BMBF-Forschungsschwerpunkt
ATLAS Experiment
Physics on the TeV-scale at the Large Hadron Collider

FSP 101 ATLAS

Aspects of Vector Boson Scattering at ATLAS

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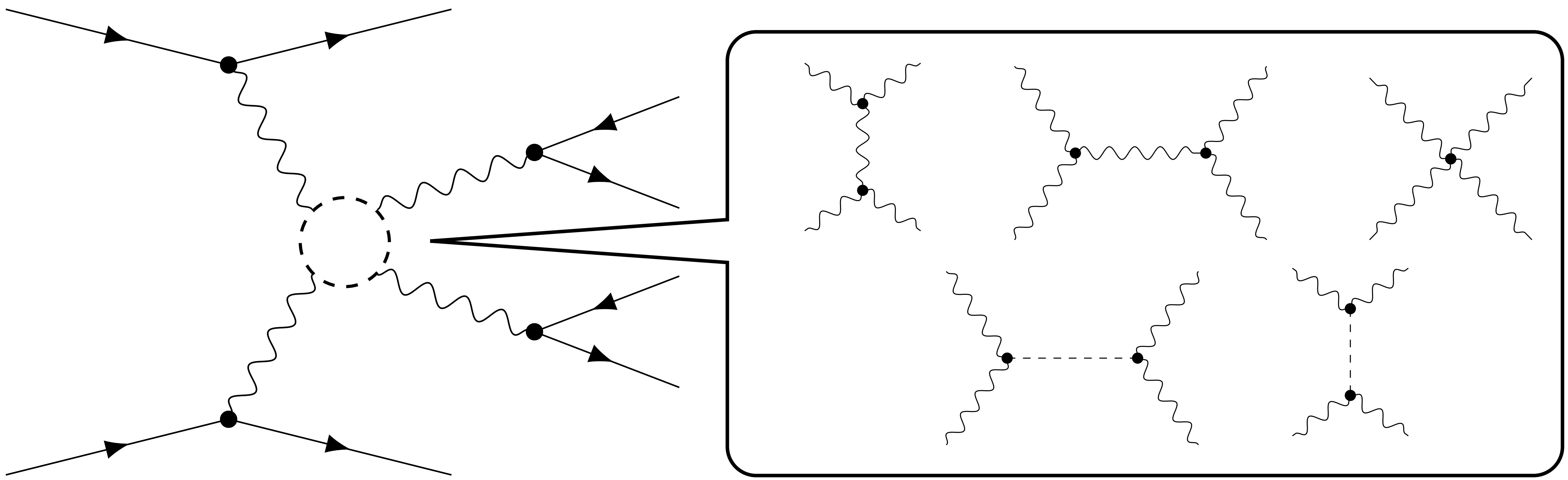
PHYSICS AT THE TERA SCALE
Helmholtz Alliance

TECHNISCHE UNIVERSITÄT DRESDEN

GRADUIERTEN KOLLEG
Masse-Spektrum-Symmetrie

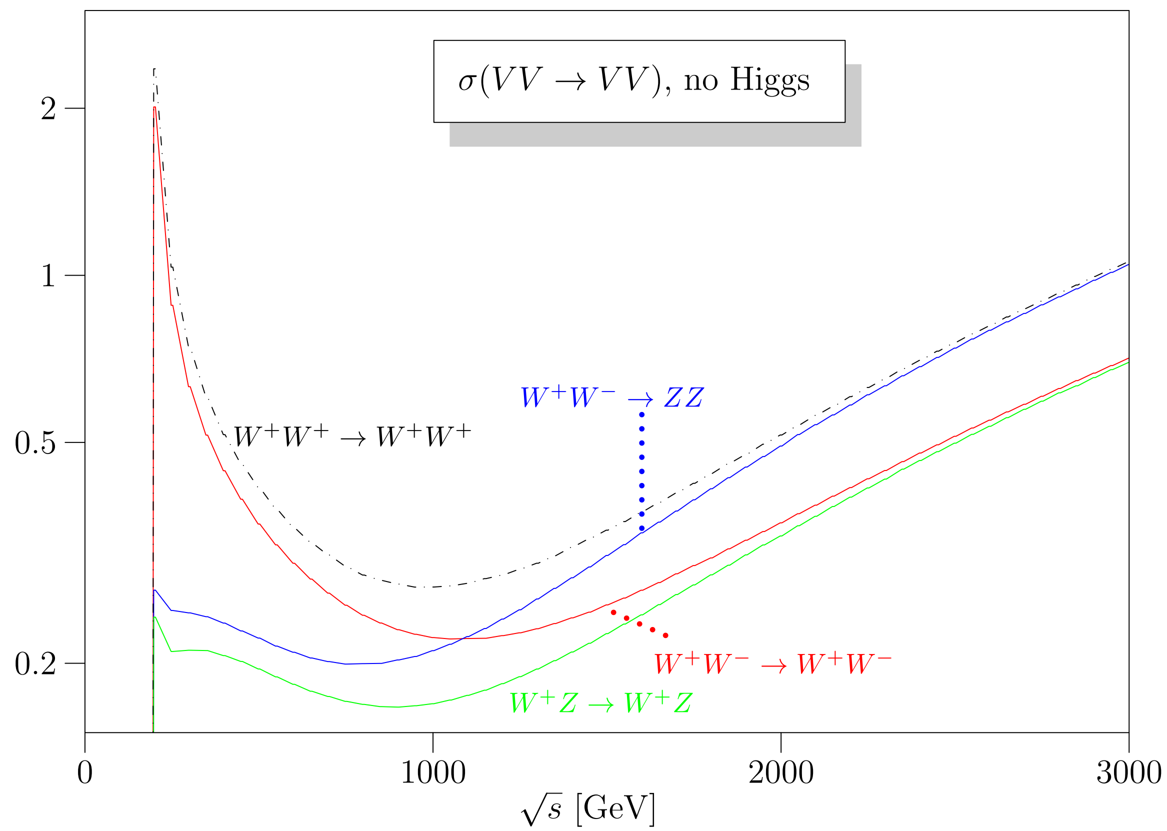
Vector Boson Scattering

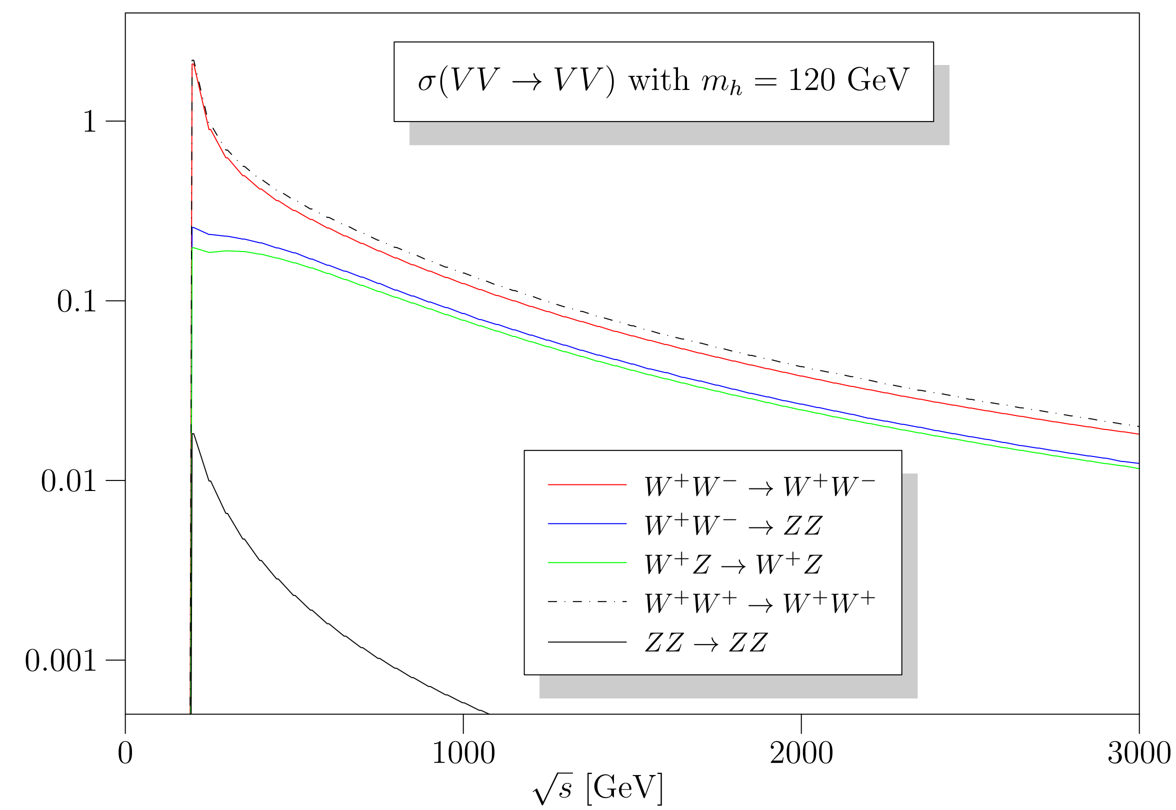


- Vector Boson Scattering (VBS) contains
  - the triple gauge boson vertices
  - the quartic gauge boson vertex
  - the interaction of the Higgs boson with the gauge boson of the weak interaction

Vector Boson Scattering

- in Standard Model without a Higgs, the VBS cross section would violate unitarity
- probe for SM as well as other higgsless models
- can also be used to examine physics beyond the SM such as anomalous quartic gauge couplings (aQGCs)
- plan is to measure WW -> WW in the same sign channel
- building on that, extraction of electroweak contribution to the process and limits on aQGCs



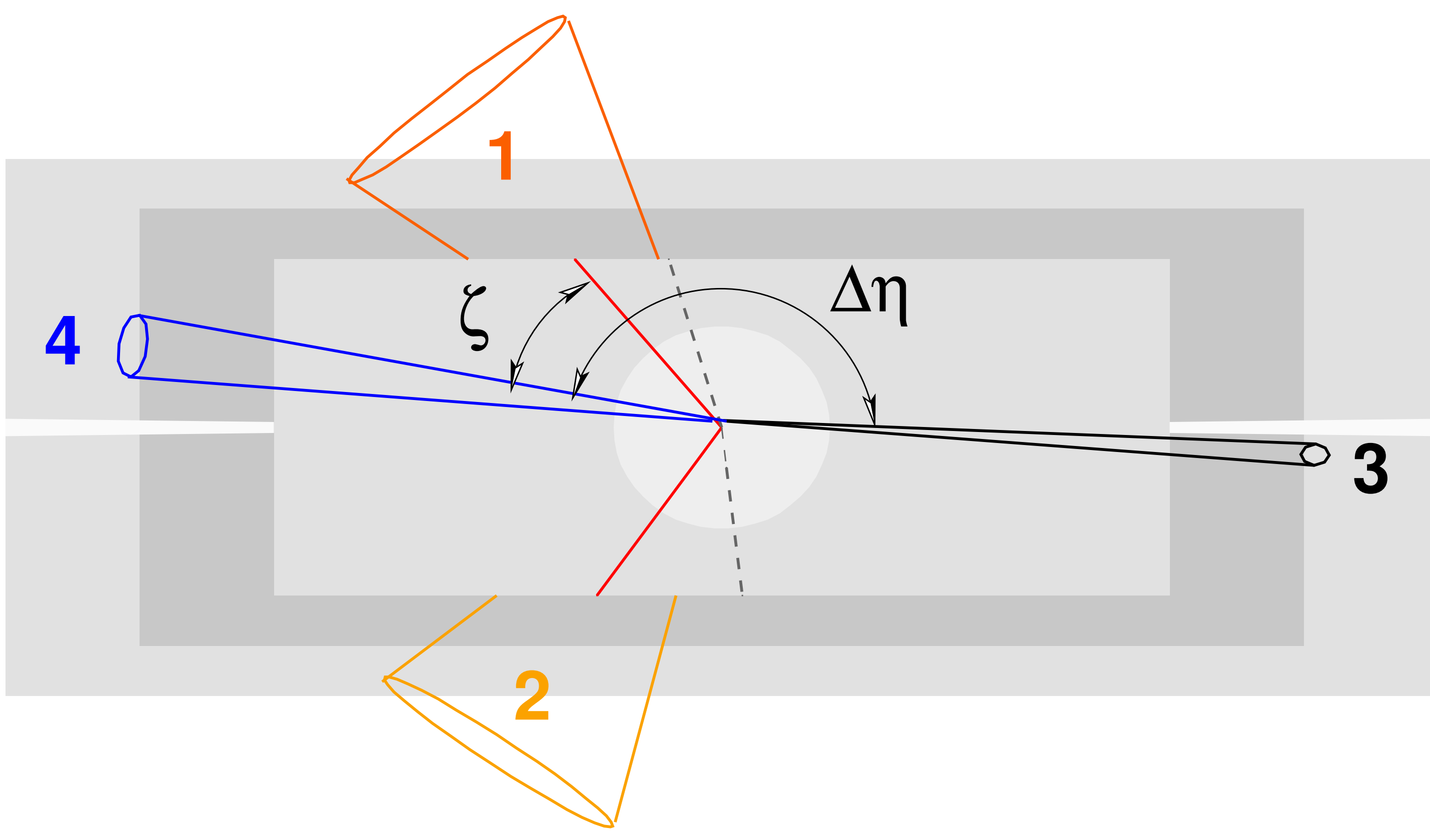


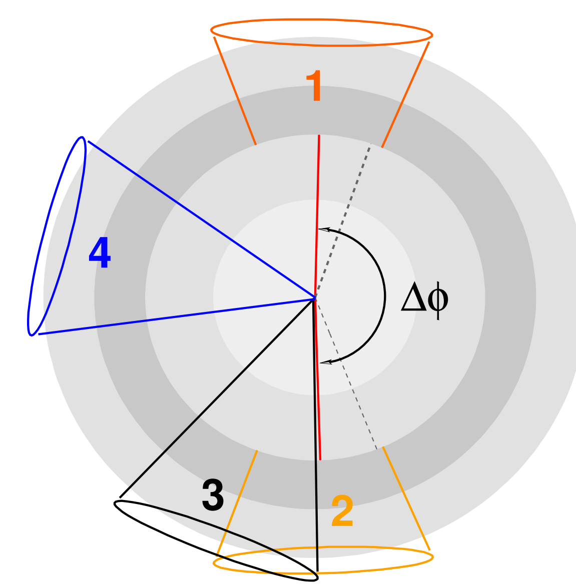
arXiv:0806.4145 [hep-ph]

General event layout

- two highly energetic jets (called tagging jets) (3,4)
- large pseudo rapidity gap between jets
- large invariant mass of dijet system
- two leptons that lie between the tagging jets (1,2)

$$\zeta_{ll} \equiv \min\left\{\min\{\eta_1^l, \eta_2^l\} - \min\{\eta_1^{jet}, \eta_2^{jet}\}, \max\{\eta_1^{jet}, \eta_2^{jet}\} - \max\{\eta_1^l, \eta_2^l\}\right\}$$





Object Selection

- Jets
  - calibrated (2011 input)
  - $p_T > 30$ GeV
  - $|\eta| < 4.5$
  - not LooserBad
  - $|JVF| > 0.5$
  - Overlap Removal
    - jets near electrons (0.3)
    - jets near muons (0.3)

- Electrons
  - scaled and smeared
  - author 1 or 3
  - OQ good
  - $p_T > 15$ GeV
  - $|\eta| < 2.47$, excluding crack region
  - tight++ (using macro)
  - $|z_{0theta}| < 0.5$
  - $|d_{0\_sig}| < 3$
  - etcone30/pt < 0.14
  - ptcone30/pt < 0.13
  - overlap removal
    - electrons near muons (0.1)

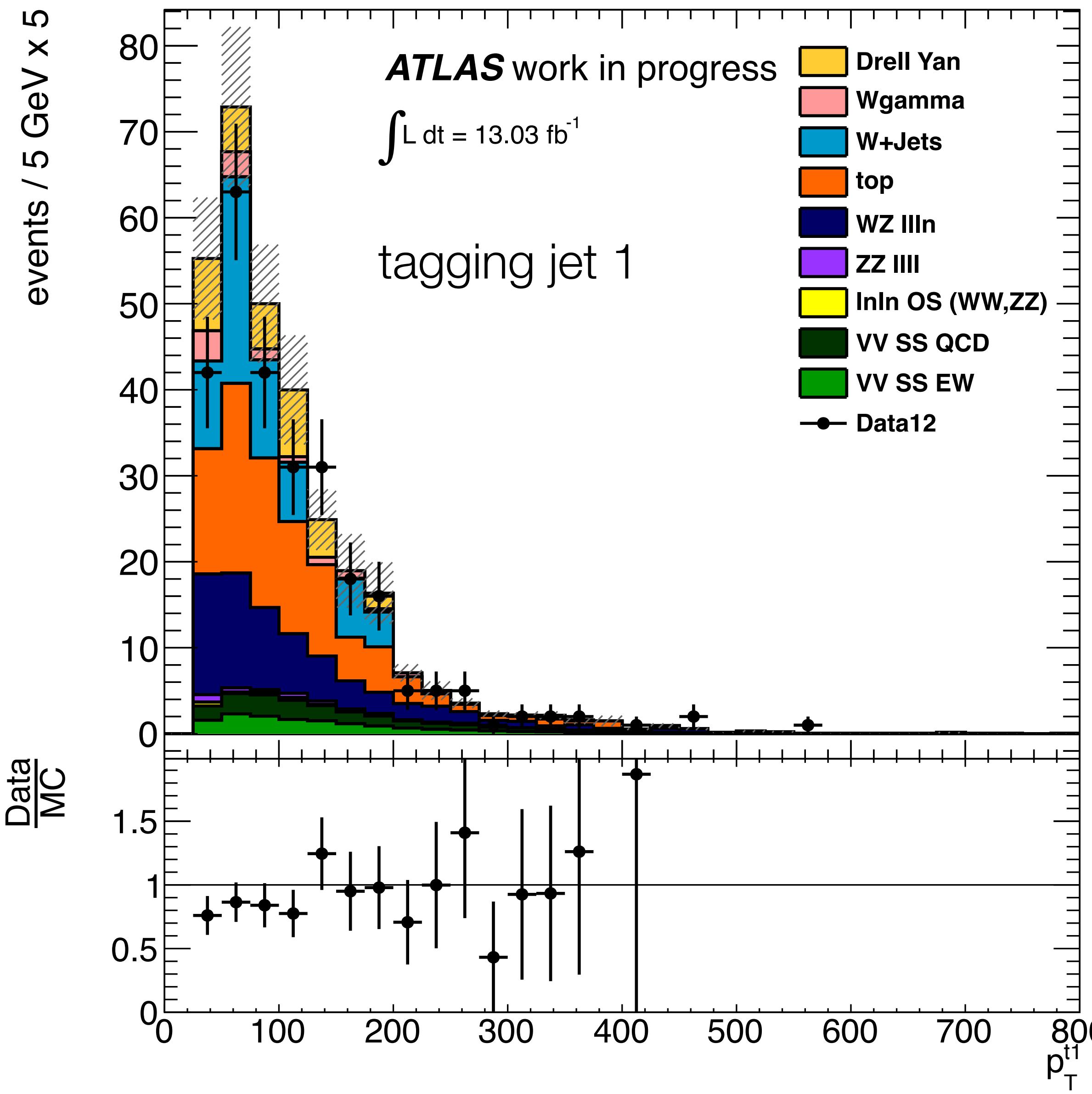
- Muons
  - scaled and smeared
  - STACO
  - combined + tight
  - $p_T > 15$ GeV
  - $|\eta| < 2.5$
  - MCP Recommendations
  - $|z_{0theta}| < 0.5$
  - $|d_{0\_sig}| < 3$
  - etcone30/pt < 0.14
  - ptcone30/pt < 0.15

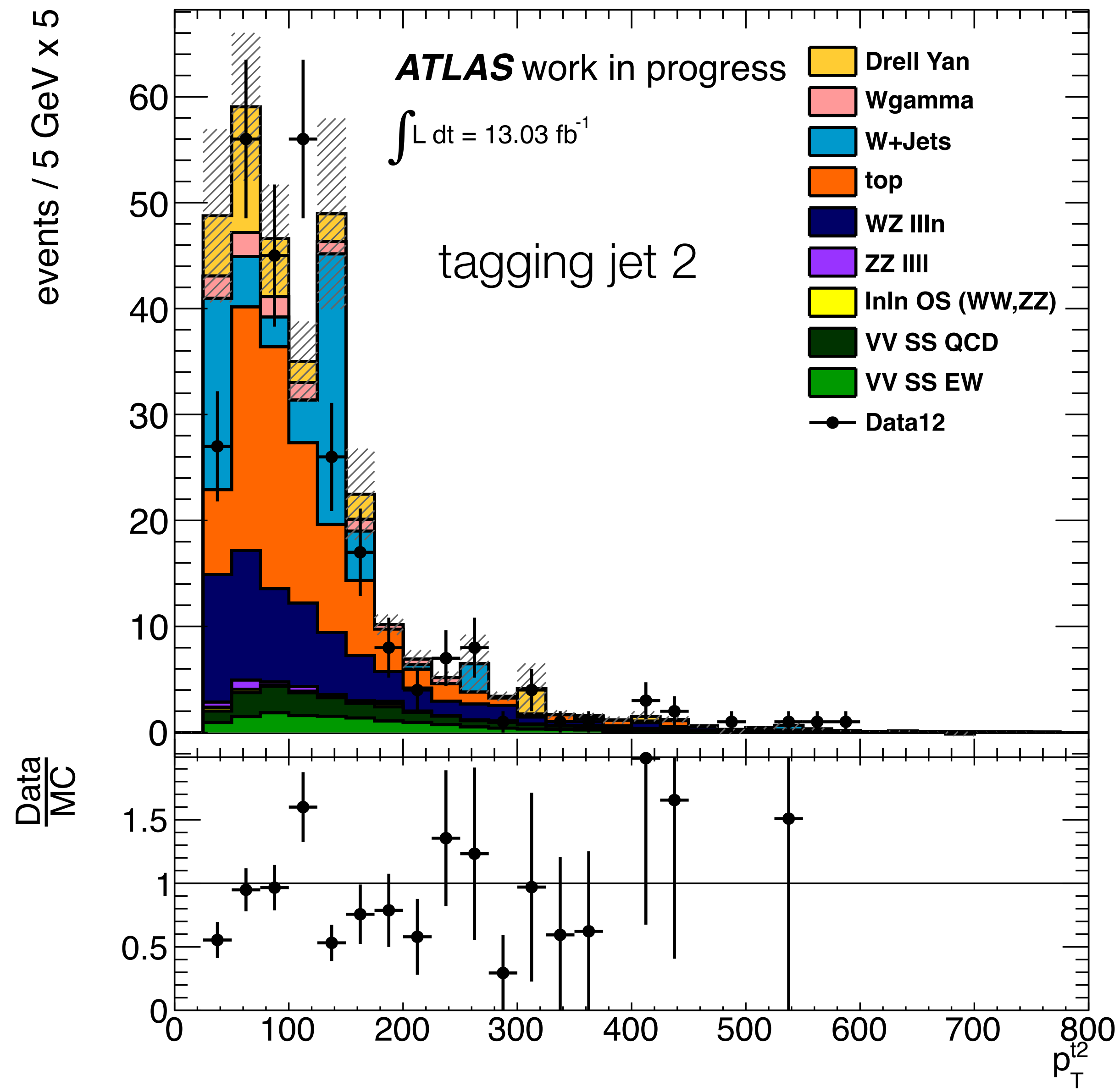
CutFlow

- Baseline Selection
  - GRL
  - Pileup Reweighting
  - Detector Quality
  - MET Cleaning(0)
  - Primary Vertex
  - Trigger
  - N_Lep(2)
  - N_Jets_MinGeV(2, 30)

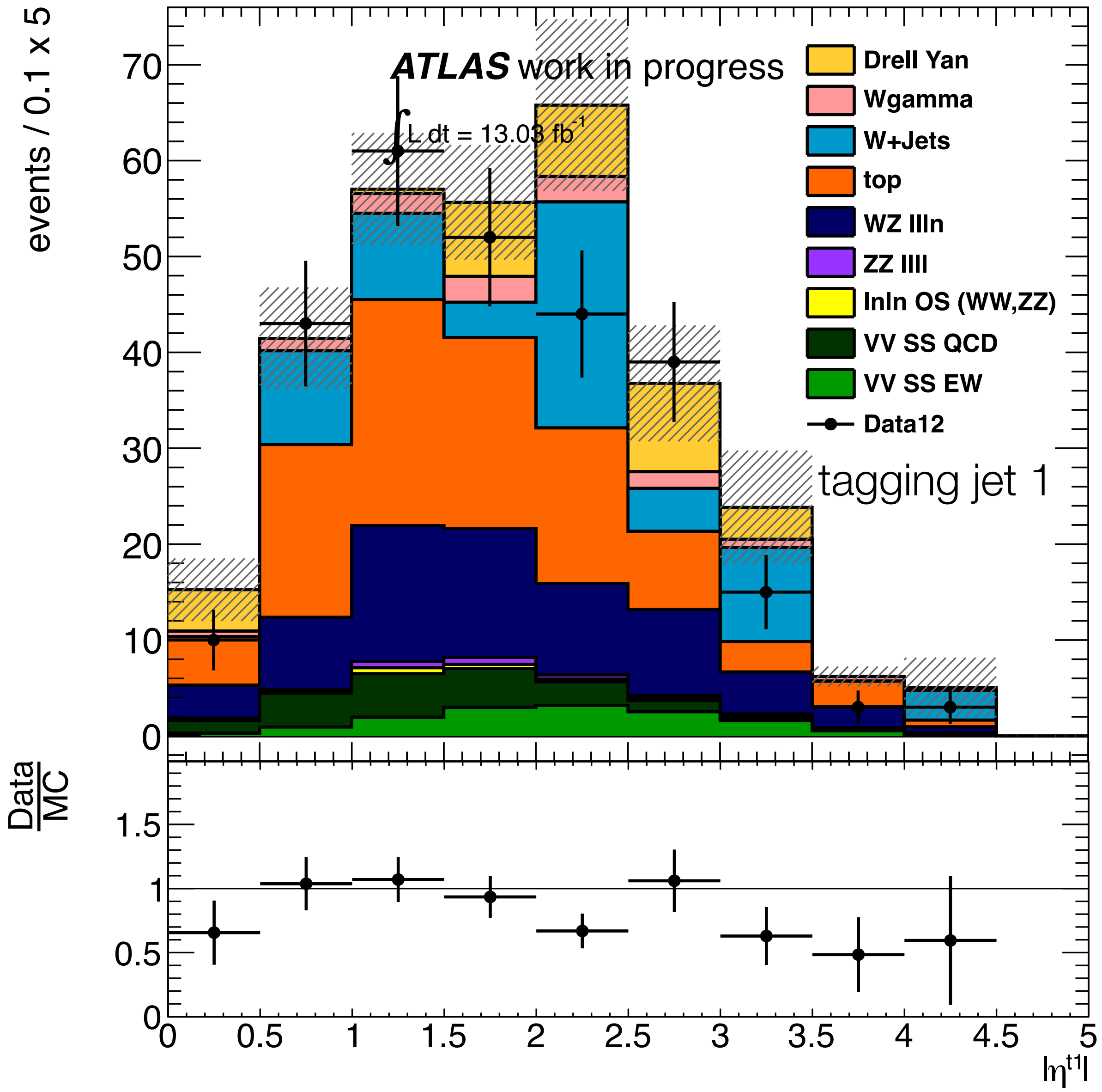
- Signal Regions
  - N_Leptons (according to channel)
  - Trigger Match
  - Lep2_p_T > 20 GeV
  - M_ll > 20 GeV
  - Lepton same sign cut
  - MET > 40 GeV
  - Z_Window veto (ee only)
  - M_jj > 150 GeV
  - Lep_Centrality > -0.5
  - Delta_AbsEta_jj > 2.4
  - M_jj > 500 GeV

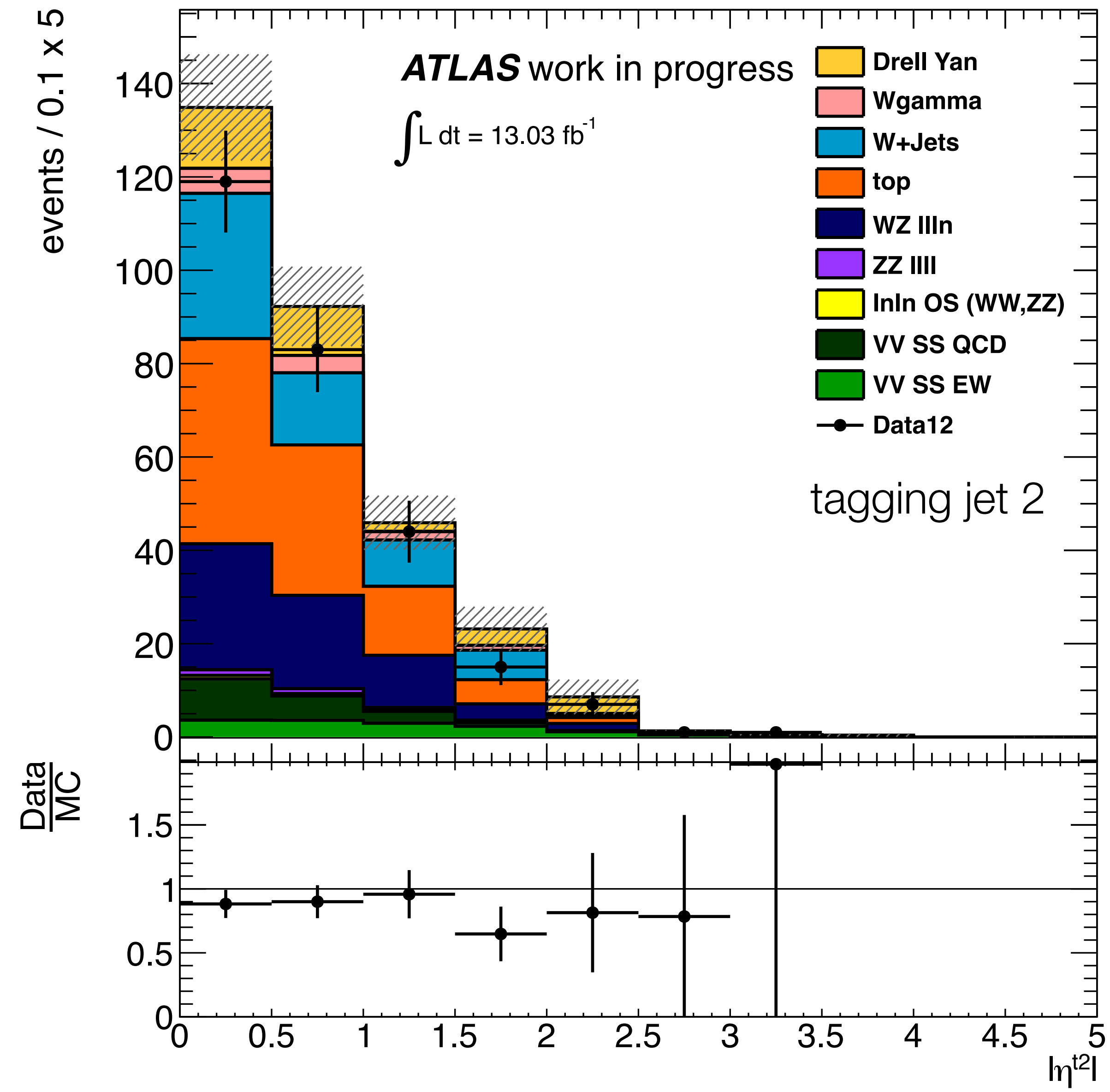
Modeling of tagging jets





Modeling of tagging jets

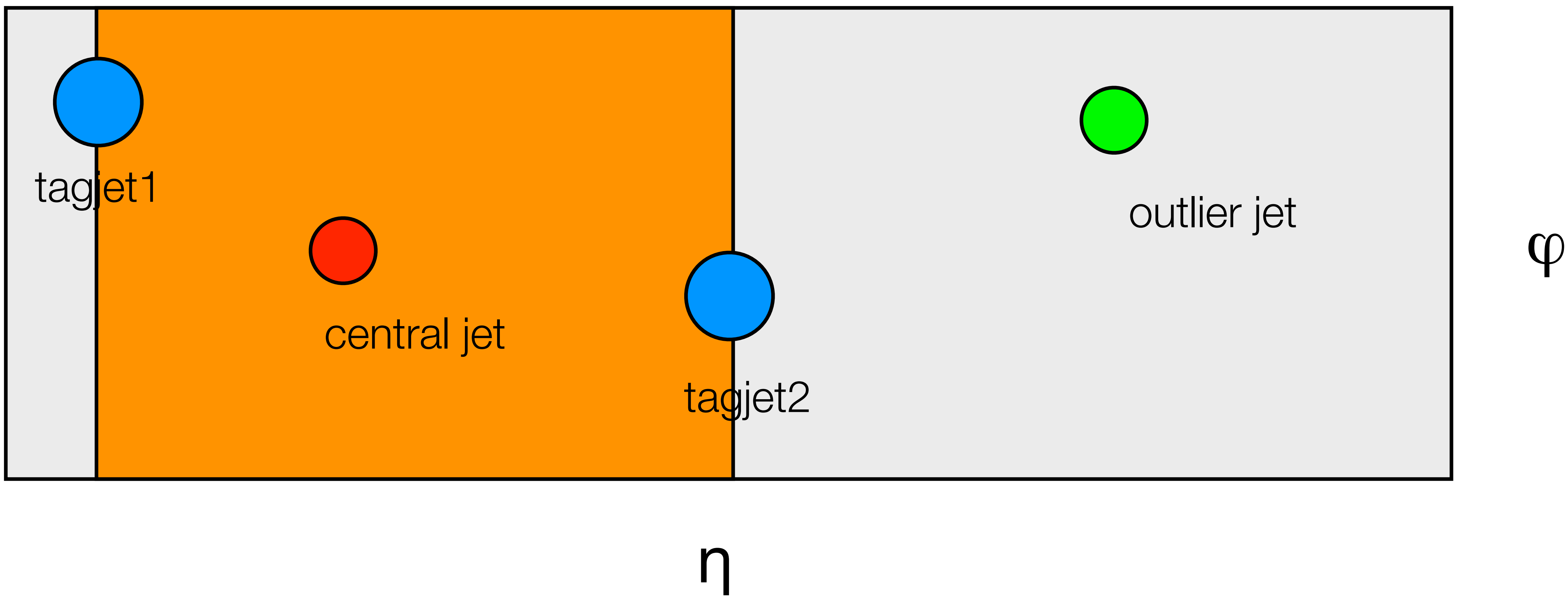




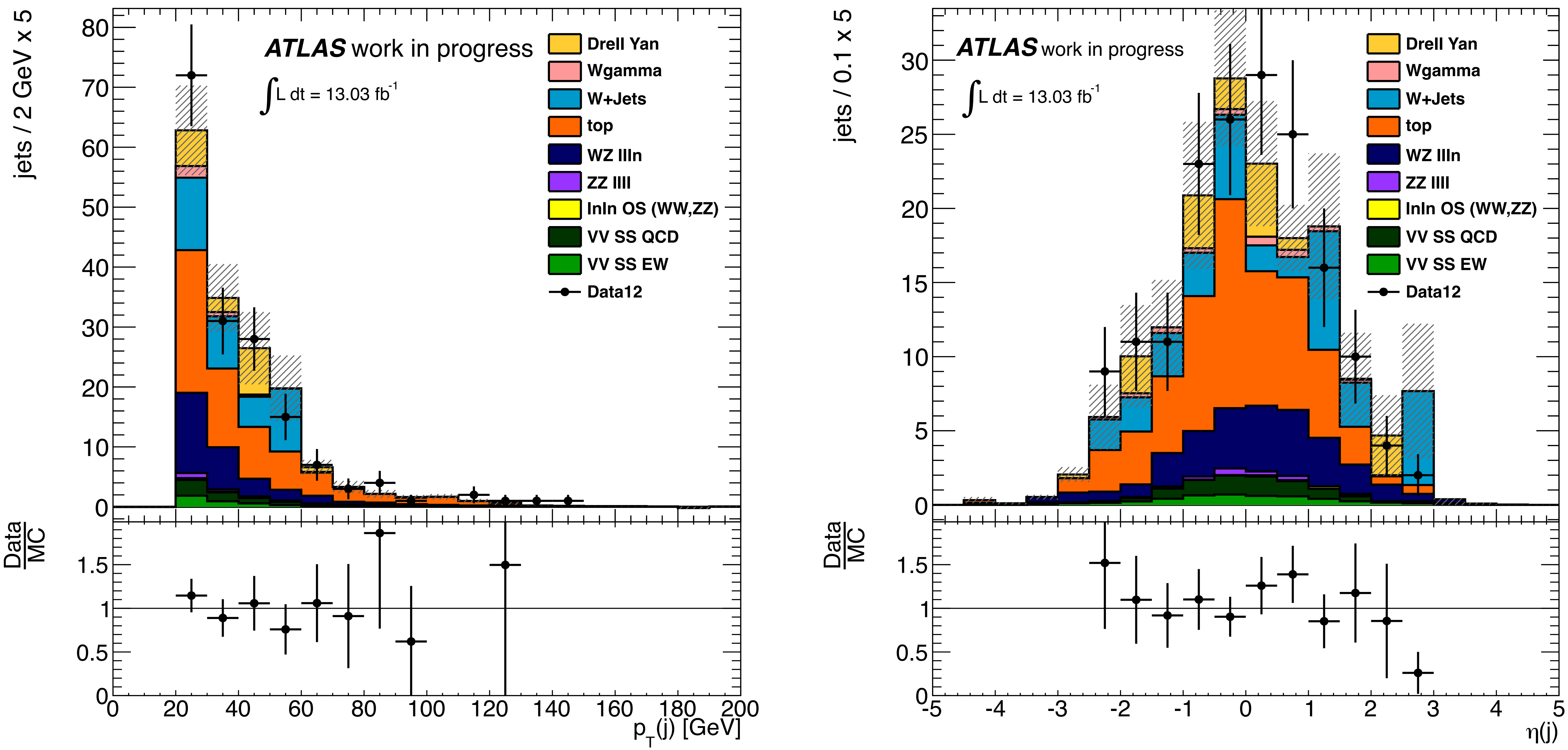
- tagging jets seem sufficiently well modeled
- most of the time there is a forward jet and a rather central jet

Central Jet Veto

- Idea: signal is characterized by colorless exchange -> no jet activity between tagging jets expected
- could a veto on additional jets help against background?
- all plots done after M_JJ > 150 GeV cut

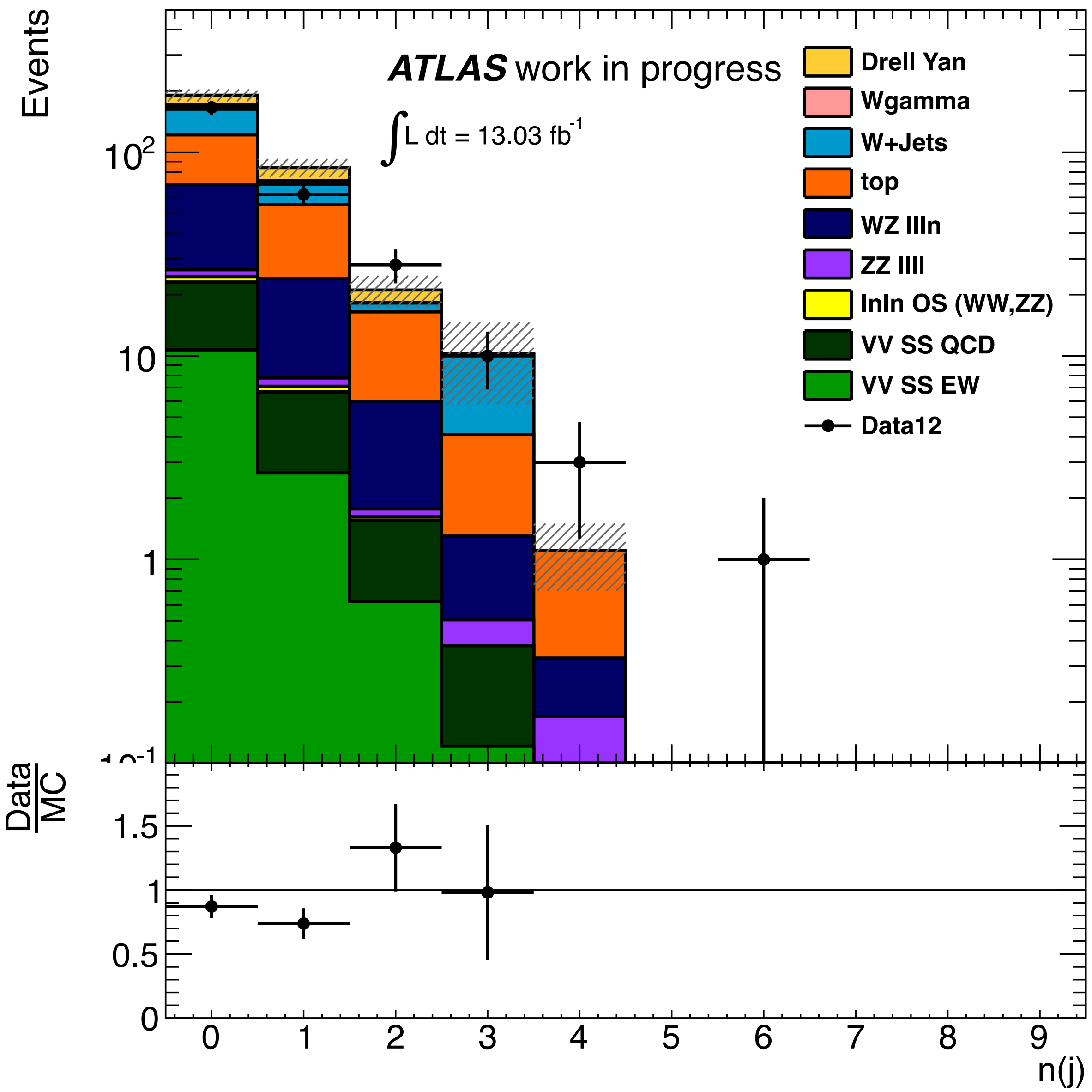


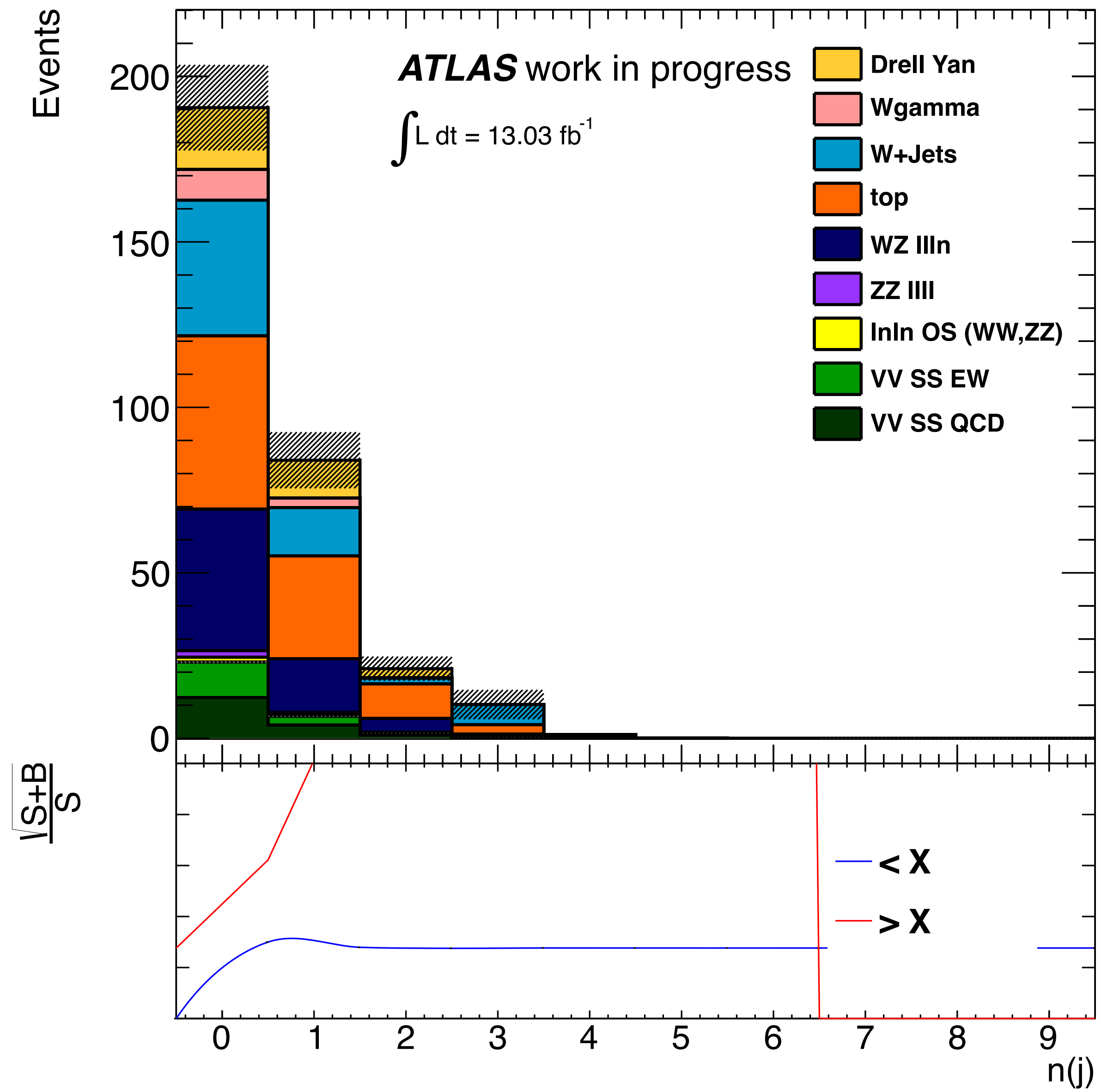
Properties of Central jets



- central jets sufficiently well described by MC

Properties of Central jets





- central jet veto worsens the relative error on the measurement of ssWW EW+QCD
- decided to drop central jet veto

anomalous Quartic Gauge Couplings

- studies done by Carsten Bittrich
- way to describe physics beyond the kinematic reach of the LHC
- effects from new physics are described by effective Lagrangian
- extension of the effective Lagrangian via terms containing additional dimension eight operators

$$\mathcal{L}_{\mathrm{eff}} = \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{c_i}{\Lambda_i}\mathcal{O}_i$$

- gives changed parameters:

$$c_i^{VV'} = c_{i,\mathrm{SM}}^{VV'} + g^2 \Delta c_i^{VV'}$$

Used Models

- VBF@NLO
  - implements a light SM Higgs boson
  - anomalous gauge couplings parameterized with $\Delta c_i^{WW} = \frac{g^2 v^4 f_i}{8\Lambda^4}$
  - Unitarization done via Form Factors

- WHIZARD
  - Higgs Boson represented by scalar sigma-resonance with m_H = 126 GeV
  - Extension of Lagrangian with anomalous couplings: $\Delta c_i^{WW} = g^2 \alpha_{i+4}$
  - Unitarization done via K-matrix formalism

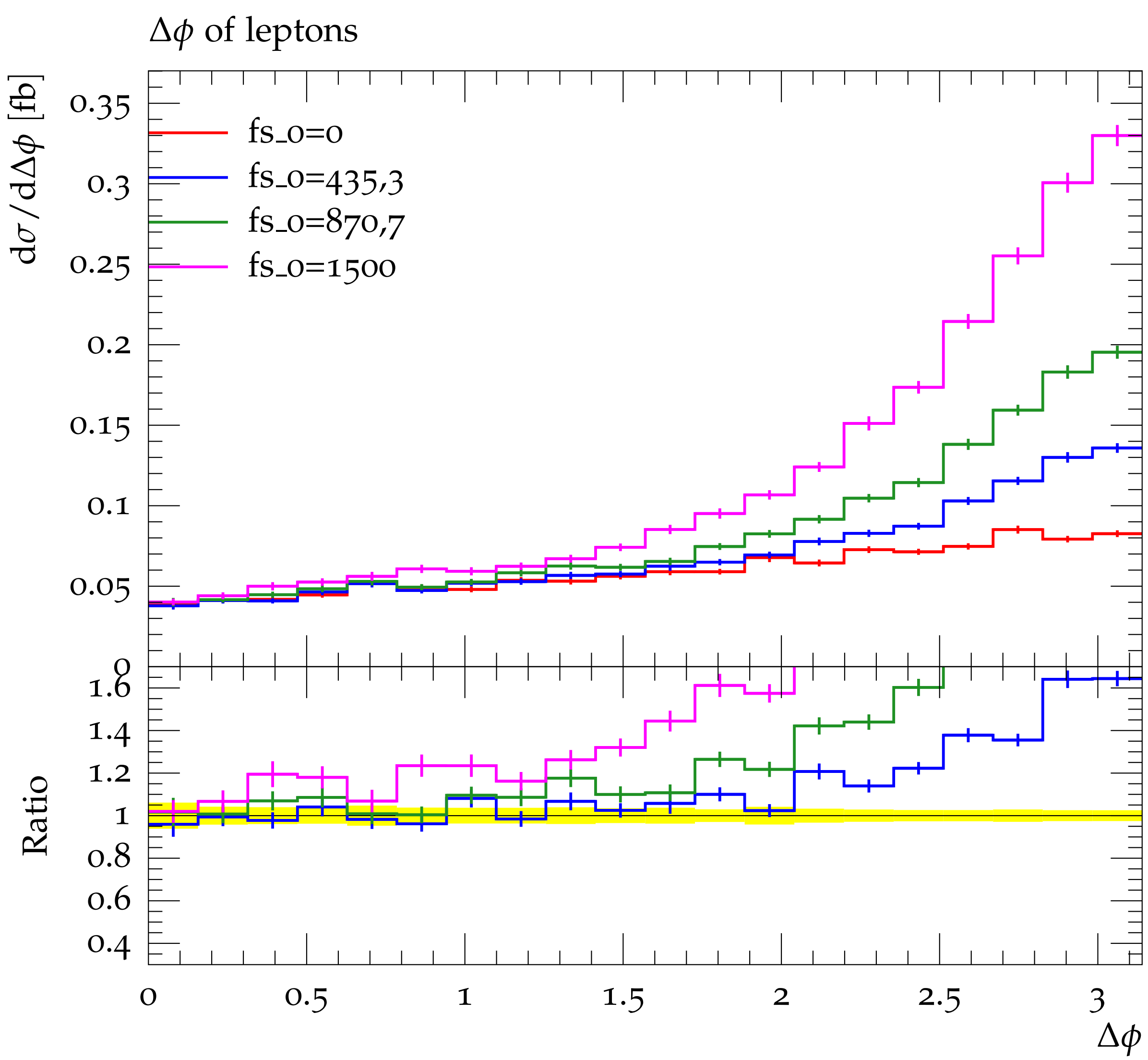
Scenario

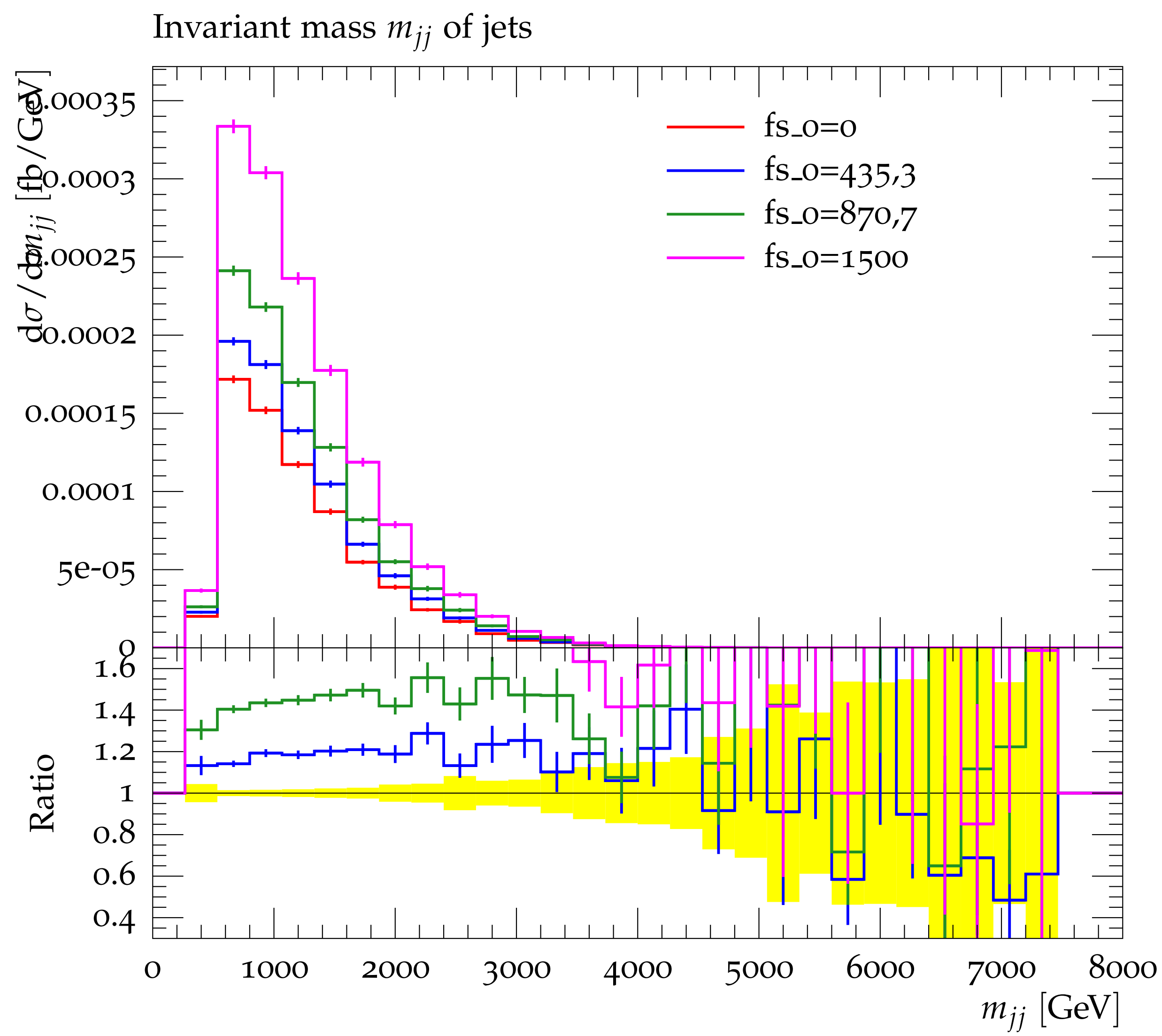
- Center-of-mass energy: 8 TeV
- final state: $jje^+\nu e^+\nu$
- Fiducial volume:

$$
\begin{aligned}
p_T(l_1) &> 25\,\mathrm{GeV} \\
p_T(l_2) &> 20\,\mathrm{GeV} \\
|\eta(l)| &\in [0, 1.37] \cup [1.52, 2.47] \\
M_{ll} &> 20\,\mathrm{GeV} \\
\zeta &> -0.5 \\
E_{\mathrm{T,\ miss}} &> 40\,\mathrm{GeV}\,.
\end{aligned}
$$

$$
\begin{aligned}
p_T(j_1) &> 30\,\mathrm{GeV} \\
p_T(j_2) &> 30\,\mathrm{GeV} \\
|\eta(j)| &< 5 \\
M_{jj} &> 500\,\mathrm{GeV} \\
|\eta_{jj}| &> 2.4
\end{aligned}
$$

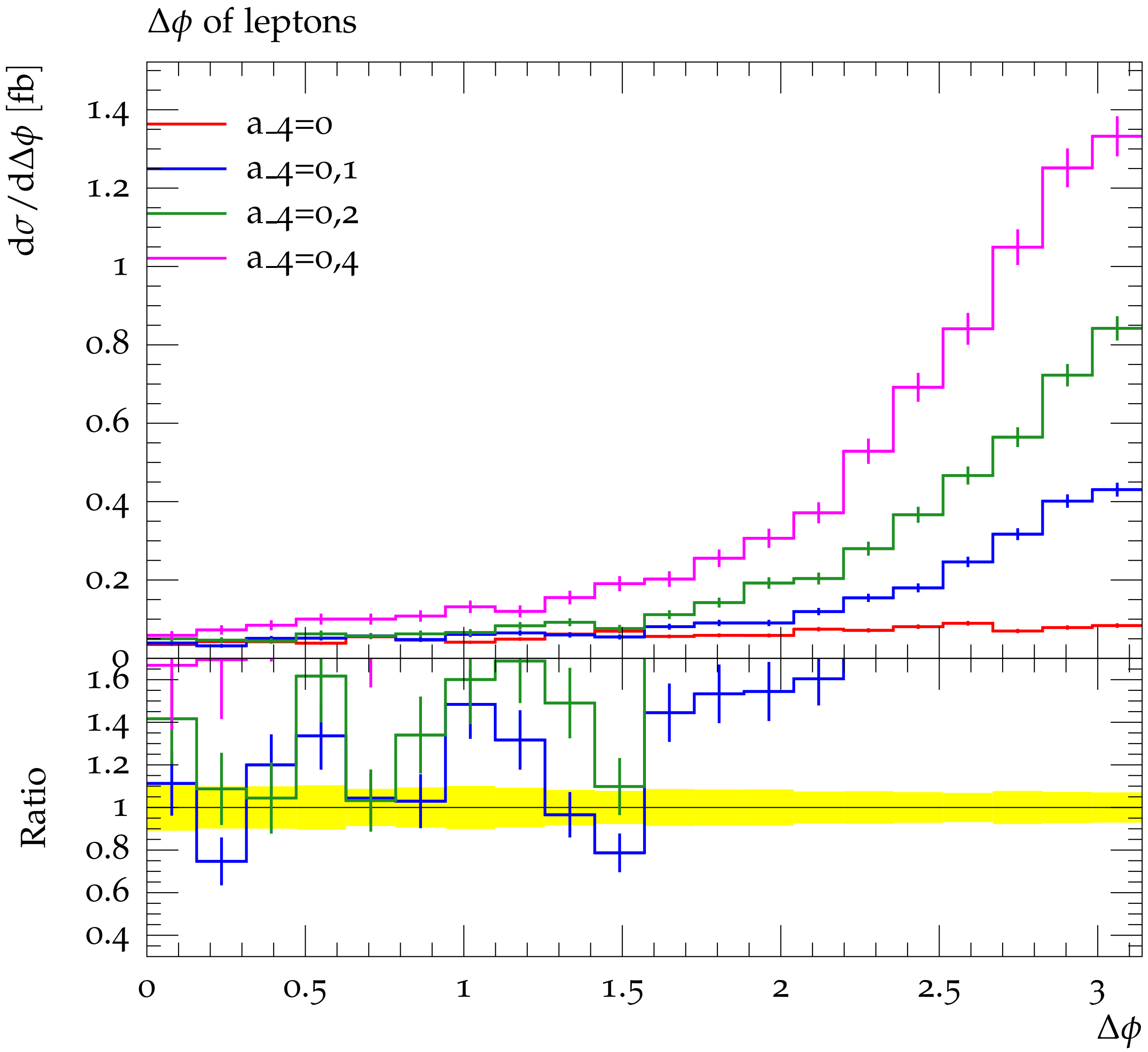
VBF@NLO

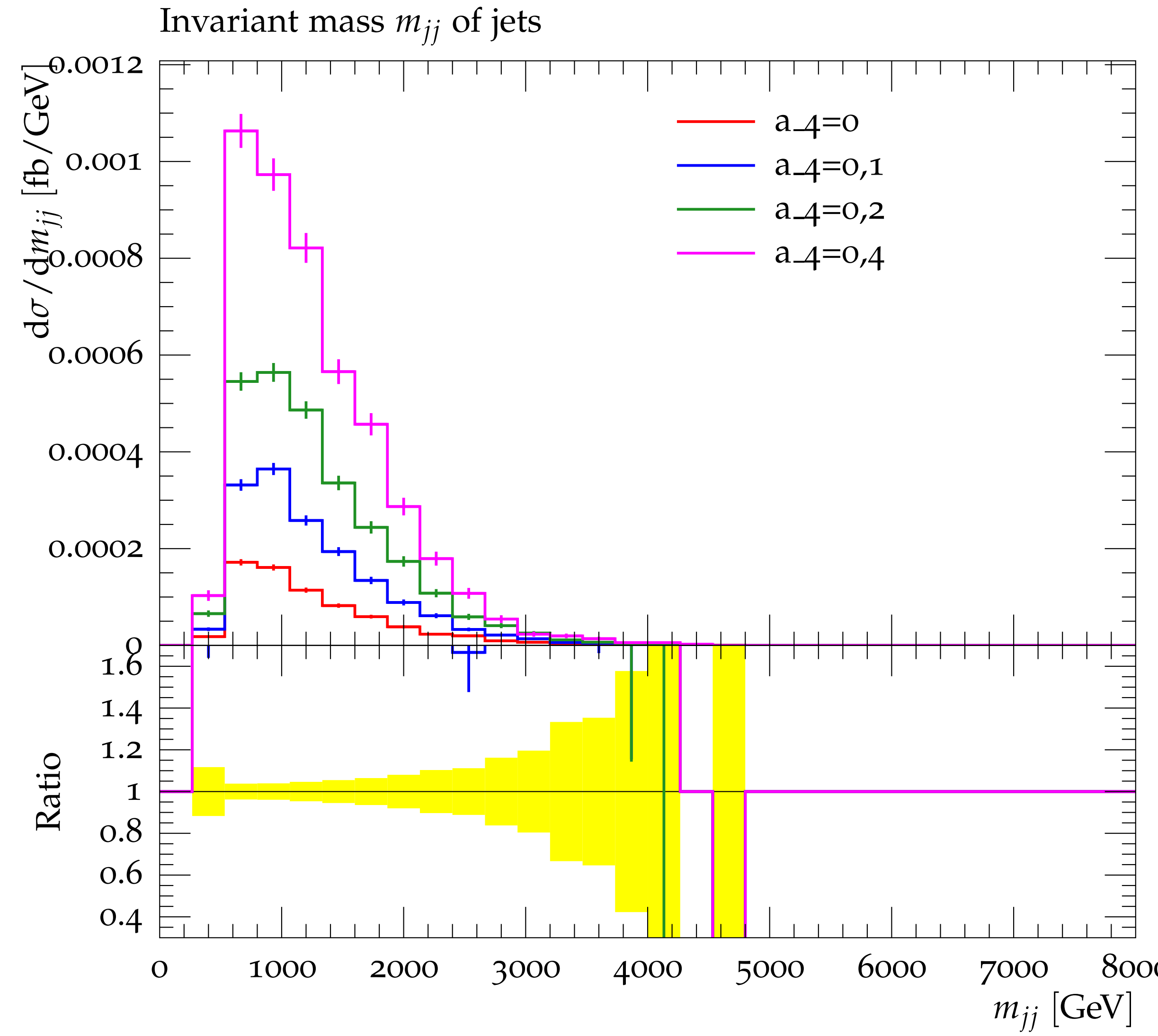




- Delta Phi and invariant mass of tagging jets are most sensitive variables

Whizard



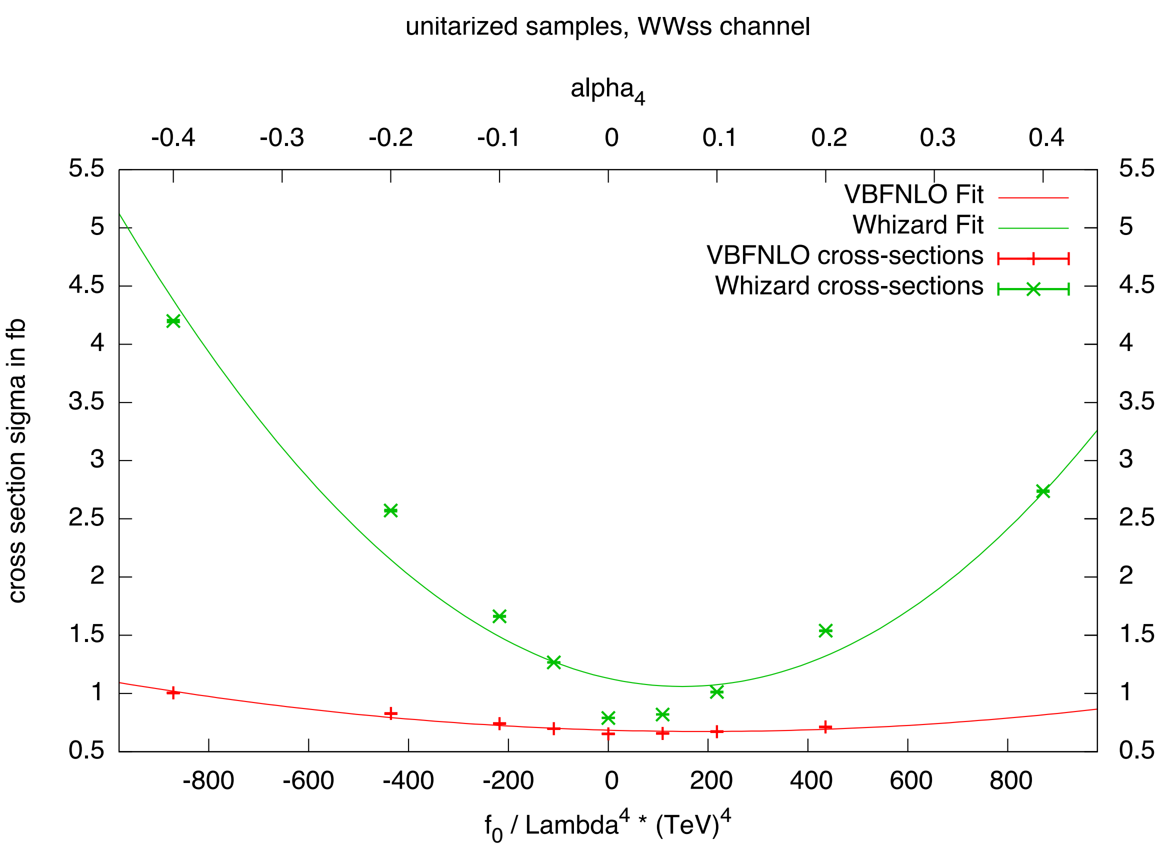


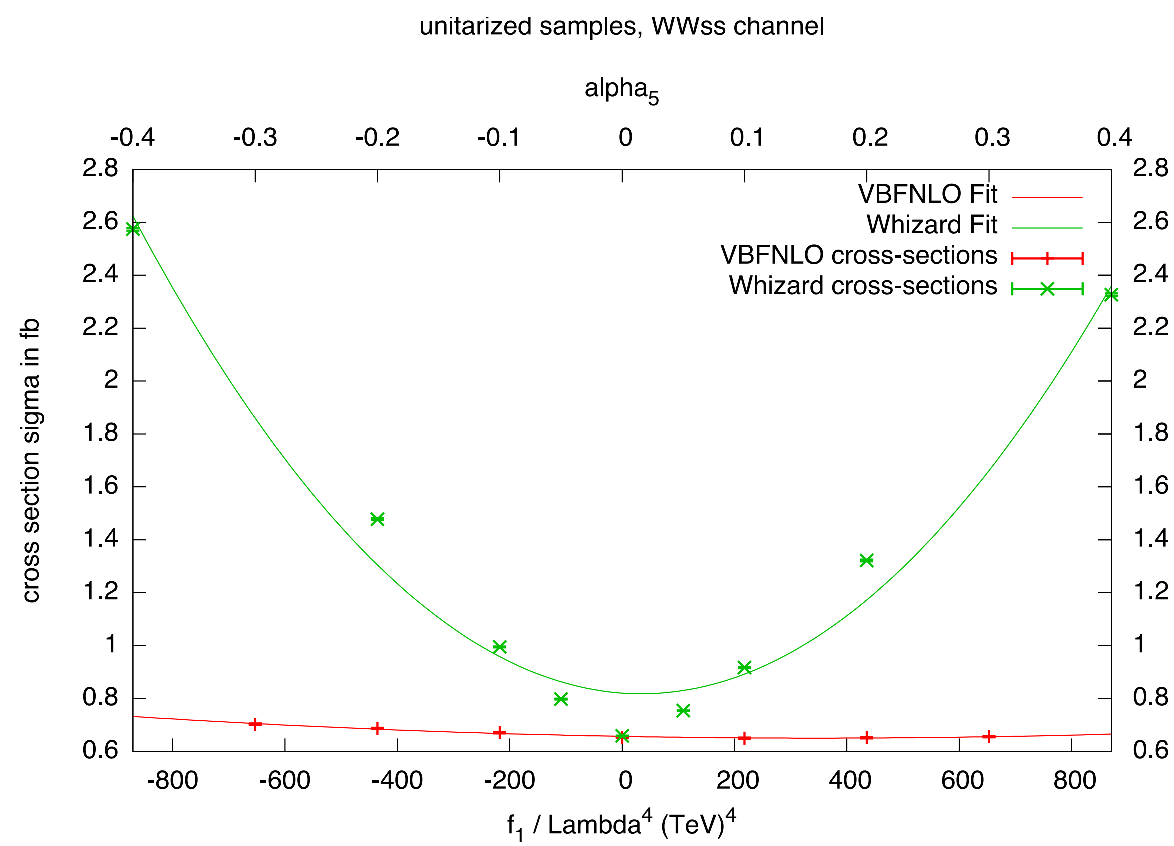
- Δφ of leptons and invariant mass of tagging jets are most sensitive variables

Cross section comparison

$$\alpha_{i+4} = v^4 \frac{f_i}{8\Lambda^4} = \frac{v^4}{8\,(\mathrm{TeV})^4}\tilde{f}_i \qquad \text{with} \qquad \tilde{f}_i = f_i \cdot \frac{\mathrm{TeV}^4}{\Lambda^4}$$

$$\overset{\text{e. g.}}{\Rightarrow} \qquad \alpha_4 = 0.05 \quad \overset{?}{\approx} \quad \tilde{f}_0 = 100$$





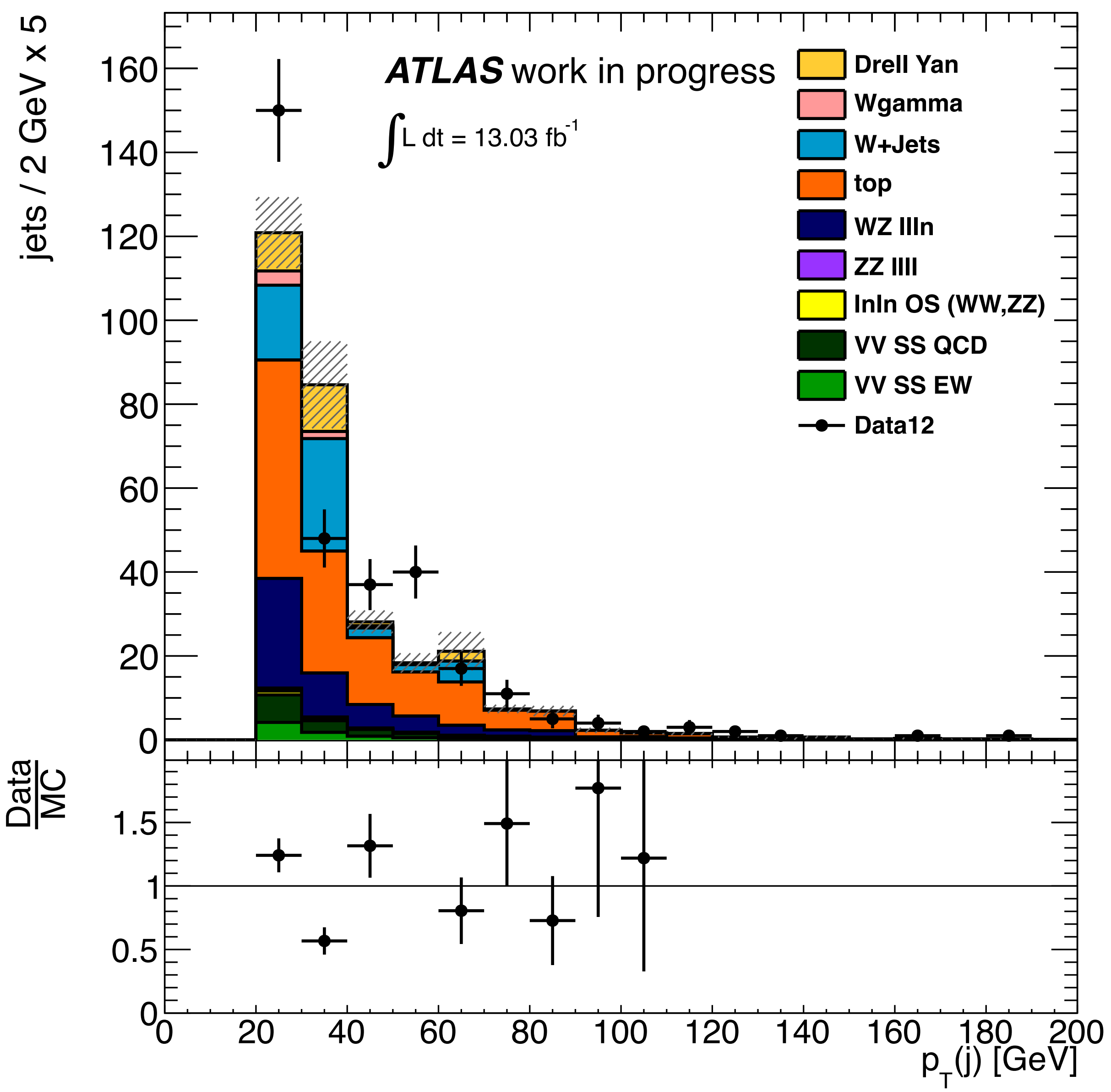
Comparison of dependency of cross sections on α_4 and f_0 with $\alpha_5 = f_1 = 0$ (left) or α_5 and f_1 with $\alpha_4 = f_0 = 0$ (right) for different generators. (—): VBF@NLO, (—): Whizard

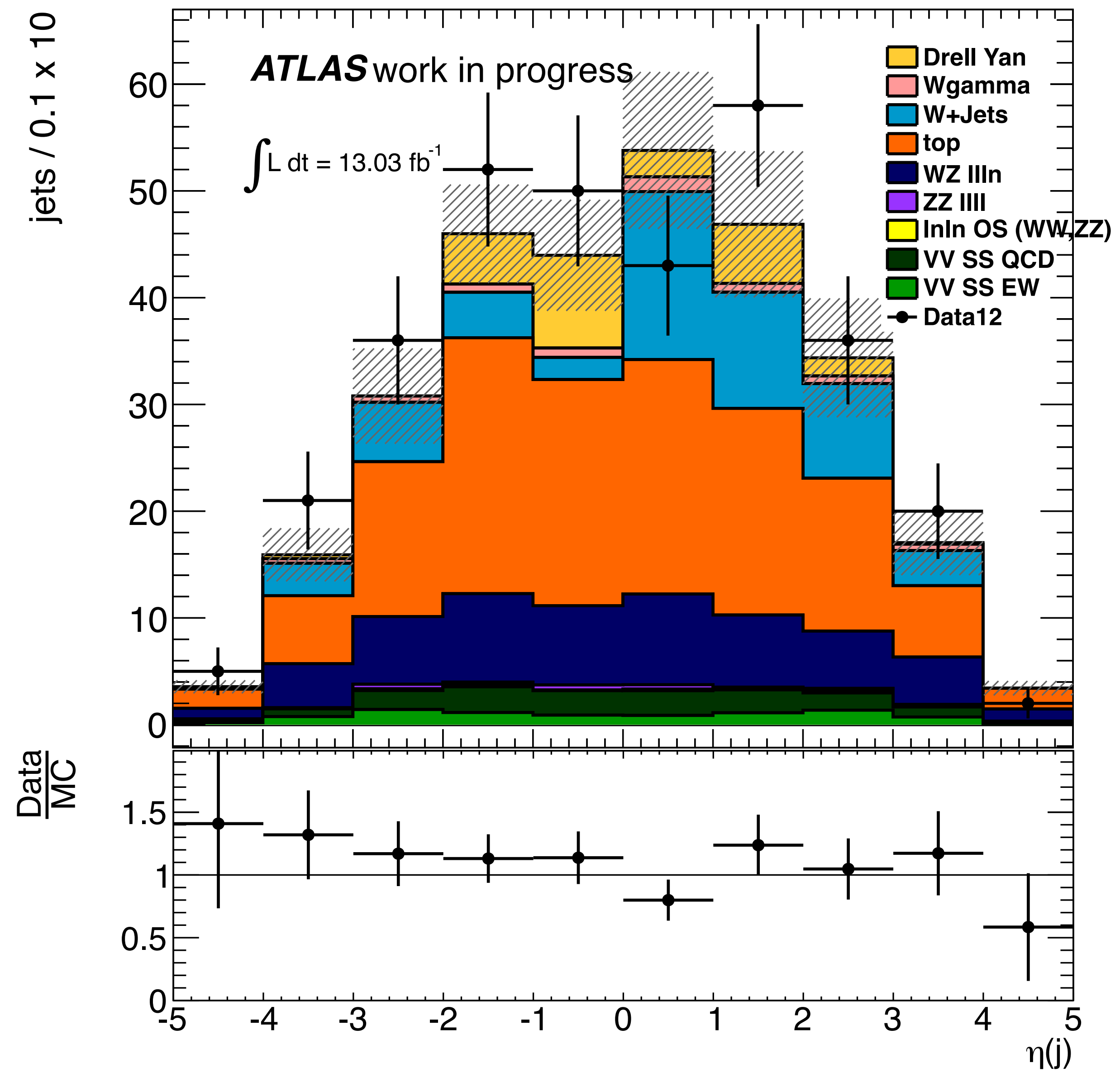
Conclusion

- want to measure the VBS cross section
- after that extract electroweak contribution and set limits on aQGCs
- tagging jet kinematics seem to be well modeled by MC, data driven background estimation is on its way
- Central Jet Veto does not help with measurement of VBS cross section, seems also to be the case for the electroweak contribution extraction
- studies on generator level show that $\Delta\phi$ of leptons and invariant mass of the tagging jets seem to be the best distributions to separate different strengths for aQGCs
- differences for generators are still under investigation

Thank you for your attention!

Properties of Outlier jets





Properties of Outlier jets