RF Simulations

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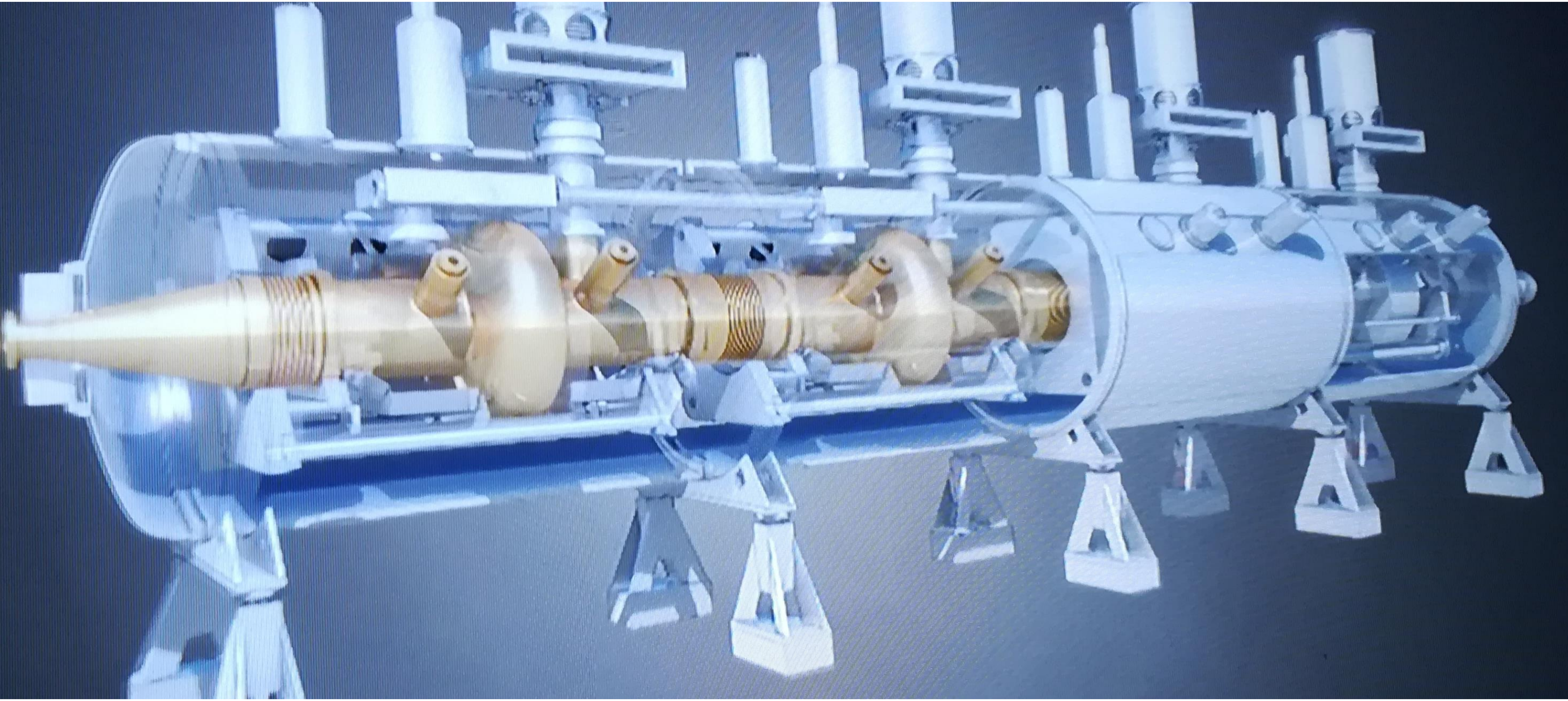
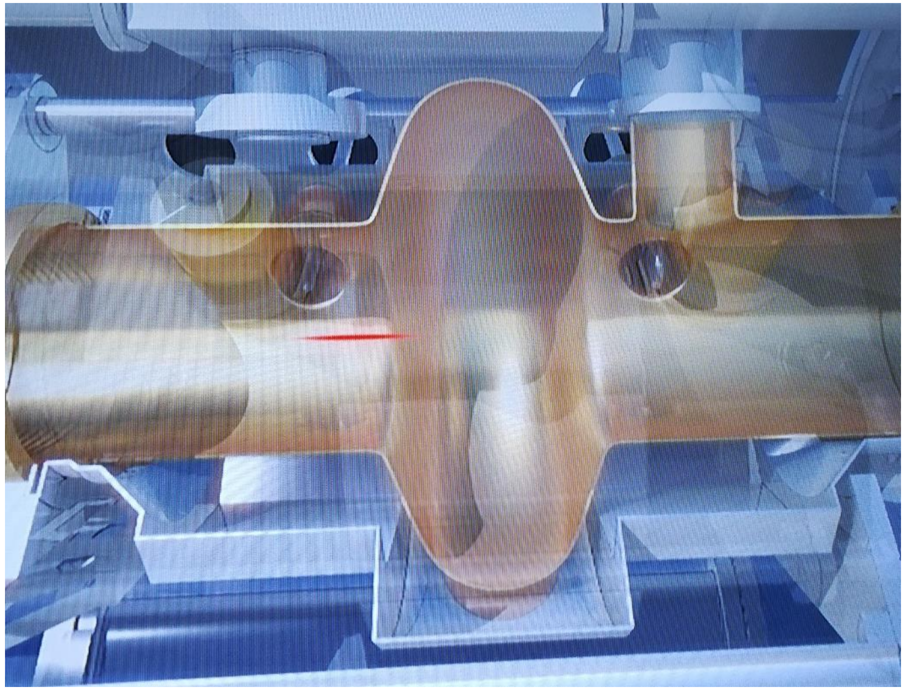
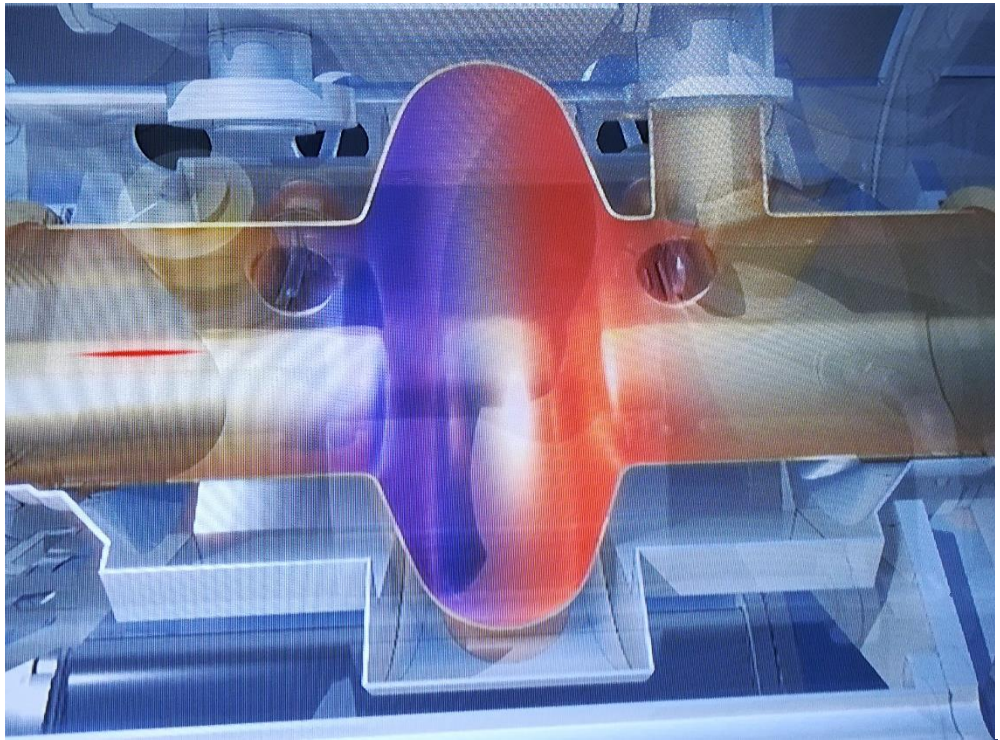
Source: Microcosm (CERN)

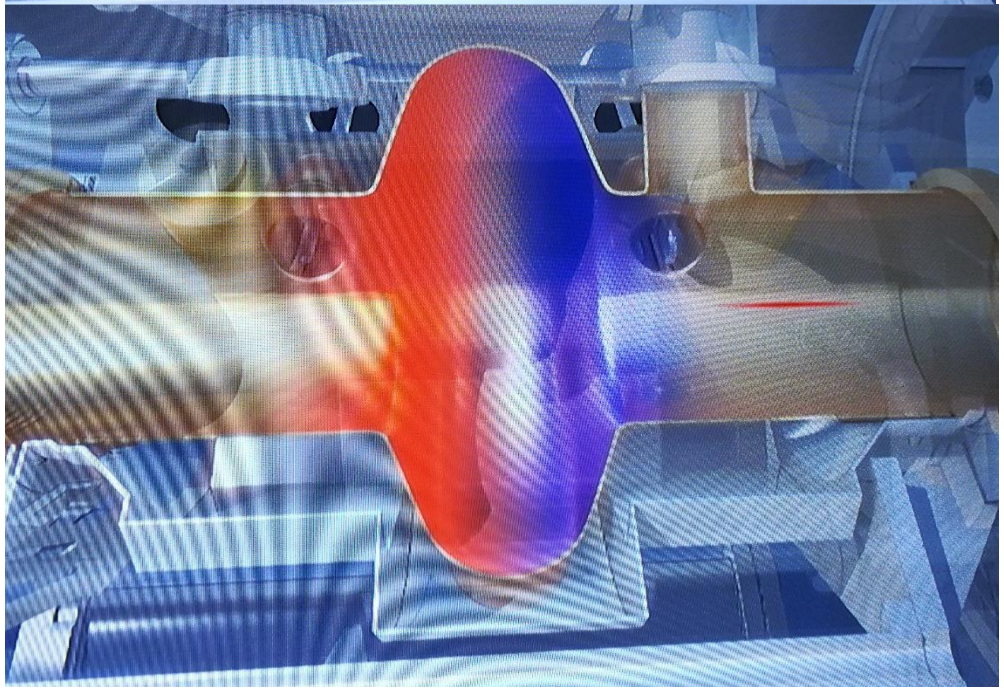


LHC Accelerating Cavities

Source: Microcosm (CERN)

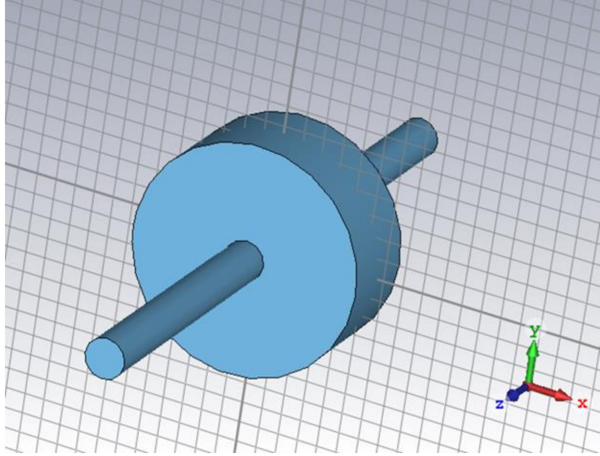






Source: Microcosm (CERN)

Pill Box Cavity



Set parameters: particle velocity (and charge)

- Frequency and length of the cavity depend on these parameters

Velocity $v_P \approx c$

Frequency $f \approx \frac{2.405 \cdot c_0}{2\pi r} = 1GHz$

Length $s = \frac{v_P}{2f} = \frac{c}{2f} \approx 0.15m$

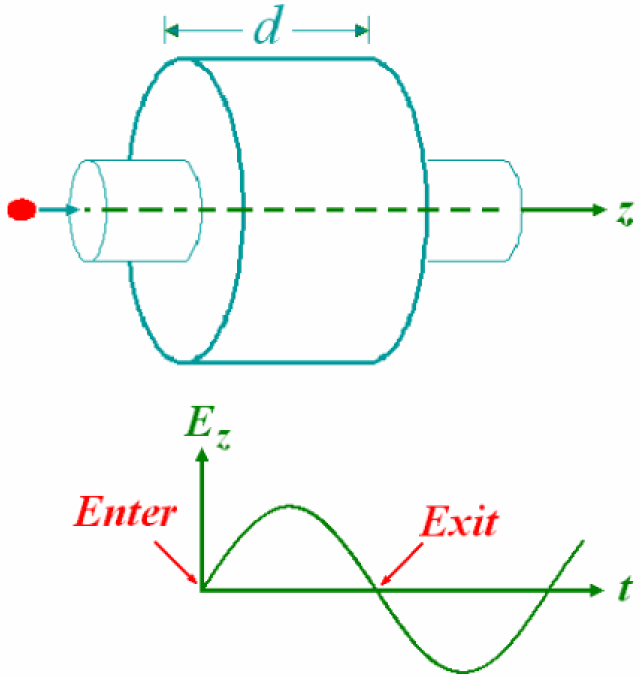
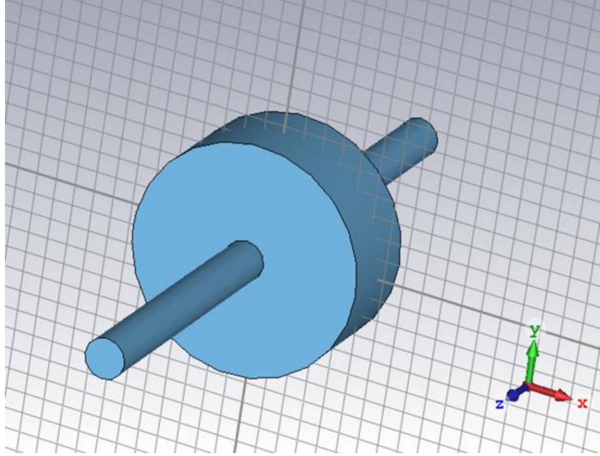


Figure 6: Pill-box cavity with beam tubes and the plot of the cavity electric field vs. time.

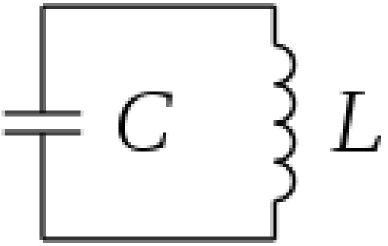
https://www.classe.cornell.edu/public/SRF/2006/SRF060424-03/SRF060424-03.pdf; p.3

Further Optimization



(I) Minimize losses

$$Q_0 = \frac{\omega W_s}{P_s} \sim \frac{Energy\ stored}{Power\ loss}$$



https://de.wikipedia.org/wiki/Schwingkreis#/media/File:Schwingkreis.svg

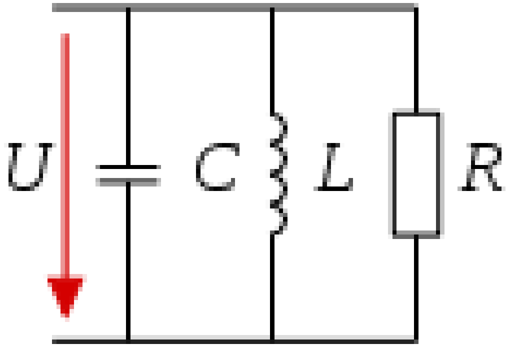
Cavity as oscillating circuit

Q_0 factor: rises with descending losses

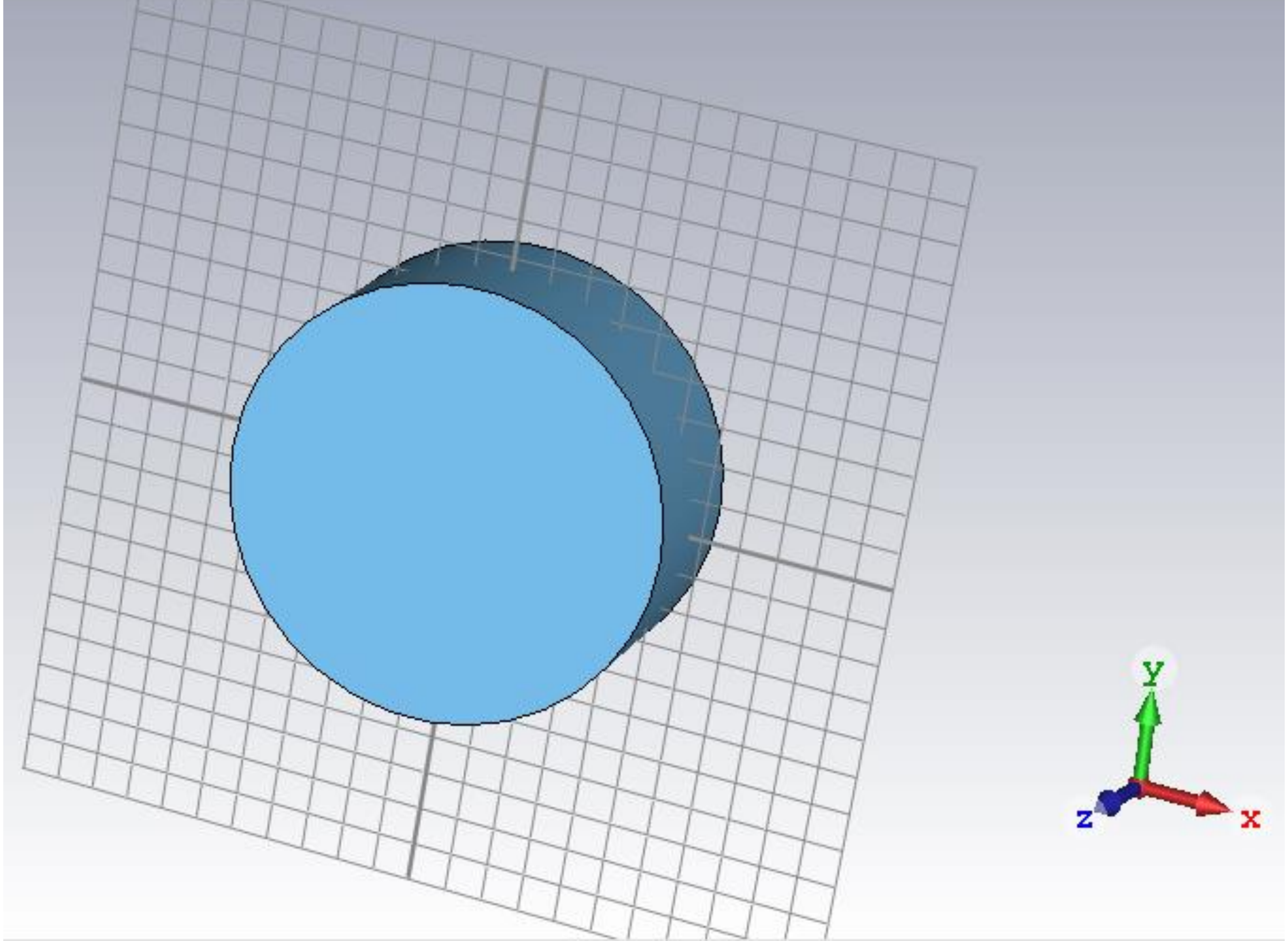
(II) Rise Efficiency

$$\frac{R}{Q} = \frac{{U_0}^2}{\omega W_s}$$

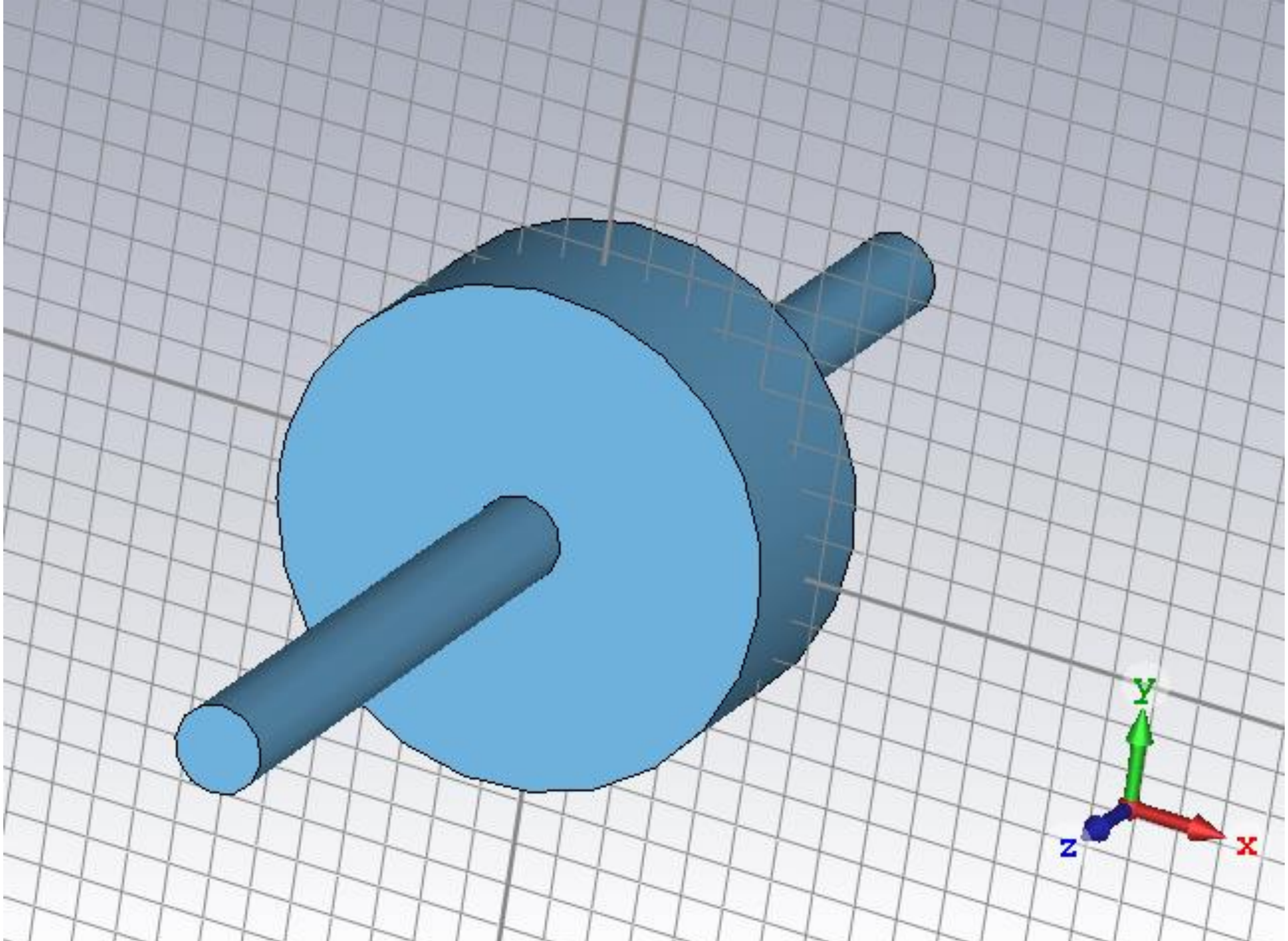
Indicates acceleration efficiency

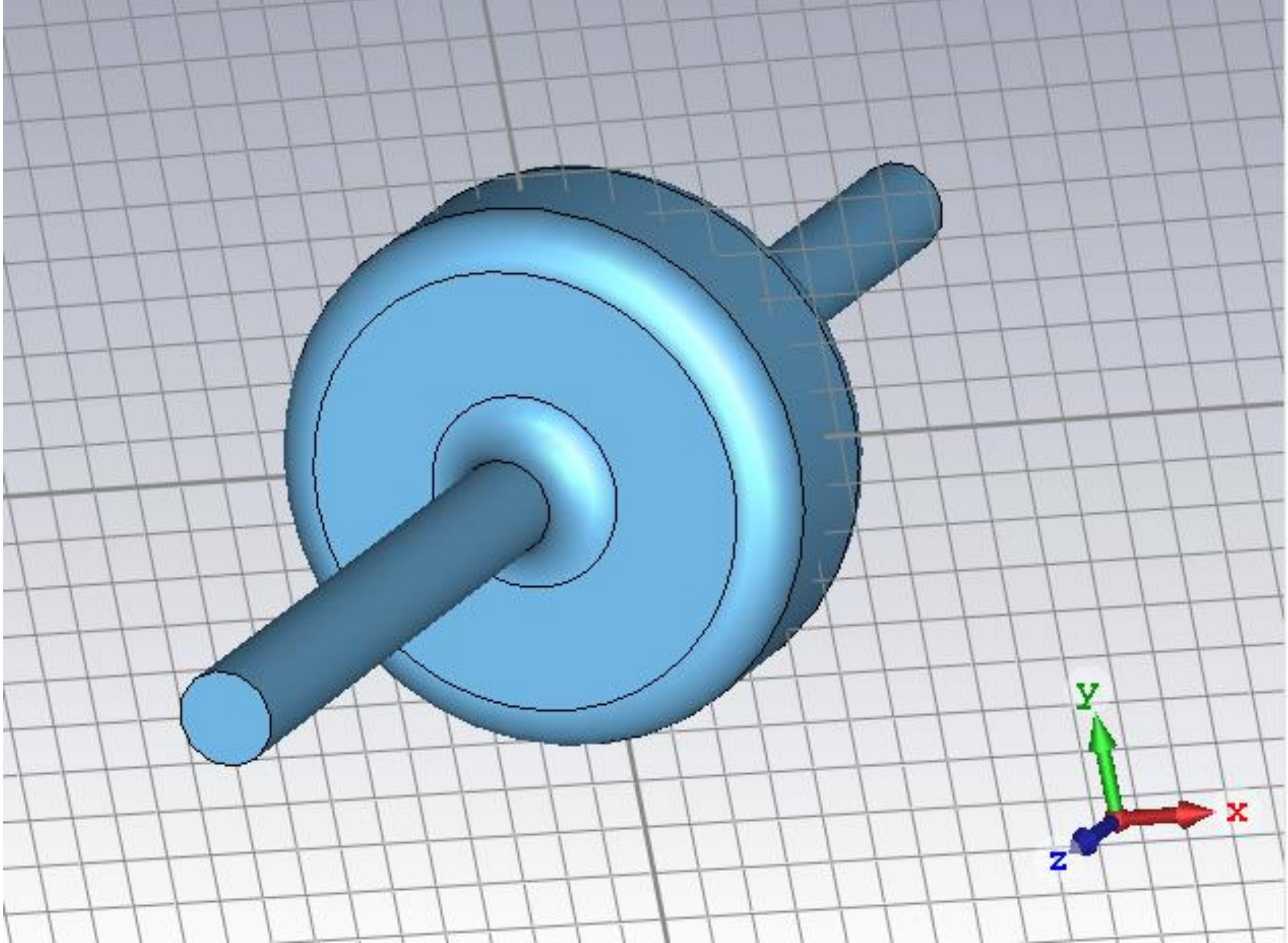


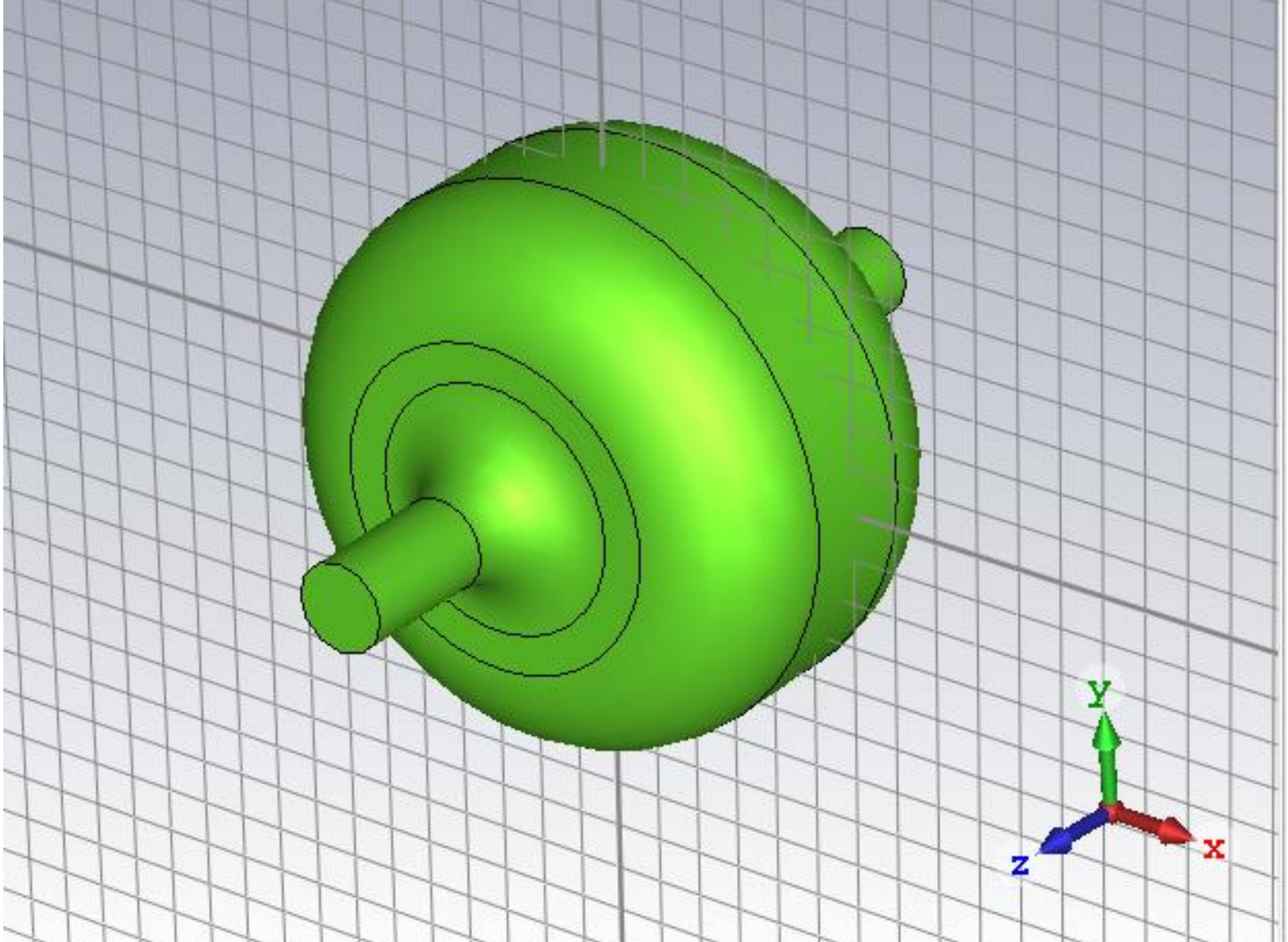
https://de.wikipedia.org/wiki/Parallelresonanz#/media/File:KondiSpuleWiderstandParallel.svg



y
z
x

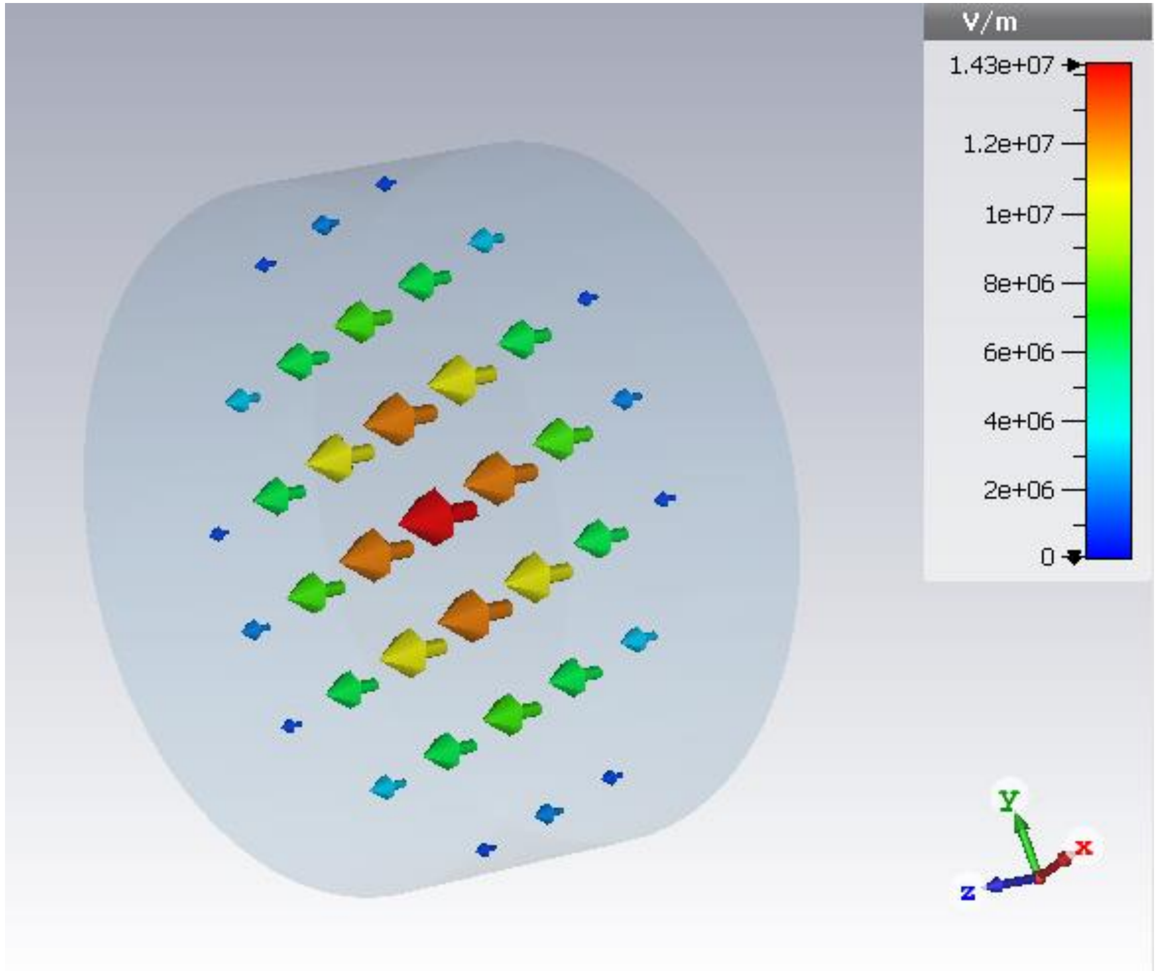

y
z
x

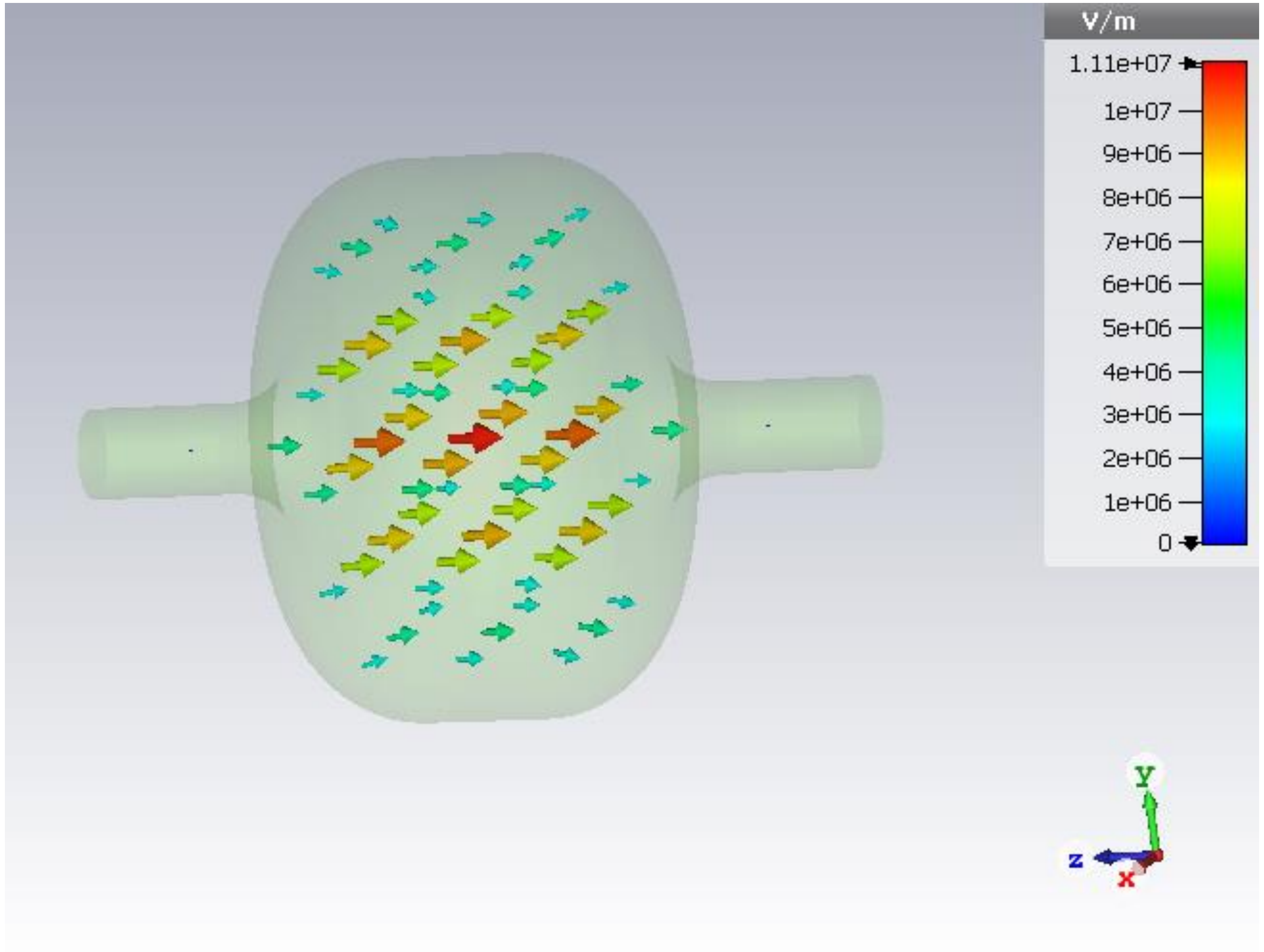

y
x
z



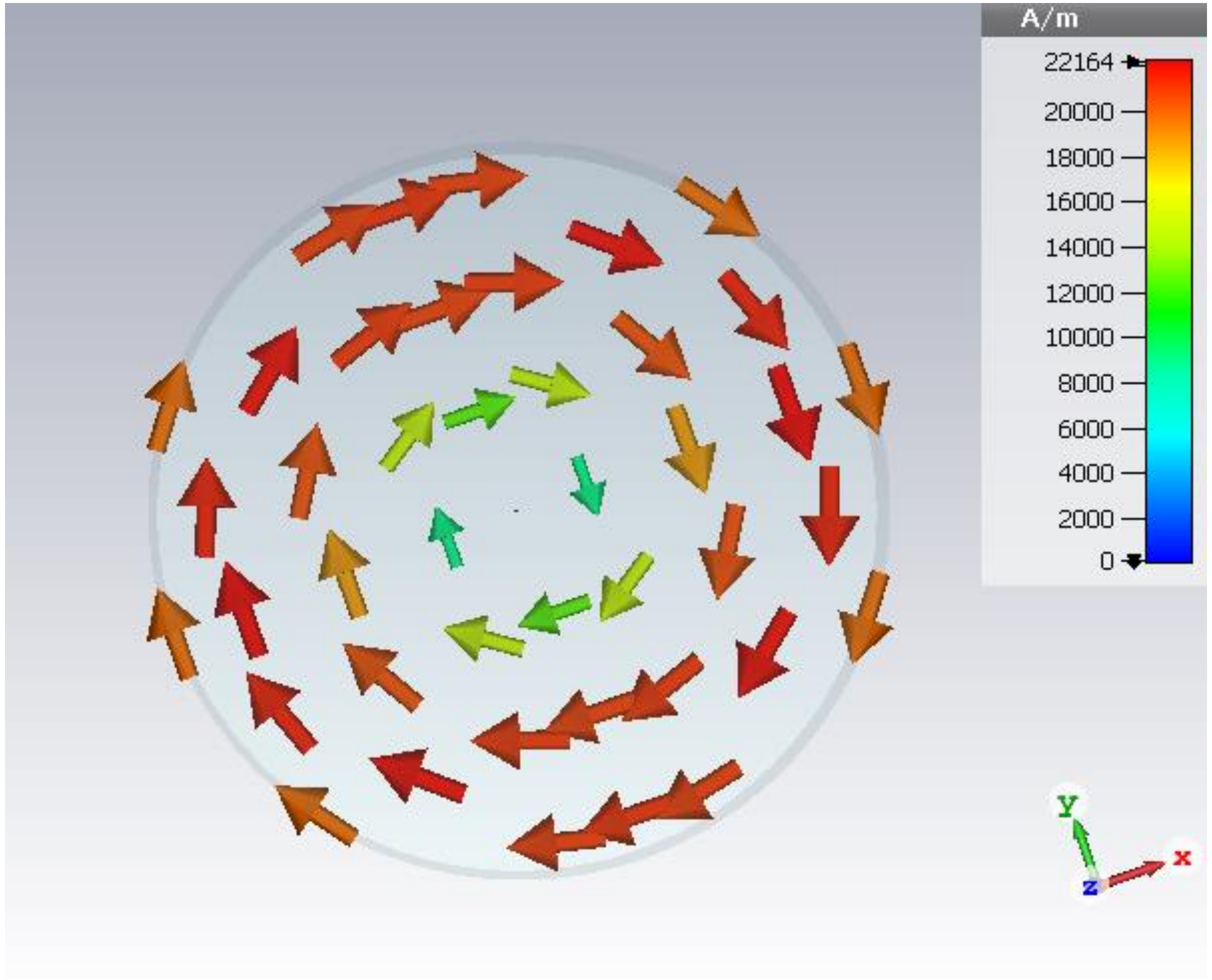
Y
Z
X

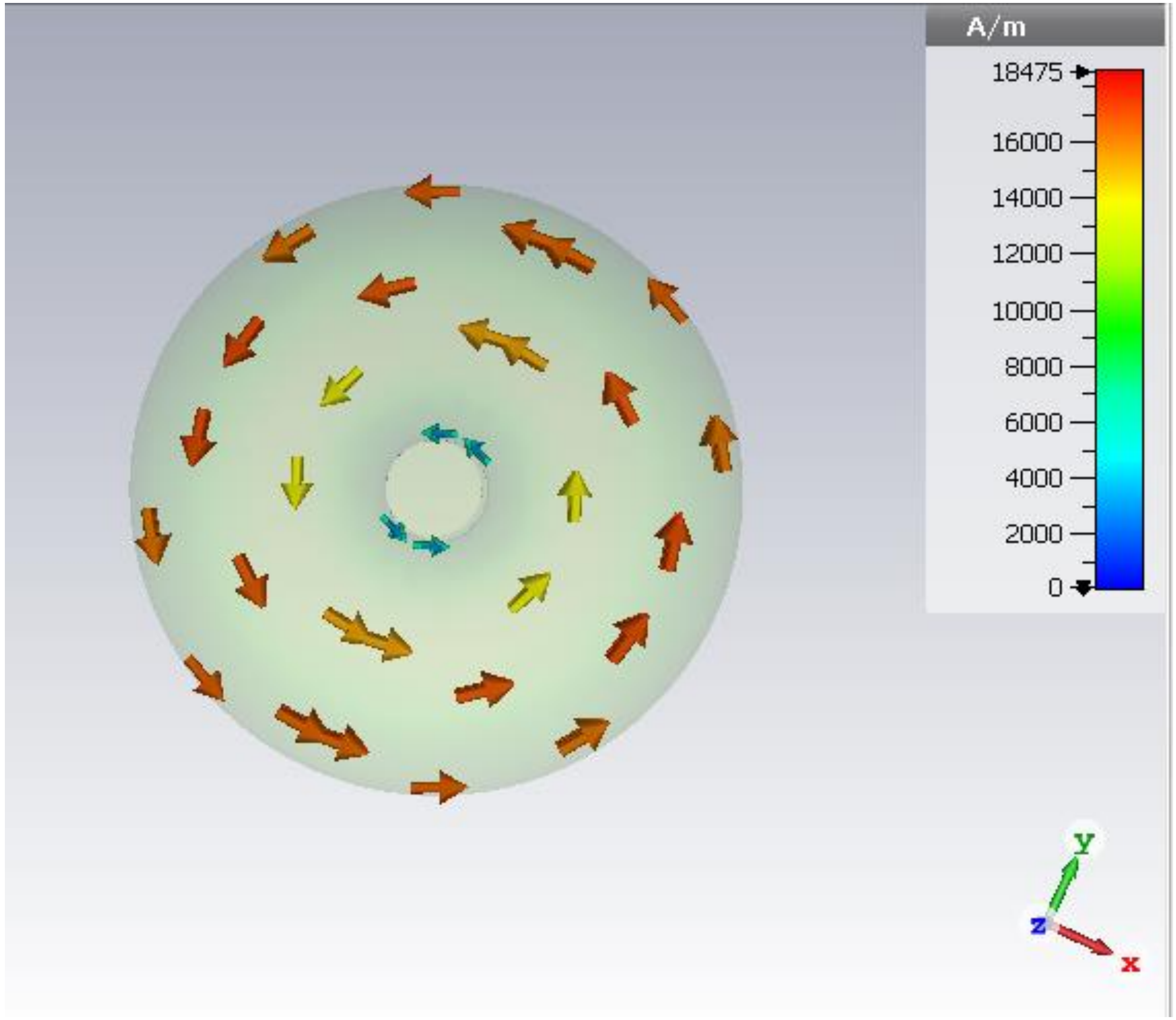
E-Field


V/m
1.43e+07
1.2e+07
1e+07
8e+06
6e+06
4e+06
2e+06
0
y
x
z

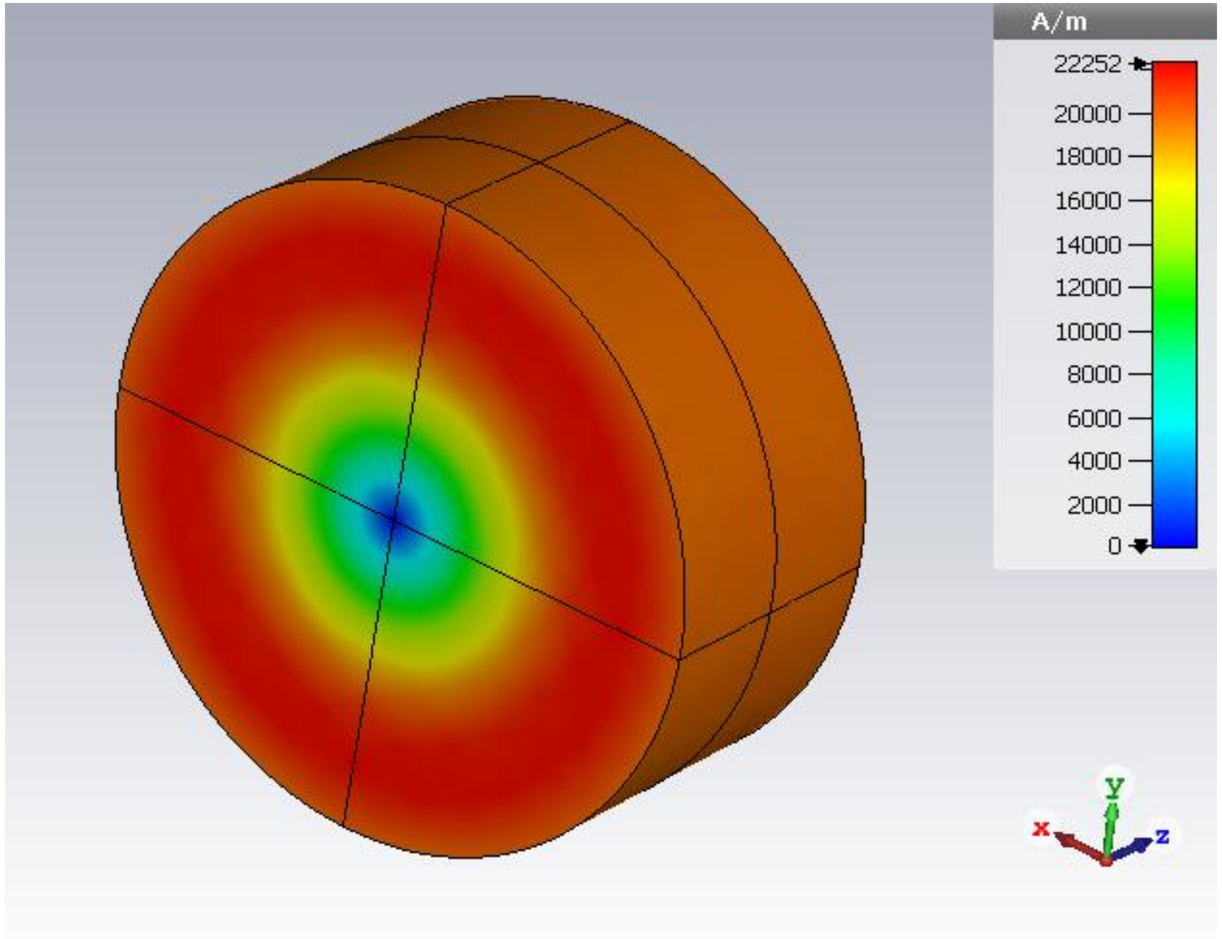

V/m
1.11e+07
1e+07
9e+06
8e+06
7e+06
6e+06
5e+06
4e+06
3e+06
2e+06
1e+06
0
y
z
x

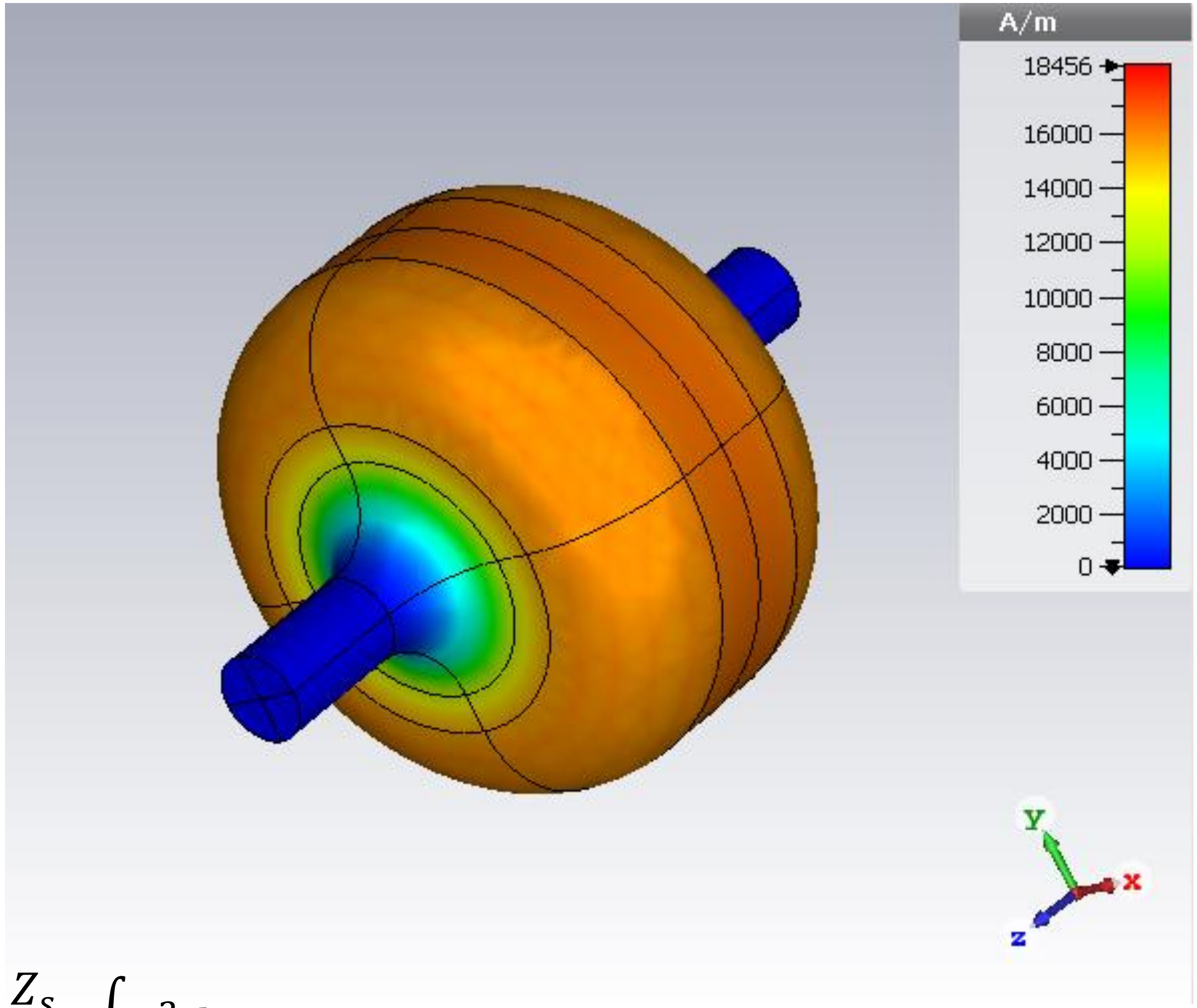
H-Field


A/m
22164
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
y
x
z


A/m
18475
16000
14000
12000
10000
8000
6000
4000
2000
0
y
z
x

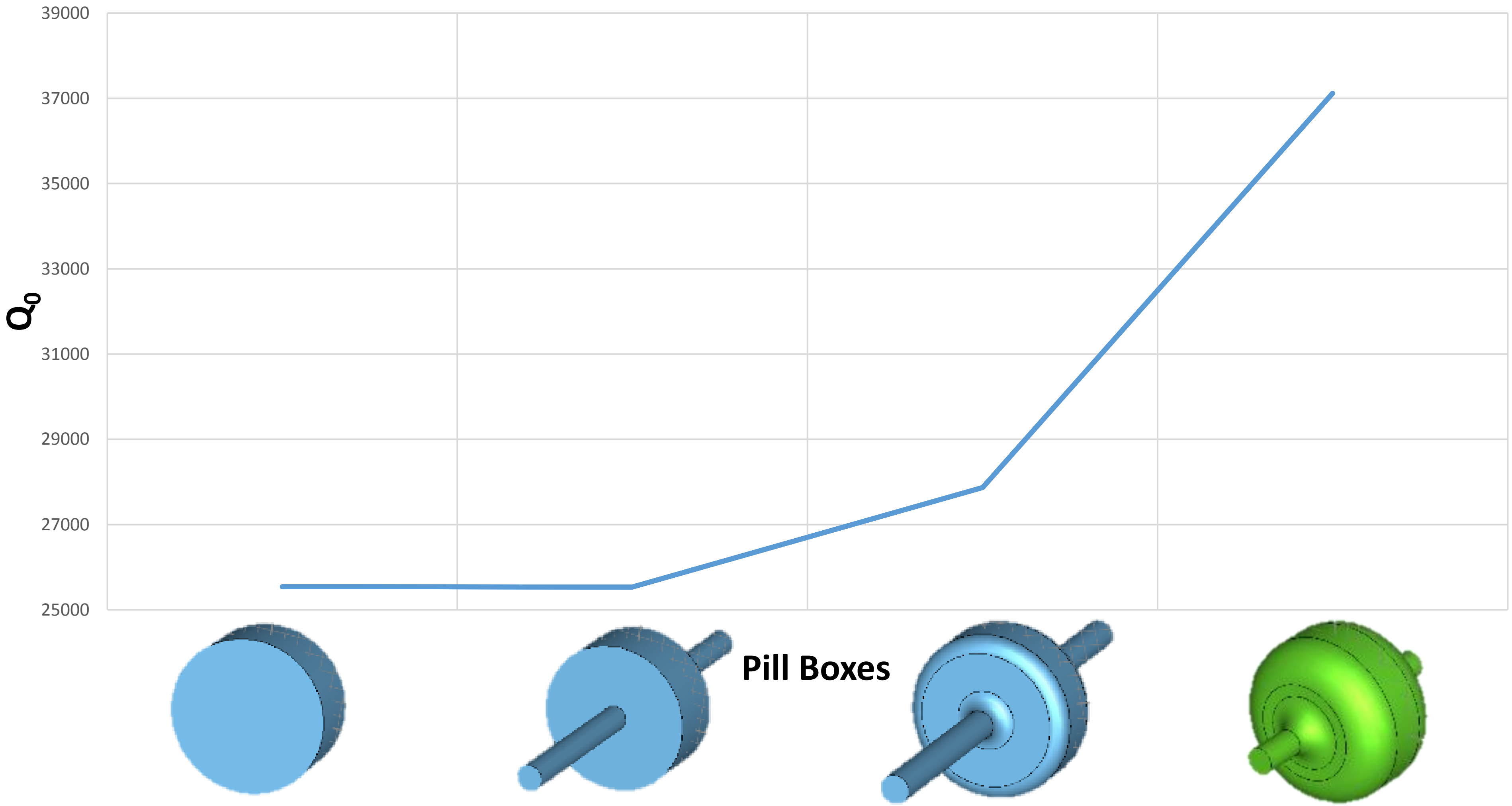
Surface Currents

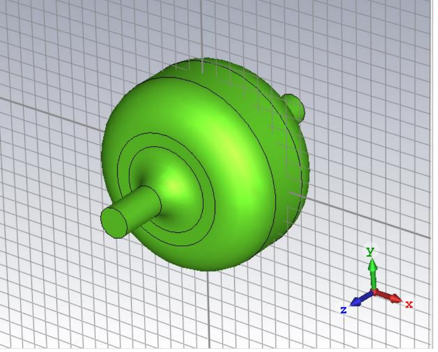




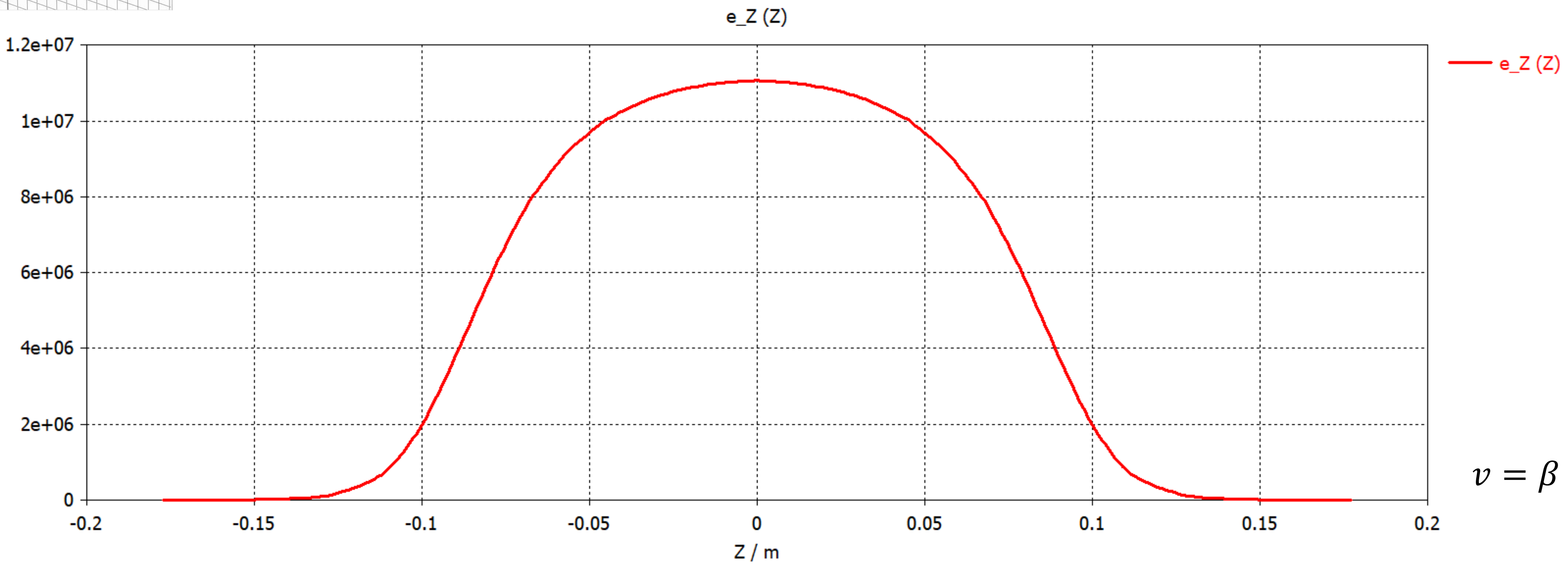
$J = \mathrm{n} \times \mathrm{H}$ $\quad P = \frac{Z_s}{2} \cdot \int J^2 dA$

Change of Q_0 during the Optimization Process





Acceleration of a Particle



$$v = \beta \cdot c_0$$

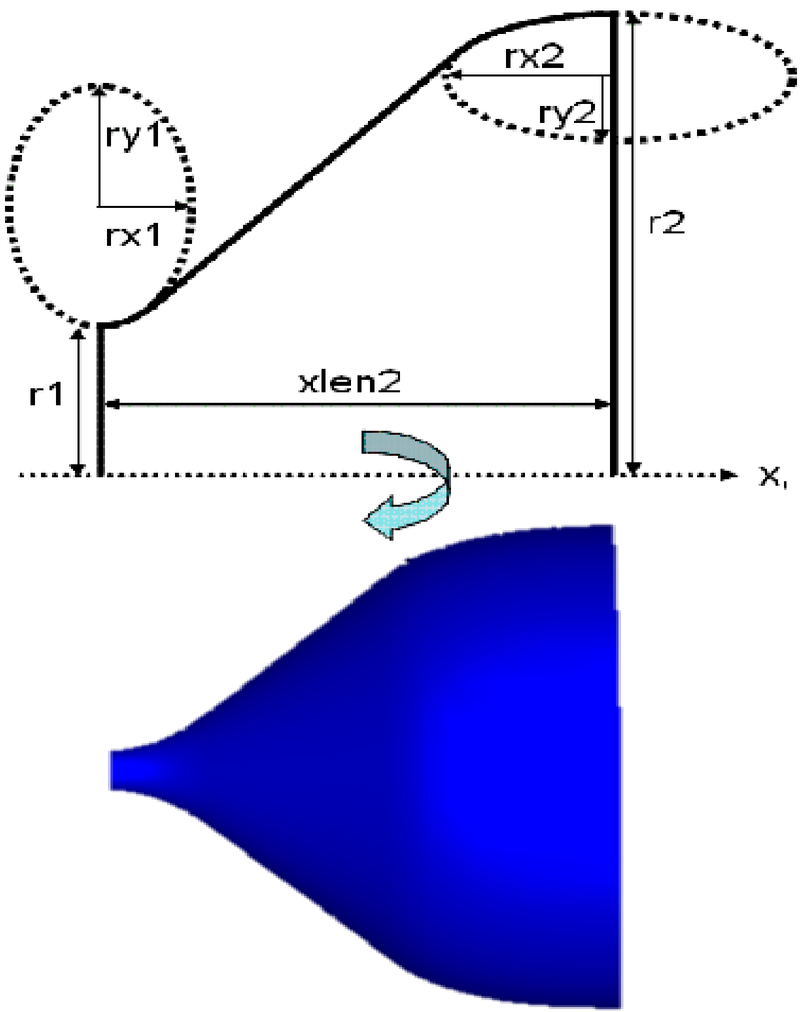
$$U = E \cdot d \qquad E(z) \neq constant: U = \int E\,dz$$

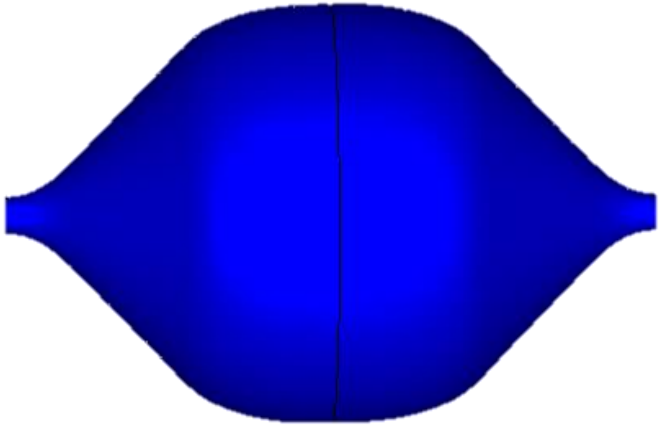
$$U_B = \int_0^l E(z) \cdot \sin\left(\frac{\omega}{v} z\right) dz = 1{,}00 \cdot 10^6\ V$$

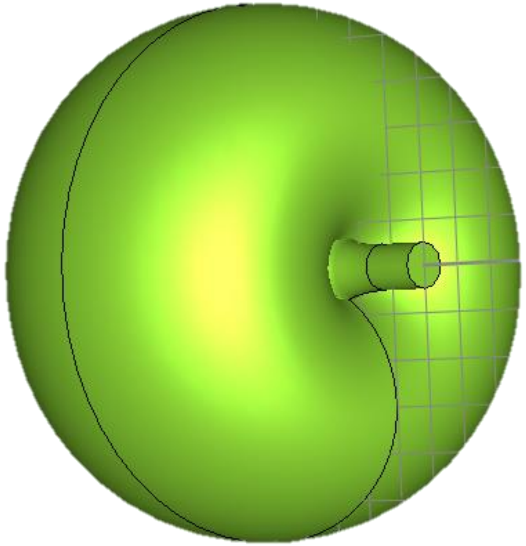
$$E(t) \neq constant: E(z,t) = \sin(\omega t) \cdot E_{max}(z)$$

$$E_{acc} = \frac{1}{l} \int_0^l E(z) \cdot \sin\left(\frac{\omega}{v} z\right) dz = 6{,}71 \cdot 10^6\,\frac{V}{m}$$

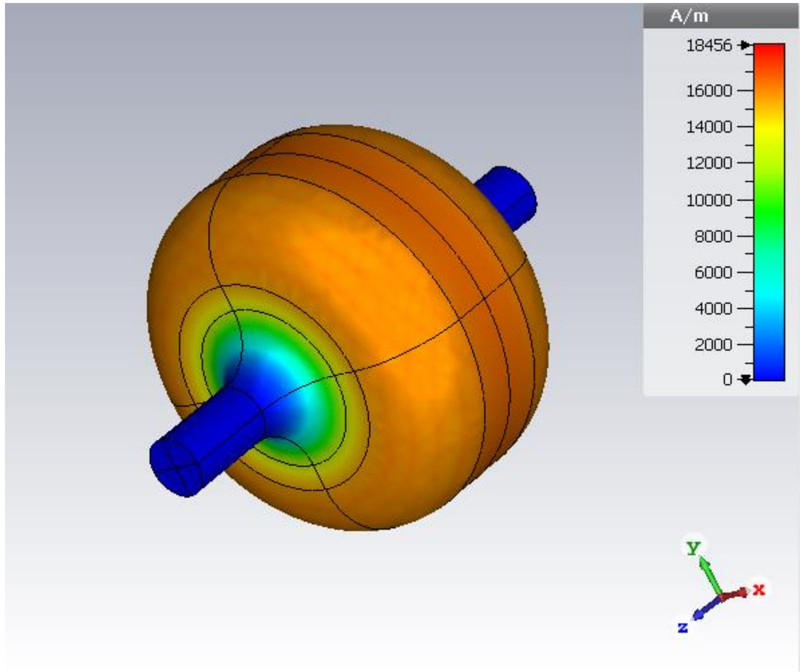
Elliptical Cavity

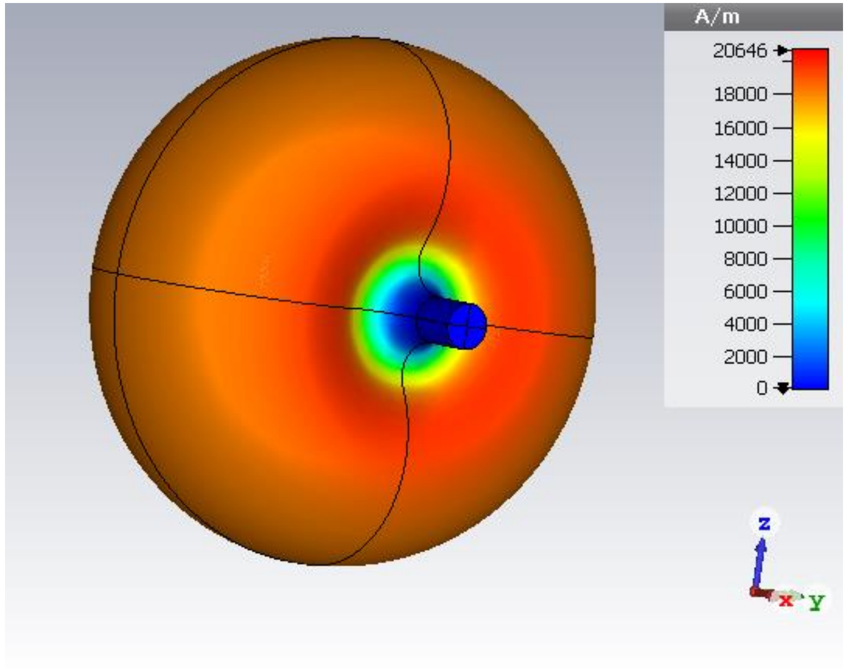




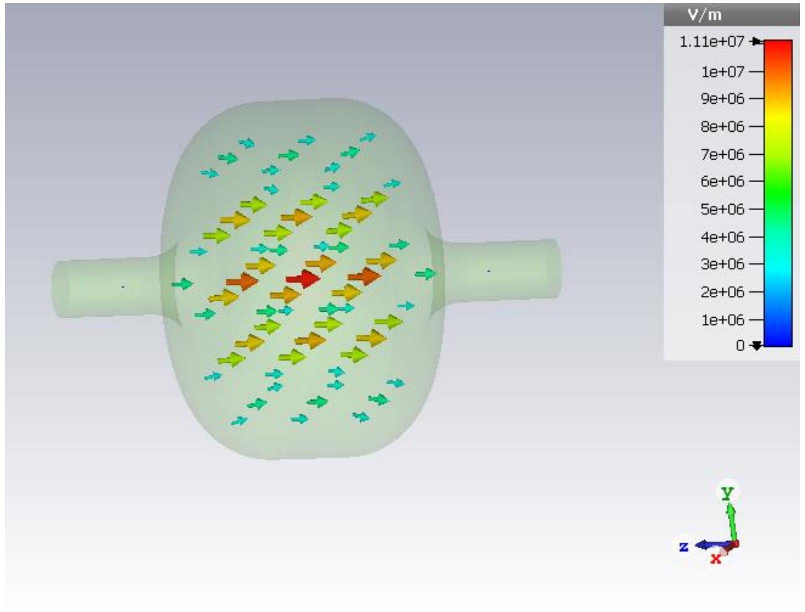


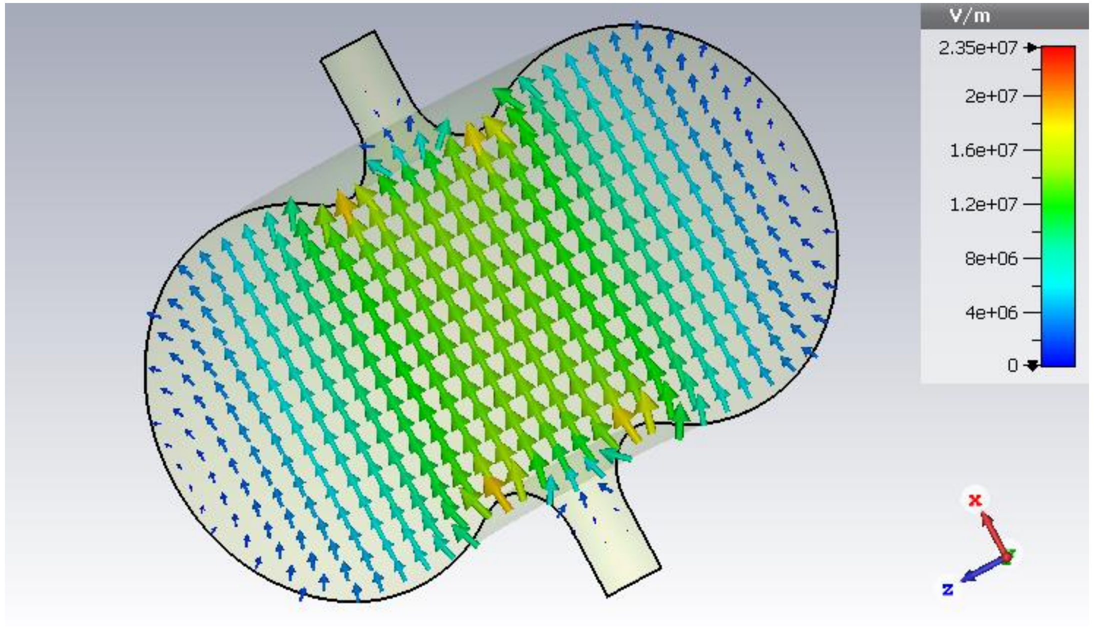
Surface currents



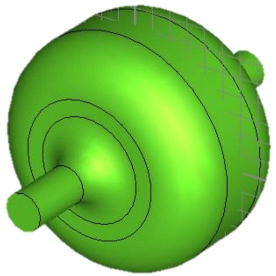


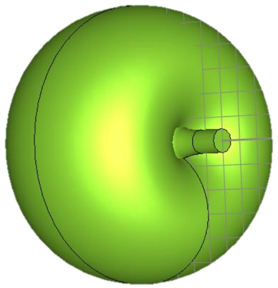
E Field





Comparison





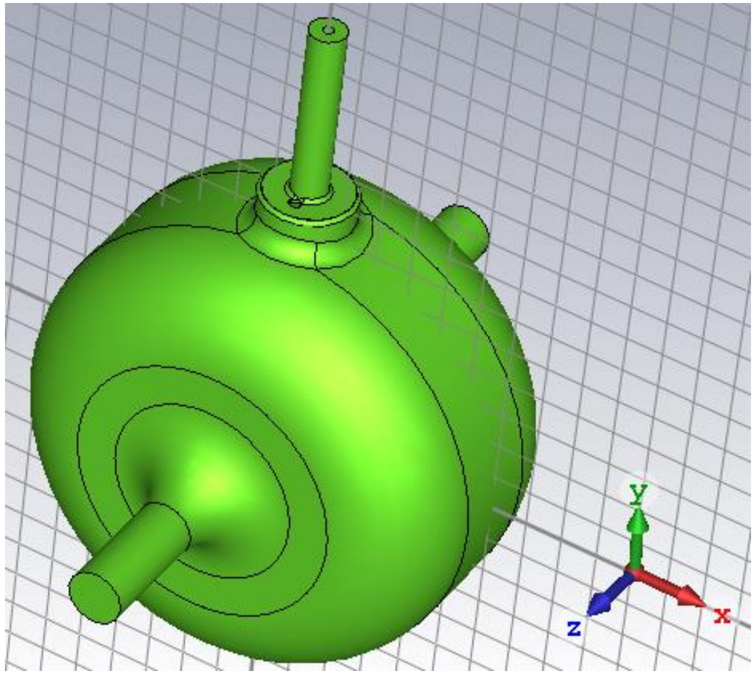
	Pill box cavity	Elliptical cavity
Voltage U [MV]	1	1
Q_0 [1]	37122	32309
R/Q [Ω]	159	231
Surface emission [1]	1.94	2.92
Magnetic quench [A/V]	3.28	3.19
P [kW]	169	134

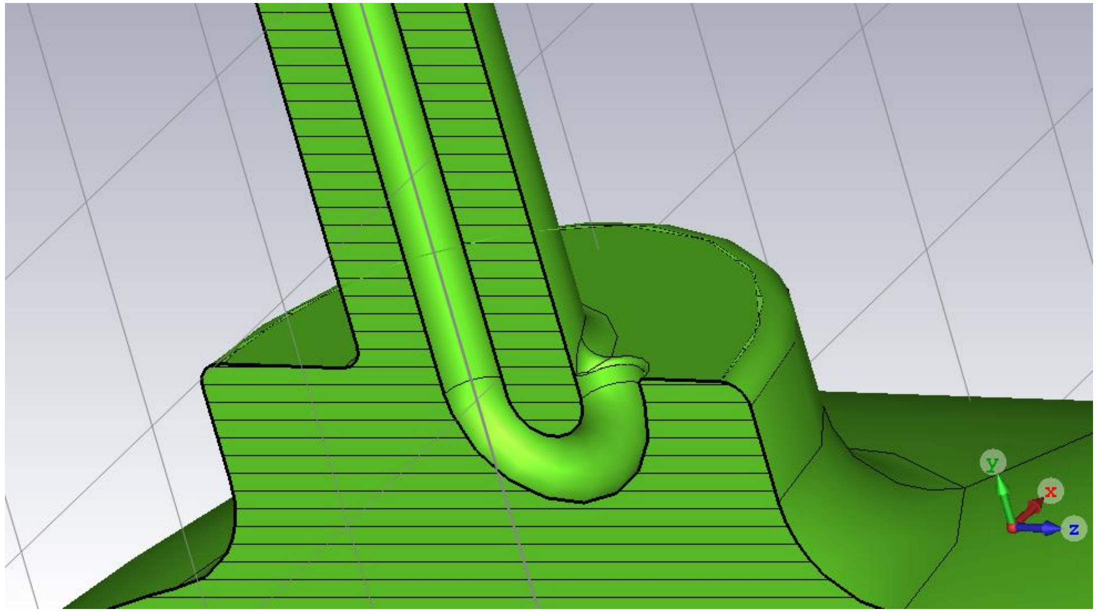
$$\frac{E_{max}}{E_{acc}}$$

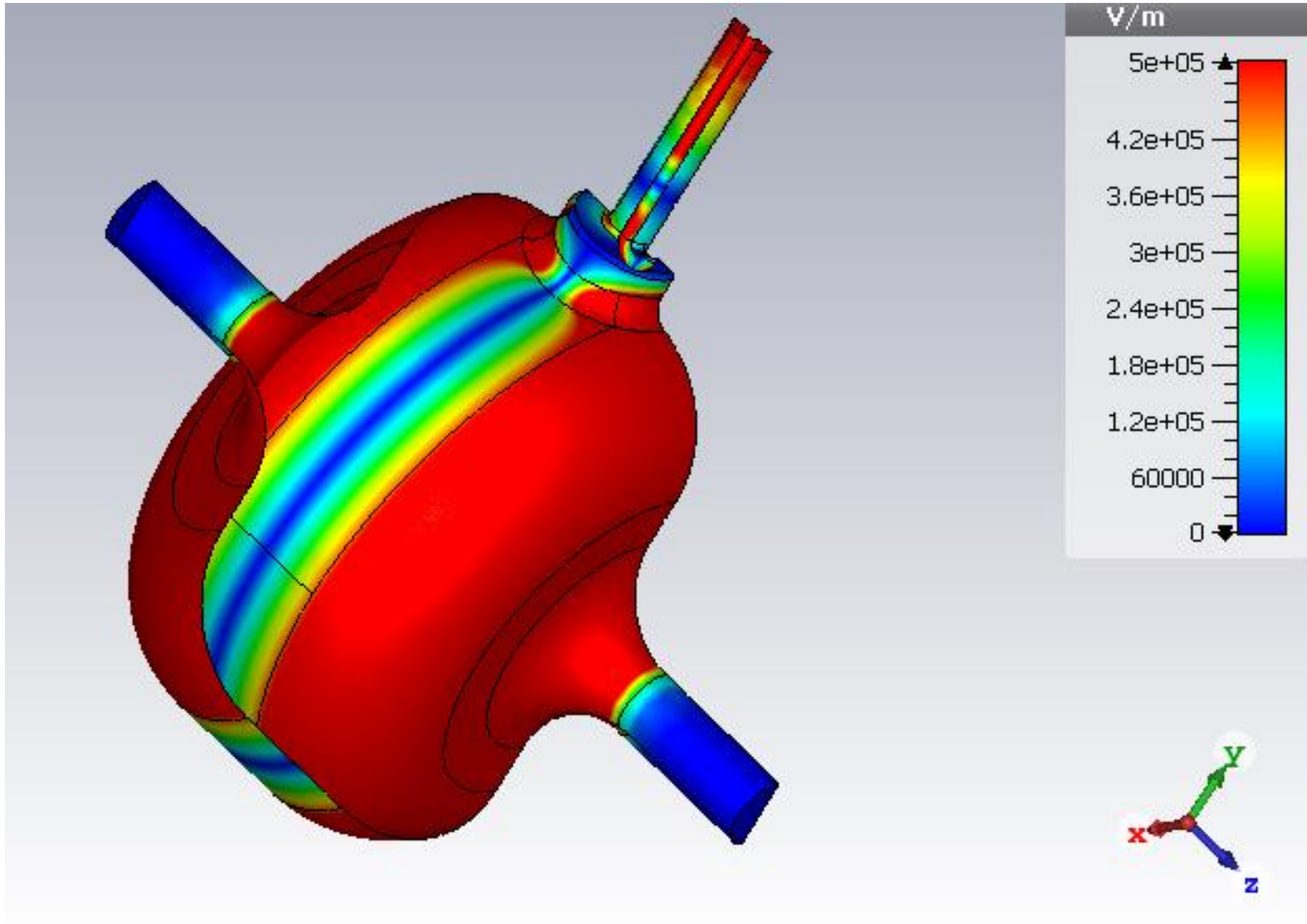
$$\frac{H_{max}}{E_{acc}}$$

$$P = \frac{V^2}{Q \cdot \frac{R}{Q}}$$

Feeding the Cavity: The Power Coupler







Thank you for listening!

Sources

- Belomestnykh, Sergey, and Valery Shemelin. "High-beta Cavity Design-A Tutorial." SRF International Workshop, Ithaca, New York. 2005.
- https://de.wikipedia.org/wiki/Parallelresonanz#/media/File:KondiSpuleWiderstandParallel.svg
- https://de.wikipedia.org/wiki/Schwingkreis#/media/File:Schwingkreis.svg
- Microcosm at CERN
- Used program for simulations: CST Microwave Studio

Coupler

$Q_0 \overset{!}{=} Q_{ext}$: matched

$Q_0 < Q_{ext}$: Not enough input

$Q_0 > Q_{ext}$: Too much input

Solving Algorithm