CTF3 ORBIT: TOOLS AND AUTOMATIC TUNING

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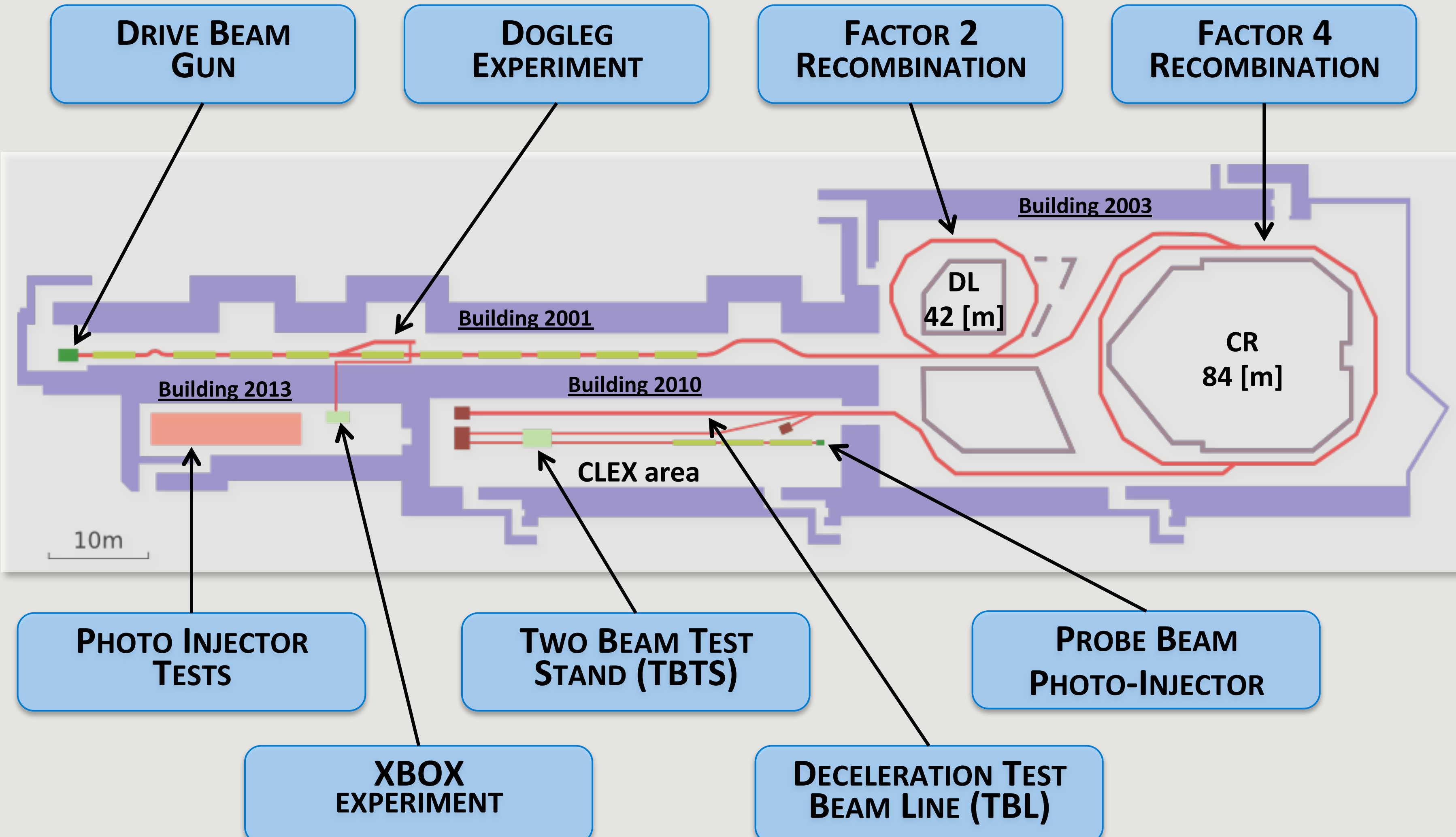
Outlook

- CTF3: the CLIC Test Facility at CERN.
- Steering necessities.
- A general feedback algorithm and its implementation.
  - Preliminary results and issues.
- Work in progress: new tools.
  - Dispersion measurement from Jitter.
  - “Jitter free steering.”
  - Dispersion matching.
- Summary.

CTF3: the CLIC Test Facility at CERN.

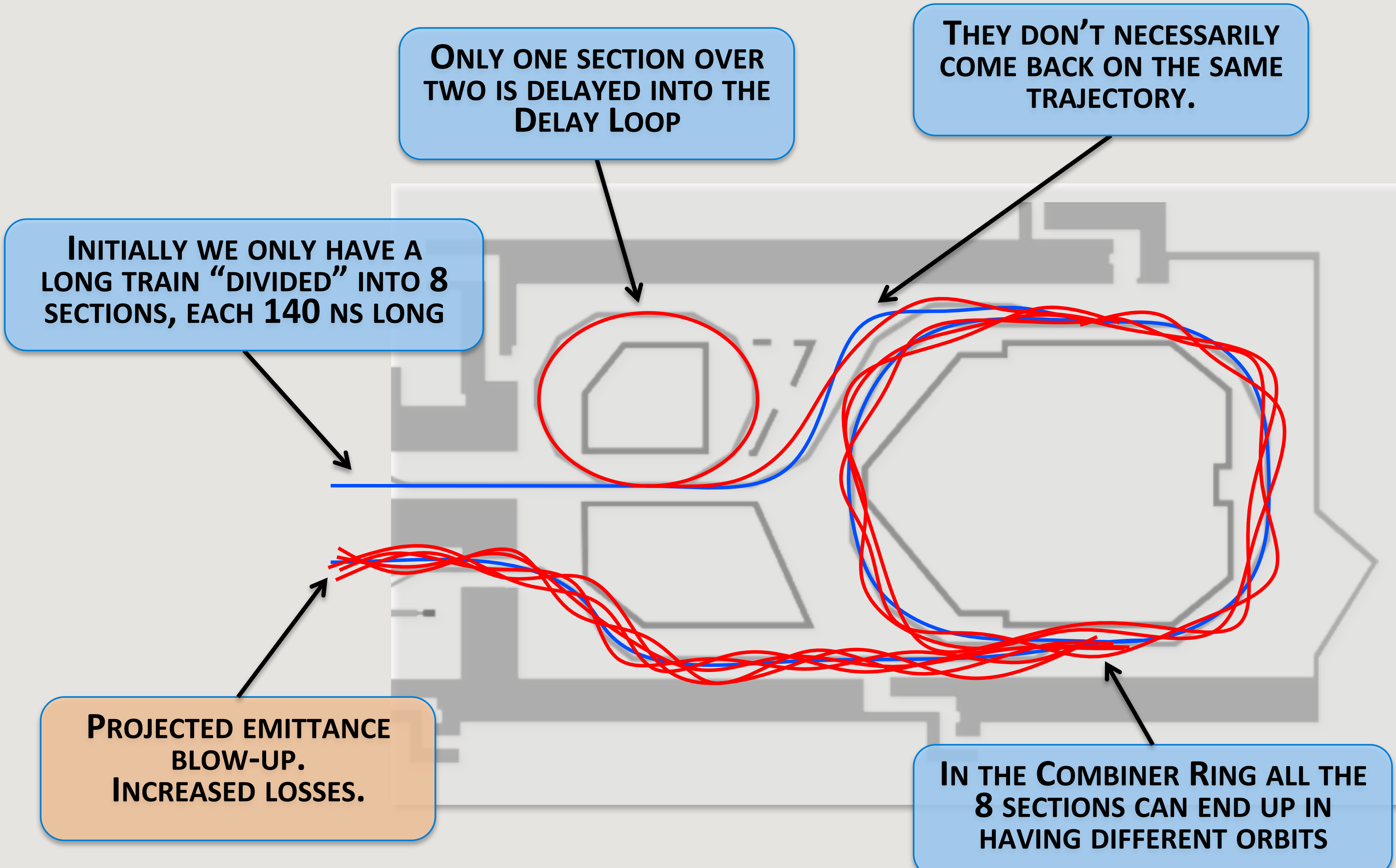


Steering necessities.

- For machine operation and optimization we need a general tool to control the orbit of the beam.
- It has to deal with some intrinsic limitations
  - Data acquisition is affected by noise
    - White noise
    - Not null dispersion and energy jitter
  - Non responsive control system
    - Delicate FRONT-ENDS
  - Instable beam (mainly coming from RF instabilities)
  - BEAM POSITION may not be a well defined measurement in case of losses
  - Challenging machine
    - MADX model not always accurate
    - Aperture limitations
- Algorithm to measure the response matrix needed
  - Has to be "fast" compared to machine faults and drifts
  - Has to be able to follow slow drifts of the machine

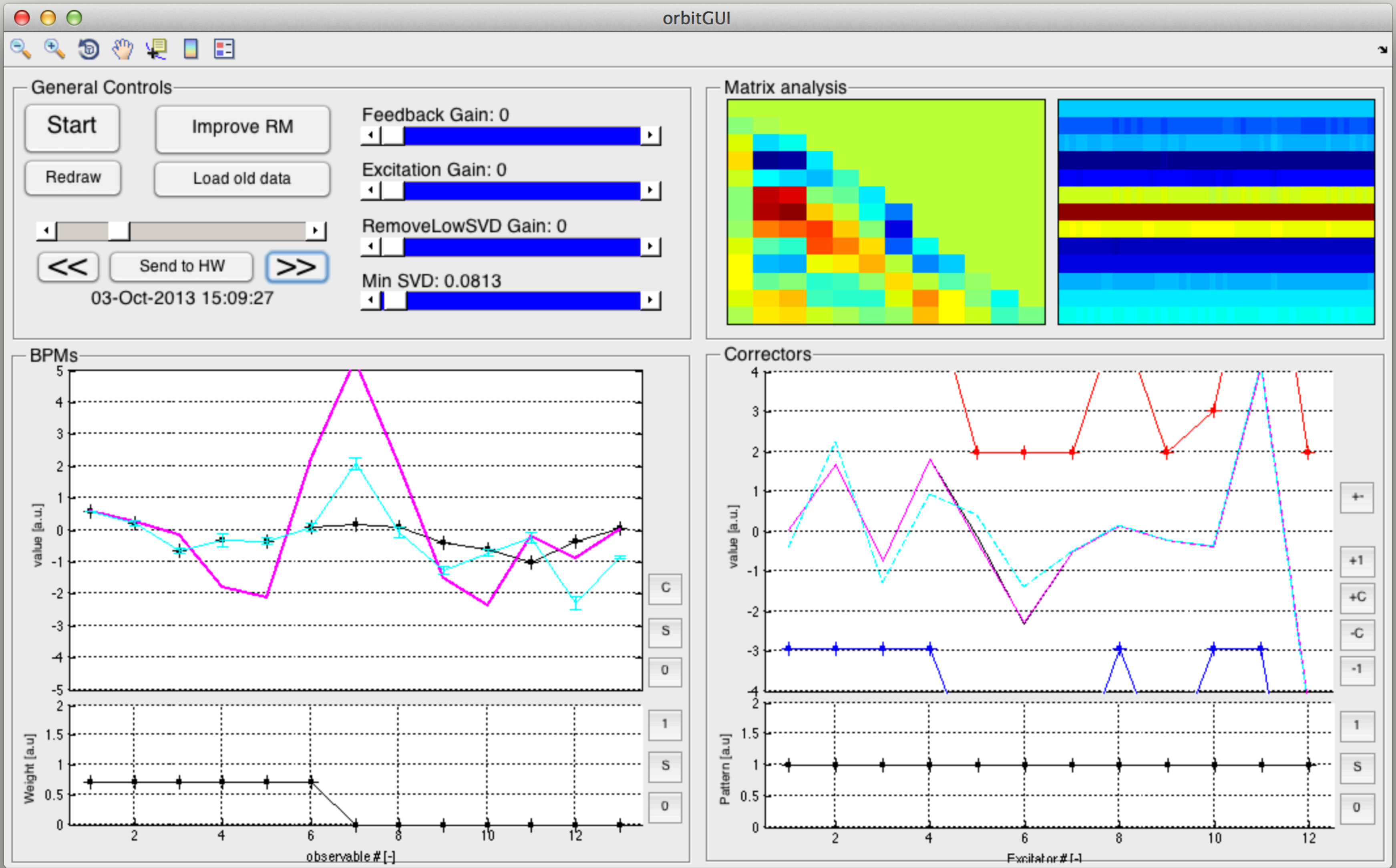
Steering necessities.

- Final aim: during recombination, different section of the initial train take different paths.



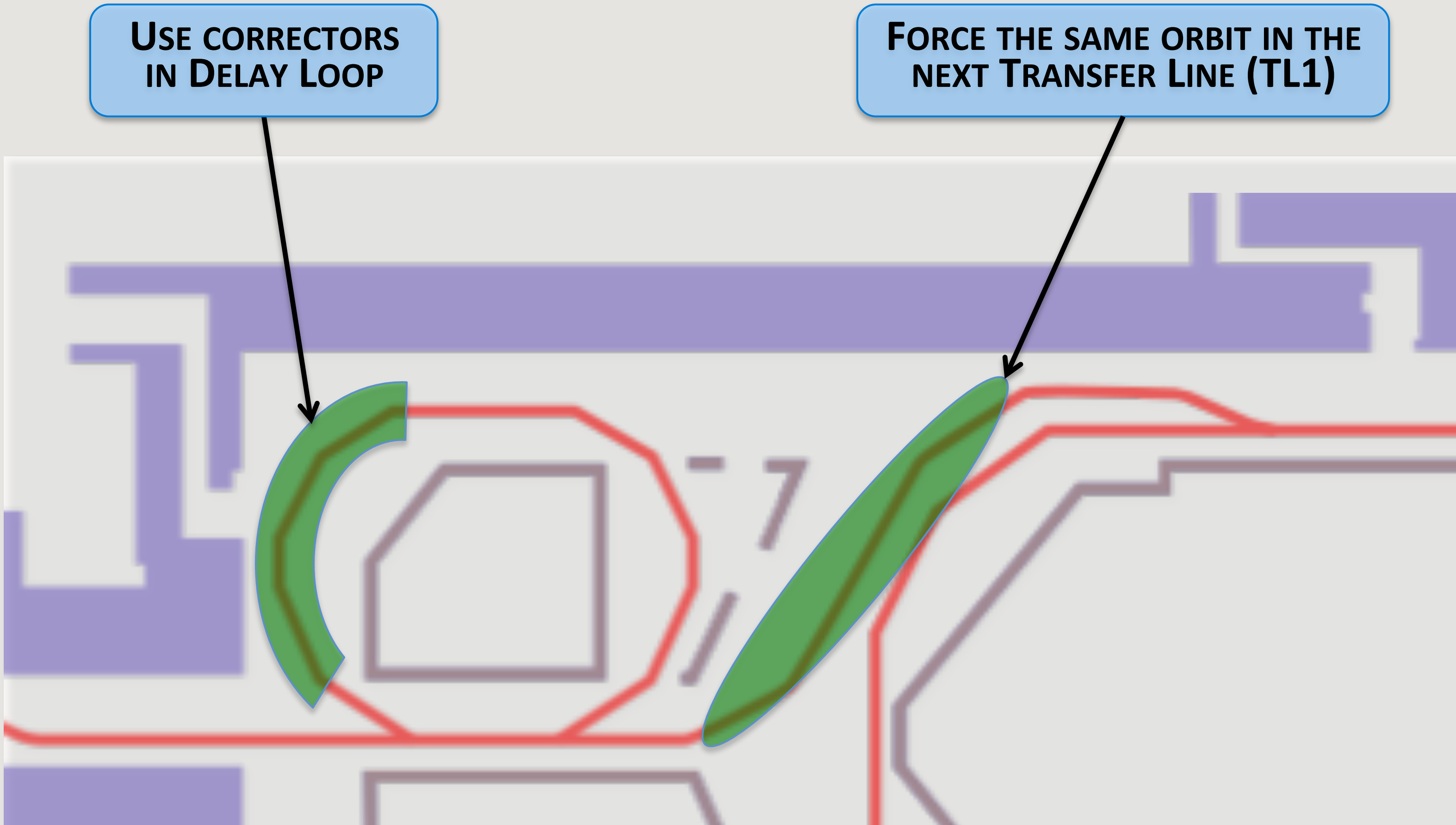
Feedback implementation

- Developed a Matlab application for generic linear feedbacks.



First attempt

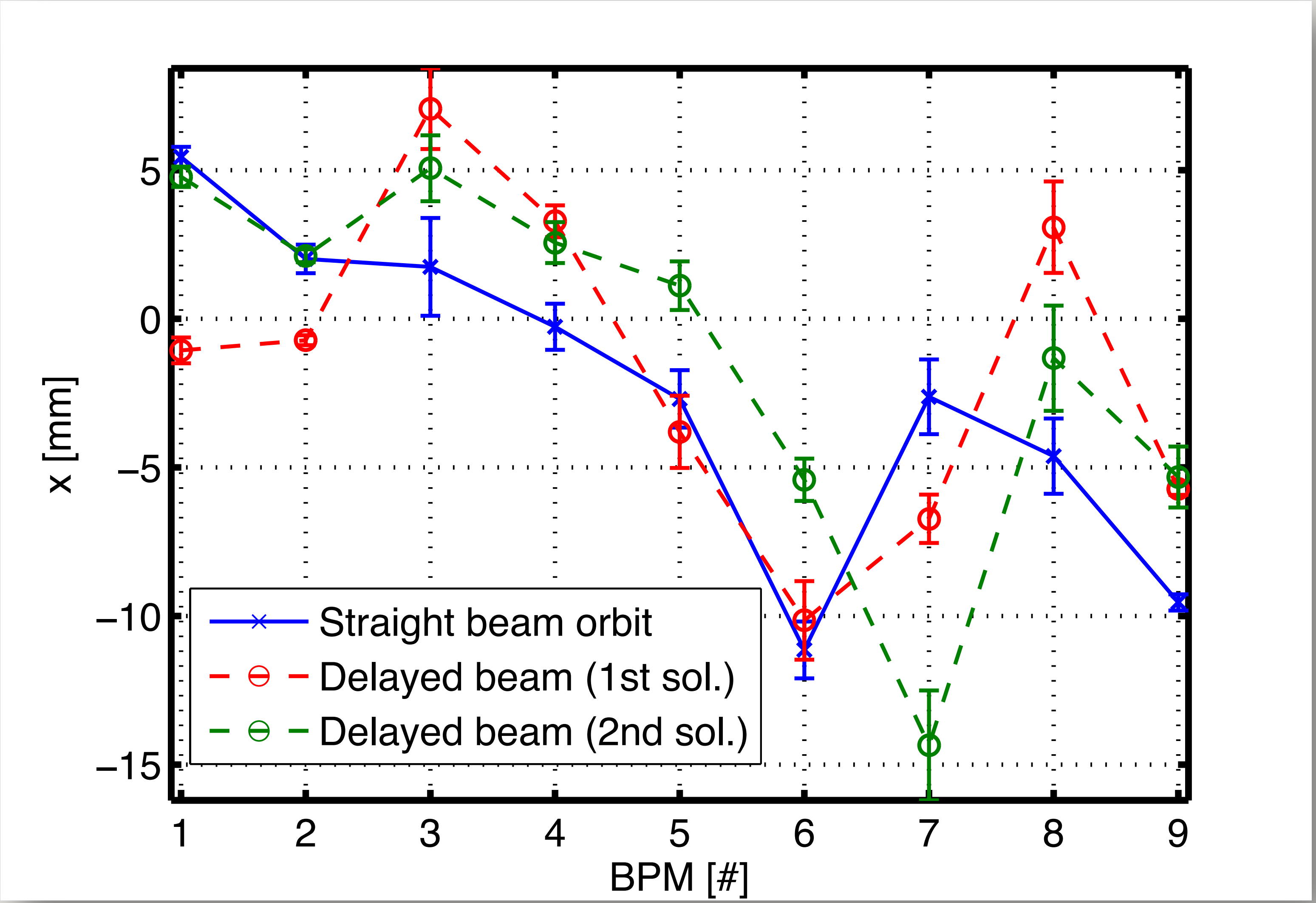
- First stage: match orbits of delayed and not-delayed trains.



- In principle only two correctors with the right phase advance are needed.
  - Aperture limitations may impose to use more correctors.

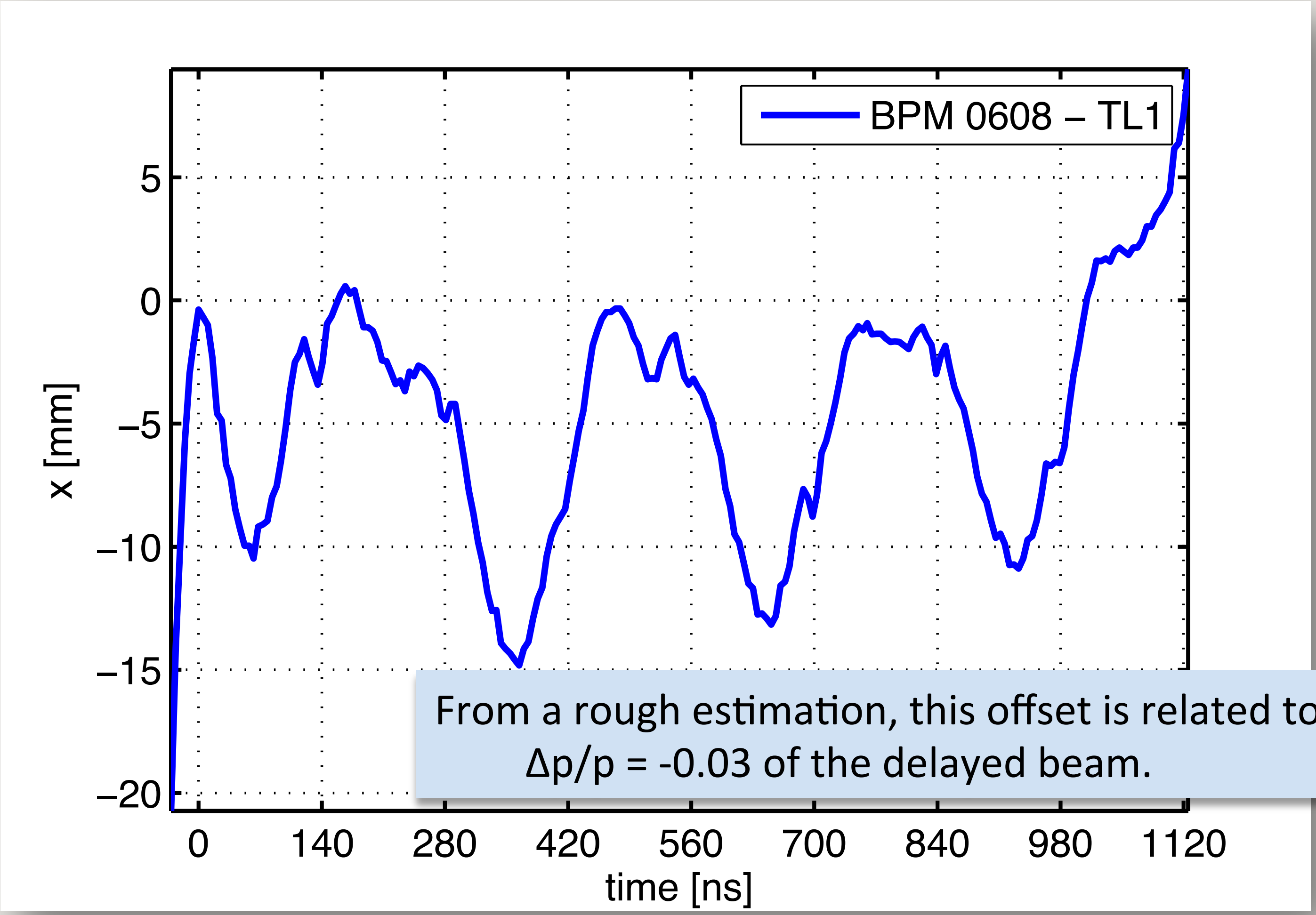
Preliminary result – 1st run 2013

"Orbit matching" in TL1



Preliminary result – 1st run 2013

- A first issue: straight and delayed beam have different energy

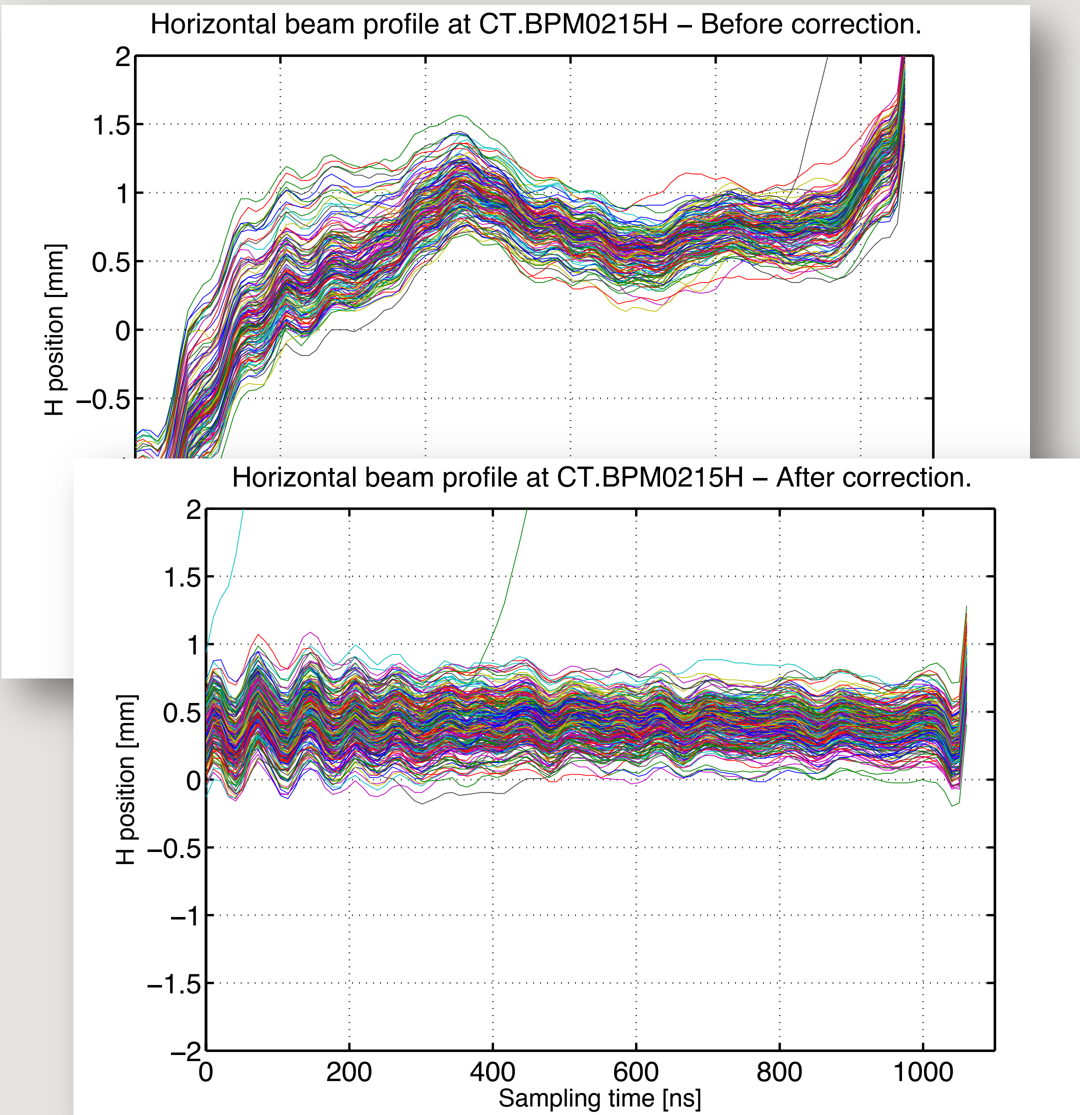


From a rough estimation, this offset is related to a $\Delta p/p = -0.03$ of the delayed beam.

Note: the injector was not properly optimized. These results were not obtained in normal condition of operation.

Detail: energy along the pulse

- After summer shutdown: looking at energy jitter markup in beam position trace in dispersive region.



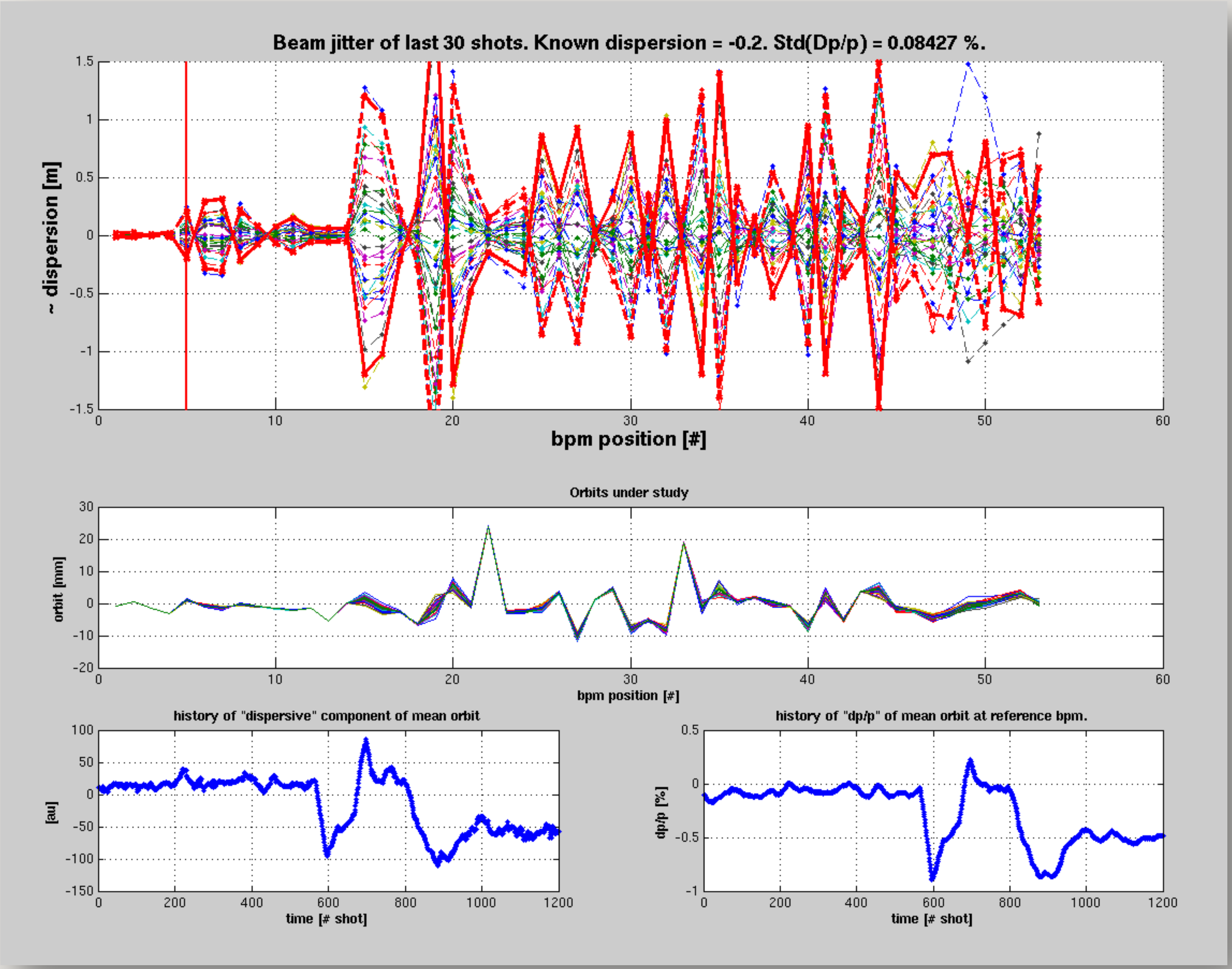
- We are affected by a natural jitter of the energy.
- Beam energy along the pulse is also **not always** flat.
- Thanks to generality of our feedback tool we can use it to shape the RF power of last linac structures to try to compensate the second effect.
- Jitter, as expected, doesn't change….

…But we can use it…

Note: 3Ghz beam for factor 4 recombination, i.e. different setup respect to previous slide!

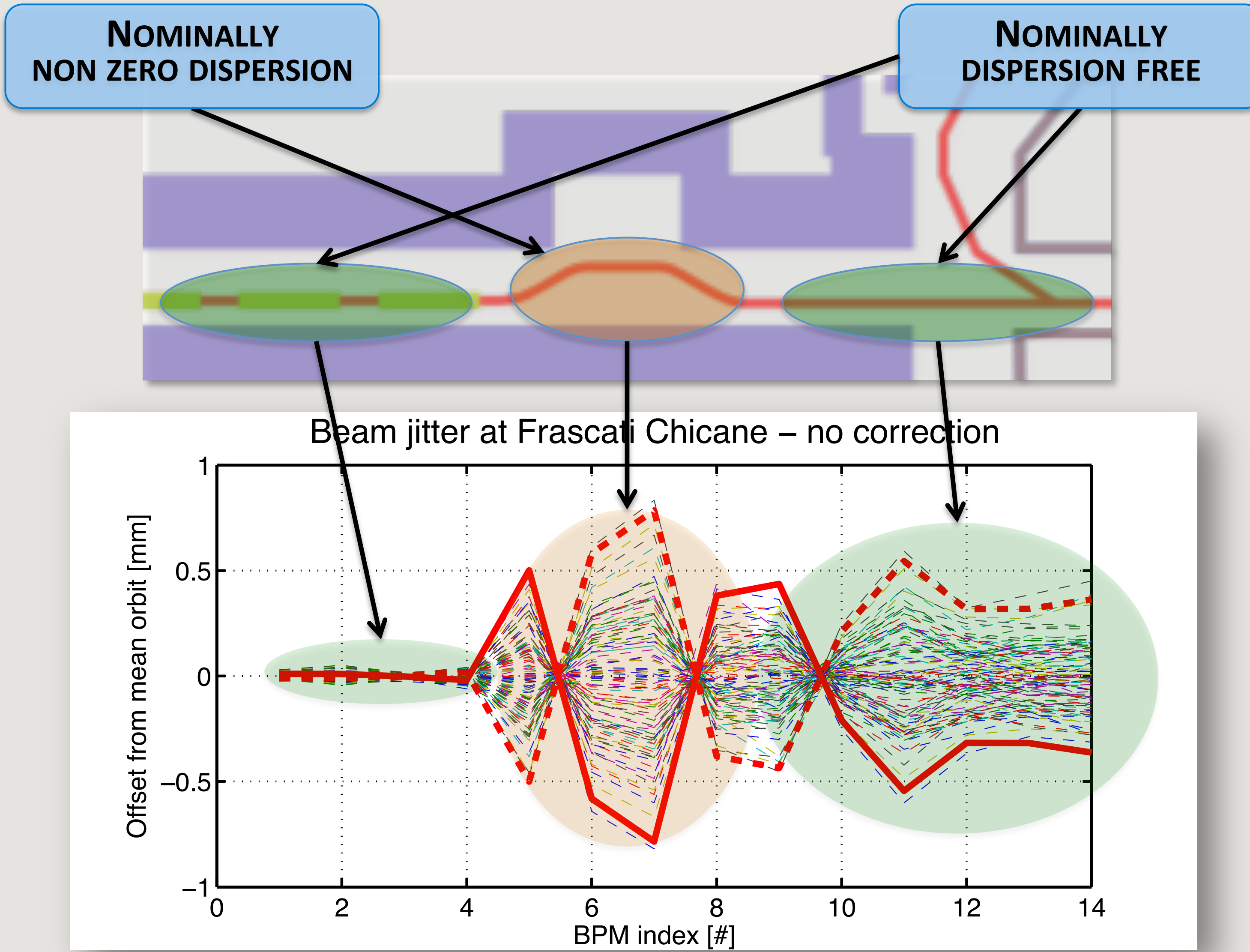
Dispersion measurement from Jitter

- Developed an application to passively measure dispersion by beam jitter.



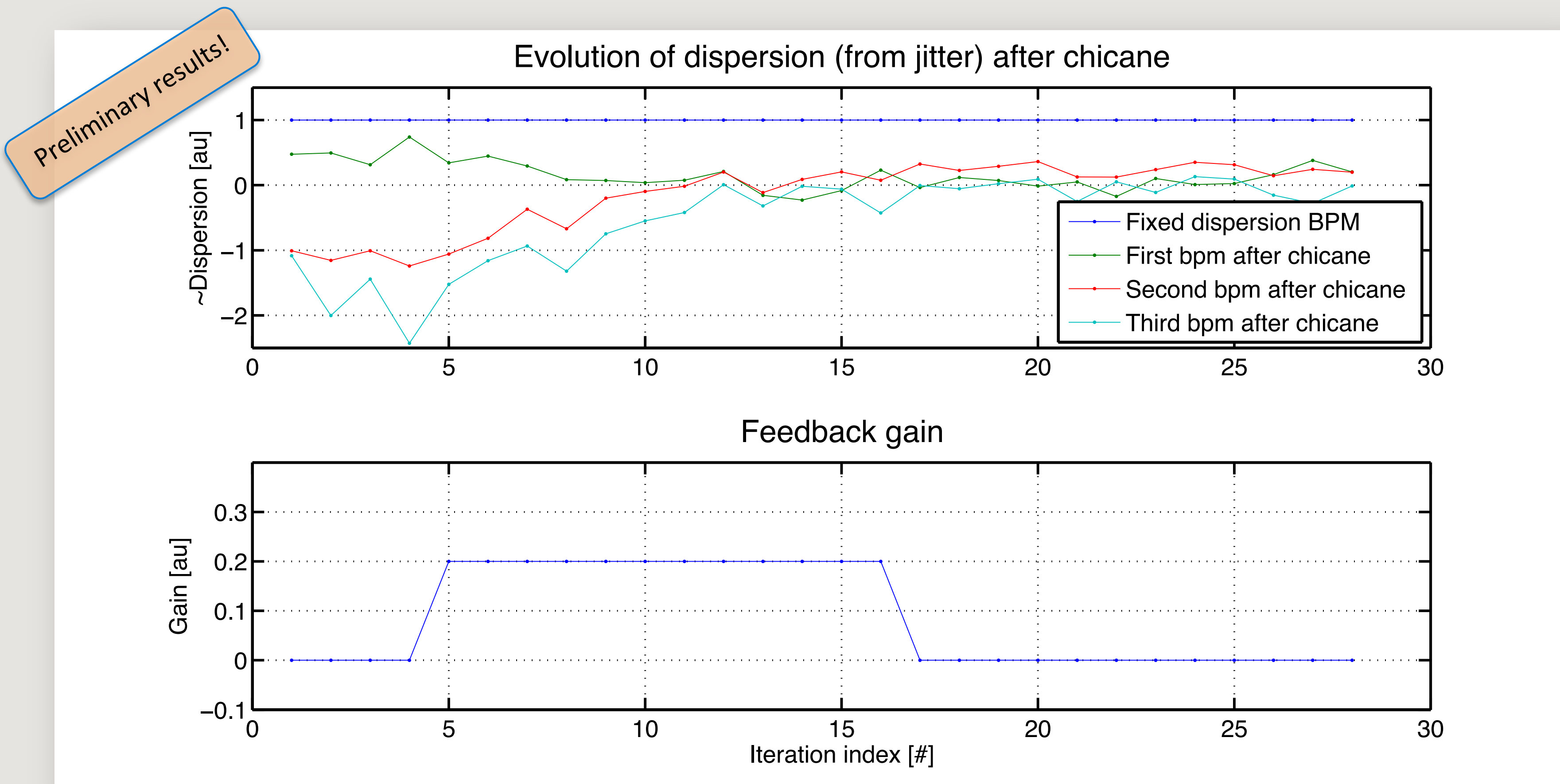
Jitter free steering

- The first area where we have dispersion is at the end of Drive Beam linac, where a chicane is installed.



Jitter free steering

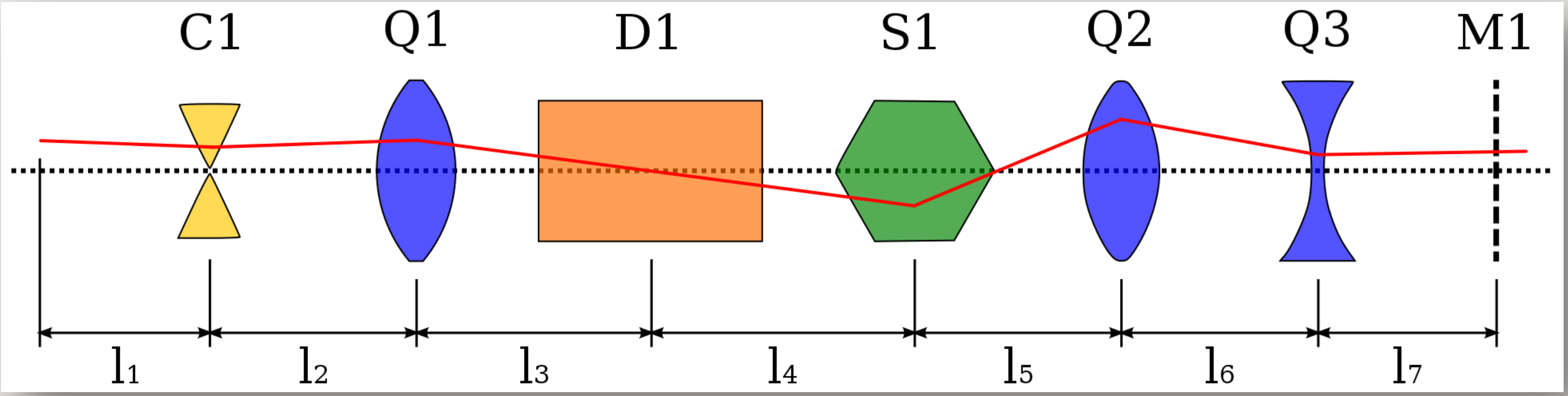
- Using the same feedback application and measuring dispersion as jitter (std).
- Change correctors inside chicane to reduce jitter (i.e. dispersion) downstream.
- Acquiring 30 beam pulses for each iteration.
- Main disadvantage: RM measurement and correction takes longer time.



Work in progress

Study: orbits and dispersion relation

- Let's consider a small line done with thin ideal elements.



- We can only **measure** the beam position at BPM location.
  - [we treat the beam as a single particle]
- We can only **set** currents of correctors, bending magnets and quadrupoles.
  - [we imagine to switch off sextupoles and higher order elements]
- In principle we **don't know** exactly:
  - Initial beam conditions (x_0, x_0', energy)
  - Element misalignments
    - [we only consider effects from quadrupoles and BPMs transvers misalignments]
  - The right balance between the current set to the dipoles and the current set to quadrupoles in order to correctly match them to the same energy.

Study: orbits and dispersion relation

- We can write the equation that takes into account all the parameters and imagine to scale all the quadrupoles together by a scaling factor **f = 1+δf**
- After some algebra and approximations, we can write:

$$x_{M1} \approx \alpha_0 + \alpha_1 I_{C1} + \alpha_2 \delta I_{D1} + \alpha_3 \delta\mathrm{f} + \alpha_4 I_{C1} \delta\mathrm{f} + \alpha_5 \delta I_{D1} \delta\mathrm{f} + \\ + \alpha_6 (\delta\mathrm{f})^2 + \alpha_7 I_{C1} (\delta\mathrm{f})^2 + \alpha_8 \delta I_{D1} (\delta\mathrm{f})^2 + O((\delta\mathrm{f})^3).$$

- At the same time we can write an approximation of the Dispersion (f=1):

$$D_{x\,M1} \approx -\alpha_3 - I_{C1}(\alpha_1 + \alpha_4) - \widetilde{I_{D1}}\alpha_2 - \delta I_{D1}(\alpha_2 + \alpha_5)$$

- *… but also the second order Dispersion:*

$$D''_{x\,M1} \approx (\alpha_3 + \alpha_6) + (\alpha_1 + 2\alpha_4 + \alpha_7) I_{C1} + (\alpha_2 + \alpha_5)\widetilde{I_{D1}} + \\ + (\alpha_2 + 2\alpha_5 + \alpha_8)\delta I_{D1}$$

- **NOTE: the coefficients α_i of first equation are easily measurable by changing the magnetic elements few times, measure the beam position and then fit the data.**

Procedure: fit dispersion (Dispersion Matching)

- A special relation can also be written to correctly scale quadrupoles and bending magnet in order to adjust the line to the energy of the beam.

$$-\widetilde{I_{D1}}(\alpha_2 + \delta f \alpha_5) = D_{x\,M1}^{\,design}$$

- Coefficients $\boldsymbol{\alpha_2}$ and $\boldsymbol{\alpha_5}$ can be measure as in previous slide, even changing only the current of the bending magnet and by scaling all the quadrupoles.

- **NOTE: This will not match the actual dispersion with the designed one.**

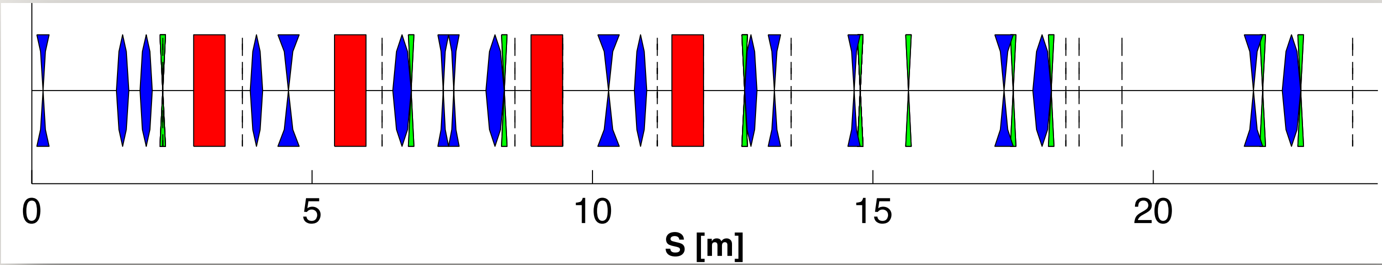
- **NOTE2: This will properly set the main magnetic element strength.**

- We need to correct for spurious dispersion by solving

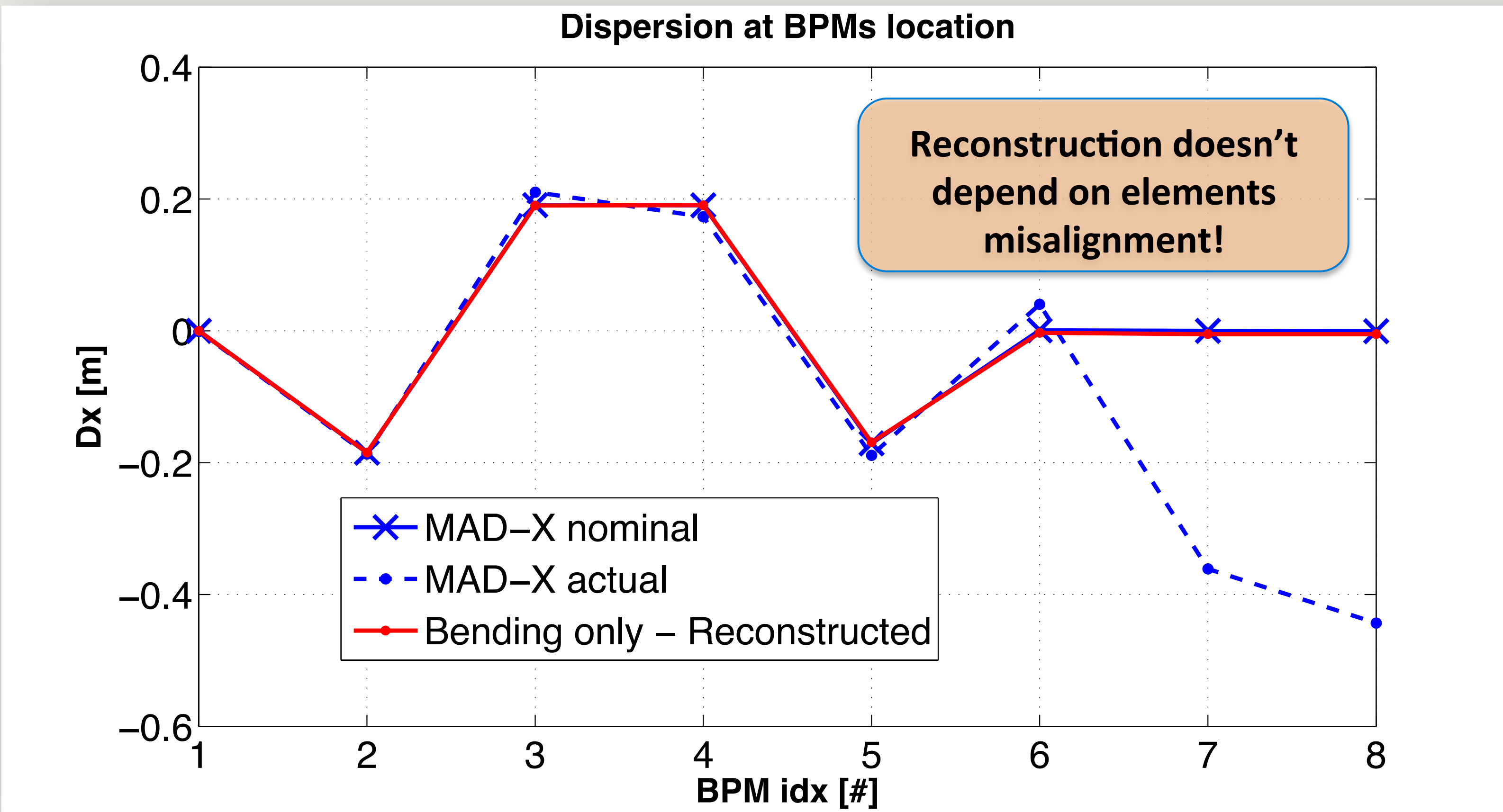
$$\alpha_3 + I_{C1}(\alpha_1 + \alpha_4) + \delta I_{D1}(\alpha_2 + \alpha_5) = 0.$$

- ***Very similar to a Dispersion Free Steering (DFS), even if line with dispersion.***

SIMULATION 1: measurement of bendings magnets Dx

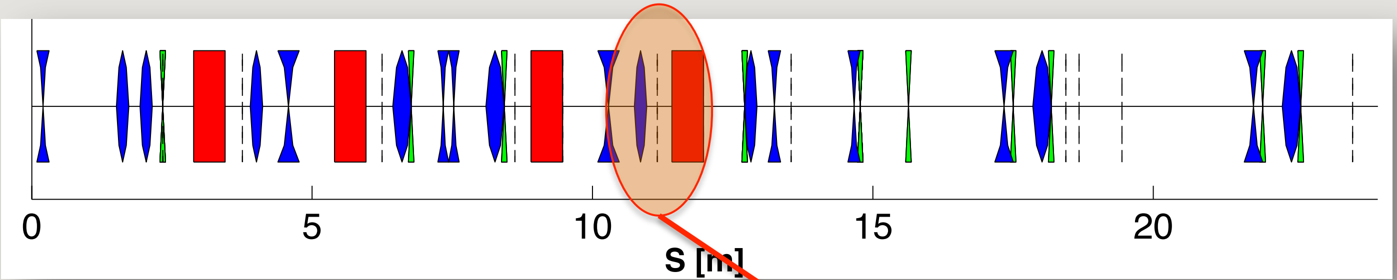


Quadrupoles misalignments σ = 1 [mm]



Reconstruction doesn't depend on elements misalignment!

SIMULATION 1: measurement of bendings magnets Dx



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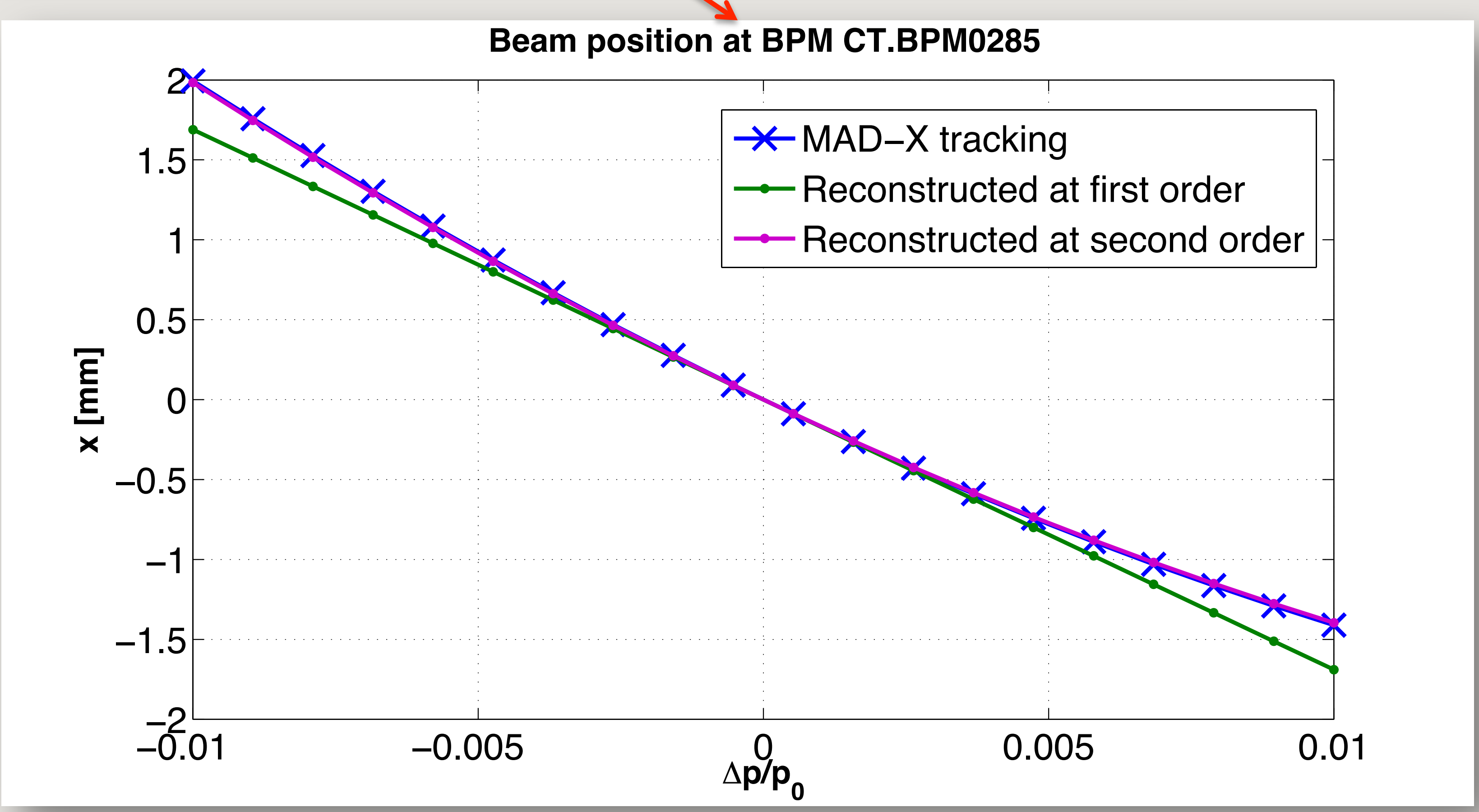

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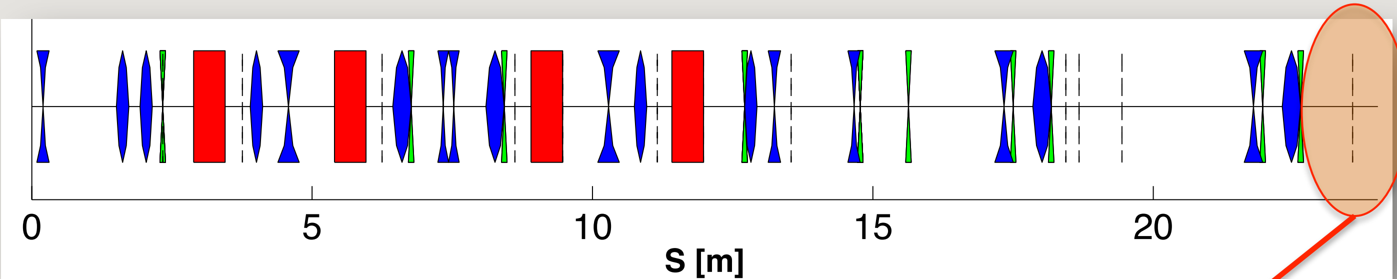

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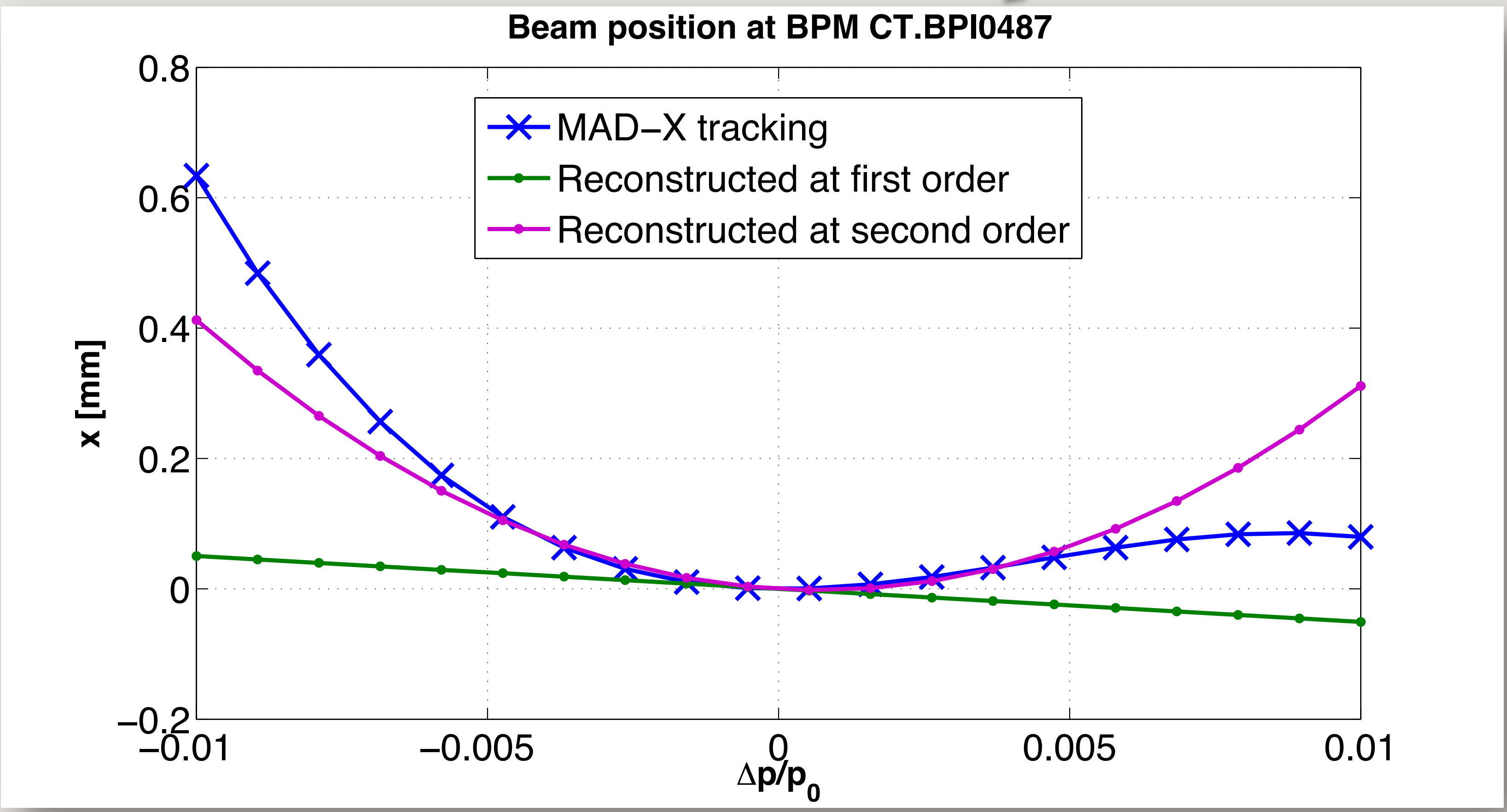

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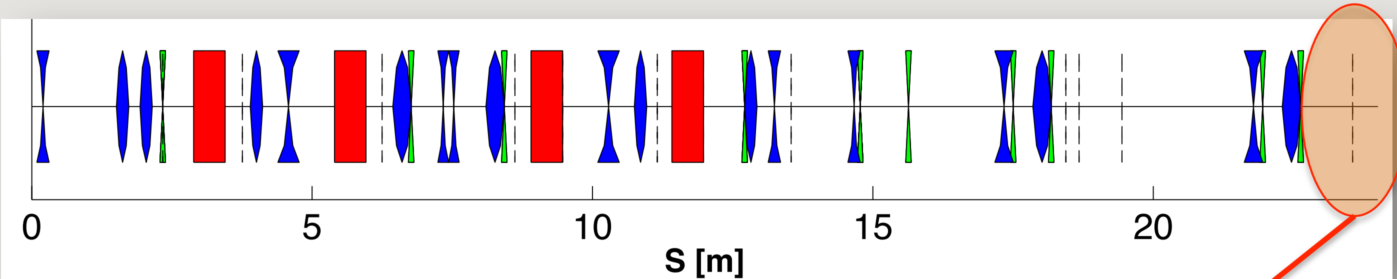

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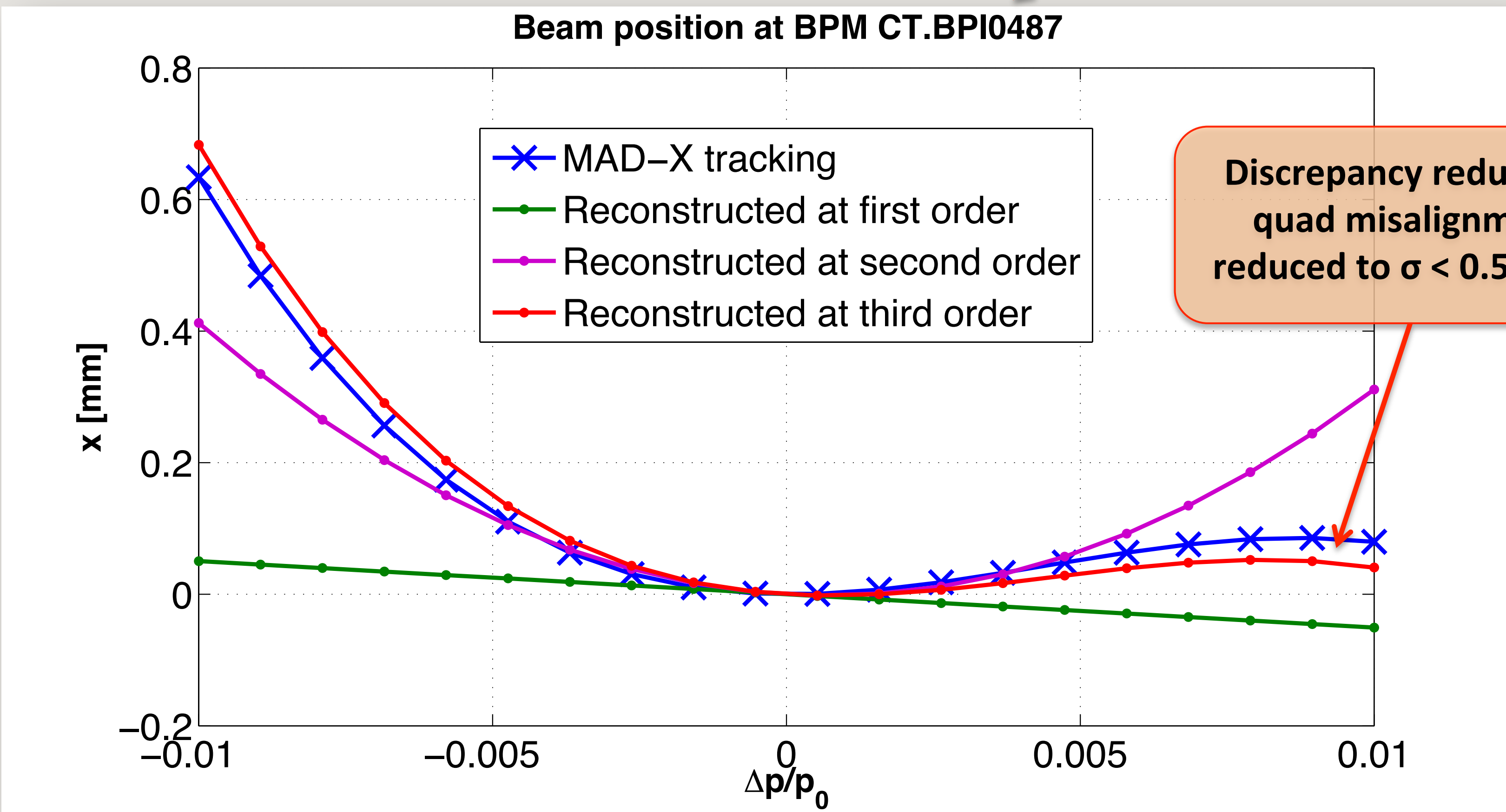
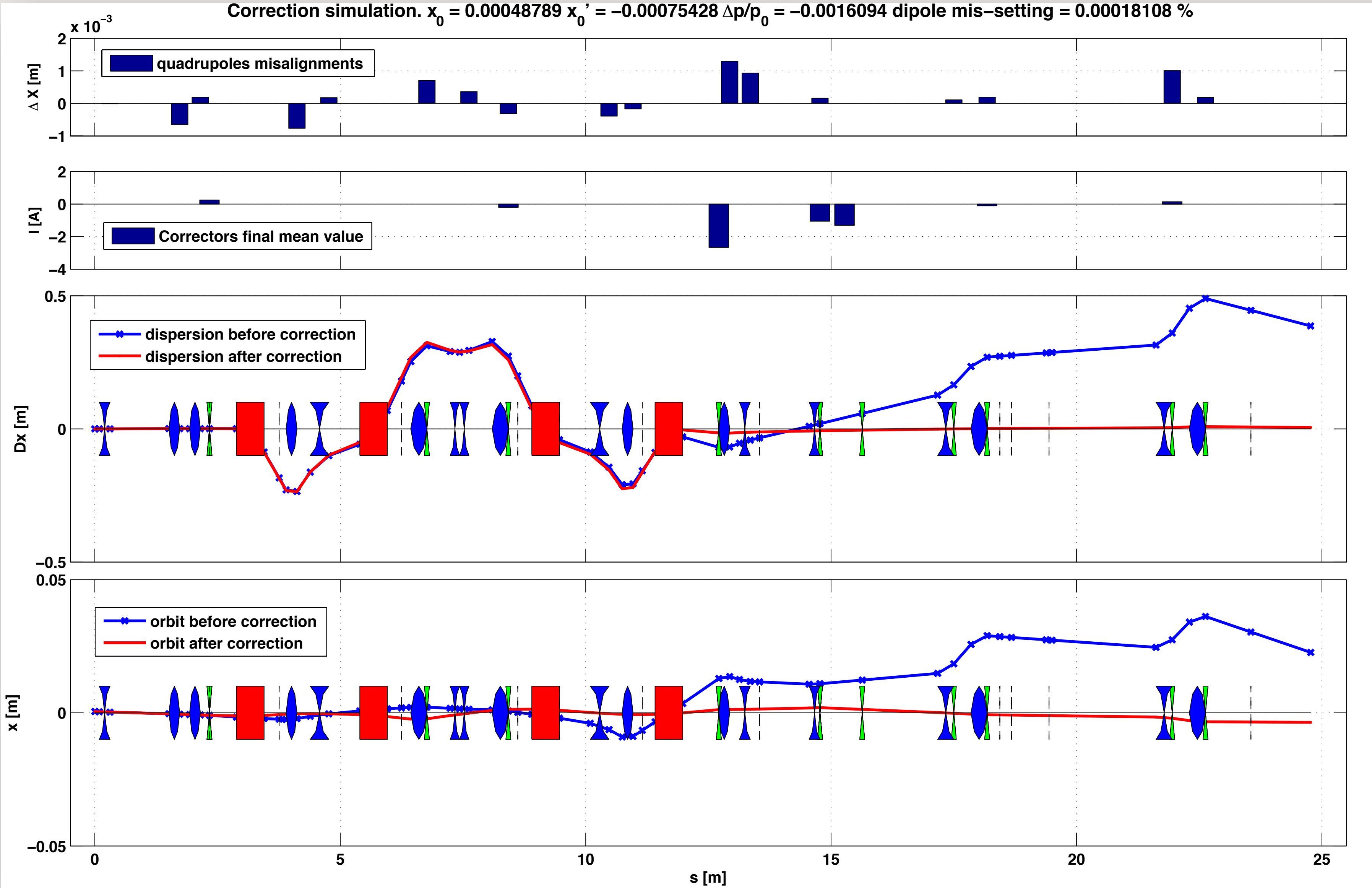


Discrepancy reduced if quad misalignment reduced to σ < 0.5 [mm]

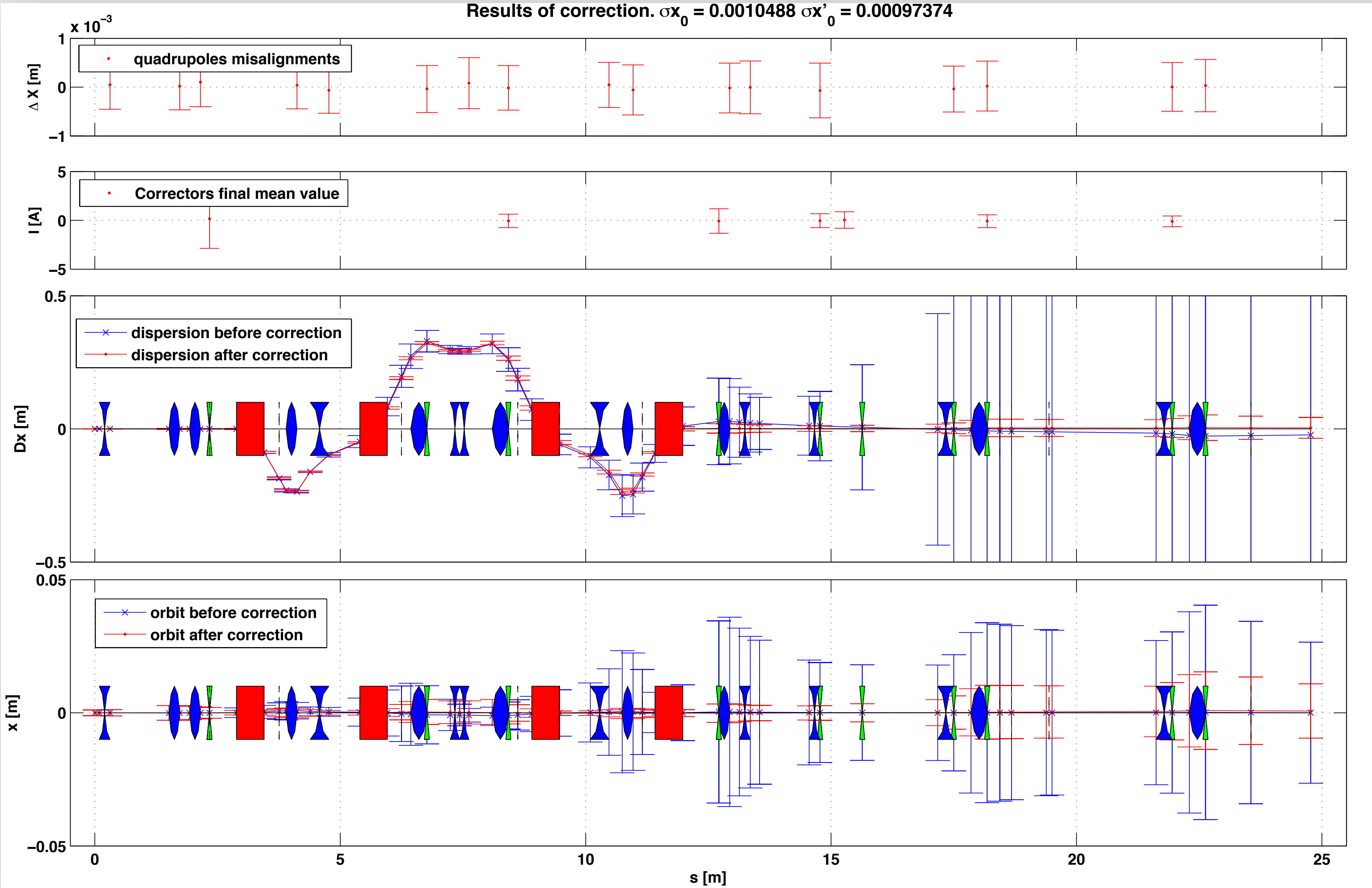
SIMULATION 2: Dispersion Matching

- ***Full correction starting from unknown energy, ratio dipoles/quadrupoles, misalignments.***



SIMULATION 2: Dispersion Matching

- ***Running 100 different machines and correcting them (noiseless!).***

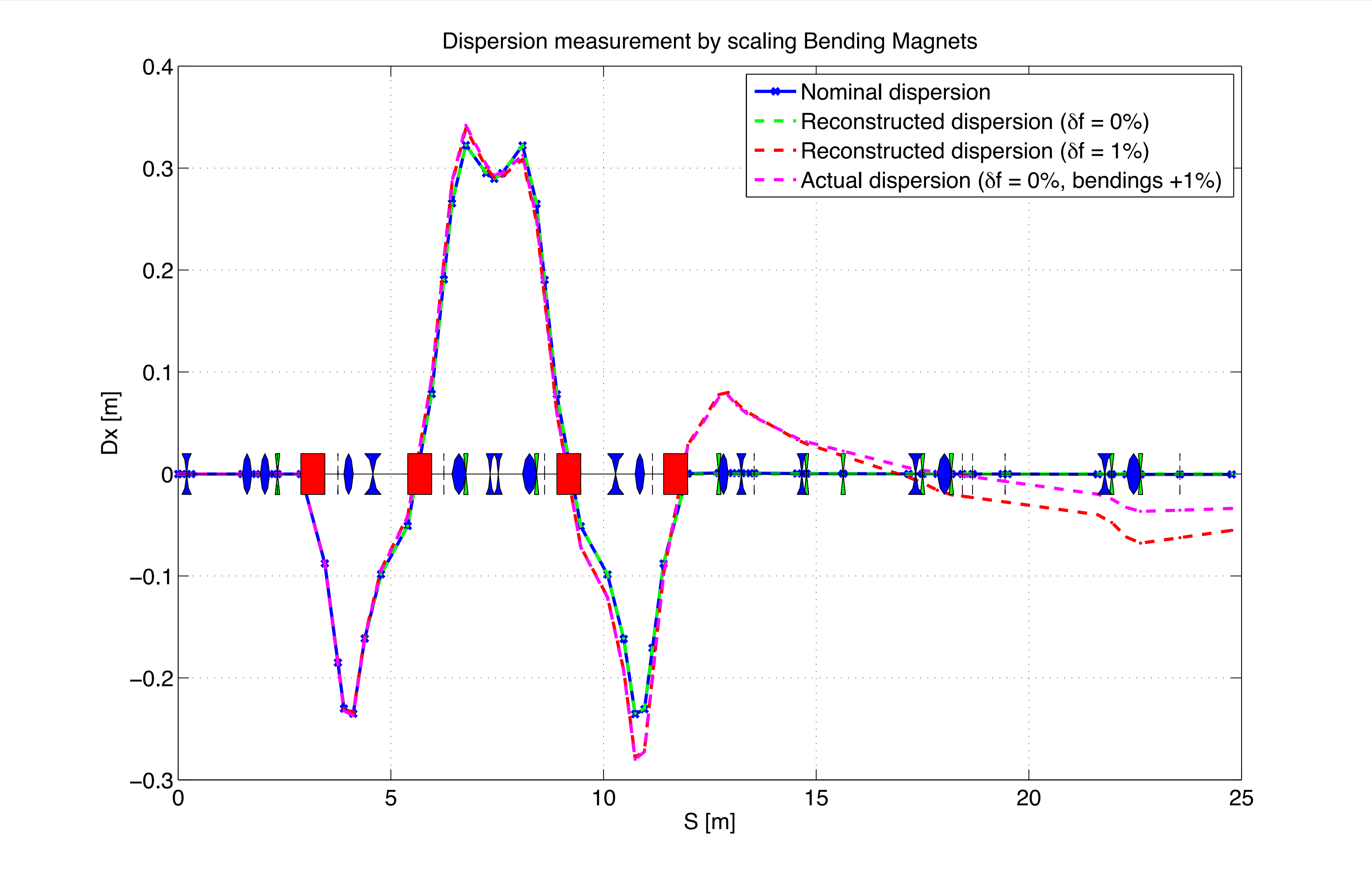


Summary

- What has been done:
  - Developed and tested a generic linear feedback.
  - Smart way to measure the response matrix: it can work in quasi-parasitic mode and/or during orbit correction.
  - First results and characterization of possible limitations.
- What is ongoing:
  - Dispersion measurements from jitter.
  - “Jitter free” steering.
  - Machine Tuning by targeting nominal dispersion.
  - Dispersion Matching Steering.
- What is next:
  - Demonstrate the possibility to match the two orbits in TL1 within noise level.
  - Apply the feedback for the full closure of CR.
  - Measure the improvement in beam emittance and power production stability.

Thank you.

Effect of mismatched quadrupoles or bendings



Effect of quadrupole misalignment