Demonstration of Using SC Software

Prach Boonpornprasert

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PITZ, DESY Zeuthen

Outline

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What is SC Software?

G.Kourkafas, DESY-Thesis-2014-044, P.95-97

- The SC software was developed by A. N. Matveenko and A. V. Bondarenko for beam matching at bERLinPro.
- SC resembles in its operation most of the common tracking and matching codes. Its major advantage is that the input beam is divided into a user-defined number of longitudinal slices.
- For each of these slides, the beam envelope equations are solved numerically for the two transverse planes.
- In this way, the resulting projected emittance is calculated from the contribution of each slice and varies accordingly along the simulated lattice.

Input/Output

SC Software manual guide

Input

- ASTRA particle distribution file or slice parameters file.
- Structure (lattice) file
- Optimization parameters file (*Optimizer.dat*)

SC Software

- Windows and Linux versions are available.
- Optimization is performed in 3 stages
  - Random search
  - Local optimizations by Broyden–Fletcher–Goldfarb–Shanno algorithm.
  - Final optimization by the same algorithm but with better accuracy.

Output

- *LocalMinima* folder
- Beam parameters evolution along Z of the final optimization (*BeamDynamics.dat*)
- Optimized lattice parameters (*Otvet.dat*)

Input: ASTRA file or slice parameter file

- ASTRA (each line for each particle)

	1	2	3	4	5	6	7	8	9	10
Parameter	x	y	z	px	py	pz	clock	macro charge	particle index	status flag
Unit	m	m	m	eV/c	eV/c	eV/c	ns	nC		

- Slice parameter file (each line for each slice)

	1	2	3	4	5	6	7	8	9	10
Parameter	ct	j	x	y	$\frac{dx_{rms}}{ds}$	$\frac{dy_{rms}}{ds}$	P	$\frac{d\delta}{ds}$	$\varepsilon_{n,s,x}$	$\varepsilon_{n,s,y}$
Unit	mm	A	m	m	1	1	MeV	m^{-1}	m	m

Input: Structure (lattice) file

- Structure file consists of 6 columns.
- Type of elements consist of free space (O), solenoids (S), quads (Q), cavity (C) and dipole (D).

O	length (m)	0	0	0	0
S	length (m)	field (T)	lower optimization bound (T)	upper optimization bound (T)	optimize
Q	length (m)	gradient (T/m)	lower optimization bound (T/m)	upper optimization bound (T/m)	Optimize
C	length (m)	acc. gradient (MeV/m)	phase of ref. slice (º)	wave vector (1/m)	0
D	length (m)	Field (T)	entry angle (º)	exit angle (º)	gap(m)

Input: Optimizer.dat

G_ε	the weight of emittance terms
ε_x	**Goal normalized Emittance x [mm.mrad]**
ε_y	**Goal normalized Emittance y [mm.mrad]**
G_β	the weight of beta terms
β_x	**Goal Beta x [m]**
β_y	**Goal Beta y [m]**
G_α	the weight of alpha terms
α_x	**Goal Alpha x**
α_y	**Goal Alpha y**
G_{max}	the weight of maximum size term
X_{max}	the maximum size
N_{slices}	the number of slices
N_{rand}	the number of attempts at random search stage
N_0	the number of local optimizations
N_{step}	the number of steps in local optimizer
dz_l	the step size in calculation equation of motion in local optimization
dz_f	the step size in calculation equation of motion in final optimization
stepi	the initial step parameter
stepf1	the final step parameter in local optimization
stepf2	the final step parameter in final optimization

The target function

$$\sqrt{G_\varepsilon\left((\varepsilon_{nx}-\varepsilon_{0nx})^2+(\varepsilon_{ny}-\varepsilon_{0ny})^2\right)+G_{\max}\left(X_{\max}-\max(x,y)\right)^2+ G_\beta\left((\beta_x-\overline{\beta_x})^2+(\beta_y-\overline{\beta_y})^2\right)+G_\alpha\left((\alpha_x-\overline{\alpha_x})^2+(\alpha_y-\overline{\alpha_y})^2\right)}$$

Output: *LocalMinima**BeamDynamics#__.txt*
Output: *BeamDynamics.dat*

- Parameter evolutions along s-axis from the final optimization

1st column	s [m]
2nd column	ε_{0nx} [mm·mrad]
3rd column	ε_{0ny} [mm·mrad]
4th column	x_{rms} [mm]
5th column	y_{rms} [mm]
6th column	ct_{rms} [mm]
7th column	β_x [m]
8th column	β_y [m]
9th column	α_x
10th column	α_y
11th column	R_{56} [m]
12th column	D [m]
13th column	D'
14th column	γmc^2 [MeV]
15th column	part of the beam without overbunching

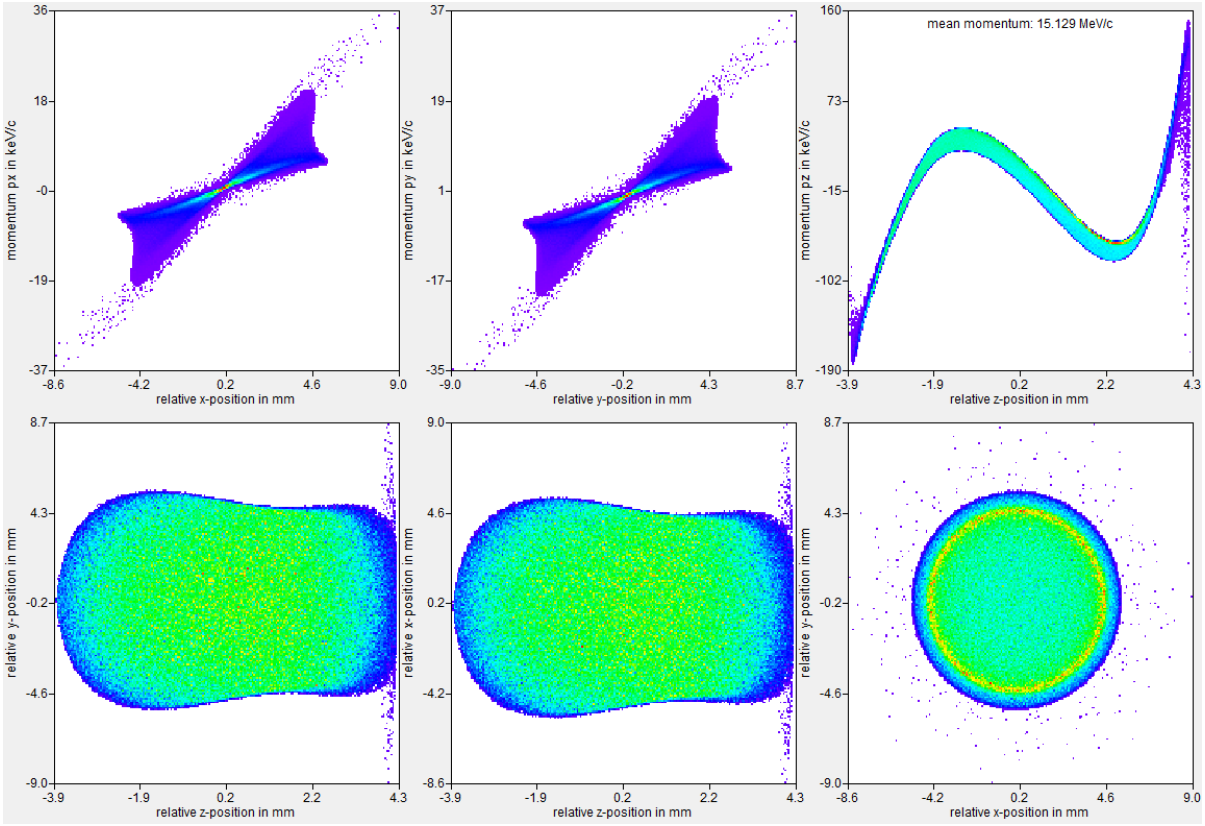
Output: Otvet.dat

The file contains m+1 columns, where m is the number of optimization parameters. Firsts m columns are field of optimized solenoids in T and gradients of quadrupoles in T/m. In the last column is the value of the target function. Each row corresponds to a local minimum of the third optimization stage. The last row corresponds to the global minimum.

Local op. #1	Optimized parameter 1	Optimized parameter 2	…	Optimized parameter ***n***	Value of target function
Local op. #2	Optimized parameter 1	Optimized parameter 2	…	Optimized parameter ***n***	Value of target function
. . .					
Local op. #m	Optimized parameter 1	Optimized parameter 2	…	Optimized parameter ***n***	Value of target function
Final opimization	Optimized parameter 1	Optimized parameter 2	…	Optimized parameter ***n***	Value of target function

EXAMPLE

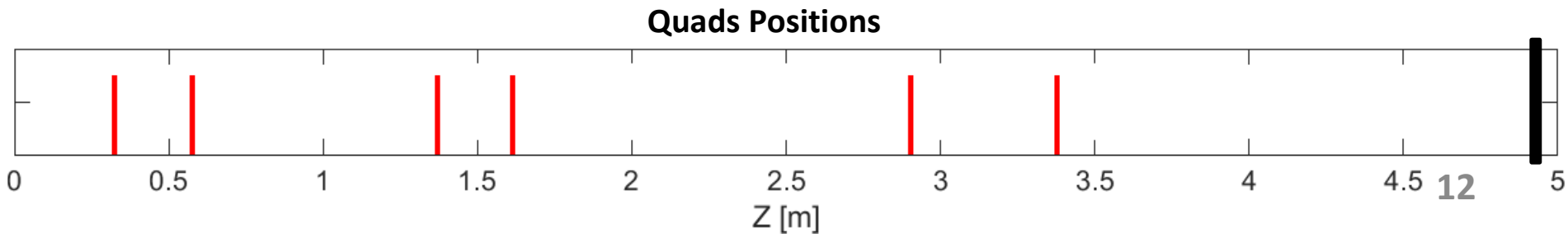
Example Input: Input Beam (ASTRA)



Charge [nC]	4
Z [m]	5.27 ➔ 0
ε_{0nx} [mm·mrad]	11.28
ε_{0ny} [mm·mrad]	11.28
x_{rms} [mm]	2.61
y_{rms} [mm]	2.61
Z_{rms} [mm]	1.952
β_x [m]	17.87
β_y [m]	17.87
α_x	-2.45
α_y	-2.45
Momentum [MeV]	15.13

Example Input : Structure file (High1.Scr1 ➔ High1.Q9 entrance)

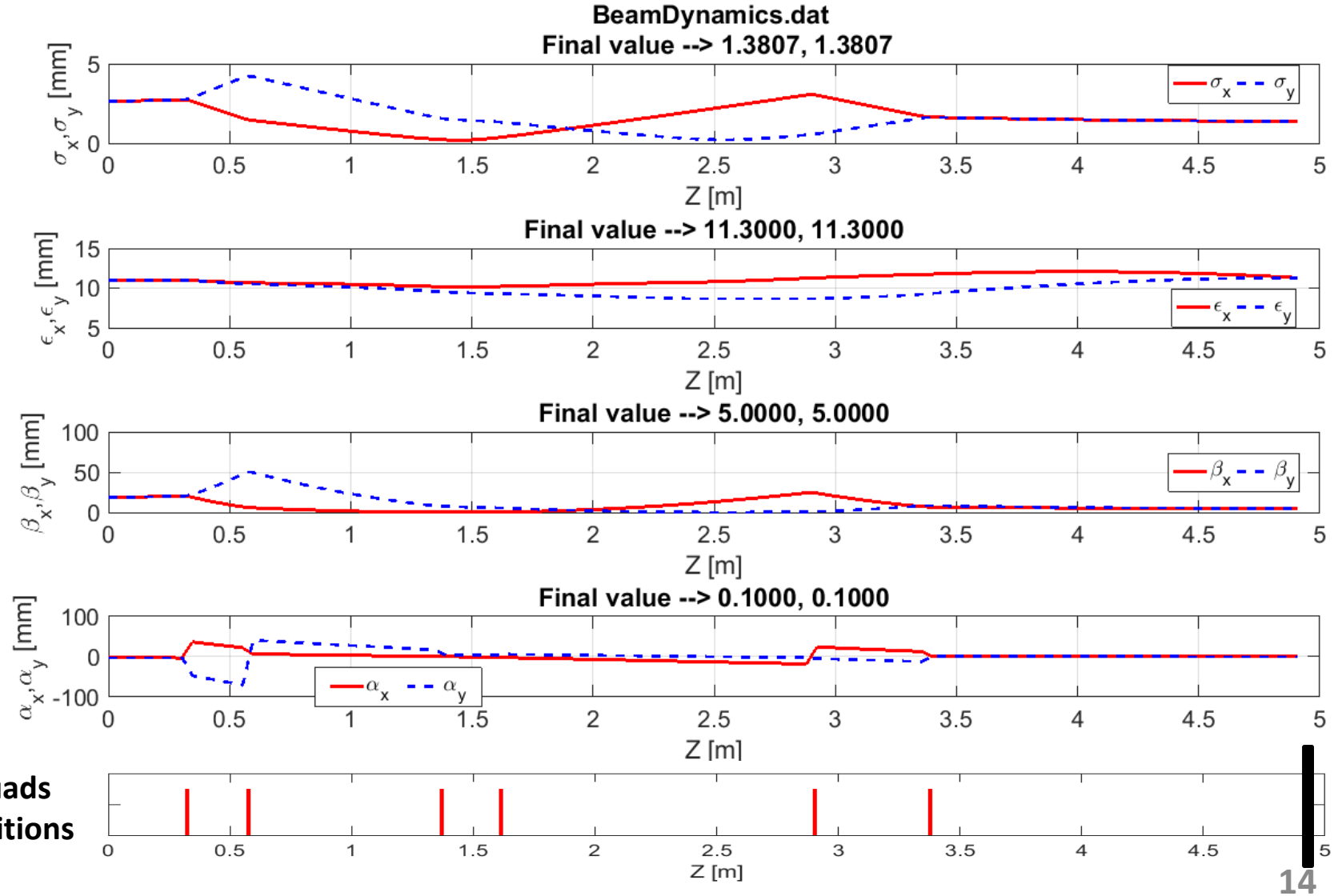
O	0.30400	0	0	0	0
Q	0.04300	0.1	-4.46	4.46	1
O	0.20700	0	0	0	0
Q	0.04300	0.1	-4.46	4.46	1
O	0.75200	0	0	0	0
Q	0.04300	0.1	-4.46	4.46	1
O	0.20200	0	0	0	0
Q	0.04300	0.1	-4.46	4.46	1
O	1.24450	0	0	0	0
Q	0.04300	0.1	-4.46	4.46	1
O	0.43200	0	0	0	0
Q	0.04300	0.1	-4.46	4.46	1
O	1.51000	0	0	0	0



Example Input : *Optimizer.dat*

10	the weight of emittance term
11.3	**goal normalized emittance x**
11.3	**goal normalized emittance y**
10	the weight of beta term
5	**goal beta x**
5	**goal beta y**
5	the weight of alpha term
0.1	**goal alpha x**
0.1	**goal alpha y**
10	the weight of maximum size term
8e-3	the maximum size
10.0	the number of slices
10000	the number of attempts at random search stage
10	the number of local optimizations
0.1	the step size in calculation equation of motion in local optimization
0.01	the step size in calculation equation of motion in final optimization
0.001	the initial step parameter
1e-6	the final step parameter in local optimization
1e-9	the final step parameter in final optimization

Example output : Plots from *Beamdynamics.dat*



Example output: *Otvet.dat*

#1	2.62	-2.41	-0.86	1.74	1.6	-1.92	0.0329689
#2	1.94	-2.26	0.35	0.61	3.33	-1.45	8.90779
#3	-2.39	2.66	-1.83	0.57	-2.04	1.91	0.0241748
#4	-4.26	3.45	-2.73	-0.7	-2.86	1.39	15.4149
#5	2.59	-1.97	-1.94	3.4	-1.45	4.68	11.3247
#6	-1.93	2.41	-0.78	-0.13	3.08	-2.02	5.58445
#7	3.07	-4.62	3.65	-3.54	1.28	-0.18	11.7917
#8	3.3	-3	0.06	2.38	-3.08	2.63	6.04446
#9	1.83	-2.96	3.41	-5.5	3.34	-1.69	7.07073
#10	-1.28	0.63	0.3	0.38	0.58	-1.21	9.44186
#11	-2.39	2.66	-1.83	0.57	-2.04	1.91	7.50E-05

Remarks

+ Final optimized values are very accurate.

- No minimum beam size condition
- New output is written with append (“a”) mode.

- Took ~10 minutes running time for 10 slices, 6 parameters.
- Comparisons with ASTRA and experiment results were already done in GK thesis but further case studies are still needed.
- We should implement procedure of beam matching during experiment (on-flight matching), the SC software may be useful.