	3D Calculation **(Model 3D, forces, integral,...)** Model: 317111-Vers21-RevA(3D) *File : 317111-jlab-report Vers 21-Rev A.doc* *13 April 2011 – S . Antoine* REVISE Par Frédérick FOREST , 10:27, 17/04/2012	**MAGNET REFERENCE:** 317111 **DESIGNATION :** Dipole **CUSTOMER :** JLAB

3D simulation

ABSTRACT :

The coil is simplified per sector and per pancake (24 circuits) and has been modeled using the vector fields software OPERA Vers 15 in order to extract coil forces.

The sector of the coil designed with the opera command “Constant perimeter End”, we have adjusted the Alpha Angle and the Radius in function of the position of the sector

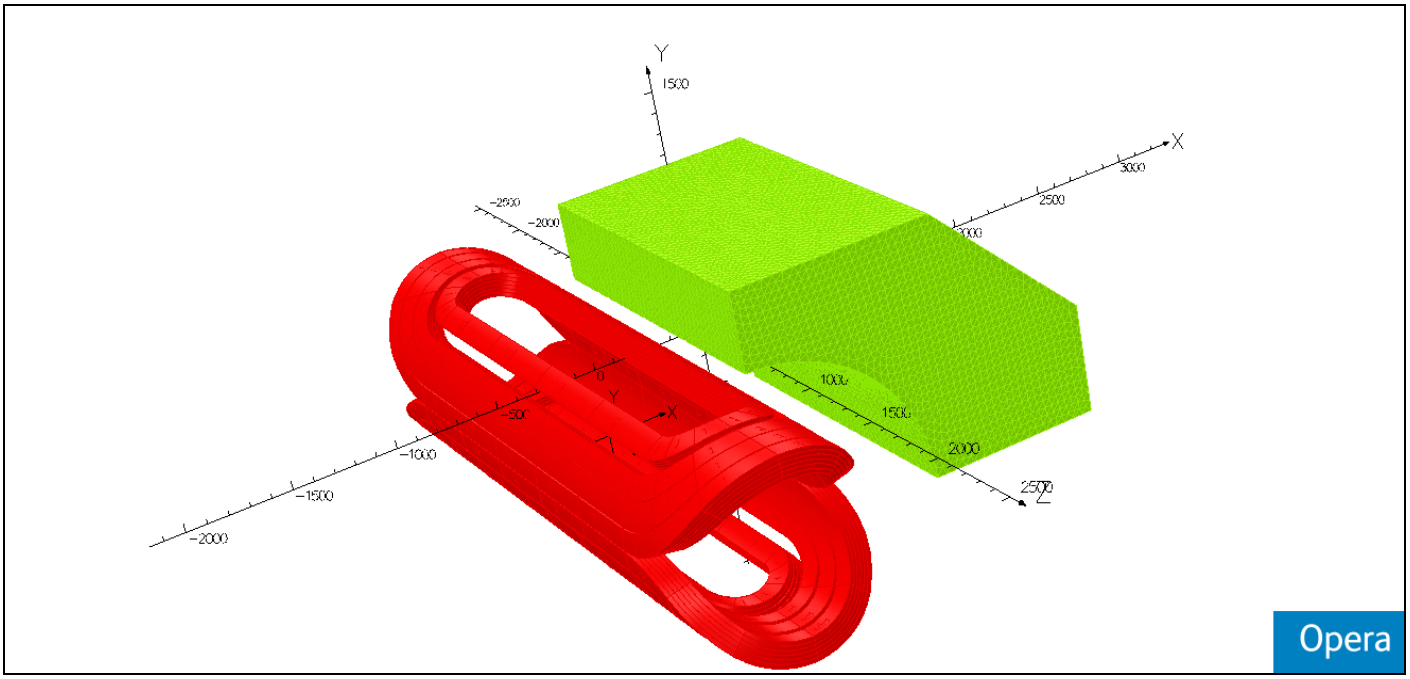
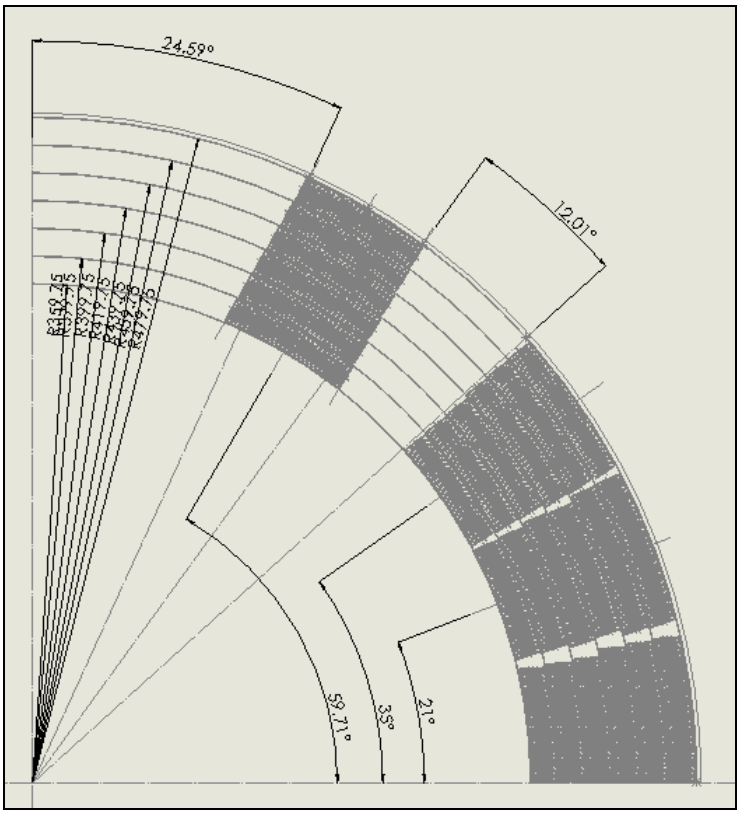


Fig. 1 – Opera Model

Definition of sector density

The current used for the simulation is 3419.4Amps , the density used "A.t /area of sector", The number total of the turns are 620. The total At is 620*3419.4=2120028 A.t.



	3D Calculation **(Model 3D, forces, integral,...)** Model: 317111-Vers21-RevA(3D) *File : 317111-jlab-report Vers 21-Rev A.doc* *13 April 2011 – S . Antoine*	**MAGNET REFERENCE:** 317111 **DESIGNATION :** Dipole **CUSTOMER :** JLAB

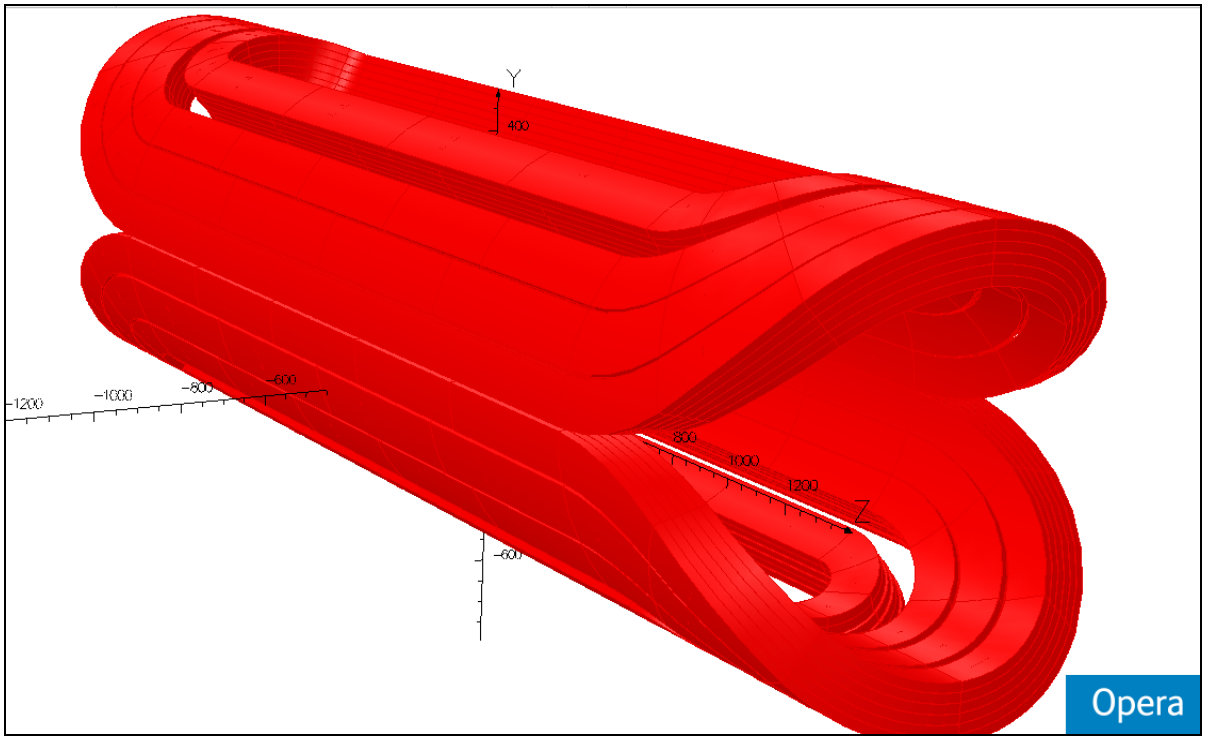


Fig. 2 – Coil Opera model

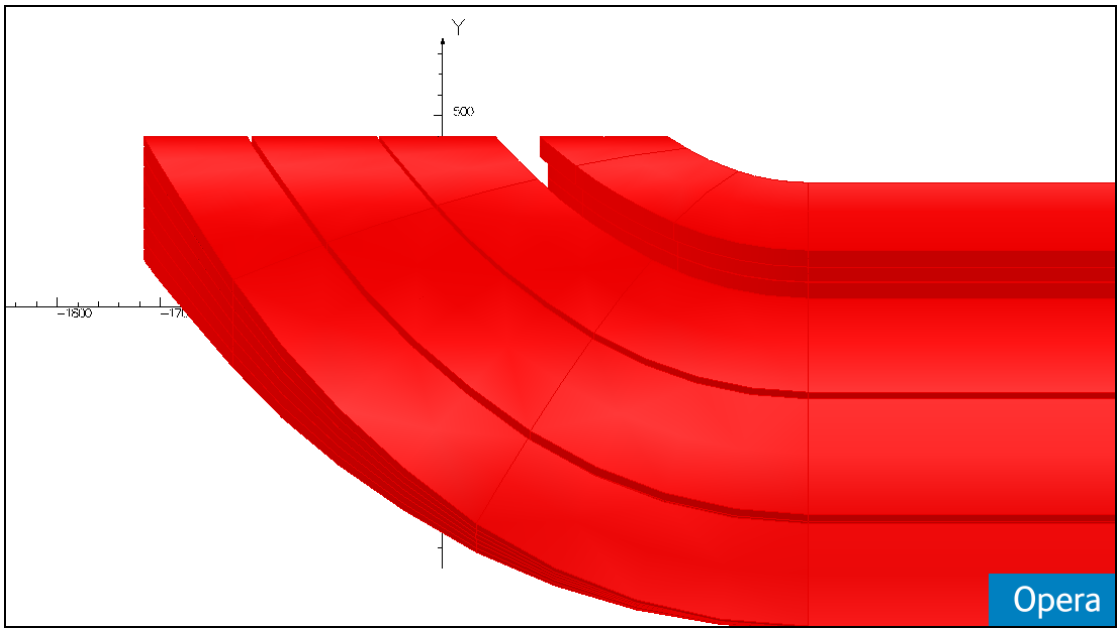


Fig. 3 – Coil Opera model

The peak field in the coil is 5.45 Tesla at 3419.4 A located at the inner end turn

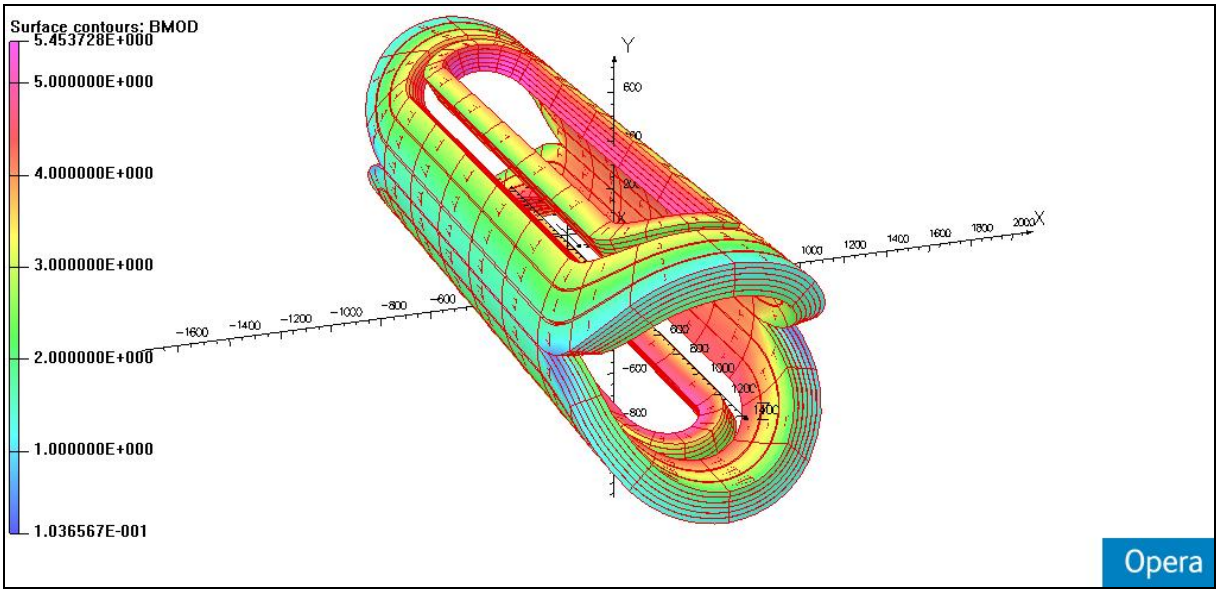


Fig. 4 – Field map on the coil surface at 3419.4 A – Field in T

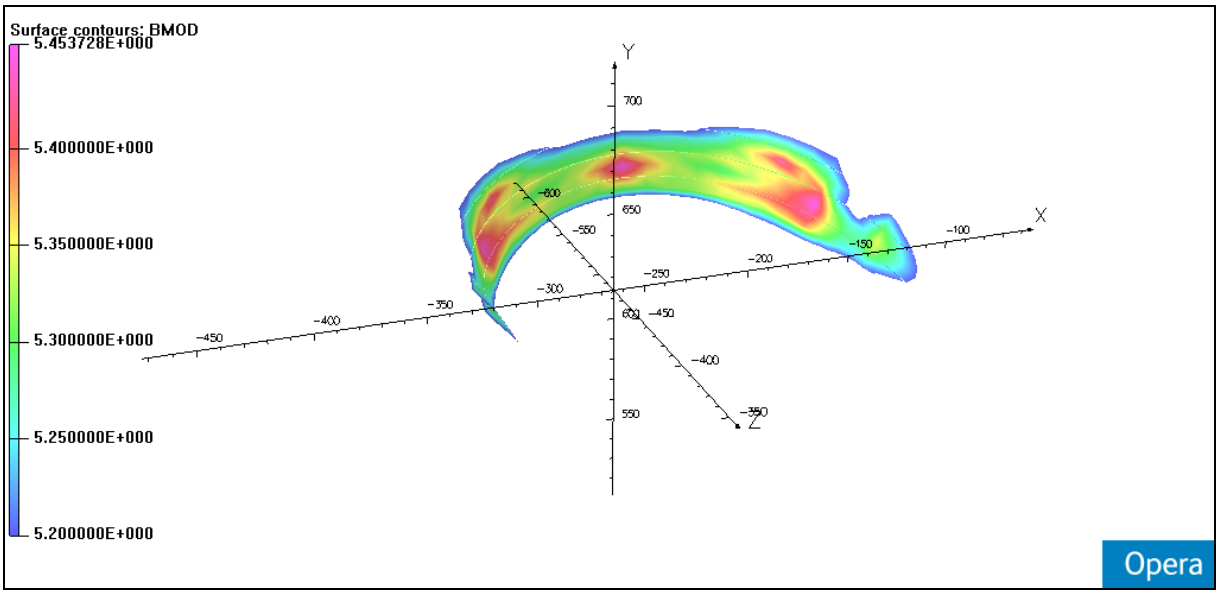


Fig. 5 – Close up view of the coil peak field area at 3419.4 A – Field in T

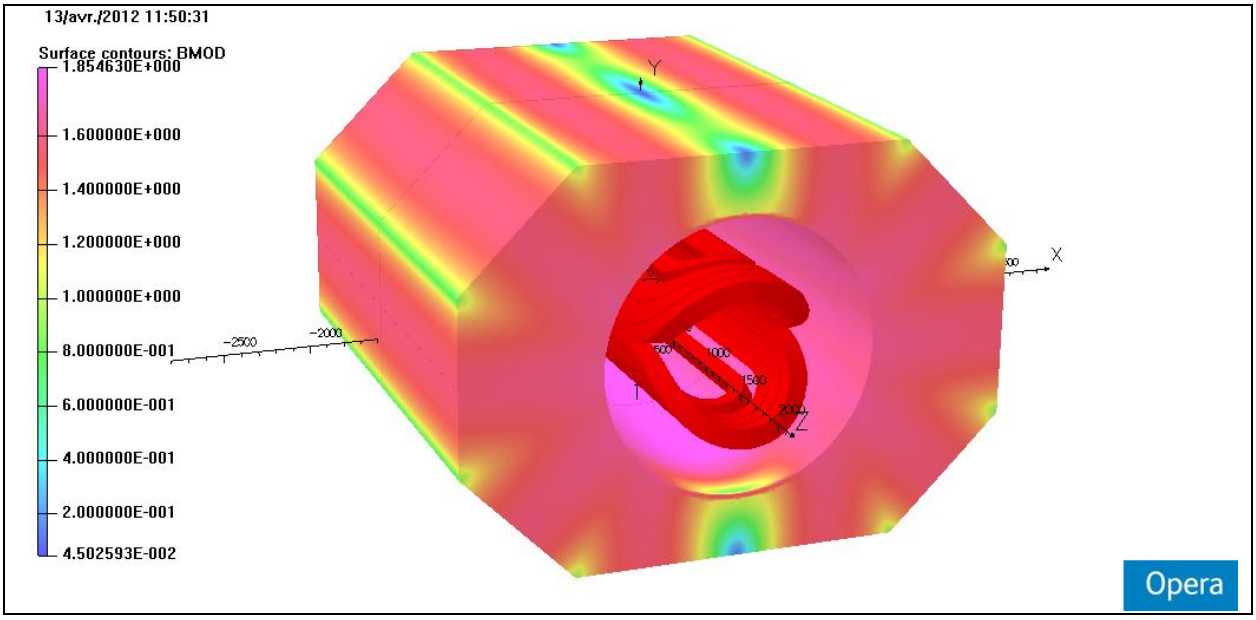


Fig. 6 – Field map in the yoke at 3419.4 A – Field in T

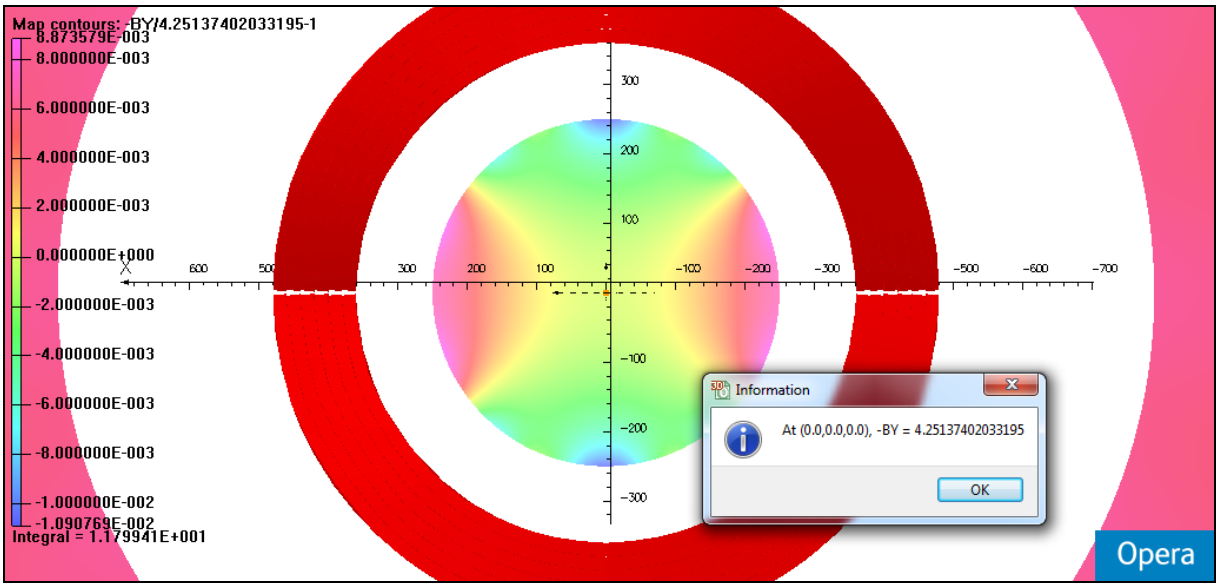


Fig. 7 – By field homogeneity circular patch Ø500mm and field in the center at 3419.4 A

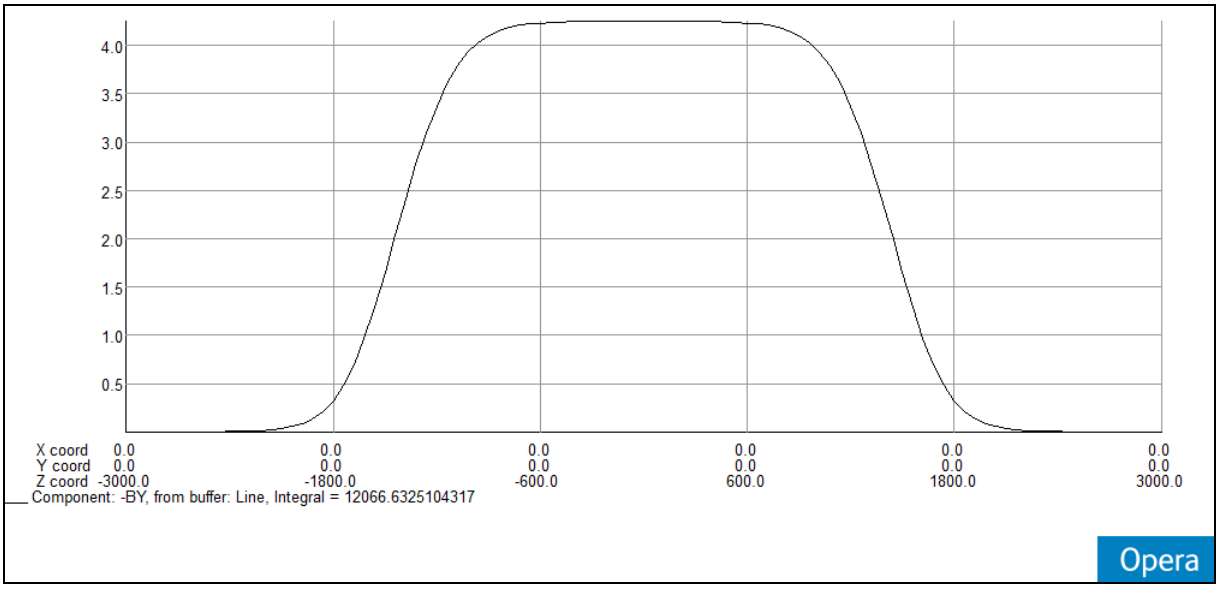


Fig. 9 – By field plot along the magnet longitudinal axis at 3419.4 A – Field in T

The integrated field By over the full length is 12.066T.m at 3419.4 A

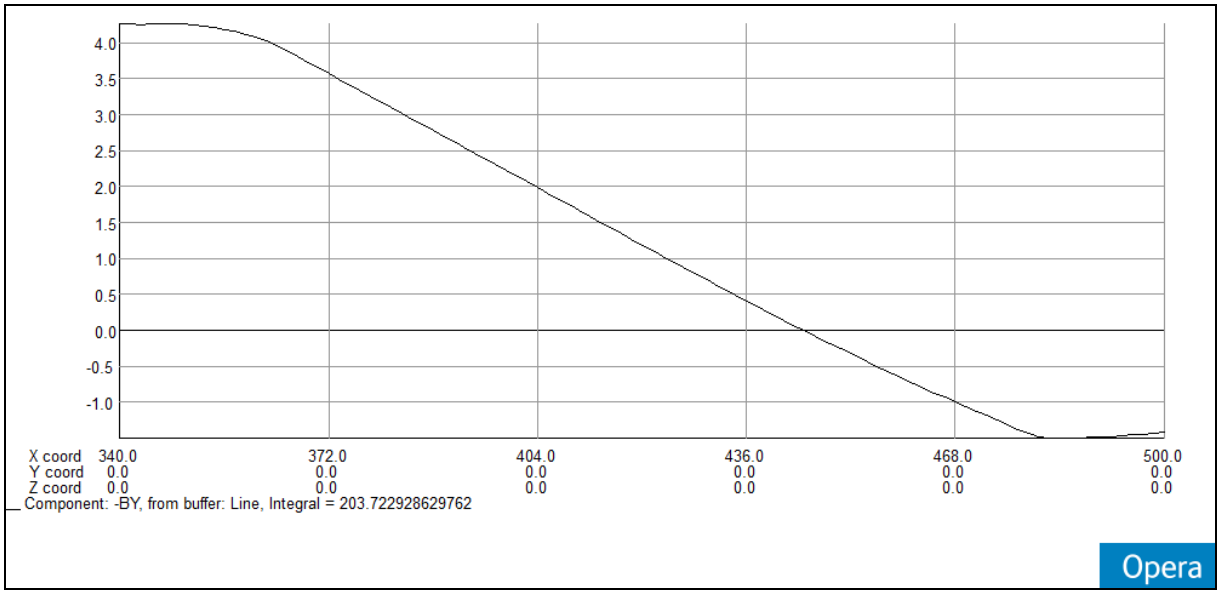


Fig. 10 - By field along X axis in the coil region at 3419.4 A, middle vertical plane (X=340 mm to 500 mm) - Field in T

The harmonics were extracted at the radius of 250mm, from the centre of the magnet out to a 3000 mm using a step of 30 mm

N°	An-Values @ In T.m	Bn-Values @ In T.m	an @ In unit (1.10⁻⁴)	bn @ In unit (1.10⁻⁴)	I cn I @ In unit (1.10-4)
1	0	**-12.0667**	0.00	10000	10000
2	**0**	1.0172E-06	0.00	0.00	0.00
3	0	0.18115125	0.00	-150.13	150.13
4	0	1.9466E-06	0.00	0.00	0.00
5	0	0.0592266	0.00	-49.08	49.08
6	0	9.836E-07	0.00	0.00	0.00
7	0	0.02701453	0.00	-22.39	22.39
8	0	1.4411E-06	0.00	0.00	0.00
9	0	0.03354977	0.00	-27.80	27.80
10	0	1.5648E-06	0.00	0.00	0.00
11	0	-0.0134153	0.00	11.12	11.12
12	0	1.1143E-06	0.00	0.00	0.00
13	0	-0.0018602	0.00	1.54	1.54
14	0	1.3307E-06	0.00	0.00	0.00
15	0	0.00257507	0.00	-2.13	2.13
16	0	2.0579E-06	0.00	0.00	0.00
17	0	-0.0001836	0.00	0.15	0.15
18	0	9.978E-07	0.00	0.00	0.00
19	0	-0.0002783	0.00	0.23	0.23
20	0	1.3098E-06	0.00	0.00	0.00
21	0	-3.283E-05	0.00	0.03	0.03
22	0	1.9417E-06	0.00	0.00	0.00
23	0	1.5263E-05	0.00	-0.01	0.01
24	0	1.4391E-06	0.00	0.00	0.00
25	0	-1.819E-05	0.00	0.02	0.02
26	0	1.1924E-06	0.00	0.00	0.00
27	0	-3.388E-05	0.00	0.03	0.03
28	0	1.1698E-06	0.00	0.00	0.00
29	0	-2.211E-05	0.00	0.02	0.02
30	0	1.4134E-06	0.00	0.00	0.00
31	0	-5.041E-05	0.00	0.04	0.04
Sum			**0.00**	**-238.39**	**264.74**

Table 1

*$ PARAMETER NAME=#fx VALUE=jcy*bz-jcz*by*
*$ PARAMETER NAME=#fy VALUE=jcz*bx-jcx*bz*
*$ PARAMETER NAME=#fz VALUE=jcx*by-jcy*bx*
*$ PARAMETER NAME=#fmod VALUE=sqrt(#fx**2+#fy**2+#fz**2)*

Lorentz forces output in the middle

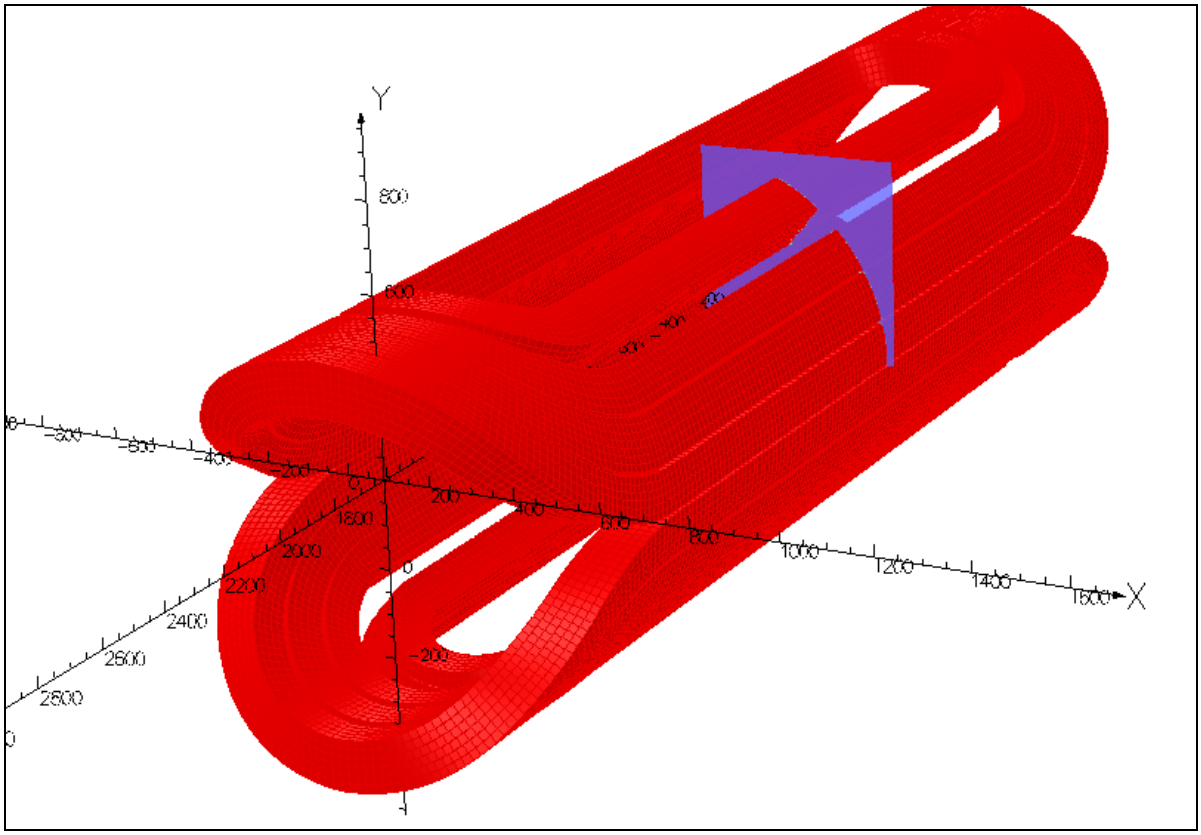


Fig. 11 – Patch location for Lorentz force calculation - Middle

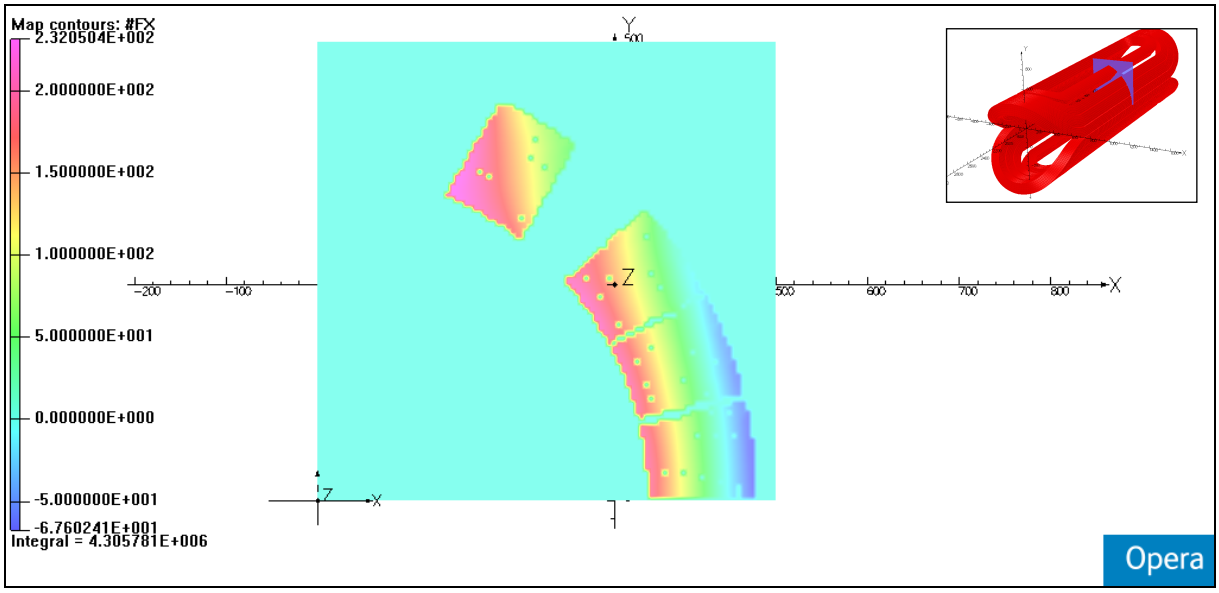


Fig. 12 –Fx force density in N/cm^3 - Integrated Fx force in N/m – 3419.4 A

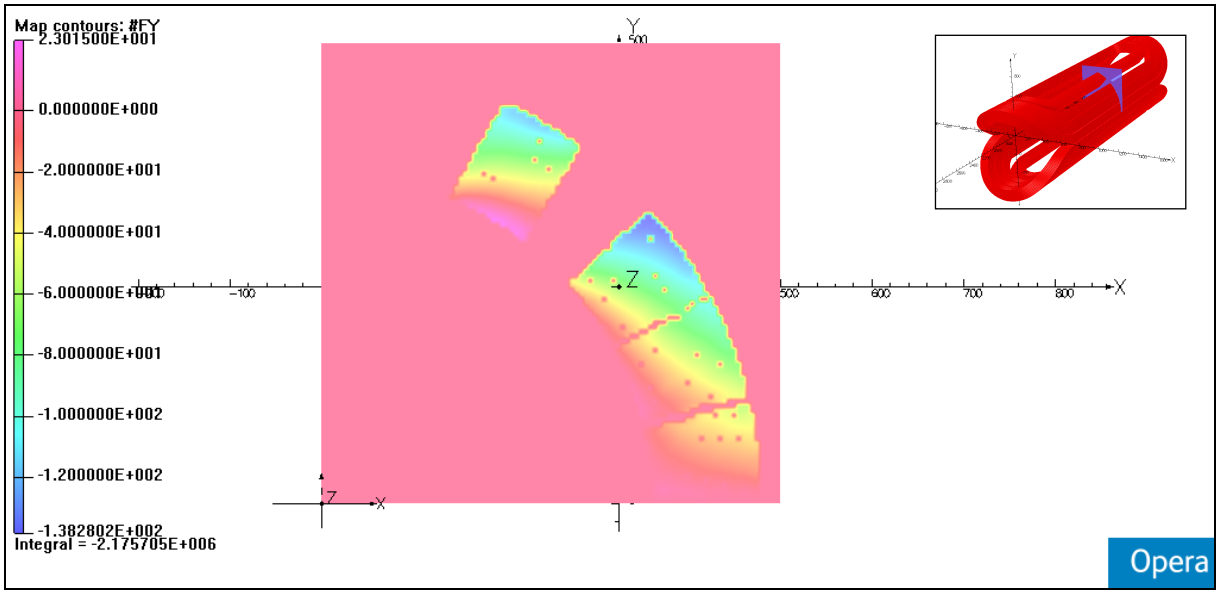


Fig. 13 –Fy force density in N/ cm^3 - Integrated Fy force in N/m – 3419.4 A

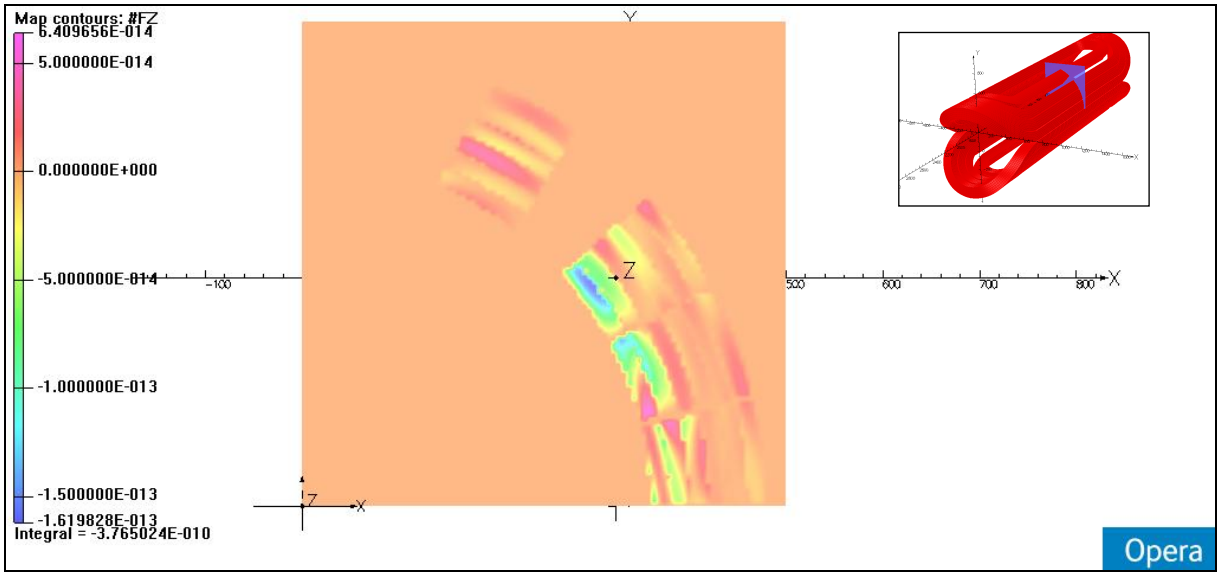


Fig. 14 –Fz force density in N/ cm^3 - Integrated Fz force in N/m – 3419.4 A

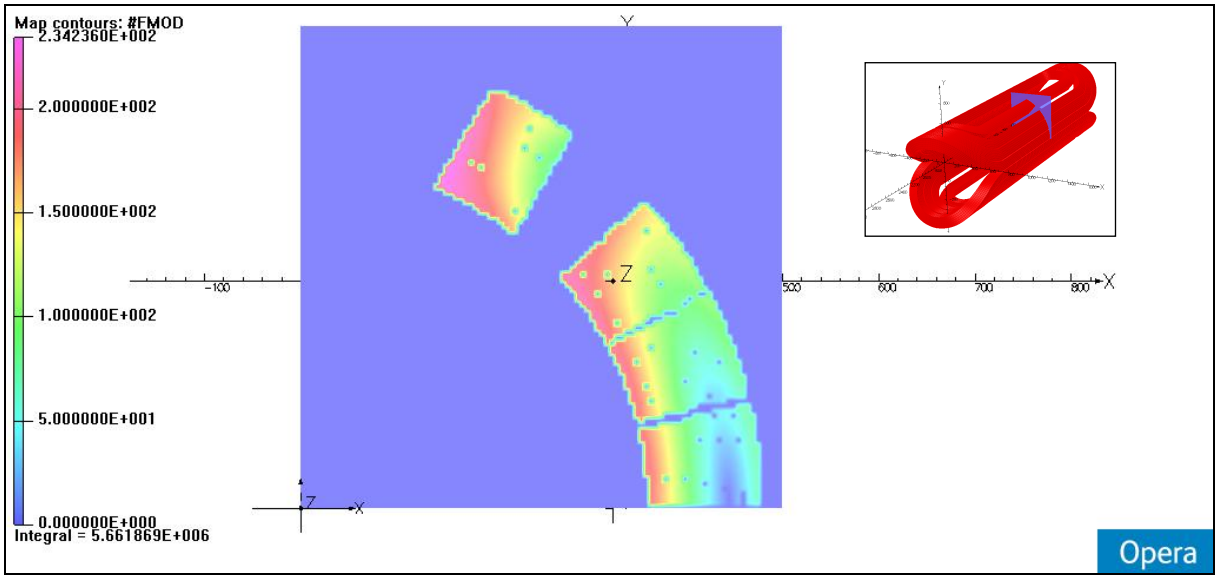


Fig. 15 –Fmod force density in N/ cm^3 - Integrated Fmod force in N/m – 3419.4 A

Lorentz forces output at the end of the straight section

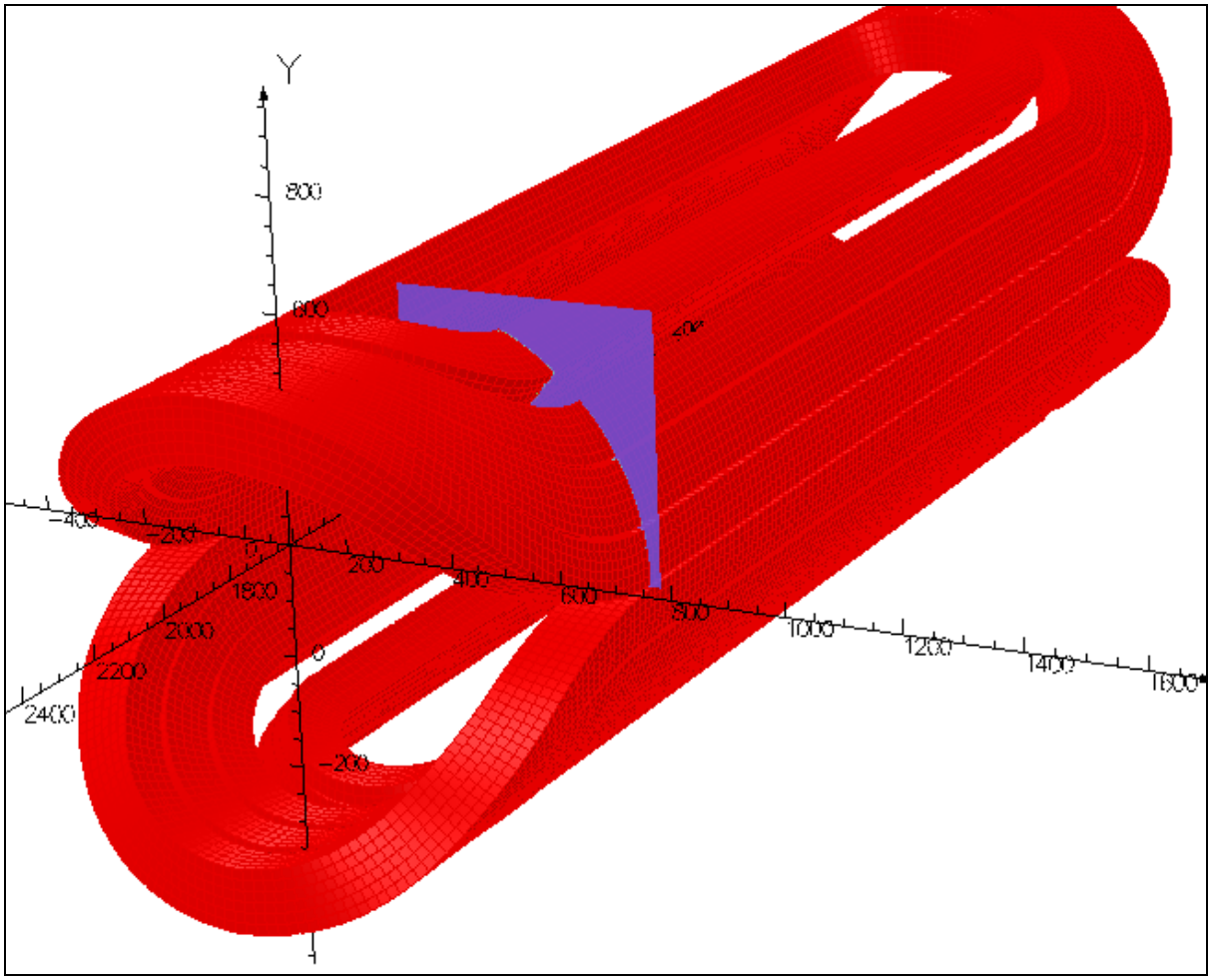


Fig. 16 – Patch location for Lorentz force calculation – End of the straight part

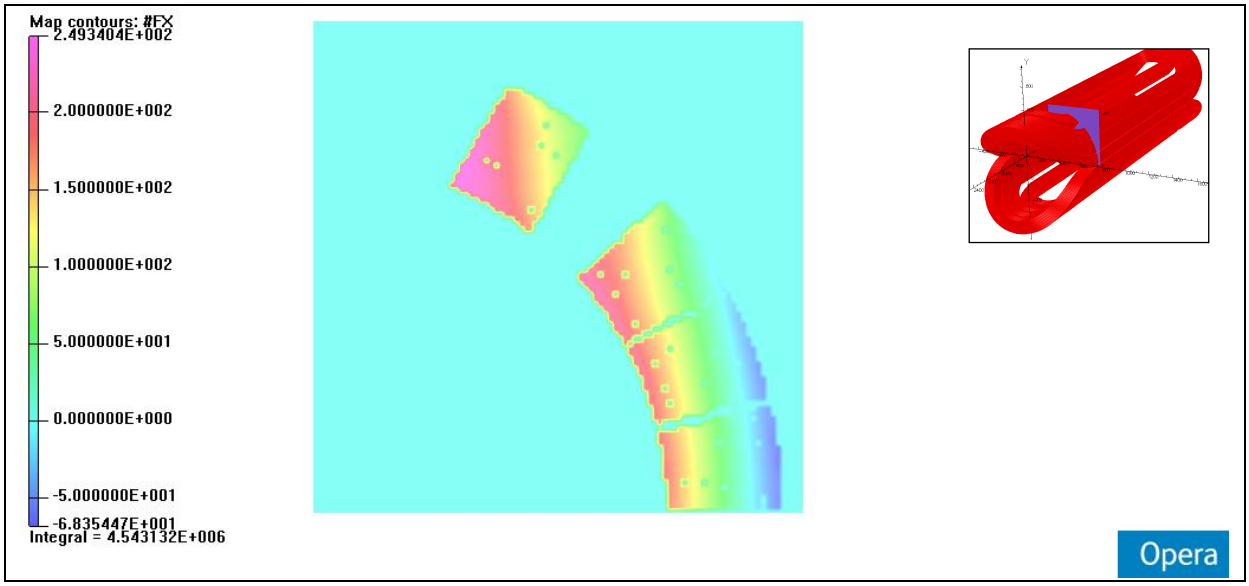


Fig. 17 –Fx force density in N/ cm^3 - Integrated Fx force in N/m– 3419.4 A

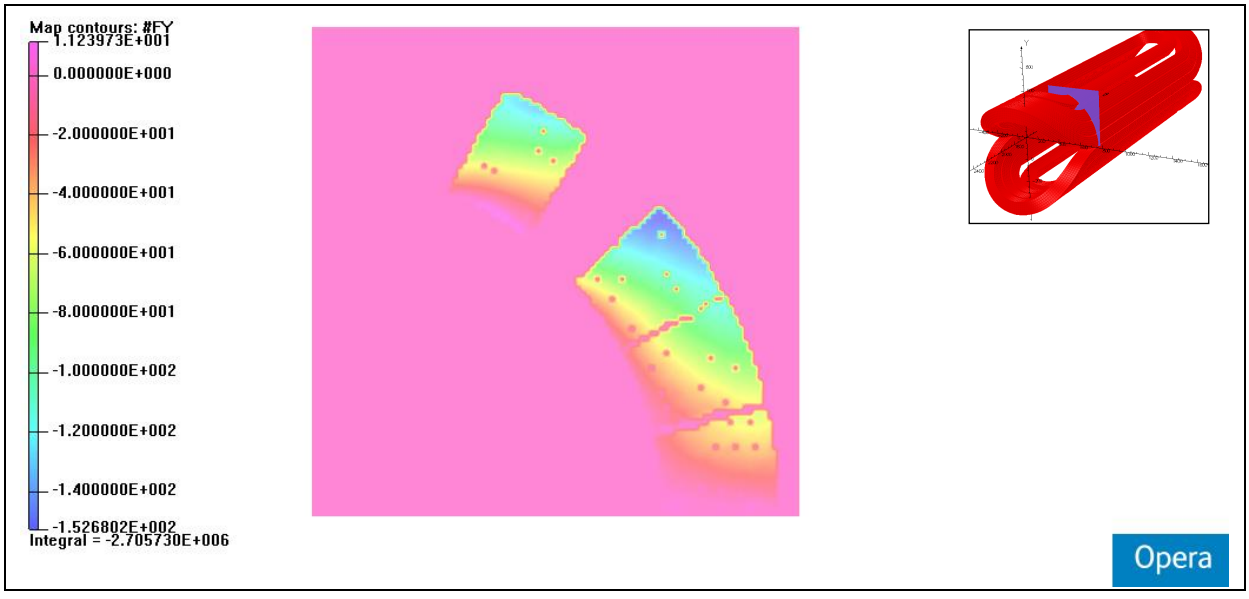


Fig. 18 –Fy force density in N/ cm^3 - Integrated Fy force in N/m – 3419.4 A

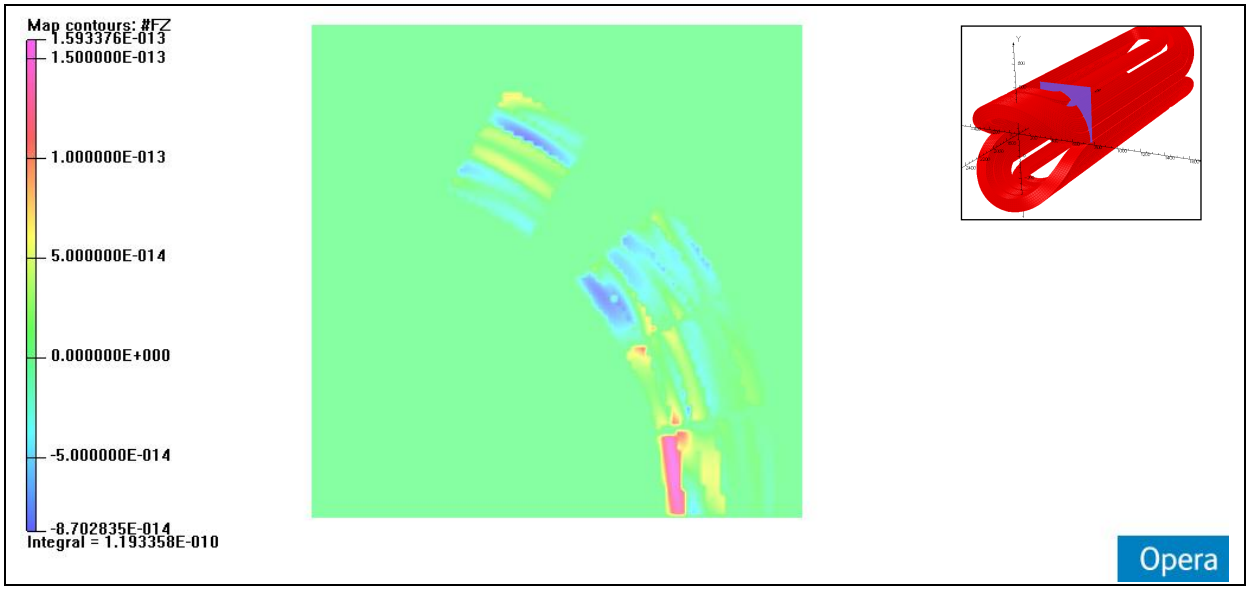


Fig. 19 –Fz force density in N/ cm^3 - Integrated Fz force in N/m – 3419.4 A

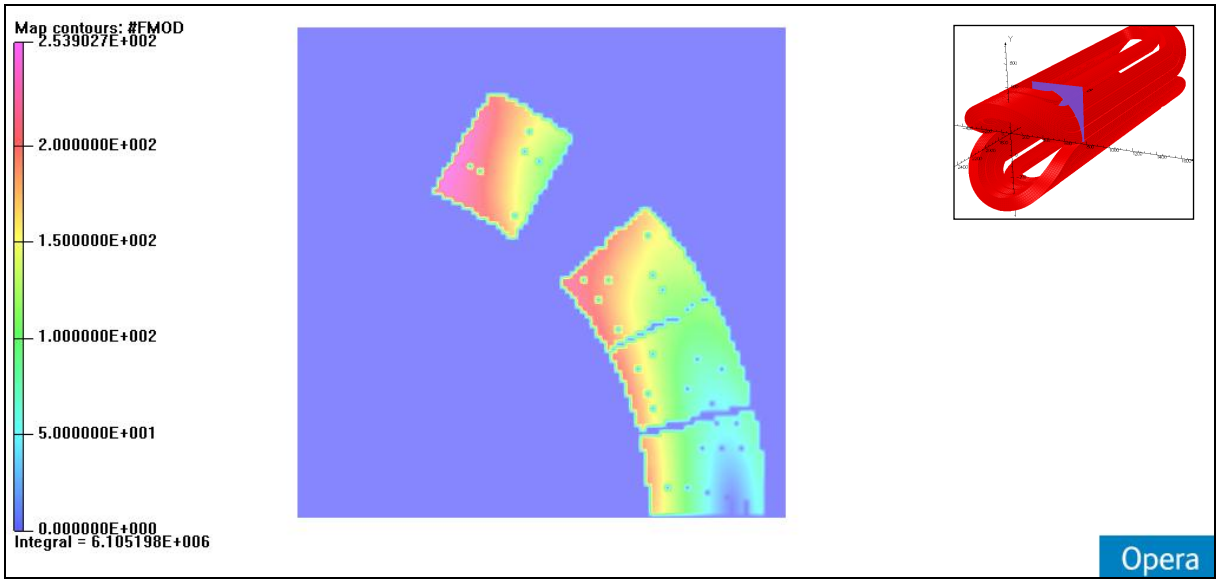


Fig. 20 –Fmod force density in N/ cm^3 - Integrated Fmod force in N/m – 3419.4 A

Lorentz forces output in the head

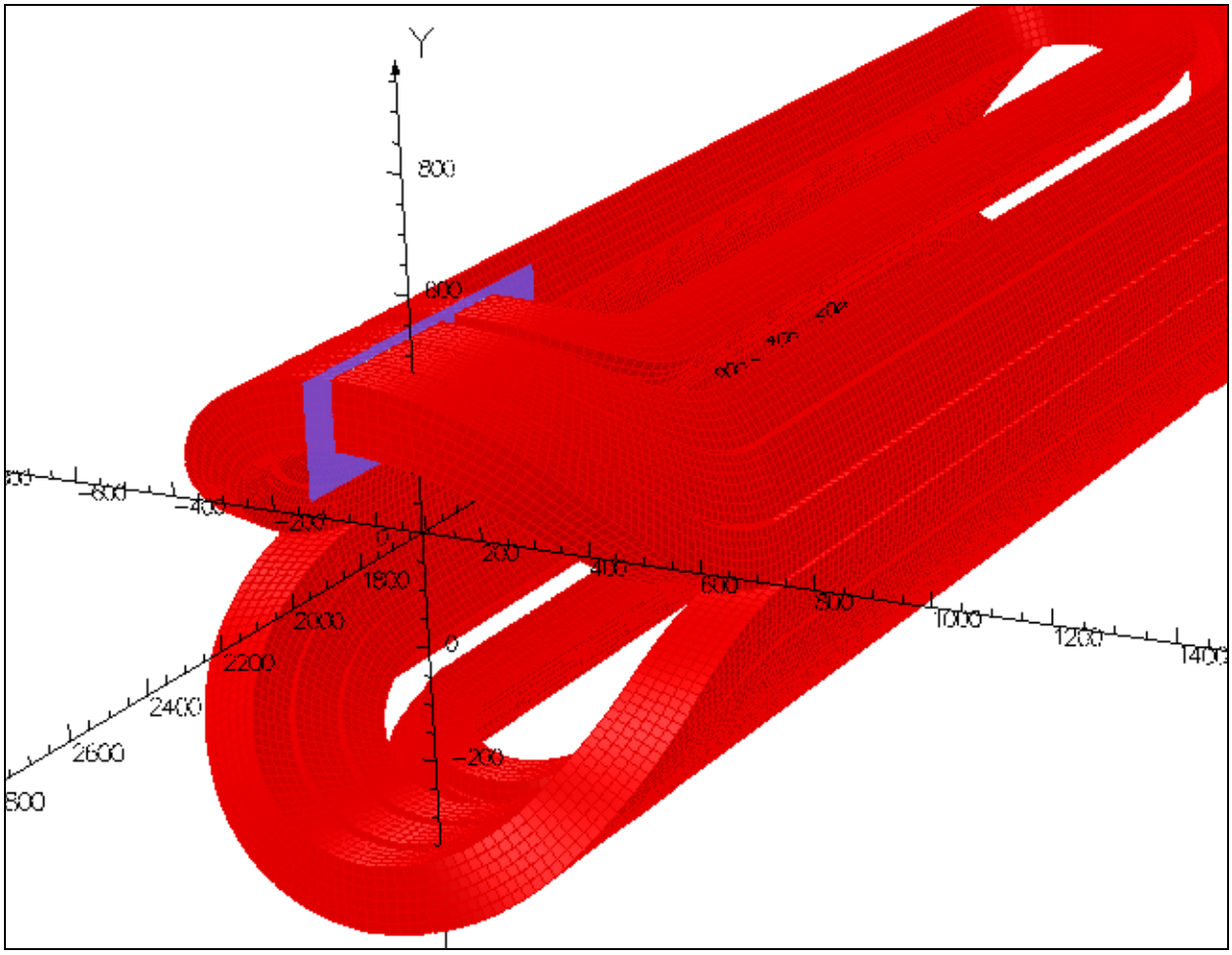


Fig. 21 – Patch location for Lorentz force calculation – Head– 3419.4 A

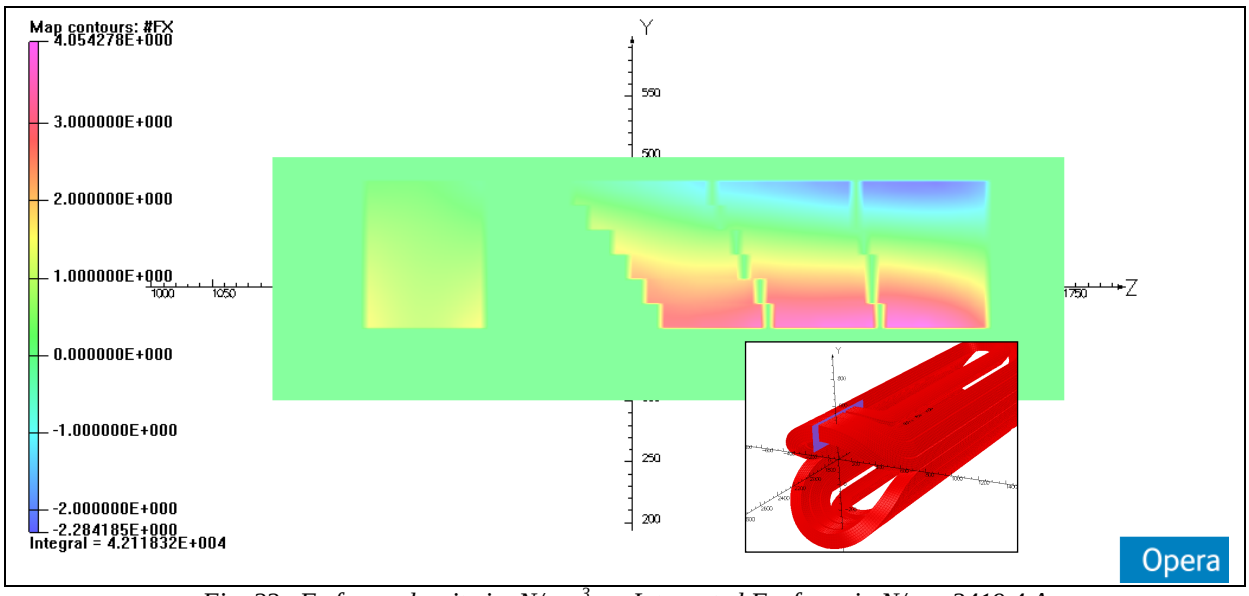


Fig. 22 –Fx force density in N/ cm^3 - Integrated Fx force in N/m – 3419.4 A

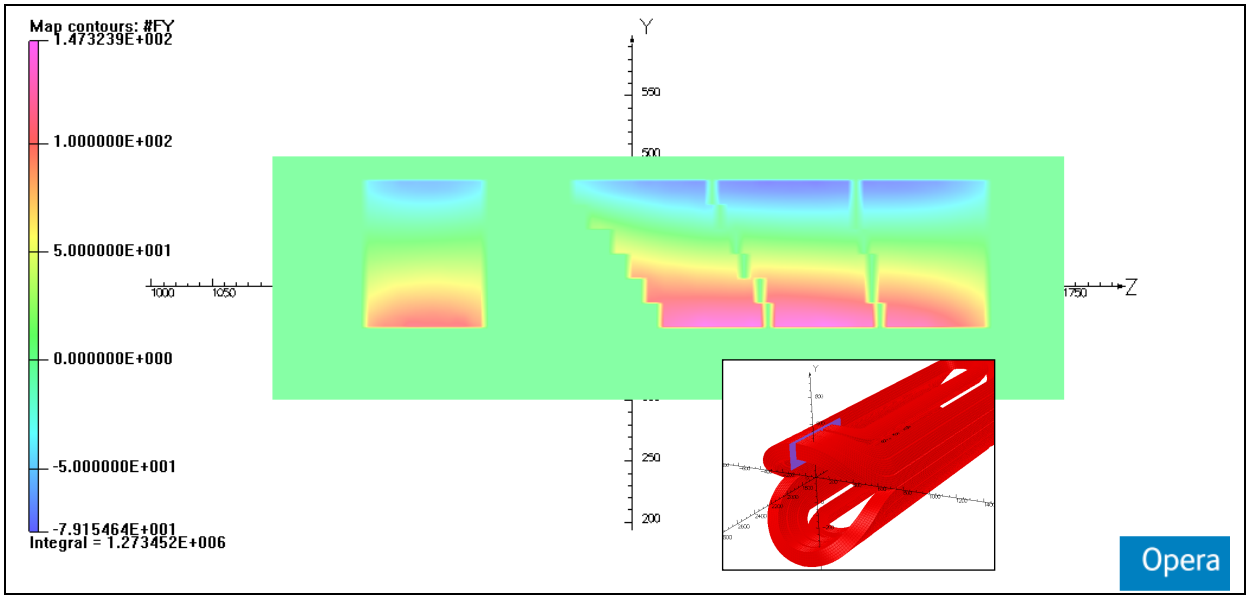


Fig. 23 –Fy force density in N/ cm^3 - Integrated Fy force in N/m – 3419.4 A

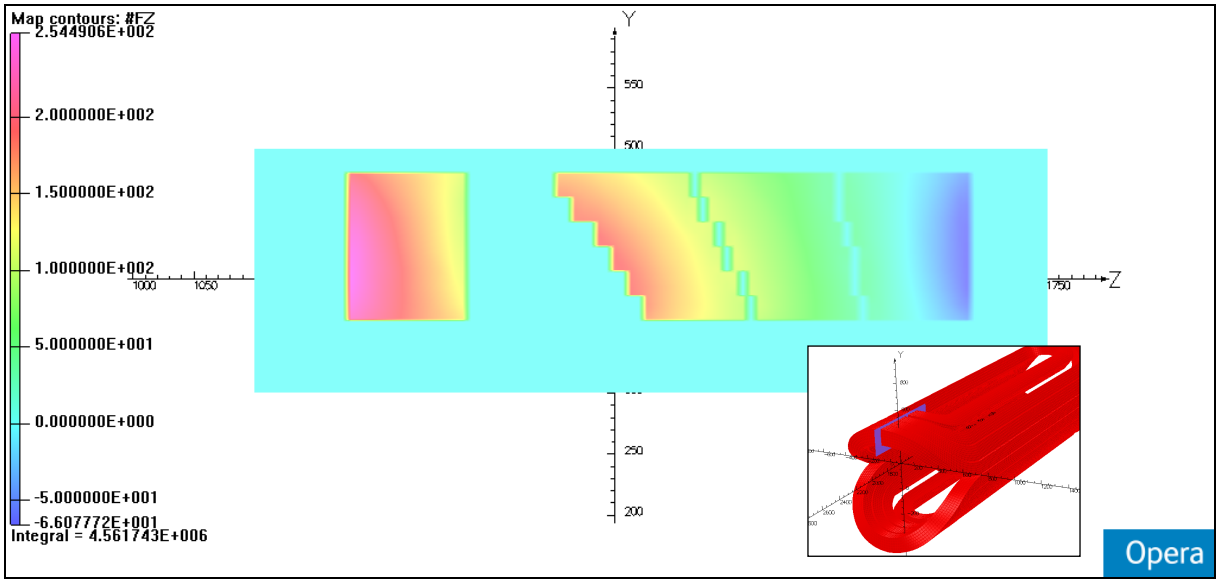


Fig. 24 –Fz force density in N/ cm^3 - Integrated Fz force in N/m – 3419.4 A

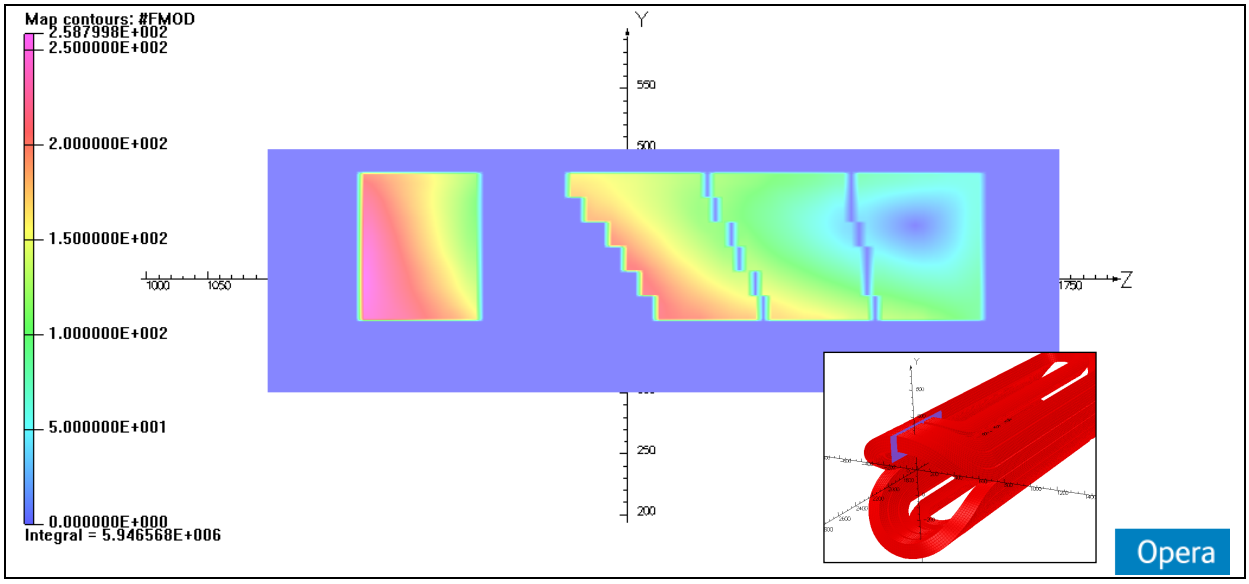


Fig. 25 –Fmod force density in N/ cm^3 - Integrated Fmod force in N/m – 3419.4 A

Lorentz forces output in the head at 45°

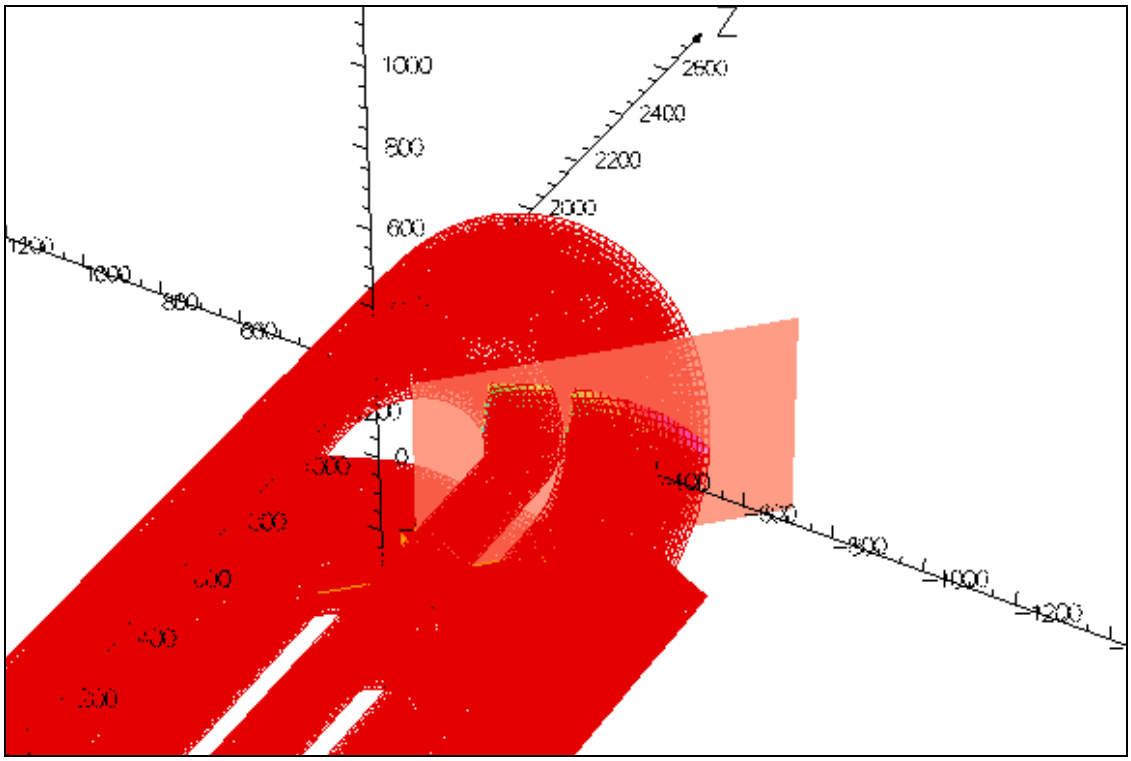


Fig. 26 – Patch location for Lorentz force calculation – Head at 45°

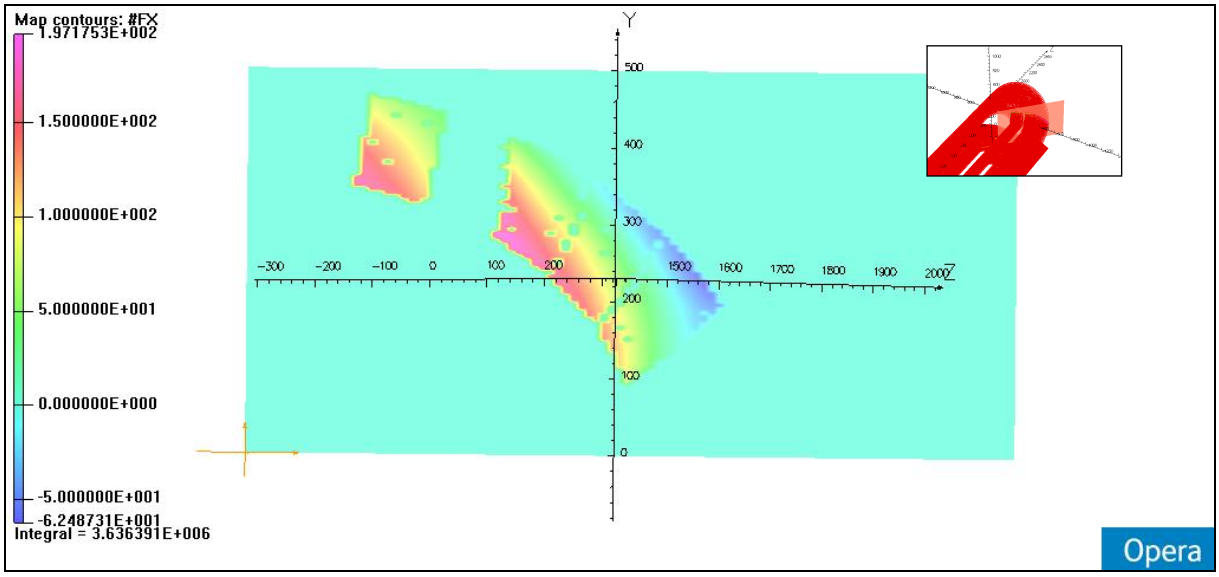


Fig. 27 –Fx force density in N/ cm^3 - Integrated Fx force in N/m – 3419.4 A

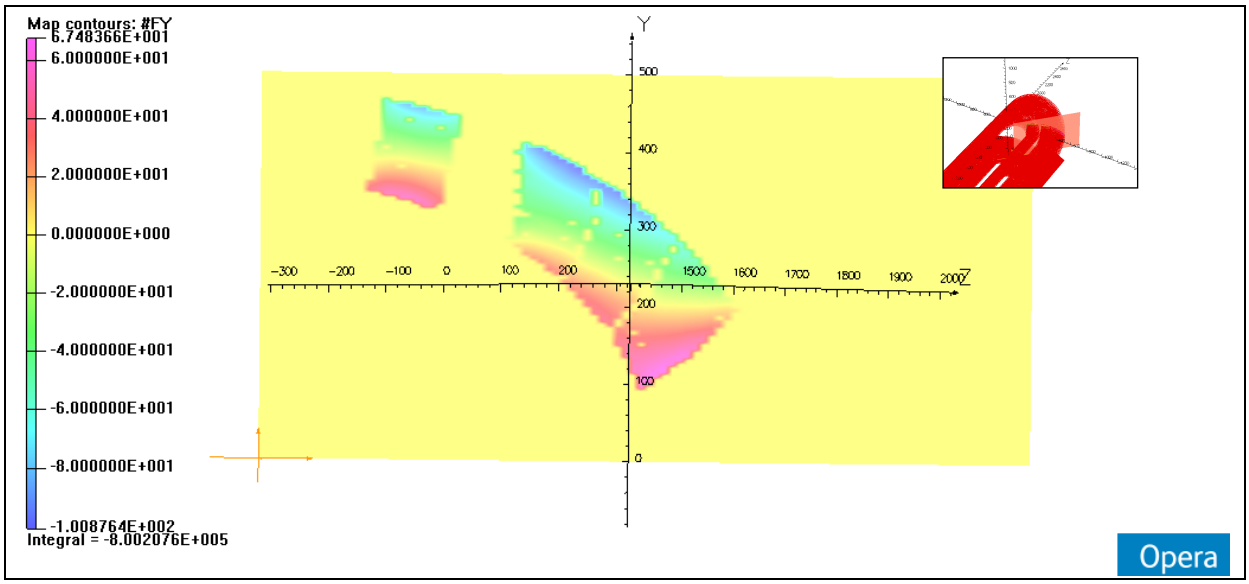


Fig. 28 –Fy force density in N/ cm^3 - Integrated Fy force in N/m – 3419.4 A

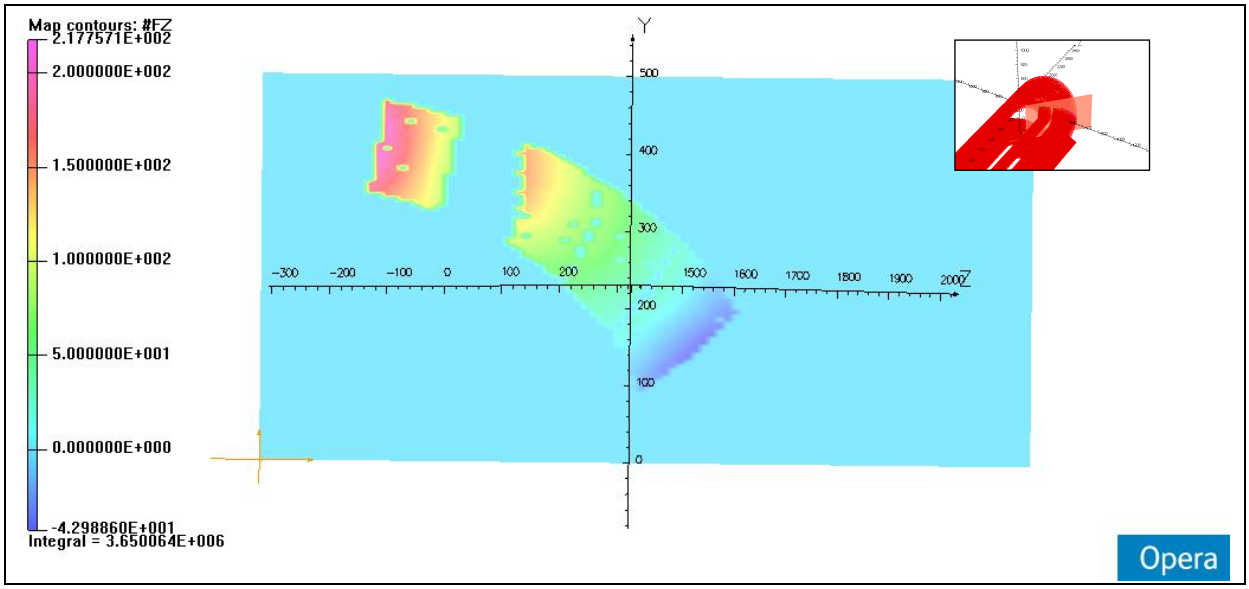


Fig. 29 –Fz force density in N/ cm^3 - Integrated Fz force in N/m – 3419.4 A

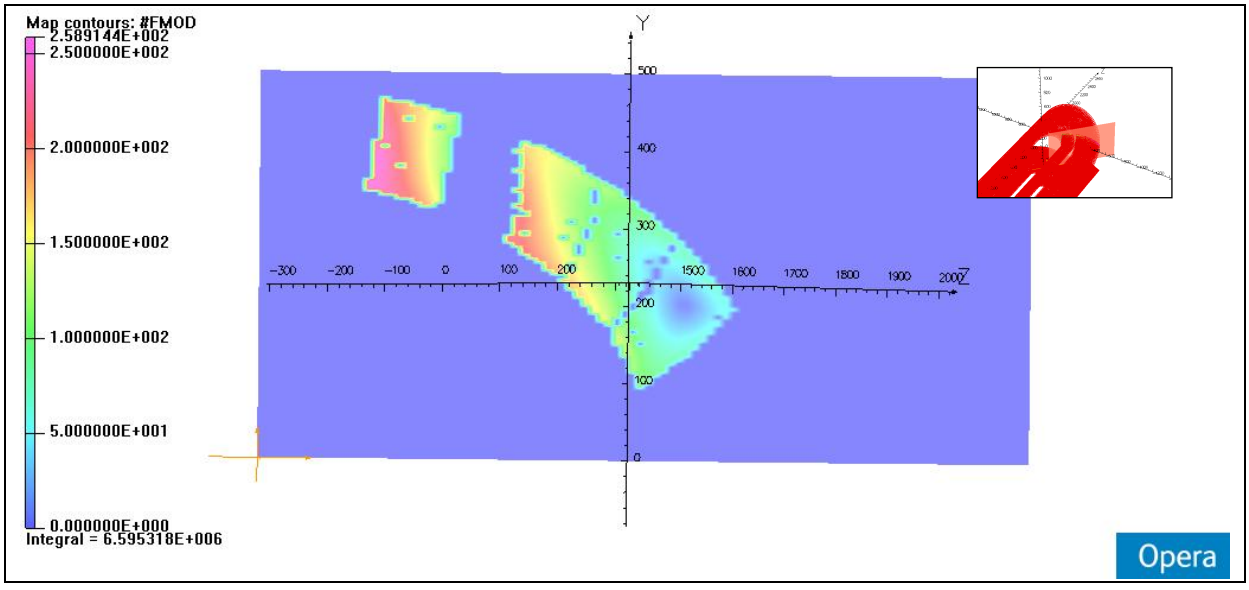
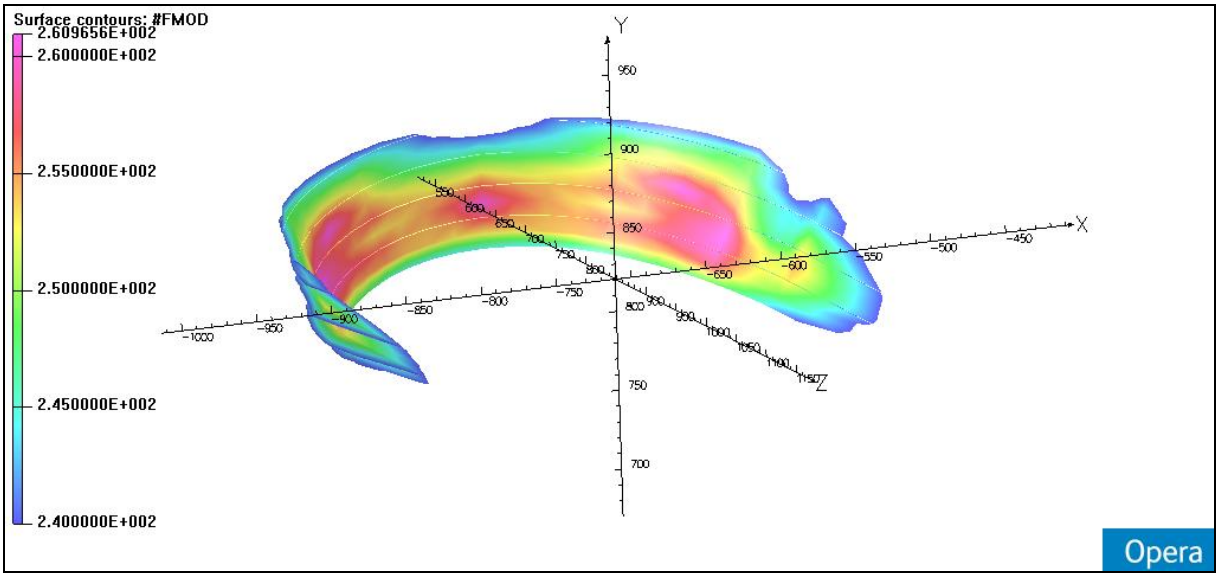


Fig. 29 –Fmod force density in N/ cm^3 - Integrated Fmod force in N/m – 3419.4 A

The peak Lorentz force density is 260.9 N/cm^3 located at the inner coil end corner



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OPERA CALCULATIONS - SUMMARY

	SIGMAPHI **3D CALCULATION** **317111-Vers21-Rev A**
Field	*4.25Tesla*
Field in a disk (R:250mm) **Mini .** **Maxi .**	 *4.205Tesla* *4.289 Tesla*
Integral	*12.066 T.m*
Lorentz force density – Peak value at the coil vertical middle plane	*Max Fx density =232 N/cm^3* *Max Fy density =147 N/ cm^3*
Lorentz force density – Peak value at the coil head	*Max Fmod =260.9 N/ cm^3*
Net sum on the forces (1/4 Model) **FX .** **FY .** **FZ .**	 *6.441 MN (3,76 MN/m)* *-3.036 MN(1,60 M/m)* *1.421 MN* *(figures in bracket are the relative force per meter for a half coil outer length of 1710 mm)*
Stored Energy	*16.15 MJ @3419.4 A*
Maximum field on the yoke	*1.85 Tesla*
Field in the coil **Mini .** **Maxi .**	 *0.104 Tesla* *5.45 Tesla*
Integrated Harmonics coefficients **b3 .** **b5 .** **b7 .** **b9 .**	 *-1.50%* *-0.49%* *-0.22%* *-0.28%*

Table 2