# Statistical models for recasting of unfolded measurements

## and combination with searches

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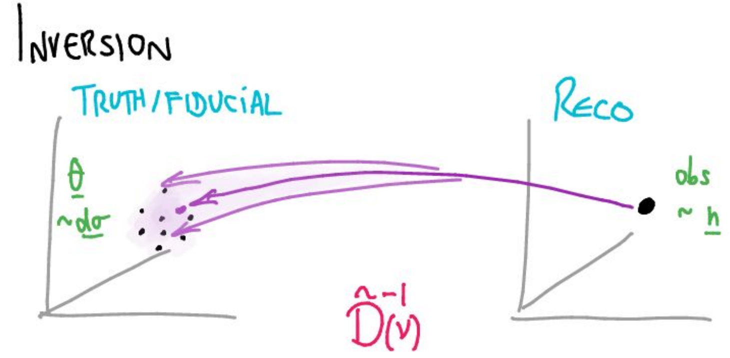
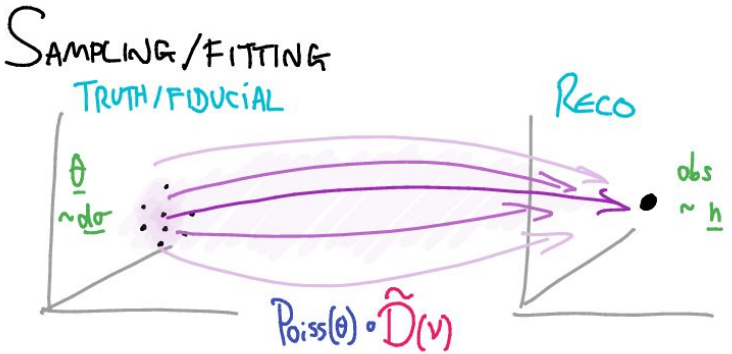
ECFA Higgs Factories, MC Generators Meeting
12 November 2021

# Executive briefing: unfolding

- **Unfolding has been around for decades**
  - General principle is to correct reco data for effects distorting our view of the physics of interest
  - LHC in particular has refined this to mean unfolding to a *fiducial volume:* correct ~only for detector effects, to a well-defined final-state, cuts similar to reco
  - Non-fiducial extrapolations, too — *in addition to fid xs*
  - ***Necessarily propagate uncertainties from both detector understanding, and the unfolding mechanism***




- **Main methods/tools**
  - **Regularised inversion:**
    - Iterative Bayes IBU (RooUnfold, pyunfold)
    - SVD/Tikhonov reg (RooUnfold, TUnfold)
  - **“Forward-propagation” with sampling/fitting:**
    - TRExfitter, pyhf?
    - PyFBU, (hunfold)



# Unfolding vs search profiling

- **MC-driven unfoldings need the same things**
  - Binned data observable
  - Binned MC truth and reco observables
    - Generally, truth/reco binnings (and even the observable!) don't need to match: *bin reco tighter*
  - A response matrix of $p(\mathrm{reco}_j|\mathrm{truth}_i)$ for truth,reco bins $i,j$
    - A good unfolding requires a "tight" response matrix, not a "diagonal" one
  - Lots of standard methods to assess unfolding non-closure and MC-model dependence

- **Aim of unfolding is to extract fiducial, particle-level bin values & errors**
  - Note, not the true, integer bin-populations, but physics params e.g. $d\sigma_i$ (differential xs in bin $i$)
    $\Rightarrow L_{\mathrm{search}}(\mathrm{obs}|\mathrm{BSM\ params})$ vs $L_{\mathrm{meas}}(\mathrm{obs}|d\sigma\text{'s})$
  - Different methods use different Poisson/multinomial internal models, plus inversion heuristics
  - Fit methods not so different from a BSM-search fit/scan: POIs are bin-values, not model params
  - We don't often think of measurements as limit contours in a $N_{\mathrm{bin}}$-dim space, but they are!

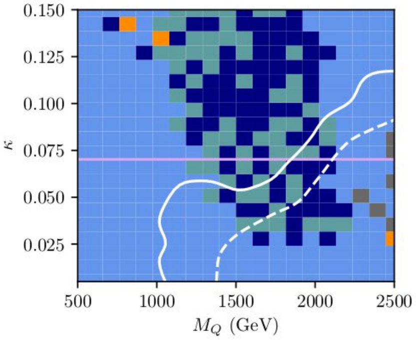
- **Systematic uncertainties**
  - Need some mechanism to propagate systematic uncertainties
  - Intrinsic/natural in fit/scan methods, just extend the param space to bin vals $\oplus$ nuisances
  - More *ad hoc* in (most?) inversion tools — updates coming in RooUnfold?

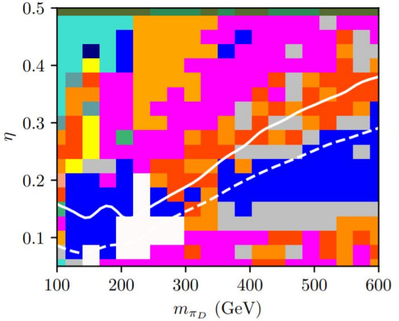
# Stat models from unfolding, and combination

- **Search-likelihood publication quite advanced now**
  - Particularly via pyhf, path to common format for Poisson model in searches
  - Don’t want measurements to get left out, cf. e.g. Contur (and others’) uses of LHC measurements for complementary BSM constraints

- **Statistical models from unfolding tools**
  - Obvious for sampling tools: Poisson likelihood/posterior are explicit
  - Maybe less clear for inversion tools, but means and (correlated) uncertainties calculated ⇒ implicit b2b Gaussian pdf — maybe templated wrt nuisances
  - **Obstacles to encoding unfolded likelihoods in pyhf?**
  - **Alternatively, publish sampled point sets?**

- **Issues shared with searches**
  - elementary nuisances needed for fully coherent combination
  - some standardisation and versioning of nuisance names needed — and gauging degree of correlation between versions (nice problem to have…)
  - Freq vs Bayes: combining likelihoods & posteriors?



# Summary/discussion

## Input from toolkit authors

- Inversion and sampling methods — developments, current and planned output data and formats.
- Possible to achieve technical compatibility with pyhf/etc. direct searches?
- In pyhf and similar tools: how best to encode Gaussian uncertainty models? Extend pyhf, build on pyhf, include one more stat distribution in common format?

## Experience of unfolding with model publication

- 2x public ATLAS top analyses, 1 total, 1 differential
- More?

## Experience of combination (e.g. Convino)

- Need for standards / understanding of common & related systematics
- Combining limits from different stat paradigms

## More?