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COMMENTS FROM DIRECT PHOTON ROUND TABLE DISCUSSION

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GENERAL COMMENTS ON THE RESULTS PRESENTED

Much beautiful experimental and theoretical work was presented, which led me to the following observations.

Systematic Errors

All experiments have them, and even the theory has them. Let's pay them more respect. Note that when a theorist says that different choices of structure functions or scales give different answers, that is a systematic error.

Very Impressive Theoretical Predictions

The predictions cover many orders of magnitude and many combinations of incident and outgoing particles. Yet, practically no data point varies from the theory beyond the quoted error (statistical and systematic). In a sense we were much more lucky 9 to 10 years ago, in 1978-1979, when the predictions disagreed with each other by factors of ≈ 100. At that time, experimentalists could try to get their data points right to the best of their ability. They didn't have the added worry of whether the points were above or below "Aurenche et al.". For a flavor of the era see Ref. 1.

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Very Impressive Experimental Results

The experiments are very difficult. This is indicated by the large systematic errors quoted. Nevertheless, 6 different methods for measuring direct photons have been presented here, and all give impressive results:

Granular, High Spatial and Energy Resolution Detector: R806..., WA70, UA6, E705, E706, NA3, NA24;

Statistical Method, probability of conversion for 1 and 2 photon clusters: R108, UA2;

External Conversion, pair spectrometer: NA3;

Internal Conversion, low mass muon pairs: UA1;

Lateral Shower Structure after Converter: R110;

Statistical Method, accompanying energy in cone and shape of longitudinal energy deposition: UA1.

THE NEXT STEP

It is now quite clear that the direct photon process exists in hadron collisions, as predicted by QCD. The beauty of this process has been recognized since the very beginning: there is direct and unbiased access to one of the interacting constituents, the photon. The dominant subprocess is the QCD Compton effect.[2] The time for precision tests is upon us. Even at this meeting, people are beginning to be concerned about disagreements on the order of 5% to 10%.

It is generally accepted, by anyone who has done such a measurement, that the clearest way to test QCD is to make pair measurements, i.e. to measure both of the outgoing hard constituents.[3-8] An excellent discussion is given by Owens.[8]

Consider a high granularity, high resolution, direct photon detector, with solid angle $\approx$ 0.25 steradian, composed of rapidity aperture, $\Delta y = 0.25$, and azimuthal aperture, $\Delta\phi = 1$ radian, all in the p-p cm. system. This detector could be used in conjunction with a large central detector which would detect the jet from the recoiling quark. In fact, it is only necessary to detect the leading particle to determine the rapidity of the recoiling jet with adequate precision.[9] The constituent center-of-mass kinematics can be reconstructed by this method, with a precision of $\approx \pm 0.03$ for the cosine of the constituent c.m. scattering angle, $\cos\theta^*$.

The objective of the measurement would be to map out in detail the constituent center-of-mass subprocess angular distribution for direct photon production. Similar data for neutral-pion production would be obtained simultaneously. According to QCD, the direct photons are produced by a Compton subprocess, and should exhibit that characteristic angular distribution, while the pions are produced with a t-channel pole and should show the characteristic "Rutherford Scattering" anglular distribution (see Fig. 1). The same idea is discussed by Owens in Fig. 33 of Ref. 8. A simple way to do the experiment, conceptually, is to imagine 5 different rapidity settings for the photon detector, say y = 0, 0.25, 0.5, 0.75 and 1.0. In each of these settings, configurations would be selected in which the recoiling jet is back-to-back in rapidity to the photon, within an interval of ±0.1. This procedure restricts the rapidity of the constituent subprocess c.m. system, so that it is essentially the same as the p-p c.m. system, to a precision of ≈ ±0.1.

The cross-section measurement, with both "particles" at zero rapidity, can be used to constrain the uncertainties of the structure functions and coupling constant, or to measure them.[6] This is similar to, but more precise than, the information gained from a single-particle inclusive measurement. The rest of the points in the angular distribution are normalized by the value at $\cos\theta^* = 90°$, y = 0. If it were not for higher order effects in QCD, this normalized distribution would give the constituent c.m. scattering angular distribution directly. In Fig. 1, the pure subprocess distributions are given. If the measurements were to be made, and come out this way, it would provide a simple and elegant demonstration of the validity of hard QCD, particularly for the Compton subprocess.[8]

Of course, at this meeting, we are all more sophisticated. The running of the QCD coupling constant with momentum transfer has not been included in the figure, either directly, or in the secondary effect of non-scaling in the structure functions. This touches at the heart of the higher order correction issue, namely the correct definition of Q^2 to use in the coupling constant. If $\hat{s}$ is the correct value of Q^2 for the Compton subprocess, then Q^2 will not change over the angular distribution at fixed photon energy, and the angular distribution will remain unchanged from that of the subprocess. It is known, of course, that the

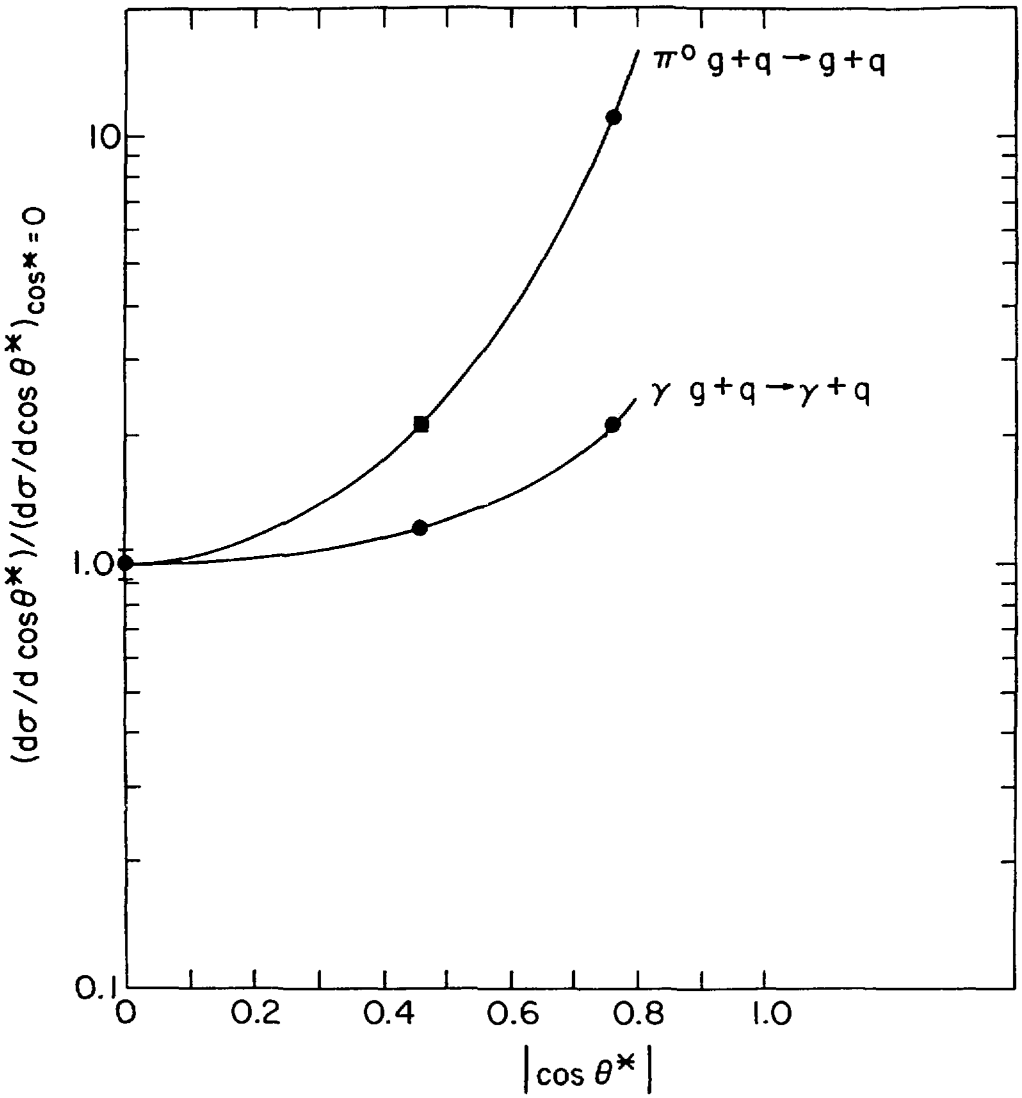

Figure 1. Constituent center-of-mass subprocess scattering angular distributions for direct photon production and neutral-pion production as indicated. The data points and error bars on the figure are to be ignored.

variation of the QCD coupling constant and non-scaling effects in the structure functions are essential to explain the already existing data of $\pi^0-\pi^0$ and jet-jet production.[3-5,7-8] The point of this comment is to ask the theorists how these effects will modify the photon-jet angular distributions in either of the second-order scale schemes, the optimized scale or the physical scale. Patrick, Andy go to it! The experimentalists should not rest either, let's try to get the data to 5% precision, including systematics!

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