

# Emittance measurement tools: EmWiz suite.

Introduction to EmWiz suite

FastScan

EmCalc

Memory watcher

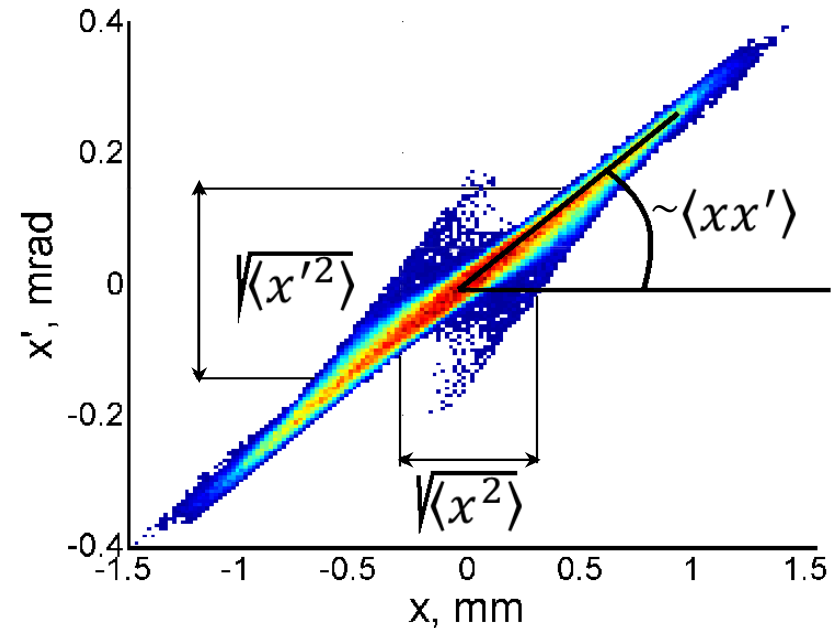
Grygorii Vashchenko  
PITZ annual teaching  
Zeuthen, 14.01.2016

- 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:

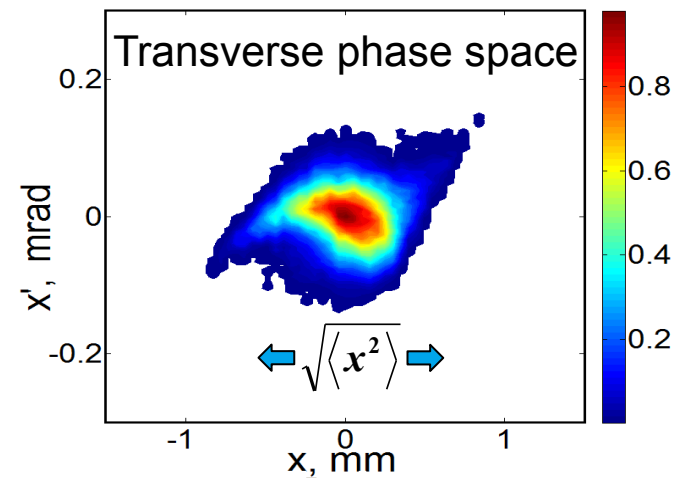
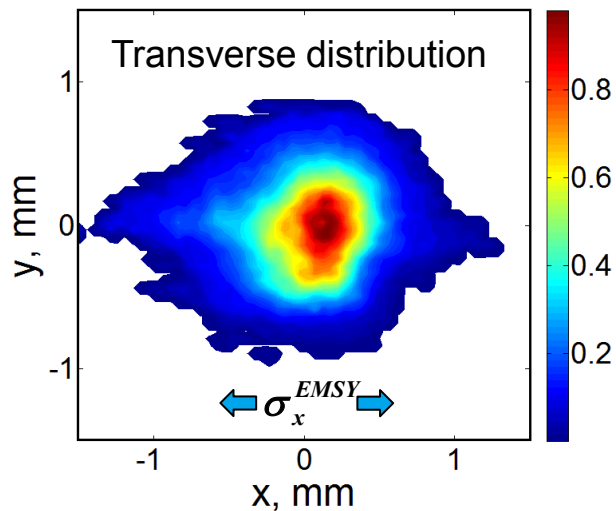
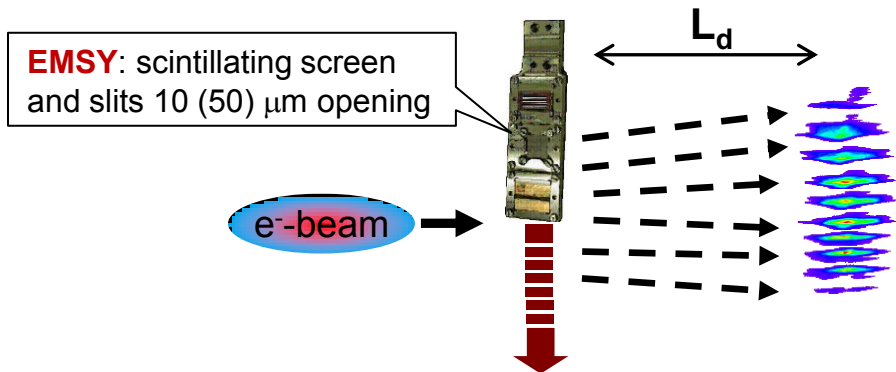
$$\varepsilon_{n,x} = \beta\gamma\sqrt{\langle x^2 \rangle \langle x'^2 \rangle - \langle xx' \rangle^2}$$
$$\beta = \frac{v}{c}, \gamma = \frac{1}{\sqrt{1 - \beta^2}}$$

- Normalized transverse rms emittance for both planes:

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



# Emittance measurements method and procedure



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

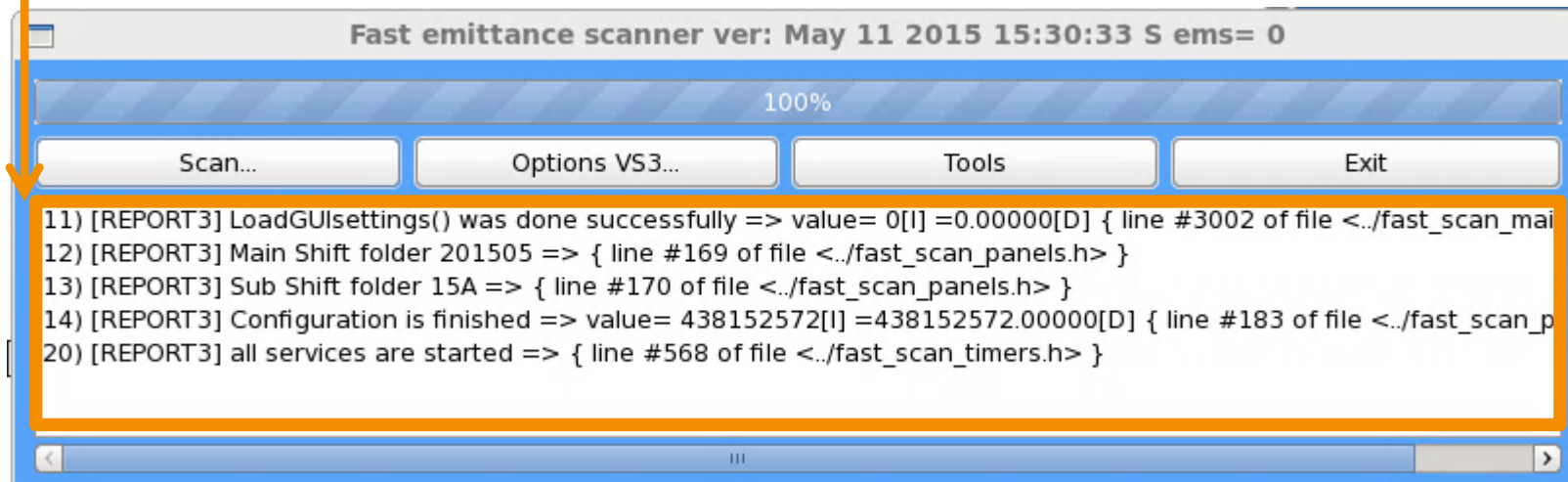
**Scaling factor** is introduced to correct for low intensity losses from beamlet measurements

## 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.



## Reports, warnings and errors display area



# FastScan: Scan button

Fast emittance scanner ver: May 11 2015 15:30:33 M ems= 0; menu rolling in 594 sec.

100%

Scan[] Options VS3... Tools... Exit

11) [REPORT3] LoadGUIsettings() was done successfully => value= 0[I] =0.00000[D] { line #3002 of file <../fast\_scan\_main.h> }  
12) [REPORT3] Main Shift folder 201505 => { line #169 of file <../fast\_scan\_panels.h> }  
13) [REPORT3] Sub Shift folder 15A => { line #170 of file <../fast\_scan\_panels.h> }  
14) [REPORT3] Configuration is finished => value= 438152572[I] =438152572.00000[D] { line #183 of file <../fast\_scan\_panels.h> }  
20) [REPORT3] all services are started => { line #568 of file <../fast\_scan\_timers.h> }

Scan \

**Program status:** Must-Have-File is not filled **Status line**

**Active process:** Fast scan, EMSY and MOI... **Progress bar** 100%

**System status (0 => OK):** last API = 0, TINE = 0, **API errors** Shutter is CLOSED **Shutter status**

**Grabbing** Fast scan, EMSY and MOI... Interrupt all processes

**Output path** ...ance/201505/15ABSA2\_Doff\_sta Open Get new shift Get old shift

**EMSY/Axis : EMSY path** EMSY1X : PITZ.DIAG/XPS\_ADAMAND/HIGH1.EMSY1X

**Server(name) => Camera(name)** 3 => **Server** (FG65.Prosilica), **Camera** (High1.Scr4 (Bin2x2))

**Actuator linear speed** 20.000 mm/sec **Act.lin.pos** 41.000 mm **From** 88.20 mm => **To** 90.40 mm

**Actuator rotatory speed** 2.000 mrad/sec **Act.rot.pos** 0.610 mrad **From** -1.63 mrad => **T** 1.35 mrad

**Information** News about this program version. Look ToolTip.

# FastScan: Scan button

Fast emittance scanner ver: May 11 2015 15:30:33 M ems= 0; menu rolling in 594 sec.

100%

Scan[] Options VS3... Tools... Exit

11) [REPORT3] LoadGUIsettings() was done successfully => value= 0[I] =0.00000[D] { line #3002 of file <../fast\_scan\_main.h> }  
12) [REPORT3] Main Shift folder 201505 => { line #169 of file <../fast\_scan\_panels.h> }  
13) [REPORT3] Sub Shift folder 15A => { line #170 of file <../fast\_scan\_panels.h> }  
14) [REPORT3] Configuration is finished => value= 438152572[I] =438152572.00000[D] { line #183 of file <../fast\_scan\_panels.h> }  
20) [REPORT3] all services are started => { line #568 of file <../fast\_scan\_timers.h> }

Scan \

**Program status:** Must-Have-File is not filled **Inactive on start**

**Active process:** No active process 100%

**System status (0 => OK):** last API = 0, TINE = 0, Shutter is CLOSED

**Grabbing** Fast scan, EMSY and MOI... Interrupt all processes

**Output path** ...ance/201505/15ABSA2\_Doff\_sta Open Get new shift Get old shift

**EMSY/Axis : EMSY path** EMSY1X : PITZ.DIAG/XPS\_ADAMAND/HIG

**Server(name) => Camera(name)** 3 => Server (FG6S.Prosilica), Camera (High1.Sc

**Actuator linear speed** 20.000 mm/sec **Act.lin.pos** 41.000 mm **From** 88.20 mm => To 90.40 mm

**Actuator rotatory speed** 2.000 mrad/sec **Act.rot.pos** 0.610 mrad **From** -1.63 mrad => To

**Information** News about this program version. Look ToolTip.

**Actuator DOOCS address**

**Camera**

**Scan parameters**



# FastScan: Options VS3 (video system 3)

Fast emittance scanner ver: May 11 2015 15:30:33 M ems= 0; menu rolling in 593 sec.

100%

Scan... Options VS3[] Tools... Exit

```
11) [REPORT3] LoadGUIsettings() was done successfully => value= 0[I] =0.00000[D] { line #3002 of file <../fast_scan_main.h> }
12) [REPORT3] Main Shift folder 201505 => { line #169 of file <../fast_scan_panels.h> }
13) [REPORT3] Sub Shift folder 16M => { line #170 of file <../fast_scan_panels.h> }
14) [REPORT3] Configuration is finished => value= 464749050[I] =464749050.00000[D] { line #183 of file <../fast_scan_panels.h> }
20) [REPORT3] all services are started => { line #568 of file <../fast_scan_timers.h> }
```

**Options VS3**

**Control mode** manual mode **Manual actuator control, automatic is not implemented**

**EMSY device** EMSY1Y **Actuator to control**

**Video server** #3 => **FG6S.Prosilica => Camera: High1.Scr4 (Bin2x2), ID = 122, Fr.rate = 10.00** **Camera selector**

**Scan from** mm 65.00 => **Scan range** manual mode, selectable by hand

**Scan to** mm 67.20 => manual mode, selectable by hand

**Fill must file** Open... **Musthaves**

**Set own file name**

**Set path addition** => 201505/16M +

**Set custom shift**  /





| Set values for musthaves file                   |                                     |
|---|-------------------------------------|
| Beam mean momentum after the Gun, [MeV/c]       | <input type="text" value="6.048"/>  |
| Beam momentum spread after the Gun, [KeV/c]     | <input type="text" value="25"/>     |
| Gun reference phase, [deg]                      | <input type="text" value="0"/>      |
| Beam mean momentum after the Booster, [MeV/c]   | <input type="text" value="21.242"/> |
| Beam momentum spread after the Booster, [KeV/c] | <input type="text" value="74.7"/>   |
| Booster reference phase, [deg]                  | <input type="text" value="0"/>      |
| Laser beam, Xrms                                | <input type="text" value="0.362"/>  |
| Laser beam, Yrms                                | <input type="text" value="0.364"/>  |
| Laser beam, Rise                                | <input type="text" value="0"/>      |
| Laser beam, Fall                                | <input type="text" value="0"/>      |
| Laser beam, FWHM                                | <input type="text" value="11.5"/>   |
| Actuator speed [0.5], mm/s                      | <input type="text" value="0.2"/>    |
| <input type="button" value="Close"/>            |                                     |

Gun phase w.r.t. MMMG phase

Booster phase w.r.t. MMMG phase

Fast emittance scanner ver: May 11 2015 15:30:33 m ems= 0; menu rolling in 598 sec.

100%

Scan... Options VS3... **Tools[]** Exit

```
20) [REPORT3] all services are started => { line #568 of file <../fast_scan_timers.h> }
22) [REPORT3] MUST: GunMom=6.048 GunMomRMS=25.000 GunPhase=0.000 MeanMom=21.242 MeanMomRMS=74.700
23) [REPORT3] Must File is loaded OK /afs/afh.de/group/pitz/doocs/measure/TransvPhSp/2015/ProjEmittance/config_fs.txt :
25) [REPORT3] SaveMustHavesFile() #0A GUI-config/musthaves file is saved /afs/afh.de/group/pitz/doocs/measure/Transv
26) [REPORT3] SaveMustHavesFile() #0A GUI-config/musthaves contains 6.048000 25.000000 0.000000 21.242
27) [REPORT3] SaveMustHavesFile() #0A GUI-config/musthaves file is saved /afs/afh.de/group/pitz/doocs/measure/Transv
28) [REPORT3] SaveMustHavesFile() #0A GUI-config/musthaves contains VS=3 ED=1 OneXfrom=88.70
```

**Tools /**

**EmWiz status:** Measurement can be started

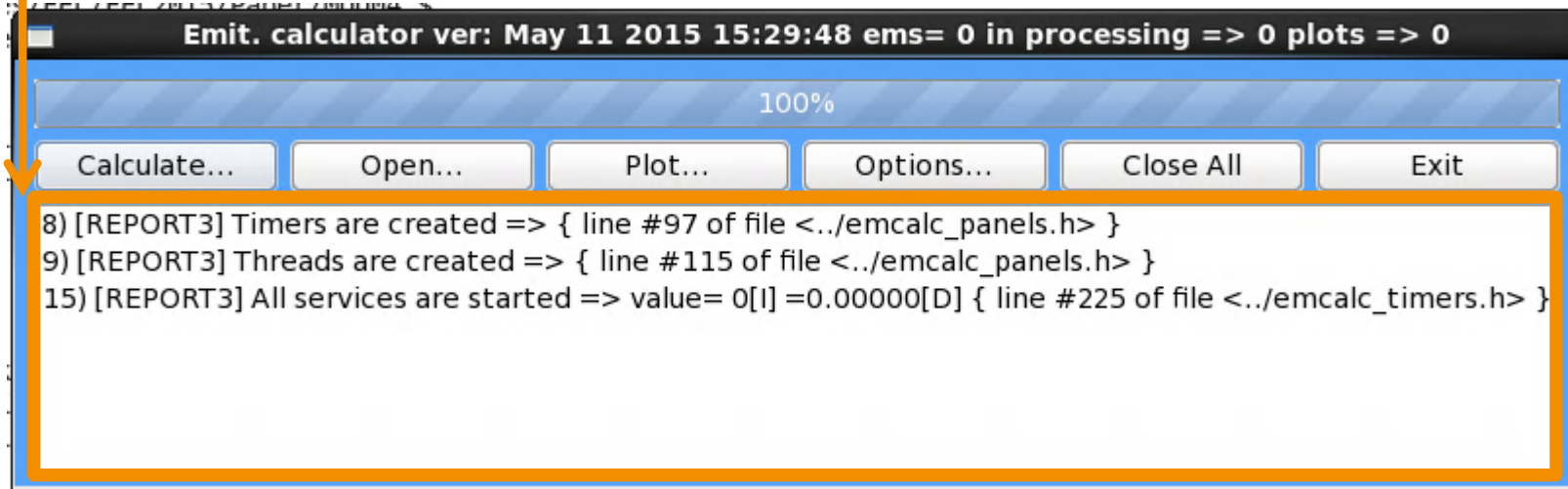
**Emittance Calculator 3**

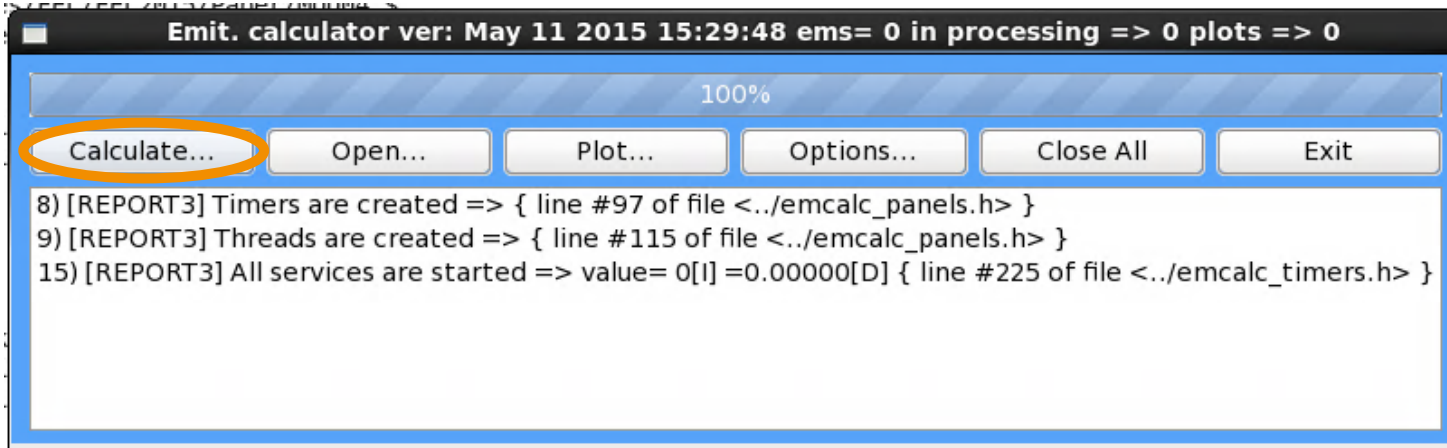
**Check scan region**  **Device:** EMSY1Y **Path:** PITZ.DIAG/XPS\_ADAMAND/HIGH1.EMSY1Y

**Tune angle orientation**  **Device:** EMSY1B **Path:** PITZ.DIAG/XPS\_ADAMAND/HIGH1.EMSY1B

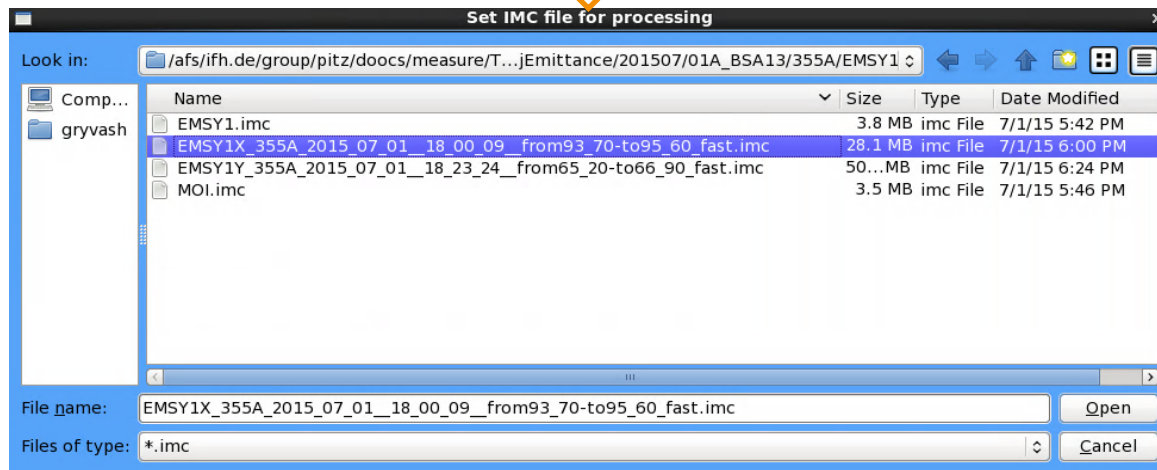


Reports, warnings and errors display area



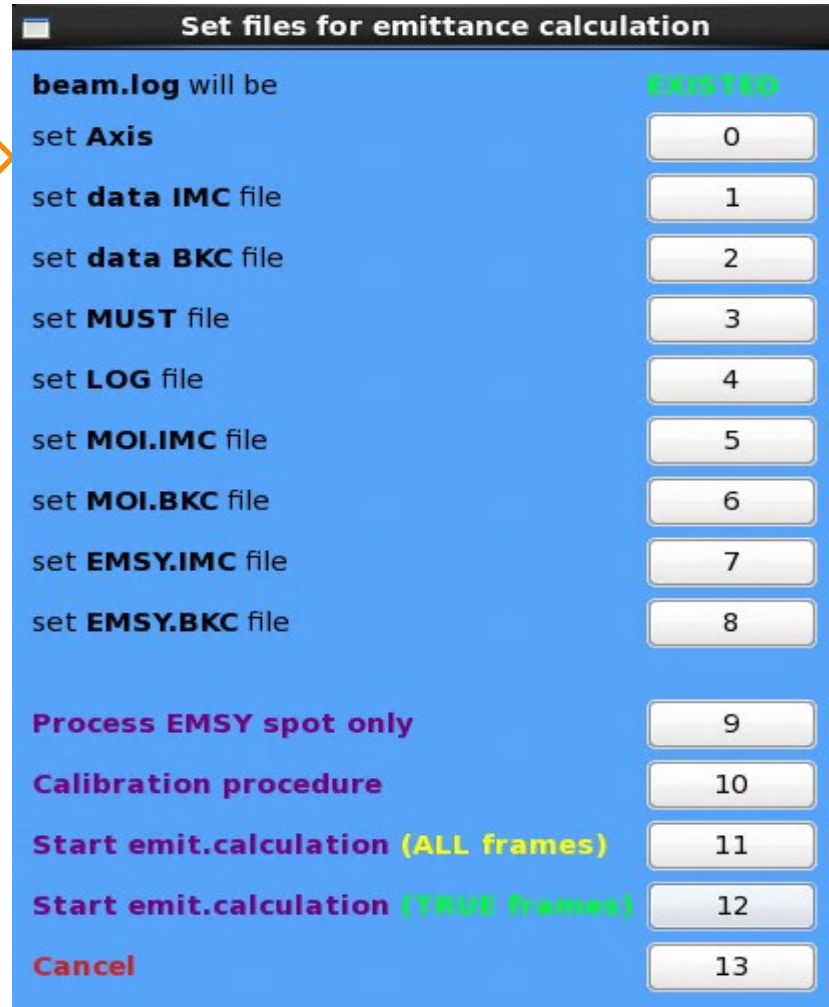


Choose a scan file for analysis



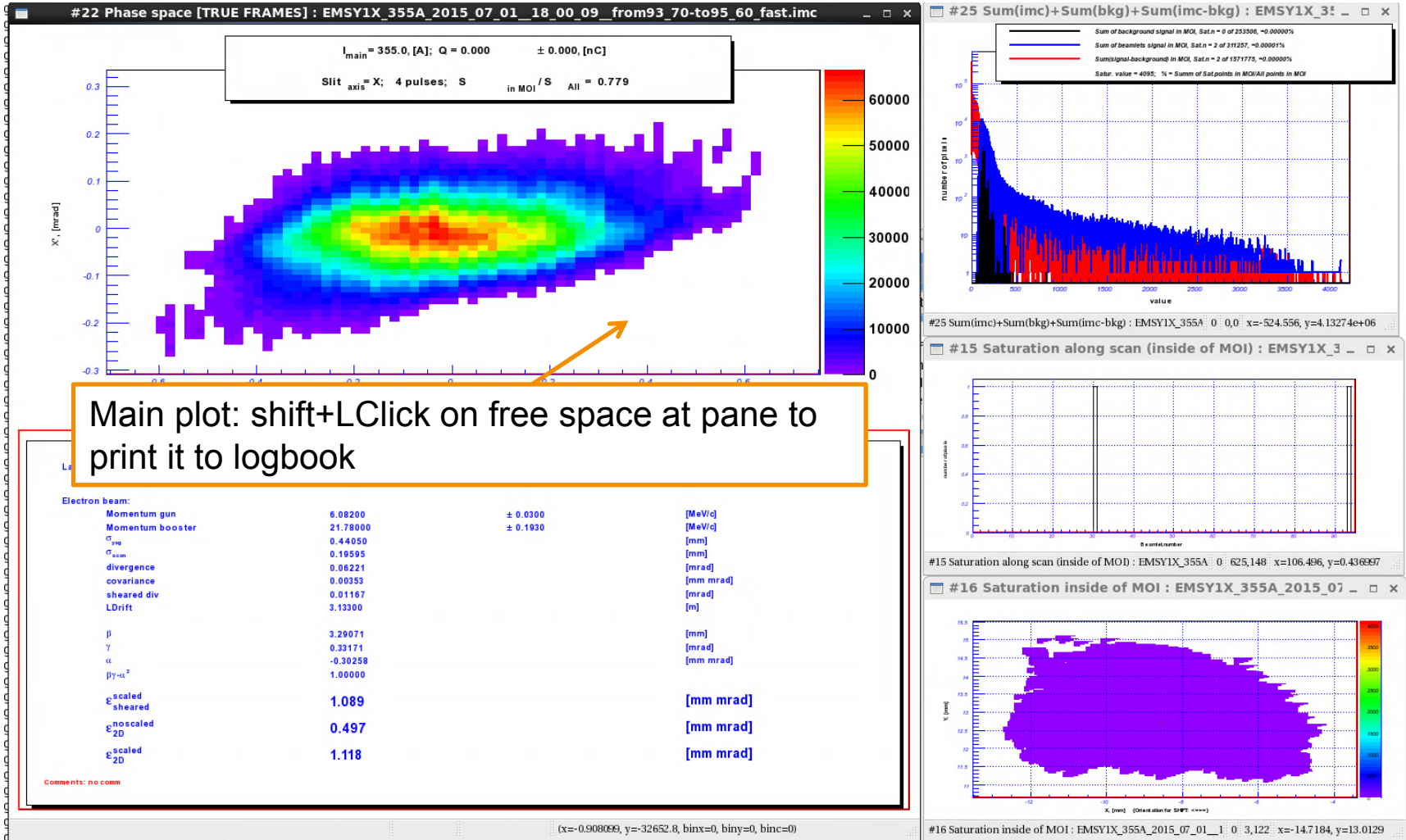


For the data which was already processed the “beam.log” file containing information about: calculated beam size at EMSY, beam momentum after the gun, beam momentum after the booster etc. is already exist. It can be necessary to refresh this file in some cases, for example if the filter settings for EMSY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

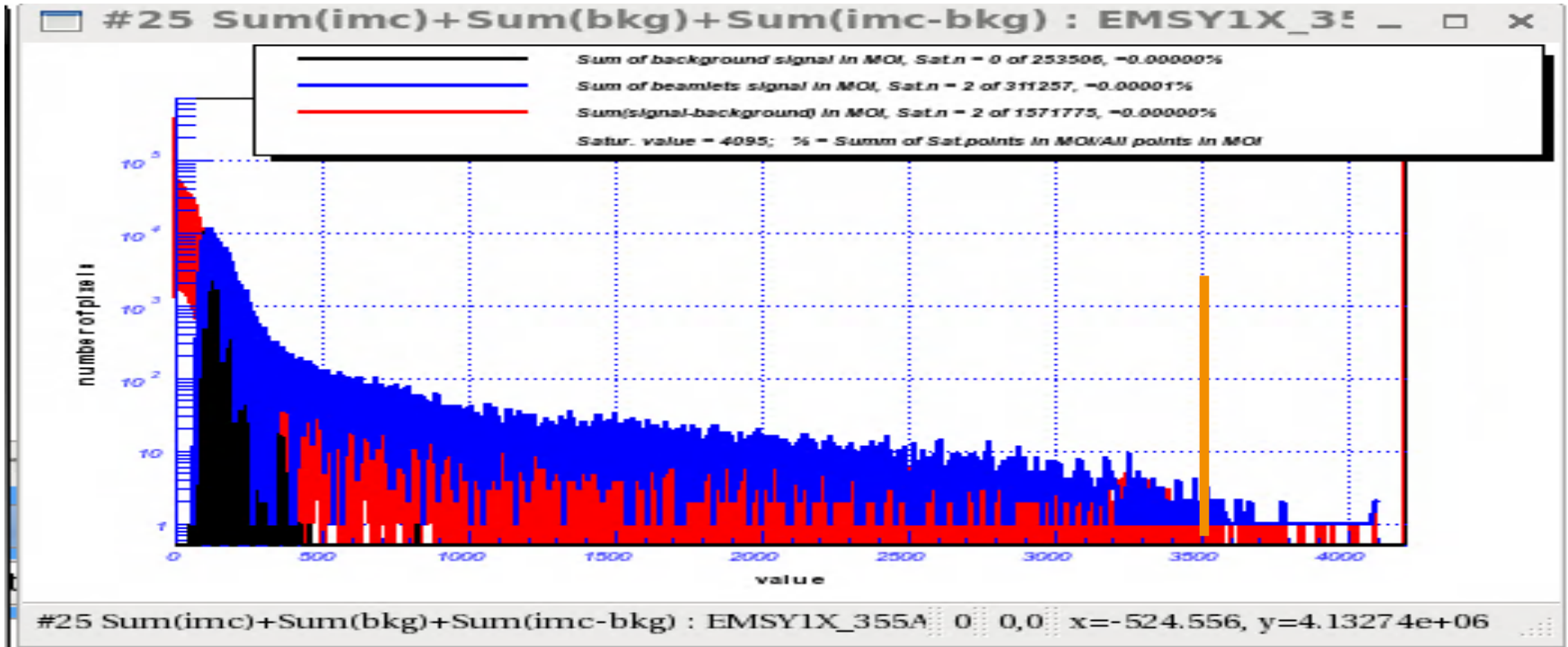


# EmCalc: Calculate => resulted plots

Three plots are displayed if default settings are used:



# EmCalc: Calculate => resulted plots



Signal distribution plot, in MOI only:

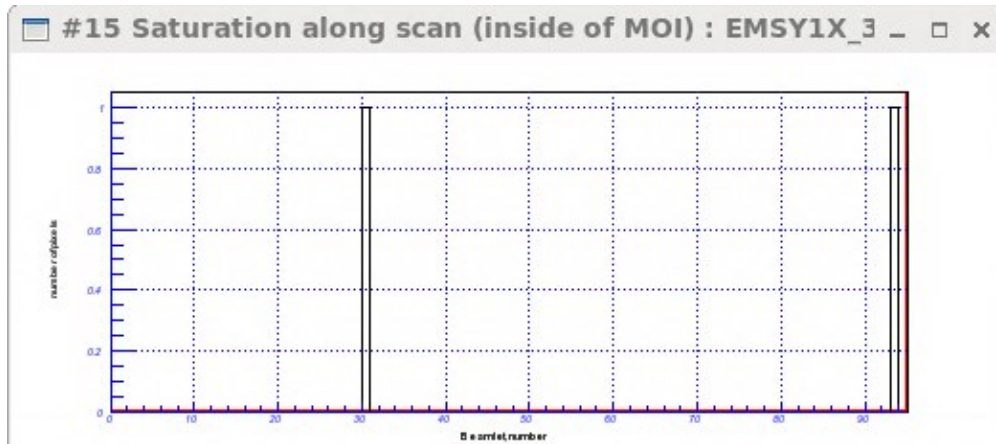
Black: Distribution of pixel values for background images (averaged)

Blue: Distribution of pixel values for signal images (averaged)

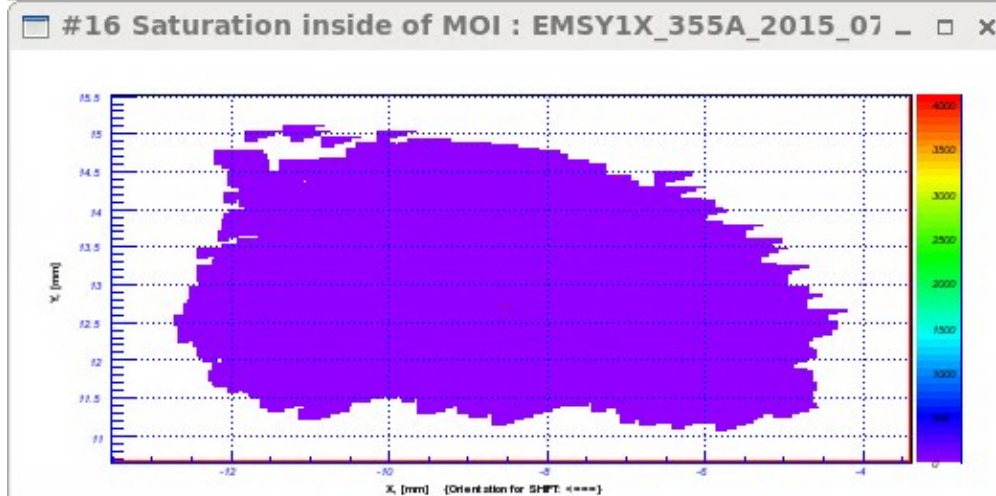
Red: Distribution of pixel values for signal-background images (averaged)

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



#15 Saturation along scan (inside of MOI) : EMSY1X\_355A\_0 625,148 x=106.496, y=0.436997

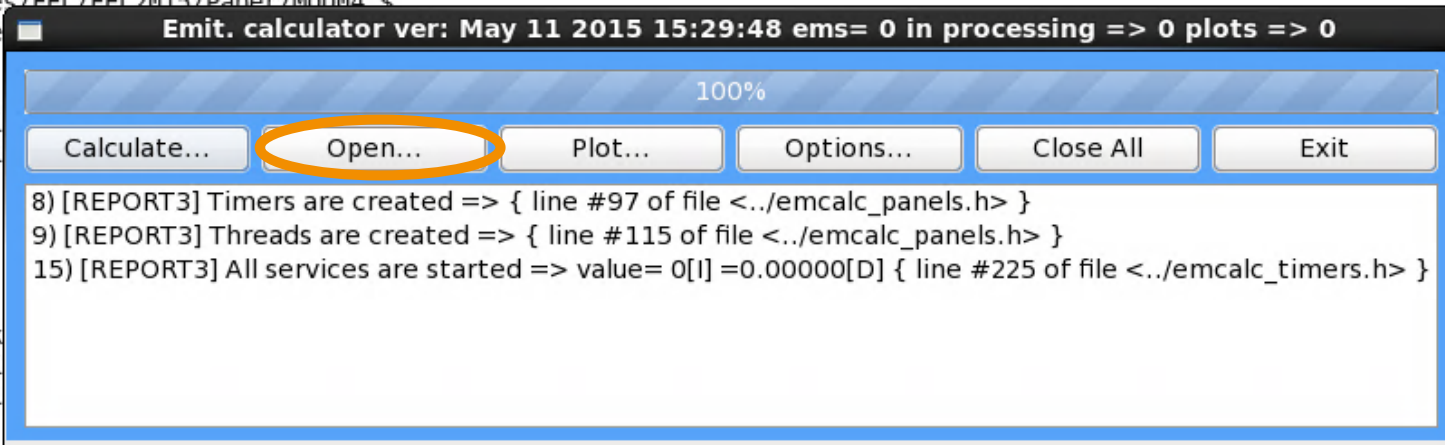


#16 Saturation inside of MOI : EMSY1X\_355A\_2015\_07\_01\_\_1 0 3,122 x=-14.7184, y=13.0129

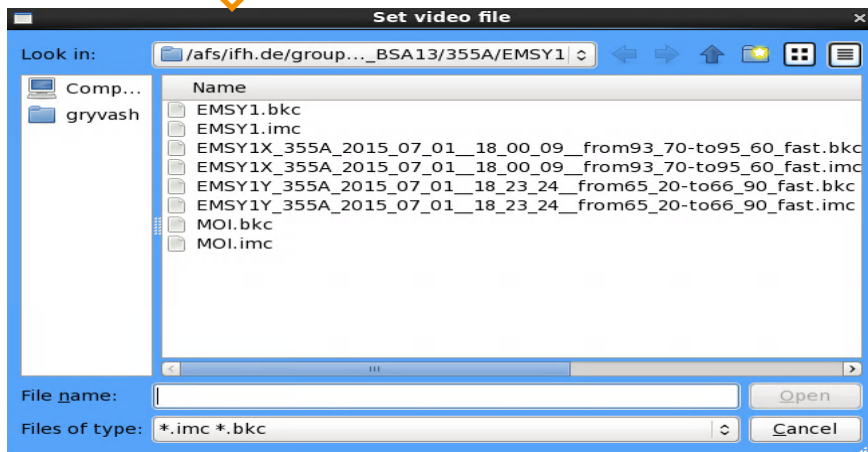
2D and 1D plot for saturated pixels (red dots in 2D) inside the MOI. Normally amount of saturated pixels shouldn't exceed 10-20. Exceptions: hot spots on YAG screen.



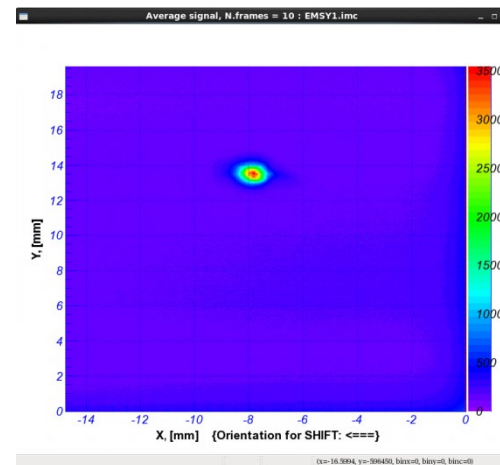
# EmCalc: Open



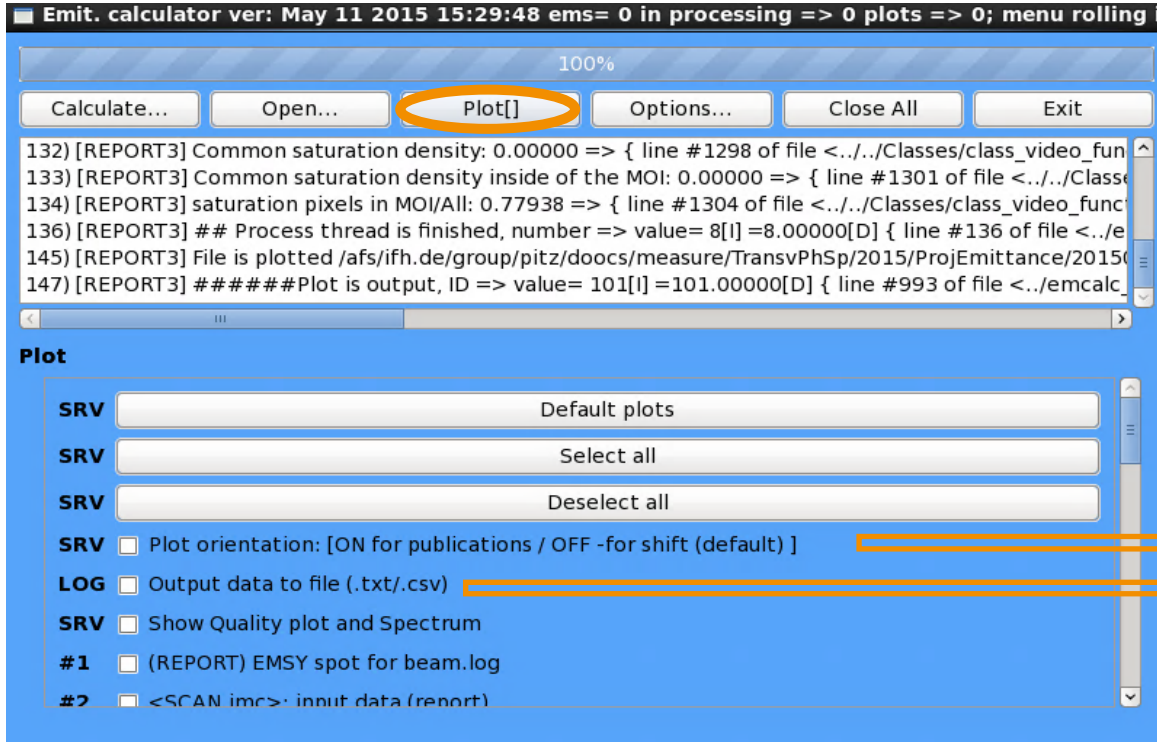
Choose an \*.imc or \*.bkc



Raw data averaged over amount of frames



## Output and plot settings



X axis direction

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

## Options for calculation

132) [REPORT3] Common saturation density: 0.00000 => { line #1298 of file <../Classes/class\_video\_fun  
133) [REPORT3] Common saturation density inside of the MOI: 0.00000 => { line #1301 of file <../Classes  
134) [REPORT3] saturation pixels in MOI/All: 0.77938 => { line #1304 of file <../Classes/class\_video\_func  
136) [REPORT3] ## Process thread is finished, number => value= 8[I]=8.00000[D] { line #136 of file <../e  
145) [REPORT3] File is plotted /afs/ifh.de/group/pitz/doocs/measure/TransvPhSp/2015/ProjEmittance/2015  
147) [REPORT3] #####Plot is output, ID => value= 101[I]=101.00000[D] { line #993 of file <../emcalc\_

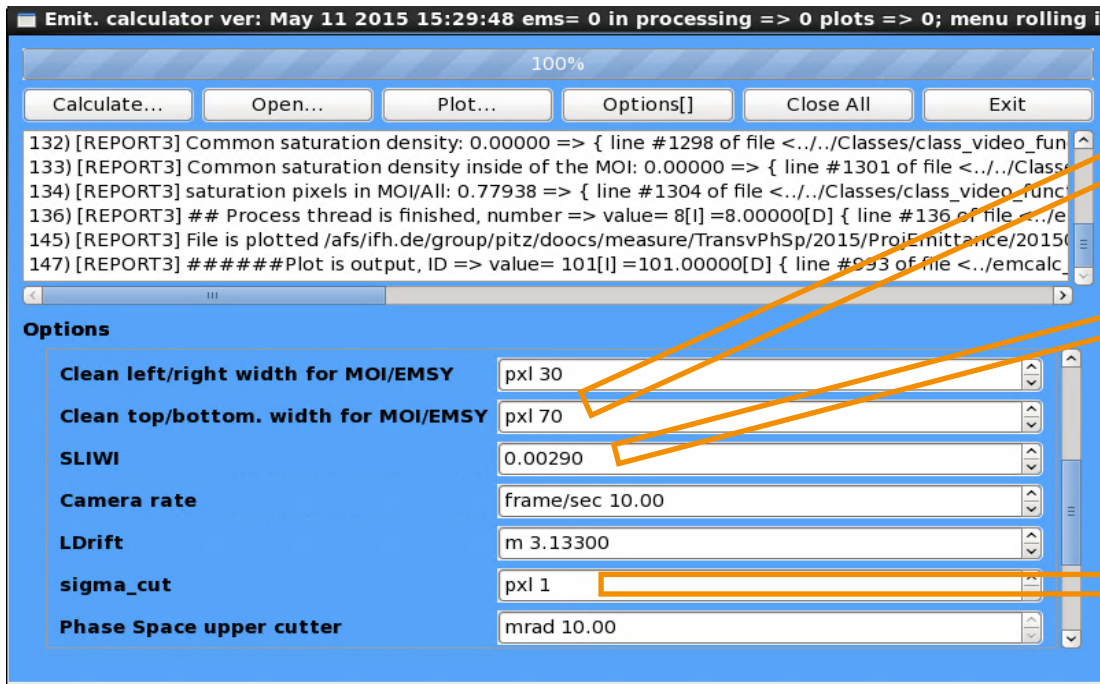
**Options**

|                                     |           |
|-------------------------------------|-----------|
| Set default values                  | Set       |
| Log-file VS2 to VS3                 | Convert   |
| Charge cut, N.plot points           | point 100 |
| Charge cut, cut value               | % 10.00   |
| MOI_cut                             | pxl 3     |
| BEAM_cut                            | pxl 3     |
| Clean left/right width for MOI/EMSY | pxl 30    |

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

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

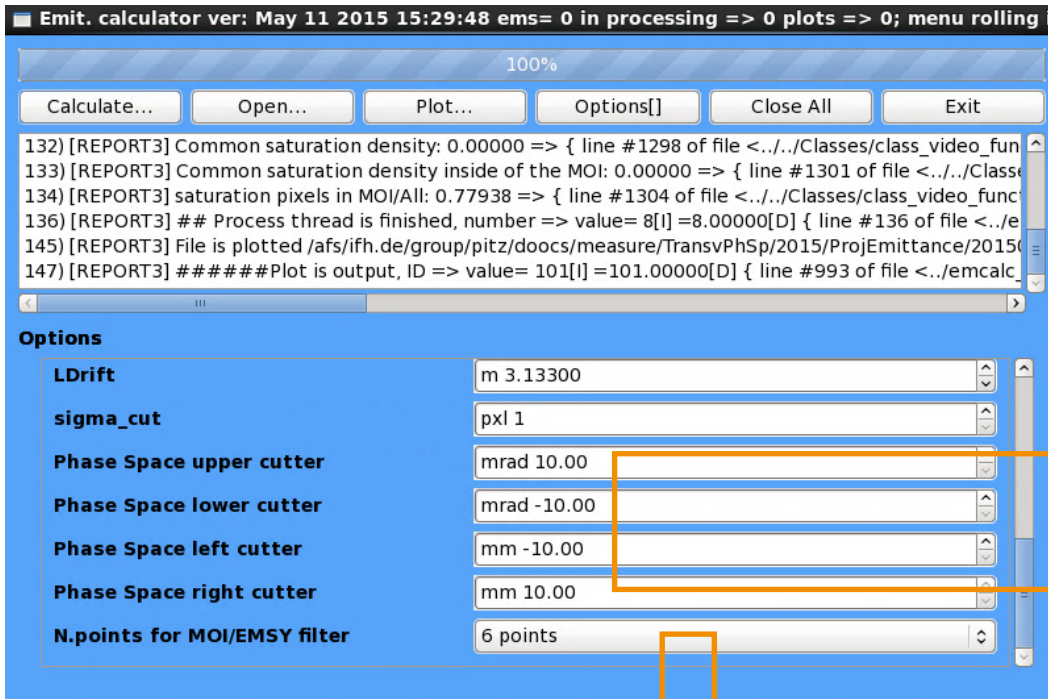
Amount of points for “neighbors filter”



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



Same as for EMSY/MOI

Parameter for “recover” filter → strength of the filter

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

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/](https://pitz.desy.de/pitz_intern/emittance/)