BREMSSTRAHLUNG TAGGING OF HIGH-ENERGY ELECTRONS

C. A. Heusch
California Institute of Technology

ABSTRACT

A brief survey is given of means in which electrons in the 100-GeV region can be identified. It is pointed out that in addition to other established techniques, the tagging of electrons by bremsstrahlung quanta may provide an excellent signature. The inefficiencies encountered in the bremsstrahlung tagging of photons are not found here.

High-energy proton accelerators have been shown to yield electron fluxes appropriate for many important experiments which demand energies not accessible to present or presently projected electron accelerators. The origin of these secondary electron beams from hadronic collisions often will cause sizeable hadronic contaminations. It is therefore useful to look for means to purify these beams or, if that appears preferable, to tag the electrons.

The identification of high-energy electrons is possible in several ways which have been described in the literature:

1. Threshold Cerenkov Counters
2. DISC Counters
3. Tagging by Synchrotron Radiation
4. Shower Counters.

The Cerenkov method[1,2] will probably not be economically feasible with electrons of energy above 100 GeV[1] due to the length needed for threshold counters, and the small divergence and momentum bite needed for utilization of Cerenkov radiation, whereas the intensity requirements will frequently demand a large $\Delta p/p$ for the beam.

The third method was considered by Luckey[2] and may be useful if the beam runs through many meters of high magnetic fields; however, the cost of alternate-field magnets as considered in Ref. 2, as well as the inefficiency involved in detecting the low-energy photons emitted ($E_\gamma < 50$ MeV at $E_e = 100$ GeV), will limit the range of application. The emission of synchrotron radiation may also be useful for separating the electrons away from the hadrons in the beam. An electron of 100 GeV will lose approximately 50 MeV per meter of 20 kG field it traverses. With conventional magnets, it would lose 1% of its energy in 20 m of 20 kG field, a number which may look discouraging in view of the wide bandpass indicated for reasonable intensities.

Should we take superconducting magnets, the situation changes. The energy loss in GeV per meter of magnetic field B (in kG) for electrons of energy E (in GeV) is[2]

$$\Delta E = 1.3 \times 10^{-8} E^2 B^2 ,$$

so that, at 80 kG, the beam energy would be degraded by ~800 MeV/m, which definitely becomes of interest. We will, however, hardly be able to utilize this method in the initial beam layout .

Shower counters can be used either destructively, transforming the entire energy carried by the electron into an electromagnetic cascade and somehow integrating over its total charged path length, or non-destructively, so that only a fraction of the electrons' energy will be deposited in the counter. In the first case, the counter has about 100% efficiency, but must be placed downstream from the experimental interaction region (useful in inelastic or elastic eN scattering); in the latter, the counter may be inserted in the beam line upstream of the target, but the thicker and more efficient it becomes, the more it will degrade the electron beam. In practice, a shower counter thick enough to give a clear signal (≥ 5 times minimum) can rarely be tolerated in the beam line.

Electron tagging by bremsstrahlung production--This note is being written to point out an additional possibility of electron identification, making use of the bremsstrahlung produced by electrons passing through a thin high-Z radiator. Lead blocks have in the past been used to clean up negative beams of their electron content; since the ratio of interaction length to radiation length is $\lambda/X^o = 30/1$, several radiation lengths can be inserted to effectively degrade electron energies, while they barely interfere with the hadron beam. Toner[3] pointed out that a wide bandpass optical system may be made to subsequently accept electrons that lose 10% or less of their energy in a thin radiator, while the beam resolution may be as good as 0.1%.

This method becomes available only at very high electron energies, since a sizable fraction of electrons has to radiate quanta of easily detectable energy, viz. upward of several hundred MeV. Low-energy photons do not give uniquely recognizable signals. In a thin radiator of thickness t (in units of X^o), the number of photons radiated between energies E_1 and E_2 is approximately

$$\int_{E_1}^{E_2} N_\gamma(k)\, dk = t \,\ell n \frac{E_2}{E_1} \ .$$

The energies E_1 and E_2 are given respectively by the minimum photon energy that is reliably detectable in the shower counter (which we will conservatively assume to be 0.5 GeV); and by the largest energy loss permitted by the beam transport downsteam from the radiator (which we will take to be 10%). For a 1/30 radiation-length radiator and a 100 GeV/c incident beam, this example would lead to a fraction of tagged electrons of $(1/30)\ \ell n\ 20 \simeq 0.10$. This fraction may be somewhat increased by the use of a thicker radiator; then the appropriate thick-radiator approximation will have to be used.

This disadvantages of this method are obvious. A second focus is needed for the charged beam; and, worse, only about 0.1 of the electrons will be utilized.

There are, however, important advantages. The residual contamination at the second focus is essentially zero, since we demand a coincidence between the electron and the tagging photon (background processes are, e.g., $\pi^- Z \to \pi^0 \pi^- Z$, where the π^0 heads toward the shower counter and the π^- will be mistaken for an electron). Detection efficiency of the shower counter is close to 100%, so that no further loss occurs. And the energy information from the shower counter further helps to identify the electron of proper energy.

Electron tagging by bremsstrahlung is, of course, the exact analogue of the well-known method of photon tagging. It has, however, one important advantage over photon tagging: the precision of photon tagging is limited by the occurrence of double bremsstrahlung or two-photon emission in the optical process. These pitfalls do not exist in our case. No matter whether one or several photons are emitted in the radiator, the shower counter is sensitive only to their total energy.

It may well prove that in view of the excellent signature for those electrons that did radiate in the thin radiator, more intense (and thereby more highly contaminated) electron beams will become usable for electron experimentation, thus making up for the intensity degradation.

REFERENCES

[1] A. Roberts, Lawrence Radiation Laboratory UCRL-16830, Vol. III, p. 192.

[2] D. Luckey, Tagging Counters for Electrons in the 100-GeV Range, National Accelerator Laboratory 1968 Summer Study Report C. 3-68-88, Vol. III, p. 147.

[3] W. T. Toner, Electron and Photon Beams at NAL, National Accelerator Laboratory 1968 Summer Study Report B. 9-68-31, Vol. II, p. 125.