Review of LHC experimental results on low mass bosons in multi Higgs models

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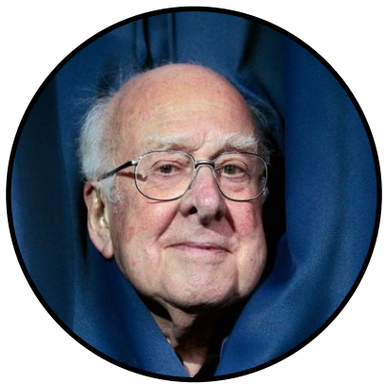
Exotic Higgs

Discovered one Higgs boson, but (disappointingly) Standard Model-like



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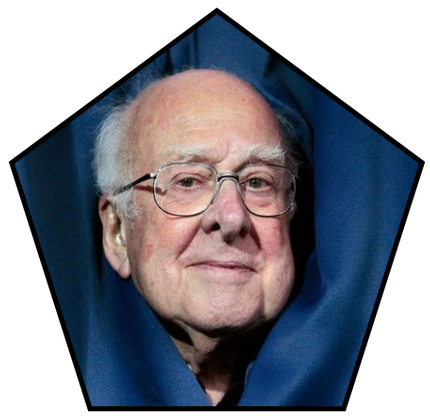
Much lighter?

CP-odd?



Couples to new (invisible) particles?

Can occur in non-minimal supersymmetry, Higgs-portal models, PYO …

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Focus on this today

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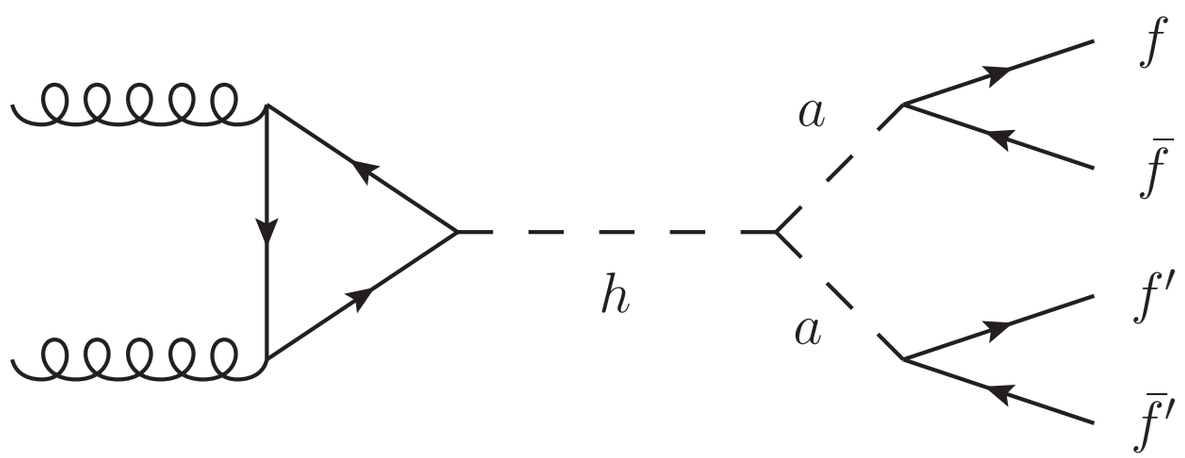
- ~~MSSM~~ → NMSSM
  - Add Singlet/ino to solve μ-problem + ease m_h fine-tuning
  - Keeps all the advantages of SUSY (solve hierarchy problem, DM, …)
  - End up with 7 Higgs bosons
  - Can have light a_1 or h_1 - not found in MSSM!
  - MSSM looking increasingly less likely from latest LHC results

Light Higgs detection

- **Production**: gluon-gluon fusion → h → a ("light" = $m_a < 62.5$ GeV)
- **Decay:** mass-dependent, like the SM Higgs: $\tau\tau$, μμ, bb common
  - But largest BR not always best!



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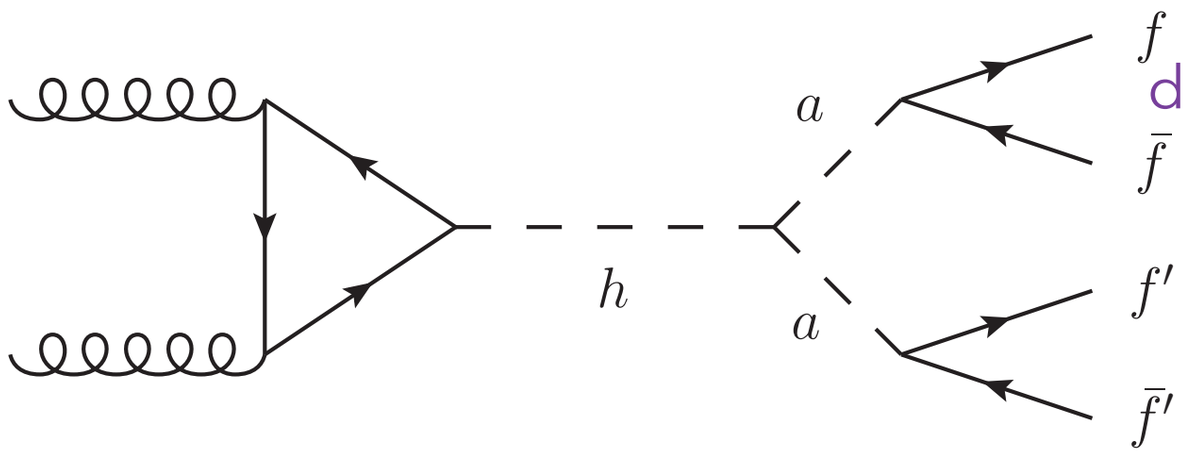
If $m_h >> m_a$ → a boosted

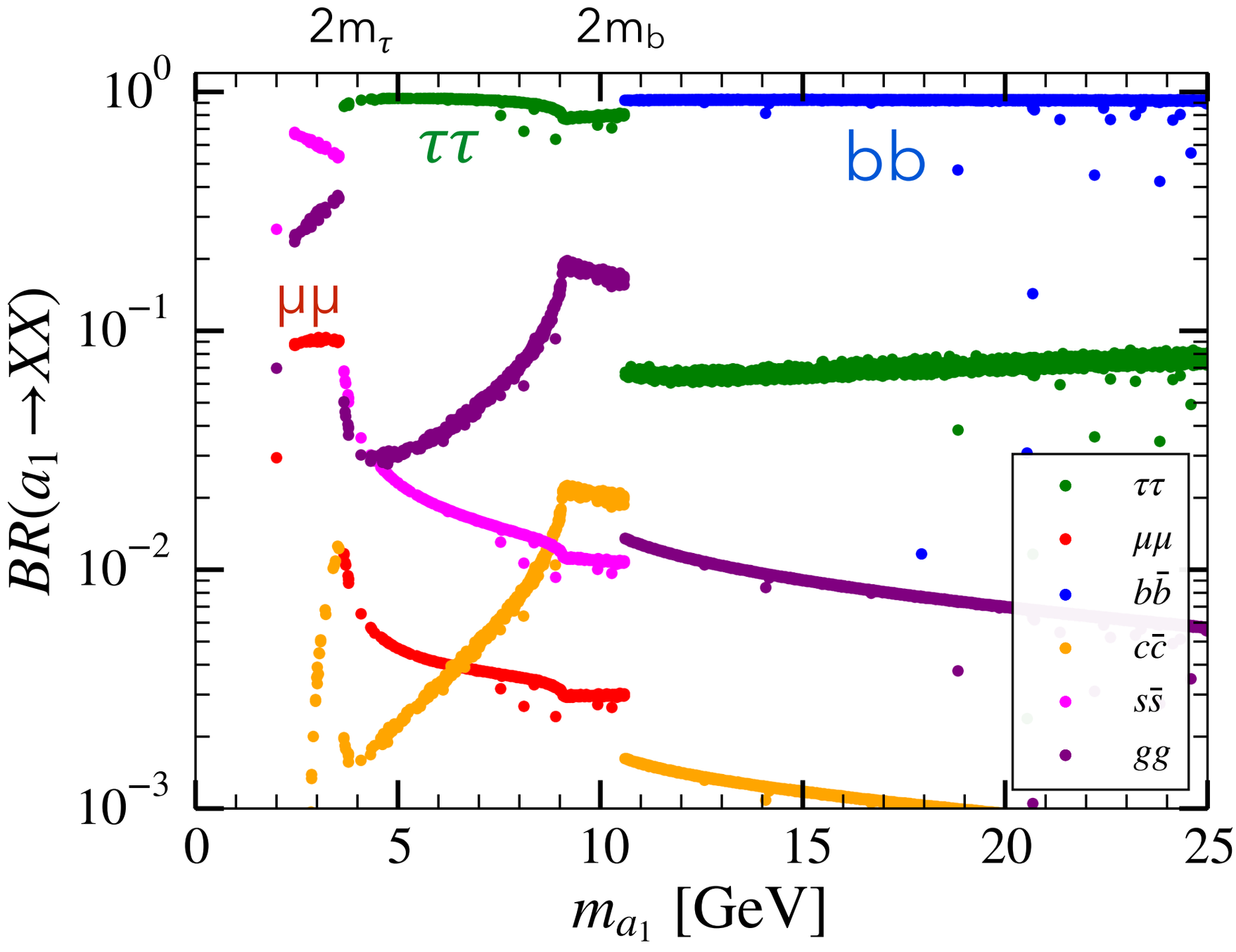
→ relevant for $m_a \lesssim 20$ GeV



decay products boosted & collimated
→ harder to detect

Light Higgs detection

- e.g in NMSSM



Light Higgs detection

- μμ
  - **Pro**: fully reconstructed, can look for clean peak on continuous background
  - **Con**: small BR, esp. for $m_a > 2m_\tau$
- $\tau\tau$
  - **Pro**: large BR, esp. 4 - 10 GeV ($2m_\tau < m_a < 2m_b$)
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Can be better to pick-n-mix!

2τ2μ

2b2μ

An example CMS analysis:

4τ

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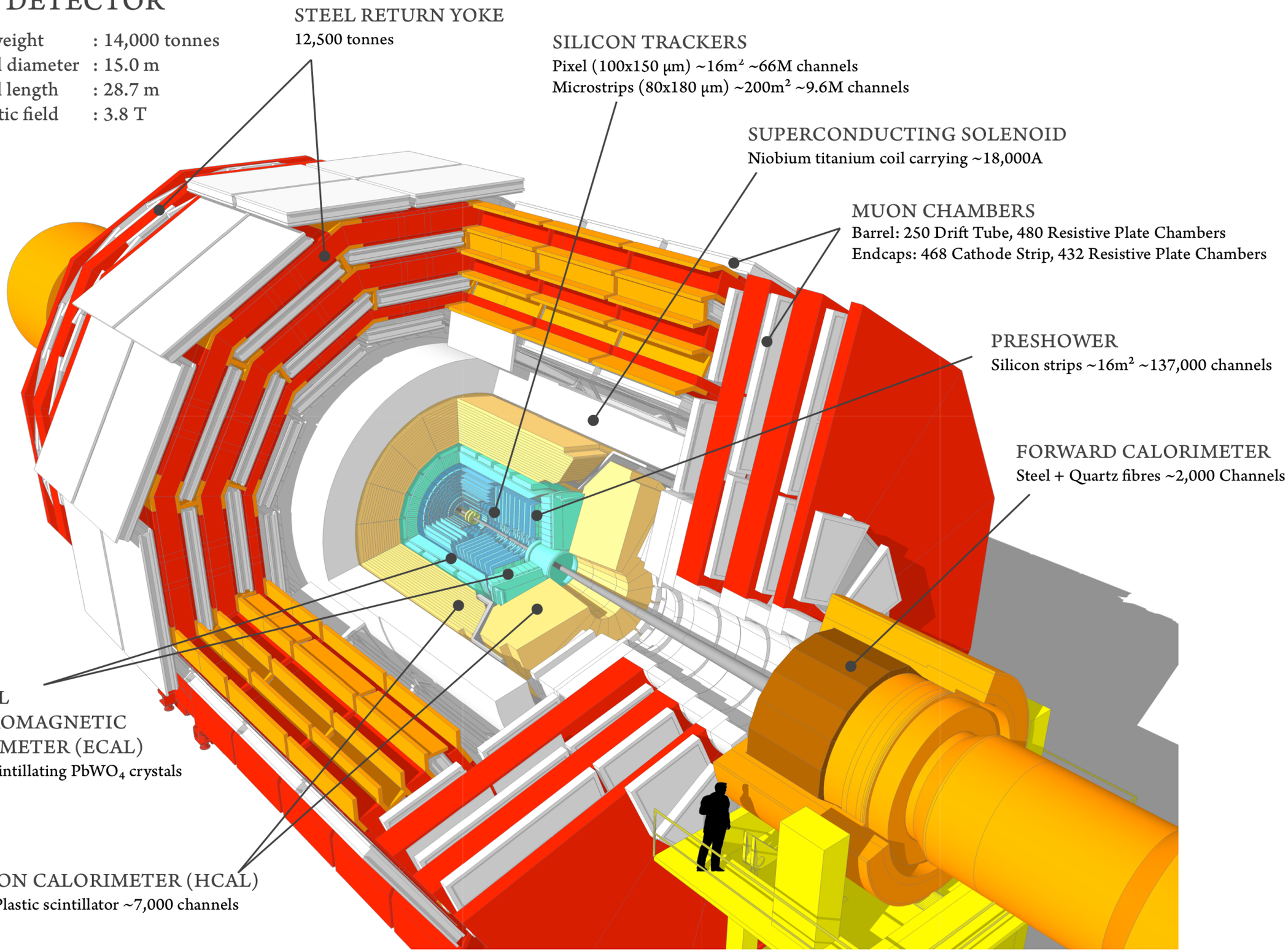
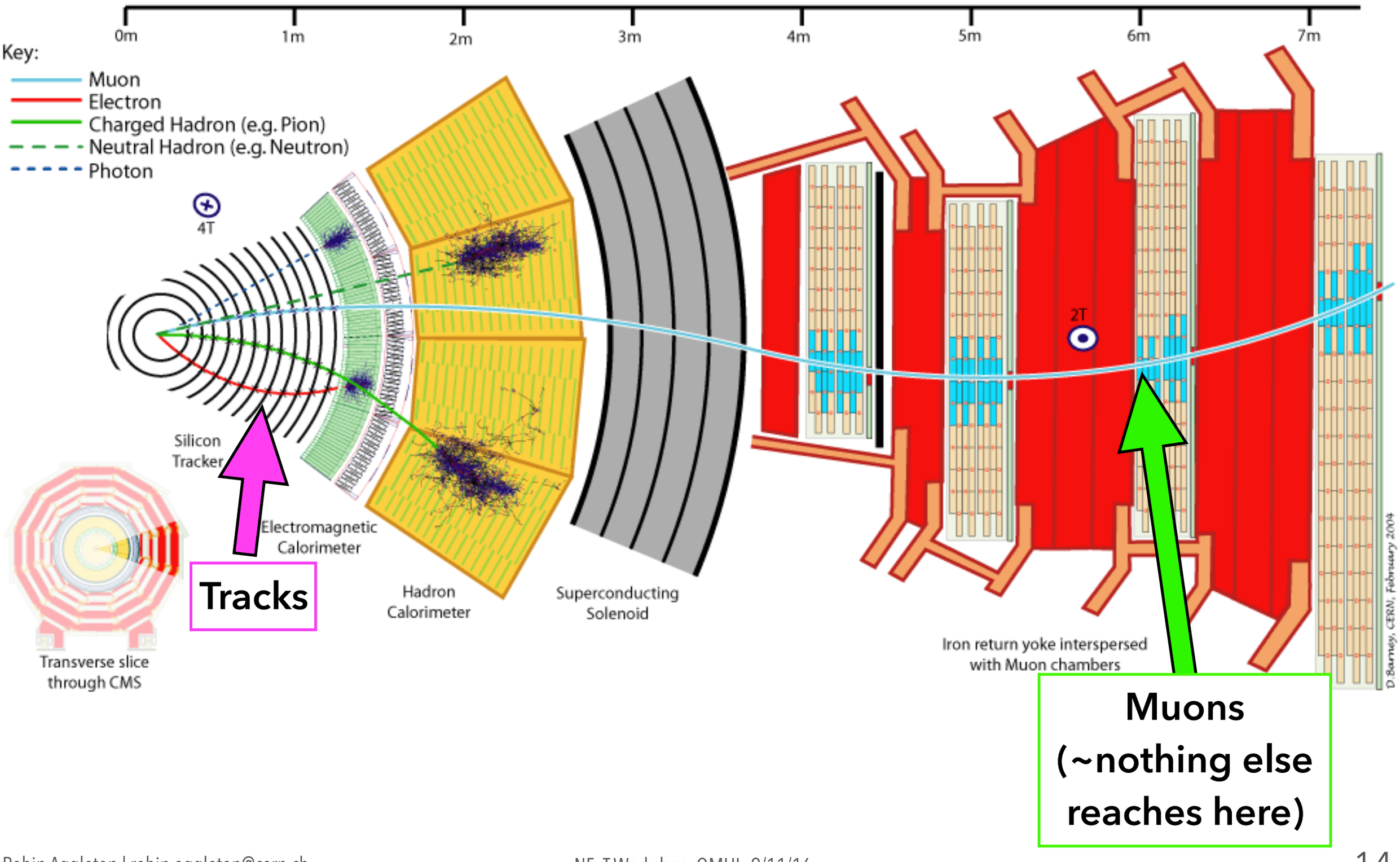
CMS

CMS DETECTOR

Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T



CMS


0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
Tracks
Muons (~nothing else reaches here)
D.Barney, CERN, February 2004

4τ

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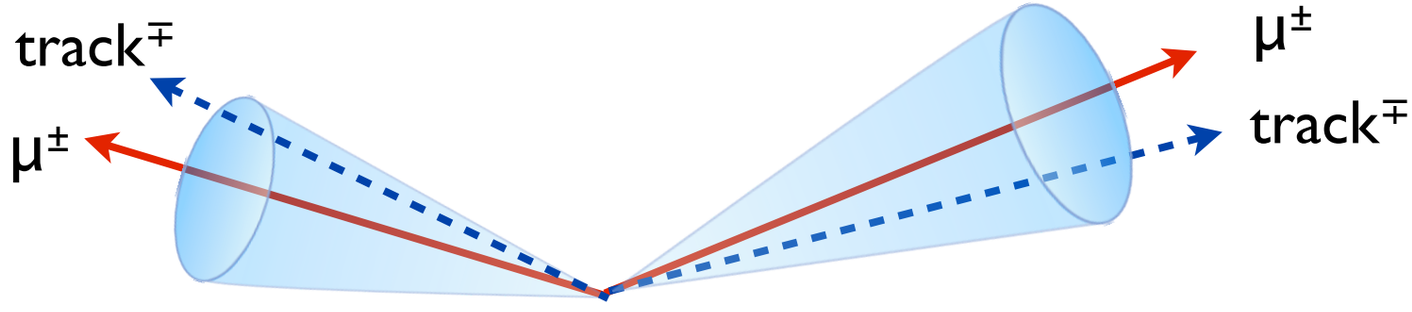
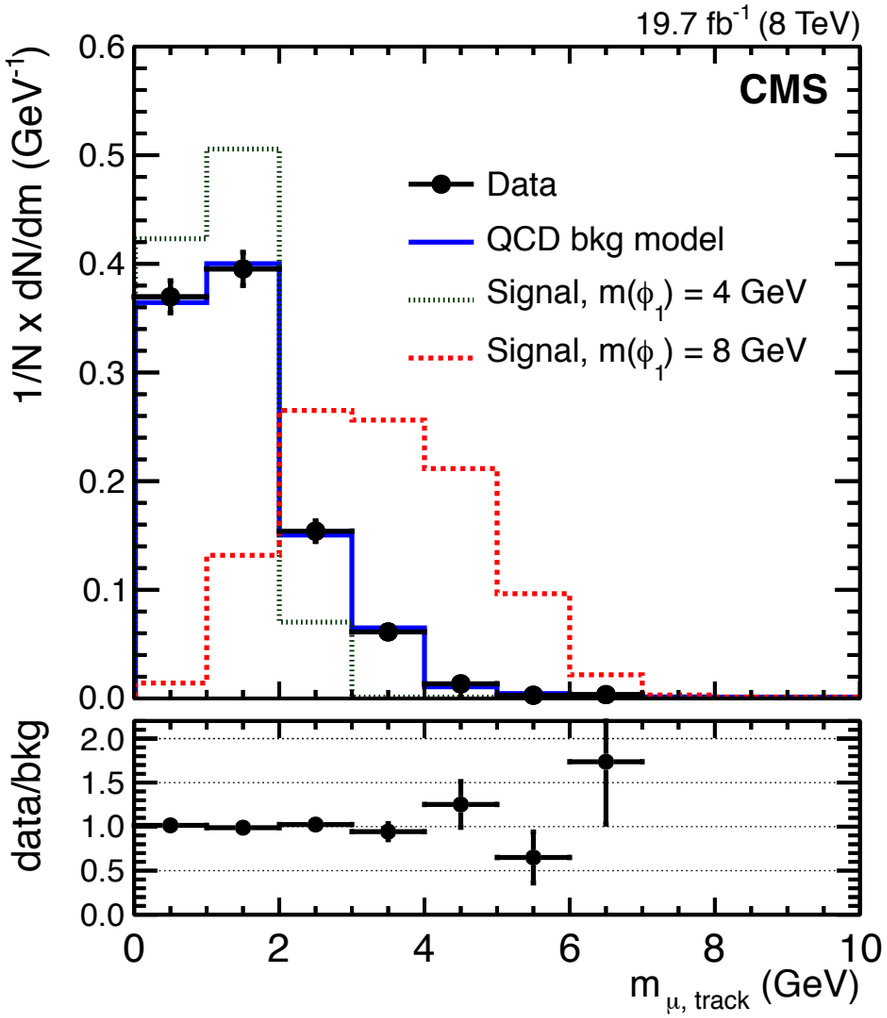
- Usual tau reconstruction inefficient - need alternate strategy
  - Most τ decay to 1 charged particle
  - Use muon + nearby track identification (clean, well measured)
- Other neat tricks
  - Separated systems
  - Charge requirements
  - Distance of track from collision point



4τ

- Main background: $b\bar{b}$ QCD (lots due to massive σ_{bb})
- Use muon-track invariant mass as discriminating variable



Better for larger masses, worse for smaller masses (looks more like QCD)

- See nothing new, set upper limit on total cross-section

Model Scans

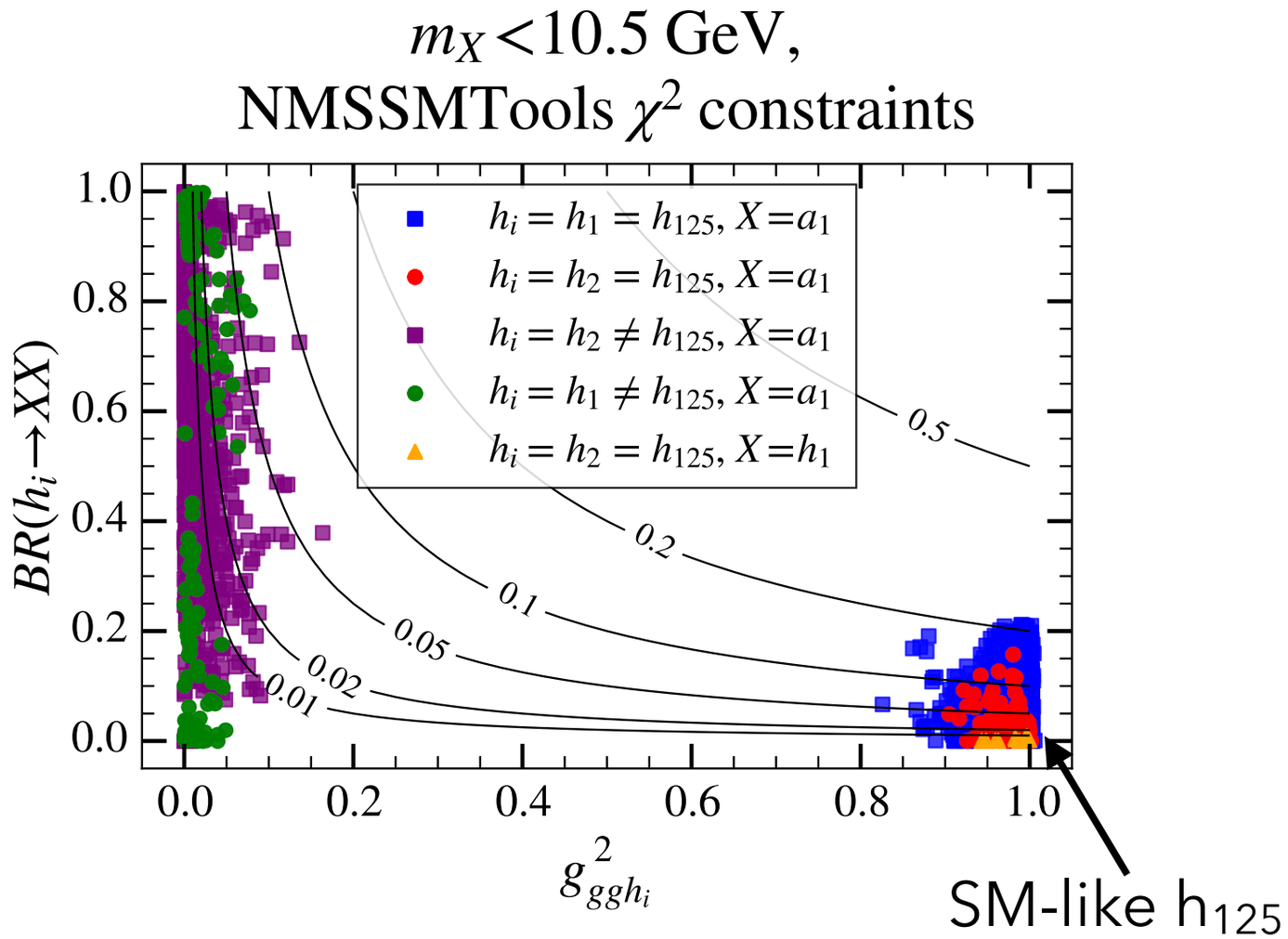
- How to compare to theory?

- Scan over model parameter space, target regions with light m_a
  - NMSSMTools, 2HDMC + HiggsBounds/Signals

- Require experimental constraints
  - Higgs rate measurements
  - Higgs exclusions
  - Flavour constraints
  - Other: g-2, DM relic density

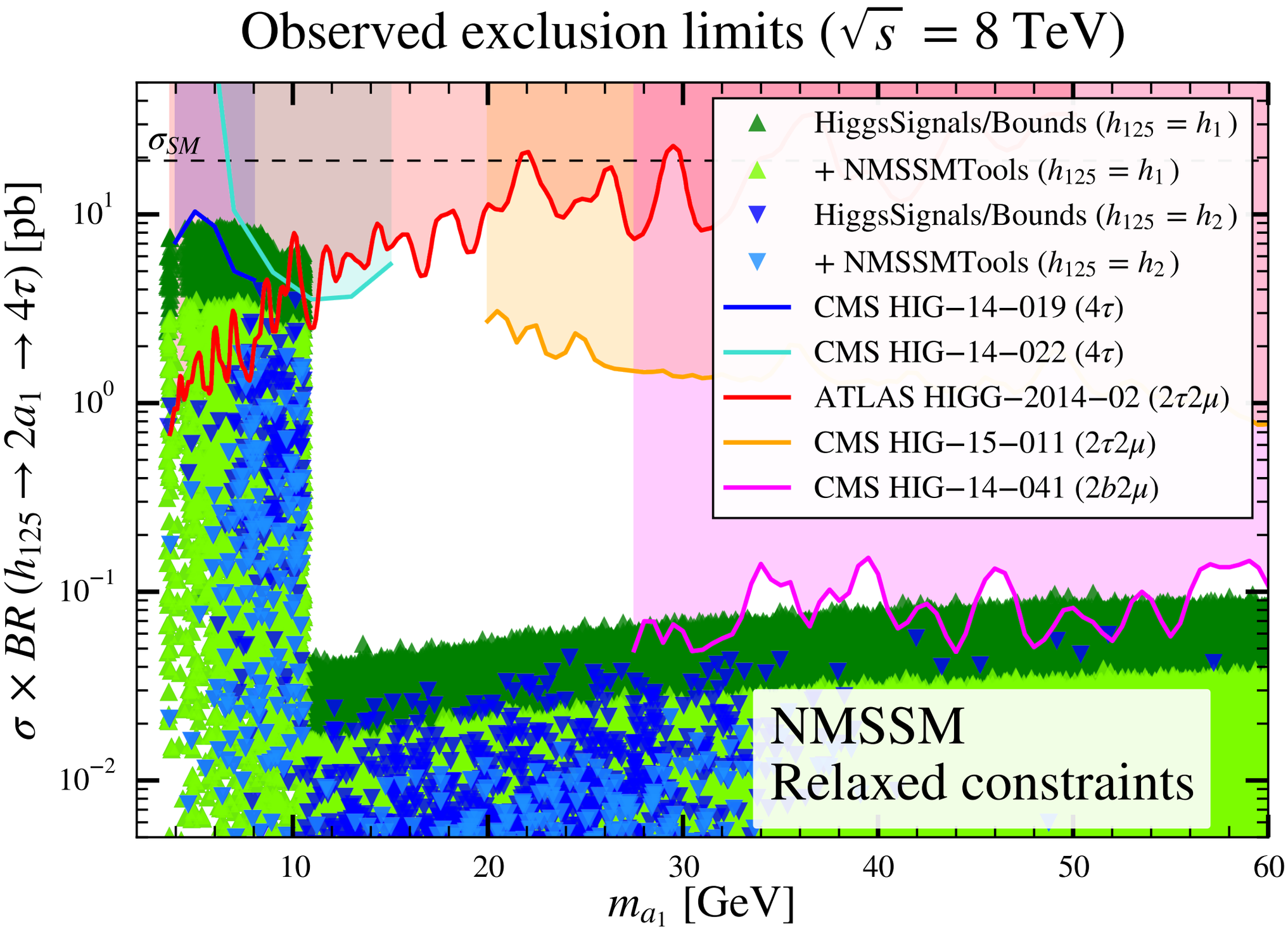
Model Scans

- Models often very flexible - **constraints mainly from Higgs signal rates** (reduces BR(h_{125} → BSM))
  - depends on how you interpret constraints
- Also affects ggh coupling

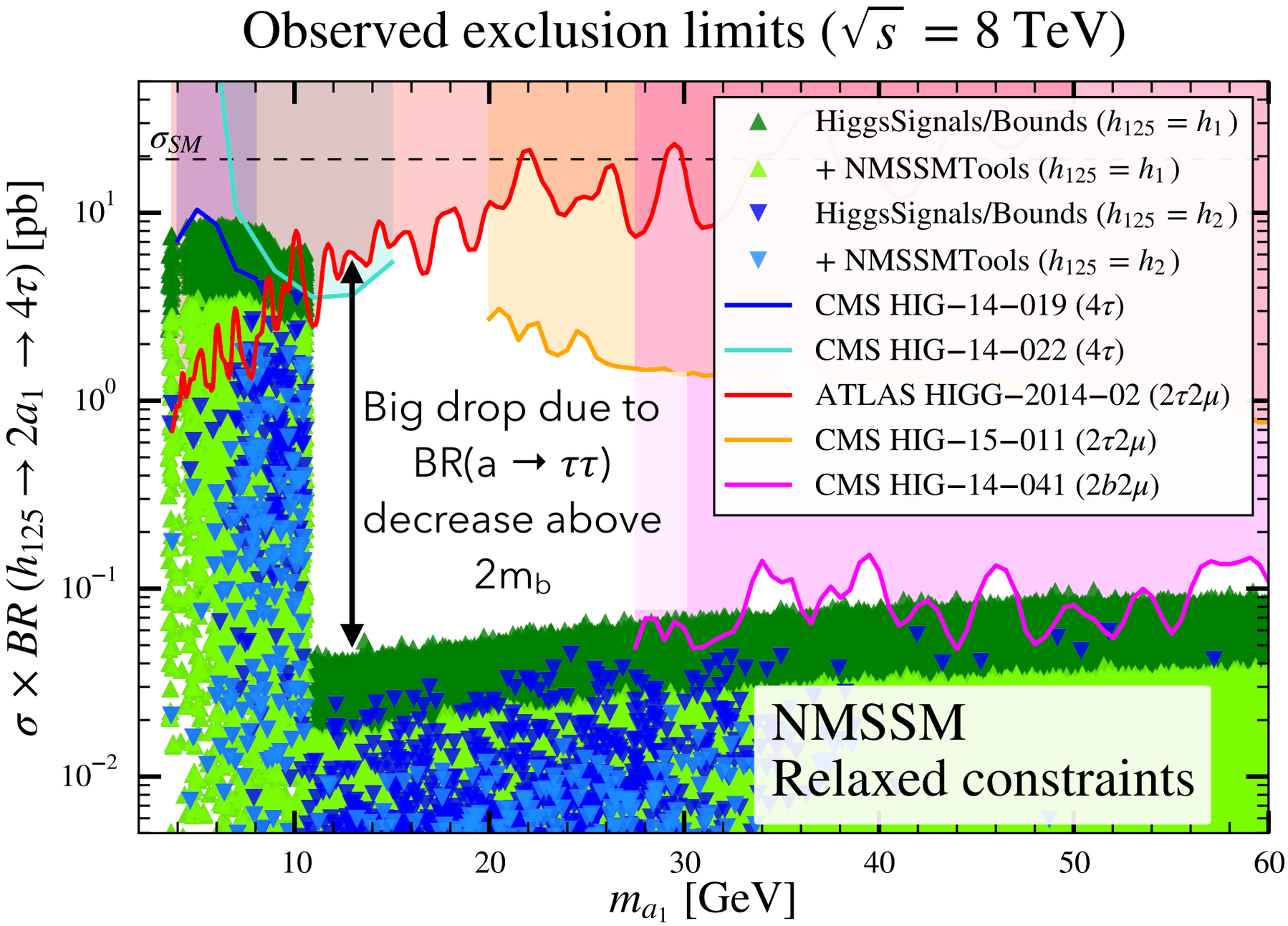


Scan results - NMSSM

Convert all searches to same final state equivalent

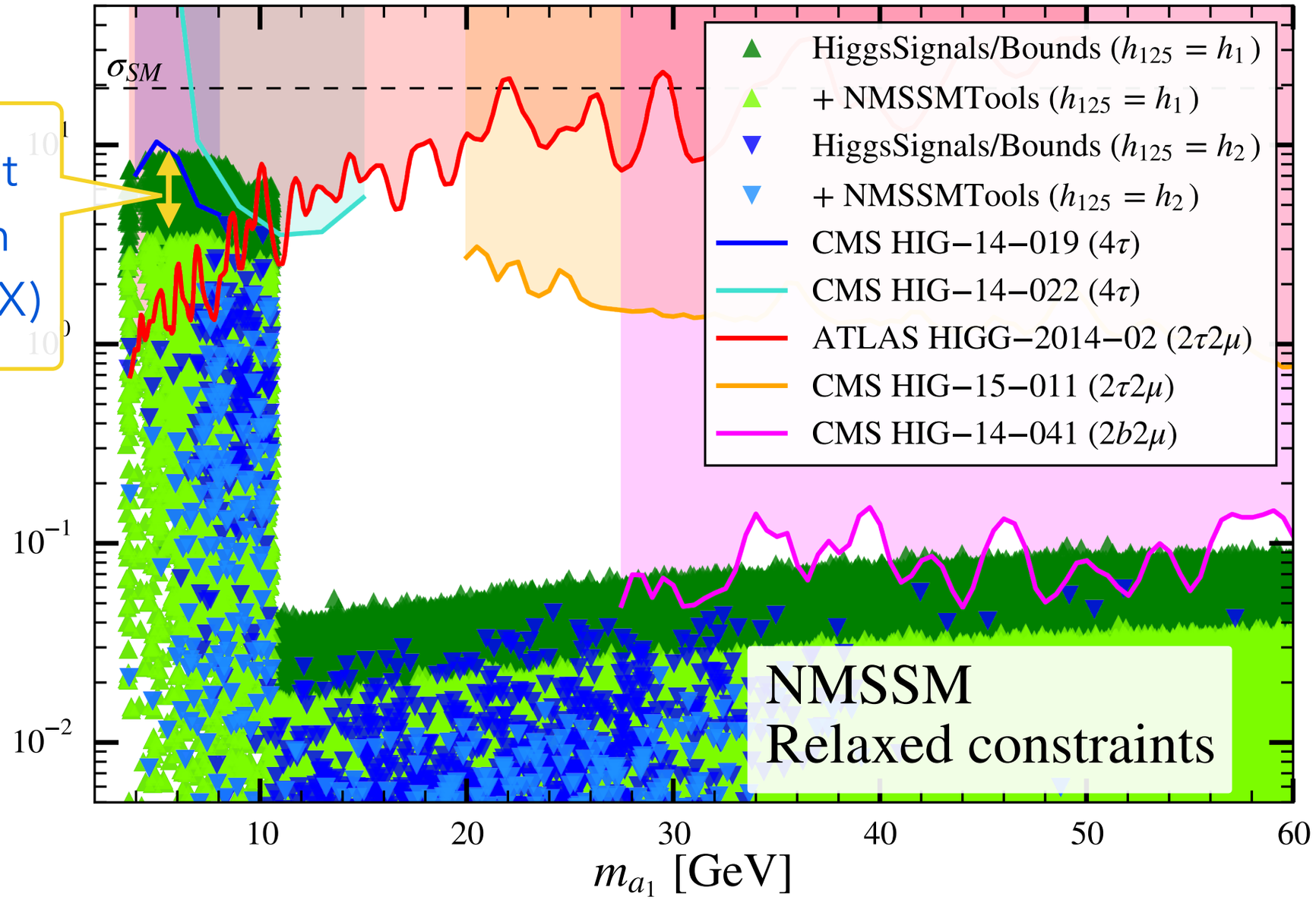


Scan results - NMSSM

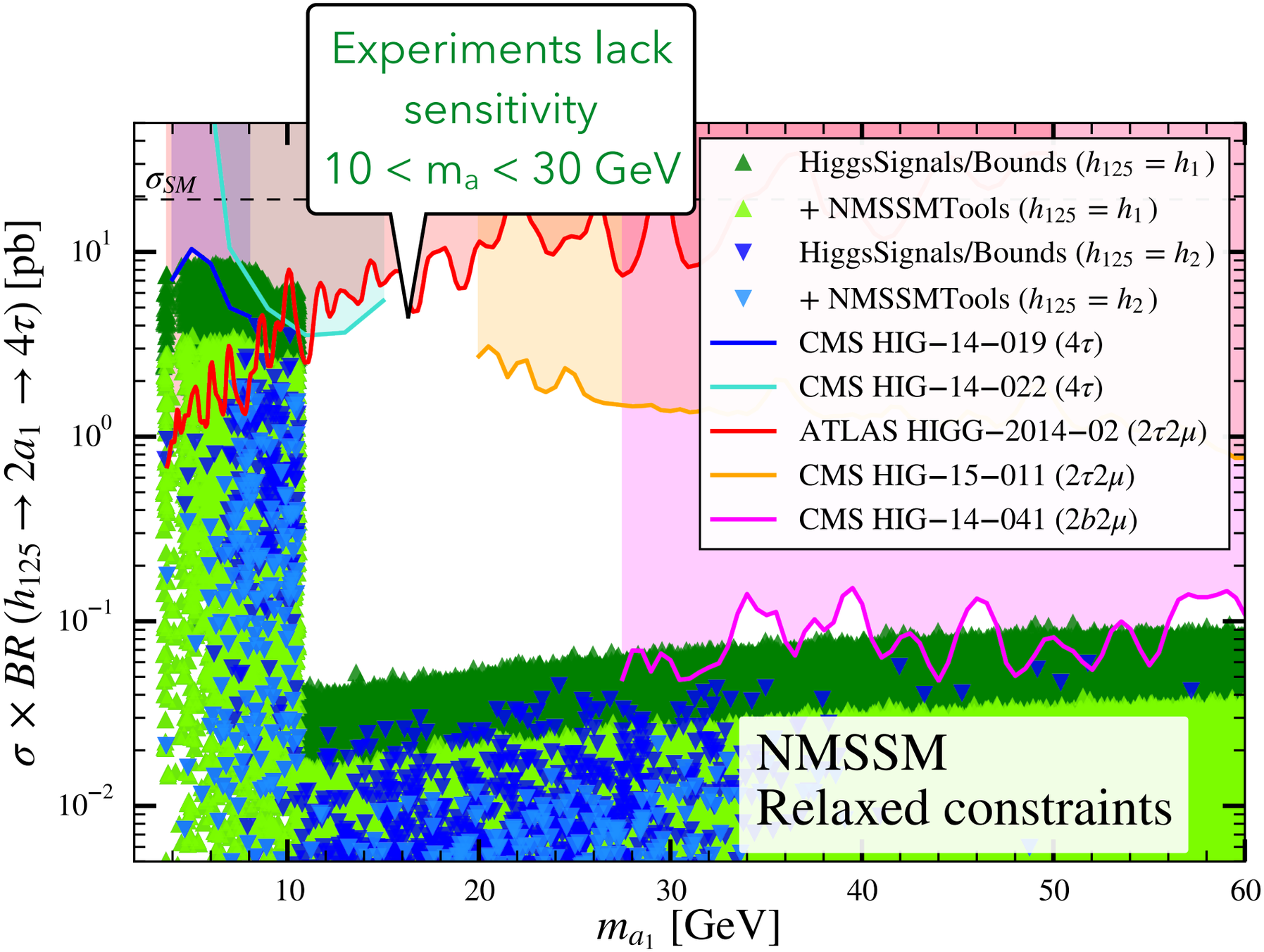


Scan results - NMSSM

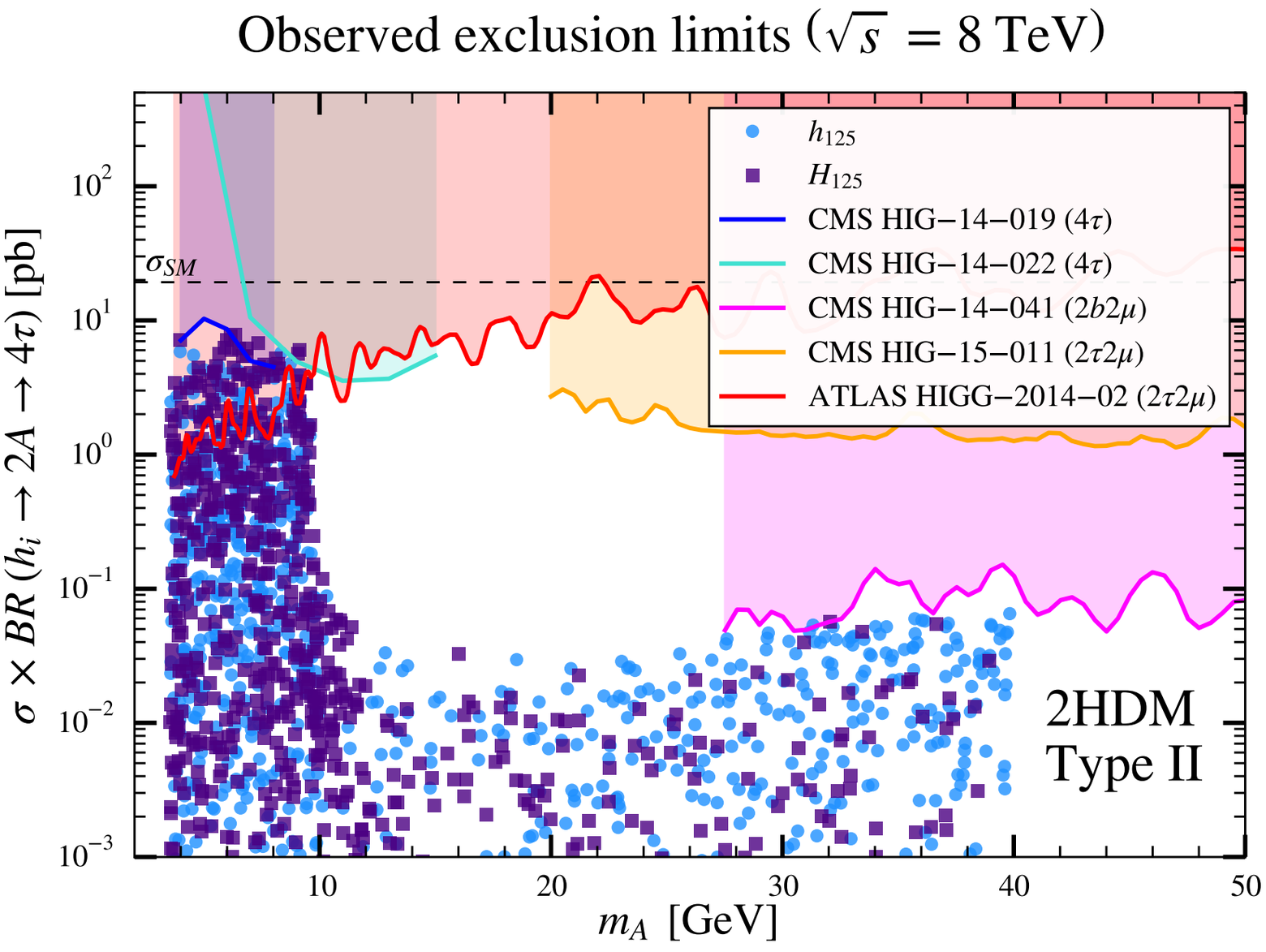
Stricter limit from NT on BR($h_{125} \rightarrow XX$)



Scan results - NMSSM



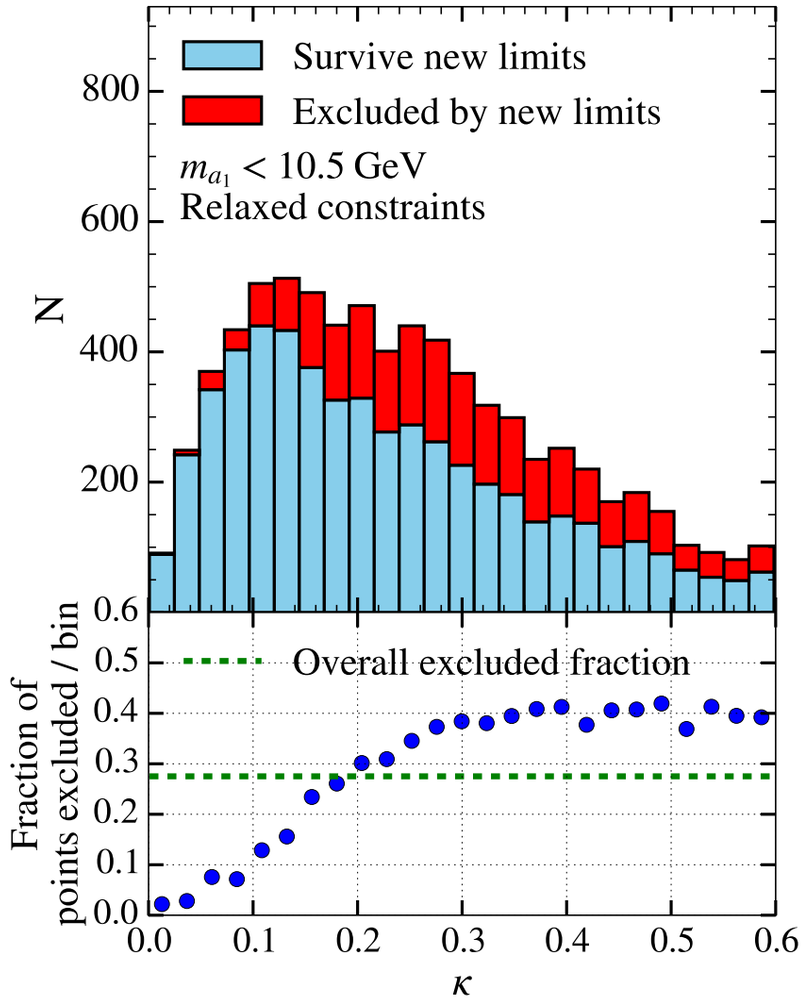
Scan results - 2HDM



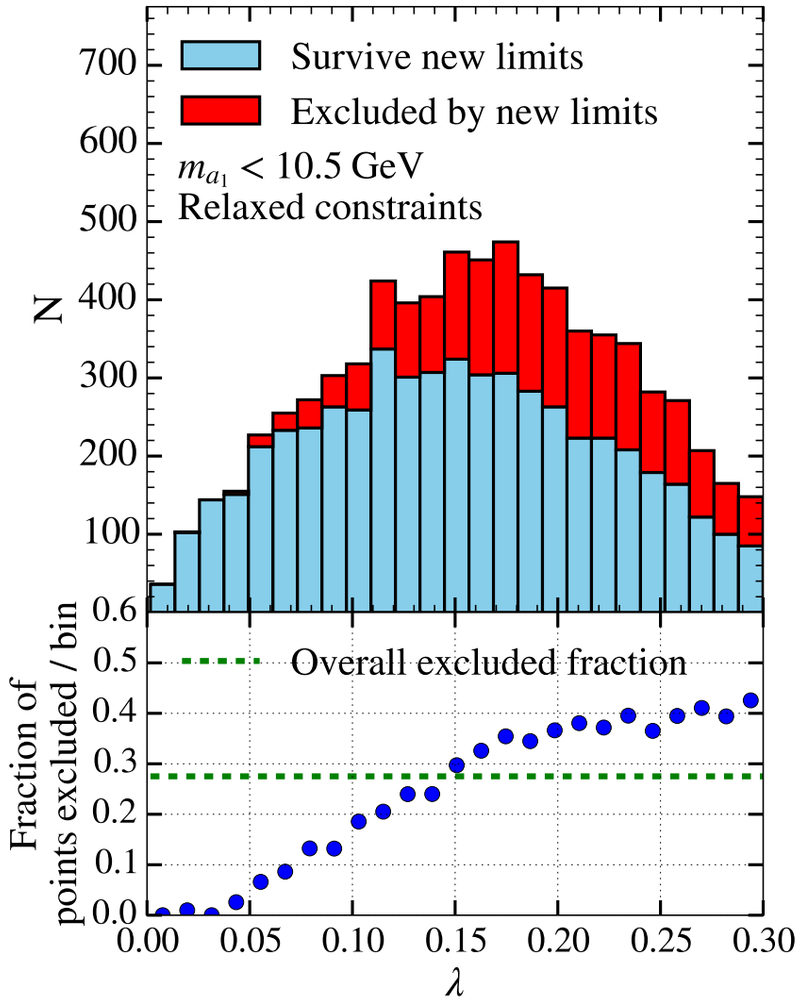
Similar conclusion in 2HDM - experiments, not model, more constraining

Parameter constraining

- How do these affect NMSSM model parameters?



κ = singlet self-coupling (κS^3)



λ = singlet-doublet coupling (μ → λ⟨S⟩)

Experimental limits starting to exclude larger κ, λ

Conclusion

- LHC Run 1 has produced a wide range of searches for low mass Higgs
- Starting to cut out parameter space
  - Can do better than indirect limit from visible Higgs searches
- What will Run 2 bring?
  - S:B improves!
  - More ∫L
  - But more pileup, and larger trigger thresholds