

Flight Simulator (DFS & WFS) in the ATF LINAC and ATF2 EXT



P. Korysko*, A. Latina

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*pierre.korysko@cern.ch

Outline

- ATF2 @ KEK: Motivation and Objectives
- ATF Matlab Flight Simulator
- DFS and WFS in the LINAC
- DFS and WFS in the EXT
- ATF2 Python Flight Simulator

The ATF2 at KEK



The Accelerator Test Facility 2 (ATF2)

先端加速器試験棟
E29見学ルート



途中、せまい所、床の段差、天井の低い所があるから気をつけてネ！
緊急時は、係員の誘導に従って下さい。



ナノビームの測定



ナノビームの実現



ダンピングリングの出入口



パネル展示
ガイドツアーの
集合場所
!! スタート !!



レーザー光を利用して電子ビームの生成



電子ビームのエネルギーは
13億電子ボルト



ダンピングリングで高品質に

国際リニアコライダー(ILC)計画
先端加速器試験装置
(ATF)

Extraction Line

- Final Focus prototype for ILC and CLIC

Damping ring

- Nanometre vert. norm. emittance

Linac:

- 80m, S-band, 1.3 GeV

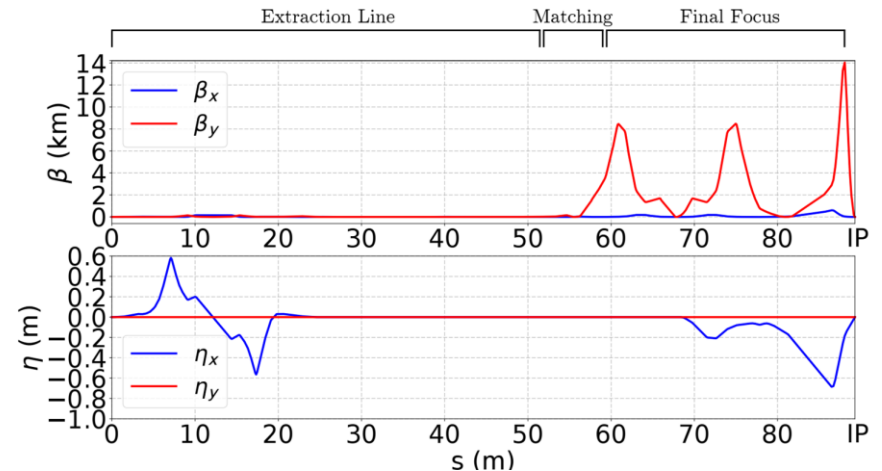
ATF2 studies

CLIC related studies in ATF2:

- Final Focus System (FFS) studies : local chromaticity correction scheme.
- Wakefields Mitigation Tools implementation.
- Beam Instrumentation tests (Cavity-BPMs, OTR/ODR beam profile monitors, etc).
- **Automatic Beam-Based Alignment (BBA) and tuning procedures (DFS, WFS, etc) tests.**
- R&D work on the extraction kicker from the DR.

Table : Beam and optics parameters for ATF2 beamline.

Parameter	Symbol	Value
Length of ATF2	L	90 m
Beam energy	E	1.28 GeV
Bunch population	N_e	1.0×10^{10}
Beta functions at IP	β_x^*/β_y^*	40 mm/0.10 mm
Beam sizes at IP	σ_x^*/σ_y^*	8.9 μm /37 nm
Bunch length	σ_z	7 mm



Automatic Beam-Based Alignment

DFS simultaneously corrects the orbit, x_i , and minimizes the difference between the nominal and a dispersive trajectory, $x_{\Delta E,i}$. This corresponds to minimizing:

$$\chi^2 = \sum_{\text{bpms}} x_i^2 + \omega^2 \sum_{\text{bpms}} (x_{\Delta E,i} - x_i)^2 + \beta^2 \sum_{\text{corrs}} \theta_j^2$$

which is equivalent to solving the system of equations:

$$\begin{pmatrix} \mathbf{x} \\ \omega(\mathbf{x}_{\Delta E} - \mathbf{x}) \\ \mathbf{0} \end{pmatrix} = \begin{pmatrix} \mathbf{R} \\ \omega\mathbf{D} \\ \beta\mathbf{I} \end{pmatrix} \begin{pmatrix} \theta_1 \\ \vdots \\ \theta_m \end{pmatrix}$$

$$\begin{aligned} \text{with } R_{ij} &= \frac{\partial y_i}{\partial \theta_j} \\ D_{ij} &= R_{\Delta E, ij} - R_{ij} \\ \omega^2 &= \frac{\sigma_{\text{bpm resolution}}^2 + \sigma_{\text{bpm position}}^2}{2\sigma_{\text{bpm resolution}}^2} \end{aligned}$$

It is a least-square problem that can be solved using an SVD.

R and **D** are the response matrices. The free parameter ω accounts for the relative weight of the orbit w.r.t. the dispersive term; β is a regularization parameter.

Results in the ATF2 extraction line (2019)

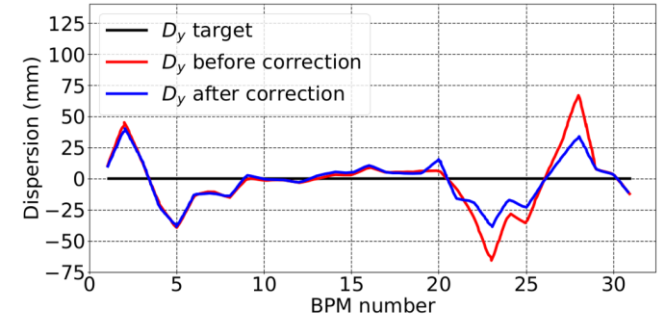
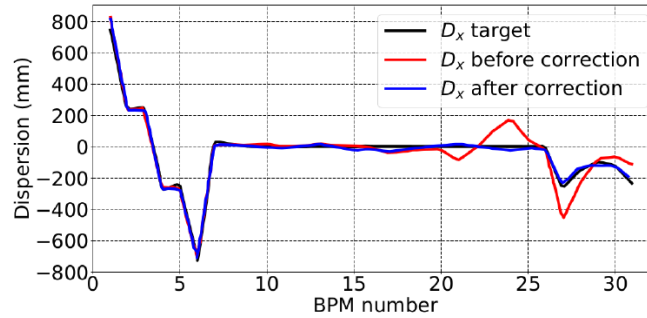
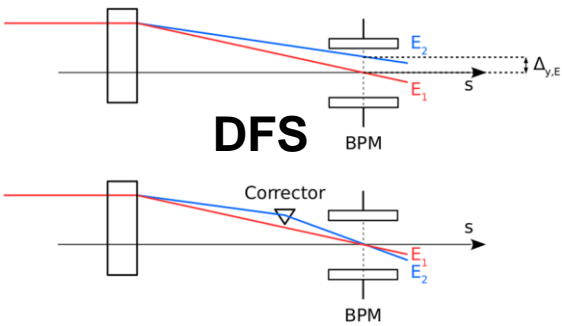


Figure: Schematic of the Dispersion Free Steering correction.

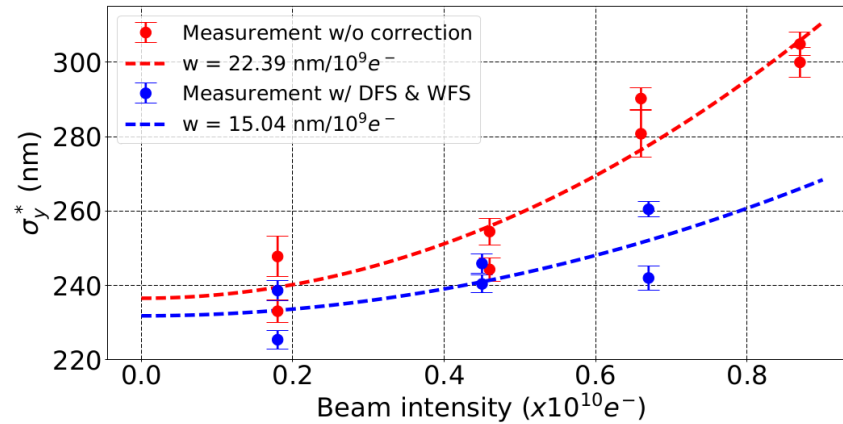
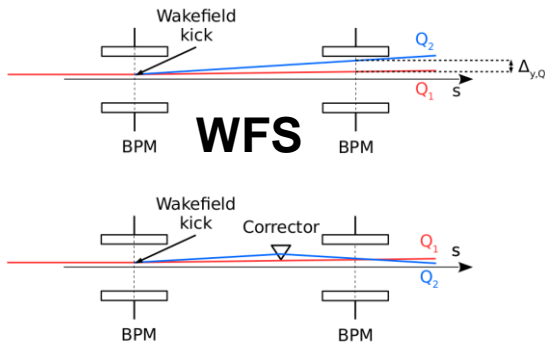


Figure: Schematic of the Wakefields Free Steering corrections.

Figure: Measurement: impact of DFS and WFS on the vertical beam size at the IP.

ATF Matlab Tools: Flight Simulator



ATF LINAC Matlab Flight Simulator

The Matlab Flight Simulator **SYSID** (System Identification) scripts were updated to work on the **ATF LINAC**.

STR(LT)

LINAC/BT Steering-Magnets

	File	Set	I(A)	Status		File	Set	I(A)	Status
ZH1L	1.60	1.60	1.63	ON	ZX10T	-0.50	-0.50	-0.68	ON
ZV1L	0.33	0.33	0.35	ON	ZV10T	0.00	0.00	0.00	OFLIN
ZV2L	0.00	0.00	0.00	ON	ZX11T	0.81	0.81	0.66	ON
ZH2L	0.05	0.05	0.06	ON	ZH10T	0.00	0.00	0.00	OFLIN
ZV3L	0.00	0.00	0.00	ON	ZV11T	0.00	0.00	-0.70	OFLIN
ZH3L	-0.01	-0.01	-0.00	ON	ZX12T	0.90	0.90	0.92	ON
ZH4L	-0.62	-0.62	-0.63	ON	ZY20T	0.34	0.34	0.35	ON
ZV4L	-0.51	-0.51	-0.51	ON	ZY21T	-0.25	-0.25	-0.26	ON
ZH5L	0.00	0.00	0.01	ON	ZY22T	-1.26	-1.26	-1.28	ON
ZV5L	0.00	0.00	0.01	ON	ZY23T	-1.47	-1.47	-1.50	ON
ZH6L	-0.07	-0.07	-0.07	ON	ZX30T	0.00	0.00	0.00	ON
ZV6L	-0.23	-0.23	-0.22	ON	ZX31T	0.00	0.00	0.00	ON
ZH7L	-0.35	-0.35	-0.36	ON	ZV30T	0.09	0.09	-0.00	ON
ZV7L	0.00	0.00	-0.00	ON	ZH30T	-1.79	-1.79	-1.88	ON
ZH8L	0.10	0.10	0.10	ON	ZX32T	2.05	2.05	1.98	ON
ZV8L	-0.13	-0.13	-0.14	ON	ZV40T	-1.50	-1.50	-1.58	ON
ZH9L	-0.39	-0.39	-0.40	ON	ZH40T	-2.10	-2.10	-2.18	ON
ZV9L	-0.08	-0.08	-0.09	ON	ZX50T	1.29	1.29	1.32	ON
ZH10L	-0.22	-0.21	-0.23	ON	ZX51T	-1.70	-1.70	-1.74	ON
ZV10L	-0.41	-0.41	-0.42	ON	ZX52T	0.93	0.93	0.85	ON
ZH11L	0.09	0.09	0.10	ON	ZV50T	0.38	0.38	0.38	ON
ZV11L	0.38	0.38	0.40	ON	ZH50T	1.35	1.35	1.39	ON
ZH12L	0.04	0.04	0.04	ON	ZV51T	0.08	0.08	0.08	ON
ZV12L	-1.42	-1.42	-1.44	ON					
ZV13L	-0.69	-0.69	-0.70	ON					
ZH1P	0.00	0.00	-0.08	ON					
ZV1P	0.00	0.00	-0.15	ON					
ZH2P	0.00	0.00	-0.20	ON					
ZV2P	0.00	0.00	-0.07	ON					

SET FILE set24may21_1646.dat

ON OFF RESET

CERN SYSID

ATF2 ONLINE BBA

Correctors

Pattern: Z*

ZH1L
ZV1L
ZV2L
ZH2L
ZV3L
ZH3L
ZH4L
ZV4L
ZH5L
ZV5L
ZH6L
ZV6L
ZH7L
ZV7L
ZH8L
ZV8L
ZH9L
ZV9L
ZH10L
ZV10L
ZH11L
ZV11L
ZH12L
ZV12L
ZV13L
ZH1P
ZV1P
ZH2P
ZV2P

Info

new_SYSID_20240521_201020

Current corr: ZH1L

Options

N. of samples: 100

Max strength: 0.06 kG*m

Cycle mode: Repeat all

Horizontal excitation: 0,4 mm

Vertical excitation: 0,3 mm

Plot Orbits

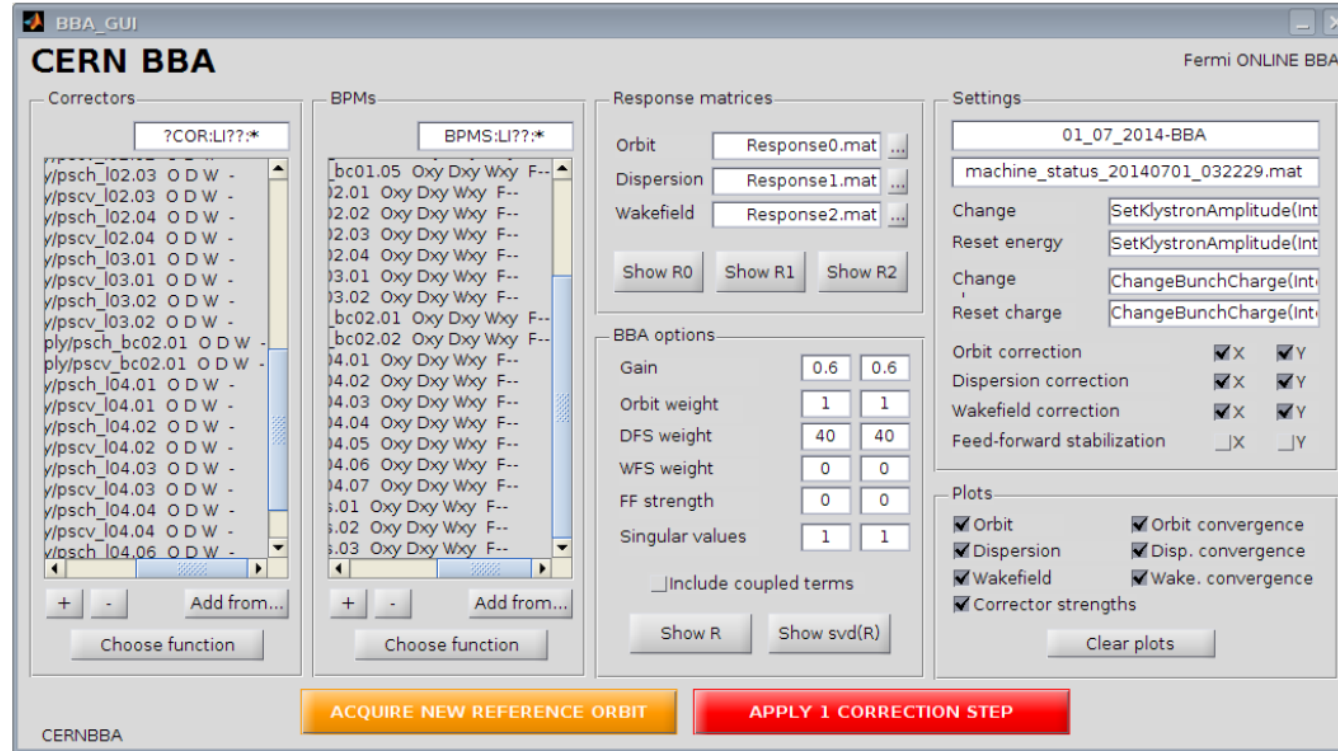
START

STOP

CERNBBA v0.01

Matlab BBA Interface

Beam-based Alignment Tool



DFS and WFS in the ATF LINAC



Change Energy in ATF LINAC

To change the **beam energy** in the LINAC, the **Phase** of the Klystron #1 was **increased by 5 degrees**:

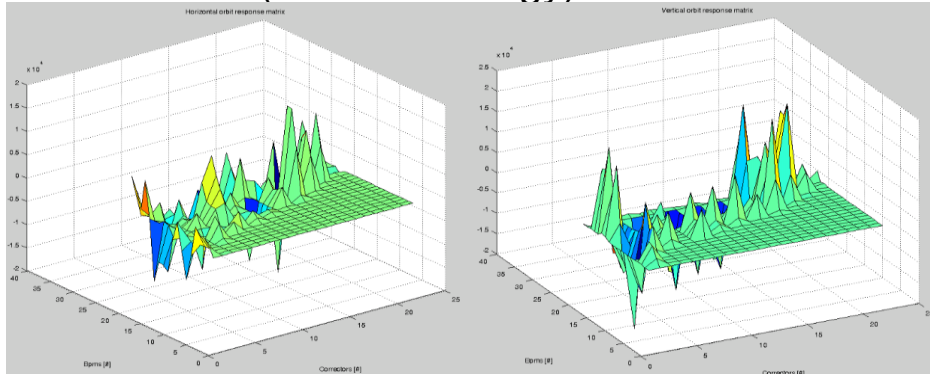
The image displays two screenshots of the 'Linac RF' control window, specifically the 'LINAC RF PHASE CONTROL' section. A red circle highlights the 'SET' column for Klystron #1 in the first screenshot, which shows a value of 78.00. A red arrow points from this circle to a second red circle in the second screenshot, which highlights the 'SET' column for Klystron #1 showing a value of 83.00. The 'STEP' column for Klystron #1 is set to 1.0 in both screenshots. The 'Injector Phase' button is visible in the 'STEP' column for Klystron #0 in both screenshots.

	HV	TRG	RF	POUT	FILE	SET	MON	STEP
#0	●	●	●	40.3	-126.0	127.00	-126.7	#0 Injector Phase
#1	●	●	●	45.3	82.0	78.00	78.0	#1 ▲ ▼ 1.0

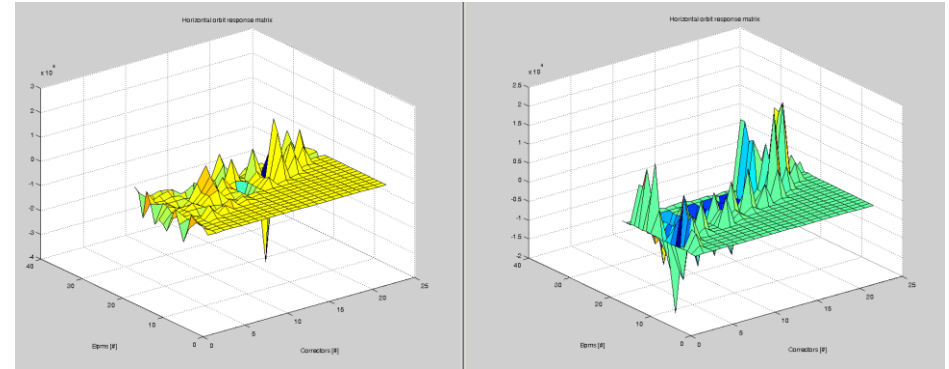
	HV	TRG	RF	POUT	FILE	SET	MON	STEP
#0	●	●	●	40.3	-126.0	127.00	-126.7	#0 Injector Phase
#1	●	●	●	45.3	82.0	83.00	83.0	#1 ▲ ▼ 1.0

ATF LINAC Response Matrices (DFS)

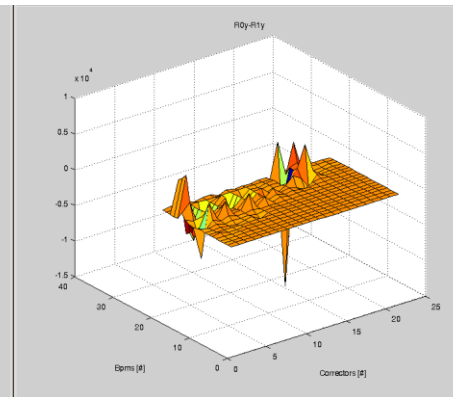
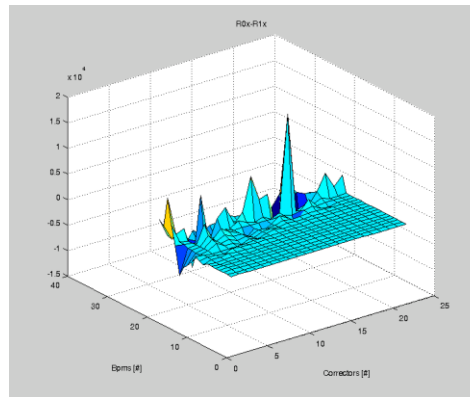
Response Matrices in the ATF LINAC:
R0 (nominal energy)



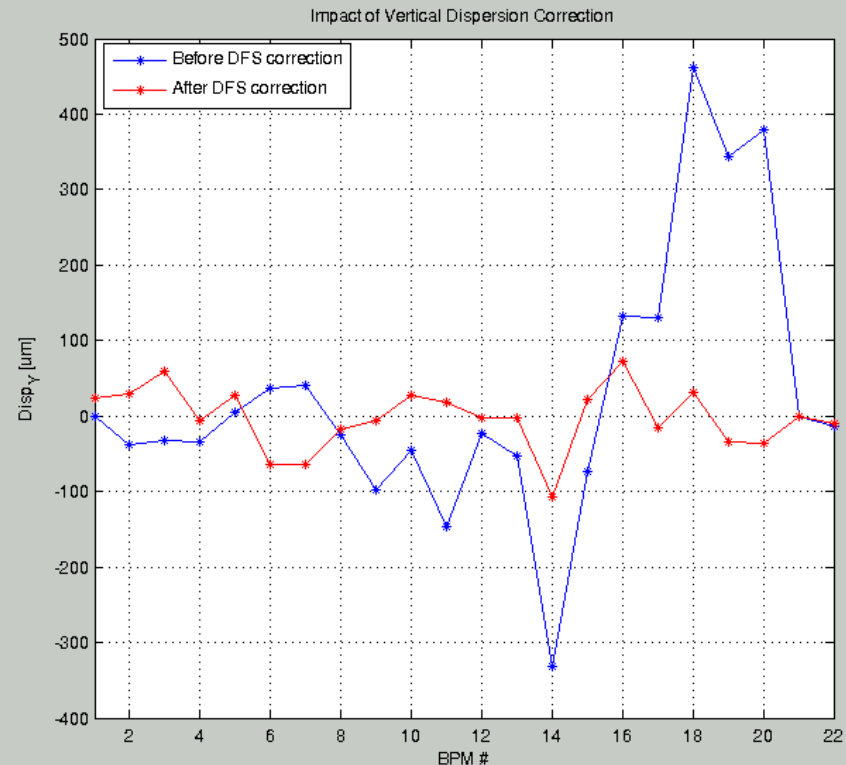
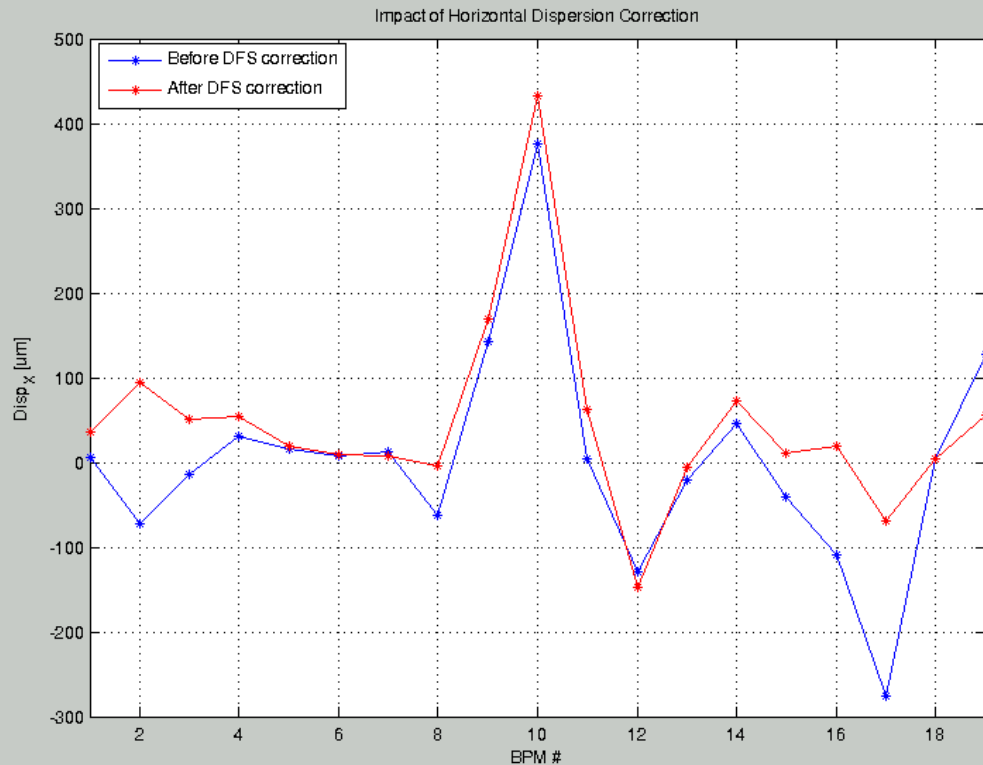
R1 (lower energy)



R1 - R0



DFS Correction in the ATF LINAC



Good vertical dispersion correction

WFS in the ATF LINAC

To change the **beam charge** in the LINAC, the **Laser** amplitude was decreased by 20%:

The image displays two side-by-side screenshots of the 'BEAM CONTROL' software interface. A red arrow points from the 'Laser' section of the left screenshot to the 'Laser' section of the right screenshot, indicating a change in the laser amplitude.

Left Screenshot (Initial State):

- BEAM OUTPUT:** ON, OFF, RESET. STATUS: BEAM ON.
- DR MODE:** NORMAL, STORAGE, SCRUBBING. DCCT: 1.80 mA, STORAGE START: 2.20 mA, REFILL START: 1.50 mA.
- TRAIN MODE:** SINGLE, TWO, THREE. ATF2 SynchronizedTrain change.
- LASER:** 1 bunch(es) / Train. Set (%) Read (%): #1 30.00 30.00.
- BUCKET SELECT:** TWO: SELECT 0, 98wt 1; THREE: SELECT 0, 110, 220wt 1.
- BEAM RECOVERY:** BH10T: SET 319.36, CUR 326.75, VOL 29.73, STATUS ON. MOD #0: TRG ON, RF ON. DRRF: RF ON, VCSUM 0.3226 MV.
- BEAM GATE:** ON, OFF. STATUS TRIGGER: GUN, EXT Kicker.

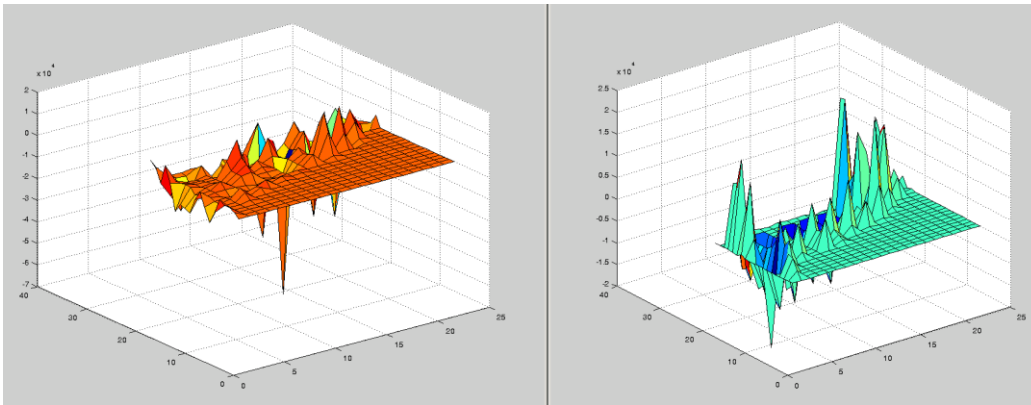
Right Screenshot (Final State):

- BEAM OUTPUT:** ON, OFF, RESET. STATUS: BEAM ON.
- DR MODE:** NORMAL, STORAGE, SCRUBBING. DCCT: 0.72 mA, STORAGE START: 2.20 mA, REFILL START: 1.50 mA.
- TRAIN MODE:** SINGLE, TWO, THREE. ATF2 SynchronizedTrain change.
- LASER:** 1 bunch(es) / Train. Set (%) Read (%): #1 10.00 10.01.
- BUCKET SELECT:** TWO: SELECT 0, 98wt 1; THREE: SELECT 0, 110, 220wt 1.
- BEAM RECOVERY:** BH10T: SET 319.36, CUR 326.75, VOL 29.49, STATUS ON. MOD #0: TRG ON, RF ON. DRRF: RF ON, VCSUM 0.3226 MV.
- BEAM GATE:** ON, OFF. STATUS TRIGGER: GUN, EXT Kicker.

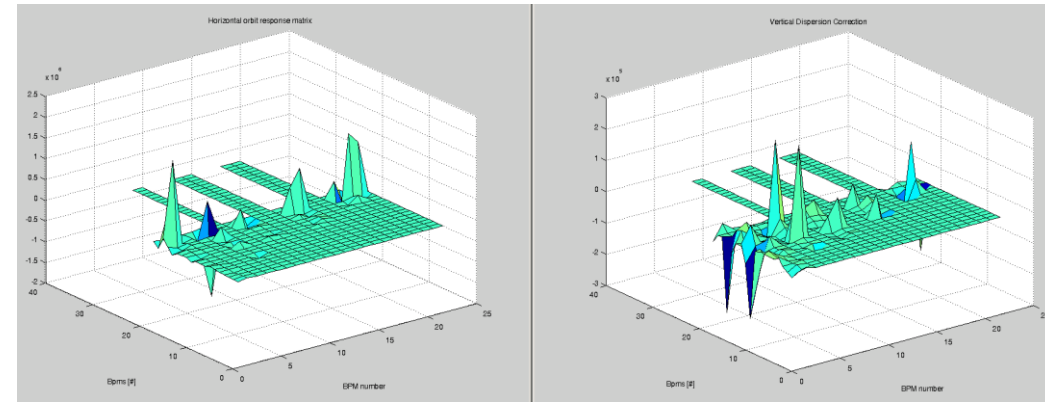
ATF LINAC Response Matrices (WFS)

Response Matrices in the ATF LINAC:

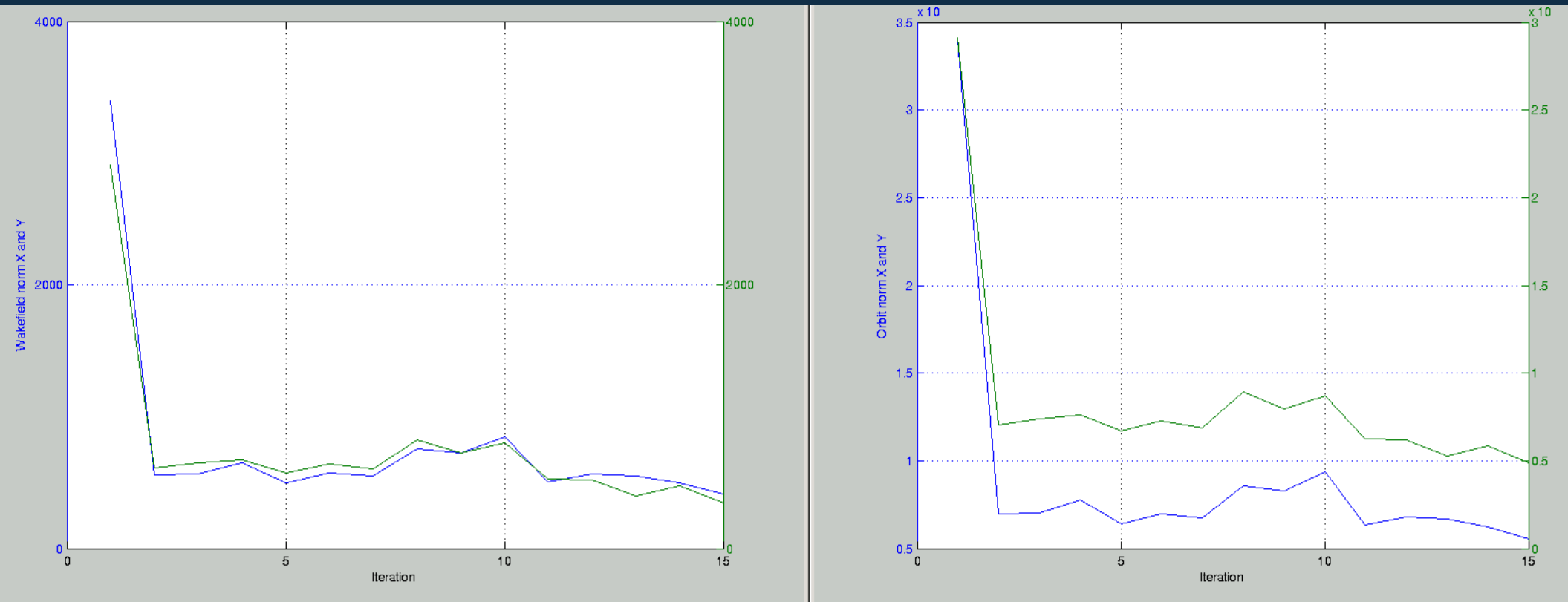
R0 (0.4E10 e-)



R1 (0.2E10 e-)



WFS Correction in the ATF LINAC



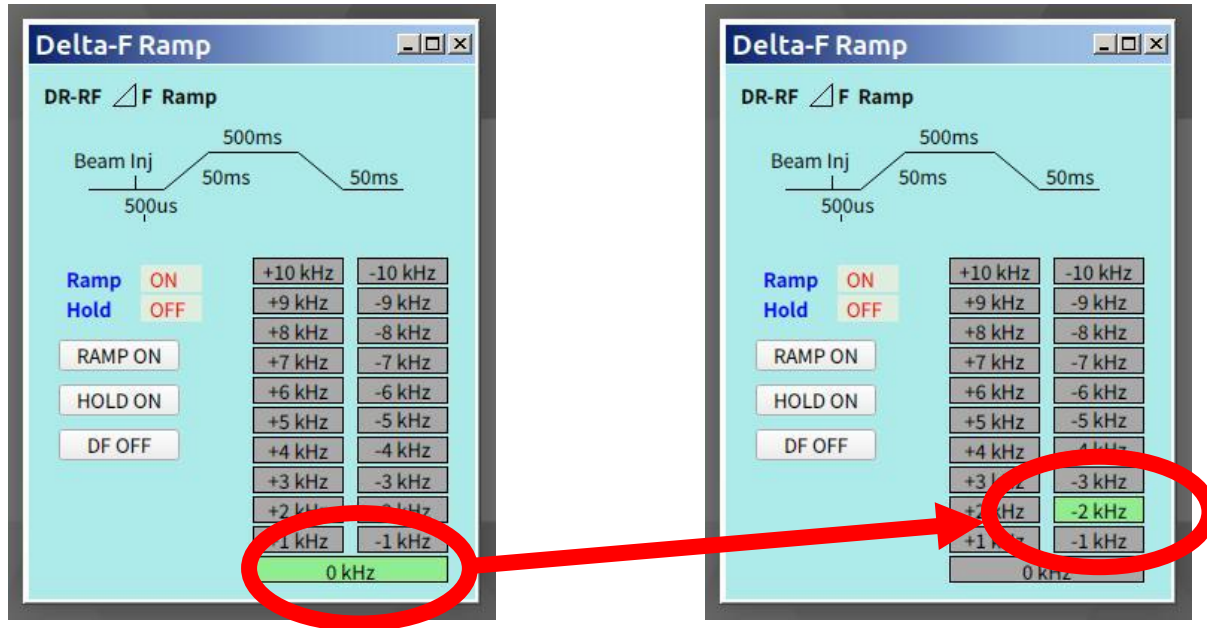
WFS correction convergences for both X and Y

DFS and WFS in the ATF2 EXT



Change Energy in ATF2 EXT

To change the **beam energy** in the EXT, the **DR Delta-F** was decreased by 2 kHz:

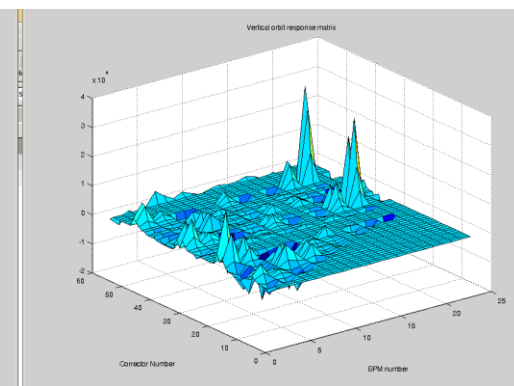
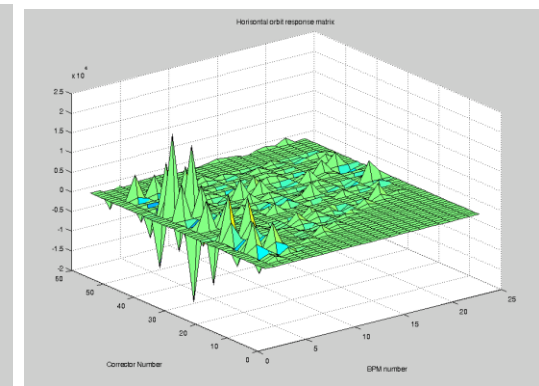
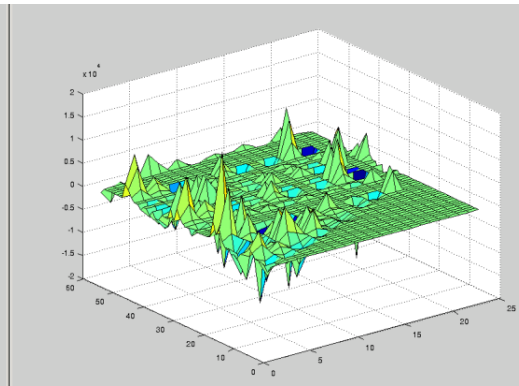
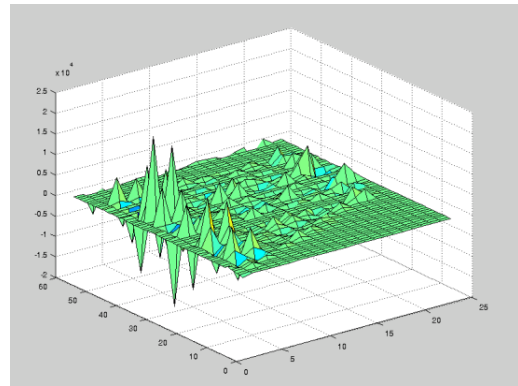


ATF2 EXT Response Matrices (DFS)

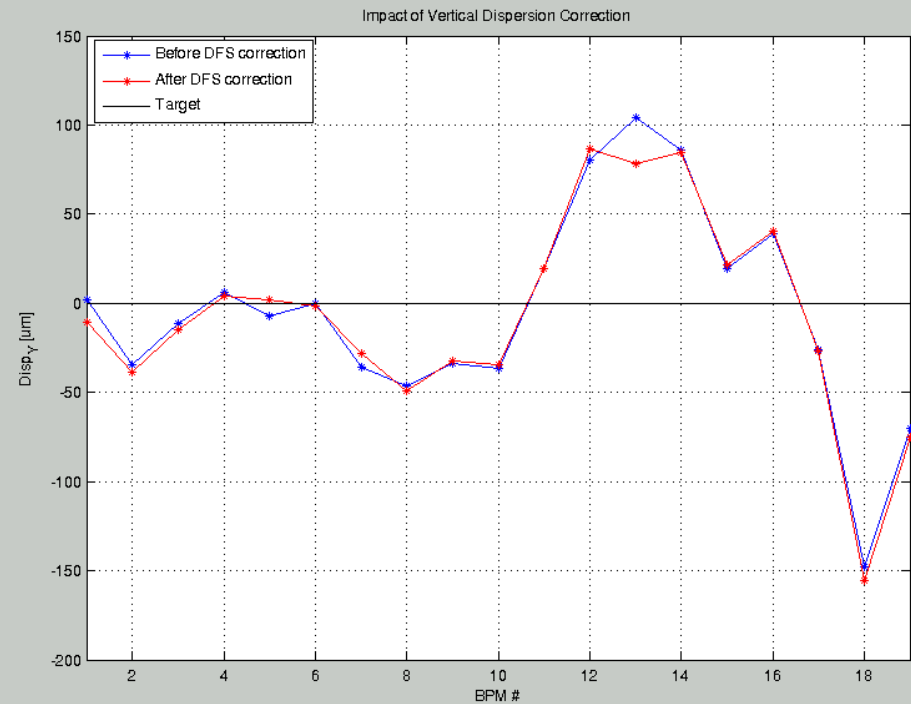
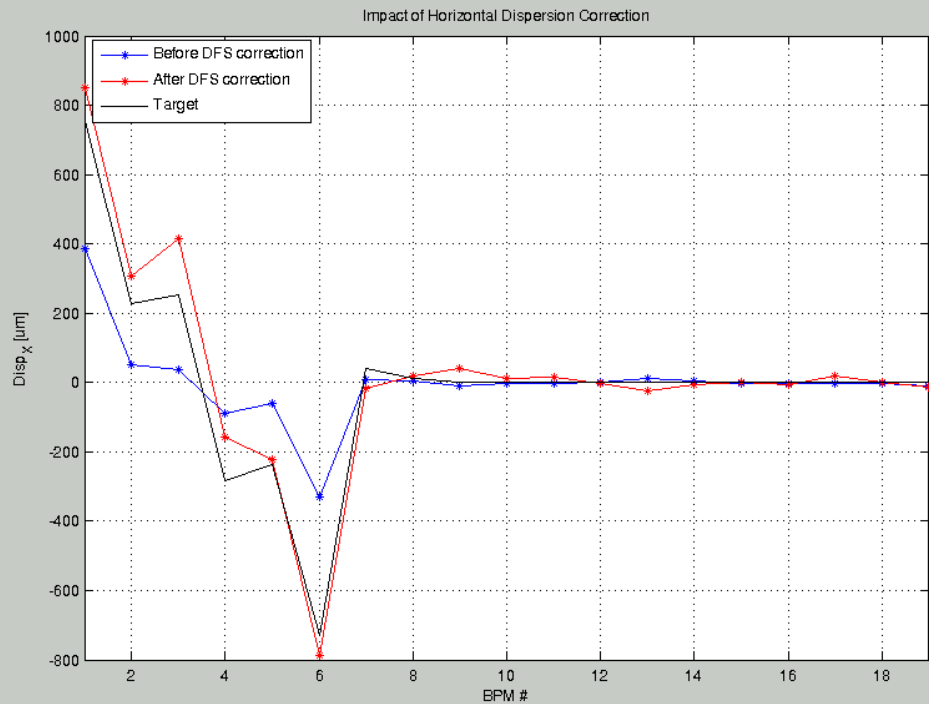
Response Matrices in the ATF2 EXT:

R0 (nominal energy)

R1 (lower energy)



DFS Correction in ATF2 EXT



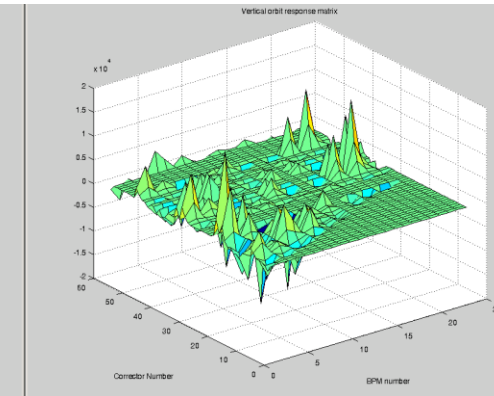
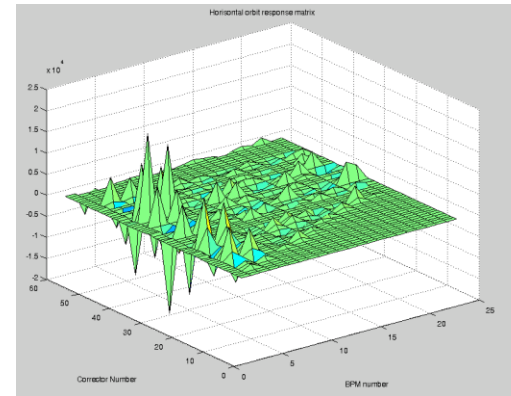
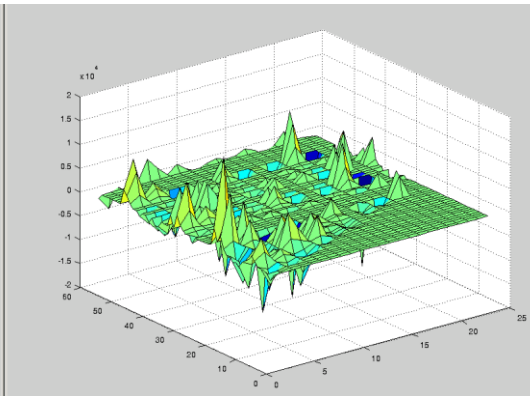
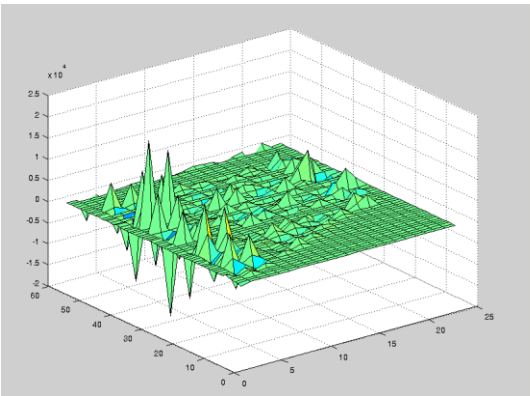
Good Horizontal dispersion correction

ATF2 EXT Response Matrices (WFS)

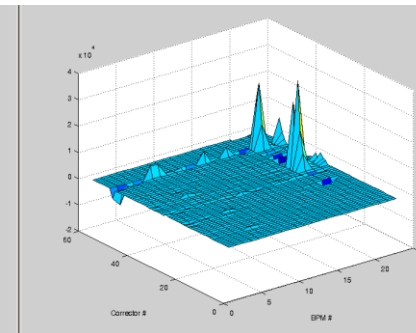
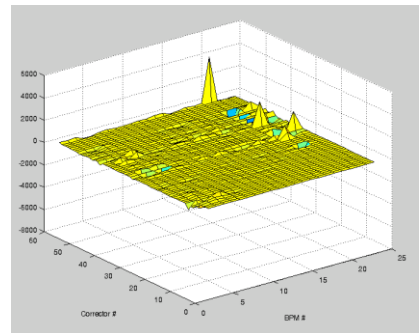
Response Matrices in the ATF2 EXT:

R0 (0.2E10 e-)

R1 (0.4E10 e-)



R1 - R0



ATF Python Flight Simulator



Python Flight Simulator

CLIC Simulations / Flight Simulator

F Flight Simulator

☆ Ajouter aux favoris 0

↩ 43 validations 1 branche 0 étiquette



Update

Andrea Latina rédigé dans 37 minutes

a6e9fceb

master flight-simulator

Historique

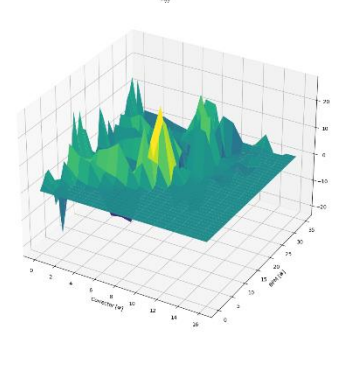
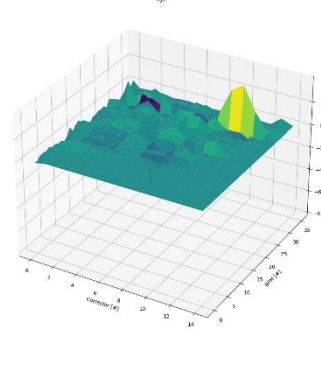
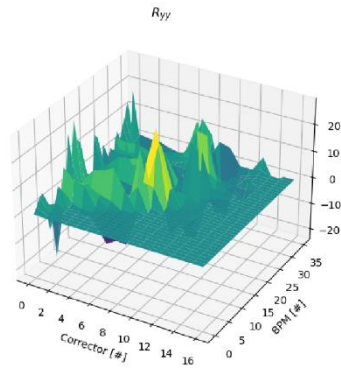
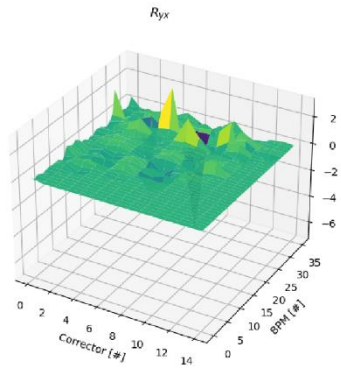
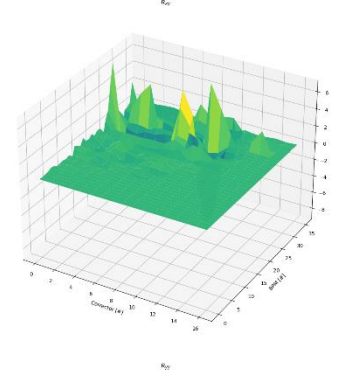
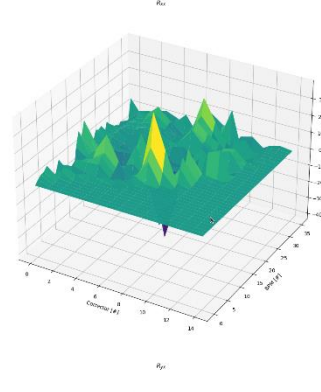
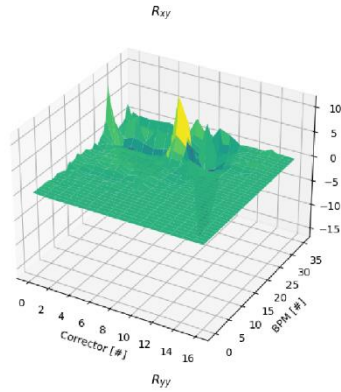
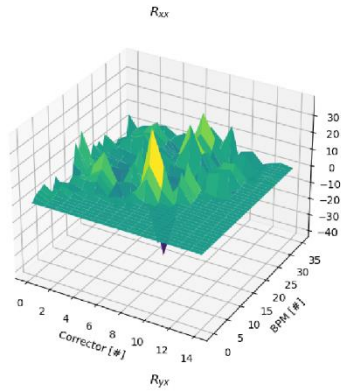
Rechercher un fichier

Code

Nom	Dernière validation	Dernière mise à jour
ComputeResponseMatrix.py	Update	dans 37 minutes
DFS_Correction.py	Update	il y a 9 minutes
DFS_WFS_Correction.py	Update	il y a 9 minutes
InterfaceATF2_Ext.py	Update	il y a 9 minutes
InterfaceATF2_Linac.py	Update	il y a 9 minutes
Response.py	Update	il y a 9 minutes
RestoreState.py	Update	il y a 3 heures
State.py	Update	il y a 19 heures
SysID.py	Update	il y a 2 heures
SysID_GUI.py	Update	il y a 2 jours

<https://gitlab.cern.ch/clic-simulations/flight-simulator>

Python Response Matrices (DFS)



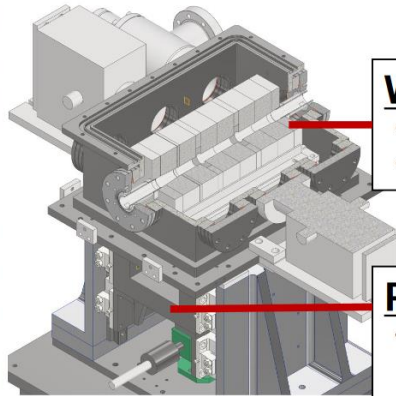
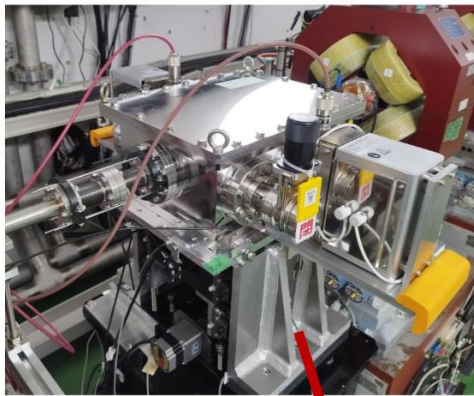
Movable Wakefield Source



Movable Wakefield Source

Installed a movable wakefield source to generate targeted wakefield kick

- **Evaluate the acted wakefield kick at the single wakefield source**
 - Measure the beam orbit change downstream from the wakefield source after the wakefield source is moved



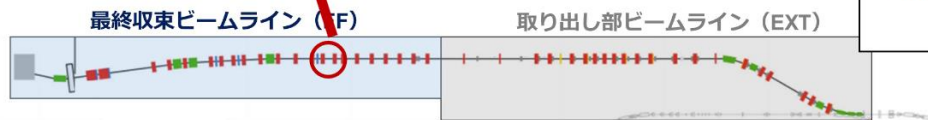
Wakefield study chamber

- Produce the target wakefield source
- Set on the block with arbitrary inside structure

Easy to compare with simulation results

Position adjustment mover

- Control the wakefield kick strength by adjusting the position of the wakefield source
- movable range : Ver. ± 10 mm (1 μ m step)
Hor. ± 6 mm (10 μ m step)



8

Yuki Abe

Conclusions & Plans

- Matlab Flight Simulator (FS), DFS and WFS gave good results in LINAC and EXT.
- New Framework in Python being implemented (to replace Matlab).
- To do: Python FS GUI in PyQT6 and interface with simulation (RF-Track).
- To do: Apply BBA (DFS & WFS) in the DR.
- To do: Use, optimize and apply correction with the Movable Wakefield Source.

Thank you

