

Enhancing Fusion Efficiency Through Electromagnetic Field Manipulation

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Section "Thermonuclear Fusion"



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Introduction

"KOMANDA" Conference Inbox



Денис Дежнёв 30 Mar



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Hello, dear colleagues!

We are glad to inform you that you have won the grant competition for participation in the "KOMANDA" Conference, which will be held in St. Petersburg (Russia) from September 3 to 6, 2025.

Your scientific abstracts were among the top 5 best works sent by citizens of partner countries of the Rosatom State Corporation.

In the next 2 weeks, the leaders of our scientific sections or editorial staff will contact you regarding the design of your abstracts. It may be necessary to correct something in the Word files, these are ordinary minor working moments.

Thank you for your scientific work! We will be glad to see you at our Conference in September!

I apologize for the 3-day delay in informing you.

Best regards,

Dezhnev Denis,

Chairman of the XI Conference "KOMANDA"

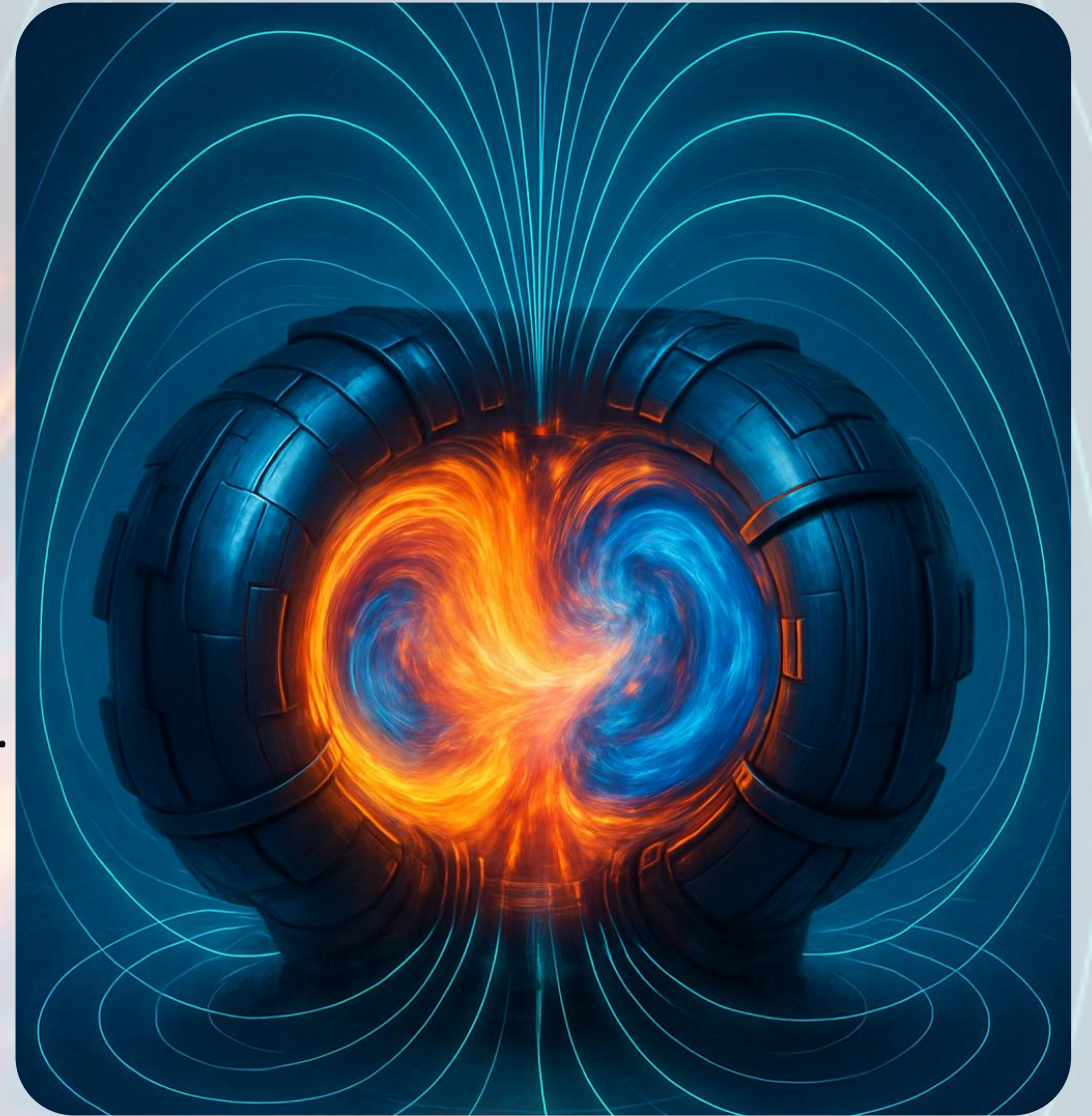
Introduction

Fusion Reactions & Tokamak Overview

- 1) Plasma: ionized gas with free charged particles.
- 2) Fusion needs >100 million $^{\circ}\text{C}$ to fuse deuterium and tritium nuclei.
- 3) Heating uses 3 systems, each >1 million watts.
- 4) Magnetic fields (10,000x Earth's) confine plasma in the Tokamak.
- 5) Plasma density must be high for fusion collisions.

Research Focus

- 1) Thermal heating is inefficient and costly.
- 2) Goal: Use high-voltage capacitors to manipulate electric fields and improve fusion efficiency.



Methodology

Drift Velocity equation :

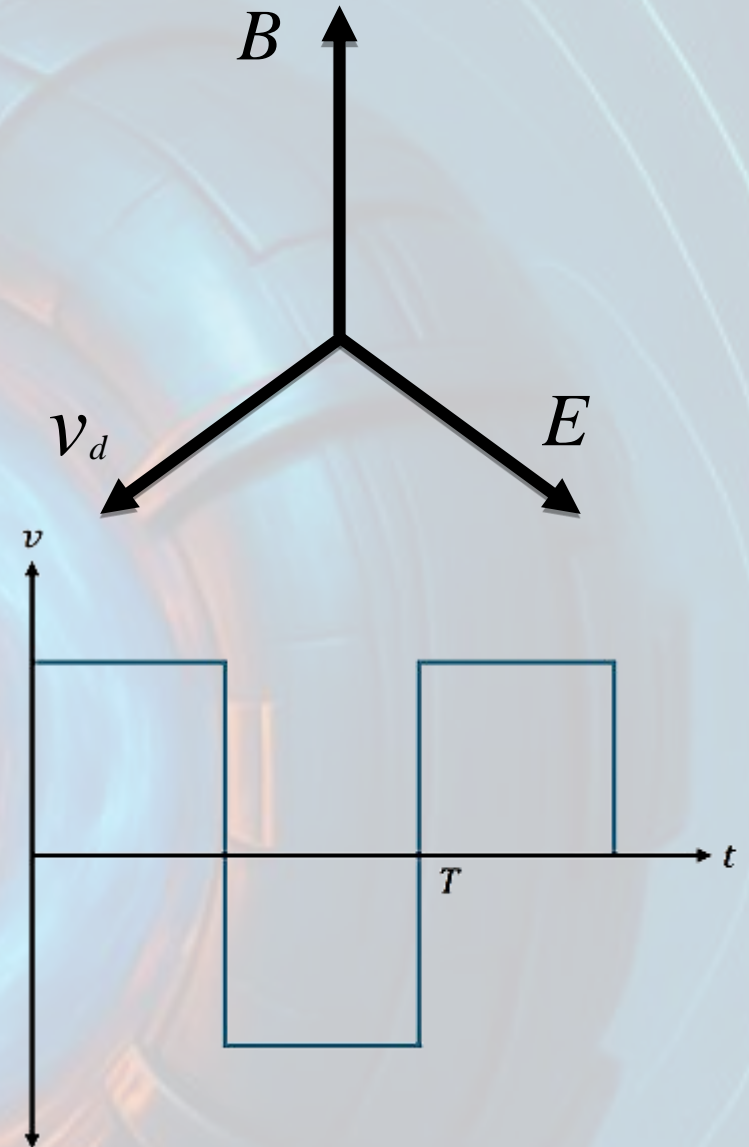
- The Perpendicularity of the electric field to the magnetic field gives a drift velocity to the particles, which equals:

$$v_d = \frac{\vec{E} \times \vec{B}}{B^2}$$

- Where E is the electric field in Volts per meter and B is the magnetic field in Tesla. E can be written as follows:

$$E = \frac{V}{d}$$

- d is the distance between the two plates, and V is the voltage.



Methodology

Voltage source and capacitor characteristics:

To calculate the periodic time of the electric voltage, Velocity can be written in this formula:

$$\int v_d dt = \frac{2\pi r_{avg}}{N_{Capacitors}} \longrightarrow \frac{1}{B} \int E dt = \frac{2\pi r_{avg}}{N_{Capacitors}}$$

$$t = \frac{2\pi r_{avg} B}{N_{Capacitors} E} \longrightarrow T = \frac{4\pi r_{avg} B}{N_{Capacitors} E}$$

$$f = \frac{N_{Capacitors} E}{4\pi r_{avg} B}$$



Approach 1 “Checking the Feasibility”

Fusion cross section “probability”:

Gamow–Sommerfeld factor:

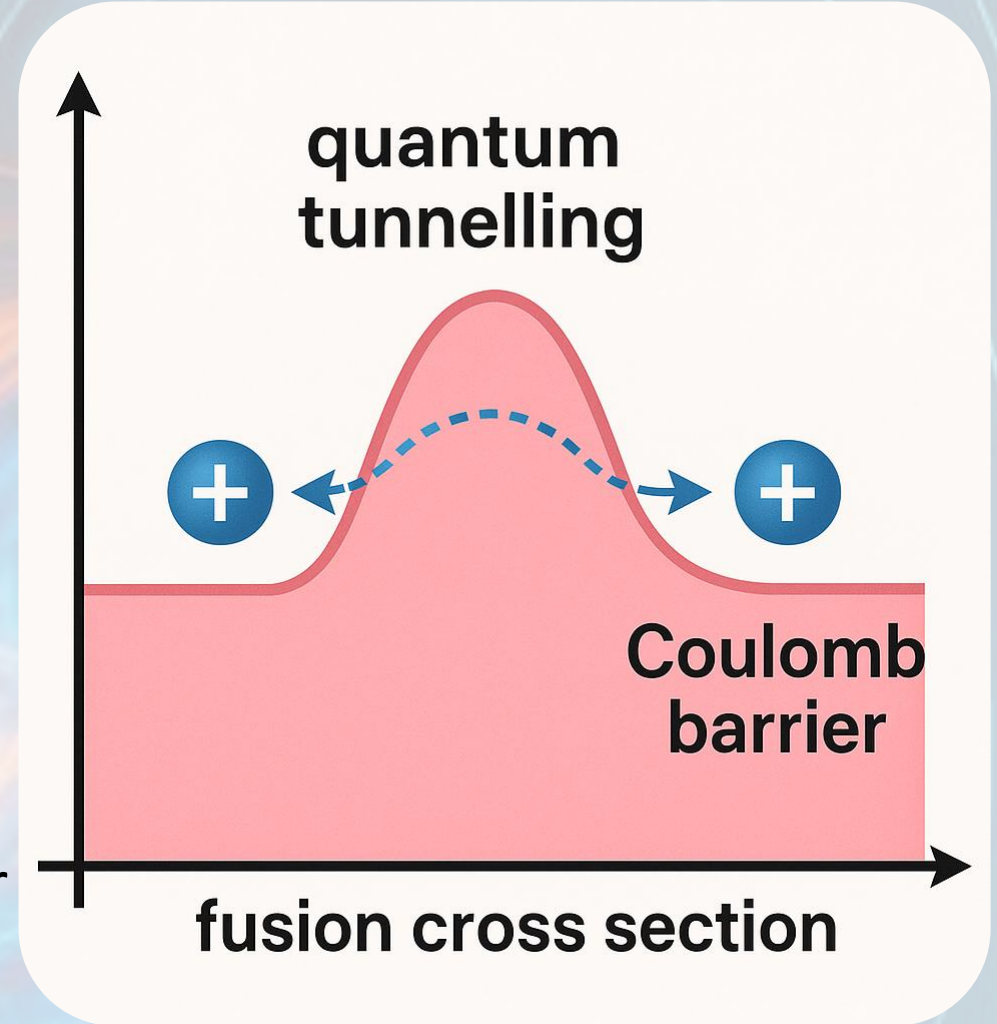
$$P_e = e^{-\sqrt{\frac{E_G}{E_k}}} = e^{-\frac{B_G}{\sqrt{E_k}}}$$

Where:

P_e : the probability that corresponds to the Fusion cross section.

$B_G = \pi\alpha Z_1 Z_2 \sqrt{2m_r c^2} \rightarrow$ Gamow Energy parameter

$$m_r = \frac{m_D m_T}{m_D + m_T} \quad \alpha \approx \frac{1}{137}$$



Approach 1

“Checking the Feasibility”

Nuclear Fusion D-T Reaction Calculations:



$$\rightarrow m_r = \frac{2.01410179 \times 3.01604928}{2.01410179 + 3.01604928} = 1.20764370076 \text{ amu}$$

$$\rightarrow B_G = \pi \times \frac{1}{137} \times \sqrt{2m_r c^2} = 4.352560565 \times 10^{-7} \text{ J}^{\frac{1}{2}} = 34.38 \text{ KeV}^{\frac{1}{2}} = 1.0874 \text{ MeV}^{\frac{1}{2}}$$

$$\rightarrow E_k = \frac{1}{2} m_r v_{relative}^2 = \frac{1}{2} m_r \times \left(\frac{2E}{B}\right)^2 = 2m_r \left(\frac{E}{B}\right)^2$$

$$\rightarrow E_{developed} = P_e \times 17.59 = 17.59 \times \exp\left(-\frac{B_G}{\sqrt{E_k}}\right)$$

Approach 1

“Checking the Feasibility”

Nuclear Fusion D-T Reaction Calculations

”continue”:

$$E_{developed} = 17.59n_i \exp\left(-\frac{const}{V}\right)$$

Saha equation For Ionized plasma ”unapplicable”

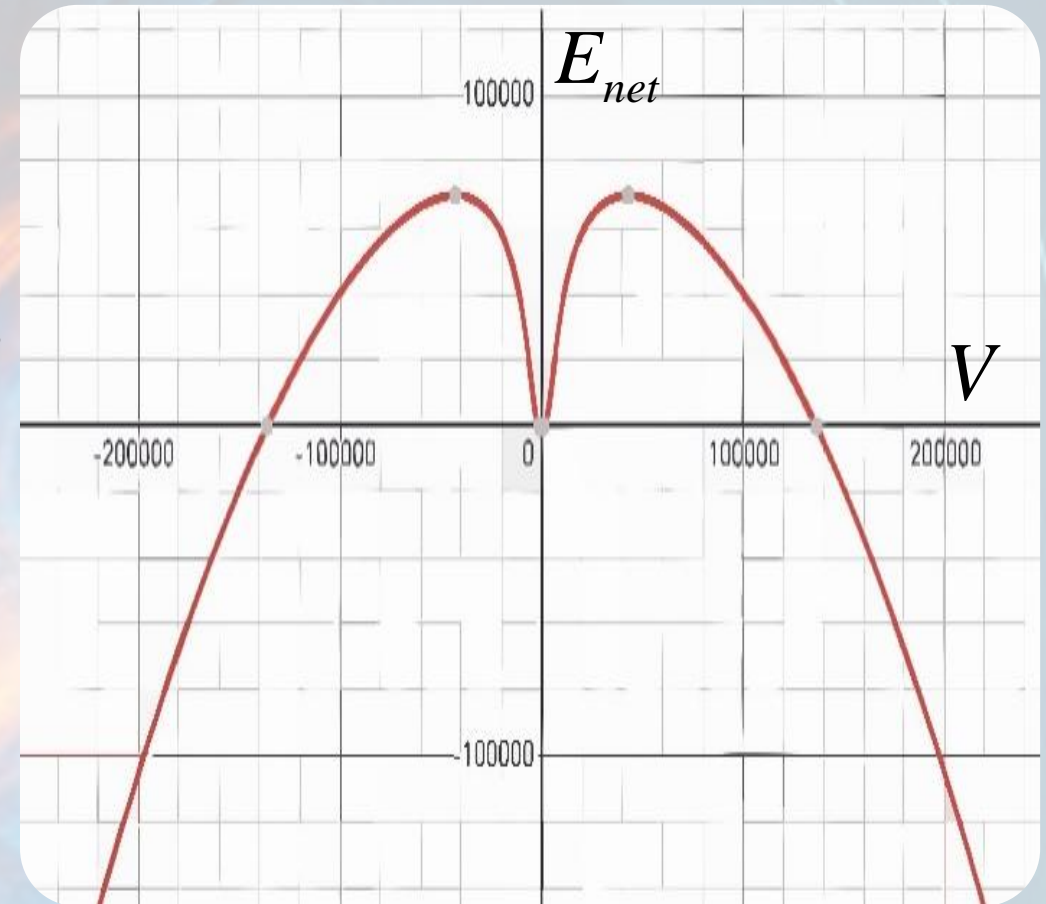
$$\frac{n_i}{n_n} = 2.4 \times 10^{21} \times \frac{T^{3/2}}{n_i} e$$

Electric losses:

$$\rightarrow E_{loss} = \frac{1}{2} CV^2 \rightarrow E_{total} = 2E_{loss} = CV^2$$

$$\rightarrow E_{net} = E_{developed} - E_{loss} - E_{thermal} \text{ (neglected)}$$

$$\rightarrow E_{net} = 17.59n_i \exp\left(-\frac{const}{V}\right) - CV^2$$



Approach 2 “More Accurate and Realistic”

D-T fusion cross-section using Bosch-Hale parameterization:

$$\sigma_{fusion} = S(E) \frac{1}{E} \exp\left(-\frac{B_G}{\sqrt{E}}\right)$$

Where :

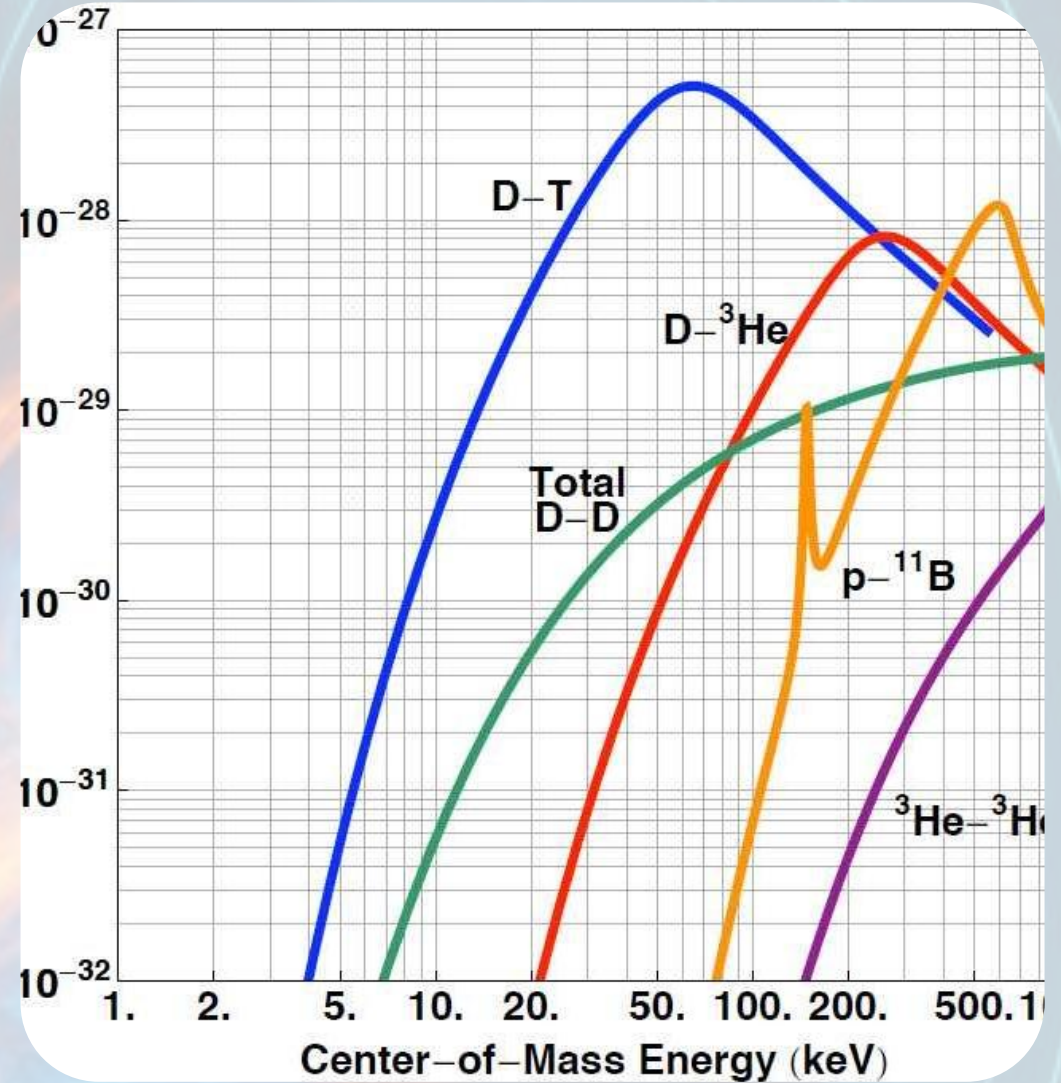
$S(E)$: Astrophysical S-function

1) “Original Bosch-Hale form”:

$$S(E) = \frac{A_1 + A_2 E + A_3 E^2 + A_4 E^3 + A_5 E^4}{1 + B_1 E + B_2 E^2 + B_3 E^3 + B_4 E^4}$$

2) Empirical Logarithmic S-Factor Fit “7-parameter form”:

$$S(E) = \exp\left(a_1 + a_2 E^{-1} + a_3 E^{-\frac{1}{3}} + a_4 E^{\frac{1}{3}} + a_5 E + a_6 E^{\frac{5}{3}} + a_7 \ln E\right)$$



Approach 2

“More Accurate and Realistic”

D-T fusion reaction rate under Electromagnetic drift and thermal Heat effects:

Thermal RMS velocity:

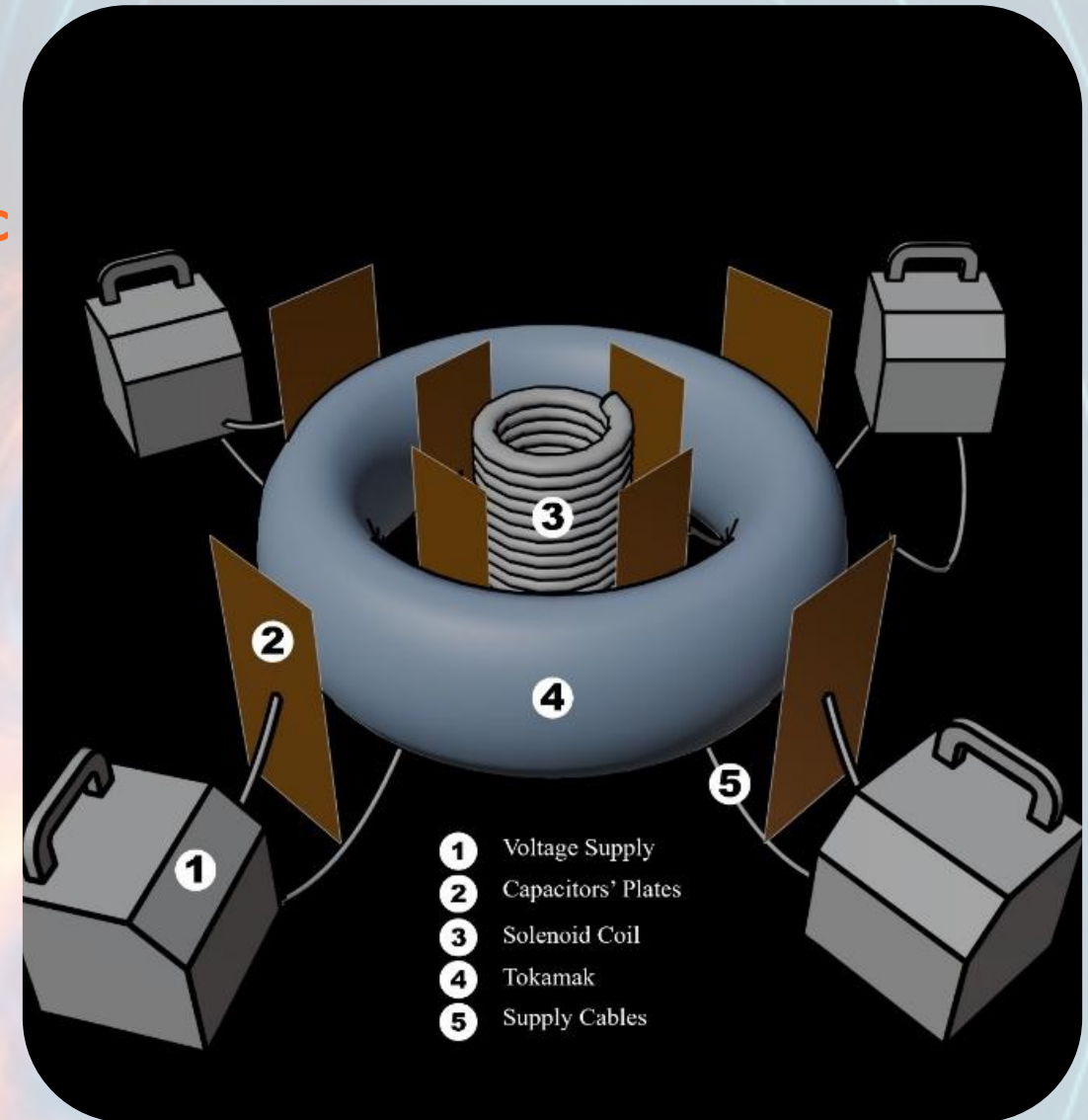
$$v_{thermal} = \sqrt{\frac{3K_B T}{m_r}}$$

Drift velocity:

$$v_d = \frac{\vec{E} \times \vec{B}}{B^2} = \frac{E}{B} \rightarrow \text{perpendicularity}$$

Effective velocity:

$$v_{eff} = 2\sqrt{v_d^2 + v_{thermal}^2}$$



Approach 2 “More Accurate and Realistic”

D-T fusion reaction rate under Electromagnetic drift and thermal Heat effects:

➔ D-T fusion rate : $R_{fusion} = n_D n_T \langle \sigma v \rangle = n_D n_T \sigma_{fusion} \times v_{eff} \frac{\text{reactions}}{m^3 \cdot s}$

➔ D-T fusion power density: $Power_{fusion} = R_{fusion} \times E_{fusion} (17.59 \text{ MeV})$

➔ Number density : $n_D = \frac{\rho \times fr}{m_D} N_A$, $n_T = \frac{\rho \times (1 - fr)}{m_T} N_A$

➔ Net power density: $Power_{net} = Power_{fusion} - Power_{losses}$

$$Power_{net} \geq 0 \rightarrow \text{Lawson ignition criterion}$$

Approach 2

“More Accurate and Realistic”

Operation losses density:

1) Thermal Heat losses :

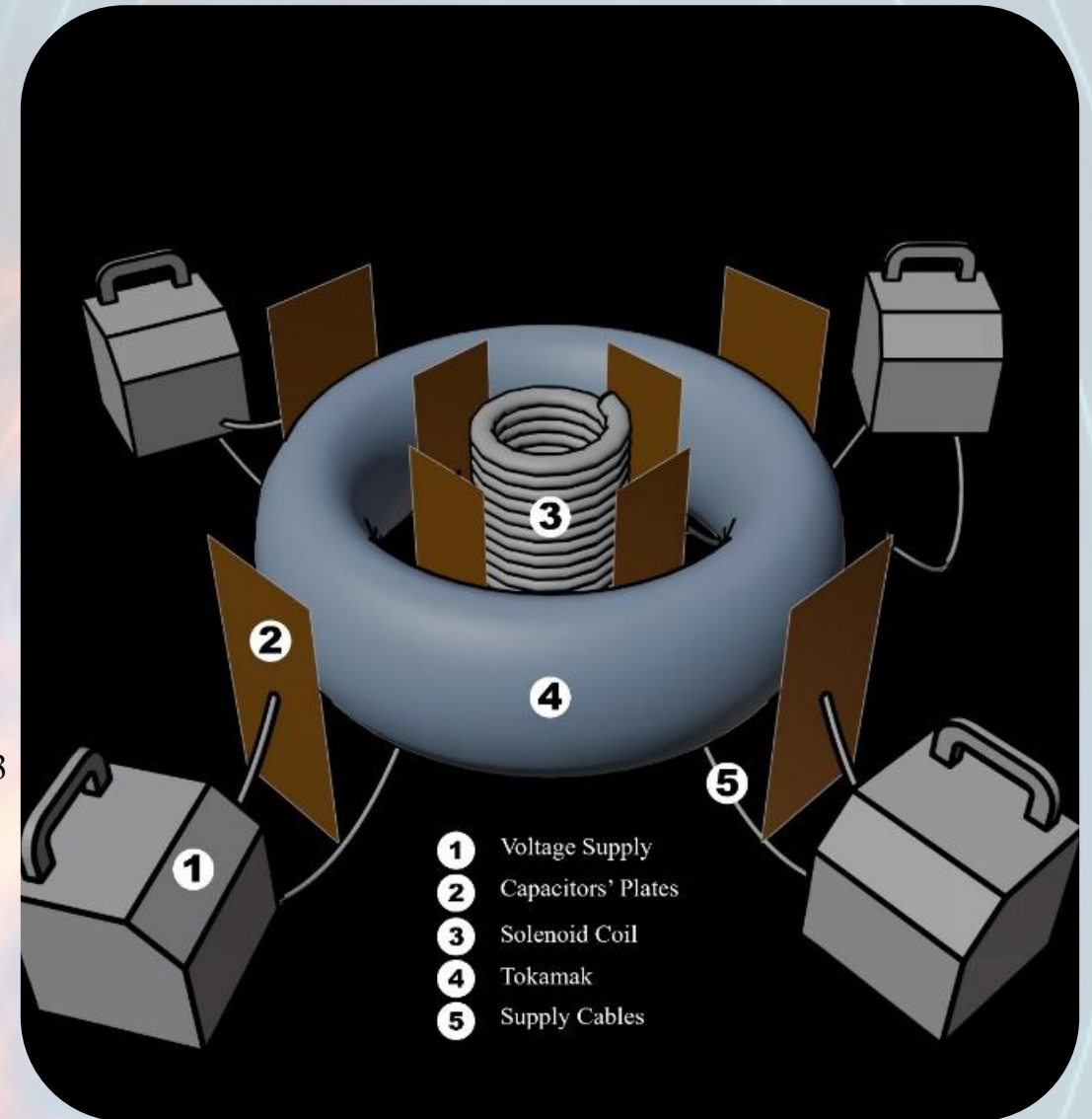
$$E_{thermal} = 3(n_D + n_T)KT \quad J/m^3$$

2) Electromagnetic losses :

$$E_{electromagnetic} = \frac{1}{2}(n_D m_D + n_T m_T) \left(\frac{E}{B} \right)^2 J/m^3$$

3) Full Ionization Energy losses:

$$E_{ionization} = 13.6e(n_D + n_T) \quad J/m^3$$



Approach 2 “More Accurate and Realistic”

4) Bremsstrahlung (radiation loss) “J.Wesson”:

$$P_{br} = 5.35 \times 10^{-37} Z_{eff} n_e n_i \sqrt{T_{keV}} \quad \text{W/m}^3$$

$$n_e = n_i = (n_D + n_T)$$

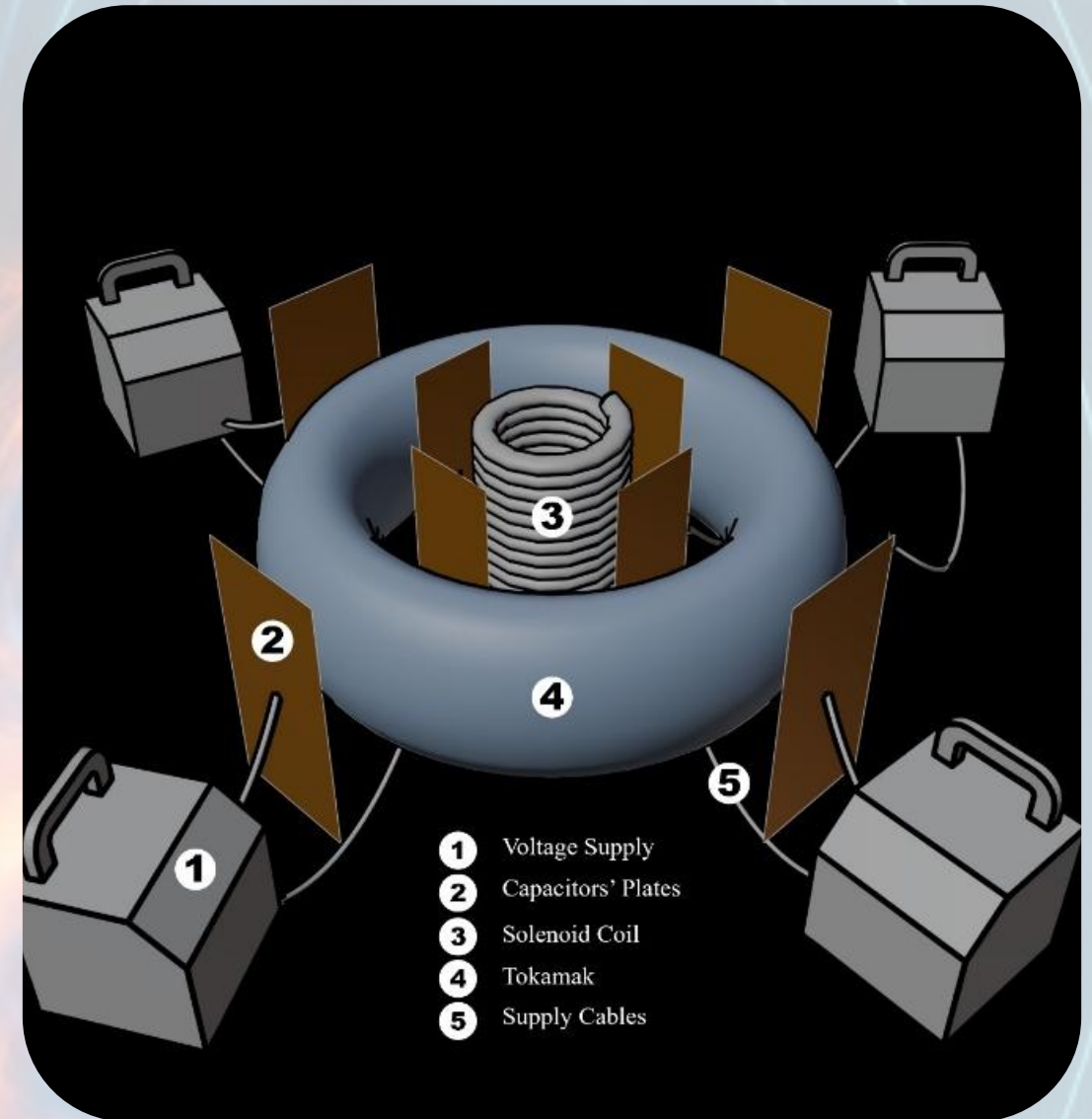
For D-T Plasma: $Z_{eff} = 1$

Lawson Ignition Criterion:

$$P_{net} = P_{fusion} - P_{br} - \frac{E_{EM} + E_{th} + E_{ion}}{\tau} \geq 0$$

Where τ is the Confinement time

$$1eV = 11604.5^\circ K$$



Approach 2

“More Accurate and Realistic”

D-T Fusion Code Summary

- 1) Calculates fusion rates using a formula (Bosch-Hale) that includes both particle drift and random motion.
- 2) Accounts for all major energy losses: ionization, electric drift, heating, radiation, etc.
- 3) Combines electric and thermal speeds to find the real effective collision speed that causes fusion.
- 4) Uses plasma size and density to find total fusion power and energy losses.
- 5) Checks if fusion power is greater than all losses to see if net energy gain is positive and that ignition is possible.

The Modelling Code:  [GitHub Link](#)

Conclusion

- 1) The research aims to enhance the fusion efficiency by using high-voltage capacitors to manipulate the electric field and control plasma behavior.
- 2) By precisely regulating the external voltage, the method increases the energy and collision probability of hydrogen isotopes, improving fusion reaction rates.
- 3) The approach offers a more efficient alternative to thermal heating by directly influencing charged particle motion through electromagnetic field manipulation.
- 4) The study successfully identifies optimal operational parameters that maximize net energy output while minimizing energy loss, especially Bremsstrahlung (radiation loss) “.

THANK YOU FOR YOUR ATTENTION

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