CLEAR Operational Improvements

CLIC Mini Week
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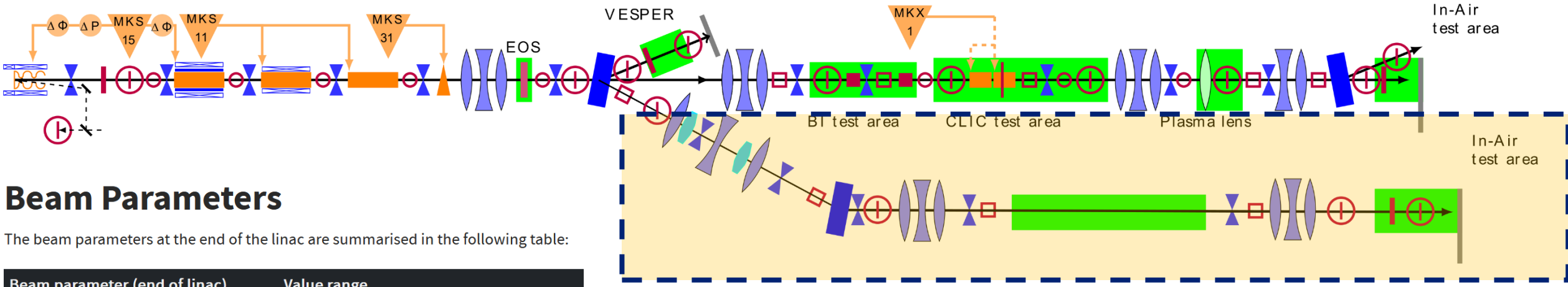
E. Granados – M. Calderon (Laser)

S. Doebert - S. Curt – A. Chauchet (RF)

Introduction



Beam Parameters

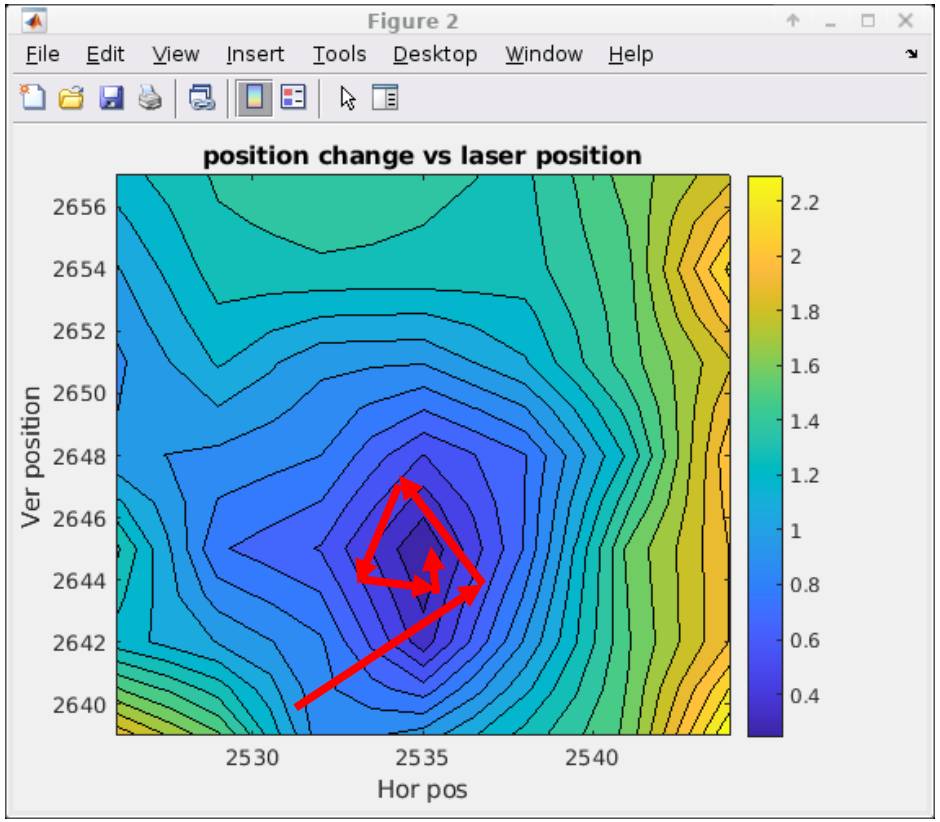
The beam parameters at the end of the linac are summarised in the following table:

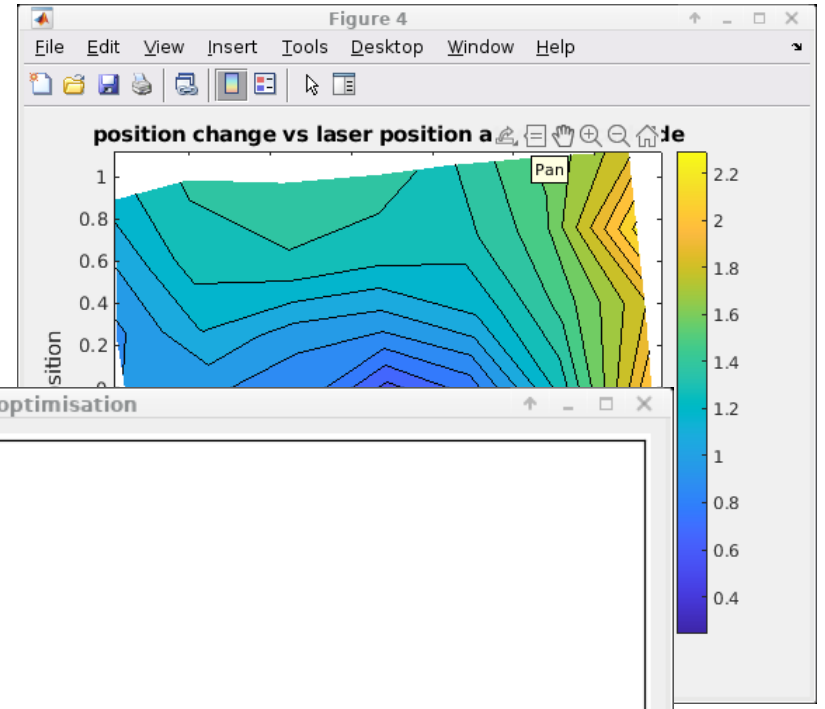
Beam parameter (end of linac)	Value range
Energy	60 - 220 MeV
Bunch charge	0.01 - 1.5 nC
Normalized emittances	3 um for 0.05 nC per bunch 20 um for 0.4 nC per bunch (in both planes)
Bunch length	~100 um - 1.2 mm
Relative energy spread	< 0.2 % rms (< 1 MeV FWHM)
Repetition rate	0.8 - 10 Hz
Number of micro-bunches in train	1 - 150
Micro-bunch spacing	1.5 or 3.0 GHz

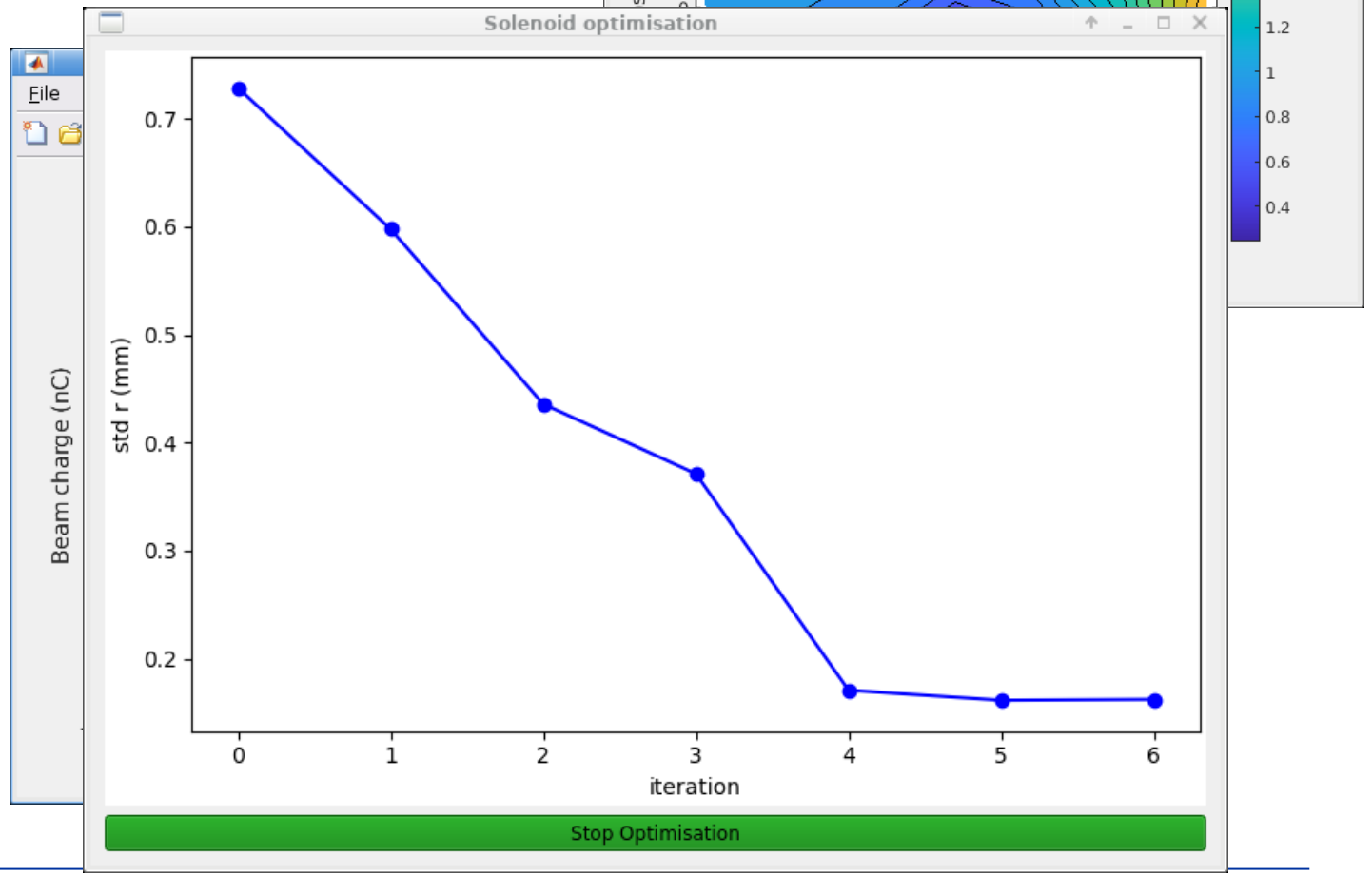
- A test facility at CERN with high availability, easy access and high-quality e- beams for wide range of users
- Wide range of beam parameter
  - Single bunch multi bunch wide energy change etc..
- Many applications on different location of beamline
  - No fixed optics, need for fast tuning of machine, fast determination of beam parameters on beamline

Machine startup tool

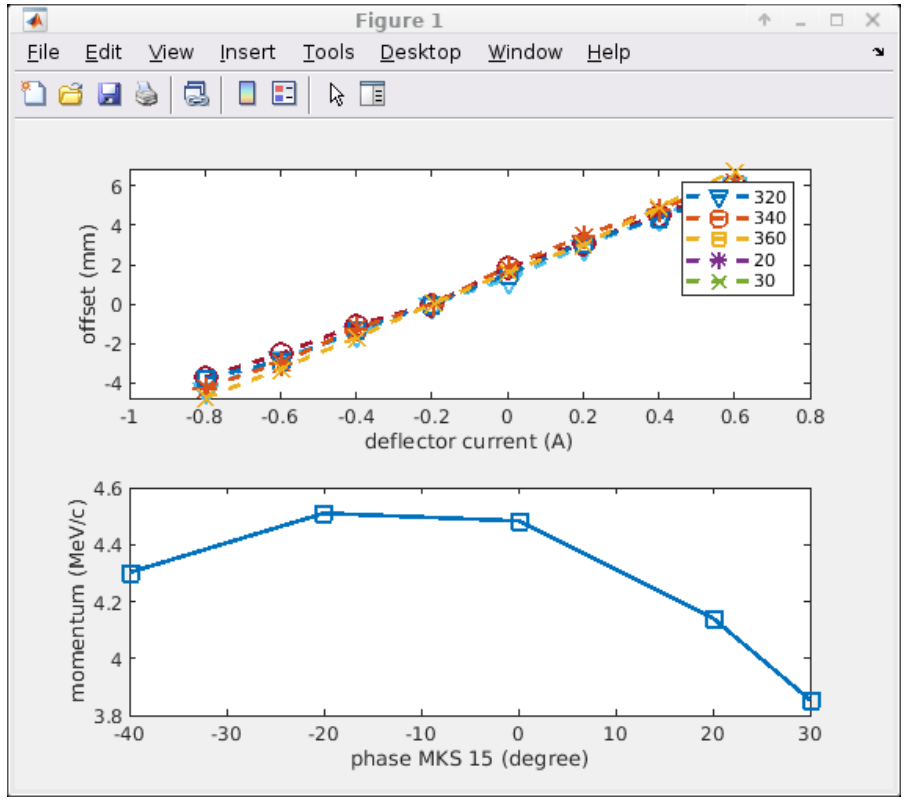
- Especially after long shutdown (i.e. weekends) or temperature change we have drift in RF or change on laser position on cathode.
- To start machine we have developed such a tool that finds optimum operation phase and laser position



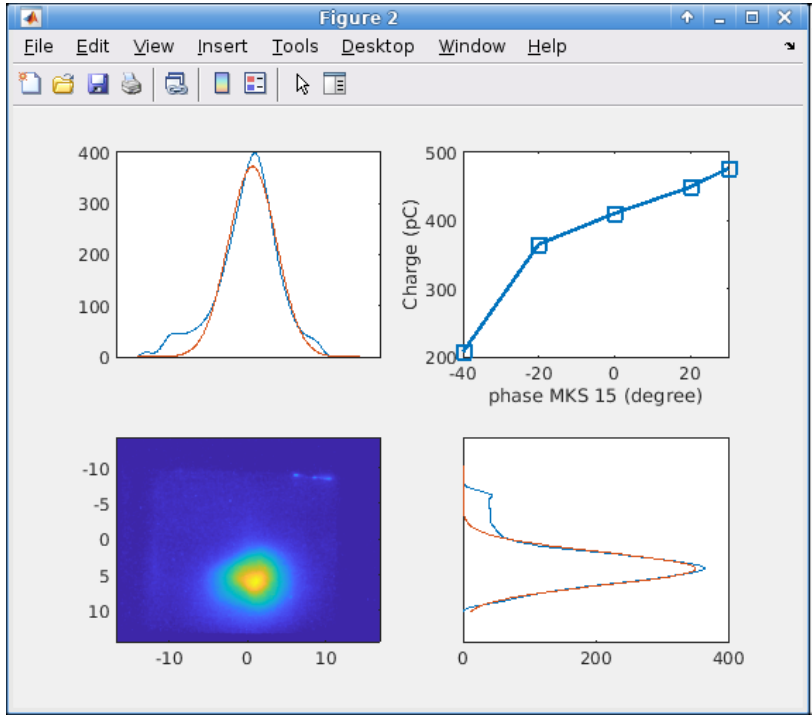


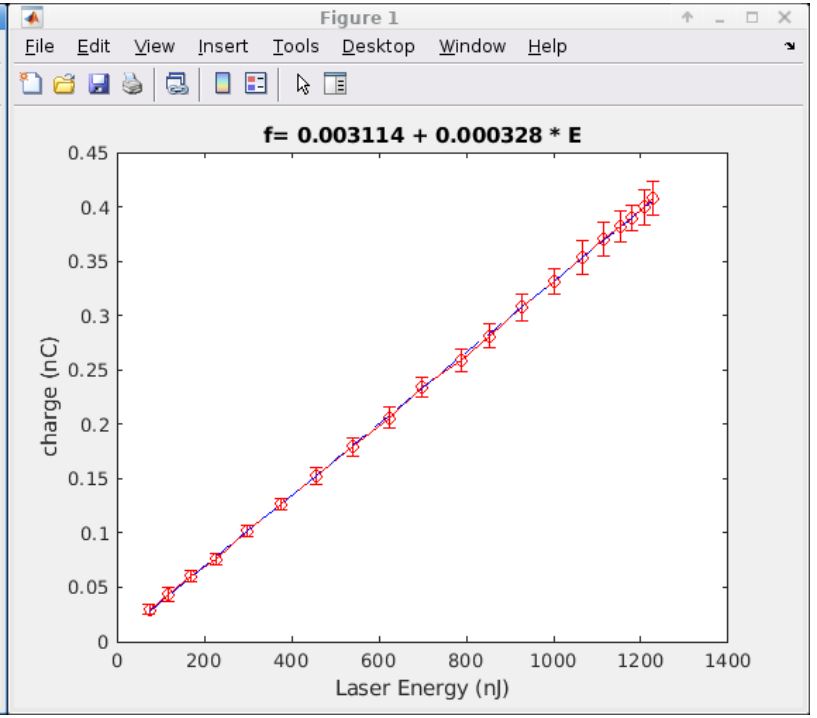


Energy and quantum efficiency measurement

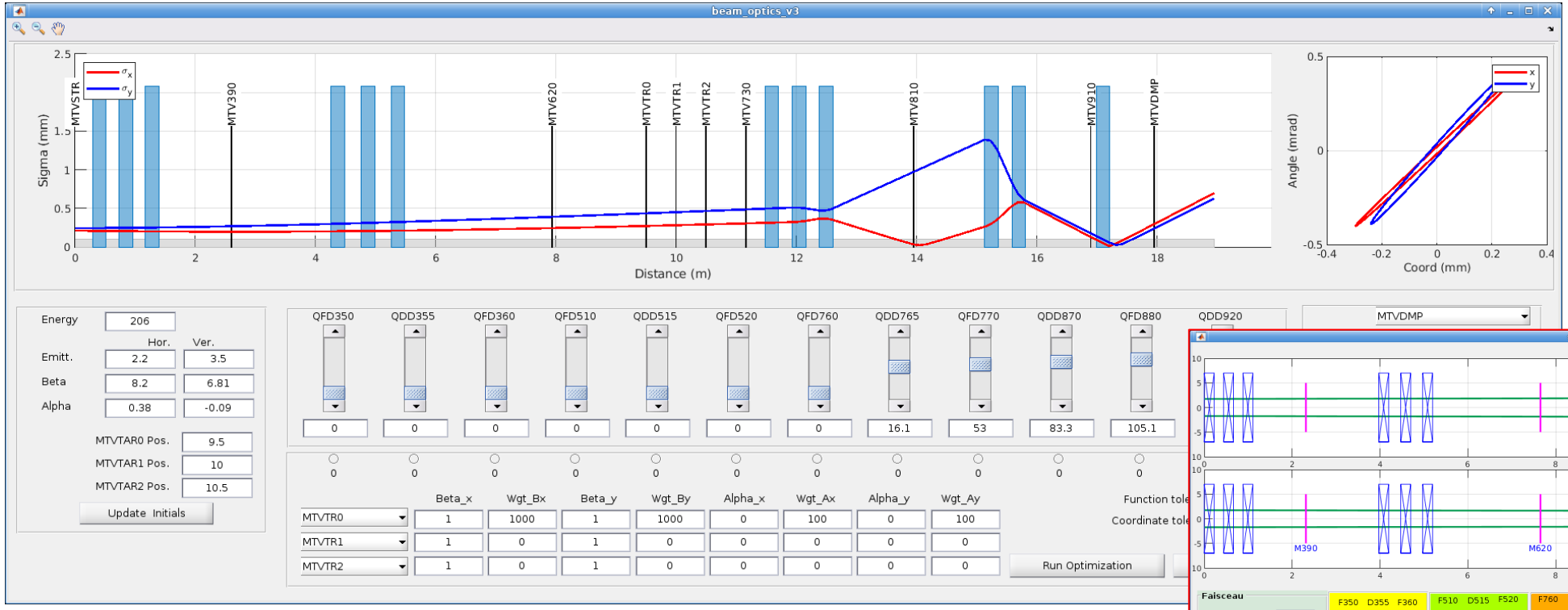


- To measure the quantum efficiency and gun gradient for given settings we have developed a tool which uses corrector as spectrometer and analyses all data.
- The tool is almost used weekly
- The stored data allows us to compare results with simulation



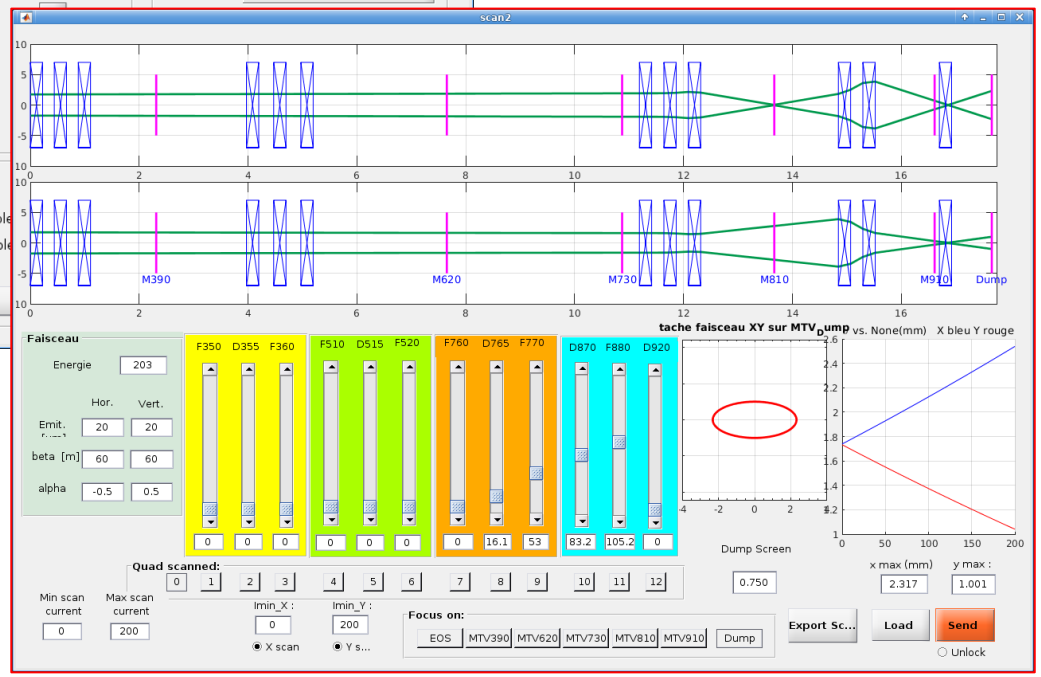


Flight simulator



Tool to predict ranges of quadrupule currents especially for quadrupole scan

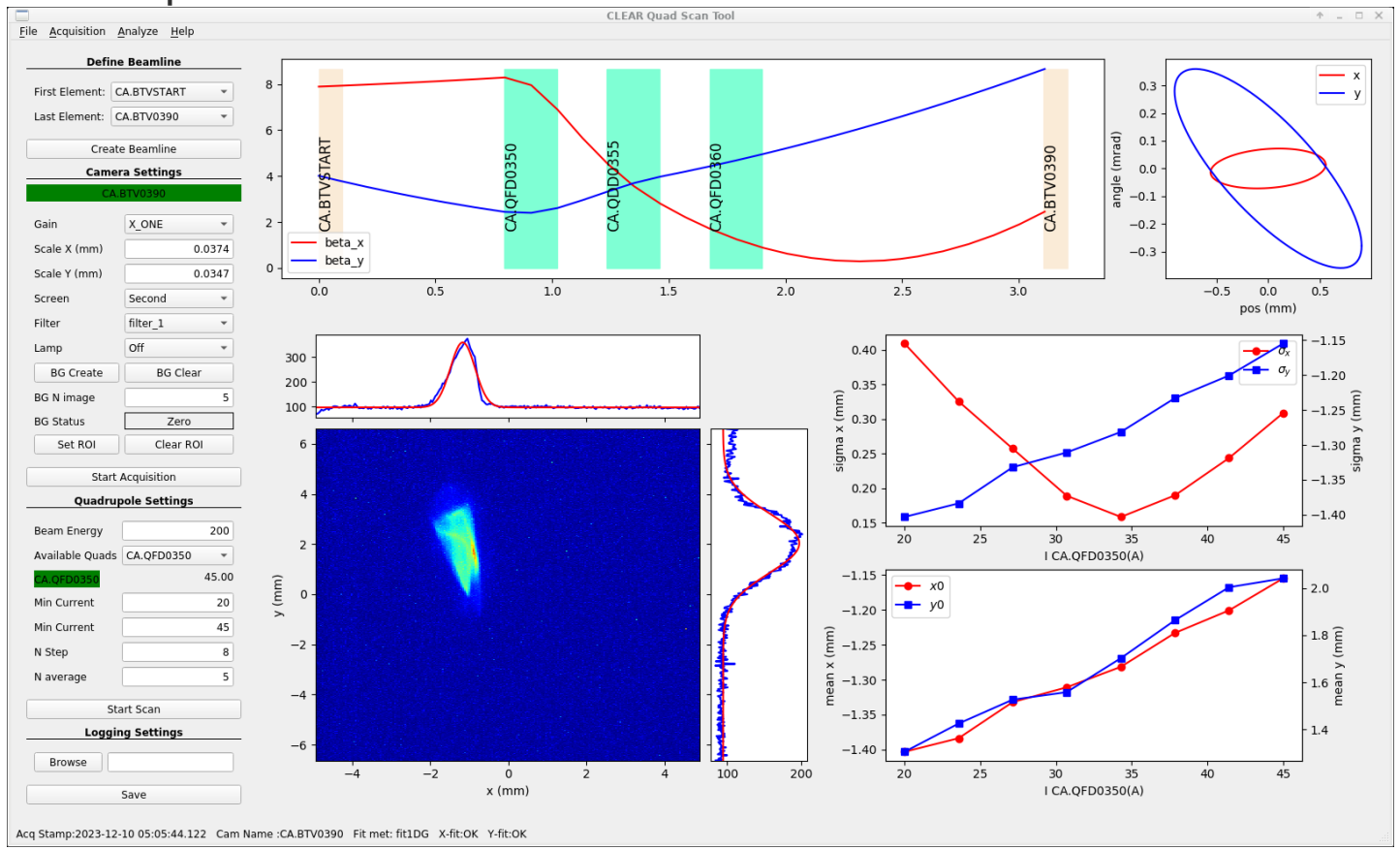
Credit: W. Farabolini



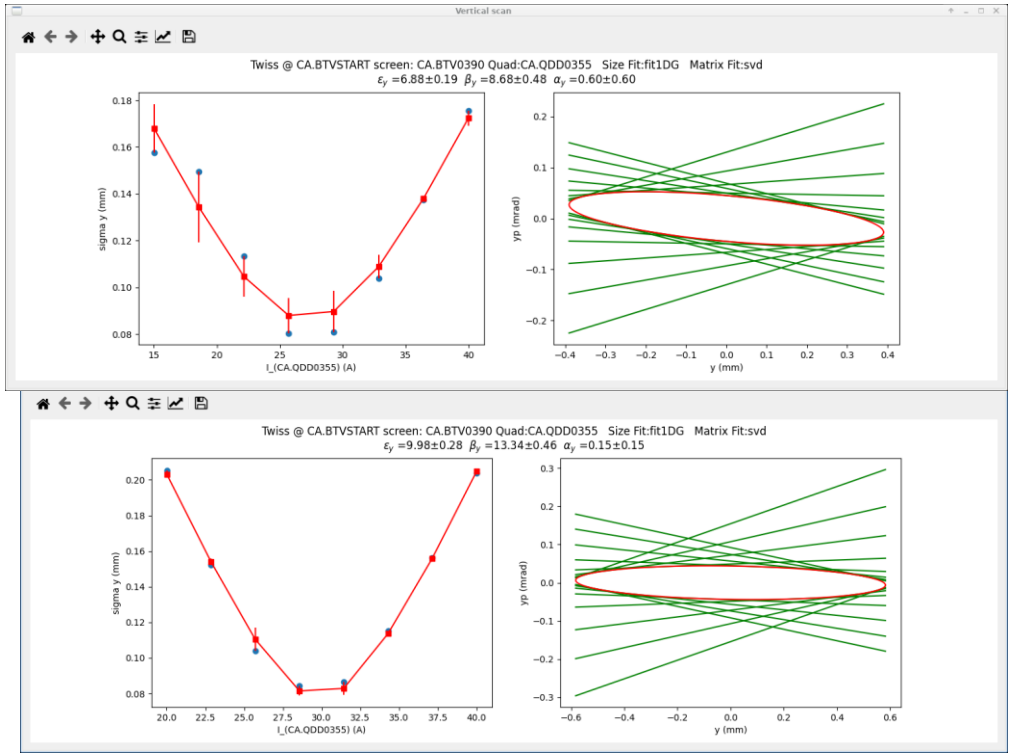
- We do not have a fixed optics for the machine.
- Any location on beamline can be a place for an experiment.
- Generic tool which beamline is created using MADX sequence file communicates with control system and optimizes beamline for given target parameters

Quadrupole scan tool

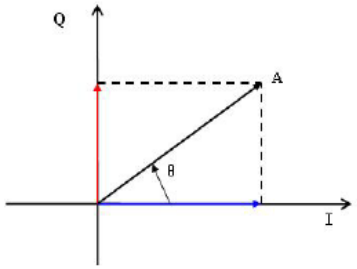
- We need to know Twiss parameters on any location of beamline (where the experiments are performed)
- We have developed a tool on which the beamline is loaded from MADX file.
- One can select the location upstream where the Twiss parameters needed to compute..



- Different computation methods and fittings are implemented…
  - Least square, SVD, matrix inverse
  - 1D Gauss, 2D Gauss, Super-Gauss, 2D Weighed



Cavity BPM calibration

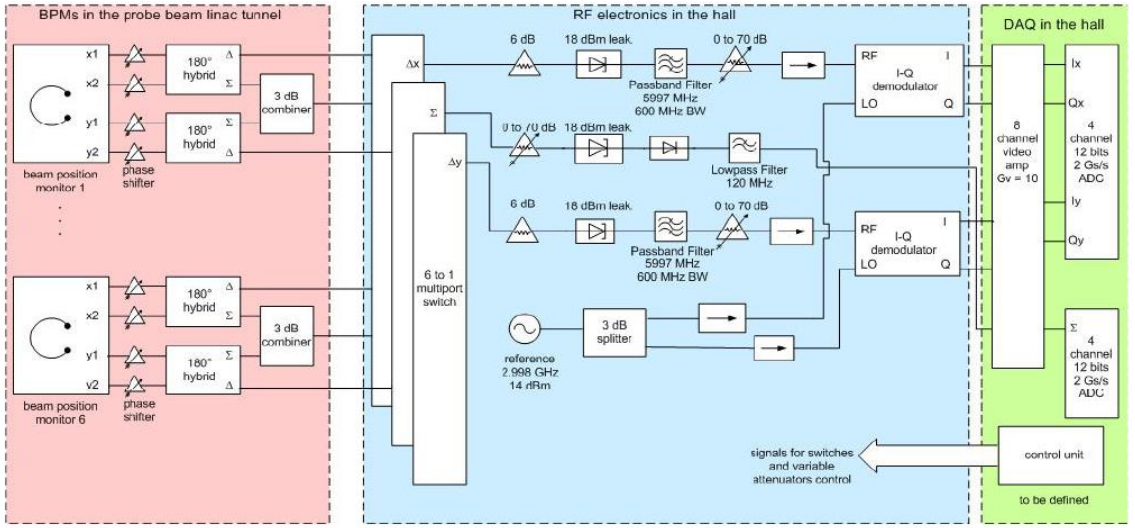


$$A = \sqrt{I^2 + Q^2}$$

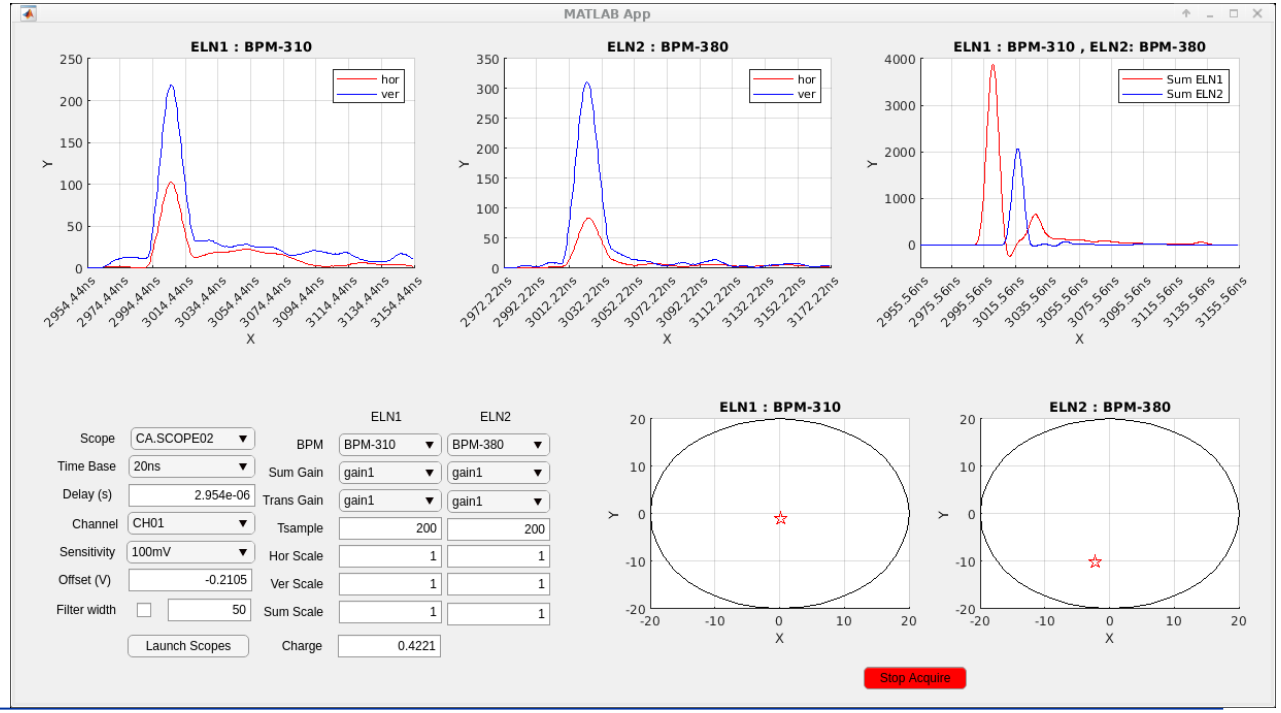
$$\cos\theta = \frac{I}{A} \qquad \sin\theta = \frac{Q}{A}$$

$$\Delta = I\cos\theta + Q\sin\theta$$

$$P = \frac{\Delta}{\Sigma}$$



- We have 5 cavity BPMs (6 GHz dipole mode, 4 GHz monopole mode) installed along linac but two electronics for acquisition
- The I/Q modulated signal was available but no position information
- A tool has been developed to calibrate and acquire the cavity BPMs

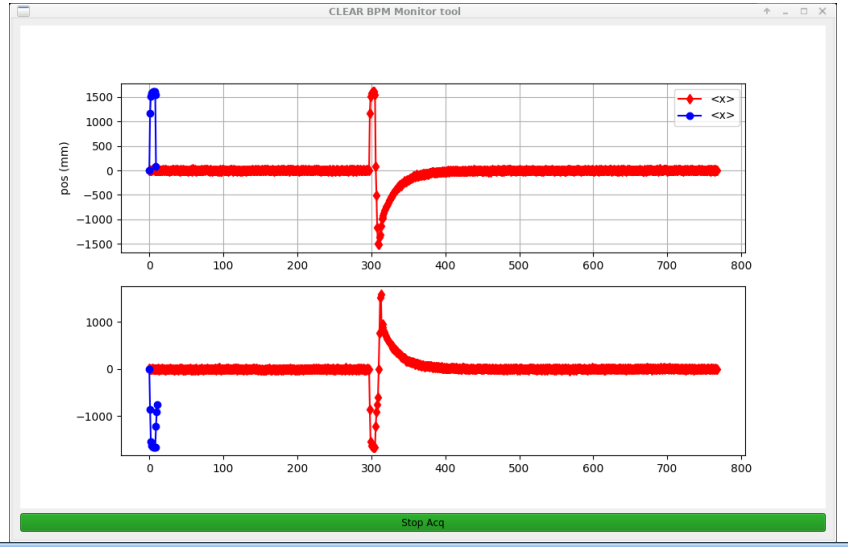


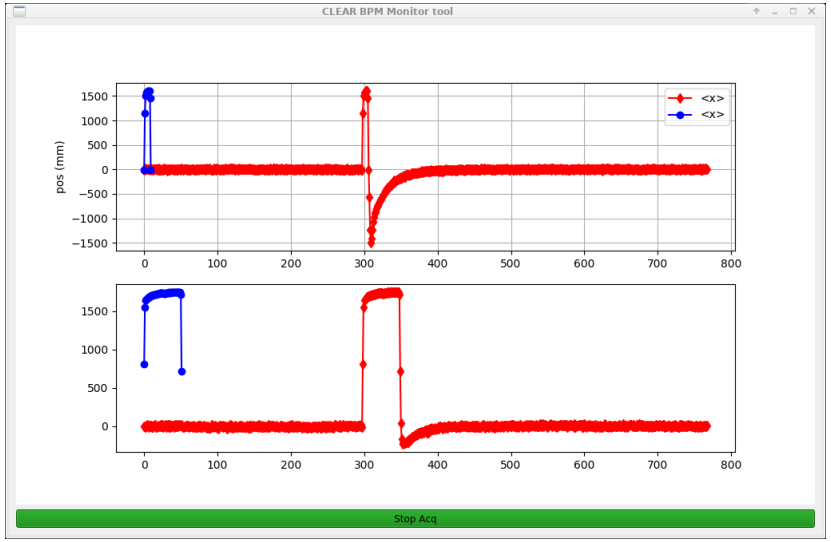
Inductive BPM Calibration

We have 5 inductive BPMs along beamline

An algorithm to “catch” correct portion of signal and do the computation

BPMs are calibrated by using last screen as well as cross calibration

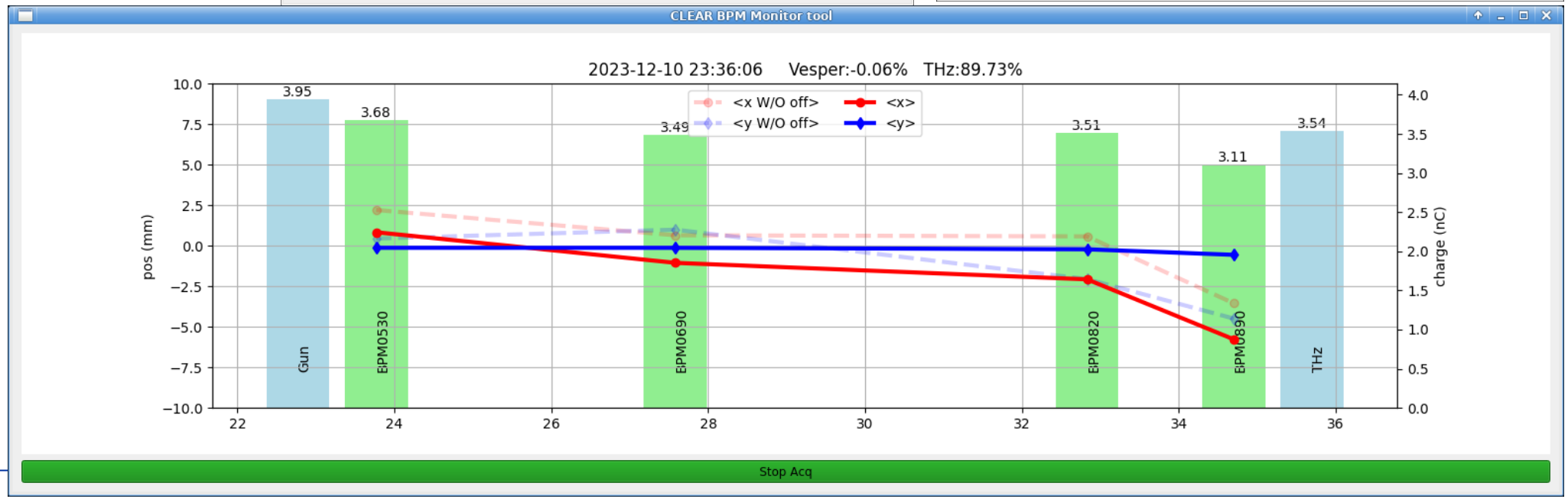




$$\Sigma = H_+ + H_- + V_+ + V_-$$

$$\Delta H = \frac{H_+ - H_-}{\Sigma}$$

$$\Delta V = \frac{V_+ - V_-}{\Sigma}$$



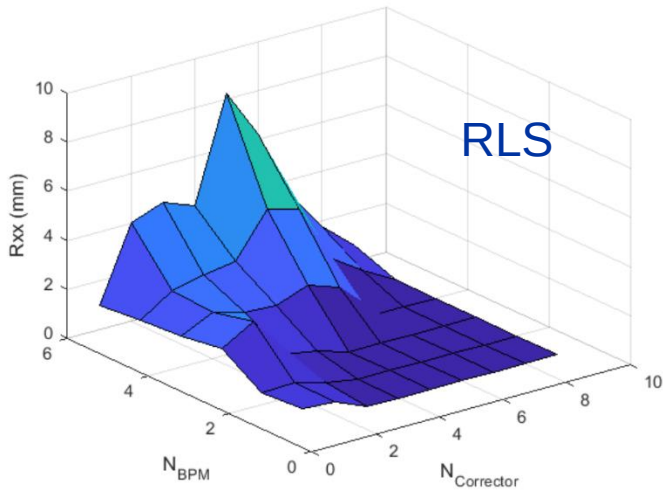
Beam Based Alignment

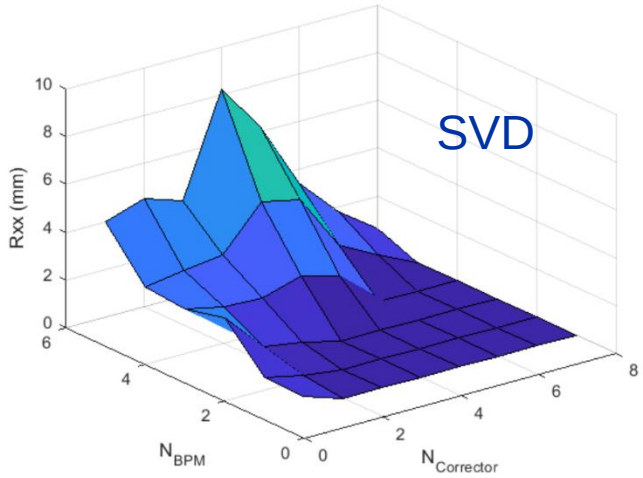
$$X = X_0 + R\Theta, \qquad R_{i,j} = \frac{\Delta x_i}{\Delta \theta_j},$$

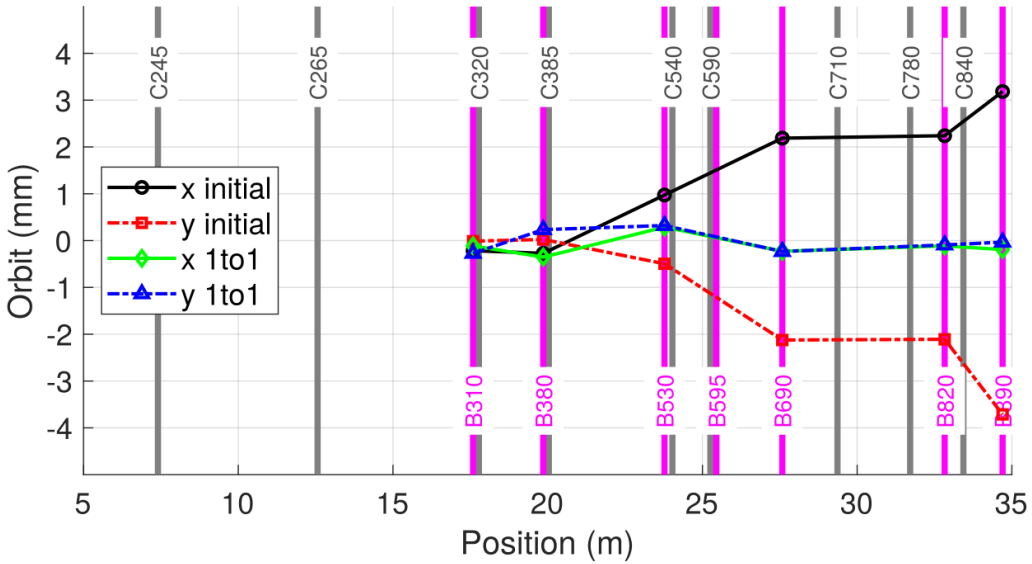
$$\Theta = (R^T R)^{-1} R^T \Delta X$$

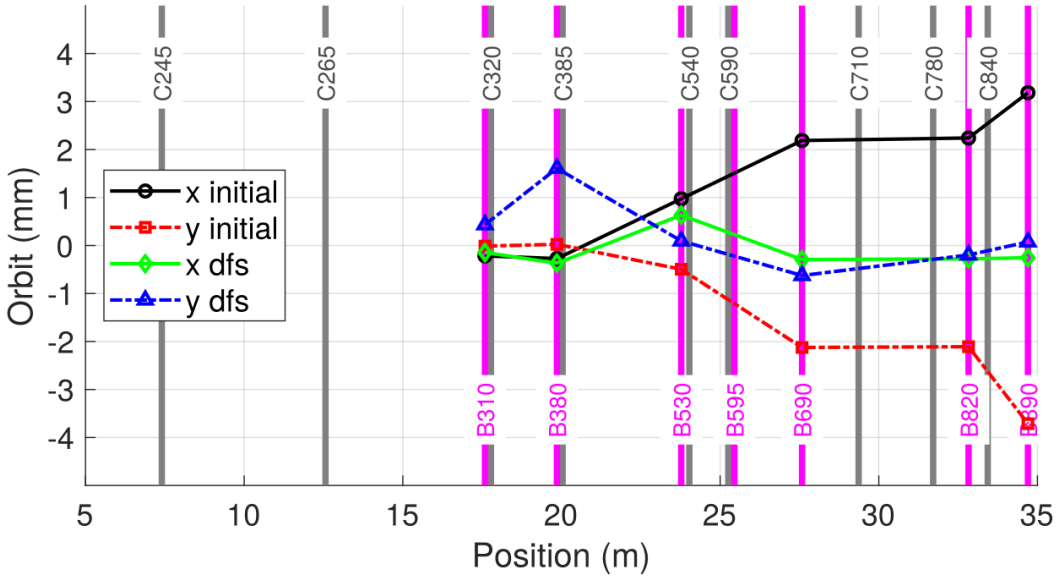
DFS: $$\begin{pmatrix} X \\ \omega(X - X') \\ 0 \end{pmatrix} = \begin{pmatrix} R \\ \omega(R - R') \\ \kappa I \end{pmatrix} \times \Theta,$$

- Operational BPMs allowed us to do high level beam physics.
- We have developed an automated response matrix generation tool.
  - Random or excitation in sequence of correctors for given machine setting
  - R: for nominal energy, R' : for reduced energy
- Based on chose one can create response matrix based on different algorithms (RLS, SVD) apply one-to one steering or DFS
- Full process takes about 30 min



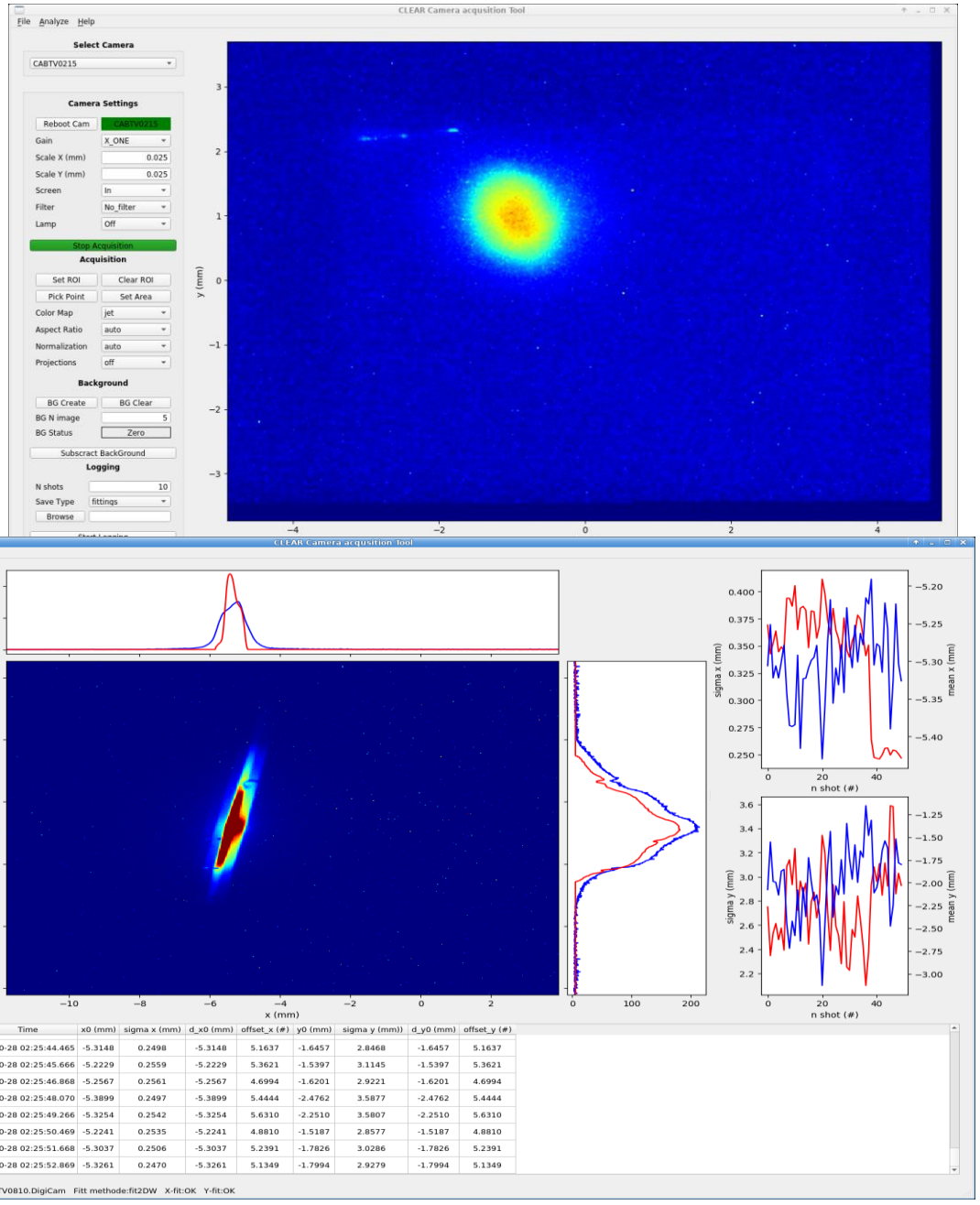






Camera acquisition

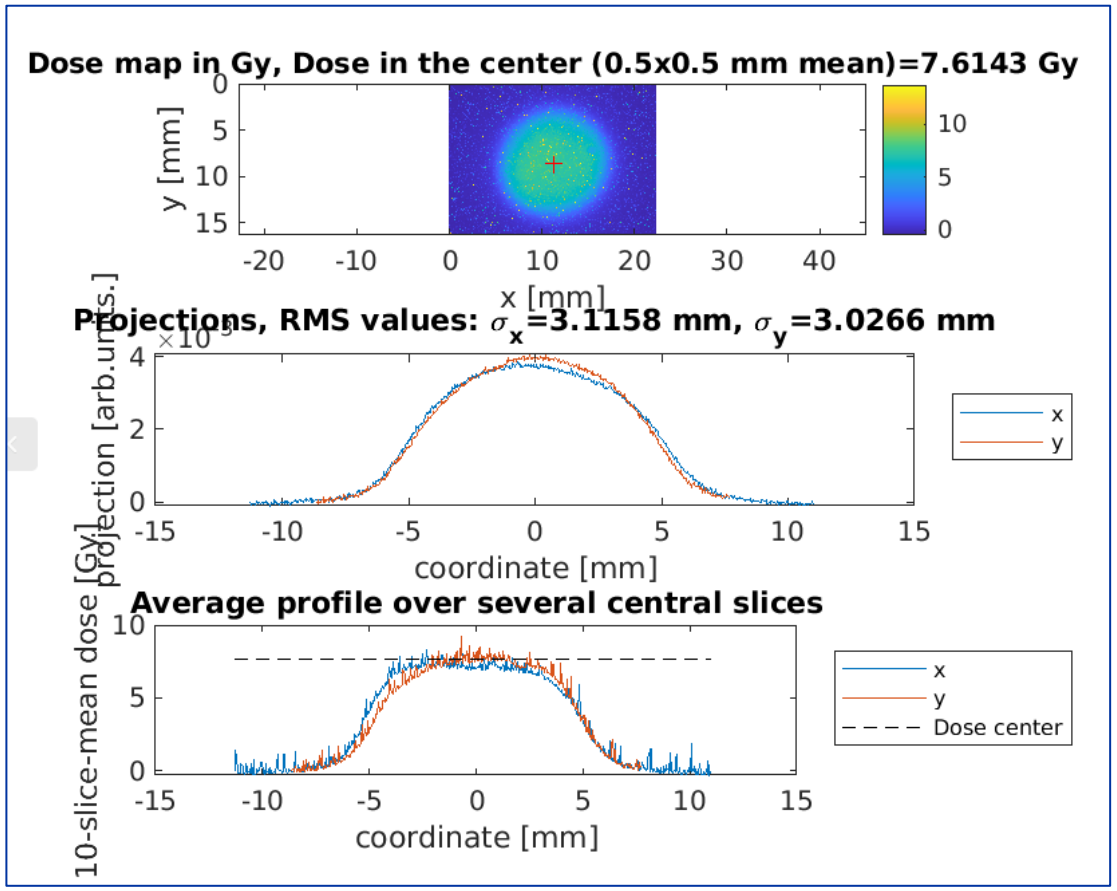
- After last upgrade of camera system CLEAR has two family of cameras (we call digital/analog)
- However all other hardware still relies on analog system
  - Screen, filter, pusher etc..
- Generic camera acquisition tool communicating both FESA clases.
- Image processing algorithms such as filter, sharpening etc.. Are implemented
- Background subtraction based on frame, edge frame edge is avalible
- Various fittings algorithms are implemented
  - 1D Gauss, 2D Gauss, Super-Gauss, 2D Weighed
- Some fits CPU consuming, needs improvement, i.e. fitting in linear equation system..

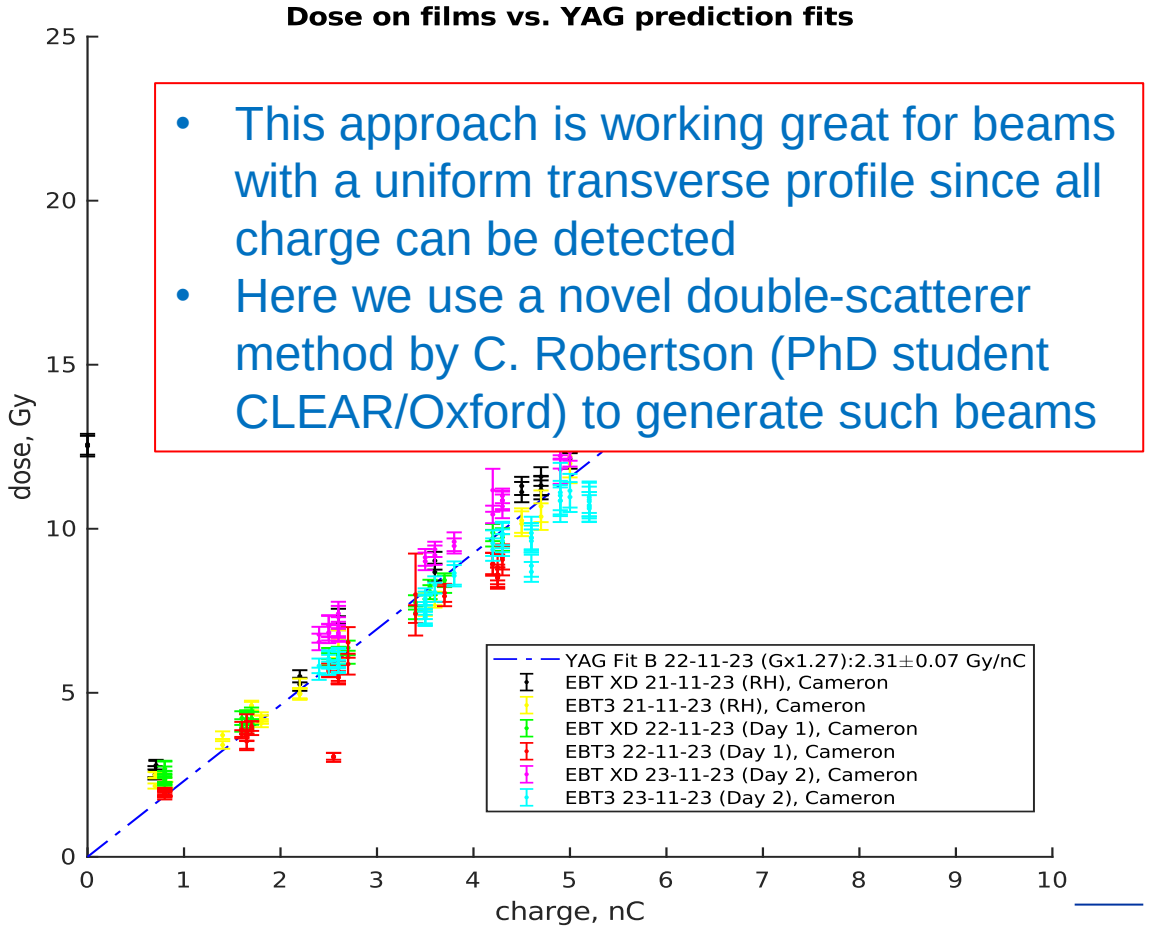


Dose prediction based on the charge density measurements

Credit A. Malyzhenkov

- Measuring transverse profile and charge allows to retrieve 2D charge density of electron beams
- Based on the empirical data one can translate the charge density nC/mm^2 to dose in Gy and compare with dose deposition films
- With a thin YAG screen such approach will allow online noninvasive prediction (to be tested in 2024)



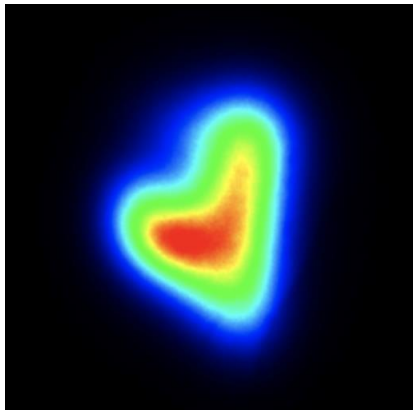


- This approach is working great for beams with a uniform transverse profile since all charge can be detected
- Here we use a novel double-scatterer method by C. Robertson (PhD student CLEAR/Oxford) to generate such beams

Conclusions

- Many aspects of the machine operation were improved during 2023 despite very limited time for the Machine Development (MD)
  - Some of them are not mentioned here
- Machine operation for users/operators is constantly improving after MDs!
- We still have a lot of opportunities for improvement in 2024,
  - Starting from inteligent tracking of laser timing, aligning of the beamline elements, fully operation all BPMs and advancing operational tools…
- The proper trajectory and predictable orbit would be even more critical for the commissioning and successful operation of the second beamline
  - we would have to close the dispersion in wide energy and spread range!
- Many of the existing operation procedures can be automatized making life of operators easier and more efficient use..
  - Turns out opportunities for more experiments and additional MD

Thank you for your attention



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