Teaching: Thermal momentum imaging

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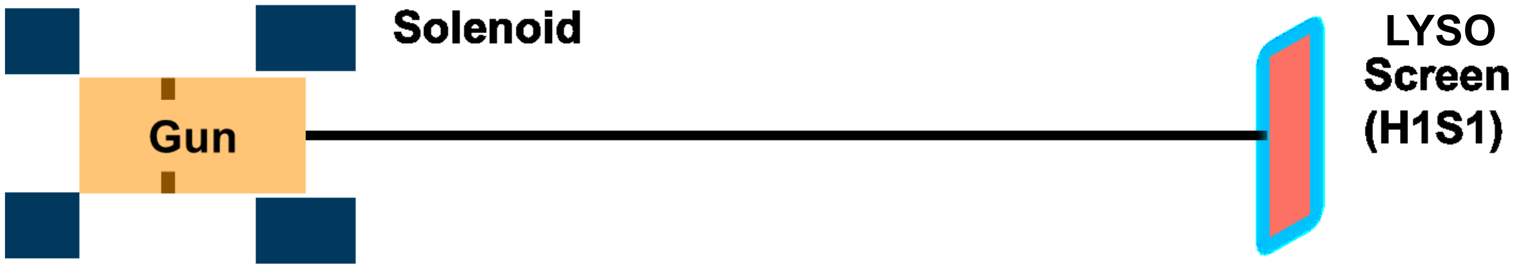
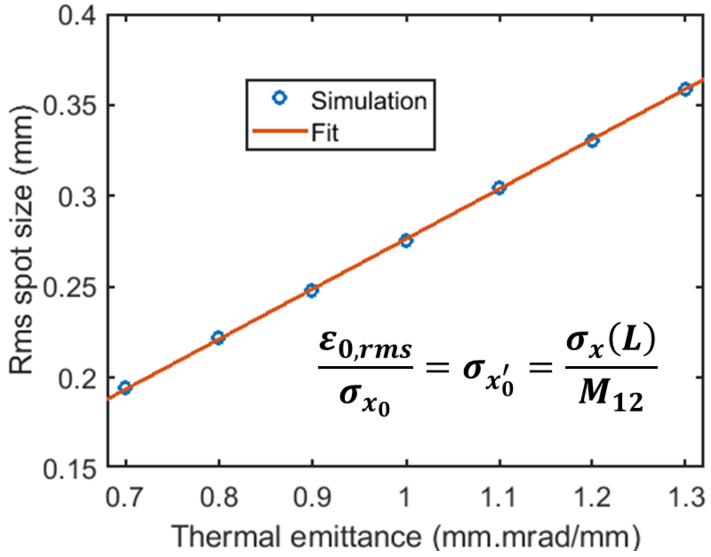
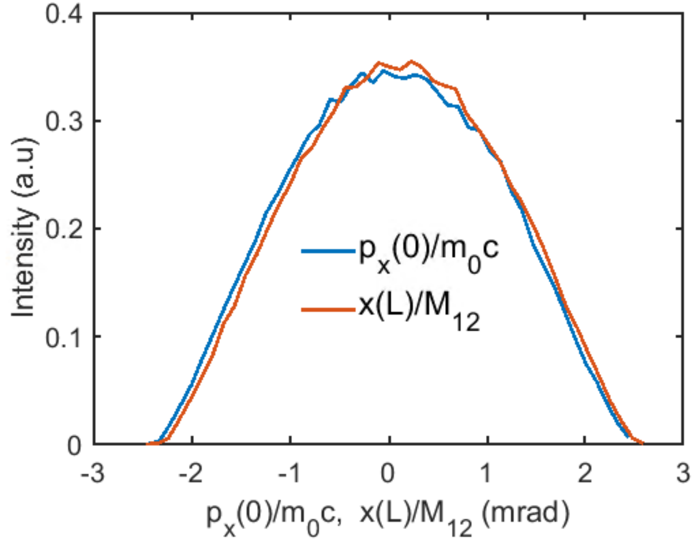
Thermal momentum imaging

Short summary

- ➢ A method to measure thermal emittance
  - ✓ Single-shot
  - ✓ Time-saving
- ➢ Elements required in the beam line
  - ✓ Gun + Solenoid + collimator@low.scr2
  - ✓ A high efficiency screen (like LYSO@high1.scr1)
  - ✓ A high efficiency camera optics (collect screen light using lens right before vacuum view port)
- ➢ Measurement step
  - ✓ Sharp gun resonance, then LEDA scan
  - ✓ Solenoid scan
  - ✓ Grab and save data through Video Client 3
- ➢ Laser BBA should be done and laser length 6~7 ps FWHM to reduce the RF kick.

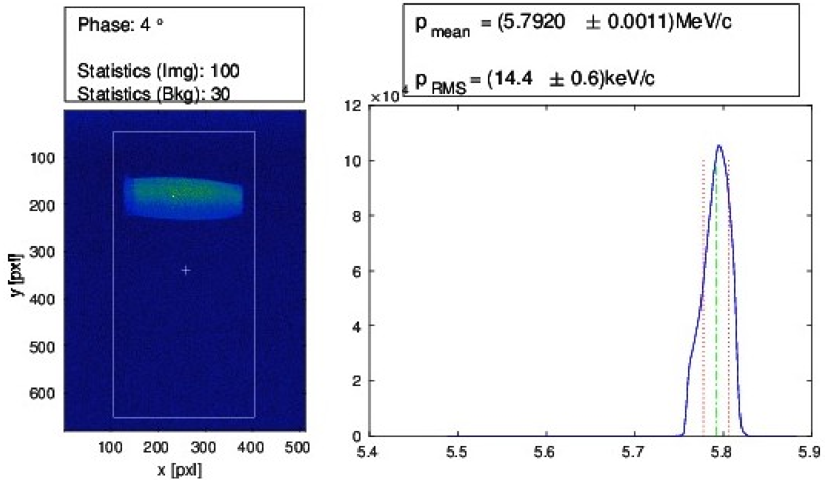


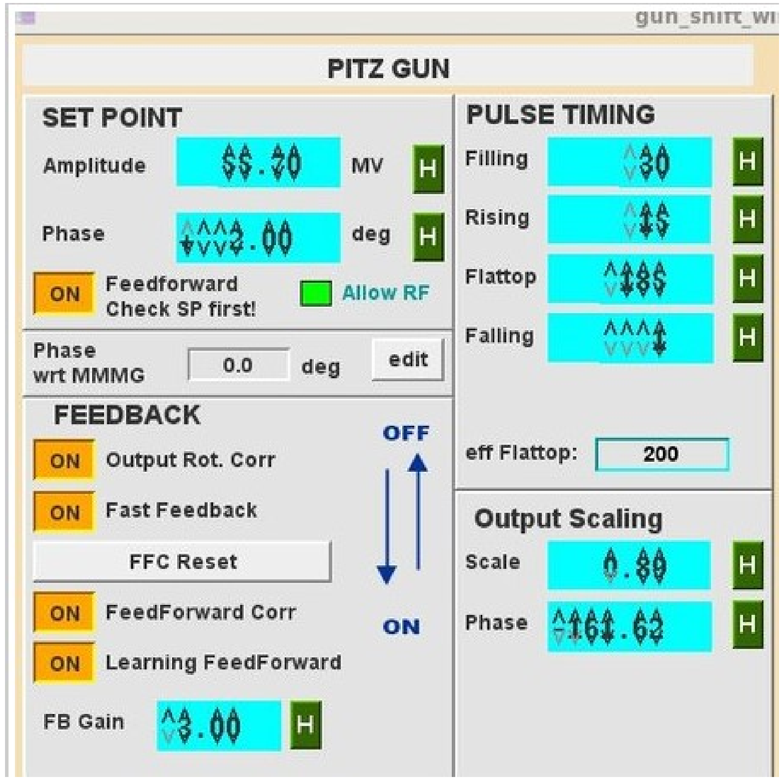


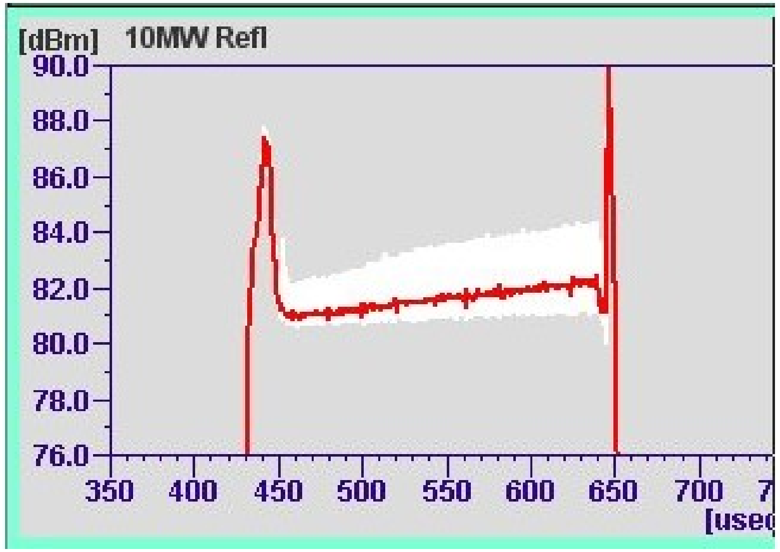


Gun set up

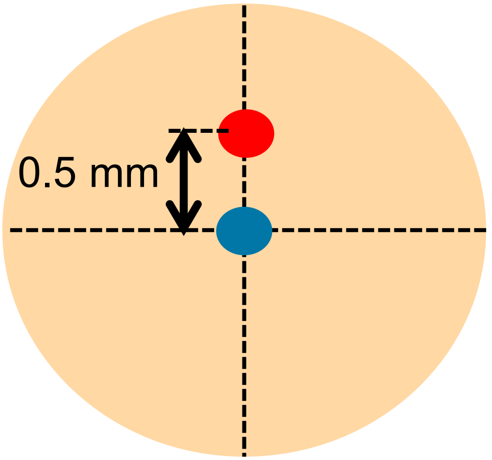
- Gun's set point
  - ✓ Amplitude: ~55.7 MV (the expected beam momentum is ~5.8 MeV/c)
  - ✓ With sharp gun resonance (almost flat reflection)
  - ✓ Phase: MMMG (Routine) or MMMG – 8.8 (Map)   (LEDA scan needed)
- Reason for this set point
  - ✓ Proper beam size (0.27 mm rms for 1 mm mrad/mm)
  - ✓ Acceptable space charge limit (~ 100 fC for BSA 1 mm)
  - ✓ Relatively less dark current than routine working point
- Water temperature tuning for sharp resonance
  - ✓ To minimize the couple kick effect on bunch train







Solenoid set up

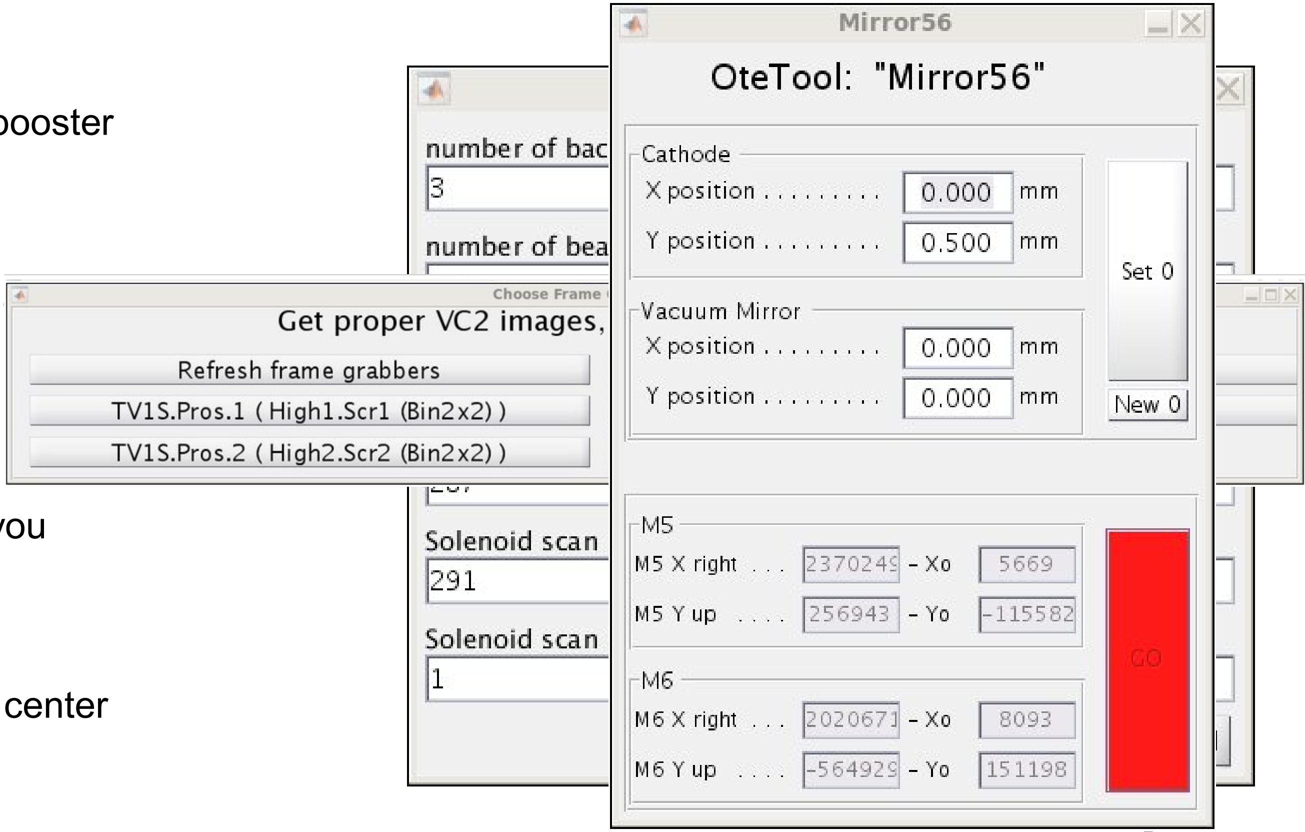


Purpose: Solenoid current should be set to satisfy the imaging condition (M11=0).

Script: solenoid_scan.m
Path: \\afs\ifh.de\group\pitz\doocs\measure\scripts\SVN\MatlabScripts\Laser_BBA

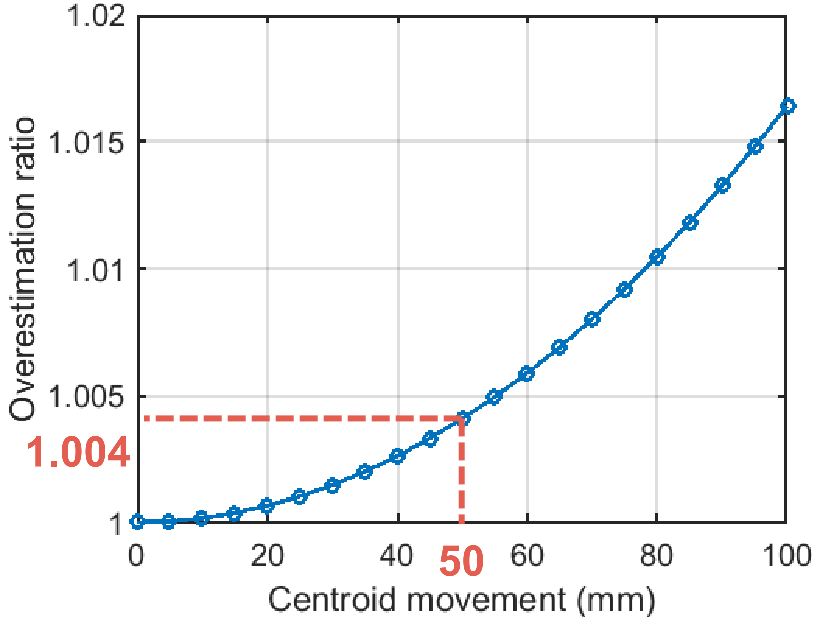
Script: mirror56.m
Path: \\afs\ifh.de\group\pitz\doocs\measure\scripts\SVN\MatlabScripts\QEmap

Step:
1. Set BSA~1mm, LT to be 0.00 (to minimize bunch charge)
2. Insert collimator at low.scr2, steer the beam to High1.scr1 LYSO (booster and high section quads off)
3. Optional: if beam asymmetry is bad, run gun quads optimizer
4. Open two matlab windows, one for M56, one for solenoid_scan.m
5. Run the solenoid_scan.m, input the basic information including sol scan range and step size
6. Choose High1.Scr1
7. Choose VC2 (don’t care the VC2 intensity)
8. A small window appears to remind you move the laser
9. Run the mirror56.m in another Matlab platform, input the position you want to move towards (like (0, 0.5))
10. Press ‘Done’ in the tips to continue
11. Choose VC2 (don’t care the VC2 intensity)
12. A small window appears to remind you move the laser back to the center
13. Input (0, 0) in the windows from the mirror56 script
14. Choose the interested region for every picture



Solenoid set up

For the solenoid scan results, centroid movement should be lower than **100 um**. If the laser movement is 500 um, it would overestimate by 1.7% for 0.277 mm rms final beam (corresponding to 1 mm mrad/mm at MMMG). Usually we manage to stay below 50 um.



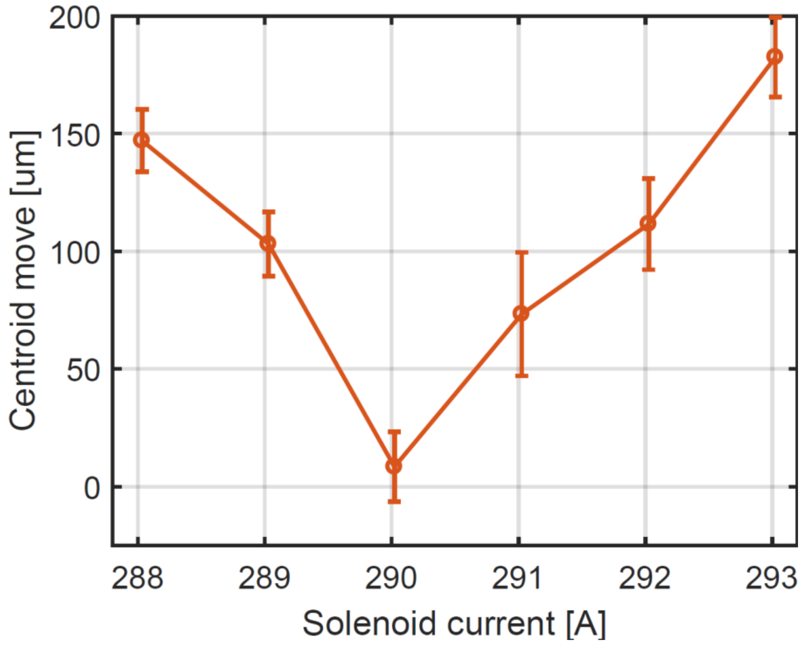
The solenoid current for imaging, as a reference for the range choice

Beam momentum: 5.8 MeV/c (Gun SP55.7)
MMMG ~ 287 A
MMMG - 8.8 ~ 290 A

Beam momentum: 3.28 MeV/c (Gun SP30?)
MMMG ~ 162 A
MMMG – 9 ~ 162.5 A

Beam momentum: 4.28 MeV/c (Gun SP40?)
MMMG ~ 211 A

Beam momentum: 6.61 MeV/c (Gun SP60?)
MMMG ~ 328 A



Thermal imaging

Set solenoid to the current corresponding to M11=0

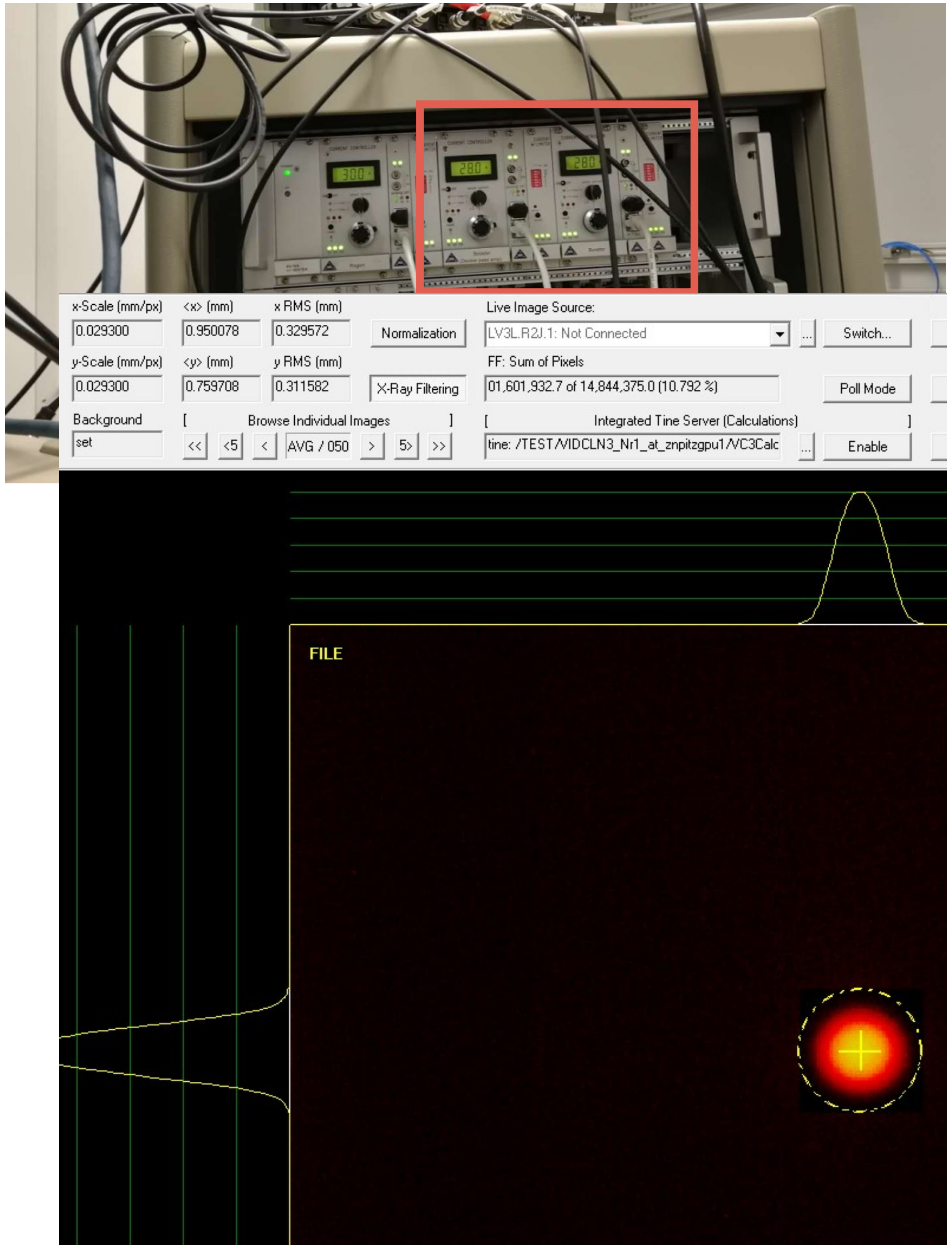
Tune down the pump current to have smaller charge. (18~20 A)

Choose LT~20, 10 pulses, BSA 1 mm. The gain of camera is set to 23 and the exposure time is 10 us. In Video Client 3, we recommend to choose ‘LV gradient’ as color mode and ‘Circular’ as area of interest.

Subtract the average background. Turn on the x-ray filtering and choose the measure area to roughly fit the beam. When the pixel sum of the electron beam is 1.4~1.6 * 10^6, the pump current is suitable.

An easy way to estimate the charge

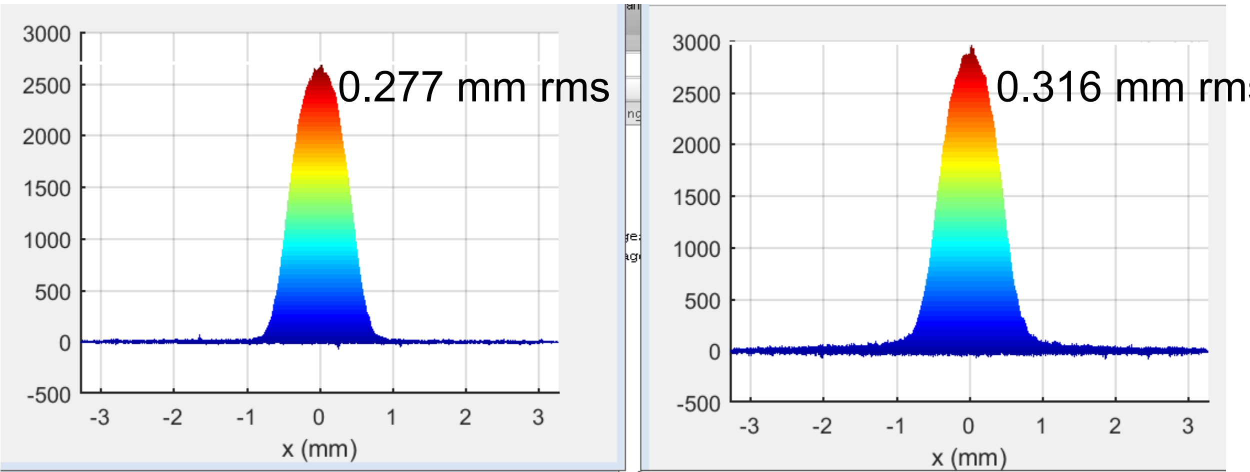
Charge per pulse (pC) = $\frac{Pixel\ sum}{3.6\times10^{6}\times Pulse\ number}$ (better to stay below 0.1 pC)



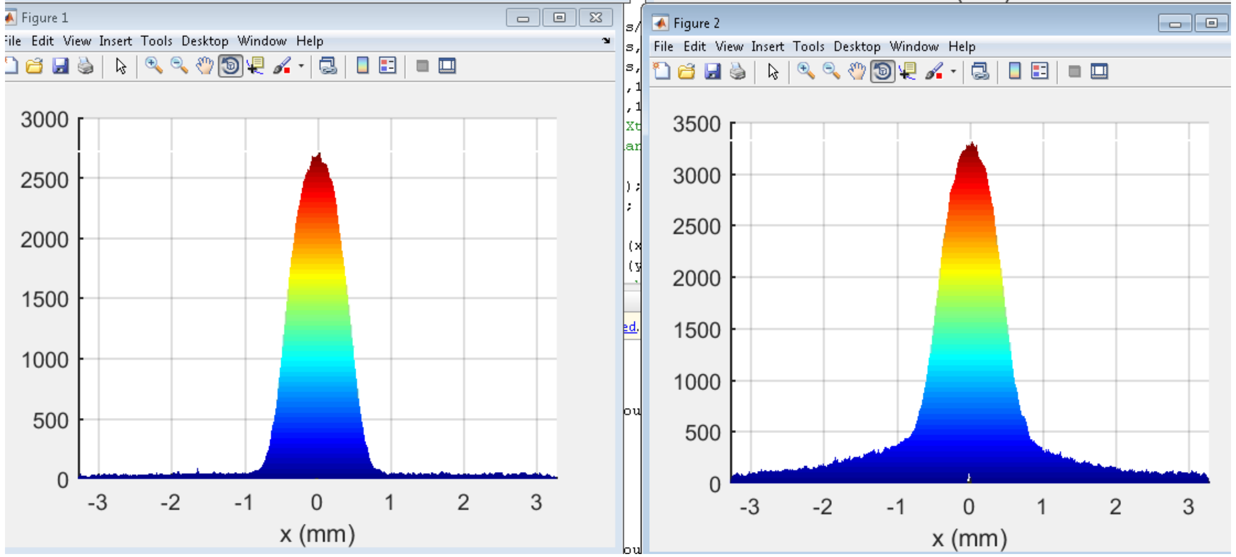
Collimator effect on thermal momentum imaging

The collimator at Low.Scr2 is recommended to use for cleaner background.

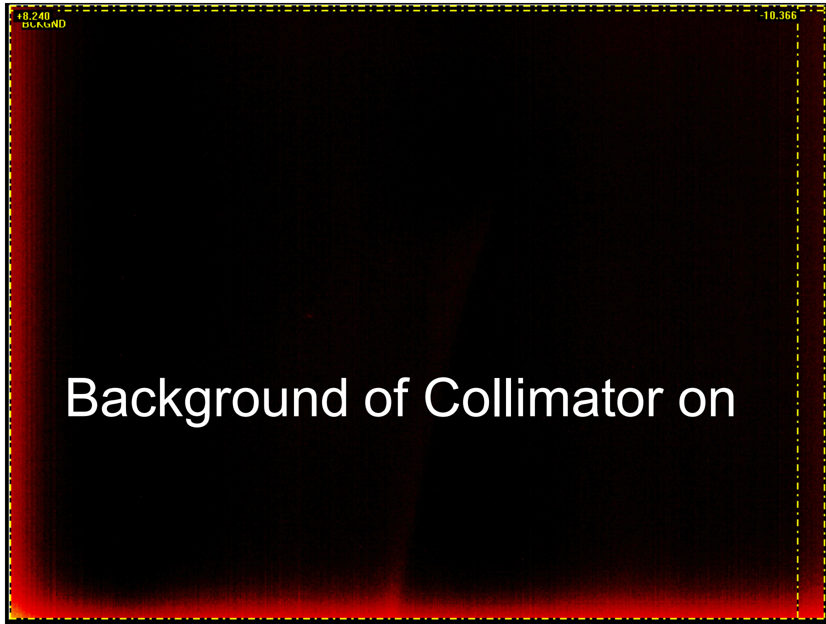
Collimator on | Collimator off

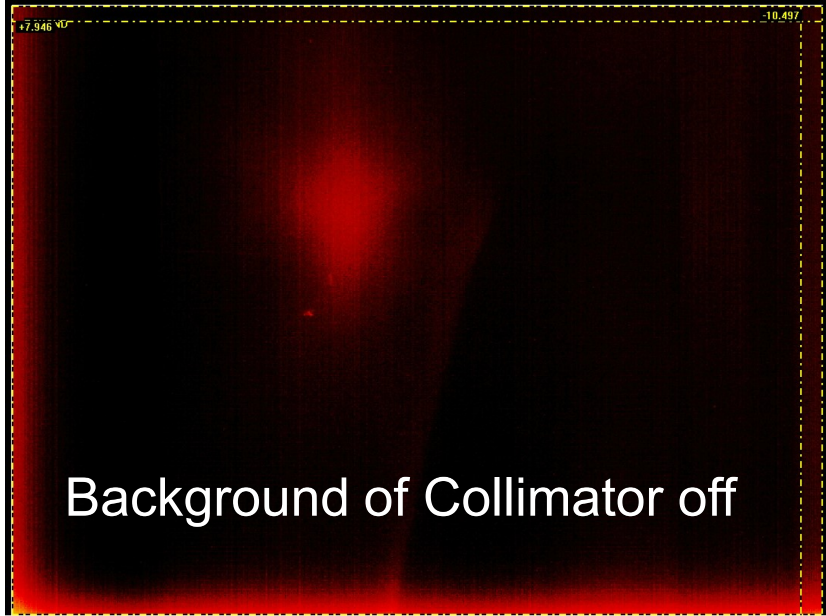


Subtract the average background



Before subtract the average background





Save & analyze

When the above steps have been done, please choose ‘Grab and save’ to save figures to \\afs\ifh.de\group\pitz\doocs\measure\TransvPhSp\2019\ProjEmittance

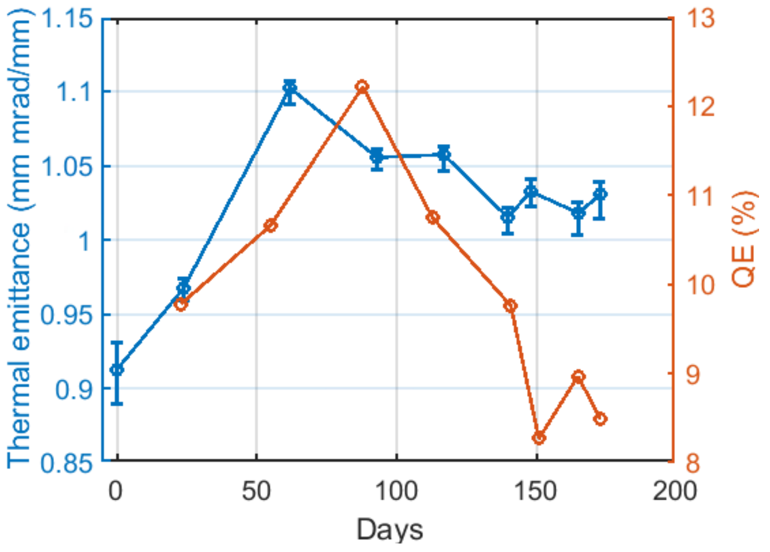
Formula to calculate the thermal emittance

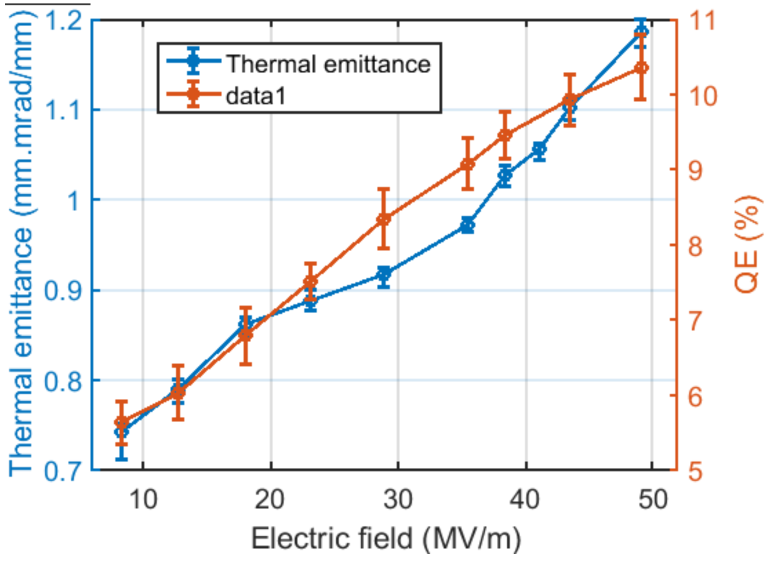
$$Thermal\ emittance = \frac{Rms\ spot\ size\ (mm)}{M_{12}}\ mm \cdot mrad/mm$$

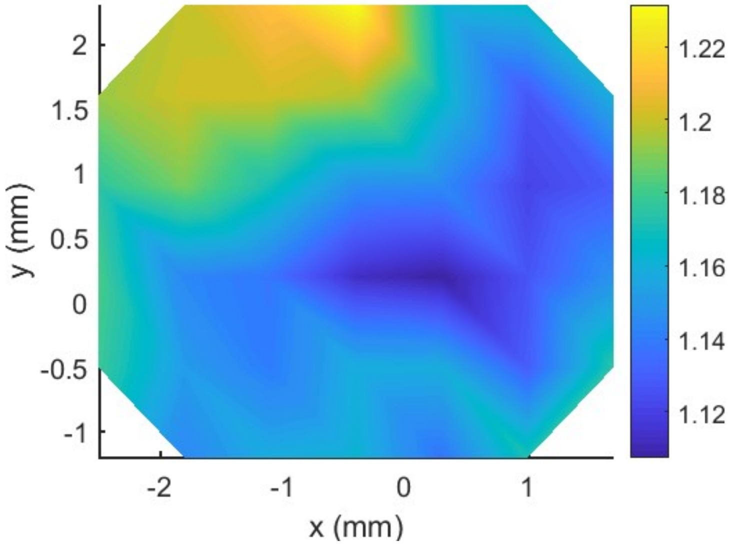
Momentum (MeV/c)	RF Phase	M_{12}
5.8	MMMG	0.2775
5.8	MMMG - 8.8 (mapping phase)	0.2495
3.28	MMMG	0.5105
3.28	MMMG – 9 (mapping phase)	0.4745
4.28	MMMG	0.3805
6.61	MMMG	0.2414

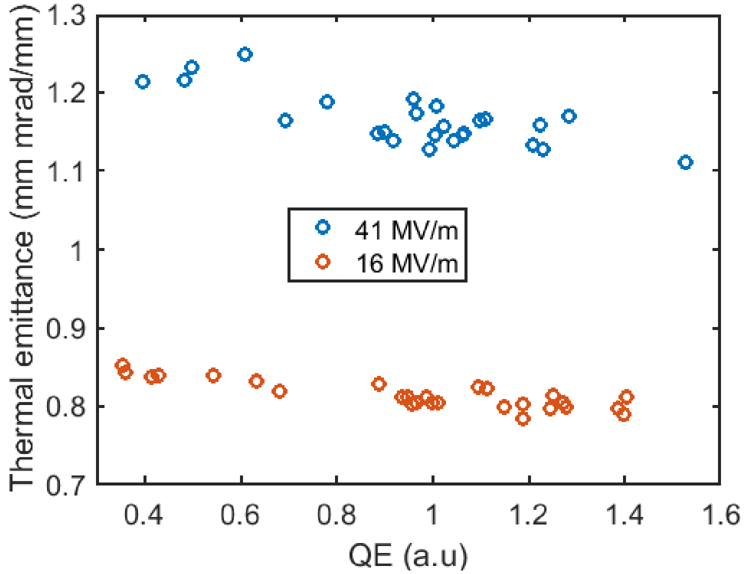
Typical Experiment

- Routine thermal emittance measurement at MMMG phase with 5.8 MeV/c
- Measure the relation between thermal emittance and electric field
- Thermal emittance map (thermal emittance vs position, thermal emittance vs QE) This experiment should be carried out at RF phase MMMG – 8.8.
- ……









Thanks for your attention