# Derivas em Tokamaks

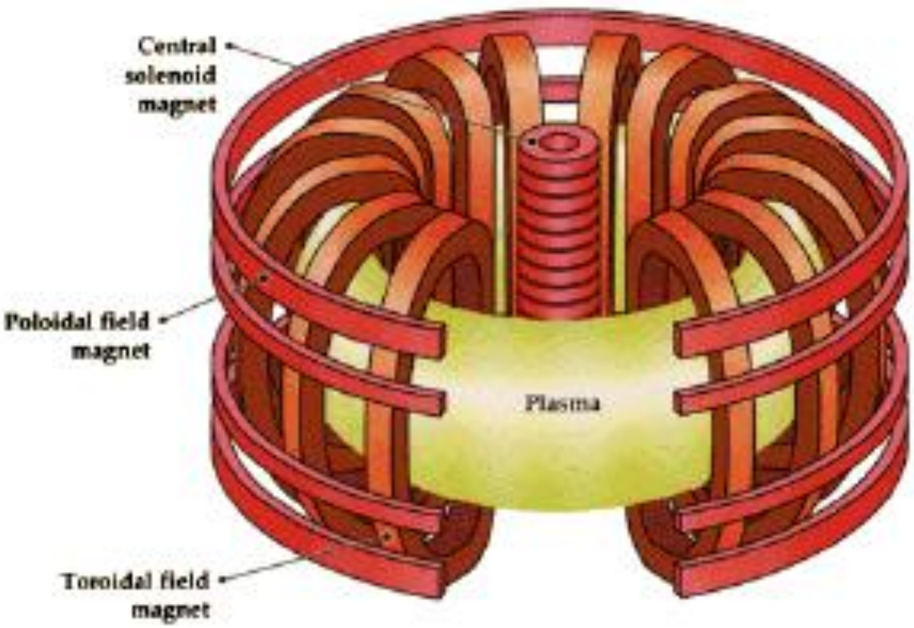
Ilustrações Complementares

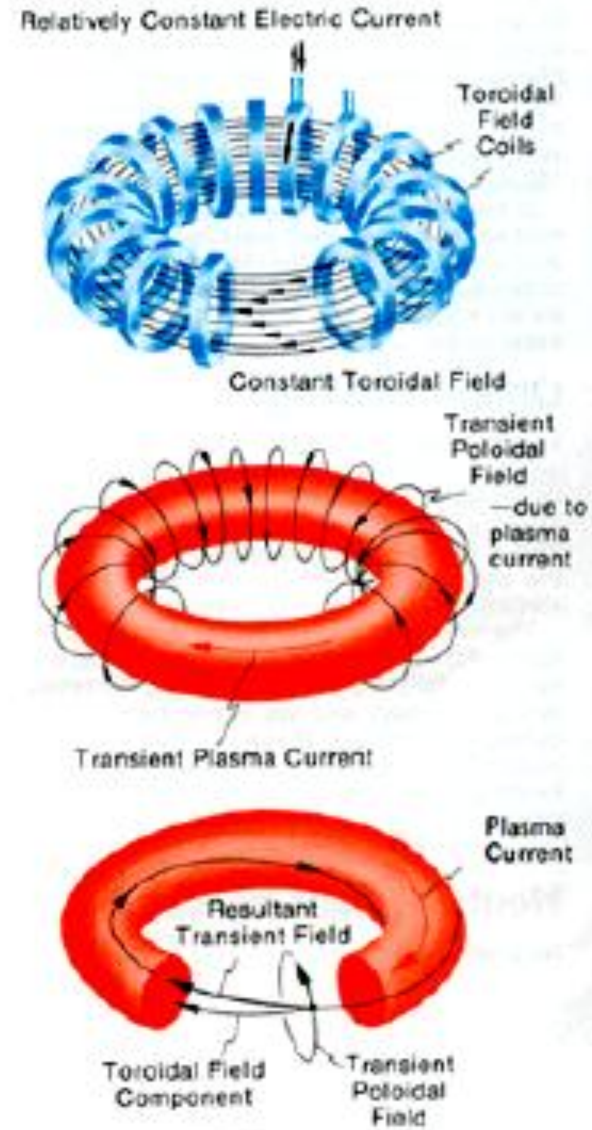
# The configuration of a Tokamak.

*TOroidalnaya KAmera ee MAgnitnaya Katushka,"*

or "Toroidal Chamber in Magnetic Coil"

This is a device to magnetically confine a plasma, so that it can be heated to fusion temperatures.



# Deriva no campo magnético uniforme

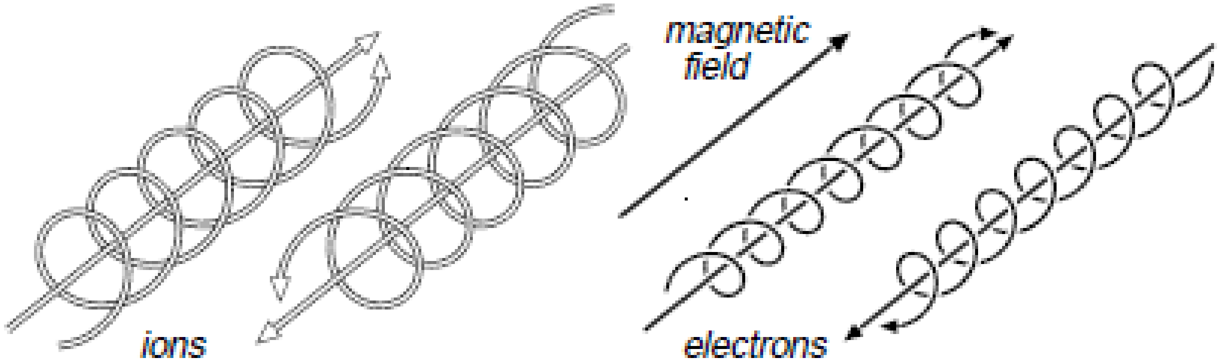
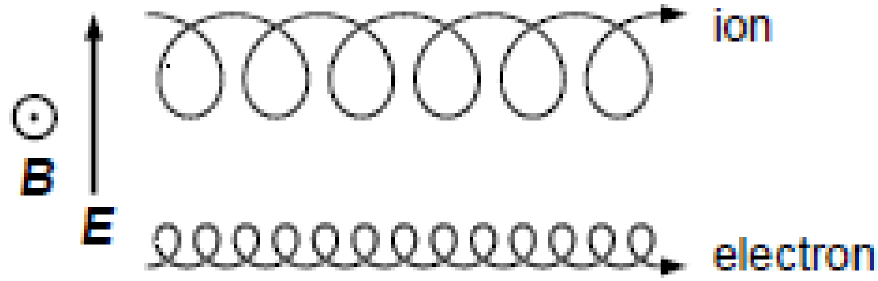



Figure 2: Orientation of the gyration orbits of electrons and ions in a magnetic field. The guiding center motion is also shown.

# Deriva nos campos elétrico e magnético uniformes

$$v_E = \frac{E \times B}{B^2}$$

Figure 4: $E \times B$ drift of ions and electrons.

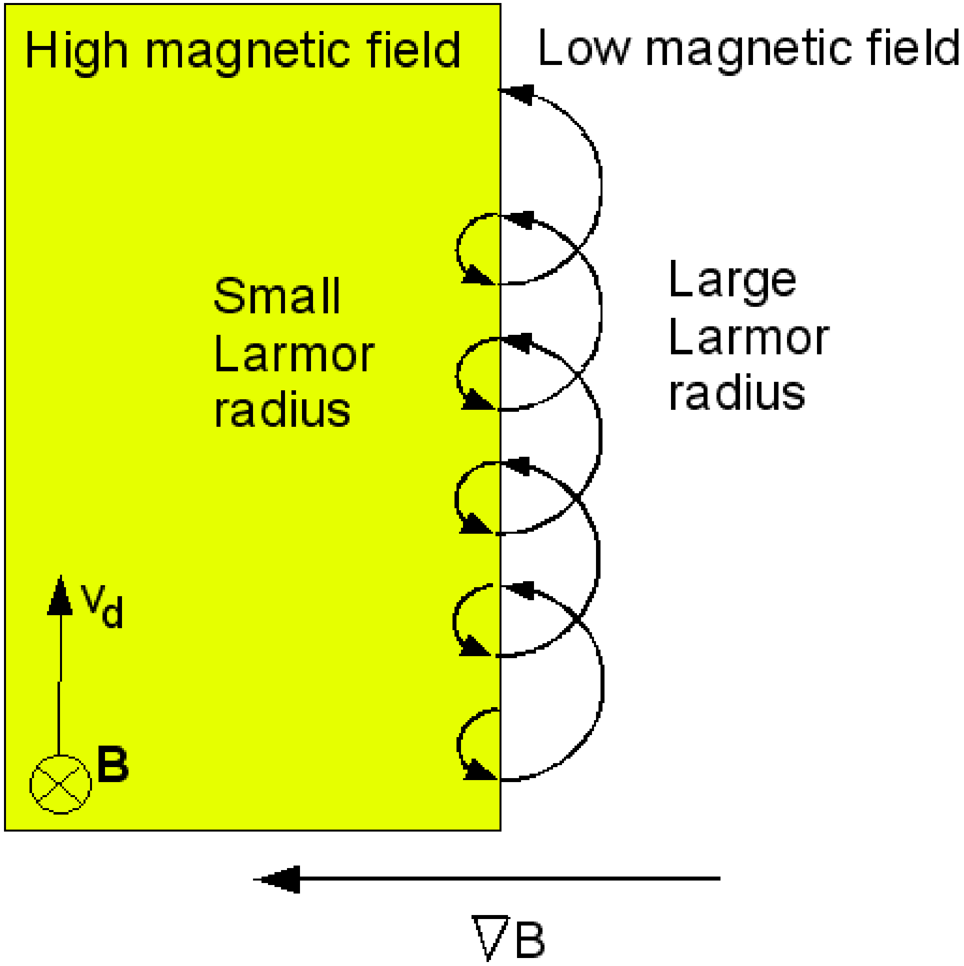


# Campo magnético não uniforme

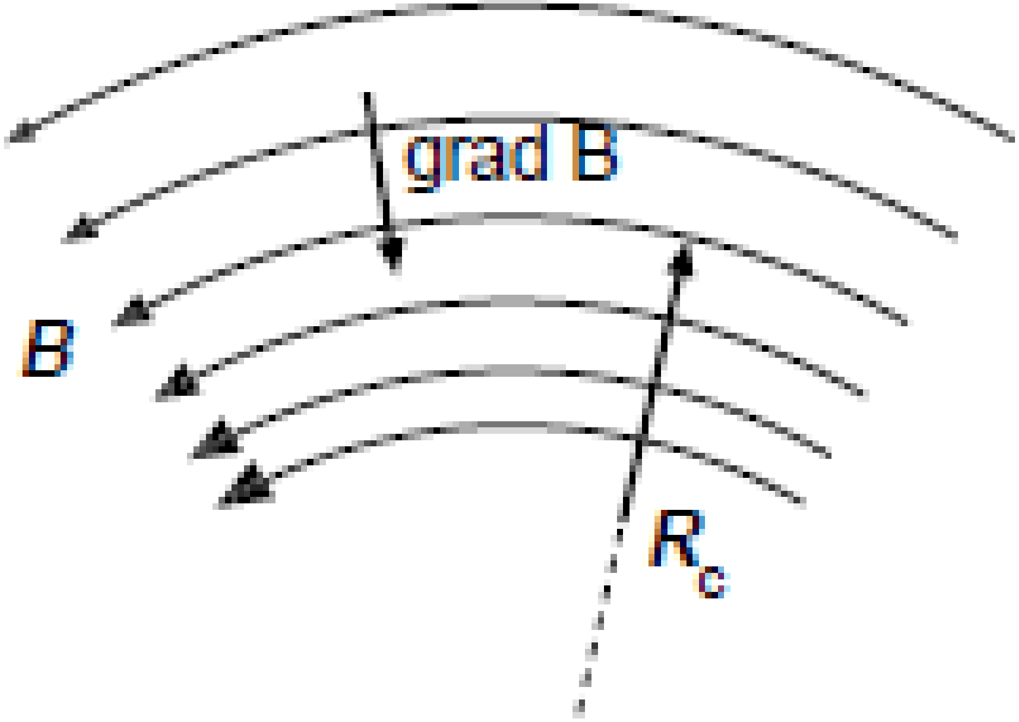
$$F = -\frac{mv_\perp^2}{2qB}\nabla B$$

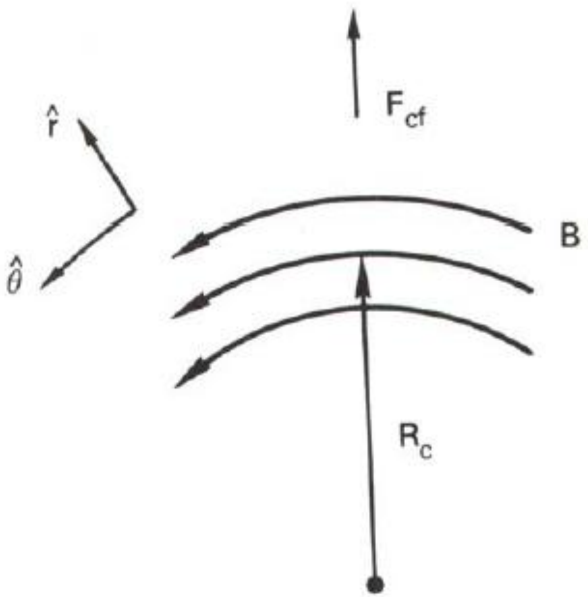
$$\underline{v}_F = \frac{1}{q}\frac{\underline{F}\times\underline{B}}{B^2}$$

$$\mathbf{v}_d = \frac{mv_\perp^2}{2qB}\frac{\mathbf{B}\times\nabla B}{B^2}$$

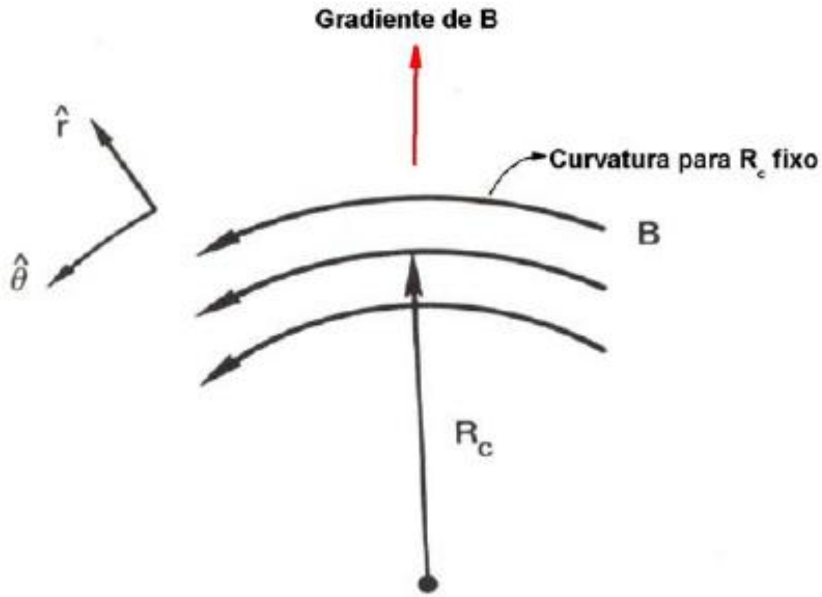


# Gradiente do campo magnético no tokamak






*Curvatura de* $\vec{B}$ .



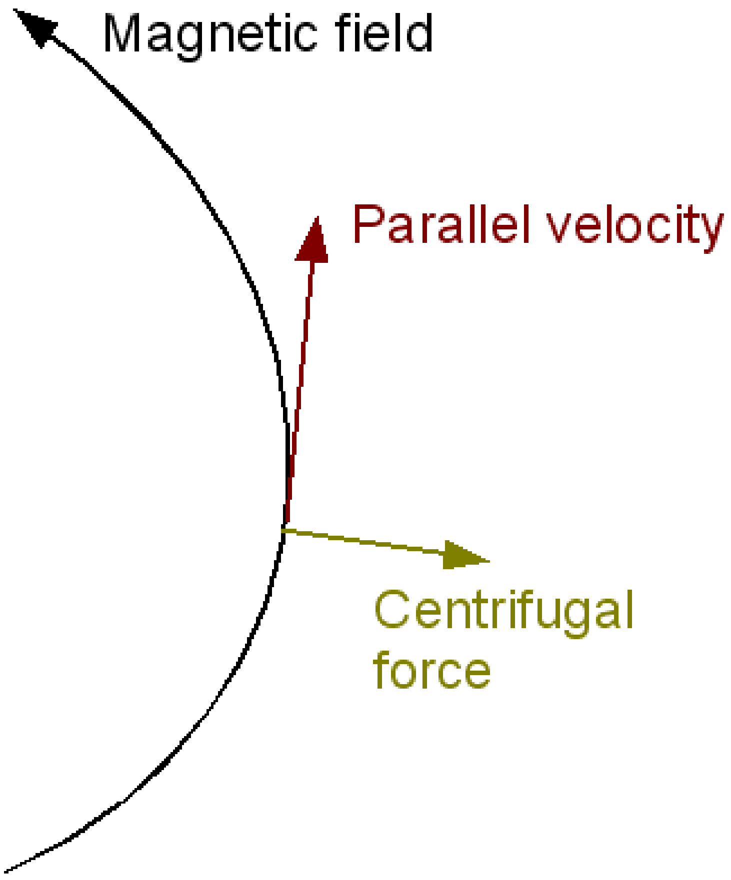

*Direção da Curvatura e do Gradiente de* $\vec{B}$

# Campo magnético curvo

- Na partícula, em um campo magnético curvo, atua uma força centrifuga

$$\mathbf{F} = \frac{mv_{\parallel}^2}{R_{\text{curv}}}\mathbf{e}_{\text{curv}}$$

$$\mathbf{v}_d \approx \frac{mv_{\parallel}^2}{qB}\frac{\mathbf{B}\times\nabla B}{B^2}$$



# All together ....

$$\mathbf{v} = v_{||}\mathbf{b} + \mathbf{v}_g + \frac{\mathbf{E}\times\mathbf{B}}{B^2} + \frac{m}{qB^2}\frac{\mathrm{d}\mathbf{E}_\perp}{\mathrm{d}t} + \frac{mv_{||}^2 + mv_\perp^2/2}{qB}\frac{\mathbf{B}\times\nabla B}{B^2}$$

Gyration

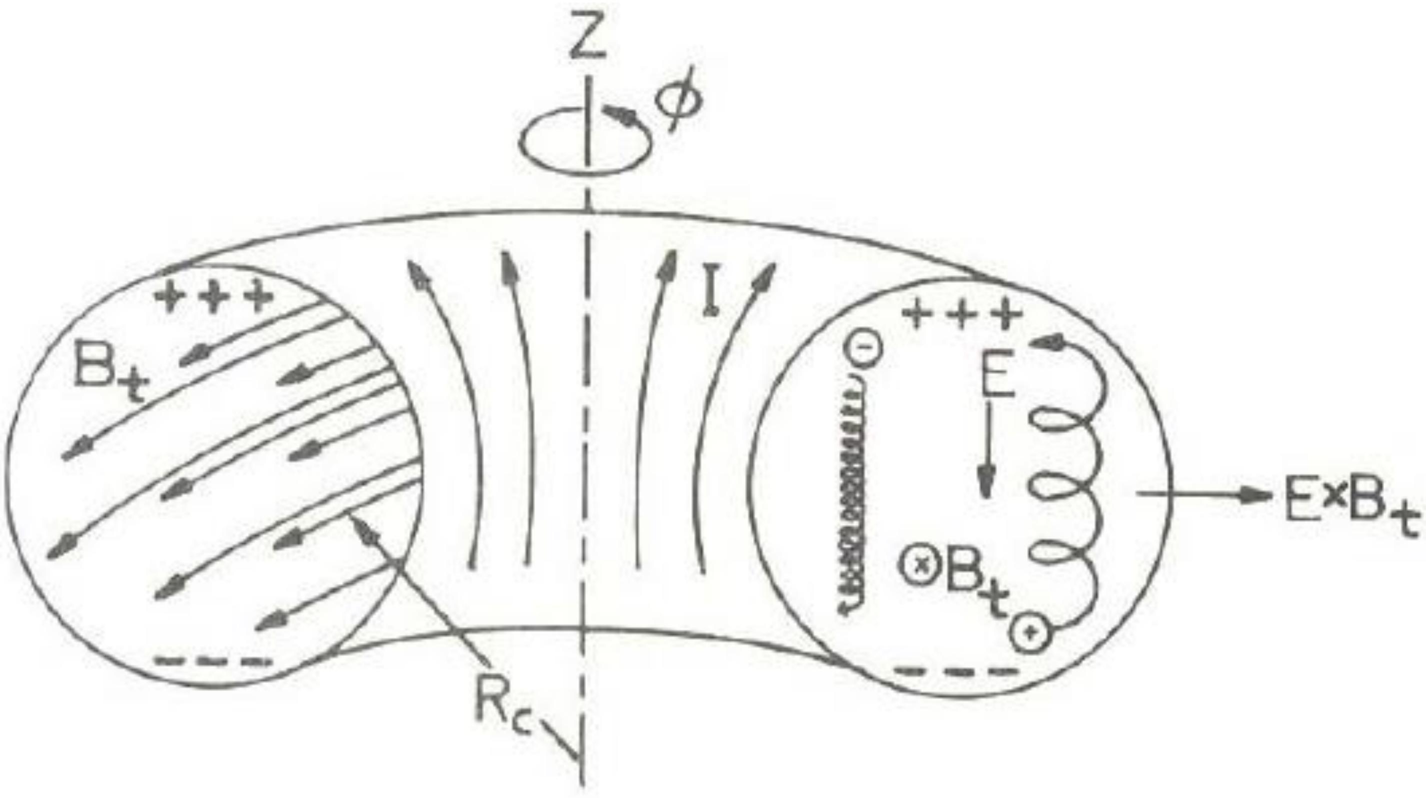
Grad-B and curvature drift

Pololarization drift

Parallel motion

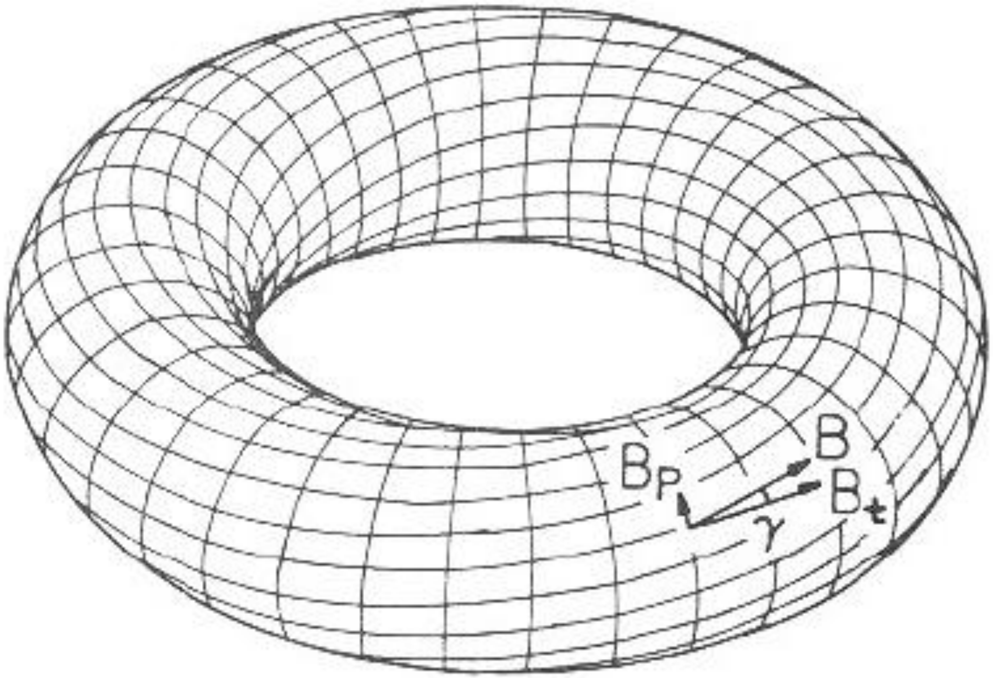
ExB drift

# Inviável
# Confinamento num campo magnético toroidal



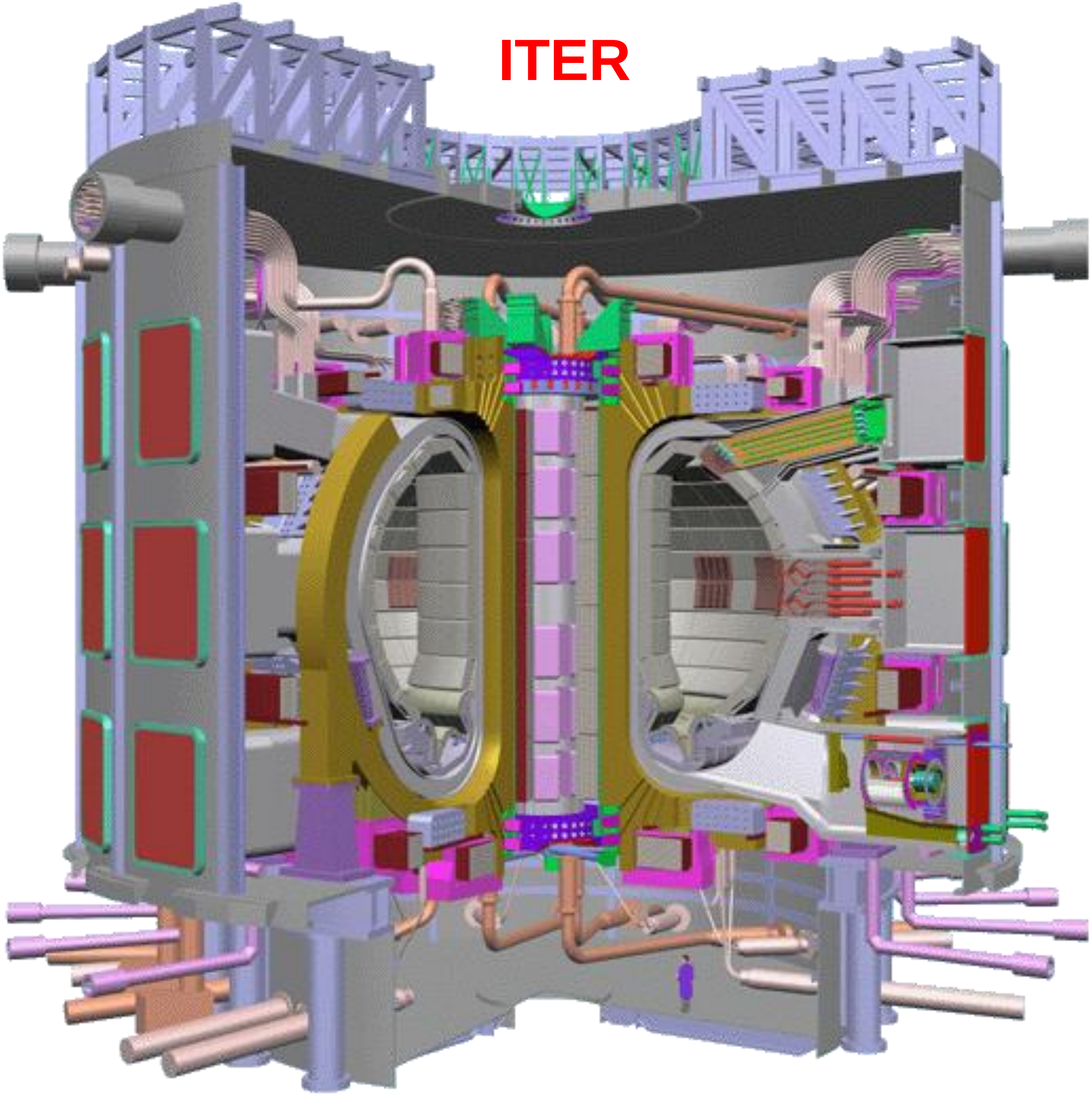

*Deriva devido á Configuração Toroidal das Linhas de Campo Magnético num TOKAMAK.*

# Campo magnético helicoidal




*Linhas e Superfície de Campo Magnético Toroidal.*

# ITER



# Main Plasma Parameters and Dimensions

| | |
|---|---|
| Total fusion power | 500 MW *(700MW)* |
| Q = fusion power/auxiliary heating power | ≥ 10 |
| Average neutron wall loading | 0.57 MW/m² *(0.8 MW/m²)* |
| Plasma inductive burn time | ≥ 300 s |
| Plasma major radius | 6.2 m |
| Plasma minor radius | 2.0 m |
| Plasma current ($I_p$) | 15 MA *(17.4 MA)* |
| Vertical elongation @95% flux surface/separatrix | 1.70/1.85 |
| Triangularity @95% flux surface/separatrix | 0.33/0.49 |
| Safety factor @95% flux surface | 3.0 |
| Toroidal field @6.2 m radius | 5.3 T |
| Plasma volume | 837 m³ |
| Plasma surface | 678 m² |
| Installed auxiliary heating/current drive power | 73 MW *(100 MW)* |

Wendelstein 7-X

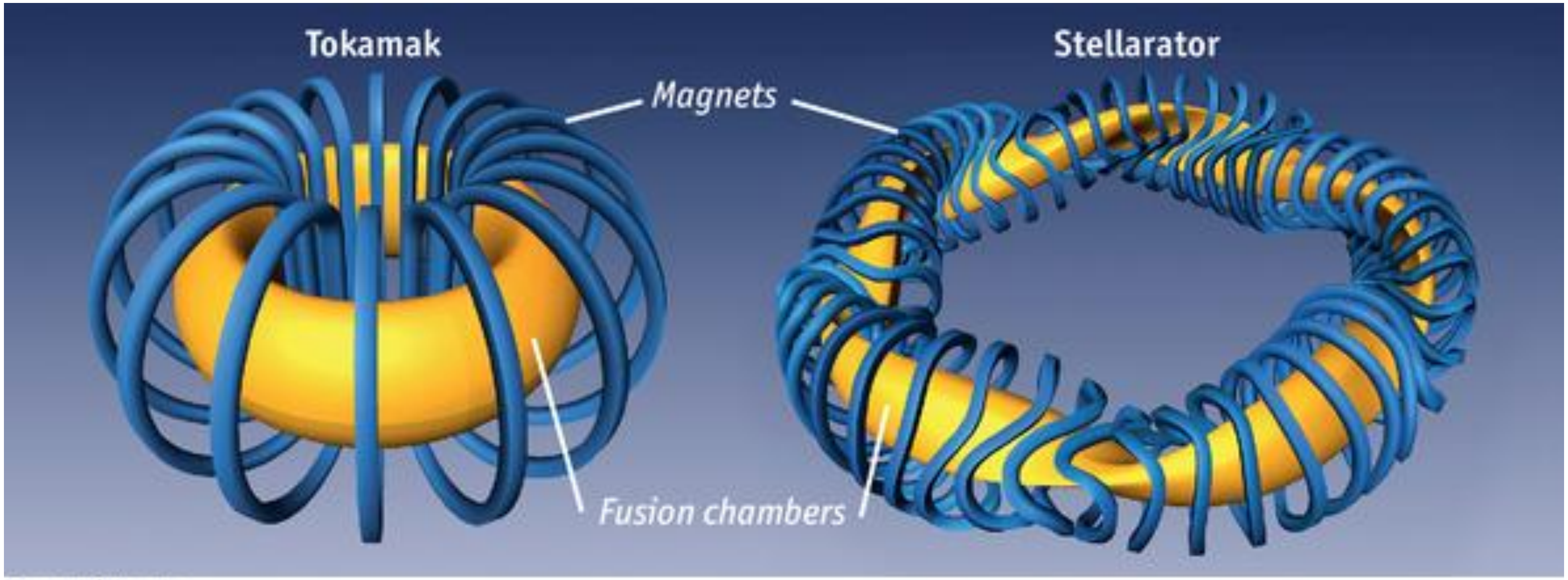


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Fig. 4: The Wendelstein 7-X fusion device. Credit: Max Planck Institute for Plasma Physics, Greifswald/Kemnitz

The outer vessel of Wendelstein 7-X equipped with a variety of ports. Blue: five auxiliary coils, which are provided by Princeton Plasma Physics Laboratory. They are to help precise setting of the magnetic fields at the plasma edge. Credit: (Graphic: IPP)

# Wendelstein 7-X

Wendelstein 7-X at the Greifswald branch of IPP is a large stellarator with modular superconducting coils which enable steady state plasma operation in order to explore the reactor relevance of this concept.

Quality comparable to that of a tokamak of the same size. But it will avoid the disadvantages of a large current flowing in a tokamak plasma: With plasma discharges lasting up to 30 minutes, Wendelstein 7-X is to demonstrate the essential stellarator property, viz. continuous operation.

major radius = 5.5 m    minor radius = 0.53 m    field = 3 Tesla

Plasma discharges started on December 2015. Upgrade started in 2016. New discharges will start in 2017.