ESS Injector: *some simulations*

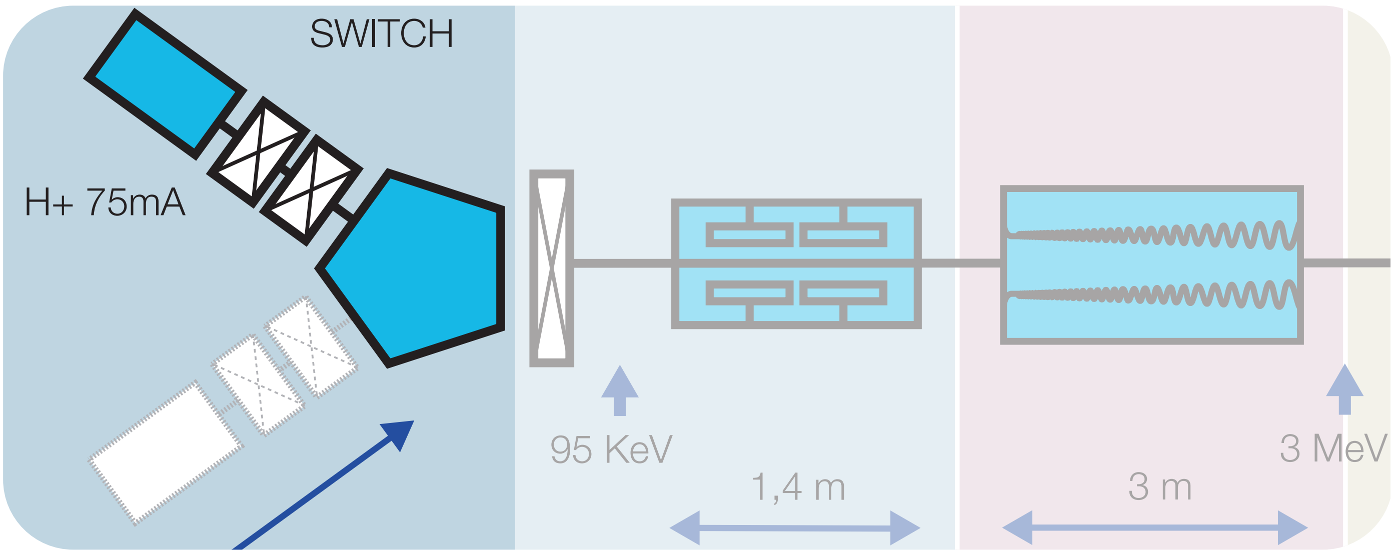
4th SPL Collaboration Meeting jointly with ESS

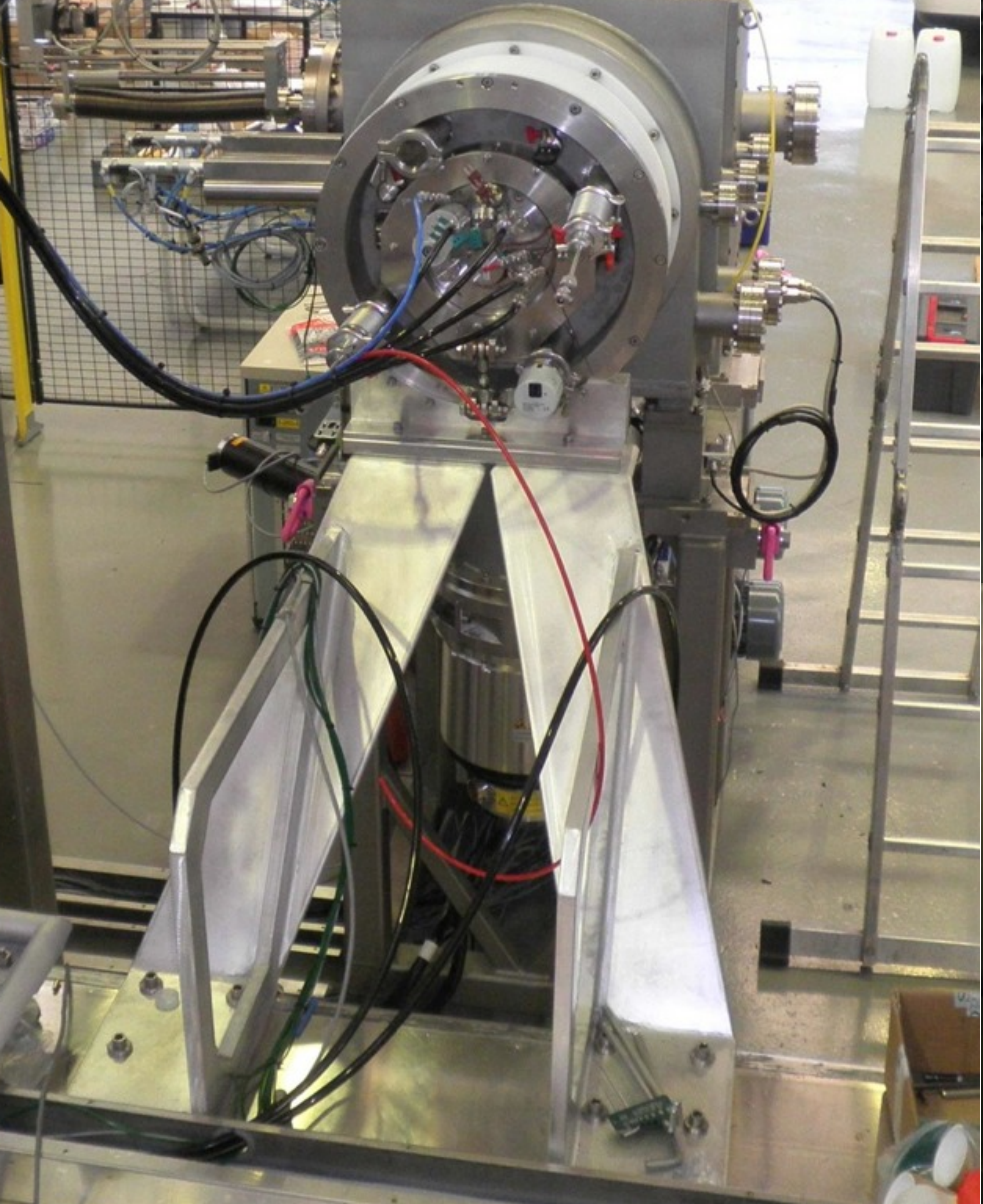
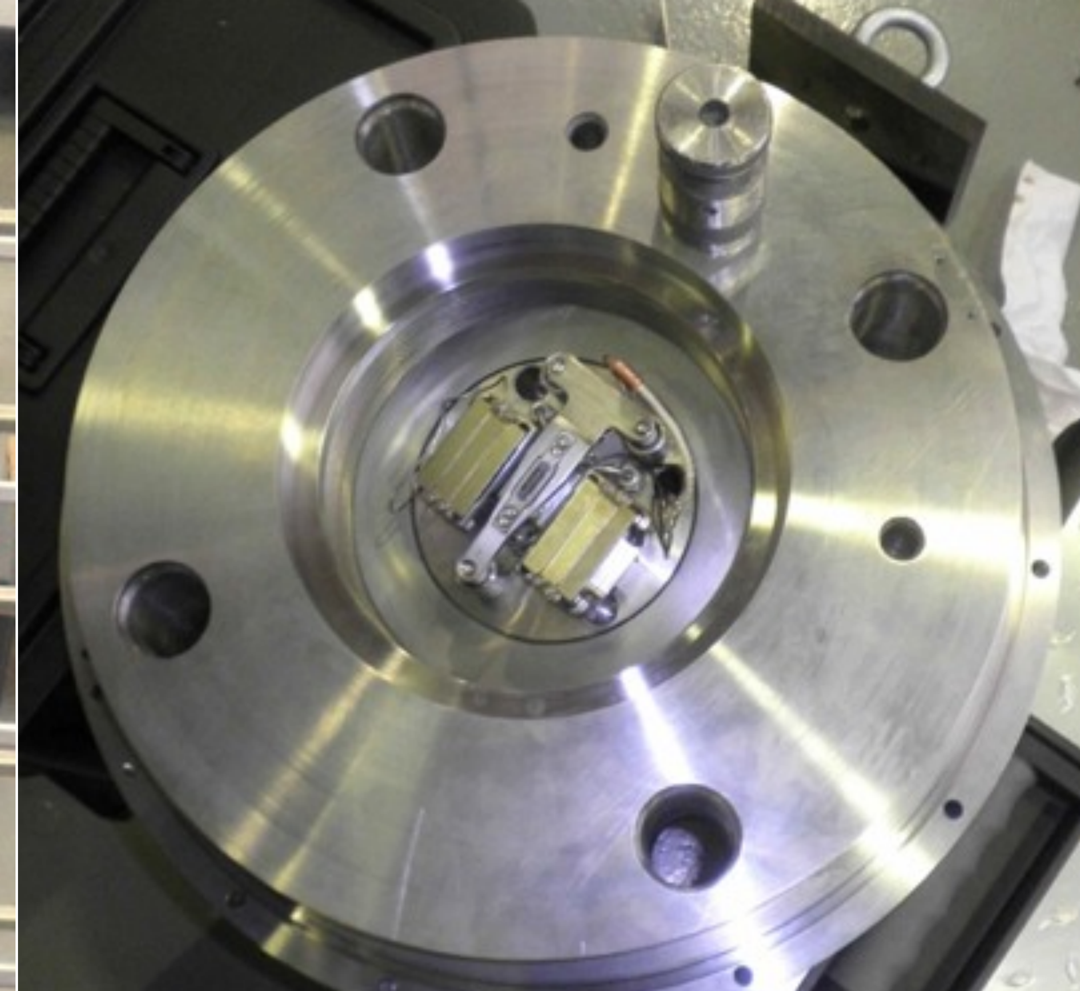
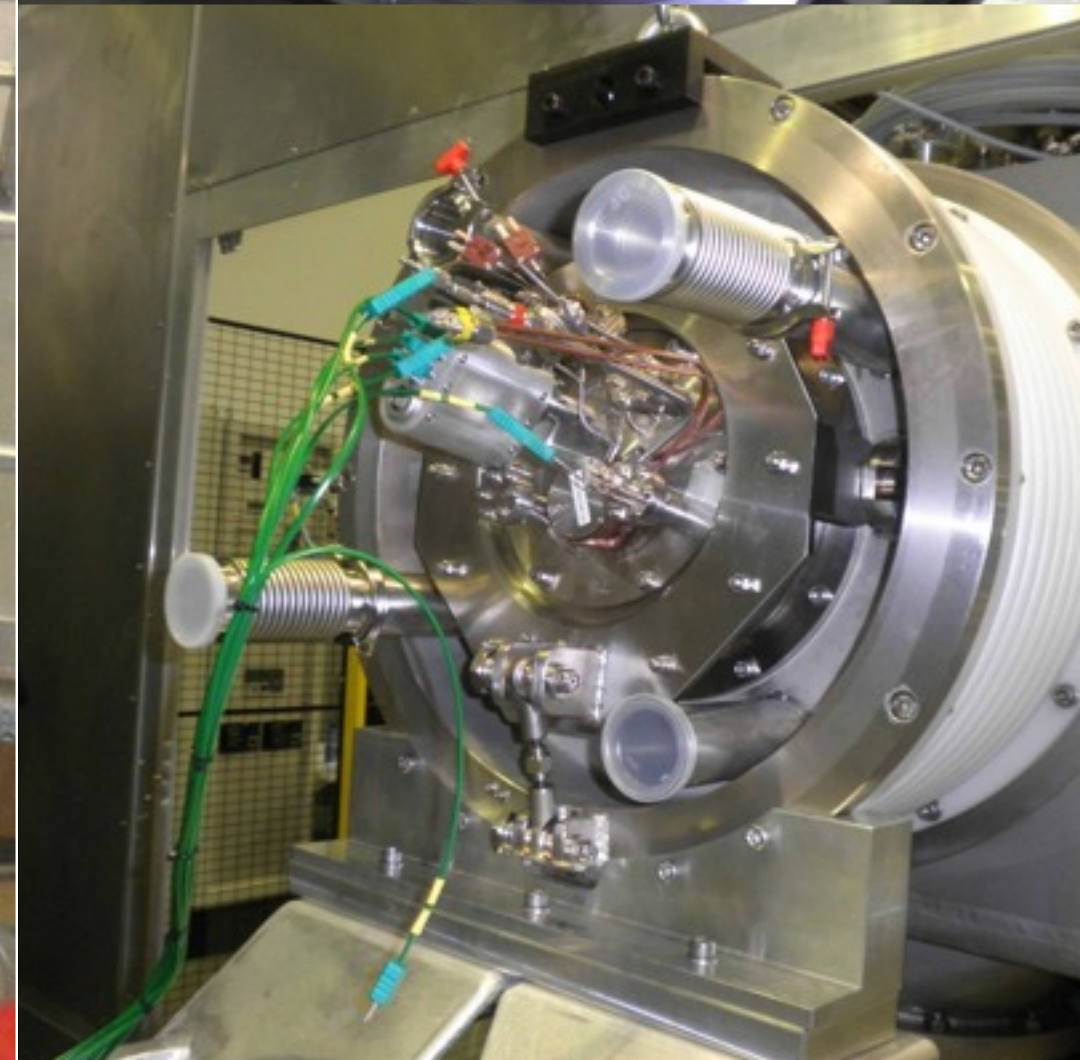
from 30 June 2010 to 02 July 2010 (Europe/Stockholm) *Grand Hotel*

ESS - Bilbao

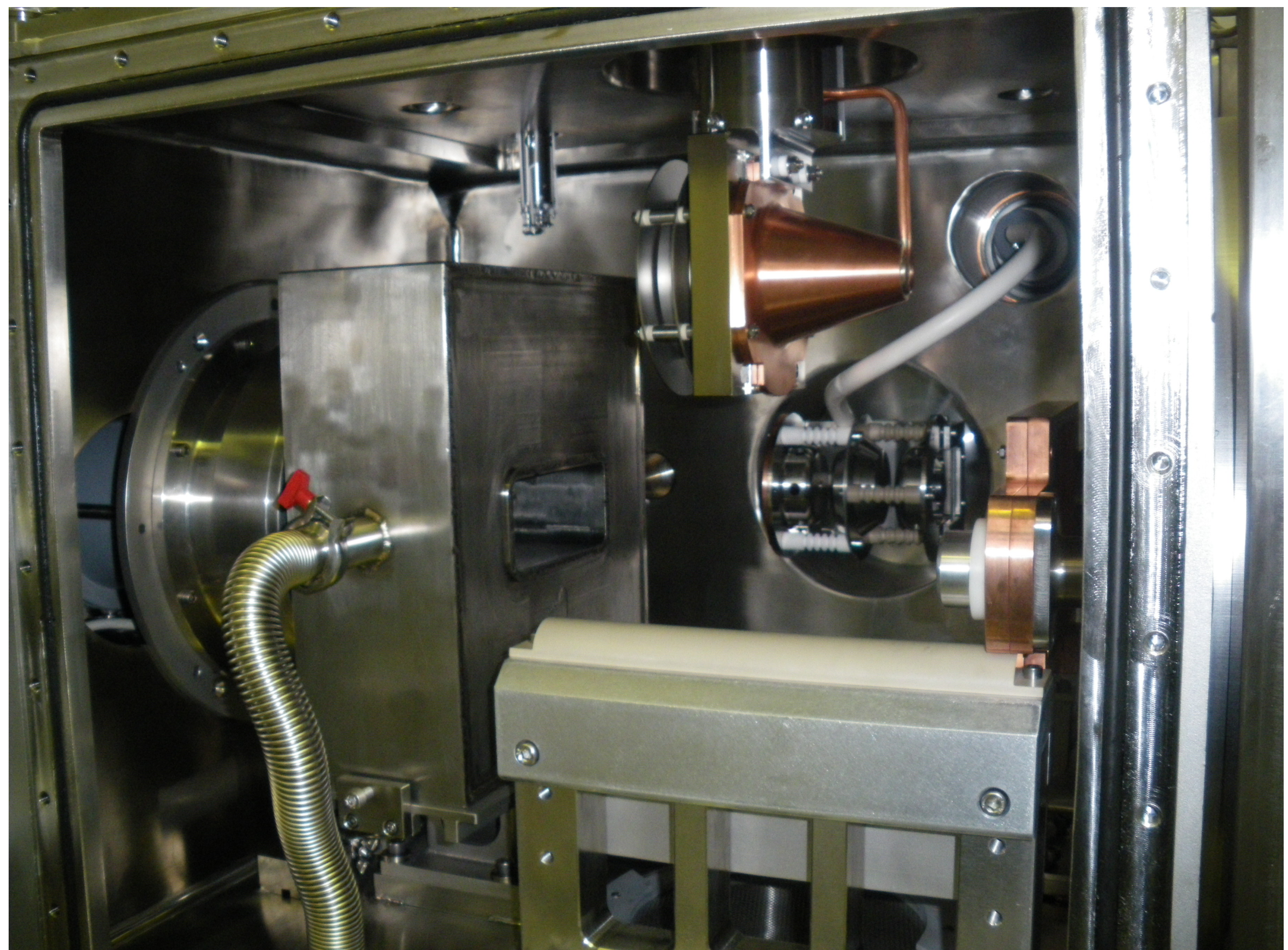
I. Bustinduy, D. Fernandez, D. de Cos, L. Usategui, P. Echebarria, A. Vizcaino, J. Muñoz, D. Cortazar, L. Mugira, S.Djekic, J. Feucthwanger, J. Fernandez, N. Garmendia, H. Hassanzadega, M. Eguiraun, I. Arredondo, J. Jugo, G. Harper, et al.

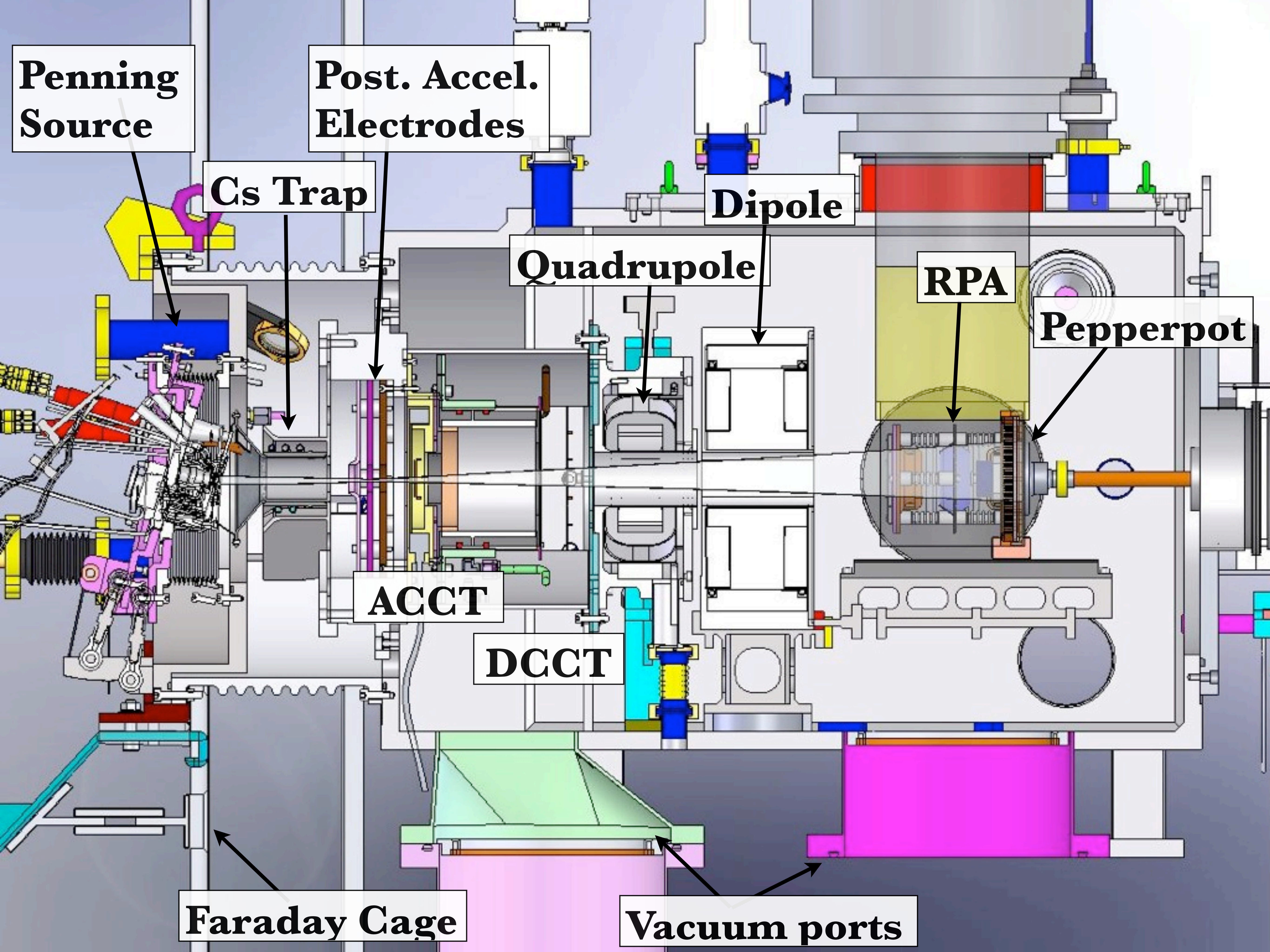
H^- Source



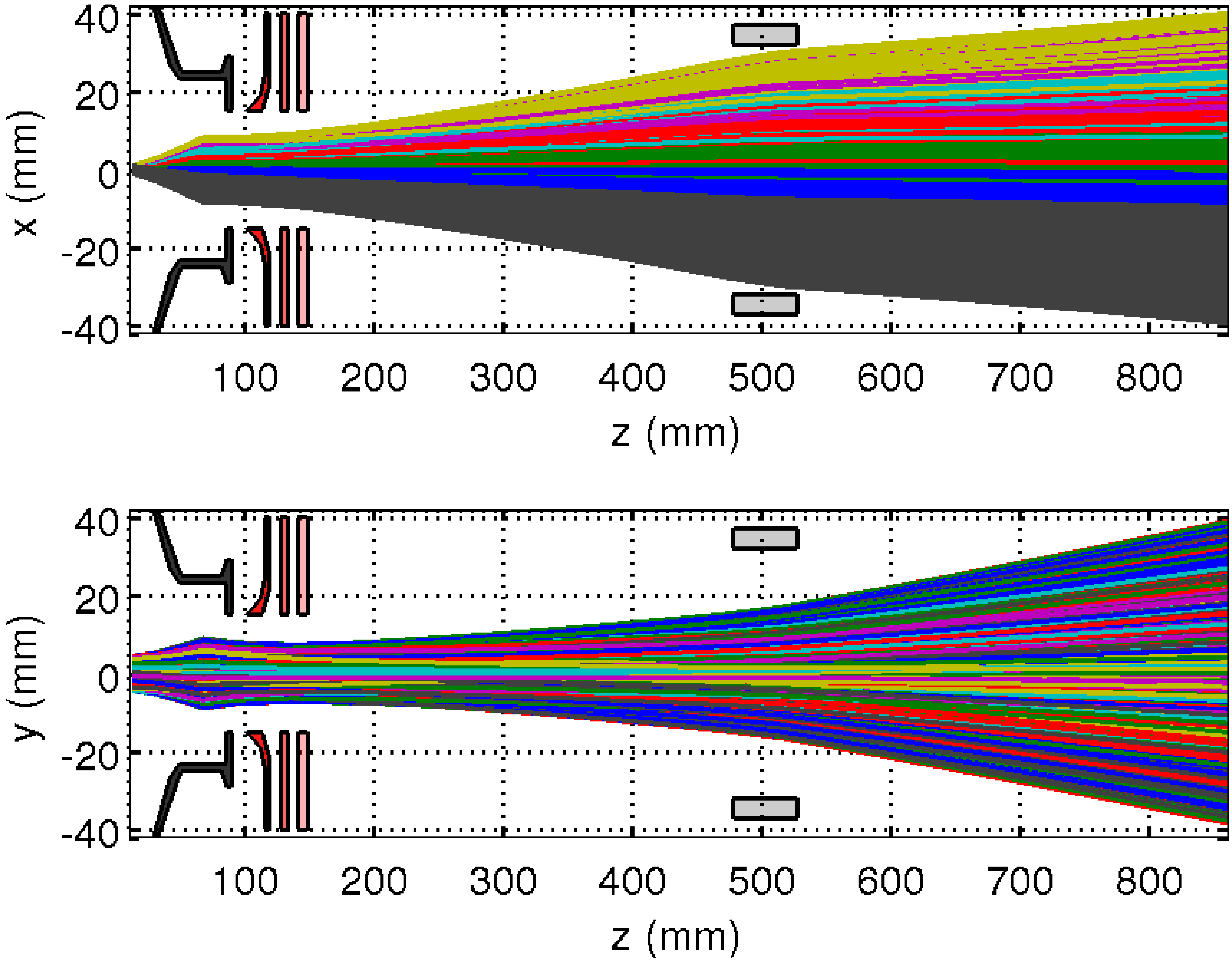





43W5



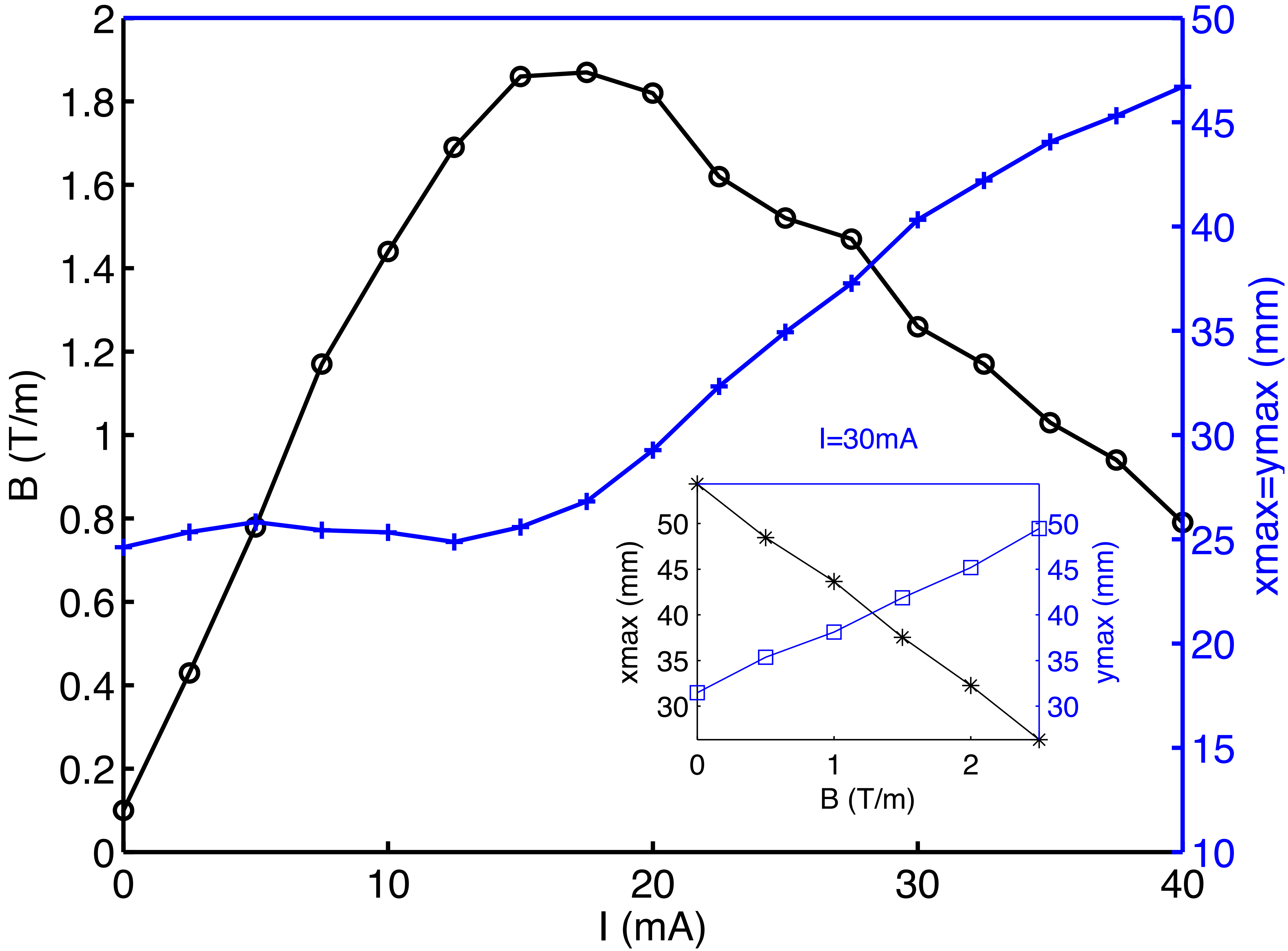


Penning Source
Post. Accel. Electrodes
Cs Trap
Dipole
Quadrupole
RPA
Pepperpot
ACCT
DCCT
Faraday Cage
Vacuum ports

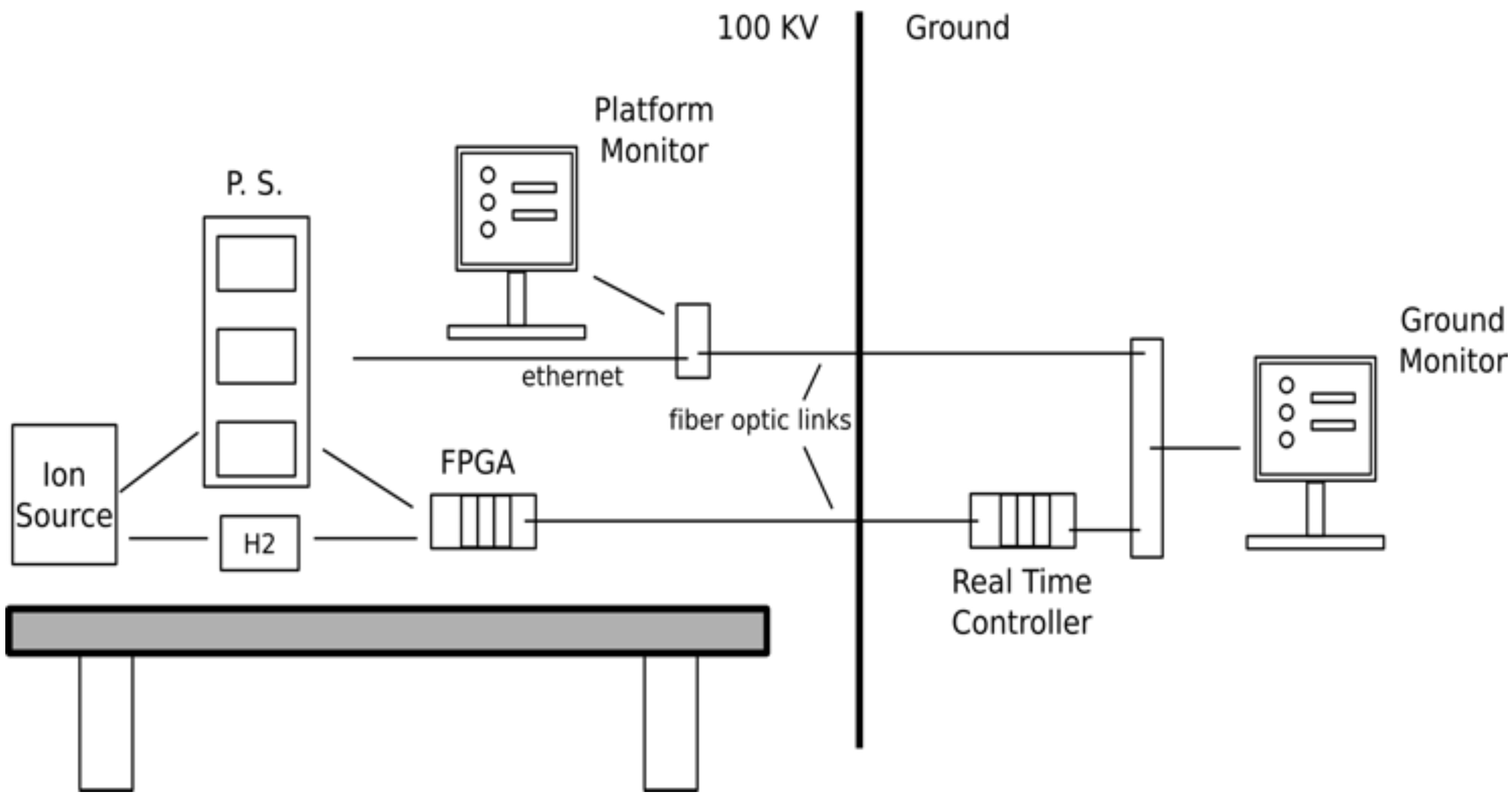


x (mm)
40
20
0
-20
-40
100
200
300
400
500
600
700
800
z (mm)
y (mm)
40
20
0
-20
-40
100
200
300
400
500
600
700
800
z (mm)

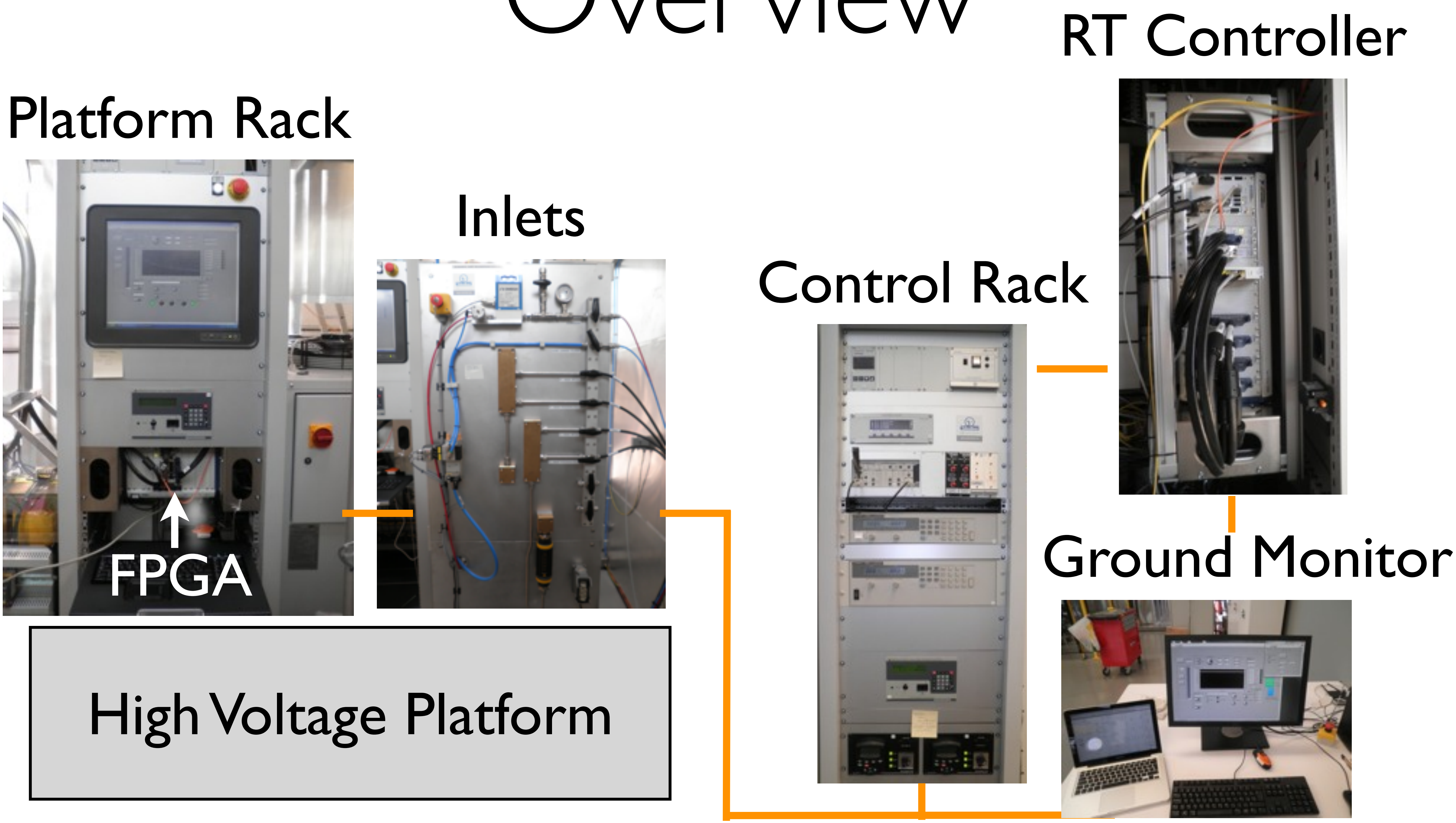
Optimum Quad Effect



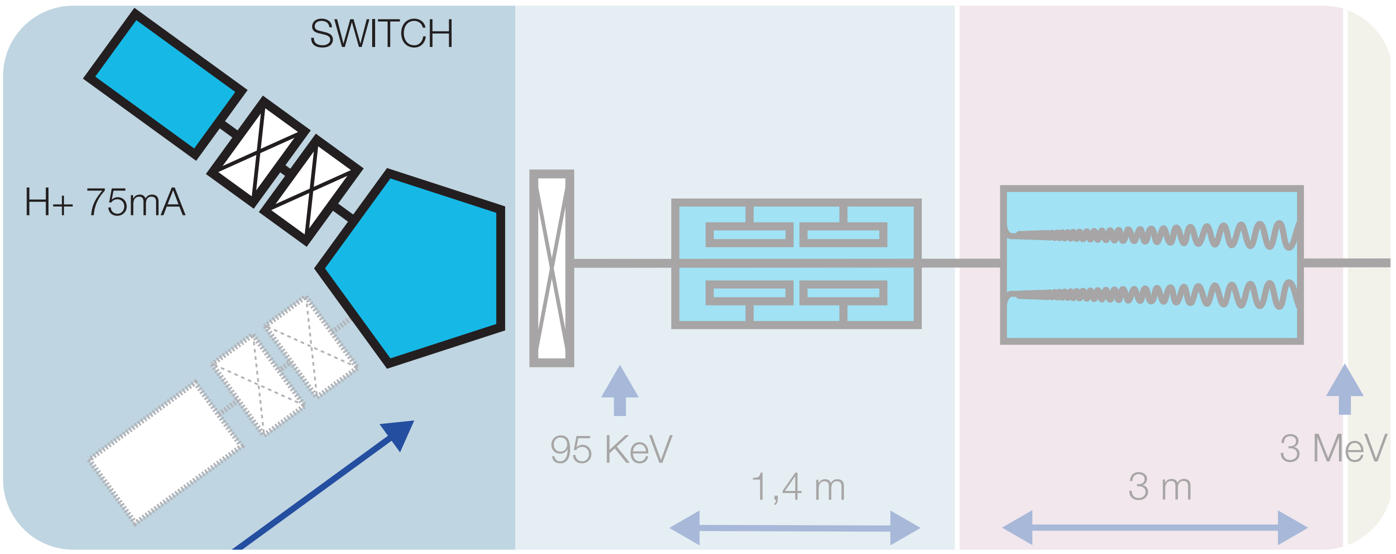
Control System: Overview



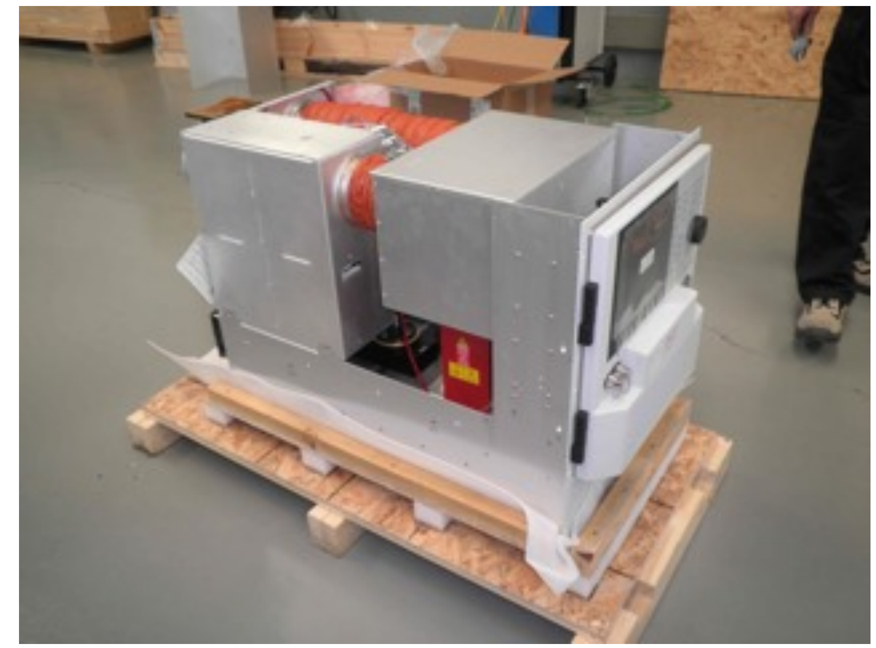
Control System: Overview



H^+ Source



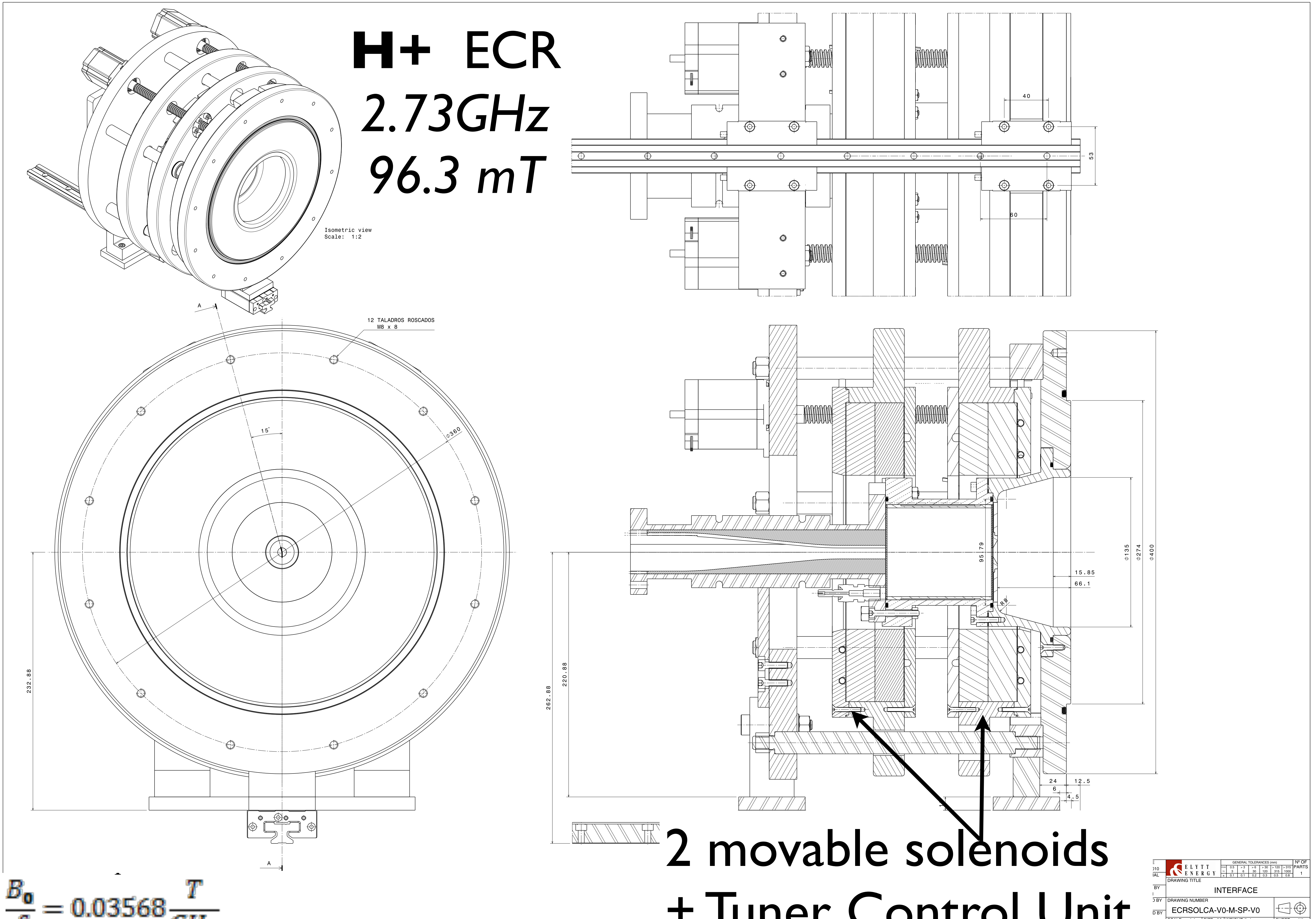
CPI S-Band CKPA
2.73GHz klystron
2.45HHz Magnetron is on its way.



H+ ECR

2.73GHz

96.3 mT

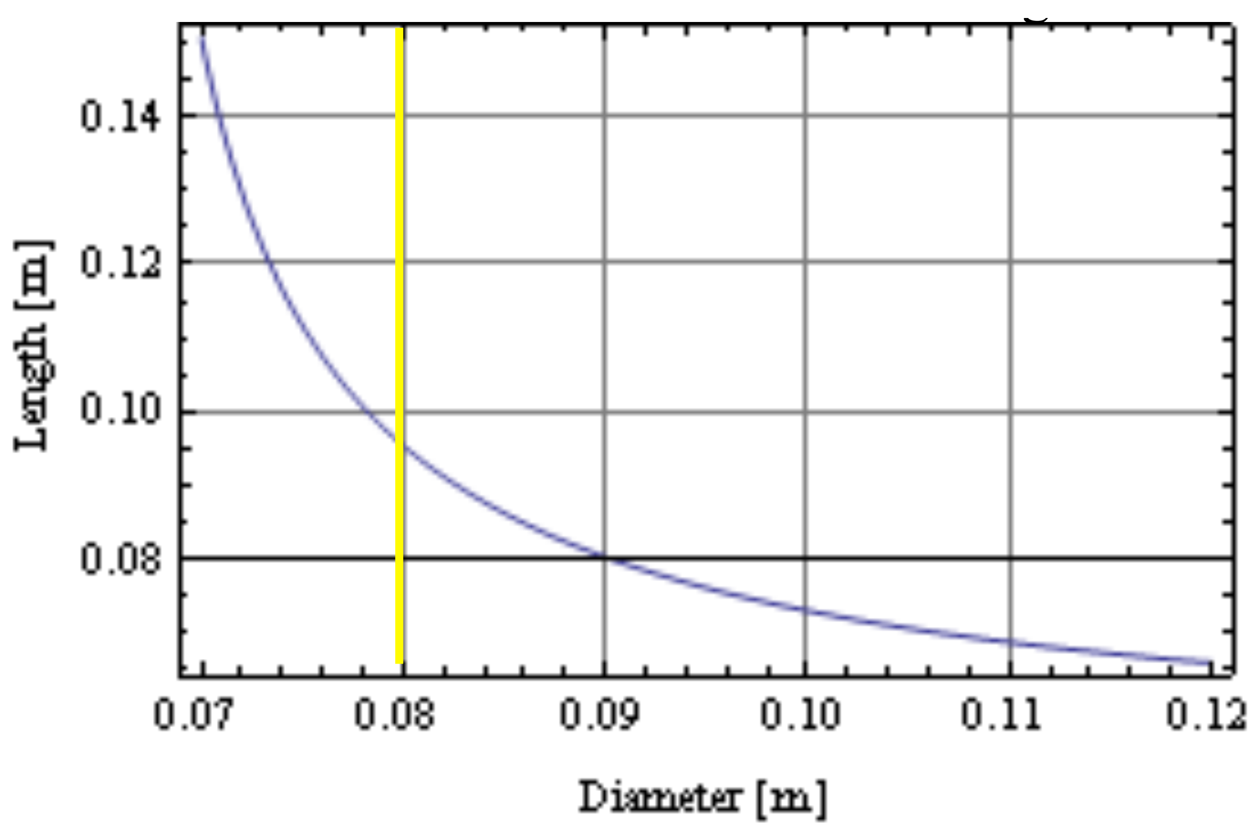


2 movable solenoids

+ Tuner Control Unit

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

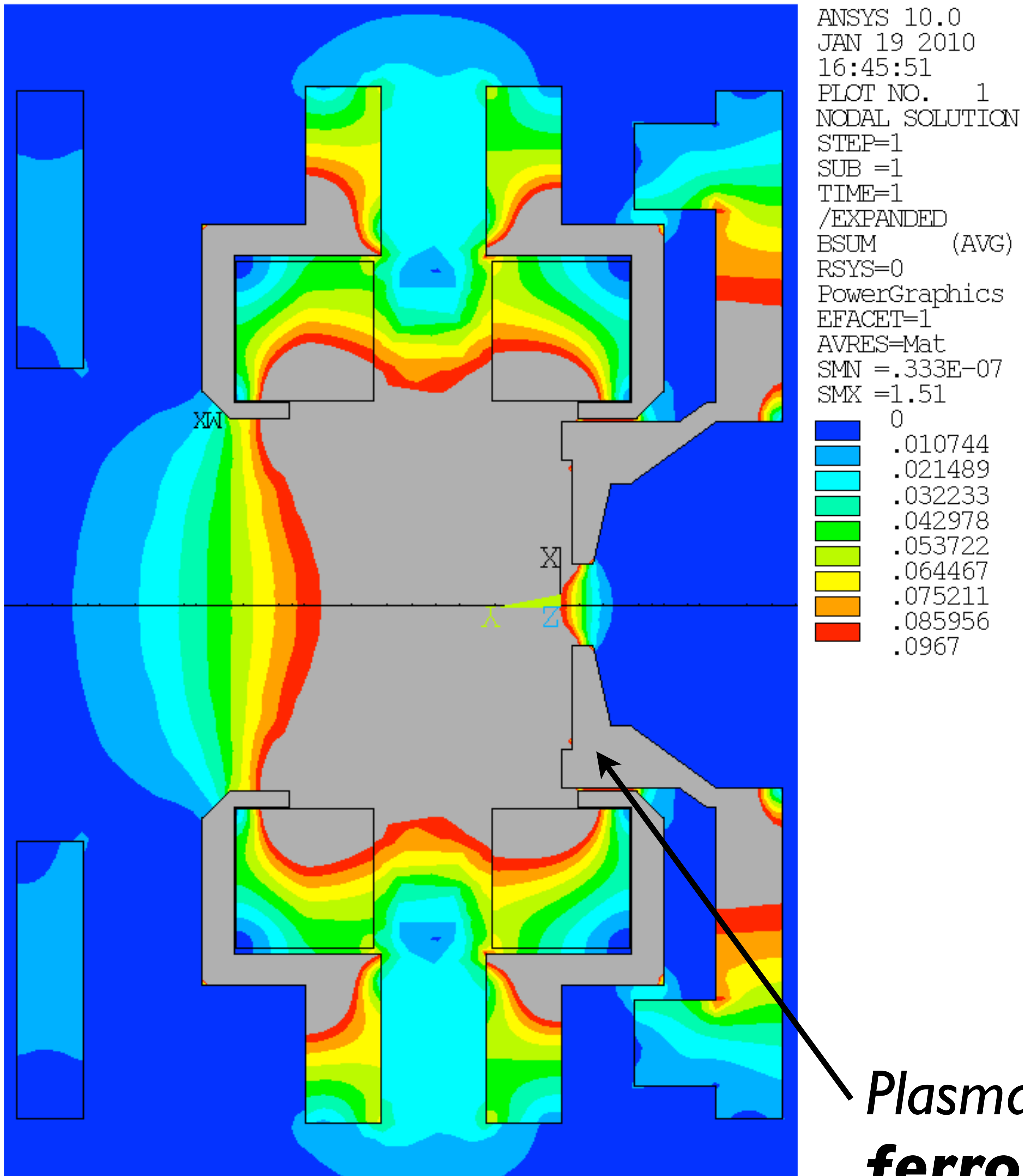
Plasma Chamber

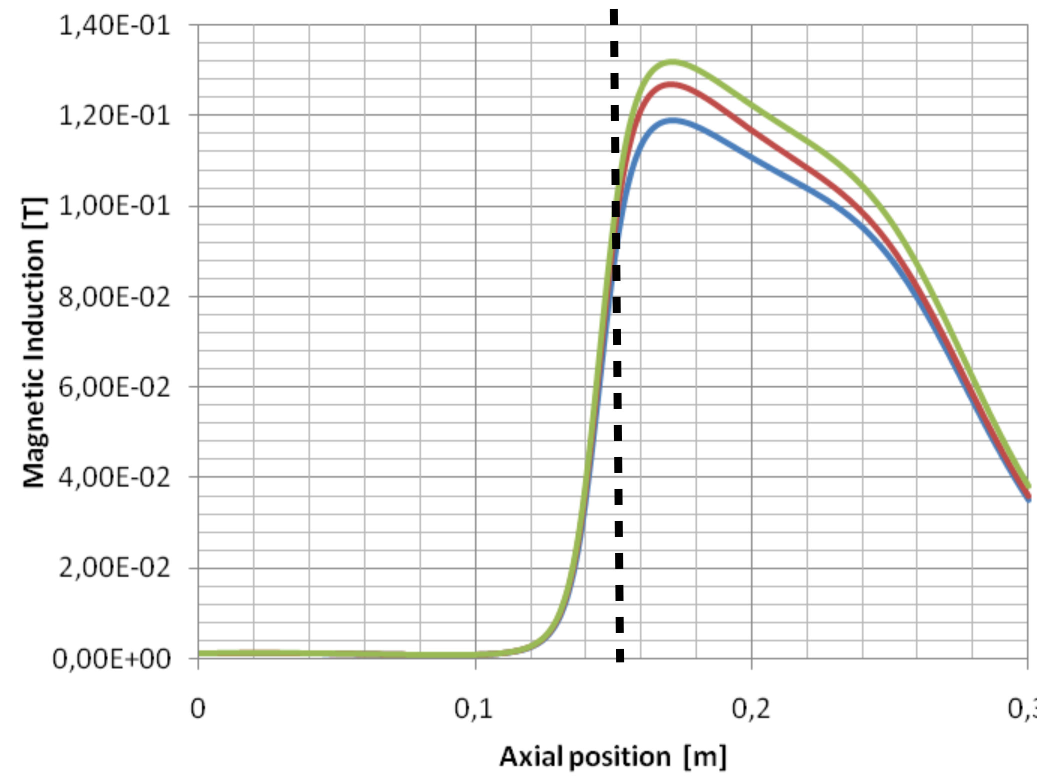


$$l = \frac{\pi}{\sqrt{\left(\frac{2\pi f}{c}\right)^2 - \left(\frac{3.682}{d}\right)^2}}$$

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]





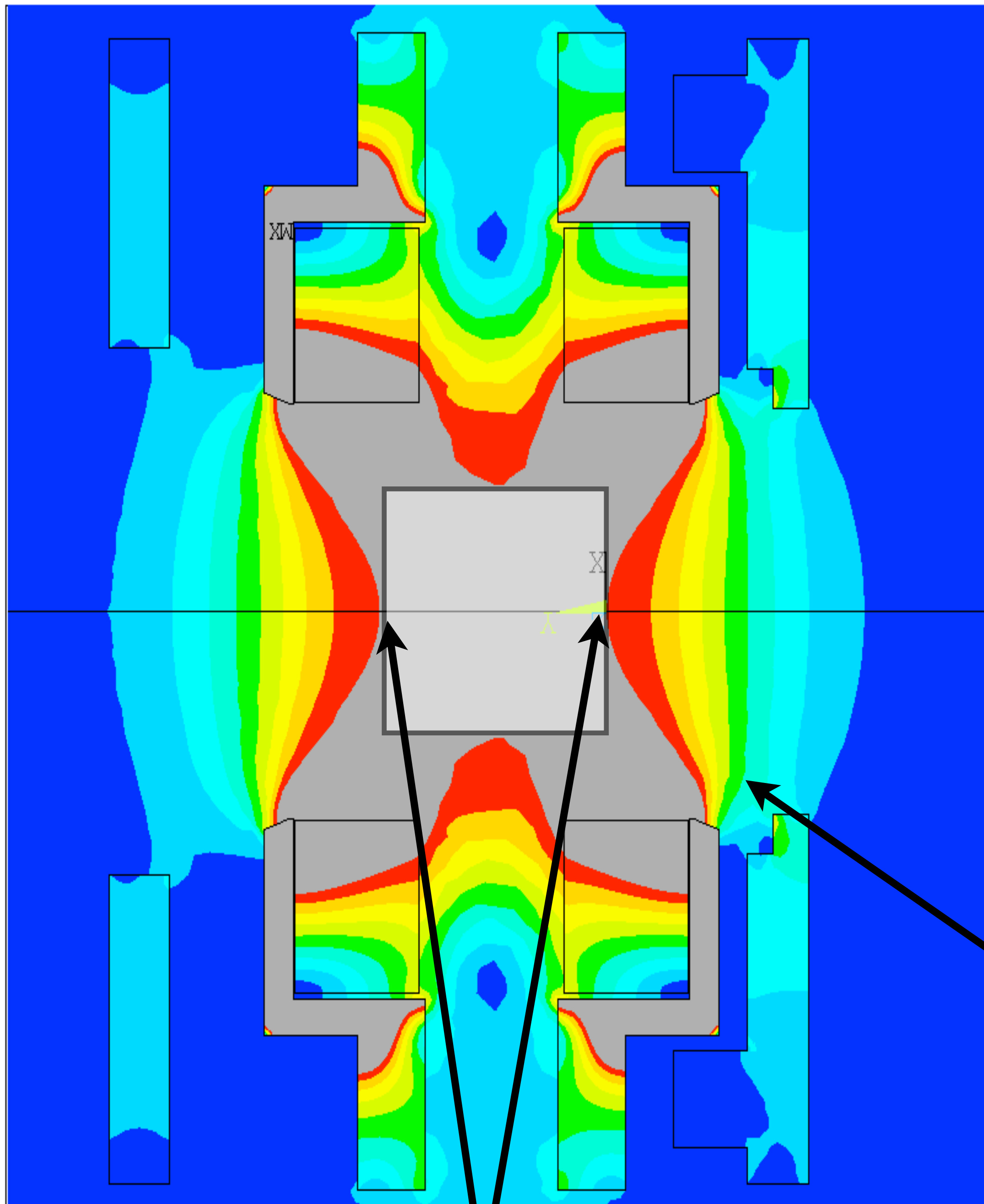
The grey region is above the ECR value.

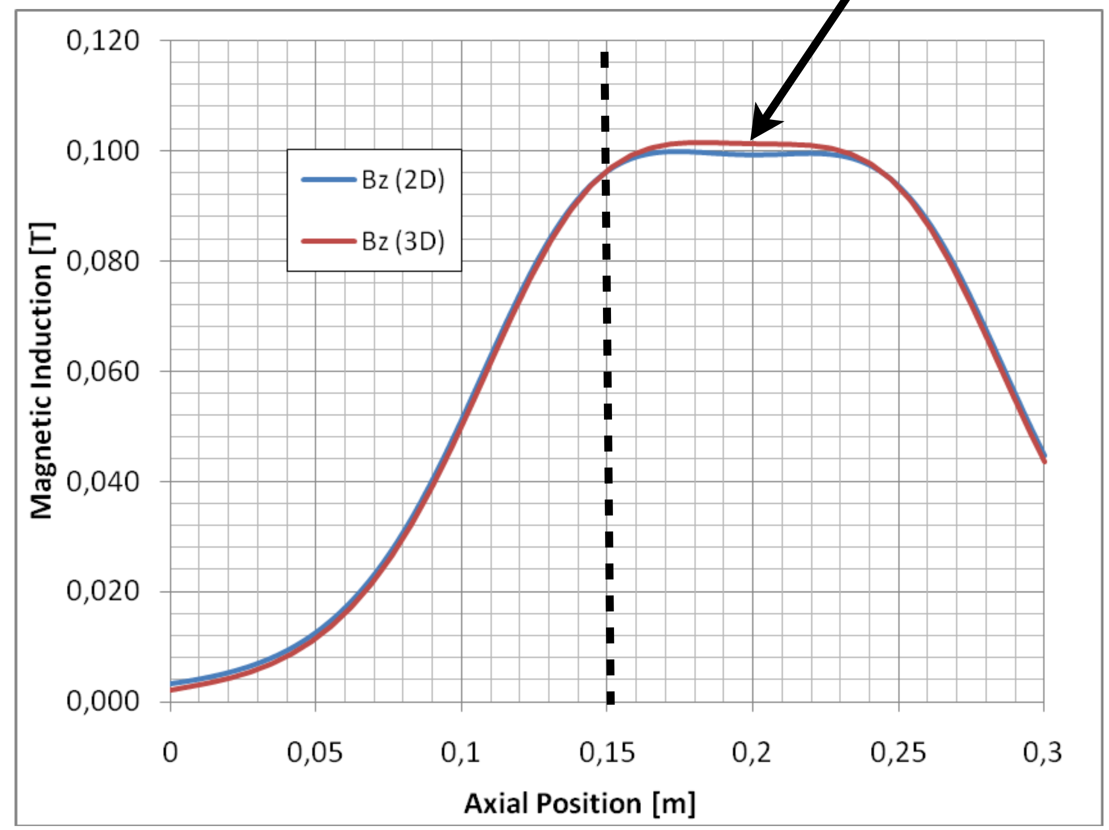
Extraction Region:

Minimize Magnetic Field

Plasma electrode in ***ferromagnetic material***

Very constant magnetic induction region in the plasma chamber





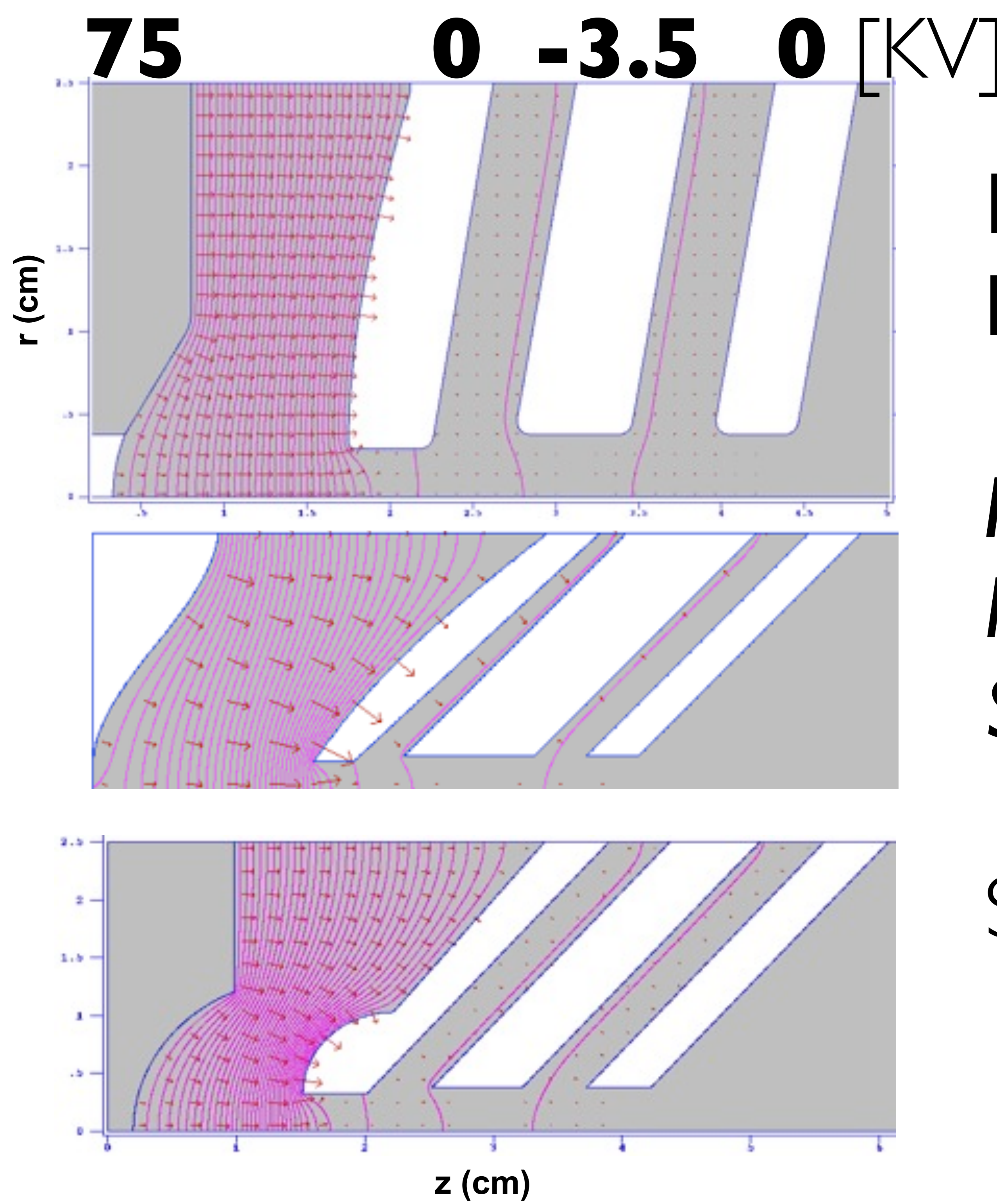
Both calculations are represented at a different magnetomotive force but at ECR field at 150 mm.

BN *disks*

To enhance the production of electrons

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

Extraction System



Different Geometries

Based on LEDA tetrode

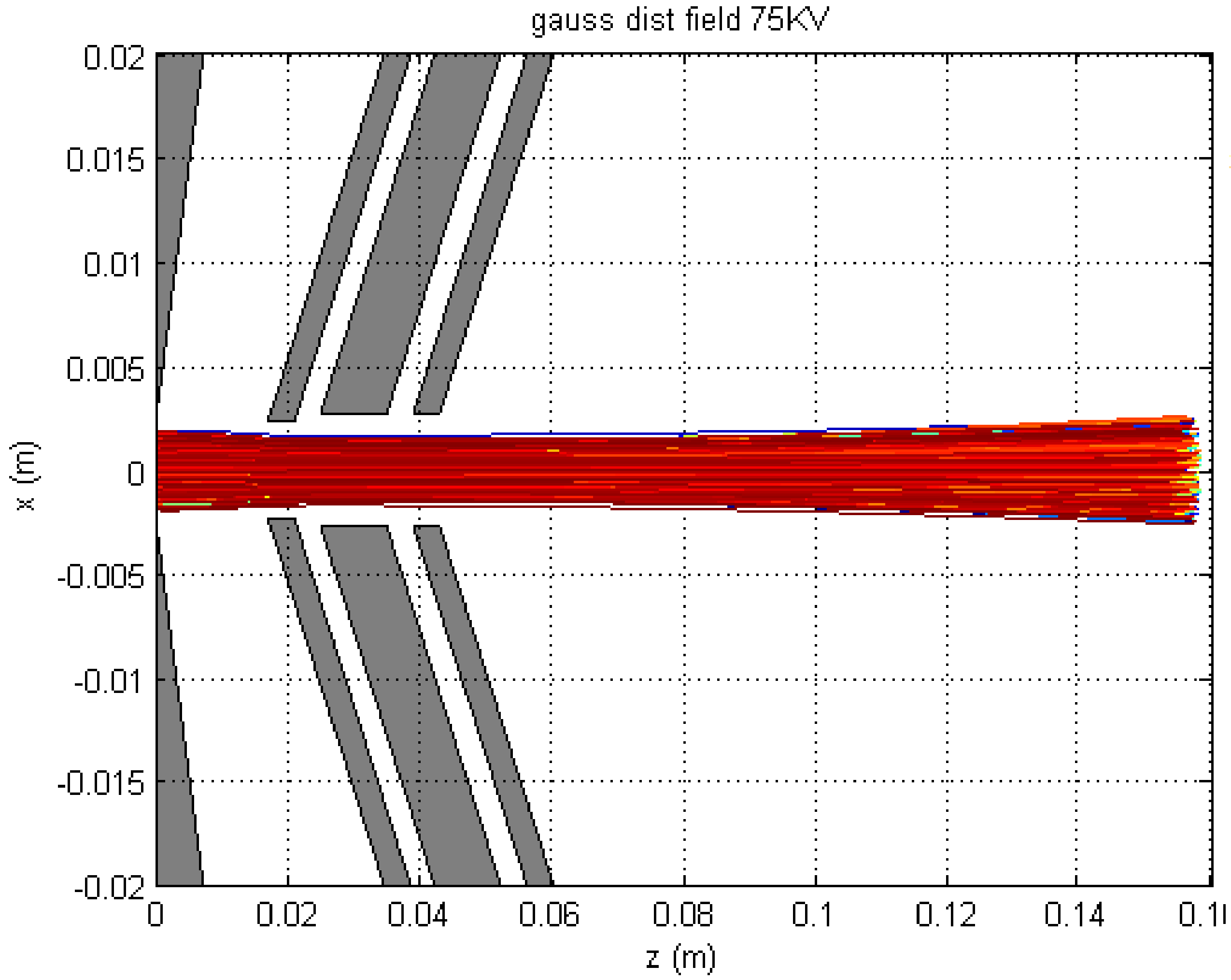
Pierce

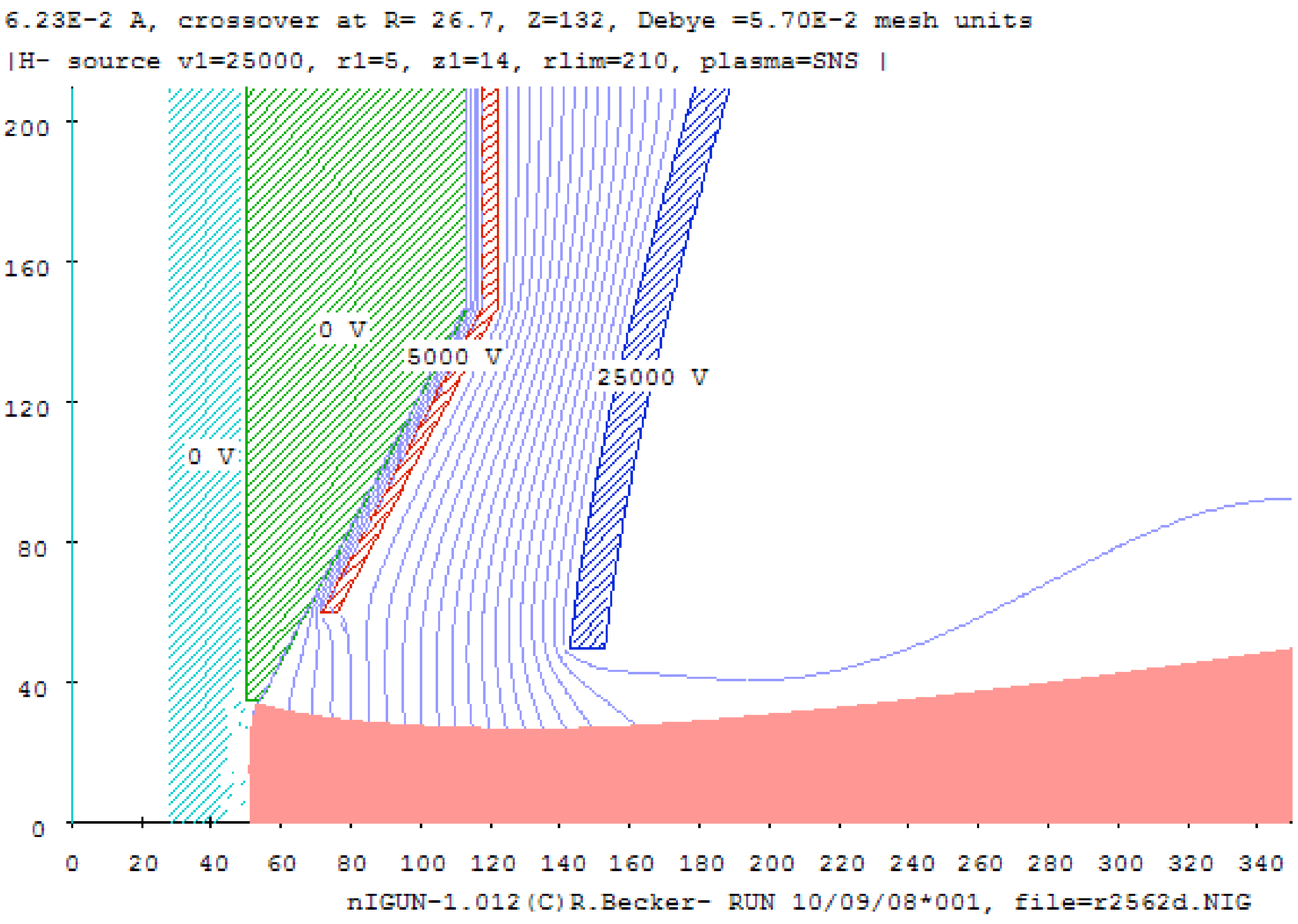
Non-Pierce

Spherical

Superfish & Comsol

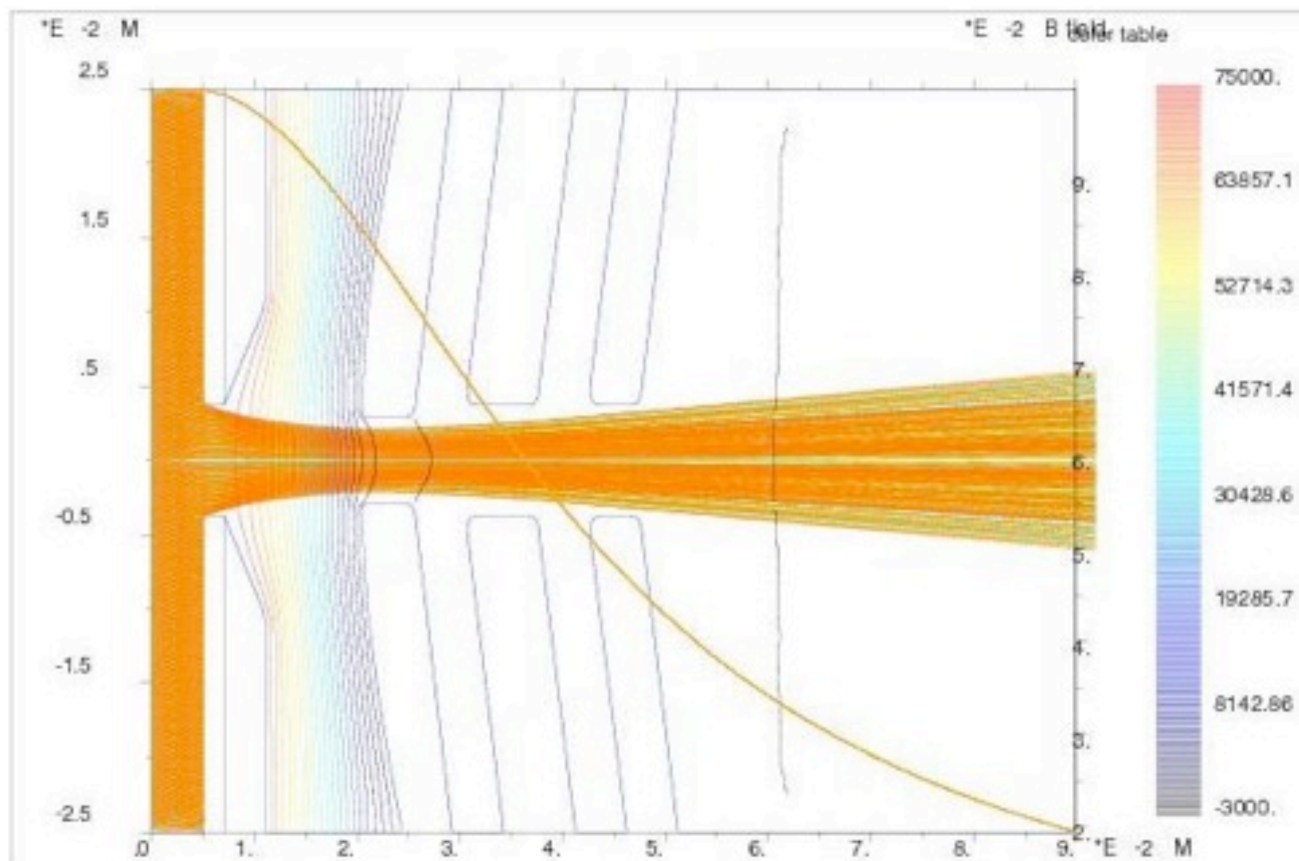
and **Particle Tracking**





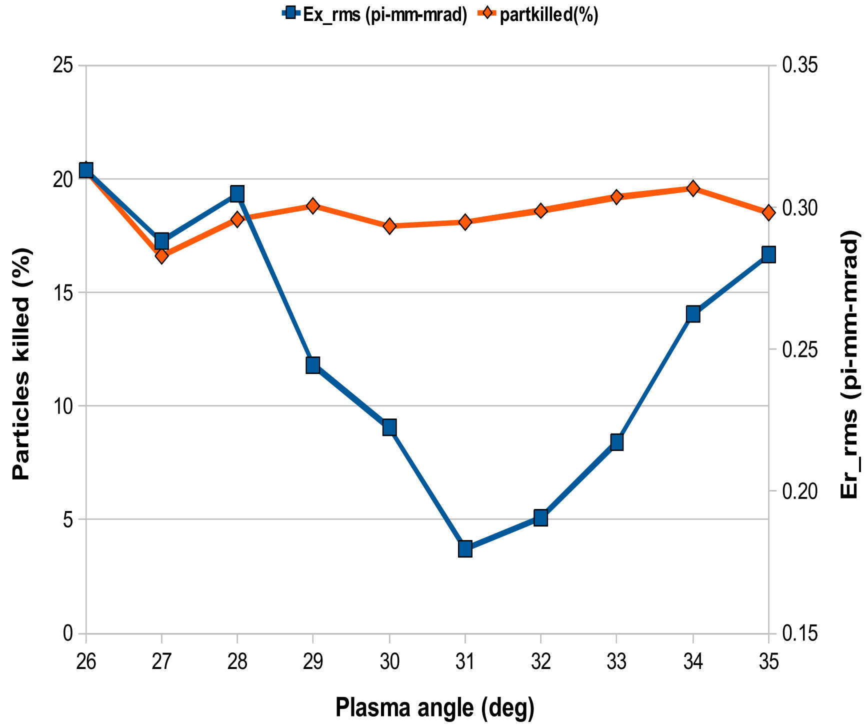
GPT & IGUN

and **Particle Tracking**

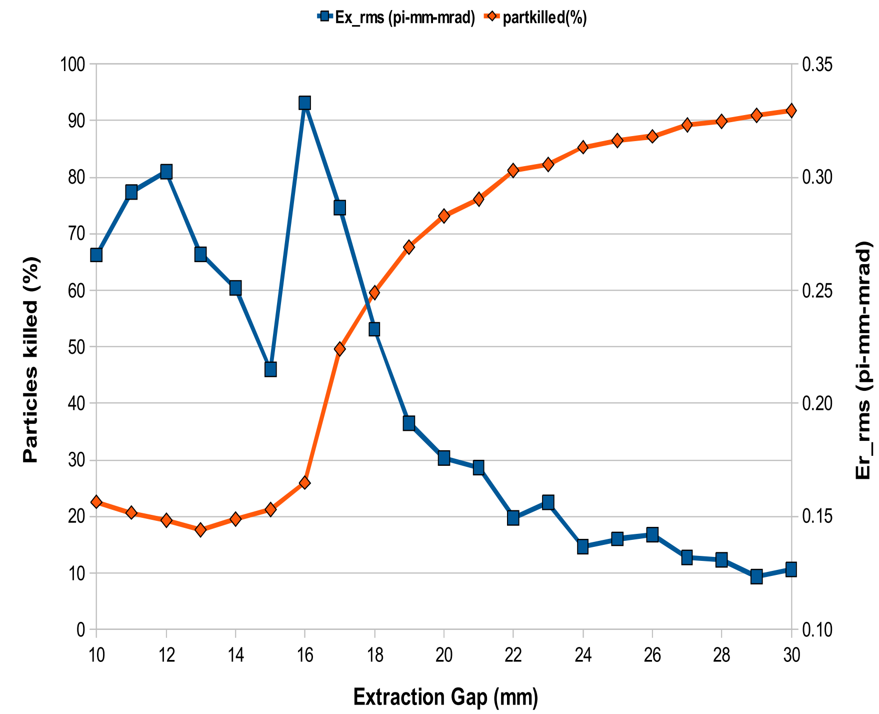


AXCEL

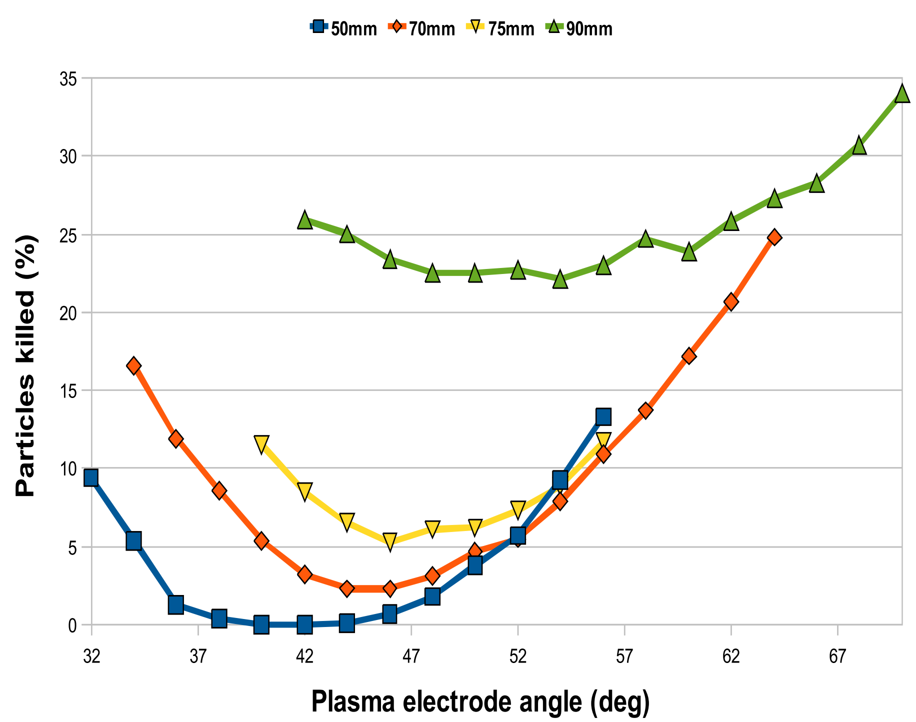
Optimization



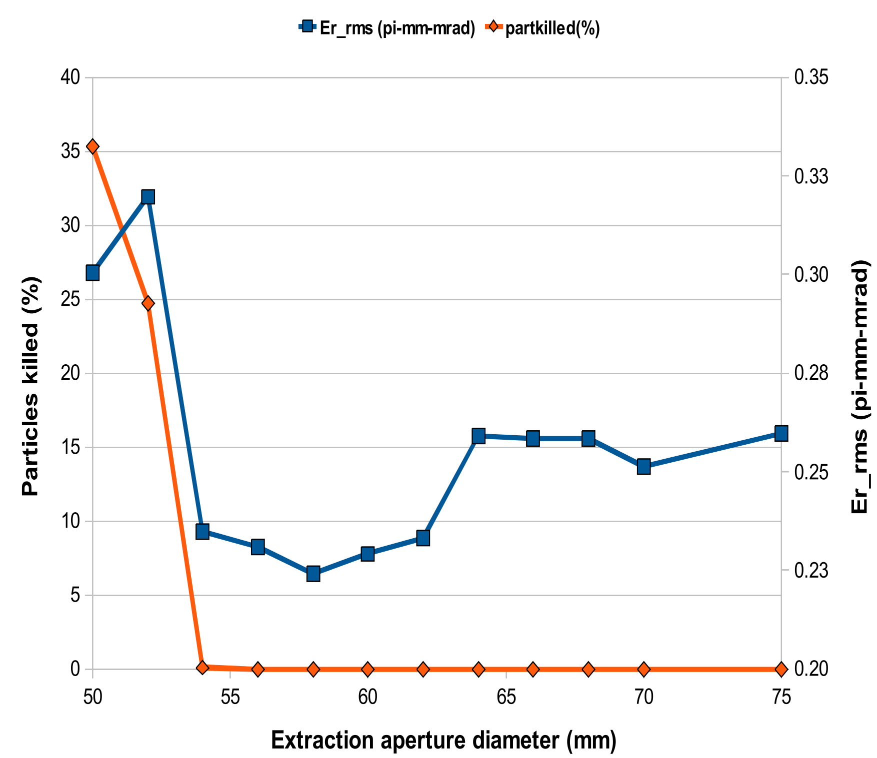
Optimization of the plasma electrode angle



Optimization of the extraction or accelerating gap



Optimization of the extraction of plasma electrode



Optimization of the extraction electrode aperture

Extraction Aperture

Aperture Diameters	Case 1	Case 2	Case 3
Plasma electrode(mm)	7.5	7.5	7.5
Extraction electrode(mm)	5.0	7.5	5.0
Repeller electrode(mm)	5.0	7.5	7.5
Ground electrode(mm)	5.0	7.5	7.5

Table 1. Three analyzed cases for the tetrode system design and their electrode aperture diameters.

- **Beam physics parameters: rms emittances and percentage of lost particles**

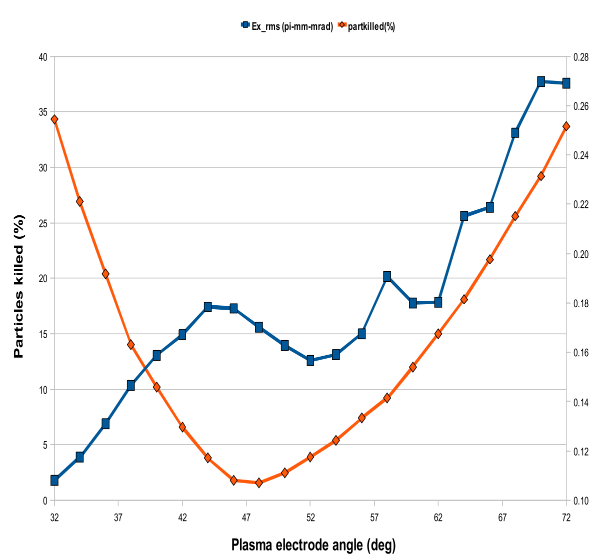


Figure 6. **__Case1:__** Percentage of lost macroparticles and rms emittance versus plasma electrode angle for a 19mm extraction gap.

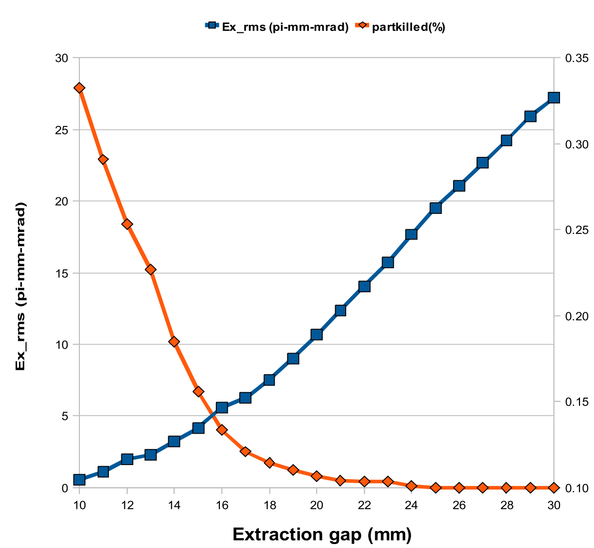


Figure 7. **__Case2:__** Percentage of lost macroparticles and rms emittance versus extraction gap for a 48deg plasma electrode angle.

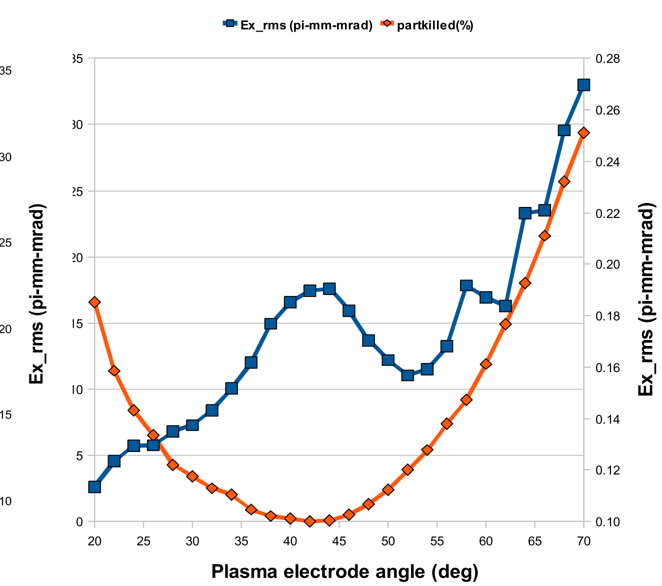


Figure 8. **__Case3:__** Percentage of lost macroparticles and rms emittance versus plasma electrode angle for a 19mm extraction gap.

Plasma Electrode

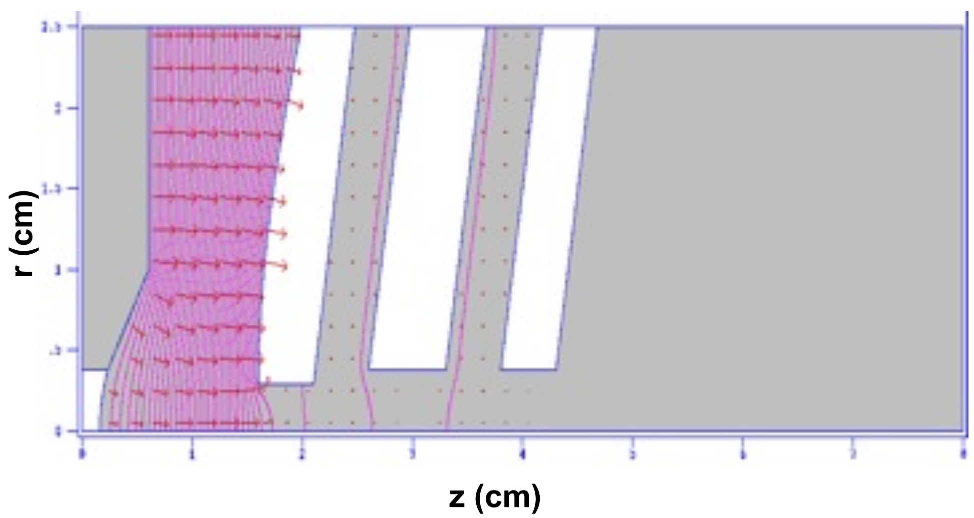


Figure 9. Poisson electrostatic solution and beam particle trajectories. Plasma aperture set at 75mm diameter. Extraction gap fixed. Plasma angle is then varied**.**

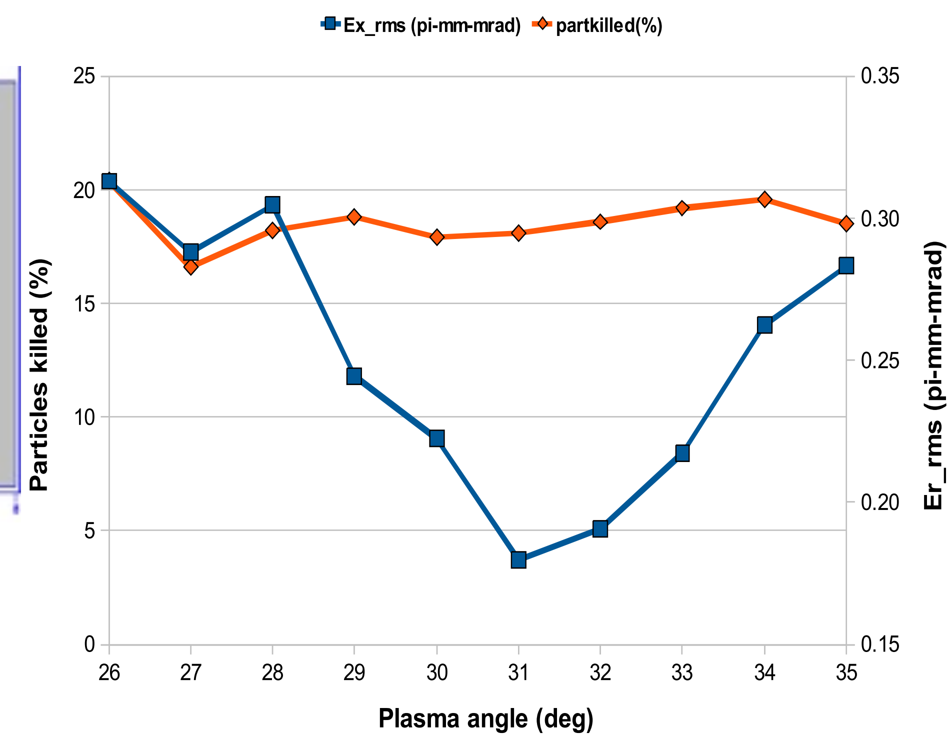


Figure 1. Beam transverse rms emittances and percentage of particles killed calculated at 600mm versus plasma electrode angle.

The optimum plasma electrode angle is 31deg!

Extraction Gap

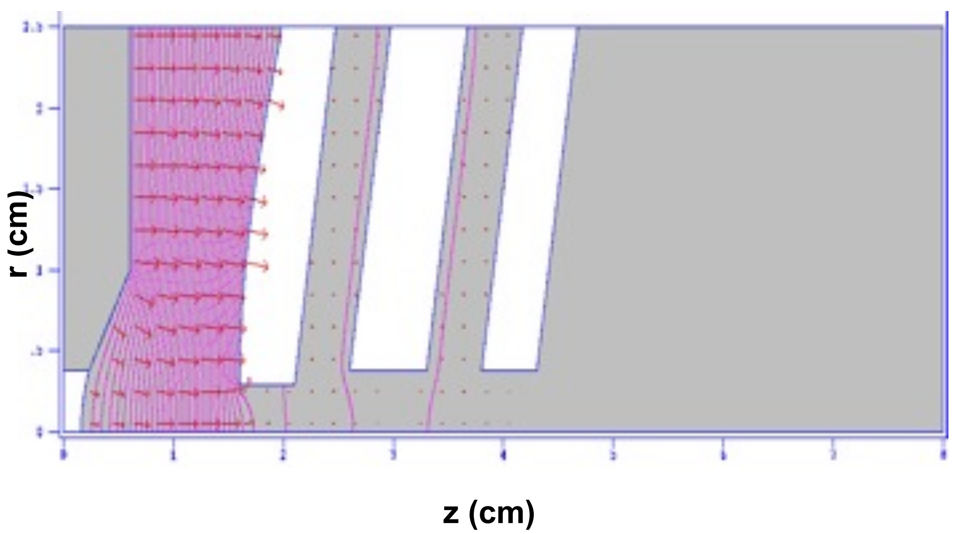


Figure 9. Poisson electrostatic solution. Plasma aperture set at 75mm. Plasma angle of **31º**. Extraction gap is then varied.
.

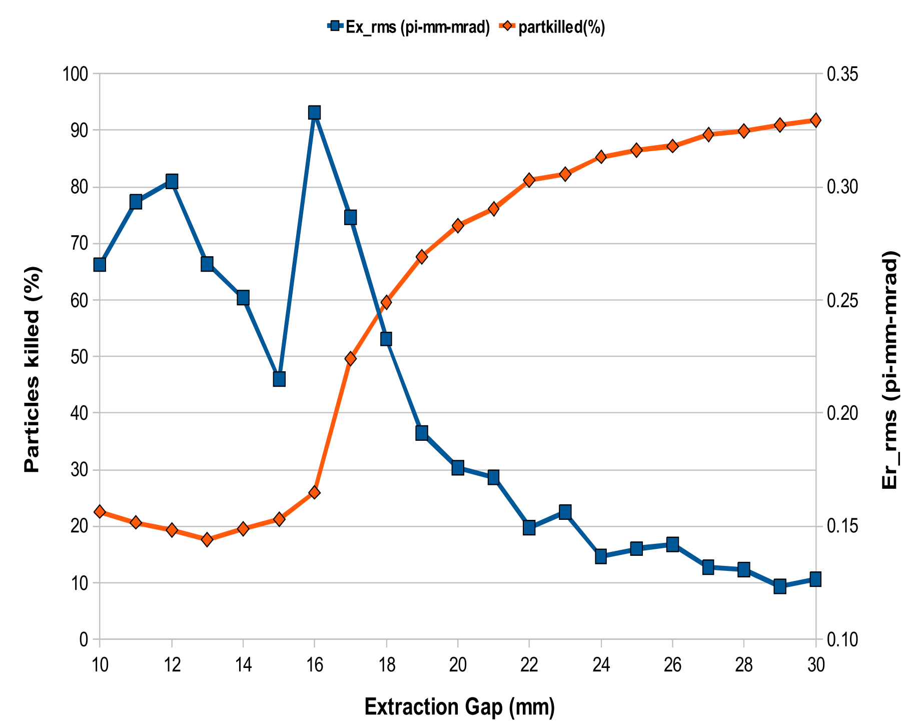


Figure 2. Beam transverse rms emittances and percentage of particles killed calculated at 600mm versus extraction gap.

The optimum plasma accelerating gap is 14mm!

Extraction Aperture

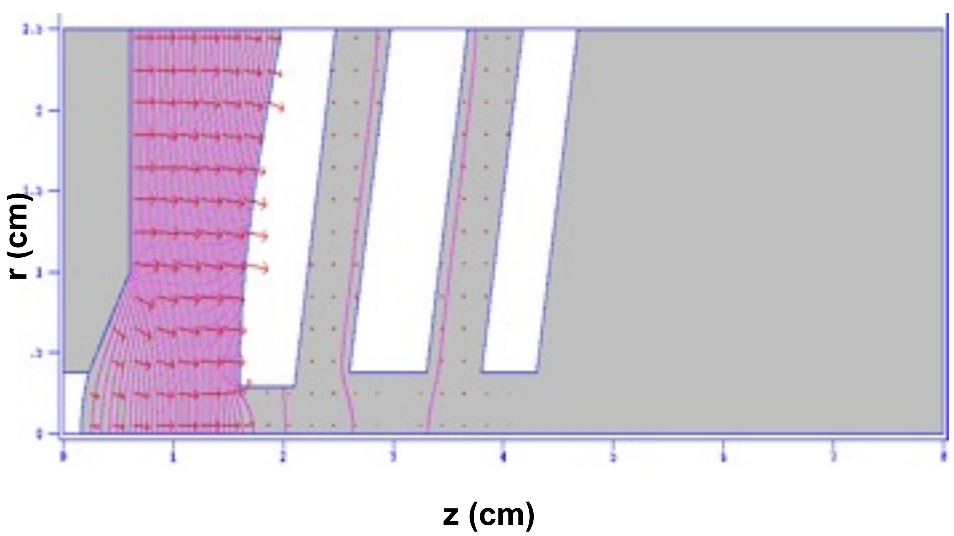


Figure 9. Poisson electrostatic solution. Plasma aperture set at 75mm. Plasma angle of **31º**. Extraction gap place at **14mm** and its diameter is then optimized.
.

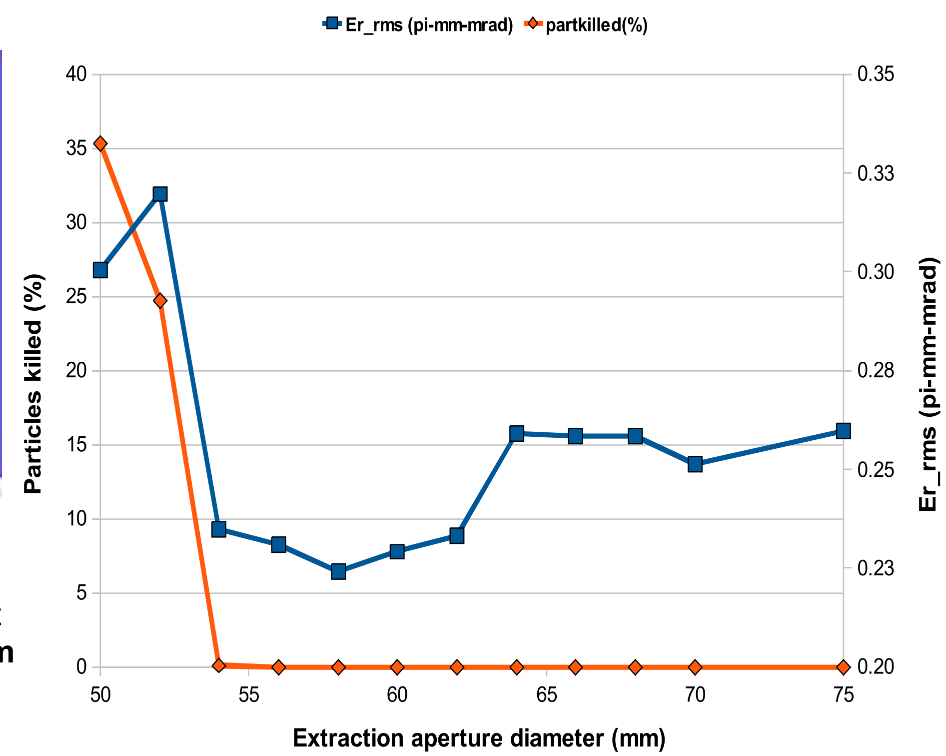
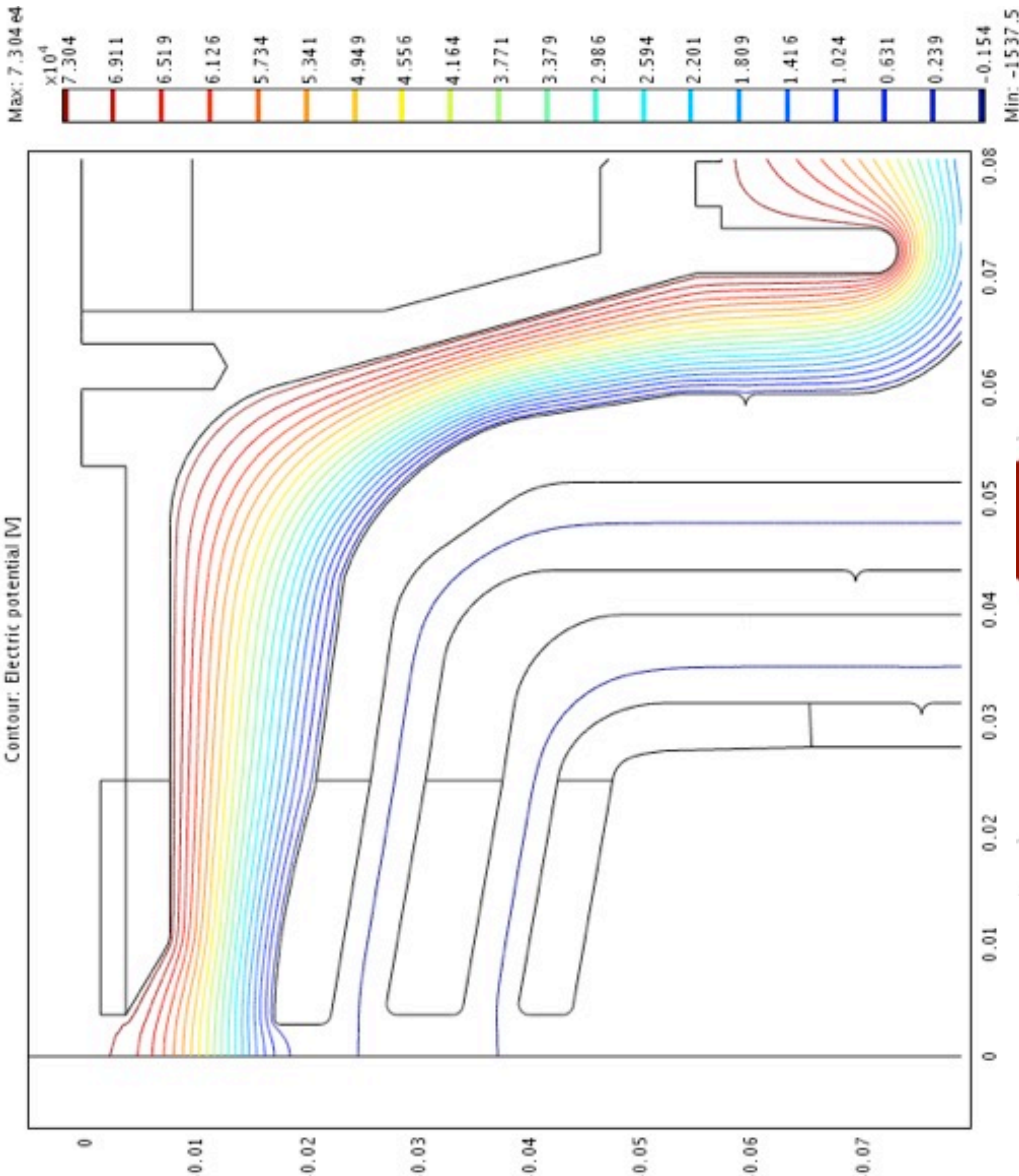
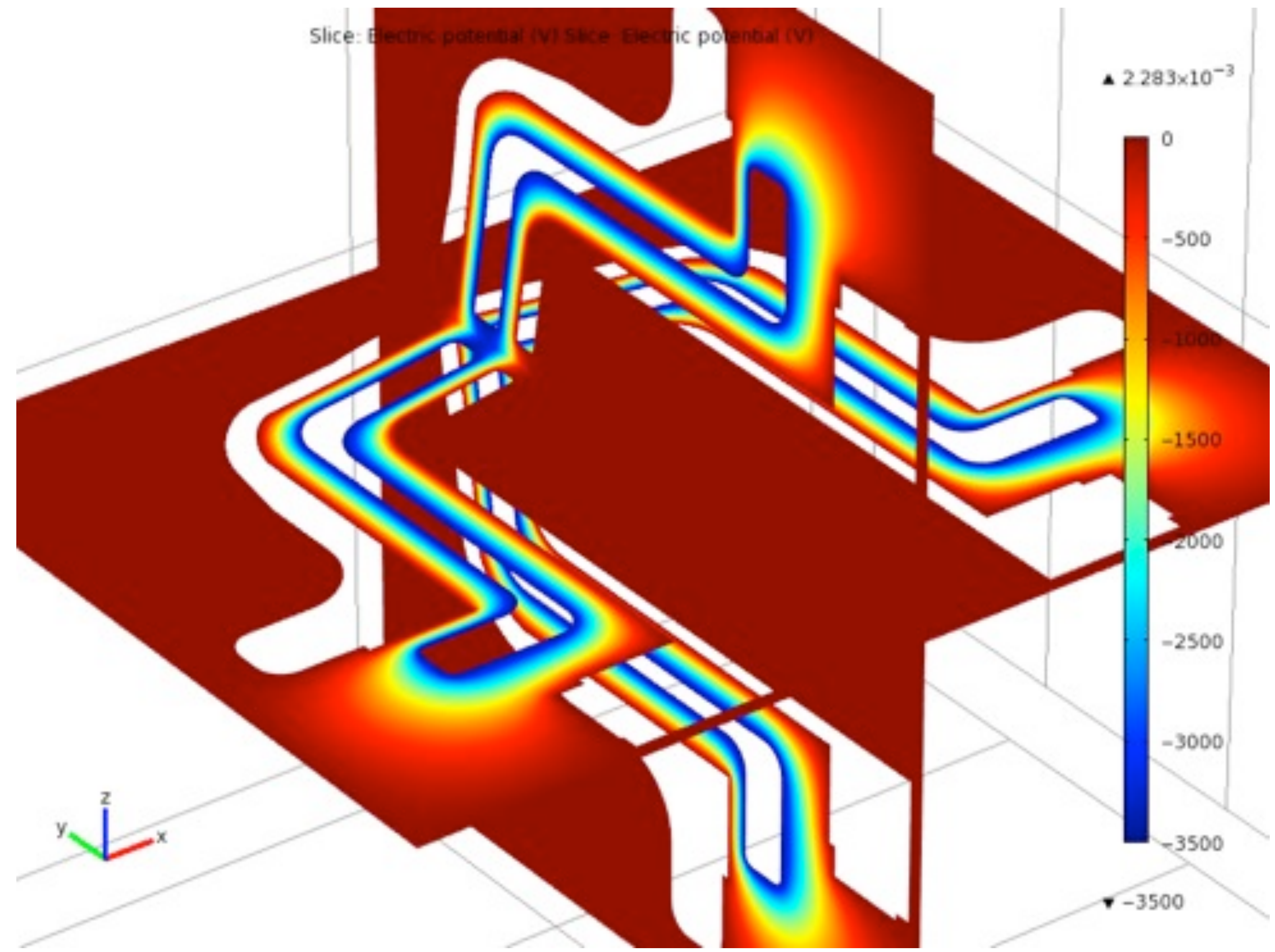


Figure 3. Beam transverse rms emittances and percentage of particles killed versus extraction electrode aperture diameter calculated at 530mm.

The optimum extraction electrode aperture is 5.8mm diameter!

Extraction System



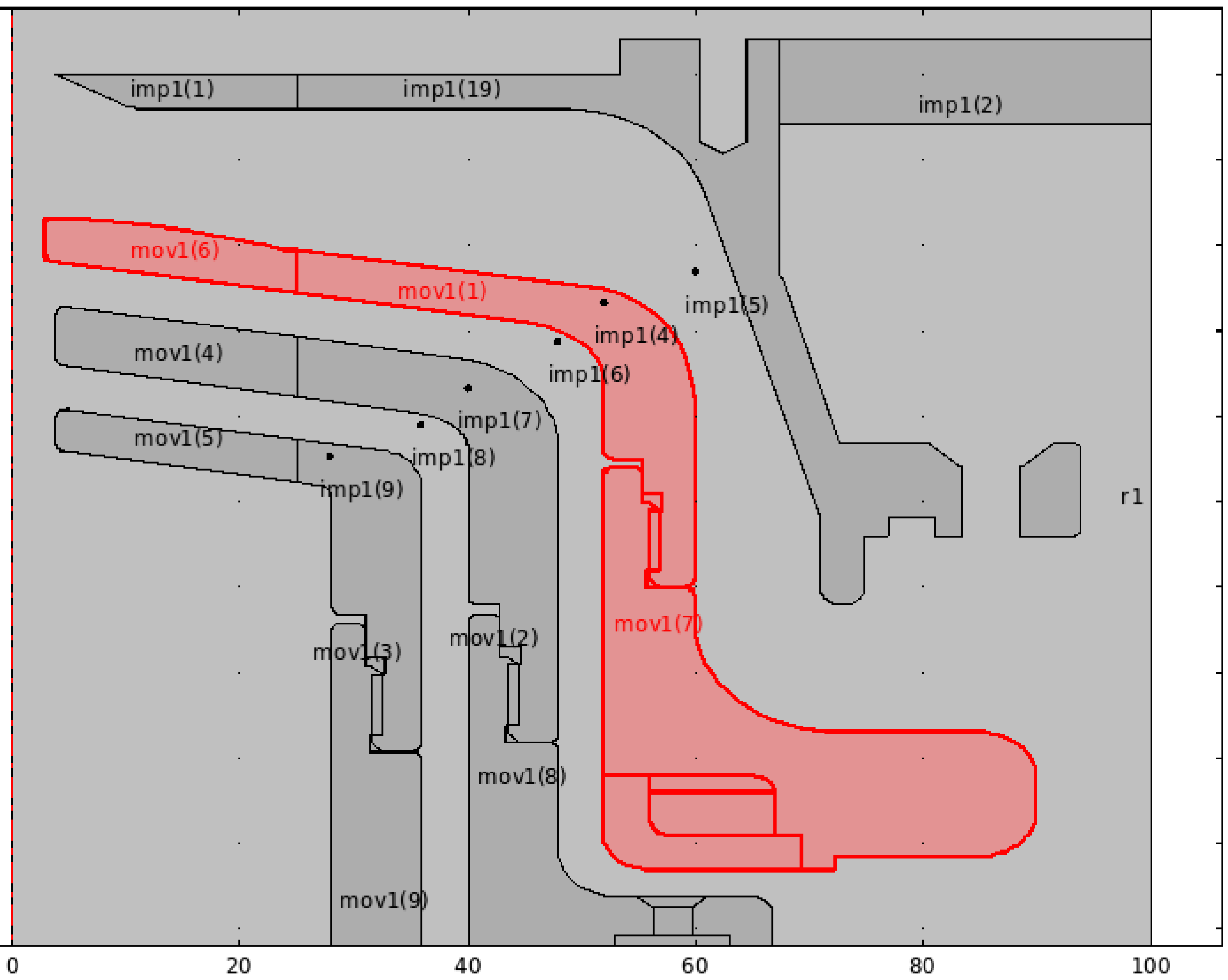


High Voltage Breakdown

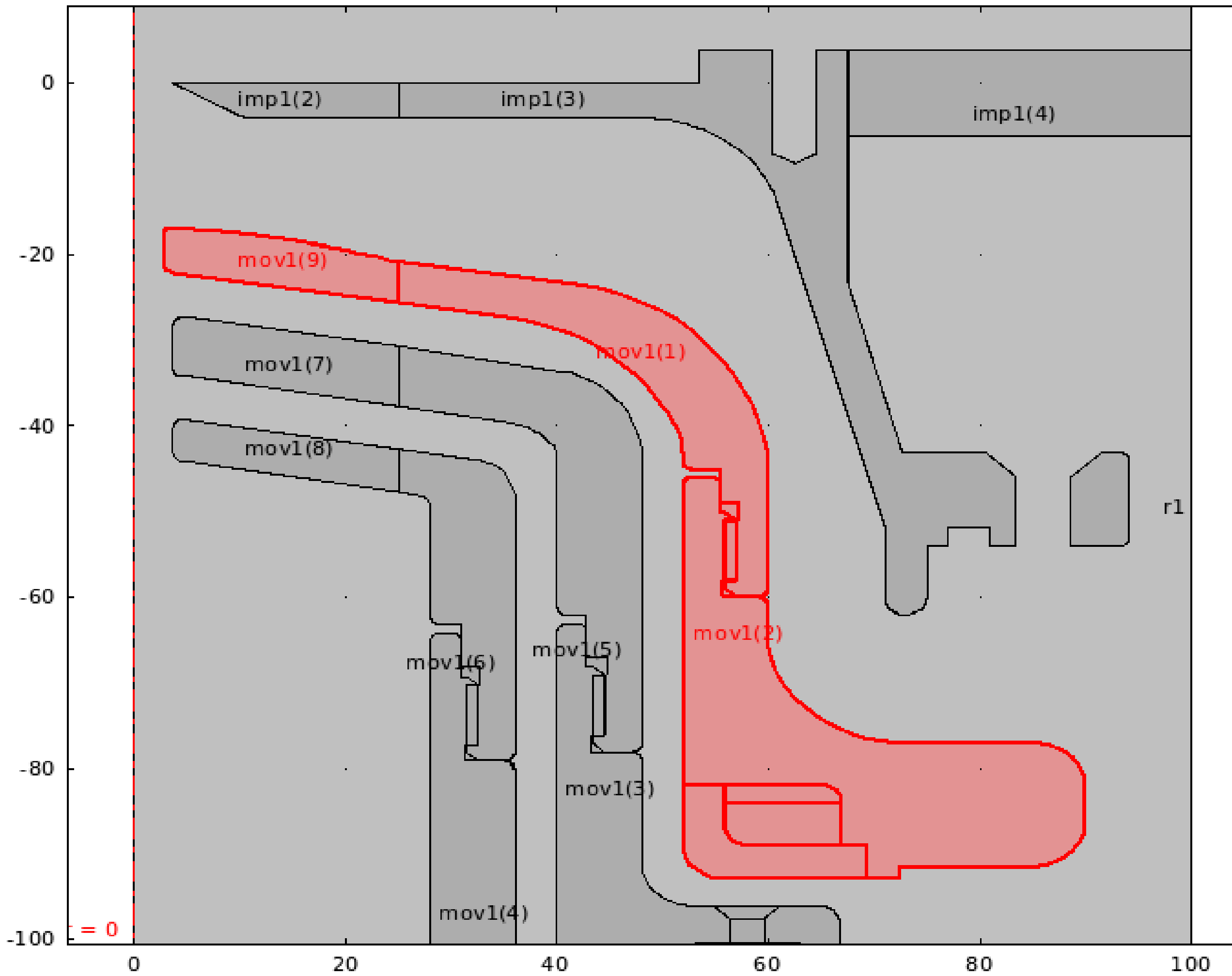
Electric field<100kV/cm

Extraction System

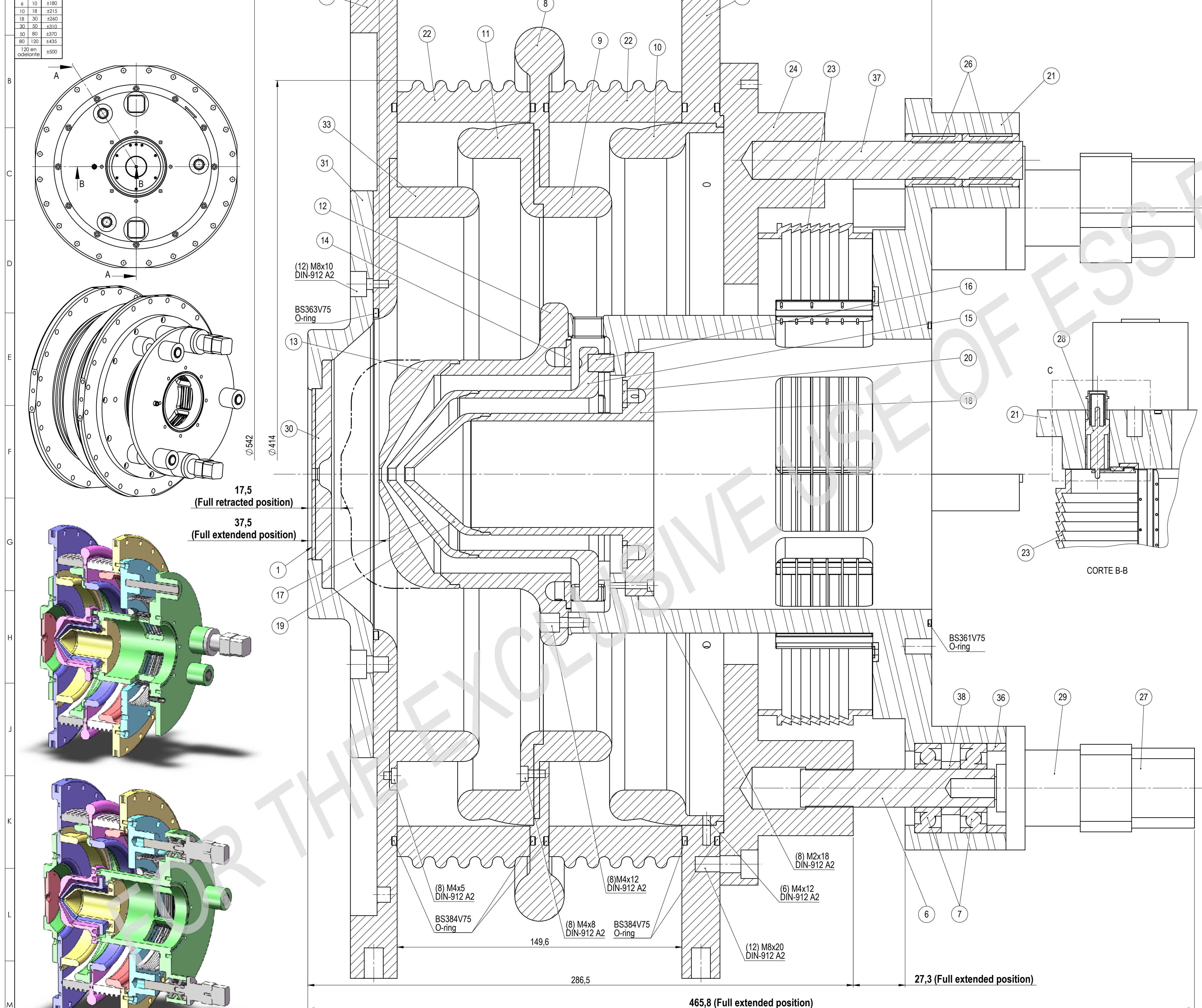
Model 1



Model 2



6	10	±180
10	18	±215
18	30	±260
30	50	±310
50	80	±370
80	120	±435
120 en adelante		±500

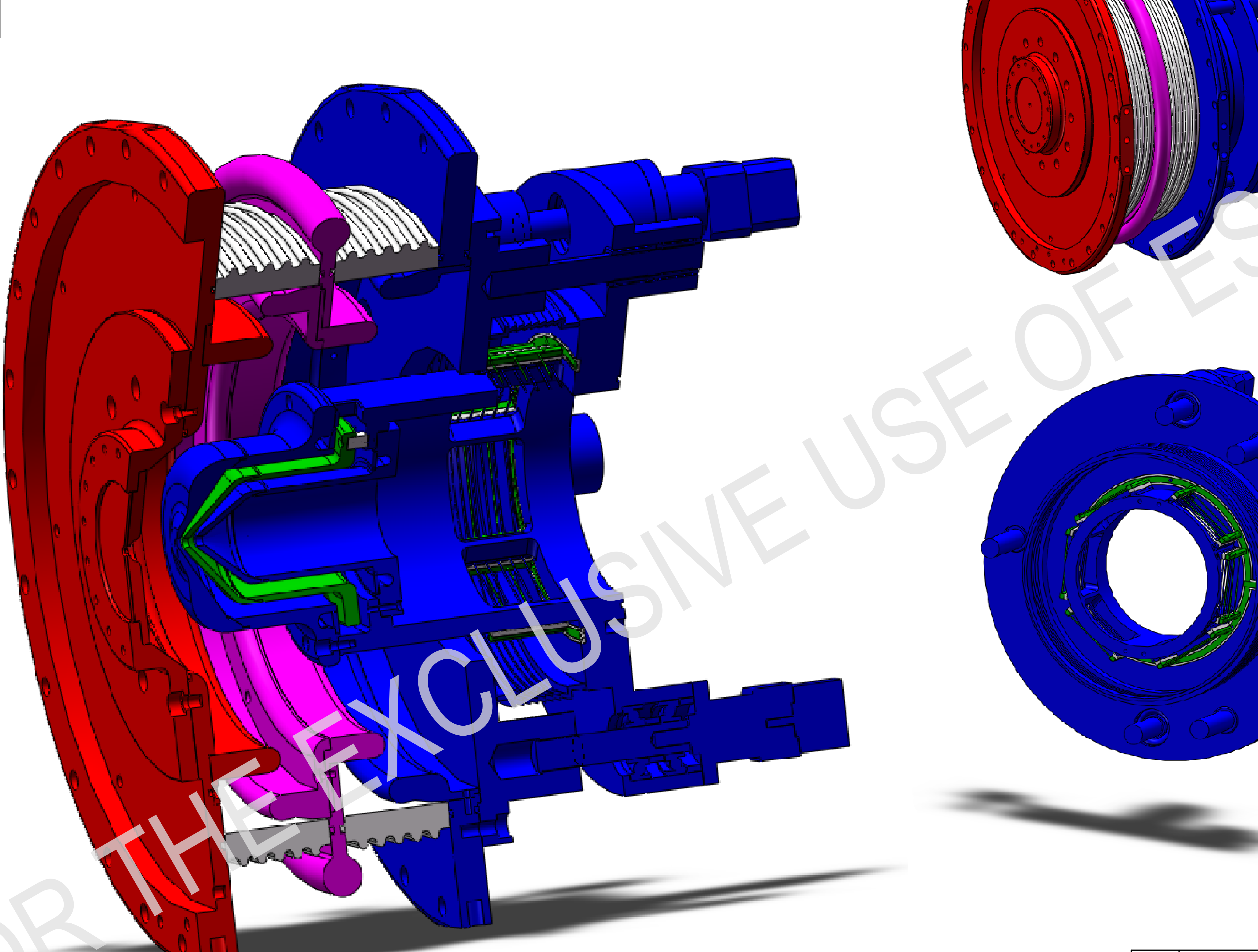


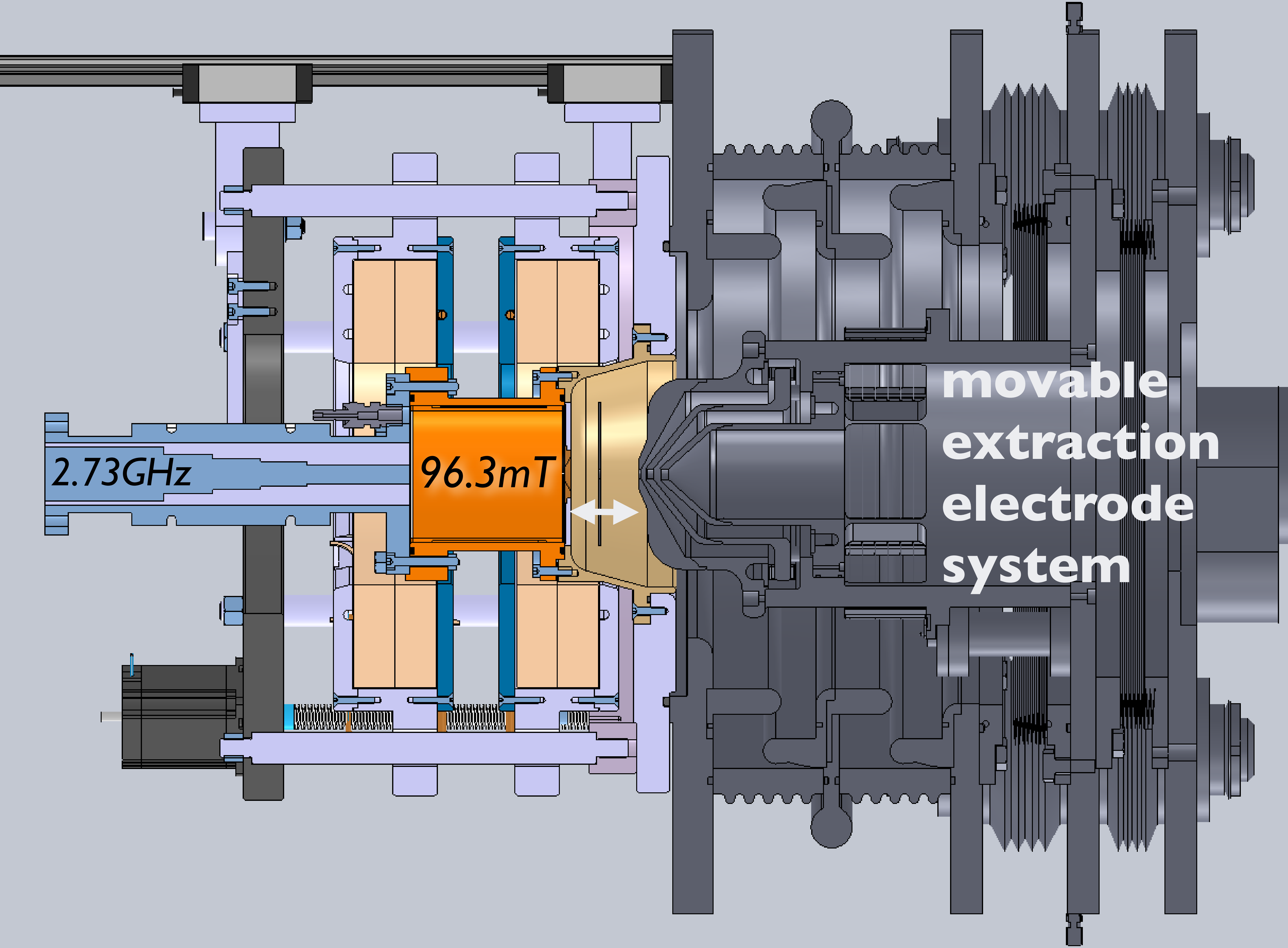
38	Spacer
37	Shaft W20
36	Preload r
33	Plasma_sh
32	Plasma_outer
31	Plasma_electro
30	Plasma_elec
29	PLANETARY GEA
28	Negative_feed_c hv-5-reces
27	MOTOR_ENCODER S1.0H220
26	inafag_kh20_7uvv 8dp34cifnr
25	Ground_outer
24	Ground_connex_f able
23	Flexible be
22	External_insu
21	Electrodes_suppo
20	Electrode4
19	Electrode4_
18	Electrode4_
17	Electrode3_
16	Electrode3_ir
15	Electrode3_
14	Electrode2_
13	Electrode2_
12	Electrode2_
11	Divider_Shield_Kof de
10	Divider_shield_
9	Divider_sh
8	Divider_ring-33k
7	DIN 628 - 72 10,SI,NC,10
6	D20_Threade
5	Copper_electric_f or
4	Copper_electric_ ator
3	Copper_electri
2	Copper_elect
1	Boron_nitride
N.º DE ELEMENTO	DESCRIPC

Conjunto Movable-electrode extra

N - Pieza	Denominación observació

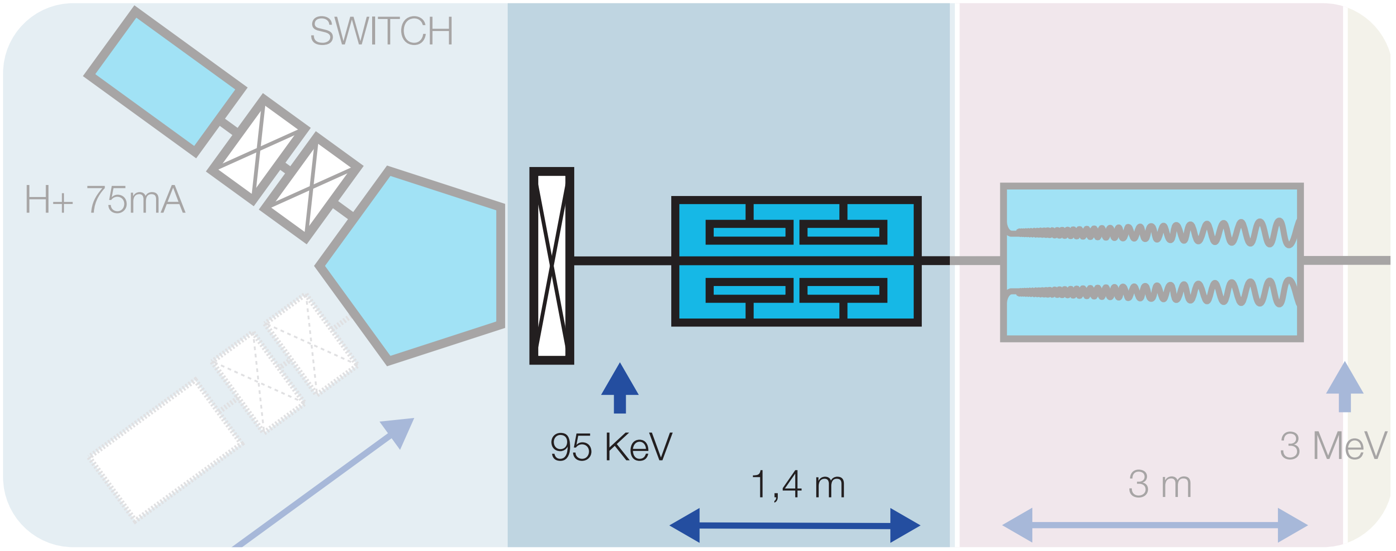
	Fecha	Nombre
Dibujado	17-02-2010	R.Caballero
Comprobado	17-02-2010	J.Galipienzo
Conforme		

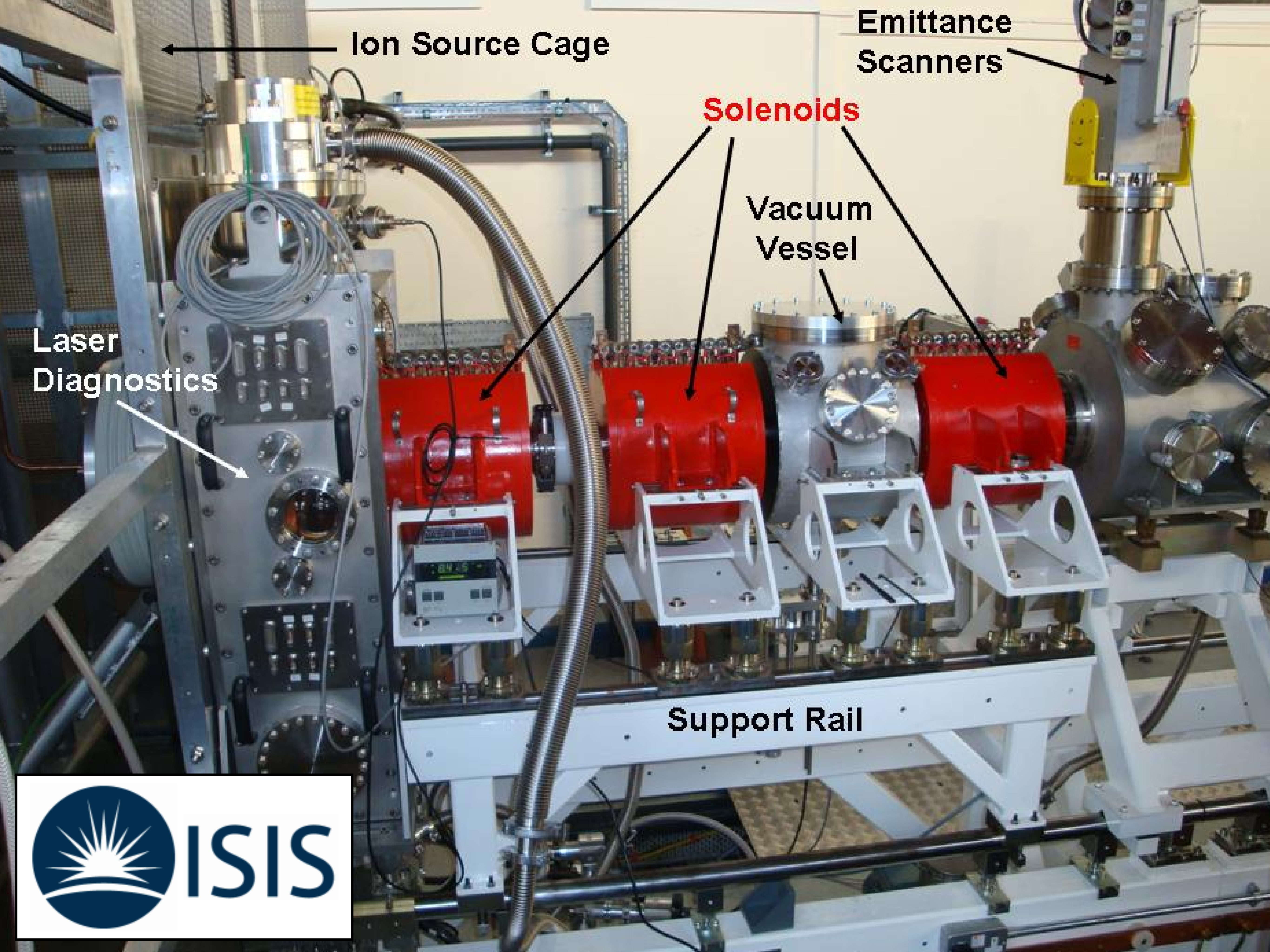




2.73GHz
96.3mT
movable
extraction
electrode
system

LEBT

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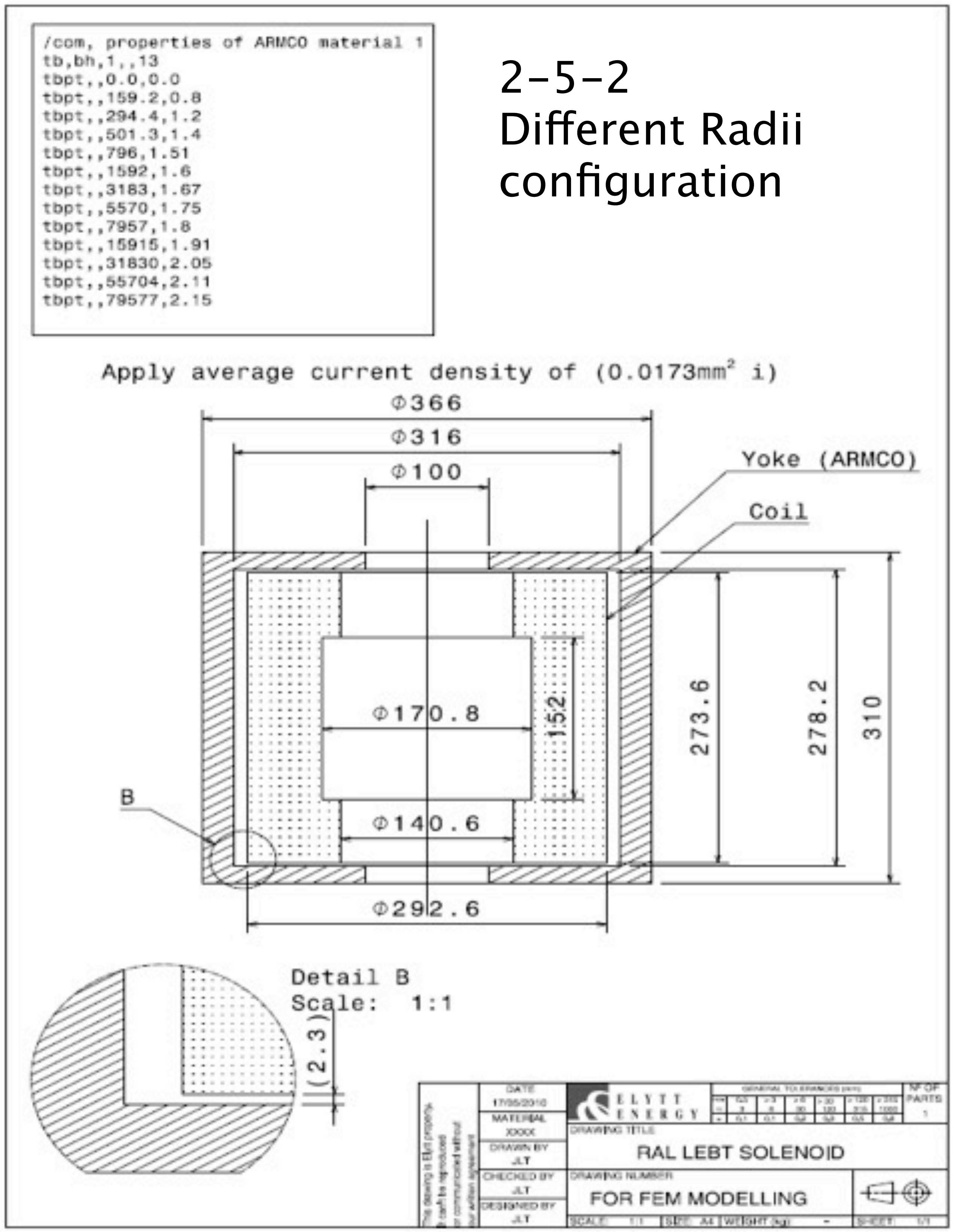
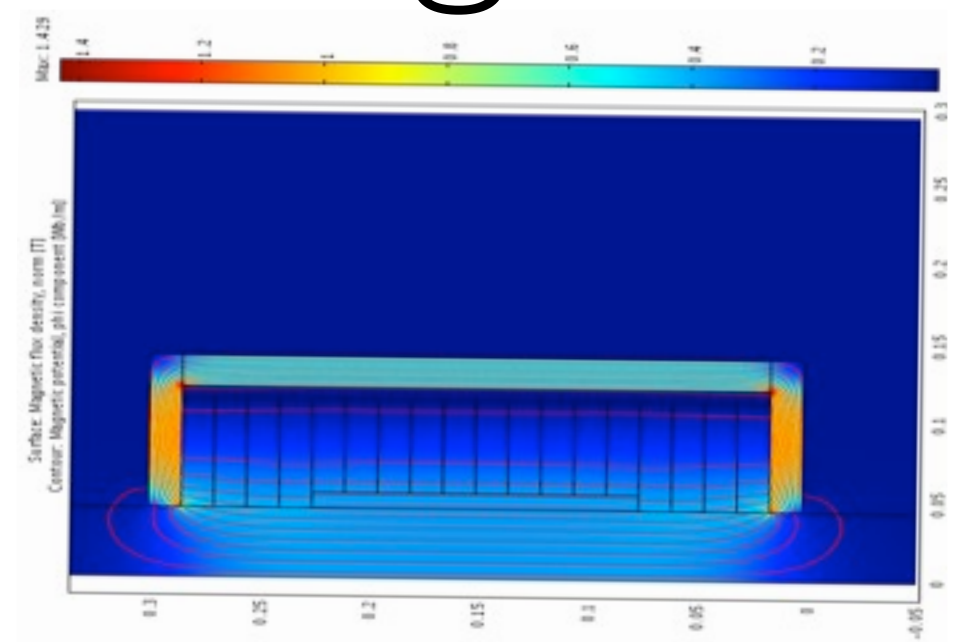
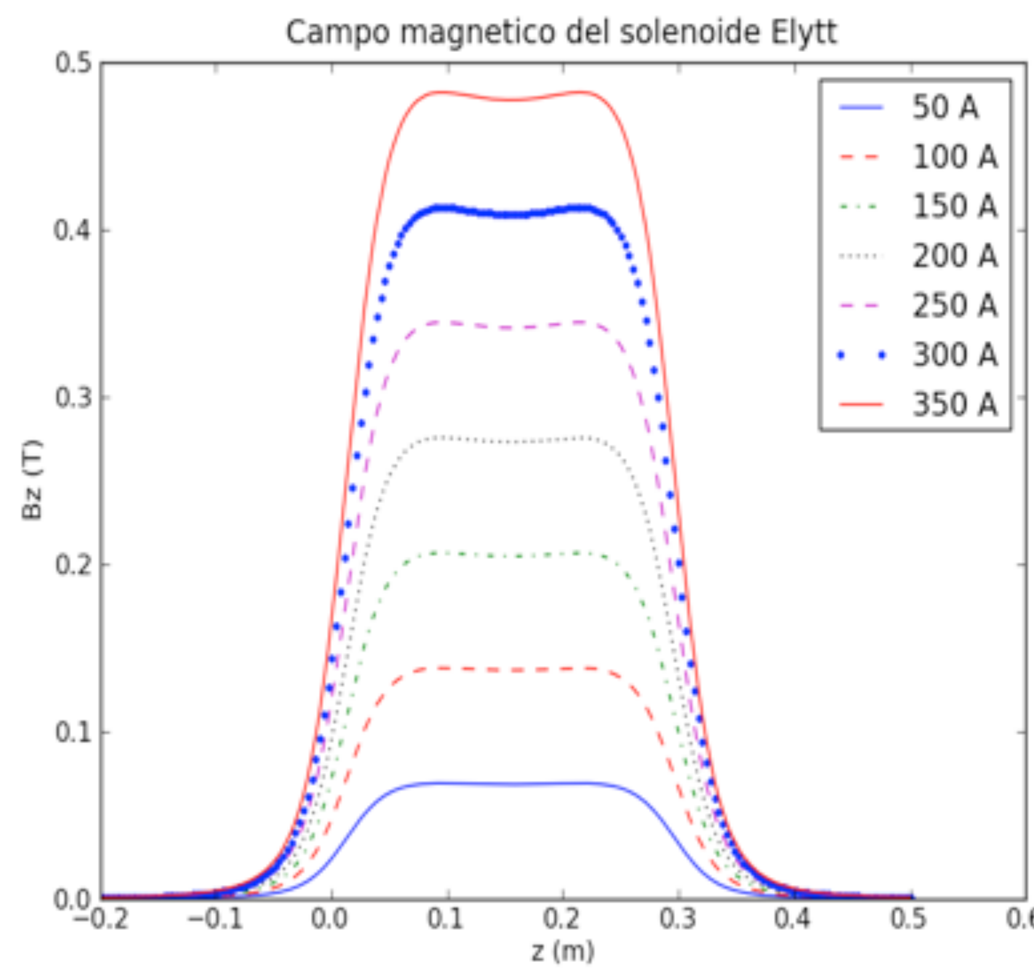
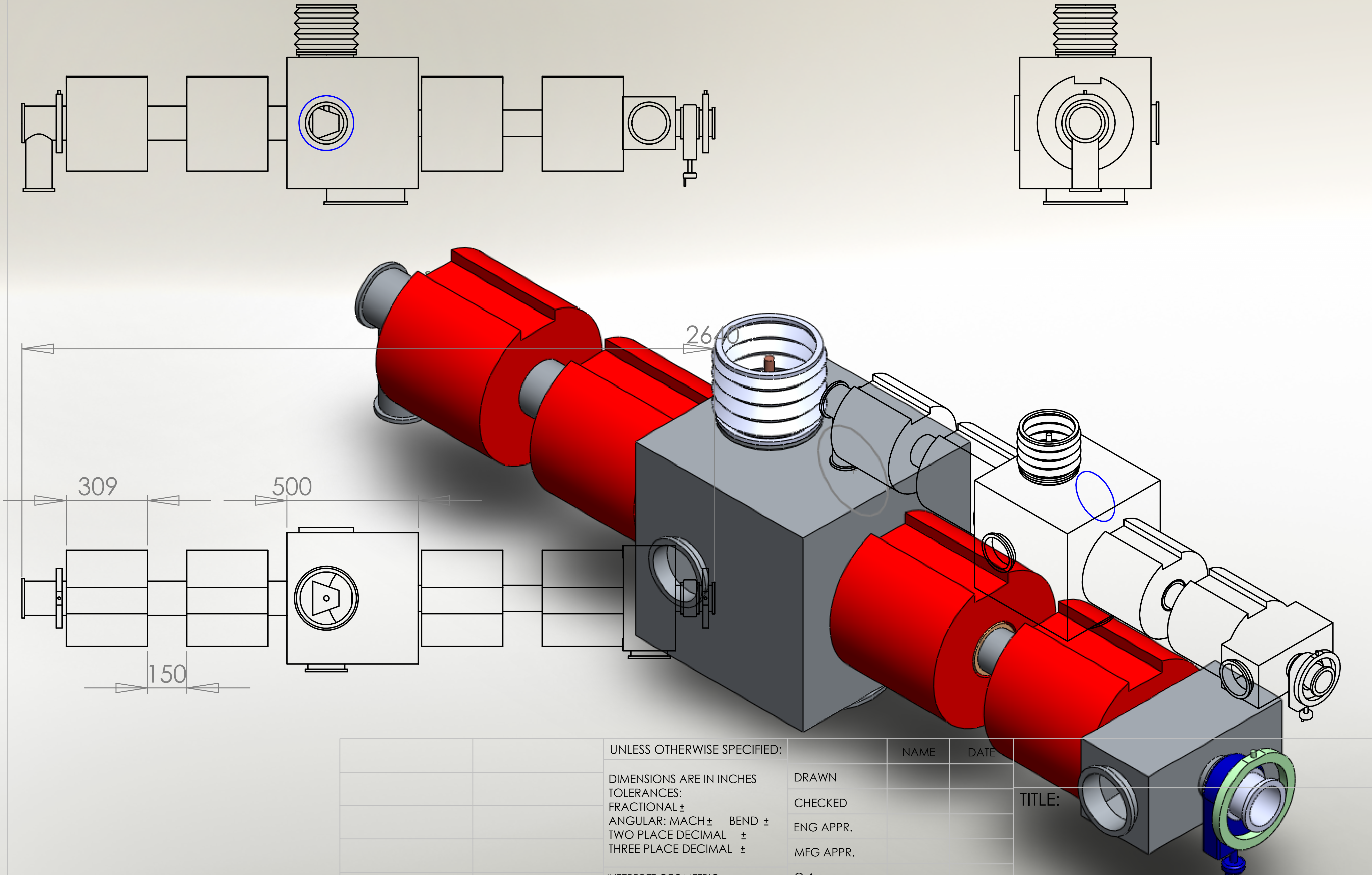
Emittance
Scanners
Solenoids
Vacuum
Vessel
Laser
Diagnostics
Support Rail
ISIS

Solenoid Design









UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC
TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
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ENG APPR.		
MFG APPR.		
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COMMENTS:		

TITLE:

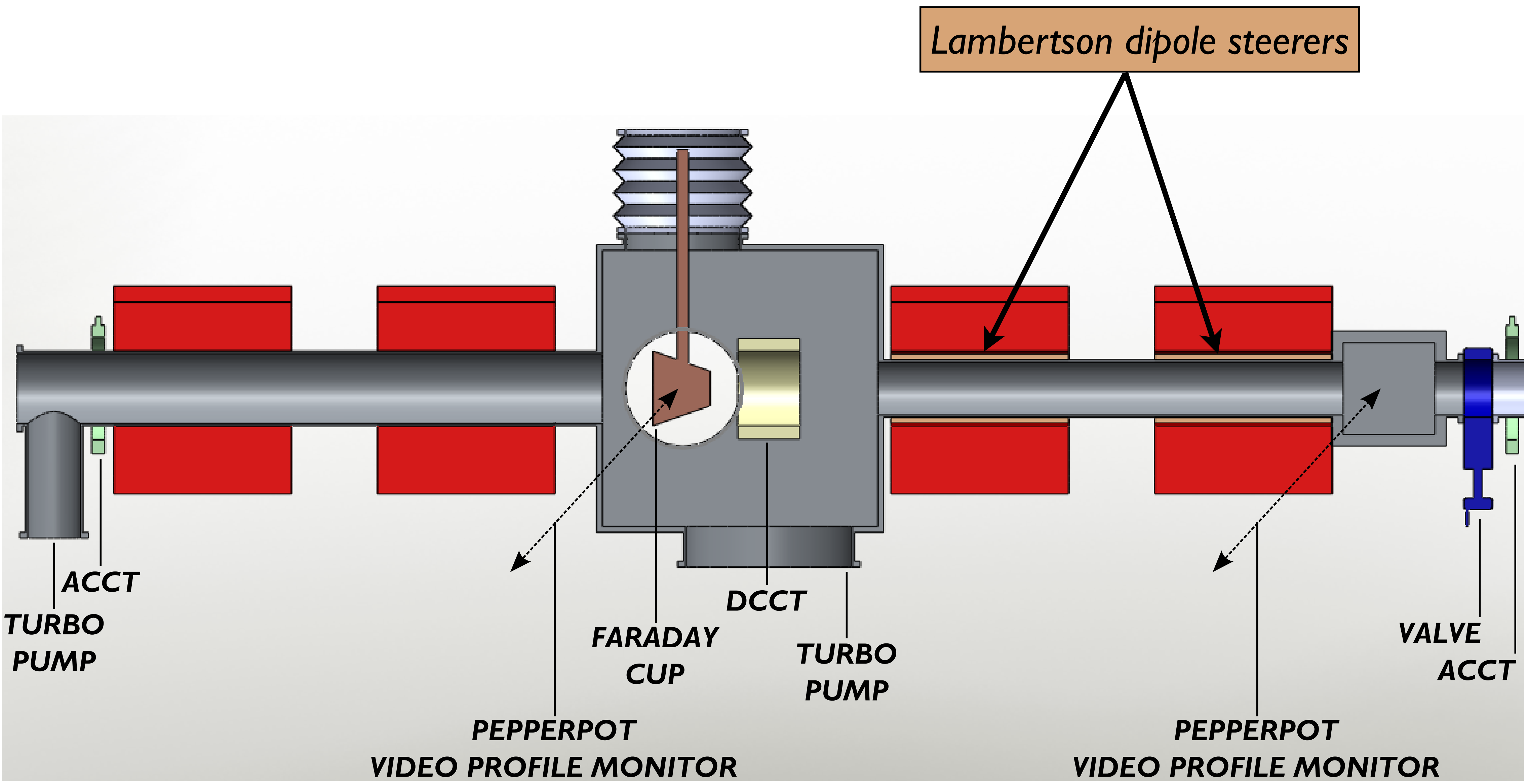
SIZE	DWG. NO.	REV
A	Lebt_v4	

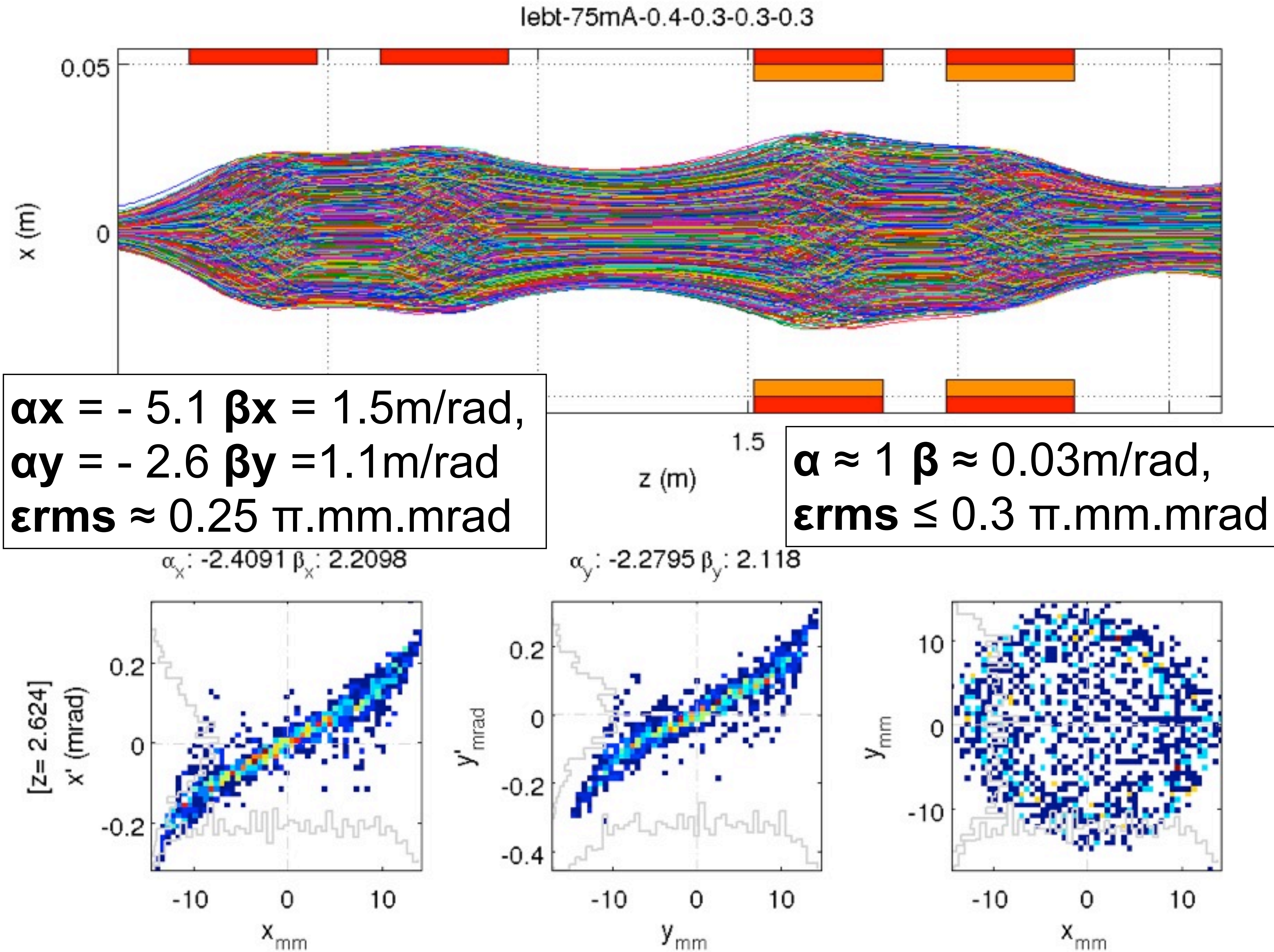
SCALE: 1:50 WEIGHT: SHEET 1 OF 1

NEXT ASSY	USED ON
APPLICATION	

5 4 3 2 1

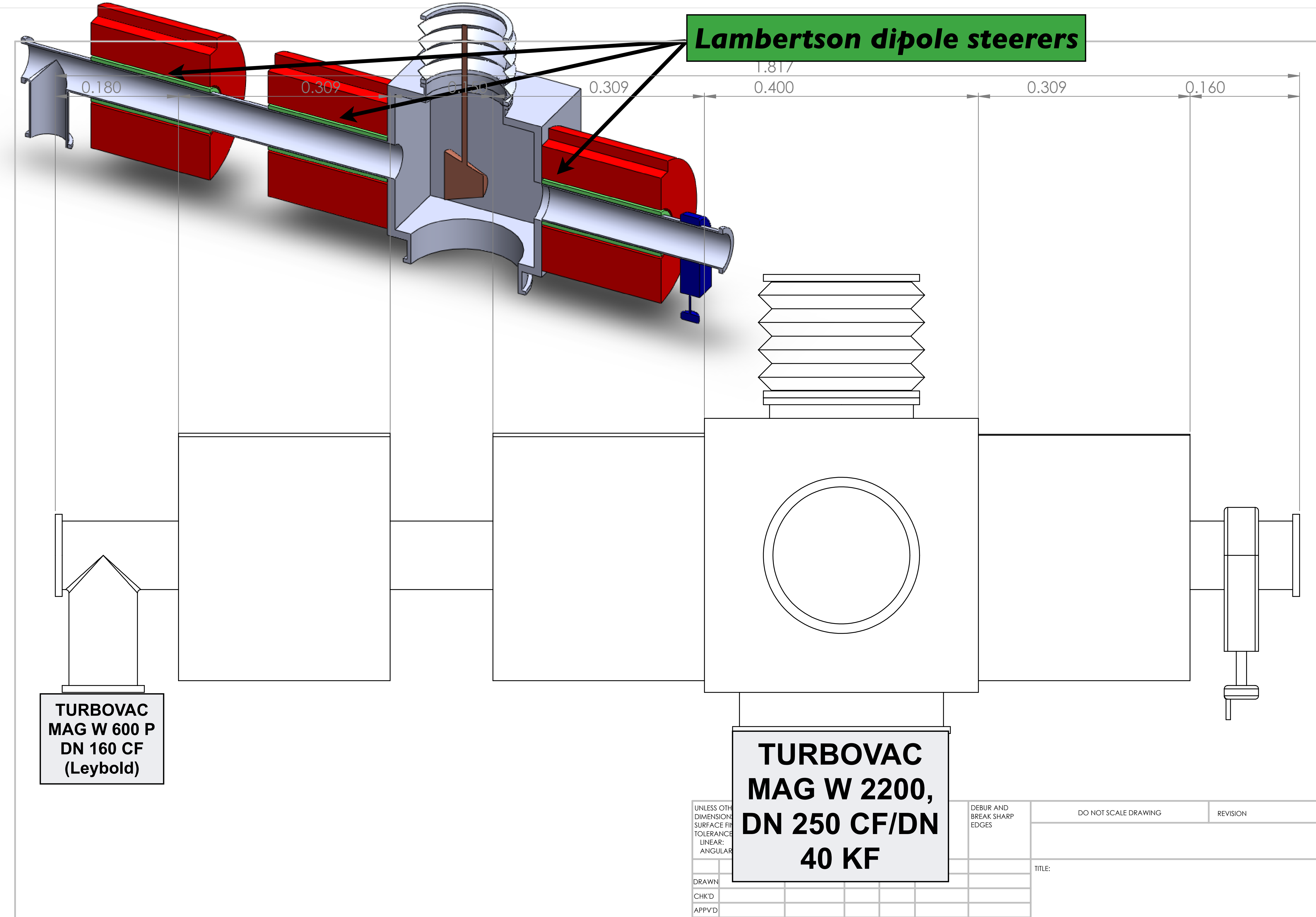
Diagnostics





αx = - 5.1 **βx** = 1.5m/rad,
αy = - 2.6 **βy** =1.1m/rad
εrms ≈ 0.25 π.mm.mrad

α ≈ 1 **β** ≈ 0.03m/rad,
εrms ≤ 0.3 π.mm.mrad



Lambertson dipole steerers
1.817
0.180
0.309
0.150
0.309
0.400
0.309
0.160
TURBOVAC MAG W 600 P DN 160 CF (Leybold)
TURBOVAC MAG W 2200, DN 250 CF/DN 40 KF
UNLESS OTH
DIMENSIONS
SURFACE FIN
TOLERANCE
LINEAR:
ANGULAR
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
TITLE:
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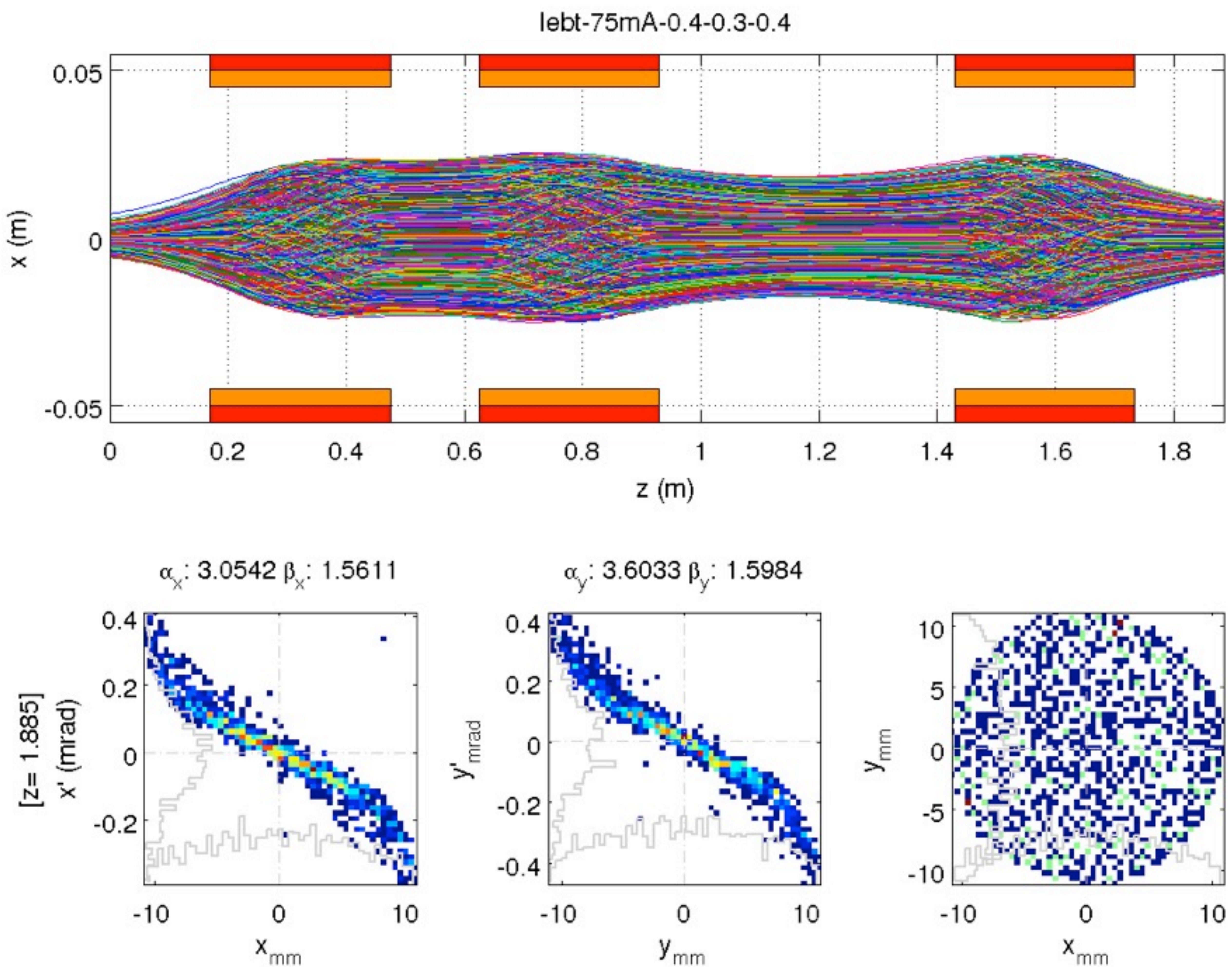
CHK'D
APPV'D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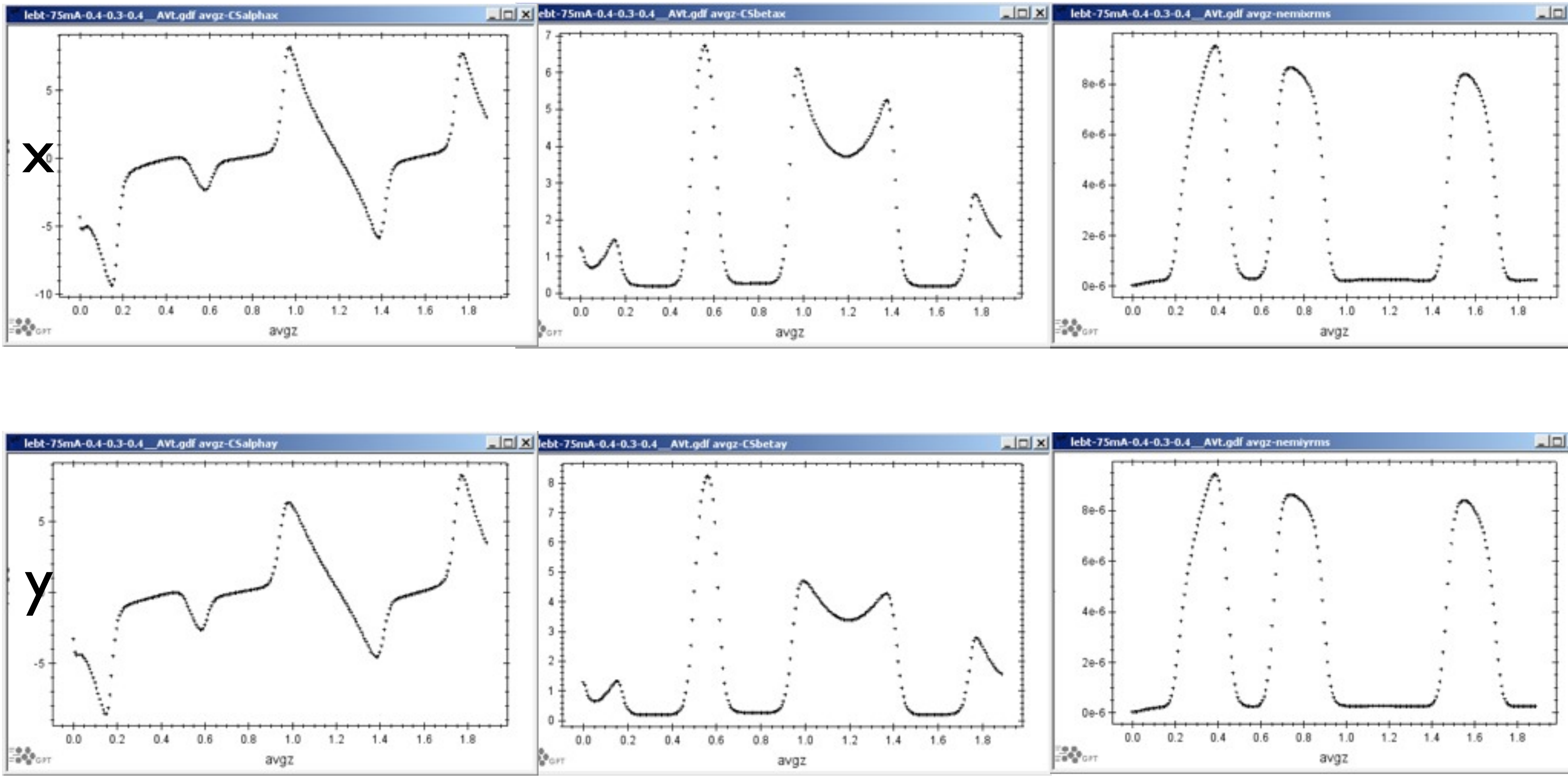
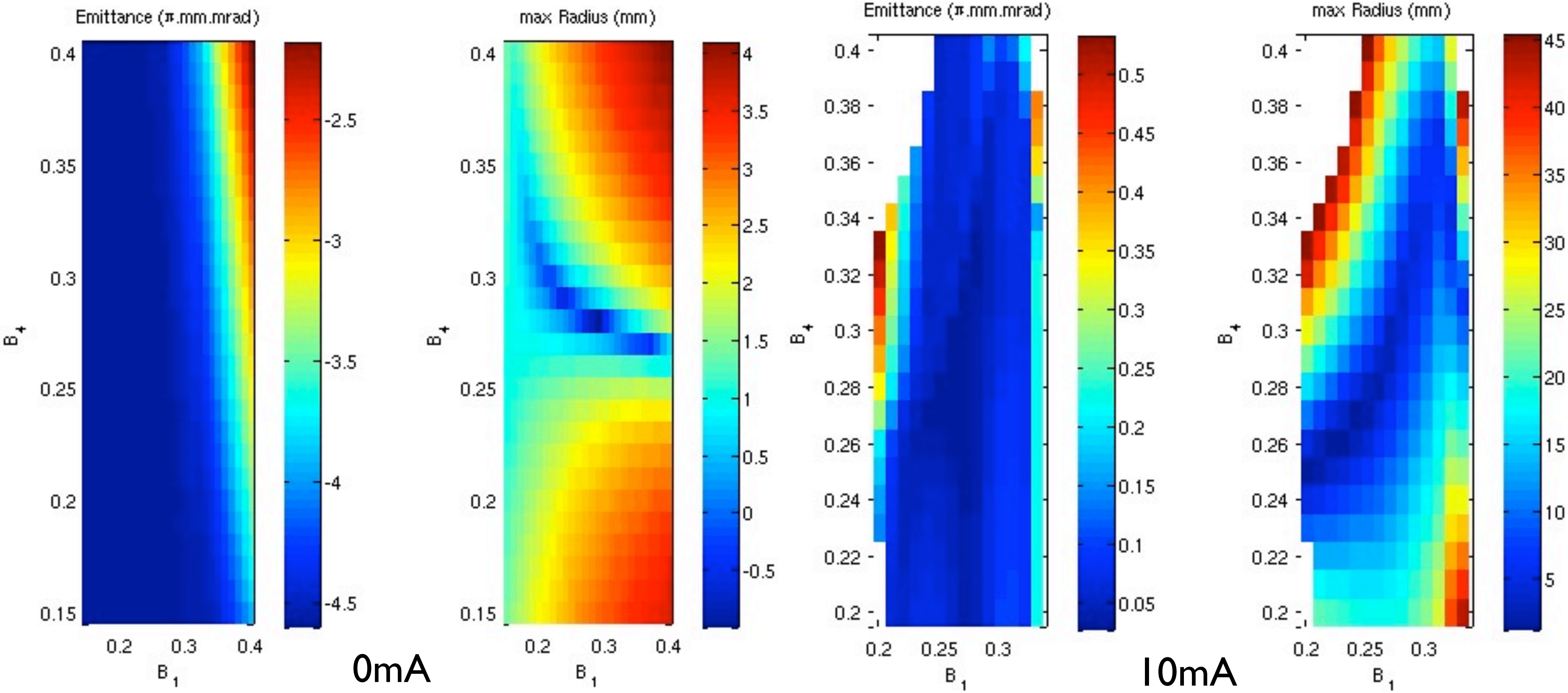
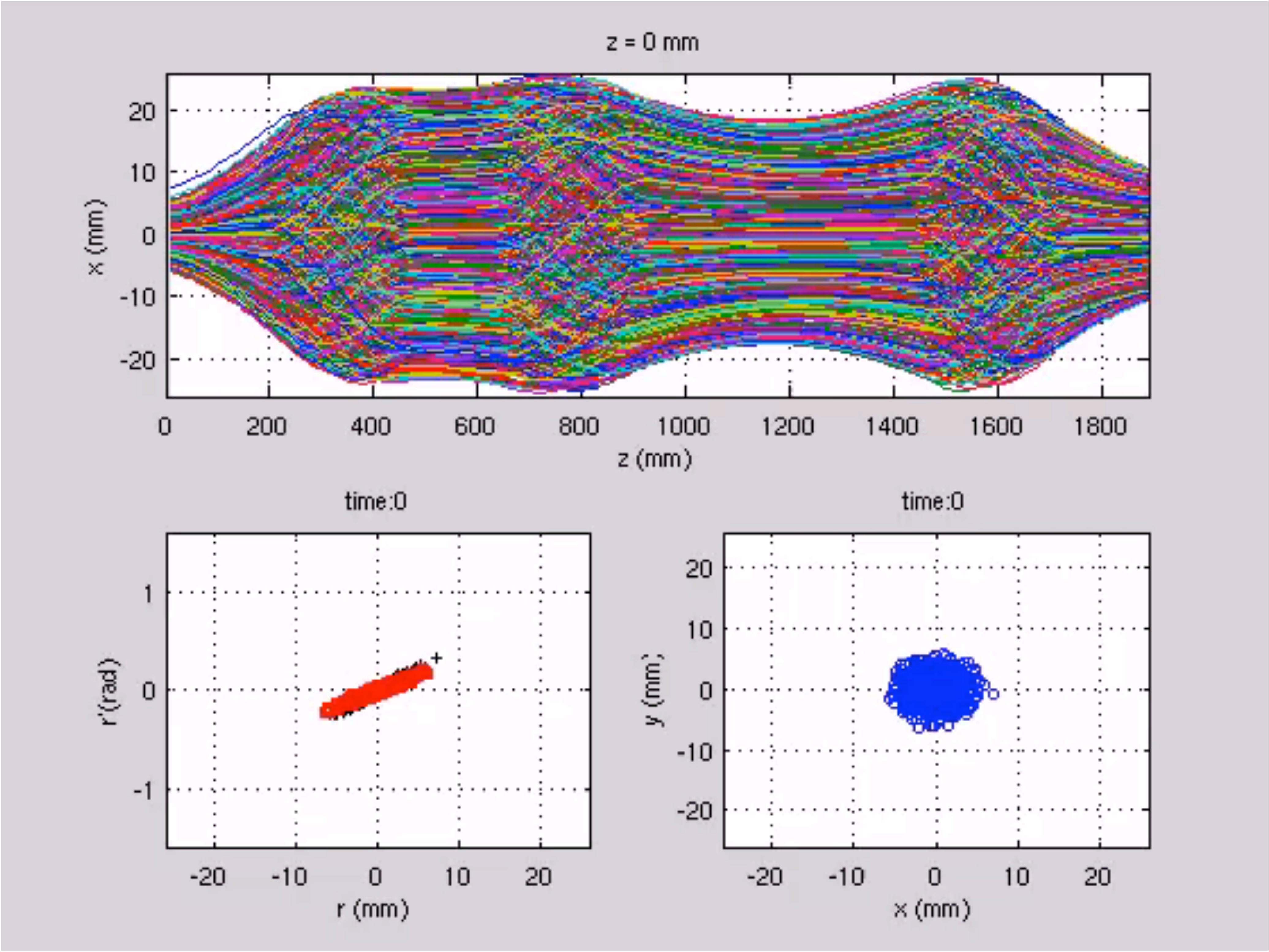
0.05
0
-0.05
x (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
z (m)
αx: 3.0542 βx: 1.5611
αy: 3.6033 βy: 1.5984
[z= 1.885]
x' (mrad)
0.4
0.2
0
-0.2
-10
0
10
x mm
y' mrad
0.4
0.2
0
-0.2
-0.4
-10
0
10
y mm
y mm
10
5
0
-5
-10
-10
0
10
x mm

α β nεrms

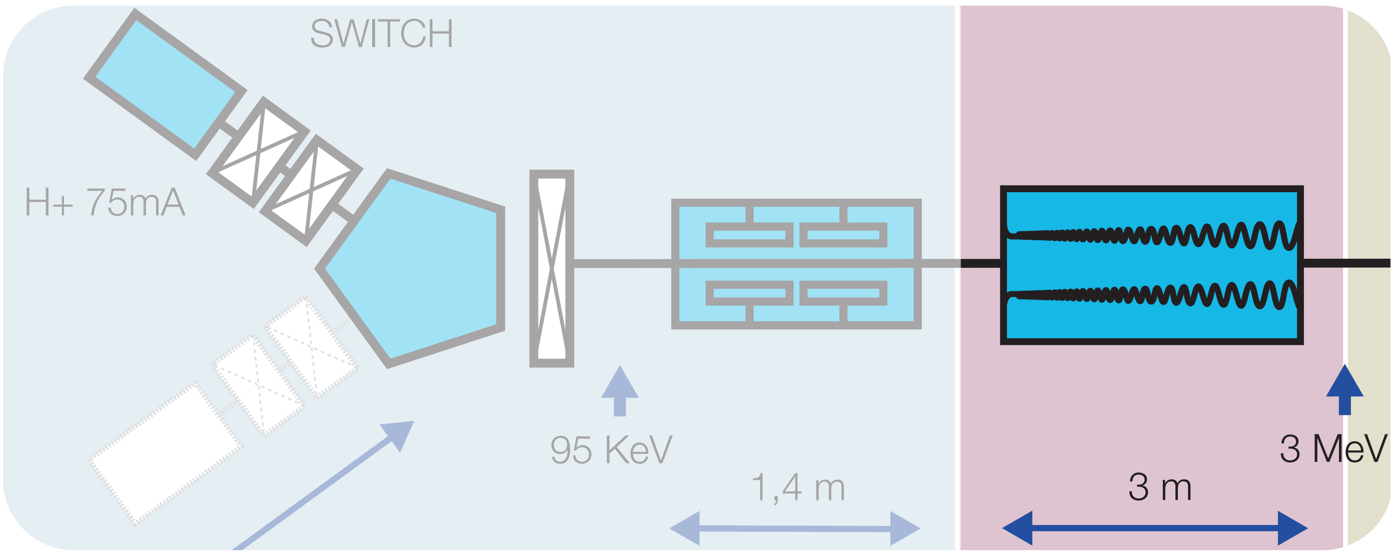

x
y
lebt-75mA-0.4-0.3-0.4__AVt.gdf avgz-CSalphax
lebt-75mA-0.4-0.3-0.4__AVt.gdf avgz-CSbetax
lebt-75mA-0.4-0.3-0.4__AVt.gdf avgz-nemixrms
lebt-75mA-0.4-0.3-0.4__AVt.gdf avgz-CSalphay
lebt-75mA-0.4-0.3-0.4__AVt.gdf avgz-CSbetay
lebt-75mA-0.4-0.3-0.4__AVt.gdf avgz-nemiyrms
avgz


Emittance (π.mm.mrad)
max Radius (mm)
Emittance (π.mm.mrad)
max Radius (mm)
B 4
B 1
0mA
10mA

LEBT a movie



RFQ



RFQ a first design

75mA, ωi = **75KeV, ωo= 3MeV**
5000 particles
εrms emittances of **0.2** π mm mrad
4D waterbag and 2D longitudinal distributions

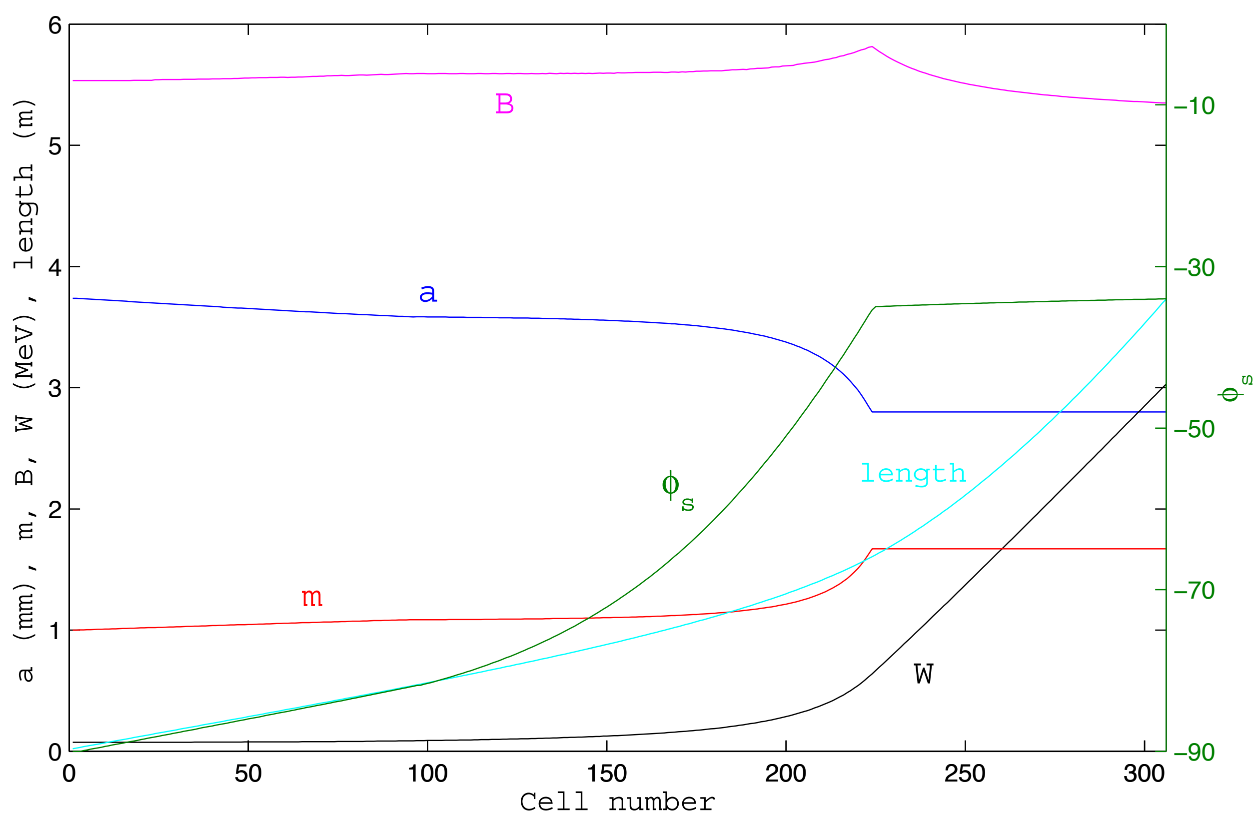


Figure 1: Evolution of RFQ parameters as a function of RFQ cell number.

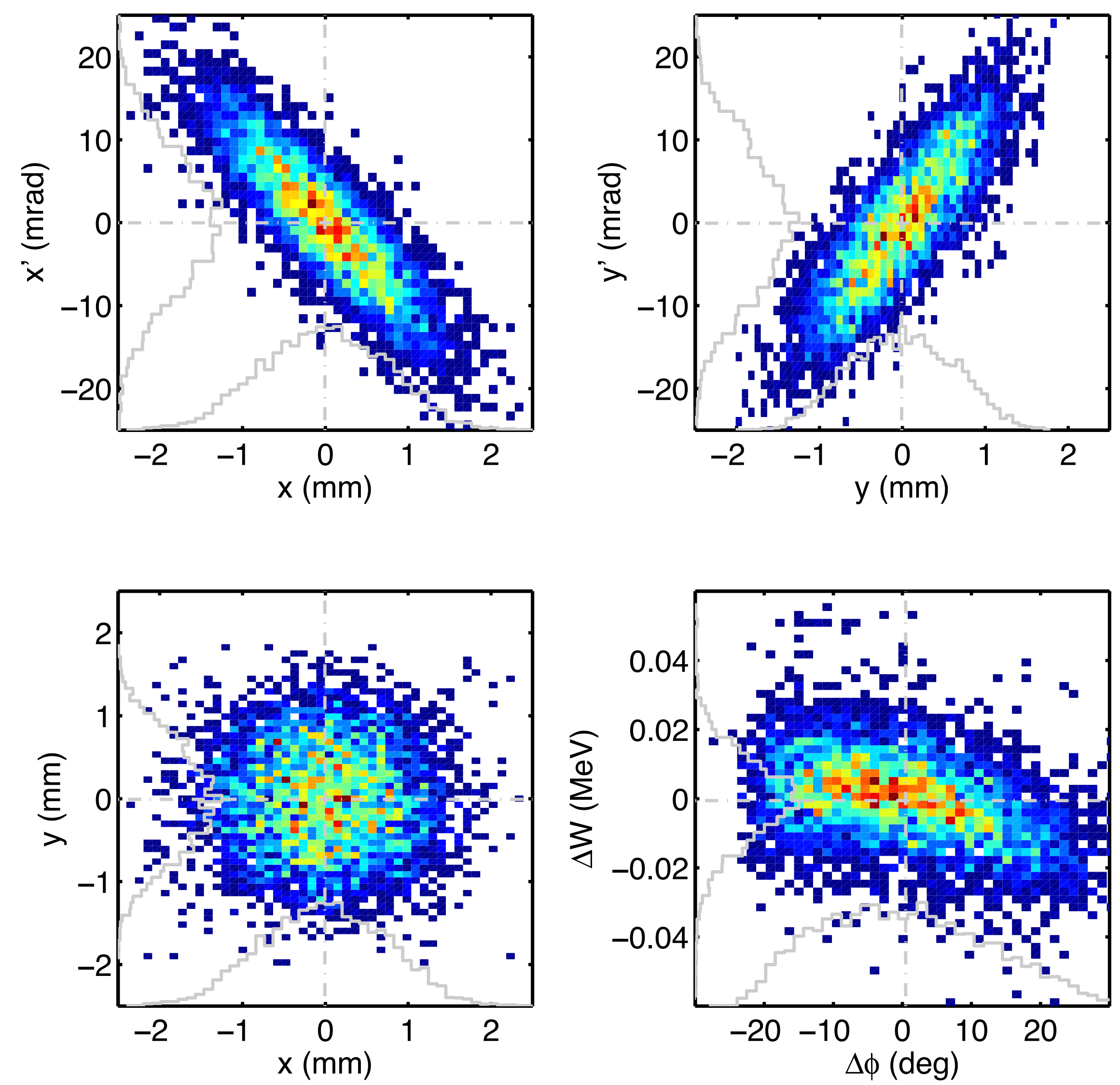
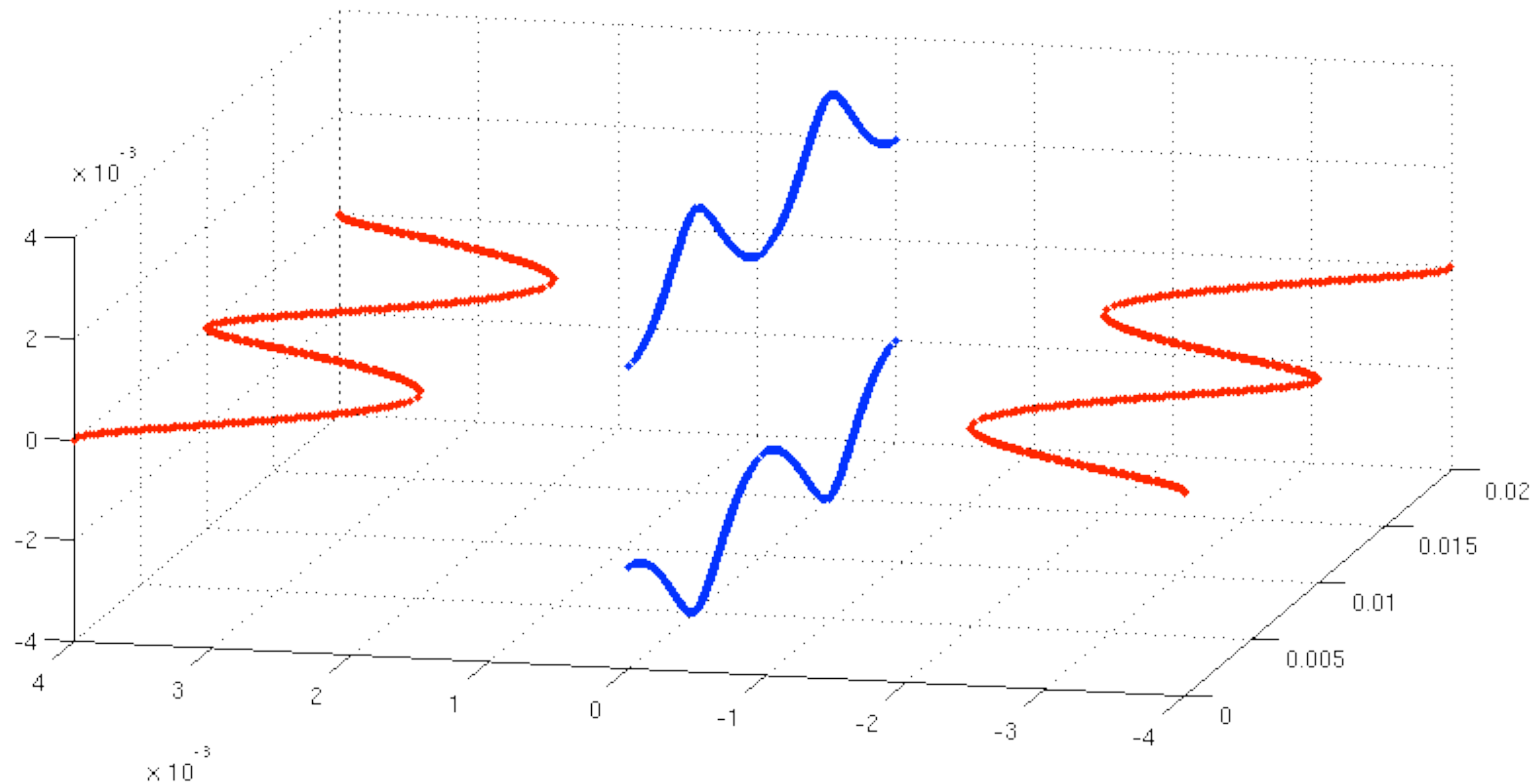


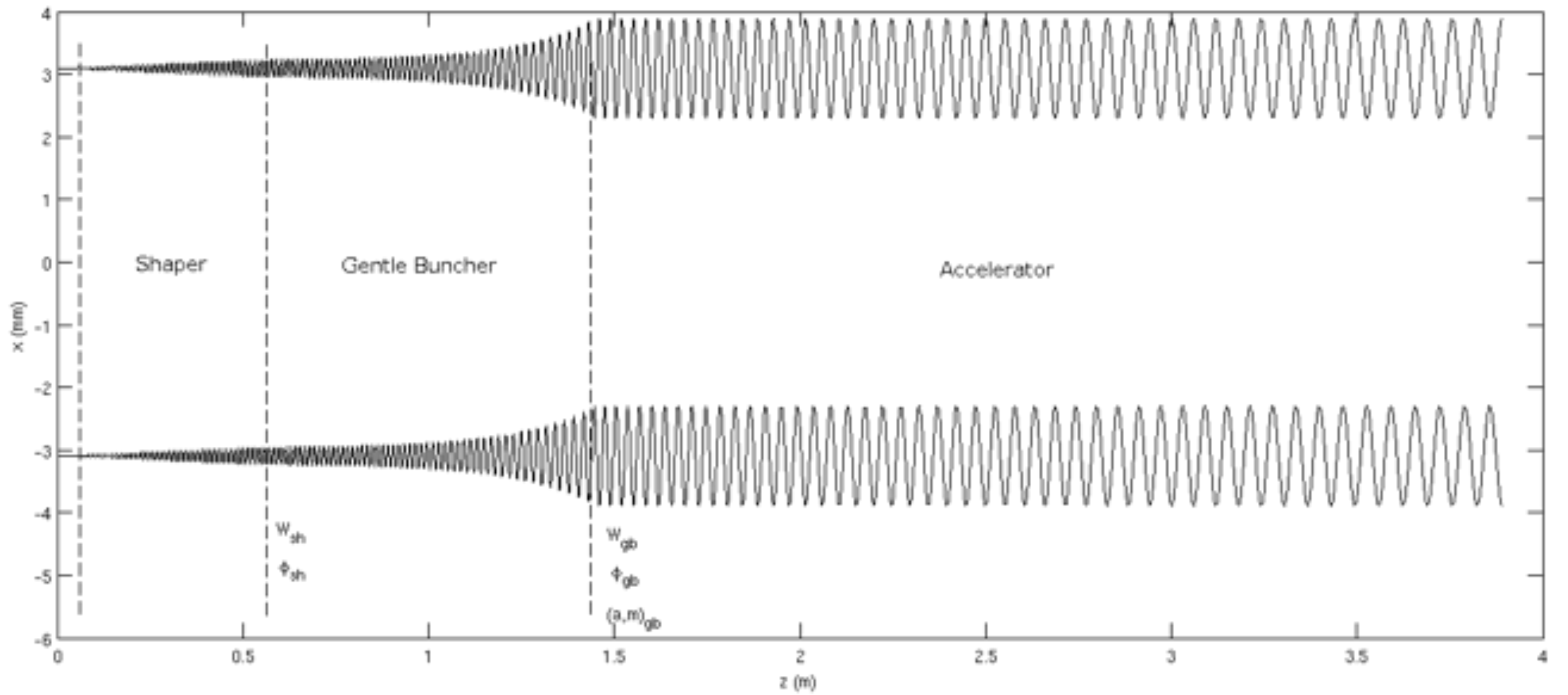
Figure 2: Beam conditions at the output of the RFQ. Top: Transverse phase-spaces. Bottom-left: Trasverse plane distribution. Bottom-right: Longitudinal phase-space.



- Codes used: **RFQSIM** (Alan Letchford) combined with **Trace2D** (LANL).
- RFQSIM is used to design the **vane profile** of the RFQ, as well as to perform **particle tracking** simulations.
- Trace2D is used to find the **matched beam** characteristics at the RFQ input

(typical values: α~1, β~ 0.03 mm/mrad)

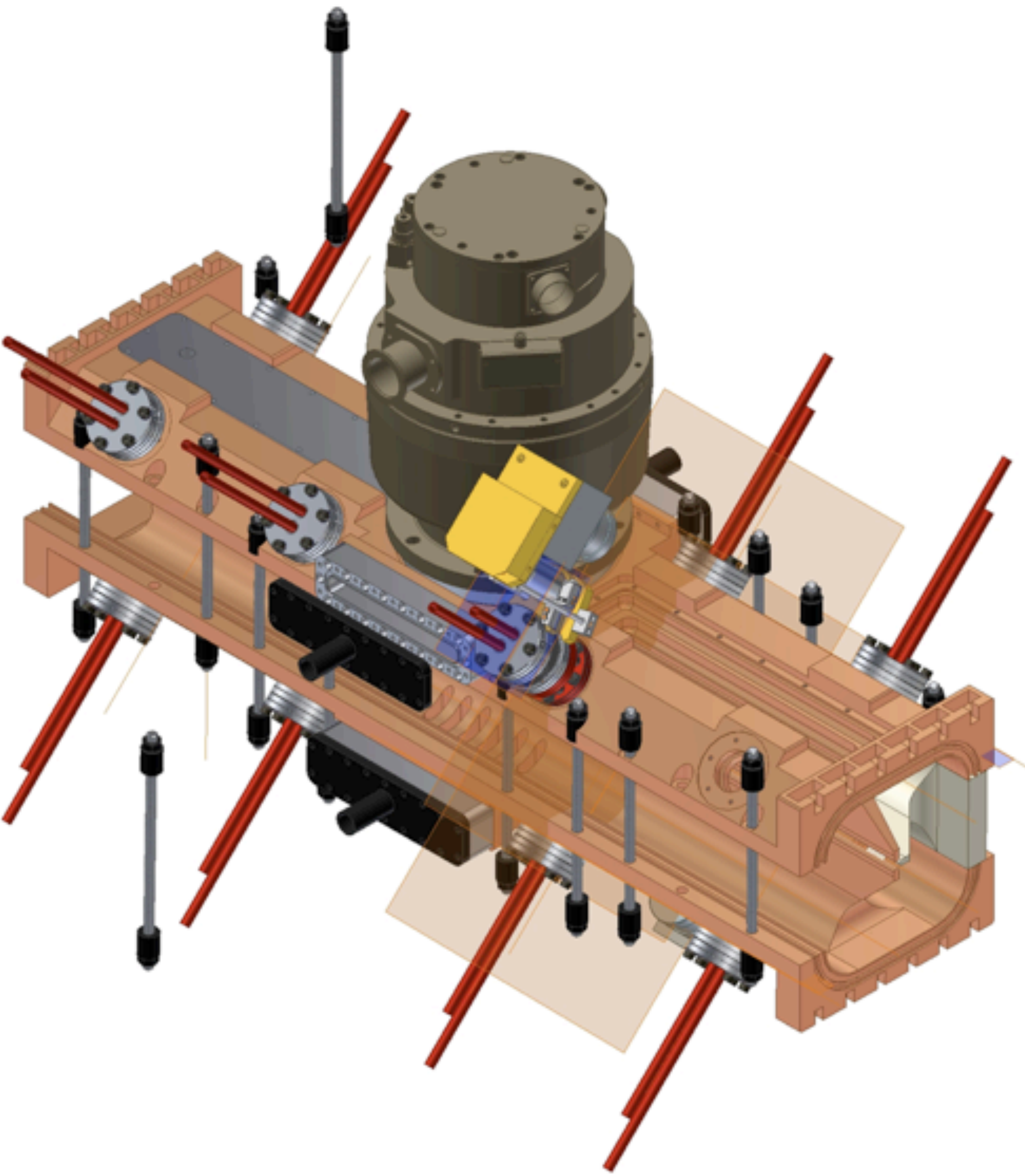
Type	4-Vane
RF Frequency	352 MHz
Species	Protons
Input Energy	75 keV
Output Energy	3 MeV
Max. Current	75 mA
Peak Surface Field	≤ 1.8 × Kilpatrick Limit
Pulse Length	Up to 2 ms
Repetition Rate	50 Hz
Duty Cycle	8%

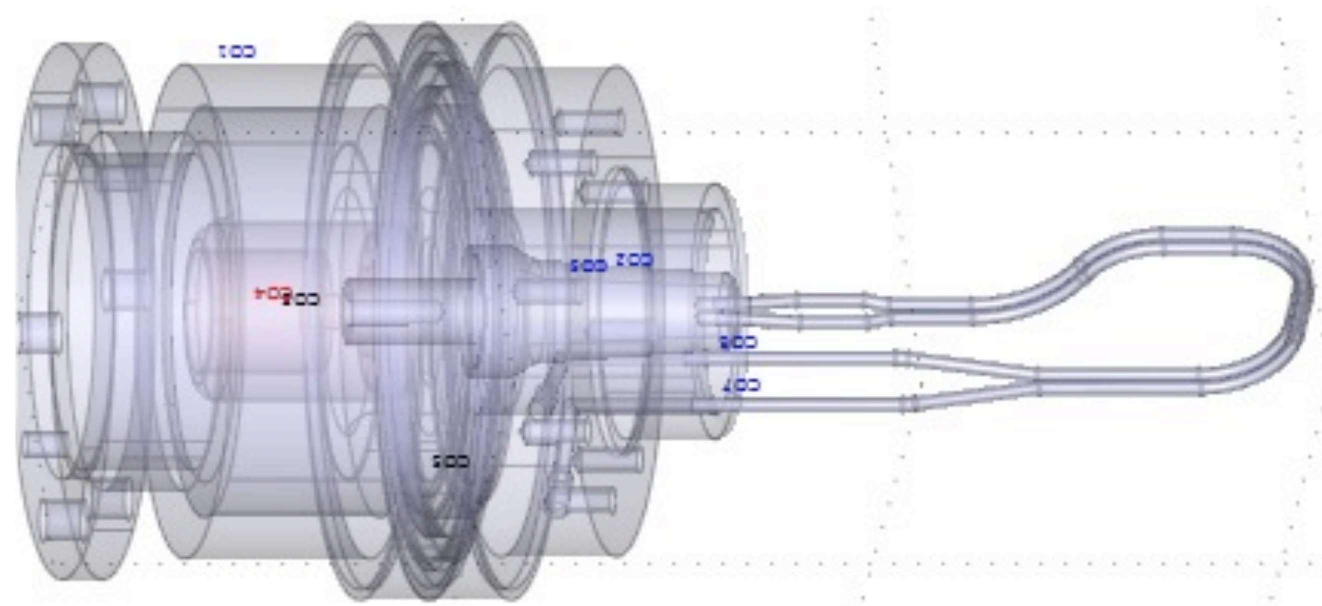


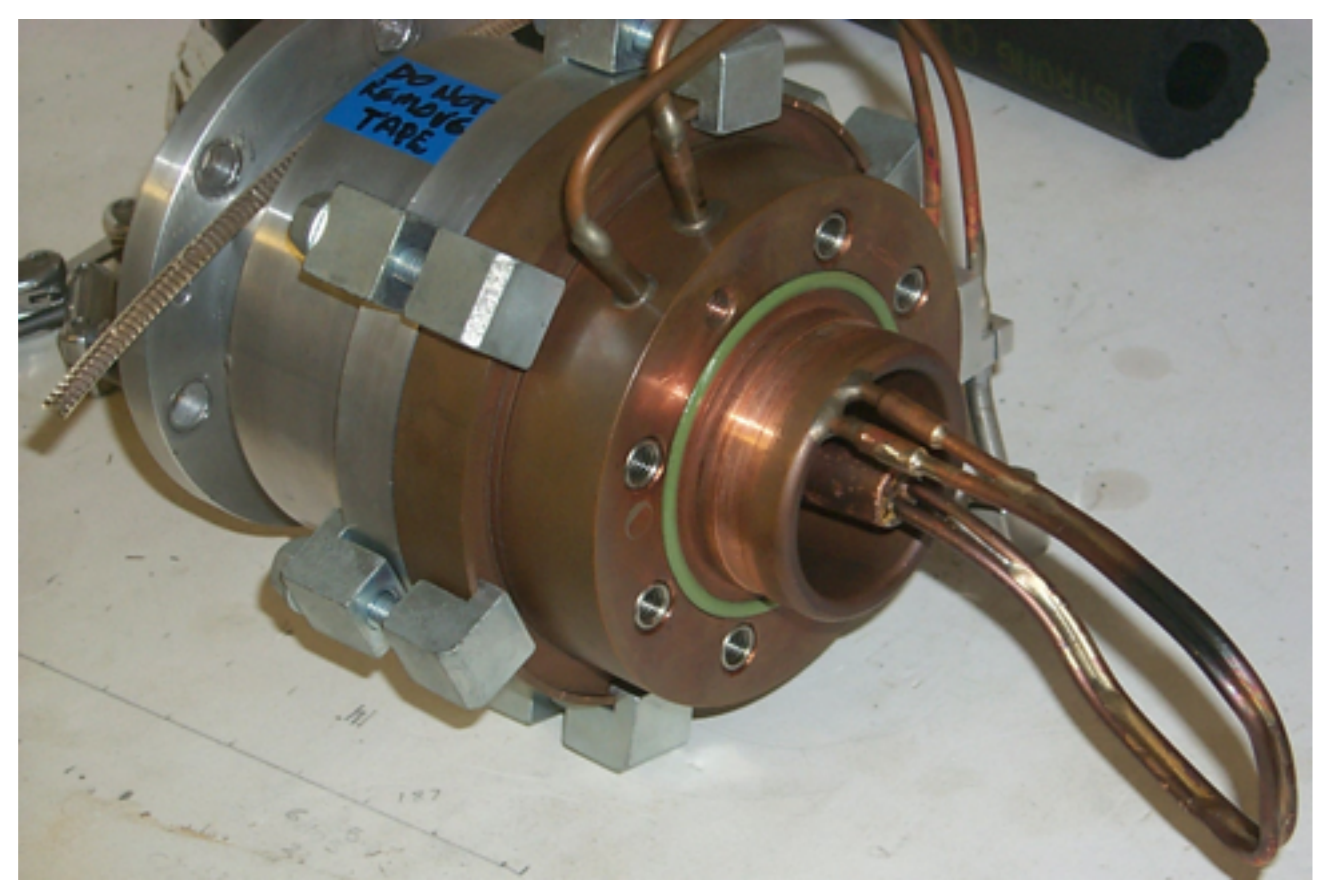
ϕ_{sh}	ϕ_{gb}	ϕ_f	a(mm)	m	W_{gb} (MeV)	I_{lim} (mA)	BF	Long (m)	Cells	Δε (%)	Transm. (%)
-85	-40	-30	2.3	1.67	0.50	205.2	1.80	4.11	339	3.5	97.7
-82	-39	-32	2.3	1.69	0.50	194.8	1.79	3.9	307	3.2	96.7
-82	-39	-30	2.3	1.69	0.50	194.8	1.79	3.87	306	3.5	96.7
-82	-39	-28	2.3	1.69	0.50	194.8	1.79	3.84	305	2.8	96.4
-80	-38	-30	2.2	1.75	0.50	182.6	1.83	3.55	270	5.2	94.4
-80	-40	-30	2.4	1.62	0.45	201.0	1.76	3.88	284	6.2	96.1
-82	-41	-30	2.4	1.60	0.45	211.2	1.77	4.08	309	4.7	96.2
-84	-38	-30	2.2	1.76	0.55	186.6	1.82	3.94	334	2.2	96.9
-83	-38	-30	2.3	1.72	0.55	189.0	1.77	4.08	346	4.0	97.0
-82	-38	-30	2.3	1.72	0.55	189.0	1.77	4.05	342	3.0	95.8

Bravery factor between **1.8-1.9**, Accelertaion capacity (**>0.5**), Focusing Eficiency B (**> 5**)

RF Design - COUPLER







RFQ a movie