Beam Dynamic Issues at the CTF3 Linac & Delay Loop

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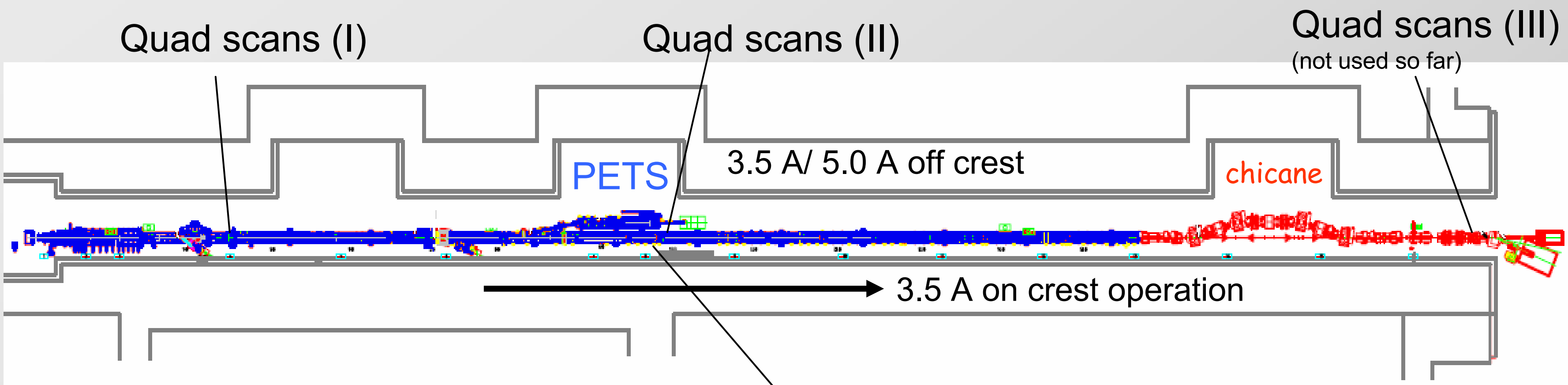
Outline

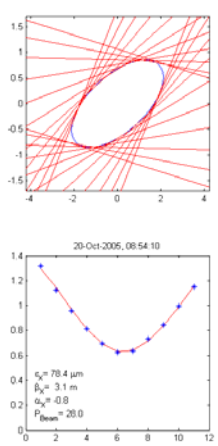
Collaboration Meeting

- **Measurement of the transverse beam emittance and Twiss parameters in the Linac:**
  - **Different modes of operation (on/off crest acceleration)**
  - **Different beam currents (**3.5 A **/ 5 A)**
  - **Comparison with simulations**
  - **How to get a better understanding of the emittance in the future**
- **Machine operation with delayed filling**

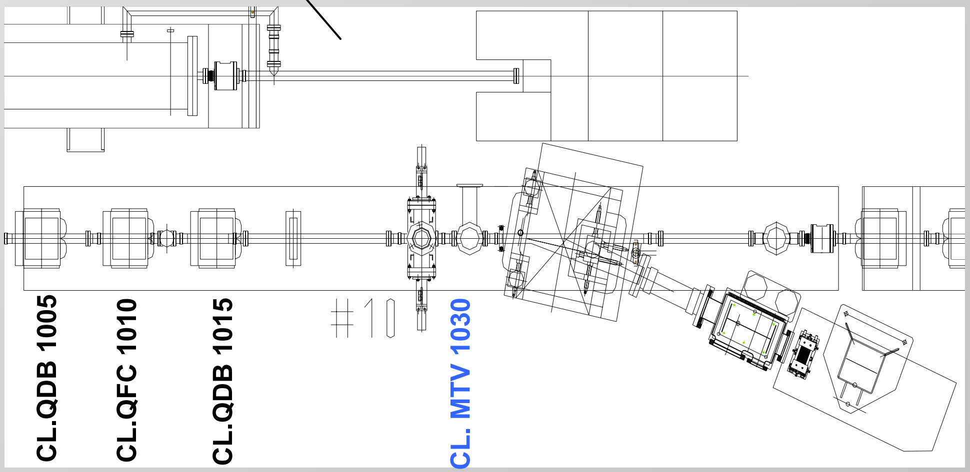
- **Delay Loop:**
  - **"Injection problem" into the Delay loop**
  - **DL optics and dispersion measurement**

CTF3-Linac – Emittance measurements





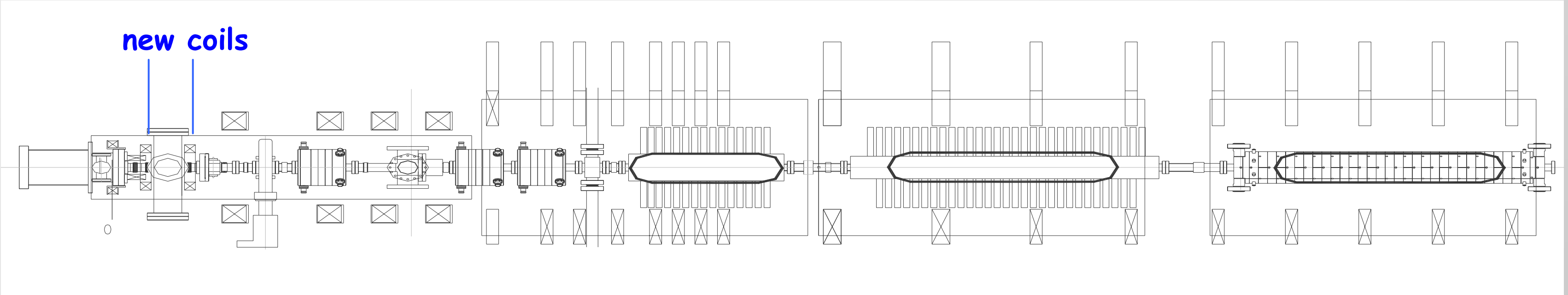
Typical quadrupole scan



- Comparison of simulated and measured emittances in girder 5.
- Re-matching of the optics from girder 5 to 10 or PETS.

Results I

CTF3 Injector in 2005, new coils (decrease of emittance by a factor 2 (Parmela Simulations))



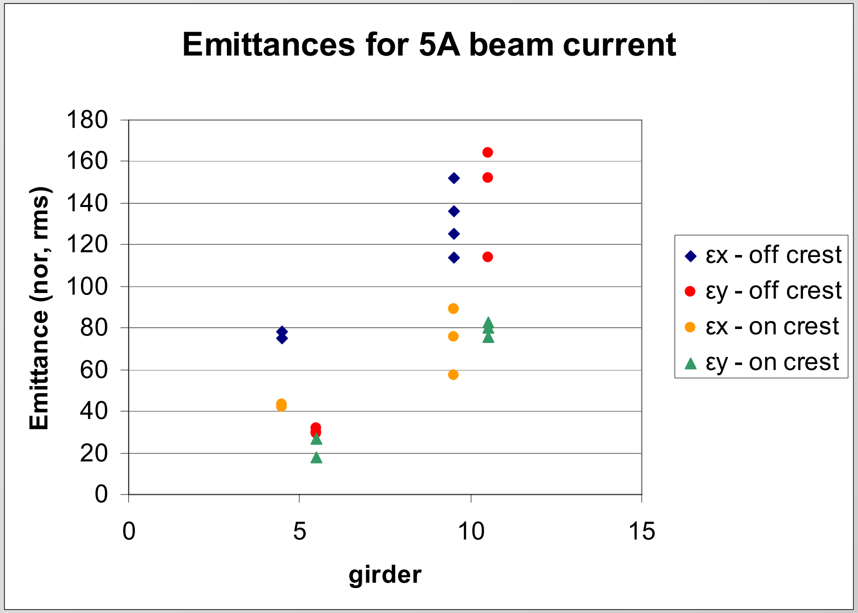
Overview on results (For the first time intensive studies in the CTF3 Linac performed, 5A)

- Nominal emittance (normalised, rms): 100 π mm mrad (for 3.5 A on crest operation)
- Simulation: 15 - 25 π mm mrad (3.5 A/ 5 A, on/off crest, after magnetic chicane)

current [A]	on/off crest	girder	$E_{x,n,rms}$ [π μm]	$E_{y,n,rms}$ [π μm]
5.0	on	5	45	25
5.0	off	5	75	30
5.0	on	10	85	80
5.0	off	10	130	140

Results II

current [A]	on/off crest	girder	$E_{x,n,rms}$ [π μm]	$E_{y,n,rms}$ [π μm]
5.0	on	5	45	25
5.0	off	5	75	30
5.0	on	10	85	80
5.0	off	10	130	140



- Excellent results for vertical emittance – almost as simulated!
- Factor 2 larger horizontal emittance
- Emittance increase from girder 5 to girder 10, but still below nominal.
- Important for the PETS operation

What are the Problems?

Girder 5: $\varepsilon_x \sim 2 \times \varepsilon_y$

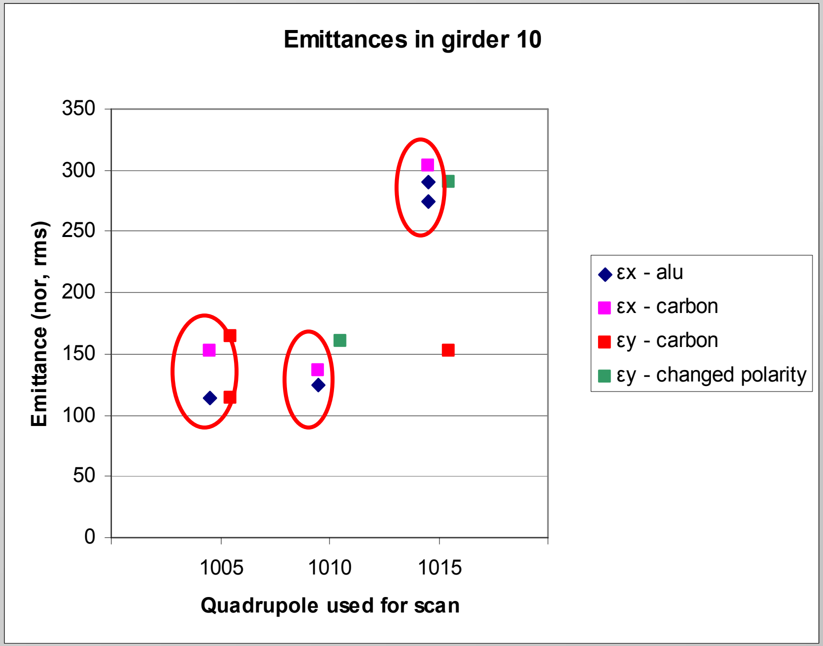
Indeed a beam property? Beam is round in girder 10.

Could be a resolution problem (experience from girder 10 for some quad scan ranges). In girder 5 we have just 2 quadrupoles, difficult to find a proper scan range.

Large emittance values when measured with QDB1015.

Resolution problem for scans with QDB1015 (small beam waist, < 0.2 mm).

Estimate for an overall uncertainty (use of different screens, filters) ~ 20%



What to do?

Scans with opposite polarity of quadrupoles to distinguish if the difference in horiz. and vert. emittance is a beam property or a resolution problem.

Problem 2 & 3

Emittance growth from girder 5 to 10

Beam related or measurement problem (different magnification, resolution for screens in girder 5 and 10)

What to do?

- Same magnification for beam diagnostic instrumentation in girder 5 and 10 (already done).

(- use quadrupoles in girder 9 for quad scans.)

Larger emittances for off crest operation (~ factor 2)

Beam itself (larger energy spread, shorter bunches…)

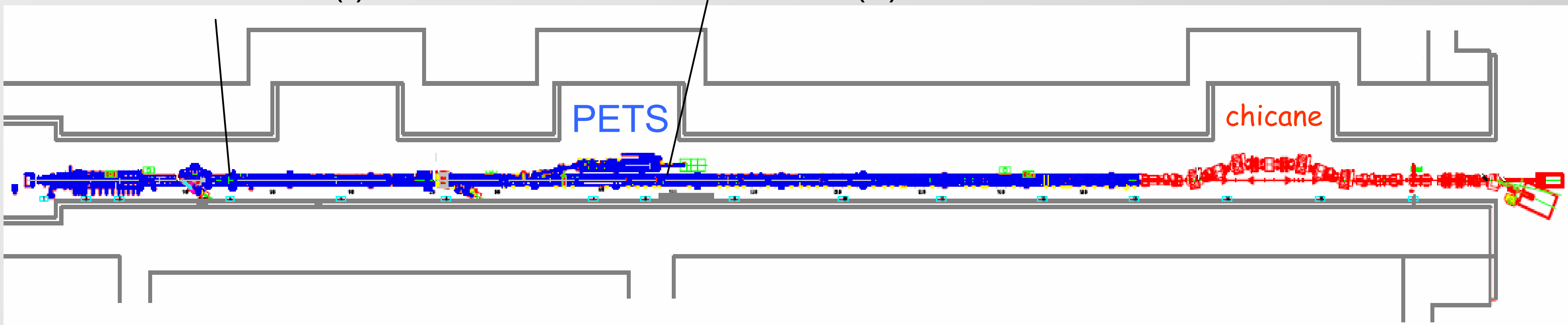
→ dispersion, chromatic effects, wakefields,…?

What to do?

- Quadrupole scans at the end of the Linac, to see how the emittance behaves.
- Measurements with different off crest values

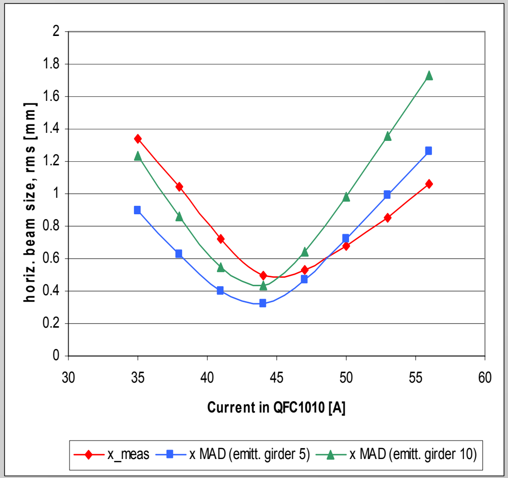
Re-matching of the optics

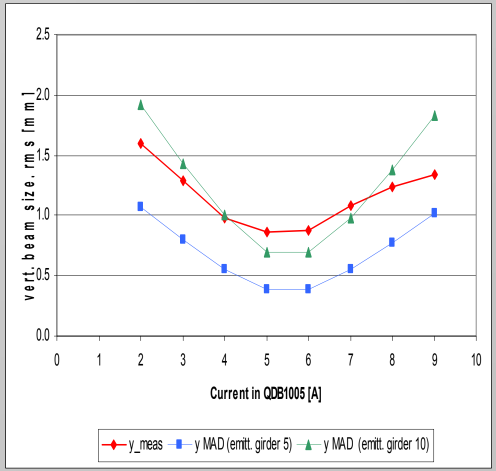
Quad scans (I) Quad scans (II)



Setting up procedure:

- Quad scan (I) in girder 5
- Re-matching of the optics to girder 10 using MAD
- Quad scan (II) in girder 10





Measured rms normalised emittance (5A on crest operation):

$\varepsilon_x = 45 \Rightarrow 85\ \pi$ mm mrad

$\varepsilon_y = 25 \Rightarrow 80\ \pi$ mm mrad

Conclusions for the transverse beam parameters

- The new coils in the injector improved clearly the emittance.
  → facilitated beam set-up for PETS operation and improved transmission through the PETS (up to 90%).
- For on crest operation the measured emittances are smaller than the nominal.
- Measurements in girder 5 show that we are not far from simulations.
- The agreement between the MAD model and machine is convincing.

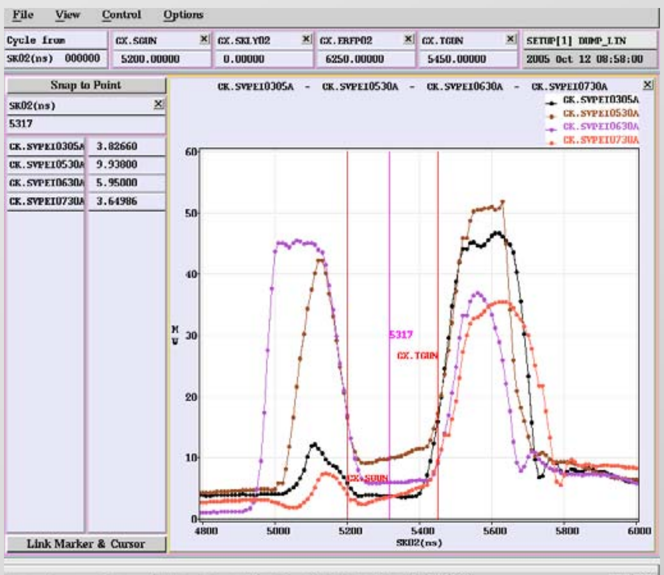
BUT

- There are problems which have to be understood (emittance growth,…)
- **We have to dedicate more time for a detailed study during the next run!** (most important message of the talk)

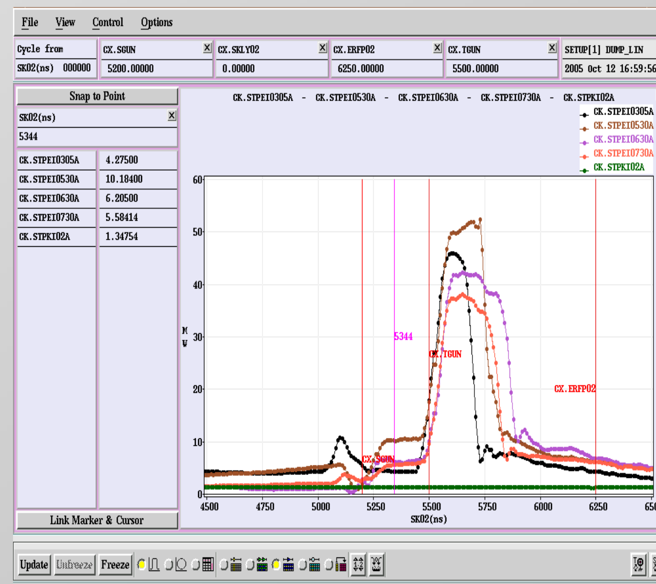
Delayed filling

The beginning of the beam pulse (transient, ~ 100 ns) has a higher energy than the steady state.

→ **The timing of the RF pulses is shifted in order to compensate this effect.**



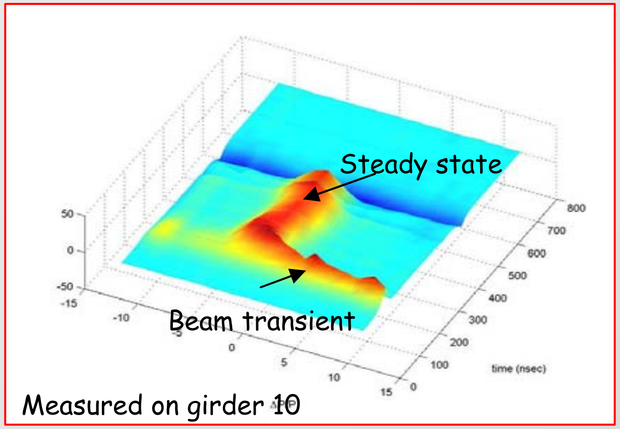
"normal" filling



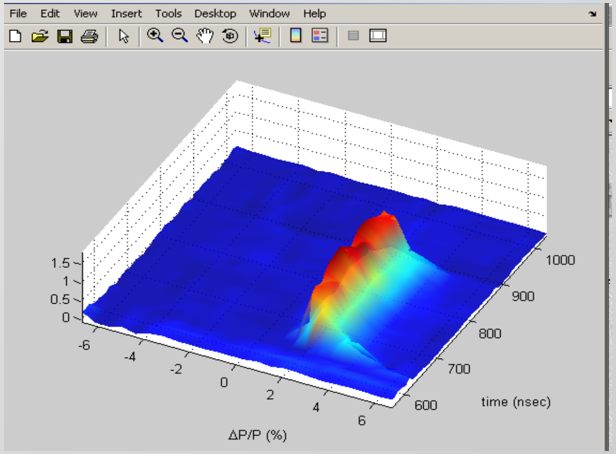
delayed filling
(beam is earlier in time)

Success of the delayed filling

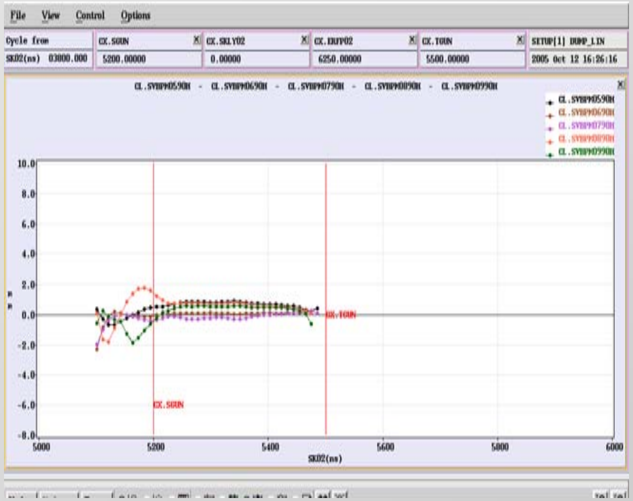
Time evolution of the beam energy spread



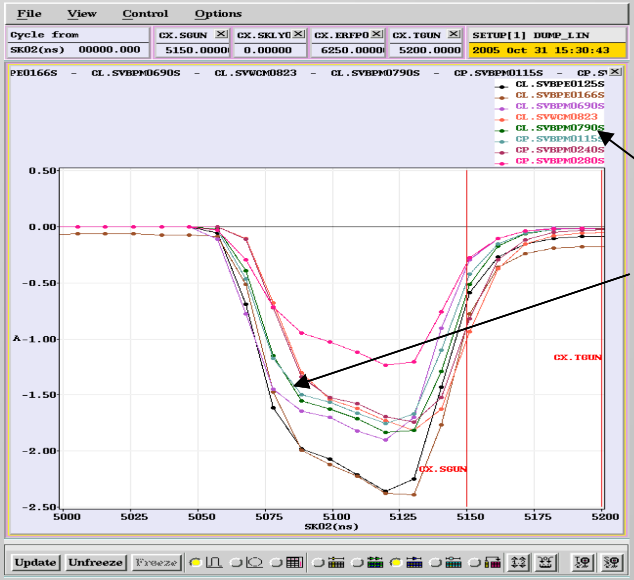
"normal" filling



delayed filling

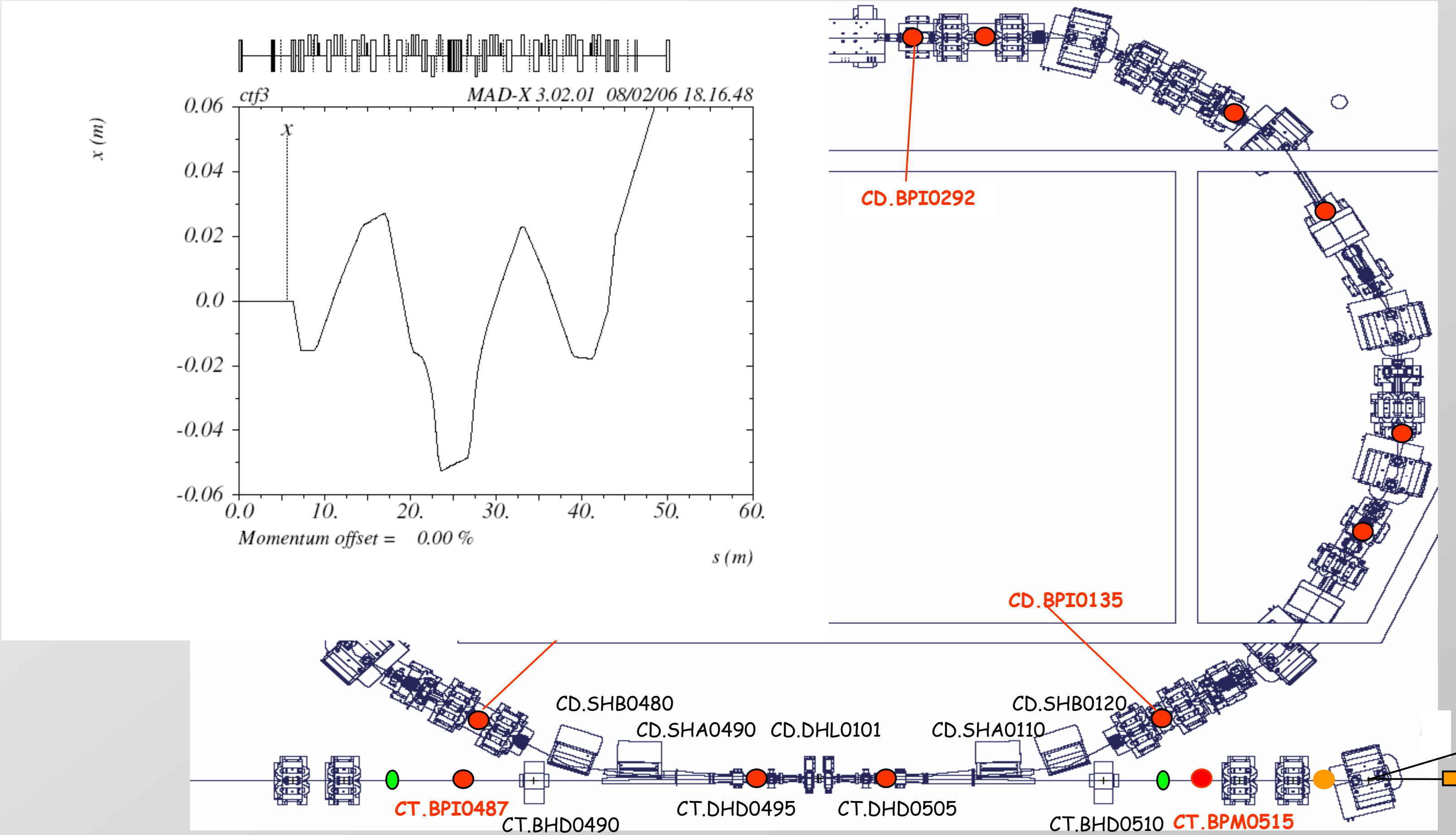


Horizontal beam position constant over the pulse.



No losses in PETS chicane!

DL - Injection Problem

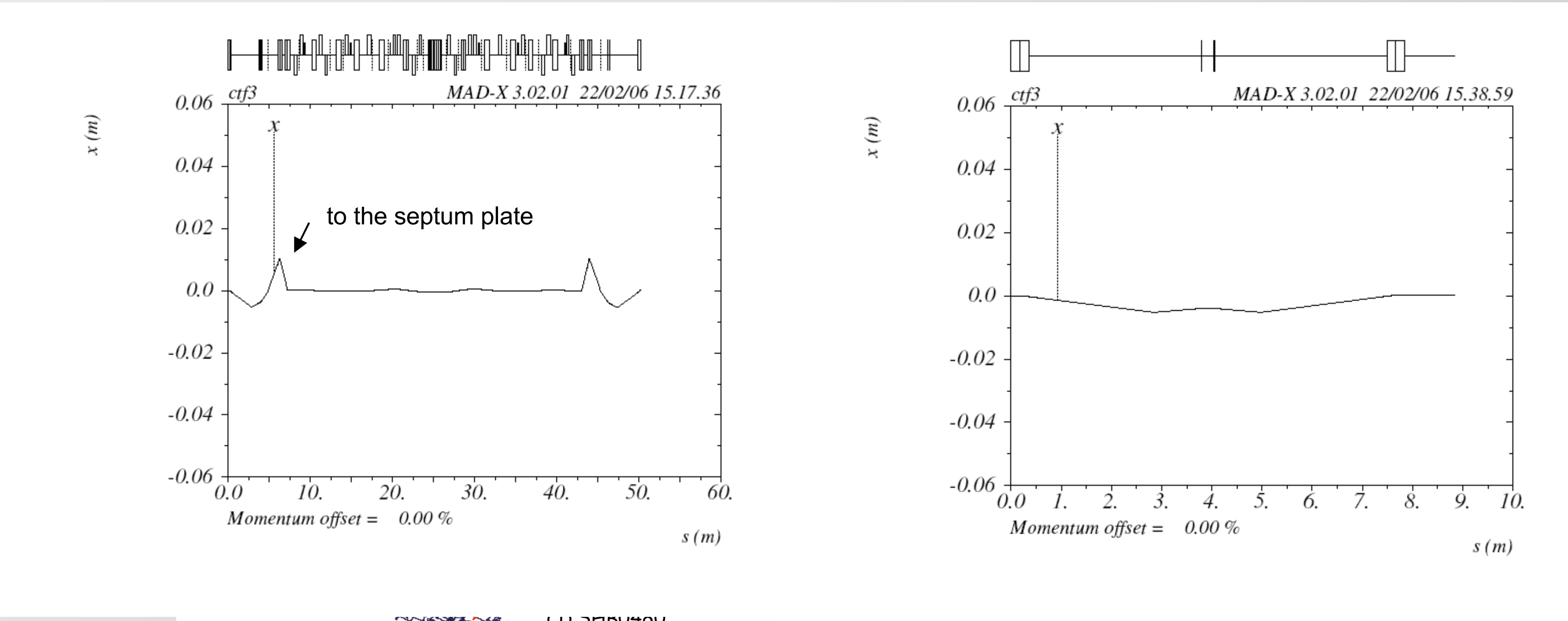


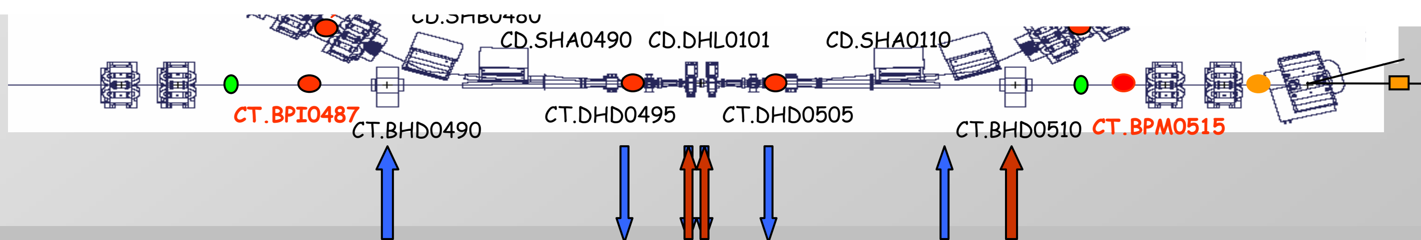
assumed in MAD: 3 * 7.5 mrad kicks (BHD0490, DHD0495/0505) are subtracted from first septum

reality: septa are powered in series, kicks have to be considered in both septa

→ **Offset of 15 mm at the end of the second septum in the survey file!**

DL injection compensation





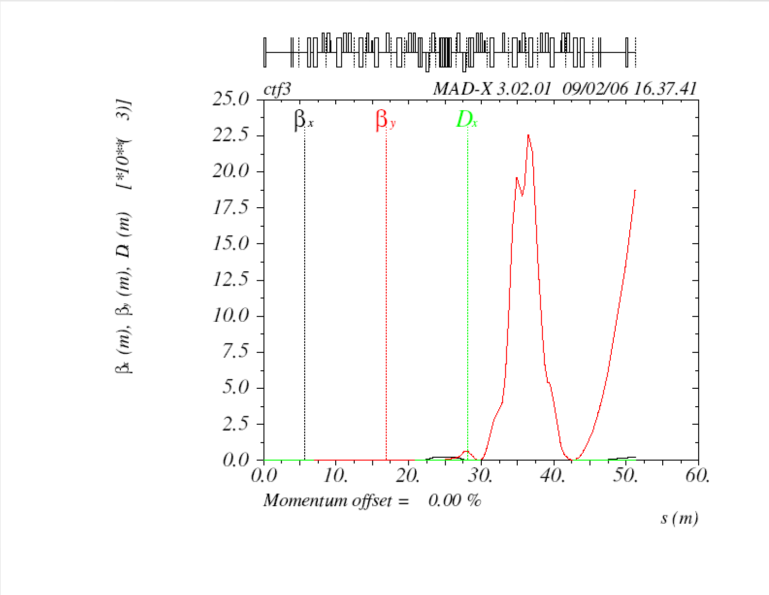
Going into the DL (in operation): playing with injection bend, steerers, transverse deflector, septa to get the beam around.

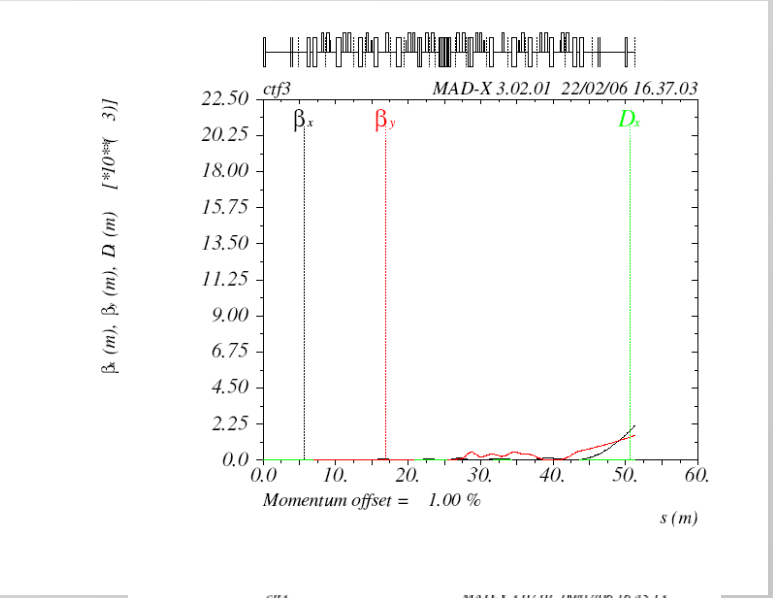
With MAD: constraints: x = x' =0 @ BPI0135, small x @ entrance of first septum

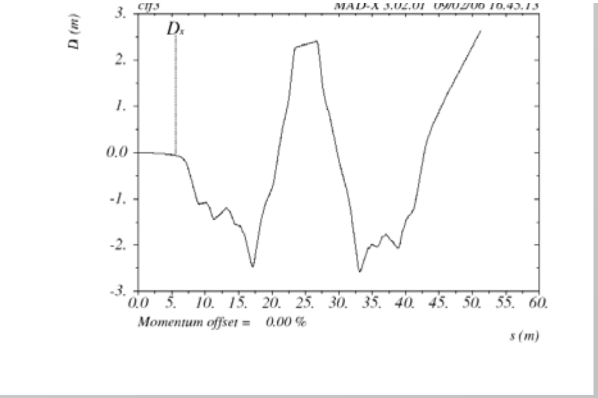
Going straight: One has to profit from the transverse deflector, kick changes sign.

Twiss parameters and Dispersion for operational settings

Operational settings: 3 quadrupoles off, just one defocussing quad on!







We don't know the initial conditions!

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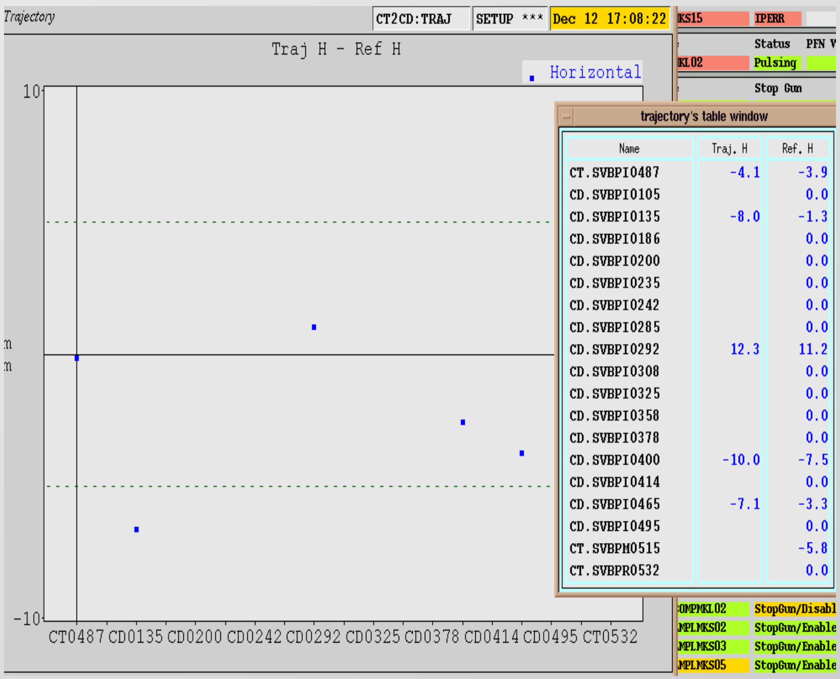
We have to perform a quad scan after the end of the Linac.

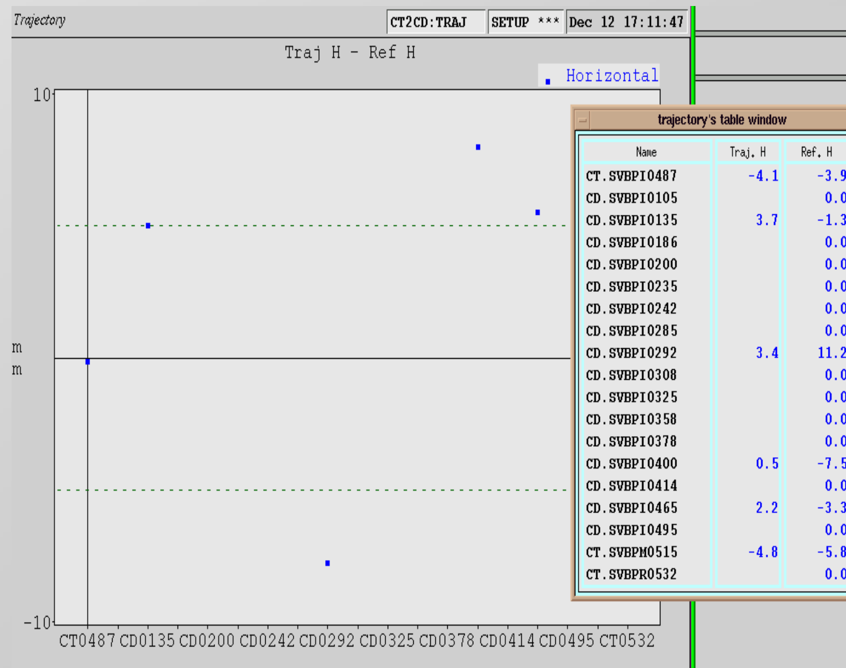
- Check quadrupole polarities in the machine (QDF0280 inverted…)

Dispersion measurement I

- Scaling of the Delay loop magnets +/-1%
- Did we indeed scale by +/- 1% or +/- 0.5%?



Scaling magnets down

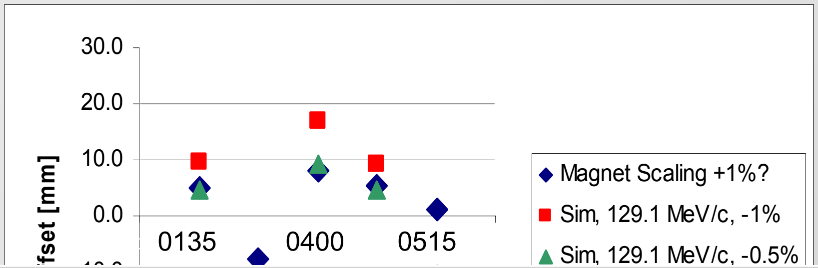


Scaling magnets up

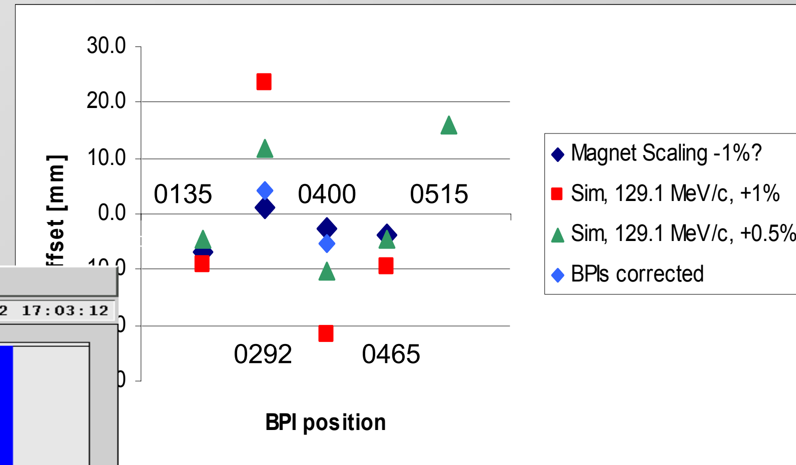
Dispersion measurement II

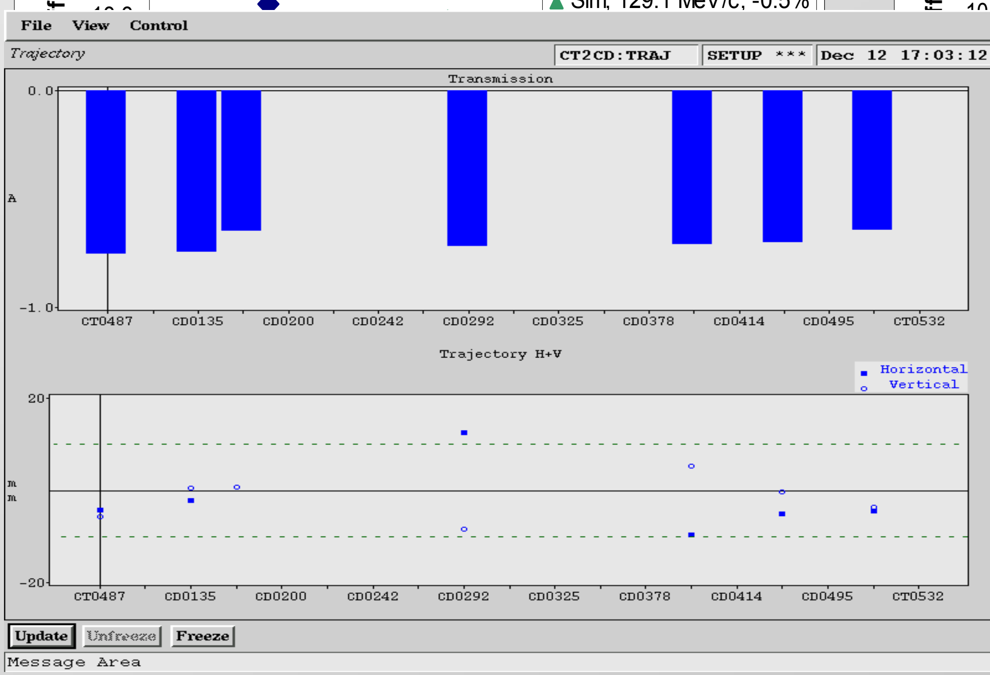
MAD Simulations: Energy calculated from bending magnet and Septa currents, Machine quadrupole settings.

Scaling magnets up



Scaling magnets down



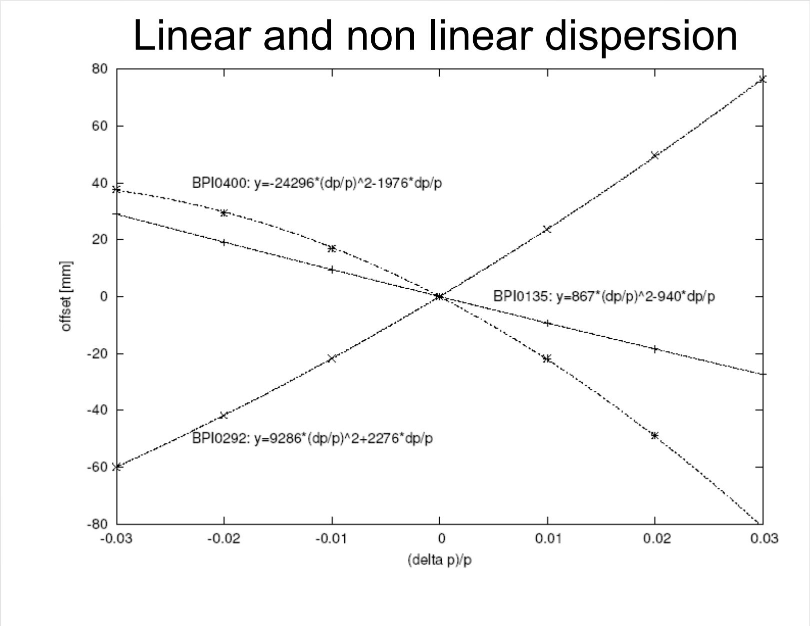


aling, otherwise factor 2.

ge offset in the reference trajectory

en moving further to the outside

Dispersion measurement III



Conclusions:

Measurement done only once, starting from a poor ref. trajectory, using just 4 BPIs

→ reasonable agreement between measurement and simulations.

Things to improve:

- **Start from better ref. trajectory**
- **More BPIs (+3?)**
- **Perform measurement with several (Delta p)/p settings**

MERCI !