Electroweak production of a Z boson in association with forward/backward jets

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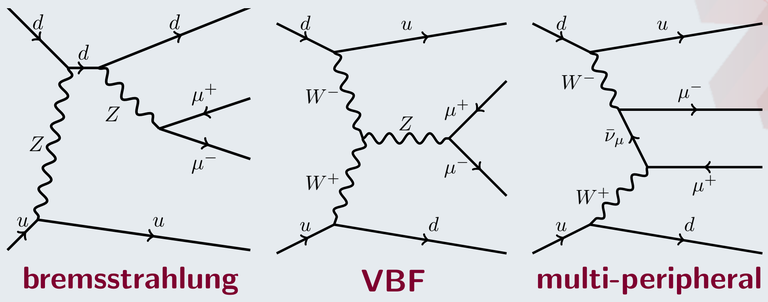
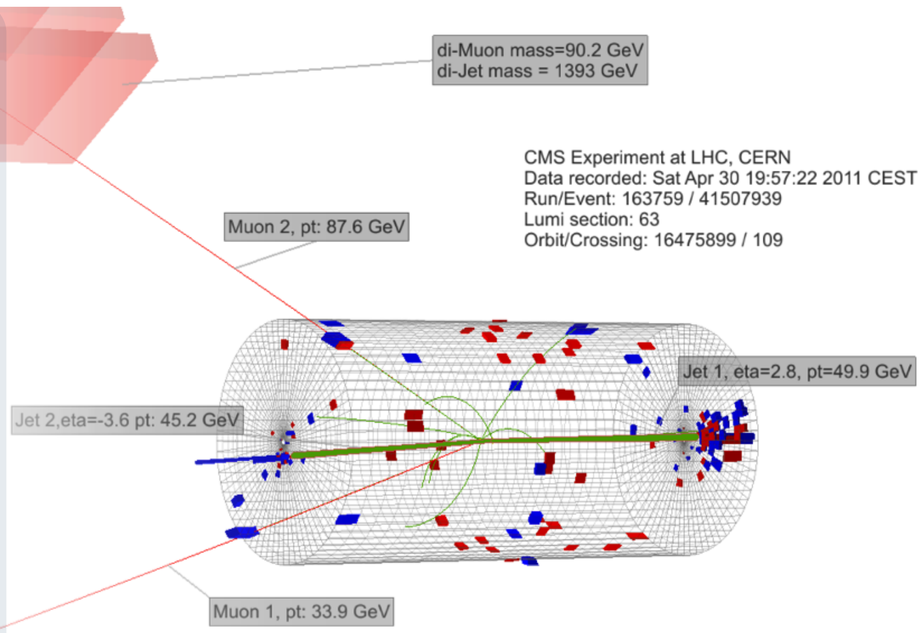
Electroweak production of a Z boson in association with two jets



In proton-proton collisions at the LHC, the dominant source of events with the $lljj$ final state is through mixed electroweak and strong processes of order $O(\alpha_{EW}^2\alpha_{QCD}^2)$, also known as Drell-Yan plus two jets. Pure electroweak production of a Z boson in association with two jets is a rarer process. Different classes of pure electroweak processes $O(\alpha_{EW}^4)$, $lljj$ processes are possible: vector boson fusion (VBF), bremsstrahlung and multi-peripheral. Because of large gauge cancellations between them, these classes cannot be isolated in data. The search for these pure electroweak processes exploits some distinctive event properties:

- Central Z decay associated with two energetic forward-backward light-quark jets
- A large η separation between the jets and large invariant dijet mass
- Colour exchange suppresion between the tagging quark jets

The results of our analysis pave the road for the more general study of vector boson fusion processes and for measurements of electroweak gauge couplings and vector boson scattering.



Background modeling

Two alternative background models for the Drell-Yan plus jets background have been developed:

Simulation-based

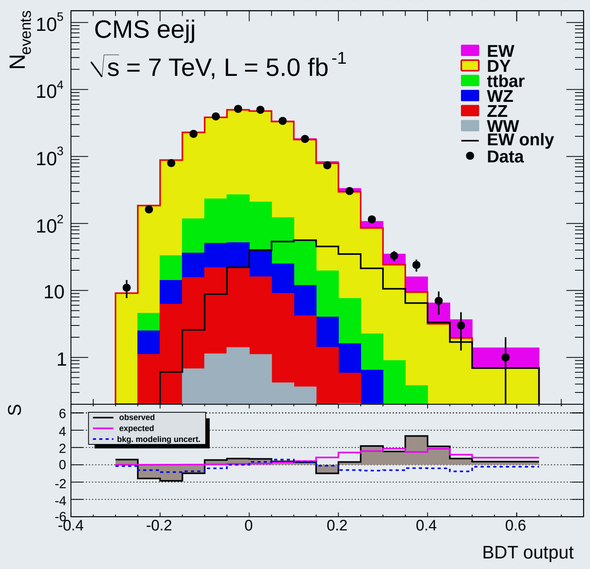
The simulation for Drell Yan plus jets is based on MADGRAPH + PYTHIA and lacks higher order virtual corrections. Predictions from MCFM are used to derive LO to NLO correction factors based on the dijet invariant mass M_{jj} and on the rapidity of the Z boson in the dijet rest frame (y^*).

Data-based

The production of γ plus two jets is expected to resemble Drell Yan processes and can therefore be used to model the shape of the tagging jets. A γ plus 2 jets sample is selected in data in a similar way as the Z plus 2 jets selection. The photon p_T is reweighted to the Z boson p_T in order to mitigate the differences induced by the specific γ or Z sample.

Signal discrimination

Simulation based method 7TeV



No single variable provides enough signal separation power. Multivariate (MVA) methods are used to discriminate the electroweak $jjll$ signal from the background.

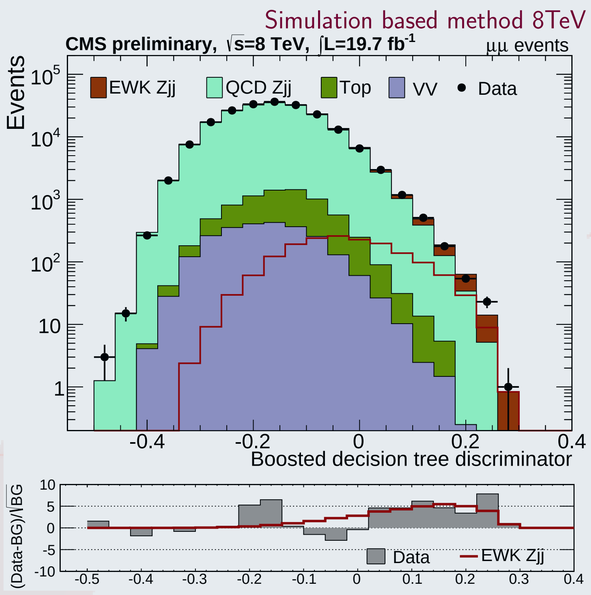
A boosted decision tree (BDT) is built from:

- the p_T's of the two tagging jets and the Z boson
- the dijet invariant mass M_{jj}
- the pseudorapidity distance $\Delta\eta_{jj}$ between the two jets
- the sum $\eta_{j_1} + \eta_{j_2}$ of the pseudorapidities of the jets
- the azimutal angles between the Z boson and the jets: $\Delta\phi(Z, j_1)$, $\Delta\phi(Z, j_2)$ and $\Delta\phi_{jj}$
- $y^* = y_Z - \frac{y(j_1)+y(j_2)}{2}$
- the quark-gluon likelihood for the tagging jets

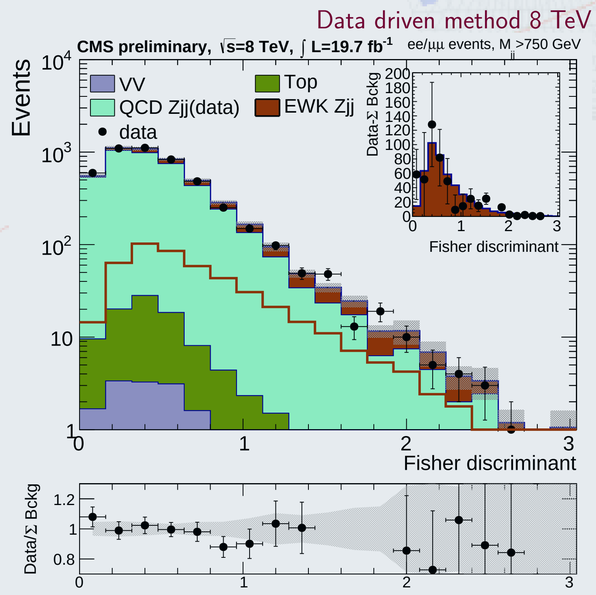
A simpler Fisher discriminant using dijet kinematics is also used:

- M_{jj} and $\Delta\eta_{jj}$
- the relative p_T imbalance: $\frac{|\vec{p}_T(j_1,j_2)|}{|\vec{p}_T(j_1)|+|\vec{p}_T(j_2)|}$

Simulation based method 8TeV



Data driven method 8 TeV



Cross section measurement

The electroweak $lljj$ cross section is extracted after fitting the data with the expected shapes for signal and background. After fitting for the signal strength it is extrapolated to the kinematic region $M_{ll} > 50$ GeV, $M_{jj} > 120$ GeV, $p_T^j > 25$ GeV and $|\eta_j| < 4$ (7TeV) or $|\eta_j| < 5$ (8TeV).

7 TeV

$$\sigma_{meas}^{EW\ lljj} = 154 \pm 24\ (\text{stat}) \pm 46\ (\text{syst}) \pm 27\ (\text{theory}) \pm 3\ (\text{lumi})\ \text{fb}$$

NLO prediction from VBFNLO: $\sigma_{NLO}^{EWlljj} = 166$ fb

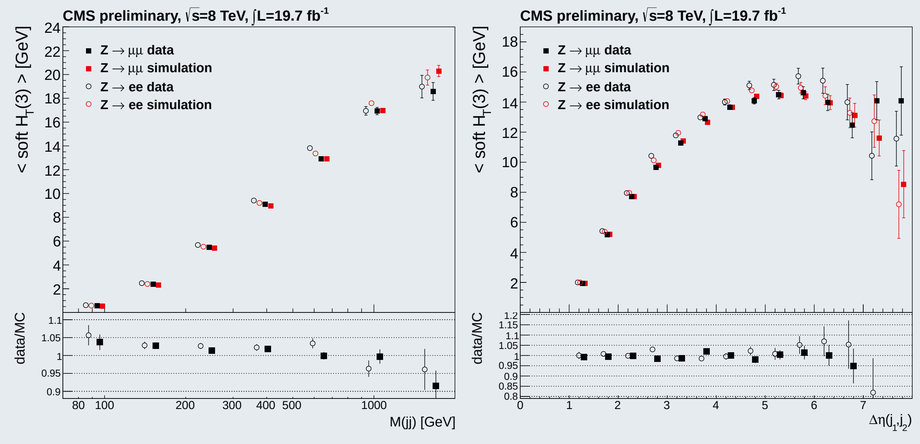
8 TeV

$$\sigma_{meas}^{EW\ lljj} = 226 \pm 26\ (\text{stat}) \pm 35\ (\text{syst})\ \text{fb}$$

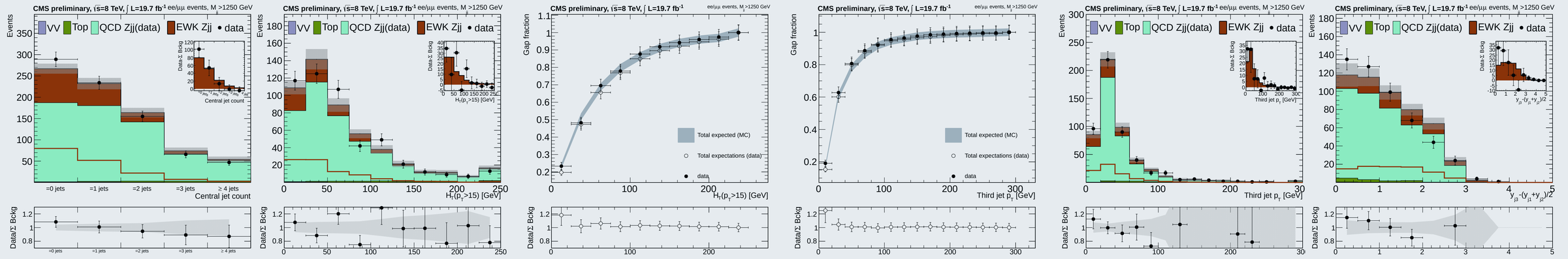
NLO prediction from VBFNLO: $\sigma_{NLO}^{EWlljj} = 239$ fb

Central hadronic activity with soft track jets

The hadronic activity in Z plus 2 jets events is studied using soft track jets, built with tracks of $p_T > 300$ MeV that are associated with the primary vertex in the event. Track-based observables are insensitive to the presence of additional event pile-up interactions. By excluding the tracks associated with the leptons and tagging jets, only the additional track jet emmission is considered. The three leading soft track jets with $p_T > 1$ GeV in the pseudorapidity distance of the tagging jets are selected and their scalar sum of the p_T's versus M_{jj} and $\Delta\eta_{jj}$ is observed to be in good agreement with the simulation.



Central jet activity in a high purity region



A study is done on the emission of a third (and extra) jets in a region with higher signal purity. Only central jets with $p_T > 15$ GeV, which have a pseudorapidty within the tagging jets, are selected. The observed central jet multiplicity and scalar sum H_T of the p_T of these jets is observed to be in good agreement with the prediction.

The efficiency of a hadronic veto has been tested. The gap fraction correspond to the fraction of events which do not have a third jet with a p_T above a given threshold or H_T above a given threshold. Both data-driven and simulation based background prediction agree within uncertainties.

The transverse momentum of the third jet is well described by the predictions. The third jet is observed to be slightly more central than expected as can be seen from the third jet rapidity in the dijet rest frame.

References

- 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 the electroweak production cross section of the Z boson with two forward-backward jets in pp collisions at $\sqrt{s} = 8$ TeV" , CMS Physics Analysis Summary FSQ-12-035

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