High Energy Photon Interactions at the LHC

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Abstract. Experimental prospects for studying high-energy photon interactions at the LHC are discussed. Rôle of the forward proton detectors in selection and reconstruction of such events is briefly described. Physics cases for the two-photon fusion and photon-proton interactions are introduced. Several examples, as the associated WH photo-production, or two-photon production of supersymmetric pairs are given. Finally, a possibility of studying the photon interactions in ion collisions is shortly discussed.

Keywords: photon-photon and photon-proton interactions, electroweak processes, Higgs boson, searches for supersymmetry.
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INTRODUCTION

The proton beam energy of the LHC will be so high that not a negligible fraction of the *pp* collisions will involve high energy two-photon (and photon-proton) processes, where the protons emitting a photon will survive the interaction. Such protons are scattered at very small angles, comparable to the beam angular divergence at the interaction point (IP). The scattered protons can however be measured when a significant fraction of the initial proton energy is carried away by a photon. In such a case these protons are more strongly deflected by the beam-line magnets and can be detected in the so-called Roman pots installed far away from the IP and close to the proton beam. Tagging photon interactions using forward proton detectors opens up a novel domain of research at the LHC [1]. The *double tagging* corresponds to the case when the two scattered protons are detected, whereas the *single tagging* occurs when only one proton is detected. In this case, however also those two-photon events are tagged where one proton does not survive the interaction. In fact, these *inelastic* two-photon events have even higher effective luminosity than the nominal, *elastic* events. The effective luminosity, available for the tagged two-photon collisions, reaches 1% of the *pp* luminosity for the $\gamma\gamma$ center of mass energy W > 100 GeV. One should note also that the luminosity spectrum extends to large values of W, even beyond 1 TeV.

The ultimate resolution of the scattered proton momentum is determined by the beam properties at the IP, its lateral size and angular divergence [1]. Good resolution of p_T is essential in case when a good separation of the two-photon and pomeron-pomeron events is needed.

Similarly, one can identify photo-production processes. Here, the effective luminosity of photon-quark (or photon-gluon) collisions is much higher and extending to even higher energies. In Figure 1 the γq luminosity S_γ (and its integral) is shown as a function of the photon-quark *cms* energy. This quantity can be used, assuming factorization, to convert γp to *pp* cross sections as follows: $\sigma_{pp} = \int\sigma_{\gamma p}(W)S_\gamma(W)dW$. Similar values of S_γ have been obtained for the effective photon-gluon luminosity.

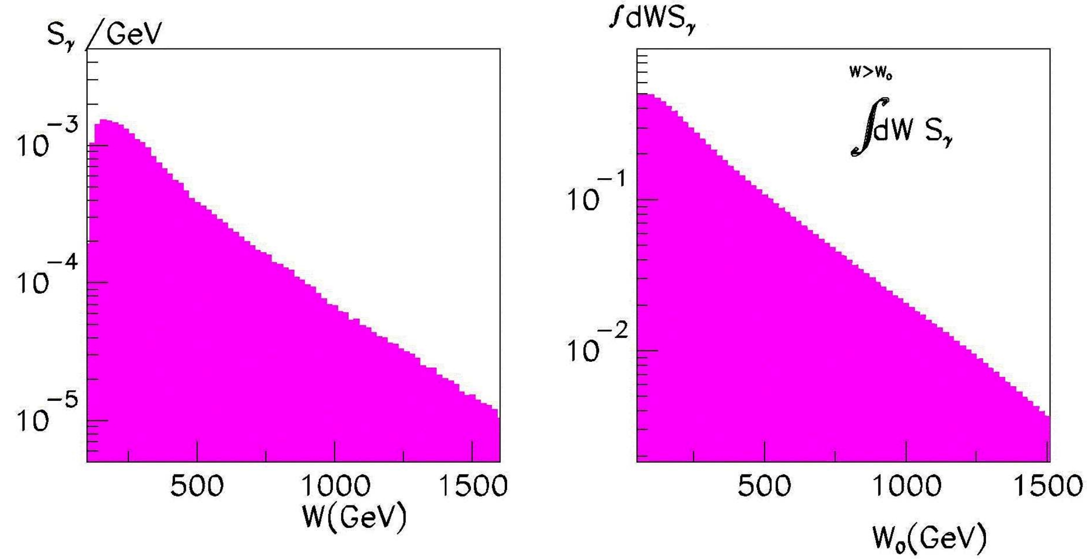

FIGURE 1. Effective luminosity spectrum S_γ of the photon-quark collisions (left plot), using MRST2001 pdfs; and its integral between an initial cms energy W_0 and the kinematical limit (right plot).

PHYSICS CASE

γγ collisions

Possibility of using γγ collisions at the LHC to search for new particles was already considered theoretically some time ago – see, for example [2]. The exclusive production of the Standard Model (SM) Higgs boson has been an especially attractive case, but the corresponding cross section is small [3]. This is quite opposite for the W boson pair production via the γγ fusion – the cross section at the *pp* level is large, above 100 fb, and the average *cms* energy is high, above 300 GeV. Detecting these events would allow for very significant improvement (with respect to the present limits), in sensitivity to anomalous quartic gauge couplings [4]. Similar results are obtained for the $\gamma\gamma \rightarrow ZZ$ process (in the SM strongly suppressed).

If the super-symmetric particles exist and are not too heavy they could be also studied in a very complementary way using the exclusive γγ production. In Figure 2 the tagged production rates of pairs of charginos, charged Higgses and sleptons are shown. Clearly, if the sparticle masses are in the 150–250 GeV range, the number of events becomes interesting already for the low luminosity running of the LHC. One should note that contrary to the inclusive case, one is dealing here with very simple production mechanism and final states, as well as much better constrained initial state.

γp collisions

The Higgs boson associated photo-production at the LHC, $\gamma p \rightarrow WHX$, yields a cross section above 50 fb for $M_H < 170$ GeV. This is naturally much smaller than for the inclusive case but has much more favorable background conditions. For example, the cross section of the main reducible $\bar{t}t$ background is almost thousand times bigger than the WH signal in the inclusive case, but only about 50 times in case of the photo-production [5]. Similarly, the irreducible background $\bar{b}bW$, for $H \rightarrow \bar{b}b$, is more than 100 times bigger for the inclusive case and is only a couple of times bigger for photo-production. The higher signal-to-background ratio and better event reconstruction (thanks to photon energy measurement and less busy event ‘environment’) in the WH photo-production, should allow to provide a useful and complementary information for not too heavy Higgs boson.

In addition, the $\bar{t}t$ photo-production is interesting by its own. It has a respectable cross-section of about 3 pb and proceeds mainly via the photon-gluon fusion. The high statistics samples should be therefore collected and used for precision measurement of the top mass and its charge, for example.

Finally, the single W photo-production, $pp \rightarrow pWX$, at high transverse momentum will be studied in a very similar way as the related process, $ep \rightarrow eWX$, at HERA. High statistics samples will be again available and should allow for stringent tests of the SM.

Ion collisions

In ion collisions at the LHC photon interactions are strongly enhanced due to coherent coupling to the large ion charge Z. For example, two-photon interactions in the coherent domain scale as Z^4. This usually leads to improved signal to background ratio, as the latter often scales like A^2. This opens up new, very interesting field of research including both photon-photon and photon-nucleon interactions, and studies of low-x phenomena, heavy quark production, or of the electroweak processes as the W pair production via γγ fussion, for example [6].

Recently proposed forward detectors will be crucial for these studies allowing for detection of protons in pA, and light ions in AA interactions [7].

CONCLUSIONS

Preliminary results of novel studies of the photon-induced processes at the LHC strongly indicate that it could provide valuable and complementary information to the nominal measurements, in particular in the electro-weak sector. Forward proton detectors are instrumental in this context [7].

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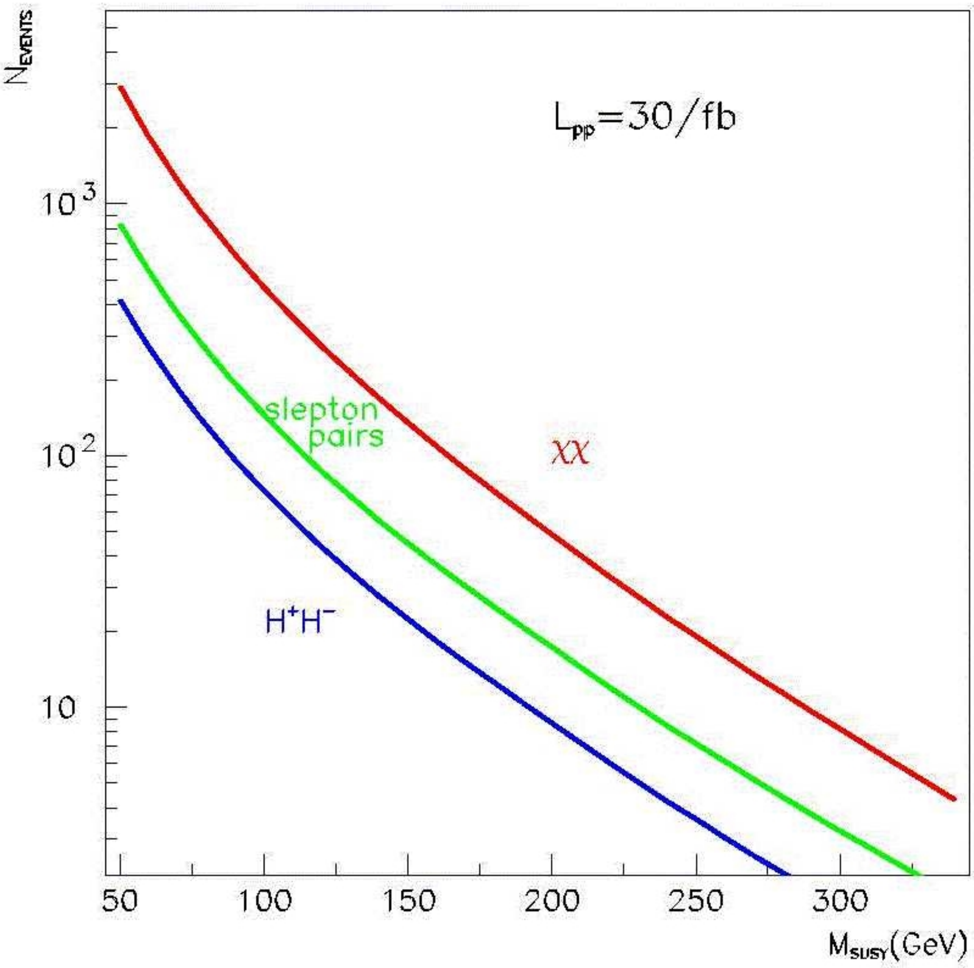

FIGURE 2. Number of super-symmetric pairs produced, assuming single tagging and the 30 fb^{-1} integrated luminosity, as a function of the chargino, slepton and charged Higgs mass, respectively. The 70–700 GeV photon tagging range is assumed.

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