Search for additional neutral MSSM Higgs bosons in the ττ final state in CMS

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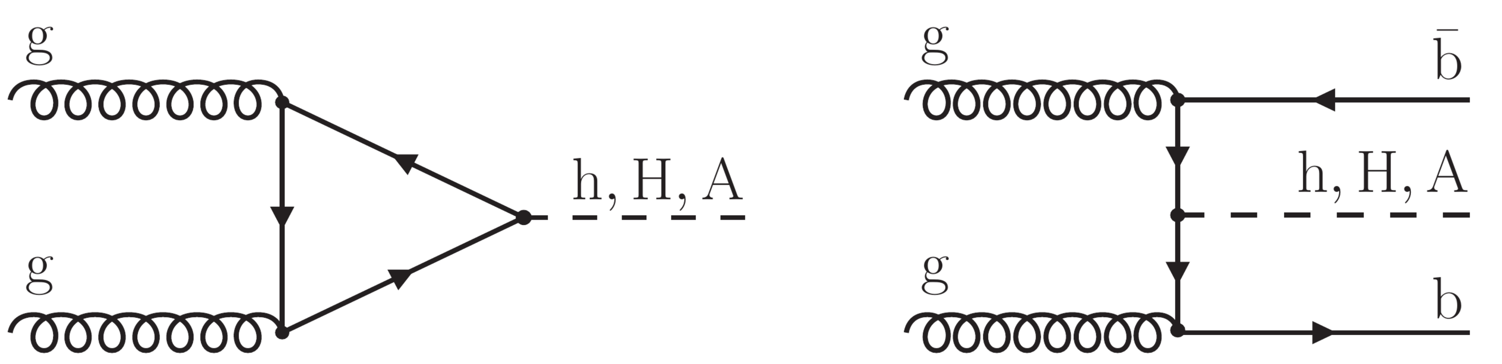
More neutral Higgs bosons?

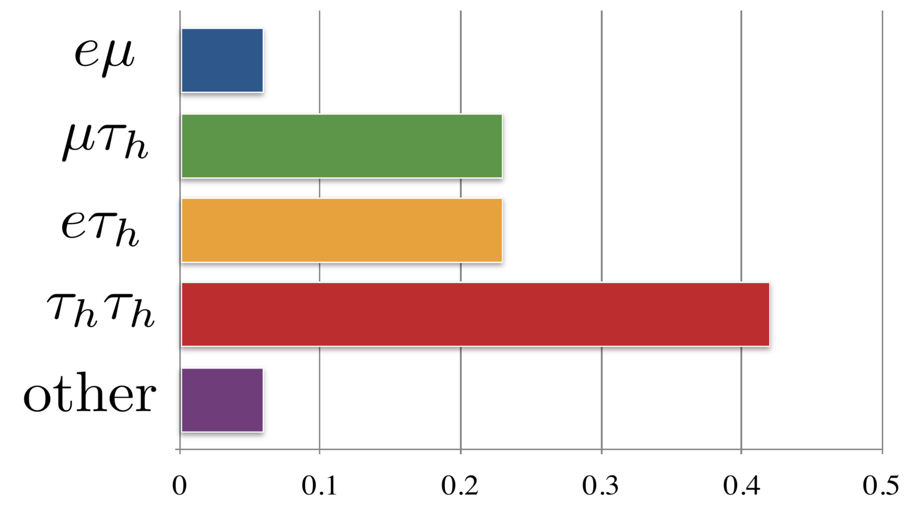
The **Minimal Supersymmetric extension to the Standard Model** (MSSM) predicts the existence of five physical Higgs bosons:
2 charged Higgs $H^{\pm}$, 3 neutral Higgs Φ: two scalars h, H and a pseudo scalar A.

Two parameters are used to describe the model:
- **Mass** of **pseudo scalar** Higgs boson m_A.
- **The ratio of the vacuum expectation values of the two Higgs doublets** $\tan\beta$.



gluon fusion, $gg\Phi$ **b-associated Higgs production,** $bb\Phi$

Final states for di-τ system

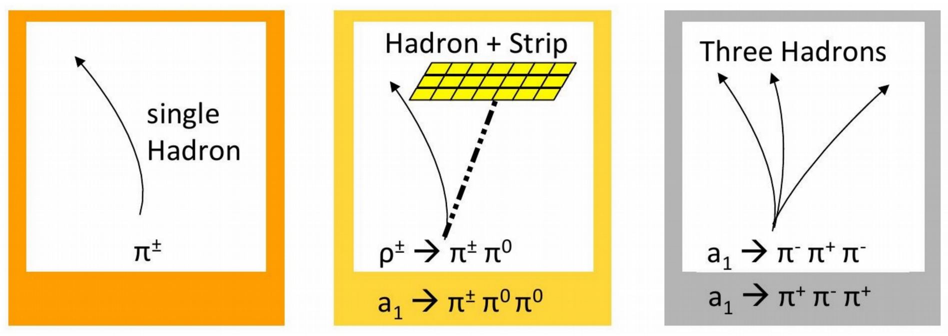


4 di-τ final states with largest branching ratios studied in this analysis:
$\tau_h\tau_h, e\tau_h, \mu\tau_h, e\mu$

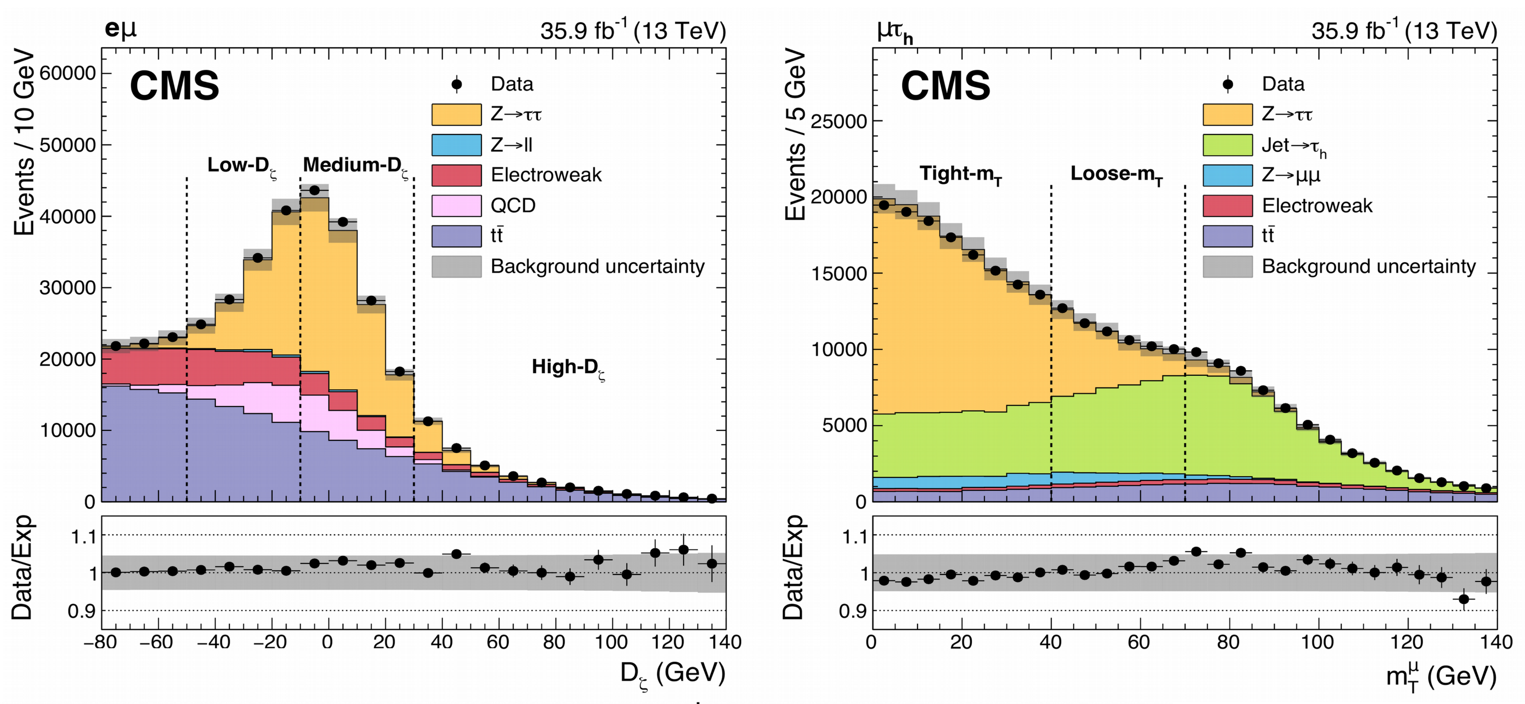
The 2 remaining final states (ee, $\mu\mu$) are not studied, because of the huge background from DY process

Hadronic taus are reconstructed using **hadron** (combinations of track from $\pi^{\pm}$) + **strip** (e/γ candidate clusters from π^0) algorithm[1].

3 reconstructed decay modes:
1 prong, 1 prong+π⁰(s), 3 prongs



Event selection and categorization



	No b-tag			b-tag		
$H\to\tau\tau\to e\mu$	Low-D_ζ	Medium-D_ζ	High-D_ζ	Low-D_ζ	Medium-D_ζ	High-D_ζ
$H\to\tau\tau\to e\tau_h$	Loose-m_T	Tight-m_T		Loose-m_T	Tight-m_T	
$H\to\tau\tau\to \mu\tau_h$	Loose-m_T	Tight-m_T		Loose-m_T	Tight-m_T	
$H\to\tau\tau\to \tau_h\tau_h$						
$Z\to\mu\mu$						
$t\bar{t}(e\mu)$						

Signal region (SR)
Control region

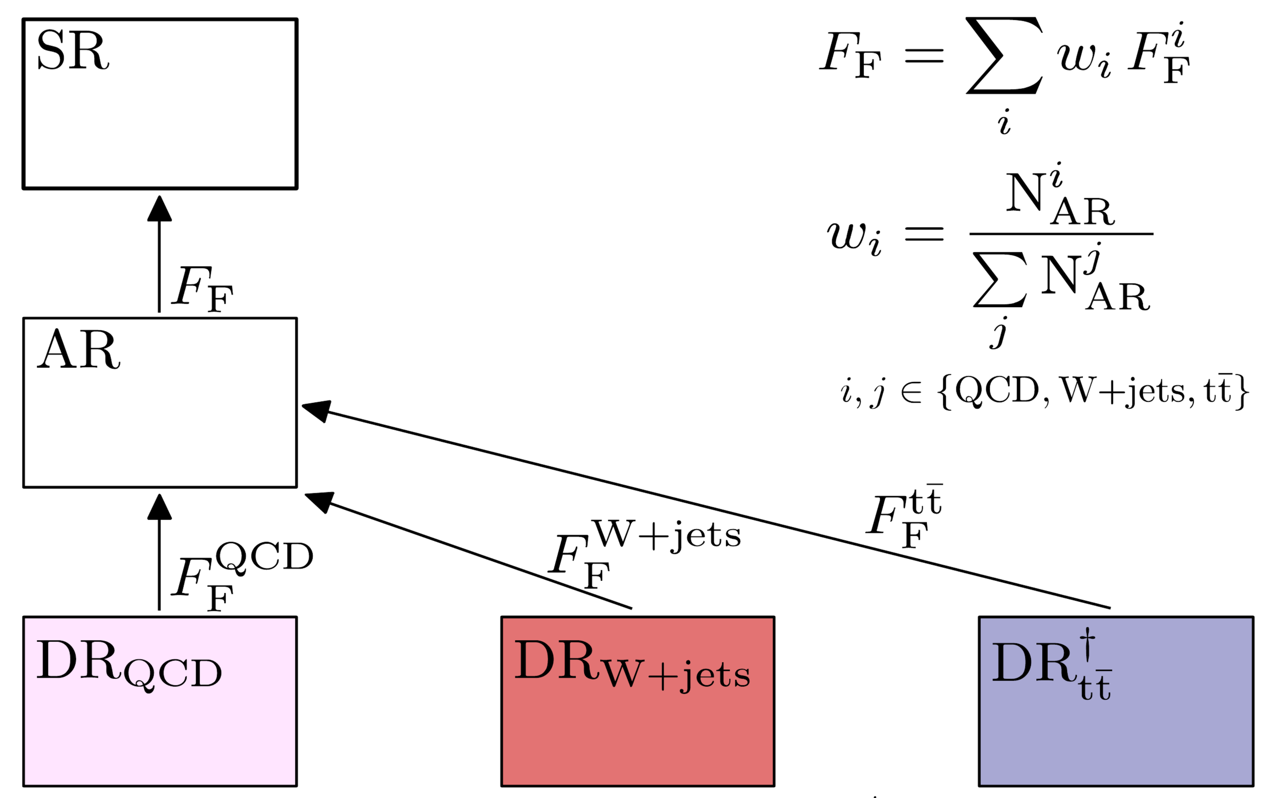
Two categories per final states:
- **No b-tagged jet** category targeting $gg\Phi$
- **With b-tagged jet** category targeting $bb\Phi$

Fake taus background

One of the main backgrounds comes from the **fake taus**: jets misidentified as hadronic taus.

Background estimated through the **fake Factor Method:**

- **Determination Regions** (DR) are used to estimate the ratio between fake taus and genuine taus
- This ratios are applied to simulated events in an **Application Region** (AR) to estimate the background in the **Signal Region** (SR)



$$F_F = \sum_i w_i F_F^i$$

$$w_i = \frac{N^i_{AR}}{\sum_j N^j_{AR}}$$

$i, j \in \{\mathrm{QCD}, \mathrm{W{+}jets}, t\bar{t}\}$

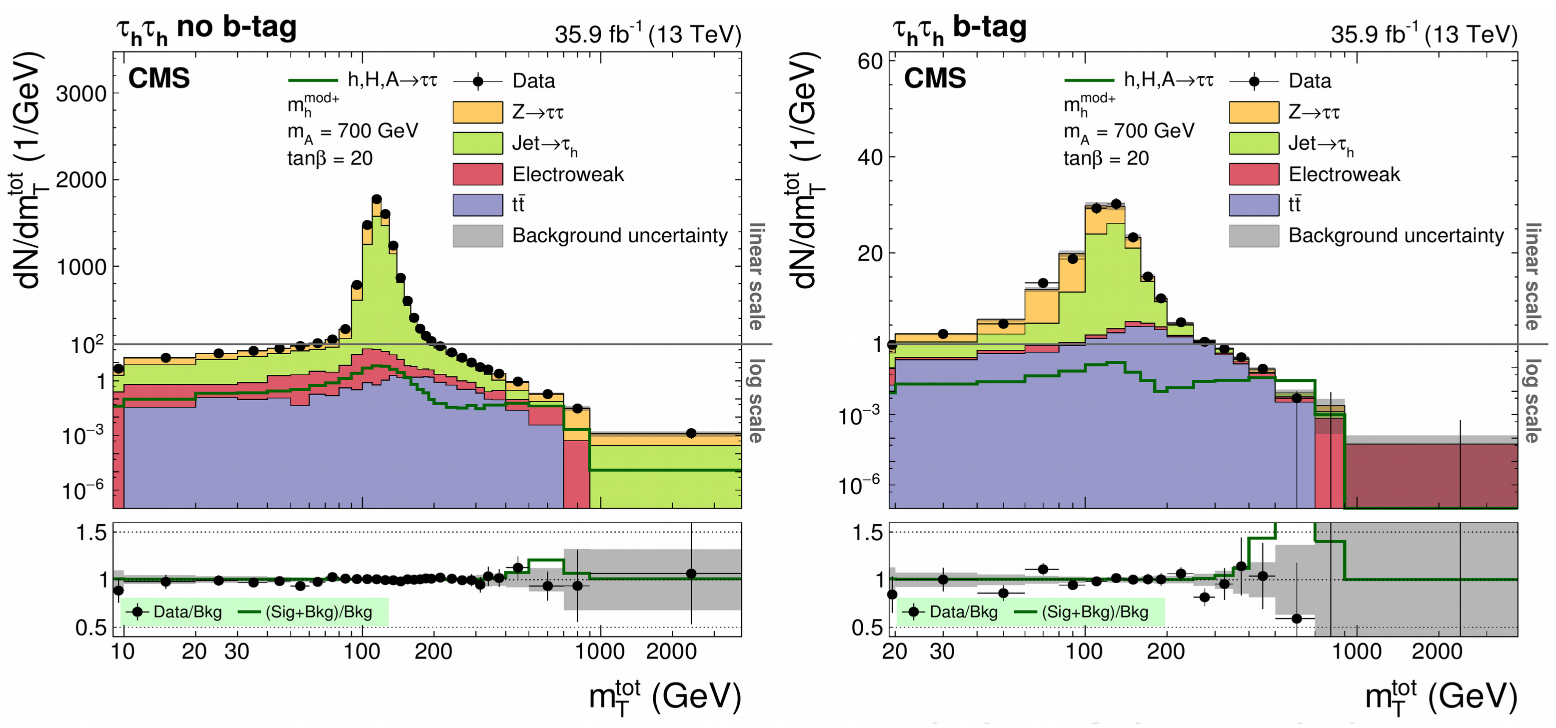
†Taken from simulation

Signal extraction and results

Fit on all categories using **total transverse mass** variable as final discriminant to extract signal:

$$m_T^{tot} = \sqrt{m_T^2(p_T^{\tau_1}, p_T^{mis}) + m_T^2(p_T^{\tau_2}, p_T^{mis}) + m_T^2(p_T^{\tau_1}, p_T^{\tau_2})}$$

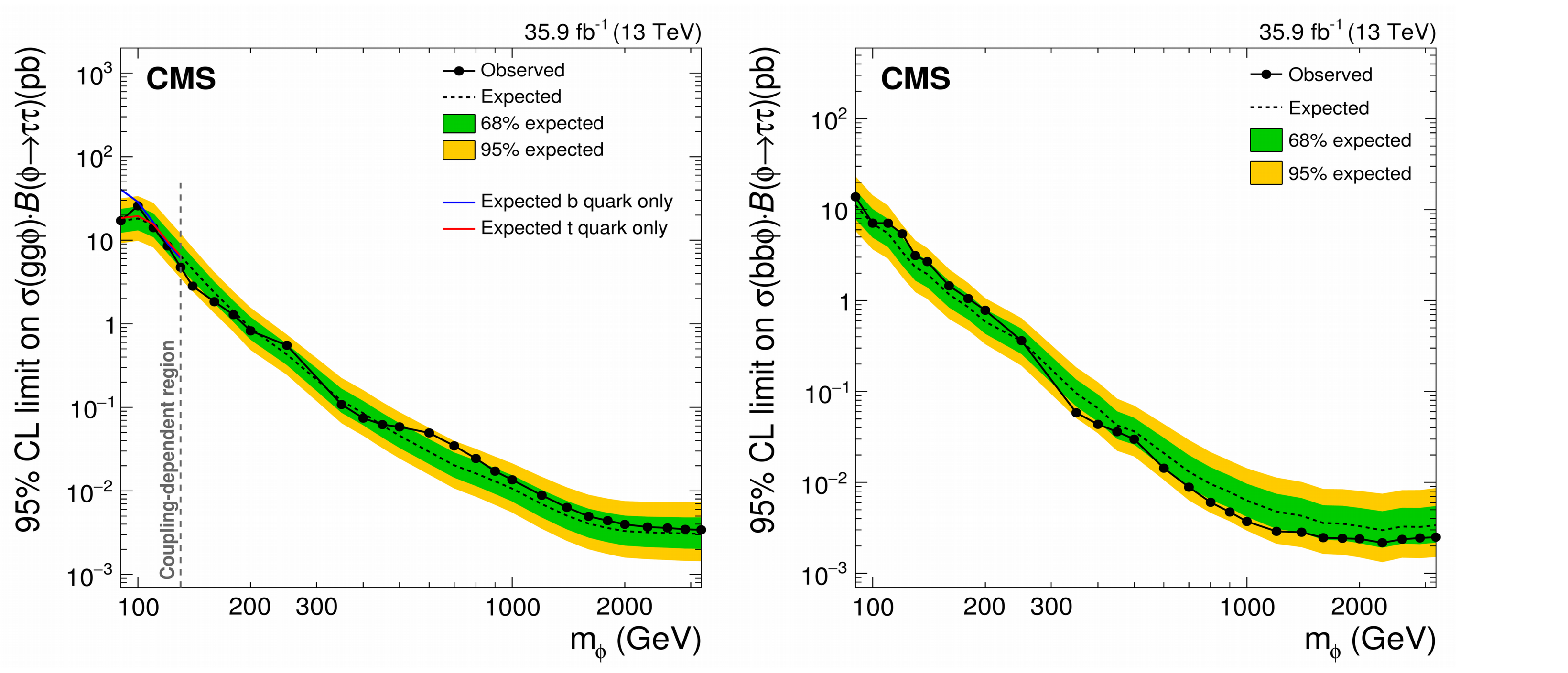
where: $m_T(l_1, l_2) = \sqrt{2\, p_T^1\, p_T^2\, (1-\cos\theta_{1,2})}$



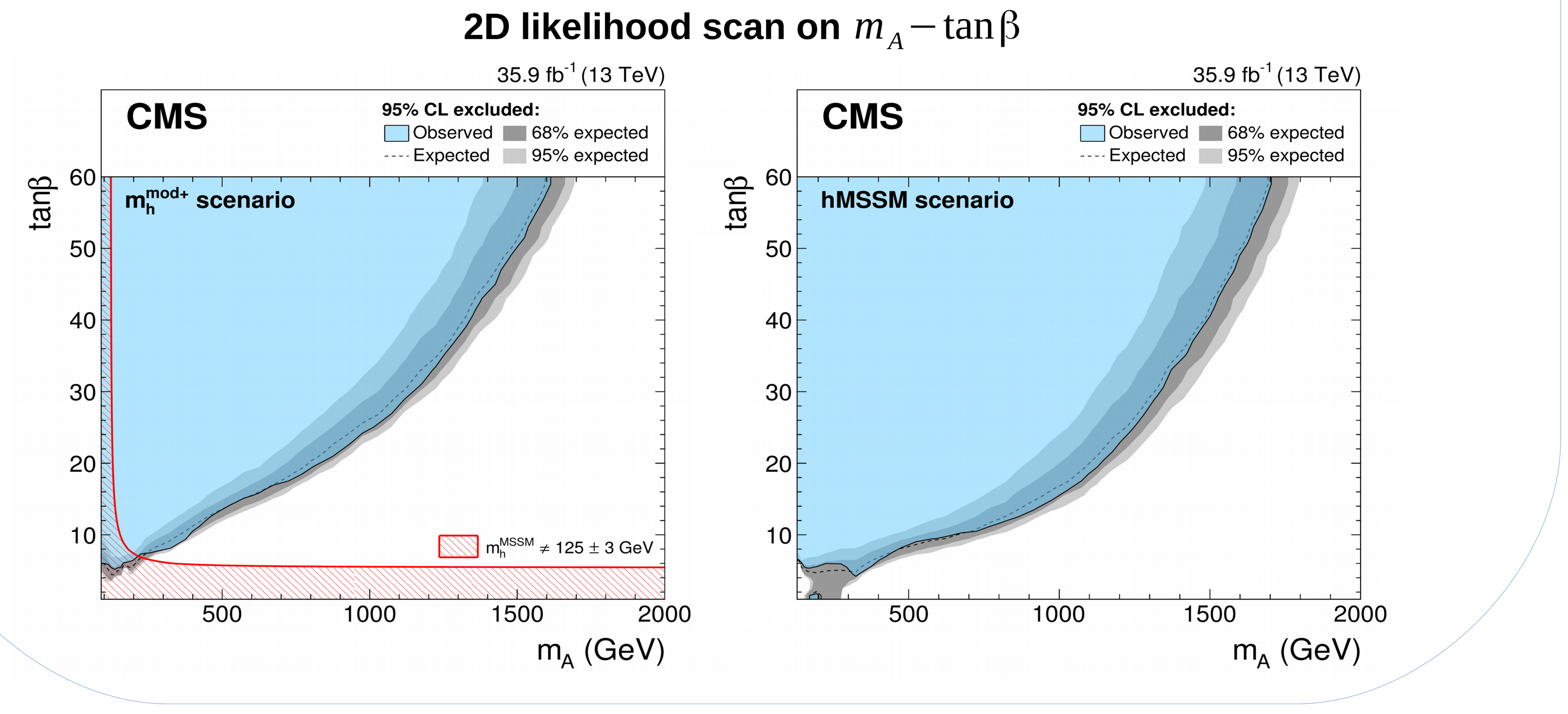
No Signal observed → setting exclusion limits

Improved model constraints and limits on the cross section

Model independent limit on cross-section times branching ratio between 90 and 3200 GeV



2D likelihood scan on $m_A - \tan\beta$



References

CMS-HIG-17-020

1. Performance of reconstruction and identification of τ leptons in their decays to hadrons and ν_τ in the CMS detector at LHC with the 2016 data, CMS-PAS-TAU-16-003
2. Search for additional neutral MSSM Higgs bosons in the di-tau final state in pp collisions at sqrt(s) = 13 TeV, CMS-HIG-17-020

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