High duty factor RF gun

R. Rimmer

- Conventional photocathode RF guns employ ~1.5 cell pillbox (e.g. A0).
- These give good emittance at high gradient / low duty factor.
- For CW or high duty factor thermal limitations may apply.
- A re-entrant shape for the gun cell with good cooling may help.
- Over 60 MV/m should be achievable with a 1.3 GHz gun at 10 kHz.

  Duty factor = 5%

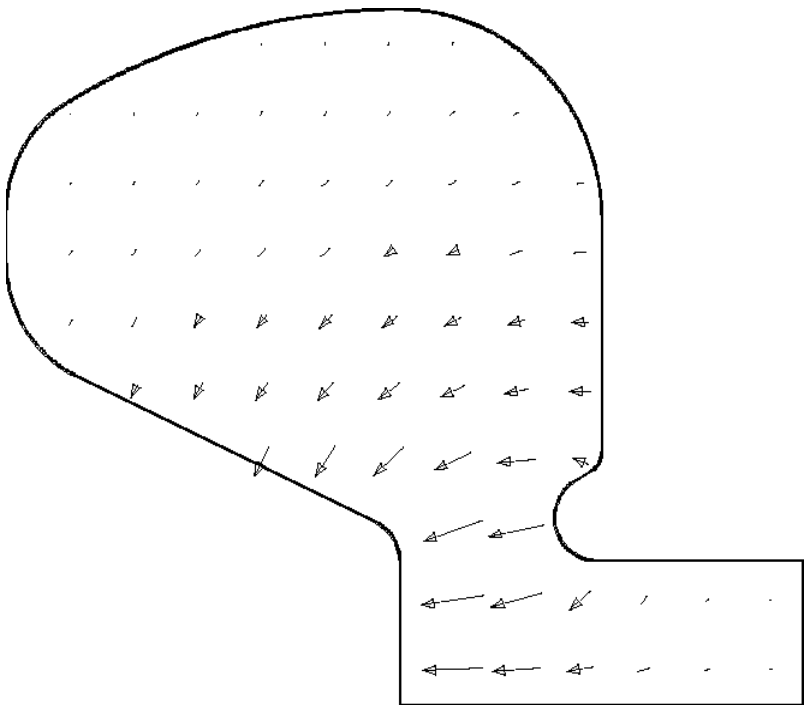
  Average cavity power = 14 kW

  Peak wall density ~ 100 W/cm2.

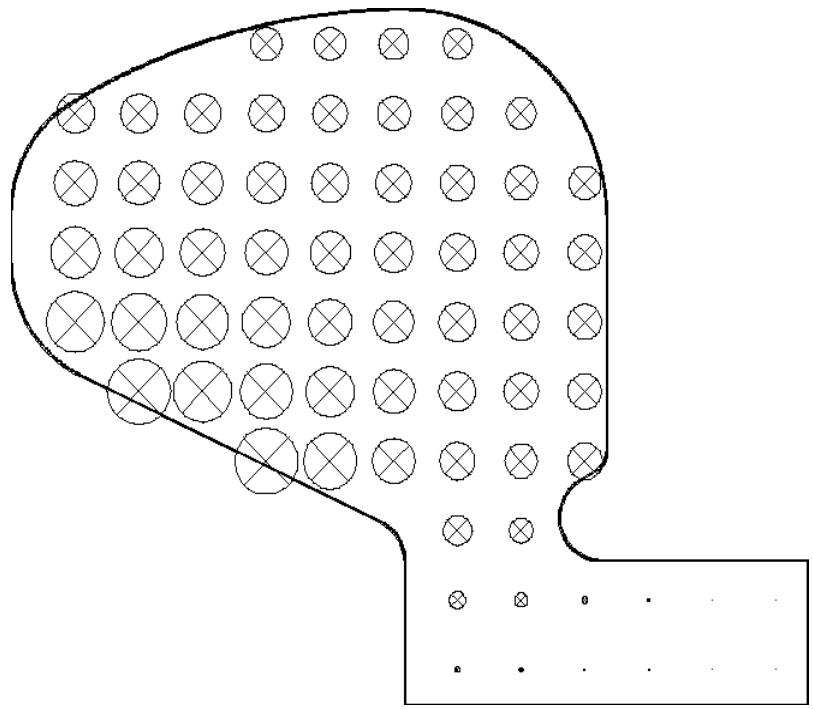
  Thermal stresses << endurance limit of copper at 10,000 cycles.

- Table 1 shows the parameters of re-entrant cavities at three different frequencies and the approximate values for a 1.3 GHz pillbox for comparison.
- It remains to be seen whether the beam quality from the reentrant cavity is the same as that from the pillbox gun.
- Plan to evaluate with MAFIA / Parmela

Possible re-entrant RF gun for CW or high duty factor operation



URMEL model E field



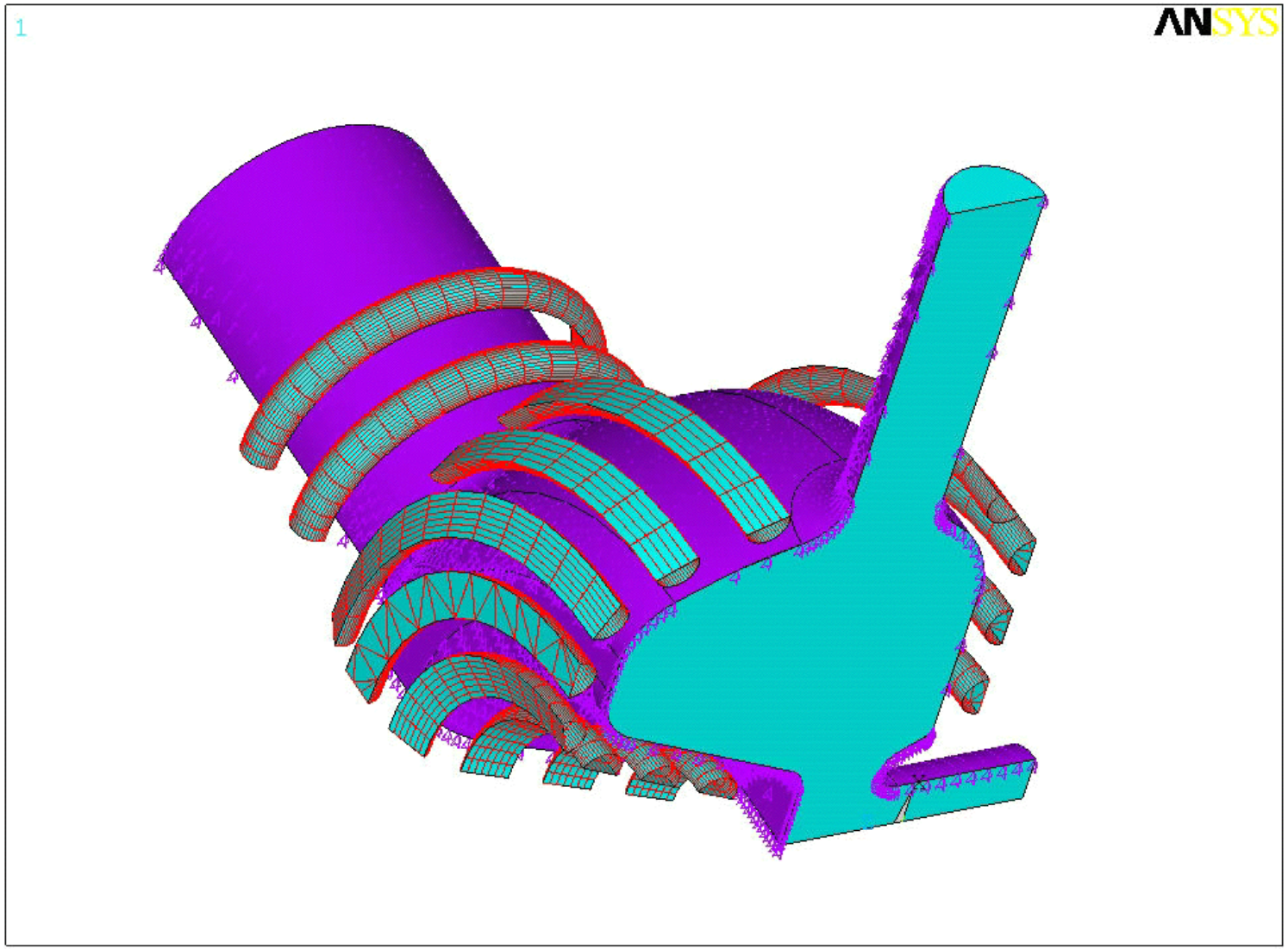
URMEL model H field

Table 1. Parameters of reentrant and pillbox gun cavities

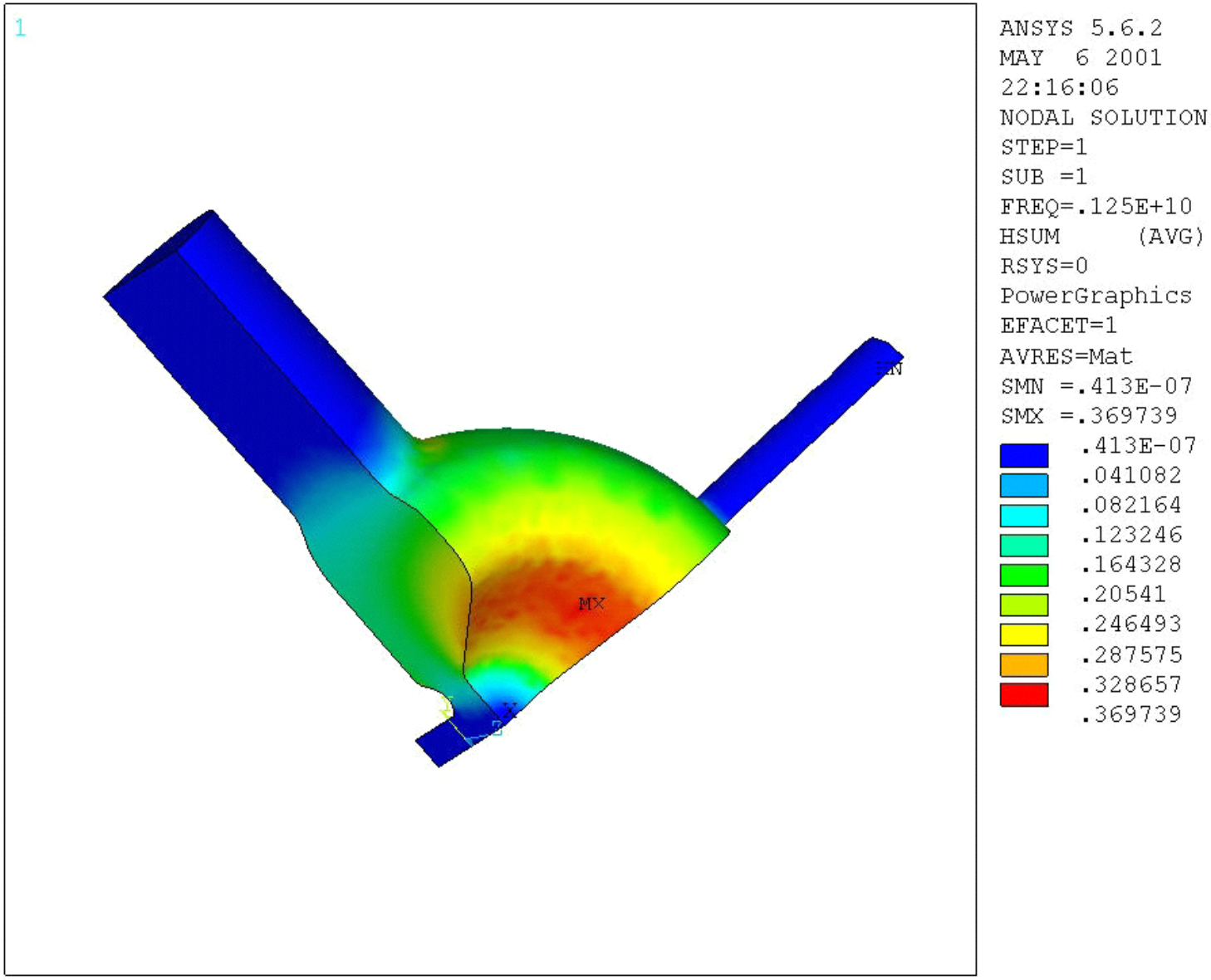
gun	freq	Eo cath..	Pc	beta	Pkly	rep rate	duty factor	av. Pwr	Max Pdens
	(MHz)	MV/m	kW	(coup.)	kW	kHz	(3 τfill)	kW	W/cm^2
pepii_mod	476	16.7	100.7	1	100.7	CW	1	100.71	99.0
	476	35.0	442.4	1	442.4	10	0.228	100.67	98.9
	476	22.6	184.4	7.4	439.7	100	0.542	99.94	98.2
1300a	1300	13.8	13.6	1	13.6	CW	1	13.62	99.0
	1300	62.0	274.9	1	274.9	10	0.050	13.74	99.9
	1300	40.1	115.0	7.4	274.2	100	0.119	13.68	99.5
2600a	2600	11.0	3.4	1	3.4	CW	1	3.41	99.7
	2600	82.6	192.3	1	192.3	10	0.018	3.41	99.8
	2600	53.5	80.7	7.4	192.3	100	0.042	3.41	99.7
pillbox*	1300	13.8	129.0	1	129	CW	1	129	207
	1300	37.8	968.0	1	968	10	0.064	62	100
	1300	24.6	408.0	7.4	973	100	0.152	62	100

* estimated from Superfish data.

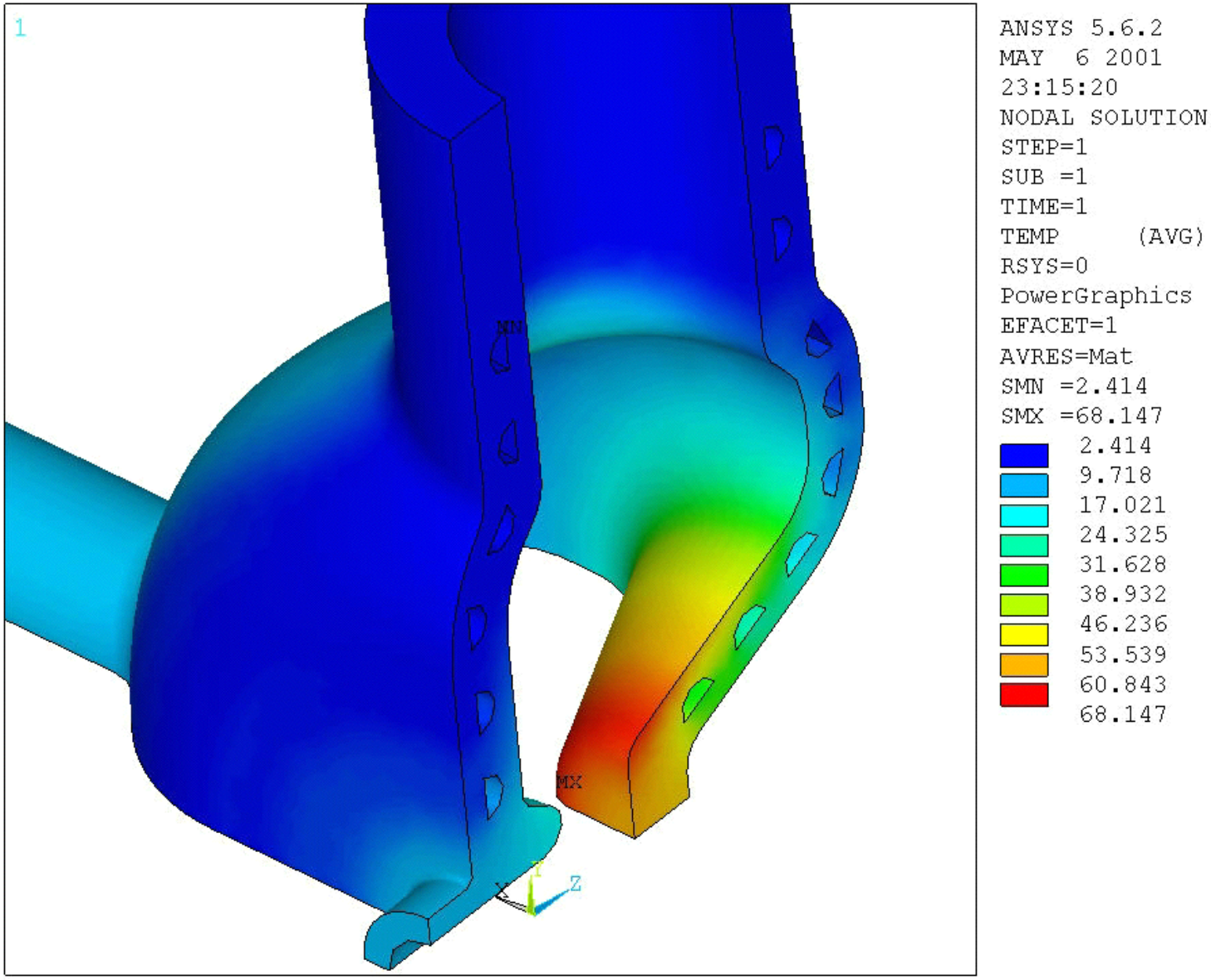
Kilpatric ~21 MV/m @476 MHz, ~32 MV/m @ 1.3 GHz, ~44 MV/m @ 2.6 GHz



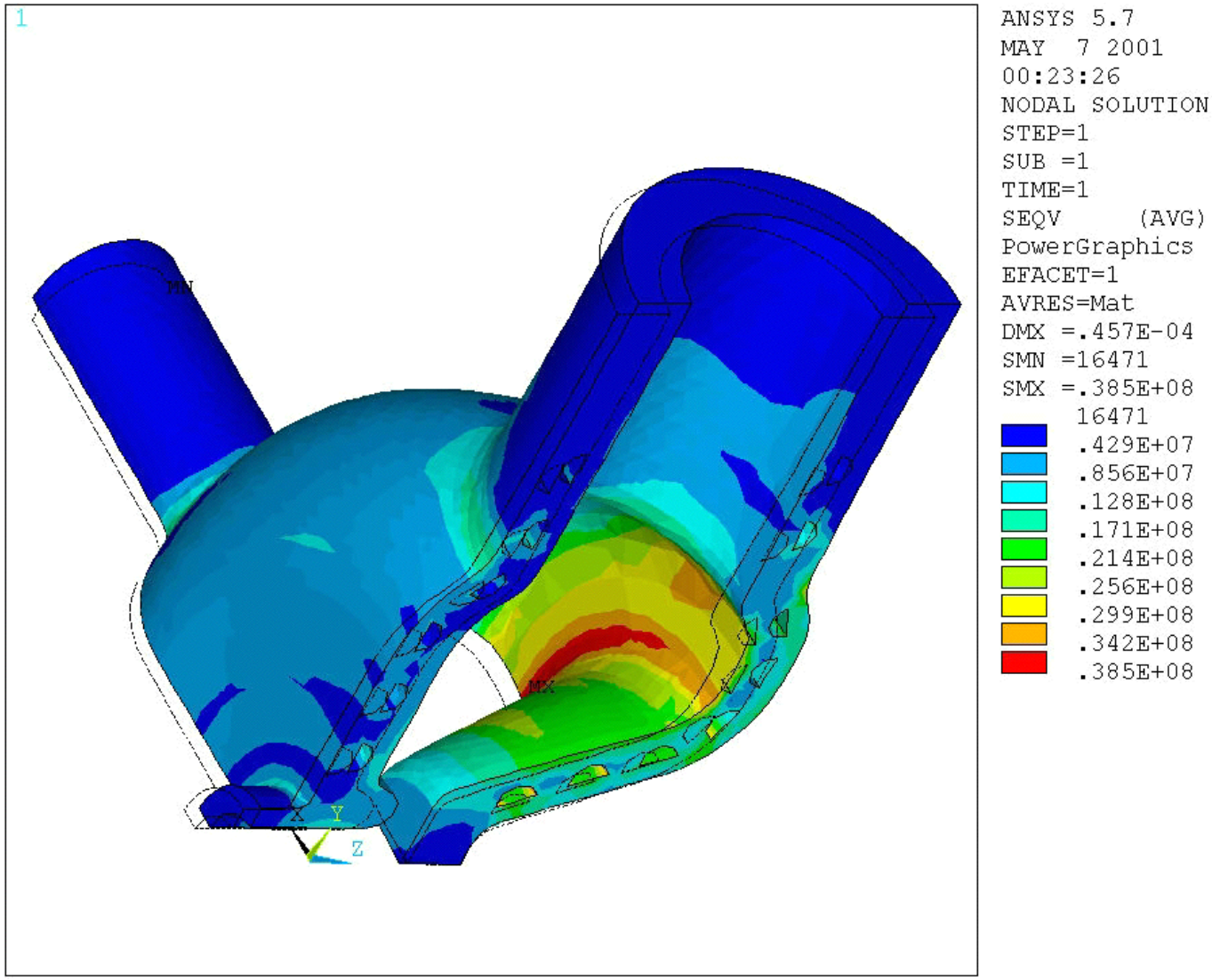
ANSYS model of 1.3 GHz gun cavity with cooling channels
(Neal Hartman.)



Surface magnetic field, max towards base of nosecone



Temperature rise over ambient for 13.6 kW average power



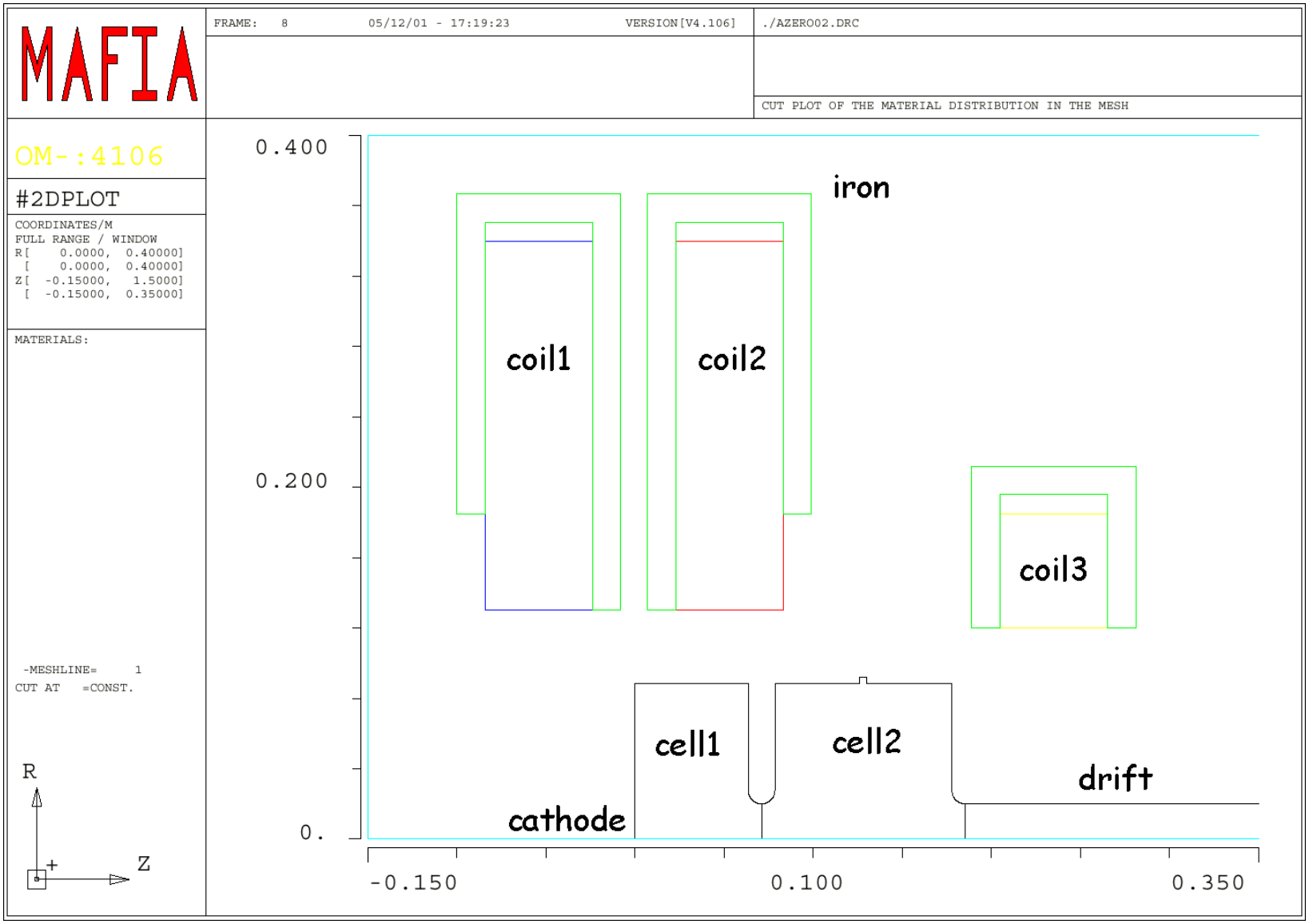
Von Mises stress for 13.6 kW average power. Max=38.5 MPa (~5500 psi).
(PEP-II 10,900 psi @ 150 kW, limit for Cu ~18,000 psi @ 10,000 cycles)

MAFIA gun calculation

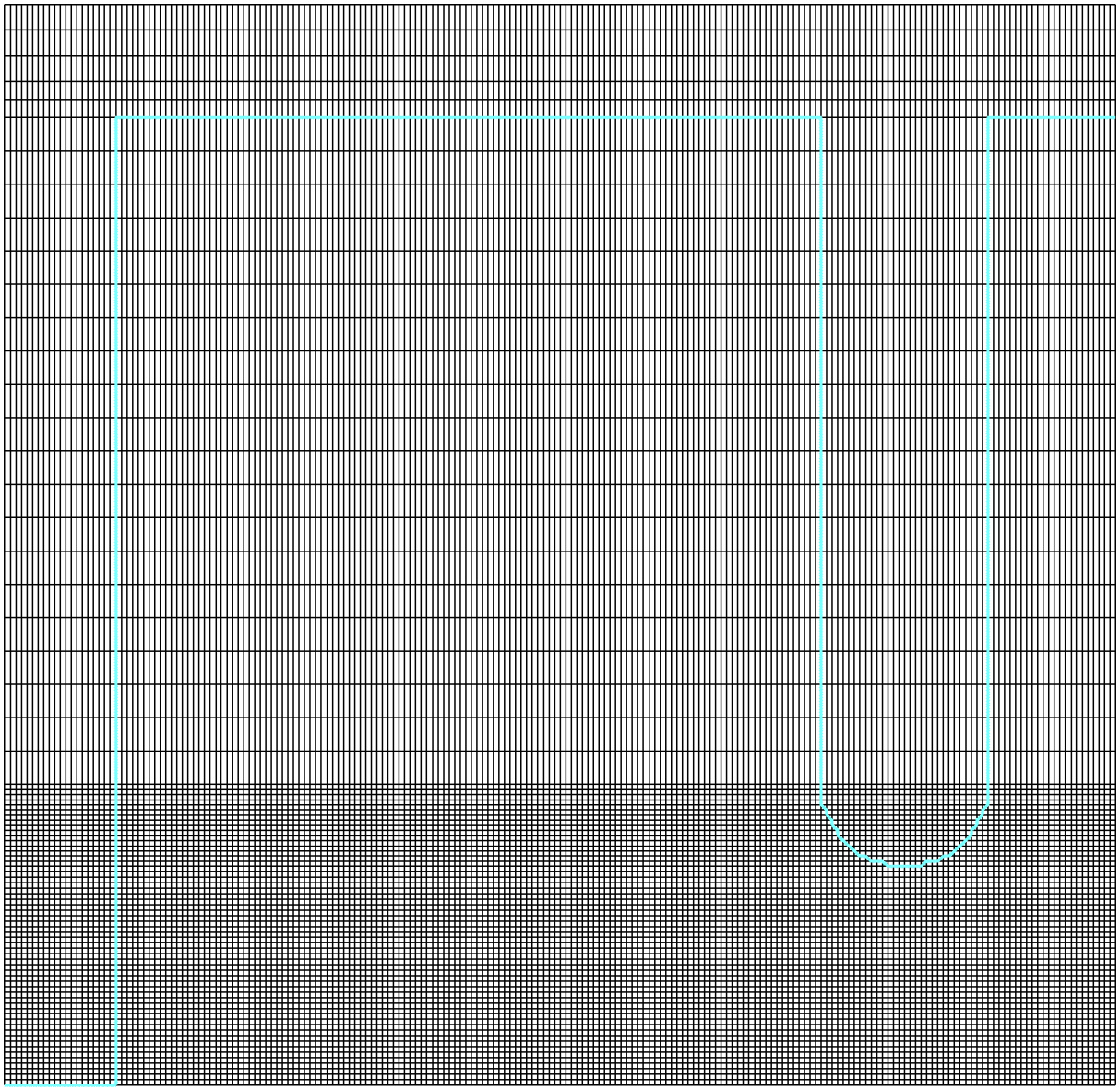
- Use MAFIA 2D PIC module "TS2"

  Solve for static magnetic field in "S"
  Solve for cavity fields in "E"
  load into TS2 and push particles

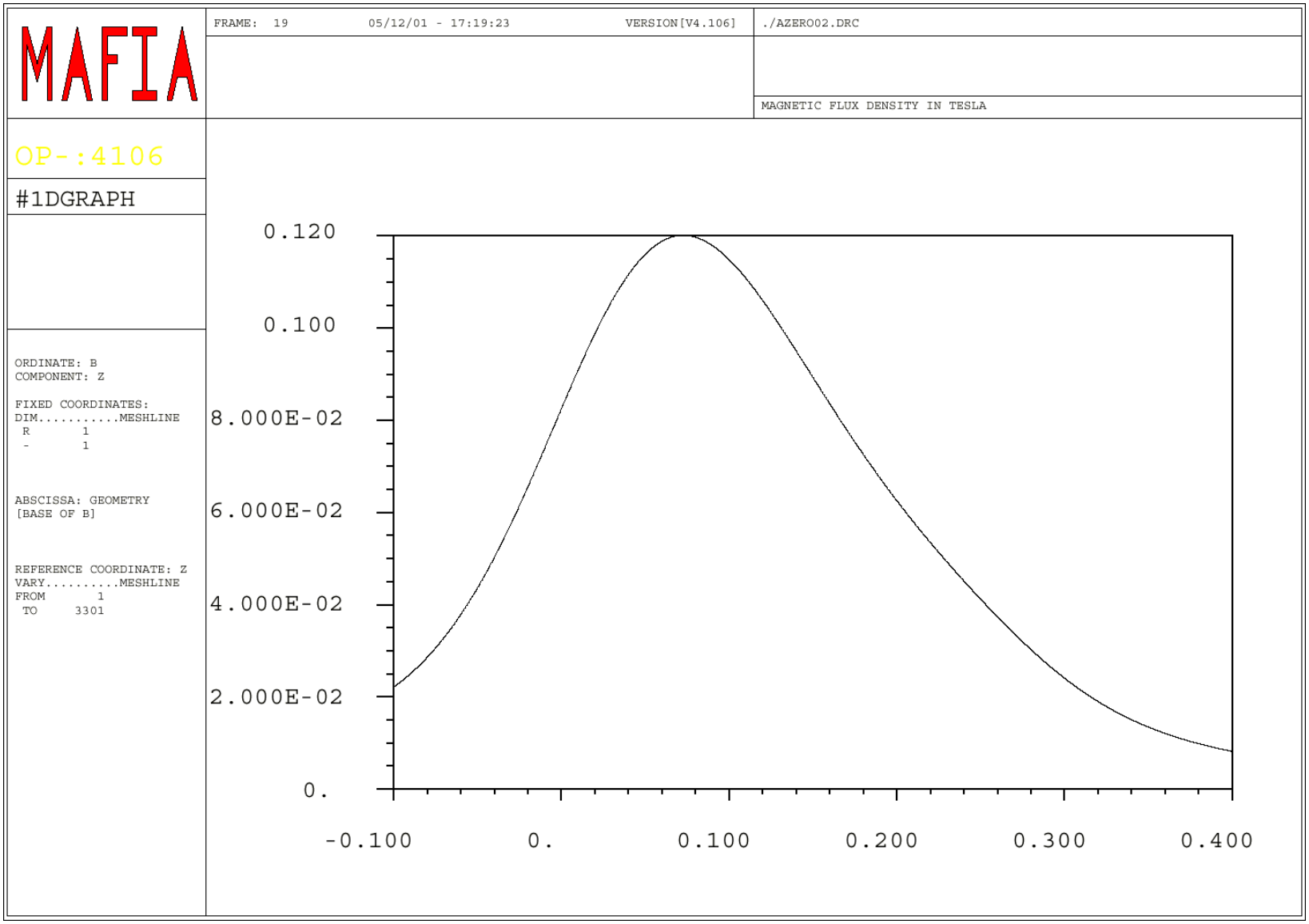
- Attempt to calibrate against Parmela and A0 measurements.



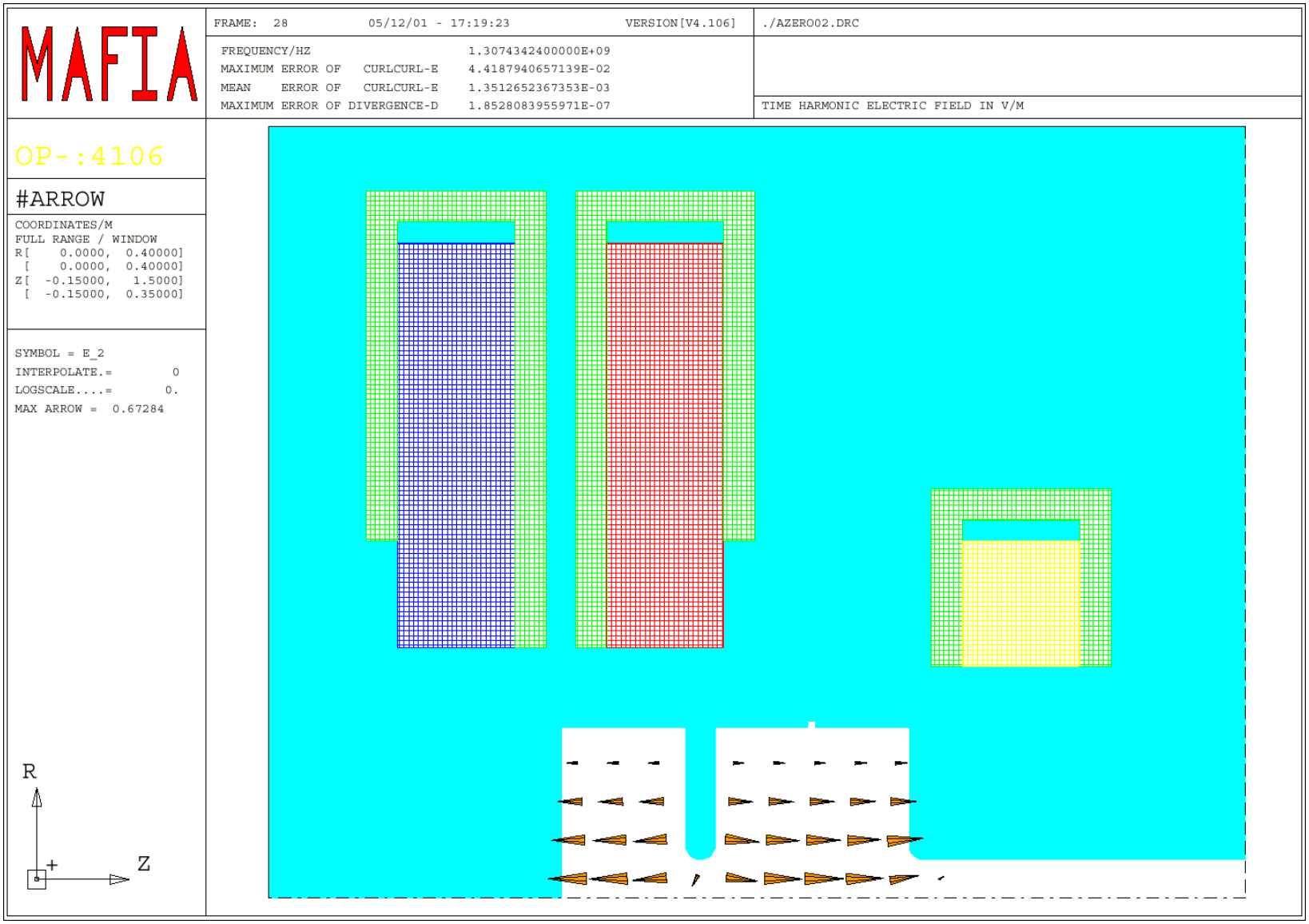
MAFIA model of A0 gun components



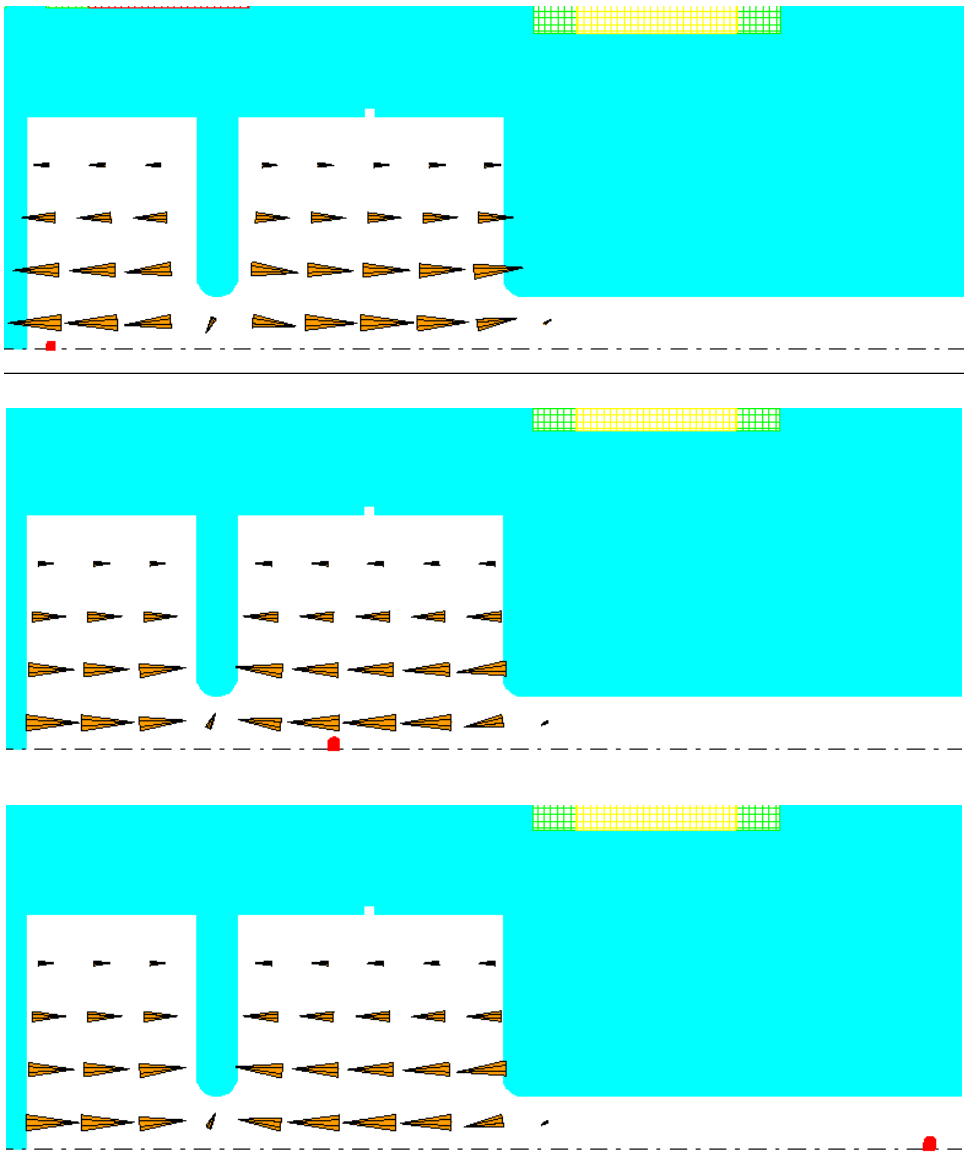
Gun-cell mesh (0.5 mm in beam region)



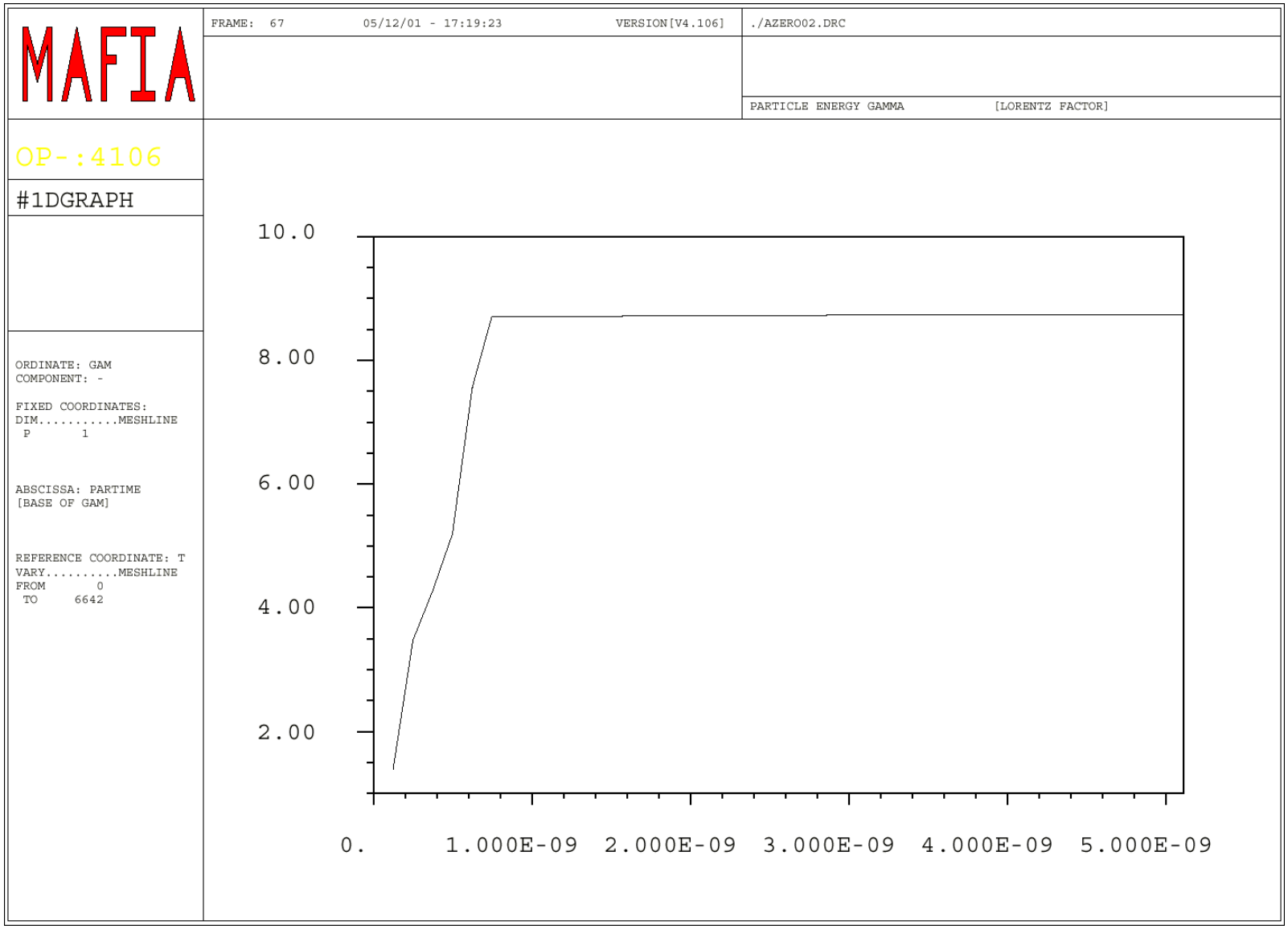
Bz on axis for 0-170-70 A current settings



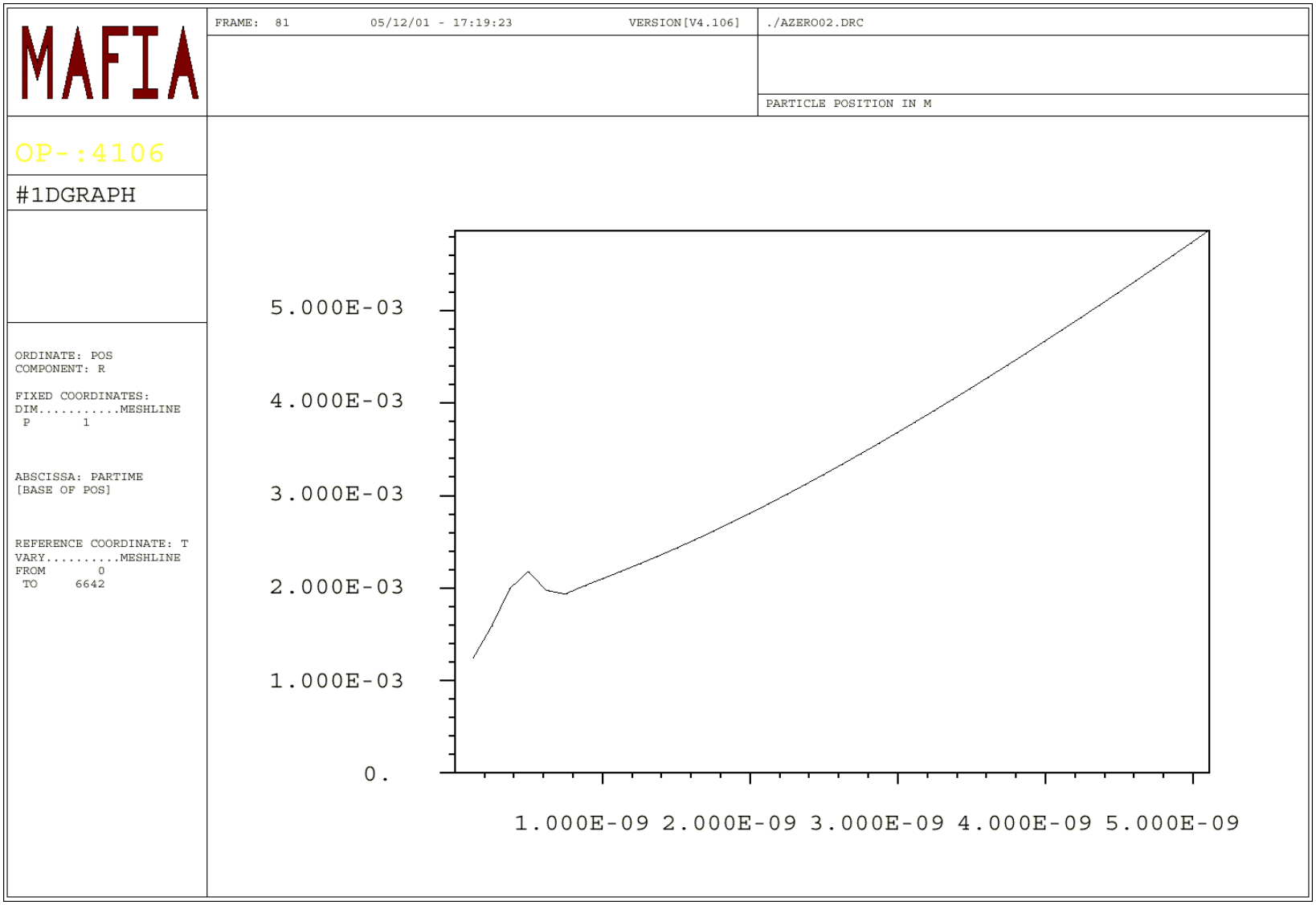
MAFIA solution for Pi mode



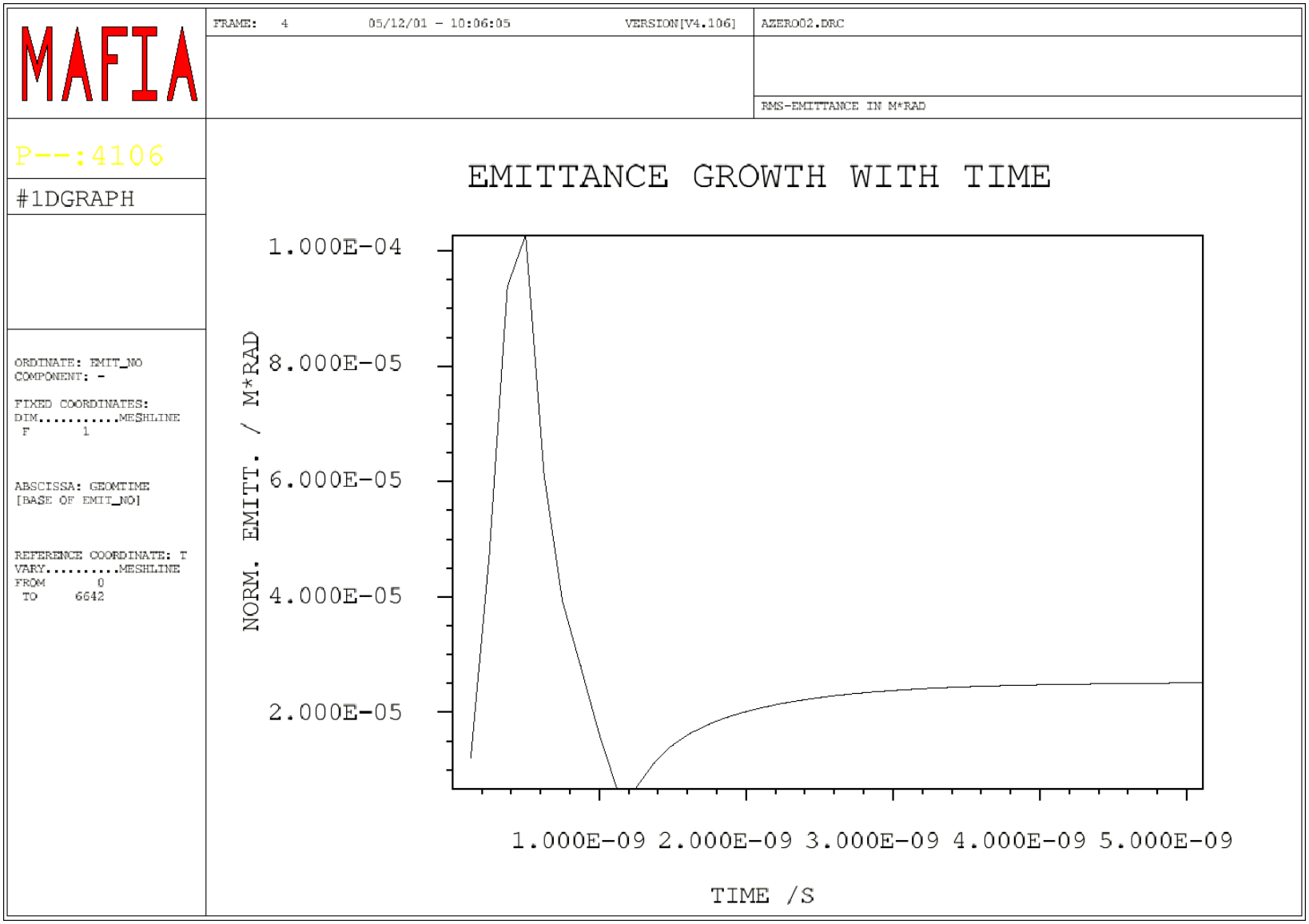
track particles through time-varying fields


MAFIA
FRAME: 67
05/12/01 - 17:19:23
VERSION[V4.106]
./AZERO02.DRC
PARTICLE ENERGY GAMMA
[LORENTZ FACTOR]
OP-:4106
#1DGRAPH
ORDINATE: GAM
COMPONENT: -
FIXED COORDINATES:
DIM.....MESHLINE
P 1
ABSCISSA: PARTIME
[BASE OF GAM]
REFERENCE COORDINATE: T
VARY.....MESHLINE
FROM 0
TO 6642
10.0
8.00
6.00
4.00
2.00
0.
1.000E-09
2.000E-09
3.000E-09
4.000E-09
5.000E-09

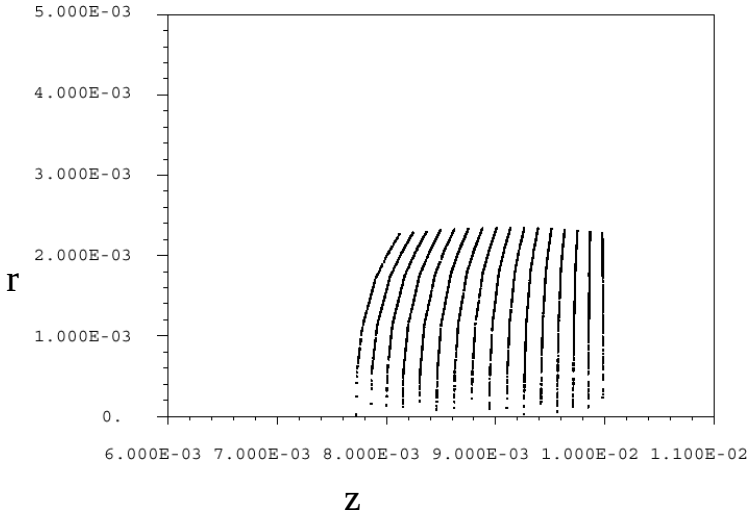
Gamma vs. t



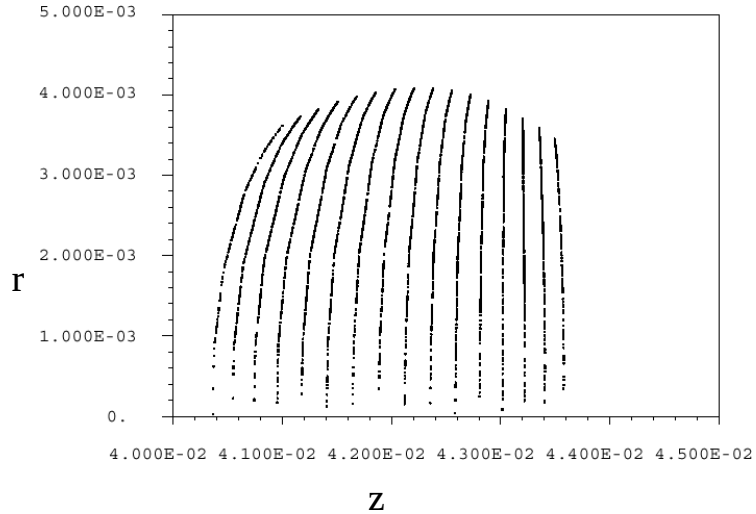
rms radius vs. time



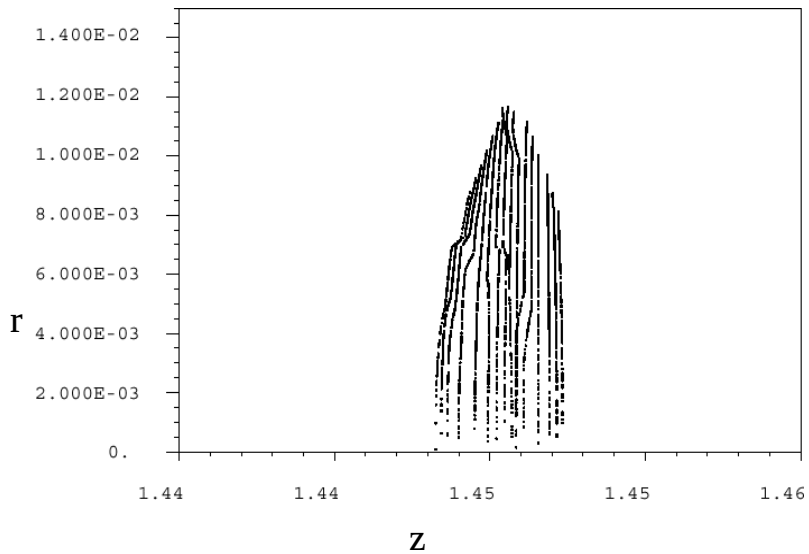
MAFIA transverse emittance vs. time (different from Parmela!)



approx. 9 mm from cathode



about middle of first cell



near end of drift (~1.45m)

Summary of gun results (preliminary)

Coil currents	0-170-70 A
Peak cathode field	35 MV/m
Launch phase	20°
Bunch length	11.7 ps FW (square pulse)
Bunch charge	1 nC
Spot radius	2 mm (uniform distribution)
final energy	3.93 MeV, 1% spread (at 1.46m)
final bunch length	3.52 ps, 1.1 mm sigma
final bunch radius	11.7 mm max., 7.6 mm rms
Norm. Trans. rms emit.	25 mm-mrad (at 1.46m) mostly azimuthal?
Norm. Long. rms emit.	1.3 e-7 eVsec (at 1.46m)

To do:

Continue calibration of MAFIA

- try to reach convergence with Parmela, A0 experiments.
- try to reproduce trends with launch phase, gradient, charge, spot size, solenoid fields etc.
- replace pillbox gun with reentrant version
- overall optimization for femtosource.

Investigate RF sources
ANSYS analysis of final gun design
High-power test a prototype?