Photon-initiated production of a di-lepton final state at the LHC: cross section versus forward-backward asymmetry studies

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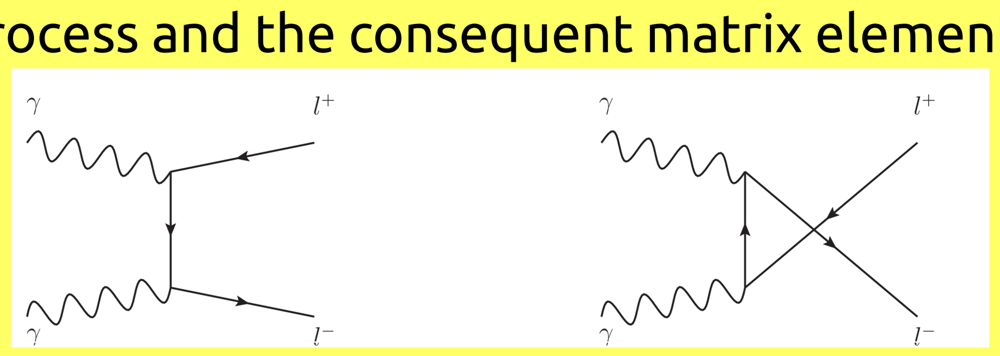
The LHC as photon collider

Although being an hadron collider, the LHC has successfully explored the Electro-Weak sector of the Standard Model, culminating with the Higgs discovery in 2012. We are able to extract high precision measurement in a huge hadronic background noise thanks to the good understanding of the proton structure. PDFs collaborations have greatly improved recently by including new high precision data from HERA and Fermilab. Theoretical uncertainties follow the same trend, since NLO and NNLO QCD corrections have been extensively discussed together with QED corrections.

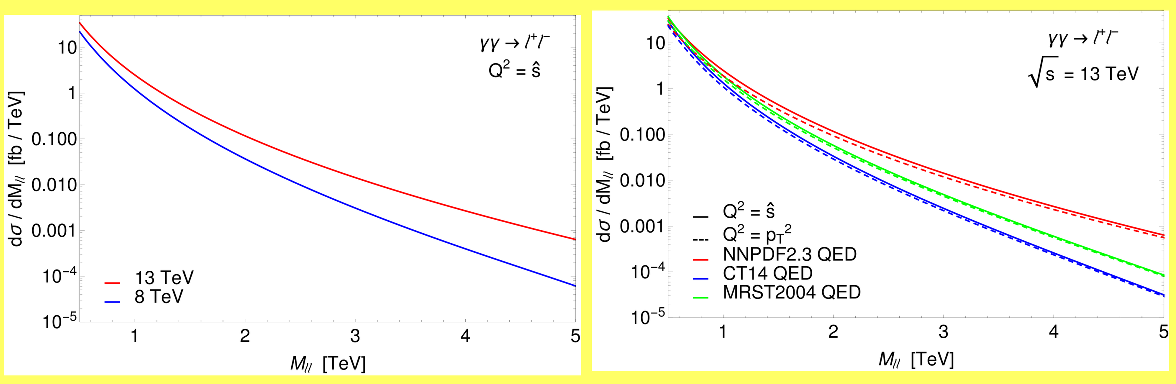
In order to be consistent with the partonic matrix elements, the PDF sets indeed should have both QCD and EW corrections in the Dokshitzer-Gribov-Lipatov-Altarelli-Parisi (DGLAP) evolution kernels. Also recently PDFs collaborations have consistently included the photon in this picture considering it as a parton constituent of the proton.

Real photons from QED PDFs

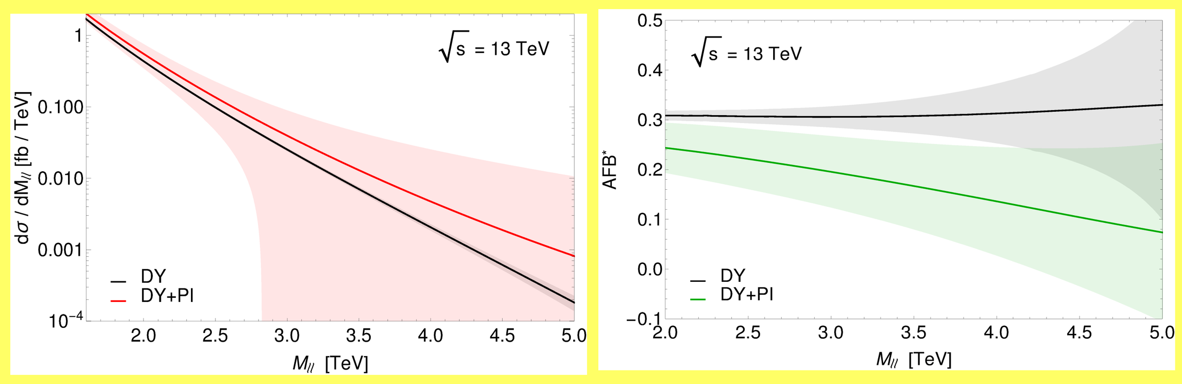
With those new PDF sets we can include the contribution of those real photon (zero virtuality) that are not accounted in the Equivalent Photon Approximation (EPA), which instead can be used to estimate the contribution of quasi-real photon (small virtuality). We have considered the contribution of Photon Initiated (PI) processes to the dilepton channel. This is indeed the golden channel for the detection of BSM neutral resonances through Drell-Yan (DY) production, and for this purpose is mandatory to have a precise determination of the SM background. The interaction of two photons produces a dilepton pair in the final state through the exchange of a fermion in the *t*- or *u*- channels. The Feynmann diagrams contributing this process and the consequent matrix element are given below:



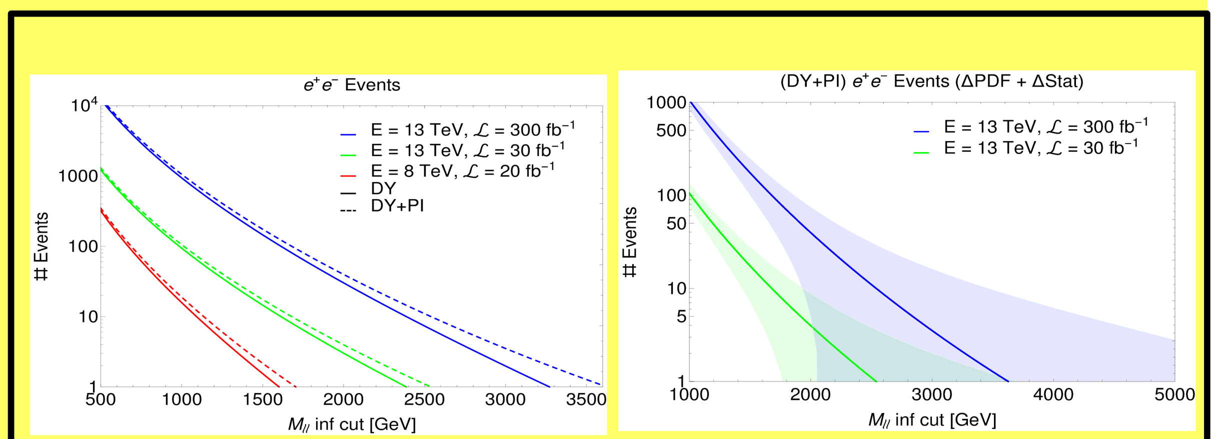
$$|\mathcal{M}|^2 = 2e^4\left(\frac{u}{t}+\frac{t}{u}\right)$$



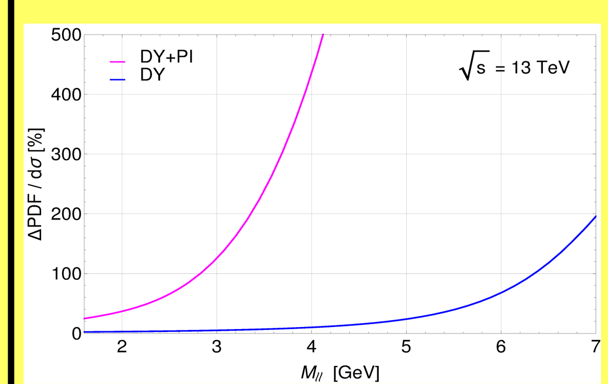
The PI contribution to the dilepton channel is substantial. It affects the SM background shape especially at high invariant masses. The NNPDF2.3QED prediction (left plot) is compared with the CT14QED and MRST2004QED results (right plot) for two different factorization scale choices. The discrepancies between different PDF collaborations predictions can be large.



The NNPDF2.3QED set is provided with a set of "replicas" that can be used to estimate the systematic PDF uncertainty. The central values predicted by the different collaborations are now consistent within the error, that comes out significantly large (left plot). Still we can exploit the feature of observables like the Forward-Backward Asymmetry (AFB) since, being a ratio of cross section, systematic effects are here naturally cancelled (right plot).



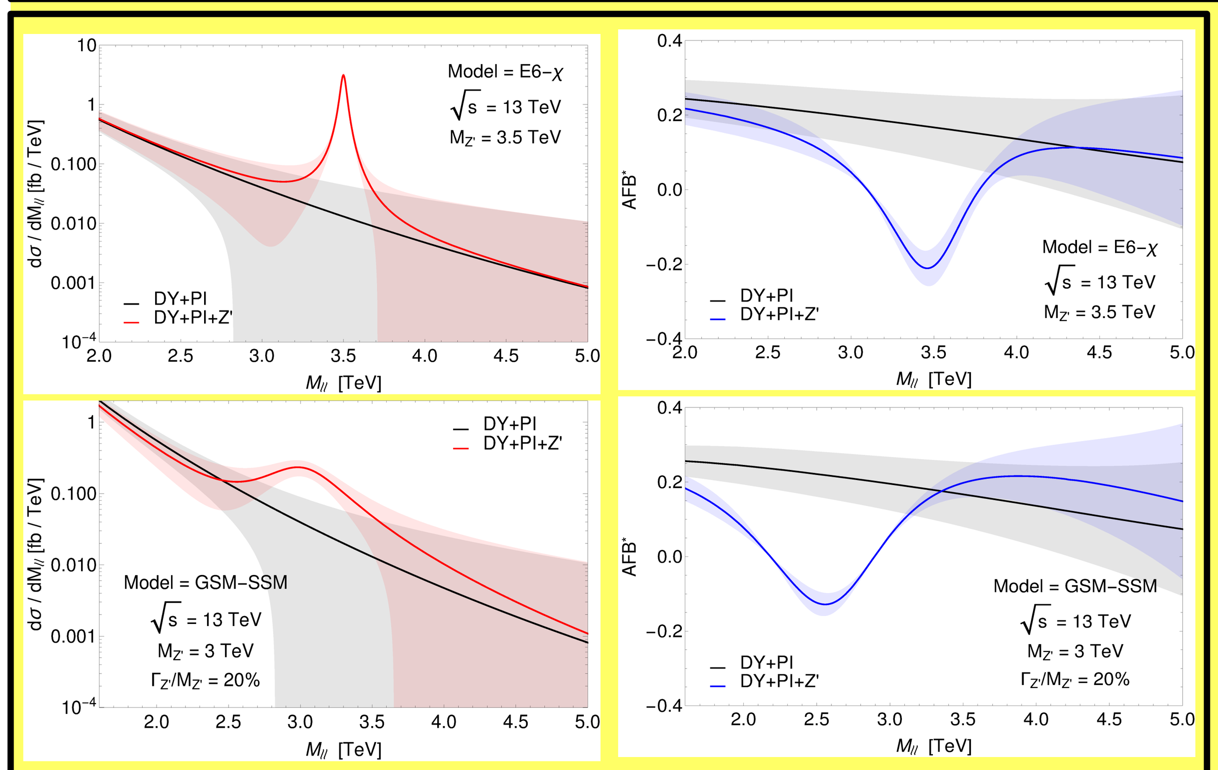
The SM prediction on the number of events has to take into account the PI contribution and its uncertainty. The latter strongly limits the theoretical predictive power.



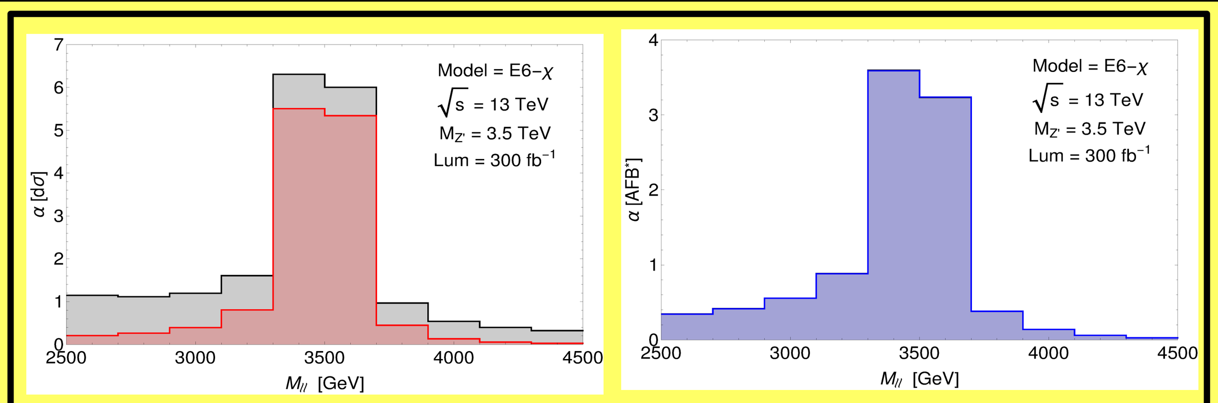
The high invariant mass region of the dilepton spectrum is dominated by the error.

BSM searches in PI background

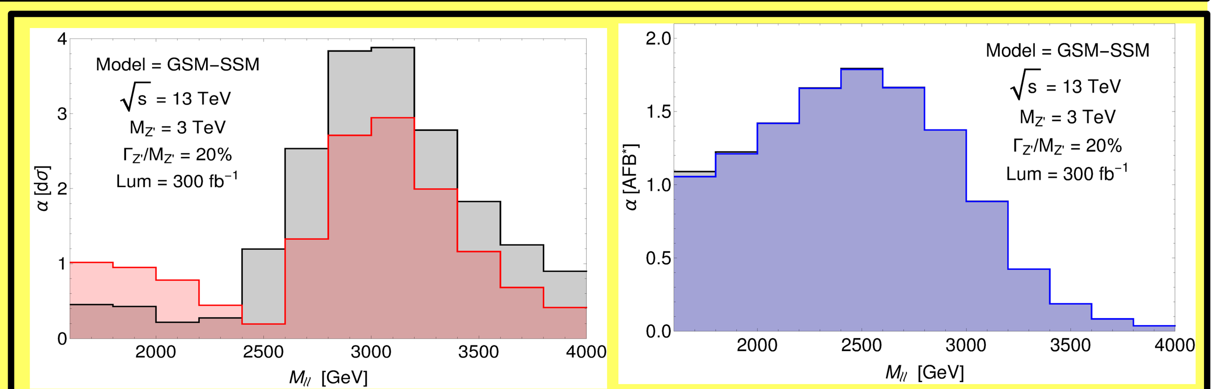
Neutral spin-1 heavy resonances (***Z'***s) are predicted in several BSM models and in the dilepton channel often we have the best sensitivity on their signal. In the experimental analysis for these objects, either through a "bump" search or a "counting event" strategy for the two scenarios of narrow and wide resonances respectively, the inclusion of the PI events as part of the SM background is crucial. We are showing this effect in the case of two benchmark models for the study of ***Z'*** phenomenology, the **E6-χ** and the **Sequential Standard Model (SSM)**, which cover both the narrow and wide resonance cases. Being much less affected by systematic effects, we recommend the inclusion of the AFB observable to support the analysis.



Invariant mass and AFB distribution in presence of ***Z'***s as predicted in two benchmarks. The shaded areas represent the PDF uncertainty.



Significance of the narrow ***Z'*** signal for the two observables: in the coloured areas we have correctly included the PI events in the signal, while in the grey areas they are considered as part of the BSM signal. The AFB observable appear more stable since the PI process do not produce any angular asymmetry.



In the non resonant case, the correct modelling of the SM background is even more essential since many PI events are expected in the high invariant mass region during high luminosity stages. Here the AFB provides an important support not only for the interpretation, but also for the discovery of non resonant objects.

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