Simulations of the booster position at the EXFEL

(preliminary)

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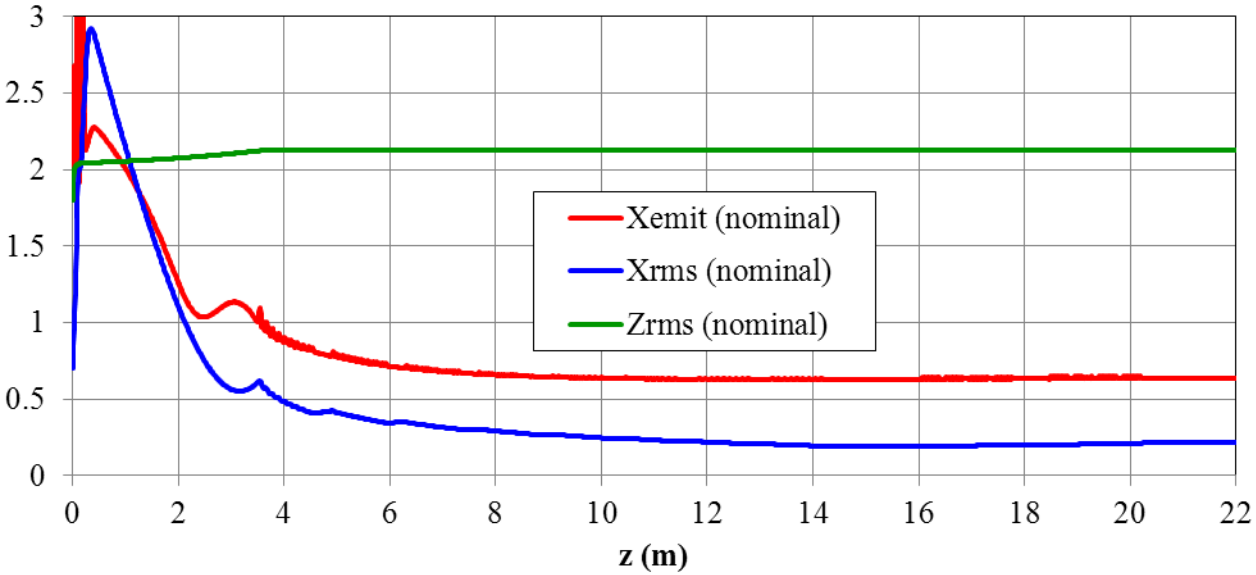
Motivation

- Simulations of the optimum CDC booster position at PITZ (M. Khojoyan)
- Nominal simulations of the EXFEL photo injector →slightly over-focused beam in front of the ACC1



conditions for the beam → e.g. "invariant envelope": the beam should be at a laminar waist at the booster linac entrance (i.e. $\sigma_{x,y} = 0$) and the energy gain in the booster γ'_{boost} should be related to the rms beam size σ_w, the incoming mean beam energy γ and the peak current I_p via the equation [Serafini]:

$$\gamma'_{boost} = \frac{2}{\sigma_w}\sqrt{\frac{I_p}{3I_A\gamma}}$$

This estimation → ~19, ASTRA optimization → ~34

Nominal and re-optimized setups

			European XFEL photo injector		
			cylindrical pulses with flattop temporal profiles		
	ACC position →		nominal	optimized (bp)	
Cathode laser	rt/FWHM\ft	ps	2/21.5\2	2/21.5\2	
	Trms	ps	6.272	6.272	
	Transverse duistribution		radial homogeneous		
	XYrms	mm	**0.415**	***0.468***	←
RF gun	Th. emit.	mm mrad	0.351	0.396	
	Ecath.	MV/m	60.58		
	Phase	deg	**-1.5**	***-0.87***	←
	MaxBz	T	**-0.22745**	***-0.22874***	←
ACC1	**center of the 1st TESLAcav.**	**m**	4.0401	***3.499***	← bp
	MaxE(1-4)	MV/m	**33.5187**	***31.36***	← bp
	MaxE(5-8)	MV/m	**33.5187**		
Electron beam	Charge	nC	**1**		
	Ek(after ACC1)	MeV	150.63	146.01	
	Proj. emittance	mm mrad	0.629	0.629	
	Th. / proj.	%	56	63	
	<Sl. emit.>	mm mrad	0.550	0.519	
	Rms bunch length	mm	2.128	2.030	
	Peak current	A	44.2	45.9	
	Long. emittance	mm keV	533	446	
	<Brightness>	A/(mm mrad)^2	111	124	

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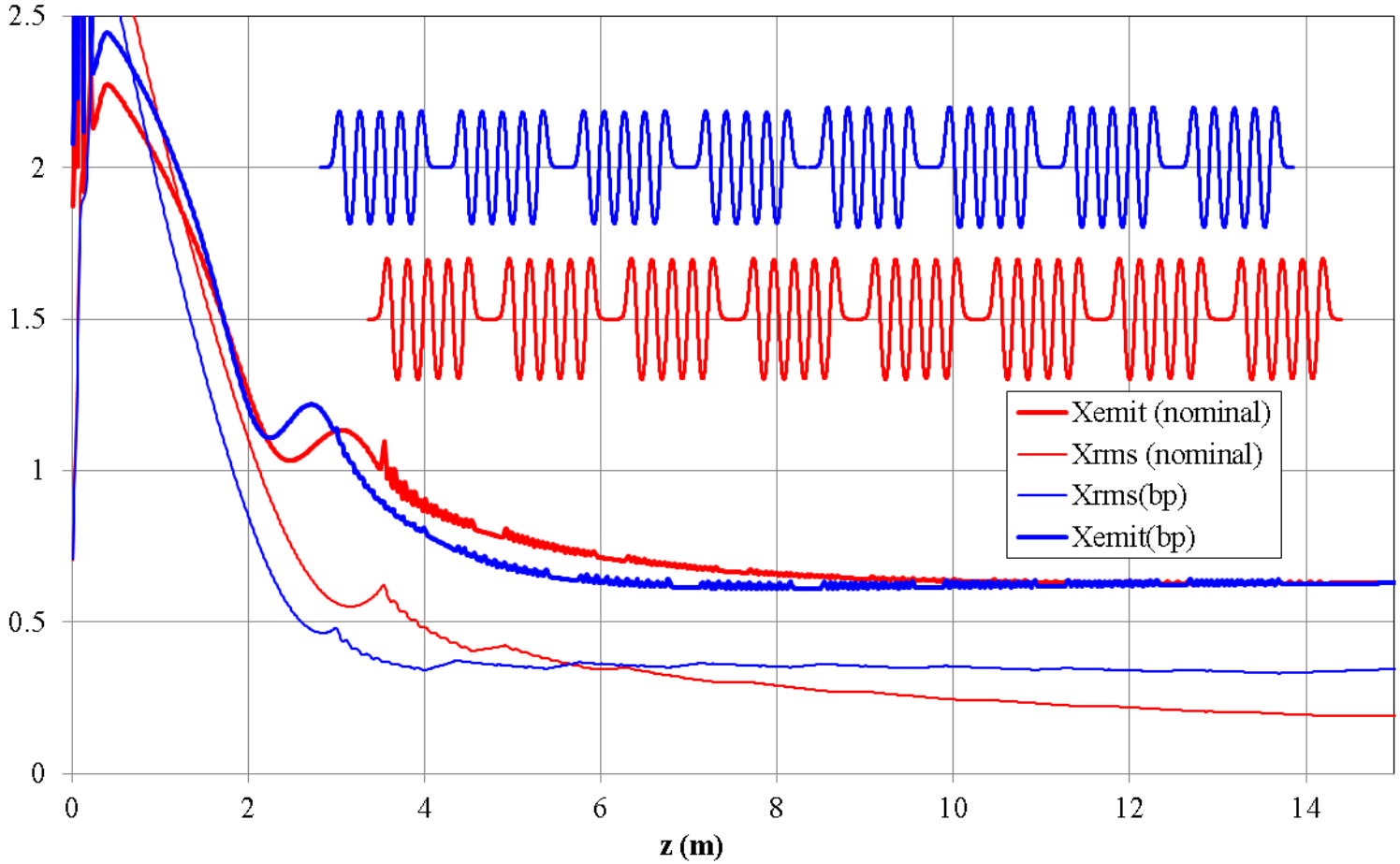
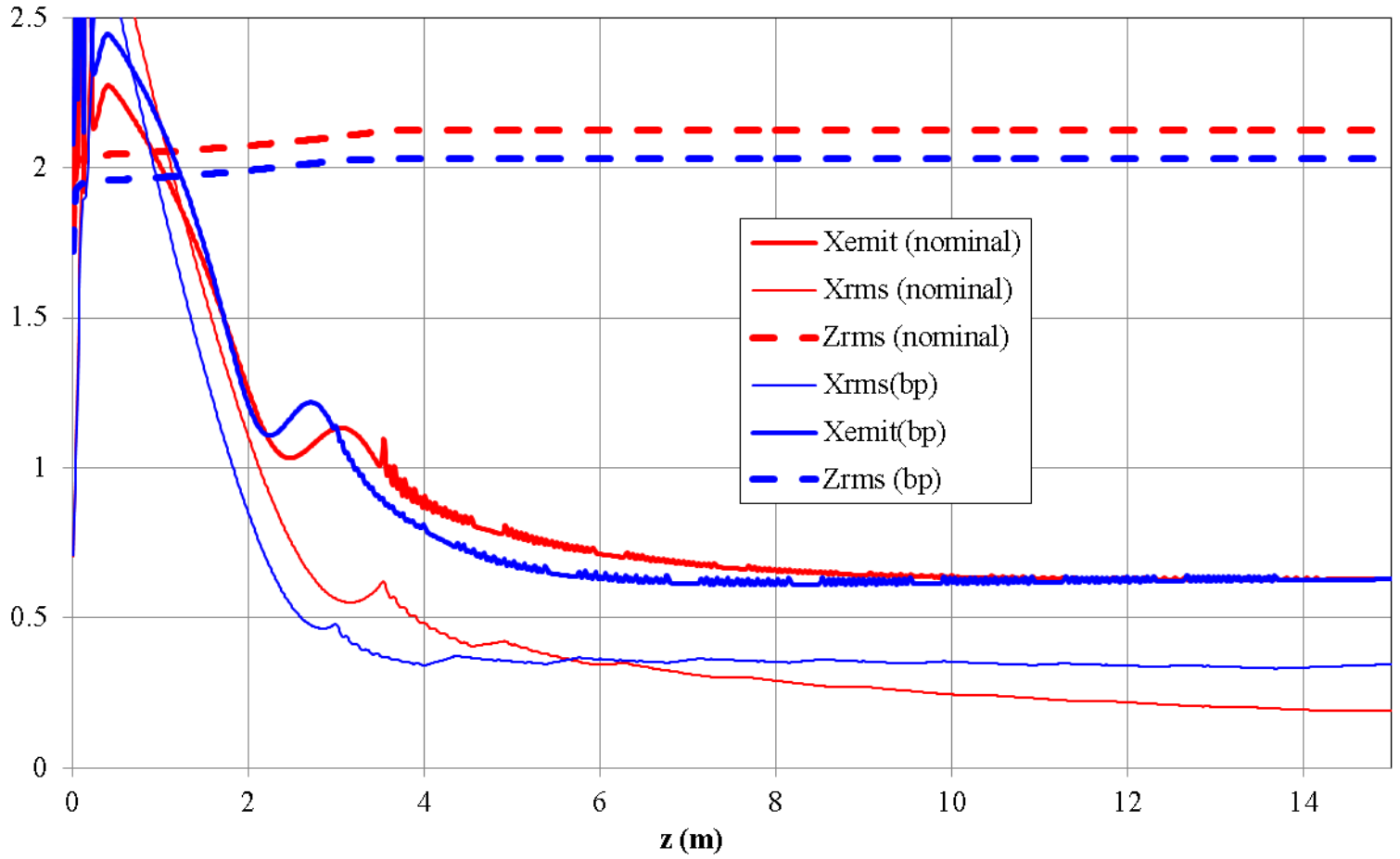
Nominal and re-optimized (bp) setups



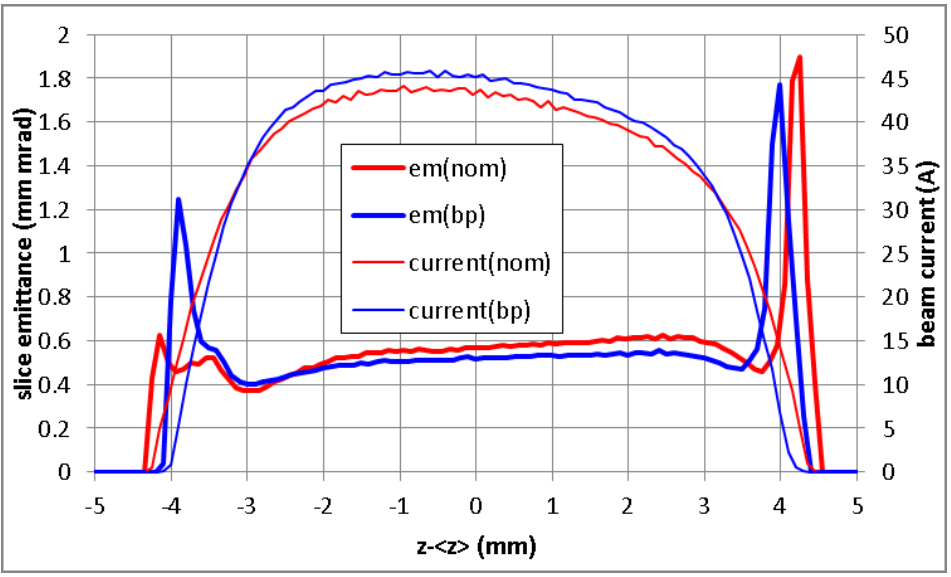
- ACC1 is by -0.54m upstream shifted
- Laser spot size at the cathode is by 13% larger → SC density at the cathode is by 21% smaller, therm. emit.(56%➔63%)
- Gun phase +1deg → a bit higher emission field
- Booster gradient (1/2 ACC1) is a bit smaller → inv. envelope?
- Solenoid peak field is by 0.6% higher – earlier focusing

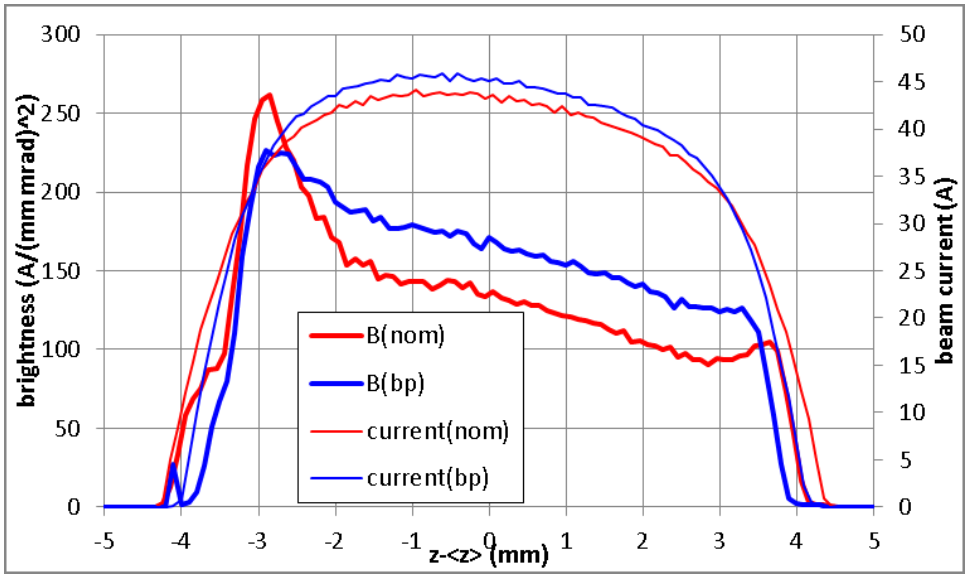
Nominal and re-optimized (bp) setups



- Beam size: smaller at waste, main focusing by the 1st TESLA cavity, then→~const
- Emittance (projected): stronger reduction in the booster (1st ½ ACC1), then →~const = nominal
- Bunch rms length is by ~5% smaller (reduced longitudinal SC effect)

Nominal and re-optimized (bp) setups





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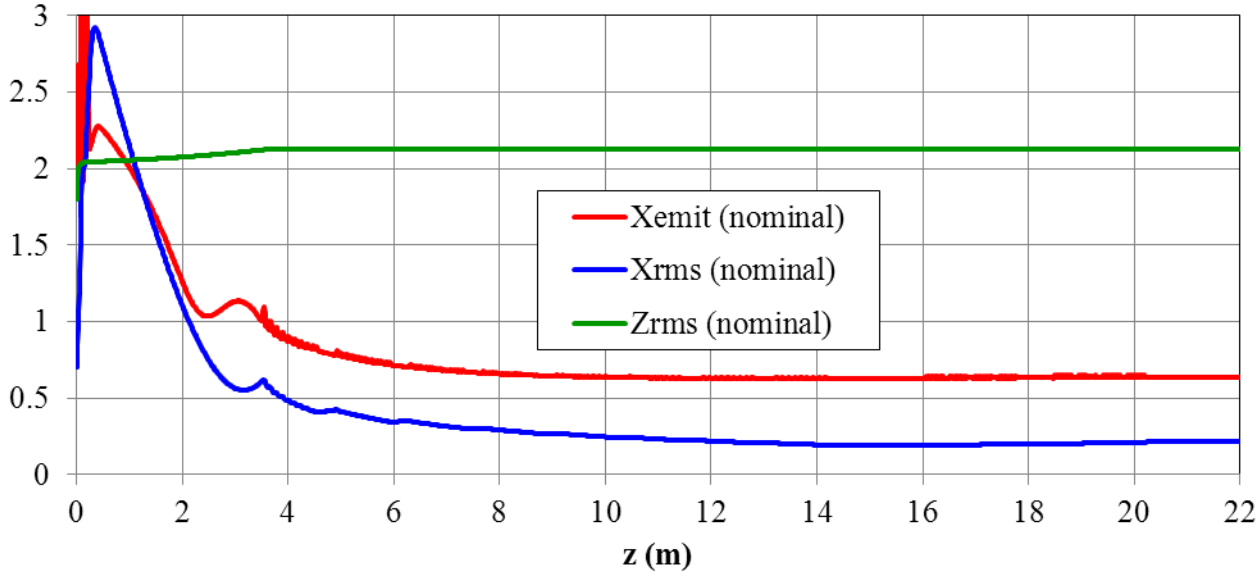
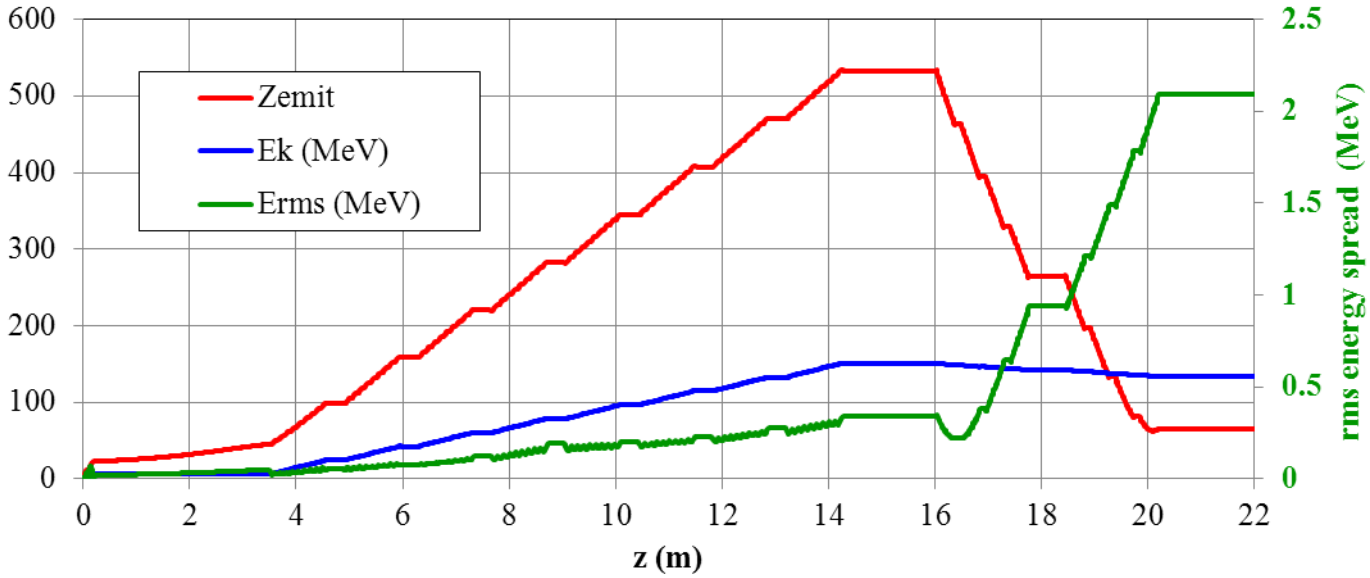
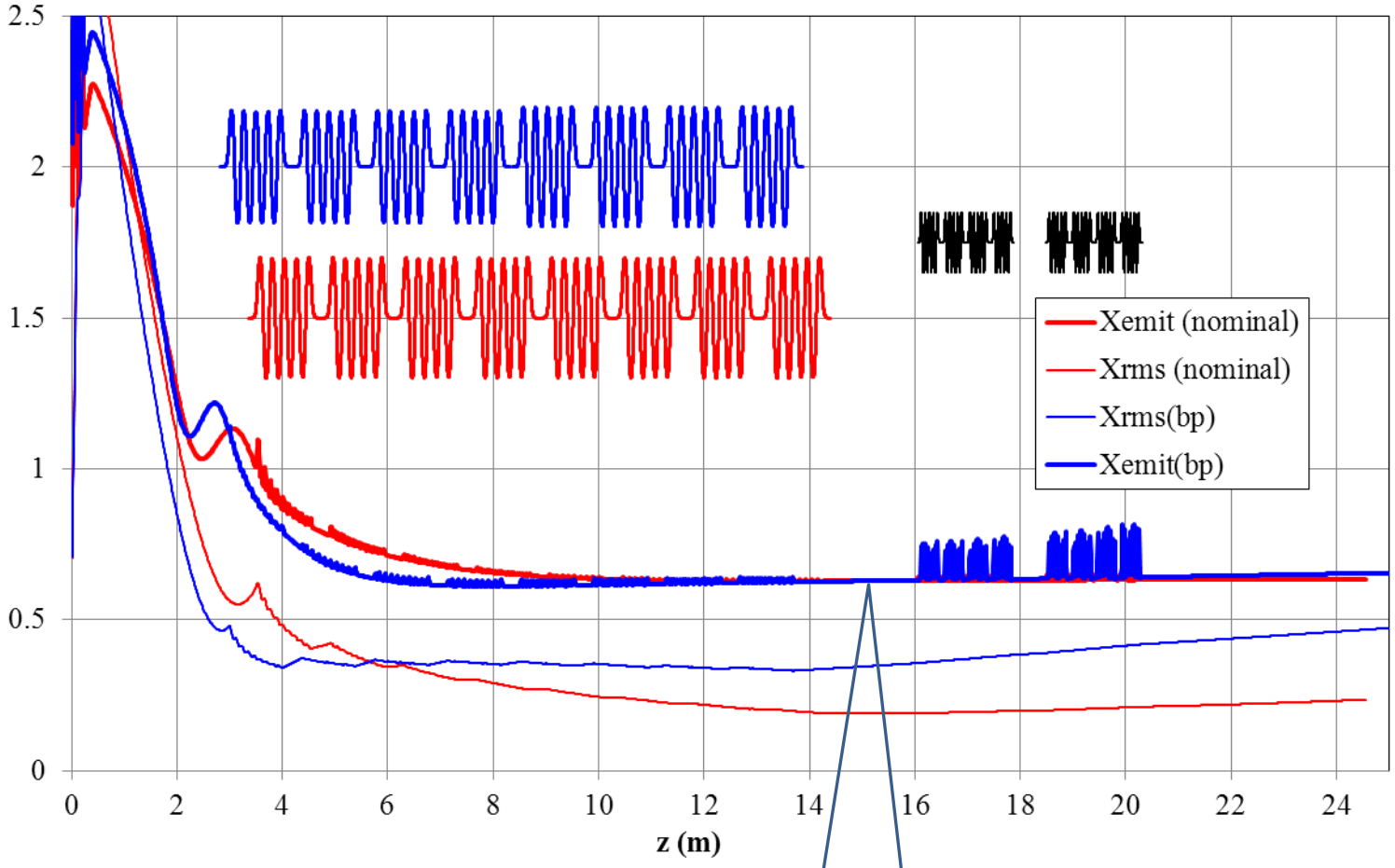
- therm. emit.(56%➔63%)
- by ~6% smaller! (9% in the center!)
- 5% shorter!
- 4% higher!

+3rd Harmonic Section (nominal)



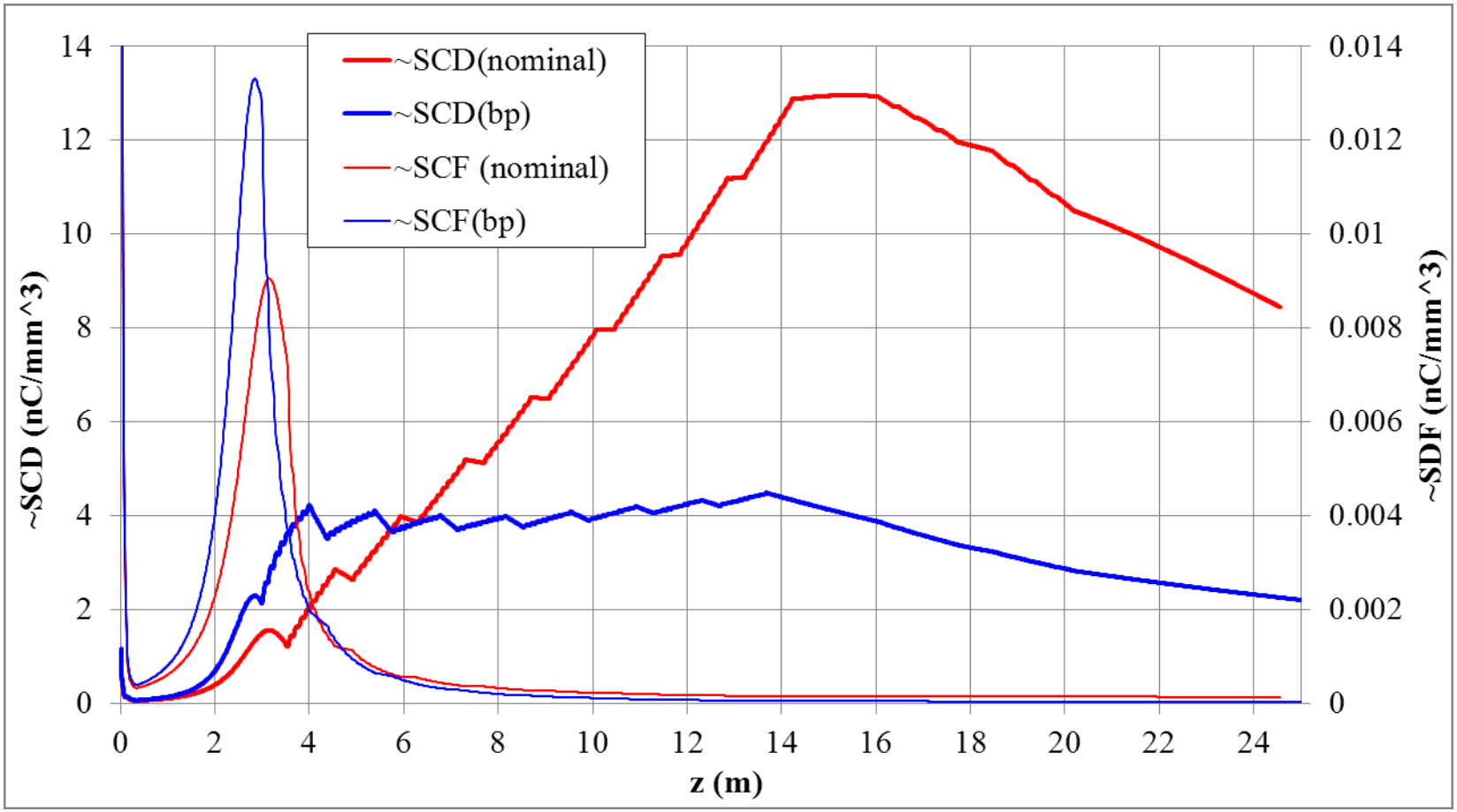


+3rd Harmonic Section (nominal and bp)



Matching quads (14.6 and 15.7m) were not applied

Space charge effect evaluation



Space charge density $SCD \propto \frac{Q}{\sigma_x \sigma_y \sigma_z}$

Space charge force $SCF \propto \frac{Q}{\gamma^2 \sigma_x \sigma_y \sigma_z}$

Conclusions (preliminary)

- "BP-setup" (shorter length of the downstream drift to ACC1):
  - Same projected emittance as for the nominal case
  - 5% smaller average slice emittance
  - 5% sorter bunch and ~4% higher peak current
  - Higher (by 12%) average brightness
  - larger (by 13%) laser spot size at the cathode → "+" or "–"?
  - Beam size in ACC1 is ~const. →"+" or "–"?
  - Space charge effect is different
  - …

- Outlook:
  - Beam matching into 3rd harmonic section
  - Booster phase tuning?
  - More flexible usage of the ACC1?
  - More thorough check of the "invariant envelope" approach (comp. to BD simulations
  - Tolerances and imperfections
  - …