UNFOLDING THE HIGGS

DIFFERENTIAL CROSS-SECTION MEASUREMENTS OF THE HIGGS BOSON

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ATLAS EXPERIMENT

Nikhef

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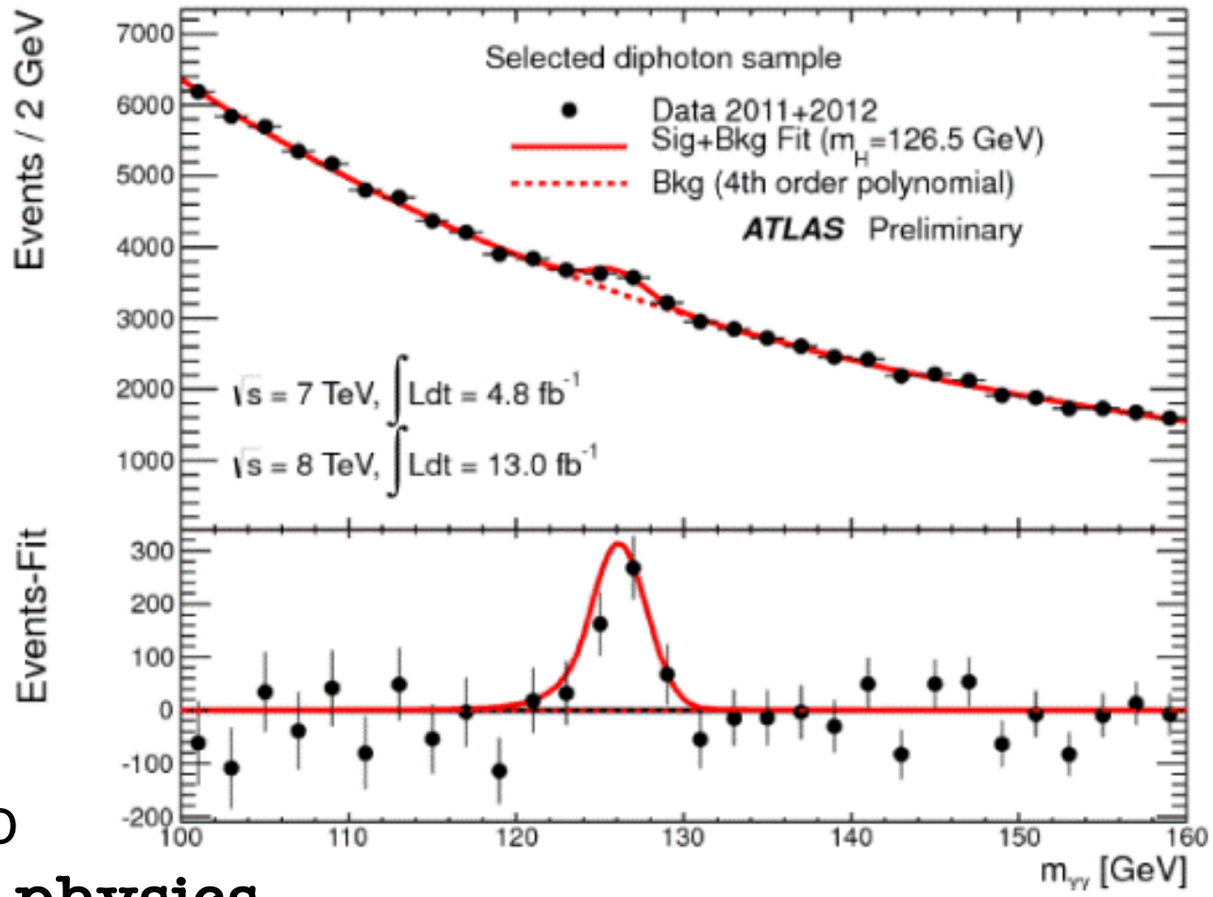
OUTLINE

- What after the Higgs?
- H->WW
  - ✦ Inclusive cross section
  - ✦ Differential cross section
- Unfolding: What, Why and How?
- Conclusion

WHAT AFTER THE HIGGS?

The Higgs Boson has been discovered in 2012 by both ATLAS and CMS experiments at the LHC, CERN.



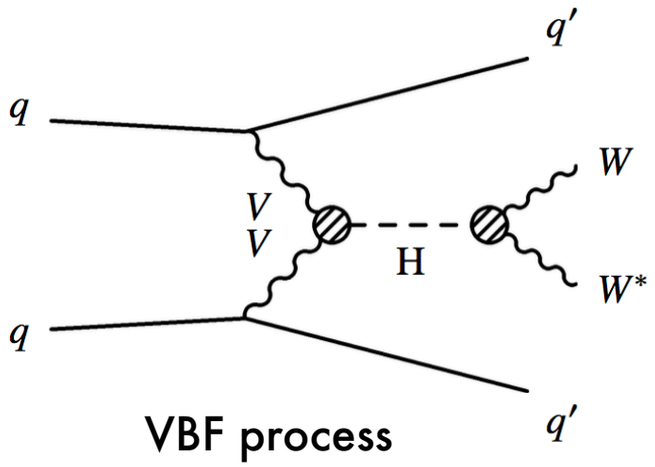
- **What after that?**

  - ✦ **precise measurements** of the properties of the Higgs Boson

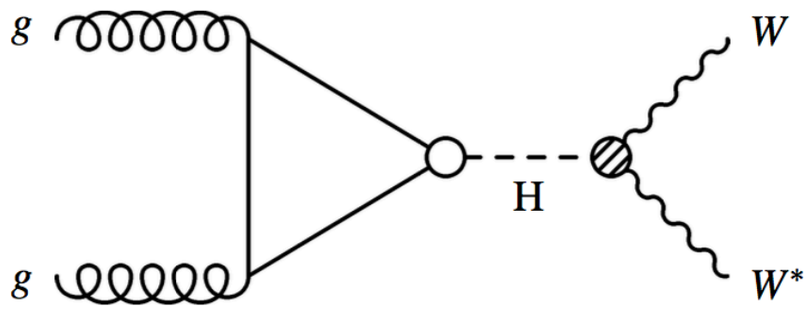
  - ✦ investigate new methods to probe SM predictions and to test for the presence of **new physics**.

WHY H->WW ?

- H->WW has the **2nd largest branching fraction** after H-bb decay channel
- **A cleaner signal** than H->bb which allows precise Higgs boson cross-section measurements.
- GGF process measurements **probes the Higgs boson couplings** to gluons and heavy quarks.
- VBF process directly **probes the couplings** to W and Z bosons.

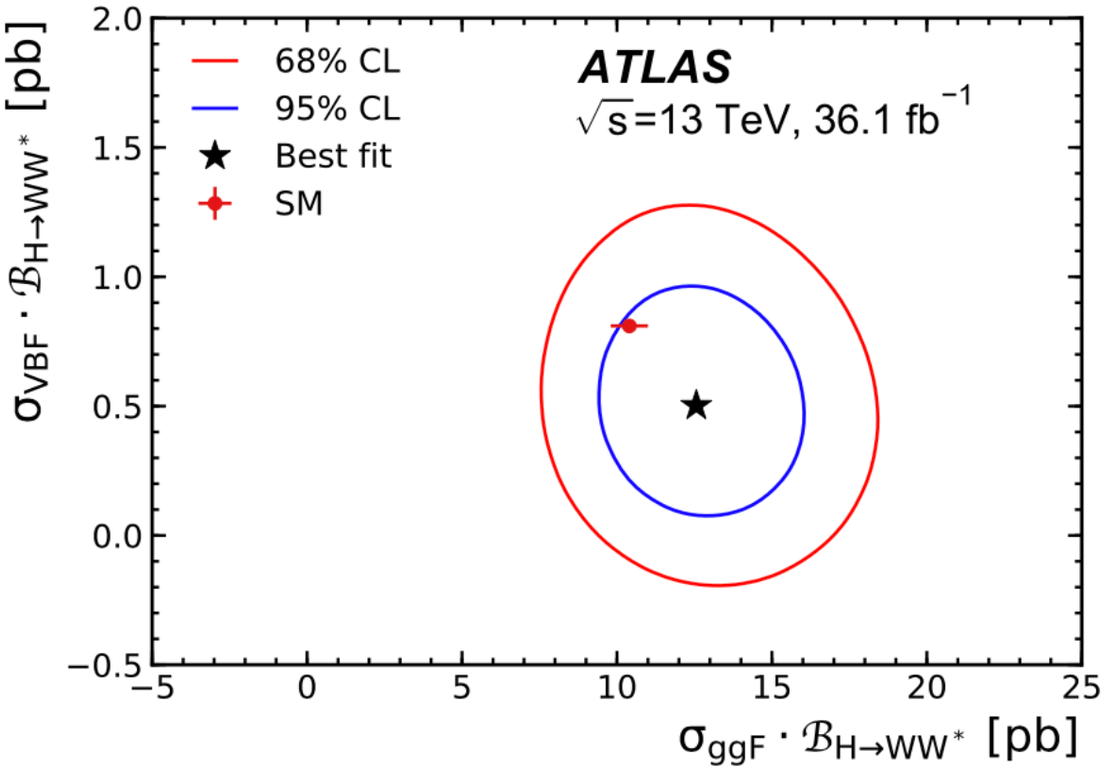


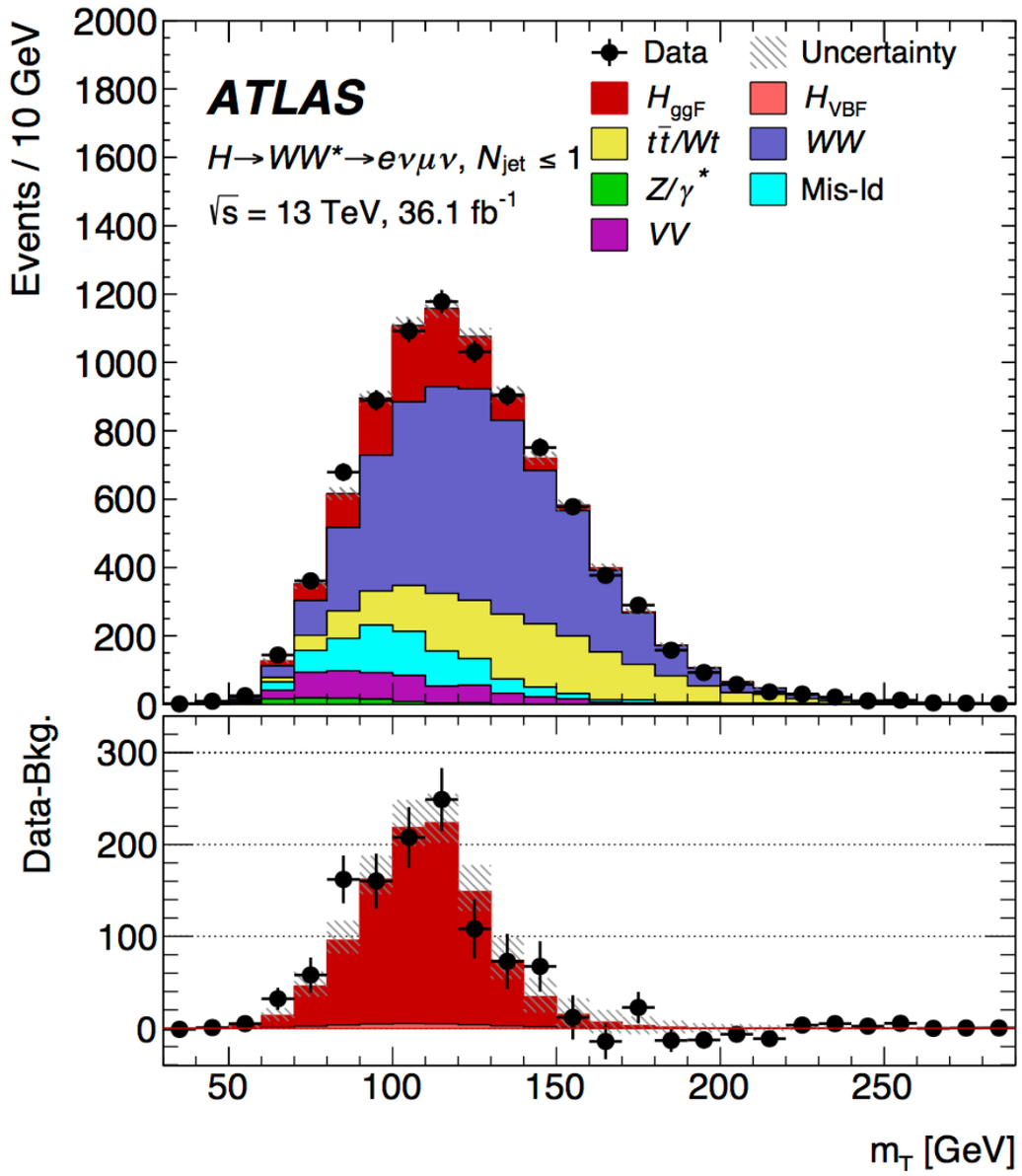
VBF process



GGF process

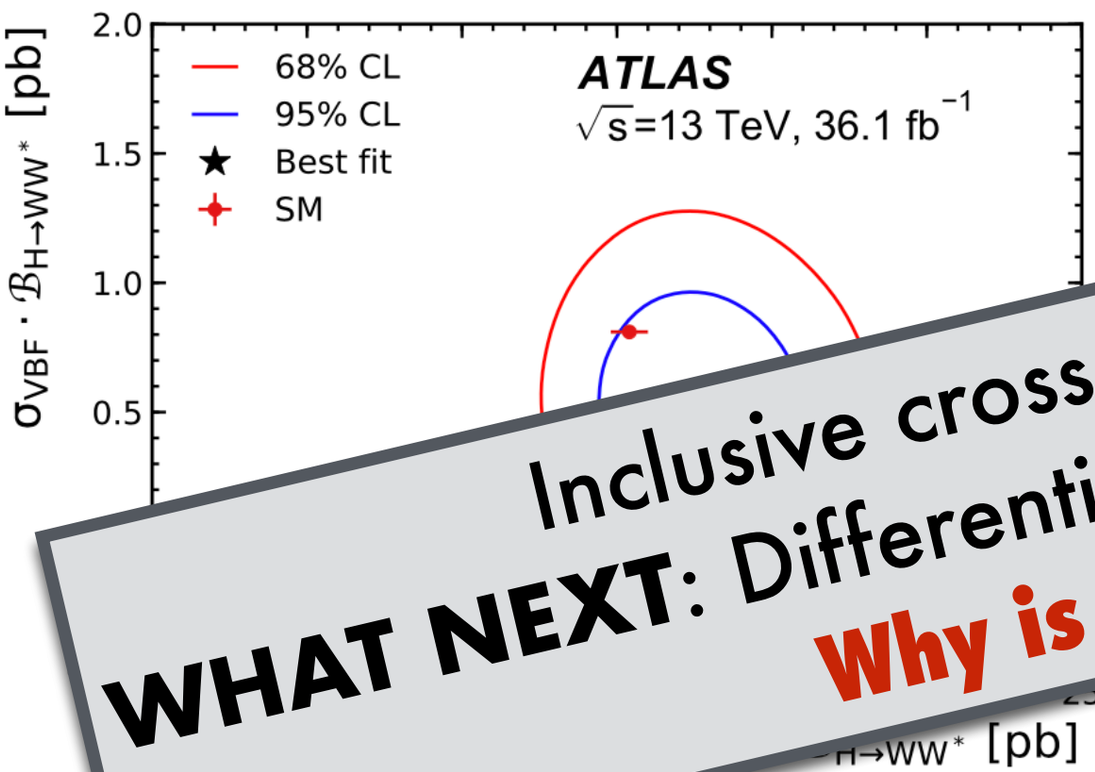
INCLUSIVE CROSS-SECTION

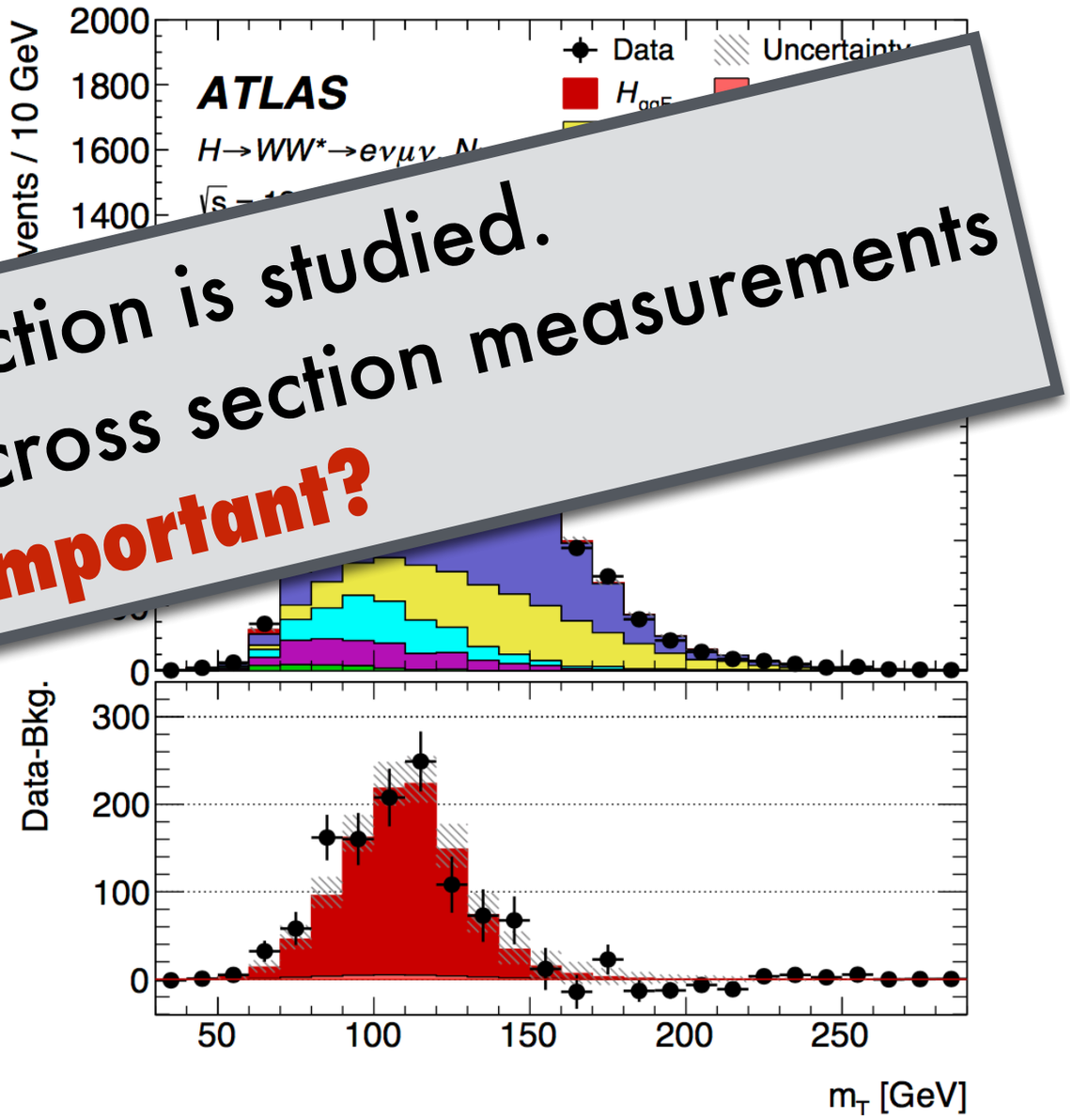




The total signal observed, in both shape and rate, and the inclusive cross-section are in agreement with the SM predictions.

INCLUSIVE CROSS-SECTION





Inclusive cross section is studied.

WHAT NEXT: Differential cross section measurements

Why is it important?

The [illegible] signal observed, in both shape and rate, and the inclusive cross-section are in agreement with the SM predictions.

WHY DIFFERENTIAL CROSS-SECTION?

- New physics may contribute in the gluon-gluon fusion loop and manifest itself through deviations from the distributions predicted by the SM.
- Extends information on the Higgs boson couplings:
  - Extracted by fitting parametrised spectra to a combination of differential cross sections.
- Constrain model parameters.
- Enhance sensitivity to BSM effects by looking at shapes instead of just the total rates.

To measure truth-level differential cross-sections,
we need to do UNFOLDING!

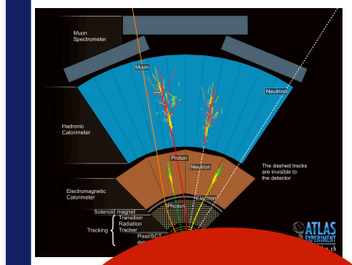
WHAT IS UNFOLDING?

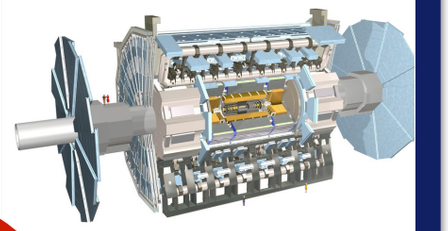
(A GENERAL IDEA)

Take what we have: **DATA**

Real p-p collisions

Particle Detector (ATLAS)





What we have!

What we want!

MEASUREMENT

UNFOLDING

What we can!

Monte Carlo Generator

What we can!

Detector Simulation

SIMULATION

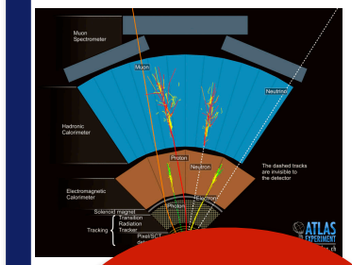
Use what we can: **SIMULATED EVENTS**

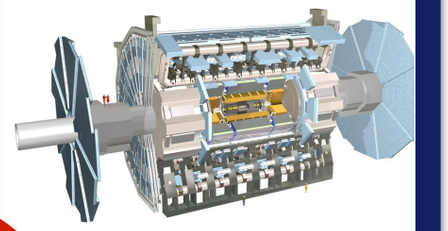
Real p-p collisions

What we want!

MEASUREMENT

Particle Detector (ATLAS)



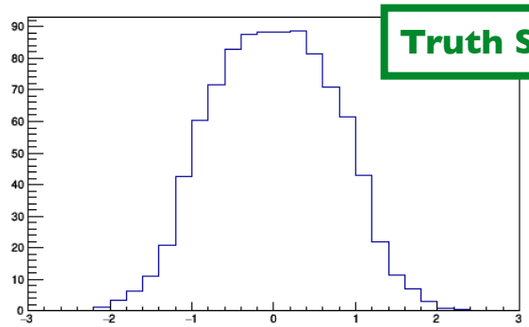


What we have!

SIMULATION

What we can!

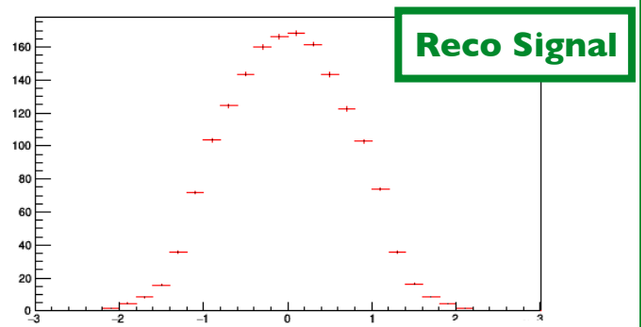
Monte Carlo Generator



UNFOLDING

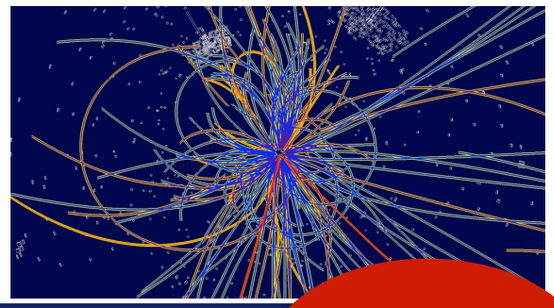
What we can!

Detector Simulation

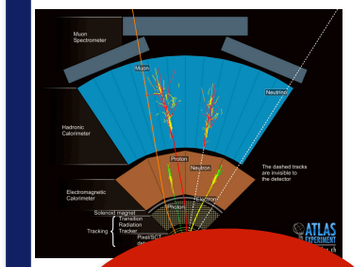


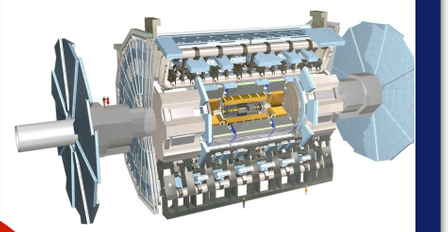
Measure what we want: **CROSS-SECTIONS INDEPENDENT OF THE DETECTOR EFFECTS**

Real p-p collisions



Particle Detector (ATLAS)





What we want!

What we have!

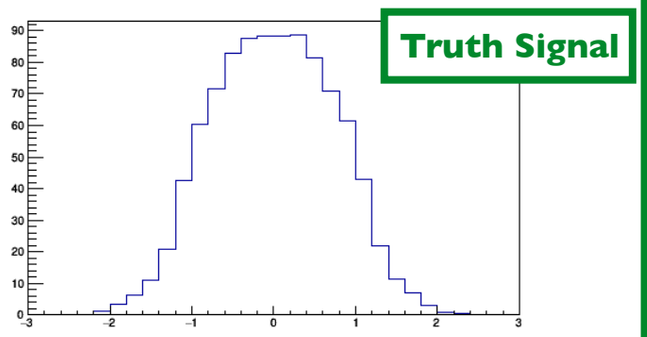
MEASUREMENT

SIMULATION

UNFOLDING

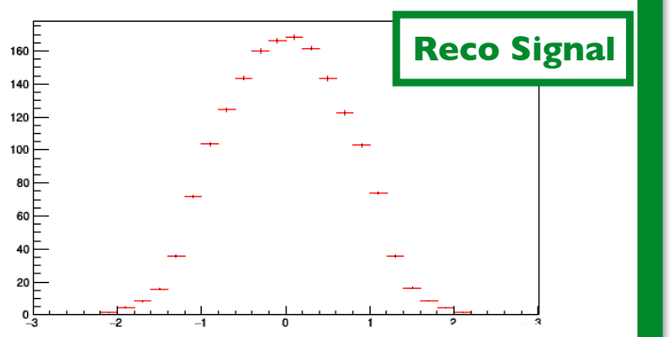
What we can!

Monte Carlo Generator



What we can!

Detector Simulation



WHY IS UNFOLDING ESSENTIAL?

- Independent of detector effects and thus they will stay valid even after we have no ATLAS simulation.

- More useful to theorists who want to compare their own theories or generators to what the data tell us.

- Model-independent and don't make a lot of assumptions.

HOW TO DO UNFOLDING?

$$\text{Reconstructed Signal (R)} = \text{Response Matrix (R.M.)} * \text{Truth Signal (T)}$$

Step 1

SIMULATION

MEASUREMENT

Simulated R = R.M. * Simulated T

Measured R = R.M. * Measured T

(data)

(Unfolded data distribution)

Step 2

Unfolding

Measured T = **R.M.$^{-1}$** * Measured R

(Unfolded data distribution)

(data)

Reconstucted signal: Detector Level Distribution

Truth signal: True distribution

Response matrix: Reconstructed observable correlated to truth observable

HOW TO DO UNFOLDING?

$$\text{Reconstructed Signal (R)} = \text{Response Matrix (R.M.)} * \text{Truth Signal (T)}$$

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(data) (Unfolded data distribution)

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(Unfolded data distribution) (data)

Unfolding

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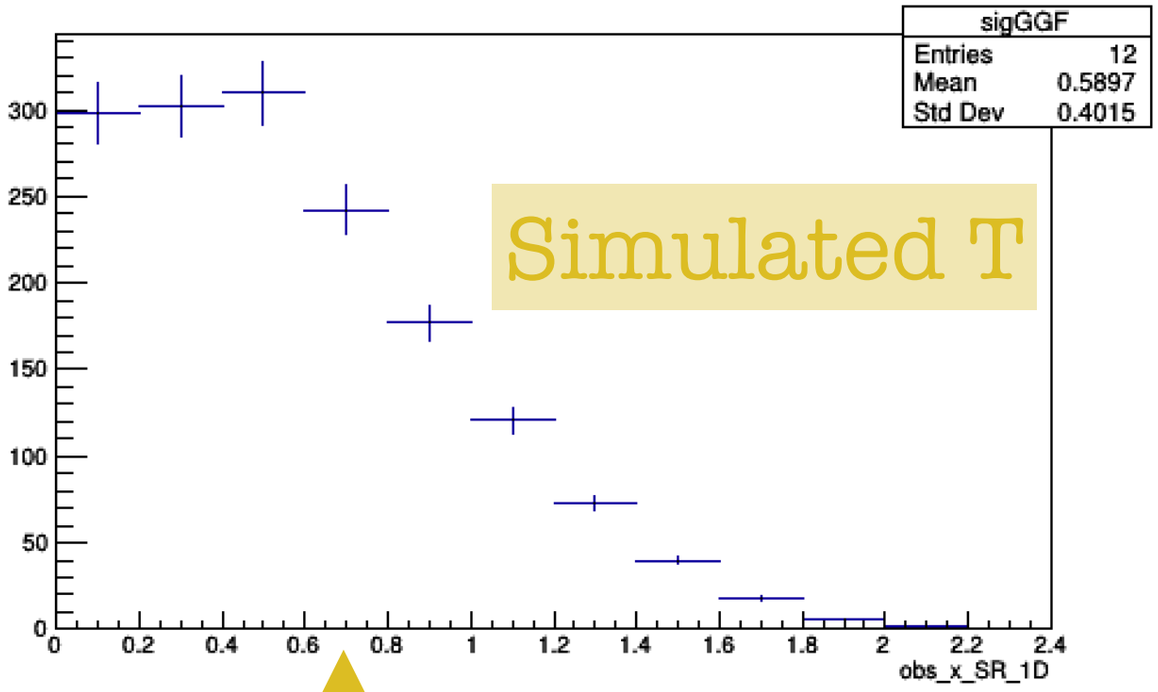
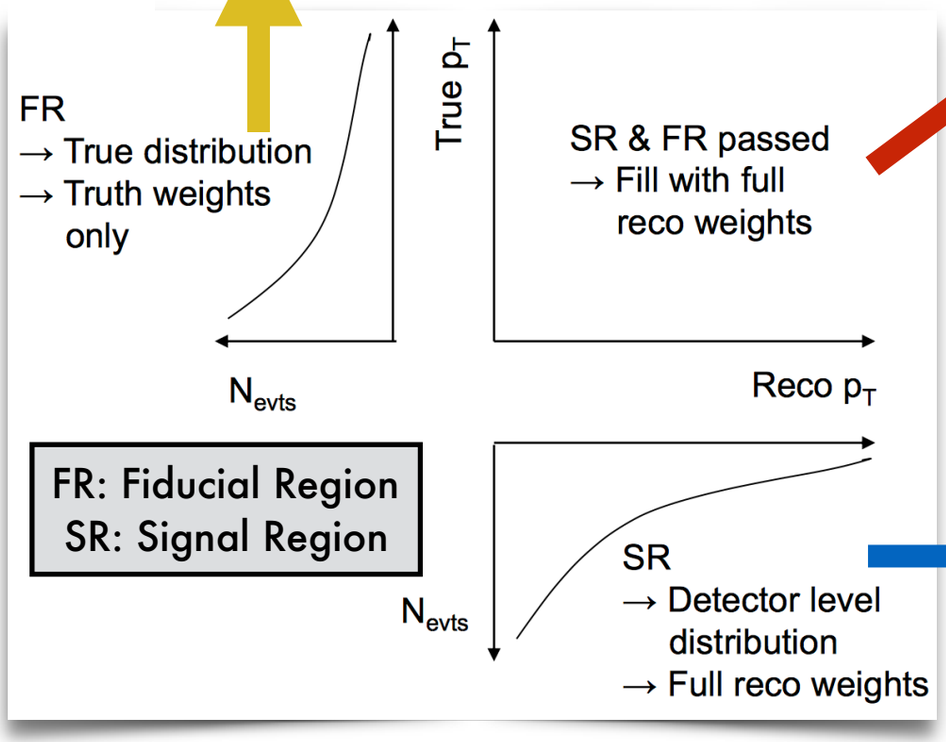
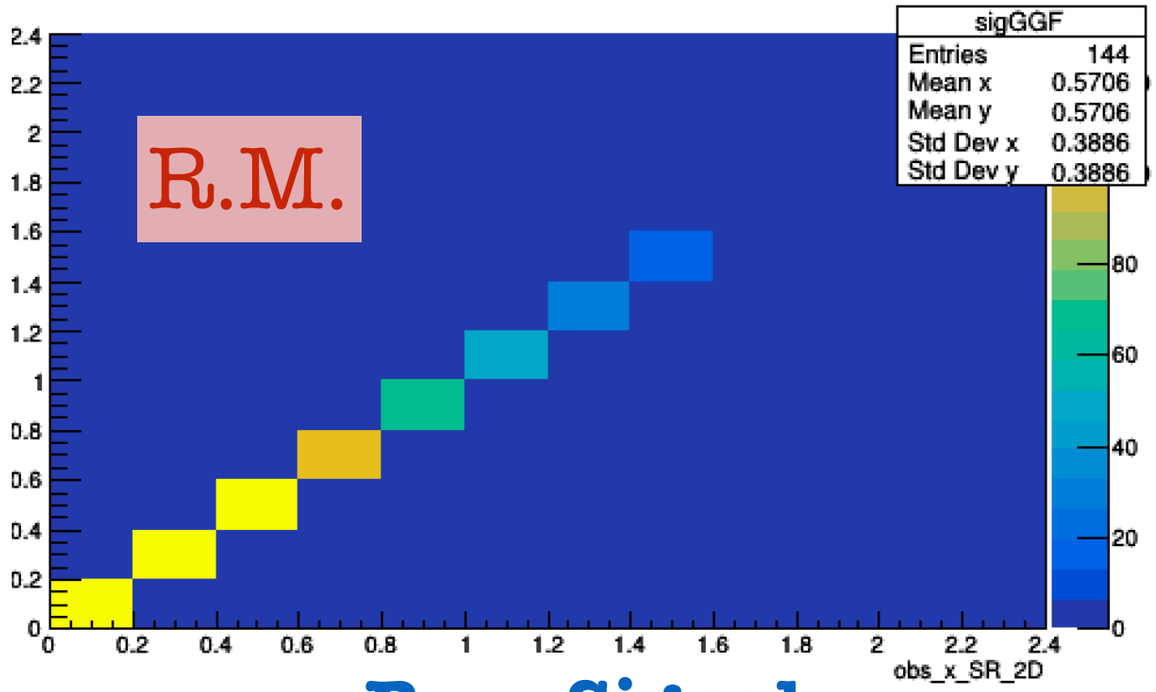
SIGNAL MC-SIMULATED INPUTS

Truth Signal

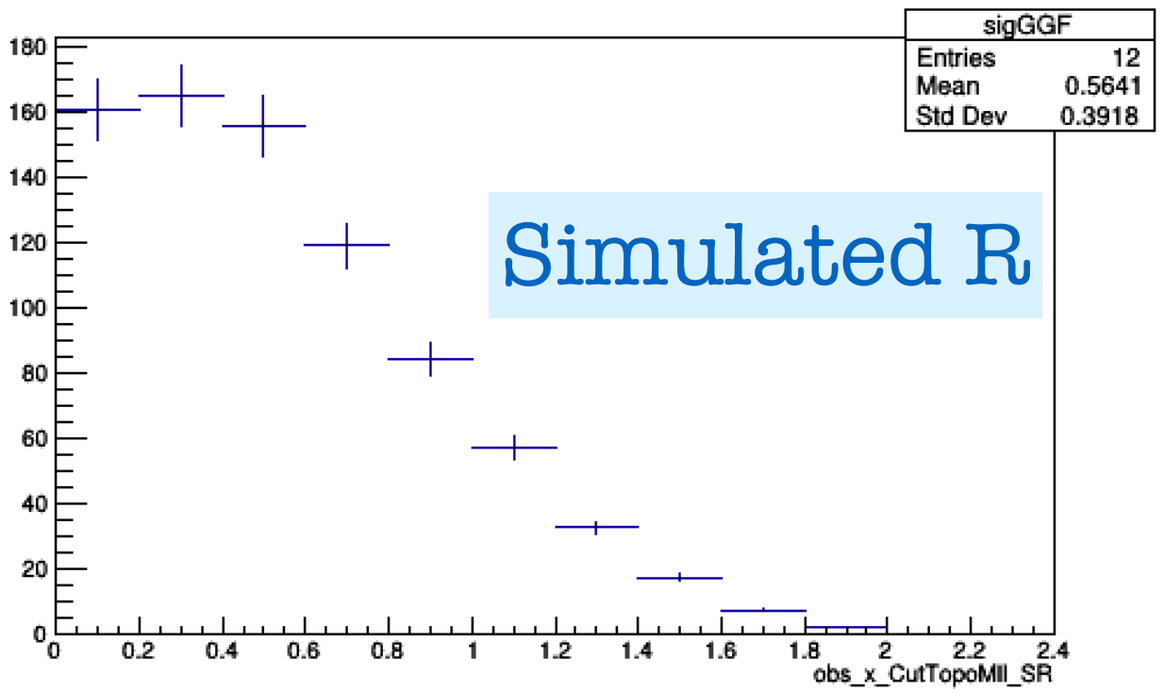




Response Matrix



Reco Signal



HOW TO DO UNFOLDING?

Reconstructed Signal (R) = Response Matrix (R.M.) * Truth Signal (T)

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MEASUREMENT

Measured R = R.M. * Measured T

(data) (Unfolded data distribution)

Step 2

Unfolding

Measured T = **R.M.$^{-1}$** * Measured R

(Unfolded data distribution) (data)

Reconstucted signal: Detector Level Distribution

Truth signal: True distribution

Response matrix: Reconstructed observable correlated to truth observable

HOW TO DO UNFOLDING?

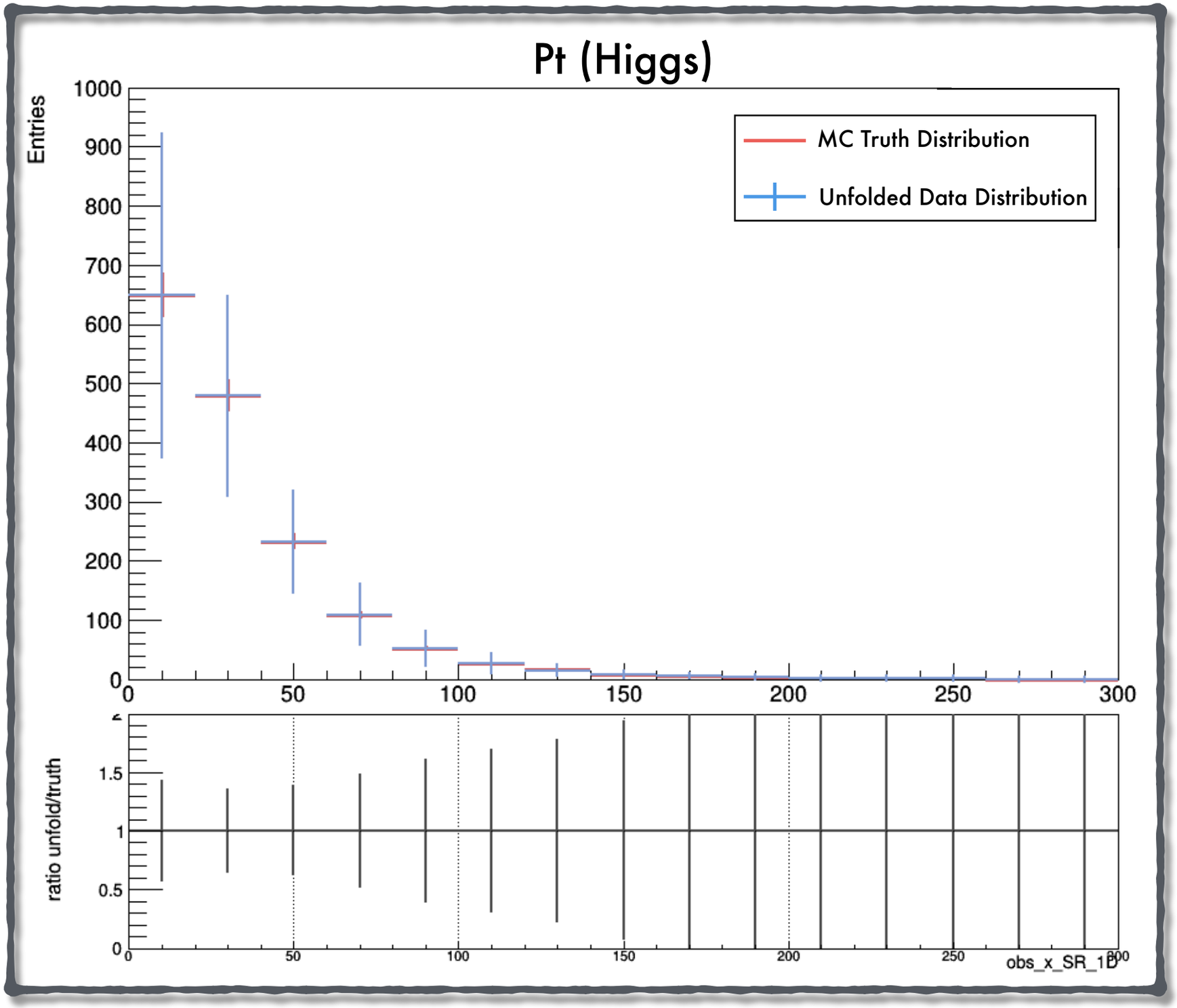
- **Transfer from reco to true observable value.**

- Two unfolding methods being studied in H-WW channel:
  - Iterative Bayesian Unfolding
  - Single Value Decomposition (SVD) Unfolding

- The distributions are corrected for detector efficiencies and resolutions.

- Statistical and systematic uncertainties are propagated through these corrections.

UNFOLDED DATA DISTRIBUTION



This is the unfolded data distribution for the asimov dataset and as expected, the central values are the same as the MC true distribution.

Actual data is blinded!

CONCLUSION

- The **first** **differential cross section measurement** for H->WW decay channel for data recorded at 13 TeV centre of mass energy.

- All the Higgs channel are performing differential analyses and lately there is also been a differential combination of H->$\gamma\gamma$ and H->ZZ

- By developing a differential analysis for H-WW, we aim to contribute to the next round of this combination.

THANK YOU! :)