Thesis

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Abstract

This paper reviews

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1 The Wγ Process

1.1 Standard Model Wγ Production

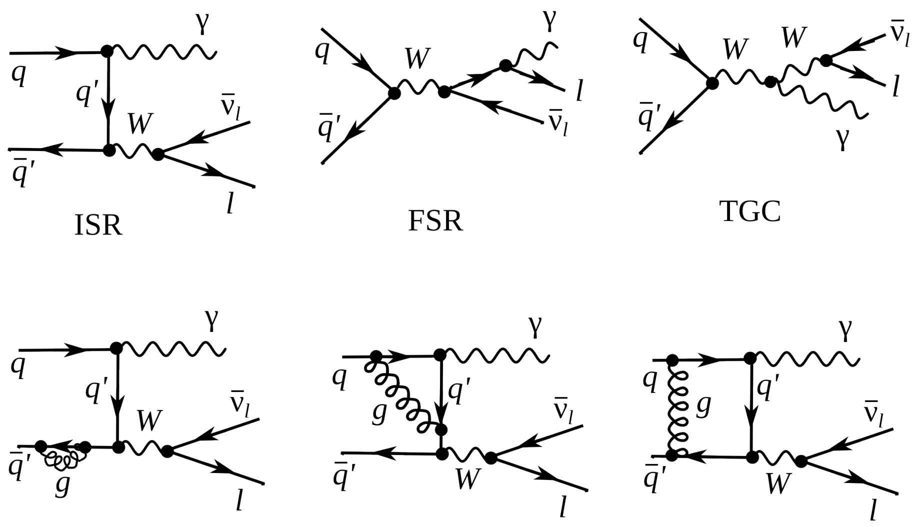

Figure 1: Feynman diagrams of Wγ production

The cross section of an interaction of two particles can be interppreted as an area around one of the particles which has to be crossed by the other particles so that these two particles would interact. The cross section characterizes the probability of two particles to interact. In the narrower case, the propability of two particles to interact in the exactly way to give a given final state.

A number of particles passing through the area $d\sigma$ per unit time is $dN = L \cdot d\sigma$, where L is the luminosity (the number of particles passing through the unit area per unit time). This expression is used to measure the cross section in collision experiments. The actual quantity which can be measured is a number of events of a given process and the luminosity is determined by collider characteristics. L may not be uniform in time however we are usually interested in measuring the total or differential cross section as a function of a certain kinematic paratemeter of a final state particle or of a system of final state particles.
However, to measure the cross section we need to know total number of events of the given process but we cannot detect events which are out of the detector acceptance or which do not fall into the selection criteria we are using in the analysis. Therefore, the bnumber of events dN has to be corrected in a measurement: $dN \rightarrow \frac{dN}{A \cdot \epsilon}$, where A is a detector acceptance and ϵ is an efficiency of a signal process to pass selection conditions. Other corrections to dN may have to be applied depending on the analysis.

To compute a cross section theoretically, one has to use Fermi's Golden rule which for the scattering of two particles
$1 + 2 \rightarrow 3 + 4 + ... + n$
has the following form:

$$\sigma = \frac{S\hbar^2}{4\sqrt{(p_1 p_2)^2 - (m_1 m_2 c^2)^2}} \int |M|^2 (2\pi)^4 \delta^4(p_1 + p_2 - p_3 - p_4 - ... - p_n) \prod_{j=3}^{n} \frac{1}{2\sqrt{\bar{p}_j^2 + m_j^2 c^2}} \frac{d^3\bar{p_j}}{(2\pi)^3}$$

To estimate the amplitude M, one has to use the Feynman calculus.

In case of $W\gamma$, it is the probability of a quark and an antiquark to annihilate with the production of a lepton ($\mu^{\pm}$ or $e^{\pm}$), a neutrino or antineutrino and a photon. The corresponding Feynman diagrams in the LO are shown in Fig. 1, top.

There are many NLO corrections are possible to these diagrams. QED corrections would mean radiations of extra photons by charged particles, exchange of photons between different charged particles or a photon can be radiated and absorbed by the same charged particle forming a loop. Similarly, weak corrections are possible however they would be much weaker than the QED corrections. But even the QED corrections are too weak compared to QCD corrections which include gluon loops at the same quark line and exchange of a gluon between two different quark lines (Fig. 1, bottom).

1.2 Anomalous Wγ Production

ATGC

Maybe, general words about ATGC, where does it come from

How it would affect the distributions and cross section

Specific for Wg process, WWg TGC

1.3 Measurements in the Past

1.3.1 Measurement of the Wγ cross section in pp collisions at $\sqrt{s} = 7$ TeV at CMS

The most recent measurement of the Wγ cross section by the CMS is performed based on 5 fb^{-1} of data collected in 2011 at $\sqrt{s}$ =7 TeV of LHC. The measurement was performed in the $e\nu\gamma$ and $\mu\nu\gamma$ final states. Only photons with the transverse momenta of p_T^γ >15 GeV were considered. The same CMS detector was used as for the analysis reported in this disseratation. The detector is described in Sec.[REFERENCE].

For the $W\gamma \rightarrow \mu\nu\gamma$ events the isolated single muon trigger is used, it includes requirements of p_T^μ >30 GeV and $|\eta^\mu|$ <2.4(2.1) for Run 2011A(2011B). For the electron channel, the isolated single electron trigger was used. The trigger requirements were p_T^e >32 GeV except a small fraction of data where it was p_T^e >27 GeV, $|\eta_3|$ >3, M_T^W >50 GeV, where $M_T^W = \sqrt{2 \cdot p_T^e \cdot MET \cdot (1 - cos\Delta\phi(e, MET))}$ is a transverse mass of a W boson.

The Wγ process signature is a prompt,isolated photon, a prompt isolated energetic lepton (μ or e) and a significant missing trensverse energy due to the neutrino. Therefore, the event-level selection requirements included one well-identified lepton with kinematic requirements p_T^l >35 GeV, $|\eta^\mu|$ <2.1, η^e <2.5, one well-identified photon with p_T^γ > 15 GeV, $|\eta^\gamma|$ <2.5, and M_W^T >70 GeV. To reject events from $Z\gamma \rightarrow ll\gamma$ process, events with the second reconstructed lepton of the same flavor were vetoed. The second muon veto requirements included p_T^μ >10 GeV, $|\eta^\mu|$ <2.4. The second electron veto requirements included p_T^μ >20 GeV, $|\eta^\mu|$ <2.5, and weak electron identification criteria. The separation between a photon and a lepton were required to be $\Delta R(l, \gamma) = \sqrt{\Delta\eta(l, \gamma)^2 + \Delta\phi(l, \gamma)^2}$ >0.7.

The $p_T^\gamma > 15 GeV$ and $\Delta R(l, \gamma)$ >0.7 are also phase space requirements. They are necessary to avoid divergence of the total cross section and also to supress the contribution from the FSR diagram and, therefore, make the TGC contribution more significant.

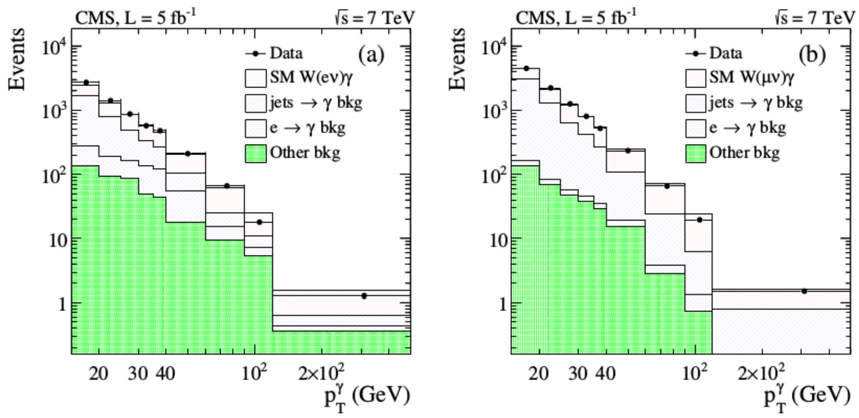

Figure 2: The distribution fo the p_T^γ of Wγ candidates in the analysis of 7 TeV CMS data. Data vs signal MC + background estimates. Left: $W\gamma \rightarrow e\nu\gamma$, right: $W\gamma \rightarrow \mu\nu\gamma$. Figure from [REFERENCE]

Events selected according with the criteria described represent a mixture of the signal and background events. The major source of the background is the fake photon background where hadronic jets are misidentified as photons. Such events originate from W+jets process mostly but Z+jets and $\bar{t}t$+jets events contribute to this source of the background as well. The template method was used as a major method to estimate this background. The shower-shape variable $\sigma_{i\eta i\eta}^\gamma$ was used as a discrimination variable. The ratio method was used as a cross check by measuring and comparing the probabilities for jets to pass photon or jets selection criteria.

The second major background for the electron channel is the fake photon background where electron can be misidentified as a photon. Such events are coming from Z+jets events. Diboson processes contribute to this background for both channels. The fake rates are estimated from the $Z \to ee$ sample, by checking how often one of the electrons would pass photon selection criteria given the other one passed stringent electron selection criteria.

Other sources of backgrounds include real-γ backgrounds, fake lepton + real photon and fake lepton + fake photon sources.

The p_T^γ spectra of the selected events in data superimposed with selected events in the simulation of the signal and estimated background contribution for the muon and electron channels are shown in Fig. 2. The figure shown a good agreement within the estimated uncertainties.

The estimated cross sections are:
$\sigma(pp \to W\gamma \to e\nu\gamma)$=36.6±1.2(stat.)±4.3(syst.)±0.8(lumi) pb
$\sigma(pp \to W\gamma \to \mu\nu\gamma)$=37.5±0.9(stat.)±4.4(syst.)±0.8(lumi) pb
And the combination result:
$\sigma(pp \to W\gamma \to l\nu\gamma)$=37.0±0.8(stat.)±4.0(syst.)±0.8(lumi) pb

The paper also provides the cross section measurements for p_T^γ >60 GeV and for p_T^γ >90 GeV. The combination of two channels for p_T^γ >60 GeV is σ =0.76±0.05(stat.)±0.08(syst.)±0.02(lumi) pb while the theoretical NLO prediction is σ =0.58±0.08 pb. The result for p_T^γ >60 GeV is σ =0.200±0.025(stat.)±0.038(syst.)±0.004(lumi) pb while the theoretical NLO prediction is σ =0.173±0.026 pb.

1.3.2 Measurement of the Wγ cross section in pp collisions at $\sqrt{s}$ = 7 TeV at ATLAS

ATLAS collaboration also required each candidate event to have an exactly one lepton, at least one isolated photon and a significant missing transverse energy. The phase space requirements are the same as those for CMS: p_T^γ > 15 GeV and $\Delta R(l, \gamma)$ >0.7 however other selection critea are slightly different: p_T^l > 25 GeV, E_T^{miss} >35 GeV, M_T^W > 40 GeV. In the electron channel Z mass window cut was applied to reduce the contribution from $Z \to e^+e^-$ events.

The sideband method was used to estimate the major background (jets→ γ).

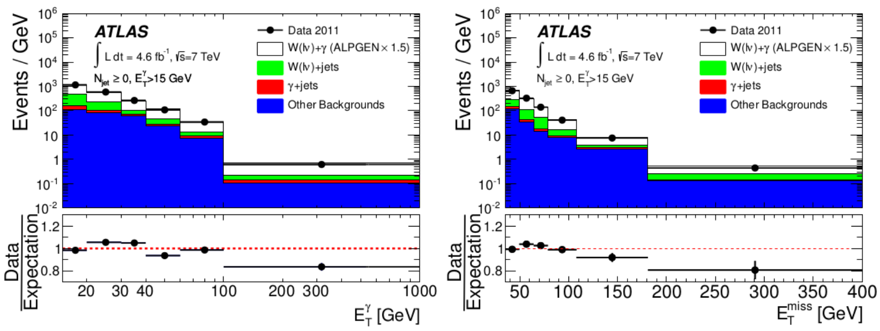

Figure 3: The distribution fo the p_T^γ (left) and E_T^γ (right) of Wγ candidates in the analysis of 7 TeV ATLAS data. Data vs signal MC + background estimates. Figure from [REFERENCE]