Study of ACC1 Voltage Amplitude Changing Effects on SASE at FLASH

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MPY, DESY

Introduction

ACC1 beam energy changing effects

Case1 V_{acc1}~161MV

Works well

Case2 V_{acc1}~166MV

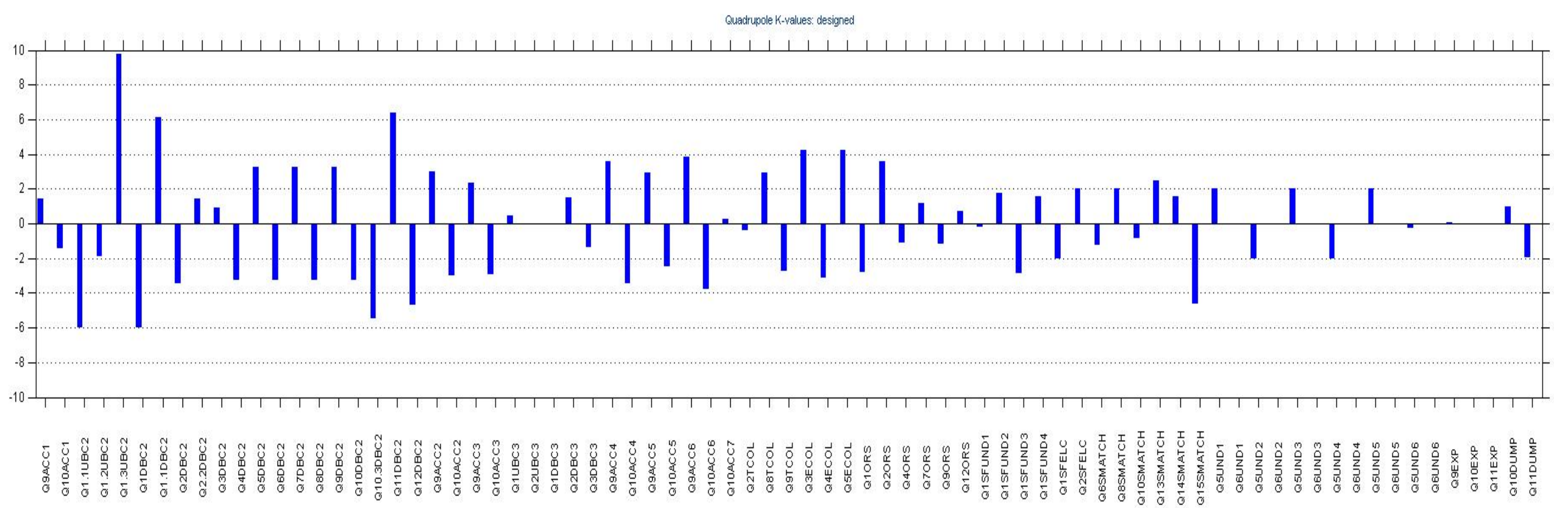
SASE FEL can’t be tuned by adjusting the RF parameters of the accelerating modules.

Start to End Simulation of FLASH

Some setting points of the machine come from the logbook

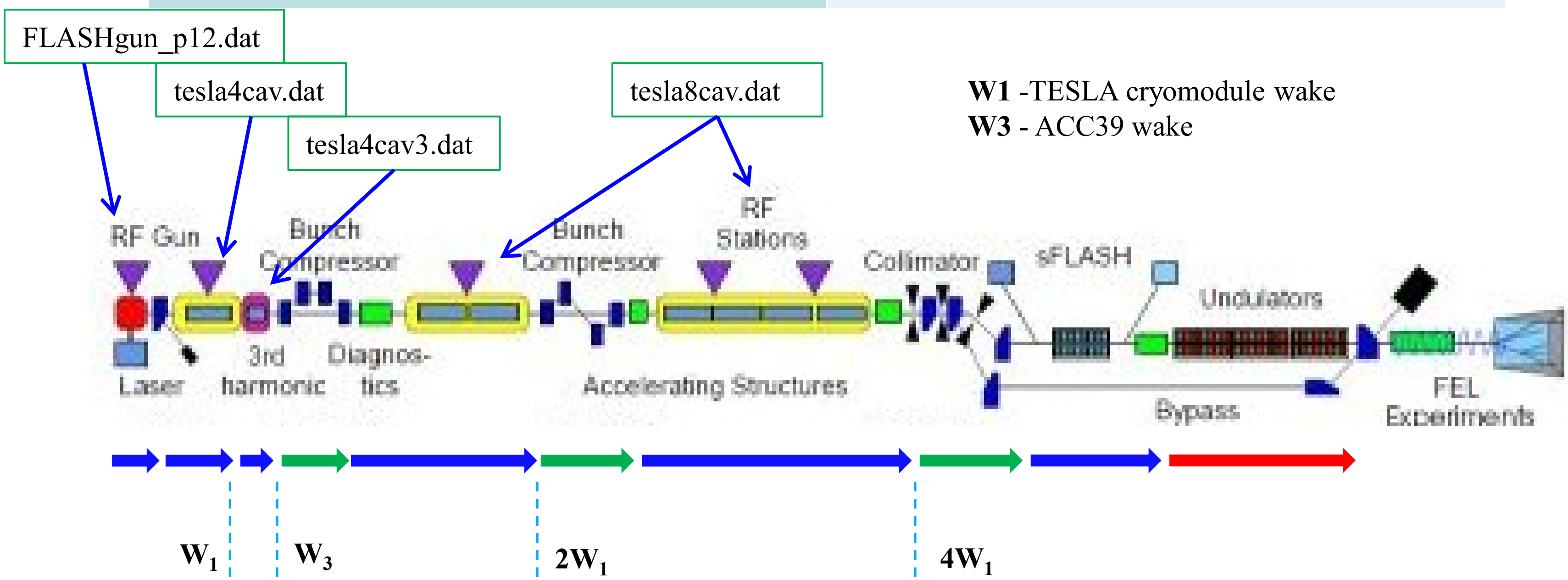
- RF parameters value of accelerating modules
- Bunch charge Q=0.22nC
- Exciting current of the bunch compressors

Field strength of the quadrupole magnets (Elegant lattice file)



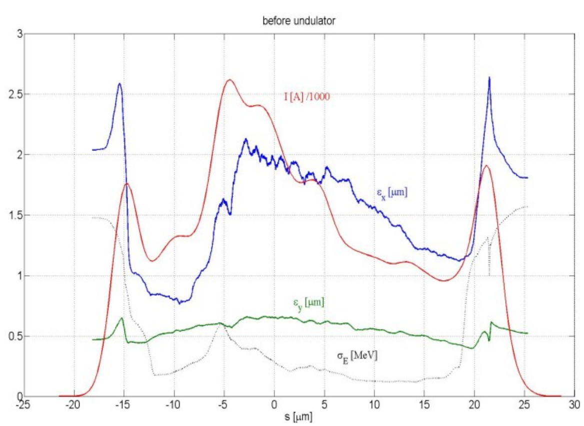
Calculation Codes used during the simulation

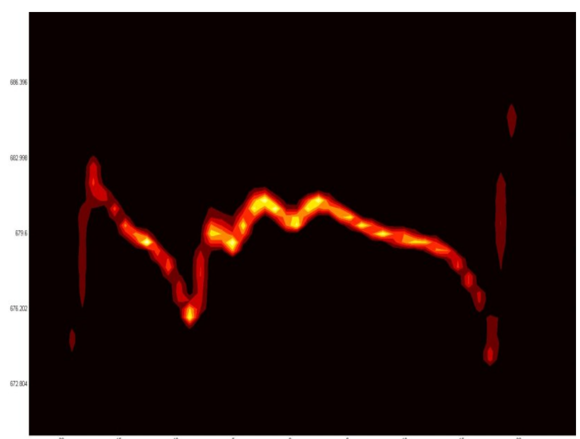
RF Gun	ASTRA
ACC1	ASTRA
ACC39	ASTRA
BC2	CSR-TRACK
ACC2/3	ASTRA
BC3	CSR-TRACK
ACC4/5/6/7	ASTRA
Dogleg section	CSR-TRACK
Drift space (straight section)	ASTRA
Radiation Calculation	GENESIS

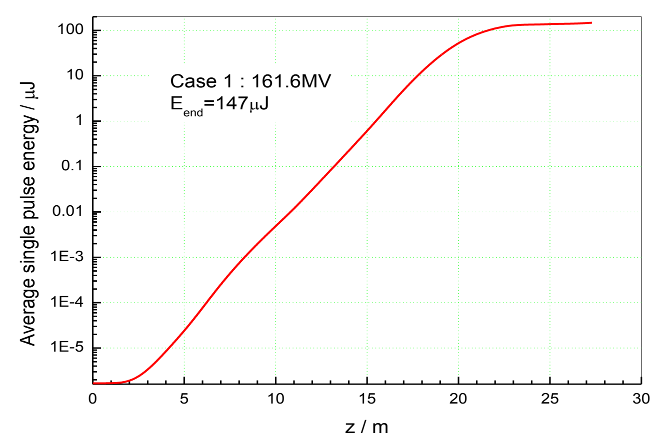


Calculation results

End of the element	Beam Energy E	Energy Spread	σ_z	I_{peak}
RF Gun	5MeV	22.3keV	1.599mm	~13A
ACC1	166.3MeV	715.4keV	1.602mm	~13A
ACC39	146.8MeV	1067keV	1.601mm	~13A
BC2	146.7MeV	1050keV	0.2944mm	~72A
ACC2/3	456.2MeV	1917.keV	0.2926mm	~72A
BC3	455.1MeV	1686keV	0.0112mm	~2250A
ACC4/5/6/7	680.8MeV	1163keV	0.0112mm	~2250A
Dogleg section	679.6MeV	890.2keV	0.0112mm	~2500A
Drift space	679.7MeV	1891keV	0.0112mm	~2500A







Study of ACC1 beam energy changing effects

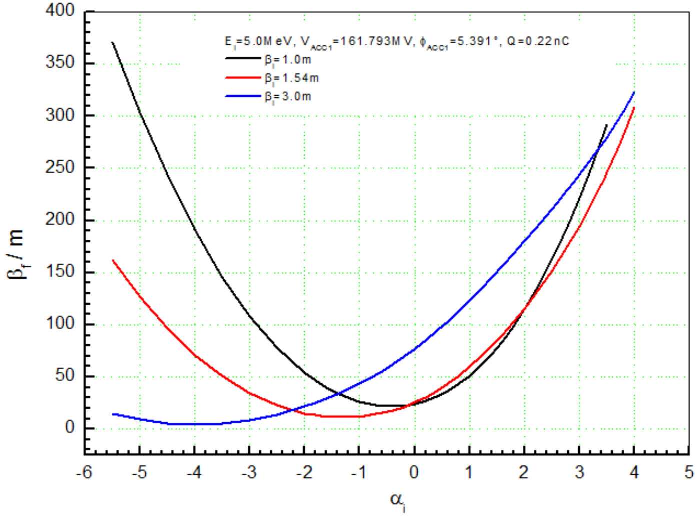
Difference between the two cases **(Based on the logbook setting points)**

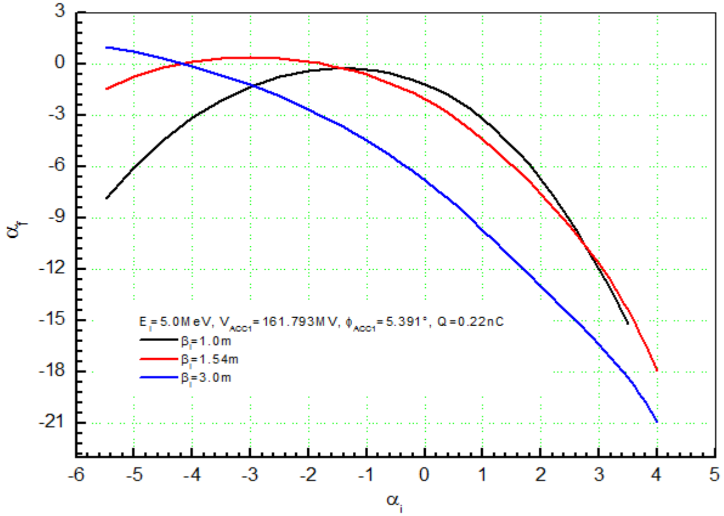
1. Voltage amplitude of ACC1
2. Voltage amplitude and phase shift of ACC39,which should be adjusted slightly in order to get the proper current profile in each case.
3. Curvature radius of BC2, which depends on the same exciting current (72.7A) but different beam energy in the two cases.
4. Normalized field strength of the quadrupole magnets between ACC1 and ACC2.
5. Voltage amplitude and phase shift of ACC2 and 3. In order to get the same beam energy at the end of ACC2 and the same peak current 2.5kA after BC3 in the two cases.

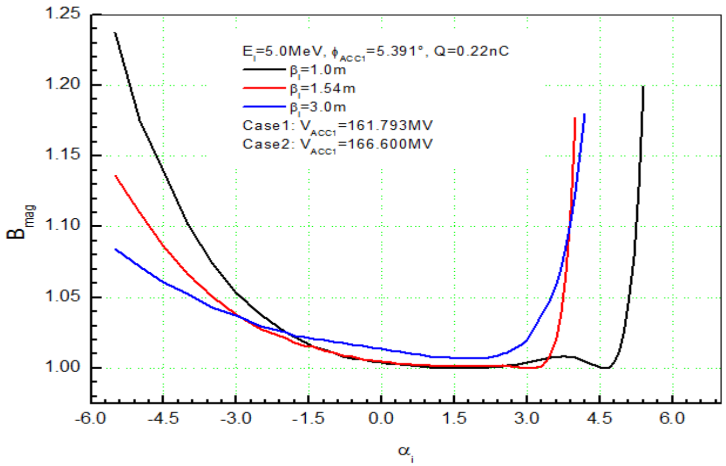
Beam optics and B_{mag} calculation of ACC1

ASTRA code (i: z=2.6m, f: exit of ACC1)

$$B_{mag} = \frac{1}{2}\left[\frac{\beta(E_2)}{\beta(E_1)} + \frac{\beta(E_1)}{\beta(E_2)} + \left(\alpha(E_2)\sqrt{\frac{\beta(E_1)}{\beta(E_2)}} - \alpha(E_1)\sqrt{\frac{\beta(E_2)}{\beta(E_1)}}\right)^2\right]$$



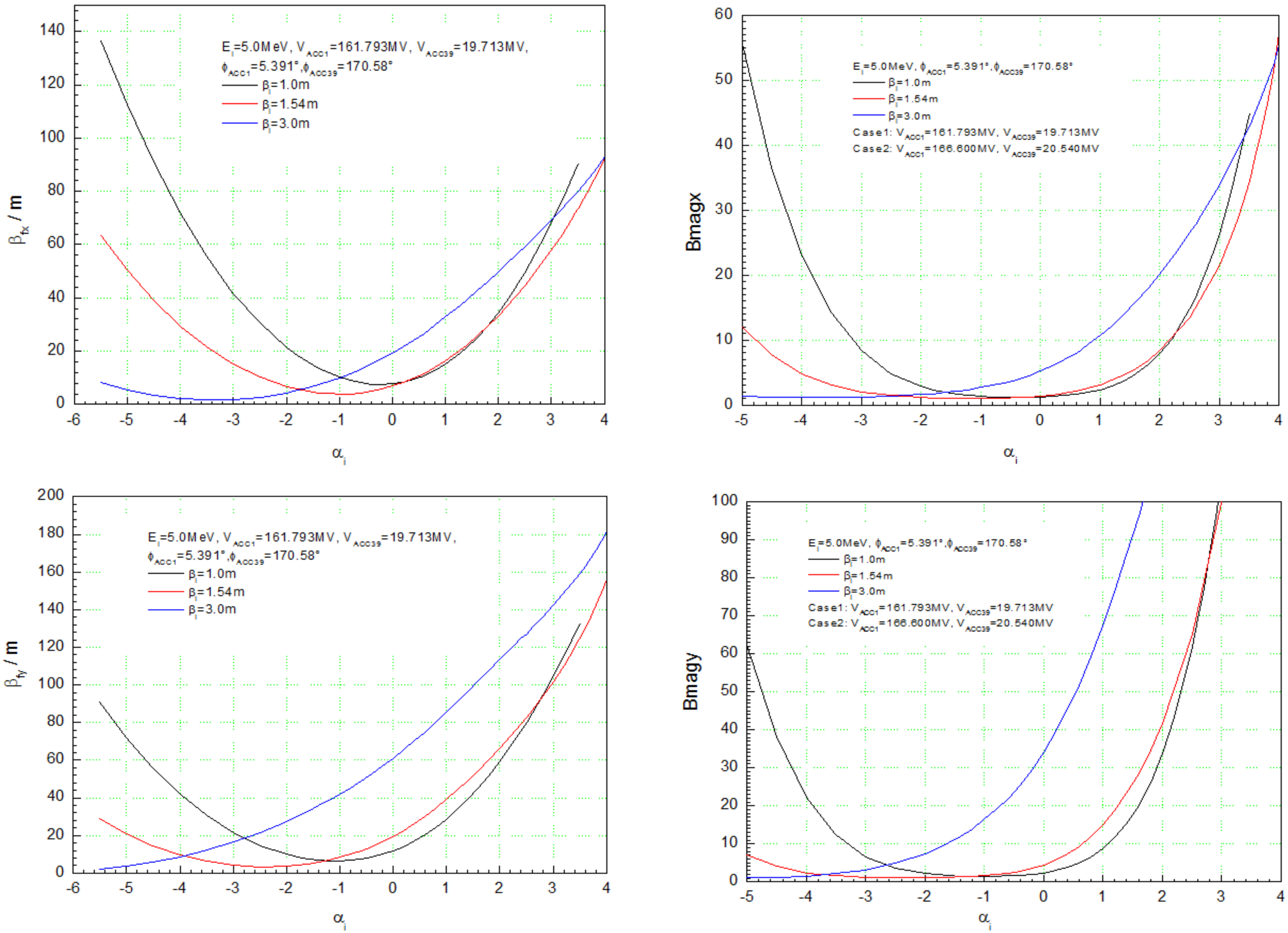




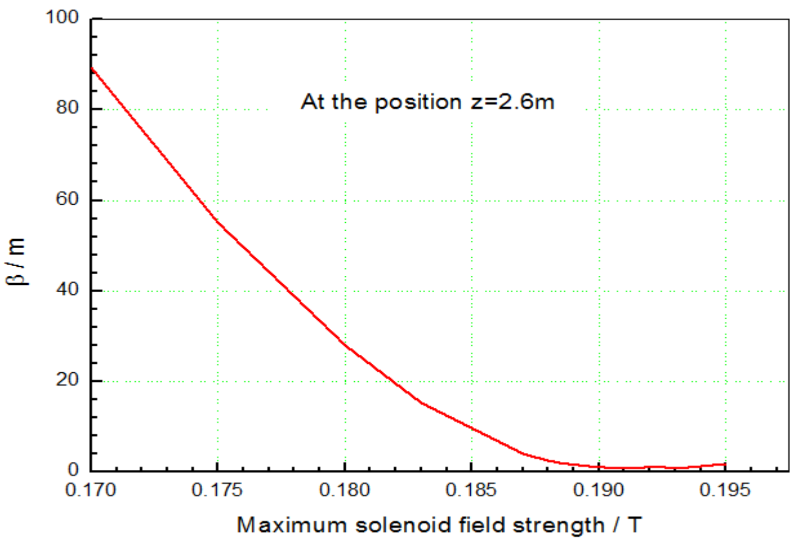
With different initial Twiss parameters

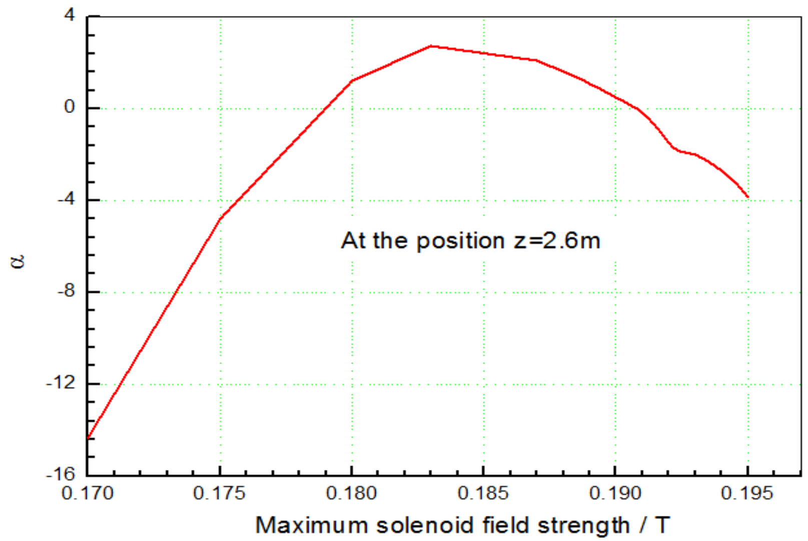
Beam optics calculation from the end of ACC1 to the entrance of ACC2

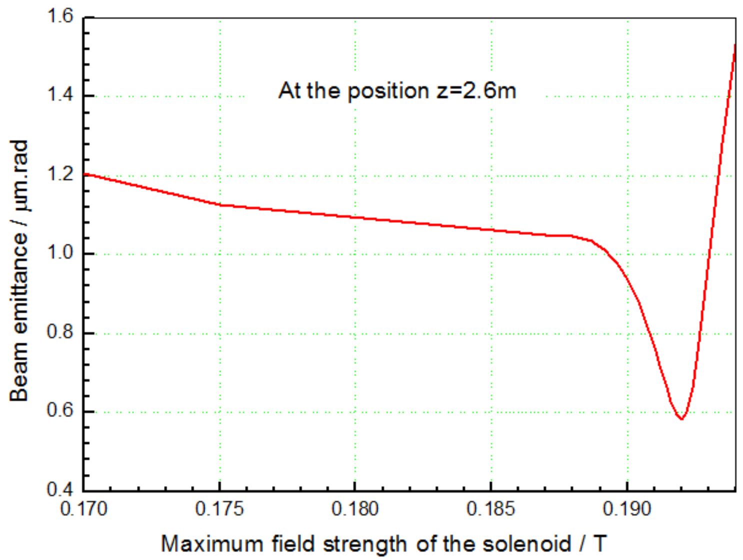
Elegant code (i: z=2.6m, f: Entrance of ACC2)



Solenoid emittance compensation study (ASTRA code)







When the maximum field strength of the solenoid is 0.1920T, minimum beam emittance has been obtained.

Beam dynamics simulation from start to the end of BC3 (ASTRA+CSRTrack)

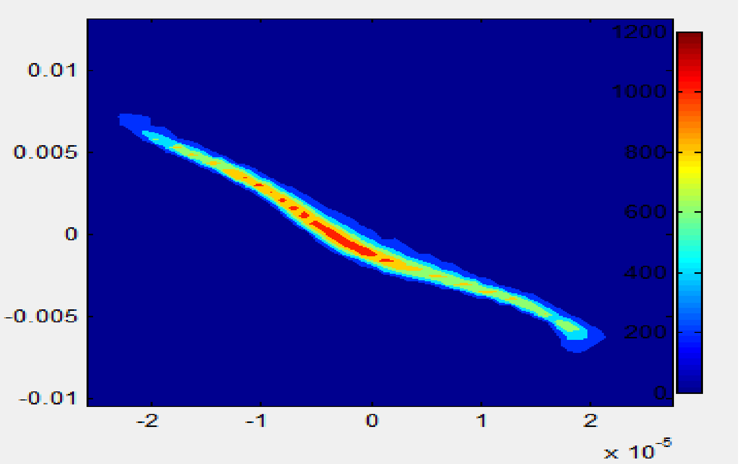
Case1

Element	Phase shift	V_{max}
RF Gun	2°	
ACC1	2.33°	161.619MV
ACC39	162.545°	20.3658MV
ACC2/3	17.85°	318.47MV
ACC4/5	0°	225.6MV
ACC6/7	11.0°	0.0MV

Case2

Element	Phase shift	V_{max}
RF Gun	2°	
ACC1	2.33°	166.600MV
ACC39	162.864°	21.3074MV
ACC2/3*	22.3°	323.30MV
ACC4/5	0°	225.6MV
ACC6/7	11.0°	0.0MV

End of the element	Beam Energy E	
	Case1	Case2
RF Gun	5MeV	5MeV
ACC1	166.9MeV	171.9MeV
ACC39	147.6MeV	151.6MeV
BC2	147.5MeV	151.5MeV
ACC2	298.8MeV	298.8MeV
ACC3	450.0MeV	450.0MeV



Bmag calculation

$B_{solenoid}$~0.1880T → After the gun, z=2.6m, β=2.6m, α=1.64

Horizontal direction

	Case1			Case2			B_{magx}
	β_x (m)	α_x	ε_x	β_x (m)	α_x	ε_x	
ACC1	141.0	-10.4	7.44e-7	149.0	-10.9	7.45e-7	1.00536
ACC39	200.0	39.2	8.03e-7	214.0	39.6	8.06e-7	3.56974
BC2	4.83	5.96	7.97e-7	8.99	8.0	8.02e-7	3.7696
Entrance of ACC2	36.7	-6.27	1.11e-6	30.3	-8.11	1.03e-6	**6.22962**
ACC2	254	-12.6	1.15e-6	390	-23.2	1.10e-6	5.92906
ACC3	108.0	12.3	1.24e-6	242	23.6	1.25e-6	4.84467
BC3 !!!!!!	18.7	-4.35	2.79e-6	16.5	-5.1	2.87e-6	**1.93547**

Vertical direction

	Case1			Case2			B_{magy}
	β_y (m)	α_y	ε_y	β_y (m)	α_y	ε_y	
ACC1	139.0	-10.2	7.55e-7	147.0	-10.7	7.57e-7	1.00515
ACC39	199.0	-7.43	7.78e-7	213.0	-8.64	7.80e-7	1.22297
BC2	5.84	-11.1	1.20e-6	3.02	-8.16	1.21e-6	6.88761
Entrance of ACC2	32.0	-0.802	1.94e-6	41.6	-5.68	2.18e-6	**9.30595**
ACC2	43	-0.308	1.95e-6	215	-9.54	2.25e-6	9.000
ACC3	2.71	-0.319	1.99e-6	21.1	4.92	2.62e-6	7.47733
BC3 !!!!!!	63.8	-2.2	1.99e-6	113	-8.42	2.80e-6	**6.9442**

$B_{solenoid}$~0.1920T (Minimum beam emittance) After the gun, β=1.036m, α=-1.485

Horizontal direction

	Case1			Case2			B_{magx}
	β_x (m)	α_x	ε_x	β_x (m)	α_x	ε_x	
ACC1	33.8	-0.250	6.00e-7	28.6	-0.143	6.04e-7	1.01676
ACC39	22.9	5.75	6.18e-7	19.7	4.65	6.22e-7	1.06245
BC2	1.01	-0.713	6.23e-7	0.973	-0.345	6.26e-7	1.06136
Entrance of ACC2	13.4	-0.296	7.13e-7	16.0	-1.54	6.48e-7	**1.60534**
ACC2	27.5	-0.926	7.23e-7	67.1	-2.86	6.45e-7	1.49883
ACC3	16.5	1.21	7.50e-7	26.1	2.91	6.76e-7	1.42057
BC3 !!!!!	3.01	-0.495	2.99e-6	3.17	-0.749	3.57e-6	**1.02595**

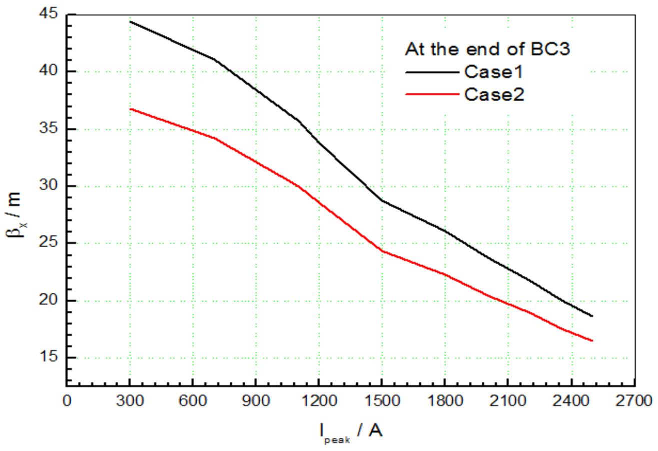
Vertical direction

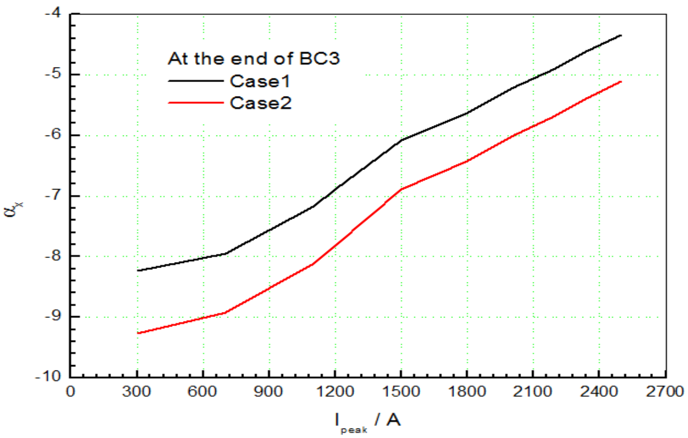
	Case1			Case2			B_{magy}
	β_y (m)	α_y	ε_y	β_y (m)	α_y	ε_y	
ACC1	33.9	-0.264	6.00e-7	28.6	-0.155	6.03e-7	1.0172
ACC39	24.1	0.456	6.16e-7	20.6	0.275	6.20e-7	1.02004
BC2	2.96	-3.04	6.41e-7	1.83	-2.13	6.38e-7	1.16863
Entrance of ACC2	4.86	0.437	6.72e-7	7.34	-0.346	6.64e-7	**1.42125**
ACC2	24.5	-2.13	6.81e-7	30.1	-1.63	6.69e-7	1.41761
ACC3	20.0	0.90	6.87e-7	9.81	0.829	6.69e-7	1.4177
BC3 !!!!!	7.40	-0.369	6.78e-7	17.6	-1.16	6.63e-7	**1.4162**

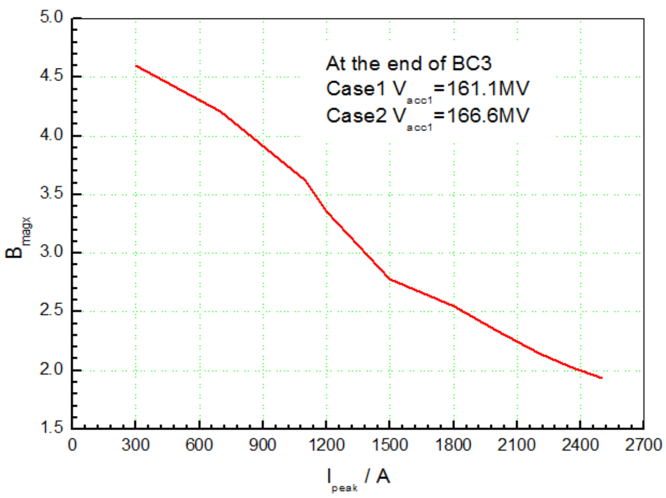
Study the collective effects on beam emittance and α, β functions in BC3

(CSRTrack code)

Using same parameters value of BC3, same initial twiss Parameters, same initial bunch length, different peak current



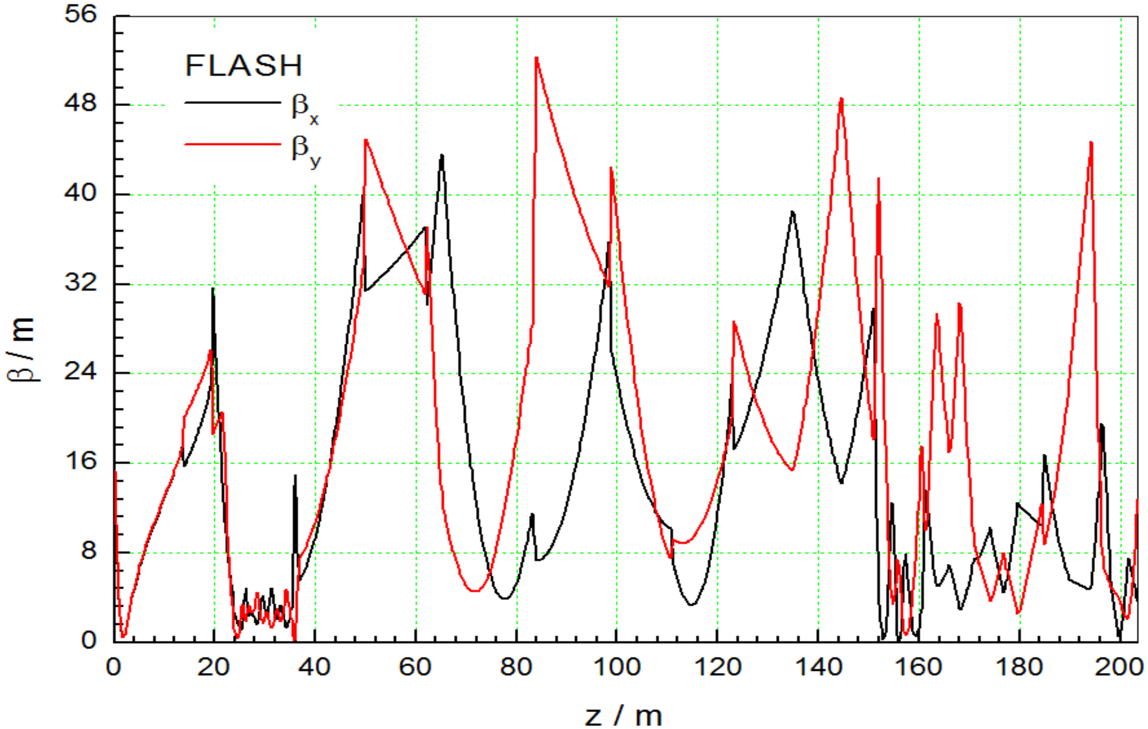




Problems

(1) Don’t know the exact parametes value of the gun and the solenoid which will determin the beam initial condition.

(2) Design optics of FLASH should be considered



Design Optics of FLASH

Work in Progress

1. Confirmation of the power distribution of cavity1-4 and cavity5-8 in ACC1 section.

   $V_{cav1-4}=V_{cav5-8}$

2. Confirmation of the power distribution of ACC2 and ACC3.

   V_{ACC2}/V_{ACC3}~138.8/177.4

3. In Case1, matching the beam optics before ACC39 by adjusting the field strength of the quadrupole magnets between ACC1 and ACC39. In Case2, using the same quadrupole field gradient as in Case1.
4. Making a comparison between the two cases.
5. …..