Summary of projected emittance measurements at FLASH

Accelerator & FEL Studies (October 06, December 06 & January 07, February 07)

People involved:

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Pedro Castro, Lars Froehlich, Martin Sachwitz (Wire scanners studies)

FLASH seminar, 17th of April of 2007

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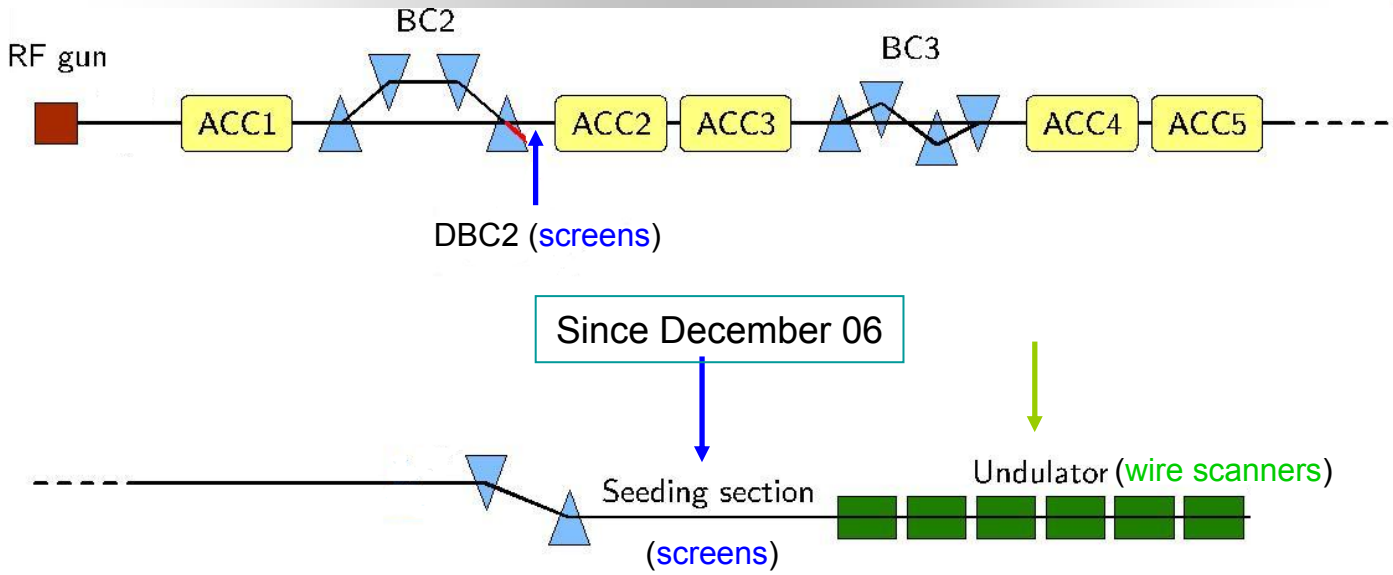
Overview



- When: FEL studies (28-10-06)
  Accelerator studies (17-12-06, 20-12-06 , 21-01-07)
  FEL studies (17-02-07, 21-02-07, 22-02-07)
- Where: DBC2, SEED (for the 1st time) and undulator
- Standard conditions: on crest for all accelerator modules, 1nC (22-02-07, SASE conditions)

Presented values correspond to 100% emittances

About the measurements at the SEED section:
We had to steer the beam when going from one screen to the next one and OTR intensity was low at 2SUND3 & 14SEED. This is probably due to a misalignment of the optical set-up and/or of the OTR screen

About the measurements in the undulator:
3 available wires: 10 μm C, 10 μm W & 50 μm W (the “usual one” before that measurements)
In some measurements, the combination of beam sizes, optics and energy gave non real emittances

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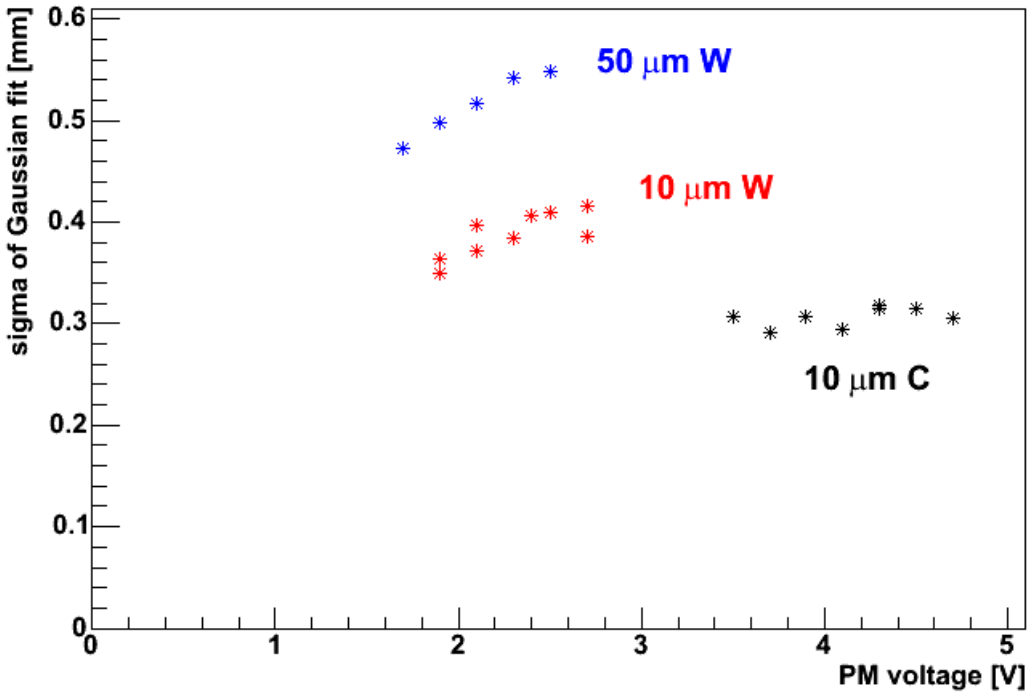
Measurements at WS5UND5.hor 25-01-07 (P. Castro)



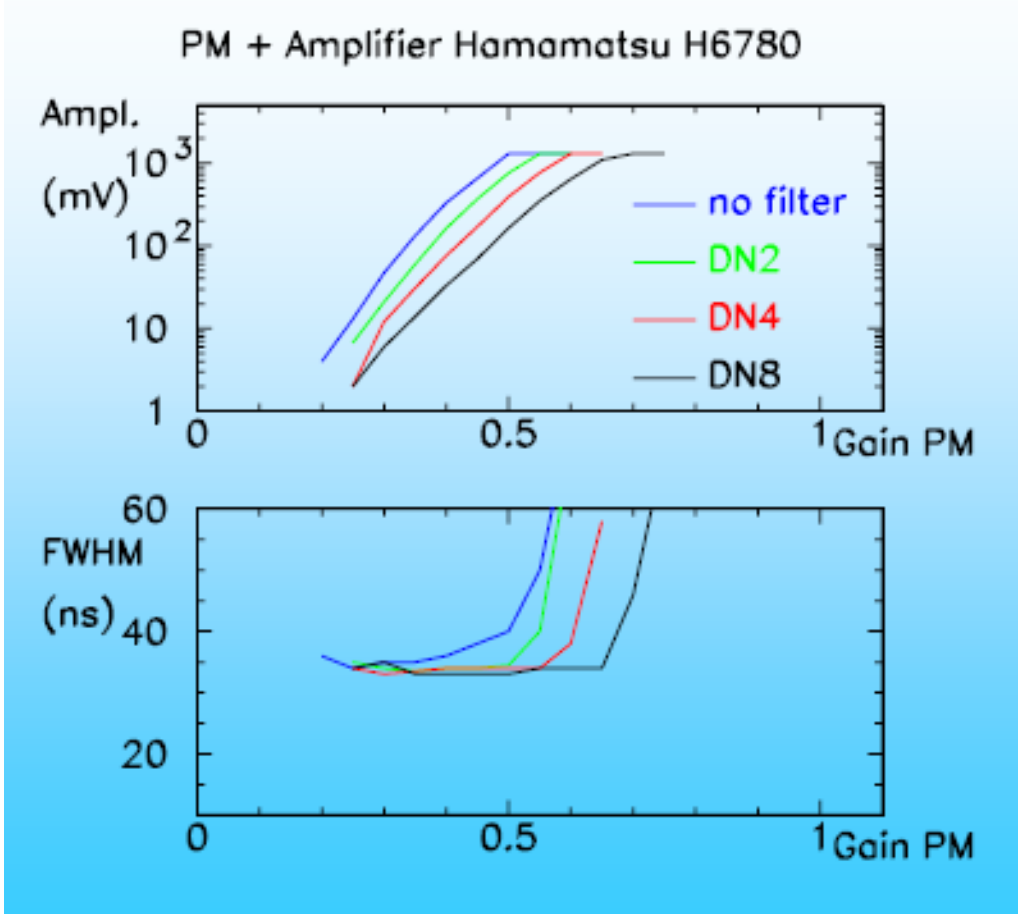
Beam size depends heavily on the wire (and for the Tungsten wires it also depends on the PMV)

The problem is that there is too much light for the tungsten wires, which leads to a non-linear behavior of the PM

(shower ~ $d^2 \cdot A^2$; A(C)=12, A(W)=74)

Possibilities: use filters in front of PM, use scintillators in the sides of the undulator, use other PM … and **use the carbon wires for the emittance measurements**

Measurements with PM
First week of February 2007 (M. Sachwitz)



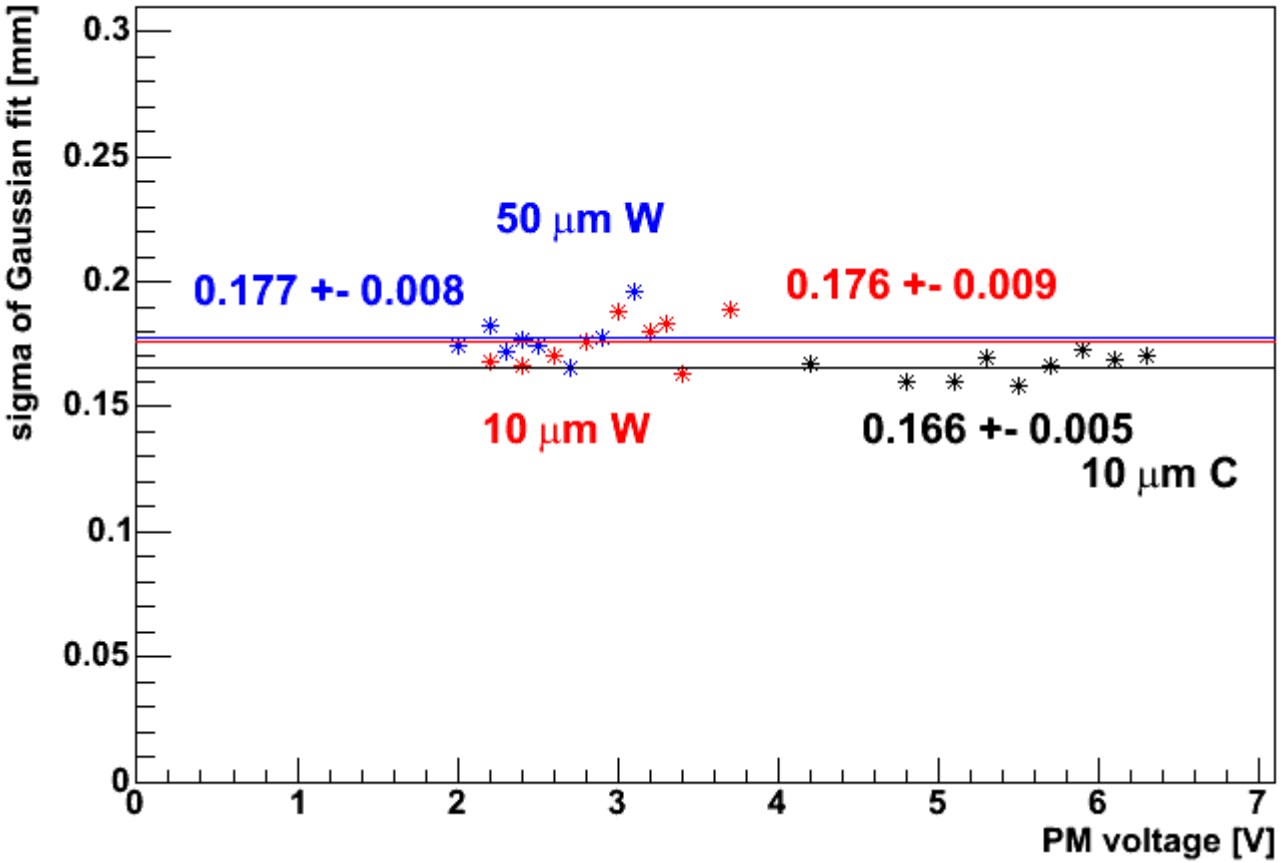
Light source: blue LED, saturates at around 0.5V (equivalent to 5V in the FLASH gui)

Measurements without filters and with filters of factors 2, 4 and 8

A filter helps to reach the linear range and to reduce FWHM next to the saturation point

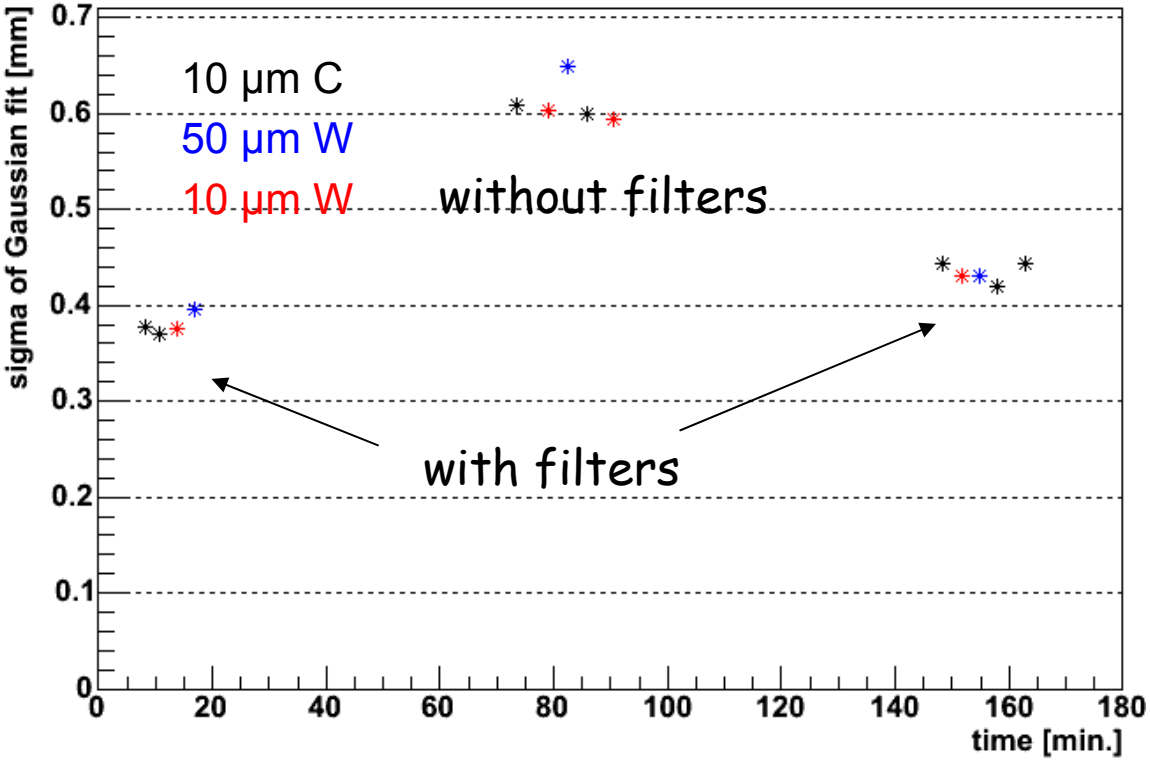
The decision was to test a filter with an attenuation factor of 32

Measurements at WS5UND5.hor (with filters)
17-02-07 (P. Castro, L. Froehlich, E. Prat)

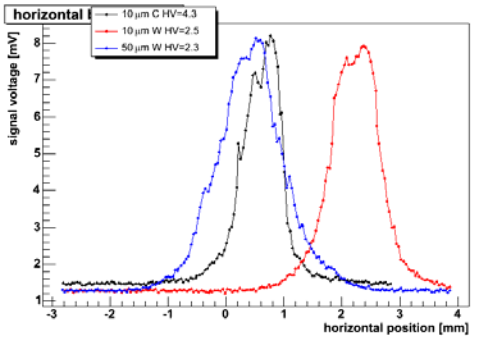


~ constant beam size for different wires and PMV's

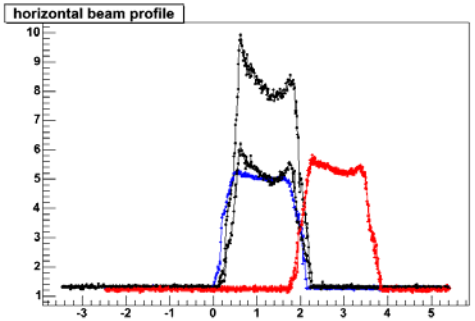
Measurements at WS5UND5.hor 21-02-07 (P. Castro, M. Sachwitz)



25-01-07 – ~Gaussian beam



21-02-07 – Weird and big beam



~ constant beam size for the different wires, with and without filters (!)
(one would expect size measured with the carbon wire to be independent if filter or not)

Anyway, the decision was to put the filters for all the wires…
… which are already placed

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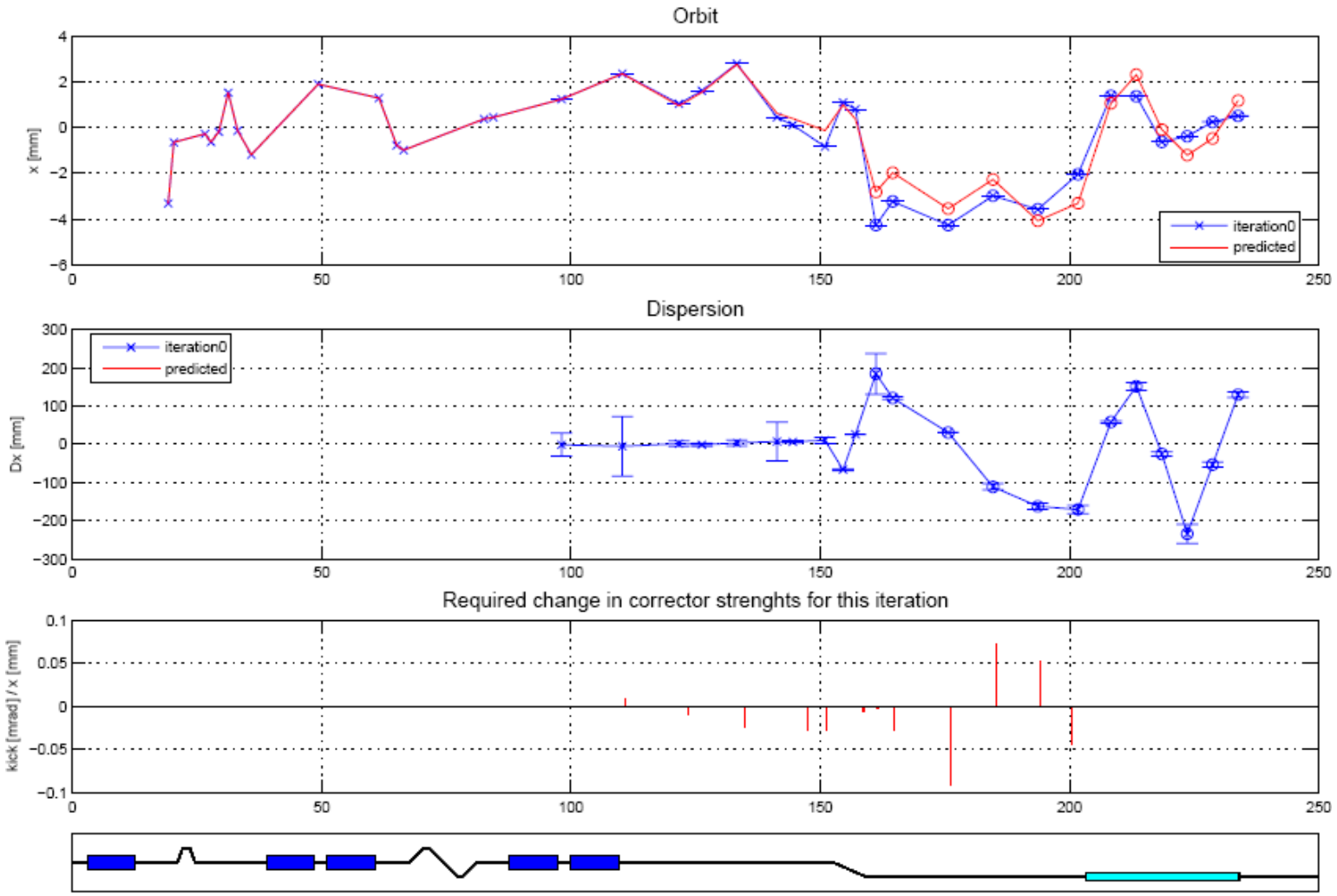
Summary table for the 28th of October

Where & when	Comments	ε_x [mm mrad]	ε_y [mm mrad]
Injector 11.08h	Matched	11.6 ± 0.5	5.5 ± 0.1
Undulator 11.08h	On crest in all the modules – 50 μm W wire – Not matched	-	10.0 ± 0.4
Undulator 13.37h	20 deg off ACC45 - 50μm W wire – Not matched	-	14.0 ± 0.3
Undulator 18.19h	20 deg off ACC45 + dispersion correction - 50μm W wire – Not matched	19.9 ± 0.6	-
Undulator 19.28h	20 deg off ACC45 + dispersion generated - 50 μm W wire - Not matched	-	-
Undulator 21.13h	On crest in all the modules – 50 μm W wire – Not matched	-	10.3 ± 0.5
Undulator 22.16h	20deg off ACC1 – 50 μm W wire – Not matched	-	14.3 ± 0.7

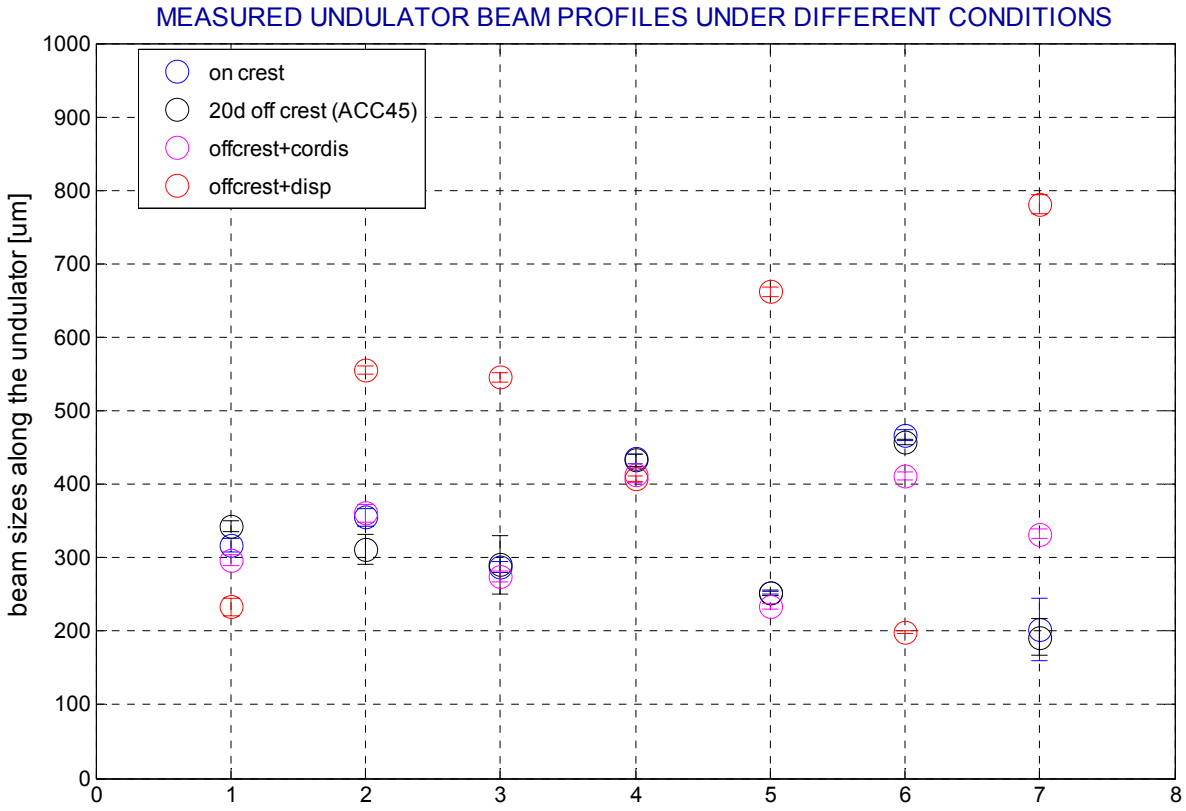
DBC2 section Big emittances

Undulator Much bigger and/or imaginary emittances

Generation of horizontal dispersion ↓Q3/5ECOL by 10%



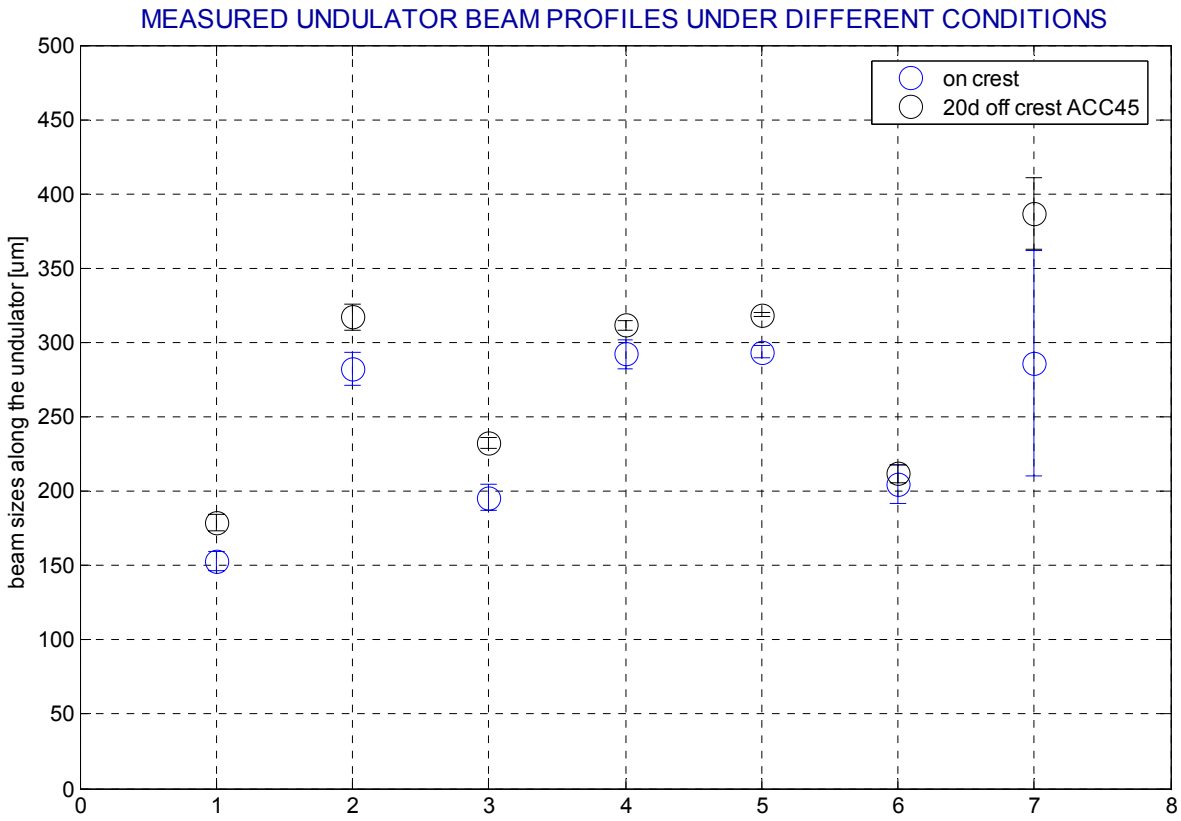
Beam profile measurements
ACC45 20 deg off crest (Horizontal plane)



	Dispersion [mm] (from ACC45)		
	Initial	After correction	After generation
21SEED	5	2	-170
5UND1	-17	-5	70
5UND2	0	3	155
5UND3	31	6	-20
5UND4	14	2	-230
5UND5	16	-8	- 50
5UND6	-20	-10	120

No difference when one goes to 20 degrees of crest
Reasonable results with extra dispersion (except for 21SEED and 5UND5)

Beam profile measurements
ACC45 20 deg off crest (Vertical plane)



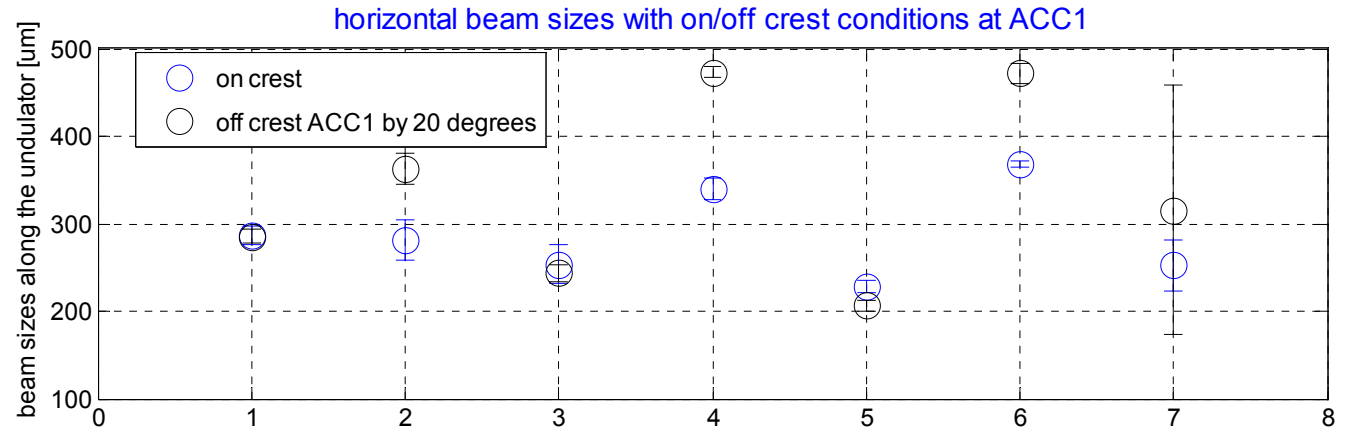
	Dispersion [mm] (from ACC45)
21SEED	-3
5UND1	-32
5UND2	-9
5UND3	32
5UND4	25
5UND5	-23
5UND6	-7

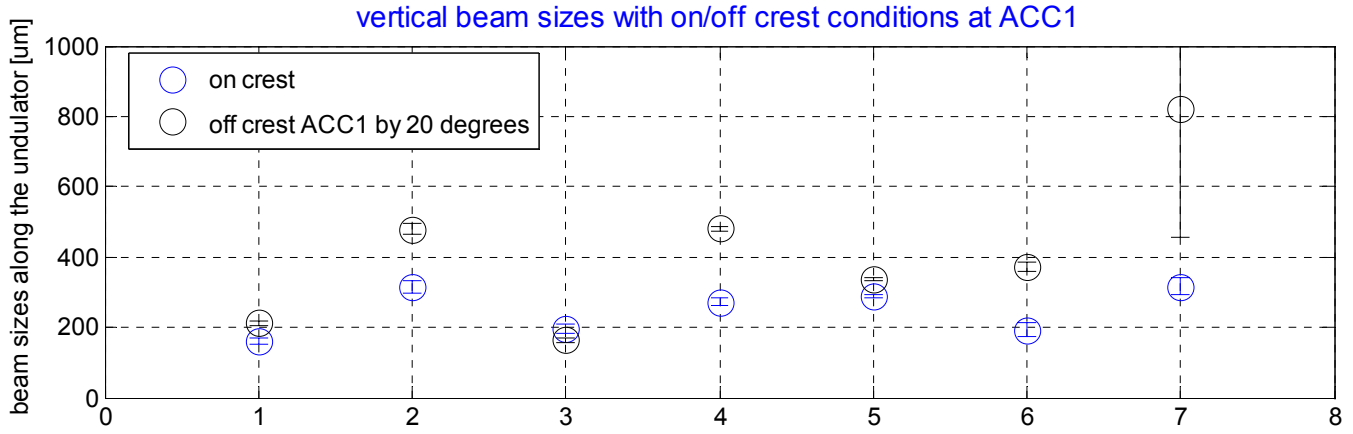
Unlike in the horizontal plane, here the beam size went systematically a little bit up at off crest condition.

Dispersion from ACC45 is similar but can play a bigger role since vertical beam sizes are smaller.

Dispersion coming upstream ACC1 can be bigger in the vertical plane.

Beam profile measurements
ACC1 20 deg off crest





Increasing of beam sizes specially at UND1, UND3 & UND5
Probably due to dispersion… (we could not measure it)

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Summary table for the 17th of December

Where & when	Comments	ε_x [mm mrad]	ε_y [mm mrad]
Injector 17.49h	Matched	3.3 ± 0.1	3.4 ± 0.1
Seed 18.22h	Matched	3.9 ± 0.2	2.7 ± 0.1
Seed 21.56h	Sext off – only vertical is matched	6.0 ± 0.2	3.3 ± 0.1
Seed 22.23h	Sext off – only horizontal is matched	5.2 ± 0.1	1.4 ± 0.1
Seed 23.03h	Design optics in seed & und – matched	3.4 ± 0.1	2.8 ± 0.1
Undulator 19.03h	50 μm W wire – Not matched	6.2 ± 1.4	9.9 ± 1.3
Undulator 19.39h	50μm W wire – unsuccessful attempt to match	-	6.9 ± 1.7
Undulator 23.31h	Design optics in seed & und – 50 μm W wire - Not matched	6.3 ± 1.1	12.3 ± 0.5

SEED section — Similar emittances as in the injector
Matching worked properly (except when sext were off)

Undulator — Much bigger and/or imaginary emittances
Not possible to match

Summary table for the 20th of December

Where & when	Comments	ε_x [mm mrad]	ε_y [mm mrad]
Injector 8.29h	Matched	2.9 ± 0.1	3.3 ± 0.1
Seed 9.18h	Not matched	4.4 ± 0.1	11.5 ± 0.2
Seed 10.45h	Corrected to orbit from 17-12 – matched	4.4 ± 0.1	2.6 ± 0.1
Seed 17.08h	Orbit from 17-12 + 6mm y bump in ACC23 – matched	4.1 ± 0.1	6.2 ± 0.2
Seed 18.27h	Corrected to orbit from 17-12 – matched	3.8 ± 0.1	2.6 ± 0.1
Und. 18.52h	50 μm W wire	10.4 ± 0.3	-

SEED section
Similar emittances as in the injector
6mm vertical orbit bump in ACC23 caused emittance increase by more than a factor of 2
Matching worked properly

Undulator
Much bigger and/or imaginary emittances
Not possible to match

Summary table for the 21st of January

Where & when	Comments	ε_x [mm mrad]	ε_y [mm mrad]
Injector 10.55h	Matched	3.7 ± 0.1	3.2 ± 0.1
Seed 12.30h	Matched	3.7 ± 0.2	4.7 ± 0.2
Undulator 13.38h	10μm C wire – not matched	4.1 ± 0.4	5.6 ± 0.2
Undulator 15.50h	10 μm C wire – not matched	4.4 ± 0.7	4.1 ± 1.3
Undulator 16.51h	10μm C wire – not matched	5.0 ± 0.3	-
Undulator 17.30h	10μm W wire – not matched	9.8 ± 0.2	10.3 ± 2.4
Undulator 18.05	50μm W – not matched	11.5 ± 0.7	-
Undulator 19.47h	10μm C / orbit changed – not matched	3.6 ± 0.6	-

Undulator

The different wires give different emittances
Emittances with the 10 μm carbon wire are similar to the ones measured at the SEED section
Not possible to match

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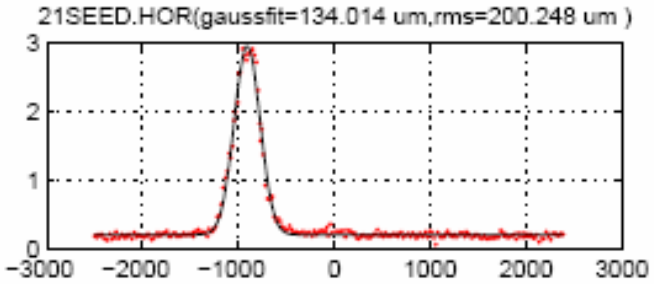
Summary table for the 17th of February

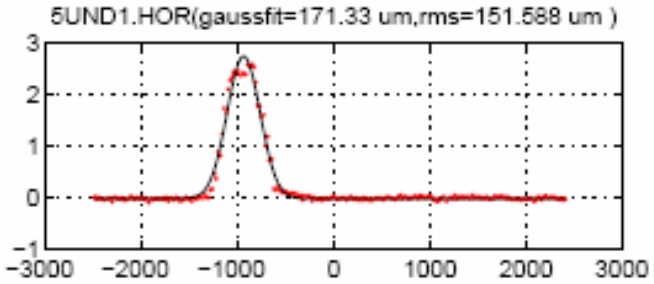
Where & when	Comments	ε_x [mm mrad]	ε_y [mm mrad]
Injector 08.47h	Matched	3.7 ± 0.1	3.8 ± 0.1
Seed 12.30h	Matched	2.7 ± 0.2	3.0 ± 0.1
Undulator 17.01h	10μm C wire, Mx = 1.039, My = 1.145	4.3 ± 0.3	4.4 ± 0.3
Undulator 17.55h	10μm C wire, Mx = 1.025, My = 1.163	5.1 ± 0.3	4.4 ± 0.2
Undulator 18.11h	10μm C wire, Mx = 1.050, My = 1.113	5.1 ± 0.2	5.1 ± 0.2
Undulator 18.45h	10μm C wire, Mx = 1.031, My = 1.052	5.2 ± 0.2	4.9 ± 0.2

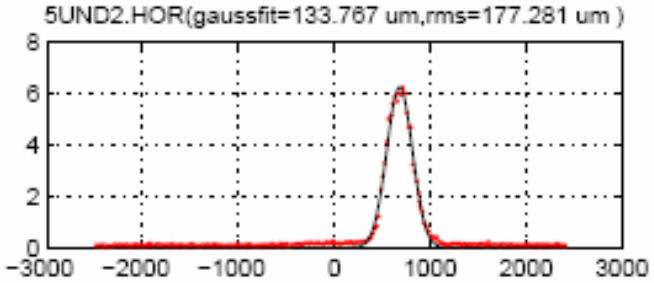
SEED section — Similar emittances as in the injector
Matching worked properly

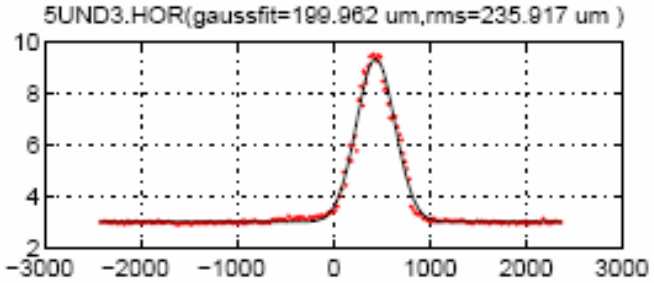
Undulator — Similar emittances as in the injector

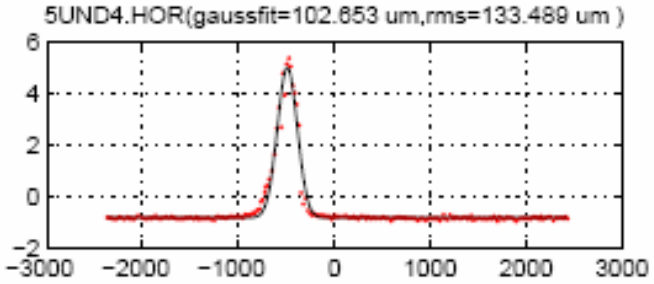
Taking rms or gaussian beam sizes: Beam profiles example (17-02-07)











- A gaussian fit represents well the beam
- rms is very sensitive to the beam tails

Taking rms or gaussian beam sizes: Emittance results (17-02)

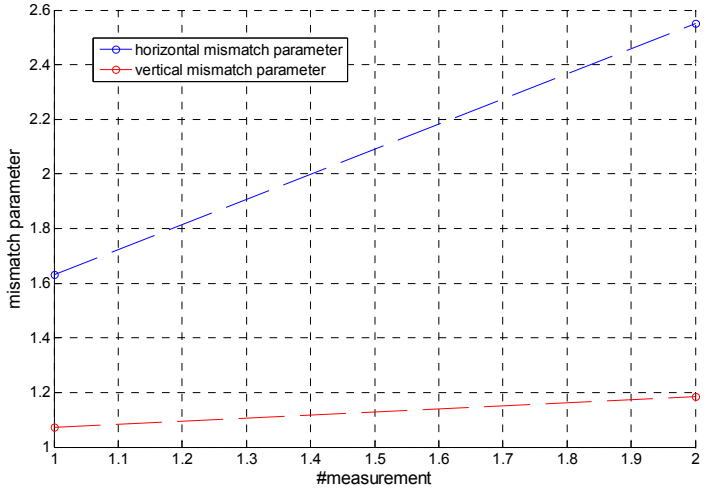
Where & when	ε_x [mm mrad]		Mismatch x		ε_y [mm mrad]		Mismatch y	
	rms	gauss	rms	gauss	rms	gauss	rms	gauss
Undulator 17.01h	4.3	3.3	1.039	1.167	4.4	3.6	1.145	1.053
Undulator 17.55h	5.1	3.8	1.025	1.021	4.4	3.9	1.163	1.257
Undulator 18.11h	5.1	4.0	1.050	1.070	5.1	4.4	1.113	1.072
Undulator 18.45h	5.2	3.6	1.031	1.053	4.9	4.2	1.052	1.017

- Emittance systematically smaller taking gaussian beams
- Similar mismatch parameters

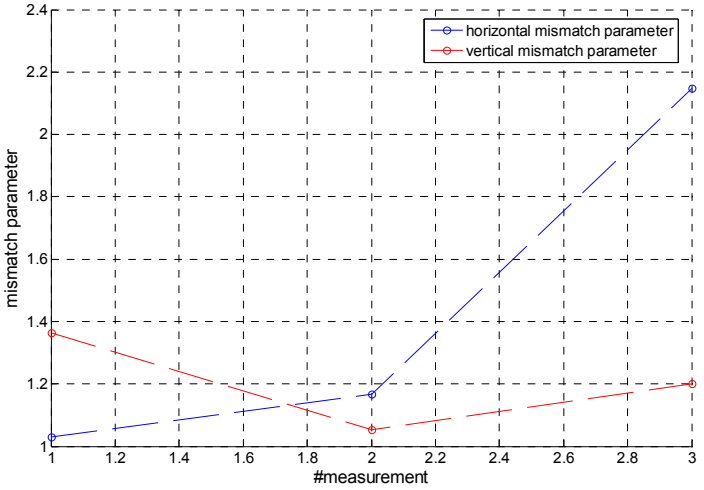
Matching in the undulator

New matching routine:
- It uses the toolbox from Vladimir and Nina
  - Option to limit the quad currents
  - Option to user quads which share power supplies
  - Option to choose between Gaussian or rms beam sizes

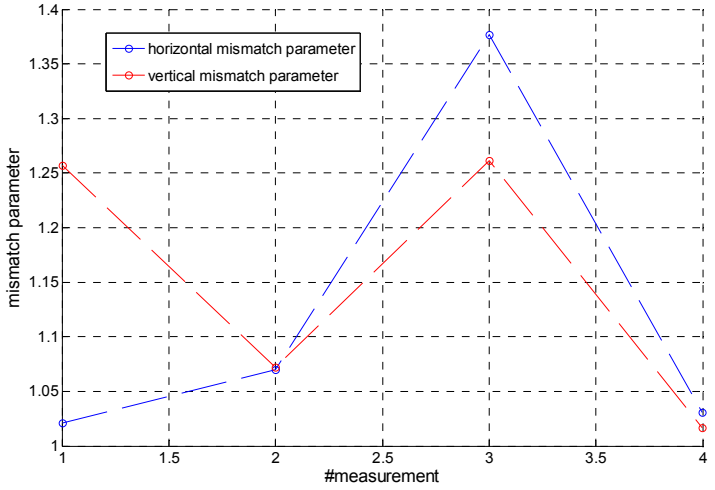
With rms beam sizes



With gaussian beam sizes



With gaussian beam sizes



- Limiting the quad current variation helps
- Taking Gaussian beam sizes instead of rms sizes helps
- Cycling should do the rest

Summary table for the 21st of February

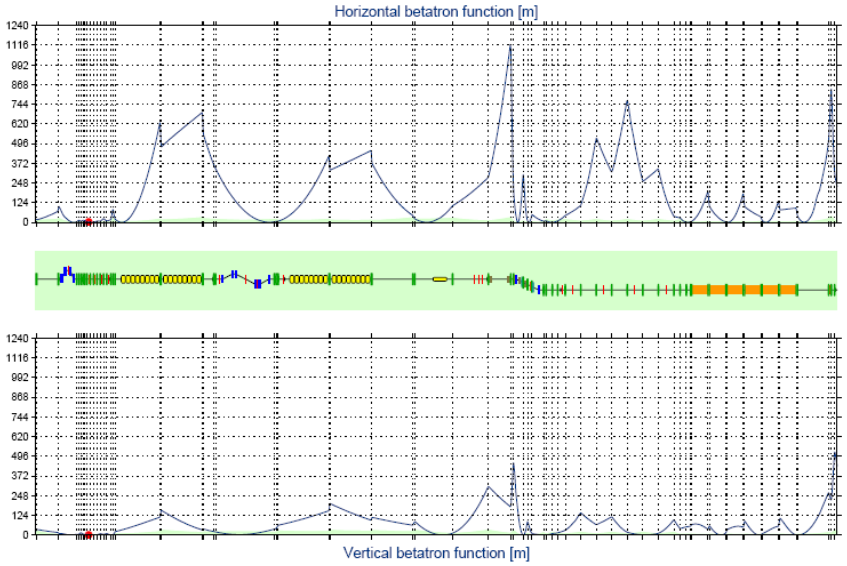
Where & when	Comments	ε_x [mm mrad]	ε_y [mm mrad]
Injector 18.18h	Matched	4.8 ± 0.2	3.4 ± 0.2
Seed	Not proper measurement		
Undulator 22.28h	10μm C wire, Mx = 1.256, My = 2.073	4.2 ± 0.5	4.4 ± 0.7
We started from scratch here…			
Undulator 00.13h	10μm C wire, Mx = 1.528	5.8 ± 0.6	-
Undulator 01.31h	10μm C wire, Mx = 1.342, corrected dispersion	4.3 ± 0.4	-
Undulator 02.18h	10μm C wire, Mx = 1.136, 6 degrees off crest at ACC1	6.3 ± 2.4	-
Injector 03.03h	Mx = 3.422, My = 1.713	3.7 ± 1.5	3.0 ± 0.2

DBC2 section	Big initial mismatch in the 2nd attempt
SEED section	Not proper measurement since strong dependence of the beam size on the horizontal position
	Matching did not work
Undulator	Imaginary calculated emittances in the vertical plane
	Not possible to try matching

Playing around with Q9/10ACC5

	Beam size at 21SEED	
	σ_x [μm]	σ_y [μm]
Reference	153 ± 14	319 ± 12
↑Q9ACC5 by 0.5A	69 ± 18	301 ± 13
↓Q9ACC5 by 0.8A	416 ± 32	329 ± 20
↓Q10ACC5 by 0.8A	82 ± 20	292 ± 8

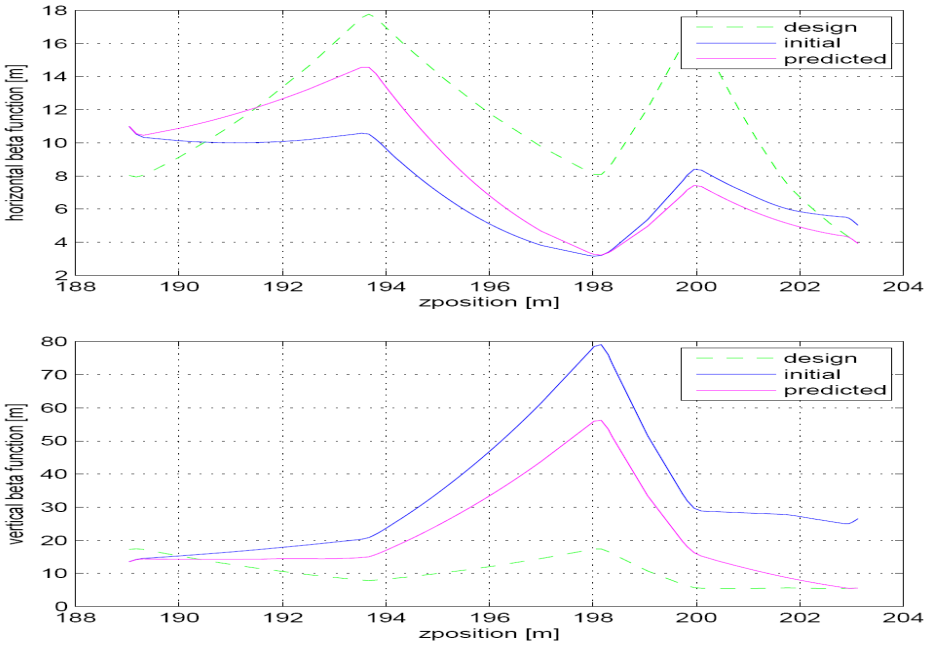
Modifying Q9ACC5 and Q10ACC5 had an effect to the beam only in the horizontal plane



	Design		Calculated from DBC2 meas.	
	β_x [m]	β_y [m]	β_x [m]	β_y [m]
Q9ACC5	14.4	24.2	452	94
Q10ACC5	13.1	26.9	404	105

Measurements on the 22nd of February SASE conditions

Where & when	Comments	ε_x [mm mrad]	ε_y [mm mrad]
Undulator 20.49h	10μm C wire, Mx = 1.025, My = 3.011	8.2 ± 0.5	6.2 ± 1.3
Undulator 21.44h	10μm C wire , Attempt to match, Mx = 1.163, My = 1.706	8.4 ± 0.4	6.9 ± 0.5



Just 1 measurement and 1 matching attempt
No time for more ☹

Contents

Summary and next steps

Summary

- Emittances in the injector between 3 and 4 mm mrad (since December 2006)
- Emittance measurements done at the SEED section for the 1st time: similar emittances as in the injector, matching worked properly most of the times.
- Beam size measurements in the undulator (and therefore emittance) depend strongly on the used wire. This is due to a non-linear behavior of the PM when the input light is too big (for the Tungsten wires). A filter in front of the PM has been placed in order to solve this problem.
- Emittance measurements in the undulator with the carbon wire gave similar values as in the injector and the SEED section.
- Improvement of the matching in the undulator (but still not enough).
- Not proper status of the machine makes measurements very complicated.

Next steps

- Replacement of 4 OTR stations in the SEED section by 4 OTR + WS stations during the shutdown.
- Improve the matching tool.
- Next measurements after the shutdown