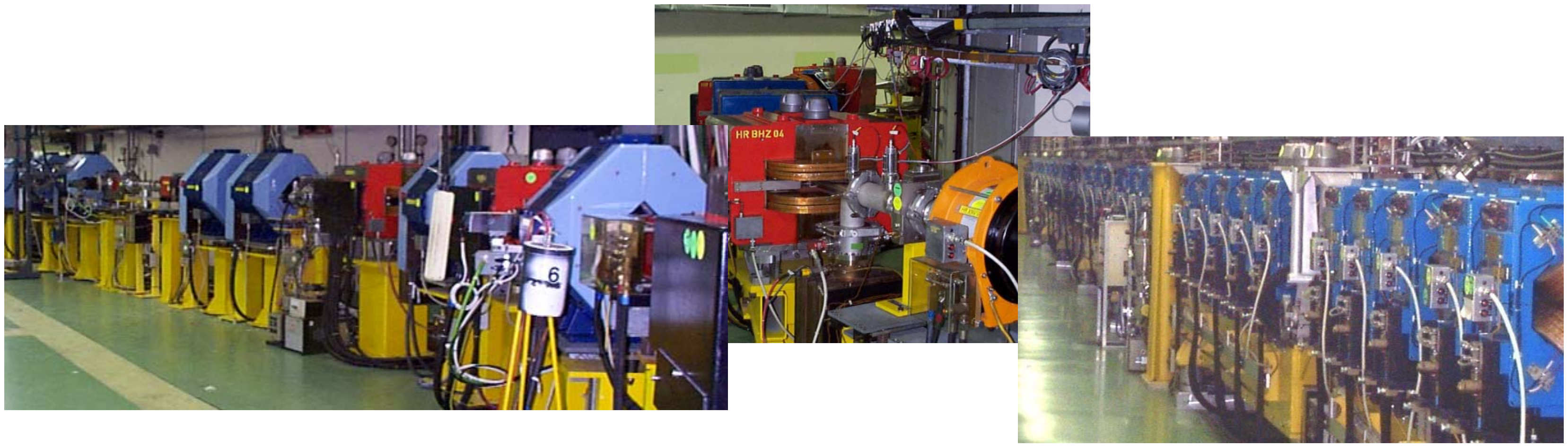
Tools in CTF3

Simona Bettoni
for the CTF3 operation team



Outline

→ The modeling:

→ Quad scans

→ Online model

→ The automatization of the measurements in CTF3:

→ Reading and writing on the machine

→ The measurements:

→ kick measurements

→ Dispersion measurements

→ Tune measurements

→ The tools:

→ Orbit correction in the ring

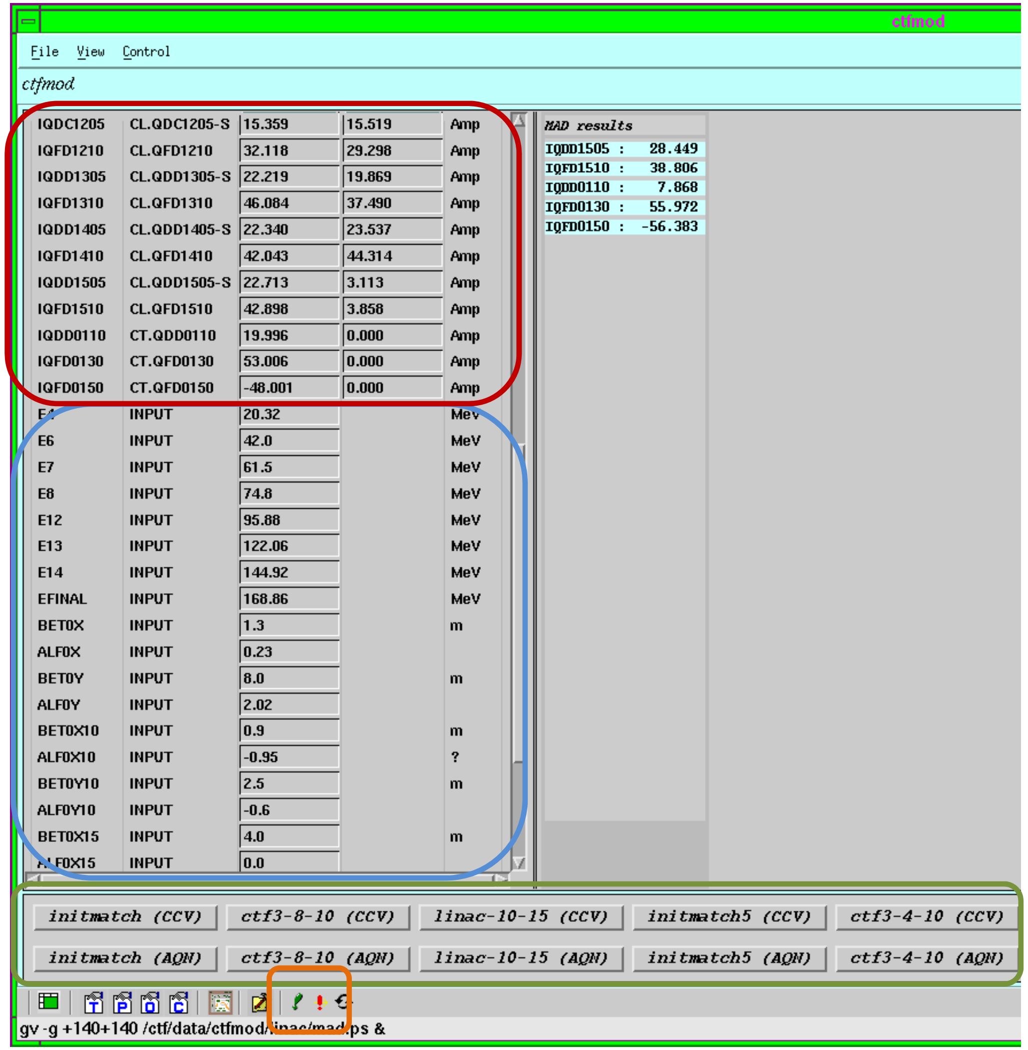
→ Orbit correction in the LINAC (see E. Adli talk)

Online MAD-X model of the machine

The currents in the machine are read and the K values are calculated

Energy profile and starting optical parameters (LINAC) are used

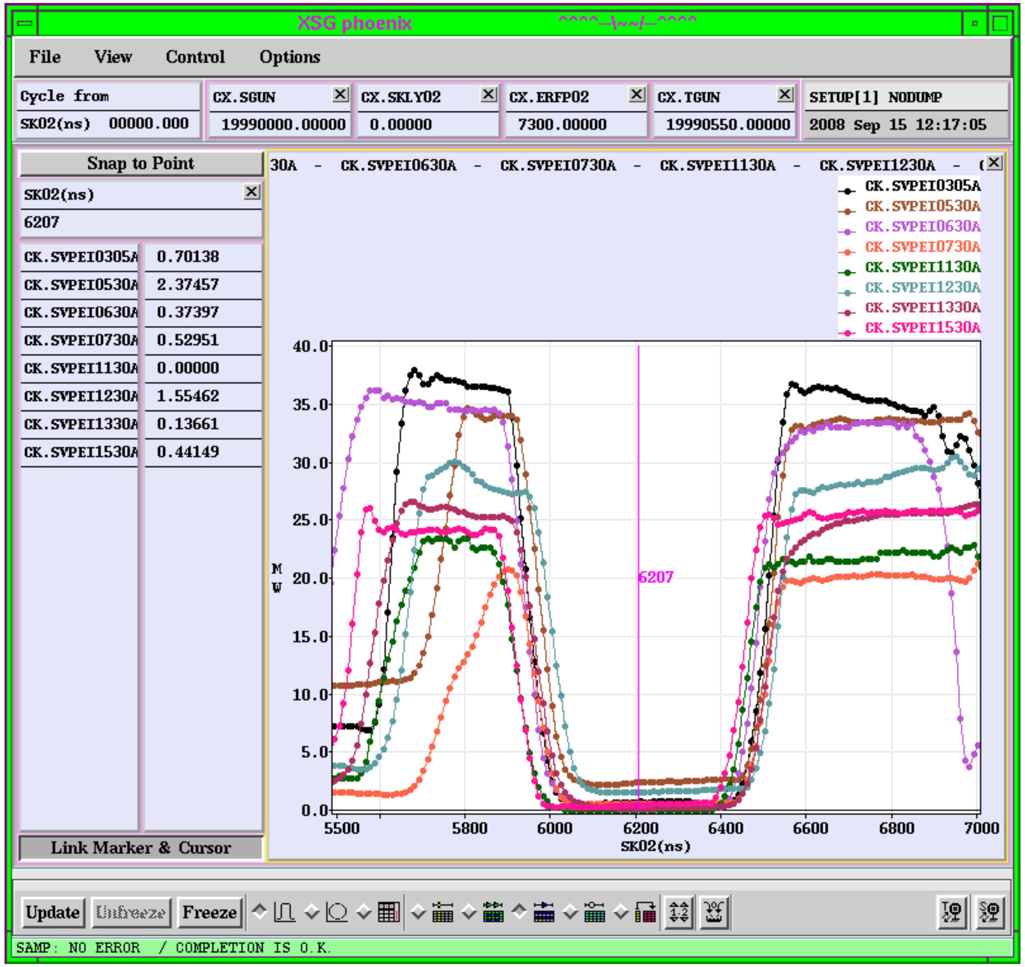
Several matchings can be easily integrated



The currents of the quads can be read and directly sent to the machine

Online MAD-X model of the machine: energy profile

- The energy profile is determined from the loading in the klystrons
  - Excel spreadsheet used



Input power in a klystron and beam current

↓

Extracted power

↓

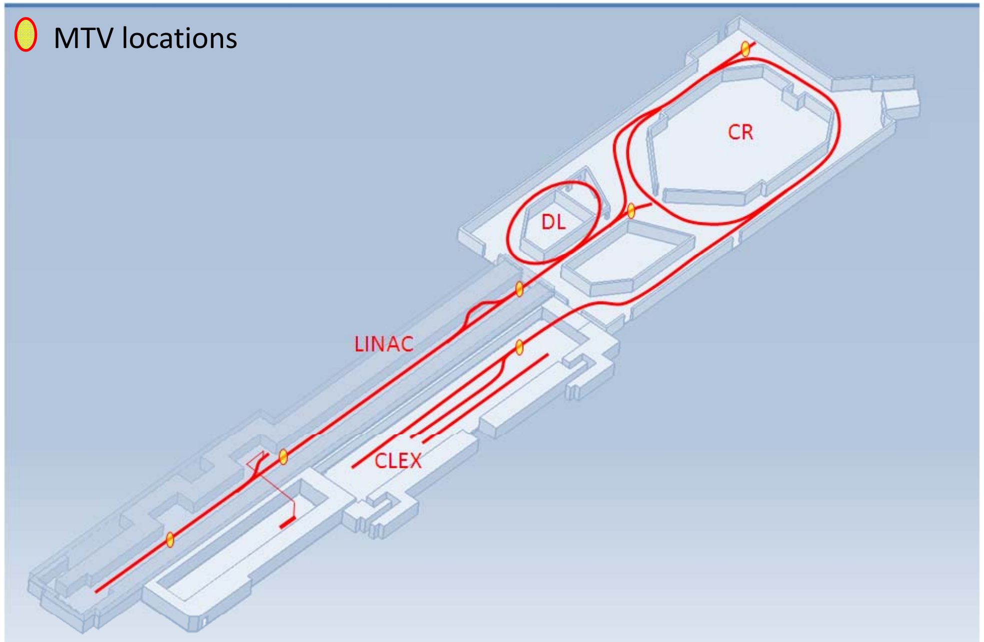
Beam acceleration

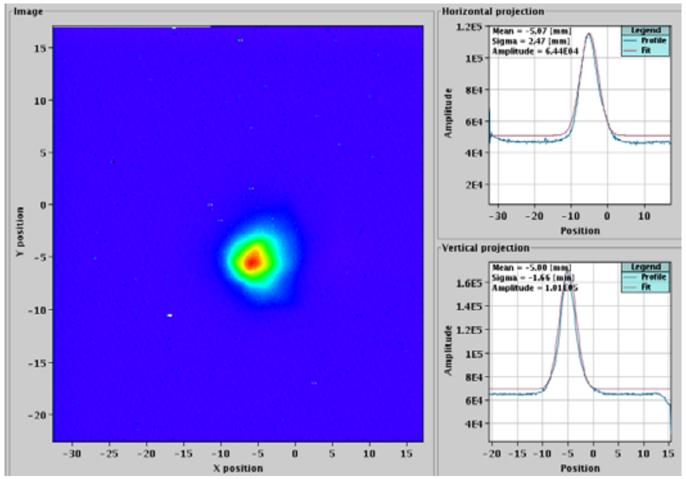
↓

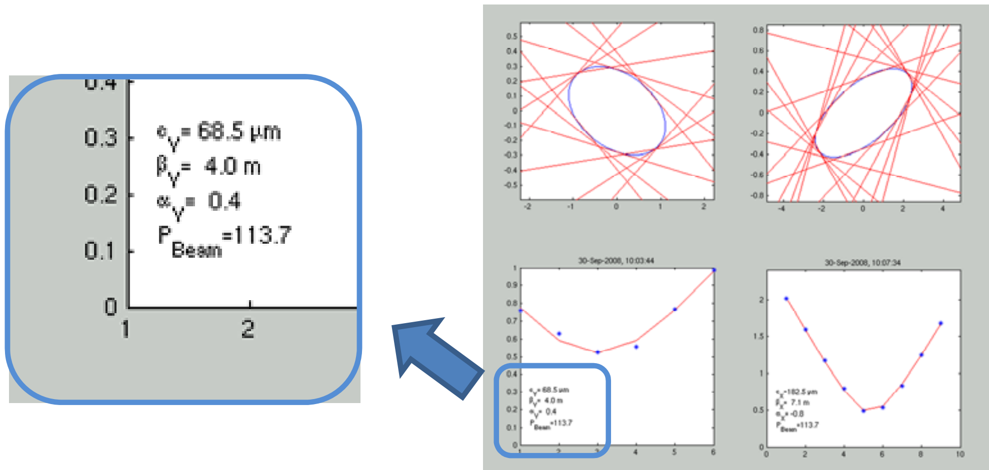
Beam energy variation in each structure

Online MAD-X model of the machine: initial conditions

→ Six monitors are installed in the machine to measure the twiss parameters and the emittances







Reading and writing on the machine

→ For each part of the machine a Matlab function defines the structure of the line or the ring (kind of equipment and name in the MAD model, status of the device)

function [quads, dipols, hcors, vcors, mons] = cr()

Magnets

Beam position monitors

Part of the machine

→ Function to read the orbit

function [hmean, vmean, currmean] = readorbit (devdescr, navg, nturn)

Positions and beam current

Device description and # averaging and turns (ring)

→ Function to automatically read and write the currents in the magnets

function readvalues = readdevices(devdescr)

function writedevices(devdescr,values)

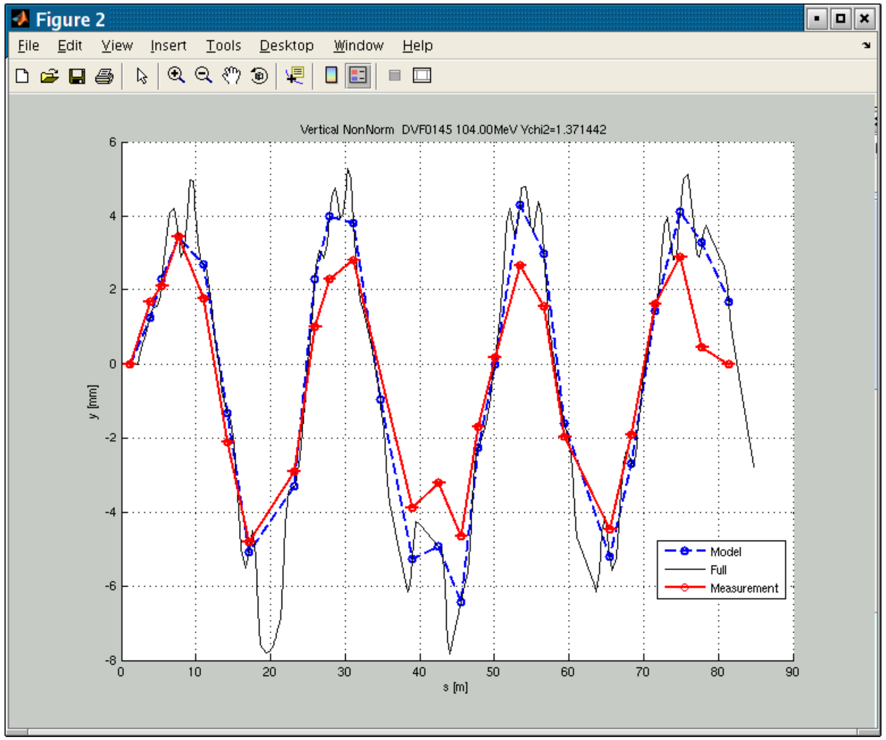
Kick measurements

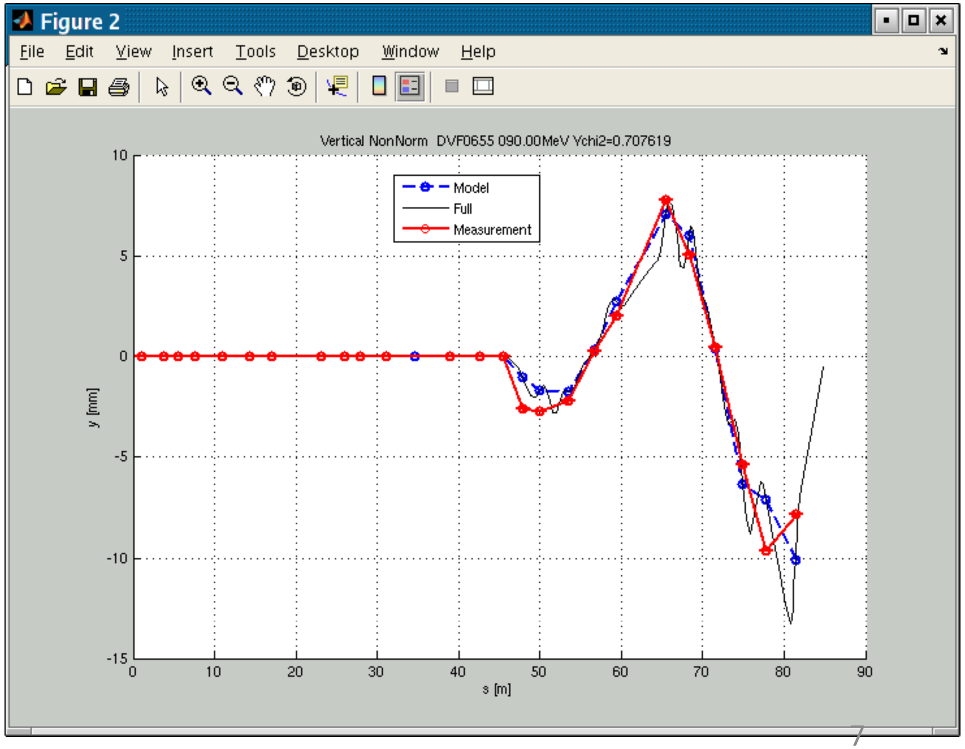
→ A reference orbit and the beam current along the line (ring) are measured

→ The current in a corrector is changed

→ The new orbit and the current in each beam position monitor are saved

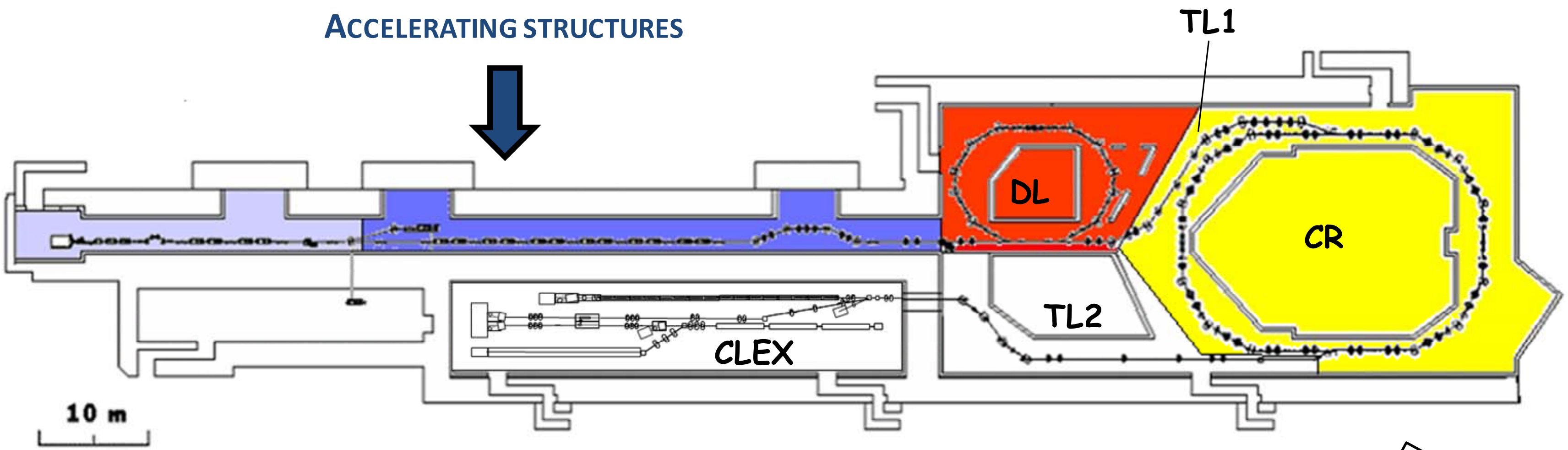
→ The orbit variation is compared to the MAD model prediction





Dispersion measurements: local

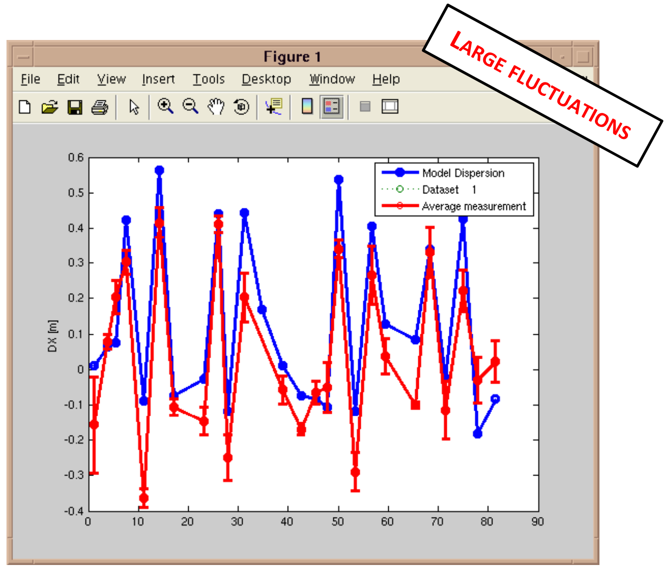
→ The contribution to the dispersion of each part of the machine is isolated and compared to the model predictions assuming 0 incoming dispersion



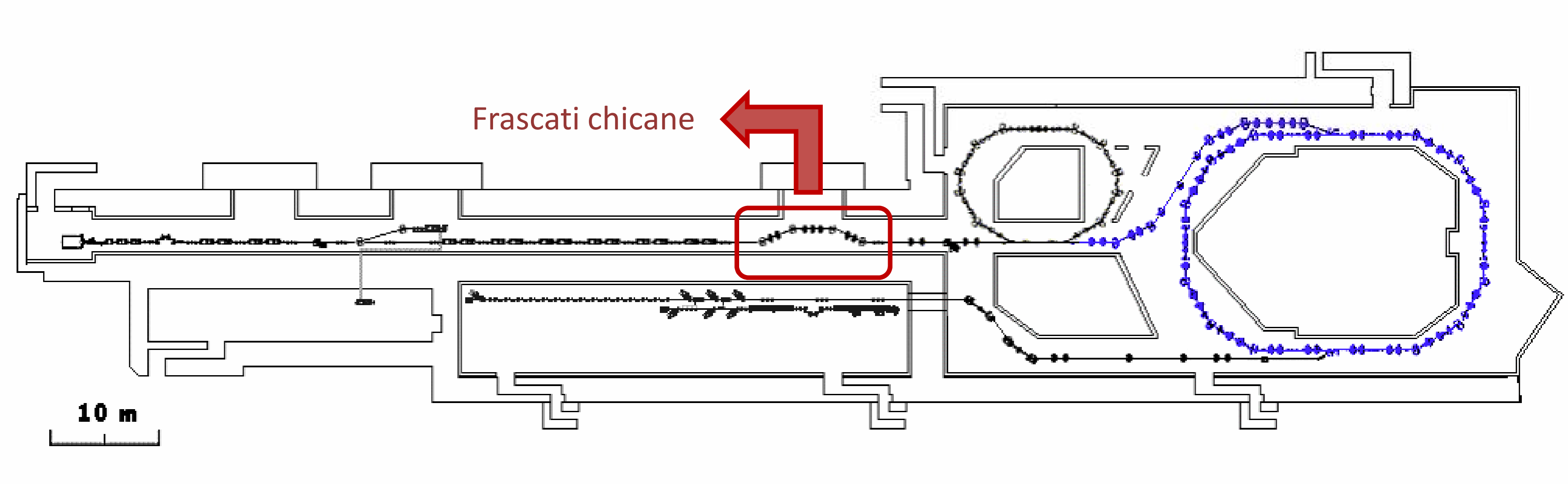
→ A reference orbit along the line (ring) is measured

→ The magnets in the line (ring) are scaled (typically of fraction of % or %)

→ From the orbit variation the dispersion is calculated



Dispersion: online and global measurement



→ A reference orbit of one shot saved along the machine

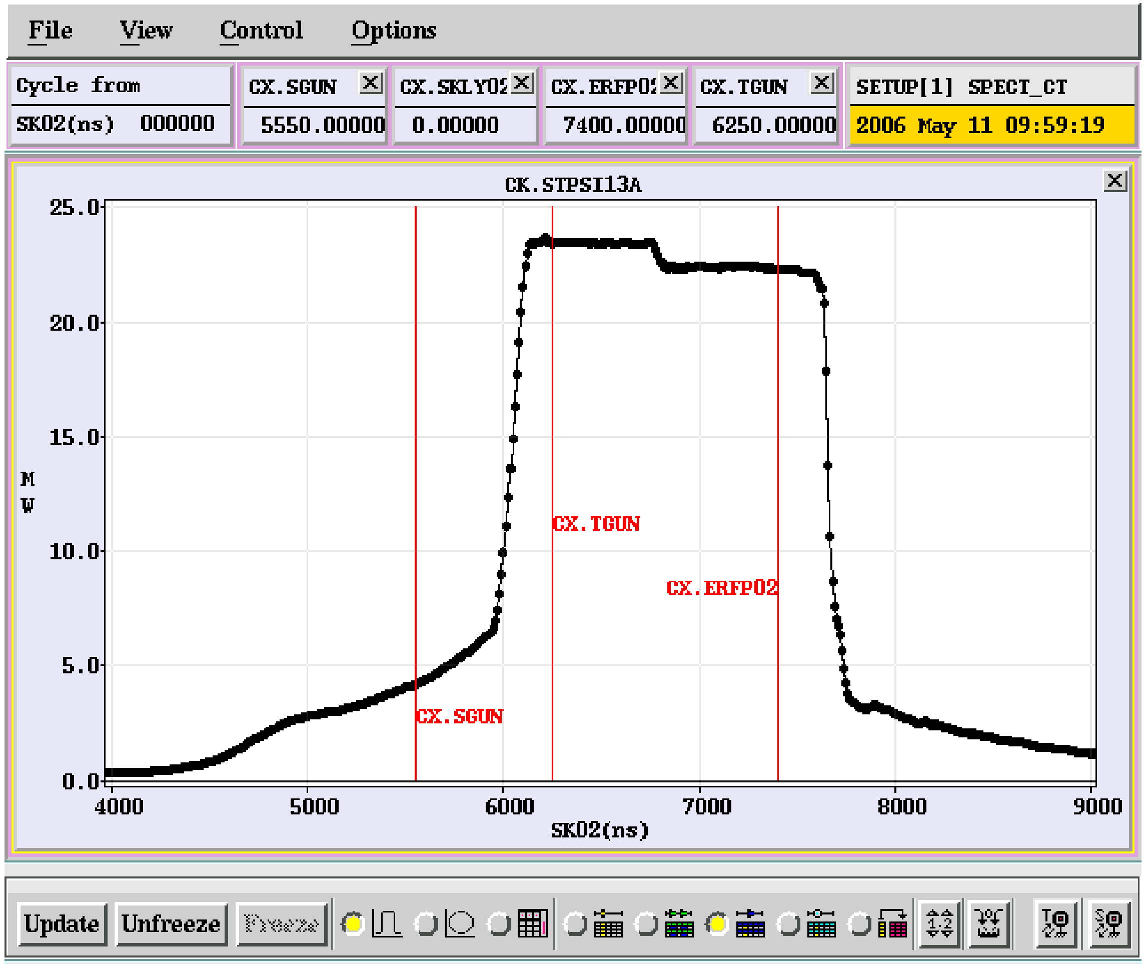
→ The orbit variation in a not free and well known dispersion (Frascati chicane) is used to compute the shot to shot energy deviation: from Δx (Δy) to $\Delta p/p$

→ Known the energy jittering, measuring the orbit deviation along the entire machine, the dispersion is computed: from $\Delta p/p$ to D_x (D_y)

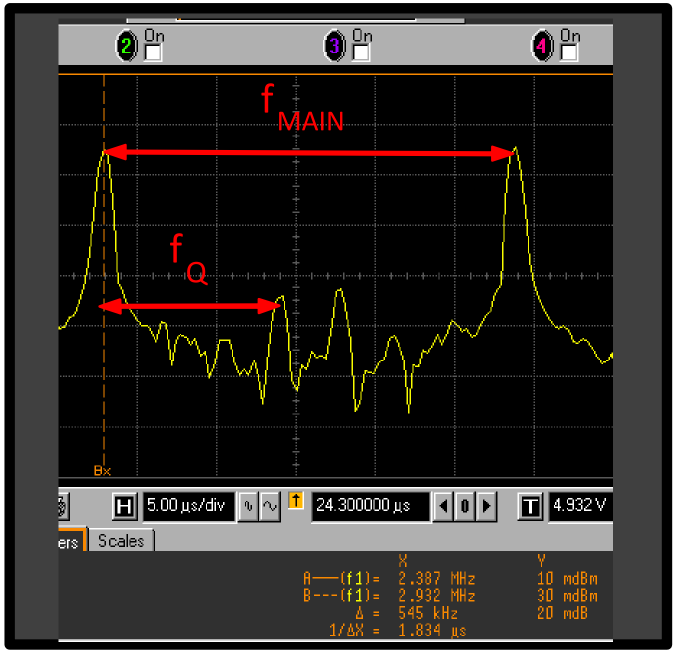
Dispersion measurements: energy step

→ An energy variation along the pulse in the last klystron of the LINAC is introduced

→ The beam position difference between the different parts of the pulse in the BPM is used to determine the dispersion



Tune measurements

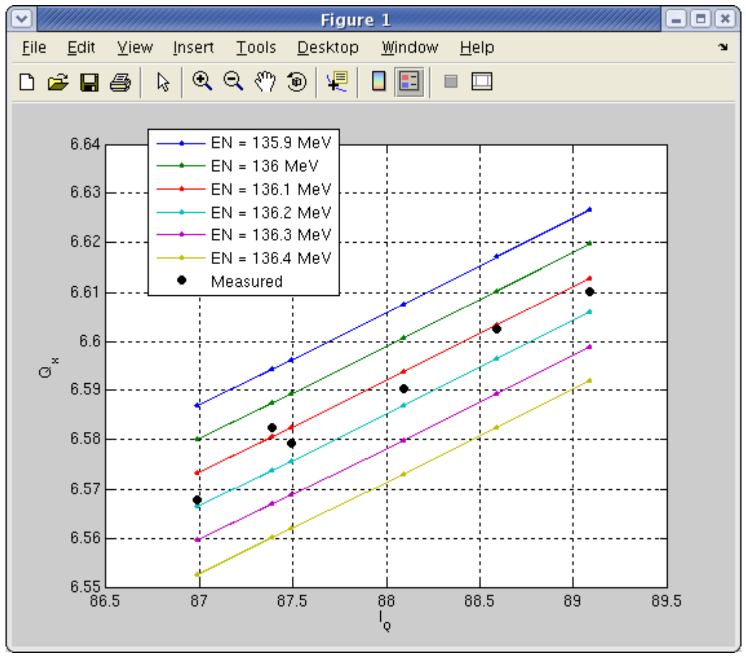


→ The measurement:

- → Tune determined from the Fourier transform of the H (V) signal in a BPM (scope signal)
- → Compromise between oscillation amplitude and number of turns (typically about 200)
- → Scan varying the current in a quads family

→ The model comparison:

- → Scan of the tunes as a function of the current in a quads family
- → Automatic scan over the energy range



Orbit correction: the algorithm

$$\min \left\| x_{BPM} - x_{REF} - RM \cdot I \right\|_I$$

RM: response matrix
X_{BPM}: transverse beam displacement at BPM
x_{REF}: reference orbit at BPM
I: currents in the correctors

$$\Delta x \equiv x_{REF} - x_{BPM}$$

$$\min \left\| \Delta x + RM \cdot I \right\|_I$$

* SVD decomposition

$$\Delta I = \tilde{R}(\varepsilon) \cdot \Delta x \quad \text{where} \quad \tilde{R}(\varepsilon) \equiv V \cdot \tilde{W}(\varepsilon) \cdot U^T$$

Singularity rejection parameter (eps)

$\varepsilon = 0$ ⇒ Normally most accurate orbit correction, BUT large current values can be obtained

$\varepsilon = 1$ ⇒ No orbit correction ($\tilde{R}(\varepsilon)$ null matrix)

Closed orbit correction using singular value decomposition of the response matrix, Y. Chung, G. Decker, K. Evans Jr., PAC 93 proceeding.

Orbit correction: the algorithm improvement

Best eps value iteratively determined:

→ Tolerance on the maximum allowed beam displacement and maximum value of the currents in the correctors

```
eps_start = 1
n_max_step = 10000;
fact = 1;
```

Starting inputs

```
for i = 1:n_max_step
if i == 1
    eps(i) = eps_start*fact;
else
    eps(i) = eps(i-1)*fact;
end
```

Eps value

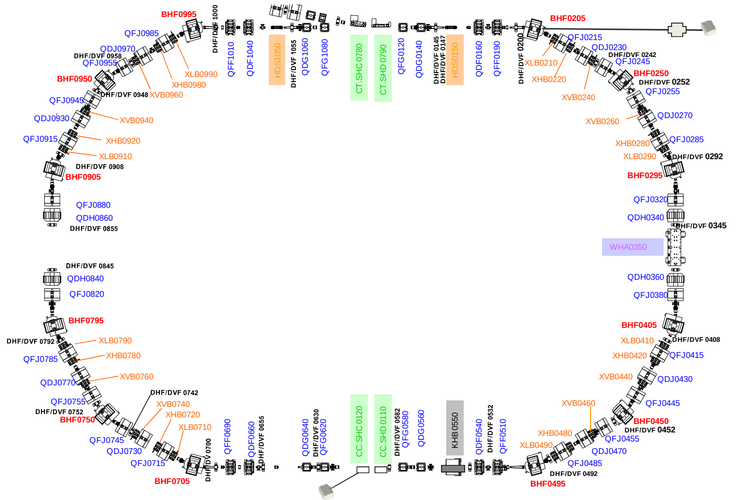
```
[theta_s,thetap_s,corr_s,final_s,idec_s] = correction_1_mod(eps(i),RM',x_BP');

Curr_tot_s(i,:) = start_corr'+theta_s;
Curr_tot_max(i) = max(abs(start_corr'+theta_s));
if abs(Curr_tot_max(i)) > max_I_corrs_tol
    fact = 1.1;
else
  x_max_exp = max(abs(x_BP+RM'*theta_s));

   if x_max_exp < tol
      break
   else
   end
    fact = 0.9;
end
end

Curr_tot = Curr_tot_s(end,:);
```

Check and new eps value

Orbit correction: the response matrix

Orbit closure:

→ The response matrix is built using both the first and the second turn orbits



Kick at corrector 252

Turn 1 (blue)
Turn 2 (red)

Correctors	145-S	200	242	252	292	345	408	452
BPM/BPI	155	195	208	248	275	305	395	405

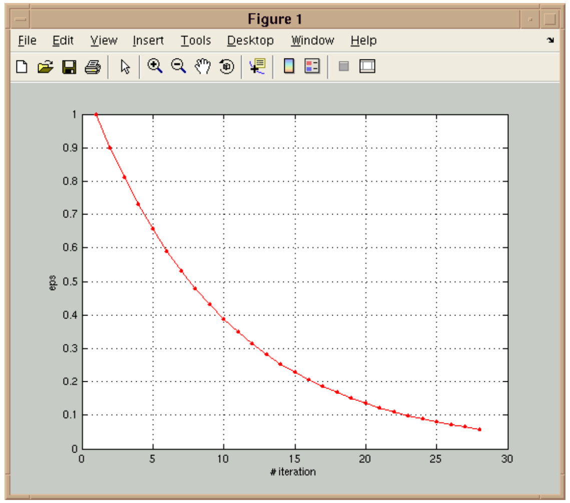
Kicks in the correctors:

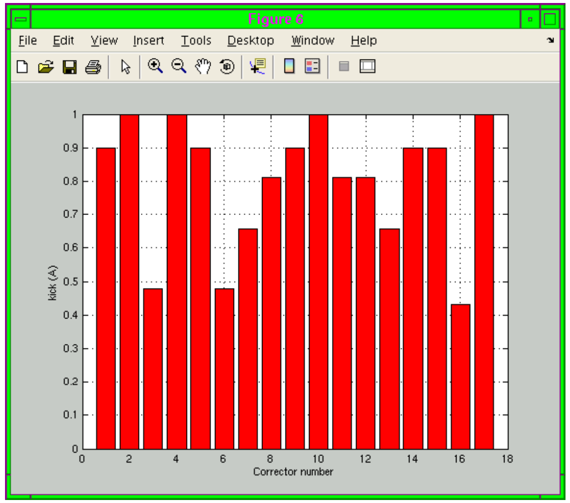
→ The value of the kick in each corrector is determined according to the maximum tolerated losses in the last read BPM/BPI

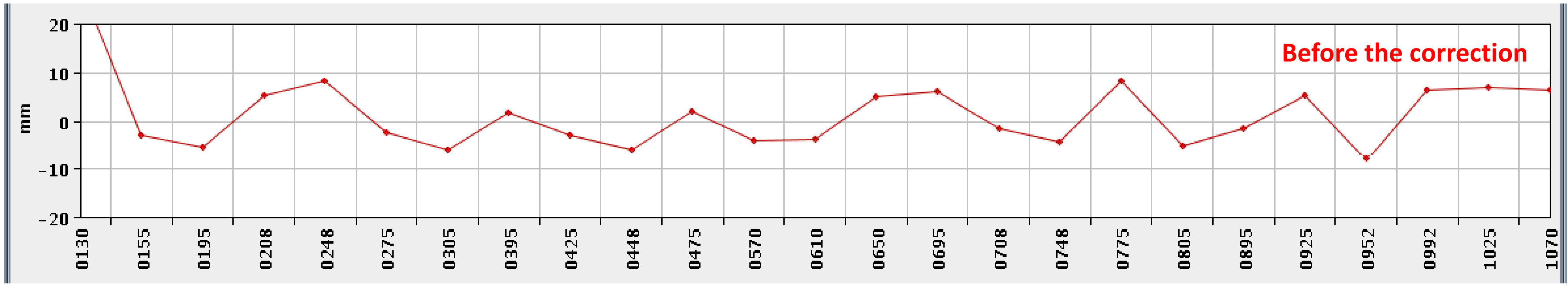
Orbit correction: the results

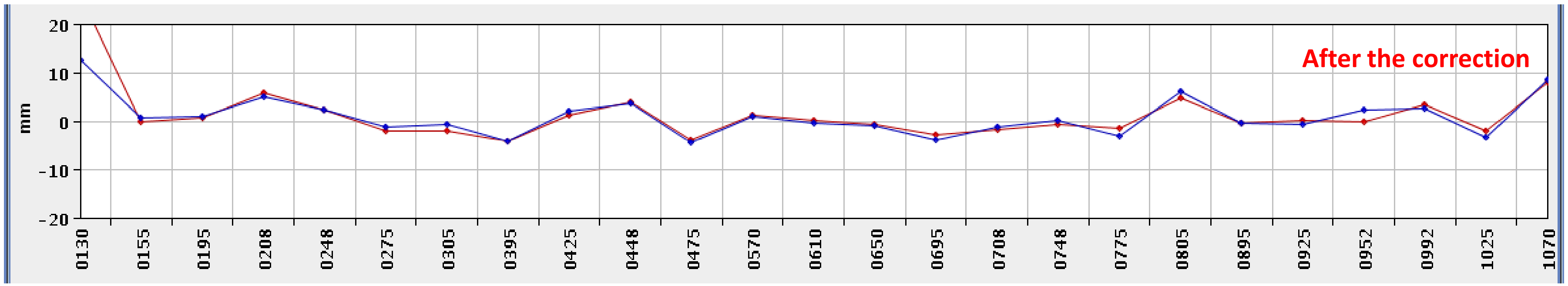
Inputs:

- → Tolerated maximum x-displacement = 4 mm
- → Maximum current in the corrections = 10 A
- → Maximum allowed losses = 10%



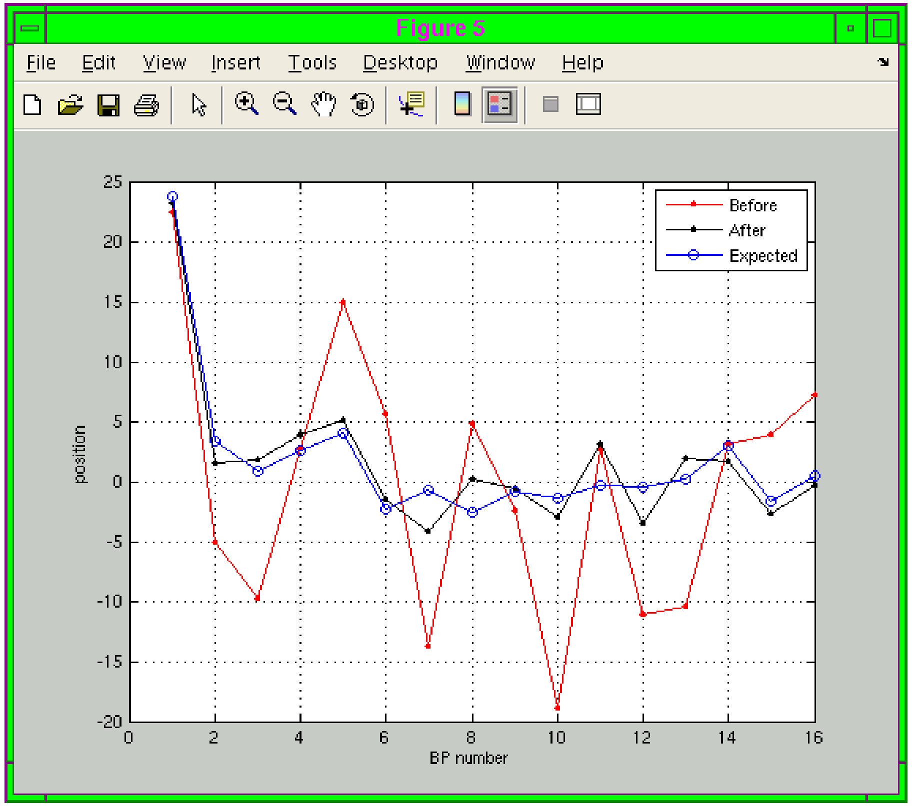


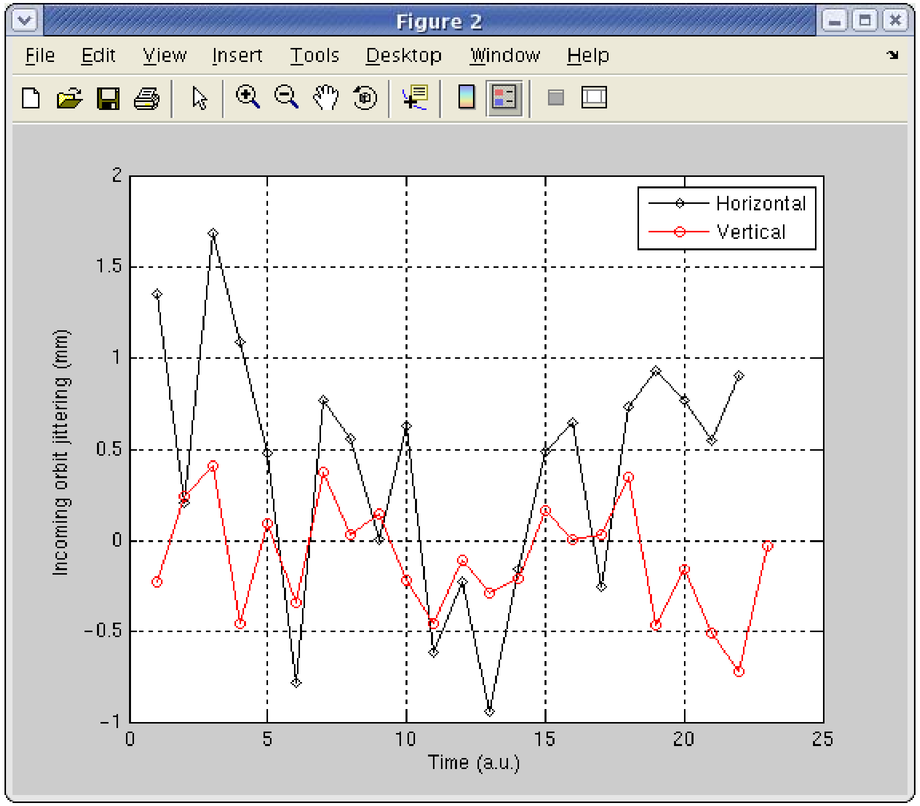




Orbit correction: the energy jittering

→ Tolerance on the orbit correction limited by the incoming orbit jittering





→ Possible cures:

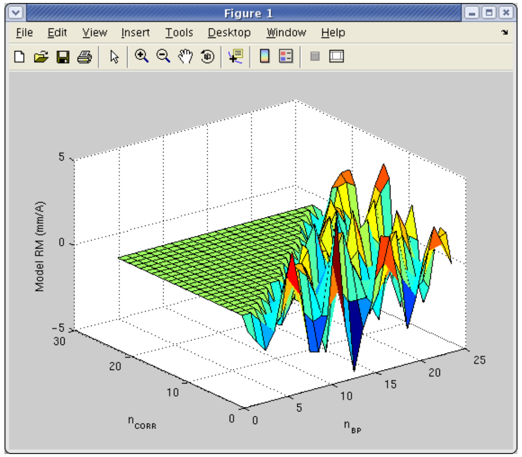
- → Increase the number of averaging (time consuming)
- → Subtract the orbit jittering due to dispersion pattern (to be tested next week)

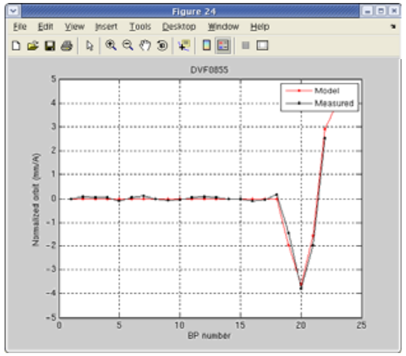
Orbit correction: model-based correction

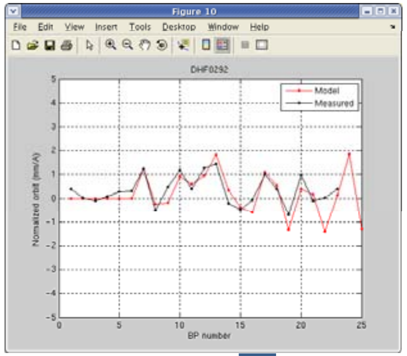
Use the model response matrix to correct the orbit at least for the first iteration:

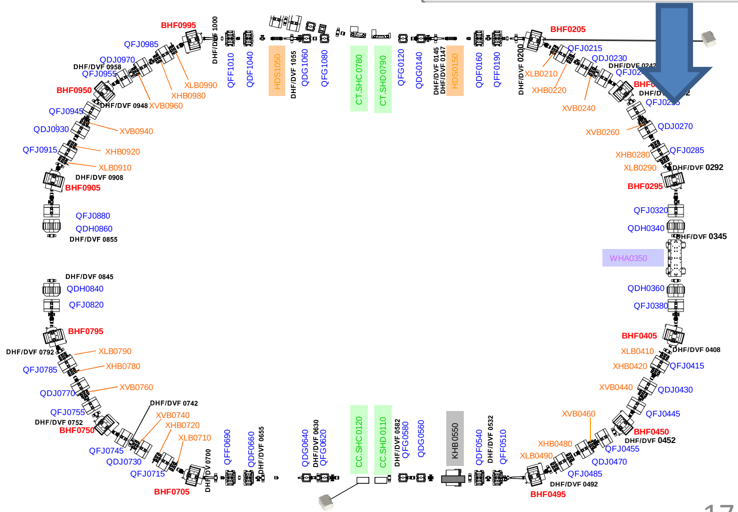
→ Quicker (response matrix measurement takes about 20 minutes)

→ Immediately scaled for the energy









Conclusions

→ In CTF3 Matlab scripts have been developed to modify the machine settings and read the orbits in the machine. This allows to do **automatically**:

- → Kick measurements
- → Dispersion measurements
- → Quad scans

→ Several tools have been developed to determine the optics model and to operate the machine:

- → Online model
- → Tune measurements
- → Orbit correction

→ Future developments:

- → Better study of the dependence of the measurements (kick and dispersion) on the energy jittering
- → Tune measurement automatization
- → Integration of the Matlab tools in the control system (more user-friendly)

Extra slides

Orbit correction: the results (vertical)

Inputs:

- → Tolerated maximum y-displacement = 1.5 mm
- → Maximum current in the correctors = 10 A
- → Maximum allowed losses = 10%