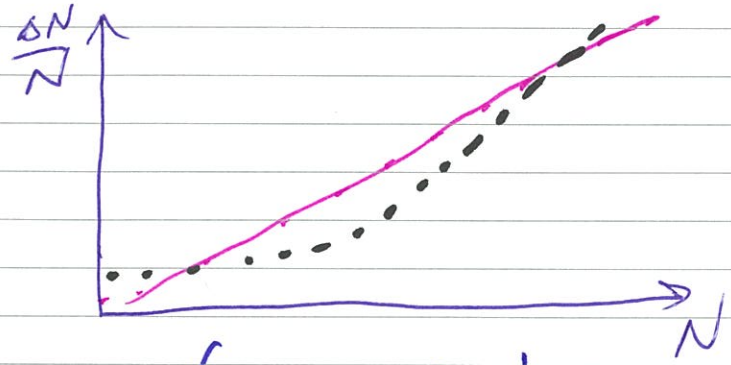
5/23/2018

V. Shiltsev

* fractional beam loss increases with SC



α also depends on:

1) Transv. painting ~1
2) collim/halo ~ ?
3) symmetry ~2
4) ripple ~3
5) fast acceleration ~$\sqrt{2}$ ...?
6) Machine nonlinearities ~2

* take for simplicity

(1) $$\frac{\Delta N}{N_p} \sim \alpha \cdot \Delta Q_{sc}, \quad \Delta Q_{sc} = \frac{r_p N_p}{4\pi\varepsilon_n \beta\gamma^2}$$

* assume that energy loss per meter is limited (e.g. 1 W/m)

$$\Delta N \cdot \gamma \leq F_{accr} \cdot C$$ (circumference)

(2) that limits $$\Delta N \leq \frac{F \cdot C}{\gamma}$$

* put (2) in (1)

$$\frac{r_p N_p}{4\pi\varepsilon_n \beta\gamma^2} \leq \frac{F}{\alpha \cdot N_p} \cdot \left(\frac{C}{\gamma}\right) = \frac{\text{Coeff}}{\alpha N_p}$$

(approx const, 2T B-field)

E_n	β	γ	$\beta\gamma^2$	Ratio
400	0.7	1.4	1.37	1
800	0.81	1.8	2.62	1.9
2000	0.94	3	8.5	6.2
3000	0.97	4	15.5	11.3
5000	1	5.94	35	25
80000	1	8.9	80	58

* Now, if machine acceptance is limited (ε_n), then

$$N_p \sim \sqrt{\varepsilon_n} \cdot (\beta\gamma^2)^{1/2} \cdot \frac{1}{\sqrt{\alpha}}$$

* So if we need to increase $N_p \to N_p \times 9$, we either

- $\gamma = 1 \to \gamma = 9$ (new linac)

or

- 2nd harmonic RF (factor ~2 in α) $\to N_p \times \sqrt{2}$
- Space-charge compens (factor ~2) $\to N_p \times 2$
- Integr. optics/NL collimation (factor ~10 in α) $\to N_p \times 3$

altogether ~ 9

V. Shiltsev, F. Schmidt

June 4, 2018

Space-Charge Assessment of proton RCS's

	ΔQ_{SC}	Beam loss $\Delta N/N$	Emittance $\Delta \varepsilon$	Time (ramp) / #TURNS	C, m	superperiod P	E_{inj} / E_{extr} (kin, GeV)	TUNES $Q_{x,y}$	N^{tot} per bunch	N_{bunch}
PS-B	~0.6	5%	5%	36ms (ramp) →0.9s	157 m	16	0.05 / 1.4	4.3, 4.45	2.5e12	2.5e12
PS	0.35	5%	5%	~1s	628 m	50	1.4 / 28	6.12 / 6.24	1.5e13	2.5e12
SPS	0.2	8÷10%	10%	~15s	6.9 km	6	28 / 450	20.13 / 20.18	(72 bunches)	1.2e11 → →2.3e11
JPARC RCS	0.3–0.35	0.25%	~30% (2005)	~6ms (25 Hz)	348 m	3	0.4 / 3	6.45 / 6.32	~8e13	3.1e13
JPARC MR	0.35	3.5%		0.1+0.2= =0.3s	1567 m	3	3 / 30	21.35 / 21.43	2.5e14	3.1e13
FNAL BOOSTER	0.35-0.4	6-7%	10-30%	~4ms (15 Hz)	475 m	24	0.4 / 8	6.7 / 6.8	4.3e12	5.5e10
PIP-II	0.3-0.4	0.2%	<10%		636 m	12	0.8 / 8	21.6	36e12	