



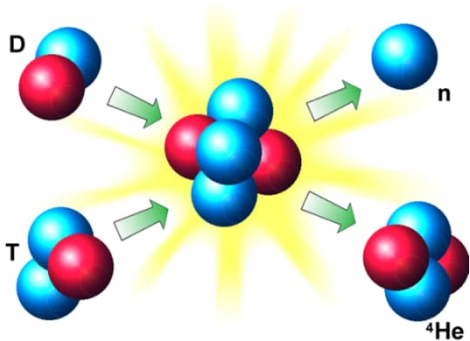
VTT

# Fuusiotutkimus eilen, tänään ja tulevaisuudessa

Tuomas Tala,  
Research Professor, Head of FinnFusion

31/03/2026 VTT – beyond the obvious

# Nuclear Fusion: in Principle a Simple Way to Produce Baseload Energy

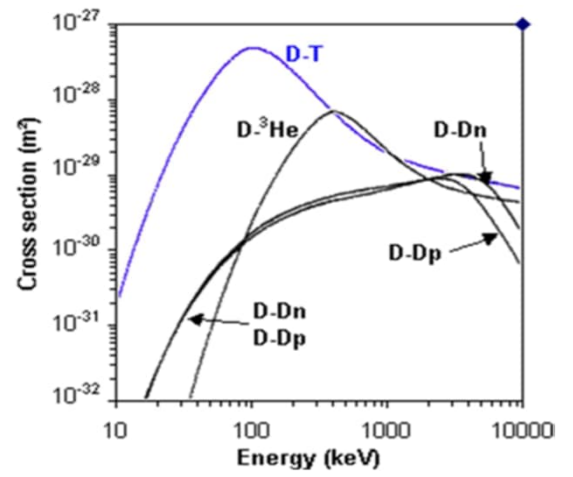
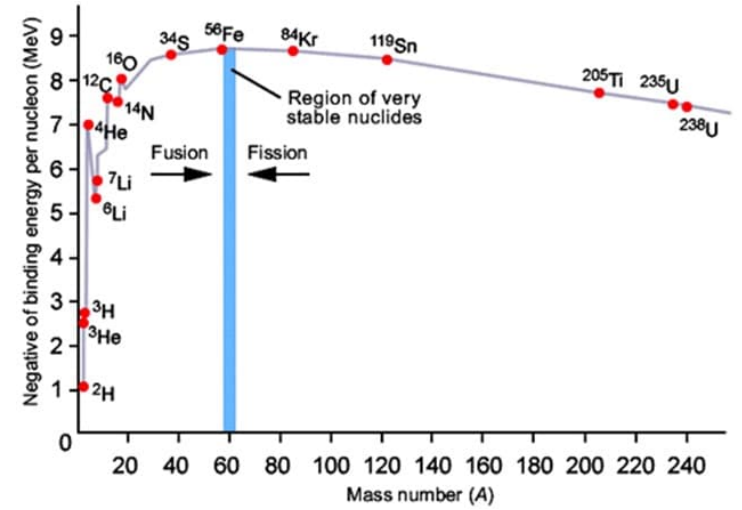


- ❑ Two light nuclei merge together and release energy
- ❑ Largest energy release for the lightest isotopes of H and He  
⇔ largest change in binding energy



$E=mc^2$

- ❑ Requires:
  - ✓ high enough temperatures  $\Rightarrow$  plasma
  - ✓ Sufficient density and reasonable confinement time  $T$  for the plasma
  - ✓ ... and small power losses



# Triple Product and Lawson Criterion to Achieve Fusion Gain

- Three things are required to achieve fusion:
  - Sufficiently high density  $n$  for the fusing particles to find each other
  - Sufficient temperature  $T$  to overcome the Coulomb barrier
  - Sufficient confinement time  $\tau$  for the fusing particles to fuse
  
- **Fusion triple product  $n\tau T$** : measure of plasma performance
  
- **Lawson criterion**: The overall condition which the three quantities meet for a plasma to yield more energy than needed for its heating

Thermal break-even

$$Q = \frac{P_{fusion}}{P_{heating}} > 1$$

Technical break-even

$$Q_{el} = \frac{P_{fus,el}}{P_{tot,el}} > 1$$

Commercial break-even

$$Q = \frac{P_{fusion}}{P_{heating}} > \approx 30$$

# Content of This Talk

- Past: History of the fusion research
- Present: Status now and new achievements
- Future: new developments and directions

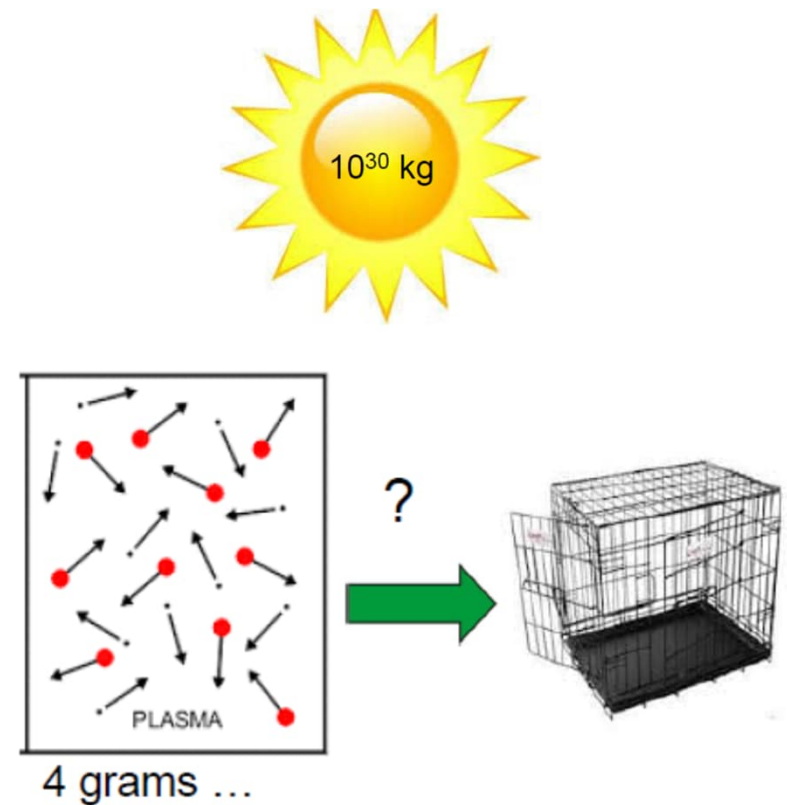
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# Already in the Past Fusion Power Works... but so Far Only in the Sun and Stars



The difference in the mass between the sun and our tokamaks is not tiny





# ITER Project

- ITER Goals:
  - Achieve  $Q > 10$  (500MW fusion power with 50MW of input power)
  - Demonstrate Tritium breeding from the Lithium Li-6 isotope
  - Contribute to the demonstration of the integrated operation of technologies for a fusion power plant
  - Demonstrate the safety characteristics of a fusion device
- ITER is the largest joint endeavour on earth, with EU contribution of 45% and 8% contribution from China, India, Japan, Korea, Russia, US each, including more than half of world's population
- Estimate at completion 22 billion euros

First discussions on ITER project



ITER Agreement in Elysee Palace in Paris in 2006



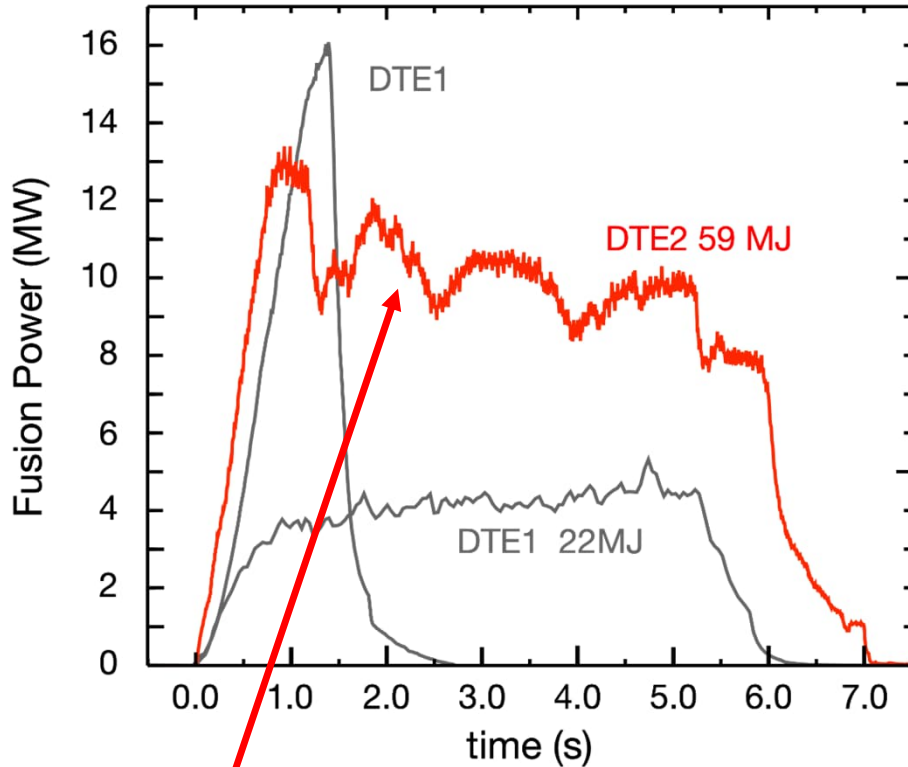
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# New Fusion Energy World Record Achieved in Joint European Torus (JET) Tokamak in United Kingdom in 2022

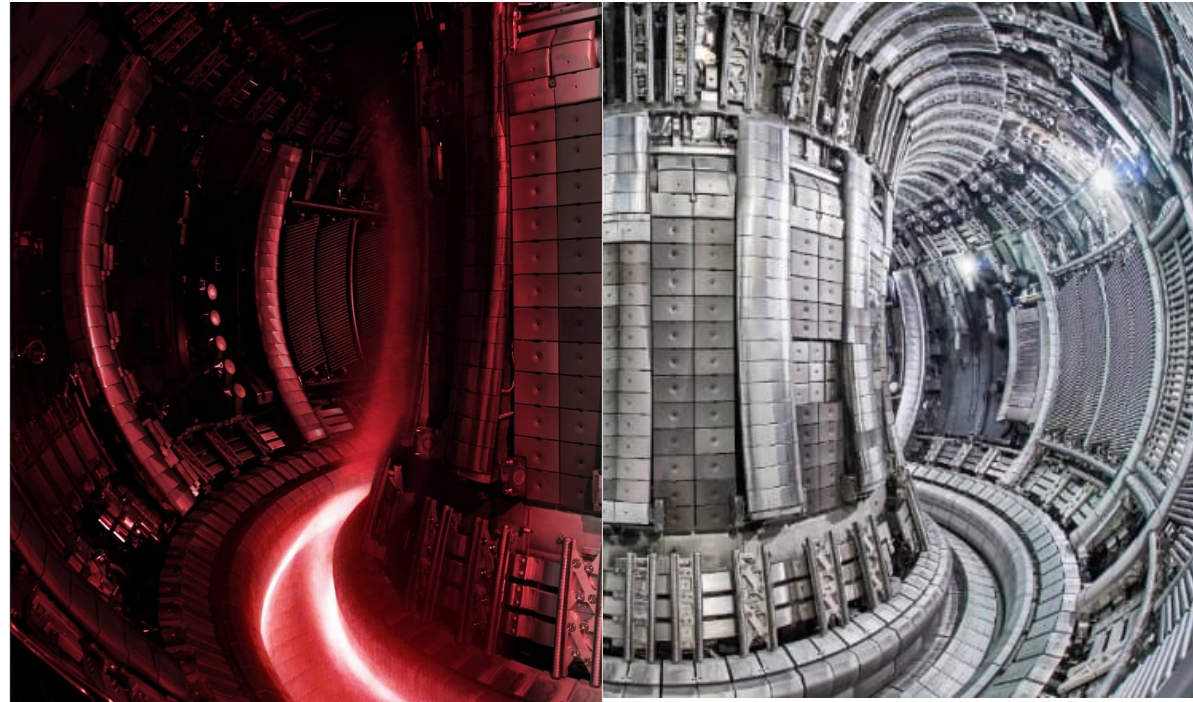


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100  $\mu\text{g}$  of tritium and 70  $\mu\text{g}$  of deuterium were needed

To generate this with fossil fuels you need:  
1.06 kg of natural gas or  
3.9 kg of lignite coal



JET tokamak,  $V=80\text{m}^3$

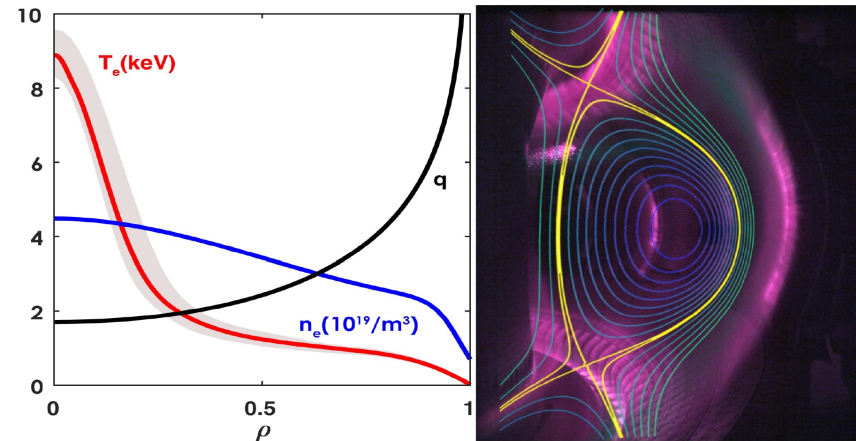
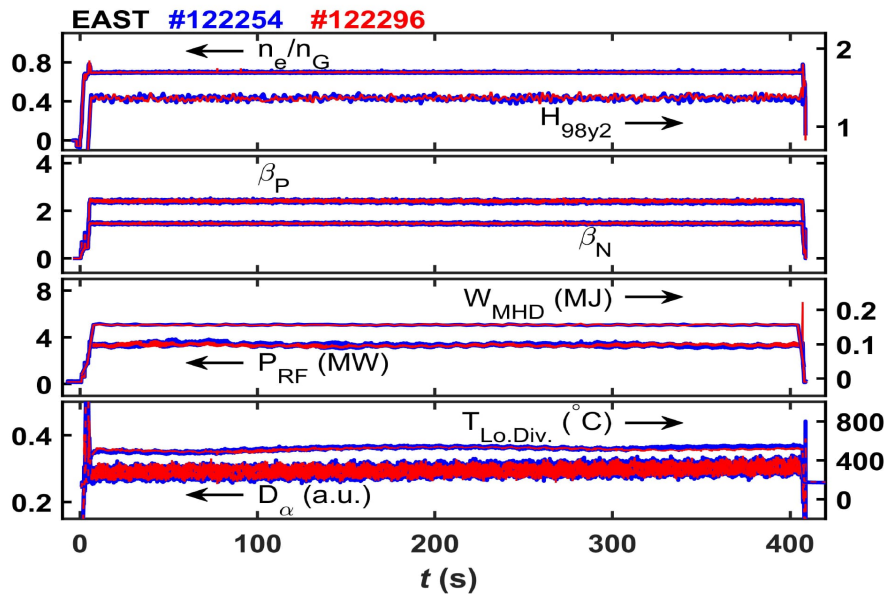
# VTT Scientist Having a Scientific Discussion on JET World Fusion Energy Record with the Prince of Wales at JET on 31 Jan 2022



# New World Record in High Performance Pulse Length: China's 'Artificial Sun', EAST Tokamak, Runs for 403s in Steady-state High-confinement Plasma Operation

## Reliable 403 Seconds Stationary H-mode Plasmas Demonstrated on EAST

At 21:00 on April 12, the first 403-second steady-state H-mode plasma was achieved on EAST, which is a new record of pulse length on high performance operation in tokamaks. On the second day at 19:00, the EAST team repeated this operational scenario, demonstrating the reliable capability of the device.

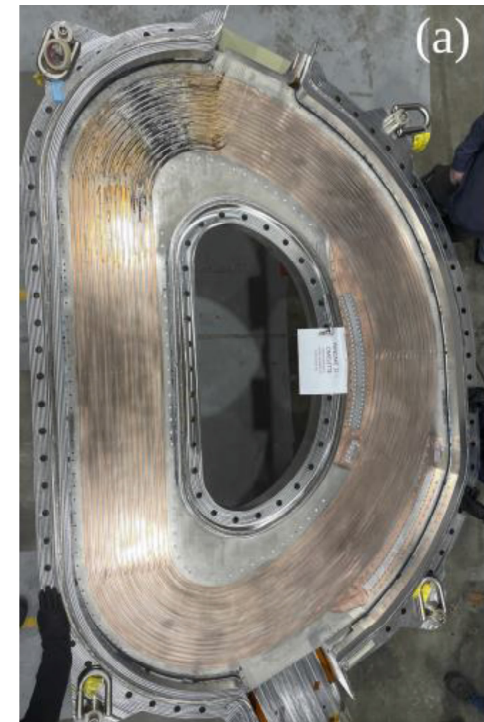
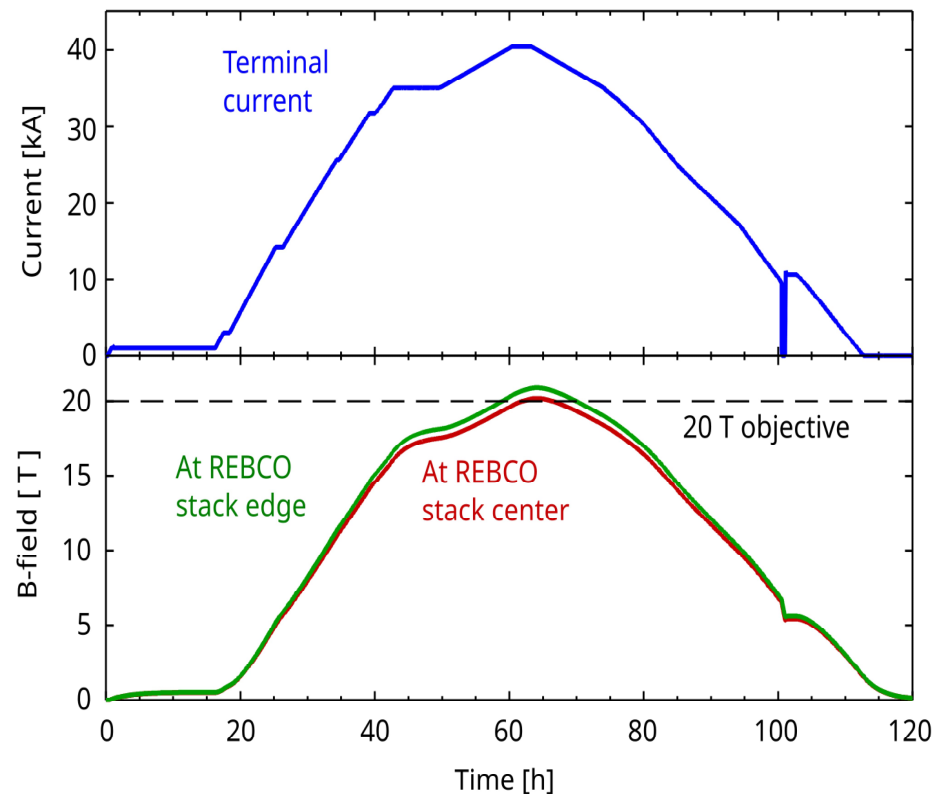


# EAST Control Room, Hefei China



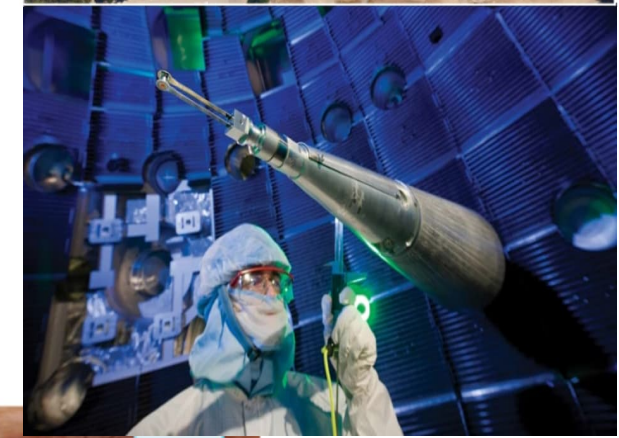
# Commonwealth Fusion Systems Inc. Builds the World-Record Super-Conducting Magnet: $B=20.1\text{T}$

- Compact, high field REBCO high-temperature super-conducting magnet; large magnet design space
- Resistant to quench; robust to REBCO defects and local damage
- Potential to eliminate active quench detection/mitigation systems



# National Ignition Facility at Lawrence Livermore National Lab Exceeds Thermal Break-Even ( $Q_{th} > 1$ ) in Fusion in Dec 2022

- NIF is based on laser fusion with 192 lasers directed onto a pea-sized gold cylinder containing a frozen pellet of Deuterium and Tritium
- Record experiment used those 192 lasers at 2.05MJ, releasing 3.15 MJ of fusion energy — 54% more than went into the reaction. Break-even of fusion energy (Lawson criterion) demonstrated on earth
- Although the fusion reactions produced more than 3 MJ of energy — more than was delivered to the target — NIF’s lasers consumed 322 MJ of energy in the process. Still, the experiment qualifies as exceeding thermal break-even, a benchmark criterion for fusion reactions.



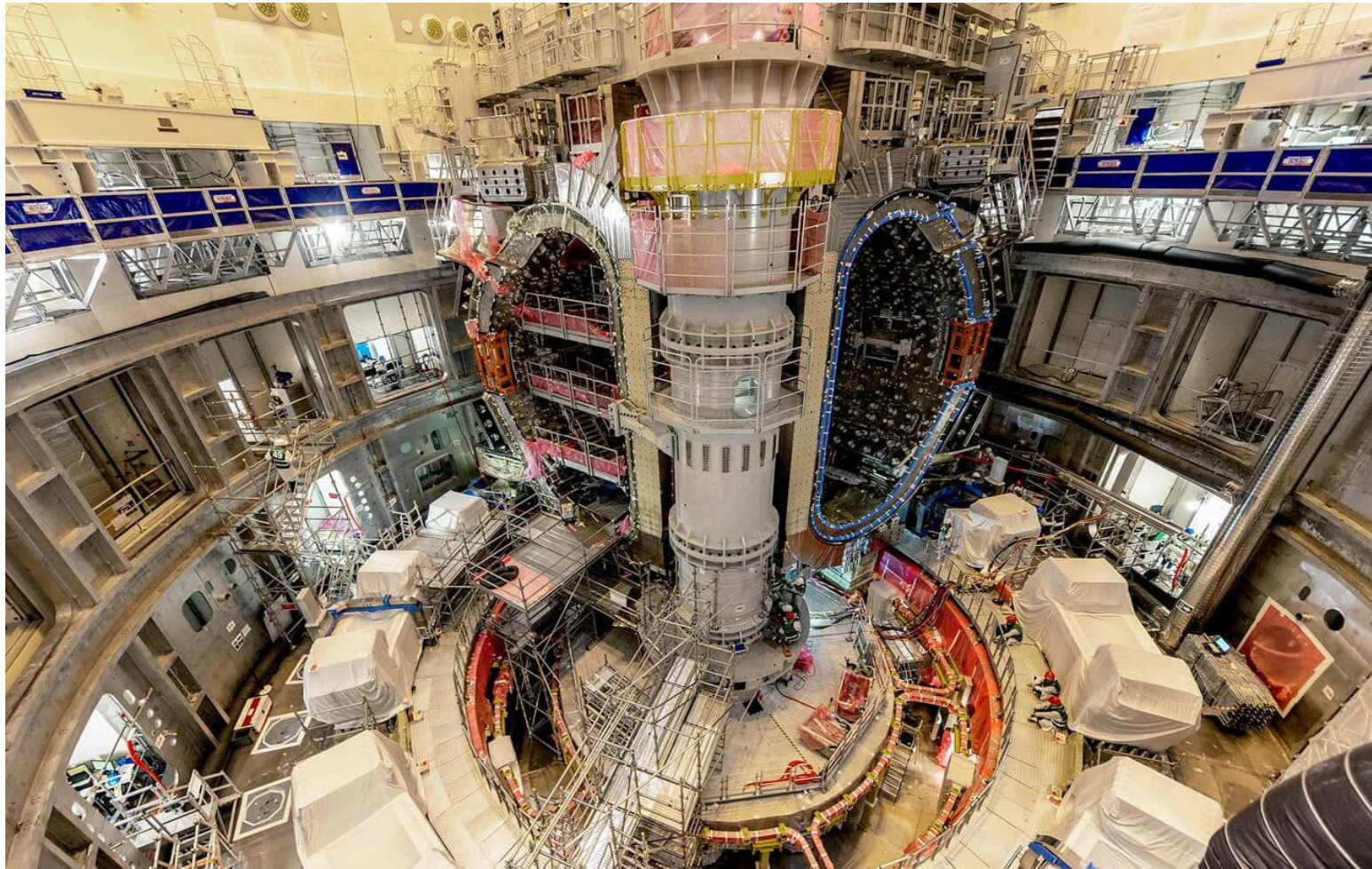
# About 80% of ITER Has Been Constructed



VTT

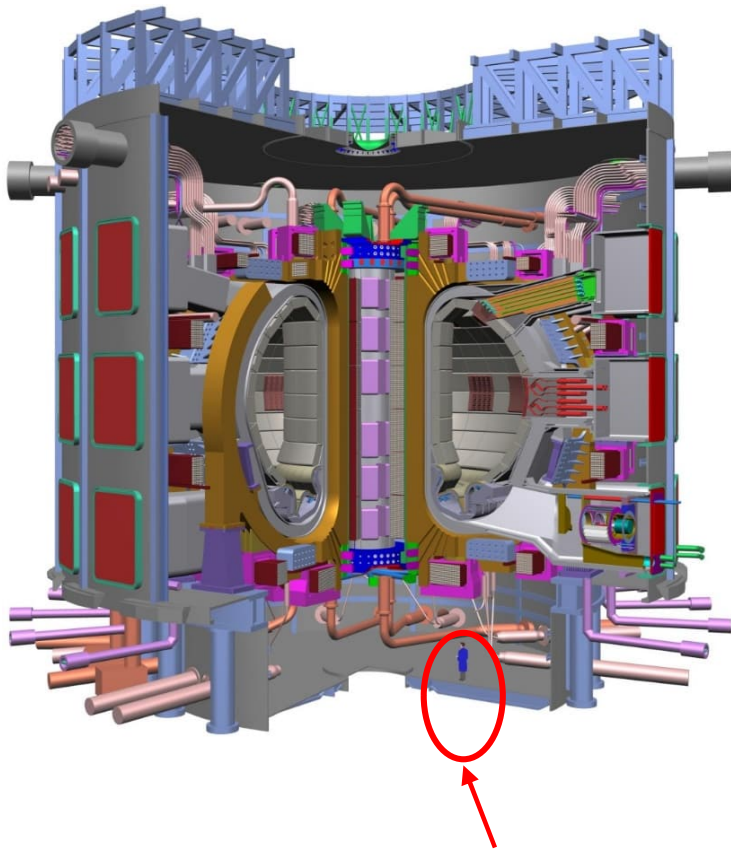
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# ITER Tokamak Assembly, 1/3 of the Vacuum Vessel Welded Together in February 2026



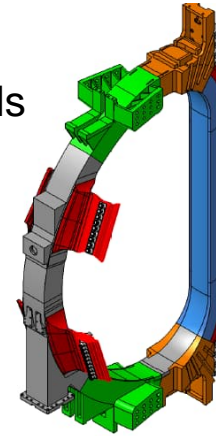
31/03/2026

# Engineering Challenges in This First-of-a-kind Project ITER Are Unprecedented



Standard technician

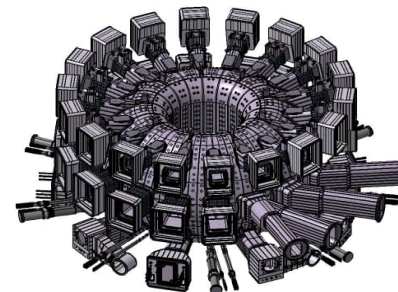
Toroidal field coils



16 x 9 m, ~360 t  
(EU, JP – 18 coils)



Boeing 747-300  
(maximum take-off weight ~377 t)



7300t, 324 m tall

Vacuum Vessel Weighs about 25% less than the Eiffel Tower (more with in-vessel components included)

# Public Sector Funding – Growth and Inspiration!



- ✓ **USA:** **\$790M** Department of Energy (DoE) office of Fusion Energy Sciences (FES)  
**\$690M** National Nuclear Security Administration (NNSA)



- ✓ **United Kingdom:** **£650M** for fusion energy (e.g. STEP project), **~£15B** by 2040 for STEP



- ✓ **European Union:** **\$600M** various fusion projects (expectation), **ITER: €1B** / year through F4E



- ✓ **Germany:** **€2.9B** for fusion research by 2029



- ✓ **South Korea:** **\$866M** for development of fusion reactors and related infra



- ✓ **Japan:** investments of **\$400M** in research at NIFS; plans to commercialize fusion



- ✓ **China:** spending **\$1.5B** on fusion energy development

# Largest Private Sector Investments



✓ **Commonwealth Fusion Systems: \$3.0B**, SA  
Alphabet, *Bill Gates*, Tiger Global Management, *Richard Branson*, Mark Zuckerberg, Breakthrough Energy Ventures

✓ **TAE: \$1.8B**, USA  
*Chevron*, *Paul Allen* (Microsoft), Alphabet, Reimagined Ventures, Venrock

✓ **Pacific Fusion: \$900M**, USA  
Breakthrough Energy Ventures, Eric Schmidt, *Mustafa Suleyman* (DeepMind), *Reid Hoffman* (LinkedIn)

✓ **Helion: \$1.03B**, USA  
Microsoft as first reactor customer; *Sam Altman* (OpenAI), *Reid Hoffman*, *Peter Thiel* (PayPal), *George Soros*, Nucor, KKR, BlackRock

✓ **General Fusion: \$490M**, Canada  
*Jeff Bezos*, Temasek, BDC Capital, Chrysalix Venture Capital

✓ **Zap Energy: \$327M**, USA  
*Chevron*, Breakthrough Energy Ventures (Bill Gates), Lowercarbon

✓ **Tokamak Energy: \$285.65M**, UK  
David Harding, Furukawa Electric Co, Hans-Peter Wild (Capri-Sun founder)

✓ **Proxima Fusion: \$130M + \$2B** from Bavaria State German Government, Germany  
Cherry Ventures, Balderton Capital

✓ **Marvel Fusion: \$109.3M**, Germany  
*Deutsche Telekom*, b2venture, Earlybird, HV Capital



# Private Sector Players in Fusion in 2024

United States						
Canada	Great Britain		Germany		Japan	
Italy	France	Sweden	Israel	Australia	New Zealand	China

Credit: Kyoto Fusionneering  
Fusion Industry Association survey – The Global Fusion Industry in 2024

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# After All These Recent Fusion World Records



## What Are the Future Avenues?

**Large Size Reactors: ITER, EU-DEMO...**

**Smaller Size Reactors: most private fusion enterprises, UK fusion program, ...**

**Alternative Fusion Confinement Concepts: mirror machines, cusps**

**Laser fusion: remains to be seen...**

# Global Fusion Landscape (My Personal View)

## ■ Expected in 2020's

- Next major step in 2027-2029: thermal break-even in magnetically confined tokamak plasma
  - Political powerplay between US (SPARC at CFS) and China (BEST in Hefei)

$$Q = \frac{P_{fusion}}{P_{heating}} > 1$$

- After the successful demonstrations of thermal break-even, new wave of investments, funding, enthusiasm, new private start-ups and further government interest will arise in late 2020's
- Strong fusion strategies with significant funding in place already now in CN, JP, UK, US, GE, (EU soon), Finland to come soon
- Supply chain may become a bottleneck for growth/progress

# Global Fusion Landscape (Our Personal View)

## Expected in 2030's

- Stellarator concept will achieve thermal break-even
- ITER operation will also start in mid 2030's
- Various other pilot plants will start operation (net electricity output)
- ARC by Commonwealth Fusion Systems will start operation in mid 2030's (net electricity output)
- Only strong companies survive in the “play-off phase”
- Large governmental pilot plants will also start operation in 2030's (EU fusion pilot plant, STEP in UK, FAST in Japan, Germany, Korea, ...)
- Opportunities of the innovative/alternative confinement concepts (like Novatron and other mirror machines, cusps and z-pinches) will become clarified
- Laser fusion...?

Thermal break-even

$$Q = \frac{P_{fusion}}{P_{heating}} > 1$$

Technical break-even

$$Q_{el} = \frac{P_{fus,el}}{P_{tot,el}} > 1$$

# Europe's Fusion Turning Point

Why Bavaria's €400M  
Bet on Proxima Fusion  
Matters

FINANCIAL TIMES  
Nuclear fusion start-up wins Bavarian state  
backing for €2bn test plant

**\sifted/**  
Nuclear startup Proxima Fusion eyes  
€1.2bn from German government

**New Civil Engineer**  
MoU signed to develop Europe's first commercial scale nuclear  
fusion power plant in Germany

**THE ENGINEER**  
Proxima targets grid-connected fusion in 2030s

**The Economist**  
Business | Breeding Unicorns  
At last, reasons to be cheerful  
about European tech

Published: 4.3.2026

## Europe's Turning Point for Fusion: Why Bavaria's €400M Bet on Proxima Matters

# What Is Happening in Finland in Future?

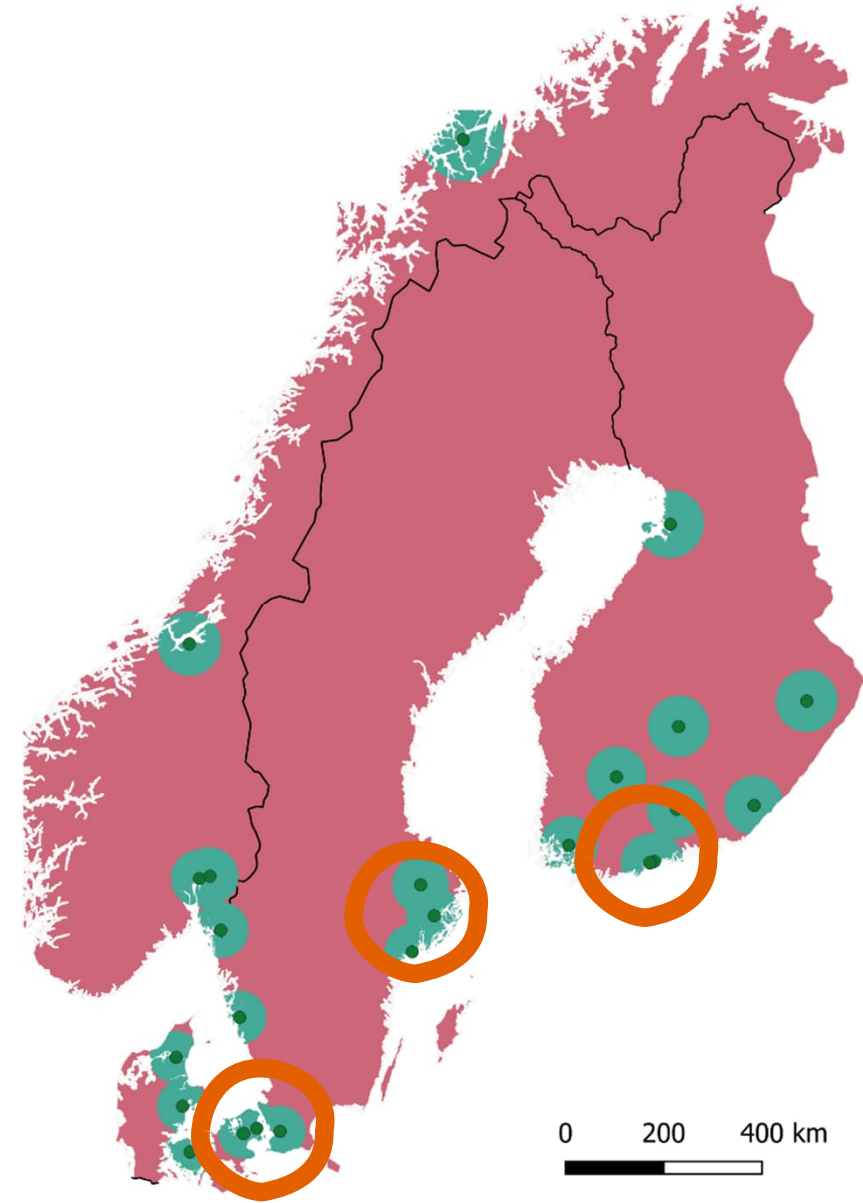
The Finnish regulatory approach is moving toward regulating experimental fusion under the Radiation Act, enabling more innovation-friendly licensing from 2027.

The Finnish Government released the new nuclear Act on 12 March 2026.



# VTT Performed a Project for Novatron Fusion Group Ltd to Identify Potential Locations for a Fusion Pilot Facility Novatron 3 (N3) within the Nordic Region

- Fusion or nuclear technology research centres
- Universities with physics or nuclear engineering education
- Top-three regions stand out clearly
  - Copenhagen/Malmö
  - Helsinki Metropolitan area
  - Stockholm-Nyköping (incl. Studsvik)
- All of them easily fulfill the logistics criteria



# Radiation safety and emergency planning

## Main concern: tritium

Losses during normal operation  
Releases in accident scenarios  
Generally relatively low dose effect

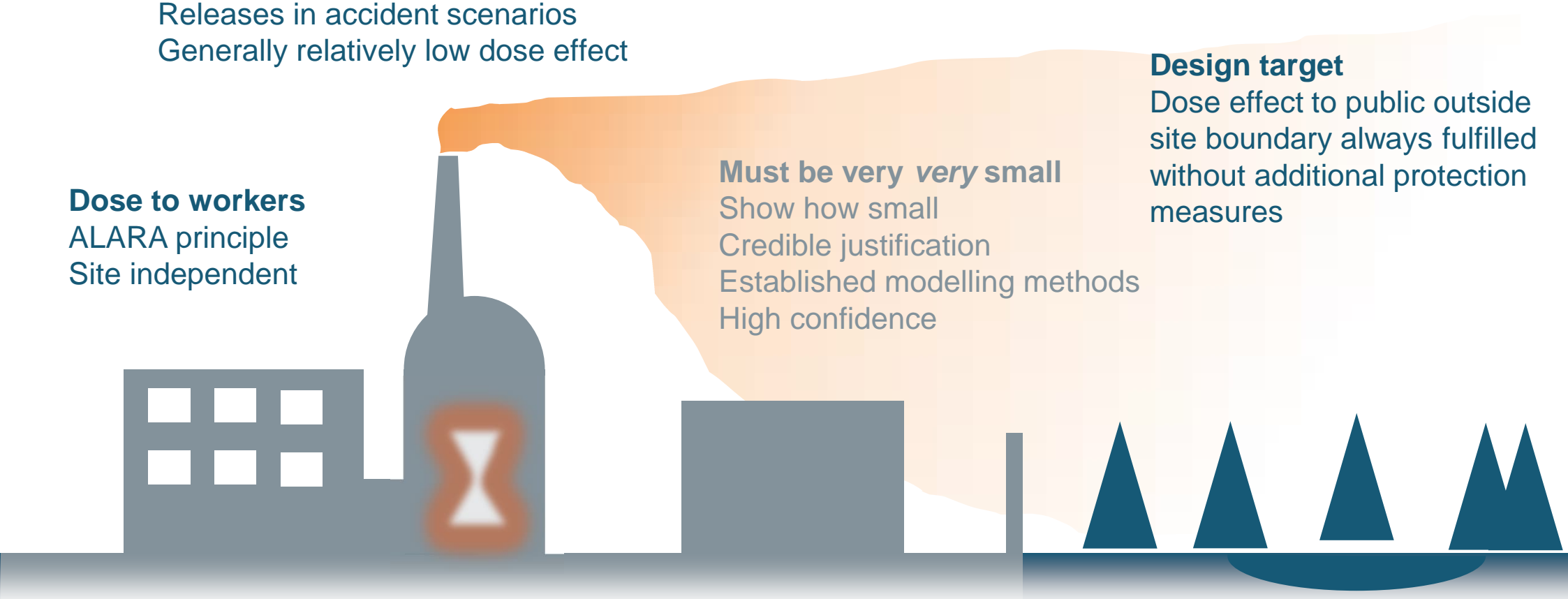
**Dose to workers**  
ALARA principle  
Site independent

## Must be very very small

Show how small  
Credible justification  
Established modelling methods  
High confidence

## Design target

Dose effect to public outside  
site boundary always fulfilled  
without additional protection  
measures





# Future Fusion Research Landscape Looks Super-Exciting with All the New Private Sector Players Combined with the Public Effort – We Will Know If, How and Who Will Get the Holy Grail of Fusion in the Next Two Decades

By primary HQ

