Mitigating detector effects in measurements with the ATLAS Experiment

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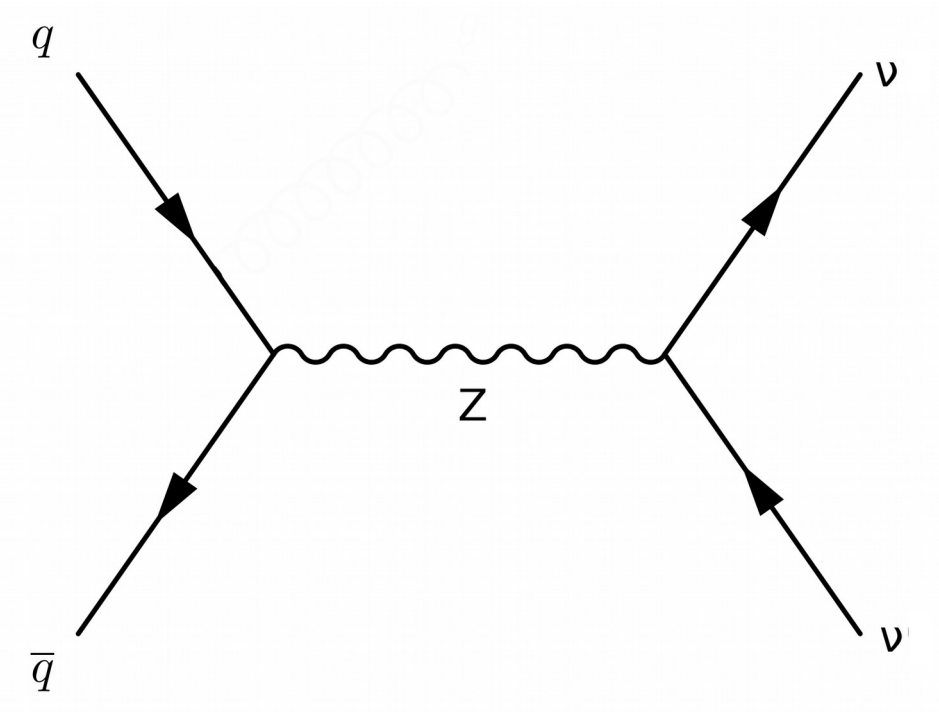
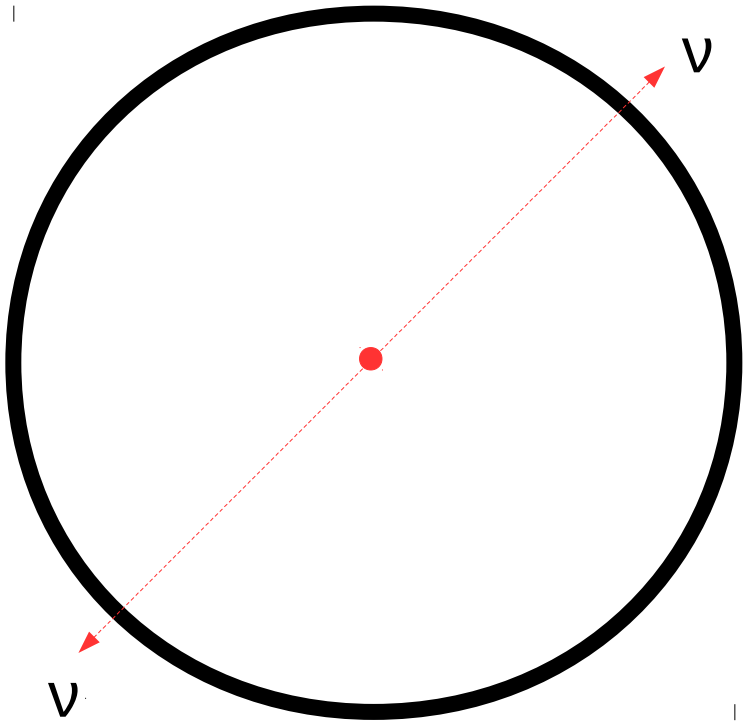
Bundesministerium für Bildung und Forschung
FSP 103 ATLAS
INTERNATIONAL MAX PLANCK RESEARCH SCHOOL
PT FS FOR PRECISION TESTS OF FUNDAMENTAL SYMMETRIES

The measurement: $Z \to \nu\nu$

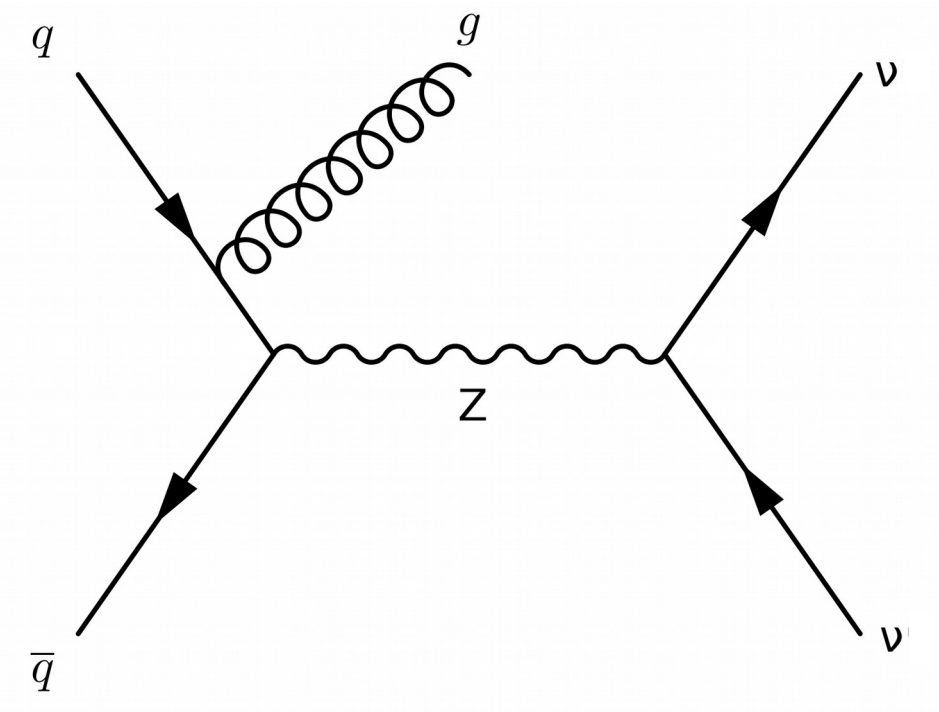
Want to measure $Z \to \nu\nu$

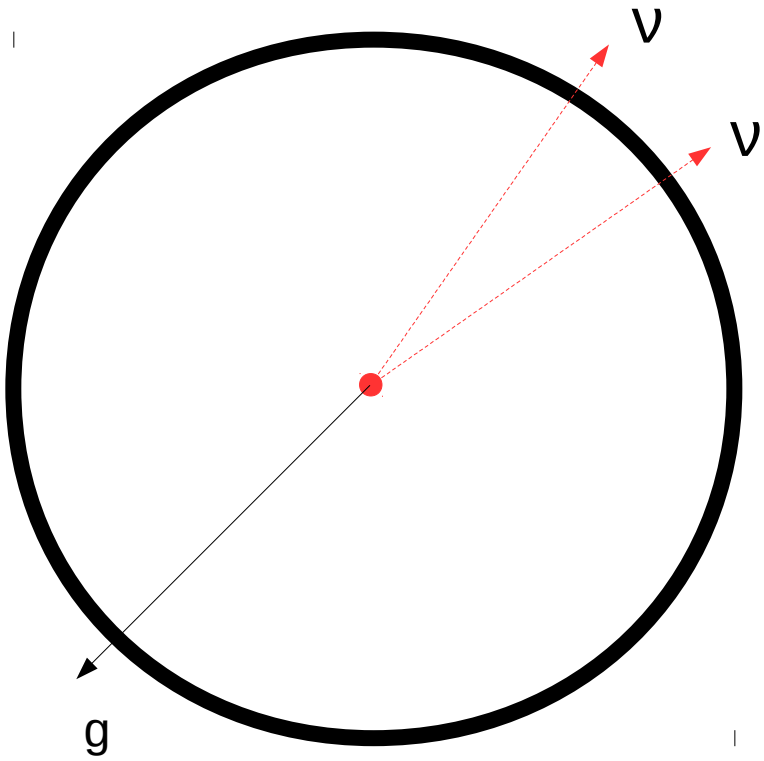




The measurement: $Z \rightarrow \nu\nu$ + jets

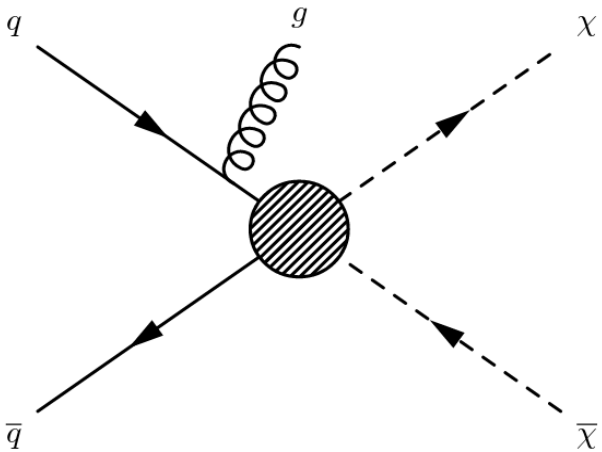
Really: Want to measure $Z \rightarrow \nu\nu$ + jets

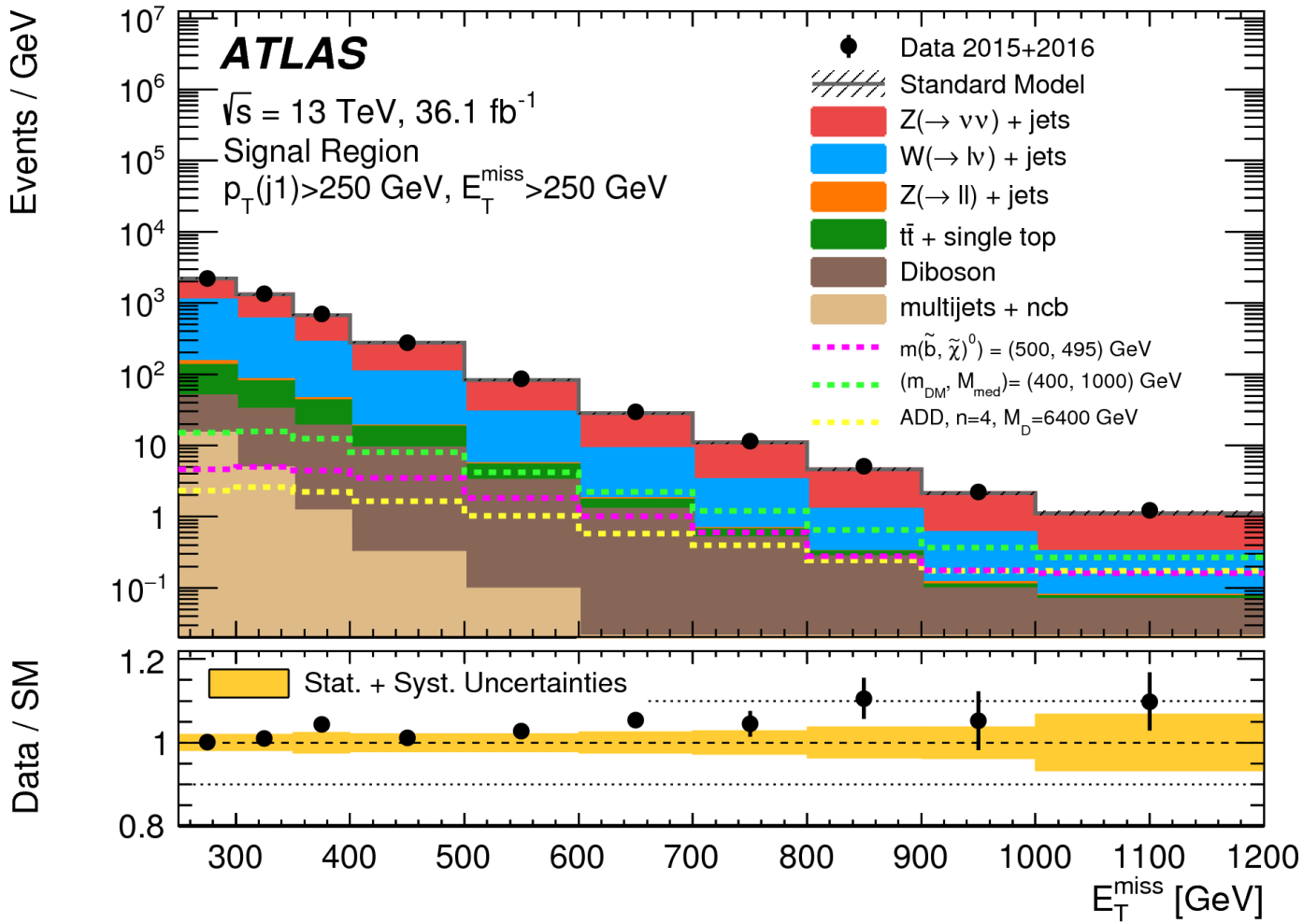




Could measure this for a search

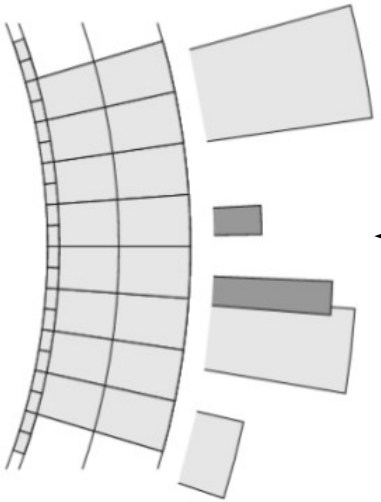
JHEP 1801 (2018) 126

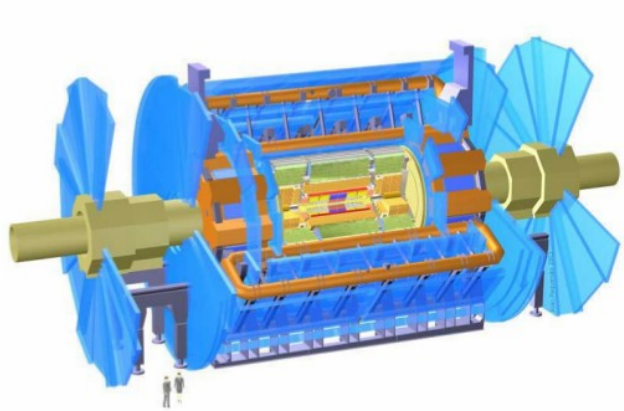




Search has limitation: choice of model

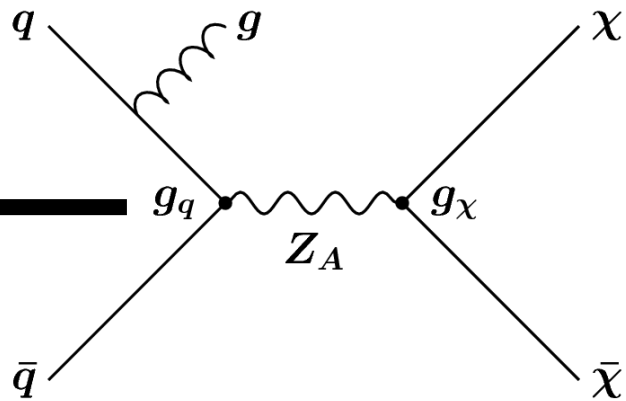
Data @ detector level





Full ATLAS simulation

theory



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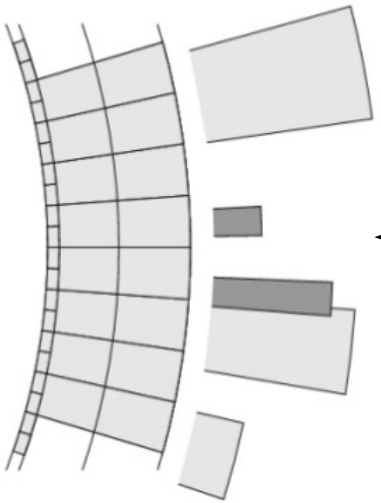
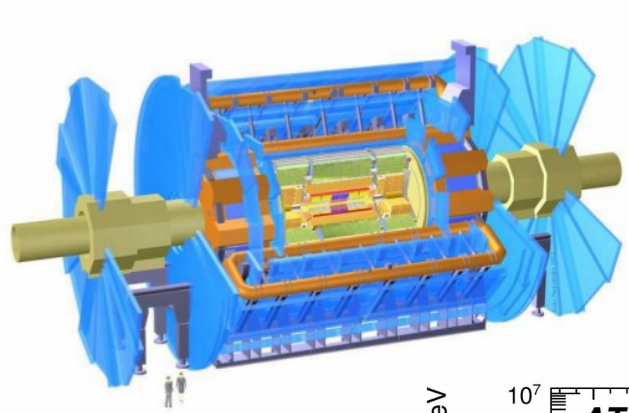
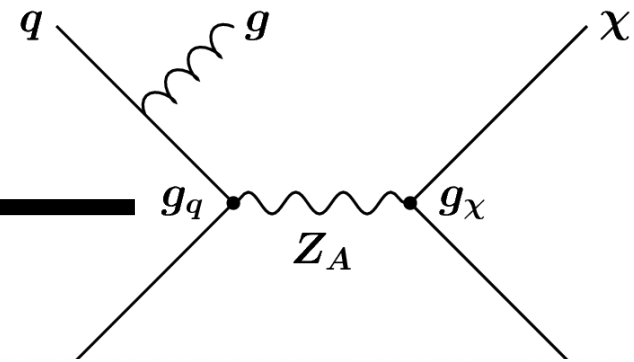
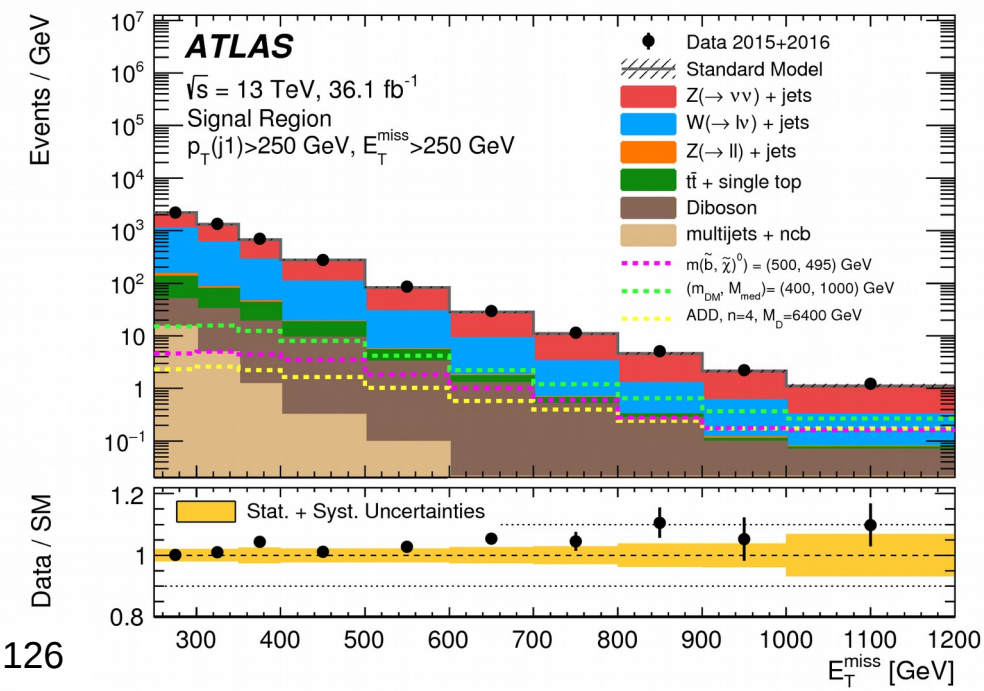




Full ATLAS sim





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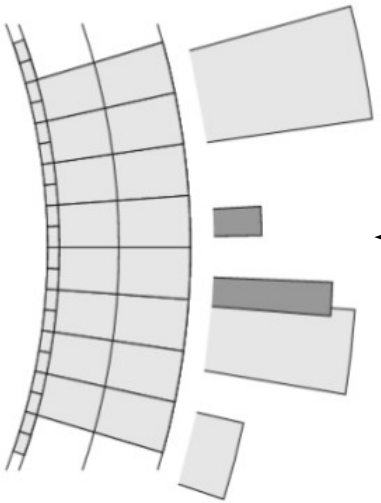
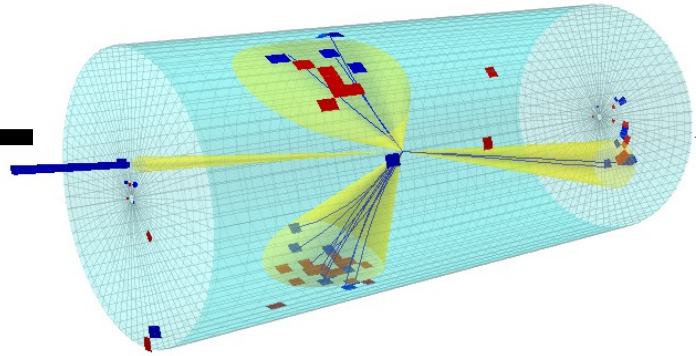
New theories difficult to constrain

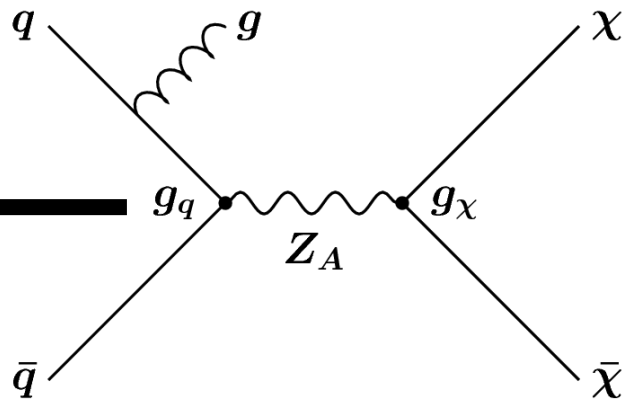
JHEP 1402 (2014) 057

Data @ detector level

theory



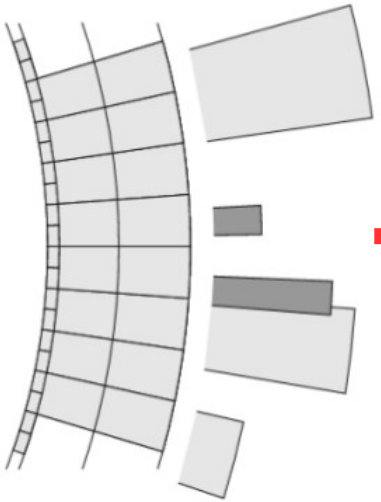


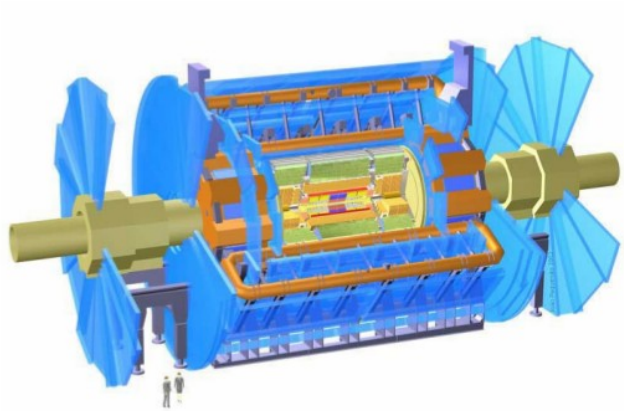


Delphes (parametrized detector simulation)

Bring data to theories!

Data @ detector level





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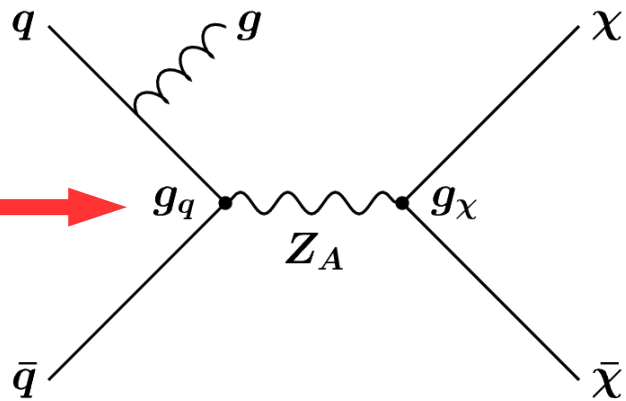
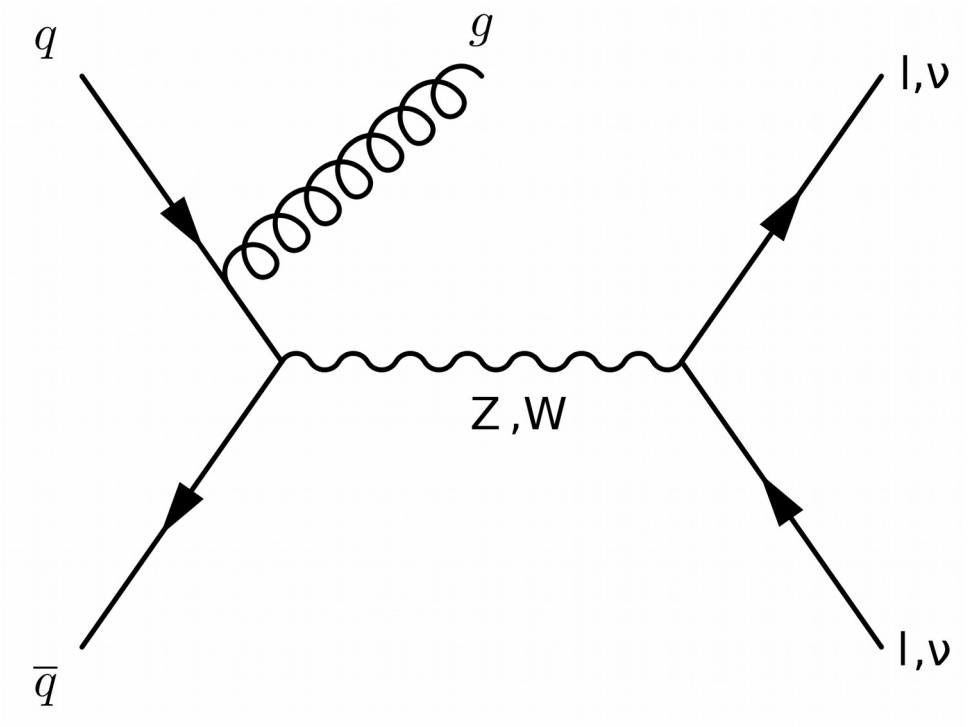


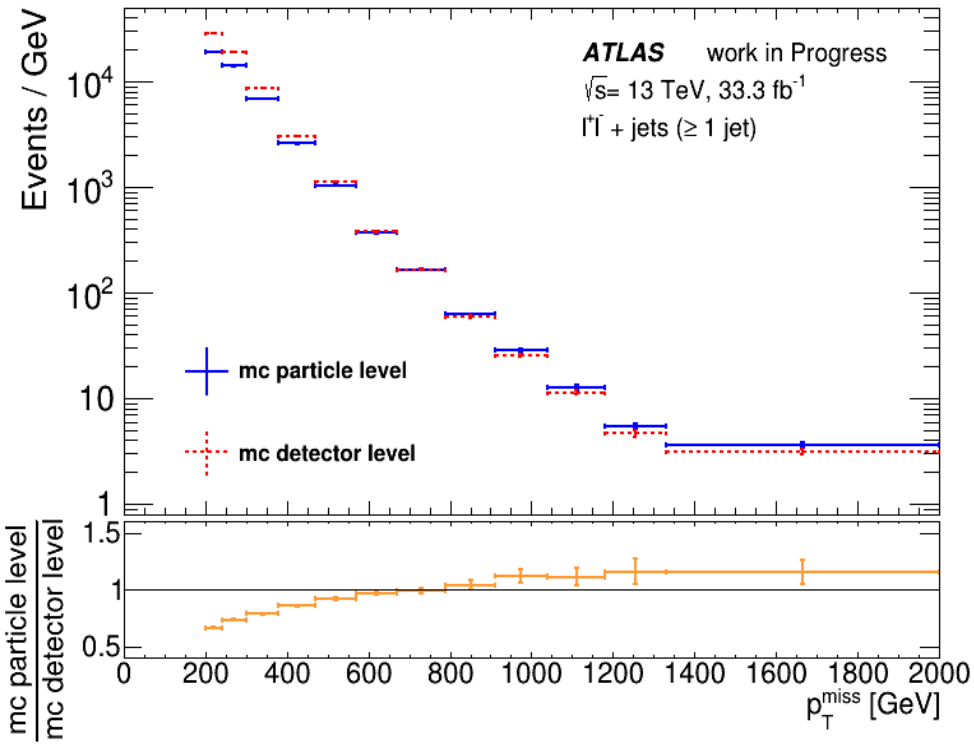
Unfolding

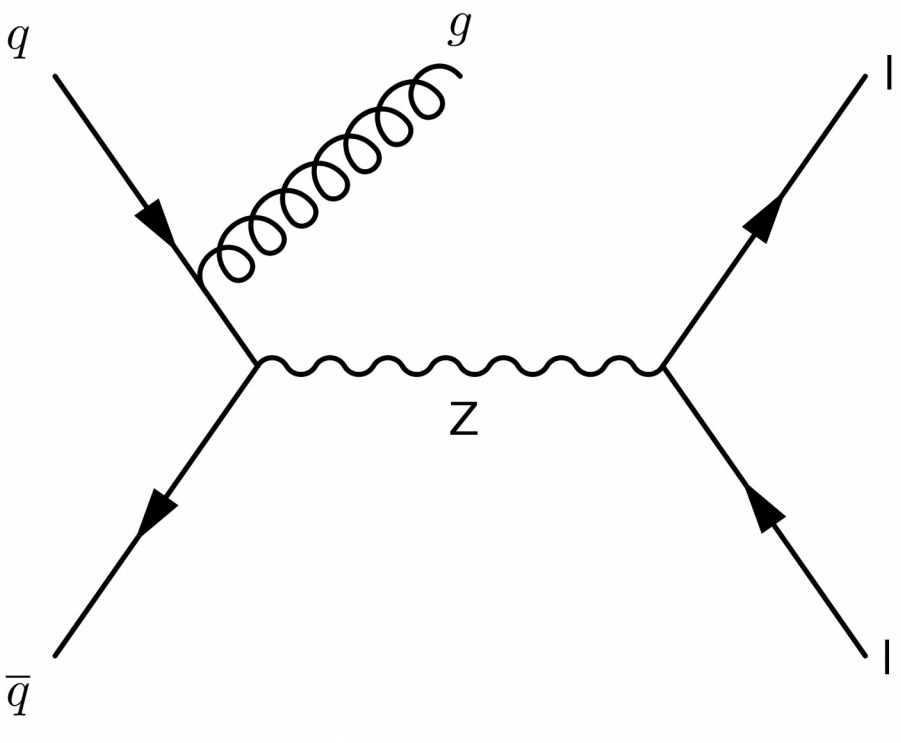
Detector simulation

- Differences between detector- and particle level
  - Fakes
    - Found @ detector level
    - not present @ particle level
  - Misses
    - Not found @ detector level
    - present @ particle level
  - Migrations
    - Present in both, but in different bins



Monte Carlo knows



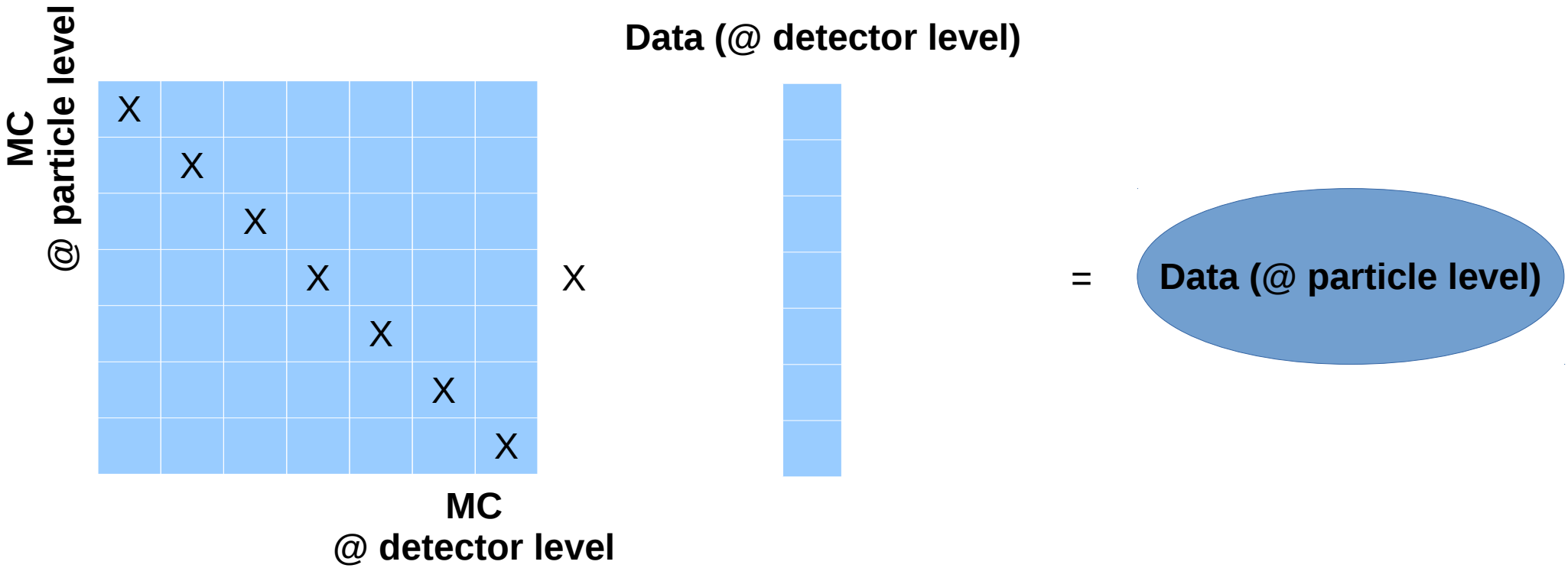


Bin-by-Bin Unfolding

$$\frac{\text{MC @ particle level}}{\text{MC @ detector level}} \times \text{Data (@ detector level)} = \text{Data (@ particle level)}$$

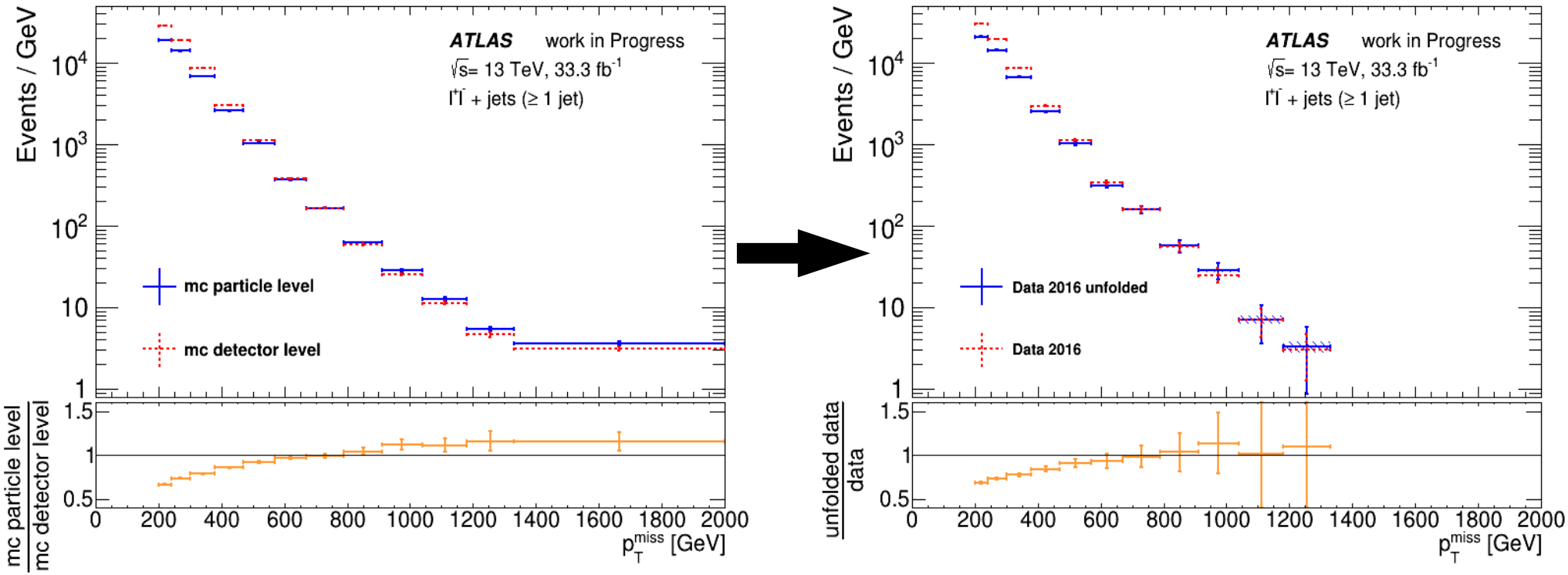
Binwise correction factors

Bin-by-Bin Unfolding



Migration matrix diagonal if resolution is negligible

Monte Carlo knows



Drawback: relies entirely on MC prediction

Iterative Dynamically Stabilized Unfolding

arXiv:1106.3107

Bayes Theorem: $$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

B = detector level
A = particle level

Iterative Dynamically Stabilized Unfolding

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P(A) Monte Carlo Prediction

P(B) Data

Iterative Dynamically Stabilized Unfolding

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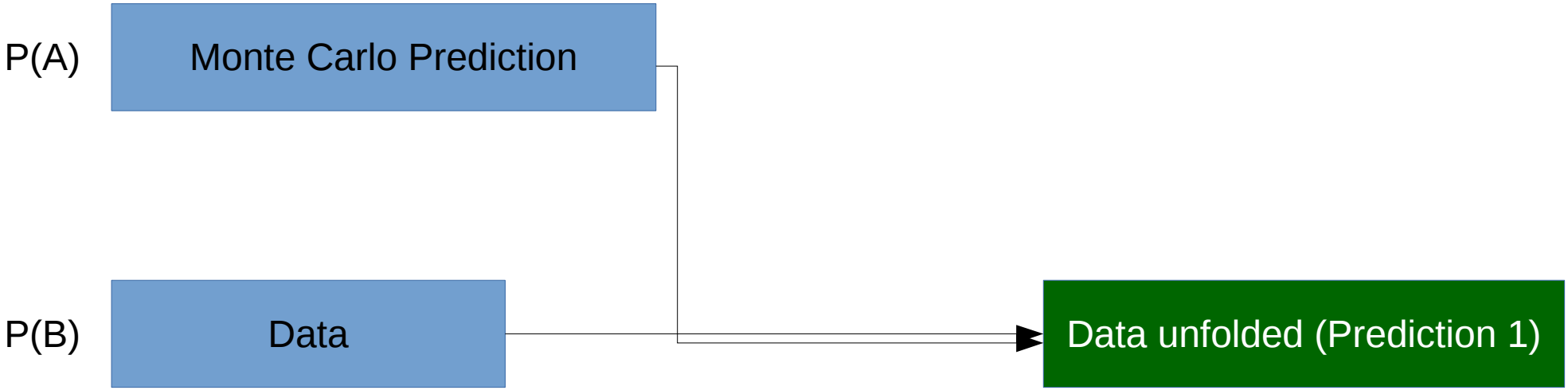

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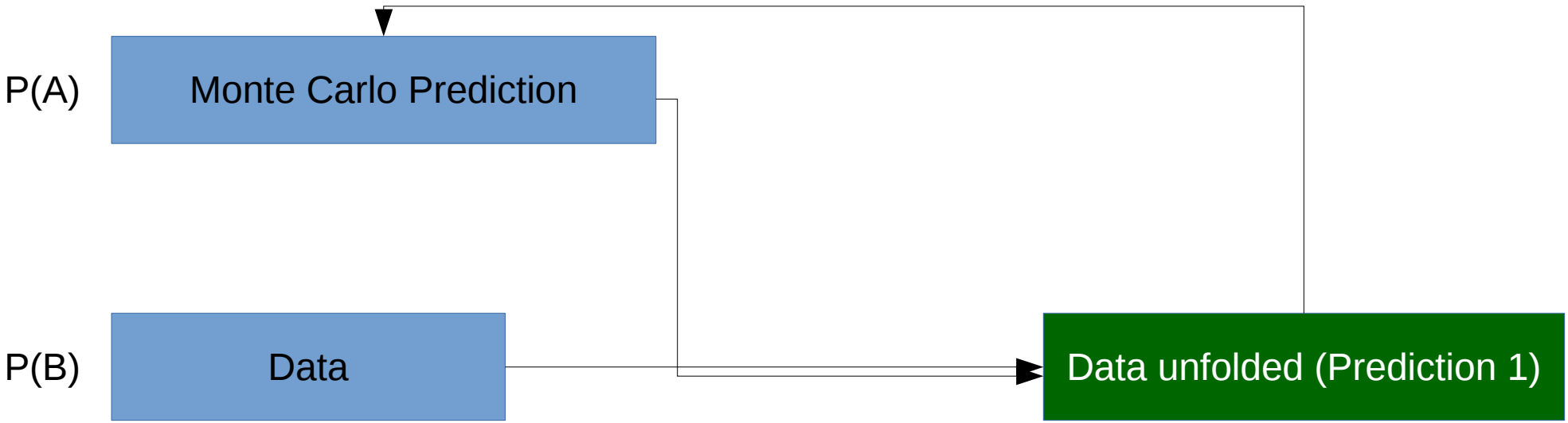

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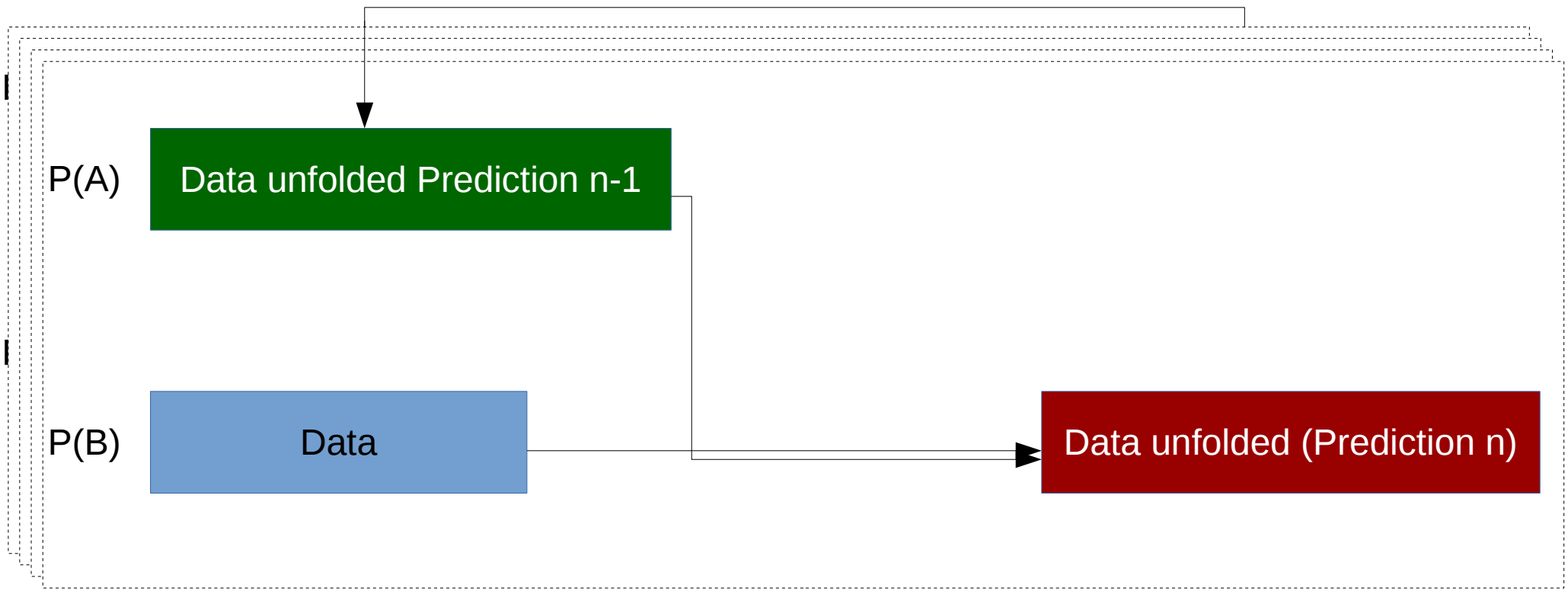
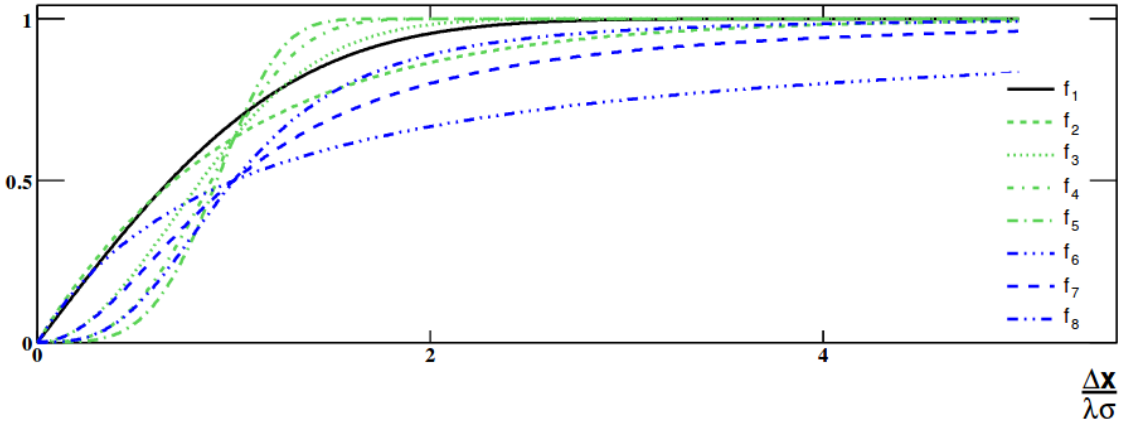


IDS regularization

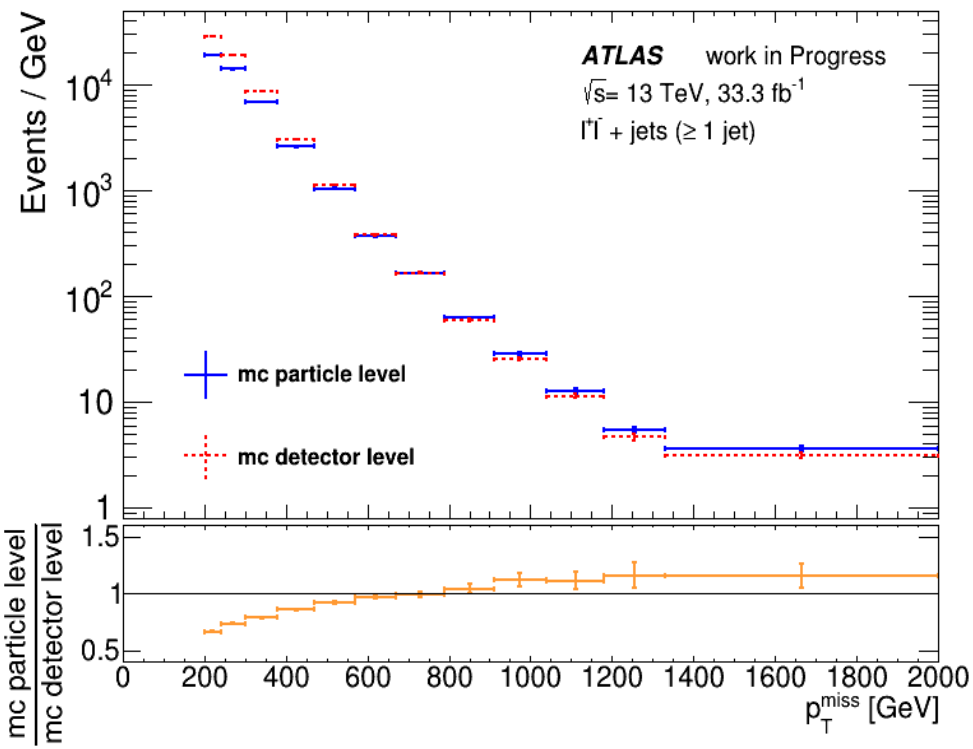
- Bayes unfolding: Regulatized by number of iterations

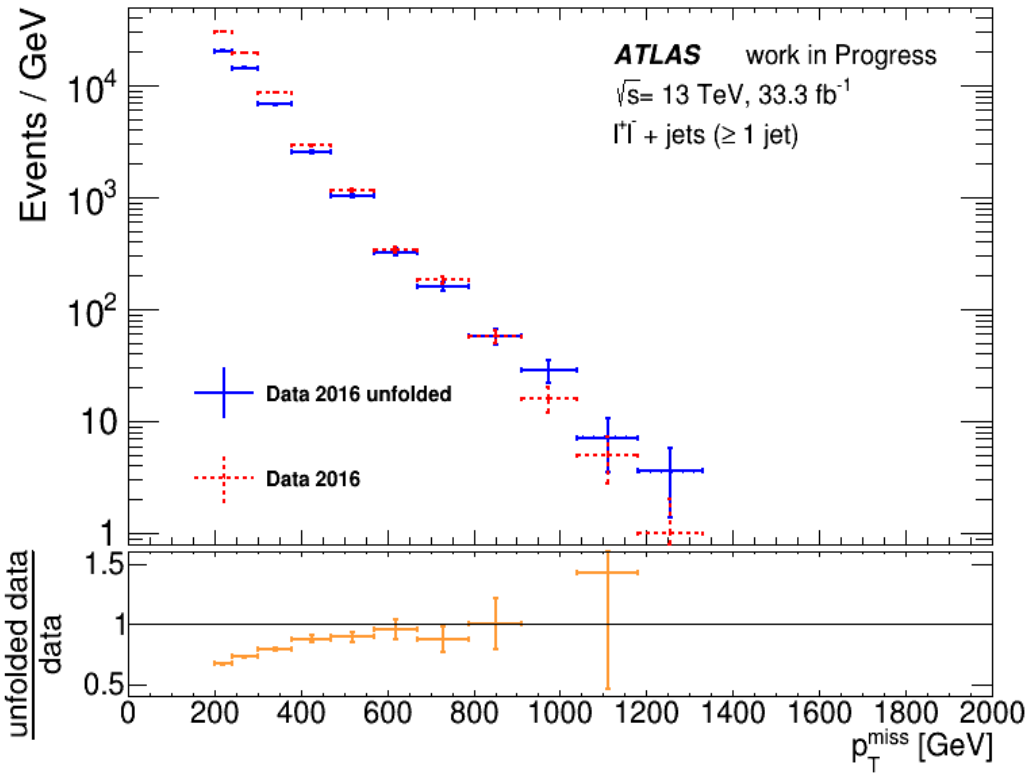
- IDS unfolding: Regularized by change in interation
  - If small changes remain, unfolding stops

$$u_j = t_j \cdot \frac{N_d^{MC}}{N_{MC}} + B_j^u + \sum_{k=1}^{n_d} f\left(|\Delta d_k|, \tilde{\sigma} d_k, \lambda\right) \Delta d_k \tilde{P}_{kj} + \left(1 - f\left(|\Delta d_k|, \tilde{\sigma} d_k, \lambda\right)\right) \Delta d_k \delta_{kj},$$



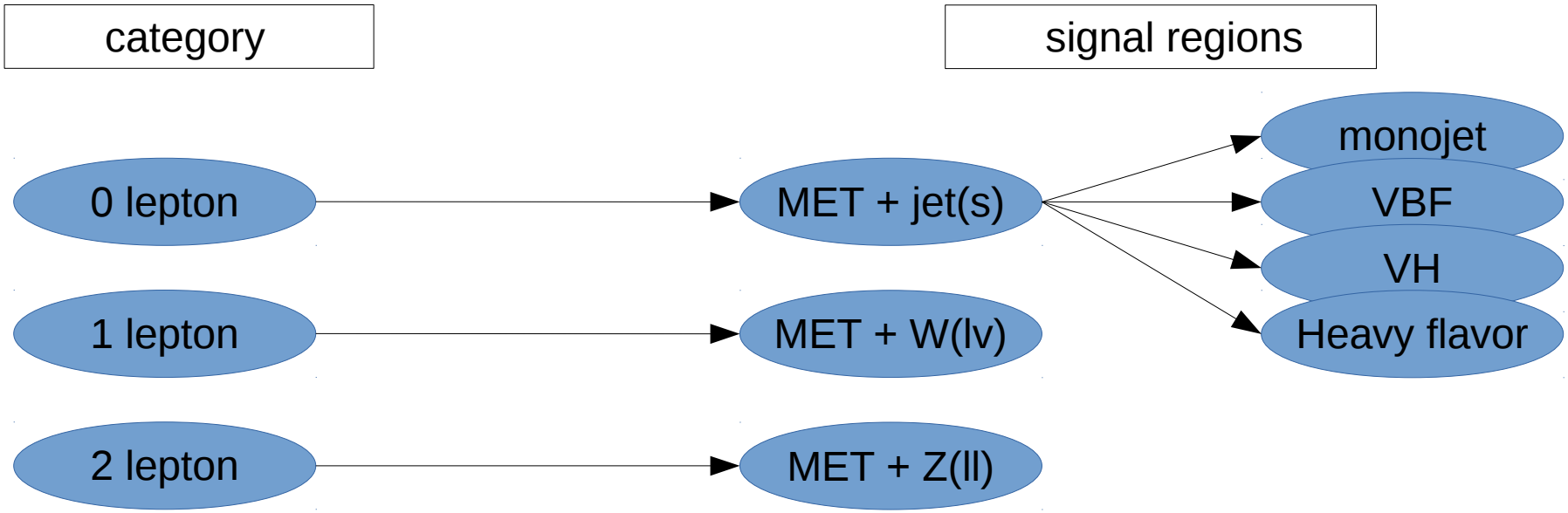
IDS unfolding used in analysis





Outlook

- Measurement in several lepton categories:



- Unfold and combine them all at particle level

Summary

- Unfolding has many advantages
  - Increases longevity
  - Simplifies combination of results
- Detector-corrected measurement sensitive to anomalous MET+jet production published recently
  (Eur. Phys. J. C 77 (2017) 765)
- Next iteration extends this approach
  - More sophisticated unfolding
  - Combination of several topologies at particle level

Summary

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Thanks for the attention!

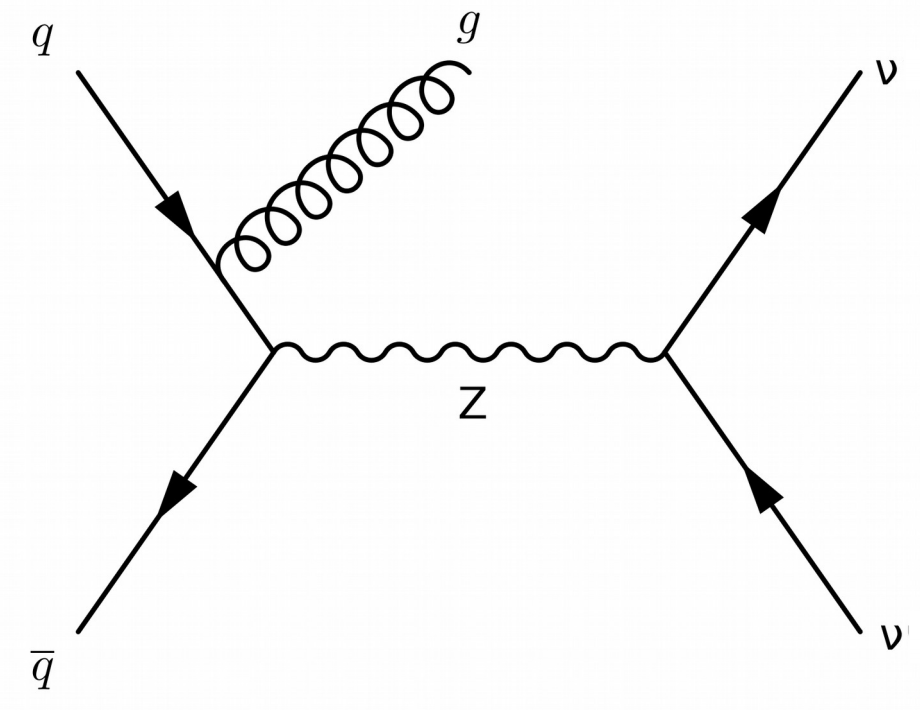
BACKUP

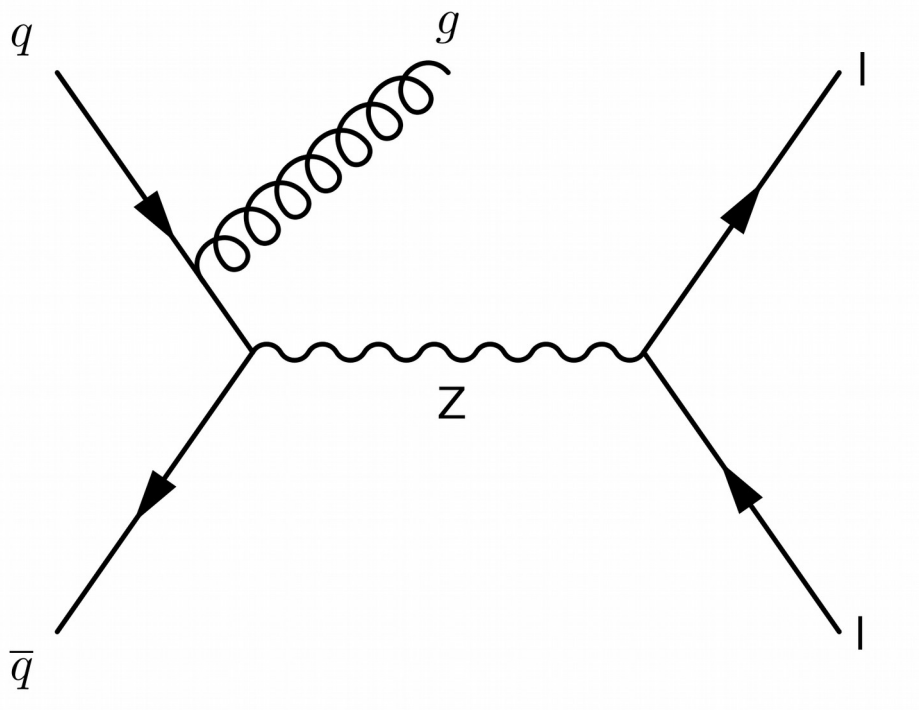
Detailed event selection

Numerator and denominator	≥ 1 jet	VBF
$p_{\mathrm{T}}^{\mathrm{miss}}$	$> 200\,\mathrm{GeV}$	
(Additional) lepton veto	No e, μ with $p_{\mathrm{T}} > 7\,\mathrm{GeV}$, $\lvert\eta\rvert < 2.5$	
Jet $\lvert y\rvert$	< 4.4	
Jet p_{T}	$> 25\,\mathrm{GeV}$	
$\Delta\phi_{\mathrm{jet_i,p_T^{miss}}}$	> 0.4, for the four leading jets with $p_{\mathrm{T}} > 30\,\mathrm{GeV}$	
Leading jet p_{T}	> 120 GeV	$> 80\,\mathrm{GeV}$
Subleading jet p_{T}	–	$> 50\,\mathrm{GeV}$
Leading jet $\lvert\eta\rvert$	< 2.4	–
m_{jj}	–	$> 200\,\mathrm{GeV}$
Central-jet veto	–	No jets with $p_{\mathrm{T}} > 25\,\mathrm{GeV}$
Denominator only	≥ 1 jet and VBF	
Leading lepton p_{T}	$> 80\,\mathrm{GeV}$	
Subleading lepton p_{T}	$> 7\,\mathrm{GeV}$	
Lepton $\lvert\eta\rvert$	< 2.5	
$m_{\ell\ell}$	66–116 GeV	
ΔR (jet, lepton)	> 0.5, otherwise jet is removed	

Can also measure a ratio

Measure ration of Z→νν + jets and Z→ll + jets





$$R_{\mathrm{miss}} = \frac{\sigma(\not{p}_{\mathrm{T}} + \mathrm{jets})}{\sigma(Z \to \ell^+\ell^- + \mathrm{jets})}$$

Can also measure a ratio

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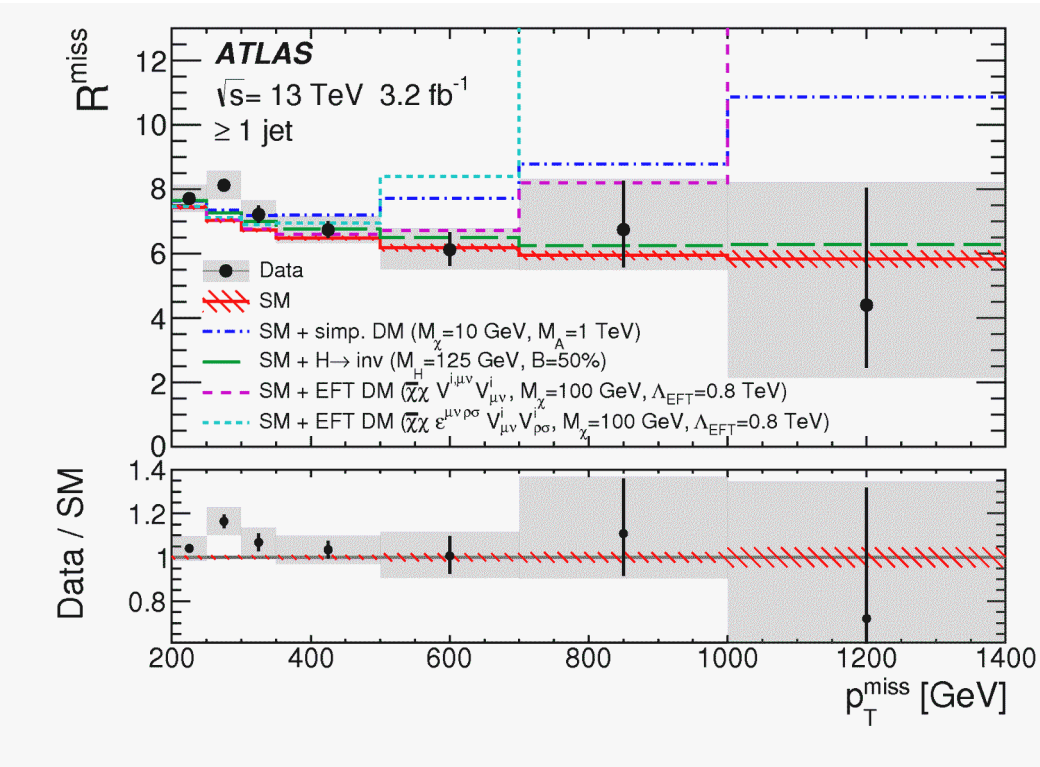
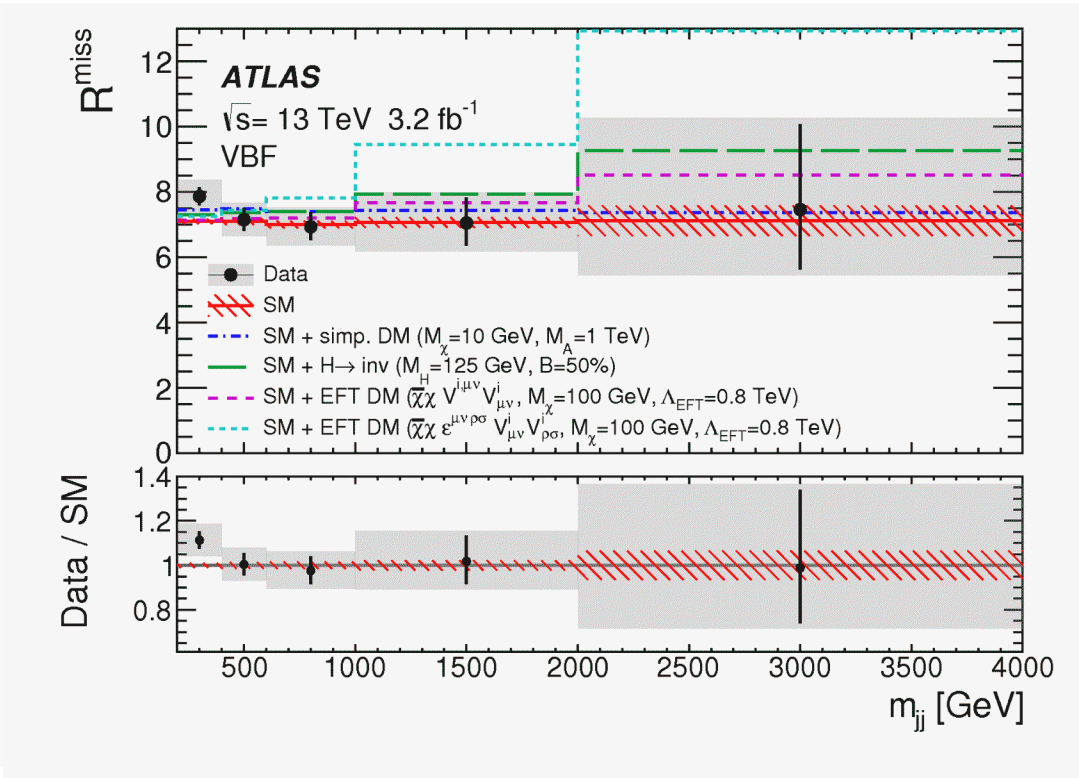
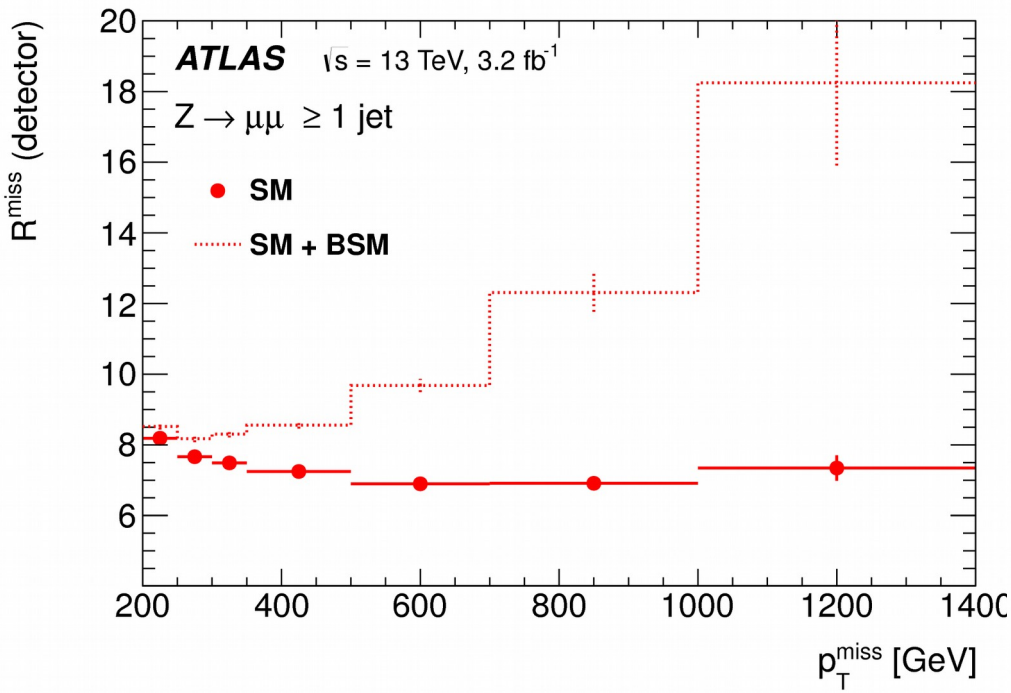


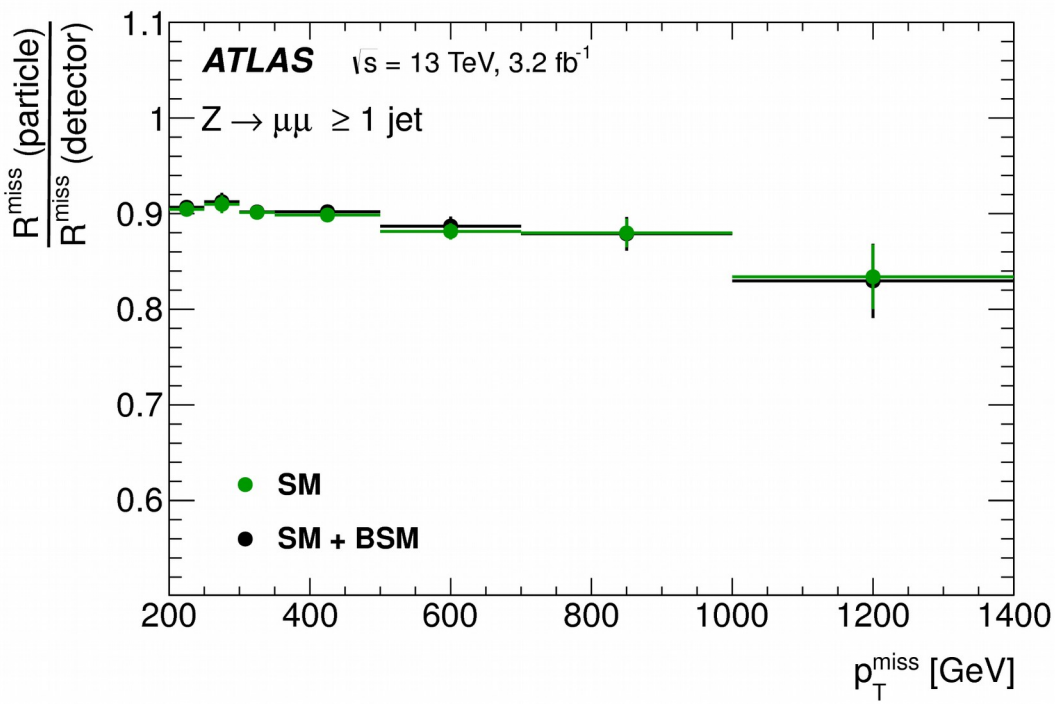


Bin-by-Bin Unfolding in searches

Eur. Phys. J. C 77 (2017) 765

Relies 100% on Monte Carlo modeling of the events!





Can still be perfectly applicable if "mismodeling" does not affect the correction factors

Here:
BSM signal large enough to modify correction factors, would show large deviations in data