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AUSTRALIA



AUSTRALIAN  
INSTITUTE OF  
ENERGY



**Australian Nuclear  
Association**

**Meeting of the Four Societies**

# ***FUSION ENERGY***

**Matthew Hole, Australian National University**

**6 pm Wednesday 18 February 2026**



Australian  
National  
University

# Fusion Energy: billions in private cash is flooding into fusion. *Will it pay off?*

Professor Matthew Hole<sup>1\*</sup>

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<https://maths.anu.edu.au/ptm>

[1] Mathematical Sciences Institute, Australian National University, ACT 0200, Australia

[2] School of Computing, Australian National University, ACT 0200, Australia

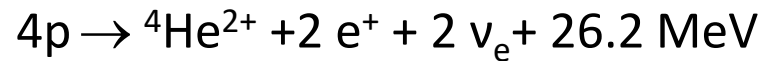
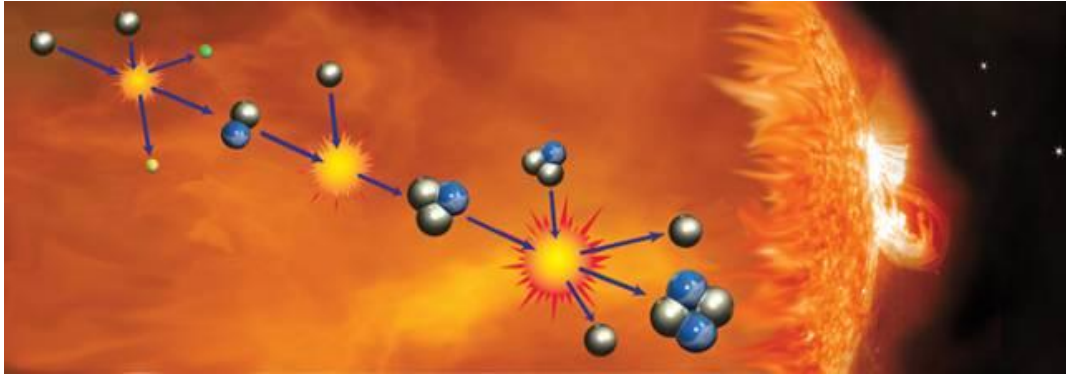
[\*] ITER Science Fellow,

International Fusion Research Council, IAEA;

Chair, Australian ITER Forum

18 February 2026

# Fusion: the process that powers the Sun, the stars, and nearly *all* life.

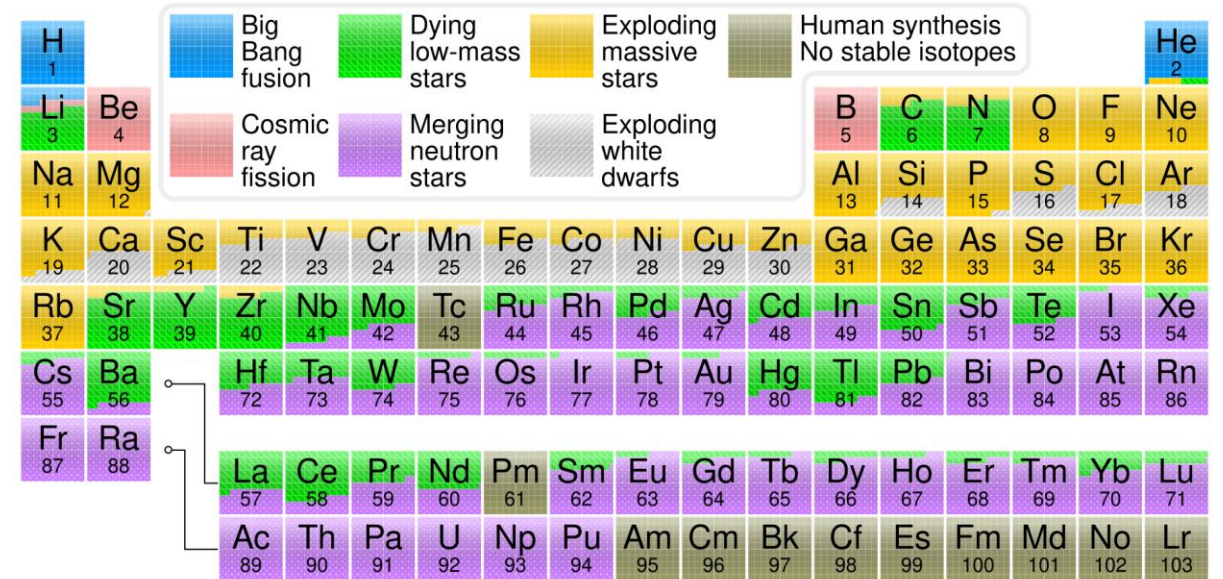


99.97% of the natural (biological and physical) processes on Earth are driven by the Sun

The Sun 4.6 billion years old, and will burn for another 5 billion years.

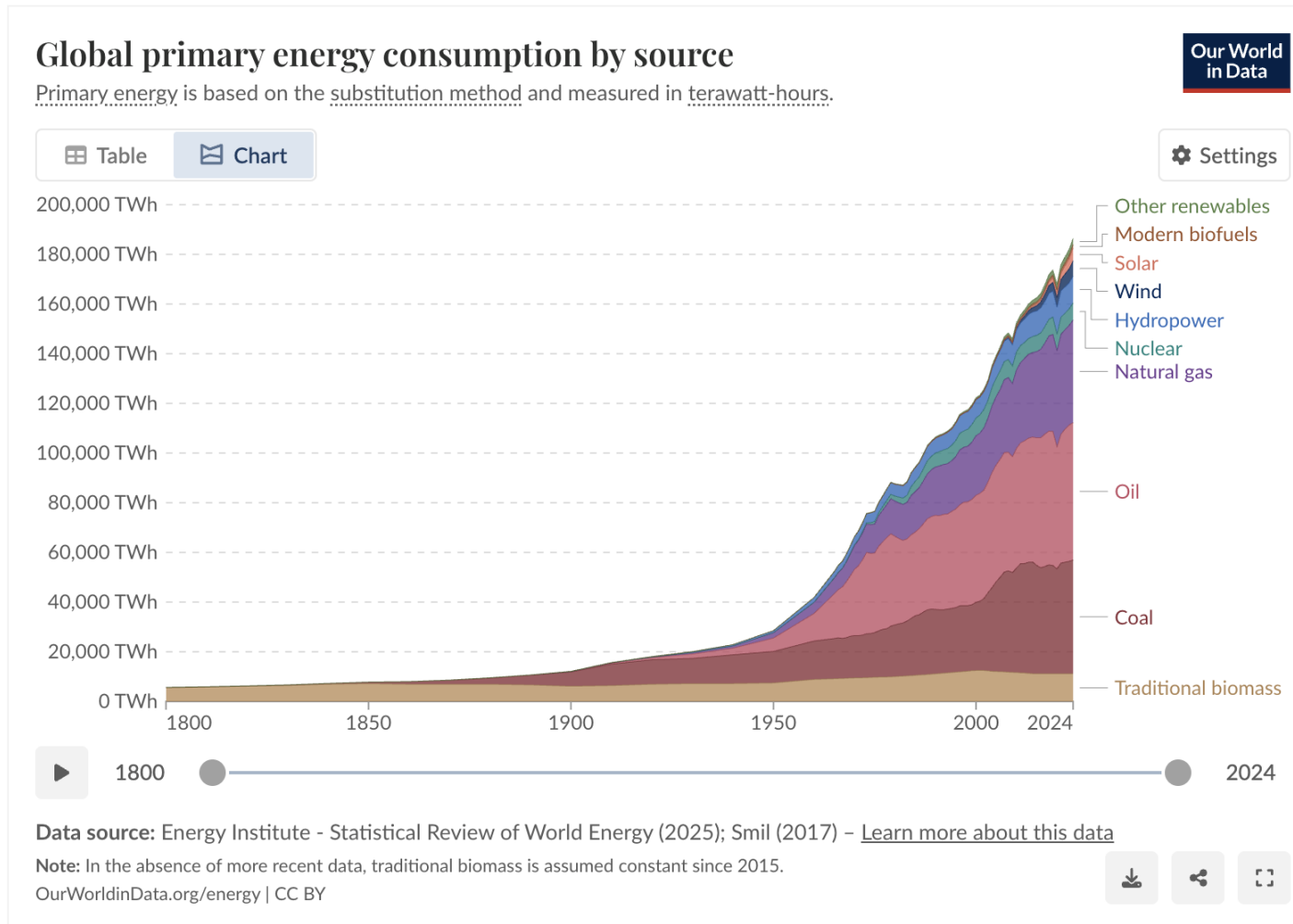
→ The natural world is sustainable and solar-fusion powered...

## Fusion also formed most of the elements



H, He formed in big-bang fusion of quark-gluon plasma  
 Li, Be, B formed by cosmic ray spallation  
 Li < Z < Fe formed by stellar processes  
 Z > Fe generated mainly by supernovae + merging stars

# Fossil Fuels: the culprit for CO2 emissions & global warming



83.1% from fossil + biofuels  
13.2% from renewable  
3.7% nuclear

## Why should Australia care?

- We are the world's largest (by export value) coal exporter,
- We are the world's 3<sup>rd</sup> largest fossil fuel exporter
- Our domestic emissions are the highest (per capita) in the OECD
- Our exported + domestic fossil fuels emissions are around 4.5% of global emissions, 80% of which is overseas

→ Greenhouse emissions don't respect national borders. The problem is global.

# What is the role of Nuclear? (Fission or Fusion)

- Solar power could supply all of Earth's needs if storage and transmission are solved. (e.g. A 600kmx600km solar PV grid in Alice Springs sunshine could meet global power consumption of 20TW continuous power).
  - However even *if* solved, **energy-security a significant geopolitical driver.**
  - $P_{\text{plant}} \sim 1\text{-}2\text{GW}$  electric, area = 5-10 km<sup>2</sup>.
  - Nuclear is the most land-efficient large-scale energy source available.
  - That's why:
    - France, Japan, and South Korea fit huge energy output into small countries
    - Nuclear pairs extremely well with renewables if land, materials, or transmission are constrained.
  - Global nuclear capacity on track to double by 2050.
- **While Australia is blessed with renewables, civilisation needs nuclear.**  
*The sector will only grow.*

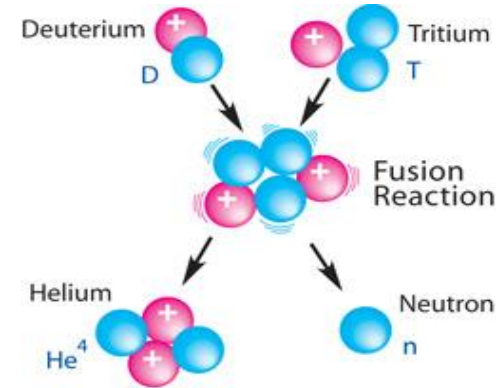
# Fusion, Fission, and Combustion

## Controlled fusion :

Deuterium, Tritium are hydrogen isotopes.

Energy gain: 450:1

co-discovered by Australian Sir Marc Oliphant 1932



$$1\text{eV} = 1.6 \times 10^{-19} \text{ J}$$

Reaction	Energy	Energy/mass
$D + T \rightarrow {}^4\text{He} (3.5\text{MeV}) + n (14.1\text{MeV})$	17,600,000eV	3.5MeV/amu
$D + D \rightarrow {}^3\text{He} (0.82) + n (2.45\text{MeV})$	3,270,000eV	0.8MeV/amu
$D + D \rightarrow T (1.01\text{MeV}) + H (3.03\text{MeV})$	4,030,000eV	1.0MeV/amu
$D + {}^3\text{He} \rightarrow {}^4\text{He} (3.6\text{MeV}) + H (14.7\text{MeV})$	18,300,000eV	3.7MeV/amu
$p + {}^{11}\text{B} \rightarrow 3 {}^4\text{He} (2.9\text{MeV})$	8,700,000 eV	0.7MeV/amu
$\text{U}^{235} + n \rightarrow \text{Xe}^{134} + \text{Sr}^{100} + n$	200,000,000eV	0.9MeV/amu
$\text{C}_6\text{H}_2 + 6.5 \text{O}_2 \rightarrow 6 \text{CO}_2 + \text{H}_2\text{O}$	30eV	0.01eV/amu

# *BIG Idea:* Fusion (and nuclear) uses small amounts of resource for big energy production



+

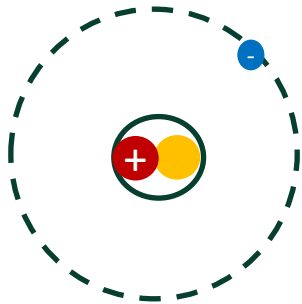


= Energy

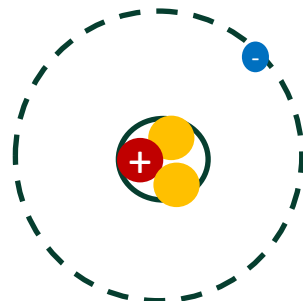
## *On Earth, fusion could provide:*

- Large-scale energy production
- Deuterium is an essentially limitless fuel, available all over the world
- No greenhouse gases
- Intrinsic safety
- No long-lived radioactive waste (if aneutronic fusion  $p\text{-}^{11}\text{B}$  – virtually none)

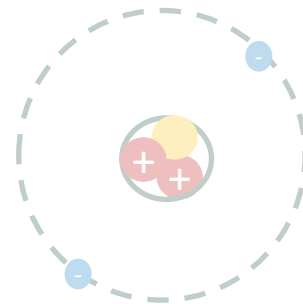
# Fusion Fuels (H, D, B) very abundant



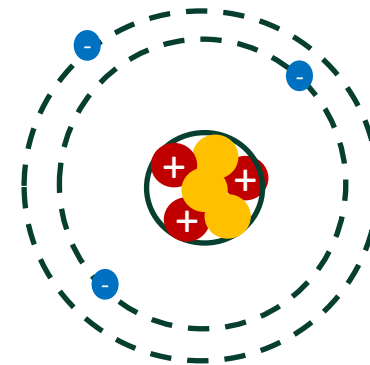
Deuterium



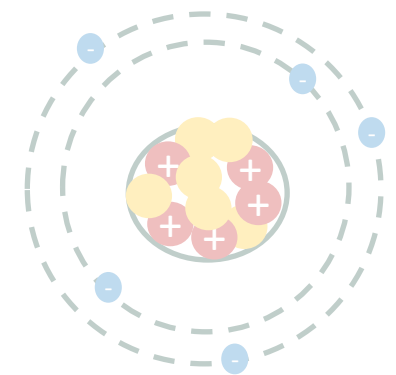
Tritium



Helium 3



Lithium 6



Boron 11

**NB:** 99.9885% of all visible matter is Hydrogen

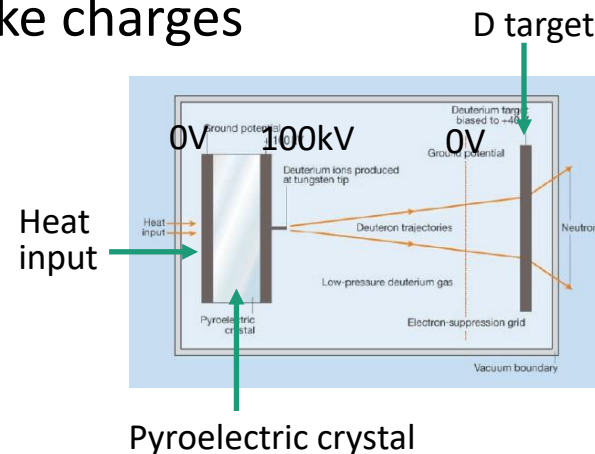
<i>Relative Abundance</i>	1D : 6000H	1T : $10^{17}$ H. Manufactured: ${}^6\text{Li} + n \rightarrow {}^4\text{He} + \text{T}$ ${}^7\text{Li} + n \rightarrow {}^4\text{He} + \text{T} + n$	1: $10^{12}$ H (Earth) 1: $10^4$ H (moon)	1Li: $10^6$ H (Earth) 1Li:1000H (solar system)	1B :1400 H (Earth)
<i>Exhaustion lifetime at 20TW continuous power</i>	D-D reaction 50 billion years (10 x age of Universe)	D-T reaction $10^4$ years (Earth) $10^{20}$ years (solar system)	D- ${}^3\text{He}$ ~ weeks (Earth only), ~1000 yrs (Moon Mining)		P- ${}^{11}\text{B}$ $10^8$ years

# How to achieve fusion reactions ?

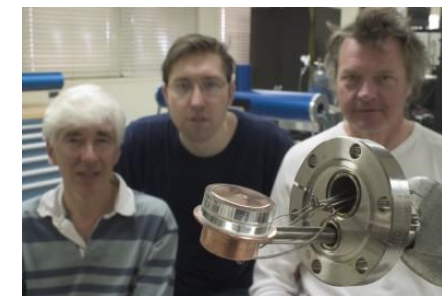
**Aim :** Overcome electrostatic repulsion between like charges

## Particle acceleration

(e.g. Linear accelerator, pyroelectric crystal, beam-target [laser-block], beam-beam )

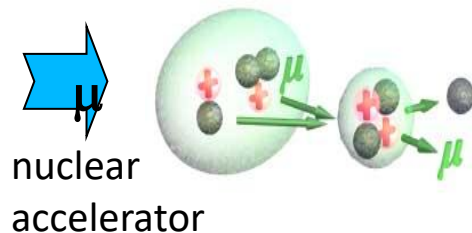


Nature 434 1115, 2005



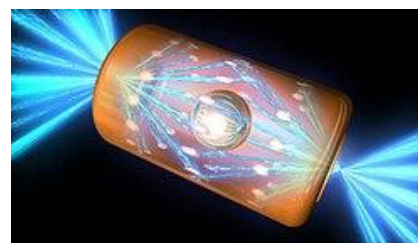
## Catalytic process

(e.g. Muon catalysis)



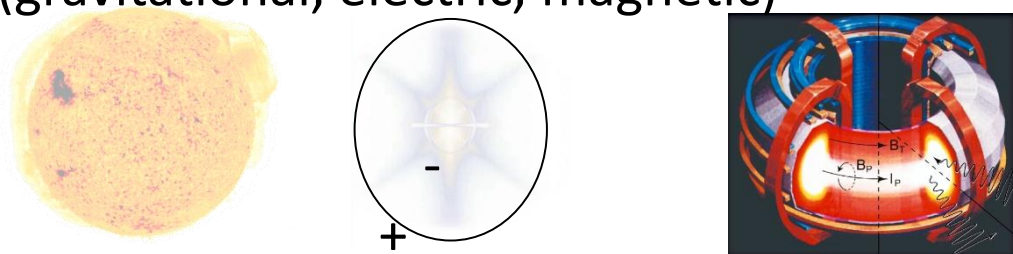
## Inertial compression (confinement)

(e.g. laser target fusion)



## Confinement (plasma near thermal equilibrium)

(gravitational, electric, magnetic)



National Ignition Facility, USA

# How to achieve fusion power ?

**Aim :** Overcome electrostatic repulsion between like charges + **confinement** + **power gain**

- Achieve sufficiently high

ion temperature  $T_i$

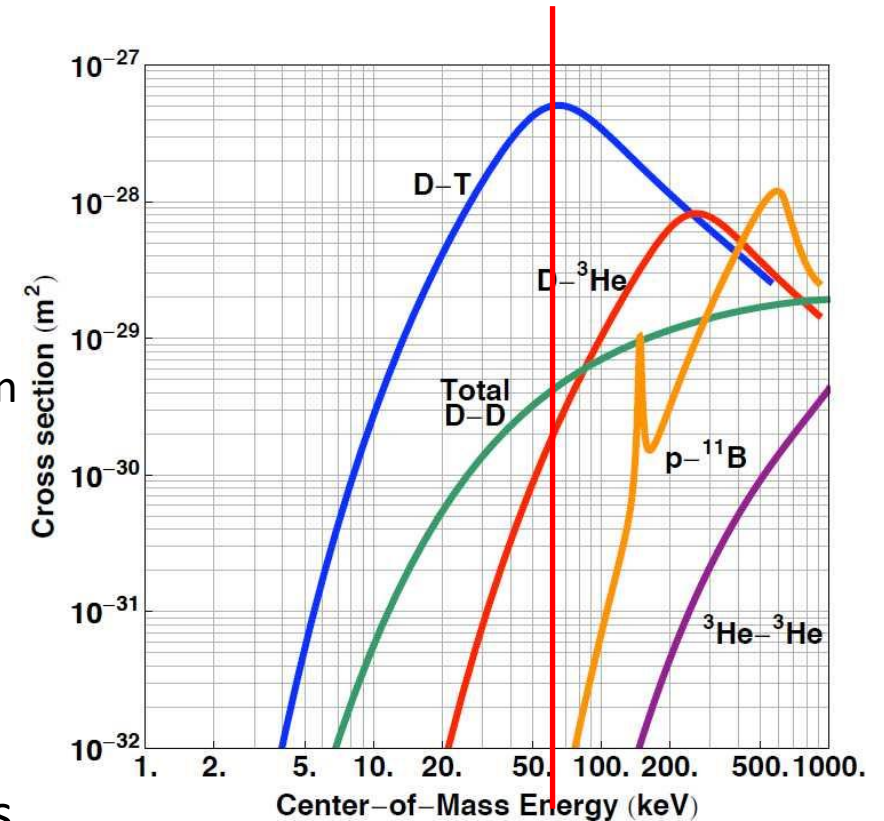
⇒ exceed Coulomb barrier

density  $n_D \propto$  energy yield

energy confinement time  $\tau_E$

$\tau_E$  = insulation parameter: e.g. time taken for a jug of hot water to lose energy to the surroundings

Thermal collision-cross section of reaction



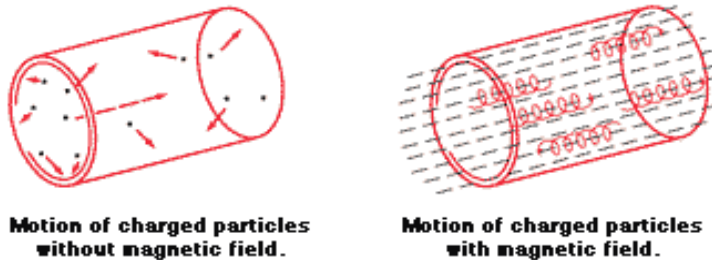
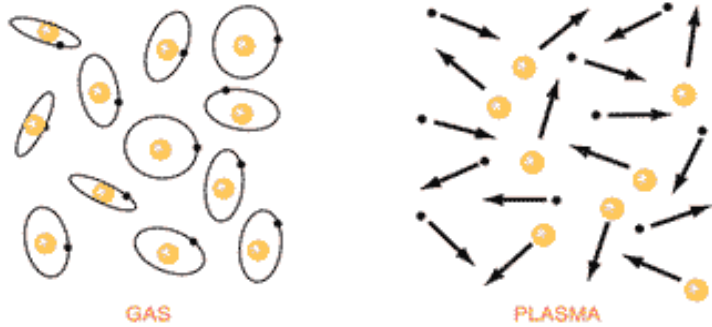
- “Lawson” ignition criteria : Fusion power > heat loss

Fusion triple product  $\longrightarrow n_D \tau_E T_i > 3 \times 10^{21} \text{ m}^{-3} \text{ keV s}$

- Turns out  $n_D \tau_E$  has a minimum at  $T_i = 14 \text{ keV} \approx 150 \text{ million } ^\circ\text{C}$

# Plasma: the 4'th state of matter

- plasma is an ionized gas



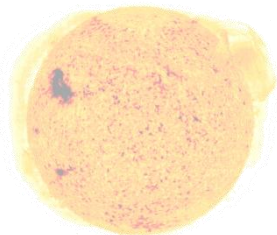
Motion of charged particles without magnetic field.

- 99.9% of the visible universe is in a plasma state



Inner region of the M100 Galaxy in the Virgo Cluster, imaged with the Hubble Space Telescope Planetary Camera at full resolution.

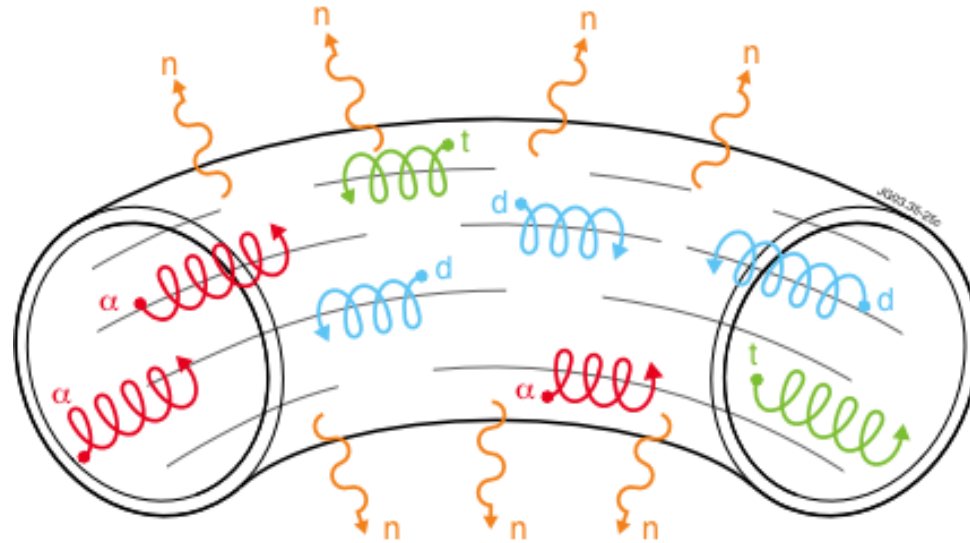
- On Earth usually seen as either the Sun, Aurora or Lightning



Tromsø  
January 2026

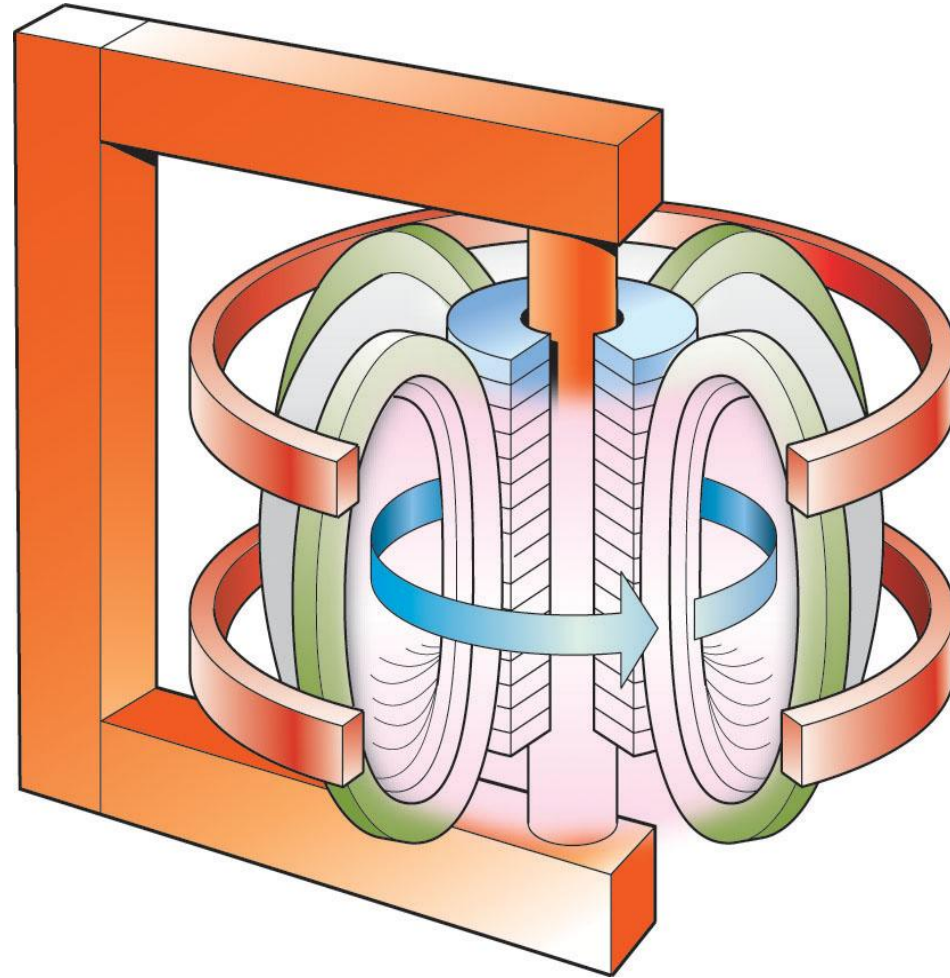
# Toroidal Magnetic Confinement

- **Magnetic fields** cause charged particles to spiral around field lines. Plasma particles are lost to the vessel walls only by relatively slow diffusion across the field lines

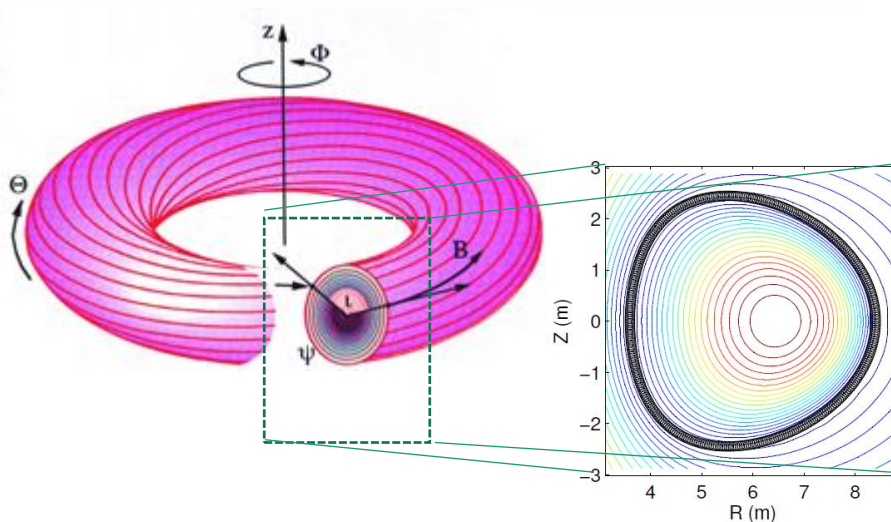
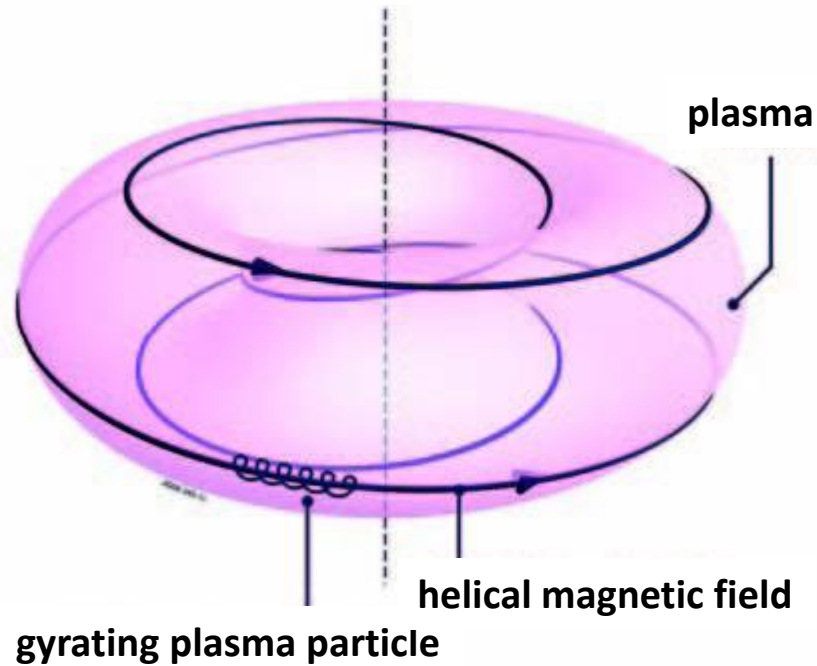


- Only charged particles ( $D^+$ ,  $T^+$ ,  $He^+$ ...) are confined. **Neutrons** escape and release energy by collision with walls.
- **Toroidal** (ring shaped) device: a closed system to avoid end losses
- Highest performance been demonstrated in a tokamak (strong field, large current)

# Components of a Tokamak

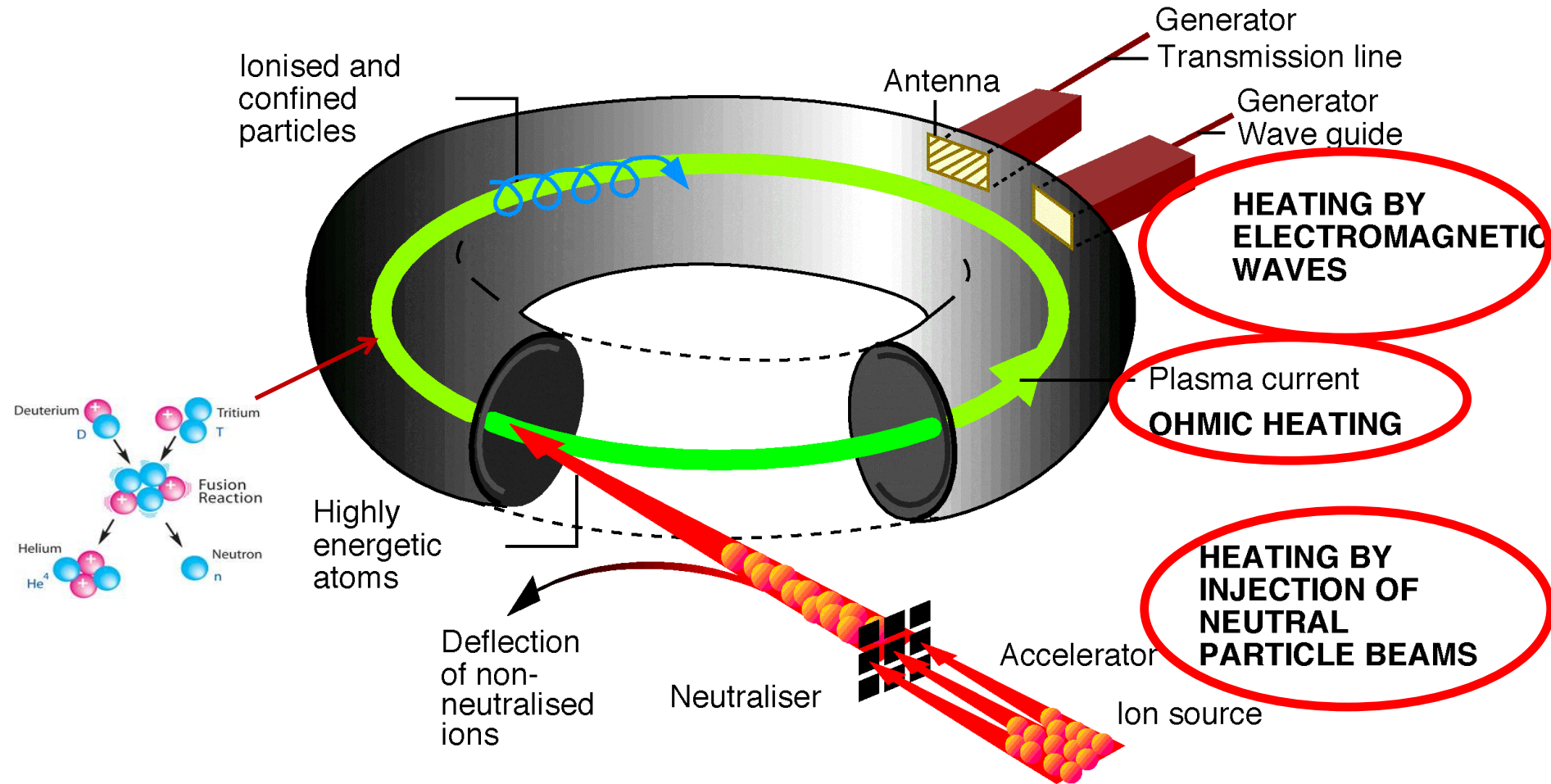


# In a tokamak fields lie in flux surfaces



- If magnetic field sufficiently strong ions and electrons bound to field lines
- In a “perfect” tokamak field lines lie in flux surfaces
- Different flux surfaces are  $\sim$  thermally insulated
- Flux surfaces support pressure gradient
- Tokamaks maximise core pressure, needed to initiate fusion

# How to obtain extreme temperatures?



Positive ion beams:  $E \sim 100\text{keV}$

Negative ion beams:  $E \sim 1\text{MeV}$



# What's new in confinement?

NEWS | 09 February 2022

## Nuclear-fusion reactor smashes energy record

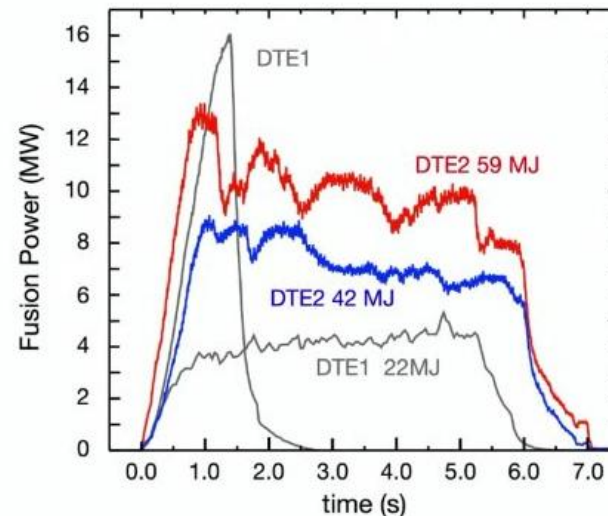
Nature

The experimental Joint European Torus has doubled the record for the amount of energy made from fusing atoms – the process that powers the Sun.

[Elizabeth Gibney](#)



### High fusion power produced and sustained for 5 seconds



- ▶ **First-ever high confinement plasmas using D-T with beryllium / tungsten wall**
- ▶ **Confirming predictions** of plasma behaviour advances development of ITER high performance scenarios

# “We have ignition”

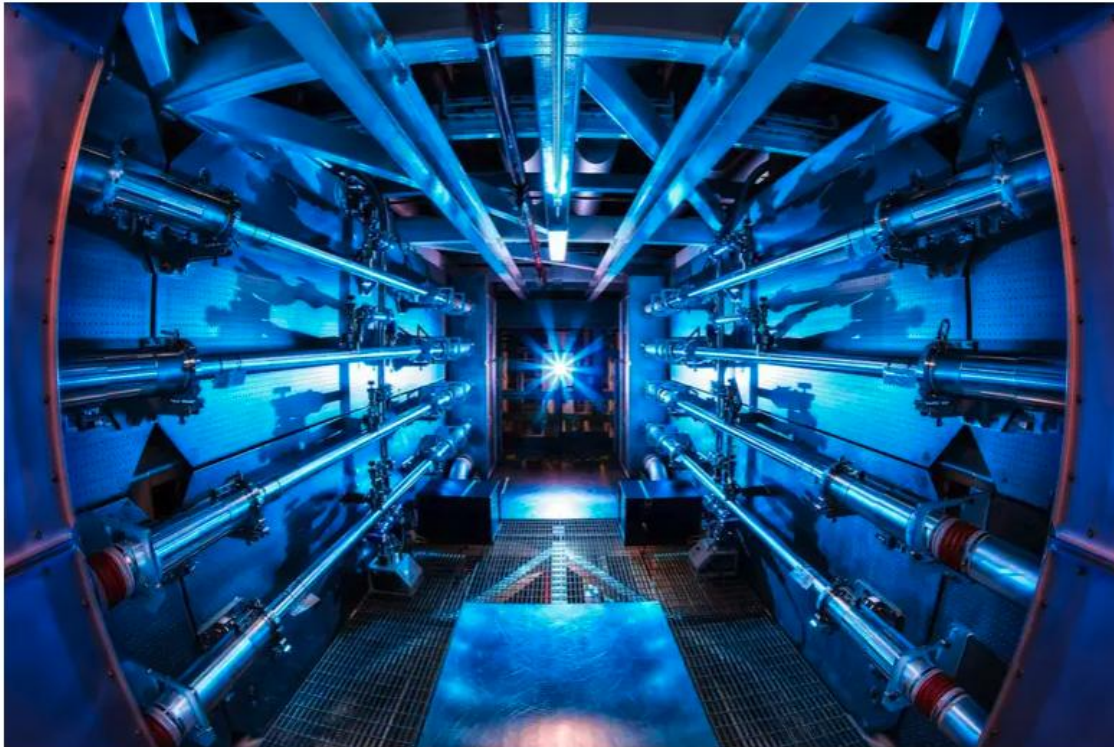
## Ignition confirmed in a nuclear fusion experiment for the first time

A 2021 experiment achieved the landmark milestone of nuclear fusion ignition, which data analysis has now confirmed – but attempts to recreate it over the last year haven’t been able to reach ignition again



PHYSICS 11 August 2022

By [Karmela Padavic-Callaghan](#)



The National Ignition Facility at Lawrence Livermore National Laboratory  
Science History Images / Alamy Stock Photo

11 August 2022

New Scientist

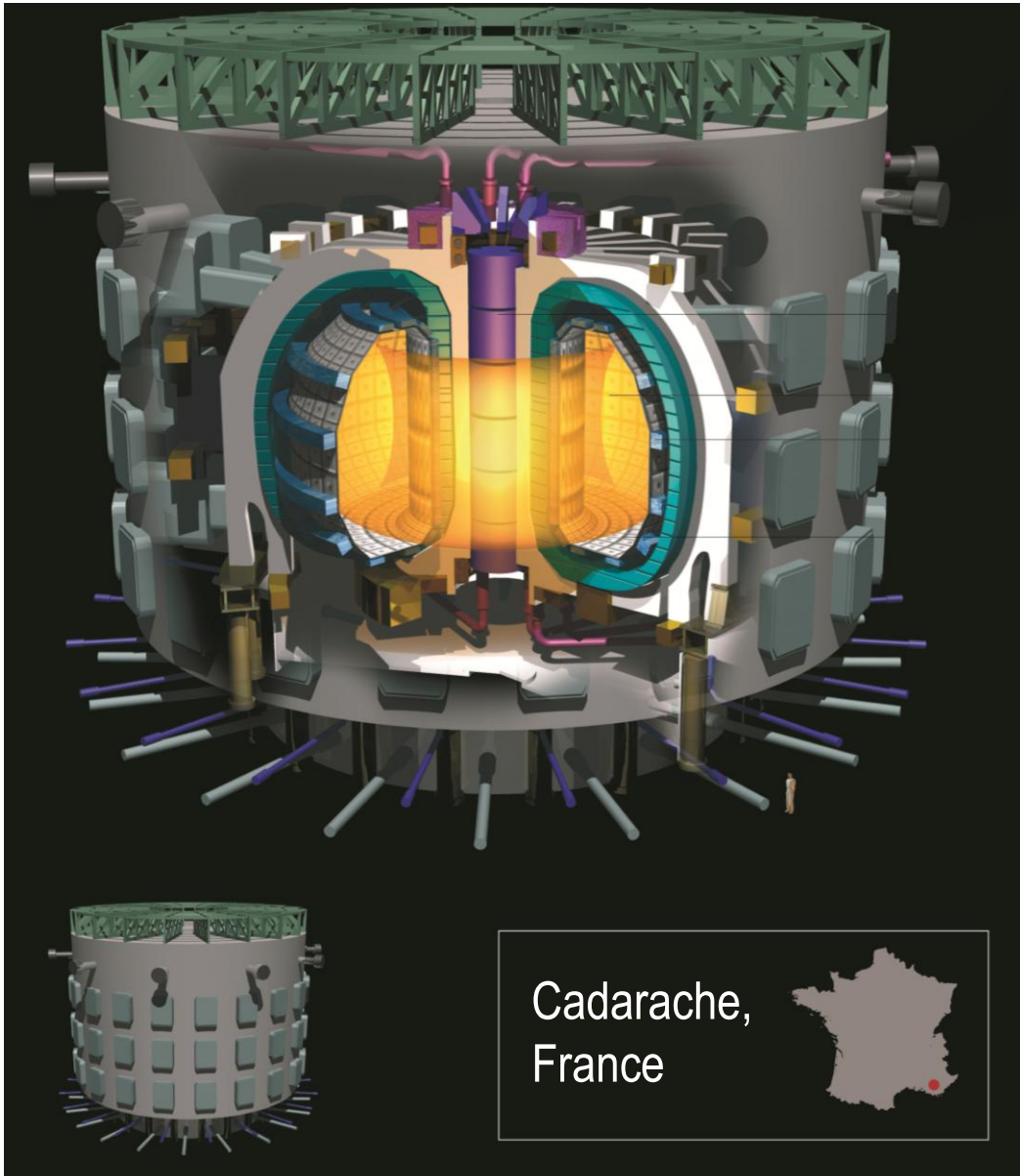
“On 8 August, 2021, 192 laser beams pumped vastly more [power](#) than the entire US electric grid into a small gold capsule and ignited, for a fraction of a second, the same thermonuclear fire that powers the [Sun](#).”

# What is the next step along the tokamak path?

ITER – ‘the path’, formerly known as  
International Thermonuclear Experimental Reactor

- 1) Achieve a deuterium-tritium plasma in which the fusion conditions are sustained mostly by internal fusion heating. **Achieve a burning plasma.**
- 2) Generate 500 MW of fusion power for long pulses  
*(long pulse or continuous is critical to fusion energy)*
- 3) Contribute to the demonstration of the integrated operation of technologies for a fusion power plant
- 4) Test tritium breeding
- 5) Demonstrate the safety characteristics of a fusion device

# ITER – a snapshot

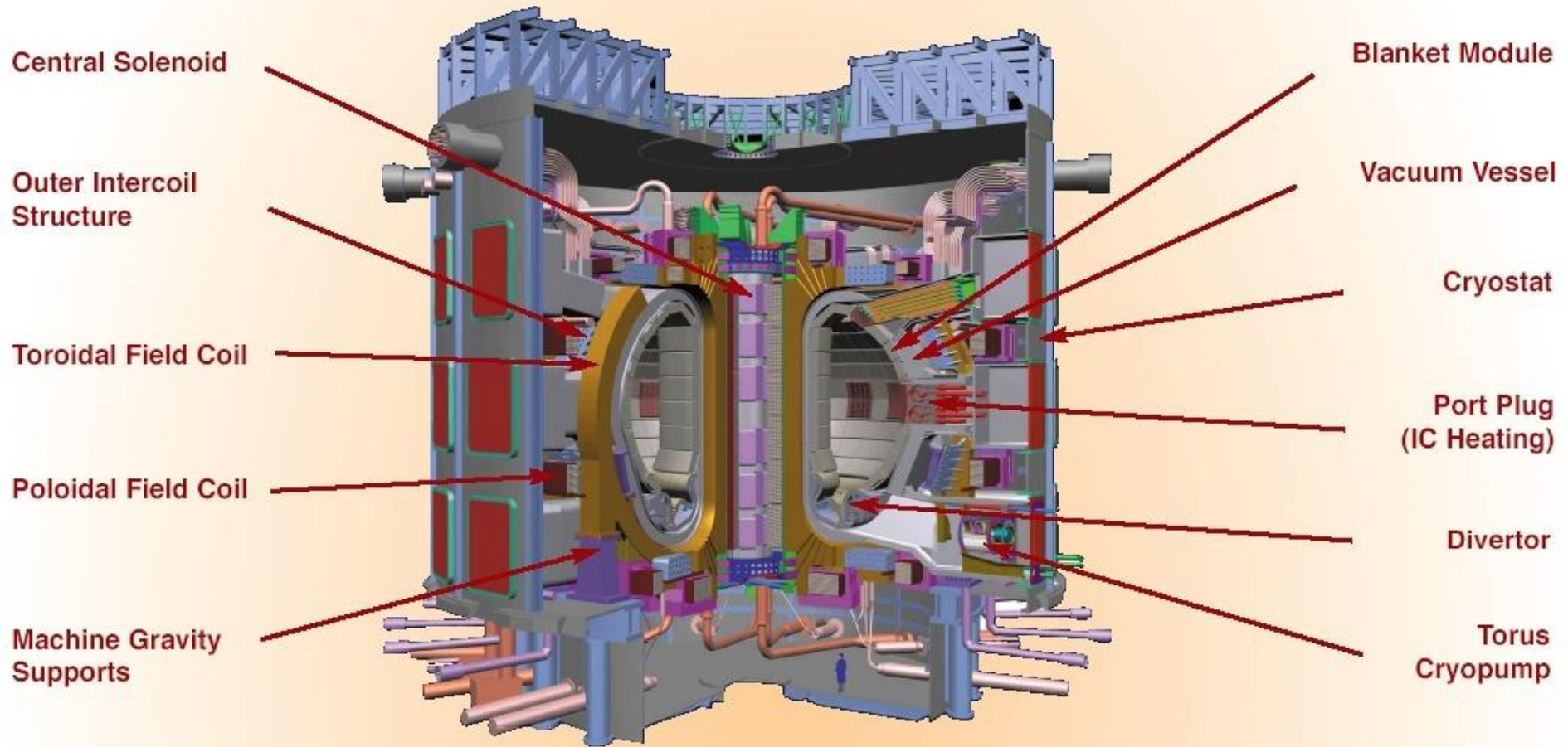


- Fusion power = 500MW
- Power Gain (Q) > 10
- Temperature ~ 100 million °C
- Growing Consortium



- Collaboration agreements with
  - International Atomic Energy Agency
  - Principality of Monaco 16/01/2008
  - CERN – 10/03/2008
  - **Australia 30/09/2016**
  - Khazakstan 11/06/2017

# ITER in detail

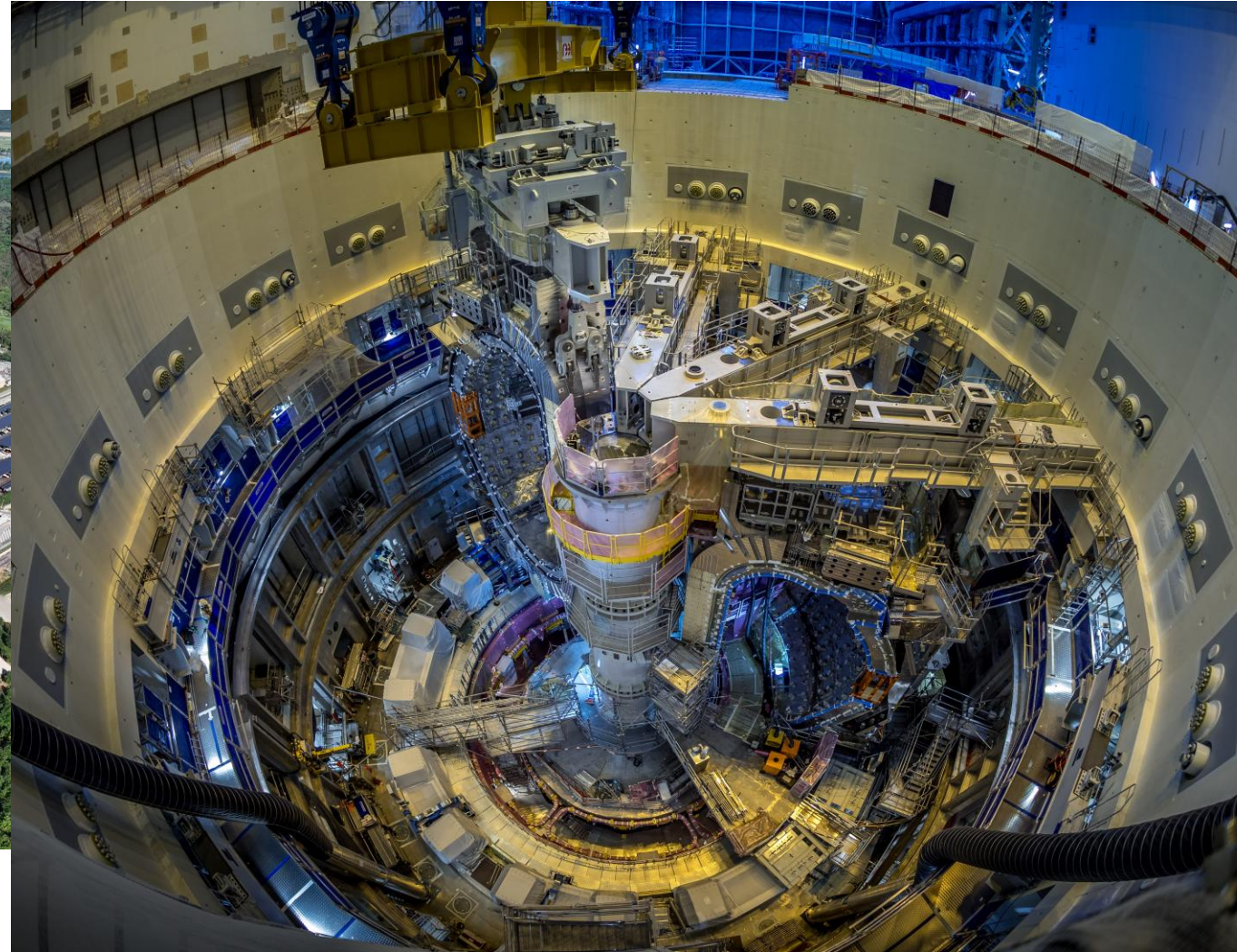


Total Fusion power	500MW	Toroidal field @6.2m	5.3T
Minor (a), major (R) radius	2.0m, 6.2m	Plasma Volume	837 m <sup>3</sup>
I <sub>p</sub> , plasma current	15MA	Auxillary heating, current drive	73MW

# ITER construction more than 85% completed

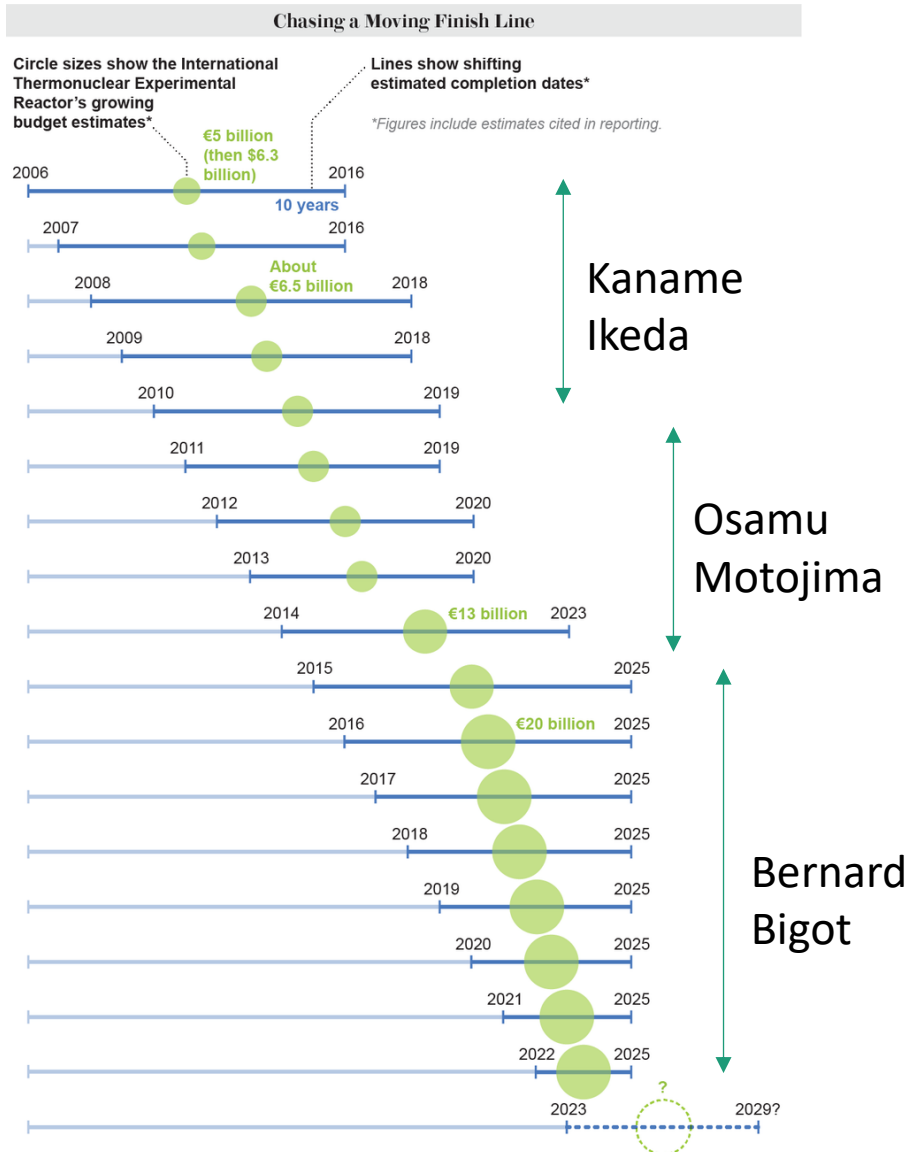
29 January 2026

May 2025



4 (/9) sector modules installed

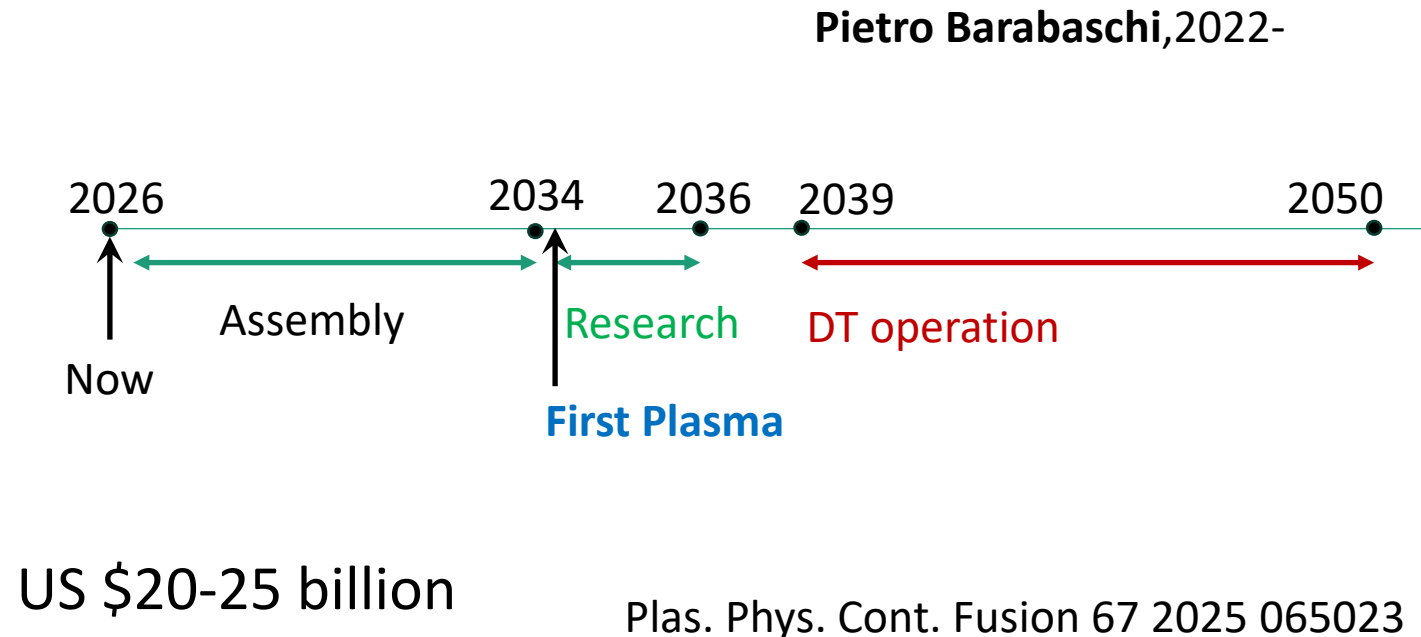
# ITER has had its fair share of delays...



Scientific American, June 2023

## Reasons for Delay:

- Project management and scope changes
- Design complexity and component inconsistency
- Covid-19 pandemic
- Regulatory hurdles



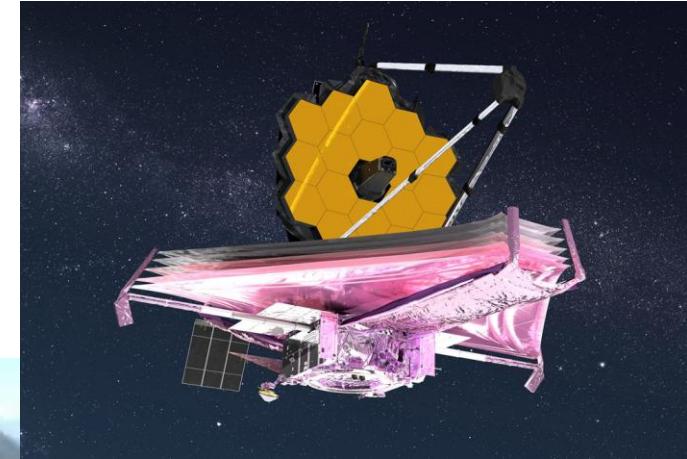
# ...but it's not alone: nearly all first-of-a-kind are over budget and schedule

James Webb Space Telescope.

Initial designs in 1996.

Aimed for launch in 2007 at US\$1bn.

Final launch in late 2021. Final cost US\$10bn.



F35 Joint Strike Fighter

Initial design work 2001.

Full rate production 2015. Cost ?

Full rate production 2024. Lifetime cost US\$2000 bn.



Olkiluoto Nuclear Power Plant Unit 3, Finland

Construction start 2005.

Scheduled operation 2009 at €3.2 billion

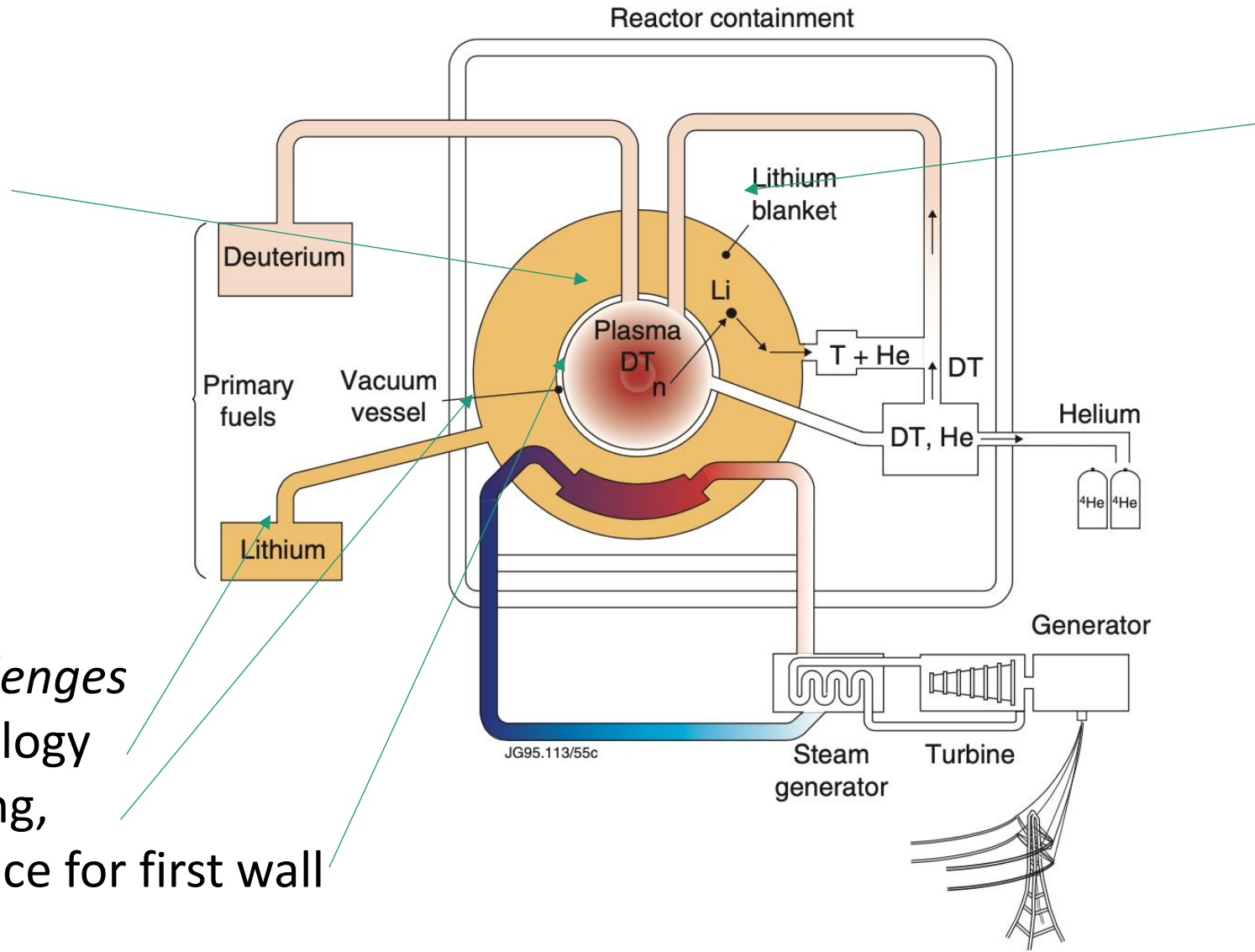
Commercial Operation 2023. Final cost €11 billion.



# Fusion power plant schematic (ITER is not a power plant)

Very complicated nonlinear plasma physics!

*Emergent challenges* nuclear technology remote handling, Materials science for first wall



Blanket required to generate lithium.  
(Build radius determined by slowing down of neutrons)

# Economics of Fusion Power – Tokamak Design

1GWe DEMO2 reference design

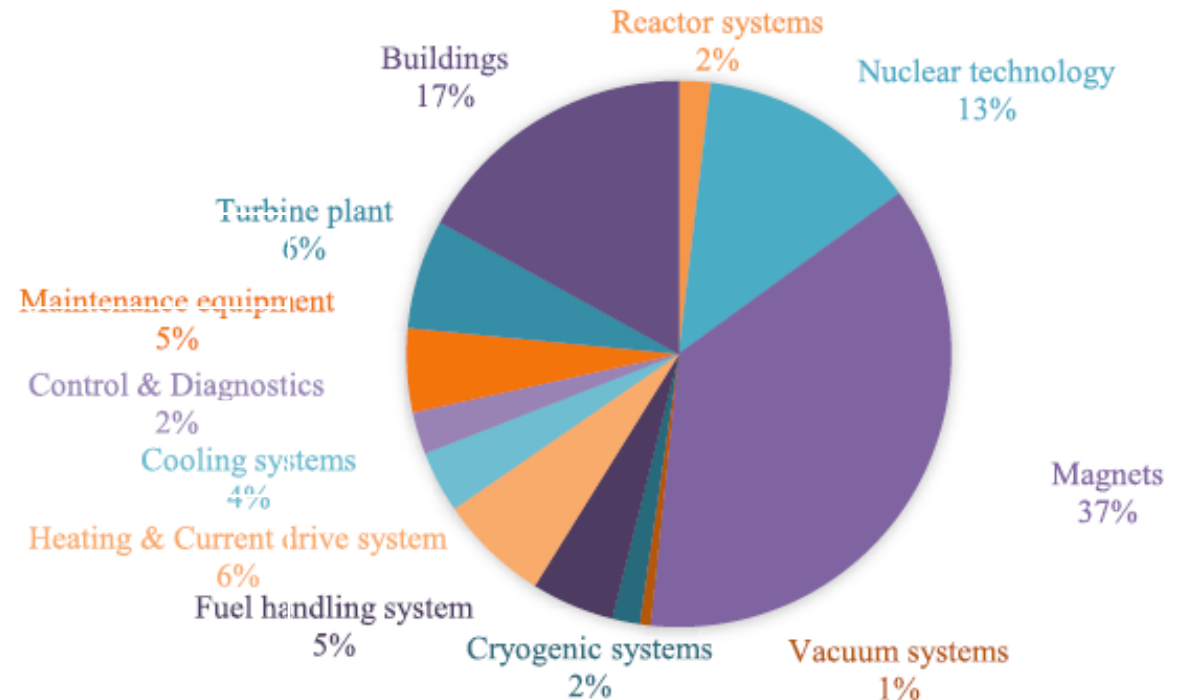
[Kemp R. IDM EU\_D\_2LCBVU, EUROfusion. 2015]

EU study: “Approximation of the economy of fusion energy”

[Entler *et al* Energy 152 (2018) 489-497]

<b>Fusion Power</b>	<b>3255MW</b>
Thermal Power	4149MW
Gross Electric Power	1660MW
Net Electric Power	953MW
Plant self-consumption	707MW
Plant availability fraction	75%
Fusion fuel (per day)	< 2kg

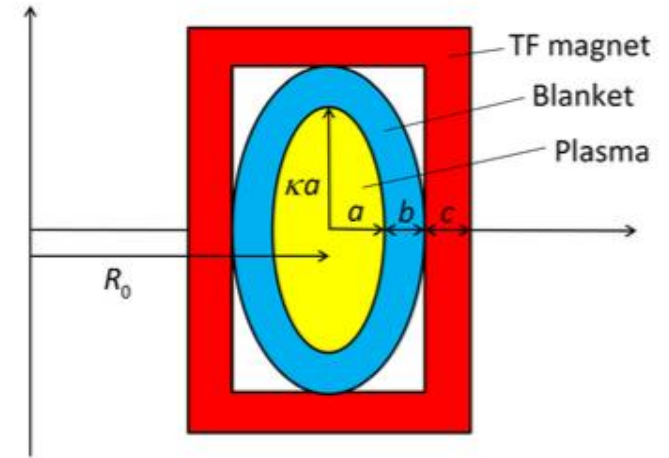
Direct Construction Cost: \$M8525



# Tokamak-reactor design

Reactor determined by engineering, **nuclear** and **physics** constraints:

- Plasma unstable at high elongation  $\rightarrow \kappa < 1.7$
- Blanket width set by neutron slowing down to max T breeding  $\rightarrow 1\text{m}$
- Neutron wall loading limits + a/R choice  $\rightarrow R_0=5.4\text{m}$
- $\tau_E$  increases with  $|B|$ . Superconducting choice  $\text{Nb}_3\text{Sn} \rightarrow B < 6.8\text{T}$
- Coil winding thickness  $c$  set by winding pack and  $J \times B$  limits.  $\rightarrow c \sim 1\text{m}$
- $n_D \tau_E T_i$  peak at  $T_i \rightarrow 14\text{keV}$  (set by collision cross-section)
- Assume  $P_{\text{fus}}$  produced  $P_{\text{Elec}}$  with thermal efficiency  $\eta = 0.4 \rightarrow p \sim 8 \text{ atm.}$
- Ideal gas equation  $\rightarrow n_{\text{core}} \sim 1.5 \times 10^{20} \text{ m}^{-3}$   
 $(n_{\text{air}} = 2.5 \times 10^{25} \text{ m}^{-3}, n_{\text{diamond}} = 1.7 \times 10^{29} \text{ m}^{-3}, n_{\text{Sun}}(0) = 9 \times 10^{31} \text{ m}^{-3})$
- $P_\alpha > P_{\text{losses}} \rightarrow I_p \sim 15\text{MA}$
- Steady state,  $I_{\text{ohmic}} = 0. I_p = I_{\text{CD}} + I_{\text{BS}}.$   
 $I_{\text{CD}} < 2.2\text{MA}$  RF current drive, (coupling efficiency  $\sim 50\%$ , recirculating power  $< 10\%$ )  
 $\rightarrow f_{\text{BS}} = I_{\text{BS}}/I_p > 84\%$

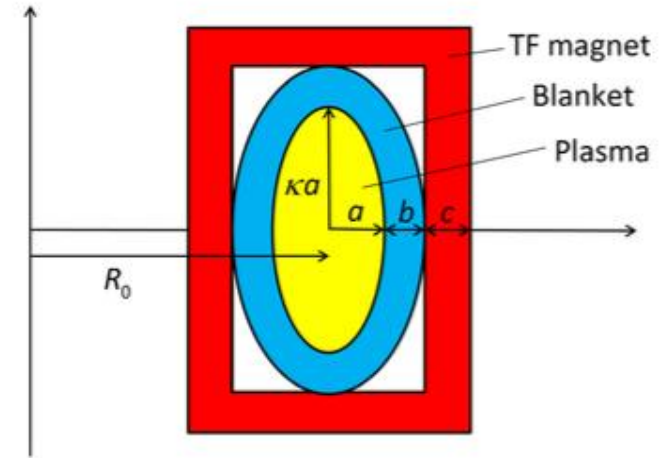


**[Solar core is 100x more dense than Iron!]**

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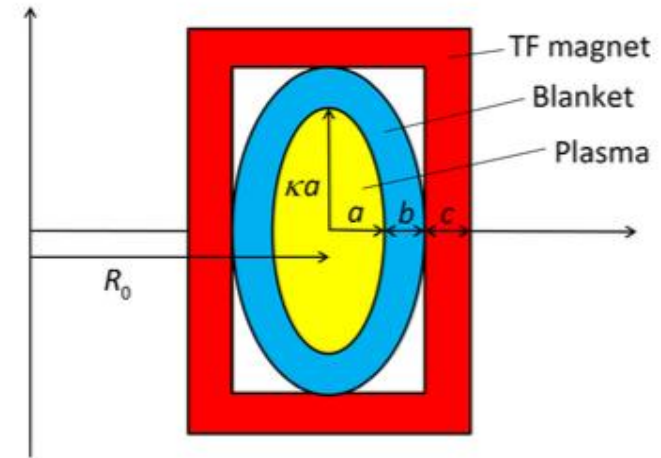
ITER choices

$f_{\text{BS}} = 25-35\%.$  X

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- $P_\alpha > P_{\text{losses}} \rightarrow I_p \sim 15\text{MA}$
- Steady state,  $I_{\text{ohmic}} = 0$ .  $I_p = I_{\text{CD}} + I_{\text{BS}}$ .  
 $I_{\text{CD}} < 2.2\text{MA}$  RF current drive, (coupling efficiency  $\sim 50\%$ , recirculating power  $< 10\%$ )  
 $\rightarrow f_{\text{BS}} = I_{\text{BS}}/I_p > 84\%$



Relax

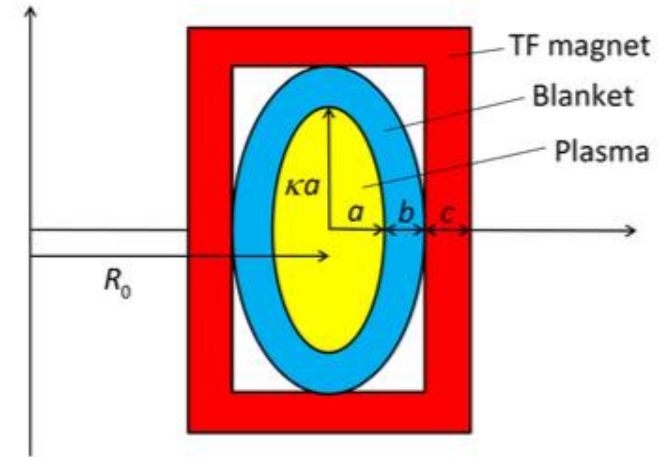


CFS SPARC/ARC: Change Superconducting to REBCO/YBCO high temperature tape.

# Tokamak-reactor design

Reactor determined by engineering, **nuclear** and **physics** constraints:

- Plasma unstable at high elongation  $\rightarrow \kappa < 1.7$
- Blanket width set by neutron slowing down to max T breeding  $\rightarrow 1\text{m}$
- Neutron wall loading limits + a/R choice  $\rightarrow R_0=5.4\text{m}$
- $\tau_E$  increases with  $|B|$ . Superconducting choice  $\text{Nb}_3\text{Sn} \rightarrow B < 6.8\text{T}$
- Coil winding thickness  $c$  set by winding pack and  $J \times B$  limits.  $\rightarrow c \sim 1\text{m}$
- $n_D \tau_E T_i$  peak at  $T_i \rightarrow 14\text{keV}$  (set by collision cross-section)
- Assume  $P_{\text{fus}}$  produced  $P_{\text{Elec}}$  with thermal efficiency  $\eta = 0.4 \rightarrow p \sim 8 \text{ atm.}$
- Ideal gas equation  $\rightarrow n_{\text{core}} \sim 1.5 \times 10^{20} \text{ m}^{-3}$   
 $(n_{\text{air}} = 2.5 \times 10^{25} \text{ m}^{-3}, n_{\text{diamond}} = 1.7 \times 10^{29} \text{ m}^{-3}, n_{\text{Sun}}(0) = 9 \times 10^{31} \text{ m}^{-3})$
- $P_\alpha > P_{\text{losses}} \rightarrow I_p \sim 15\text{MA}$
- Steady state,  $I_{\text{ohmic}} = 0. I_p = I_{\text{CD}} + I_{\text{BS}}.$   
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Relax



Tokamak Energy, UK

Spherical Tokamak for  
Electricity Production  
(STEP), UK

# Tokamak-reactor design

Reactor determined by engineering, **nuclear** and **physics** constraints:

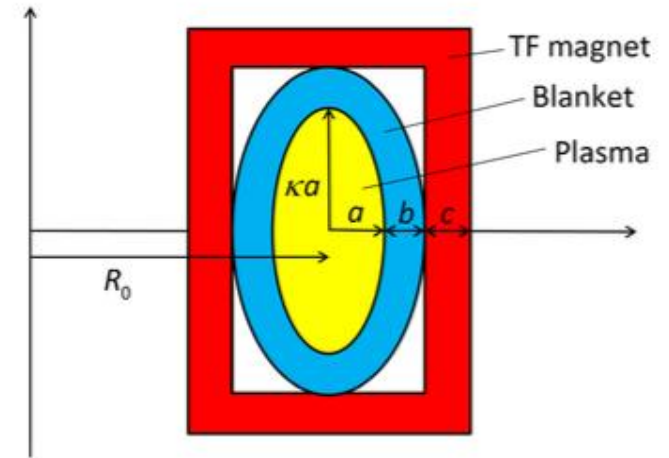
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- $P_\alpha > P_{\text{losses}} \rightarrow I_p \sim 15\text{MA}$

Steady state,  $I_{\text{ohmic}} = 0$ .  $I_p = I_{\text{CD}} + I_{\text{BS}}$ .

Automatic

$I_{\text{CD}} < 2.2\text{MA}$  RF current drive, (coupling efficiency  $\sim 50\%$ , recirculating power  $< 10\%$ )

$\rightarrow f_{\text{BS}} = I_{\text{BS}}/I_p > 84\%$



Relax



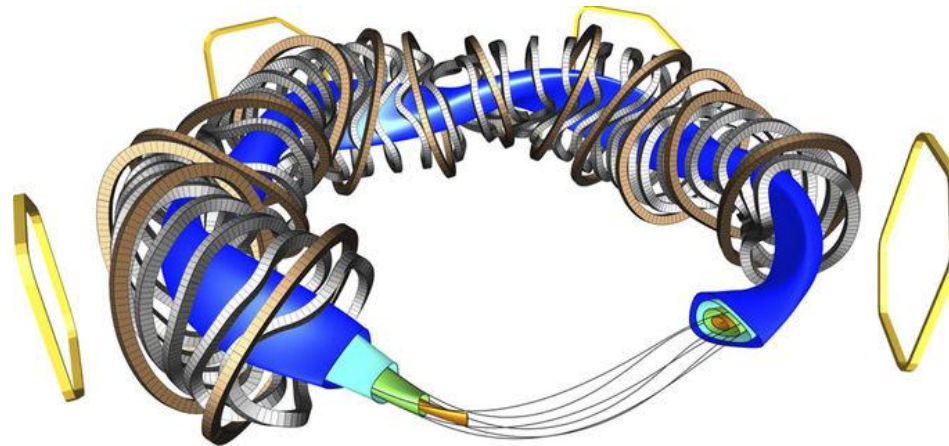
Stellarator

Wendelstein 7-X  
Type I Energy  
Gauss Fusion

# Stellarators: confinement with a twist

- Tokamak: field line helicity created by internal plasma current
- Stellarator: field line helicity created by twist of field coils
  - ✓ Eliminates disruptive current-driven instabilities,
  - × field coils are an engineering challenge,
  - × flux surfaces aren't guaranteed.

e.g. W7-X : a first-generation computationally optimised stellarator (low neoclassical transport, low current, good stability, and “good” flux surfaces)



- € 1 billion experiment. Construction started in ~2000.
- Aim: evaluate fusion reactor using stellarator technology.
- Opened by Chancellor Merkel in February 2016

# Parameter space of optimised stellarators is vast

Simons Foundation Collaboration on Hidden Symmetries and Fusion Energy, 2018 - 2025

<https://hiddensymmetries.princeton.edu/>



**Objective:** To create and exploit an effective mathematical and computational framework for the design of stellarators with hidden symmetries. (*good flux surfaces, good particle confinement, high bootstrap fraction*)

**Deliverables:** Optimum design principles of a stellarator, a modern optimization code (SIMSOPT) that can exploit the full power of petascale and exascale computers, and designs of next-generation stellarator experiments

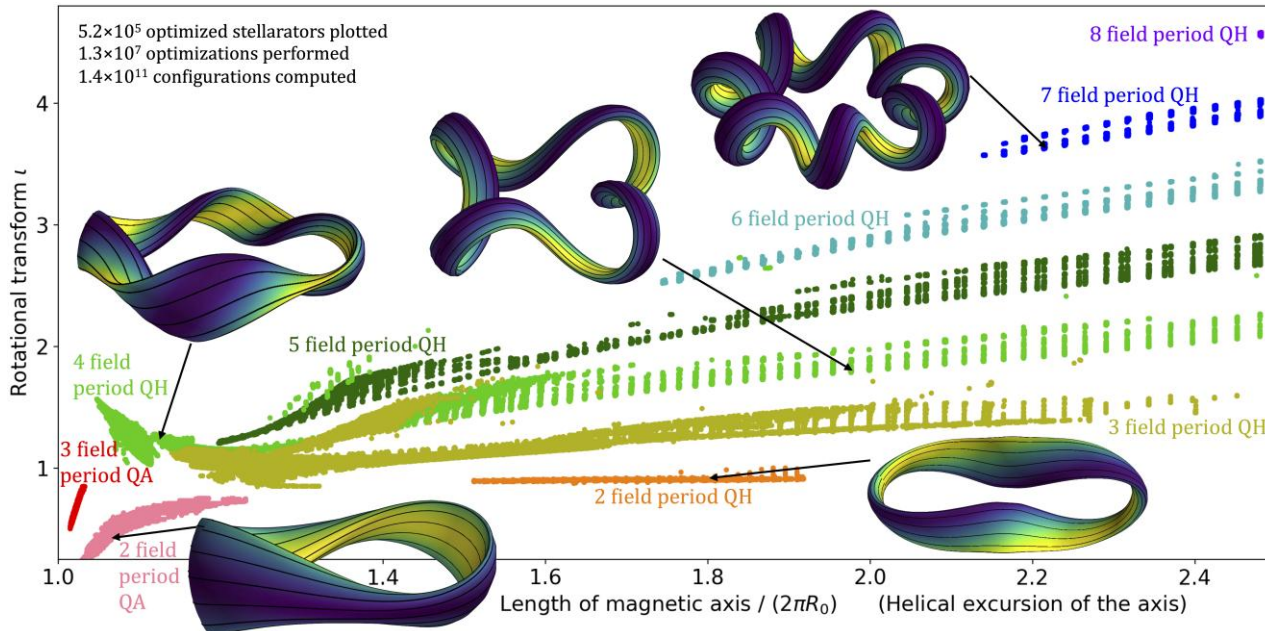
**Not Guaranteed!**

**Not Automatic!**

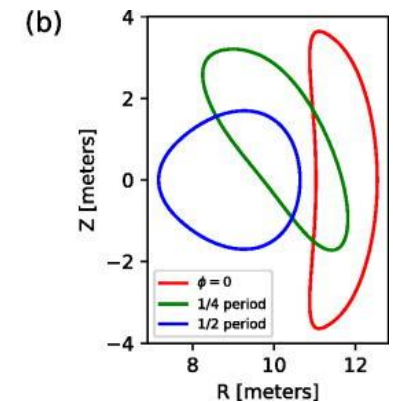
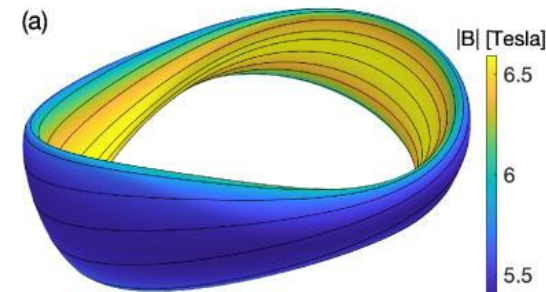
<https://github.com/hiddenSymmetries/simsopt>

M. Landreman, Journal of Plasma Physics, 88(6), 905880616, 2022

M. Landreman et al *Physics of Plasmas* 29, 082501 (2022)



Optimized quasi-axisymmetric configuration with energetic particle confinement, self-consistent bootstrap

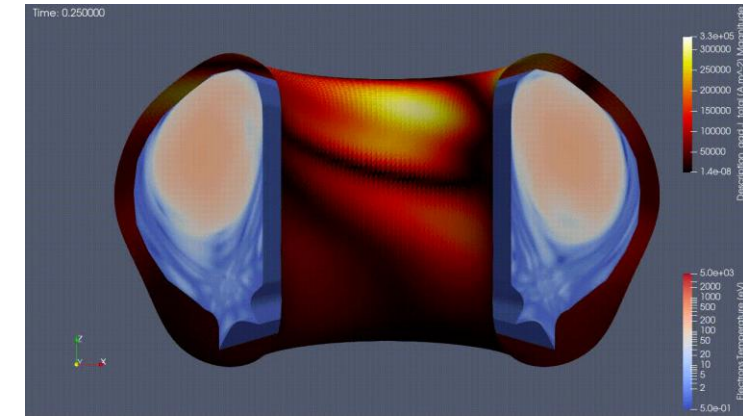


# Potential game changers for fusion

- Superconducting Magnet Technology: higher field strength, lower cryogenic cost
- Integrated Modelling : self-consistent core-edge simulation
- AI : Surrogate modelling, Control
- Design Optimisation
- Advanced divertor materials
- Radiation resistant structural materials
- Ignition & JET record stored energy shots
- Increasing urgency of climate action
- Wave of capital from tech billionaires

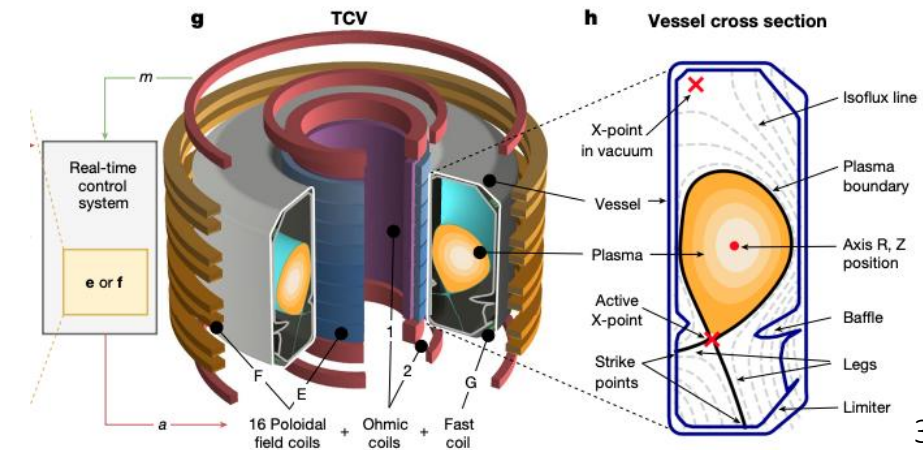
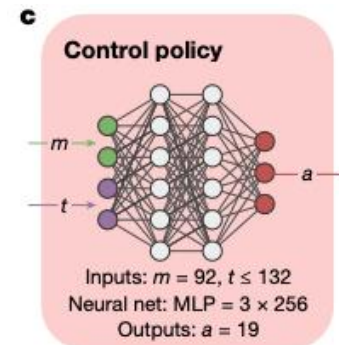
S. Pinches *et al* Dec. 2025

--Visualization with IMAS-ParaView  
<https://github.com/iterorg/organization/IMAS-ParaView>  
of induced currents in vacuum vessel and plasma electron temperature during disruption in ITER simulated with JOEUK code  
<https://jorek.eu/>.



J. Degraeve *et al* Magnetic control of tokamak plasmas through deep reinforcement learning, Nature 602, 2022

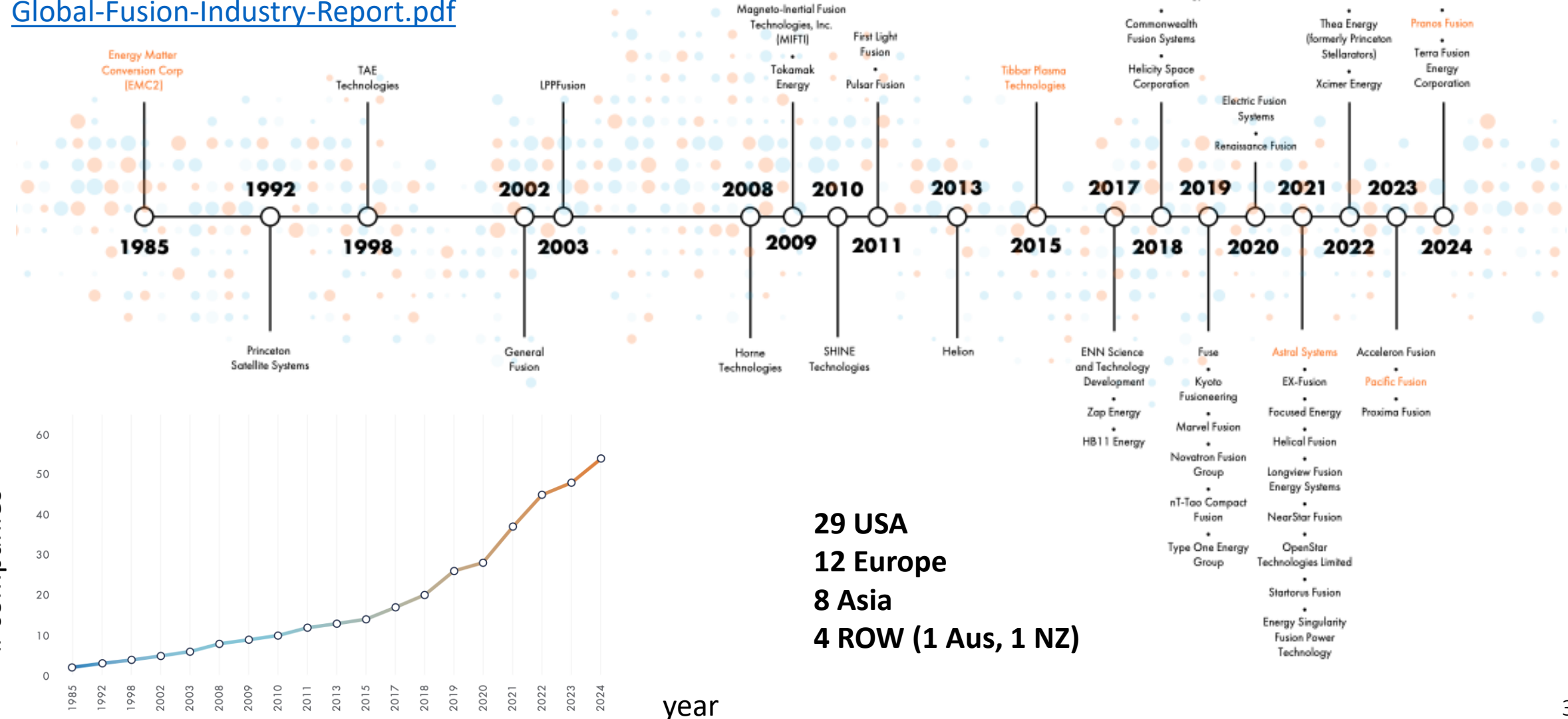
- Collaboration between DeepMind and EPFL, Switzerland
- Demonstration of real time control using a PINN



# The rise of the private sector

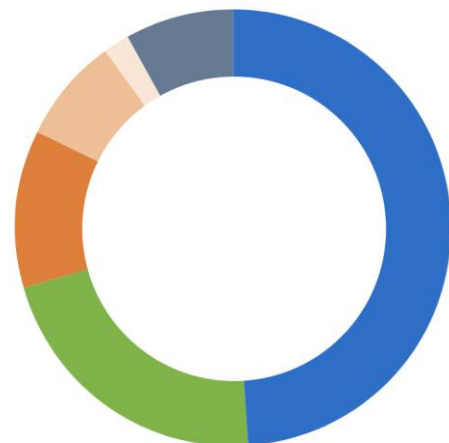
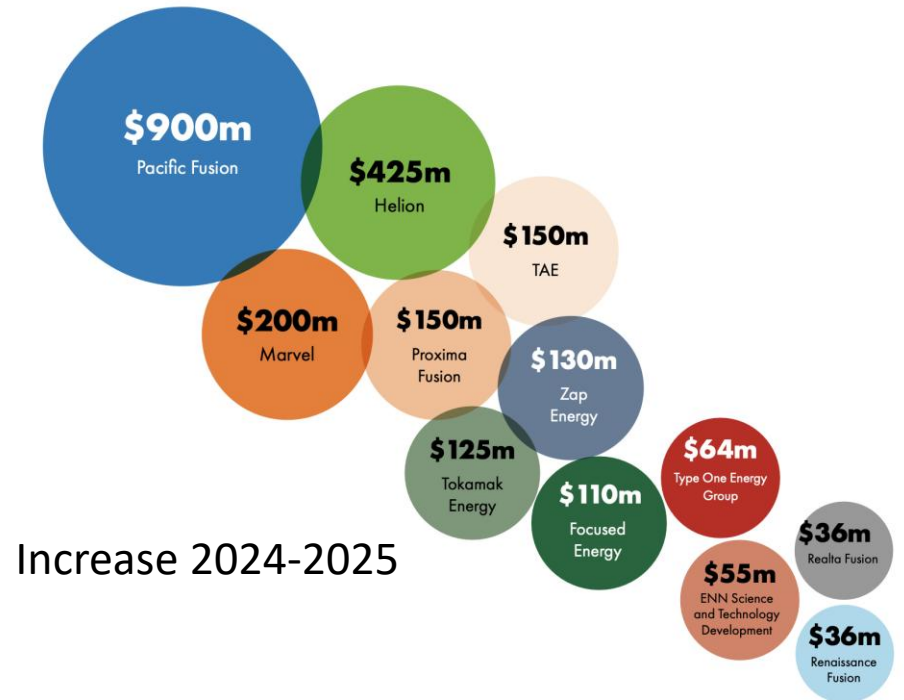
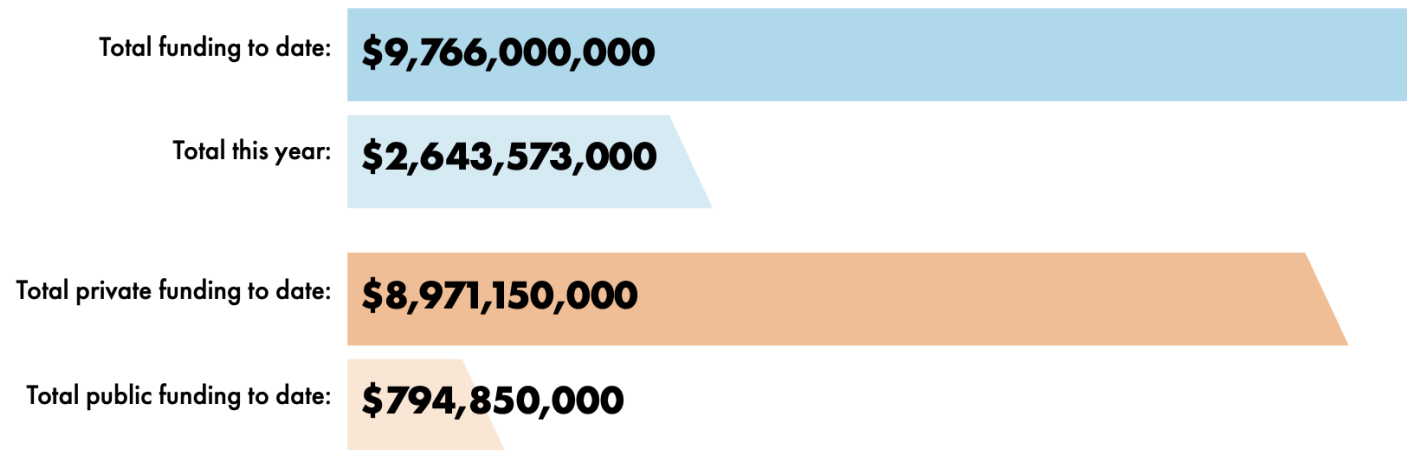
22 July 2025

<https://www.fusionindustryassociation.org/wp-content/uploads/2025/07/2025-Global-Fusion-Industry-Report.pdf>



# Cumulative funding exceeds \$USD10 billion

## TOTAL FUNDING TO JULY 2025



### General approach

- **25** Magnetic confinement (inc. Tokamak, Stellarator)
- **11** Inertial confinement
- **6** Magneto-inertial
- **4** Hybrid electrostatic confinement
- **1** Muon-catalyzed fusion
- **4** Non-traditional concepts/Not stated

### Billion Dollar Companies

- Commonwealth Fusion Systems ~USD\$3bn
- TAE Systems ~USD\$1.3bn (post Trump Media Merger 18/12/2025)
- Helion Energy Systems ~USD\$1bn

# Commonwealth Fusion Systems (CFS)

Commonwealth Fusion Systems (CFS) spin-out from the Massachusetts Institute of Technology (MIT) in 2018

CFS aims to commercialize fusion energy rapidly using high-field tokamak technology coupled with advanced materials — especially *high-temperature superconductors (HTS)*.

SPARC = physics + technology demonstrator

- Uses D-T cycle
- Conventional aspect ratio tokamak
- $R_0 \sim 1.85\text{m}$ ,  $a \sim 0.57\text{m}$
- High field strength 12.2T on-axis (23T peak)
- $I_p \sim 8.7\text{MA}$
- Energy gain  $Q > 2$
- Fusion power: 50-140MW
- Pulse length  $\sim 10\text{s}$  (inductive)
- Claims operational by end of 2026.



# Commonwealth Fusion Systems (CFS)

Commonwealth Fusion Systems (CFS) spin-out from the Massachusetts Institute of Technology (MIT) in 2018

CFS aims to commercialize fusion energy rapidly using high-field tokamak technology coupled with advanced materials — especially *high-temperature superconductors (HTS)*.

ARC = First commercial power plant

- Uses D-T cycle
- Conventional aspect ratio tokamak
- $R_0 \sim 3.3\text{m}$ ,  $a \sim 1.1\text{m}$
- High field strength 9.2T on-axis (23T peak)
- $I_p \sim 9.2\text{MA}$
- Energy gain  $Q > 10$
- Fusion power: 200MW electric (500MW thermal)
- Continuous operation
- Claims  $f_{BS} = 63\%$ . Hard.
- Claims operational by early 2030's

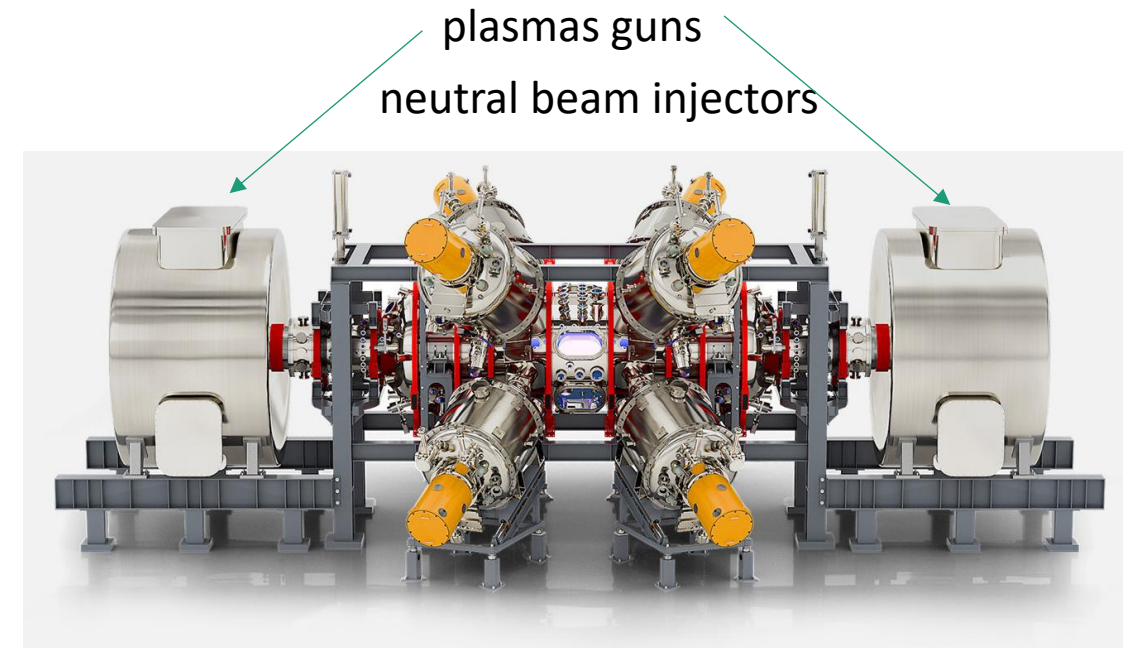


# TAE (Tri Alpha Energy) Technologies

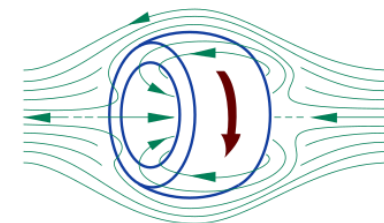
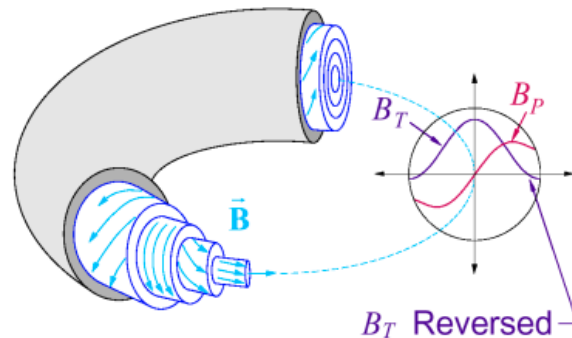
Founded in 1998, TAE is one of the longest-running and most capital-raised fusion startups globally (Foothill Ranch, California, USA).

To develop a practical, commercially viable fusion power system using a reverse field pinch

- Multi-fuel strategy:
  - D-T fusion: intermediate steps and validating concepts
  - P-<sup>11</sup>B fusion: long term vision
- Power generation by slowing down of  $\alpha$ 's to drive a current (direct), or heating a blanket and a heat-exchanger (indirect)
- Claims commercially viable by early 2030's



Reverse field as toroidal field is reversed at edge



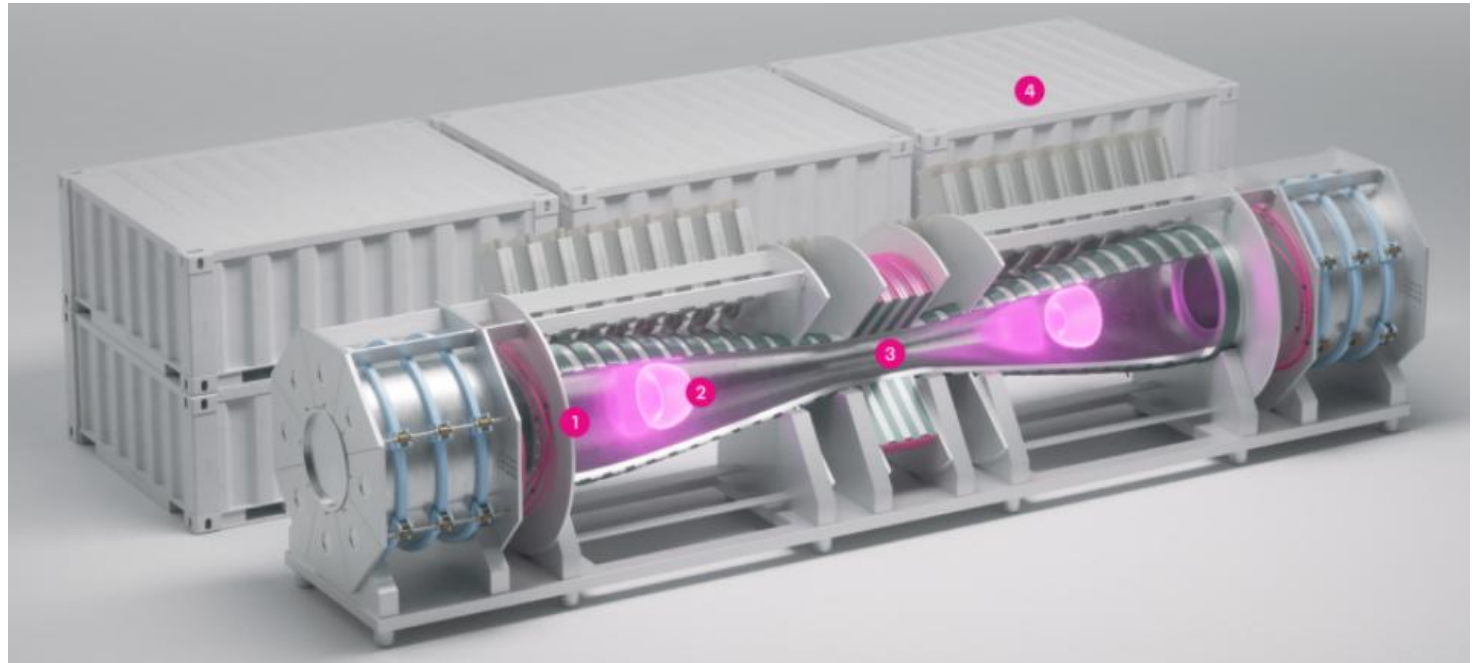
# Helion Energy

Helion Energy's fusion concept is a distinctive magneto-inertial, pulsed fusion approach using Field-Reversed Configuration (FRC) plasmas, with a design that aims to generate electricity *directly* from the fusion process rather than through a heat-to-steam cycle.

To develop a commercially viable P-<sup>11</sup>B fusion power system using a reverse field pinch

## Technology Concept

1. Formation of RFP configurations
2. Acceleration of RFP plasmas
3. Compression. Plasma heated to fusion conditions
4. Recoil: Plasma expansion produces change in field induces current.

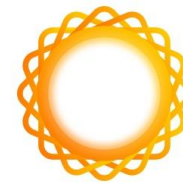


Committed to providing electricity to Microsoft data centres from 2028.

## Sydney, Australia

- Uses P-<sup>11</sup>B reaction
- Non-thermal ignition via laser-driven plasma block acceleration
  - Use **petawatt-class lasers**
  - Generate extremely high electric fields
  - Directly accelerate plasma blocks (non-thermal ignition)
  - Trigger an avalanche reaction of alpha particles
- Founded 2017, building on work of Heinrich Hora
- Raised ~AUD\$32m to date
- Claims commercially viable in the 2030's

Dr Warren McKenzie – CEO  
<https://hb11.energy/contact/>



- Uses P-<sup>11</sup>B reaction
- Levitated dipole magnetic confinement
- Founded late 2021, funded late 2022
- Raised \$20m USD
- ~70 employees
- First plasmas October 2024 in “Junior” experiment
- 5.7 tesla magnet in a 5.2 metre vacuum vessel
- ~50 kW EC heating
- Design of 2<sup>nd</sup> generation device underway
- Claims commercially viable by about 2030



NZ Government backs fusion energy research (by NZ\$35m)  
 4 February 2026.

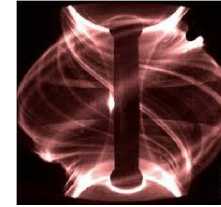
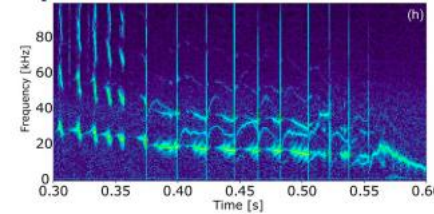
Ratu Mataira – Founder  
[leni@digpr.co.nz](mailto:leni@digpr.co.nz)

# The UK Approach to Fusion



- A substantial fusion program since the 1950's.
- Hosted Joint European Torus (1983-2023)
- UK program has centred on developing the spherical torus (first demonstrated by ANSTO in 1988).

- START (1991-1998)
- MAST (1999-2013)
- MAST Upgrade (2015-)



- Massive expansion in funding / program over last 5 years
  - £650m Fusion Futures program Infrastructure, Skills, Industrial and commercial opportunities. October 2023 -2027.
  - £UK2.5 bn confirmed for ambitious **Spherical Tokamak for Energy Production (STEP)**. June 2025

- **Spherical Tokamak for Energy Production (STEP).**

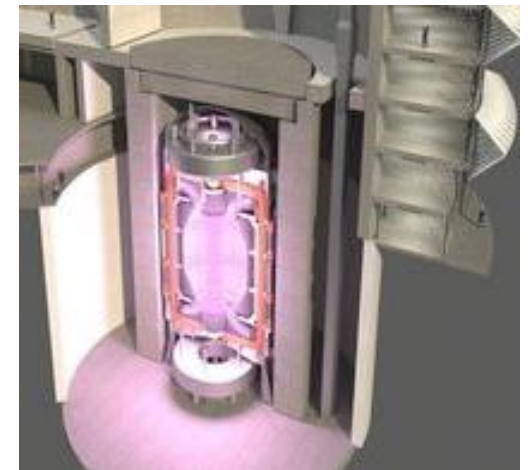
Deliver a UK prototype fusion energy plant targeting 2040. Aims to demonstrate

- nett electrical power to grid
- Tritium self sufficiency
- Maintainable reactor system
- Commercially relevant plant architecture

<https://stepfusion.com/>



Site selection in West Burton, Nottinghamshire. (former coal power plant)



# Burning plasma Experimental Superconducting Tokamak

BEST = compact, high-field tokamak under construction in Hefei, China

1 October 2025

- Uses D-T cycle
- Conventional aspect ratio tokamak
- $R_0 \sim 3.6\text{m}$ ,  $a \sim 1.1\text{m}$
- High field strength 6.15T on-axis
- $I_p \sim 4\text{-}7\text{MA}$
- Energy gain  $Q > 1\text{-}5$
- Fusion power: 20-200 MW
- Pulse length  $\sim$  hours
- Claims operational by end of 2027.
- $> \$1\text{bnUSD}$  invested.



*Very ambitious timeline:*

- Construction began in mid 2023
- May 2025, full device assembly commences
- October 2025. Dewar base, the vacuum vessel housing magnets installed

Builds on success of EAST  
(Experimental Advanced  
Superconducting Tokamak)  
Hefei, Chinese Academy of  
Sciences



# Australia: A pioneer in Fusion Science

**1934** Sir Mark Oliphant discovers He3+, T, and D-D reaction

**1958** Sir Mark Oliphant initiates plasma physics research at ANU

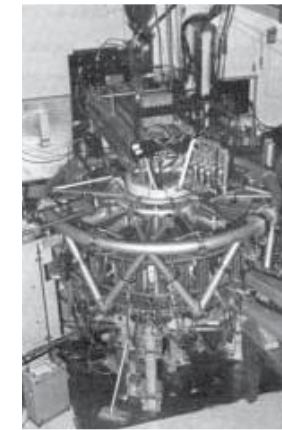
## Innovations (incomplete list)

- 1963 First tokamak outside Russia –Liley
- 1970 Lagrangian WKB to describe waves + particles - Dewar
- 1973 Nonlinear wave saturation - Dewar
- 1974 Discovery of Alfvén gaps in toroidal confinement – Dewar
- 1978 Laser-driven plasma blocks - Hora
- 1979 Invention of the rotamak - Jones
- 1980 Construction of TORTUS tokamak at Univ. Sydney – Cross
- 1983 Definitive treatment of ballooning modes in 3D - Dewar
- 1985 First heliac confinement device (SHEILA) - Hamberger
- 1988 First demonstration of a steady-state spherical torus configuration - Collins
- 1992-2018 First hot heliac confinement device (H-1) - Blackwell
- 1996 Spontaneous transitions to improved confinement (H-mode) - Shats
- 2003 Development of time resolved coherence imaging - Howard
- 2012 Bayesian implementation of magnetic force balance - Hole
- 2012-15. Formulation of generalised Taylor relaxation to describe 3D fields – Dewar / Hole
- 2015 Computation of continuum damping in 3D fields – Bowden / Hole
- 2015 Pioneered use of GISAXS to characterise He formation in Tungsten – Corr
- 2016 Entire new class of energetic particle driven modes – Qu / Hole

Sir Mark (1901-2000)



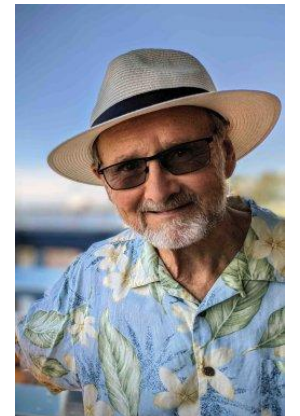
LT4 Tokamak



H-1 Heliac



Prof. Dewar  
1944 - 2024

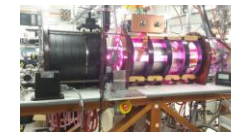
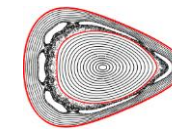


# Fusion relevant Australasian research activity



Australian National University

- Theory and modelling
- Experimental plasma science



**ANSTO**  
Science. Ingenuity. Sustainability.

- Operates OPAL research reactor
- Nuclear materials engineering (work on W and alloys with UKAEA)



**UNSW**  
THE UNIVERSITY OF NEW SOUTH WALES

- Neutron shielding materials (with ANSTO, Tokamak Energy)

**ATOMCRAFT**

**HB11 ENERGY**  
LASER BORON FUSION

- Laser Fusion Energy technology with advanced fuels and proton-driven fast ignition

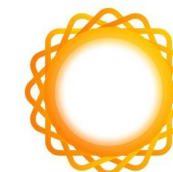


MERANTI RESEARCH

Plasma Storage Ring, Perth

**Curtin University**

- Atomic collision physics for neutral beam heating, diagnostics and first wall



**OPENSTAR**  
TECHNOLOGIES LTD

Levitated dipole, Wellington NZ

**THE UNIVERSITY OF WESTERN AUSTRALIA**

**Griffith UNIVERSITY**  
Queensland, Australia

- plasma theory / mathematics
- runaway electron modelling
- disruption mitigation



The University of Sydney

- Plasma theory/ mathematics
- Gridded inertial electrostatic confinement

**Helixos**

Fusion Consultancy, US, Aus

**Cruxis Fusion** “hybrid magnetic and electrostatic confinement device that has achieved a virtual cathode without the need for physical grids.”

[Joe.Khachan@sydney.edu.au](mailto:Joe.Khachan@sydney.edu.au)

# Strong international dimension to research

Collaborators include ....



UK Atomic Energy Authority



한국핵융합에너지연구원  
KOREA INSTITUTE OF FUSION ENERGY



# Is there an overlap with AUKUS?

*In discussion with ...*

Paul Methven, Director of STEP (Royal Navy Rear Admiral, Director Nuclear Submarine Acquisition 2017-2020)

Dougie Auld, UKAEA Chief Engineer (Royal Navy Nuclear Engineer, 32 years)

- Complex systems modelling
- Neutronics
- Control systems
- Uncertainty quantification
- Artificial Intelligence
- Materials Science
- Tritium handling (awareness)
- Electrical power distribution and storage,
- Thermal cycling and hydraulics
- Systems Engineering
- Health physics
- Safety case and safety case handling



*“Fusion is the miracle drug that attracts students to nuclear science”*

Prof. Sir Steve Cowley, Director of Princeton Plasma Physics Laboratory, UKAEA Director



UNSW SYDNEY

# ATOMCRAFT

## First tokamak designed, built and operated by undergraduates

### Our Purpose

An ambitious student project for training the next generation of engineers and scientists in advanced technologies

Marcus Borscz (student)  
[m.borscz@student.unsw.edu.au](mailto:m.borscz@student.unsw.edu.au)  
A/Prof. Patrick Burr (academic)  
[p.burr@unsw.edu.au](mailto:p.burr@unsw.edu.au)

### Our Team

- 55 undergraduates (and growing) across eight schools of engineering and the school of physics
- Divided into three departments: Power & Plasma Engineering, Plant Engineering, Project Management

### Our Machine

- Small-scale tokamak with ohmic and ECR heating (@2.45 GHz)
- $R_0 \sim 0.3$  m,  $B_\phi \sim 0.1$  T, aspect ratio  $\sim 3.5$
- Targeting 100 ms pulses with  $H_2$  at  $I_p \sim 5$  kA

### Our Skill Areas

- Plasma modelling (DYON, FreeGS, Tokamaker)
- Plasma diagnostics (Langmuir probe, Rogowski coil, spectroscopy)
- RF waveguide engineering
- Vacuum vessel design and fuel delivery
- Glow discharge cleaning
- Supercapacitor energy storage
- Switched-mode power supplies
- FPGA engineering

### Our Partners



### Our Timeline

- February 2024** – Project Launch
- January 2025** – Begin Vacuum Vessel Manufacture
- November 2025** – Full-Scale Glow Discharge Demo, Coils Operating at 10% Target Current
- July 2026** – First plasma
- November 2026** – Begin ECRH operation



# Wrapping up: Topics covered (1/2)

- Introduced fusion
- Placed nuclear power (inc. fusion) in context to global energy needs
- Described different approaches to fusion power
- Introduced and focused on technology most likely to work – toroidal confinement
- Introduced ITER, tokamak reactors and stellarators
- Outlined rise of the private sector and major UK and China programs
- Sketched Australian R&D: past to present

# Wrapping up: Take-away (2/2)

- Fusion is common in the Universe.
- Fusion on Earth is hard, but the rewards if realised immense.
- D-T fusion is hard. P-B fusion is ***much*** harder.
- Large scale energy utilities based on existing well-established but obsolete technologies (e.g. coal) take ~ 10 years. *Possible exception is China.*
- The next step experiment ITER is making progress. For the first time ever, ahead of schedule. DT operations envisaged from 2039.
- ITER is not a power plant.
- Unlikely fusion will contribute to grid before 2050.
- New configurations (stellarators) and new technologies (high temp superconductors, advanced materials, AI) offer hope fusion can be accelerated.
- There's an opportunity to embrace the primary R&D program (ITER), new configurations, new technologies and the private sector to increase awareness and Australian participation in global fusion R&D.
- Rejuvenation of community self-assembly via survey and follow up meeting in March



## Australian Fusion Energy R&D Survey

The purpose of this survey is to collect input on interest in community / collective engagement in advancing fusion energy R&D in Australia. These invaluable insights will be used to shape an agenda for a zoom meeting in March, whose purpose will be to re-examine self-assembly and advocacy in Australia in the field of fusion energy R&D.

<https://forms.office.com/r/WQpyia4y8f?origin=lprLink>