DISCUSSION OF POSSIBLE USES OF RF BEAM STRUCTURE IN COUNTER EXPERIMENTS AT NAL

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ABSTRACT

The purpose of this note is to review the arguments concerning possible improvements in the performance of certain counter experiments at NAL which require high-intensity secondary beams (10^7 - 10^8 particles/pulse) by utilizing rf structure in the slow extracted proton beam (at frequencies of 50 to 200 Mc/sec), so that a decision can be made relative to the inclusion of this feature in the final design of the flat-top and extraction systems hardware of the 200-GeV accelerator. We therefore discuss possible ways to utilize the rf structure of the main-accelerator proton beam in the performance of counter experiments at NAL. Initially, experiments in which the 53 Mc/sec structure of the accelerator beam might enhance the utilization of high-intensity π, μ, e, and γ beams are discussed. The beam detector systems required, and some difficulties and limitations of the rf structured beam, are considered. On balance, it appears to us that early provision of bunched beam for experiments is not warranted.

I. INTRODUCTION

At present high-energy proton accelerators such as the BNL AGS, the highest usable secondary particle beam intensities in many classes of experiments is $\sim 10^6$ - 10^7 particles per second (instantaneous rates). This limitation is due to two factors: 1) many secondary particle beam yields are limited to approximately 10^6 - 10^7 particles/sec; and 2) the maximum usable pulse rate of present day electronics is ~ 100 Mc/sec so that one is limited to intensities about 10^6/second in order to keep accidental and dead-time counting effects to the required low levels if one is doing a 1% experiment. With the expected improvements in intensities of secondary particle beams at the AGS in the next two years, and assuming that the reliable repeatibility of fast electronics can be improved to ~ 200 Mc/sec, the situation will not be significantly improved--with a beam $\sim 4 \times 10^7$ particles/sec and with 200 Mc/sec electronics, there will be correction effects of the order of 20% due to accidental and dead-time counting effects in the beam detection system.

When the 200-BeV NAL machine comes on the air, secondary particle fluxes on the order of 10^8/sec may be quite common. Especially for high-precision (1%) experiments using these beams, it will be necessary either 1) to reduce the secondary beam fluxes to $\sim 10^6$ particles/sec, or 2) to improve our methods for counting these high-intensity beams. One such new method, which we have investigated, is to provide rf bunching of the extracted proton beam. Another such method, which we discussed with James Christenson and others at the 1969 NAL Summer Study, is to use an electronic "confusion eliminator" which has already been successfully used at intensities $\sim 10^7$/sec. It may well be that the entire question of bunching the extracted beam can become irrelevant if "confusion eliminators" can be improved to work reliably at high intensities approaching 10^8 particles/sec.

II. DISCUSSION OF RF BUNCHING OF THE EXTRACTED PROTON BEAM

The modulation frequency of the accelerated 200-BeV proton beam is 53 Mc/sec with a momentum compaction of about one part in 10^4. If one were to turn off the rf at the beginning of the flat-top, and to allow the beam to debunch by coasting, it would take some 200-300 milliseconds for the beam to debunch (assuming that it does not re-bunch due to the presence of the rf cavities, which because of their impedance tend to re-bunch the beam). In order to reduce the time for debunching to a more reasonable value, debunchers will be added to increase the momentum spread to about one part in 10^3. This will cause the beam to debunch in 20 to 30 milliseconds. Additional servo systems will be added to prevent the cavities from re-bunching the beam. For some classes of experiments, a random beam is much more desirable than a bunched beam, so these debunching features should certainly be included in the beam extraction system. However, if the arguments for bunching the beam for some experiments turn out to have merit, it may also be useful not to use the debunching equipment and to extract the beam with the 53 Mc/sec rf structure still in it. In fact, it might be desirable at a later date to add rf systems that would re-bunch the beam at frequencies higher than 53 Mc/sec up to a limit of about 200 Mc/sec which is close to the pulse rate limit attainable by the fast electronics. (If the beam were bunched at a frequency of 500 Mc/sec, it would be practically impossible to tell the difference between this beam and one which was random.)

Assuming that we keep the rf structure in the beam at 53 Mc/sec, and that the flat-top is 1 second, there would be about 5×10^{13} protons/sec (instantaneous) striking the target, or 10^6 protons per rf bunch. The width of a bunch is approximately 2 nanoseconds and the separation between bunches about 20 nanoseconds. As discussed below, we believe that by using such a bunched beam, one can count secondary beam particles at the rate of 2×10^7/sec in such a way that there would be no corrections necessary for accidental and dead-time counting effects. Should the bunch frequency be increased to 100 Mc/sec, the counting rate could be 4×10^7 particles/sec with 1 nanosecond bunches and 10 nanosecond intervals between bunches. The limit would probably be 8×10^7 particles/sec with 1/2 nanosecond bunches and 5 nanosecond intervals. These rates are calculated on the following basis: if the average number of secondary particles per bunch is 1, then Poisson statistics tell us that about 40% of the bunches contain 1 and not more than 1 beam particle.

III. USE OF THE BUNCHED BEAM IN COUNTER EXPERIMENTS

With about 10^6 protons per rf bunch striking a secondary beam production target, a number of the secondary particle beams studied at the NAL 1969 Summer Study would have ~0.5 - 2 secondary beam particles/rf bunch. A scintillation counter placed in the secondary beam would be used to measure whether 0, 1, or ≥ 2 secondary particles passed through the counter in a given rf bunch. The timing of these particles is, of course, known quite precisely from a train of rf clock pulses generated by the main-accelerator control system. The number of beam particles passing through the scintillation counter would be determined by pulse height analysis of the output of the counter. This pulse height analysis technique has already been successfully used at the BNL AGS and at Serpukhov. To study further the pulse height analysis techniques, it would be possible to perform a more specific experiment in the next few months at the external beam area of the PPA with a π^- beam of 10^6/sec (average). The PPA can be used since it has a beam bunched at 30 Mc/sec, 3-nsec bunches spaced 30 nsec apart.

Subsequent detector signals would only be recorded when one and only one secondary particle passed through the "confusion eliminator" counter. Since the dead-time between bunches is long compared with the resolving time of the electronics, there will be no corrections at all in such experiments for accidental and dead-time counting effects. Counting rates, even for high precision experiments, could then be much higher than $\sim 10^6$ beam particles/sec and scattered particle analysis and detection would be somewhat simpler. For those experiments where detection and analysis of low-momentum recoil protons or neutrons is important, it is also quite possible that the time-of-flight feature of the clocked bunch beam could be used to advantage.

IV. CLASSES OF EXPERIMENTS WHERE RF-BUNCHED BEAMS MIGHT BE ADVANTAGEOUS

1. Scattering experiments with $\gtrsim 10^7$ muons/sec
2. Scattering experiments with $\geq 10^7$ electrons/sec, this includes tagged-photon experiments
3. Scattering experiments using $\gtrsim 10^7$ pions/sec
4. Experiments with tagged neutrino beams
5. Experiments with polarized protons which are tagged with π^-'s from $\Lambda \to p\pi^-$ decays
6. Scattering experiments using $\gtrsim 10^7$ antiprotons or kaons/sec

It has been pointed out by James Christenson that the bunched-beam technique suffers badly whenever an intense halo is associated with a secondary particle beam--such as with a muon beam. The anti-coincidence counter used to detect and reject halo-associated events will turn off the experiment whenever a halo beam particle is present. At high halo rates, several $\times 10^7$ particles/sec, the experiment would be turned off most of the time by the anti-coincidence counter.

V. CLASSES OF EXPERIMENTS WHERE THE RF-BUNCHED BEAM APPEARS TO BE DETRIMENTAL

1. Experiments where the incident particle beam intensity exceeds $\sim 10^8$/sec
2. Experiments involving the primary proton beam
3. Experiments involving a diffracted proton beam
4. Particle production and beam-survey experiments
5. Neutron and K^0 beam experiments
6. In experiments with very low intensity beams, there is neither advantage nor disadvantage in the use of the clocked-bunched beam

VI. CONCLUSIONS

1. The accelerator will clearly have to provide a debunched beam for a substantial fraction of the experimental program. The inclusion of the added complications of extraction of a bunched beam leads to obvious operating difficulties, particularly if a given 1-second flat-top pulse must provide partially bunched and partially random beam extraction.

2. It appears that bunching of the secondary particle beams, either directly by adding a high frequency (200 Mc/sec, say) rf cavity in the secondary beam line, or artificially by improving electronic "confusion elimination" (to prevent detection of 2 or more particles arriving within 5 nanoseconds of each other) are better methods than the use of an extracted bunched beam. Development of higher speed "electronic confusion eliminators" is clearly very desirable and appears likely to be a more

promising approach than the development of a 200 Mc/sec bunched beam especially because this would eliminate the aforementioned operational difficulties associated with a bunched beam.

VII. RECOMMENDATION

We recommend that unless specific proposals are made and approved which quite definitively demonstrate a requirement for a bunched slow extracted beam, no plans for extraction of a bunched beam should be included in the initial phase of slow extracted beam operations at NAL.