118th FCC-ee Optics Design Meeting

Consolidated FCC-ee filling scheme

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Thanks to:

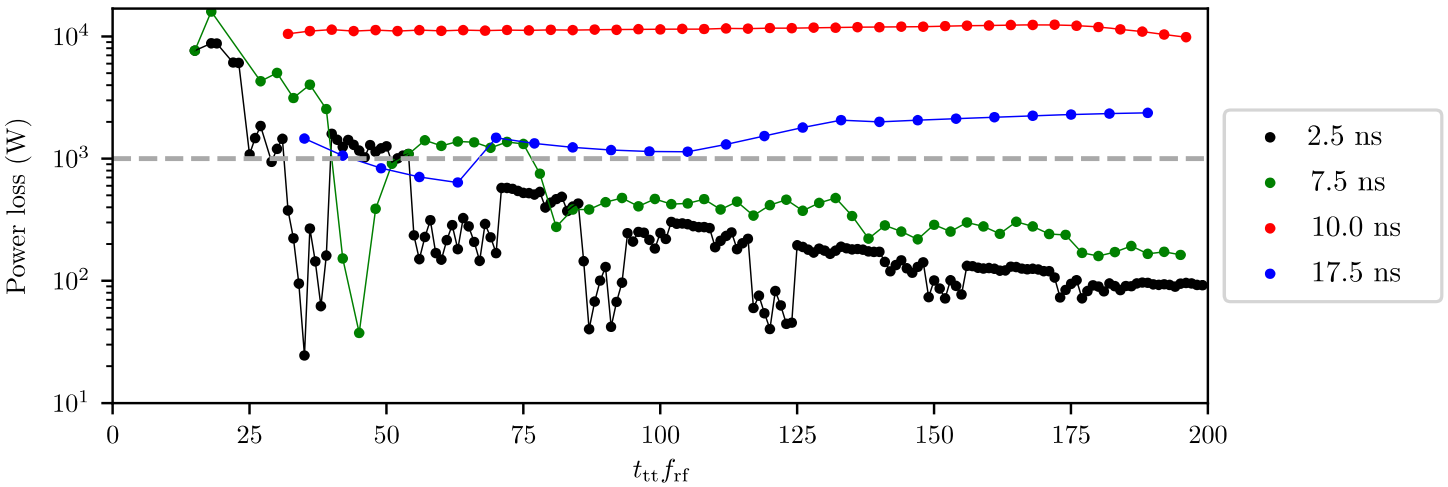
M. Benedikt, O. Etisken, S. Ogur, K. Oide and F. Zimmermann

FCCee bunch spacing considerations

- **High power losses** (above 1 kW) for bunch spacing of 10 ns and 17.5 ns
- Larger bunch spacings are desirable for e-cloud/ion instabilities
- For Z production, 16640 bunches filling uniformly the collider/booster require average bunch spacings < 20 ns (ratio of harmonic number to number of bunches ~19.6 ns)
- Consider **mini-trains** of **20 ns** with **shorter 15-17.5 ns gaps** between them (see M. Benedikt in 96th FCC-ee Optics Design Meeting)

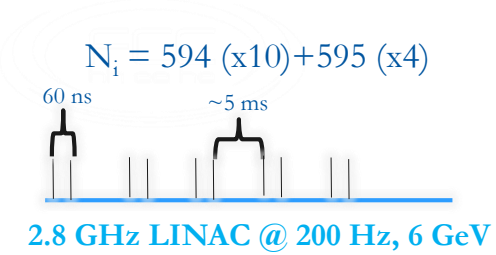
PHYSICAL REVIEW ACCELERATORS AND BEAMS **21,** 071001 (2018)

$f_r = 694 \pm 5$ MHz, $R/Q = 12\ \Omega$, $Q = 640$



Ivan Karpov, Rama Calaga, and Elena Shaposhnikova
CERN, CH 1211 Geneva 23, Switzerland

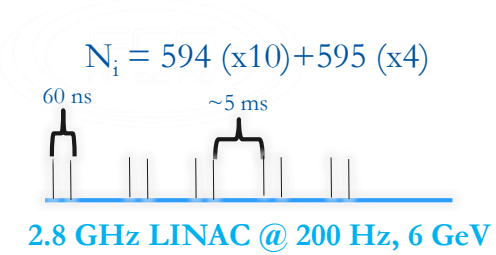
Filling scheme for Z (20 ns)



2.8 GHz LINAC @ 200 Hz, 6 GeV

- **2.8 GHz** linac accelerating **2** bunches with repetition rate of **200 Hz** with **60 ns** bunch spacing (**8** SPS buckets)
- Injected **594/595** times @ **6 GeV** into SPS with 1 linac bunch to 1 ring bucket (**400 MHz** RF system), up to **1188/1190** bunches
- **198** mini-trains with **6** bunches (**20 ns**) and **71/126** mini-train gaps (15/17.5 ns), kicker gap of **120 ns**

Filling scheme for Z (20 ns)



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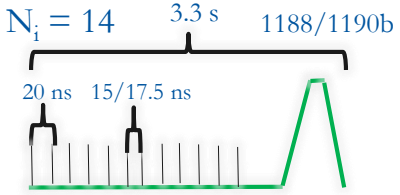
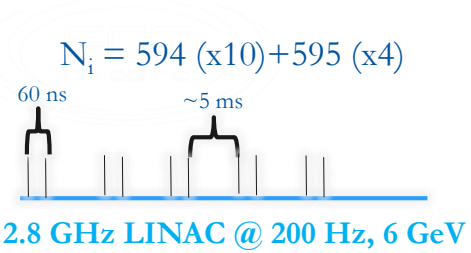


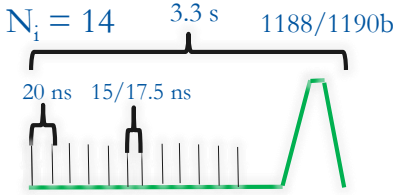
SPS from 6 to 16 GeV

- **2.8 GHz** linac accelerating **2** bunches with repetition rate of **200 Hz** with **60 ns** bunch spacing (**8** SPS buckets)
- Injected **594/595** times @ **6 GeV** into SPS with 1 linac bunch to 1 ring bucket (**400 MHz** RF system), up to **1188/1190** bunches
- **198** mini-trains with **6** bunches (**20 ns**) and **71/126** mini-train gaps (15/17.5 ns), kicker gap of **120 ns**
- SPS ramp to **16 GeV** with **0.125 s** ramp time and cycle length of **3.3 s**
- Transferred to main Booster (**14** SPS cycles), with **400 MHz** RF frequency, to a bunch structure required by the collider (**16640** bunches)

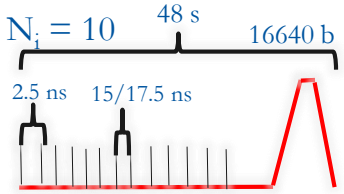
Filling scheme for Z (20 ns)



2.8 GHz LINAC @ 200 Hz, 6 GeV



SPS from 6 to 16 GeV



BR from 16 to 45.6 GeV

- **2.8 GHz** linac accelerating **2** bunches with repetition rate of **200 Hz** with **60 ns** bunch spacing (**8** SPS buckets)
- Injected **594/595** times @ **6 GeV** into SPS with 1 linac bunch to 1 ring bucket (**400 MHz** RF system), up to **1188/1190** bunches
- **198** mini-trains with **6** bunches (**20 ns**) and **71/126** mini-train gaps (15/17.5 ns), kicker gap of **120 ns**
- SPS ramp to **16 GeV** with **0.125 s** ramp time and cycle length of **3.3 s**
- Transferred to main Booster (**14** SPS cycles), with **400 MHz** RF frequency, to a bunch structure required by the collider (**16640** bunches)
- Ramp time of **0.37 s**, and total cycle length of **48 s**
- Transferred to collider by **accumulating current** for the full filling (**bootstrapping**), or **single injection** for top-up
- **Top-up target time** based on **5 %** of current drop due to corresponding **lifetime**, always achieved

FCCee injector parameters

Accelerator	FCCee-Z		FCCee-W		FCCee-H		FCCee-tt	
Energy [GeV]	45.6		80		120		182.5	
Type of filling	Full	Top-up	Full	Top-up	Full	Top-up	Full	Top-up
LINAC # bunches, with 2.8 GHz RF	2				1			
LINAC repetition rate [Hz]	200		100					
LINAC/PBR bunch population [10^{10}]	2.13	1.06	0.94	0.56	0.94	0.56	1.38	0.83
# of LINAC injections	594/595		500		328		48	
PBR bunch spacing [ns]	15/17.5/20 ns		22.5		67.5		450	
# PBR cycles	14		2		1			
PBR # of bunches	1188/1190		1000		393		50	
PBR cycle time [s]	3.3		5.4		3.6		0.8	
PBR duty factor	0.76		0.49		0.23		0.05	
BR # of bunches	16640		2000		328		48	
BR cycle time [s]	47.9		13		6.9		5.7	
#of BR cycles	10	1	20	1	20	1	20	1
# of injections/collider bucket	10	1	20	1	20	1	20	1
Total number of bunches	16640		2000		328		48	
Filling time (both species) [sec]	958.8	95.9	520	26	277.2	13.9	227.7	11.4
Injected bunch population [10^{10}]	2.13	1.06	1.44	1.44	1.13	1.13	1.38	0.83

Further considerations

- Filling scheme of the new PBR (2.8 km)
- Is 15 ns bunch spacing viable (e-cloud/ions considerations)?
- Adapting new linac parameters