

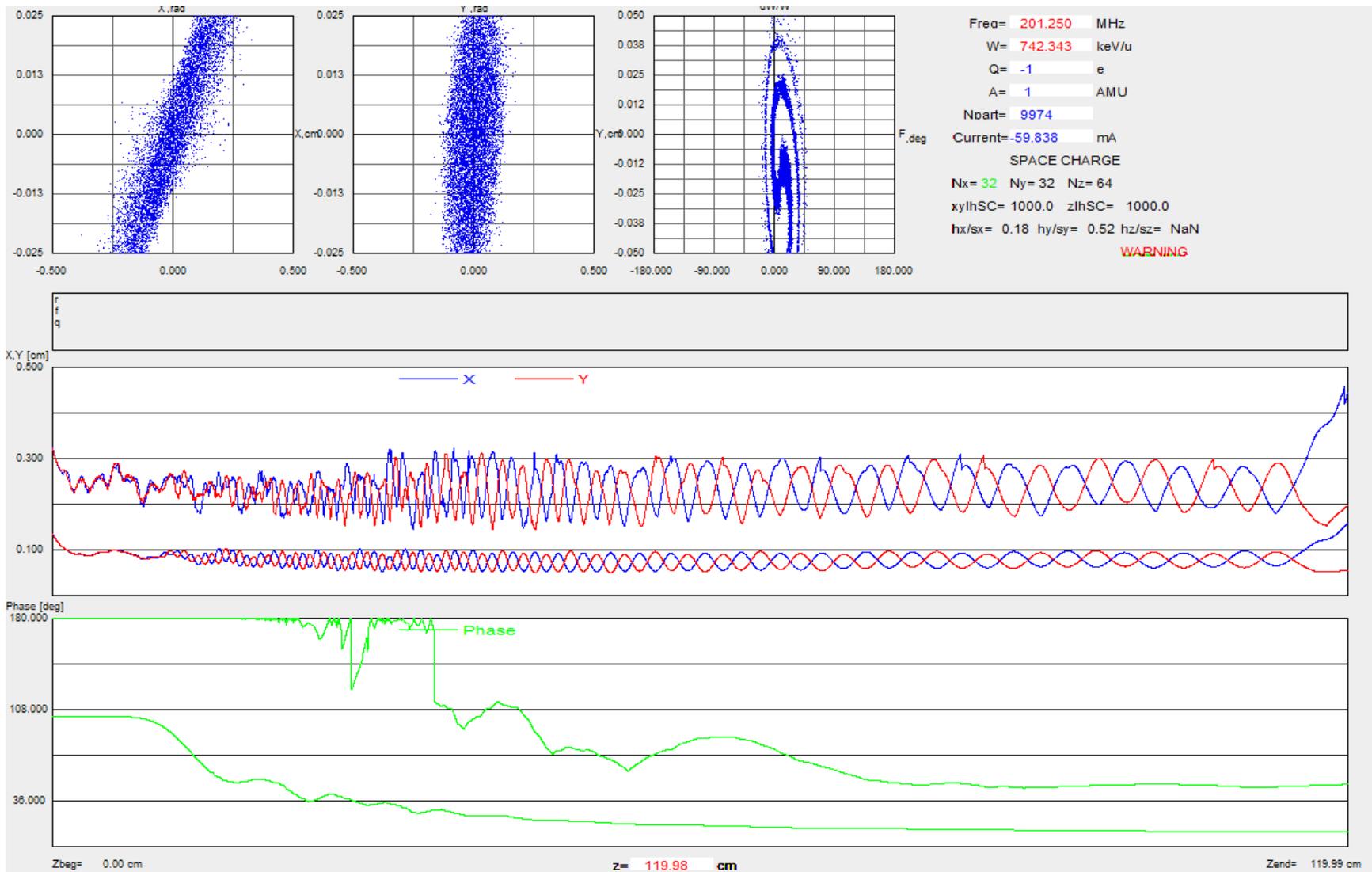
# PIP RFQ in TRACK with 3D Fields

J.-P. Carneiro / APC

13-AUG-2013

PIP RFQ in TRACK using  
potential expansion in a multi-  
cell RFQ (parmteqm conversion)

# PIP RFQ in TRACK – ANALYTICS FROM PARMTEQM. MATCHED with 1.5 and 5.1 cm/rad 99.7 % transmission. 0.3 mm-mrad all along the RFQ.

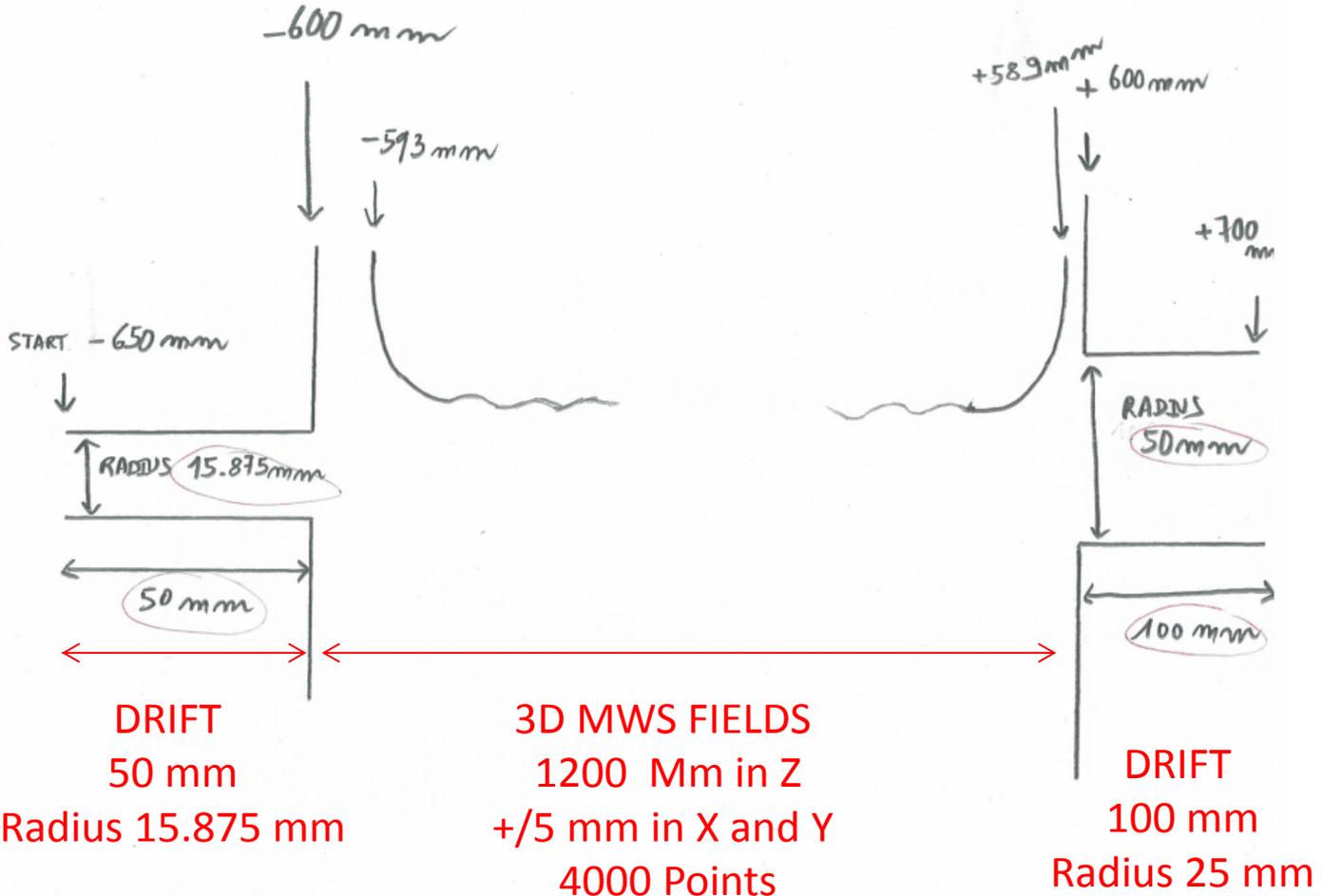


# PIP RFQ in TRACK using 3D Fields from MWS

Model `_v7a_` provided by S. Kurennoy  
(LANL) and fields from R. Kostin and  
G. Romanov (FNAL)

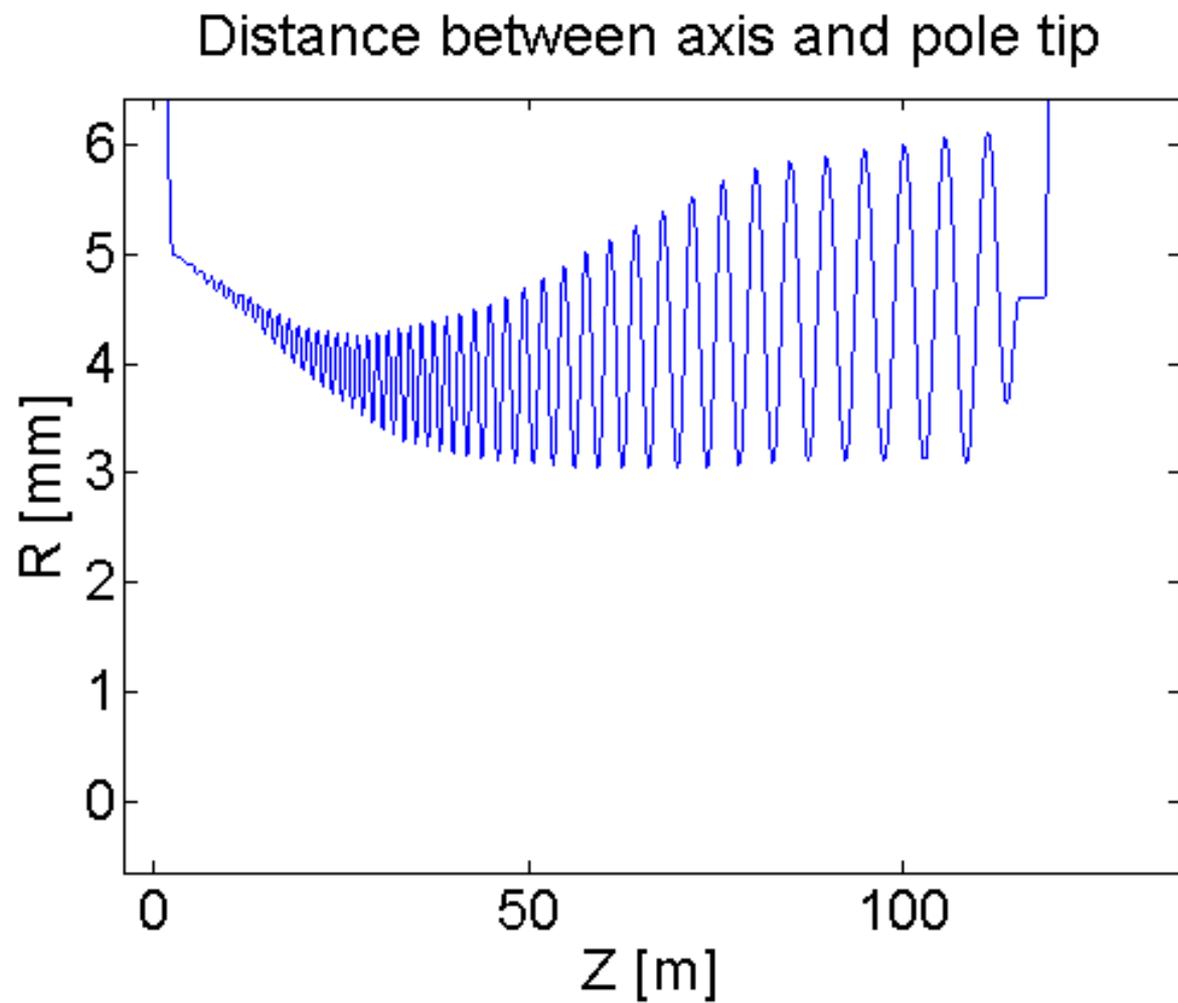
How is the PIP RFQ implemented into TRACK as of now ?

DRIFT-3D FIELD- DRIFT (50 mm + 1200.15 mm + 100 mm)



PIP RFQ IN MWS v7a

12-AUG-2013



How are the losses monitored in the TRACK 3D RFQ ?

As of today in TRACK losses are monitored only by the field extension (particle out of the field = lost).

Vanes apertures are being implemented (this week). More precise lost pattern should be available soon.

From S. Kurennoy document

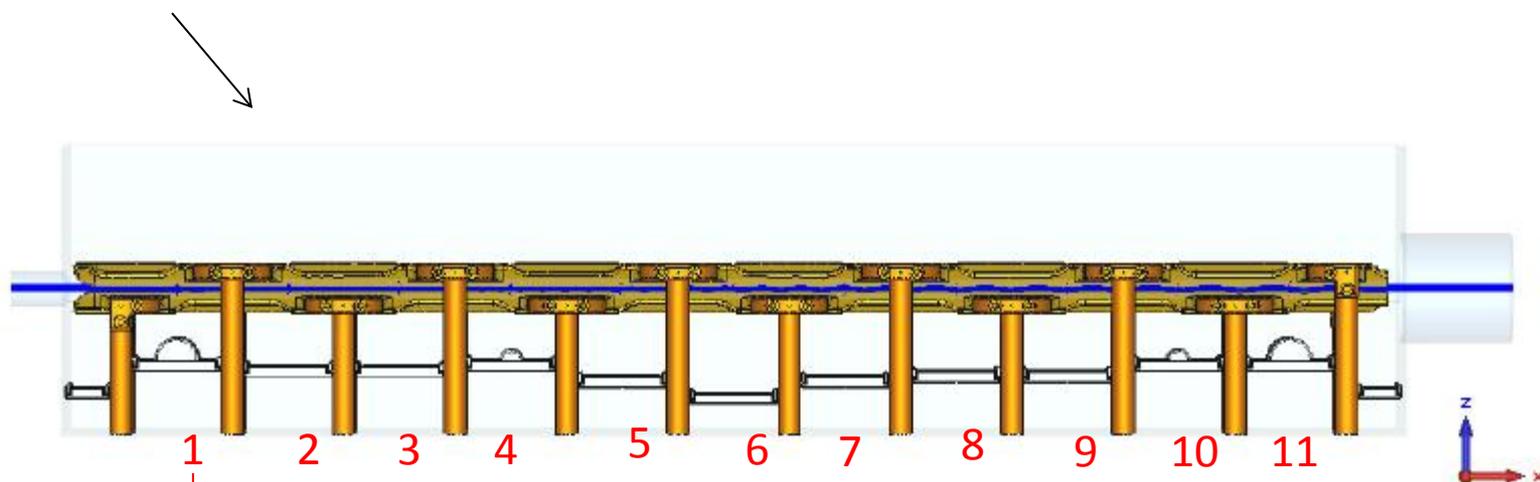


Figure 7: Side view of the RFQ MWS model C.

Tuning Cell with half-moons in Cells 1 + 4 + 10 +11

# How confident should we be in the MWS model of the TRACK 3D RFQ ?

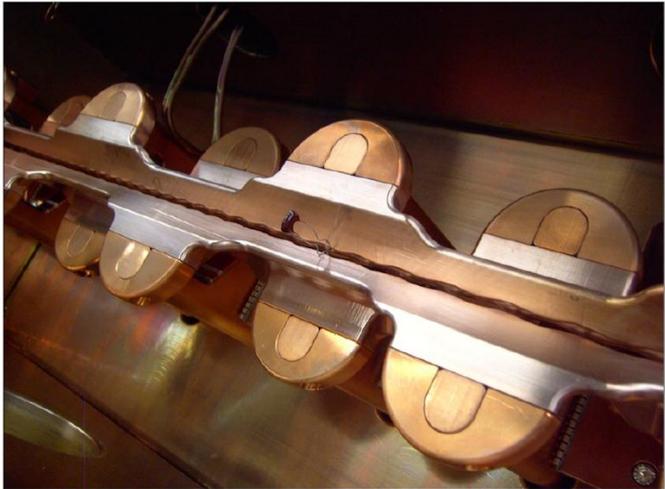
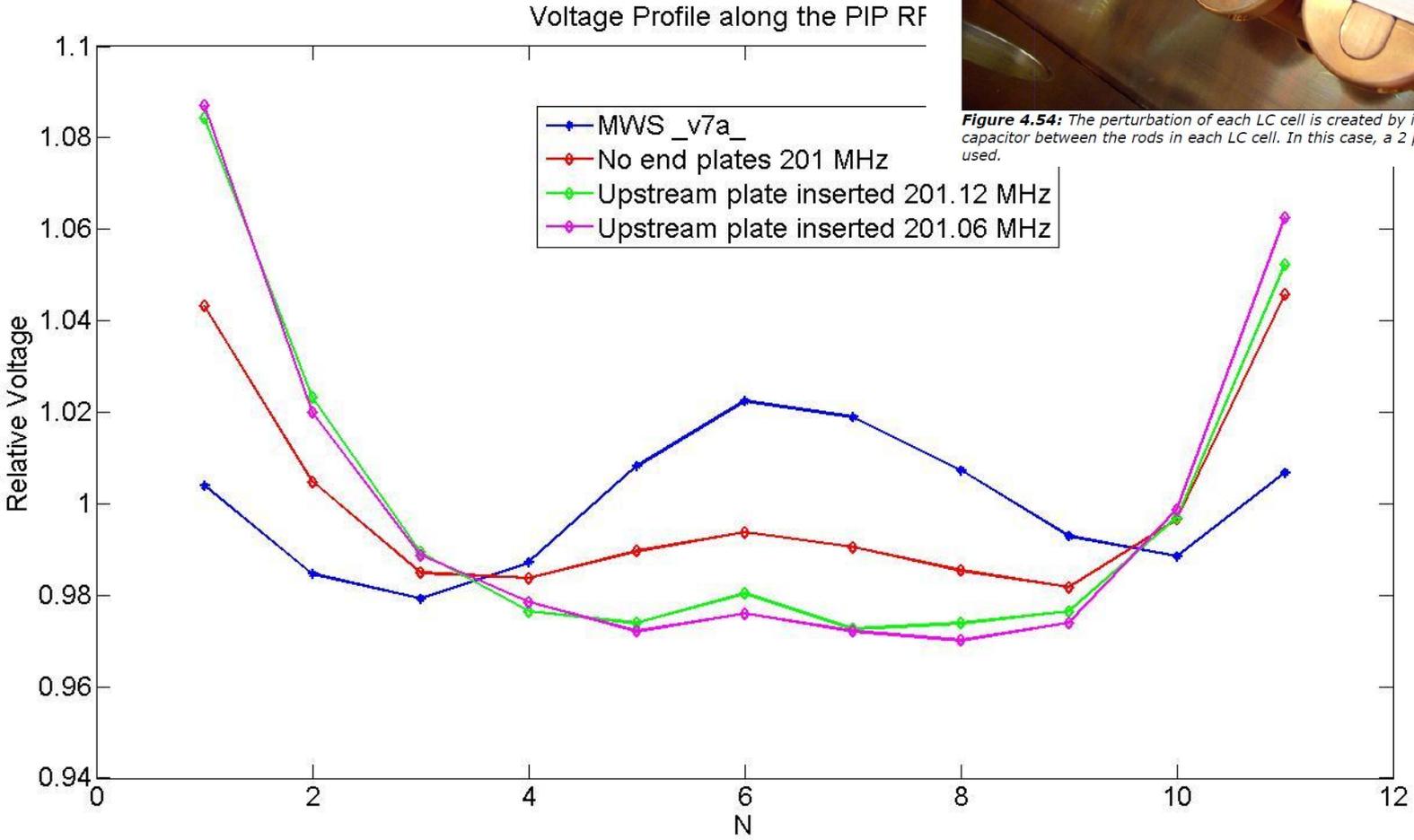
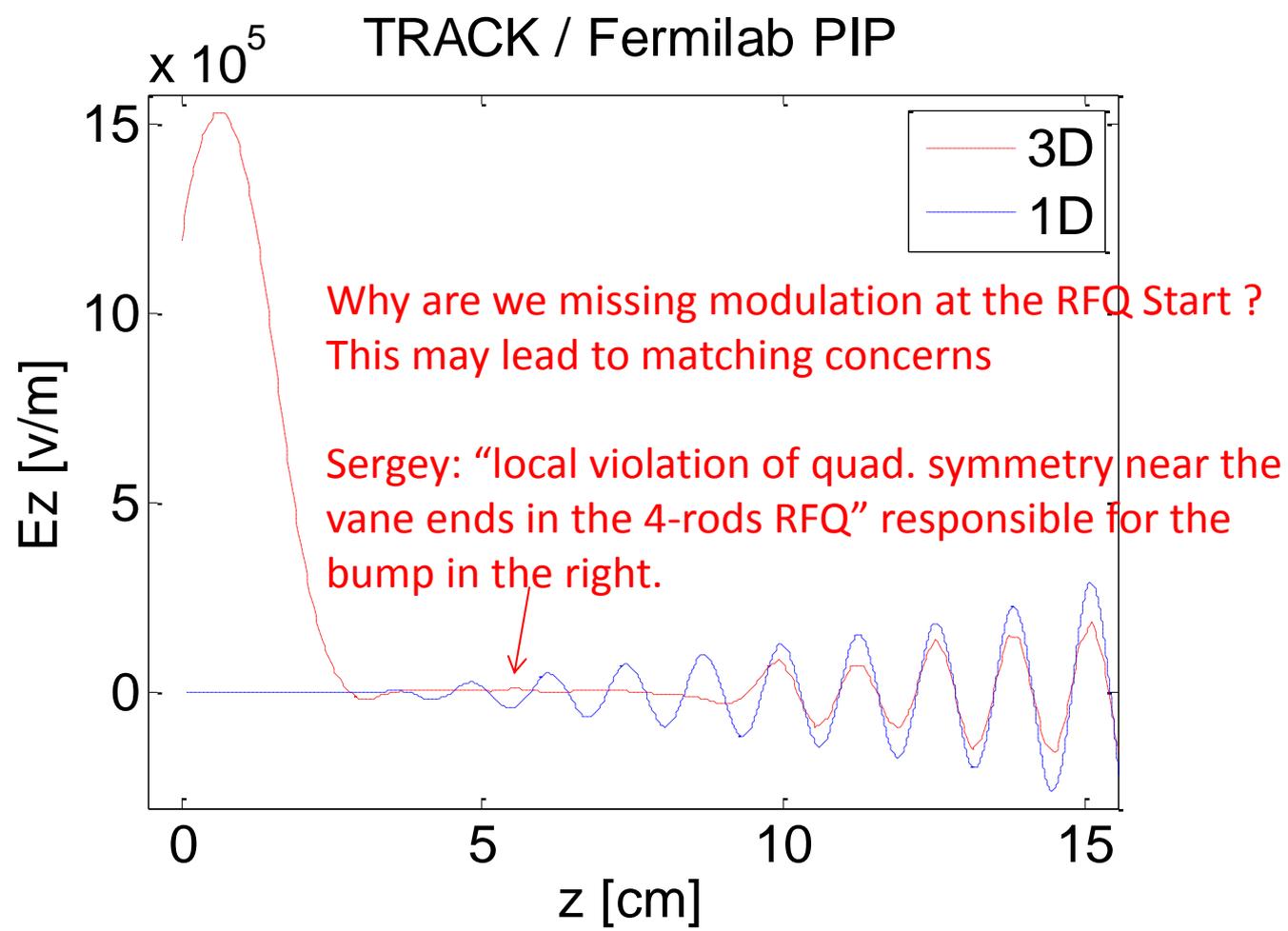


Figure 4.54: The perturbation of each LC cell is created by inserting a capacitor between the rods in each LC cell. In this case, a 2 pF capacitor is used.



Field on Geometrical Axis.

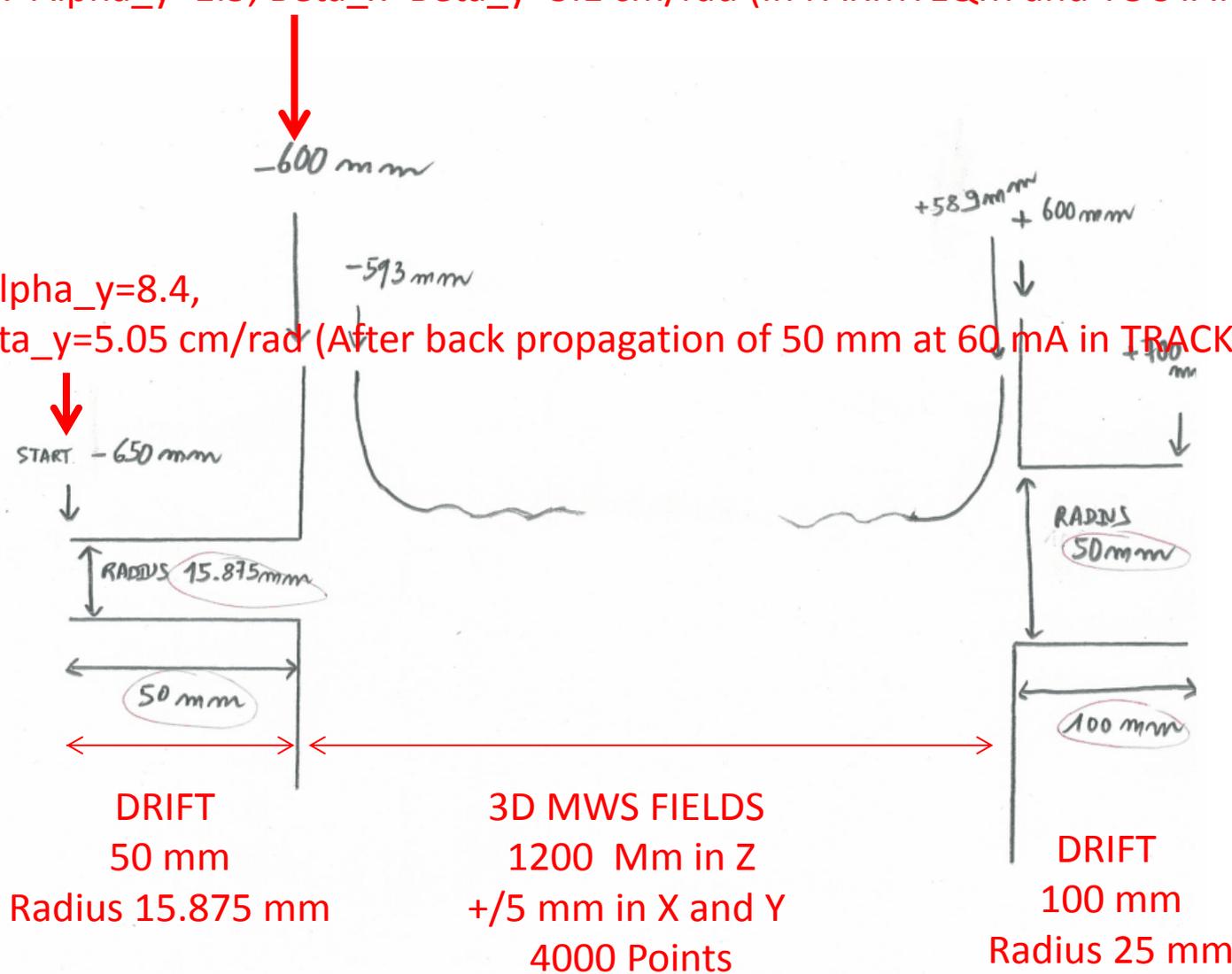
TRACK Analytical (from PARMTEQM conversion) Vs TRACK 3D Fields (from MWS)



Back Propagation of 50 mm to fetch the TWISS parameters at the beam pipe entrance?

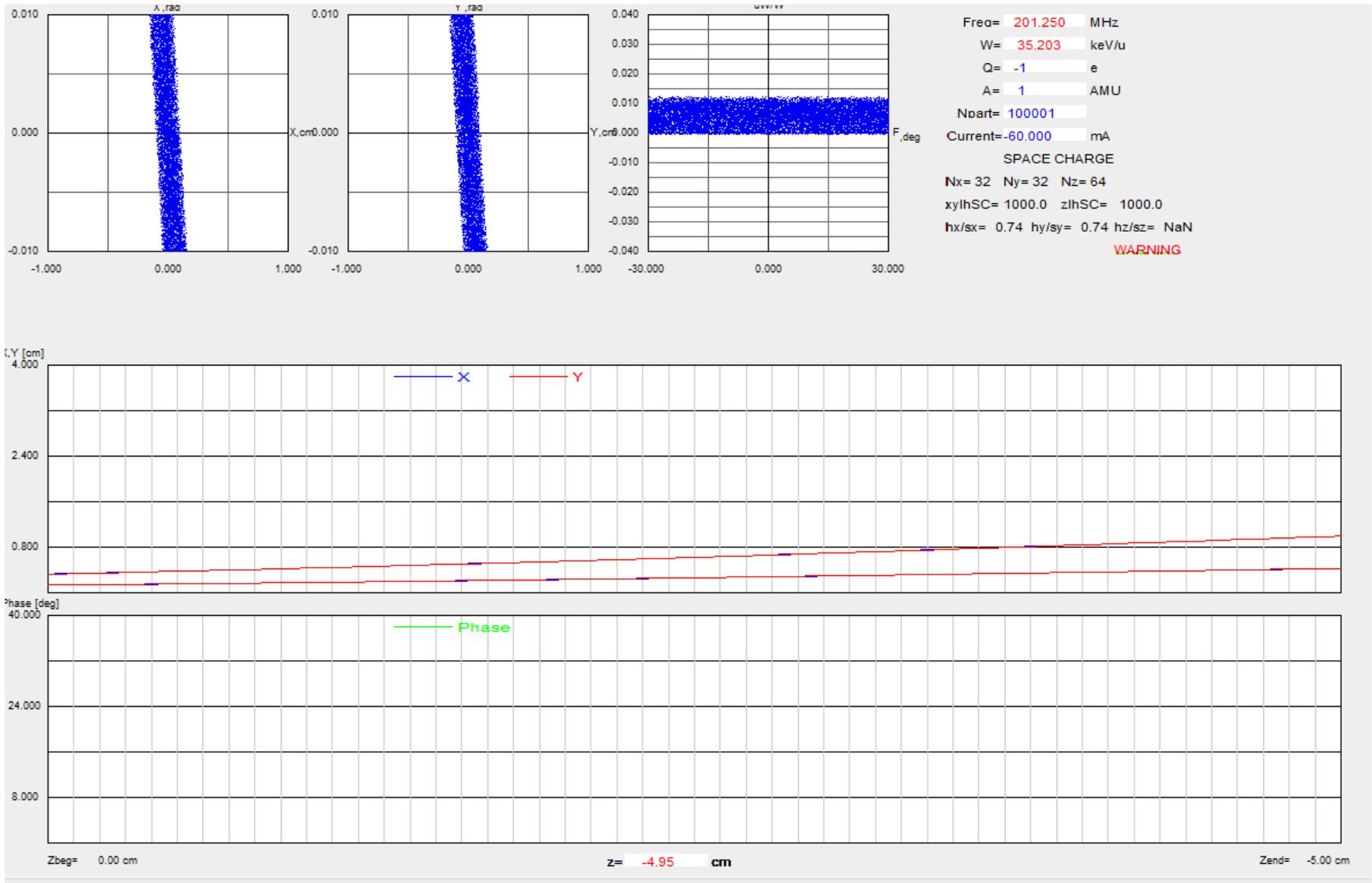
Alpha\_x=Alpha\_y=1.5, Beta\_x=Beta\_y=5.1 cm/rad (In PARMTEQM and TOUTATIS)

Alpha\_x=Alpha\_y=8.4,  
Beta\_x=Beta\_y=5.05 cm/rad (After back propagation of 50 mm at 60 mA in TRACK)

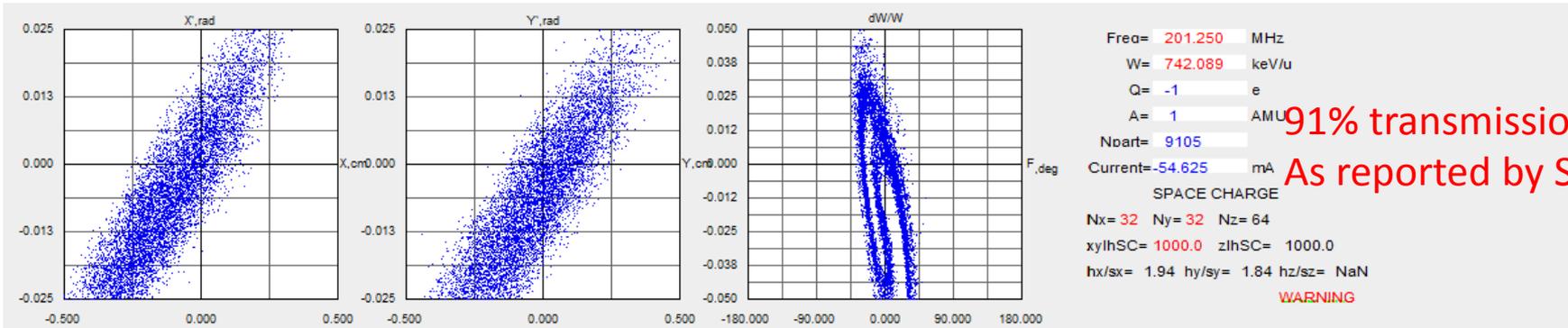


Alpha\_x=Alpha\_y=8.4,

Beta\_x=Beta\_y=5.05 cm/rad (After back propagation of 50 mm at 60 mA in TRACK)

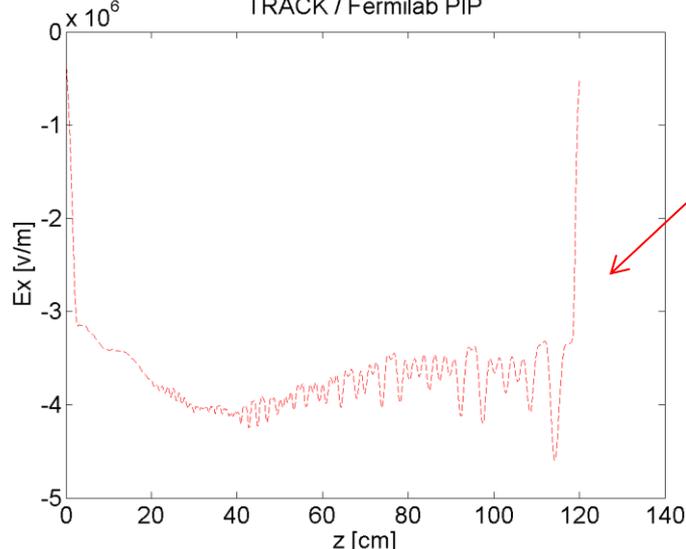
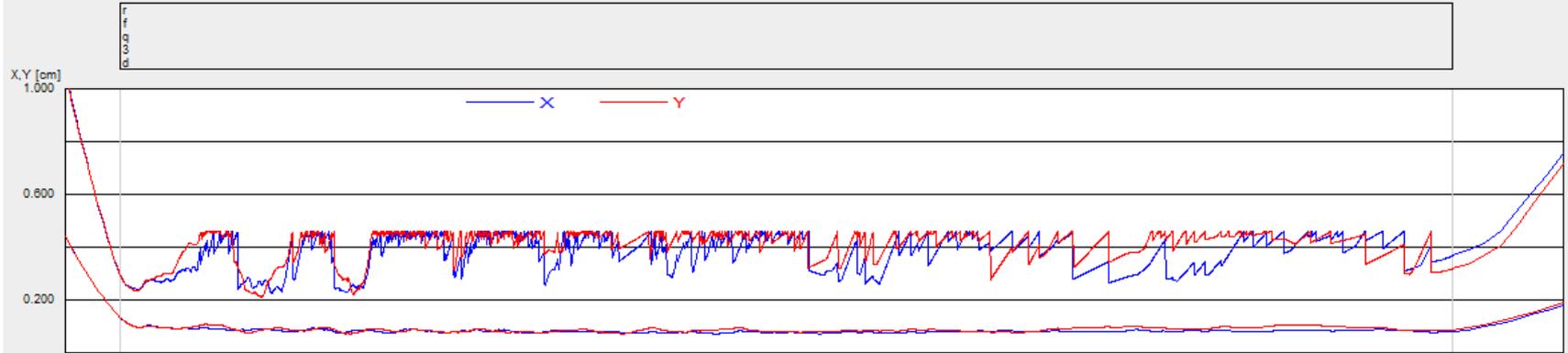


# TRACK with 3D FIELDS. Injection Down in the RFQ geometrical axis.

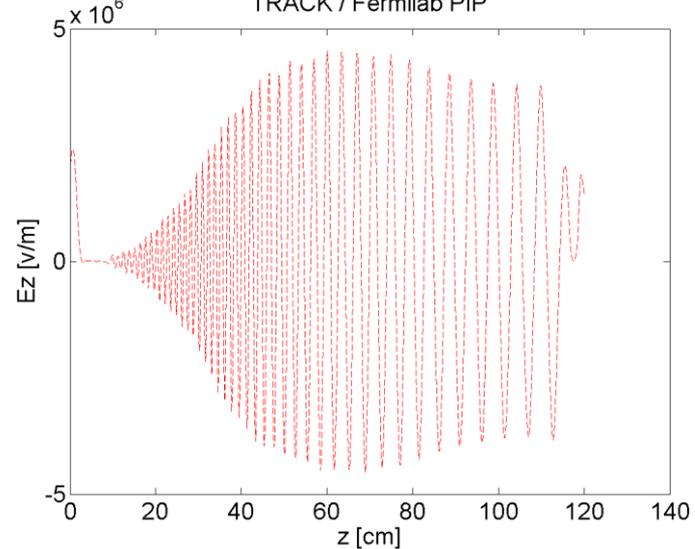


Freq= 201.250 MHz  
 W= 742.089 keV/u  
 Q= -1 e  
 A= 1 AMU  
 Noart= 9105  
 Current=-54.625 mA  
 SPACE CHARGE  
 Nx= 32 Ny= 32 Nz= 64  
 xylhSC= 1000.0 zlhSC= 1000.0  
 hx/sx= 1.94 hy/sy= 1.84 hz/sz= NaN  
**WARNING**

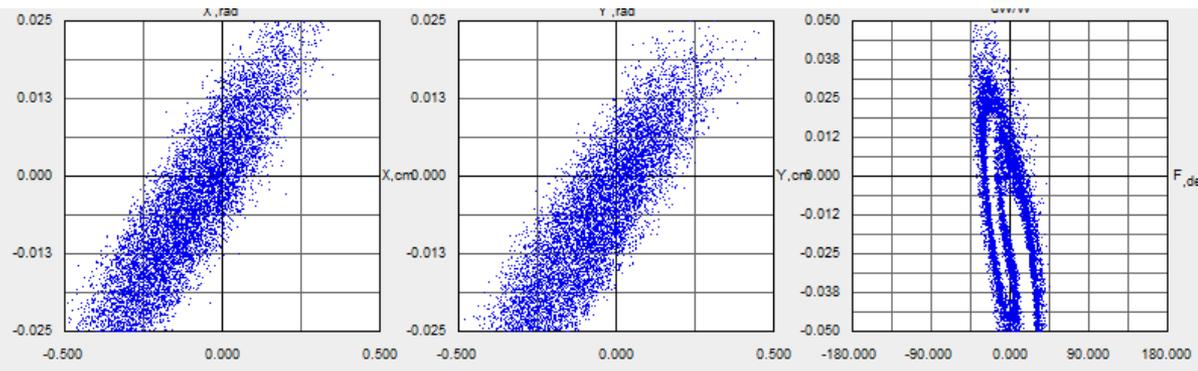
**91% transmission**  
**As reported by Sergey**



Dipole Field  
 big on geo.  
 axis



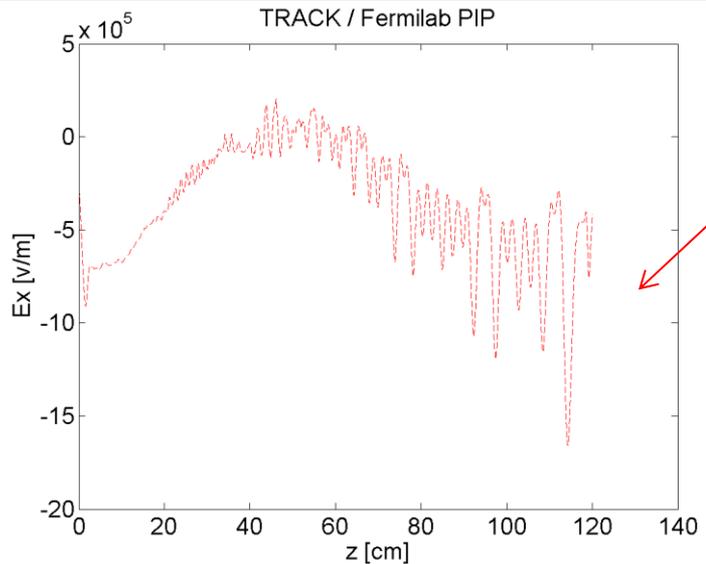
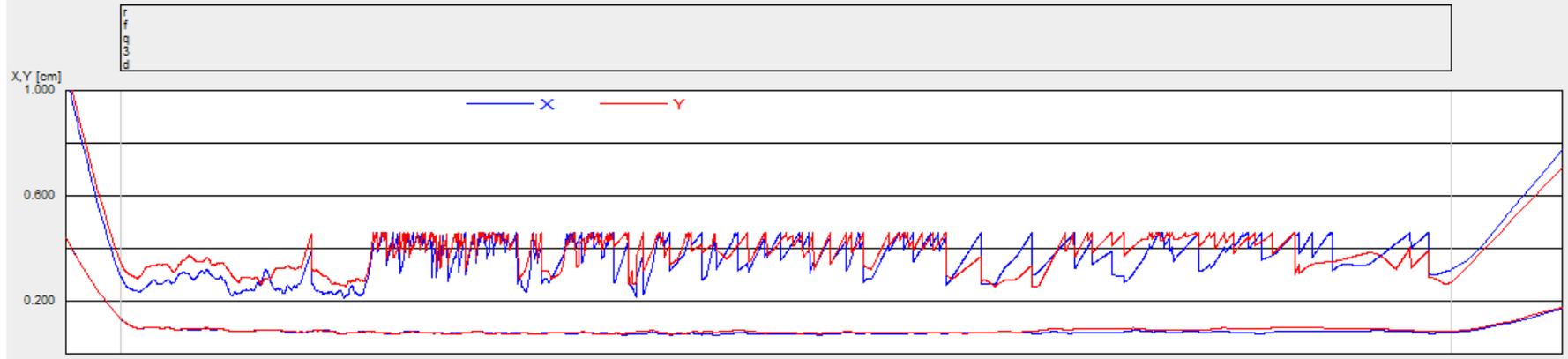
# TRACK with 3D FIELDS. Injection Down in Y by -0.5 mm of RFQ geometrical axis.



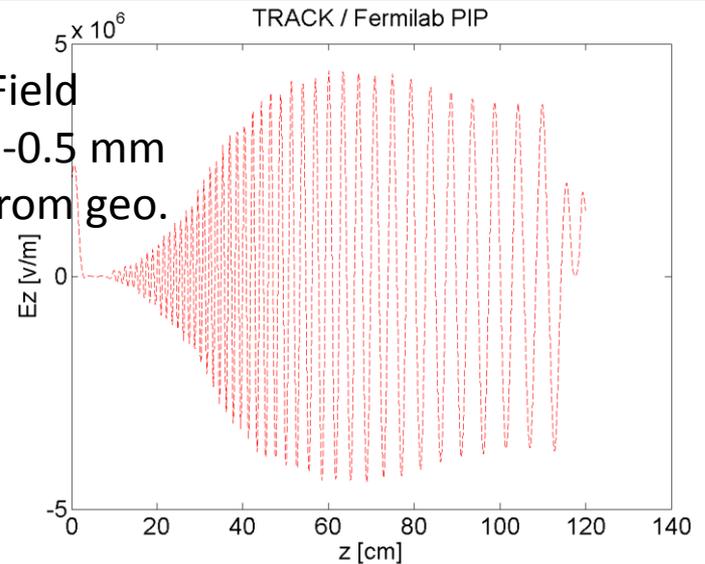
Freq= 201.250 MHz  
 W= 741.093 keV/u  
 Q= -1 e  
 A= 1 AMU  
 Npart= 9602  
 Current=-57.606 mA  
 SPACE CHARGE  
 Nx= 32 Ny= 32 Nz= 64  
 xylhSC= 1000.0 zlhSC= 1000.0  
 hx/sx= 2.04 hy/sy= 1.96 hz/sz= NaN

Up by +5%  
 Sergey reported  
 +2 or +3 %

WARNING



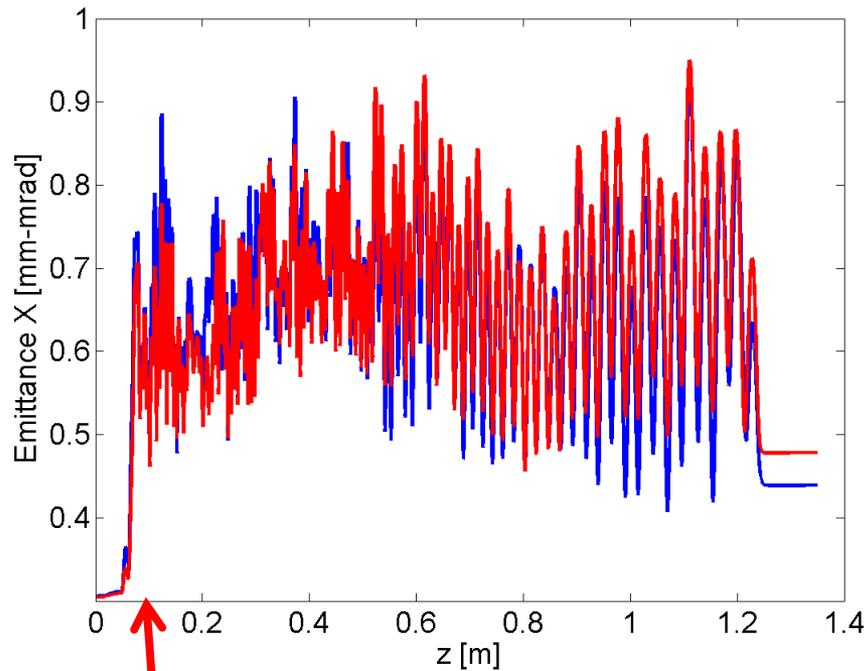
Dipole Field  
 smaller -0.5 mm  
 Lower from geo.  
 axis



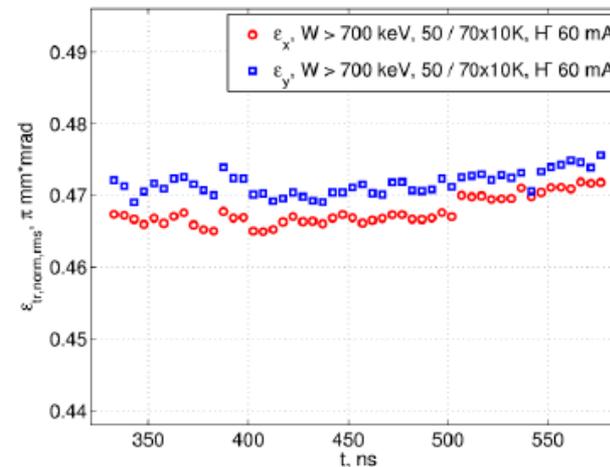
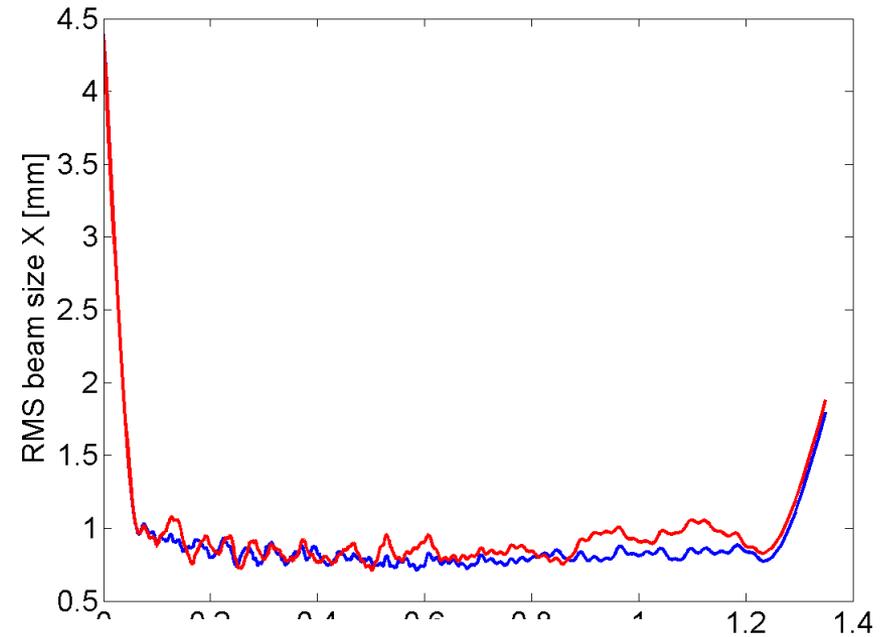
Are you matched with:  $\text{Alpha}_x = \text{Alpha}_y = 8.4$ ,  $\text{Beta}_x = \text{Beta}_y = 5.05$  cm/rad  
(After back propagation of 50 mm at 60 mA in TRACK) ?

Could this matching be improved ?

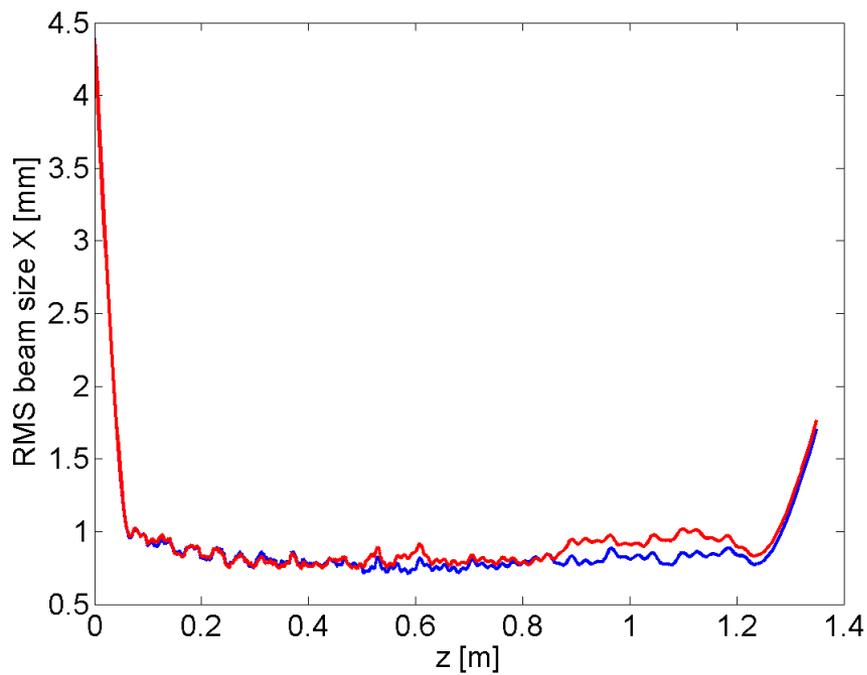
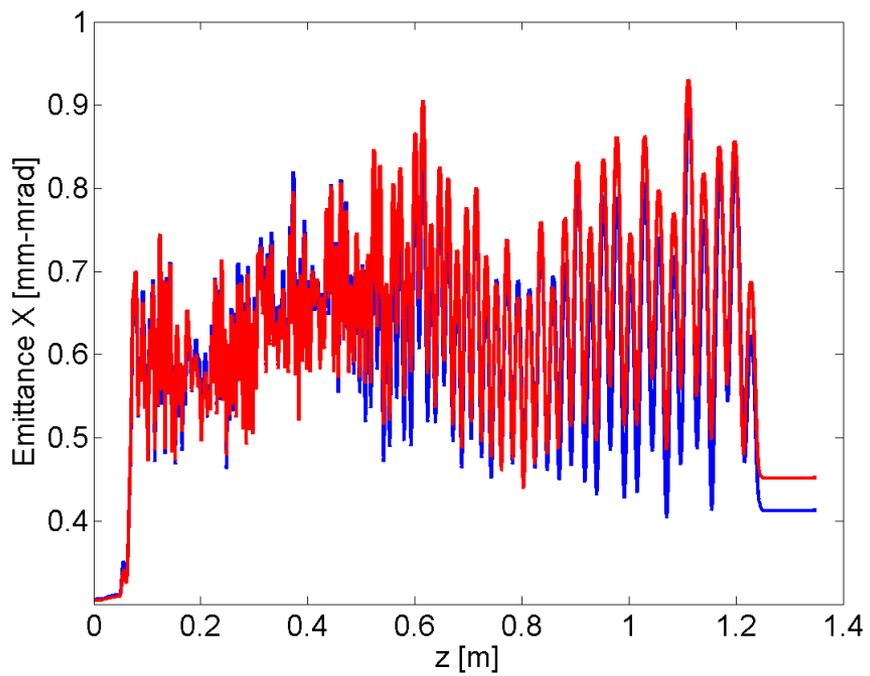
Injection on RFQ geometrical axis



Emittance Increase Takes Place at the Start of the RFQ



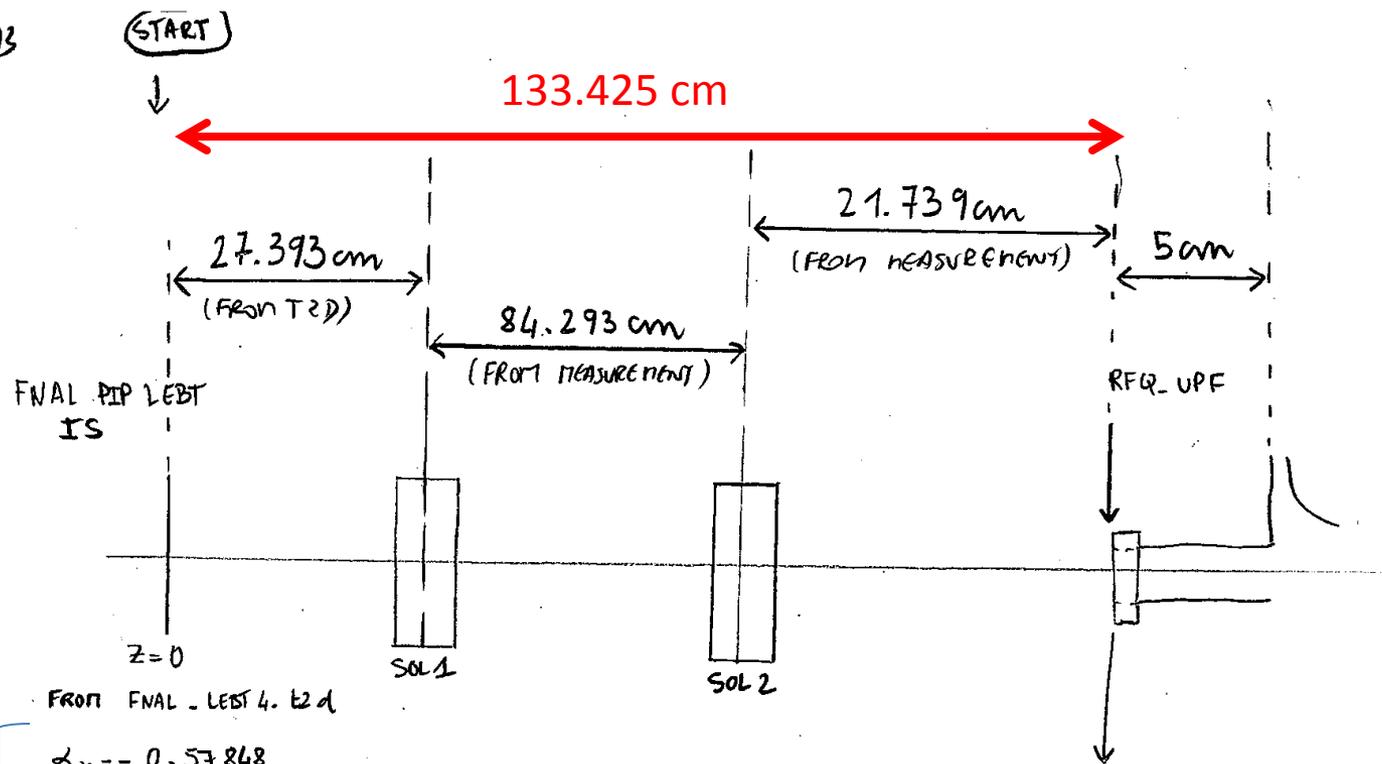
# Injection down by -0.5 mm on RFQ geometrical axis



PIP LEBT

# PIP LEBT DISTANCES (MODEL IN TRACE2d, TRACEWIN and TRACK)

13-AUG-2013  
JPC



FRONT FINAL LEBT 4. E2d

Asymmetric

$$\alpha_x = -0.57848$$

$$\beta_x = 5.2649 \times 10^{-2} \frac{\text{mm}}{\text{mrad}}$$

$$\alpha_y = -0.40643$$

$$\beta_y = 5.6954 \times 10^{-2} \frac{\text{mm}}{\text{mrad}}$$

$$\alpha_x = 8.4 \quad \beta_x = 0.5 \text{ mm/mrad}$$

$$\alpha_y = 8.4 \quad \beta_y = 0.5 \text{ mm/mrad}$$

} IF 50mm DRIFT TUBE AT 60mA

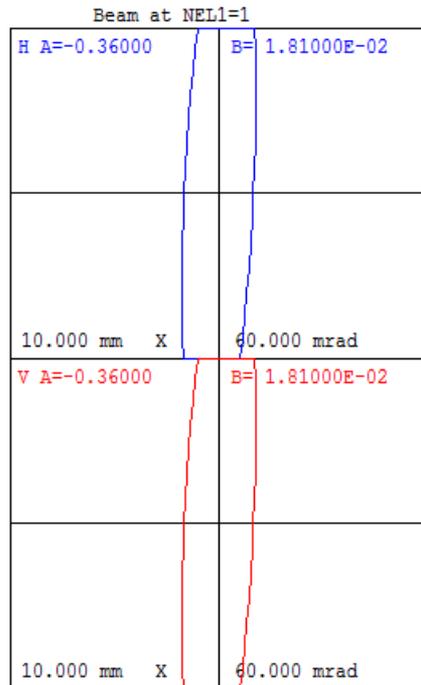
$$\alpha_x = 4.7 \quad \beta_x = 0.3 \text{ mm/mrad}$$

$$\alpha_y = 4.7 \quad \beta_y = 0.3 \text{ mm/mrad}$$

} IF 50mm DRIFT TUBE AT 0mA (100% NEUTRALIZED)

Here we start with a symmetric beam. And fetch 1.5 / 5.1E-2 at RFQ entrance (at the plate)

Sol1 = Sol2. 100% neutralized. Exact matching found.



```

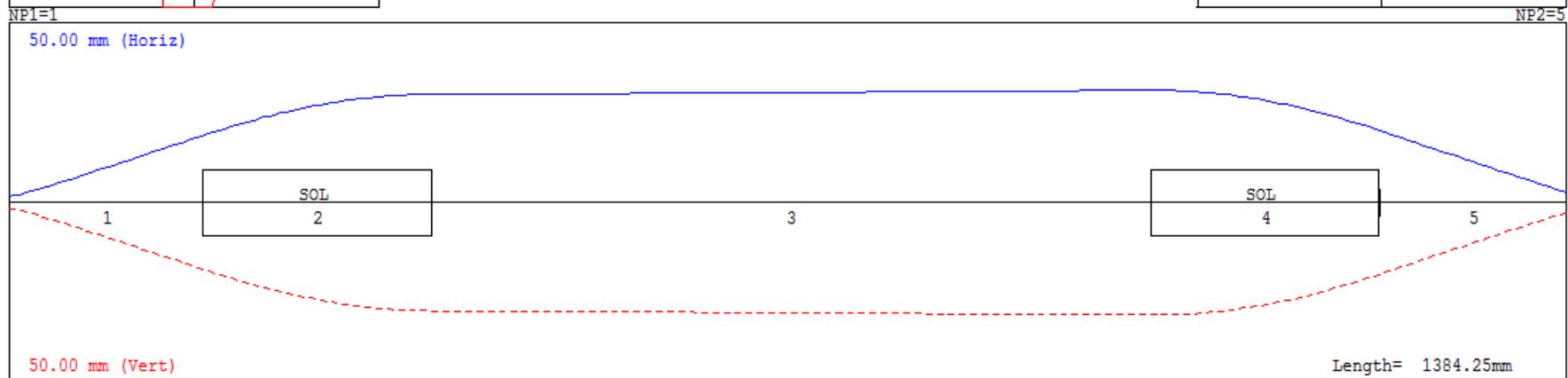
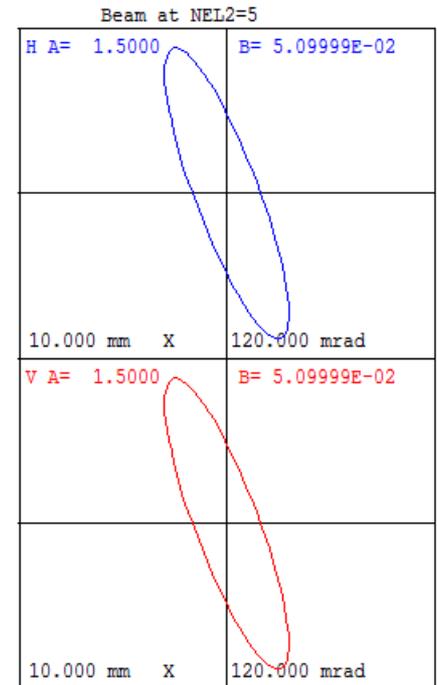
I = 0.0 mA    Q = -1
W = 0.035 to 0.035 MeV
FREQ = 201.25 MHz    WL = 1489.65 mm
EMITI = 176.0 176.0
EMITO = 176.0 176.0
N1 = 1    N2 = 6
PRINTOUT VALUES
PP PE    VALUE
1 1      172.09
1 2      2377.68
MATCHING TYPE = 5
DESIRED VALUES (BEAMF)
Alpha    Beta
x 1.5000 0.0510
y 1.5000 0.0510
MATCH VARIABLES (NC=4)
MFP MPE    VALUE
1 2      2377.68
1 4      2370.67
    
```

```

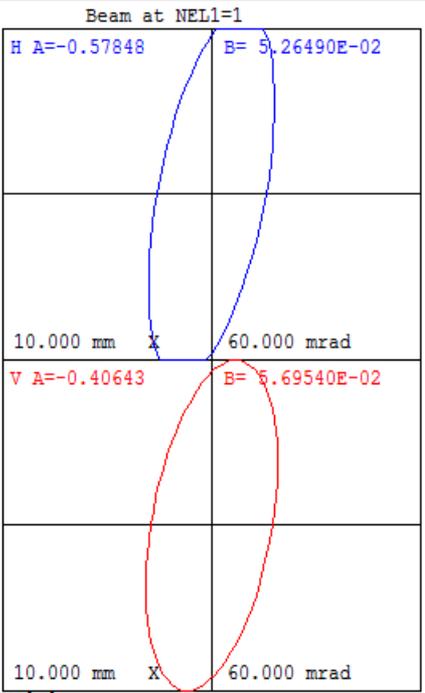
Trace 2-D 2006.02 1-12-2006
FILE: fnal_lebt4_12AUG2013.t2d
DATE: 08/13/2013
TIME: 08:39:30
    
```

```

Matching... (NIT=10)
0.0000 2377.68 2370.67
    
```

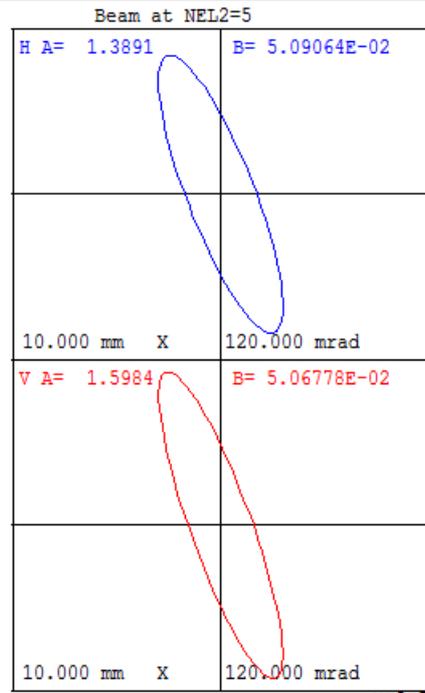


Here we start with the **asymmetric** beam. And fetch 1.5 / 5.1E-2 at RFQ entrance (at the plate)  
**Sol1 is about 20% lower than Sol2. 0 mA all along the LEBT. Matching not found.**



```

I = 0.0 mA      Q = -1
W = 0.035 to 0.035 MeV
FREQ = 201.25 MHz  WL = 1489.65 mm
EMITI = 176.000 176.000
EMITO = 176.086 176.086
N1 = 1  N2 = 6
PRINTOUT VALUES
PP PE VALUE
1 1 172.09
1 2 2014.36
MATCHING TYPE = 5
DESIRED VALUES (BEAMF)
Alpha Beta
x 1.5000 0.0510
y 1.5000 0.0510
MATCH VARIABLES (NC=4)
MPP MPE VALUE
1 2 2014.36
1 4 2530.74
  
```

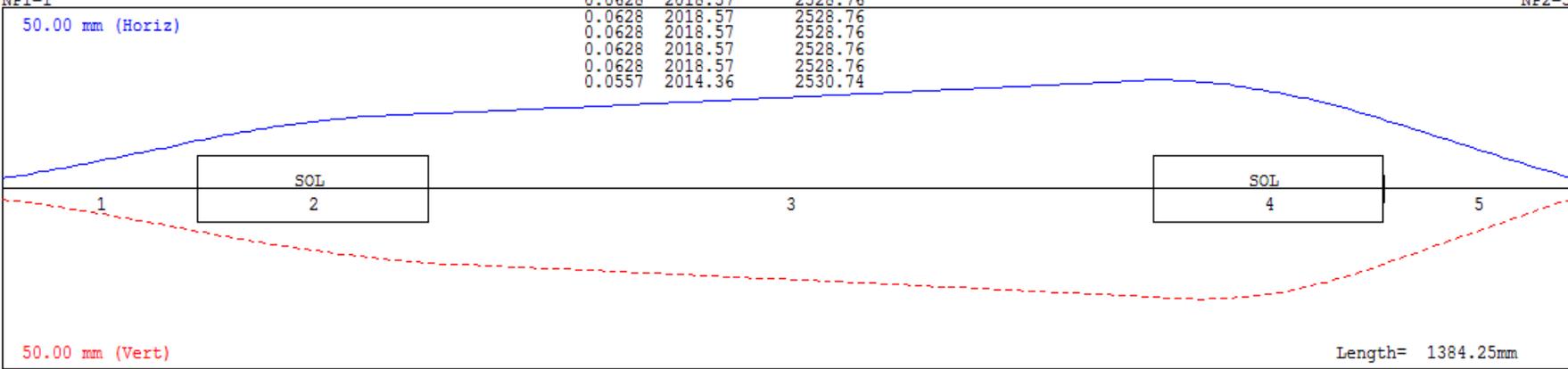


```

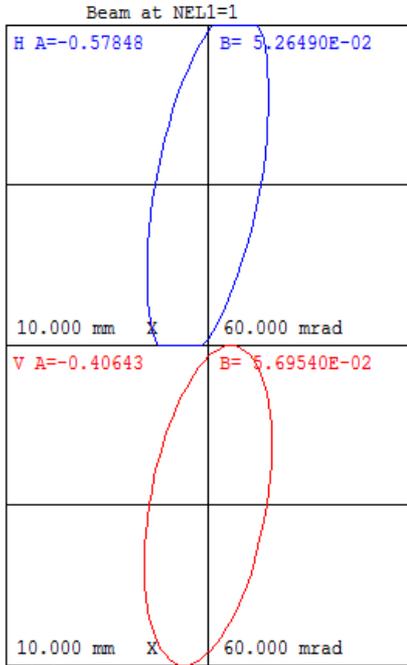
Trace 2-D 2006.02 1-12-2006
FILE: fnal lebt4 12AUG2013.t2d
DATE: 08/13/2013
TIME: 08:43:50
  
```

Matching... (NIT=10)

0.0557	2014.36	2530.74
0.4036	1861.58	2536.07
5.4475	2196.37	2963.83
0.0570	2014.46	2531.00
0.0697	2021.33	2526.92
0.0628	2018.54	2528.76
0.0628	2018.57	2528.76
0.0628	2018.57	2528.76
0.0628	2018.57	2528.76
0.0628	2018.57	2528.76
0.0557	2014.36	2530.74



Here we start with a symmetric beam. And fetch  $8.4/5E-2$  at RFQ entrance (at the plate)  
**Sol1 about 20% lower than Sol2. 0 mA in LEBT. Exact matching not found.**



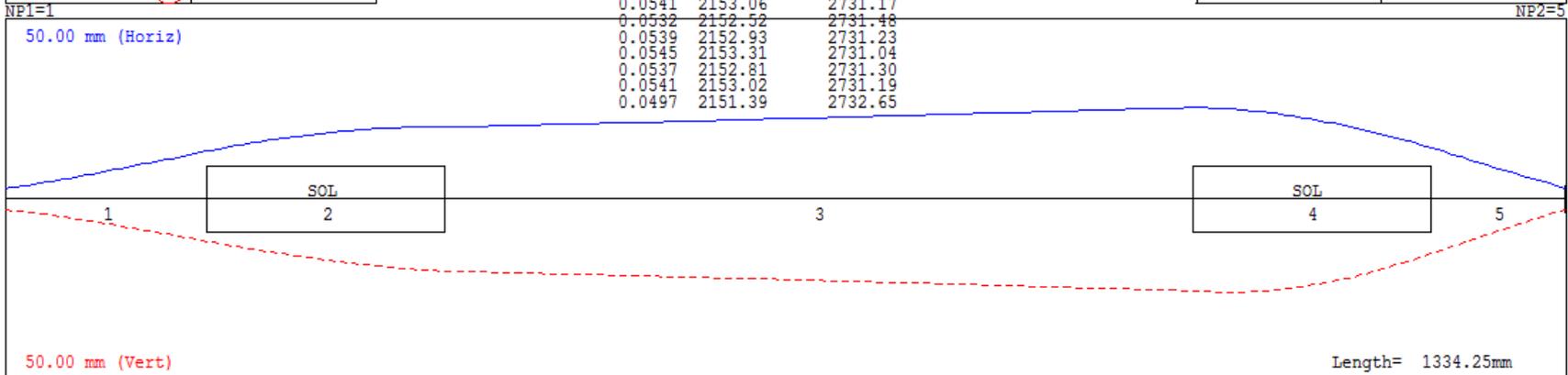
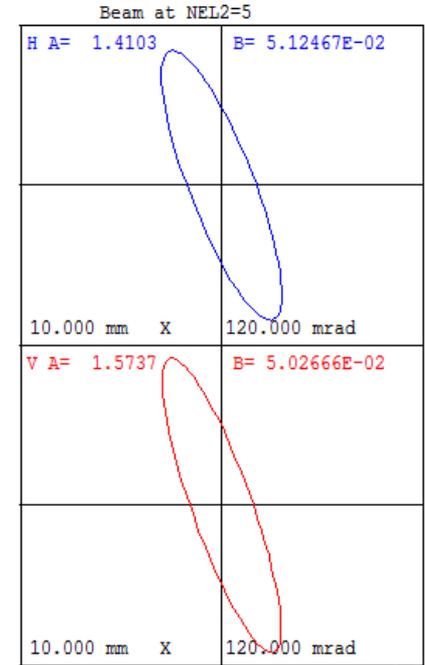
```

I = 0.0 mA Q = -1
W = 0.035 to 0.035 MeV
FREQ = 201.25 MHz WL = 1489.65 mm
EMITI = 176.000 176.000
EMITO = 176.291 176.291
N1 = 1 N2 = 6
PRINTOUT VALUES
PP PE VALUE
1 1 172.09
1 2 2151.39
MATCHING TYPE = 5
DESIRED VALUES (BEAMF)
Alpha Beta
x 1.5000 0.0510
y 1.5000 0.0510
MATCH VARIABLES (NC=4)
MPP MPE VALUE
1 2 2151.39
1 4 2732.65
    
```

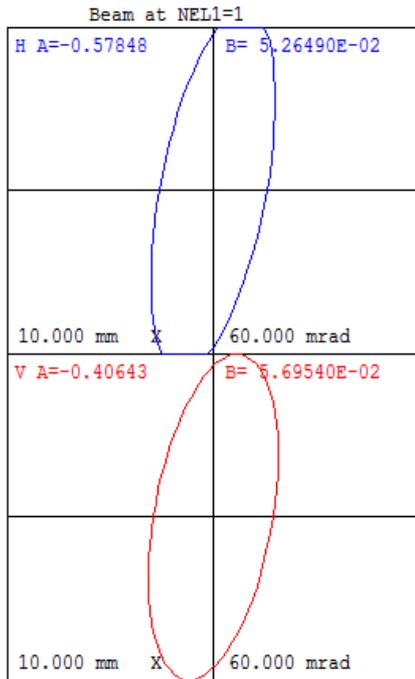
Trace 2-D 2006.02 1-12-2006  
 FILE: fnal lebt4 12AUG2013.t2d  
 DATE: 08/13/2013  
 TIME: 08:53:05

Matching... (NIT=10)

0.0497	2151.39	2732.65
5.0094	2008.01	2337.46
0.2207	2035.19	2760.68
0.0504	2151.70	2732.37
0.0540	2152.99	2731.20
0.0552	2156.95	2731.17
0.0538	2152.85	2731.28
0.0541	2153.06	2731.17
0.0532	2152.52	2731.48
0.0539	2152.93	2731.23
0.0545	2153.31	2731.04
0.0537	2152.81	2731.30
0.0541	2153.02	2731.19
0.0497	2151.39	2732.65

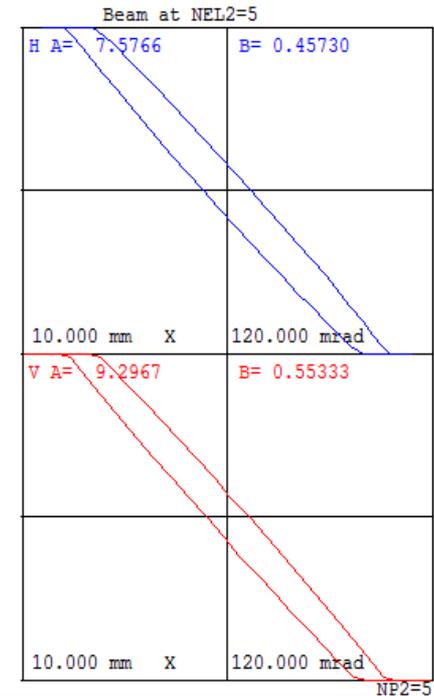


Here we start with the **asymmetric** beam. And fetch 8.4/5E-2 at RFQ entrance (at the plate)  
**Sol1** about 20% lower than Sol2. 0 mA in LEBT. Exact matching not found.



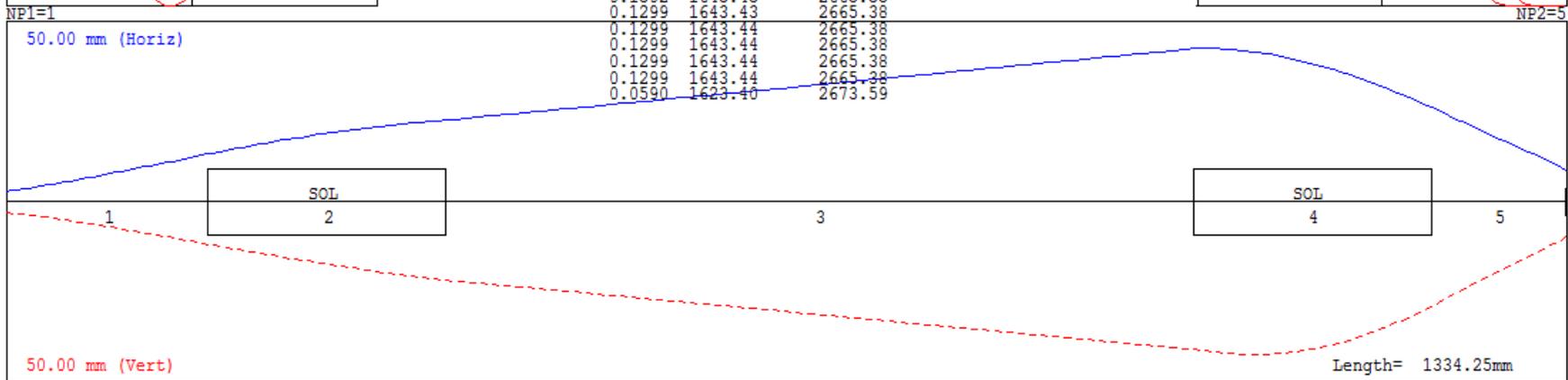
```

I = 0.0 mA Q = -1
W = 0.035 to 0.035 MeV
FREQ = 201.25 MHz WL = 1489.65 mm
EMITI = 176.00 176.00
EMITO = 176.01 176.01
N1 = 1 N2 = 6
PRINTOUT VALUES
PP PE VALUE
1 1 172.09
1 2 1623.4
MATCHING TYPE = 5
DESIRED VALUES (BEAMF)
Alpha Beta
x 8.4102 0.5037
y 8.4360 0.5059
MATCH VARIABLES (NC=4)
MPP MPE VALUE
1 2 1623.4
1 4 2673.59
  
```

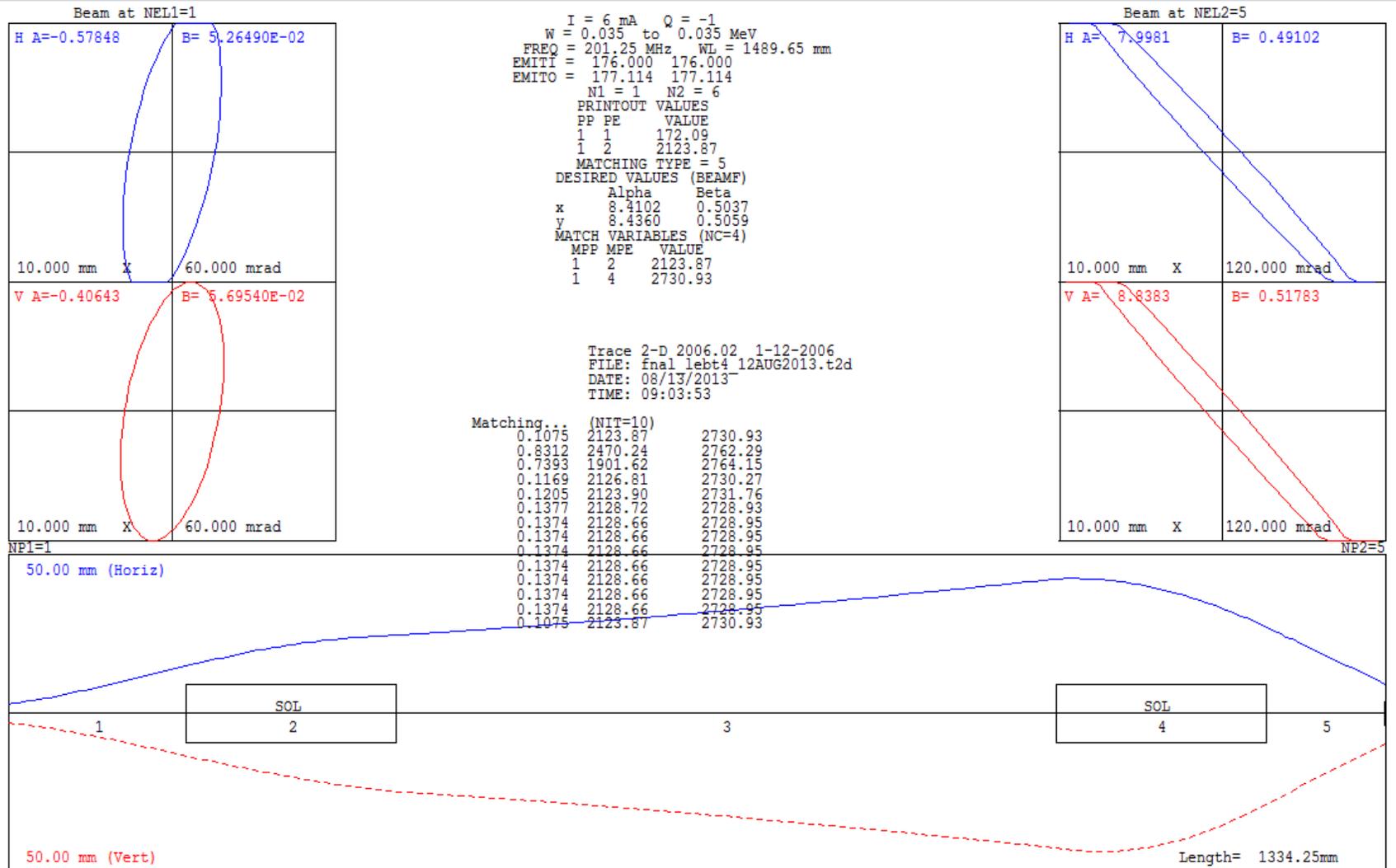


Trace 2-D 2006.02 1-12-2006  
 FILE: fnal lebt4 12AUG2013.t2d  
 DATE: 08/13/2013  
 TIME: 08:56:12

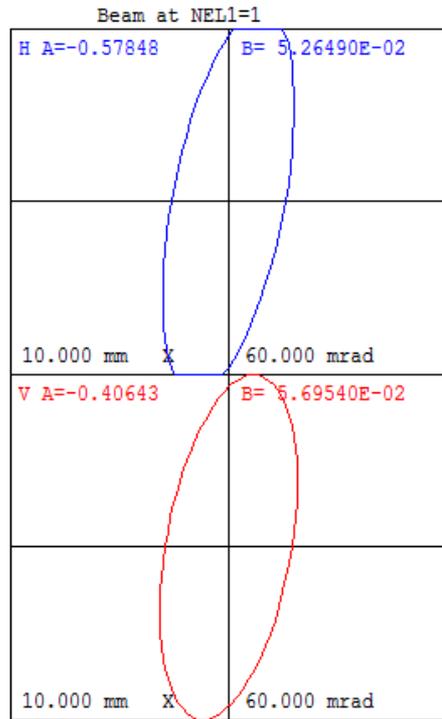
Matching... (NIT=10)		
0.0590	1623.40	2673.59
13.8609	1678.14	3128.07
5.7789	1589.31	2872.46
0.0700	1622.95	2672.20
0.2871	1631.18	2686.51
0.4203	1575.24	2698.74
0.1412	1648.73	2663.99
0.1302	1643.43	2665.35
0.1299	1643.43	2665.38
0.1299	1643.44	2665.38
0.1299	1643.44	2665.38
0.1299	1643.44	2665.38
0.0590	1623.40	2673.59



Here we start with the **asymmetric** beam. And fetch 8.4/5E-2 at RFQ entrance (at the plate)  
**Sol1** about 20% lower than Sol2. 6 mA in LEBT . Exact matching not found.

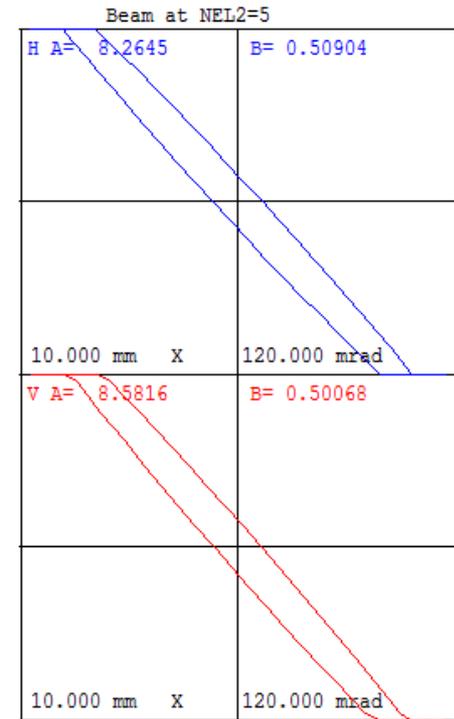


Here we start with the **asymmetric** beam. And fetch 8.4/5E-2 at RFQ entrance (at the plate)  
**Sol1** about 10% lower than Sol2. 6 mA in LEBT . Exact matching not found.



```

I = 12 mA      Q = -1
W = 0.035 to 0.035 MeV
FREQ = 201.25 MHz      WL = 1489.65 mm
EMITI = 176.00      176.00
EMITO = 180.45      180.45
N1 = 1      N2 = 6
PRINTOUT VALUES
PP PE      VALUE
1 1      172.09
1 2      2407.83
MATCHING TYPE = 5
DESIRED VALUES (BEAMF)
Alpha      Beta
x      8.4102      0.5037
y      8.4360      0.5059
MATCH VARIABLES (NC=4)
MPP MPE      VALUE
1 2      2407.83
1 4      2784.02
  
```

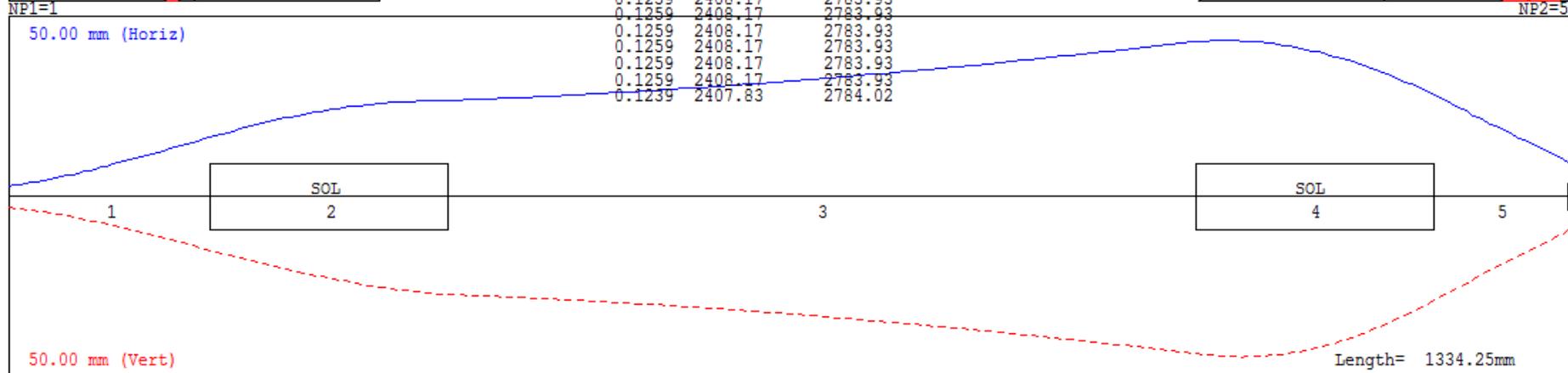


```

Trace 2-D 2006.02 1-12-2006
FILE: fnal lebt4 12AUG2013.t2d
DATE: 08/13/2013
TIME: 09:07:02
  
```

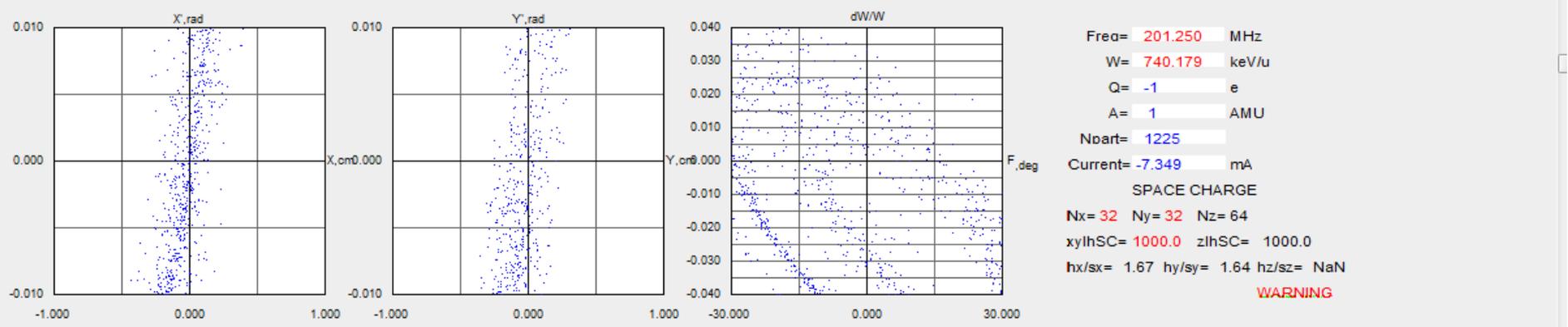
```

Matching... (NIT=10)
0.1239 2407.83      2784.02
10.2659 2415.91      2425.40
1.1062 2214.65      2810.07
0.1261 2408.24      2783.92
0.1245 2407.94      2784.07
0.1259 2408.17      2783.93
0.1259 2408.17      2783.93
0.1259 2408.17      2783.93
0.1259 2408.17      2783.93
0.1259 2408.17      2783.93
0.1239 2407.83      2784.02
  
```

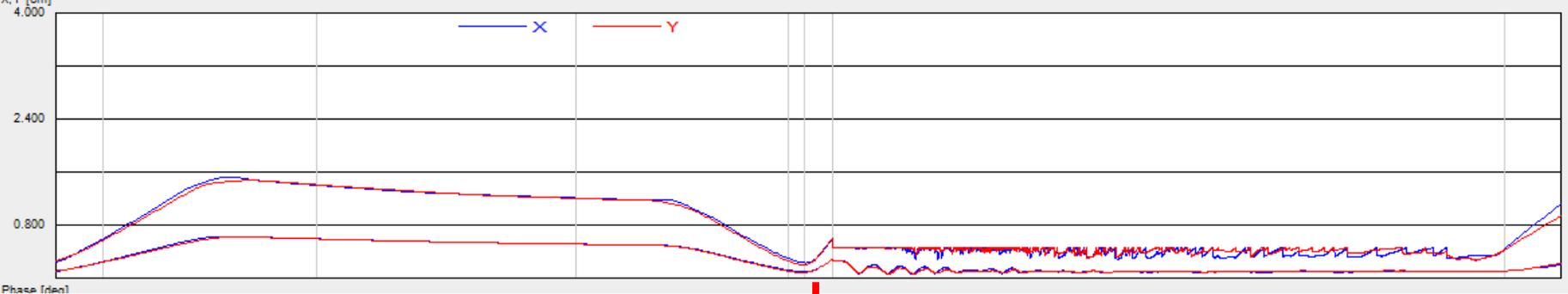


PIP LEBT  
As of TODAY

LEBT actual running. With Sol1 at 438 Amps and Sol 2 at 475 Amps.  
 Here we consider 0 mA (100% neutralized) up to the entrance of the RFQ 50 mm beam tube.  
 The RFQ 50 mm beam tube is at 60 mA (no neutralization in the beam tube).  
 Transmission is about 12 %  
 From TRACK.



Sol1 3756 G; ~ 438 A      Sol2 4071 G; ~ 475 A

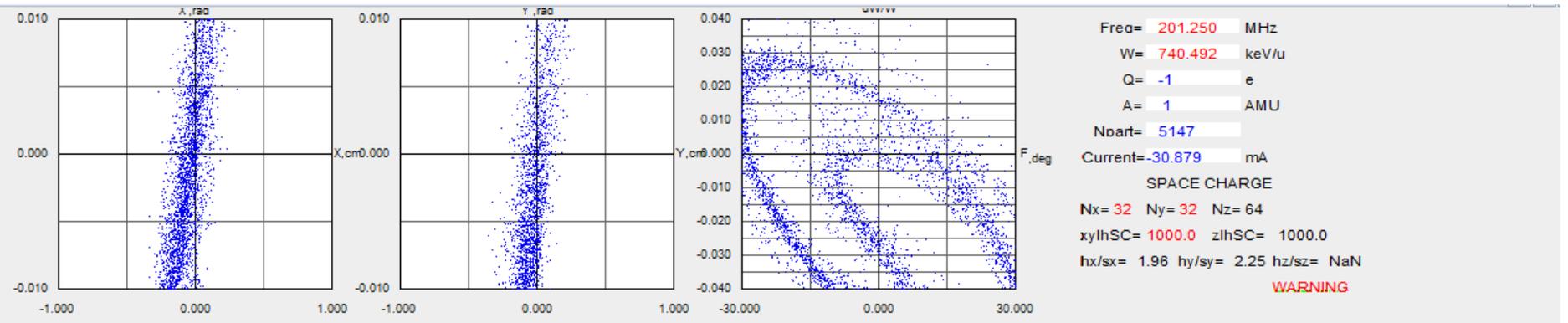


← 0 mA →  
 ↓ 60 mA

LEBT actual running. With Sol1 at 438 Amps and Sol 2 at 475 Amps.  
Here we consider 0 mA (100% neutralized) up to the entrance of the RFQ.  
The 50 mm RFQ beam tube is at 0 mA (100% neutralization in the beam tube).

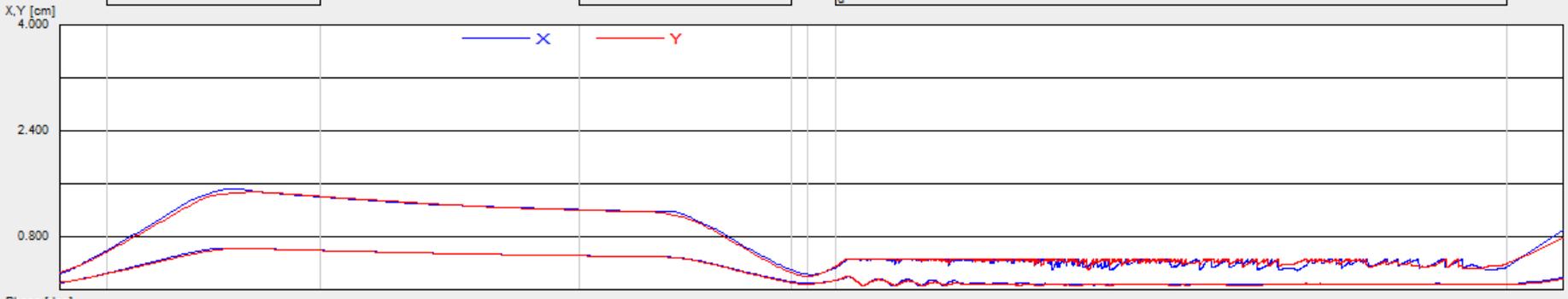
**Transmission is about 51 %**

From TRACK.



**3756 G; ~ 438 A**

**4071 G; ~ 475 A**

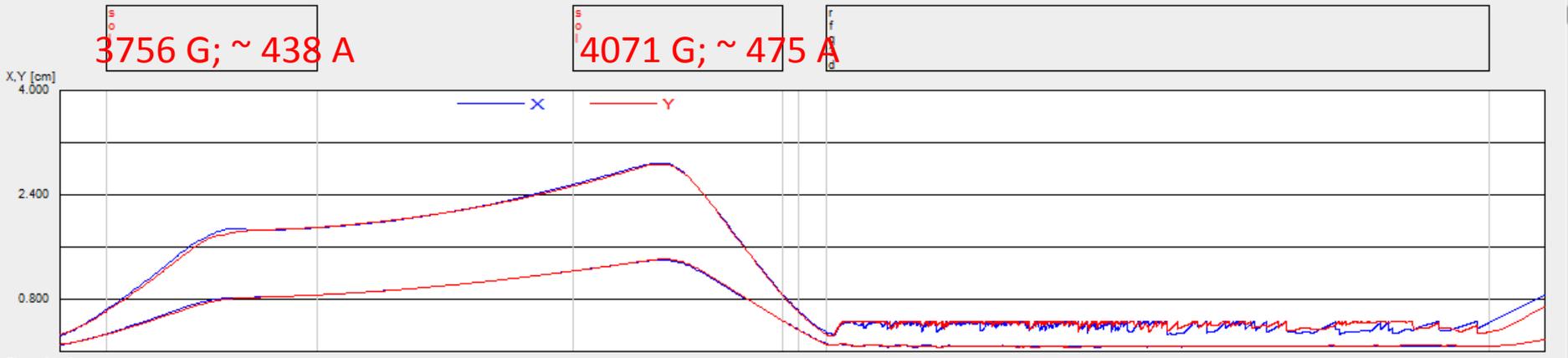
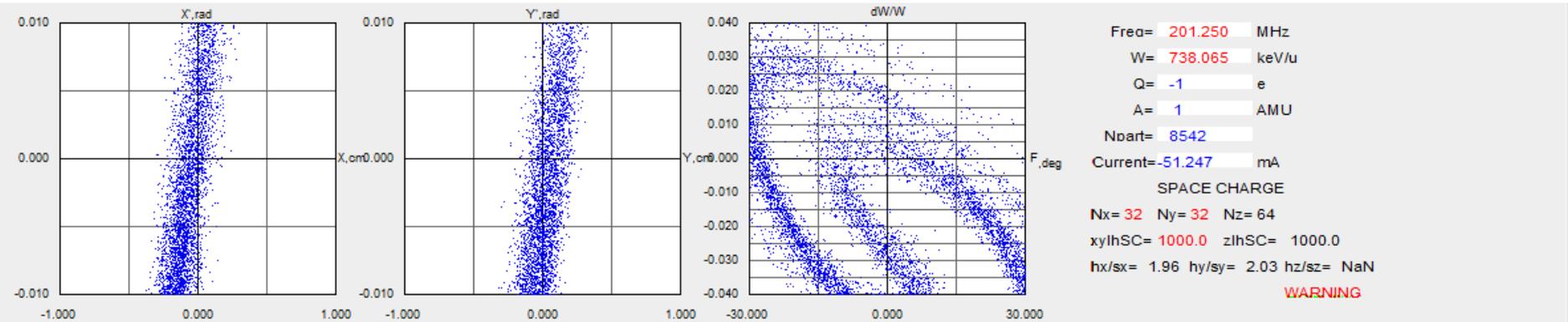


**0 mA**

LEBT actual running. With Sol1 at 438 Amps and Sol 2 at 475 Amps.  
Here we consider 6 mA (90% neutralized) up to the entrance of the RFQ.  
The 50 mm RFQ beam tube is at 6 mA (90% neutralization in the beam tube).

**Transmission is about 85 % (!)**

From TRACK.

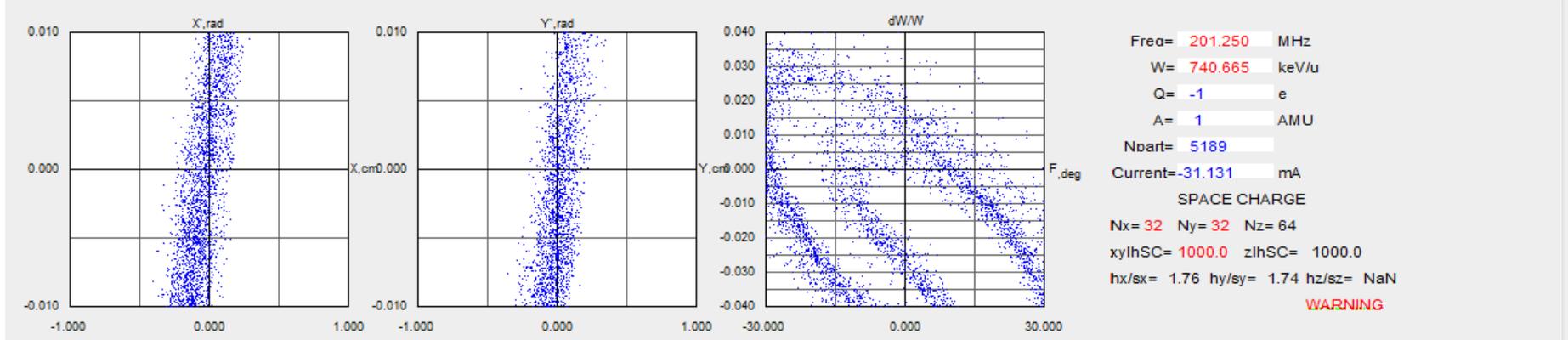


6 mA

LEBT actual running. With Sol1 at 438 Amps and Sol 2 at 475 Amps.  
 Here we consider 12 mA (80% neutralized) up to the entrance of the RFQ.  
 The 50 mm RFQ beam tube is at 12 mA (80% neutralization in the beam tube).

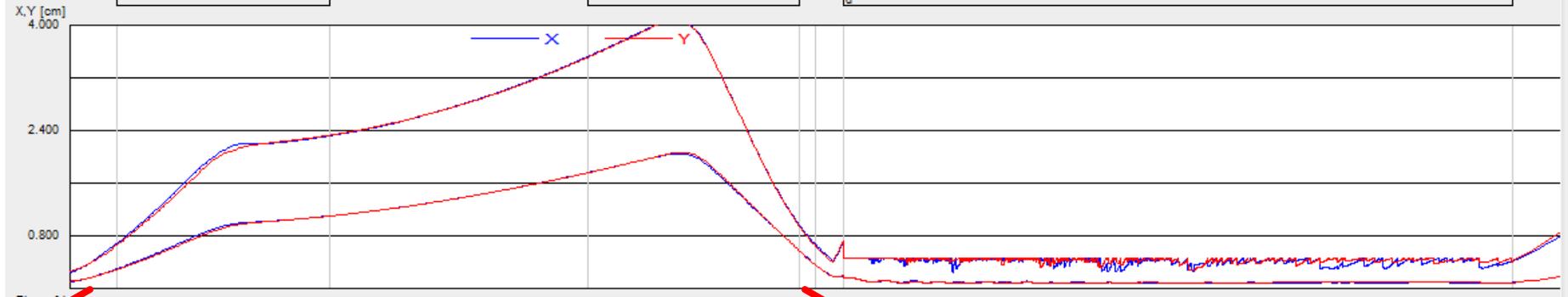
**Transmission is about 51 %**

From TRACK.



**3756 G; ~ 438 A**

**4071 G; ~ 475 A**



**12 mA**

## CONCLUSION AND NEXT STEPS

- TRACK3D and Particle Studio give good agreement.
- Insert (this week ?) the aperture vanes in TRACK. Peter gave agreement.
- Ask BNL about the TWISS at the source
- Perform with Saclay SOLMAXP simulation for space charge neutralization in LEBT
- BNL and WARP ?
  
- Check with LANL (Rybarczyk, Larry) about Particle Studio Input Distribution

## Acknowledgment

- Many thanks to CY Tan, R. Zwaska, F. Garcia, S. Kurennoy, N. Solyak, G. Romanov, R. Kostin, V. Kapin, P. Ostroumov, B. Mustapha for your help in performing this work.