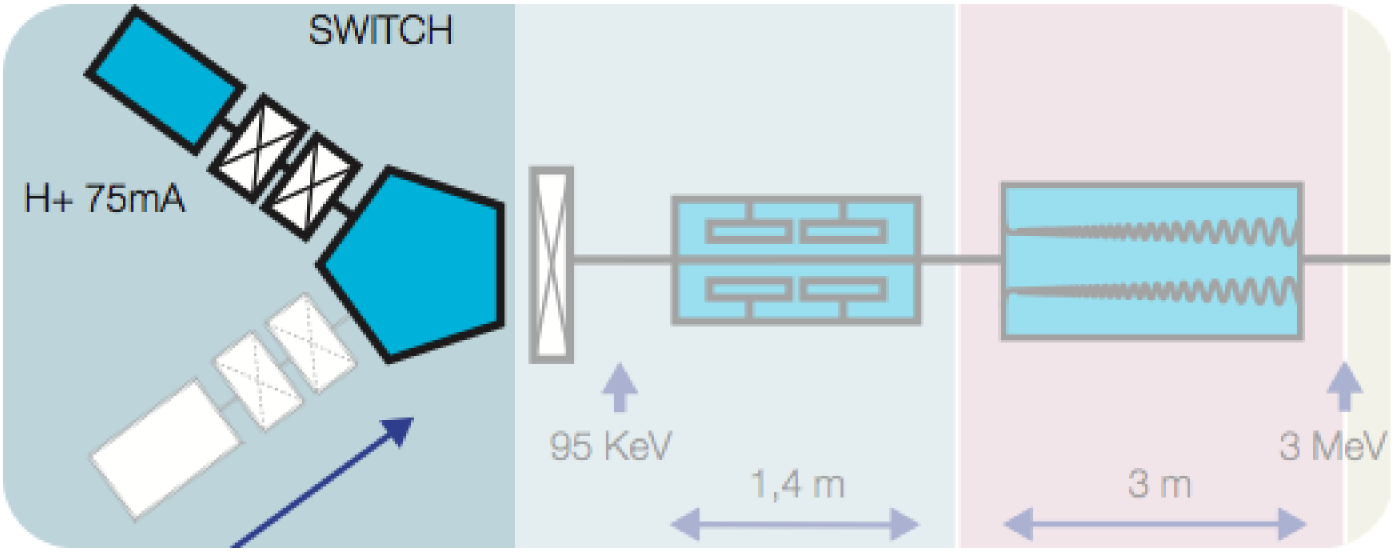
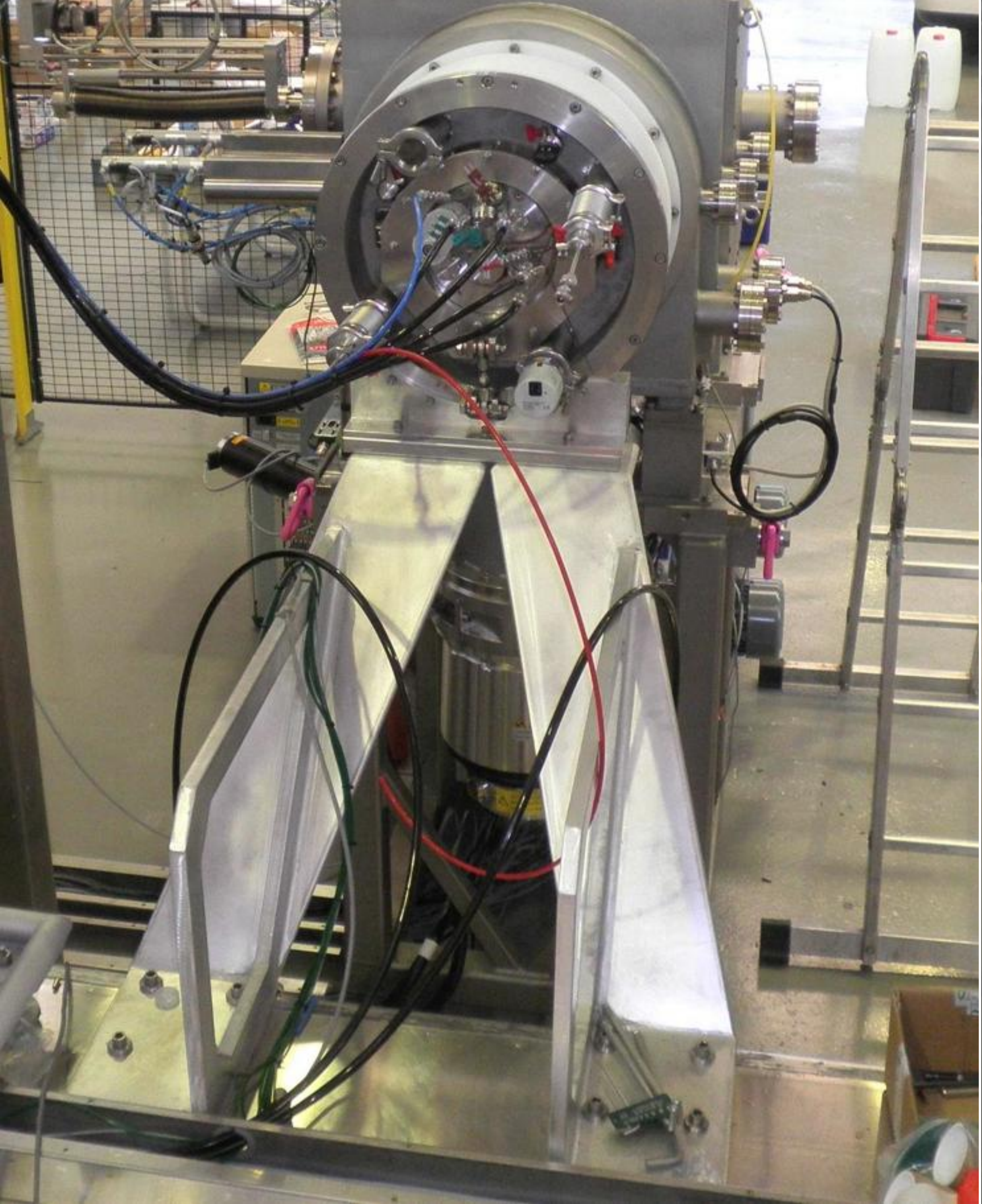
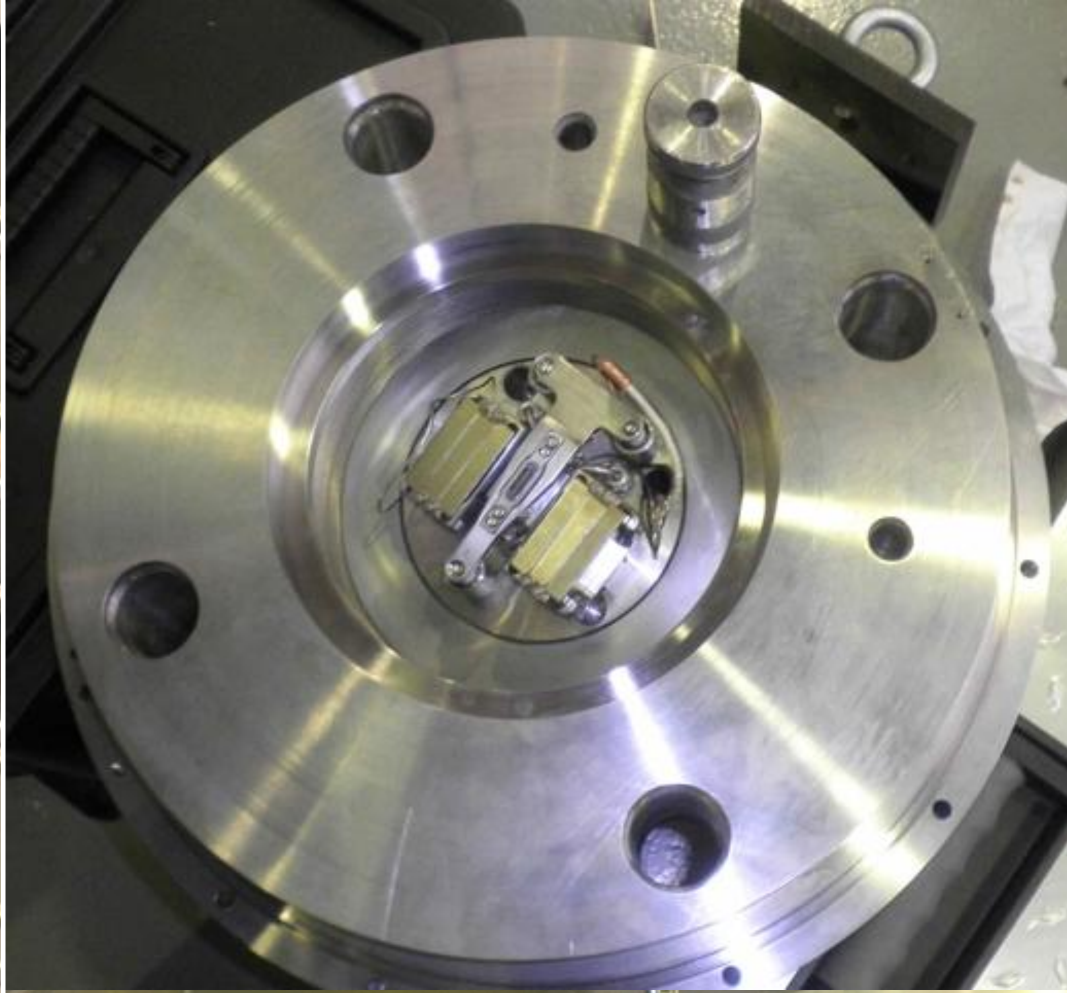
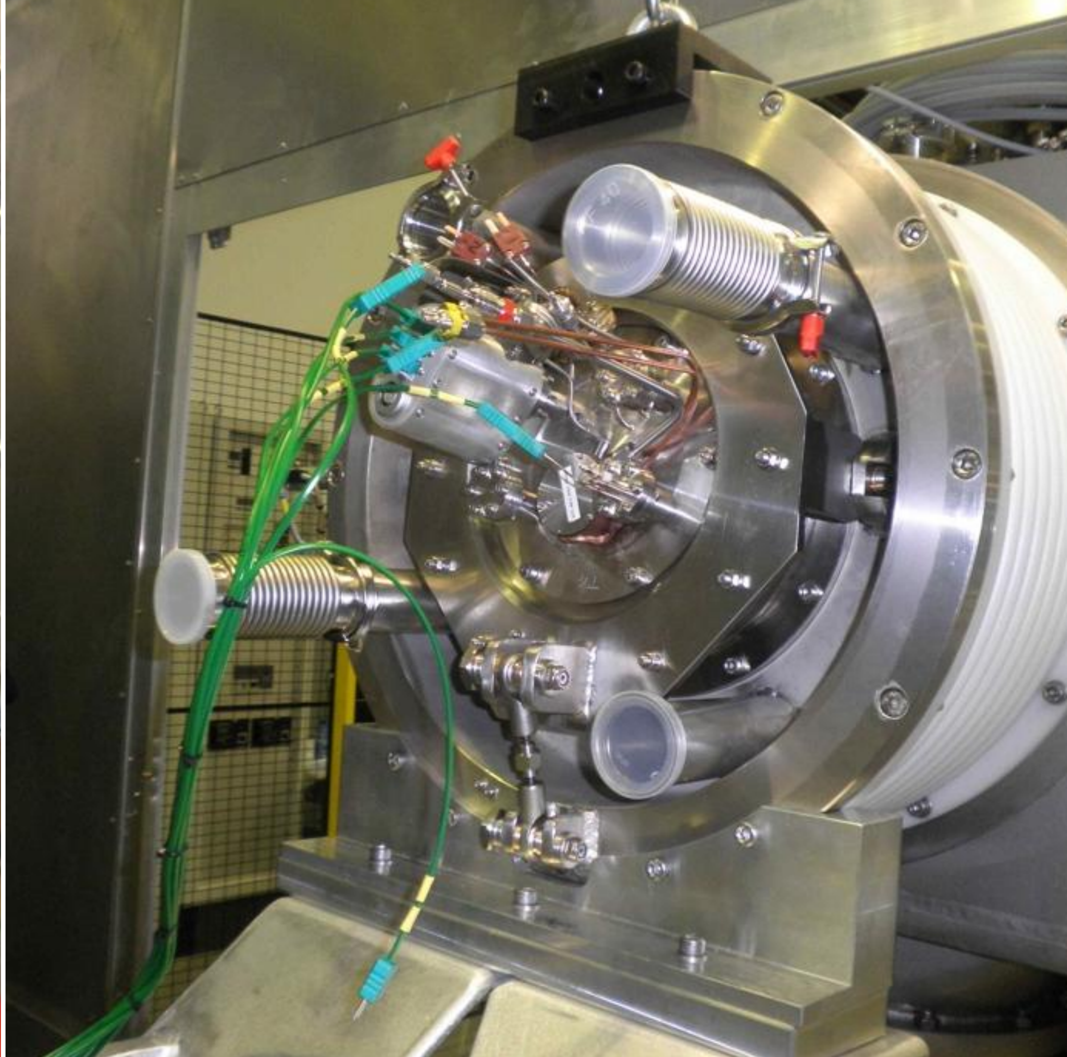
First LEBT Simulations for the Bilbao Accelerator Ion Source Test Stand

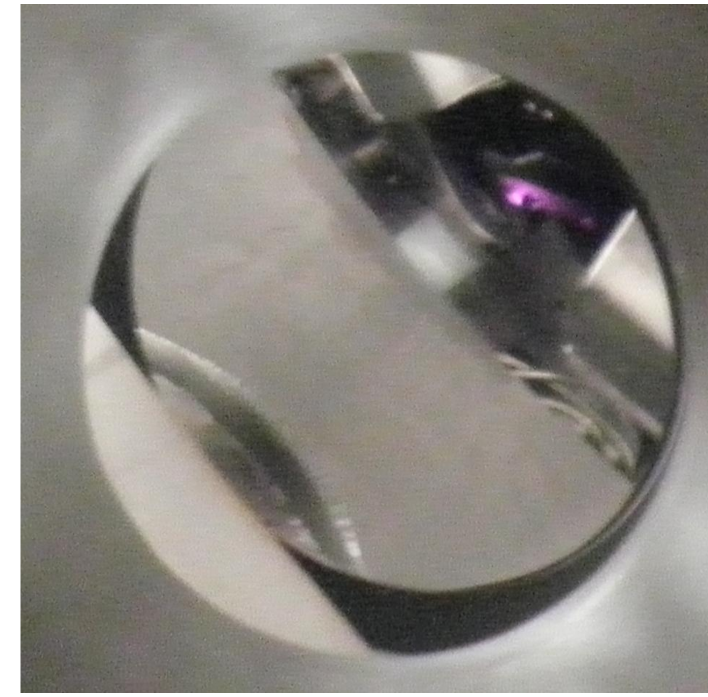
Ibon Bustinduy, Jean Paul Carneiro et al.

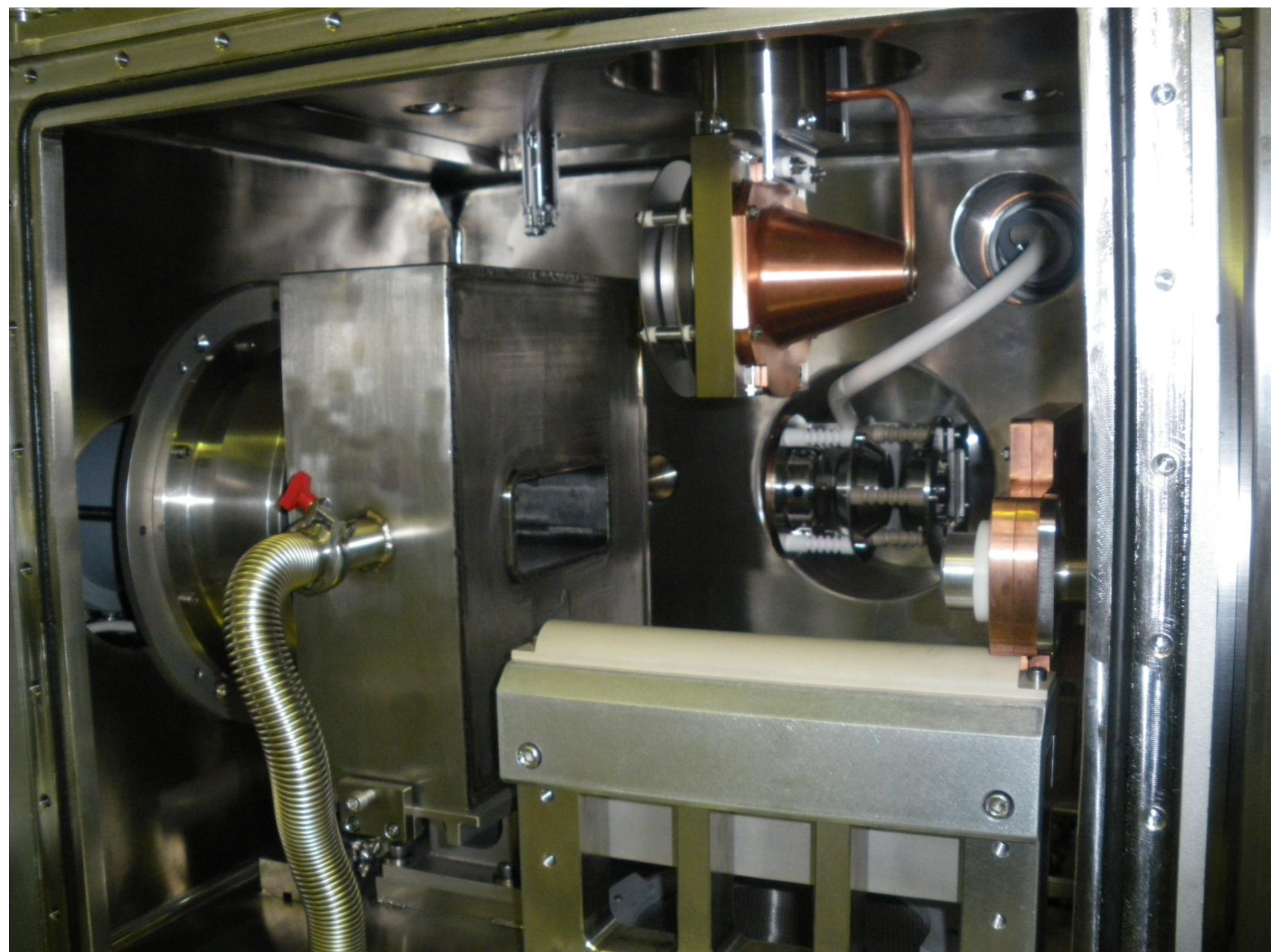
46th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams
September 27 – October 1, 2010
Swiss Holiday Park, Morschach, Switzerland

H^- Source

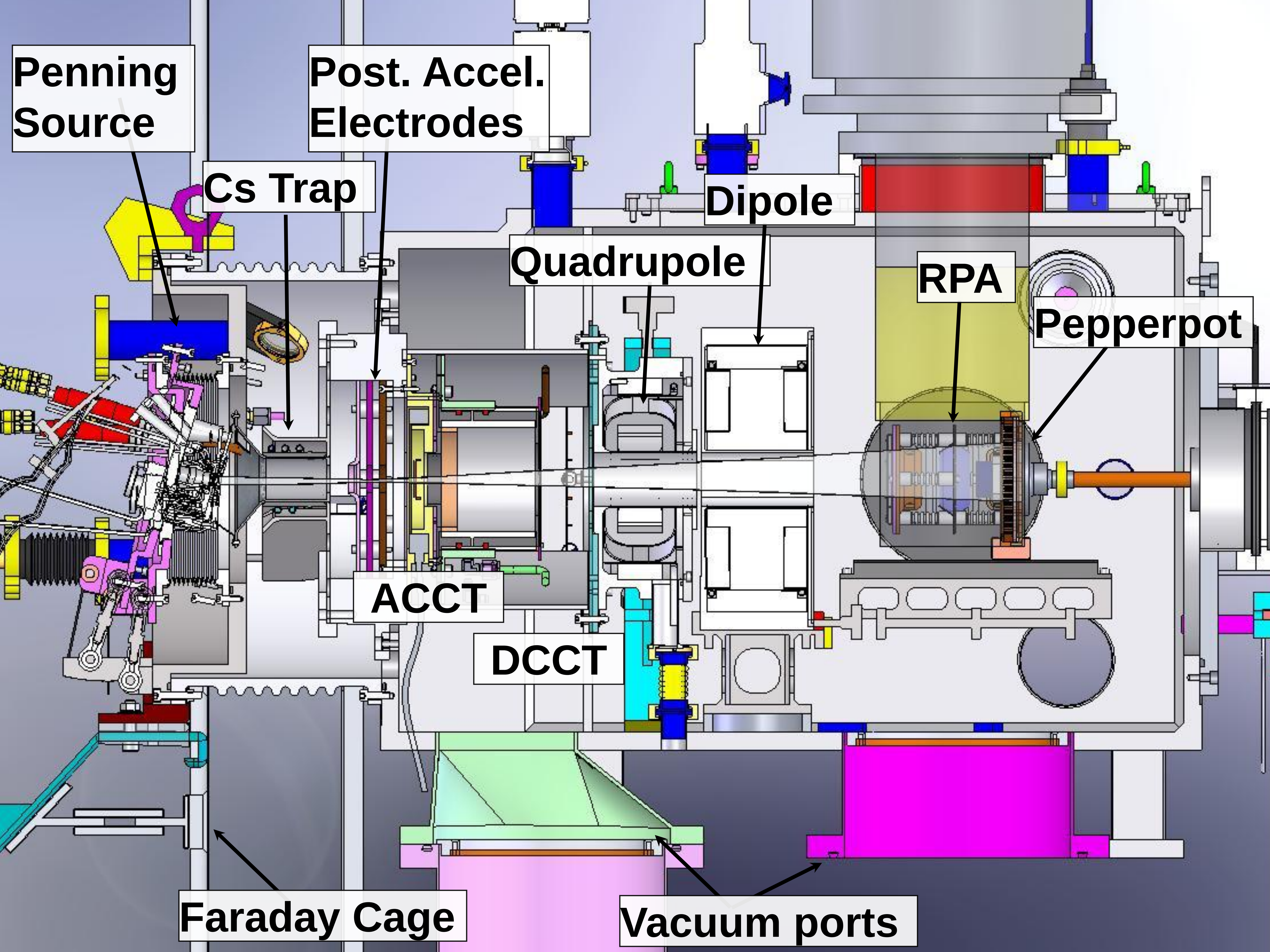


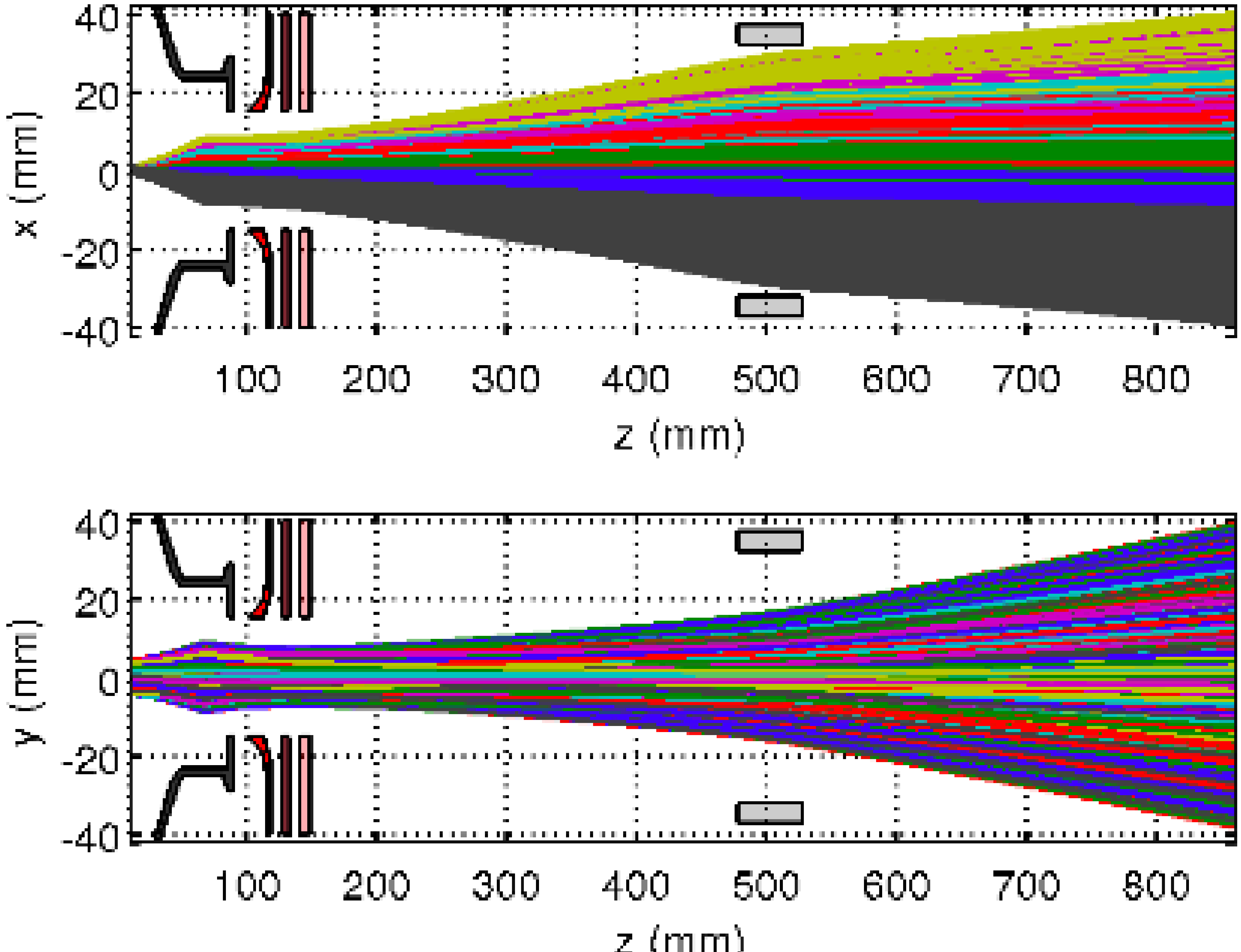






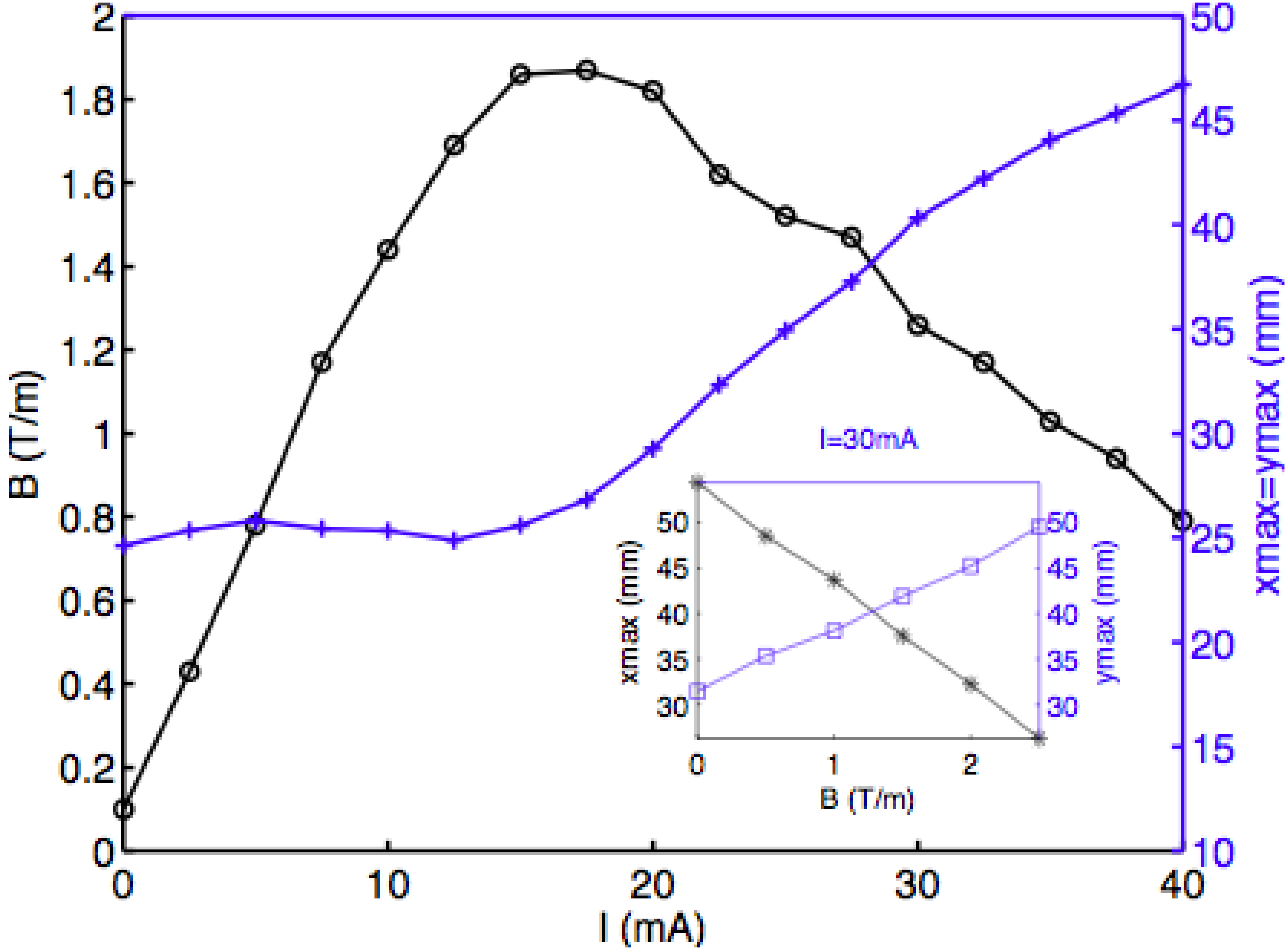


ISIS

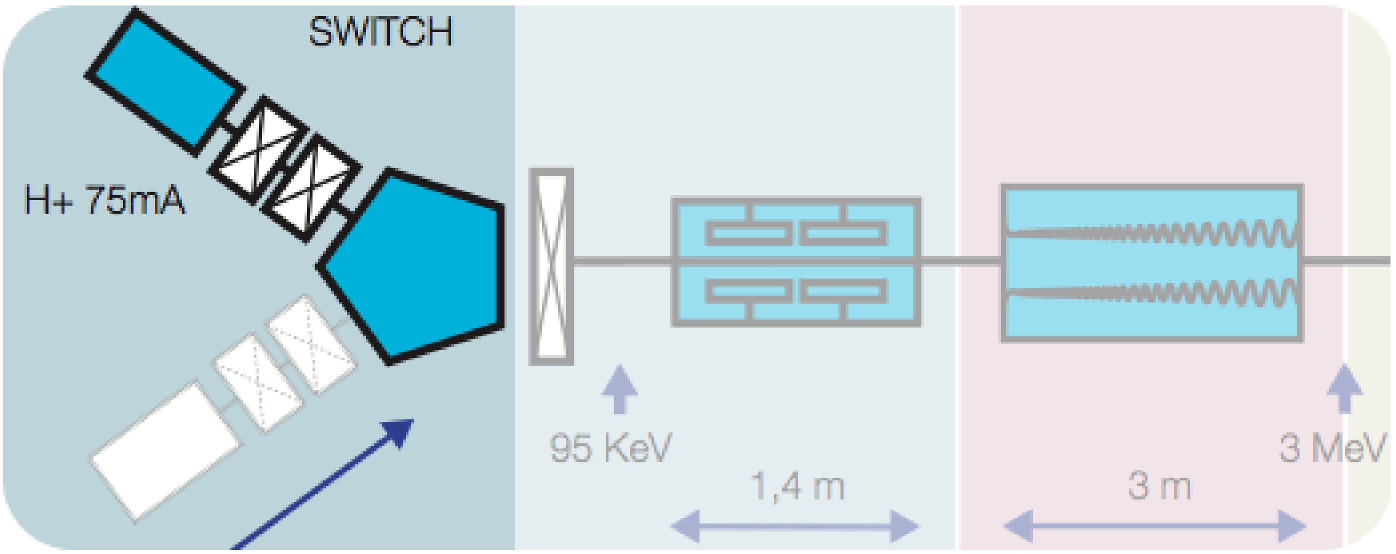

Penning Source
Post. Accel. Electrodes
Cs Trap
Dipole
Quadrupole
RPA
Pepperpot
ACCT
DCCT
Faraday Cage
Vacuum ports


40
20
0
-20
-40
x (mm)
100
200
300
400
500
600
700
800
z (mm)
40
20
0
-20
-40
y (mm)
100
200
300
400
500
600
700
800
z (mm)

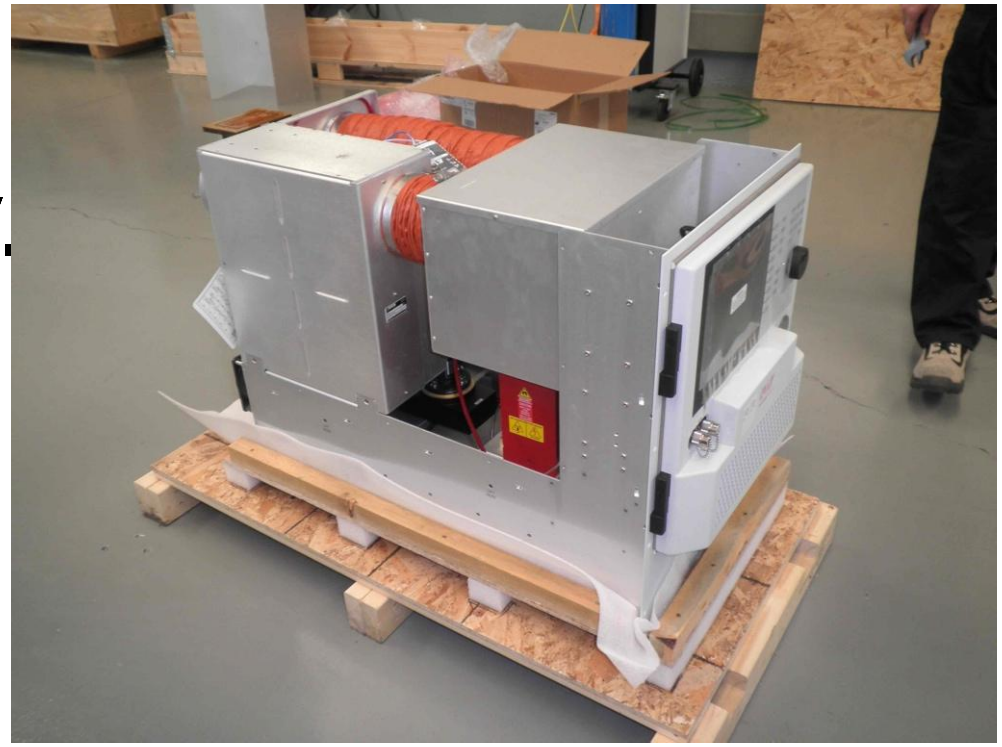
Optimum Quad Effect

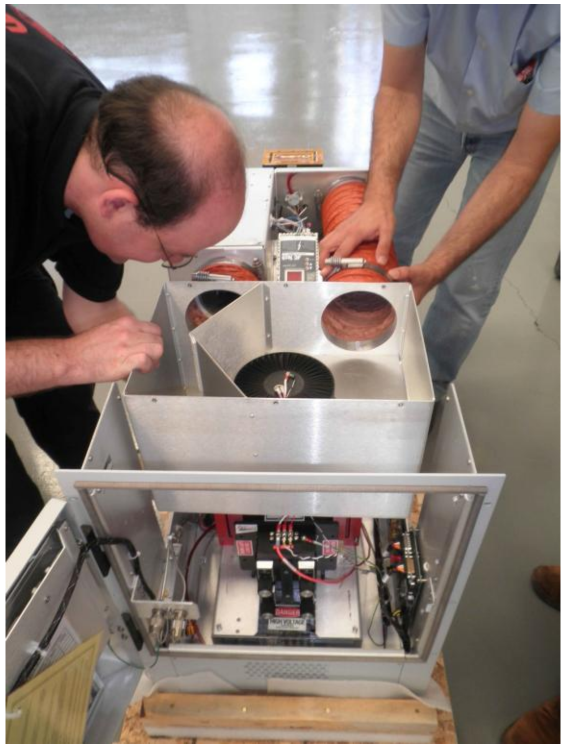


H^+ Source



CPI S-Band CKPA
2.73GHz klystron
2.45HHz Magnetron on its way.

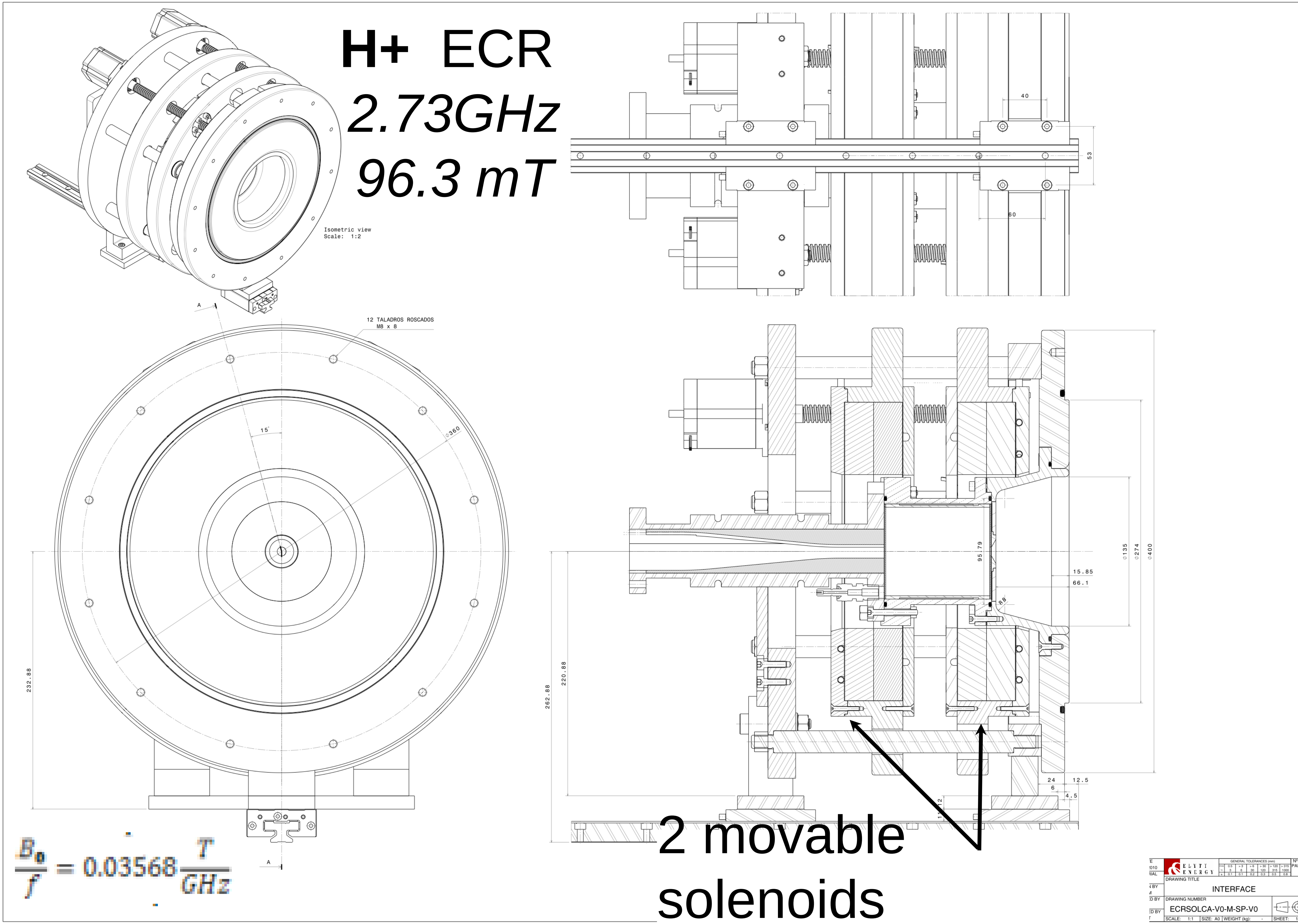




H+ ECR

2.73GHz

96.3 mT

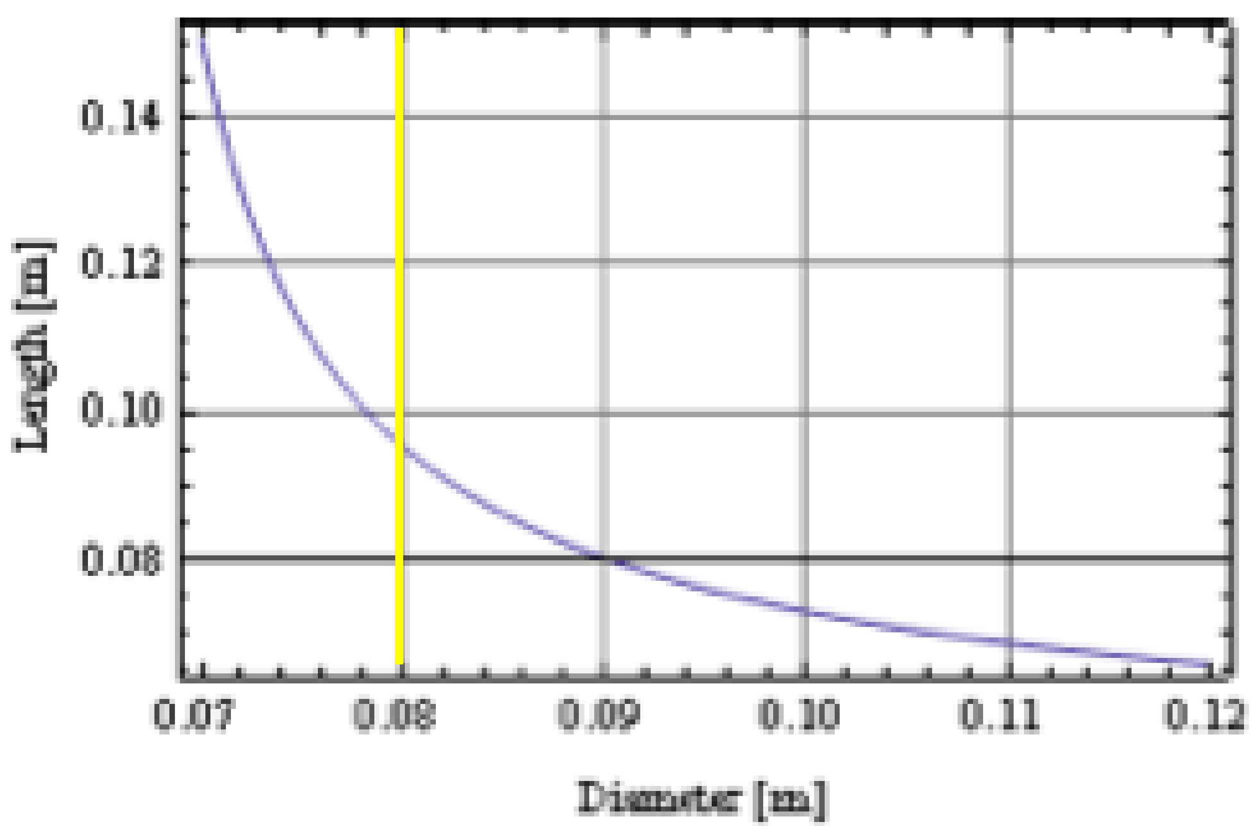


$$\frac{B_0}{f} = 0.03568 \frac{T}{GHz}$$

2 movable solenoids

+ Tuner Control Unit

Plasma Chamber

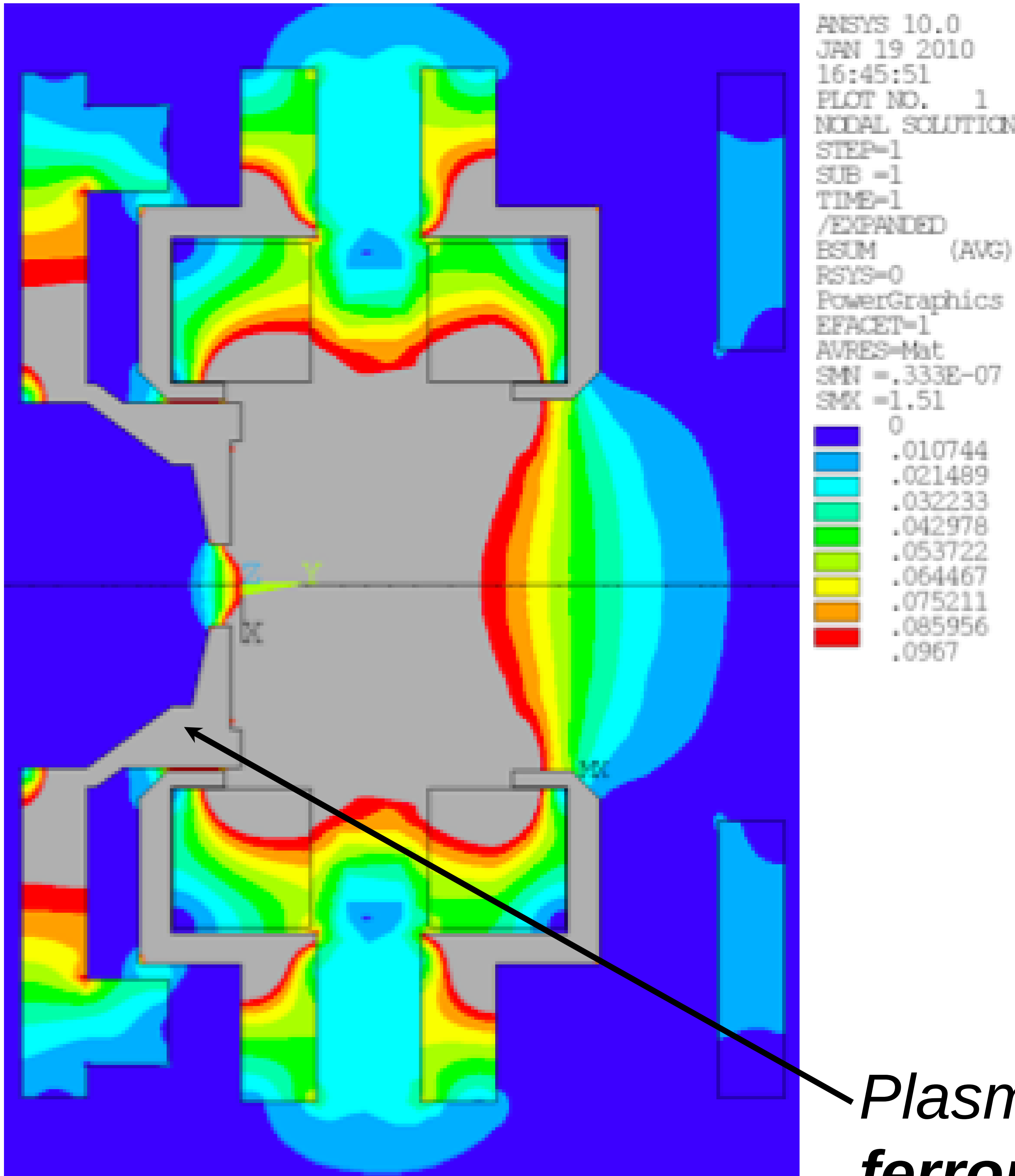


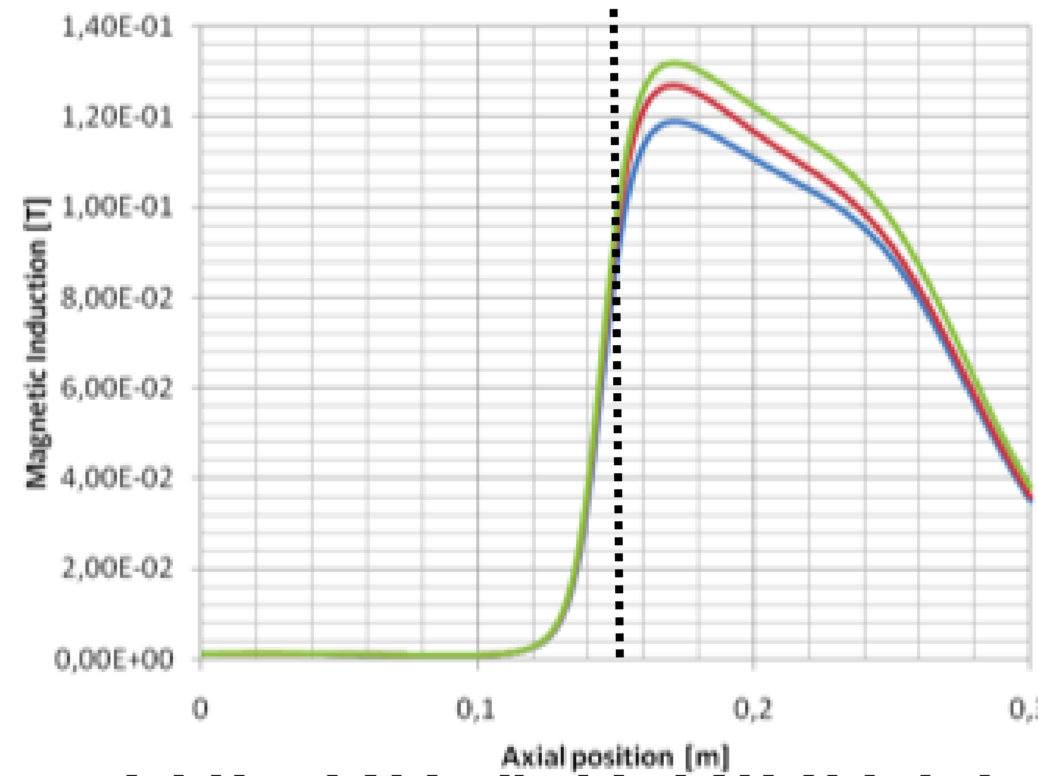
$$l = \frac{\pi}{\sqrt{\left(\frac{2\pi f}{c}\right)^2 - \left(\frac{3.682}{d}\right)^2}}$$

TE_{111} resonance condition at 2.7*GHz*

Diameter of 80*mm* and a length of 95.4*mm*

Field map of the magnetic induction [T]





The grey region is above the ECR value.

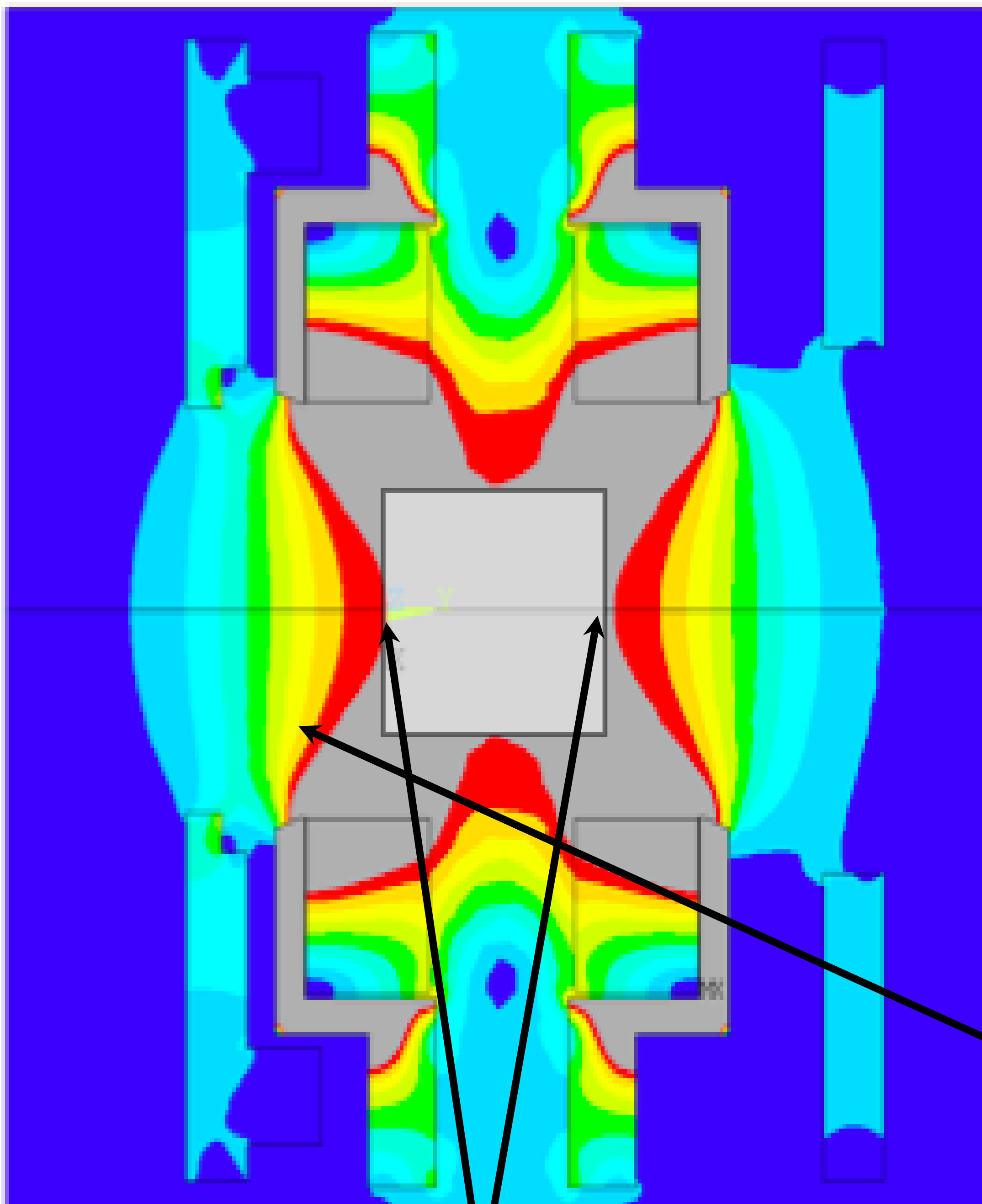
Extraction Region:

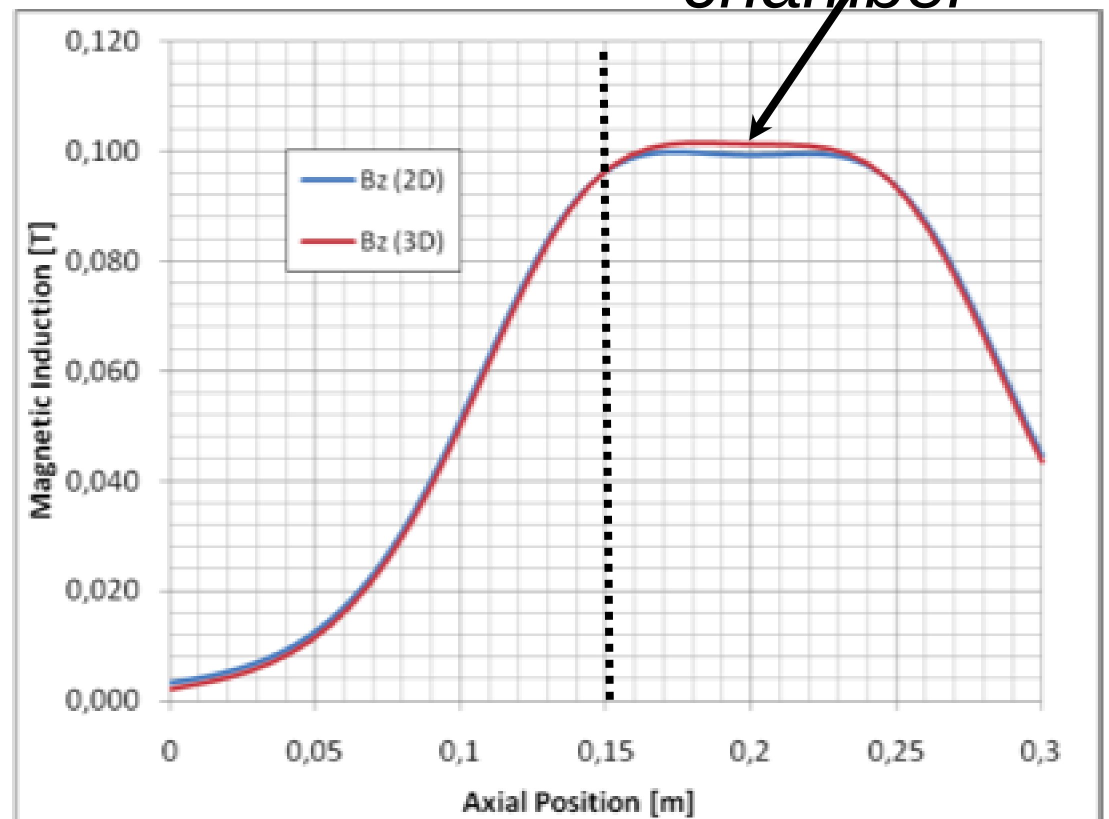
Minimize Magnetic Field

Plasma electrode in ***ferromagnetic material***

Field map of the magnetic induction [T]

Very constant magnetic induction region in the plasma chamber



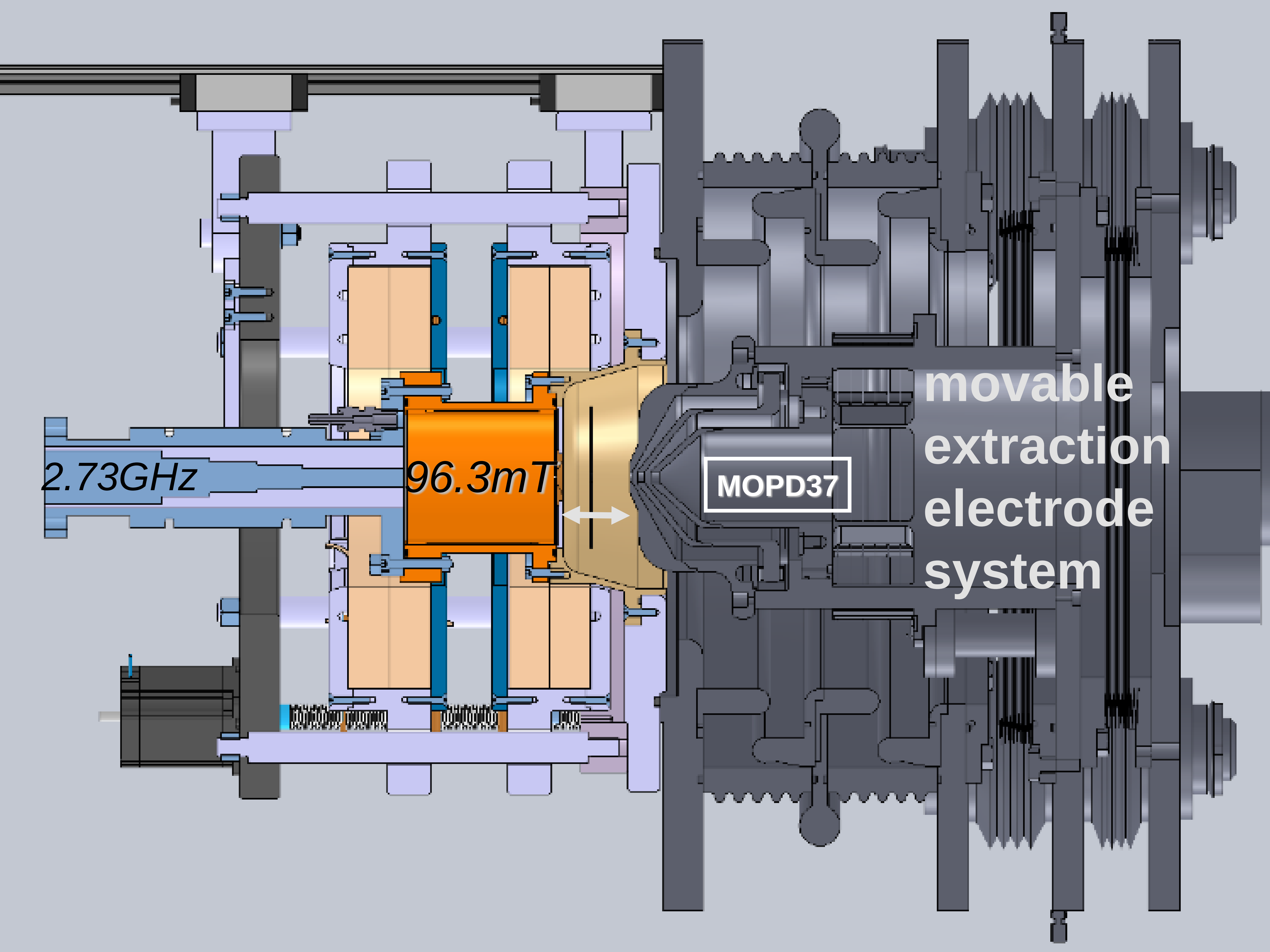


Both calculations are represented at a different magnetomotive force but at ECR field at 150 mm.

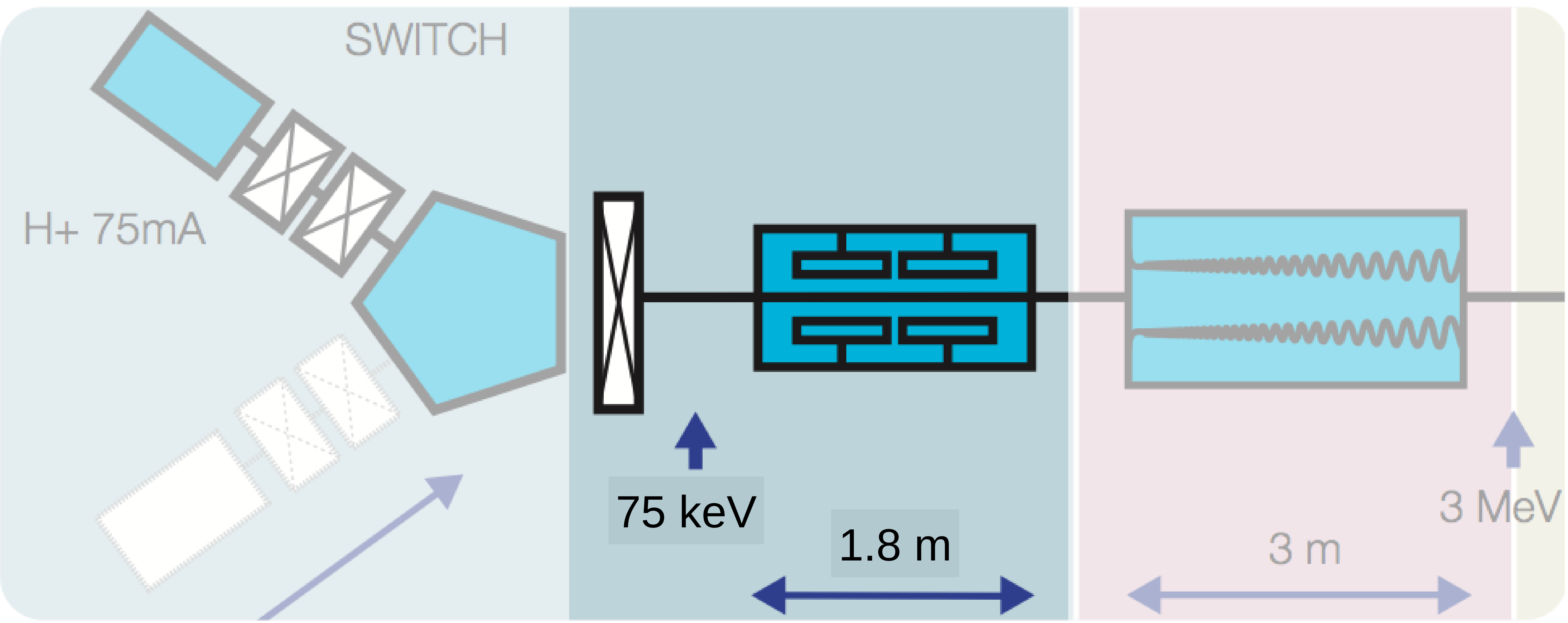
***BN** disks*

To enhance the production of electrons

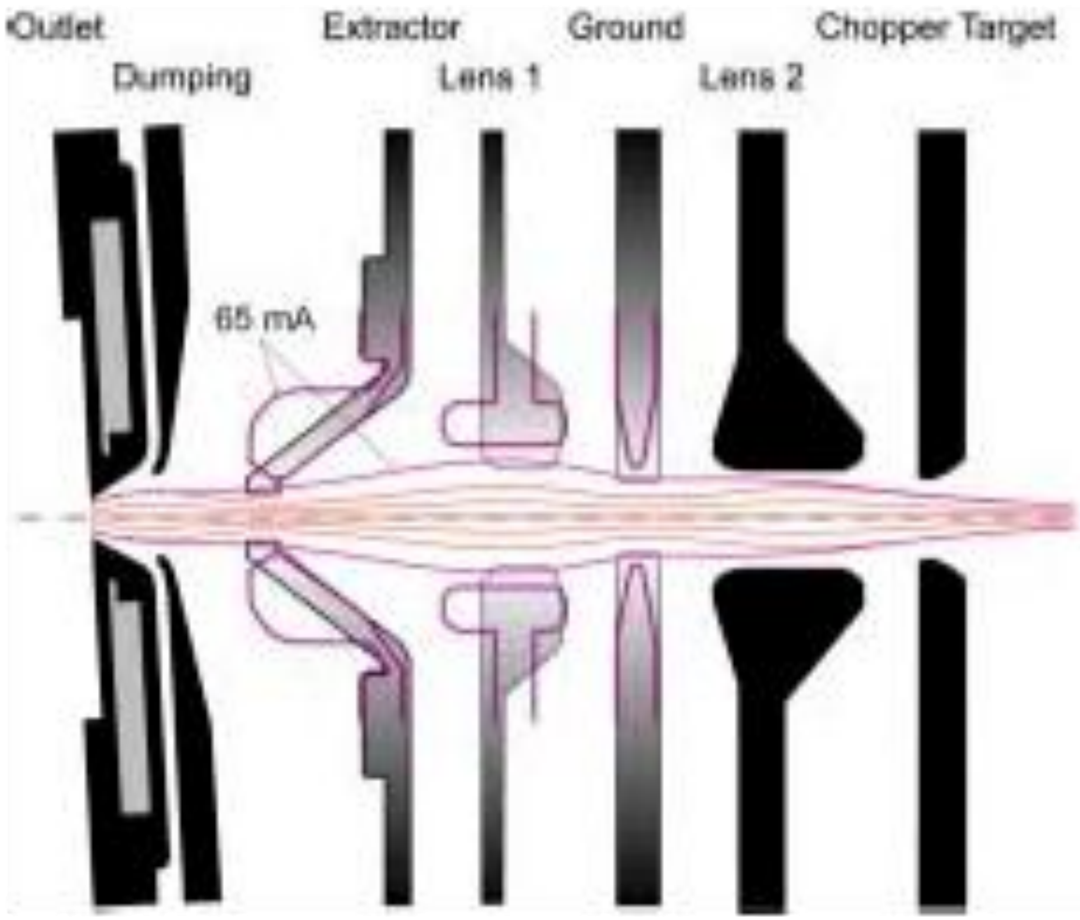
*Plasma electrode in **non magnetic material***


2.73GHz
96.3mT
MOPD37
movable
extraction
electrode
system

LEBT:low energy beam transport



Electrostatic?



-SNS: two electrostatic einzel lenses

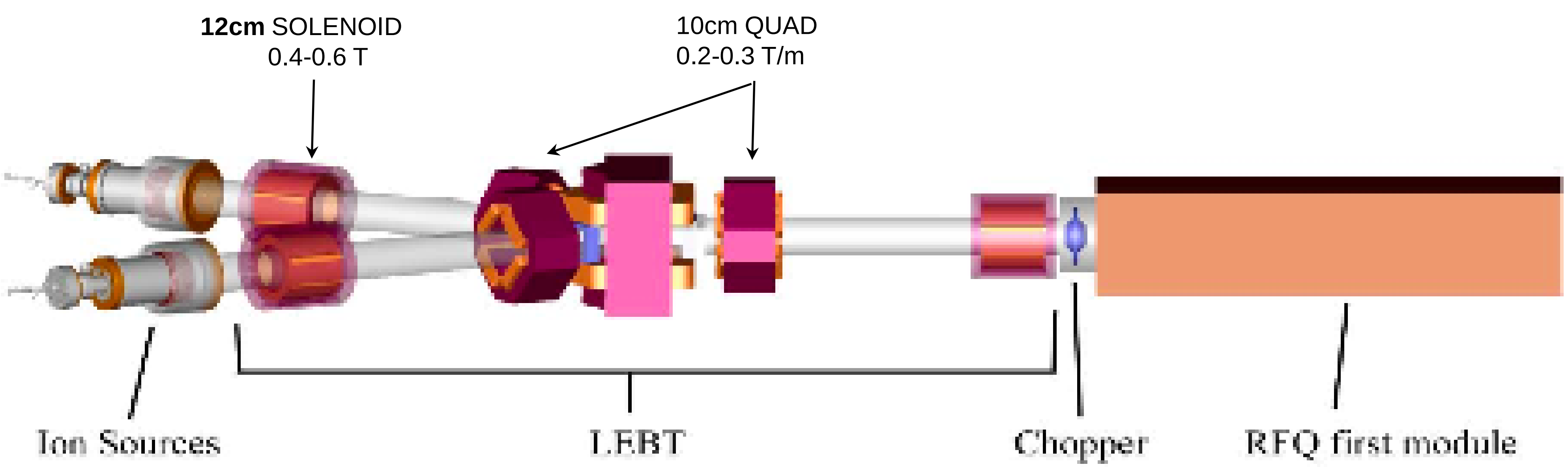
-No space charge compensation
-pre-chopping and angular steering

Faded solid shapes depict the early 35-mA Startup LEBT.
Open contours depict the 65-mA Production LEBT

EVOLUTION OF THE LEBT LAYOUT FOR SNS*
J. Reijonen, R. Thomae, and R. Keller
Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA

OR Magnetic?

- Switching between the two ion sources within less than an hour. (99.5% availability).



Proceedings of PAC07, Albuquerque, New Mexico, USA TUPAS075

THE NEW LEBT FOR THE SPALLATION NEUTRON SOURCE POWER UPGRADE PROJECT *

B. X. Han[#] and M. P. Stockli, SNS, ORNL, Oak Ridge, TN 37831, U.S.A.

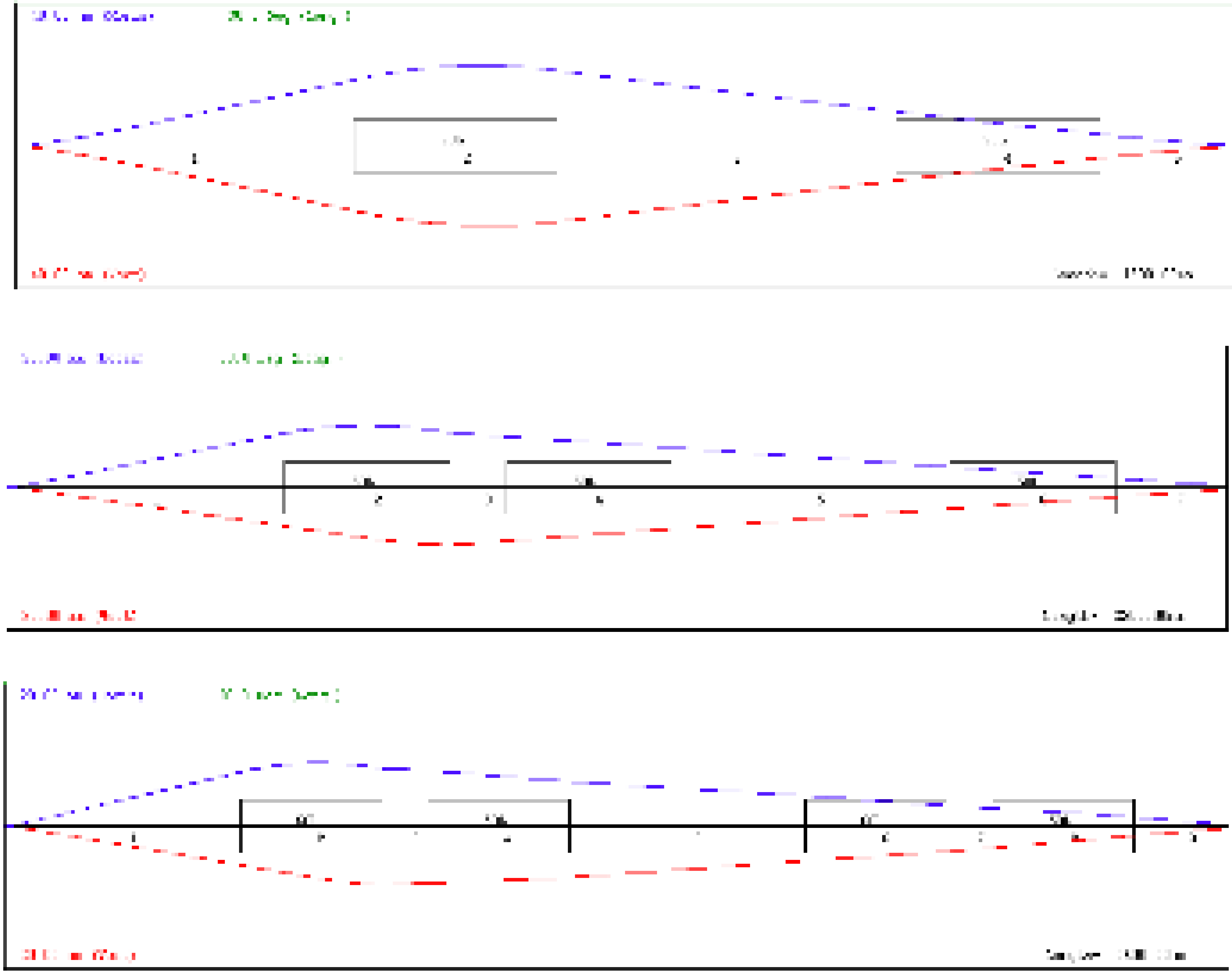
How many Solenoids?

trace3D

H^- ➜

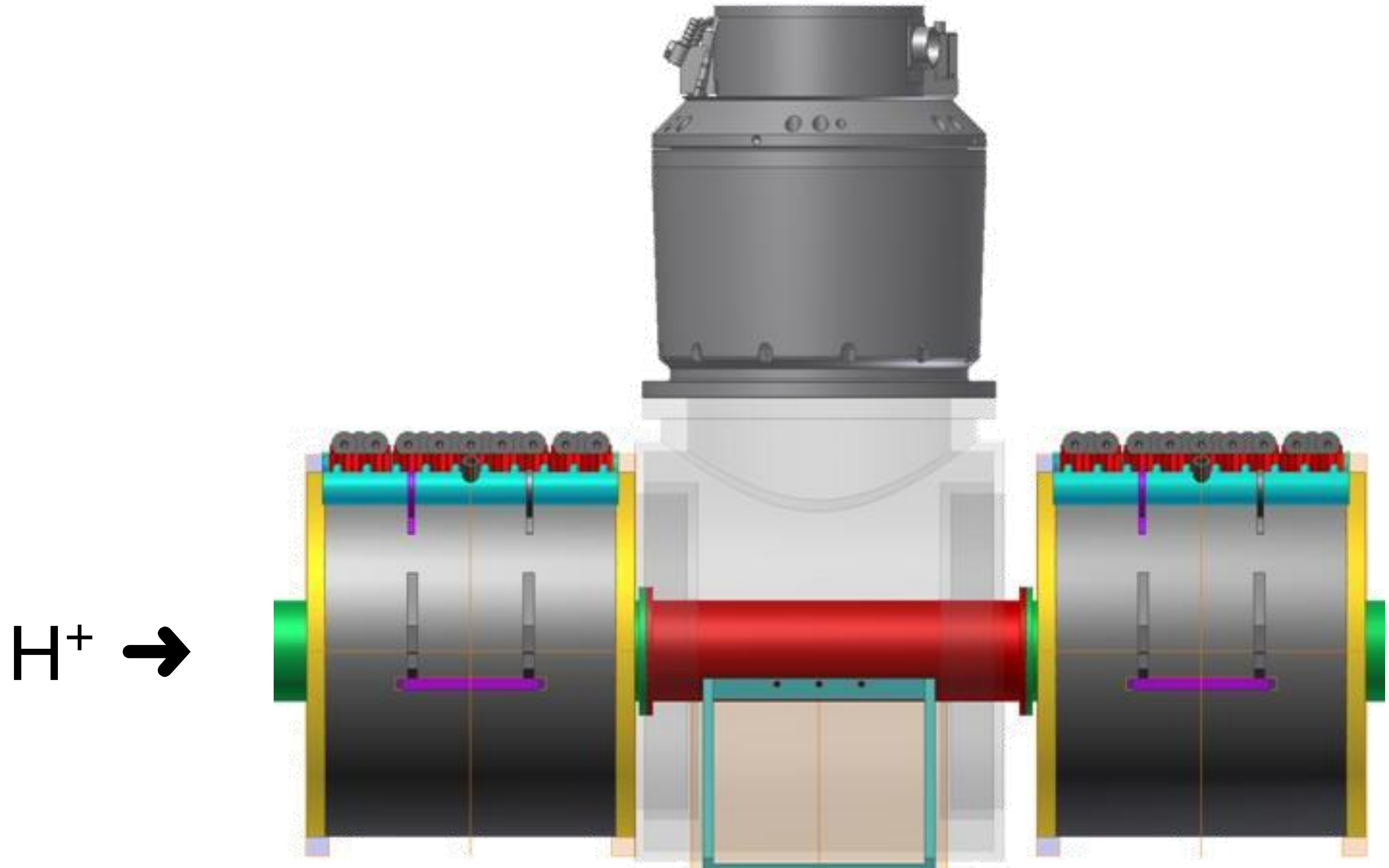
H^+ ➜

D^+ ➜



I from 0mA to100mA

Axisymmetric beam ✔
Non-Axisymmetric beam ✘

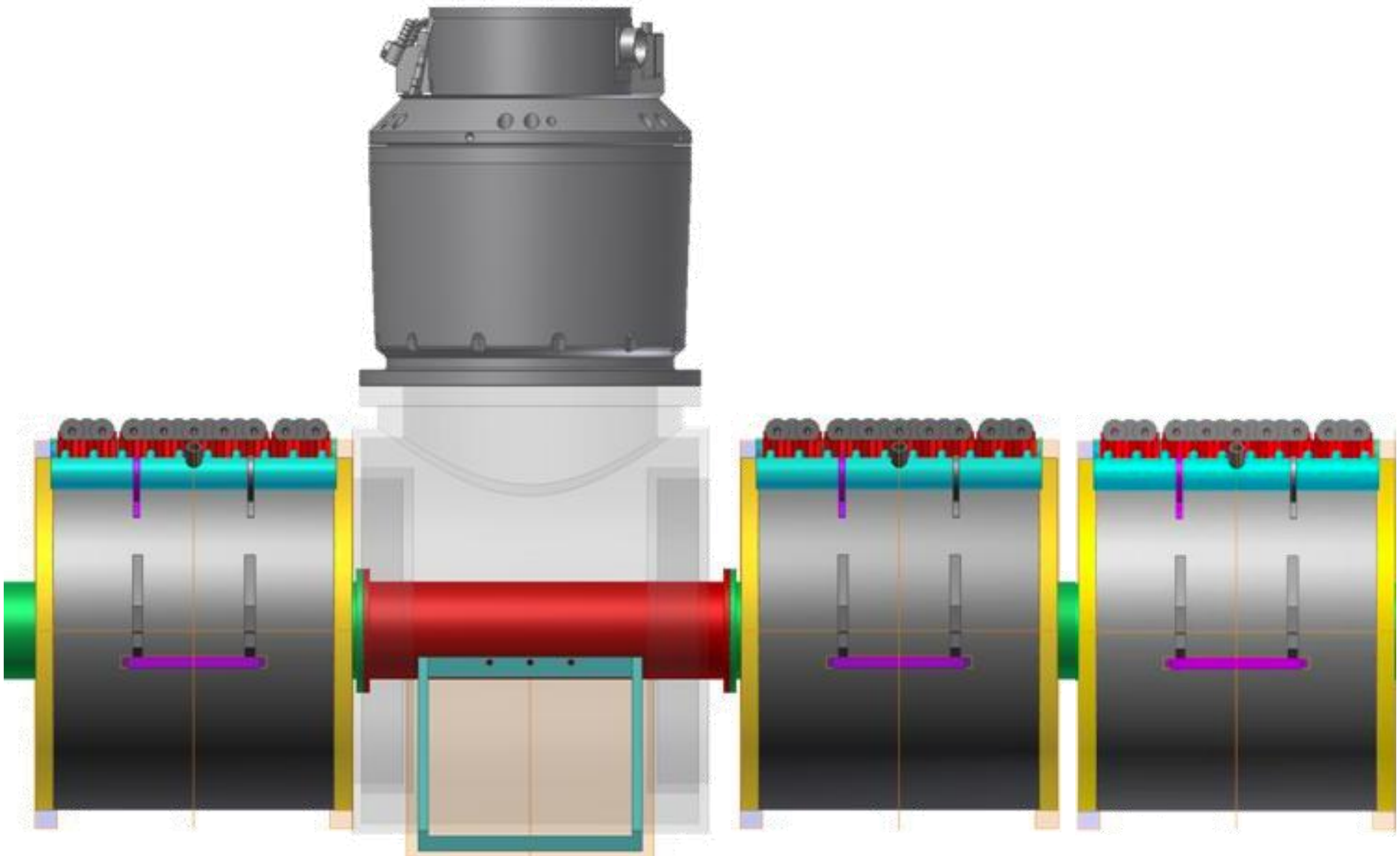


How many Solenoids?

Axisymmetric beam ✔

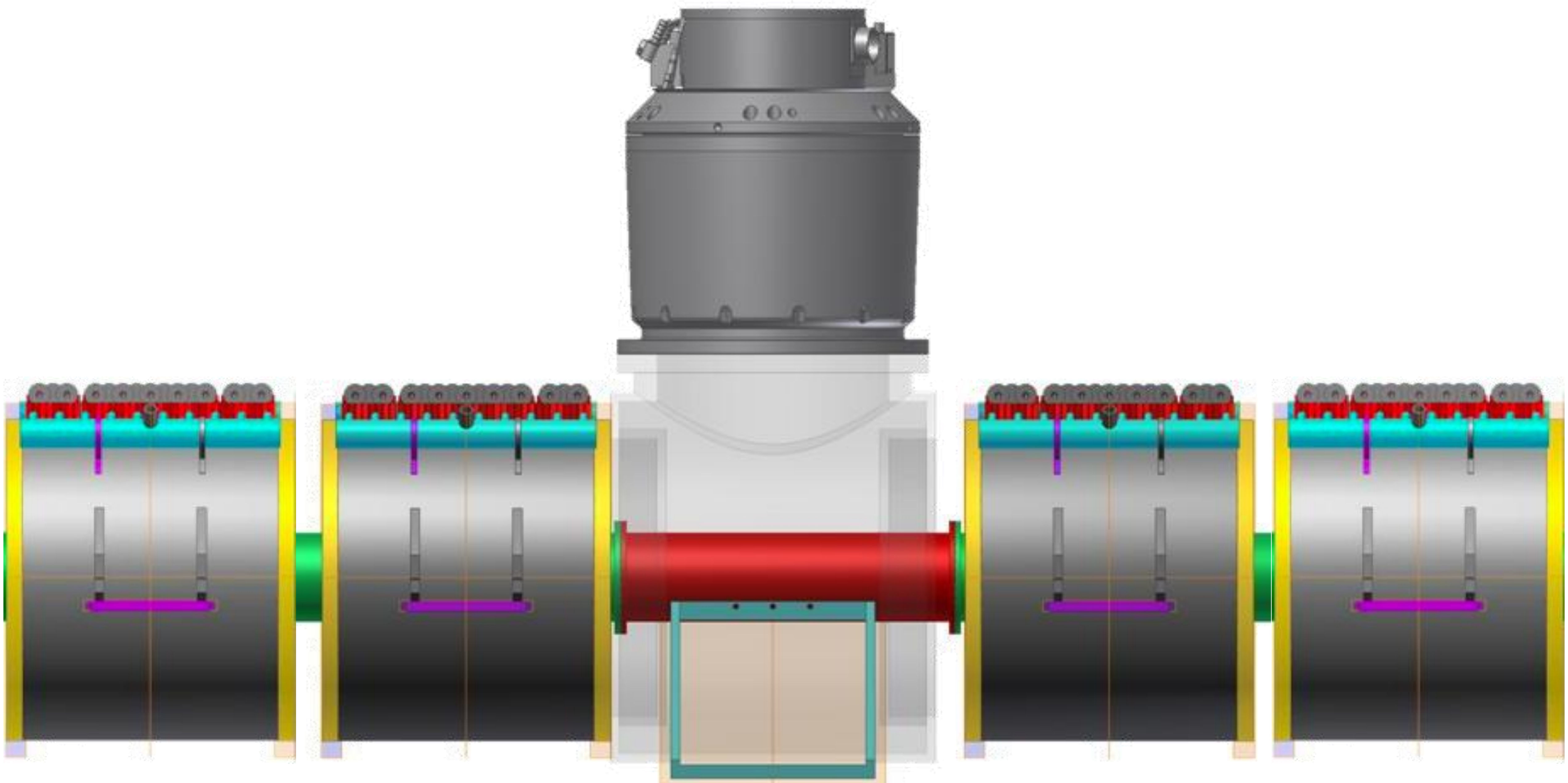
Non-Axisymmetric beam ✔

H+ ➜



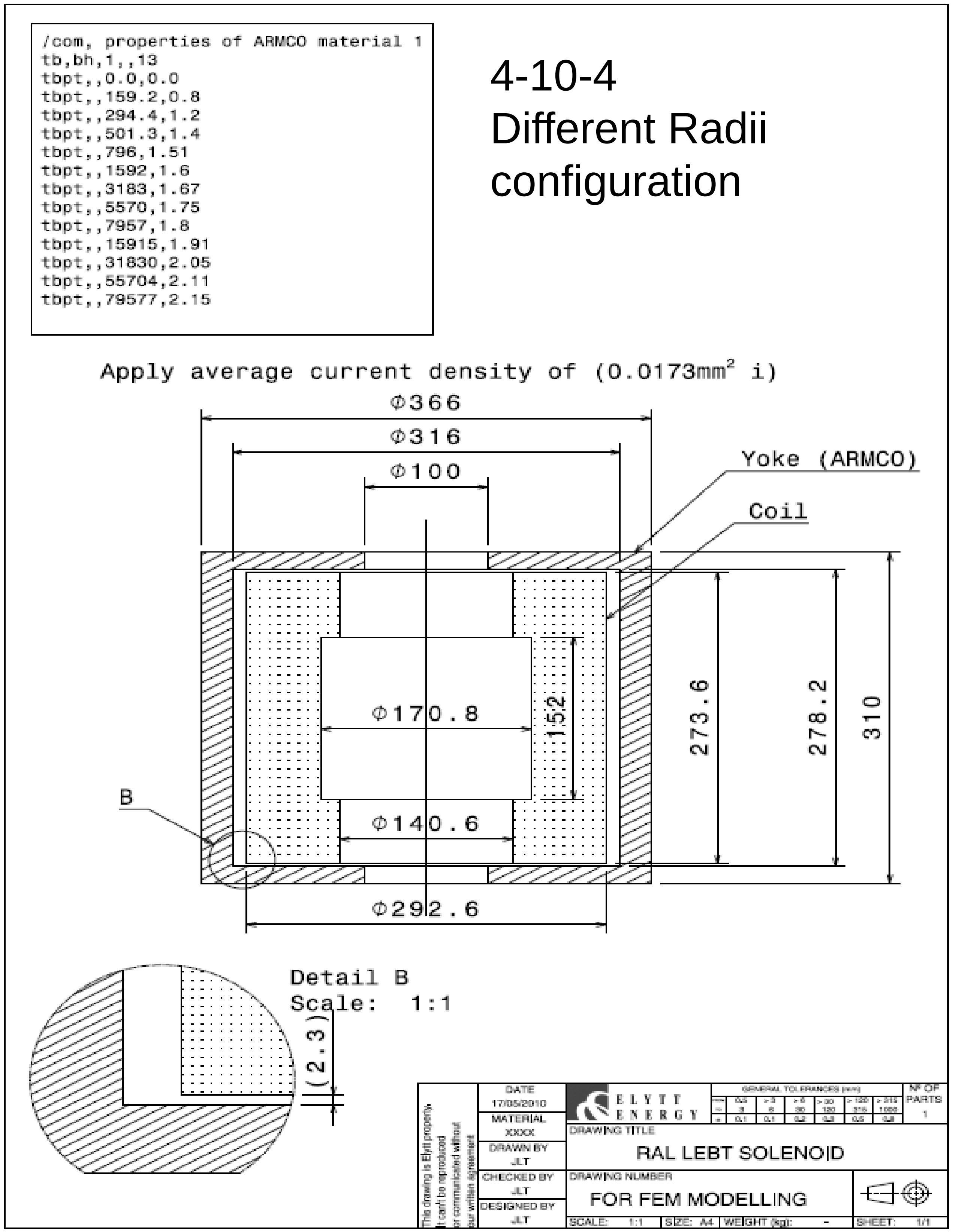
How many Solenoids?

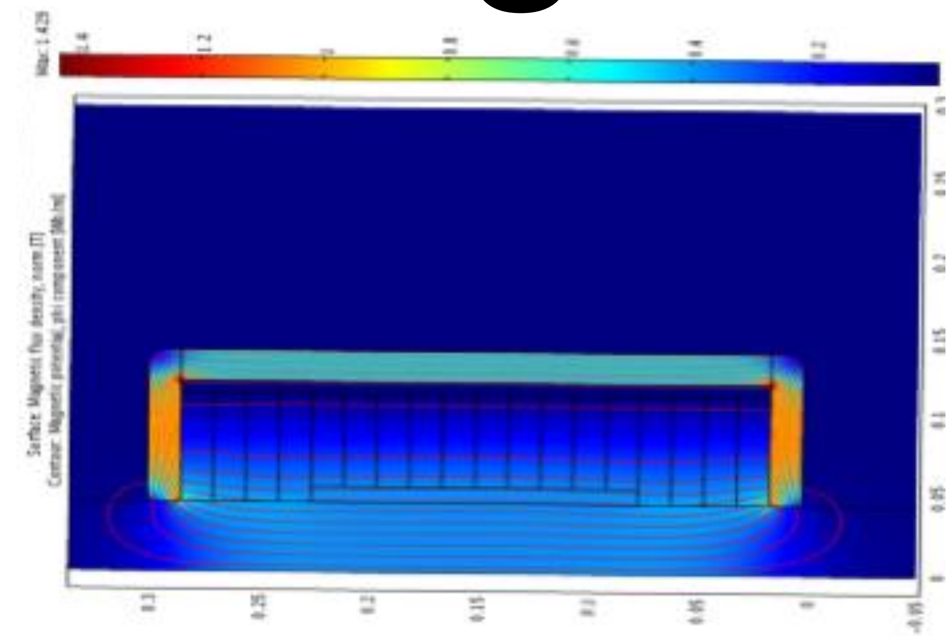
Any kind of beam ✔

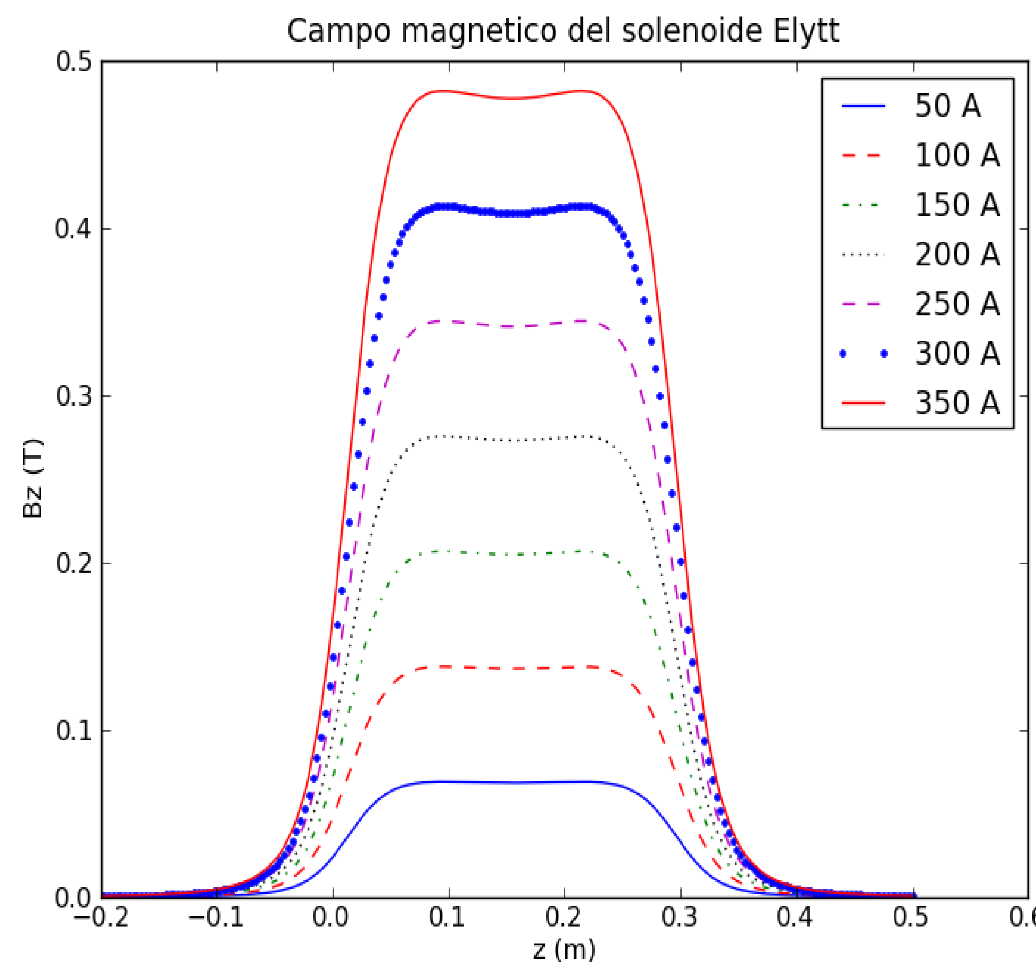


Solenoid Design

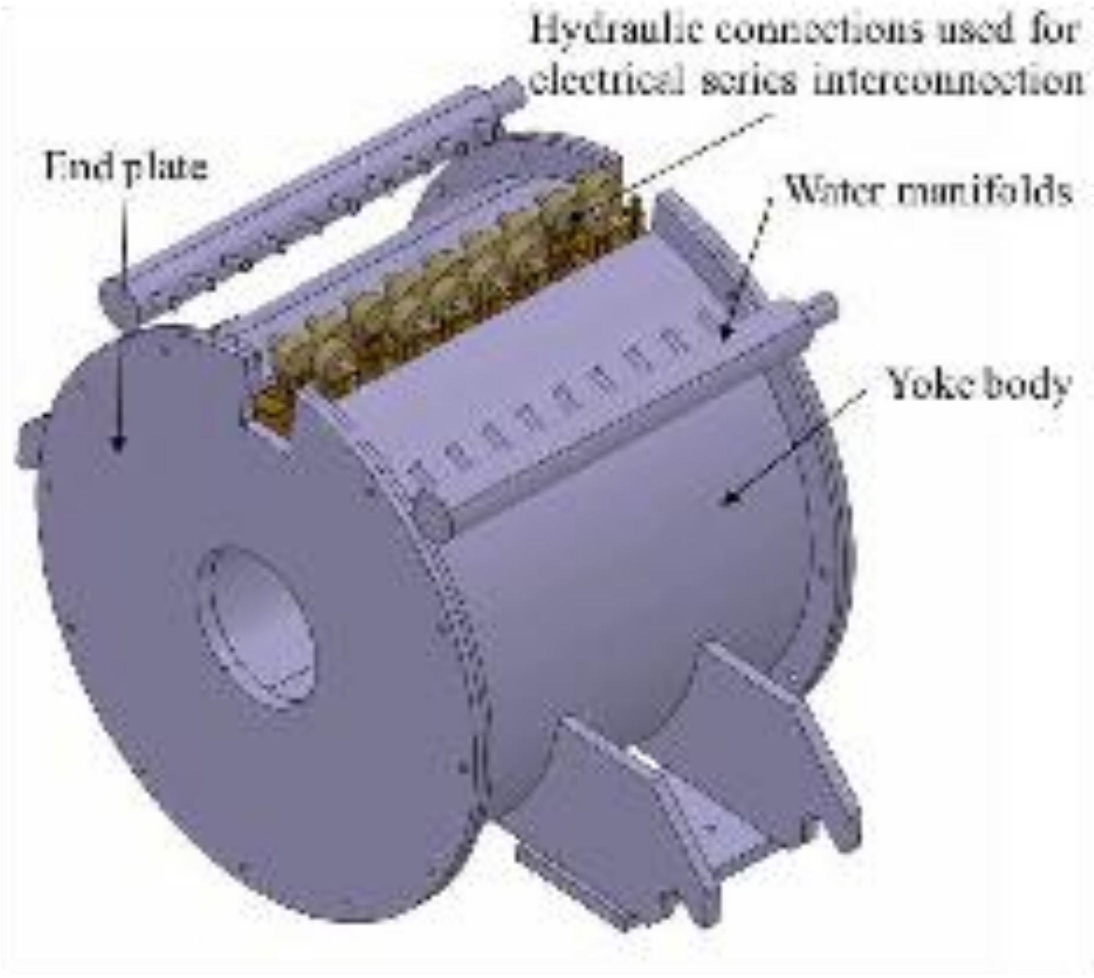
Solenoid Design



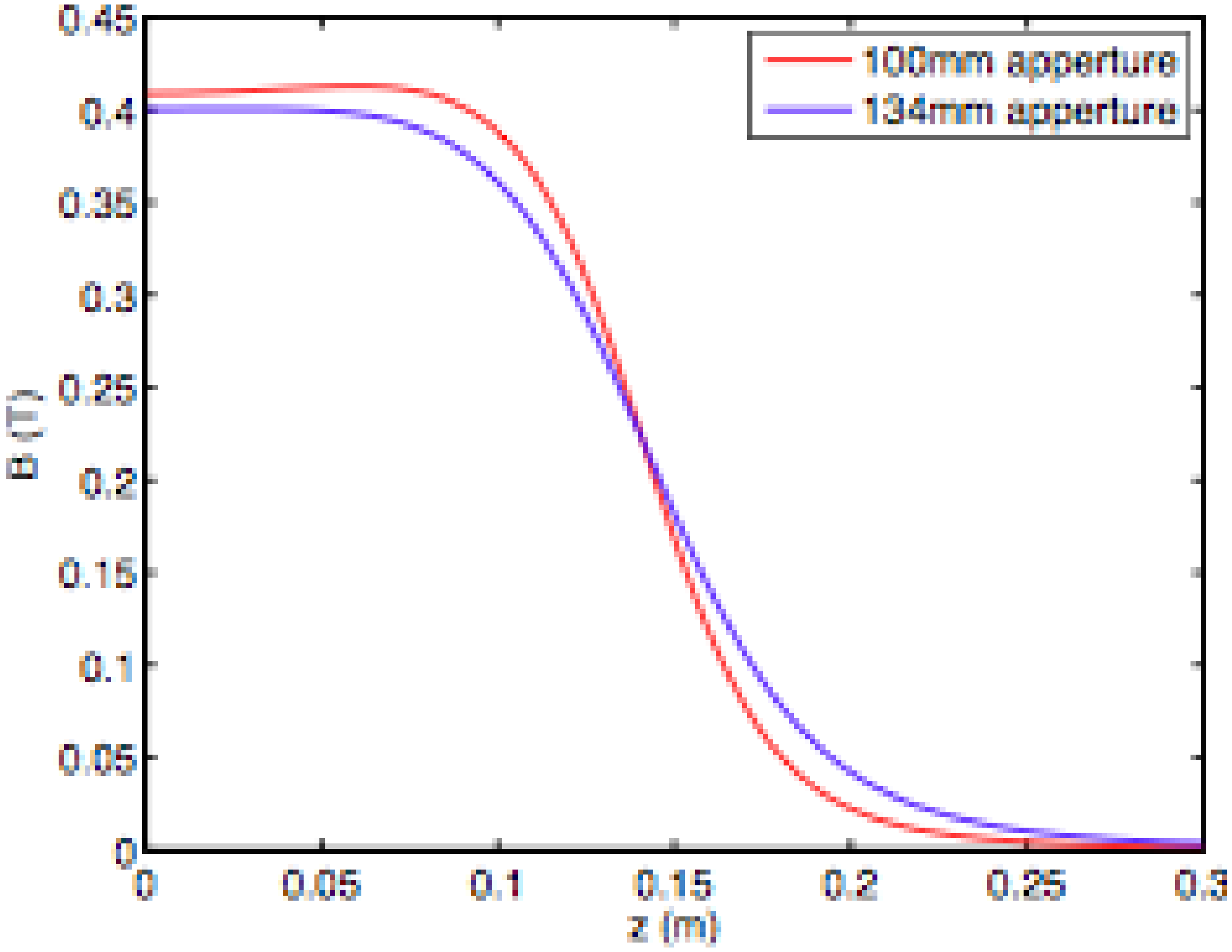




Solenoid Design

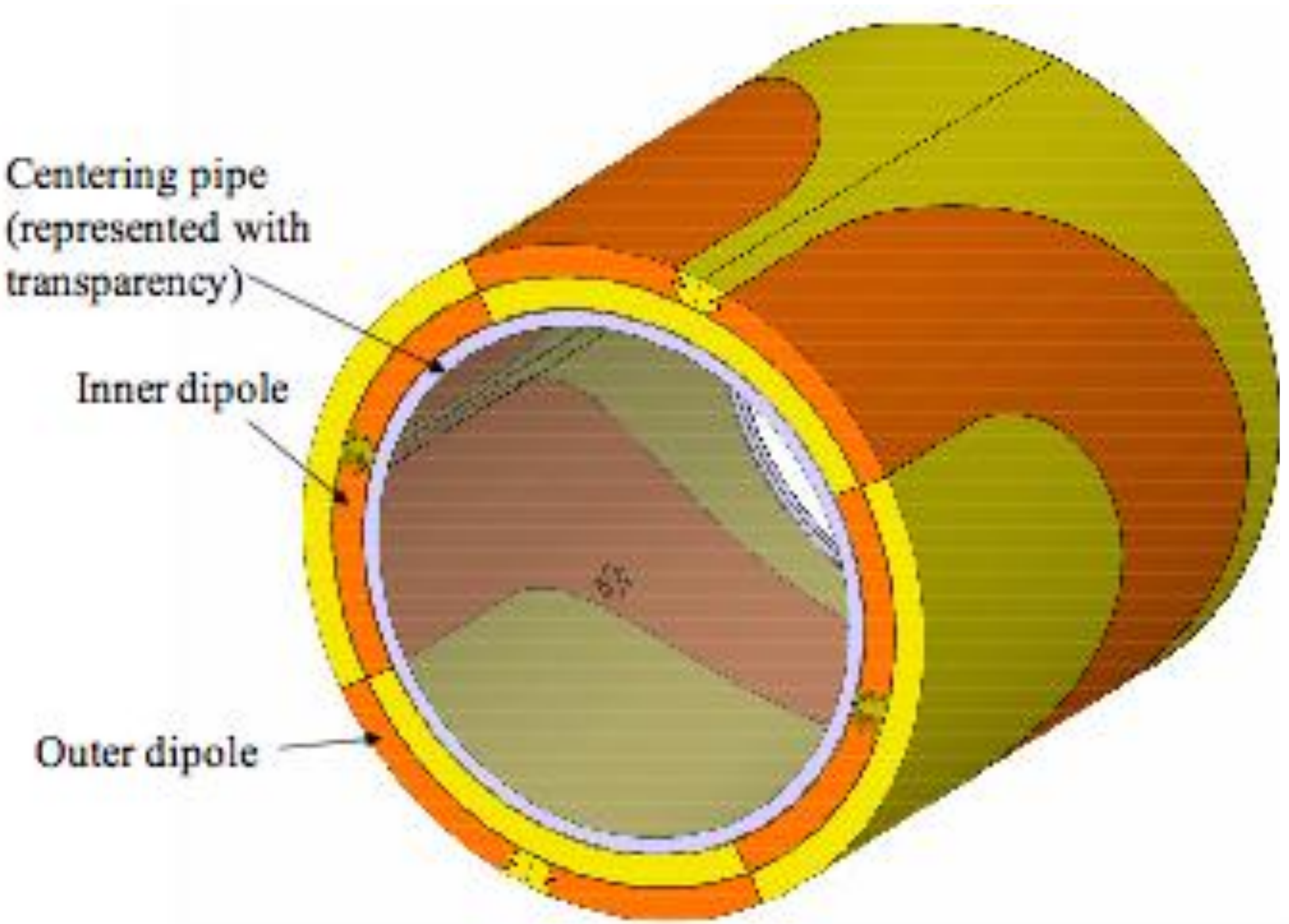


Isometric view of the solenoid assembly

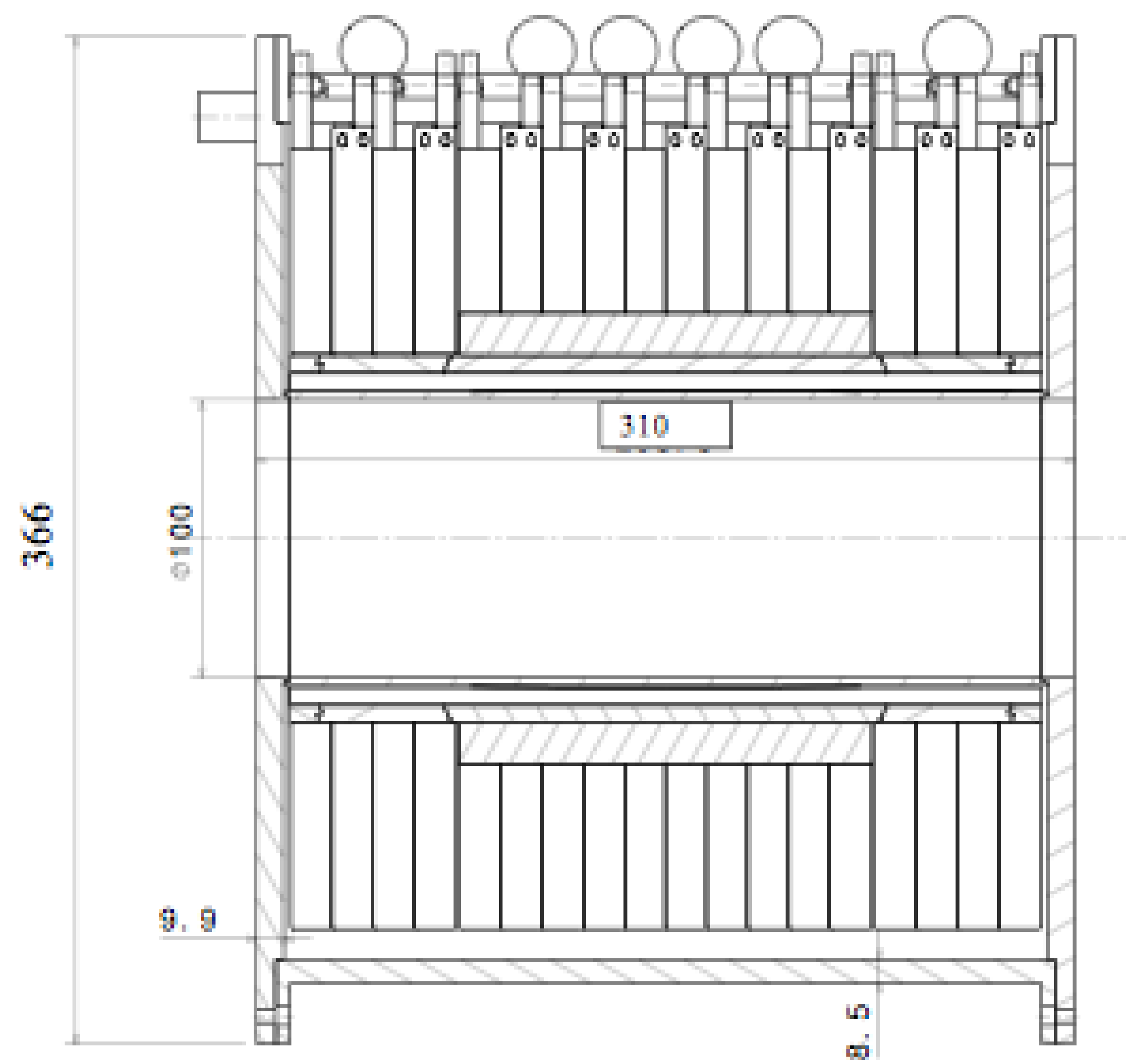


On axis field for the solenoid with and without steering dipoles, for a current of 300 A.

Solenoid Design

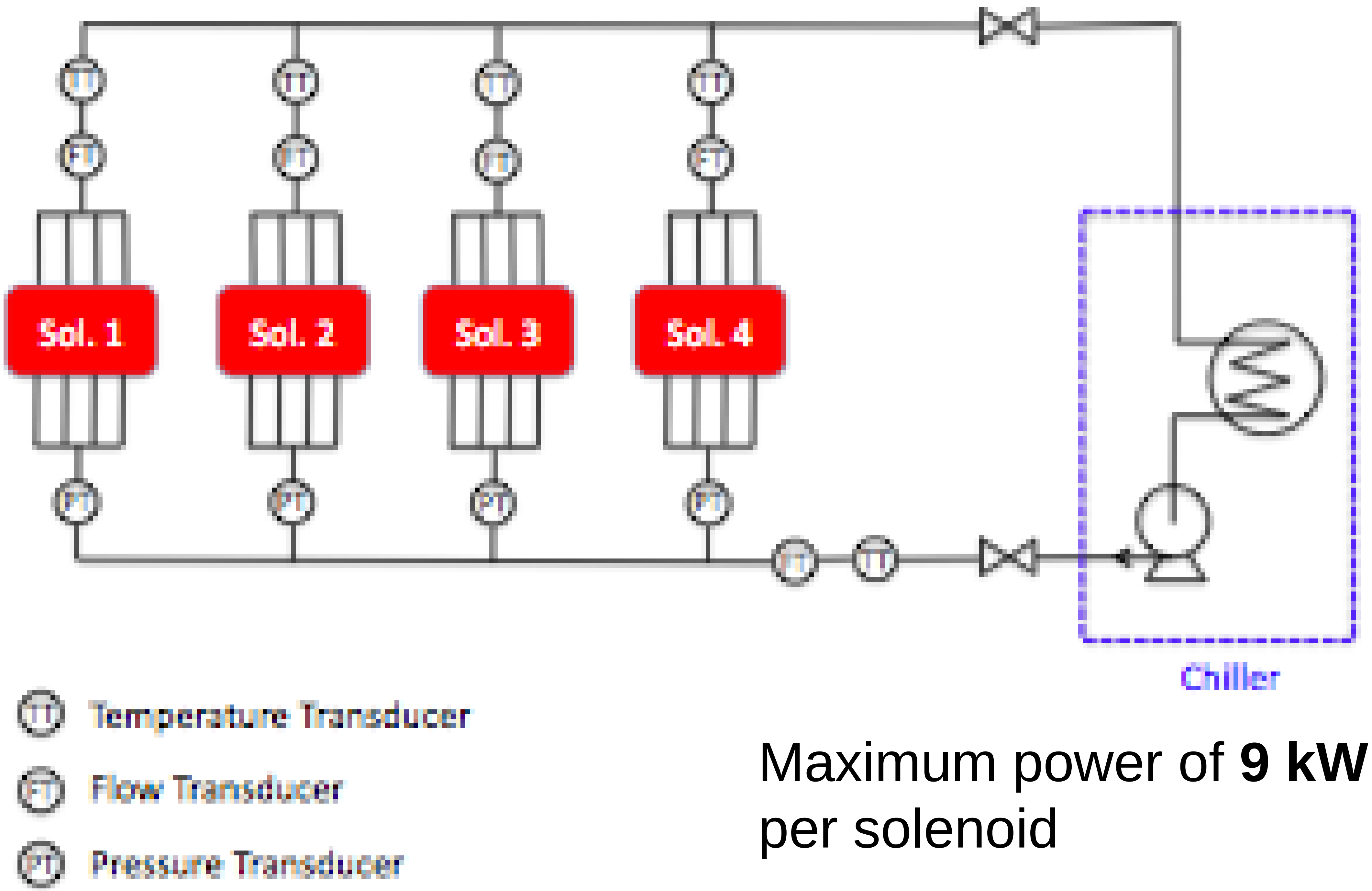


Section of the nested dipoles



Section of the solenoid dipole assembly

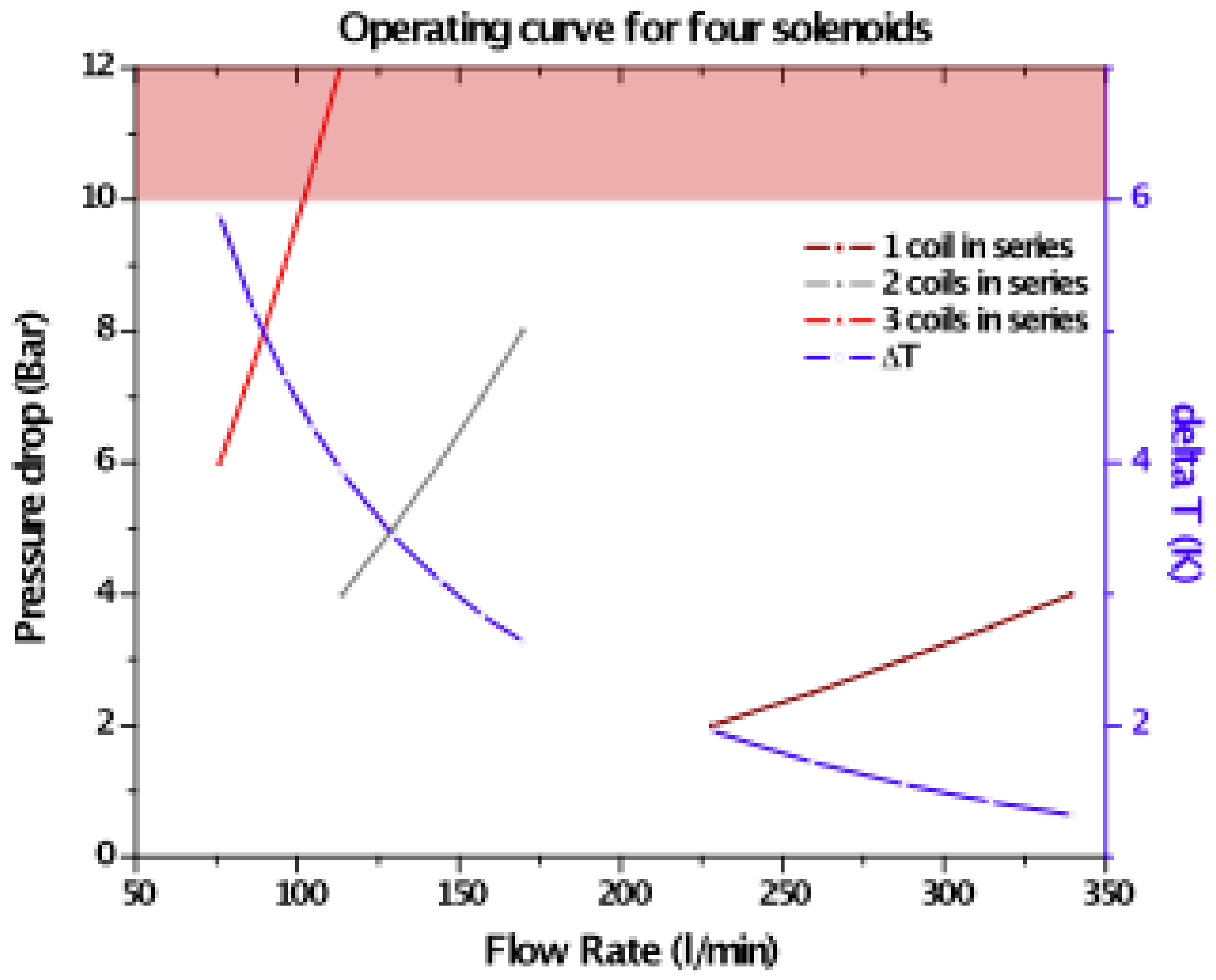
Cooling



Maximum power of **9 kW** per solenoid

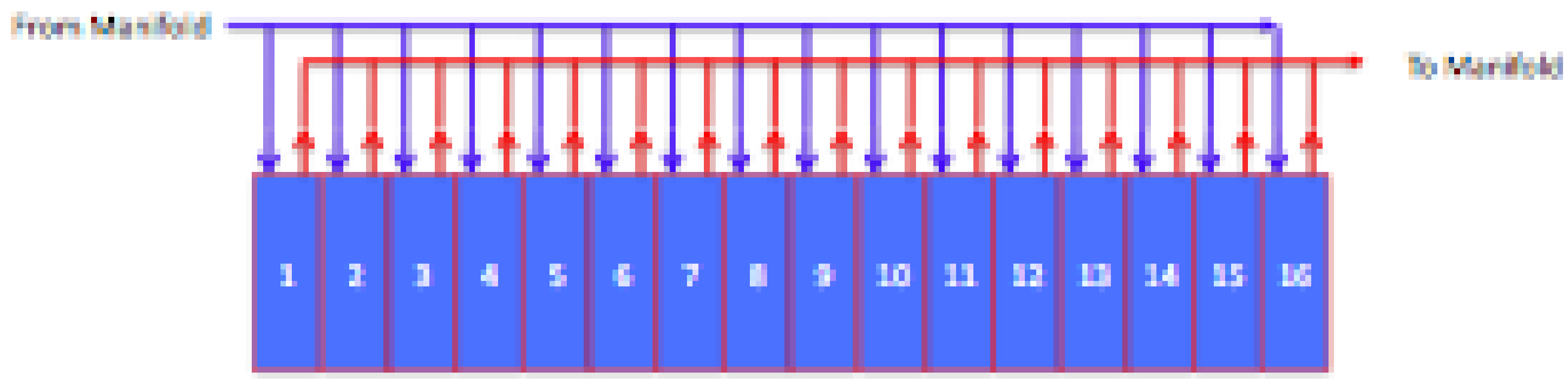
Schematic of the cooling water connections to the solenoids, including the placement of temperature, pressure and flow transducers.

Cooling

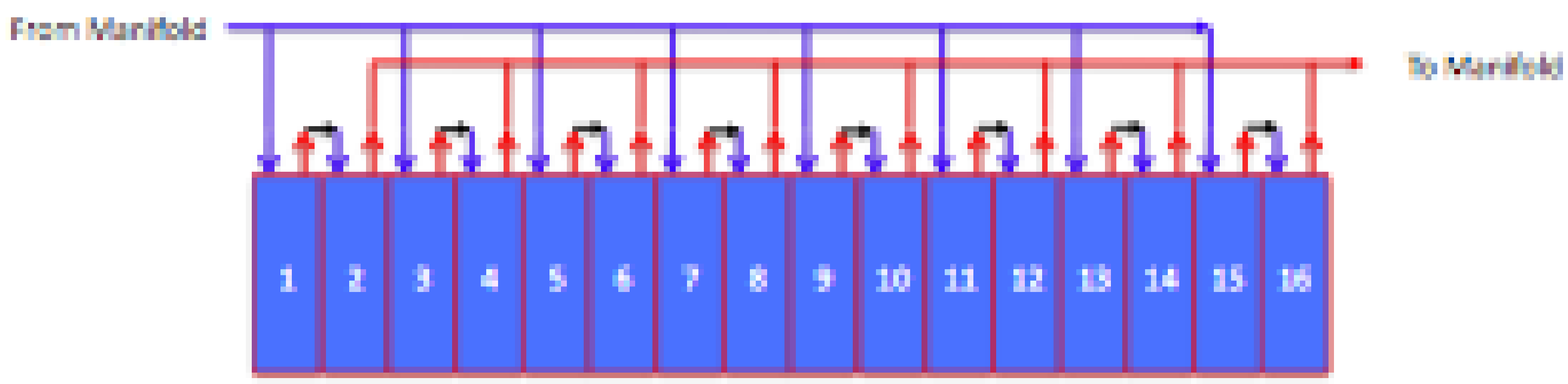


Operating curves for a four solenoid system, the solenoids are connected in parallel and in each solenoid 1, 2 or 3 of the individual coils are connected in series, the blue trace corresponds to the temperature increase of the cooling water (righthand scale) for the corresponding flow rate

Cooling



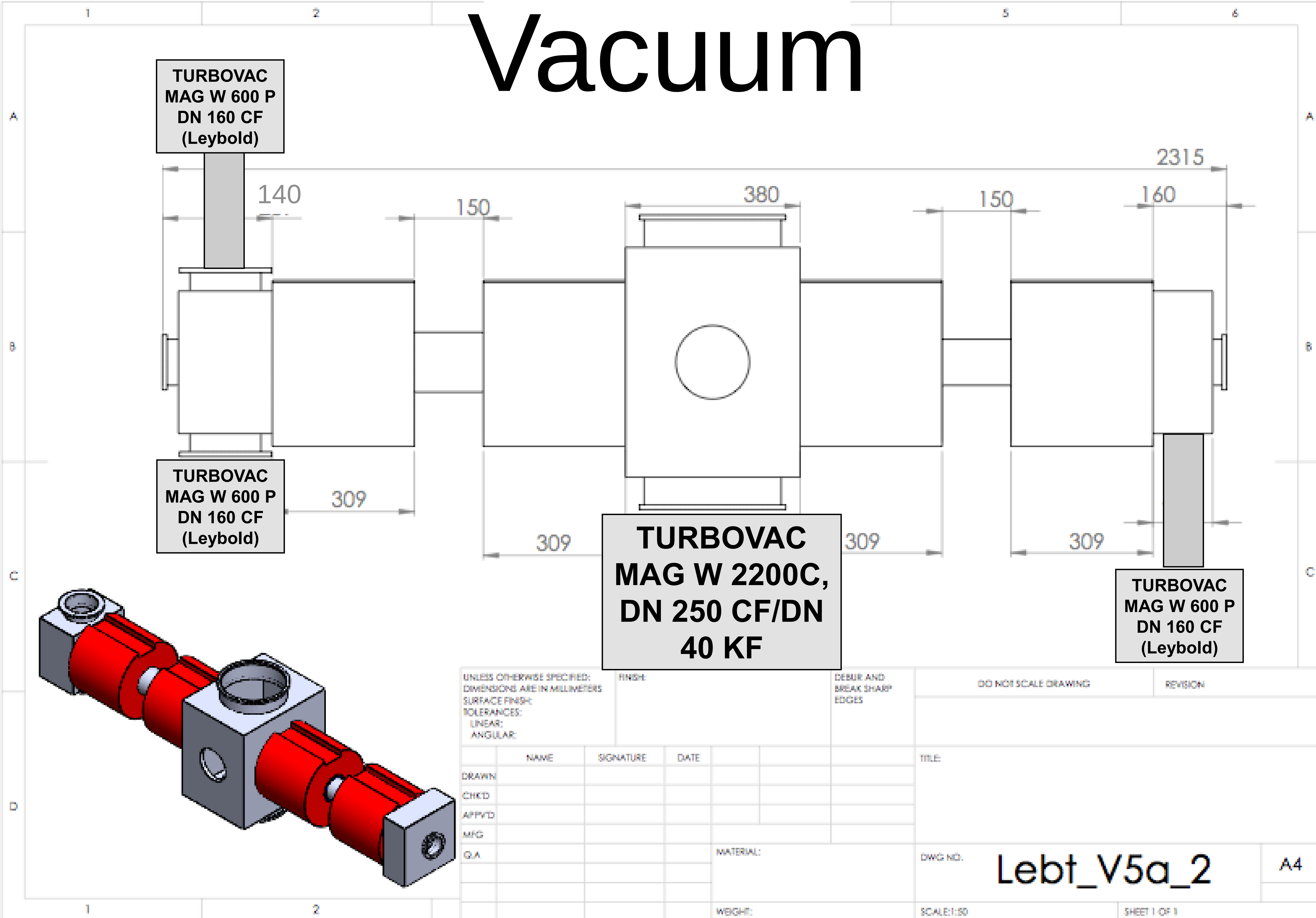
1 coil in series

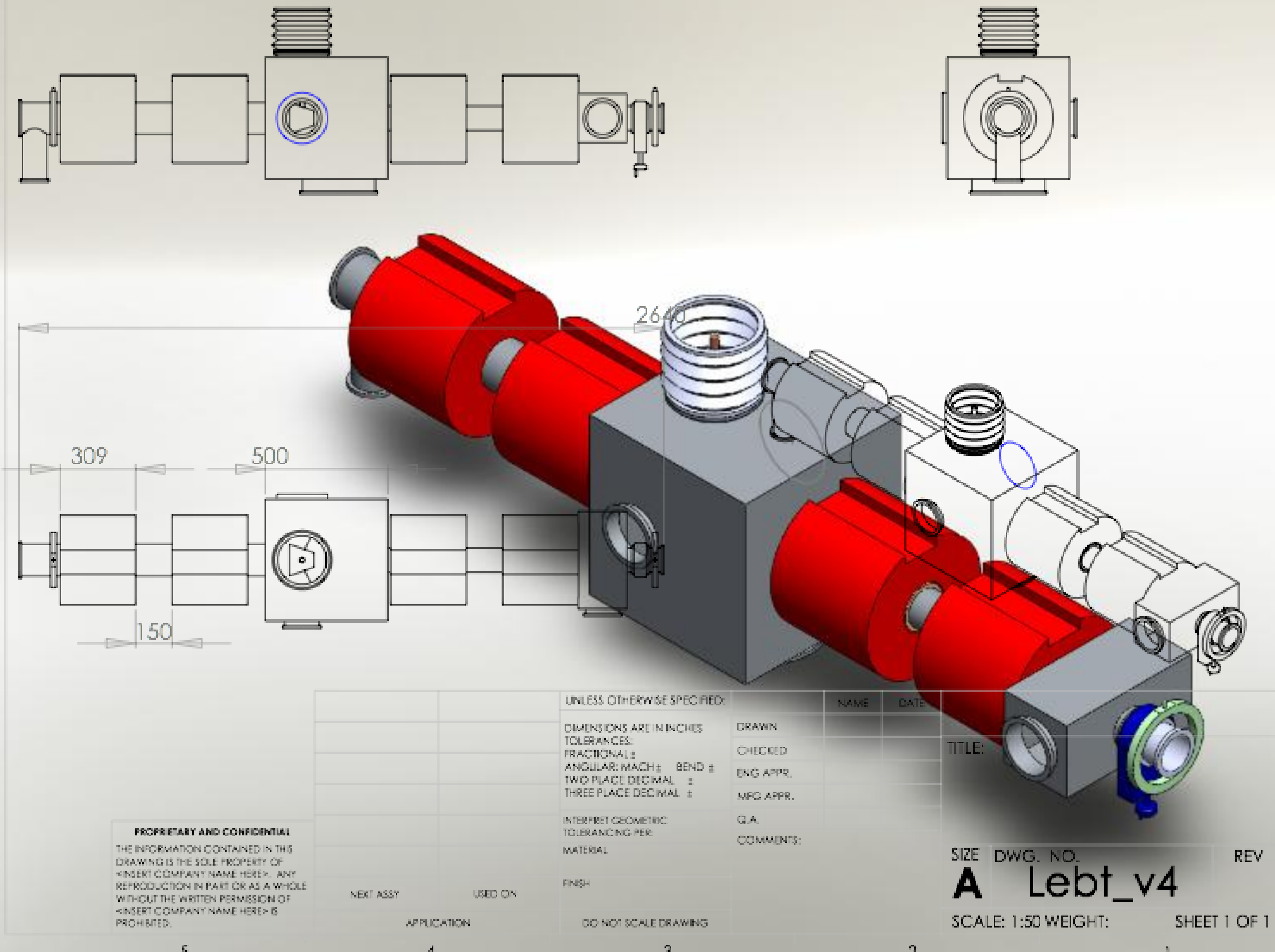


2 coils in series

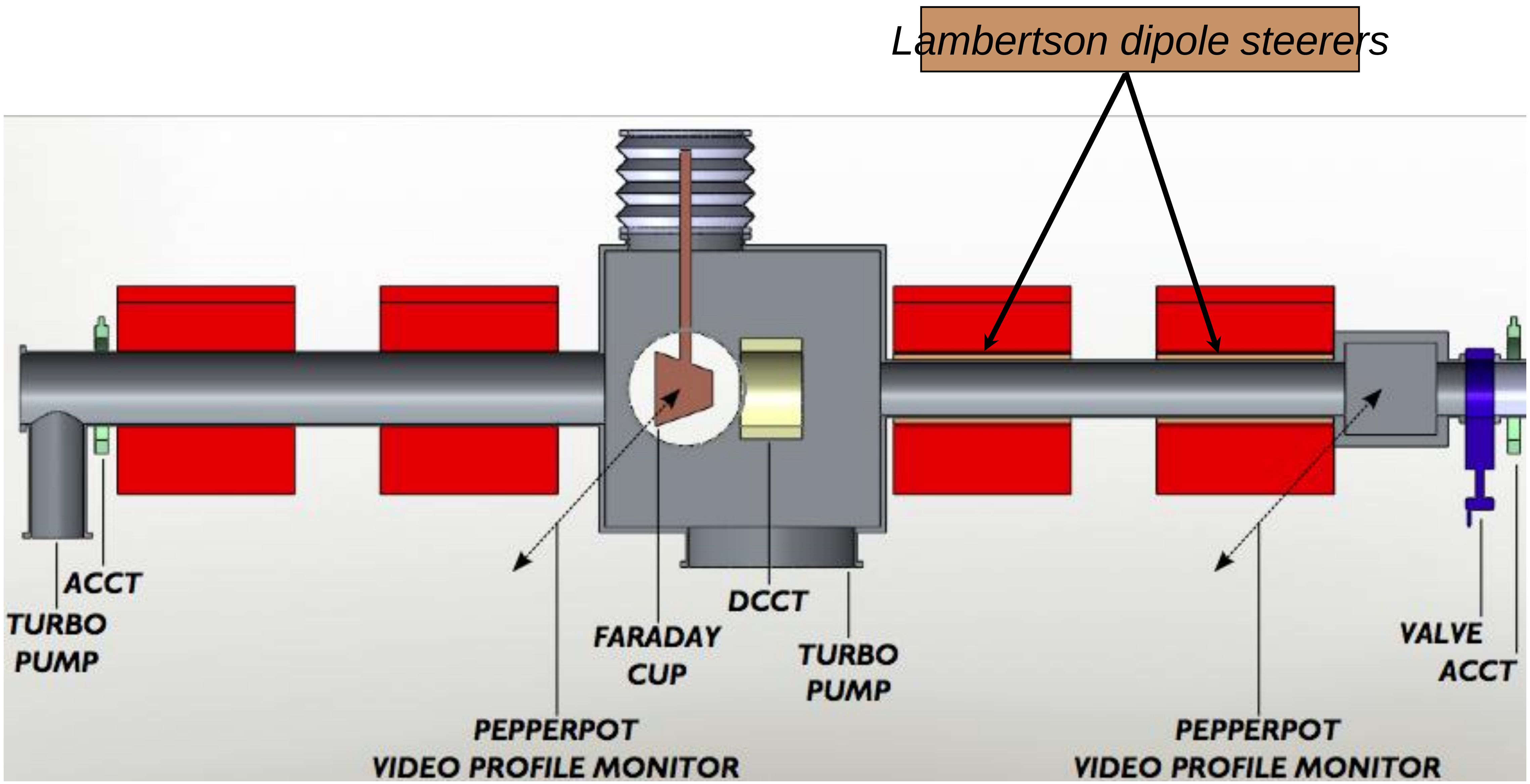
Two examples of possible connection schemes, the individual coils in the solenoid are labeled 1 though 16. Top panel shows all coils connected to the manifold in parallel. Bottom panel shows sets of two coils connected in series, and the sets connected in parallel to the manifold.

Vacuum


TURBOVAC MAG W 600 P DN 160 CF (Leybold)
TURBOVAC MAG W 600 P DN 160 CF (Leybold)
TURBOVAC MAG W 2200C, DN 250 CF/DN 40 KF
TURBOVAC MAG W 600 P DN 160 CF (Leybold)
2315
140
150
380
150
160
309
309
309
309
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Lebt_V5a_2
A4
SCALE:1:50
SHEET 1 OF 1

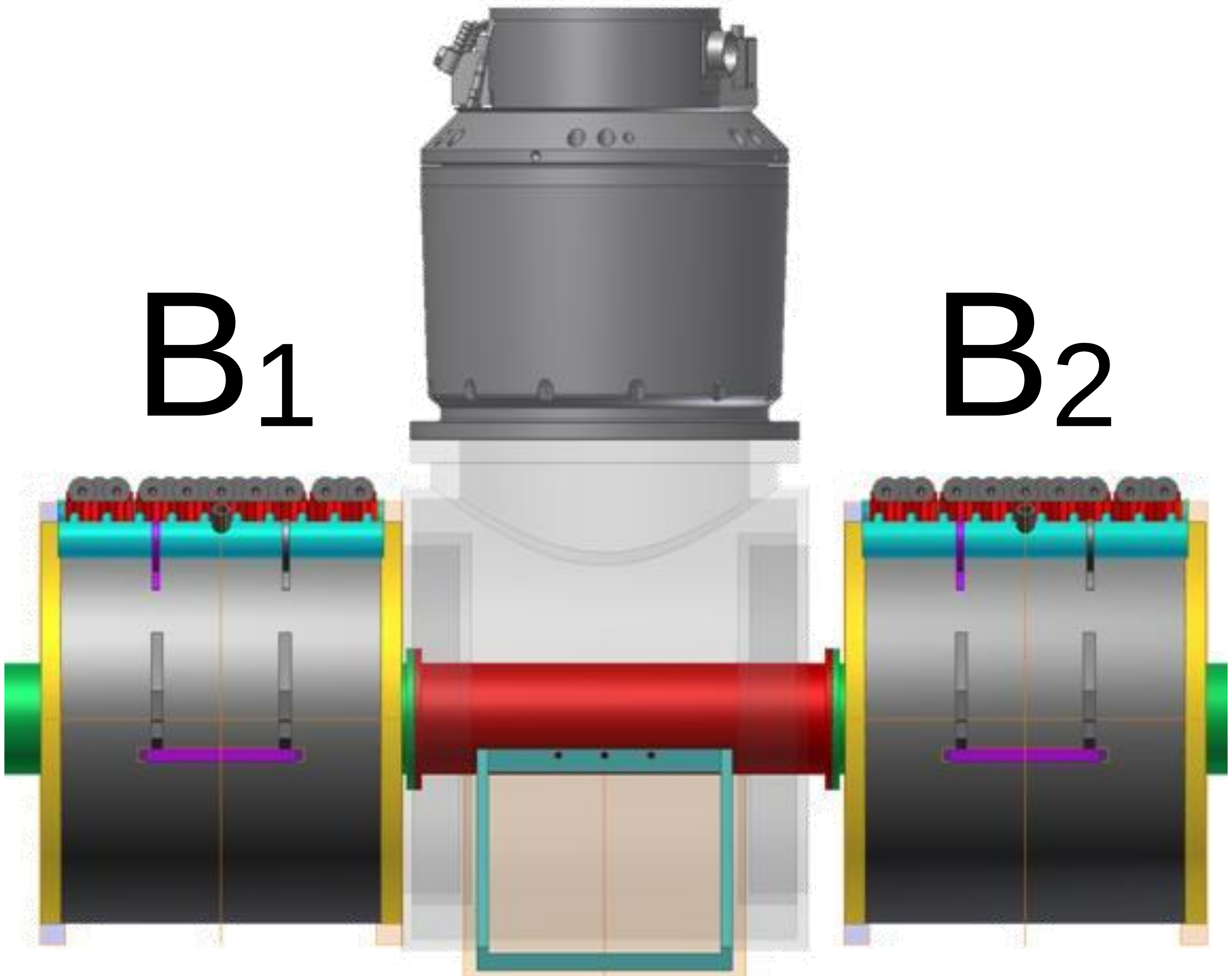

2640
309
500
150
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
SIZE
DWG. NO.
REV
A
Lebt_v4
SCALE: 1:50 WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
5
4
3
2
1

Diagnostics



Beam | Dynamics

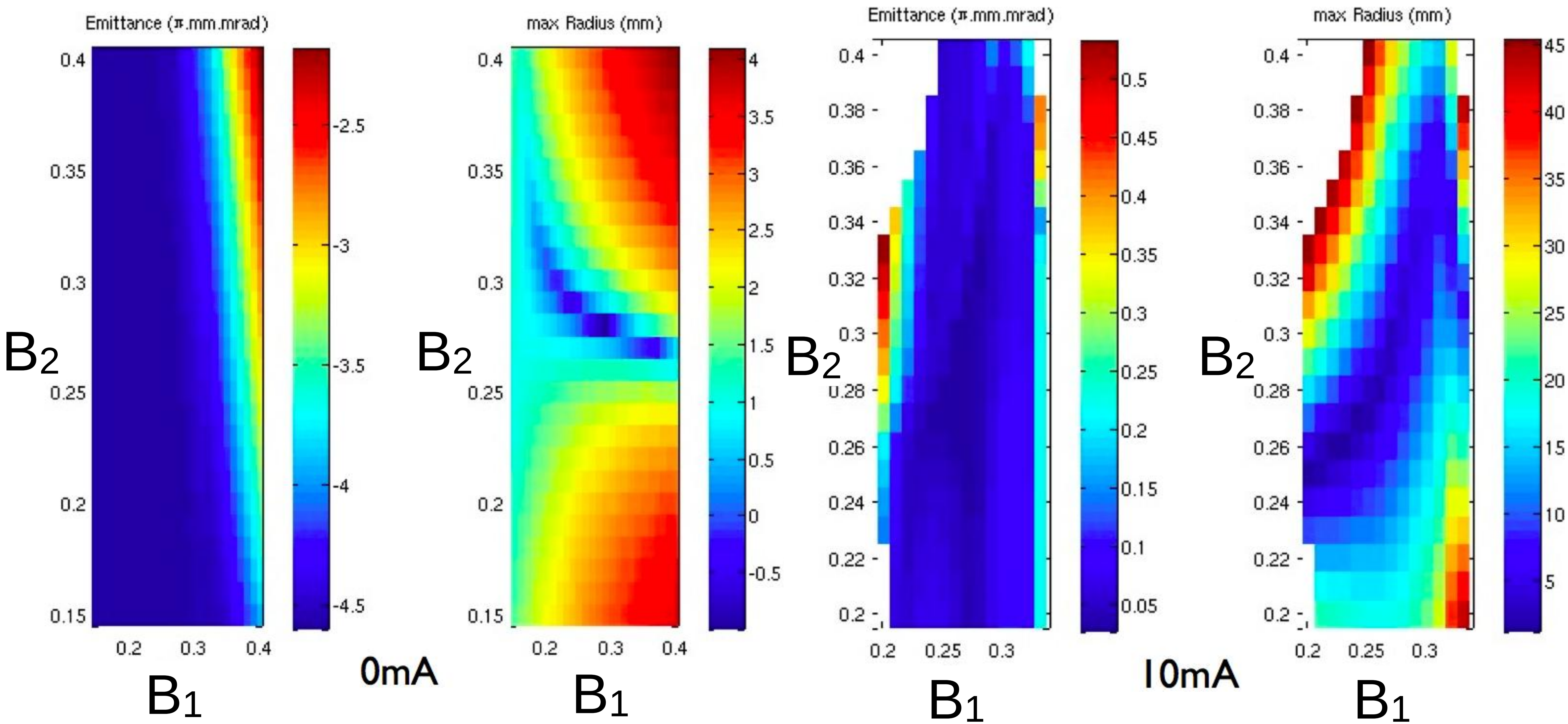
2D configuration search



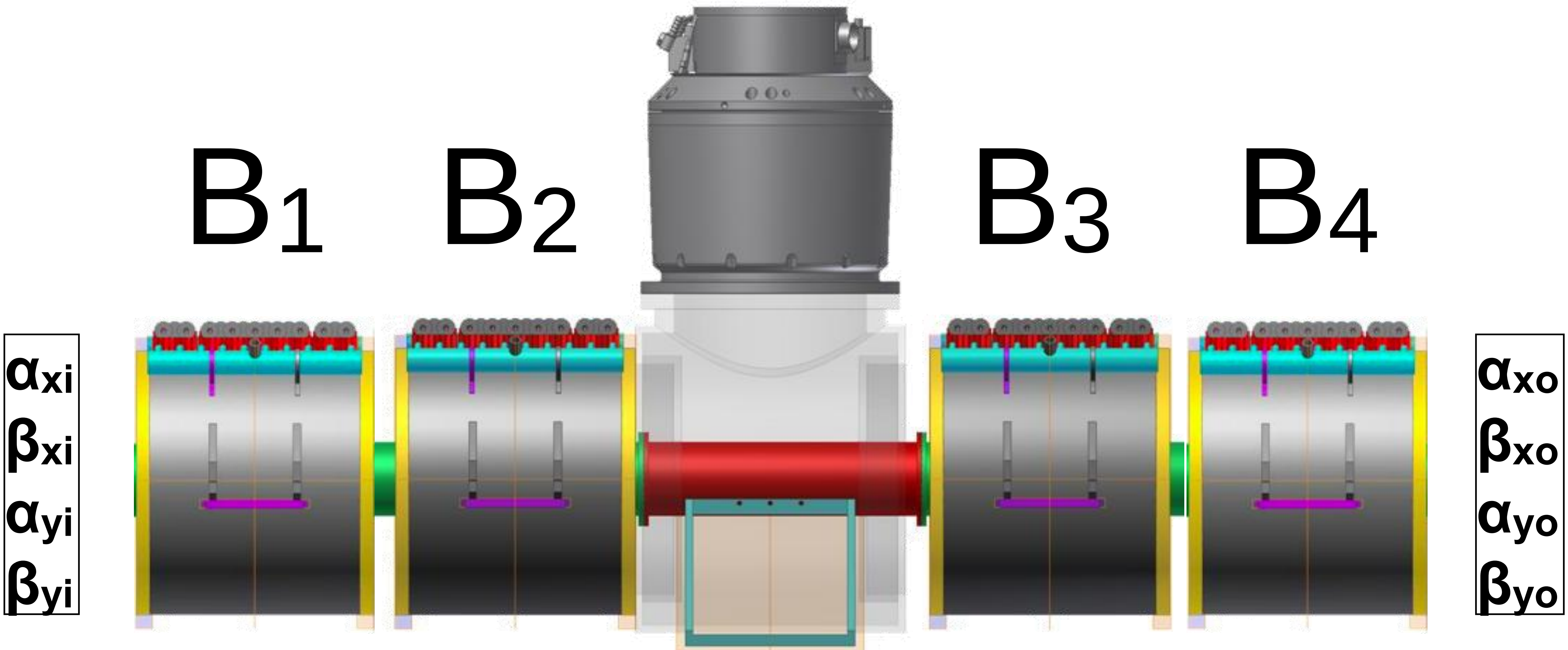
α_i
β_i

$\alpha_o \approx 1$
$\beta_o \approx 0.03$ m/rad

2D configuration search

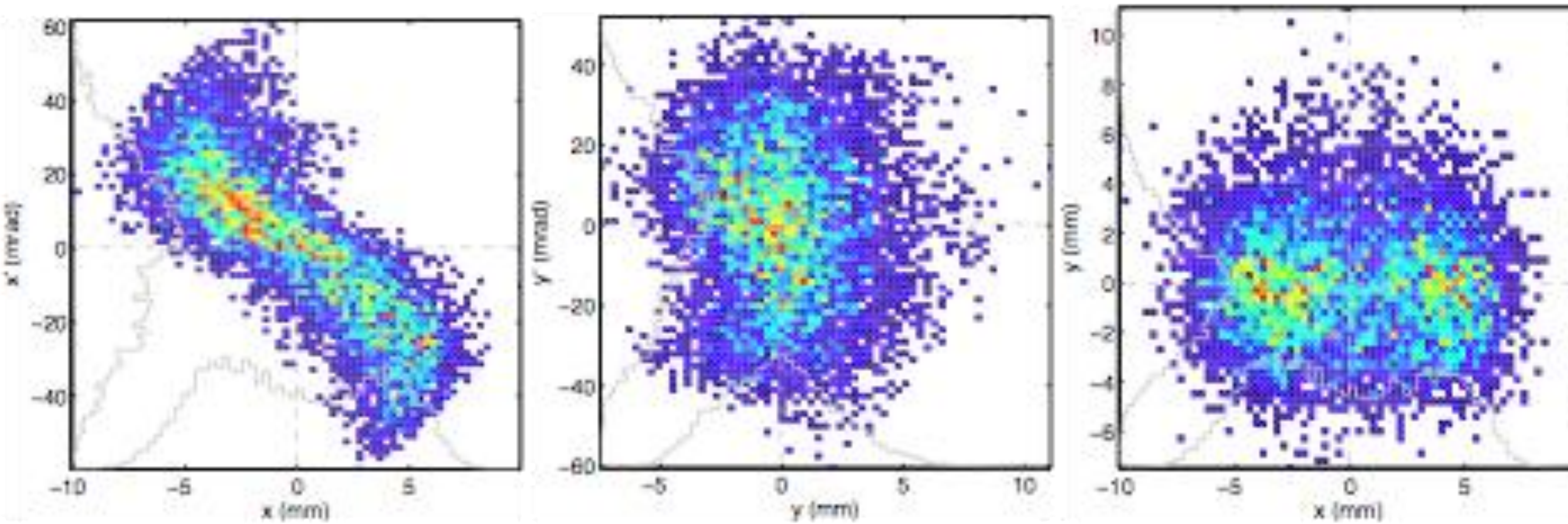


4D configuration search



Pepperpot data set

nemixrms: **0.57691** π.mm.rad nemiyrms: **0.61818** π.mm.rad



numpar: **10,000**

CSα_{xi}: **1.4366**

CSβ_{xi}: **0.2940** m/rad

CSα_{yi}: **0.0726**

CSβ_{yi}: **0.1286** m/rad

Desired Output

CSα_{xo} = **1.008**

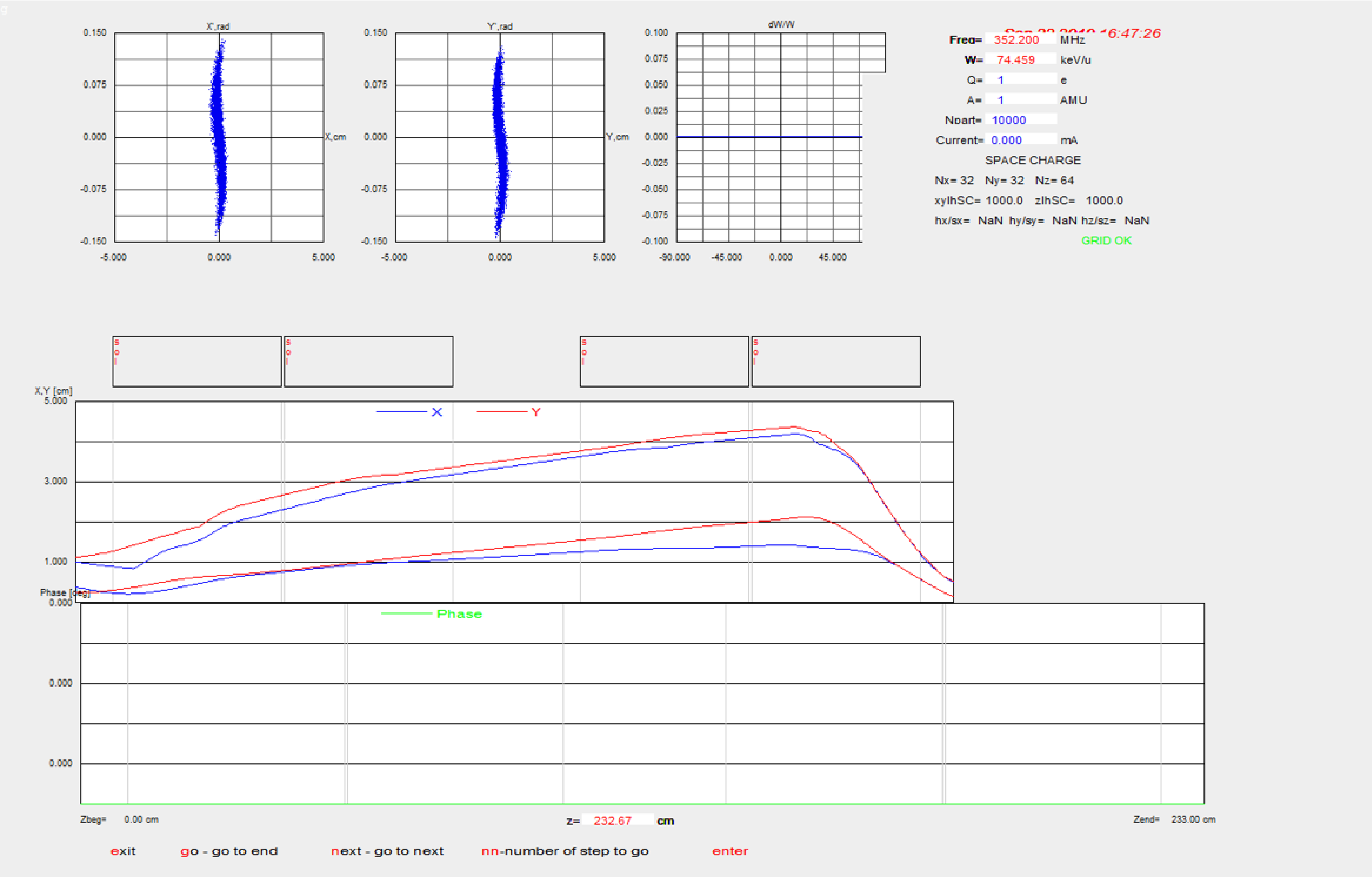
CSα_{yo} = **0.978**

CSβ_{xo} = **0.027**m/rad

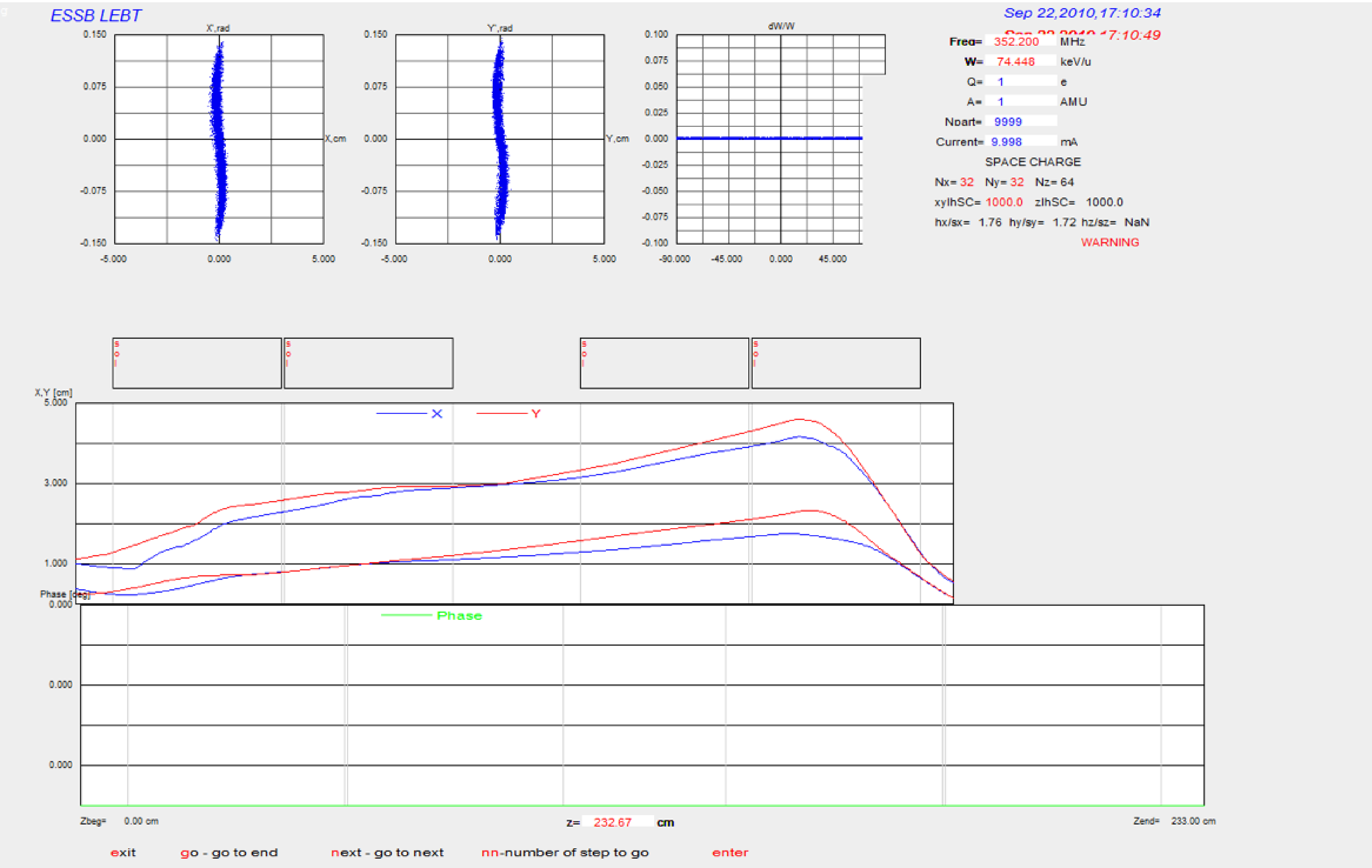
CSβ_{yo} = **0.0305** m/rad

4D Search through Realistic Pepperpot data Trace2D+TRACK

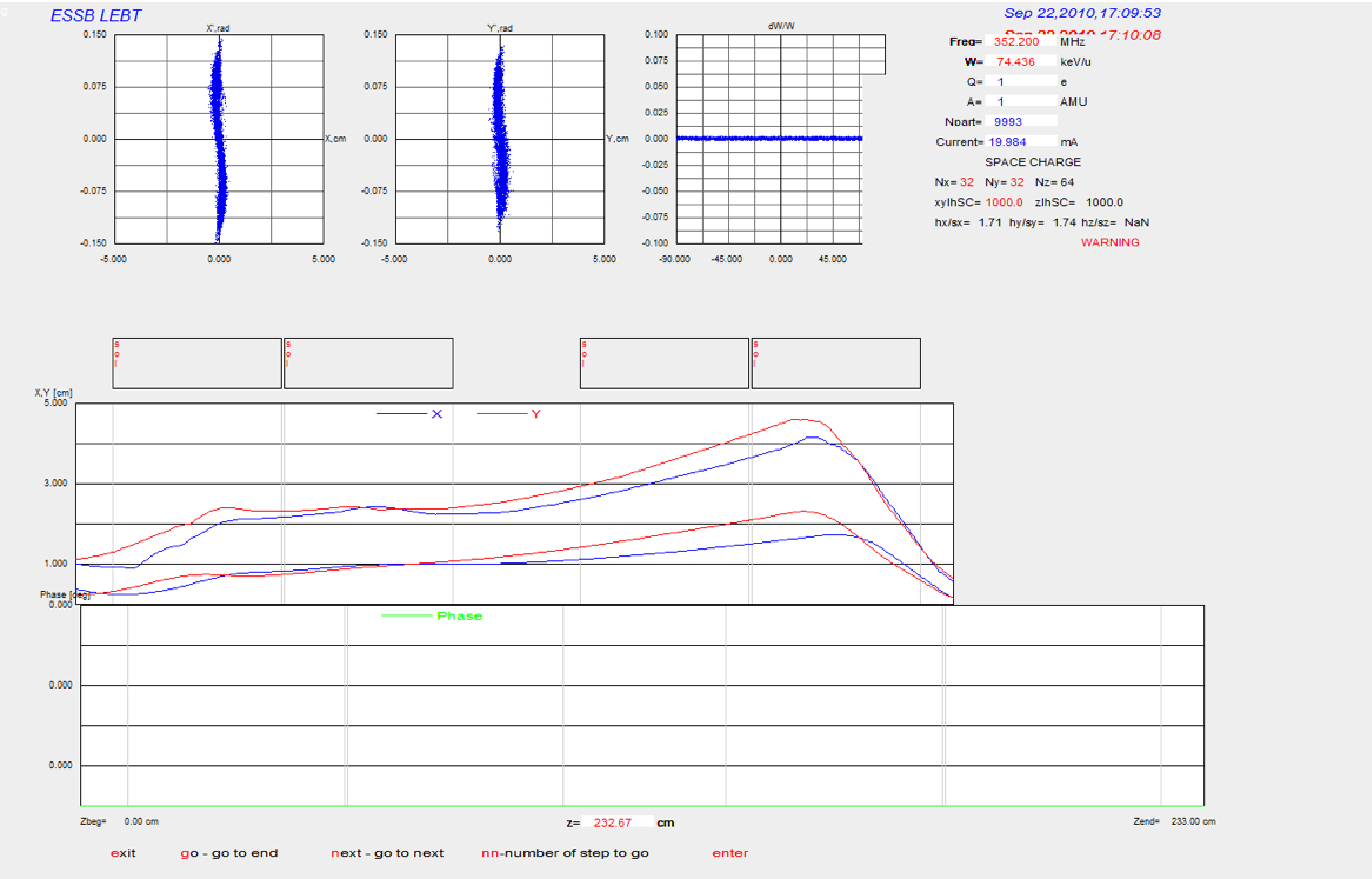
TRACK I=0mA b=[0.256-0.106-0.603-0.328]



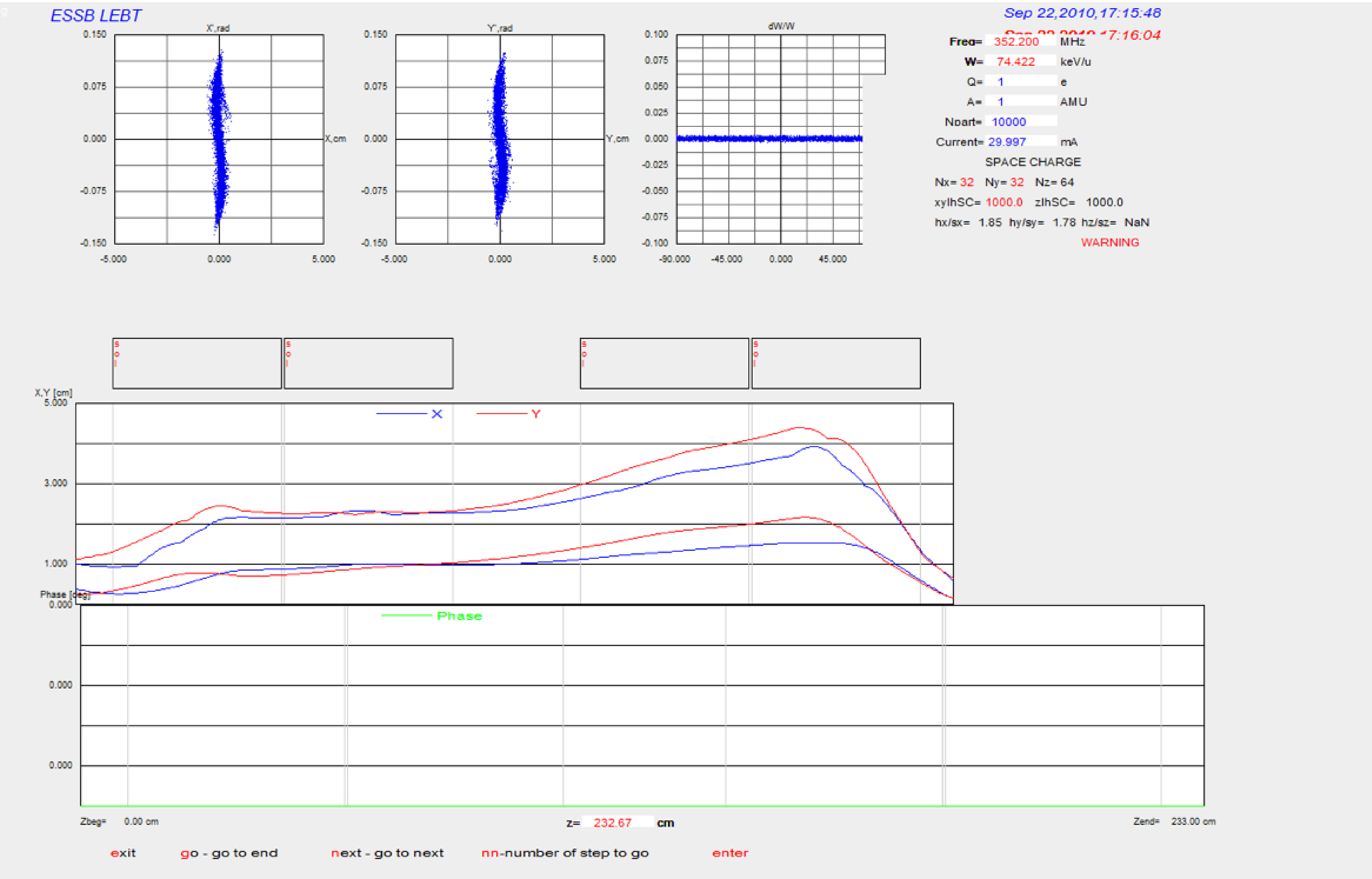
TRACK I=10mA b=[0.302-0.141-0.049-0.341]



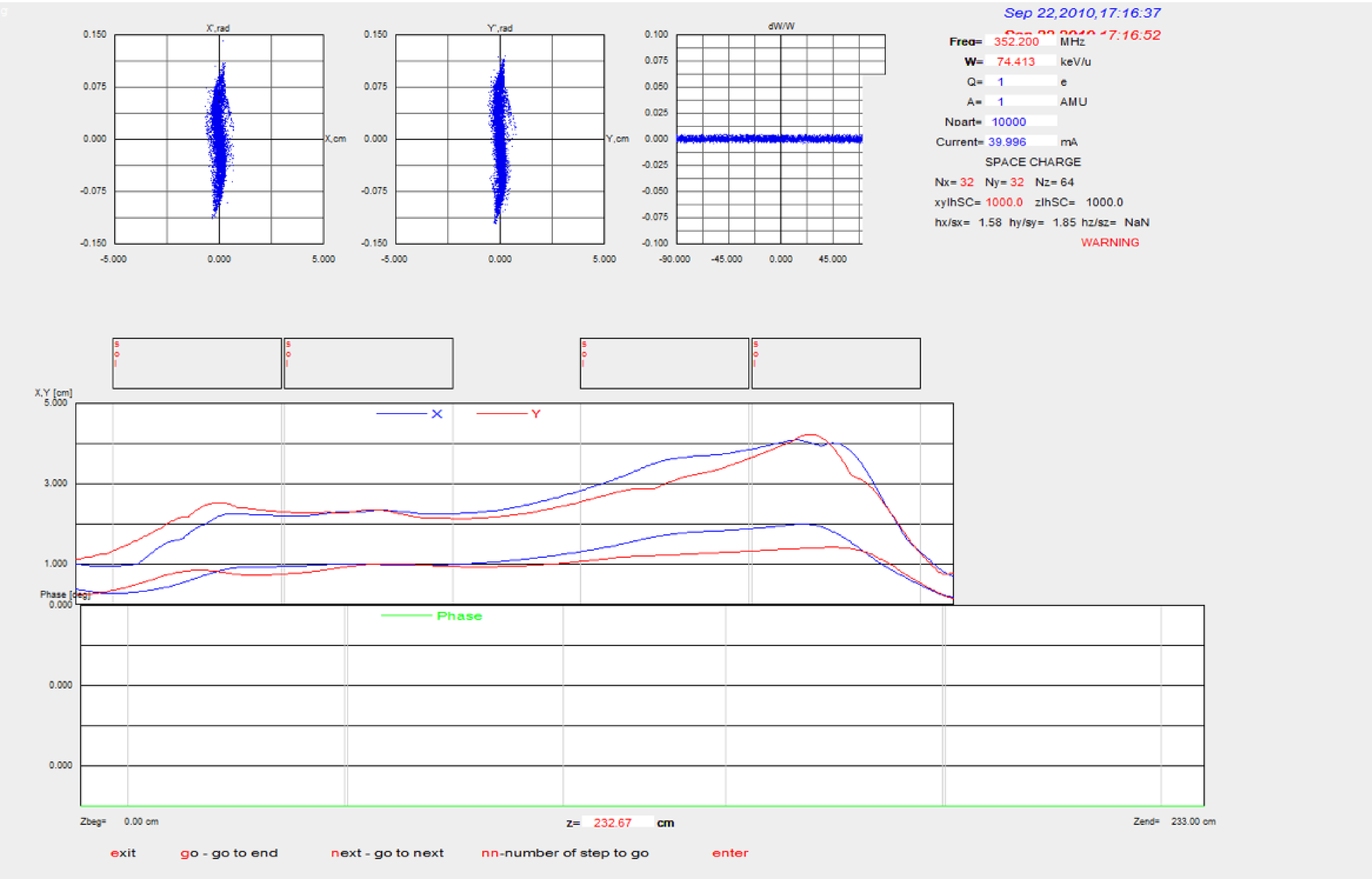
TRACK I=20mA b=[0.341-0.189-0.050-0.354]



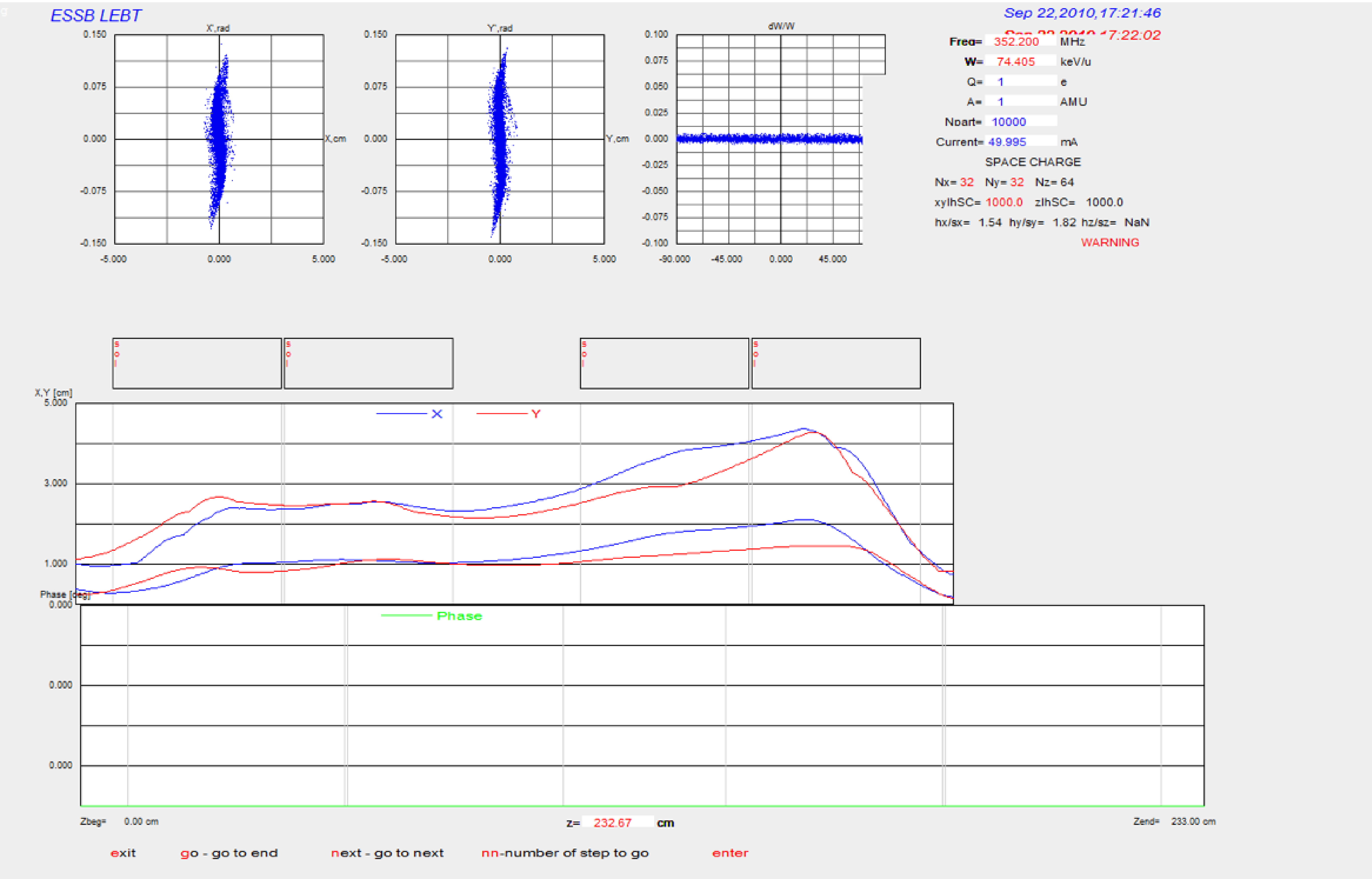
TRACK I=30mA b=[0.378-0.215-0.140-0.354]



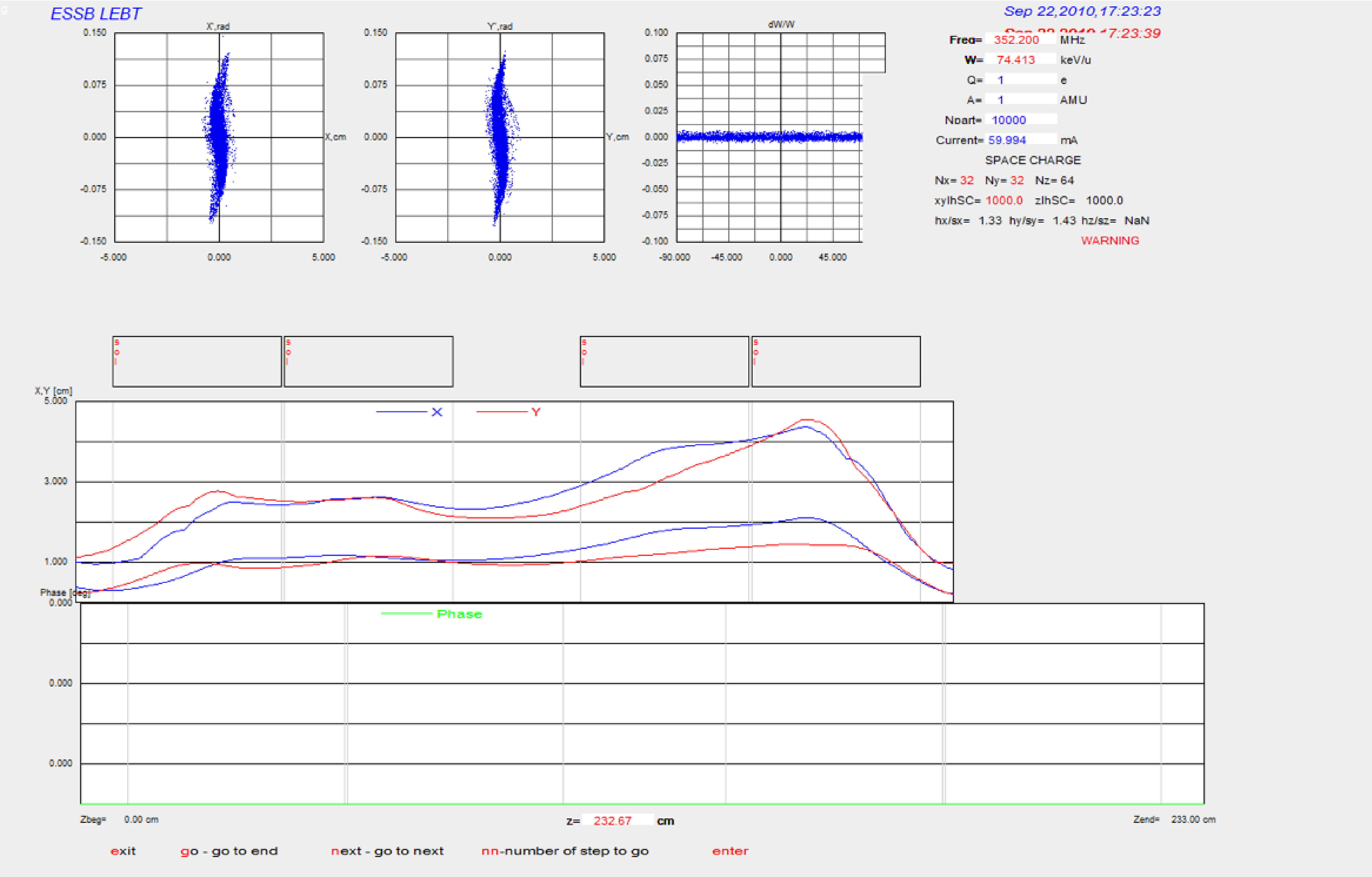
TRACK I=40mA b=[0.392-0.250-0.180-0.361]



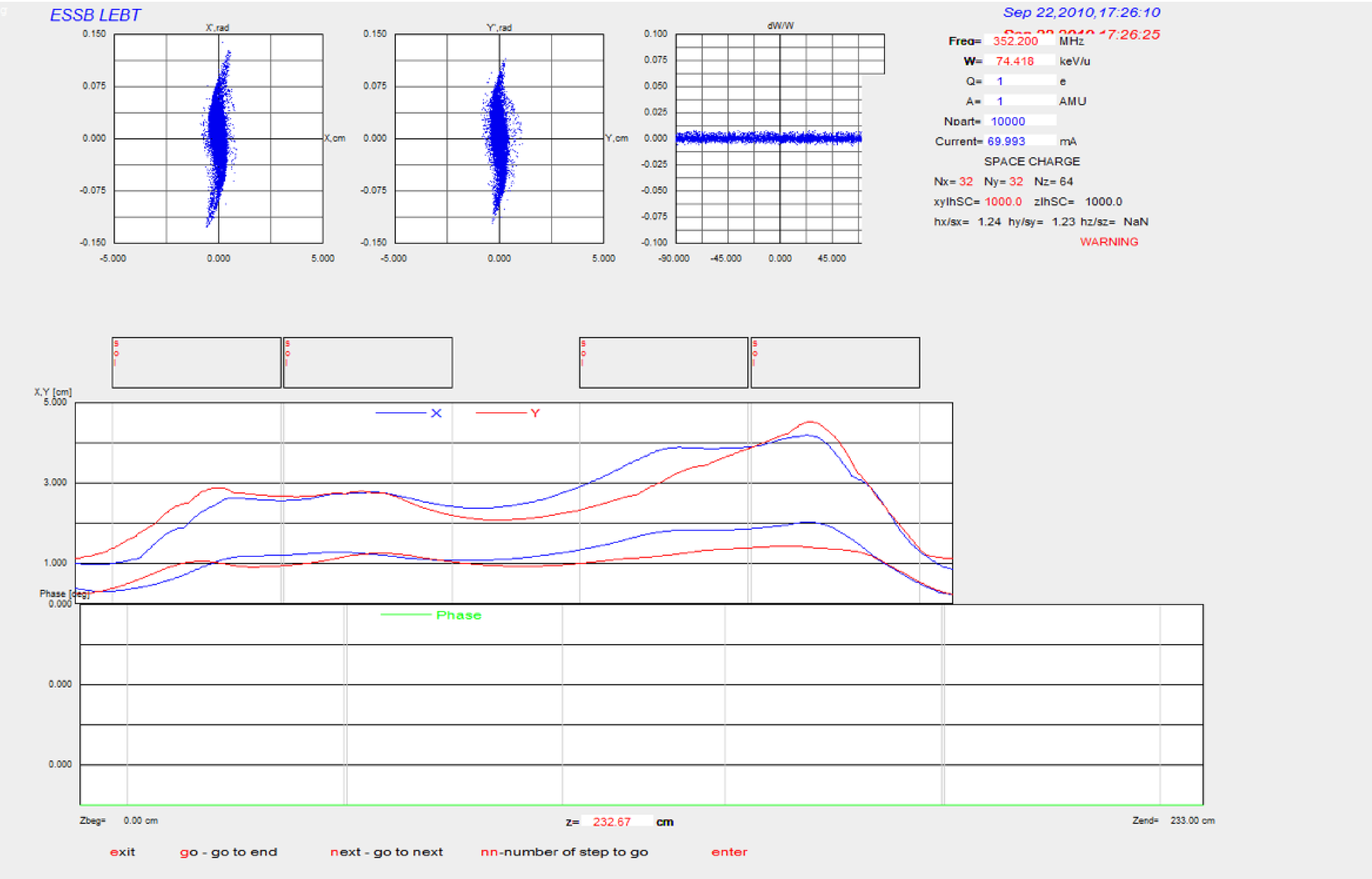
TRACK I=50mA b=[0.392-0.266-0.180-0.370]



TRACK I=60mA b=[0.400-0.280-0.200-0.370]



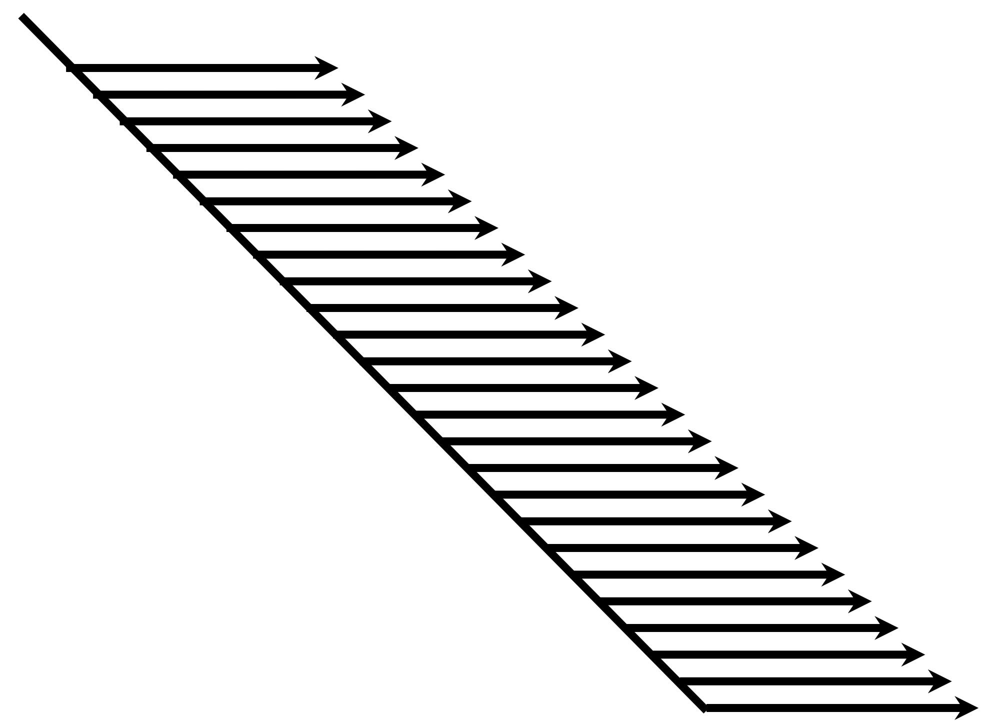
TRACK I=70mA b=[0.400-0.290-0.220-0.375]



4D Search through
Realistic Pepperpot
data
GPT

Space Charge Matching Algorithm

- Simple Search Algorithm:**4 nested cycles**

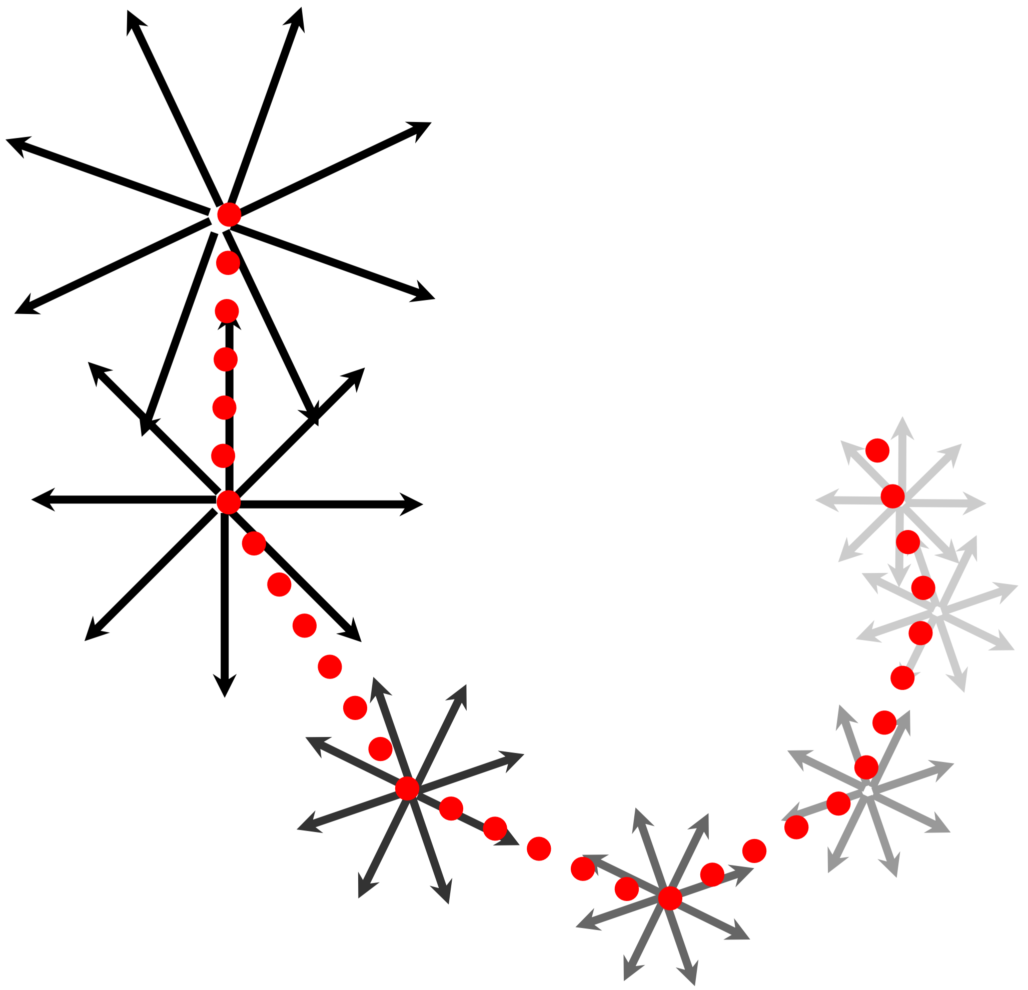


- Bi=[0:∂B:0.4]
- Take ∂B=0.1T for instance, **5** possibilities per solenoid. 5^4=**625** total runs.
- Take ∂B=0.01T for instance, **41** possibilities per solenoid. 41^4=**2,825,761** total runs.

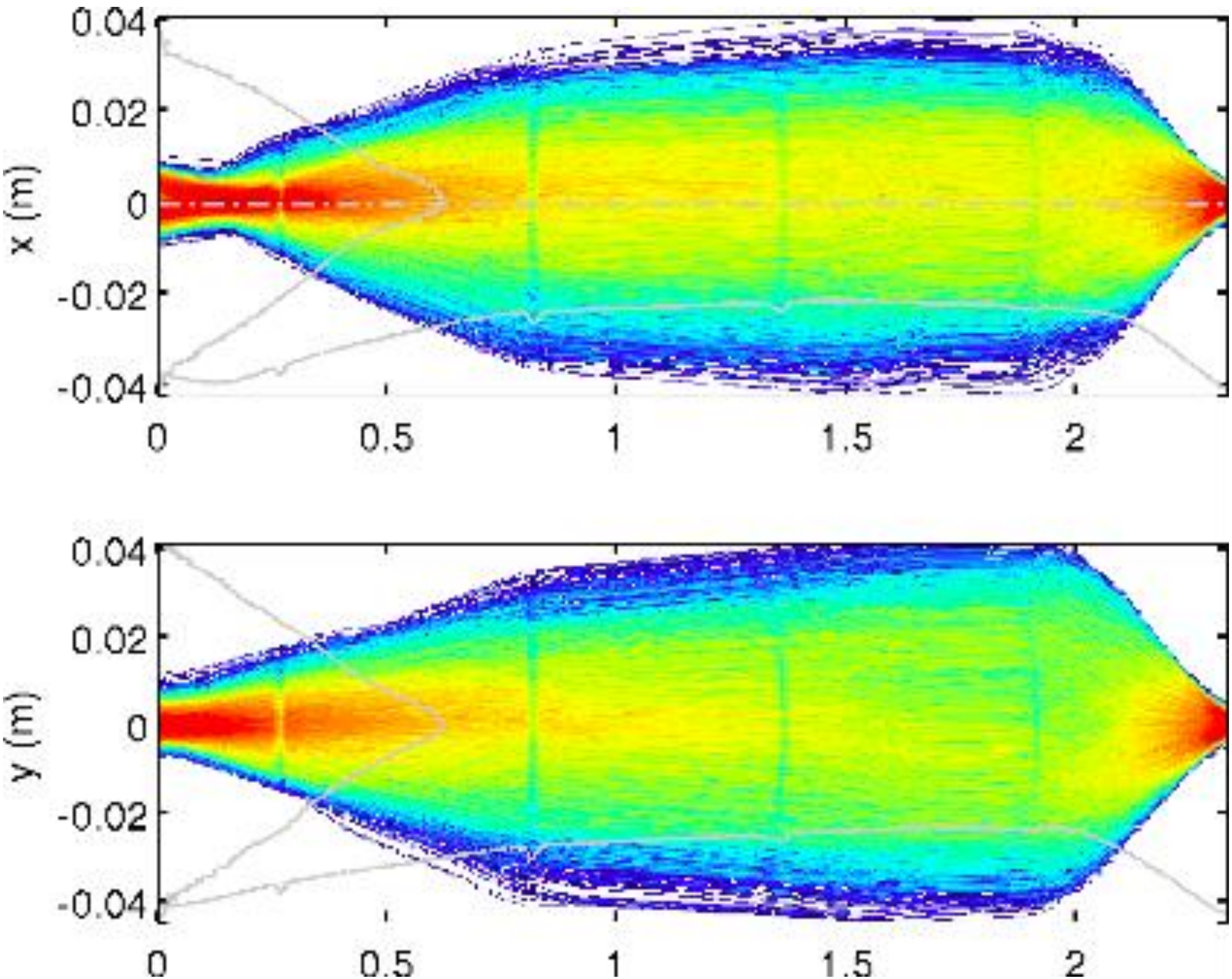
784hrs!
(1month)

Space Charge Matching Algorithm

- Evolutive Algorithm
- Each universe will be made by: [Bi-∂B,Bi Bi+∂B]
- A total of $\mathbf{3^4=81}$ possibilities per node where ∂B will be adapting to the new solution.
- Much quicker convergence.



I=0mA b=[0.18438-0.16562-0.0875-0.31719]

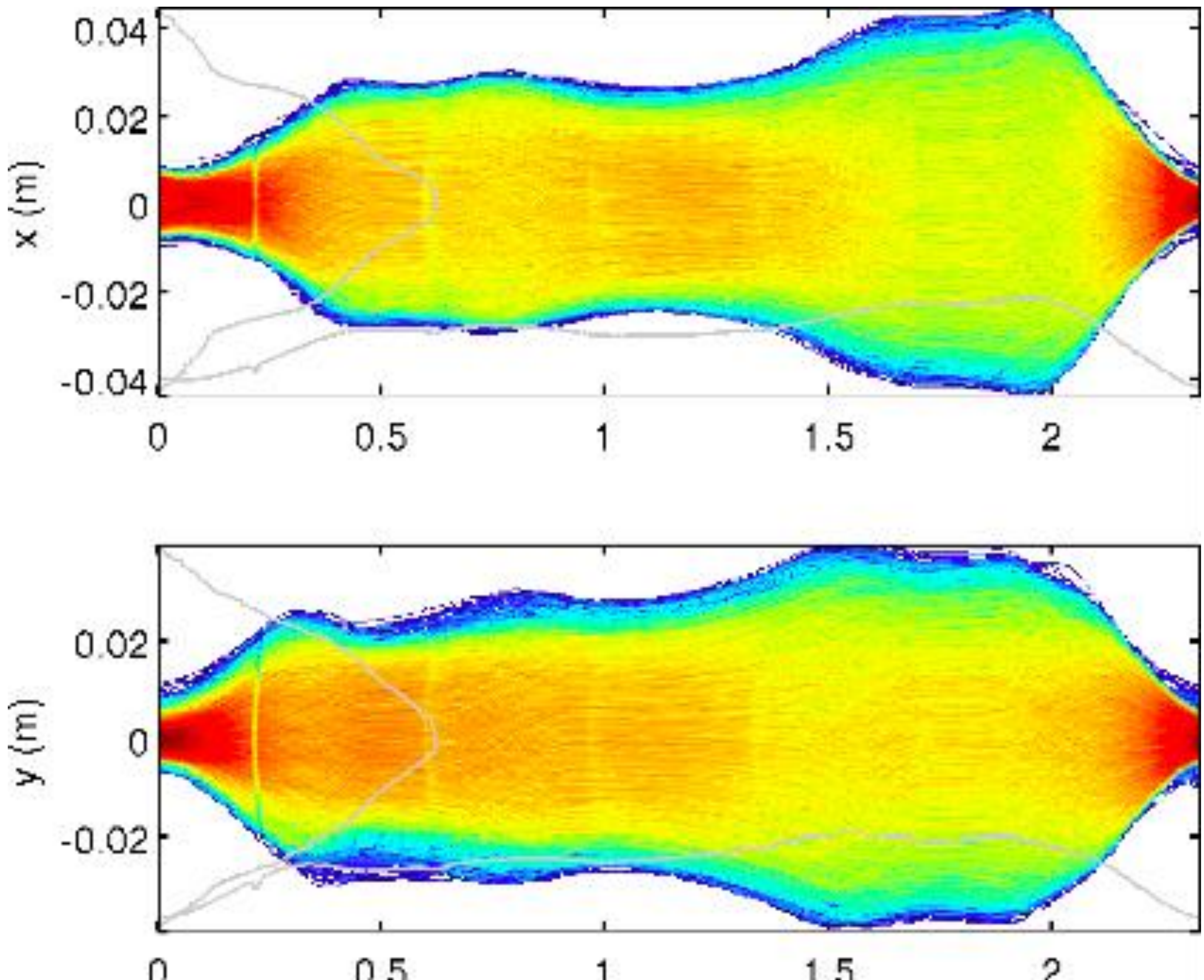


17 x 81: 1,377 calculations required

~30% emittance increase

I=70mA b=[0.4-0.26875-0.2125-0.36875]

12 x 81: 972 calculations required

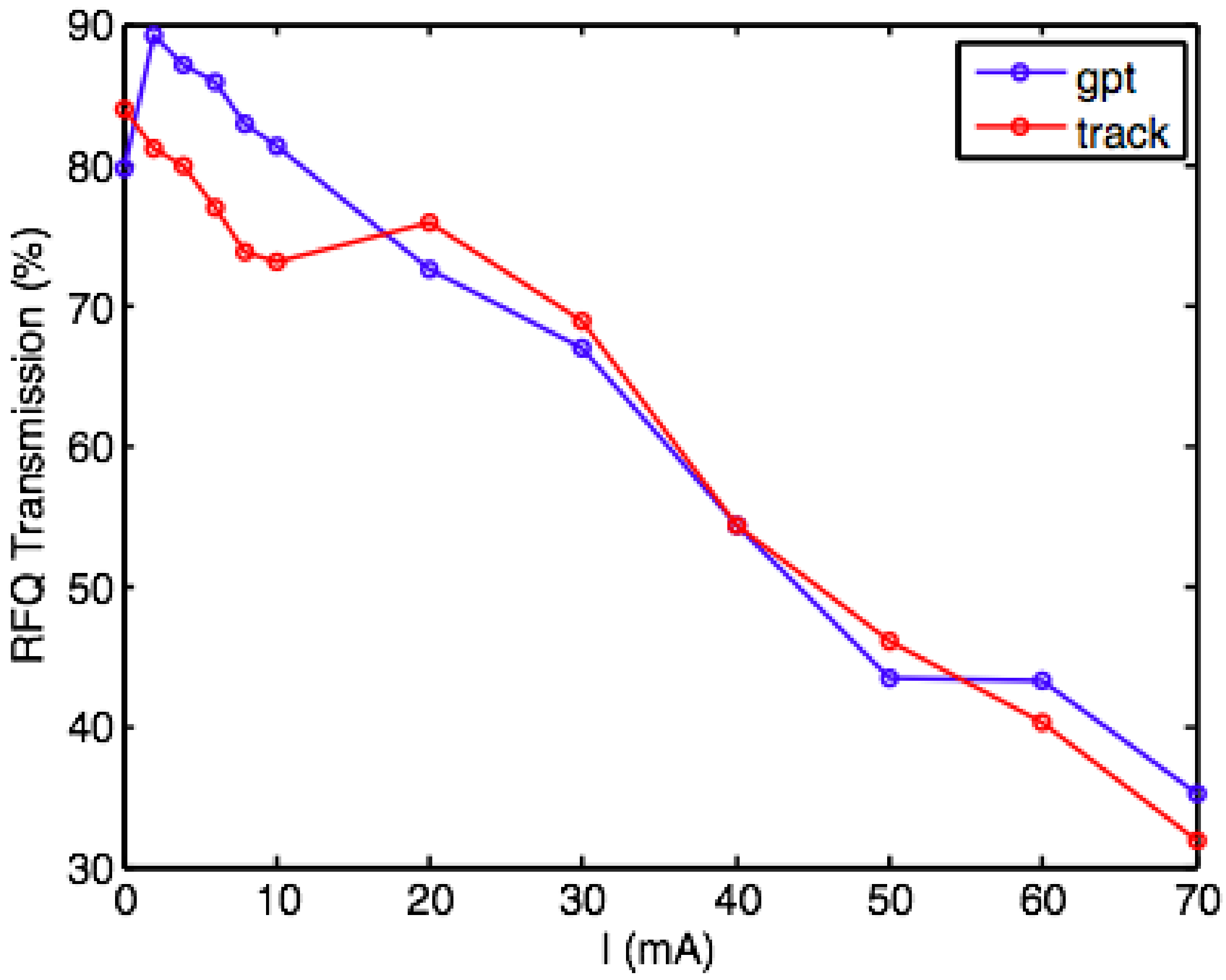


~96% emittance increase

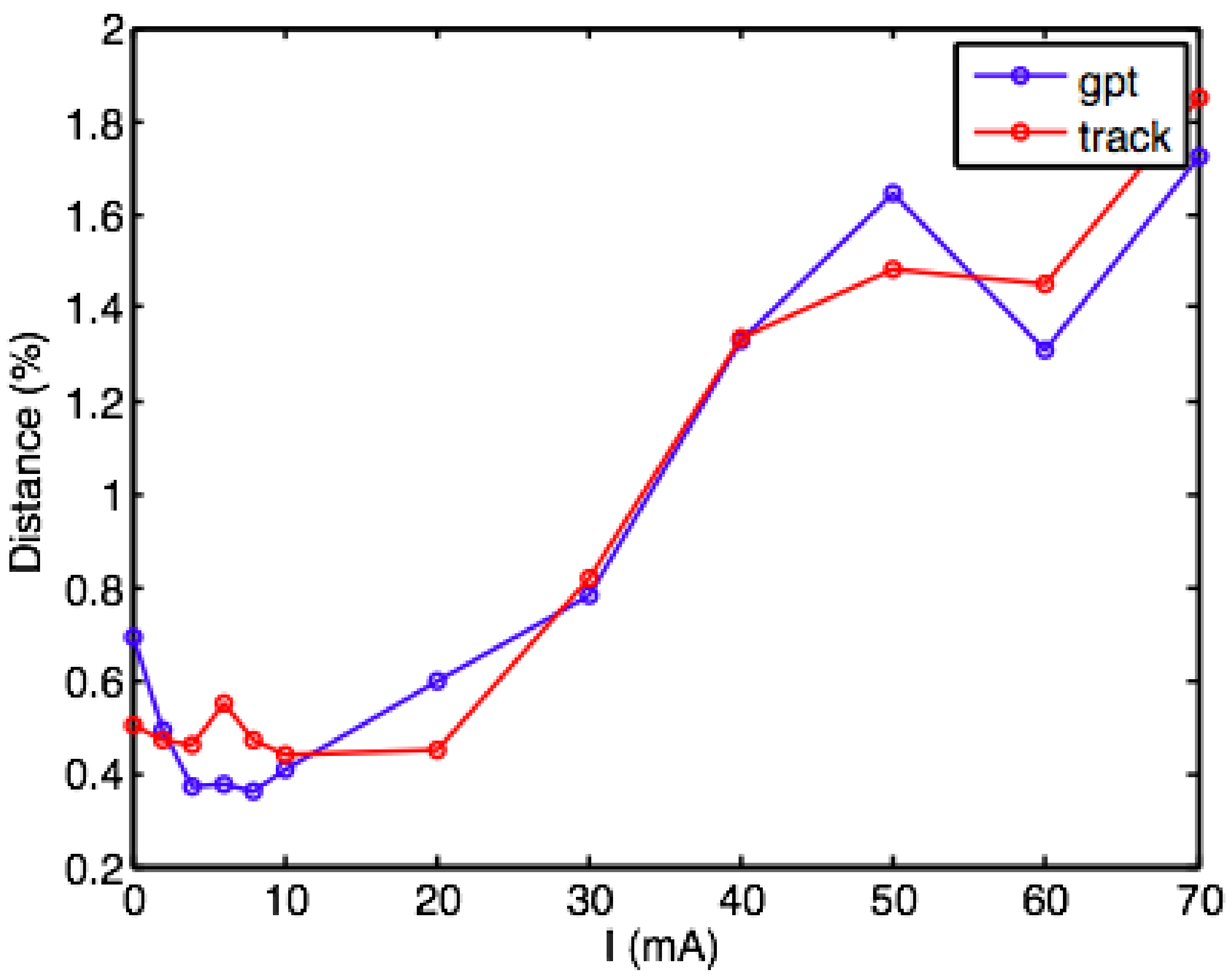
Table 1: Measured parameters at the RFQ input for different ion currents. Only a representative fraction of the simulations is presented here. Note that I(mA) refers to the non-neutralized current.

I (mA)	Software	B1 (T)	B2 (T)	B3 (T)	B4 (T)	$T\alpha_x$	$T\alpha_y$	$T\beta_x$ (m/rad)	$T\beta_y$ (m/rad)	$\Delta n\epsilon_x$ (%)	$\Delta n\epsilon_y$ (%)	RFQ Transmission (%)
0	GPT	0.184	0.165	0.087	0.317	0.564	0.755	0.0377	0.0391	34.84	27.95	79.8
	TRACK	0.256	0.106	0.603	0.328	0.650	0.660	0.0309	0.0302	38.98	34.71	84.0
2	GPT	0.365	0.050	0.018	0.035	0.732	0.672	0.0336	0.0331	30.59	16.94	89.2
	TRACK	0.272	0.094	0.077	0.329	0.740	0.630	0.0312	0.0297	47.35	41.28	81.1
4	GPT	0.353	0.0719	0.008	0.350	0.829	0.7661	0.0333	0.0323	34.43	26.34	87.1
	TRACK	0.282	0.101	0.079	0.331	0.810	0.610	0.0319	0.0299	54.05	42.93	80.0
6	GPT	0.350	0.100	0.025	0.350	0.956	0.789	0.0339	0.0364	39.22	29.34	85.9
	TRACK	0.292	0.086	0.108	0.327	0.750	0.520	0.0303	0.0285	65.77	47.86	76.9
8	GPT	0.331	0.131	0.008	0.350	0.878	0.728	0.0326	0.0327	51.33	39.82	82.9
	TRACK	0.300	0.117	0.076	0.336	0.660	0.690	0.0303	0.0292	44.01	77.43	73.8
10	GPT	0.333	0.145	0.042	0.350	0.911	0.685	0.0329	0.0346	58.74	36.00	81.3
	TRACK	0.302	0.141	0.049	0.341	0.750	0.660	0.0309	0.0293	55.73	70.86	73.1
20	GPT	0.339	0.195	0.089	0.353	0.822	0.523	0.0346	0.0353	79.55	35.71	72.5
	TRACK	0.351	0.189	0.050	0.354	0.850	0.600	0.0309	0.0334	60.75	49.50	75.8
30	GPT	0.340	0.234	0.098	0.362	0.769	0.397	0.0354	0.0404	72.97	36.98	67.0
	TRACK	0.378	0.215	0.140	0.354	0.510	0.350	0.0295	0.0325	54.05	52.78	68.9
40	GPT	0.308	0.275	0	0.384	0.613	0.243	0.0355	0.0602	68.65	46.80	54.3
	TRACK	0.392	0.250	0.180	0.361	0.180	0.190	0.0453	0.0308	55.73	54.43	54.3
50	GPT	0.295	0.281	0	0.390	0.425	0.125	0.0327	0.0687	83.21	58.95	43.5
	TRACK	0.392	0.266	0.180	0.370	0.010	0.040	0.0416	0.0300	75.82	69.21	46.1
60	GPT	0.375	0.244	0.195	0.355	0.394	0.298	0.0361	0.0568	68.32	52.35	43.2
	TRACK	0.400	0.180	0.200	0.370	0.130	0.280	0.0490	0.0430	95.91	84.00	40.2
70	GPT	0.400	0.269	0.212	0.369	0.076	0.251	0.0417	0.0648	95.70	97.63	35.1
	TRACK	0.400	0.290	0.220	0.375	0.000	0.220	0.0548	0.0570	105.96	93.86	31.8

RFQ | Transmission



CS | Distance



Conclusions

- Obtained Results are similar
- It is more important to get a good match with **ß** than with **α**
- A good *seed* required, otherwise «*weak focusing*» & «*strong focusing*» are indistinguishable.

Summary

- Ion Sources
- LEBT Magnetic Design
- LEBT Cooling system
- LEBT Code/methodology comparison

Thank you

I. Bustinduy, D. de Cos, J. Feuchtwanger, J.L. Munoz, F.J. Bermejo, ESS-Bilbao, Spain
S. Lawrie, D. Faircloth, A. Letchford, J. Pozimski, STFC/RAL, Chilton, Didcot, Oxon, UK
S. Jolly, P. Savage, Imperial College of Science and Technology, UK
J.Back, Warwick University, UK
J. Lucas, Elytt Energy, Madrid, Spain
J.P. Carneiro, IkerBasque Foundation, Chicago, USA

THE UNIVERSITY OF WARWICK ikerbasque Basque Foundation for Science eman ta zabal zazu Universidad del País Vasco Euskal Herriko Unibertsitatea ISIS Imperial College London