

XFEL Photo Injector Simulations

*Preliminary trials to shorten an electron bunch
and increase a beam current*

M.Krasilnikov, PITZ

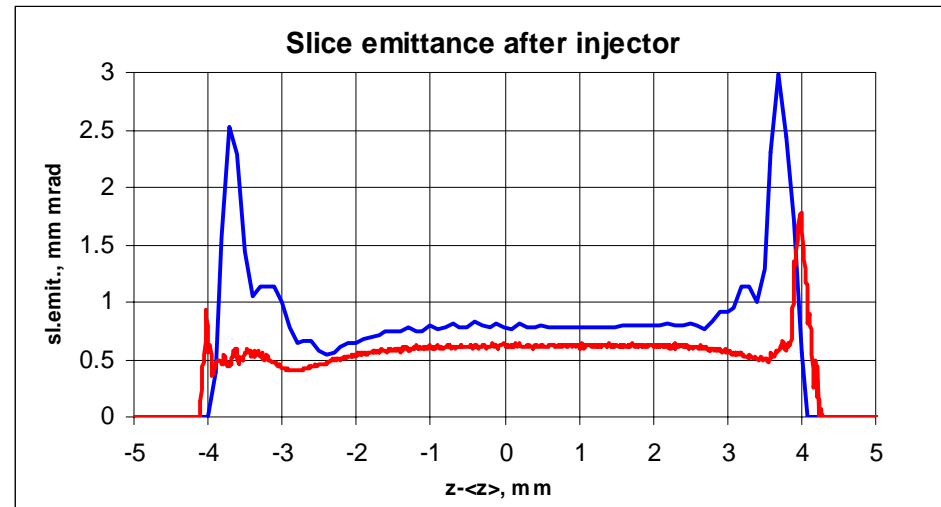
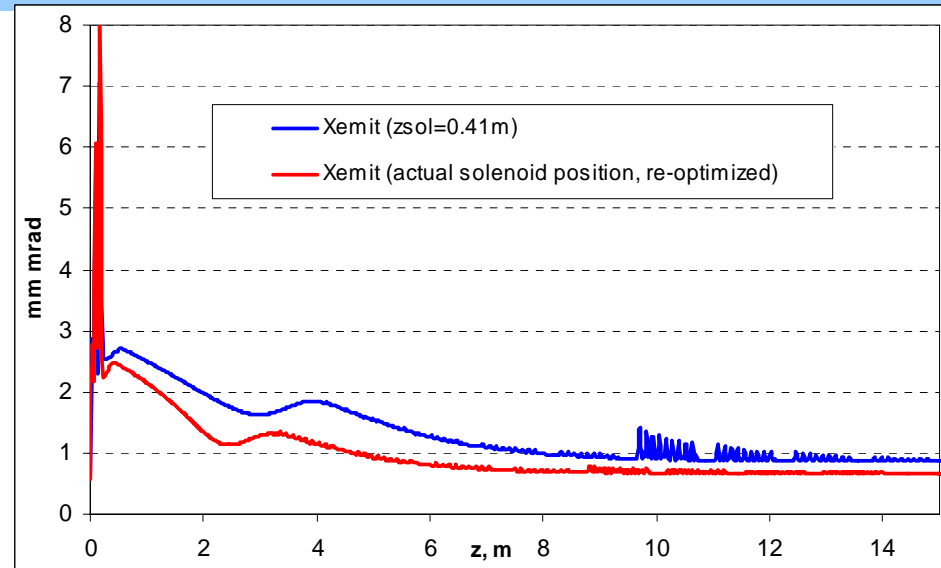
Beam Dynamics Meeting, 20.11.2006

Outline

- Method 1: Cathode laser shorting – 10ps instead 20ps FWHM
- Method 2: Velocity bunching by the first TESLA cavity in ACC1

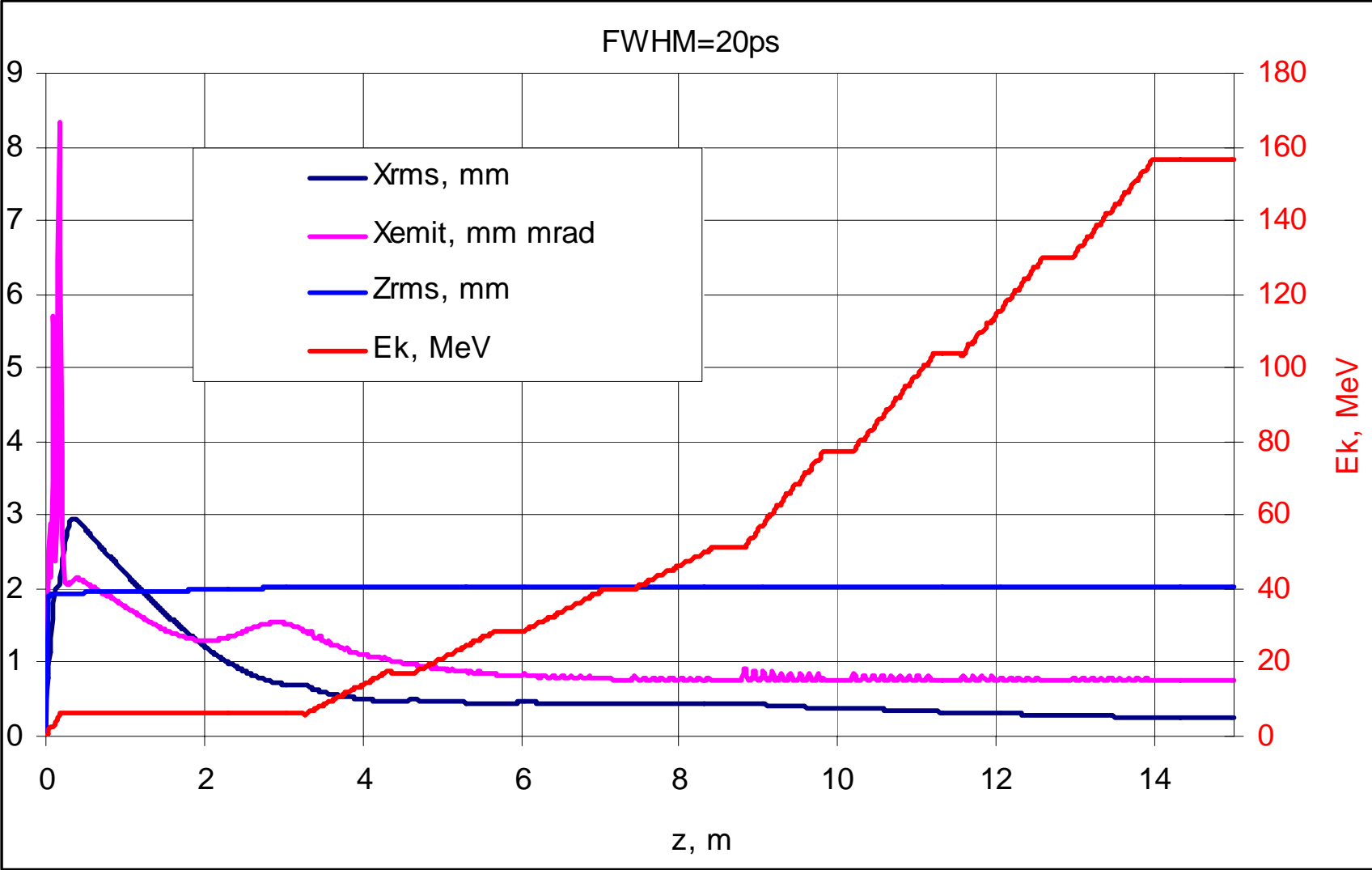
Optimization for nominal (20ps) cathode laser duration

				homogen.	homogen.
cathode laser	transverse	distribution		homogen.	homogen.
		XYrms	mm	0.55	0.438
	temporal	distribution		flat-top	flat-top
		Lt	ps	19.6	20
		rt	ps	2	2
	thermal	Trms	ps	5.69	5.8
Ek		eV	0.55	0.55	
gun	RF	emittance	mm mrad	0.46	0.37
		Ecath	MV/m	60	60
	solenoid	launch phase	deg	-1.64	-0.55
		z-position	m	0.41	0.276
		MaxB(1)	T	-0.1938	-0.22466
		MaxB(2)	T	0.000551	0.01113
booster	4xTESLA	z-position	m	4.66(+1.66)	3.77(+0.78)
		E _{max}	MV/m	15	21.5
		phase	deg	-16	-15.7
ACC1	4xTESLA	E _{max}	MV/m	50	50
		phase	deg	-16	-15.7
sim.	ASTRA	number of part.		200k	200k
e-beam	@z=15m	charge	nC	1	1
		energy	MeV	143	157
		trans.emittanc	mm mrad	0.87	0.676
		slice emit.(cer)	mm mrad	0.83	0.639
		rms en. spread	MeV	1.8	2.1
		long.emittance	mm keV	346	460
		rms length	mm	1.9	2.0



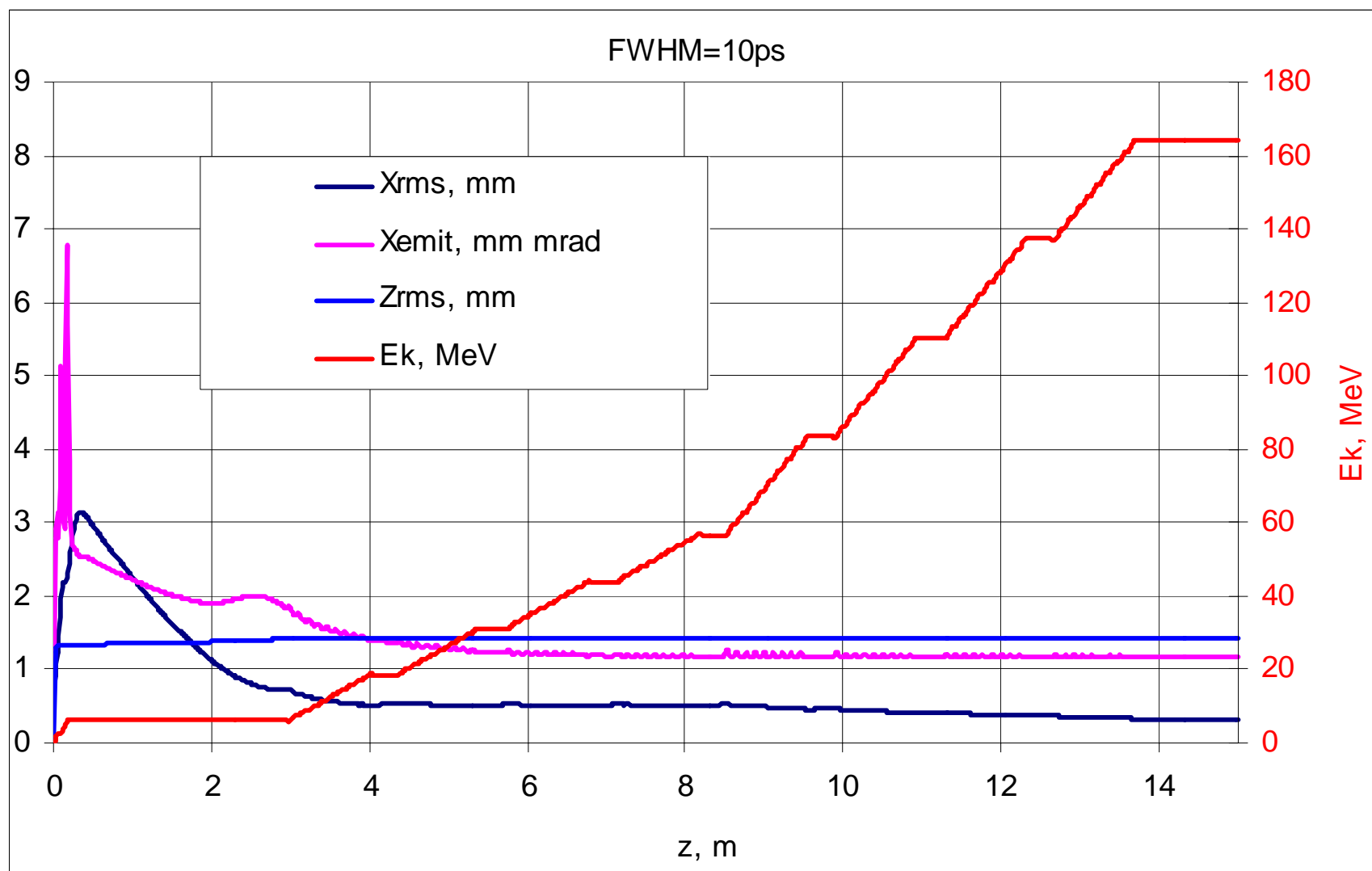
Method 1: Cathode laser shorting – 10ps instead 20ps FWHM

“Nominal” → Cathode laser FWHM=20ps



10 ps cathode laser FWHM, preliminary (10k ASTRA macroparticles) optimization

Cathode laser: FWHM=10ps, rise/fall time=2ps

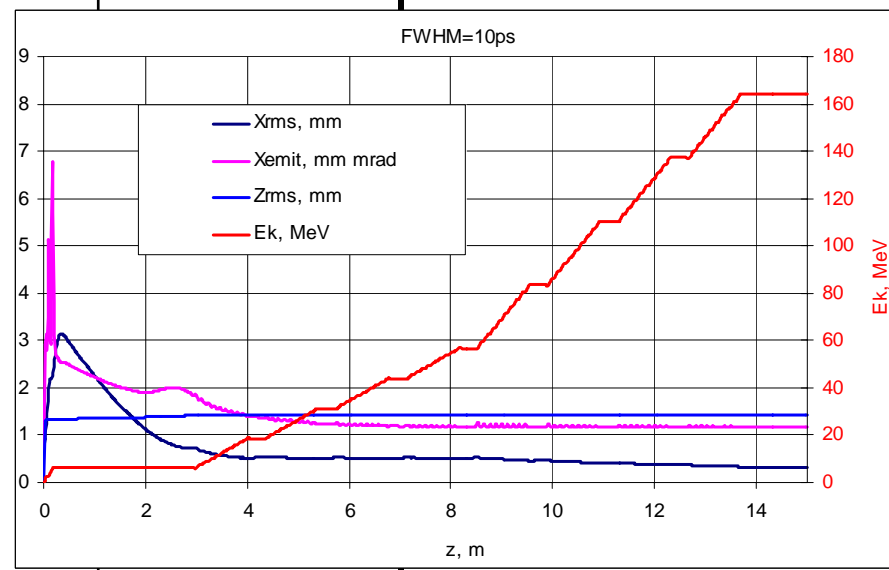
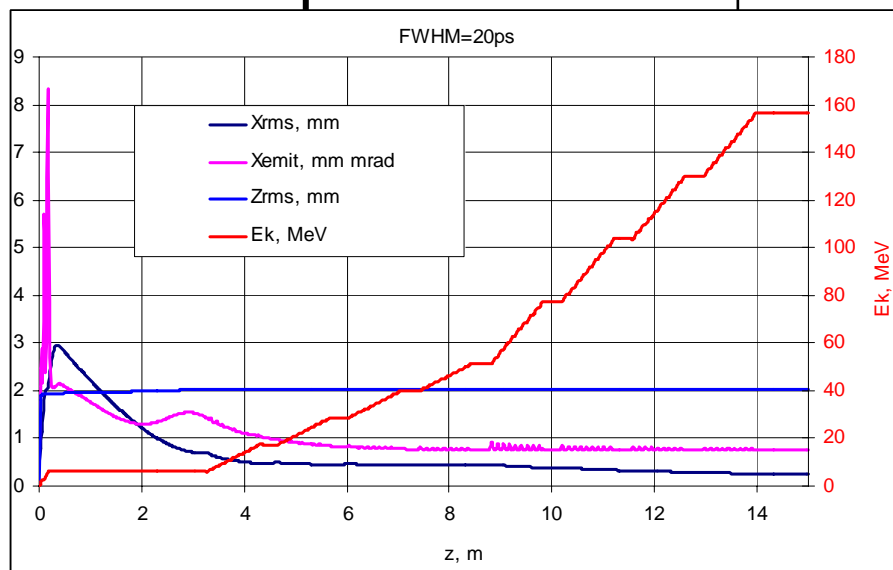


10 ps cathode laser FWHM, preliminary (10k ASTRA macroparticles) optimization

Optimized parameters

	20 ps	10 ps
Cath.laser XYrms, mm	0.438	0.559
Gun phase, deg	-0.56	-5.11
Solenoid peak field, T	-0.22466	-0.225203
Booster Emax, MV/m	21.5	23.5399
Booster phase, deg	-15.7	-9.796
Booster position, m	3.77(+0.78)	3.49(+0.5)

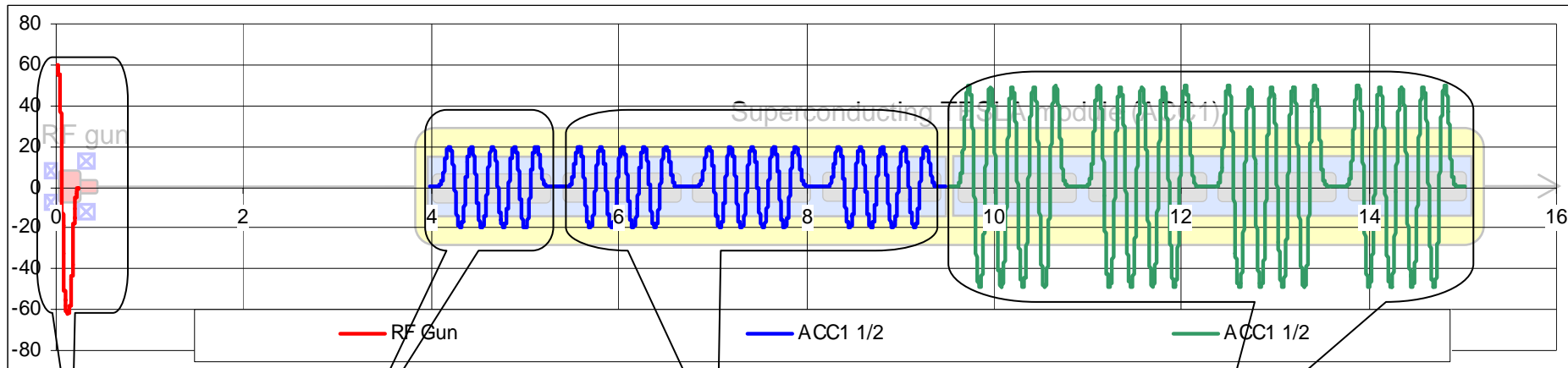
Cathode laser:
 •FWHM=10ps
 •rise/fall time=2ps
 •Ek=0.55eV



Bunch rms length, mm	2.1	1.4
Norm.tr.emittance, mm mrad	0.68	1.17

← LSC

Method 2: Velocity bunching



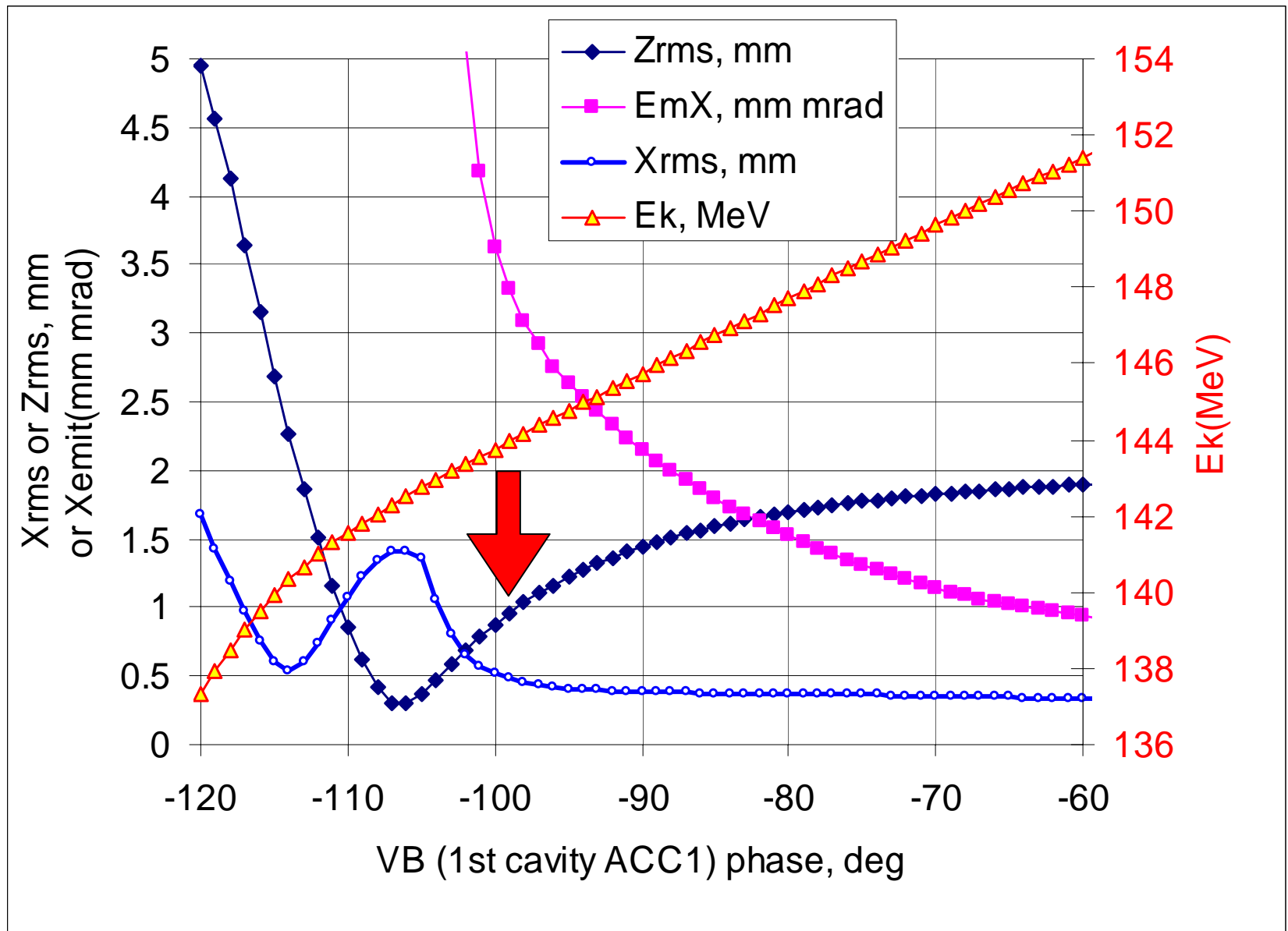
RF gun

VB

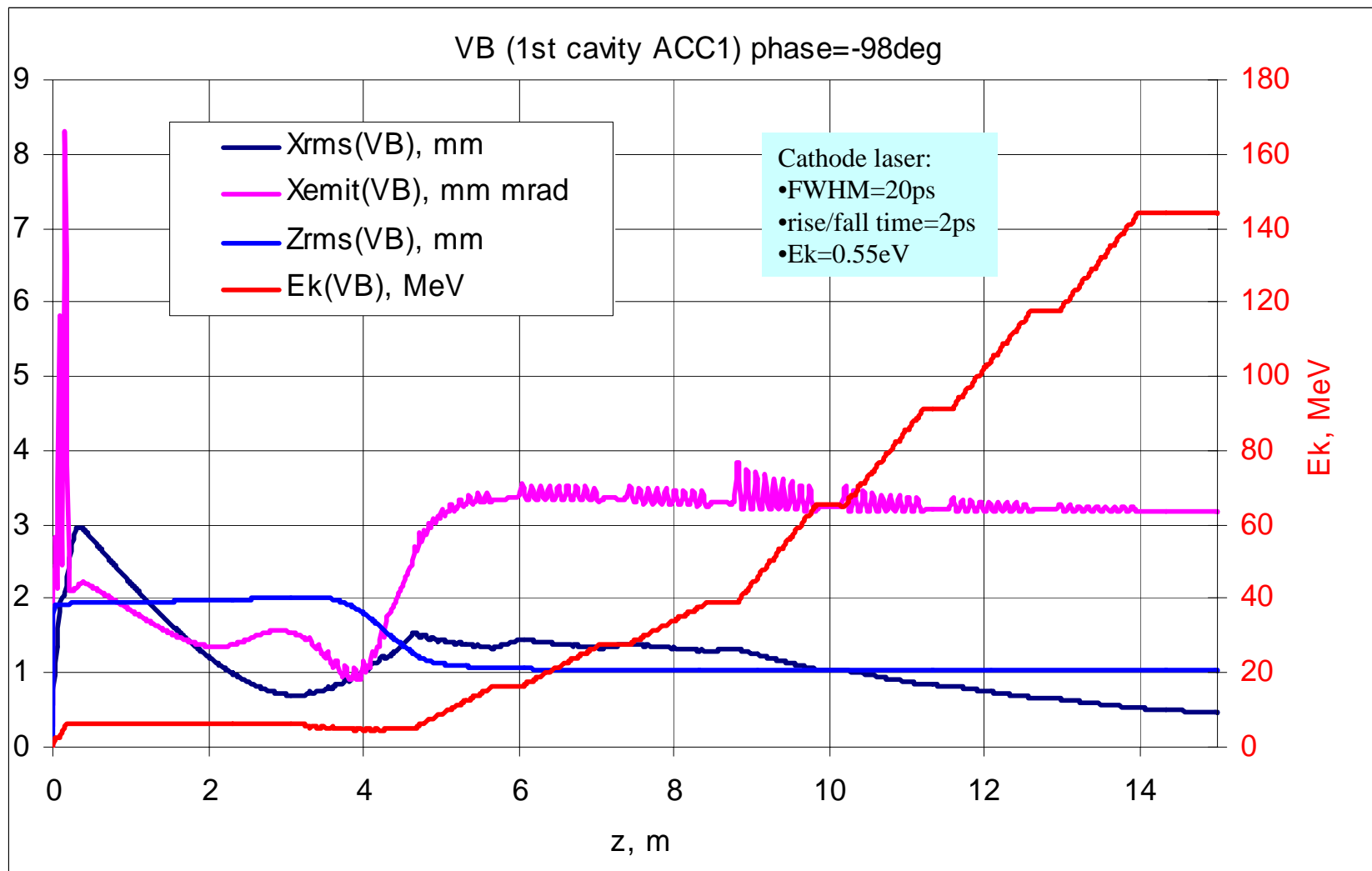
booster

acceleration

Velocity bunching. Beam parameters vs. first cavity phase



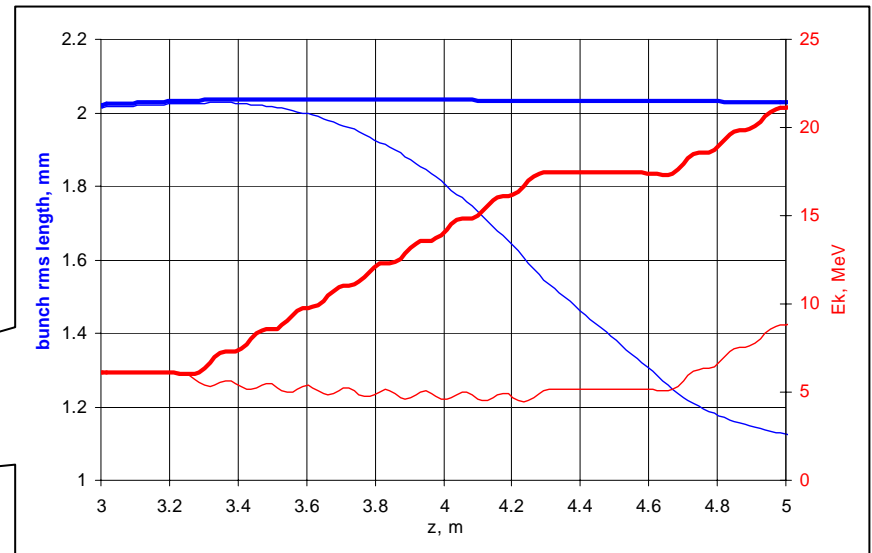
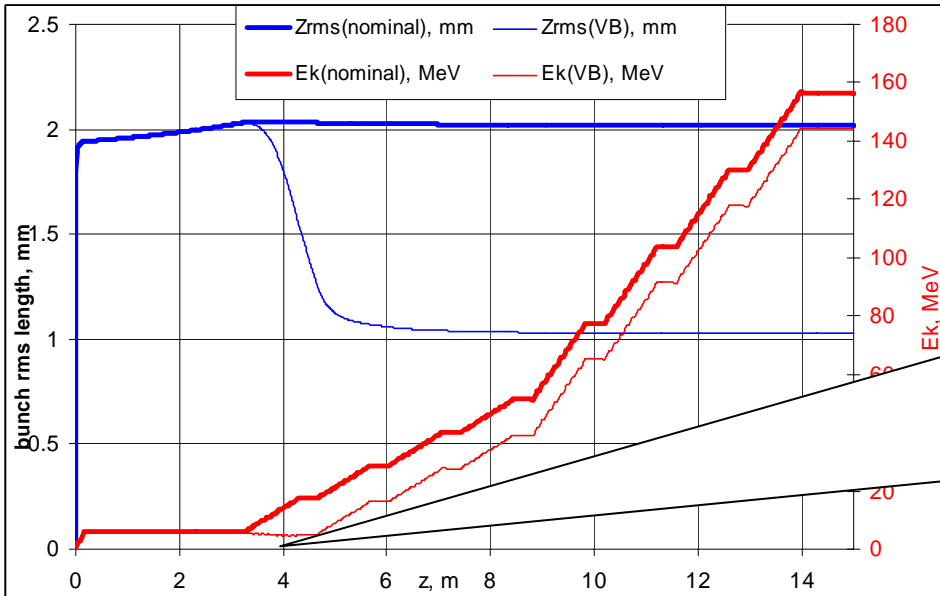
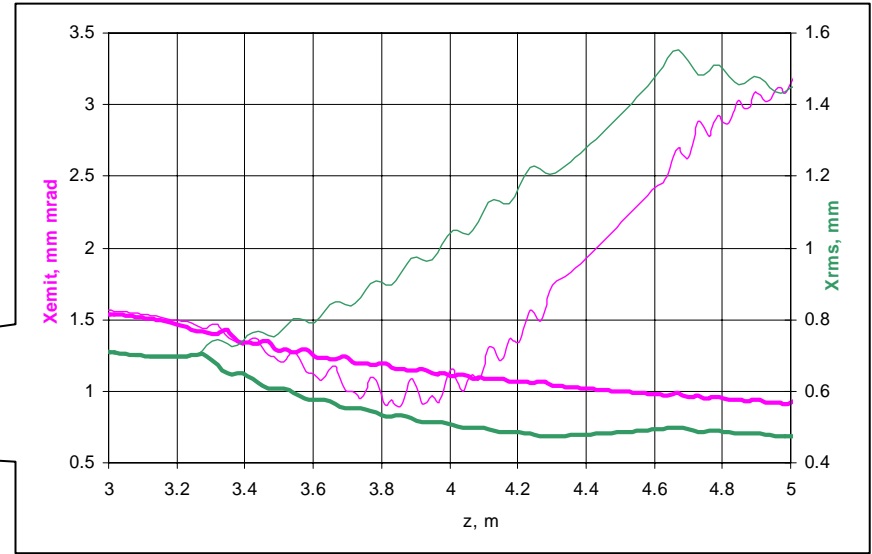
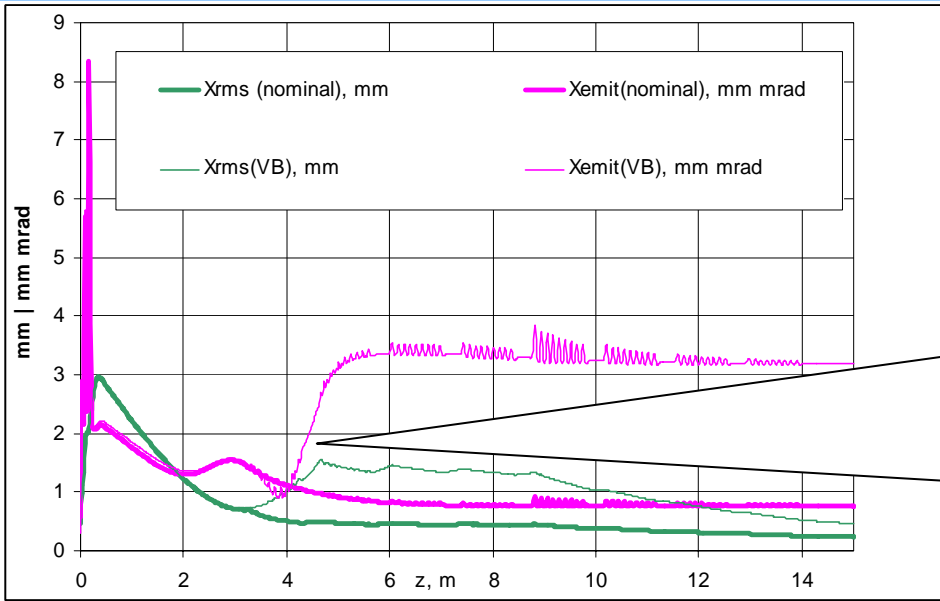
Velocity bunching. First cavity phase=-98deg



Not optimized:

- Main solenoid and cathode laser XYrms
- ACC1 position and booster gradient and phase

Velocity Bunching (VB) vs. Nominal Case (20ps)



10ps and Velocity Bunching (VB) vs. Nominal Case (20ps)

Based on **projected** parameters

	nominal	10ps	VB*
Zrms	2.1	1.4	1.03
Xemit	0.68	1.17	3.19
Q	1	1	1
~B	1.03	0.52	0.10

$$? B \sim \frac{Q}{Z_{rms} \epsilon^2} ?$$

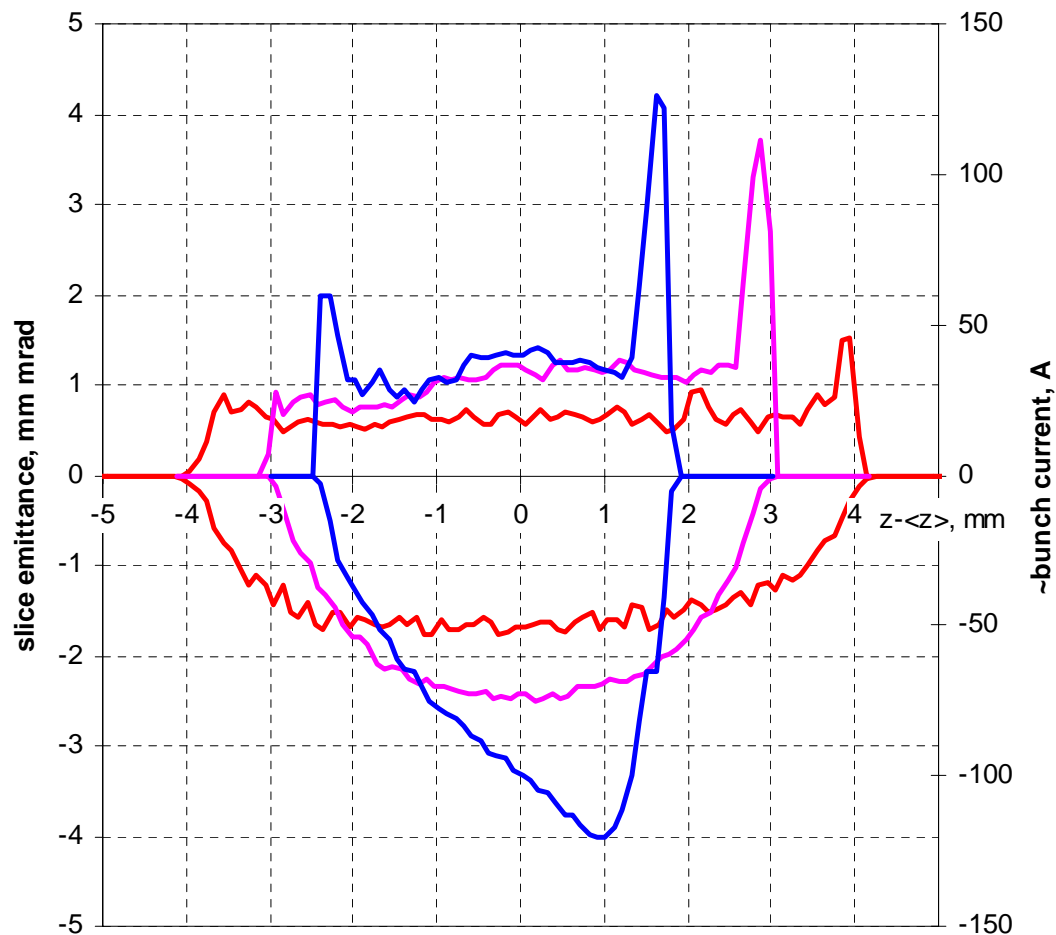
XFEL photo injector options:

- Case 10 ps in a factor 2 worse
- VB* in a factor 10 worse

VB* = not optimized velocity bunching

Slice parameters at z=15m

Slice emittance and beam current distribution



— ~em(nominal) — ~em(10ps) — ~em(VB)
— ~I(nominal) — ~I(10ps) — ~I(VB)

- Nominal 20 ps
- 10 ps FWHM
- Velocity bunching (VB)

Based on **slice** parameters

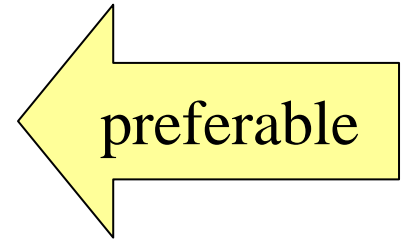
	nominal	10ps	VB	
I _{peak}	50	75	100(center)	120(peak)
X _{emit}	0.6	1.2	1.3	1.2
~B	139	52	59	83

XFEL photo injector options:

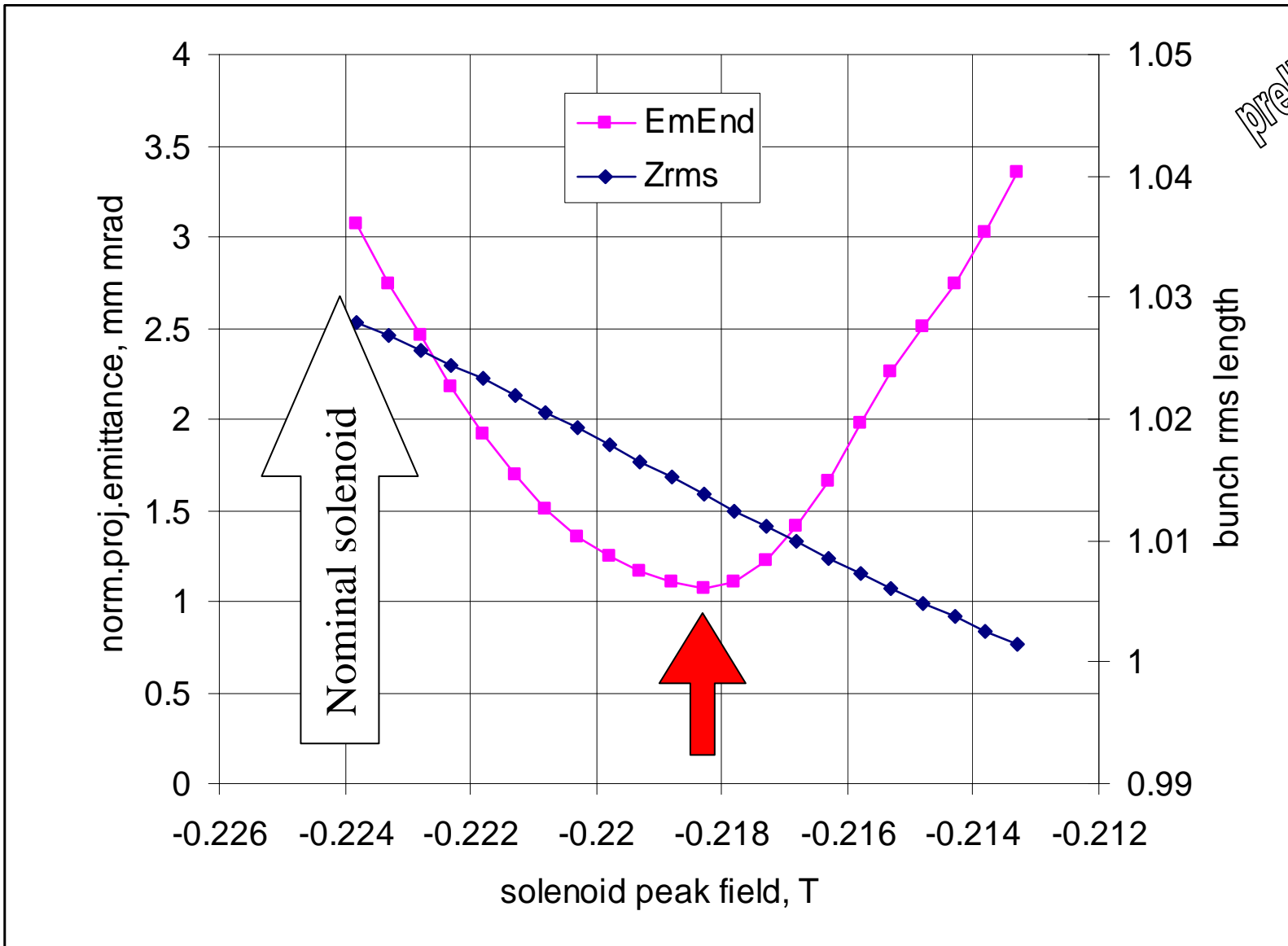
- Case 10 ps in a factor ~2.7 worse
- VB in a factor ~1.7-2.3 worse

Velocity bunching optimization

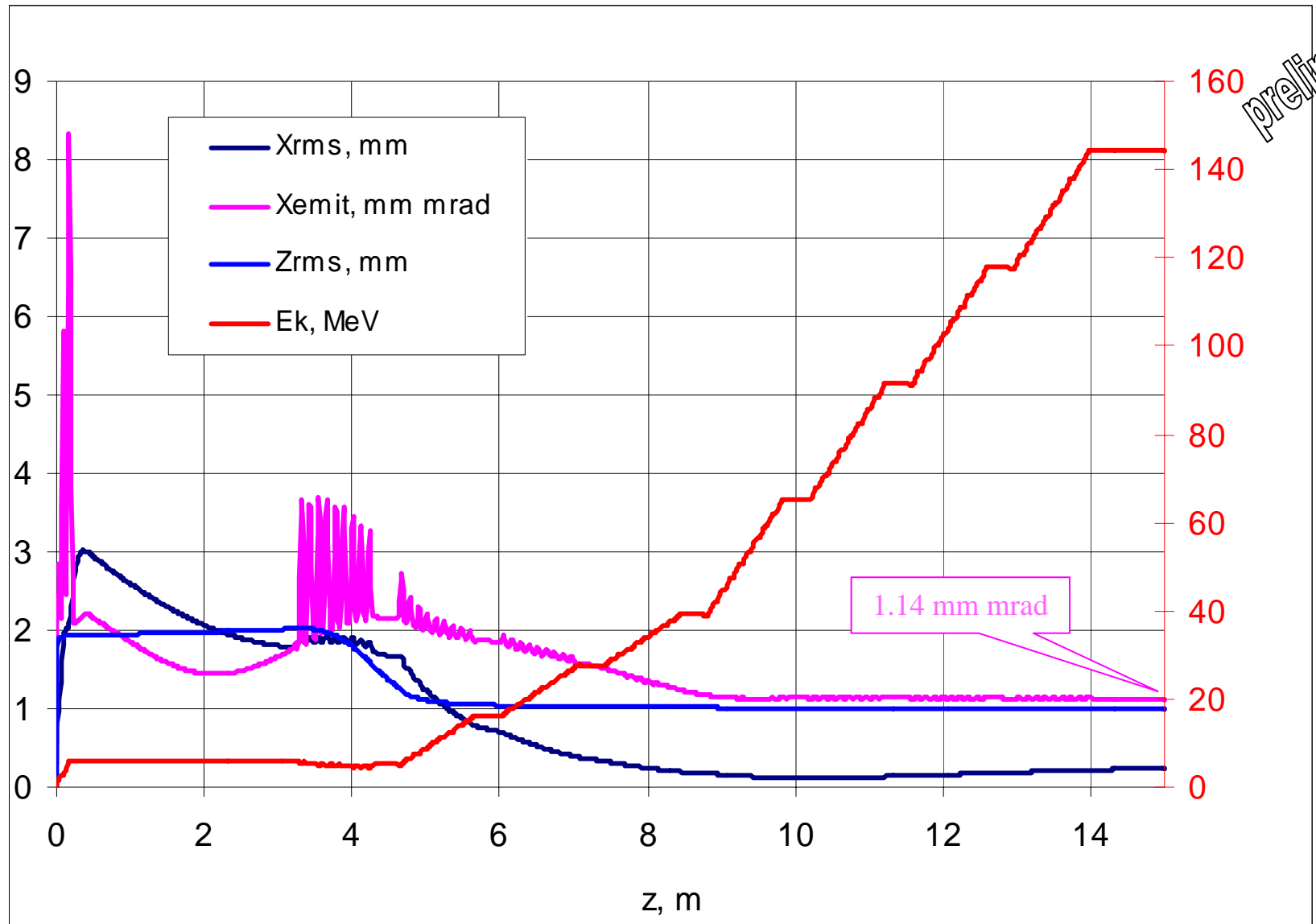
- Fixed setup (ACC1 position):
 - Tune I_{main} and cathode laser XY_{rms}
 - VBuncher gradient and phase
 - Booster gradient and phase*
 - ACC1(2nd half) gradient and phase**
- CDS buncher+solenoid around + ACC1:
 - Plenty optimization work



Appendix. Velocity bunching, solenoid scan



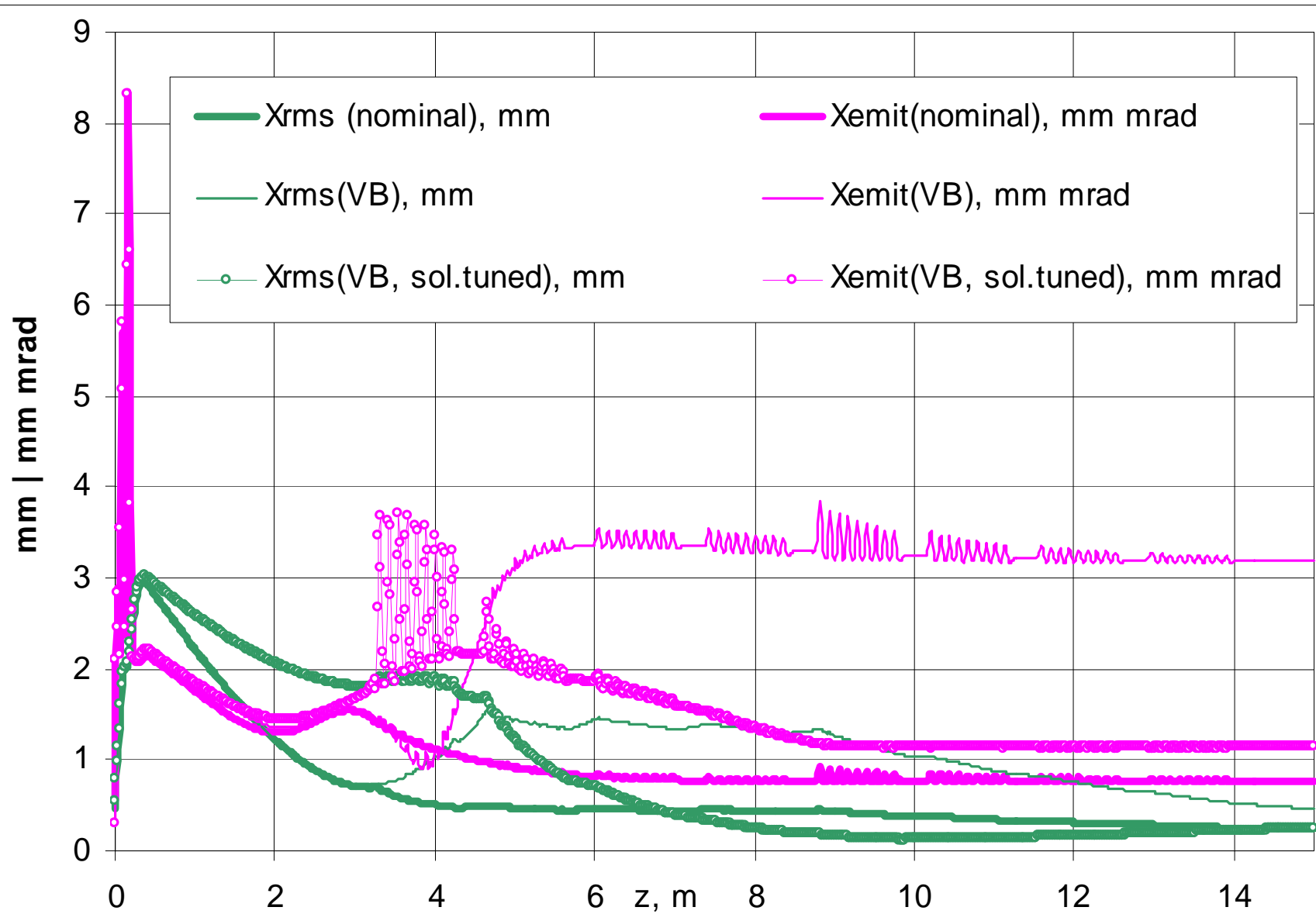
Appendix. Velocity bunching, “tuned” solenoid



preliminary

1.14 mm mrad

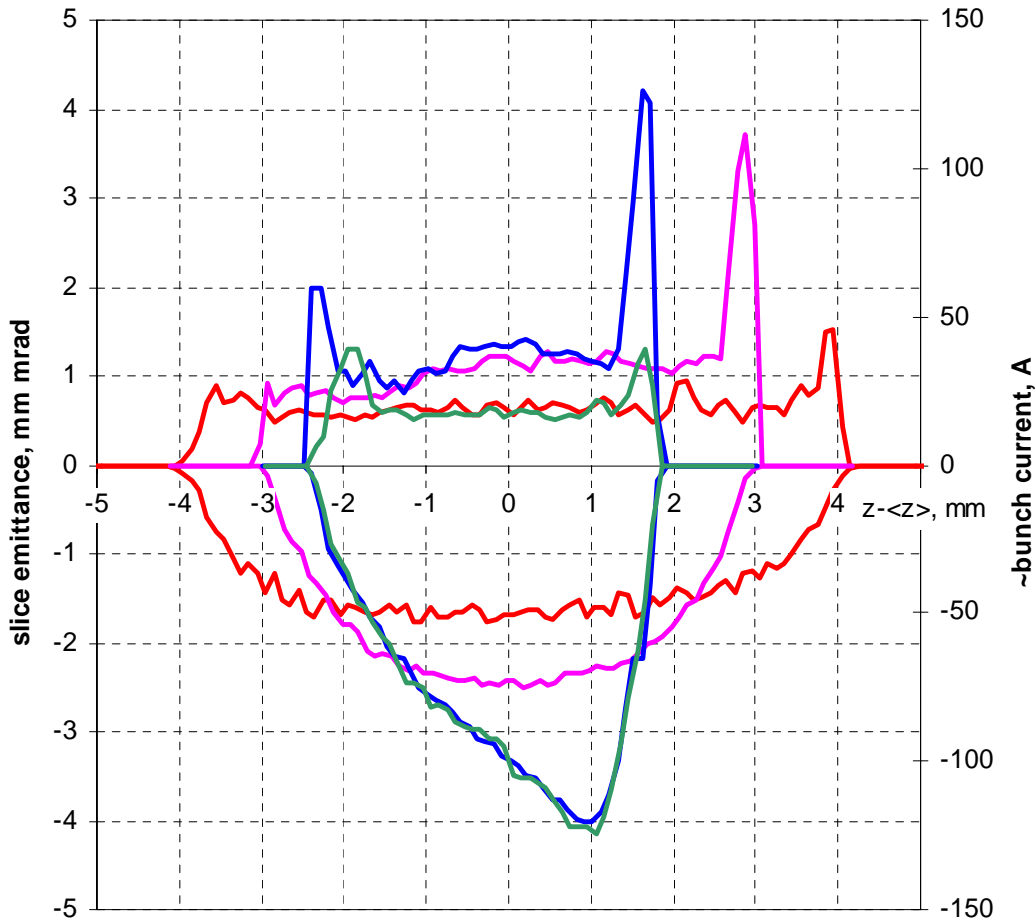
Appendix. Velocity bunching, “tuned” solenoid



Slice parameters [2(10)k particles]

preliminary

Slice emittance and beam current distribution



Based on **projected** parameters

	nominal	10ps	VB	VB (sol.tuned)
Zrms	2.1	1.4	1.03	1.01
Xemit	0.68	1.17	3.19	1.14
Q	1	1	1	1
~B	1.03	0.52	0.10	0.76

Based on **slice** parameters

nominal	10ps	VB		VB (sol.tuned)	
50	75	100	120	100	120
0.6	1.2	1.3	1.2	0.6	0.6
139	52	59	83	278	333

?additionally: optimize the current ramping?

Conclusions (preliminary)

- Shorting the cathode laser (10ps instead 20ps) results only in ~25% shorter electron bunch but emittance growth in a factor of 2
- Fixed XFEL photo injector setup is more preferable for the option with velocity bunching using 1st cavity of ACC1
- More optimization studies are necessary
- More detailed specifications on electron beam properties after the photo injector (emittance, bunch length, current profile, energy spread, long.emittance etc) would simplify and accelerate these studies.