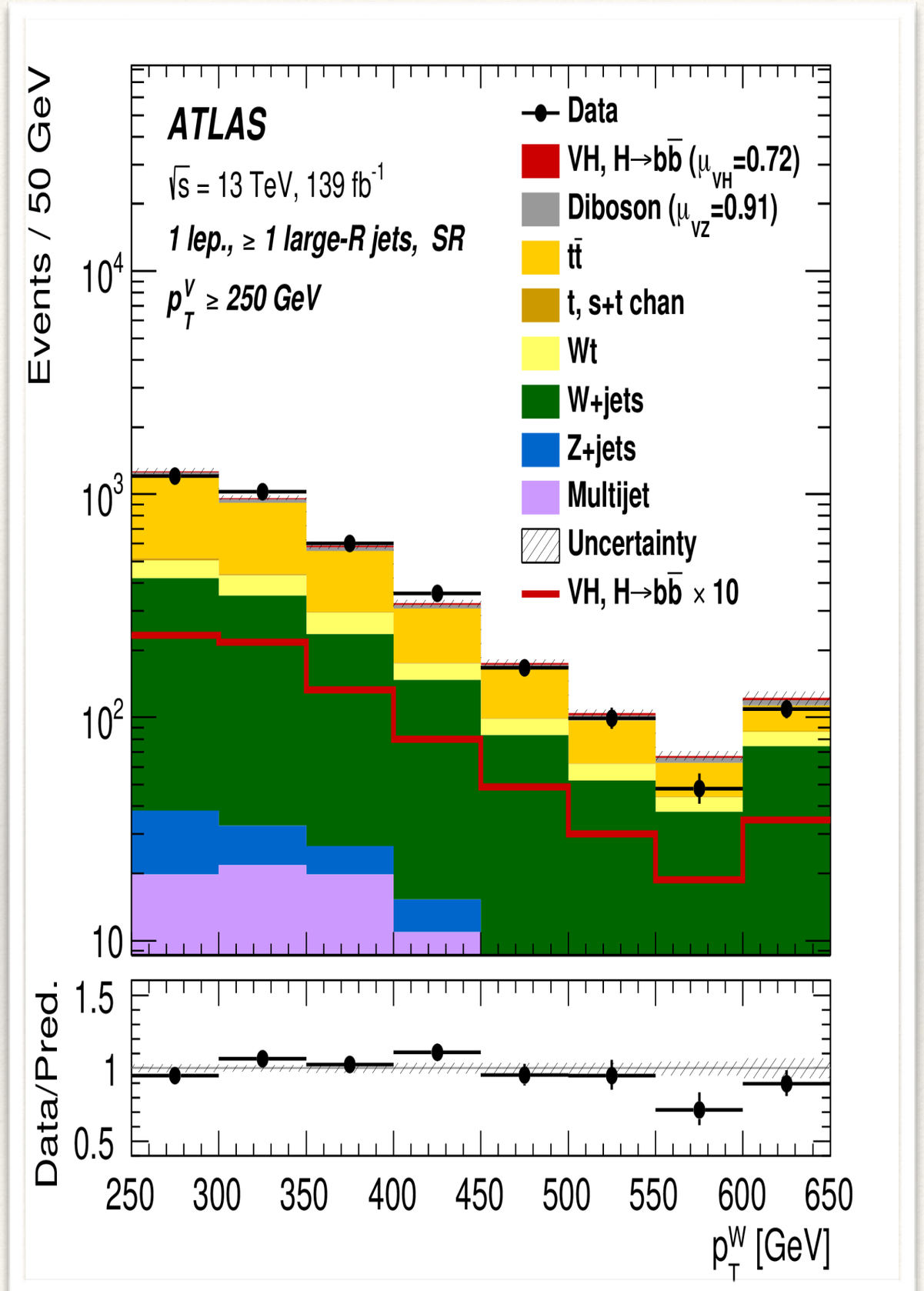
EFT WG — Validity discussion

On the impact of dimension-eight

Veronica Sanz (UV & Sussex)



Generally speaking

Interpretation of LHC data in terms of EFTs
is a way of organising our thinking, general enough to explore unknown possibilities but still with some expansions/assumptions
Technically is also useful:

- **Combination**: LHC Higgs and EW production, low energy, EWPTs
- **Consistency:** Backgrounds and signal
- **Matching:** Direct connection to models
- **Precision:** higher-order EW and QCD, dimension-eight, validity EFT

SMEFT amplitude

$$\mathcal{A} \sim \left(A_{\rm SM} + \frac{A_{\text{dim-6}}}{\Lambda^2} + \frac{A_{\text{dim-8}}}{\Lambda^4} + \dots \right)$$

at LO, SM^2,
at NLO, interf. SM*d6
at NNLO, d6^2 and interf. SM*d8

EFTs (like loops) are expansions

when our data isn't too good, leading-order may be good enough
as our data becomes better, higher-orders need to be taken into account

EFTs are expansions in momenta

The further we go in energy reach, the more sensitive we are to them

Interpretation LHC data with dim-6 well established, why dim-8?

evaluating dim-8 effects is useful to account for more general EFT effects
like different energy dependences, and quantify limits of EFT validity
and, in some cases, current obs can be sensitive to dim8

I am going to discuss effects of dim-8 in a second,
but remember that I will be talking about ONE of the
possible expansions

Choose your poison…

Loops **and** non-linear effects (e.g. Composite Higgs) can compete with these dim-8 higher-order effects

e.g. (loop x dim-6) may be more important than (SM x dim-8) or (dim-6)^2, depending on the scale of new physics

e.g. in CHMs the scale of non-linearity may be few hundreds of GeVs, and more important than mass-suppressed EFT contributions & restricting to the SMEFT you won't be able to see that

The **list of dimension-six operators** compatible with the SM symmetries is long,
yet one can still sit down and start thinking about them
write all the possibilities in a reasonable amount of time
THEN one has to think much harder about how many actually independent operators there are, and make choices (bases) on which ops to use

You can imagine that the **list of dimension-eight operators** is much longer,
and a touch-and-feel approach is not good anymore:
development of new techniques to find all the independent dimension-eight operators and their correct description

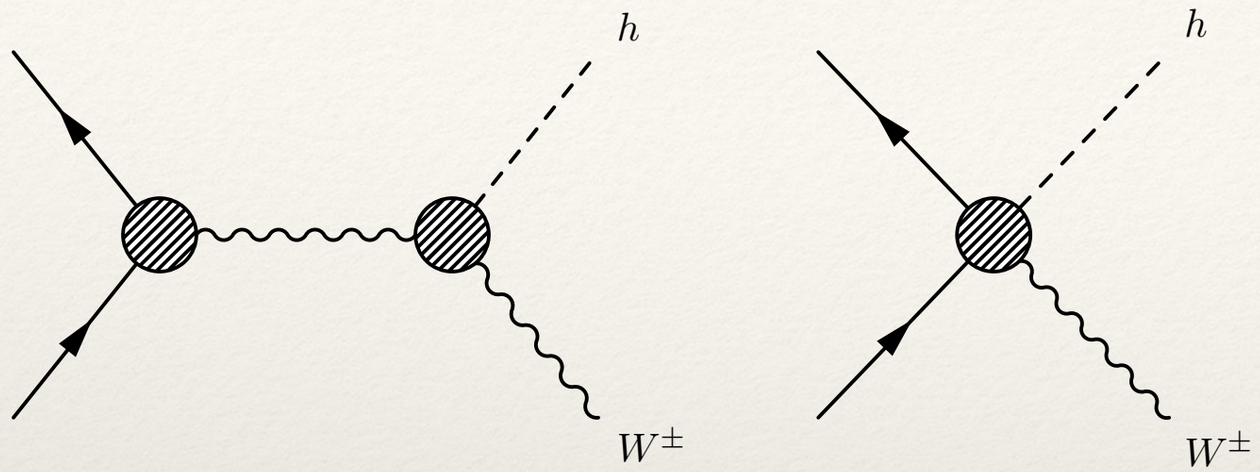
here **Hilbert series** *Hays, Martin, VS, Setford* **1808.00442**

but lots of new approaches

XEFT ***Passarino*** **1901.04177, +*David* 2009.00127**
Durieux, Machado **1912.08827**
Craig et al. **2001.00017**
Geometric ***Helset, Martin, Trott*** **2001. 01453, +** ***Hays*** **2007.00565**
Convex ***Zhang, Zhou*** **2005.03047**
Complete d8 ***Li, Ren, Shu, Xiao, Yu*** **2005.00008**
Complete d9 +*Zhen* 2007.07899
Murphy **2005.00059**

Example: effect of dim8 on WH

When/how dim8 effects appear in this process



1. changes vertex qqV
2. changes vertex hVV
3. new contact int. qqVh

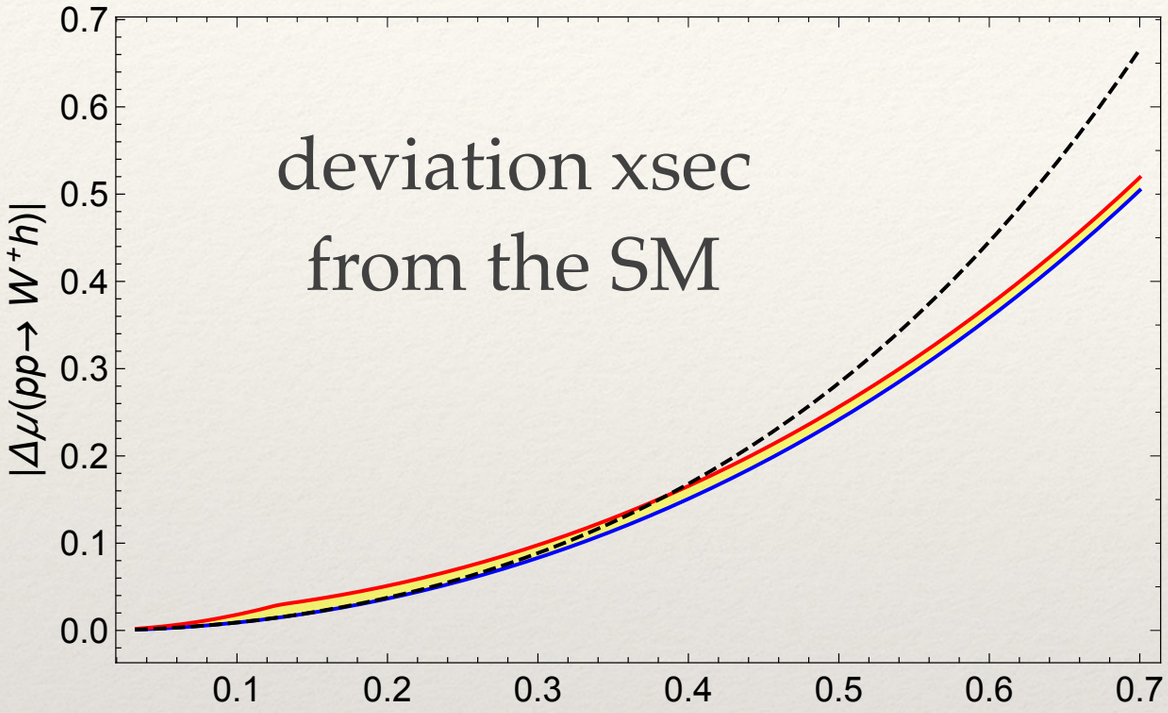
e.g. produces s-hat effects proportional to d6^2 and d8

$$\hat{\sigma}(pp \to W^+ h) \sim \left(\frac{\hat{e}^2}{4608\,\pi\,\sin^4\hat{\theta}}\right)\frac{\hat{v}^2}{m_W^2}\frac{\hat{s}}{\Lambda^4}\Big(e^2\,(c_{8,3Q1} - c_{8,3Q2} + c_{8,3Q3} + c_{8,3Q4}) + 8\,\sin^2\theta\,(c_{Hq}^{(3)})^2\Big) + \mathcal{O}(\hat{s}^0).$$

but the d6 coefficient modifies qqV couplings,
very well constrained by LEP,
so the leading E^2 dependent term is a dim8 operator

So are the d8 effects very important?

The answer, in short, is **not**
taking into account the current limits and considerations of validity



blue: no dim8

red: dim8 but validity conds*

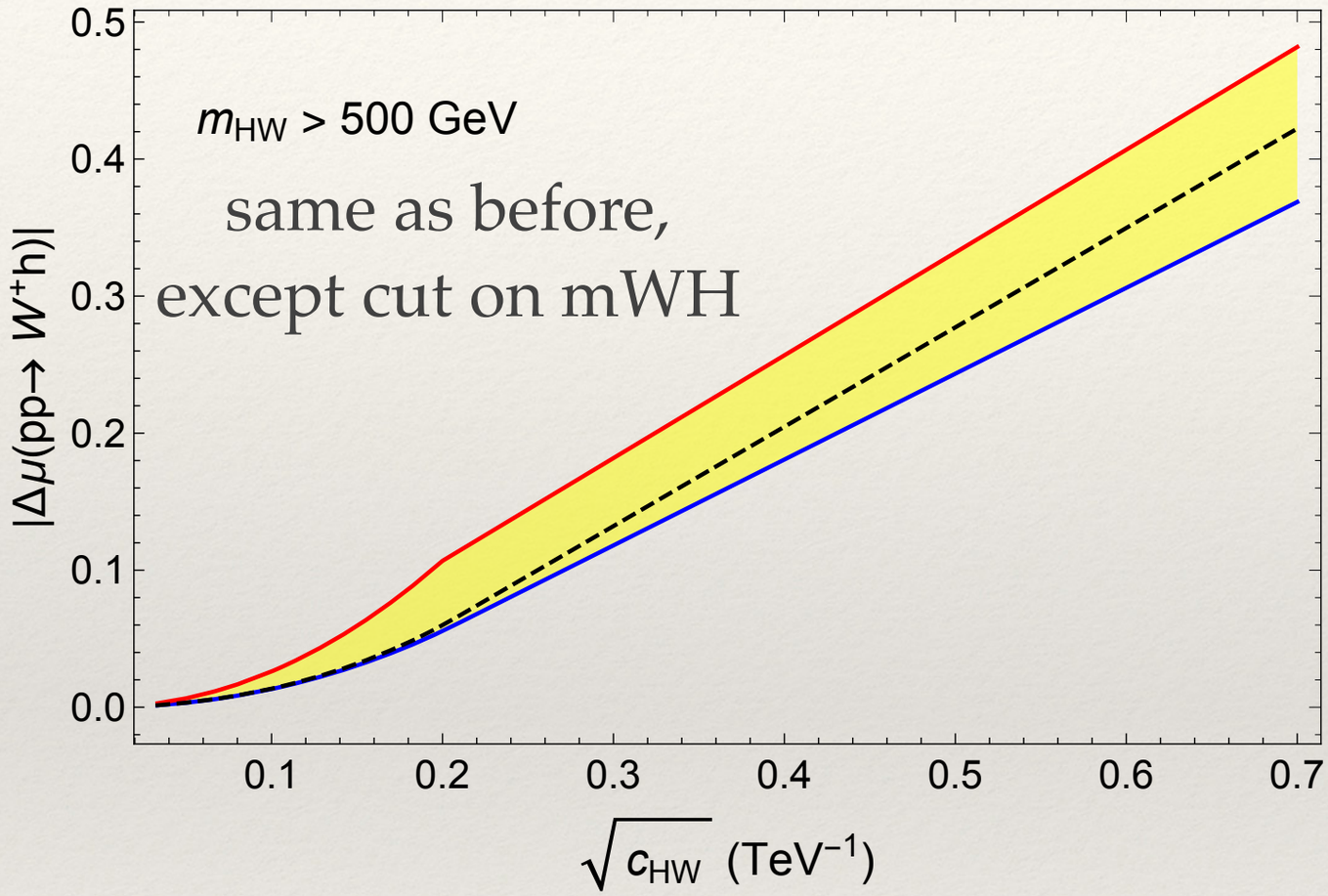
dashed: dim8, and all coeffs equal $c_{HW} = c_{8,i}$

Conclusion: given all the constraints on validity, setting a reasonable limit on a dim-6 operator should not be upset by possible dim8 operators

* EFT validity conditions are met: i) the $A_{\rm SM} \times A_{\text{dim-8}}$ contribution to the cross section of $\mathcal{O}(1/\Lambda_8^4)$ is greater than the quadratic dimension-8 contribution, $|A_{\text{dim-8}}|^2 \sim \mathcal{O}(1/\Lambda_8^8)$; and ii.) the SM interference with dimension-6 at $\mathcal{O}(1/\Lambda_6^2)$ is larger than SM interference with dimension-8 at $\mathcal{O}(1/\Lambda_8^4)$. The first condition is independent of the dimension-6 effect,

Does this mean we can forget about dim8?

The answer is, eventually, **no**
we're talking about few percent variation in inclusive xsec,
but larger for differential



higher-order dim8 effects should be taken into account as
another source of theoretical error
and can be used as a criteria for expansion validity