Alternative Fusion Concepts

Roger Jaspers

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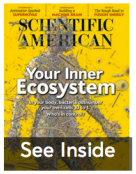

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On the road to unlimited energy, the world's most complex science experiment encounters a few potholes

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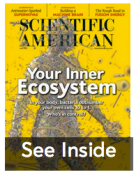

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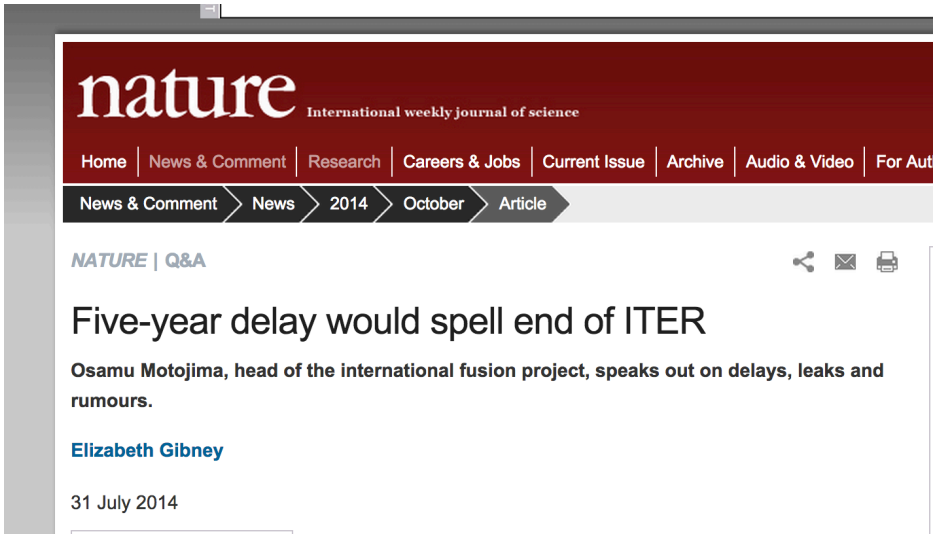

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NATURE | Q&A

Five-year delay would spell end of ITER

Osamu Motojima, head of the international fusion project, speaks out on delays, leaks and rumours.

Elizabeth Gibney

31 July 2014

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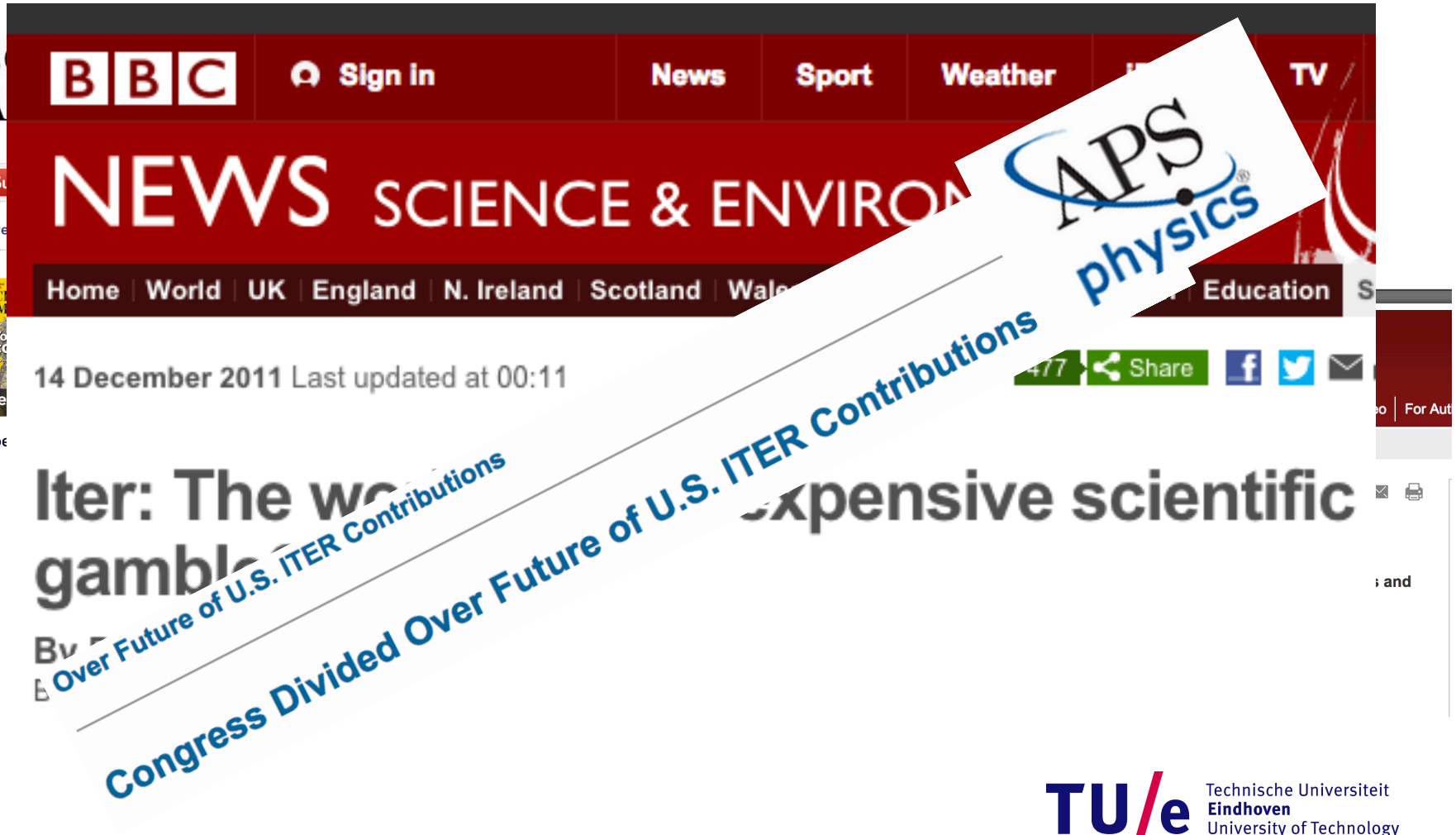

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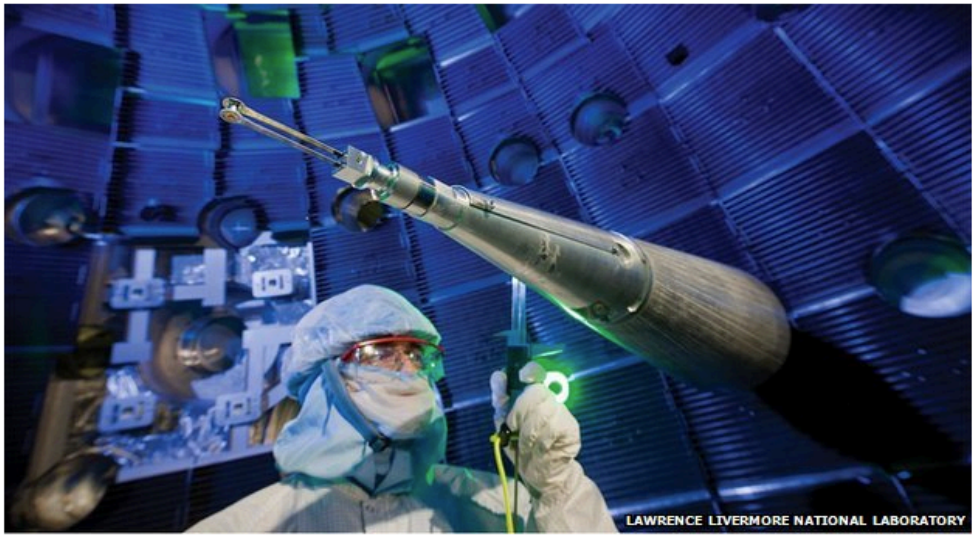
Laser fusion experiment extracts net energy from fuel

Milestone is passed on the long road to fusion energy.

Philip Ball



The achievement is the first of its kind anywhere in the world

Read the news….

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US Teen Builds Nuclear Fusion Reactor in Dad's Garage

Part of the nuclear fusion reactor that US teen Conrad Farnsworth built in his dad's garage.

23:40 03/06/2013 © Conrad Farnsworth

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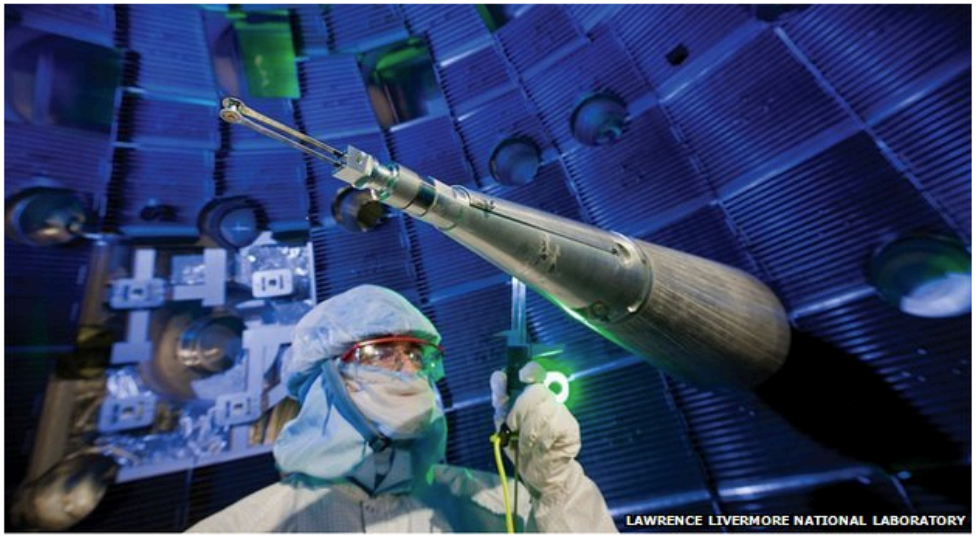

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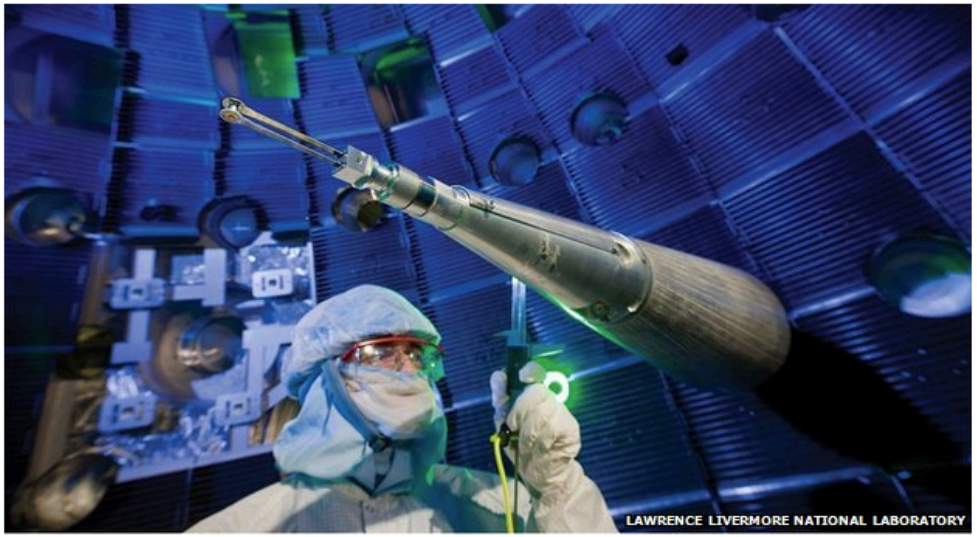

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Mining the Moon for Helium-3

The achievement is the first of its kind anywhere in the world

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Nuclear fusion breakthrough: US scientists make crucial step to limitless power

Published time: February 13, 2014 01:47
Edited time: February 14, 2014 10:01

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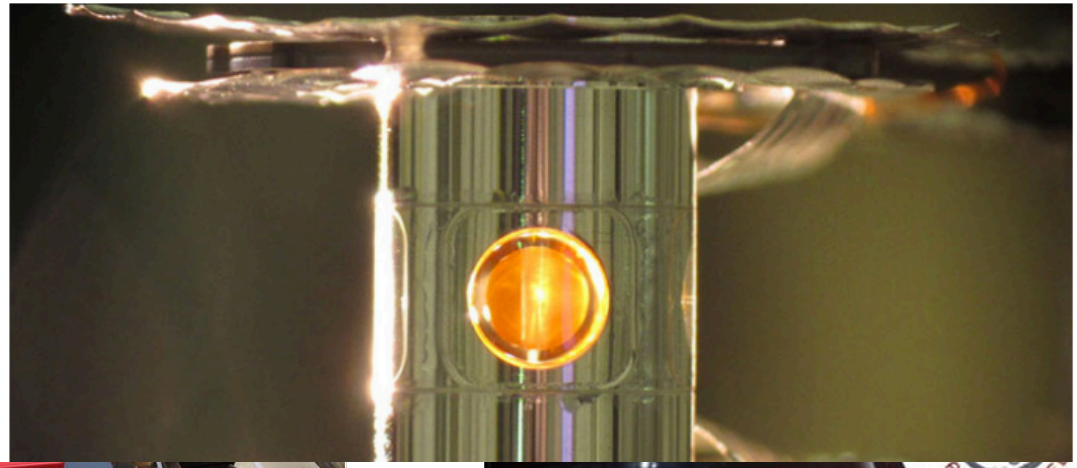

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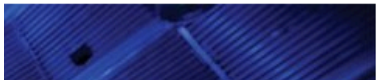
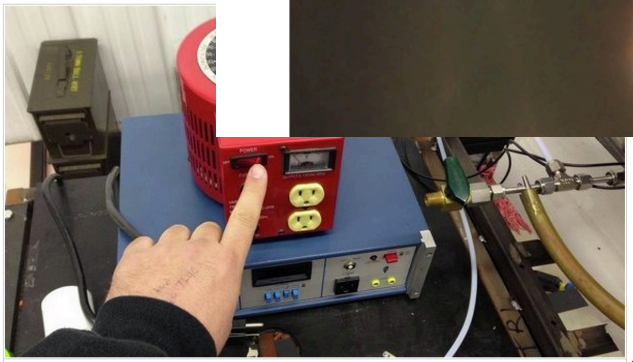
net energy from



US Teen Builds Nu
Garage



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Mining the Moon for Helium-3

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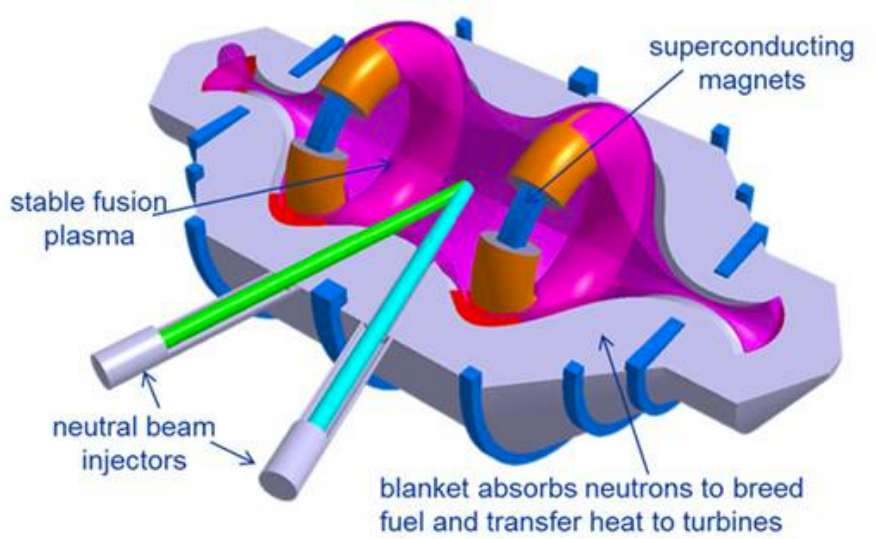
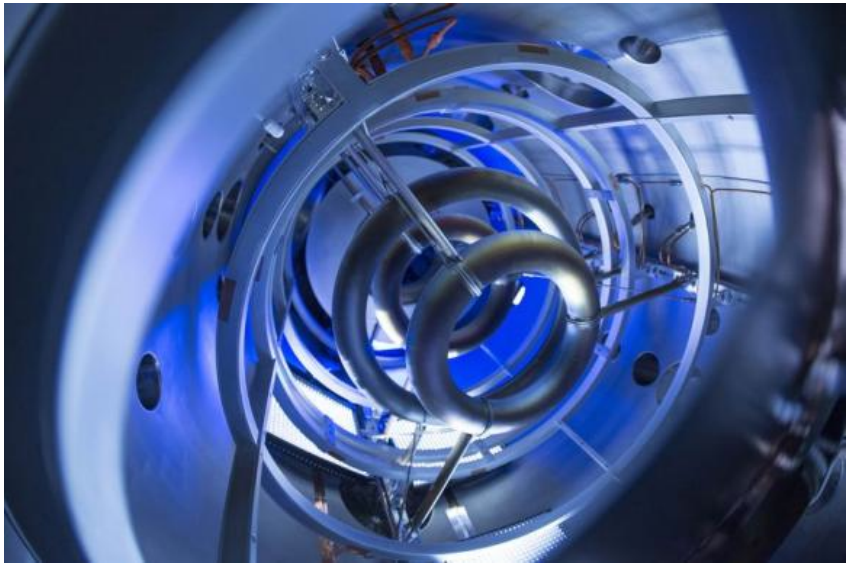
Read the news….(last week)

Lockheed says makes breakthrough on fusion energy project



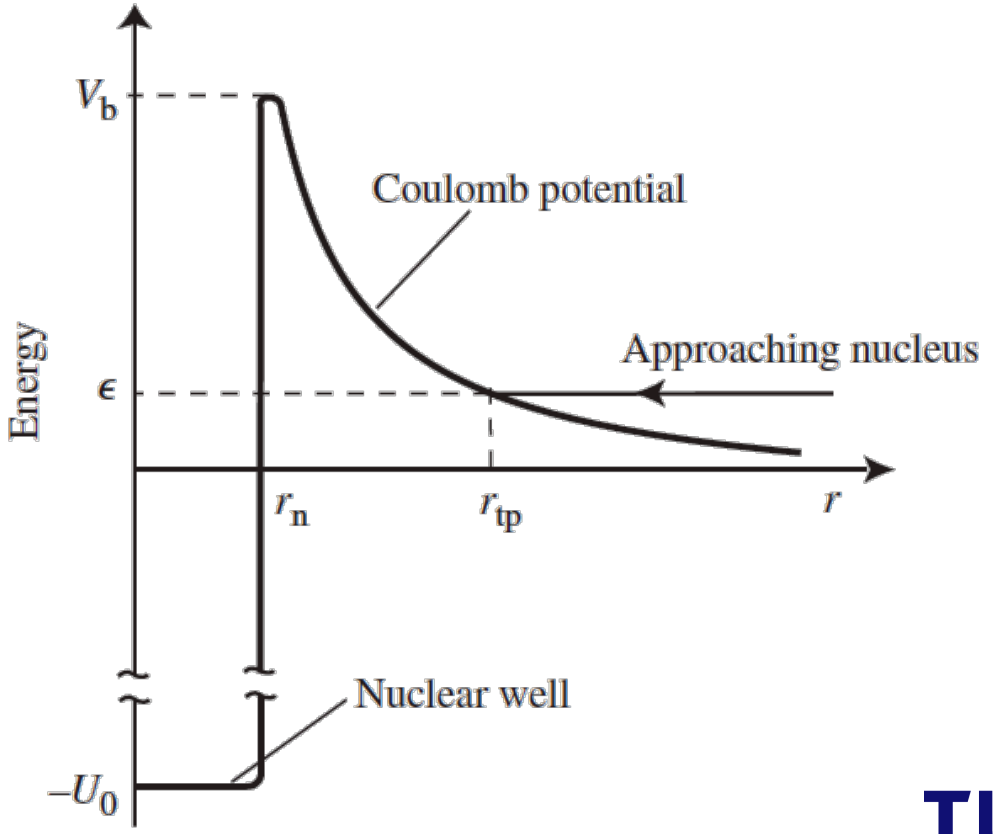


This talk

Can we be smarter than ITER?

Why fusion cannot work….

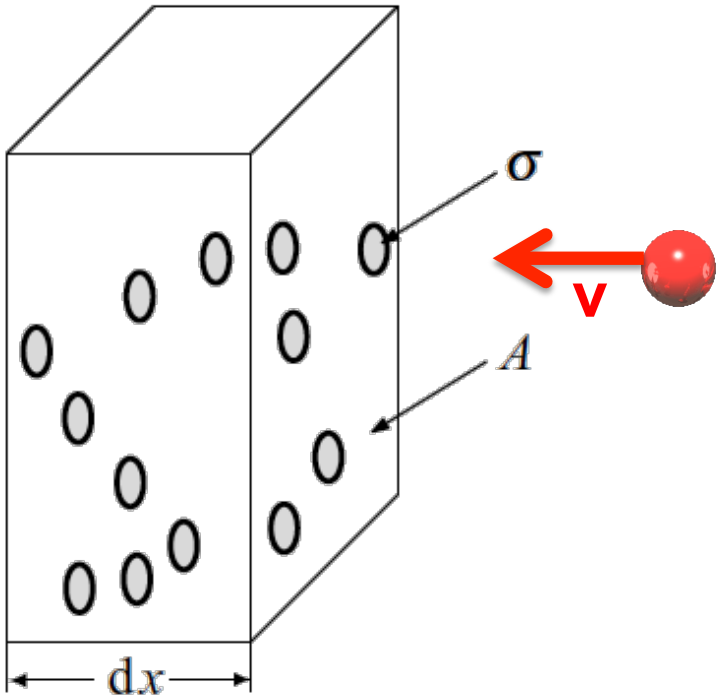
1. High energy needed to overcome Coulomb barrier

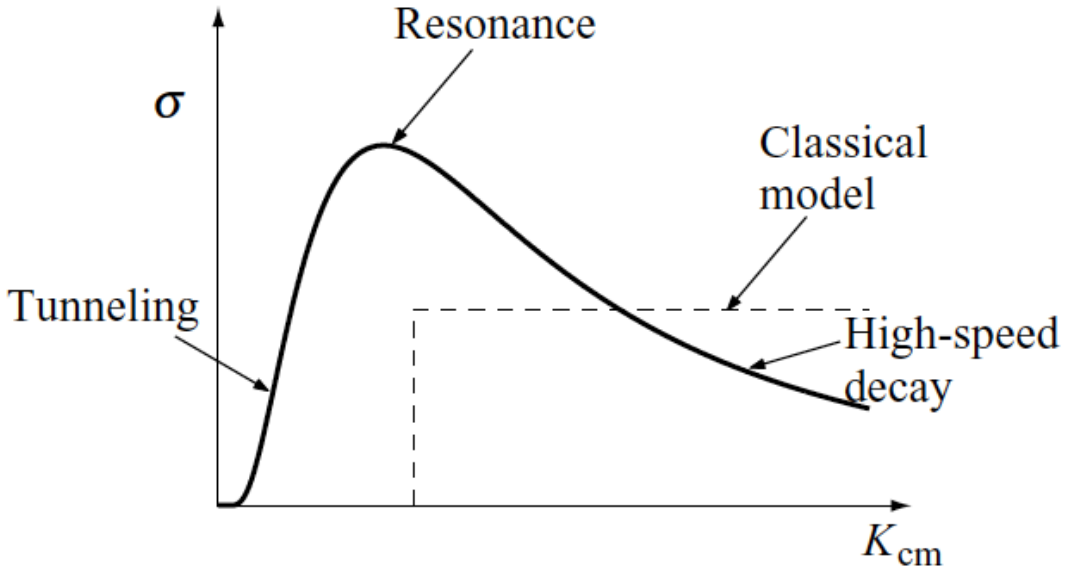


From: Freidberg - PPFE

Why fusion cannot work….

2. Small cross-section σ



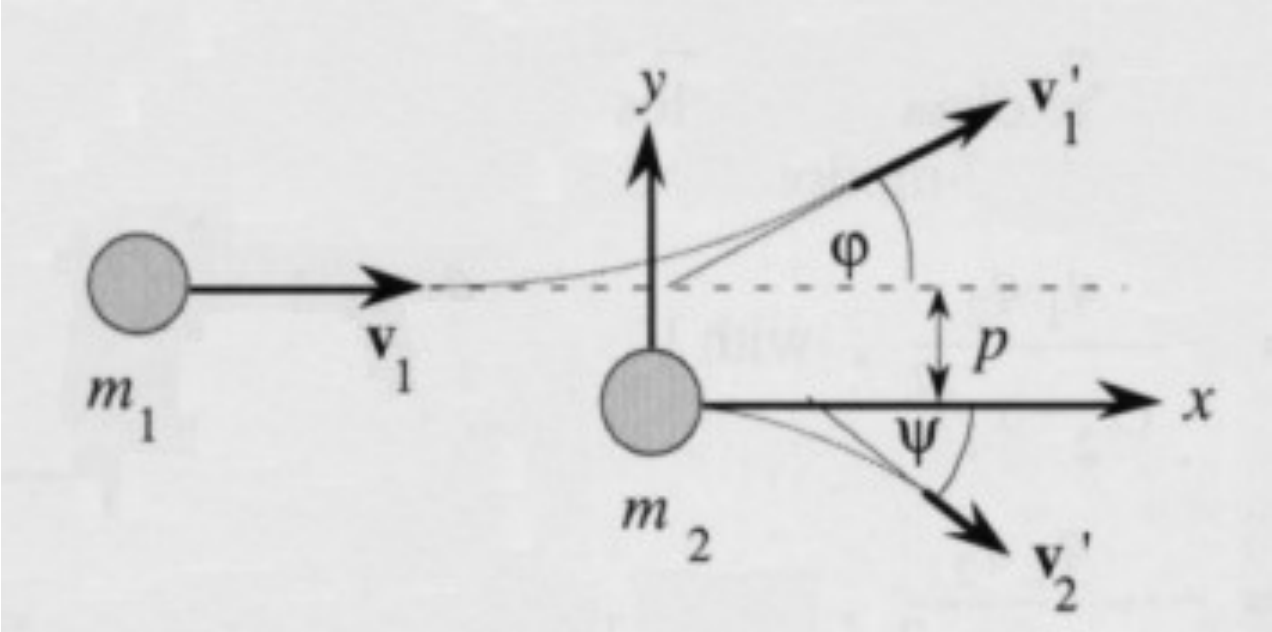


From: Freidberg - PPFE

reaction rate ~ n.σ.v

Why fusion cannot work….

3. Coulomb collision



Why fusion cannot work….

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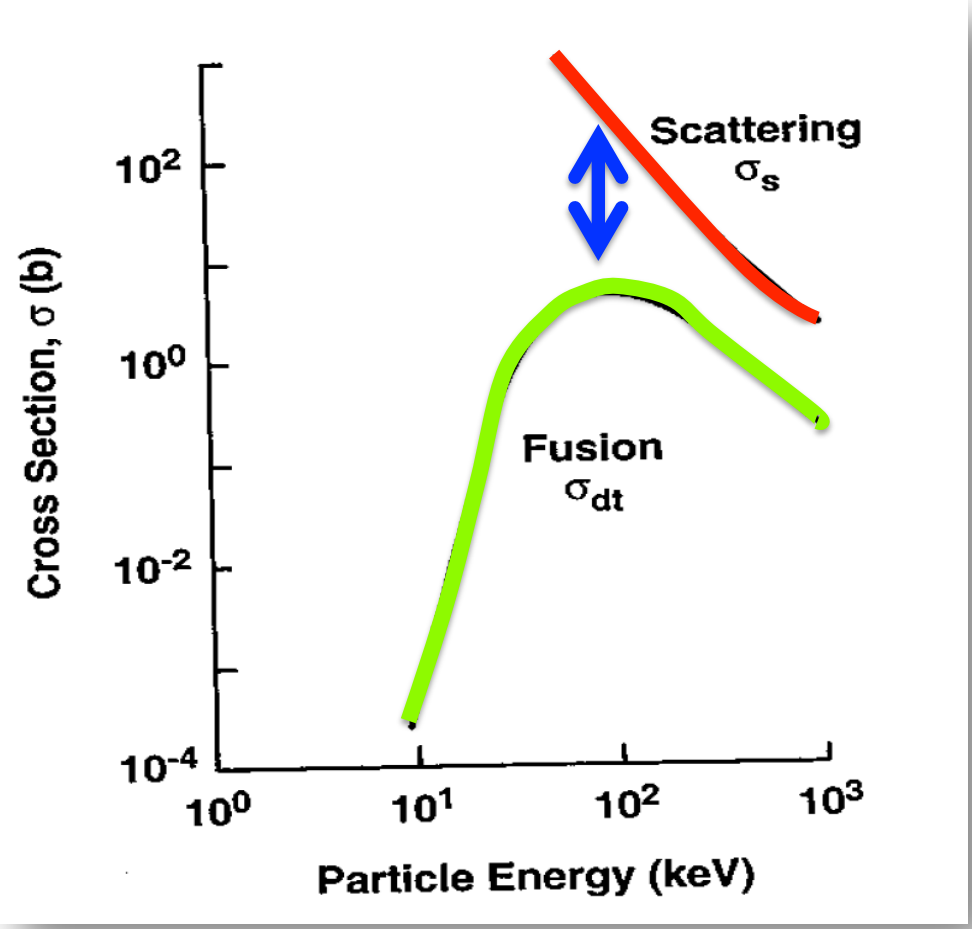
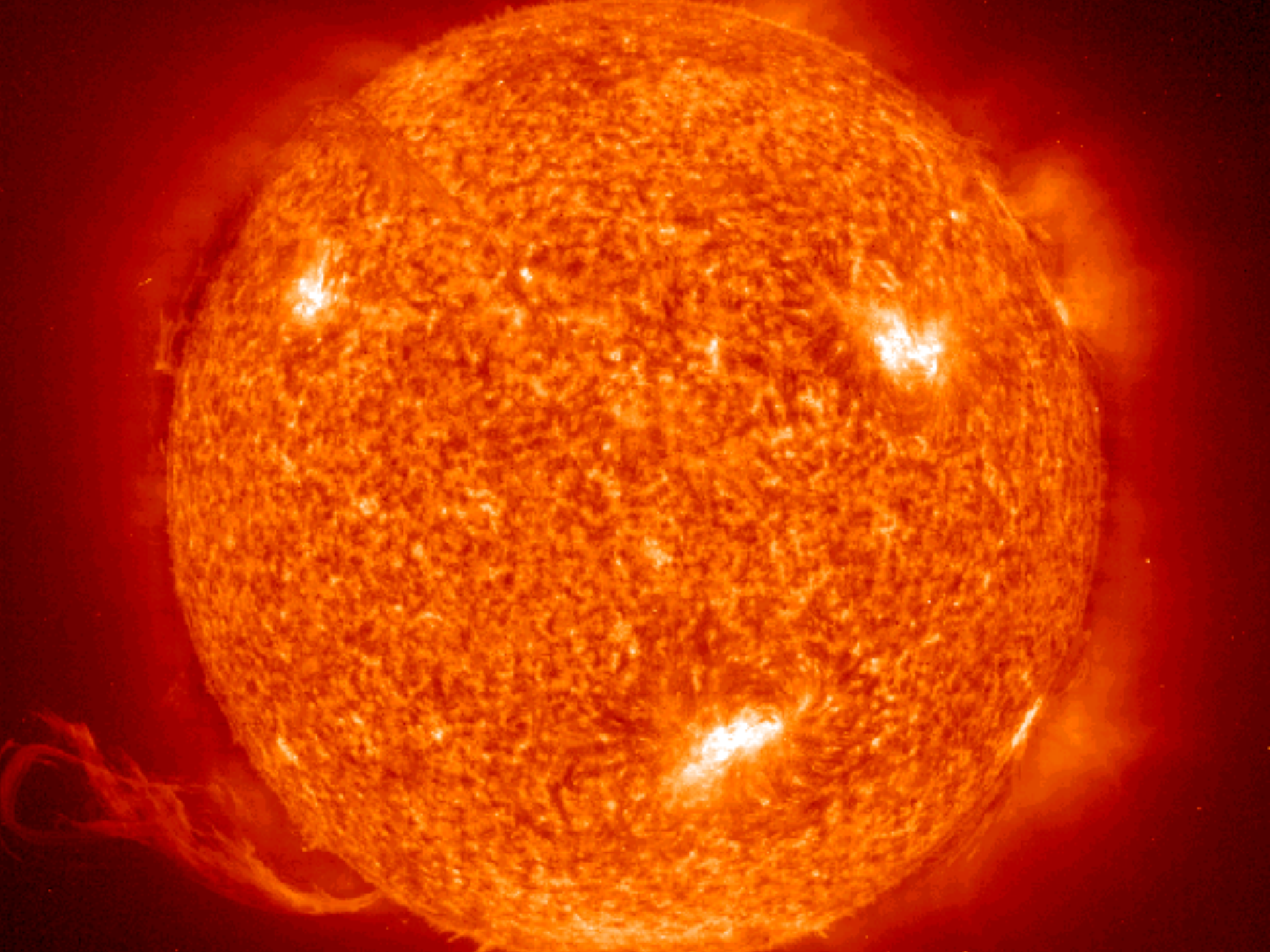
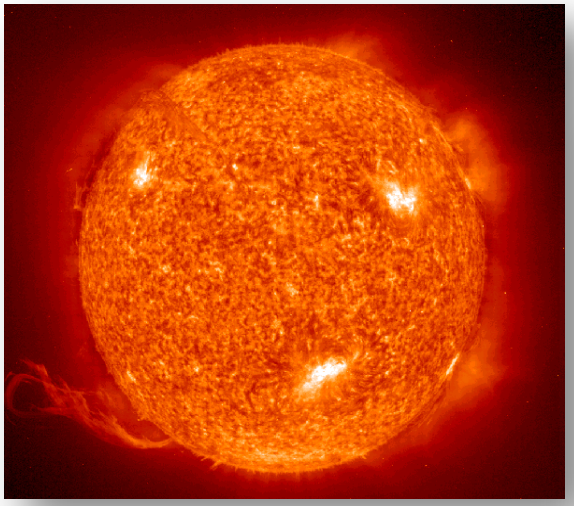




…unless the energy is confined

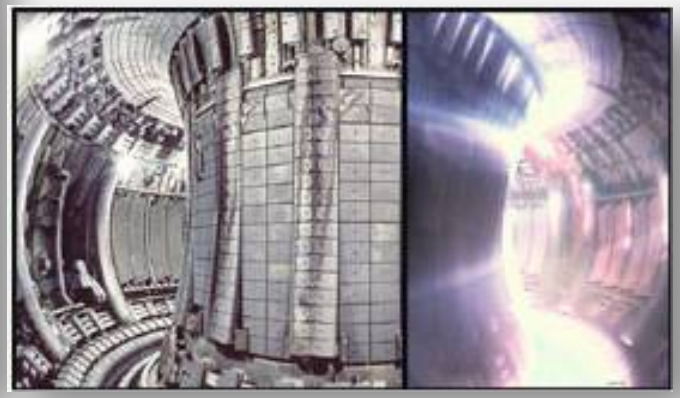
→ Keep energy in the system → confinement

Gravitation



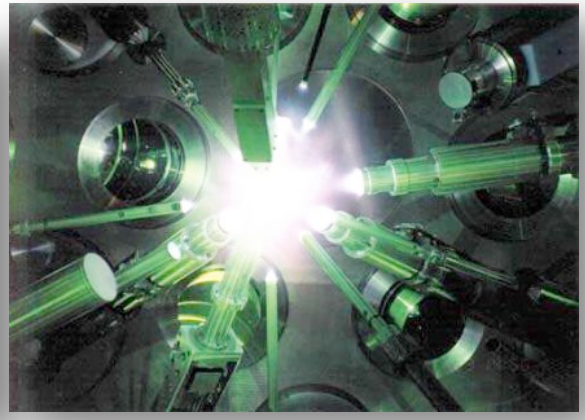
Size:	$1.3\ 10^{8}$ m
Duration:	10^{15} s
Pressure:	10^{9} atm

Magnetic



10 m
10 s
2 atm

Inertial



10^{-2} m
10^{-8} s
10^{9} atm

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Burn Criterion

Fusion Power > Heating Power (= Loss Power)
= energy / energy confinement time

$$n_d n_t \langle \sigma v \rangle E_\alpha > \frac{W}{\tau_E^*} = \frac{3nT}{\tau_E^*}$$

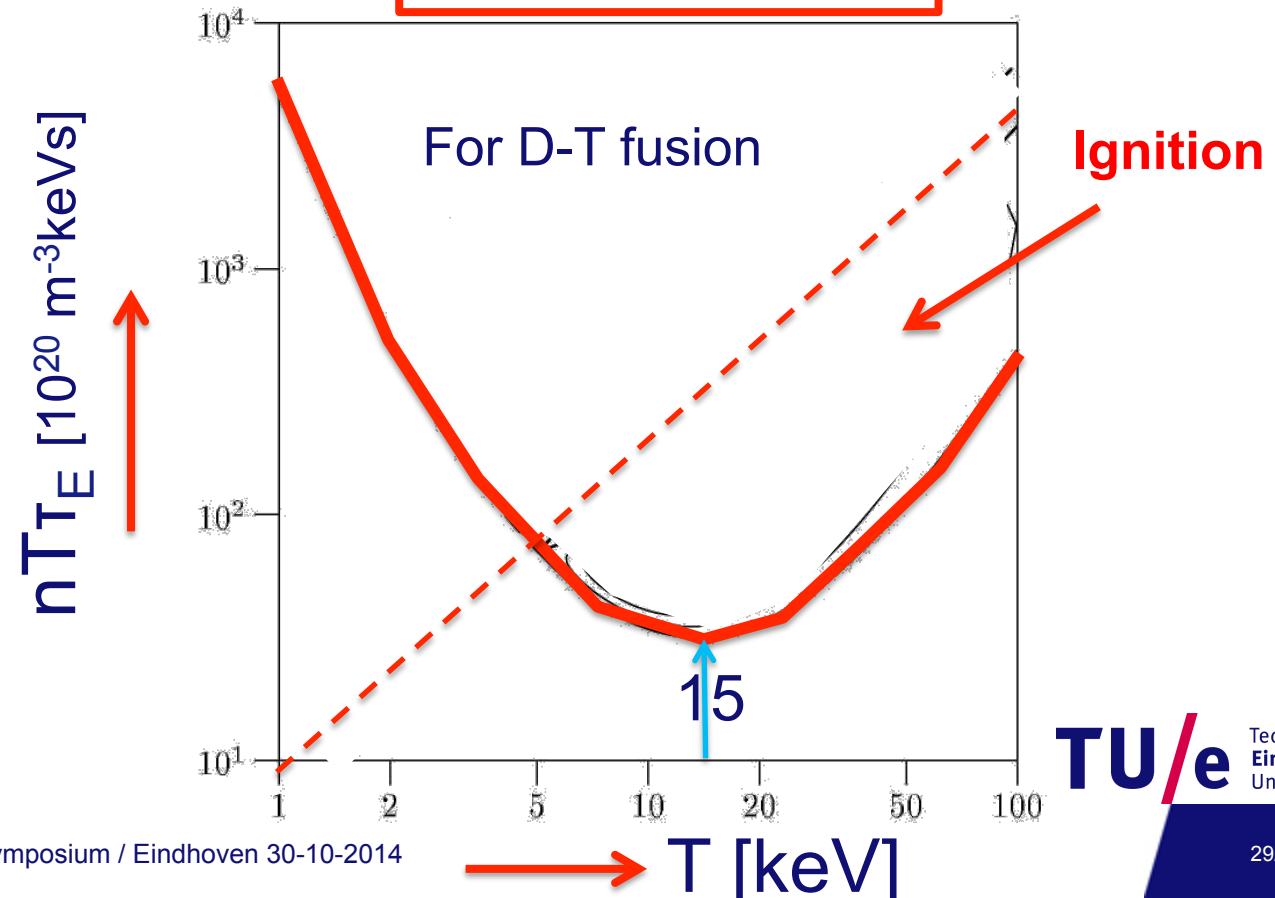
$$\frac{n}{4} \langle \sigma v \rangle E_\alpha > \frac{3T}{\tau_E^*}$$

$$nT\tau_E^* > \frac{12T^2}{\langle \sigma v \rangle E_\alpha}$$

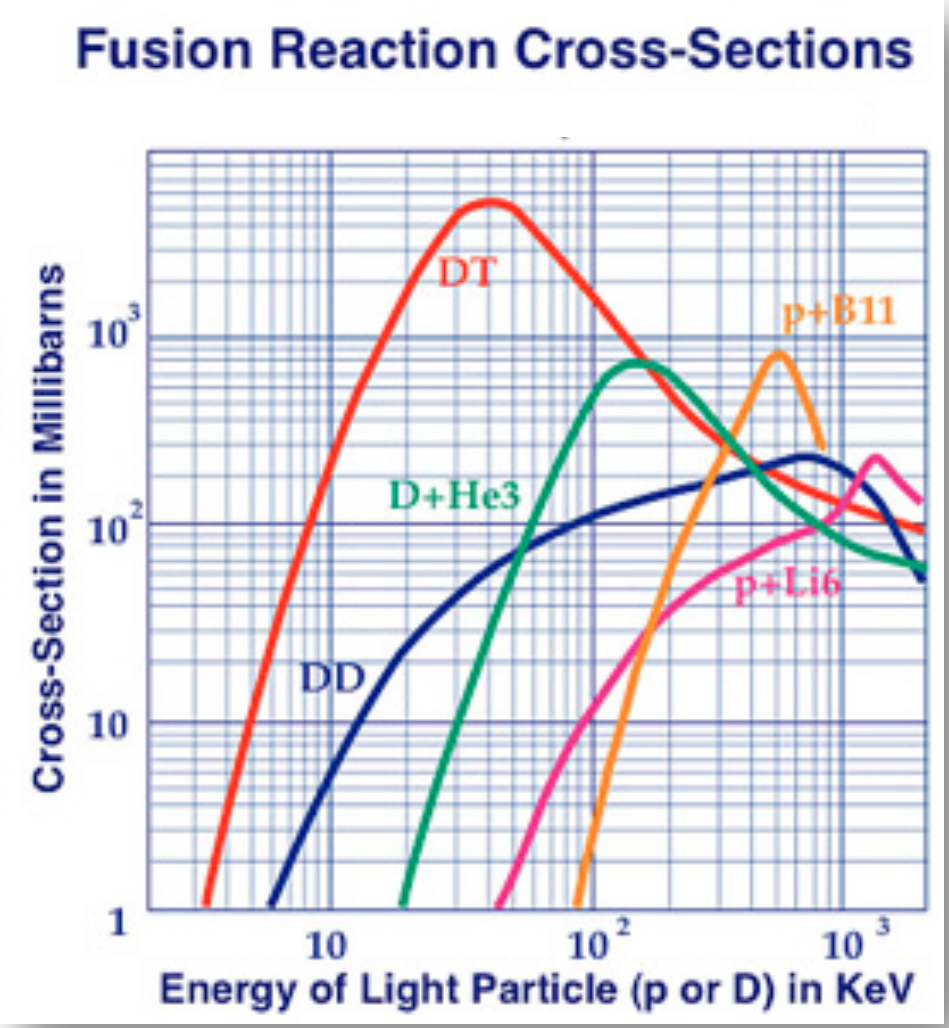
Burn Criterion

Fusion Power > Heating Power

$$nT\tau_E^* > \frac{T^2}{\langle \sigma v \rangle}.Const.$$



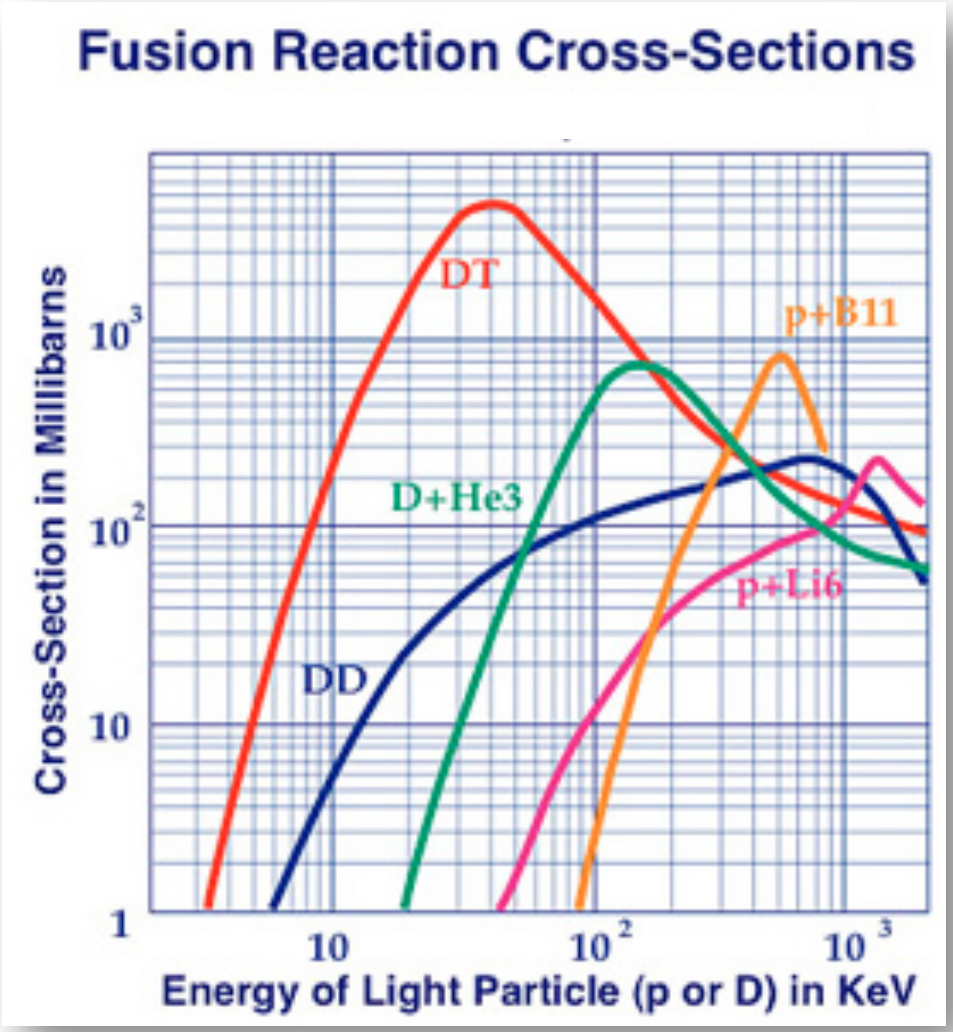
Other fusion processes



Intermediate Summary

- Confinement is needed
- $nT\tau_E$ criterion should be fulfilled
- Optimum temperature = 15 keV (165 million K)
- D-T fusion reaction by far the easiest

A-neutronic fuel



$^{3}He + D \rightarrow {}^{4}He + p + 18.3\ MeV$

$p + {}^{11}B \rightarrow 3\ {}^{4}He + 8.7\ MeV$

Pressure limit

Density lower > 5 x

Cross section lower > 5 x

Fusion power lower > 125!!!

(and losses unchanged….)

Unrealistic as first step.

First demonstrate D-T concept.

A-neutronic fuel

$^{3}He + D \rightarrow {}^{4}He + p + 18.3\ MeV$

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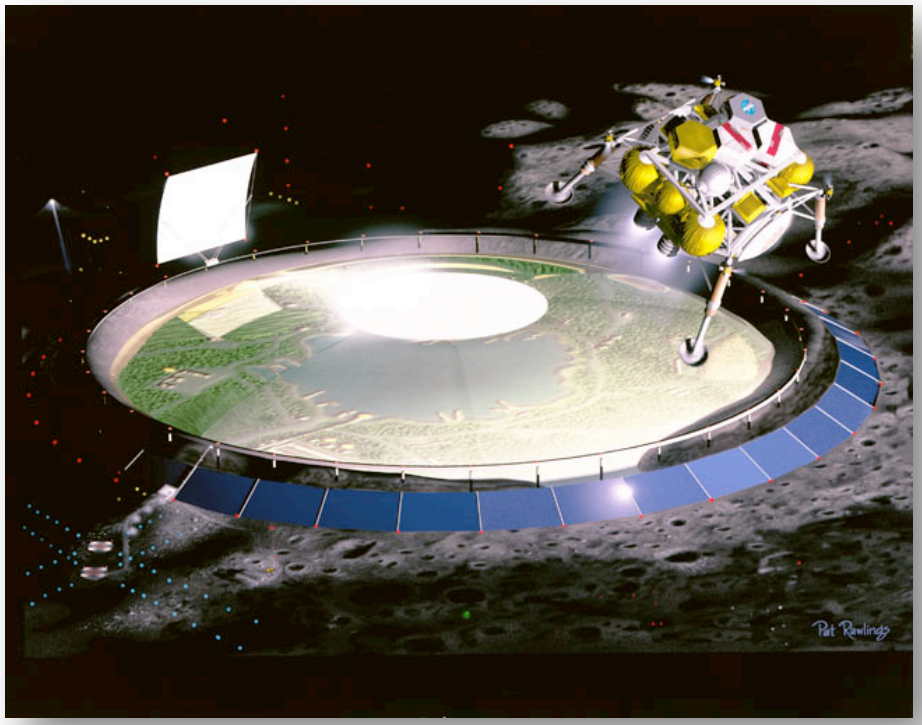


Pressure limit

- Density lower > 5 x
- Cross section lower > 5 x
- Fusion power lower > 125!!!

(and losses unchanged….)

Unrealistic as first step.
First demonstrate D-T concept.

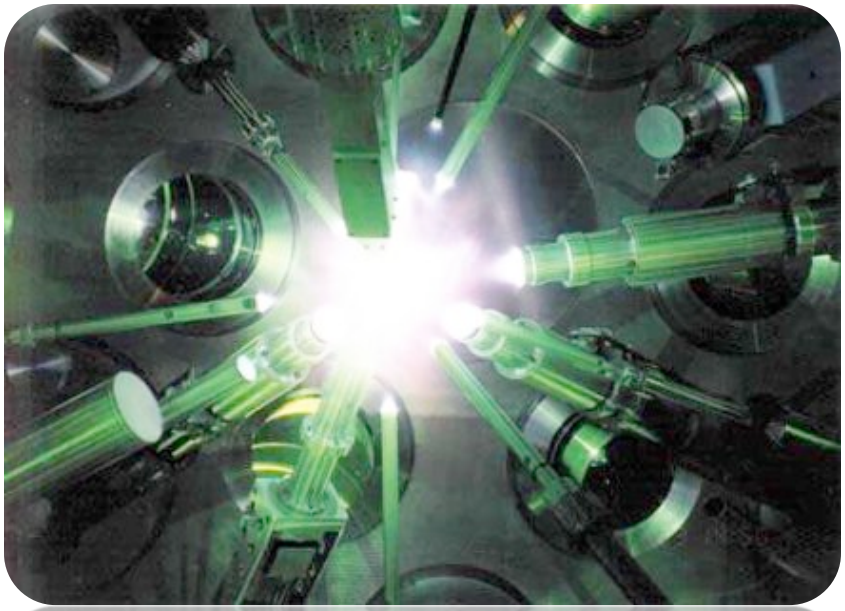
Consequence

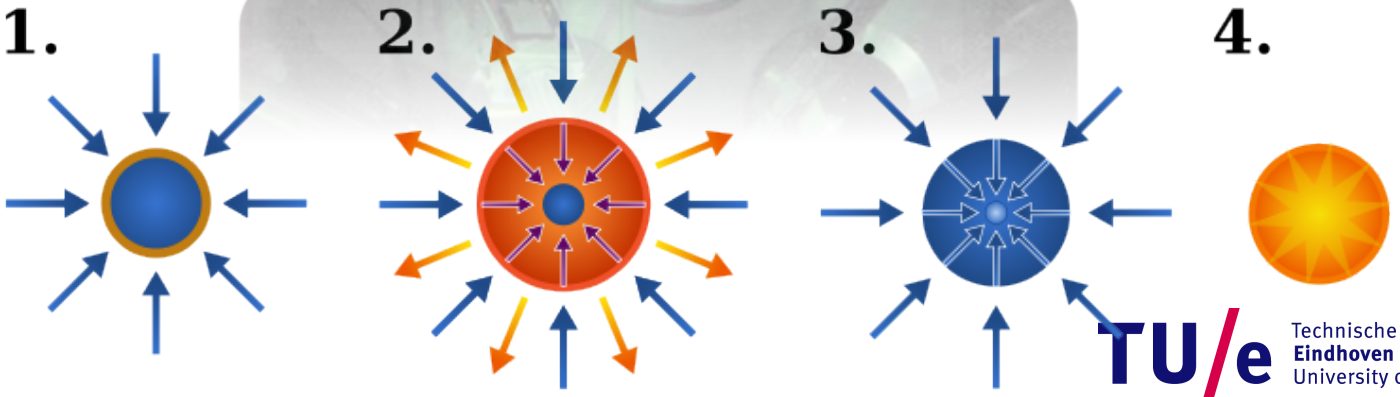
D-T fusion →

1. Tritium has to be bred (n+Li → He +T)
2. Neutron makes this reactor a nuclear facility
   → big facility…

Generic for all fusion concepts!

‘Proven’ to work…: laser fusion





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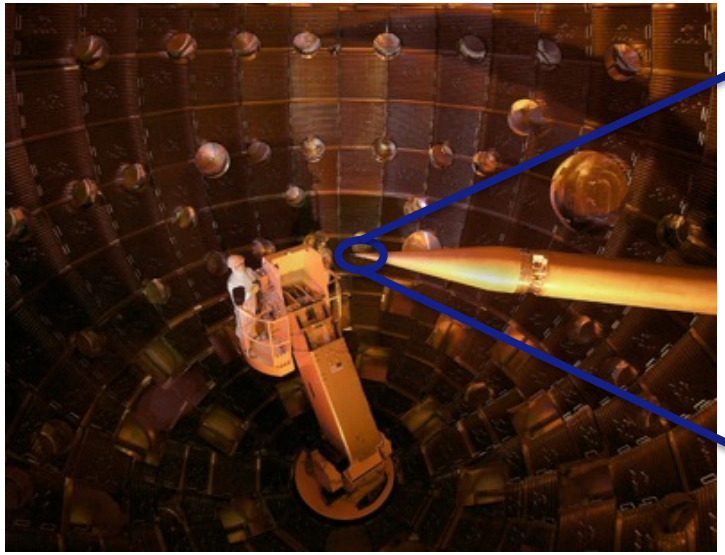
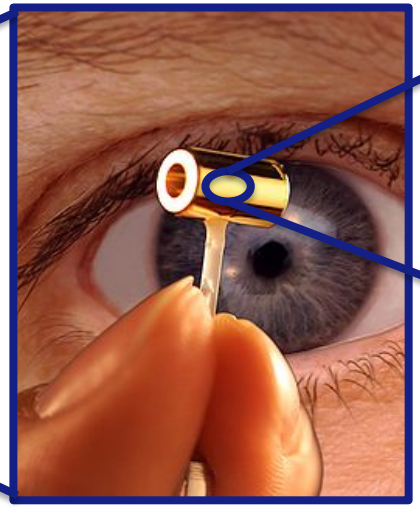
‘Proven’ to work…: laser fusion

Reaction chamber

Hohlraum

Pellet





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‘Proven’ to work…: laser fusion

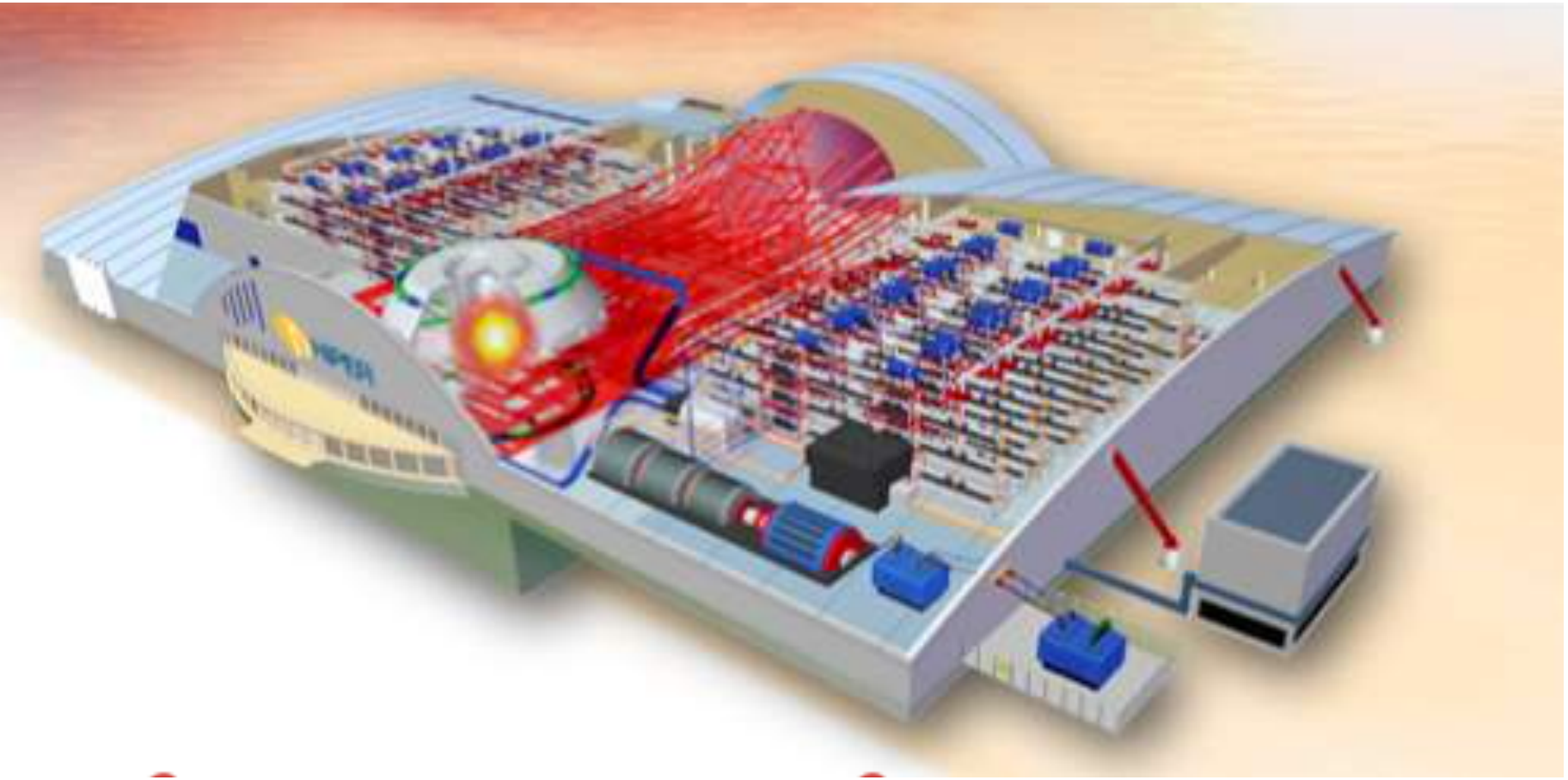
- **Laser efficiency 1 %**
  - **NIF: 500 TW, 4 MJ laser → 400 MJ from grid**
  - **Absorbed laser power < 1 % → 20 kJ**

  - **Max Fusion Power ~ 25 kJ → < 10 kJ to grid…..**

- **Pellet costs : 10.000 $ → 0.1 $**
- **Repetition: 1/week → 10/s**

- **Smarter than ITER…..???**

‘Proven’ to work…: laser fusion

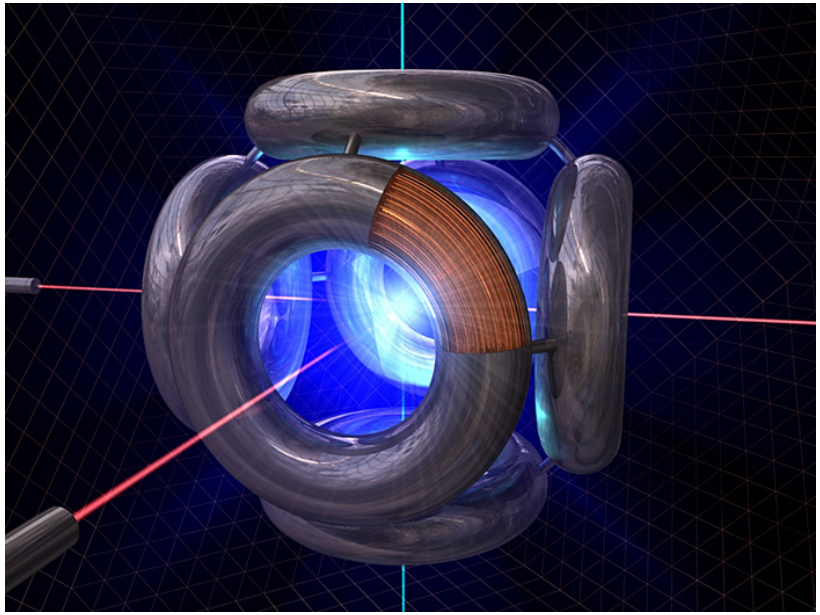


‘commercially’ available…

- **Fusor : electrostatic confinement**

‘commercially’ available…as neutron source

- **Fusor : fundamental issues**
  - **Grid losses → virtual grid**
  - **Sustaining a Non-Maxwellian distribution**
  - **Electron losses**



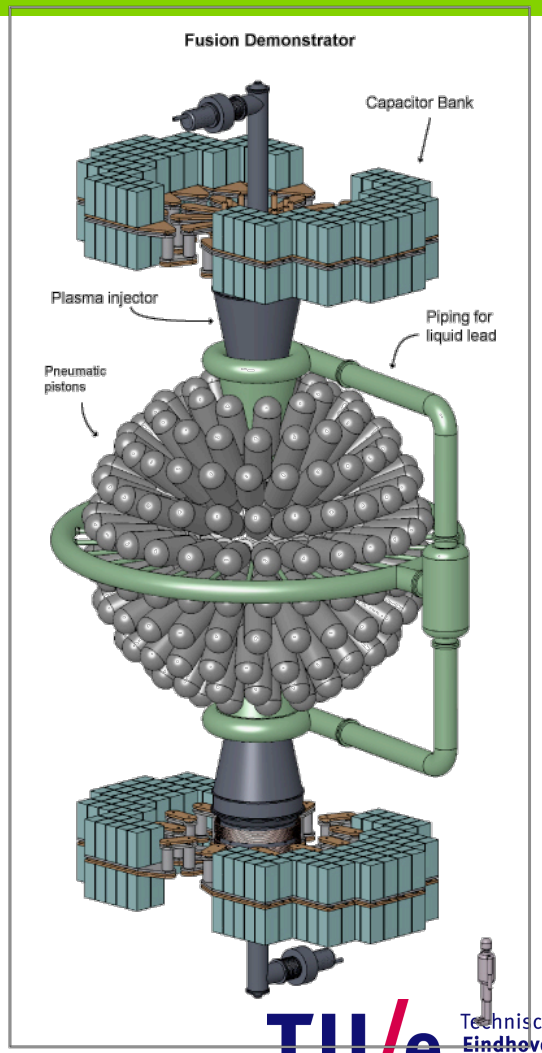
The best of two worlds…??

Magnetic target fusion

magnetic confinement

inertial confinement

Still to be demonstrated…



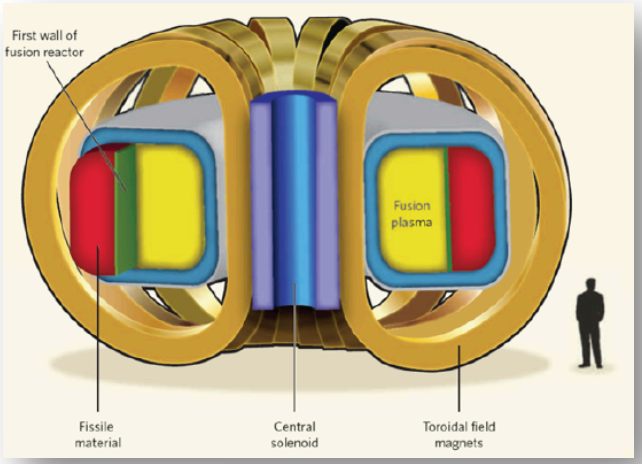
The best of two worlds…??

Fusion – Fission Hybrid

Fusion: 17 MeV / neutron

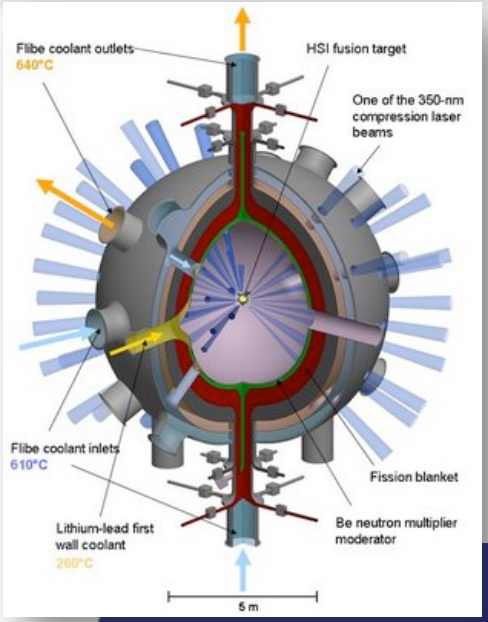
Fission: 200 MeV / neutron

use neutron from fusion for fission !



- → **No chain reaction**
- → **^{238}U fissile**
- → **Waste reduction (by 95 %)**

- → **No ignition needed for Fusion**

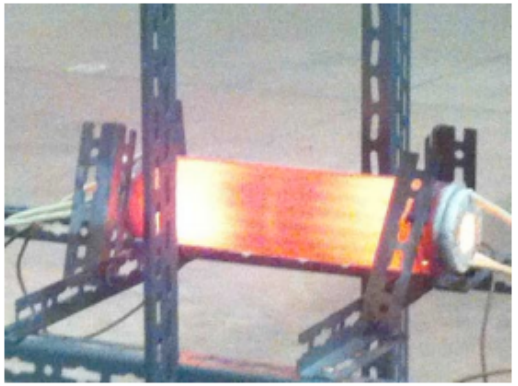


Revival of Cold fusion…??

Low energy nuclear reaction

- The three miracles
  - No radiation
  - No neutrons
  - Why Coulomb barrier penetrated?

- Claim: E-CAT (Rossi): 1 MWh
  - But….Secret



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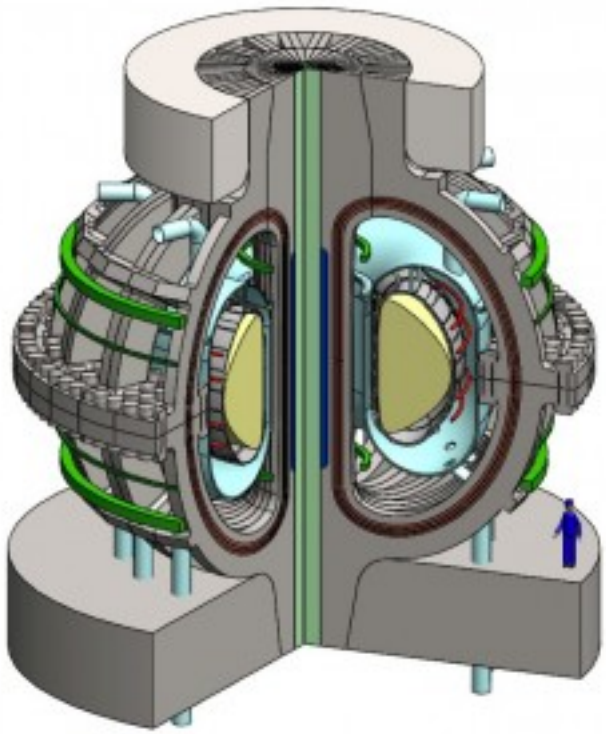
Smaller is better ….(and cheaper)

$P_{fusion} \sim p^2 \times Volume \sim B^4 \times Volume$

$P_{loss} \sim Area$

→ Large machines
→ Larger magnetic fields

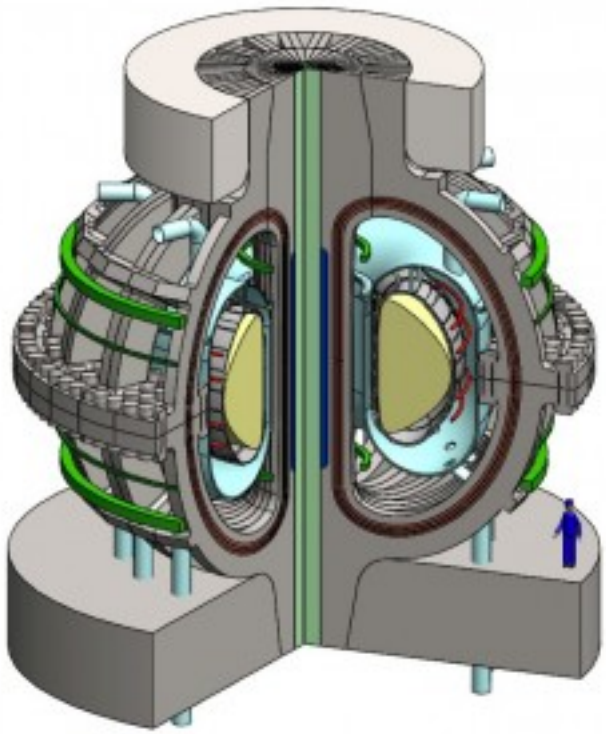
ITER: super conducting → B_{max} – 15 T



Smaller is better ….(and cheaper)

But engineering constraints:

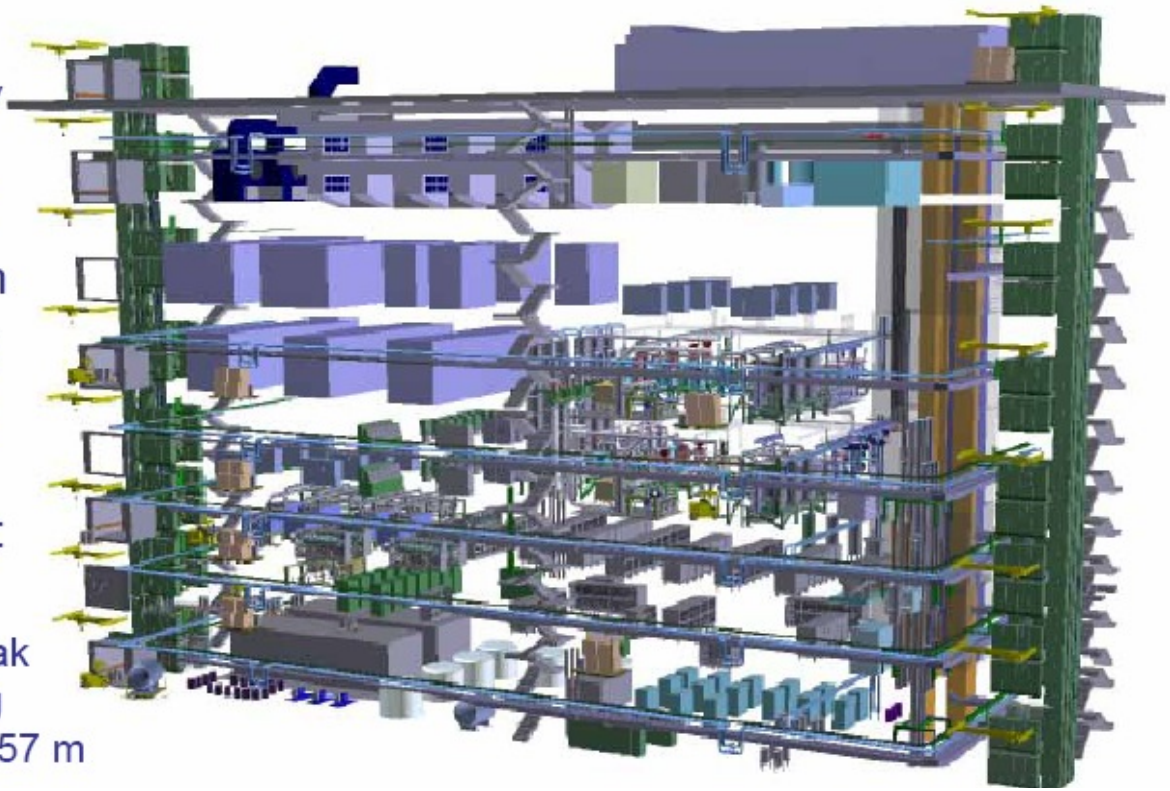
- Neutron stopping and tritium breeding
- Tension in coils
- Superconductivity
- Maximum power loading
- Maximum neutron loading



Just another small problem….

Tritium Plant Building Systems Layout

- 7 Floors
  - 2 below grade
- L = 80 m
- W = 25 m
- H = 35 m
- Release point elevation: 60 m
  - Tokamak building height: 57 m



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Can we be smarter than ITER?

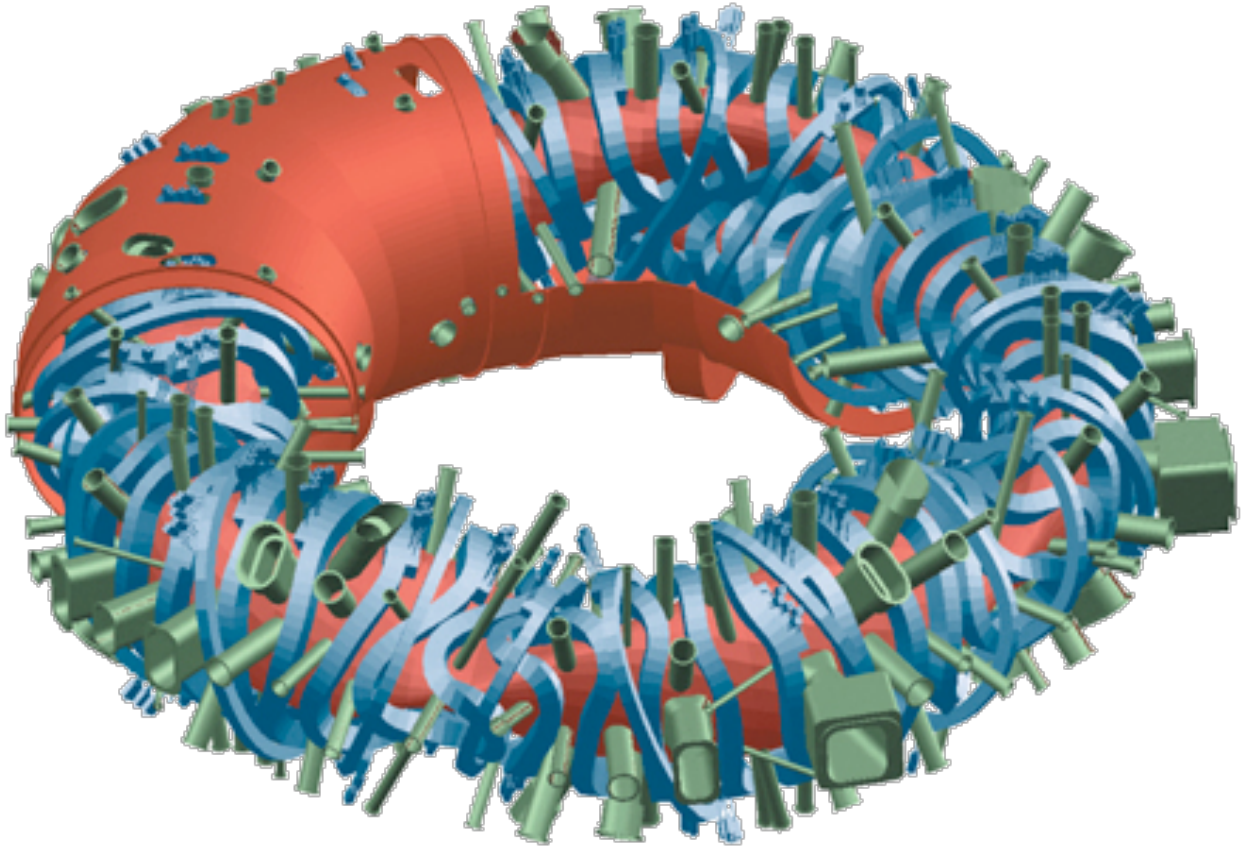
Sure, but…

- Easiest with D-T
- Neutron radiation
- Tritium production
  - → Nuclear device
  - → Big, expensive

Comparable to ITER

ITER is well ahead. Let's first make that a success !

Can we be smarter than ITER?



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