Reinterpretable results - Theory Perspective

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Reinterpretation in BSM theories

> **Several approaches**

- **Read off limits from plots yourself:** usually provided in factorized approach,

$$\sigma_{\text{bound}} = \sigma_{\text{prod}} \times \text{BR}$$

where σ_{prod}, BR are calculated by reinterpreter

- **use automatized tools** as e.g. HiggsBounds [Bechtle, Heinemeyer, Klingl, Stefaniak, Weiglein, Wittbrodt]

- **perform detailed study using recasting tools** (many on the market) which include event generation for parameter points etc

What we are talking about...
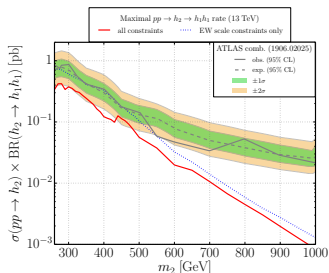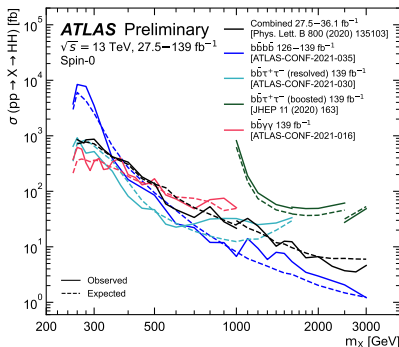

bounds $\implies$ interpretation

Comments from HiggsBounds authors [factorized approach]

- for 125, 125 final states: **please provide mass-grids !!**
  otherwise interpolation for intermediate mass-points
  non-trivial

> **Going away from 125...**

- provide **bounds for single final states** [combination assumes a
  specific model]
- **best of all worlds: publish log likelihoods as a function of
  rates in all sub-channels**, depending on all involved scalar
  masses (e.g. for $h_3 \to h_1 h_2$)
- ⇒ **related issues discussed extensively in arXiv:2109.04981**
- more discussion in Eur.Phys.J.C 80 (2020) 12, 1211

BP5 recast: $h_3 \to h_1 h_1 \to b\bar{b}b\bar{b}$ [BP from Eur.Phys.J.C 80 (2020) 2, 151]

Enlarging the scope of resonant di-Higgs searches: Hunting for Higgs-to-Higgs cascades in 4b final states at the LHC and future colliders [Barducci, Mimasu, No, Vernieri, Zurita; JHEP 2002 (2020) 00]
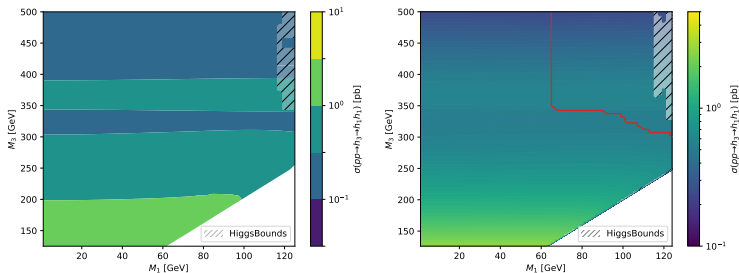
$\Rightarrow$ region stemming from resonance searches (ATLAS, $36\,\mathrm{fb}^{-1}$, Phys.Rev.Lett. 121 (2018) no.19, 191801; CMS, $36\,\mathrm{fb}^{-1}$, Phys.Rev.Lett. 122 (2019) no.12, 121803) **extended**

- Required: **information on selection efficiency per event; validate intermediate selection cut results; expected background**

> **in more detail**

- identification efficiencies + $p_\perp$ smearing for components (leptons, jets, etc.), e.g. via Delphes.

- cut flow table for selection cuts applied to signal model events

- Expected total background passing the selection cuts with errors in each signal region.

- Good: cutflow for two different benchmark models, with **different topologies** [SciPost Phys. 9 (2020) 2, 022]

- for BDTs: code (or pseudocode) (generator-level/ Delphes-level output); map of the final BDT output versus signal model parameters for validation

60 page document, giving detailed recommendations on presentation of

- analysis description
- primary data
- background estimates
- correlations
- smearing functions and efficiencies
- simplified model interpretation
- full likelihoods
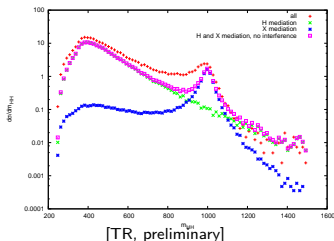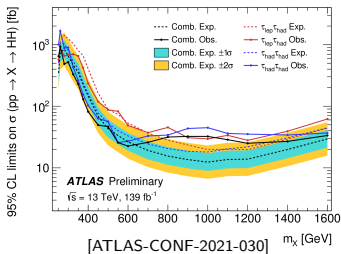- statistical methods
- reproduction metadata

Discussion/ Open issues

- other possible issues: finite width effects

$\Longrightarrow$ **width-dependence of results** $\Longleftarrow$

[ATLAS-CONF-2021-030]

[TR, preliminary]

Appendix

1. upper limits on the cross sections of the signal processes should be presented as a function of all relevant kinematical parameters, e.g. the masses and total widths of the involved scalar boson(s);

2. the search results should always contain the expected and the observed limit;

3. if the signal is comprised of several signal channels (i.e. different production and/or decay modes), the limit is set on a common scale factor the signal strength μ - or a total signal rate. In this case, the signal efficiency of each signal channel should be provided as a function of all relevant kinematical parameters (see point 1);

4. if the limit is presented as a normalized signal rate (e.g. to the SM prediction), the reference signal rate should be quoted by the experimental analysis along with the result, thus enabling the recalculation of the limit on the signal rates absolute value;

5. the search limit should always be presented at 95% C.L.;

6. in addition, it would be beneficial to present results as exclusion likelihoods, using the same parametrization as the one used for the 95% C.L. upper limit (see point 1).
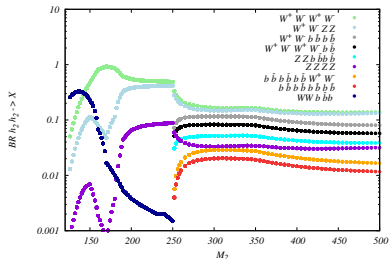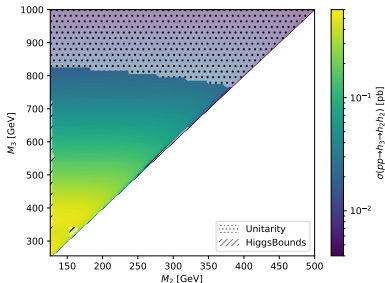
extending general recommendations in SciPost Phys. 9 (2020) 2, 022

recast of $36\,\mathrm{fb}^{-1}$ study for $h \to$ inv, interpreted in Inert Doublet Model
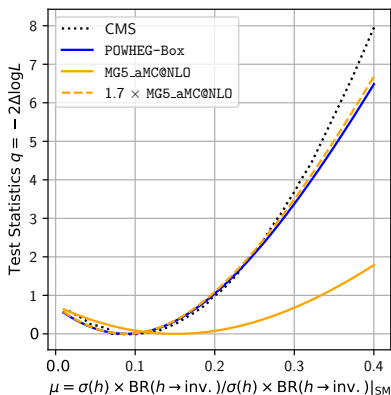
BP6: $h_3 \to h_2 h_2$ $(h_1 = h_{125})$ [up to 0.5 pb]

! $36\,\mathrm{fb}^{-1}$ **searches start being sensitive** [1811.11028] !

search stops at 340 GeV $\Rightarrow$ larger reach would be better !!!

$$\sigma_{\mathbf{gg} \to \mathbf{h_3}}(\mathbf{M_3}) \sim 0.06\,\sigma_{\mathbf{gg} \to \mathbf{h_3}}^{\mathsf{SM}}(\mathbf{M_3})$$

$h_{125}h_{125}h_{125}h_{125}$ **up to 14 fb**