

The CMS Detector

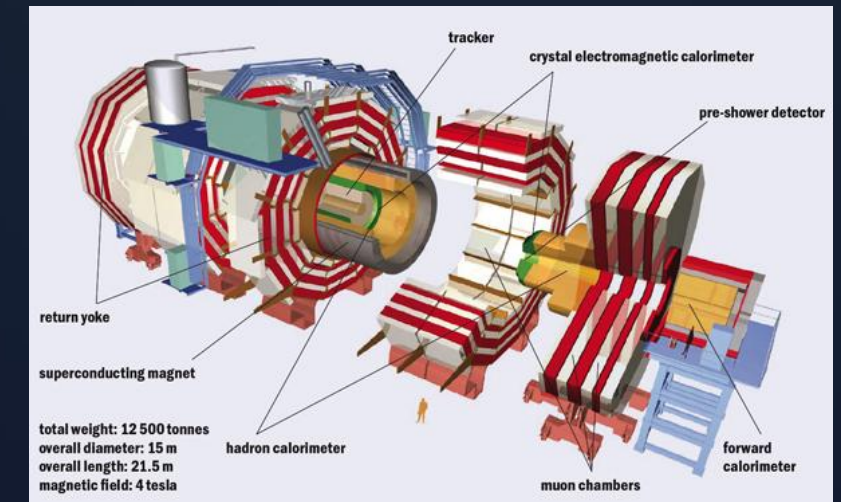
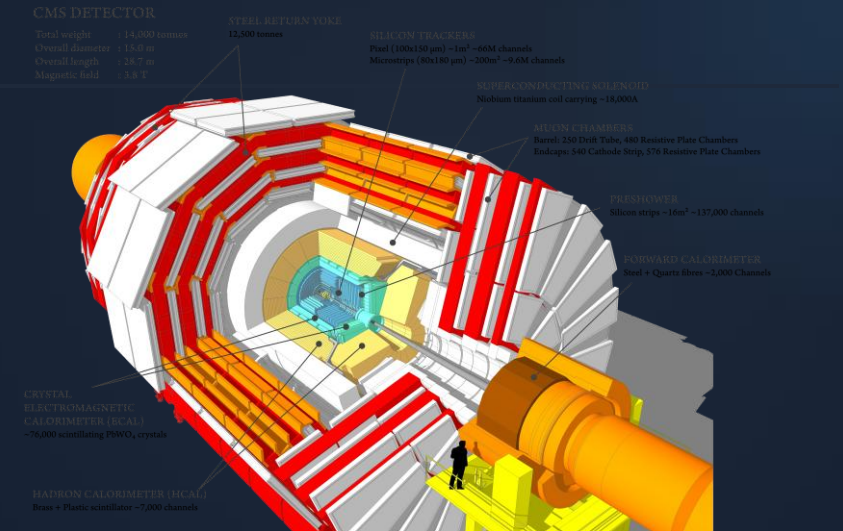


Architecture, Magnet System, Performance & Physics
Results

3D Architecture & Structure

3D Modular Design

- ↻ **Central Barrel:** Divided into 5 massive steel wheels surrounding the solenoid.
- **Endcaps:** 3 vertical disks at each end seal the detector volume.
- ≡ **Scale:** Overall length of 21 m, diameter of 15 m, and a weight of 14,000 tonnes.
- 🔧 **Maintenance:** Elements slide back on tracks to allow underground access.



Solenoid & Return Yoke

Solenoidal Central Field

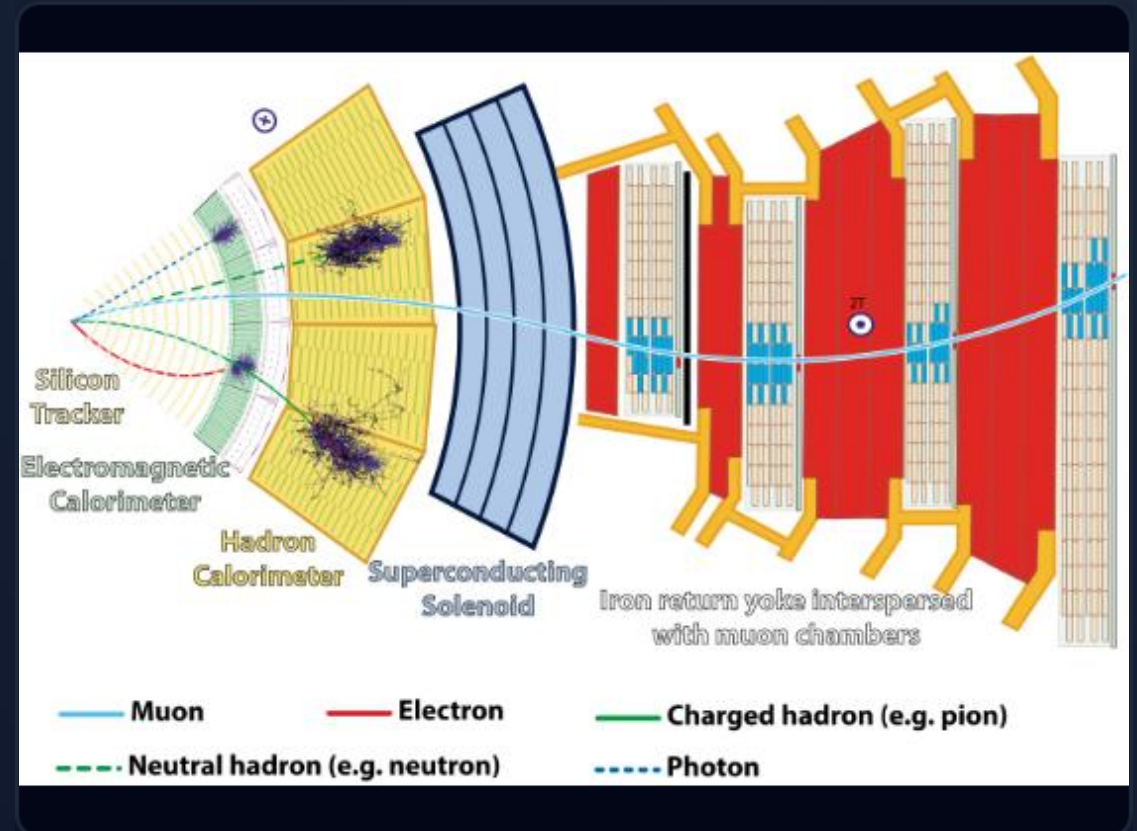
- U Superconducting solenoid coil (6 m diameter, 12.5 m length) operating at 18 kA and 4.5 K.
- 📌 Delivers a uniform **3.8 T solenoidal magnetic field** along the beam axis inside the inner volume.

Reverse Yoke Field

- 🛡️ 10,000-tonne iron return yoke carries the returning magnetic flux.
- ↻ Produces a **2.2 T magnetic field in the reverse direction** within the iron return yoke.
- 📍 Trajectory bending in reverse direction provides independent muon momentum validation.

Concentric Subdetector Layers

- ⚙️ **Inner Tracker:** Silicon Pixels (124M) & Strips inside the solenoid.
- ⚡ **ECAL:** 75,848 homogeneous Lead-Tungstate ($PbWO_4$) scintillating crystals.
- 🛡️ **HCAL:** Brass/Scintillator sampling calorimeter for hadrons.
- 🎯 **Muon System:** DT, CSC, and RPC chambers inside the iron yoke.



Detector Performances



Tracker Momentum

High-precision tracking in 3.8 T solenoidal field:

$$\frac{\sigma(p_T)}{p_T} \approx 15 \% \cdot p_T [\text{TeV}] \oplus 0.5 \%$$

yields resolution at $p_T \approx 1.5 \%$

$$p_T = 100 \text{ GeV}$$



ECAL Energy

Homogeneous crystal energy resolution:

$$\frac{\sigma(E)}{E} = \frac{2.8 \%}{\sqrt{E}} \oplus \frac{0.12}{E} \oplus 0.3 \%$$

enabling sharp mass $H \rightarrow \gamma\gamma$ reconstruction.



Secondary Vertices

Pixel tracker resolution for B hadron decay vertices:

$$\sigma_{xy} \approx 10 \mu\text{m} - 20 \mu\text{m}$$

crucial for identifying displaced vertices () in B-tagging.

$$c\tau \approx 450 \mu\text{m}$$

Physics Performance: $H \rightarrow 4\ell$

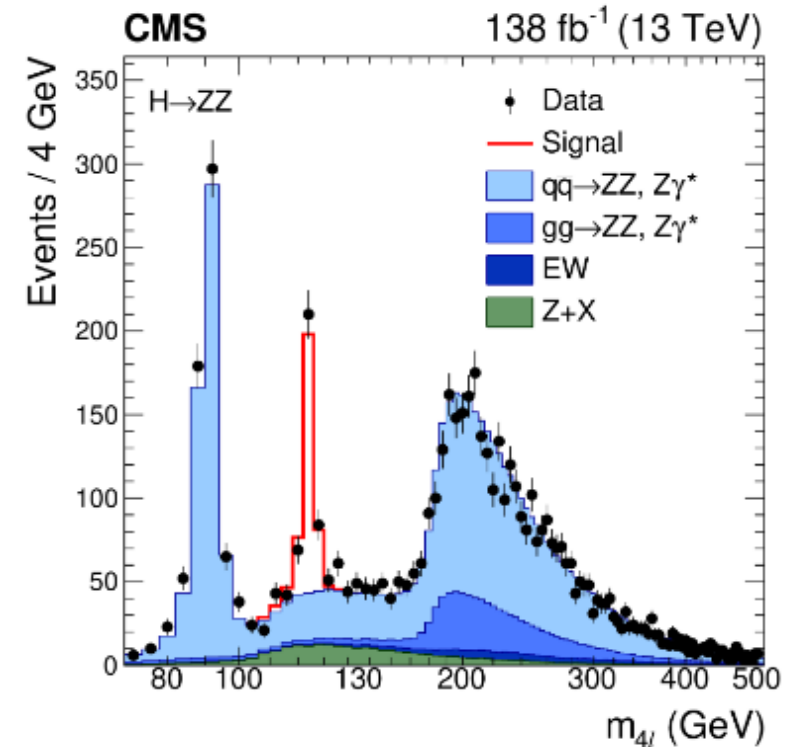
Golden Discovery Channel

- ★ **Clean Signature:** Decay mode ().

$$H \rightarrow ZZ^* \rightarrow 4\ell \quad 4e, 4\mu, 2e2\mu$$

- 🎯 **Peak Resolution:** Sharp four-lepton invariant mass peak near 125GeV

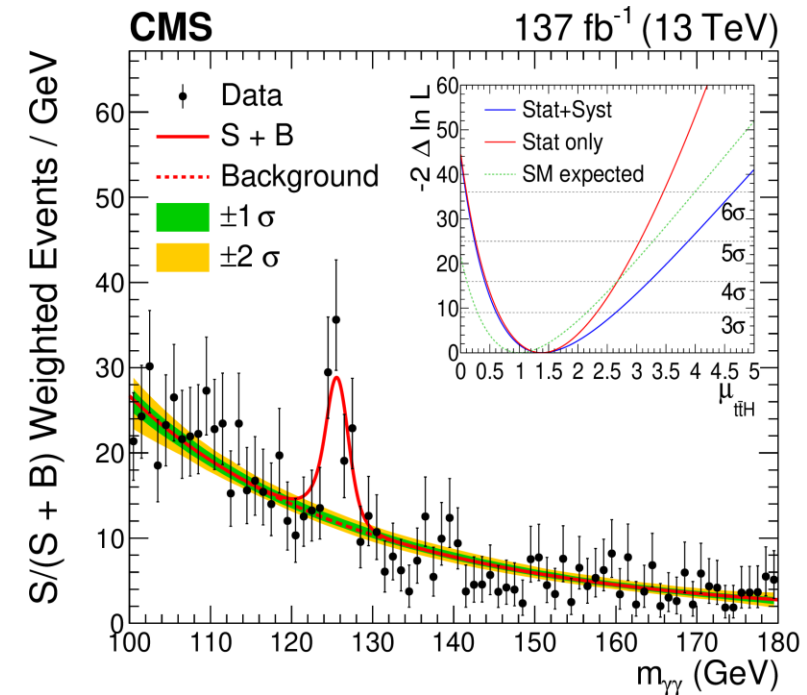
- 🔧 **High Precision:** Combines inner tracker precision and muon/ECAL performance with very low background.



Physics Performance: $H \rightarrow \gamma\gamma$

Electromagnetic Calorimeter Power

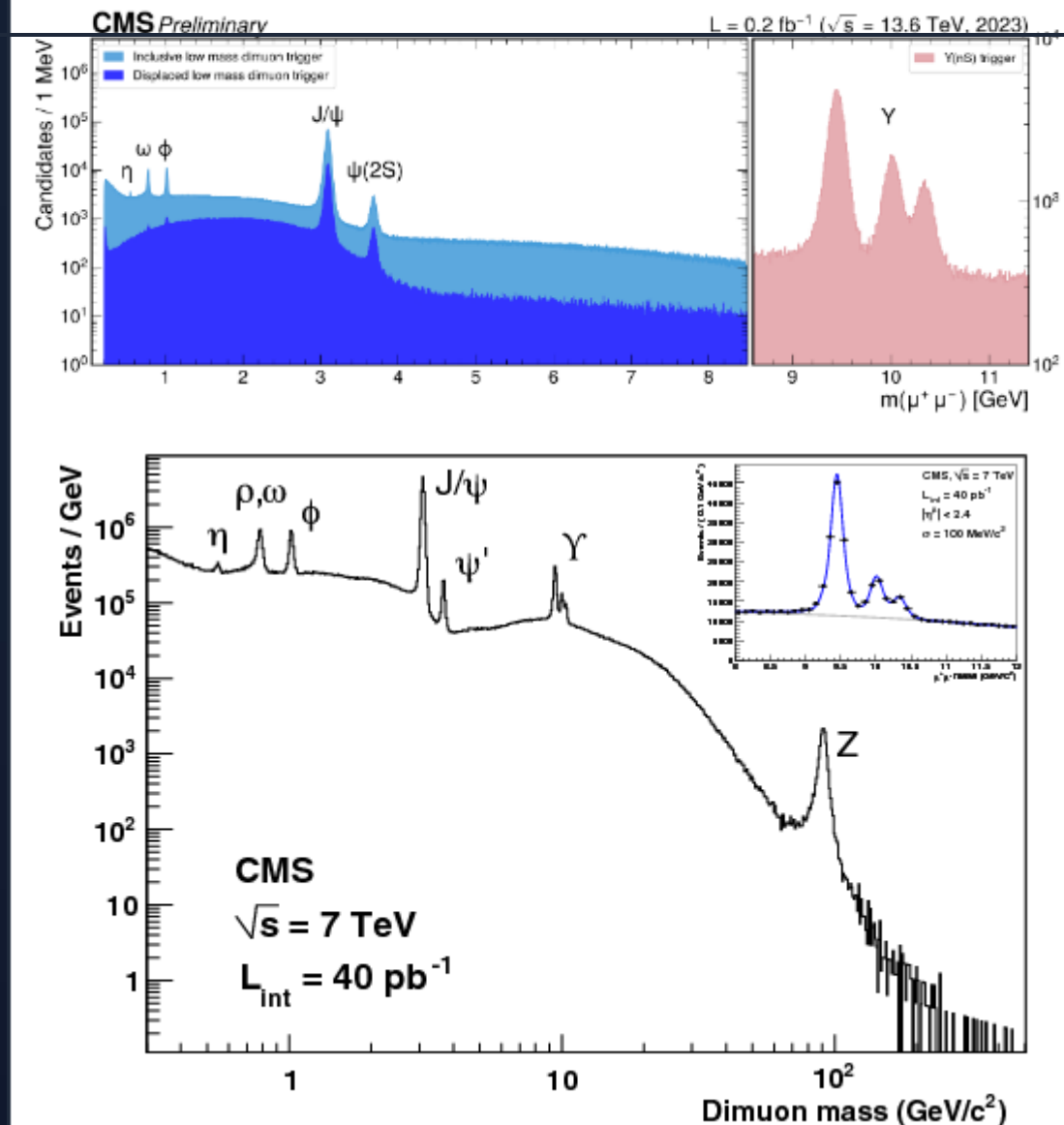
- 🌀 **Diphoton Resonance:** Narrow signal peak over a large, continuous diphoton background.
- 💎 **ECAL Energy Resolution:** Homogeneous PbWO_4 crystal resolution provides superb mass resolution (). $\approx 1 - 2\text{GeV}$
- 📍 **Vertexing:** Accurate tracking identifies the diphoton interaction vertex.



Dimuon Mass Spectrum

Resonance Spectrum & Triggering

- Wide Mass Range: Clear observation of resonances from vector mesons and Z decay.
- Trigger Performance: Demonstrates inclusive vs displaced low-mass dimuon triggers at high rate.
- Muon Calibration: Serves as a standard candle for momentum resolution and efficiency.



Questions & Discussion

Lectures on Experimental Subnuclear Physics

CMS Collaboration • CERN European Organization for Nuclear Research
Compact Muon Solenoid Experiment