Exploring Lepton-Flavor Violation (LFV) in $H \to e\mu$.

Search for the LFV decay of the Higgs boson and additional Higgs bosons in the $e\mu$ final state [1]

Daina Leyva Pernía (DESY) on behalf of the CMS Collaboration

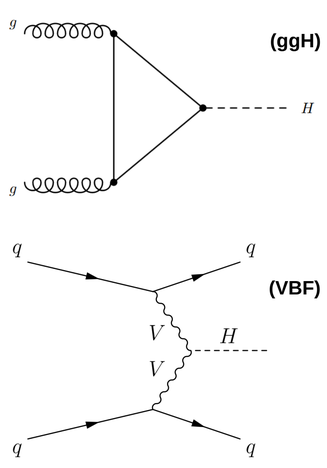
Why search for a LFV Higgs decay?

The Yukawa couplings of the Standard Model (SM) Higgs boson are diagonal only, evidence of LFV in the Higgs sector will necessarily imply new physics

Many BSM theories allow for off-diagonal couplings: $Y_{e\mu}, Y_{e\tau}, Y_{\mu\tau}$

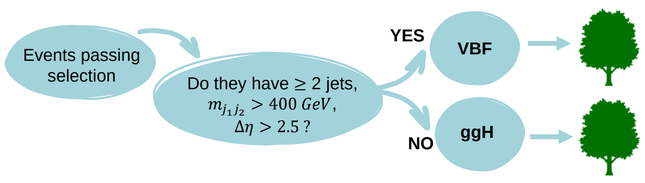
Searches for LFV decays of additional Higgs with $\mathrm{m_H} < 2 \times \mathrm{m_W}$ are particularly important to constrain Type-III 2HDM parameter space [2]

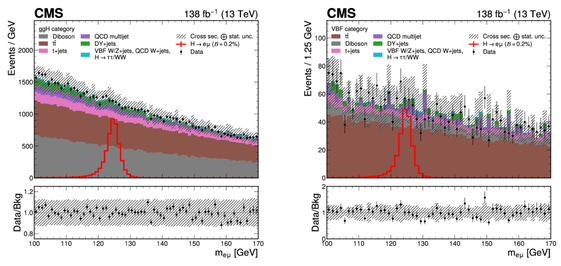
Targeted production modes



Event selection and categorization

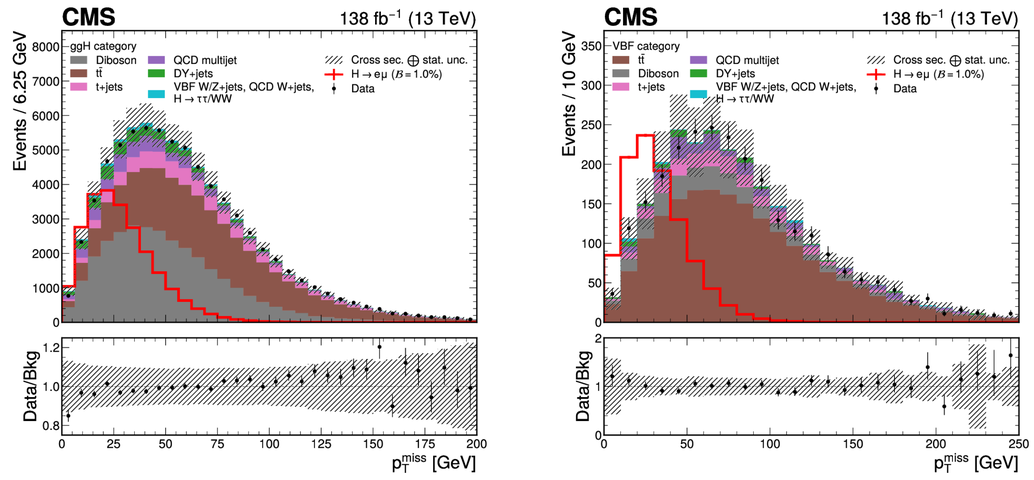
- Signal: oppositely charged electron-muon pairs (+ jets)
- Veto events with additional e, μ, τ_h, MET or b-tagged jets





The ggH and VBF BDTs

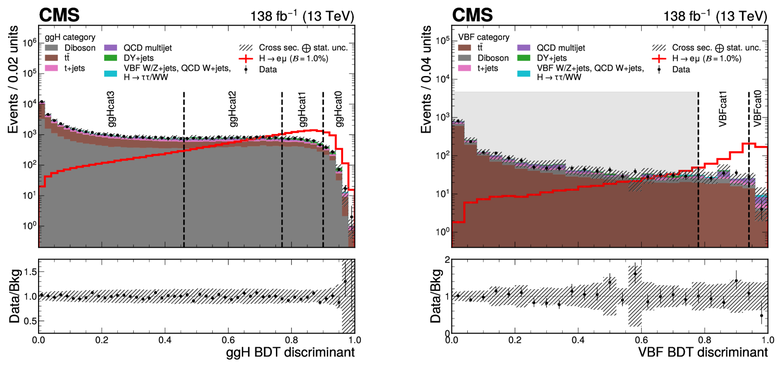
- BDT trained with MC simulations of Higgs mass hypotheses and background processes
- Input variables were chosen to be uncorrelated with $m_{e\mu}$
- Total weights of signal and background samples equalized during the training



p_T^{miss} has the strongest discriminating power

Sensitivity optimization

Further categorisation of ggH and VBF depending on the signal purity



Vertical lines illustrating sub-categories' boundaries

Events in shaded region discarded due to low sensitivity

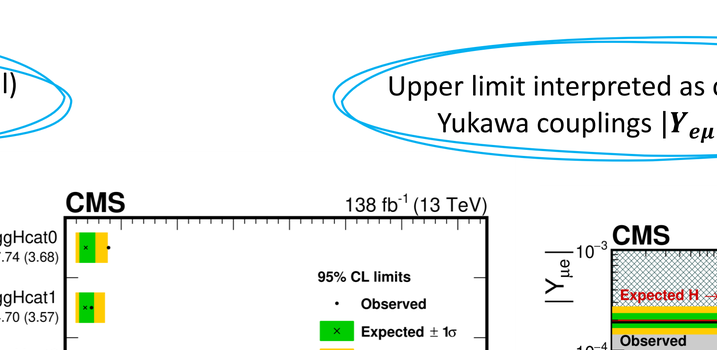
Background expectation agrees well with the data

Sub-categories defined optimizing the expected median significance with an injected signal at $B(H(125) \to e\mu) = 5.9 \times 10^{-4}$ [3]

Analysis category	BDT discriminant	σ_{eff} (GeV)	S	ggH mode fraction (%)	VBF mode fraction (%)	B	$S/\sqrt{B}$
ggH cat 0	0.89–1.00	1.7	22.4	94.2	5.8	79.1	2.5
ggH cat 1	0.77–0.89	2.1	55.4	96.4	3.6	399.3	2.8
ggH cat 2	0.46–0.77	2.4	60.4	96.0	4.0	1045.9	1.9
ggH cat 3	0.00–0.46	2.5	20.9	94.4	5.6	3755.4	0.3
VBF cat 0	0.94–1.00	1.9	2.2	23.7	76.3	1.1	2.2
VBF cat 1	0.78–0.94	2.2	2.4	42.2	57.8	9.7	0.8
VBF cat 2	0.00–0.78	2.4	2.3	61.8	38.2	161.3	0.2

Signal and background modelling

The VBF (ggH) signal $m_{e\mu}$ distributions are fitted with a sum of two (three) Gaussian functions
Each category, production mode, and mass points fitted separately



Systematic uncertainties affect the event yield from 0.1 to 20%

e and μ momentum scale (resolution) syst. effect on model parameters is 0.1% (10%)

Fit parameters between available mass point samples interpolated with 1D splines

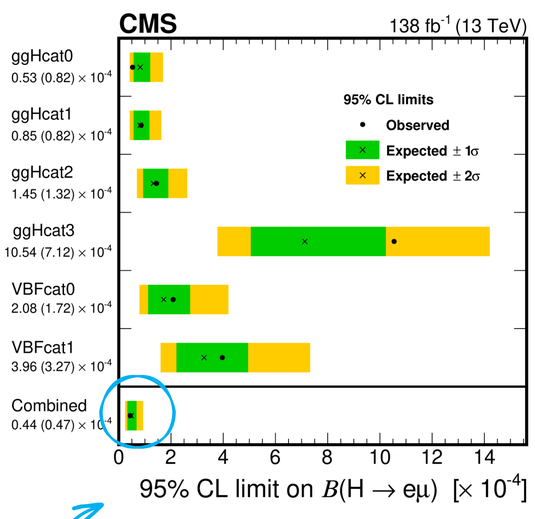
Background estimated in a data-driven approach. Modelled using Bernstein polynomials

$$\sum_{i=1}^{N} p_{1i} \binom{N}{i} x^i (1-x)^{N-i}$$

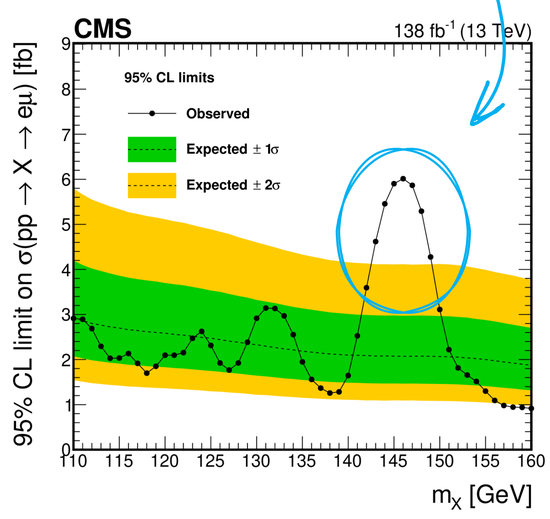
Systematics associated to the bias of the background model choice addressed with a bias study. The contribution ranges from 6.9% to 14.4% of the total uncertainty

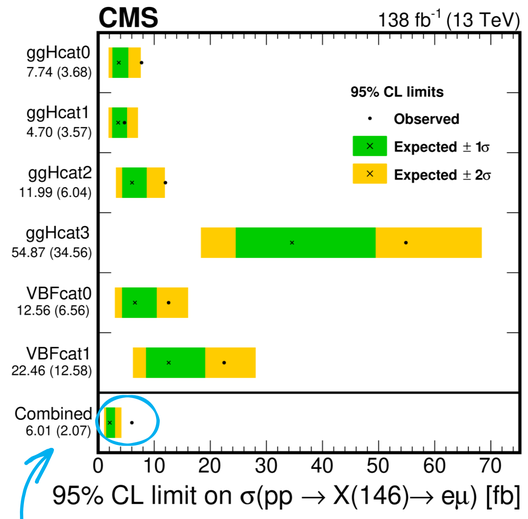
Results and Summary

No excess of data above background prediction for $H(125) \to e\mu$ observed

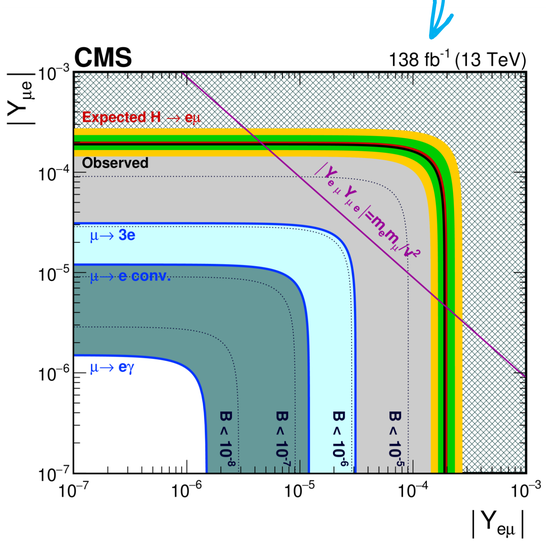


Excess of 3.8 (2.8) σ local (global) observed at $m_X = 146\ GeV$





Upper limit interpreted as constrain on LFV Yukawa couplings $|Y_{e\mu}|$ and $|Y_{\mu e}|$



Calculated observed (expected) 95% CL upper limit on $B(H \to e\mu)$ of 4.4 (4.7) $\times 10^{-5}$

Best fit combining all categories:
$\sigma(pp \to X(146) \to e\mu) = 3.89^{+1.11}_{-1.08}(stat.)^{+0.57}_{-0.34}(syst.) fb$

These are the most stringent limits set thus far from direct searches!

[1] CMS Collaboration, "Search for the lepton-flavor violating decay of the Higgs boson and additional Higgs bosons in the $e\mu$ final state in proton-proton collisions at $\sqrt{s} = 13\ TeV$", arXiv:2305.18106
[2] R. Primulando, J. Julio, and P. Uttayarat, "Collider constraints on lepton flavor violation in the 2HDM", Phys. Rev. D 101 (2020) 055021
[3] ATLAS Collaboration, "Search for the Higgs boson decays $H \to ee$ and $H \to e\mu$ in pp collisions at $\sqrt{s} = 13\ TeV$ with the ATLAS detector", Phys. Lett. B 801 (2019) 135148

European Physical Society Conference on High Energy Physics 21–25 August 2023