HIGHER ORDER MODE BEAM BREAKUP LIMITS IN THE SUPERCONDUCTING CAVITIES OF THE SPL

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Abstract

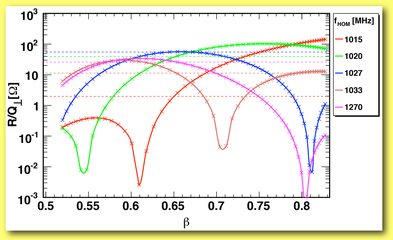
The Superconducting Proton Linac (SPL) at CERN is part of the planned injector upgrade of the LHC. Initially used at low duty cycle as LHC injector it has the potential to be upgraded as a high power proton driver for neutrino physics and/or radioactive ion beams.

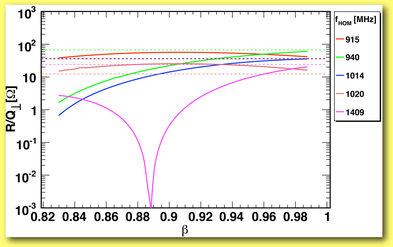
In this paper the influence of the beam parameters on the build-up of Higher Order Mode (HOM) voltages is studied together with their interaction on the beam. For this purpose we use bunch tracking simulations in the longitudinal and transverse plane in order to define Beam Break-Up (BBU) limits. These simulations take into account changing values for the HOM frequency spread and are carried out using various distances between the HOM frequencies and the main machine lines.

R/Q⊥(β) Analysis

$$R/Q_\perp(\beta) = \frac{\int_0^L E_z(\rho = r) e^{i\omega_n z c/\beta} dz}{(r\omega_n/c)^2 \omega_n U_n} \quad [\Omega]$$

No	β_d	f [MHz]	R/Q⊥(β) [Ω]		
			β_d	max	avg
1	0.65	1015	2	143	49
2	0.65	1020	39	107	60
3	0.65	1027	55	57	19
4	0.65	1033	11	30	12
5	0.65	1270	26	34	10
6	1	915	35	57	48
7	1	940	76	60	44
8	1	1014	37	36	27
9	1	1020	12	25	20
10	1	1409	24	20	12





Simulation Parameter

- no alignment errors in the focusing elements
- all cavities have zero transverse displacement
- beam is injected on axis
- one dipole mode per cavity
- longitudinally matched beam
- no HOM monopoles
- all errors are Gaussian distributed
- HOM excited by beam noise

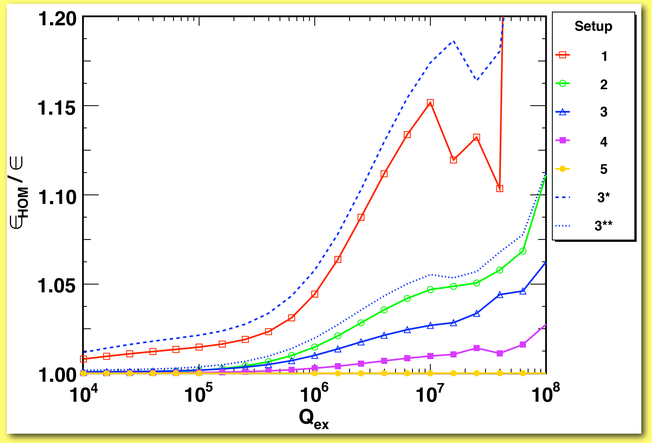
Parameter	Mean	σ (old)
x_{Input} [mm]	0	0.3
x'_{Input} [mrad]	0	0.3
I_{Beam} [A]	0.4†	3% (10%)
f_{HOM} [MHz]	various	1.0 (0.1)

†10 times nominal beam current

Transverse Simulations

Setups to study the effect of f_{HOM} and R/Q⊥(β):

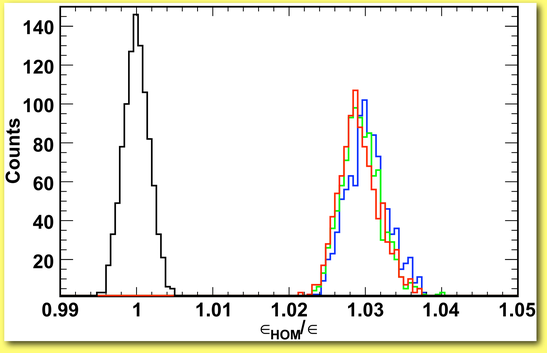
1. Highest R/Q⊥(β) value at cavity beam β
2. Mode 2 and 6, f_{HOM} =1056.6 MHz
3. Mode 2 and 6
4. Mode 5 and 10
5. f_{HOM} = 2817.6 MHz, R/Q⊥(β) ~ 0.2

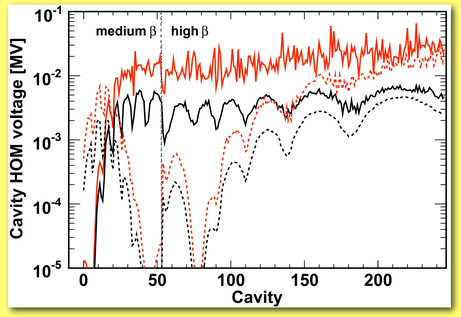


*old simulation input parameter and const. R/Q⊥; **const. R/Q⊥

Statistical Analysis

3 runs (each 1000 simulations) with variation in the frequency pattern (green), the beam pattern (blue, black - without HOM) and both patterns (red).



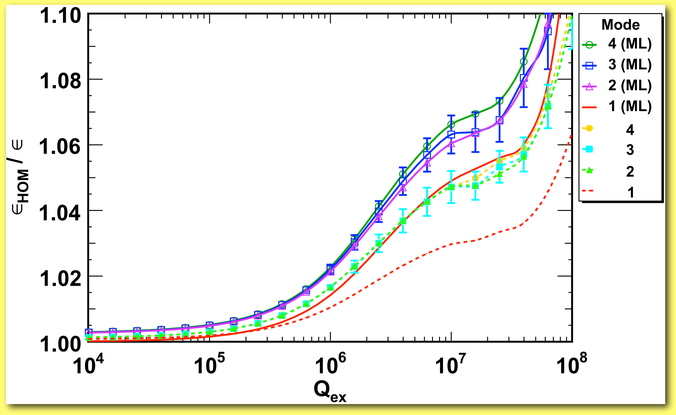


The average (black) and maximum (red) observed HOM voltage after 1000 simulations at $Q_{ex}=10^7$ in case of HOM setup 3 (solid) and 5 (dashed).

Influence Of Chopping

The charge per pulse stays constant. HOM Setup 3 is used and additionally f_{HOM} is shifted to a machine line (ML).

	Chopping	f_{ML} [MHz]
1	no	1056.60
2	5/8	1012.48
3	50/80	1016.98
4	500/800	1018.30



Conclusions & Outlook

One of the significant findings to emerge from this study is that the review of the simulation input parameter led to significant change in the simulated emittance growth. It has been pointed out, that chopping causes an additional transverse emittance growth, however it was found to be within tolerable limits.

In this investigation, the aim was to define upper limits for the damping requirements. Even when using ten times the design current simulation results in the transverse plane showed that a Q_{ex} of 10^6 - 10^7 is acceptable.

Future studies will concentrate on analyzing the effects of chopping on the longitudinal plane and of alignment errors.