# Introduction to CMS Open Data

Kati Lassila-Perini

Helsinki Institute of Physics (HIP)

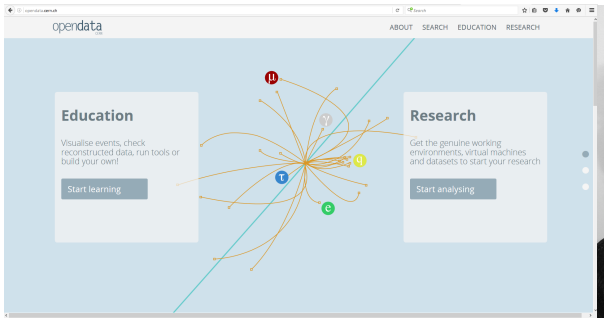
CERN 21.02.2017

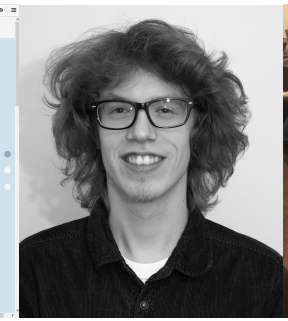
# Acknowledgements

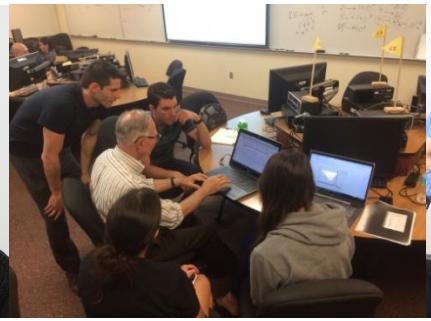
Material shown in this presentation comes from

- CERN Open Data Portal and contributors ▸ Go
- Paavo Rikkilä (a future physics teacher, trainee at CERN and HIP)
- Project coder ▸ (more)
- Working group 5 of the CERN High-School Physics Teacher course July 2016 ▸ (more)

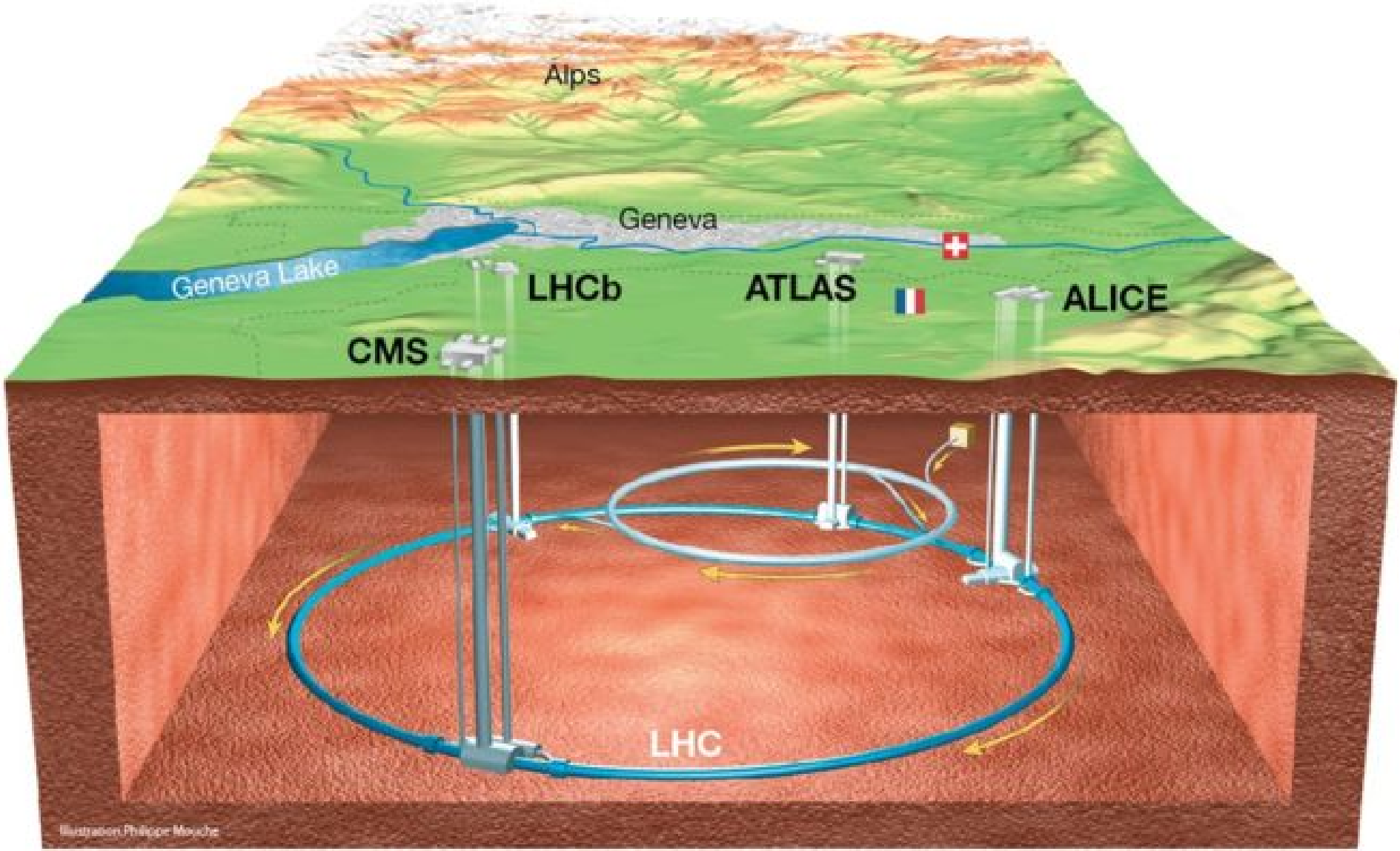
Great thanks to all of them!

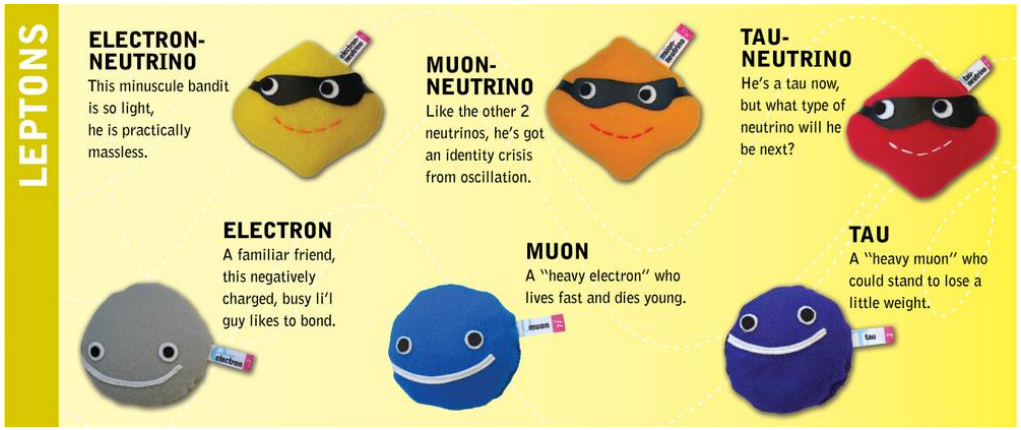


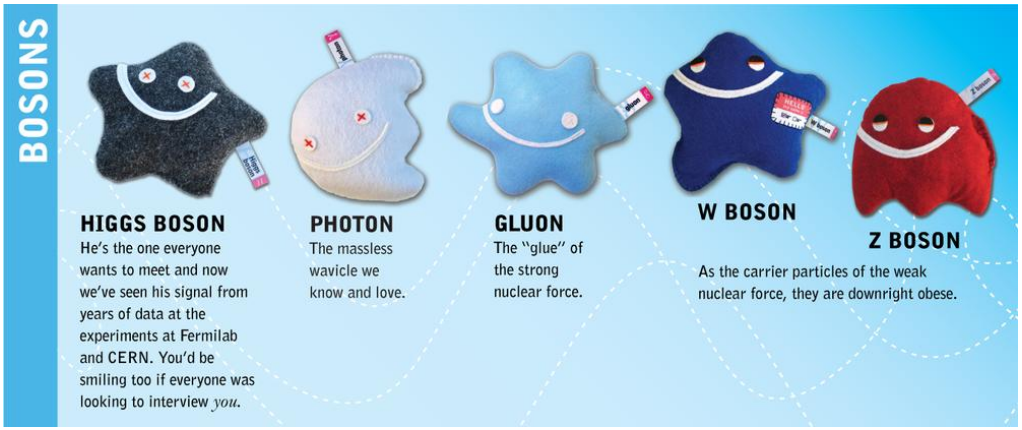





# LHC at CERN



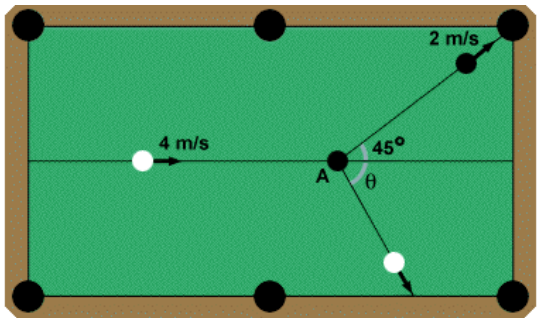




Figures: The particle zoo

# Particle collisions

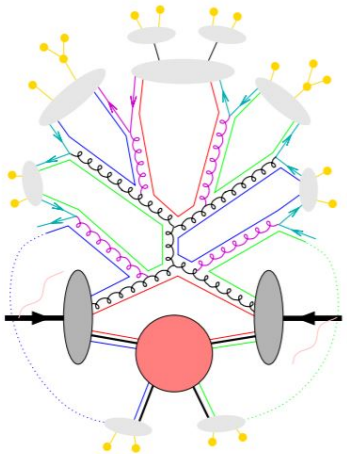
From

Photo credits: Manatari

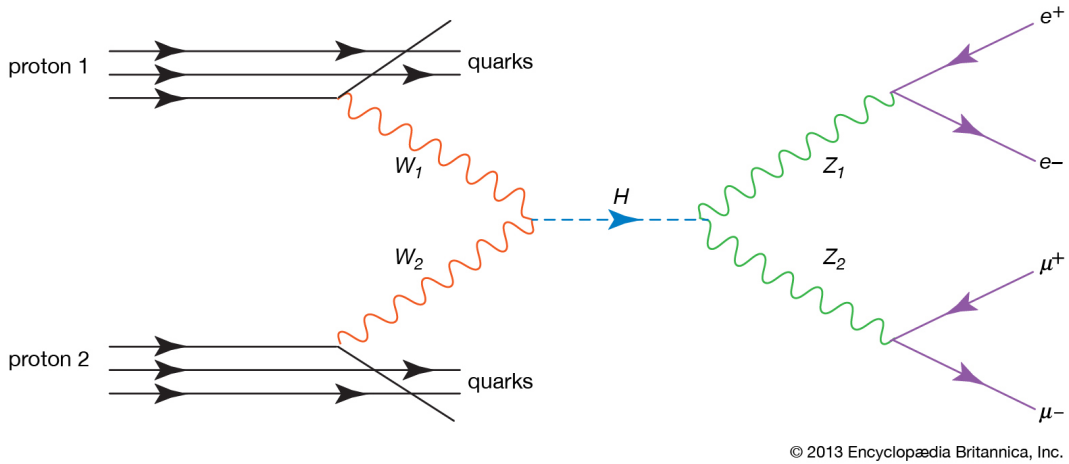



SparkNotes Editors. (n.d.). SparkNote on Linear Momentum: Collisions. Retrieved February 20, 2017,

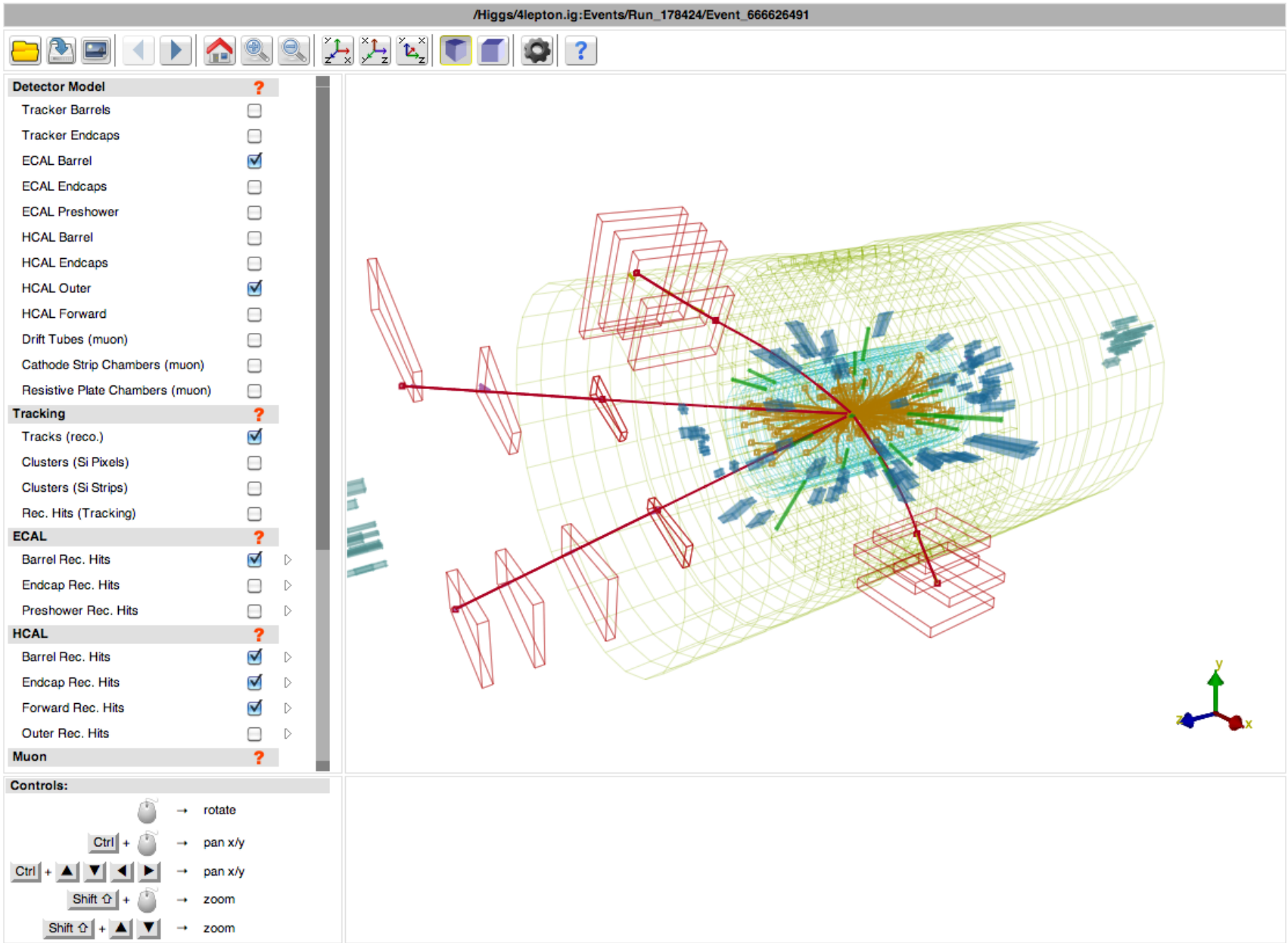
to



Zeppenfeld - Lecture



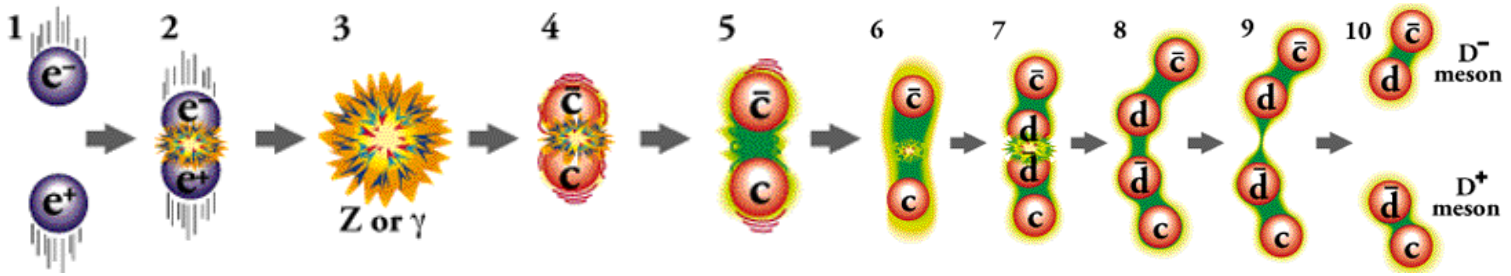

Encyclopedia brittanica


/Higgs/4lepton.ig:Events/Run_178424/Event_666626491
Detector Model
Tracker Barrels
Tracker Endcaps
ECAL Barrel
ECAL Endcaps
ECAL Preshower
HCAL Barrel
HCAL Endcaps
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
Muon
Controls:
rotate
Ctrl + pan x/y
Ctrl + pan x/y
Shift + zoom
Shift + zoom

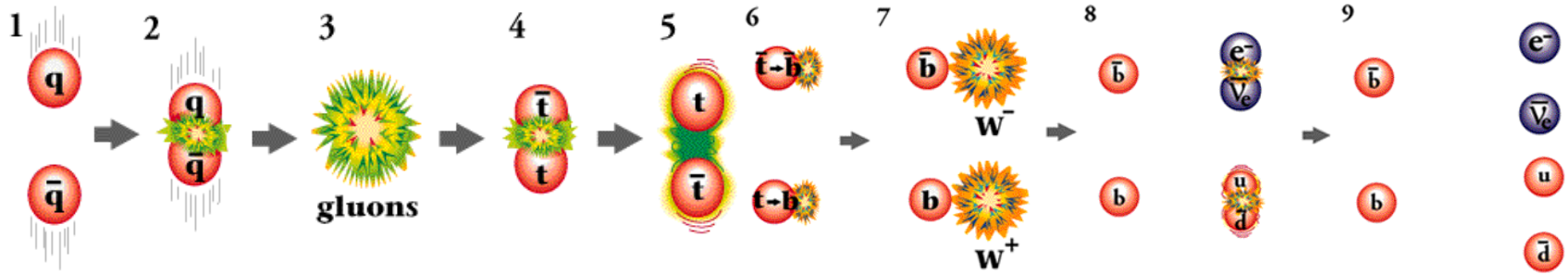
# What happens in a collision?

Examples:

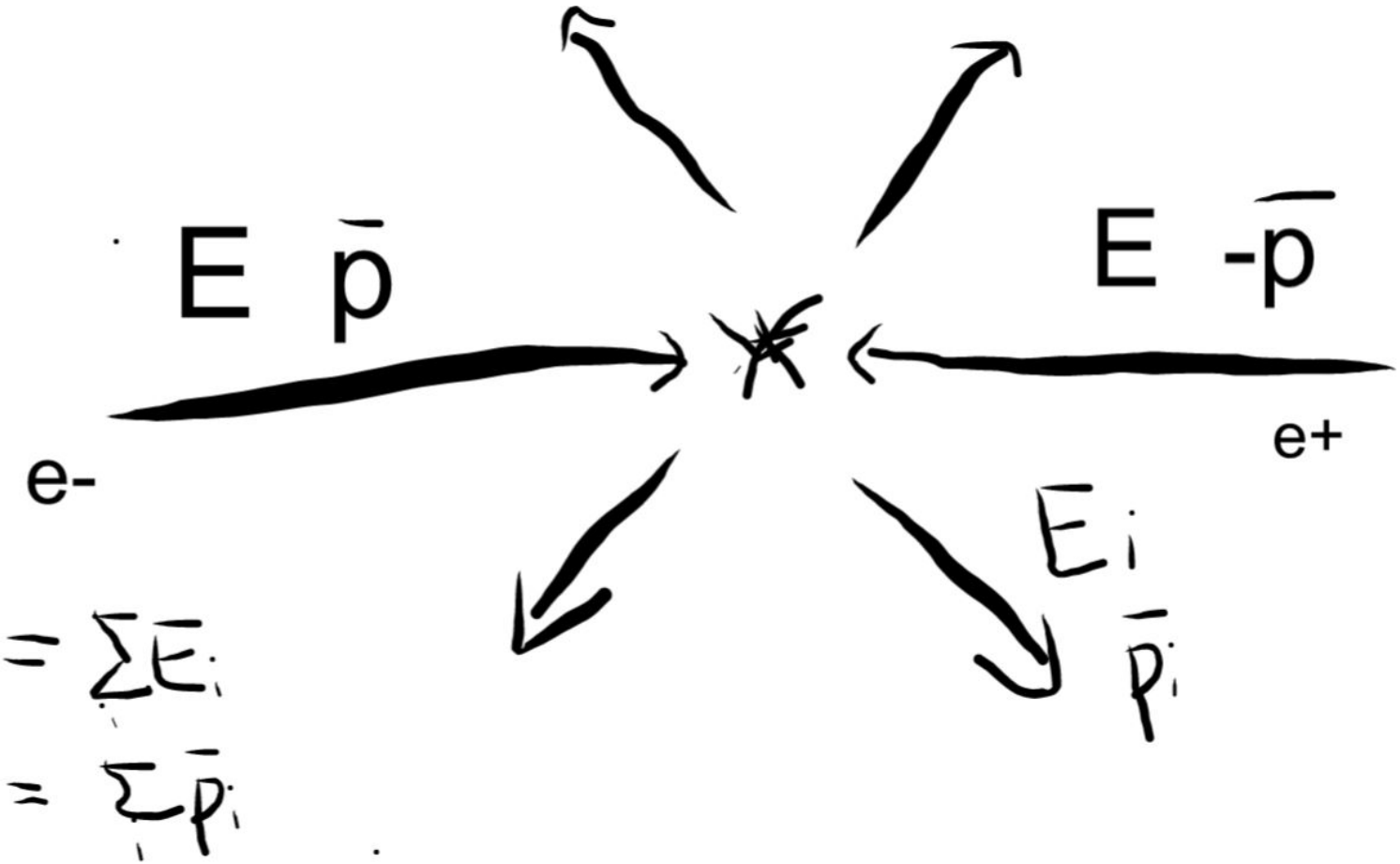
- Electron-positron collision




- Proton-(anti)proton collision

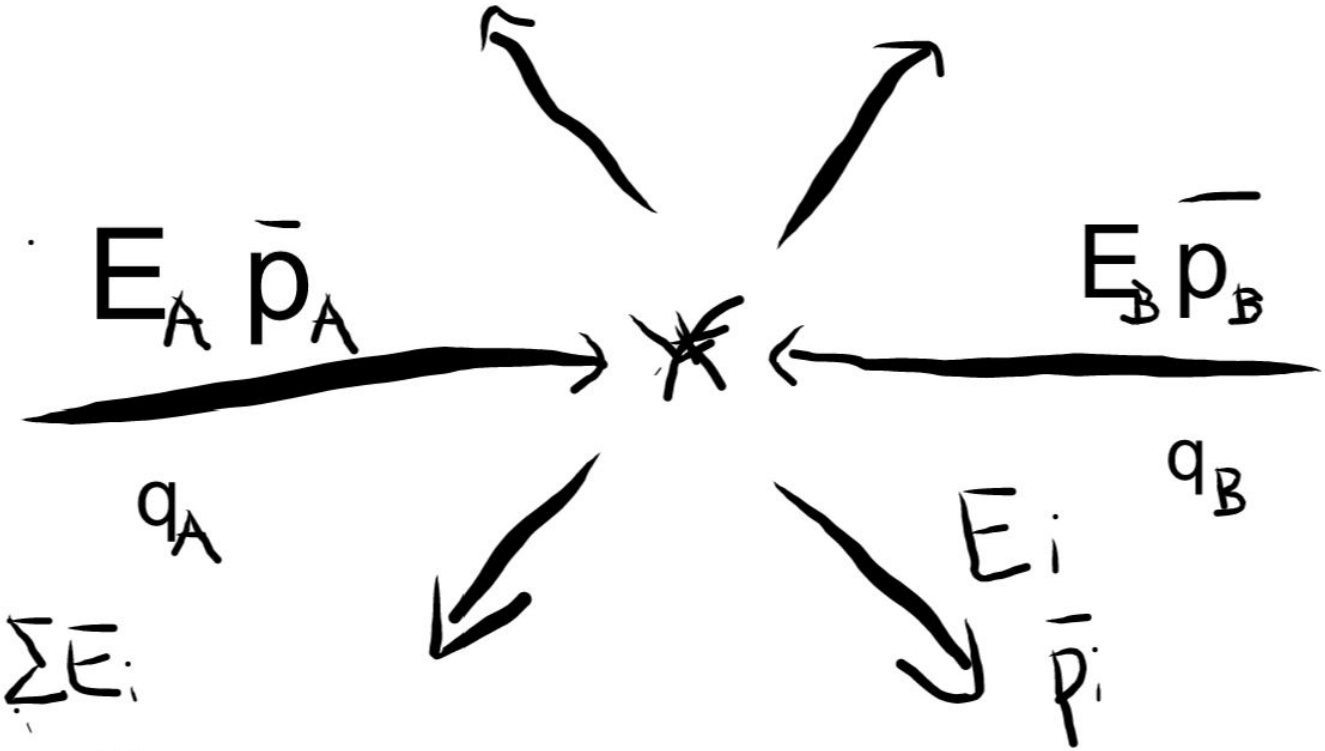



Figures: The Particle Adventure



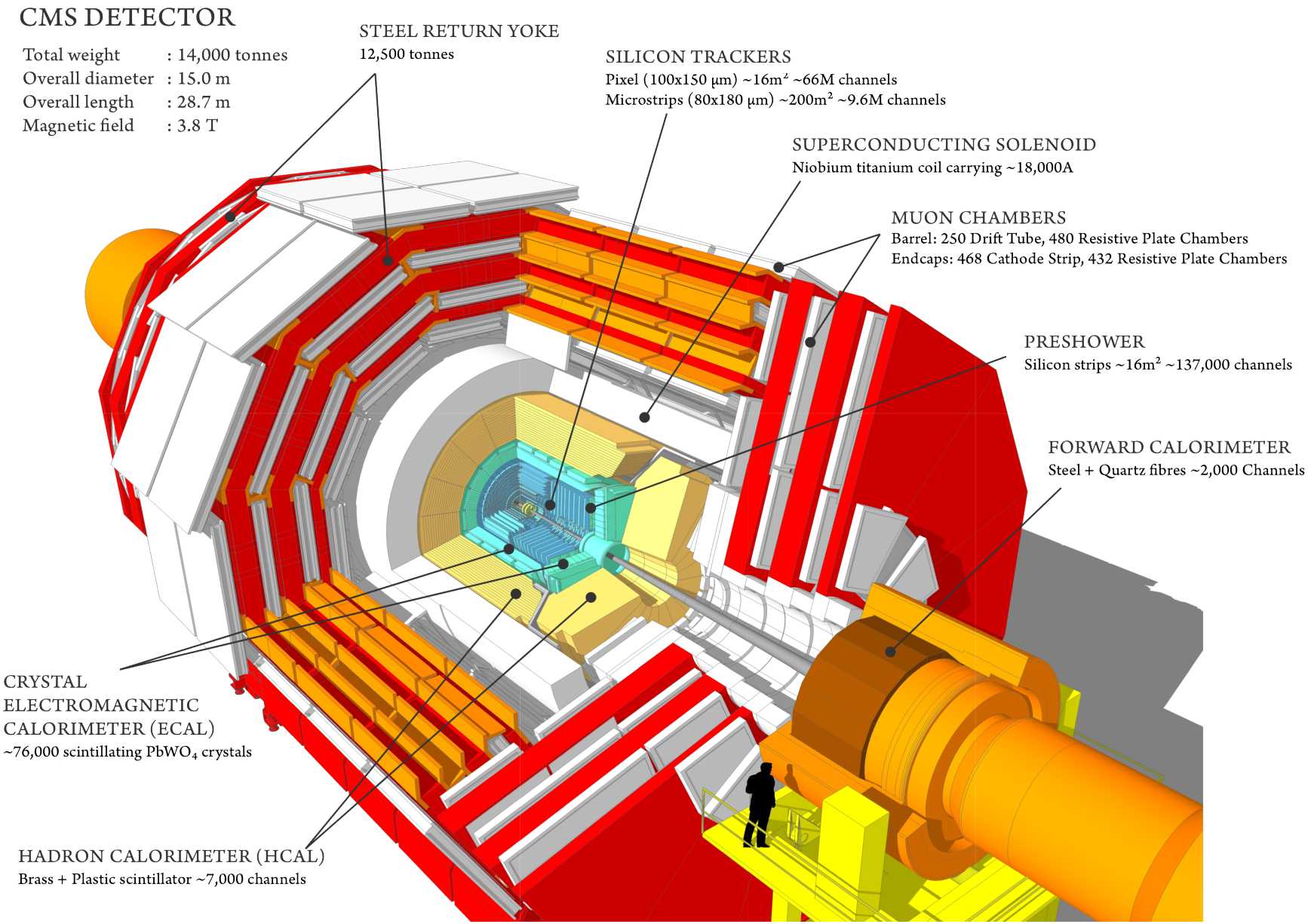

$$2E = \sum E_i$$

$$0 = \sum \vec{p}_i$$

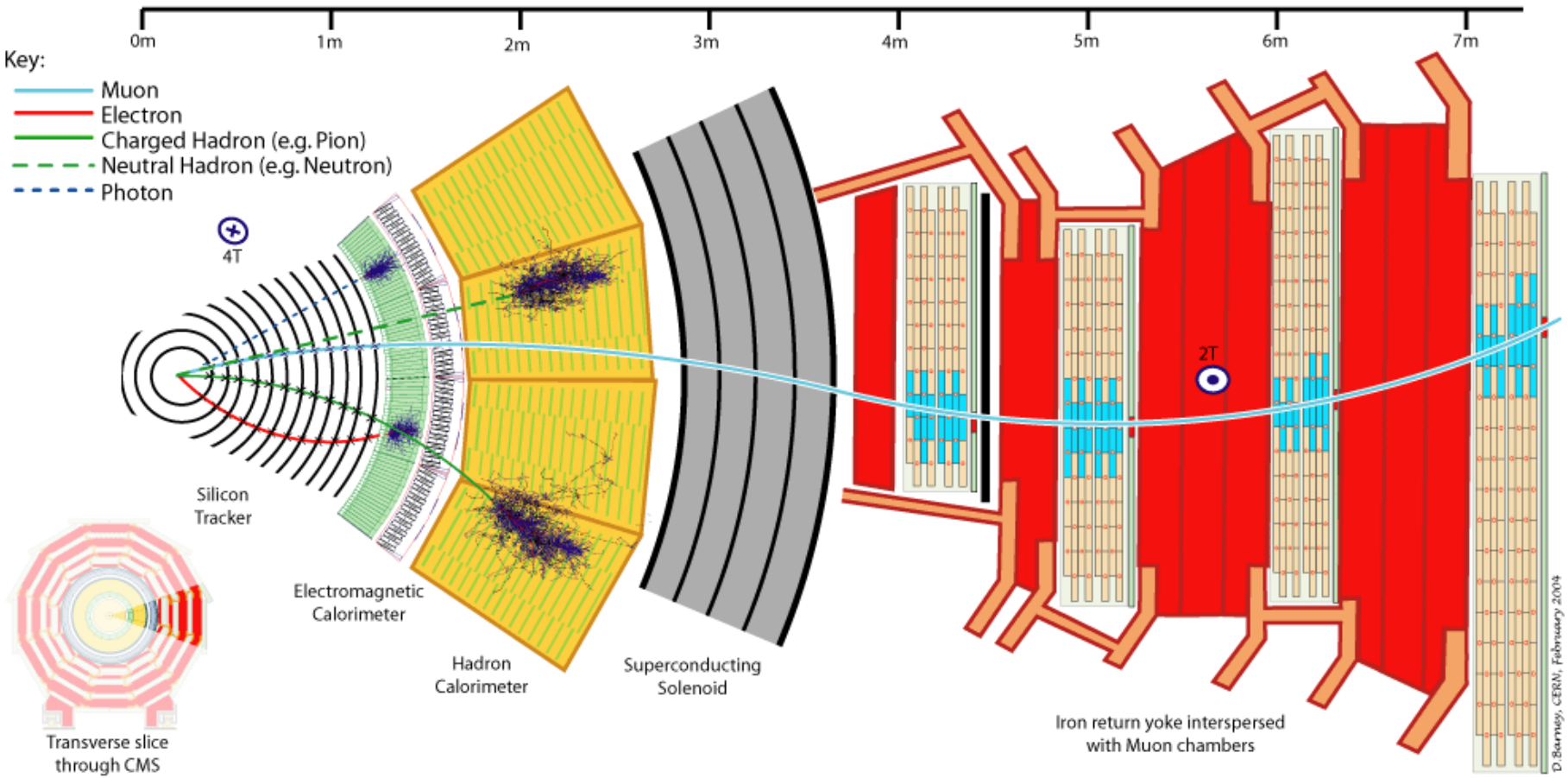



$? = E_A + E_B = \sum E_i$

$? = \bar{p}_A + \bar{p}_B = \sum \bar{p}_i$

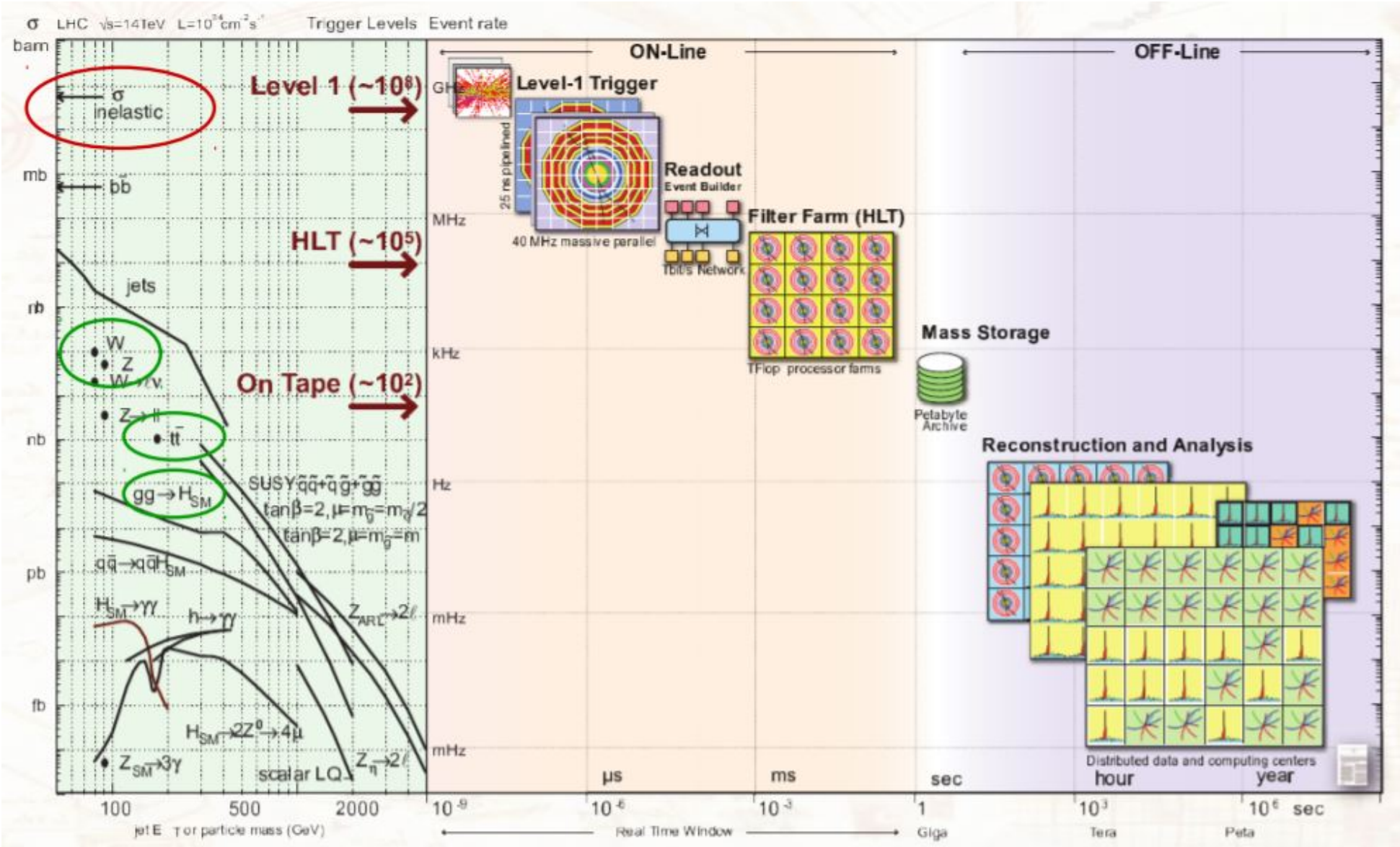

CMS DETECTOR
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T
STEEL RETURN YOKE
12,500 tonnes
SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels
SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers
PRESHOWER
Silicon strips ~16m² ~137,000 channels
FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating PbWO4 crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

# How do we detect particles?



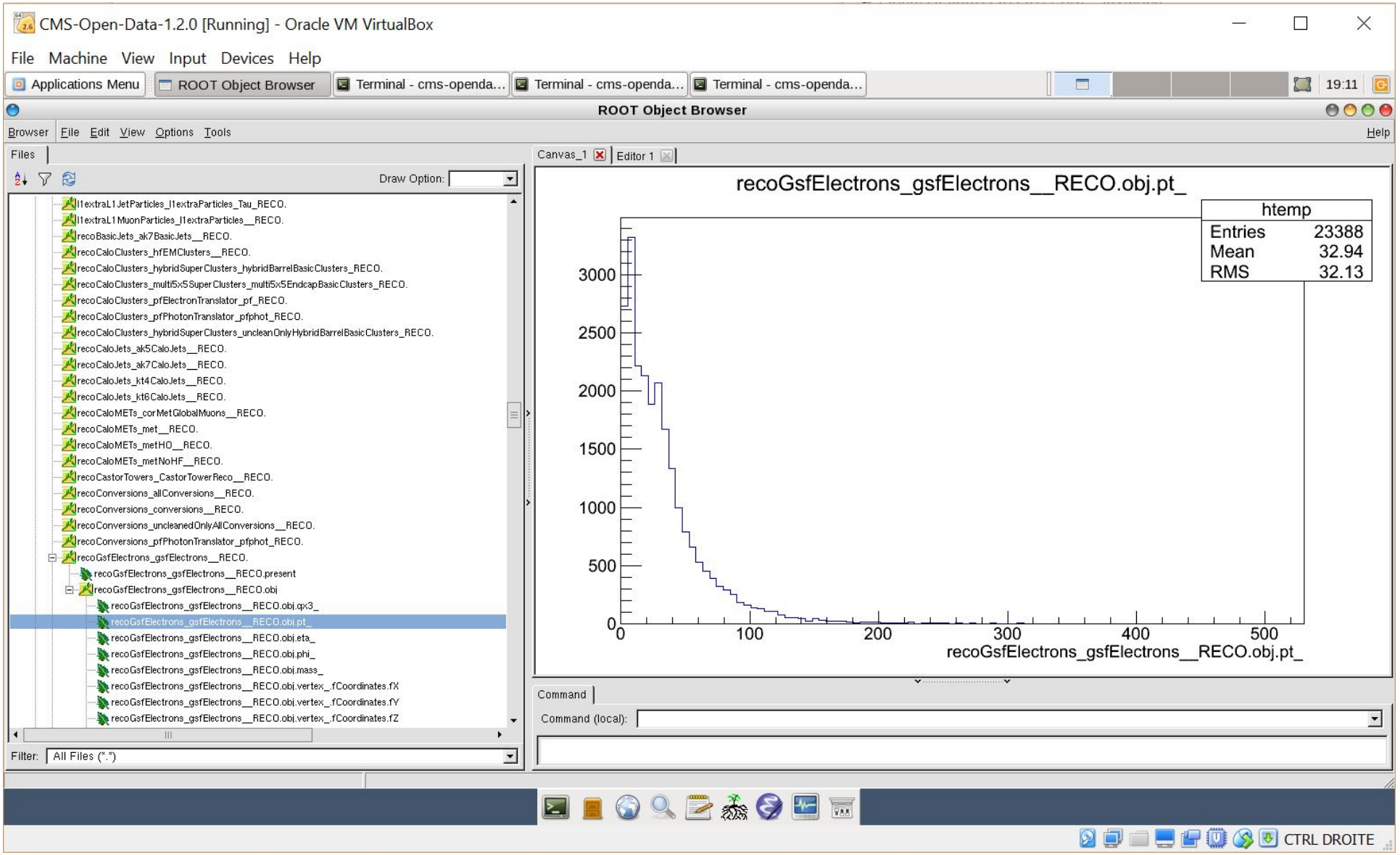

▸ Interactive view

# How do we get the data?




Andrea Bocci - Triggers for LHC Physics

# What do the data look like?



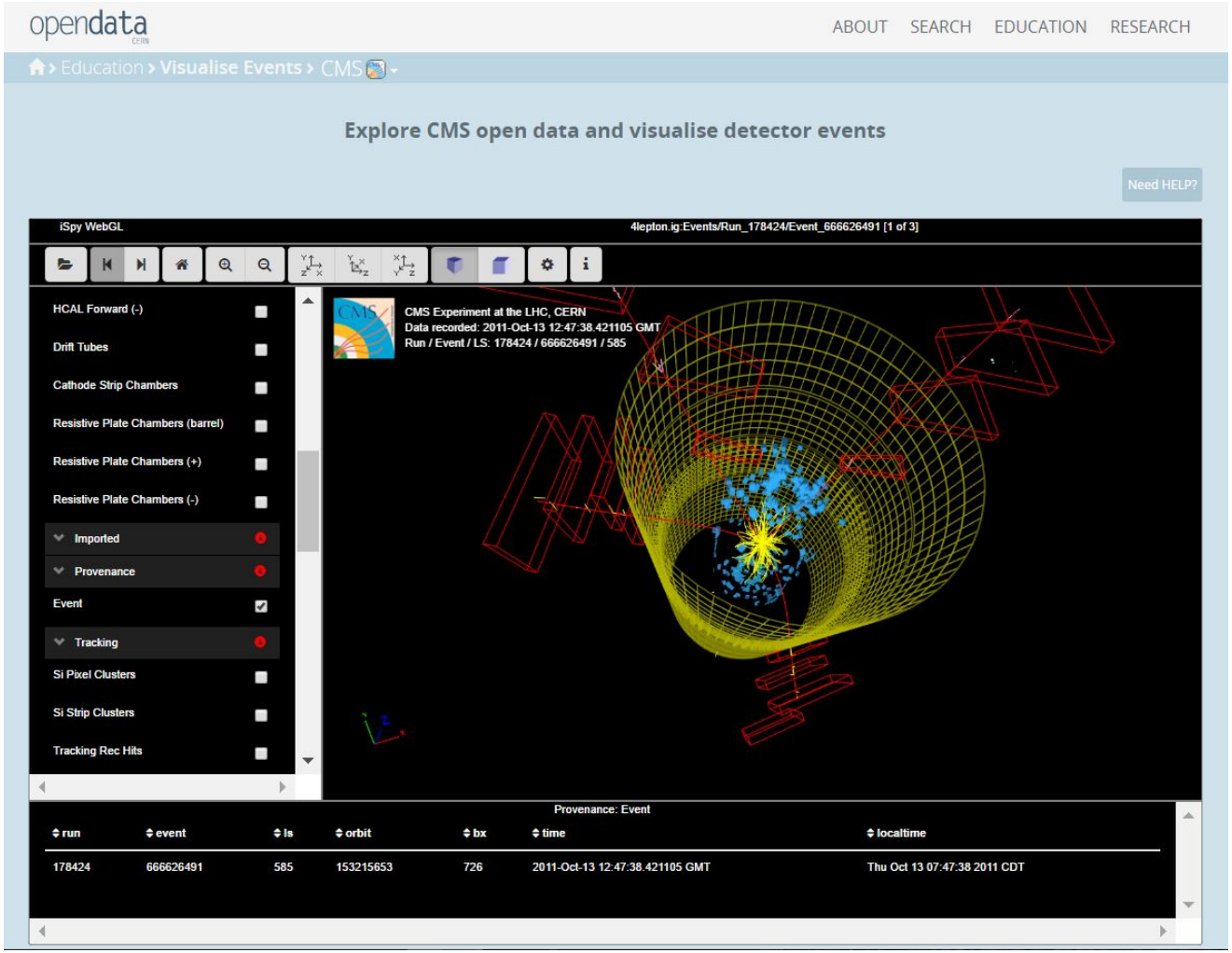
# How can **you** look at the data?

1. Visualize particle collisions: ▸ Go
   - Immediate, right in your browser, possibly in your phone
   - Minimum time 15 min
   - Any level
2. Study simplified data derived from the original data
   - Use spread-sheets, scilab, or python in jupyter notebooks
     - ★ ▸ Teachers ▸ Excel for students ▸ Excel instructions ▸ SciLAB instructions
     - ★ ▸ Getting started with Jupyter ▸ Learning material in Finnish
   - Minimum time estimated 1.5 hours, for a quick online view: ▸ Go
   - High-school level
3. Analyse data like a physicist
   - Download the virtual machine image ▸ Go
   - Run an example code (C++, python) ▸ Go
   - Minimum time <1 hour to get started (copy-paste), but much longer to learn about data analysis
   - University level

# Some important concepts for particle data analysis

- We search and/or measure short-lived particles which cannot be directly observed
  - Observe their decay products.
- Rely on quantities that stay constant (initial state - final state):
  - Conservation laws (energy - momentum)
  - Invariant mass: $m = \sqrt{(E_1 + E_2)^2 - |\vec{p_1} + \vec{p_2}|^2}$
- Many similar or similar looking signatures
  - Signal - background
  - Examples: Higgs boson decaying into ▸ two photons ▸ four leptons
- Statistical analysis requires a lot of data.

# Getting started with the event display




- Tutorial
- Activities
- Go