

Fusion Reactor Technology II

(459.761, 3 Credits)

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Introduction

Text and References:

- A.A. Harms, K.F. Schoepf, G.H. Miley, D.R. Kingdon, "Principles of Fusion Energy", World Scientific Publishing Co. Pte. Ltd. (2000)
- 세키 마사히로, 핵융합로 공학 개론, 일간공업신문사 (2001)
- 일본, Report on Technical Feasibility of Fusion Energy and Extension of the Fusion Program and Basic Supporting Research (2000)
- 유럽연합, A Conceptual Study of Commercial Fusion Power Plants, EFDA-Report (2005)
- 미국, Advanced Tokamak Fusion Power Plant ARIES-AT, Report (2000)
- 일본, 2050년에 토카막형 실용 핵융합 플랜트를 가동시키기 위해서, Journal of Plasma and Fusion Research (2005)

Introduction

Project: To establish your own tokamak reactor concept

Evaluation

- Attendance: 10%
- Homework: 10%
- Midterm exam: 20%
- Final exam: 30%
- Project: 30%

Contents

Week 1. Review of Tokamak Reactor Concept

Week 2-4. Tokamak Reactor Critical Issues

Week 5. Blanket Concept

Week 6. First Wall Loading and Wall Impurity Effects

Week 7. Blanket Neutronics and Energetics

Week 9. Radioactivation

Week 10. Blanket Structure and Breeding Materials

Week 11-12. Types of Blanket in ITER and DEMO

Week 13. Plasma Facing Components

Week 14. Fuel Cycle System

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Week 13. Plasma Facing Components

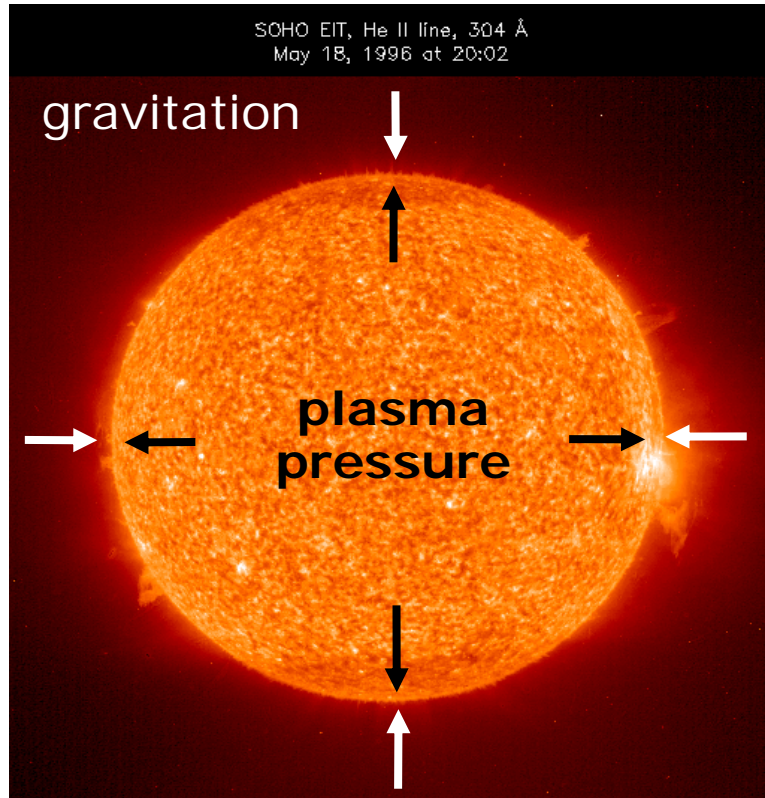
Week 14. Fuel Cycle System

To build a sun on earth

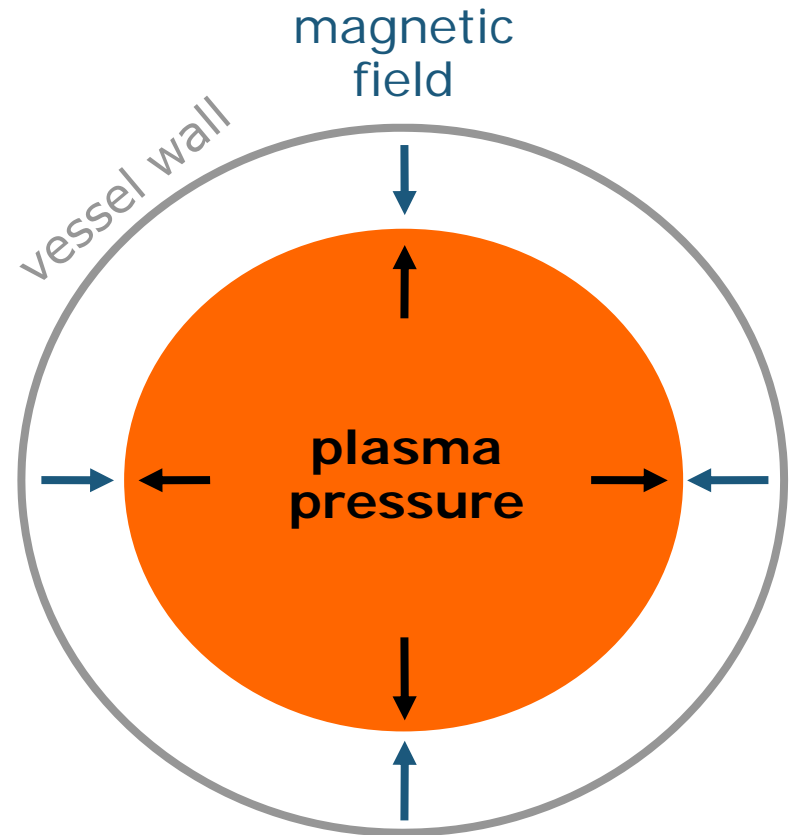


Magnetic confinement

- Imitation of the Sun on Earth

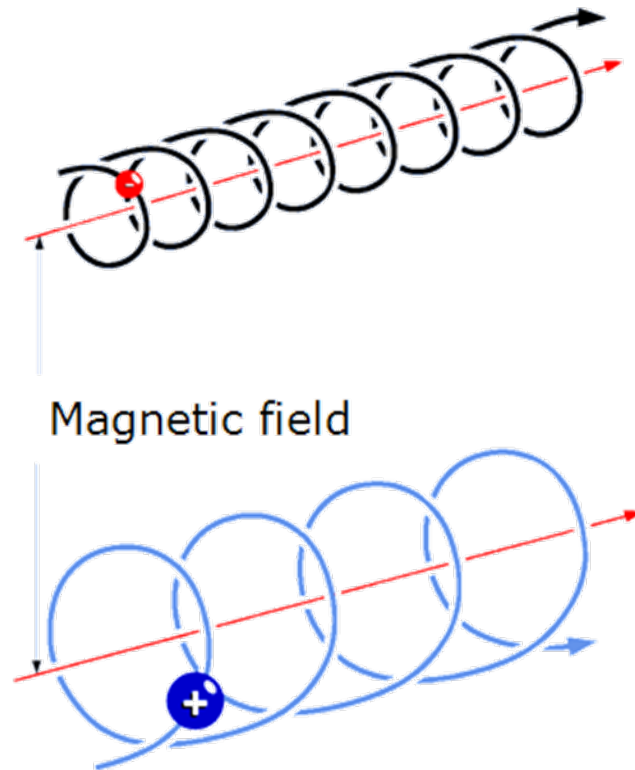
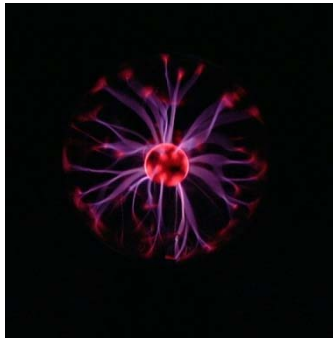


Equilibrium in the sun



Plasma on earth
much, much smaller & tiny mass!

Magnetic confinement

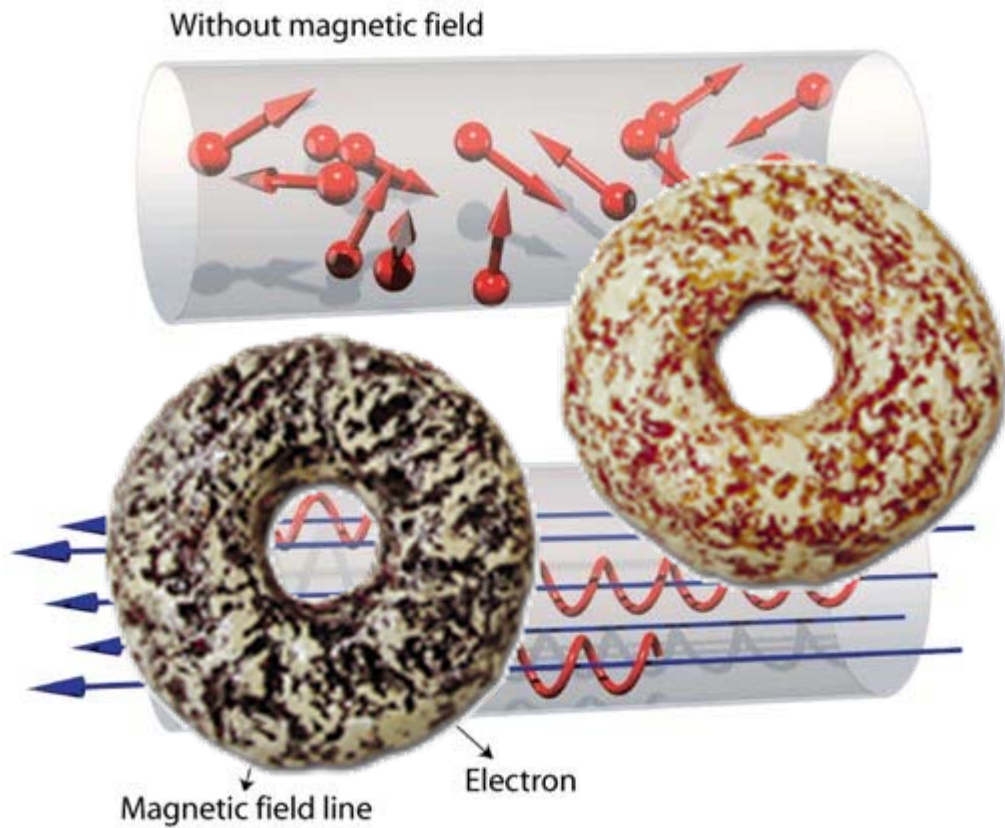


Magnetic
field



ion

Tokamak

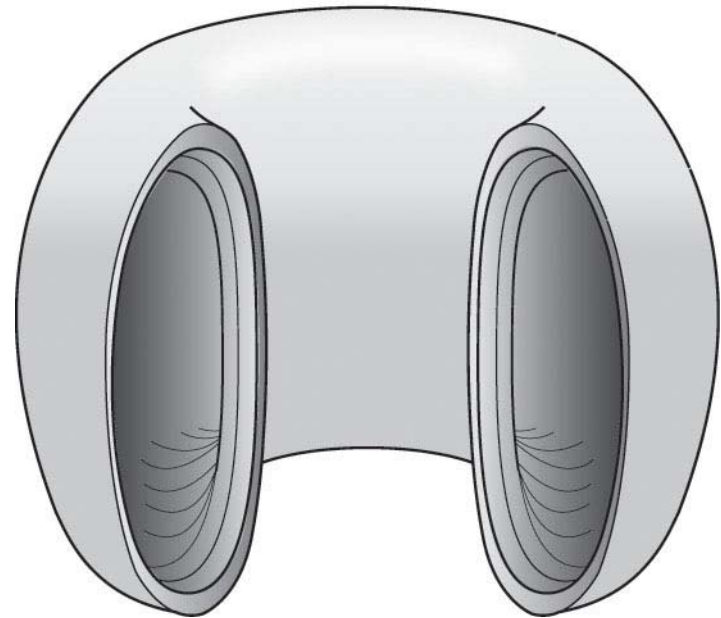
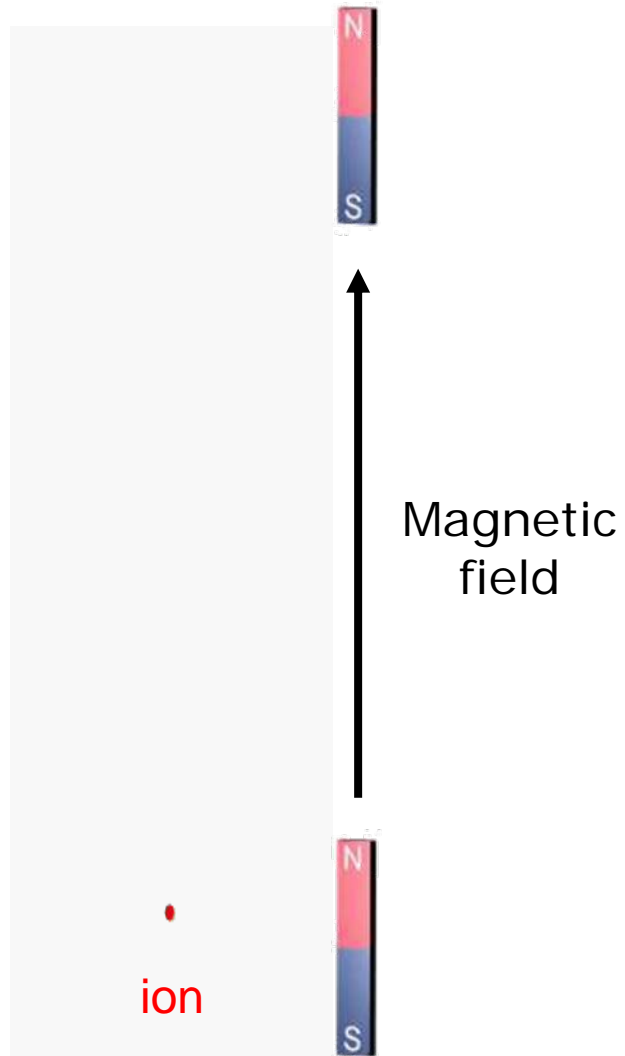


Magnetic
field



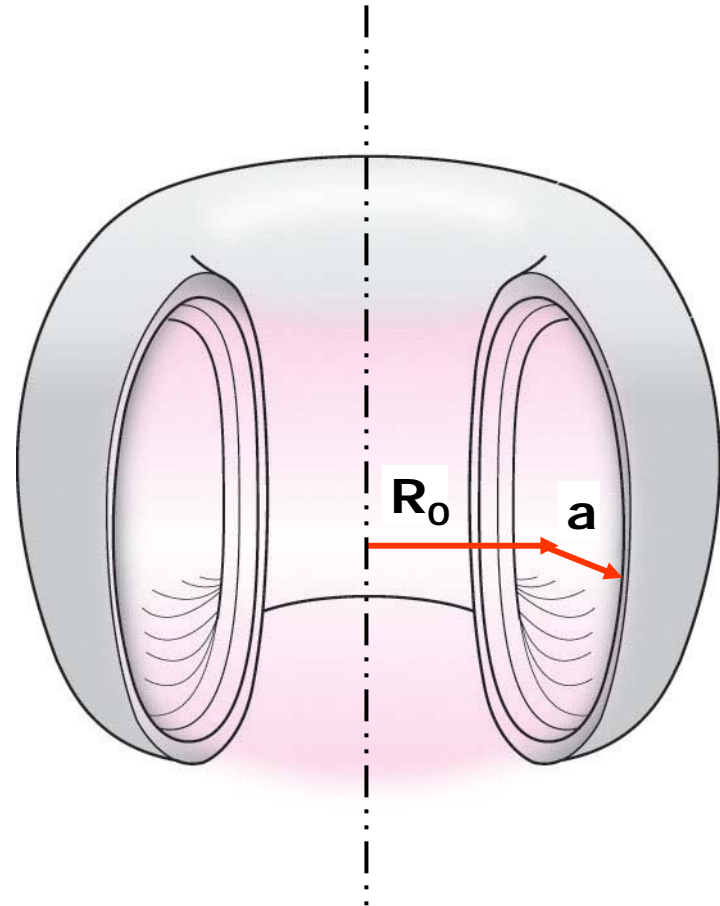
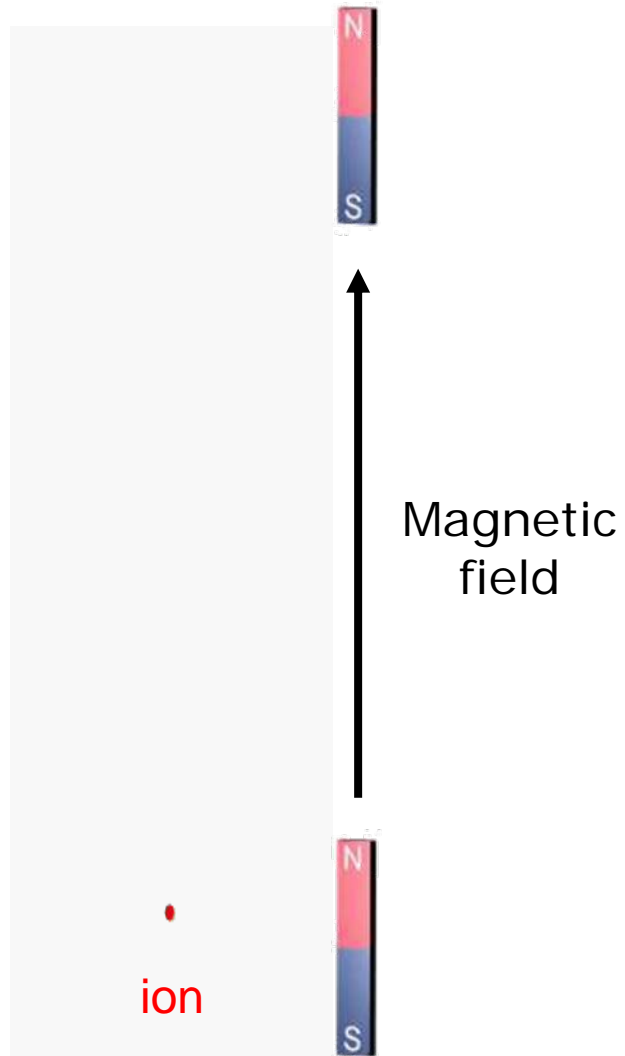
ion

Tokamak



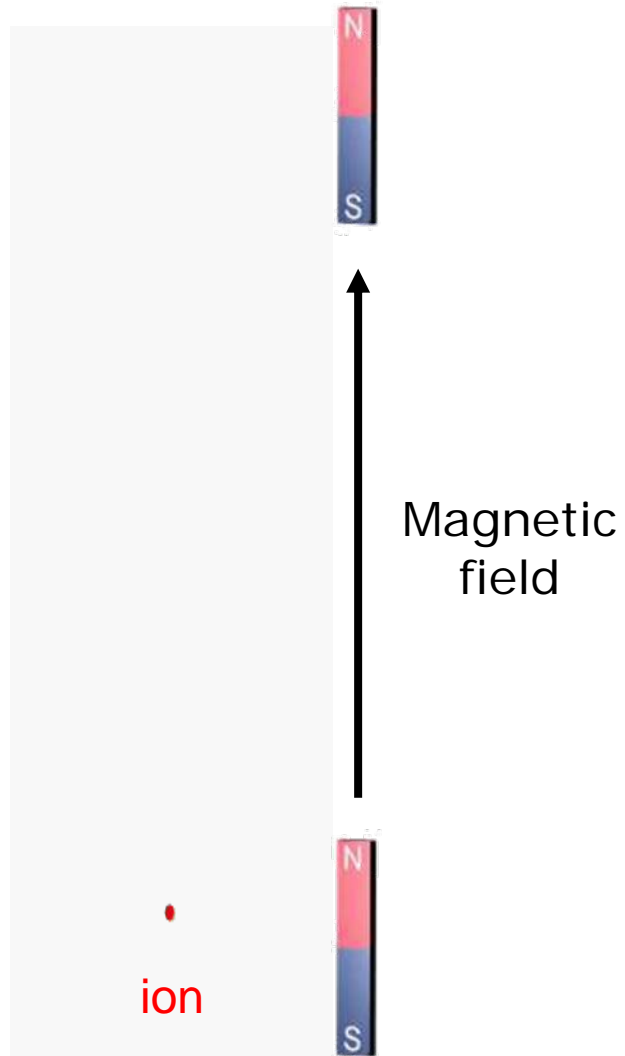
Donut-shaped vacuum vessel

Tokamak

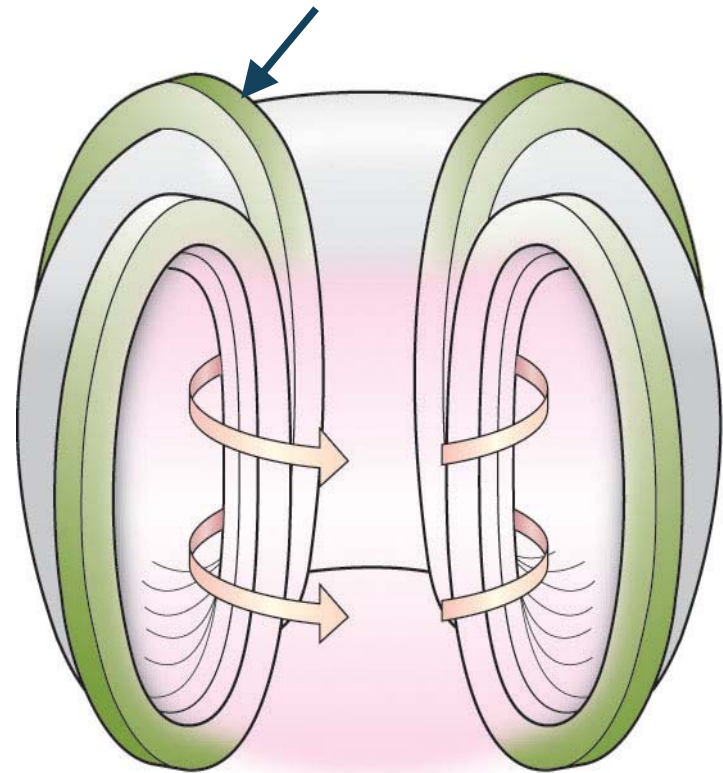


Plasma needs to be confined
 $R_0 = 6.2 \text{ m}$, $a = 2.0 \text{ m}$ in ITER

Tokamak



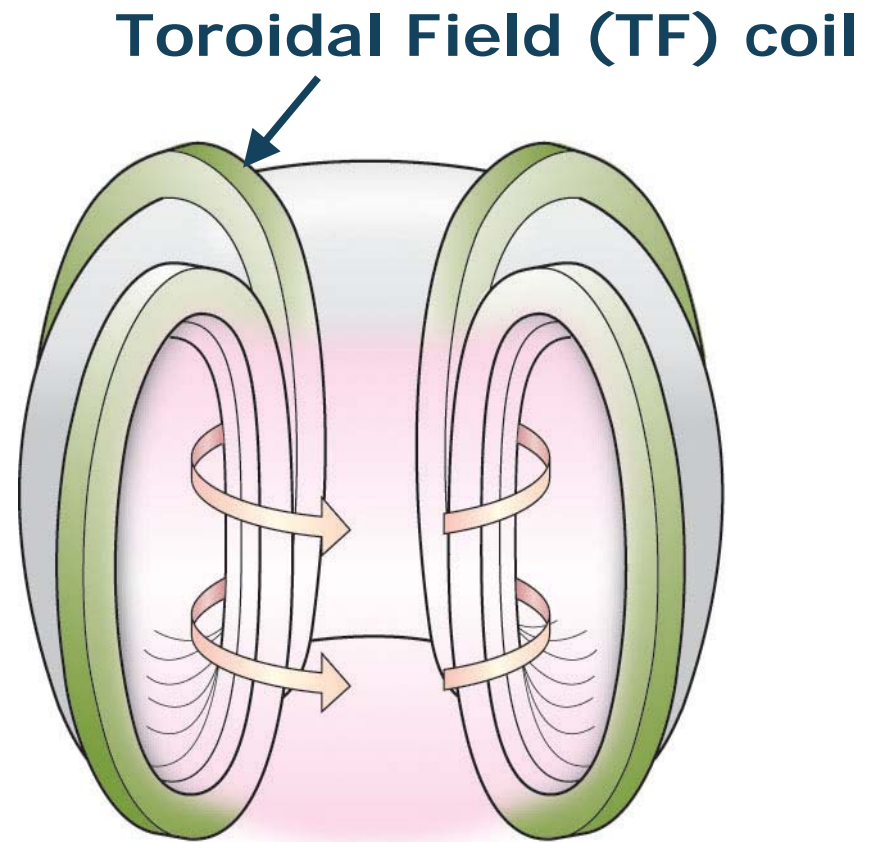
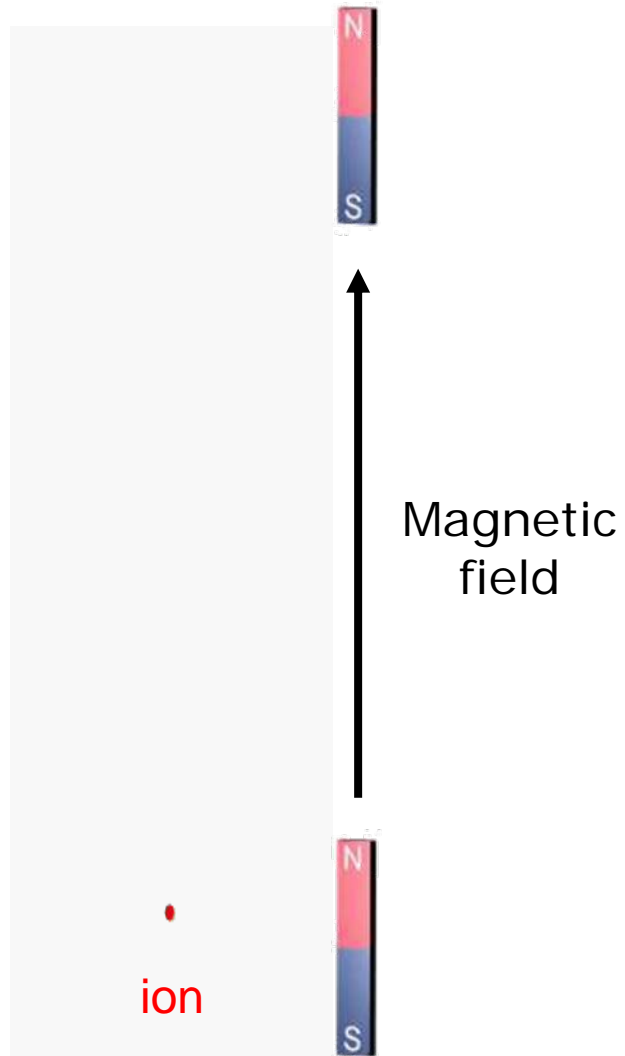
Toroidal Field (TF) coil



Applying toroidal magnetic field

5.3 T in ITER

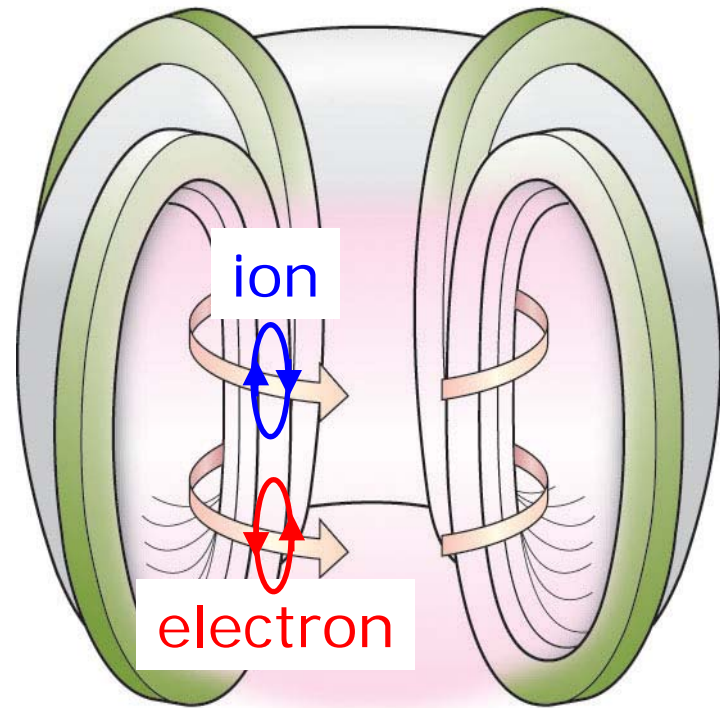
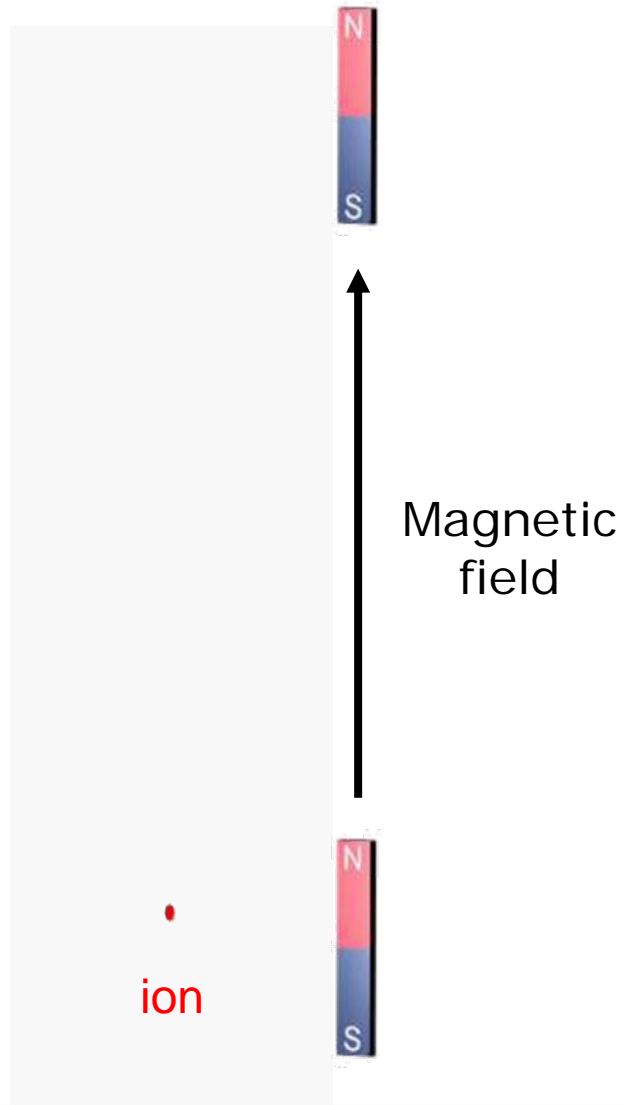
Tokamak



Magnetic field of earth?

0.5 Gauss = 0.00005 T

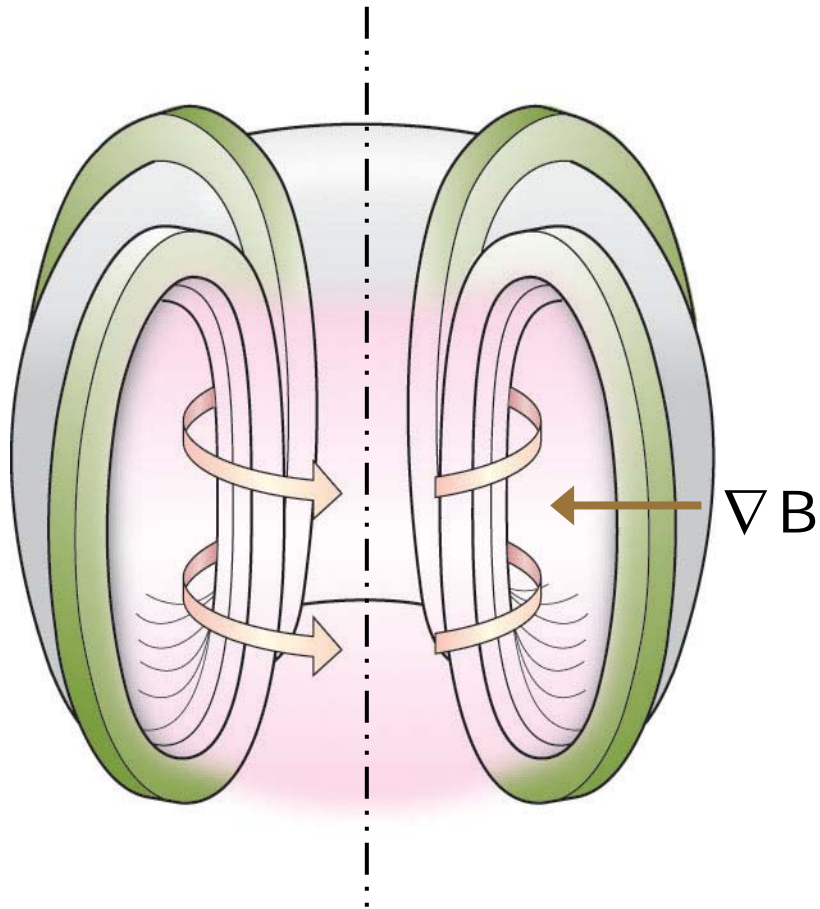
Tokamak



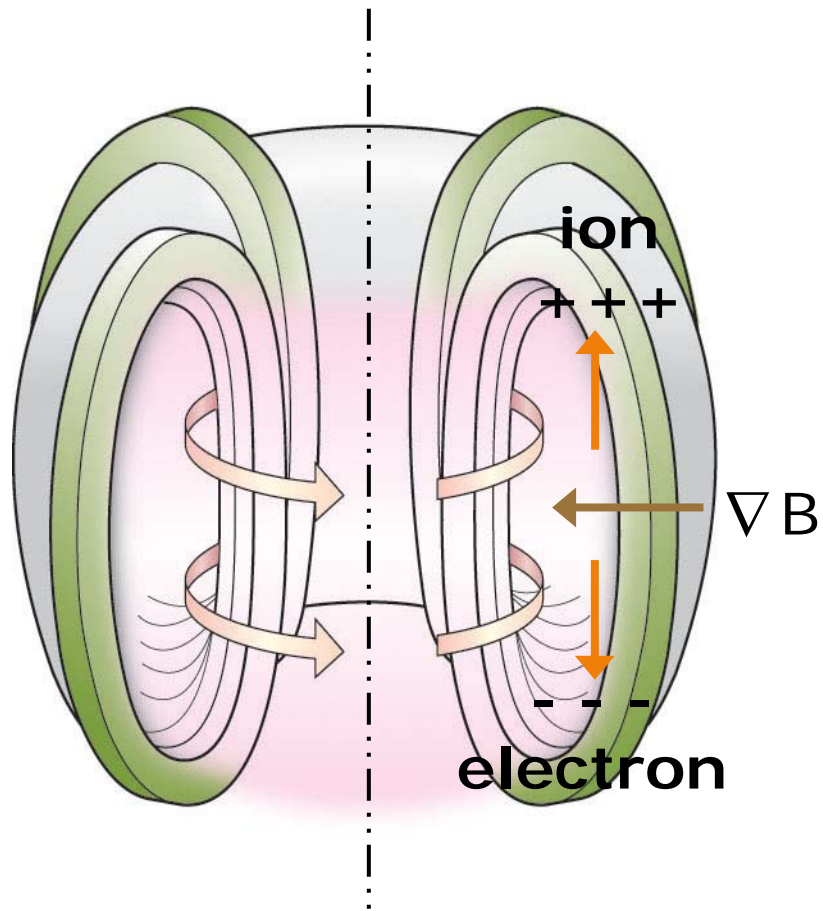
Applying toroidal magnetic field

5.3 T in ITER

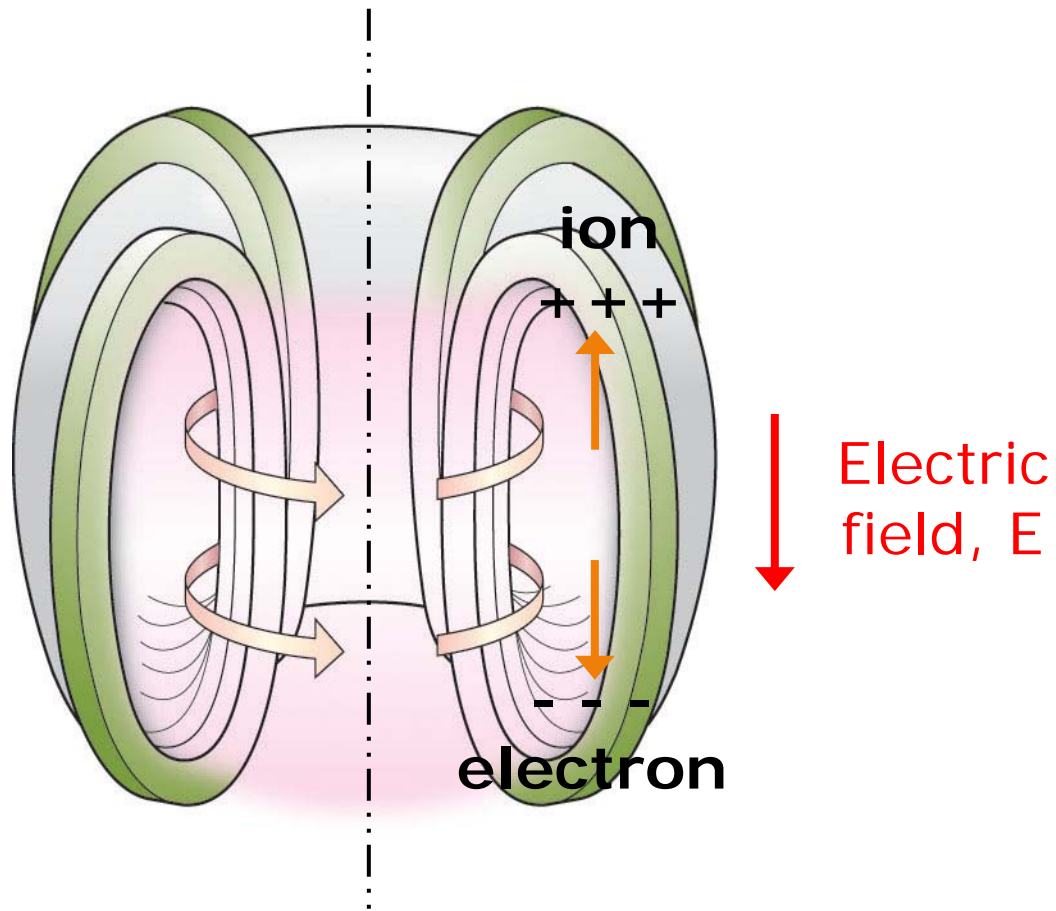
Tokamak



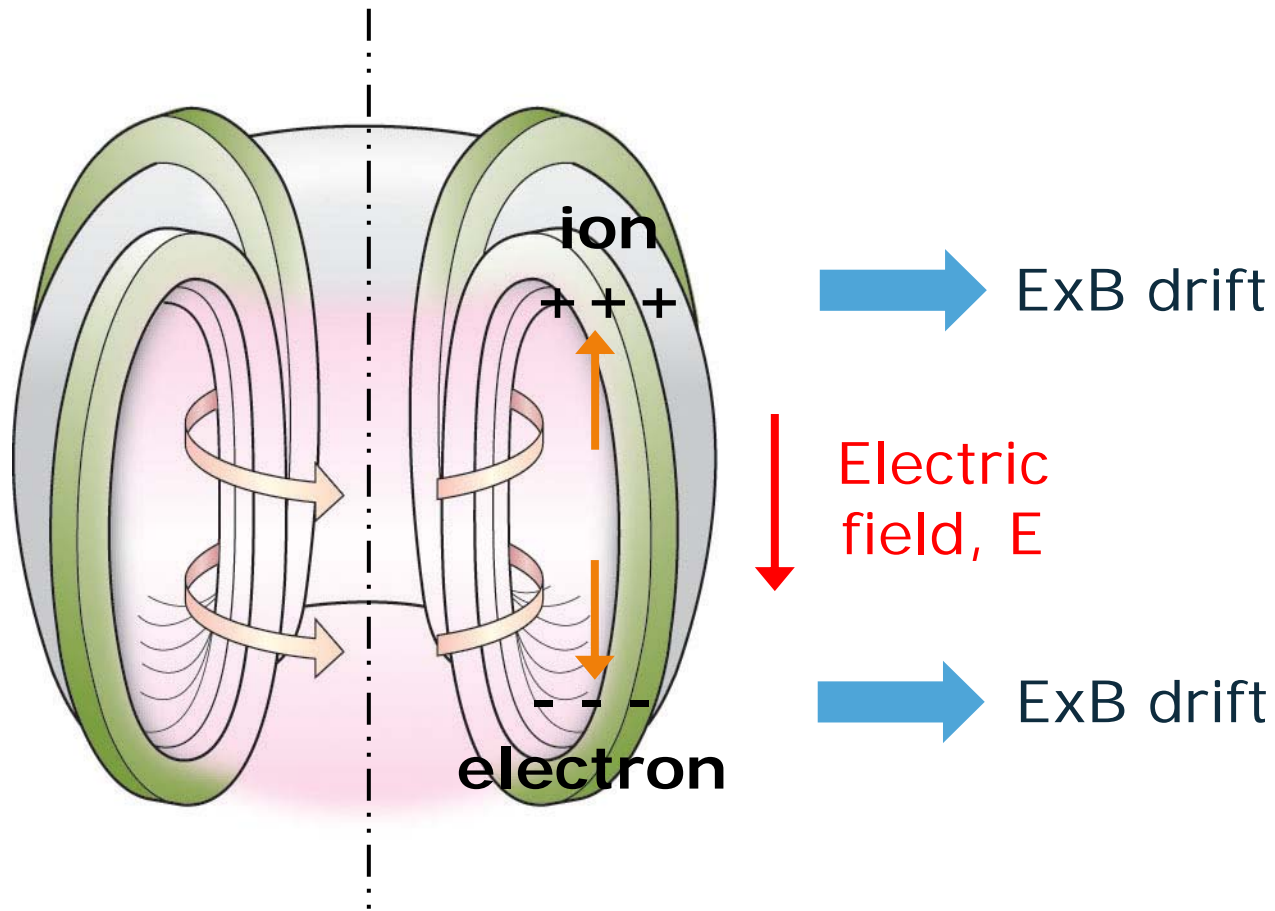
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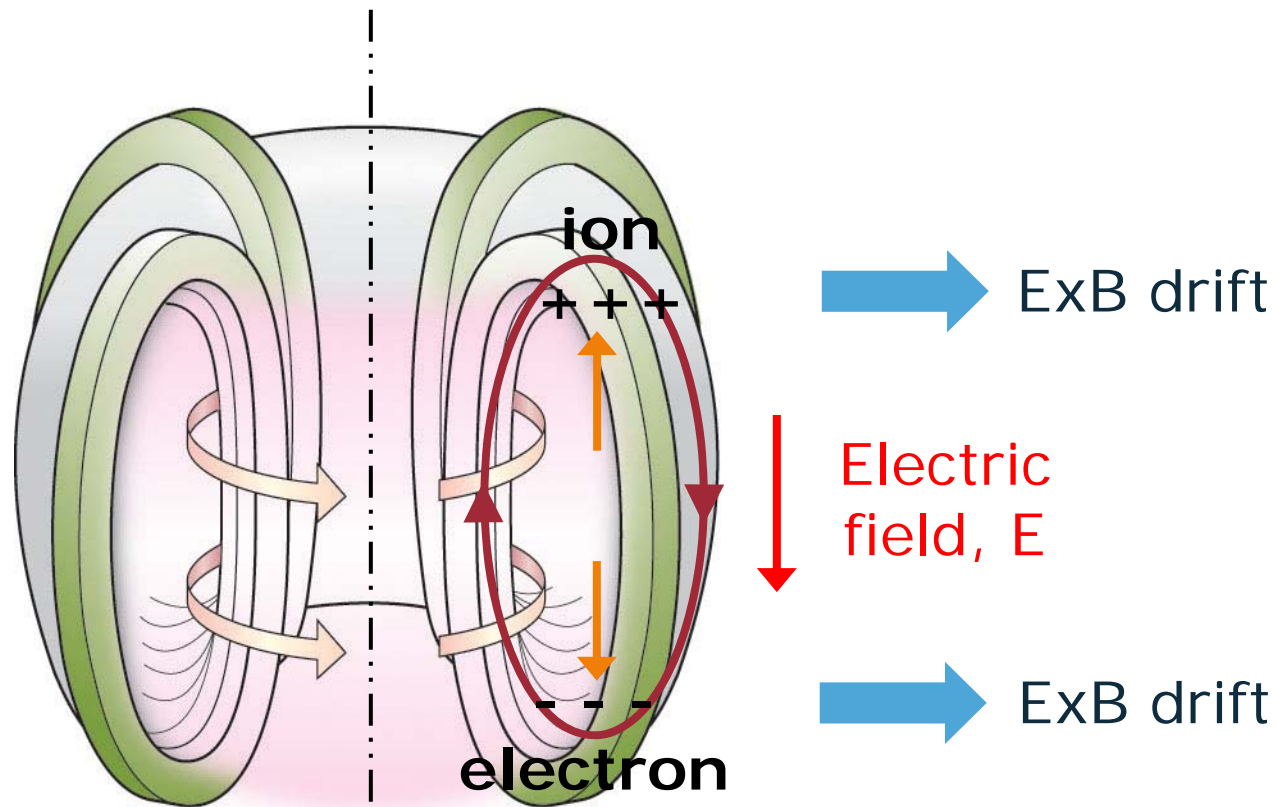
Tokamak



Tokamak



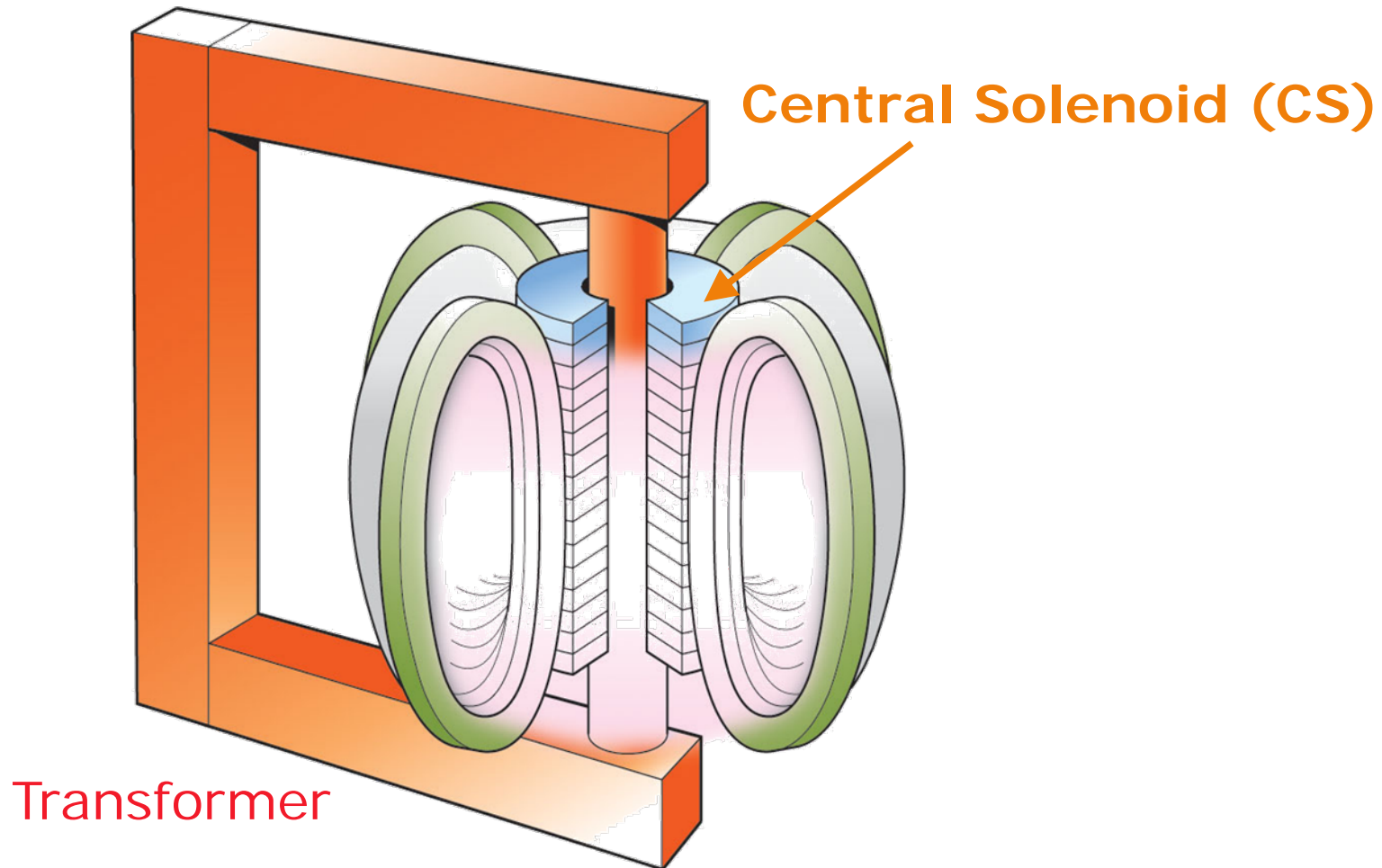
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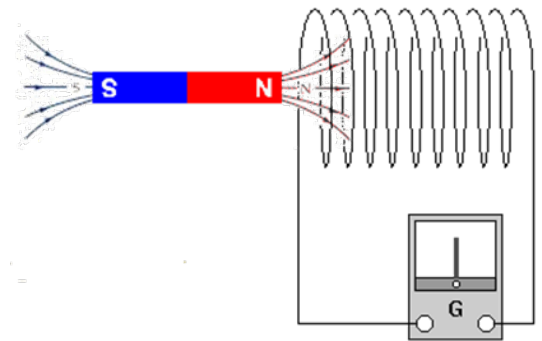
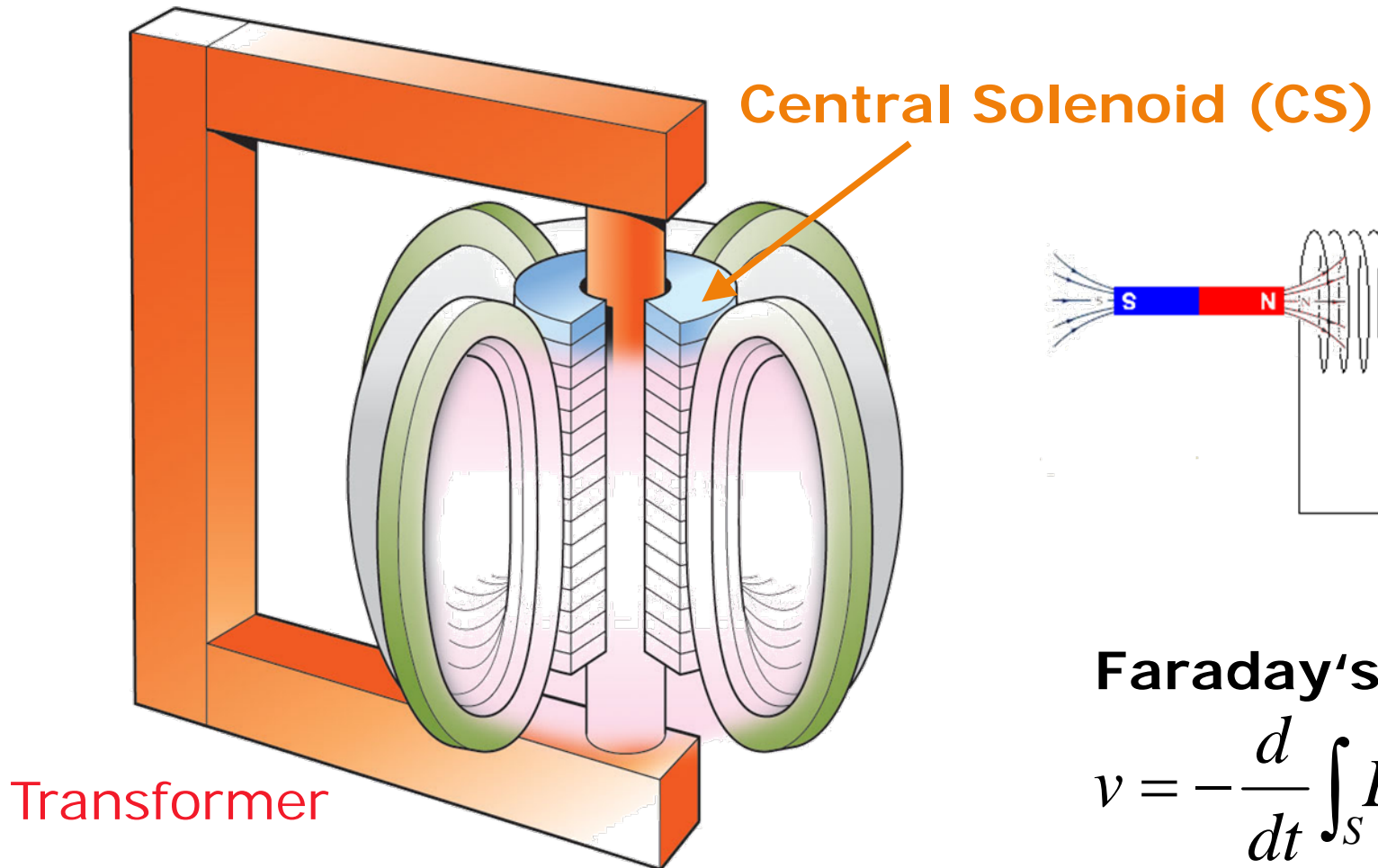
Poloidal magnetic field required

Plasma current → Tokamak

Tokamak



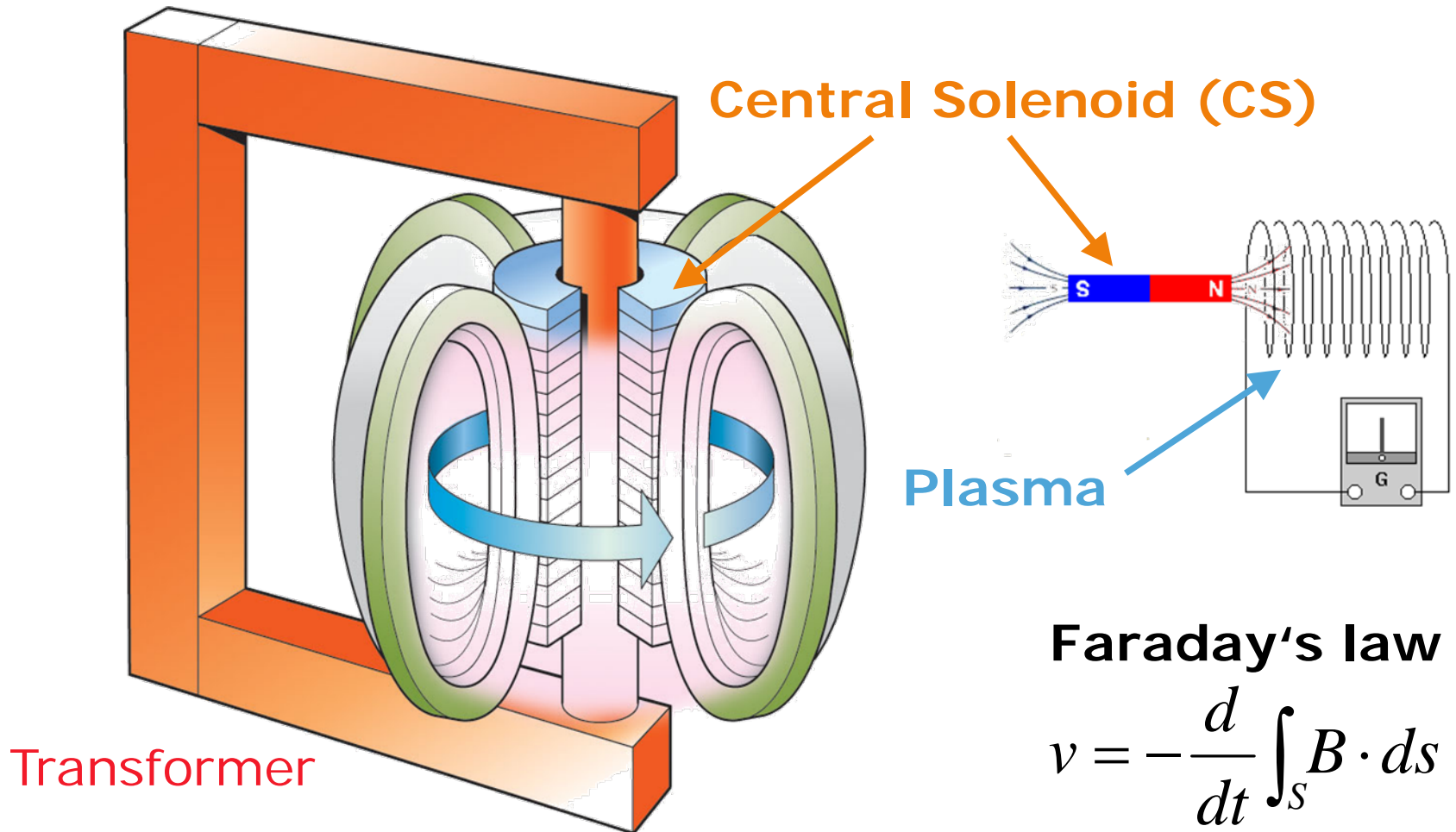
Tokamak



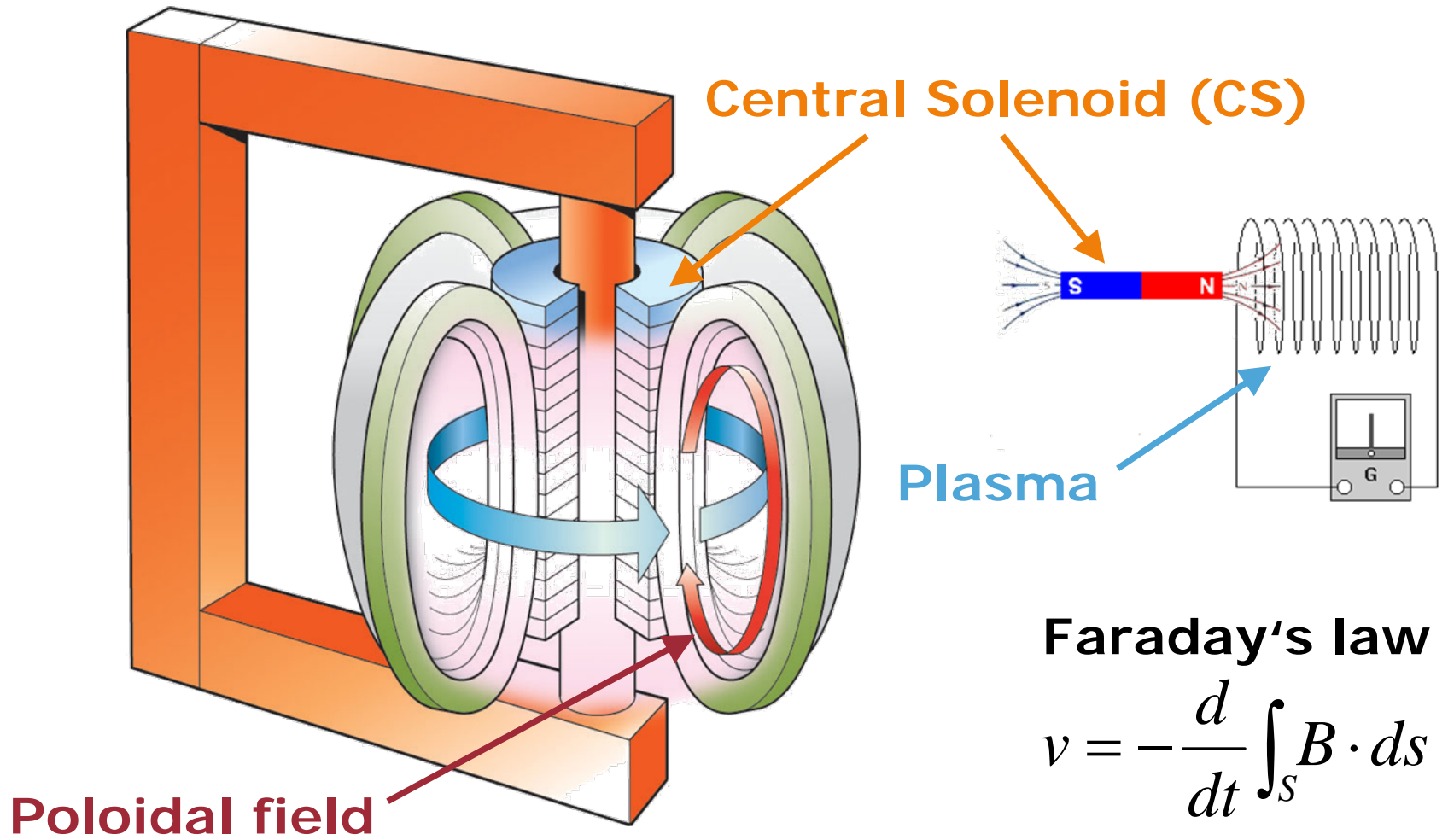
Faraday's law

$$\mathcal{V} = -\frac{d}{dt} \int_S \mathbf{B} \cdot d\mathbf{s}$$

Tokamak



Tokamak

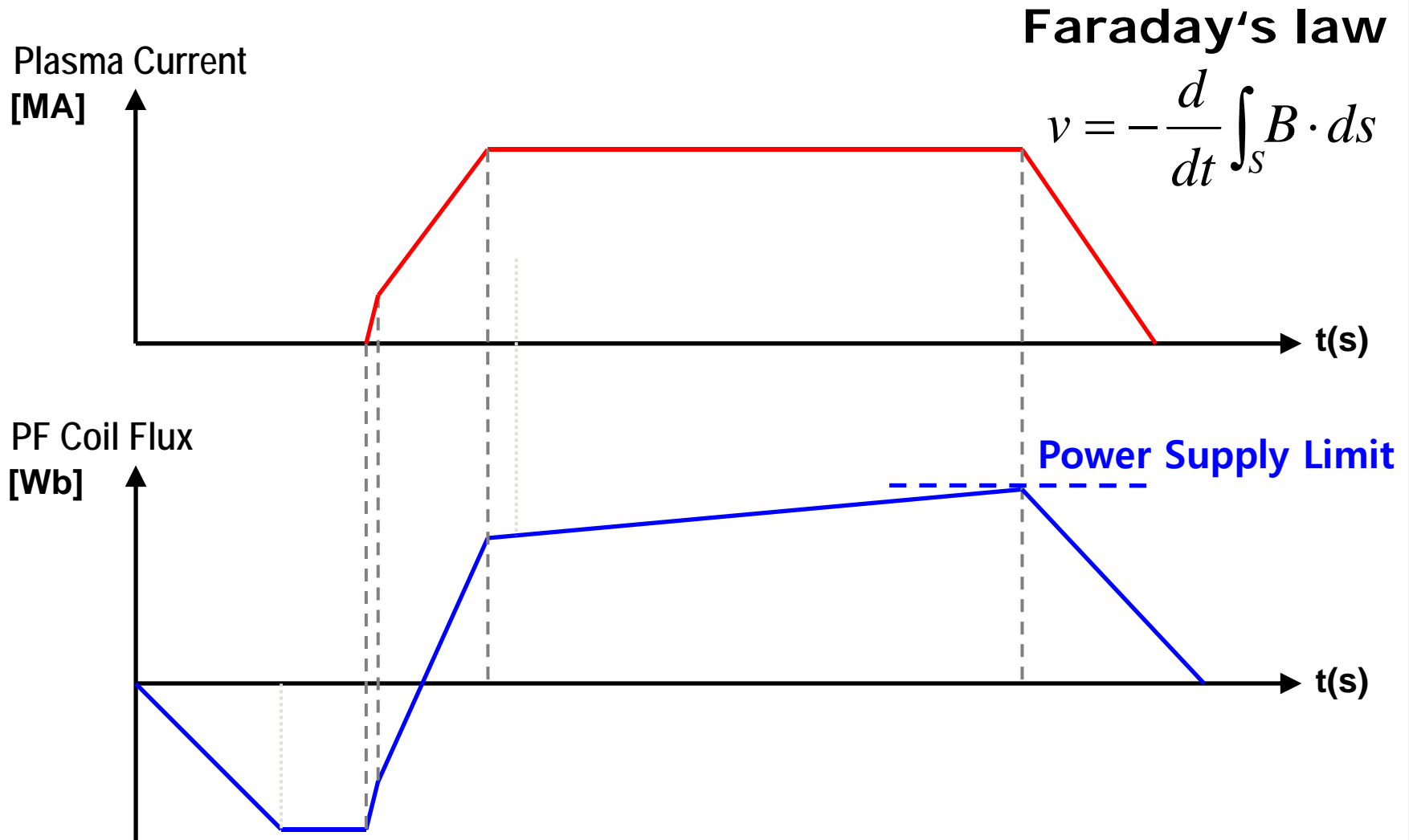


Faraday's law

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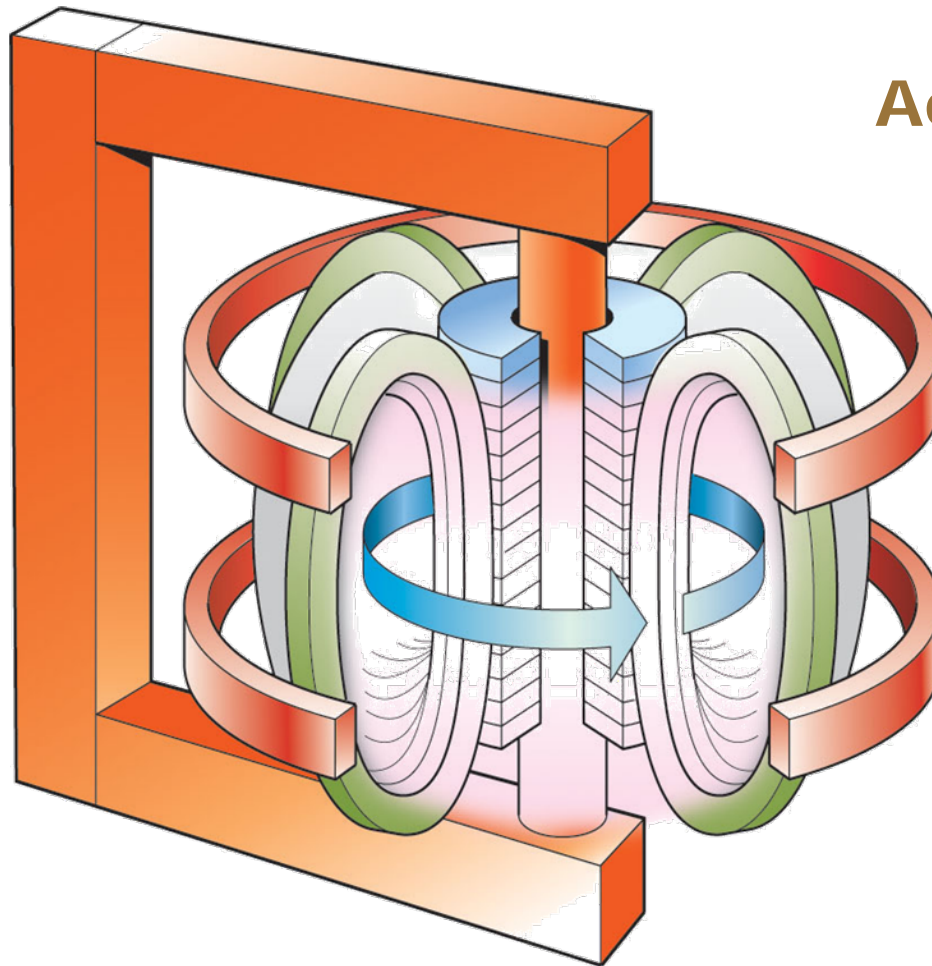
Pulsed Operation!

Pulsed Operation

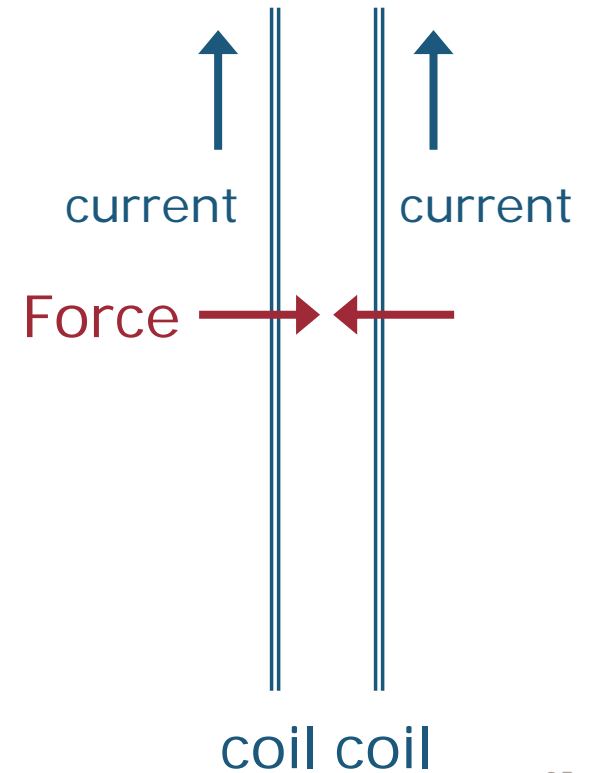


Inherent drawback of Tokamak!

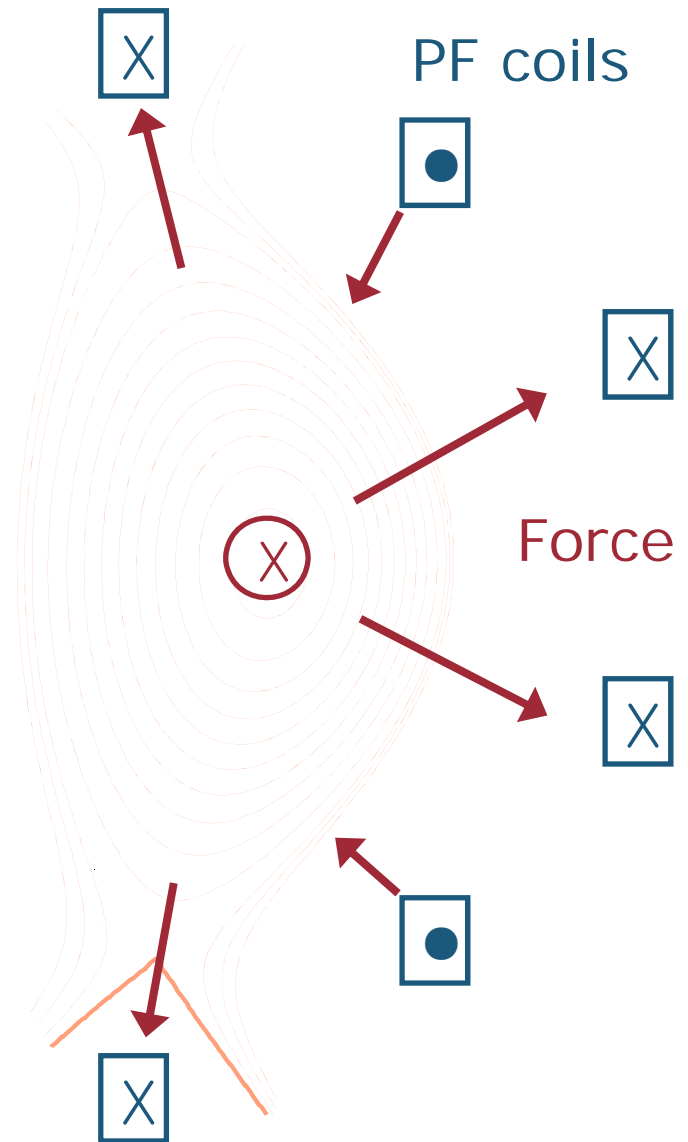
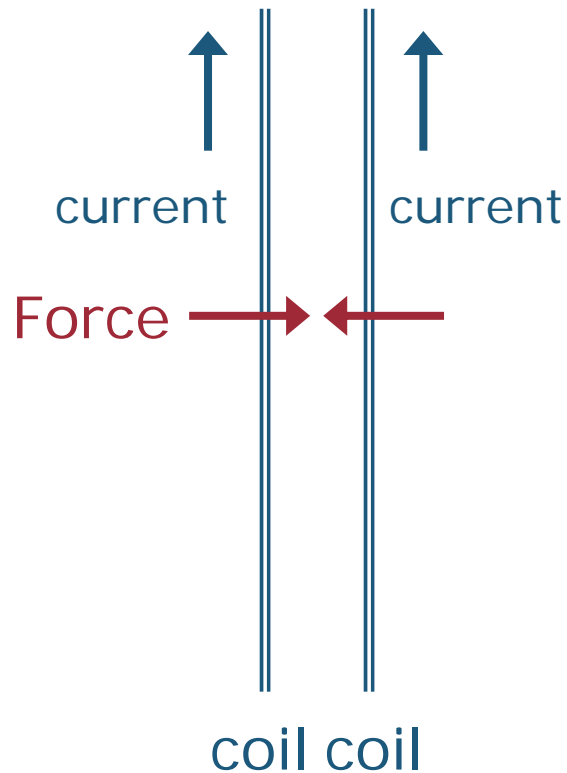
Tokamak



Adding vertical field coils (PF)

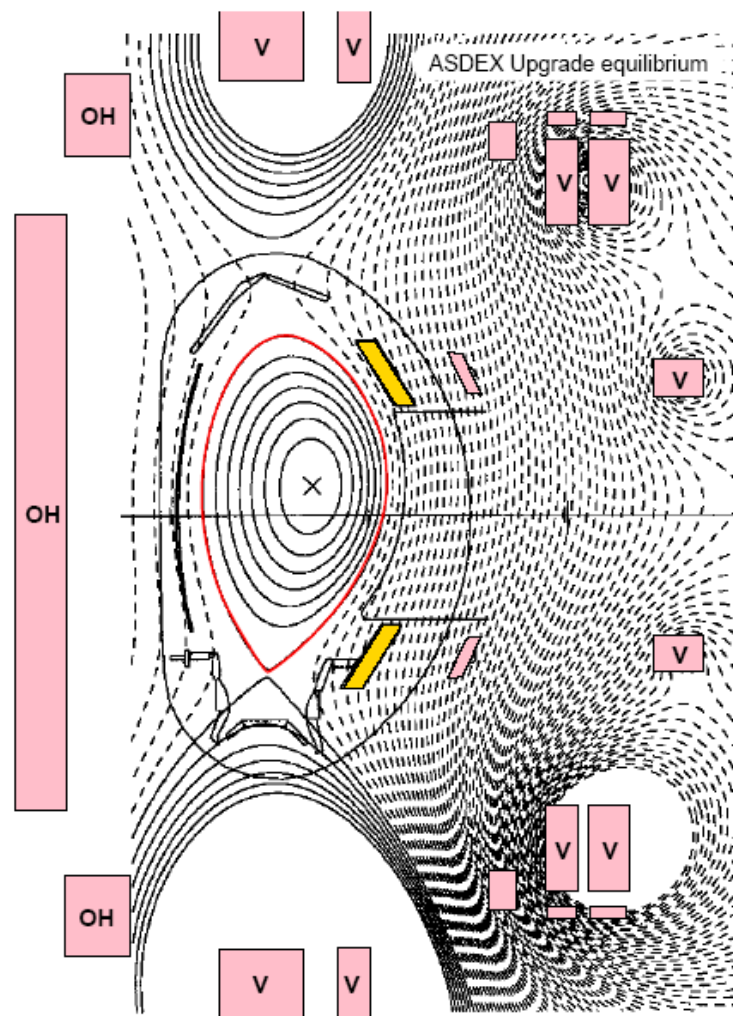
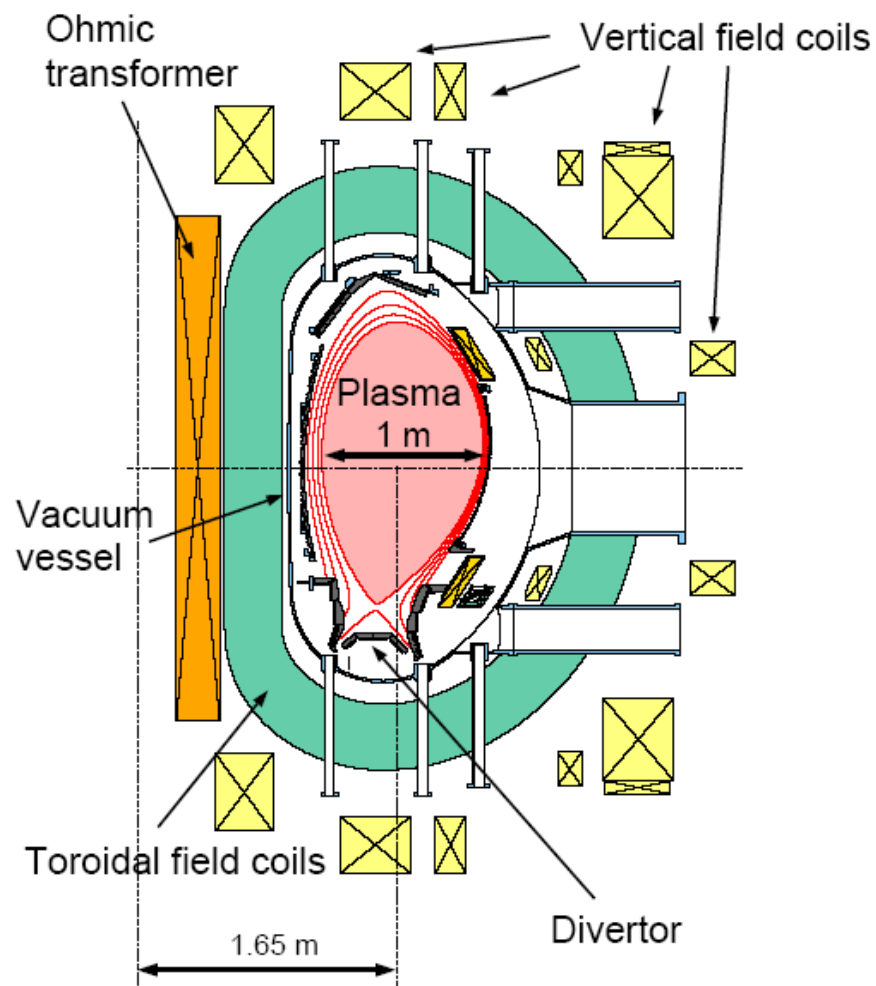


Tokamak

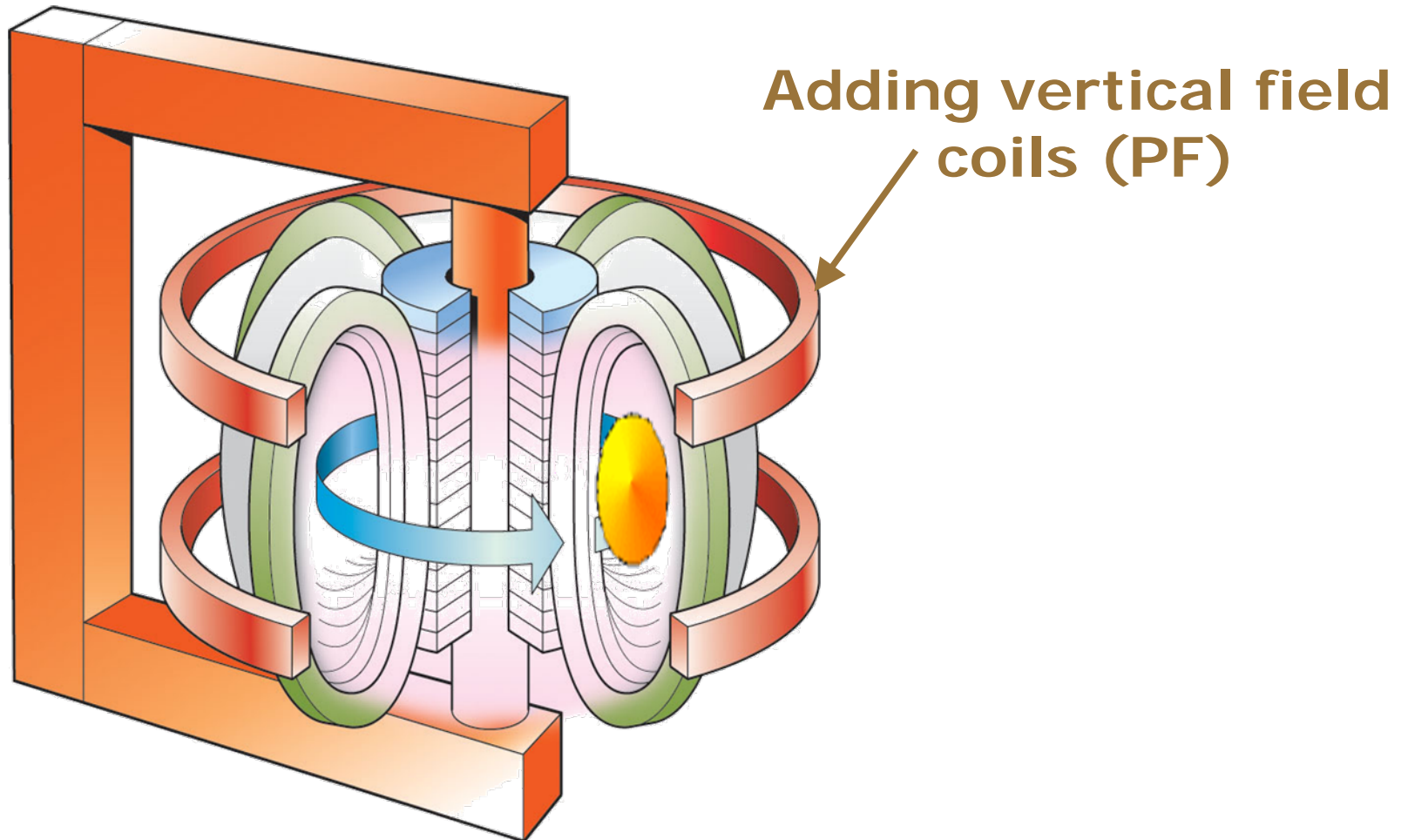


Plasma shaping by PF coils

Tokamak



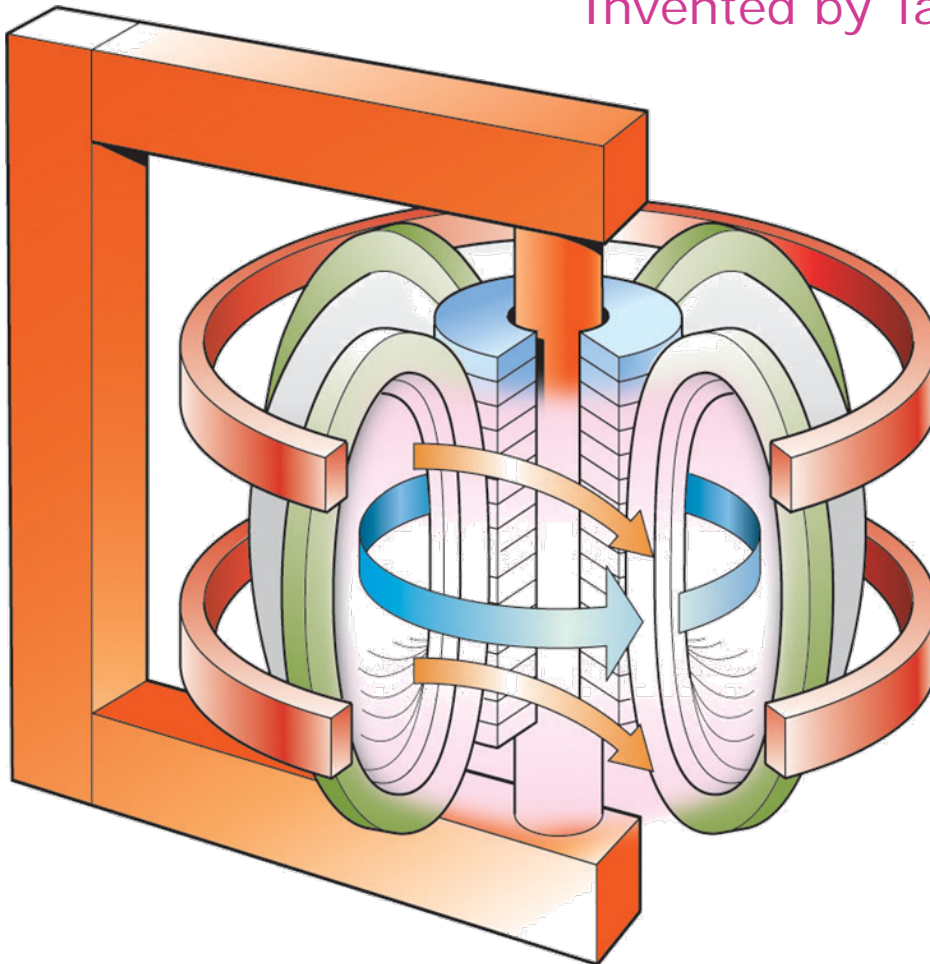
Tokamak



Plasma shaping by PF coils

Tokamak

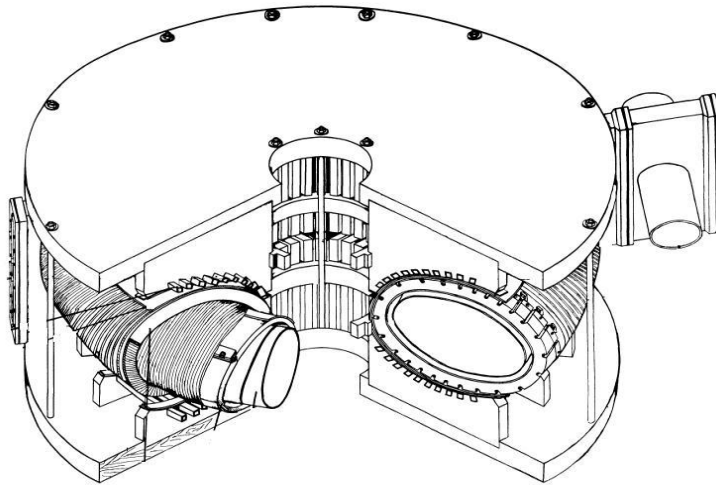
Invented by Tamm and Sakharov in 1952



Toroidalnaja kamera magnitnaja katushka
(Toroidal chamber magnetic coil)

Tokamak

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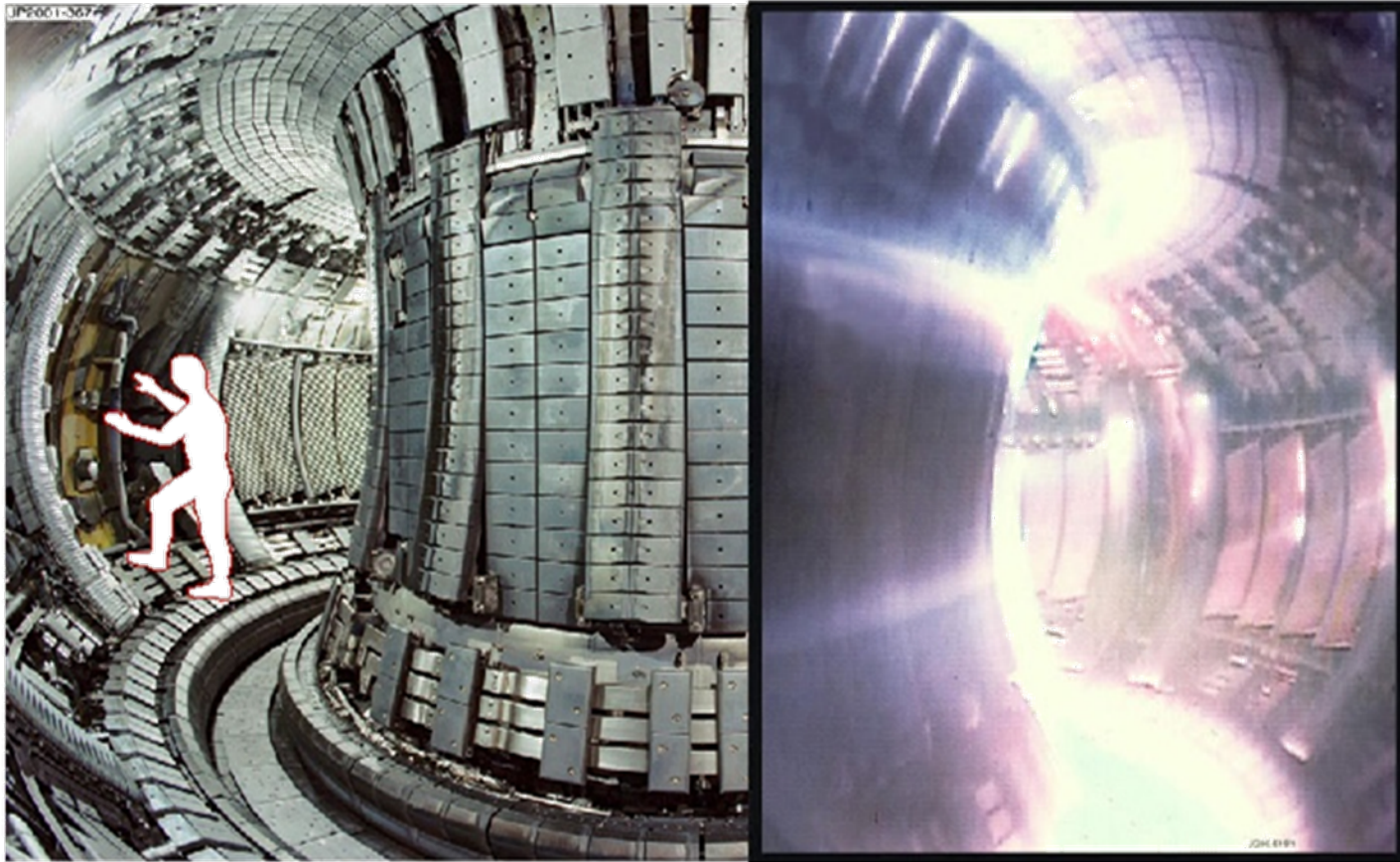


Cutaway of the Toroidal Chamber in
Artsimovitch's Paper *Research on
Controlled Nuclear Fusion in the USSR*

Toroidalnaja kamera magnitnaja katushka
(Toroidal chamber magnetic coil)

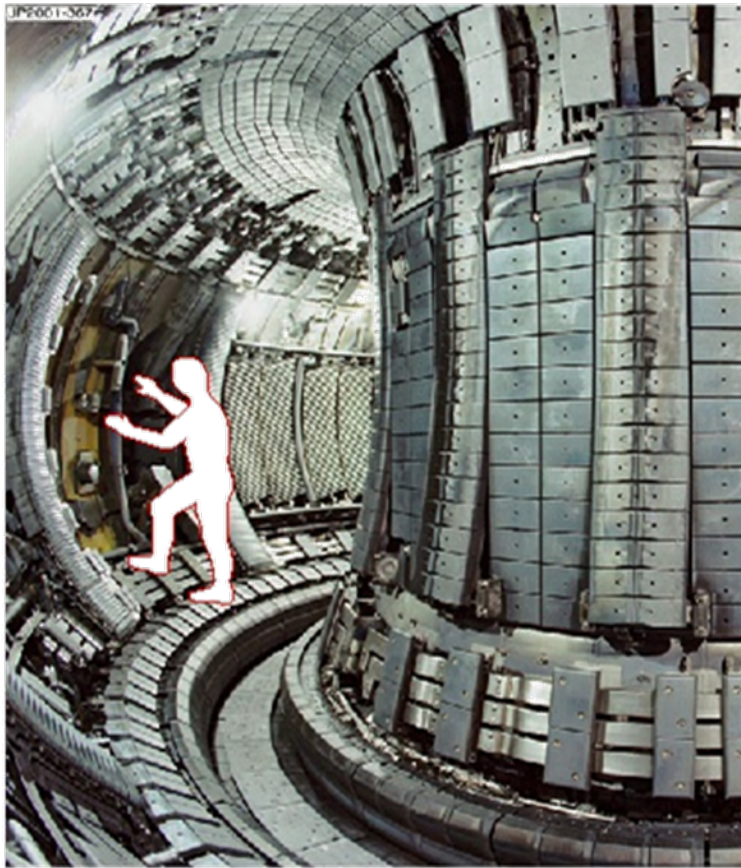
Tokamak

JET (Joint European Torus): $R_0=3\text{m}$, $a=0.9\text{m}$, 1983-today



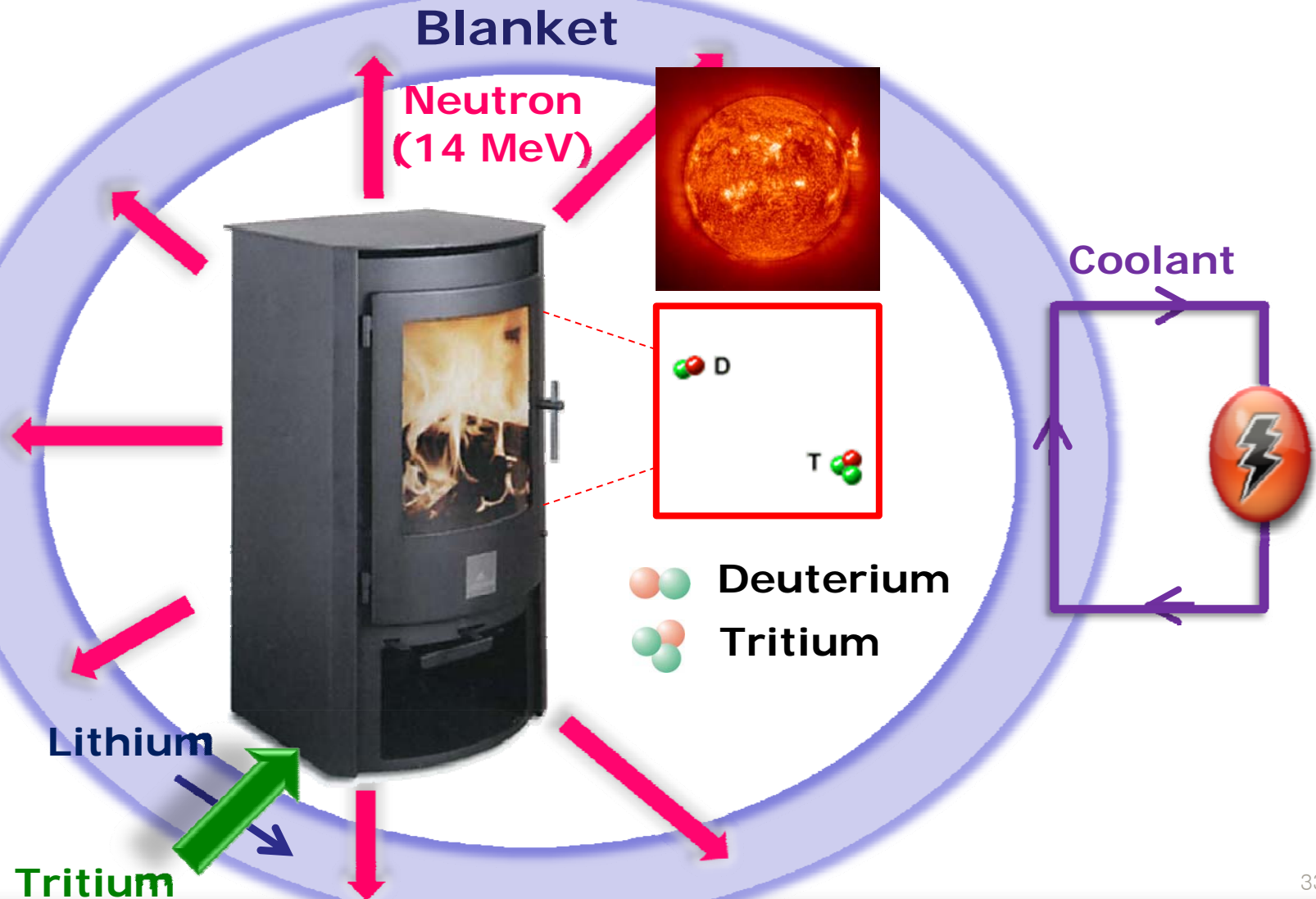
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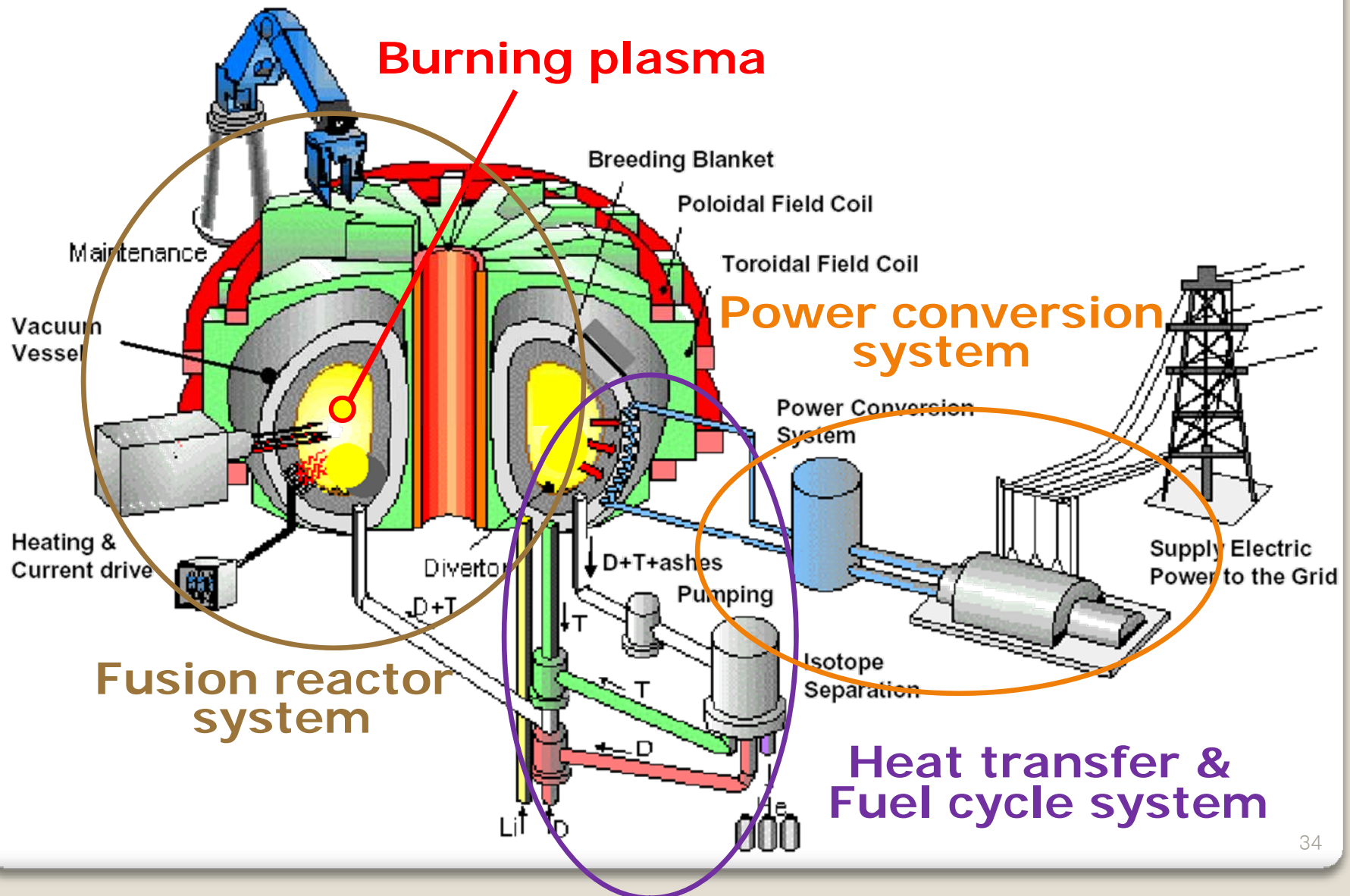


64.59 39.009 1.23

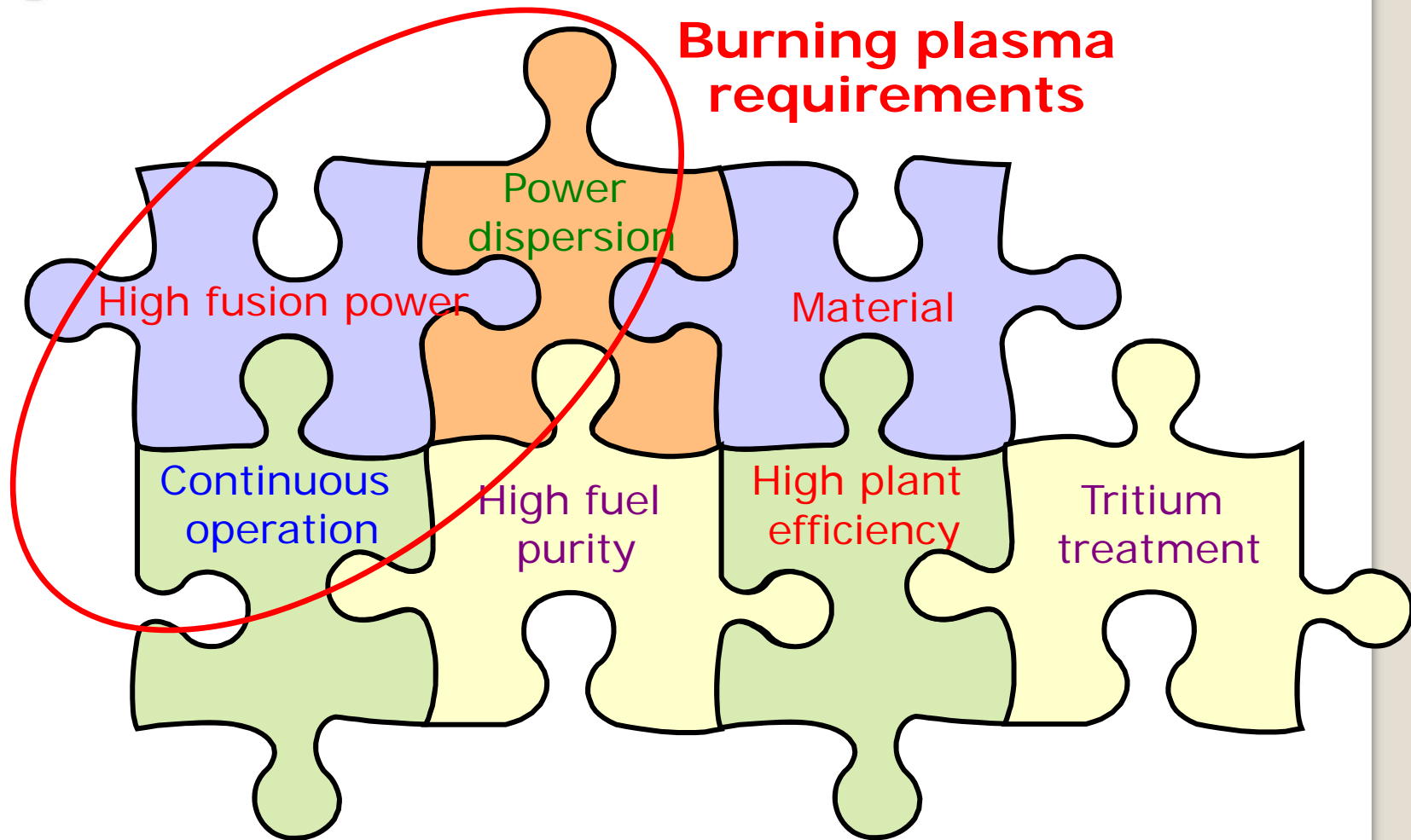
Fusion Power Plant (FPP) System



Fusion Power Plant (FPP) System



Requirements for FPP



Burning Plasma Requirements

