Intensity Issues in Proton Accumulator

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Mechanics of the proposed Proton Accumulator can be found in beams-doc-1782. Figure below shows intensities of 8GeV protons in the Booster, Accumulator and Recycler.

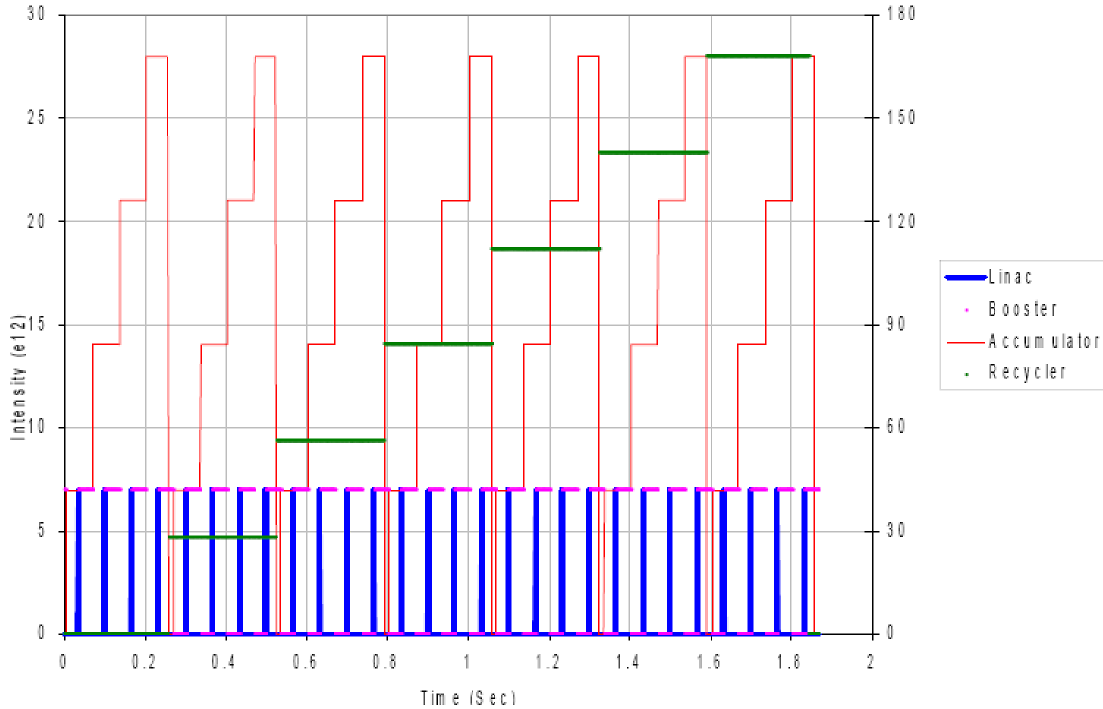

Fig.1: Intensities along Proton Accumulator chain machines.

Part #1: Space Change issues:

Let's start with Laslett space-charge tune shift :

$$\Delta \nu_{SC} = \frac{N_{tot} r_p B_f}{4\pi\varepsilon_n \beta\gamma^2} \quad (1)$$

where *N_tot* is total number of particles in the ring, *r_p=1.53 10^-18m* is proton classical radius, *E_n* is rms normalized emittance (1/6 of FNAL 95% emittance value), *beta* and *gamma* are usual relativistic parameters, and *B_f >1* is a peak to average current ratio. Eq.(1) assumes that the ring circumference is completely filled with particles and reflects the fact the SC tune shift (which is essentially a single bunch phenomena) in longer machine is proportional to ring circumference.

If one takes intensities as shown in Fig.1 then $\Delta \nu_{SC}$ is equal to:

a) 0.033 in the Booster at N_tot=7e12, emm=2 (equivalent to 12 pi) and B_f=5 (approx 1.7 ns rms)
b) 0.066 in the Accumulator at the end of momentum stacking of 4 Booster batches when N_tot=28e12, emm=2, B_f=2.5 (is it a valid assumption?)
c) 0.46 in the Recycler which is (7 times longer) since the very first injection with B_f=2.5

Possibilities/issues:

a) transverse emittance in fact is smaller (as small as 6 pi or 1 pi rms) so space-charge tune shift will be larger but nothing prevents from blowing it up as much as acceptance or losses allow; I think factor of 2 blowup may be possible (to 24 pi or 4 pi rms) – that will reduce the tuneshift by factor of 2;

b) Bunching factor B_f of 2.5 in Accumulator and RR - can it be made as small as that?

c) major difficulty is that beams should stay for extended period of time in Accumulator and Recycler (about 1e5 and 2e5 turns compared to some 5000 at the *end* present Booster cycle where $\Delta\nu_{SC}$ is about 0.02 and some percents of beam power loss is seen already. Longer life allows coherent and incoherent SC phenomena to develop fully, and, e.g., momentum stacking in Accumulator might lead to much bigger longitudinal emittances then anticipated.

Part #2: e-cloud issues:

Electron cloud instability has been observed in Tevatron if 53 MHz bunch intensity exceeds 40e9 (see beams-doc-1991) at 150 GeV. Vacuum pressure rise was detected in some 30 m of warm pipe at C0 and measured vertical emittance growth was ~ 30pi/hr. Scaling that to 8 GeV protons (20 times lower energy) in 3000 m long (100 times longer than in Tevatron) Recycler filled with 168e12 proton bunches one would expect to see 130 pi/sec growth if single bunch intensity matters (and much worse if total beam intensity leads to e-cloud build up).

Possibilities:

a) the latter growth rate is factor of 100 too high to be acceptable for Recycler in the proposed scheme.
b) There are ways to affect e-cloud: i) 50 Gauss solenoids as in B-factories; ii) beam pipe coating (ZrN?) to reduce SEY; iii) e-cloud suppressing electrode in the vacuum pipe. I do not know what kind of gain one might get with these methods.

For discussion:

At it was correctly pointed out, any Proton Driver solution for >2MW will have same problems in Main Injector. Advantages of the MI wrt RR and Accumulator is that in some 100 ms (10000 turns) of acceleration, the energy is ~doubled so SC and e-cloud will be much less of an issue. Experience with slip-stacked beam tells that at about ¼ of the needed bunch intensity, the SC and e-cloud are not too serious issues for 0.2-0.3 s.