Electroweak Z-boson production by the CMS experiment at the LHC for $\sqrt{s} = 7$ TeV and 8 TeV

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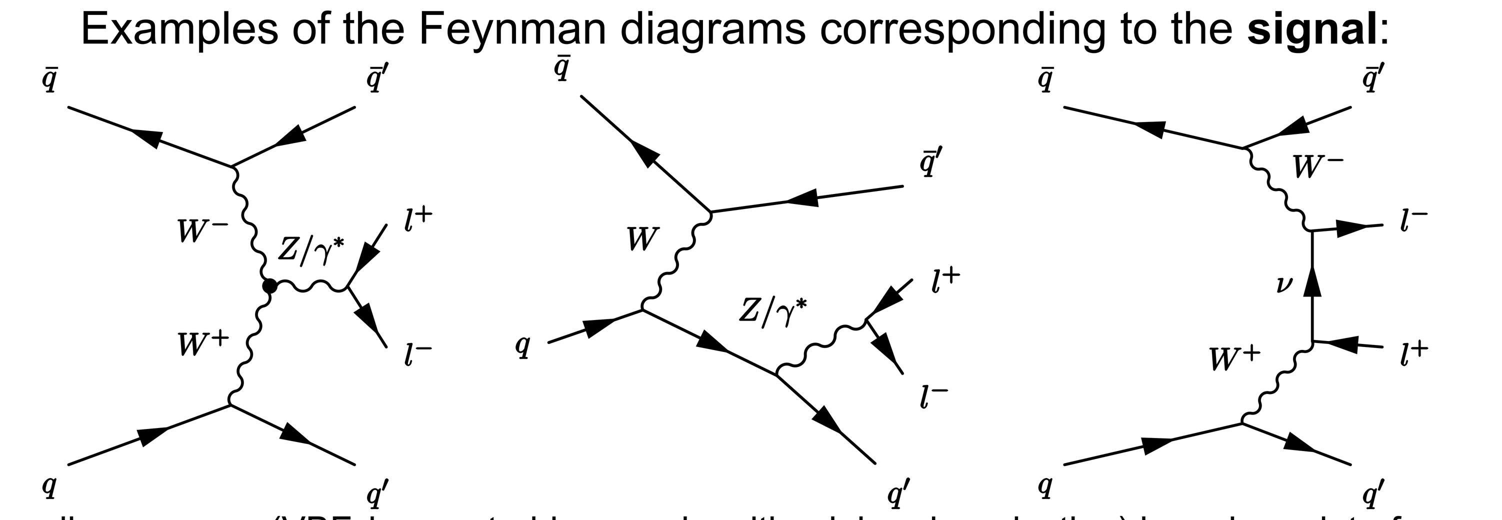
The processes of interest: signal and background

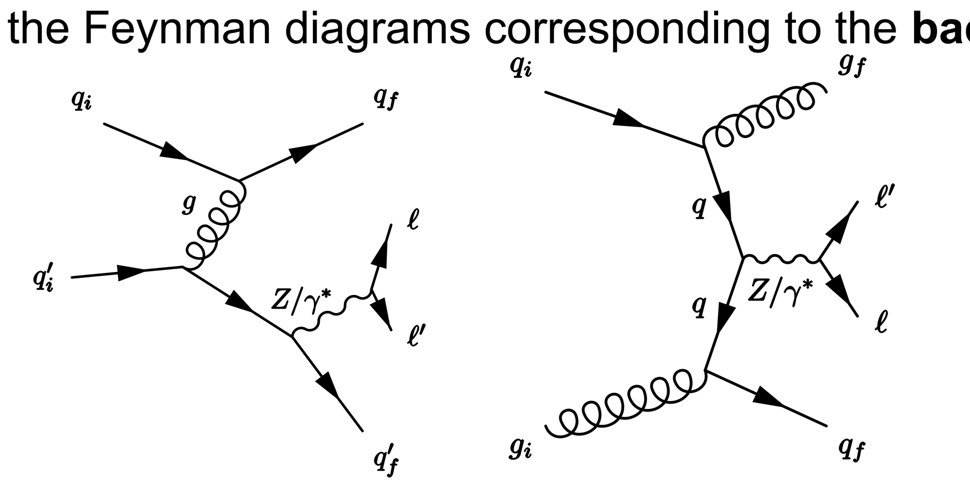
The production of a Z boson in association with two jets in proton-proton collisions is dominated by a mixture of electroweak and strong processes of order $\mathcal{O}(\alpha_s^2\alpha_{EW}^2)$. Purely electroweak production (**signal**) is expected at order $\mathcal{O}(\alpha_{EW}^4)$.

Examples of the Feynman diagrams corresponding to the **signal**:



these diagrams are (VBF, bremsstrahlung and multiperipheral production) have large interference.

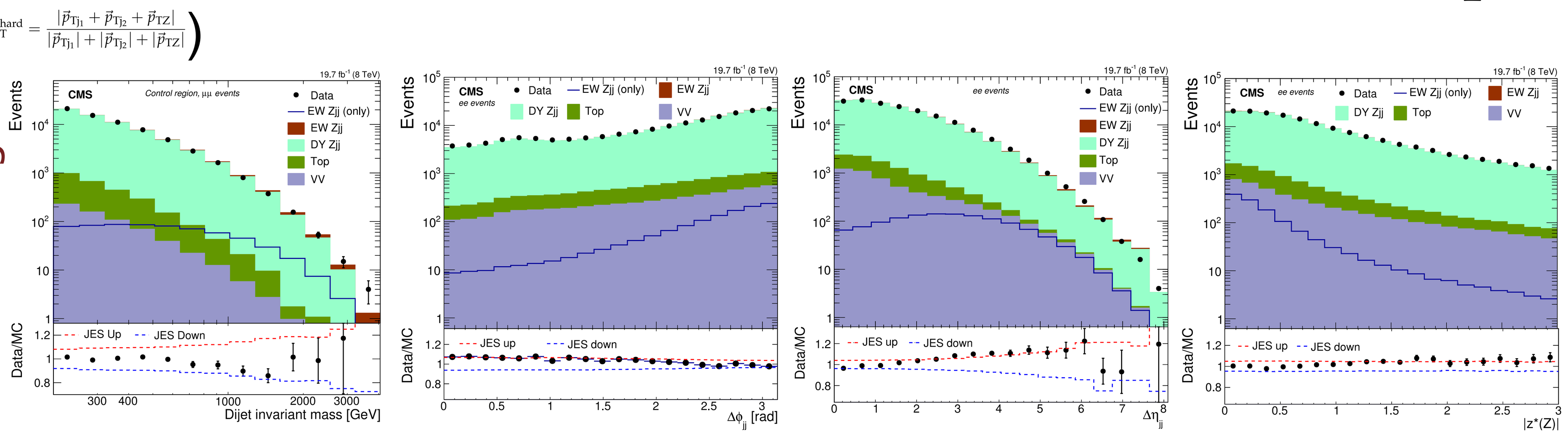
Examples of the Feynman diagrams corresponding to the **background**:



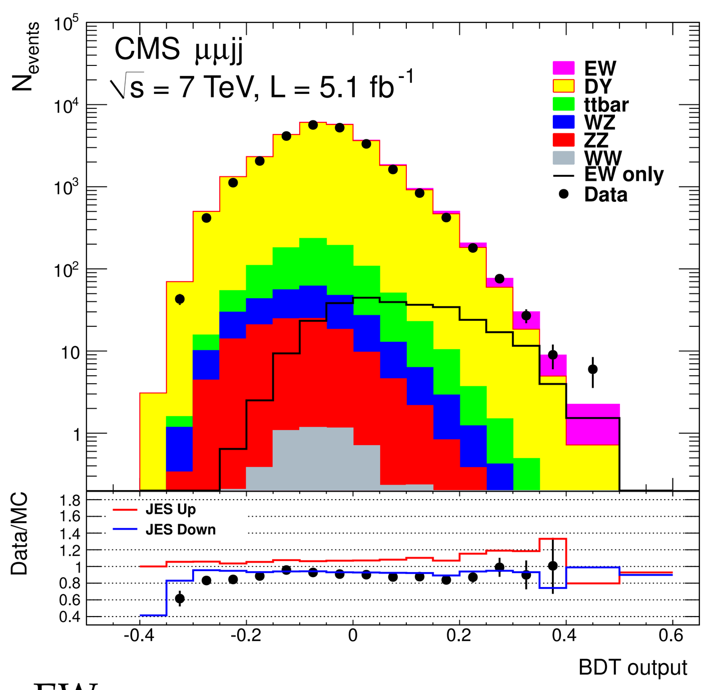
Background modelling and control regions

Background is modelled using either MC simulation (MadGraph+Pythia+(k-factor correction)+detector simulation) or are based on gamma+jet sample reweighted to make gamma spectrum resemble Z-boson spectrum. Control regions are used to validate jet energy response and efficiency, as well as to check the MC background modelling. The following figures demonstrate good agreement between the cross sections obtained from data and those modelled using MC generation for the control kinematic region (where signal is negligible) selected using the event balance variable Rp_T^{hard} ($Rp_T^{hard} = \frac{|\vec{p}_{T_{j1}}+\vec{p}_{T_{j2}}+\vec{p}_{TZ}|}{|\vec{p}_{T_{j1}}|+|\vec{p}_{T_{j2}}|+|\vec{p}_{TZ}|}$)

Control region



Result for $\sqrt{s} = 7$ GeV



Kinematic selection:

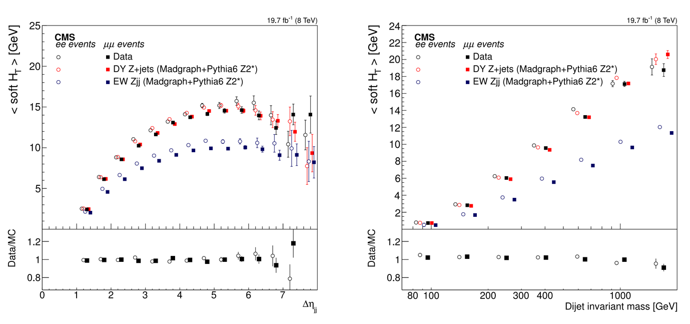
$$p_T^{j1} > 65\,\text{GeV},\ p_T^{j2} > 40\,\text{GeV},\ |\eta_j| < 3.6$$
$$|y^*| < 1.2$$
$$m_{j1j2} > 600\,\text{GeV},$$
$$y^* = y_Z - 0.5(y_{j1} + y_{j2})$$

$$\sigma^{EW}_{\ell\ell\ (\ell=e,\mu)} = 154 \pm 24\,(\text{stat.}) \pm 46\,(\text{exp. syst.}) \pm 27\,(\text{th. syst.}) \pm 3\,(\text{lum.})\,\text{fb}.$$

Theoretical prediction at NLO (from VBFNLO) 166 fb

Hadronic activity: high purity tracks

High-purity tracks associated with Primary Vertex are clustered into "soft track-jets". Only jets with rapidity between "tagging jets" are retained. The first 3 jets with the highest p_T are taken to calculate the scalar sum of p_T.



Good agreement between data and MC

Physics motivation:

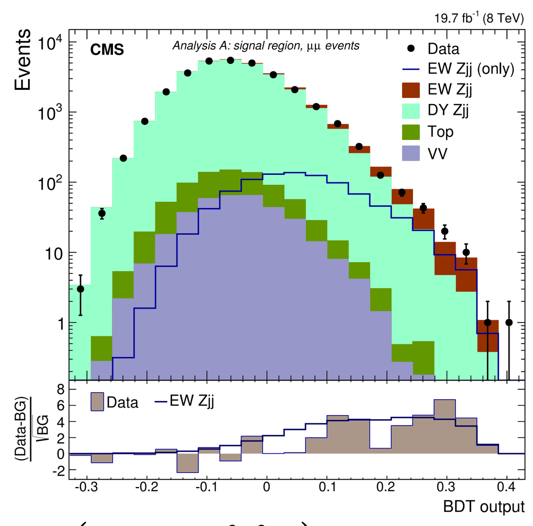
1. When isolated from the backgrounds, the properties of purely electroweak Zjj events can be compared with SM predictions (e. g. probe for anomalous triple-gauge couplings)
2. probing the hadronic/jet activity in the selected events in particular can shed light on the selection (or vetoing) of additional parton radiation to the tagging jets
3. establish foundation for the more general study of the VBF (vector-boson fusion) processes (Higgs, beyond SM)

Cross section extraction method

The cross section extraction is based on the fit of the experimentally obtained spectrum with the linear combination of the modelled **signal** and **background**. The interference between the EW Zjj and the DY Zjj processes is taken into account in the fitting procedure by parametrisation of the magnitude of the interference as a function of dijet mass derived from MadGraph simulation. To enhance separation between them, a multivariate analysis (MVA) technique is used. Choice of MVA variables is based on distinctive characteristics of the signal such as:

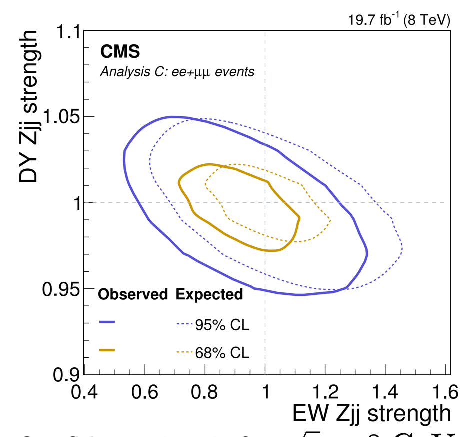
1. large rapidity separation between the jets associated to Z-boson (tagging jets) production because of small-angle scattering of the two initial partons
2. larger invariant mass of the tagging jet pair (M_jj), because of topological confiuguration and large p_T of the outgoing partons
3. Z-boson candidate is expected to be produced centrally wrt. tagging jets
4. balance of the "Z-boson - tagging jets" subsystem in the transverse momentum plane
5. absence of gluon jets (CMS quark/gluon jet discriminant was used)

Result for $\sqrt{s} = 8$ TeV



Kinematic selection:

$p_T^{j1} > 50$ GeV, $p_T^{j2} > 30$ GeV
$|\eta| < 4.7$,
$m_{j1j2} > 200(450)$ GeV,
$|y^*| < 1.2$,
$(|y_Z| < 1.4442$,
$p_{TZ} > 50$ GeV)



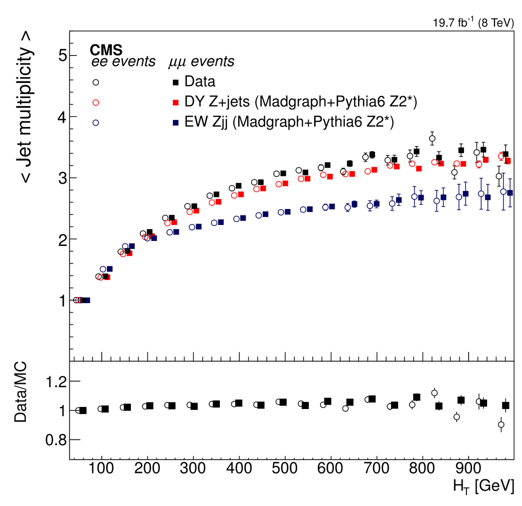
Confidence levels for $\sqrt{s} = 8$ GeV, strength $= \frac{\sigma}{\sigma_{th}}$

$$\sigma(\text{EW}\ \ell\ell\text{jj}) = 174 \pm 15\,(\text{stat}) \pm 40\,(\text{syst})\ \text{fb}$$

Theoretical prediction at LO
$\sigma_{LO}(\text{EW}\ \ell\ell\text{jj}) = 208 \pm 18\,\text{fb}$

It is a more precise result than for $\sqrt{s} = 7$ TeV thanks to the increased integrated luminosity, improved selection method, more precise modelling of signal and background

Hadronic activity: jet radiation patterns



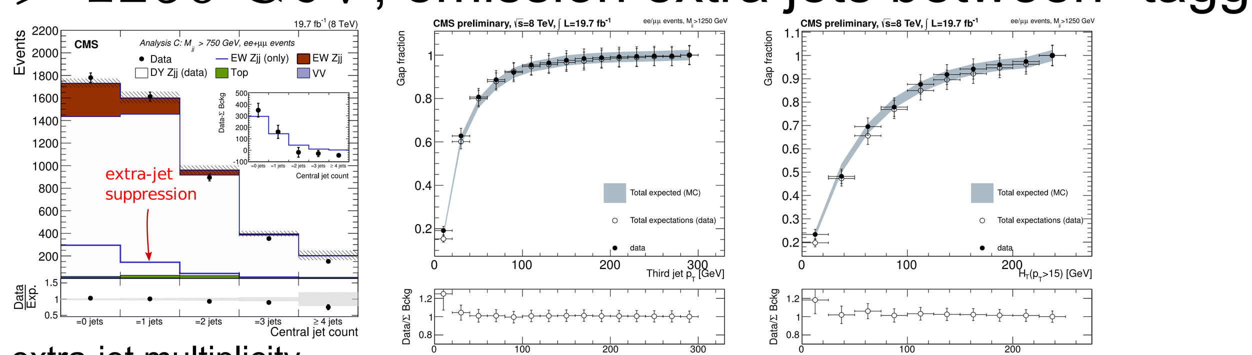
For the jets of the events used in the analysis above, several jet observables are measured:

1. number of jets
2. scalar sum of jet pT
3. maximal pseudorapidity interval
4. cosine of the azimuthal angle between jets

They all have good agreement between data and MC.

Hadronic activity: high signal purity region

For two regions of high signal purity $M_{jj} > 750$ GeV and > 1250 GeV, emission extra jets between "tagging jets" is studied.



extra-jet multiplicity

Jet veto efficiency as a function of the third jet p_T and h_T.

Signal events exhibit large suppression of extra-jet emission. Good agreement between data and MC.

CMS Collaboration, "Measurement of the hadronic activity in events with a Z and two jets and extraction of the cross section for the electroweak production of a Z with two jets in pp collisions at $\sqrt{s} = 7$ TeV", JHEP 10 (2013) 101, (arXiv:1305.7389)
CMS Collaboration, "Measurement of electroweak production of two jets in association with a Z boson in proton–proton collisions at $\sqrt{s} = 8$ TeV", EPJC 75 (2015) 66, (arXiv:1410.3153)