News from beam-beam SixTrack development

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WP2 meeting 23/5/2017

Beam-beam kick recap.

- Strong beam is sliced in both 4D and 6D model according to the longitudinal charge distributions and centroid positions
- 4D uncoupled beam-beam kick uses d_x, d_y, Σ_{xx}, Σ_{yy} to calculate the kick in $\Delta p_{x,y}$ for each weak particle
- 6D beam-beam effects are introduced by the Synchro beam mapping such that
  - $\Delta p_{x,y}$ is calculated for the d_x, d_y, Σ_{xx}, Σ_{yy} at the effective interaction point using (ct, p_x, p_y, Σ) at the reference IP
  - a Δp_t (emerging from the ct dependence) is also applied
  - with crossing angle a translation, rotation and a boost change the reference frame in which $<p_{x,y}>$, X,Y, $P_{x,y} = 0$
- With coupling the uncoupled form is used in a rotated frame (ct dependent for the 6D kick)

1. 1976, "Potential of a Three-Dimensional Gaussian Bunch", S. Kheifets, PETRA Note 119, 3D electric potential
2. 1980, Closed expression for the electrical field of a two-dimensional Gaussian charge, M. Bassetti, A. Erskine, CERN-ISR-TH-80-06; 4D beam beam kick
3. 1992, A Symplectic Beam-Beam Interaction with Energy Change, K. Hirata, F. Ruggiero, SLAC-PUB-10055, KEK Preprint 92-117; Synchro beam mapping (SBM) for head-on beam-beam effects.
4. 1994, Don’t Be Afraid of Beam-Beam Interactions With a Large Crossing angle, K. Hirata. SBM with crossing angle
5. 2001, 6D Beam-Beam Kick including Coupled Motion, L.H.A. Leunissen, F. Schmidt,G. Ripken; SBM with crossing angle and coupling

Options in Standard SixTrack BB interface

`lhc=0`, uses as input:

- position of the strong beam w.r.t the weak beam
- Σ_{xx}, Σ_{yy} and other Σ elements are calculated from the weak beam optics
- slicing is computed internally using as input number of slices, crossing angle (`xang`), and slices slope (`xstr`) [1];

`lhc=1`, as before but inverting x with y;

`lhc=2`, as `lhc=1`:

- Σ_{xx}, Σ_{yy} are taken as input in `fort.2` (generated by MadX from the values created by the beam-beam macros)
- other elements of Σ are computed like `lhc=1`;

[1] J. Barranco, On-going SixTrack code development, 30/5/2013, LHC-Beam-beam meeting

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6D Beam-Beam in SixTrack

Timeline:

- 1996 6D kick BCC code from Hirata
- 2000 6D code in SixTrack with coupling (coupling not used in production)
- 9/2/2011 lhc=2 option introduced by E. Laface for flat beam with 4D lenses
- 30/12/2013 lhc=2 fix for 6D and phi2 for effective crab angle by J. Barranco for 6D
- **24/3/2014 discussion and decision to change 6D interface to fix 6D issues:go on with previous fix in the short term, then implement general solution**
- 11/5/2014 lhc=2 option in SixTrack release for Boinc
- 11/9/2015 sigma matrix calculation in MadX requested
- 24/9/2015 last test/code/manual sent by Javier and reviewed/integrated by Kyrre
- 12/4/2017 MadX production release with sigma matrix calculation available
- 19/4/2017 Javier code merged with new expert interface merged by Kyrre and Riccardo
- 10/3/2017 Gianni started verifying equations from papers and code,
  bug in 6D boost identified and fixed by Gianni and merged by Riccardo,
  likely bug in coupling angle sign and other numerical issues under investigations
- 5/5/2017 beam-beam macro beam being adapted by Dario
- 5/5/2017 bug in sigma matrix calculation identified by Dario and corrected by Irina
- 17/5/2017 impact of boosti bug assessed with a tune scan by Dario
- 17/5/2017 macro completed and mask updated and tested in SixDesk (studies on going) by Dario

Generalization of the interface

Needed to simulate in 6D:

- flat optics without relying on weak optics information
- crab crossing or other complex strong charge distributions
- dynamic effects like separation collapse or strong orbit noise using DYNK (to do)

EXPERT interface

- Position of the strong beam w.r.t the weak beam, Σ elements, crossing angle are taken as input and completely decoupled from weak beam.
- 1-slice 6D element supported to allow arbitrary longitudinal distribution and crab crossing with RF curvature via external slicing
- No special slice slope angle

New developments from release 4.6.16: [1]

- Standard and Expert method produces same results
- Standard and Expert interface now coexists and Expert input format is generated by SixTrack

[1] K. Sobjak, https://github.com/SixTrack/SixTrack/pull/246

New Input Format for BB elements

BEAM

This variable still to be kept because was used for other purposes. (lhc=9)

I[ppb] $\varepsilon_{n,x}$ $\varepsilon_{n,y}$ σ_z[m] σ_e[m] ibeco ibtyp lhc ibbc — **Beam params**

"Exact" BB kicks (ibtyp=1) and linear coupling (ibbc=1) NOT TESTED with these new inputs!!!

name_4D nsli Σ_{xx}[mm^2] Σ_{yy}[mm^2] Sep$_x$[mm] Sep$_y$[mm] strength-ratio — **4D**

6D:

name_6D nsli θ/2 [rad] ?[rad] Sep$_x$[mm] Sep$_y$[mm]

Σ_{xx} [mm^2] Σ_{xxp} [mm mrad] Σ_{xpxp} [mrad^2] Σ_{yy} [mm^2] Σ_{yyp} [mm mrad]

Σ_{ypyp} [mrad^2] Σ_{xy} [mm^2] Σ_{xpy} [mm mrad] Σ_{xpyp} [mrad^2] strength-ratio

If a BB element is divided in several 4D or 6D different elements this variable sets the strength wrt to the total kick.

NEXT BEAM

Number of slices:

- 0 means 4D
- ≥ 1 means 6D

2.2000E+11 2.5 2.5 7.5e-02 1.10e-04 1 0 0 0 — **Beam params**

bb_par.l5b1_18 0 5.92e-06 2.45e-06 2.43e+01 3.83e-04 1 — **4D**

6D:

bb_ho1b1_0 15 0.0 295e-03 9.69123123e-07 -1.37123123e-06

5.021231233e-05 -4.256123123e-09 3.069123123e-07 5.021231233e-05 3.007123123e-08

2.231123123e-03 4.075123123e-08 1.231123123e-07 -4.264123123e-07 2.236123123e-03 1

NEXT

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J. Barranco, Status of new input definition of the beam-beam lens in SixTrack, 13/11/2015, 59th WP2 meeting

EXPERT interface (example)

Standard

```
bb_ho5b1_0    20  9.111827660e-07  -1.350224489e-06   1.000000000e+00   5.026457379e-05   5.026457406e-05   0.000000000e+00
bb_ho1b1_0    20  9.669766338e-07  -1.378612898e-06   1.000000000e+00   5.026457379e-05   5.026457406e-05   0.000000000e+00

BEAM
2.2000e+11 2.5 2.5 7.5000e-02 1.1000e-04 1 0 0 0
bb_ho5b1_0 15 295e-6 0.0 295e-6
bb_ho1b1_0 15 295e-6 1.57 295e-6
NEXT
```

Expert

```
bb_ho5b1_0    20  0.000000000e+00  0.000000000e+00   0.000000000e+00   0.000000000e+00   0.000000000e+00   0.000000000e+00
bb_ho1b1_0    20  0.000000000e+00  0.000000000e+00   0.000000000e+00   0.000000000e+00   0.000000000e+00   0.000000000e+00

BEAM
EXPERT
2.2000e+11 2.5 2.5 7.5000e-02 1.1000e-04 1 0 0 0
bb_ho5b1_0 15 2.9500000000001e-004 0.0000000000000e+000 9.1118276600001e-007 -1.3502244890000e-006
 5.0034903462428e-005 -9.593556151459e-008 2.24428543738e-003 5.021051982892e-005 7.5280318127904e-007
 2.2365333052480e-003 -1.663390341512e-009 -1.5308153223e-009 7.342199089562e-010 -6.517402396885e-009 1.000
bb_ho1b1_0 15 2.9500000000001e-004 1.5700000000001e+000 9.66976633800002e-007 -1.3786128980000e-006
 5.0520079639196e-005 -6.010182490910e-007 2.22276103671e-003 5.028688389602e-005 7.7037643894229e-007
 2.2330903791604e-003 -3.652801218428e-009 2.66101452881e-008 3.638680415249e-008 1.1594595769731e-007 1.000
NEXT
```

Expert input is also written by SixTrack in the standard output

Update beam-beam macros

Former 4D beam-beam MadX macros from Stephane now write in the mask SixTrack Expert input by computing missing Σ-matrix elements for each slice

- centroid with crab effects and $\Sigma_{11,33}$ were already computed
- first sanity checks shows good agreement with previous models (cannot be reproduced fully because they were inconsistent)
- Test on full studies on-going
- Tracking with Beam 4 under investigation

Mad vs SixTrack
Sigma matrix calculations

	mad/six	mad	sixtrack
sig11	1.00000002447	0.002246565358	0.00224656530302
sig12	1.00000002437	0.0001498270964	0.000149827092749
sig22	0.999999999265	6.00464297e-05	6.00464297441e-05
sig33	0.999999994158	0.01125155011	0.0112515501757
sig34	0.999999994116	-0.0007503841707	-0.000750384175115
sig44	0.999999999041	6.003852509e-05	6.00385251476e-05
sig13	1.00000001226	0.0001896193048	0.000189619302476
sig14	1.00000001153	-1.264601973e-05	-1.26460195841e-05
sig23	1.00000001153	1.264601973e-05	1.26460195842e-05
sig24	1.00000001202	-1.686933683e-06	-1.68693366273e-06

Differences old to new macros

Old macros for 6D

- $\Sigma_{11,33}$ and x_{B2},y_{B2} computed from an ideal machine
- x_{B1},y_{B1} add from imperfect orbit by MadX
- Crossing angle input manually
- $\Sigma_{12,22,34,44,13,14,23,24,34}$ computed by Sixtrack based B1 optics
- $\Sigma_{13,14,23,24,34}$ discarded

New macros for 6D

- Σ_{full} for and x,px,y,py for B1,2 computed from an ideal machine in MadX
- $\Sigma_{13,14,23,24,34}$ discarded pending verifications
- Input for Beam 1
- Beam 4 possible (under development)

Review of the the 6D beam-beam routines

(Is the physics implemented correctly?)

Review of the 6D beam-beam routines

Addressing two questions:

- **What is the code supposed to do?**
  - Mathematical derivation of the implemented numerical model
- **Is the code doing what it is supposed to do?**
  - Verify the implementation of the above numerical model

Mathematical derivation

The code implements the **Synchro Beam Mapping** in the presence of:

- **Crossing angle** (ϕ)
- Arbitrary **crossing plane** (α)
- Optics at the IP described by a **general 4D correlation matrix** (Σ-matrix) → hour glass effect, elliptic beams, alphas, and linear coupling at the IP are included in the modeling)

This makes the **mathematical derivation quite heavy**

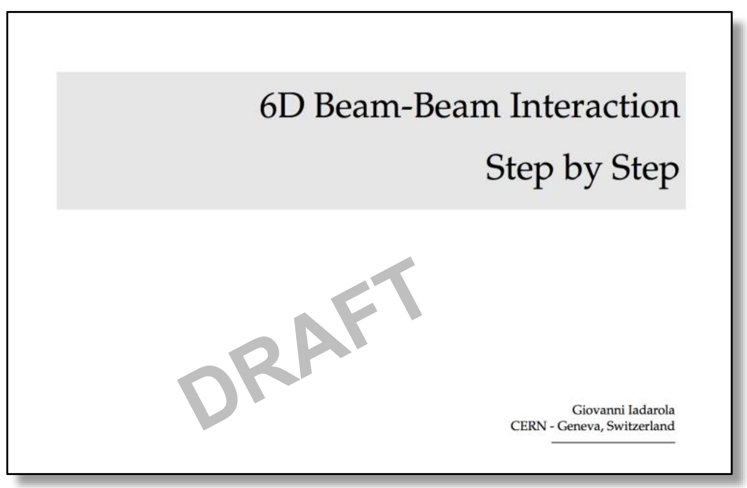
Implementation in Sixtrack in **largely based on**:

- *6D Beam-Beam Kick including Coupled Motion, L.H.A. Leunissen, F. Schmidt, G. Ripken, 2001*

… but **important parts** (e.g. inverse boost, “optics de-coupling” including longitudinal derivatives) are **not reported in the paper nor anywhere else**, to our best knowledge…

Mathematical derivation

- Invested some time in **understanding and re-constructing the mathematical treatment** trying to use as little as possible the source code as a reference
  - → **Independent reconstruction** of the equations to verify the implementation in Sixtrack and to be used as a basis for a modern implementation (GPU compatible, for example)
  - → **Parts not available in literature** (mainly inverse Lorentz boost, and a large fraction of the coupling treatment) **had to be re-derived**
- Drafted a **document** including the full set of equation to enable a possible re-implementation (and avoid that somebody has to redo the same exercise in ten years)


6D Beam-Beam Interaction

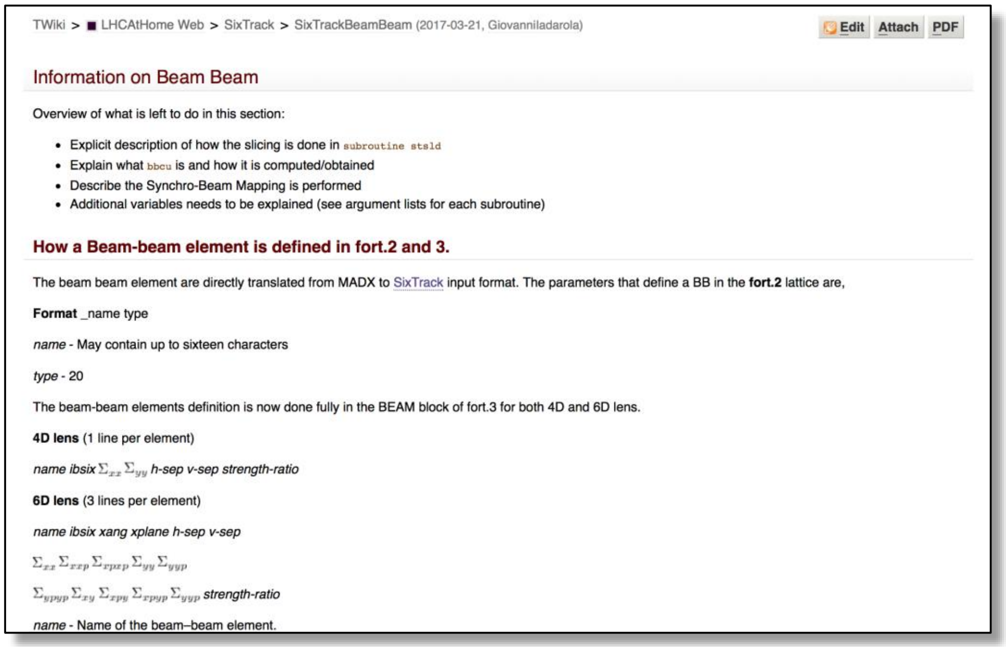
Step by Step

DRAFT

Giovanni Iadarola
CERN - Geneva, Switzerland

Verification of the implementation

- Started from **previous work** done by J. Barranco
  - Identified and described the **interface of the main functional blocks**
  - Built tables with the descriptions of the cumbersome **notation** used in the code



TWiki > LHCAtHome Web > SixTrack > SixTrackBeamBeam (2017-03-21, Giovanniladarola)   Edit Attach PDF

Information on Beam Beam

Overview of what is left to do in this section:

- Explicit description of how the slicing is done in `subroutine stsld`
- Explain what `bbcu` is and how it is computed/obtained
- Describe the Synchro-Beam Mapping is performed
- Additional variables needs to be explained (see argument lists for each subroutine)

How a Beam-beam element is defined in fort.2 and 3.

The beam beam element are directly translated from MADX to SixTrack input format. The parameters that define a BB in the **fort.2** lattice are,

Format _name type

name - May contain up to sixteen characters

type - 20

The beam-beam elements definition is now done fully in the BEAM block of fort.3 for both 4D and 6D lens.

4D lens (1 line per element)

name ibsix Σ_{xx} Σ_{yy} *h-sep v-sep strength-ratio*

6D lens (3 lines per element)

name ibsix xang xplane h-sep v-sep

Σ_{xx} Σ_{xxp} Σ_{xpxp} Σ_{yy} Σ_{yyp}

Σ_{ypyp} Σ_{xy} Σ_{xpy} Σ_{xpyp} Σ_{yyp} *strength-ratio*

name - Name of the beam–beam element.

- Moved to the understanding and testing of the source code…

Verification of the implementation

- Very difficult to identify problems by using the full tracking simulations
  - Need to test the single routine **"on the bench"**

- **Procedure** being performed for each functional block
  - Built a **quick C/python implementation** from the equations in the document
  - Extracted the **corresponding sixtrack source code** and compiled as of a stand-alone python module (f2py)
  - **"Stress test"** performed on the two: consistency checks, comparison against each other

Verification of the implementation

- **Present status** of the verification for the different functional blocks:

Module	Tests performed	Outcome
Boost/anti-boost	• Comparison Sixtrack vs C/python routine • Checked that the two cancel each other	**Bug** identified and **corrected**
Beam-beam forces (with potential derivatives w.r.t. sigmas)	• Comparison sixtrack vs C/python routine • Force compared against Finite Difference Poisson solved (PyPIC) • Other derivatives compared against numerical integration/derivation	**All checks passed**
Beam shape propagation and coupling treatment	• Comparison Sixtrack vs C/python routine • Comparison against MAD for a coupled beam line • Crosscheck with numerical derivation	Ongoing: • **Uncoupled beams look OK** • **Coupling** under investigation: different **problems** already identified
Computation of the kicks	Still to be tested	Still to be tested
Slicing	Still to be tested	Still to be tested

- Complete review to be presented later this year

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Problem in the inverse boost

- Problem **identified with "bench-test"** (large crossing angle, test particle very off momentum and large px, py)
- Boost and anti-boost should cancel each other exactly

Error after boost + anti-boost

Python test routine		SixTrack routine	
x	4.3e-19	**x**	6.5e-19
px	0.0	**px**	0.065
y	4.3e-19	**y**	4.3e-19
py	3.e3-17	**py**	0.027
sigma	0.0	**sigma**	0.0
delta	1e-16	**delta**	2.0e-17

Problem in the inverse boost

- Problem **identified with "bench-test"** (large crossing angle, test particle very off momentum and large px, py)
- Boost and anti-boost should cancel each other exactly

Discrepancy found between in the anti-boost between derived equations and SixTrack source code:

$$p_x = p_x^* \cos\phi + h \cos\alpha \tan\phi \quad (95)$$
$$p_y = p_y^* \cos\phi + h \sin\alpha \tan\phi \quad (96)$$

```
TRACK(2)=(TRACK(2)+CALPHA*SPHI*H1)*CPHI
TRACK(4)=(TRACK(4)+SALPHA*SPHI*H1)*CPHI
```

The lines should be:

```
TRACK(2)=(TRACK(2)*CPHI+CALPHA*TPHI*H1)
TRACK(4)=(TRACK(4)*CPHI+SALPHA*TPHI*H1)
```

- Digging a bit we found out that the issue was already present in Hirata's code from 1996, on which the Sixtrack implementation is based

Problem in the inverse boost

- Problem **identified with “bench-test”** (large crossing angle, test particle very off momentum and large px, py)
- Boost and anti-boost should cancel each other exactly

Error after boost + anti-boost

Python test routine		SixTrack routine		SixTrack corrected	
x	4.3e-19	**x**	6.5e-19	**x**	6.5e-19
px	0.0	**px**	0.065	**px**	**5.55e-17**
y	4.3e-19	**y**	4.3e-19	**y**	4.3e-19
py	3.e3-17	**py**	0.027	**py**	0.1e-19
sigma	0.0	**sigma**	0.0	**sigma**	0.0
delta	1e-16	**delta**	2.0e-17	**delta**	2.0e-17

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Problem in the inverse boost

- Problem confirmed by Riccardo simulating a beam-beam interaction with **zero intensity in the strong beam**

Original implementation

Coordinates before interaction

dump_ip.dat

# ID	turn	s[m]	x[mm]	xp[mrad]	y[mm]	yp[mrad]	dE/E[1]	ktrack
1	1	0.00000	1.444989354E-01	1.217984946E-02	2.341007330E-02	-1.973240618E-03		
2	1	0.00000	1.444989354E-01	1.217984946E-02	2.341007330E-02	-1.973240618E-03		
3	1	0.00000	2.169989354E-01	1.829089161E-02	1.931331047E-01	-1.627923509E-02		
4	1	0.00000	2.169989354E-01	1.829089161E-02	1.931331047E-01	-1.627923509E-02		
5	1	0.00000	2.894989354E-01	2.440193375E-02	3.628561362E-01	-3.058522956E-02		
6	1	0.00000	2.894989354E-01	2.440193375E-02	3.628561362E-01	-3.058522956E-02		
7	1	0.00000	3.619989354E-01	3.051297588E-02	5.325791676E-01	-4.489122400E-02		
8	1	0.00000	3.619989354E-01	3.051297588E-02	5.325791676E-01	-4.489122400E-02		
9	1	0.00000	4.344989354E-01	3.662401801E-02	7.023021991E-01	-5.919721844E-02		
10	1	0.00000	4.344989354E-01	3.662401801E-02	7.023021991E-01	-5.919721844E-02		
1	2	0.00000	1.308501246E-01	8.514045445E-03	-9.961266845E-03	3.153912424E-04		
2	2	0.00000	1.308501246E-01	8.514045445E-03	-9.961266845E-03	3.153912424E-04		
3	2	0.00000	1.041820622E-01	-1.200951762E-02	-8.217894405E-02	2.601833146E-03		
4	2	0.00000	1.041820622E-01	-1.200951762E-02	-8.217894405E-02	2.601833146E-03		
5	2	0.00000	7.751399978E-02	-3.253308068E-02	-1.543977321E-01	4.888381596E-03		
6	2	0.00000	7.751399978E-02	-3.253308068E-02	-1.543977321E-01	4.888381596E-03		
7	2	0.00000	5.084593752E-02	-5.305664373E-02	-2.266176309E-01	7.175036594E-03		
8	2	0.00000	5.084593752E-02	-5.305664373E-02	-2.266176309E-01	7.175036594E-03		
9	2	0.00000	2.417787538E-02	-7.358020677E-02	-2.988386405E-01	9.461798139E-03		
10	2	0.00000	2.417787538E-02	-7.358020677E-02	-2.988386405E-01	9.461798139E-03		

Coordinates after interaction

dump_bb.dat

# ID	turn	s[m]	x[mm]	xp[mrad]	y[mm]	yp[mrad]	dE/E[1]	ktrack
1	1	0.00000	1.444989354E-01	1.217984945E-02	2.341007330E-02	-1.973250177E-03		
2	1	0.00000	1.444989354E-01	1.217984945E-02	2.341007330E-02	-1.973250177E-03		
3	1	0.00000	2.169989354E-01	1.829089158E-02	1.931331047E-01	-1.627927274E-02		
4	1	0.00000	2.169989354E-01	1.829089158E-02	1.931331047E-01	-1.627927274E-02		
5	1	0.00000	2.894989354E-01	2.440193367E-02	3.628561362E-01	-3.058532567E-02		
6	1	0.00000	2.894989354E-01	2.440193367E-02	3.628561362E-01	-3.058532567E-02		
7	1	0.00000	3.619989354E-01	3.051297574E-02	5.325791676E-01	-4.489140898E-02		
8	1	0.00000	3.619989354E-01	3.051297574E-02	5.325791676E-01	-4.489140898E-02		
9	1	0.00000	4.344989354E-01	3.662401777E-02	7.023021991E-01	-5.919752266E-02		
10	1	0.00000	4.344989354E-01	3.662401777E-02	7.023021991E-01	-5.919752266E-02		
1	2	0.00000	1.308501246E-01	8.514045441E-03	-9.961266845E-03	3.153866850E-04		
2	2	0.00000	1.308501246E-01	8.514045441E-03	-9.961266845E-03	3.153866850E-04		
3	2	0.00000	1.041820622E-01	-1.200951763E-02	-8.217894405E-02	2.601823666E-03		
4	2	0.00000	1.041820622E-01	-1.200951763E-02	-8.217894405E-02	2.601823666E-03		
5	2	0.00000	7.751399978E-02	-3.253308074E-02	-1.543977321E-01	4.888313646E-03		
6	2	0.00000	7.751399978E-02	-3.253308074E-02	-1.543977321E-01	4.888313646E-03		
7	2	0.00000	5.084593752E-02	-5.305664388E-02	-2.266176309E-01	7.174856626E-03		
8	2	0.00000	5.084593752E-02	-5.305664388E-02	-2.266176309E-01	7.174856626E-03		
9	2	0.00000	2.417787538E-02	-7.358020705E-02	-2.988386405E-01	9.461452606E-03		
10	2	0.00000	2.417787538E-02	-7.358020705E-02	-2.988386405E-01	9.461452606E-03		

Corrected implementation

Coordinates before interaction

dump_ip.dat

ID	turn	s[m]	x[mm]	xp[mrad]	y[mm]	yp[mrad]	dE/E[1]	ktrack
1	1	0.00000	1.444989354E-01	1.217984946E-02	2.341007330E-02	-1.973240618E-03	1	
2	1	0.00000	1.444989354E-01	1.217984946E-02	2.341007330E-02	-1.973240618E-03	1	
3	1	0.00000	2.169989354E-01	1.829089161E-02	1.931331047E-01	-1.627923509E-02	1	
4	1	0.00000	2.169989354E-01	1.829089161E-02	1.931331047E-01	-1.627923509E-02	1	
5	1	0.00000	2.894989354E-01	2.440193375E-02	3.628561362E-01	-3.058522956E-02	1	
6	1	0.00000	2.894989354E-01	2.440193375E-02	3.628561362E-01	-3.058522956E-02	1	
7	1	0.00000	3.619989354E-01	3.051297588E-02	5.325791676E-01	-4.489122400E-02	1	
8	1	0.00000	3.619989354E-01	3.051297588E-02	5.325791676E-01	-4.489122400E-02	1	
9	1	0.00000	4.344989354E-01	3.662401801E-02	7.023021991E-01	-5.919721844E-02	1	
10	1	0.00000	4.344989354E-01	3.662401801E-02	7.023021991E-01	-5.919721844E-02	1	
1	2	0.00000	1.308501247E-01	8.514045444E-03	-9.960917299E-03	3.153577120E-04	9	
2	2	0.00000	1.308501247E-01	8.514045444E-03	-9.960917299E-03	3.153577120E-04	9	
3	2	0.00000	1.041820623E-01	-1.200951763E-02	-8.217756745E-02	2.601701095E-03	9	
4	2	0.00000	1.041820623E-01	-1.200951763E-02	-8.217756745E-02	2.601701095E-03	9	
5	2	0.00000	7.751400004E-02	-3.253308069E-02	-1.543942171E-01	4.888044424E-03	9	
6	2	0.00000	7.751400004E-02	-3.253308069E-02	-1.543942171E-01	4.888044424E-03	9	
7	2	0.00000	5.084593802E-02	-5.305664374E-02	-2.266108663E-01	7.174387701E-03	9	
8	2	0.00000	5.084593802E-02	-5.305664374E-02	-2.266108663E-01	7.174387701E-03	9	
9	2	0.00000	2.417787621E-02	-7.358020679E-02	-2.988275150E-01	9.460730924E-03	9	
10	2	0.00000	2.417787621E-02	-7.358020679E-02	-2.988275150E-01	9.460730924E-03	9	

Coordinates after interaction

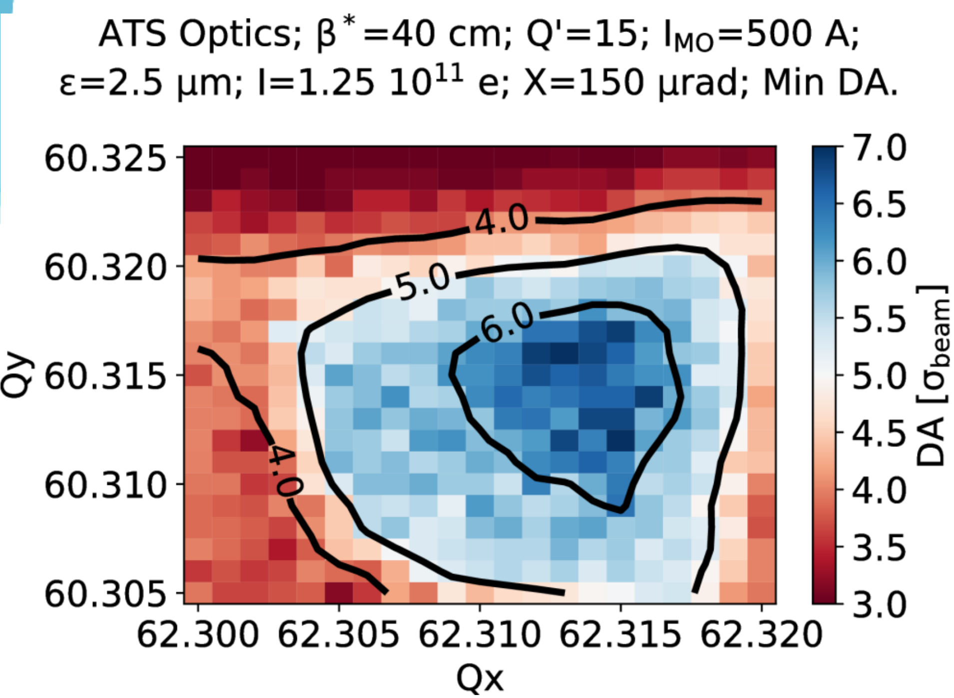
dump_bb.dat

ID	turn	s[m]	x[mm]	xp[mrad]	y[mm]	yp[mrad]	dE/E[1]	ktrack
1	1	0.00000	1.444989354E-01	1.217984946E-02	2.341007330E-02	-1.973240618E-03	1	
2	1	0.00000	1.444989354E-01	1.217984946E-02	2.341007330E-02	-1.973240618E-03	1	
3	1	0.00000	2.169989354E-01	1.829089161E-02	1.931331047E-01	-1.627923509E-02	1	
4	1	0.00000	2.169989354E-01	1.829089161E-02	1.931331047E-01	-1.627923509E-02	1	
5	1	0.00000	2.894989354E-01	2.440193375E-02	3.628561362E-01	-3.058522956E-02	1	
6	1	0.00000	2.894989354E-01	2.440193375E-02	3.628561362E-01	-3.058522956E-02	1	
7	1	0.00000	3.619989354E-01	3.051297588E-02	5.325791676E-01	-4.489122400E-02	1	
8	1	0.00000	3.619989354E-01	3.051297588E-02	5.325791676E-01	-4.489122400E-02	1	
9	1	0.00000	4.344989354E-01	3.662401801E-02	7.023021991E-01	-5.919721844E-02	1	
10	1	0.00000	4.344989354E-01	3.662401801E-02	7.023021991E-01	-5.919721844E-02	1	
1	2	0.00000	1.308501247E-01	8.514045444E-03	-9.960917299E-03	3.153577120E-04	9	
2	2	0.00000	1.308501247E-01	8.514045444E-03	-9.960917299E-03	3.153577120E-04	9	
3	2	0.00000	1.041820623E-01	-1.200951763E-02	-8.217756745E-02	2.601701095E-03	9	
4	2	0.00000	1.041820623E-01	-1.200951763E-02	-8.217756745E-02	2.601701095E-03	9	
5	2	0.00000	7.751400004E-02	-3.253308069E-02	-1.543942171E-01	4.888044424E-03	9	
6	2	0.00000	7.751400004E-02	-3.253308069E-02	-1.543942171E-01	4.888044424E-03	9	
7	2	0.00000	5.084593802E-02	-5.305664374E-02	-2.266108663E-01	7.174387701E-03	9	
8	2	0.00000	5.084593802E-02	-5.305664374E-02	-2.266108663E-01	7.174387701E-03	9	
9	2	0.00000	2.417787621E-02	-7.358020679E-02	-2.988275150E-01	9.460730924E-03	9	
10	2	0.00000	2.417787621E-02	-7.358020679E-02	-2.988275150E-01	9.460730924E-03	9	

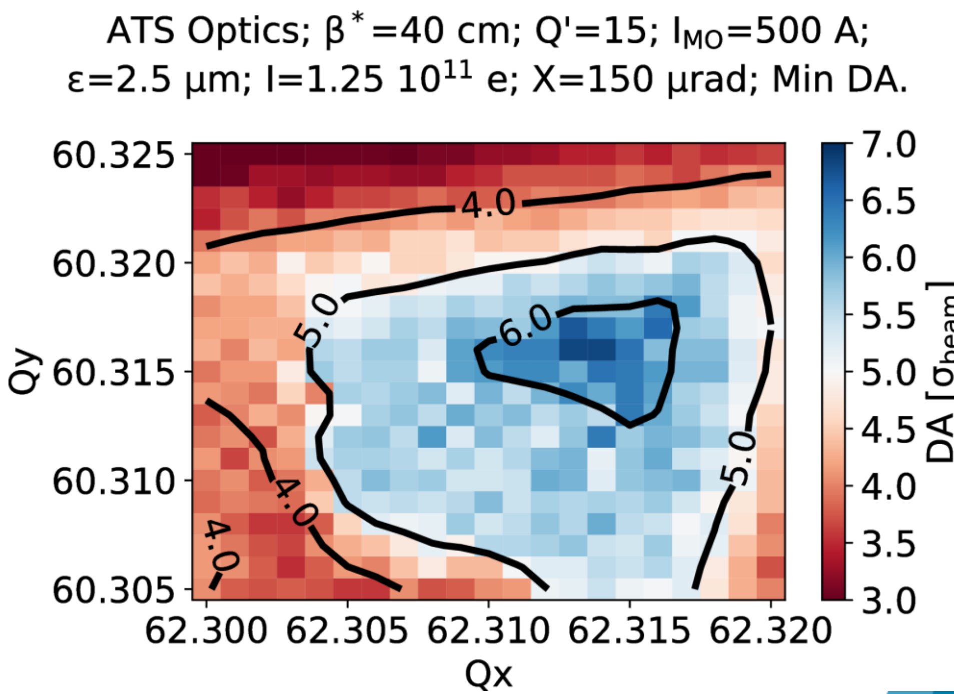
Problem in the inverse boost

- Impact on **realistic simulation study** assessed by Dario
- Tune scans comparison with 2017 ATS optics show no dramatic change, but slightly worse DA

Old version



Corrected version



HiLumi HL-LHC PROJECT