THE UNIVERSITY OF WARWICK

LEBT Beam Focusing Simulations

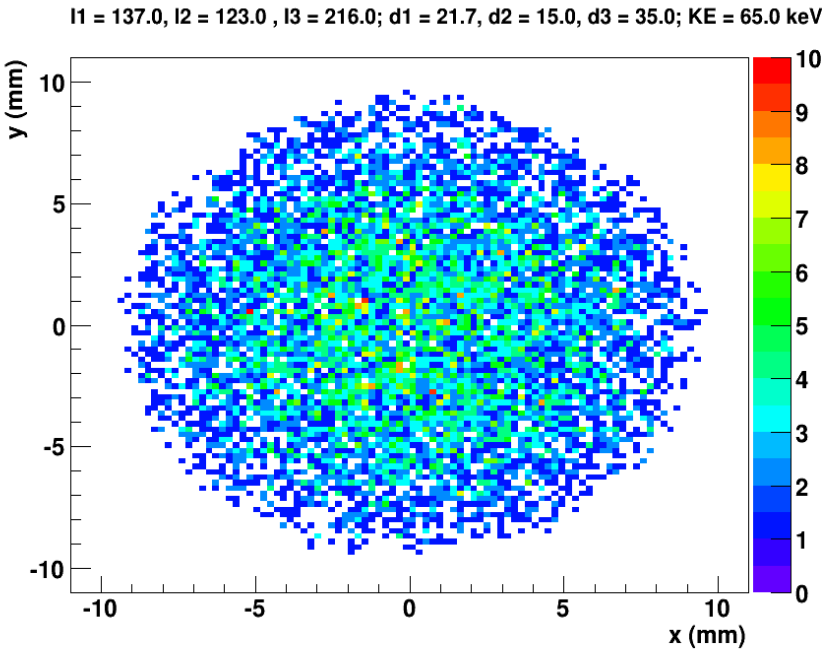
John Back
University of Warwick

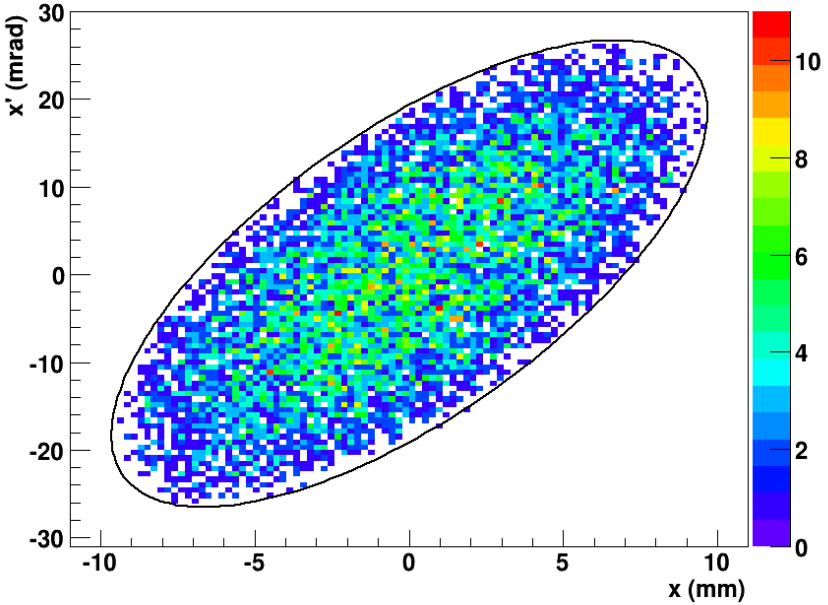
16th April 2014, FETS Mtg

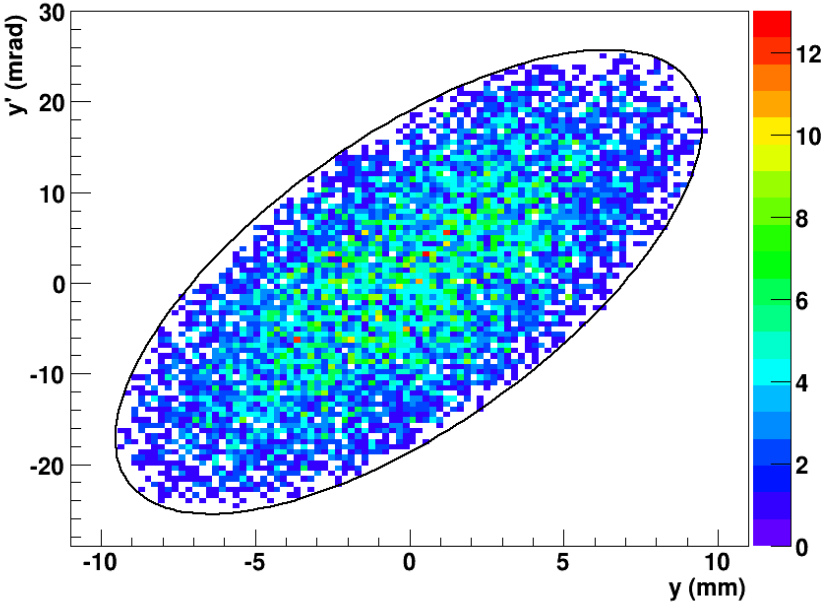
Introduction

- GPT simulations of LEBT beam focusing
  - 65 keV beam, 5 mA space charge, 10k events
  - initial beam Twiss parameters from (old) pepperpot data
- Systematic variation of (the 3) solenoid currents
  - Investigate allowed current ranges to get optimal beam focusing for RFQ acceptance
  - Choose I_1, vary I_2 and I_3 in 10 A steps (I_{max} = 250 A)
  - Focal length = final drift length where beam fraction inside RFQ acceptance ellipse is largest
  - Other drift lengths kept fixed (d_1 = 21.7cm, d_2 = 15cm, d_3 = 35cm)
- 2D histograms for main results:
  - RFQ fraction & focal length as a function of I_3 vs I_2 for given I_1

Assumed initial beam distribution







Region = Start

<x> = 0.02 mm, <x'> = 0.08 mrad

<y> = -0.02 mm, <y'> = 0.10 mrad

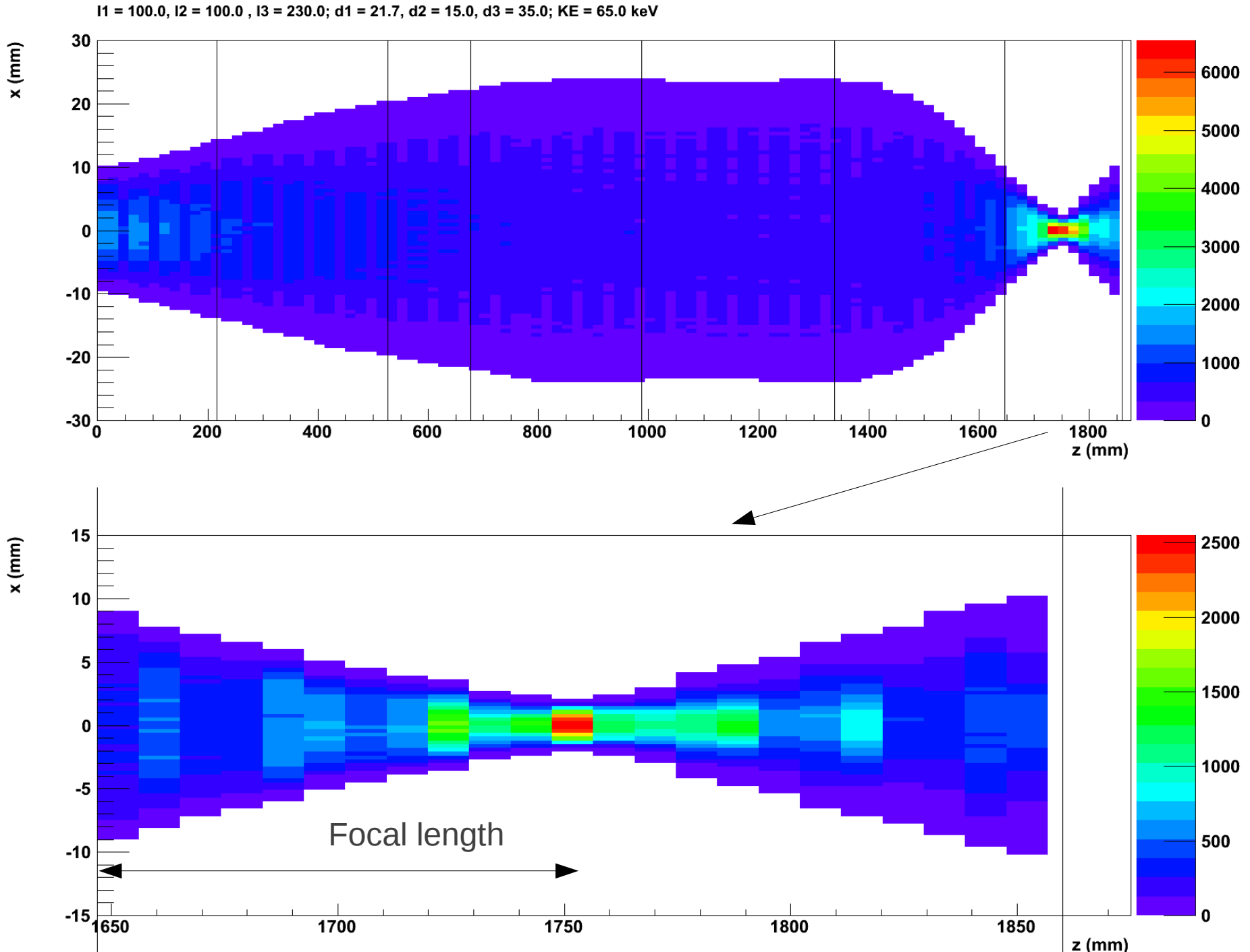
α_x = -0.96, β_x = 0.50, γ_x = 3.82; $(1 + \alpha_x^2)/\beta_x$ = 3.82

α_y = -0.92, β_y = 0.50, γ_y = 3.66; $(1 + \alpha_y^2)/\beta_y$ = 3.66

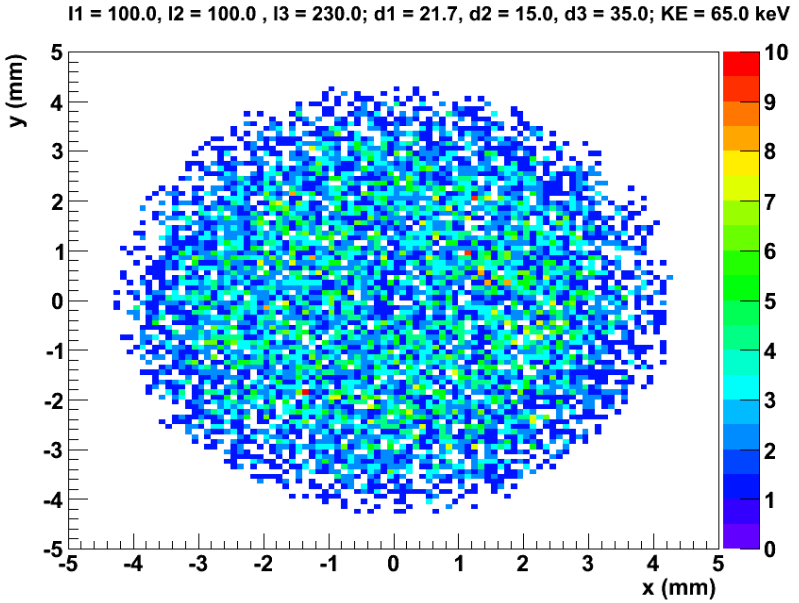
ϵ_x = 185.78, Norm ϵ_x = 2.19, Norm rms ϵ_x = 0.36

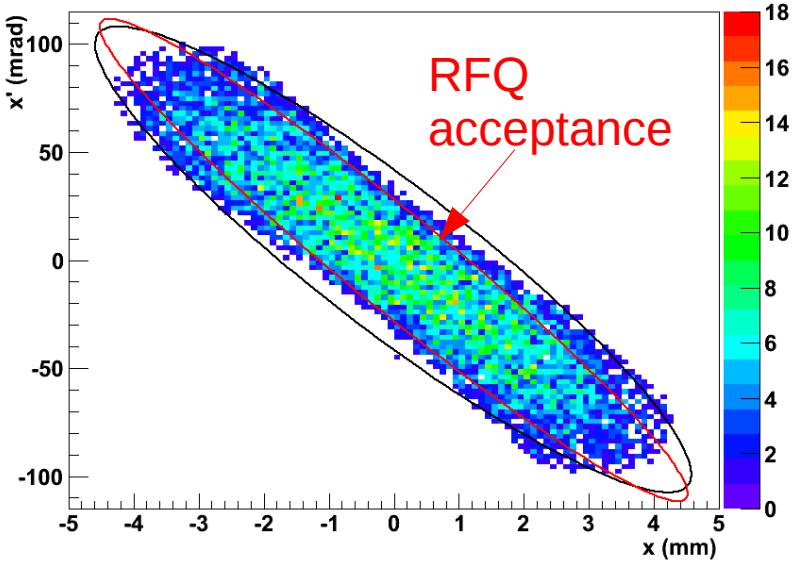
ϵ_y = 179.15, Norm ϵ_y = 2.11, Norm rms ϵ_y = 0.35

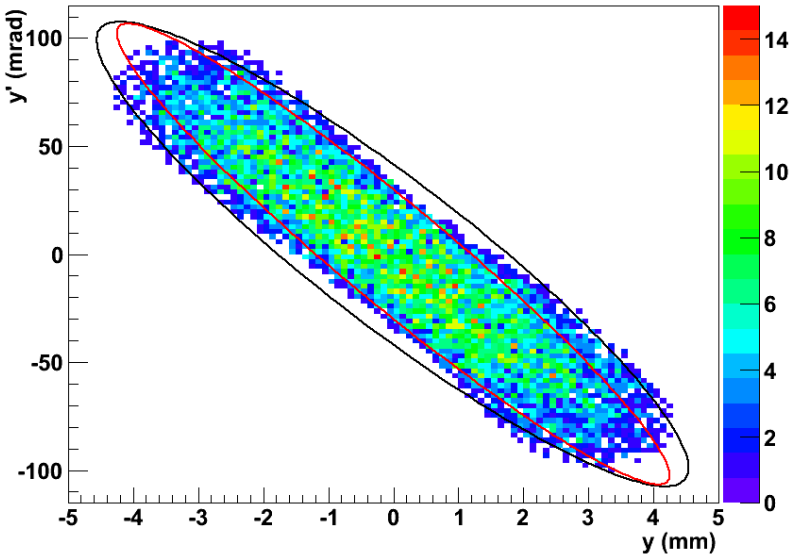
Example beam x-z envelope



Example “optimal” beam emittance at end of LEBT







Region = 60 mm from start of drift 4

<x> = -0.01 mm, <x'> = 0.35 mrad

<y> = -0.01 mm, <y'> = 0.02 mrad

α_x = 2.39, β_x = 0.11, γ_x = 60.93; $(1 + \alpha_x^2)/\beta_x$ = 60.93

α_y = 2.36, β_y = 0.11, γ_y = 60.71; $(1 + \alpha_y^2)/\beta_y$ = 60.71

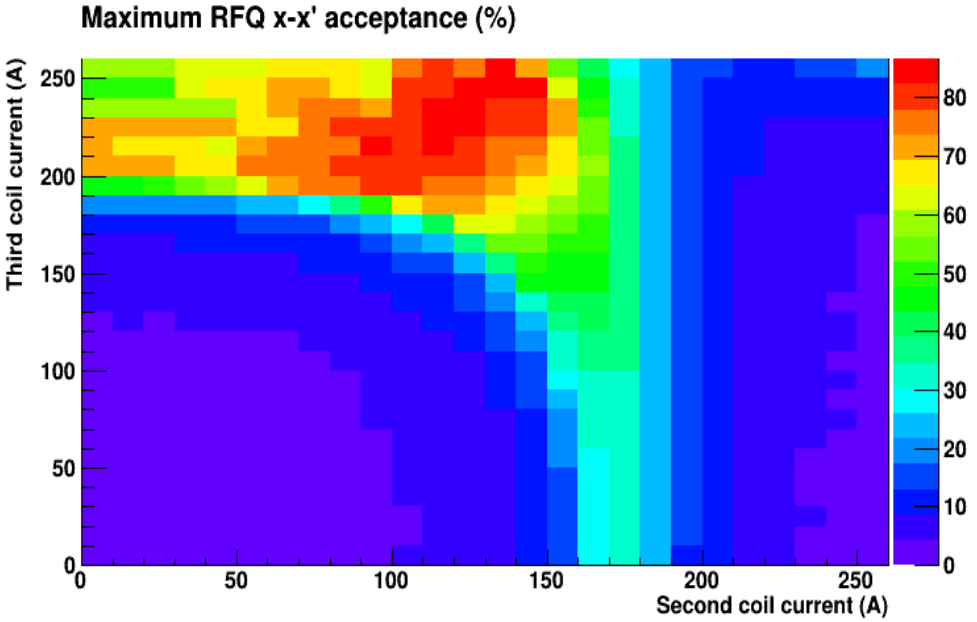
ϵ_x = 190.86, Norm ϵ_x = 2.25, Norm rms ϵ_x = 0.37

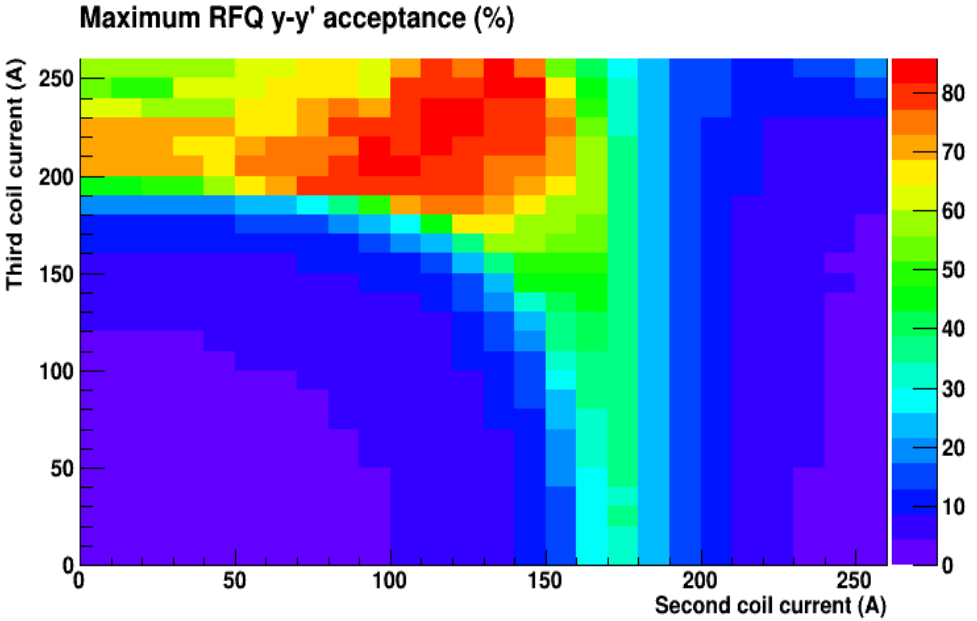
ϵ_y = 190.32, Norm ϵ_y = 2.24, Norm rms ϵ_y = 0.37

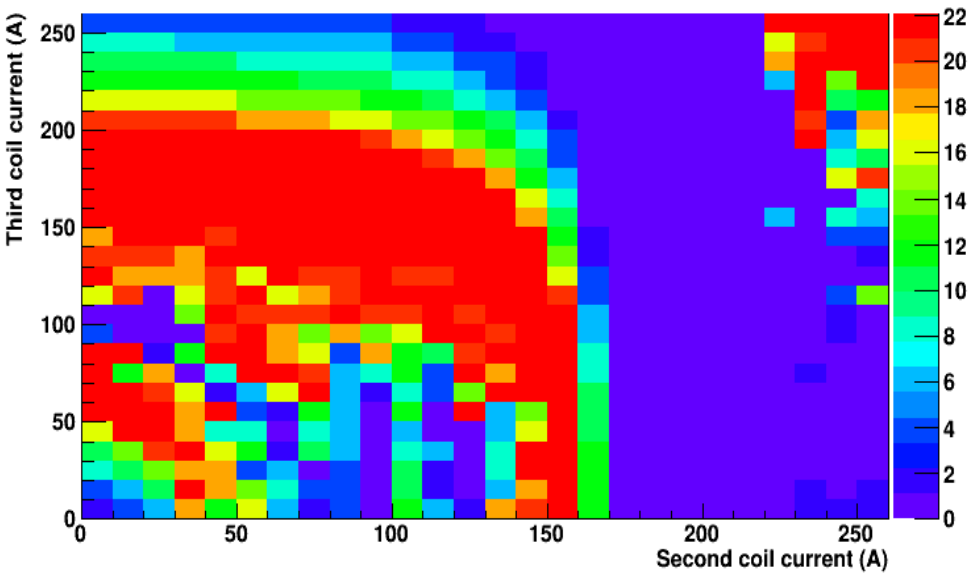
RFQ x fraction = 83.16 %, y fraction = 85.30 %

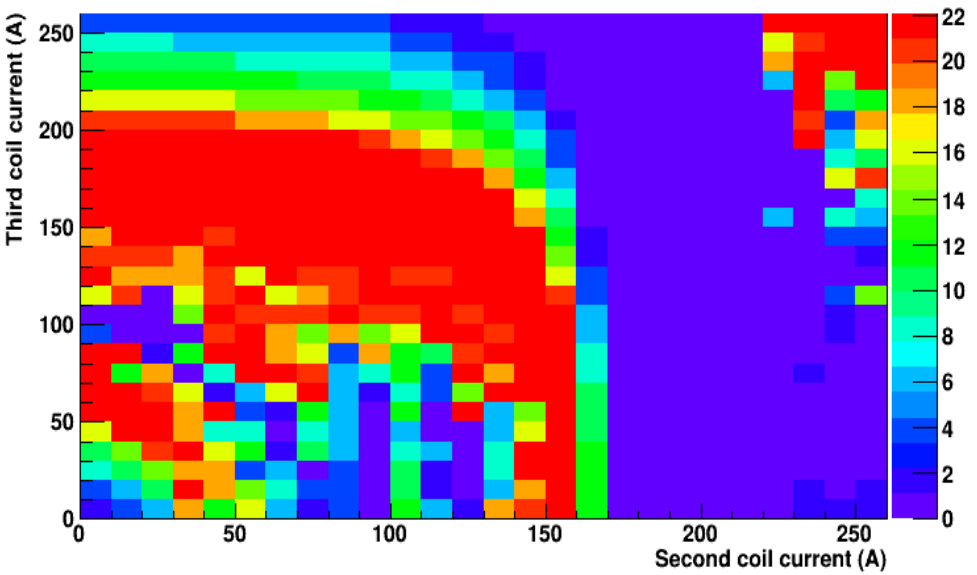
Max RFQ fraction

$I_1 = 0$ A

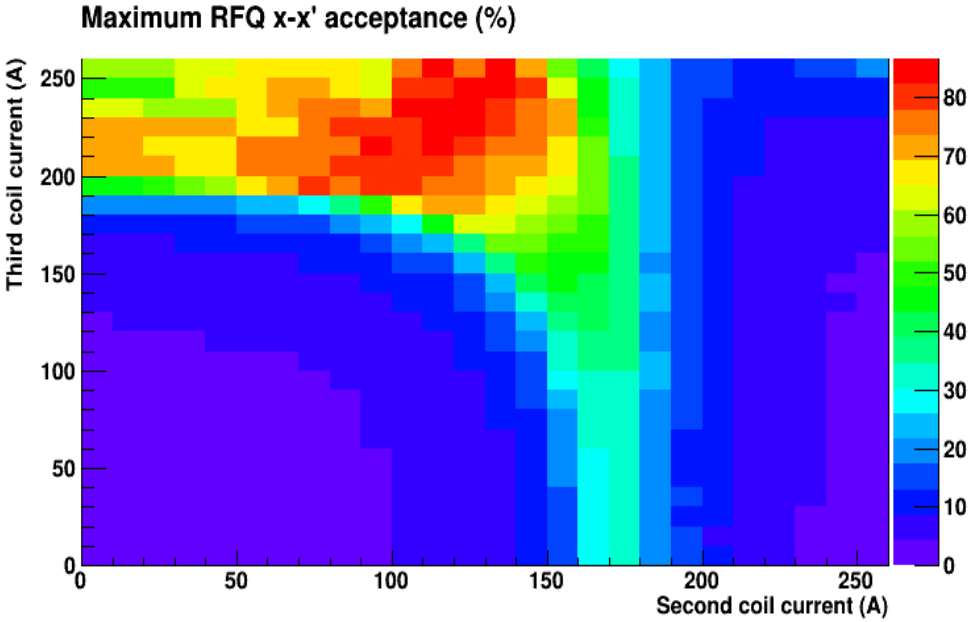

Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

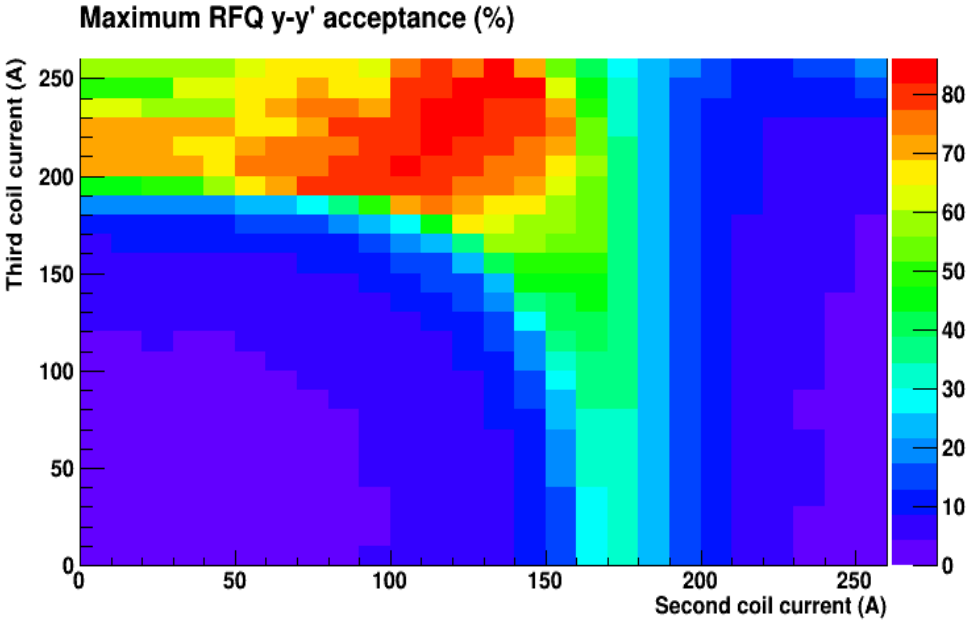

Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

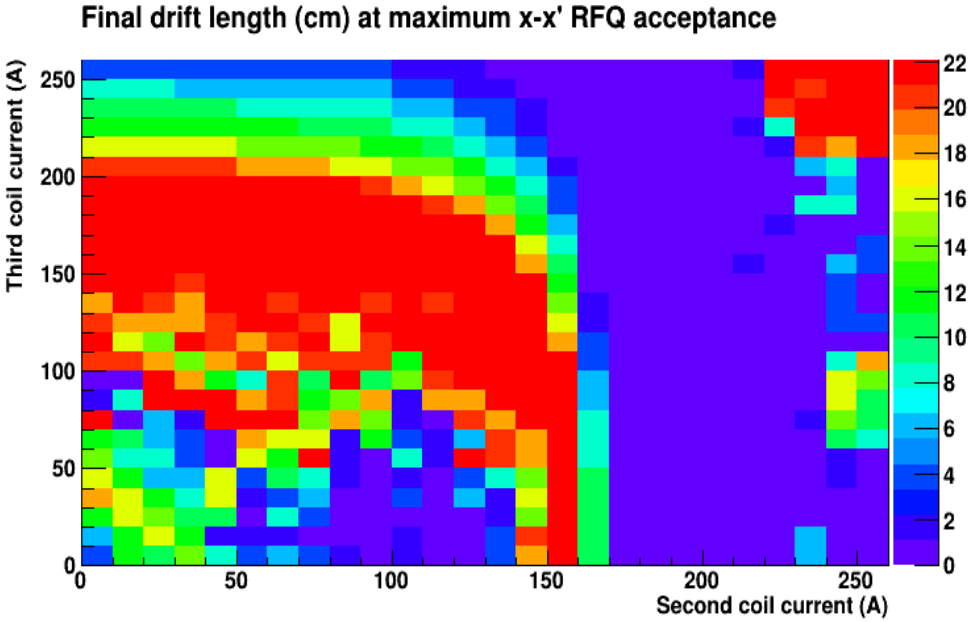

Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

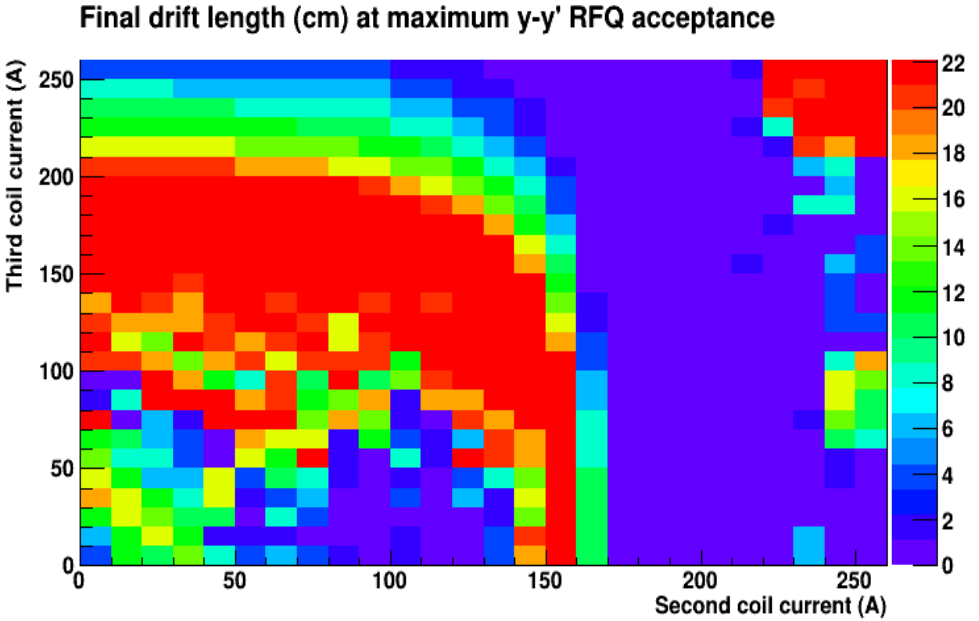

Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

$I_1 = 25$ A

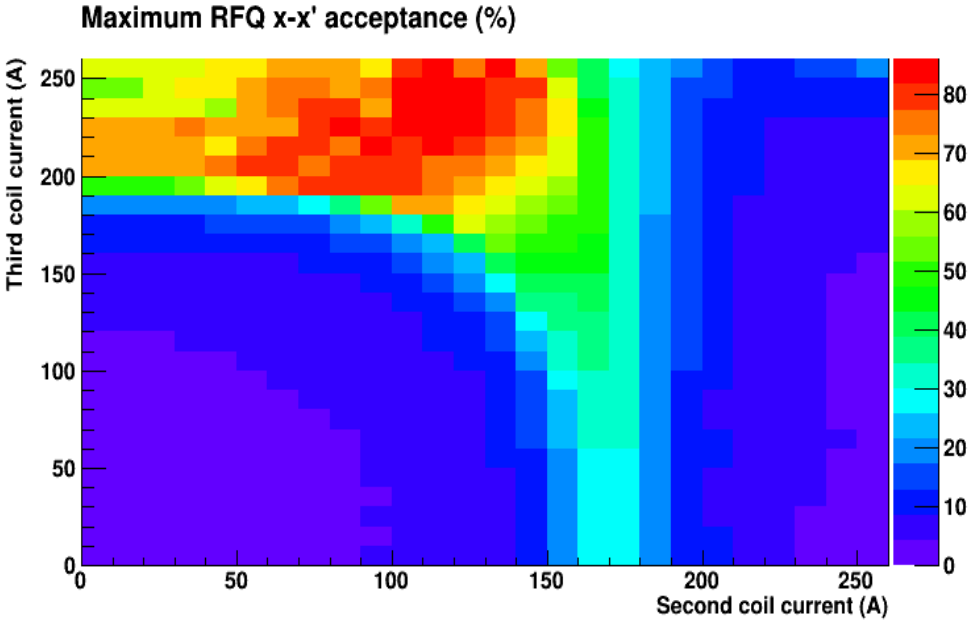

Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

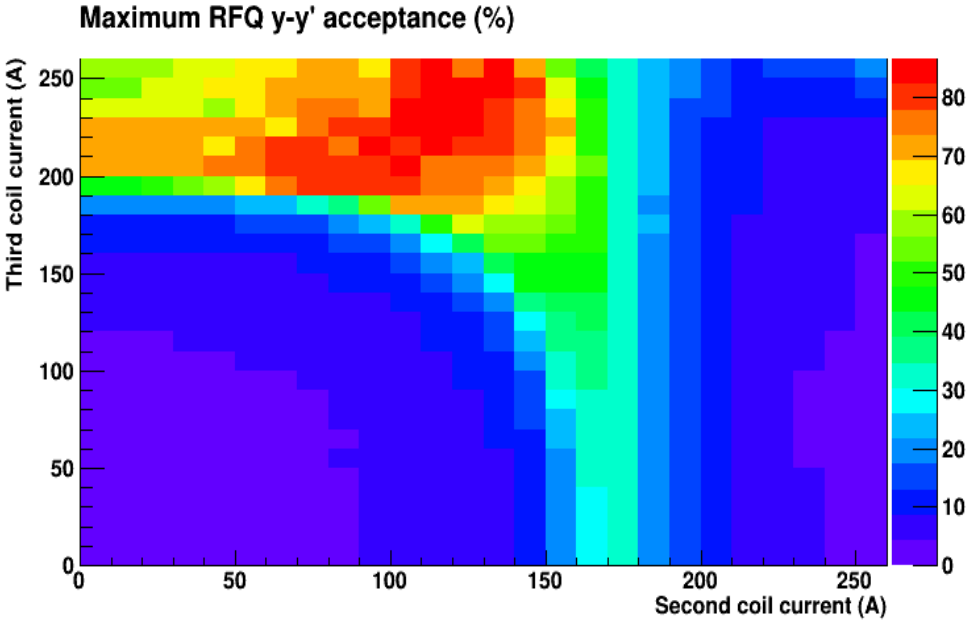

Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

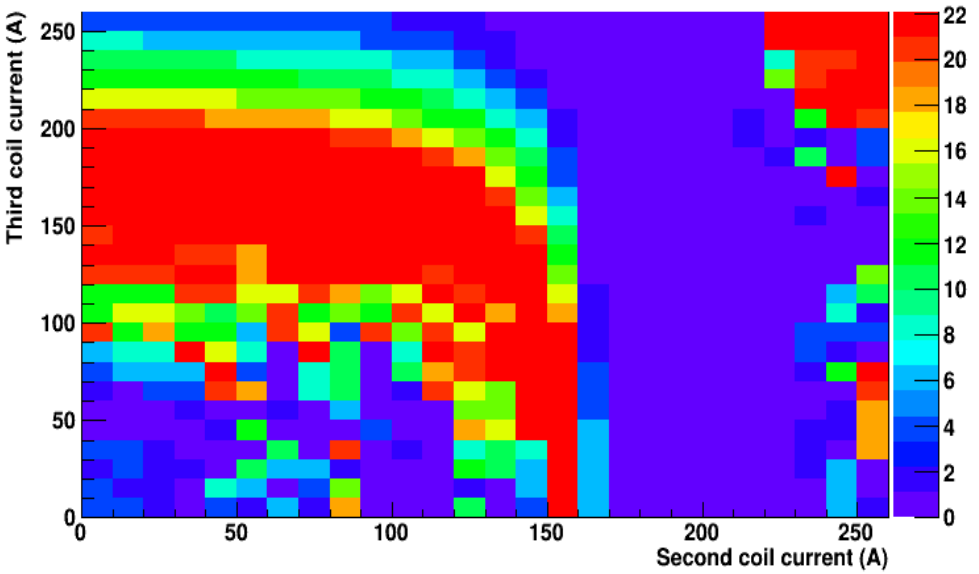

Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

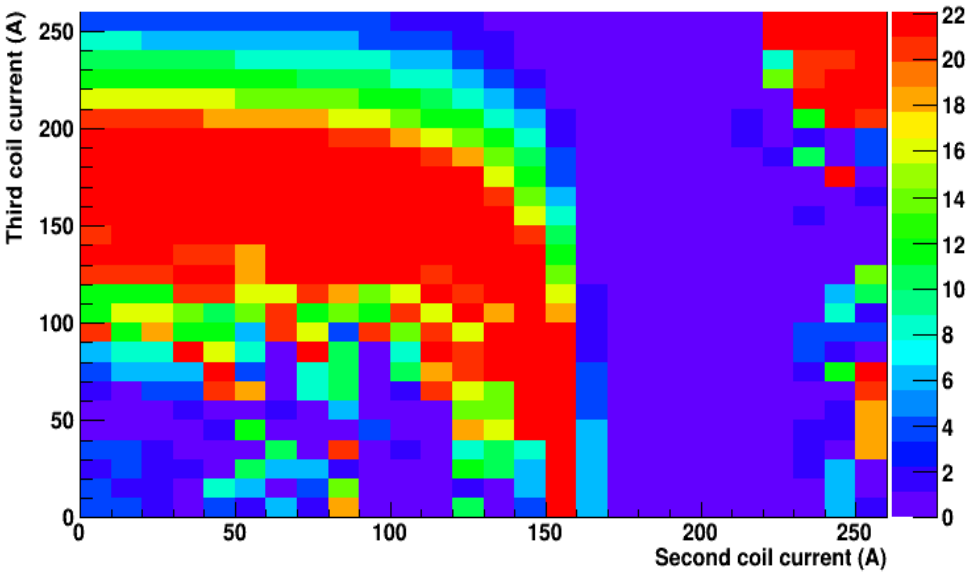

Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

$I_1 = 50$ A

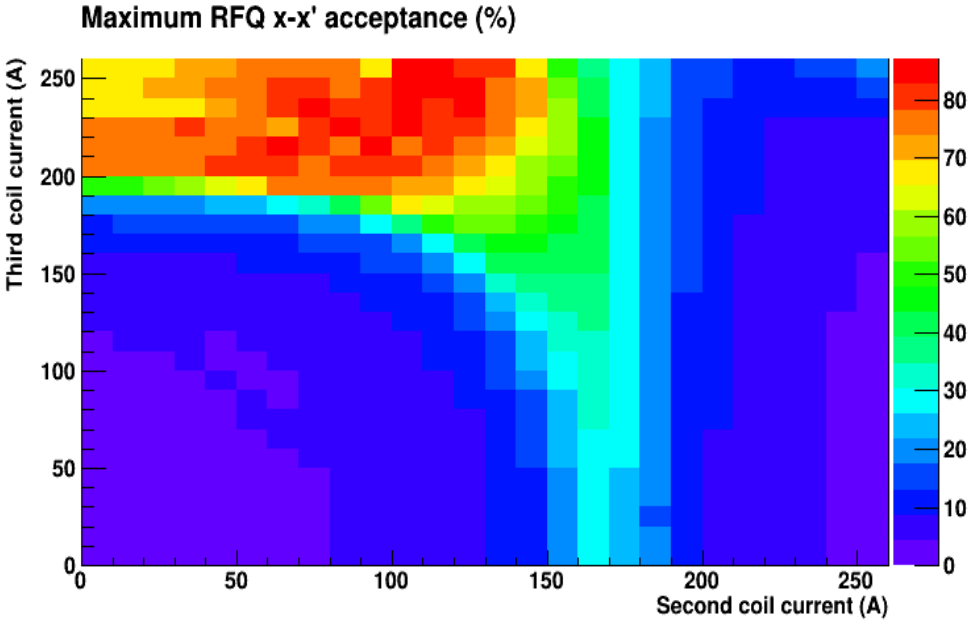

Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

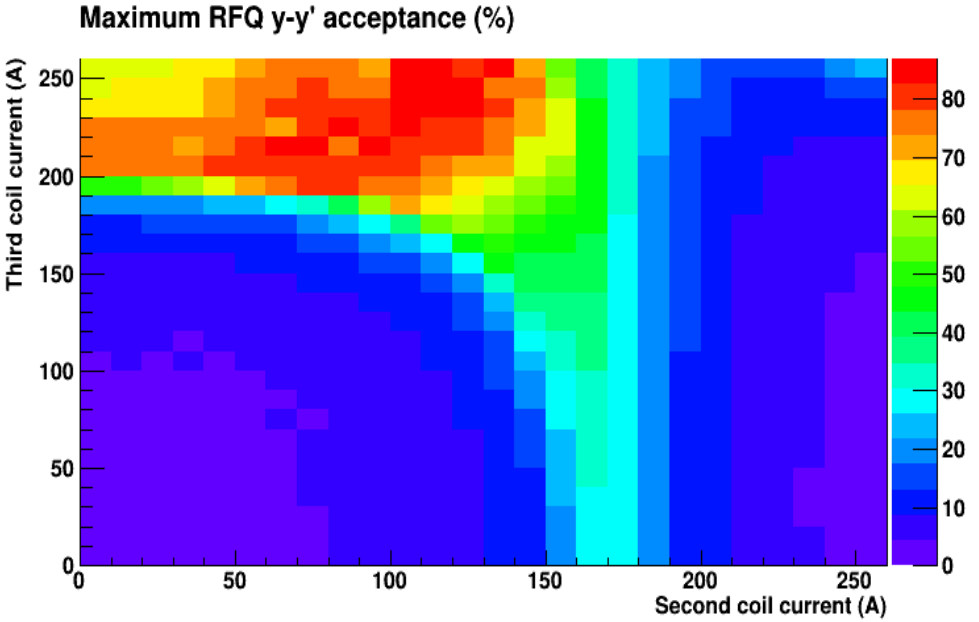

Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

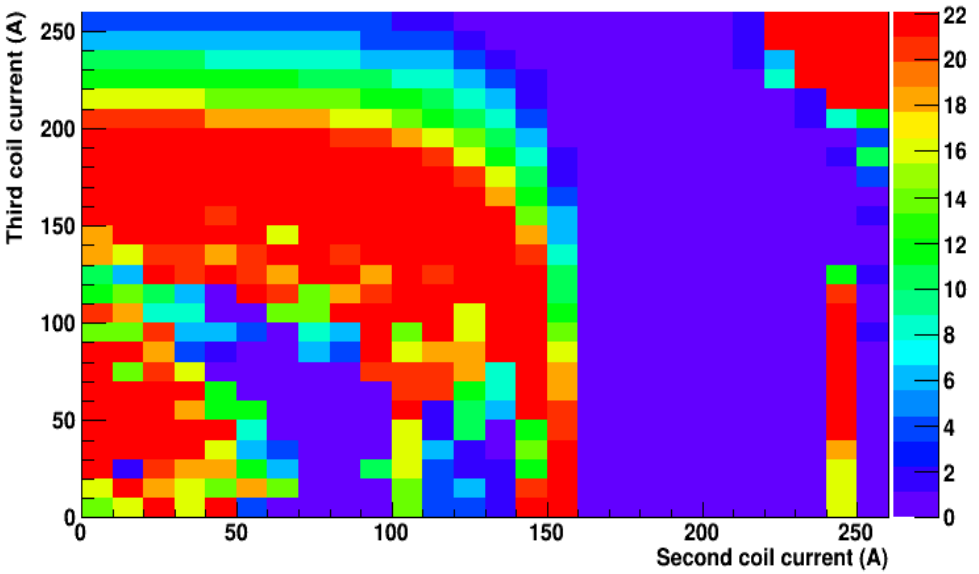

Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

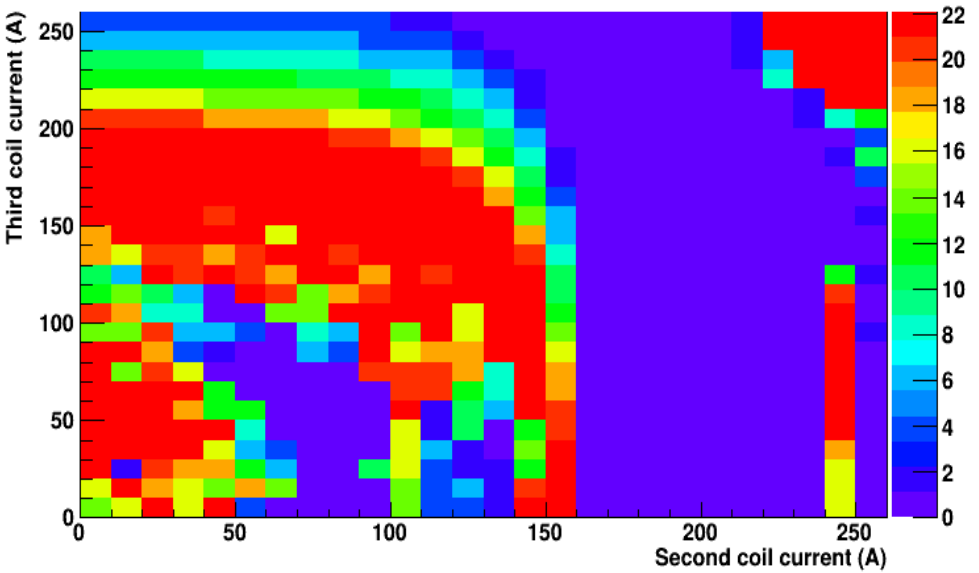

Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

$I_1 = 75$ A

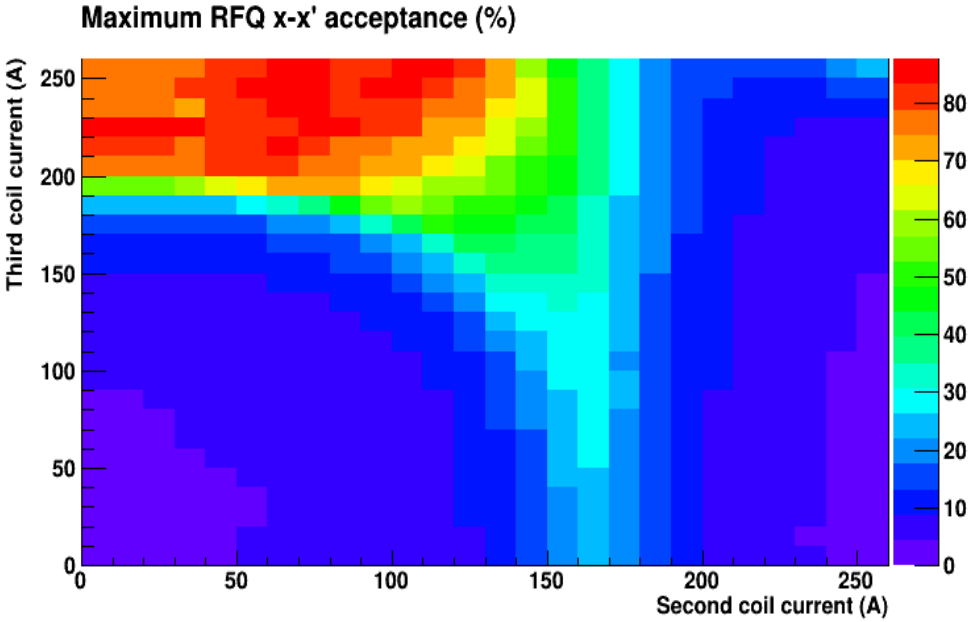

Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

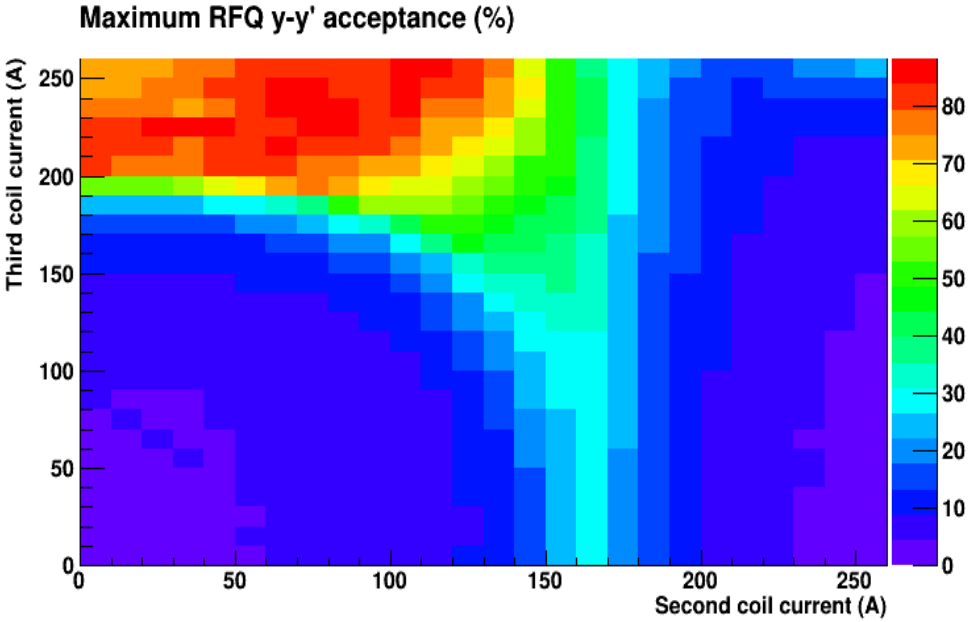

Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

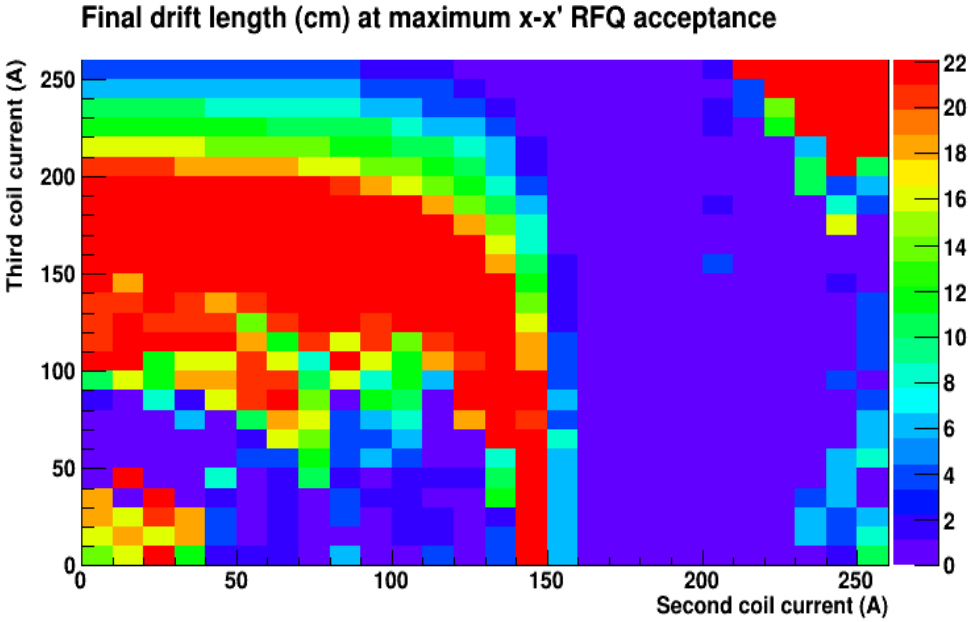

Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22


Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

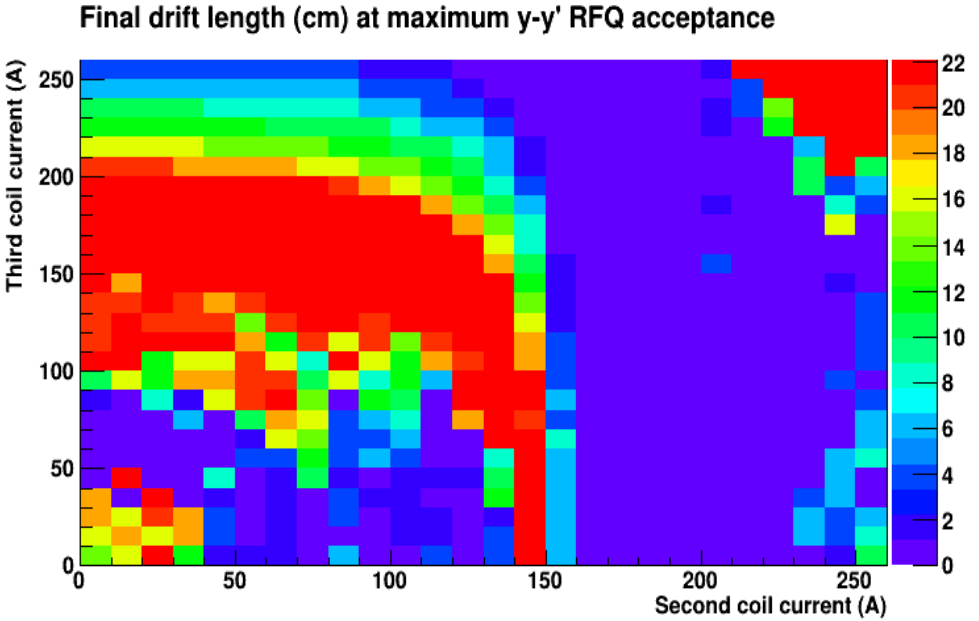
I_1 = 100 A


Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)

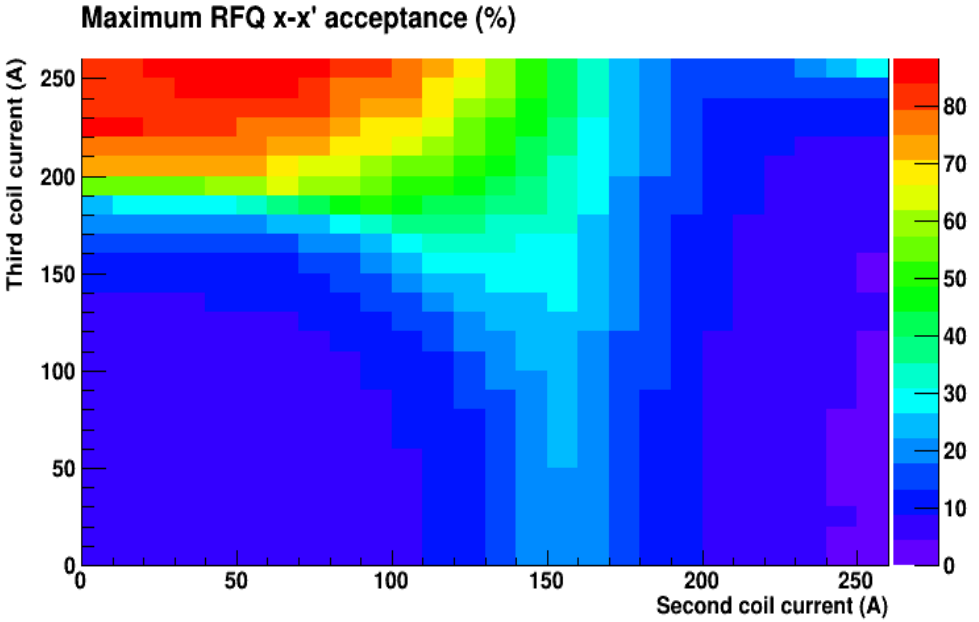

Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)

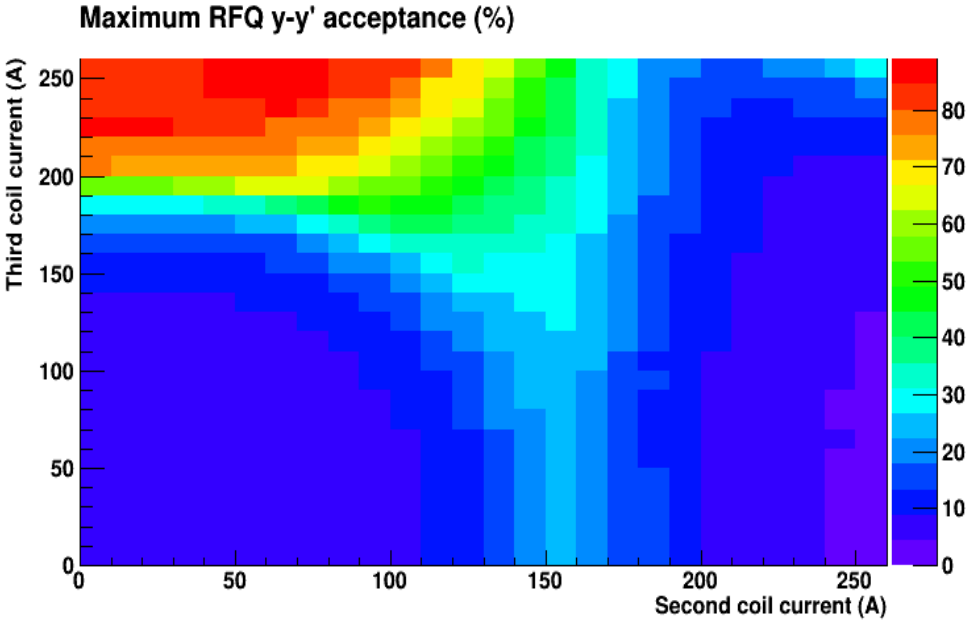

Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)

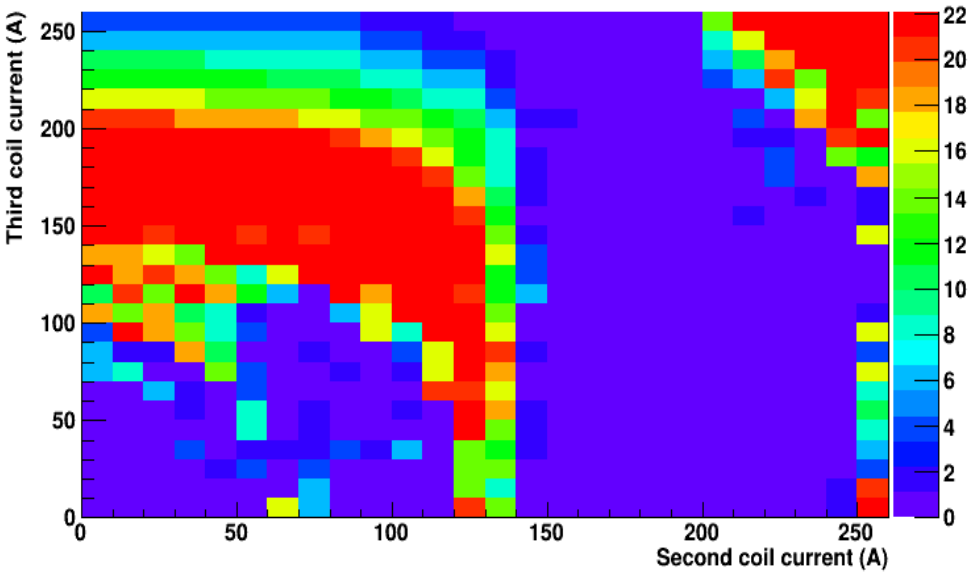
m

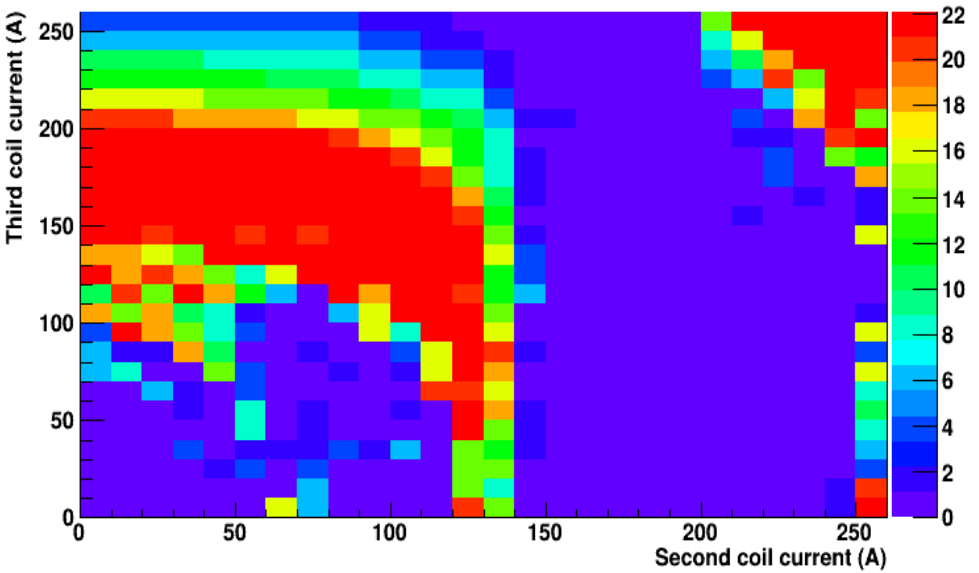

Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)

I_1 = 125 A

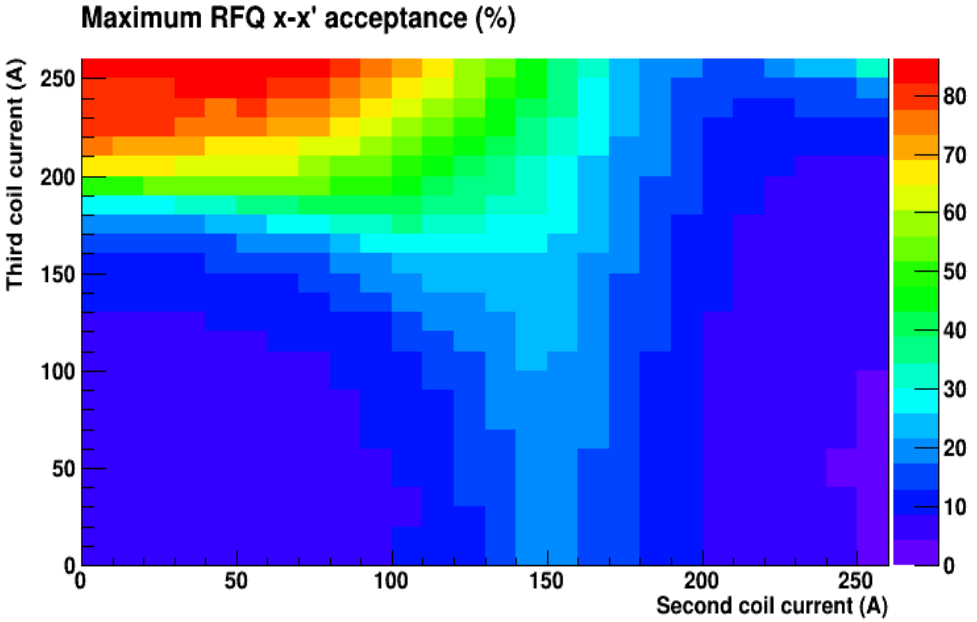

Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

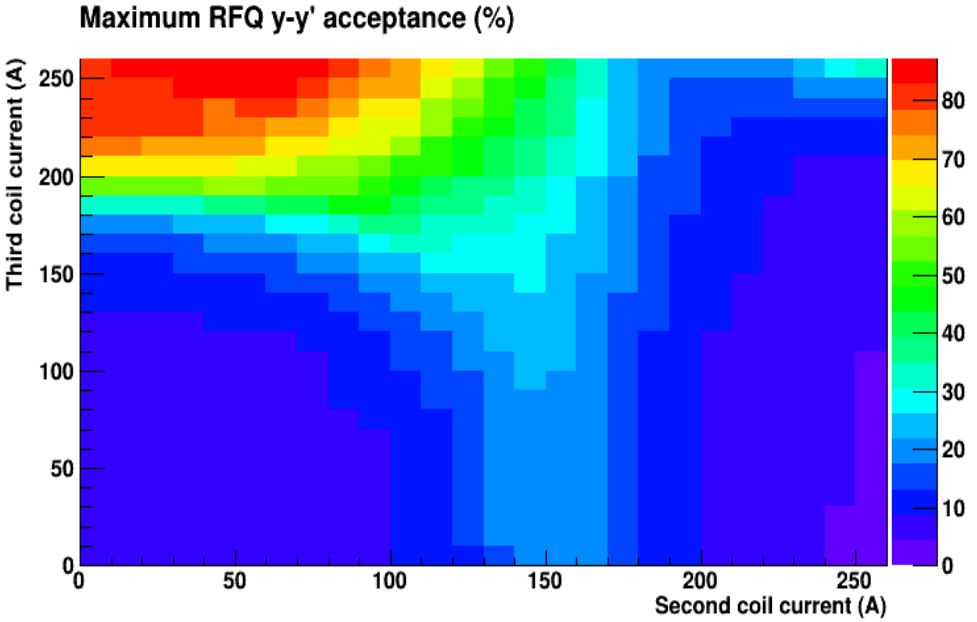

Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

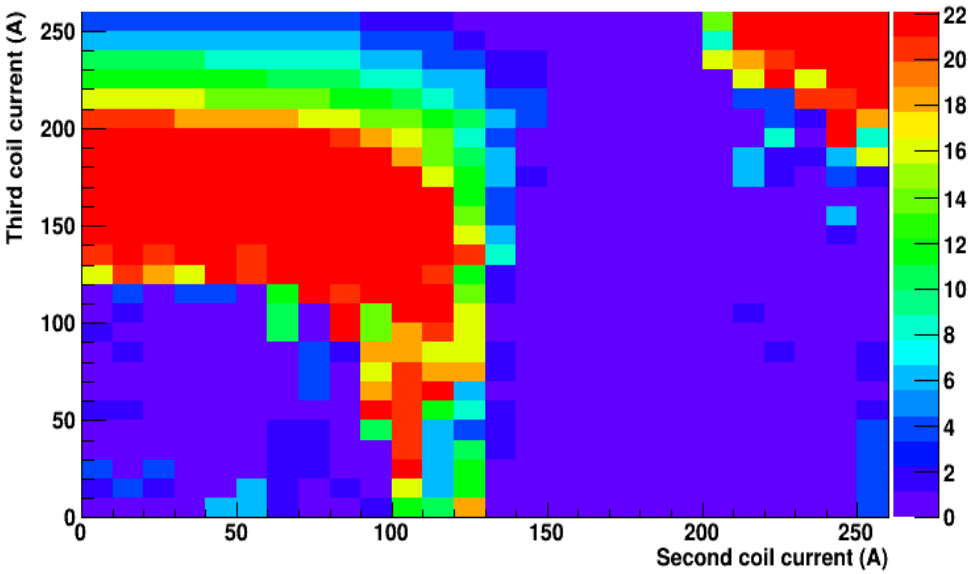

Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

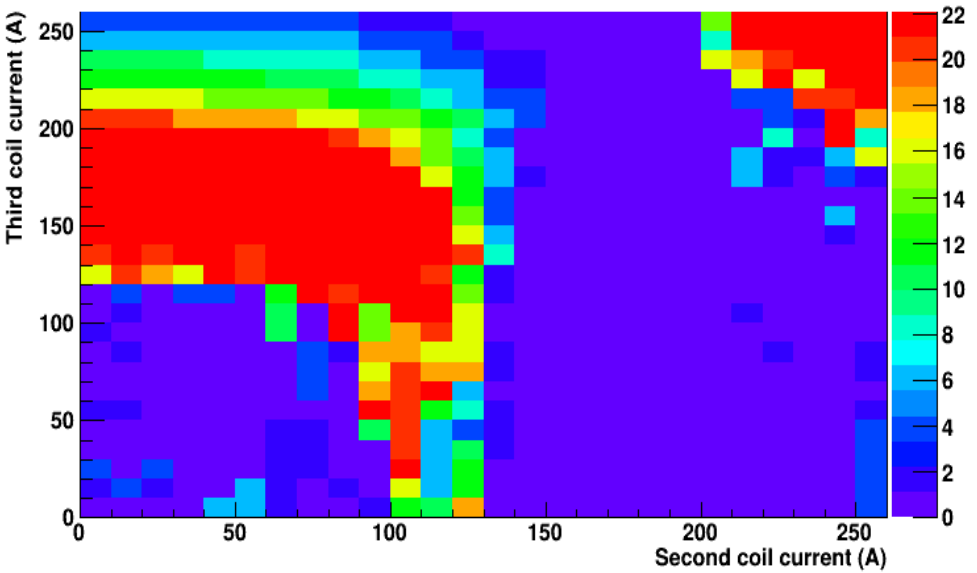

Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

I_1 = 137 A

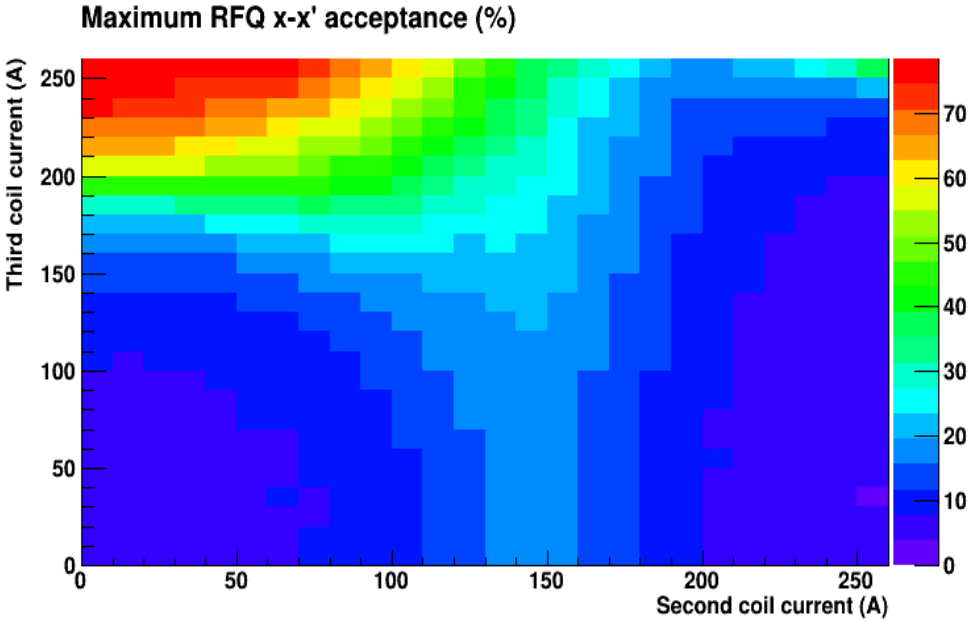

Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

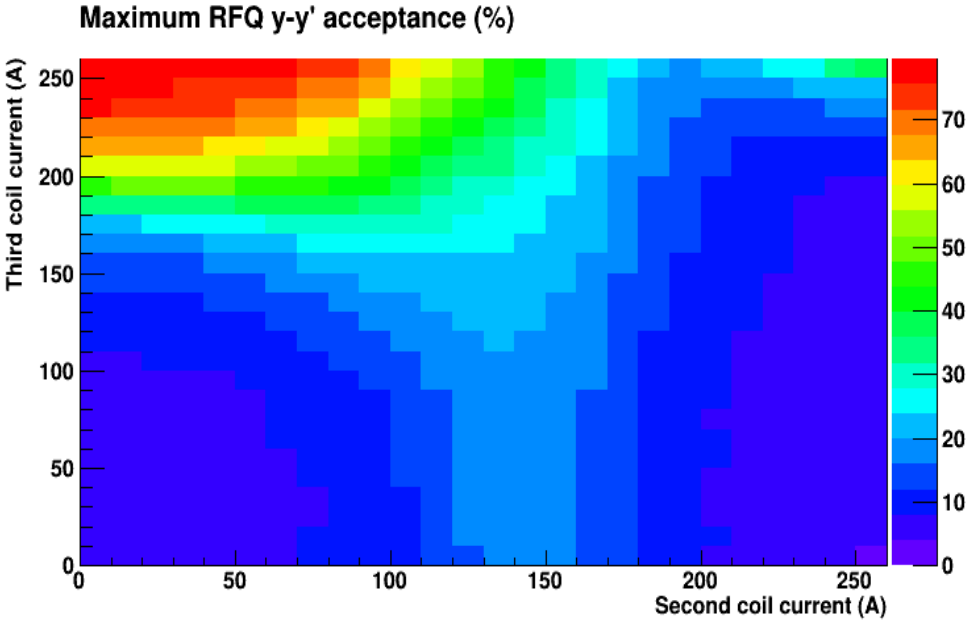

Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

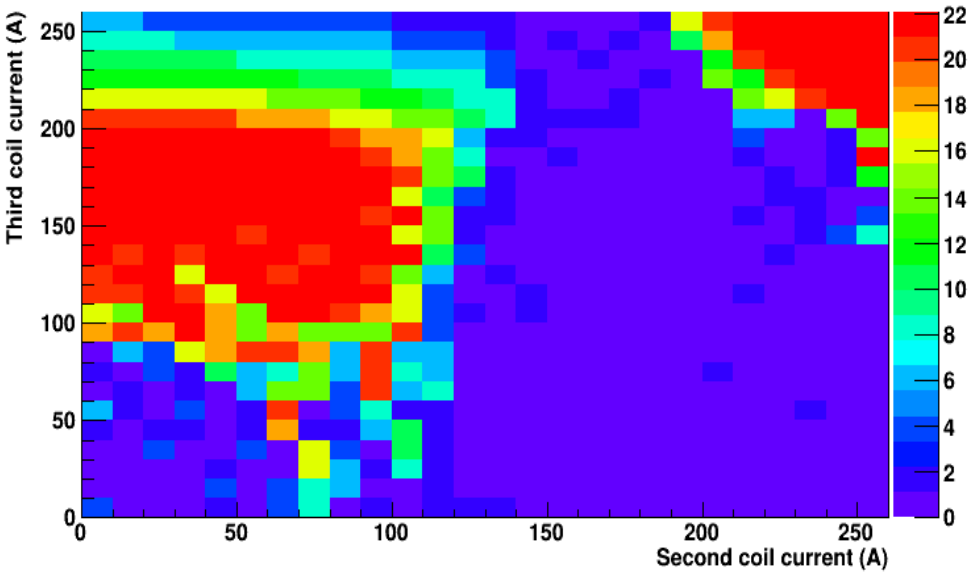

Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

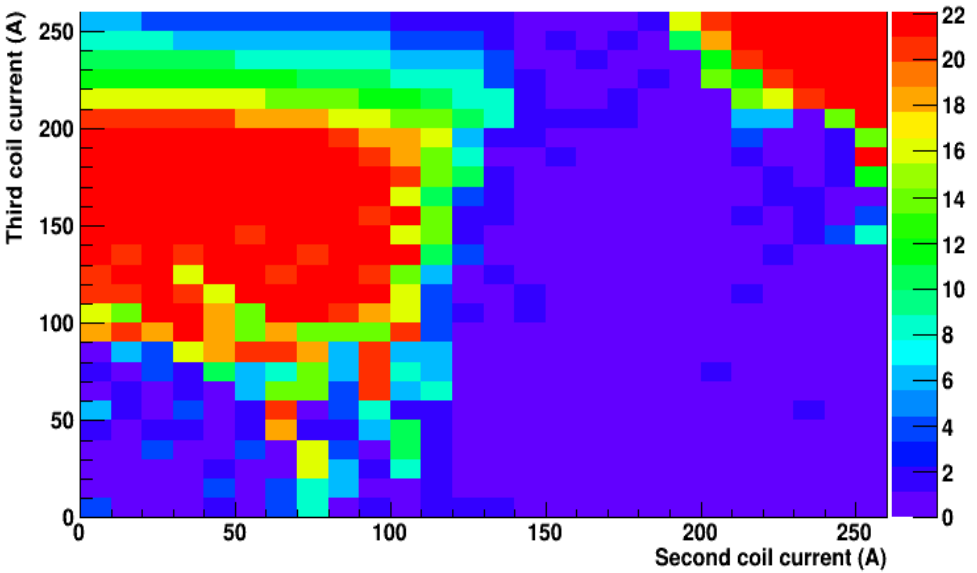

Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

I_1 = 150 A

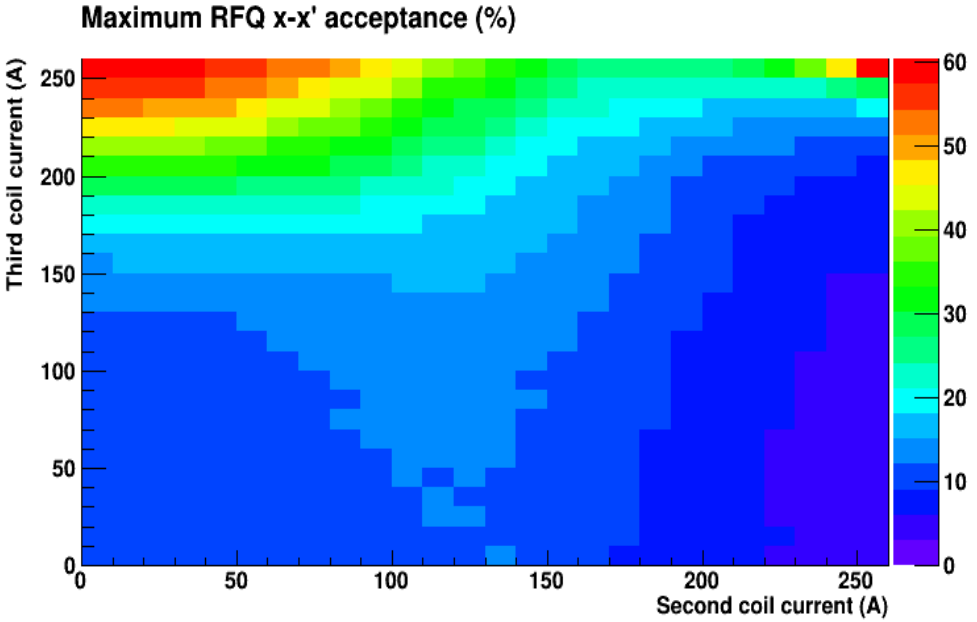

Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
10
20
30
40
60
70

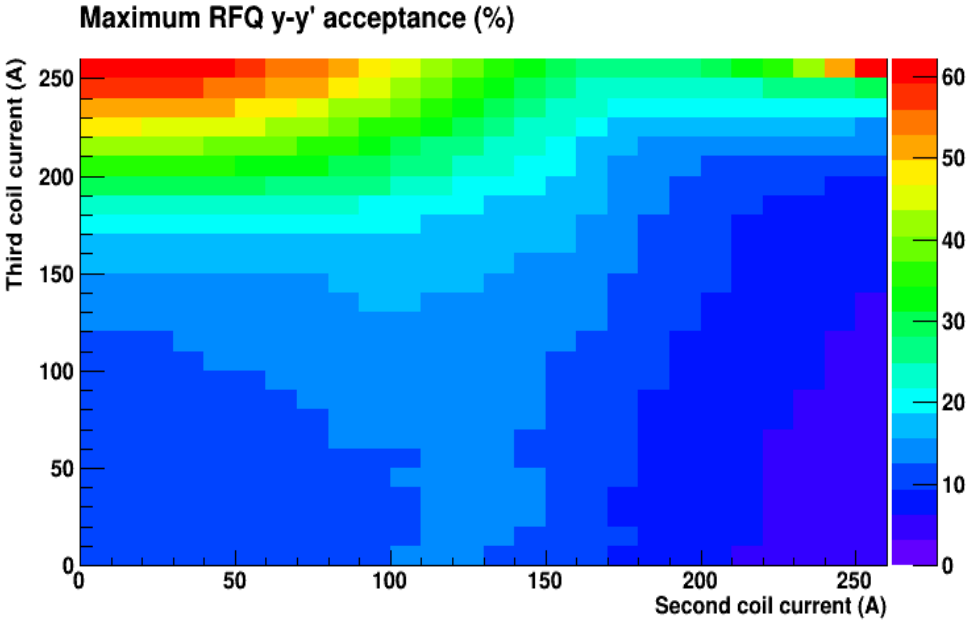

Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
10
20
30
40
60
70

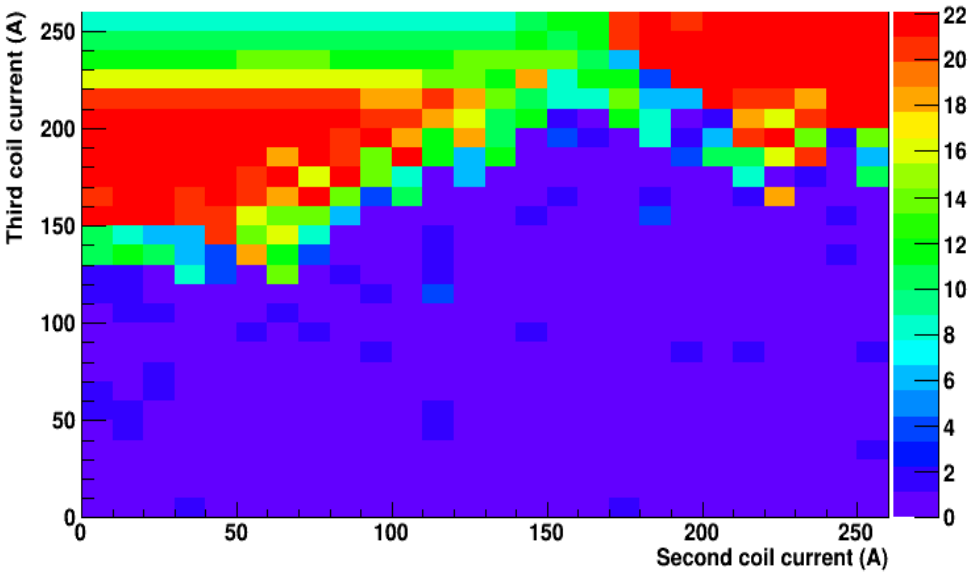

Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
2
4
6
8
10
12
14
16
18
20
22

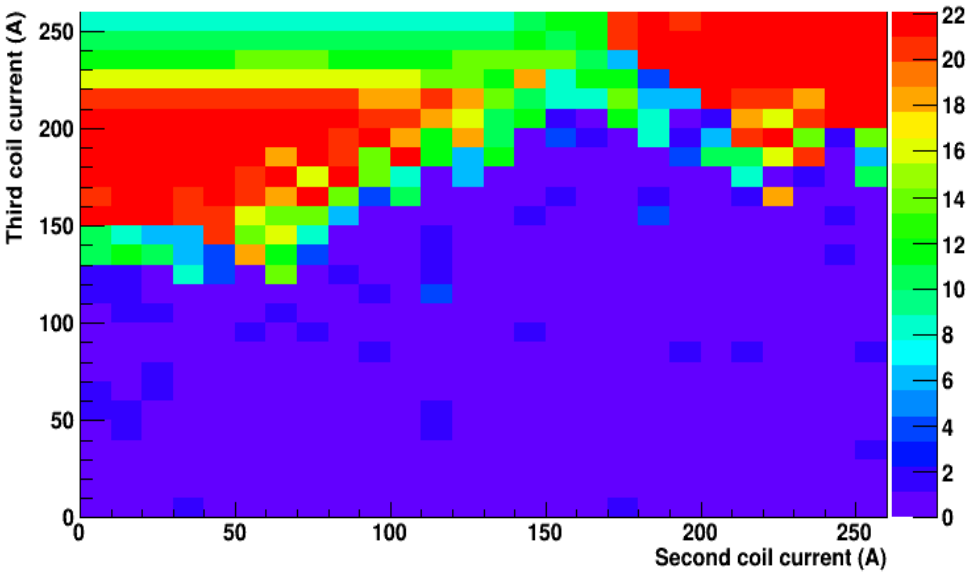

Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
2
4
6
8
10
12
14
16
18
20
22

I_1 = 175 A

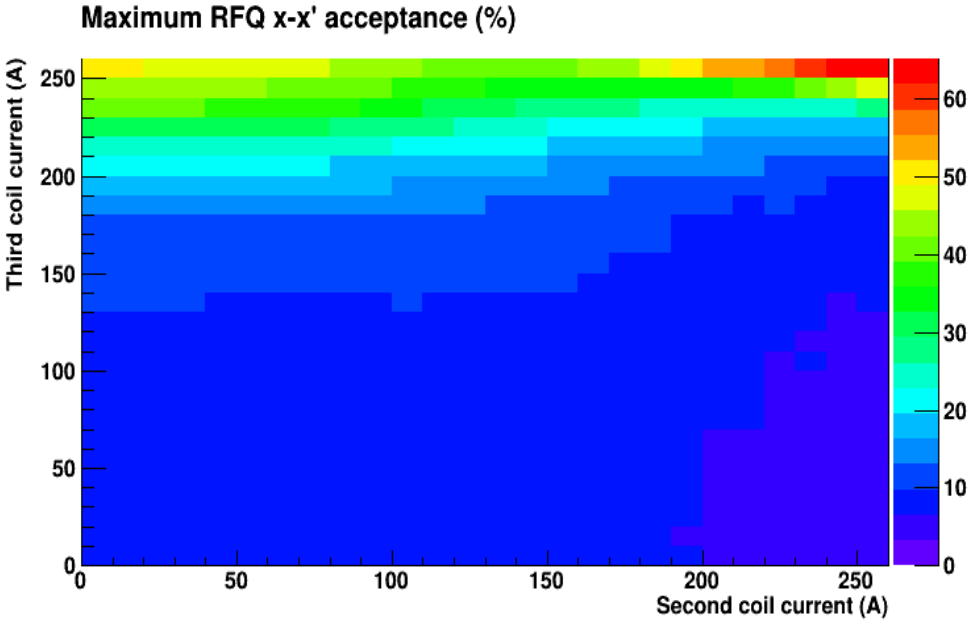

Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60

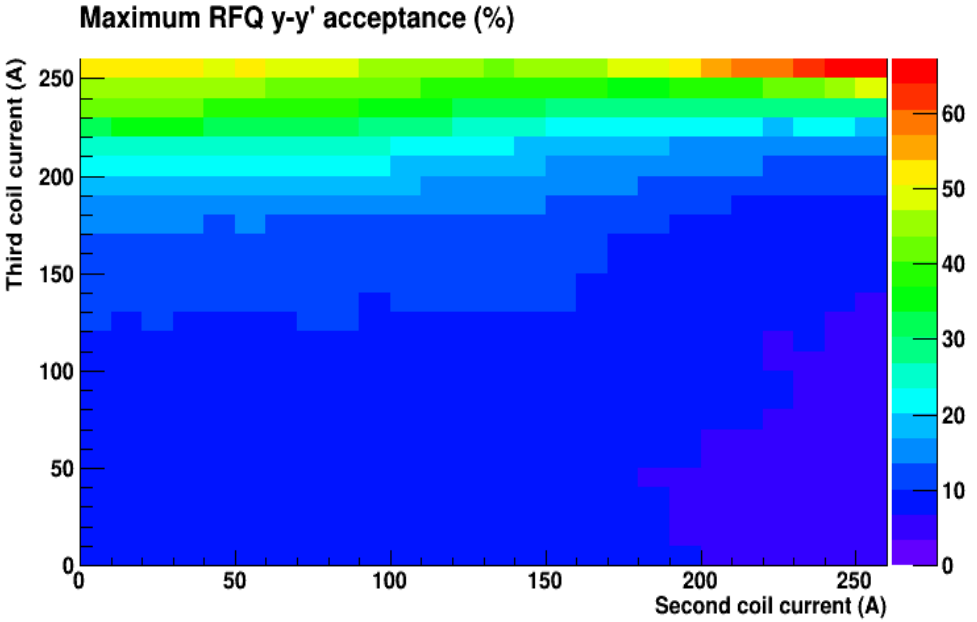

Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60

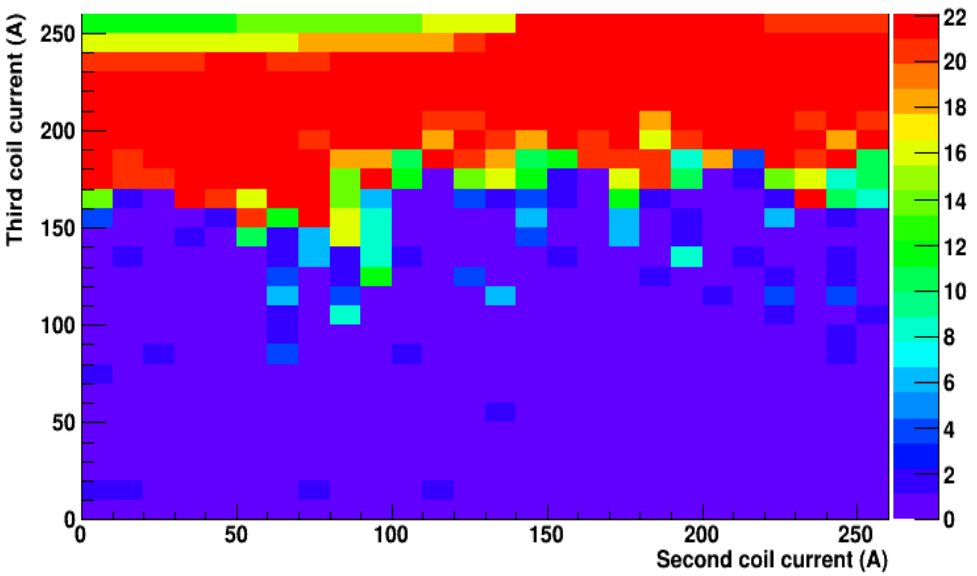

Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

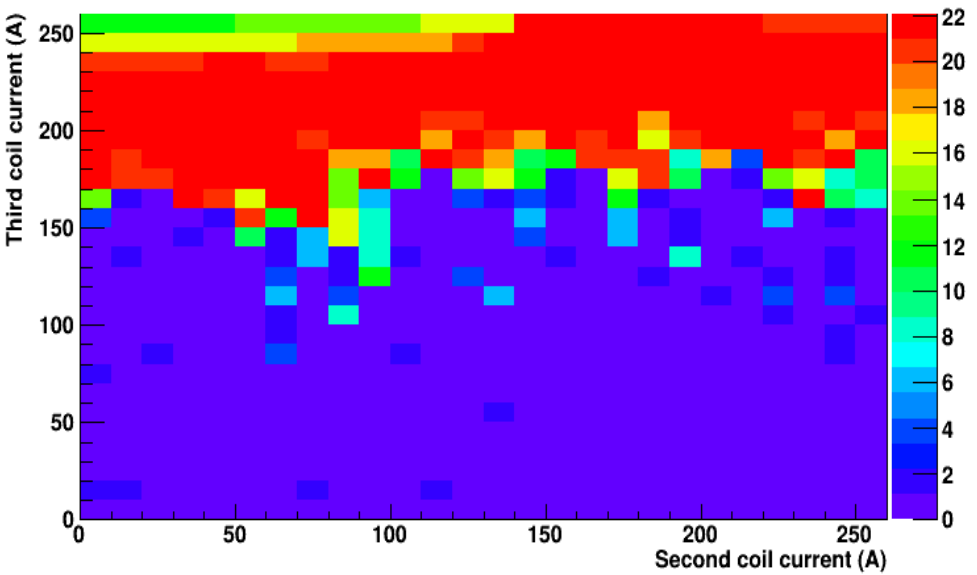

Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

I_1 = 200 A


Maximum RFQ x-x' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60


Maximum RFQ y-y' acceptance (%)
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
10
20
30
40
50
60


Final drift length (cm) at maximum x-x' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22


Final drift length (cm) at maximum y-y' RFQ acceptance
Third coil current (A)
Second coil current (A)
0
50
100
150
200
250
0
2
4
6
8
10
12
14
16
18
20
22

Solenoid currents range

I_1 (A)	I_2 (A)	I_3 (A)	RFQ eff (%)	Focus length (cm)
0	50 – 140	190 – 240	75 - 85	4 – >22
25	50 – 140	190 – 240	75 – 85	4 – >22
50	40 – 140	190 – 240	75 – 85	4 – >22
75	0 – 120	200 – 250	75 – 86	4 – 22
100	0 – 120	200 – 250	75 – 87	4 – 20
125	0 – 100	210 – 250	76 – 88	4 – 16
137	0 – 80	220 – 250	77 – 86	4 – 12
150	0 – 50	240 – 250	77 – 78	4 – 8
175	0 – 70	230 – 250	50 – 60	8 – 12
200	200 – 250	250	53 – 65	20 – >22

$I_1 \gtrsim$ 175 A gives over-focusing of the beam inside LEBT

$\Rightarrow$ high I_2 & I_3 needed to focus beam again