Summary of THz matching strategy study in Run 2

Xiangkun Li, PPS, 25/03/2021

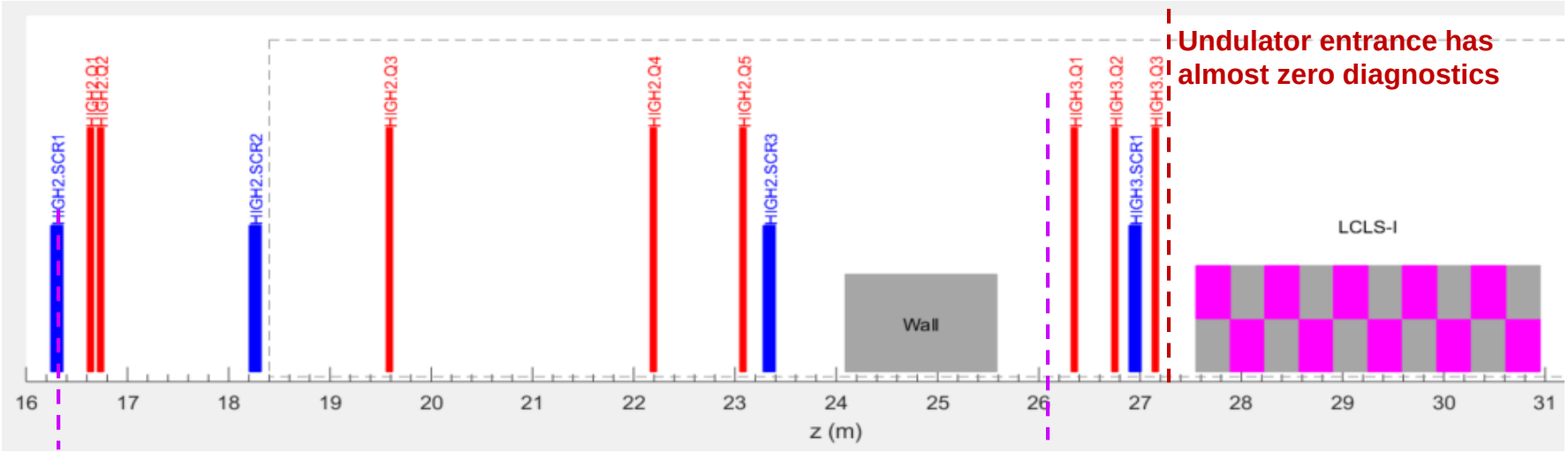
Outline

- Introduction
- Experimental results
- Summary

Introduction

Matching strategy

- Specific transverse phase spaces are expected before the undulator and parameter scan has shown that only four parameters need to be considered (Xcov, Xrms, Ycov and Yrms)
- If a round beam transport is made, the four parameters reduce to two (e.g., beam sizes at High2.Scr3 and High3.Scr1) and two free knobs are enough (one tuned in experiment and one tuned with simulations in advance)



Measure the beam envelope development after the quads at High2.Scr3 and High3.Scr1

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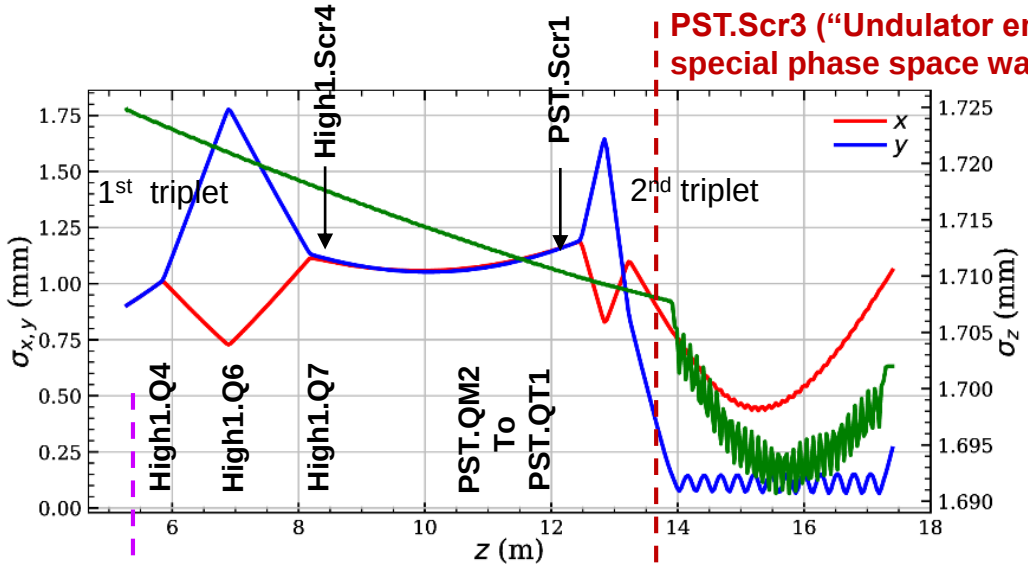
Backward simulation of beam envelope development (from High2.Scr3 to High3.Scr1) vs triplet strength

Introduction

Matching study in PST section



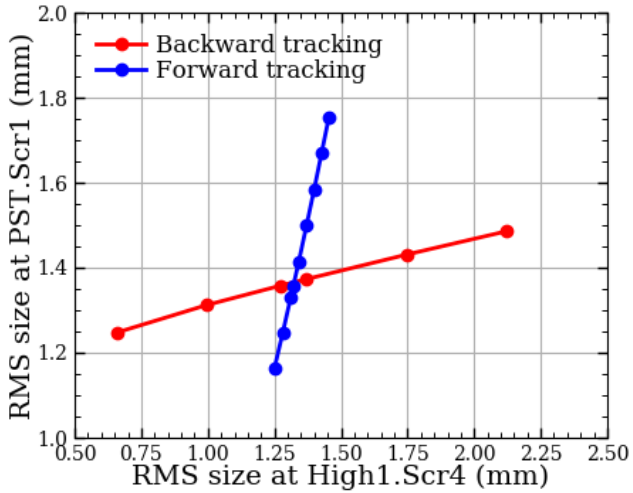
Tracking back to High1.Scr4 for the beam sizes at High1.Scr4 and PST.Scr1 vs 2nd triplet gradients

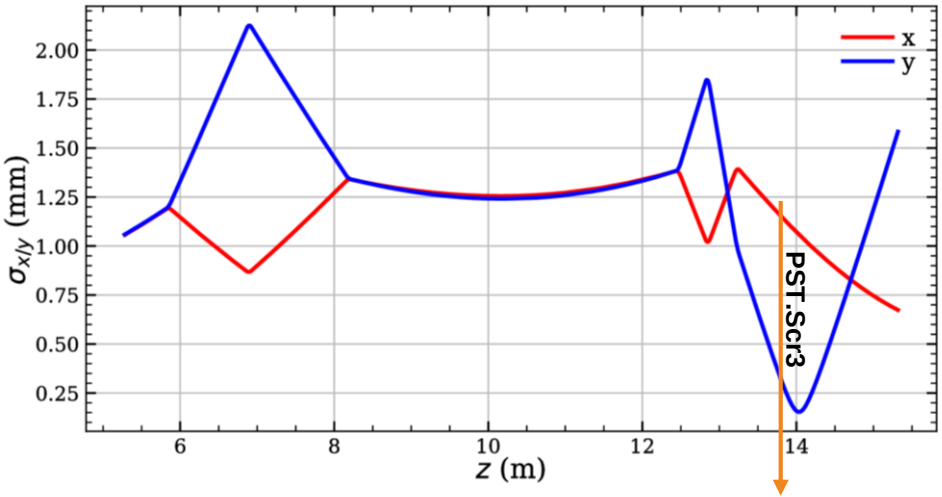
Transport the beam and get the beam sizes at High1.Scr4 and PST.Scr1 vs 1st triplet currents

Introduction

Simulation on matching at PST.Scr3

- Software: SpaceChargeOptimizer.exe





Backward tracking:

PST.Scr3 to High1.Scr4, 2nd triplet strength tuned

Forward tracking:

EMSY1 to PST.Scr1, 1st triplet strength tuned

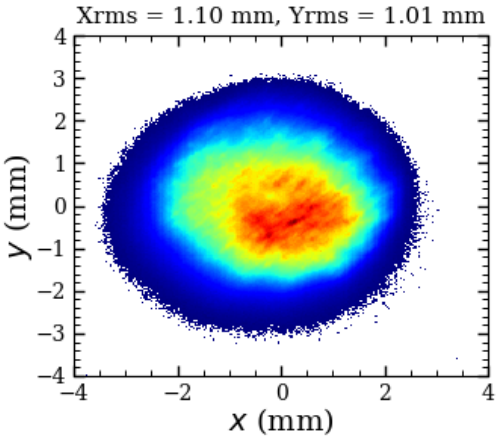
Expected:
Xrms = 1.10 mm
Yrms = 0.25 mm
Xcov = -0.50 um
Ycov = -0.30 um

Obtained:
Xrms = 1.14 mm
Yrms = 0.32 mm
Xcov = -0.47 um
Ycov = -0.33 um

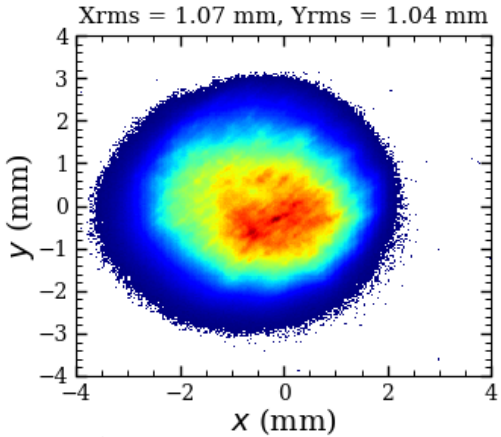
Experimental results (1)

- Tuning of round beam transport with triplet

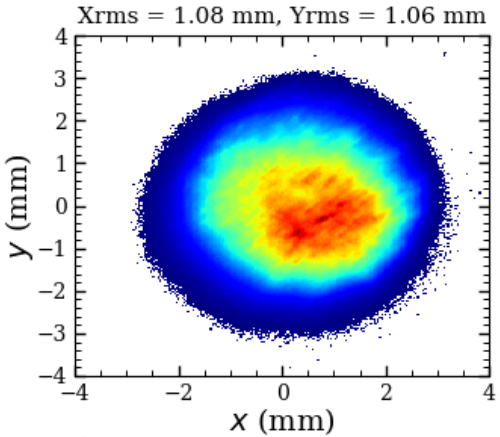
1. Set the 1st quad current (e.g., 1 A) and initialize the other two (e.g., -1 A and 0.5 A, not neccesary)
2. Monitor the beam at the 1st screen while gradually reducing the current of 2nd quad, until Xrms ~= Yrms
3. Monitor the beam at the 2nd screen while gradually increasing the current of 3rd quads, untitl Xrms ~= Yrms
4. Go back to 1st screen, check if Xrms ~= Yrms, if yes, stop; if no, repeat 2-4



1st iteration: (Xrms-Yrms)/Yrms=9%



2nd iteration: (Xrms-Yrms)/Yrms=3%



3rd iteration: (Xrms-Yrms)/Yrms=2%

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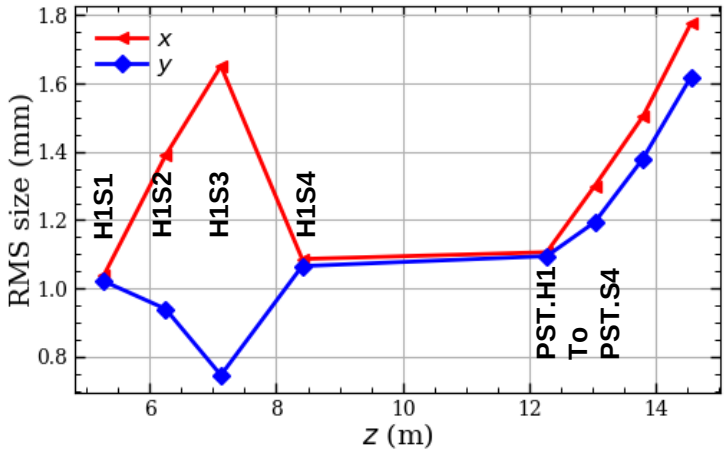
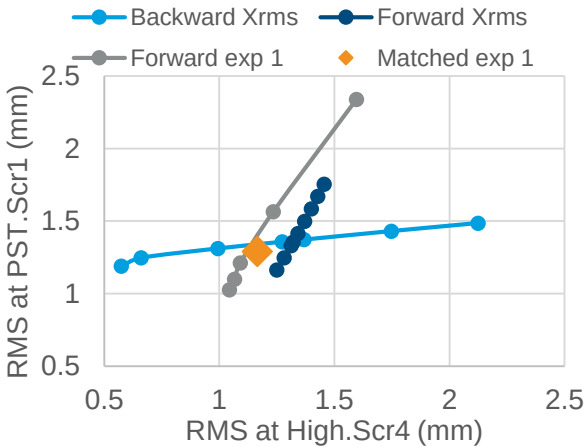
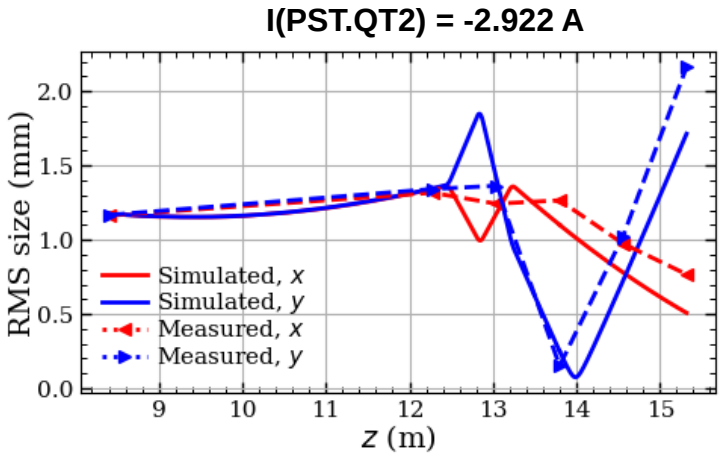


Beam not round after PST.Scr1, algorithm still needs to improve; and High1.Scr5 may help

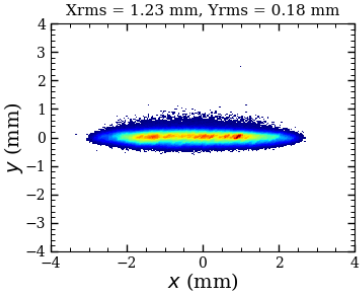
Experimental results (2)

- Matching of beam sizes at High1.Scr4 and PST.Scr1
  - Scan High1.Q4 current: for each step, make round beam transport
  - Find the intersection, guess the current of High1.Q4 by interpolation and tune the other two
  - From the intersection, guess the gradients of the 2nd triplet by interpolation and convert to currents
  - Tune a bit the current of the last quad in the 2nd triplet for better matching/transport





Expected:
Xrms = 1.10 mm
Yrms = 0.25 mm



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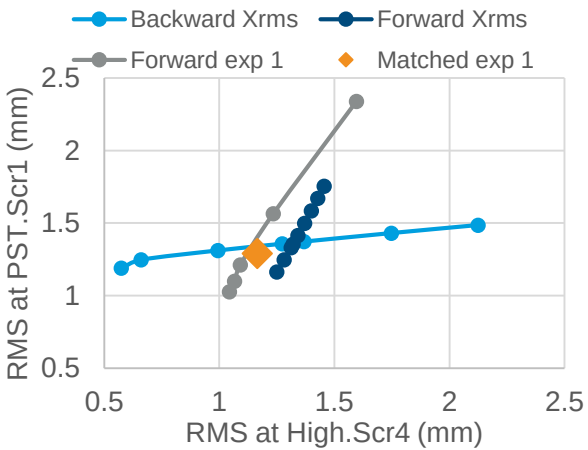

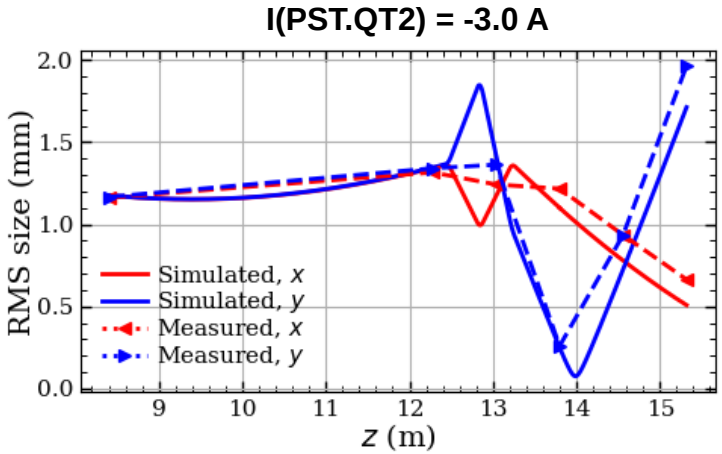

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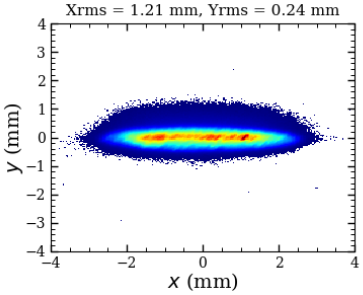

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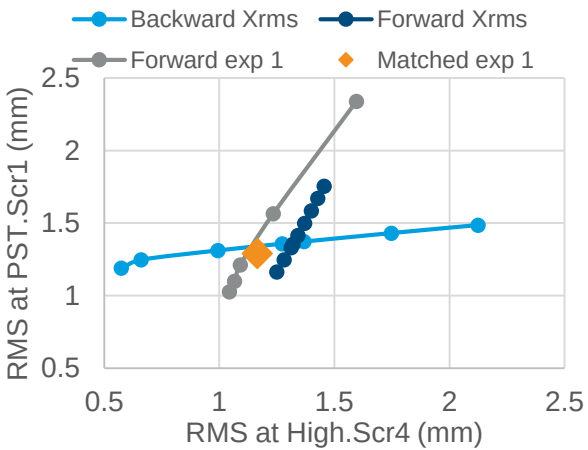

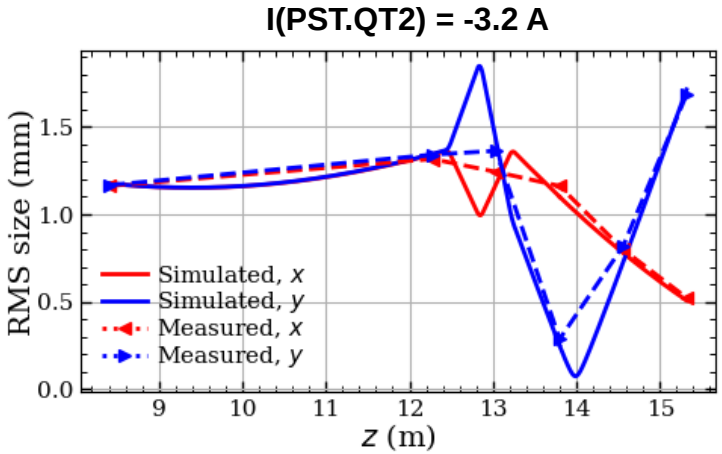

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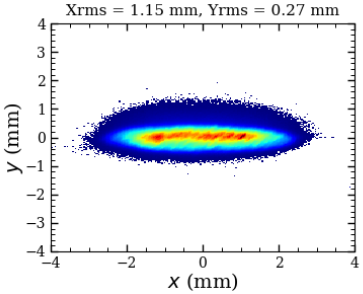
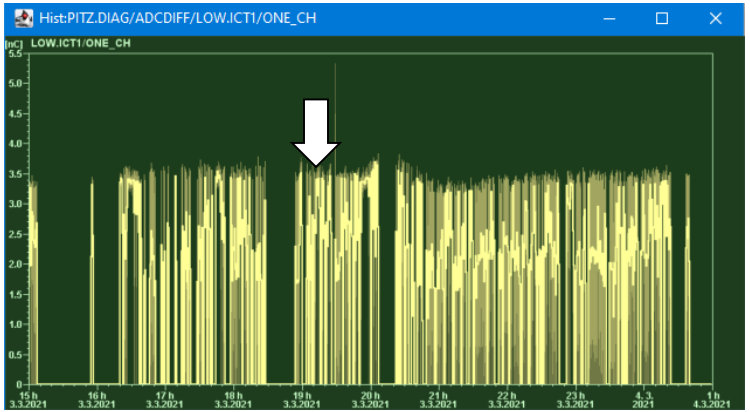


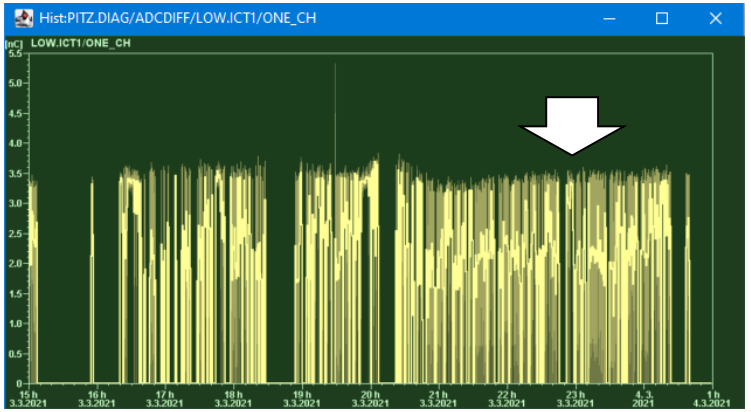
Experimental results (2)

- Problem during the matching
  - During the scan of High1.Q4 current, some inconsistent beam sizes were measured after a booster IL due to Spark WG1 tunnel shaft; Charge was checked, but looked fine (see white arrow in the charge history)
  - After going back to earlier machine status, we found the beam on High1.Scr4 was 10% larger than before
  - By reducing Imain by 2 A, the beam sizes at both High1.Scr4 and PST.Scr1 were recovered to earlier status

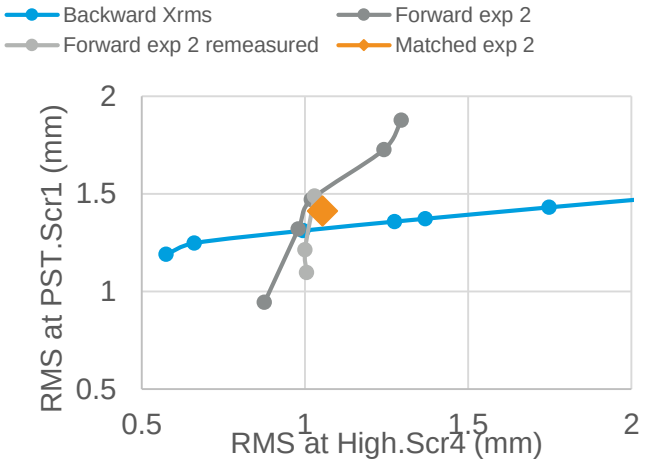
	Imain = 390 A		Imain = 388 A		
	Xrms	Yrms	Xrms	Yrms	
High1.Scr4	1.11->1.22	1.07->1.27	1.10	1.09	mm
PST.Scr1	1.20	1.23	1.19	1.23	mm

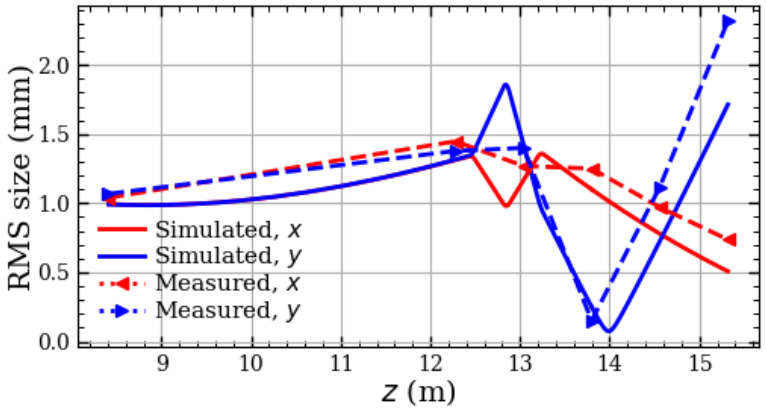


Experimental results (3)



- Repeat matching of beam sizes at High1.Scr4 and PST.Scr1
  - Start with opposite polarity for High1.Q4
  - However, the machine was not very stable and some remeasured data points deviated a lot from earlier measurements





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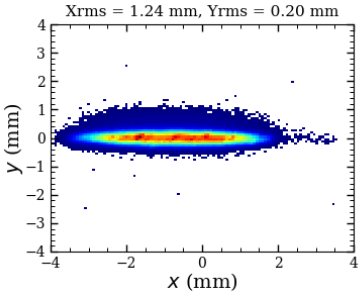
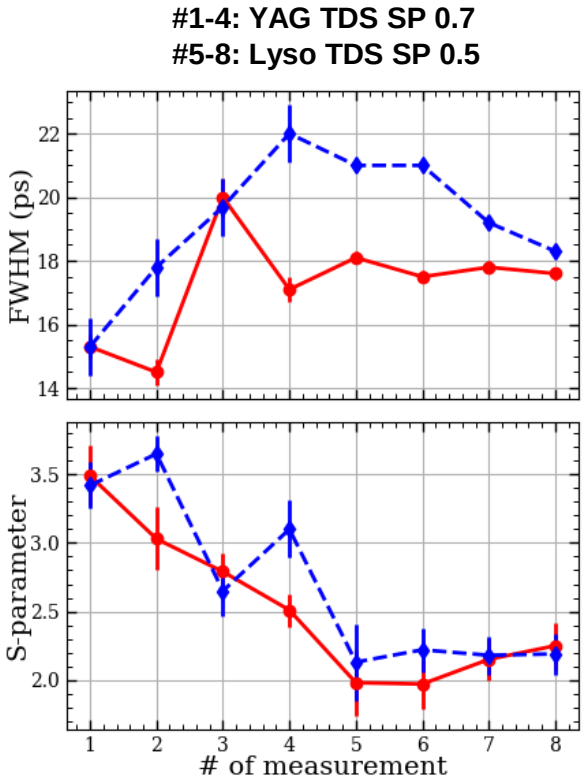
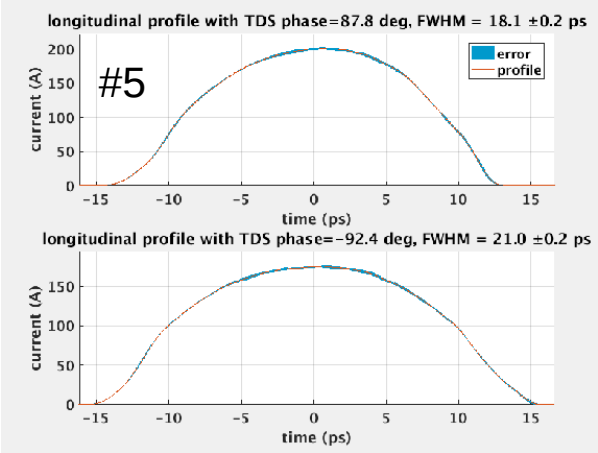


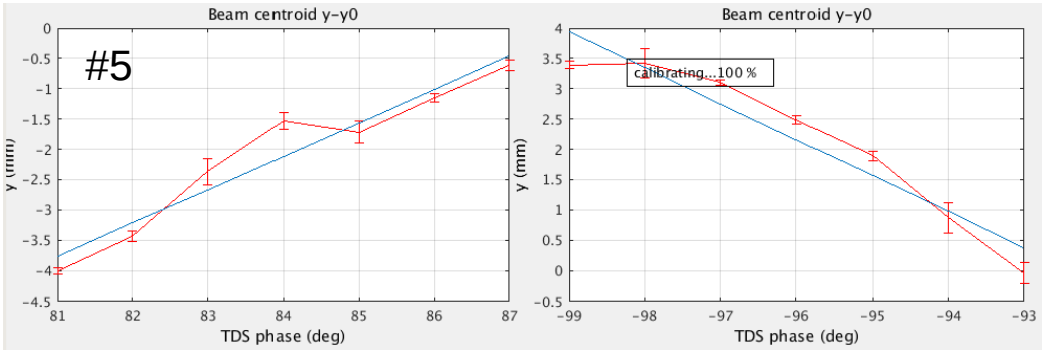
Bunch profile measurement





1. The phase scan curves were not linear
2. With 1, the S-parameter was not the same for the two zero-crossing phase
3. 1&2 put a question mark over the peak current or FWHM given by the measurement

4. Anyway, the peak current should be around 200 A



Summary

- Using two triplets in the High1 and PST sections as the knobs and the beam sizes at High1.Scr4 and PST.Scr1 as the constraints, the matching process was realized.
- By finely tuning the quads a bit under the found matching condition, the beam envelopes overlapped well with the simulated ones

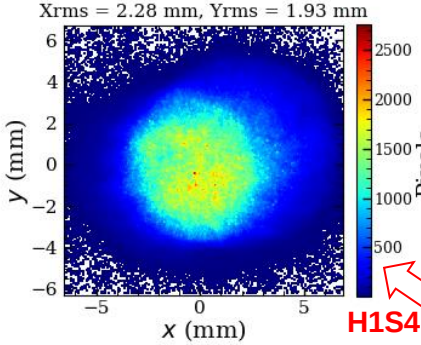
- Difficulties
  - High1.Q4 couldn’t be set steering free with the current trajectory
  - The machine was not stable during the experiment (Imain or others?)
  - Phase scan curves in TDS measurement were not linear

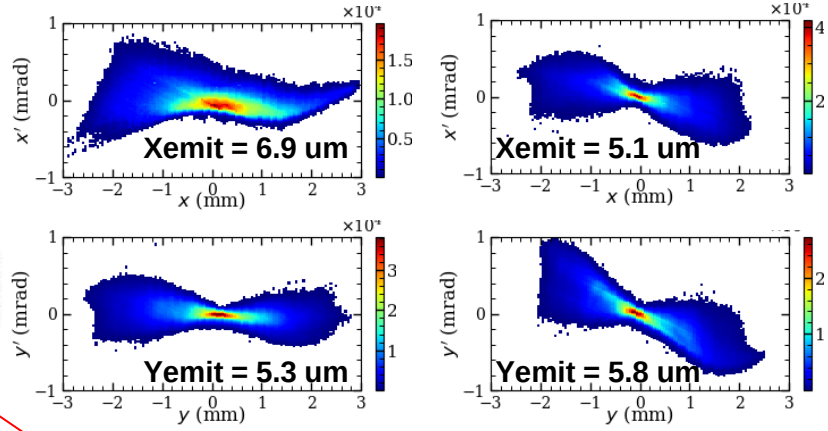
- Others:
  - Calibration of new quads

THz beam dynamics

Machine setup:

- BSA 4 mm, 4 nC, #676.1
- Gun MMMG phase, 6.7 MeV/c
- Booster MMMG, ~22 MeV/c





H1S4

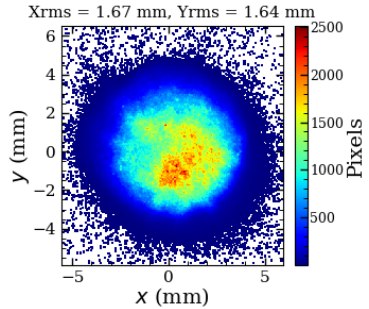
Booster steering free

Beam nicely shaped on H1S4

Results:

- After improving the transport in low section, the distortion of horizontal phase space disappeared and a nonscaled XY-emittance of ~ 5.4 um was measured at EMSY1 (~6.0 um with booster steering free steerer setting)
- Matching procedure was tested, data taken for further analysis; experience gained and script developed for the quad tuning

Steerers	Ix (A)	Ix(A)
Low.ST1	0.7	1.0
Low.ST2	0.75	-0.6
Low.ST3	0.6	1.2
Low.ST4	0.05	0.
Low.ST5	4.7	0
$\Delta\langle x' \rangle$ / mrad	**6.1**	**4.0**



Problems:

- Measurement interrupted by tunnel access and ILs; forgot to switch off the light in the tunnel after one tunnel acess → uniform noise in reconstructed phase space
- The scaling factor depended on how the EMSY1 image was processed because of the halo-like ring
- Solenoid focusing jumped first during emittance measurement (2A ↓) and then during the matching experiment (2A ↓)