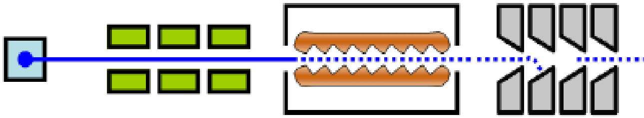

Revisiting LEBT GPT Simulations

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Introduction

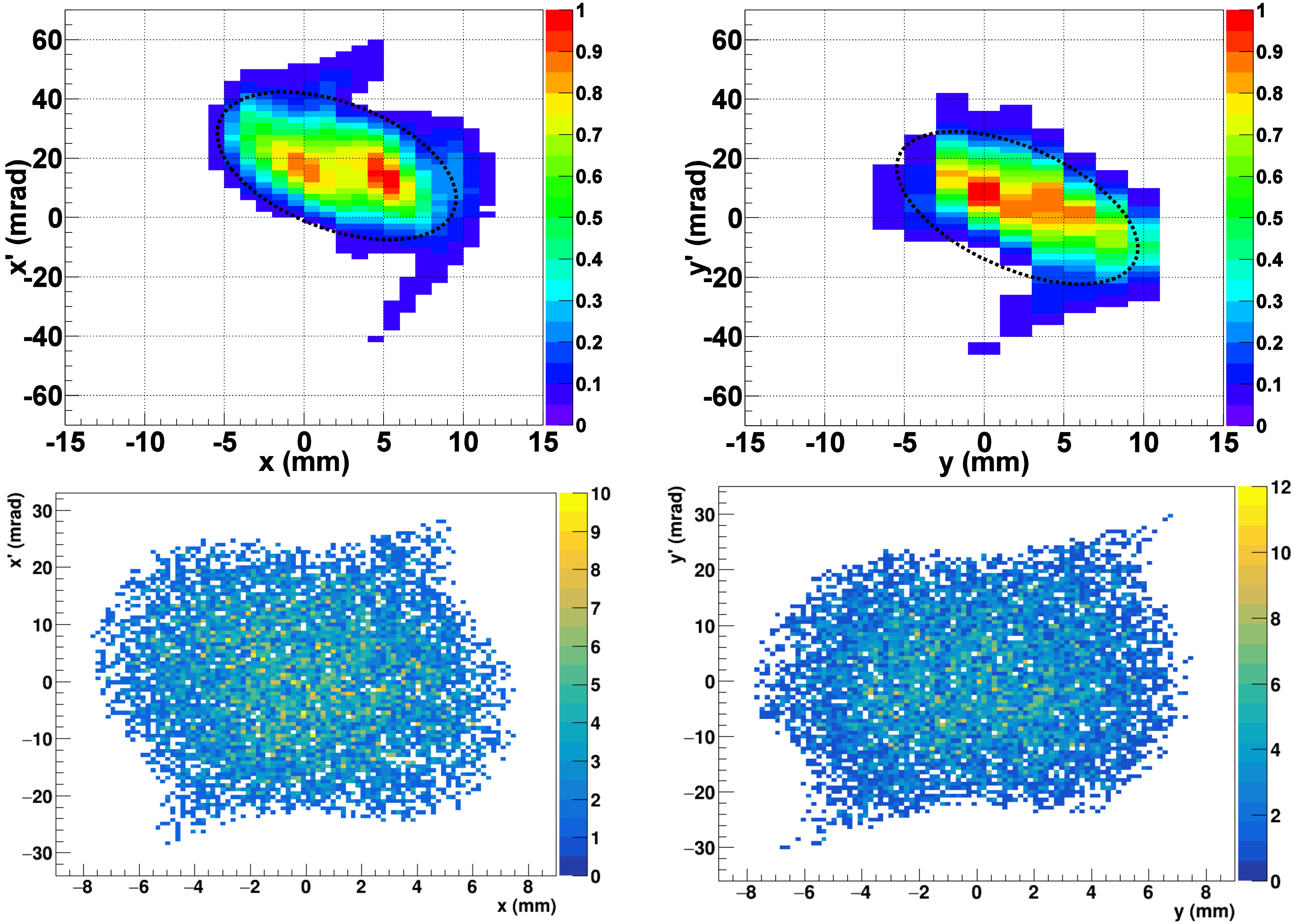
- Looking at GPT simulations of LEBT performance, comparing $\varepsilon = 0.4\pi$ (IPAC'14) & 0.25π mm mrad, 65keV beams
  - Owing to realisation that scanner data was too "coarse"

- Use IPAC'14 paper scanner data to estimate initial beam
  - Re-do Alan's reverse simulations done June'14
  - $\Rightarrow$ Initial beam is almost parallel, slightly convergent

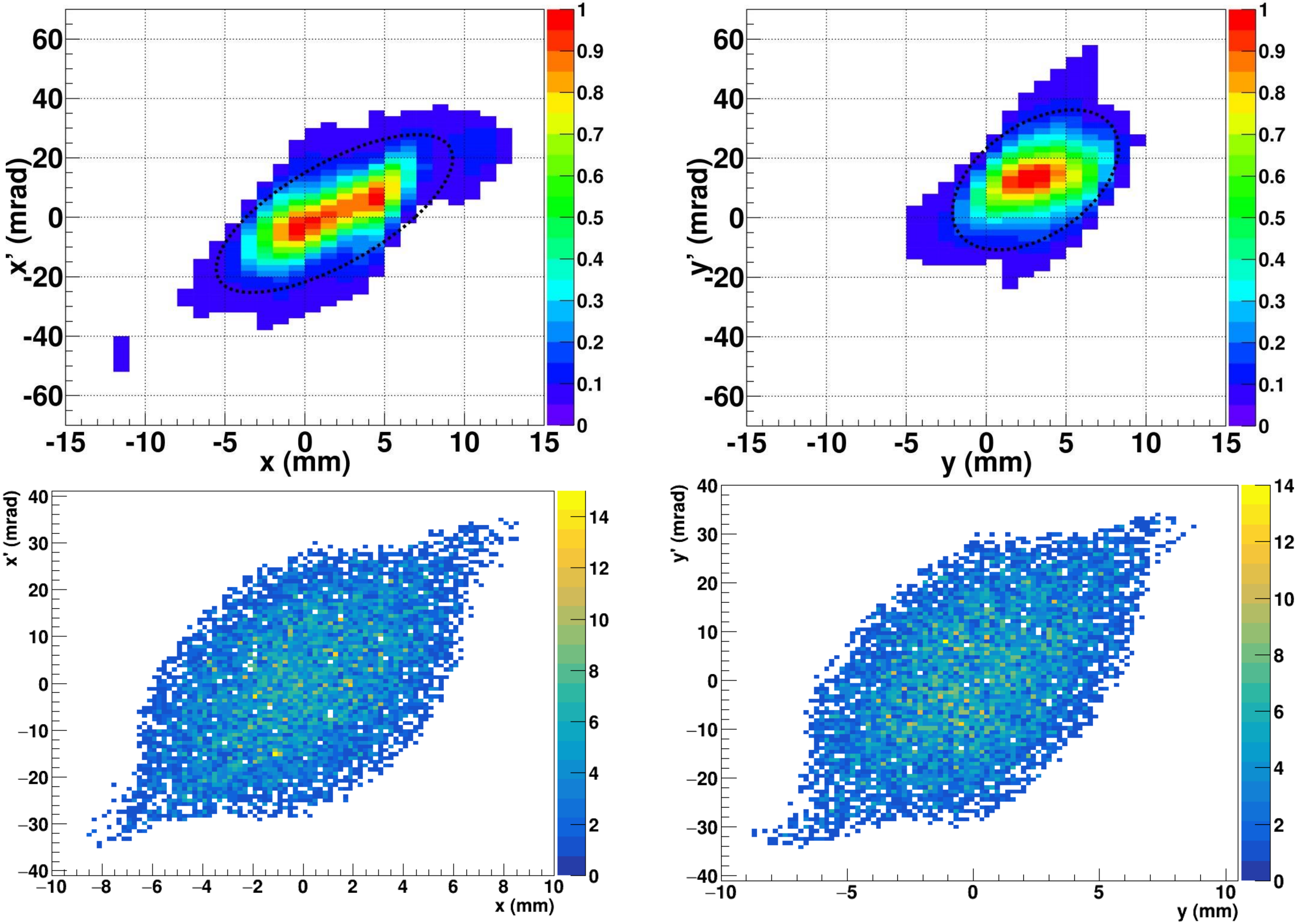
- Look at focusing solutions where 2nd solenoid is off
  - Allows us to use its steerers to adjust horiz/vert beam offsets
  - Extension of Alan's simulation work done in June'14

- Optimise 1st and 3rd solenoid currents to give best RFQ acceptance

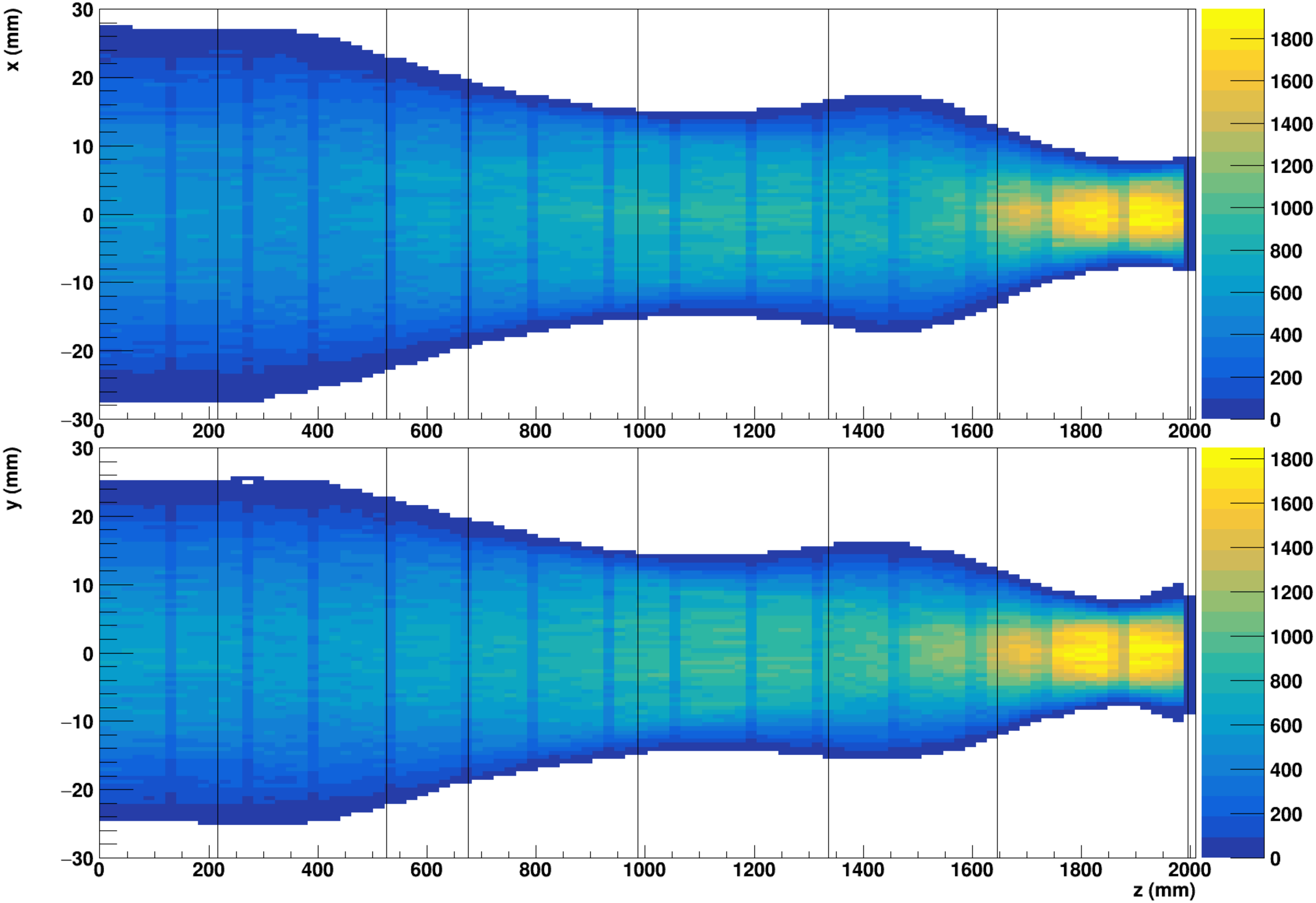
IPAC'14: I_1 = 130A, I_2 = 80A, I_3 = 220A, ε = 0.4π mm mrad
emittance scanner profiles: data (top), GPT (bottom)



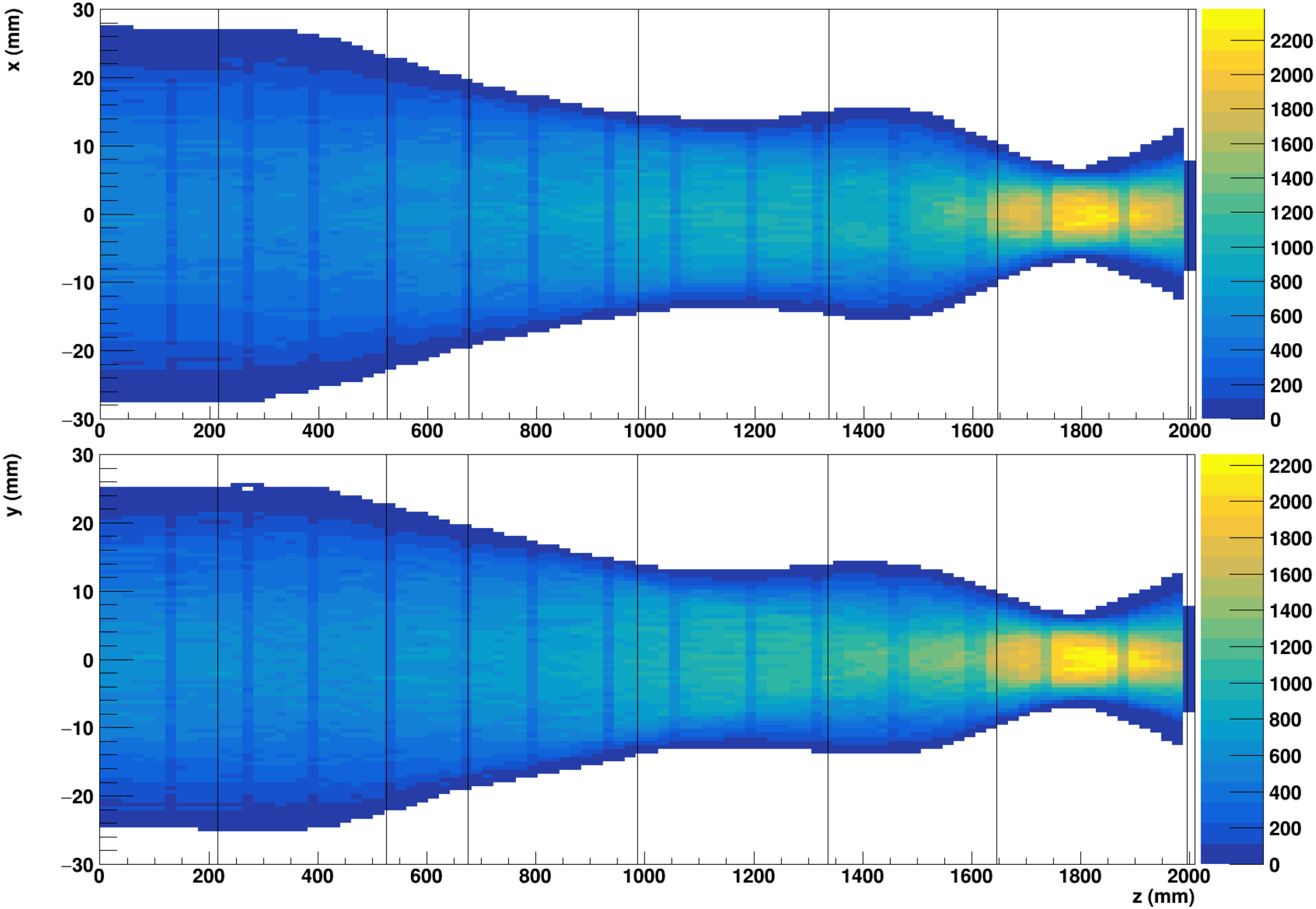
IPAC'14: I_1 = 130A, I_2 = 100A, I_3 = 245A, ε = 0.4π mm mrad emittance scanner profiles: data (top), GPT (bottom)



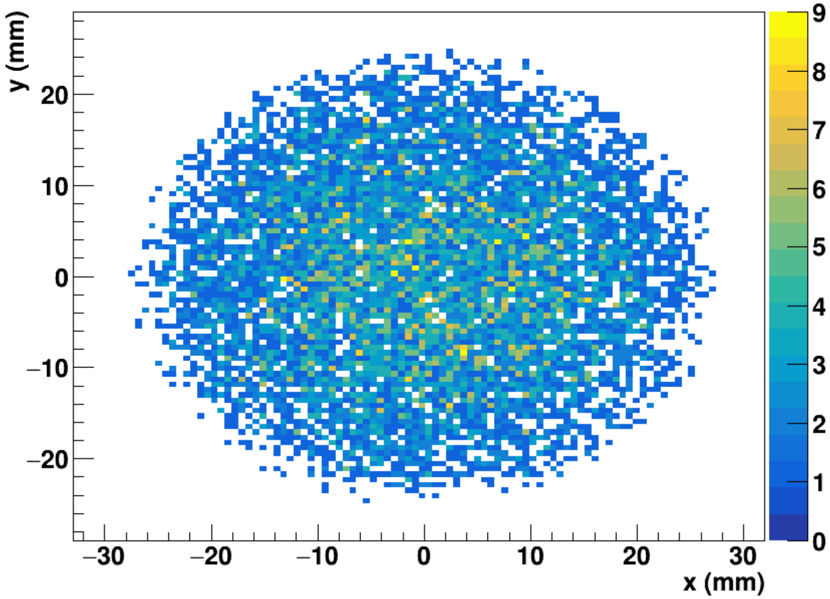
IPAC'14: I_1 = 130A, I_2 = 80A, I_3 = 220A, ε = 0.4π mm mrad
GPT beam profile, assuming space charge I = 12.5 mA

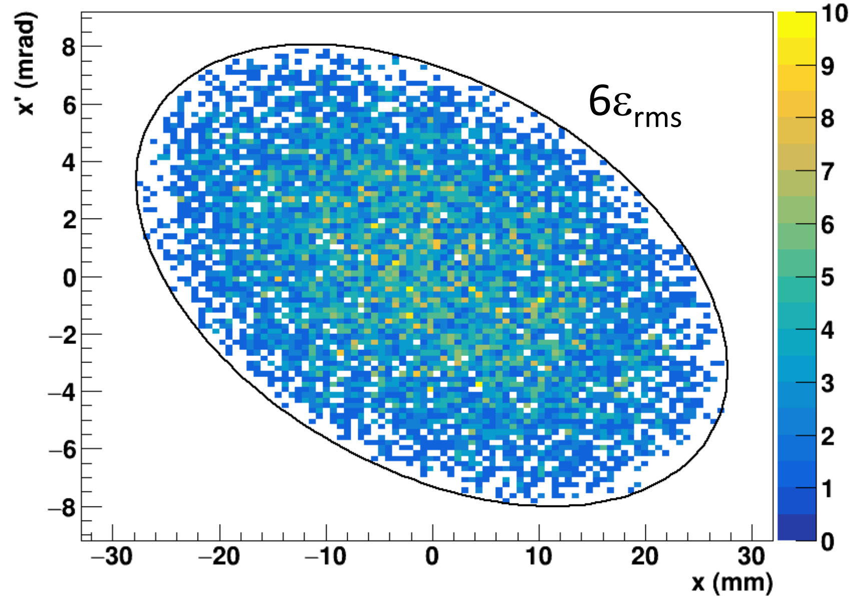


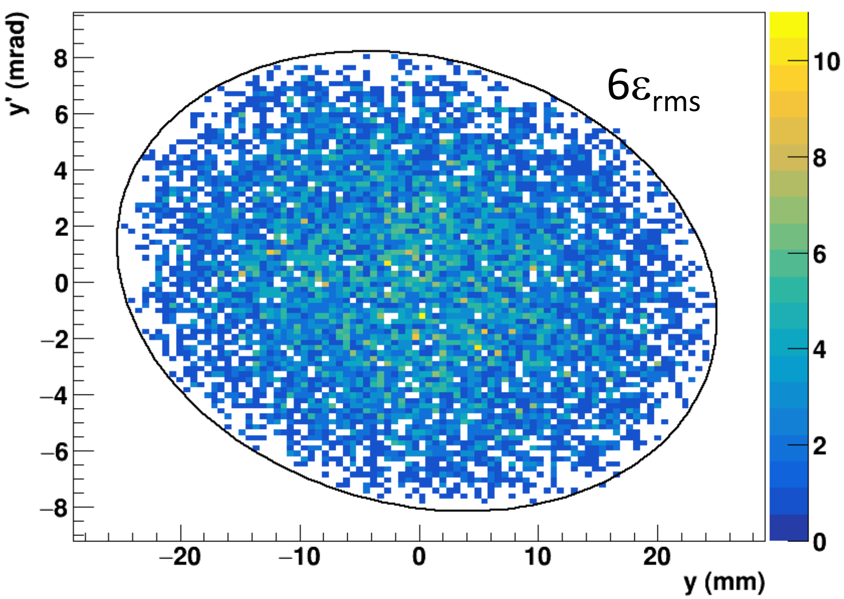
IPAC'14: I_1 = 130A, I_2 = 100A, I_3 = 245A, $\varepsilon = 0.4\pi$ mm mrad
GPT beam profile, assuming space charge I = 12.5 mA



Initial beam based on reverse sim: $\varepsilon = 0.4\pi$ mm mrad







Region = Start

<x> = -0.03 mm, <x'> = 0.02 mrad

<y> = -0.16 mm, <y'> = 0.03 mrad

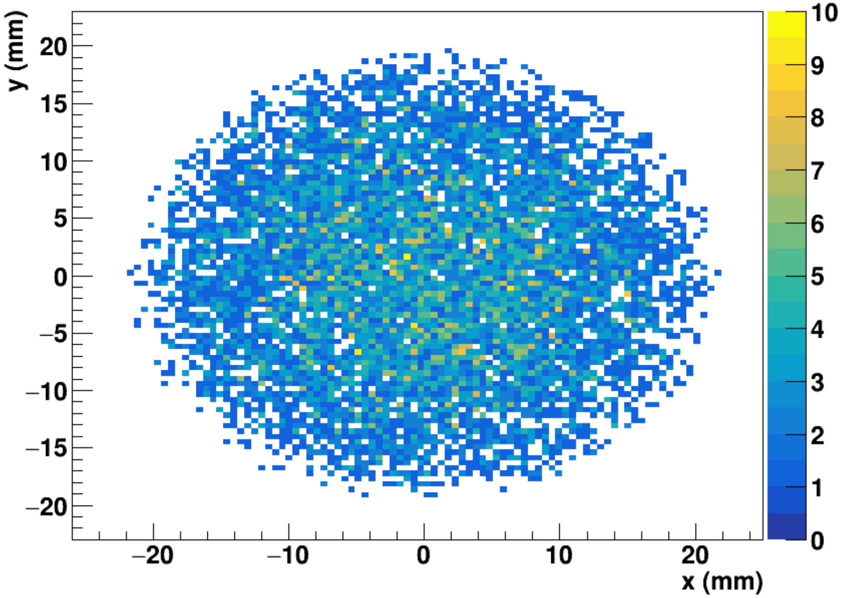
$\alpha_x = 0.45,\ \beta_x = 3.78,\ \gamma_x = 0.32;\ \ (1 + \alpha_x^2)/\beta_x = 0.32$

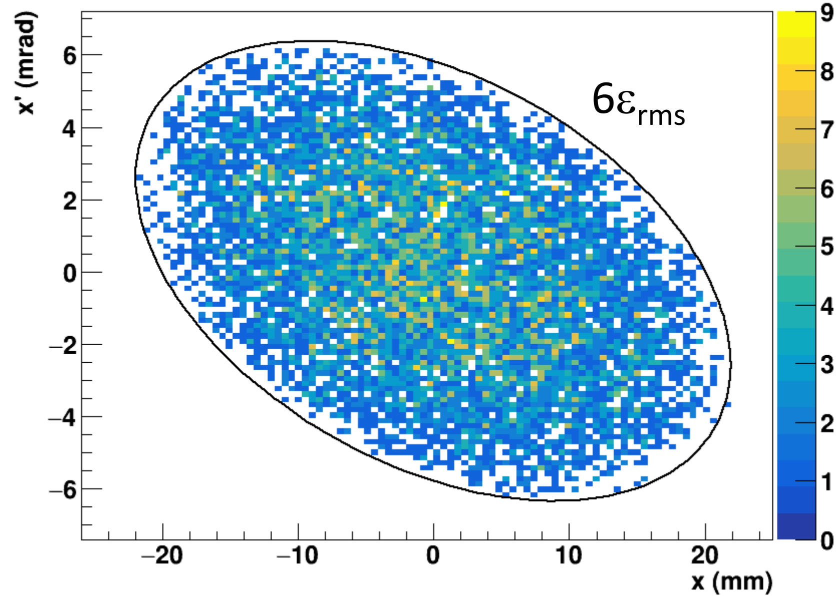
$\alpha_y = 0.17,\ \beta_y = 3.12,\ \gamma_y = 0.33;\ \ (1 + \alpha_y^2)/\beta_y = 0.33$

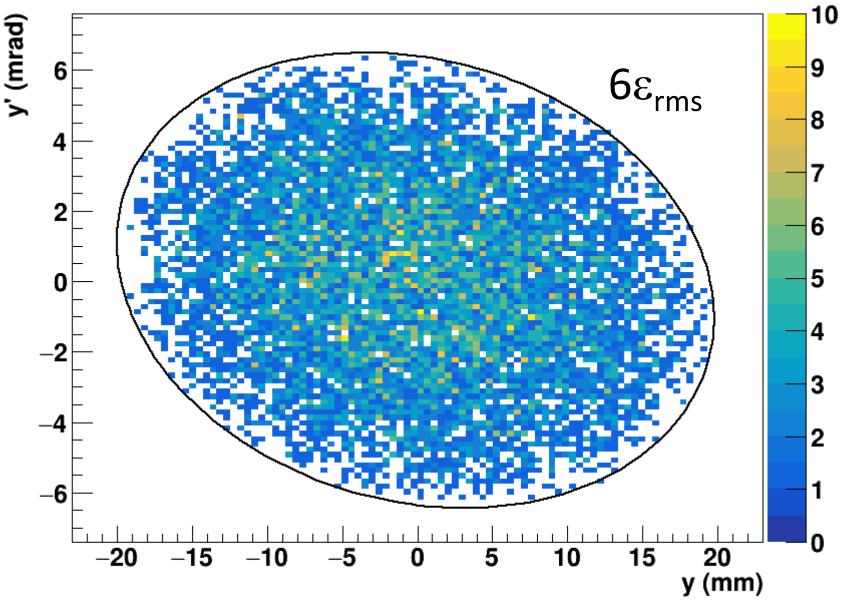
$\epsilon_x = 203.70$, Norm $\epsilon_x = 2.40$, Norm rms $\epsilon_x = 0.40$

$\epsilon_y = 202.77$, Norm $\epsilon_y = 2.39$, Norm rms $\epsilon_y = 0.40$

Initial beam based on reverse sim: ε = 0.25π mm mrad







Region = Start

$\langle x \rangle$ = -0.02 mm, $\langle x' \rangle$ = 0.02 mrad

$\langle y \rangle$ = -0.13 mm, $\langle y' \rangle$ = 0.02 mrad

$\alpha_x = 0.45$, $\beta_x = 3.78$, $\gamma_x = 0.32$; $(1 + \alpha_x^2)/\beta_x = 0.32$

$\alpha_y = 0.17$, $\beta_y = 3.12$, $\gamma_y = 0.33$; $(1 + \alpha_y^2)/\beta_y = 0.33$

ϵ_x = 127.31, Norm ϵ_x = 1.50, Norm rms ϵ_x = 0.25

ϵ_y = 126.73, Norm ϵ_y = 1.49, Norm rms ϵ_y = 0.25

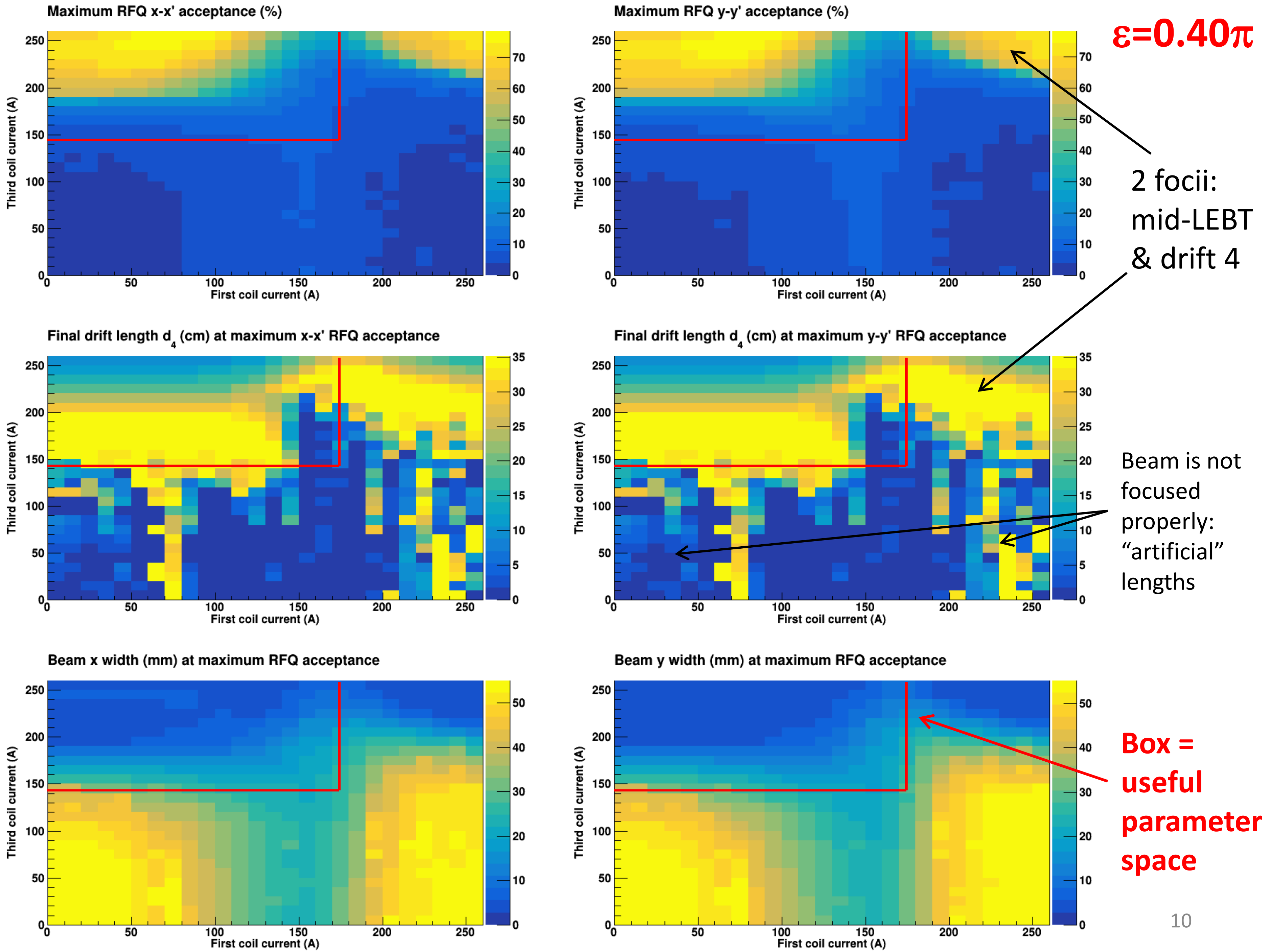
Optimisation

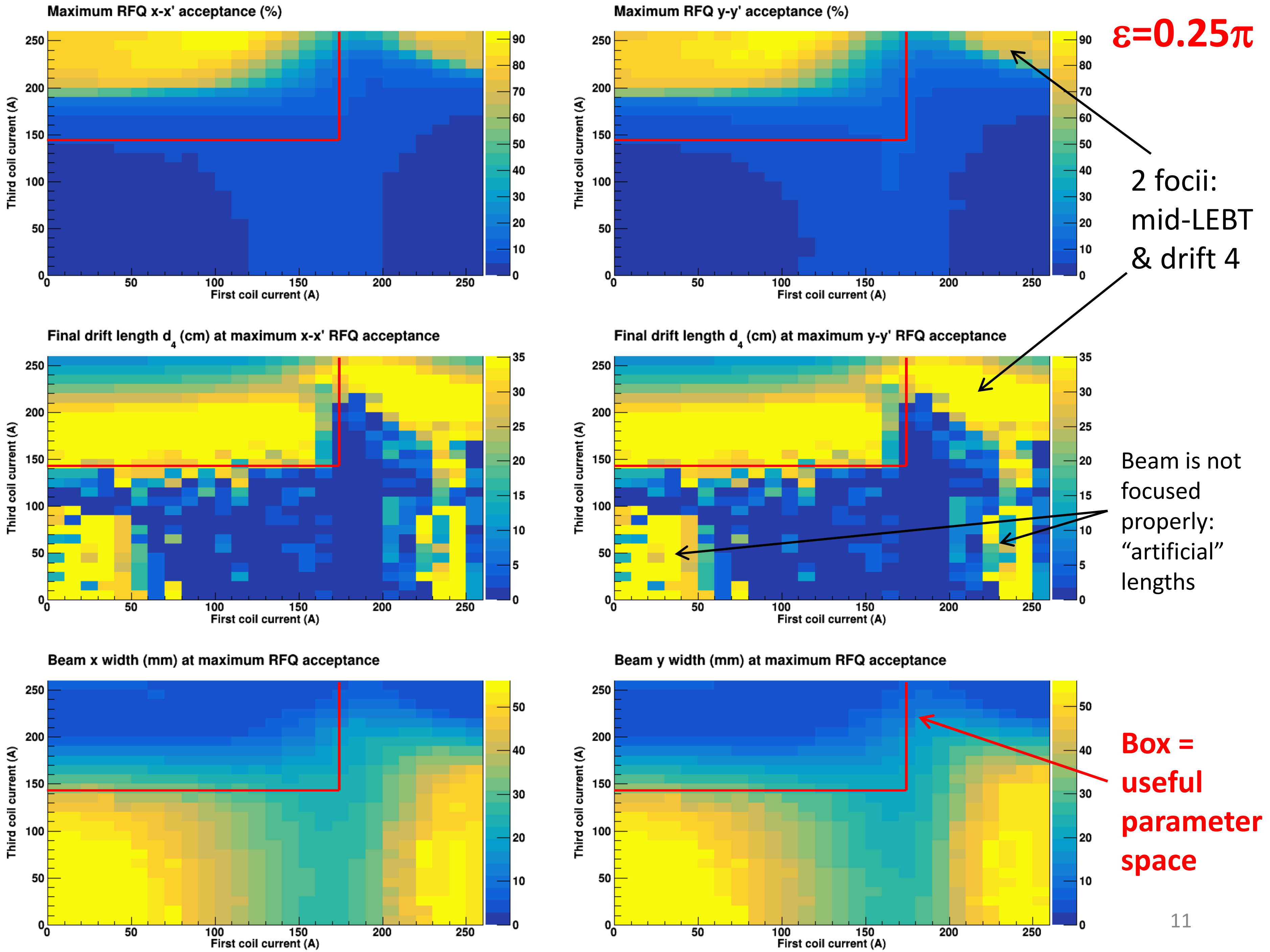
- Start with previous initial beam distributions
  - Assume $\varepsilon = 0.4\pi$ and 0.25π mm mrad; 12.5 mA space charge, 65 keV
  - Drifts: $d_1 = 21.6$ cm, $d_2 = 15$ cm, $d_3 = 35$ cm; d_4 varies
  - Solenoid lengths 31 cm, B_z (T) $\approx 1.3\text{x}10^{-3}$ I, I = solenoid current (A)
  - Solenoid r-z field map from Comsol simulation (2014 studies)

- Vary 1st and 3rd solenoid currents: I_1 and I_3
  - I_2 fixed at 0 A $\Rightarrow$ its dipole steerers "decoupled" from solenoid fields
  - Current range: 0 to 250 A; power supply limit is 245 A

- For final drift, find z position that gives largest RFQ acceptance fraction
  - Need d_4 to be within the range 13.66 ± 5.00 cm
- Choose I_1 and I_3 that gives maximum acceptance

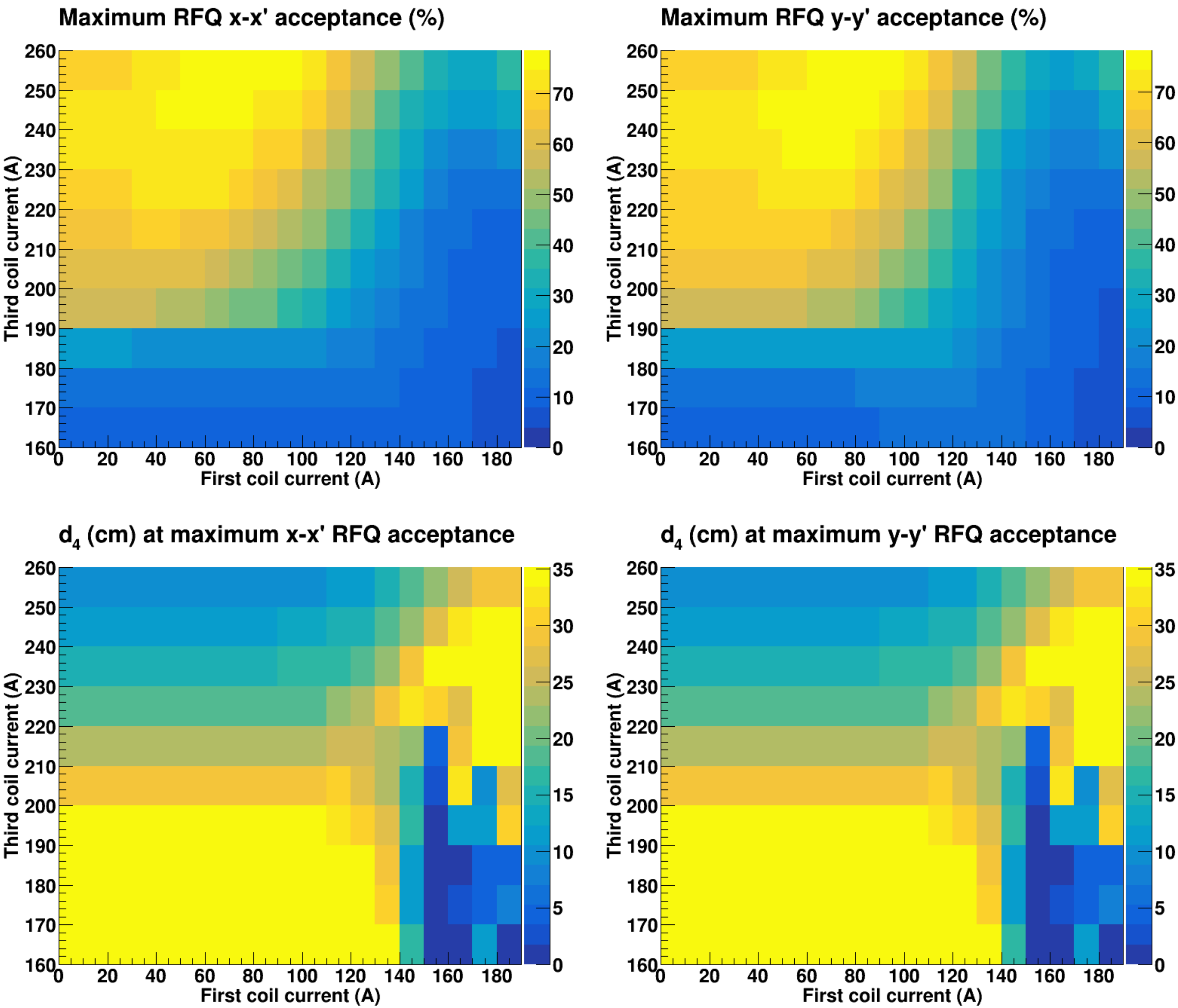
- Next series of plots for $\varepsilon = 0.4\pi$ and 0.25π mm mrad options:
  - Given I_1 and I_3: max achievable RFQ acceptance, d_4 & beam size
  - Beam envelope and RFQ acceptance for best focusing solution


Maximum RFQ x-x' acceptance (%)
Maximum RFQ y-y' acceptance (%)
Final drift length d4 (cm) at maximum x-x' RFQ acceptance
Final drift length d4 (cm) at maximum y-y' RFQ acceptance
Beam x width (mm) at maximum RFQ acceptance
Beam y width (mm) at maximum RFQ acceptance
Third coil current (A)
First coil current (A)
ε=0.40π
2 focii:
mid-LEBT
& drift 4
Beam is not
focused
properly:
"artificial"
lengths
Box =
useful
parameter
space

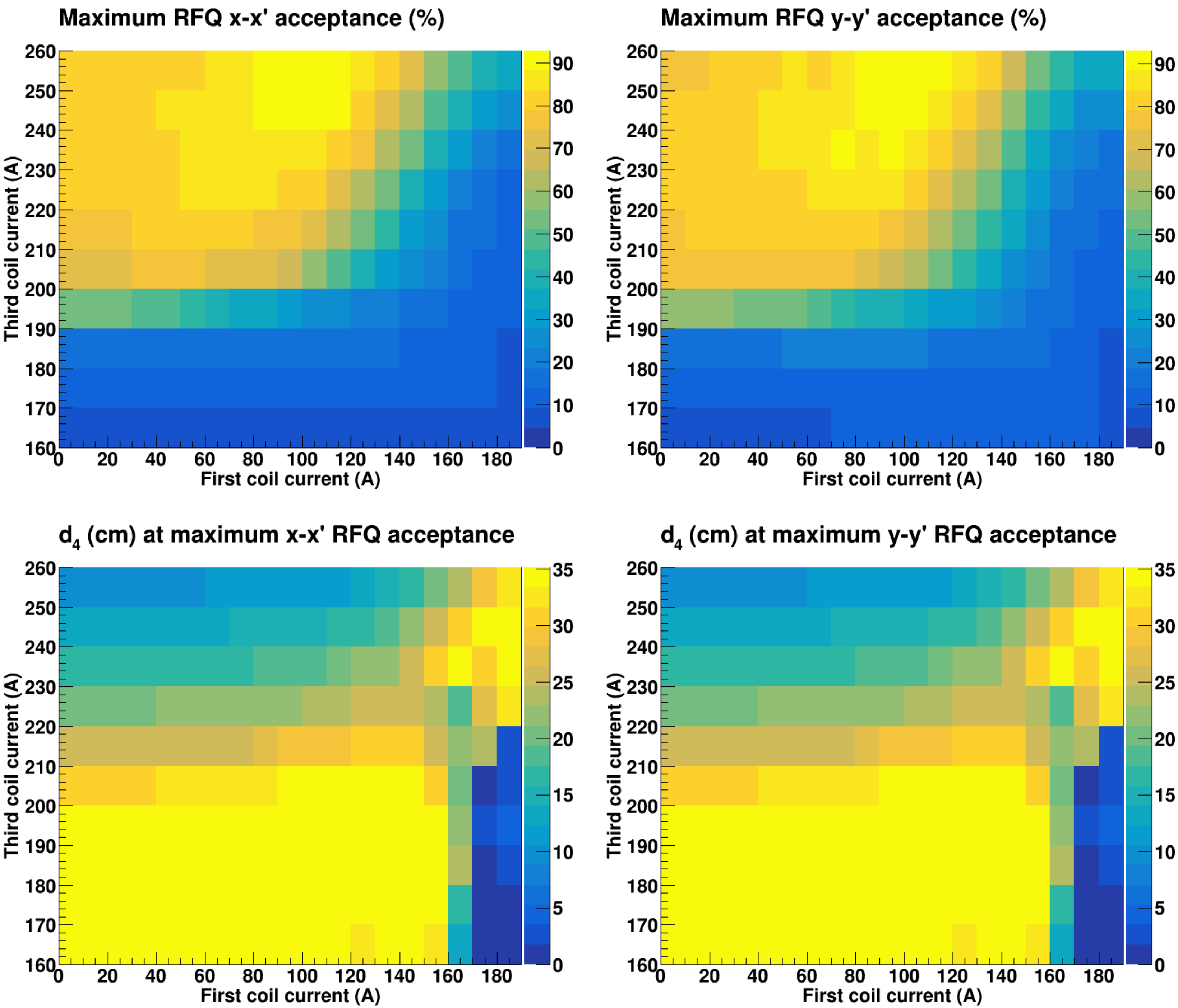


Maximum RFQ x-x' acceptance (%)
Maximum RFQ y-y' acceptance (%)
ε=0.25π
2 focii:
mid-LEBT
& drift 4
Final drift length d_4 (cm) at maximum x-x' RFQ acceptance
Final drift length d_4 (cm) at maximum y-y' RFQ acceptance
Beam is not
focused
properly:
"artificial"
lengths
Beam x width (mm) at maximum RFQ acceptance
Beam y width (mm) at maximum RFQ acceptance
Box =
useful
parameter
space
Third coil current (A)
First coil current (A)

$\varepsilon=0.40\pi$



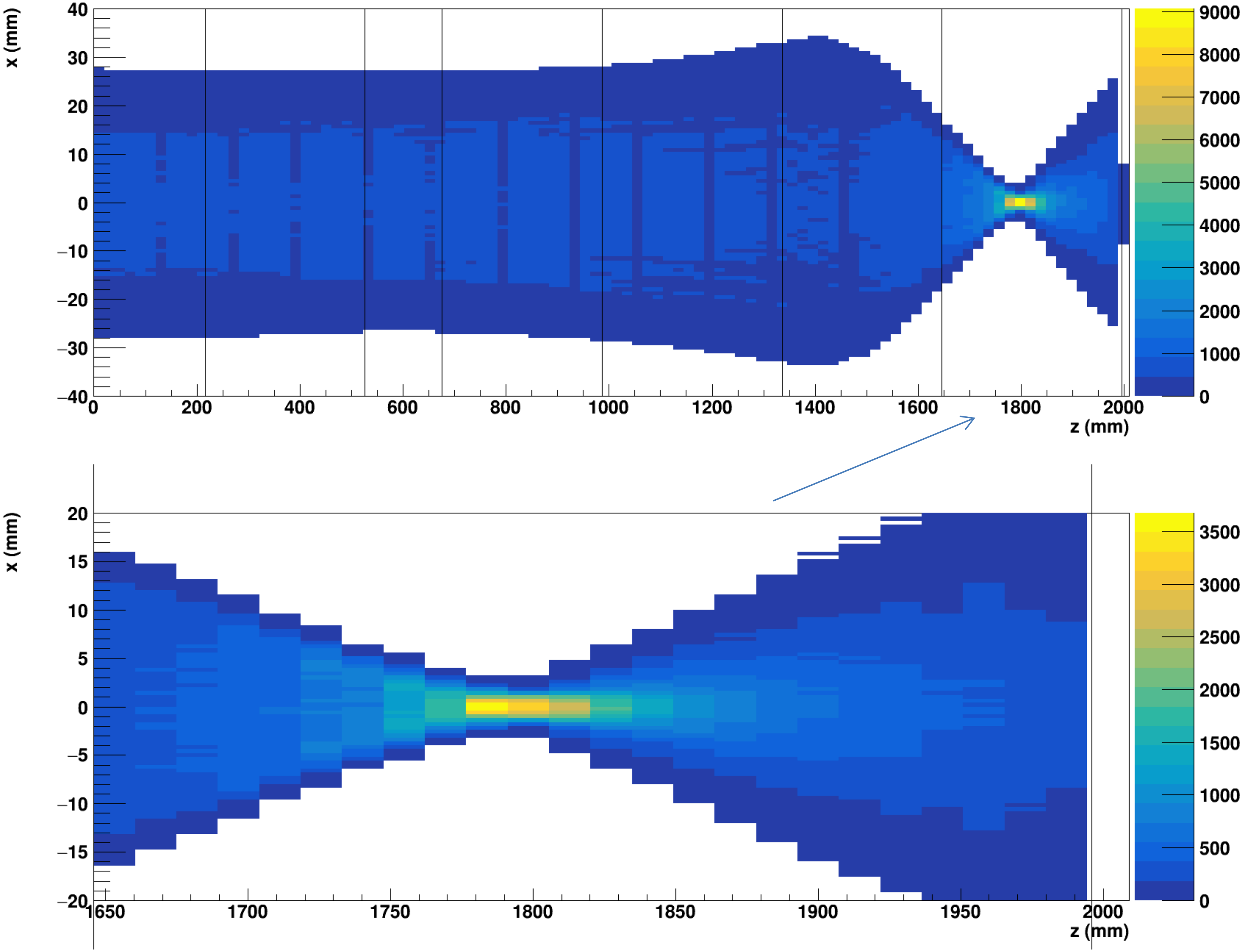
Zoomed regions of interest



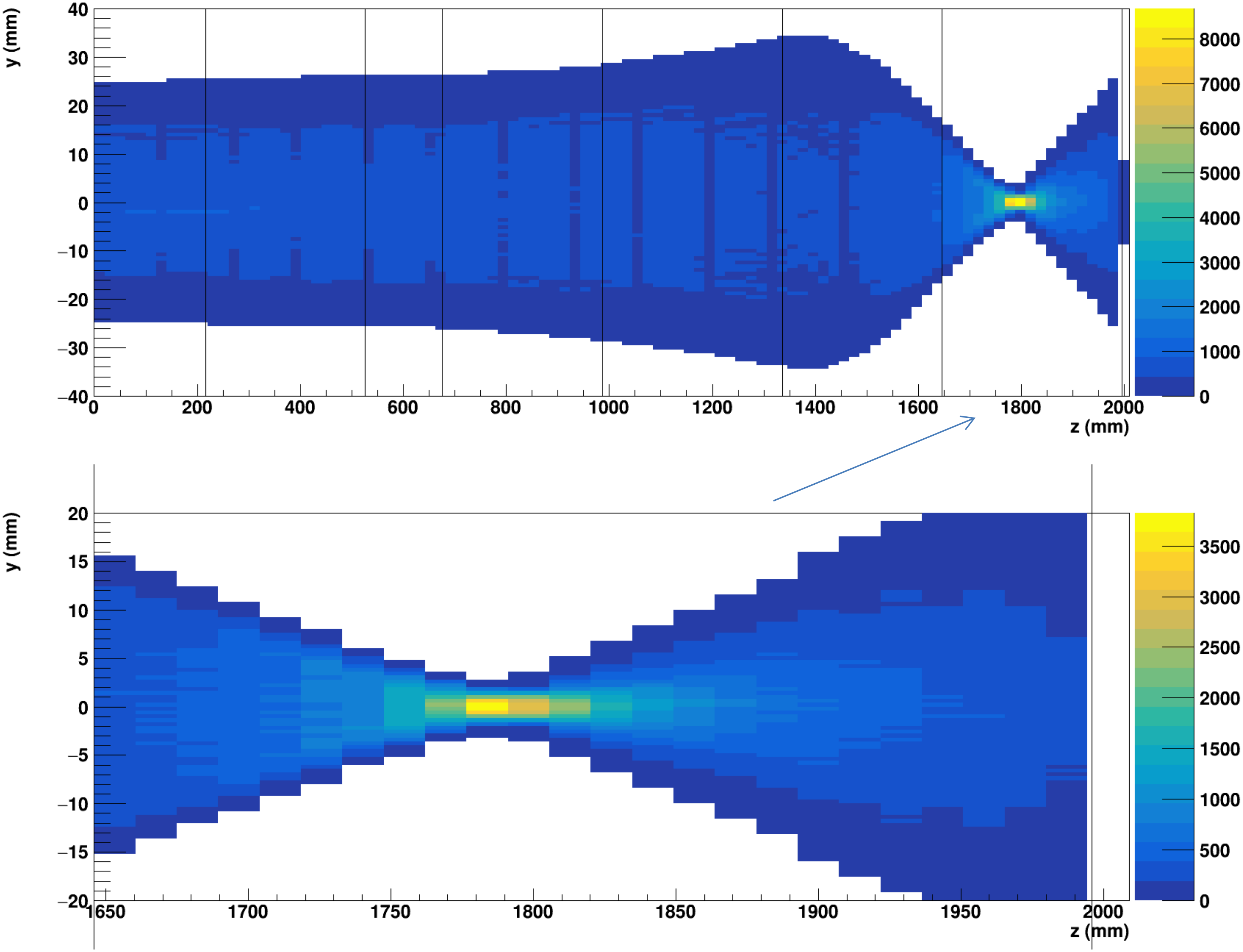
ε=0.25π

Zoomed regions of interest

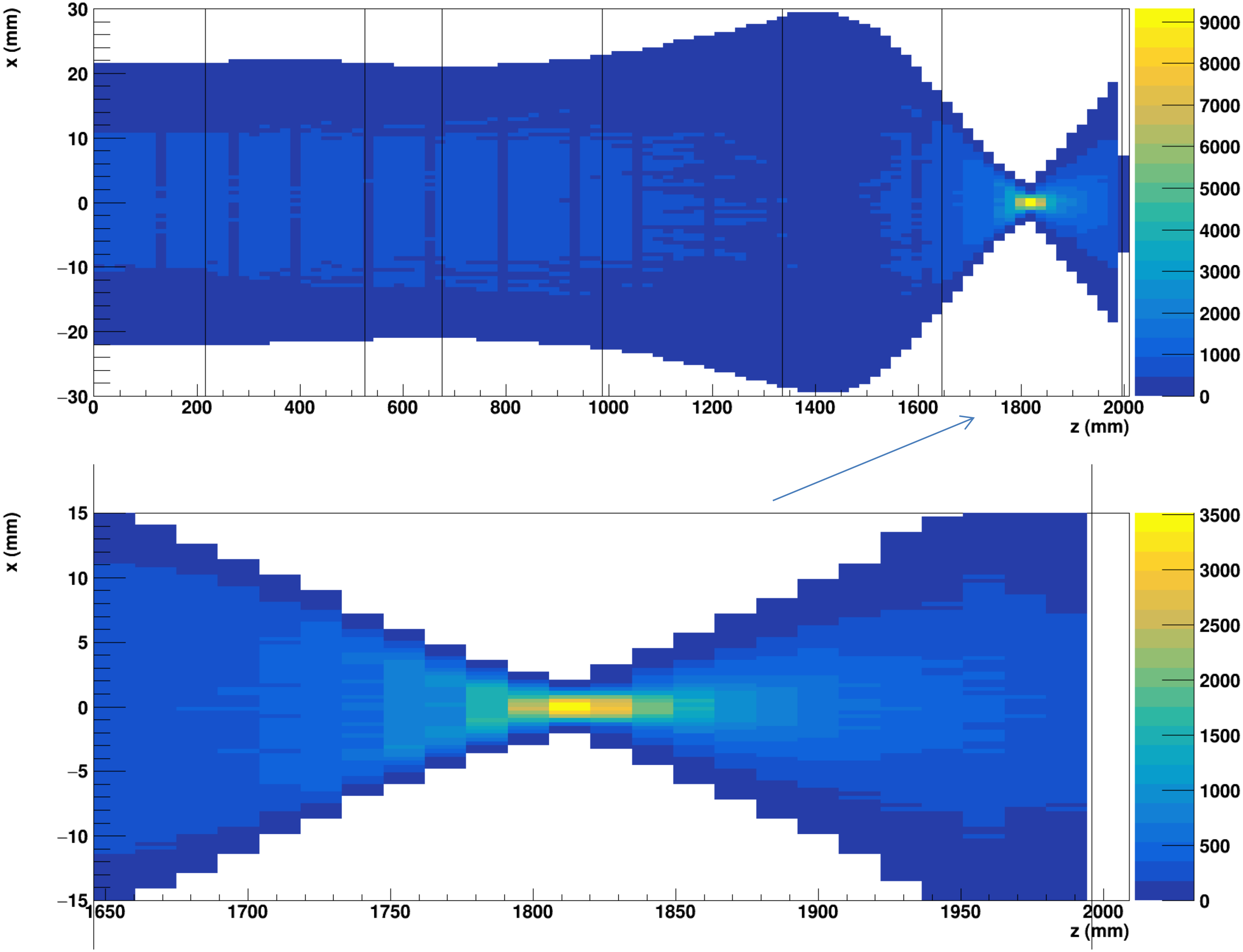
x-z profile for I_1 = 70A, I_2 = 0A, I_3 = 245A, ε=0.40π mm mrad



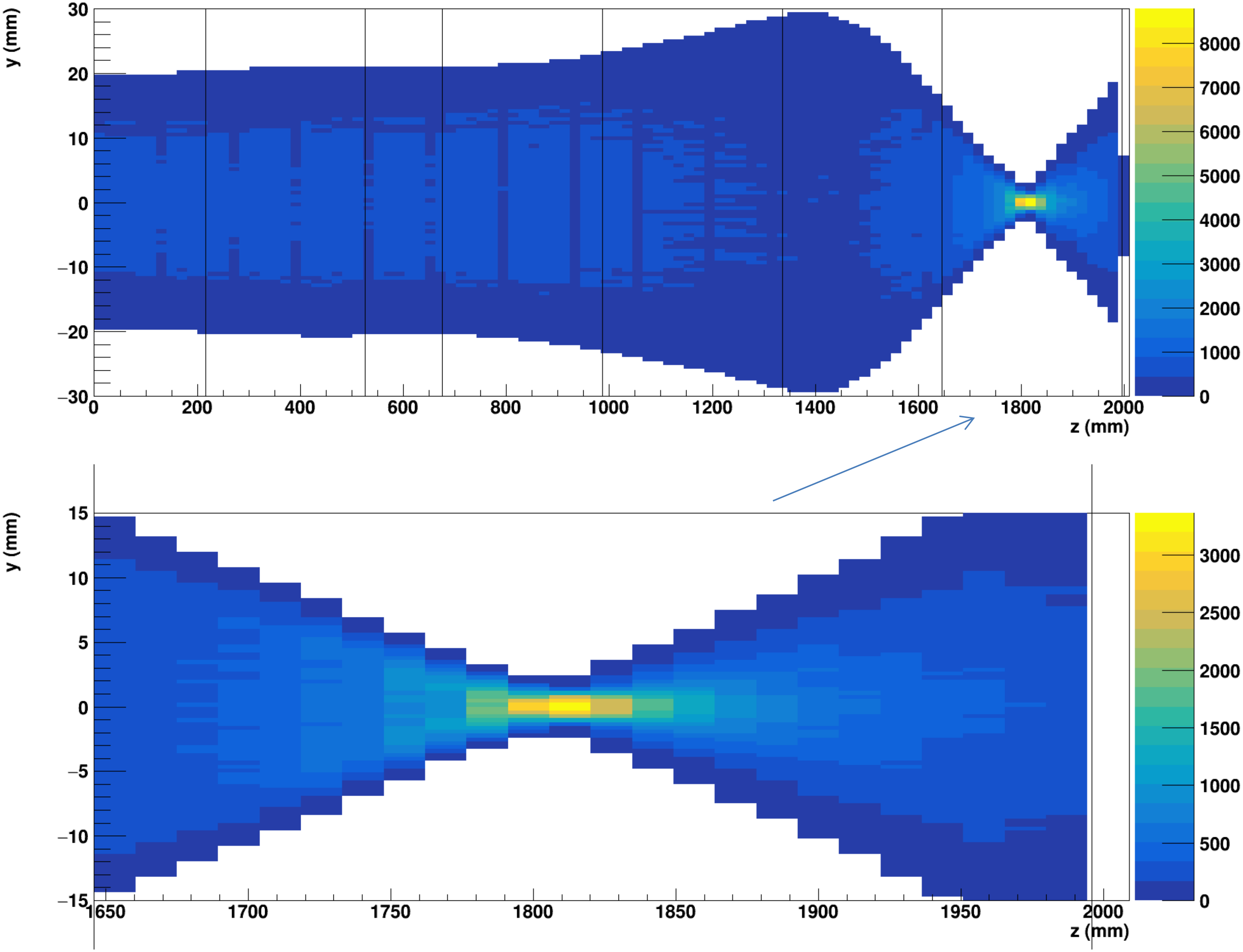
y-z profile for I_1 = 70A, I_2 = 0A, I_3 = 245A, ε=0.40π mm mrad



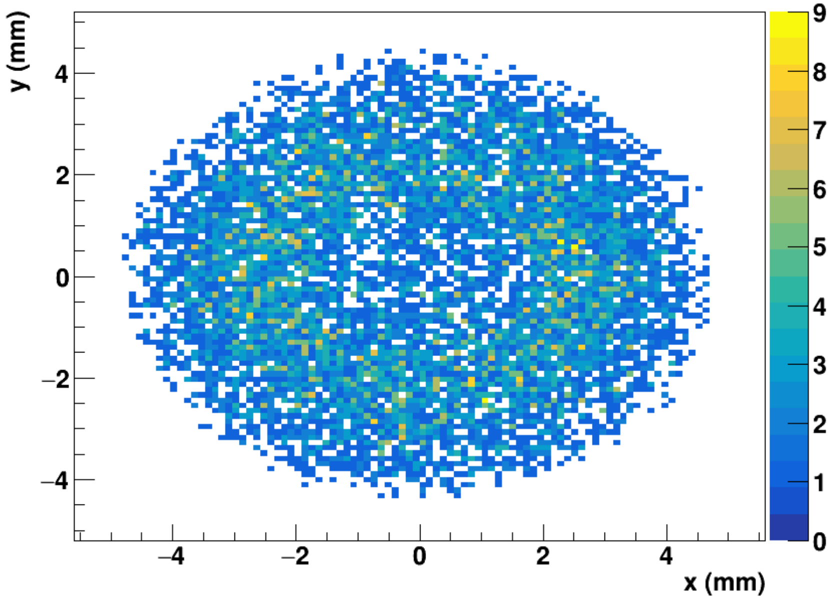
x-z profile for I_1 = 95A, I_2 = 0A, I_3 = 245A, ε=0.25π mm mrad

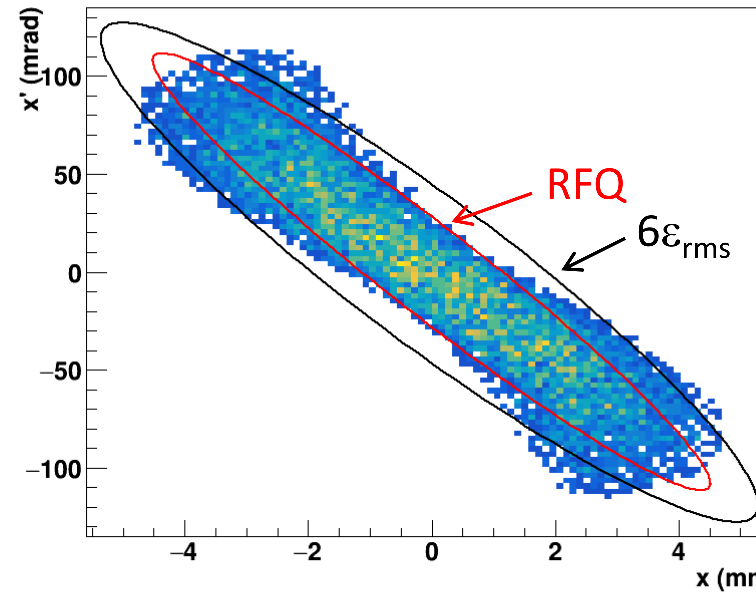


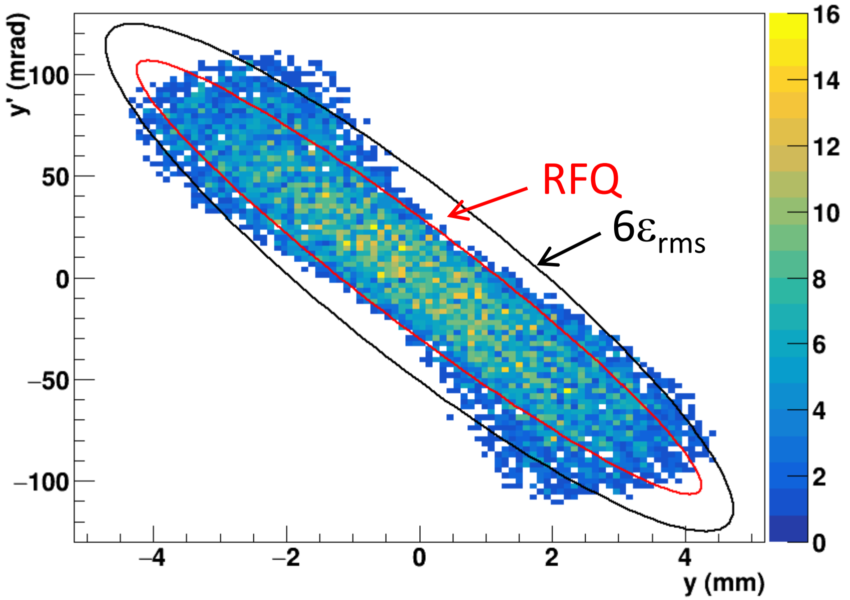
y-z profile for I_1 = 95A, I_2 = 0A, I_3 = 245A, ε=0.25π mm mrad



Acceptance: I_1 = 70A, I_2 = 0A, I_3 = 245A, ε=0.40π mm mrad







Region = 110 mm from start of drift 4

<x> = -0.03 mm, <x'> = -0.27 mrad

<y> = 0.01 mm, <y'> = -0.05 mrad

α_x = 2.60, β_x = 0.12, γ_x = 66.77; $(1+\alpha_x^2)/\beta_x$ = 66.77

α_y = 2.23, β_y = 0.09, γ_y = 64.57; $(1+\alpha_y^2)/\beta_y$ = 64.57

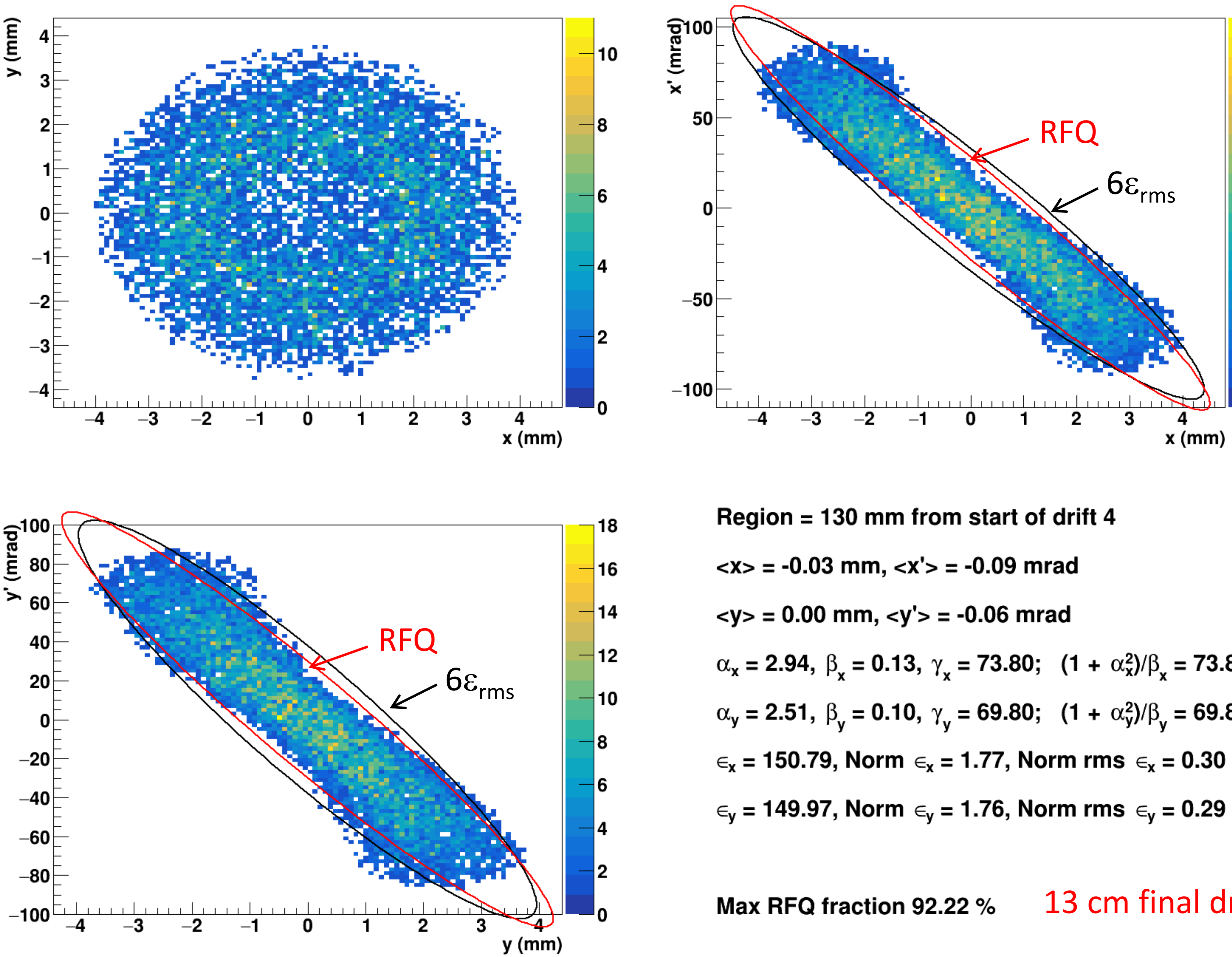
ϵ_x = 243.47, Norm ϵ_x = 2.86, Norm rms ϵ_x = 0.48

ϵ_y = 241.41, Norm ϵ_y = 2.84, Norm rms ϵ_y = 0.47

Max RFQ fraction 77.94 %

11 cm final drift

Acceptance: I_1 = 95A, I_2 = 0A, I_3 = 245A, ε=0.25π mm mrad



Region = 130 mm from start of drift 4

<x> = -0.03 mm, <x'> = -0.09 mrad

<y> = 0.00 mm, <y'> = -0.06 mrad

$\alpha_x = 2.94$, $\beta_x = 0.13$, $\gamma_x = 73.80$; $(1 + \alpha_x^2)/\beta_x = 73.80$

$\alpha_y = 2.51$, $\beta_y = 0.10$, $\gamma_y = 69.80$; $(1 + \alpha_y^2)/\beta_y = 69.80$

$\epsilon_x = 150.79$, Norm $\epsilon_x = 1.77$, Norm rms $\epsilon_x = 0.30$

$\epsilon_y = 149.97$, Norm $\epsilon_y = 1.76$, Norm rms $\epsilon_y = 0.29$

Max RFQ fraction 92.22 %

13 cm final drift

Summary

- LEBT focusing re-optimised for two scenarios:
  - $\varepsilon = 0.40\pi$ and 0.25π mm mrad
  - Better focusing possible with reduced emittance
- Focusing solution(s) with 2nd solenoid off are consistent with final drift engineering constraint $d_4 = 13.66 \pm 5.00$ cm
  $\Rightarrow$ We can use 2nd solenoid dipole steerers for beam offsets
- Optimal solutions:
  - $I_1 = 70$ A, $I_2 = 0$ A, $I_3 = 245$ A, $d_4 = 11$ cm for $\varepsilon = 0.40\pi$ mm mrad
  - $I_1 = 95$ A, $I_2 = 0$ A, $I_3 = 245$ A, $d_4 = 13$ cm for $\varepsilon = 0.25\pi$ mm mrad
- Recommended parameters when LEBT is recommissioned:
  - $I_1 = 80 \pm 20$ A, $I_2 = 0$ A, $I_3 = 245$ A (consistent with Alan's findings)
  - Slight decrease in I_3 may be needed depending on power supply reliability
  - Keep final drift d_4 fixed at present value of 13.66 cm
    - Length between solenoid 3 exit face and entrance of RFQ radial matcher