Measurements of projected emittance at FLASH

Accelerator and FEL Studies (September and October 07)

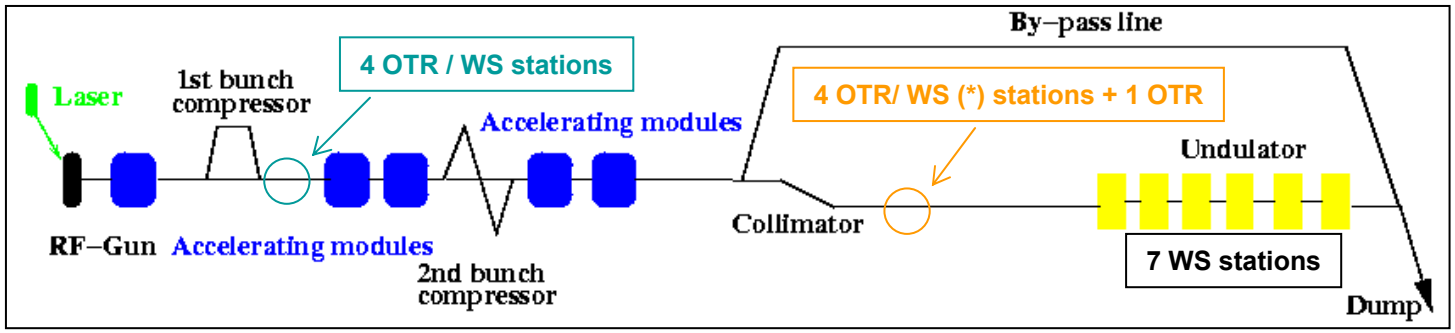
People involved:

Katja Honkavaara, Florian Loehl, Eduard Prat

Pedro Castro, Martin Sachwitz (WS studies in the undulator)

FLASH seminar, 13th of November of 2007

Overview



(*) installed during shutdown 2007
Measurements at the SEED section (with OTRs) since December 2006

- **When**: Accelerator studies (6th, 8th and 26th of September 2007), FEL studies (14th of October 2007)
- **Goals**:
  - Check functionality of filters in the undulator WS (done)
  - Study emittance transport (done)
  - Commissioning OTR/WS stations in the seed section (started)
  - Study impact of orbit through the modules on emittance (~done)
  - Continue studies on optics matching in the undulator (not done)
- **Difficulties**:
  - Problems with calibration constant of cold BPMs
  - Dark current loses → not possible to measure systematically in the undulator

WS measurements in the undulator

3 wires are available in the undulator: **50 µm T, 10 µm T and 10 µm C**

$$\#\,\text{photons} \propto d^2 \cdot A^2 \longrightarrow$$ # photons $_{50\mu mT}$ = 25 · # photons $_{10\mu mT}$ = ~**4000** · # photons $_{10\mu mC}$

Before the shutdown

Tungsten → Non-linear behavior of PM → ↑ beam sizes → ↑ calculated emittances

During the shutdown

Placement of filters with attenuation factor of 32 in front of each PM

After the shutdown (08-09-2007)

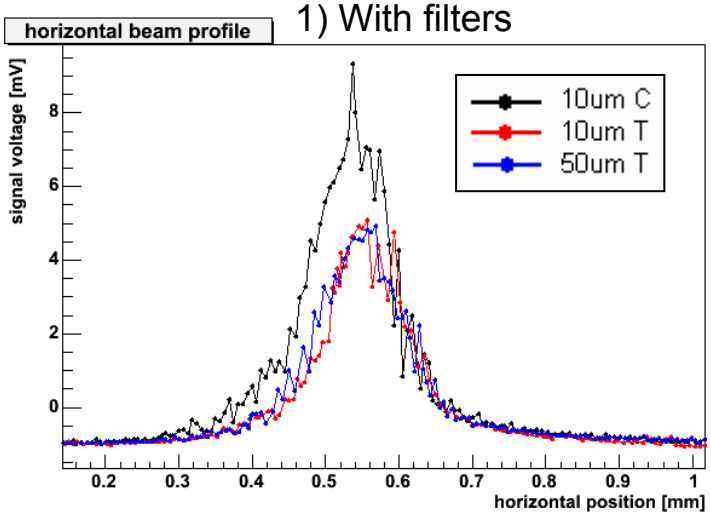
Check functionality of the filters

- Measure different wires with filters
- Remove filters and repeat measurement
- Place again filters and repeat measurement

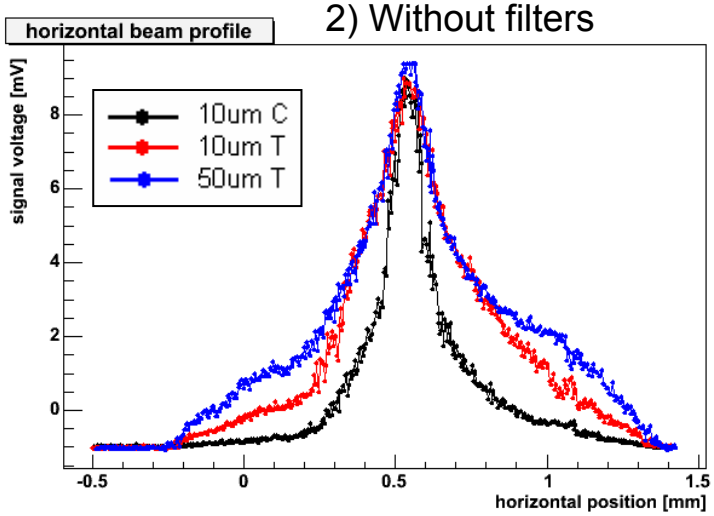
Measurements done at WS5UND4
(by P. Castro, M. Sachwitz and E. Prat)

WS measurements at 5UND4 – 08.09.07
Horizontal plane

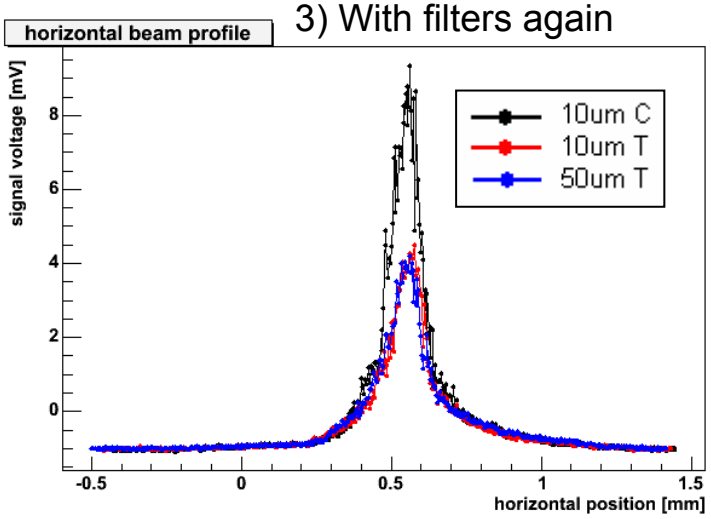
1) With filters

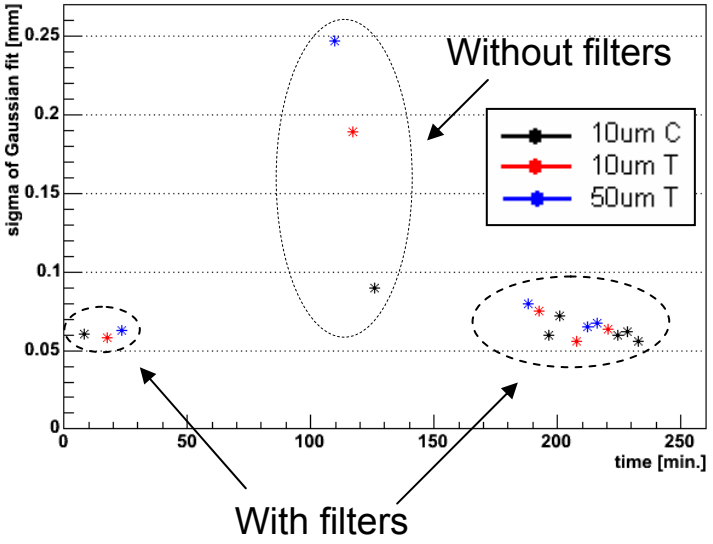


2) Without filters



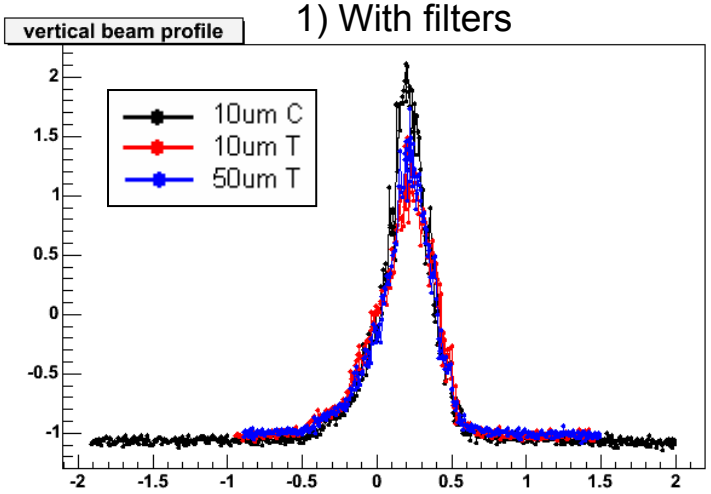
3) With filters again



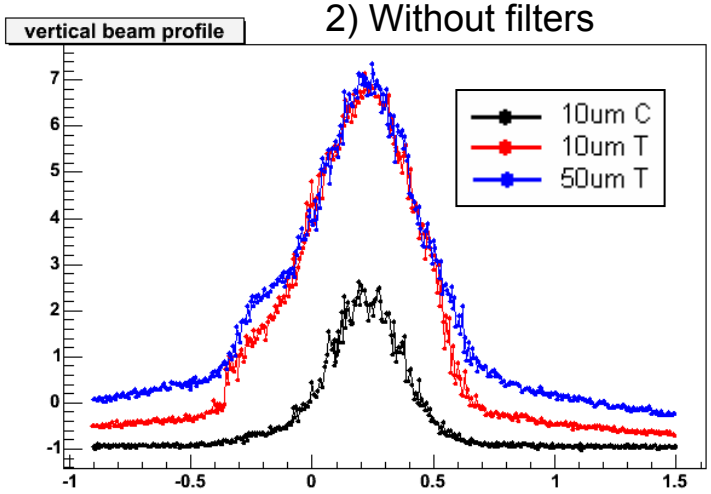


WS measurements at 5UND4 – 08.09.07
Vertical plane

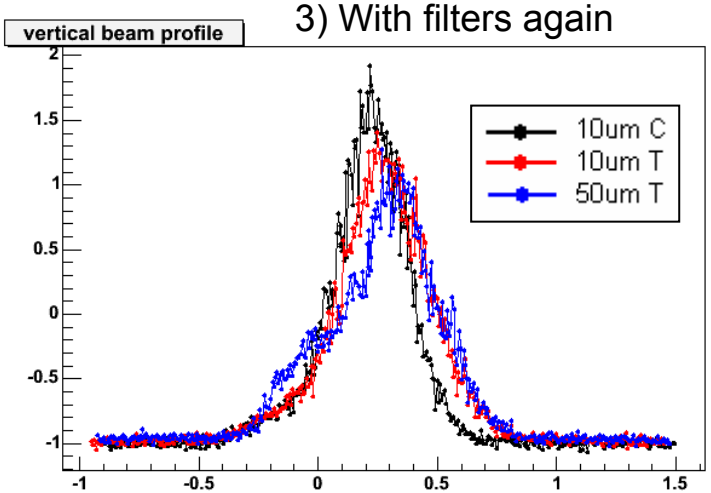
1) With filters

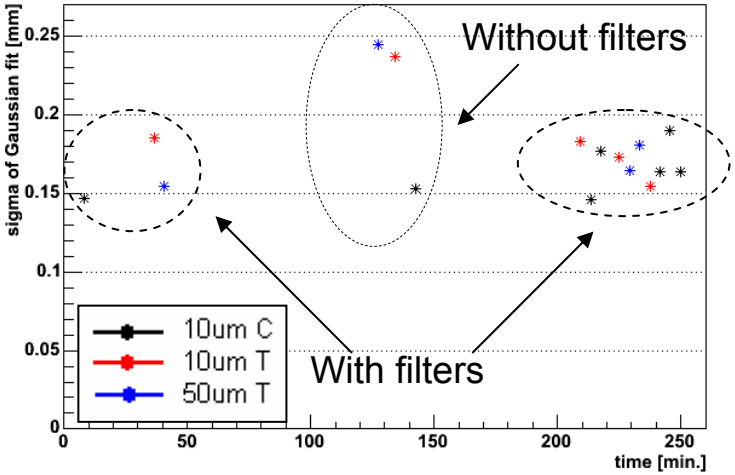


2) Without filters



3) With filters again





Emittance transport

Presented values correspond to 100% of the beam (in brackets 90% values).
Injector and SEED section: OTR were used, beam was properly matched for all the cases.
Errors show only contribution of beam size uncertainties
Conditions: 1nC / On crest through all accelerator modules

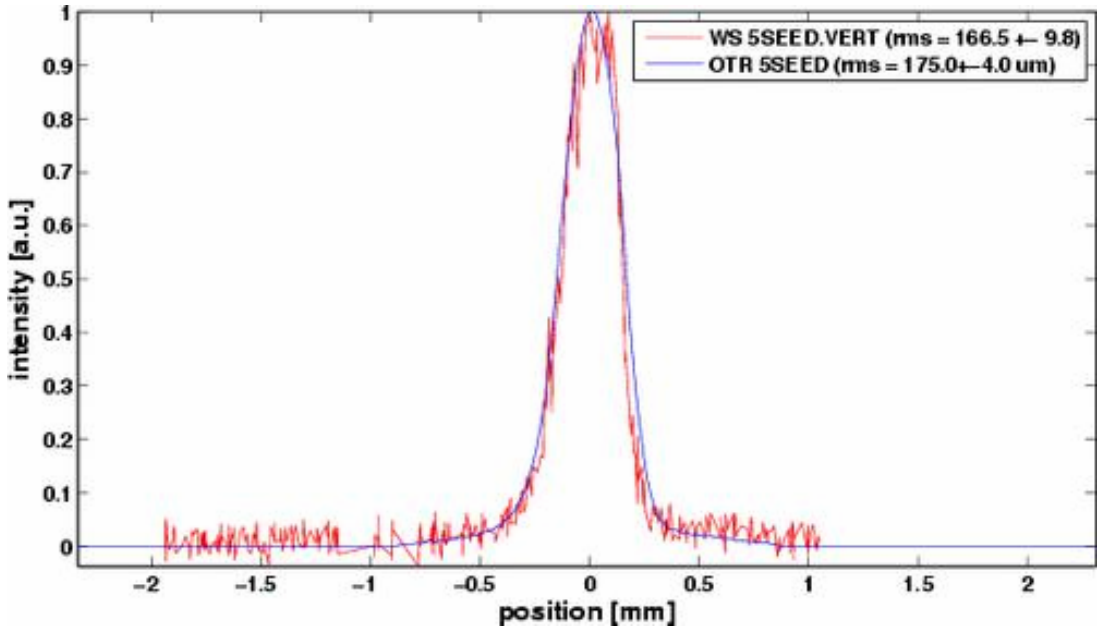
06-09-07	ε_x [µm]	ε_y [µm]
Injector 8.10h	3.6 ± 0.2 (2.1 ± 0.1)	2.9 ± 0.1 (1.5 ± 0.1)
Seed 12.33h	2.2 ± 0.1 (1.2 ± 0.1)	3.2 ± 0.2 (1.9 ± 0.1)
Seed 12.45h	2.6 ± 0.2 (1.4 ± 0.1)	3.4 ± 0.1 (1.9 ± 0.1)
Seed 13.53h	3.0 ± 0.2 (2.0 ± 0.2)	3.4 ± 0.1 (2.0 ± 0.1)

08-09-07	ε_x [µm]	ε_y [µm]
Injector 17.21h	3.7 ± 0.1 (2.2 ± 0.1)	3.6 ± 0.3 (2.1 ± 0.1)
Seed 19.35h	2.9 ± 0.1 (1.8 ± 0.04)	3.9 ± 0.1 (2.3 ± 0.1)
Seed 19.44h	2.9 ± 0.1 (1.8 ± 0.1)	3.8 ± 0.1 (2.3 ± 0.1)
Und. 15.45h	4.2 ± 0.3	2.0 ± 1.3
Und. 16.03h	4.1 ± 0.2	2.2 ± 0.5
Und. 16.28h	4.5 ± 0.3	2.8 ± 0.1
Und. 16.42h	4.3 ± 0.3	2.8 ± 0.2

SEED section	Similar emittances as in the injector Bad reproducibility of emittance the 6th of September, beam size unstable (maybe due to unstable LLRF)
Undulator	Not possible to measure the 6th of September due to dark current loses Similar emittances as in the injector and SEED section Good reproducibility of emittance and mismatch parameters in the horizontal plane but not in the vertical one

Commissioning OTR / WS stations in the SEED section

- Shutdown 2007: replacement of 4 OTR stations by 4 new OTR / WS stations
- Alignment of OTR has been improved:
  - ↓steering to center the beam in the screen
  - ↓OTR intensity dependence on beam position
- 1st preliminary measurements of comparison between OTR and WS:
  - Profiles given by OTR and WS agree well
  - WS profile is much noisier (1 profile vs 20 images) → different rms beam size
- Some problems with WS:
  - From time to time one scan didn't start
  - For every measurement day, scan positions and PMV range have to be determined

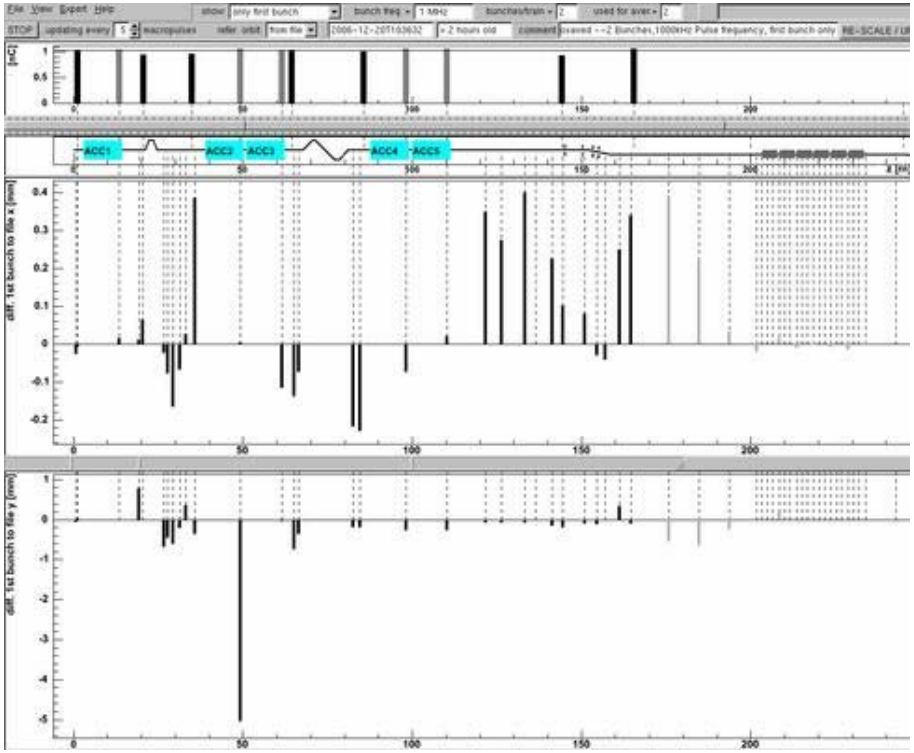


Impact of orbit bumps through accelerator modules - Motivation

20-12-06: A **-6mm** vertical bump at BPM9ACC2 caused an emittance increase from 2.6 to 6.2 μm
Beam was matched for all cases

Where & when	Comments	ε_x [μm]	ε_y [μm]
Seed 10.45h	No bump	4.4 ± 0.4	2.6 ± 0.4
Seed 17.08h	-6mm y bump	4.1 ± 0.4	6.2 ± 0.8
Seed 18.27h	No bump	3.8 ± 0.4	2.6 ± 0.4

Simulations predict much weaker effect

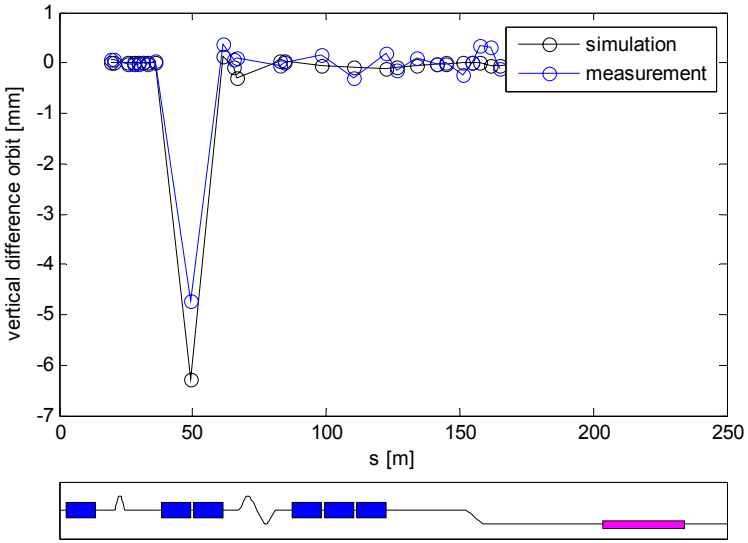


Goal of these studies:
Try to reproduce above measurement
Make a more general study of the impact of orbit through the modules:

- for both planes
- with different amplitudes
- for different modules

Impact of orbit bumps through accelerator modules - Overview

Example bump at BPM9ACC2



Day1 (1nC)
horizontal and vertical bumps at BPM9ACC2
Used correctors: H/V11DBC2, H/V10ACC2/3, H/V2UBC3
Coupled orbit not corrected

Day2 (0.9nC)
problems with calibration constant signs of cold BPMs
→ only horizontal bumps at BPM9ACC2
Used correctors:H11DBC2, H10ACC2, H10ACC3, H2UBC3

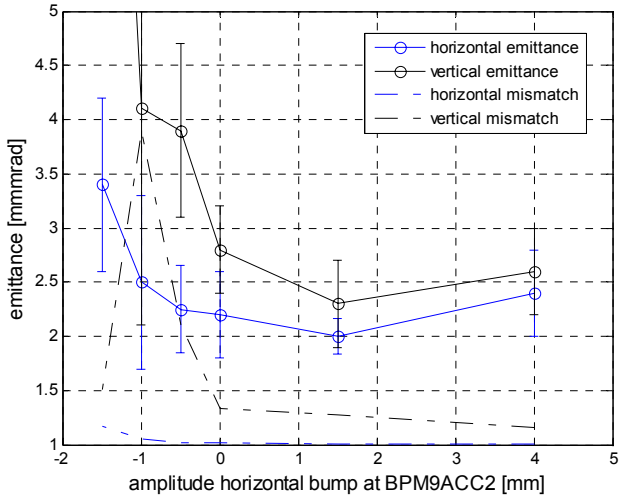
Day3 (0.6nC)
problems with calibration values of cold BPMs
→ horizontal and vertical bumps at 11DBC2 & 3DBC3
Used correctors: 11DBC2 → H9/V8DBC2, H11/V10DBC2, H/V10ACC2, H/V10ACC3, H/V2UBC3
3DBC3 → H/V1DBC3, H/V3DBC3, H/V10ACC6, H/V10ACC7

After each bump, emittance was measured at the SEED section

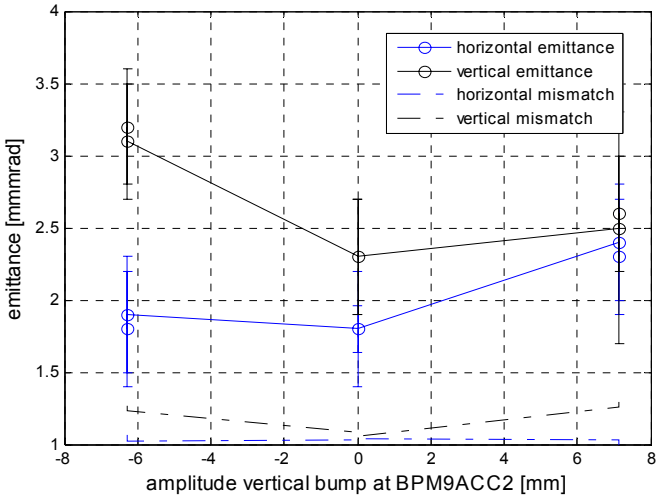
Simulations (elegant)
Steerer currents of the measurement (& bump artificially closed)
Initial distribution: 10^4 particles after ACC1, design optics, emittance=2μm
On crest through all accelerator modules, wakefields included (structure and coupler)

Bumps at BPM9ACC2 Measurements

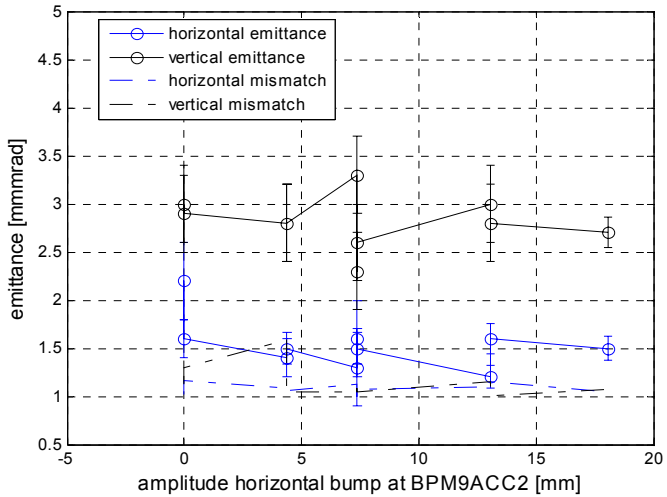
Horizontal plane (Day 1)



Vertical plane (Day 1)



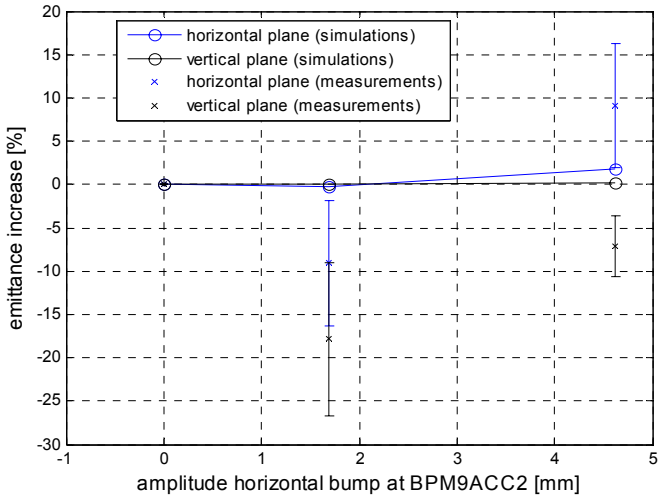
Horizontal plane (Day 2)



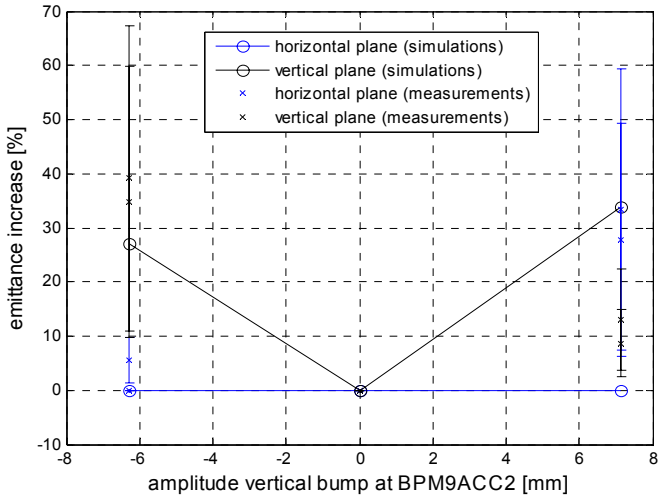
- Day 1: significant impact for both planes. Coupled effect may be because coupled orbit was not corrected.
- Day 2: much less impact

Bumps at BPM9ACC2
Measurements vs simulations

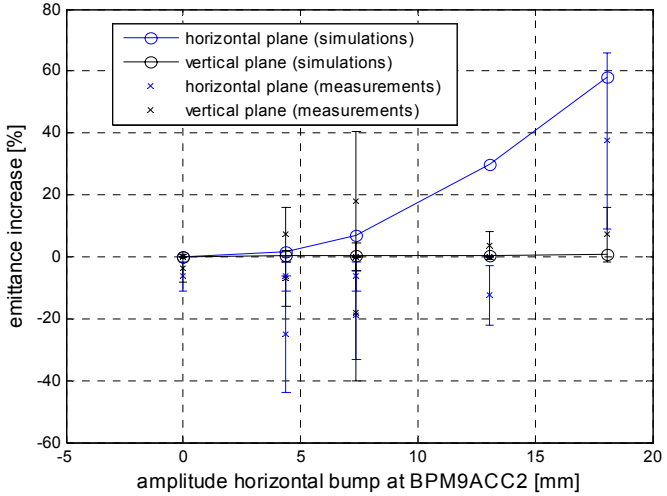
Horizontal plane (Day 1)



Vertical plane (Day 1)



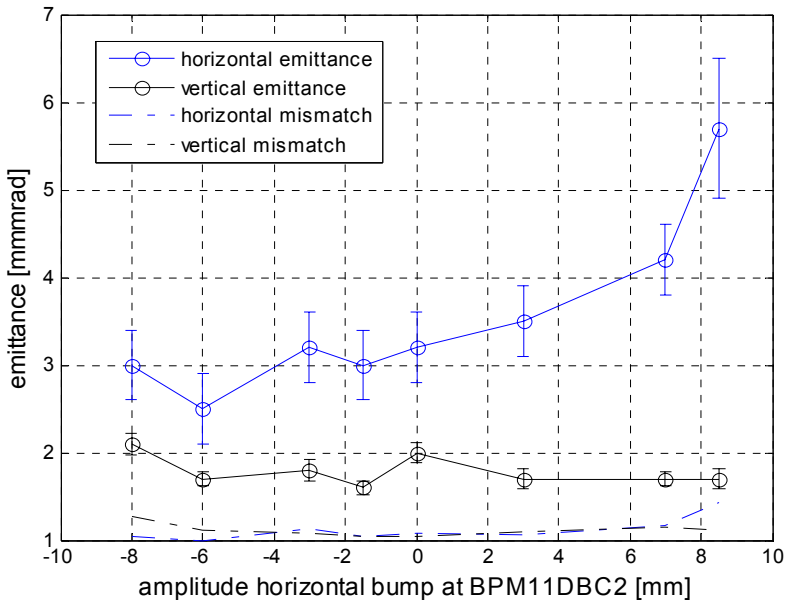
Horizontal plane (Day 2)



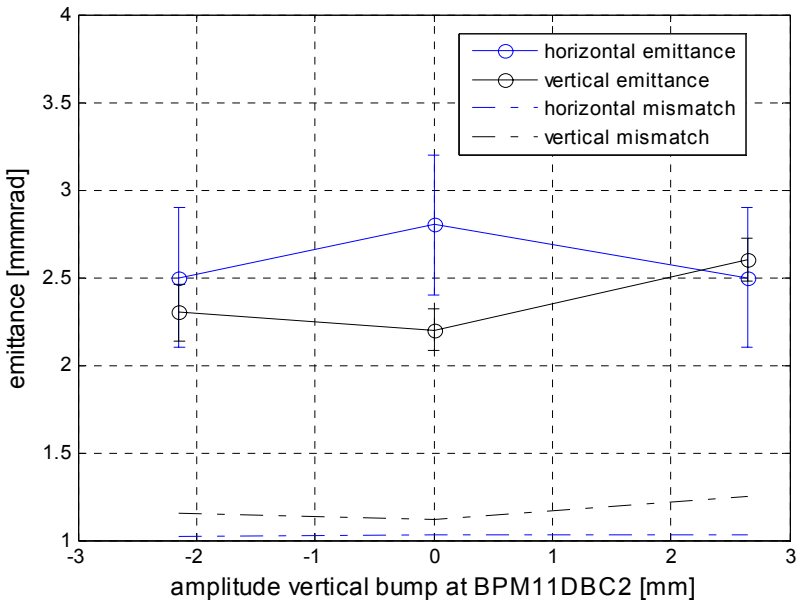
~ good agreement between measurements and simulations (without considering measurements with mismatch parameter bigger than 1.5)

Bumps at BPM11DBC2 Measurements

Horizontal plane



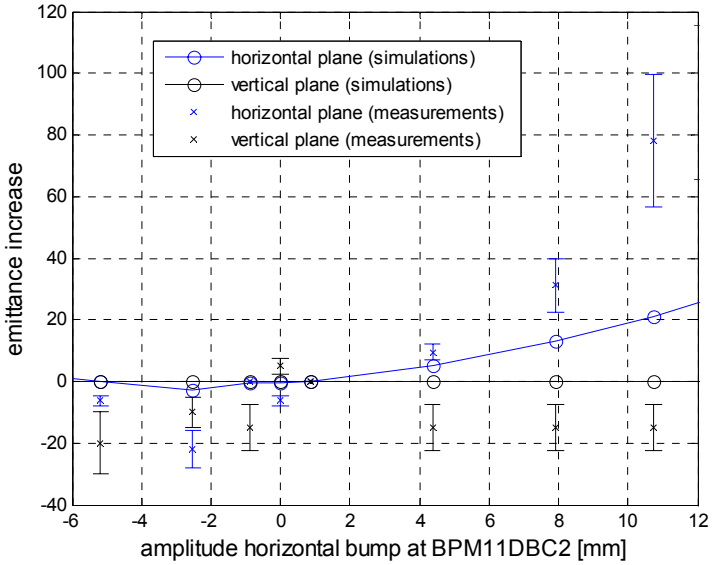
Vertical plane



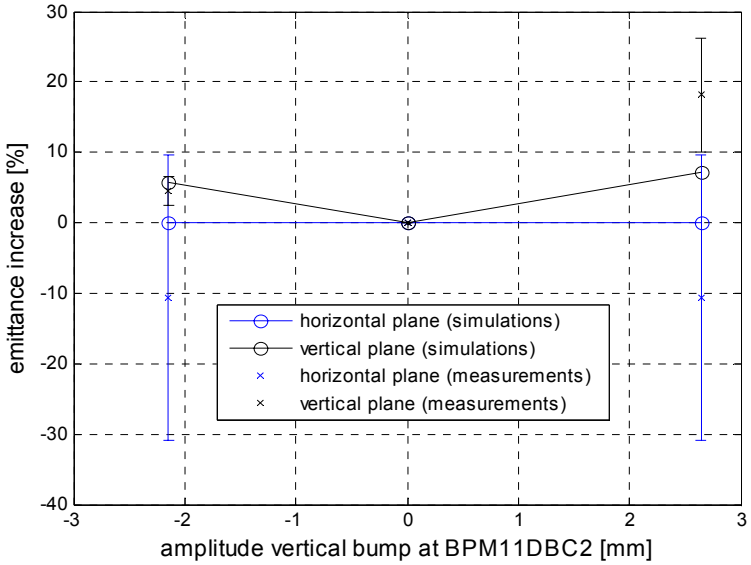
- Horizontal plane: emittance increase only for positive bumps (maybe because the zero of this BPM is shifted)
- Vertical plane: no emittance increase (but smaller bump amplitudes)

Bumps at BPM11DBC2
Measurements vs simulations

Horizontal plane



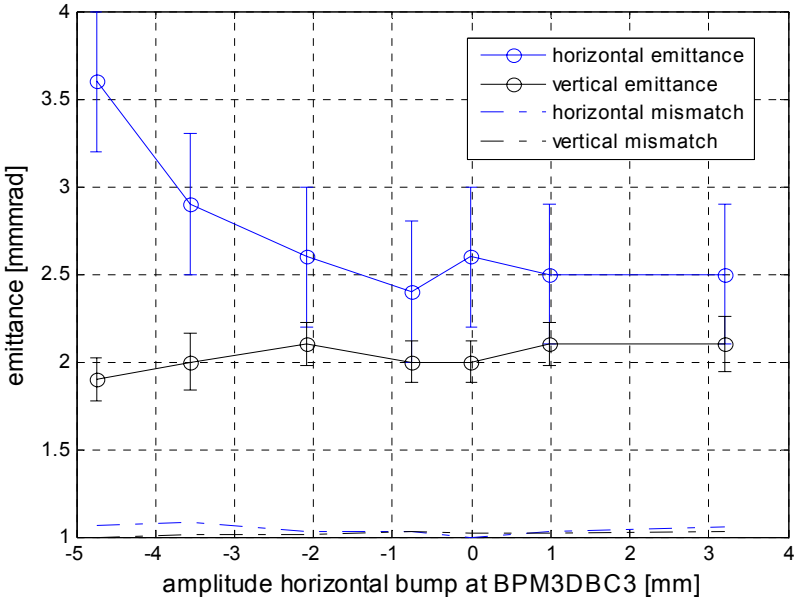
Vertical plane



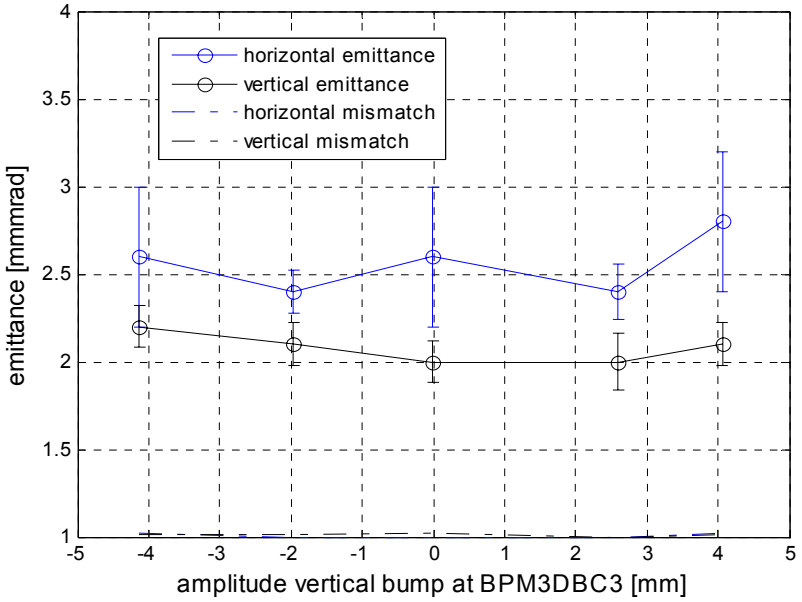
- Horizontal plane: if zero of the BPM is shifted → qualitative agreement
- Vertical plane: good agreement

Bumps at BPM3DBC3 Measurements

Horizontal plane



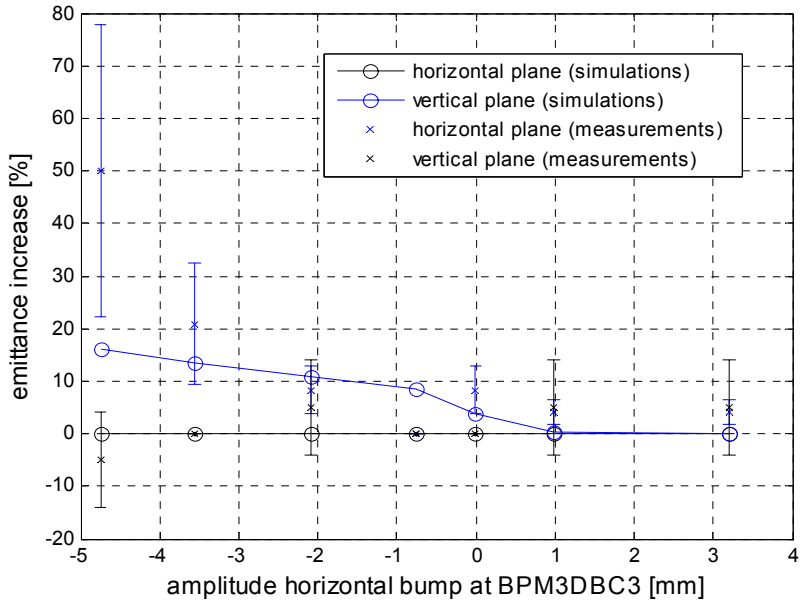
Vertical plane



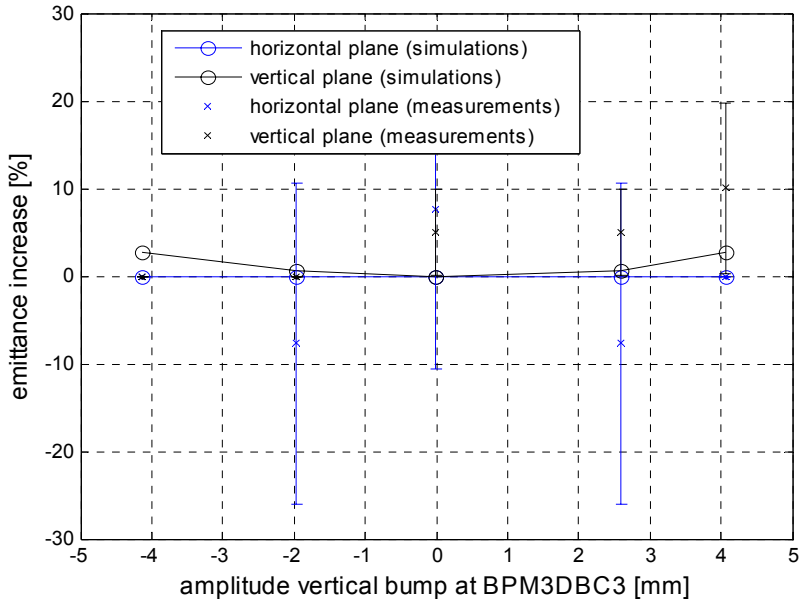
- Horizontal plane: emittance increase for negative bumps bigger than 3mm
- Vertical plane: no emittance increase

Bumps at BPM3DBC3
Measurements vs simulations

Horizontal plane



Vertical plane



- Horizontal plane: if zero of the BPM is shifted → qualitative agreement
- Vertical plane: good agreement

Summary and next steps

SUMMARY

- Attenuation filters of the WS stations in the undulator work as expected
- 1st emittance measurements after the shutdown show similar emittances along the machine:
  - 100% emittances: between 3 and 4μm
  - 90% emittances: around 2 μm (design value)
- Started commissioning of OTR/WS stations in the SEED section :
  - 1st results show a good agreement of profiles given by OTR and WS
- Studies on the impact of orbit through modules on emittance have been done:
  - Big effect measured on December 2006 not observed this time
  - Impact can be different from day to day due to various reasons: different optics, different orbit through the bunch compressors, etc.

NEXT STEPS

- Continue the commissioning of OTR/WS stations in the SEED section
- If next bump measurements → better characterization of the machine (measure beam sizes everywhere, dispersion measurement for each bump, …)