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DIPHOTON PRODUCTION AT HADRONIC COLLIDER

J. PH. GUILLET
LAPTH
Chemin de Bellevue B. P. 110
F-74941 Annecy-le-Vieux
E-mail: guillet@lapp.in2p3.fr

The main interest of double photon production is that it will be an important background for the Higgs search at LHC if the mass of the Higgs boson is light enough (i.e. $m_H < 140$ GeV). With this respect, the Tevatron enables us to make a precise comparison between theory and experiments.

1 Theoretical content of DIPHOX

The DIPHOX program [1] incorporates consistently three contributions computed at NLO accuracy. The "direct" contribution where the two photons are emitted directly from the partonic subprocess. The "one fragmentation" contribution in which one of the photons comes from the collinear fragmentation of a hard parton produced in the partonic subprocess, the other being emitted directly. And the "two fragmentation" contribution where both photons result from the collinear fragmentation of a hard parton. One must keep in mind that this distinction is schematic and ambiguous. We remind that it comes technically from the appearance of final state collinear singularities, which are factorized and absorbed into fragmentation functions at some arbitrary fragmentation scale. Each of the contributions associated with these three mechanisms thus depends on this arbitrary scale. This dependence on M_f cancels only in the sum of the three, so that only this sum is a physical observable. In addition, the "direct" contribution includes also the $\mathcal{O}(\alpha_s^2)$ box contribution $gg \to \gamma\gamma$. Whereas it is a NNLO contribution from the point of view of power counting, in the range of interest at LHC, the gluon luminosity is so large compared with the quark and antiquark one, that it nearly compensates the extra powers of α_s.

2 Other existing NLO codes

Other codes computing diphoton production at NLO accuracy exist, they are listed below.

	type of code	Direct	One Frag.	Two Frag.
Aurenche et al. [2]	I/FO	NLO	LO	none
Owens et al. [3]	G/FO	NLO	LO	none
DIPHOX	G/FO	NLO	NLO	NLO
RESBOS [4]	G/SGS	NLO	LO	none

The acronyms in the column "type of code" mean:

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I :	Inclusive
G :	Generator
FO :	Fixed Order
SGS:	Soft Gluon Summation

3 Comparison with CDF data

To test the diphoton prediction, we used the preliminary CDF runII data [5]. The following cuts are used: $P_{T\gamma_1} > 14$ GeV, $P_{T\gamma_2} > 13$ GeV, $|y_{\gamma_{1,2}}| < 0.9$. In order to remove the π^0 background, an isolation criterion is used: $E_T^{had} \leq 4$ GeV in a cone of $R_{exp} = 0.4$. Also, to prevent the two photons to be collinear, an acollinearity cut is applied: $R_{min}\ :\ \sqrt{(y_{\gamma_1} - y_{\gamma_2})^2 - (\Phi_{\gamma_1} - \Phi_{\gamma_2})^2} > 0.3$. The scale choice is taken: $\mu = \mathrm{M} = \mathrm{M}_f = M_{\gamma\gamma}/2$ and the CTEQ6M [6] parton densities are used.

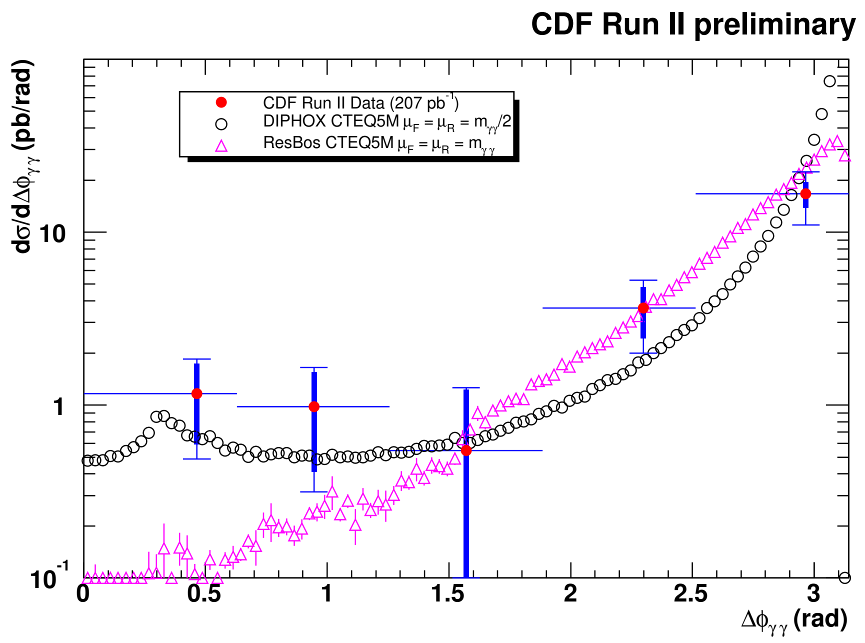

Figure 1. Azymuthal angle distribution between the two photons compared with Run II CDF data

Being based on a fixed, finite order calculation, our computer code is not suited for the study of observables controlled by multiple soft gluon emission, and has to be improved in this direction. Among these infrared sensitive observables, one may distinguish the following examples, most of which would require an improved account of soft gluon effects.

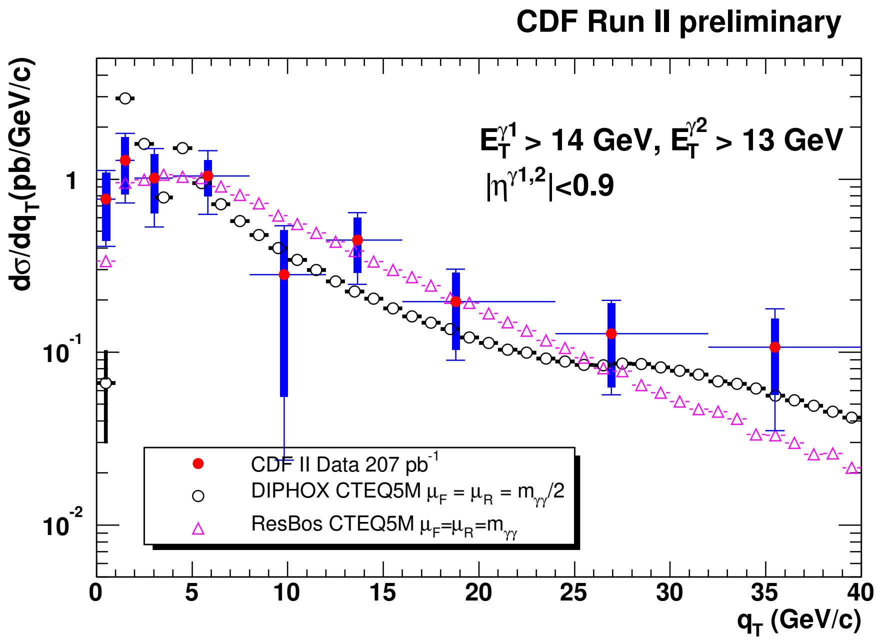

Figure 2. Transverse momentum distribution of photon pairs compared with Run II CDF data

4 Infrared sensitivity near the elastic boundary

4.1 The transverse momentum distribution $d\sigma/dq_T$ of photon pairs near $q_T = 0$

Both in the inclusive and isolated cases, this distribution is infrared sensitive observable, controlled by the multiple emission of soft and collinear gluons. A loss of balance between the contribution of real emission, strongly suppressed near this exclusive phase space boundary, and the corresponding virtual contribution, results in large Sudakov-type logarithms of m^2/q_T^2 (m being a typical scale, the invariant mass for example) at every order in perturbation. In order to make sensible predictions in this regime, these Sudakov-type logarithms have to be resummed to all orders. The treatment of the "direct" and box contributions is similar to the well-known Drell-Yan process, and has been carried out by [4] at next-to-leading logarithmic accuracy in RESBOS. On the other hand, the fragmentation contributions do not diverge order by order when $q_T \to 0$. Indeed, the extra convolution associated with the fragmentation involves an integration over the fragmentation variable which smears out this integrable singularity.

4.2 The distribution of photon-photon azimuthal angle $d\sigma/d\phi_{\gamma\gamma}$ near $\phi_{\gamma\gamma} = \pi$

This distribution is another interesting infrared sensitive observable, measured by several experiments both at fixed target and collider energies [7,8,9], though less discussed in the literature from the theoretical side. The regime $\phi_{\gamma\gamma} \to \pi$ includes back-to-back photons, a set of configurations which lie at the elastic boundary of the phase space. This case differs from the previous one for two reasons. Firstly, not only the "direct" contribution diverges order by order when $\phi_{\gamma\gamma} \to \pi$, but also both "one-" and "two fragmentation" contributions diverge as well. Secondly, in both fragmentation cases, soft gluons may couple to both initial and final state hard emitters. The resulting color structure of the emitters is more involved than in the "direct" case. Let us notice that both fragmentation components make $d\sigma/d\phi_{\gamma\gamma}$ diverge also when $\phi_{\gamma\gamma} \to 0$. The increase of the fragmentation contributions in the lower $\phi_{\gamma\gamma}$ range is the trace of this divergence, cf. Fig. 1.

5 An infrared divergence *inside* the physical region.

In the case of photons isolated with the standard fixed cone size criterion, a new problem appears in the q_T distribution. This can be seen on Fig. 2, which shows the observable $d\sigma/dq_T$ vs. q_T for isolated photon pairs, computed at NLO accuracy. The computed q_T distribution turns out to diverge when $q_T \to E_{T\,max}$ from below. Notice that the critical point $E_{T\,max}$ is located *inside* the physical region. According to the general analysis of [10], the NLO correction to $d\sigma/dq_T$ has a double logarithmic divergence at the critical point $q_T = E_{T\,max}$.

To conclude, the Tevatron diphoton data are understood although some work on the summation of large logarithms of infrared origin remains to be done before the start of the LHC.

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