

Física III 2022 (IQ) – Aula 21

Objetivos de aprendizagem

- Expressar matematicamente a Força de Lorentz
- Determinar a trajetória de partículas carregadas conhecido o campo magnético em situações simples
- Determinar ou esboçar a trajetória de partículas carregadas sob o efeito combinado de campos magnéticos e elétricos
- Determinar a força exercida sobre um condutor que porta corrente quando imerso em um campo magnético

A Força de Lorentz

- É uma lei, e ao mesmo tempo permite definir com precisão o que são os campos elétrico e magnético

$$\vec{F} = q \vec{E} + q \vec{v} \times \vec{B}$$

Força

- Segunda lei de Newton: $\vec{F} = \frac{d\vec{p}}{dt}$

- Momento (linear) relativístico: $|\vec{p}| = m \gamma v = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}}$

- Lorentz (f. Ext):

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

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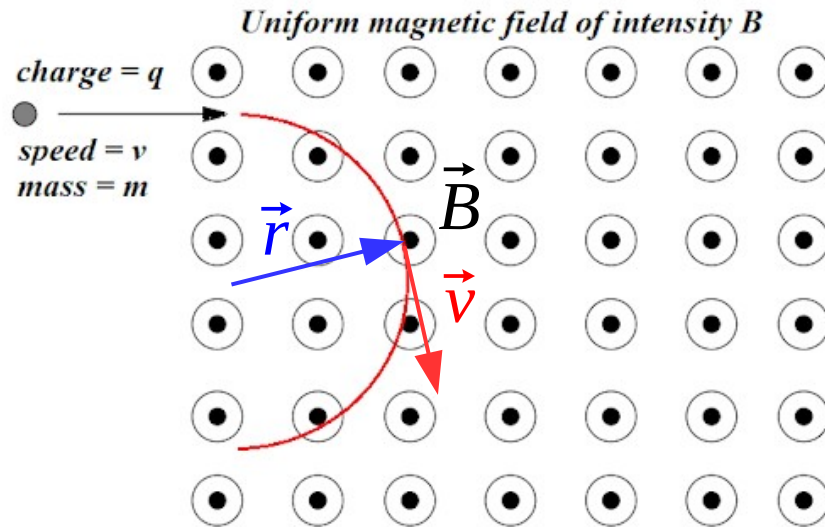
$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

Força de reação à irradiação: Força de Abraham-Lorentz (ñ. rel.): $\vec{F}_{rad} = \frac{2}{3} \frac{q^2}{4\pi\epsilon_0 c^3} \frac{d\vec{a}}{dt}$
Abraham-Lorentz-Dirac, Renormalização (QED)

Obs.: problemas com a consistência das leis da eletrodinâmica clássica.
M. Frisch, Philosophy of Science, 71 (2004) 525

Exemplo 1

- Partícula em campo magnético uniforme
- Raio de curvatura da trajetória



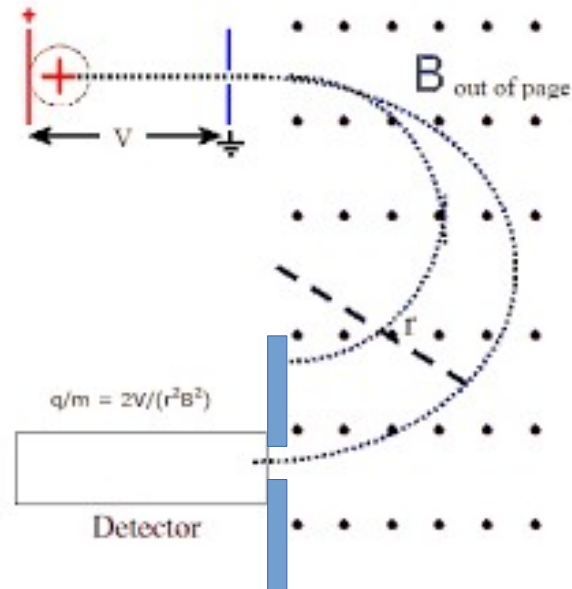
$$\vec{F} = q \vec{v} \times \vec{B} = \vec{F}_c = -\frac{m v^2}{r} \hat{r}$$

$\vec{v} \perp \vec{B}$

$$q \vec{v} \times \vec{B} = -q v B \hat{r}$$
$$q v B = \frac{m v^2}{r} \quad r = \frac{m v}{q B}$$

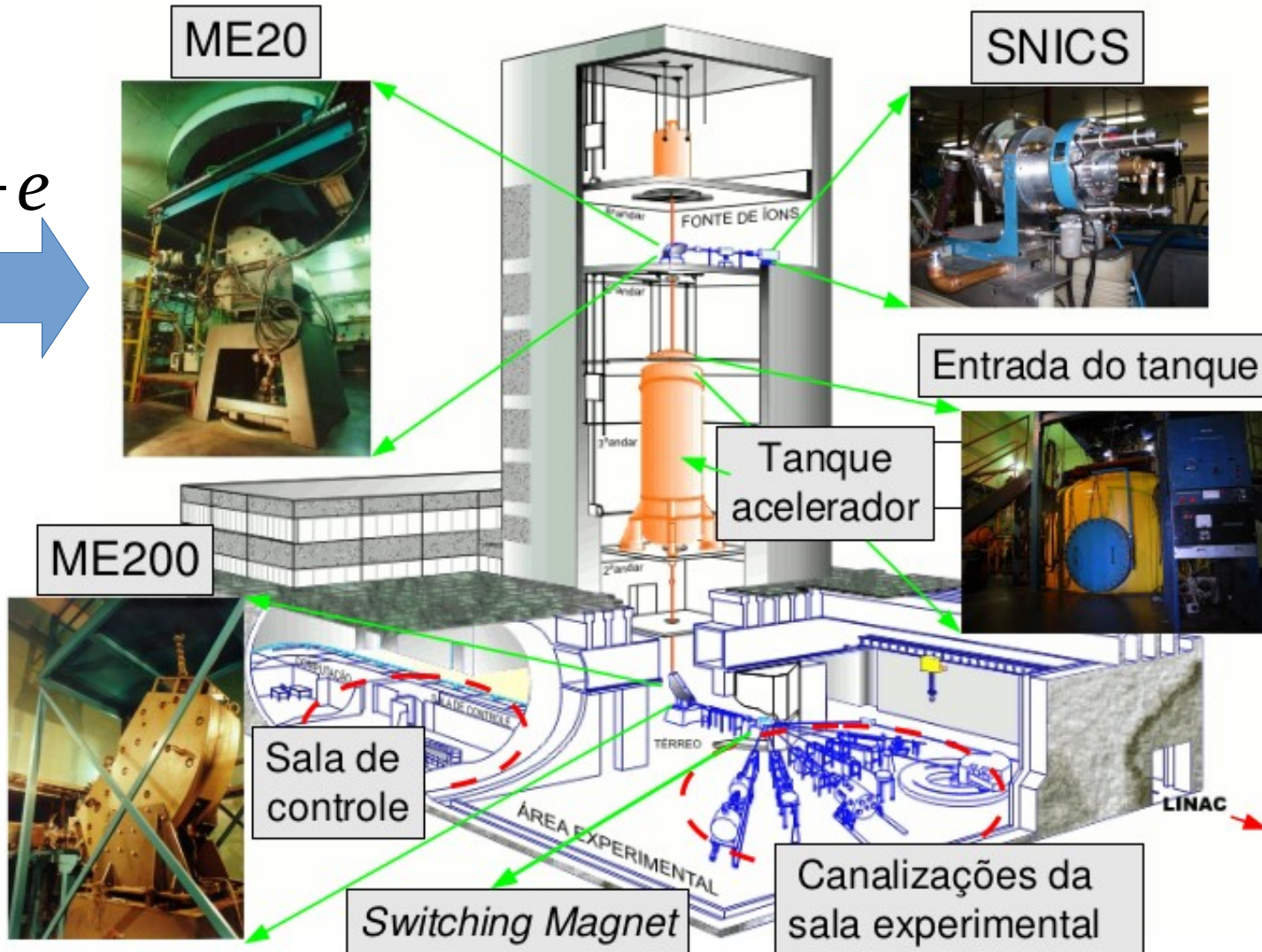
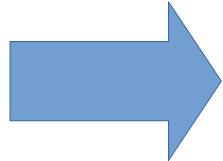
Espectrômetro de massa

- Me20 (injetor – Acelerador Pelletron)
- MAGNEX (LNS)
- ...



Acelerador Pelletron Tandem – 8UD

$$q = -e$$

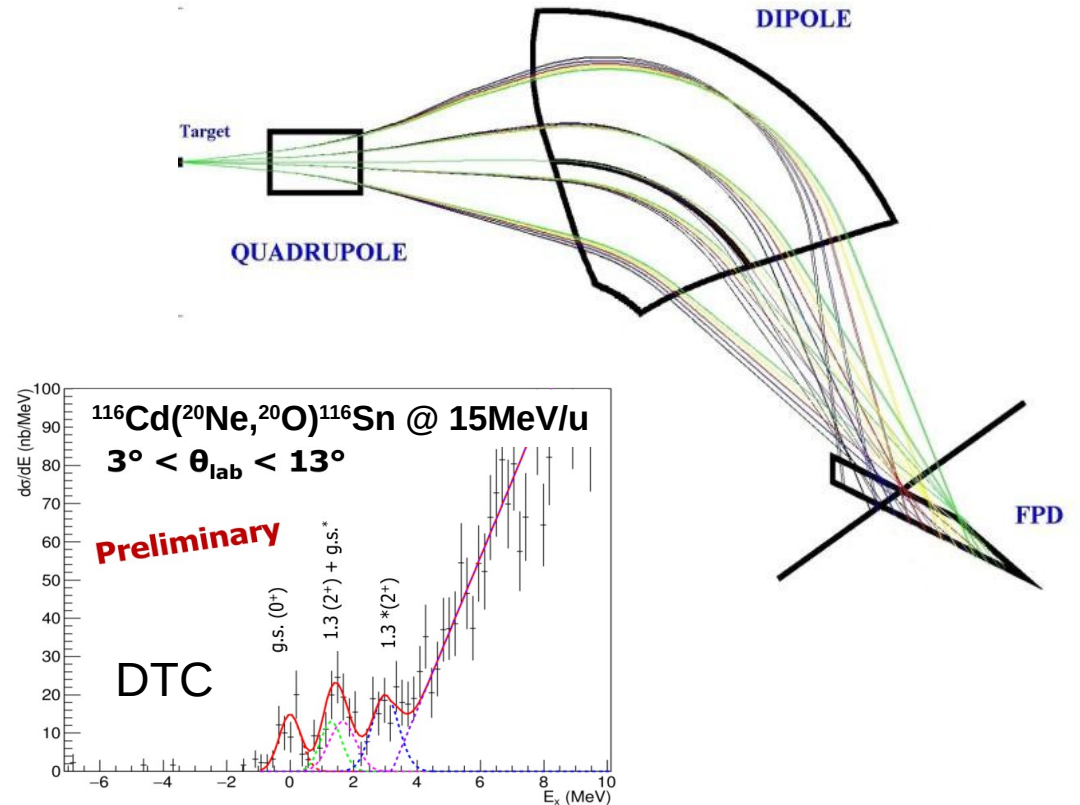


MAGNEX (LNS)

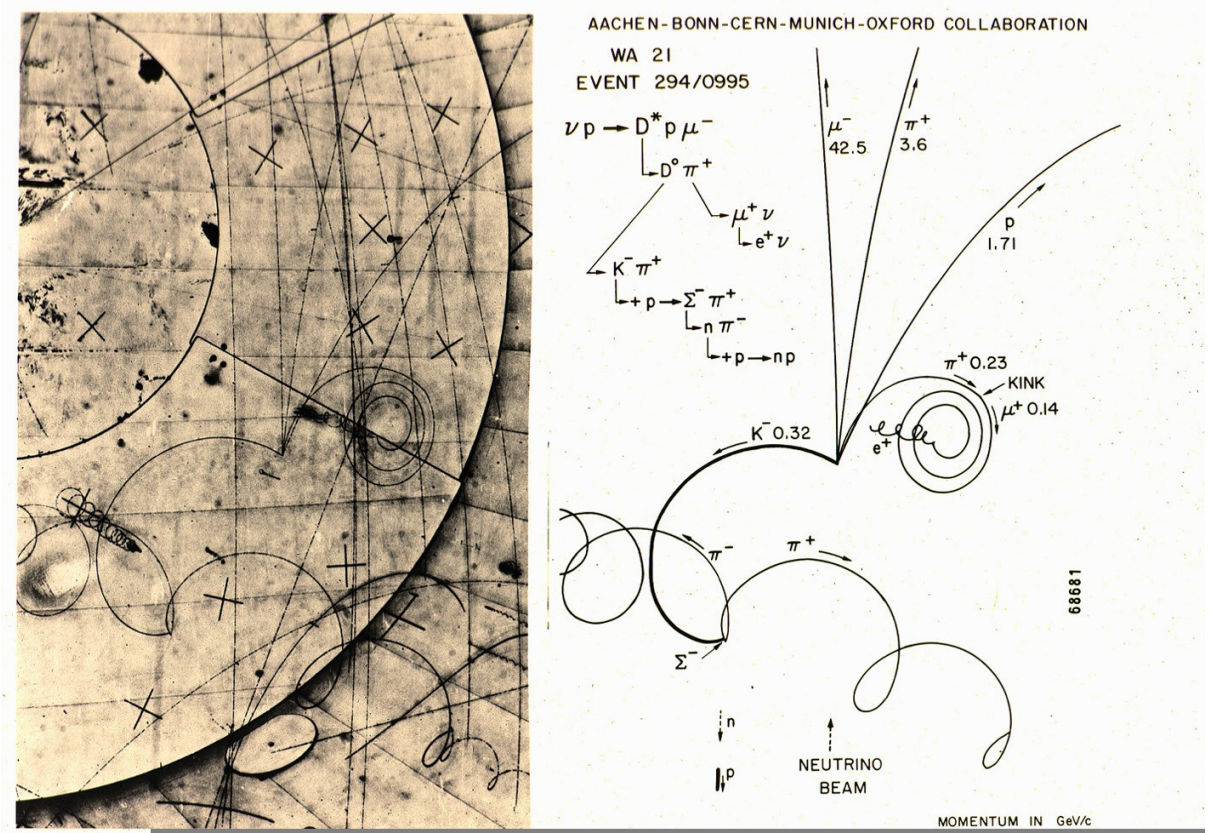
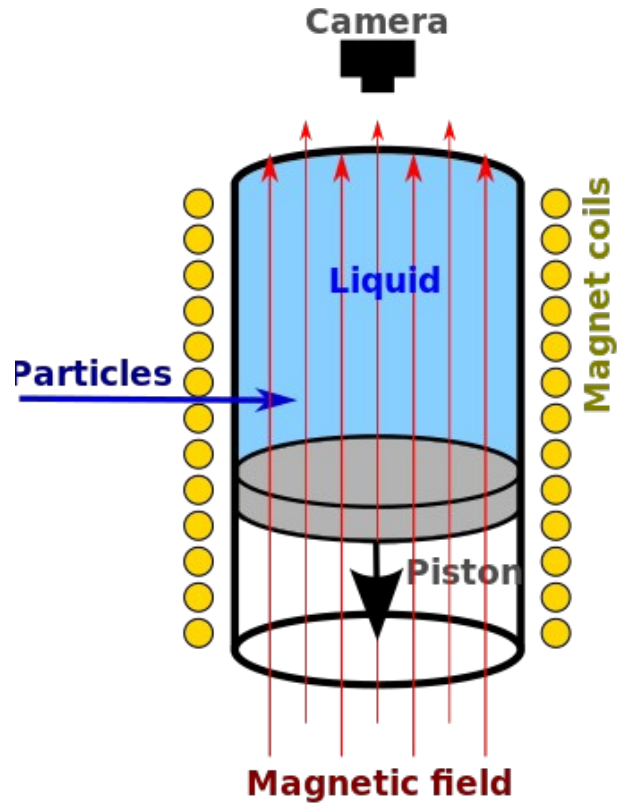


Espectro de energia (massa)

$$E = mc^2$$

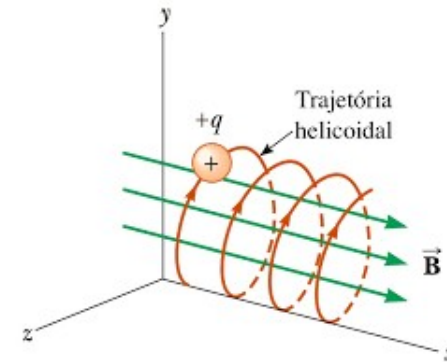
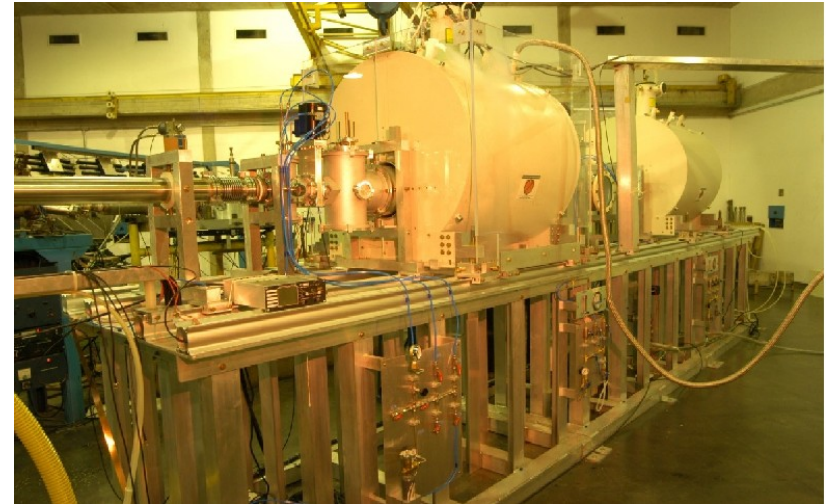
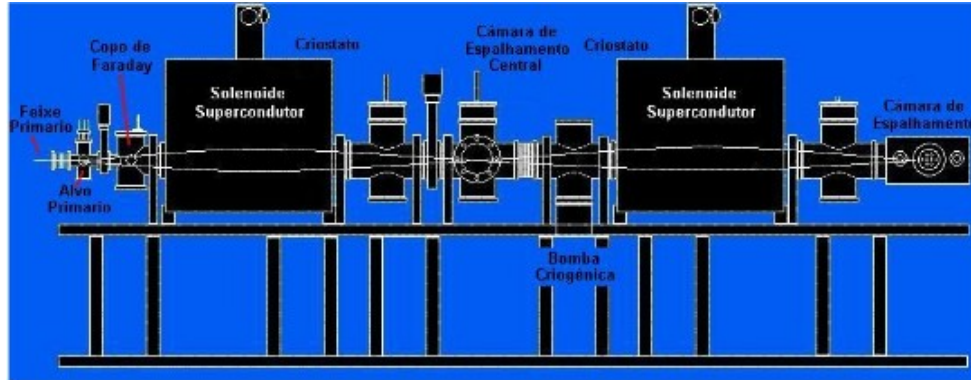


Câmara de bolhas

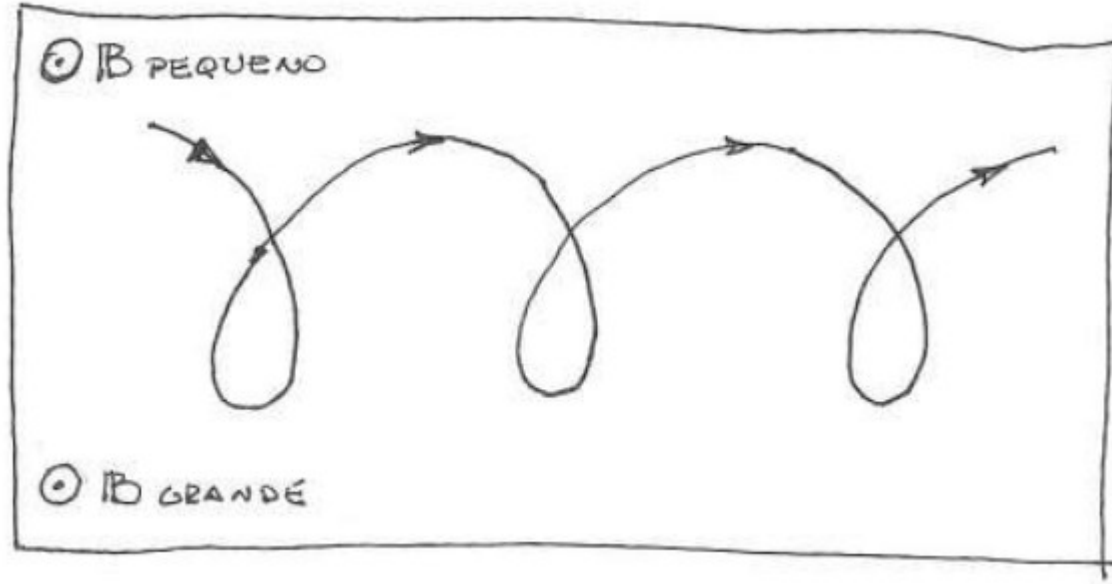


Movimento helicoidal

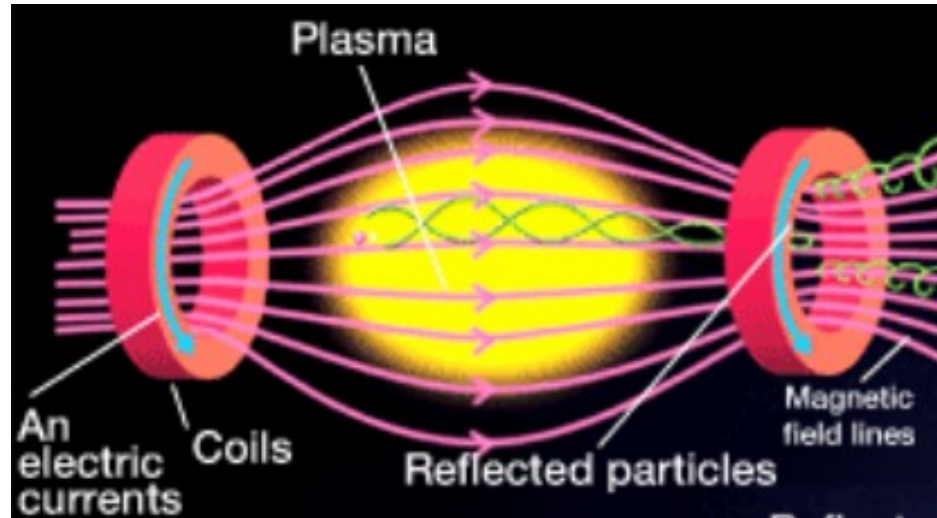
- Solenoides do RIBRAS
- 6 T



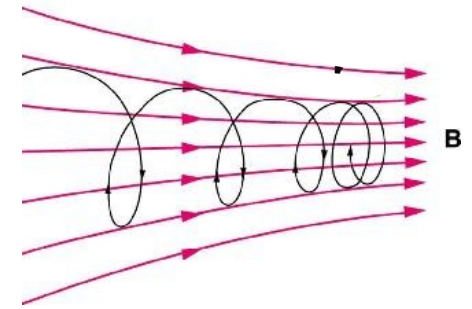
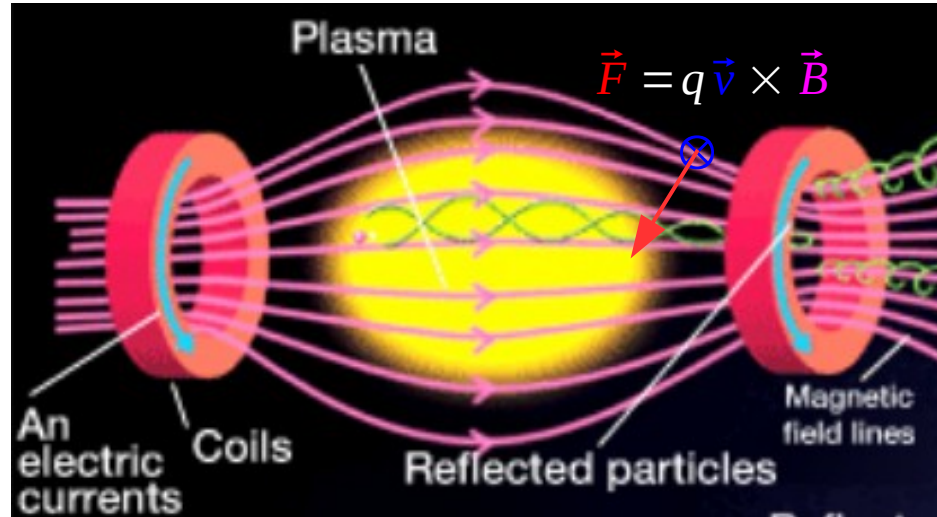
Movimento em gradiente de campo B



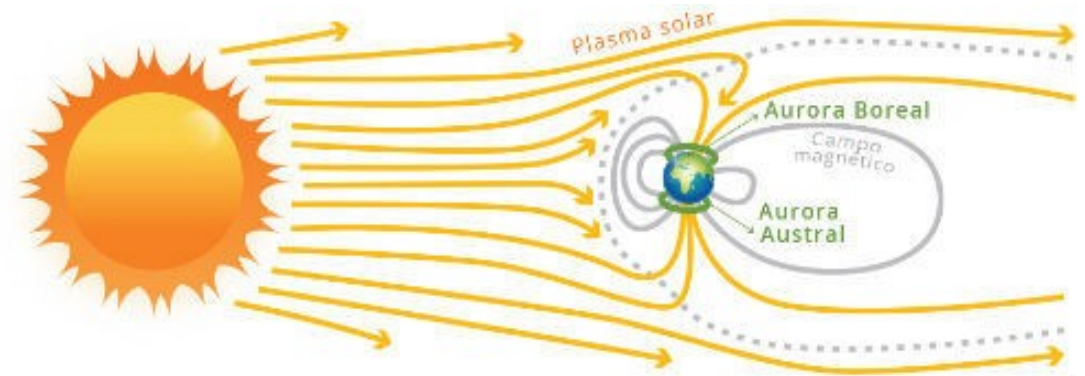
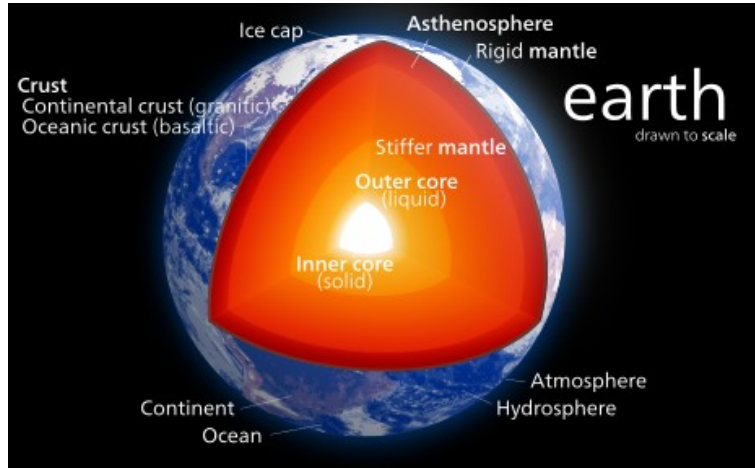
Garrafa de plasma



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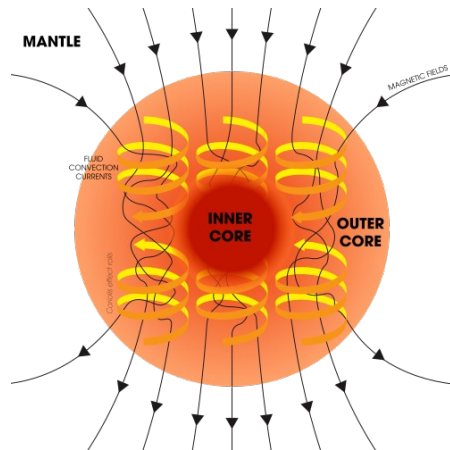
Campo da Terra e Aurora



Boreal

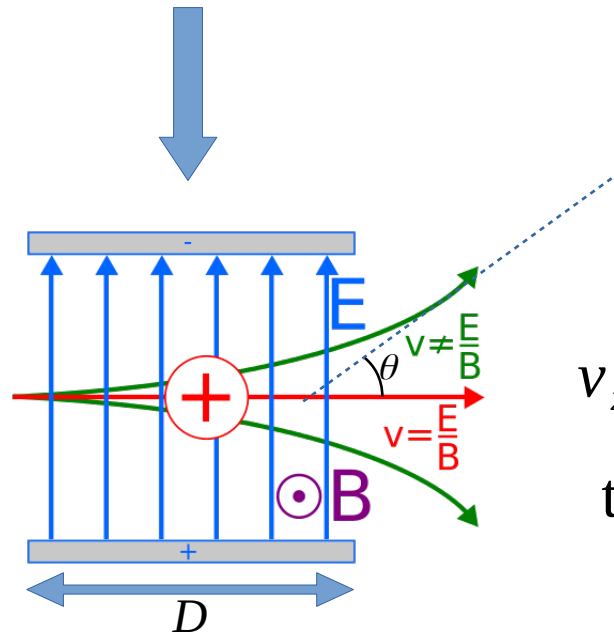


Austral



e/m e filtro de velocidades

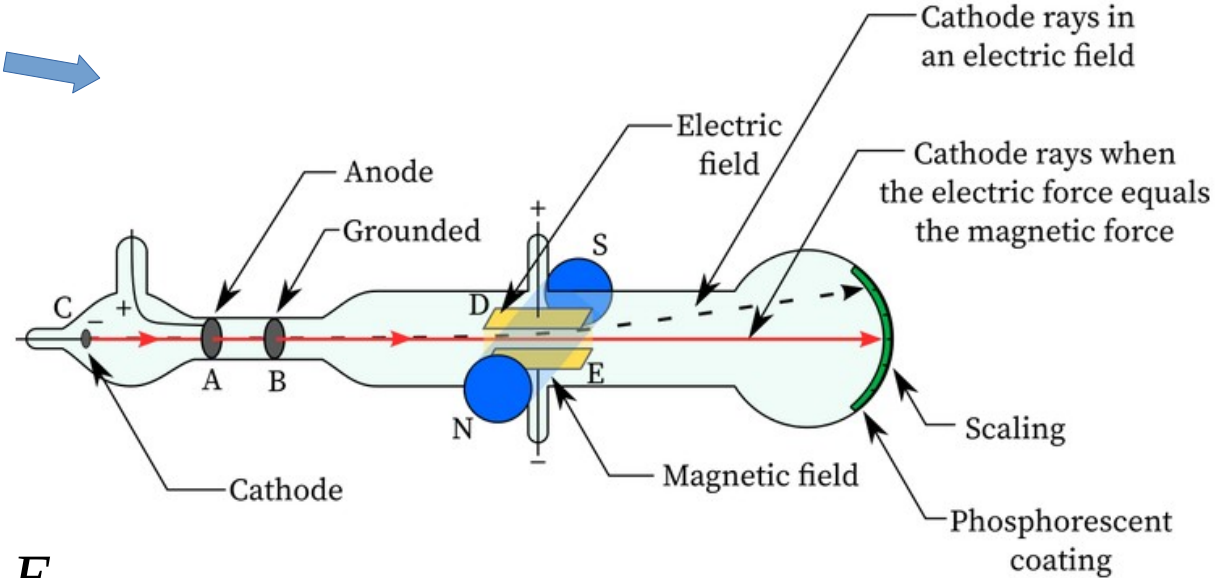
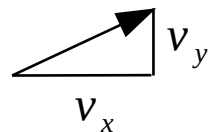
- e/m – J.J. Thomson
- Filtro de Wien



$$v_x = \frac{E}{B}$$

$$\tan \theta = 0$$

$$B \neq 0: \tan \theta = \frac{e}{m} \frac{ED}{v_x^2}$$



Força sobre fio condutor de corrente imerso em campo magnético

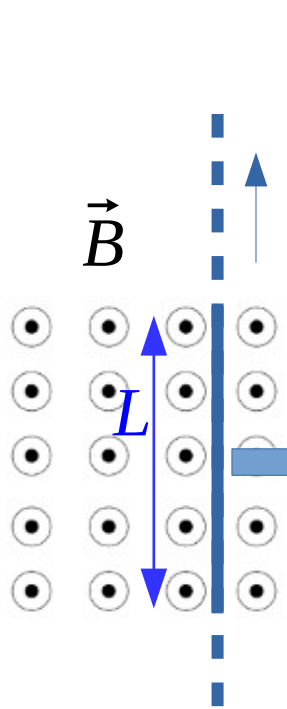


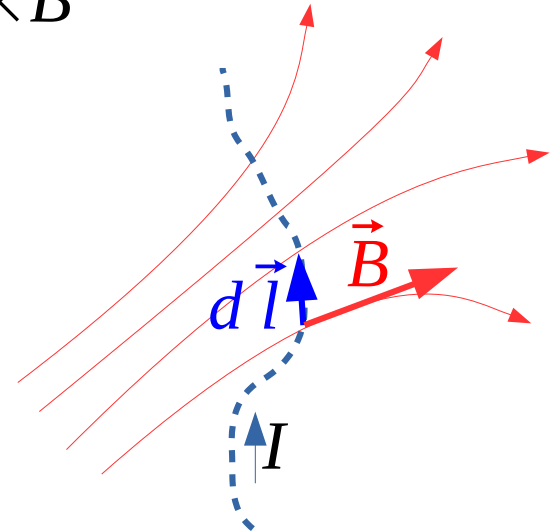
Diagram illustrating a wire of length L carrying current I in a magnetic field \vec{B} . The magnetic field is represented by a grid of circles with dots, indicating it is directed out of the page. The wire is a vertical blue line with a dashed line extending above and below it. A blue double-headed arrow labeled L indicates the length of the wire segment. A blue arrow labeled \vec{F} points to the right from the wire, representing the force. A dashed blue arrow points upwards from the wire, representing the current direction. A blue cylinder represents the cross-section of the wire with area A and normal vector \hat{n} pointing upwards.

$$I = \vec{j} \cdot \hat{n} A = \rho \vec{v} \cdot \hat{n} A = \rho v A$$

$$q = \rho L A \quad \vec{v} \parallel \hat{n} \quad \vec{v} = v \hat{n}$$

$$\vec{F} = q \vec{v} \times \vec{B} = (\rho L A) v \hat{n} \times \vec{B} = L I \hat{n} \times \vec{B}$$

Em geral: $d\vec{F} = I d\vec{l} \times \vec{B}$



Torque sobre espira etc.

- exemplo/enquete, Problemas 34-36...