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Phenomenology of Physics Beyond the Standard Model

FS 2026

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SM Higgs bosons di-photon search at the LHC

- Explain which have been the two main decay modes exploited experimentally for the discovery of the SM Higgs boson at the LHC (draw the diagrams). Why has it been decided to search for the Higgs in such small branching ratio channels?
- In the di-photon channel, which are the main reducible and irreducible backgrounds? What could be a good experimental handle to suppress the contribution from jets faking photons?
- What is the aim of introducing a categorization based on the event topology? Why has a further categorization, based on photons resolution, been introduced?
- What is the variable fitted for the statistical inference and which parameters are extracted (look at Figure 1)? Why can't the Higgs boson width be extracted from this measurement? (Hint: SM prediction $\Gamma_H = 4.1$ MeV). Can we still measure this quantity at the LHC? And what could be the relevance in the search for New Physics ? (Hint: for reference look at the publication [1])

MSSM Higgs bosons di-tau search at the LHC

- In which region of $(m_A, \tan\beta)$ is the MSSM still allowed? What is the main strategy to find the MSSM as far as the SM Higgs sector measurements? What is the alternative strategy exploiting the MSSM predictions for new scalars?
- What is the expectation for the couplings of the MSSM heavy neutral Higgses to third generation leptons varying $\tan\beta$? Which production mechanisms get enhanced in this regime?
- Consider the $A/H \to \tau\tau$ analysis. Are the τ hadronic decay final states different from a quark or a gluon jet? What can be the categorization of the $H/A \to \tau\tau$ analysis according to the τ decay modes? Why is it considered also a categorization based on b-tagged jets?
- What is the main reason for choosing a data-driven method for the background estimation $\mathrm{j} \to \tau_h$? Using as a reference [2], what are the main steps of the fake factor method ? To which backgrounds has it been applied? (Look at Figure 2). Is it really a fully data-driven method?

- In the case of $A/H \to \tau\tau$ analysis, what is the final variable used for the statistical inference? (look at Figure 3). What is the expected spectrum for the signal?

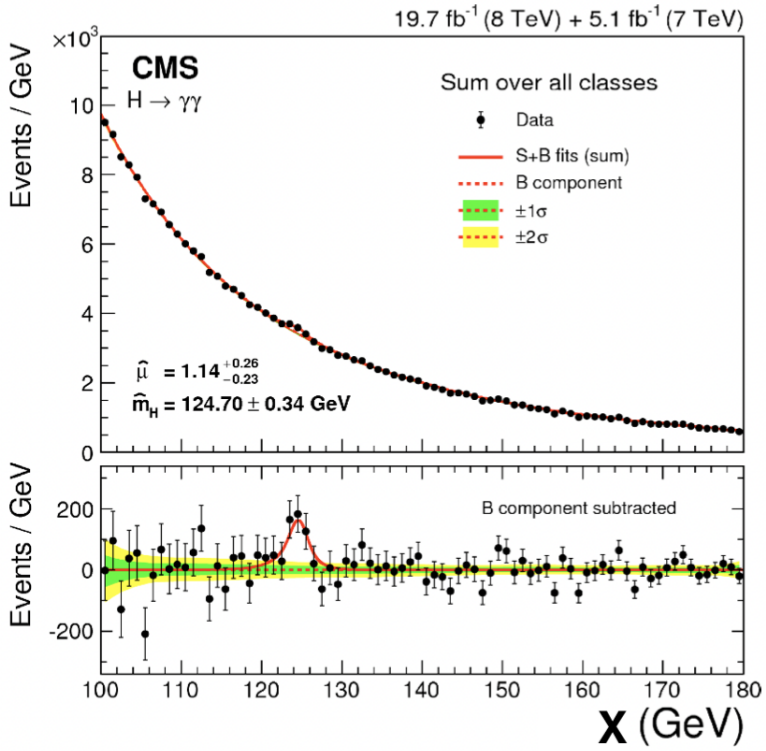


Figure 1: Fitted distribution for $H \to \gamma\gamma$ analysis [3]

References

[1] Georges Aad et al. "Evidence of off-shell Higgs boson production from ZZ leptonic decay channels and constraints on its total width with the ATLAS detector". In: (Apr. 2023). arXiv: 2304.01532 [hep-ex].

[2] Albert M Sirunyan et al. "Search for additional neutral MSSM Higgs bosons in the $\tau\tau$ final state in proton-proton collisions at $\sqrt{s} = 13$ TeV". In: *JHEP* 09 (2018), p. 007. DOI: 10.1007/JHEP09(2018)007. arXiv: 1803.06553 [hep-ex].

[3] Serguei Chatrchyan et al. "Observation of a New Boson at a Mass of 125 GeV with the CMS Experiment at the LHC". In: *Phys. Lett. B* 716 (2012), pp. 30–61. DOI: 10.1016/j.physletb.2012.08.021. arXiv: 1207.7235 [hep-ex].

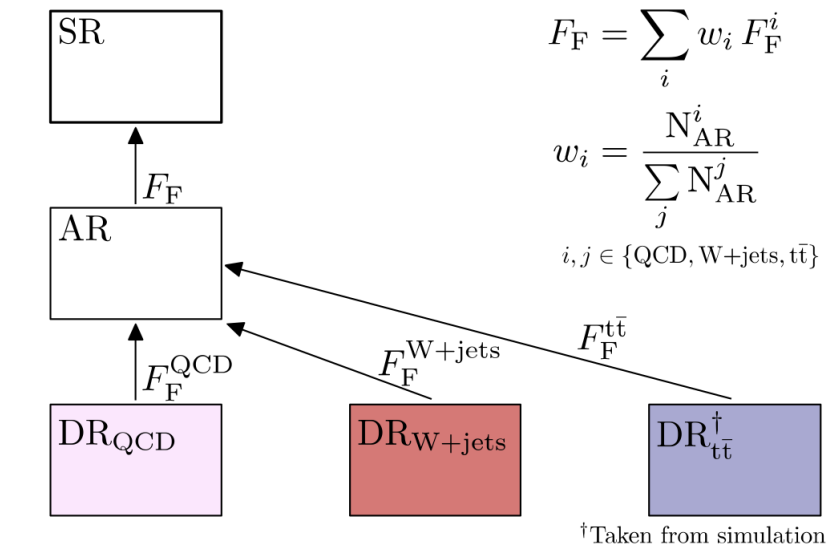


Figure 2: Fake factor method scheme [2]

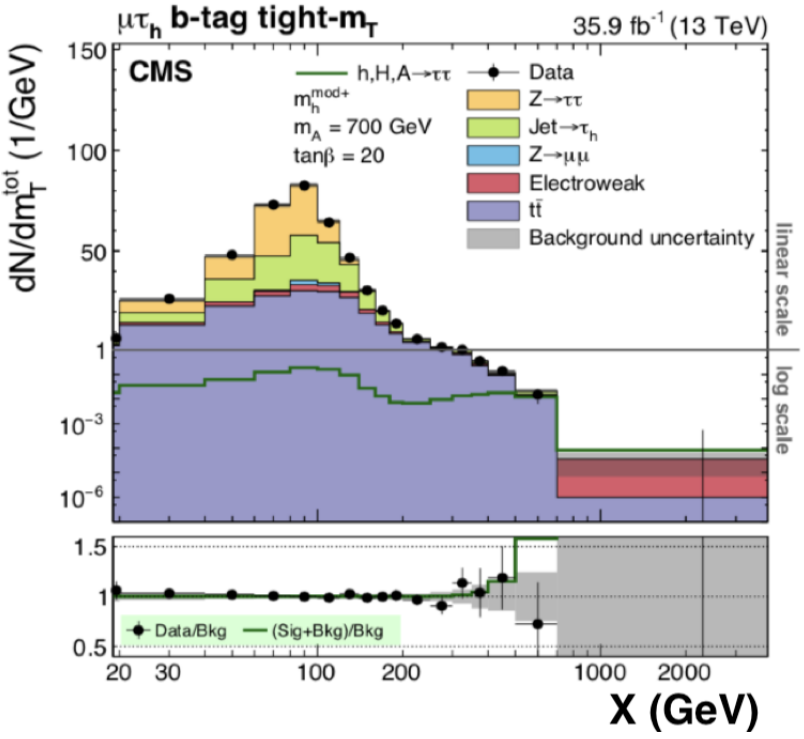


Figure 3: Final spectrum fitted for $A/H \to \tau\tau$ analysis [2]