# Summary of emittance measurements April 2006 + July 2006

- April 2006, week 14
  - F.Loehl, K.Honkavaara, S.Schreiber, Ch.Gerth, E.Sombrowski
  - Comparison with OTR + Wire scanner in DBC2
  - Effect of different injector parameters on emittance in DBC2
- July 2006, week 30
  - F.Loehl, K.Honkavaara, E.Prat, S.Schreiber, V.Balandin, N.Golubeva
  - Integration of emittance measurement program to optical tool box of V.Balandin & N.Golubeva
  - Emittance measurements in DBC2 and undulator
    - Dispersion corrections
    - On-crest / off-crest
  - Linear optics

# Summary of emittance measurements April 2006 + July 2006

- April 2006, week 14
  - F.Loehl, K.Honkavaara, S.Schreiber, Ch.Gerth, E.Sombrowski
  - Comparison with OTR + Wire scanner in DBC2
  - Effect of different injector parameters on emittance in DBC2
- July 2006, week 30
  - F.Loehl, K.Honkavaara, E.Prat, S.Schreiber, V.Balandin, N.Golubeva
  - Integration of emittance measurement program to optical tool box of V.Balandin & N.Golubeva
  - Emittance measurements in DBC2 and undulator

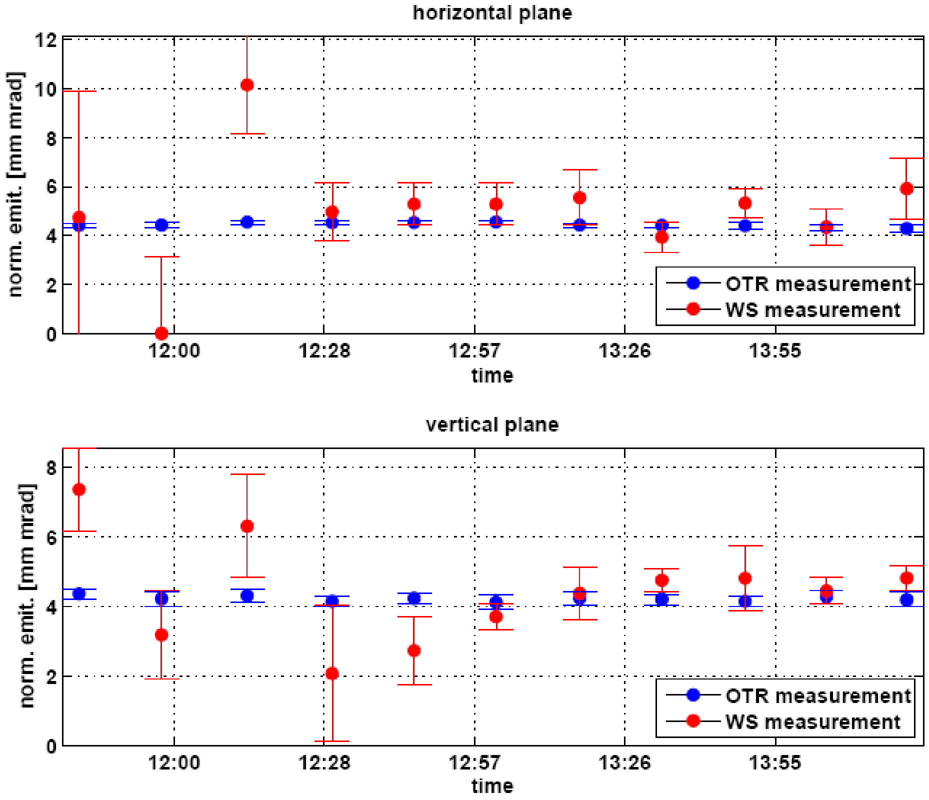
    Dispersion corrections

    On-crest / off-crest
  - Linear optics

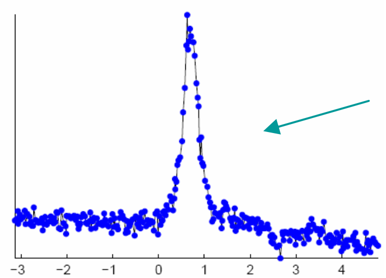
# Comparison of OTR / WS in DBC2

Emittance measured at DBC2 11 times within 2.5 hours with both OTRs and wire scanners.

100% rms values are plotted
(90% rms between 2 and 3 mm mrad)




WS measurements fluctuate a lot. Main reason is unstable baseline of the photomultiplier signals. Wire scanner measurement becomes more stable, the longer the photomultipliers are on. Photomultipliers have to warm up until one can do reliable measurements.




Example of baseline drift of a photomultiplier

# Effect of different injector parameters
# Steering – Iris size

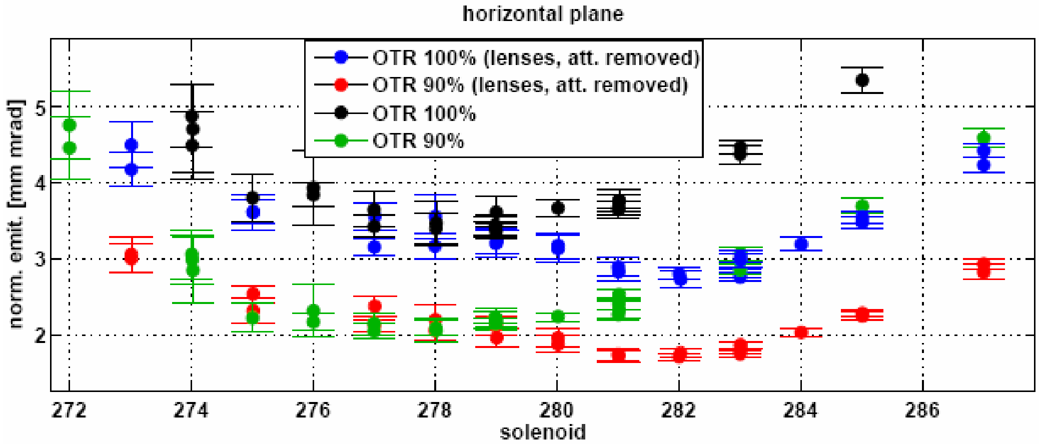
There is a strong dependence of the **steering** in the gun section, specially in the vertical plane

| **Steerer V2GUN** | Hor. (90%) [mm mrad] | Hor. (100%) [mm mrad] | Ver. (90%) [mm mrad] | Ver. (100%) [mm mrad] |
|---|---|---|---|---|
| Before steering | 1.8 | 2.9 | 2.8 | 4.2 |
| After steering | 1.9 | 3.0 | 2.1 | 3.2 |

No dependence on the **iris size** **(?!)**

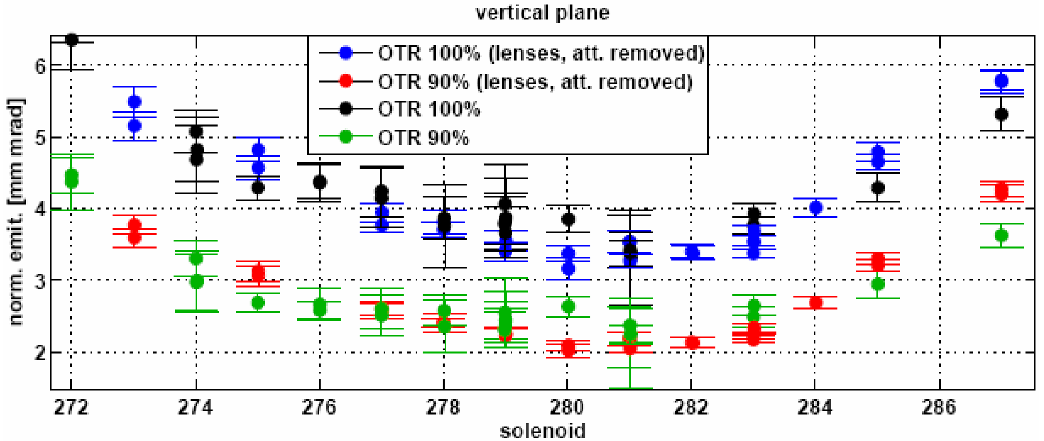
| **Iris [mm]** | Hor. (90%) [mm mrad] | Hor. (100%) [mm mrad] | Ver. (90%) [mm mrad] | Ver. (100%) [mm mrad] |
|---|---|---|---|---|
| 2.5 | 2.2 | 3.8 | 2.7 | 4.2 |
| 3.0 | 2.3 | 3.6 | 2.8 | 4.1 |
| 3.5 | 2.3 | 3.6 | 2.8 | 4.1 |

# Effect of different injector parameters
# Solenoid - Elements in the laser beam line




➢ Solenoid scan with and without 2 lenses and attenuator in the laser beam line

Gun gradient was 3.22 without the elements and 3.15 with them
This explains the higher solenoid current for the minimum emittance



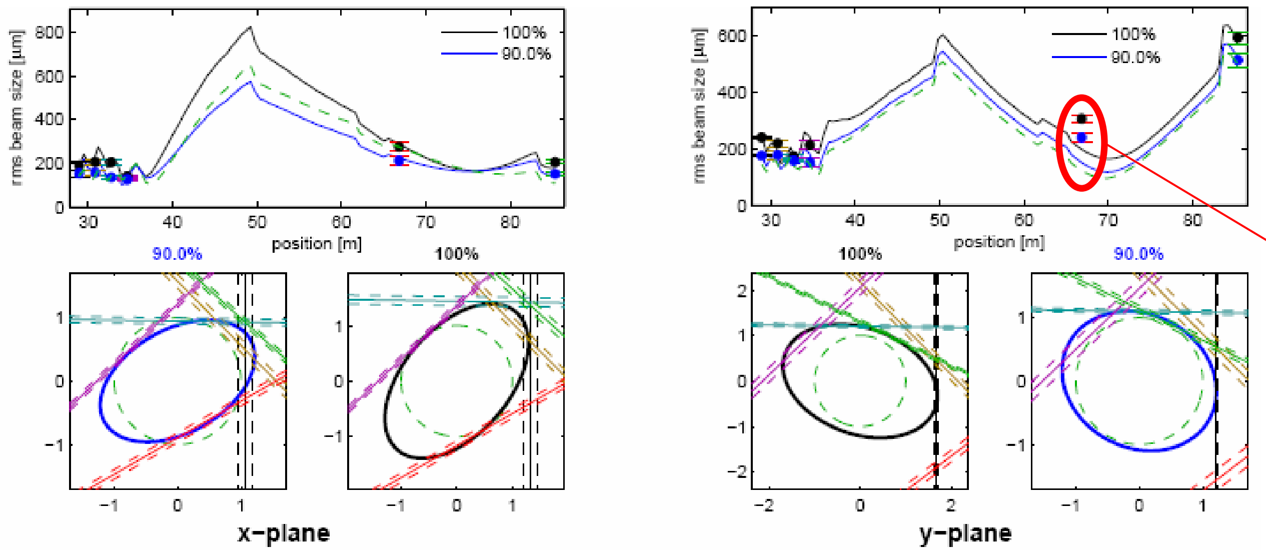

- Emittance without lenses ↓~ 30% (but with higher gun gradient!)
- With the lenses the beam is more stable

**In 2005 we regularly measured emittances of**

**~ 2 mm mmrad (100% rms)**
**~ 1.4 mm mrad (90% rms)**

# All OTR and WS available

- Emittance measurement can be performed selecting all OTRs and WS in the LINAC




Discrepancy!

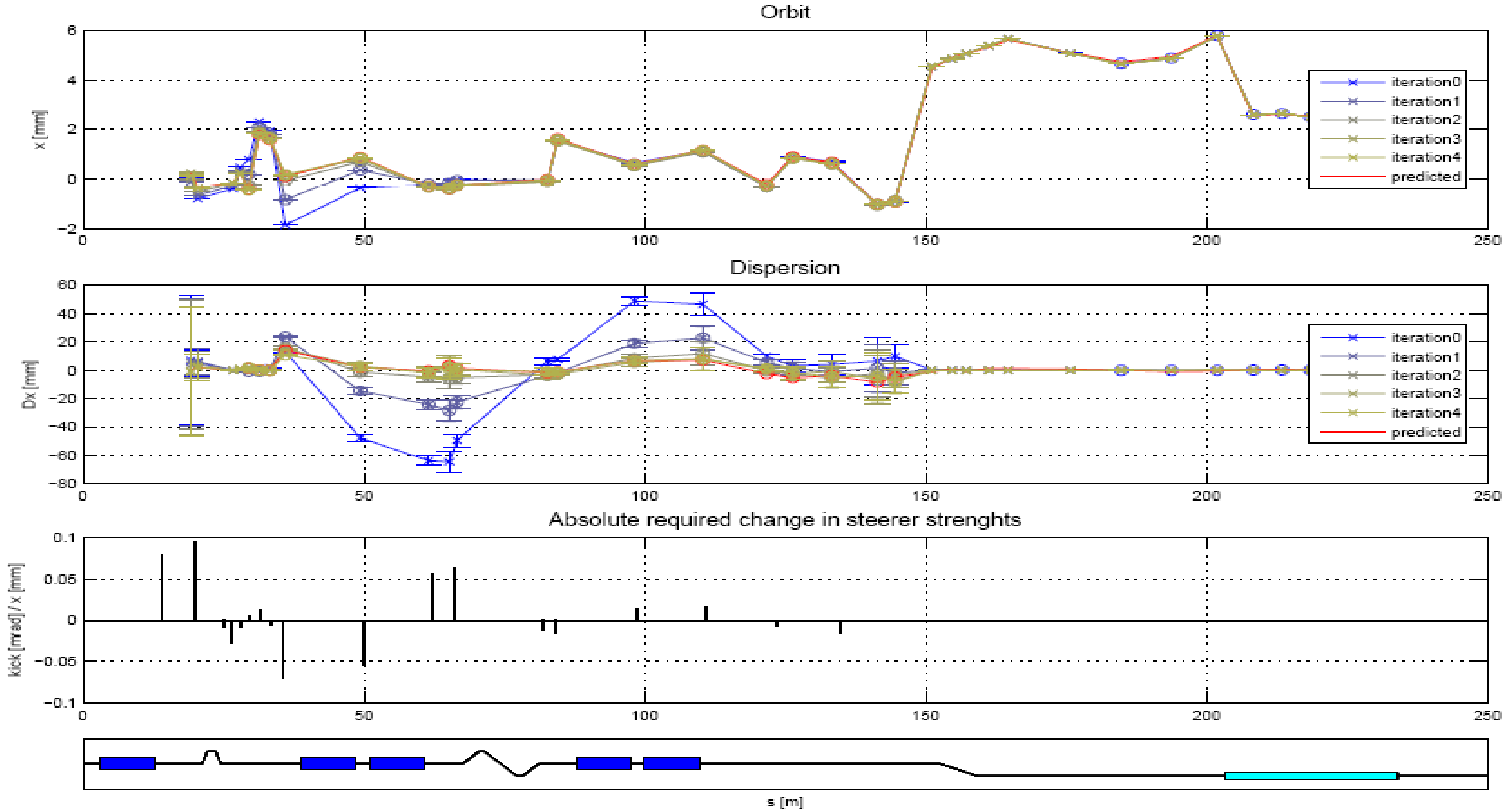
| 90.0% | 100% | | 2006−04−09T015226 | | 100% | 90.0% |
|---|---|---|---|---|---|---|
| 2.15±0.10 | 3.14±0.18 | (2.00) | $\gamma\varepsilon$ [mm mrad] | (2.00) | 4.08±0.12 | 2.65±0.08 |
| −2.07±0.16 | −1.82±0.14 | (−1.19) | $\alpha_{OTR\ 4DBC2}$ | (1.22) | 1.99±0.09 | 1.51±0.10 |
| 3.44±0.29 | 2.65±0.26 | (2.49) | $\beta_{OTR\ 4DBC2}$ [m] | (2.57) | 3.62±0.12 | 2.87±0.09 |
| 1.120 | 1.146 | (1.000) | $B_{mag}$ | (1.000) | 1.086 | 1.017 |
| | | | energy = 126.00 MeV | | | |
| | | | charge = 0.90 ± 0.02 nC | | | |
| 152.3±17.1 | 188.5±18.4 | | σ(OTR 4DBC2) | | 240.0± 5.3 | 175.5± 3.2 |
| 157.0±11.0 | 205.8±11.6 | | σ(OTR 6DBC2) | | 219.9±13.1 | 177.7±14.8 |
| 134.5± 7.1 | 204.4±11.7 | | σ(OTR 8DBC2) | | 173.5± 5.3 | 158.3± 4.5 |
| 125.0± 5.4 | 139.2± 6.2 | | σ(OTR 10DBC2) | | 214.2±16.7 | 152.2±15.9 |
| 211.6±17.8 | 275.5±20.0 | | σ(OTR 3UBC3) | | 306.7±12.6 | 240.5±15.6 |
| 151.3± 4.8 | 205.2± 9.1 | | σ(OTR 5DBC3) | | 593.1±21.6 | 513.5±26.8 |

# Summary of emittance measurements April 2006 + July 2006

- April 2006, week 14
  - F.Loehl, K.Honkavaara, S.Schreiber, Ch.Gerth, E.Sombrowski
  - Comparison with OTR + Wire scanner in DBC2
  - Effect of different injector parameters on emittance in DBC2
- July 2006, week 30
  - F.Loehl, K.Honkavaara, E.Prat, S.Schreiber, V.Balandin, N.Golubeva
  - Integration of emittance measurement program to optical tool box of V.Balandin & N.Golubeva
  - Emittance measurements in DBC2 and undulator
    Dispersion corrections
    On-crest / off-crest
  - Linear optics

# Dispersion correction

It worked properly for both planes and from every accelerator module. Values smaller than 10 mm (rms) were in all cases achieved.



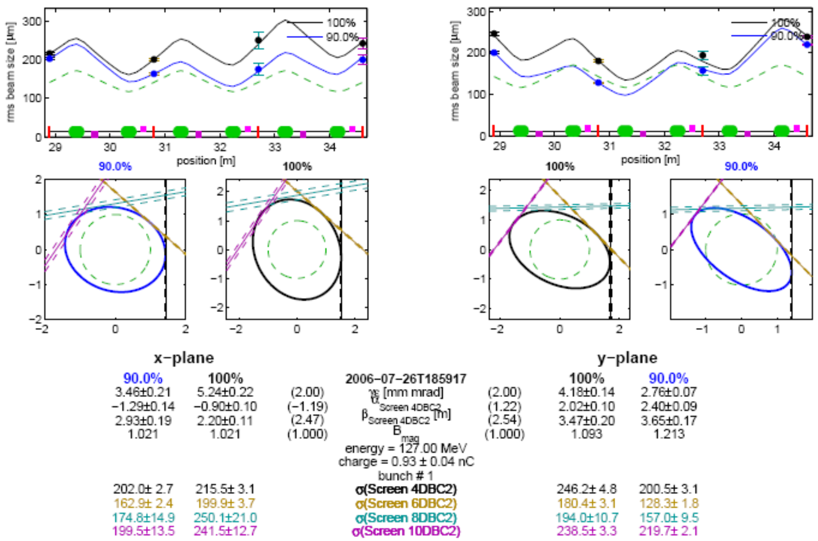

**Orbit and dispersion tool** is available

# On crest measurements (DBC2)

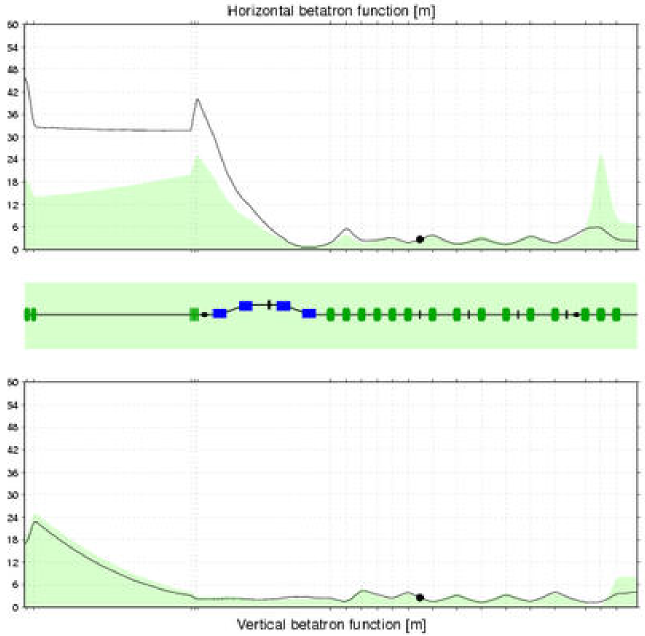
We performed an scan of the emittance versus solenoid current with the standard parameters:

- rf gun Pfwd = 3.35 MW
- laser iris = 3.0 mm
- charge = 1 nC
- bucking coil = 21.6 A
- energy = 127 MeV

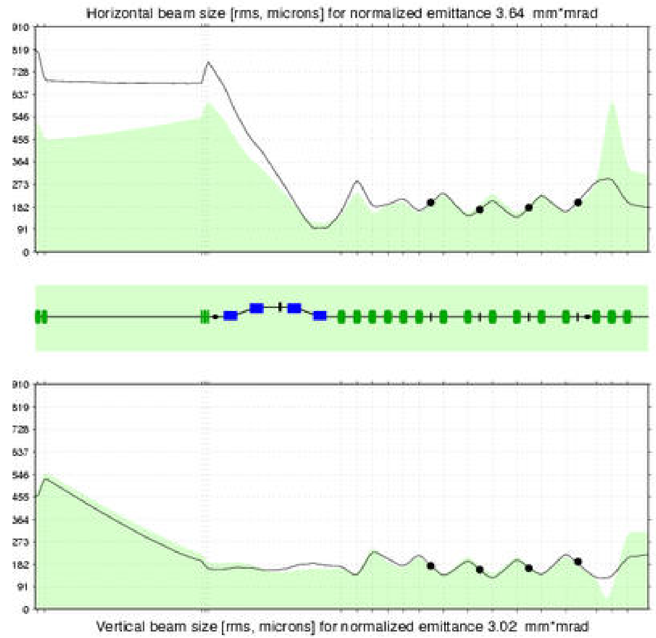
| Sol [A] | hor (90%) [mm mrad] | ver (90%) [mm mrad] |
|---|---|---|
| 278 | 3.5 | 2.8 |
| 279 | 3.1 | 2.8 |
| 280 | 3.0 | 2.3 |
| 281 | 3.1 | 3.3 |
| 282 | 3.5 | 3.6 |
| 283 | 3.8 | 3.6 |



# On crest measurements (DBC2)




**Betatron function at DBC2**
Green - design
Black point -: OTR4DBC2, measured Twiss function (90%)
Black curve - calculated betatron functions



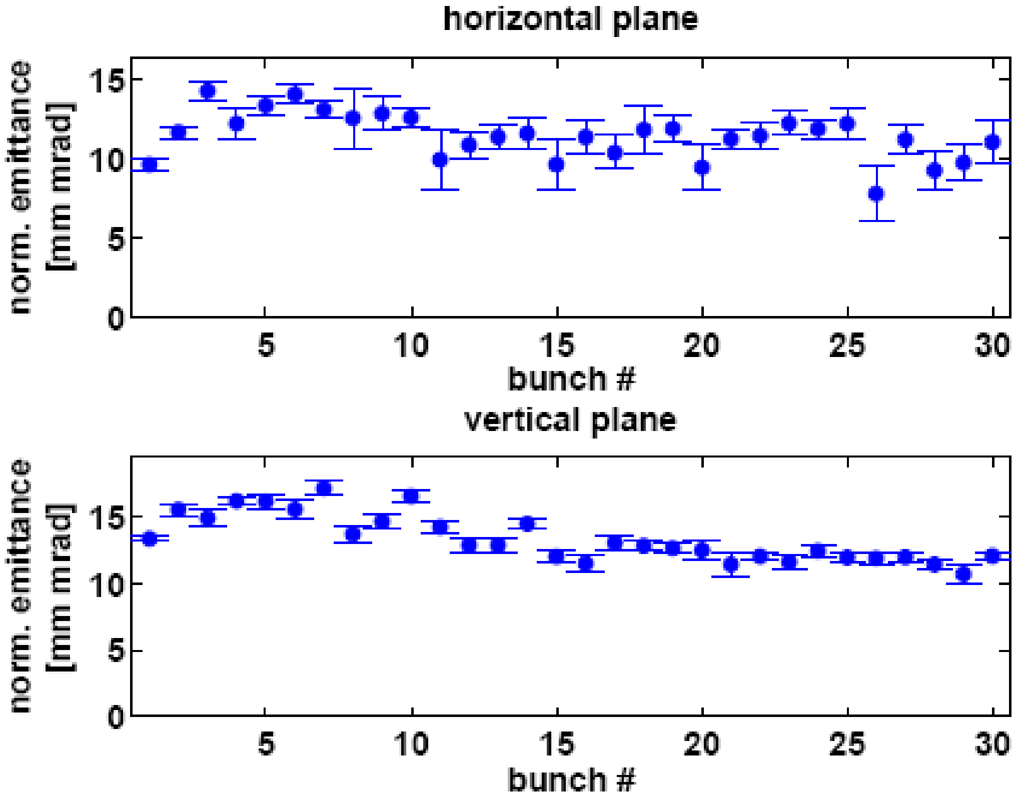

**Beam sizes at DBC2**
Green - design.
Black points - measured rms beam sizes
Black curve - rms beam size calculated using measured emittances and calculated betatron functions

# On crest measurements (Undulator)

**Not possible to match the beam in the undulator**

Emittance at DBC2 not optimized

| | $\varepsilon_x$ [mm mrad] | $\varepsilon_y$ [mm mrad] |
|---|---|---|
| 90% | 4.2 | 3.3 |
| 100% | 6.6 | 5.1 |




Measurement of the emittance for each bunch of the train

Emittances between 10 and 15 mm mrad for both planes (a factor of 2 or 3 more than at DBC2)

# On crest measurements (Undulator)

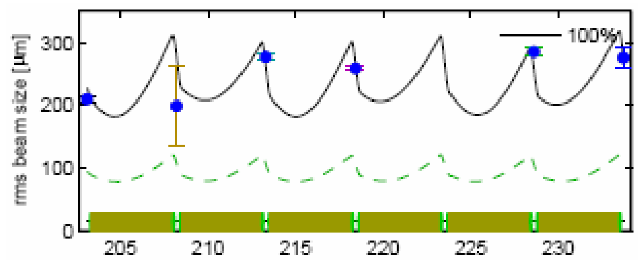
- Measurements with sextupoles off gave slightly worse emittance values.

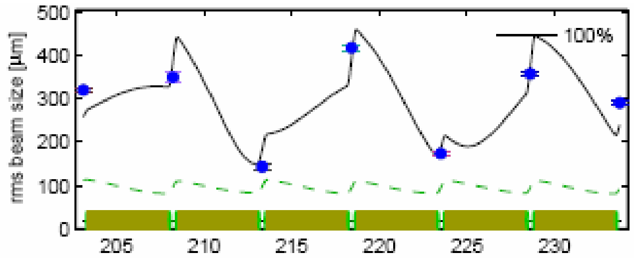
- Horizontal beam was significantly changed while vertical almost remained as it was. This is most likely because of a large off-set of the beam with respect to the center of the sextupoles.

horizontal

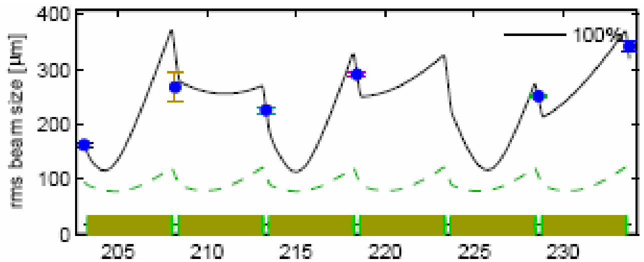
vertical

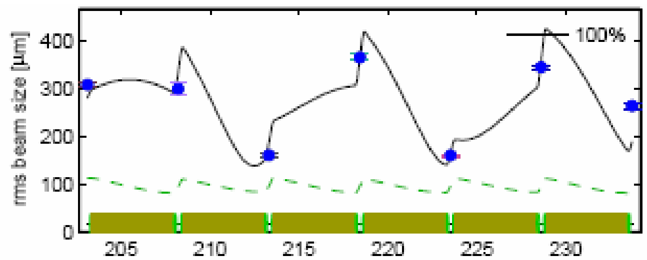
- Sext off




- Sext on



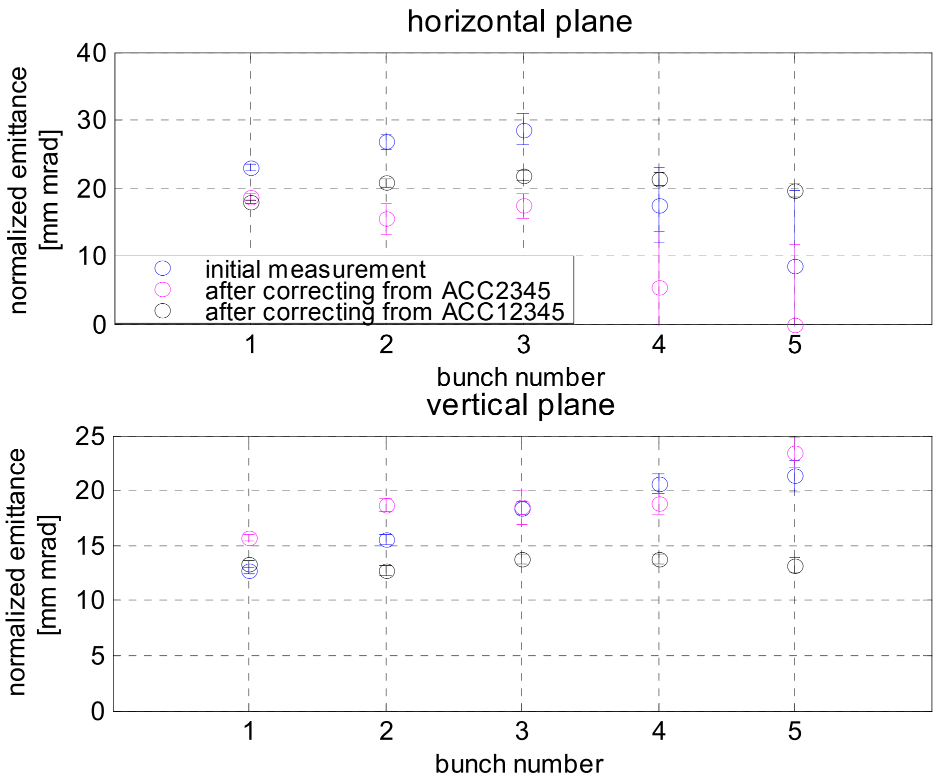




- **Dispersion correction didn't help, actually gave even worse results**

# Off crest measurements

- 100% rms emittance in DBC2 of 8.2 (hor) and 6.3 (ver) mm mrad
- Values in the undulator bigger by a factor of 3-4
- Dispersion corrected in both planes, first from ACC45 and then from ACC1 (no dispersion generated between ACC23 and ACC45)
- Final emittances smaller, but still bigger than at DBC2 by a factor of 2-3

Emittance in the undulator before and after dispersion correction

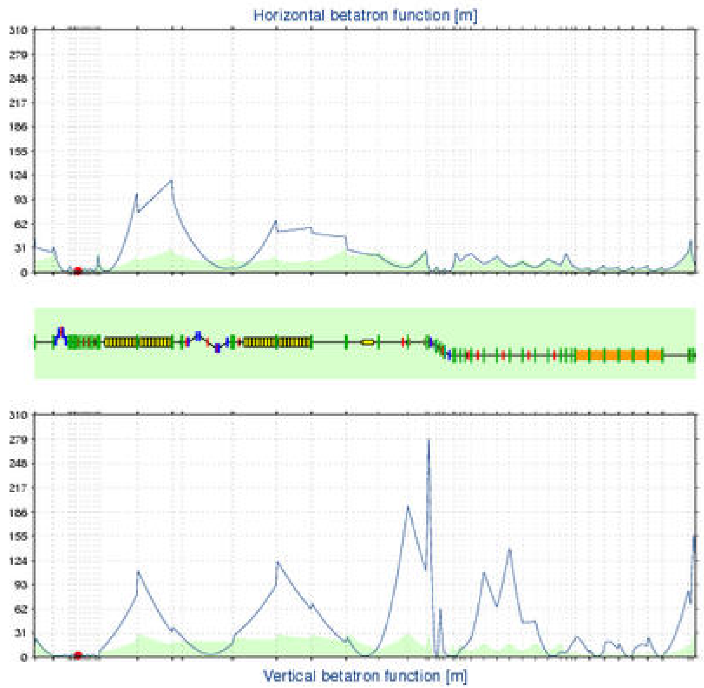


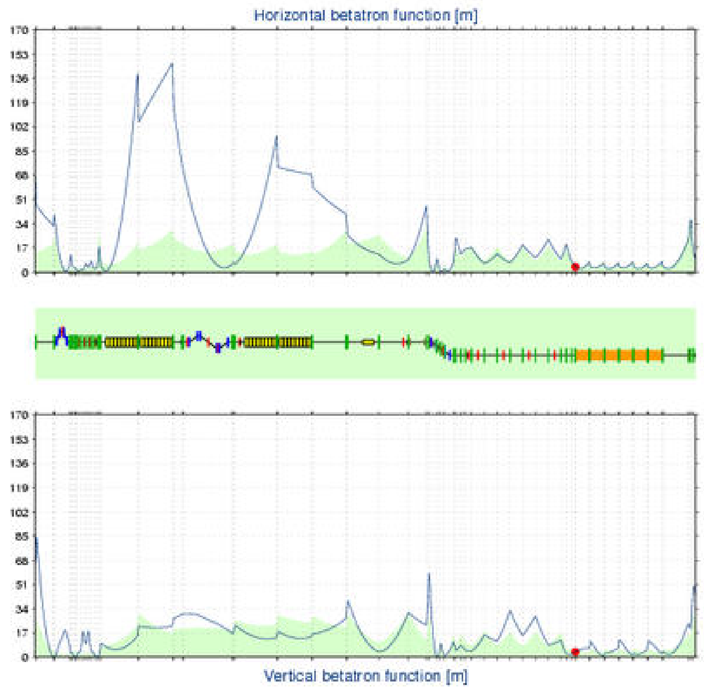
Comparison of the beta functions along the LINAC obtained by the 2 following ways

1. Measurement of the beta functions at DBC2 section and tracked up to the undulator
2. Measurement of the beta functions in the undulator and back-tracked up to BC2

On-crest case with sext off:

- ✓ agreement in the horizontal plane
- ✖ discrepancy in the vertical plane (reasons not yet understood)



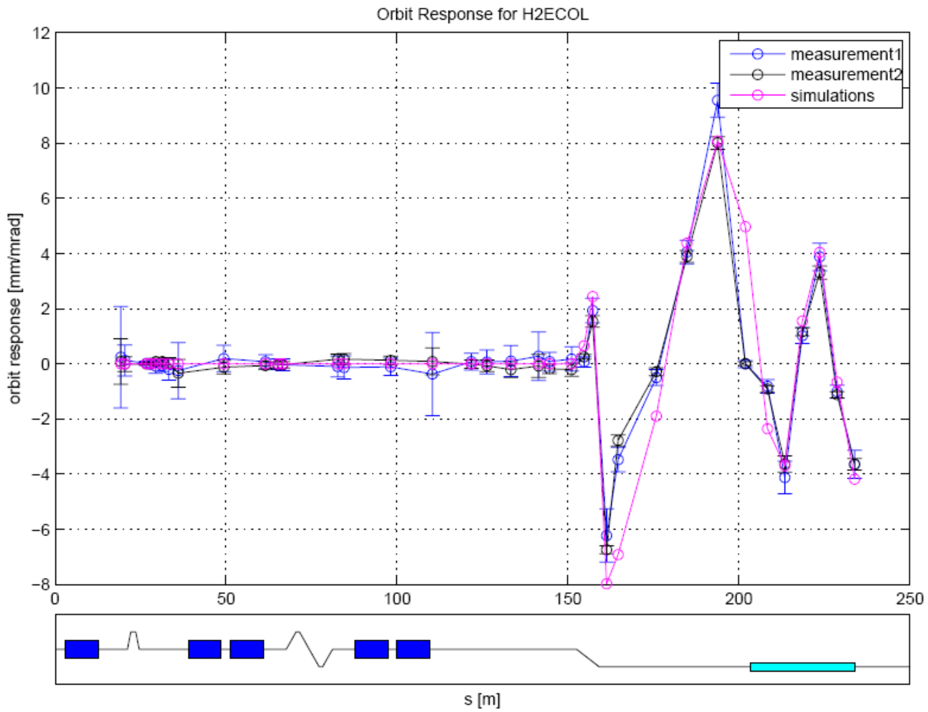



# Linear optics
# Orbit response matrix measurements

Orbit response term ⟶ $O_{i,j} = \dfrac{\Delta x_i}{\Delta \theta_j}$ Change of the orbit at the BPMs due to a change of a steerer strength (normal steerers and quadrupole movers)

Comparing the measured and design orbit response will make possible to fix errors in the machine

We have measured the complete response for all the machine (April and June 06) and the data is currently being analyzed



# Conclusions

- Emittance measured in injector larger than 2005, reason unknown (laser beamline, steering, solenoid settings, gun power etc.)
- We could not match the beam in the undulator. Emittance measured in the undulator 2-3 times larger than in DBC2. Dispersion correction helped at off-crest conditions but not at on-crest

- **Next steps**:
  - Work on the machine model
  - Check matching in the undulator
  - Simulate emittance measurement in the undulator
  - Magnet measurements of steerer with small current (0 → 350 mA)
  - Perform more measurements in DBC2 and undulator sections
  - Emittance measurements in SEED section (wire scanners installed in SEED section in Spring 2007)