



SPS-LHC transfer losses

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BE-RF-FB

LIU-SPS BD WG meeting

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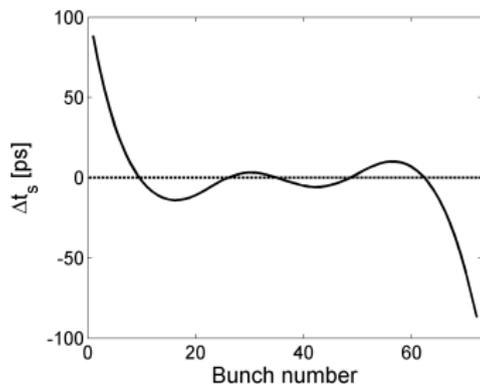
Introduction

- Voltage reduction campaign in the LHC due to beam-loading
- SPS-LHC injection losses and at flat-bottom (FB)

Procedure

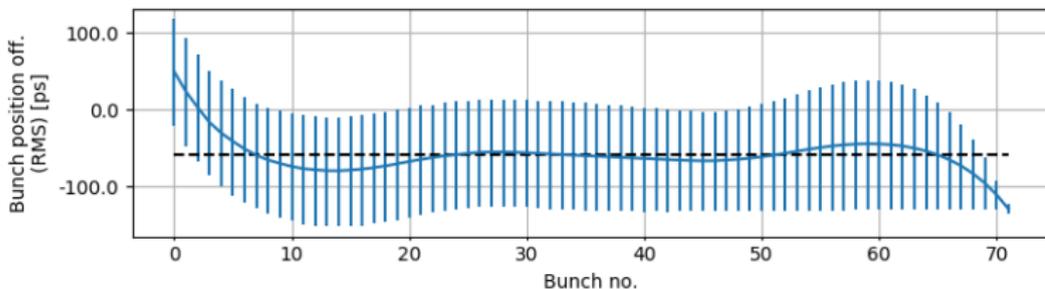
1. Benchmark with SPS model
2. Bunch generation in the SPS: present and future
3. Injection into the LHC: results with and without energy offsets and discussion

Benchmark



- Benchmark of the bunch generation in the SPS with model that reproduces measurements
- Feedback and feedforward
- Agreement of the bunch position offset w.r.t. bucket centre (full range of ~ 180 ps)

1.15×10^{11} ppb, 72b, $V_{200}/V_{800} = 7$ MV/0.65 MV
Bunch length $\tau_{4\sigma}^{\text{FWHM}} = 1.65$ ns Q26 optics ($\gamma_t = 17.95$)



Bunch generation in the SPS: present and future

Parameter	Unit	Present	Future
Bunch intensity	10^{11} ppb	1.15	2.30
No. bunches per train	1	48b (BCMS)	72b (STD)
RF voltage V_{200}/V_{800}	MV	7/1.24	10/1.50
Ave. bunch length $\tau_{4\sigma}^{\text{FWHM}}$	ns	1.55, 1.65, 1.75	1.55, 1.65, 1.75

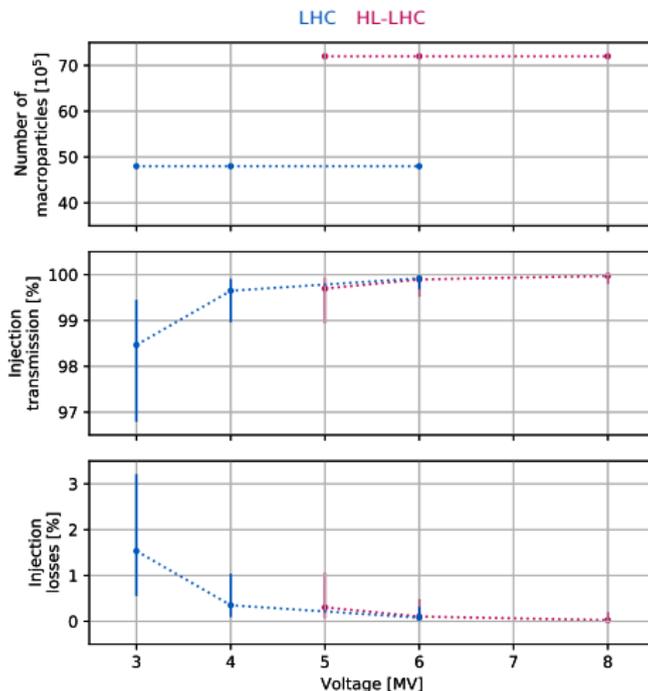
- Bunch generation matched to the RF bucket with intensity effects
 - Binominal with $\mu = 2$
 - Two cases with shorter/longer bunches lengths w.r.t. to the nominal $\tau_{4\sigma}^{\text{FWHM}} = 1.65$ ns @ extraction are studied to get error bars
- Present and future SPS impedance models (latest GitLab version)
- 10^5 macroparticles per bunch are tracked for 5×10^3 turns (~ 115 ms)
 - To check that the distribution is matched
 - **Convergence studies** (e.g. on the no. of macroparticles) are needed
- Q20 optics ($\gamma_t = 22.80$)

LHC and HL-LHC

Parameter	Unit	LHC	HL-LHC
Bunch intensity	10^{11} ppb	1.15	2.30
No. bunches per train	1	48b (BCMS)	72b (STD)
RF voltage V_{400}	MV	3, 4, 6	5, 6, 8

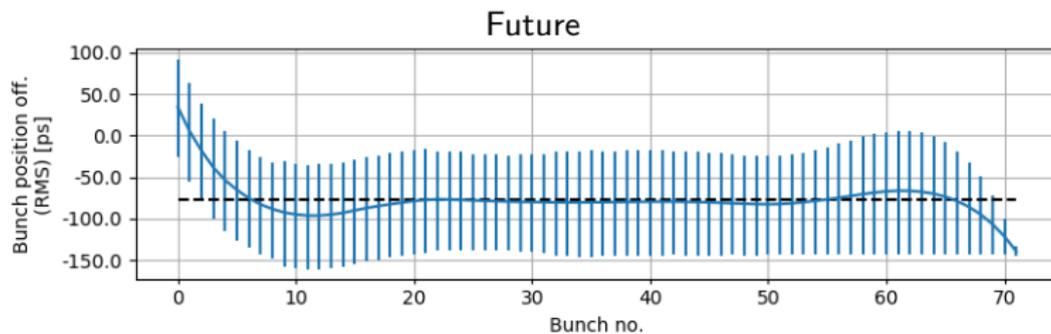
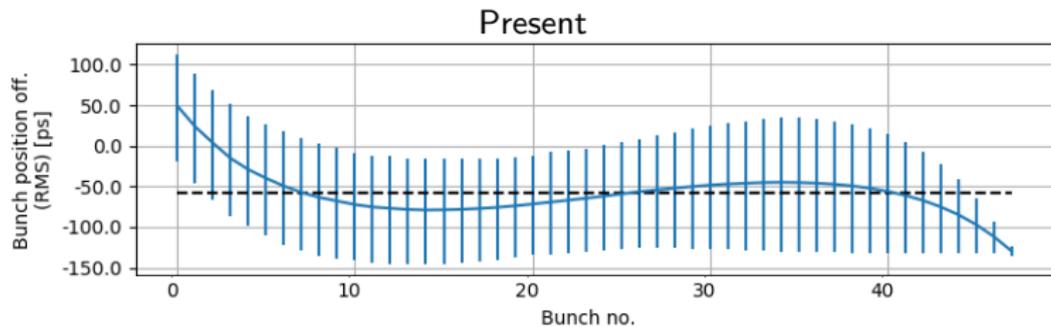
- Tracked bunches in the SPS are injected into the LHC:
 - Without injection offset: the average bunch position corresponds to the centre of the LHC bucket
 - With a 50MeV-injection offset
- Present and future LHC impedance models (ABP database)
- Quantify losses (based on the separatrix w/o intensity effects in both cases):
 - At injection: first turn
 - At flat bottom: after 5×10^3 turns (~ 445 ms)

LHC and future (no injection offset)



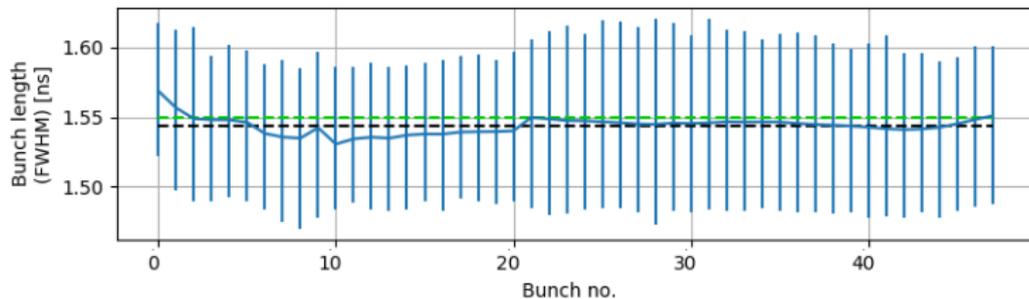
- HL-LHC performs better than expected (why?)

SPS beam-loading patterns

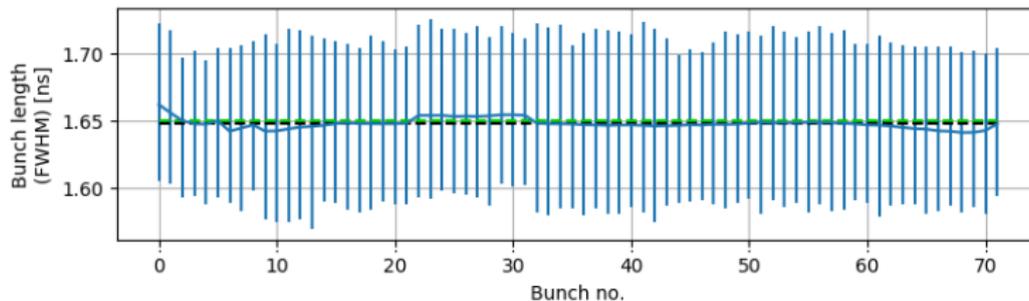


SPS beam-loading patterns

Present

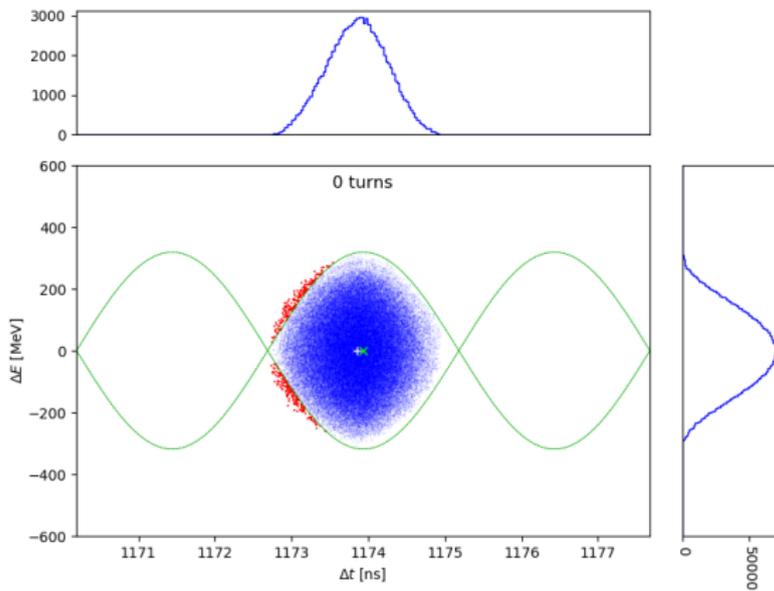


Future



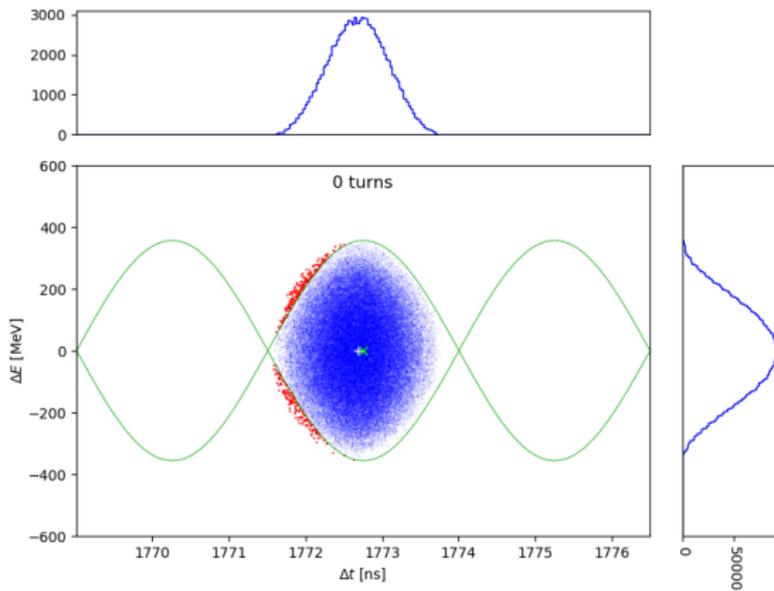
Injection into the LHC (4 MV)

Present (4 MV)



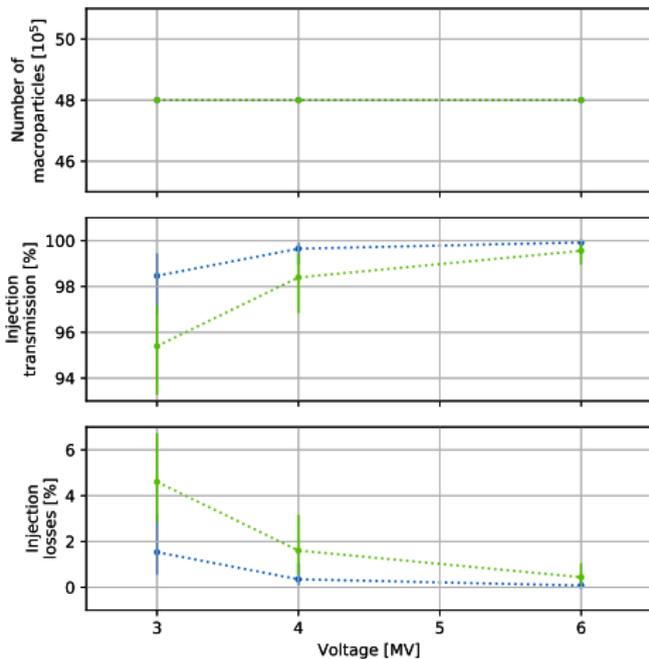
Injection into the HL-LHC (5 MV)

Future (5 MV)

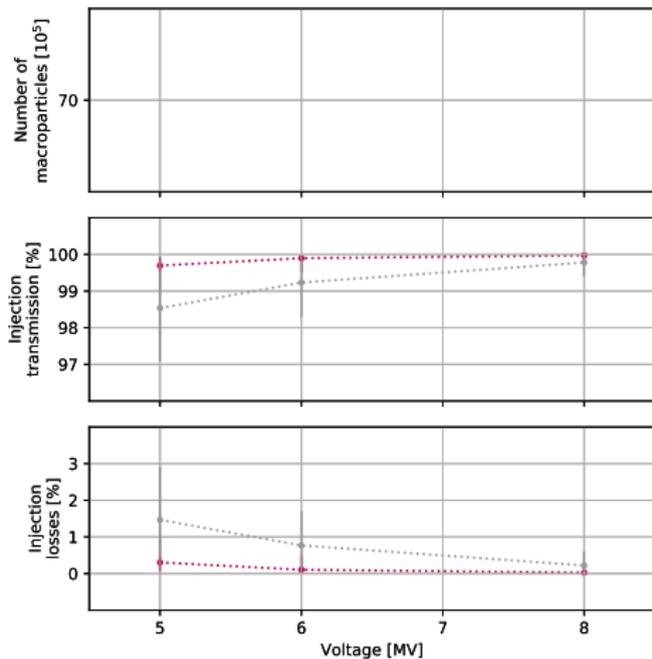


50MeV injection offset

LHC, 0MeV LHC, 50MeV

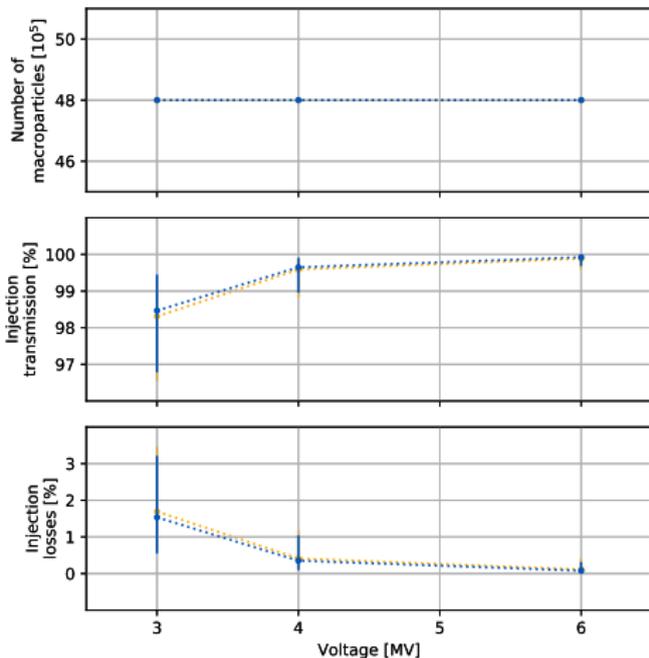


HL-LHC, 0MeV HL-LHC, 50MeV

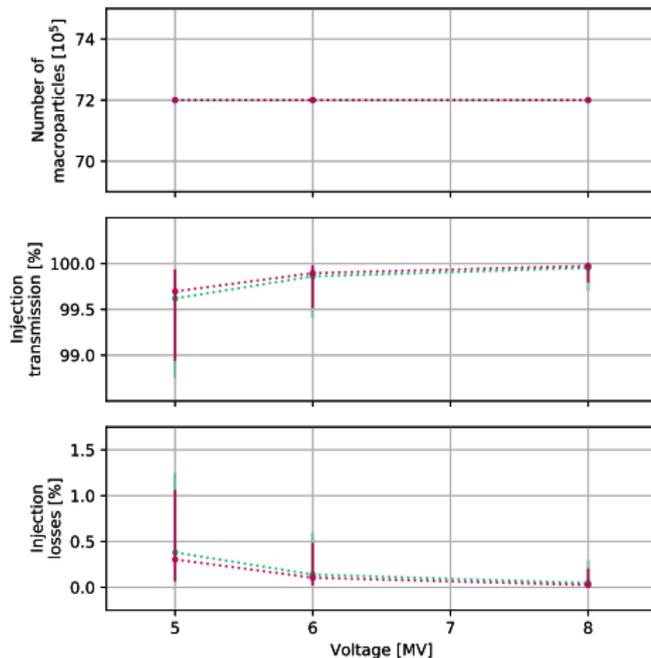


Injection vs flat-bottom (no injection offset)

LHC, inj LHC, FB



HL-LHC, inj HL-LHC, FB



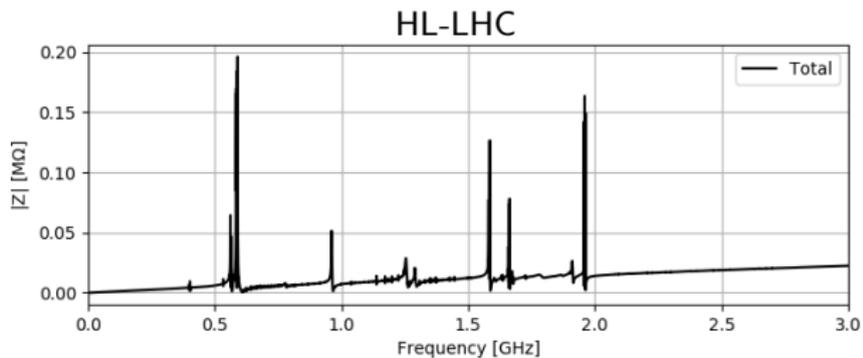
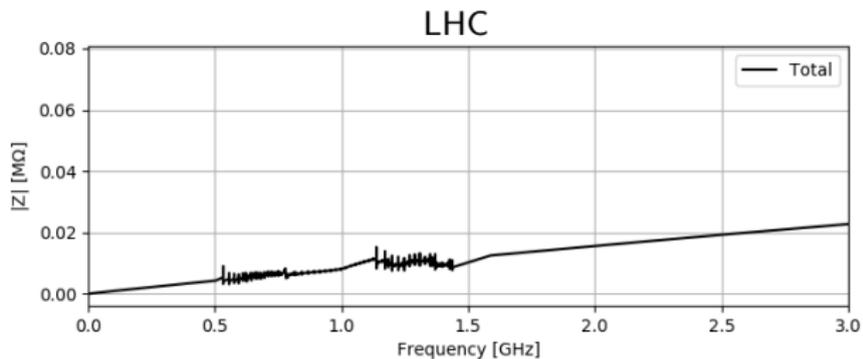
Conclusions and discussion

- Dominated by capture losses (first impression)
- Convergence studies: number of macroparticles
- HL-LHC scenario performs better than expected (why? – if it is confirmed)
 - More uniform beam-loading pattern?
- Study dependence on the distribution profile
- Does the SPS model need improvement?



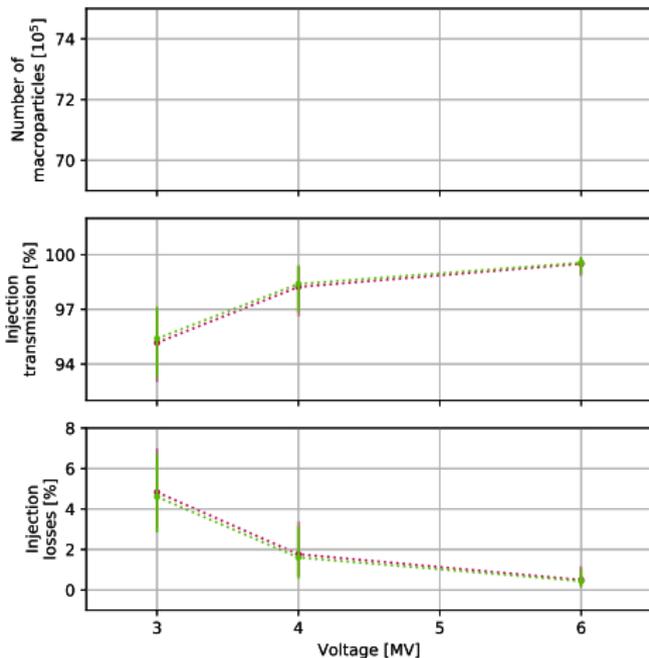
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LHC and HL-LHC impedance models

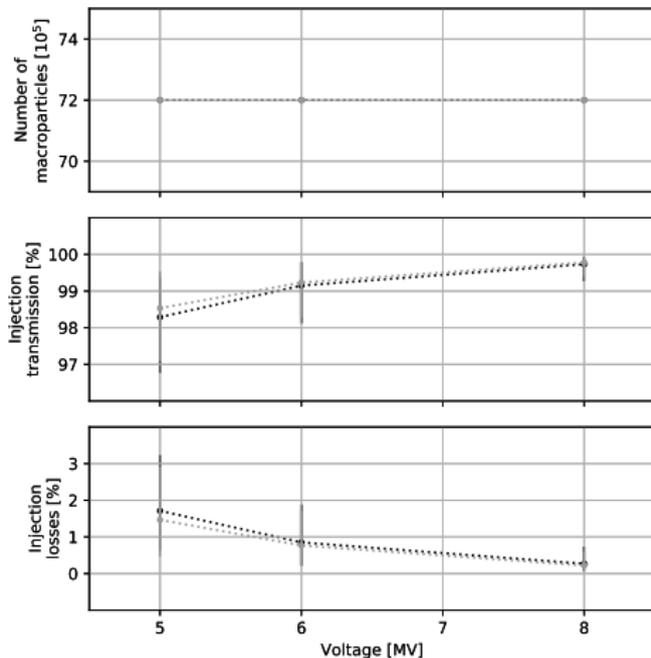


Injection vs flat-bottom (50MeV injection offset)

LHC, inj LHC, FB



HL-LHC, inj HL-LHC, FB





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