Machine QA

From an accelerator physicist perspective

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There are two types of people in this world:

1. Those who can extrapolate from incomplete data

Machine QA objectives

- Verification of the functionality of the machine
- Identification of drifts well ahead of clinical effectiveness
- Risk mitigations as identified by the risk analysis
- Standardized test method:
  - for TA changes
  - after maintenance intervention

Machine QA objectives

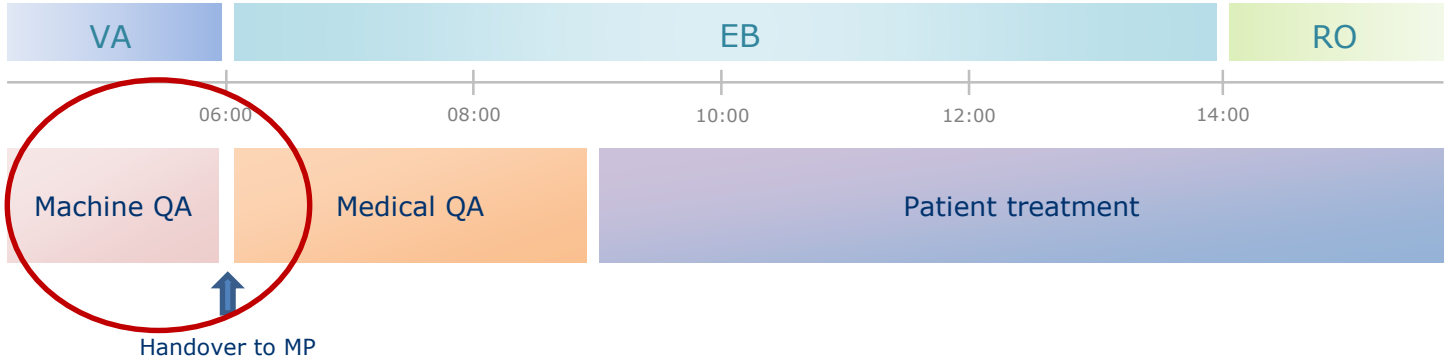
Further QA framework determining factors are:

- Enabling compliancy to standards and laws
- Fulfilling QA requirements of certain suppliers

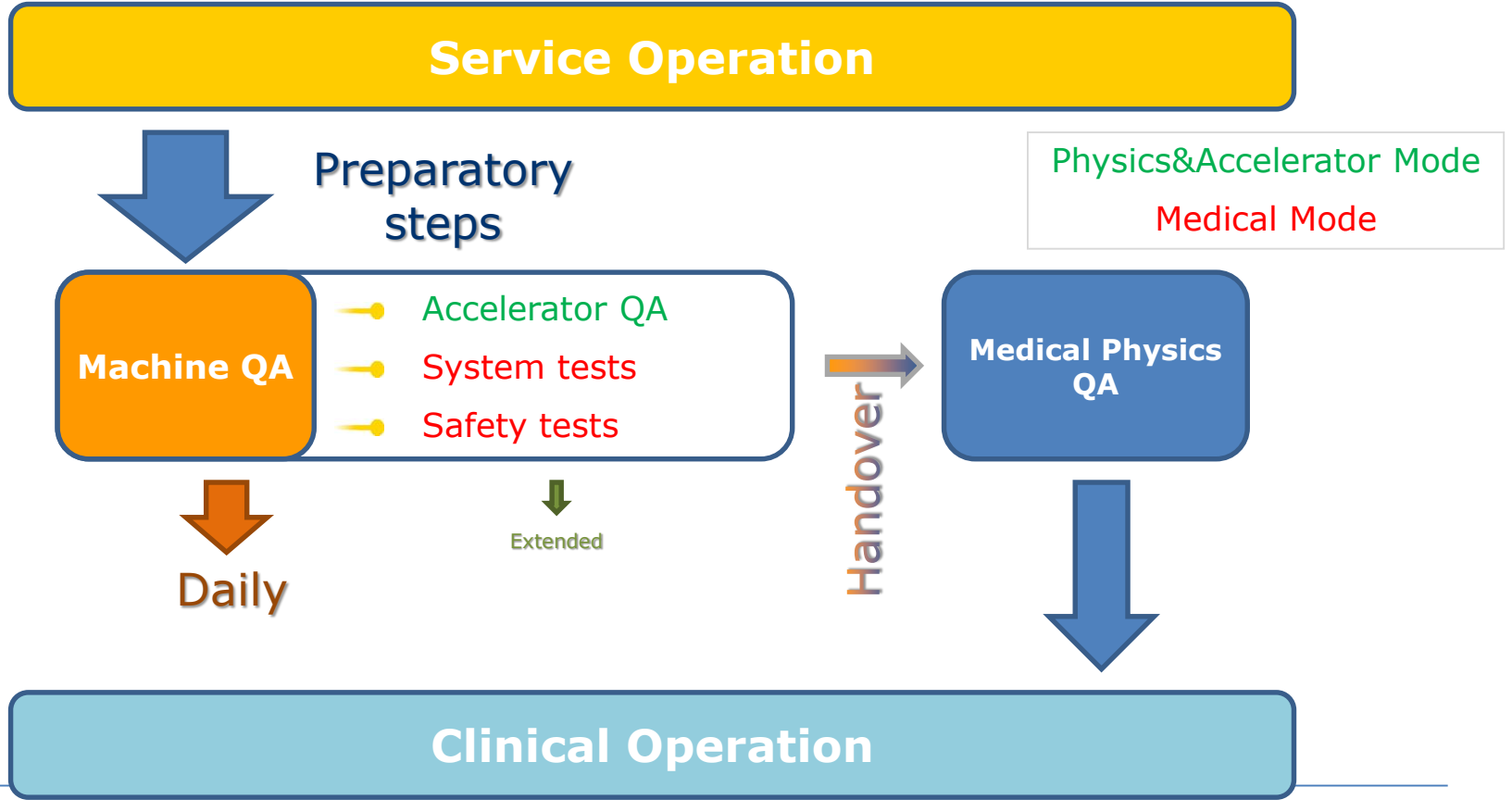
Here focus on QA of accelerator parameters with non-medically certified diagnostics.

The QA shall balance coverage and duration: a maximum of QA measurements (cycles and monitors) within a minimum of needed machine time

QA timeline


VA
EB
RO
06:00
08:00
10:00
12:00
14:00
Machine QA
Medical QA
Patient treatment
Handover to MP

Machine QA


Service Operation
Preparatory steps
Physics&Accelerator Mode
Medical Mode
Machine QA
Accelerator QA
System tests
Safety tests
Medical Physics QA
Handover
Extended
Daily
Clinical Operation

Daily QA

Use Cases:

- Handover of the machine to the user
- Product change not including an update of beam configuration data

Periodicity:

At least 1x per day

Steps:

- Accelerator QA: Beam parameters are within acceptance conditions
- Safety tests to assure patient safety
- System tests: treatment plan execution within acceptance conditions

Purpose:

- Validation of beam quality
- Ensure functionality of machine
- Risk mitigation

Extended QA

Use Cases:

- Long-term monitoring of overall machine performance
- Product Changes including an update of beam configuration data
- Debugging

Steps:

- Accelerator QA: Beam parameters are within acceptance conditions (multiple energies + intensities)
- Extended safety tests
- Extended system tests: additional dose uniformity test

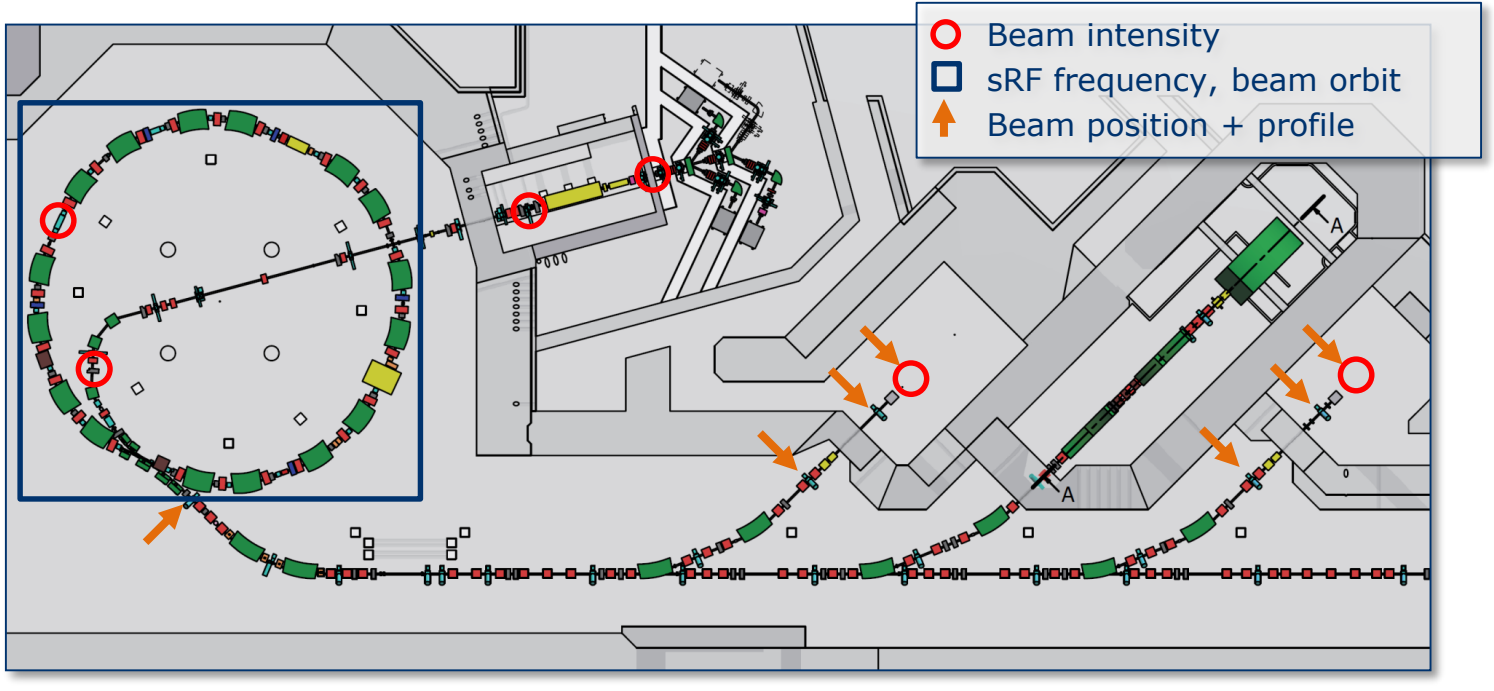
Periodicity:

At least bi-weekly

Purpose:

- Assure stability of machine, identify long-term drifts
- Debugging tool in case of a performance deviation
- Risk mitigation

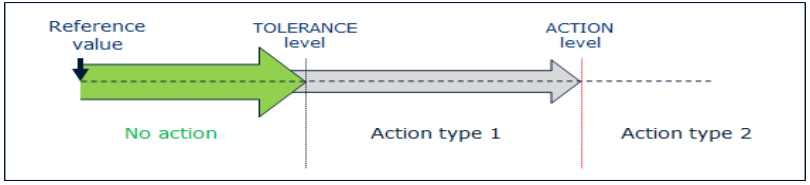
Beam Instrumentation



Beam Instrumentation

- Beam currents/intensities:
  - LEBT, LINAC, MEBT, Sync: Current transformers (DC + AC)
  - Treatment rooms: Dose Delivery System
- Beam positions and profiles:
  - WSX (planned)
  - PUX
  - Sync: Pickups (positions only)
  - HEBT: Scintillating Fibre Hodoscopes (SFX)
  - Treatment rooms: Dose Delivery System
- Beam revolution frequency:
  - Sync: sRF frequency
- Further data: sRF loop contributions,…

Action types



No action (OK):

The QA passes – machine can be used for clinical operation.
No follow-up action required.

Action type 1 (Warning):

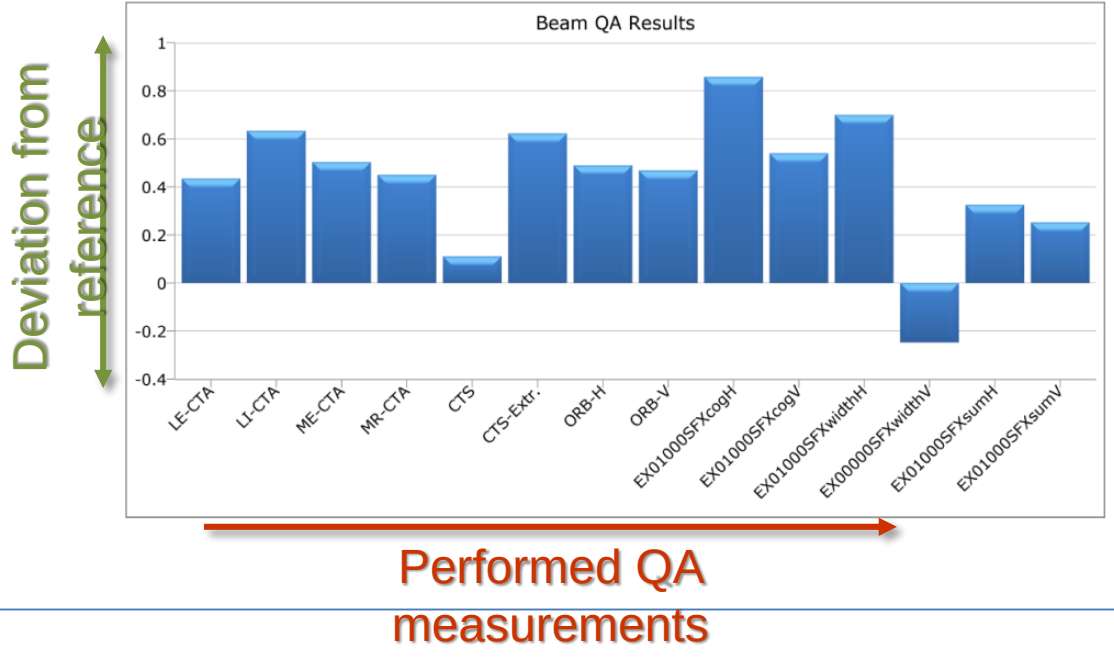
The QA passes – machine can be used for clinical operation.
User informed of the observed deviation in the respective QA protocol.

Action type 2 (NOK):

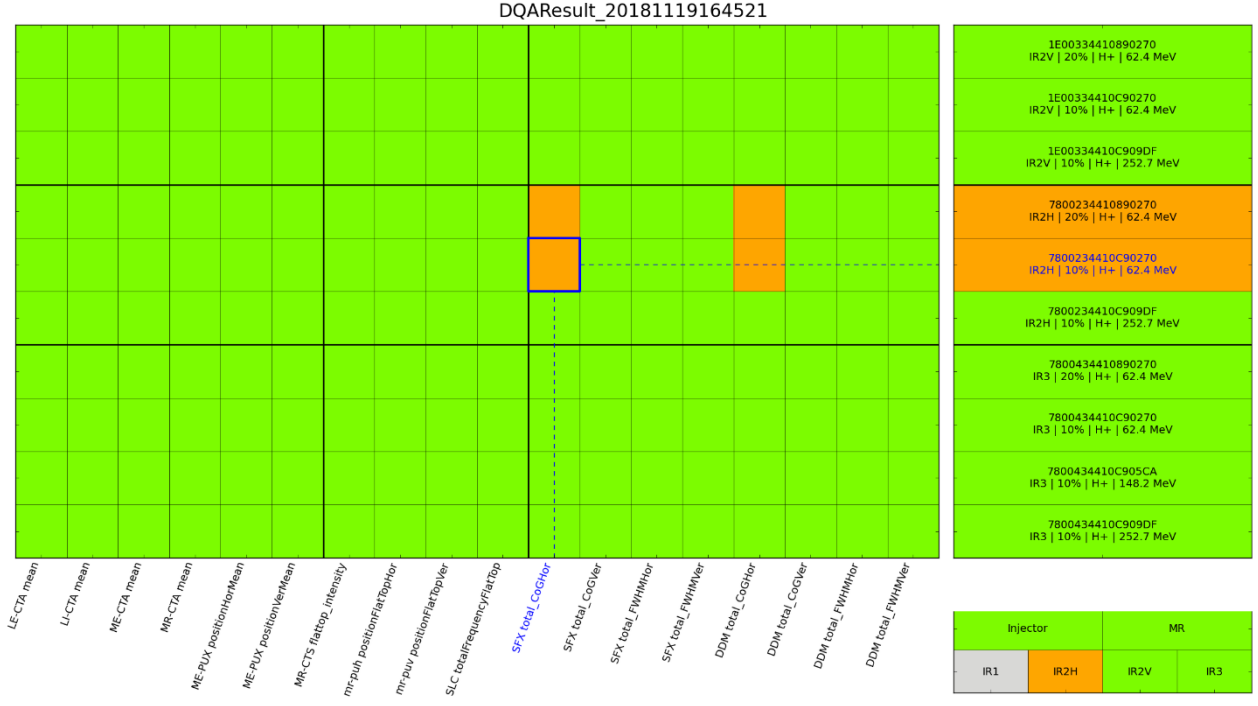
The QA fails – machine must not be used for clinical operation.
Immediate troubleshooting and corrective measure.

Machine QA: Evaluation of QA results

- Automatic report generation (pdf)
- Graphical summary of the most relevant results on front page
- Tolerance and Action levels defined vs. Reference measurements



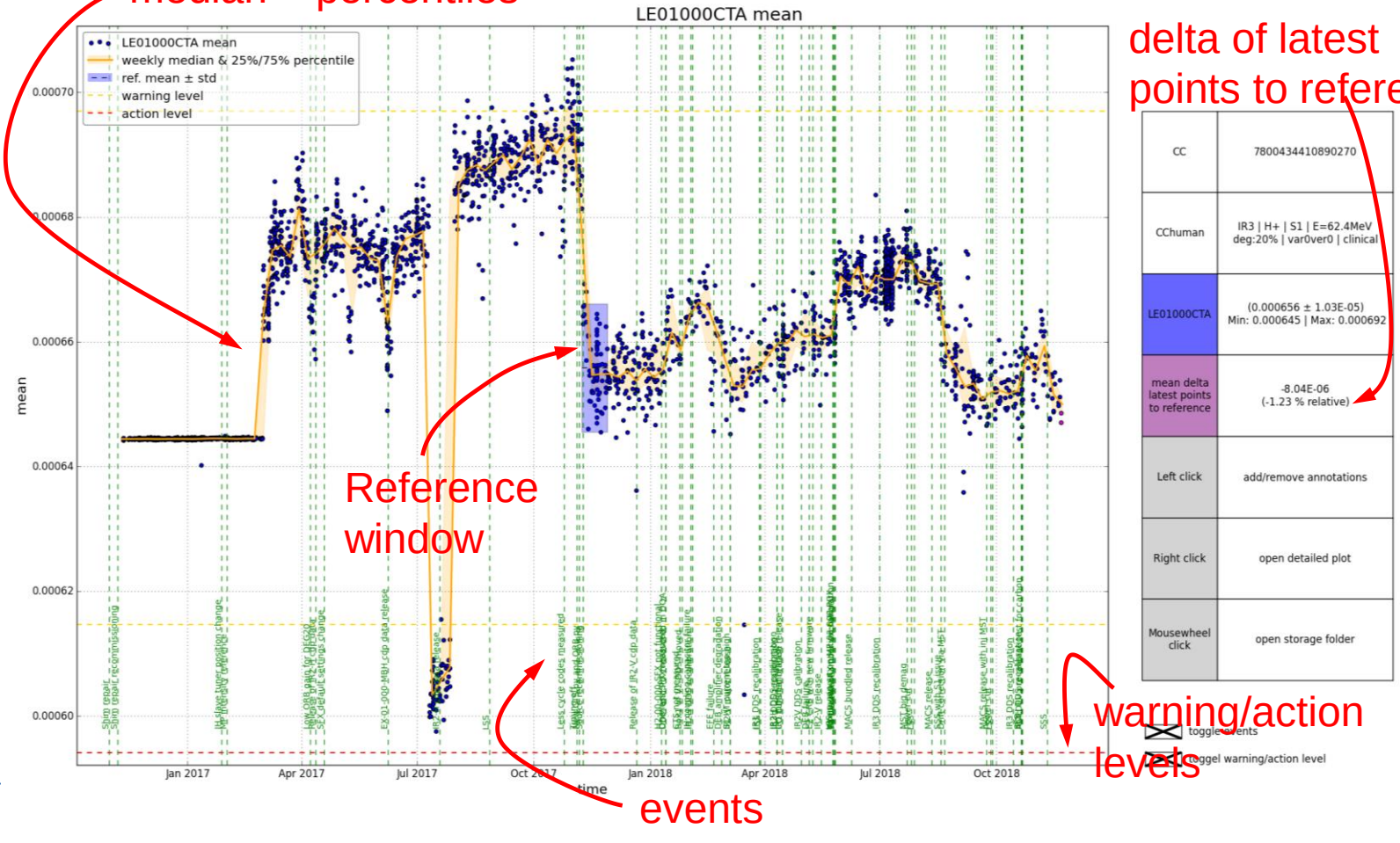
Interactive expert tool



Based on python analysis framework at MedAustron: PACMAN

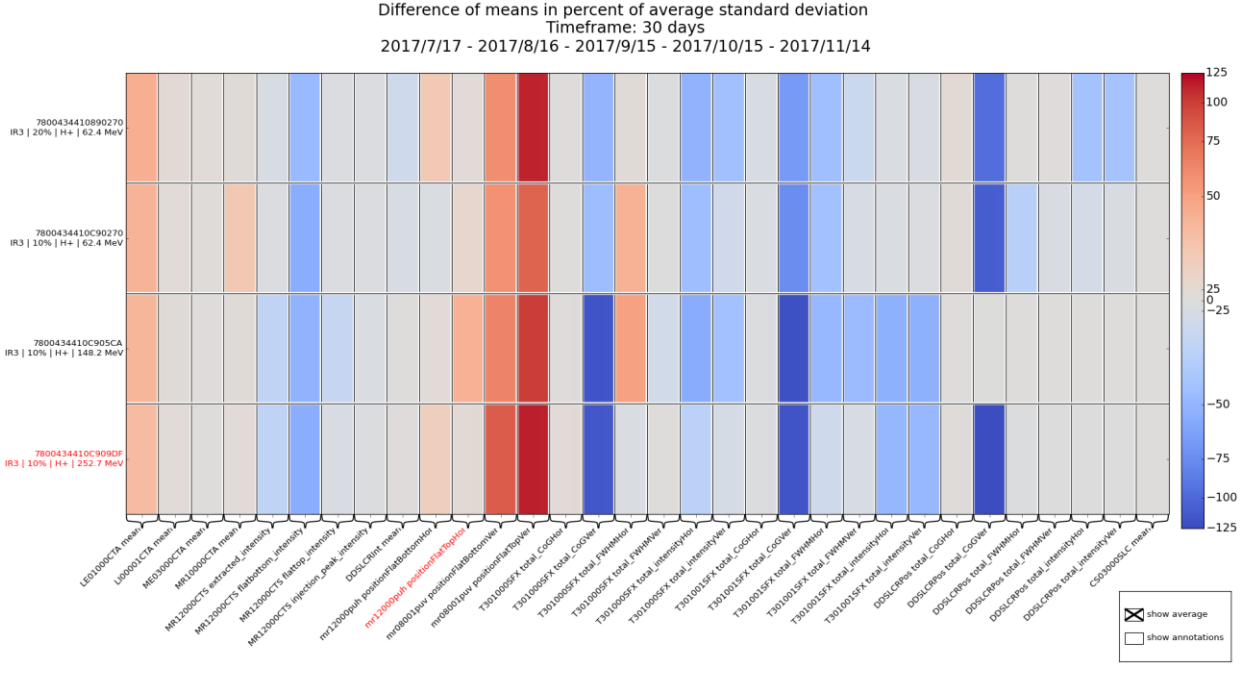
Further detailed example plots will follow.

General time trend plot



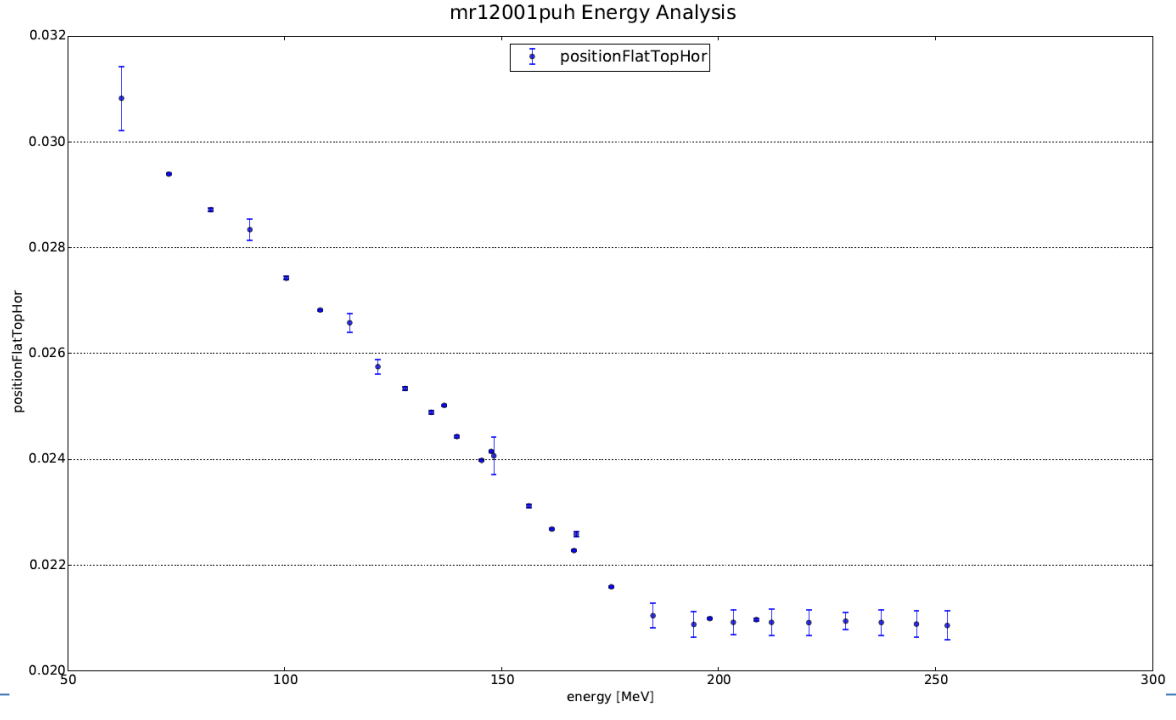
Overview of drifts

The plot shows the drift behavior of the most important monitors/attributes

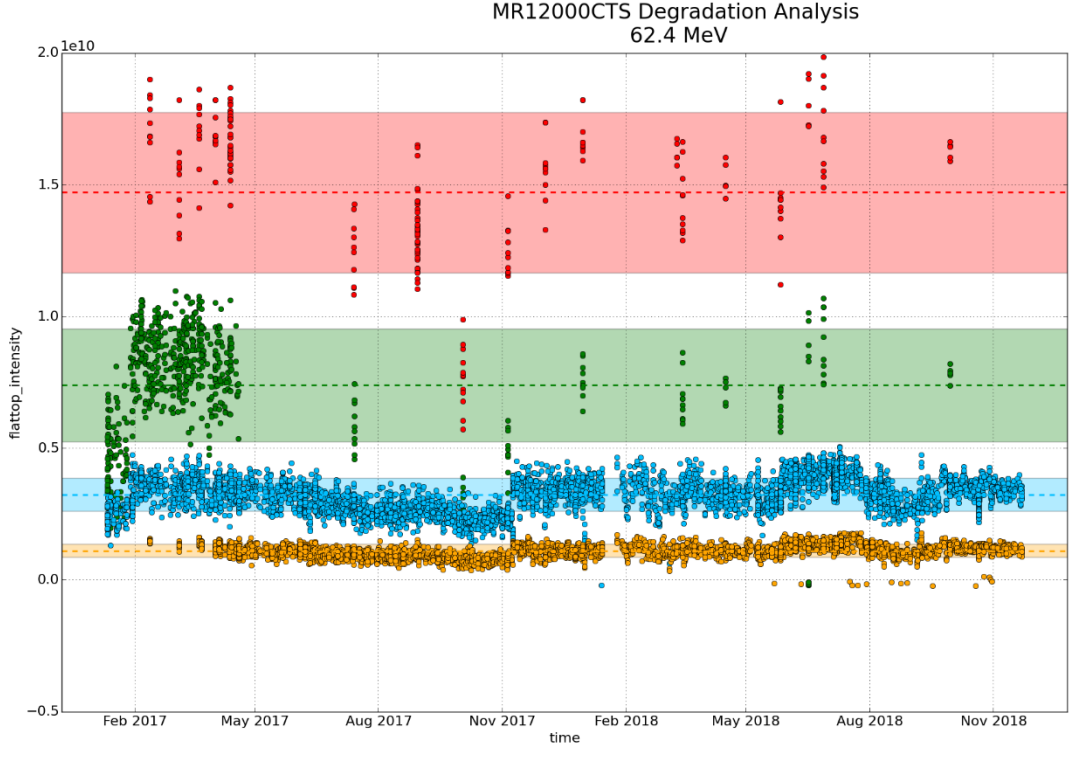


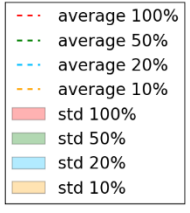
Energy dependency

Horizontal position at a pick-up in a high dispersive region



Intensity plot

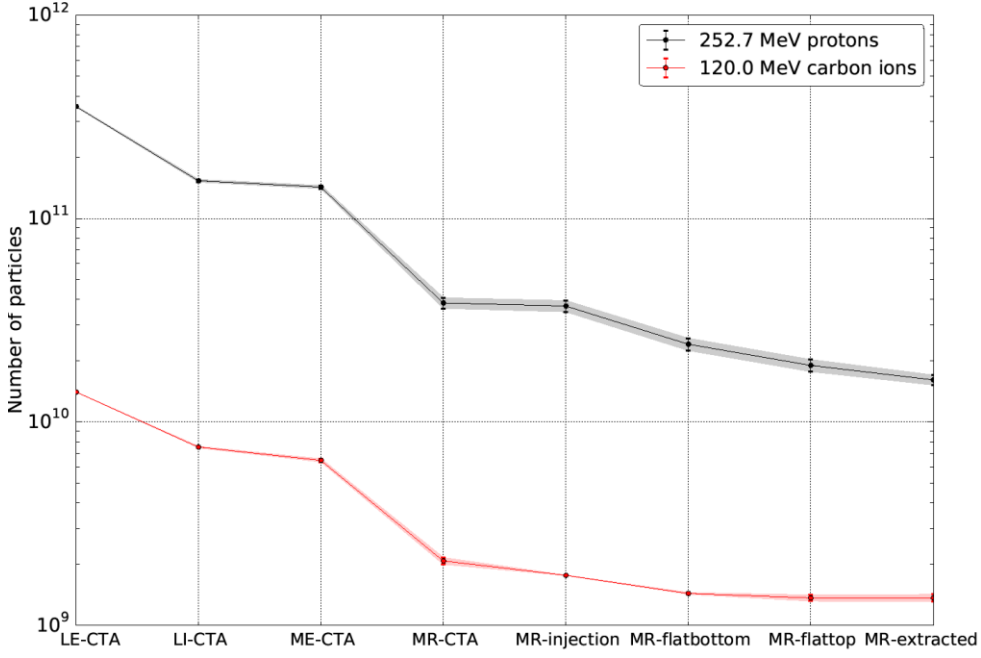




100%	mean: 1.47e+10 std: 3.04e+09 relative: 100.00 %
50%	mean: 7.39e+09 std: 2.13e+09 relative: 50.23 %
20%	mean: 3.24e+09 std: 6.25e+08 relative: 22.00 %
10%	mean: 1.10e+09 std: 2.48e+08 relative: 7.50 %

Transmission plot

The achieved intensities throughout the accelerator



Example NOK scenarios

Due to measurement error (false positive):

- Unusual high noise on monitor or faulty signal
- Monitor slightly displaced after maintenance window

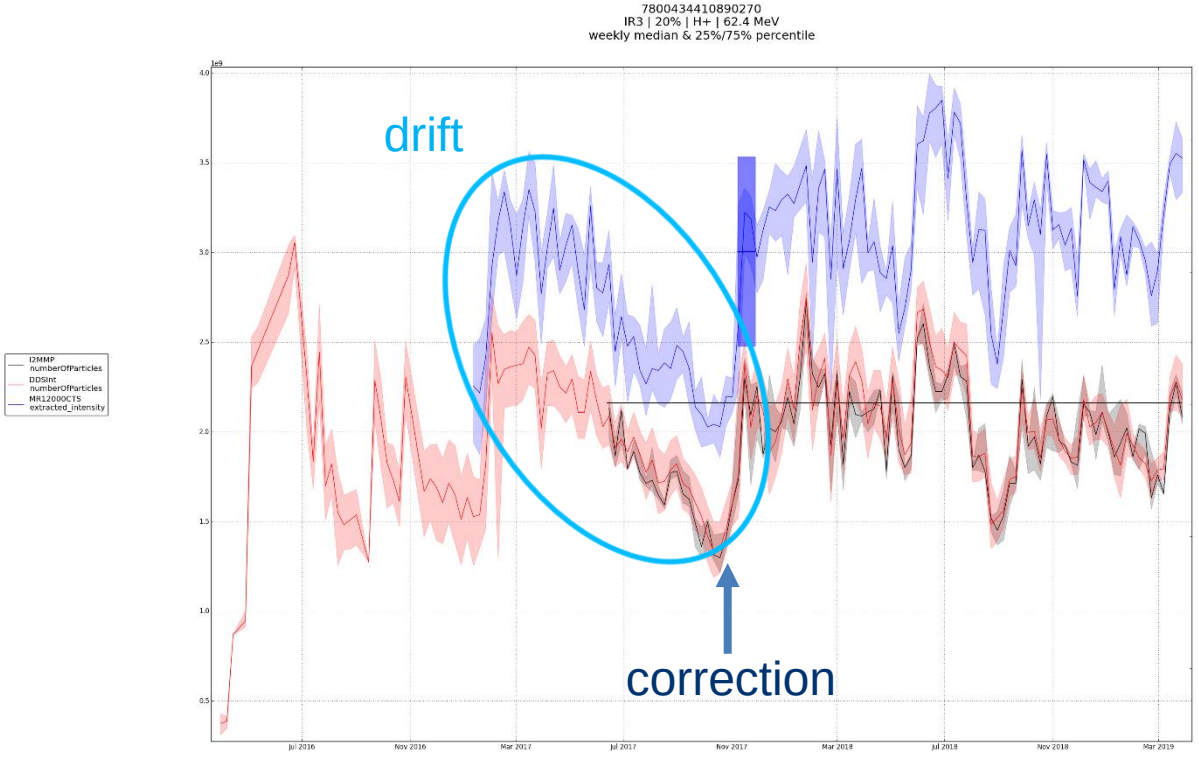
Due to beam being off (true positive):

- Magnets not properly demagnetized
- In general: machine drifts or jumps reaching action levels

Example drift scenarios at MedAustron

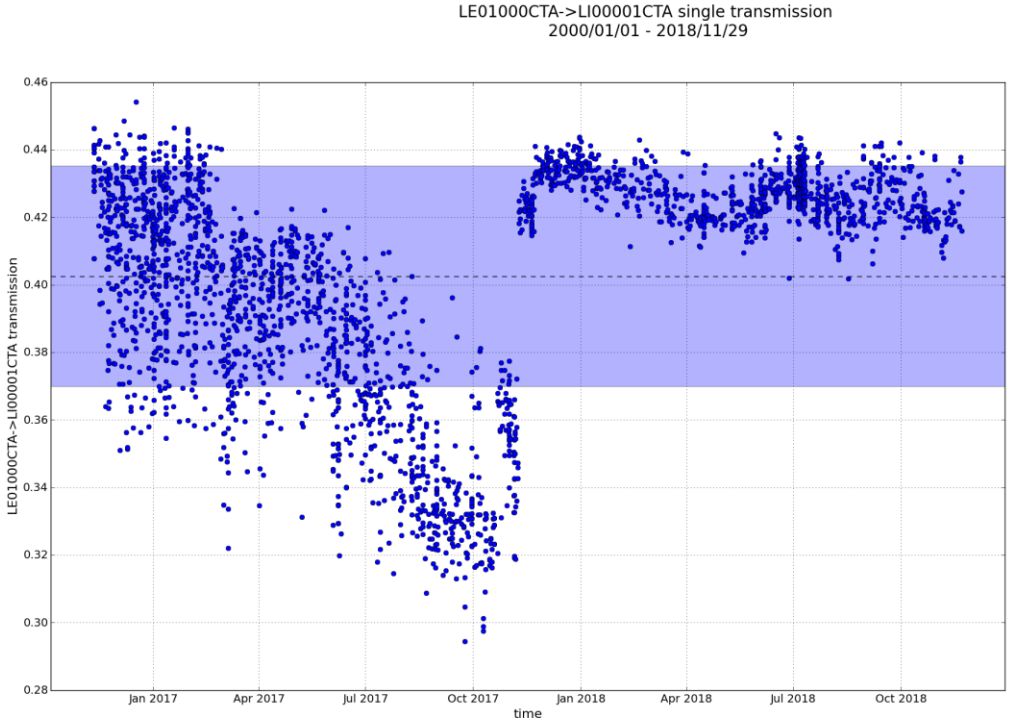
- Intensity drift with according correction
- Seasonal HEBT position drift
- Position drift with according correction

Intensity dirft example



Intensity drop, leading to recommissioning of the source in November 2017.
The recommissioning brings the required intensity back.

Transmission

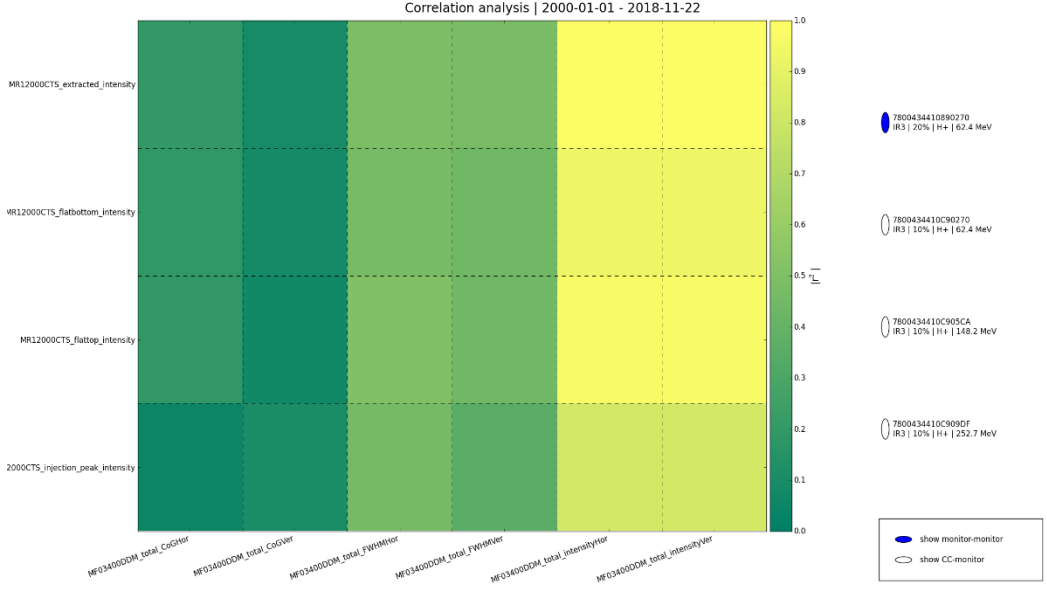


CC	7800434410890270
CChuman	IR3 | H+ | S1 | E=62.4MeV deg:20% | var0ver0 | clinical
Transmission	(0.40 ± 0.03) Min: 0.29 | Max: 0.45

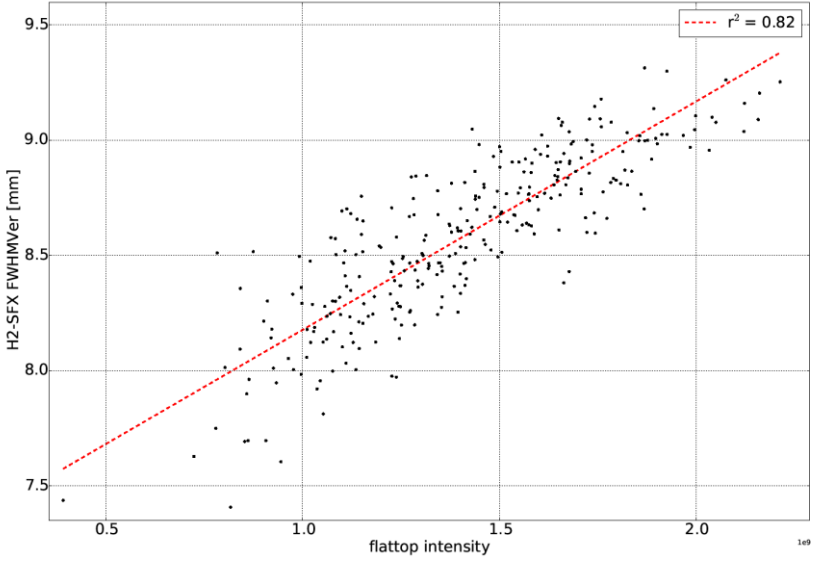
Detailed time trend of the transmission between LEBT and LINAC, with successful recommissioning of the source in November 2017.
Excellent stability of the beam in the injector: intensity fluctuations of 10 % were reduced to below 3 %.

Plot correlation

General example of correlation overview

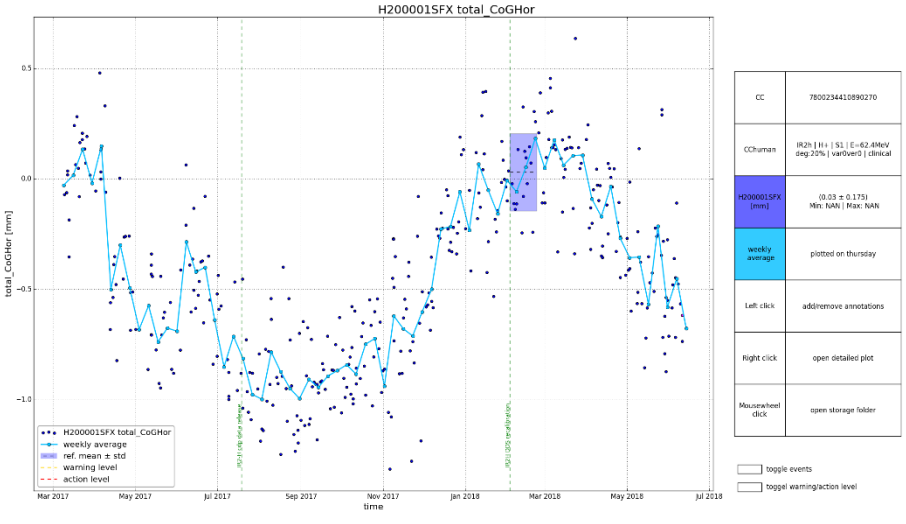


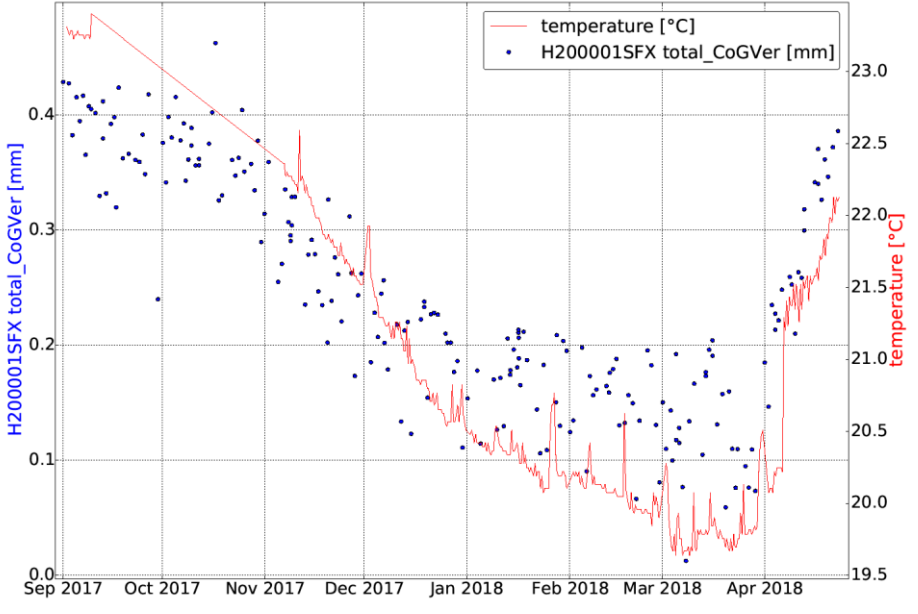
The intensity variations lead to the observation of related acceptable variations of the vertical FWHM throughout the HEBT.



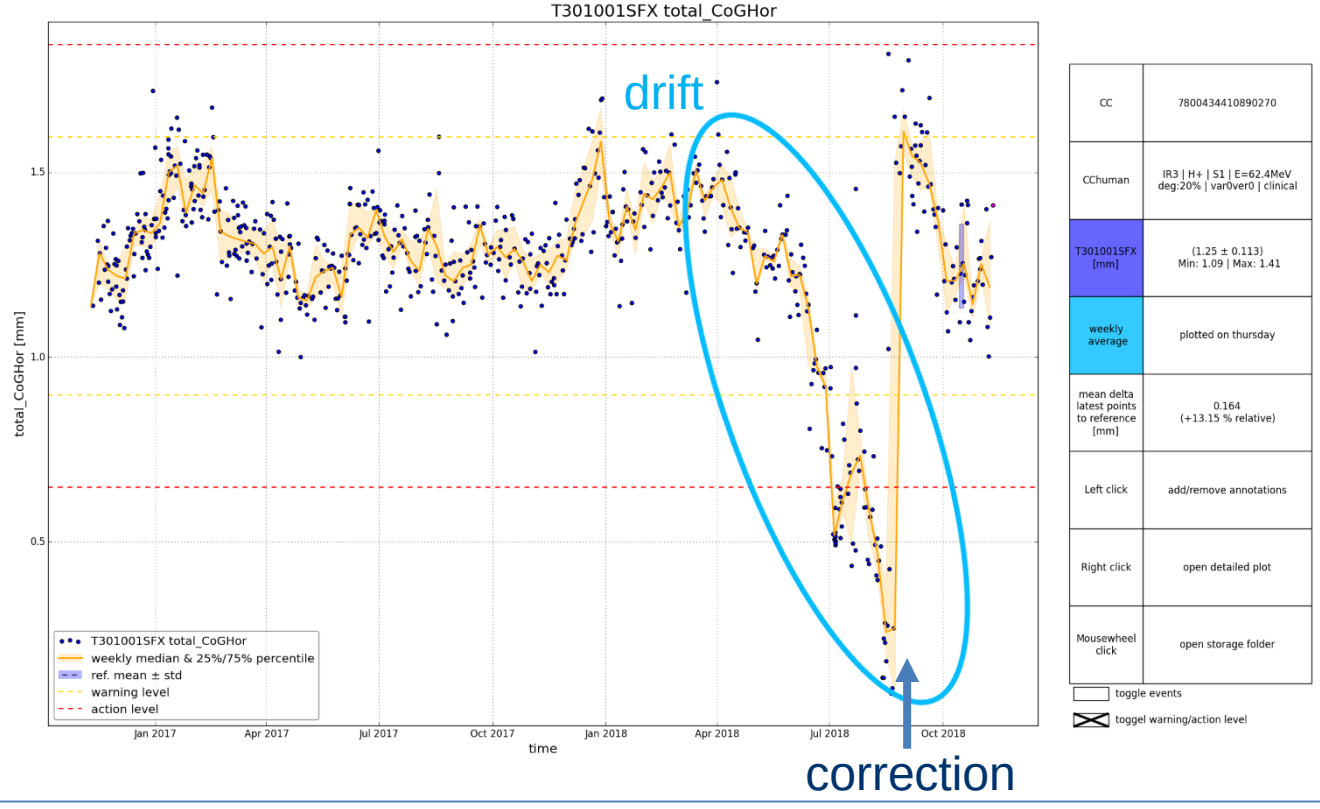
Seasonal position drift examples

Beam position temperature dependency observed for the main ring pick-ups as well as in the transfer line towards the irradiation rooms for the profile monitors.

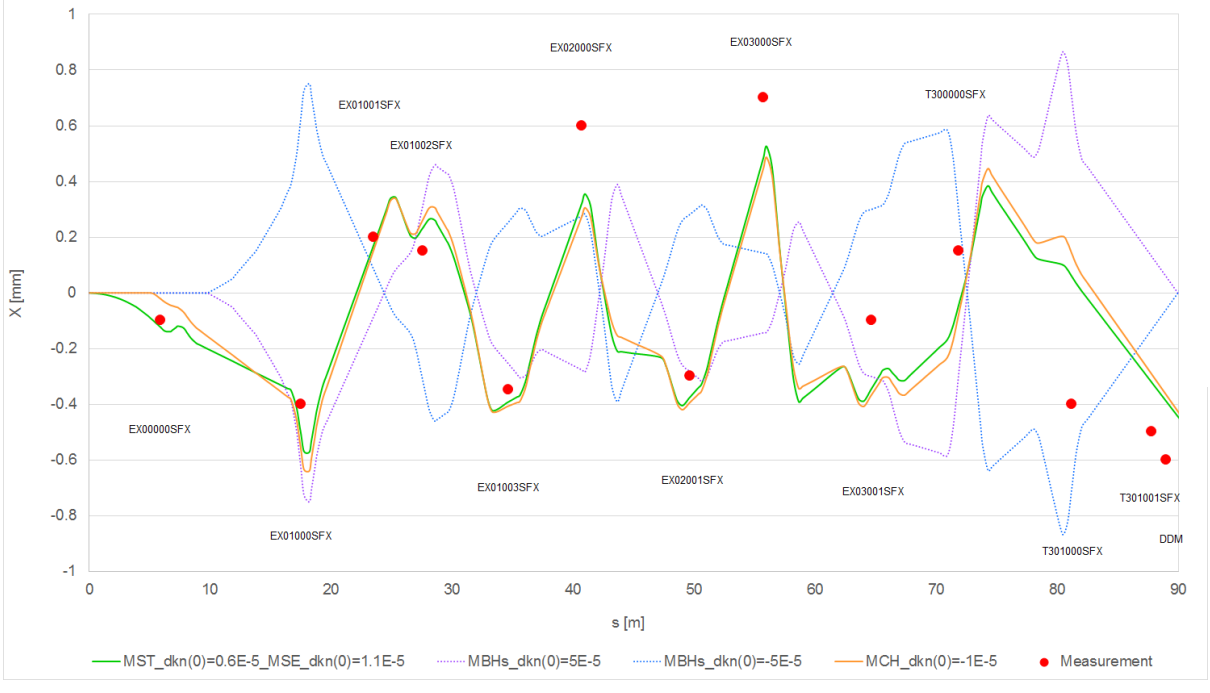


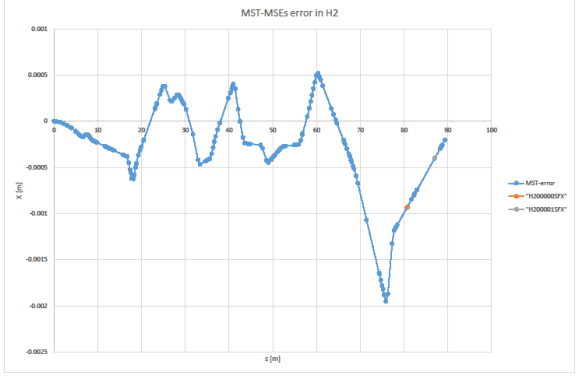


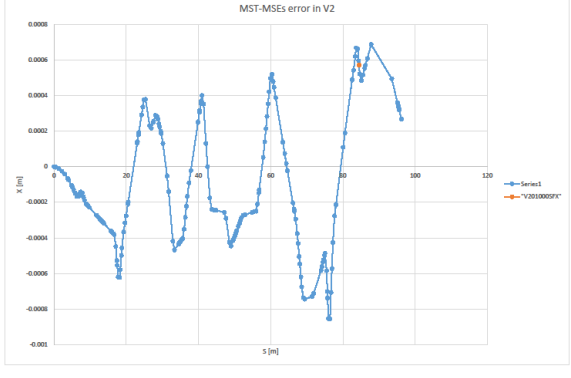
Position drift and correction



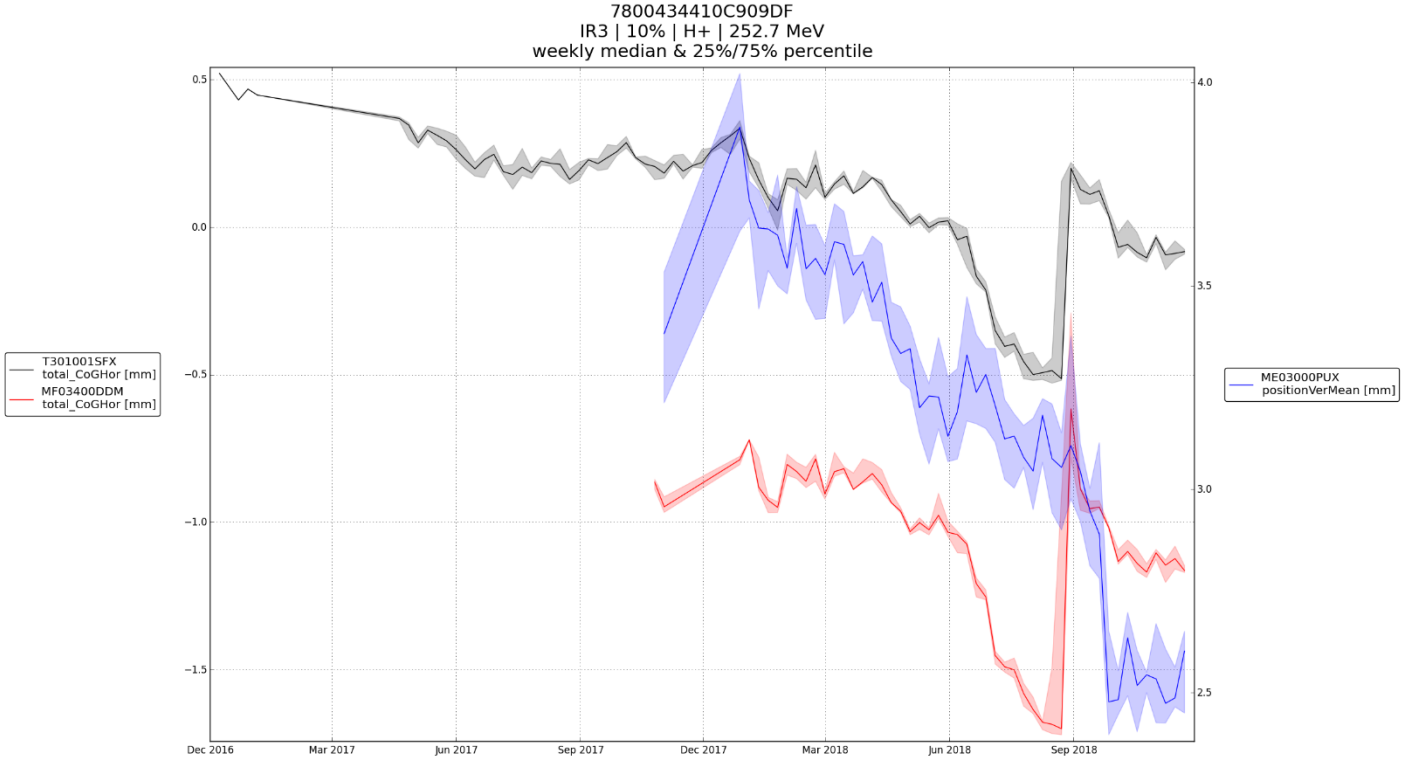
Position drift and simulations







Position drift



Famous hypothesis di Andrea De Franco (OMA fellow):

a vertical position drift in the MEBT is the root cause for the horizontal position drift in the HEBT. This might be possible via a modified phase space filling, leading to a modified transverse emittance with coupling between the planes in the ring and a slight related variation of the extracted beam position in the HEBT.