MAXIMUM INTENSITY ELECTRON AND PHOTON BEAMS FROM PHOTON ACCELERATORS

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ABSTRACT

Existing beam designs for electron and photon beams start from the requirement of beam purity and are limited in obtainable intensity. It is pointed out that, while the primary photon beam emerging from a nucleon-nucleon collision target is not useful for experimental purposes, a primary electron beam can under certain circumstances present advantages. While it is true that in general conversion of photons from π^o decay in an external radiator is preferable, this applies mainly to the upper end of the spectrum. Internal conversion allows for a larger conversion rate and makes the containment of a larger solid angle feasible. The main advantage of external conversion, the relative freedom from hadronic backgrounds, may not be so important in view of new separating techniques. Intensity gains on the order of a factor of 10 appear possible.

I. PRODUCTION OF ELECTRON-PHOTON BEAMS

Various ways of obtaining electron and photon beams at proton accelerators in the 100-GeV energy region were discussed by this author a few years ago.[1] In subsequent summer studies, particular designs were chosen by several authors[2-4] for such beam lines. The emphasis was mainly on beams free of hadronic contaminants. In this context, the most promising scheme starts with a low-Z target, where only the emerging neutral beam is utilized in order to produce electron pairs in a subsequent radiator; the initital charged beam gets deflected immediately downstream from the target.

This method minimizes the hadronic admixture in the electron (and possibly reconstituted photon) beam, especially if the beam optics downstream from the radiator discriminates against all particles that emerge from the radiator with non-negligible transverse momentum.[2] These beams can be further purified by various techniques[2,3] and will no doubt be suitable for a large class of experiments. Indeed, we believe that early realization of such a beam line in the framework of the proposed neutral beam facility at the NAL is of great importance and promise.

The electron beam intensities attainable in such a facility are of order $\lesssim 10^7$ per pulse in a typical beam line of ~ 100 GeV/c momentum, with a momentum bite of ~ 1%. If we need electronic tagging either to purify this beam or to convert it into a tagged photon beam, this is about the highest intensity present pulse techniques will permit. However, for a class of experiments, such intensities just simply will not do, and any improvement in intensity will be welcome.

In this note, we therefore want to point out possibilities to make higher intensity beams available. For some experiments, an increase in intensity may be more important than purity of the beam. In particular, inelastic electron or photon scattering experiments, where the final-state electron or photon can be detected, may fall into this category. Also, it was shown[1] that the production of polarized high-energy photons is less than marginal for the electron beams discussed above. With somewhat more intense beams, it may become possible to reach, from bremsstrahlung production in single crystals, polarized photon intensities useful for some investigations.

II. DIRECT ELECTRON PRODUCTION

The trick to be employed is simple enough, but hinges on very recent technical developments. If we are able effectively to purify an electron beam <u>without</u> going through the external conversion process $\gamma \to e^+e^-$, we can capitalize on target materials that favor conversion of photons before emission (higher Z targets), using a magnetic lens close by to contain as large a solid angle as possible. For the system starting with a neutral (γ) beam, on the other hand, the first thing we need is a large sweeping magnet to rid us of the charged particles; the solid angle to be contained is then defined by the optics downstream from the subsequent radiator.

The question is then: First, how much intensity can be gained over the scheme starting with a neutral beam? Second, how will we be able to free ourselves from the strong hadron component of the charged beam emanating from the target? It goes without saying that we will choose a negatively charged beam to avoid the preponderance of positively charged baryons.

Consider a target struck by the external proton beam of full machine energy and intensity. If the target material is of low Z, most of the photons from π^0 decay will leave the target before undergoing an interaction with the target material. If, however, we choose a higher Z material (say, Al), where the nuclear mean free path is five times the radiation length, most photons from π^0 decay will have interacted, and the resulting electron flux is larger.

Every radiative process depletes the high-energy end of the spectrum, so that this increase in electron intensity will be felt not at the top end, but rather at somewhat lower energies (say, at electron energies $\lesssim 100$ GeV). We estimate a realistic gain in electron intensity around 100 GeV of about a factor of two over external conversion. It may be mentioned that multiple coulomb scattering inside the primary target does not bother us: for practical purposes, an equal amount of electrons will be scattered into and out of a given phase space element.

Assume then that we subsequently contain a fairly large solid angle in an optical system focused on the primary target. Since no room has to be left downstream of the target for sweeping purposes, we may be able to pick up another factor of two to four in intensity.

III. BEAM PURIFICATION

The next, and decisive, question is this: we have improved our electron flux moderately (by a factor of 4-10) at the expense of an enormous increase in the hadronic component of the beam. Can we live with it? The answer may be affirmative if 1) we limit ourselves to applications where beam intensity is the overriding concern, and where we have some other means of tagging the event induced by electrons or photons rather than by hadrons, or 2) we insert beam purifying devices which do not hinge on electronic counting of individual beam particles. One such device would be a lead radiator, as suggested by Toner,[2] in which the electrons lose a certain fraction of their energy, but most hadrons pass without interacting. This has the disadvantage, in our case of very strongly contaminated beams, that in addition to a considerable deterioration of the beam phase space, a sufficient number of hadrons will emerge in the decelerated part of the beam to make repeated application advisable.

Another method is the use of two superconducting magnets in the beam line, as indicated in Fig. 1. The energy loss which electrons of energy E (in GeV) undergo in a meter of magnetic field B (in kG), due to synchrotron radiation, is

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

This means that in 1.25 m of an 80 kG field, a 100-GeV electron will lose about 1% of its energy, without any noticeable increase in phase space of the electron beam. Since π^-, K^-, $\bar{p}$, ... do not lose any appreciable amount of energy in the strong field, a $\Delta p/p$ 1% negative beam coming directly from the target can in this fashion be efficiently separated into its electronic and hadronic (plus muonic) components by insertion of two 2 m long superconducting magnets in appropriate (and separate) positions within the optical system.

The success of such a system depends, of course, on the degree to which contaminants can be kept from scattering off collimators, pole tips, etc., into the phase space of the decelerated electron beam, and on the extent to which the experiment in question can live with such contaminants. It may further be possible to give individual electrons in the beam a signature (as reviewed in Ref. 7); this depends on the final intensity of the beam and on the availability of very fast electronic devices. However, the main virtue of this system lies in the fact that it can live without the need to individually identify particles in the beam and that it therefore can go beyond the intensities allowed for by tagging methods.

REFERENCES

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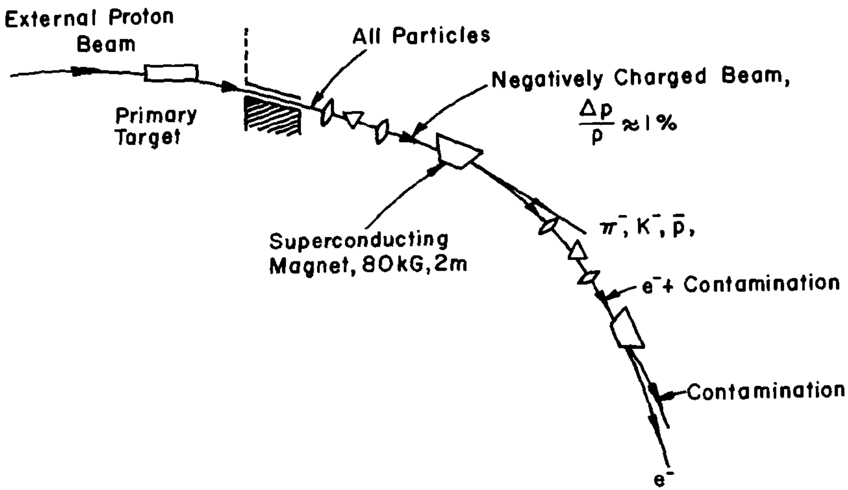

Fig. 1. Schematic layout for a possible high-intensity electron beam. For photons, a converter may be added at the downstream end.