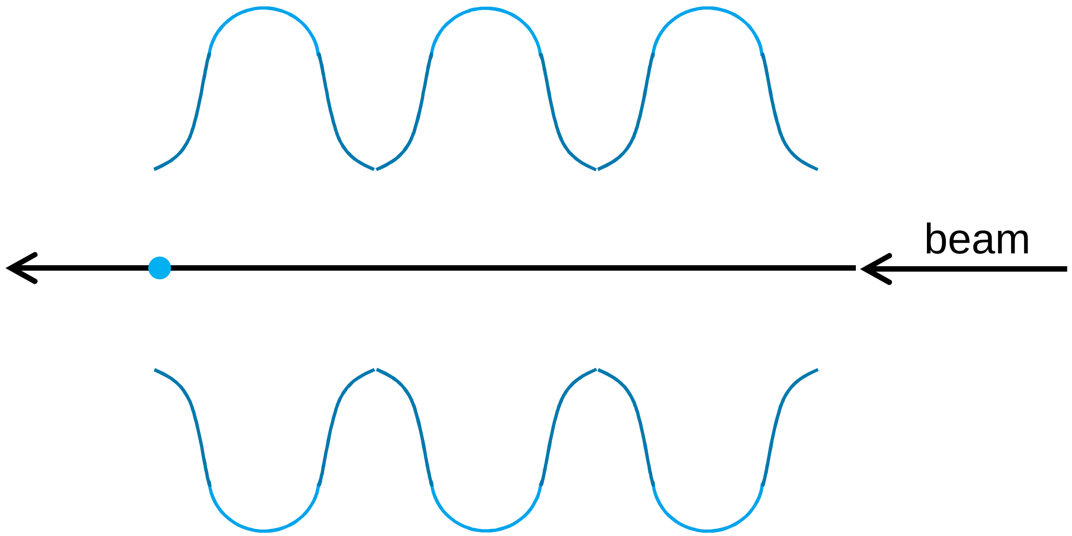
Homework



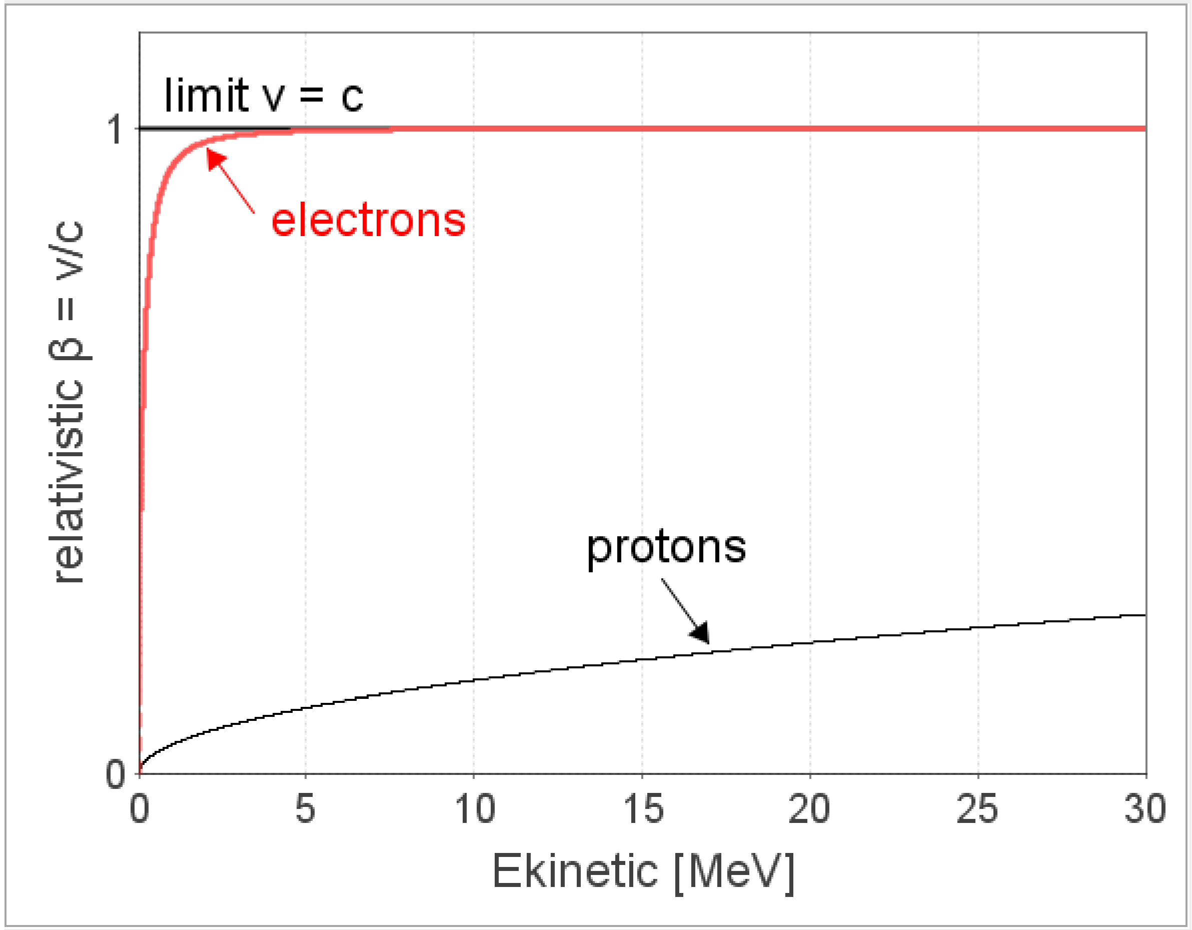
$$t = \frac{T_{RF}}{2} \quad \leftrightarrow \quad l = \cdots$$

homework !

assume $v = c$ (ultra-relativistic case)

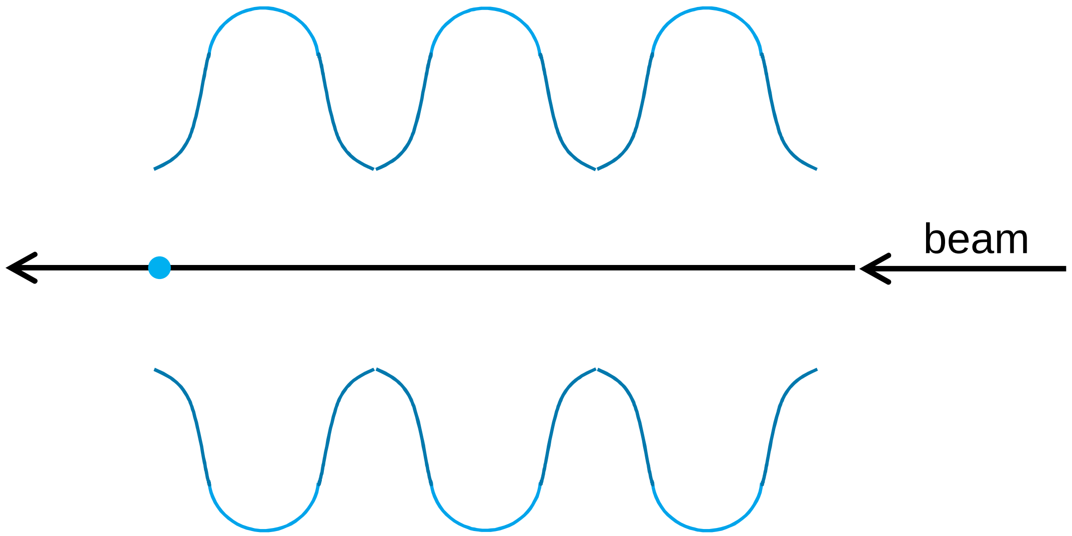
$$f_{RF} = 1.3\ \text{GHz}$$

Homework



limit v = c
1
0
electrons
protons
relativistic β = v/c
0
5
10
15
20
25
30
Ekinetic [MeV]

Homework



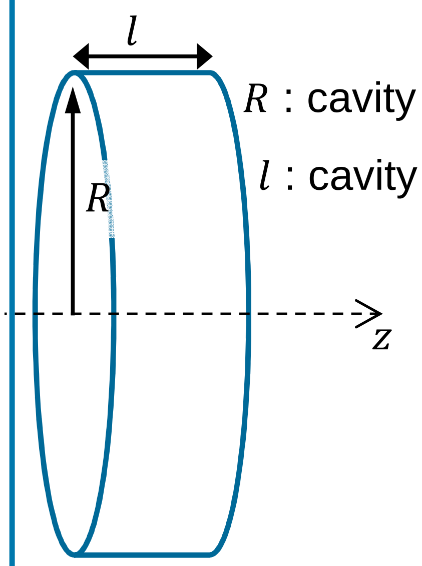
$$t = \frac{T_{RF}}{2} \quad \leftrightarrow \quad l = \frac{T_{RF}}{2}\, v = \frac{v}{2 f_{RF}} = \frac{c}{2 \cdot 1.3\ GHz} = \frac{3 \cdot 10^8}{2 \cdot 1.3 \cdot 10^9} = 0.1154\ m = L_{cell}$$

Homework

Calculate the resonant frequency of the fundamental mode in a ‘coca-cola’ tin

assume a cylindrical shape
with a diameter of 6.4 cm and a height of 12.1 cm

boundary conditions



R : cavity radius

l : cavity length

fundamental solution with $B_z = 0$ (that is, $\vec{B}$ is transverse)

$$E_z = E_0 J_0\left(x_{01}\frac{r}{R}\right) e^{j\omega t}$$

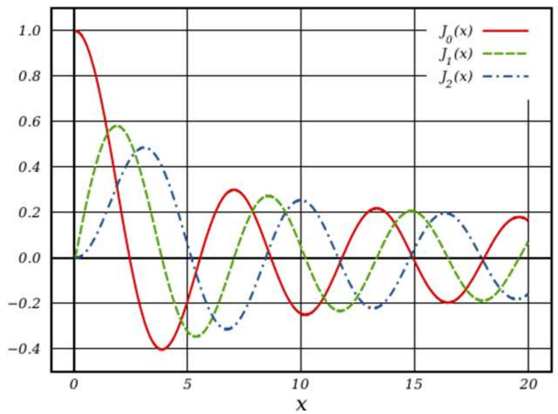
$$E_r = 0$$

$$E_\theta = 0$$

$$B_z = 0$$

$$B_r = 0$$

$$B_\theta = j\omega \frac{R}{x_{01}c^2} E_0 J_1\left(x_{01}\frac{r}{R}\right) e^{j\omega t}$$



rotation symmetry of the fields

no zeros of the axial field component in $\vec{r}$

no variation in z of the fields

J_m : Bessel´s functions

J'_m : derivative of the Bessel´s functions

angular frequency :

$$\omega = c\,\frac{x_{01}}{R} \qquad x_{01} = 2.405$$

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Calculate the resonant frequency of the fundamental mode in a 'coca-cola' tin

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$$\omega = c\frac{x_{01}}{R} = 3 \cdot 10^8 \frac{2.405}{0.032} = 2.25 \cdot 10^{10} \quad rad \cdot s^{-1}$$

$$f = \frac{\omega}{2\pi} = 3.6 \quad GHz$$

Microwave frequency bands

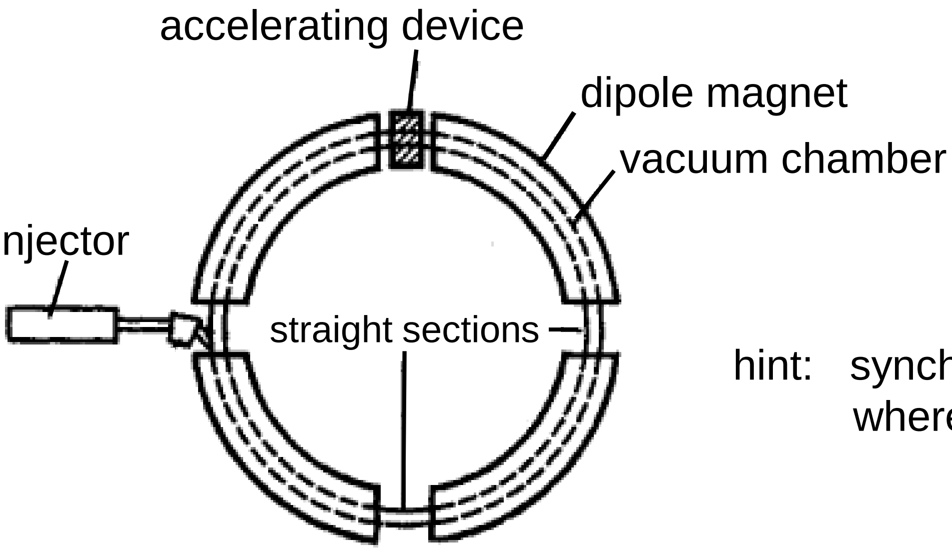
Letter Designation	Frequency range	Wavelength range	Typical uses
L band	1 to 2 GHz	15 cm to 30 cm	military telemetry, GPS, mobile phones (GSM), amateur radio
S band	2 to 4 GHz	7.5 cm to 15 cm	weather radar, surface ship radar, and some communications satellites (microwave ovens, microwave devices/communications, radio astronomy, mobile phones, wireless LAN, Bluetooth, ZigBee, GPS, amateur radio)
C band	4 to 8 GHz	3.75 cm to 7.5 cm	long-distance radio telecommunications
X band	8 to 12 GHz	25 mm to 37.5 mm	satellite communications, radar, terrestrial broadband, space communications, amateur radio
K_u band	12 to 18 GHz	16.7 mm to 25 mm	satellite communications

http://en.wikipedia.org/wiki/Microwave

Homework

Assume a non-stable charged particle with mean lifetime of τ circulating in a synchrotron whose dipoles have a magnetic field B and occupy half its circumference (dipole fill factor of 0.5)

1) Obtain an expression for the number of turns that this particle will travel around the synchrotron during the particle's mean lifetime at the lab reference system $\tau^* = \gamma\,\tau$ as a function of the dipole magnetic field B



hint: synchrotron circumference: $\mathrm{L} = 2 \cdot (2\pi\, R)$
where R is the bending radius inside the dipoles

assume $v = c$ (ultra-relativistic case)

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$\mathrm{L} = 2 \cdot (2\pi\, R)$ ➔ 1 turn = $T = \dfrac{4\pi R}{v}$

$$\vec{B} \perp \vec{v} \quad \rightarrow \quad F = qvB$$

$$\vec{F} \perp \vec{v} \quad \rightarrow \quad F = m\frac{v^2}{R}$$

(circular motion)

$$qB = \frac{mv}{R}$$

$$T = \frac{4\pi R}{v} = \frac{4\pi m}{qB}$$

$$n\,T = \tau^* = \gamma\tau \quad ➔ \quad n = \frac{\gamma\tau}{T} = \frac{\gamma\tau q B}{4\pi m} = \frac{\gamma\tau q B}{4\pi\gamma m_0} = \frac{\tau q}{4\pi m_0} B$$

Homework

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1) Obtain an expression for the number of turns that this particle will travel around the synchrotron during the particle's mean lifetime at the lab reference system $\tau^* = \gamma\,\tau$ as a function of the dipole magnetic field B

2) Apply the expression obtained in (1) for the muon with:

   mean lifetime $\tau = 2.2\,\mu s$

   charge $\mathrm{q} = 1.6 \cdot 10^{-19}\,C$

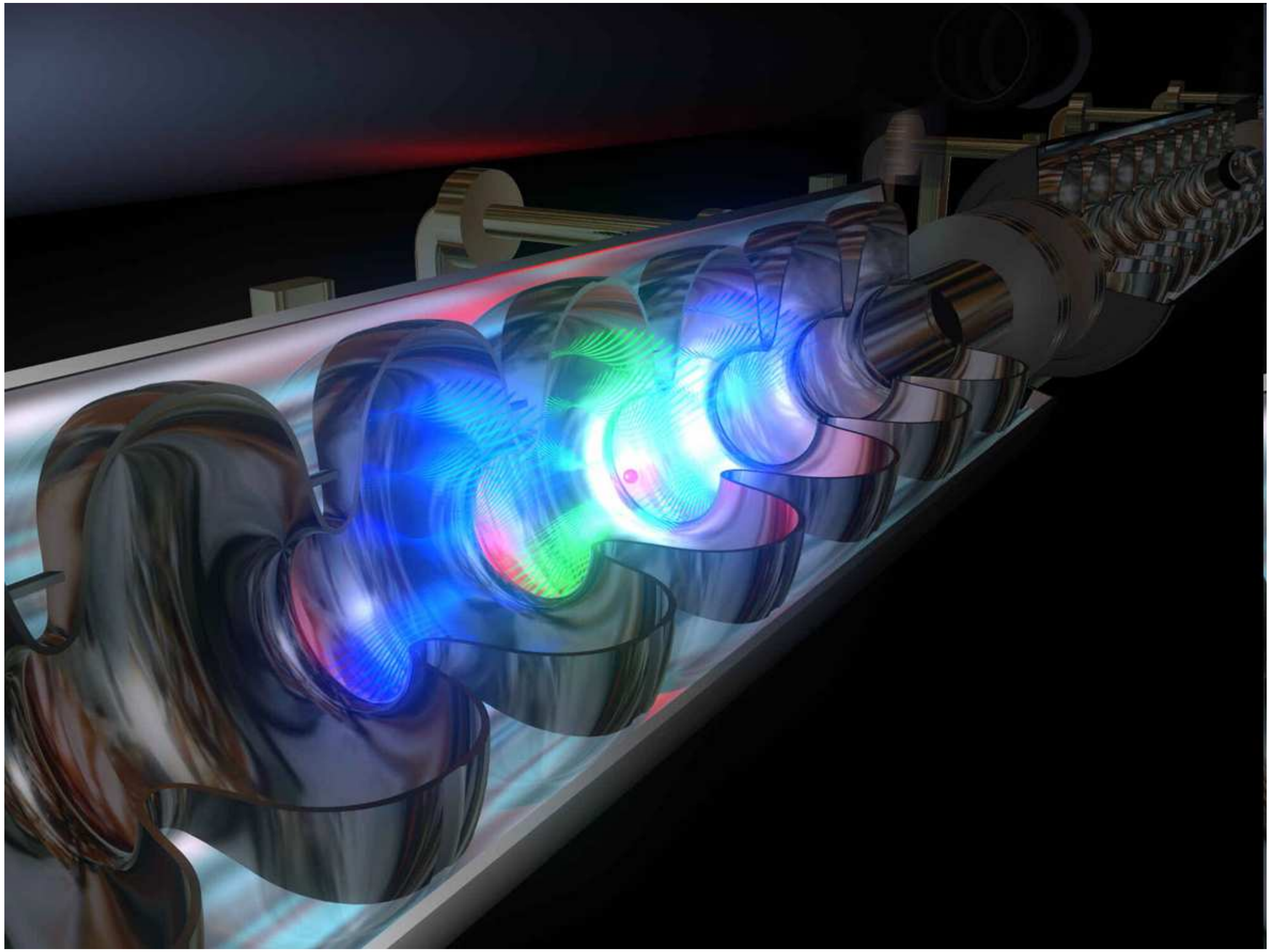
   mass at rest $m_0 = 1.88 \cdot 10^{-28}\,kg$

   and $B = 7\ T$

$$n = \frac{\tau q}{4\pi m_0} B = 150 \cdot B[T] = 1050\ \ turns$$

Hollywood? Artistic view?

"Electromagnetic fields accelerate the electrons in a superconducting resonator "

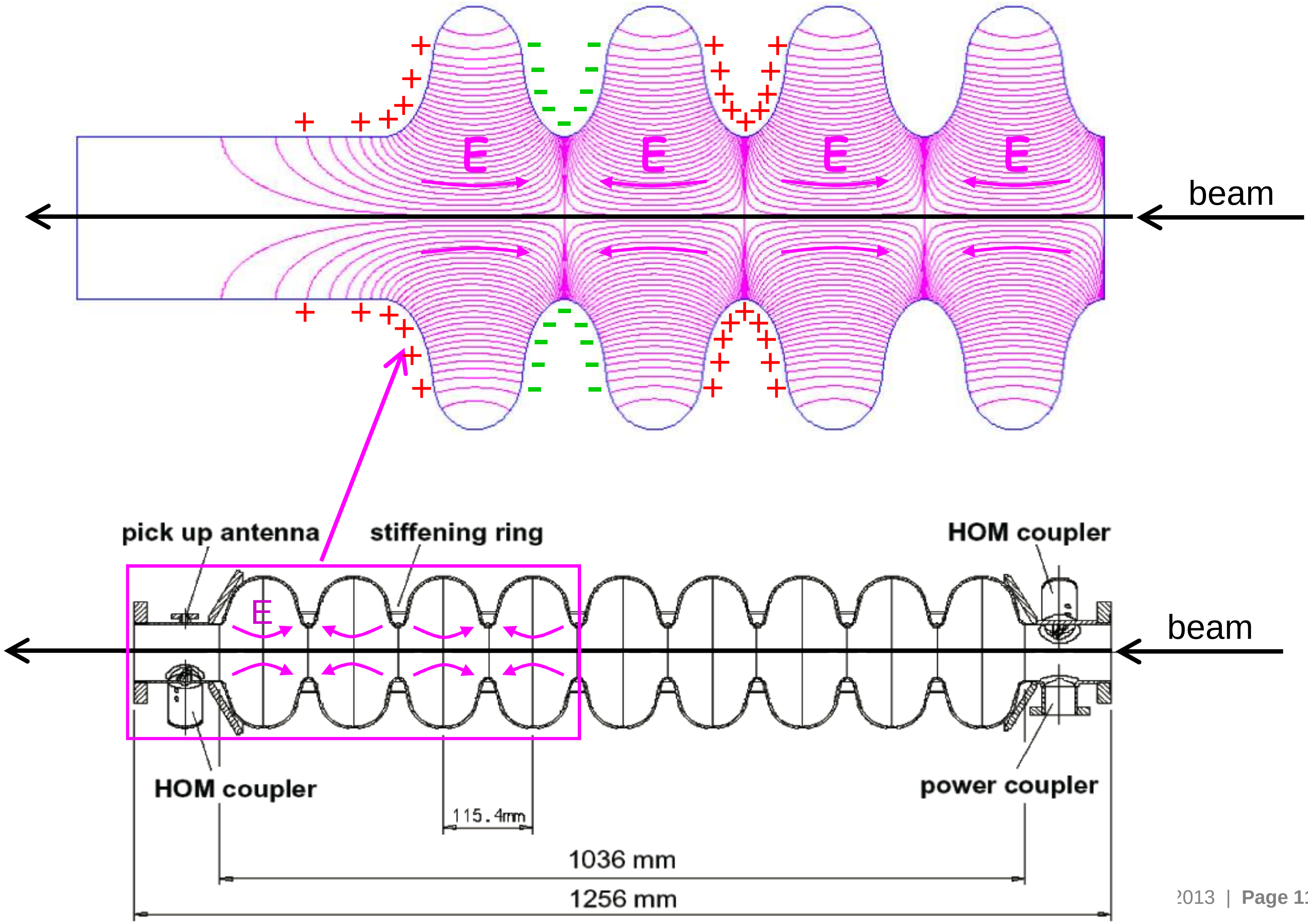


DESY→Press→Media database→XFEL (with filter: media type=movies)

https://media.desy.de/DESYmediabank/?l=en&c=3980&r=4199&p=1&f2165=1

Accelerating field map

Simulation of the fundamental mode: electric field lines



DESY

Thermal conductivity

	$[W\ m^{-1}\ K^{-1}]$
water	0.56 – 0.61
copper (at 20 C)	385 – 401
helium II	$> 10^5$