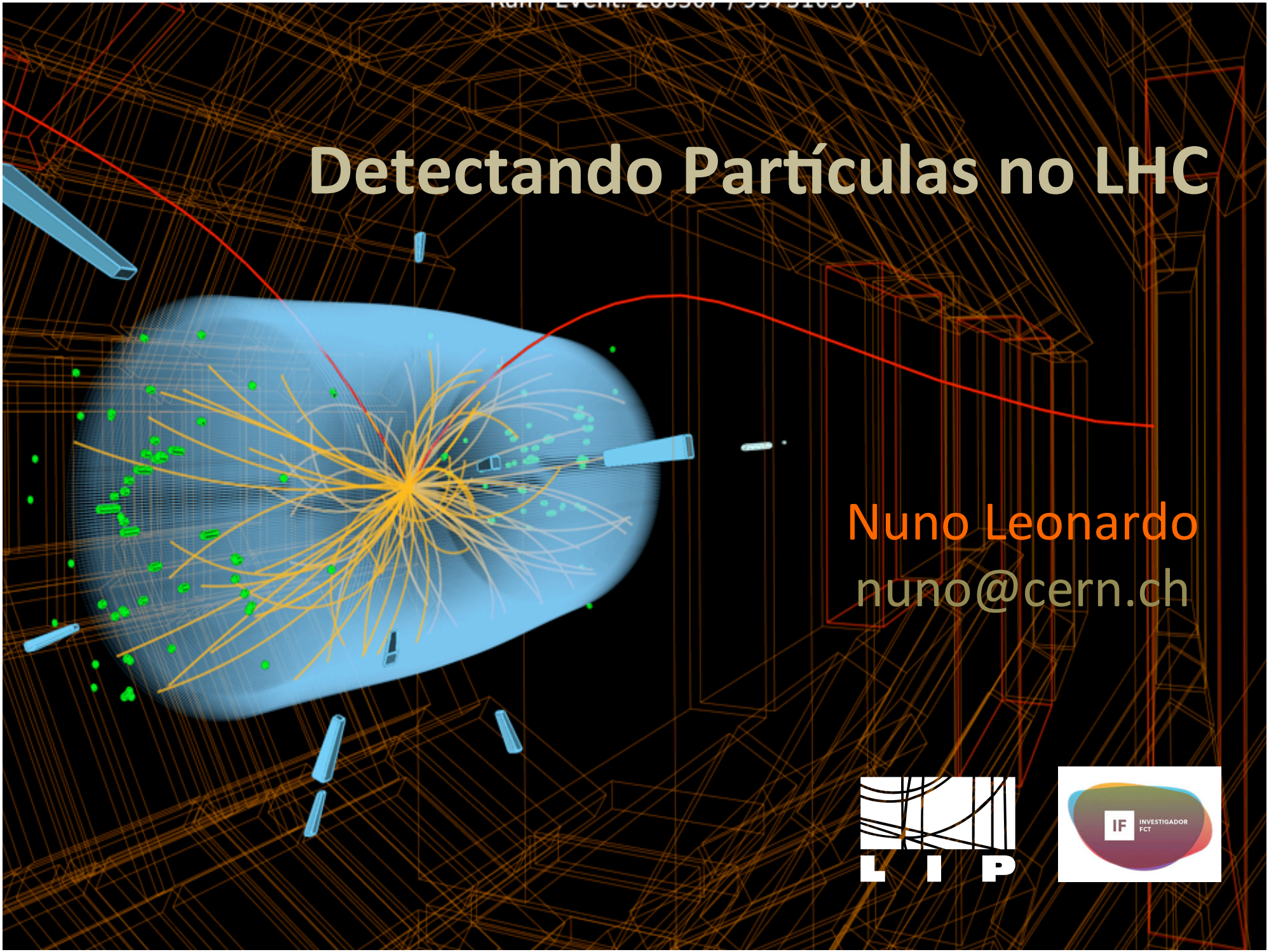
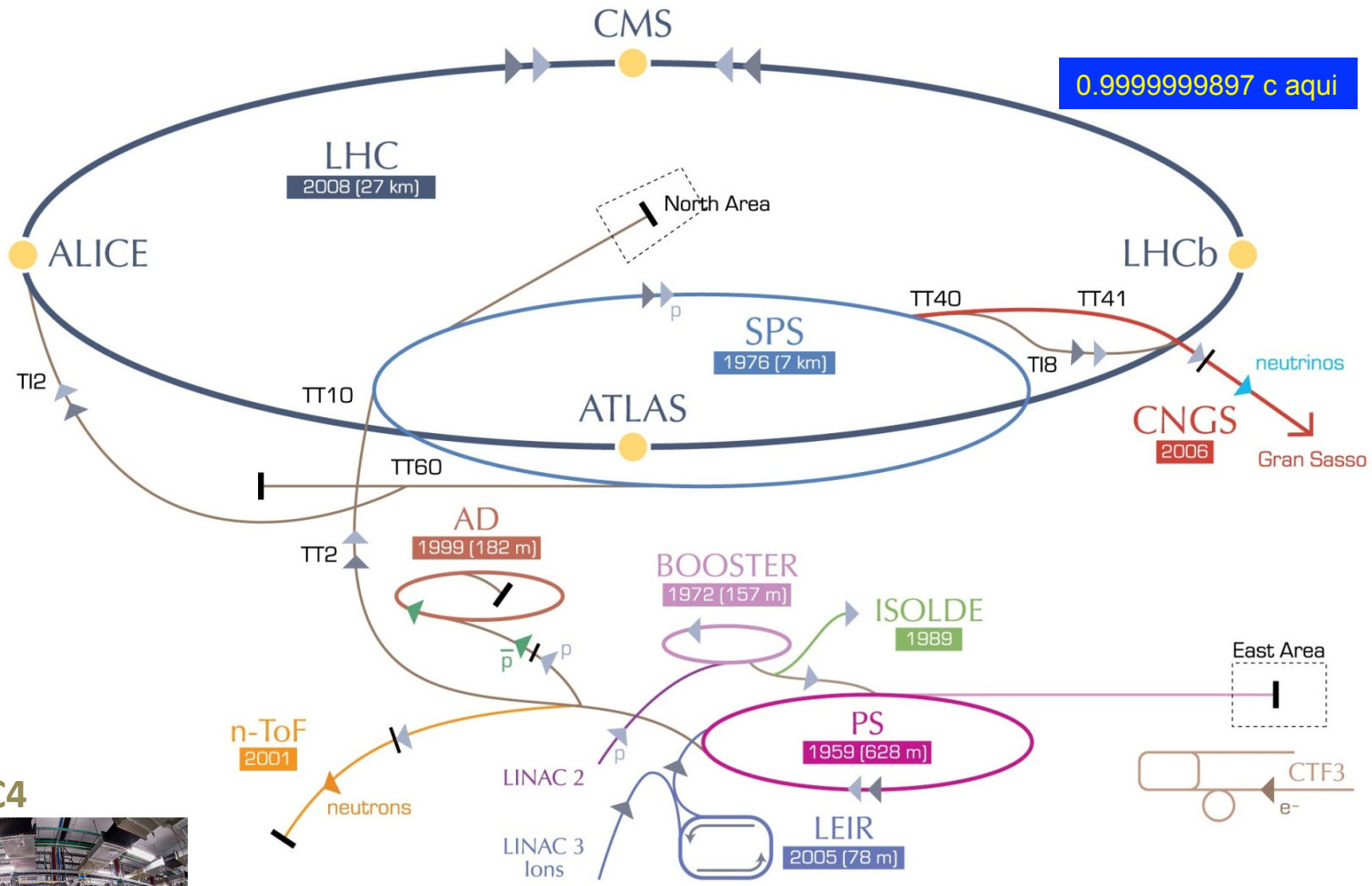


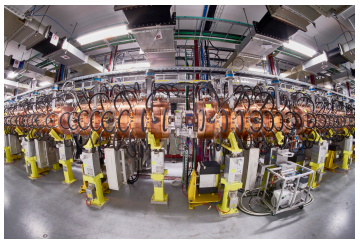
Detectando Partículas no LHC

Nuno Leonardo
nuno@cern.ch

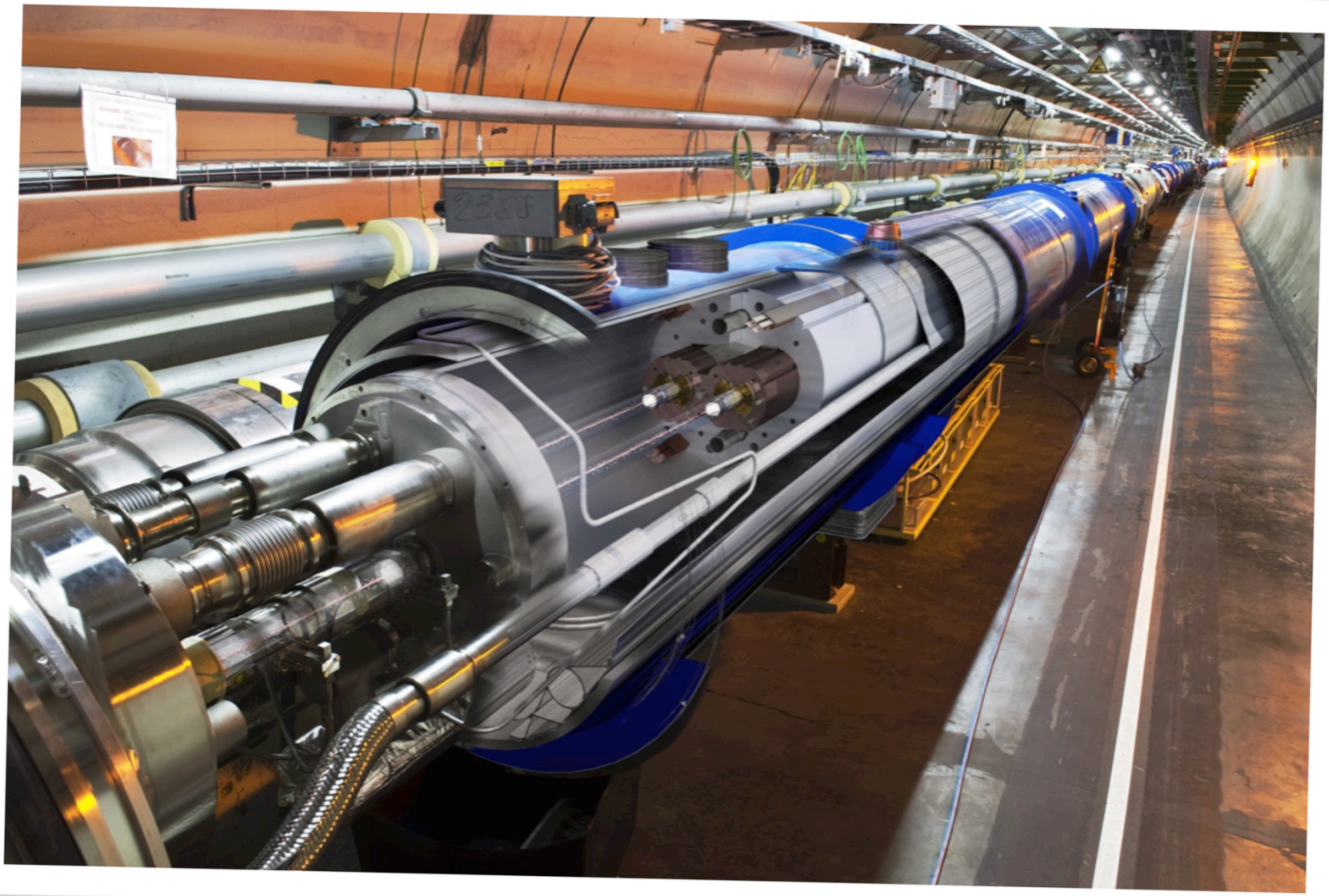
a cadeia de aceleradores do CERN, e o **LHC**



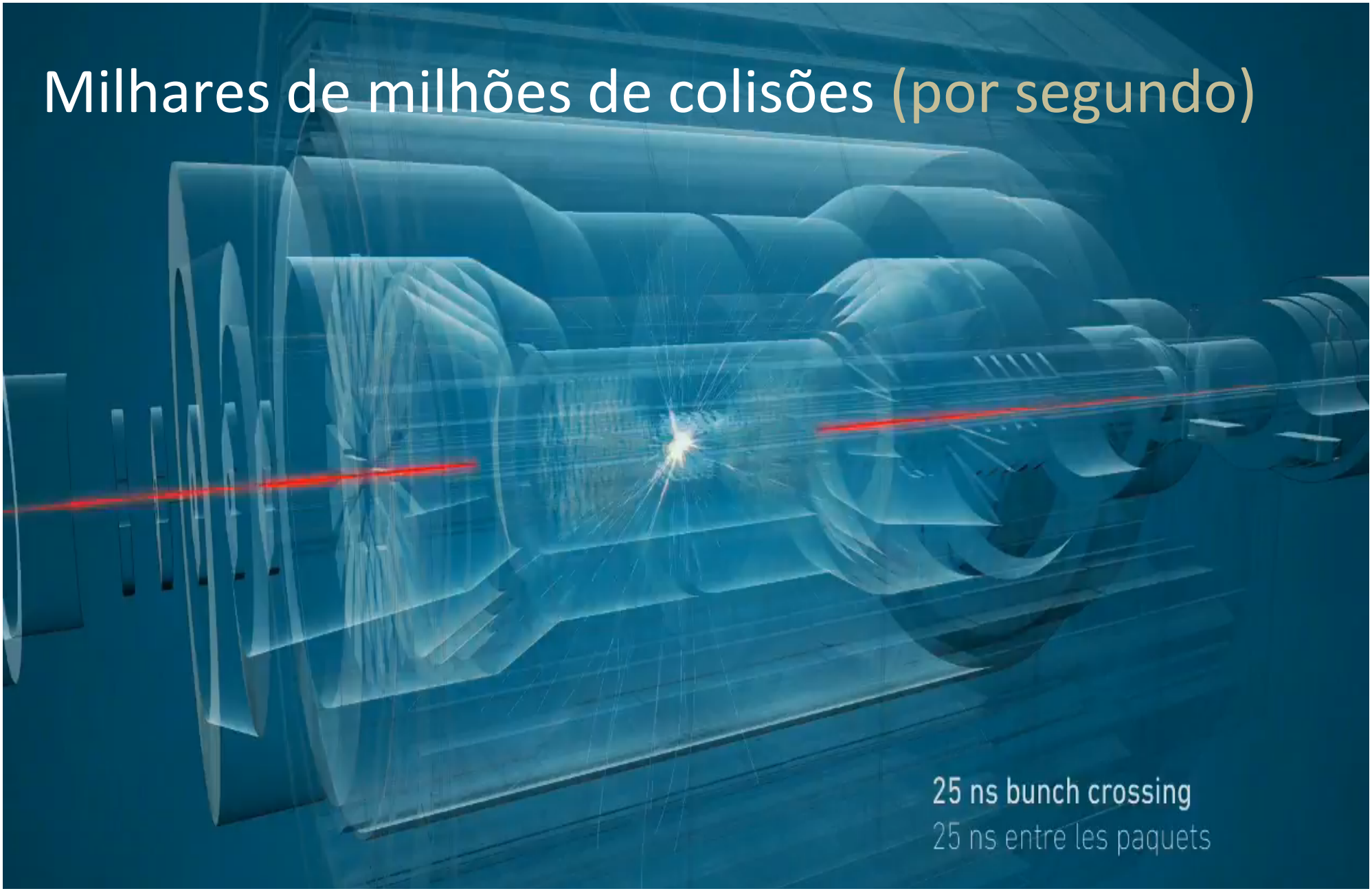
LINAC4



o magneto mais potente

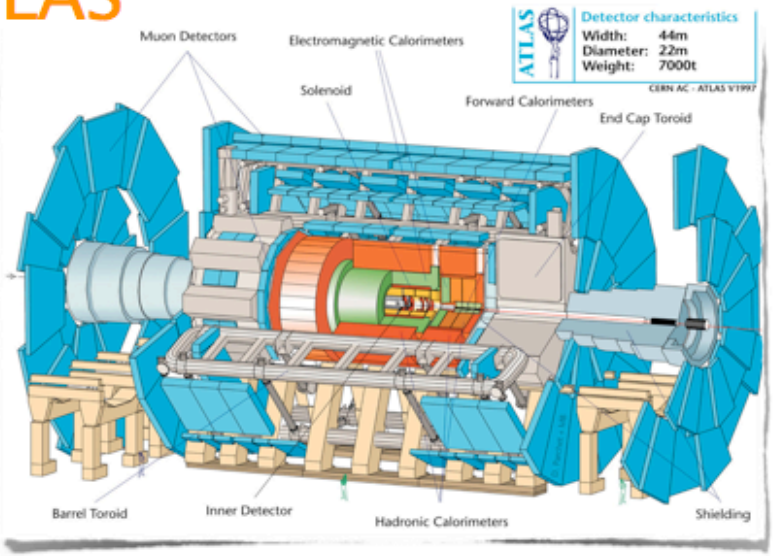


Milhares de milhões de colisões (por segundo)

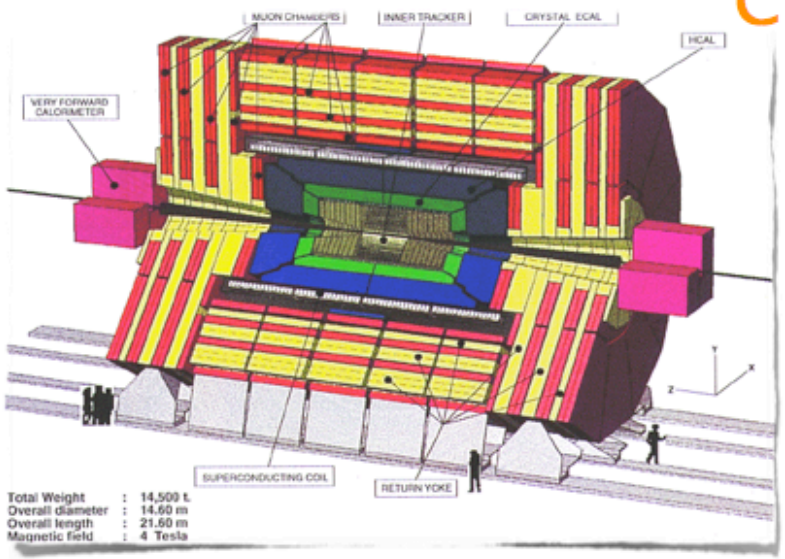


the LHC detectors

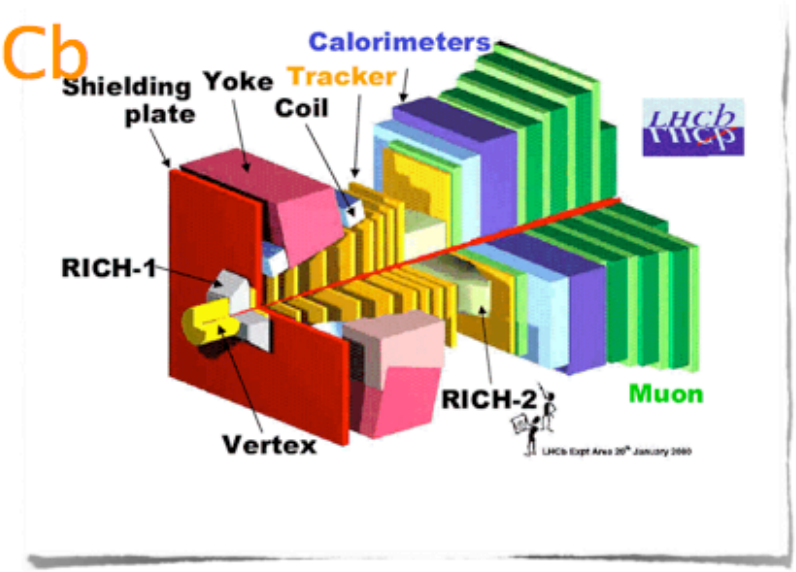
ATLAS



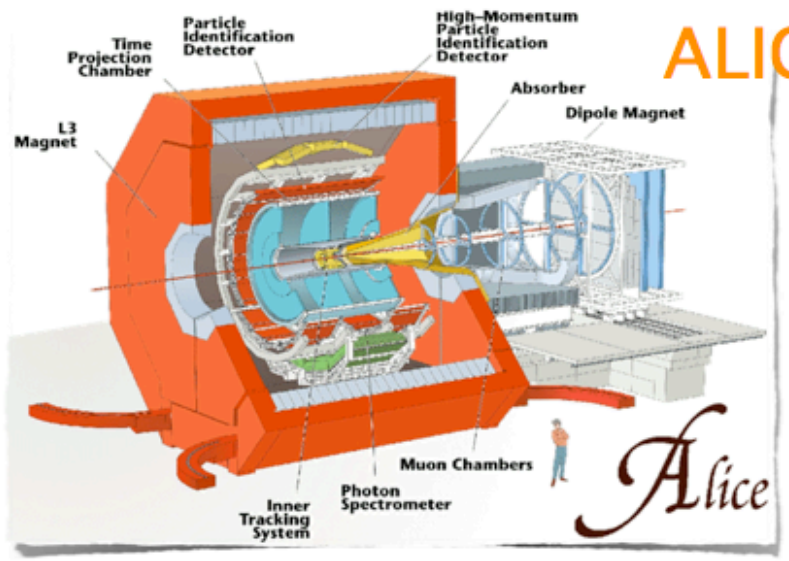
CMS

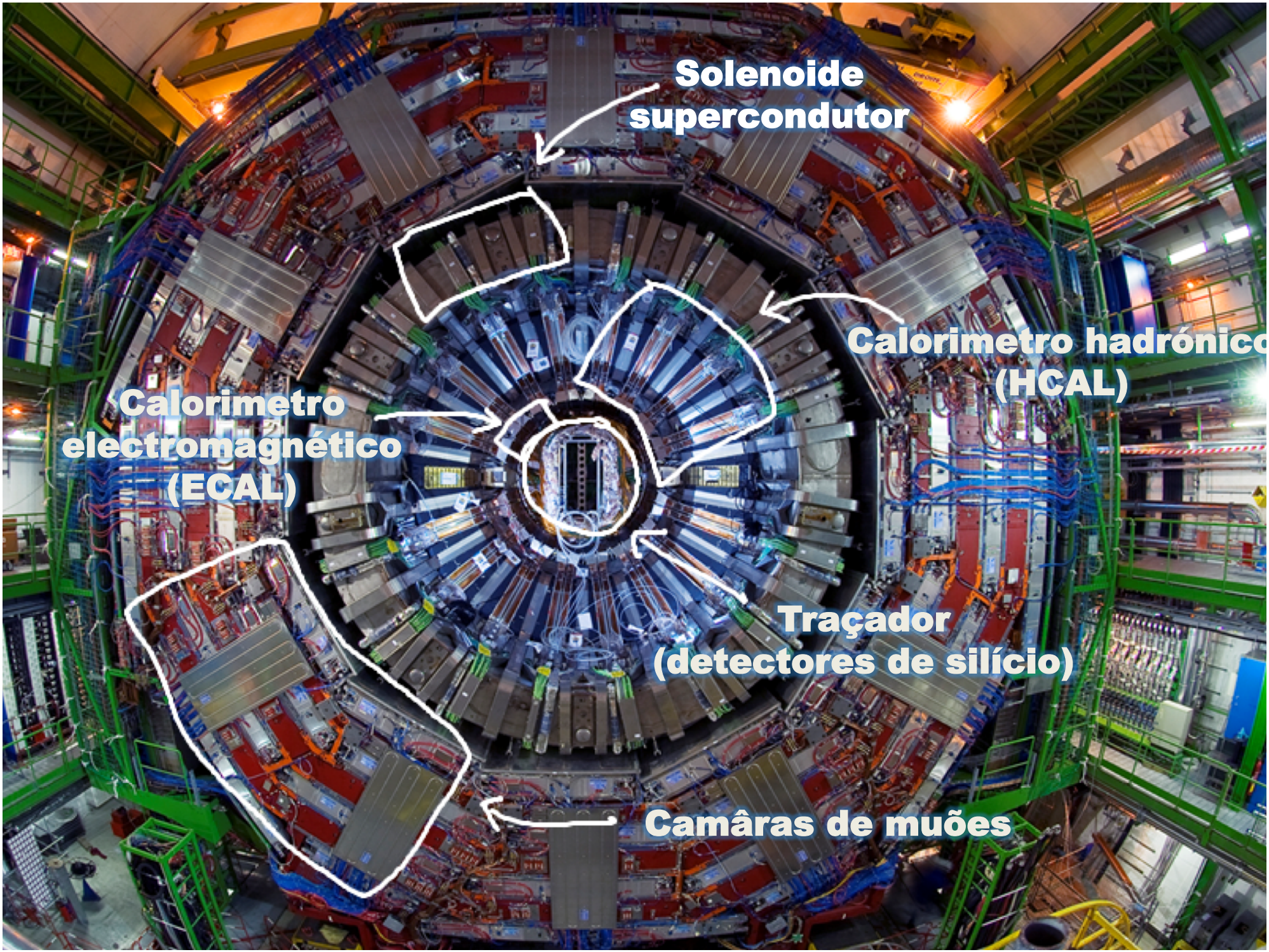


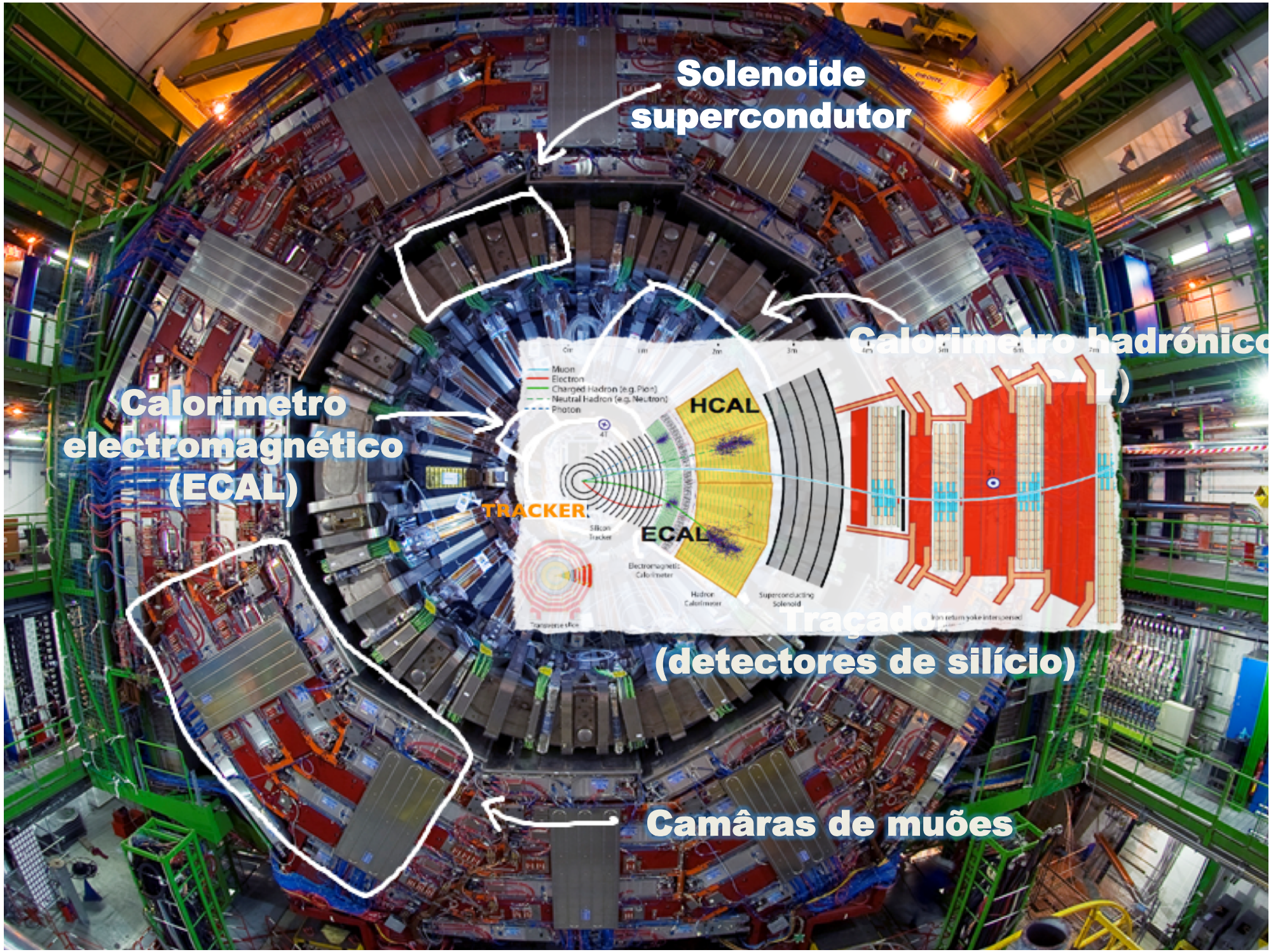
LHCb



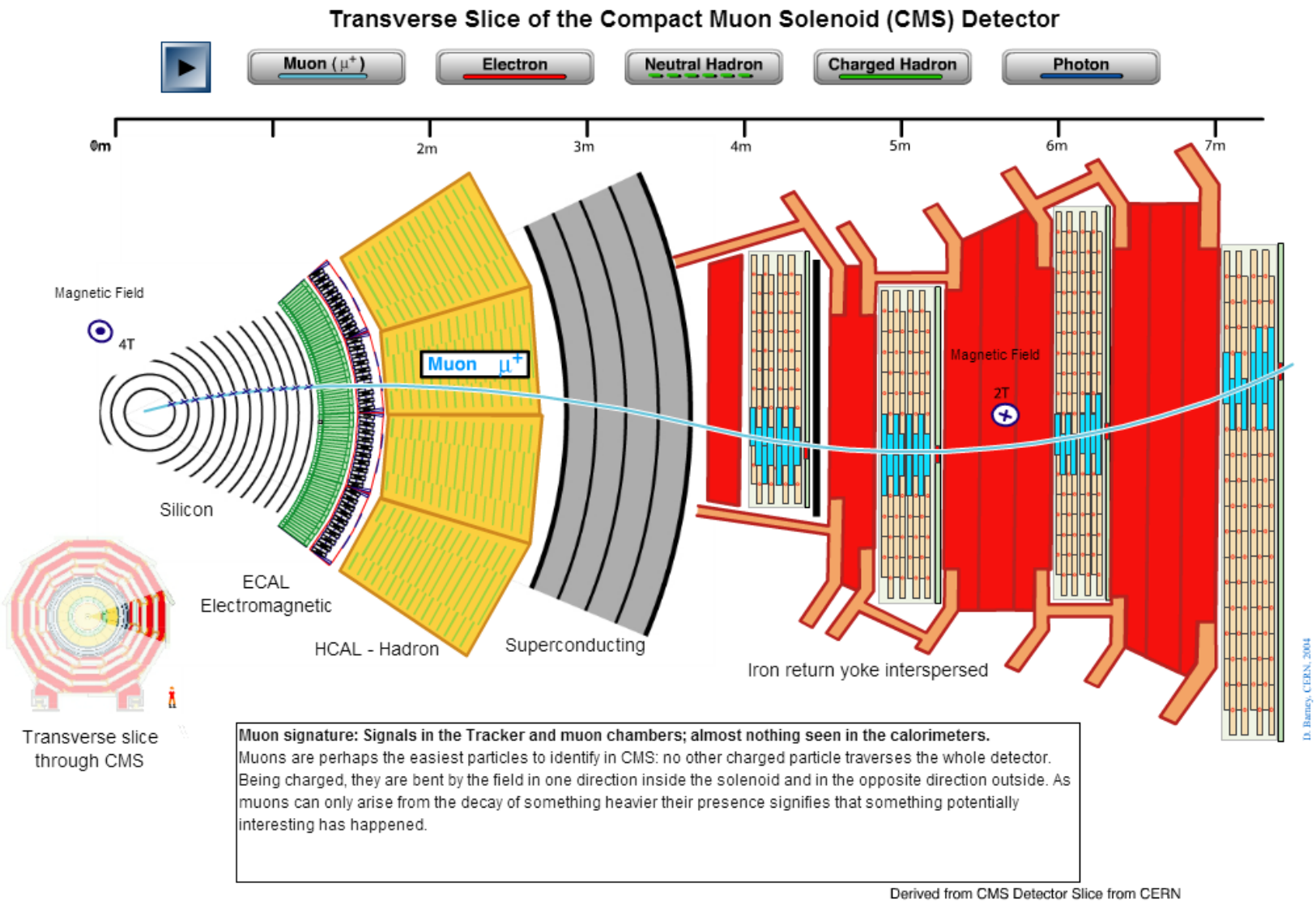
ALICE




Solenoide
supercondutor
Calorimetro hadrónico
(HCAL)
Calorimetro
electromagnético
(ECAL)
Traçador
(detectores de silício)
Camâras de muões


Solenoide
supercondutor
Calorimetro hadrónico
(HCAL)
Calorimetro
electromagnético
(ECAL)
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
HCAL
TRACKER
ECAL
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Traçador
(detectores de silício)
Camâras de muões

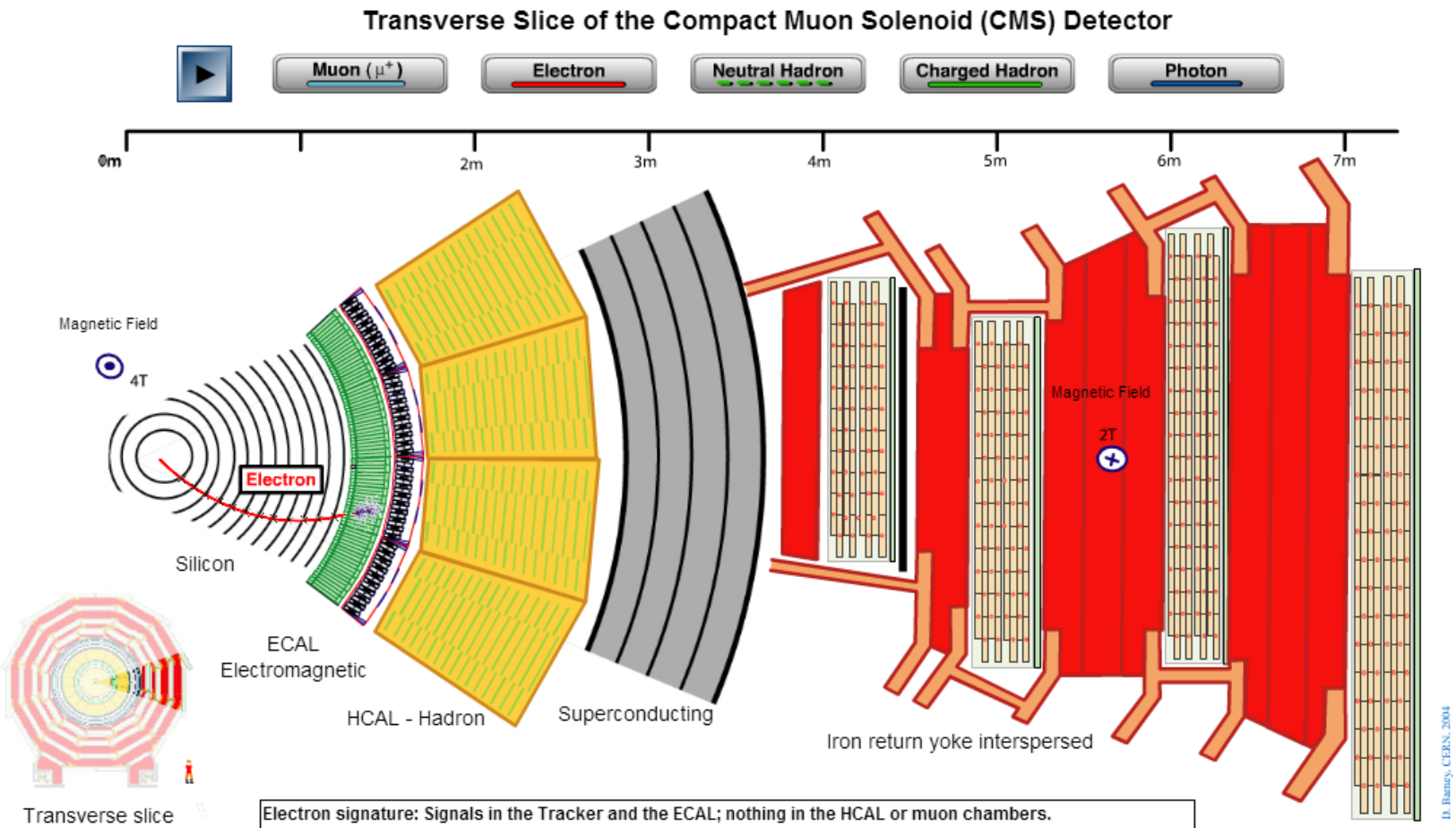
Identificando as partículas estáveis



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

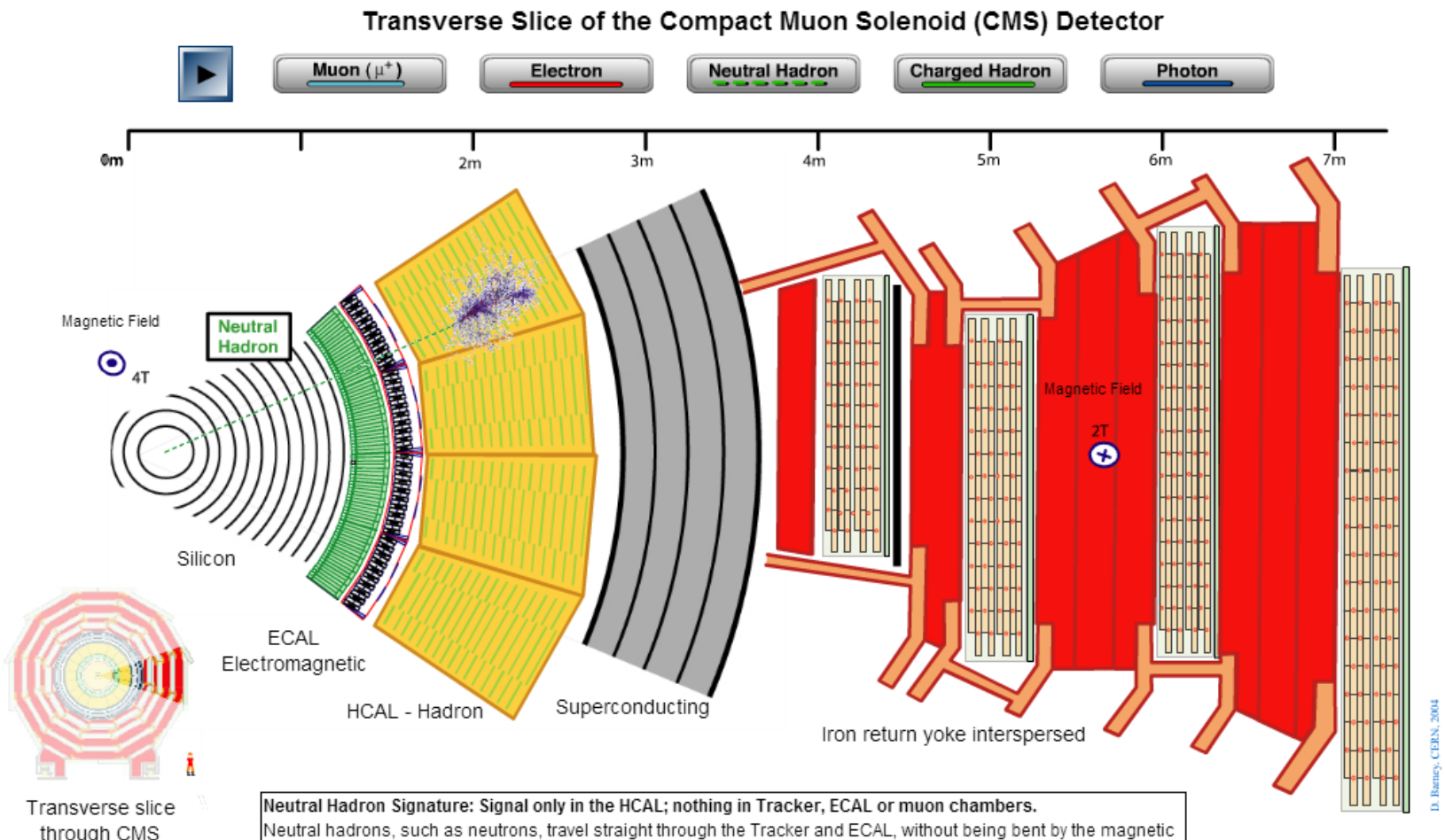
Identificando as partículas estáveis



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

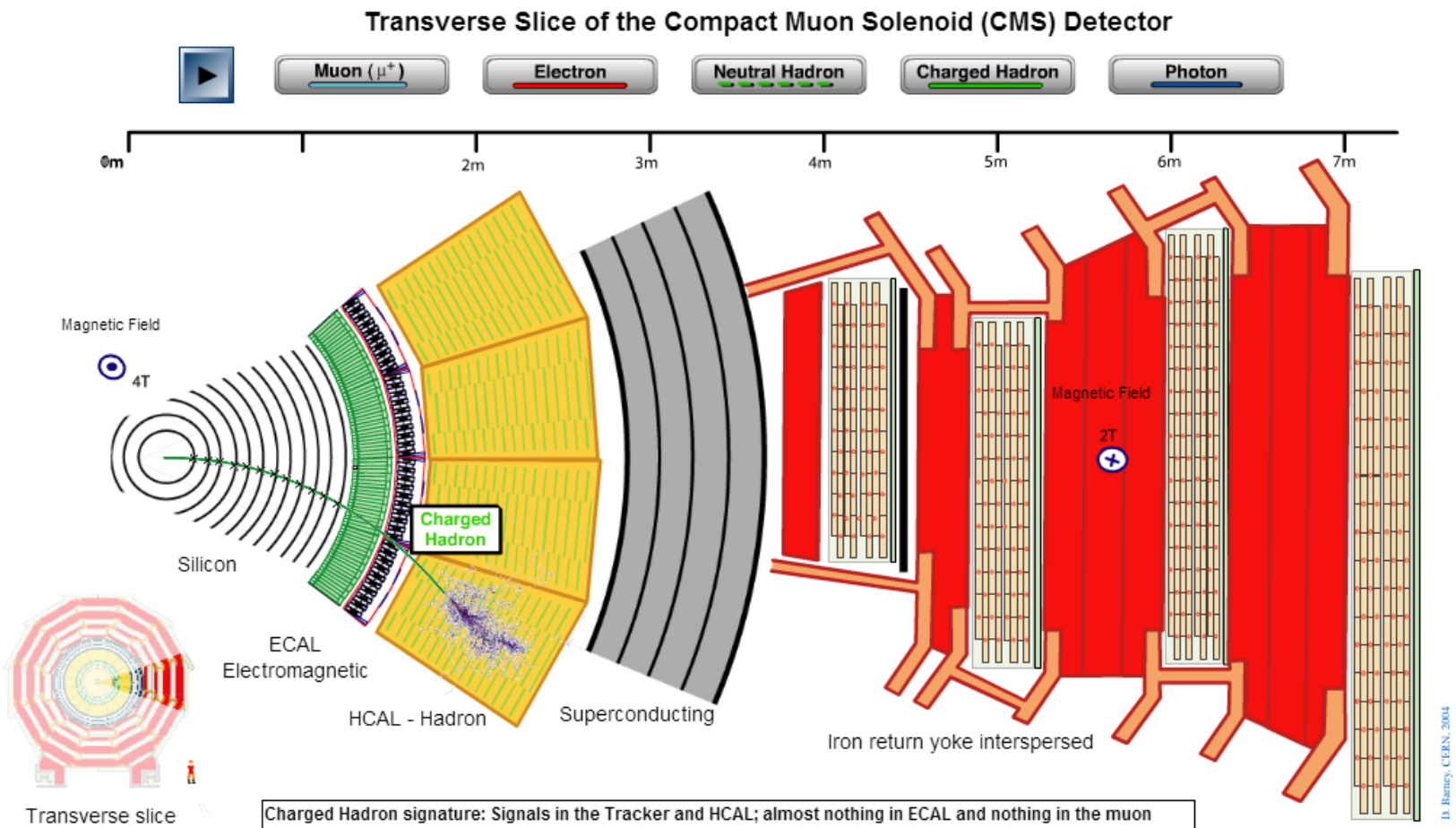
Identificando as partículas estáveis



Neutral Hadron Signature: Signal only in the HCAL; nothing in Tracker, ECAL or muon chambers.
Neutral hadrons, such as neutrons, travel straight through the Tracker and ECAL, without being bent by the magnetic field or leaving any signals. Like charged hadrons, they are slowed to a stop in the HCAL, depositing their energy and leaving signals in the form of light in the plastic scintillators. The amount of light is proportional to the energy of the incoming hadron.

Derived from CMS Detector Slice from CERN

Identificando as partículas estáveis



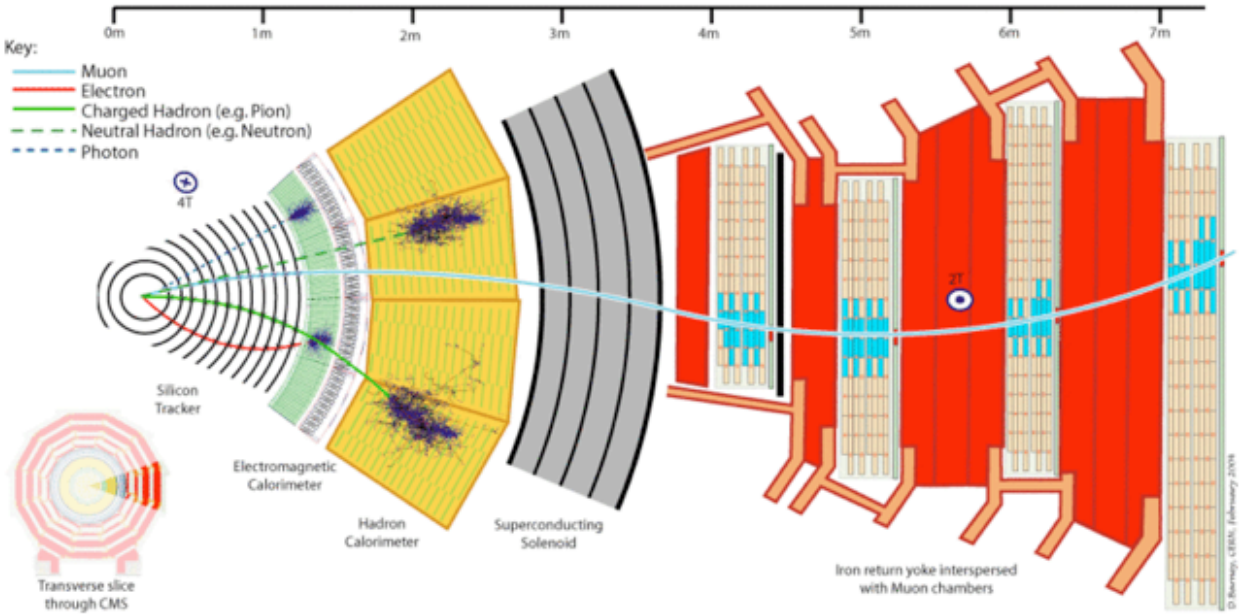
Transverse slice through CMS

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.

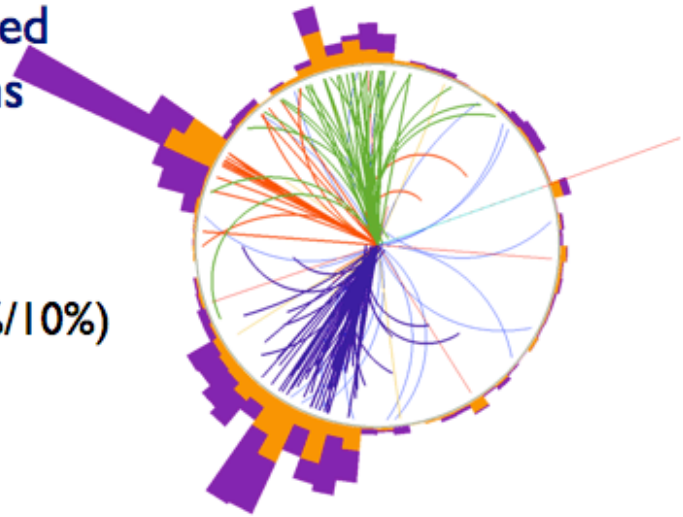
Derived from CMS Detector Slice from CERN

mas as colisões do LHC não são simples ...

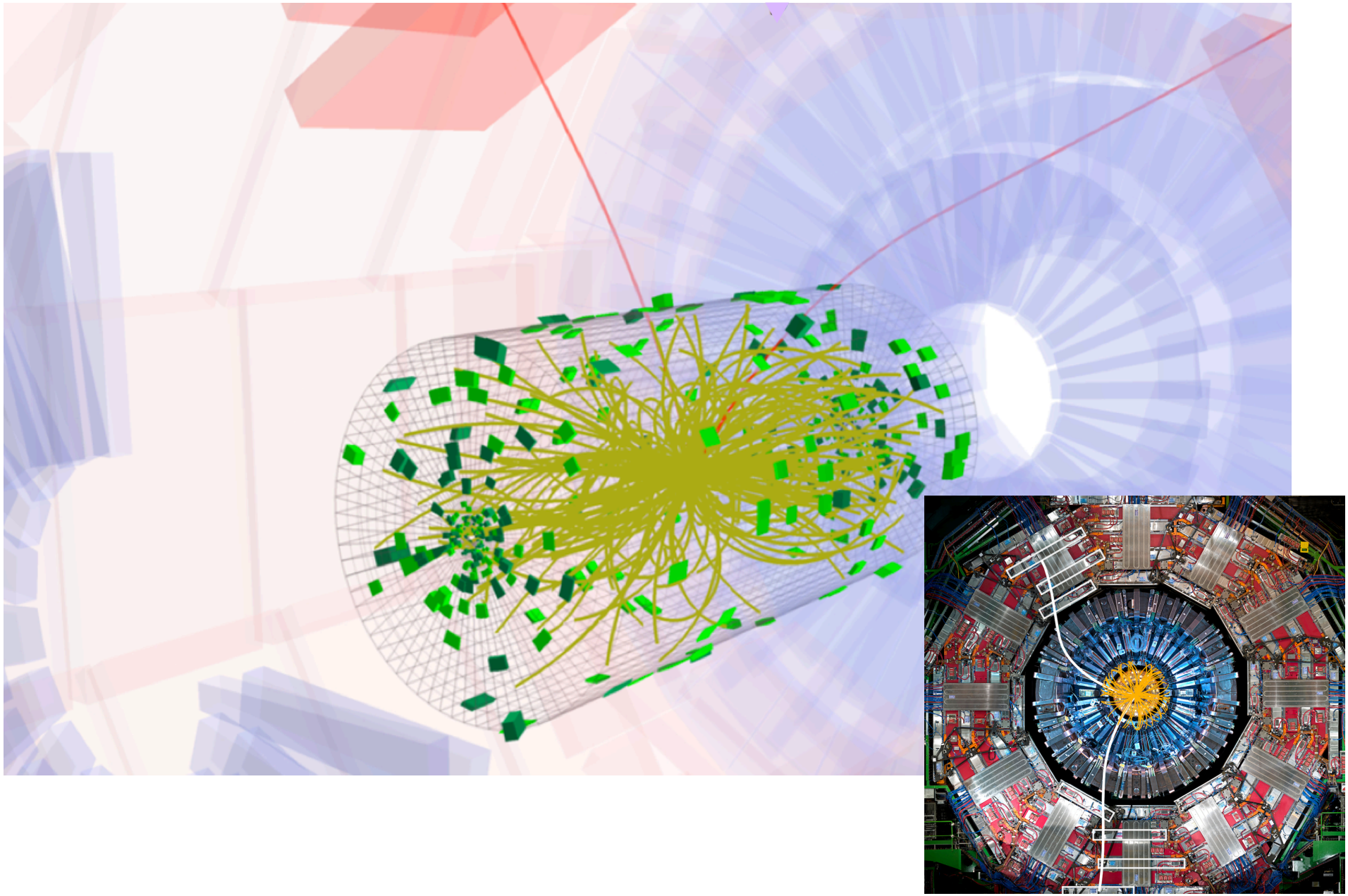
[leading order]



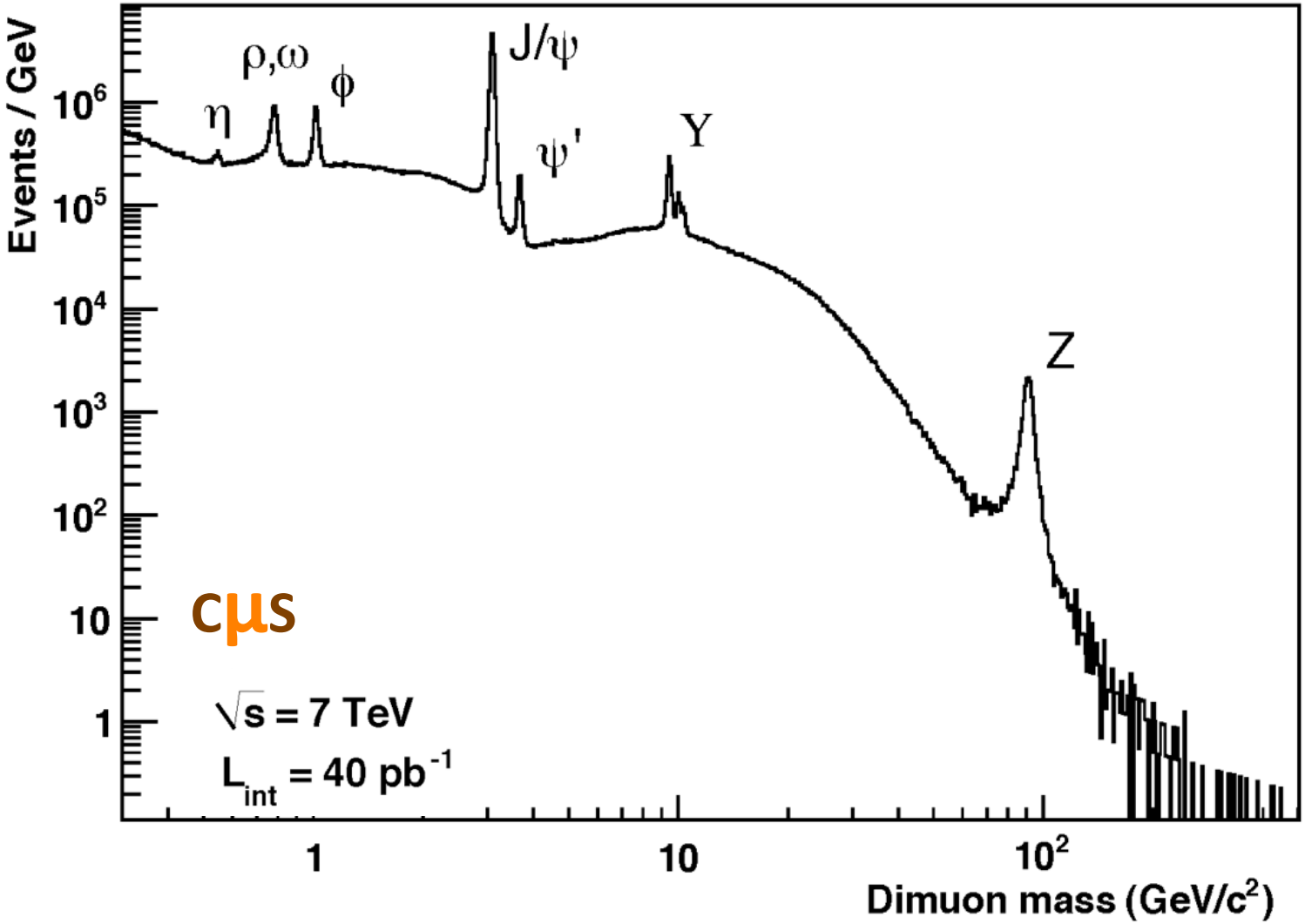
- [higher order corrections] objects are finally reconstructed using information from different detector subsystems combined in a particle flow algorithm
  - electrons radiate via bremsstrahlung
  - photons may convert to e^+e^- pairs in the tracker
  - jet (q,g) energy is formed of charged/neutral hadrons (65%/10%) and photons (25%): calorimeter and tracker info exploited
  - missing E_T requires 'full event' reconstruction



muão + anti-muão + (fundo)

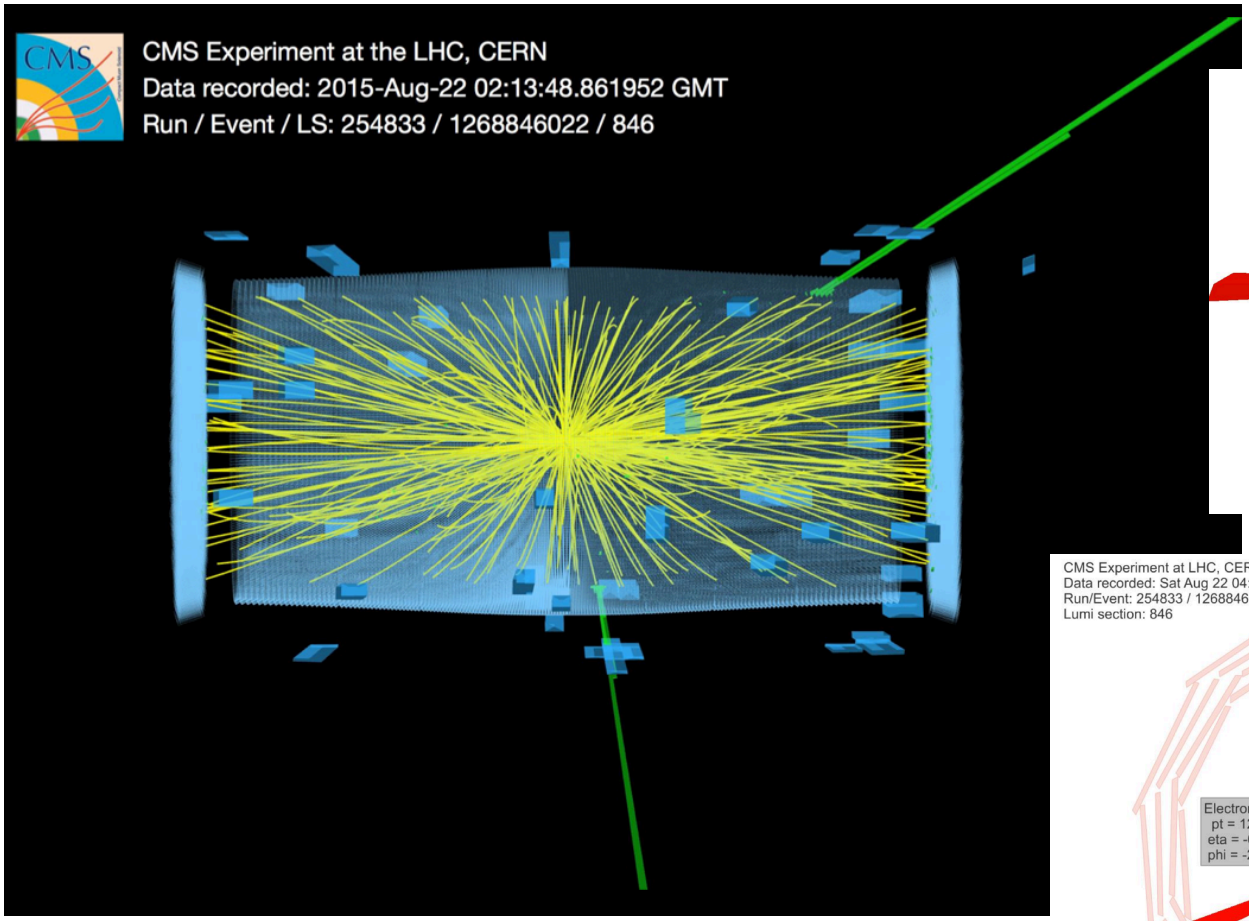


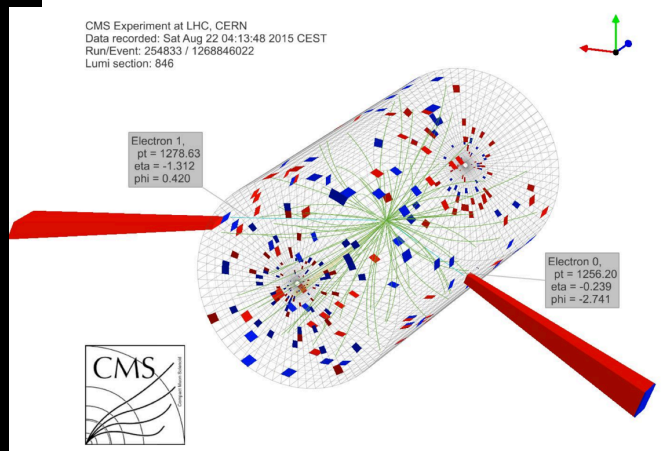
o espectro de massa $\mu^+\mu^-$

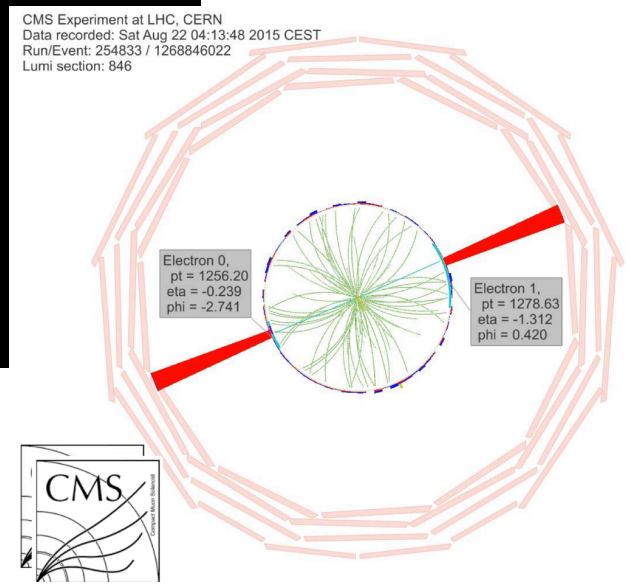


A re-descroberta do Modelo Padrão, 2010 (primeiros dados do LHC)

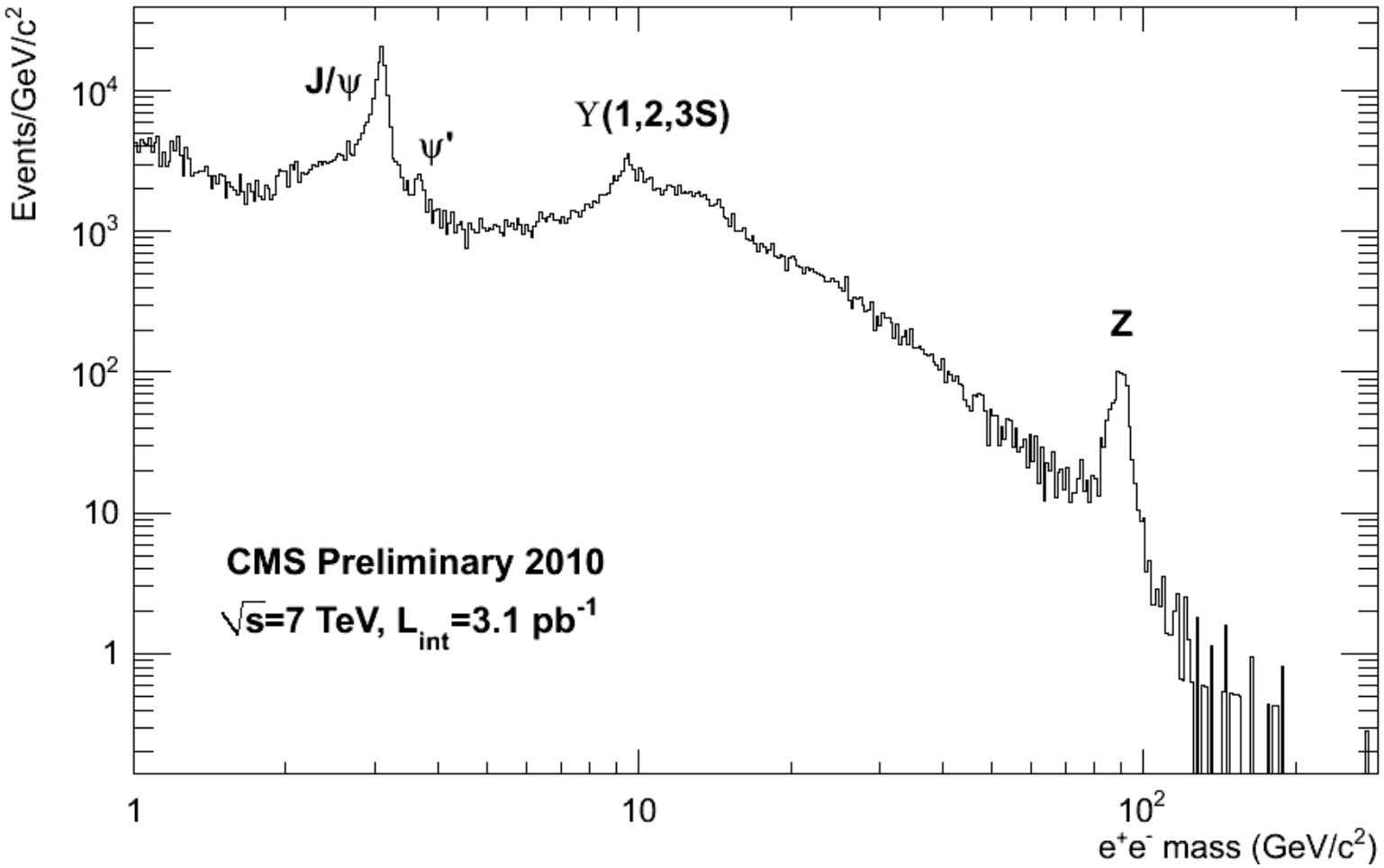
electrão + positrão + (fundo)



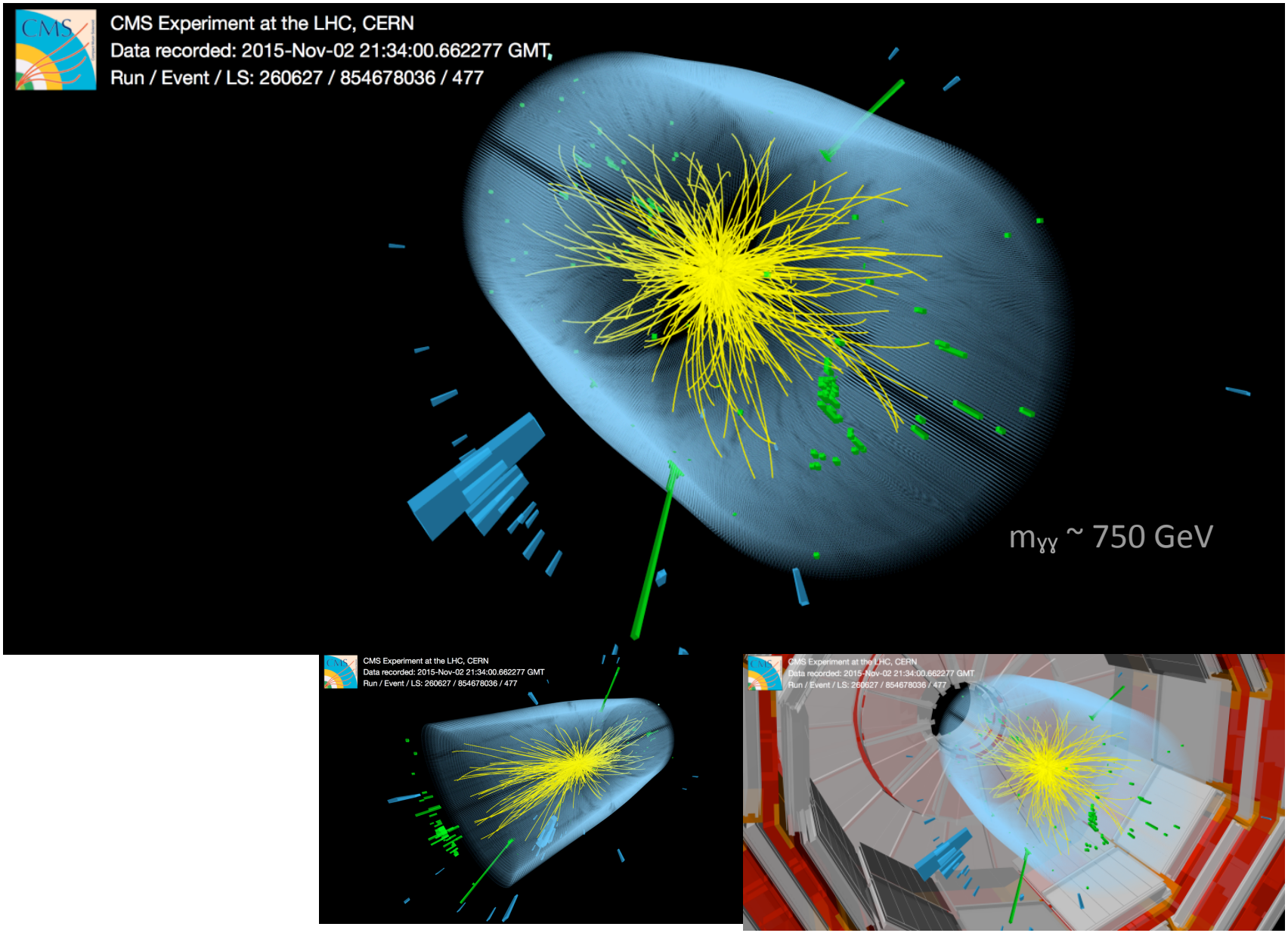


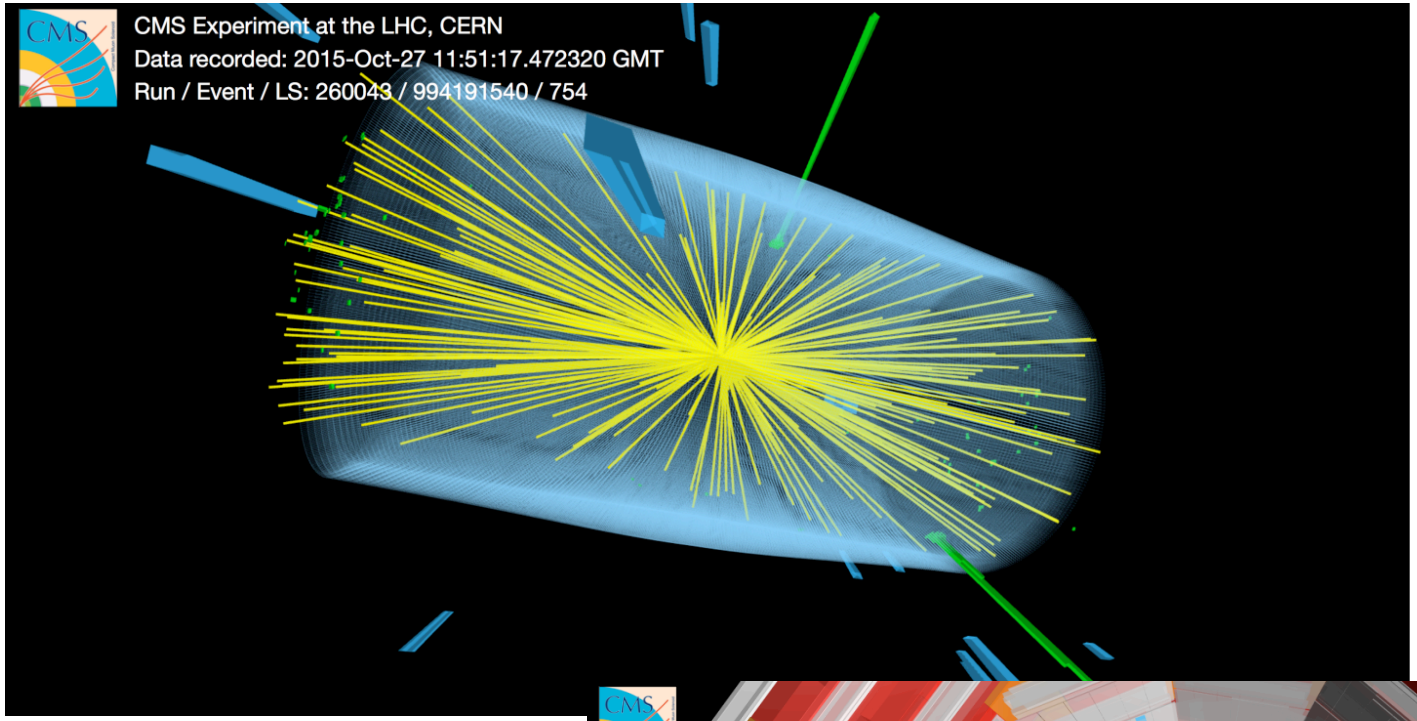


o espectro de massa e^+e^-



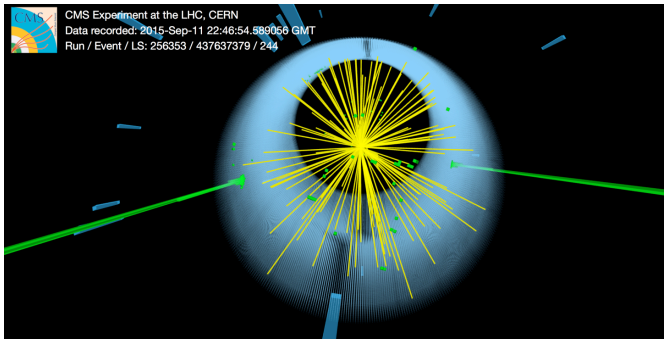
Dois fotões + (fundo)

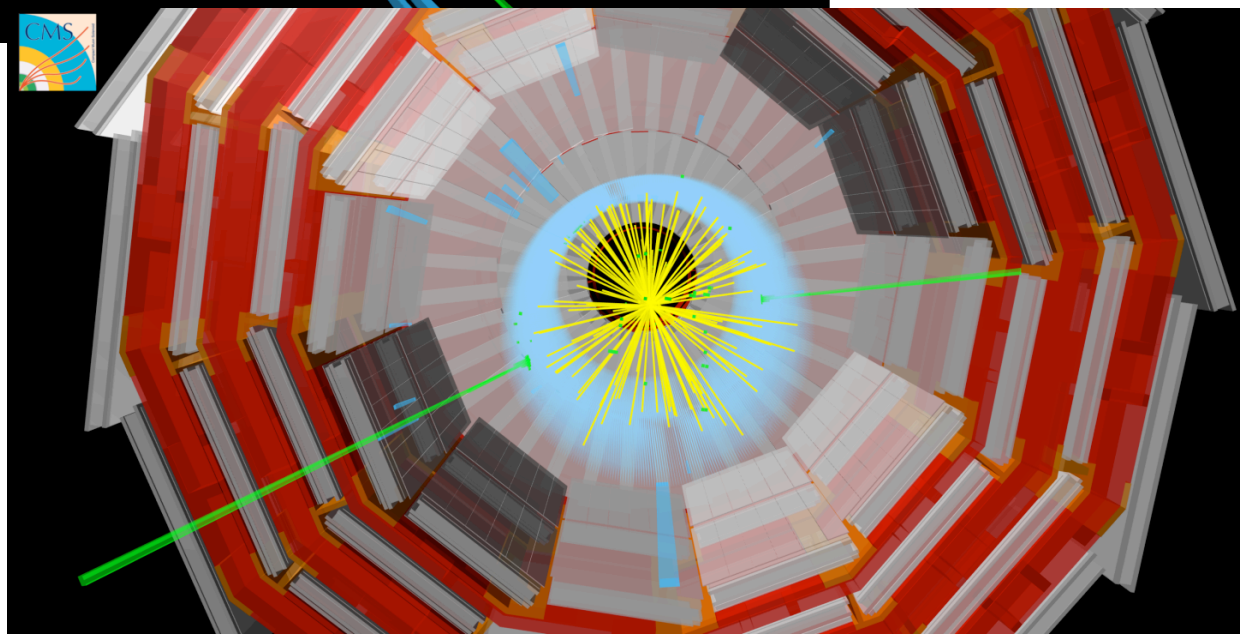


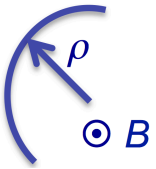


?

$m_{??}$ ~ 700 - 800 GeV

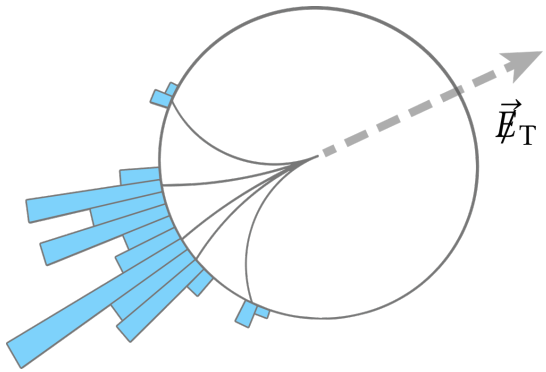


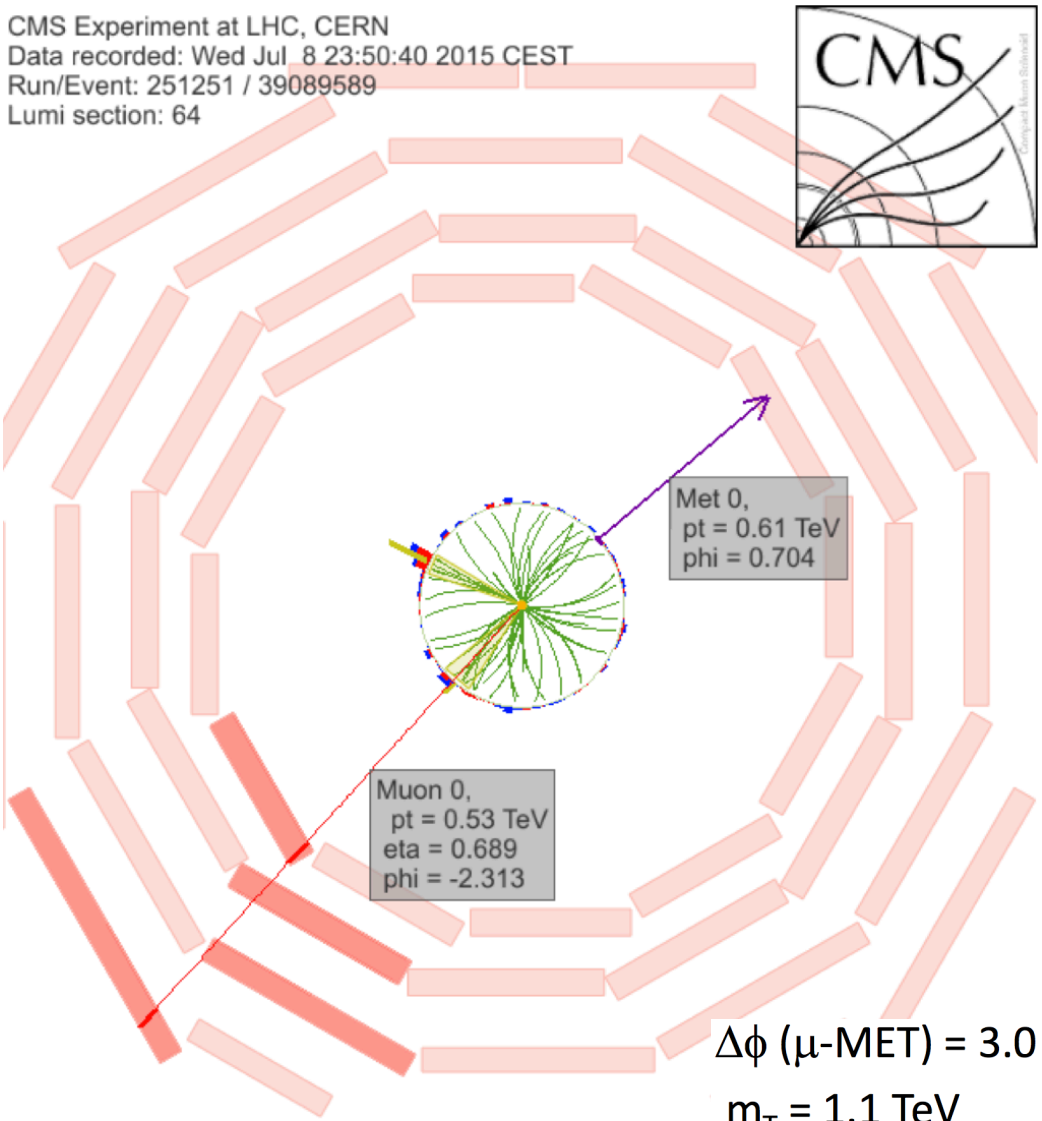




$$\rho = \frac{p}{ZeB}$$

muão + energia-em-falta + (fundo)

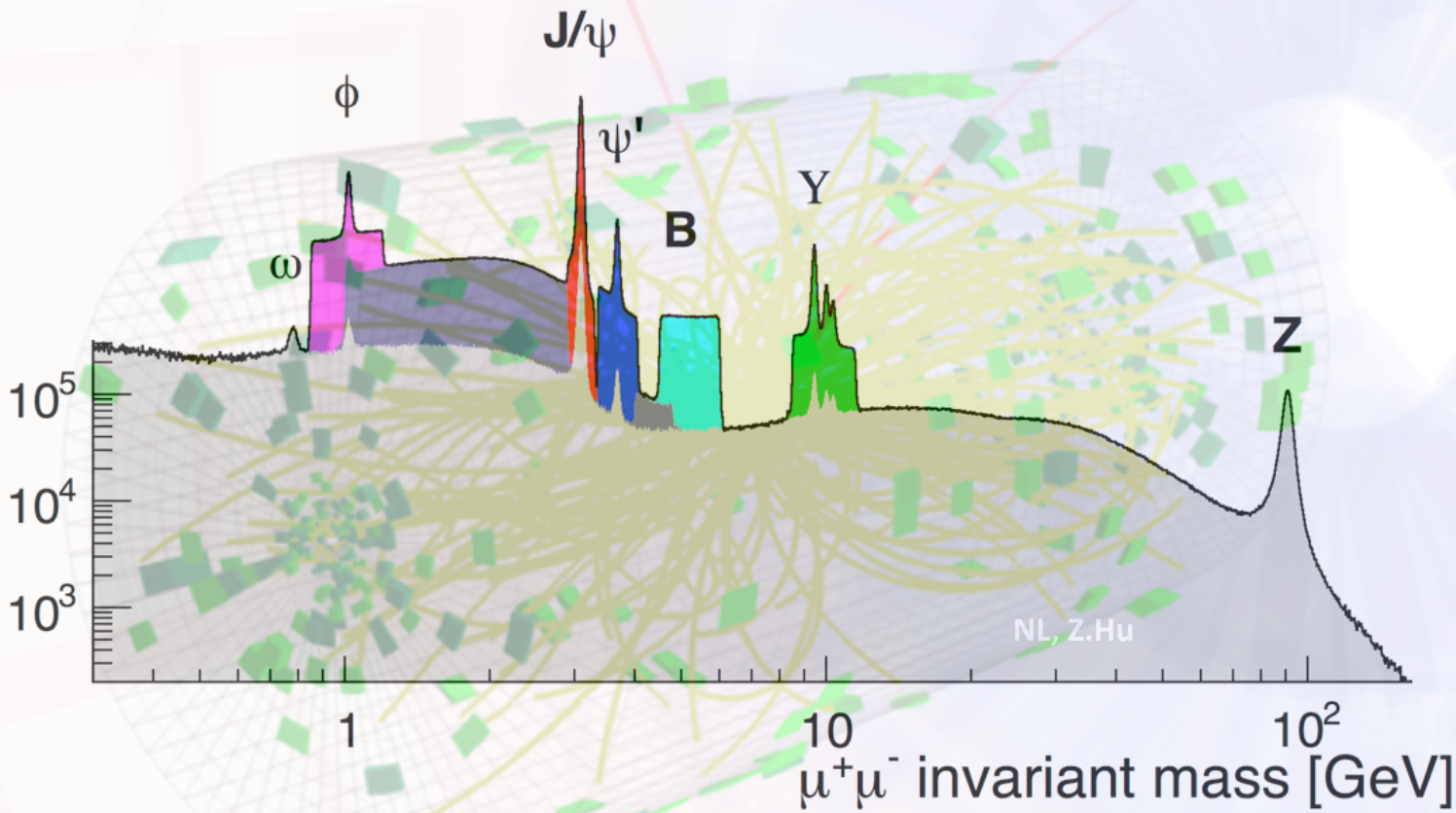


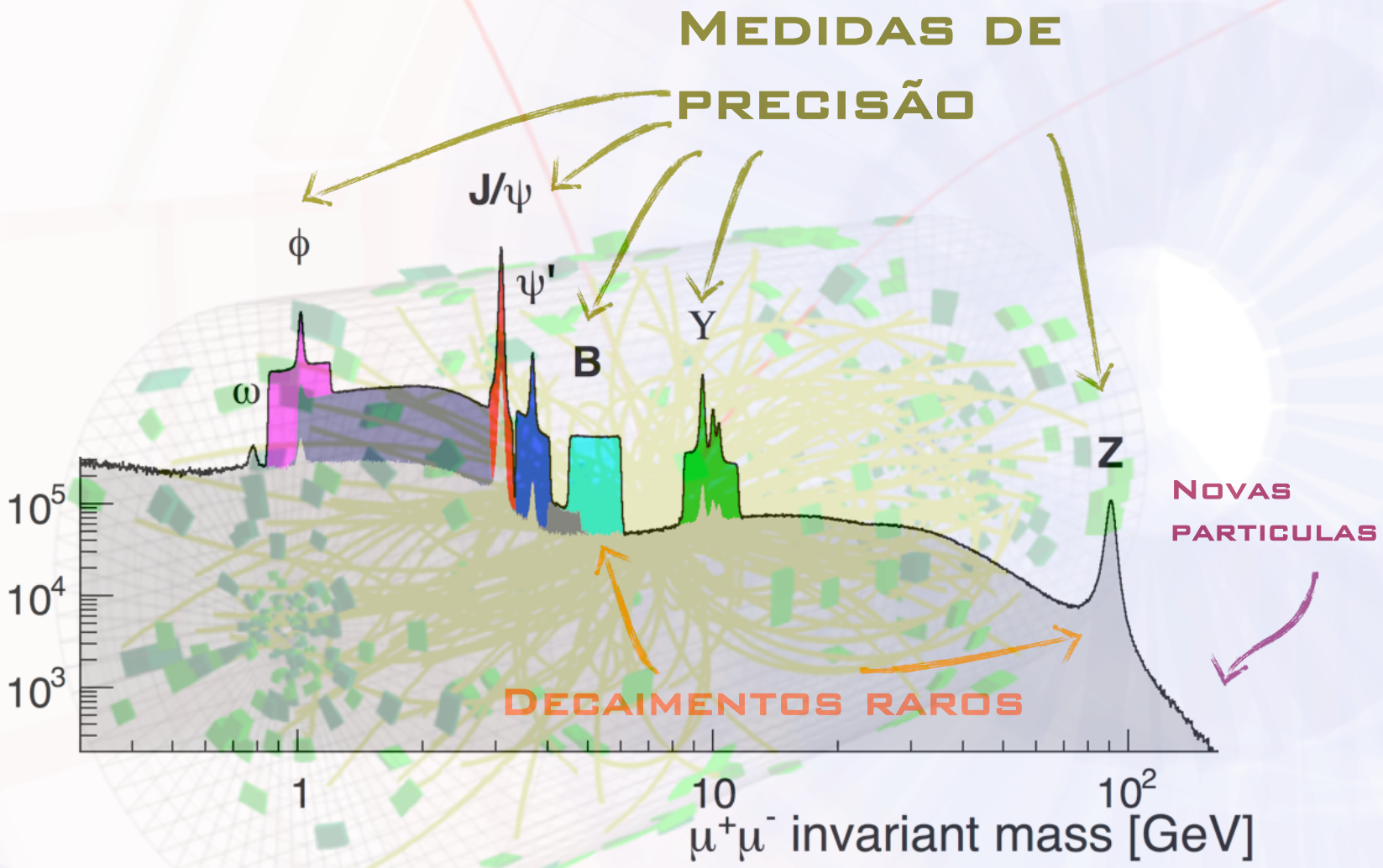


- mas … e os Neutrinos?
- os neutrinos quase que não interagem com a matéria
- São detectados indirectamente, garantindo o balanço de energia (no plano perpendicular ao feixe)
- Os neutrinos correspondem assim à energia em falta ('MET')

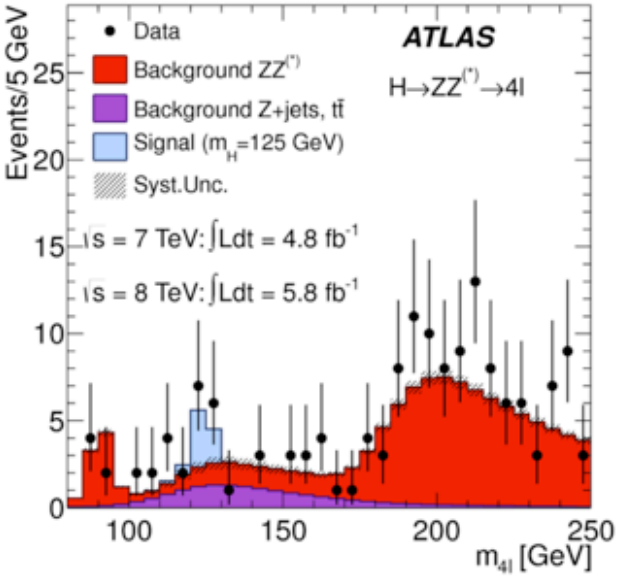
$\Delta\phi$ (μ-MET) = 3.0

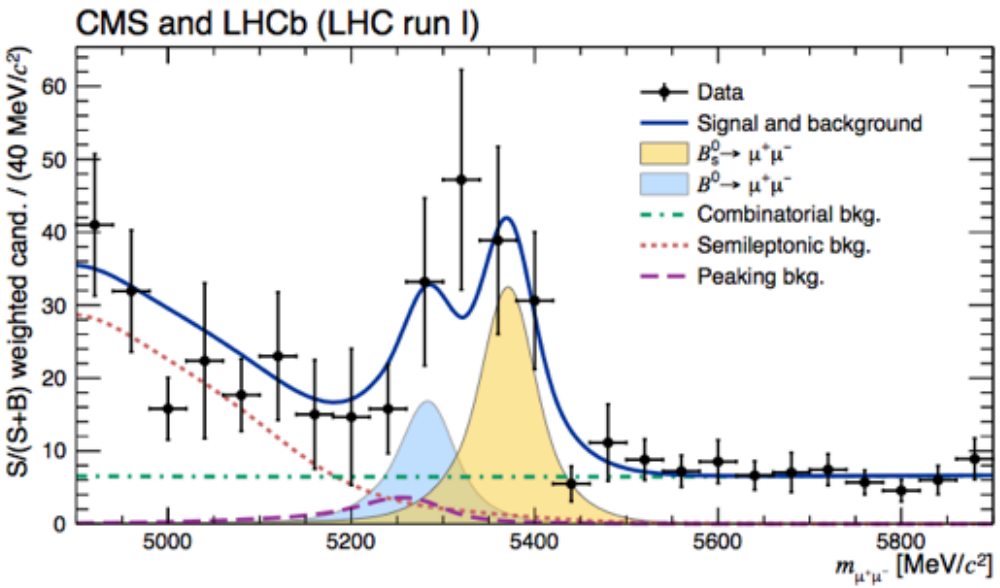
m_T = 1.1 TeV

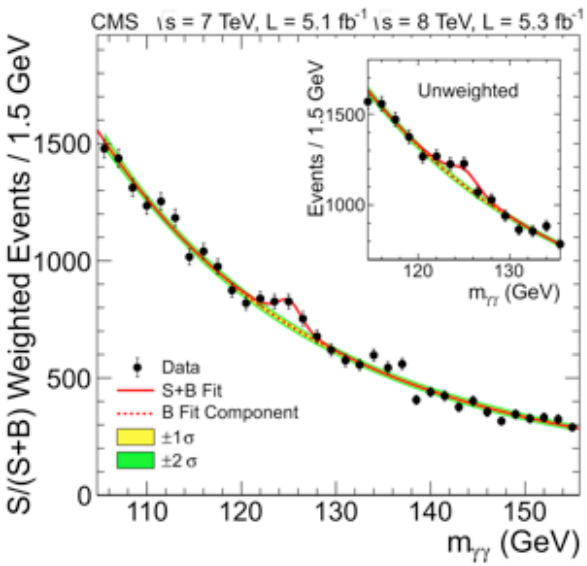

J/ψ
ϕ
ψ'
Y
B
ω
Z
10^5
10^4
10^3
NL, Z.Hu
1
10
10^2
$\mu^+\mu^-$ invariant mass [GeV]

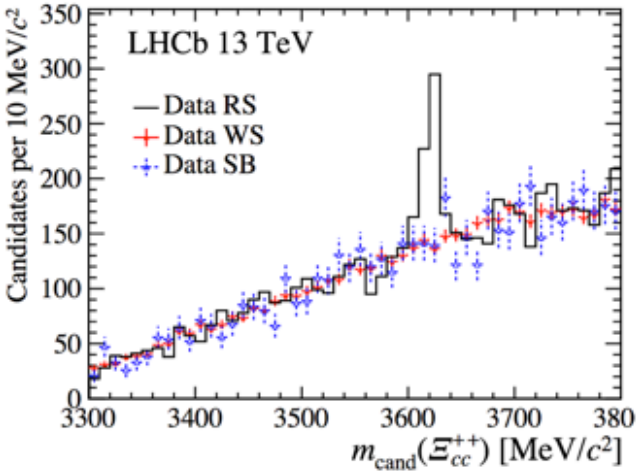

Medidas de precisão
J/ψ
ϕ
ψ'
B
Υ
ω
Z
Novas particulas
Decaimentos raros
10^5
10^4
10^3
1
10
10^2
$\mu^+\mu^-$ invariant mass [GeV]

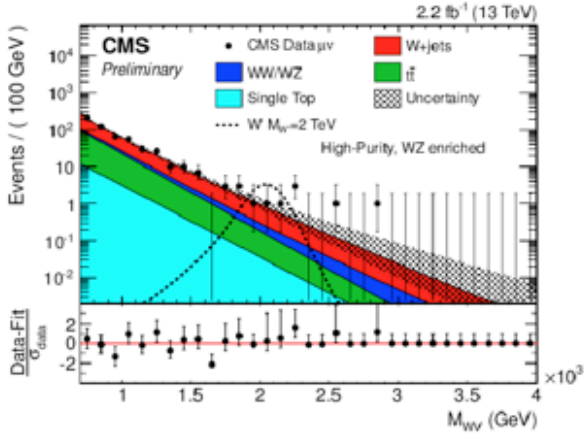
particulas novas e raras



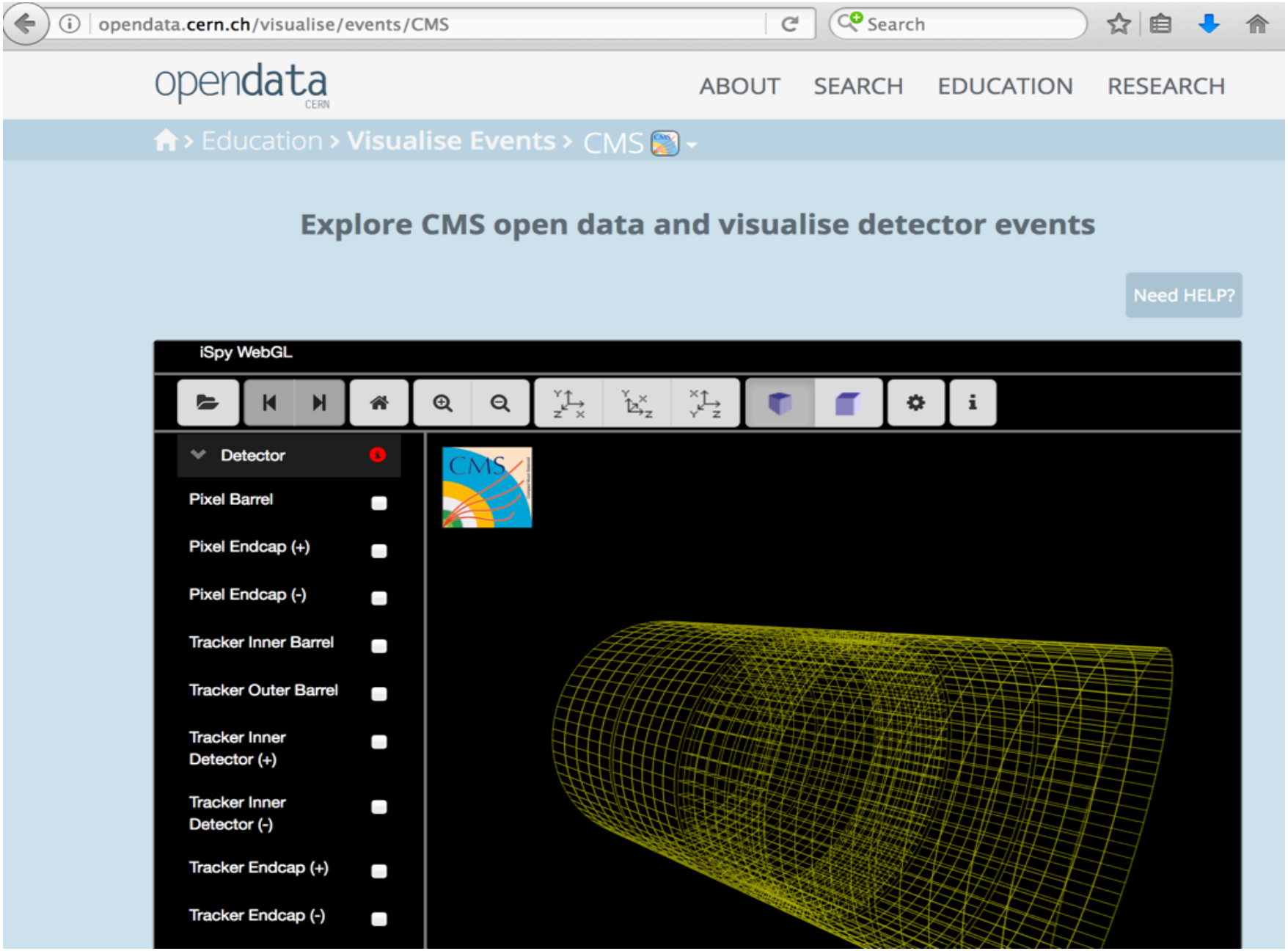


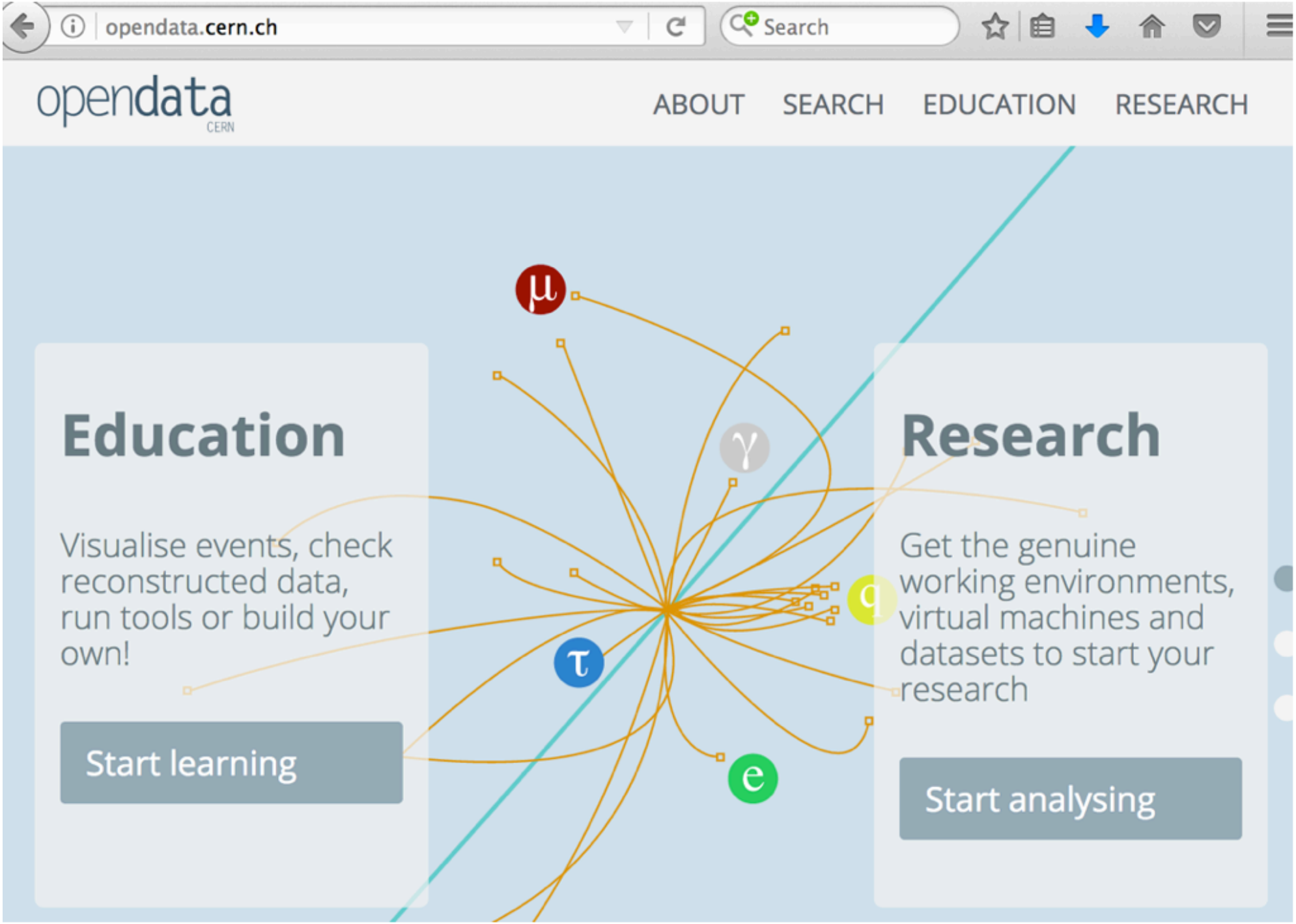






http://opendata.cern.ch/visualise/events/CMS

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Search
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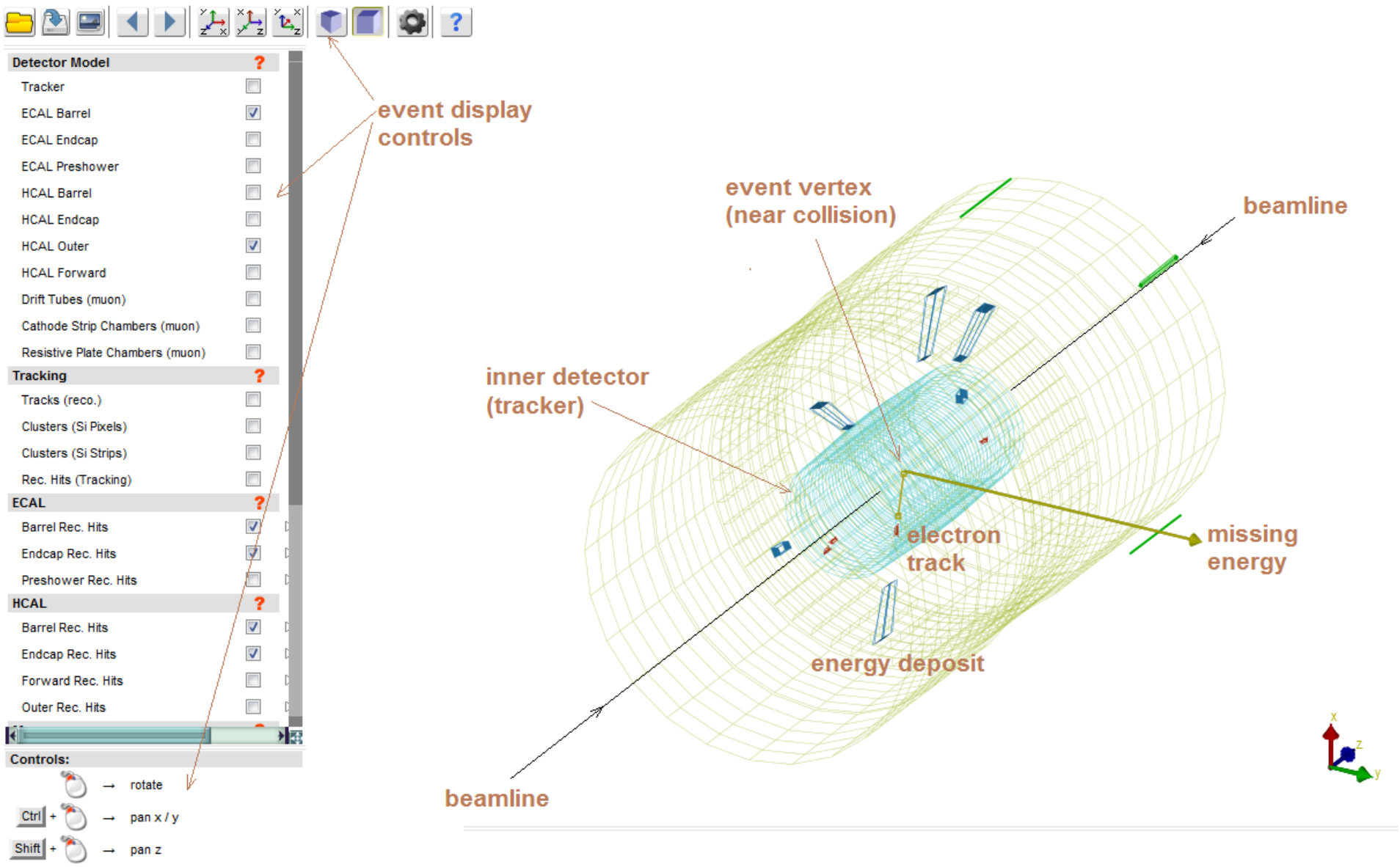
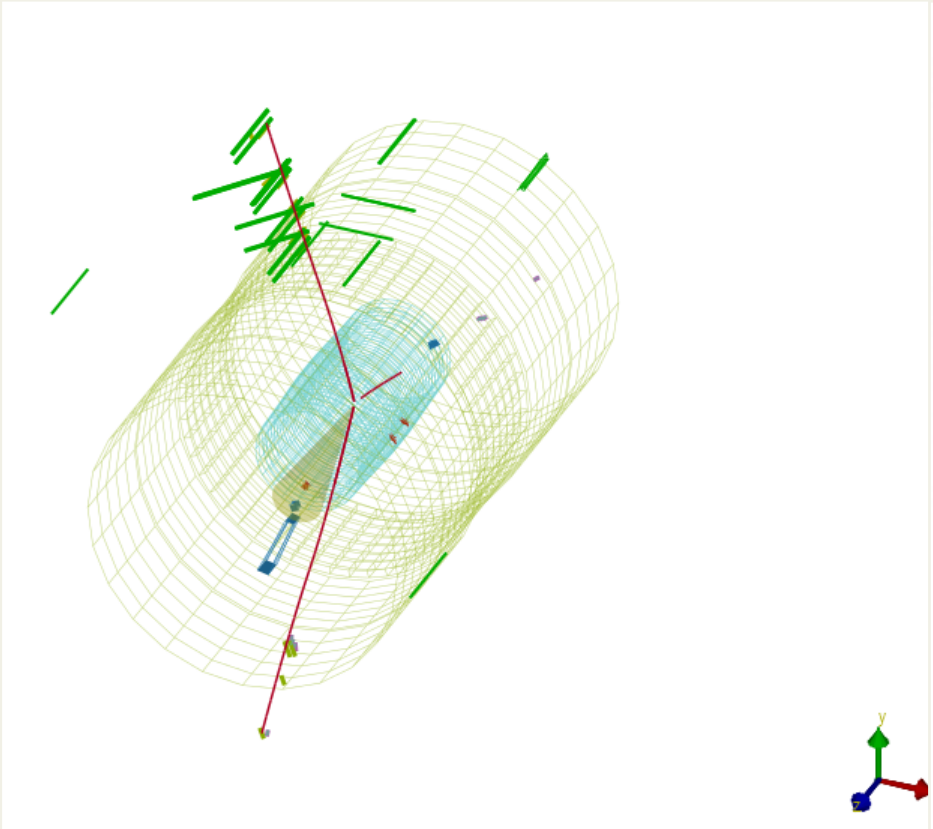
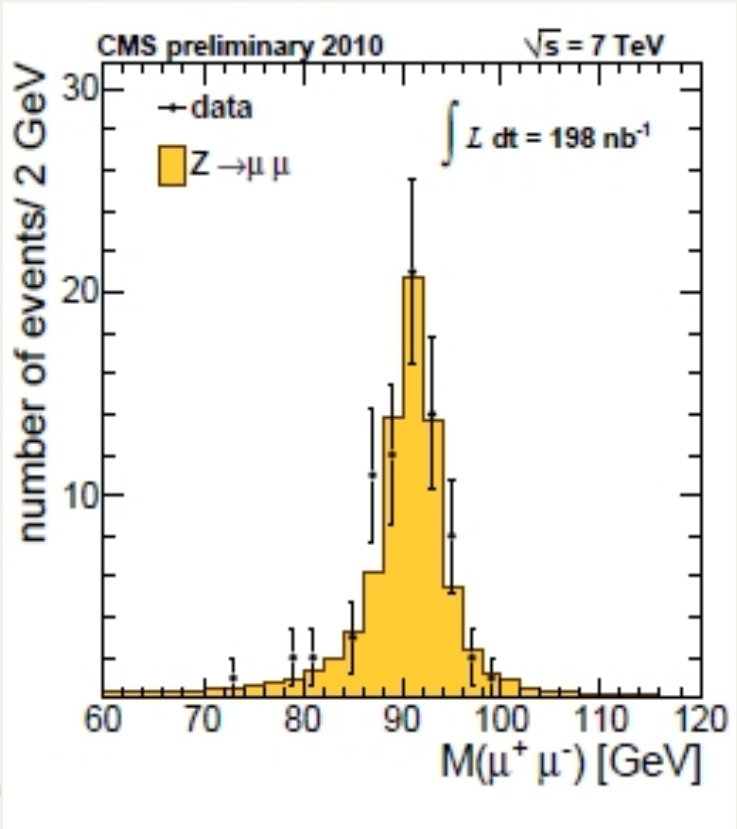
CERN
ABOUT
SEARCH
EDUCATION
RESEARCH
Education
Visualise events, check reconstructed data, run tools or build your own!
Start learning
Research
Get the genuine working environments, virtual machines and datasets to start your research
Start analysing

iSpy-Online


Detector Model
Tracker
ECAL Barrel
ECAL Endcap
ECAL Preshower
HCAL Barrel
HCAL Endcap
HCAL Outer
HCAL Forward
Drift Tubes (muon)
Cathode Strip Chambers (muon)
Resistive Plate Chambers (muon)
Tracking
Tracks (reco.)
Clusters (Si Pixels)
Clusters (Si Strips)
Rec. Hits (Tracking)
ECAL
Barrel Rec. Hits
Endcap Rec. Hits
Preshower Rec. Hits
HCAL
Barrel Rec. Hits
Endcap Rec. Hits
Forward Rec. Hits
Outer Rec. Hits
Controls:
rotate
Ctrl + pan x / y
Shift + pan z
event display controls
event vertex (near collision)
beamline
inner detector (tracker)
electron track
missing energy
energy deposit
beamline
x
z
y

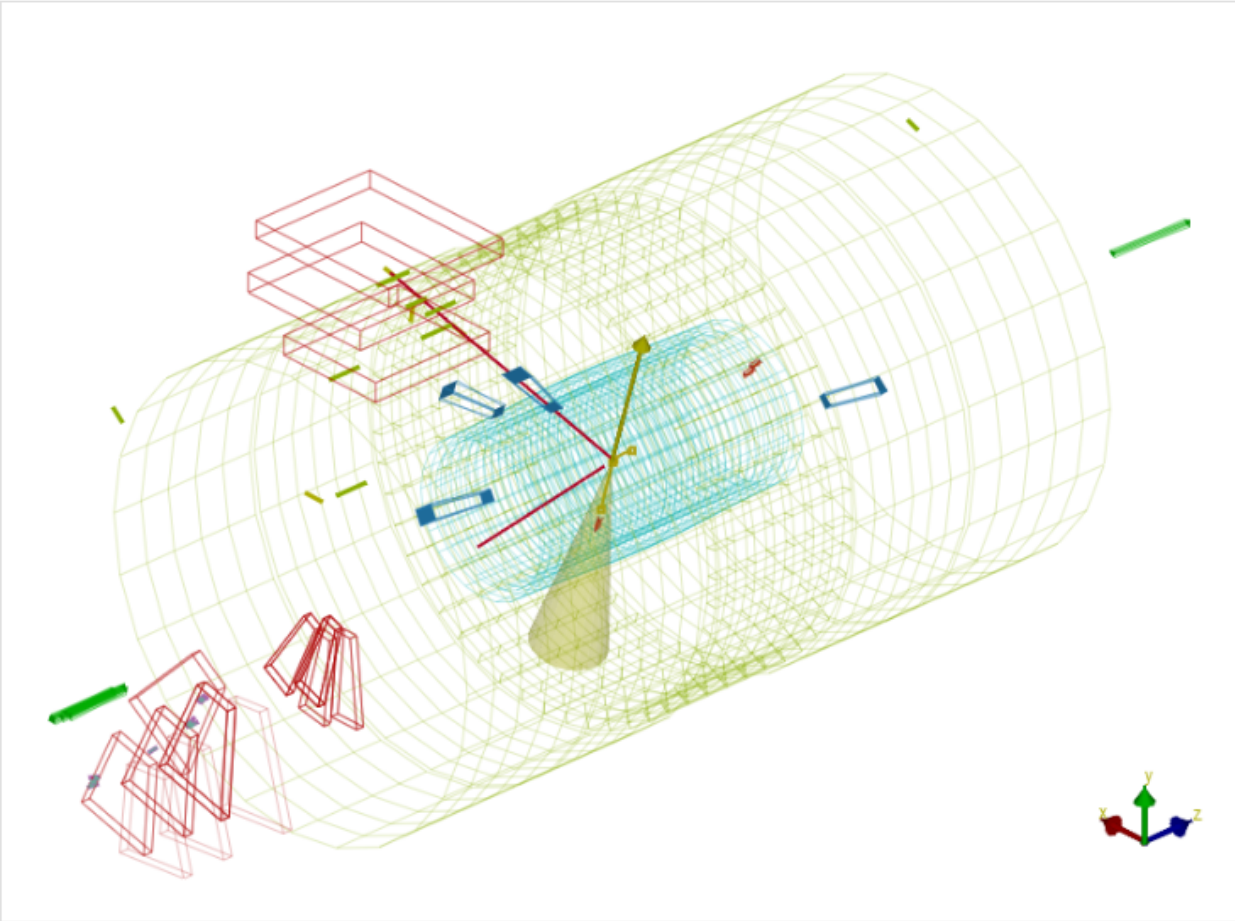
- obtendo a distribuição de massa dos candidatos Z



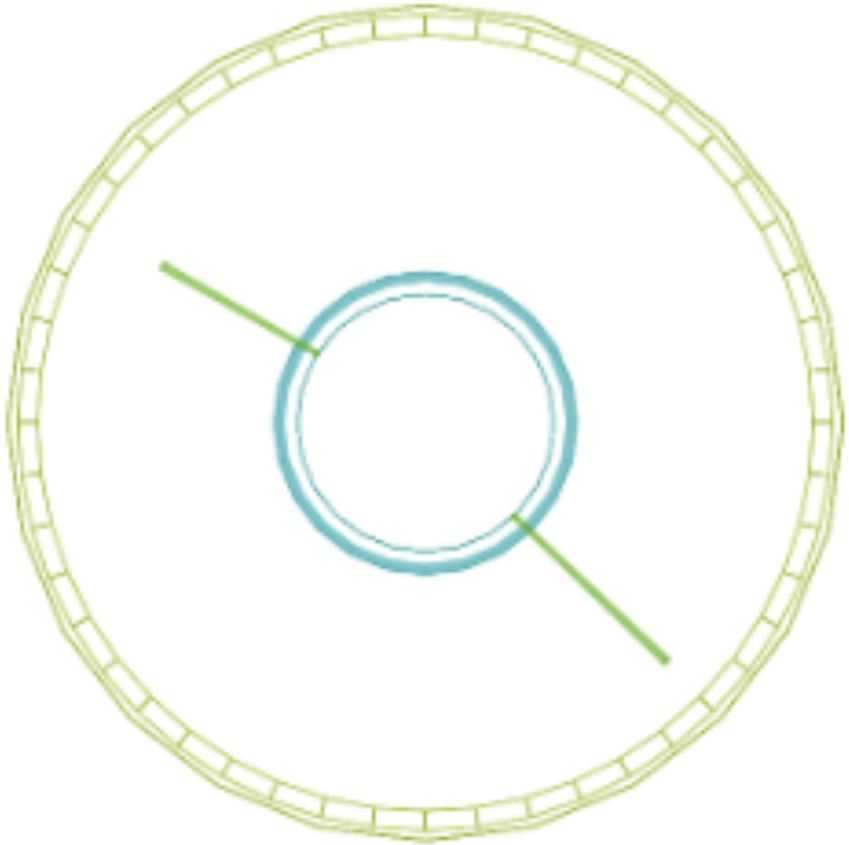


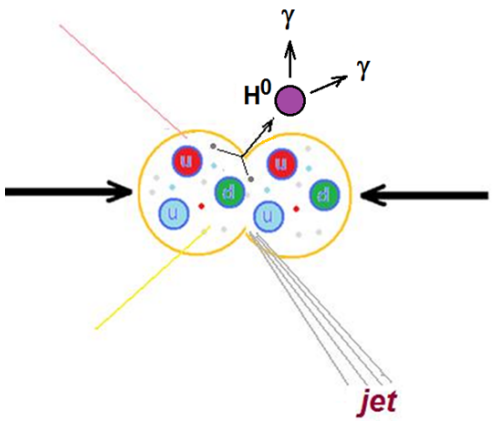
EvNo	E1	px1	py1	pz1	pt1	eta1	phi1	Q1	E2	px2	py2	pz2	pt2	eta2	phi2	Q2	M
128943239	72.89895	13.36098	-26.087	66.74727	29.3095	1.5612	-1.09746	1	37.6277	-10.9181	35.80517	-3.82334	37.3966	-0.10197	1.86677	-1	90.31227

- Busca de acontecimentos raros
- e.g. H->ZZ com Z -> $e^+ e^-$ e Z -> $\mu^+ \mu^-$



- Acontecimentos H -> γγ
  - Um dos canais de descoberta do Higgs





Depósitos de energia no ECAL,
Sem deixar sinal do traçador
(detectores de silicio)