Hyper-Nuclear
Stray Fields along Beamline

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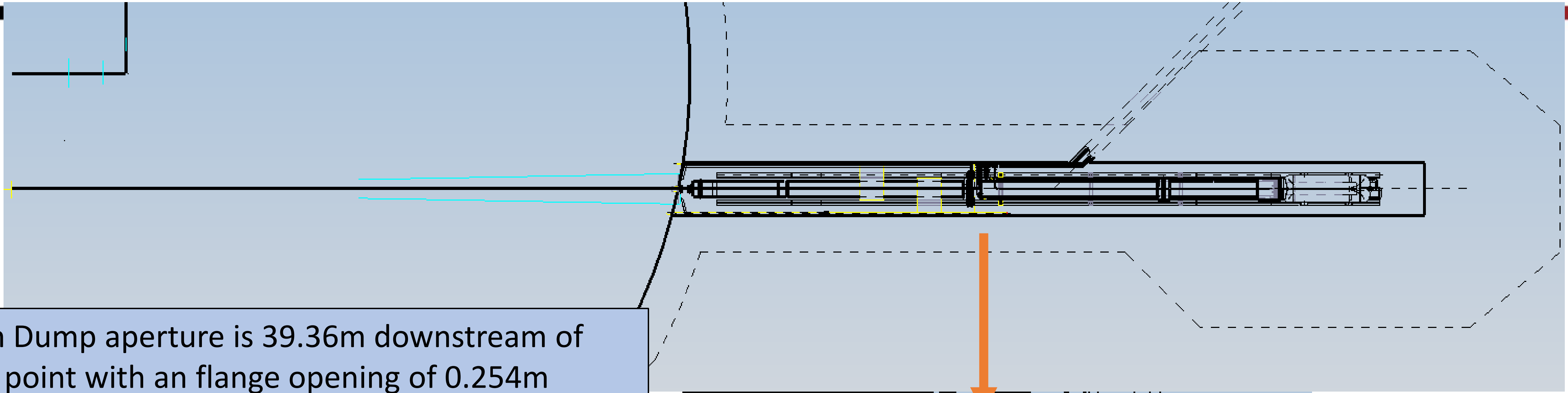
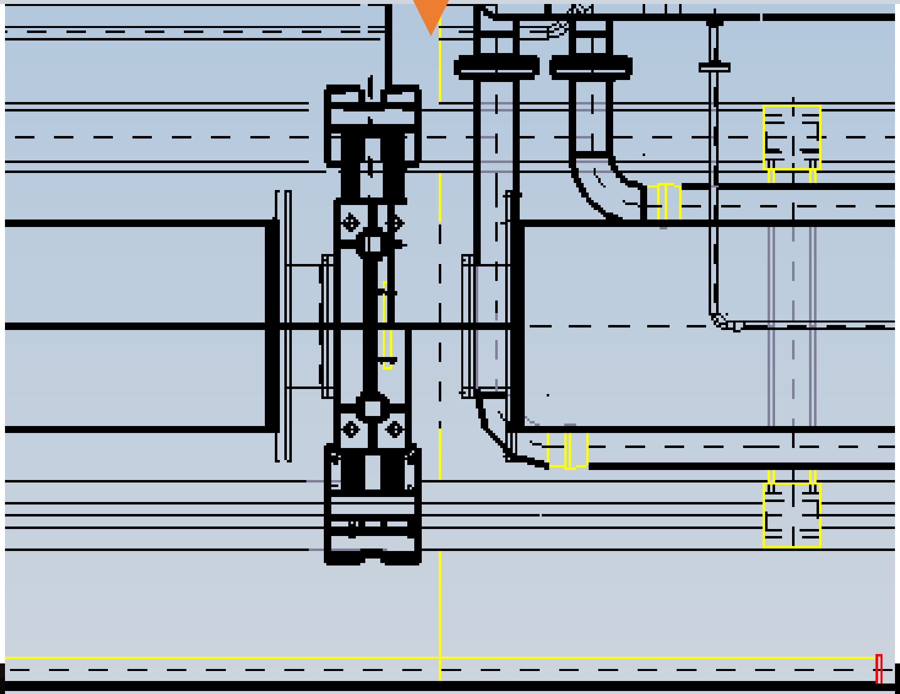
Investigation into stray field from Dipole magnets on the main beam line

- A rough order of magnitude estimate to determine if a corrective magnet or beam line shielding or both is needed.
- No stray fields from Quadrupole magnets
- Uses individual Tosca solutions and superimposes fields from all Dipole magnets.
- Field directions checked for correct polarization.
- Each Model orientated to give correct location relative to layout for Hyper-Nuclear experiment in Hall C.
- UNITS: CGS unless noted.

Hall C Beam Dump





Beam Dump aperture is 39.36m downstream of pivot point with an flange opening of 0.254m diameter. Center Window of beam dump is ~4” diameter (0.10m or 0.05m radius)

HyperNuclear target is 6.58m downstream of pivot. (33.78m target to beam dump window).
Beam mis-steering starts around PCS magnet ~1 meters downstream of target

½ Angle for beam to strike the smaller diameter window of the beam dump due to mis-steering of beam from PCS location is 1.5mrad (0.05/32.78).

Beam Dump Deflection Estimate

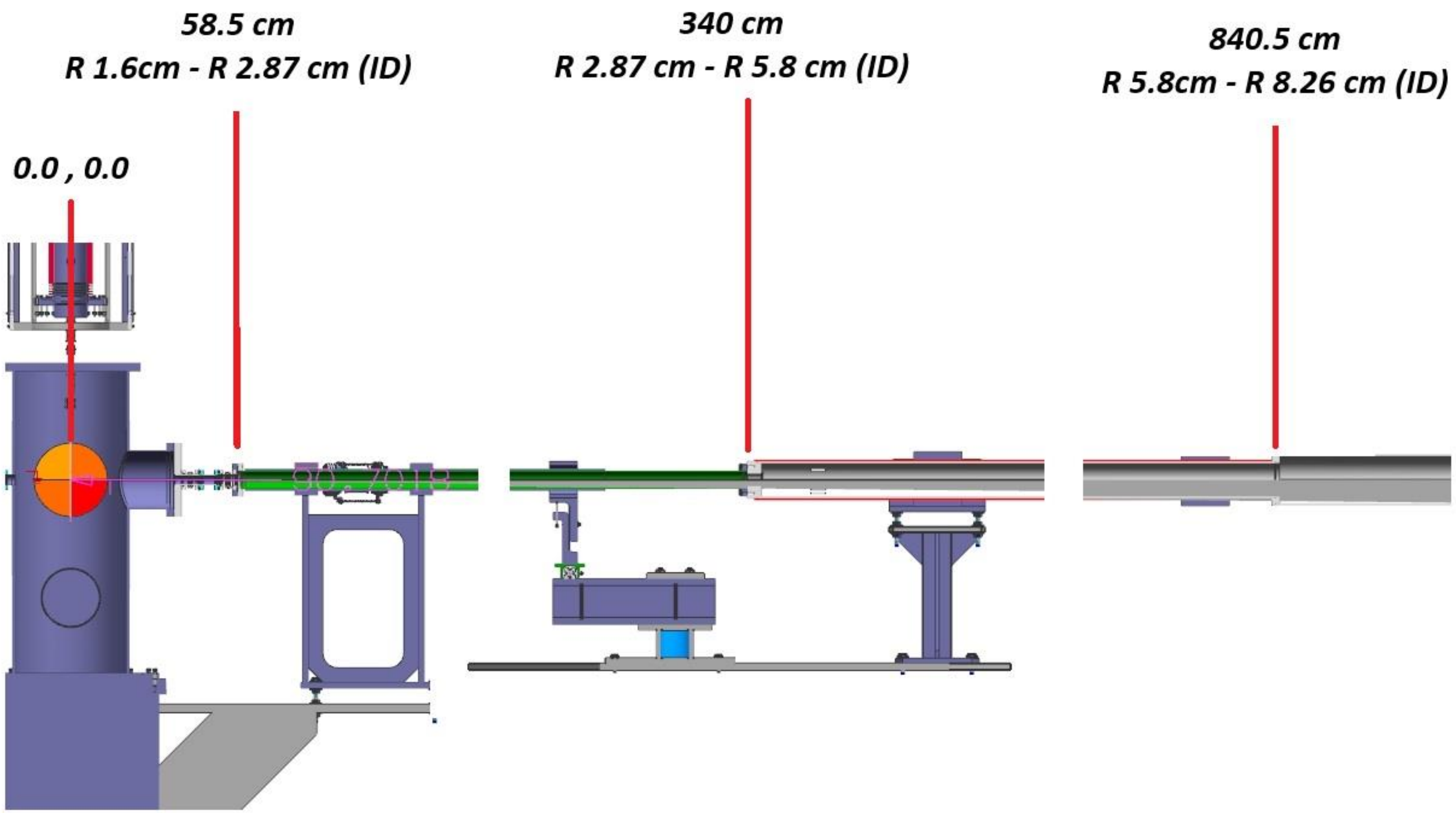
- Using the uniform Dipole estimate of
- Ø(rad) = ∫ B.dL (T.m)

  (3.3356 x p (Gev))
- p =2.24 Gev
- Angle to hit edge of beam dump's inner window is 1.5 mrad.
- Overall the Maximum stray field should be less than +/- 0.0112 T.m, but one needs to keep the beam deflection with the telescoping beam line (inside radius), to minimize scrapping within the hall.
- Additionally, individual magnet's stray fields should also keep the beam with the beam pipe inside the hall.

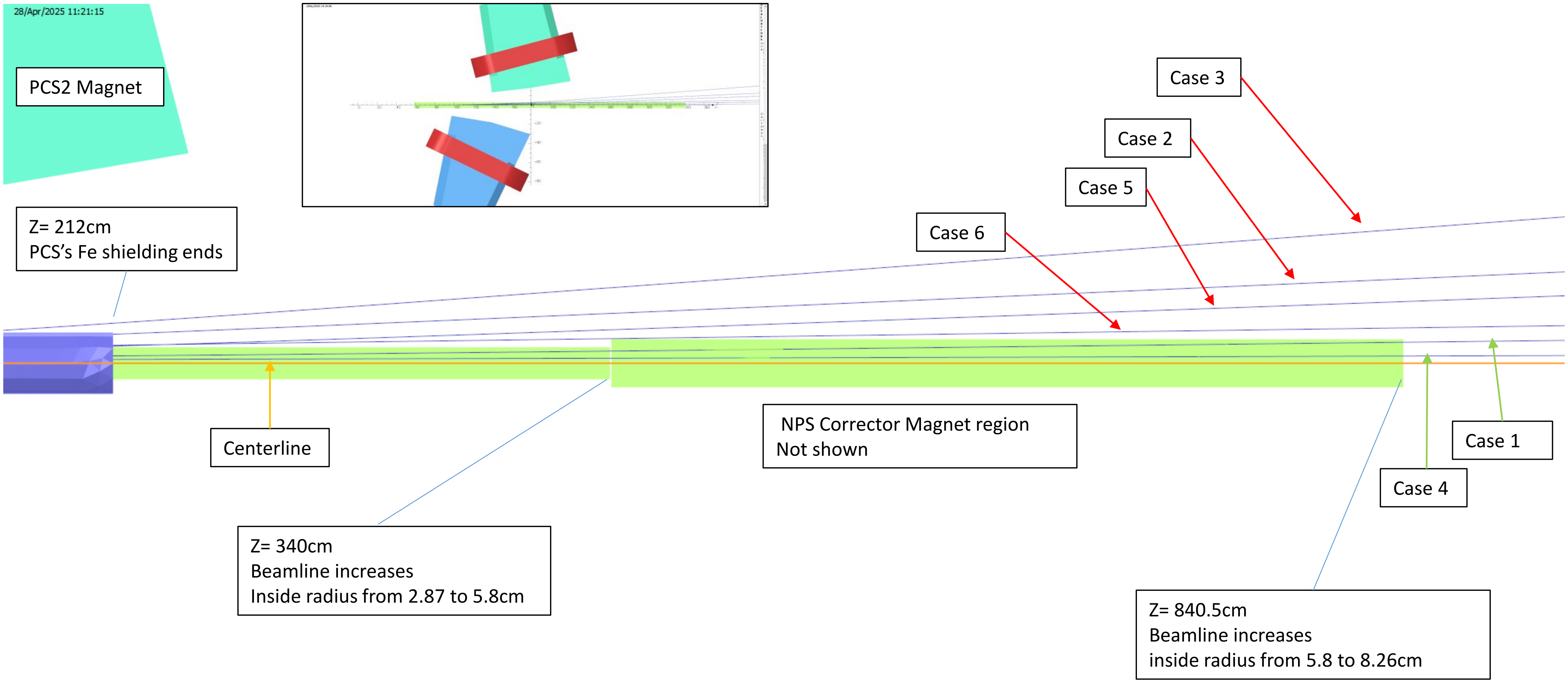
Stray Fields Summary [T.m]

Pipe Shielding	No	No	No	Yes x3	Yes x3	Yes x3	Yes x3	Yes/No/Yes
ENGE	-0.00104	-0.00104	-0.00104	-0.00113	-0.00113	-0.00113	-0.00113	-0.00113
PCS Case #	1	2	3	4	5	6	4	1
CC Polarity	PCS Neg CC	PCS No CC	PCS +CC	PCS Neg CC	PCS No CC	PCS +CC	PCS Neg CC	PCS Neg CC
PCS	0.1244	0.3427	0.5604	0.0921	0.2875	0.2666	0.0921	0.1244
HKS/HES Case #	3	3	3	4	4	4	4	4
HKS/HES	-0.3700	-0.3700	-0.3700	-0.1700	-0.1700	-0.1700	-0.1700	-0.1700
NPS Corrector							0.0424	0.0424
SUM	-0.2466	-0.0283	0.1894	-0.0791	0.1163	0.0954	-0.0366	-0.0043

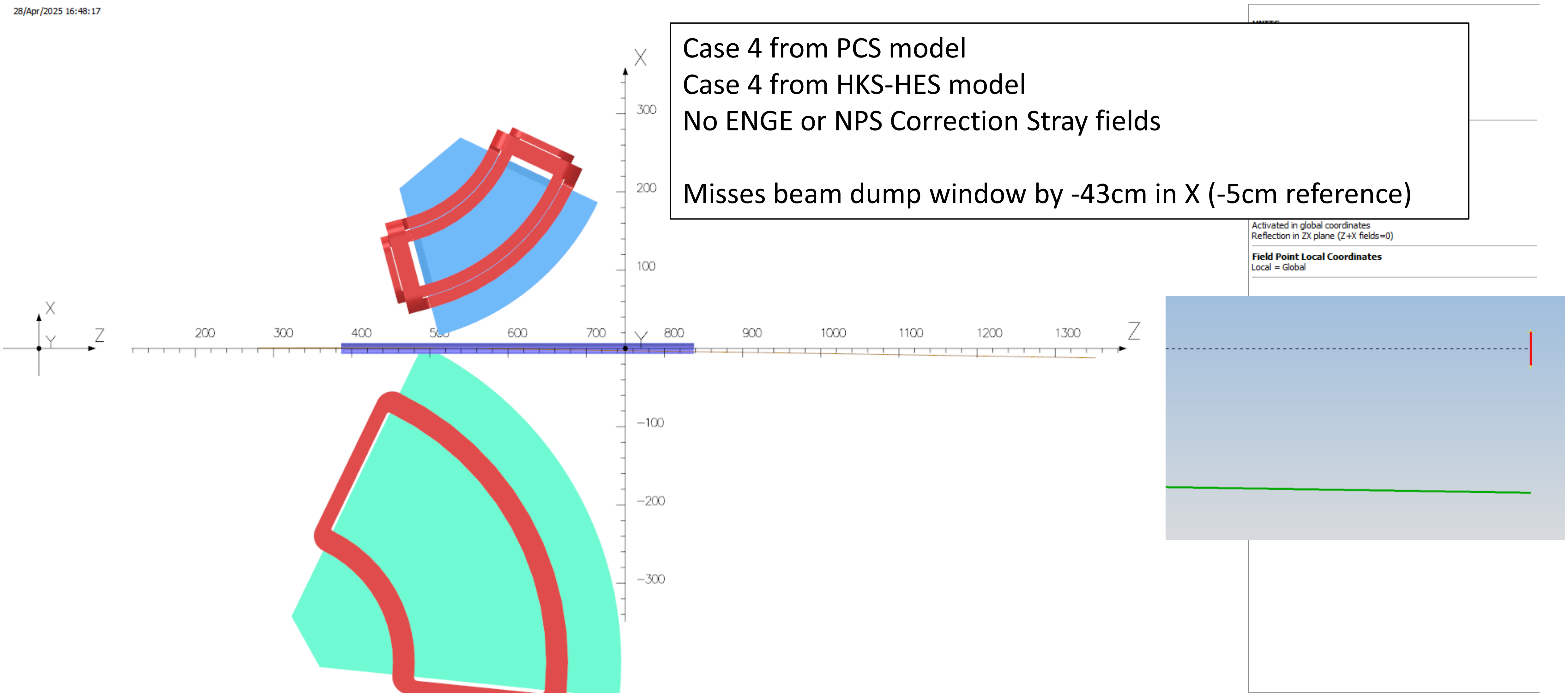
Updated Beamline to accommodate beam deflection from stray field



PCS Stray Field kick: cases



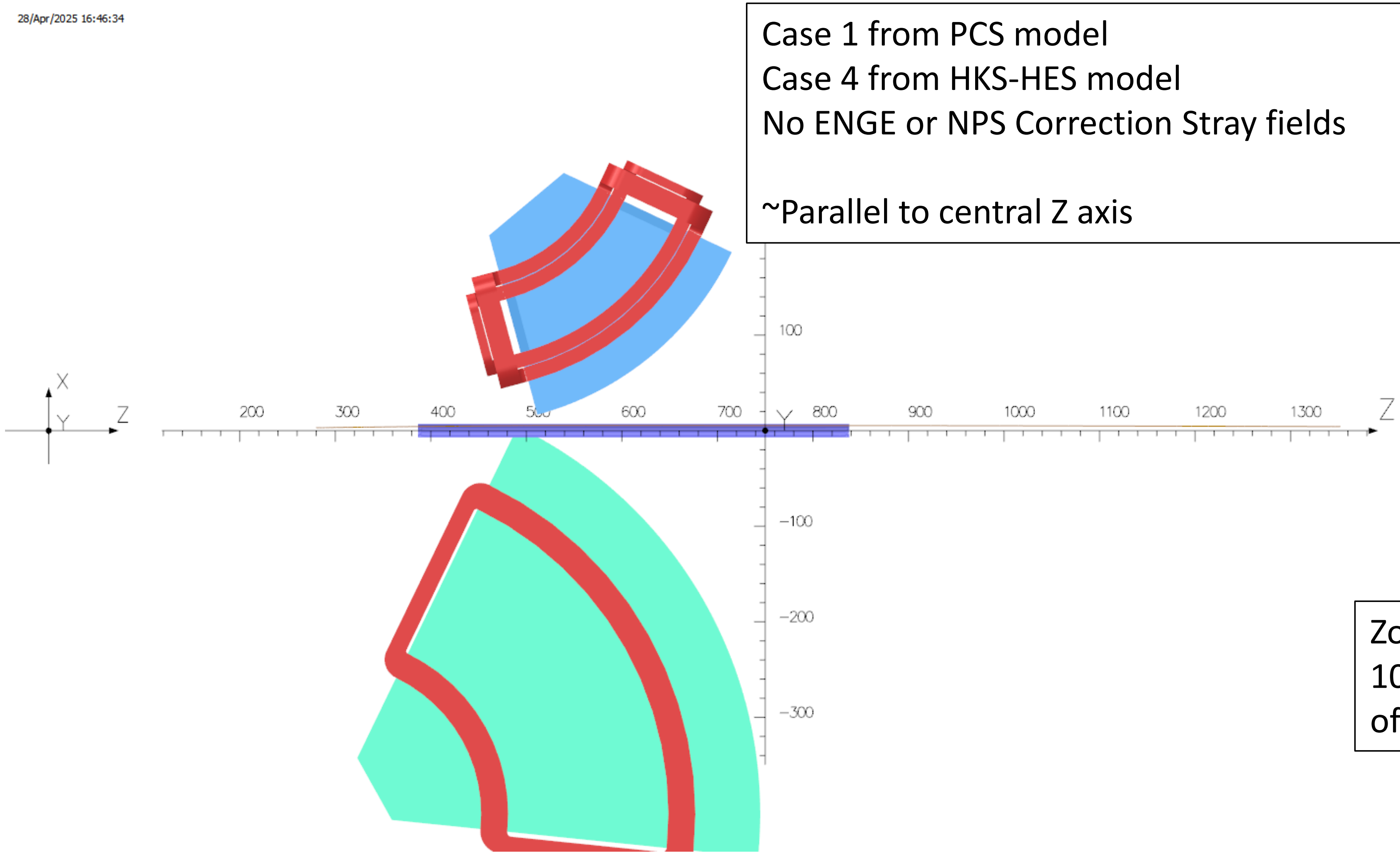
HES and HKS Ray trace



Case 4 from PCS model
Case 4 from HKS-HES model
No ENGE or NPS Correction Stray fields

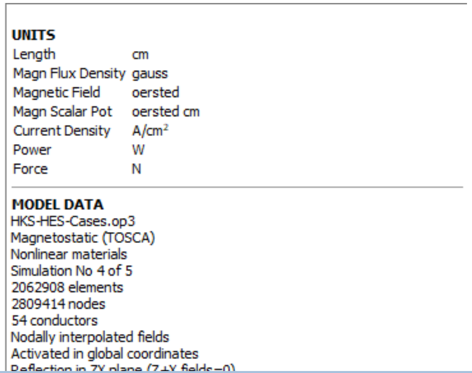
Misses beam dump window by -43cm in X (-5cm reference)

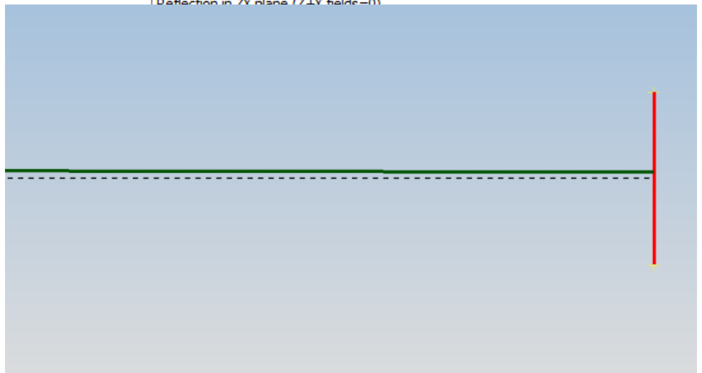
HES and HKS Ray trace Best Option



Case 1 from PCS model
Case 4 from HKS-HES model
No ENGE or NPS Correction Stray fields

~Parallel to central Z axis





Zoom in of Beam Dump Window's 10cm diameter Deflection is 0.36cm off center line

Stray Fields - Conclusion

- A combination of passive Fe Beamline shielding, negative polarity PCS correction coils and the NPS correction magnet, the integral stray field along the Z axis can be managed to stay within the Beam dump's window aperture and not exceed the beamline.

- Of the cases that keep the integral stray field within the Beam dump window and keeps the e- beam within the downstream pipe was:

  1. ENGE with beam pipe shielding (small effect – not used in raytracing slides)
  2. PCS magnets with negative polarity correction coils and with out beam pipe shielding
  3. NPS corrector magnet (if needed)
  4. HKS and HES with extended length beam pipe Shielding

Backup

Spectrometers' Parameters

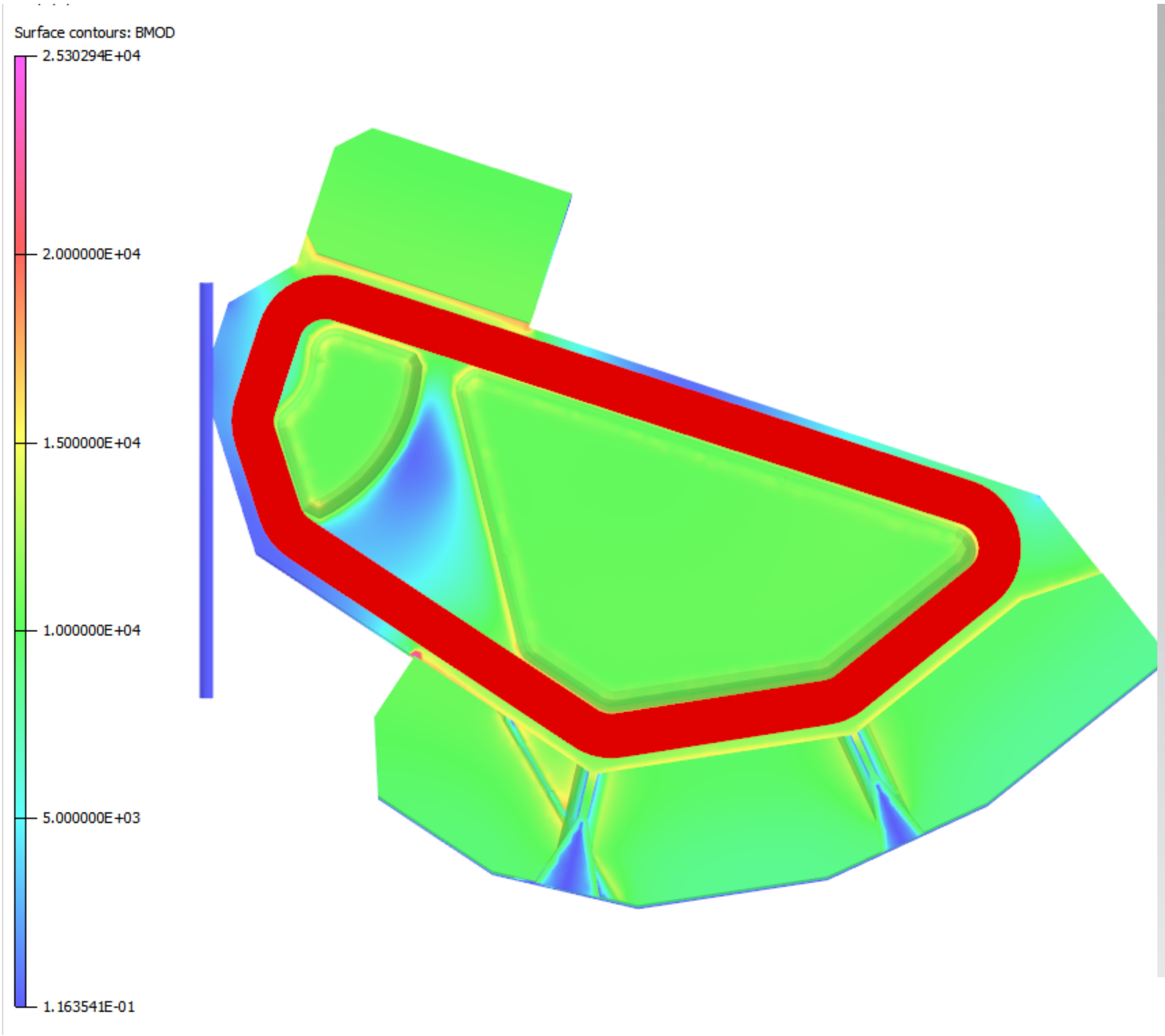
- Beam Energy e- @ 2.24 Gev
- HKS Angle at -25.8° K+ @ 1.200 Gev/c, Kaon mass : 973.721 (relative to e-)
- PCS(K+) angle is at -11.5°
- PCS (K+):
  Main coil J = -393.50 AT/cm^2, NI = -109,167.1 A.T, N = 96, I = -1,137.2 A
  Trim coil J = 666.67 AT/cm^2, NI = 88,000.0 A.T, N = 88, I = 1,000.0 A
- HES Angle at +14.9° e- @0.744 Gev/c electron mass : 1.00
- PCS(e-) angle is at +8.5°
- PCS (e-):
  Main coil J = 50.50 AT/cm^2, NI = 14,010.7 A.T, N = 96, I = 145.9 A
  Trim coil J = -666.67 AT/cm^2, NI = -88,000.0 A.T, N = 88, I = -1,000.0 A
- Enge: 110Mev/c Pions @ Angle of 210° (-30°), Pion mass : 273.1268 (relative to e)

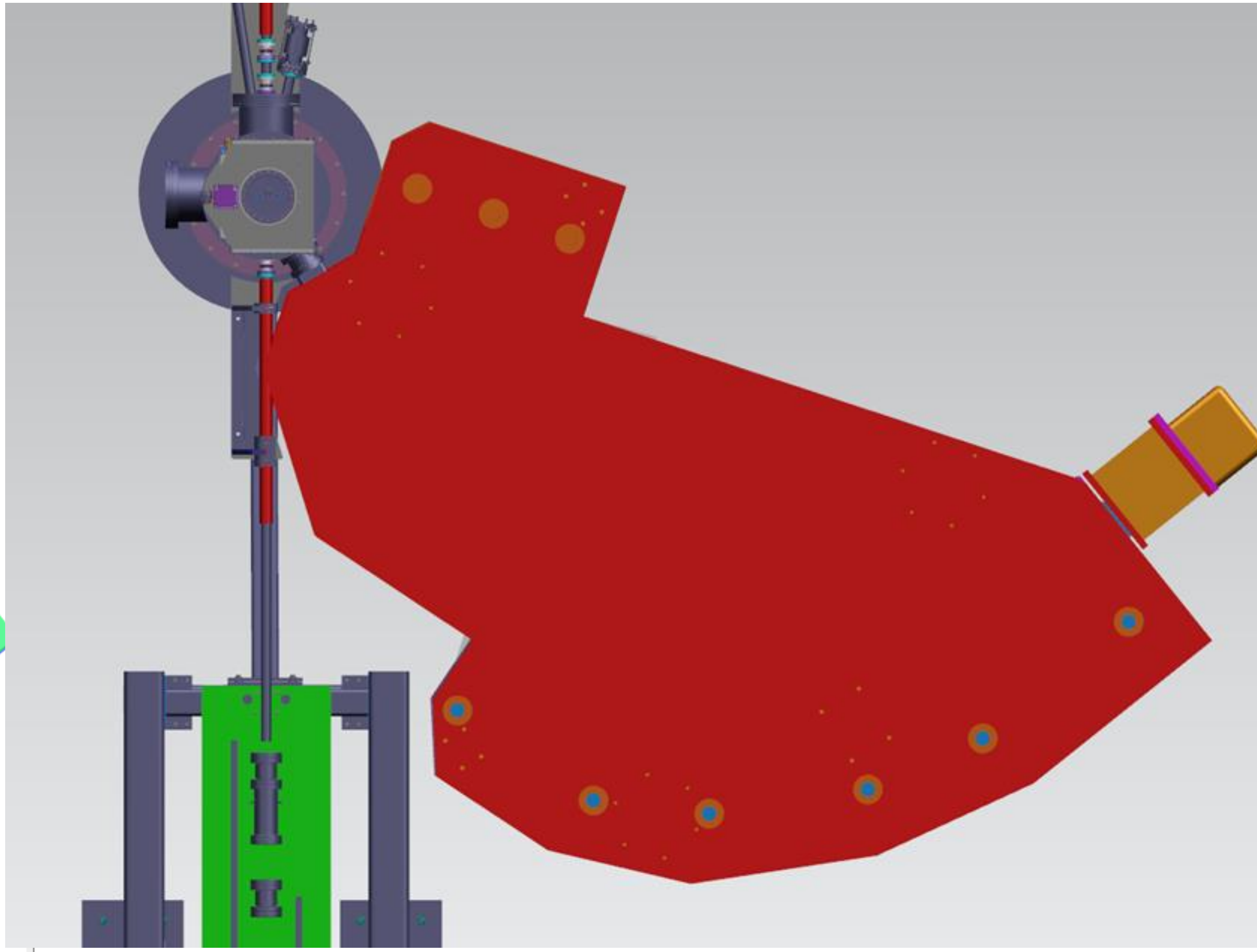
Z axis is towards Beam dump unless otherwise noted. Z=0 is HyperNuclear's Target center, not Hall C's

ENGE Magnet

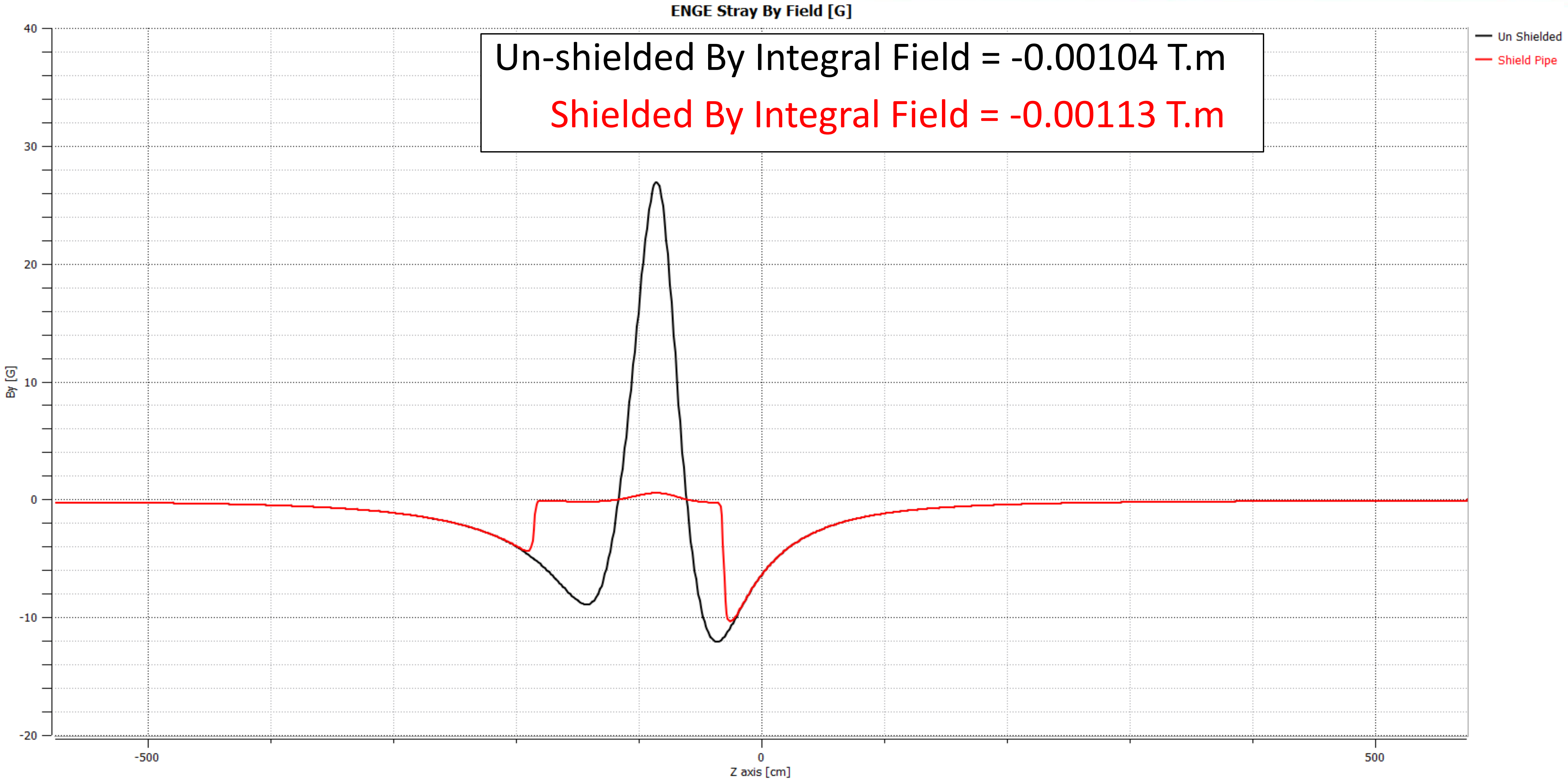
- Ideas Model File: ENGE, Part name: ENGE_Tosca_v2, FEA Model Name: ENGE_magnet_v2
- Universal Filename: ENGE2.unv
- Nodes: 3,785,034 Quad tretra Elements: 2,746,610
- Model Geometry extents: X: -325 to 875, Y: -500 to 0, Z: -575 to 625
- Iron Beam Pipe: Length = 91 Thickness = 0.48 layout in Z from -123 to -32
- NOTE: In Opera post processing, use local CS of Theta=180 to set axis to same orientation as the other magnets.
- Current Density used is J=86 A.T/cm^2 or a current of ~ 209A.
- Midplane views shown for clarity.

ENGE

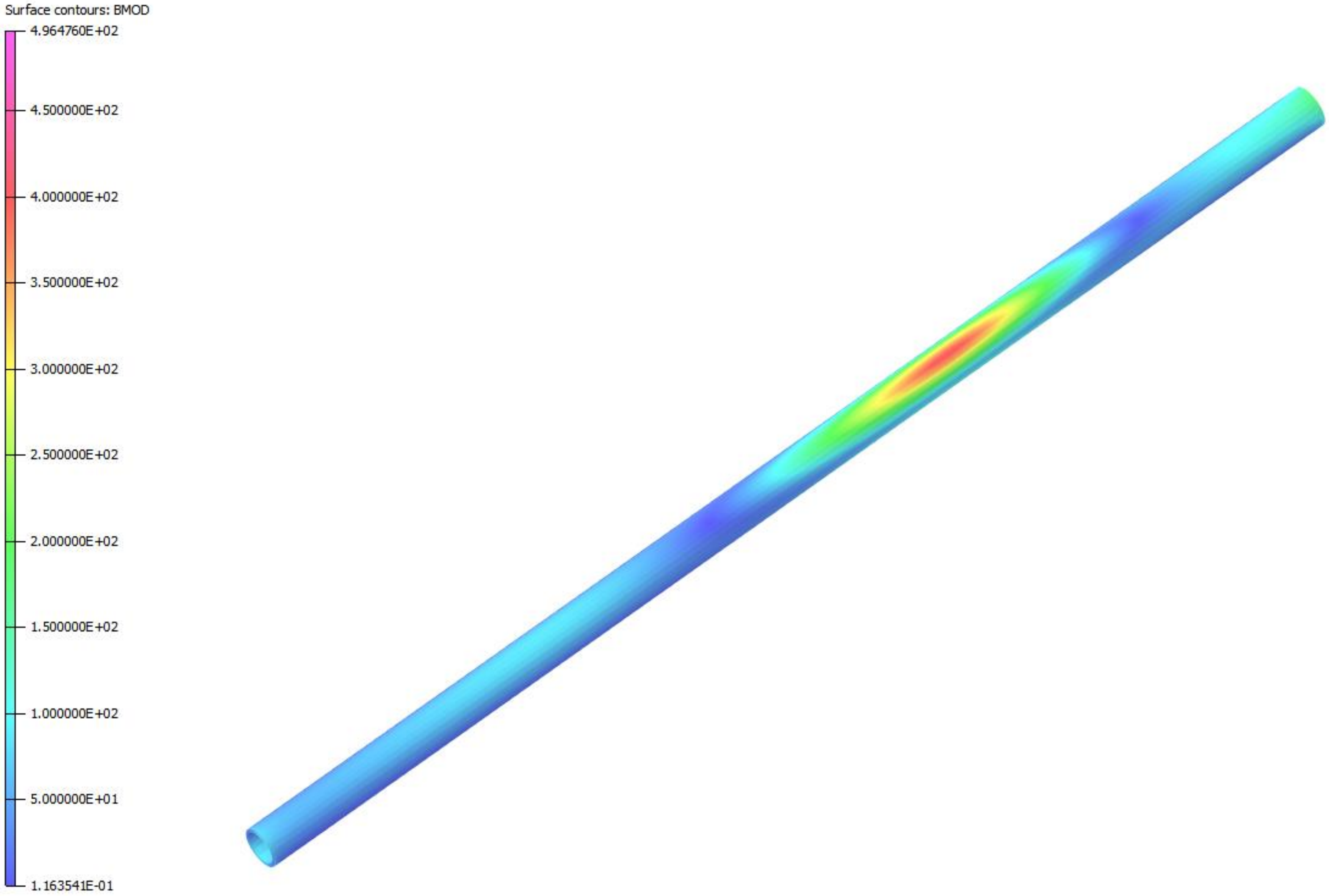

Surface contours: BMOD
2.530294E+04
2.000000E+04
1.500000E+04
1.000000E+04
5.000000E+03
1.163541E-01



ENGE - Longer Shield Pipe



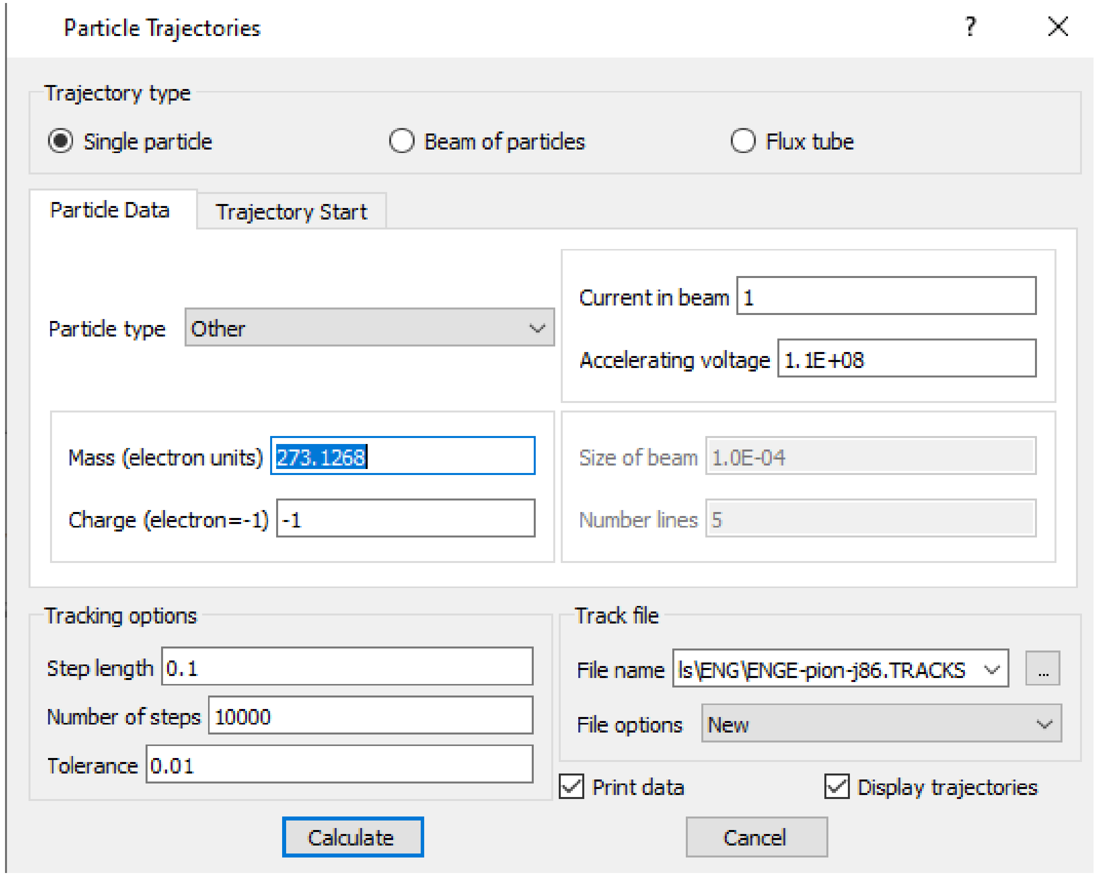
ENGE Pipe Shielding

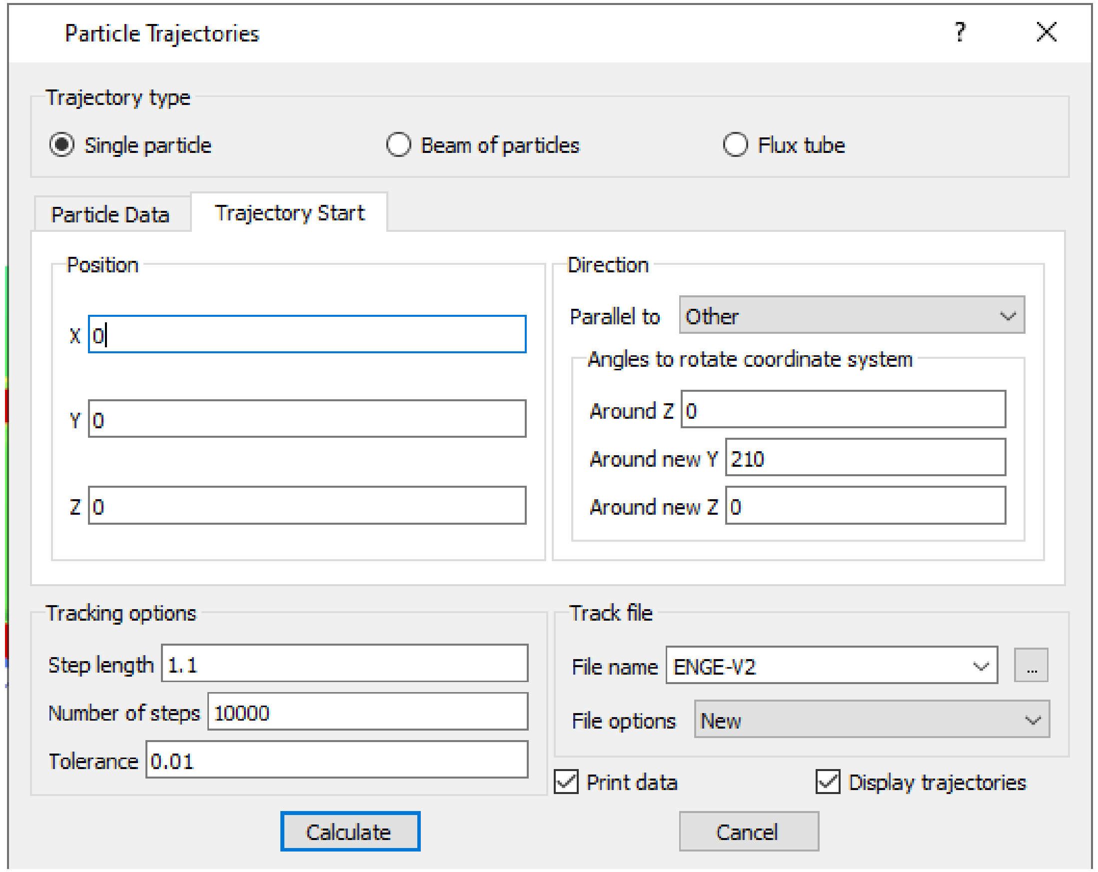


Fx = -0.2 N

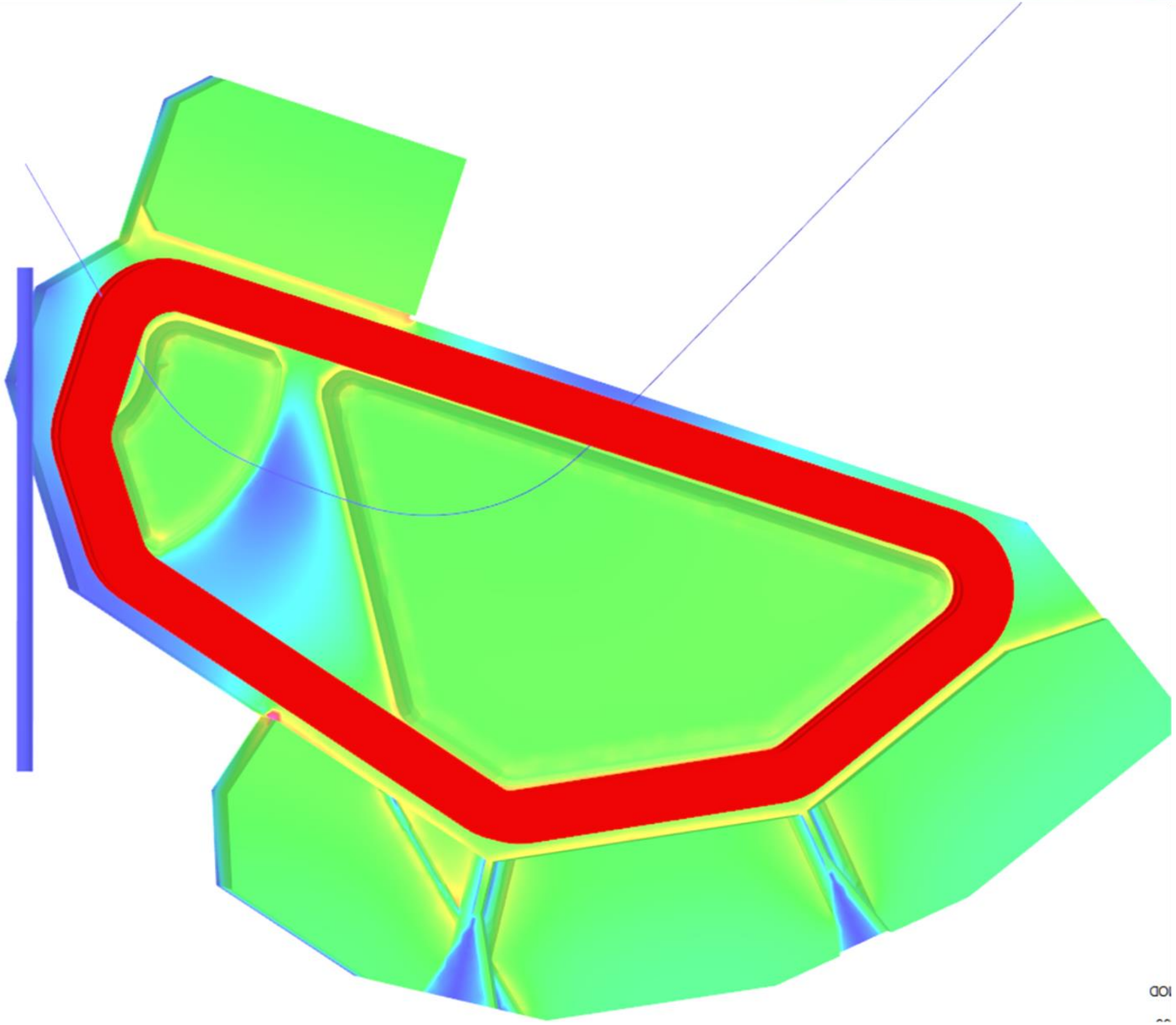
Field = ~500 G

ENGE's PION Trajectory parameters

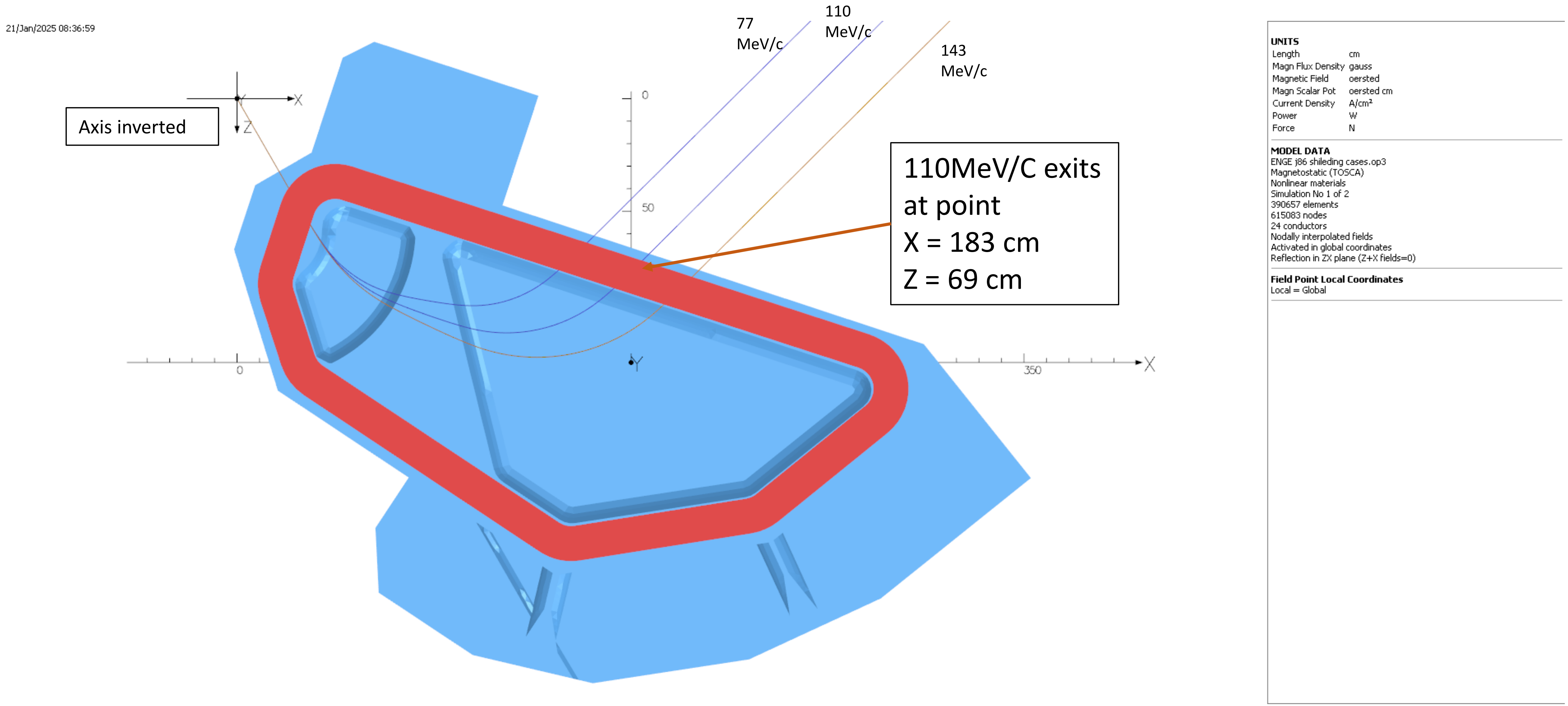




ENGE



Ray Traces for various Pion energies

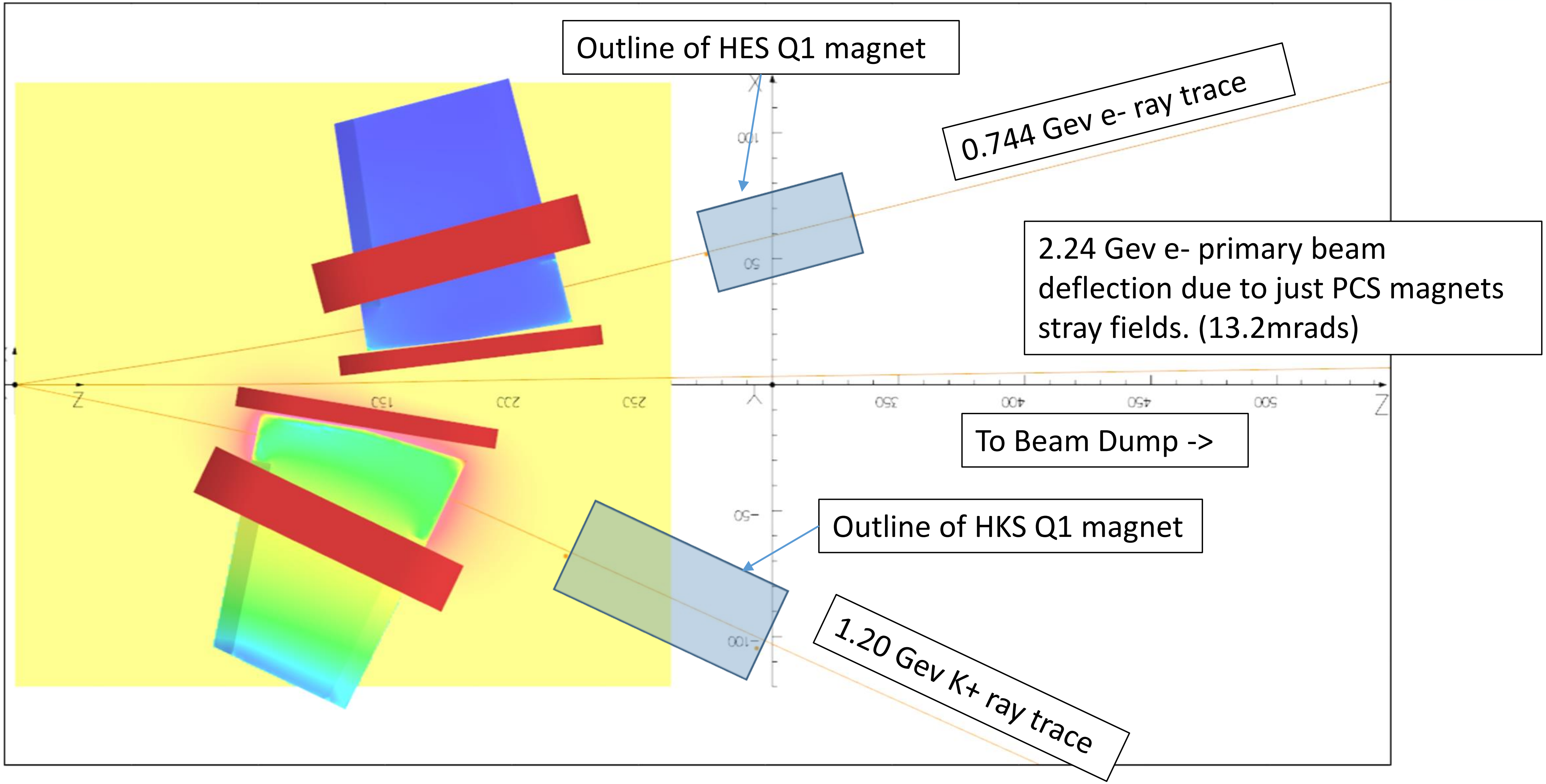


PCS Magnets

- Ideas Model File: PCS-Forces, Part name: PCS Magnets Tosca, FEA Model Name: Finer Mesh withFe pipe
- Universal Filename: PCS-forces-beampipe1.unv
- Nodes: 5,065,314 Quad tretra Elements: 3,680,097
- Model Geometry extents: X: -1,270 to 1,270 Y: 0.0 to 635, Z: -508 to 1,270
- Iron Beam Pipe: Length = 152 Thickness = 0.70 layout in Z from 60.0 to 212

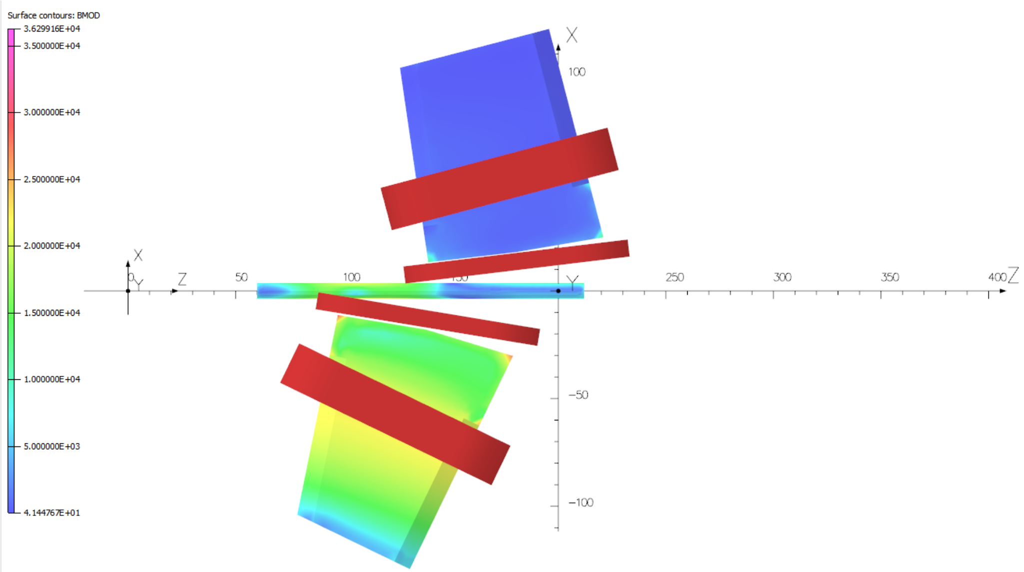
- Main Coils Current Density: J=86 A.T/cm^2 or a current of ~ 209A.
- Correction Coil's Current Density: +/- 666.67 A.T/cm^2 or Zero.

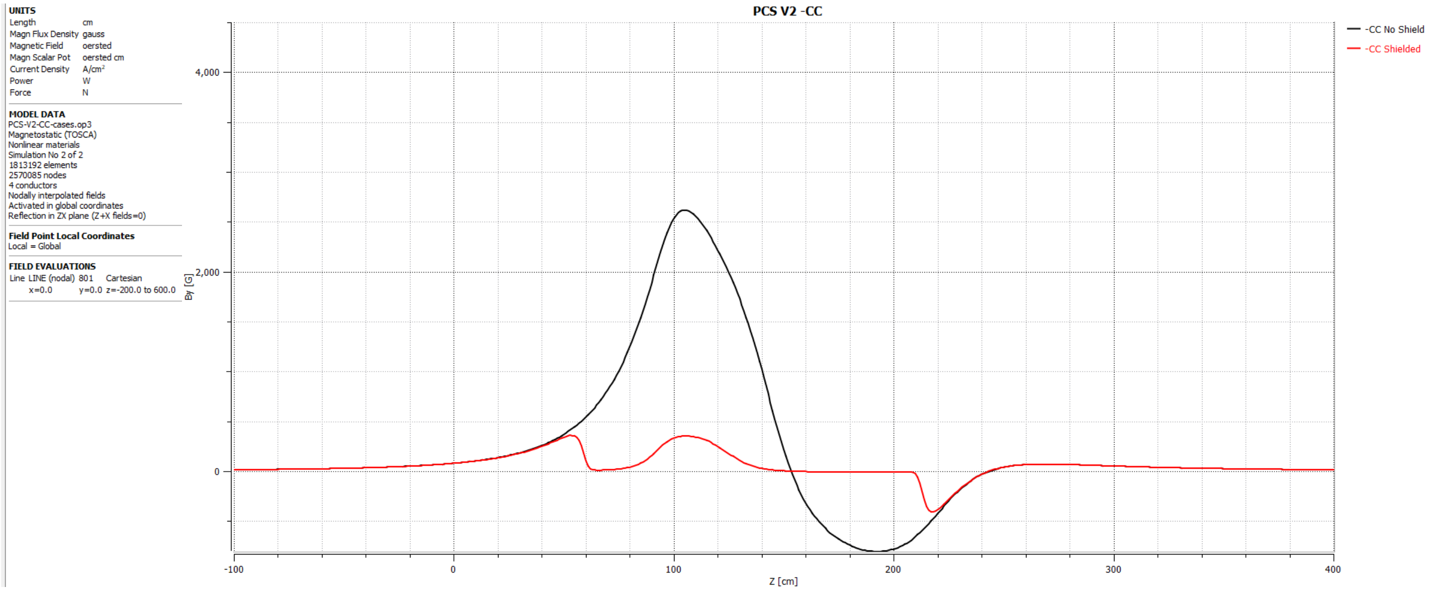
PCS Magnets: Calculated current excitations by matching rays to Q1's center points (with Correction coils on).



PCS V2 Correction Coils - Polarity

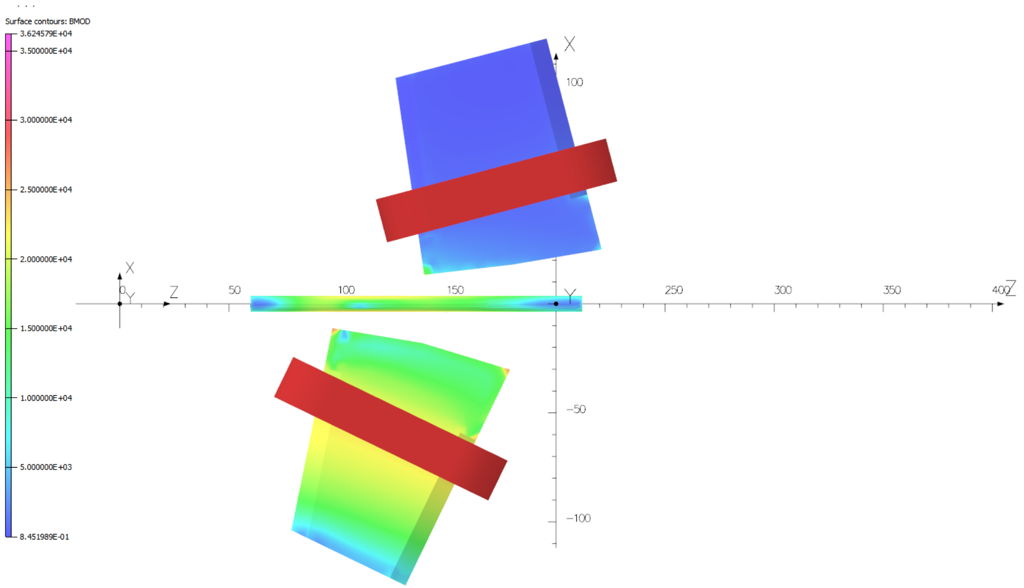
Stray field along Z axis
Without Fe shielding : 0.124 T.m   Case 1
With Fe shielding   : 0.0921 T.m Case 4

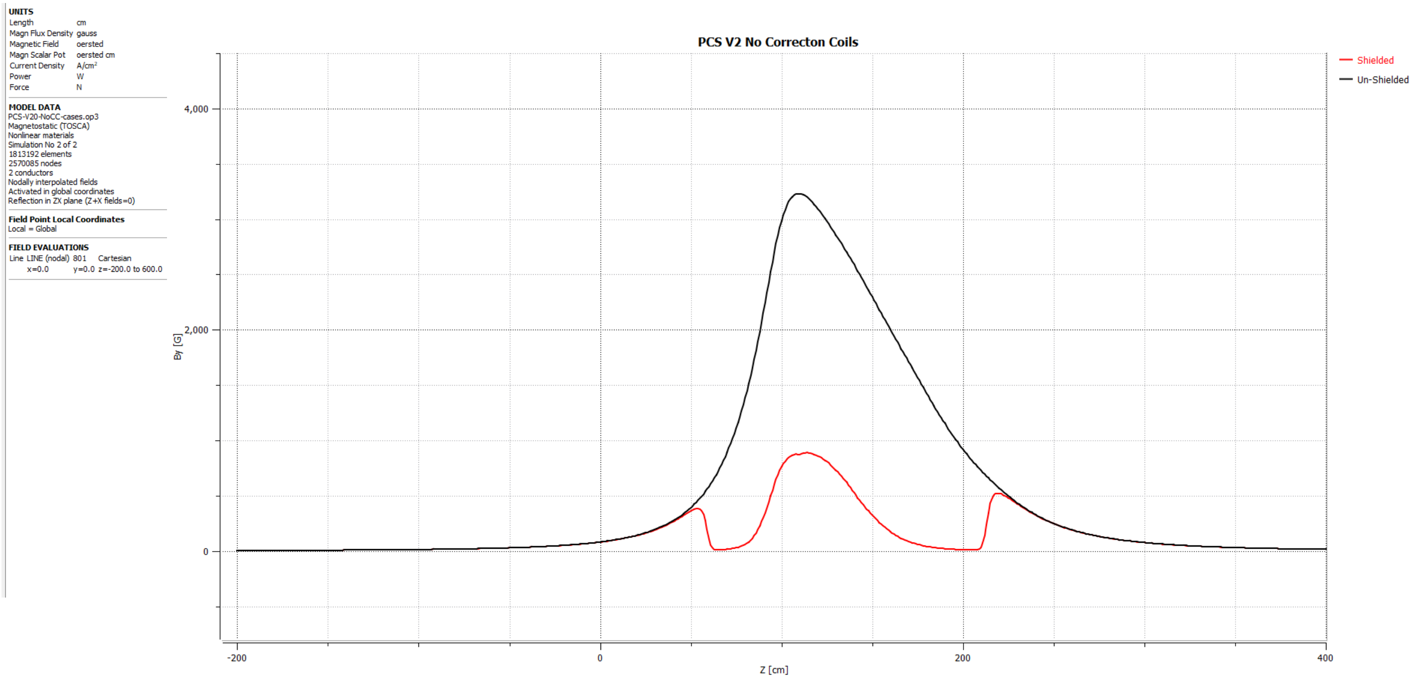




PCS V2 No Correction Coils

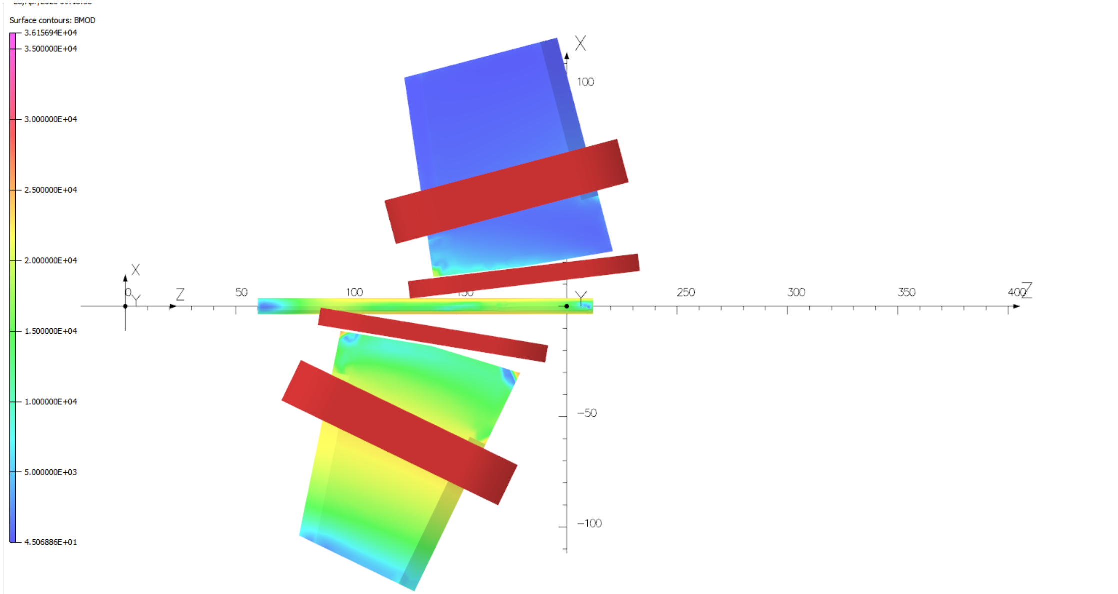
Stray field along Z axis
Without Fe shielding : 0.3427 T.m   Case 2
With Fe shielding   : 0.2875 T.m   Case 5

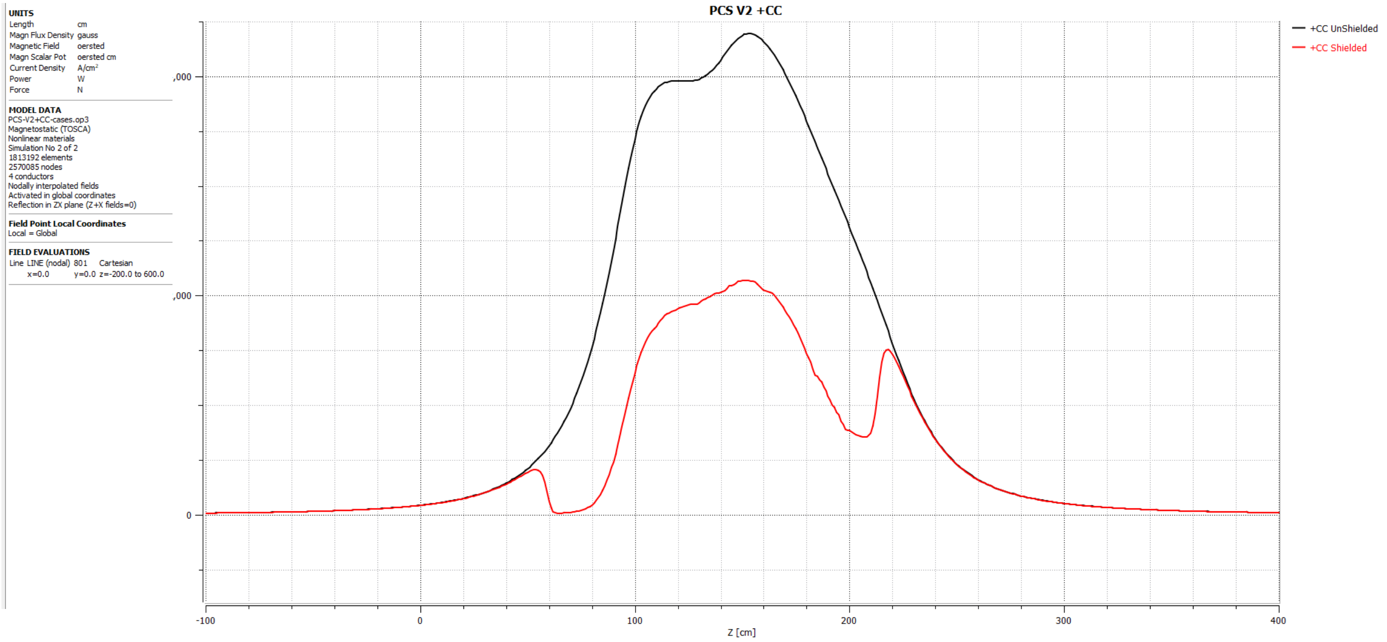




PCS V2 Correction Coils + Polarity

Stray field along Z axis
Without Fe shielding : 0.5604 T.m case 3
With Fe shielding : 0.2666 T.m case 6



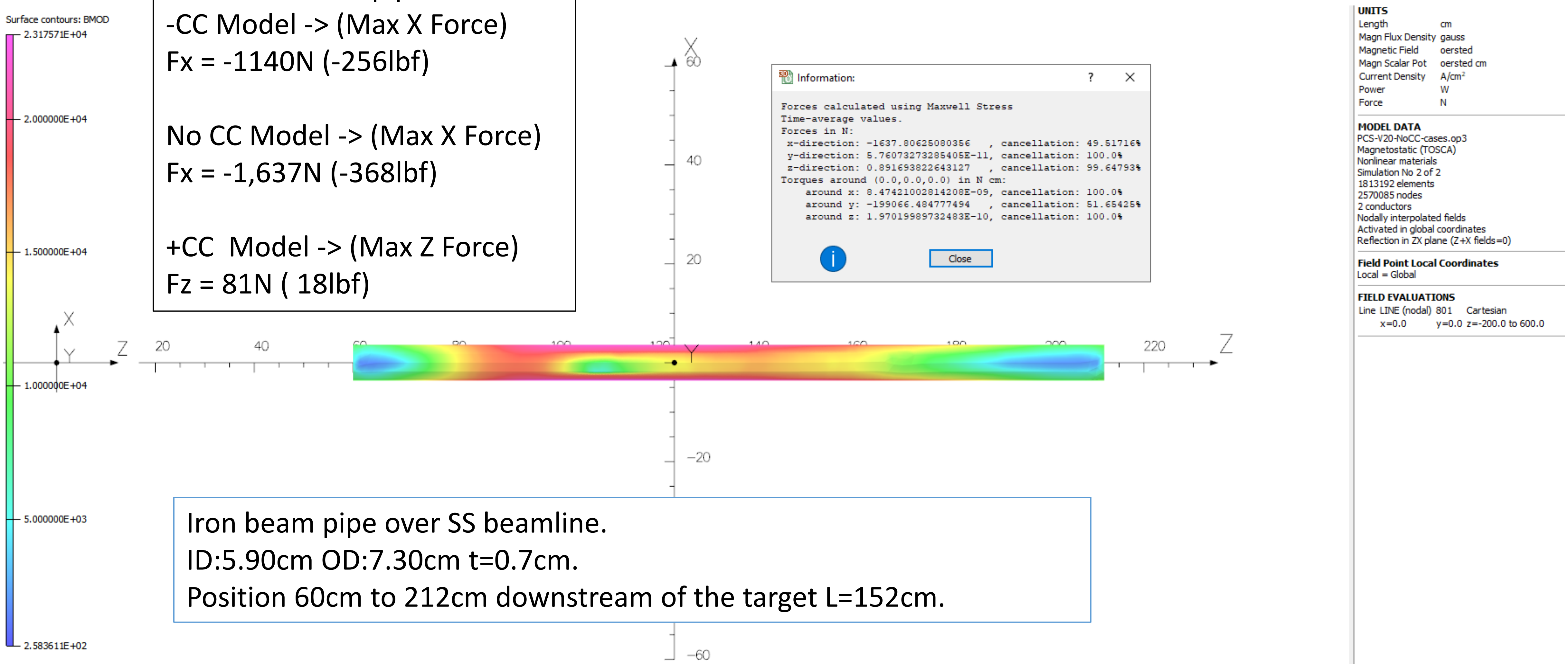


PCS Fe Beam Pipe Force

Forces on beam pipe:
-CC Model -> (Max X Force)
Fx = -1140N (-256lbf)

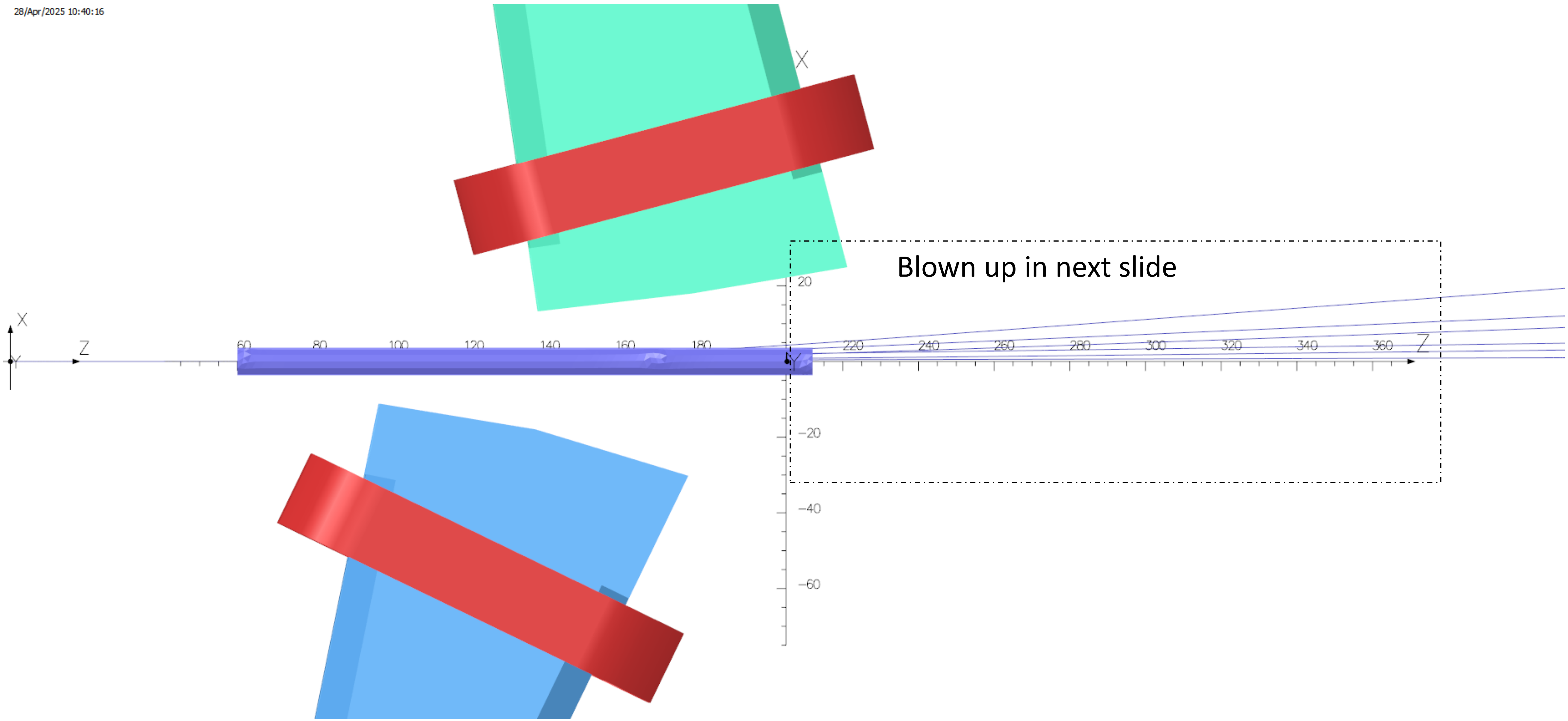
No CC Model -> (Max X Force)
Fx = -1,637N (-368lbf)

+CC Model -> (Max Z Force)
Fz = 81N (18lbf)

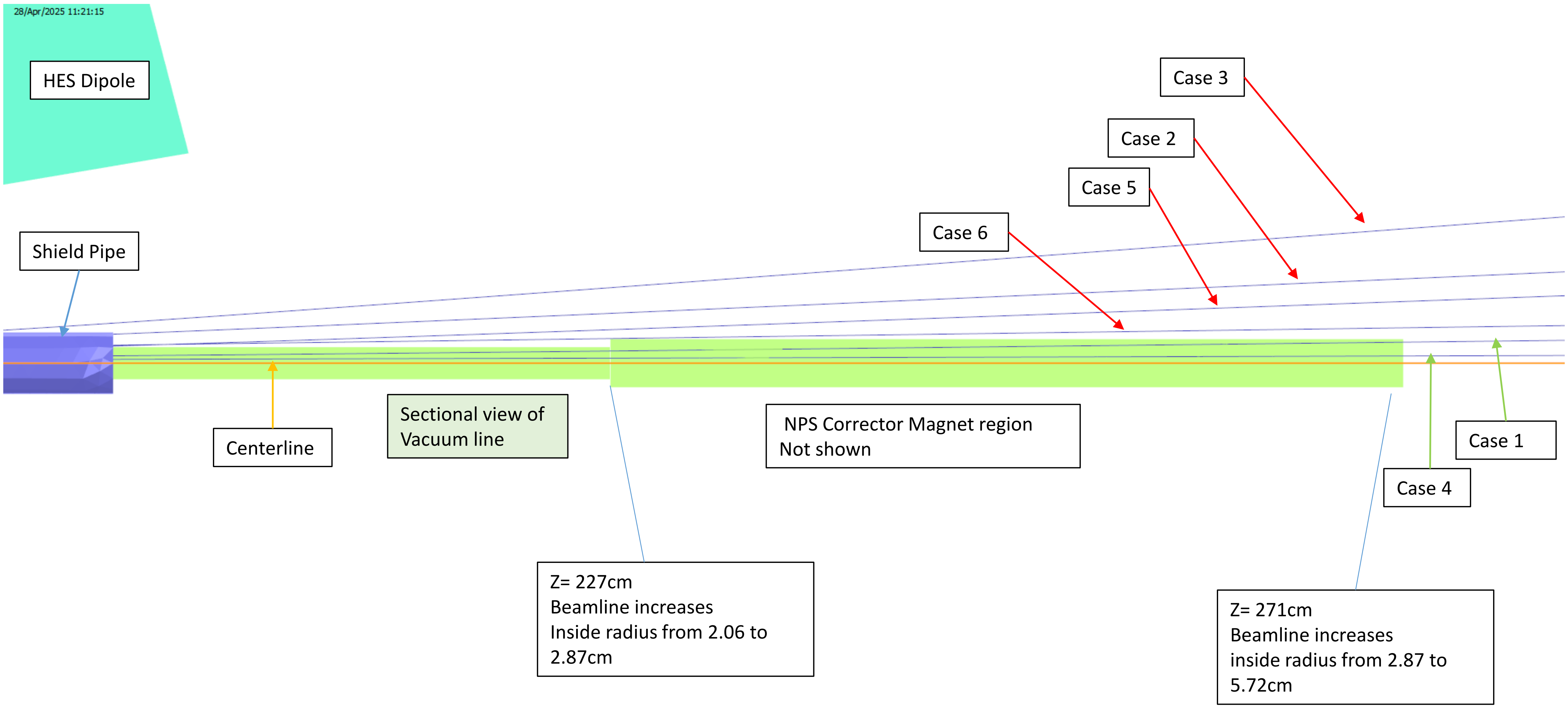


Iron beam pipe over SS beamline.
ID:5.90cm OD:7.30cm t=0.7cm.
Position 60cm to 212cm downstream of the target L=152cm.

Beam Kick due to just PCS magnets



PCS magnets Stray Field kick cases

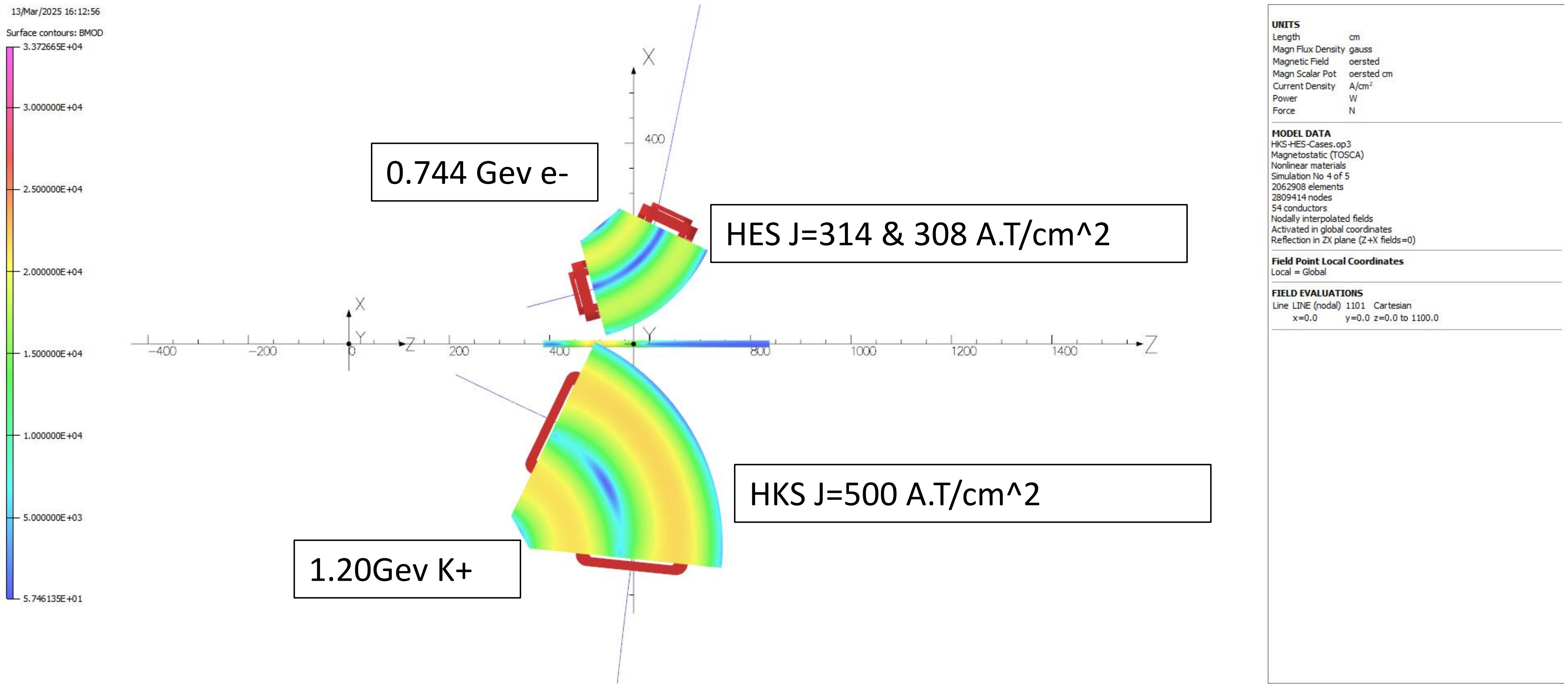


HKS & HES DIPOLE

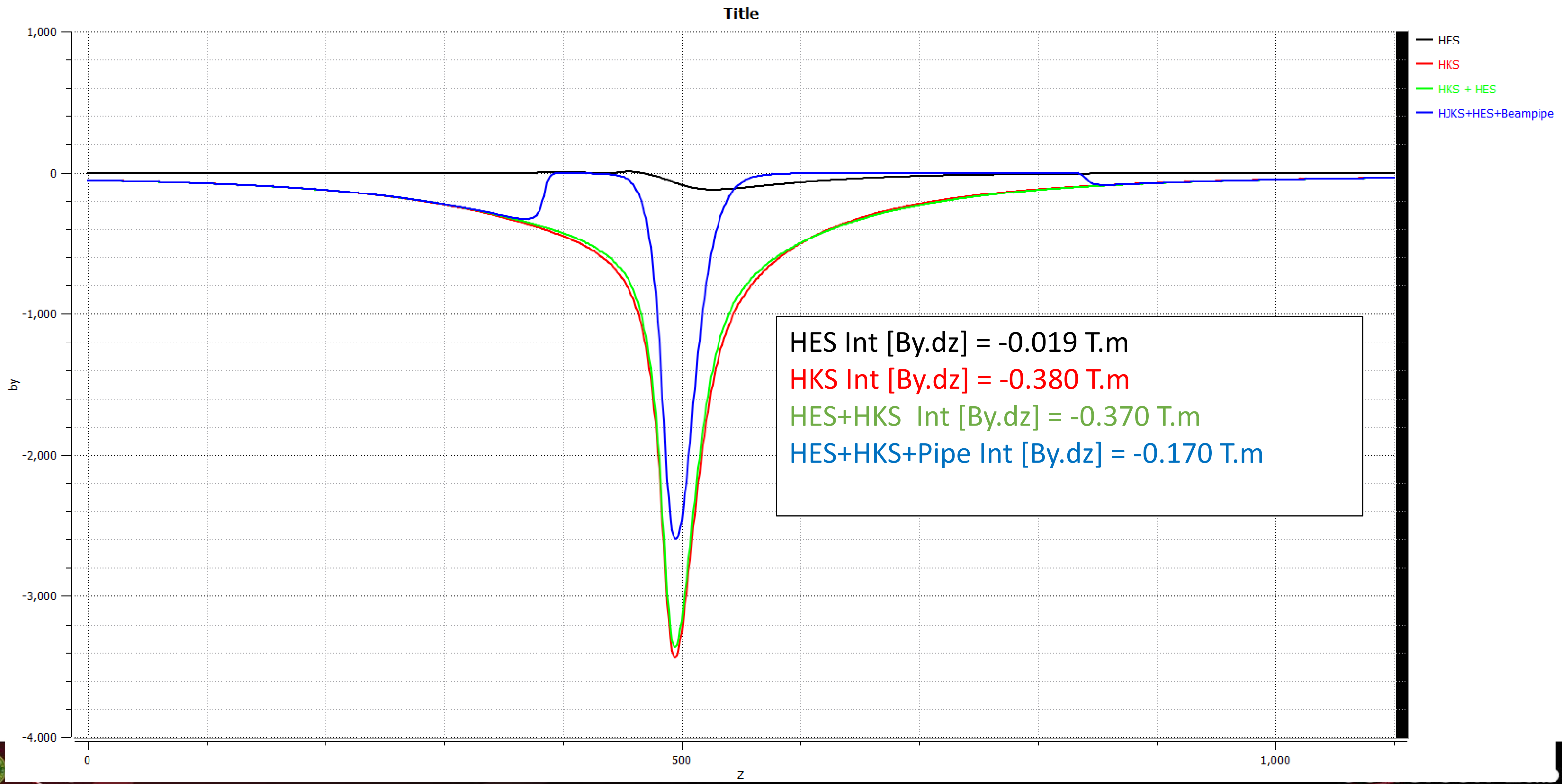
HKS DIPOLE

- Ideas Model File: HKS-Dipole
- Universal Filename: HKSandHES.inv
- Nodes: 2,809,414 Quad tretra Elements: 2,062,908
- Model Geometry extents: X: -997 to 832.5 Y: -600.0 to 0.0, Z: -193.9 to 1,352
- Iron Beam Pipe: Length = 451.4 Thickness = 0.65 (~1/4”) layout in Z from 386.3 to 838.0

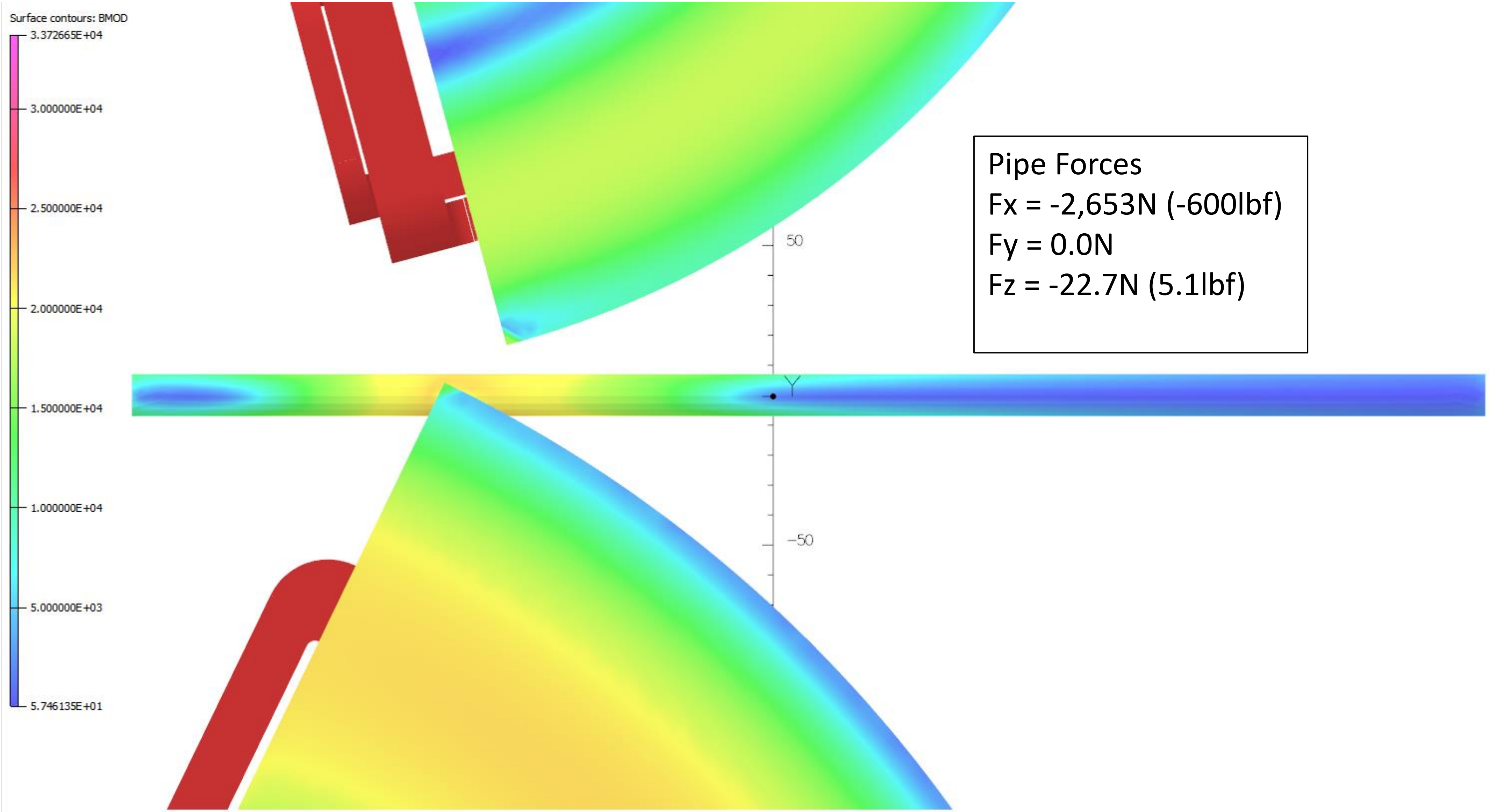
Ray Traces – To verify magnet settings are in the ball park. Simplified HKS Pole – Error ~5%



Stray Fields HKS, HES and Beam Pipe Shielding



HKS & HES Iron Beam Pipe Field Levels



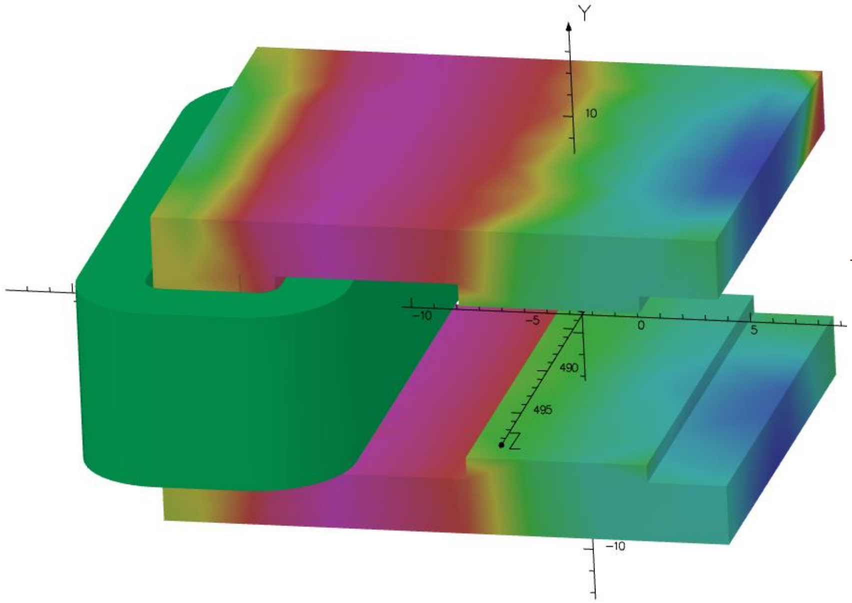
Pipe Forces
Fx = -2,653N (-600lbf)
Fy = 0.0N
Fz = -22.7N (5.1lbf)

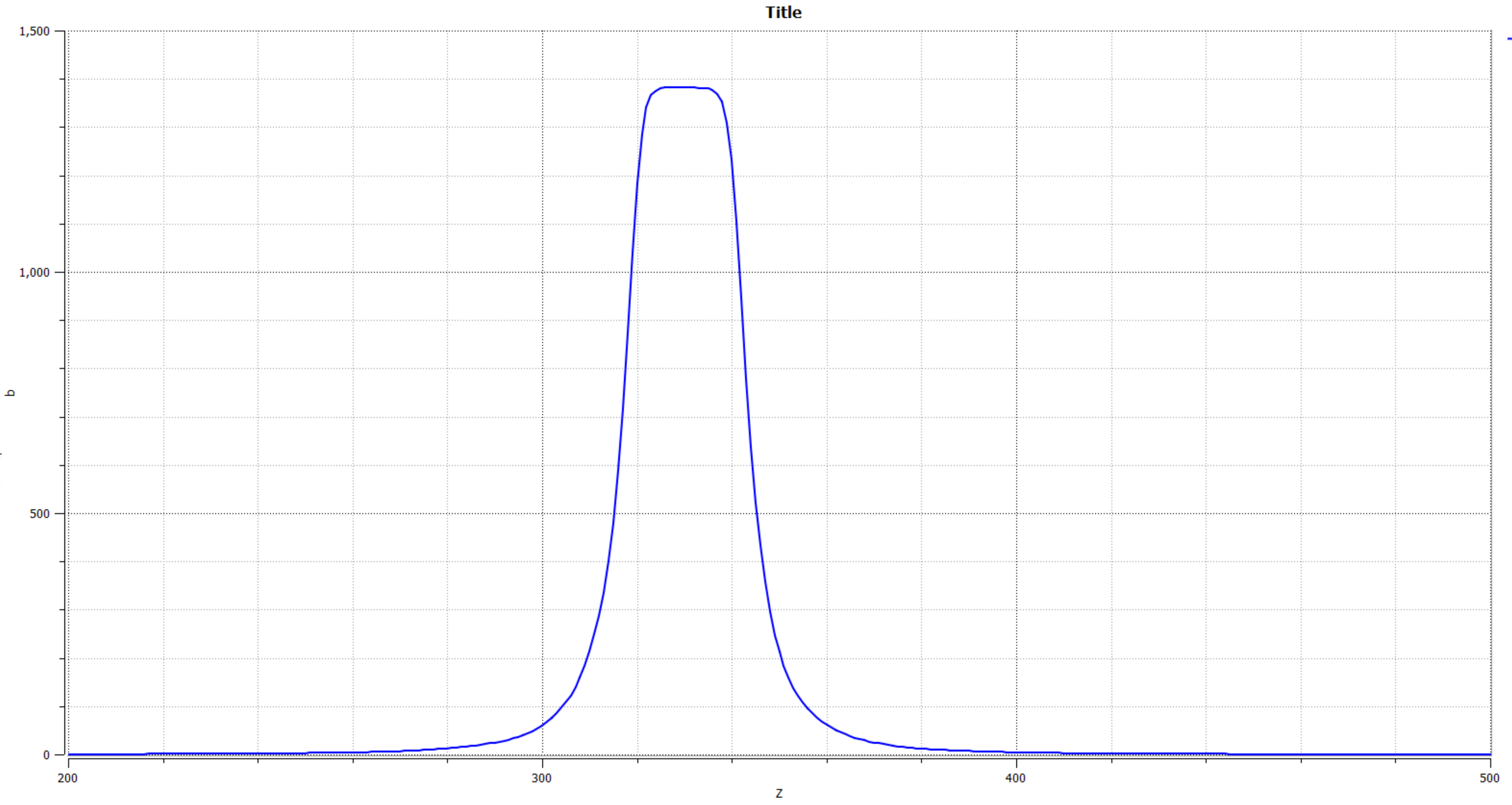
NPS Corrector Magnet

NPS Corrector Magnet @ Full Excitation

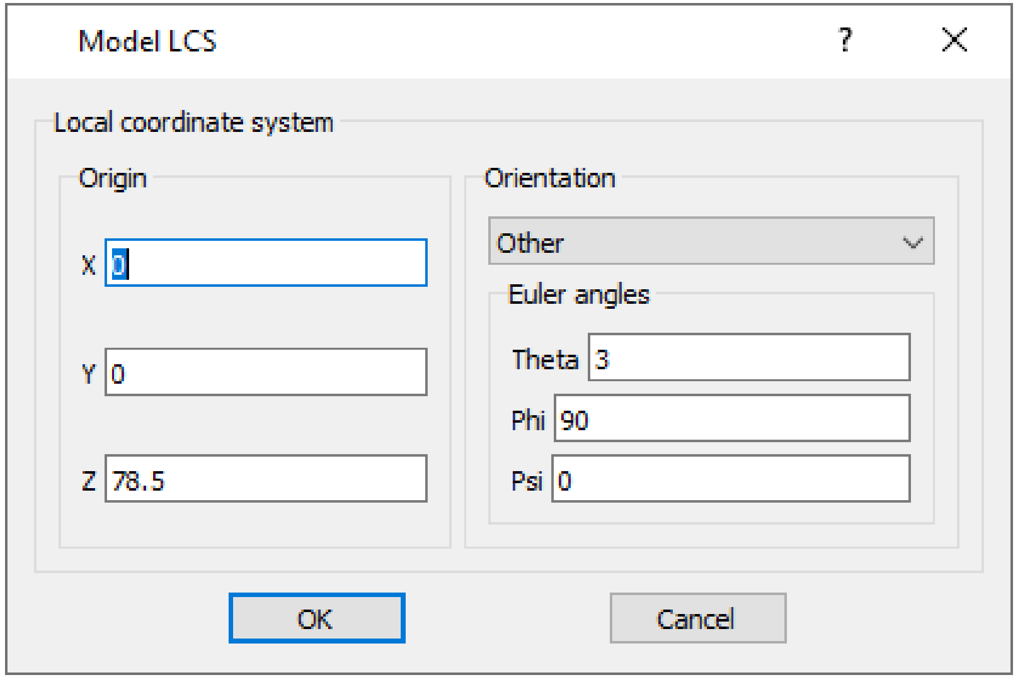
Max Field = 0.13826T T
Integral Field = 0.0424 T.m

Centered near Z=330.25 cm from target





NPS Corrector Magnet



UNITS

Length	cm
Magn Flux Density	gauss
Magnetic Field	oersted
Magn Scalar Pot	oersted cm
Current Density	A/cm^2
Power	W
Force	N

MODEL DATA
NPS-Corrector-150A.op3
Magnetostatic (TOSCA)
Nonlinear materials
Simulation No 1 of 1
680297 elements
208688 nodes
1 conductor
Nodally interpolated fields
Activated in coordinate system:
Origin: 0.0, 0.0, 78.5
Local XYZ = Global XYZ

Field Point Local Coordinates
Local = Global

Table parameters

- Units: mm and Gauss
- ENGE
  X: -700 to 700
  Y: -100 to 100
  Z: -2,000 to 0
- PCS:
  X: -700 to 700
  Y: -100 to 100
  Z: -1,000 to 2,500
- NPS CC:
  X: -700 to 700
  Y: -100 to 100
  Z: 250 to 500
- HKS+HES:
  X: -700 to 700
  Y: -100 to 100
  Z: -1,000 to 1,350