ECLOUD in PS2, PS+, SPS+: AN UPDATE*

M. A. Furman,† Center for Beam Physics, Bldg. 71R0259, LBNL, CA 94720-8211, USA

Abstract

We present an update of our results for the electron-cloud build-up for several upgrades proposed for the LHC injectors. Specifically, we have re-examined our published results for the ecloud heat load [1] from the perspective of numerical convergence of the simulations vis-à-vis the integration time step Δt. We repeated most of the simulations with ever smaller values of Δt until we reached stable results, indicating numerical convergence; this was achieved at 200–500 slices per bunch, depending on the particular case. In all cases examined, the simulated heat load decreases monotonically, until the limit is reached, as Δt decreases in the range explored, hence the stable results are more favorable vis-à-vis the heat load than the previous ones. This is particularly true for a bunch spacing $t_b = 25$ ns.

SUMMARY AND RESULTS

All assumptions for the simulation, physical parameters and notation are described in [1], particularly Table I which we reproduce below. In this update we consider only the PS and SPS upgrades, not the LHC proper. We have not re-examined any cases with bunch spacing $t_b = 12.5$ ns. The only parameter that is varied here is the integration time step Δt; all other parameters remain as specified in [1]. In particular, we have examined the build-up of the ecloud only in a dipole bending magnet for each machine, at a magnetic field B corresponding to the specified beam energy E_b, for the first batch injected into an empty chamber (2 μs long, including the gap after the bunch train). We have not examined any other regions of the machine, nor any effects from the ecloud on the beam.

Figs. 1 and 2 show the approach to numerical convergence of the heat load for the PS50 and PS75, respectively, plotted as a function of peak SEY $\delta_{\rm max}$. Numerical convergence is clear at $N_k = 501$ for $t_b = 25$ ns, but is already apparent for $N_k = 201$ for $t_b = 50$ and 75 ns. Values of Δt are indicated for the largest value of N_k. For other values of N_k, Δt scales as $(N_k - 1)^{-1}$.

Fig. 3 shows a comparison of the heat load for the PS50, for copper vs. stainless steel chamber surface. The simulated results for copper are the same as those in Fig. 5 of Ref. 1, and were obtained with $N_k = 251$ kicks per bunch for $t_b = 25$ ns, and $N_k = 201$ for $t_b = 50$ ns (we did not verify that the copper results have converged). We recall that the labels "copper" and "stainless steel" refer here to a particular choice of model parameters we used for the secondary electron emission yield and emitted electron energy spectrum. Although these two sets of model parameters were extracted from various bench measurements, we do not know whether they correspond to the actual materials that are used, or will be used, in the actual vacuum chambers of the machines. Therefore, these secondary emission models would have to be validated by new measurements in order to confirm the clear advantage of copper over stainless steel seen in Fig. 3.

Fig. 4 shows the heat load, after convergence has been reached, for the cases PS50 and PS75. This should be compared with Fig. 4 of Ref. 1. Figs. 5, 6 and 7 present similar comparisons for various competing options considered for the SPS (to be compared with Figs. 6, 7 and 8 of Ref. 1, respectively). In general, there is no qualitative difference between the options except possibly at $t_b = 25$ ns.

DISCUSSION

In the range of values for the integration step size Δt we have explored ($\Delta t = (1-30)\times 10^{-11}$ s) we have seen that the simulated heat load decreases monotonically, until a limit is reached, as Δt decreases. We conclude that the previous results, while not accurate, at least had the value of representing an upper limit for the estimated heat load. The largest fractional decrease of the heat load is seen for $t_b = 25$ ns. The previously seen inverse relationship that the heat load has with the bunch spacing is maintained by the new results. In addition to the heat load, we have also computed other quantities such as electron density (global and close to the beam), ecloud average energy per electron, electron-wall impact energy, and electron flux at the chamber walls. A spreadsheet with all such results is available upon request.

ACKNOWLEDGMENTS

I am indebted to M. Venturini for presenting some of these results at the ECL2 workshop. I am grateful to F. Zimmermann for guidance and encouragement, and to NERSC for supercomputer support.

REFERENCES

[1] M. A. Furman, "ECLOUD in PS2, PS+, SPS+," Proc. CARE-HHH-APD Workshop *Towards a Roadmap for the Upgrade of the CERN and GSI Accelerator Complex* "LHC LUMI 2006," IFIC (Valencia, Spain), 16–20 October 2006, http://care-hhh.web.cern.ch/CARE-HHH/LUMI-06/default.html. Please look only at my publication in the proceedings; the preliminary results presented in my viewgraphs should not be taken into consideration.

* Work supported by the U.S. DOE under Contract No. DE-AC02-05CH11231 and by the US-LHC Accelerator Research Program (US-LARP). Invited contribution, Proc. ECL2 Workshop (CERN, March 1-2, 2007), http://care-hhh.web.cern.ch/CARE-HHH/ECL2/default.html

† mafurman@lbl.gov

Table 1: Basic simulation input parameters.

Case	Our notation	E_b GeV	B T	(a,b) cm	N_b 10^{11}	t_b ns	(σ_x,σ_y) mm	σ_z cm	profile $\cdots$
PS2, 50 GeV extr.	PS50tb12p5	50	1.8	$(8,4)$	2	12.5	$(1,0.9)$	57.3	gauss.
	PS50tb25	50	1.8	$(8,4)$	4	25	$(1,0.9)$	93.5	gauss.
	PS50tb50	50	1.8	$(8,4)$	5.4	50	$(1,0.9)$	104	flat
	PS50tb75	50	1.8	$(8,4)$	6.6	75	$(1,0.9)$	104	flat
PS+, 75 GeV extr.	PS75tb12p5	75	2.7	$(8,4)$	2	12.5	$(0.8,0.8)$	50.5	gauss.
	PS75tb25	75	2.7	$(8,4)$	4	25	$(0.8,0.8)$	83.5	gauss.
	PS75tb50	75	2.7	$(8,4)$	5.4	50	$(0.8,0.8)$	92.3	flat
	PS75tb75	75	2.7	$(8,4)$	6.6	75	$(0.8,0.8)$	92.3	flat
SPS, 50 GeV inj.	SPS50tb12p5	50	0.225	$(7,2.2)$	1.9	12.5	$(3.1,1.6)$	14.3	gauss.
	SPS50tb25	50	0.225	$(7,2.2)$	3.8	25	$(2.8,1.6)$	23.4	gauss.
	SPS50tb50	50	0.225	$(7,2.2)$	5.2	50	$(3,1.6)$	26.1	flat
	SPS50tb75	50	0.225	$(7,2.2)$	6.4	75	$(3,1.6)$	26.1	flat
SPS, 75 GeV inj.	SPS75tb12p5	75	0.337	$(7,2.2)$	1.9	12.5	$(2.4,1.3)$	12.6	gauss.
	SPS75tb25	75	0.337	$(7,2.2)$	3.8	25	$(2.1,1.3)$	20.9	gauss.
	SPS75tb50	75	0.337	$(7,2.2)$	5.2	50	$(2.3,1.3)$	23.1	flat
	SPS75tb75	75	0.337	$(7,2.2)$	6.4	75	$(2.3,1.3)$	23.1	flat
SPS, 450 GeV extr.	SPS450tb12p5	450	2.025	$(7,2.2)$	1.9	12.5	$(1.2,0.9)$	12	gauss.
	SPS450tb25	450	2.025	$(7,2.2)$	3.8	25	$(1,0.5)$	12	gauss.
	SPS450tb50	450	2.025	$(7,2.2)$	5.2	50	$(1,0.5)$	15	flat
	SPS450tb75	450	2.025	$(7,2.2)$	6.4	75	$(1,0.5)$	15	flat
SPS+, 1 TeV extr.	SPS1000tb12p5	1000	4.5	$(6,2)$	1.8	12.5	$(0.5,0.4)$	12	gauss.
	SPS1000tb25	1000	4.5	$(6,2)$	3.6	25	$(0.6,0.4)$	12	gauss.
	SPS1000tb50	1000	4.5	$(6,2)$	5.1	50	$(0.5,0.4)$	15	flat
	SPS1000tb75	1000	4.5	$(6,2)$	6.2	75	$(0.5,0.4)$	15	flat
SPS+a, 50 GeV inj.	SPSpa50tb12p5	50	0.225	$(6,2)$	1.9	12.5	$(3.1,1.6)$	14.3	gauss.
	SPSpa50tb25	50	0.225	$(6,2)$	3.8	25	$(2.8,1.6)$	23.4	gauss.
	SPSpa50tb50	50	0.225	$(6,2)$	5.2	50	$(3,1.6)$	26.1	flat
	SPSpa50tb75	50	0.225	$(6,2)$	6.4	75	$(3,1.6)$	26.1	flat
SPS+b, 75 GeV inj.	SPSpb75tb12p5	75	0.337	$(6,2)$	1.9	12.5	$(2.4,1.3)$	12.6	gauss.
	SPSpb75tb25	75	0.337	$(6,2)$	3.8	25	$(2.1,1.3)$	20.9	gauss.
	SPSpb75tb50	75	0.337	$(6,2)$	5.2	50	$(2.3,1.3)$	23.1	flat
	SPSpb75tb75	75	0.337	$(6,2)$	6.4	75	$(2.3,1.3)$	23.1	flat
LHC nominal	LHCnom	7000	8.39	$(2.2,1.8)$	1.15	25	$(0.3,0.3)$	7.55	gauss.
LHC ultimate	LHCult	7000	8.39	$(2.2,1.8)$	1.7	25	$(0.3,0.3)$	7.55	gauss.
longer bunch	LHClb	7000	8.39	$(2.2,1.8)$	6	75	$(0.3,0.3)$	14.4	flat
longer bunch 2	LHClb2	7000	8.39	$(2.2,1.8)$	4.9	50	$(0.3,0.3)$	14.4	flat
same except gaussian	LHClb2g	7000	8.39	$(2.2,1.8)$	4.9	50	$(0.3,0.3)$	14.4	gauss.
shorter bunch	LHCsb	7000	8.39	$(2.2,1.8)$	1.7	12.5	$(0.3,0.3)$	3.78	gauss.

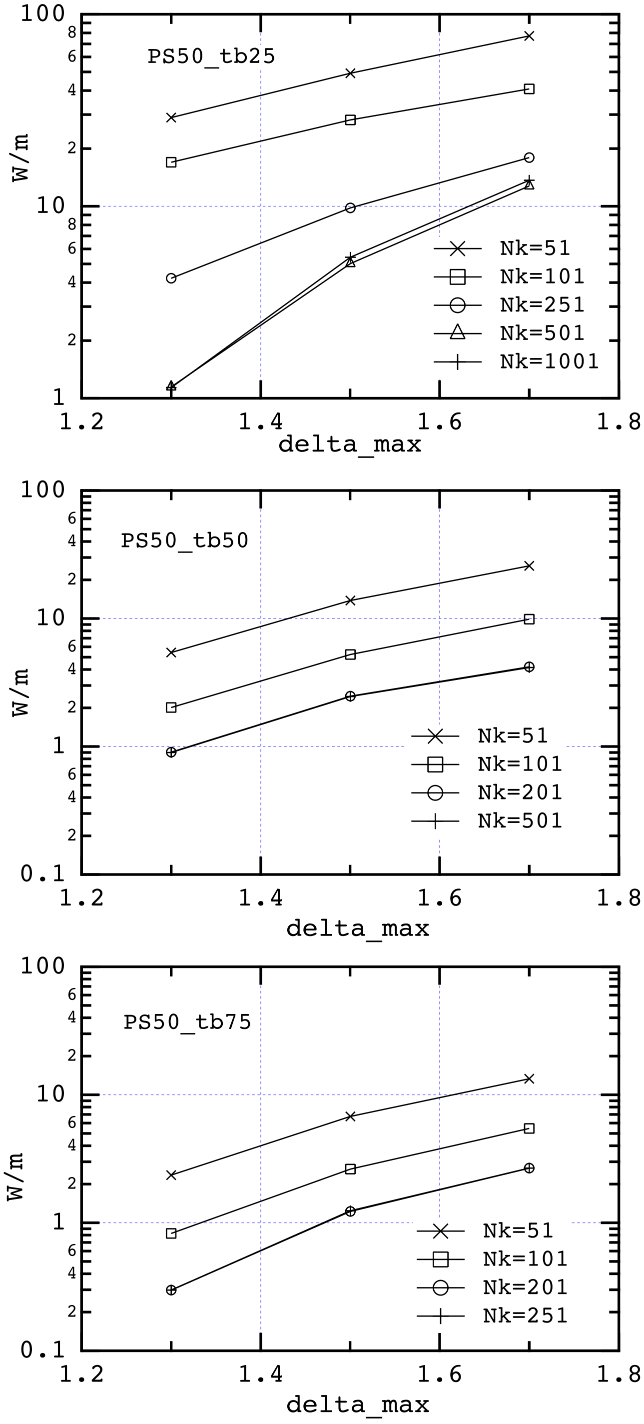

Figure 1: Simulated ecloud heat load vs. $\delta_{\max}$ for case PS50 ("PS2"), for $t_b = 25$ ns (top), $t_b = 50$ ns (center) and $t_b = 75$ ns (bottom), for various values of the number of kicks per bunch length N_k. For the highest value of N_k used, Δt has the values 1.56×10^{-11} s (top), 2.68×10^{-11} s (center) and 5.36×10^{-11} s (bottom).

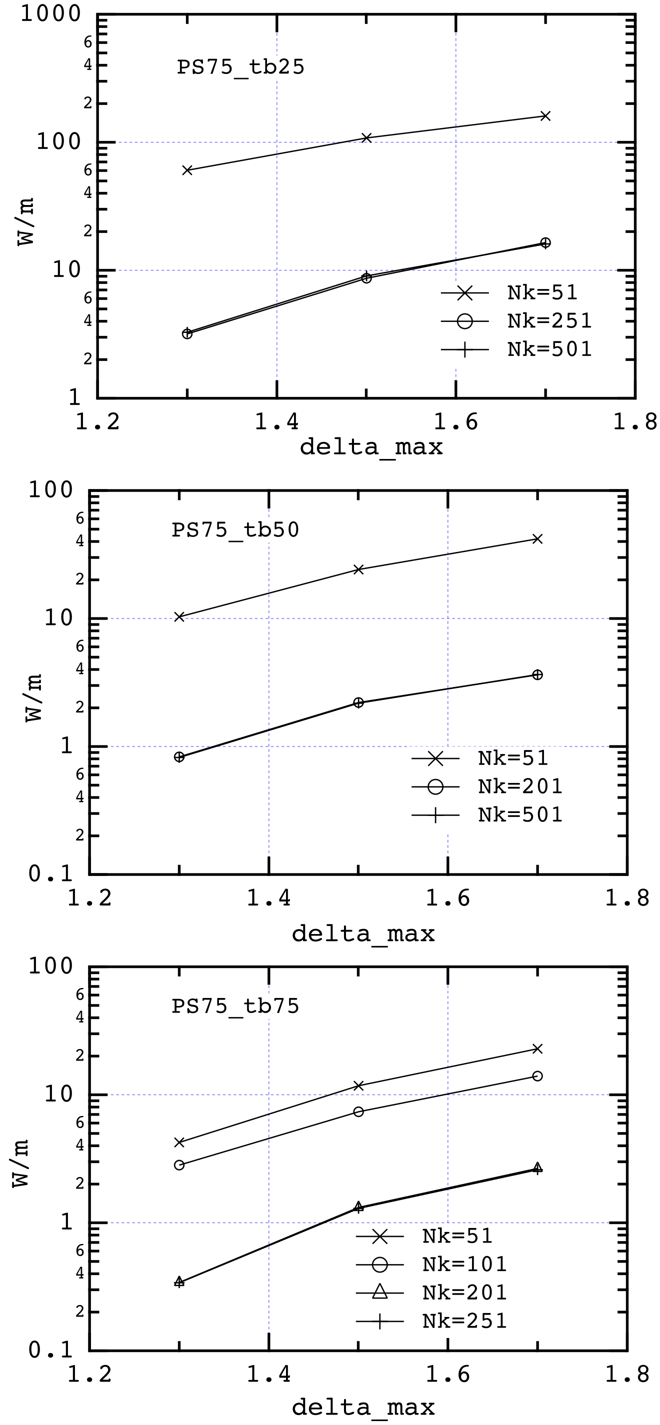

Figure 2: Simulated ecloud heat load vs. $\delta_{\max}$ for case PS75 ("PS+"), for $t_b = 25$ ns (top), $t_b = 50$ ns (center) and $t_b = 75$ ns (bottom), for various values of the number of kicks per bunch length N_k. For the highest value of N_k used, Δt has the values 2.79×10^{-11} s (top), 2.38×10^{-11} s (center) and 5.95×10^{-11} s (bottom).

DISCLAIMER

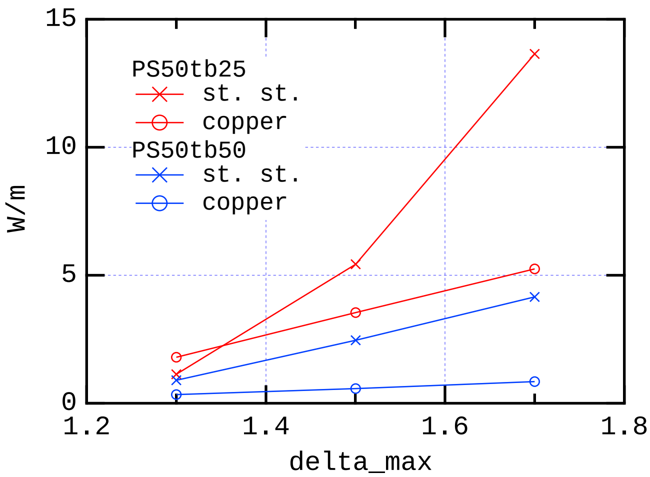

Figure 3: Simulated PS ecloud heat load vs. δ_{max} for case PS50, for copper and stainless steel chamber. The basic difference in the calculation for the two cases is the secondary emission energy spectrum of the two metals.

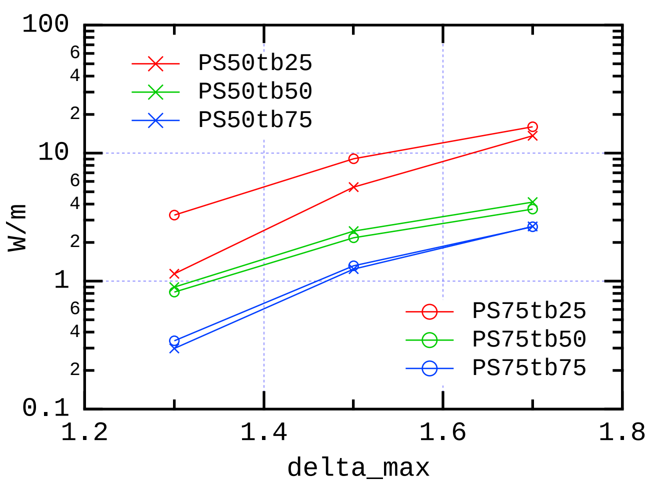

Figure 4: Simulated PS ecloud heat load vs. δ_{max} for case PS50 and PS75 (“PS2” and “PS+” in “psplusetcparameters,” respectively).

employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, or The Regents of the University of California.

Ernest Orlando Lawrence Berkeley National Laboratory

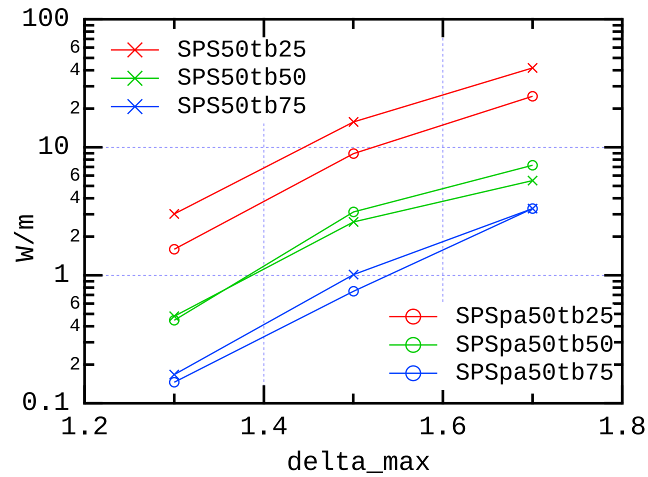

Figure 5: Simulated SPS ecloud heat load vs. δ_{max} for cases SPS50 and SPSpa50. The only difference between the calculation for these two cases is the transverse chamber size (slightly smaller for the SPSpa50).

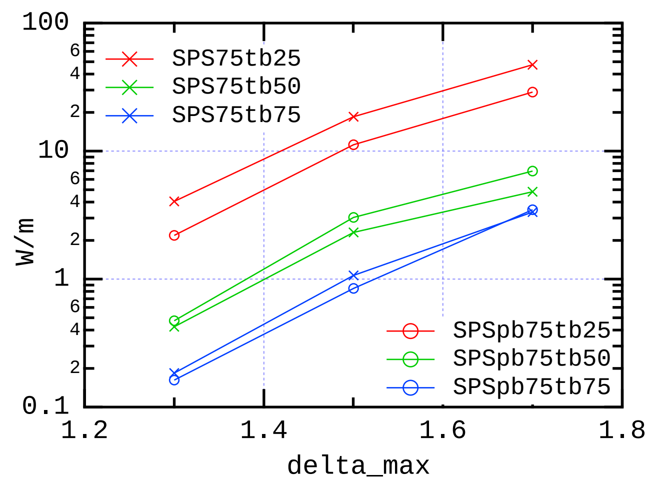

Figure 6: Simulated SPS ecloud heat load vs. δ_{max} for cases SPS75 and SPSpb75. The only difference between the calculation for these two cases is the transverse chamber size (slightly smaller for the SPSpb75).

is an equal opportunity employer.

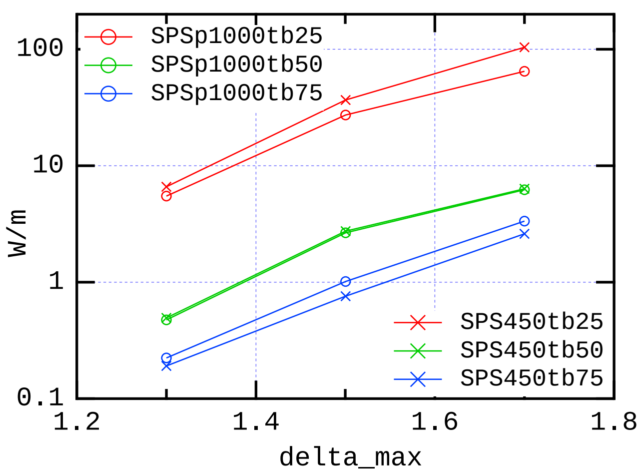

Figure 7: Simulated SPS ecloud heat load vs. $\delta_{\rm max}$ for $E_b = 450$ GeV and $E_b = 1$ TeV.