Search for resonant and non-resonant Higgs Boson pair production in the bbττ final state with the CMS detector

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LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

CERN

CMS

What do we know about the Higgs Boson?

- SM particles get their mass through the interaction with the Higgs potential

- In it's nonzero ground state, the rotational U(1) symmetry is broken → "Electroweak Symmetry Breaking"

- Understanding the Higgs Potential is central to our understanding of the Universe

- Connections to open questions:

  - Nature of dark matter

  - Nature of dark energy

  - Cosmic inflation

- To understand the Higgs potential we need to understand Higgs self coupling!

$$V(H) = \frac{1}{2}m_H^2 H^2 + \lambda_{HHH} \nu H^3 + \frac{1}{4}\lambda_{HHHH}H^4 + \ldots$$

Nature 607 60-68 (2022)
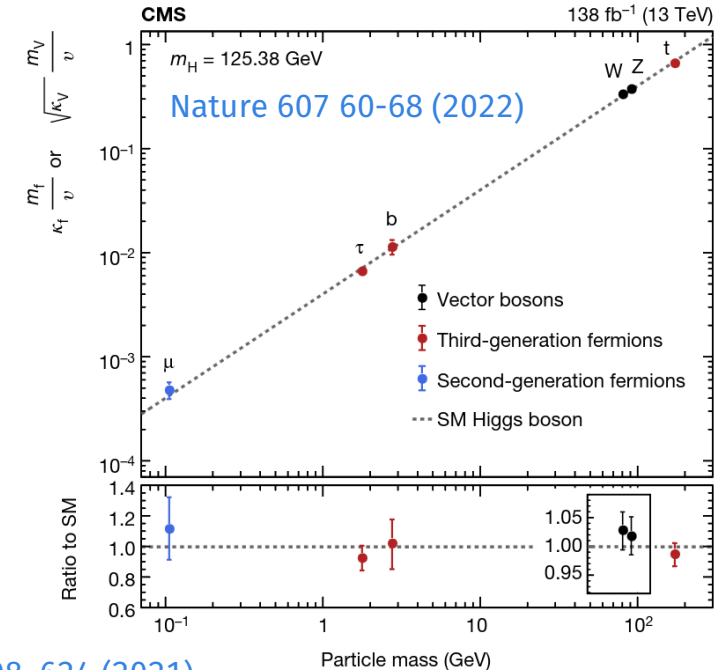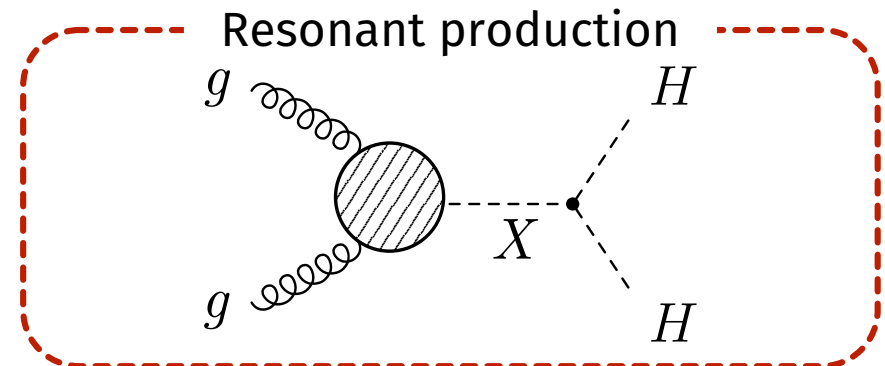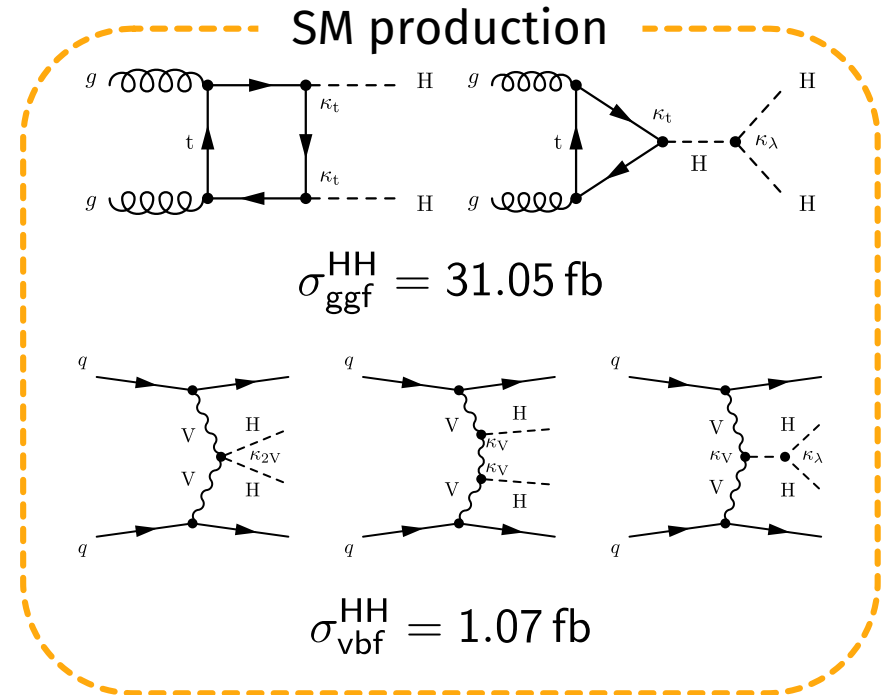

Nat Rev Phys 3, 608–624 (2021)
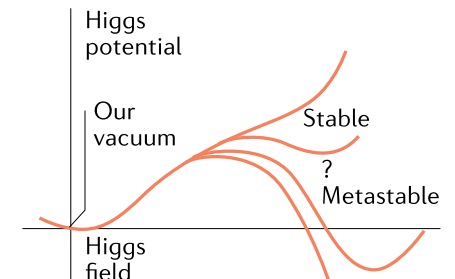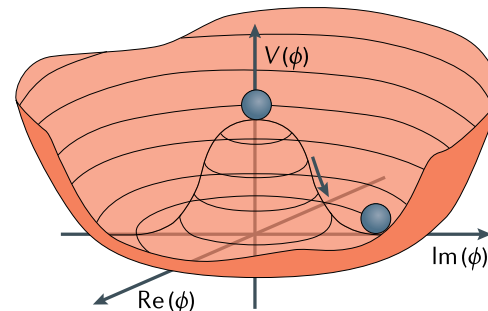
SM Higgs Boson pair production can occur through 2 production modes at the LHC

- Gluon-Gluon Fusion:

  - Box and triangle diagrams (destructive interference)

  - Access to κ_t & κ_λ

- Vector-Boson Fusion:

  - Production through Vector Boson Pairs

  - Access to κ_{2V}, κ_V & κ_λ

Resonant (non-SM) Higgs Boson pair production

- Predicted by: Singlet Model [3-5], 2HDM [6], MSSM [7,8]

- X: scalar particle (Radion/Graviton)

SM production

$$\sigma_{\text{ggf}}^{\text{HH}} = 31.05\,\text{fb}$$

$$\sigma_{\text{vbf}}^{\text{HH}} = 1.07\,\text{fb}$$

Resonant production

3

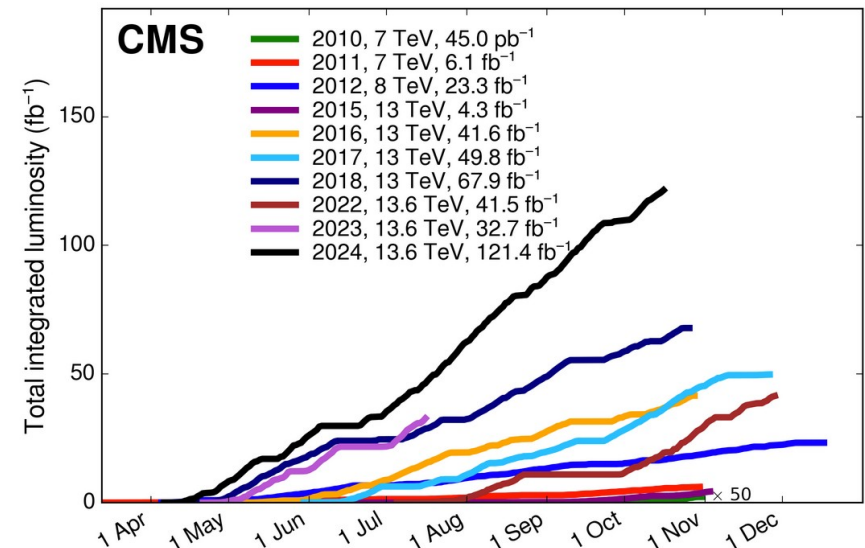**CMS DETECTOR**
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T

STEEL RETURN YOKE
12,500 tonnes

SILICON TRACKERS
Pixel (100x150 μm^2) ~1 m^2 ~66M channels
Microstrips (80-180 μm) ~200 m^2 ~9.6M channels

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000 A

MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers

PRESHOWER
Silicon strips ~16 m^2 ~137,000 channels

FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals

HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

The Compact Muon Solenoid is one of the 2 general purpose detectors at the LHC

- Superconducting Solenoid: 3.8 T

- Silicon Tracker → Crystal ECAL → Scintillator HCAL → gas ionization muon chambers

Run3 data taking is ongoing

- Integrated Luminosities:

  - Run1: 29 fb^{-1} @ 7/8 TeV

  - Run2: 138 fb^{-1} @ 13 TeV

  - Run3: 180 fb^{-1} @ 13.6 TeV already

CMS
- 2010, 7 TeV, 45.0 pb^{-1}
- 2011, 7 TeV, 6.1 fb^{-1}
- 2012, 8 TeV, 23.3 fb^{-1}
- 2015, 13 TeV, 4.3 fb^{-1}
- 2016, 13 TeV, 41.6 fb^{-1}
- 2017, 13 TeV, 49.8 fb^{-1}
- 2018, 13 TeV, 67.9 fb^{-1}
- 2022, 13.6 TeV, 41.5 fb^{-1}
- 2023, 13.6 TeV, 32.7 fb^{-1}
- 2024, 13.6 TeV, 121.4 fb^{-1}

Total integrated luminosity (fb^{-1})

4

CMS is covering a large part of the decay matrix:

- HH→bbbb JHEP 03 (2021) 257
- HH→bbττ Phys. Lett B 842 (2023)
- HH→bbγγ PLB 778 (2018) 7
- HH→bbZZ JHEP 06 (2023) 130
- HH→bbWW CMS-PAS-HIG-21-005
- HH→WWγγ CMS-PAS-HIG-21-014
- HH→WWWW+WWττ+ττττ JHEP07(2023)095
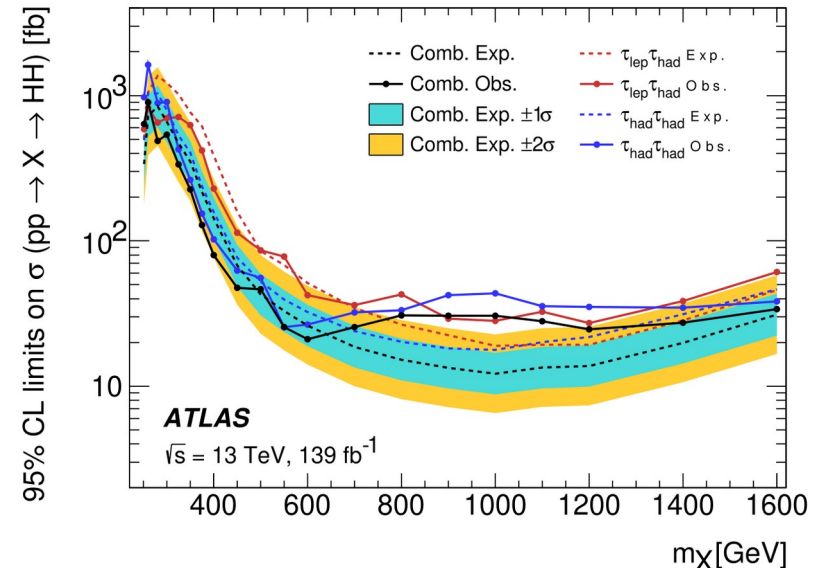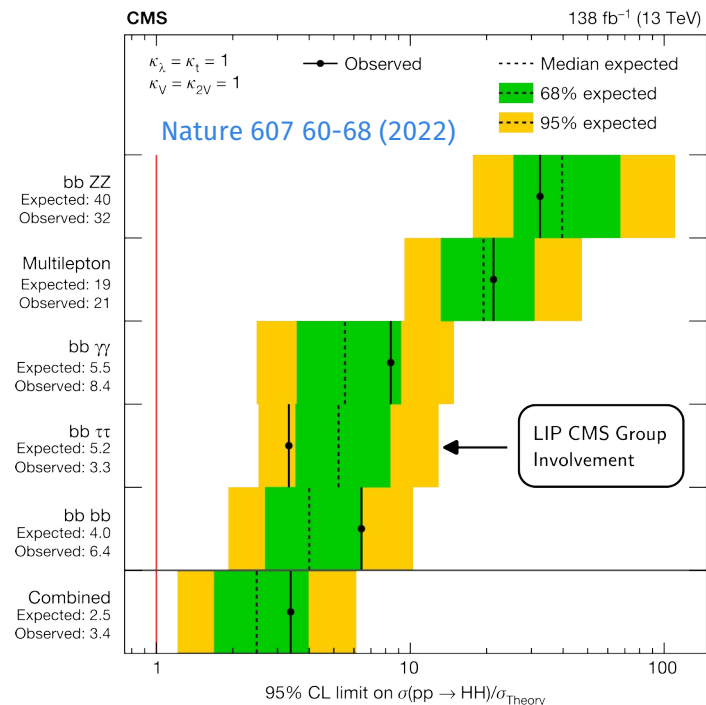
HH→bbττ is a trade-off between branching fraction and enhanced selection purity
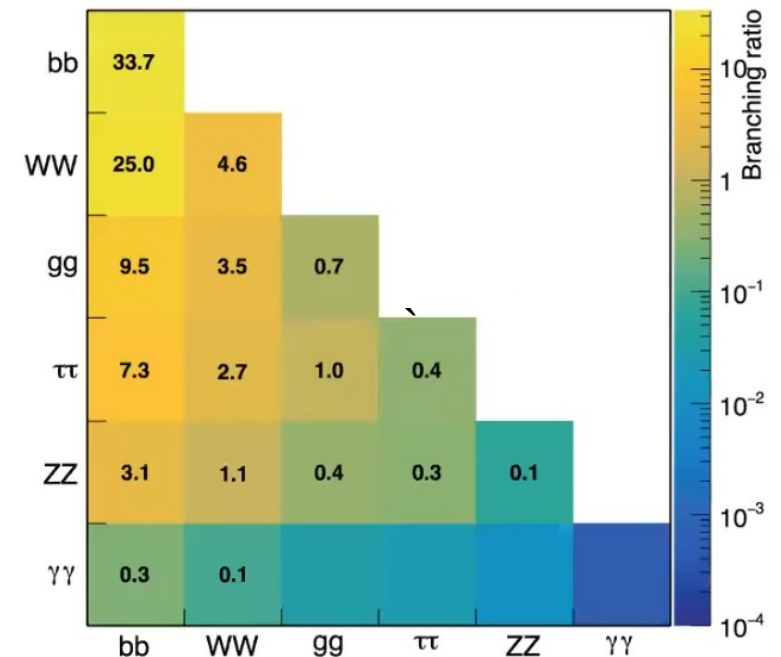
HH→bbττ is the second most sensitive to the Higgs self coupling

- Observed (expected) upper limit on the HH production cross section corresponding to 3.3 (5.2) times the SM predictions
  Phys. Lett. B, 842:137531, 2023

Full Run2 UL resonant X →HH→bbττ analysis in preparation

- ATLAS observed an excess around 1TeV

  - Local (global) significance: 3σ (2σ)

- Our publication will confirm or deny → stay tuned!

Thank you for your Attention!

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