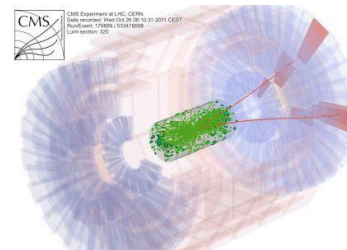




Useful Concepts and Tools

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USCMS Workshop on Open Data at UCF

June 15-17, 2016

Outline



- **Python**
- **ROOT**
- **CMS Detector**
- **Relativity and Kinematics**

Python



Python:

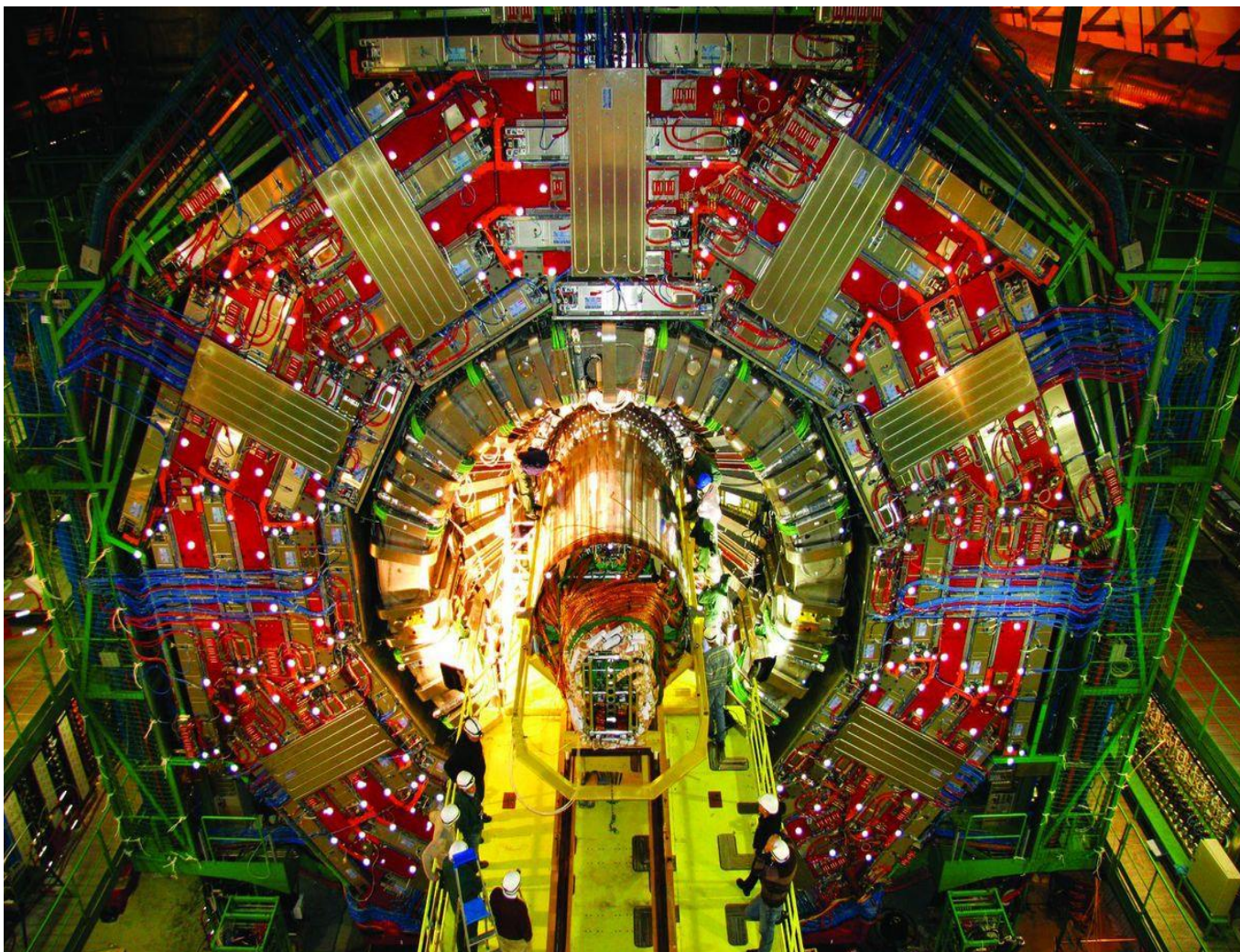
- **High level, general purpose programming language**
- **Very easy to get started with**
- **Very readable**
- **Less code compared to C++/Java**

ROOT:

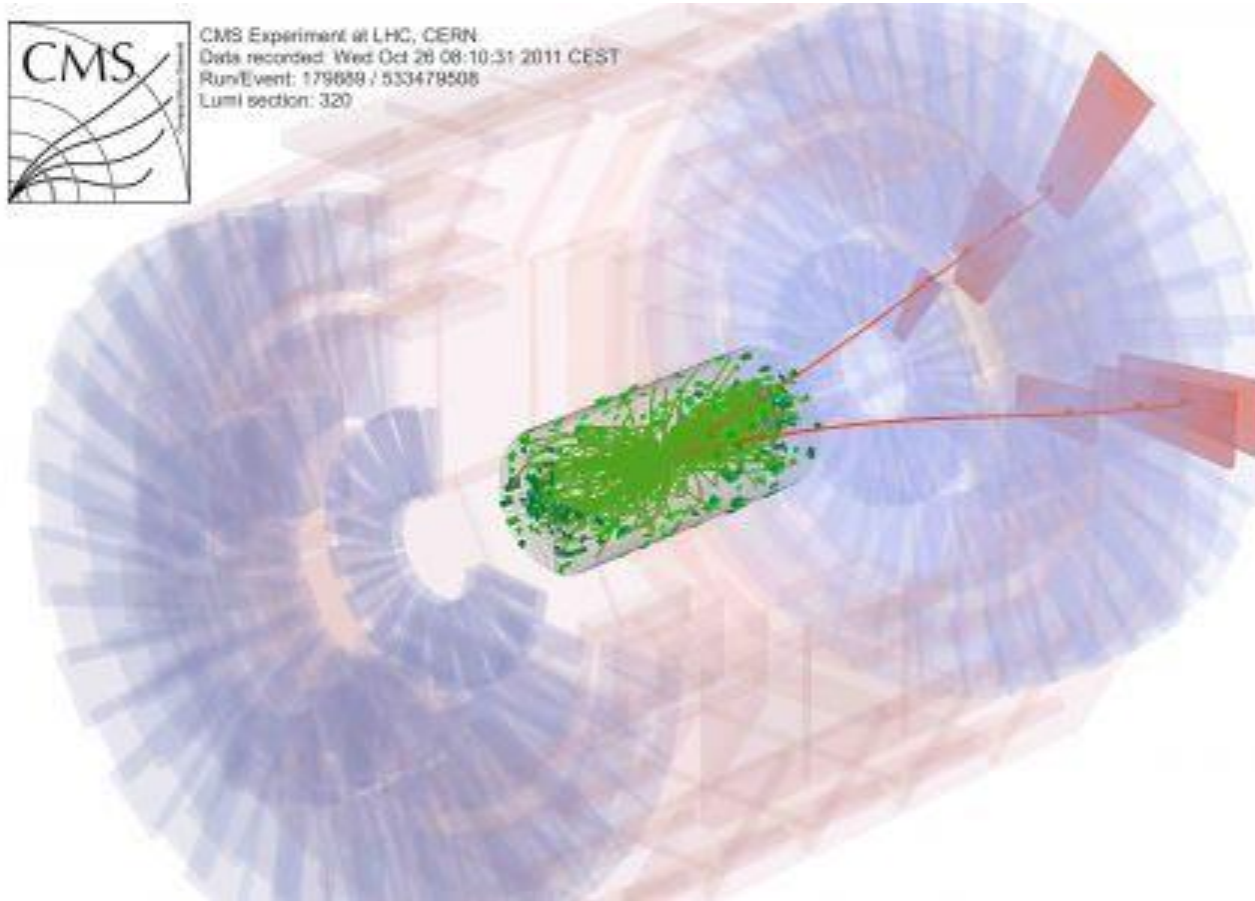
- **Software to analyze particle physics data**
- **Optimized for large datasets**
- **Histograms, statistical tools**
- **<http://root.cern.ch>**



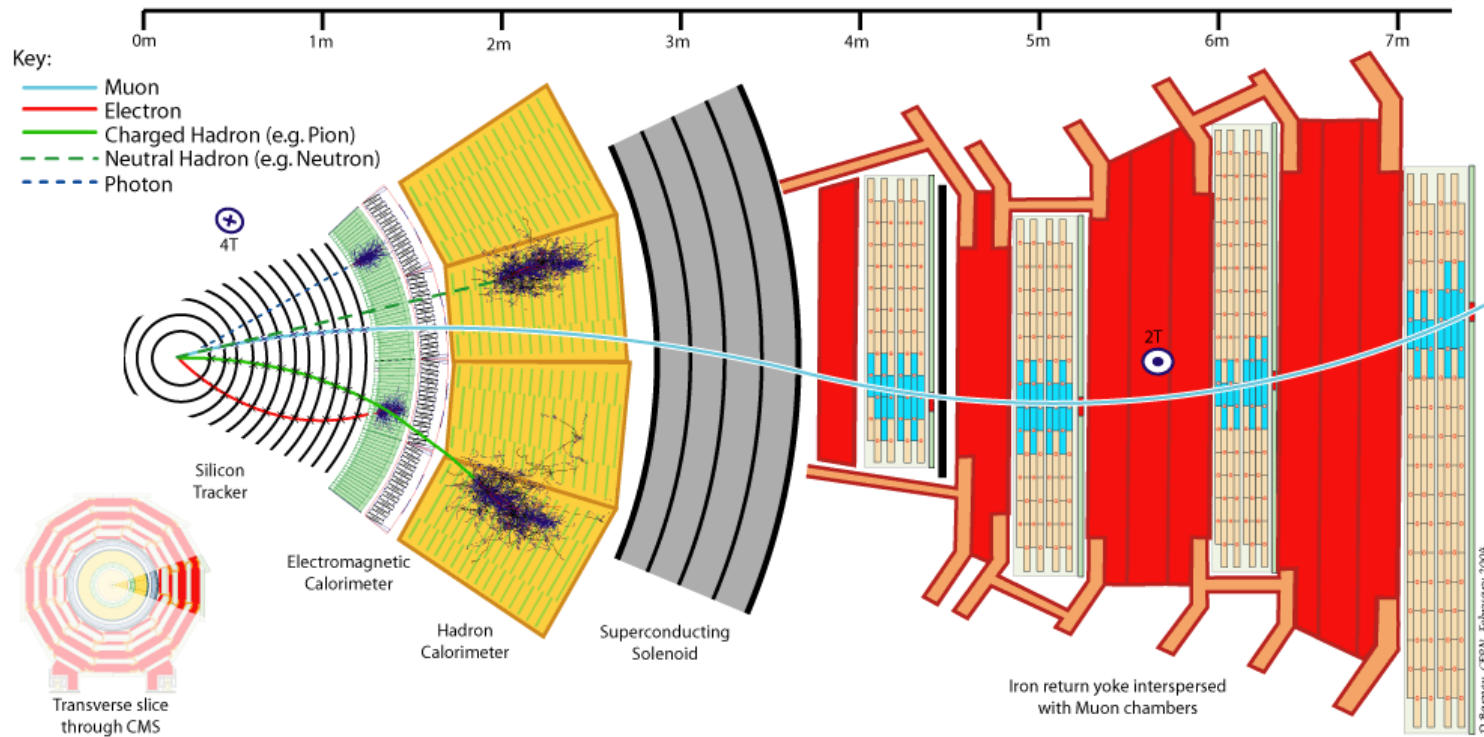
CMS Detector



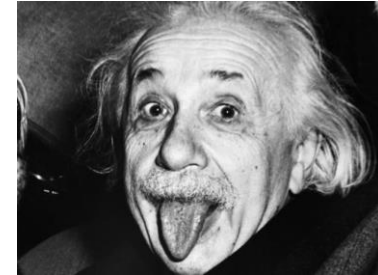
CMS Event



CMS Detector



In 1905 **Albert Einstein** derived
Theory of Relativity from a simple
idea



- **speed of light (c) is constant** in all inertial frames of reference

Consequences:

- Describe **particle location** as 4-vector: (t, x, y, z)
- Describe **particle momentum** as 4-vector: (E, p_x, p_y, p_z)



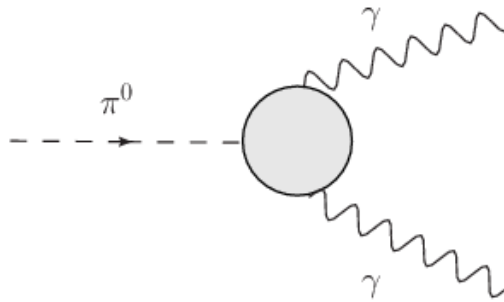
Product of two **4-vectors** is independent of coordinate system

- $E^2 - p^2 =$ **invariant quantity**
(invariant mass)

Particle Decays



Consider particle **X** that decays into two particles (γ and γ)

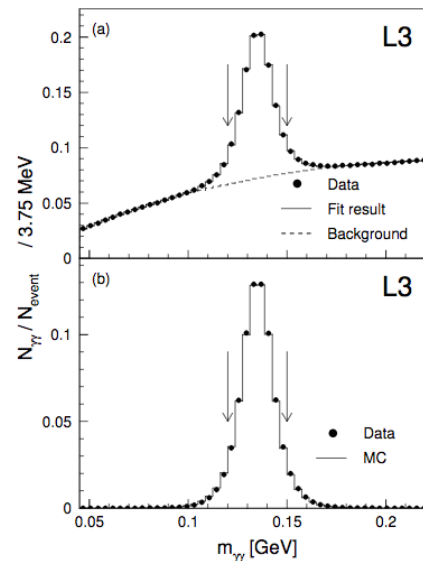


Conservation of energy-momentum implies:

- particle **X**'s mass = invariant mass of its **decay products**

Therefore expect to see a **narrow spike** in the **invariant mass** distribution where particle **X** is

- If γ and γ are born independently expect a broad mass spectrum without any spikes



Higgs Boson

