Commissioning of the Fermi@ELETTRA Fast Trajectory Feedback

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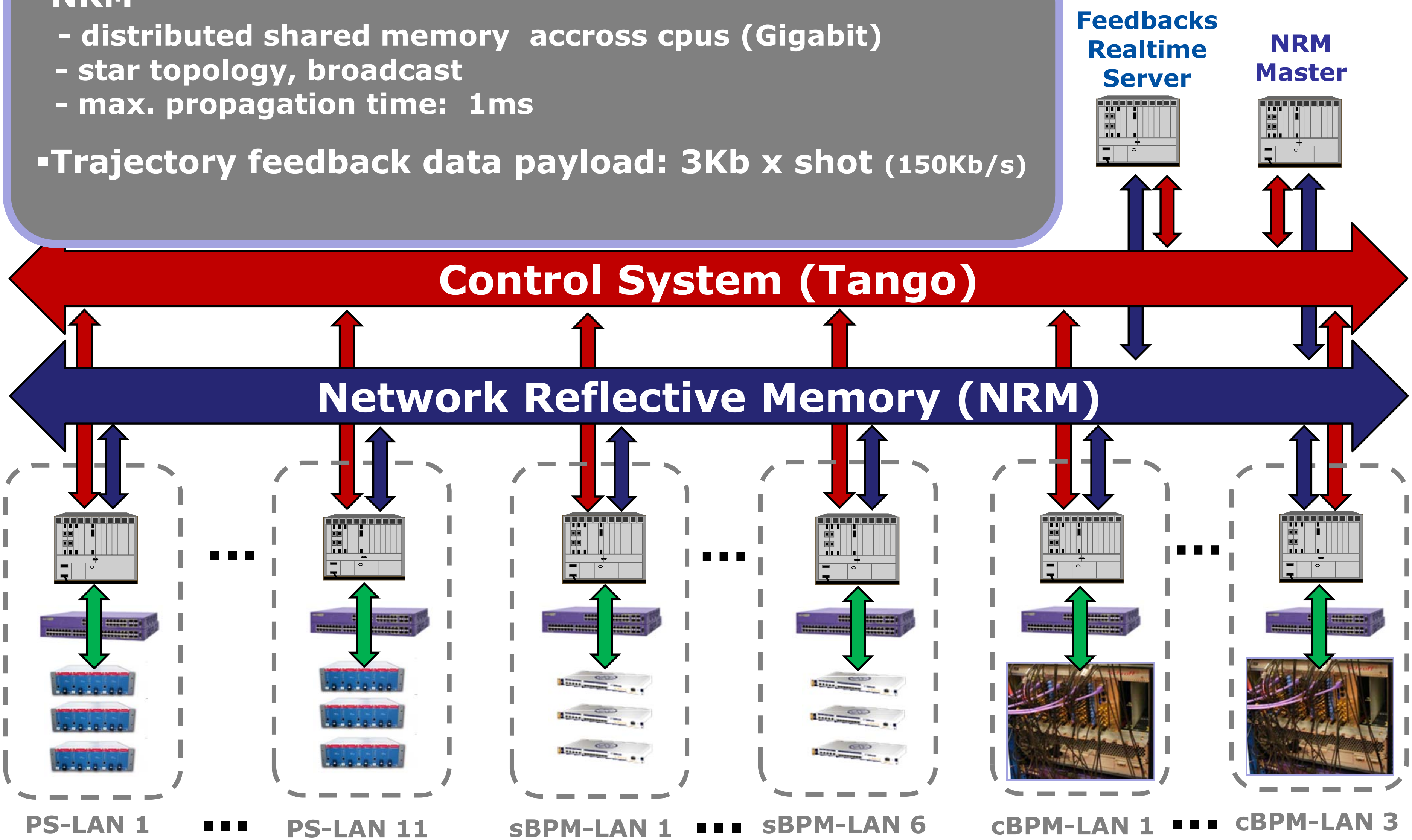
Outline

- **Feedback layout**
  - **Network**
  - **Frontend computers**
  - **Beam position monitors**
  - **Correctors**
- **Time schedule**
- **Algorithms**
- **Operative results**

Feedback network layout

- **NRM**
  - distributed shared memory accross cpus (Gigabit)
  - star topology, broadcast
  - max. propagation time: 1ms
- **Trajectory feedback data payload: 3Kb x shot (150Kb/s)**



CPU: Frontend Computers

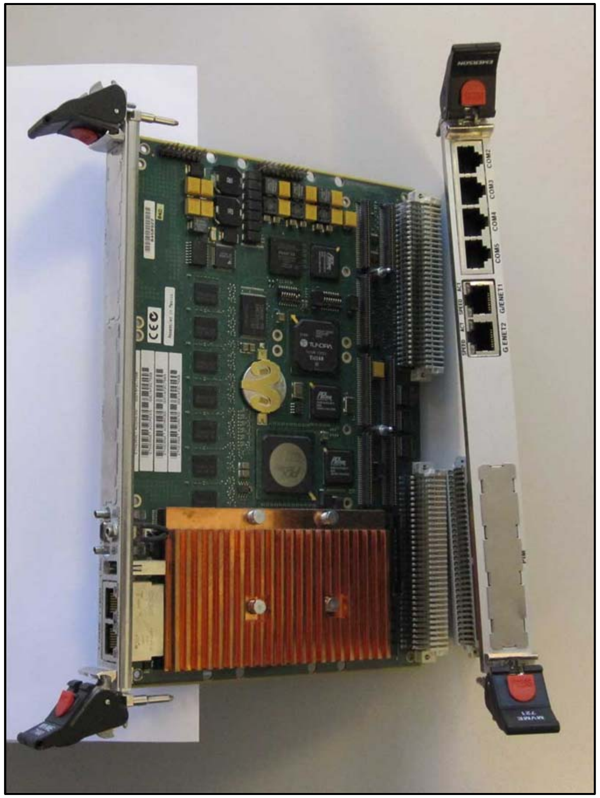
- **Operating system**: Linux, kernel 2.6.25
- **Control system**: Tango

- In order to support a **50Hz** feedback, sensor acquisitions, processing and actuator settings have to be performed in just a **few ms**.

- Worst **jitter** case for a "simple application" running in userspace (plain Linux): **37 ms**

- **Real-time patch**: Xenomai 2.4.8
- Best **jitter** case for a "small" piece of code executed in an interrupt handler (Xenomai): **23μs**

- Data acquisition and calculations are executed in the **interrupt handlers** of **Gigabit, VME,** and **programmable timers**.

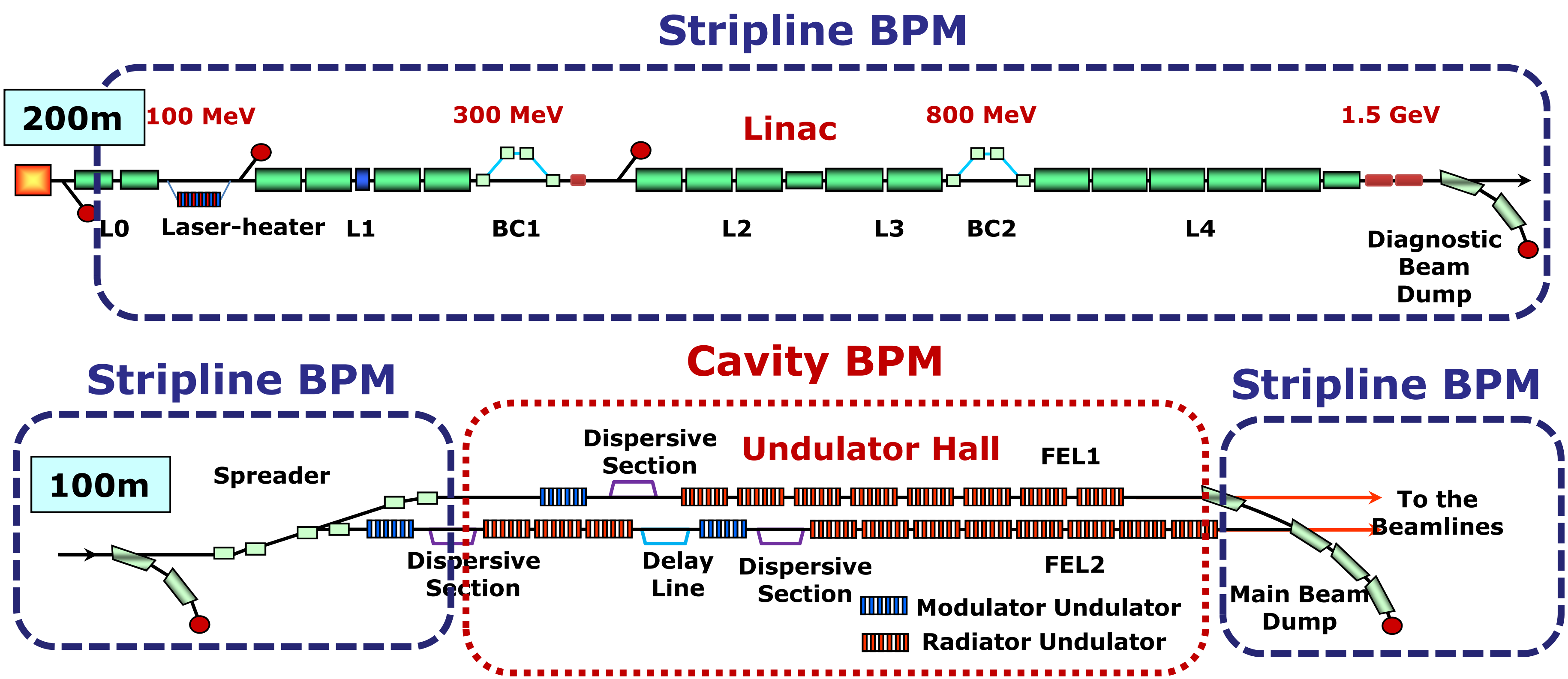


Kernel module (xx.ko)

Shared memory

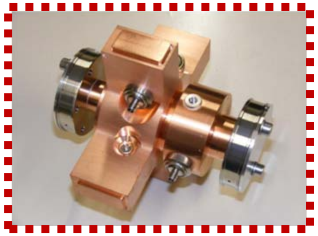
Tango Server

Beam Position Monitors



Stripline BPM

Cavity BPM



Stripline BPM

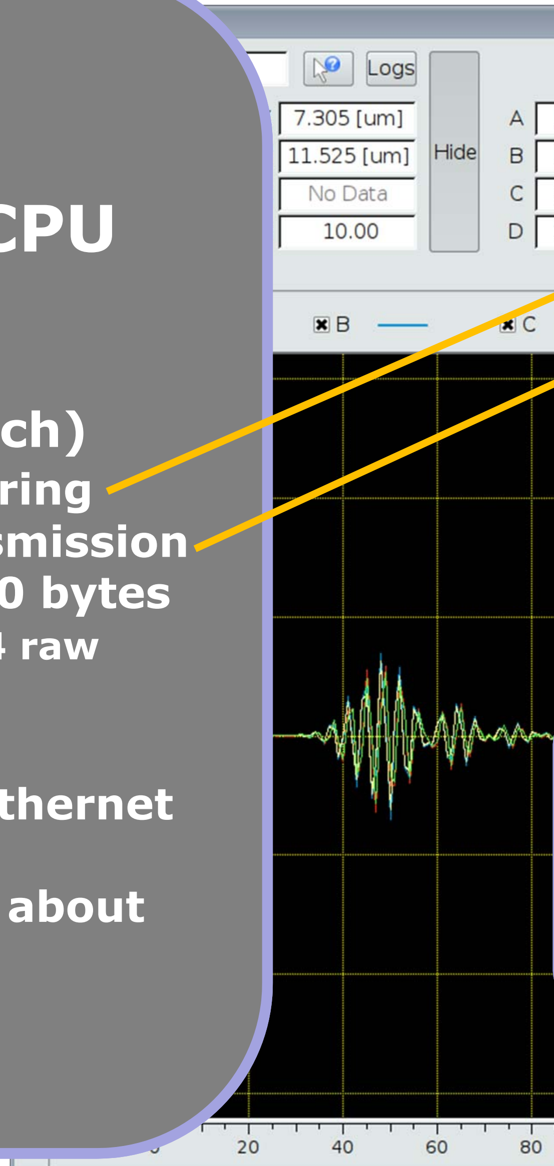
- 55 sBPM installed
- 6 VME PPC Crates
- Up to 15 sBPM x CPU

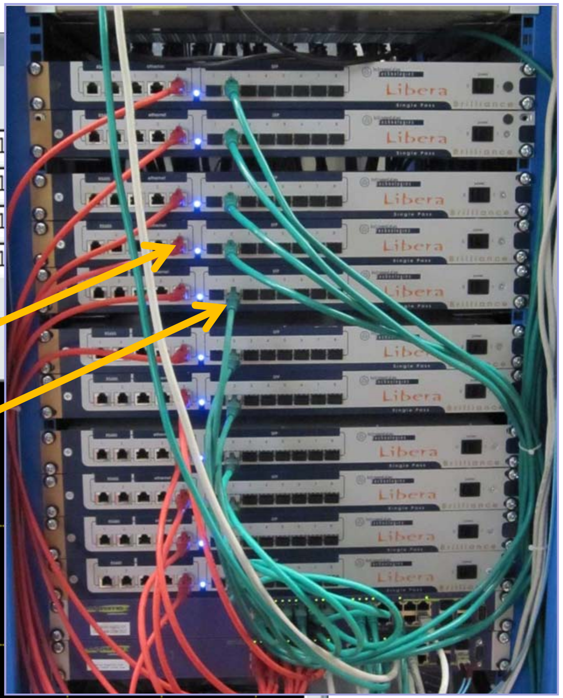
sBPM

- Libera Single Pass (I-Tech)
- 100 Mbit/s port for monitoring
- 1 Gbit/s port for data transmission
  - Each sBPM generates 1100 bytes (UDP) per shot (position + 4 raw waveforms)

CPU

- Data collected in the CPU ethernet ISR
- sBPM positions acquired in about 140 μs





- Measured resolution: **10 μm rms**
- Resolution goal: **5 μm rms**

Cavity BPM

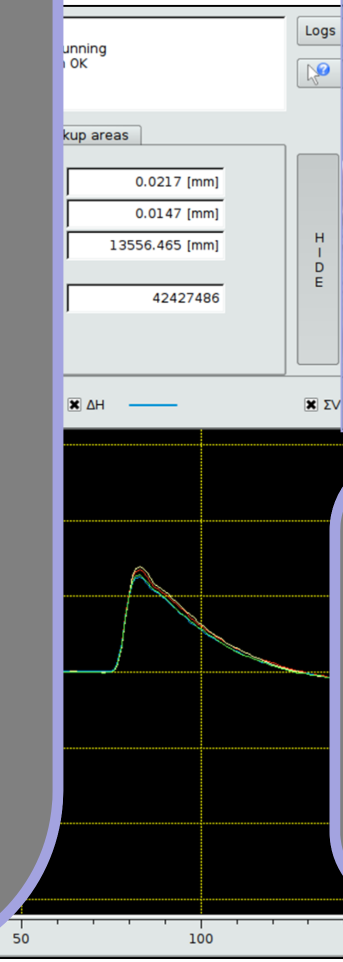
- 25 cBPM installed
- 3 VME PPC Crates
- Up to 12 cBPM x CPU

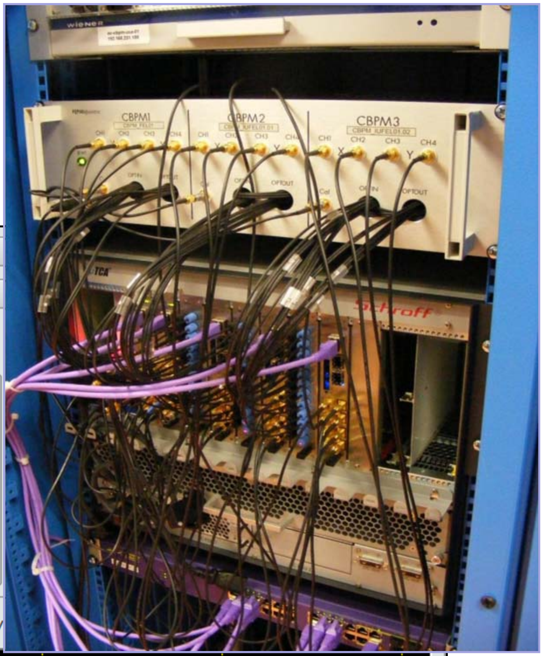
cBPM

- Two (ADC/DAC) uTCA boards (manifactured by Elettra) :
  - ADO: get signals from cBPM frontend
  - ADA: drive calibration signal
- 100 Mbit/s ethernet port for monitoring and data transmission
- Each cBPM system generates 6.3 KB each shot (4 signal waveforms + 4 calibration waveforms)

CPU

- Position calculation and supervision performed on the CPU (ethernet ISR)
- Current max rep. rate: 10 Hz





- May 2011 measured resolution:
  4 µm rms
- Sep 2011 measured resolution:
  2 µm rms
- Resolution goal:
  1 µm rms

Correctors

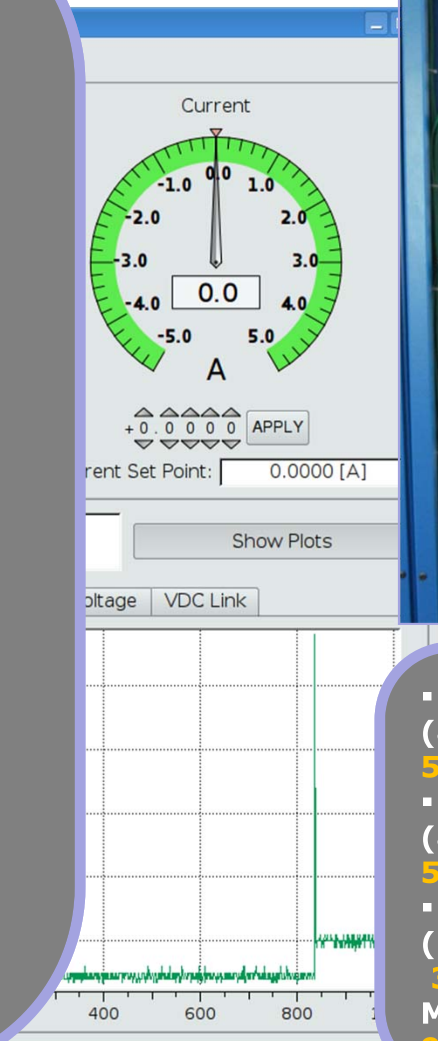
- **390 fast Power Supplies (cors,quads)**
  - **146 of them are correctors**
- **11 VME PPC crates**
- **Up to 40 PS x CPU**

PS

- **2 Models: A2605 (5Amp), A2620 (20Amp) (manifactured by Elettra)**
- **100 Mbit/s ethernet port**
- **Up to 200 Hz maximum current setting rate (UDP)**

CPU

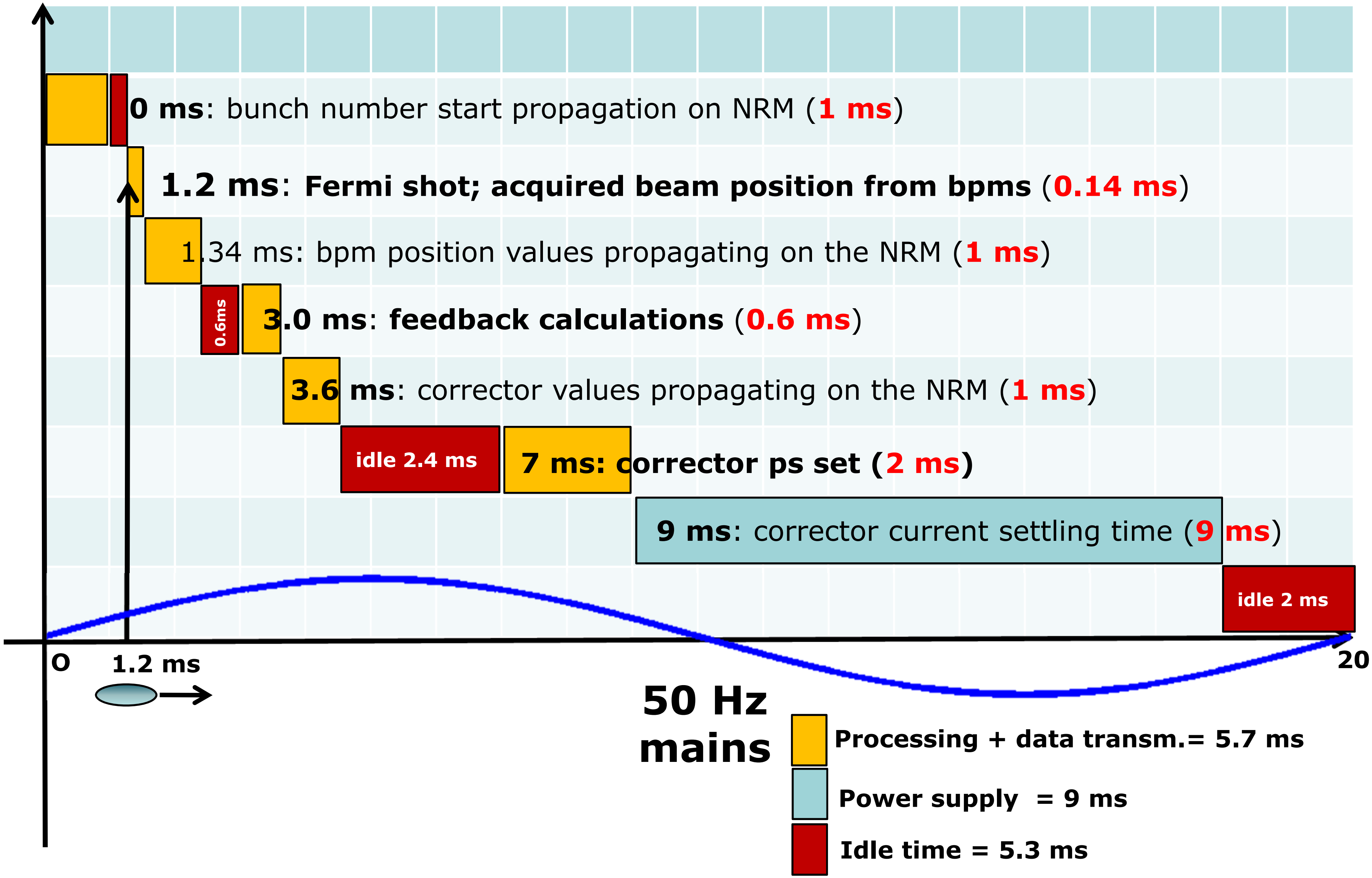
- **6 ms after the beam shot, a timer (10kHz) triggers a realtime process to send current settings (round robin scheme) to each of the PS**
- **correctors PS set in 2 ms**



- **A2605 stability (8h): 50 ppm (full scale)**
- **A2620 stability (8h): 50 ppm (full scale)**
- **Max. ripple (resistive load): 30 ppm**

Max. settling time: 9 ms

Feedback time schedule



Feedback algorithms

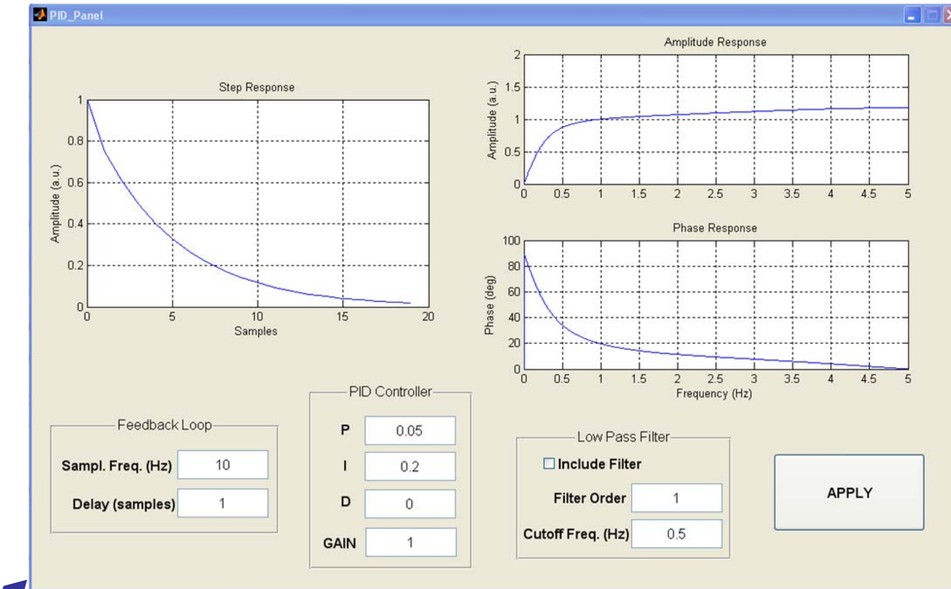
- Since all feedback operations are performed in the intra-shot period, the closed loop dynamics is only **dominated by one sample delay**.

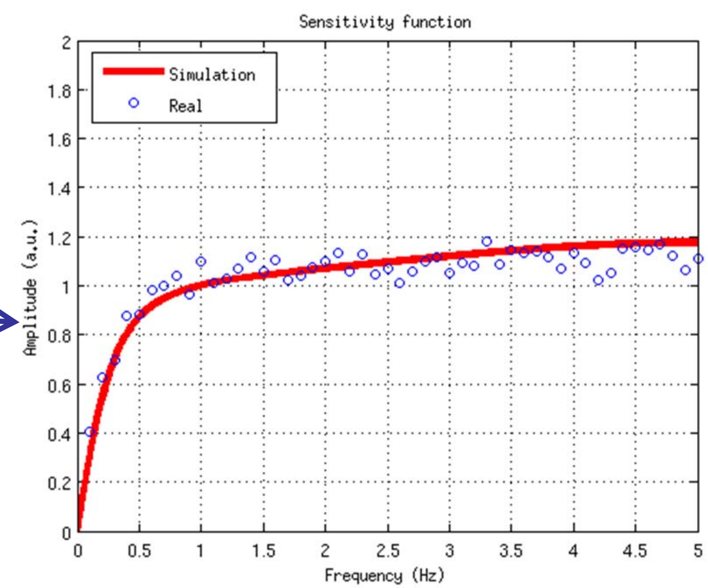
- Selectable input filters:
  - **IIR**
  - **Median**
  - **Heuristic** despiking rules
- **PID** controller + harmonic suppressors (notch filters)

- Developed a tool in Matlab to simulate the closed loop model

- Validated the real system (repetition rate 10Hz) with the model (beam excited with a set of sinusoids)

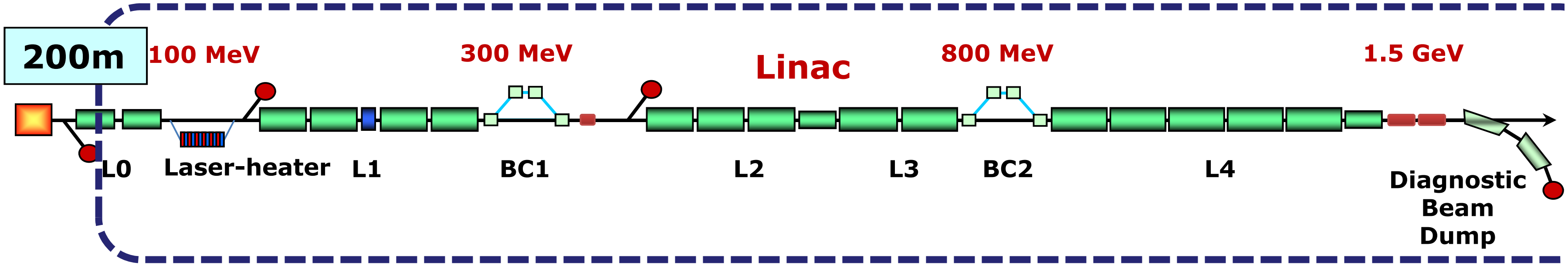
- **MIMO**: **SVD** to invert the **Response Matrix**





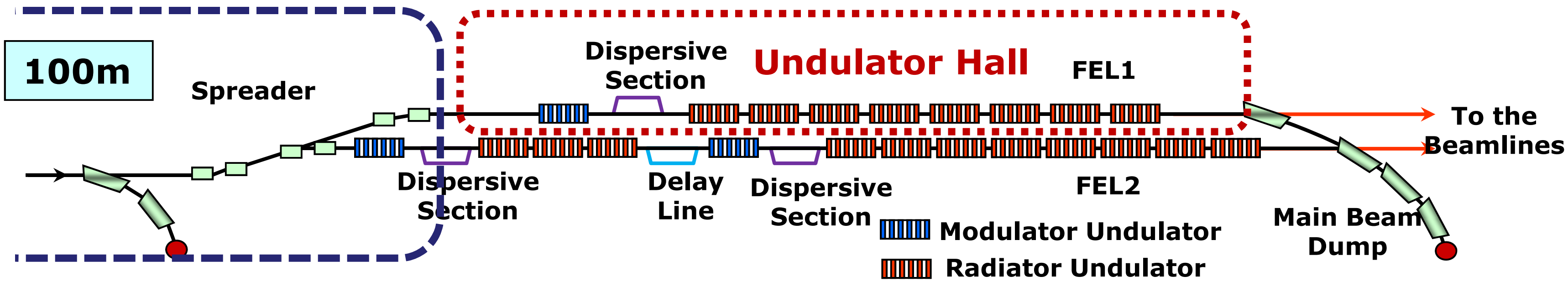
Feedback layout

Linac Fast Trajectory Feedback (FTF0)



FTF0

Undulator Fast Trajectory Feeback (FTF1)



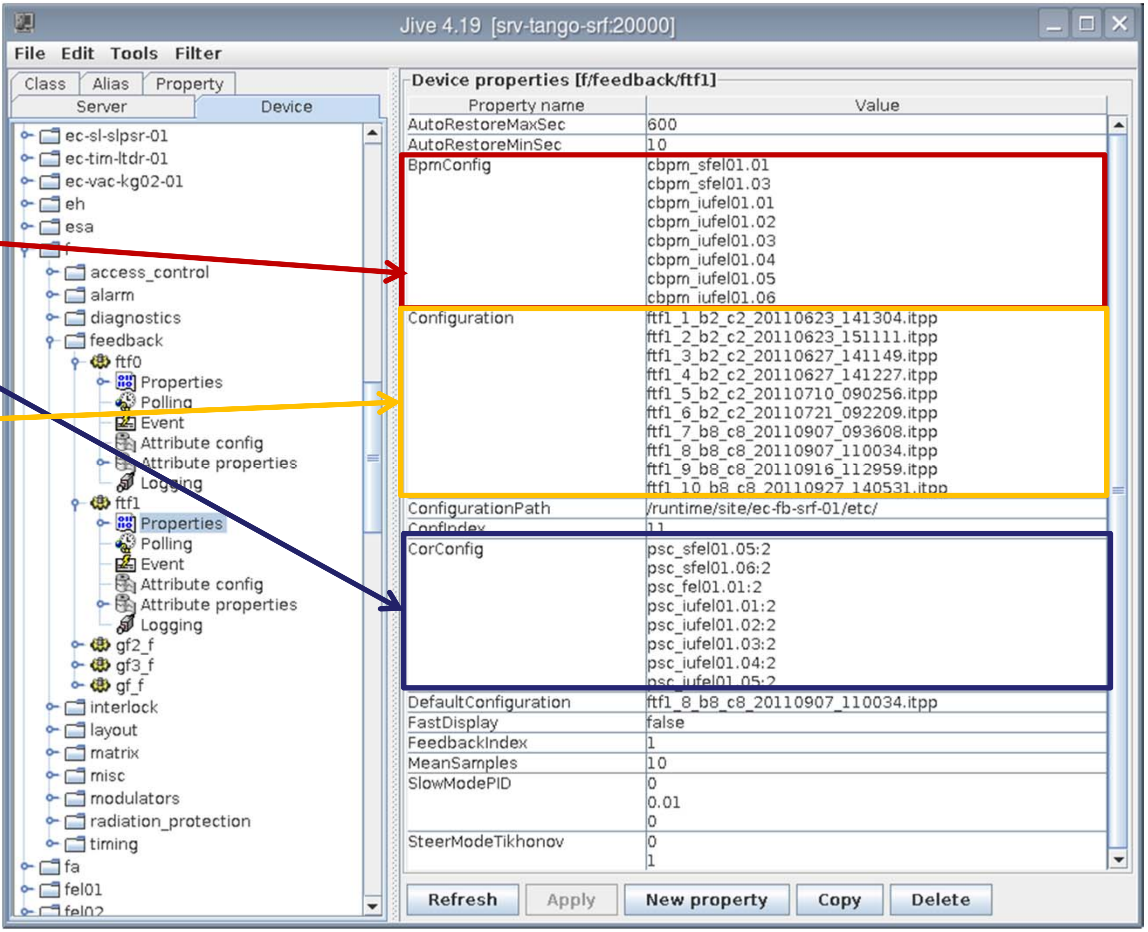
Linac Fast Trajectory Feedback: 34 BPM x 34 COR

Undulator Fast Trajectory Feedback: 8 BPM x 8 COR

Feedback configuration

- Feedback configured through Tango Devices (**BPM**, **correctors**)

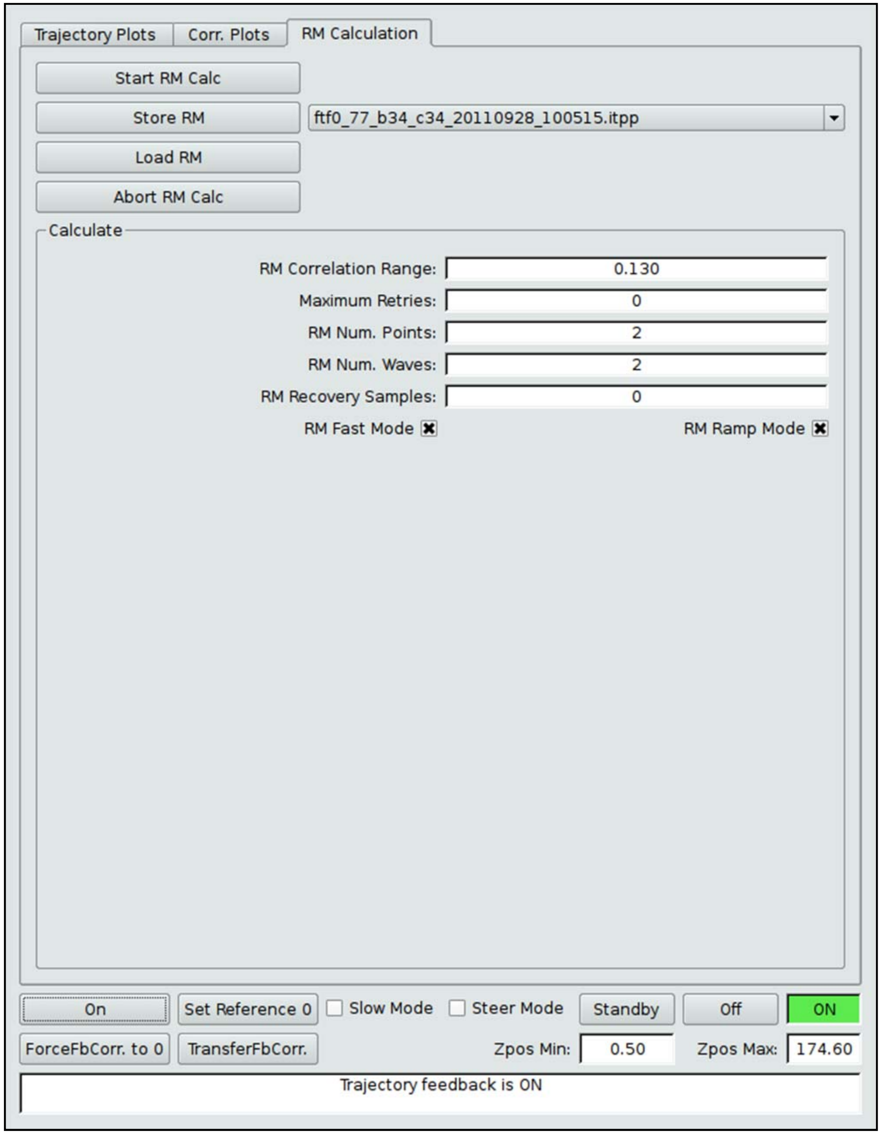
- Feedback configuration (**filters**, **matrices**, **weights**) saved and loaded from **it++** workspace files



Response matrix calculation

Shot to shot matrix calculation integrated in the feedback

- The power supplies are driven sequentially with multiple **programmable current ramps**
- In the meanwhile the BPMs are acquired **synchronously** to the corrector excitation
- If a corrector strength is so high to kick off the beam, ramp amplitude automatically is decreased and measure is repeated
- Algorithm calculates the response matrix correlating ramped kicks and trajectory distortions (linear regression)
- Calculation performed at the same time on **both planes** (option)



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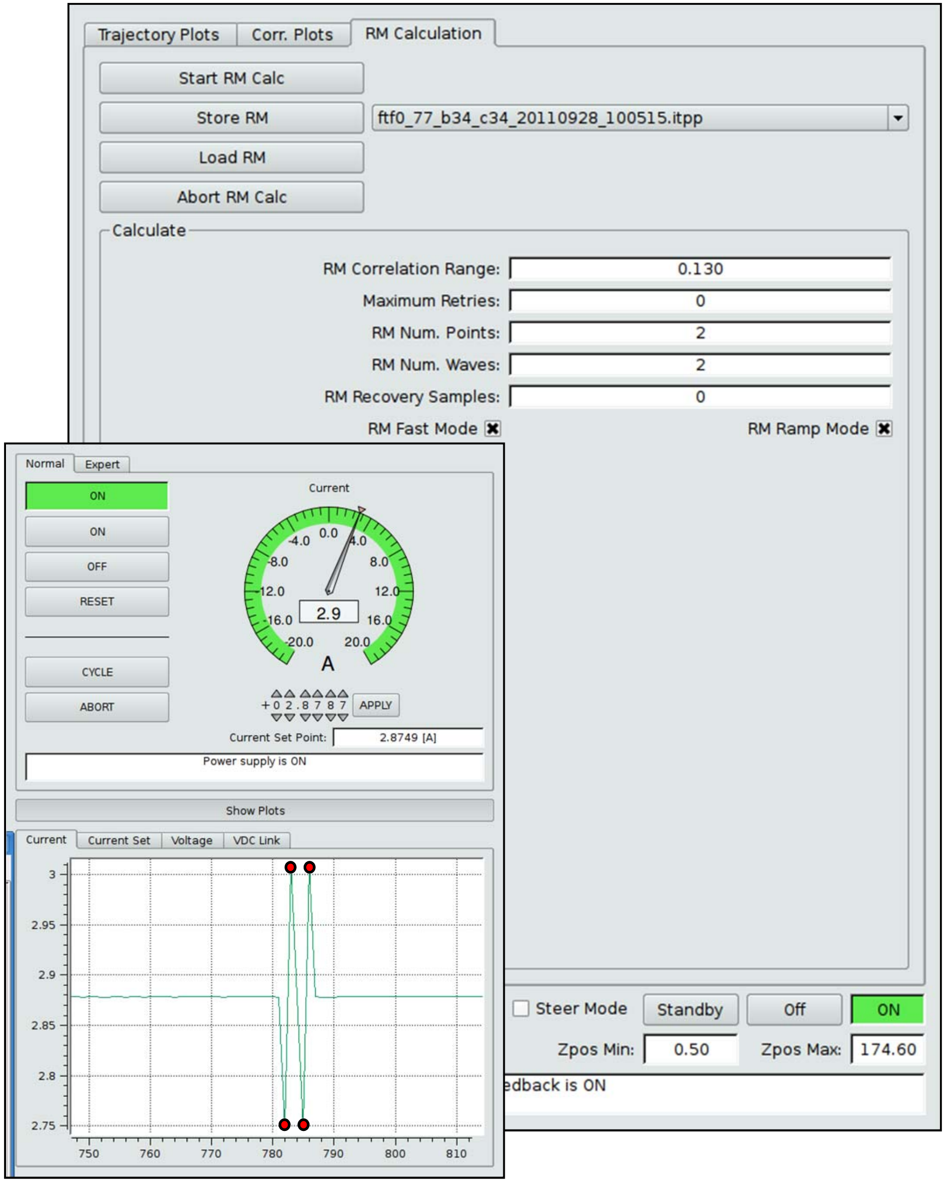
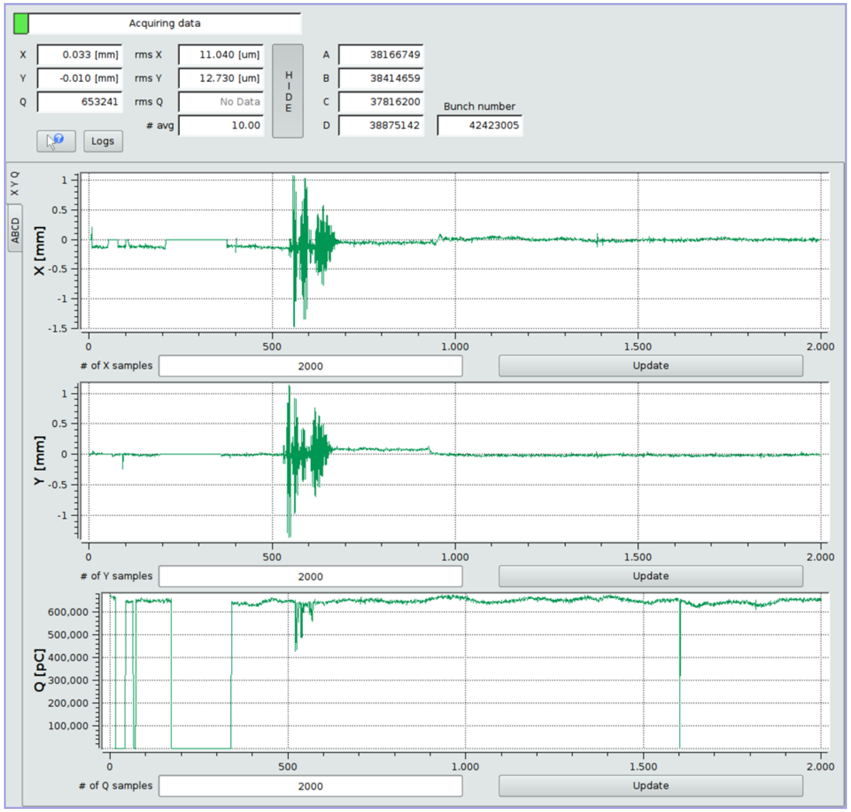


Response matrix calculation



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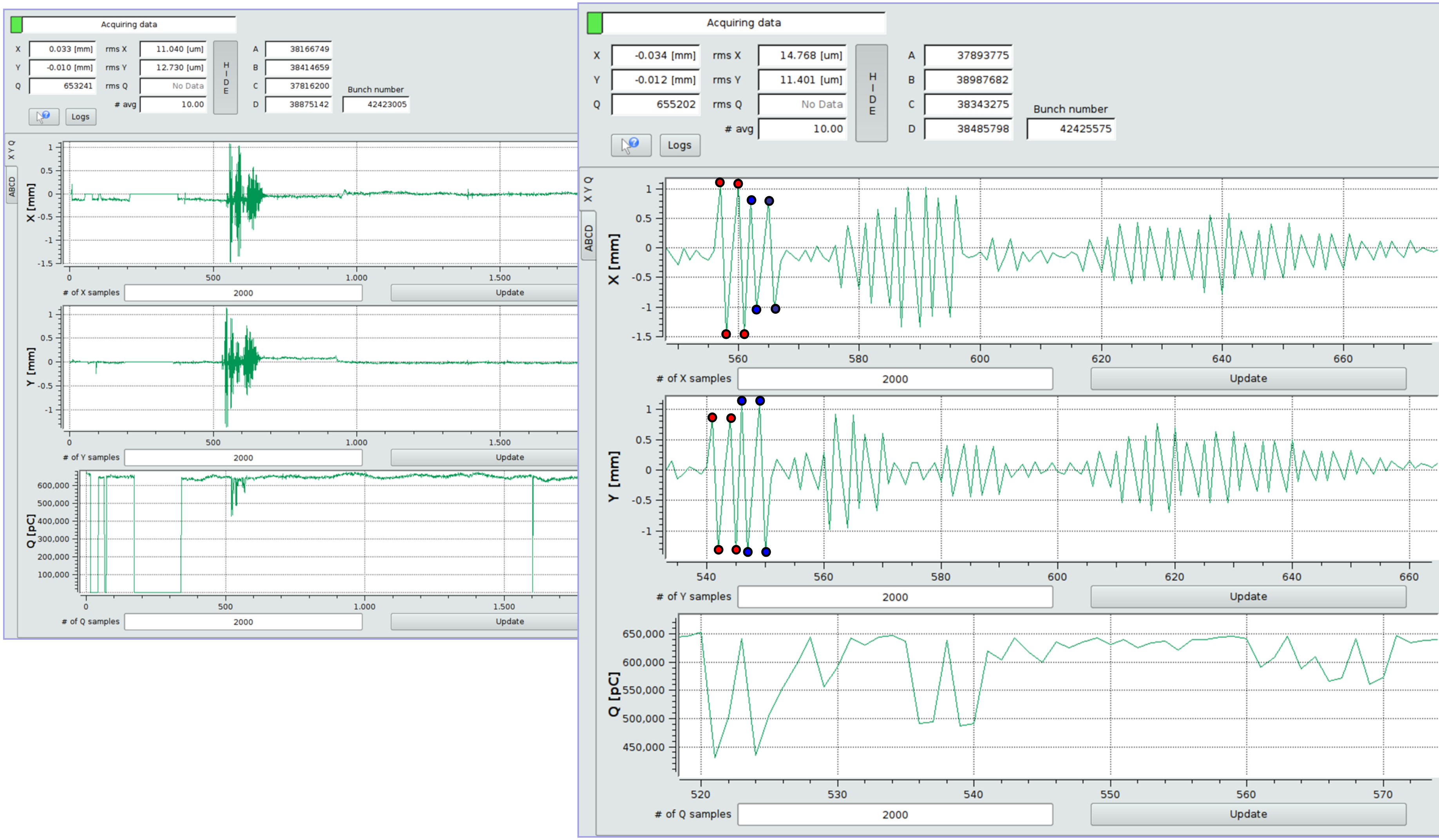
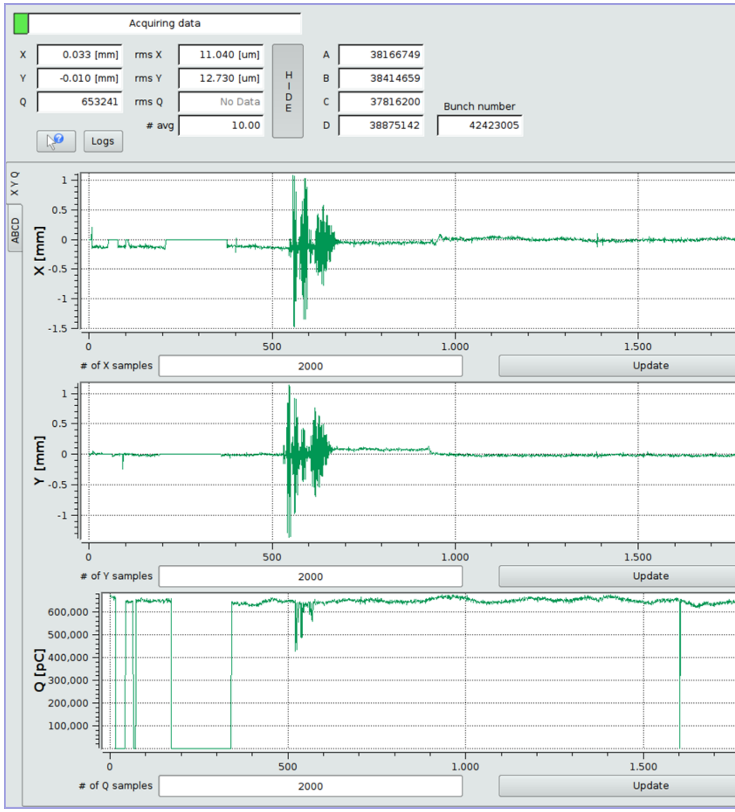
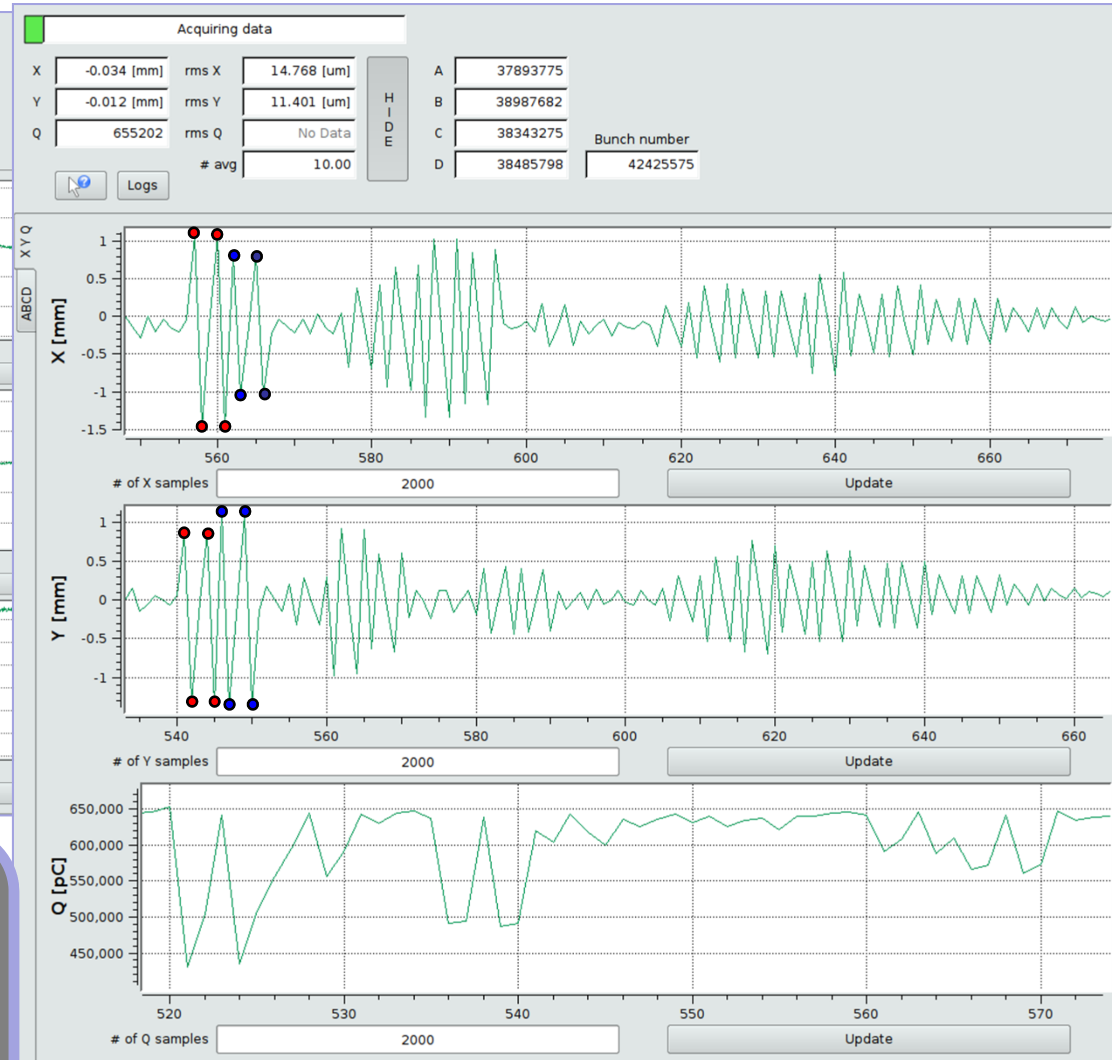


Response matrix calculation



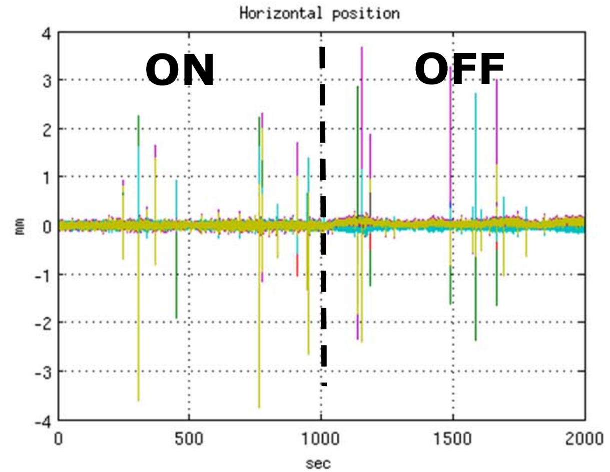


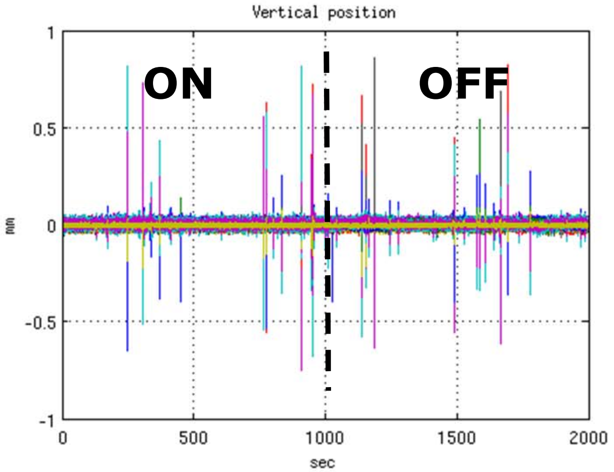
- a minimum of **4 shots** per corrector to get a reliable response matrix
- **20 s** to get the response matrix of both feedbacks at 10Hz linac repetition (4 s at 50Hz)

Closed loop data

Transverse beam stability specifications:
❑ ≤ **20 µm** rms (hor/ver) in Linac area (avoid wakefields effects)
❑ ≤ **10 µm** rms in Undulator area (to preserve FEL)

Noise sources (mainly in Linac):
- Thermal drifts
- Performance drifts of accelerators components
- Discharges in RF plants (spikes) and erratic trips of RF/Timing





Loop OFF
Hor. avg. rms: **19 µm**
Ver. avg. rms: **10 µm**
Loop ON
Hor. avg. rms: **18 µm**
Ver. avg. rms: **11 µm**

BPM resolution: 10 µm

Feedback operations

Feedback is used to:

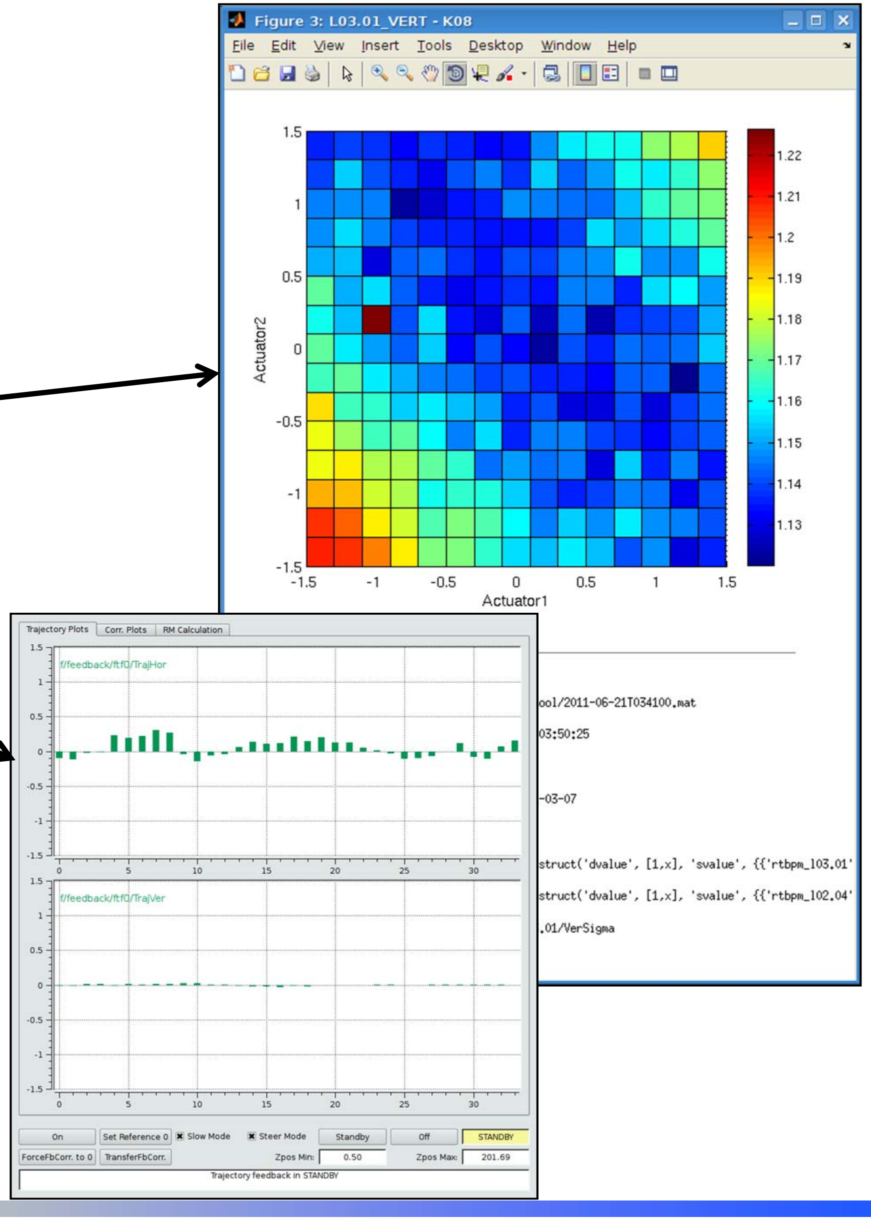
- **Stabilize the trajectory** during experimental shifts.

- Perform **trajectory scans** into accelerating structures to find the trajectory which minimizes beam emittance: this is done with feedback ON by changing the setpoints

- Restore a **golden trajectory**

- Decouple operations during machine commisioning shifts; keep the beam trajectory stable when:
  - **Change beam energy**:
    - Change RF phases
    - Switch off accelerating structures
  - **Change of machine optics**

  …..



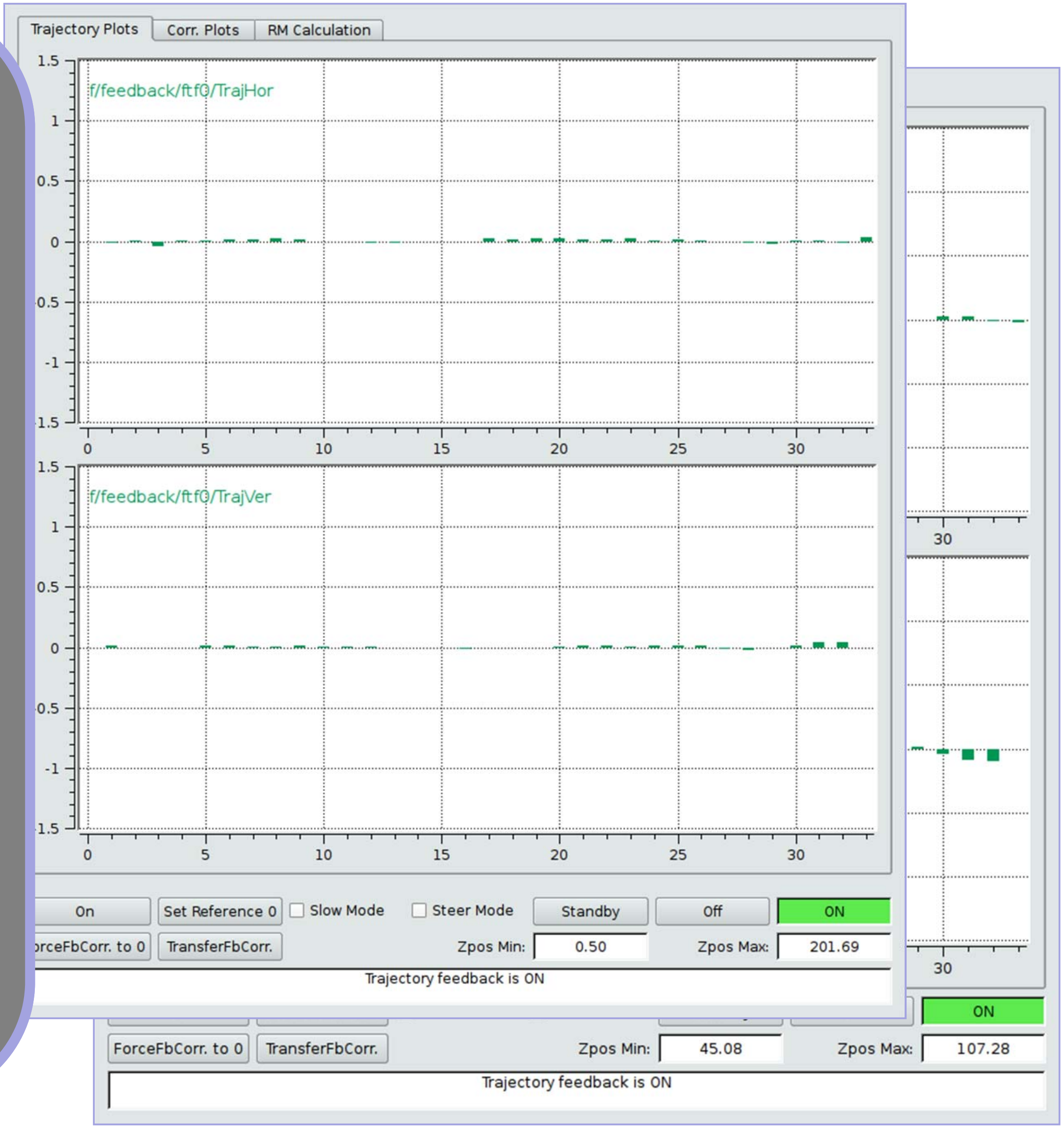
Feedback interface

GUI (provisional) configured on the fly by reading the list of bpms and correctors from the feedback Tango device

Main commands

- **On/ Off / Standby**
- **Goto Reference Trajectory**
- **SlowMode**
  true: slow controller (ki =0.01)
  false: fast controller (ki =0.2)
- **SteerMode**
  true: no SVD regularization
  false:Tikhonov regularization
- **ZposMin, ZposMax**

Apply the feedback only on a part of the machine (meters from the gun)



Many thanks for your attention!!!