Emittance measurement tools: EmWiz suite.

Introduction to EmWiz suite

FastScan

EmCalc

Memory watcher

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HELMHOLTZ GEMEINSCHAFT

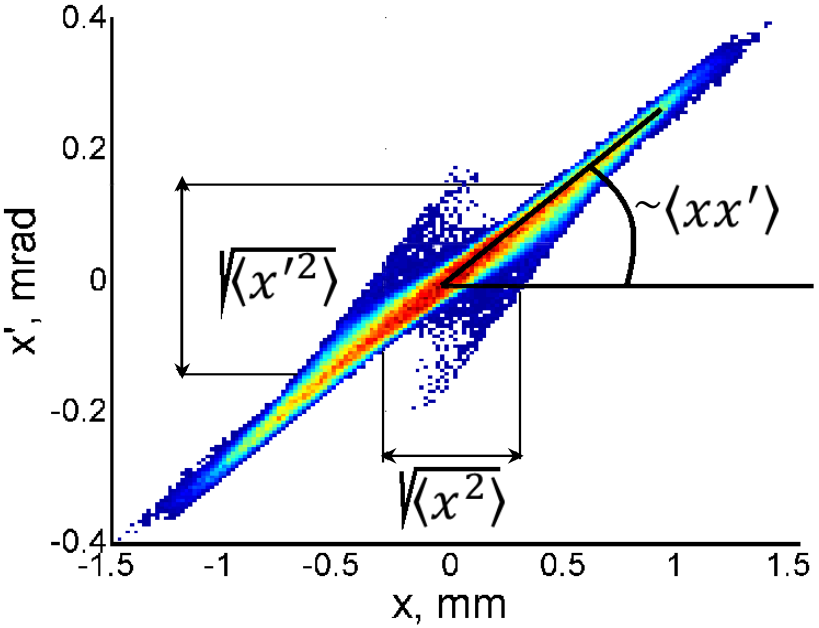
DESY

What is phase space and emittance

- The phase space of the system is the space in which all possible states of the system are represented.
- Emittance is related to the volume/area occupied by the electron beam in phase space.
- 6D phase space can be split into 3x2D phase spaces: (x, x'); (y, y'); (z, p_z)
- Normalized transverse rms emittance for X plane:

$$\varepsilon_{n,x} = \beta\gamma\sqrt{\langle x^2\rangle\langle x'^2\rangle - \langle xx'\rangle^2}$$

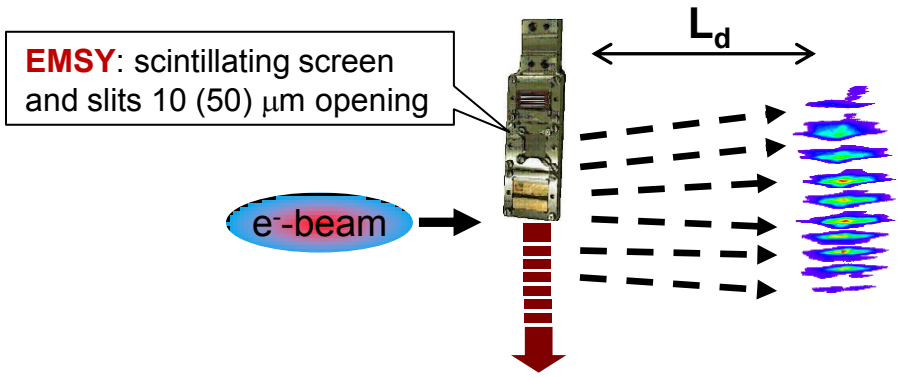
$$\beta = \frac{v}{c}, \gamma = \frac{1}{\sqrt{1-\beta^2}}$$

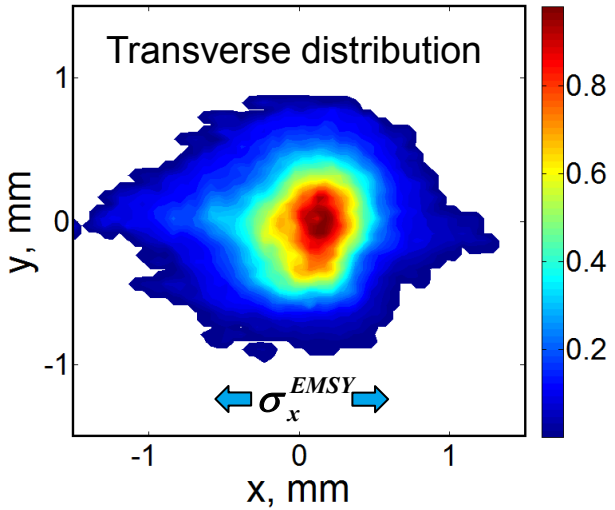


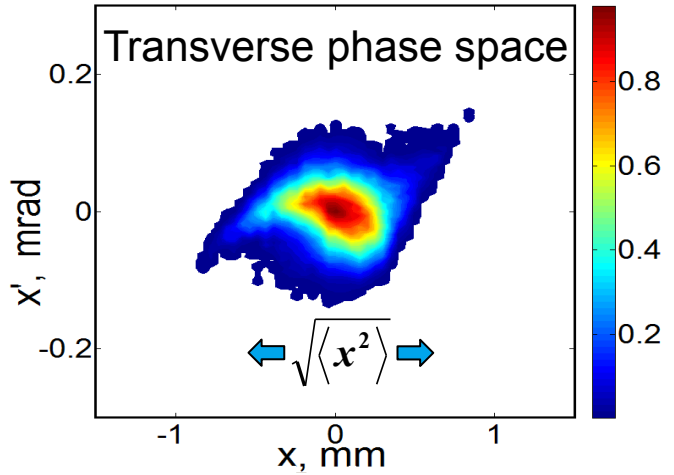
- Normalized transverse rms emittance for both planes:

$$\varepsilon_{n,xy} = \sqrt{\varepsilon_{n,x}\,\varepsilon_{n,y}}$$

Emittance measurements method and procedure







$$\varepsilon_x = \beta\gamma \frac{\sigma_x^{EMSY}}{\sqrt{\langle x^2 \rangle}} \sqrt{\langle x^2 \rangle \langle x'^2 \rangle - \langle x x' \rangle^2}$$

Scaling factor is introduced to correct for low intensity losses from beamlet measurements

Introduction

EmWiz suite consists of four programs:

- FastScan
- EmCalc
- RootPlot
- MemoryWatcher

1. Fastscan and EmCalc are two programs which are started by operators. First one to perform the measurements and the second one to perform the processing of the measured data.

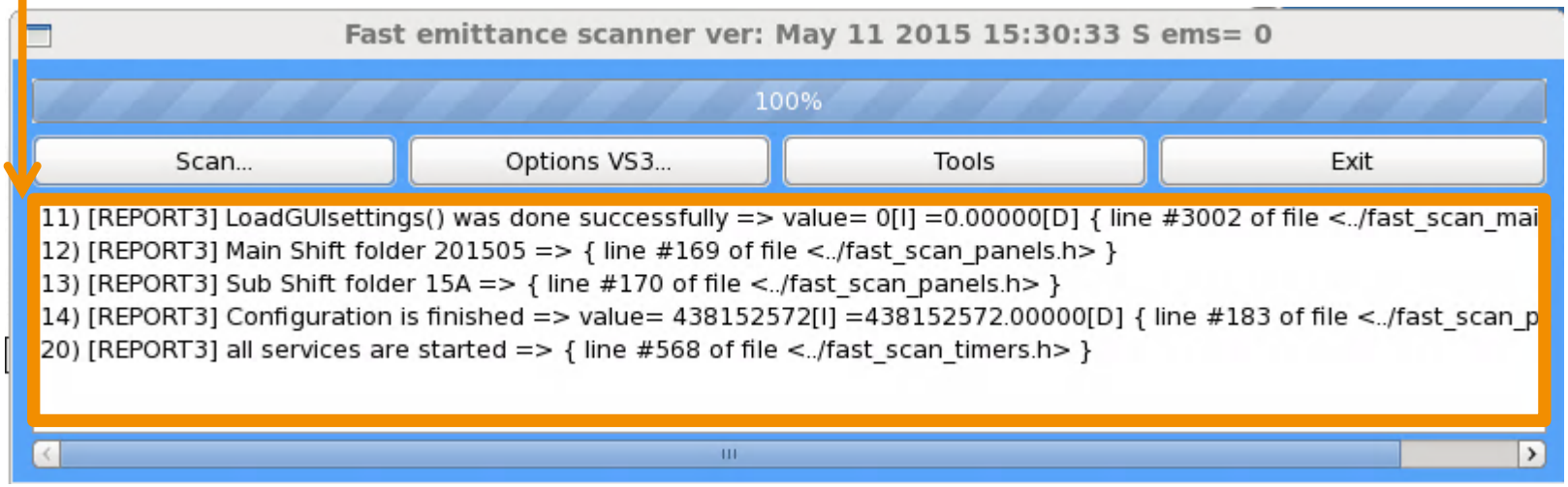
2. RootPlot and MemoryWatcher are the supporting programs which are started automatically by either FastScan or EmCalc. RootPlot is used for to display the calculated by EmCalc data (e.g. EMSY distribution, phase space, saturation plot etc.). MemoryWatcher is used to manage the sheared memory used by FastScan, EmCalc and RootPlot.

3. All the programs are written using Qt4 or QtRoot4 SDK.

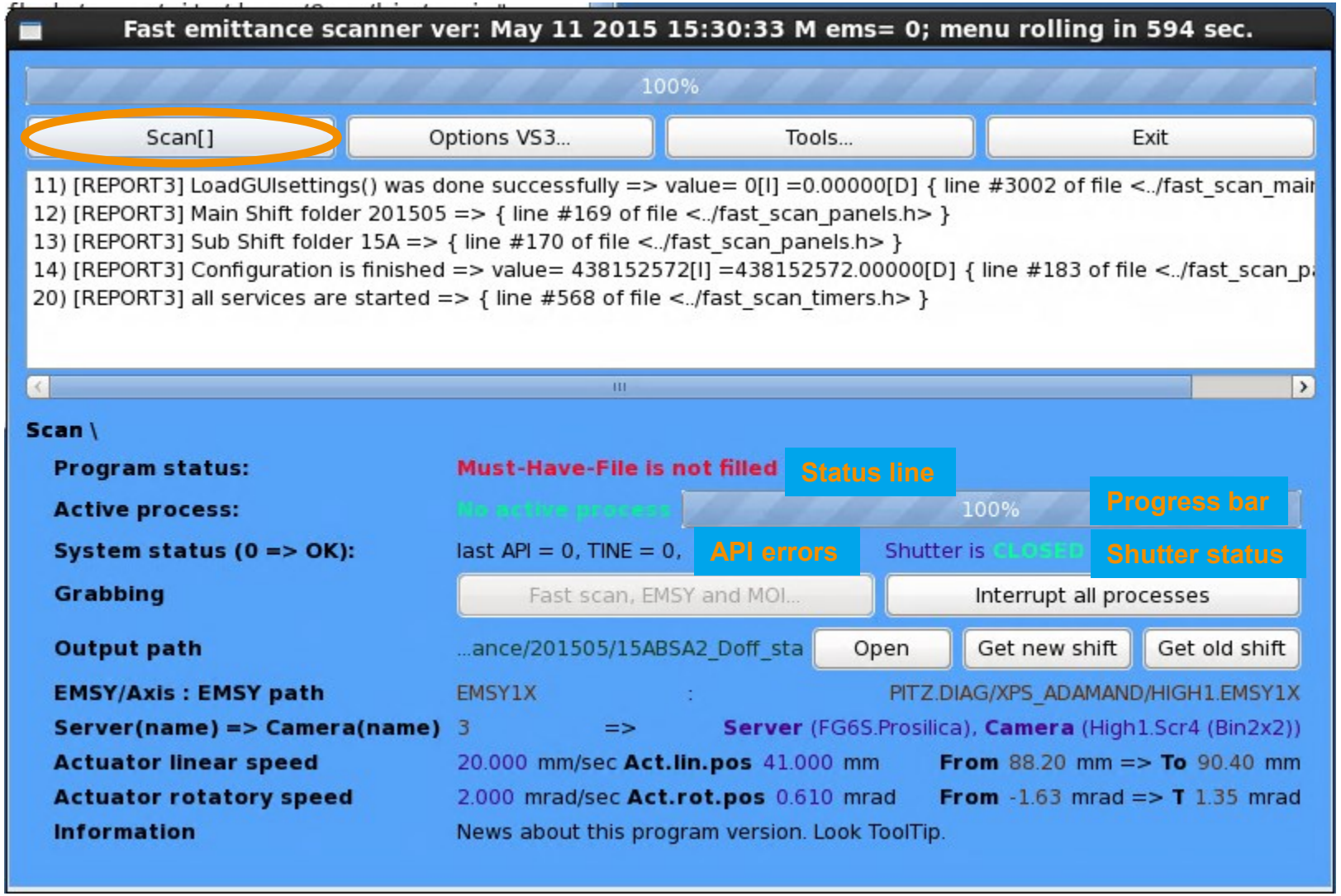
4. FastScan and EmCalc can be started by typing “fastscan3” and “emcalc3” in the Linux terminal, respectively. Their development versions (may be unstable) can be started by typing “fastscan3_test” and “emcalc3_test” in the Linux terminal, respectively.

FastScan startup

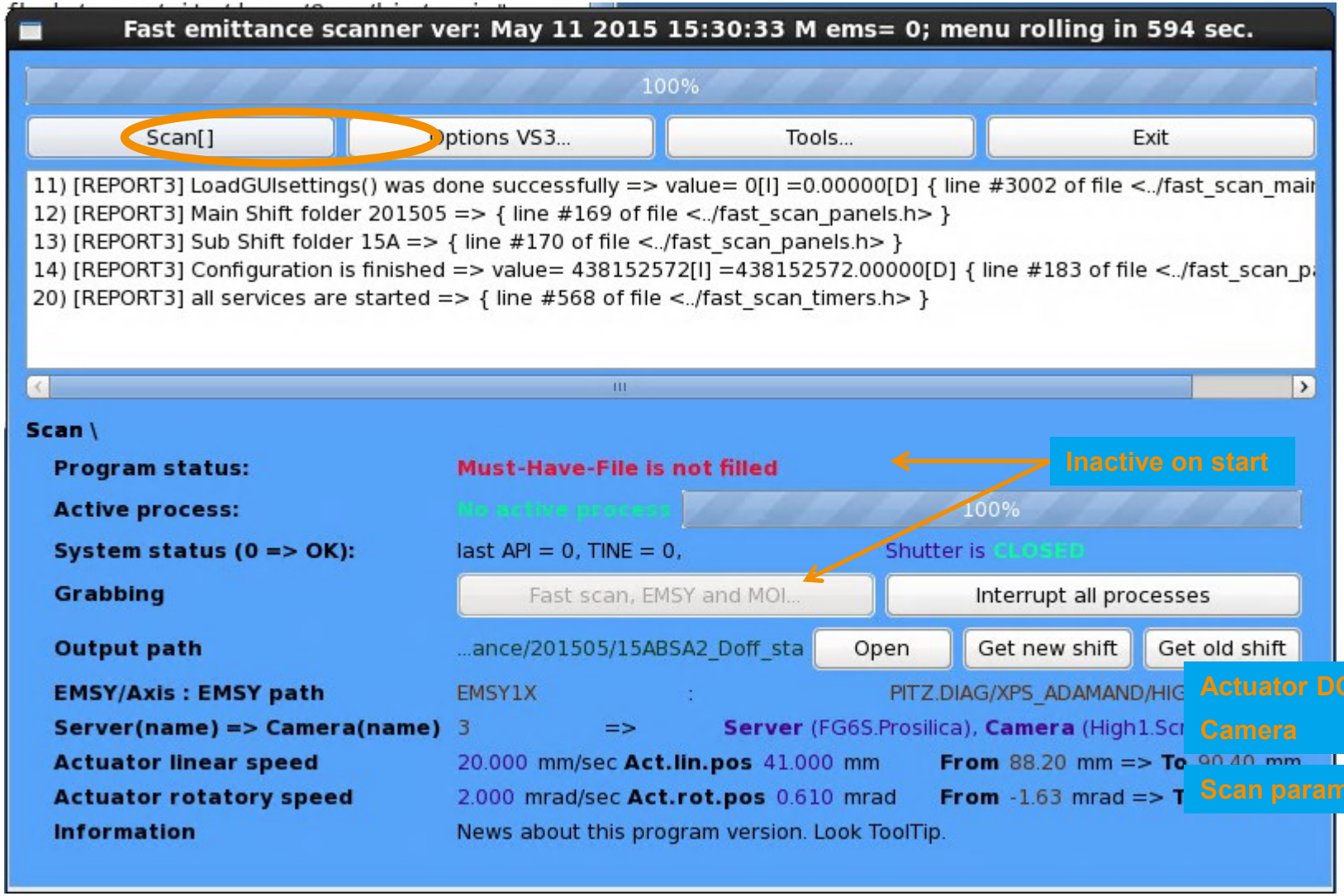
Reports, warnings and errors display area



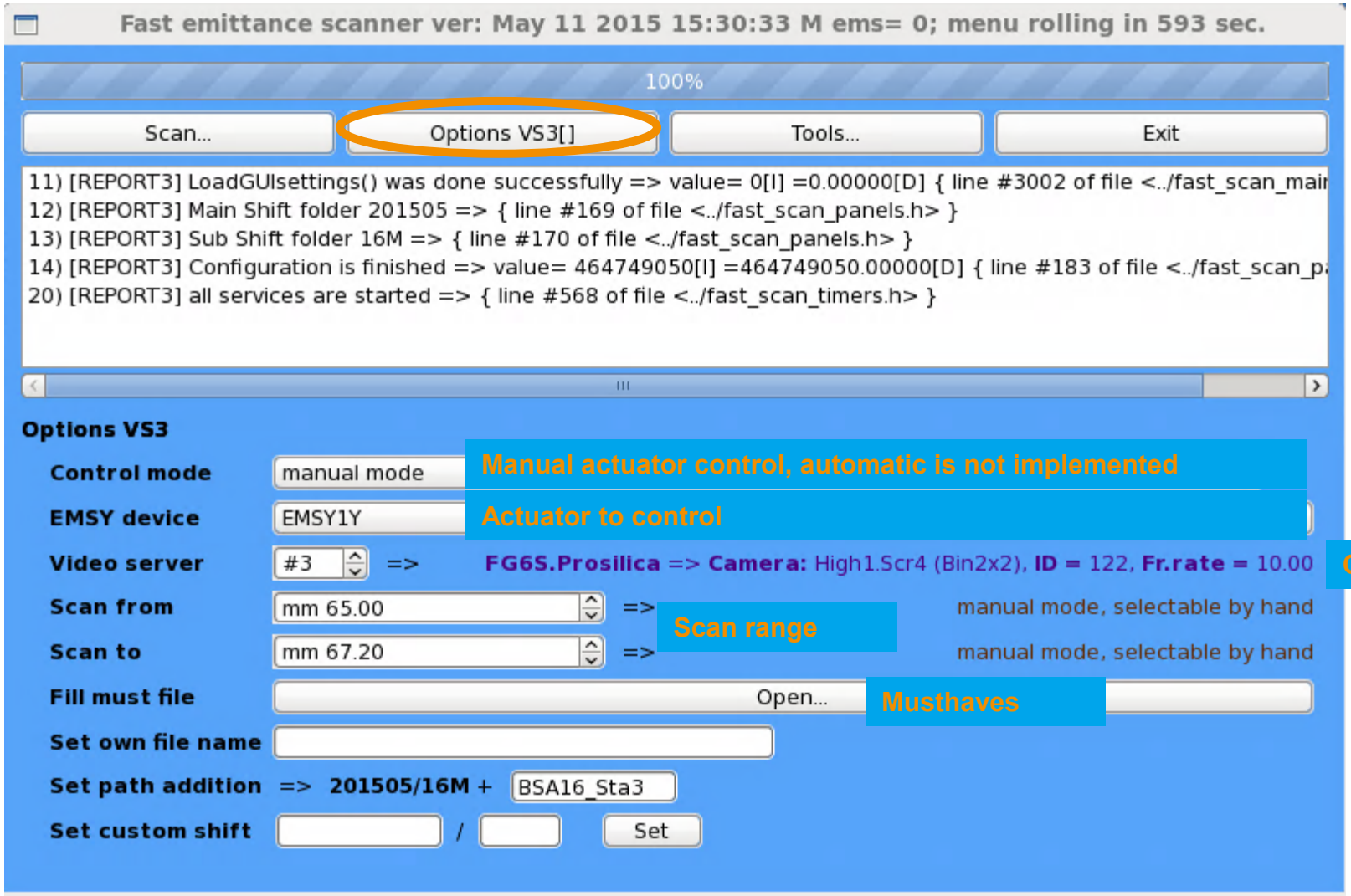
FastScan: Scan button



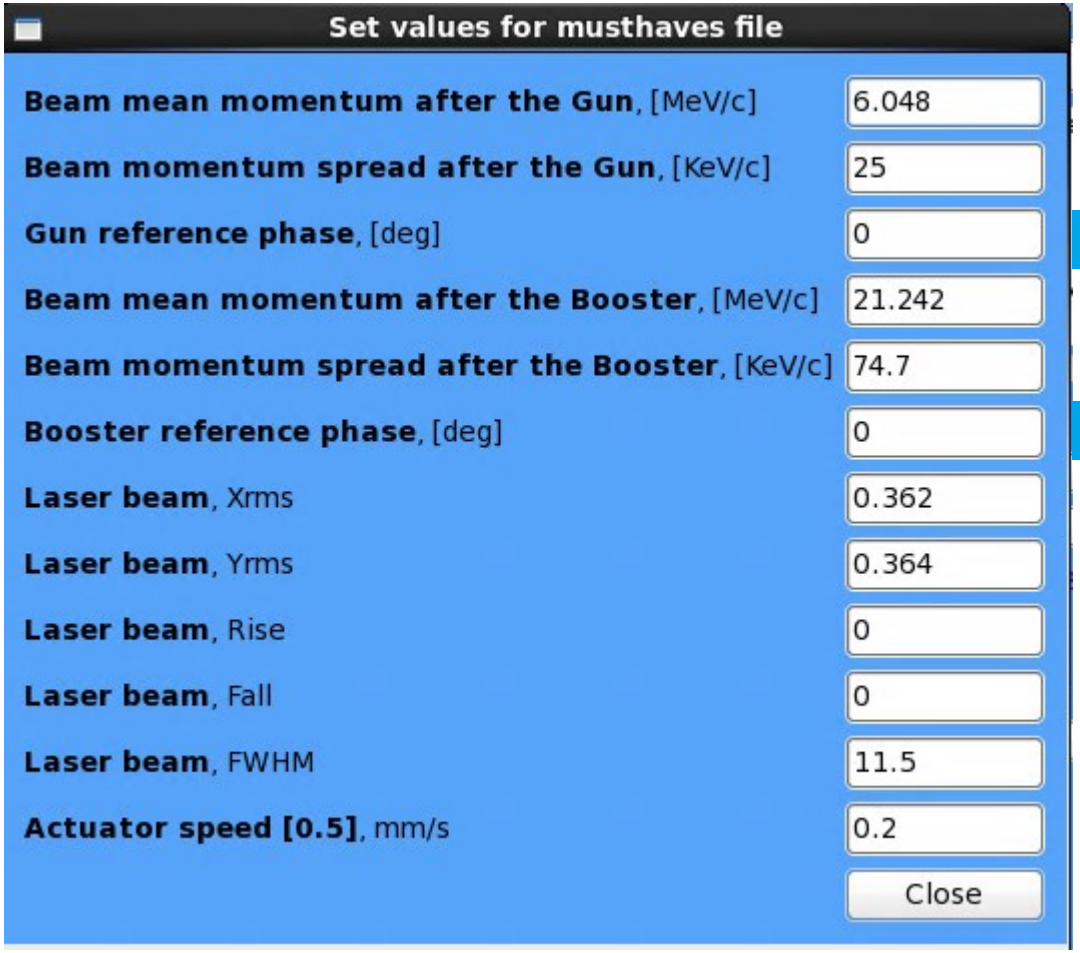
FastScan: Scan button



FastScan: Options VS3 (video system 3)



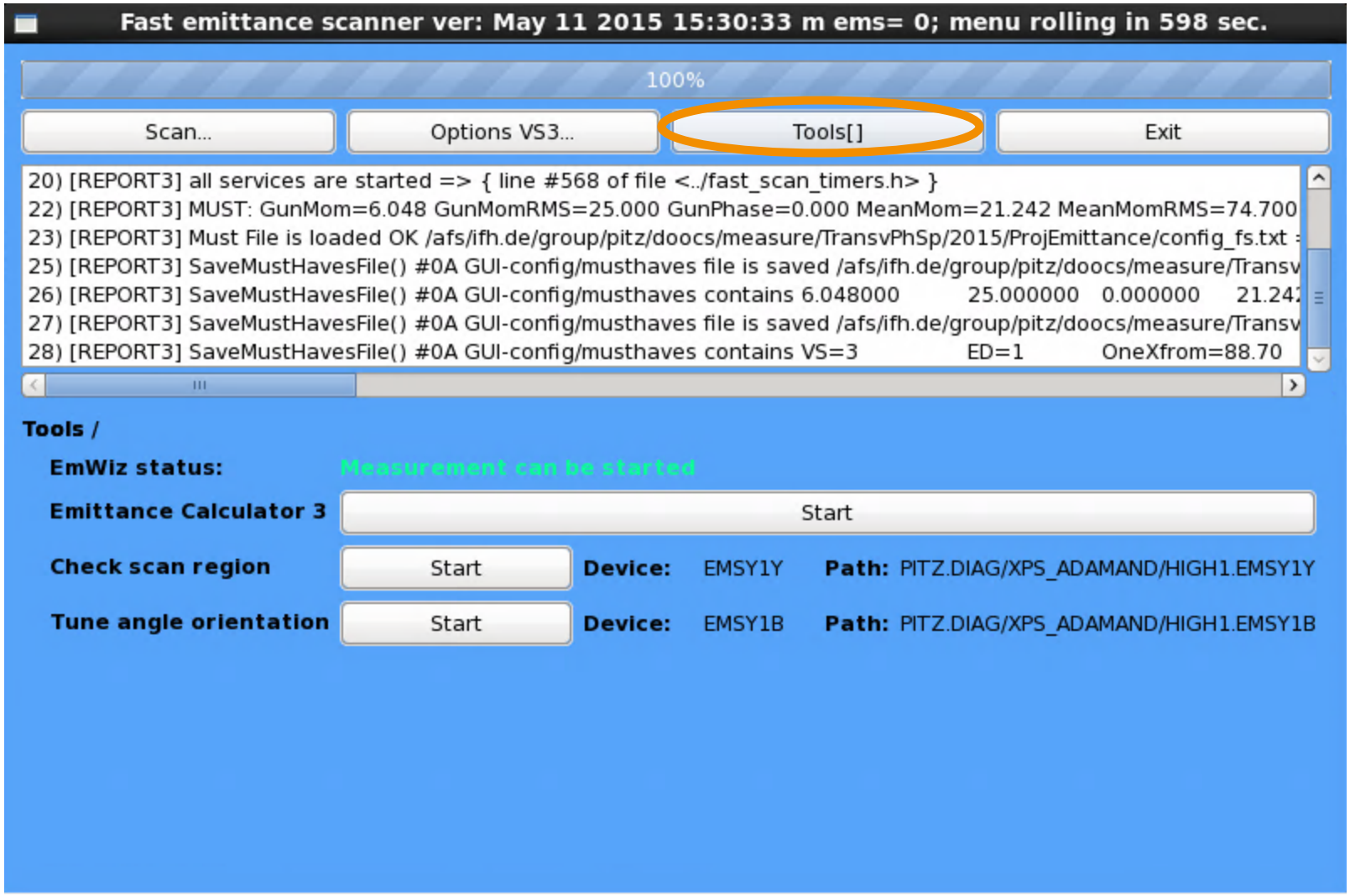
FastScan: Options VS3 ➔ Open…



Gun phase w.r.t. MMMG phase

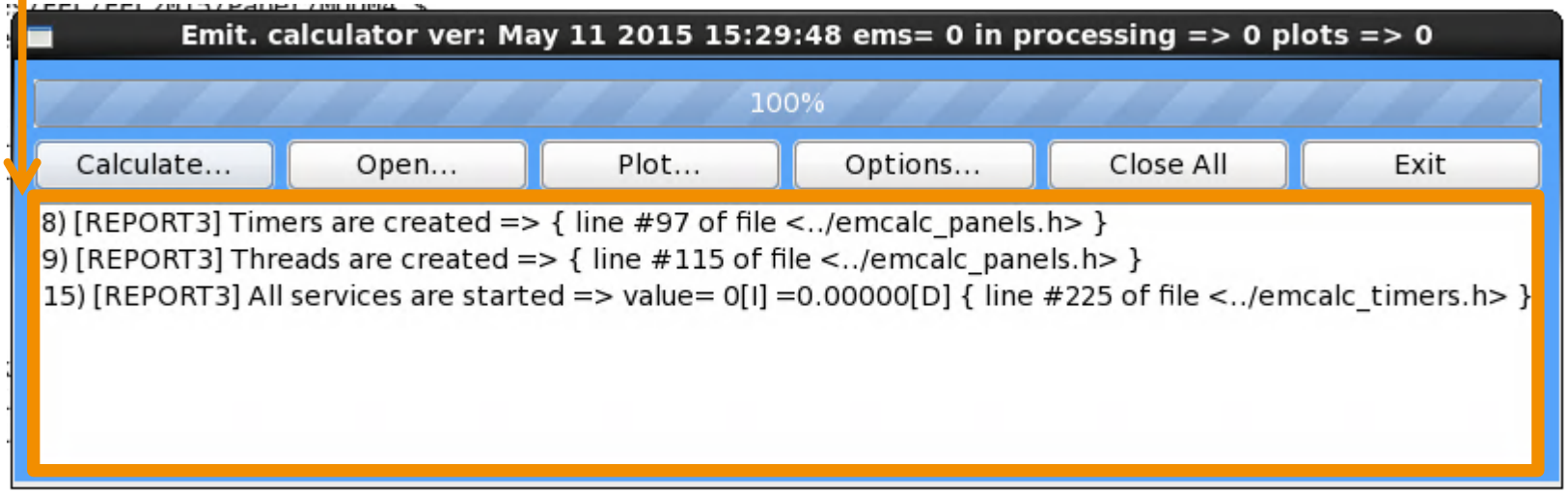
Booster phase w.r.t. MMMG phase

FastScan: Tools

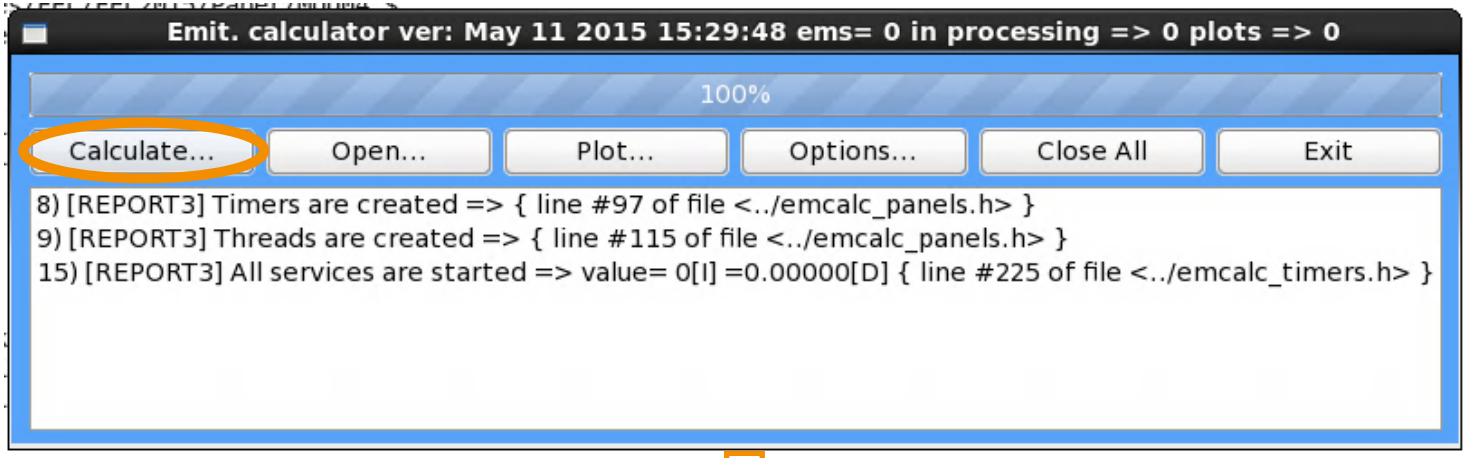


EmCalc startup

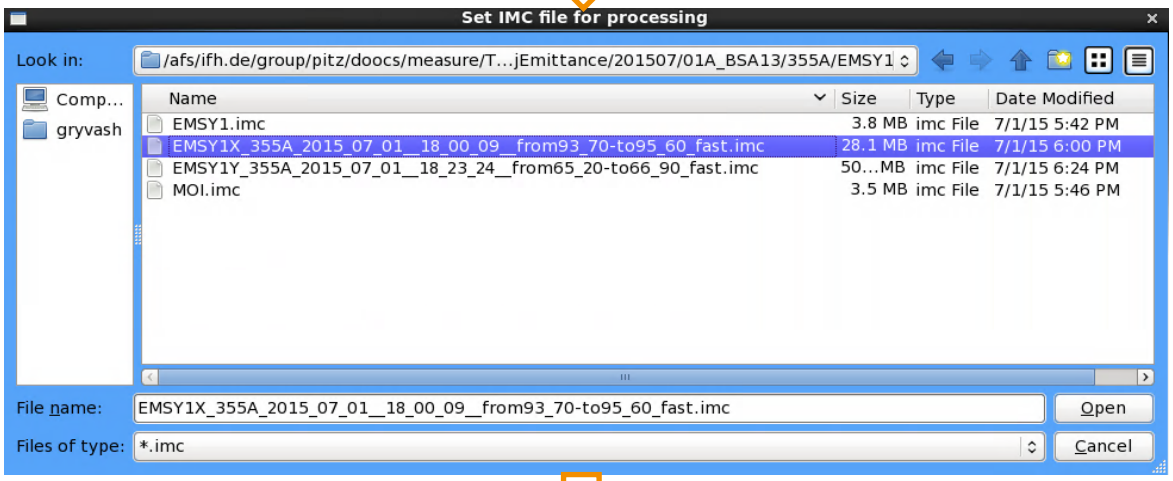
Reports, warnings and errors display area



EmCalc: Calculate



Choose a scan file for analysis

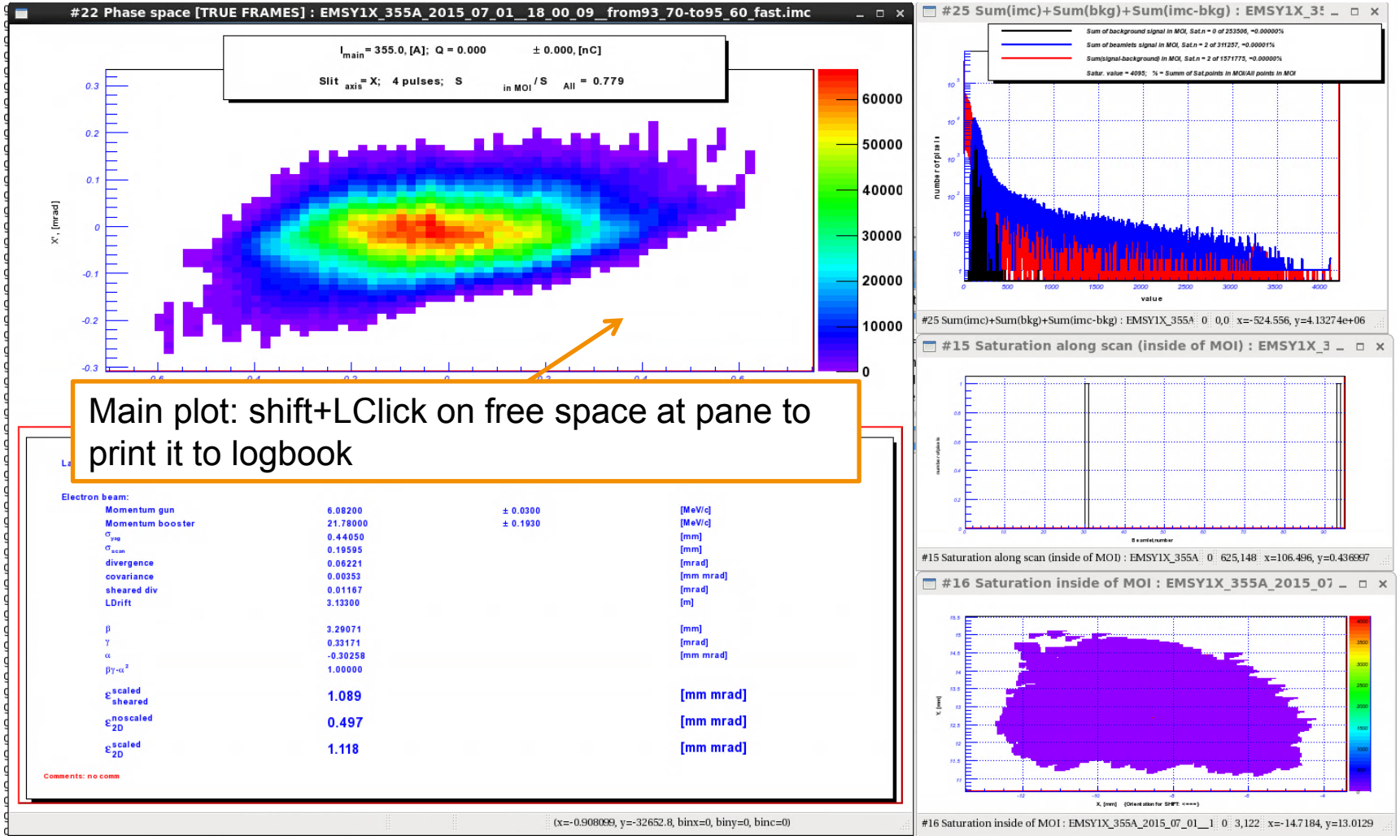


EmCalc: Calculate

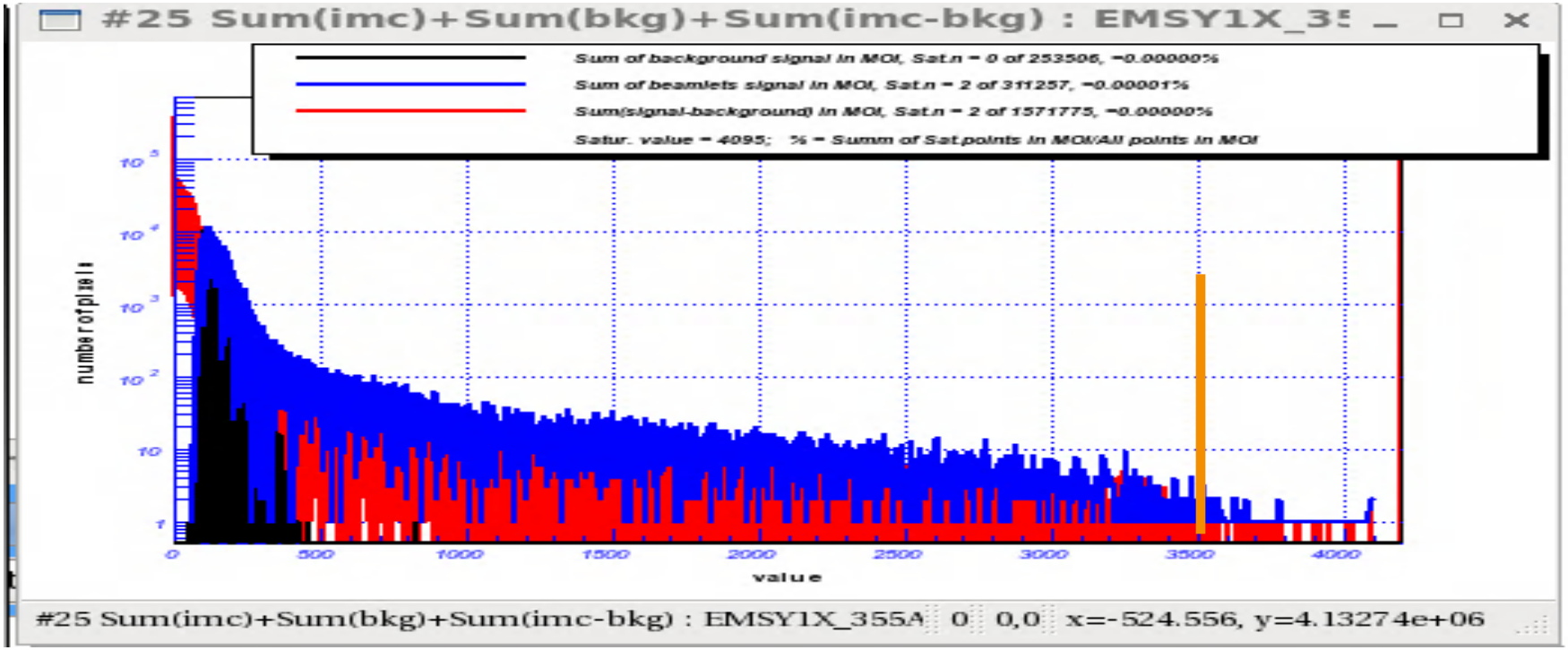
For the data which was already processed the “beam.log” file containing information about: calculated beam size at EMSY, beam momentum after the gun, beam momentum after the booster etc. is already exist. It can be necessary to refresh this file in some cases, for example if the filter settings for EMSY image processing were changed.

EmCalc: Calculate => resulted plots

Three plot are displayed if default settings are used:



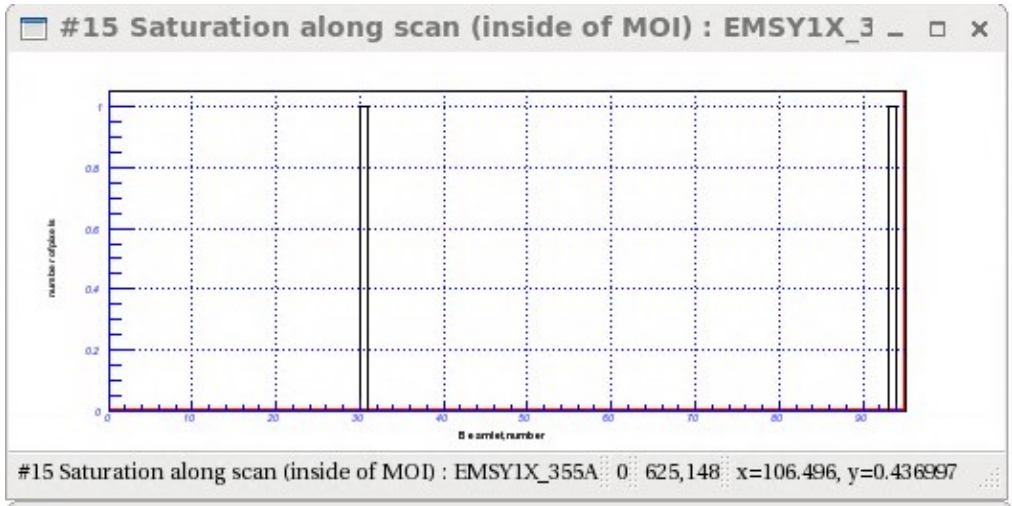
EmCalc: Calculate => resulted plots

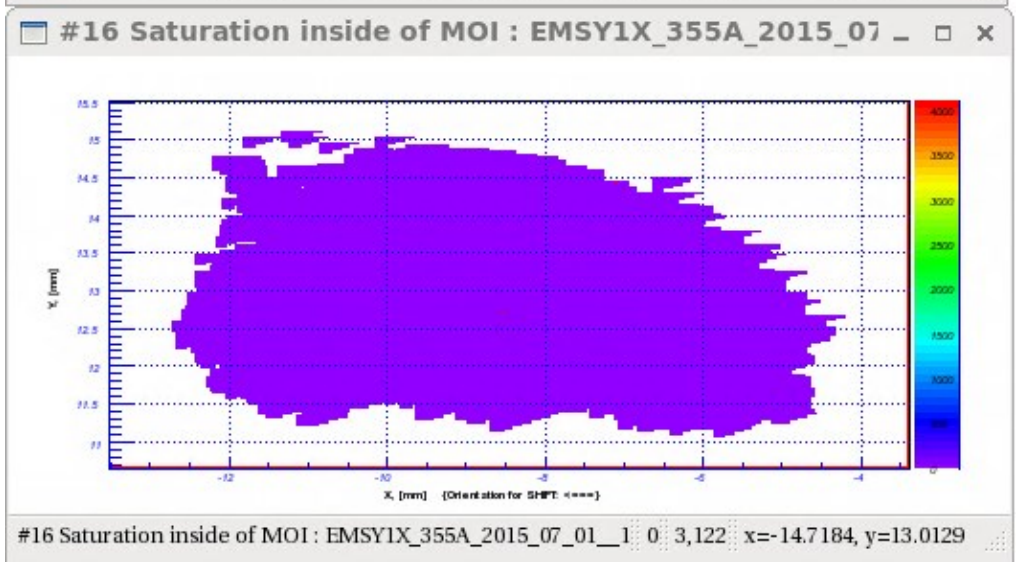


Signal distribution plot, in MOI only:
Black: Distribution of pixel values for background images (averaged)
Blue: Distribution of pixel values for signal images (averaged)
Red: Distribution of pixel values for signal-background images (averaged)

To have a good signal to noise ratio one has to use full dynamic range of the camera. Often it is hard to fulfill this condition but signal spectrum should at least reach value of 3500.

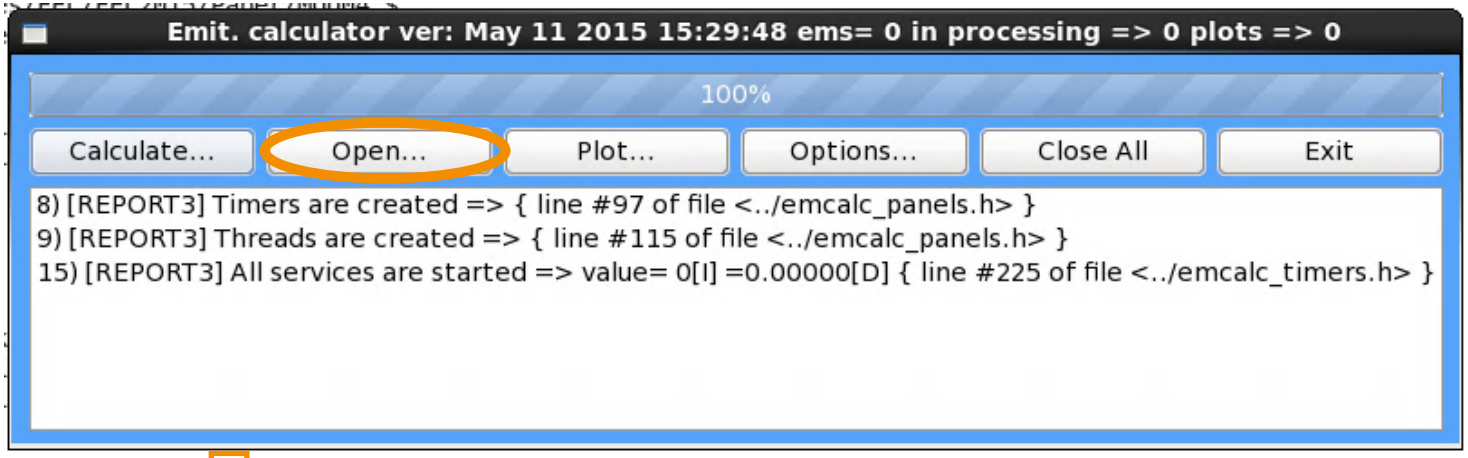
EmCalc: Calculate => resulted plots



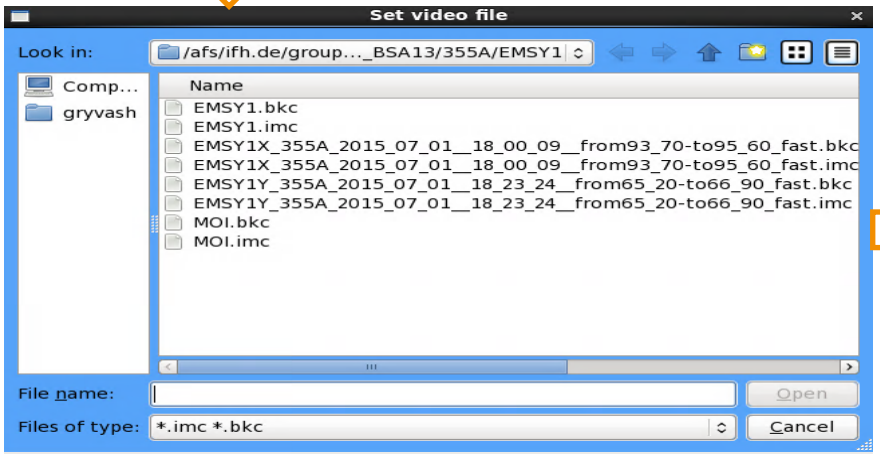


2D and 1D plot for saturated pixels (red dots in 2D) inside the MOI. Normally amount of saturated pixels shouldn't exceed 10-20. Exceptions: hot spots on YAG screen.

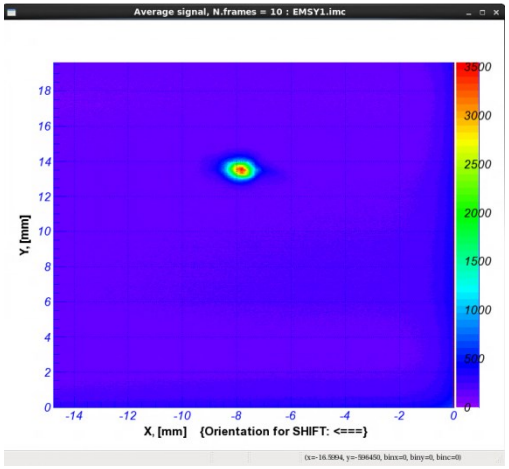
EmCalc: Open



Choose an *.imc or *.bkc

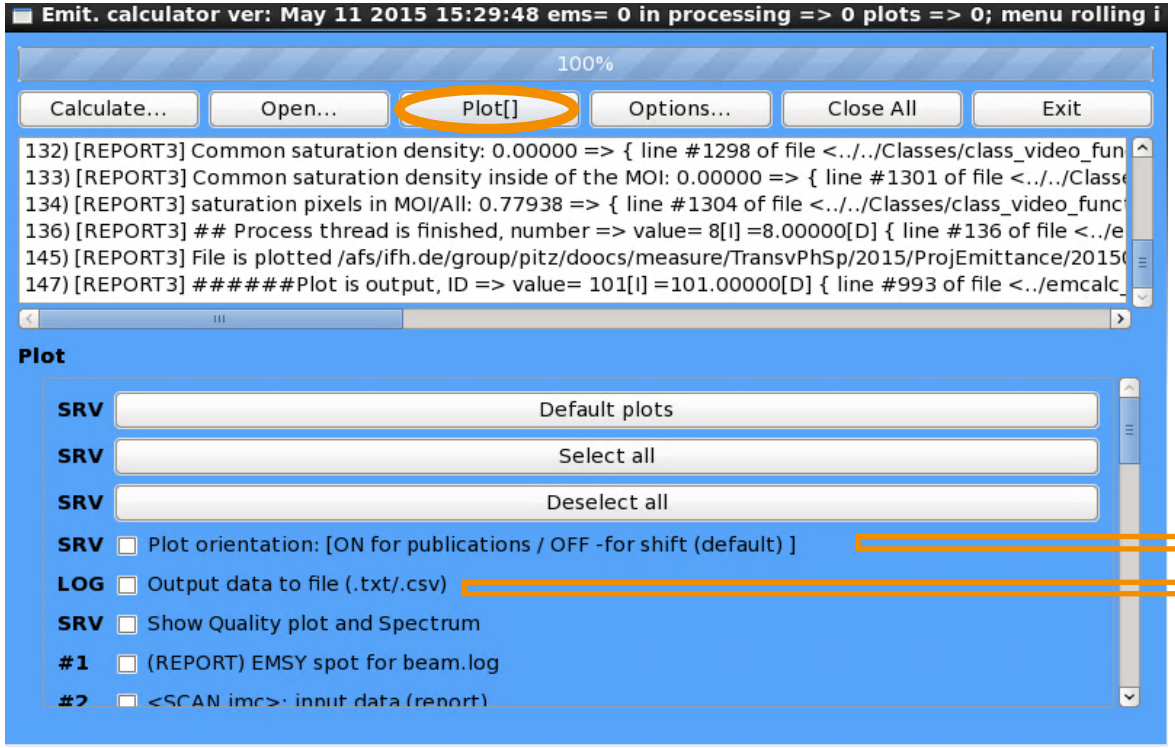


Raw data averaged over amount of frames



EmCalc: Plot

Output and plot settings

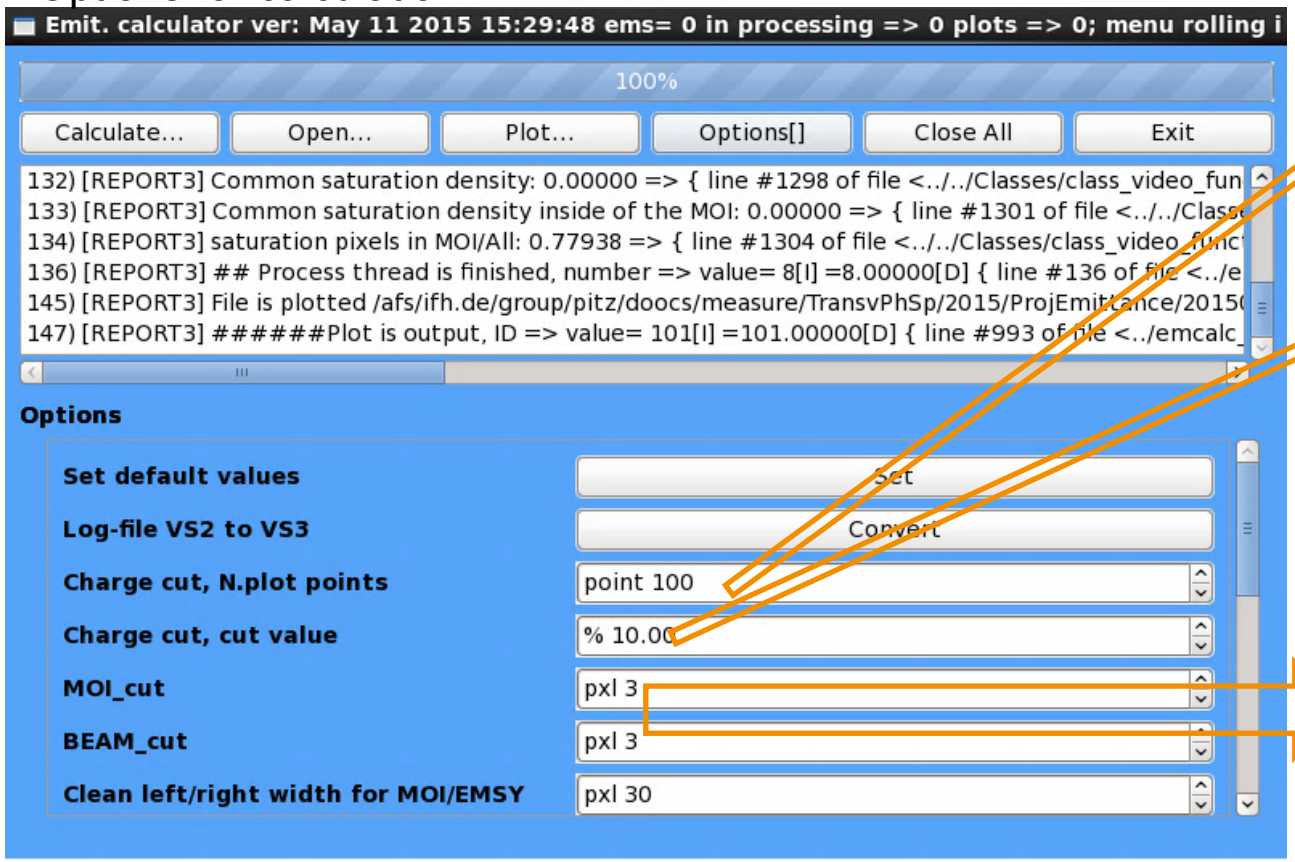


X axis direction

Save data from output plots to ASCII format: /doocs/measure/TransvPhSp/"year"/ProjEmittance/reports/"CurrentDateTime"

EmCalc: Options

Options for calculation

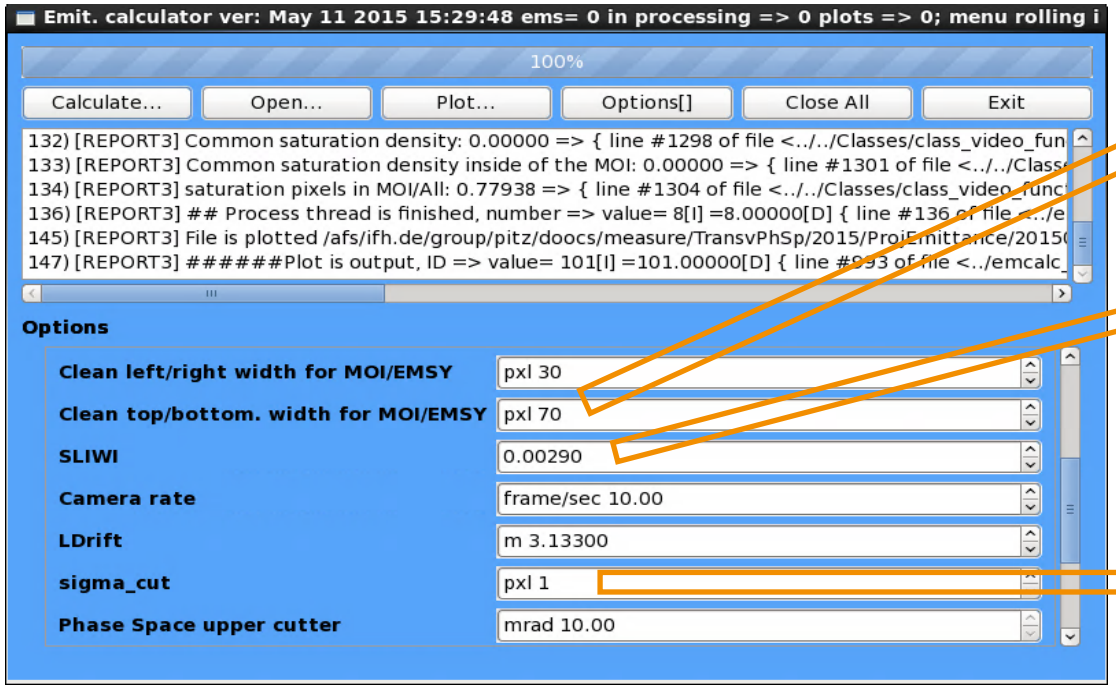


Amount of intervals for 1D emittance with charge cut applied (shown if choosen in “Plot…”)

2D phase space with charge cut of N% (shown if choosen in “Plot…”)

Amount of points for “neighbors filter”

EmCalc: Options

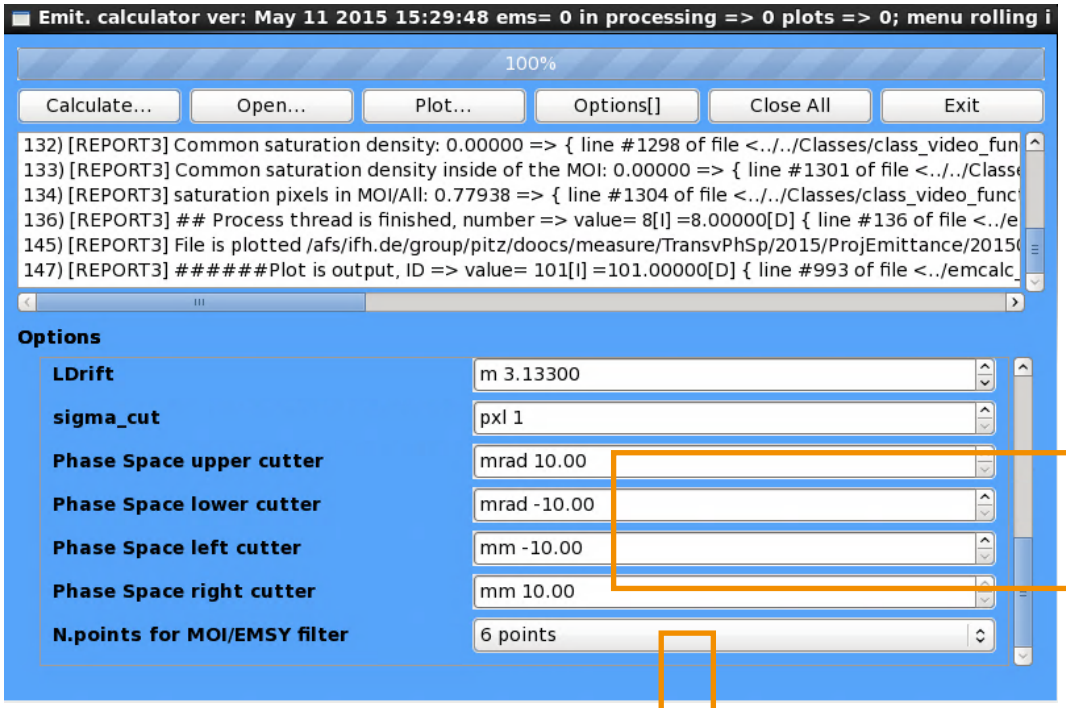


Width in pixels from all sides values of which will be put to 0.

Correction for slit width, applicable only for sheared emittance calculation ➔ out of interest

Parameter for sigma filter ➔ strength of the filter

EmCalc: Options



Same as for EMSY/MOI

Parameter for “recover” filter ➔ strength of the filter

Emittance measurement flow

Musthaves, all raw data has to be saved:

- Laser transverse profile from VC2 camera => must be saved! Not only printed to logbook.
- Laser temporal profile from OSS
- Rough adjustment of laser transmission at roughly MMMG gun phase to the desired charge value.
- Beam momentum scan using LEDA.
- Fine charge adjustment at MMMG phase found.
- Beam momentum scan using HEDA1.
- Fill musthaves for FastScan (slide 7)
- Roughly define the solenoid scan range: 6-8 A above the focus, 2-4 A below the focus a EMSY.
- Prepare Microsoft excel template to fill the data
- Take EMSY pictures using FastScan for all solenoid currents (Hint: start from highest solenoid current)
- Take MOI pictures using FastScan for all solenoid currents (Hint: start from lowest solenoid current)
- Start emittance measurement for X plane (Hint: start from highest solenoid current):
  - Find the central (roughly) beamlet and optimize the alpha EMSY angle (slide 8)
  - Do emittance measurements for each solenoid current
- Start emittance measurement for Y plane (Hint: start from highest solenoid current):
  - Find the central (roughly) beamlet and optimize the beta EMSY angle (slide 8)
  - Do emittance measurements for each solenoid current
- Do statistical emittance measurements for the solenoid current delivering the best emittance:
  - Repeat 3 times:
    1. 1xEMSY, 1xMOI, 3xEmittance for X plane
    2. 3xEmittance for Y plane

Detailed emittance measurement procedure

Very very detailed emittance measurement procedure (courtesy M. Groß) can be found here. It also includes a details of preparation procedures like LEDA, HEDA measurements etc.

https://pitz.desy.de/pitz_intern/emittance/