BNL 18283

CRISP 73-18

BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

MASTER

ACCELERATOR DEPARTMENT
Informal Report

# BREMSSTRAHLUNG RADIATION IN HIGH ENERGY PARTICLE COLLISIONS IN THE VISIBLE REGION

M. Goldhaber and I. J. Muzinich

August 1973

August 1973

# Bremsstrahlung Radiation in High Energy Particle Collisions in the Visible Region*

M. Goldhaber and I.J. Muzinich

Brookhaven National Laboratory, Upton, New York 11973

Some features of bremsstrahlung radiation are reviewed for visible region photons with possible applications to ISA luminosity measurements.

It is generally known that in the low frequency region, radiation from fast moving charged particles interacting is an important component of the cross section because of the usual infrared catastrophe. We examine the bremsstrahlung radiation from high energy charged particles where the primary collision is of small angle and dominated by the 1 quantum exchange. The Feynman graphs are sketched in Fig. 1a. The soft photon has to be emitted both before and after the Rutherford one quantum exchange process to insure gauge invariance. One need not worry about interference between the graphs of Fig. 1a and 1b because the Pauli principle is not relevant here where the two particles, if identical, are well separated in momentum.

From the standard textbook formula - see Bjorken and Drell[1] - the bremsstrahlung differential cross-section is

------------------------------

* Work performed under the auspices of U.S. Atomic Energy Commission.

$$\left.\frac{d\sigma}{d\Omega}\right)_{Br} = \left(\frac{d\sigma}{d\Omega}\right)_{Ruth.} \times \frac{\alpha}{\pi}\int\frac{d\omega}{\omega}\frac{d\Omega_k}{4\pi}\left[\frac{2(1-\cos\theta)}{(1-\hat{k}\cdot\vec{\beta}_f)(1-\hat{k}\cdot\vec{\beta}_i)} - \frac{m^2}{E_f^{\,2}(1-\hat{k}\cdot\beta_f)} - \frac{m^2}{E_i^{\,2}(1-\hat{k}\cdot\beta_i)}\right] \qquad (1)$$

where $E_i$ and $E_f$ $\vec{\beta}_i$ and $\vec{\beta}_f$ are the initial and final energies and velocities in units where c=1; $\hat{k}$ refers to the direction of the photons emitted with frequency $\omega$ and $\frac{d\sigma}{d\Omega}$ is the Rutherford cross section given by

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4E^2}\,\frac{1}{\sin^4\theta/2} \qquad (2)$$

$\cos\theta$ is the angle of scattering.

To obtain a crude estimate of the magnitude of the cross-section the integrated cross section over photon directions and frequency becomes:

$$\frac{d\sigma}{d\Omega} \approx \left(\frac{d\sigma}{d\Omega}\right)_{Ruth} \times \frac{\alpha}{\pi}\,\frac{d\omega}{\omega}\left(\frac{+4E^2\sin^2\theta/2}{m^2}\right) \qquad (3)$$

where $E_f \simeq E_i = E$ when $E \gg \omega$. This immediately gives us the angular distribution

$$\frac{d\sigma}{d\cos\theta} \approx \frac{8\pi\alpha^2}{m^2} \times \frac{\alpha}{\pi}\,\frac{1}{\theta^2}\,\frac{d\omega}{\omega} \qquad (4)$$

In order to insure that we have Coulomb scattering dominant for the primary interaction this puts our angular requirements of $\theta \lesssim \theta_0$ where $\theta_0$ is of the order of a few milliradians. We then obtain the estimate for a given angular and energy acceptance $\Delta\theta^2$ and $\Delta\omega$ for protons

$$\sigma \approx 6.22 \times 10^{-34} \; cm^2 \int \frac{\Delta\theta^2}{\theta^2} \int \frac{d\omega}{\omega} \quad (5)$$

for protons (m = proton mass), with reasonable angular acceptances for the visible region photons we estimate total cross sections of the order of $10^{-33}$ $cm^2$, which for luminosities of the order of $10^{33}$ to $10^{34}$ rate/sec x cross-section gives from 1 to 10 photon per second.

While this is marginal for pp cross sections it will be of substantial interest for electron-electron and electron-proton machines where the cross section are of orders of magnitude larger due to the small electron mass.

## Reference

1. J.D. Bjorken and S.D. Drell, Relativistic Quantum Mechanics, (McGraw-Hill Company, New York )(1965).