Measurements of Higgs Boson Couplings and Constraints on New Physics with the ATLAS Detector

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Introduction

The Higgs boson couplings are measured to probe models of new physics that may answer two outstanding questions in the Standard Model (SM):

1. **Hierarchy problem:** Why is the Higgs mass unnaturally small?
2. **Dark matter problem:** What particle is this?

Analysis procedure

The couplings are extracted using the **full LHC Run 1 data sample** (2011-2012) of ~25 fb^{-1} collected by the **ATLAS experiment**. A **combined likelihood fit** is performed to the rates measured in **all production & decay modes**.

Data

The **decay channels analyzed** are:

- h -> γγ
- h -> ZZ -> 4l
- h -> WW -> lνlν
- h -> ττ
- h -> bb
- Zh -> ll + E_T^{miss}

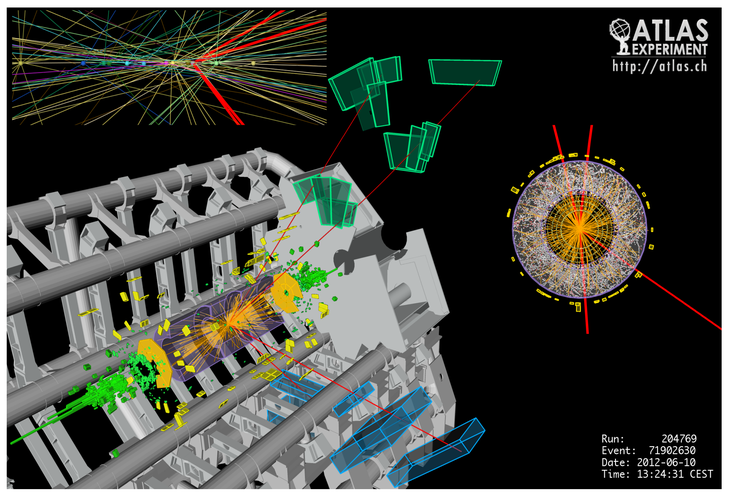

Fig. 1: Display of h->ZZ->4μ event.

Coupling measurements

The **measured couplings** to:

- vector bosons (W, Z)
- fermions (top & bottom quarks, τ lepton)

are **compatible with the SM** within ~1.5σ. Their mass dependence and the vacuum expectation value are also consistent with the SM.

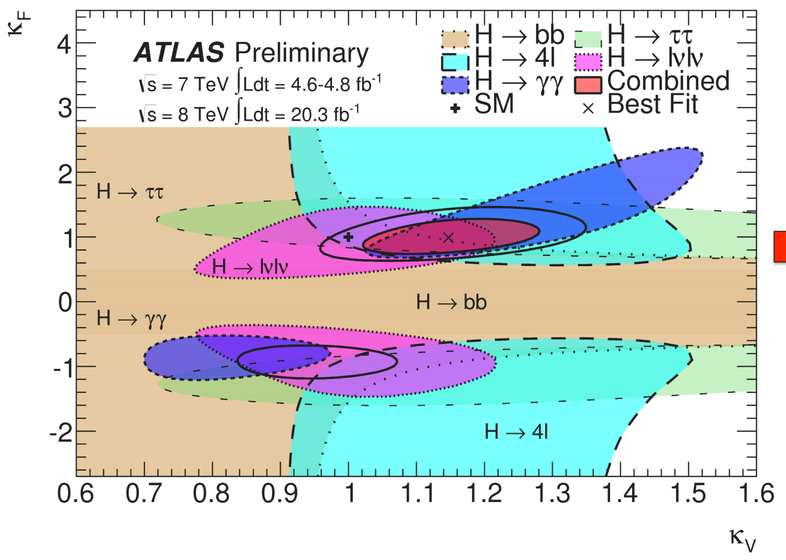

Fig. 2: Measured Higgs couplings to vector bosons, k_V, and fermions, k_F.

Higgs boson compositeness

A **composite Higgs boson** is a possible solution to the hierarchy problem. The corresponding upper limits at 95% CL on the **compositeness scale *f*** in two Minimal Composite Higgs Models (MCHM) are: ***f*>710 GeV** for MCHM4, and ***f*>460 GeV** for MCHM5.

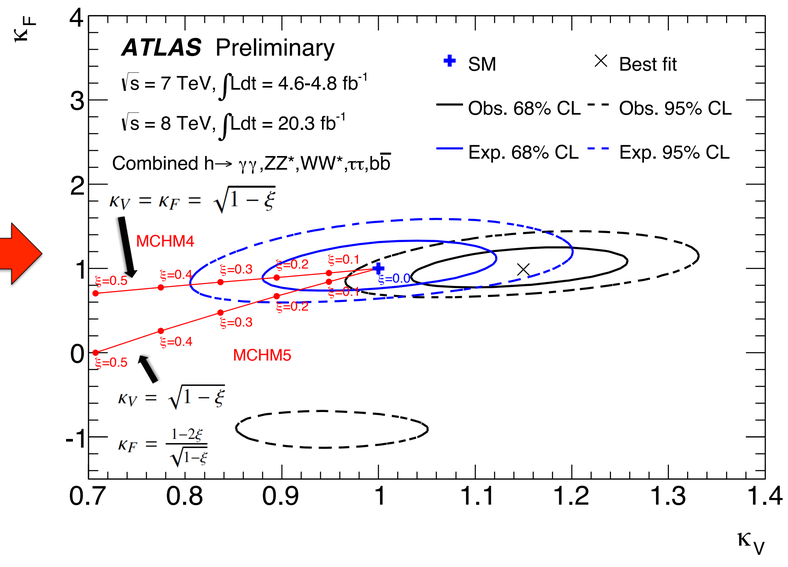

Fig. 3: Couplings predicted for a composite Higgs boson with $\xi=v^2/f^2$, where v is the vacuum expectation value and f is the Higgs compositeness scale.

Supersymmetry

A **simplified Minimal Supersymmetric Standard Model (MSSM)** is probed via Higgs couplings to:

- vector bosons (W, Z)
- up-type fermions (top quark)
- down-type fermions (b-quark and τ lepton)

For tan β>2, the lower limit on the CP-odd Higgs mass is: **m_A > 400 GeV obs.** (290 GeV exp.).

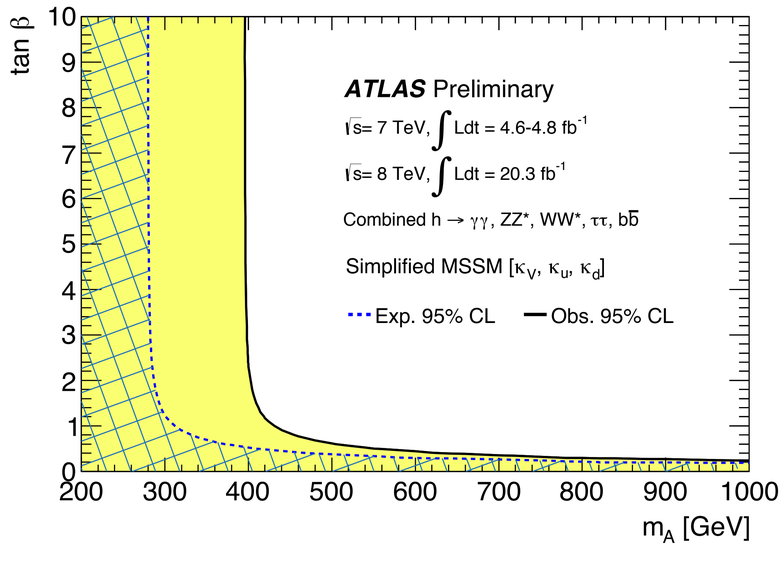

Fig. 4: Limits at 95% CL on m_A and tan β in a simplified MSSM. The shaded regions are excluded.

Higgs portal to dark matter

The Higgs boson may decay invisibly to **weakly-interacting massive particles (WIMPs), χ,** if $m_\chi < m_h/2$. An upper limit is set on the Higgs invisible branching ratio:
BR_i < 0.37 obs. (0.39 exp.).

The corresponding upper limits on the **WIMP-nucleon scattering cross-section** are **significantly more stringent** at low mass than those from direct detection experiments.

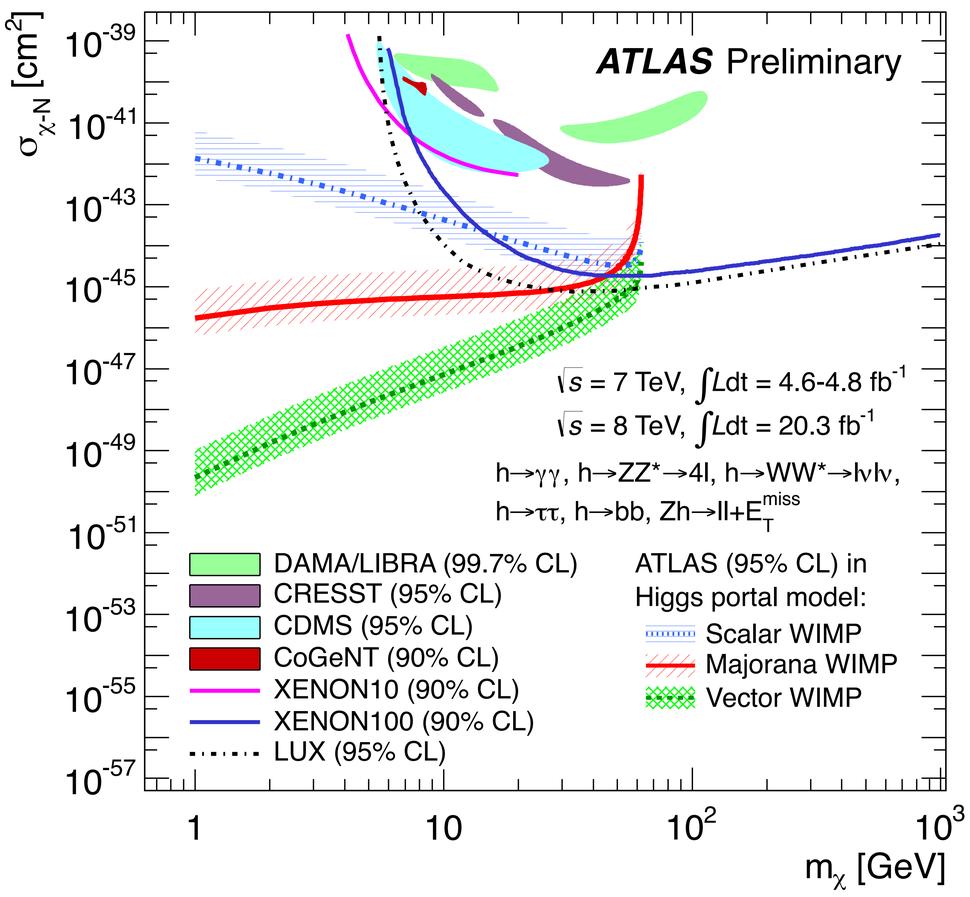

Fig. 5: Limits on the cross-section for WIMP-nucleon scattering, $\sigma_{\chi\text{-}N}$, as a function of the WIMP mass, m_χ. Overlaid are results from direct detection experiments.

Conclusions

1. The **measured Higgs boson couplings** and their mass dependence, invisible branching ratio, and vacuum expectation value are **compatible with the SM predictions**. No indication of new physics is observed.
2. **Limits are set** on the Higgs boson compositeness scale, the mass of a supersymmetric CP-odd Higgs boson, and the interaction rate of WIMP dark matter with nucleons.

References

- ATLAS Collaboration. "Updated coupling measurements of the Higgs boson with the ATLAS detector . . ." ATLAS-CONF-2014-009 (2014).
- ATLAS Collaboration. "Constraints on New Phenomena via Higgs Coupling Measurements with the ATLAS Detector". ATLAS-CONF-2014-010 (2014).
- ATLAS Collaboration. "Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC." Phys. Lett. B 726, 88 (2013).