Measurement of the EW production of Z+jets at $\sqrt{s}$ = 13 TeV with the ATLAS experiment

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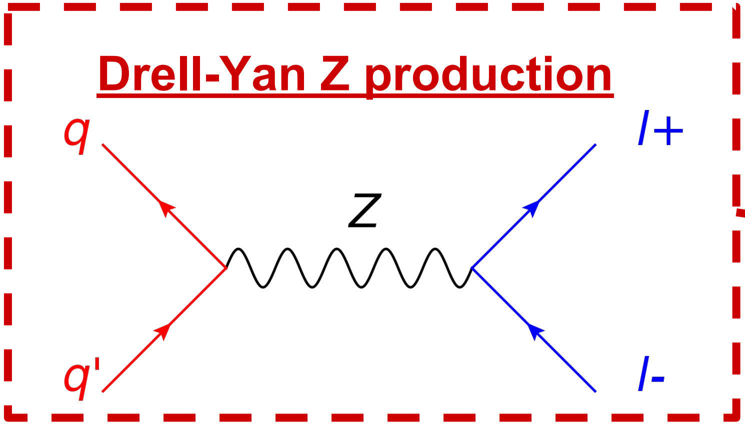
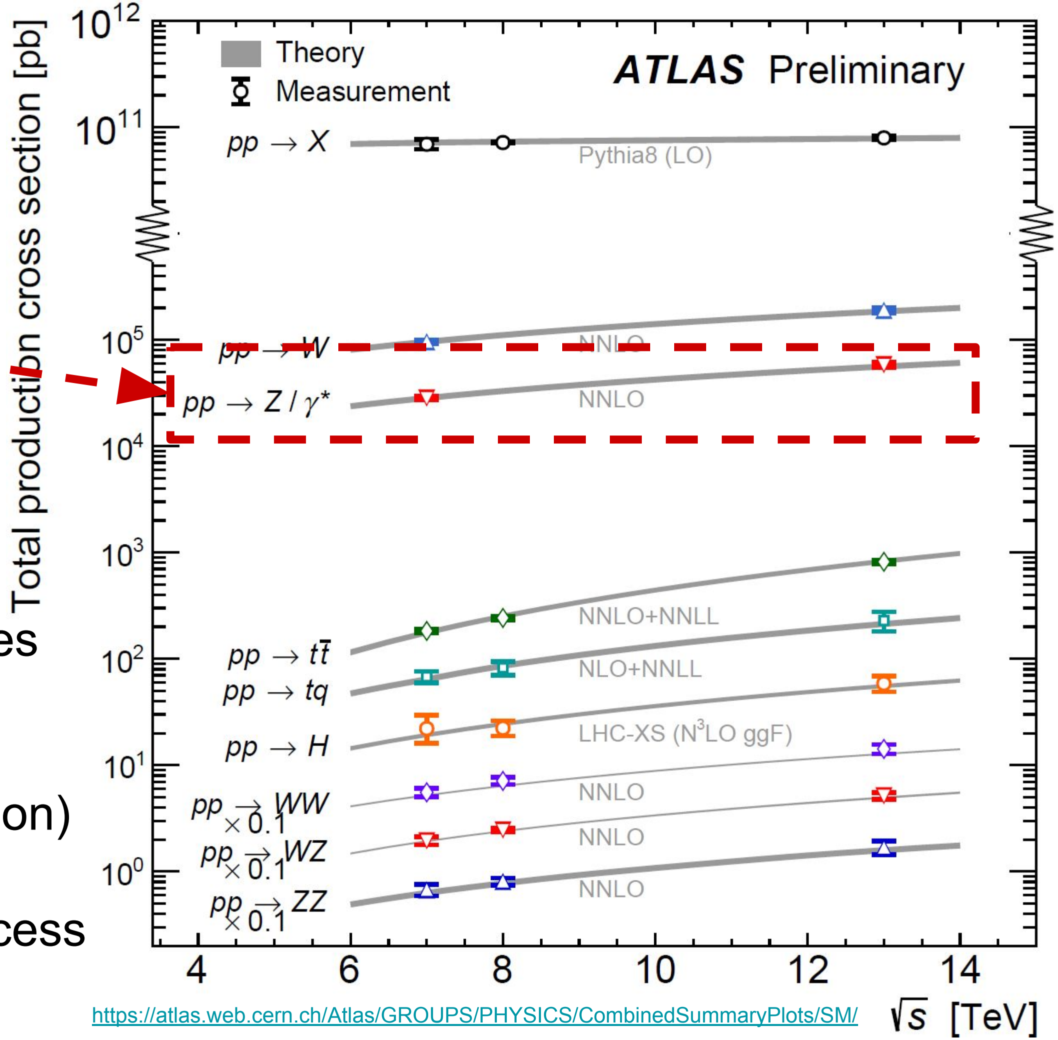
WNPPC 2019

Motivation





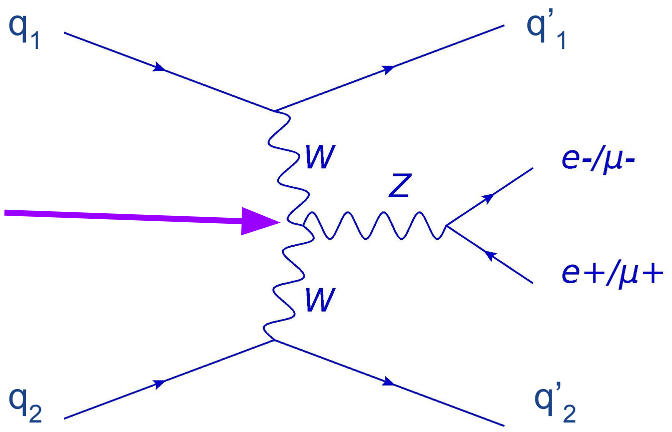
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/SM/

- Well measured leptonic final states with large statistics
- Background for many precision measurements (Higgs, top, diboson) and new physics searches
- Similarities to the VBF Higgs process

Signal: Electroweak Z + dijets

EW Z+dijets includes all processes where there is a **t-channel** exchange of a **W/Z boson** and a $\mathbf{l^+l^-jj}$ final state

Triple gauge coupling

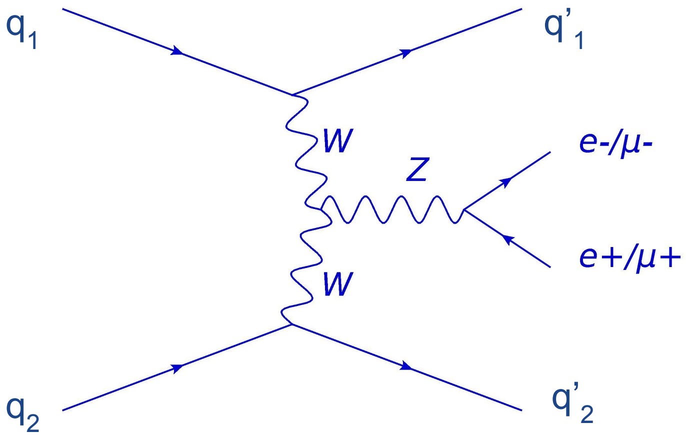


Vector boson fusion (VBF)

- Drell-Yan Z+dijets is produced frequently in pp collisions compared to EW Z+dijets (Large Background!)
- VBF Z is a probe for new physics via higher order corrections to the WWZ vertex (the triple gauge coupling)

Z+dijets production

EW Zjj has a **much smaller cross section** compared to the strong Drell-Yan process



SM Prediction: Powheg+Pythia

σ_{fid}= 125.2±3.4 fb

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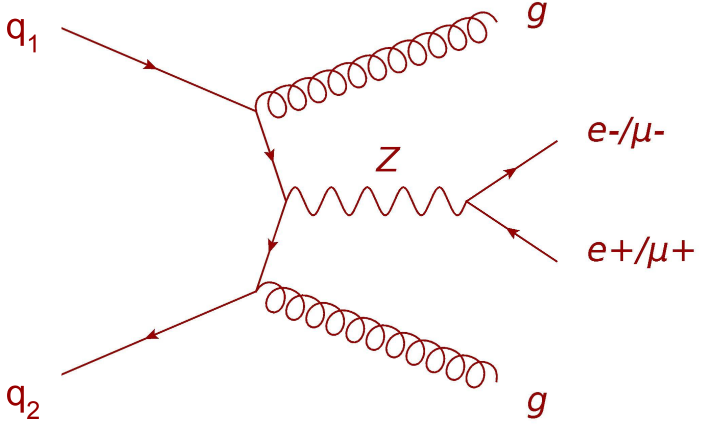

SM Prediction: CT14nnlo PDF

σ_{fid}= 0.74 ± 0.03(PDF) ± 0.01(scale) ± 0.01(other) nb

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*A factor of **6000** larger*

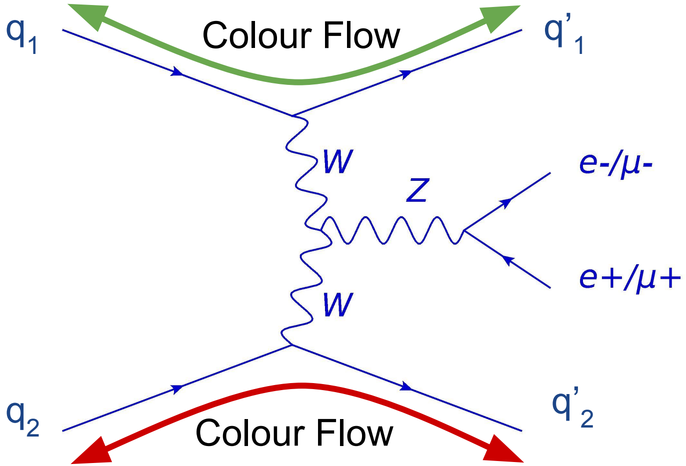
Extracting the EW signal from the dominant Drell-Yan background is challenging

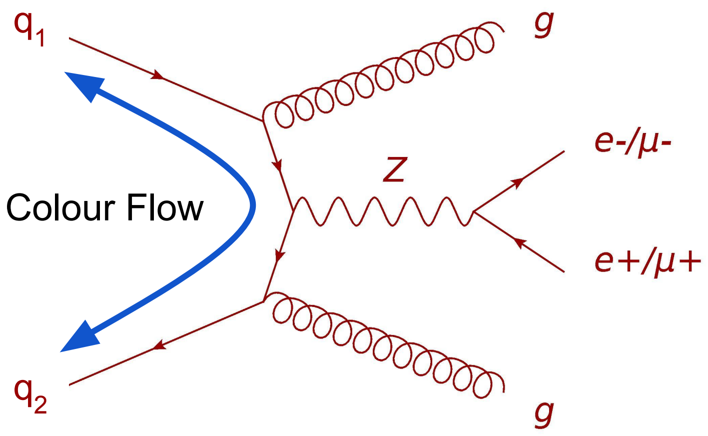
Modeling of the background is crucial

Z+dijets production

We exploit the **colour flow** difference of the production modes

- t-channel exchange of the DY production makes the quarks colour connected
- Final state will have more **hadronic activity** close to the Z boson

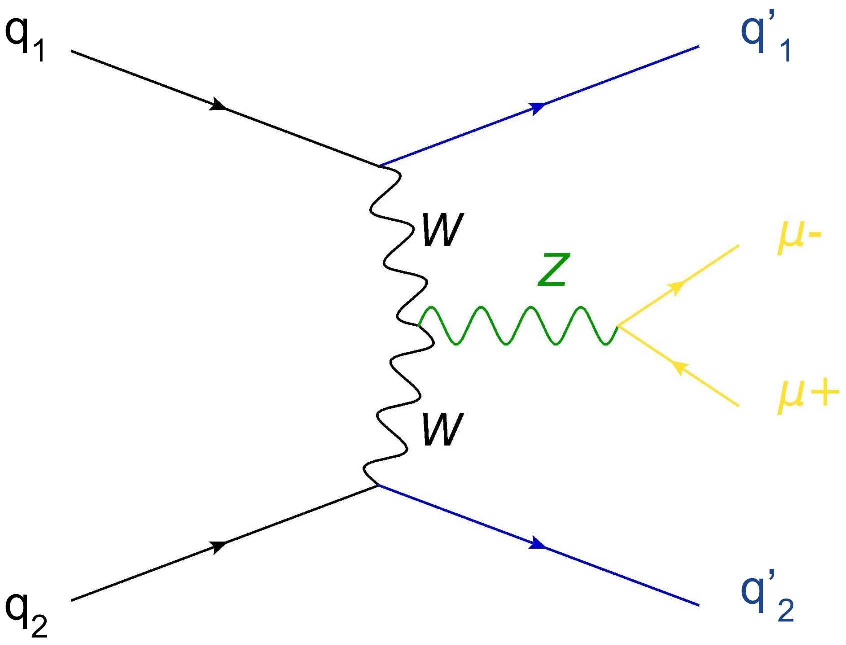


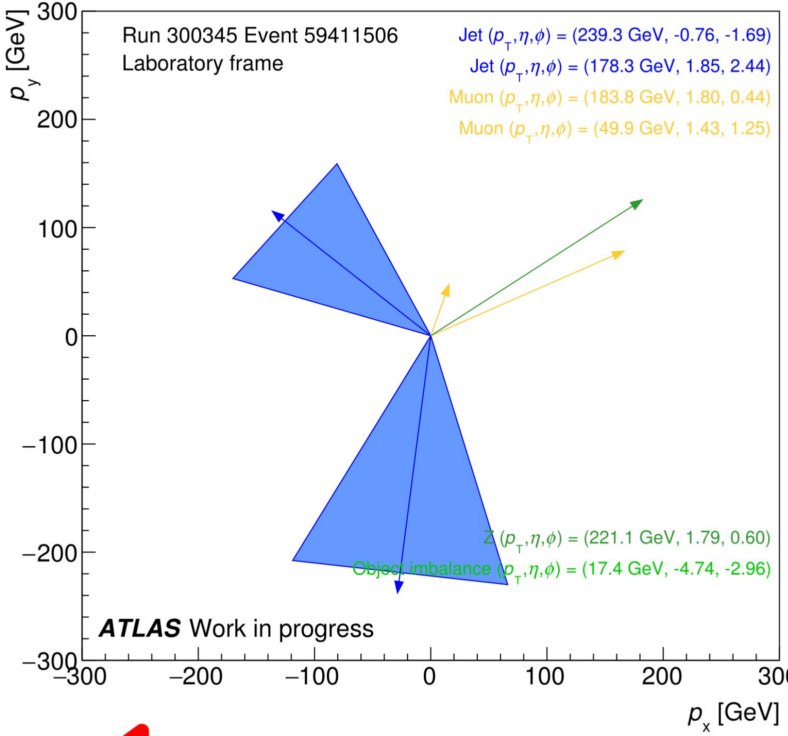


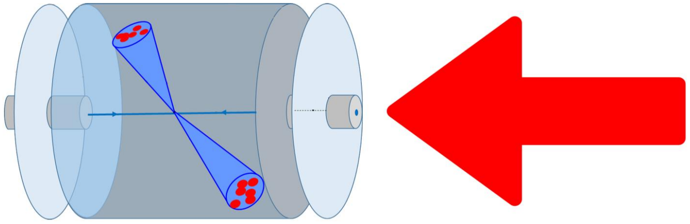
Strategy

- Find 2 high p_T jets initiated by the interacting quarks/gluons from the hard scatter
- Look for additional jets in the "**gap region**" between the 2 leading jets

EW Z+dijets: What we see with the ATLAS detector

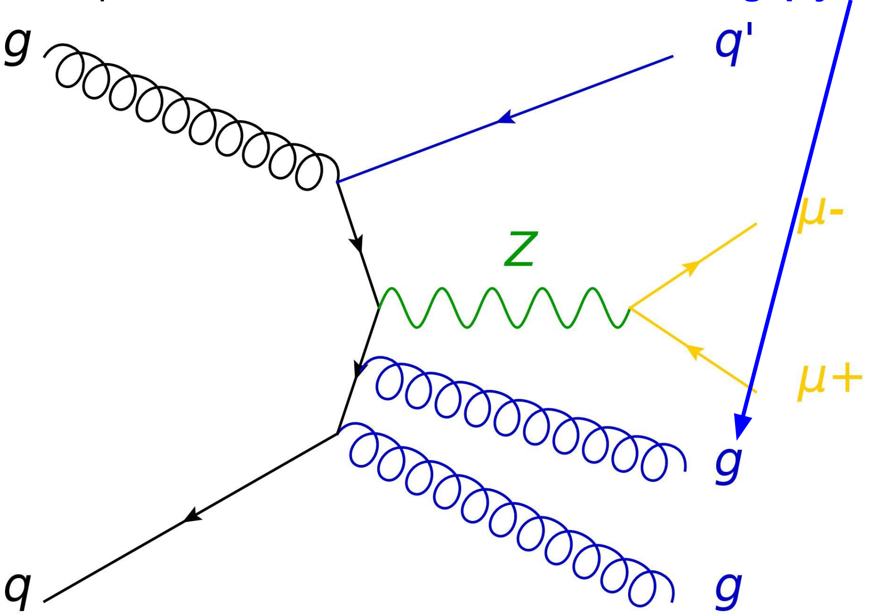


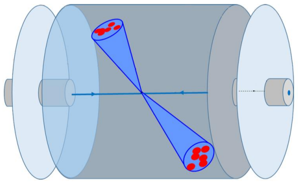


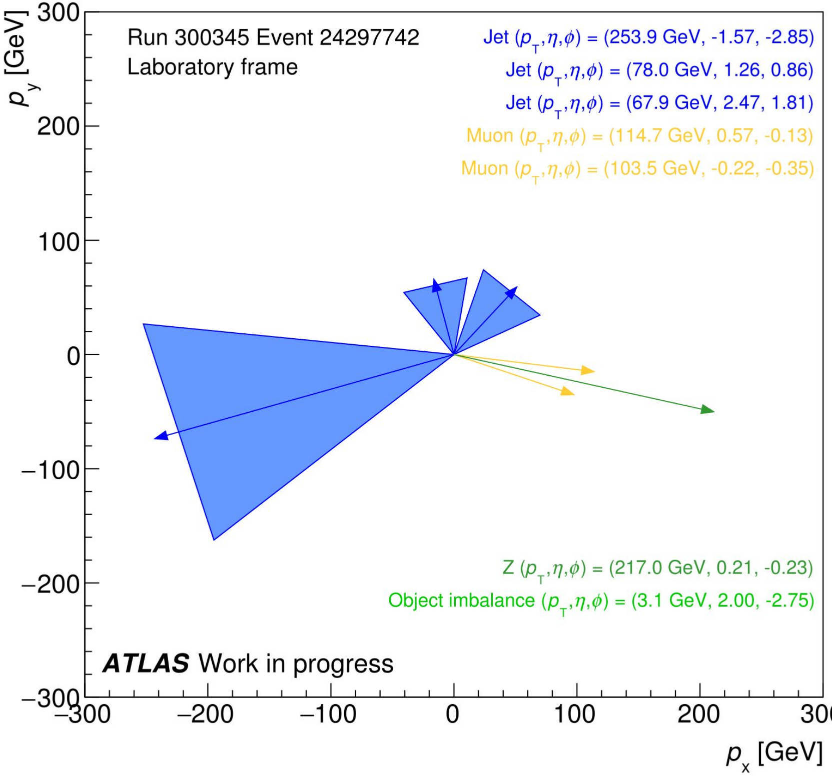


DY Z+dijets: What we see with the ATLAS detector

The Drell-Yan process is more likely to have additional hadronic activity between the two leading jets than the EW process. This is observed as so-called **gap jets**







Measurement: Cross section

SR = **S**ignal **R**egion

Drell-Yan Zjj prediction ~99% of total bkg

ttbar, dibosons ... ~1% of total bkg

EW Z+dijets cross section of bin *i*

$$\sigma_{\mathrm{fid},i} = \frac{N^{\mathrm{data}}_{\mathrm{SR},i} - N^{\mathrm{strong}}_{\mathrm{SR},i} - N^{\mathrm{non}\text{-}Z}_{\mathrm{SR},i}}{C_i\,\mathcal{L}}$$

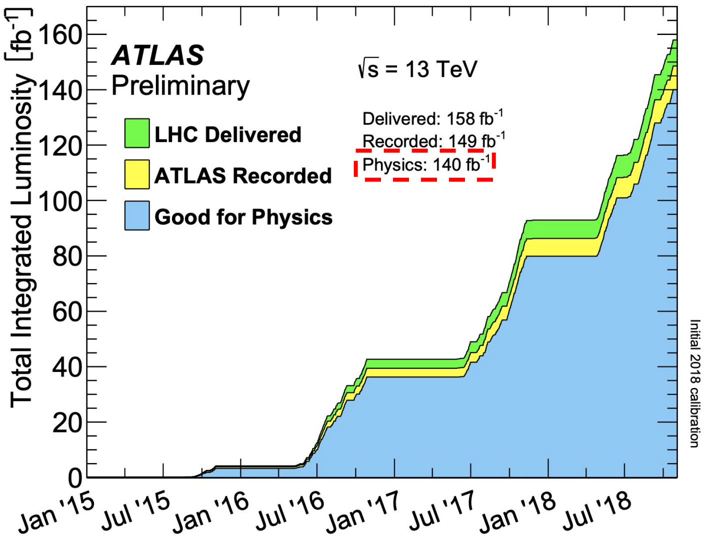
Bin-by-bin correction factor for reconstruction inefficiency

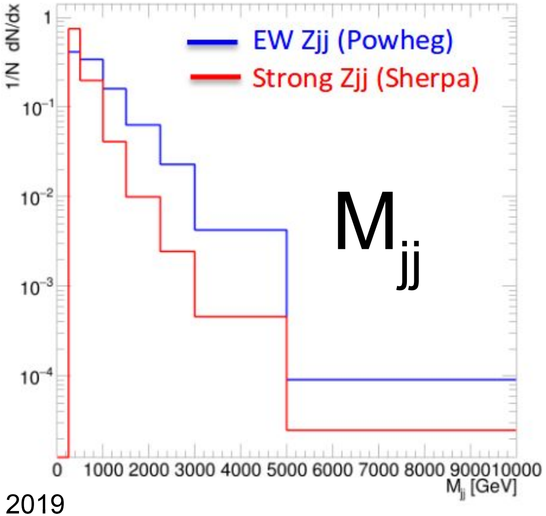
Integrated Luminosity ("size" of the dataset)

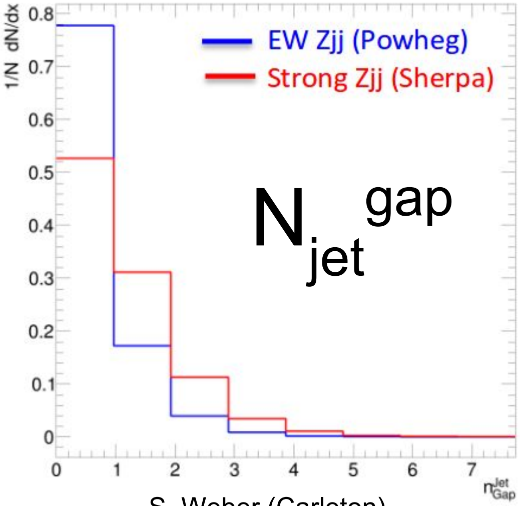
- The Drell-Yan Z+dijets accounts for the vast majority of events
- Crucial to understand this process to extract the EW Z+dijets signal

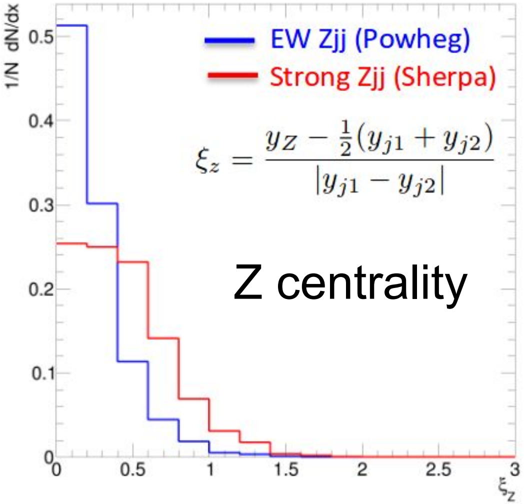
Analysis overview

- Analyzed full Run II dataset: 2015-18 data (140 fb^{-1})
- Measurements:
  - Inclusive Z+jets cross section (strong+EW)
  - Differential EW cross section as a function of **characteristic variables**:
    - Dijet invariant mass (Mjj), Number of gap jets, Z centrality







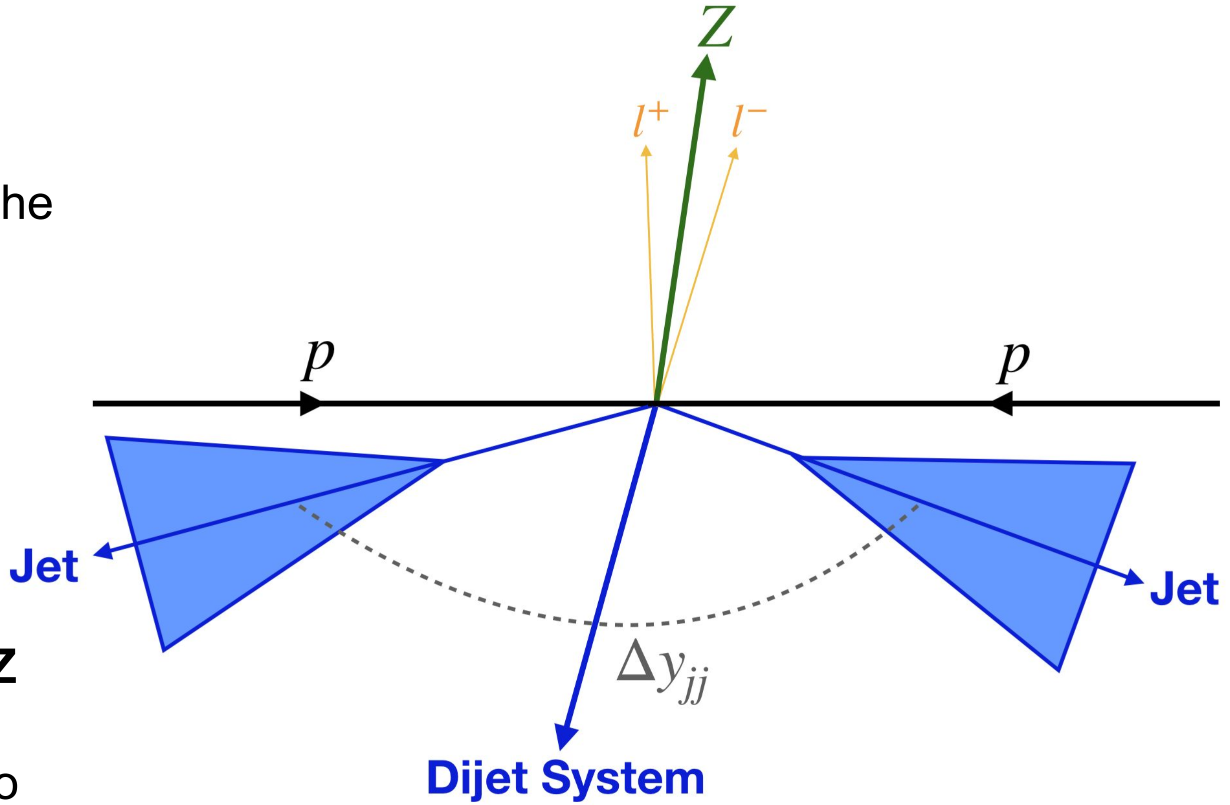


Analysis Selection

We apply cuts that enhance the **EW** signal

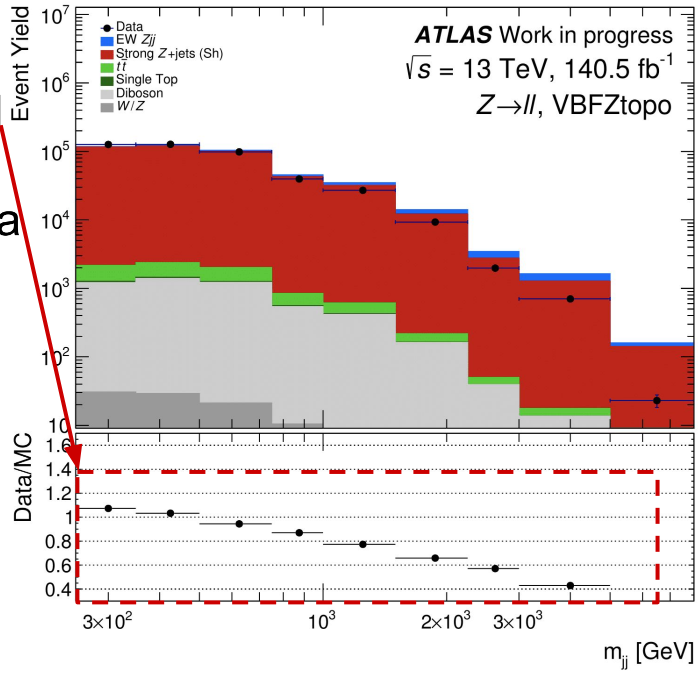
1. High mass of the **Dijet System**, m_{jj}
2. **Large gap** between the leading jets, Δy_{jj}
3. Balanced p_T

These 3 cuts define our **EW Z topology** phase space,
we split this region further into **signal** and **control** regions to understand the **strong** background



Background modelling

- The dominant strong DY background is poorly modeled
- 2 different MC predictions: **Sherpa** and **Madgraph**
  - Predictions **don't agree** with each other or the data
- Need to account for the mismodelling of the strong component if we hope to measure the EW component



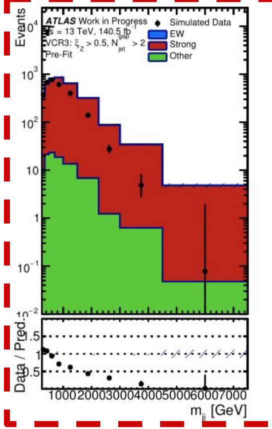
How we account for the mismodelling

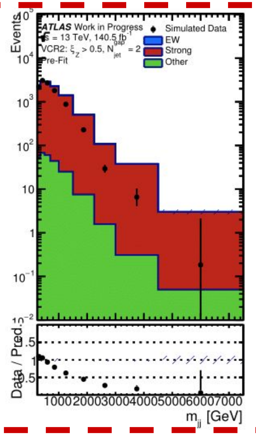
1. Divide phase space into **regions** that enhance **EW** and regions that enhance **strong**
2. Derive a **constraint from the data** in the **strong** enhanced regions
3. Apply the constraint to the **EW** enhanced regions

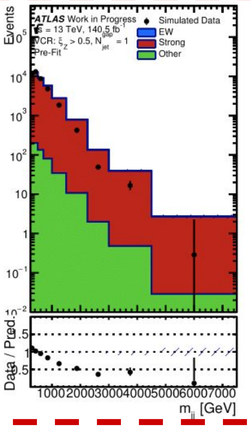
1. Divide phase space into regions

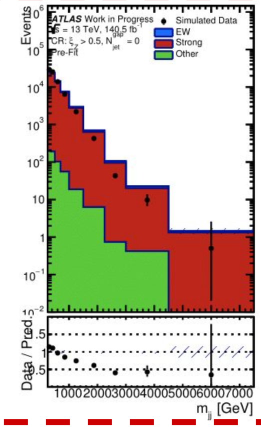
Note: Data shown is simulated Asimov data, the analysis is blinded

Control regions:
Strong process dominates
Correction to strong MC prediction derived



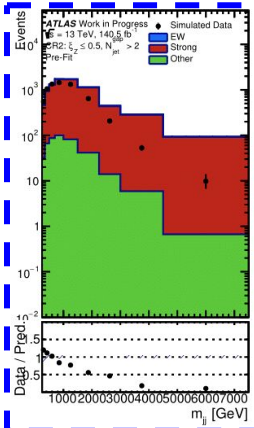


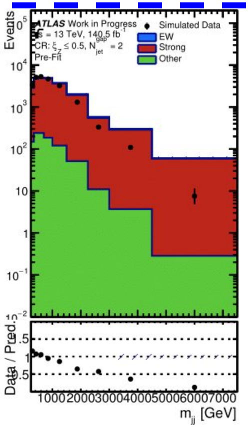


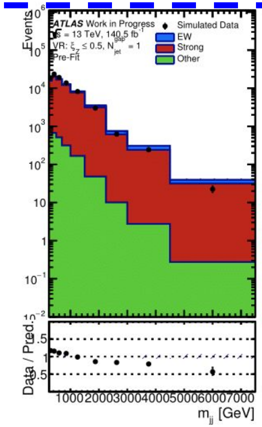


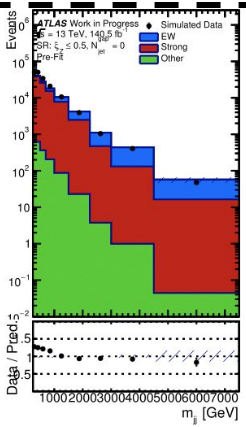
more gap jets

Validation regions:
Test the correction derived from the control regions









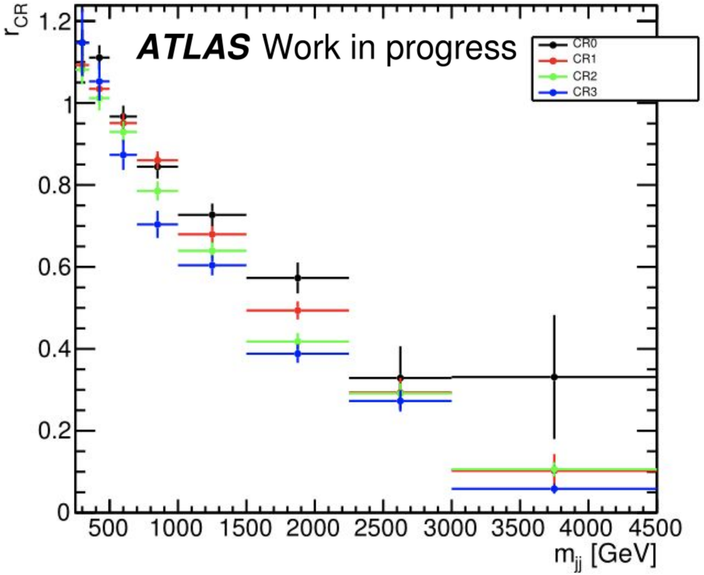
Signal region:
Enhance the EW component

2. Derive data-driven constraint in control regions

$$\frac{d\sigma_i^{\mathrm{EW}}}{dx} = \frac{\hat{N}_{\mathrm{SR},i}^{\mathrm{EW}}}{\Delta x_i\, C\, \mathcal{L}} = \frac{N_{\mathrm{SR},i}^{\mathrm{data}} - N_{\mathrm{SR},i}^{\mathrm{strong}} - N_{\mathrm{SR},i}^{\mathrm{non\text{-}Z}}}{\Delta x_i\, C\, \mathcal{L}}$$

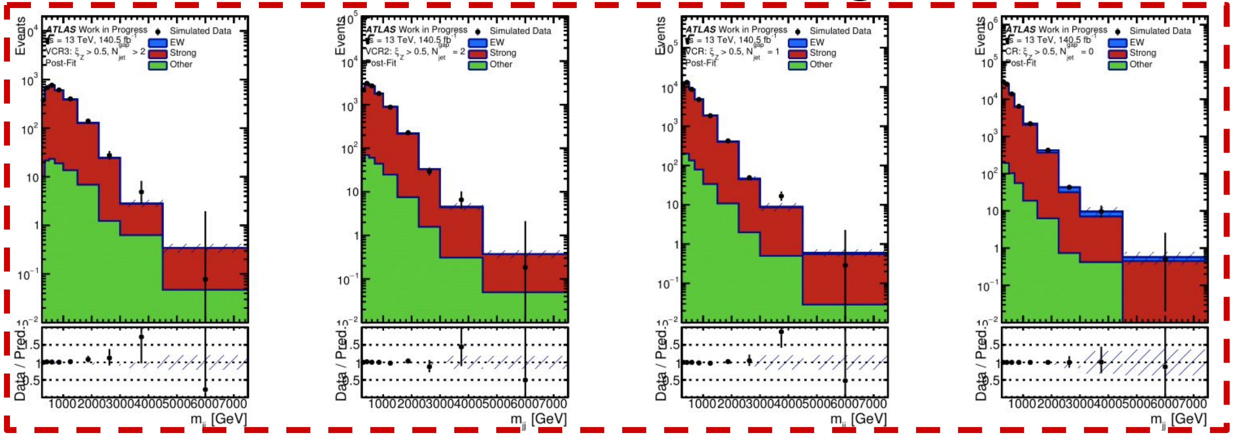
$$N_{\mathrm{SR},i}^{\mathrm{strong}} = k\, r_{\mathrm{CR},i}\, N_{\mathrm{SR},i}^{\mathrm{strong\text{-}MC}}$$

Data driven constraint derived in control region and applied to signal region



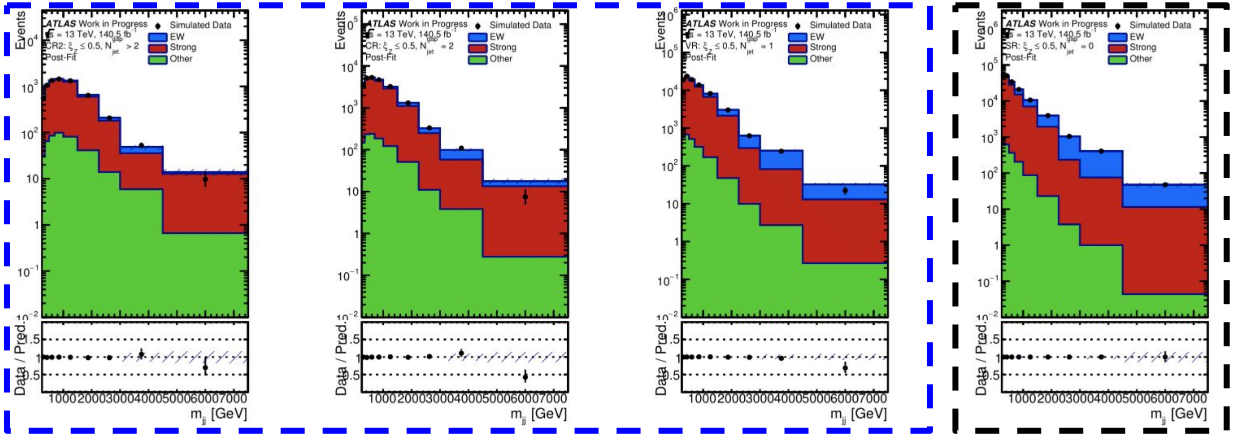
3. Apply constraint to the **EW** enhanced regions

After correcting the strong DY background the **Data to MC agreement** is improved



more gap jets

We can now extract the **EW** signal



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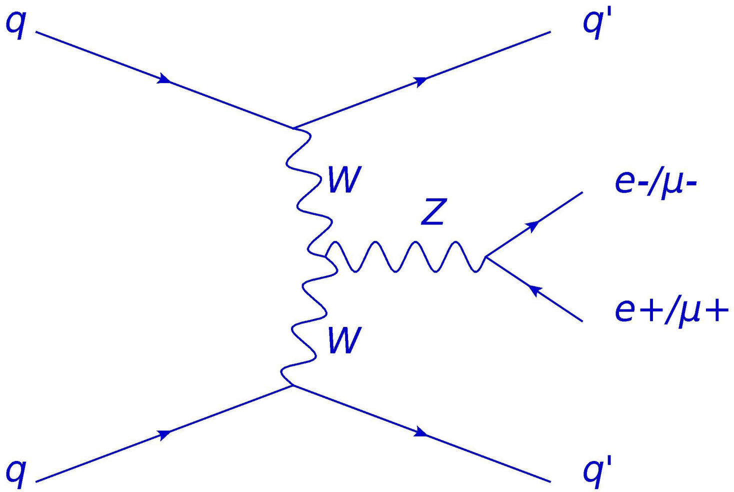
Conclusions

- Full Run II dataset analyzed, 140 fb^{-1}
- Robust analysis model to extract EW signal from QCD background by applying **data-driven constraint**
- By measuring the differential EW cross section we can test the triple gauge coupling of the **WWZ** vertex and look for deviations from the SM



Thanks for listening, questions?