Drive beam stability and reproducibility

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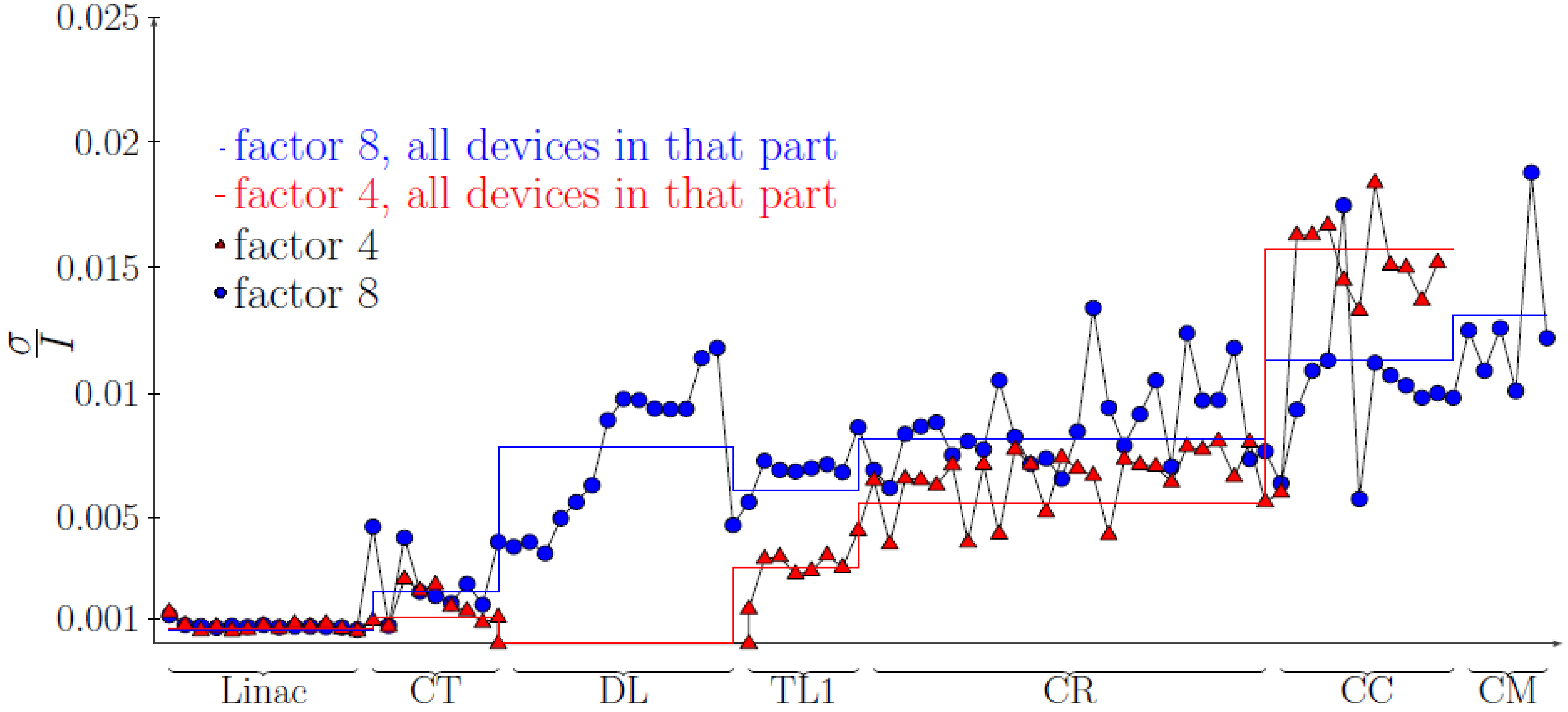
Outline

- Where we are in terms of stability.
- Improvements during last year.
- Improvements foreseen for this year
  - Feedback
  - Operational Improvements
- Reproducibility

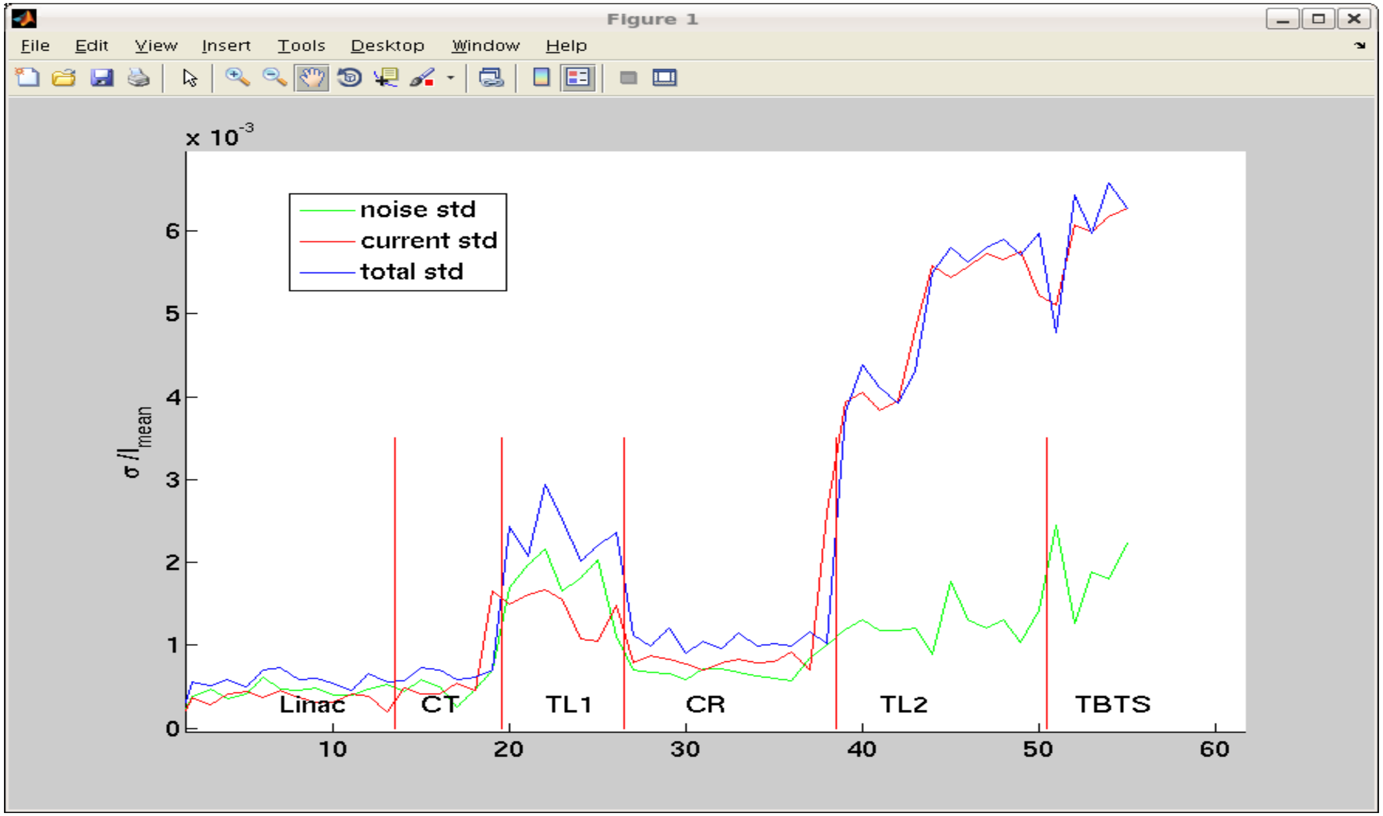
2010



0.025
0.02
0.015
0.01
0.005
0.001
$\frac{\sigma}{I}$
factor 8, all devices in that part
factor 4, all devices in that part
factor 4
factor 8
Linac
CT
DL
TL1
CR
CC
CM

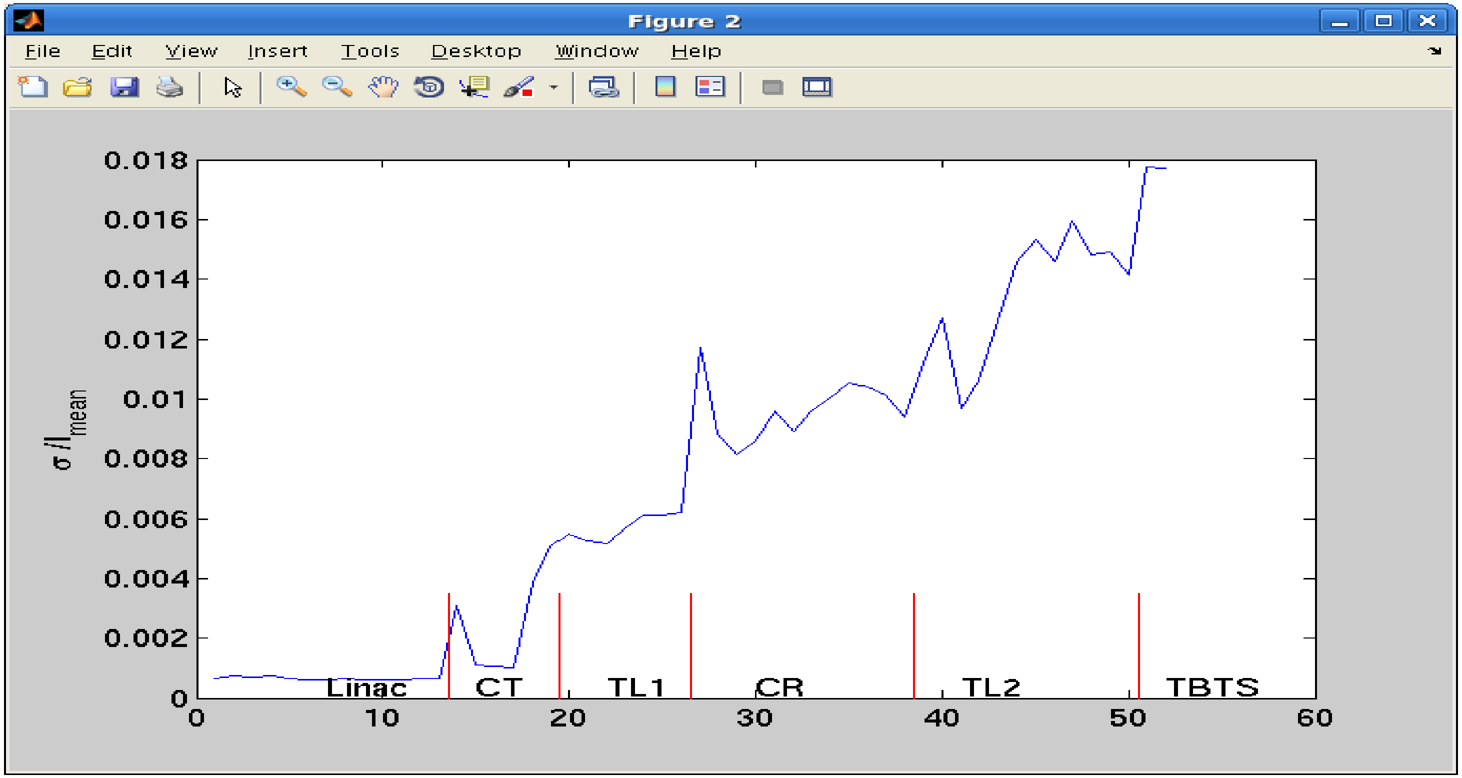
2011 factor 4

- A clear improvement in comparison with 2010.
  - We are reaching the noise level of some of the BPMs.



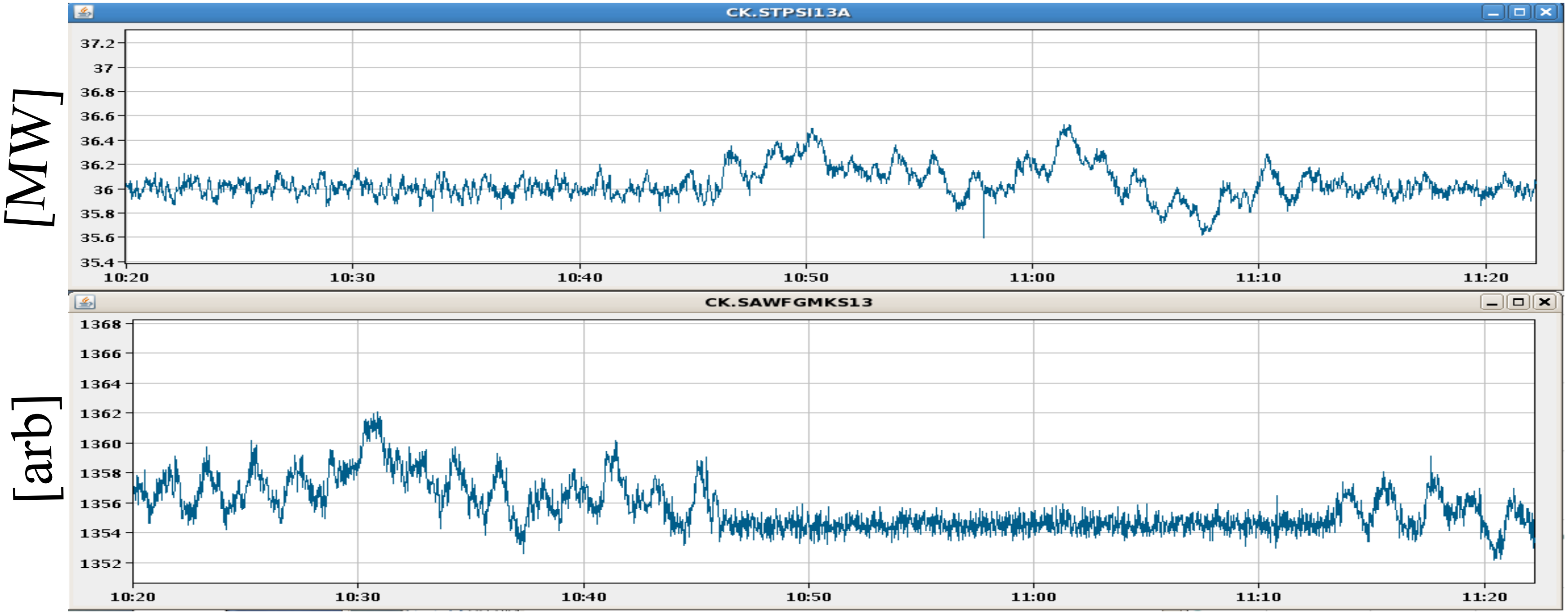
2011 factor 8

- Still roughly 1% in CR for factor 8.
  - Best I found but might be possible to find slightly lower.



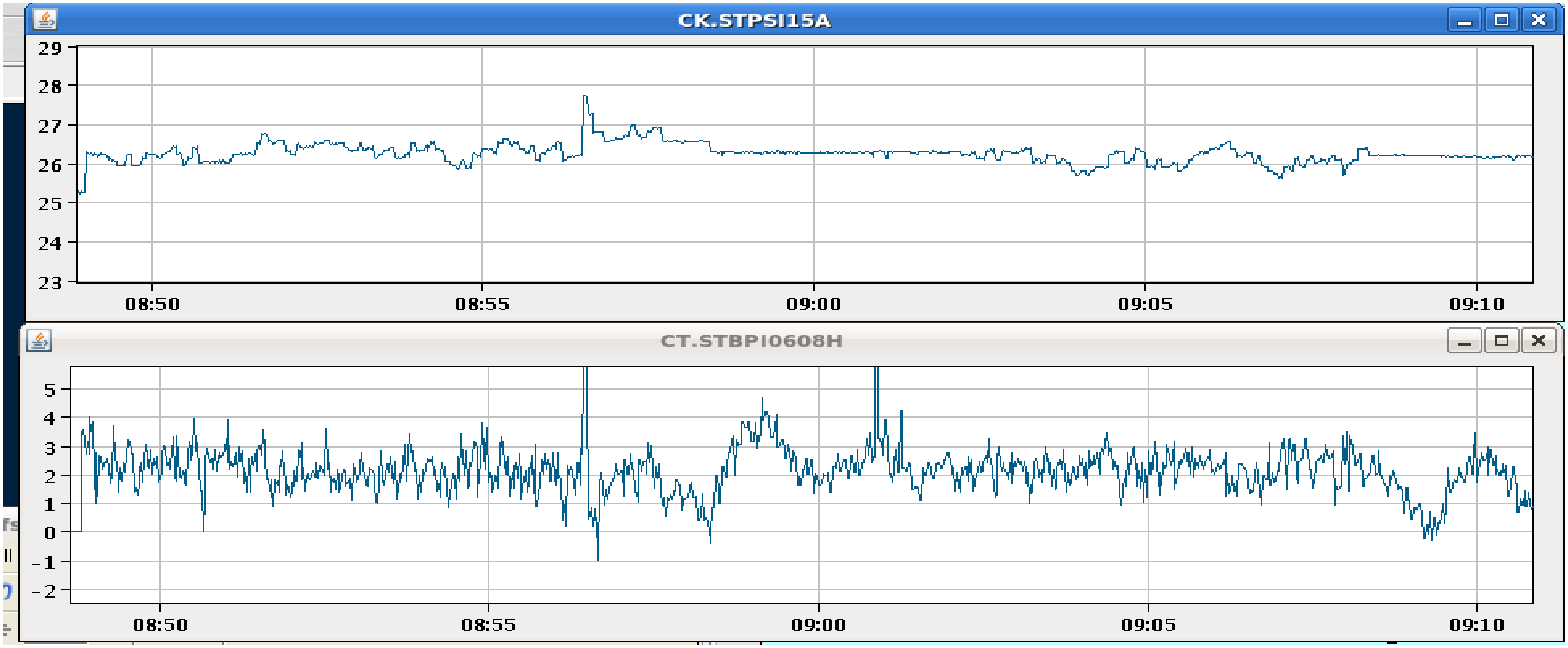
Example of when the feedback is working

- The feedback is on from 10.20 – 10.45. Off from 10.45 – 11.12. On again from 11.12.
- Clearly improves the situation
  - However, still an oscillation. Depending on outside temperature, water flow and working point, the oscillation is smaller or bigger.



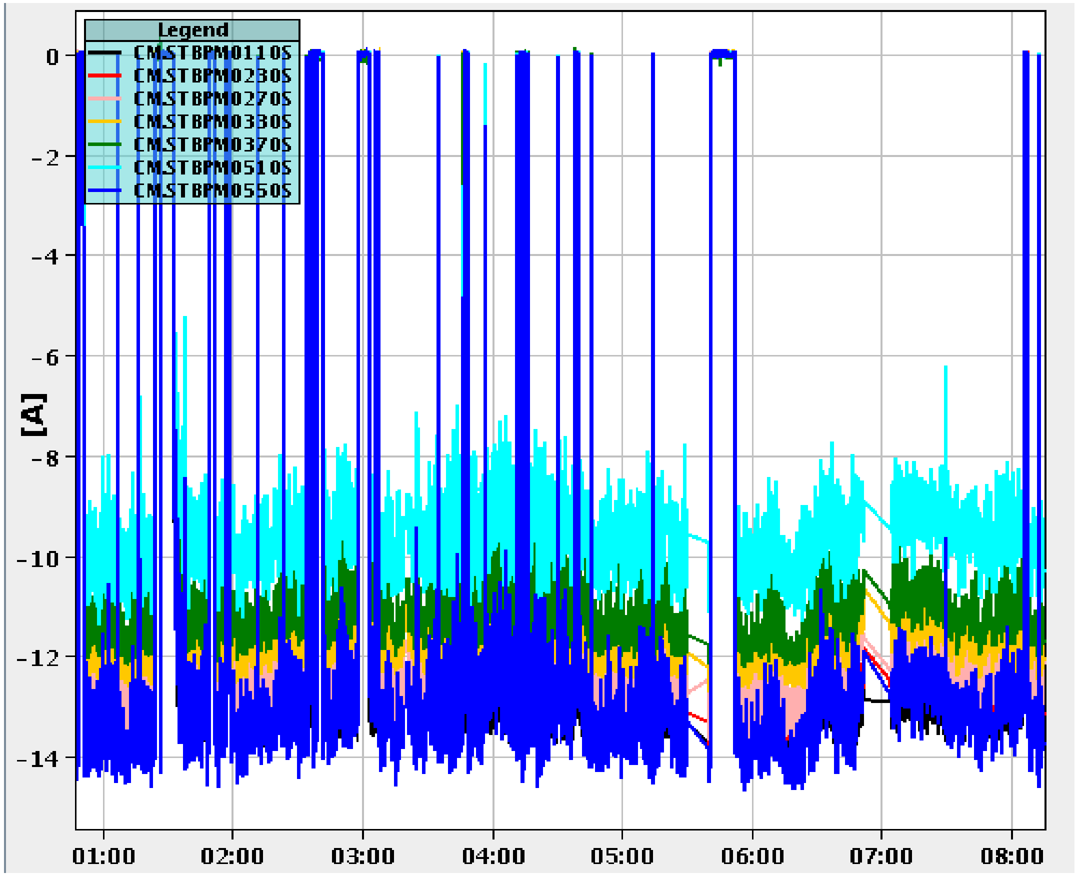
Energy control of the beam

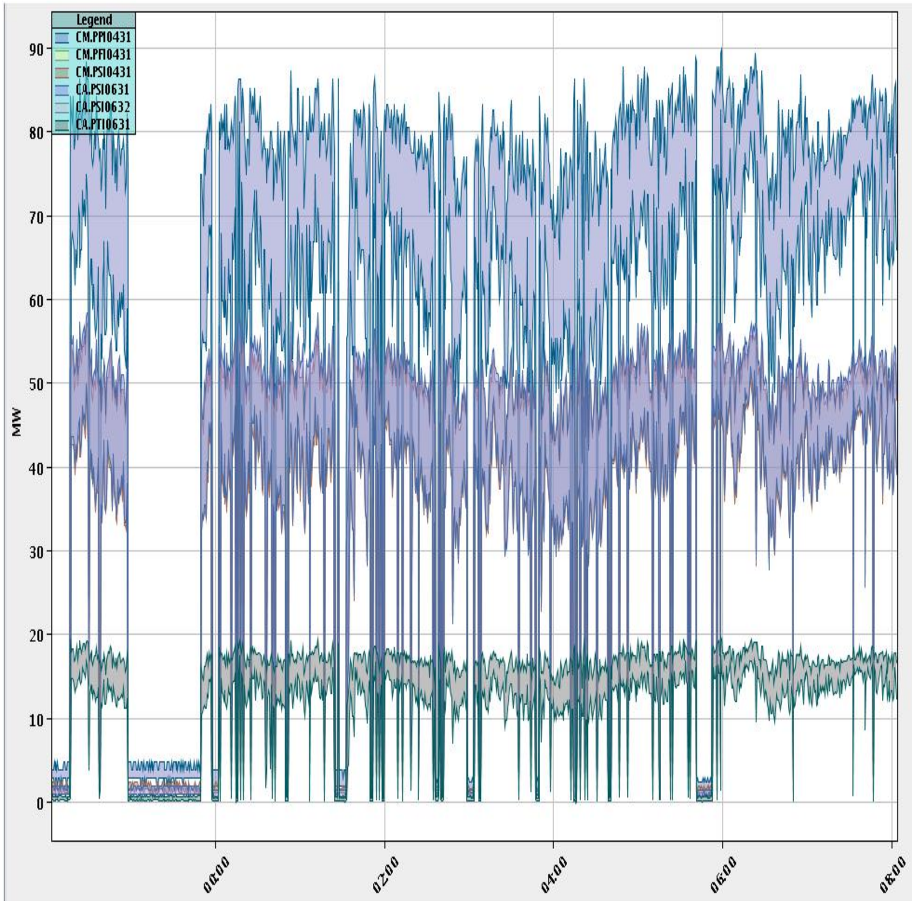
- Feedback on a dispersive pickup. Changing power of MKS15



Successful overnight operation

- Over 12 hours with the only interference of an operator being to restart the klystron. The min to max of the current is ~2A and the power ~40%





The year to come...

- New feedbacks
- Operational improvements
- Proposal for new software

List of feedbacks

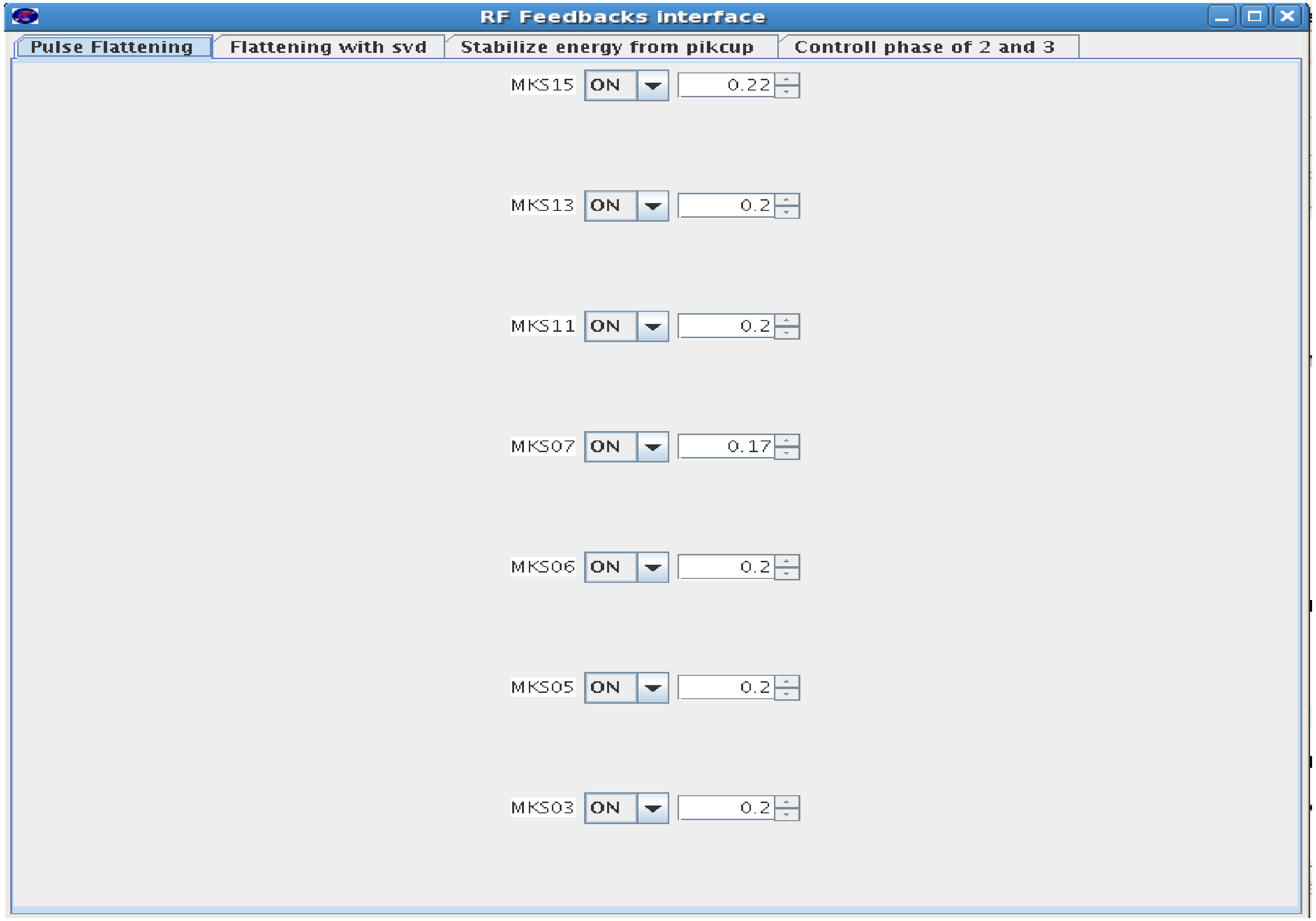
1. Find the optimal setting of the flattening feedback. Implement the possibility to use SVD for flattening.
2. Make the feedback which uses the dispersive pickup and changing power of MKS15 more robust. Make it operational for everyone.

    => Get close to the noise level of beam energy fluctuations.

3. Automatic changing of MKS02 and MKS03 in order to stabilize the power production. Will most likely need BPRs and current as help signals.

Operational Improvements 2012

- The automatic flattening is already used in operation. However, it needs to be more user friendly.



Reproducibility

- Hard to quantify.
- Reproducible, according to me, in that sense that in case of no technical problem we manage to recover reasonable quickly a nice beam.
  - However, if we leave the machine with a beam stability of 10^-3 in CR it will not be at that state next morning even if all the measurements of RF and magnets show the same.
- Still phase of MKS02 and MKS03 are the most used knobs.

Proposal for software (or use of existing)

- Must read all the knobs we change in the machine: quads, correctors, phases of klystron and so on.
  - Only store the time when the knob was changed and the new value.
  - Even with 10 000 changes per day the amount of data is small.

Motivation

We would always have an archive of the setting of the machine.

- No more lost archives!

We would have an automatic trace of the actions taken by the operator to bring the machine to a good state.

- Would help us to understand how we change the machine to recover.

=>Identify problems or automatic procedures to keep the beam more stable.

Other suggestions for improvements

- I suggest to implement the possibility to track the normalized standard deviation of the signals in the CTF3 Monitor.
  - This gives us an online observable of the stability of the signals.

Hopefully this, together with a precise tracking of the changes done in the machine, would help us understand more precisely what the reasons are for the drifts.

- **Discussion!**

Extra slides

Beam stability

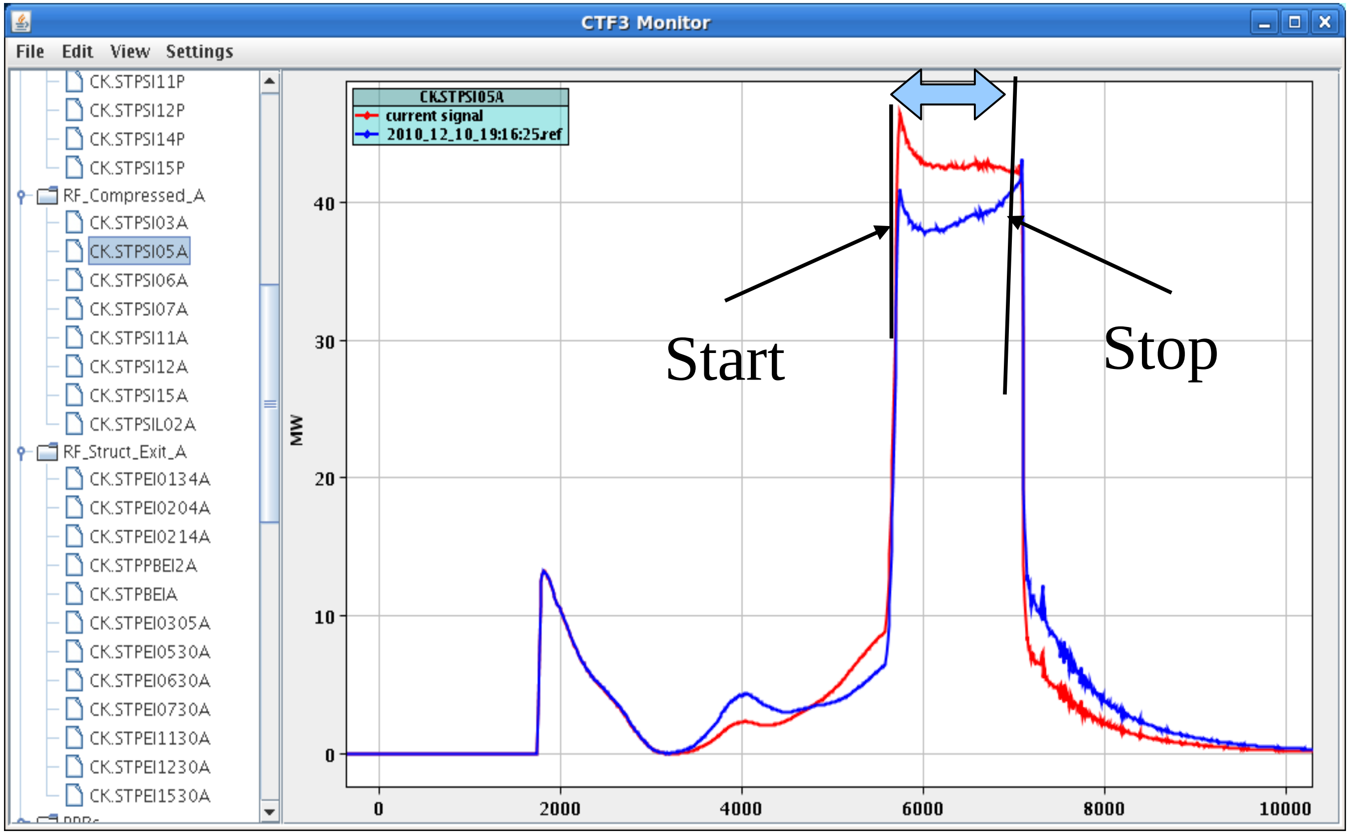
- There are at least two different types of time scales when talking about beam stability.
  - Pulse to pulse stability
  - Stability over many pulses.
- Pulse to pulse stability can not be cured by a feedback.
- However, a feedback can enable us to do better measurements to correct optics
  - => Larger acceptance!

=> Better pulse to pulse stability!

Work flow

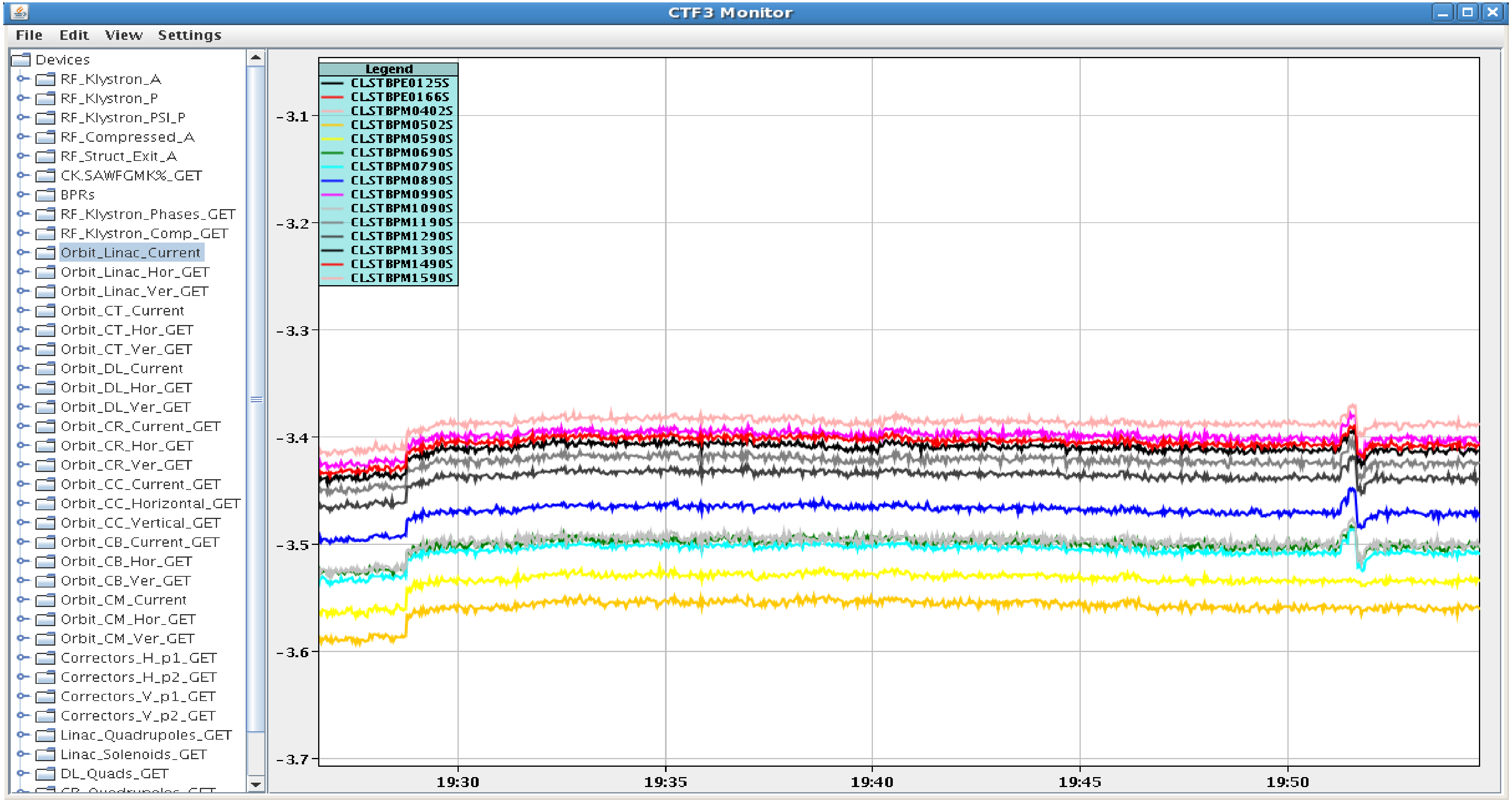
- CTF3 Monitor is the tool used to identify the drifts and jitter.
  - Possibility to load a reference to see what has changed between the two state of the machine.
  - Continues logs the mean value for each signal.
  - Can see the historical change of every parameter.
  - The correlation between two signal
    - Very important to find dynamic losses

CTF3 Monitor

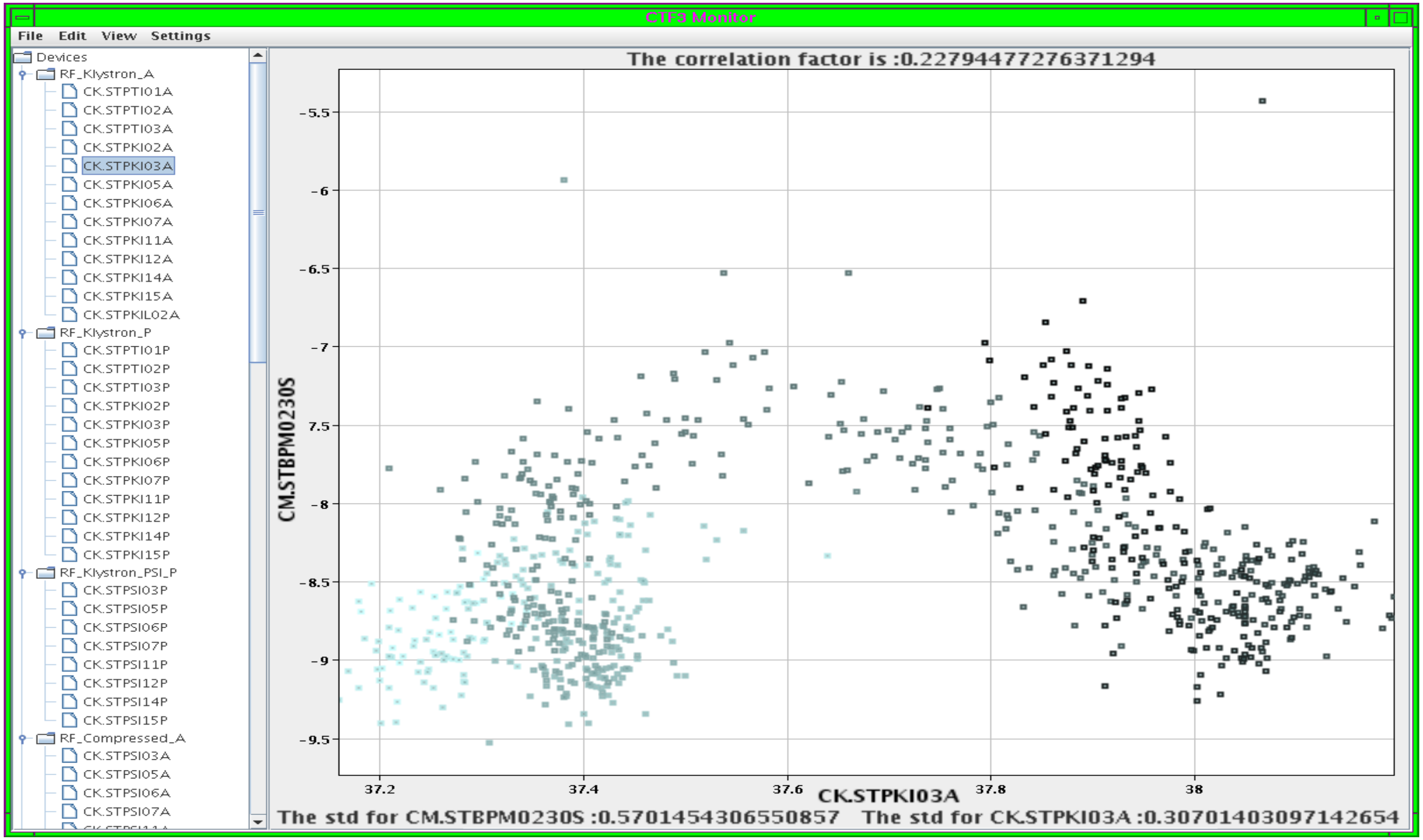


$$\chi^2 = \frac{1}{start - stop} \sum_{i=start}^{stop} \left(\frac{x_i - r_i}{\sigma}\right)^2$$

Historical view



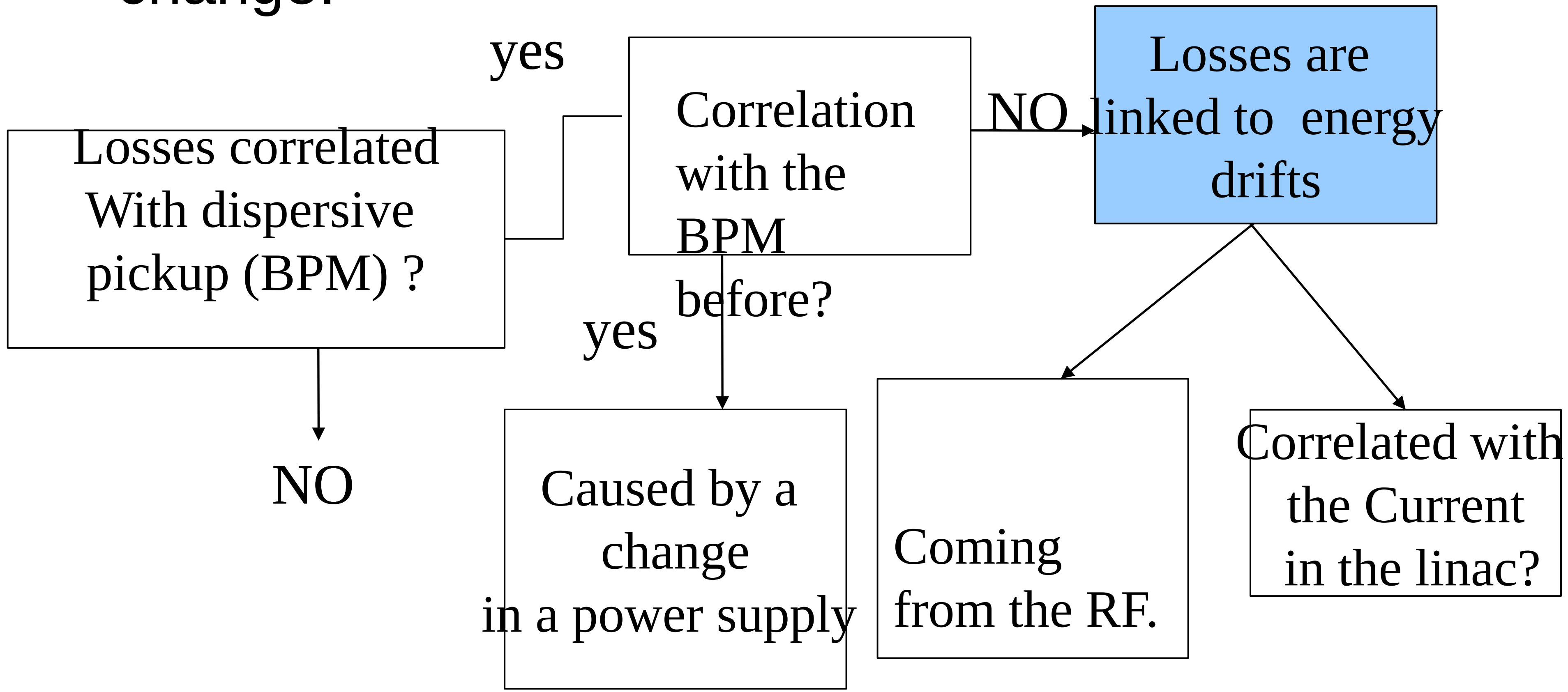
Correlation plot



$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

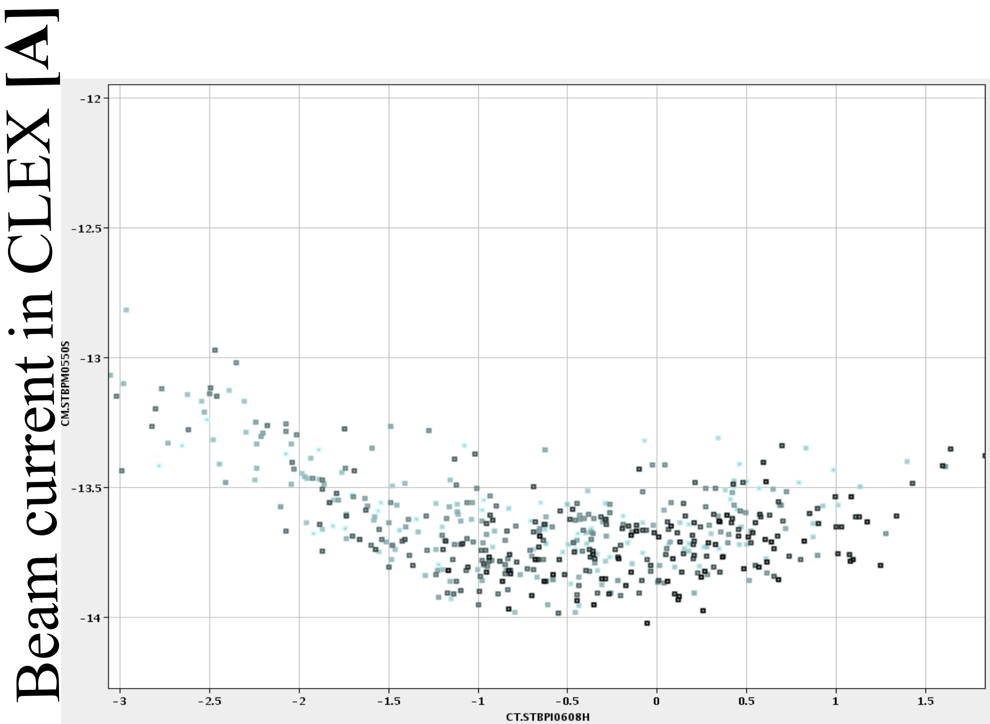
Work scheme

- Hypothesis: The dynamic loses are linked to energy change.

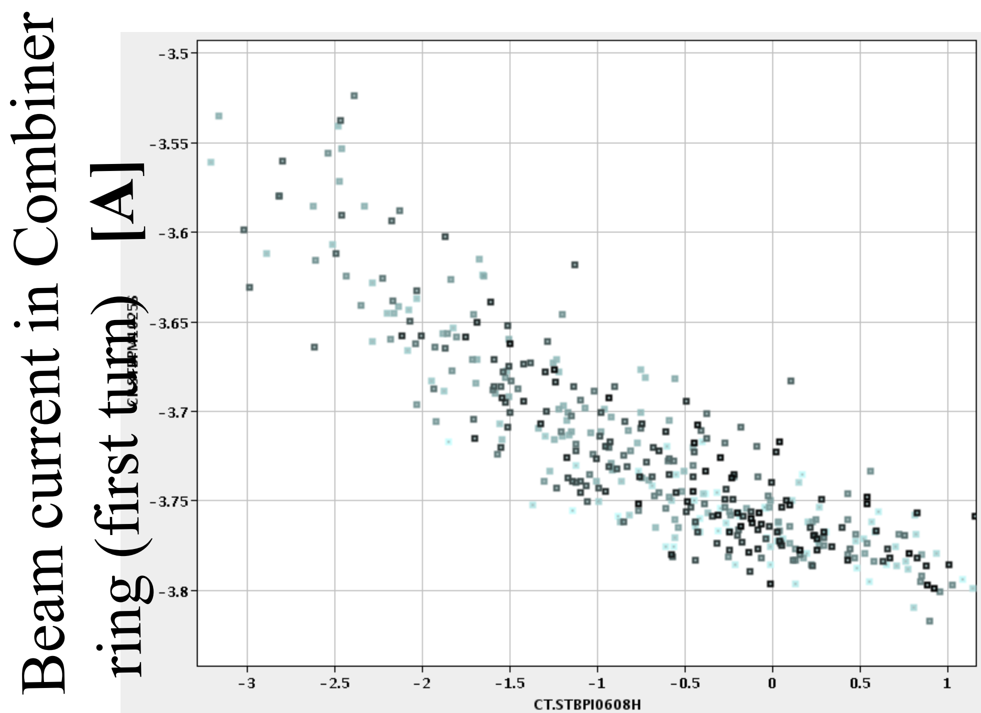


Where do the dynamic losses come from?

The losses are correlated to position in a dispersive pickup.

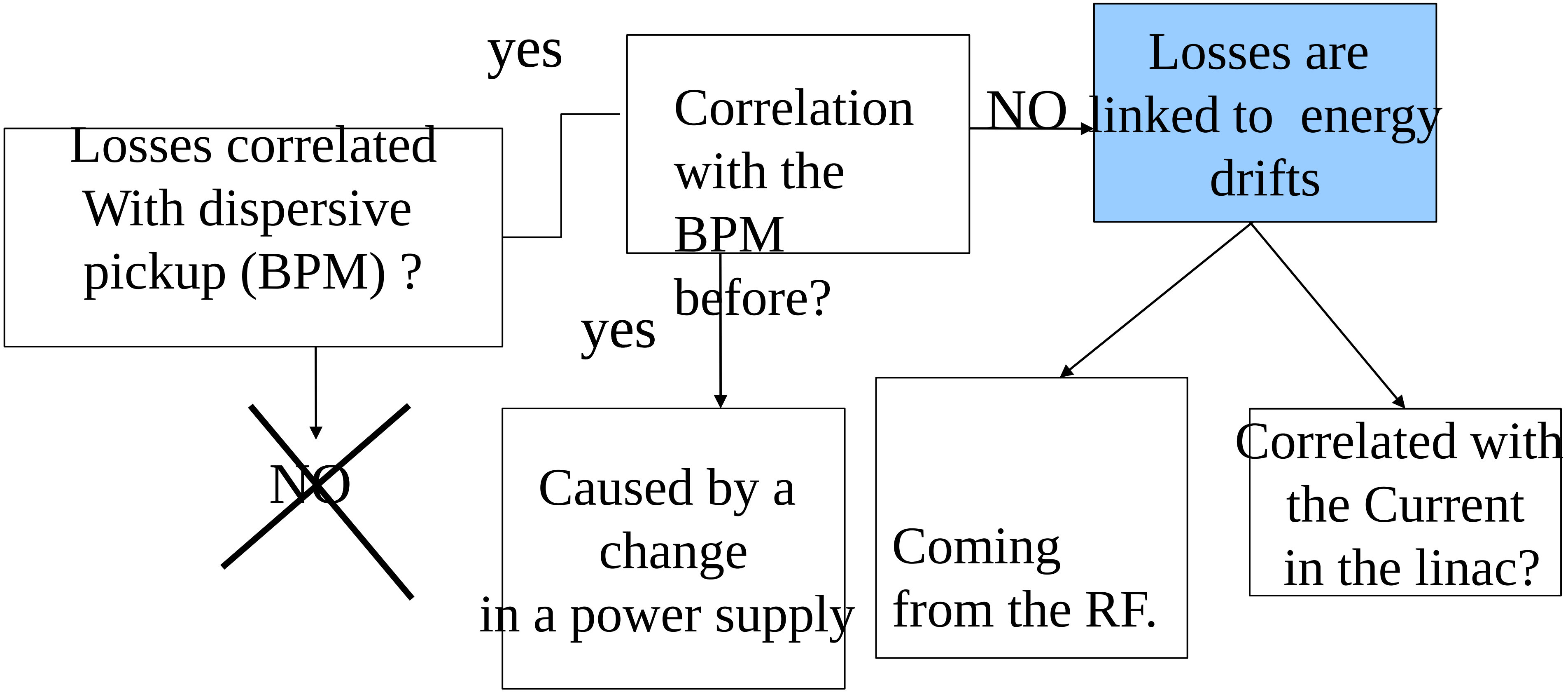


Dispersive BPM [mm]

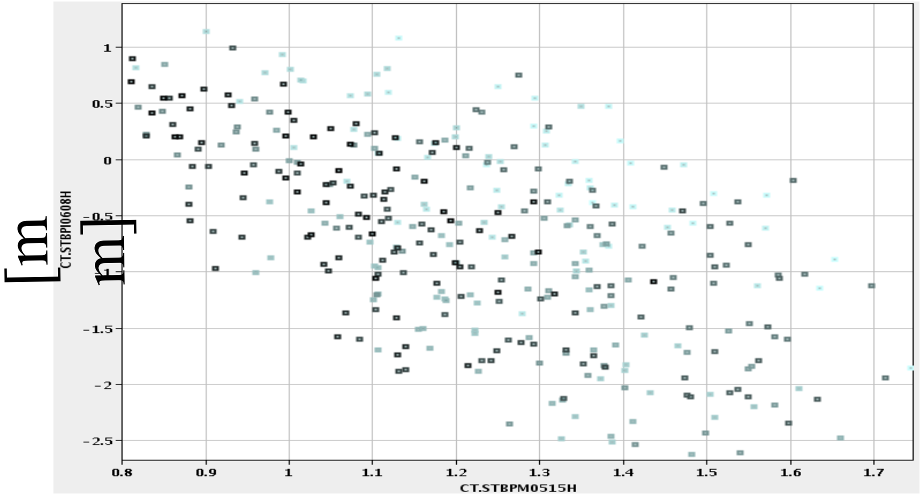


Dispersive BPM [mm]

Work scheme

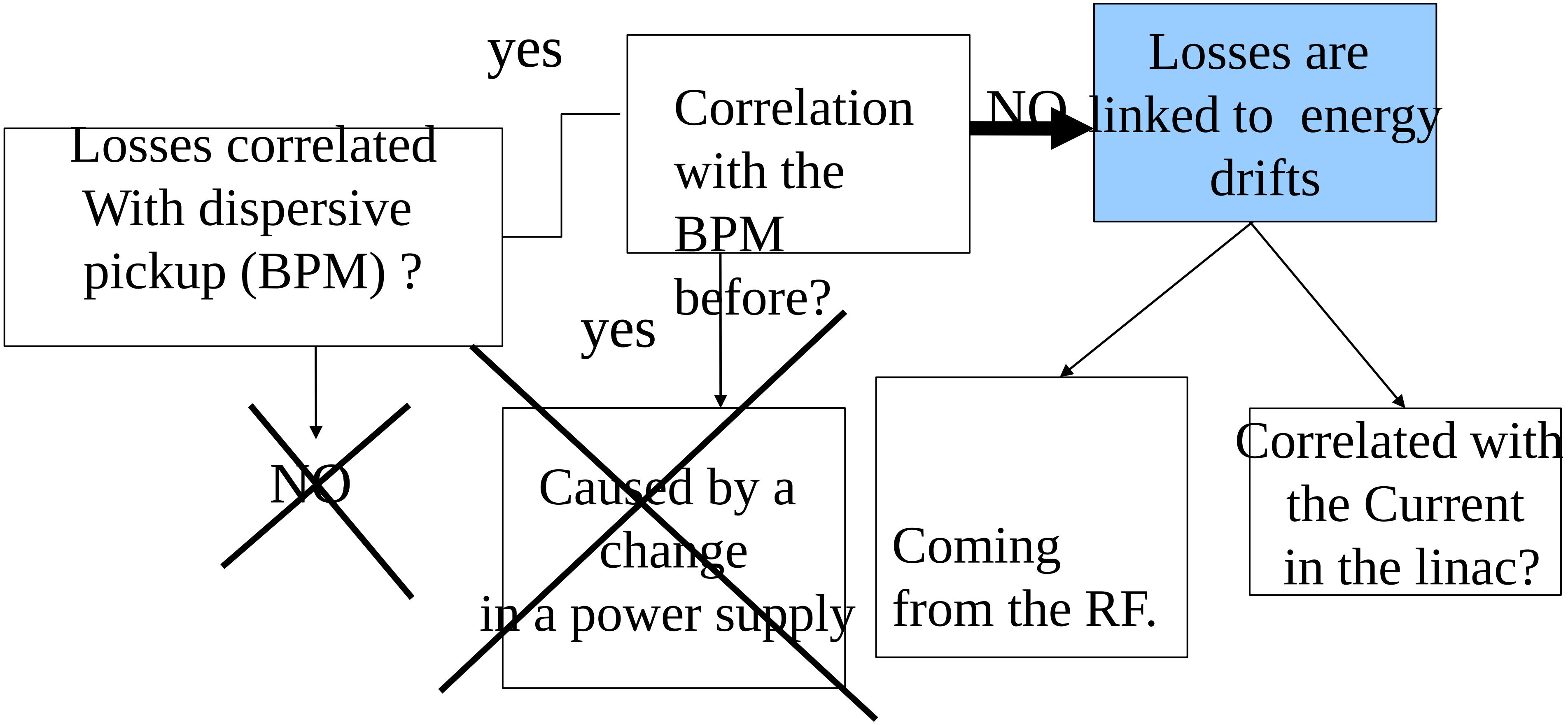

Losses correlated
With dispersive
pickup (BPM) ?
yes
Correlation
with the
BPM
before?
NO
Losses are
linked to energy
drifts
yes
NO
Caused by a
change
in a power supply
Coming
from the RF.
Correlated with
the Current
in the linac?

- Small correlation (factor 0.35) with the non-dispersive BPM before.
  - The small correlation shows that the dispersion is not perfectly closed.
  - Before the Frascati chicane the correlation is even smaller



[mm]

Work scheme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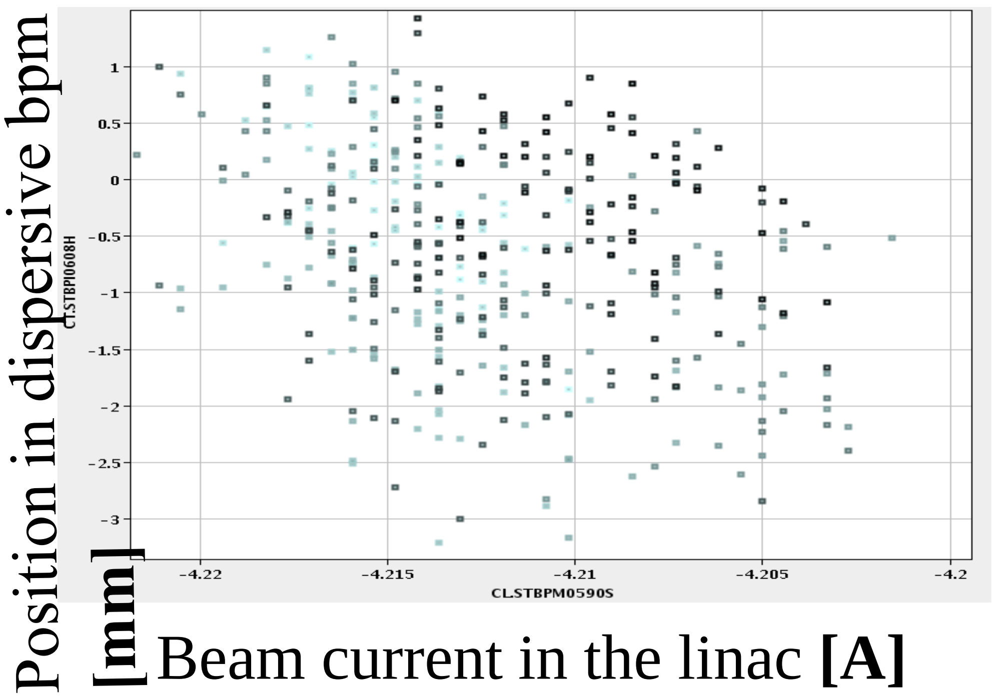
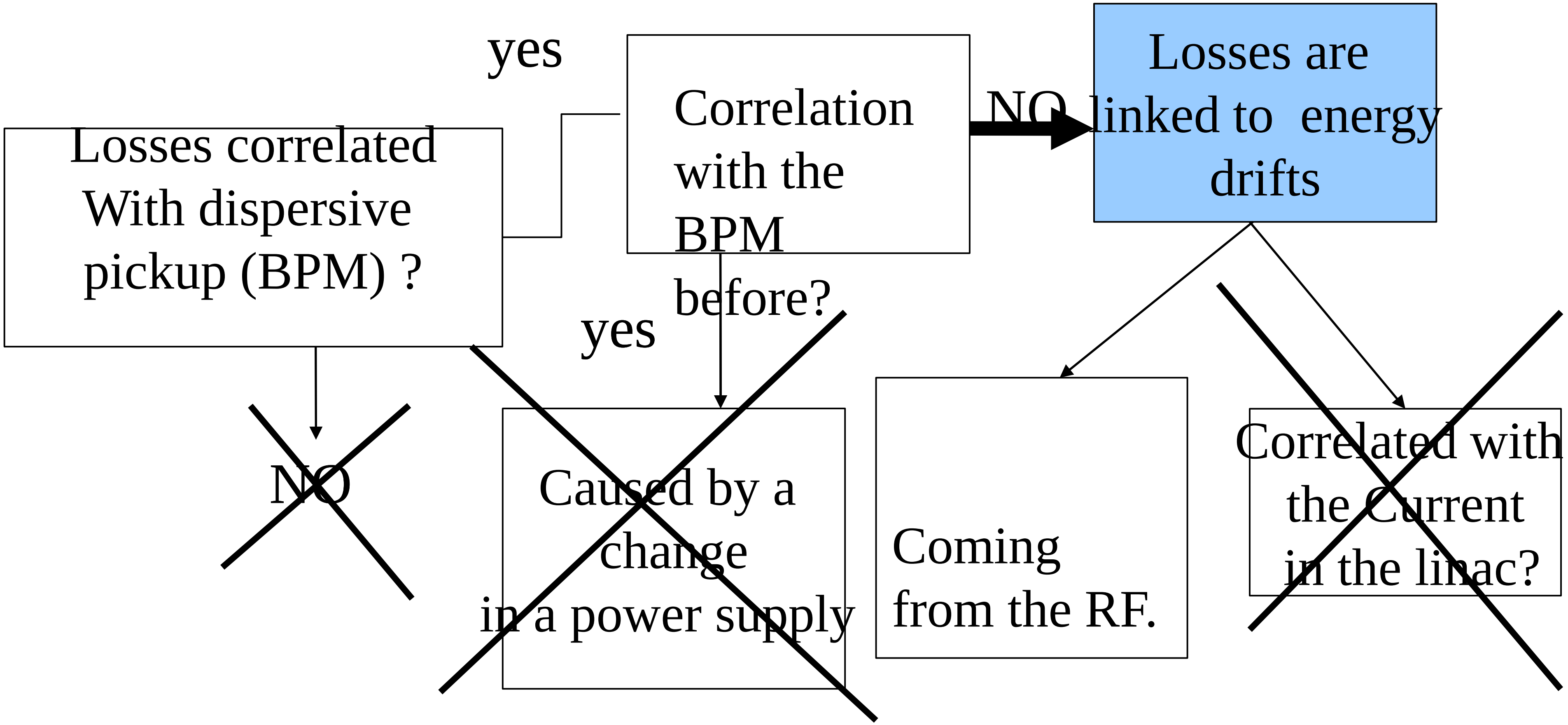
- Since we run in full loaded mode, a change in current will translate into a change in energy. If this is the cause the position in a dispersive pickup will be correlated with the beam current.



Work scheme



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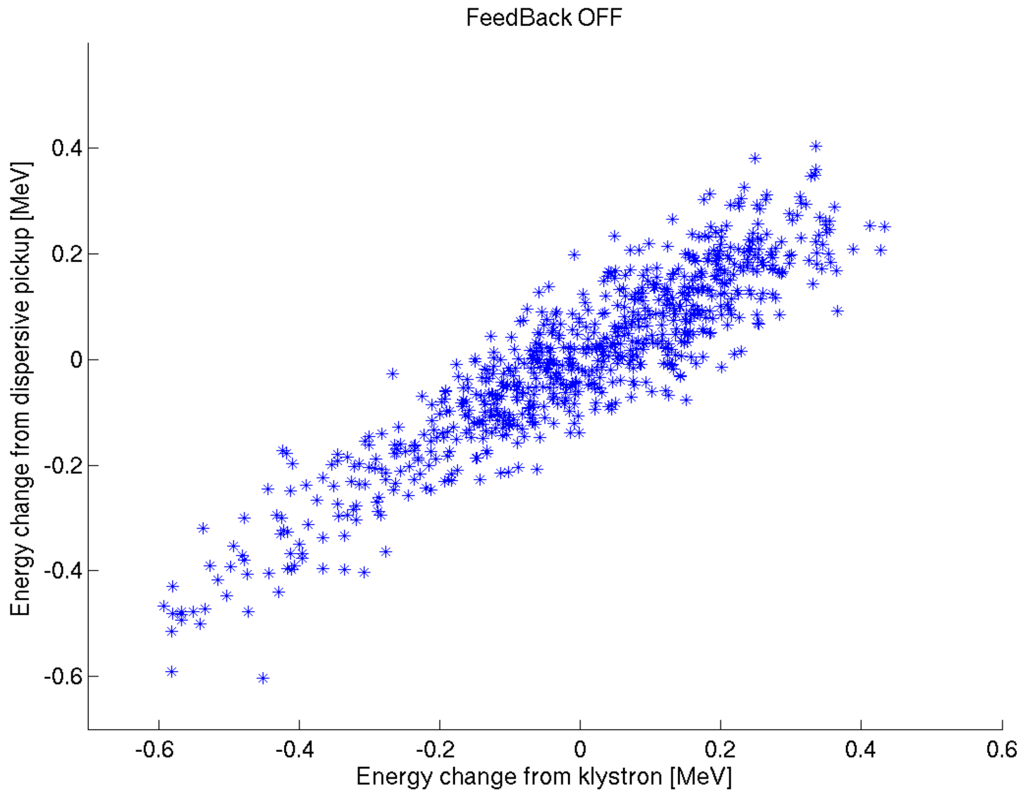
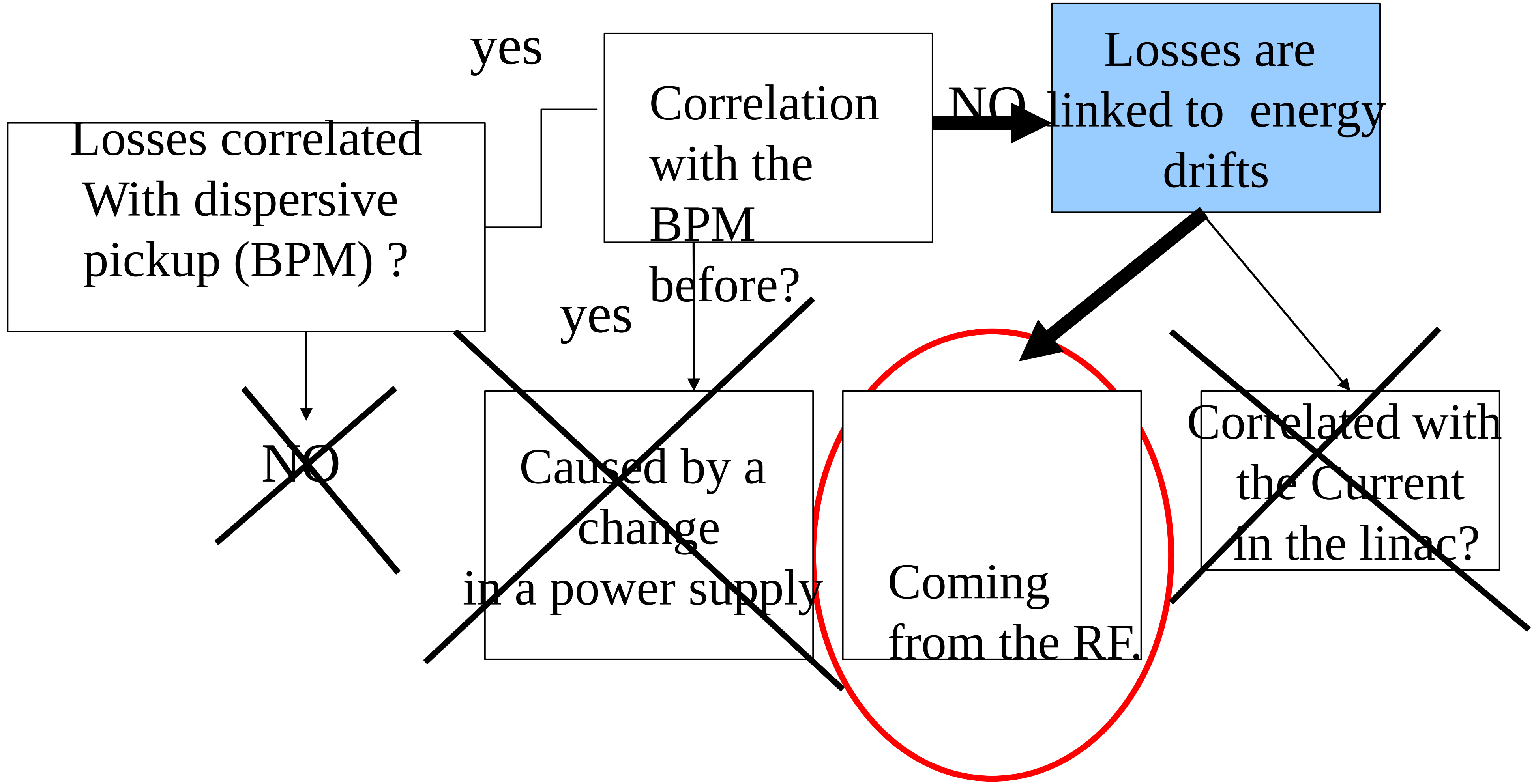
Energy change

- Measuring the output power of the klystron and convert them into an acceleration taking the beam current into account.



Work scheme



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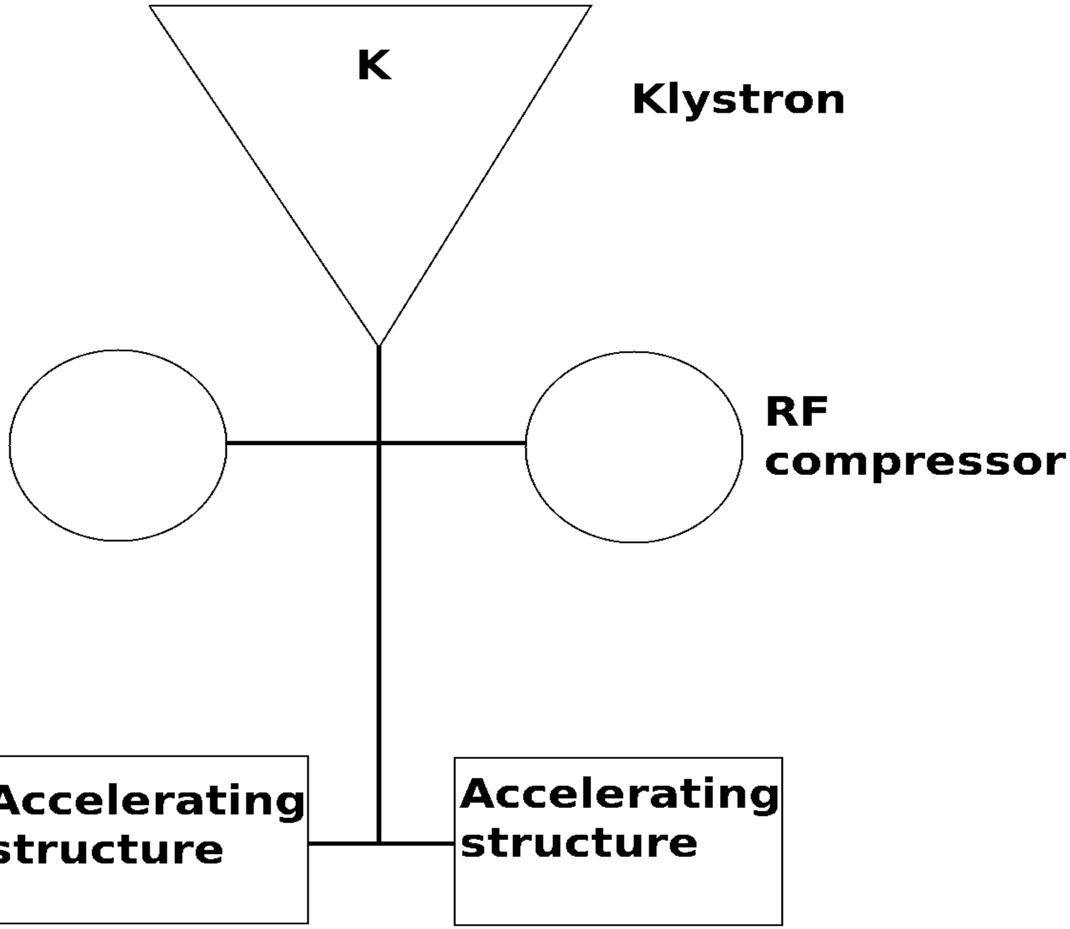
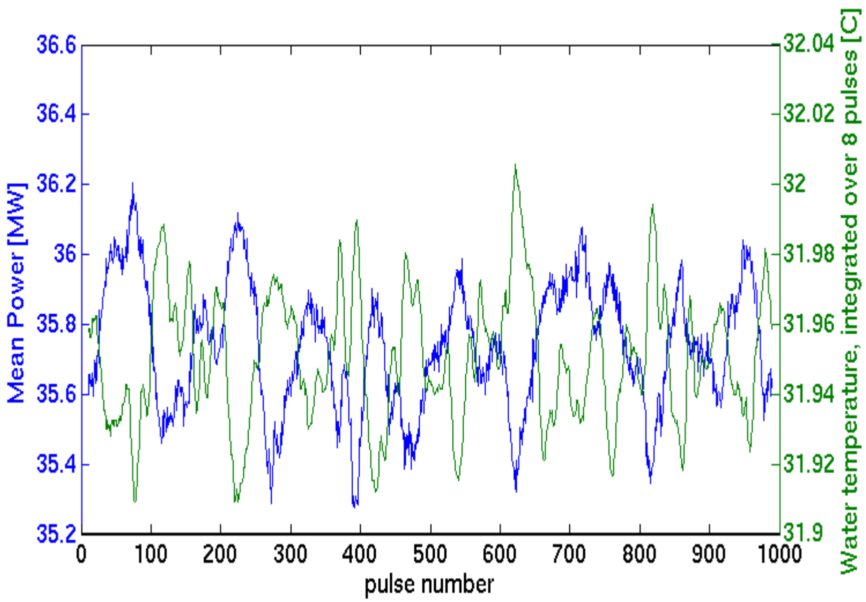
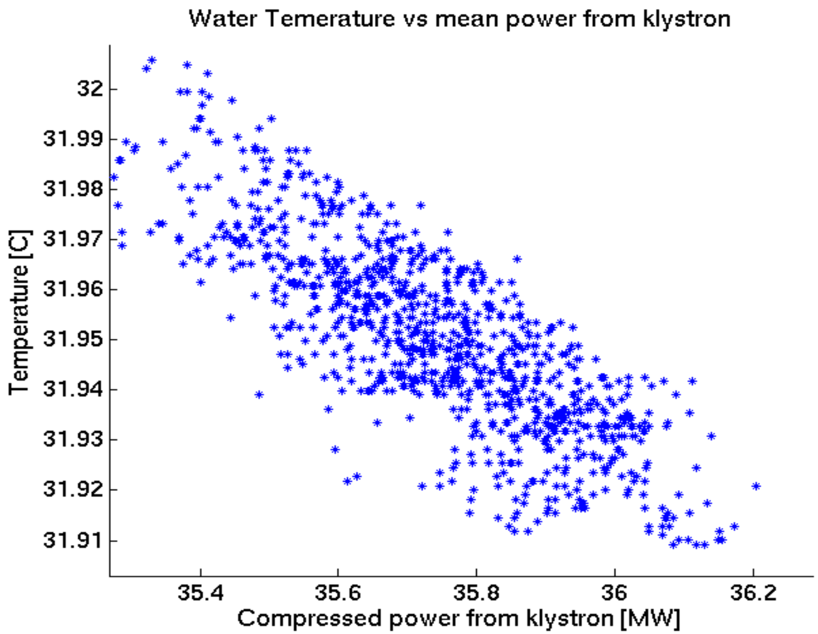
The RF-compression scheme



Water temperature

- The cooling water has a big influence on the stability of the output power.



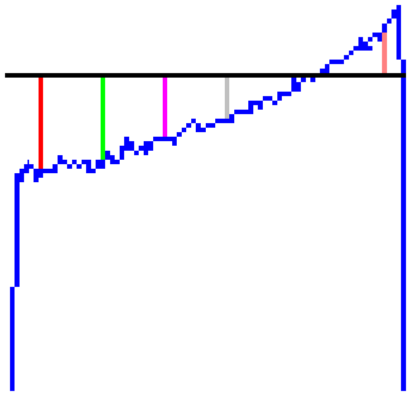


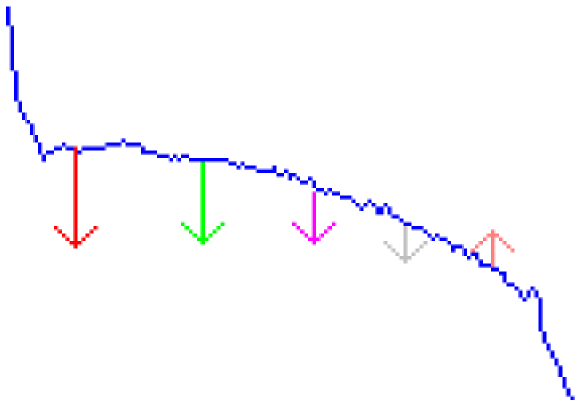
What can we do?

- The water station is controlling the temperature to a level of 0.1 degree, which is within the specification.
  - Would possibly need a large investment to reach a order of magnitude better temperature stabilization.
- We can change the pulse compression to compensate for the drifts.

How does it work

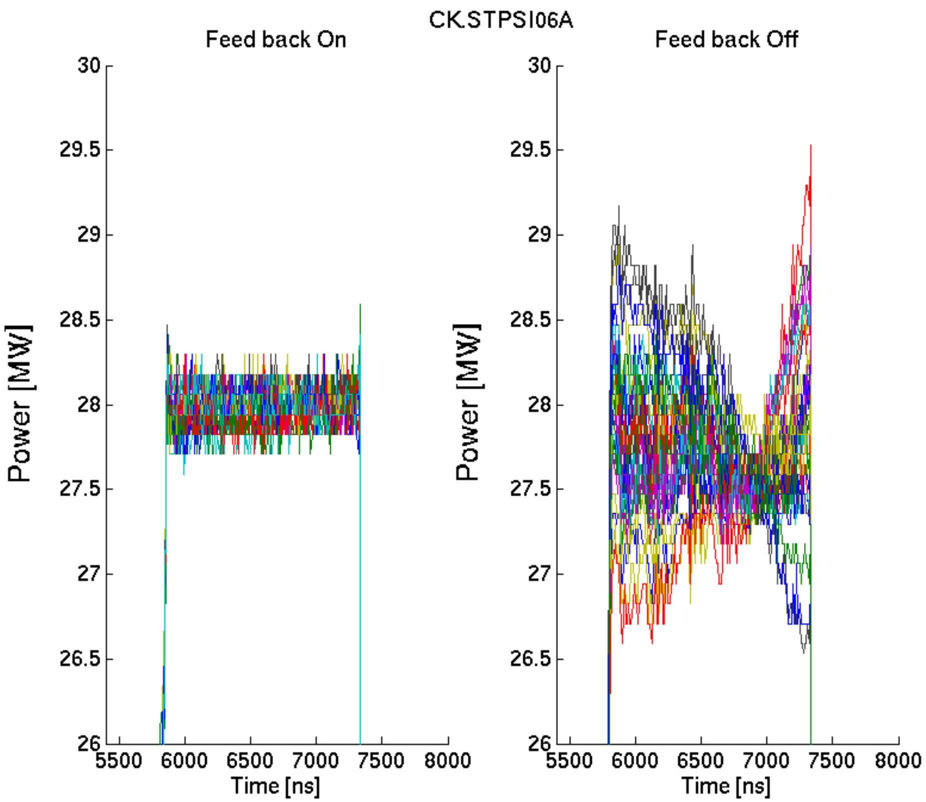
- Measure the compressed pulse and adjust the compression accordingly.
  - Non-linear system.
  - Changing one point also influences the other points.
  - --> Small steps

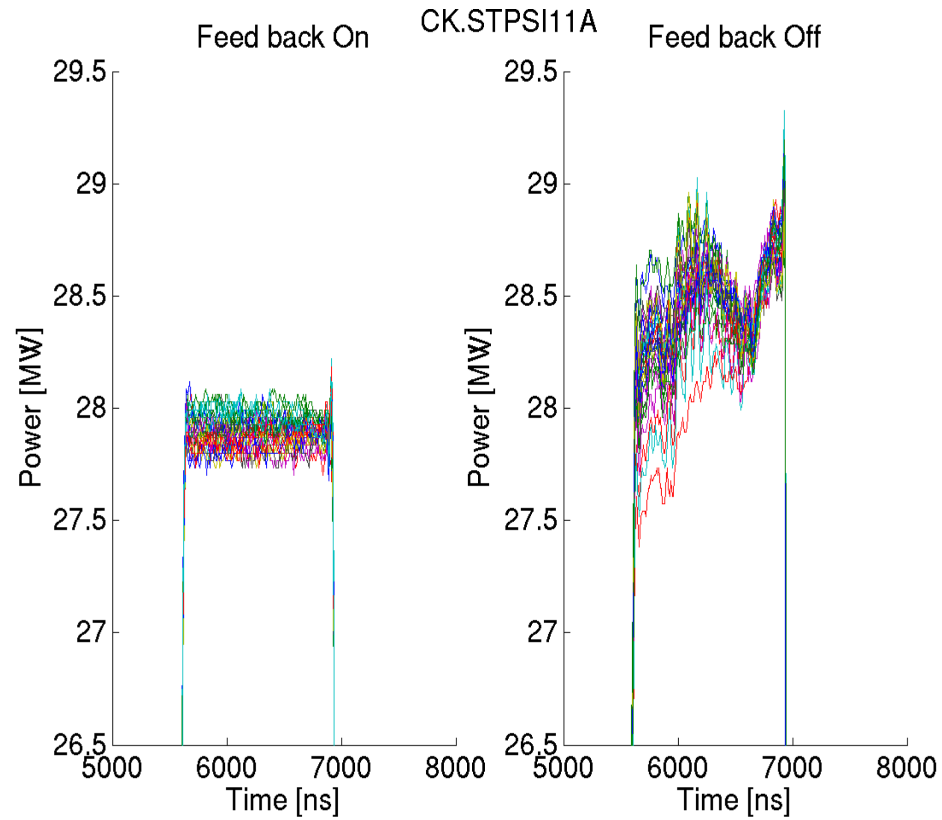




Results

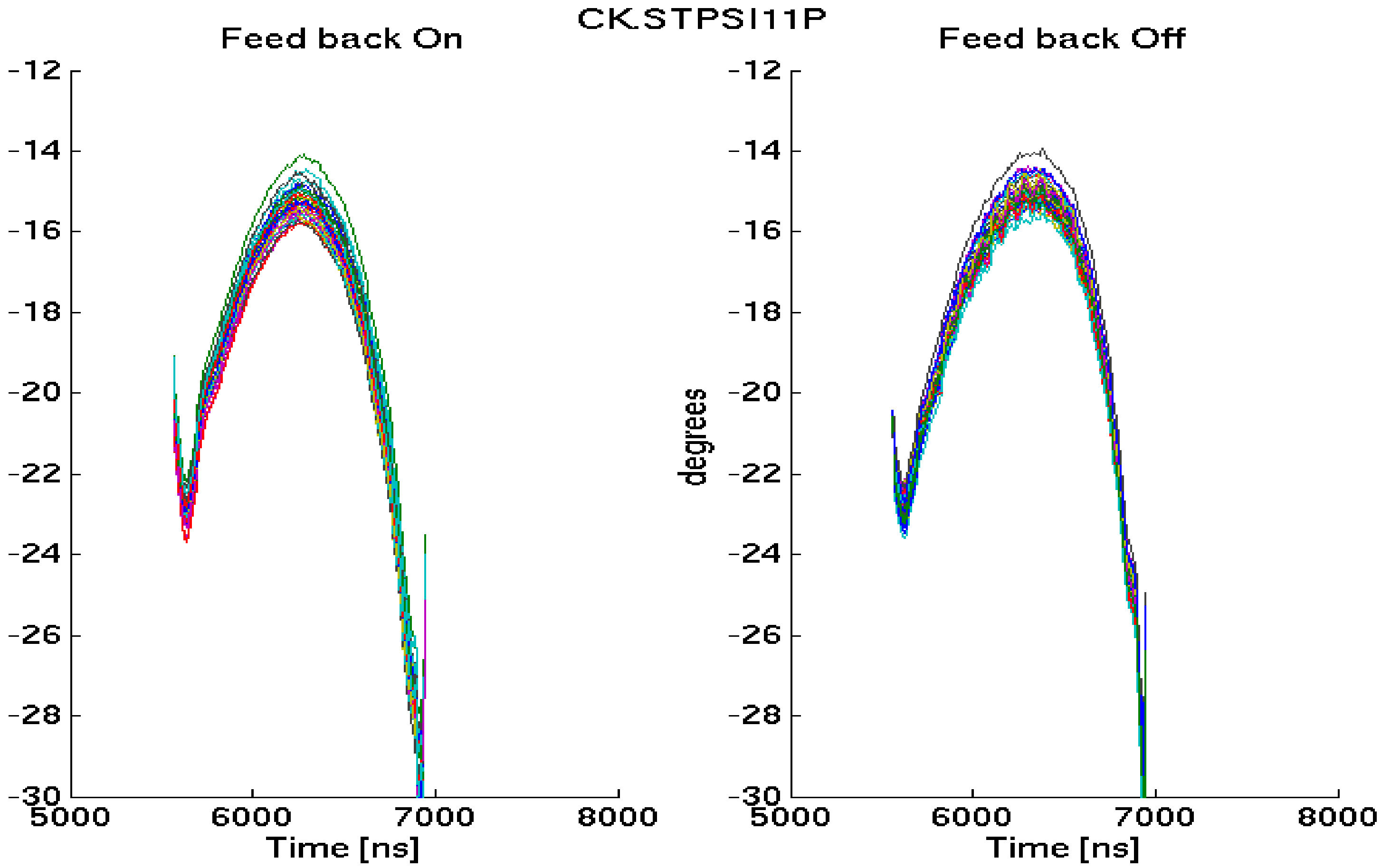
- Over 6 h, saved 1 pulse every 10 minutes





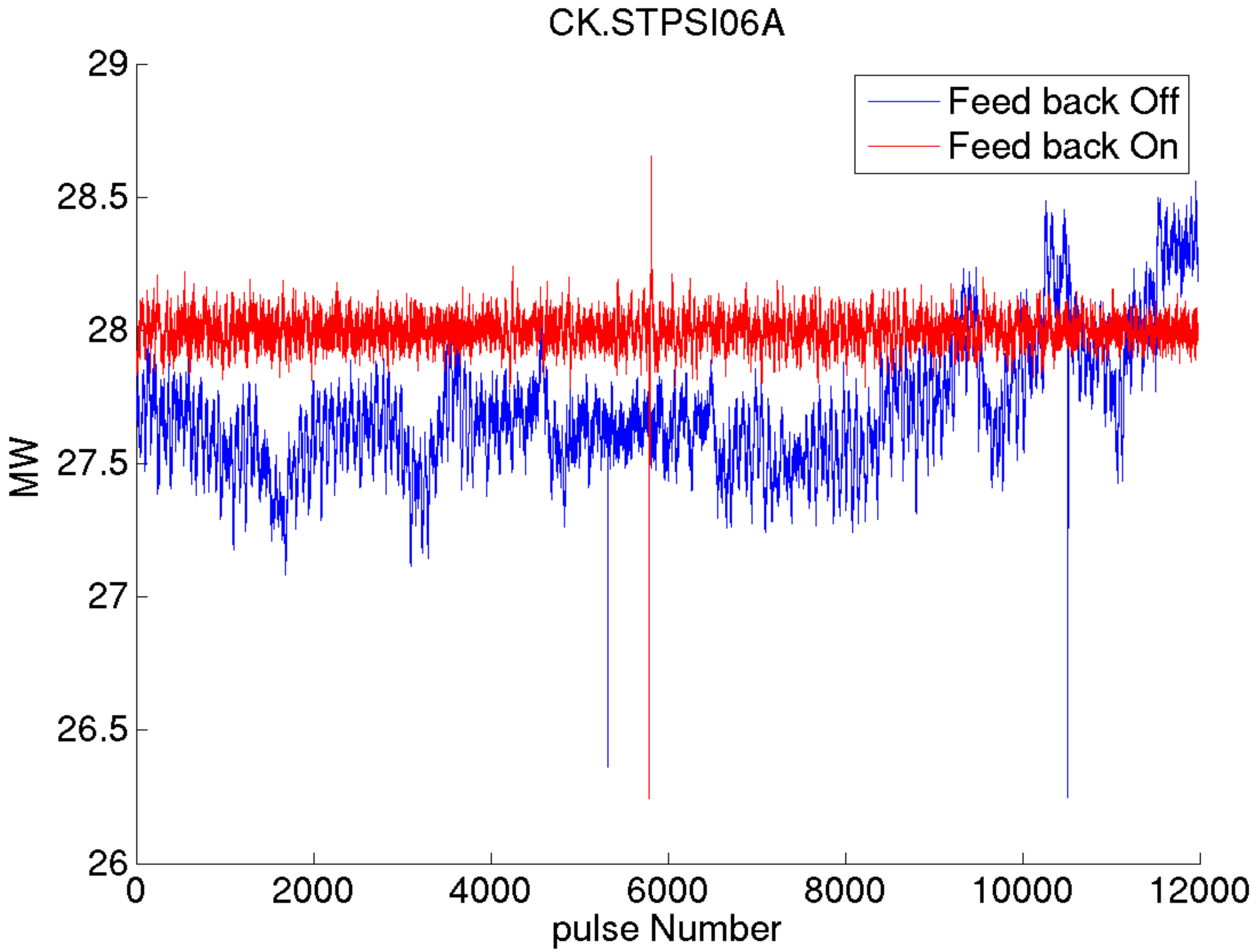
Results

- Does not affect the stability of the phase.



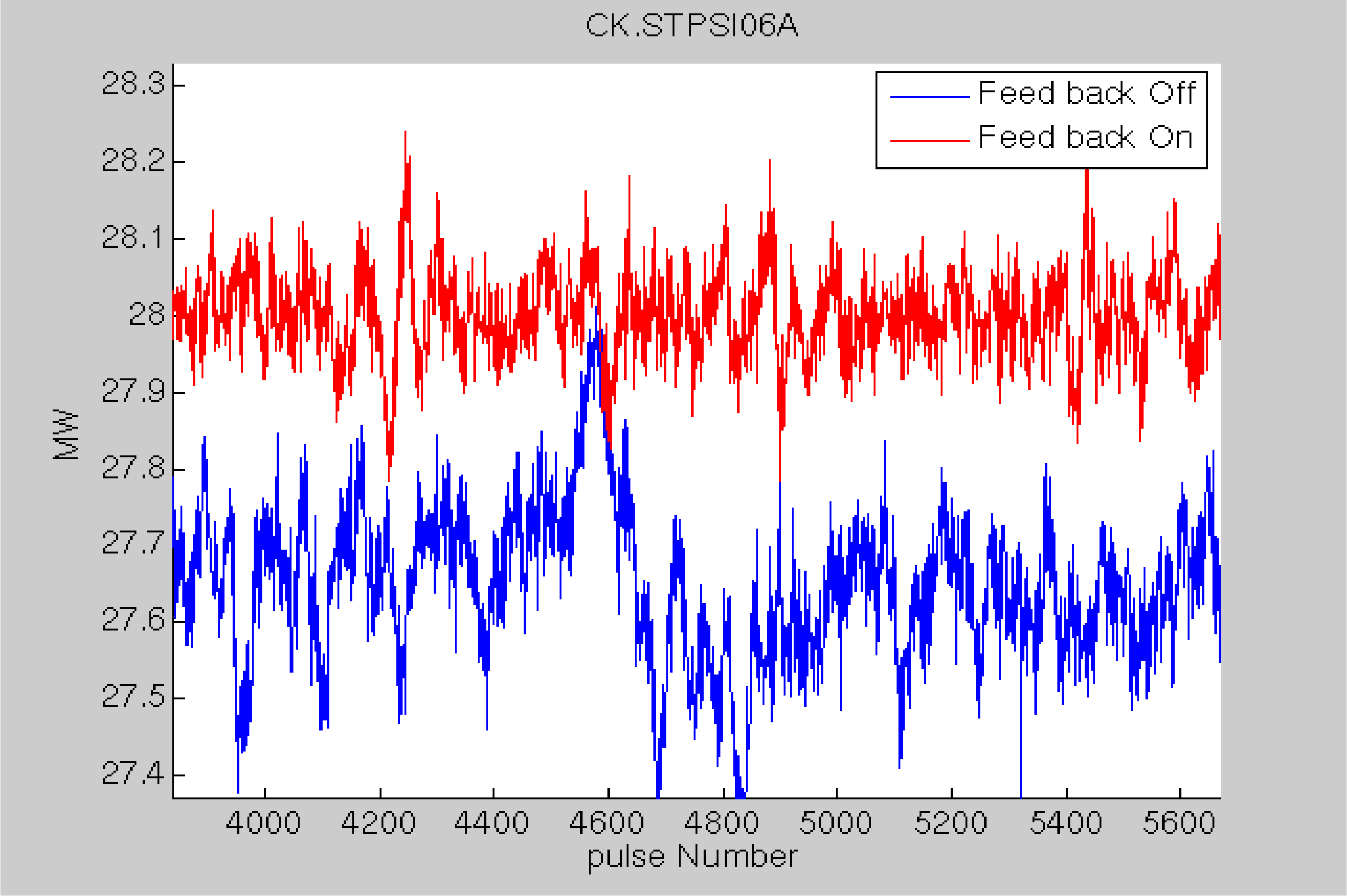
Mean amplitude of psi 06

- 12000 pulses over 4h



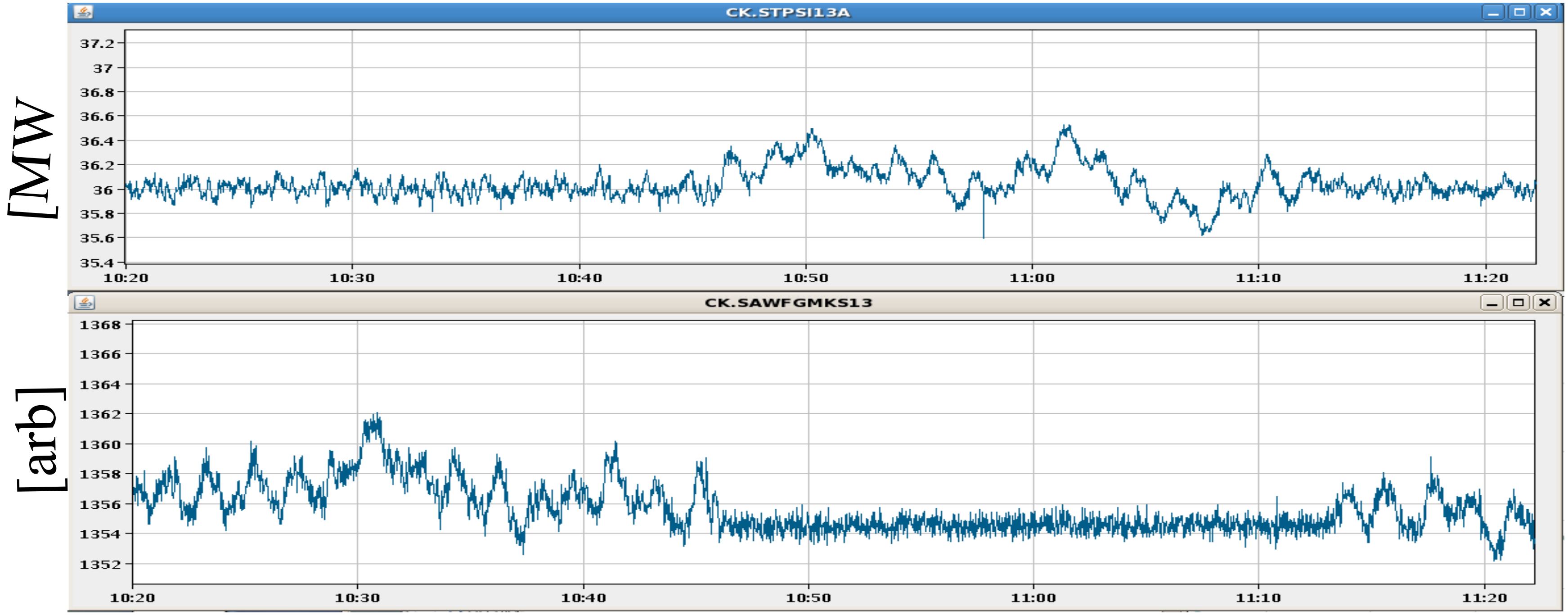
Mean amplitude of psi 06

- If we zoom in it is visible that there is a residual oscillation.



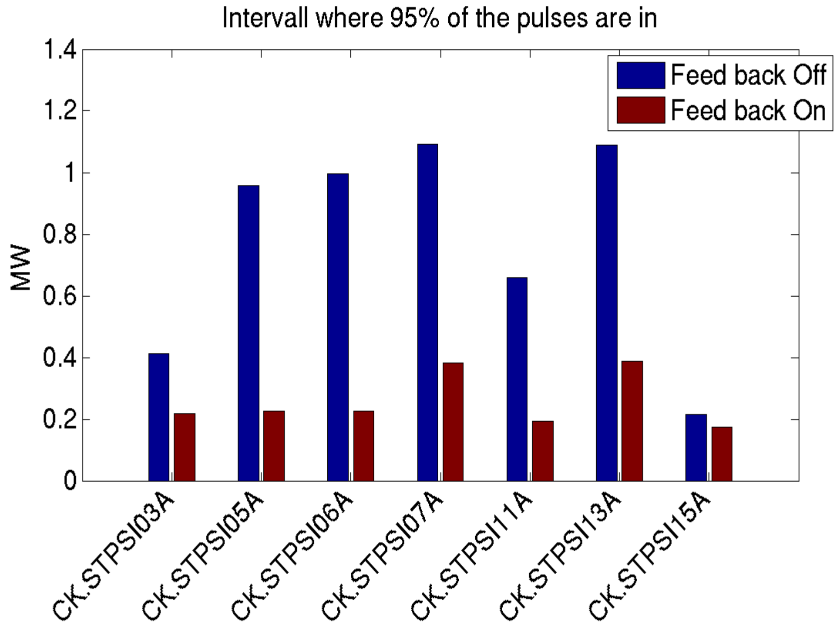
Example of when the feedback is working

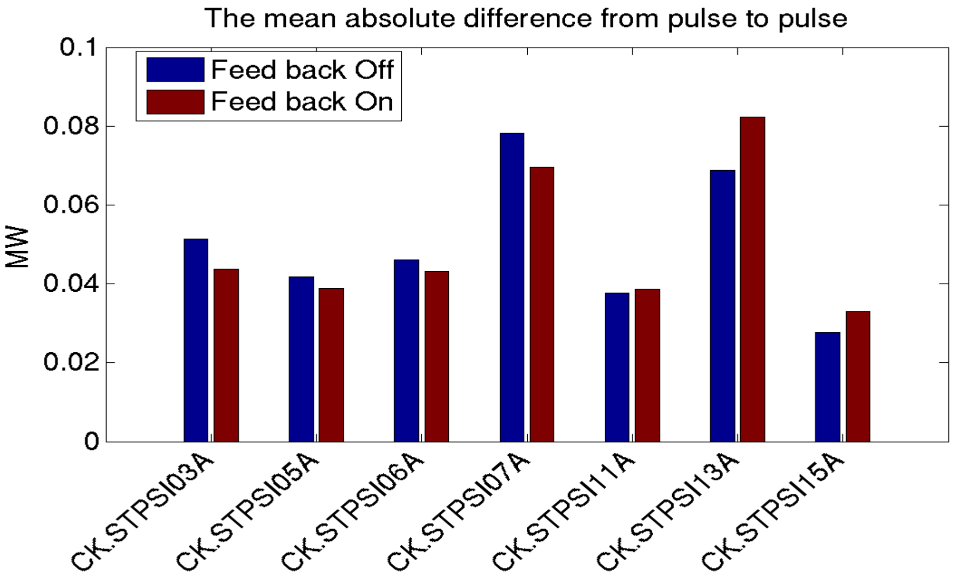
- The feed back is on from 10.20 – 10.45. Off from 10.45 – 11.12. On again from 11.12.
- Clearly improves the situation
  - However, still an oscillation. Depending on outside temperature, water flow and working point, the oscillation is smaller or bigger.



Summary of feedback performance

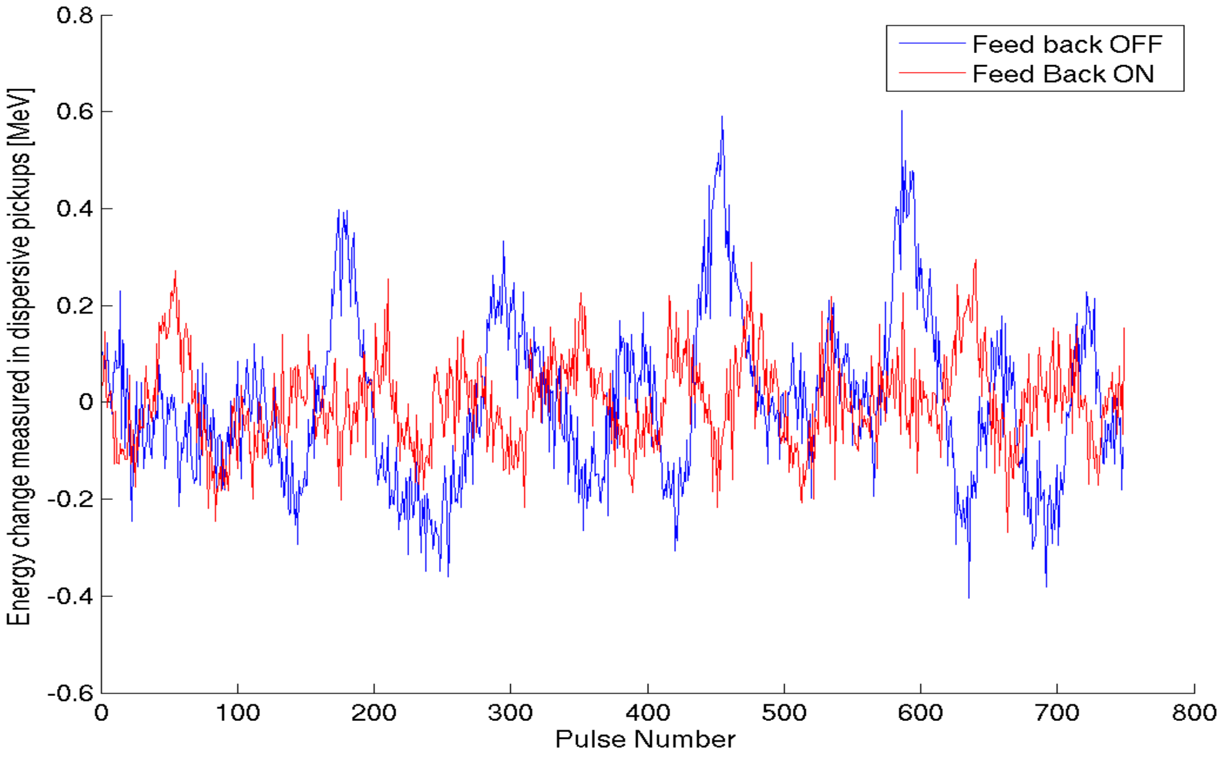
- Increase the stability of the output klystron without increasing the pulse to pulse jitter.



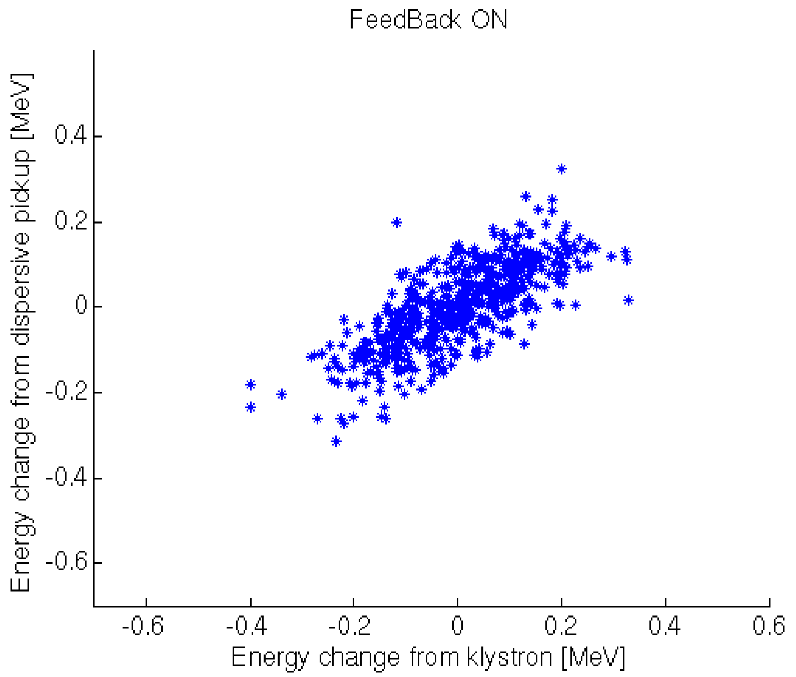


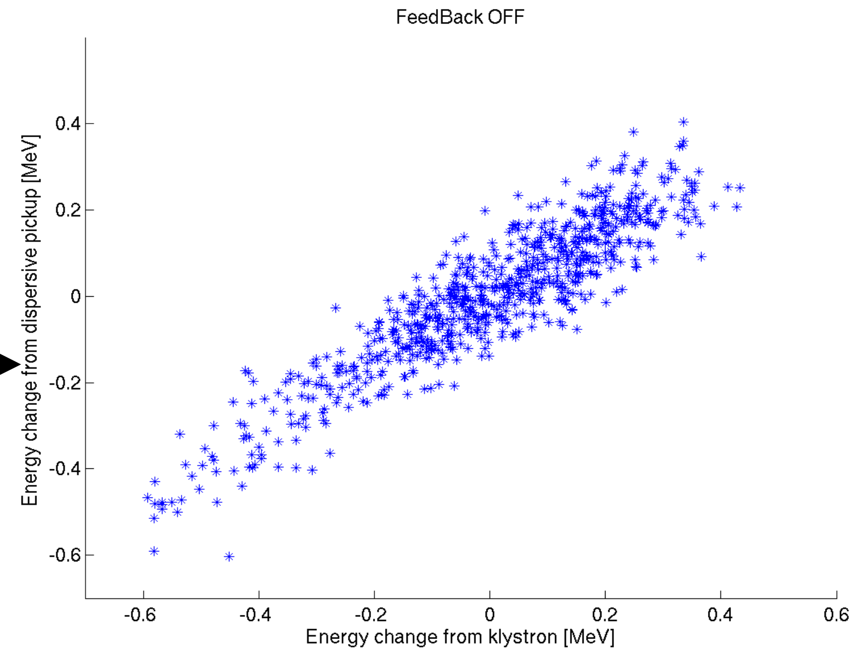
Energy drifts

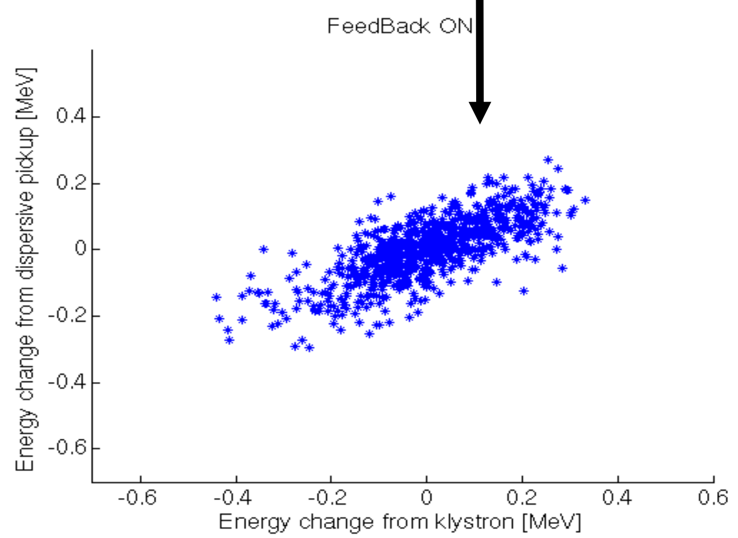
- A clear decrease in the energy drift is seen when the feed back is turned back on.



Energy with Feedback







-Every plot containing ~700 pulses.
-No klystron trip
-The measurements are taken after each other.