AN ORDER α_s MONTE CARLO CALCULATION OF HADRONIC DOUBLE PHOTON PRODUCTION

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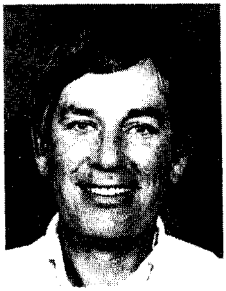


The results of an order α_s calculation of hadronic double photon production are discussed and compared with data from both colliding beam and fixed target experiments. The calculation utilizes a combination of analytic and Monte Carlo integration methods which make it easy to calculate a variety of observables and impose experimental cuts.

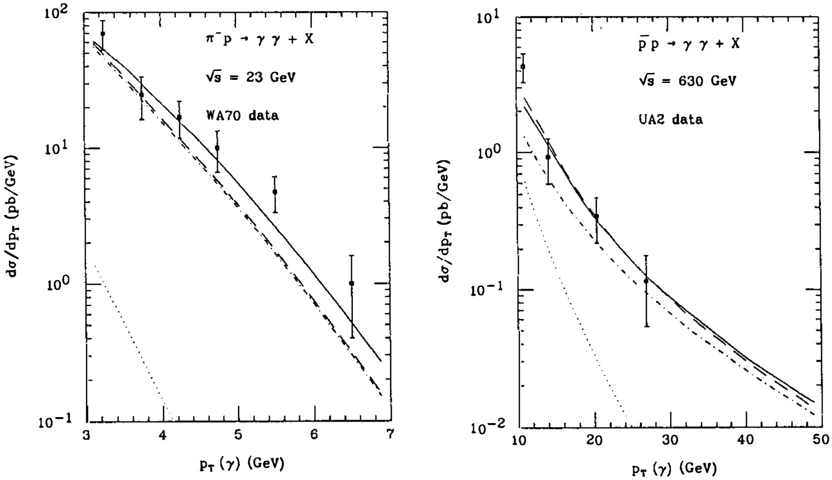
1. INTRODUCTION

In this report I will briefly present some results from a next-to-leading-logarithm (NLL) calculation of photon pair production[1]. It has generally been found that NLL calculations yield results with decreased sensitivity to the choices of the renormalization and factorization scales as compared to leading-logarithm (LL) calculations, thereby improving the precision of the theoretical results. At the LL level, the calculation of the two-photon cross section consists of four distinct contributions: 1) the Born term $q\bar{q} \to \gamma\gamma$, 2) the single bremstrahlung contributions from $gq \to \gamma q$ and $q\bar{q} \to \gamma g$ where the final state parton fragments into a photon, 3) double bremsstrahlung processes involving quark-quark, quark-gluon, and gluon-gluon subprocesses where both final state partons fragment into photons, and 4) the box contribution $gg \to \gamma\gamma$ where the gluons and the photon couple via a quark loop. The latter process is actually one order higher in α_s than the other three types, but it can make a significant contribution at collider energies where the small x_T region is probed and the gluon distributions are sizeable.

A complete NLL calculation of two photon production has been presented by Aurenche *et al.*[2]. At the parton level the calculation involved computing the contributions from the $2 \to 3$ real emission subprocesses $q\bar{q} \to \gamma\gamma g$ and $qg \to \gamma\gamma q$, as well as the one loop correction to the $2 \to 2$ subprocess $q\bar{q} \to \gamma\gamma$. In addition, the aforementioned and bremsstrahlung and box contributions were also included. The results of this calculation have been shown to be in good agreement with results from the WA-70 Collaboration[3]. However, the integration of the unobserved partons over the appropriate phase space region was done analytically, thereby making it difficult to place cuts on the photons or on the associated partons. It is sometimes necessary to employ such cuts in order to extract the two photon signal.

The calculation reported here makes use of a combination of analytic and Monte Carlo integration methods. The Monte Carlo approach to NLL calculations has some advantages over a purely analytic calculation since it allows one to calculate any number of observables simultaneously by simply histogramming the appropriate quantities. Furthermore, it is easy to tailor the Monte Carlo calculation to different experimental conditions, for example, detector acceptances, experimental cuts, and jet definitions. Also, with the Monte Carlo approach one can easily study the NLL corrections for different observables, the variation of the NLL corrections in different regions of phase space, and the dependence of the NLL cross section on the choice of scale.

Details of the method used for this calculation can be found in Ref. 1 and additional references cited therein. Briefly, two cutoffs are used to isolate the regions containing collinear singularities (δ_c) and soft singularities (δ_s) from the remainder of the three-body phase space. The three-body squared matrix elements are integrated over these singular regions analytically using dimensional regularization[4]. The collinear singularities are



Comparison of the theoretical results with data from the WA-70 (left) and UA-2 (right) Collaborations. In each case, the four curves are for the NLL results (solid), the LL results (dashed), the Born contribution (dot dashed), and box contribution (dotted).

factorized into the appropriate parton distribution and fragmentation functions. The remaining integrations over the singularity-free portions of the three-body phase space are performed using Monte Carlo methods. When all of the contributions are combined at the histogramming stage the various cutoff dependences cancel, since the cutoffs merely serve to mark the boundary between the regions where the integrations were performed using analytic or Monte Carlo methods.

2. RESULTS

The numerical results presented in this section have been obtained using the two-loop expression for α_s. Except where otherwise stated, a single scale $Q^2 = \langle p_T^2 \rangle$ with $\langle p_T^2 \rangle = [p_T^2(\gamma_1) + p_T^2(\gamma_2)]/2$, where $p_T(\gamma_1)$ and $p_T(\gamma_2)$ are the scalar transverse momenta of photons 1 and 2, has been used for the renormalization and factorization scales. For comparison, LL predictions obtained with the two-loop running coupling for α_s are also given. In order to get consistent NLL results it is necessary to use parton distribution functions which have been fit to next-to-leading order. The predictions given here have been obtained using the HMRS set B distributions[5)] for the proton and the MRSS set 2 distributions[6)] for the pion.

The left half of the above figure shows a comparison between the data from the WA-70 Collaboration[3)] and the results of our calculation. A number of cuts were employed in the WA-70 analysis. The photon with the highest transverse momentum was required to satisfy $p_T > 3.0$ GeV while the other was required to have $p_T > 2.75$ GeV. The rapidities of the two photons were also required to satisfy $-1.0 \leq y_i \leq 1.25$. A measure of the transverse momentum imbalance is given by the variable z, defined as $z = -\vec{p}_{T1} \cdot \vec{p}_{T2}/p_{T1}^2$ where $p_{T1} > p_{T2}$. A cut on z, $z \geq z_{min}$ with $z_{min} = (2.75 \text{ GeV})/p_{T1}$, was also employed. Finally, each photon which passes these cuts contributes to the result, so that there are two entries per event.

The UA-2 Collaboration has analyzed data for double photon production[7] and the right half of the figure shows our results and their data. The cuts used were $|y_i| \leq 0.76$ and $z > 0.7$ with the highest p_T photon required to have $p_T > 10$ GeV and the other $p_T > 9$ GeV. Again, there are two entries per event if both photons pass the cuts. At the low-p_T end the box contribution is about half as large as the Born term, but its contribution decreases more rapidly as p_T increases. In addition, the bremsstrahlung now makes a significant contribution over much of the p_T range shown. In contrast, the higher order corrections make little change to the LL result. It should be noted that the UA-2 results were obtained using an isolation cut on the photon candidates. However, this was done in a way which could not be duplicated at the parton level, so the curves correspond to the fully inclusive cross section. The isolation cut employed by UA-2 may reduce the bremsstrahlung component somewhat, but examination of the various components in the figure shows that the agreement with all but the first point would still be acceptable.

The CDF Collaboration is also analyzing double photon production data and some preliminary results have been compared to predictions obtained from the program described herein. Preliminary indications are that the predictions lie below the CDF results in the p_T range where data are currently available[8]. A tendency for existing NLL calculations to underestimate the collider data for single and double photon production in the p_T region below about 15 GeV has been observed and deserves continued study.

References

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