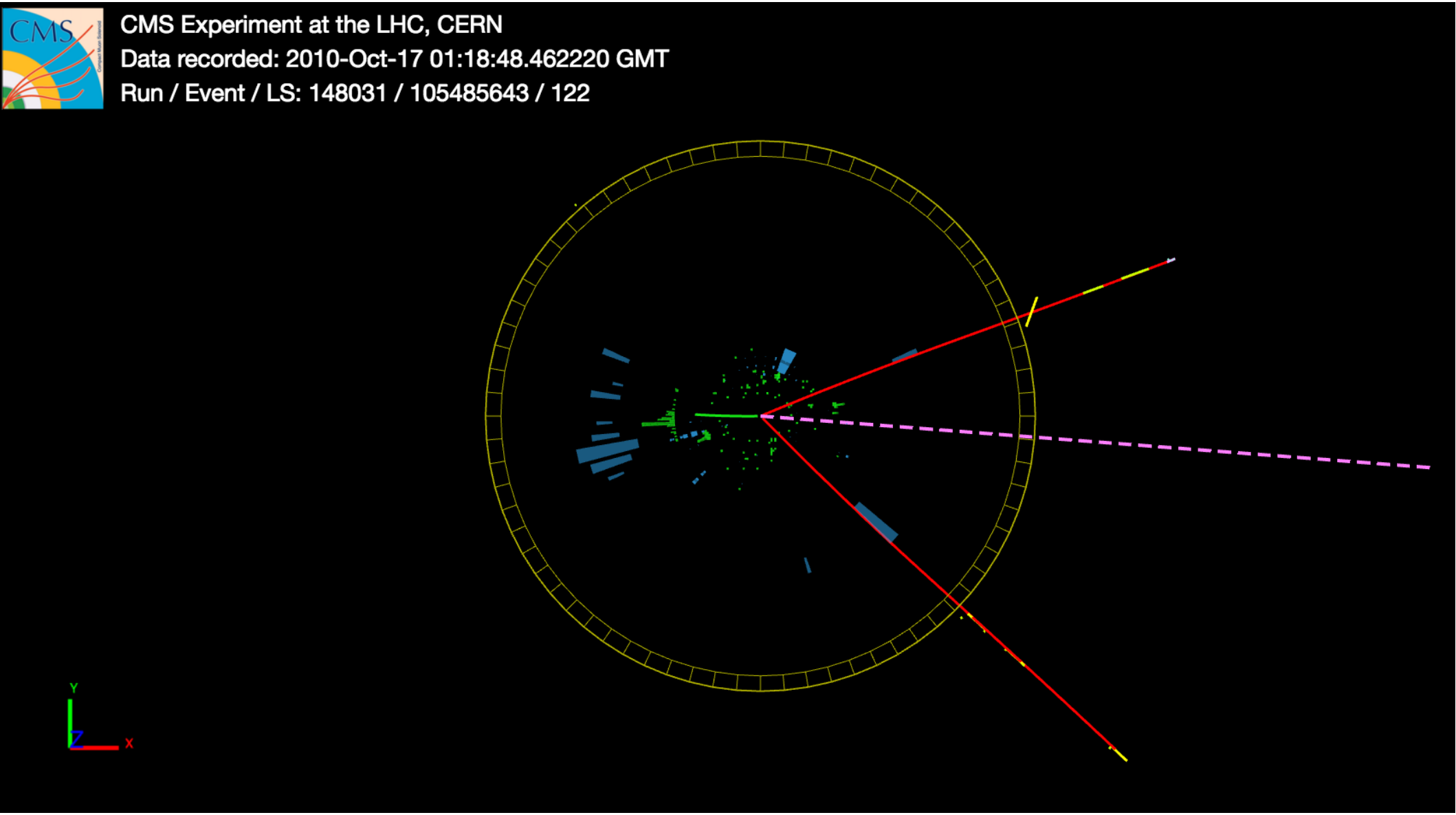
# Masse invariante  mu+ mu-



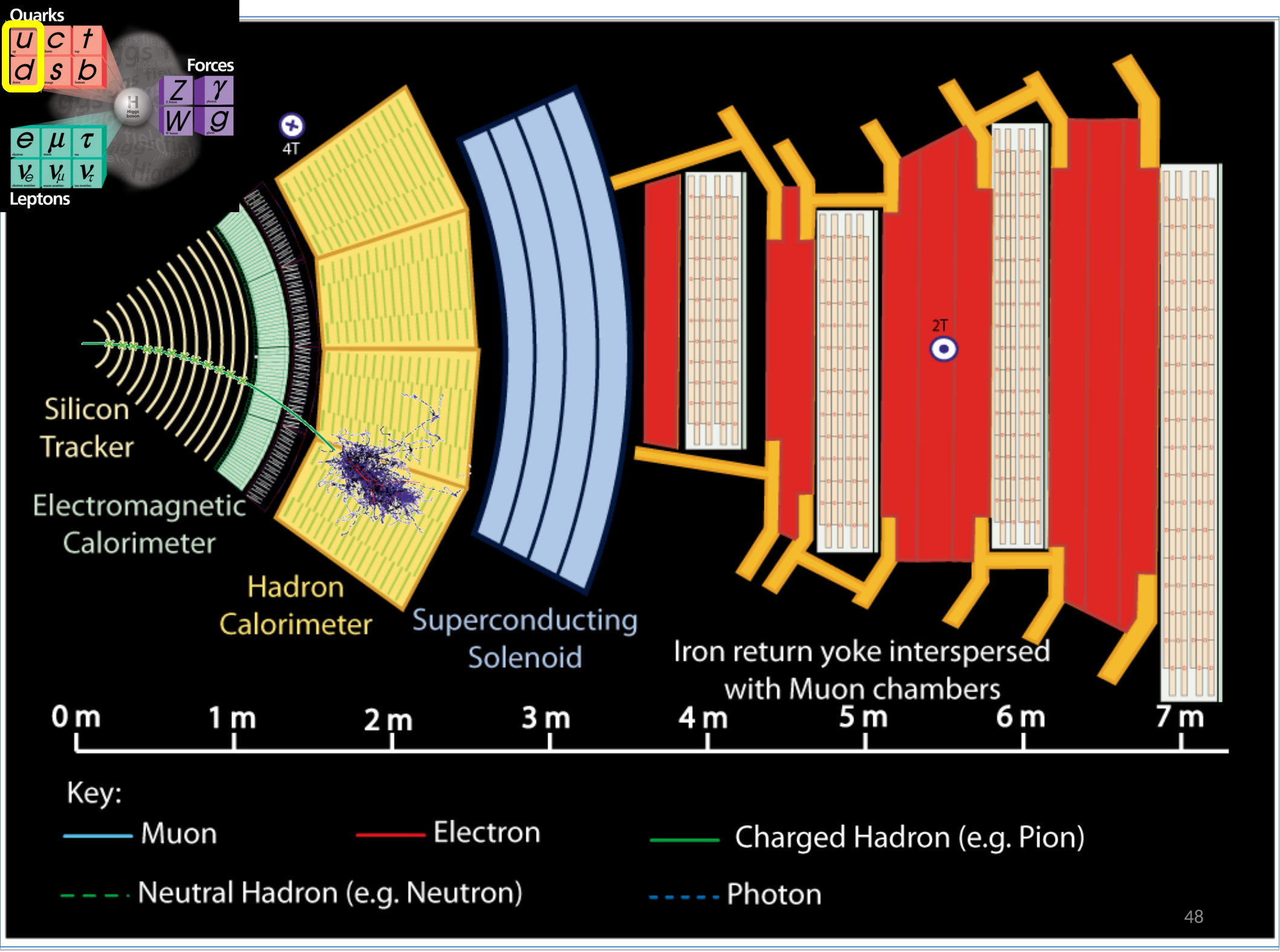

les Z ne sont pas les seuls à se désintégrer en mu+mu-

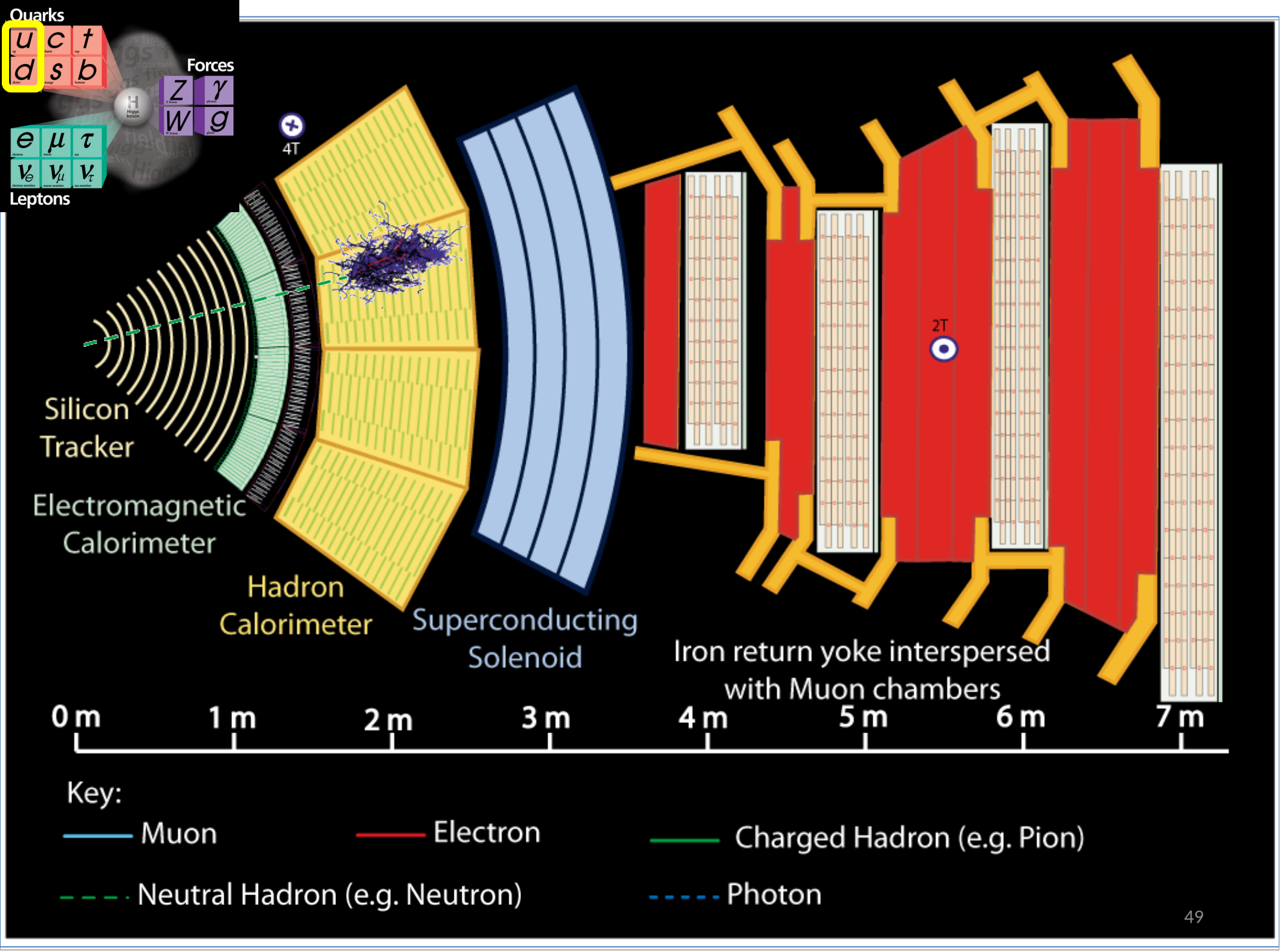
2 muons de faible impulsion (tournent beaucoup)

✉ J/psi ou Y


CMS Experiment at the LHC, CERN
Data recorded: 2010-Oct-17 01:18:48.462220 GMT
Run / Event / LS: 148031 / 105485643 / 122
Y
Z
X

# BACK-UP


Quarks
u c t
d s b
Forces
Z γ
W g
H
Higgs boson
e μ τ
νe νμ ντ
Leptons
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon


Quarks
u c t
d s b
Forces
Z γ
W g
H
Higgs boson
e μ τ
Leptons
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon