Exclusive dilepton production in pp collision at 13 TeV

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An ultra-relativistic proton has a deformed electromagnetic field due to the relativistic contraction. The transverse component of such field can be interpreted as a quasi-real photon - a photon with low value of virtuality $Q^2 = -P_\gamma^2$, where P_γ is four momentum of the photon. On experiments as is the ATLAS at the LHC, a collision of such photons can be studied.

Between the great number of final states of such collision, one particular process resulting in dilepton pair was studied. Feynman diagram of this process is in the Figure 1. Production of the dilepton pair can be used for luminosity measurements, since it contains

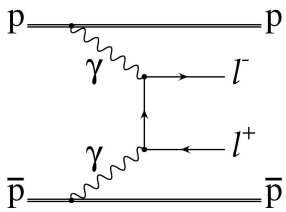


Figure 1: Feynman Diagram of exclusive di-lepton production in proton-proton collision. Taken from [1].

only two particles in the final state and is therefore easily identifiable. Situation is of course more complicated than that and theoretical cross-section is reduced due to additional interactions between the colliding protons. The difference between the theoretical σ^{theory} and measured cross-section σ^{meas} is quantized by so-called survival factor R :

$$\sigma^{meas} = R \cdot \sigma^{theory} \tag{1}$$

The interaction of the quasi-real photons is characteristic by low transverse momentum of the dilepton state. The leptons are therefore back-to-back, which is another factor useful for background subtraction.

The main background to the dilepton production is Drell-Yan process (see Figure 2), which is an interaction between quarks of the colliding protons. Since one of the propagators of this process can be the Z quarks, Drell-Yan is dominated by a resonance around the mass of the Z boson (approximately 90 GeV). Even though Drell-Yan makes up the majority of the final states containing dilepton, it is usually accompanied by a large number of additional particles and has different kinematic properties than the exclusive production and thus its contribution is significantly reduced by carefuly chosen cuts. Second most significant background is dissociation.

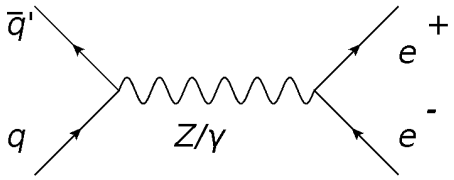
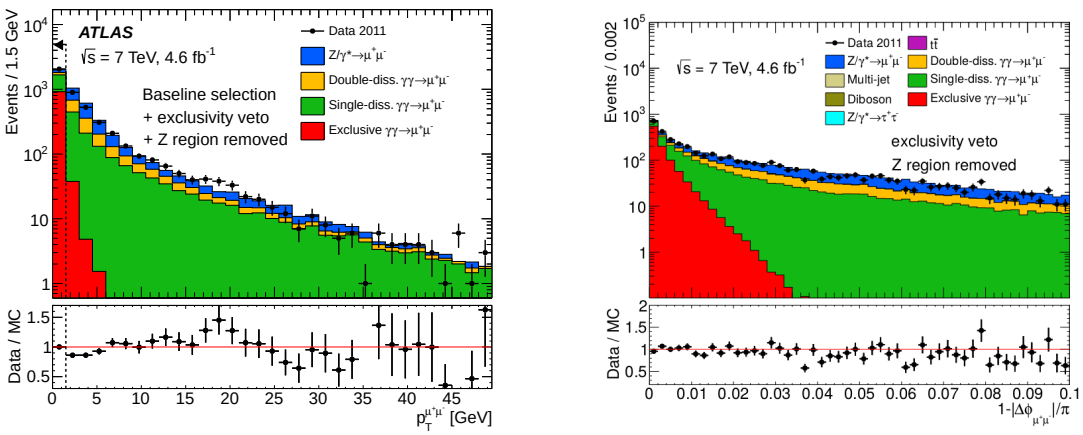


Figure 2: Feynman Diagram of Drell-Yan process. Taken from [2].

Single- and double-dissociation (SD,DD) is process where either one or both colliding protons dissociate - break into variety of final states, most of which have large rapidity. Since the ATLAS detector does not detect all outgoing particles (mainly in the forward rapidity regions), such events are often indistinguishable from the exclusive production. Mainly the SD contribution is significant even after all cuts and is subtracted using a fit of the exclusive and the single-dissociative distributions on the data.

Since the ATLAS has large number of collisions per bunch crossing, we cannot simply look for events with only two leptons and nothing else. Exclusive events can however be identified by requesting only two particles in proximity of the dilepton vertex (this selection is called exclusivity cut). Furthermore, the contribution of the Drell-Yan can be significantly reduced by removing events in the mass window around the Z-mass peak.

Finally, since the leptons are back-to-back and the dilepton system has low transversal momentum, it is useful to cut either on the angle between the two leptons (acoplanarity) or on the p_T of the dilepton. Spectrum of the dilepton pairs as function of acoplanarity and p_T from previous analysis can be found in Figure 3. This analysis was done for



(a) (b)

Figure 3: Results of exclusive dilepton analysis at 7 TeV with the ATLAS and CMS experiments. Taken from [3].

energy $\sqrt{s} = 7$ in both the ATLAS and CMS at the LHC. The results are summarized in Figure 4. The survival factor R was found to be around 80%.

The $\sqrt{s} = 13$ TeV analysis is already in progress. Aside from producing result for the new energy, examination of dependence of the survival factor on various variables (e.g. $m_{l^+l^-}, p_{T,l^+l^-}$) is planned. Current focus is on the Monte Carlo production and preliminary examination of the data from 13 TeV.

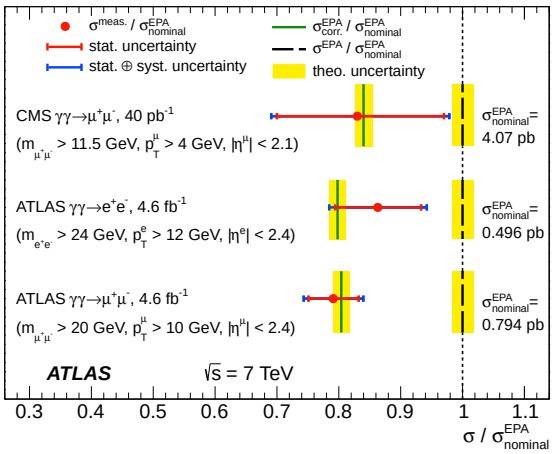


Figure 4: Results of exclusive dilepton analysis at 7 TeV with the ATLAS and CMS experiments. Taken from [3].

For some period of the 2015 LHC run, a low-p_T muon trigger was used. This allows us to do the analysis for lower transverse momentum of the muon. Preliminary results show circa 13% more selected events if the low-p_T muon trigger is implemented. Otherwise situation is similar to 7 TeV and it seems it will not be necessary to make significant adjustments to the cuts.

References

[1] Michael Albrow and Emily Nurse, A search for exclusive Z→ll events and a measurement of the $pp \to p\gamma\gamma p \to pllp$ cross section for dilepton invariant mass > 40 GeV/c^2, http://www-cdf.fnal.gov/physics/new/qcd/exclZ_08/exclusive/

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[2] nxhlh.com, Collision symmetry and measuring the asymmetry in the Drell-Yan process, http://www.nxhlh.com/collision-symmetry-and-measuring-the-asymmetry-in-the-drell-yan-process/

[Cited on 22. 2. 2016]

[3] Measurement of exclusive $\gamma\gamma \to l^+l^-$ production in proton-proton collisions at $\sqrt{s}$=7 TeV with the ATLAS detector, Phys.Lett. B749 (2015) 242-261