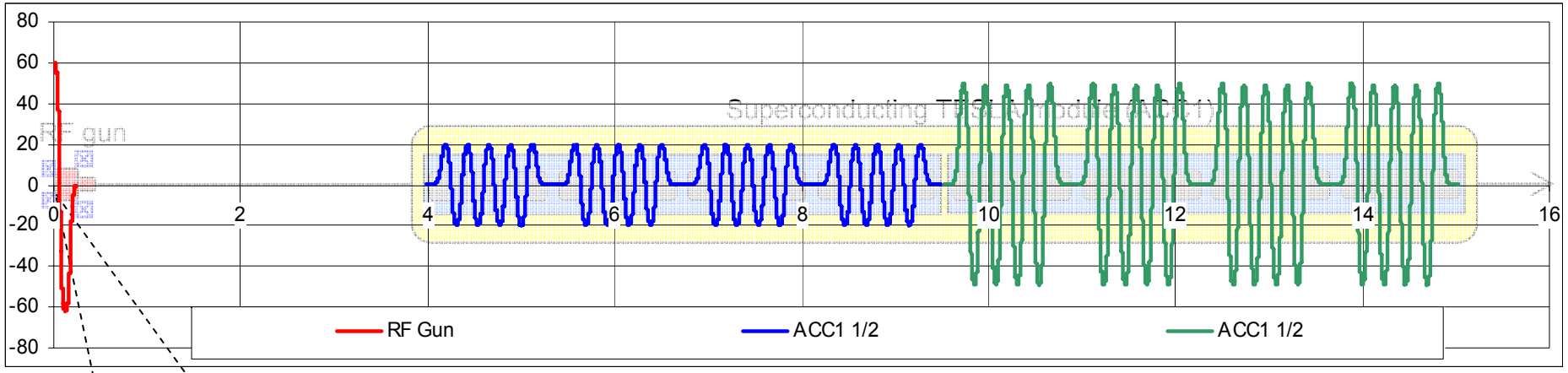
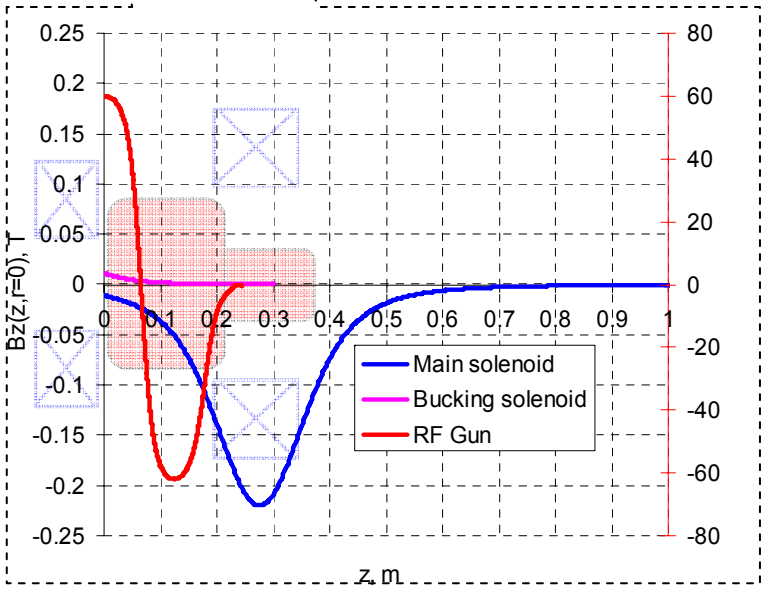
XFEL Photo Injector Simulations

M.Krasilnikov, PITZ

XFEL Photo Injector Layout





Injector parameters to be optimized:

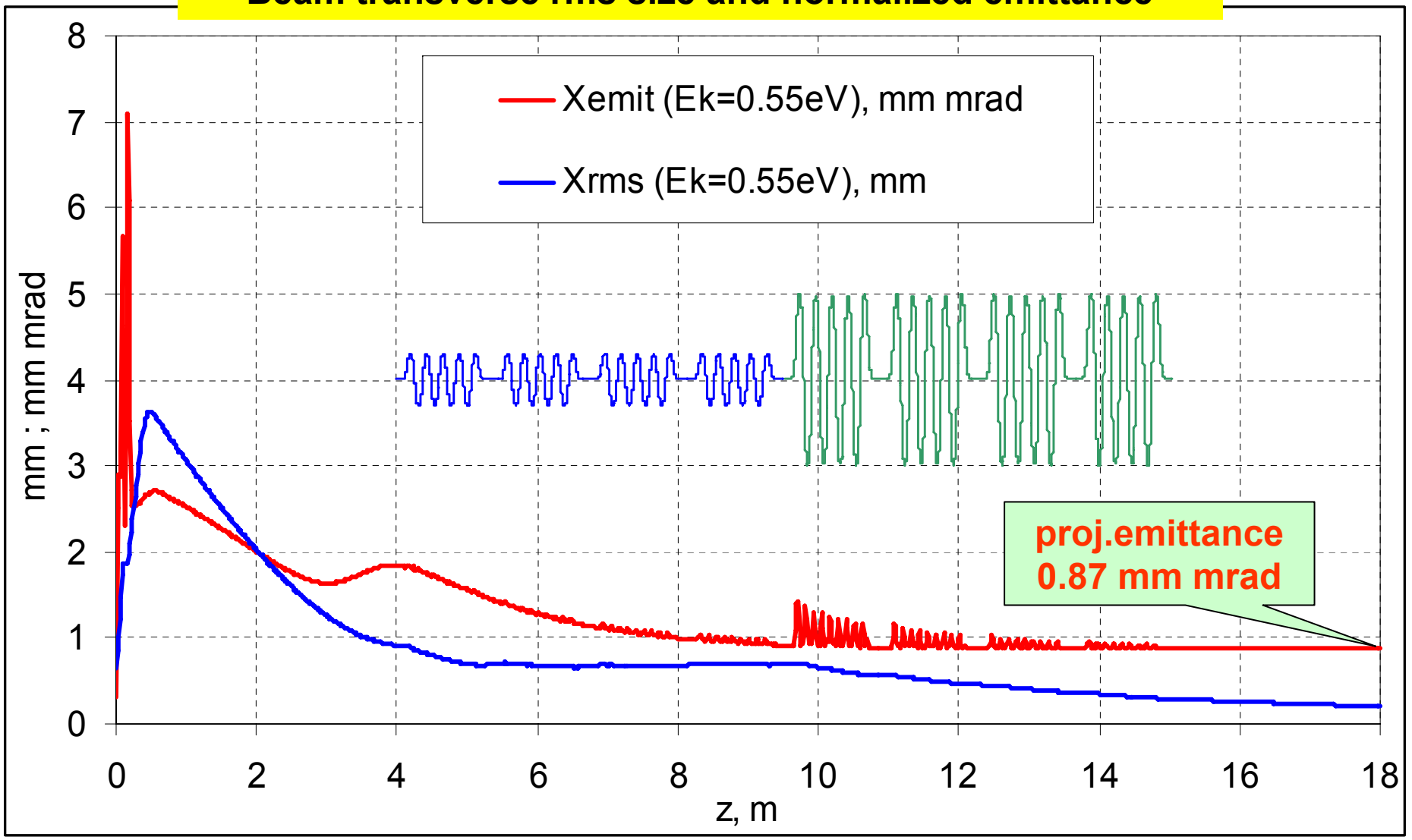
- Cathode laser: XYrms, (Trms)
- RF-Gun: launch RF phase
- Solenoid: position, peak field (current)
- Booster: position, gradient, RF phase

XFEL Photo Injector Simulations

		Parameter	Value	Unit	Optimized	Remark
Cathode laser	Temporal **flat-top**	Lt	19.6	ps	+	
		rt	2	ps		
	Transverse **radial homog**.	XYrms	0.553	mm	+	
	Thermal	Ek	0.55	eV		0.65;0.75;1.0 eV
Gun	RF	Field				efldbalanced.dat
		Ecath	60	MV/m		
		Phase	-1.63939	deg	+	rel.to max.en.gain
	Solenoid	MaxB	-0.1938	T	+	bucking applied
		Z-position	**0.41**	m	+	
ACC1	1st half	Field			+	TeSLA_4_9cells.efld
		Emax	**15**	MV/m	+	
		Phase	-16	deg	+	
		z-pos(rel. to actual)	**4.66(+1.66)**	m		center of 1st cavity
	2nd half	Emax	50	MV/m		
		Phase	-16	deg		
ASTRA		Particles	200k			

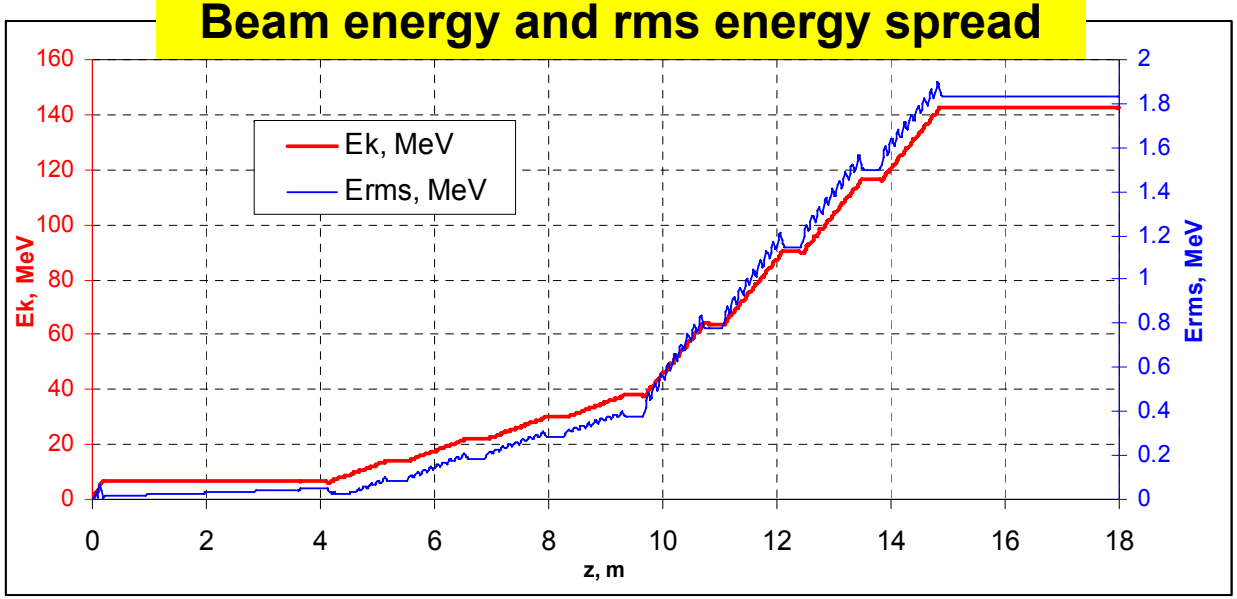
XFEL Photo Injector Simulations

Beam transverse rms size and normalized emittance

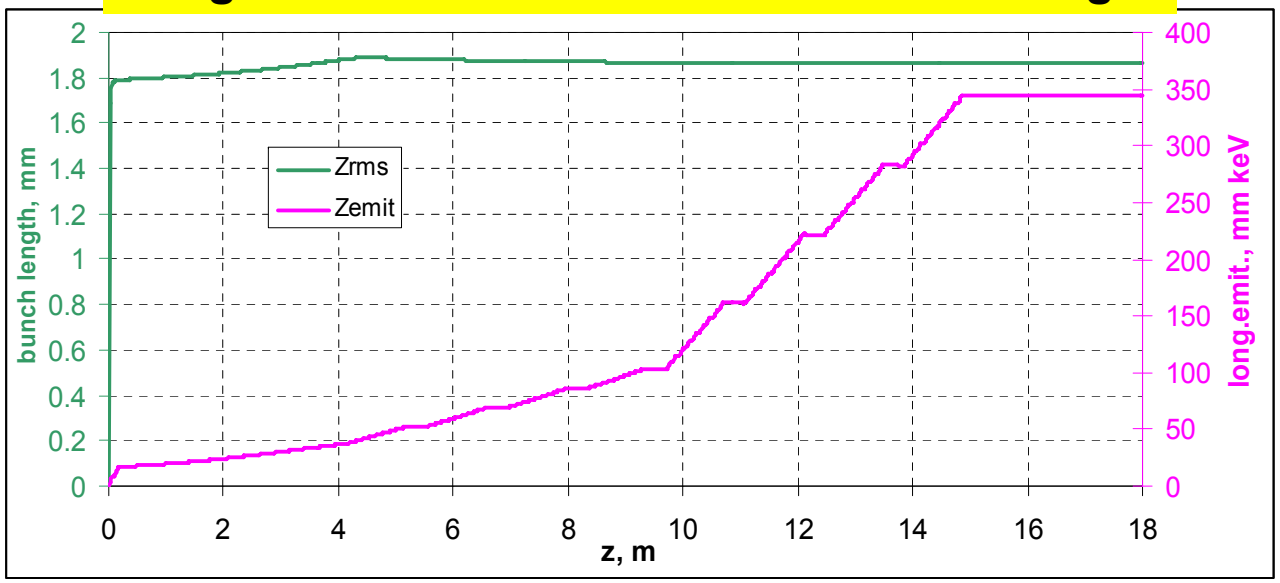


XFEL Photo Injector Simulations

Beam energy and rms energy spread



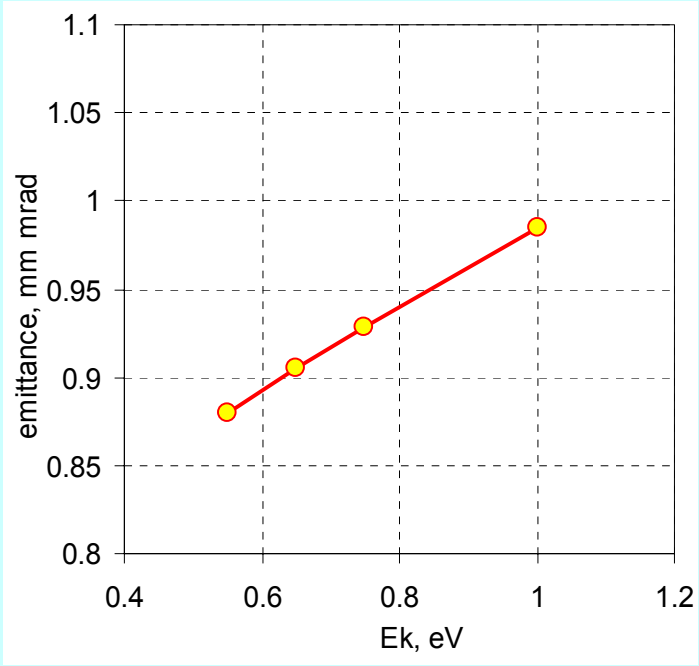
Longitudinal emittance and bunch rms length

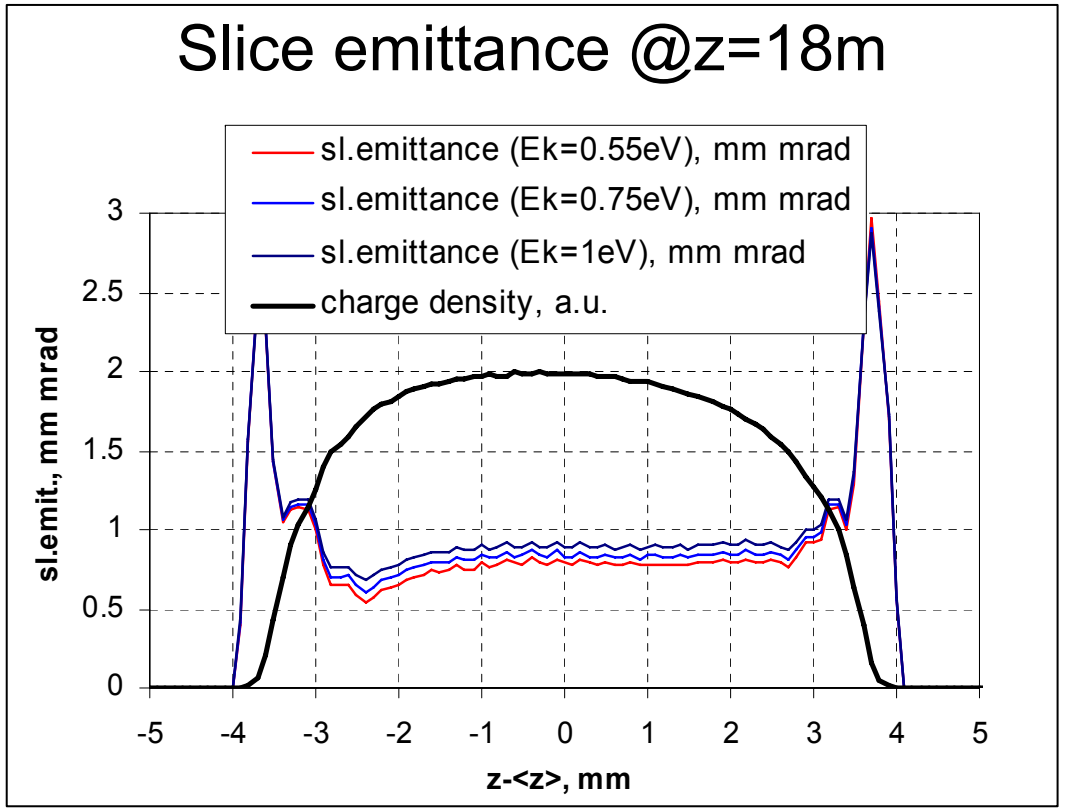


XFEL Photo Injector Simulations

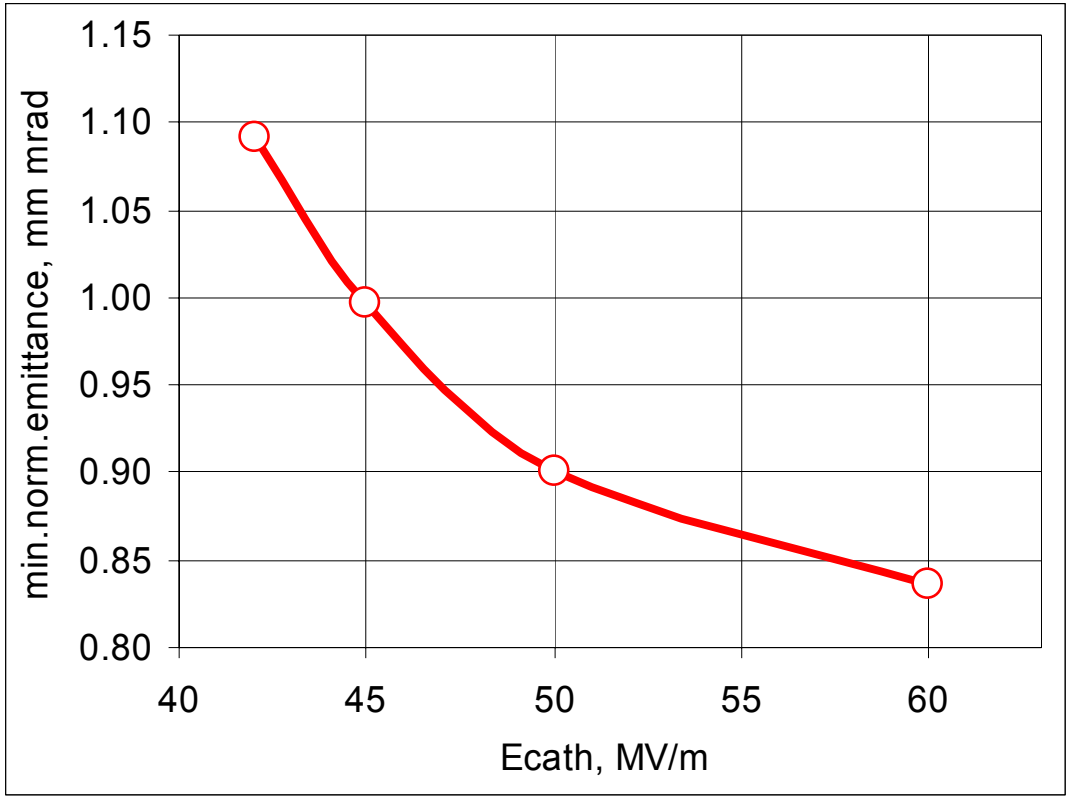
Influence of thermal emittance from the photo cathode

Normalized transverse emittance after XFEL injector as function of the initial kinetic energy of the photo emitted electrons



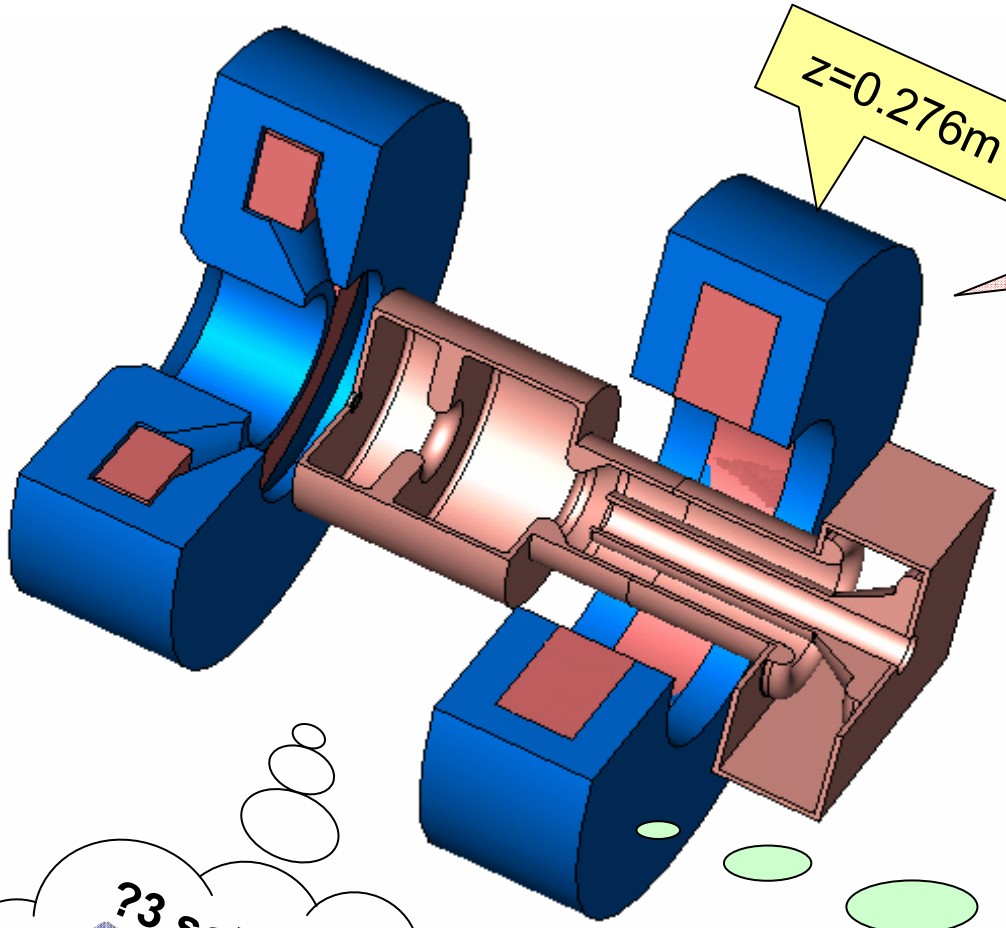


Dependence on Gun Gradient (PITZ case)

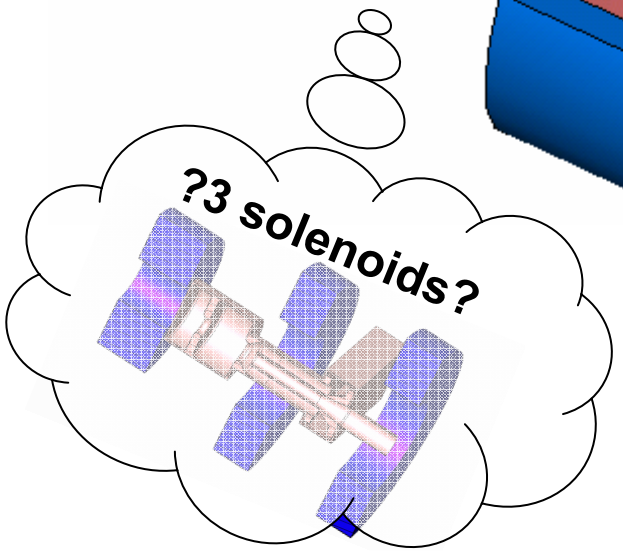


rf gun	Ecath	MV/m	42	45	50	60
	Phase	deg	-2.1	-2.0	-1.9	-1.9
cathode laser	XYrms	mm	0.69	0.67	0.61	0.56
	FWHM	ps	20	20	20	20
	Rise/fall time	ps	2	2	2	2
solenoid	Peak field	T	-0.1668	-0.1770	-0.1939	-0.2277
booster cavity	Peak Ez	MV/m	26.3	25.4	23.4	26.0
	Phase	deg	-13.6	-15.6	-16.1	-15.1
electron beam	Energy after rf gun	MeV	4.3	4.6	5.1	6.1
	after booster	MeV	18.2	17.9	17.4	19.8
	Min. XYrms	mm	0.53	0.50	0.43	0.32
	Min. emittance	mm mrad	1.09	1.00	0.90	0.84

Solenoid Position



New solenoid position requires modification of the input coupler (increased length of coaxial part).



What can be achieved with actual solenoid position?

Change the Optimization Procedure

Cathode laser (XYrms, [Trms]) +
gun parameters (RF Phase, Imain, [sol.pos])

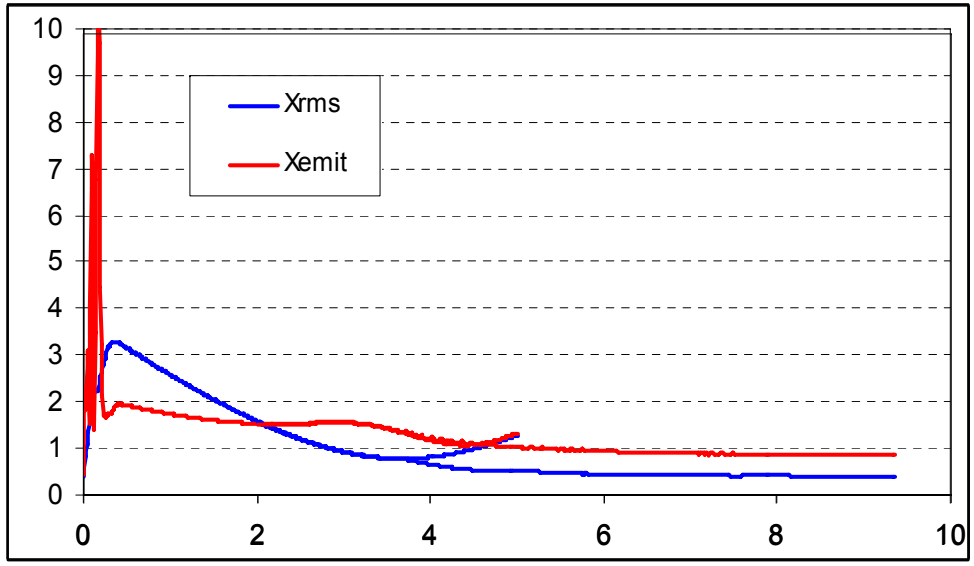
0 step. “tune” the bunch charge:
Qbunch->Q=1nC(@z=5cm)
Emission effects (SC, Schottky)

1 step. Run ASTRA till z=5m

Xrms,Xemit

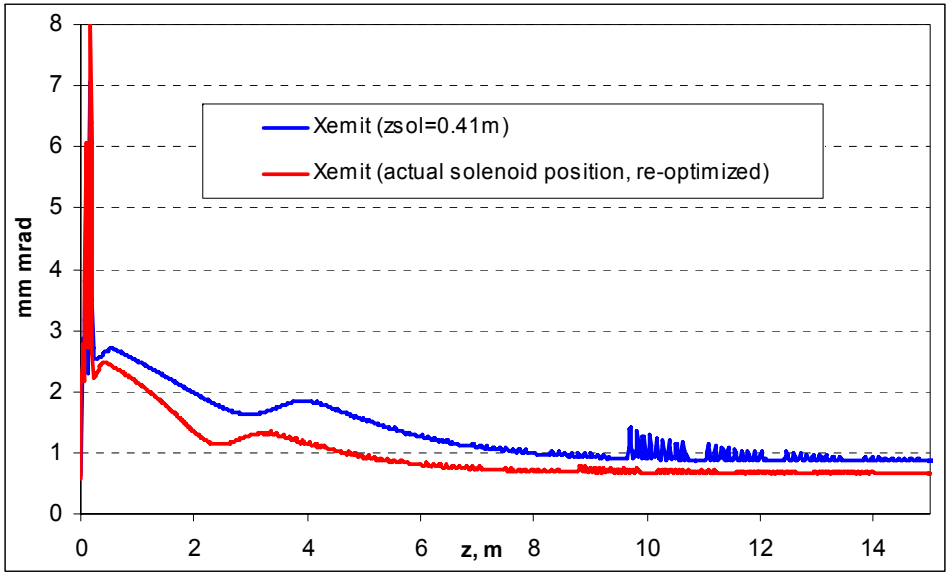
Emittance

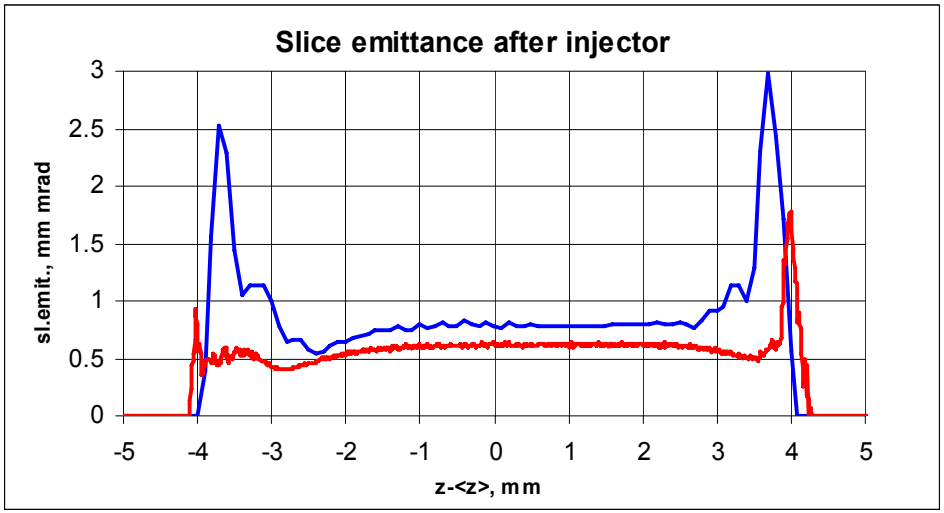
Booster optimization
(booster cavity z-position,
gradient and RF phase)
Initial guess: booster matching conditions



Re-Optimization (Actual Solenoid Position)

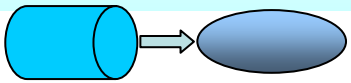
cathode laser	transverse	distribution		homogen.	homogen.
		XYrms	mm	0.55	0.438
	temporal	distribution		flat-top	flat-top
		Lt	ps	19.6	20
		rt	ps	2	2
		Trms	ps	5.69	5.8
	thermal	Ek	eV	0.55	0.55
		emittance	mm mrad	0.46	0.37
gun	RF	Ecath	MV/m	60	60
		launch phase	deg	-1.64	-0.55
	solenoid	z-position	m	**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)
		Emax	MV/m	15	21.5
		phase	deg	-16	-15.7
ACC1	4xTESLA	Emax	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.(cen	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



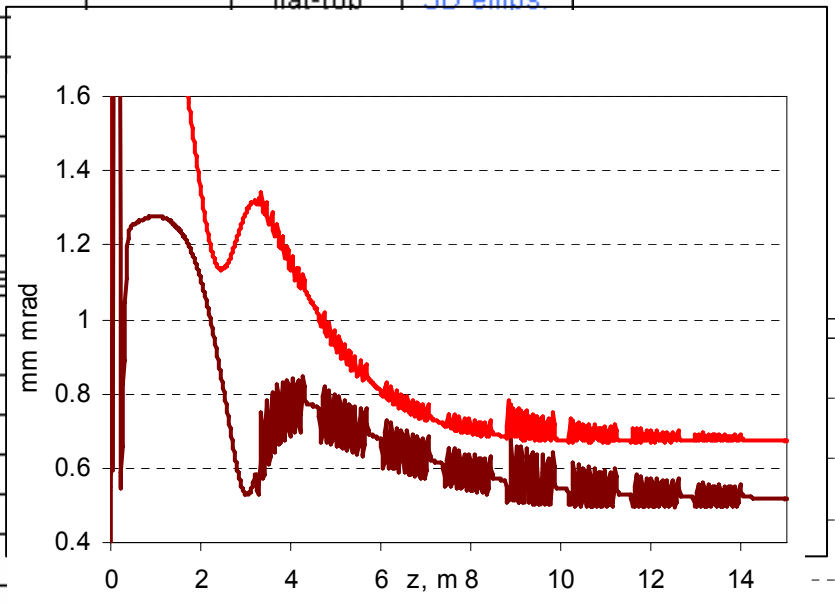


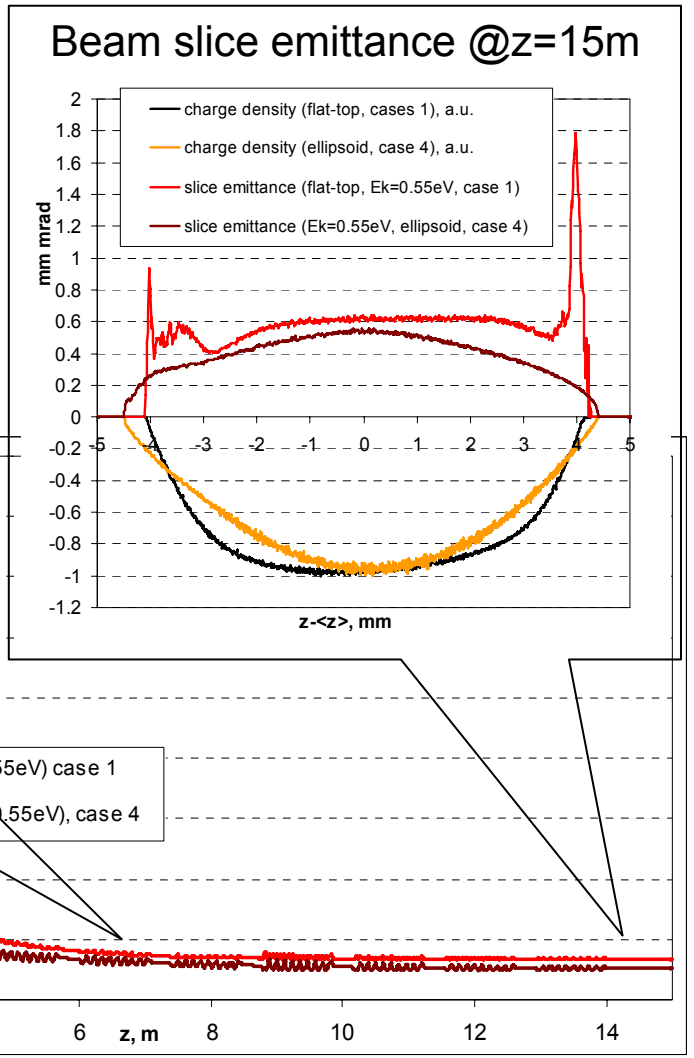
Also the current solenoid z-position is OK

Cathode Laser: Ellipsoid Vs. Cylinder



cathode laser	transverse	distribution		homogen.	3D ellips.
		XYrms	mm	0.438	0.438
	temporal	distribution		flat-top	3D ellips.
		Lt			
		rt			
		Trms			
	thermal	Ek			
		emittance			
gun	RF	Ecath			
		launch phase			
	solenoid	z-position			
		MaxB(1)			
		MaxB(2)			
booster	4xTESLA	z-position			
		Emax			
		phase			
ACC1	4xTESLA	Emax			
		phase	deg	-15.7	
sim.	ASTRA	number of part.		200k	
e-beam	@z=15m	charge	nC	1	
		energy	MeV	157	
		trans.emittance	mm mrad	**0.676**	
		slice emit.(centre)	mm mrad	0.639	
		rms en. spread	MeV	2.1	
		long.emittance	mm keV	460	
		rms length	mm	2.0	2.0





XFEL Injector Simulations: Outlook

- Studies of tolerances for cathode laser parameters: FWHM, rise/fall time, flat-top modulation
- Influence of the vacuum components (like a vacuum mirror, diagnostic cross etc) on the beam quality
- Impact of photo injector imperfections (misalignment)
- …