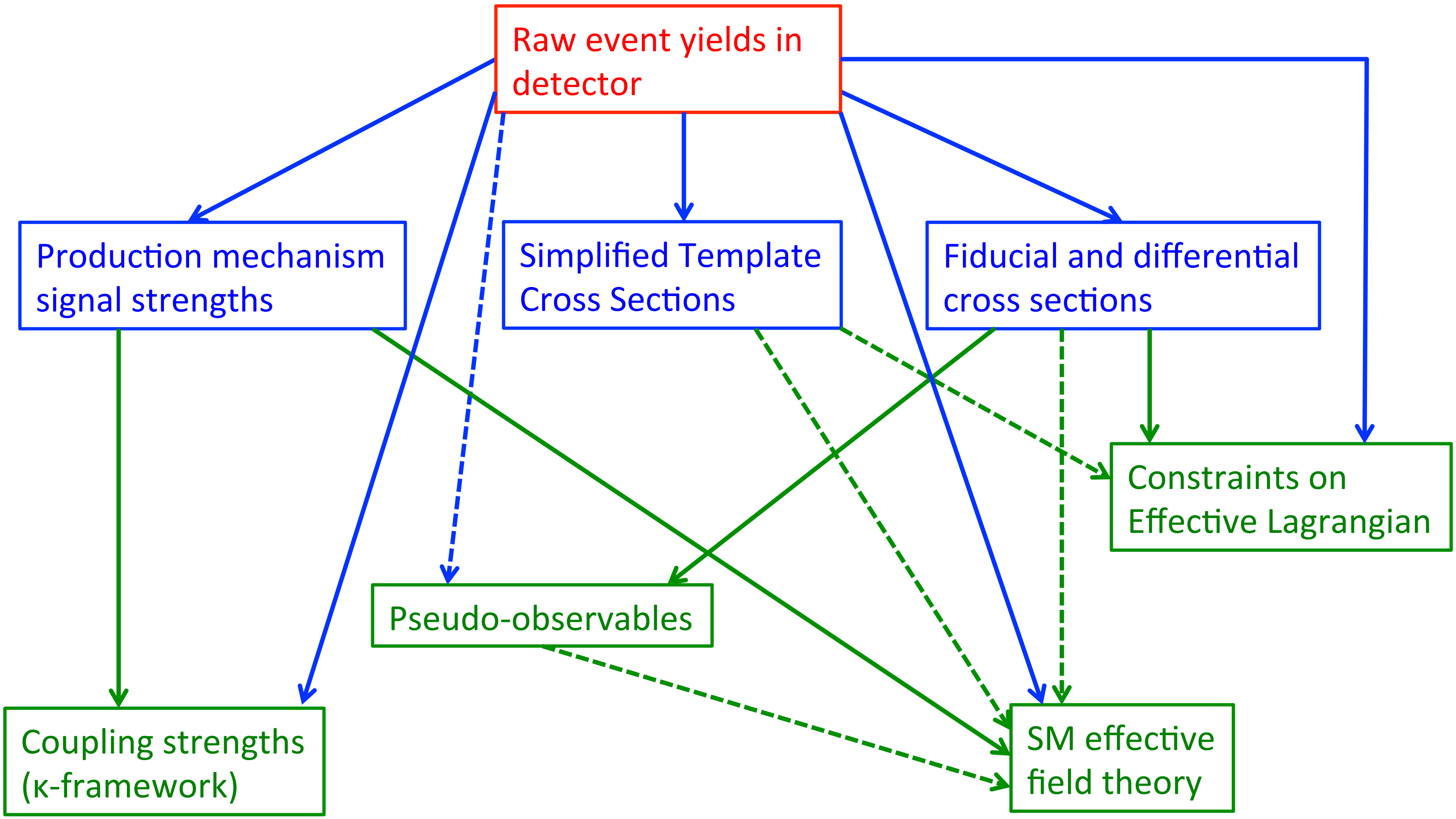
# Constraining EFT parameters using Higgs boson differential cross section measurements

Andrew Pilkington (University of Manchester)

# Different experimental approaches to probing the Higgs couplings




- Experimental measurements
- Theoretical interpretations
- Dashed means not yet demonstrated

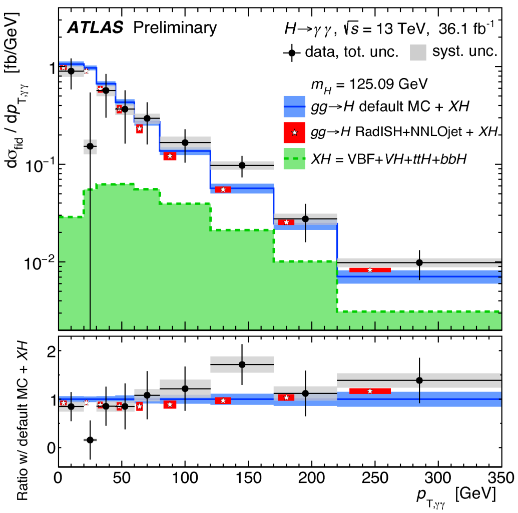
# Fiducial and differential cross section methodology

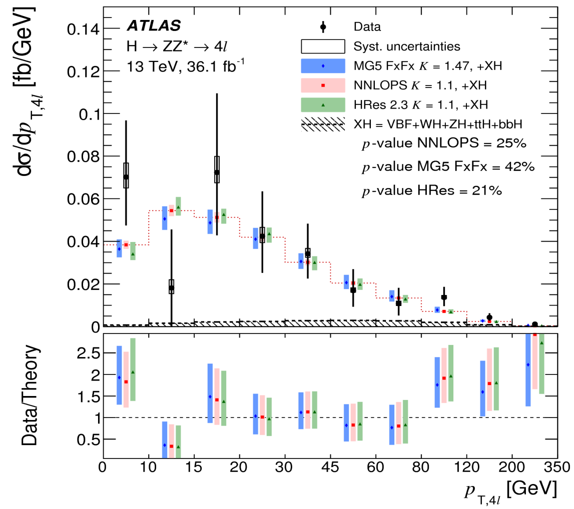
$$\sigma_i = \frac{\nu_i^{\mathrm{sig}}}{c_i \int L \, \mathrm{d}t}$$

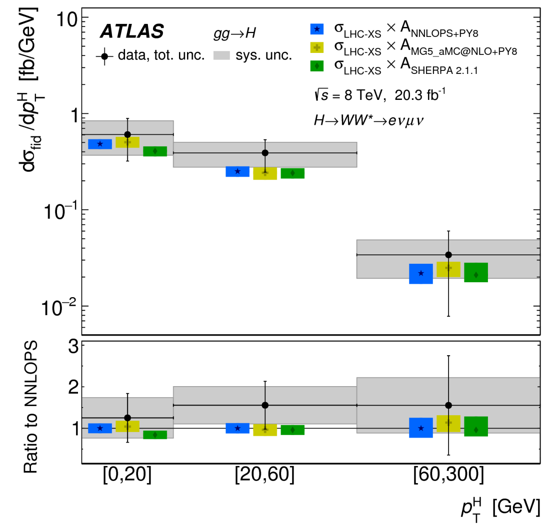
- $\sigma_i$: Cross section in a fiducial region, or bin of a differential distribution
- $\nu_i^{\mathrm{sig}}$: Number of signal events observed in the data
- $c_i$: Correction for detector resolution and inefficiency
- $\int L \, \mathrm{d}t$: Integrated luminosity of the dataset

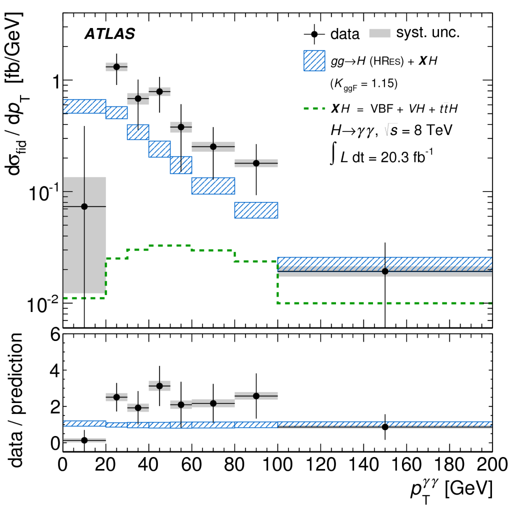
- Aim to correct data only for detector inefficiency and resolution (i.e. reduce model-dependent extrapolations)
- Run-I measurements include H->γγ, H->ZZ*, H->WW* from ATLAS and CMS
- Similar Run-II measurements with 33-36 $\mathrm{fb}^{-1}$ are imminent (most currently preliminary)

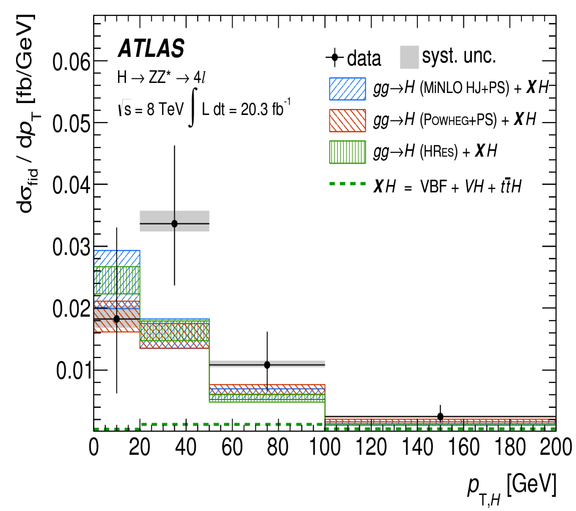
# Differential cross sections will/should become the norm



Physics Letters B 753 (2016) 69-85

# Constraints on EFT parameters from H->γγ spectra (Run-I)

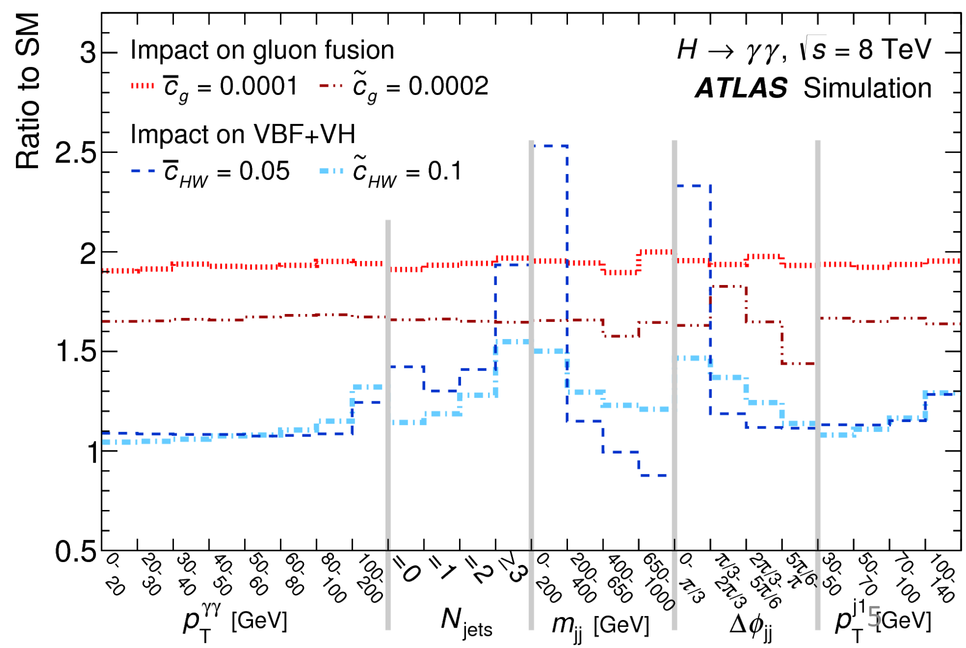
- Basic idea is to use the unfolded Higgs differential cross sections to place limit on anomalous Higgs boson interactions, specified in an effective Lagrangian:

$$\mathcal{L}_{\rm eff} = \bar{c}_\gamma O_\gamma + \bar{c}_g O_g + \bar{c}_{HW} O_{HW} + \bar{c}_{HB} O_{HB} + \tilde{c}_\gamma \tilde{O}_\gamma + \tilde{c}_g \tilde{O}_g + \tilde{c}_{HW} \tilde{O}_{HW} + \tilde{c}_{HB} \tilde{O}_{HB},$$

with CP-even (top) and CP-odd (bottom) terms that affect the Hγγ, Hgg and HVV couplings

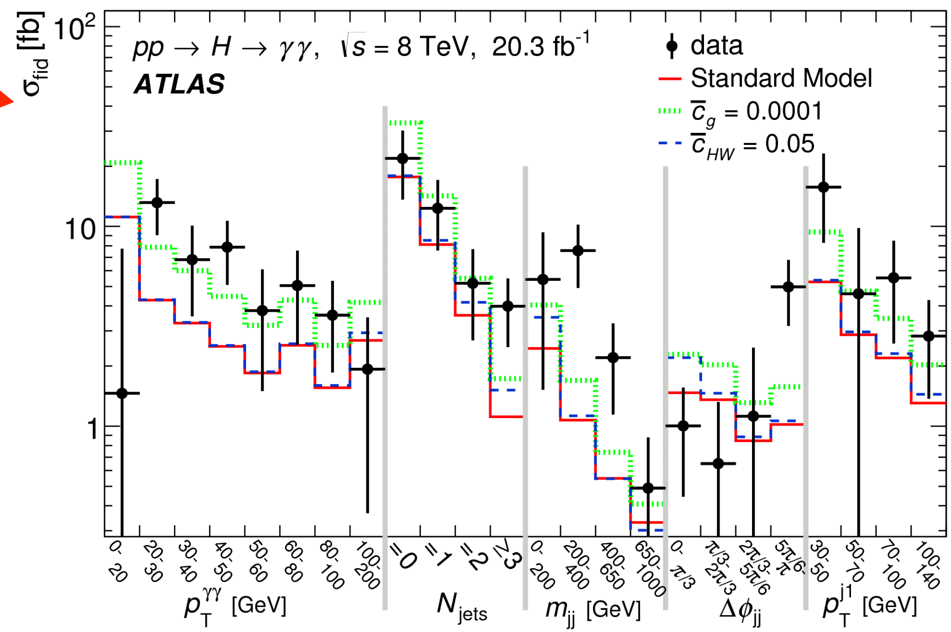
- Hgg couplings mainly produce a change in the normalisation of the gluon fusion cross section, but additional change in shape of the $\Delta\varphi_{jj}$ distribution for CP-odd

- HVV couplings change the shape of all distributions dramatically



# Method details

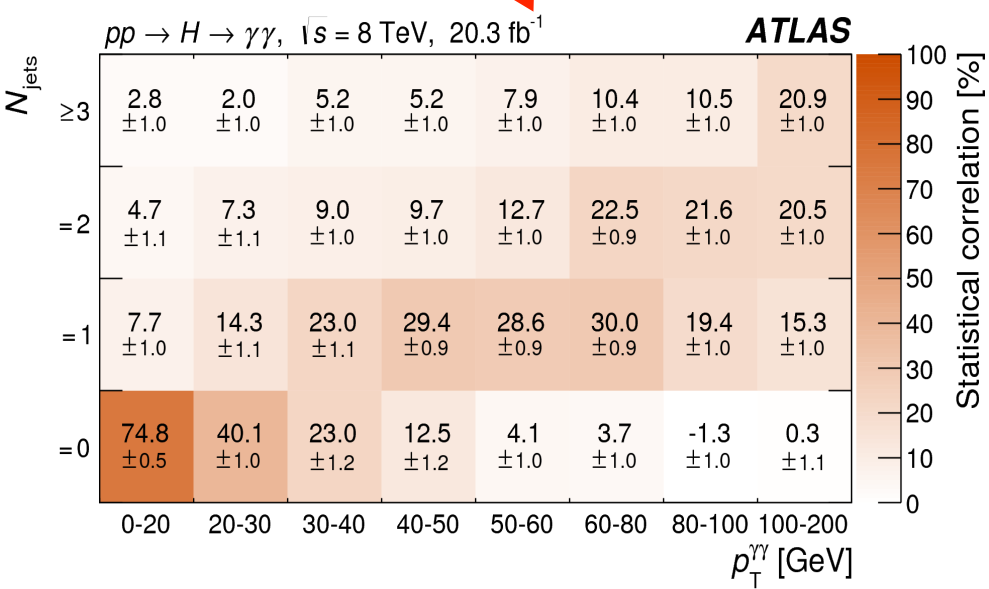
- Simultaneous fit to five differential spectra (right)




- Can test the agreement between data and any theory by:

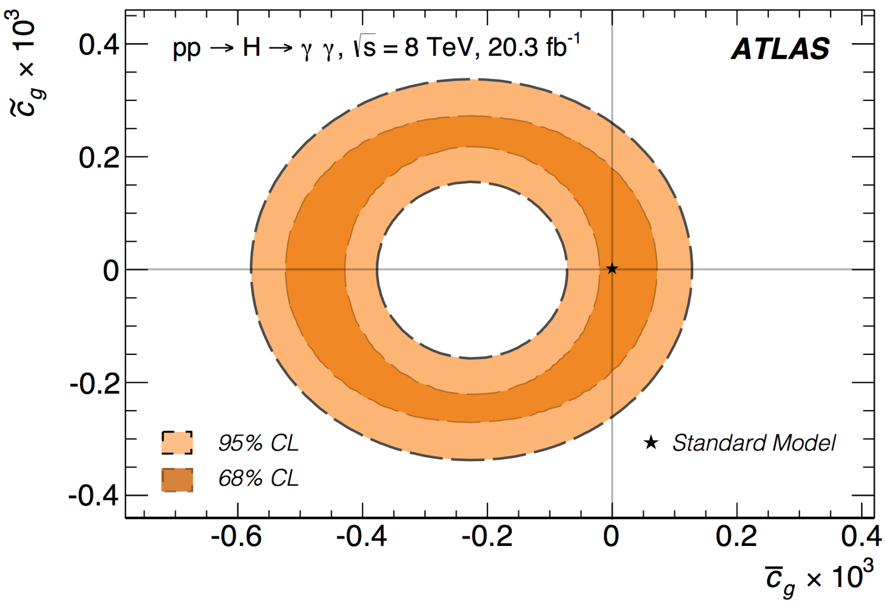
$$\chi^2 = \left(\vec{\sigma}_{\text{data}} - \vec{\sigma}_{\text{pred}}\right)^T C^{-1} \left(\vec{\sigma}_{\text{data}} - \vec{\sigma}_{\text{pred}}\right)$$

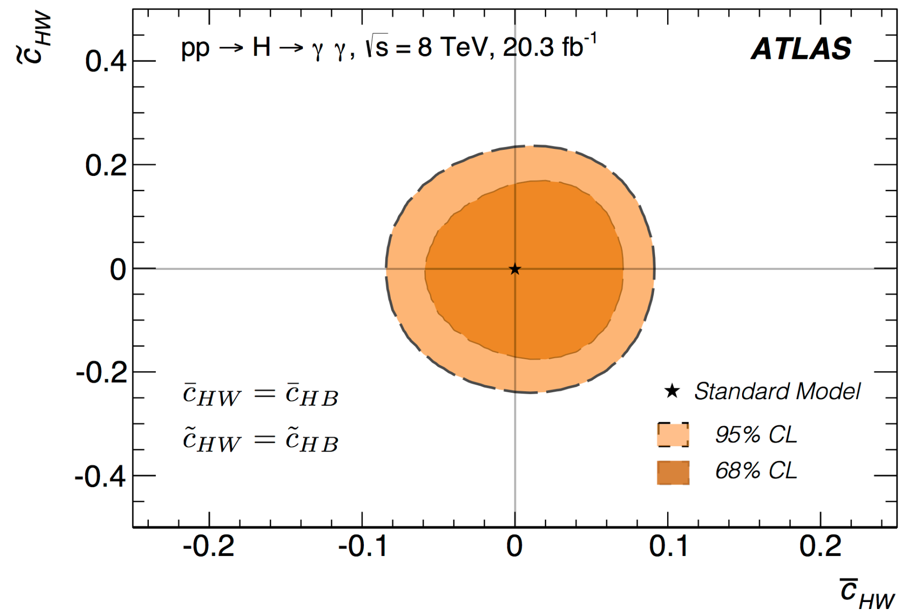
- Need statistical correlations between observables: bootstrap the data!




- Easy to generate theory predictions at the particle-level. In this paper:
  - SILH parameterisation used
  - parameter space sampled in 2D grids
  - Interpolation done on a bin-by-bin basis using Professor.

# Constraints on anomalous Higgs couplings



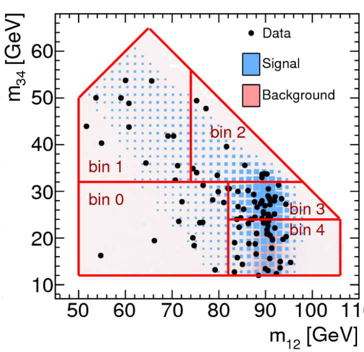



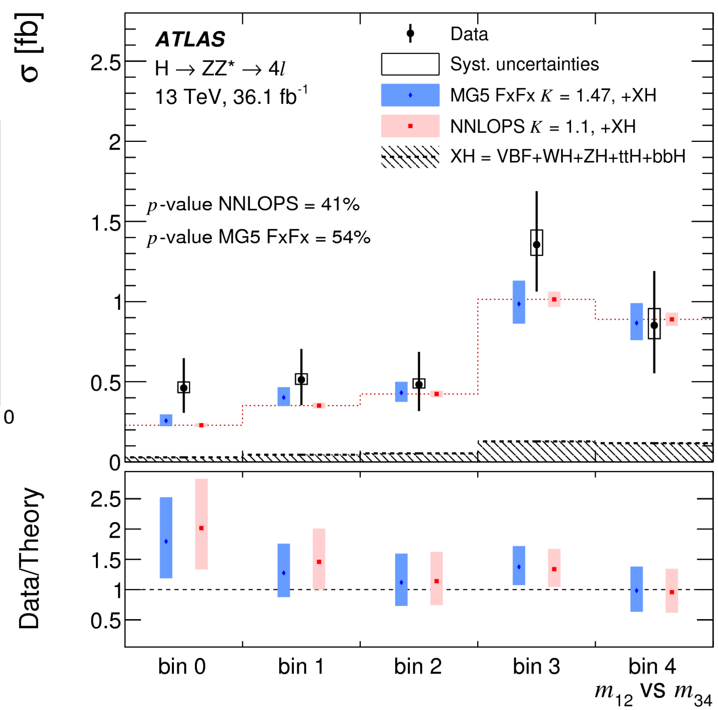

- Proof of principle: set 2D constraints on CP-even and CP-odd couplings to gluons (left) and weak bosons (right)
  - Factor seven improvement over analysis of H->VV angular distributions [EPJ C75 (2015) 476]
- All data/correlations public: can repeat with favourite basis/operator combination
- Rivet routine provided to reconstruct particle-level distributions

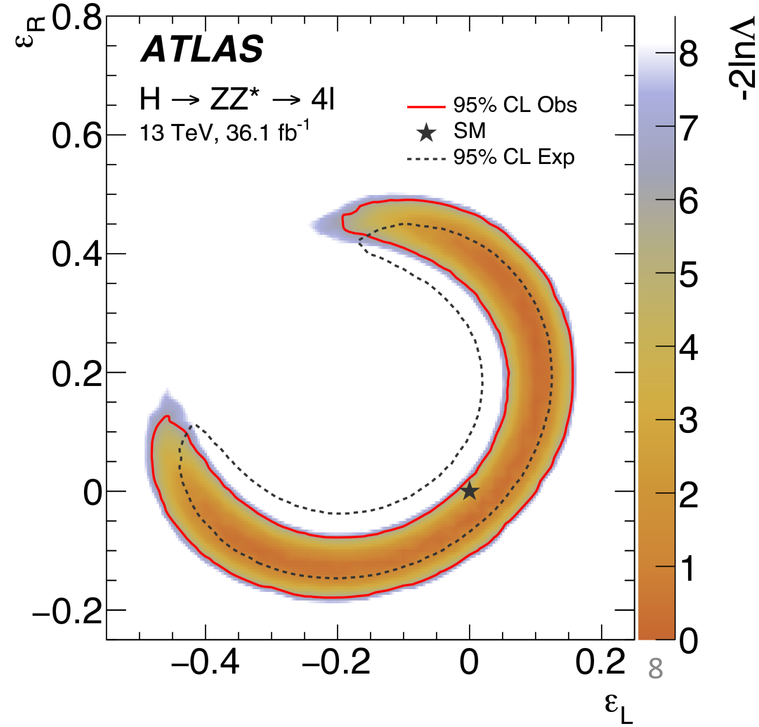
arXiv:1708.02810

# Constraints on pseudo-observable parameters in H->ZZ (Run-II)

- Similar idea pursued in recent measurement of H->ZZ differential cross sections:
  - Constraints on left- and right- handed *Hll* contact interactions set using a double-differential distribution.
  - Correlations between distributions not calculable from data for low event yields.



Fiducial and differential cross sections → Higgs effective field theory

# Constraints on EFT from differential XS?

- The previous examples set limits on specific operators
  - not close to a complete test of EFT
  - limited by use of only one decay channel
- Obvious extension: include *all* the available differential cross sections
  - Data only available for H->γγ, H->ZZ* and H->WW*. *Focus on HVV couplings?*
  - Missing correlations in published data for H->ZZ* and H->WW* (either unpublished or low-stats final state). *How to deal with this?*
  - With differential cross sections, this can be done inside or outside of experimental collaborations *if the full information is published*
- Individual channels will continue to publish sensitivity to specific operators
  - *Should we adopt a few benchmark sets of operators* to allow comparison between experiments and channels.
  - Is it useful to present constraints in a variety of different bases?

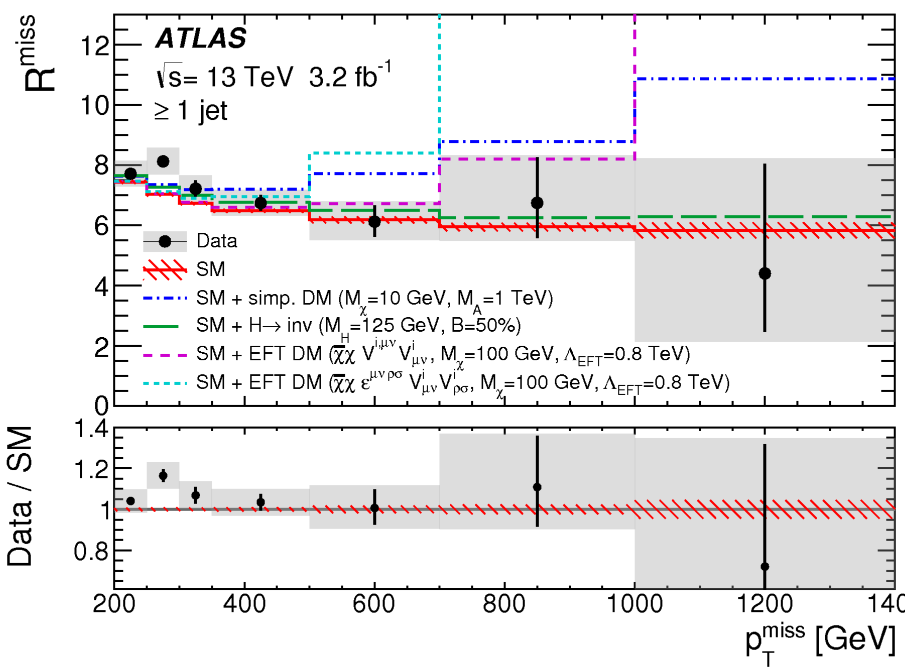
arXiv:1707.03263

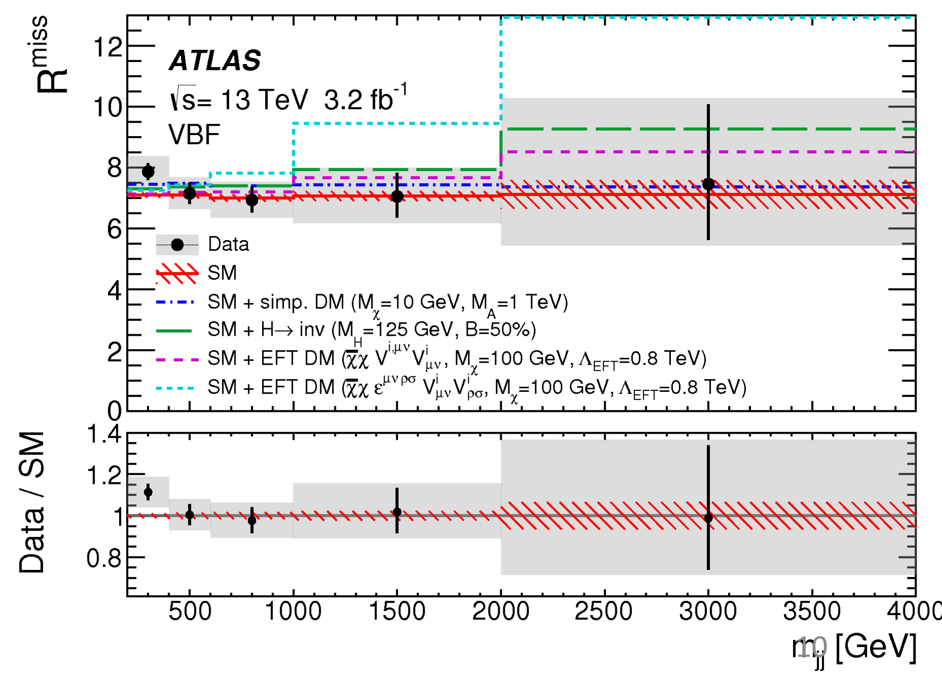
# Detector-corrected observables sensitive to dark-matter (Run-II)

- Observable is a ratio of cross sections, where the numerator can be sensitive to dark matter production:

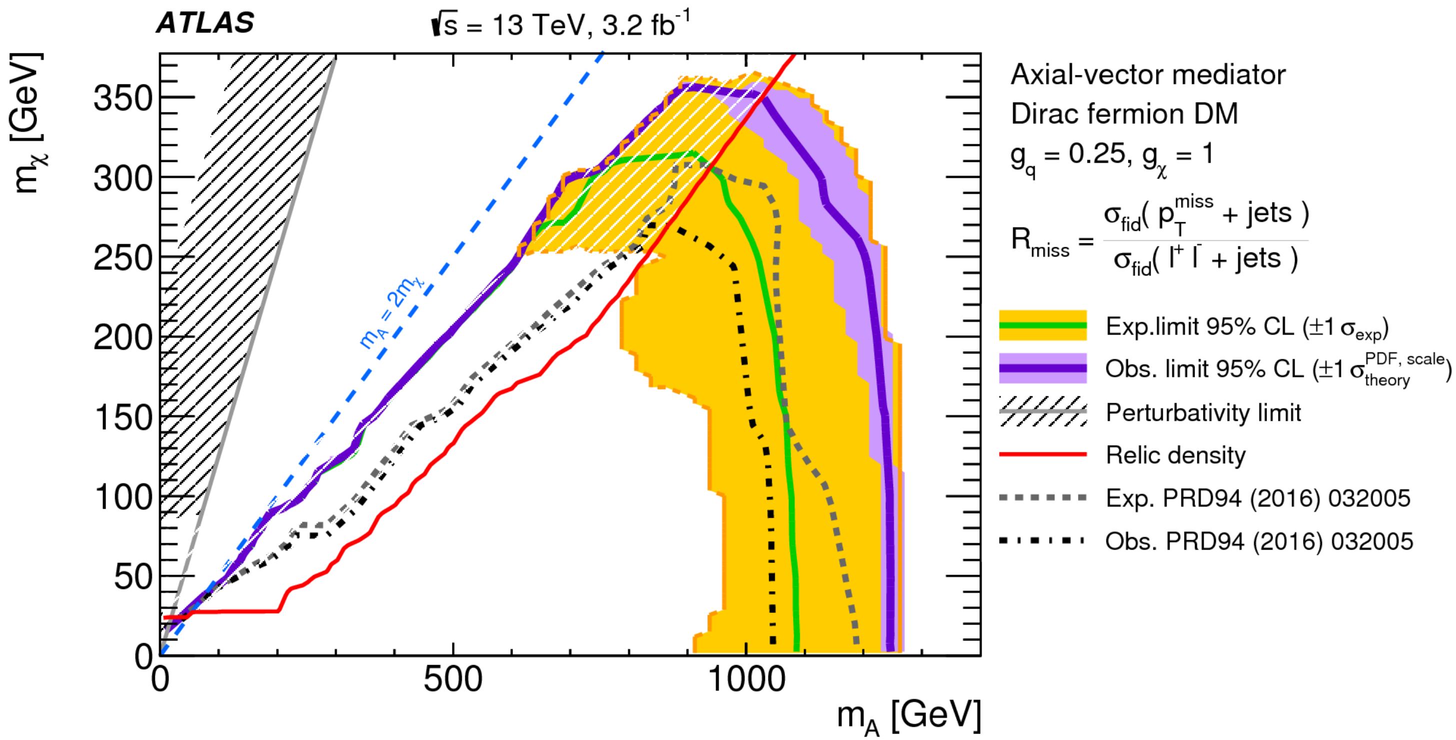
$$R^{\mathrm{miss}} = \frac{\sigma_{\mathrm{fid}}\left(p_{\mathrm{T}}^{\mathrm{miss}} + \mathrm{jets}\right)}{\sigma_{\mathrm{fid}}\left(\ell^{+}\ell^{-} + \mathrm{jets}\right)}$$

- Can probe DM EFT and invisible Higgs production (though not optimised for the latter)



# Sensitivity of detector-corrected vs detector-level analysis




- Some lessons:
  - Do not need a large significant signal to make useful detector-corrected observables
  - Correcting for detector effects does not reduce sensitivity

# Summary and outlook

- Differential cross section measurements
  - aim to correct the data only for detector inefficiency and resolution
  - are the most model independent characterisation of the data: ideal for constraining new physics from effective Lagrangians

- Constraining parameters from EFT in the future:
  - Need more distributions and double differential distributions.
  - Need more decay channels (H->γγ, H->ZZ* and H->WW* already available)
  - Need correlations between observables