Beam Structure for PRISM/PRIME from Project X

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Abstract

This note describes a possible beam structure to deliver multi-MW beam to the PRISM/PRIME experiment[1] during the Project X era. The scheme assumes that the Recycler is used as a storage ring for protons. This will allow the use of beam from the Booster in case that the experiment is ready before Project X is completed.

Introduction

At present, the Fermilab Booster provides 11 batches of 4x10^12 protons to the Main Injector. This means that the Main Injector regularly stores ~4.4x10^13 protons. Based on this, studies[2] have been conducted that show that the Recycler will be capable of accumulating 1.4x10^14 protons from Project X to be transferred to the Main Injector. In this note I will assume that the Recycler is capable of storing 5x10^13 and that Project X includes an 8 GeV, 1mA CW linac, or a pulsed linac from 3 to 8 GeV.

Beam Packaging

The system that we envision is very similar to the one that was proposed for the New Muon g-2 experiment[3]. A 1 mA CW linac makes 6.25x10^15 protons/sec, so in 10 msec it can deliver 3x10^13 protons, assuming that the H- beam is chopped, 200 ns on and 200 ns off. This is injected into the Recycler RF system with h=28. Assuming that the experiment expects ~50 nsec-long bunches, the h=28 RF system is used to do adiabatic bunching. To avoid the need for large RF voltage and at this stage, I will assume that the bunching process takes 18 msecs. So in 28 msec the beam is prepared in 28 bunches. In the next 72 msec, it is extracted one bunch at a time to the experiment and the process is repeated. This also allows for the linac to be pulsed with a 10 Hz rate. The experiment gets bunches with an average rate of 280 Hz.

Construction and Installation

Once the beam from Project X is delivered to the Recycler, the only hardware needed is a set of cavities for creating ~50 nsec bunches out of 200 ns-long beam bunches. This can be achieved by moving existing 2.5 MHz coalescing cavities from the Main Injector to the Recycler. This was suggested as a way of creating the bunch structure for the g-2 experiment. The main concerns are the design and construction of a kicker system with an average repetition rate of 280 Hz.

Conclusions

With the suggested beam delivery system, PRISM/PRIME can get up to 5.10^14 protons per second on target. Using the Recycler and coalescing cavities eliminates any new additional construction. The experiment can start delivering beam from the Booster before Project X is completed. Assuming that the total proton bunch length is 10 nsec and that we can tolerate space charge tune shift of ~0.13, these are possible options:

1. In Booster era (this means before Project X) we can run 1 Hz beam, with average rep-rate to experiment of 28 Hz in bursts of 280 Hz. So accumulation is 470ms (7*66msec), then bunching ~200msec and extraction to experiment in 280 ms, one bunch every 10 msec. This corresponds to 45 kW of average proton beam power.
2. In project X time this can be increased by a factor of 10 just by using 10 Hz injection in Recycler, corresponding to a beam power of 450kW.

3. In a final stage a new accumulation ring can be built that will not be space charge limited and will allow multi-megawatt beam power.
If experiment can run with longer proton bunch that will decrease tune shift or will allow more beam at stage 2.

References

1.PRISM/PRIME Experiment, http://www-ps.kek.jp/jhf-np/LOIlist/pdf/L25.pdf

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3. The New (g-2) Experiment, http://www.fnal.gov/directorate/program_planning/Mar2009PACPublic/Proposal_g-2-3.0Feb2009.pdf