

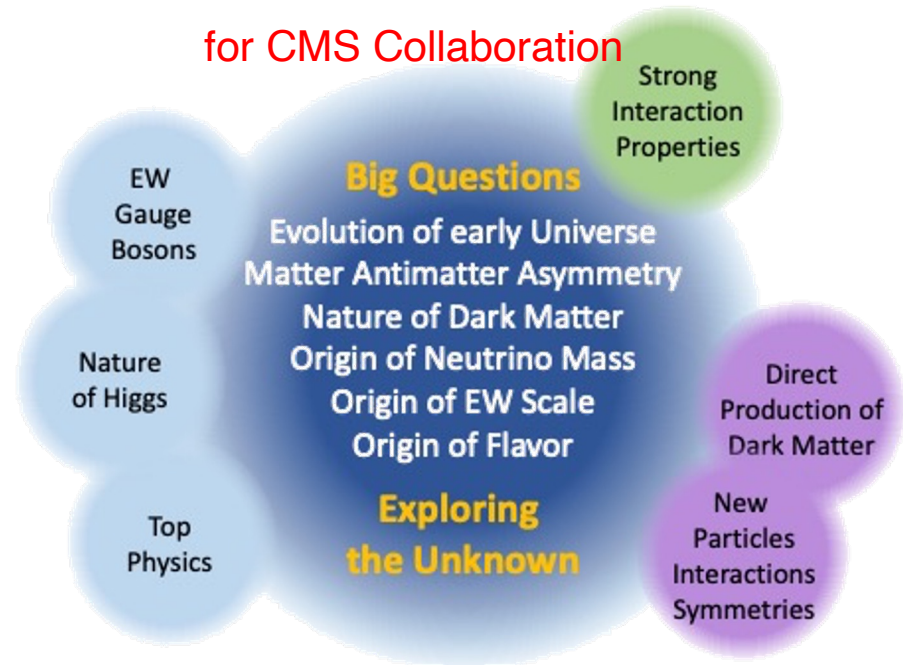


Beyond standard model searches at CMS: Highlights and prospects



Sridhara Dasu
University of Wisconsin

for CMS Collaboration





Glino-pairs, Squark-pairs, Diboson-Resonances, Heavy Fermions



gluinos

CMS

Moriond 2021

Overview of SUSY results: gluino pair production
137 fb⁻¹ (13 TeV)

$pp \rightarrow \tilde{g}\tilde{g}$

0f: arXiv:1909.03460;1908.04722;2103.01290

1f: arXiv:1911.07558

2f same-sign and $\geq 3f$: arXiv:2001.10086

$\tilde{g} \rightarrow tt\tilde{\chi}_1^0$

0f: arXiv:1909.03460;1908.04722

$\tilde{g} \rightarrow qq\tilde{\chi}_1^0$

0f: arXiv:1909.03460;1908.04722

0f: arXiv:1908.04722

2f same-sign and $\geq 3f$: arXiv:2001.10086

BF($\tilde{\chi}_1^0 \rightarrow \tilde{\chi}_2^0$) = 2.1, $x = 0.5$

BF($\tilde{\chi}_1^0 \rightarrow \tilde{\chi}_2^0$) = 2.1, $x = 0.5$

mass scale [GeV]

2 TeV

CMS (preliminary)

Moriond 2021

Overview of SUSY results: squark pair production
137 fb⁻¹ (13 TeV)

$pp \rightarrow \tilde{t}\tilde{t}$

Combination: SUS-20-102

0f: arXiv:1909.03460;1908.04722;2103.01290

1f: arXiv:1912.08887

2f opposite-sign: arXiv:2008.09396

0f: arXiv:1909.03460;1908.04722;2103.01290

1f: arXiv:1912.08887

2f opposite-sign: arXiv:2008.09396

0f: arXiv:1909.03460;1908.04722

0f: arXiv:1909.03460;1908.04722

0f: arXiv:1909.03460;1908.04722

2f same-sign and $\geq 3f$: arXiv:2001.10086

0f: arXiv:1909.03460;1908.04722

0f: arXiv:1909.03460;1908.04722

0f: arXiv:1909.03460;1908.04722

0f: arXiv:1909.03460;1908.04722

0f: arXiv:1909.03460;1908.04722

0f: arXiv:1909.03460;1908.04722

mass scale [GeV]

1 TeV

16-May-23

VV/HHVV/ resonances

Resonances

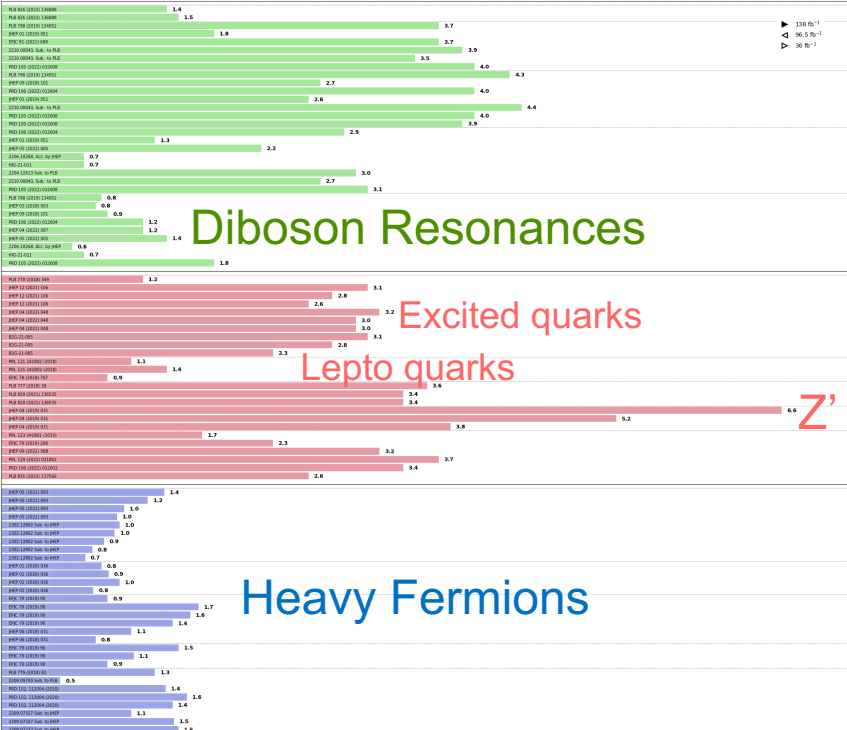
Very heavy fermions

Pair prod.



Overview of CMS B2G Results

CMS Preliminary



Diboson Resonances

Excited quarks
Lepto quarks

Heavy Fermions

1 TeV

7 TeV

Lower mass limit at 95% CL (TeV)

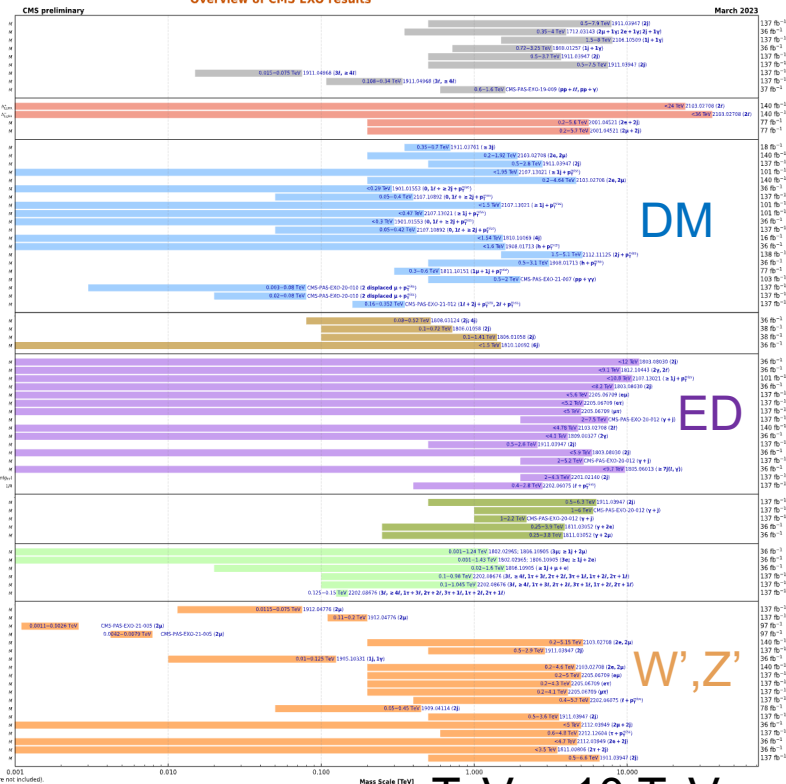
Selection of observed limits at 95% C.L. (theory uncertainties are not included). Probe up to the quoted mass limit for light LSPs unless stated otherwise. The quantities ΔM and x represent the absolute mass difference between the primary sparticle and the LSP, and the difference between the intermediate sparticle and the LSP relative to ΔM , respectively, unless indicated otherwise.



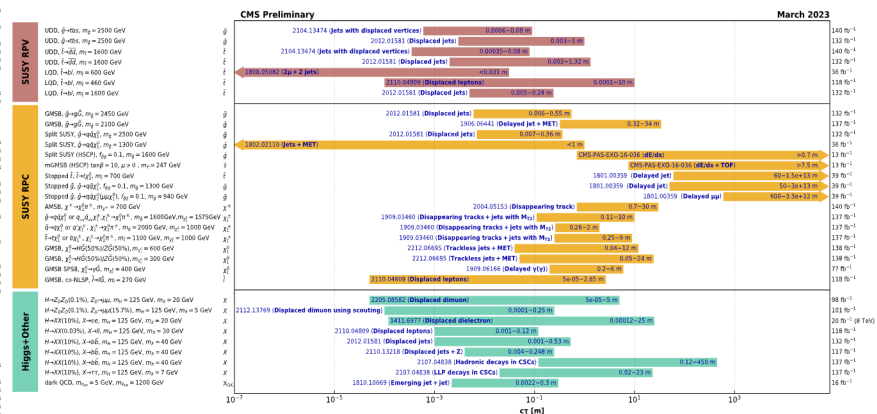
Summary of Exotica From Snowmass



Overview of CMS EXO results



Overview of CMS long-lived particle searches



Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included). The x-axis tick labels indicate the studied long-lived particle.

There is a LOT of material to chose from, and fill hours.

Will present an eclectic set of topics relevant for LCs it being LCWS-2023



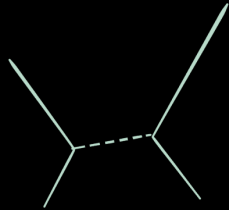
One of Nathaniel's Seven Questions



A Yukawa Force?

Someone asked, how about off-diagonal Yukawas?

Yukawa force between fundamental particles: never seen until now

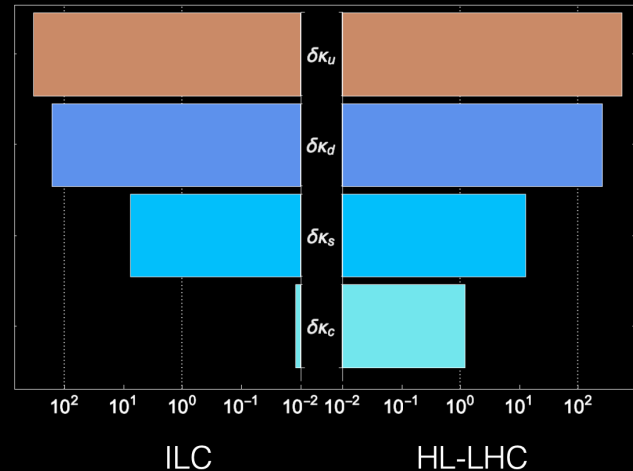


$$\frac{V_{\text{Higgs}}(r)}{V_{\text{Weak}}(r)} \sim \frac{y^2}{g^2} e^{-(m_h - m_Z)r}$$

Established by $>5\sigma$ observation of $t\bar{t}H$, $H \rightarrow b\bar{b}$ and $H \rightarrow \tau\tau$ in LHC Run 2

"Is this any less important than the discovery of the Higgs boson itself? My opinion: no, because fundamental interactions are as important as fundamental particles"

Focus now on 2nd generation. Lightness makes flavor puzzle compelling, couplings could hold key to flavor puzzle.

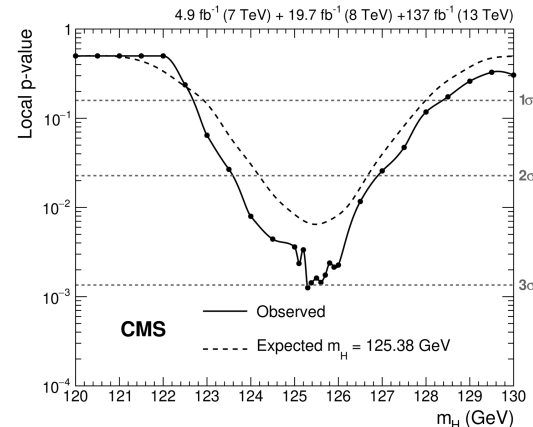
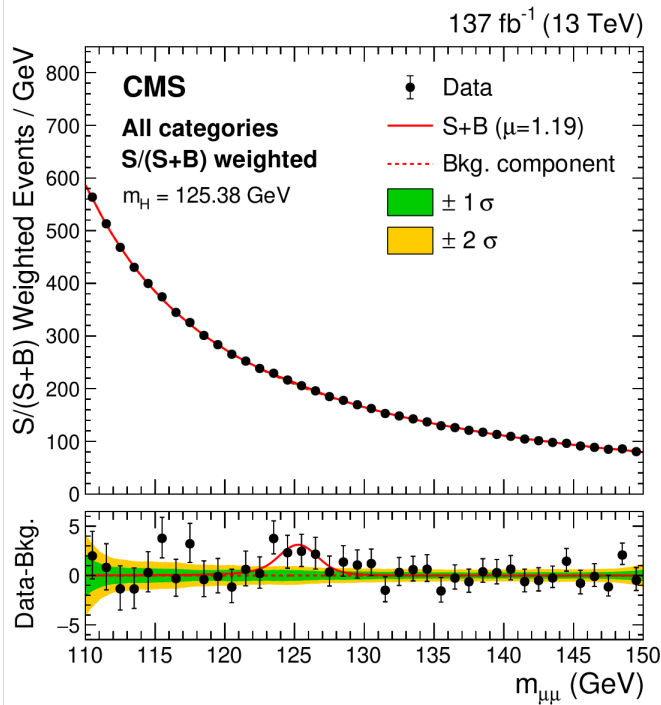
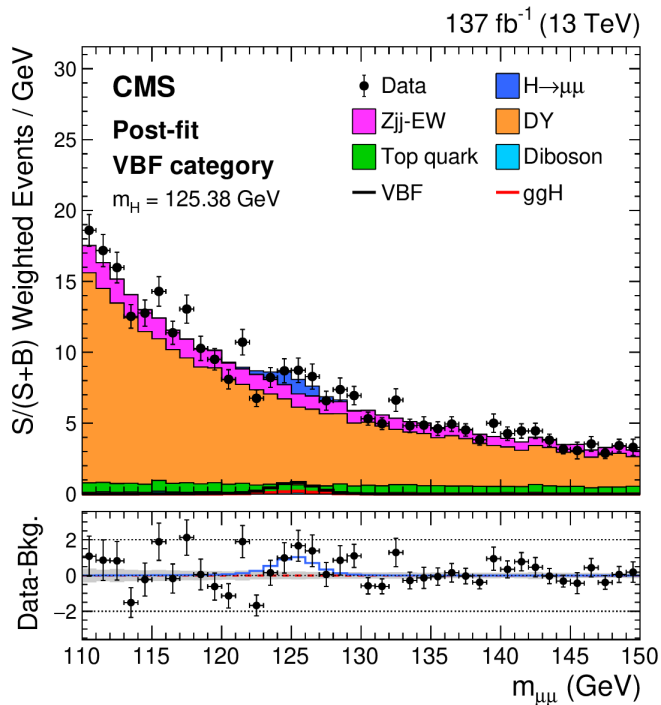




Evidence for Second Generation Yukawa

Albeit in the lepton sector

JHEP 01 (2021) 148



Continue to profit from excellent CMS muon resolution

Run-3: $>5\sigma$

HLLHC: $\Delta\kappa_\mu \sim 5\%$

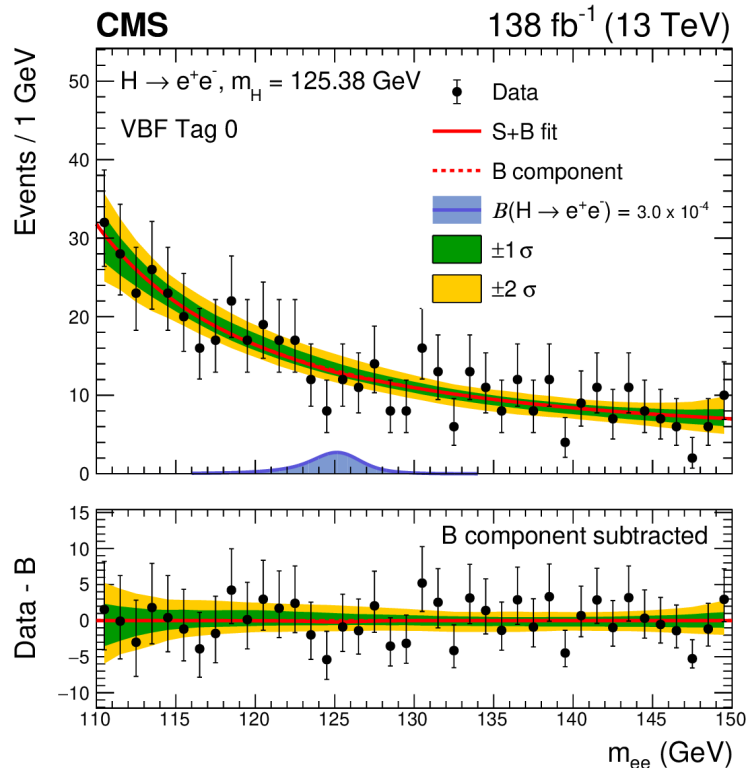
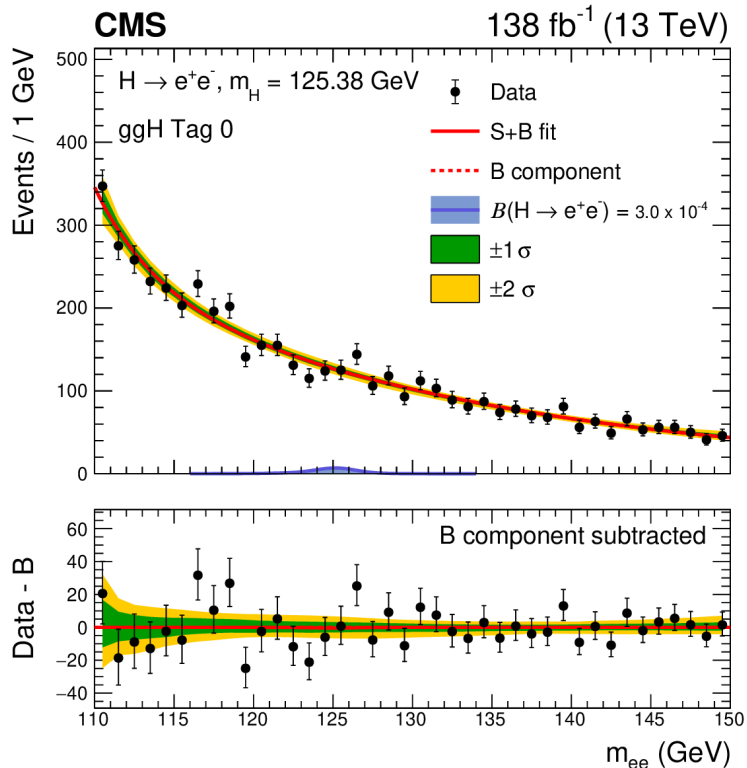


First Generation Yukawa

arXiv:2208.00265



Again in the lepton sector – if we see something it has to be BSM!

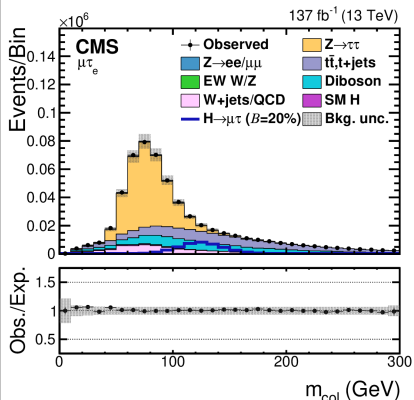
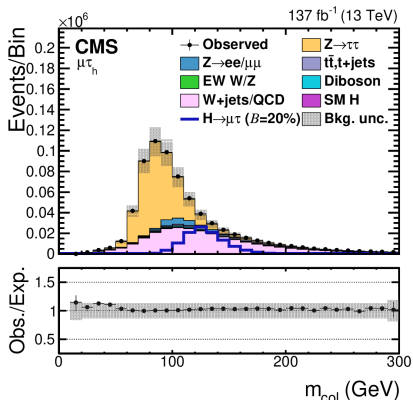


No one talks about Y_e other than FCC-ee special run



LFV: $H(125) \rightarrow \mu\tau, H(125) \rightarrow e\tau$

Phys. Rev. D 104 (2021) 032013

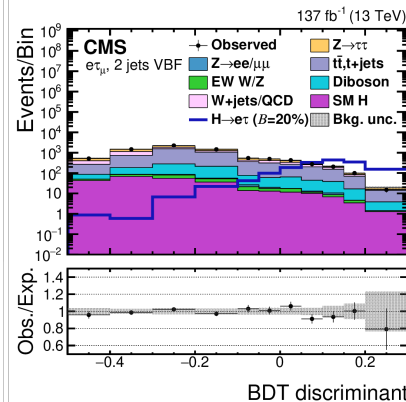
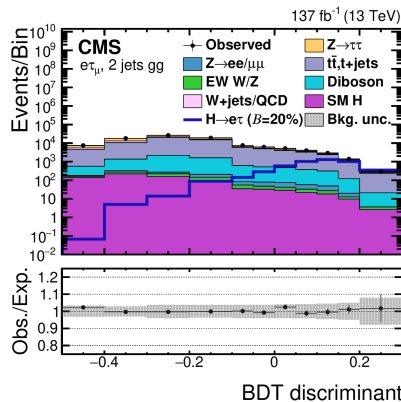
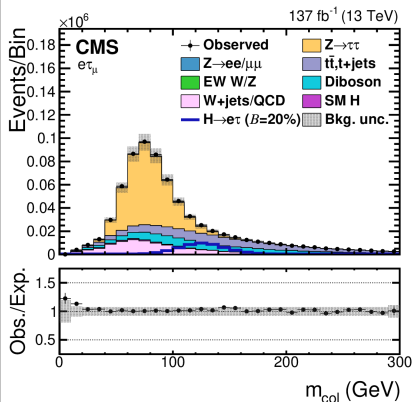
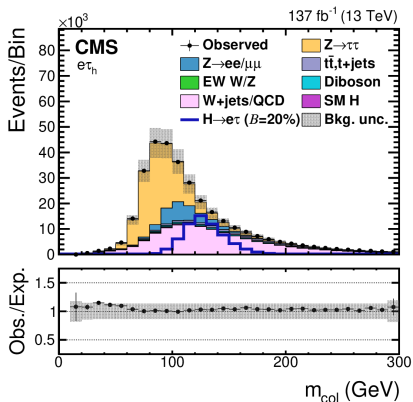
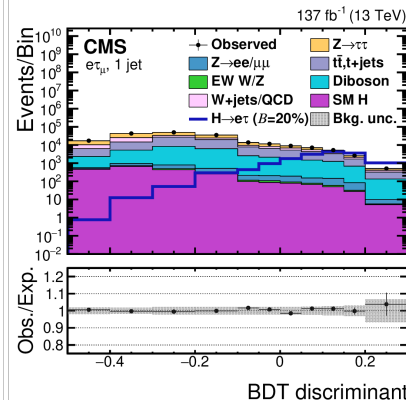
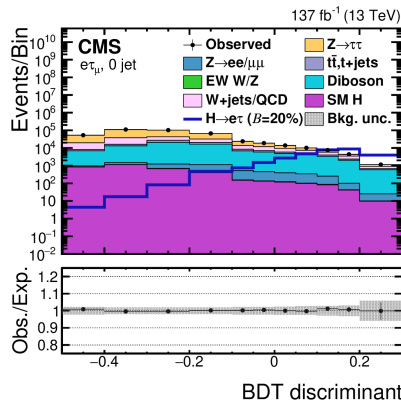


Challenges:
 Significant backgrounds
 Single lepton triggers



Embedded samples for
 $Z \rightarrow \tau\tau$

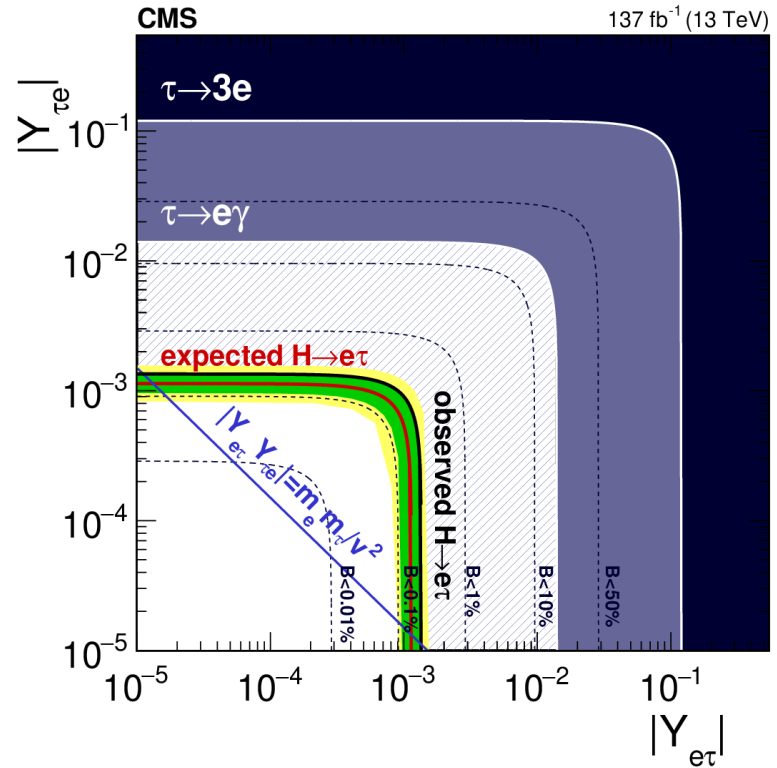
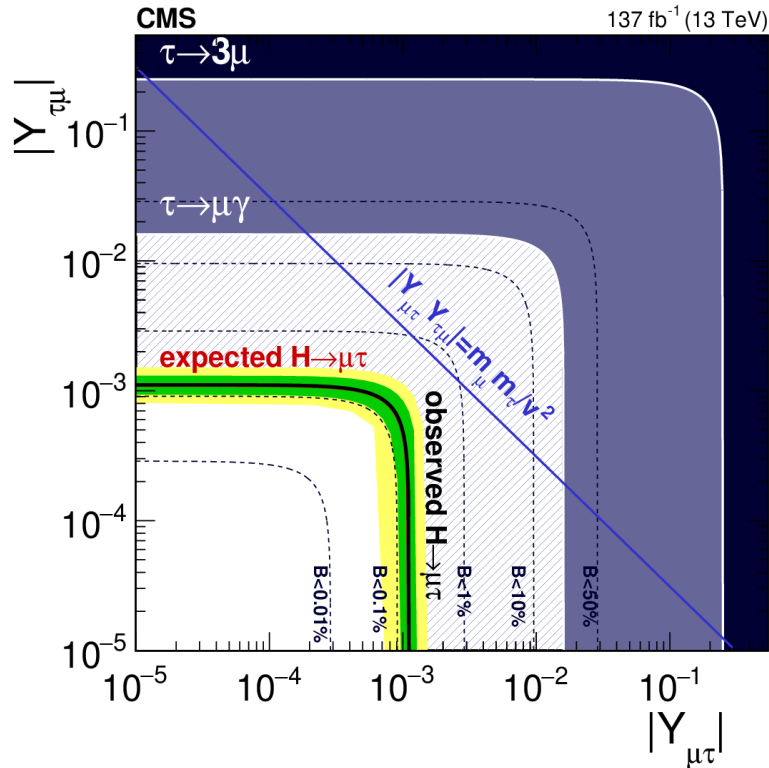
ML-based isolation
 ML-based discriminators





LFV: $H(125) \rightarrow \mu\tau, H(125) \rightarrow e\tau$

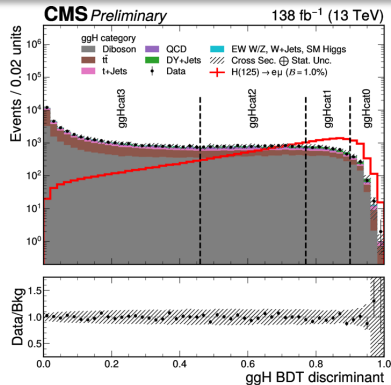
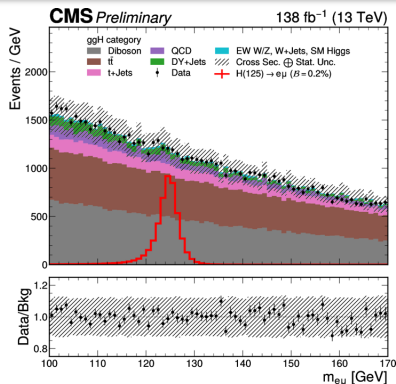
Phys. Rev. D 104 (2021) 032013



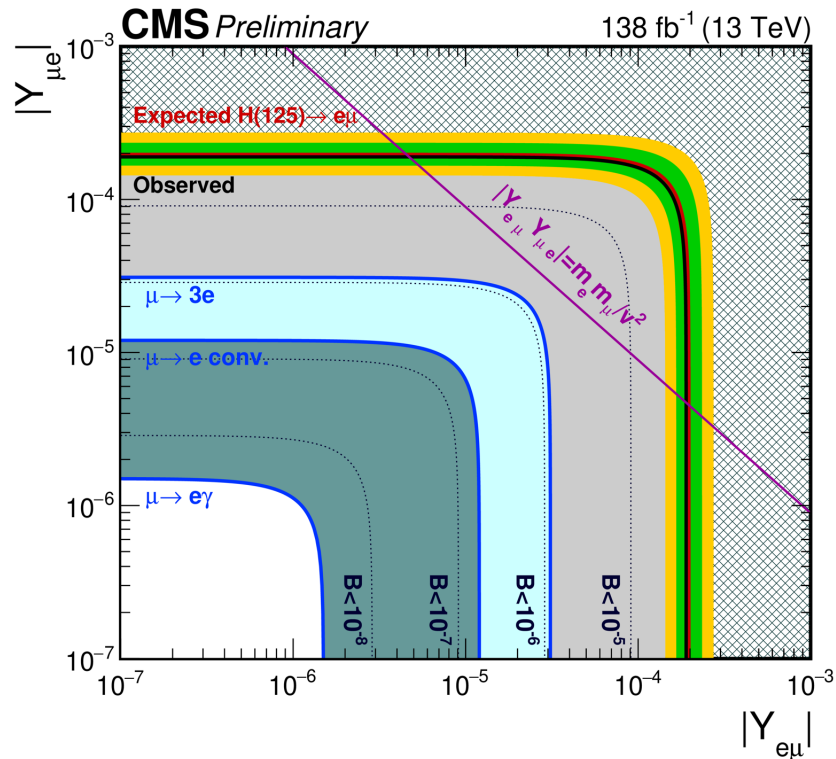
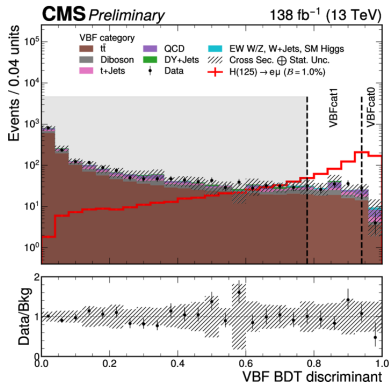
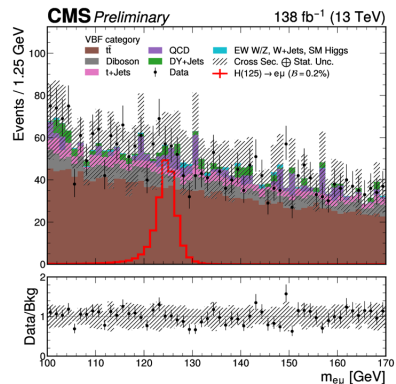


LFV: How about $H(125) \rightarrow e\mu$?

CMS-HIG-22-002



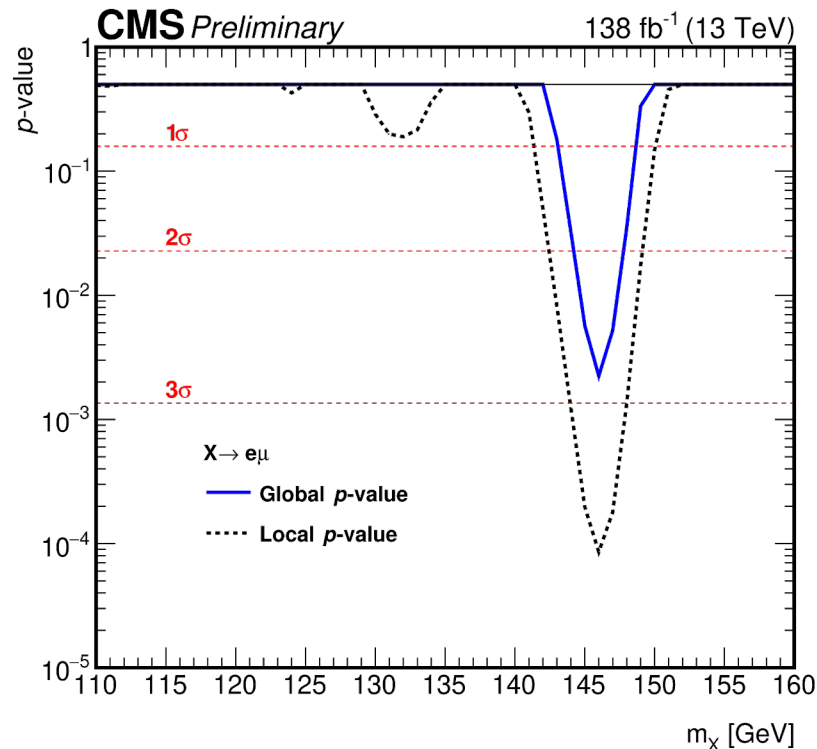
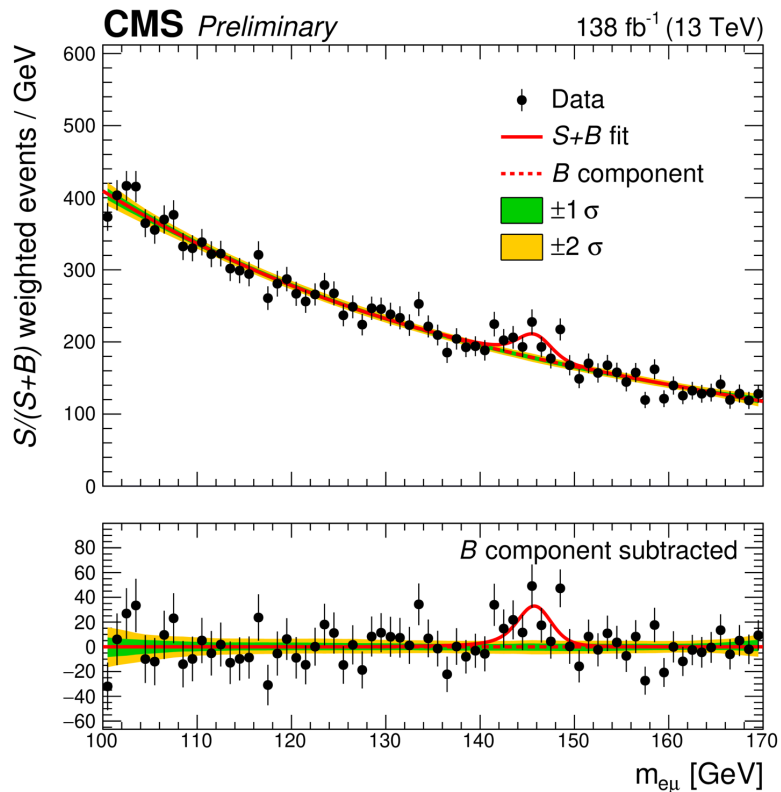
ML Discriminators →





LFV: Well $X \rightarrow e\mu$?

CMS-HIG-22-002

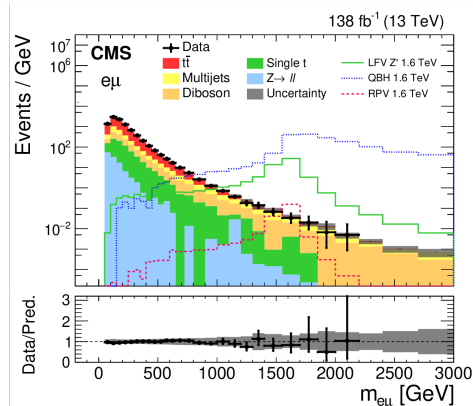
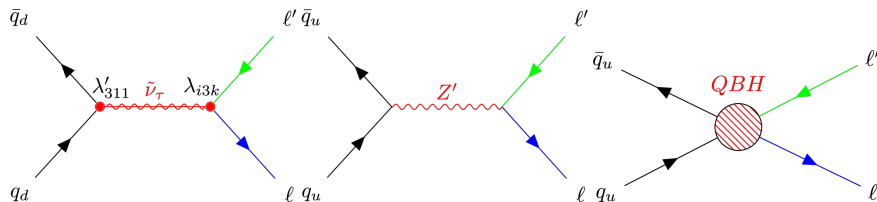


Awaiting more data ... Stay-tuned for Run-3



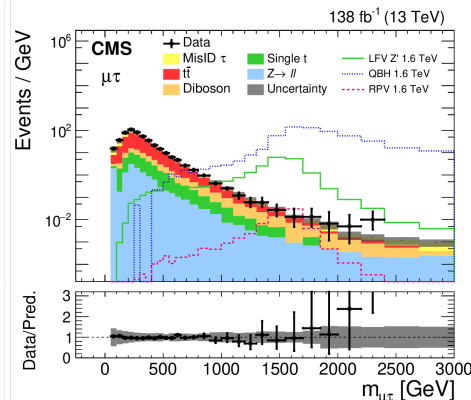
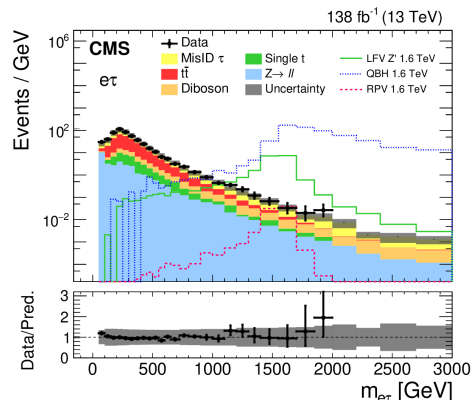
LFV: Very High Mass Objects

arXiv:2205.06709



Push to multi-TeV masses

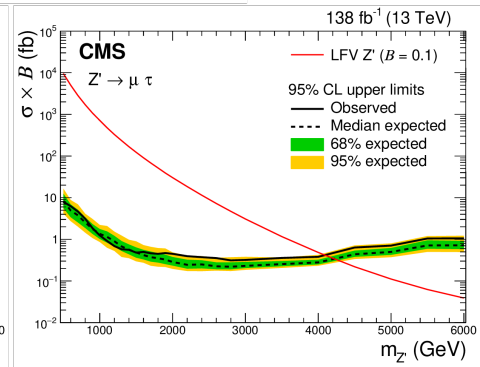
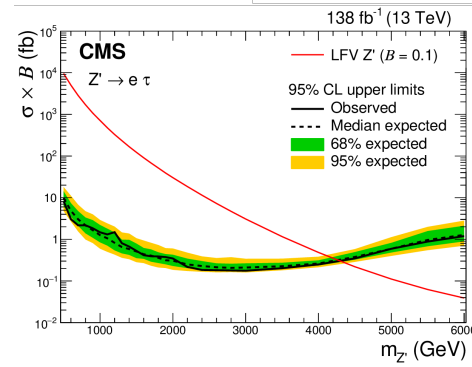
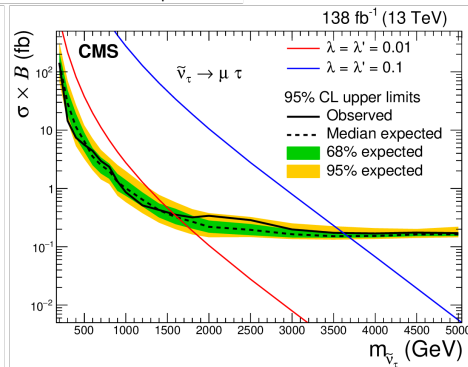
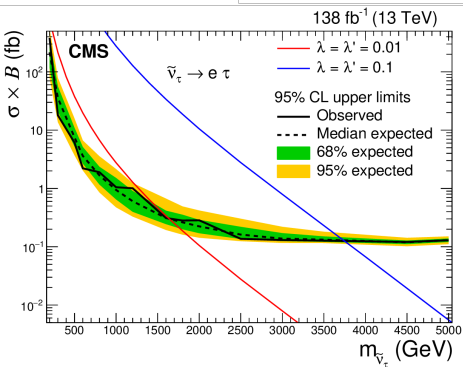
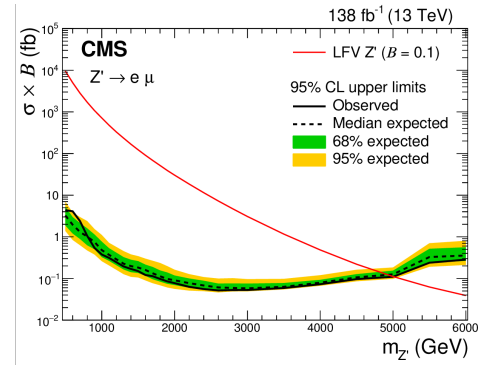
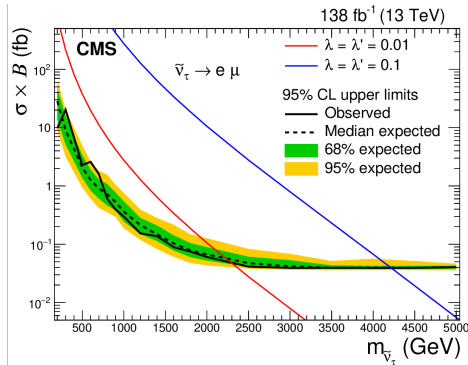
LHC shines when it comes to measuring very high P_T leptons





LFV: Sneutrino or Z' Interpretations

[arXiv:2205.06709](https://arxiv.org/abs/2205.06709)

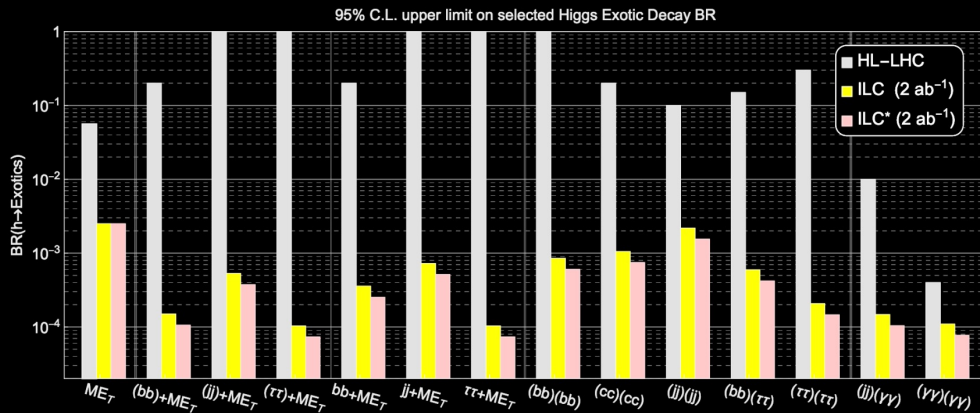
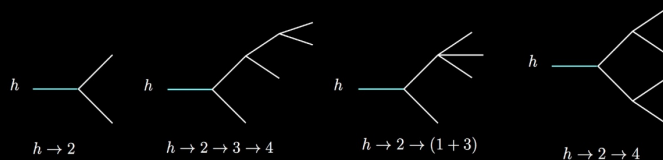
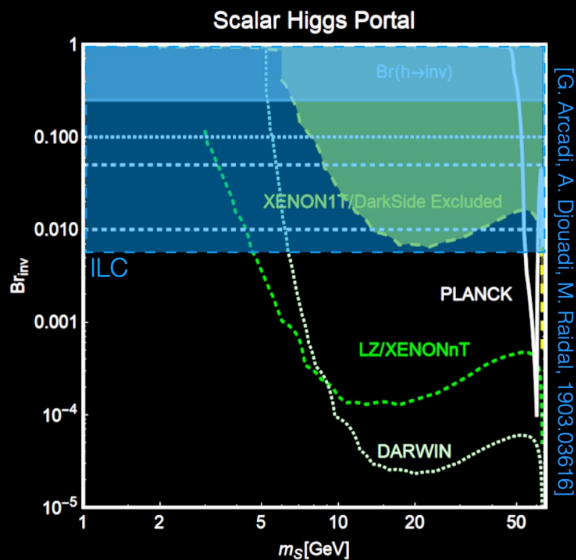




A portal to the dark sector?

$$\mathcal{L} \supset |H|^2 \mathcal{O}$$

Higgs a (the?) primary portal for coupling to SM-neutral sectors





2HDM+S: $H(125) \rightarrow aa \rightarrow \mu\mu bb$

CMS-PAS-HIG-22-007

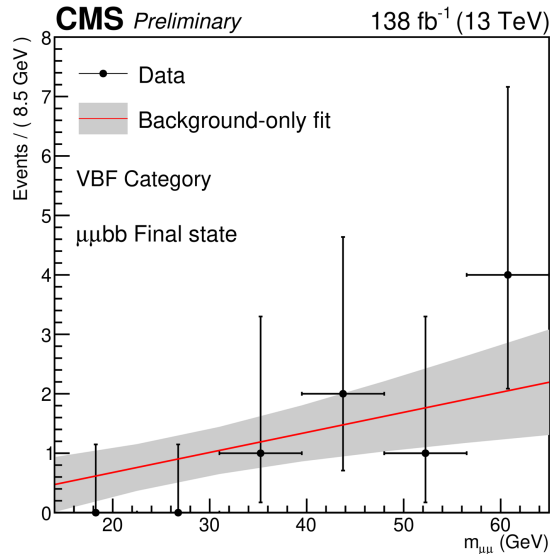
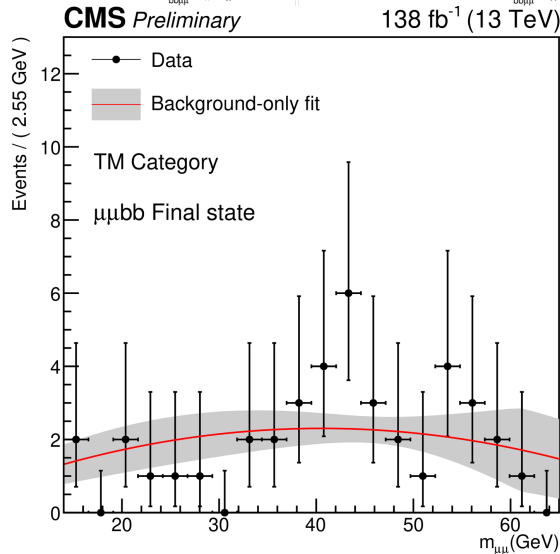
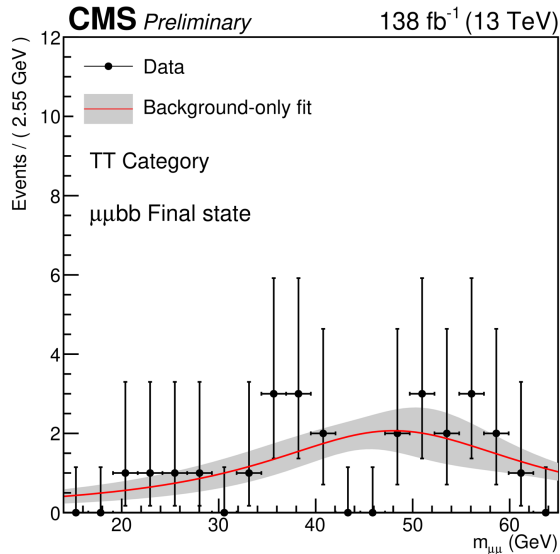
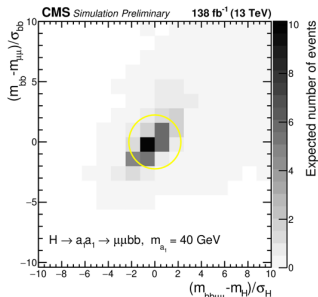
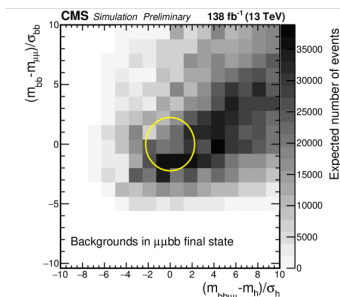


Challenges:

- High rate triggers
- Leptons from meson decays
- Large backgrounds
- Plethora of low P_T b-jets
- Combinatorics ...

Mitigation:

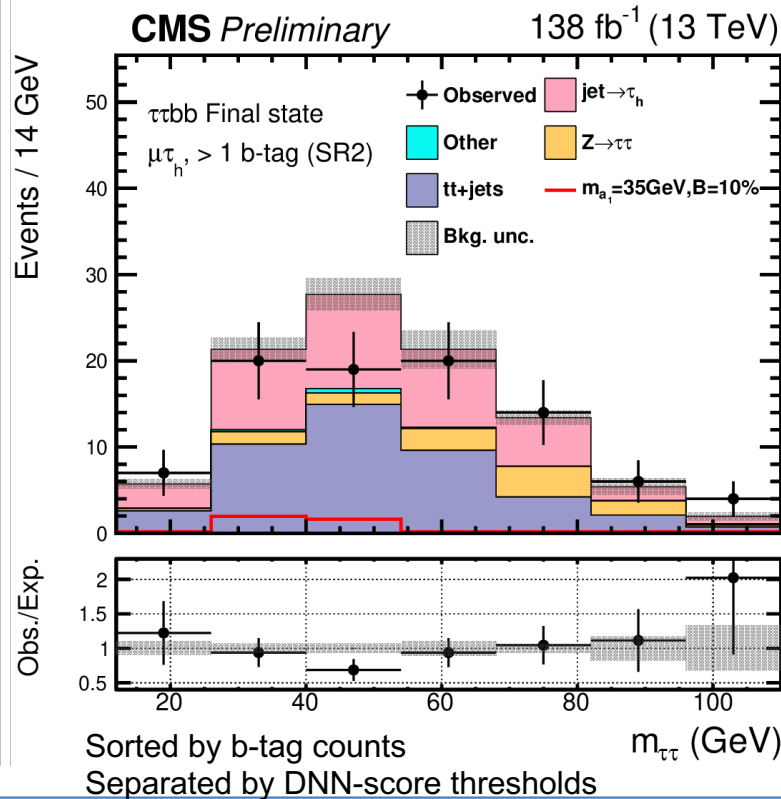
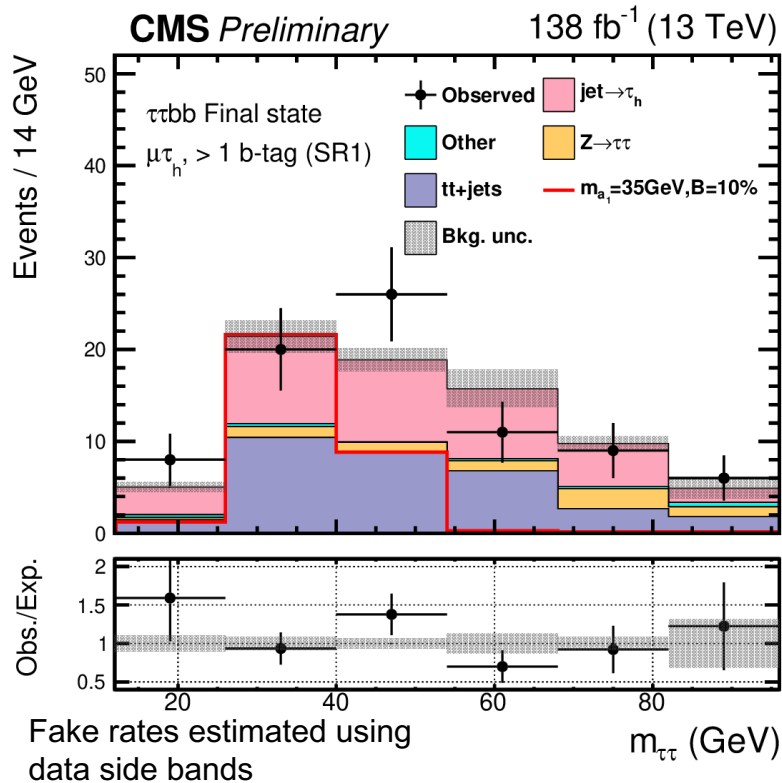
- Take advantage of topology
- Categorize by b-tag quality
- Sort by production modes
- ML-Based isolation





2HDM+S: $H(125) \rightarrow aa \rightarrow \tau\tau bb$

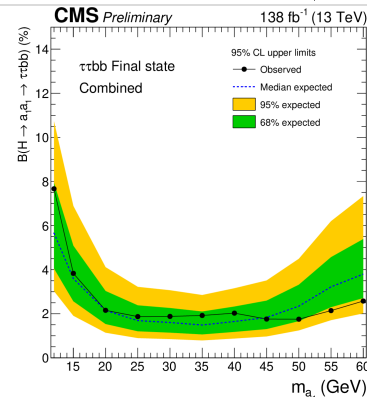
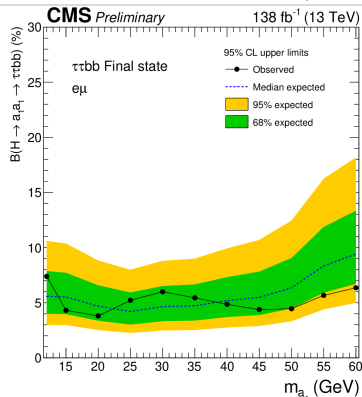
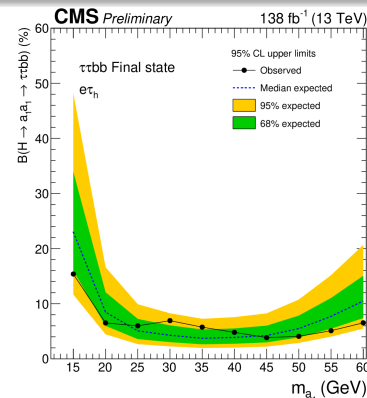
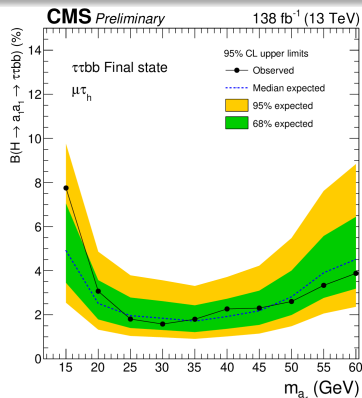
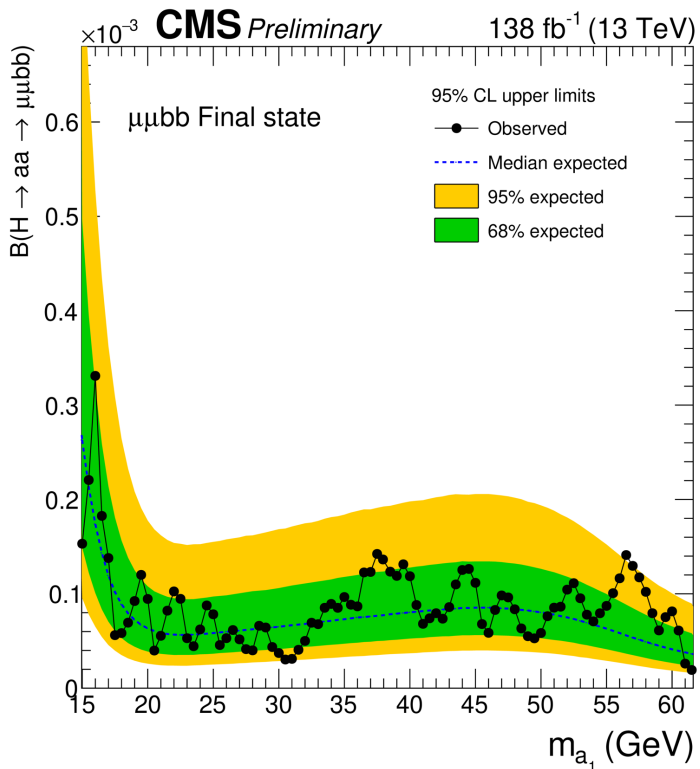
CMS-PAS-HIG-22-007





2HDM+S: $H(125) \rightarrow aa \rightarrow \mu\mu bb, \tau\tau bb$

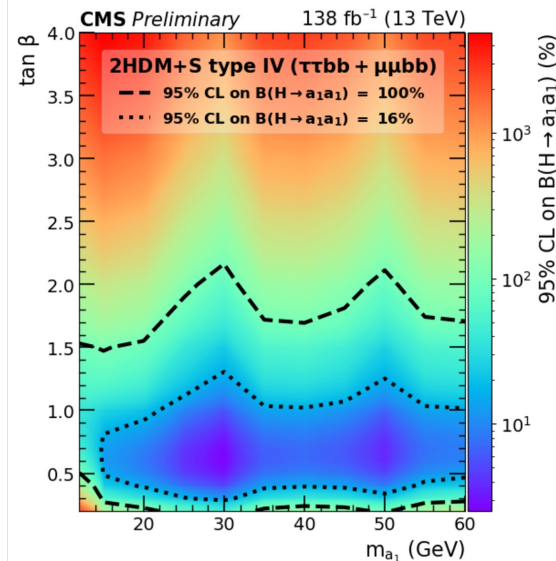
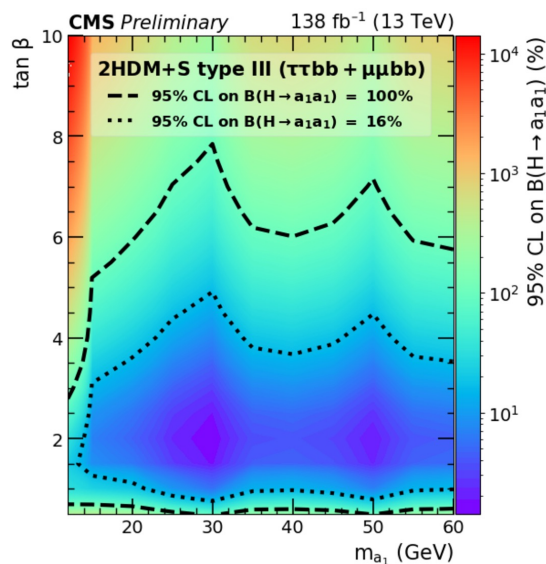
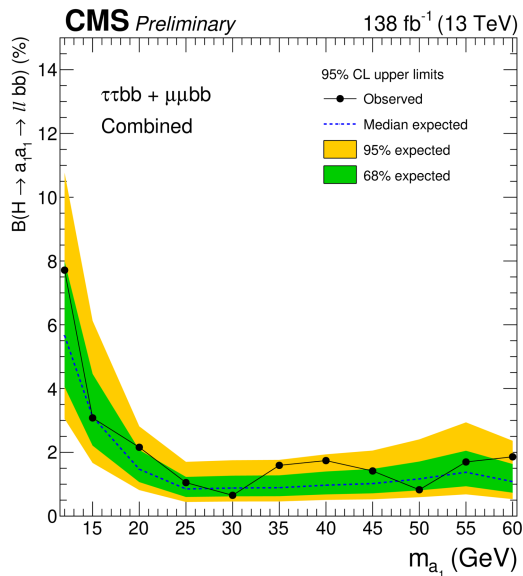
CMS-PAS-HIG-22-007





2HDM+S: $H(125) \rightarrow aa \rightarrow \mu\mu bb, \tau\tau bb$

CMS-PAS-HIG-22-007





Summary / Comments



CMS has explored very many beyond standard model physics signatures

- Nothing significant is yet to be seen
- Strongly coupled sector is limited
- Searches with luminosity increases will provide improved coverage
- Weakly coupled new physics will see most improvements
- An eclectic collection of BSM Higgs signatures is presented

HL-LHC luminosities will present challenges!

- Detector improvements should go far ... when going gets tough ...
- Higher granularity upgrades, Higher trigger rates, Precision timing, ... should help mitigate increasing pileup