Unfolding procedures

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summarizing studies and thoughts from ATLAS

2nd LHCHXS meeting on fiducial cross sections

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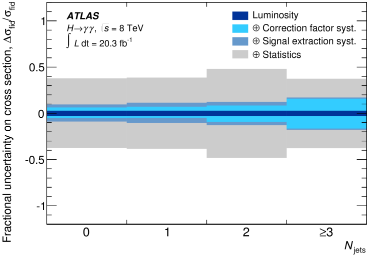
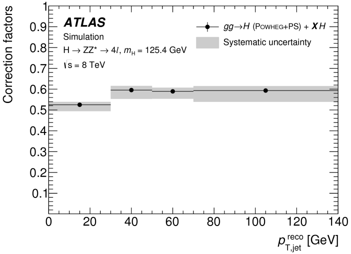
Recap of ATLAS unfolding procedure.

Detailed talk on ATLAS unfolding procedure was shown by Bijan Haney at the last meeting

- Bin-by-bin unfolding correcting for resolution, efficiency and acceptance effects: $\sigma_i = N_i^{\text{signal}}/(\mathcal{L}C_i)$
  - ★ Cross-checked against iterative unfolding
- Uncertainties on correction factors evaluated by varying composition of production modes, standard perturbative and Pdf uncertainties, ..., reweighting MC to match better measured distributions, ...
- With the present statistics, systematic uncertainties are small compared to statistical uncertainties





A few words on biases in unfolding.

- In general, unfolding introduces biases from simulation not perfectly describing the physics in data, and more important for larger bin-to-bin migrations
  - $\rightarrow$ more important for jet-related variables than photon- or lepton-related variables

Biases introduced through...

- physics/model dependence of correction factors/detector response matrix
  - ⋆ Bin-by-bin unfolding, “CMS method”, ...
- regularization procedure (usually uses MC truth distribution)
  - ⋆ Iterative unfolding, SVD, IDS, ...

Different methods are different methods and do not necessarily have identical uncertainties (statistical and systematic), biases and correlations

$\rightarrow$ Choice of method is a trade-off between biases and variance, and depends on the problem (usually no “single right solution”)

- ⋆ Of course for any method biases need to be estimated properly

Estimating uncertainties/unfolding biases.

Relevant sources of uncertainties/biases for differential Higgs cross sections

- relative contributions of the different production modes
- shape of individual spectra (missing higher-order corrections, pdf choice, ...)

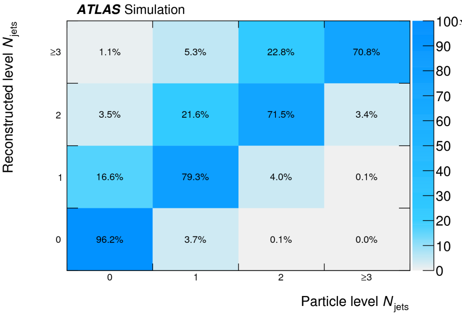
$\rightarrow$ Need to be varied in large enough range to estimate uncertainties from unfolding procedure

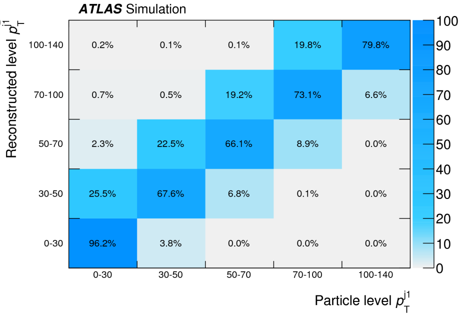
NB: Estimating these biases is an important part of determining proper regularization strength for regularized unfolding

Determination of binning.

- Binning is chosen to limit migration effects
  - ⋆ $p > 60\%$, where $p = N_i^{\text{fid+reco}} / N_{\text{reco}}$
  - ⋆ ...not a very strict requirement...
- On the other hand, larger bins can enlarge physics/model dependence

$P(\text{truth bin}|\text{reco bin})$

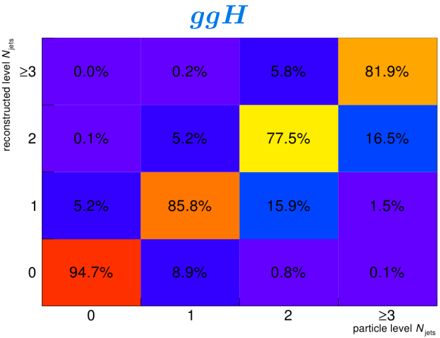


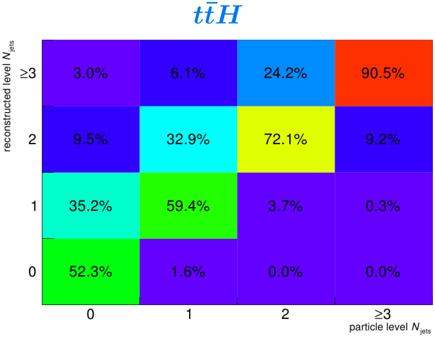


Physics/model dependence of detector response.

- Not just bin-by-bin correction factors are physics/model dependent, but also detector matrices

→ Also methods relying on the full detector response matrix need to estimate corresponding uncertainties/biases

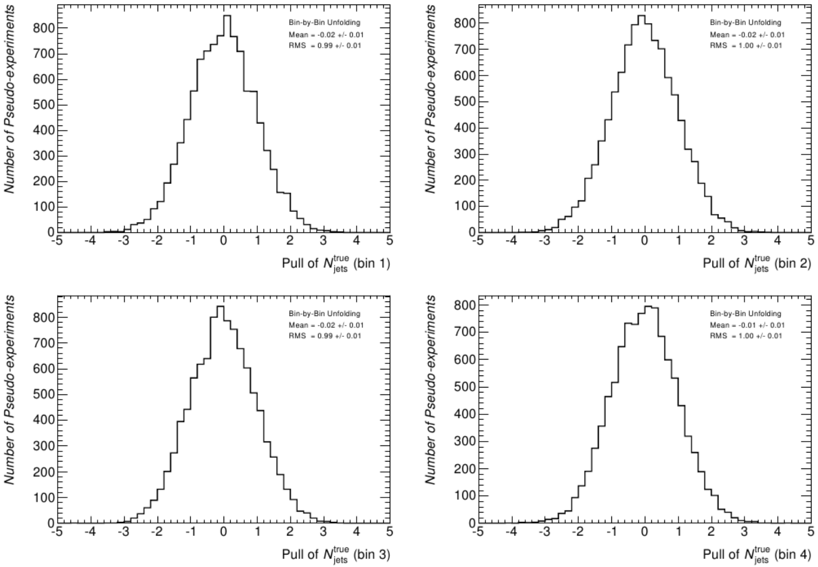




"Toy detector resolution matrices" – thanks to Dag Gillberg!

Simple unfolding tests.

- Same underlying truth distribution in “data” and “MC”



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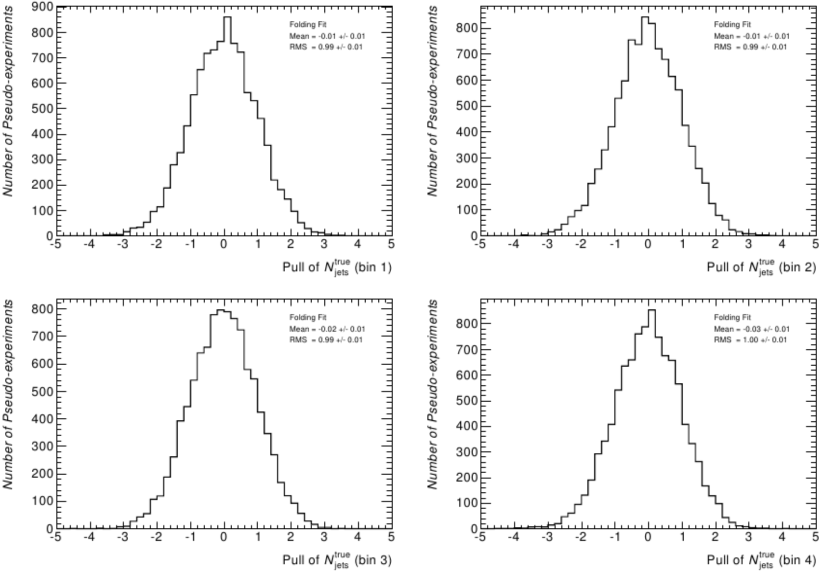

Summary.

- Simple toy tests ok: unbiased and ok coverage
- Ongoing: extend study to different underlying truth distributions in “data” and “MC” to check biases and coverage
  - ⋆ Expect to see biases with any method
  - ⋆ Corresponding uncertainties need to be estimated and should not dominate uncertainties

Backup

Bin-by-bin unfolding.

$$\frac{1}{C_i} = \frac{N_i^{\mathrm{Fid}}}{N_i^{\mathrm{Reco}}} = \frac{P_i}{\epsilon_i} \qquad P_i = \frac{N_i^{\mathrm{Fid\&Reco}}}{N_i^{\mathrm{Reco}}} \qquad \epsilon_i = \frac{N_i^{\mathrm{Fid\&Reco}}}{N_i^{\mathrm{Fid}}}$$

- Bin-by-bin correction factors, c_i, are calculated from MC simulations in order to correct for detector effects.
  - N^{Fid} is the # of truth level MC events after event selection within a fiducial volume.
  - N^{Reco} is the # of MC events after event selection with detector effects (e.g. gaps in the detector, Jet reconstruction efficiency, other smearing effects, etc.)
  - $N^{\mathrm{Fid\&Reco}}$ are events that pass the Higgs event selection under both circumstances.
- Purity, P_i, accounts for the number of fakes in a bin.
- Efficiency, ϵ_i, accounts for poor object reconstruction and identification.

[Slide from Bijan]

Unfolding uncertainties.

There is uncertainty in both N^{Reco} and N^{fid} because the generators themselves may not match reality. There is extra uncertainty specifically in N^{Reco} because the MC smearing may not match reality.

- Generator Modeling and Uncertainty
  - Alternative MC generators were used and their envelope was taken as an uncertainty.
    - eigenvector variations of the baseline CT10 PDF.
    - central values of alternative MSTW2008NLO and NNPDF2.3 PDFs.
  - Signal composition of the production modes was varied.
    - VBF+WH+ZH production XS were doubled and halved.
    - ttH production XS was multiplied x5 and x0.
  - Varying the renormalization and factorization scales by double and a half.
  - Reweighing was applied to the MC to make it more closely reflect the observed distribution of data.
    - The unfolded data distributions of p_T and |y| were compared to fiducial MC predictions. Reweighing functions from data/MC were used to correct the fiducial p_T and |y| spectrum.
    - Data tend to have harder Higgs p_T, and more forward |y|.

[Slide from Bijan]