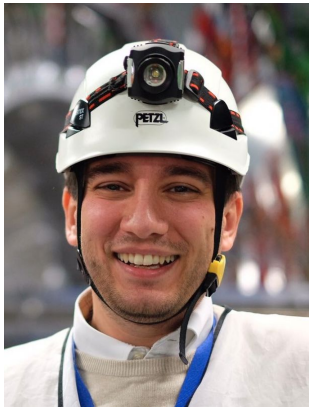
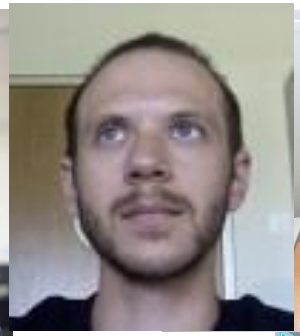
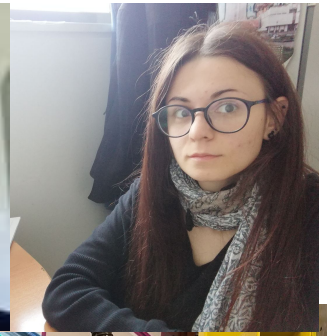
Introduzione alla CMS Masterclass

Andrea Massironi (INFN Milano Bicocca)
Giorgio Pizzati, Valentina Camagni (Università degli Studi di Milano Bicocca)

Chi siamo







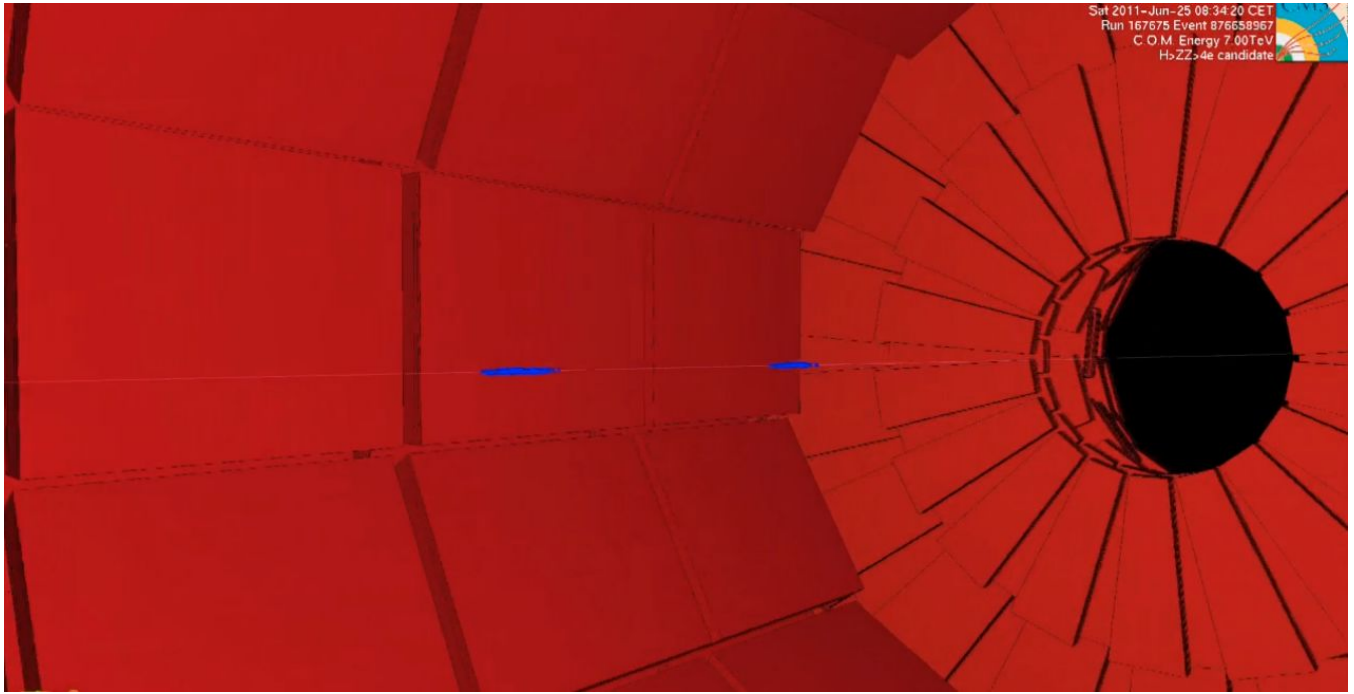



Programma della giornata

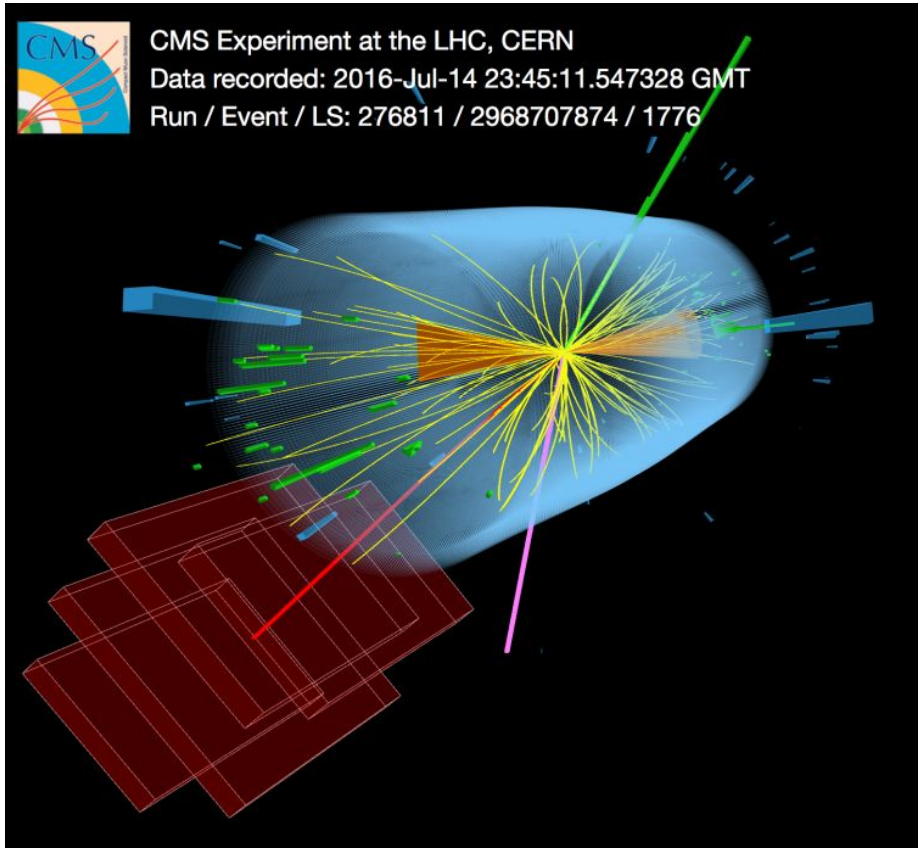
- **9:00 - 10:00** → Benvenuto e Introduzione alla fisica delle particelle
- **10:00 - 12:00** → Visita virtuale a CMS/CERN
- **12:00 - 13:00** → pausa pranzo
- **13:00:** tutti in **@ U9-07** per introduzione al pomeriggio
- **13:30 - 16:00:**
  - **@ U9 lab 905** Masterclass
  - **@ U2** incontro con studenti, ricercatori, professori, e visita al dipartimento
- **16:00 - 17:00** → **@ U9 lab 905** discussione dei risultati ottenuti con collegamento al CERN e con altri istituti da diversi posti nel mondo
- **17:00 - 18:00** → **@ U9 lab 905** conclusioni, Q&A

La collisione dei fasci di protoni

https://videos.cern.ch/record/1406325

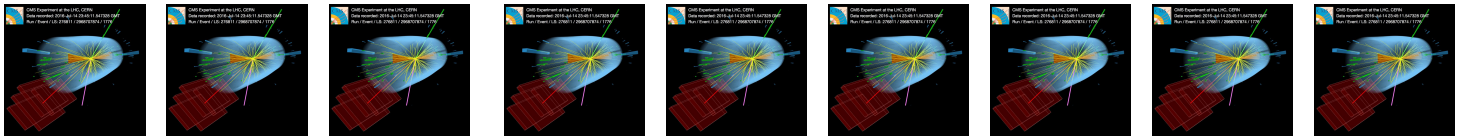


La collisione dei fasci di protoni



Masterclass

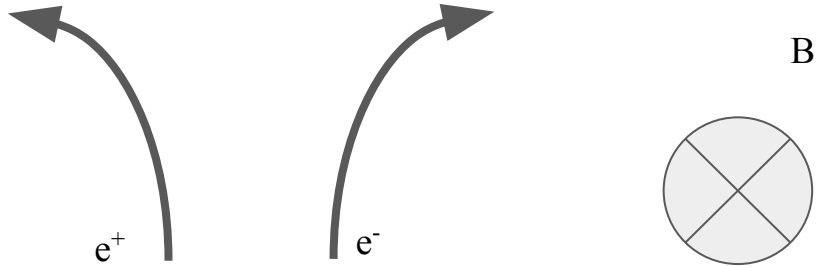
- Potrete vedere degli eventi (vere collisioni!) di CMS
- Semplice analisi degli eventi tramite *event display*
- Quando abbiamo collisioni, abbiamo una collisione ogni 25 ns
  - 40 milioni di collisioni al secondo
  - Ogni collisione e' un "evento" → in ogni evento qualcosa di differente accade



- Sarà vostro compito analizzare gli eventi, cioè identificarli e scoprire cosa è accaduto in ogni evento osservando le particelle che escono dalla collisione identificandole

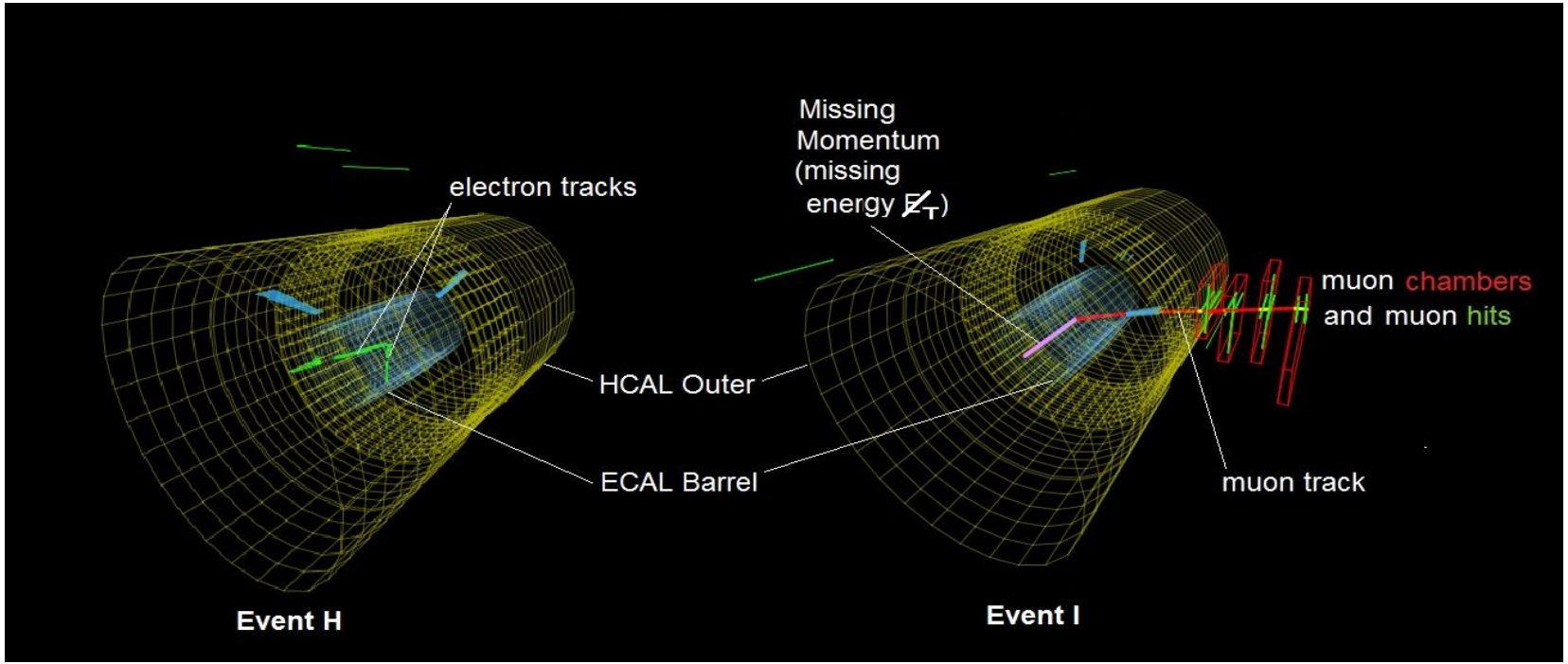
Masterclass: 1 slide di fisica, elettromagnetismo

- Particella carica che si muove in campo magnetico
  - Forza di Lorentz **F** = q**v** x **B**
    - F = forza
    - q = carica
    - v = velocita'
    - B = campo magnetico
    - x → prodotto vettoriale

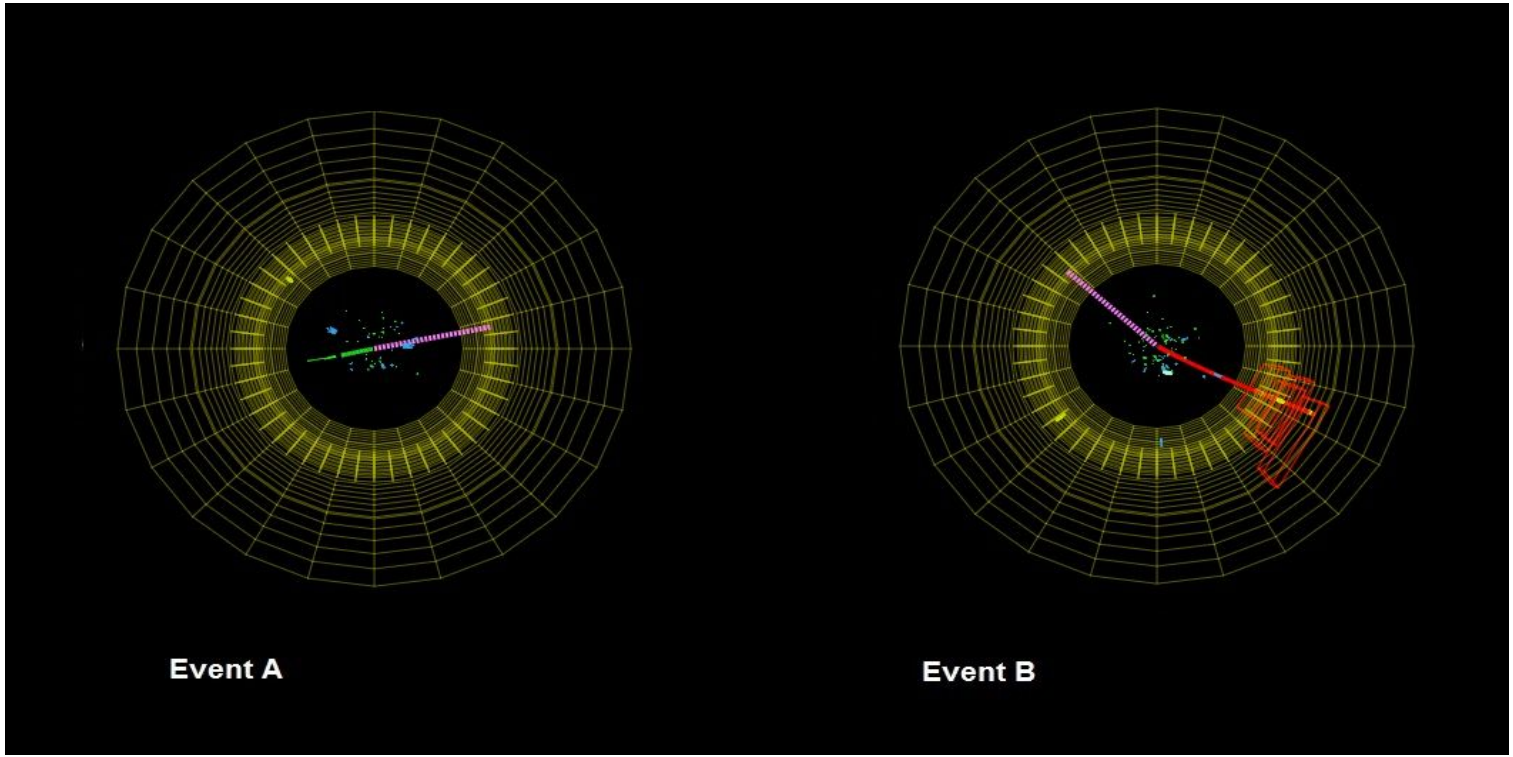


- Dato il campo magnetico generato dal solenoide di CMS, all'**interno** del solenoide:
  - Particella carica positiva → curva in senso orario
  - Particella carica negativa → curva in senso antiorario
- All'**esterno** del solenoide
  - Particella carica positiva → curva in senso anti orario
  - Particella carica negativa → curva in senso orario

Esempi


electron tracks
Missing
Momentum
(missing
energy $\not{E}_T$)
muon chambers
and muon hits
HCAL Outer
ECAL Barrel
muon track
Event H
Event I

Esempi



Come decadono le particelle

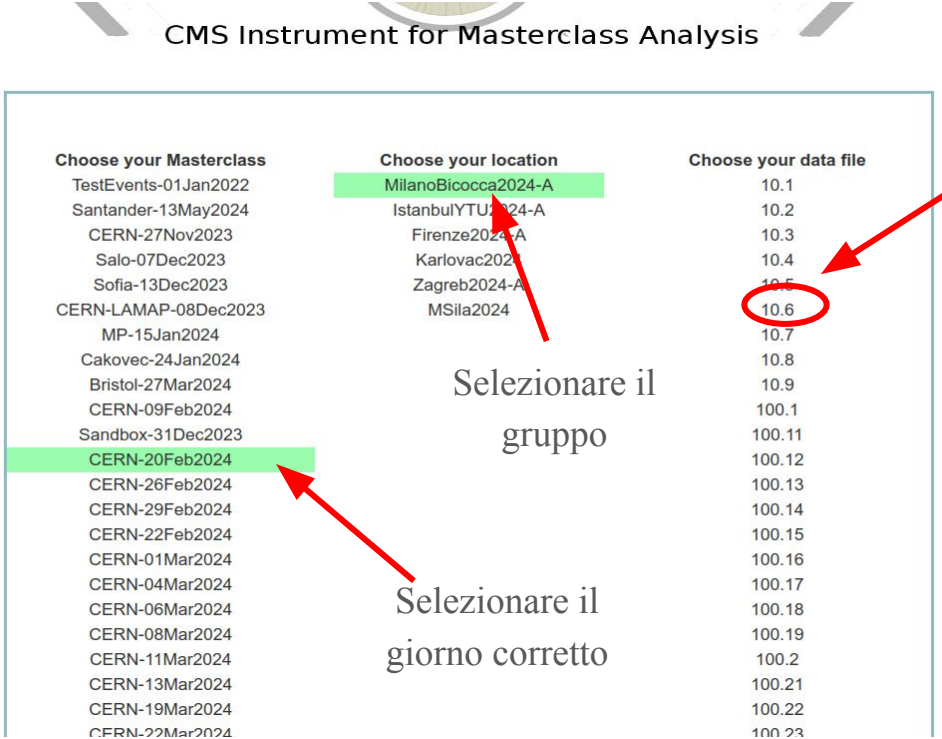
- $W \rightarrow e\ \nu$ (1 elettrone e 1 neutrino)
- $W \rightarrow \mu\ \nu$
- $W \rightarrow \tau\ \nu$
- $Z \rightarrow ee$
- $Z \rightarrow \mu\mu$
- $Z \rightarrow \tau\tau$

- Le **cariche elettriche** si conservano:
  - Il bosone W e' carico: $W^+ \rightarrow e^+\nu$
  - Il bosone Z e' neutro: $Z \rightarrow e^+e^-$
  - Il bosone di Higgs e' neutro: $H \rightarrow Z\ Z \rightarrow e^+e^-\ \ \mu^+\mu^-$

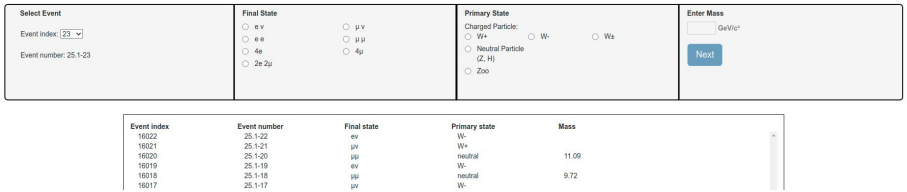
Aspetti pratici

- Ognuno di voi ha il suo insieme di “eventi” da analizzare (sono tutti diversi!)
- Abbiamo circa un’ora di tempo per completare l’esercizio
- Alle **16:00** ci ritroviamo insieme ai vostri compagni e con altri istituti dal mondo tutti insieme per discutere i risultati (qui in U9 lab 905/907)
  - Come facciamo di solito → come una conferenza!
- Altri istituti:
  - **M’sila (Algeria)**
  - **Zagreb e Karlovac (Croazia)**
  - **Firenze**
  - **Istanbul (Turchia)**
  - **Milano Bicocca**

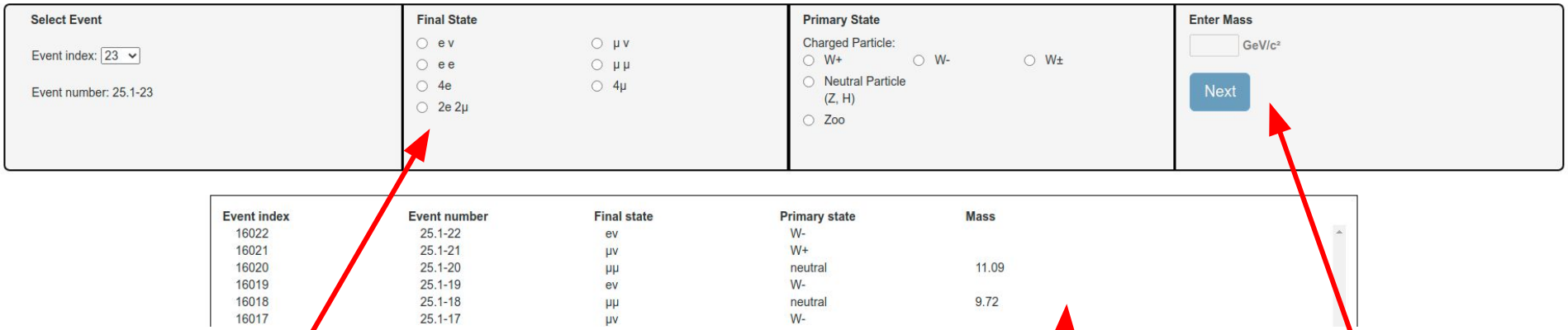
Dettagli



- Pagina **CIMA** (CMS Instrument for Masterclass Analysys)
  - https://www.i2u2.org/elab/cms/cima-wzh/
- Ognuno di voi ha accesso ad 1 file di dati
  - Troverete sul tavolo un foglio di carta con un numero: 10.1, 10.2
  - **NB: se la tabella e' gia' parzialmente riempita, iniziate dall'evento successivo all'ultimo gia' analizzato**



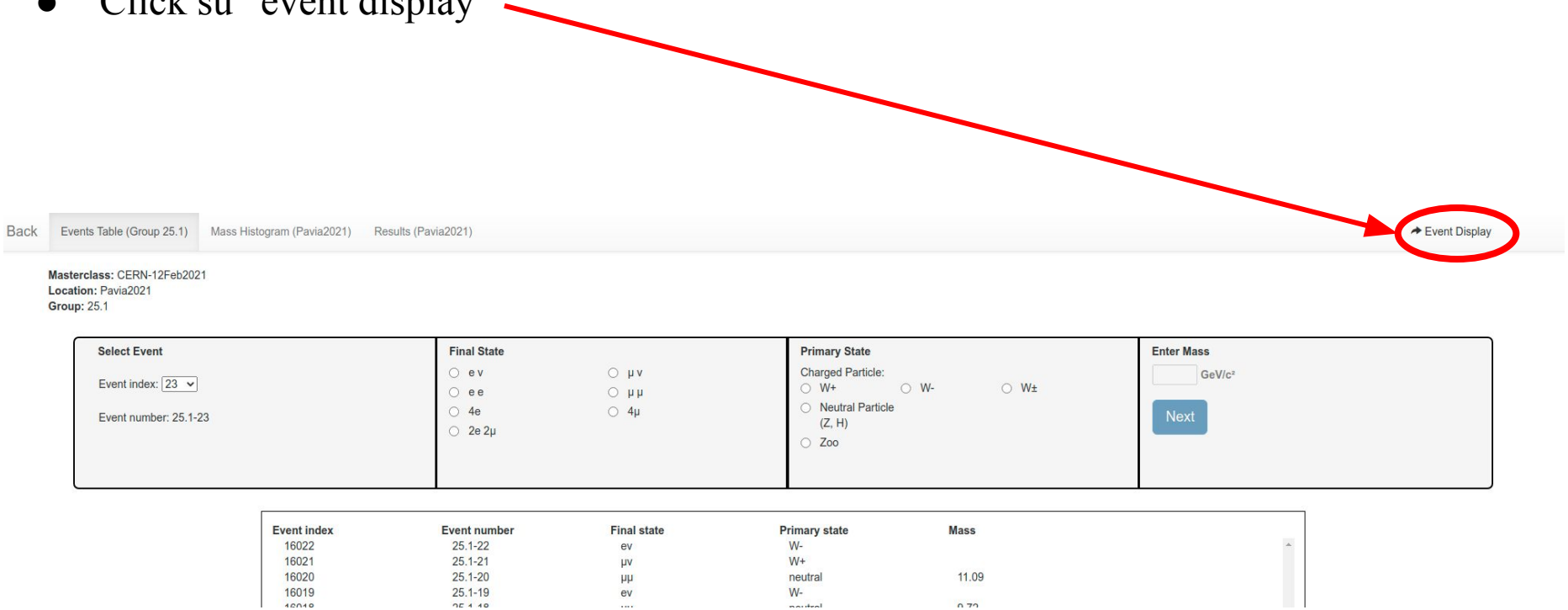
Dove inserire i risultati “evento per evento”



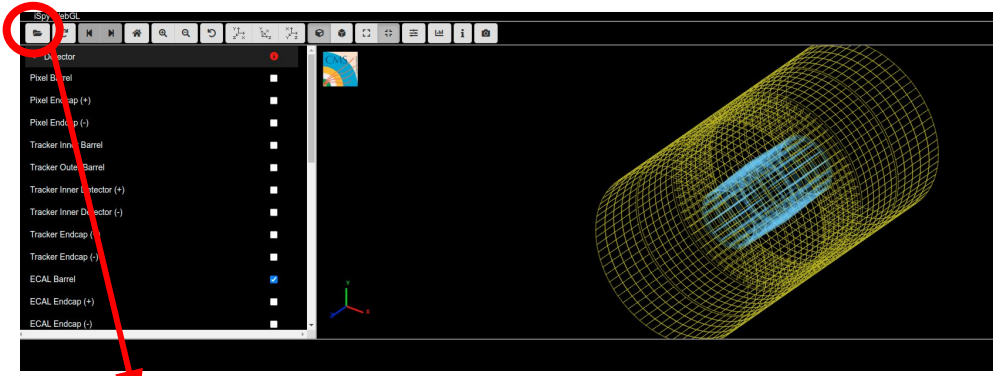
- Per ogni evento analizzato identificate che tipo di evento sia
- Per evento con più di una particella (e.g. 2 elettroni), si può inserire anche la massa invariante ricostruita
- Quando si compila il modulo in alto, la tabella sottostante si riempie evento per evento

Osservare ed identificare gli eventi

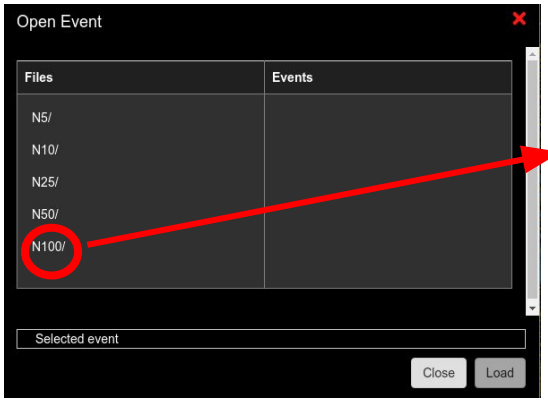
- Click su “event display”

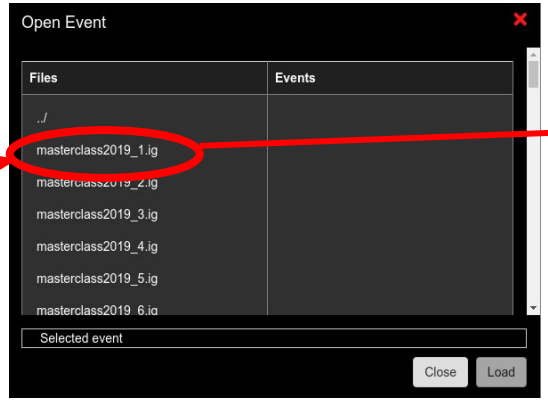


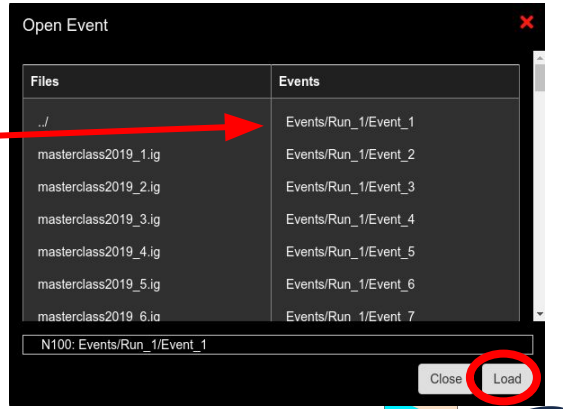
Aprire il file con gli eventi: e.g. file 100.1



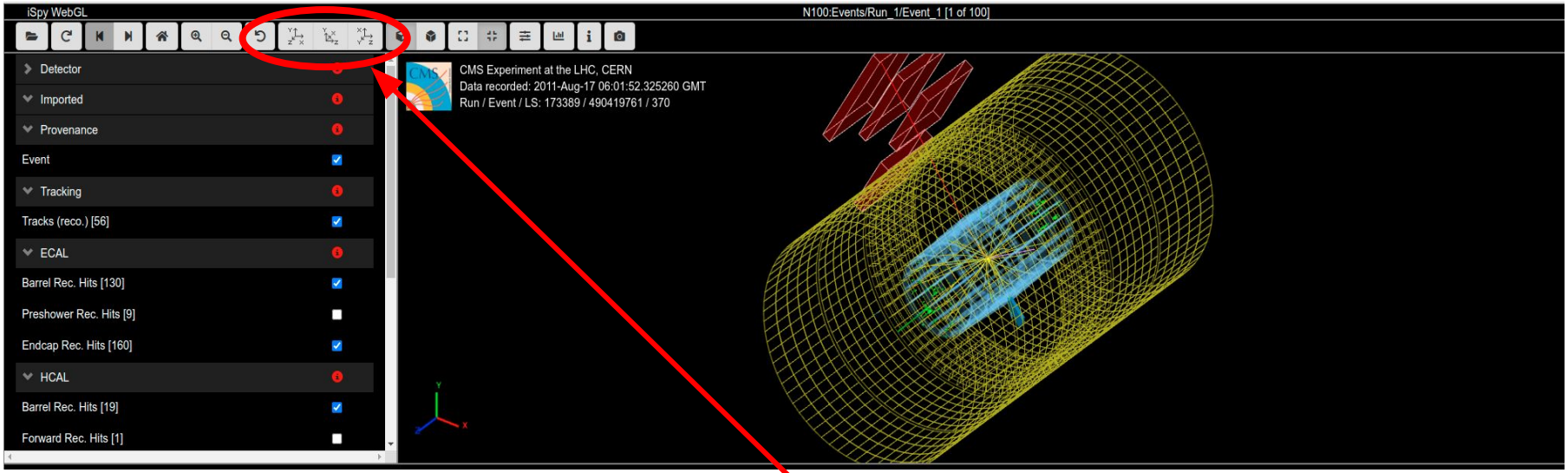
- Selezionare il file voluto: il numero che compariva sulla prima pagina web
- Selezionare il primo evento e poi "load"





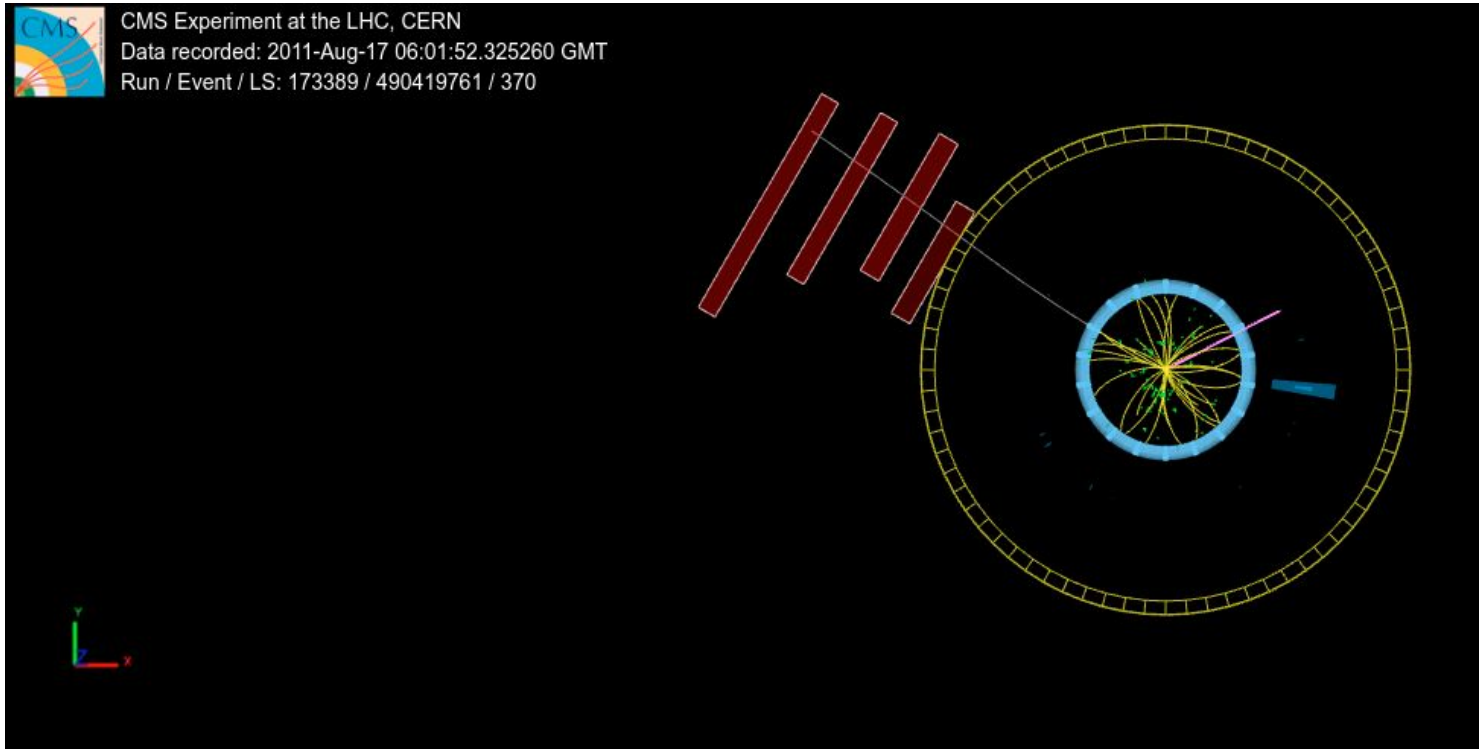


un evento!

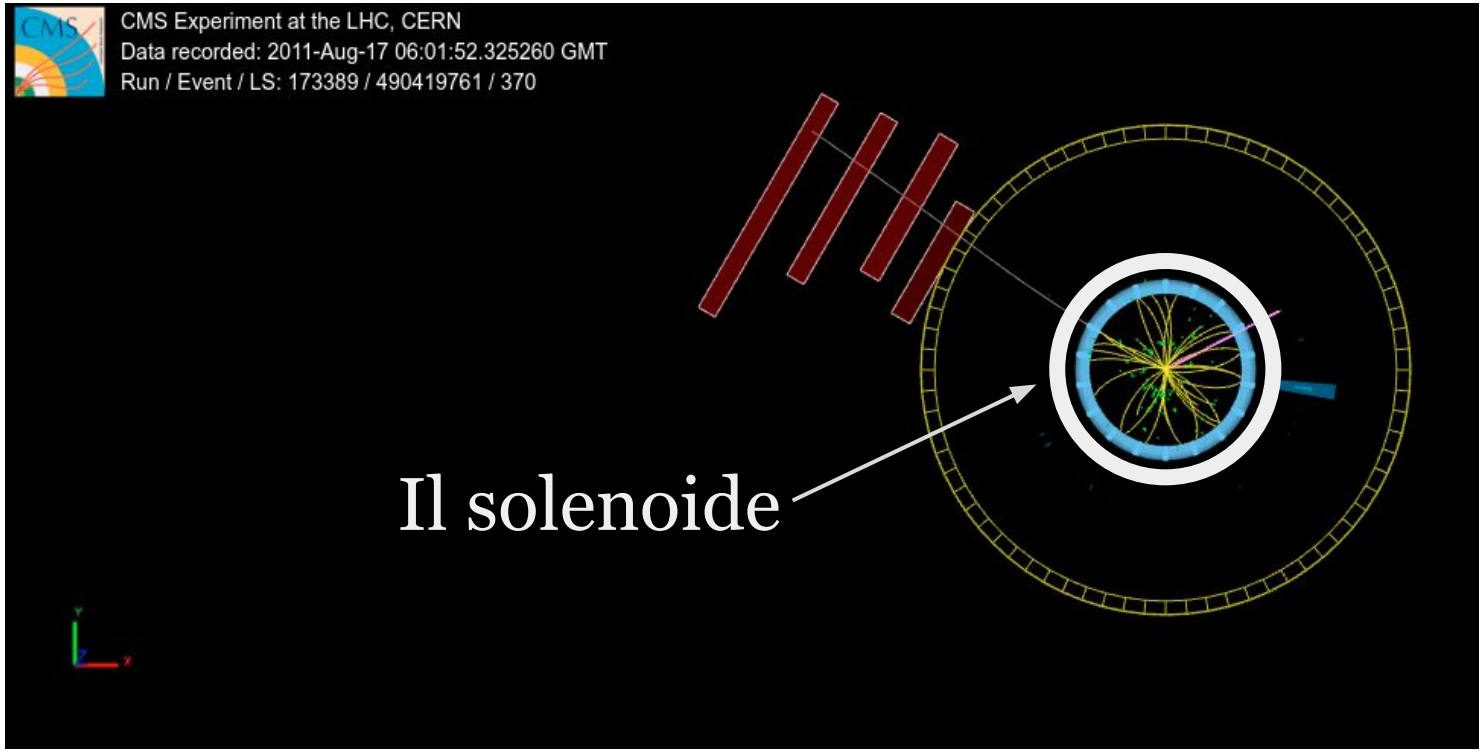


- Questo è un vero (!) evento di CMS
- Si può cambiare la visuale, attivare la visualizzazione di vari rivelatori, … giocare un po'

1 evento con 1 muone

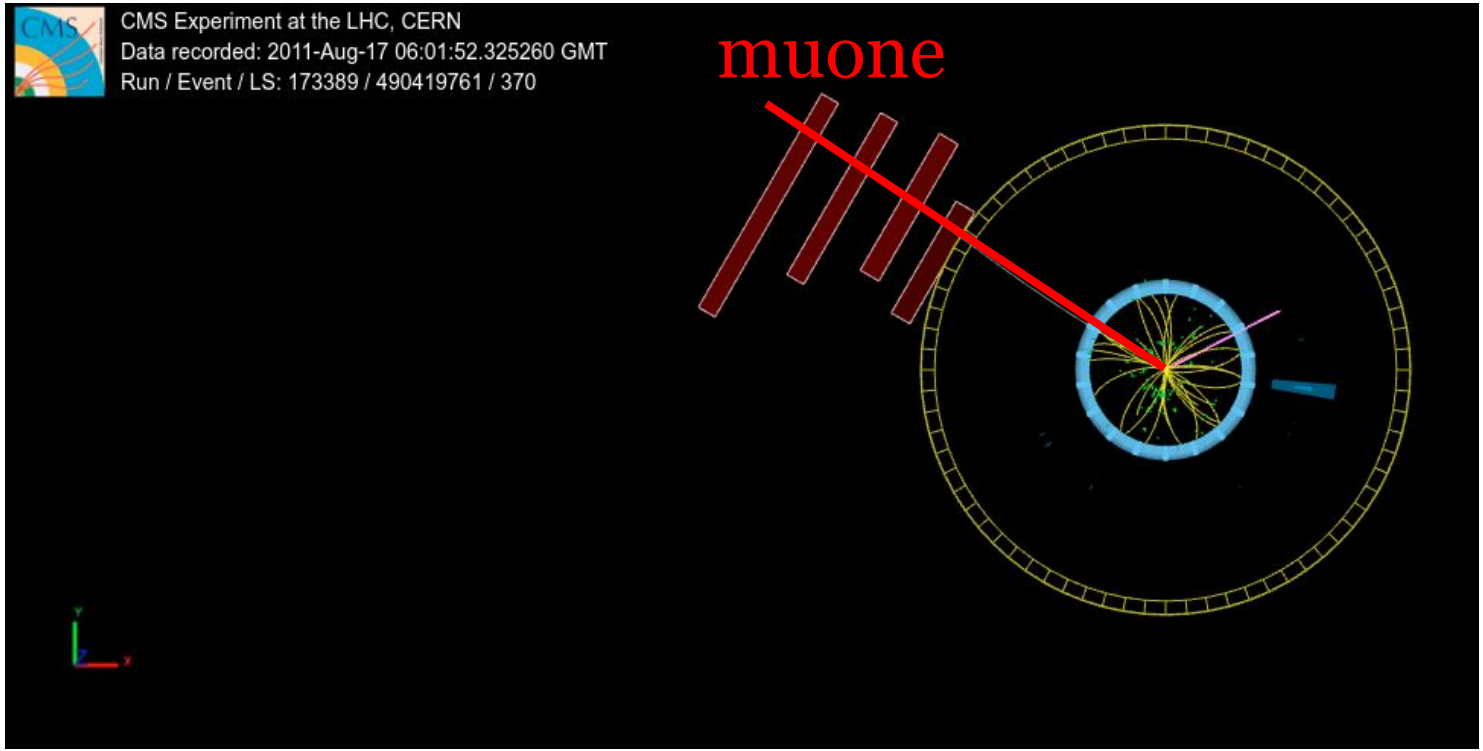


1 evento con 1 muone

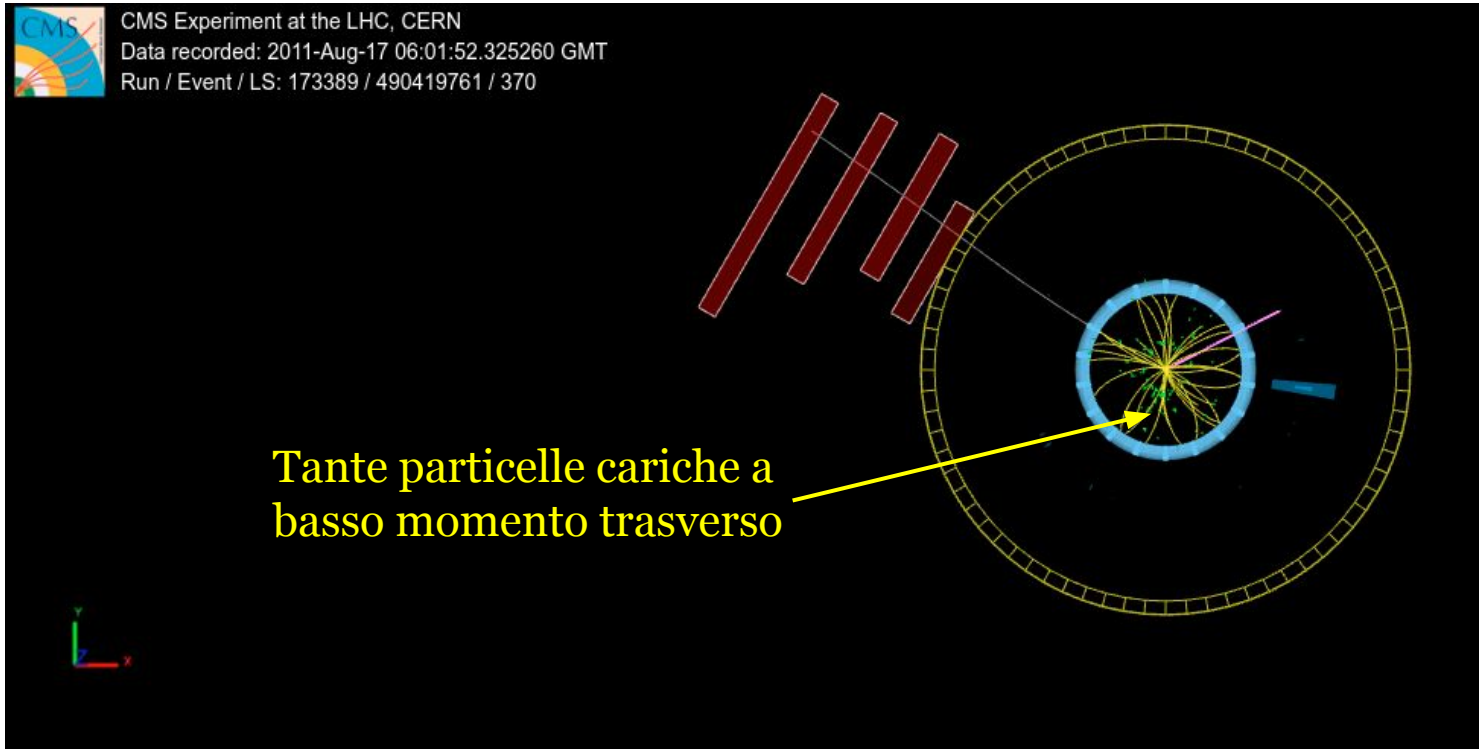


1 evento con 1 muone

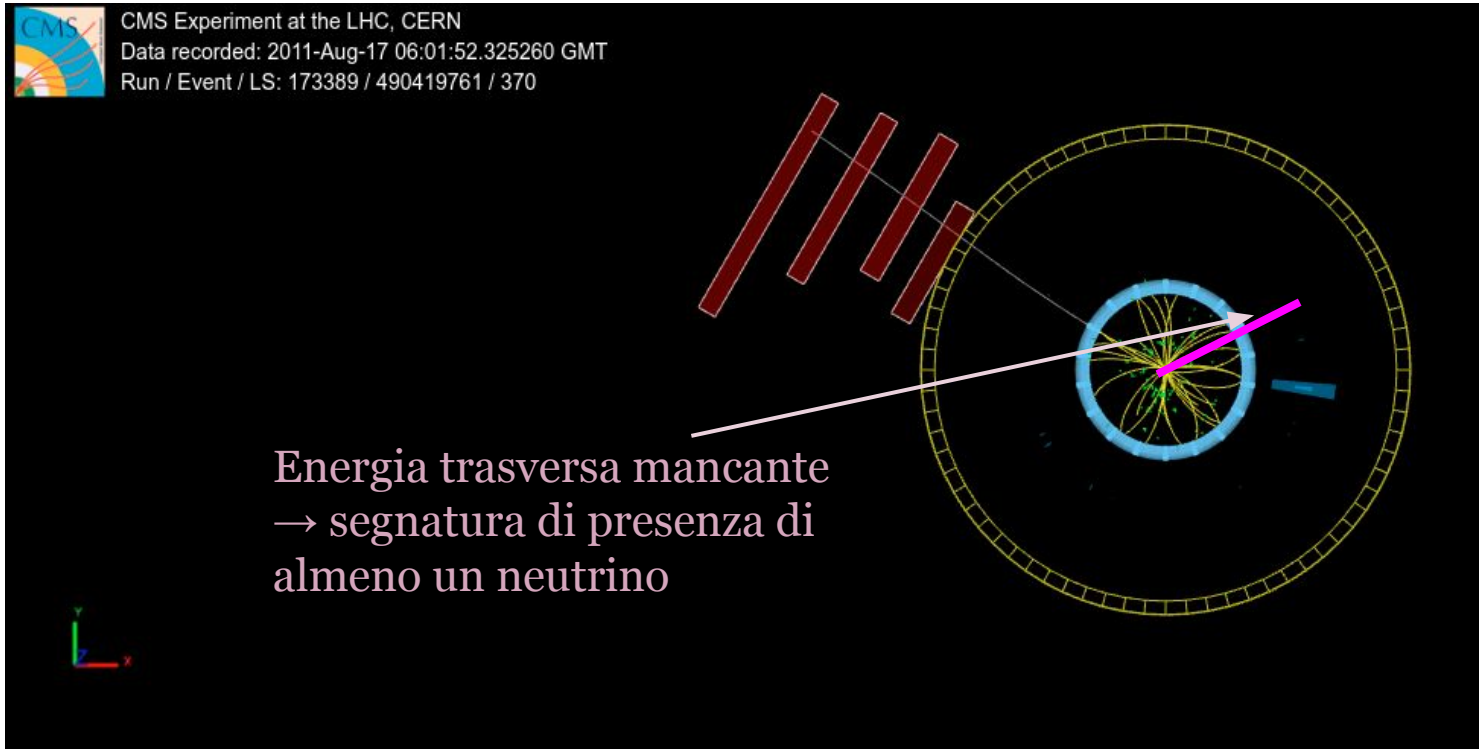
1 evento con 1 muone



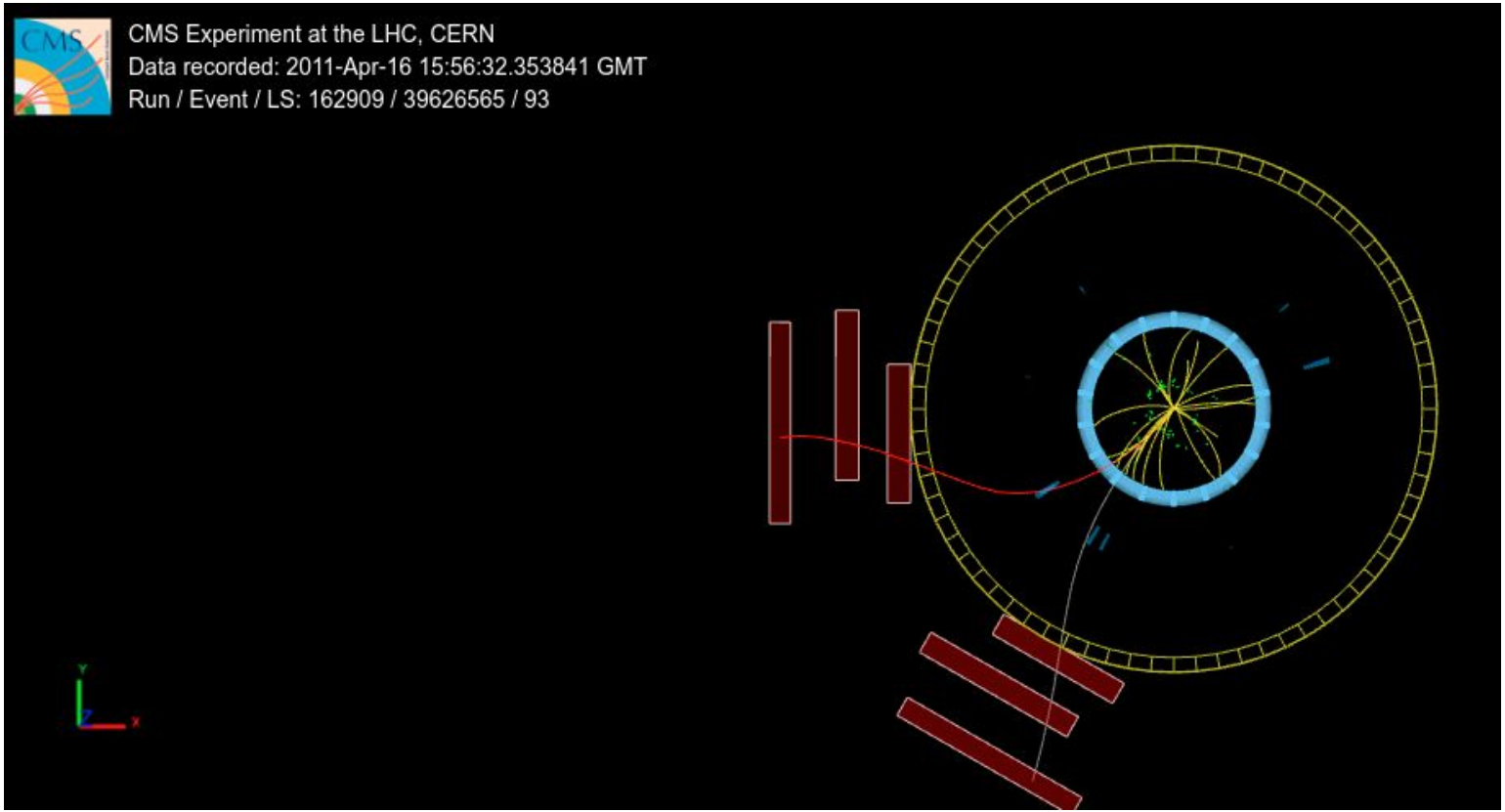
1 evento con 1 muone



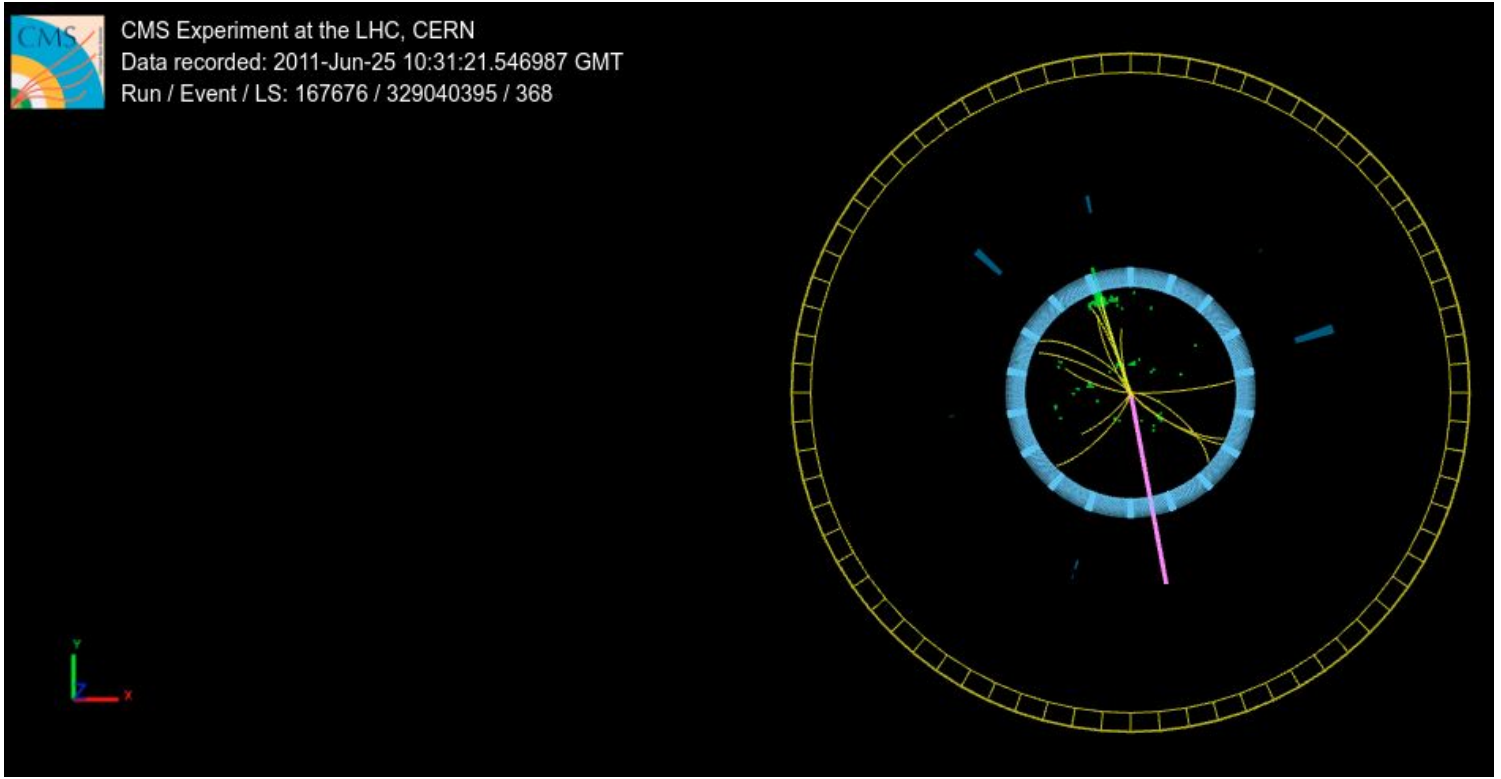
1 evento con 1 muone



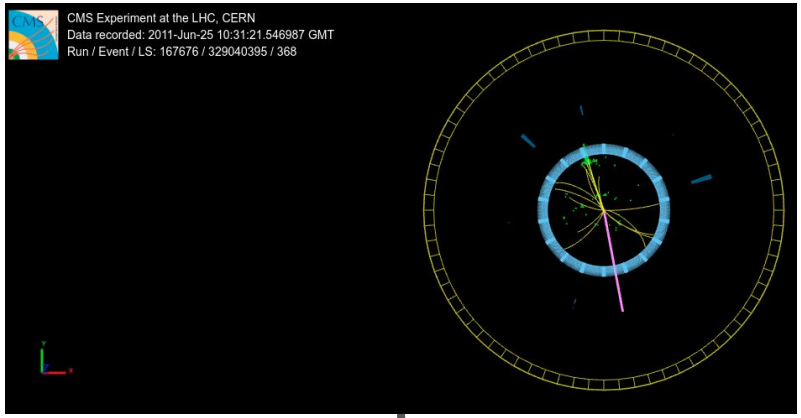
1 evento con ...


CMS Experiment at the LHC, CERN
Data recorded: 2011-Apr-16 15:56:32.353841 GMT
Run / Event / LS: 162909 / 39626565 / 93

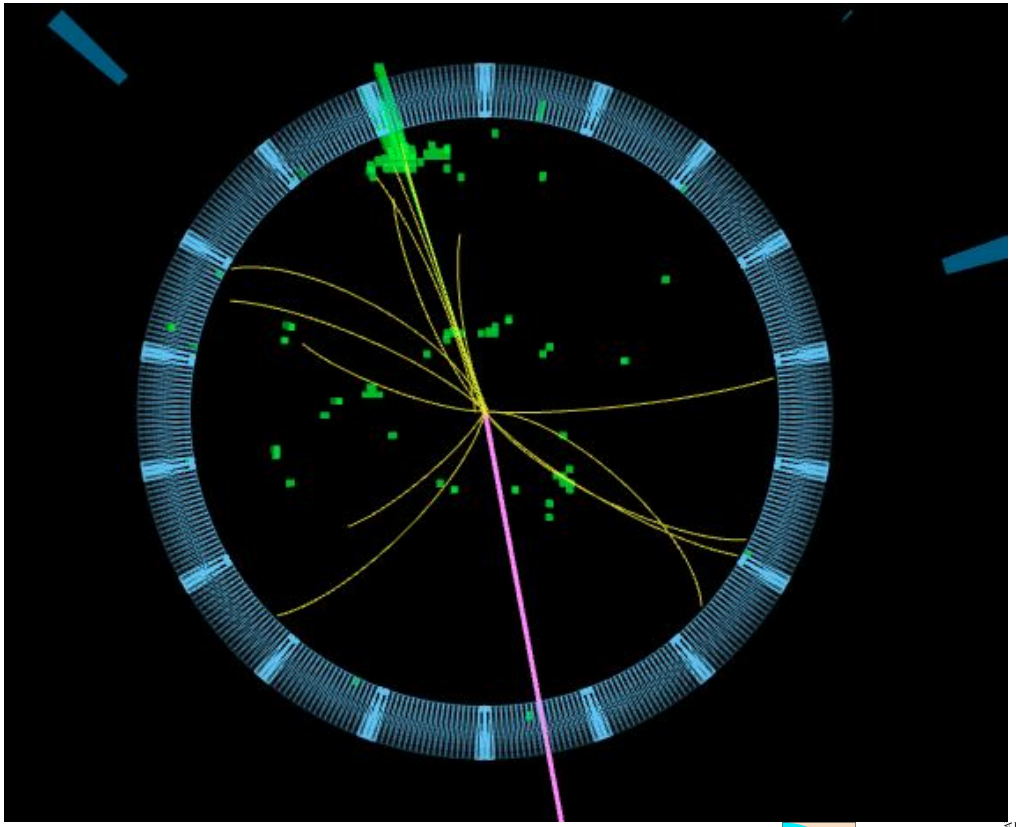
1 evento con ...


CMS Experiment at the LHC, CERN
Data recorded: 2011-Jun-25 10:31:21.546987 GMT
Run / Event / LS: 167676 / 329040395 / 368

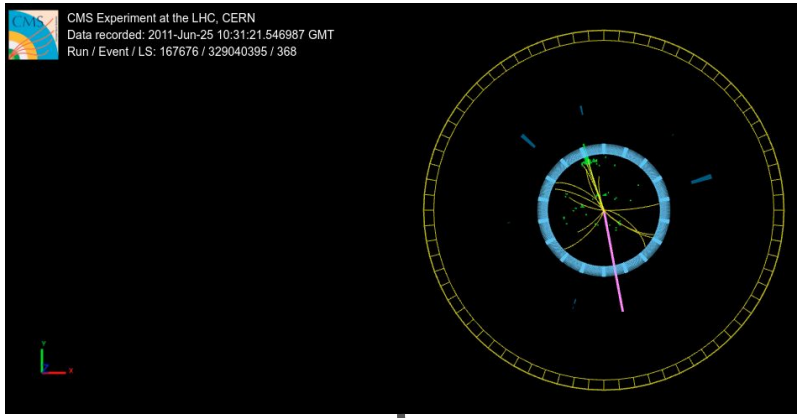
1 evento con ...



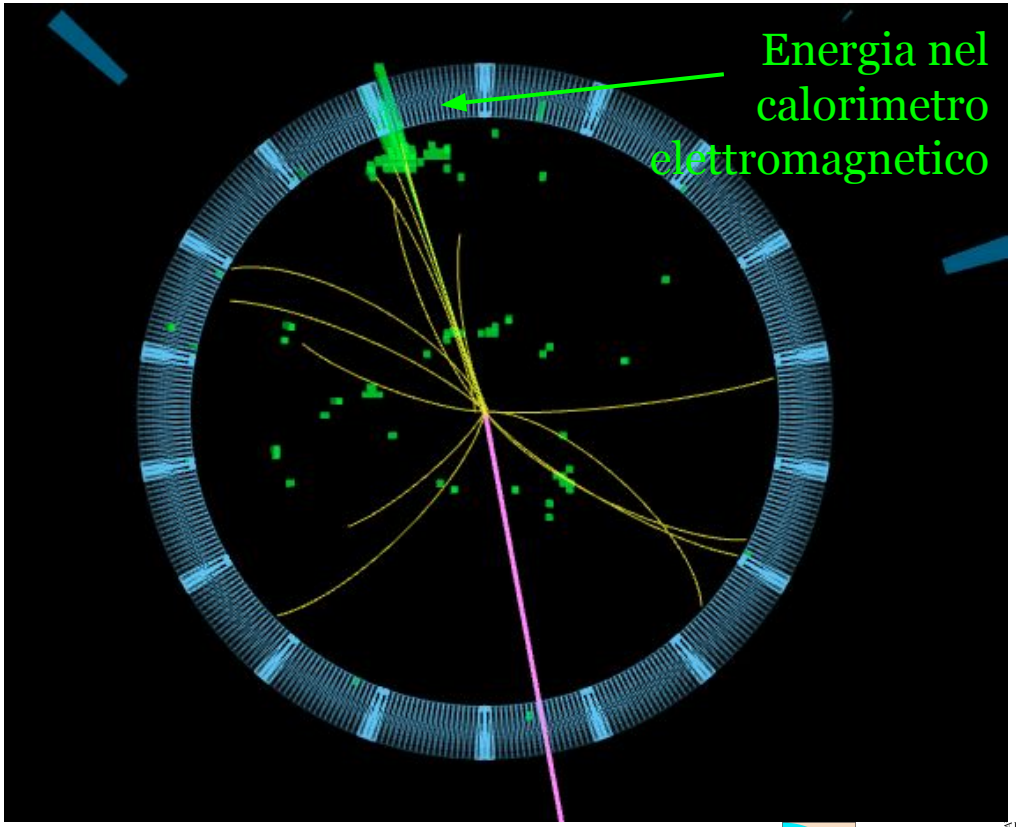
zoom



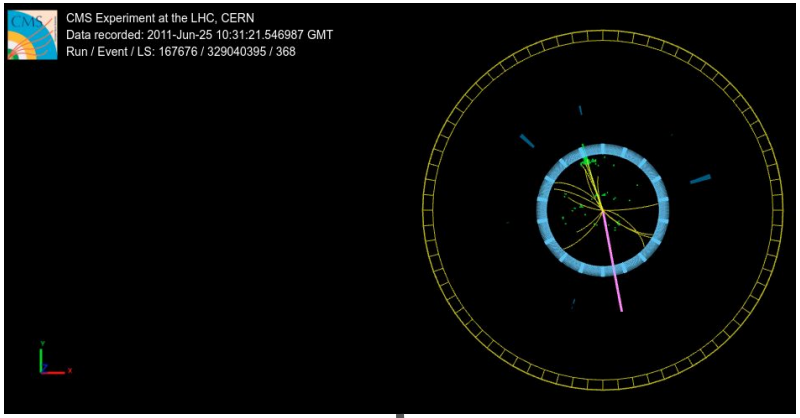
1 evento con ...



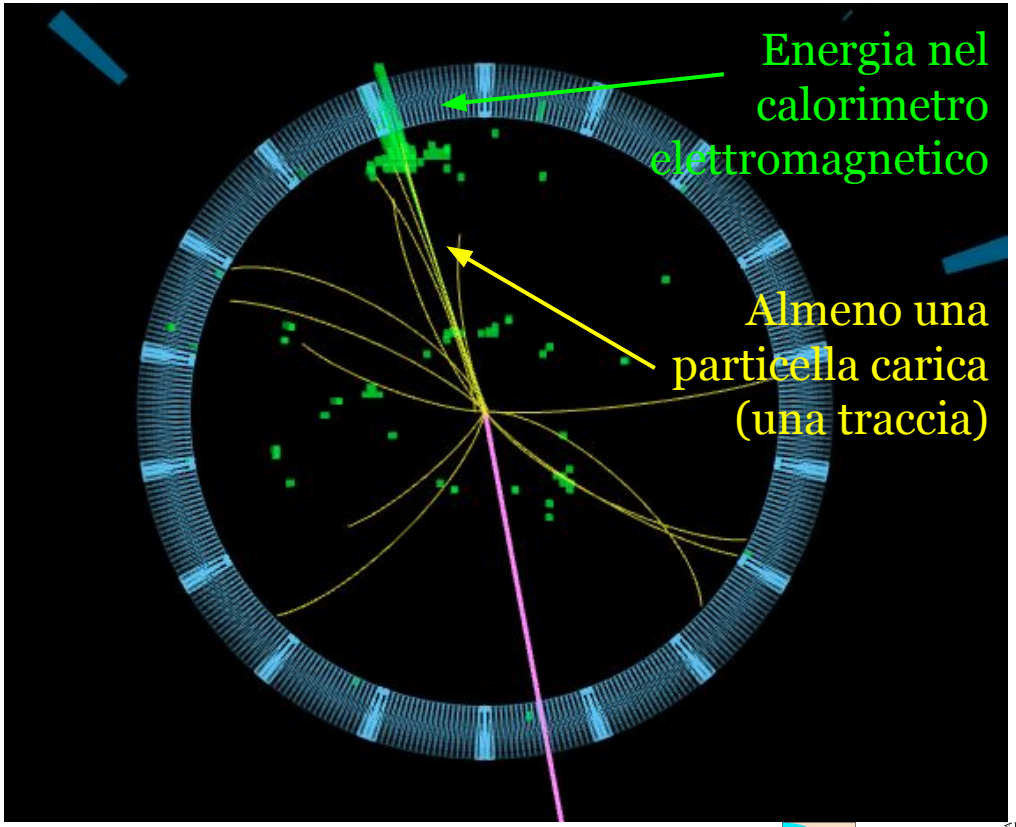
zoom



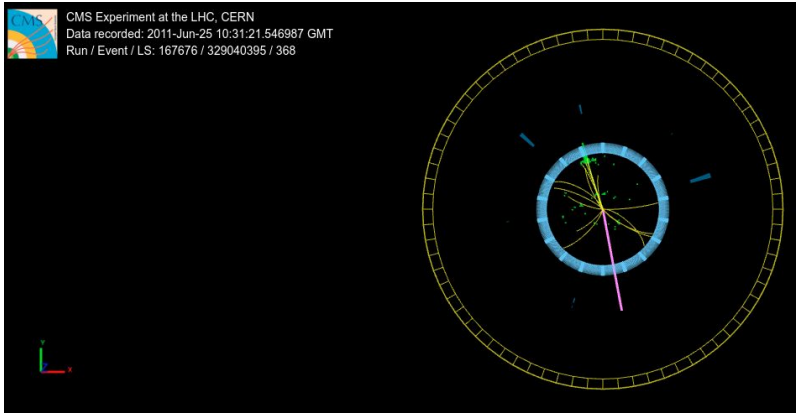
1 evento con ...

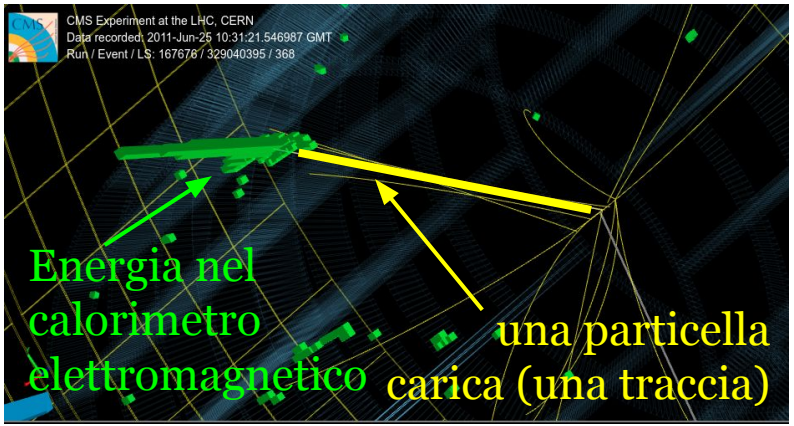


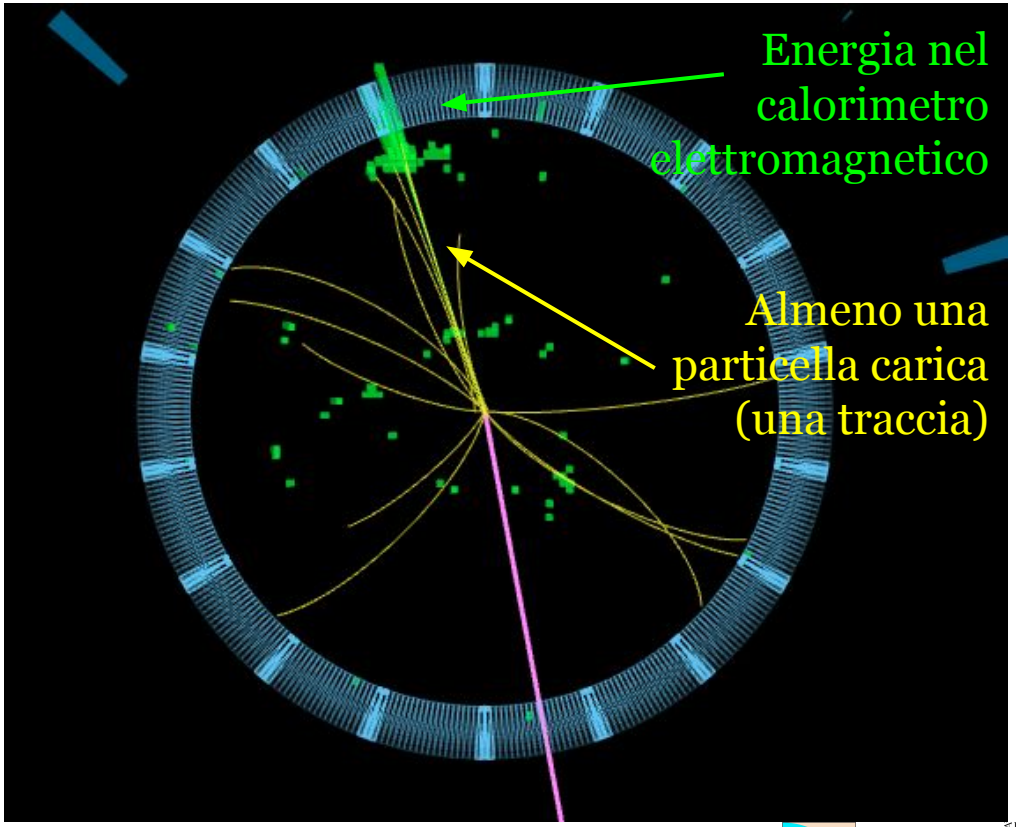
zoom



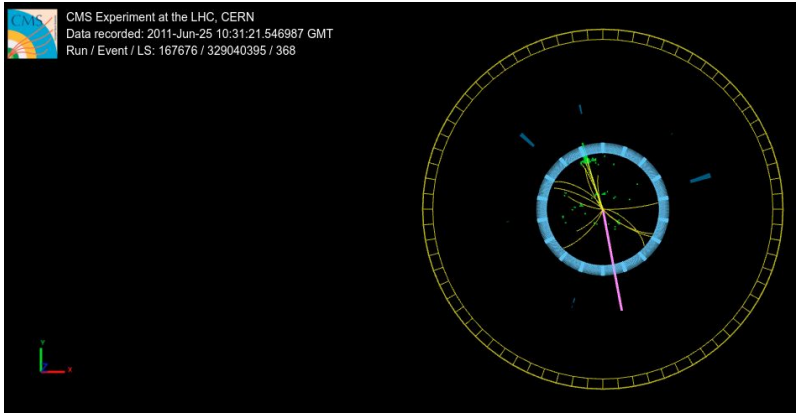
1 evento con ...

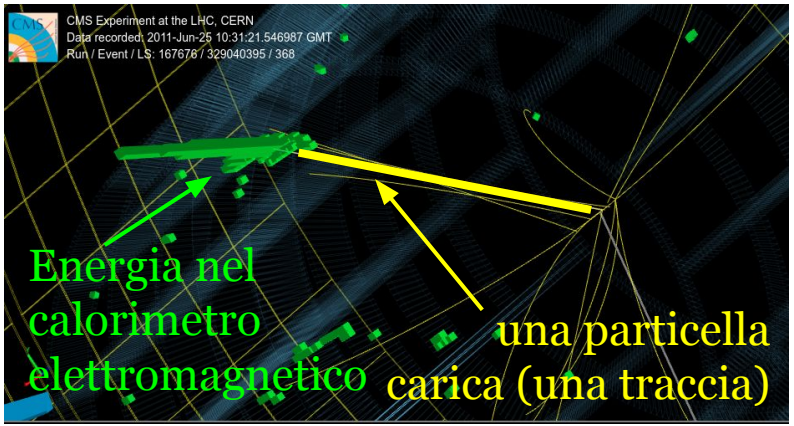

CMS Experiment at the LHC, CERN
Data recorded: 2011-Jun-25 10:31:21.546987 GMT
Run / Event / LS: 167676 / 329040395 / 368

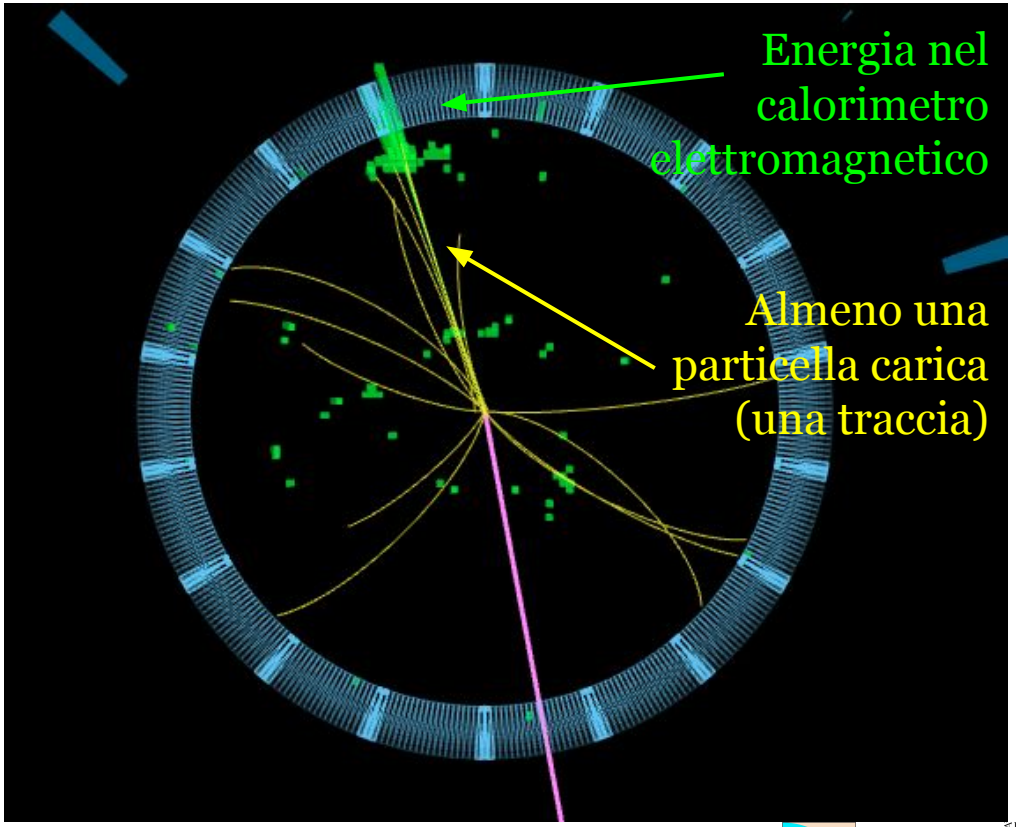

CMS Experiment at the LHC, CERN
Data recorded: 2011-Jun-25 10:31:21.546987 GMT
Run / Event / LS: 167676 / 329040395 / 368
Energia nel calorimetro elettromagnetico
una particella carica (una traccia)


Energia nel calorimetro elettromagnetico
Almeno una particella carica (una traccia)

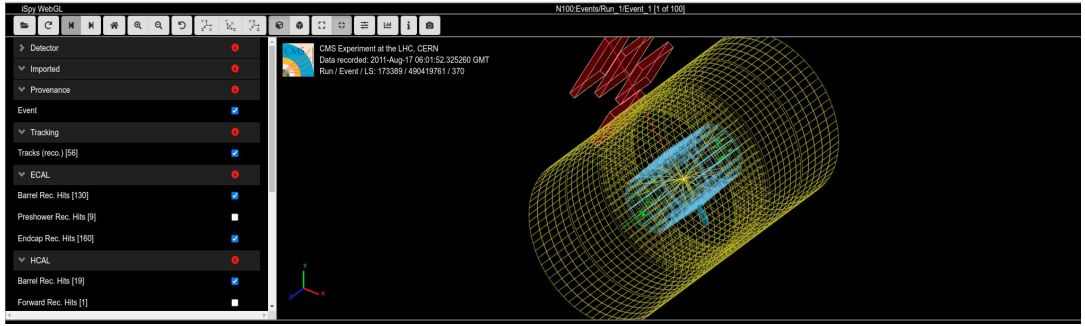
1 evento con 1 elettrone



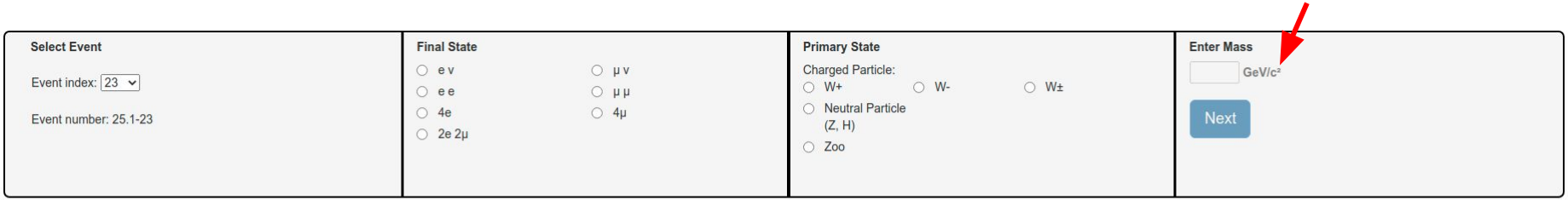




Massa



- Se selezionate piu' di una particella (e.g. due muoni) e **premete il tasto "M" della tastiera**, potete ottenere la "massa invariante del sistema di particelle" → da inserire nella tabella della prima pagina se si identificano eventi ee, μμ, eeμμ, 4e, 4μ



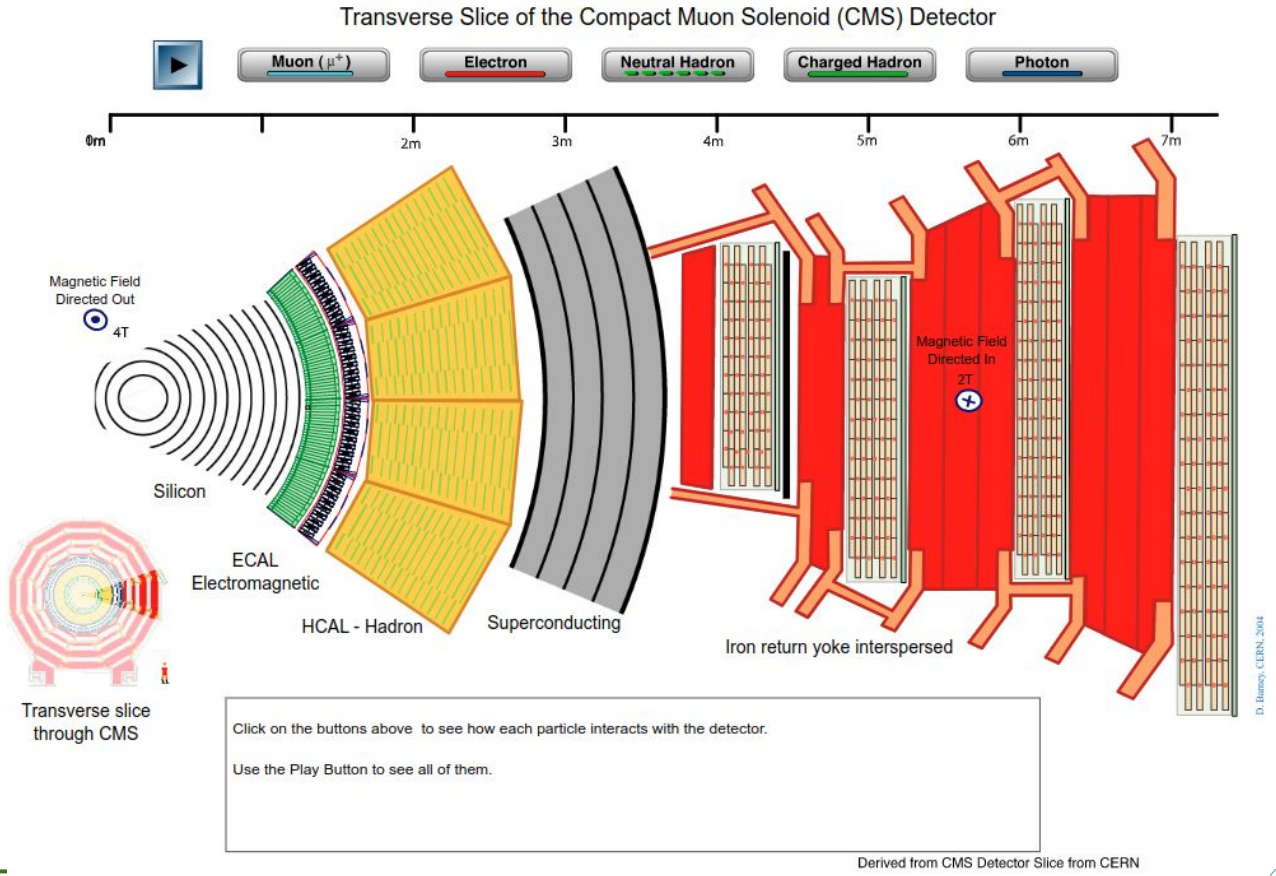
Event index	Event number	Final state	Primary state	Mass
16022	25.1-22	ev	W-	
16021	25.1-21	μν	W+	
16020	25.1-20	μμ	neutral	11.09
16019	25.1-19	ev	W-	
16018	25.1-18	μμ	neutral	9.72
16017	25.1-17	μν	W-	

Se volete contattarci

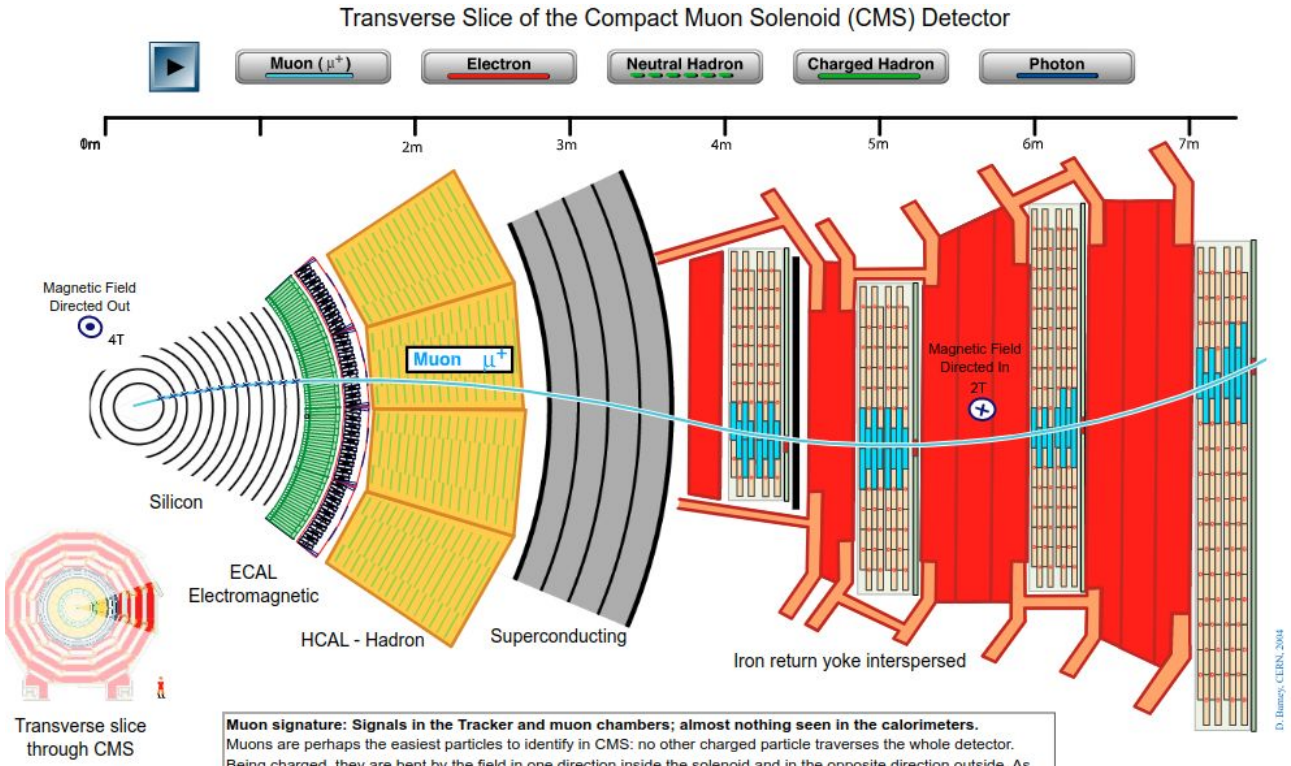
pietro.govoni@unimib.it

andrea.massironi@mib.infn.it

CMS slice


Transverse Slice of the Compact Muon Solenoid (CMS) Detector
Muon (μ^+)
Electron
Neutral Hadron
Charged Hadron
Photon
0m
2m
3m
4m
5m
6m
7m
Magnetic Field
Directed Out
4T
Magnetic Field
Directed In
2T
Silicon
ECAL
Electromagnetic
HCAL - Hadron
Superconducting
Iron return yoke interspersed
D. Barney, CERN, 2004
Transverse slice
through CMS
Click on the buttons above to see how each particle interacts with the detector.
Use the Play Button to see all of them.
Derived from CMS Detector Slice from CERN

CMS slice: muon

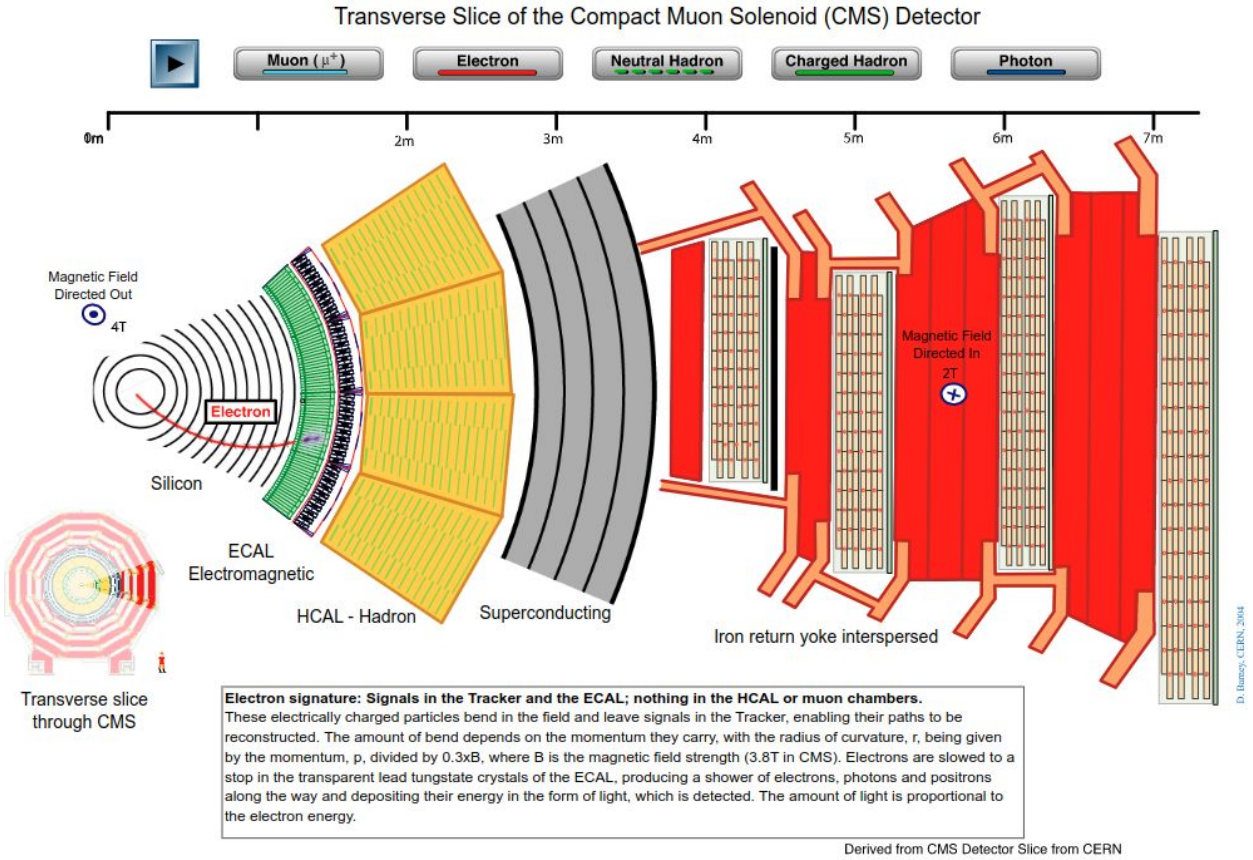


Transverse slice through CMS

Muon signature: Signals in the Tracker and muon chambers; almost nothing seen in the calorimeters.
Muons are perhaps the easiest particles to identify in CMS: no other charged particle traverses the whole detector. Being charged, they are bent by the field in one direction inside the solenoid and in the opposite direction outside. As muons can only arise from the decay of something heavier their presence signifies that something potentially interesting has happened.

Derived from CMS Detector Slice from CERN

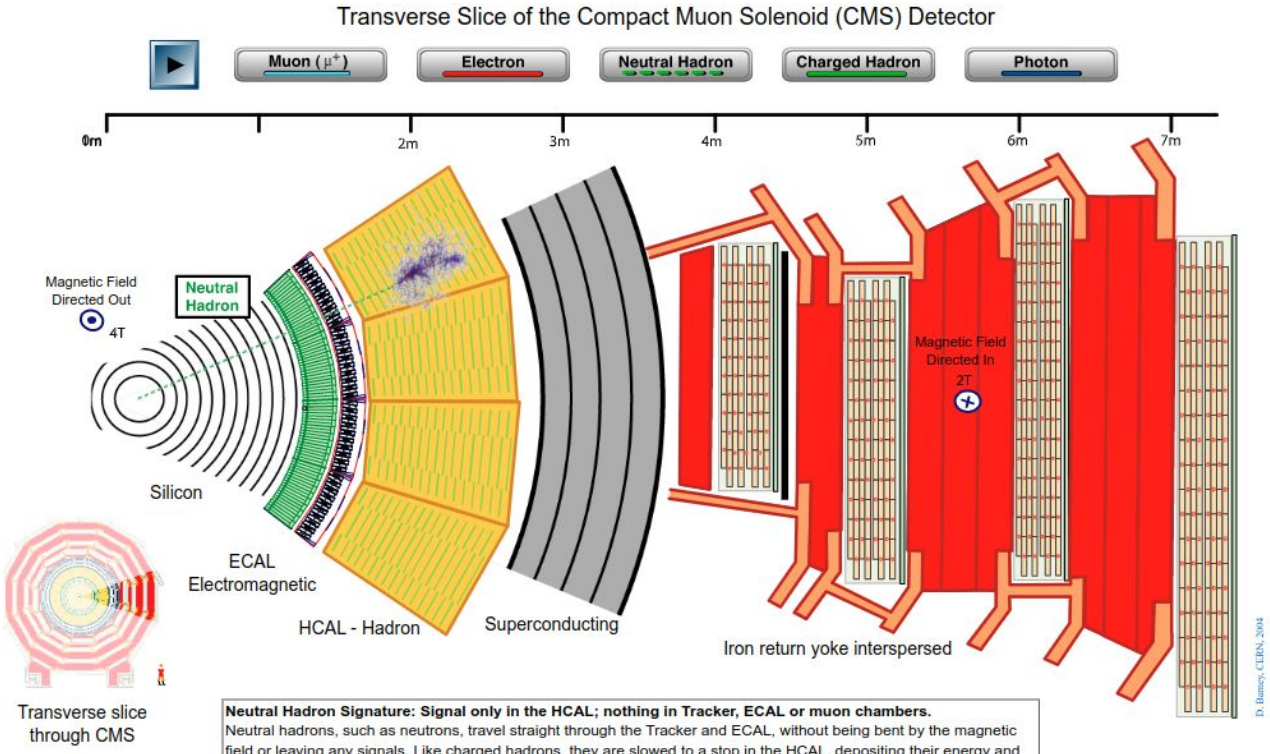
CMS slice: electron



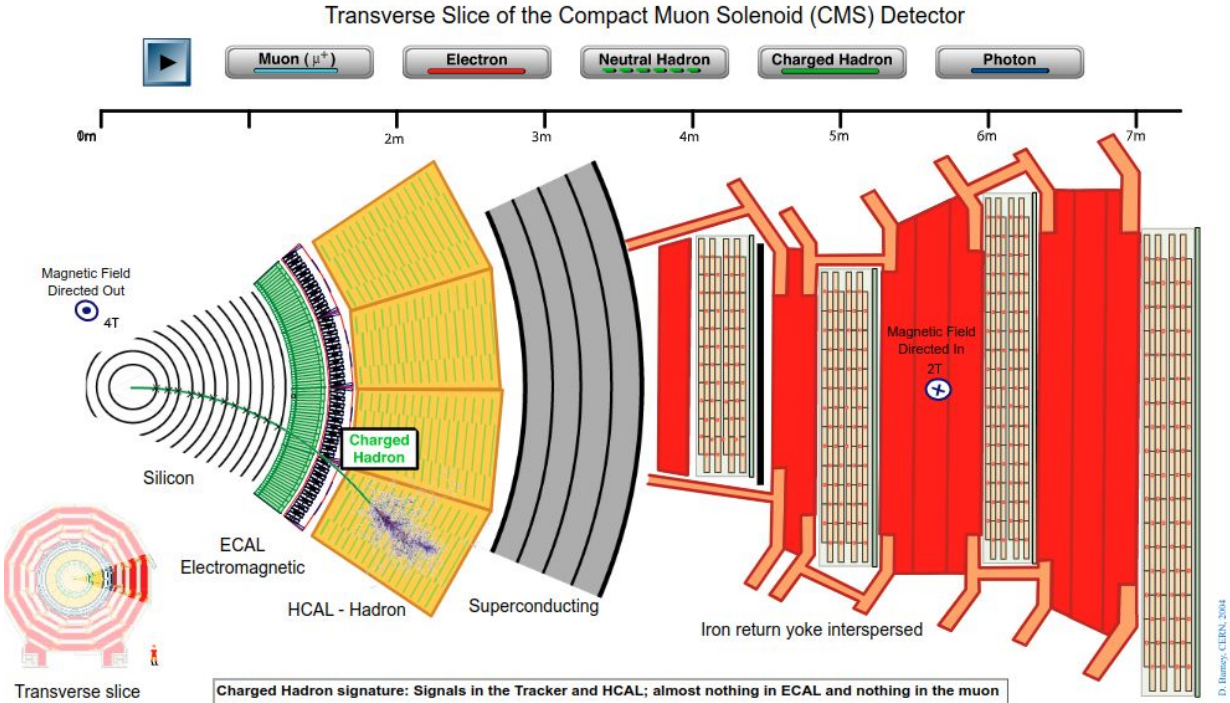
Electron signature: Signals in the Tracker and the ECAL; nothing in the HCAL or muon chambers.
These electrically charged particles bend in the field and leave signals in the Tracker, enabling their paths to be reconstructed. The amount of bend depends on the momentum they carry, with the radius of curvature, r, being given by the momentum, p, divided by 0.3xB, where B is the magnetic field strength (3.8T in CMS). Electrons are slowed to a stop in the transparent lead tungstate crystals of the ECAL, producing a shower of electrons, photons and positrons along the way and depositing their energy in the form of light, which is detected. The amount of light is proportional to the electron energy.

Derived from CMS Detector Slice from CERN

CMS slice: neutral hadron



CMS slice: charged hadron



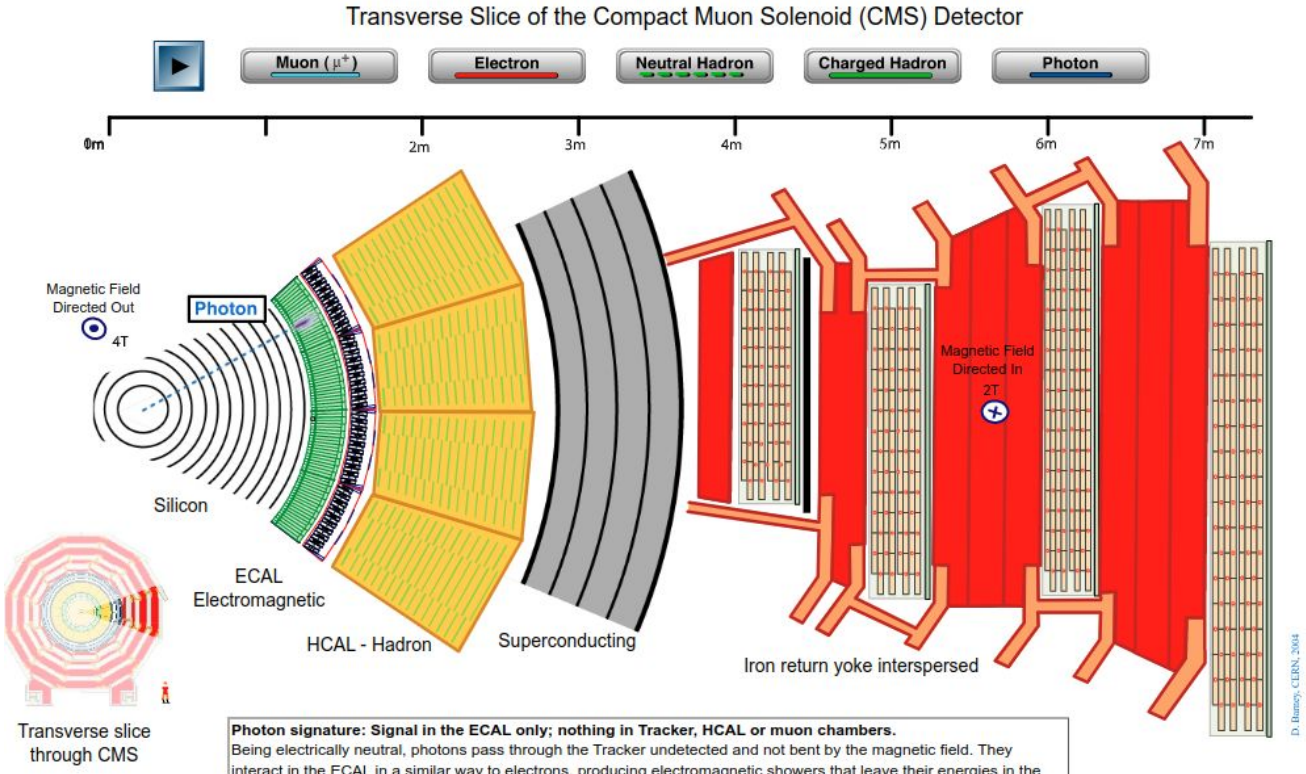
Transverse slice through CMS

Charged Hadron signature: Signals in the Tracker and HCAL; almost nothing in ECAL and nothing in the muon chambers.

Charged hadrons, such as protons and pi plus or pi minus (made of pairs of quarks), are bent by the magnetic field and travel straight through the ECAL leaving almost no signals. Upon reaching the HCAL they are slowed to a stop by the dense materials, producing showers of secondary particles along the way that in turn produce light in thin layers of plastic scintillator material. The amount of light is proportional to the energy of the incoming hadron.

Derived from CMS Detector Slice from CERN

CMS slice: photon

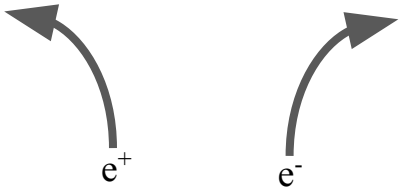


Photon signature: Signal in the ECAL only; nothing in Tracker, HCAL or muon chambers.
Being electrically neutral, photons pass through the Tracker undetected and not bent by the magnetic field. They interact in the ECAL in a similar way to electrons, producing electromagnetic showers that leave their energies in the form of light that is detected.

Derived from CMS Detector Slice from CERN

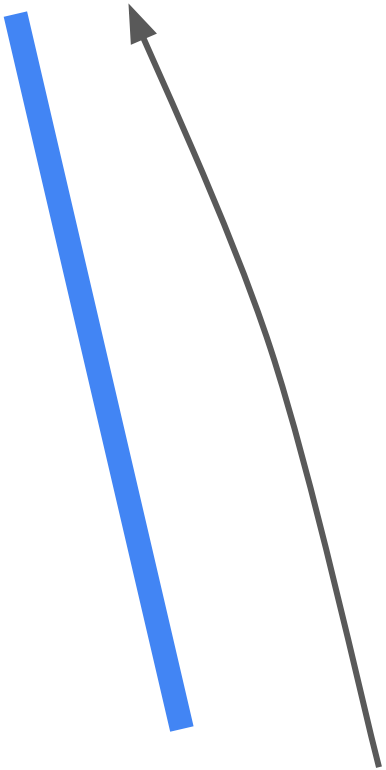
Orario o antiorario?

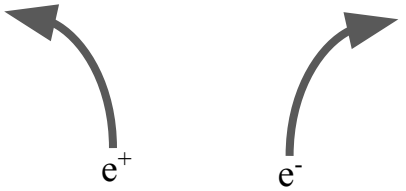
- Questa traccia curva in senso orario o antiorario?



Orario o antiorario?

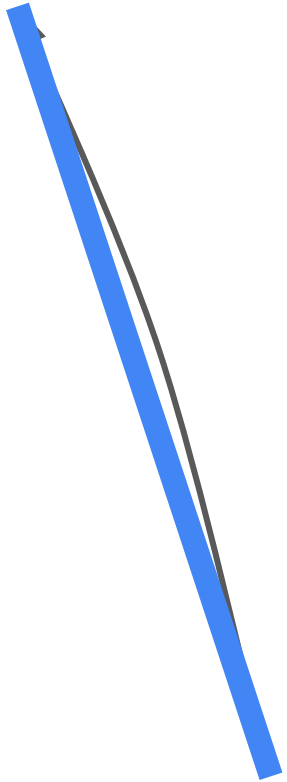
- Questa traccia curva in senso orario o antiorario?
- Prendo un righello/foglio di carta → so che e' dritto

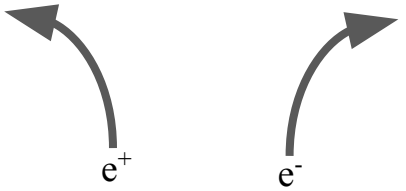




Orario o antiorario?

- Questa traccia curva in senso orario o antiorario?
- Prendo un righello/foglio di carta → so che e' dritto
- Collego due punti della traccia





Orario o antiorario?

- Questa traccia curva in senso orario o antiorario?
- Prendo un righello/foglio di carta → so che e' dritto
- Collego due punti della traccia
- Dato che vedo la traccia alla destra del righello, la traccia curva in senso antiorario