# TESLA Module RF Modeling

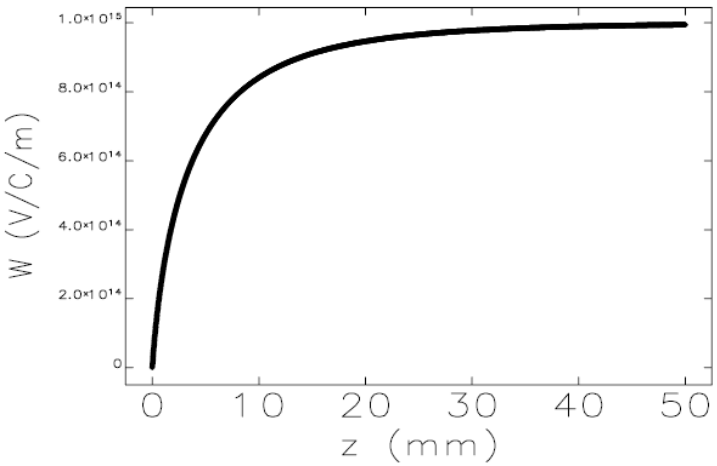
# in elegant

- Effects
  - Structure wakefields → TRWAKE (Green function)
  - Coupler wakefields → TRWAKE (Green function)
  - Coupler kicks → RFDF (Transverse deflecting cavity)
- Applications
  - Beam tilt measurements at BC2
  - Emittance growth due to orbit bump through ACC23

**FEL Beam Dynamics Meeting, 2nd of April of 2007**
**Eduard Prat, DESY**

# Structure and coupler wakes – Green functions

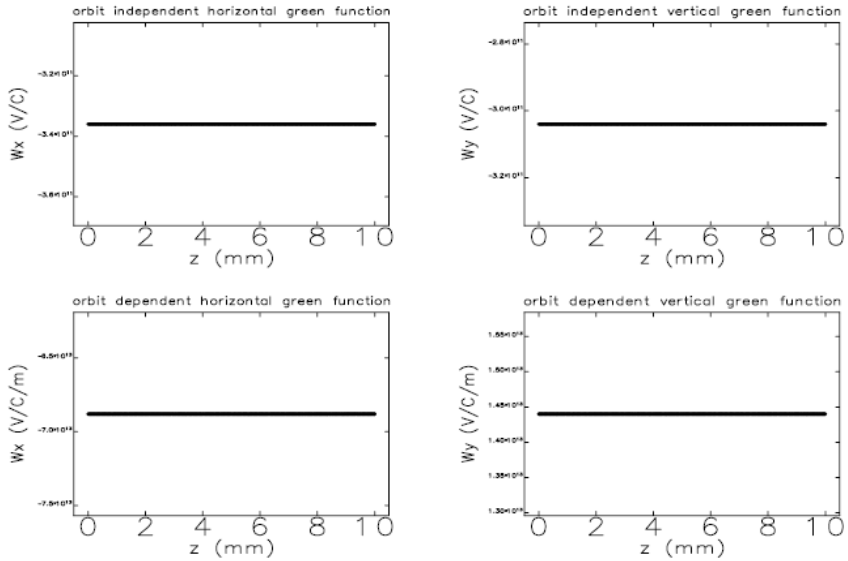
## Structure wake




$$w_T = 10^{-9}\left(1-\left(1+\sqrt{\frac{s}{0.92\cdot 10^{-3}}}\right)\cdot e^{-\sqrt{\frac{s}{0.92\cdot 10^{-3}}}}\right)\left[\frac{V}{C\cdot m\cdot \text{module}}\right]$$

Reference:
*The short-range transverse wake function for TESLA accelerating structure*
*T. Weiland, I. Zagorodnov*
*TESLA Report 2003-19*

## Coupler wake



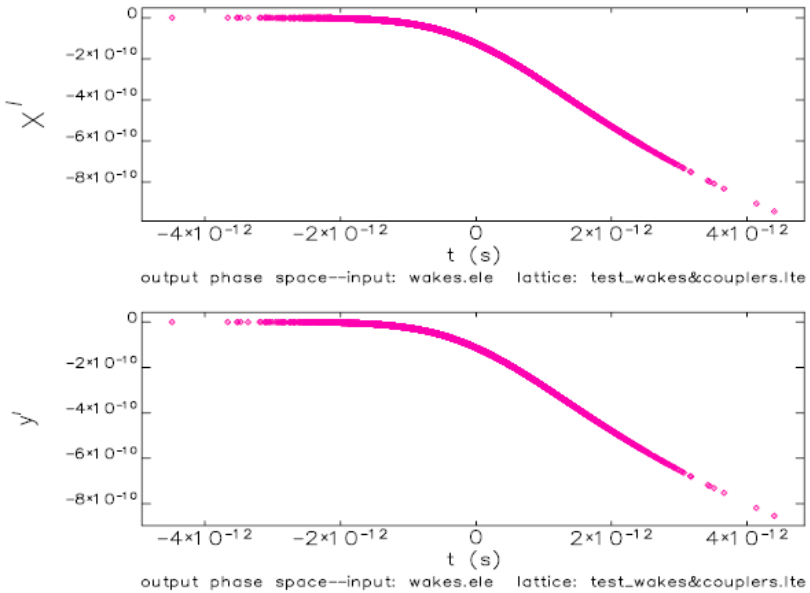

$$\mathrm{k_T}(x,y) = 1e^{-12}\left(\begin{pmatrix}-0.021\\-0.019\end{pmatrix}+\begin{pmatrix}4.3 & 0.07\\0.03 & -0.9\end{pmatrix}\cdot\begin{pmatrix}x[m]\\y[m]\end{pmatrix}\right)\left[\frac{V}{C\cdot m\cdot \text{module}}\right]$$

$$w_T(x,y) = 2\cdot \mathrm{k_T}(x,y) \qquad \text{(Igor)}$$

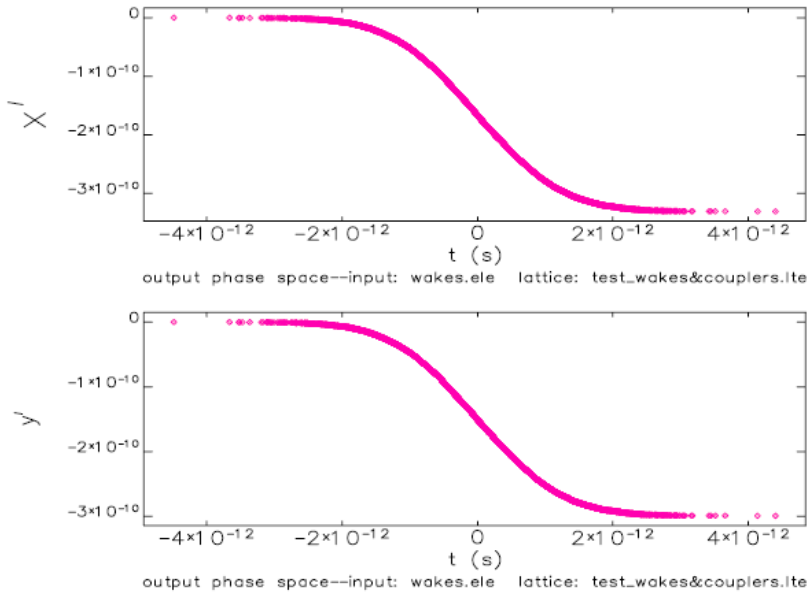
*Short Range Wakefields of the Couplers*
*I. Zagorodnov, M. Dohlus*
*HOM workshop DESY, 22-01-07*

# Effects of structure and coupler wakes to a Gaussian beam (σ=300μm)

Structure wake +orbit deviation (x=2.9mm, y=2.6mm)




Coupler wake on axes



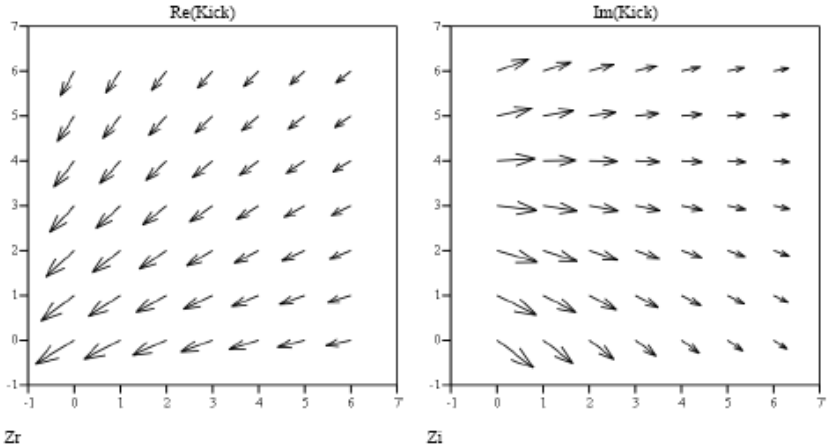

Both wakes give the same kick factor $\longrightarrow$ $\mathrm{k_T}(x,y) = 1e^{-12}\left(\begin{pmatrix} -0.021 \\ -0.019 \end{pmatrix}\right)\left[\frac{V}{C}\right]$

# Coupler kicks

**TTF coupler, upstream, old geometry, zpen=8mm**

center: $\frac{Vx_{ii,jj}}{Vz}\cdot 10^6 = -59.065 + 9.373i$

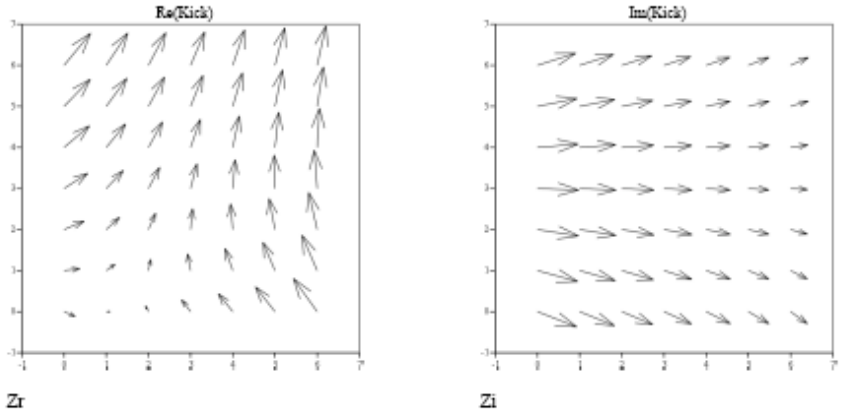
$\frac{Vy_{ii,jj}}{Vz}\cdot 10^6 = -43.218 - 1.847i$



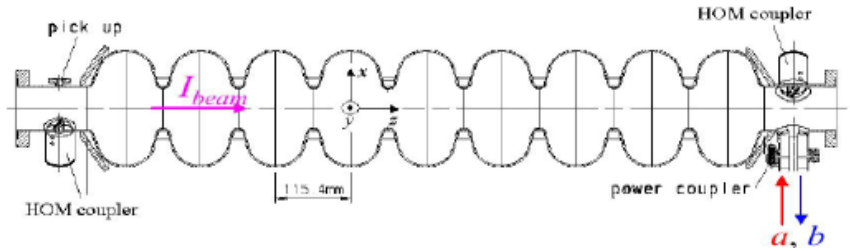

**TTF coupler, downstream, old geometry, zpen=8 mm**

center: $\frac{Vx_{ii,jj}}{Vz}\cdot 10^6 = 11.367 + 48.623i$

$\frac{Vy_{ii,jj}}{Vz}\cdot 10^6 = 45.459 - 2.77i$



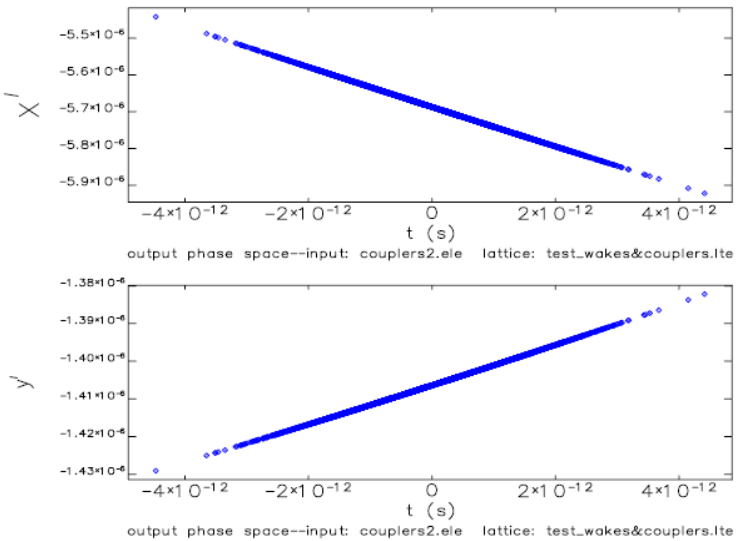

Calculations done by Martin Dohlus



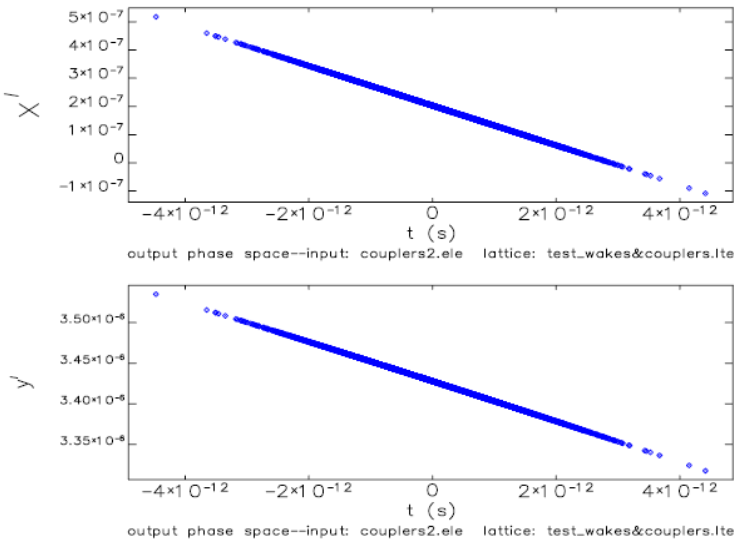

In elegant: Implemented as transverse deflecting cavities (RFDF)
Orbit dependence solved iteratively

# Effects of coupler kicks (1 cavity) to a Gaussian beam (σ=300μm)

On axes

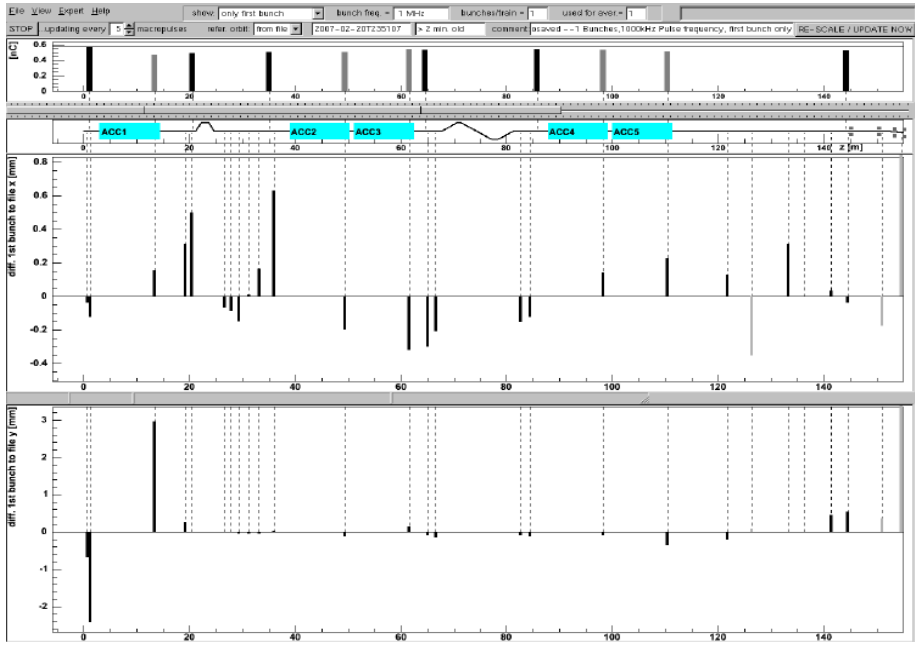


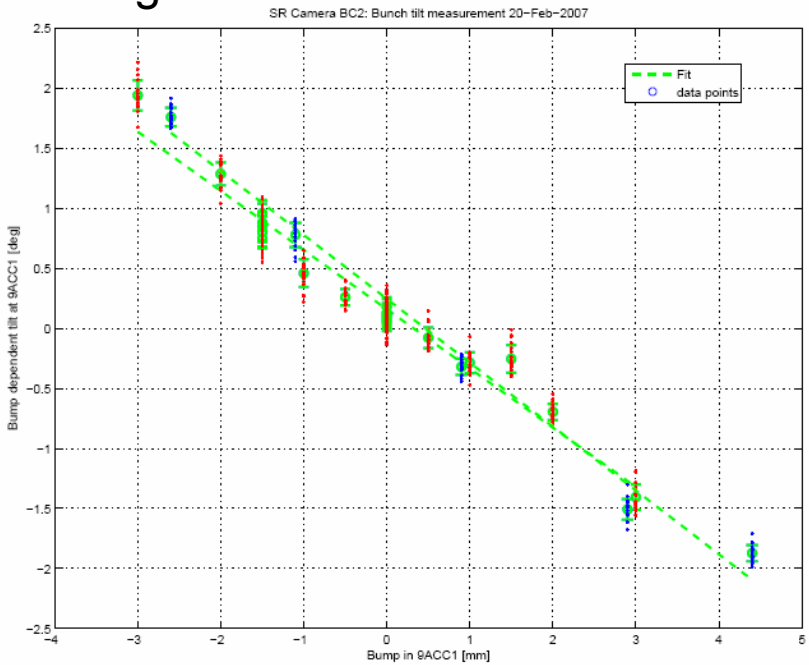

Off axes (x=2.9mm, y=2.6mm)



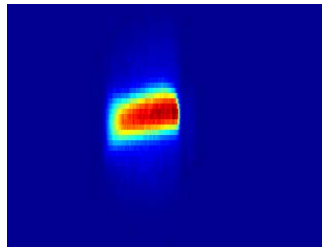
# Application: Beam tilt at BC2 (24-1-07 & 20-02-07, C. Gerth, K. Hacker, E. Prat)

The idea is going diagonally through ACC1 applying vertical orbit bumps, measure beam profile using the SR camera at BC2 &
calculate the x-y tilt for different bump amplitudes and different charges




Orbit bump refers at BPM9ACC1. Done with V2GUN and closed with V10ACC1 and V1UBC2. V2GUN is coupled.



# Simulation conditions

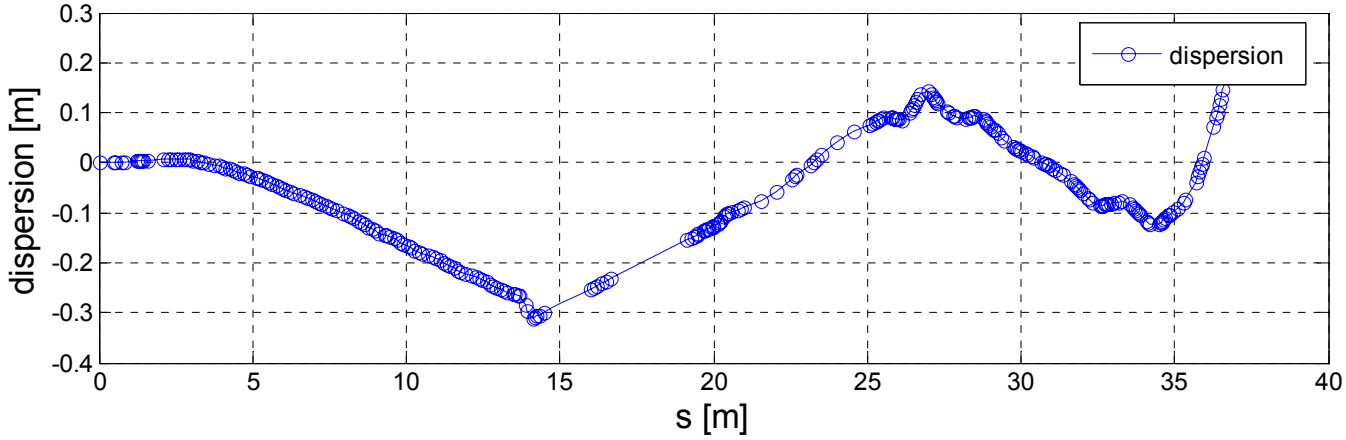
ACC1 voltage:  cavities 1 to 4 → 11.42MV/m Cavities 5 to 8 → 18.42MV/m
Energy after the gun → 4.5 MeV
Energy after ACC1 → 127 MeV
ACC1 off-crest by 8 degrees

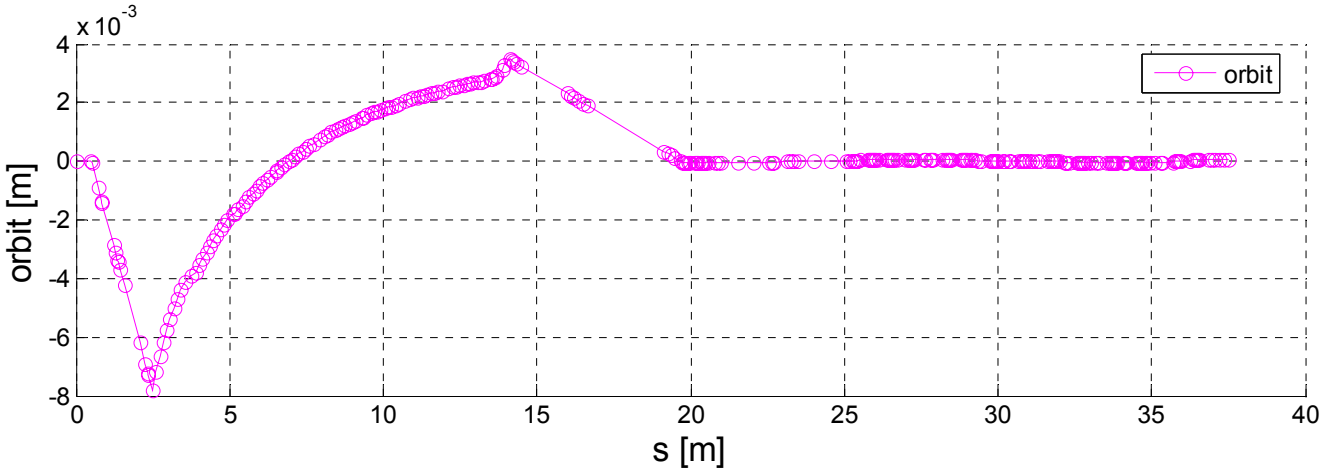
Charge = 0.6 nC

Gaussian beam: transverse emittance = 2mm mrad
Bunch length = 1.7mm
Fractional momentum spread = 0.05 / Additional momentum chirp = -2.5 $m^{-1}$

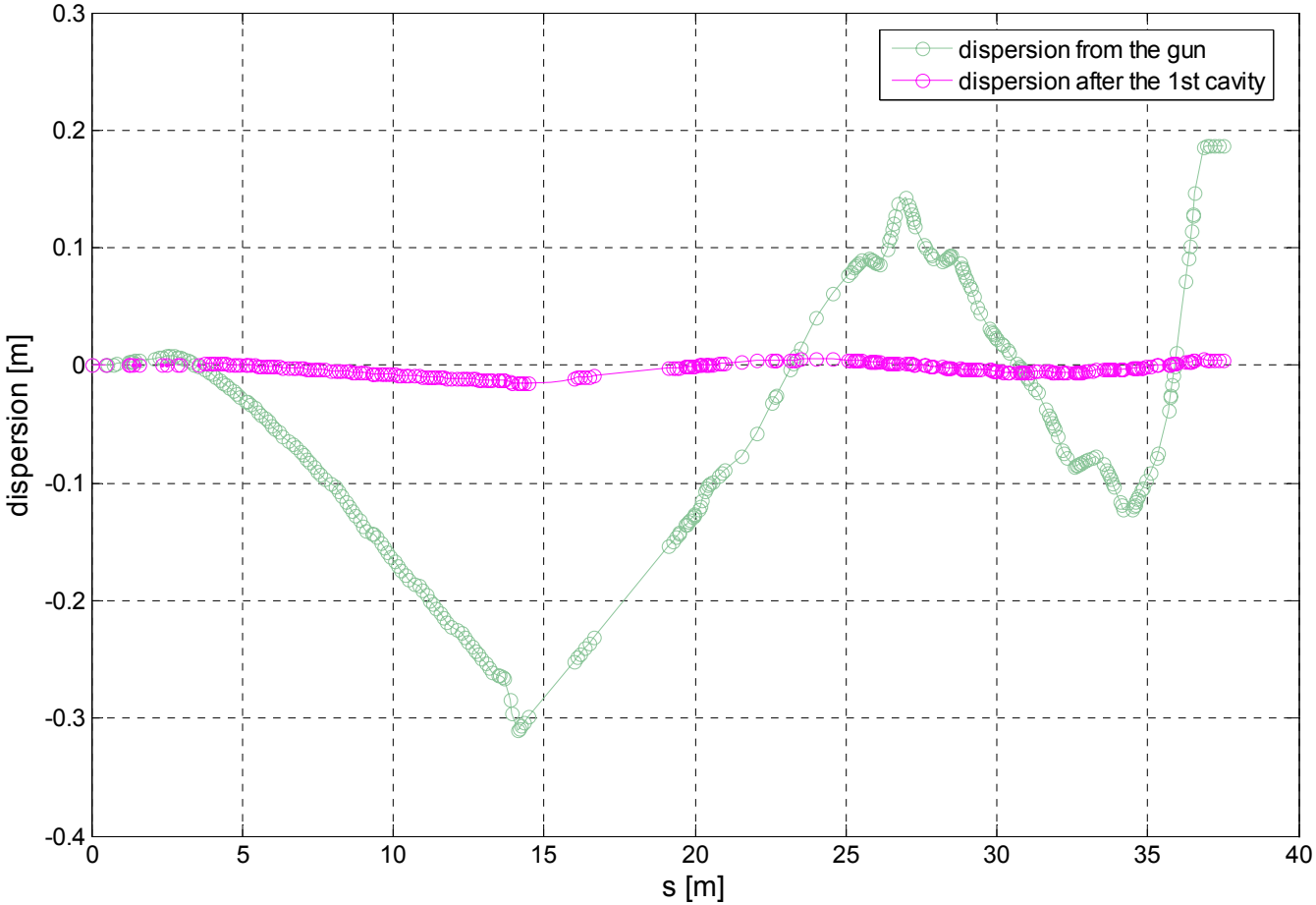
ASTRA beam (backtracked from downstream ACC1 with 8 degrees off-crest up to the GUN)

# Orbit and dispersion

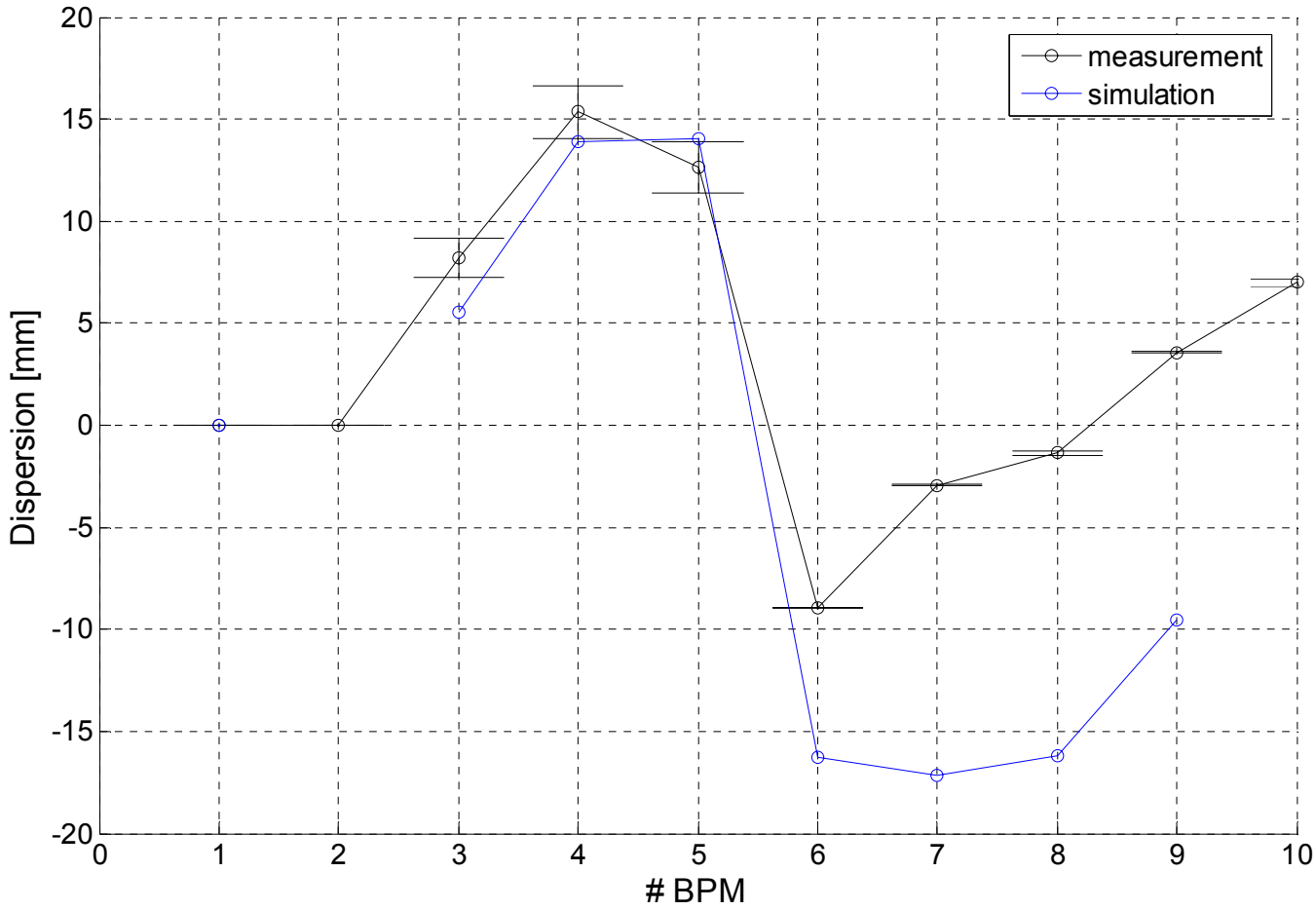


# Most of the dispersion generated at the 1st cavity of the module



# Measured vs simulated dispersion (+3mm bump)



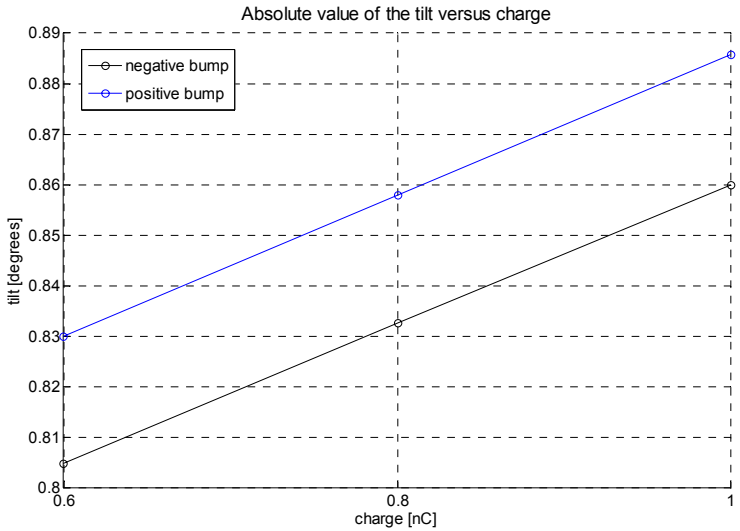
# Simulation results I (Gaussian beam)

| | Tilt (degrees) | |
|---|---|---|
| **Bump amplitude** | **+3 mm** | **-3 mm** |
| Basic case | -0.75 | 0.72 |
| + cavity wakes | -0.83 | 0.81 |
| + coupler wakes | -0.71 | 0.76 |
| + coupler kicks | -0.77 | 0.71 |
| **+ all together** | **-0.80** | **0.84** |

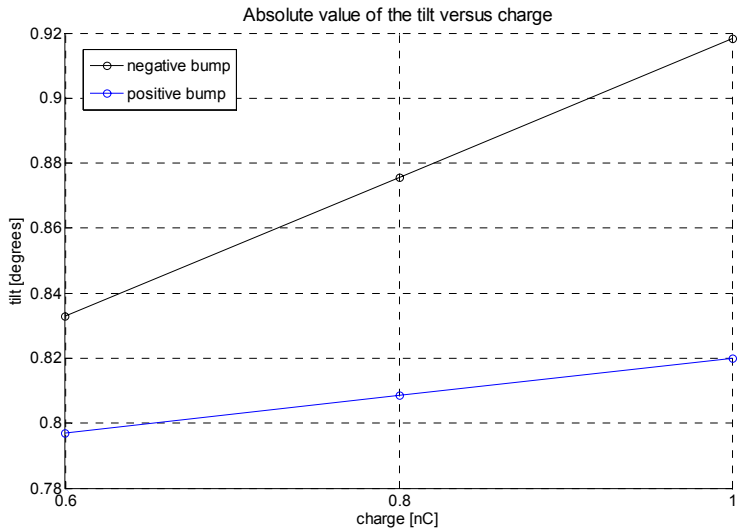
- Main contribution: dispersion generated in the module and in the quadrupoles
- Structure wakes amplifies the tilt by ~10%
- Coupler wakes and kicks: “only” add a tilt

# Simulation results II (Gaussian beam): Charge dependence

With structure wakes



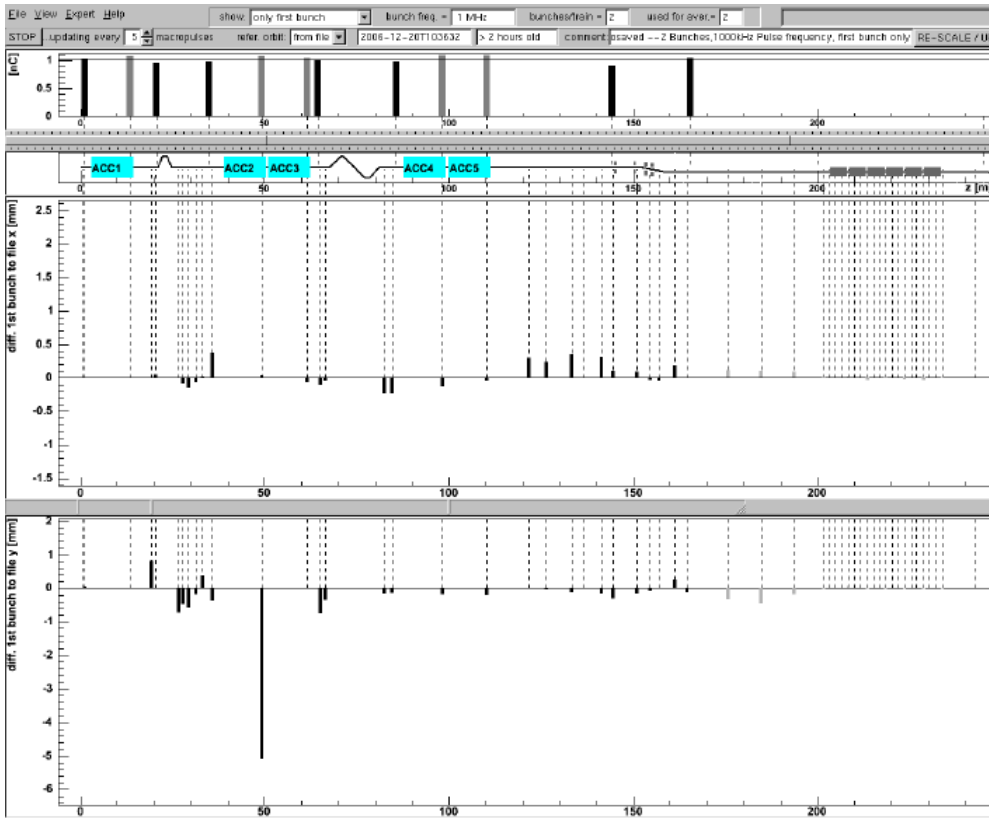

With structure wakes, coupler wakes and coupler kicks




Due to coupler effects, charge dependence on the tilt differs for positive and negative bumps

**We need more work on simulations and on the analysis of the measurements data…**
**…more results and comparisons between measurements and simulations will follow.**

# Application: Emittance increase due to orbit bump through ACC23 (20-12-06, K. Honkaavara, F. Loehl, E. Prat)




- 2 emittance measurements in the SEED section one after the other.
- The difference is going with a bump of -6 mm trough ACC23.
- This led to an emittance increase of more than a factor of 2

**Simulations including wake fields predict much smaller effect …**

**Other effects???**

| Where & when | Comments | $\varepsilon_x$ [mm mrad] | $\varepsilon_y$ [mm mrad] |
|---|---|---|---|
| Seed 17.08h | 'Good' orbit' + 6mm y bump in ACC23 – matched | 4.09 ± 0.10 | 6.18 ± 0.15 |
| Seed 18.27h | Corrected to 'good' orbit – matched | 3.83 ± 0.13 | 2.64 ± 0.08 |

Thanks to Martin and Igor for their help!