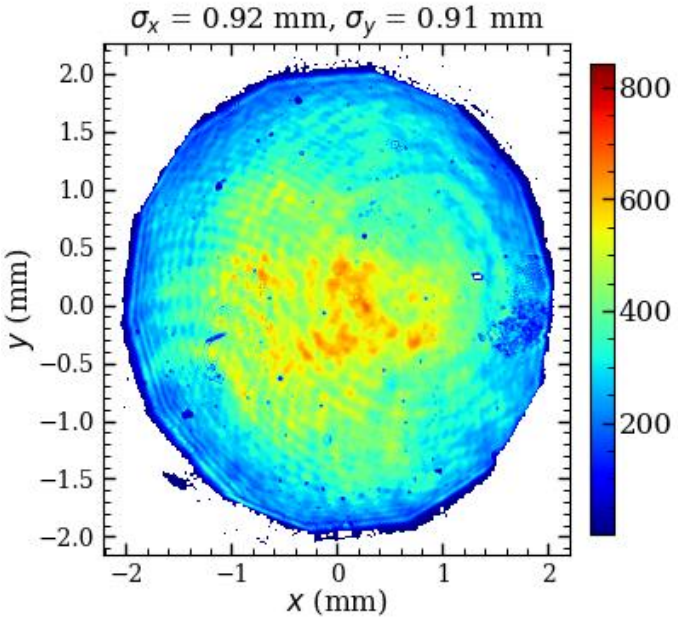
THz beam dynamics study in Run 4

Xiangkun Li, PPS data analysis report, 20.05.2021

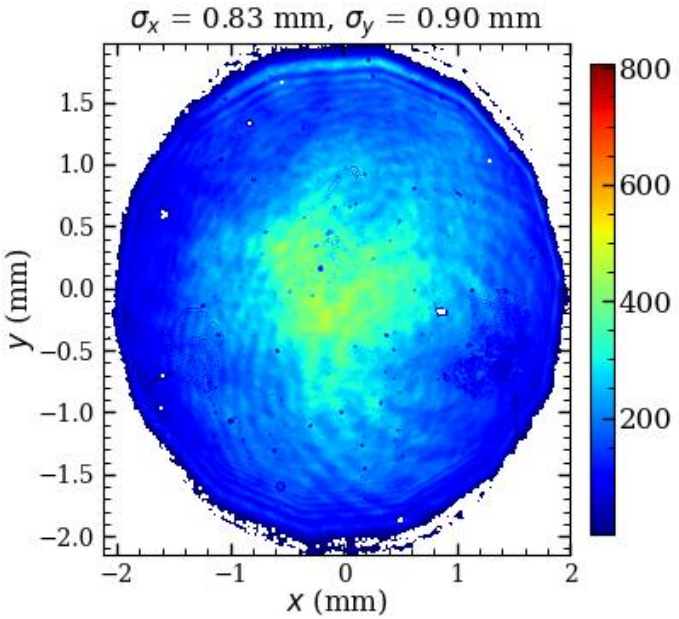
Outline

- Emittance measurement and simulation
- Beam transport measurement
- Summary

Laser transverse profile and position



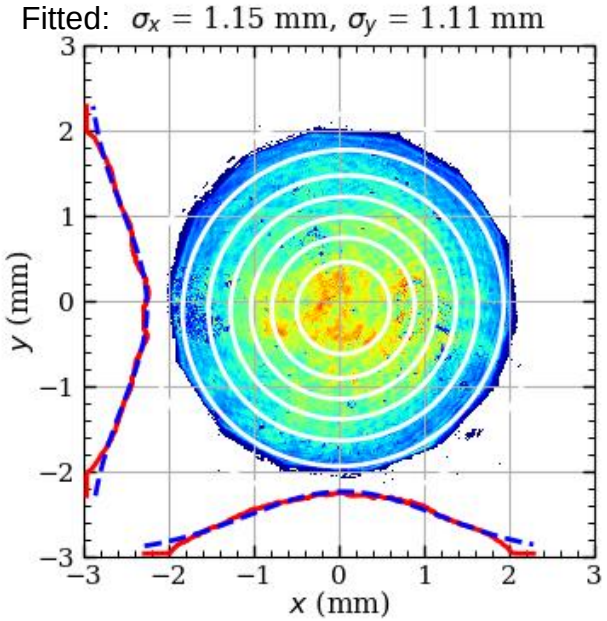
March 2021



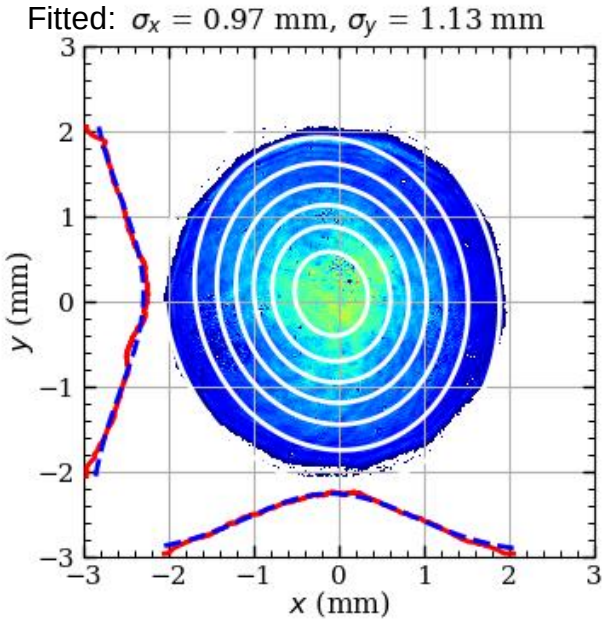
April 2021

Laser transverse profile and position

2D Gaussian fit



March 2021



April 2021

March:

σ_x/σ_y = 103.6%

x_c = -0.149 mm

y_c = 0.015 mm

April:

σ_x/σ_y = 85.6%

x_c = 0.289 mm

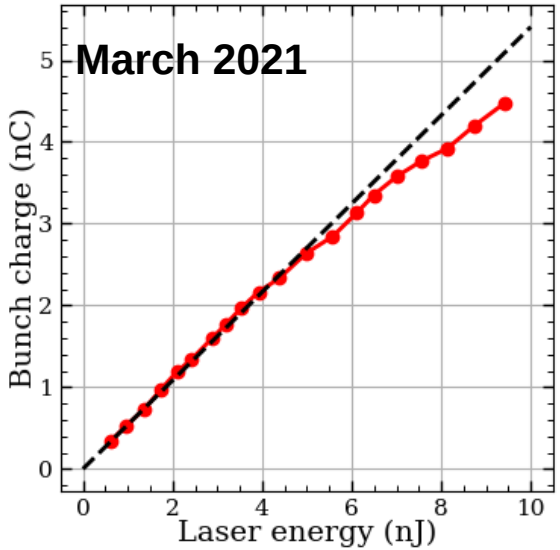
y_c = 0.445 mm

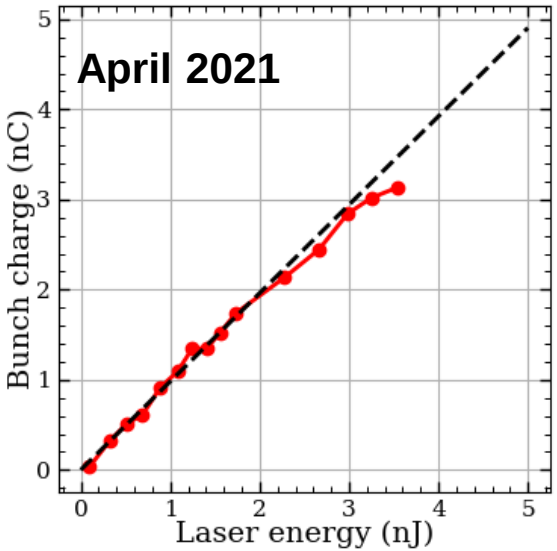
From March to April:

x_c : +437 um

y_c : +429 um

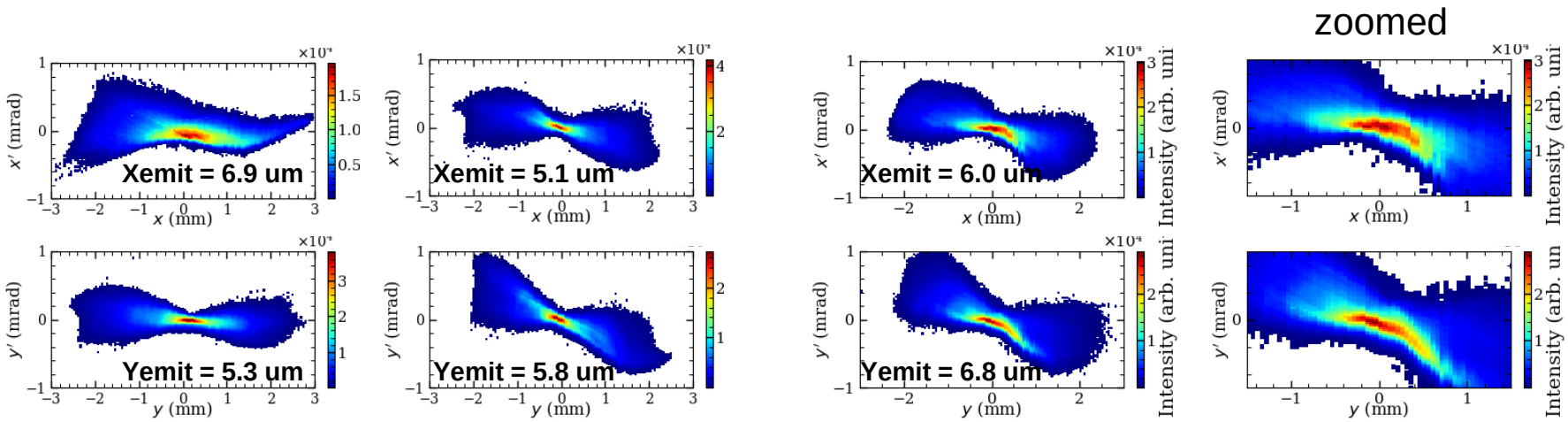
Emission curve measurement





- The experiments were performed with two different cathodes; the cathode used in April has x2 higher QE

Phase space for best emittance

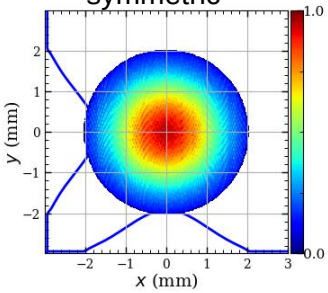


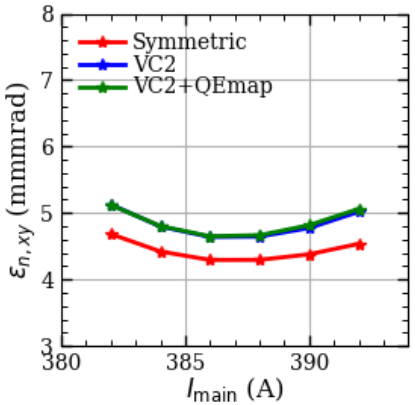
- When loading low steerers for booster steering free, the x-x' phase space became asymmetric as in March and the x-y emittance got worse by ~20%
- The core of the phase space (rightmost column) measured in April was bent, due to unknown nonlinear forces, similar to the core in the upper left plot

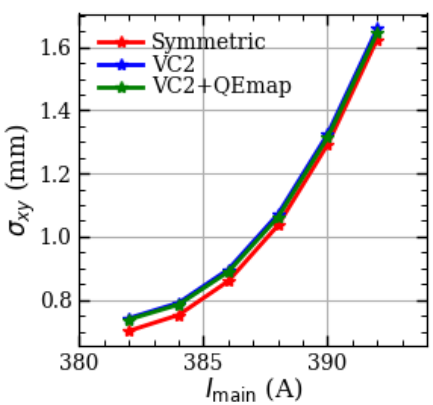
Possible reasons for the bigger emittance

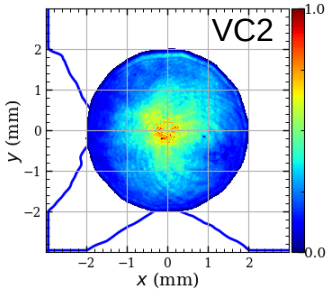
- Laser transverse distribution was not as good as in March
  - Simulated, but didn't make the emittance that worse

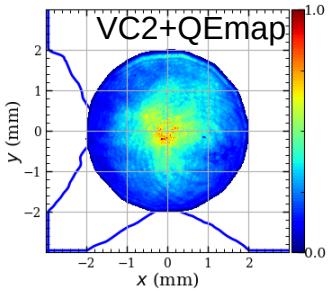
Cylindrically symmetric







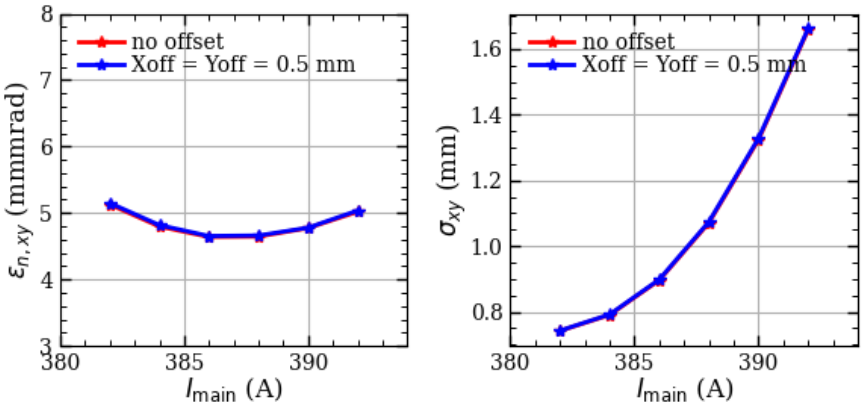




  - Space charge model transition from 2D to 3D at z=2.5 cm

Possible reasons for the bigger emittance

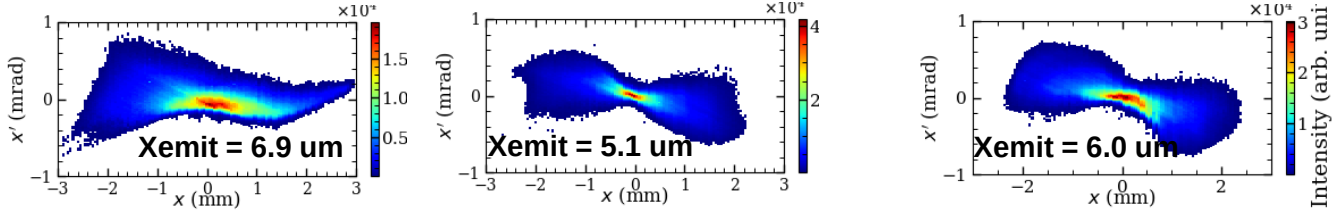
- Laser position at VC2 has drifted by 0.5 mm in both x and y planes
  - Simulated with the VC2 image as input, almost the same



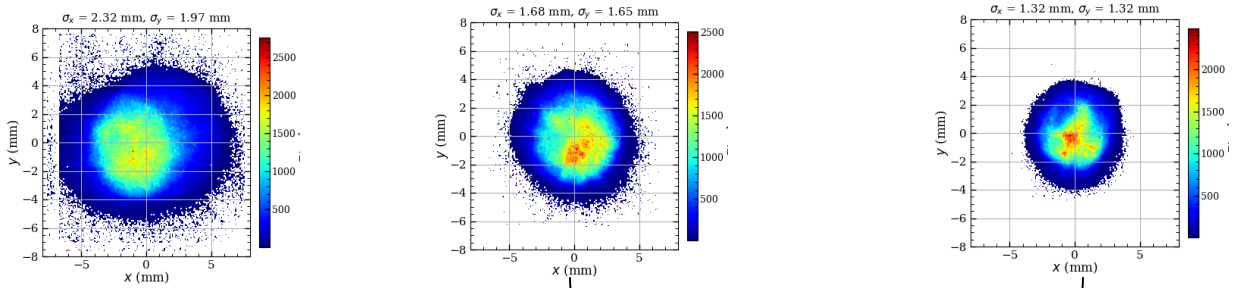
Possible reasons for the bigger emittance

- Low section steerers + trajectory in booster RF fields still to be improved

x-xp



MOI

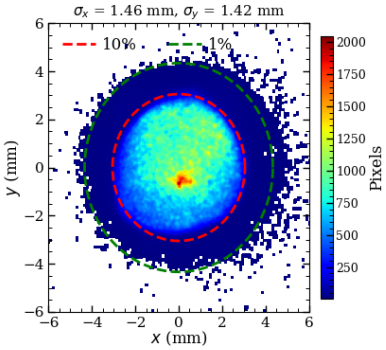


Booster steering free — March (~4 nC)

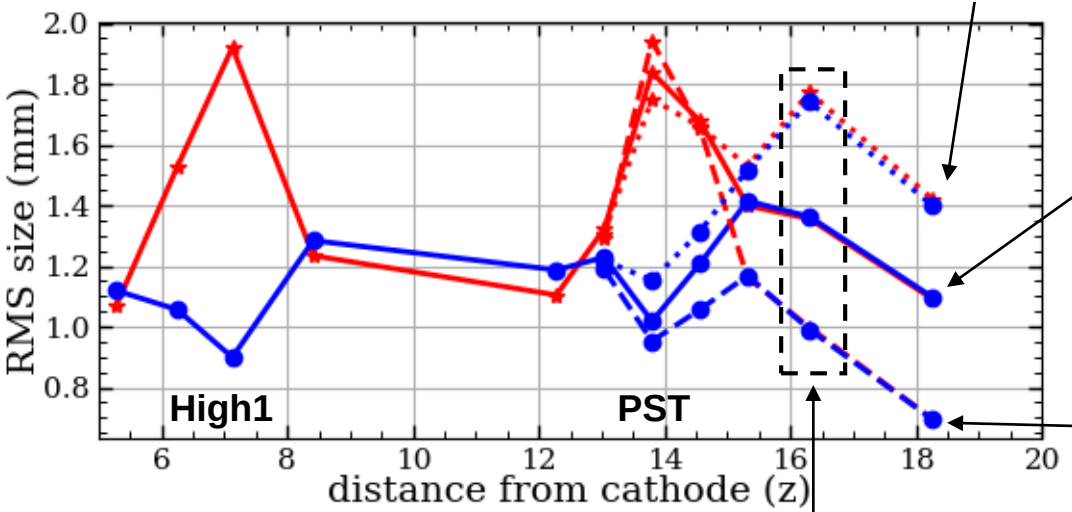
Symmetrically shaped on H1S4 — April (3-3.5 nC)

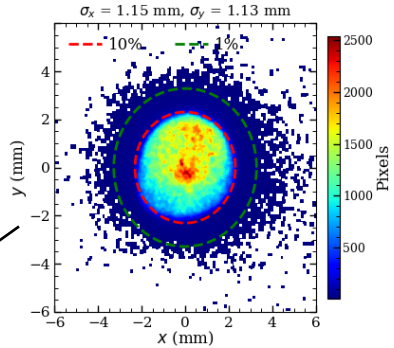
Beam transport at high charge

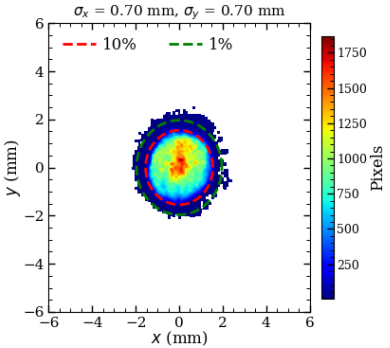
Applying different focusing in PST



Background subtraction:
Average+emcalc_filter

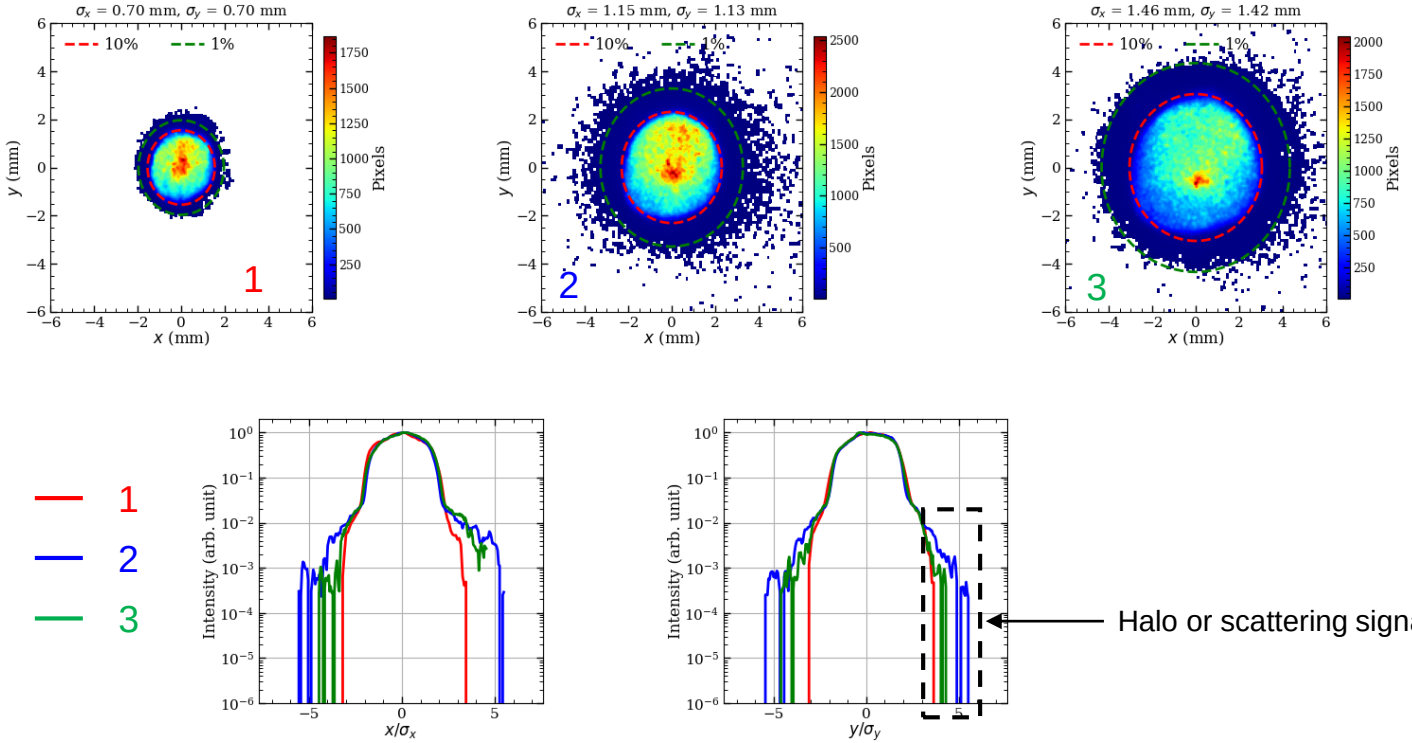






Beam size not consistent
with neighbouring screens
(scaling factor or resolution?)

Beam transport



Summary

- Optimized beam emittance at 3-4 nC with the steerer setting found in Run2, but couldn‘t recover the relatively small emittance measured in Run 2
- Transported the high charge beam to High2.Scr2 under different focusing forces from PST section

- Difficulties

* MBI laser: reduced output pulse energy due to removal of booster amplifier crystal
* MBI laser: pinhole was removed during laser repair (no mode cleaning)

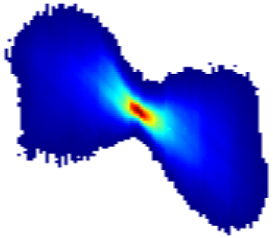
  - Bunch charge was below 4 nC for most of the measurement, and fluctuated between 3-3.5 nC in the last two shifts; and lost low.ICT1 timing for some shifts
  - High2.Scr1 beam size not consistant with that measured at neighbouring screens

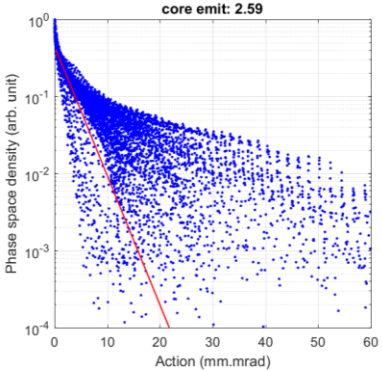
* For Pharos laser setup1: thin crystal with spatial filtering, no SLM shaping
* Measured 1x3 statistics with 50 um slit at 370 A (best nonscaled emittance with MBI) and 368 A (similar EMSY1 beam size to MBI):
* At 370 A:
* Scaled1
* Xemit= 0.717 +/- 0.012 mm mrad
* Yemit= 0.826 +/- 0.031 mm mrad
* XYemit= 0.770 +/- 0.016 mm mrad
* Nonscaled
* Xemit= 0.602 +/- 0.018 mm mrad
* Yemit= 0.723 +/- 0.045 mm mrad
* XYemit= 0.659 +/- 0.012 mm mrad
* For pharos laser setup2: thin crystal without spatial filtering, no SLM shaping
* Solenoid scan for the best emittance, found at 372 A:
* Scaled1:
* Xemit= 0.807 mm mrad
* Yemit= 0.875 mm mrad
* XYemit= 0.840 mm mrad
* Nonscaled:
* Xemit= 0.689 mm mrad
* Yemit= 0.843 mm mrad
* XYemit= 0.762 mm mrad

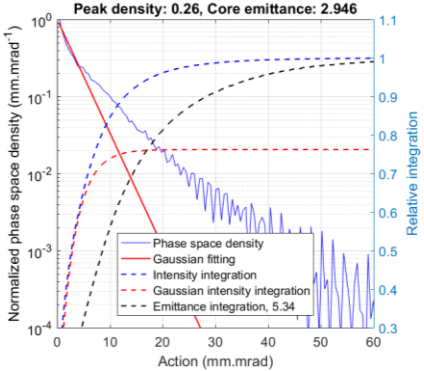
Saturday 24. April 2021 Afternoon

Phase space analysis

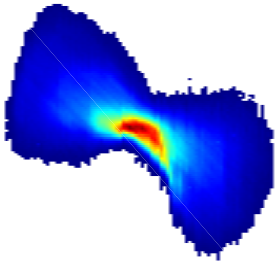
March (~4 nC)

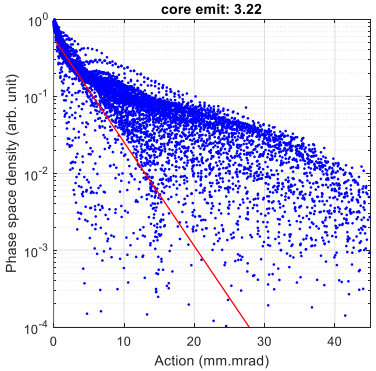


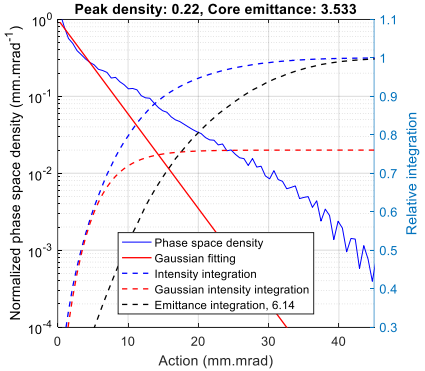




April (3-3.5 nC)

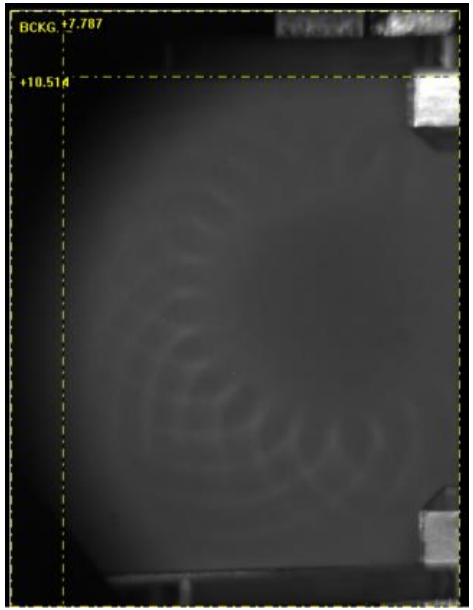




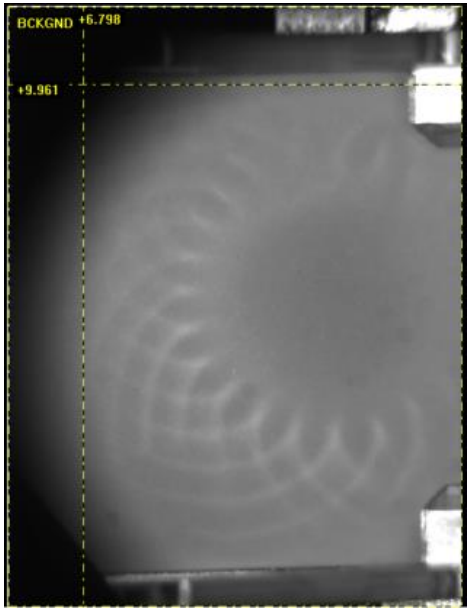


Backup

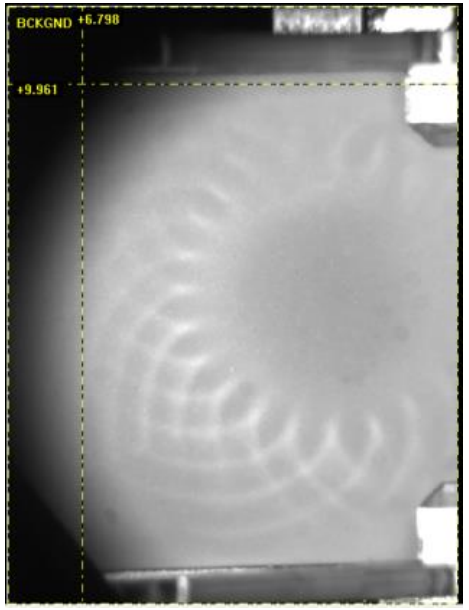
High2.Scr1



5000 us

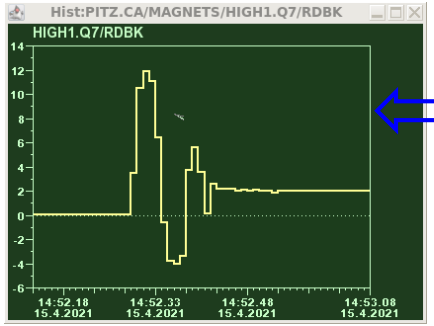


10000 us

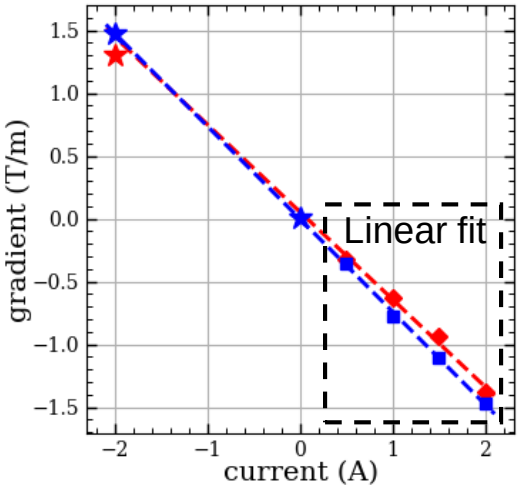


15000 us

THz beam dynamics summary (Run 4)



Red: excited directly after degaussing
Blue: excited back and forth similar to degaussing



Machine setup:

- BSA 4 mm, 3~4 nC from MBI
- Gun@MMMG+5, 6.7 MeV/c
- Booster@MMMG+20, ~21 MeV/c

Results:

- Measured the quadrupole strength when excited in different ways
- Emittance optimized with solenoid scan, best emittance (8.0 um) much larger than that measured in March (5.5 um); ~15% smaller after H1S4 lens changed from 100 to 160
- Transported the beam to High1.Scr2, with different focusing

Problems and lessons:

- Bunch charge dropped from 4 nC on the first day to ~ 3 nC two days later with higher pump current
- On the last day lost Low.ICT1 timing, therefore no monitor of charge during most of emittance measurement

- Checklist before emittance measurement (slit width, camera gain/exposure, lens, gun reflection and so on)