Ignition of a Confined Plasma

Fusion Gain Factor and the Lawson Criterion

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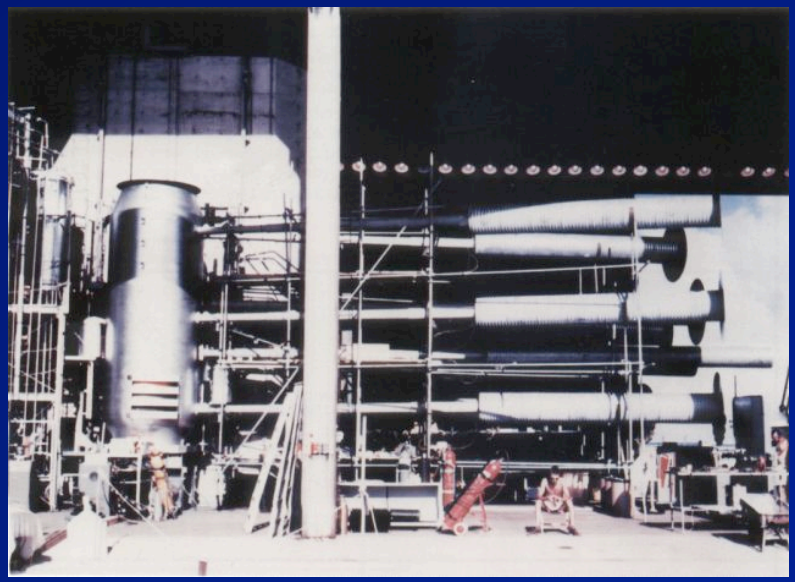
Ignition - unconfined reaction



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"Ivy Mike" The World's first Thermonuclear Explosion

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Teller-Ulam Design
“the secret of the hydrogen bomb”

Fusion Gain Factor

Ratio of power produced by fusion reaction with power needed to heat the plasma

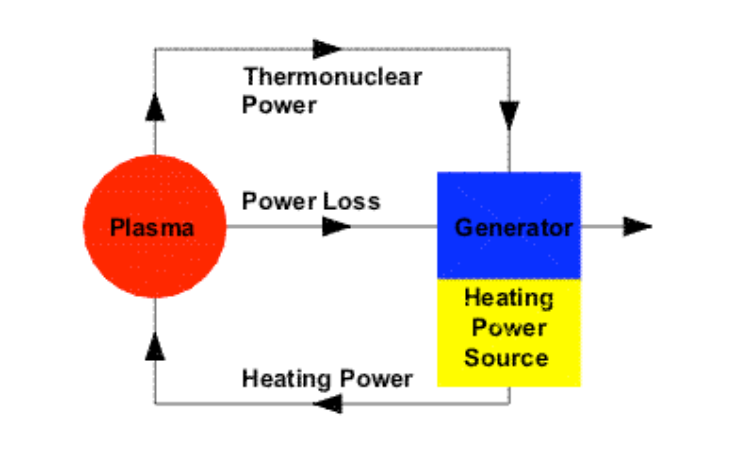
$$Q = P_{fusion} / P_{heat}$$

$Q = 1$ ⟶ Break-even

$Q = 10$ ⟶ ITER

Lawson Criterion

Determines values of the double and triple products needed for the ignition and steady-state reaction of a confined plasma



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Found at http://www.plasma.inpe.br/LAP_Portal/LAP_Site/Text/Conditions_for_Fusion.htm

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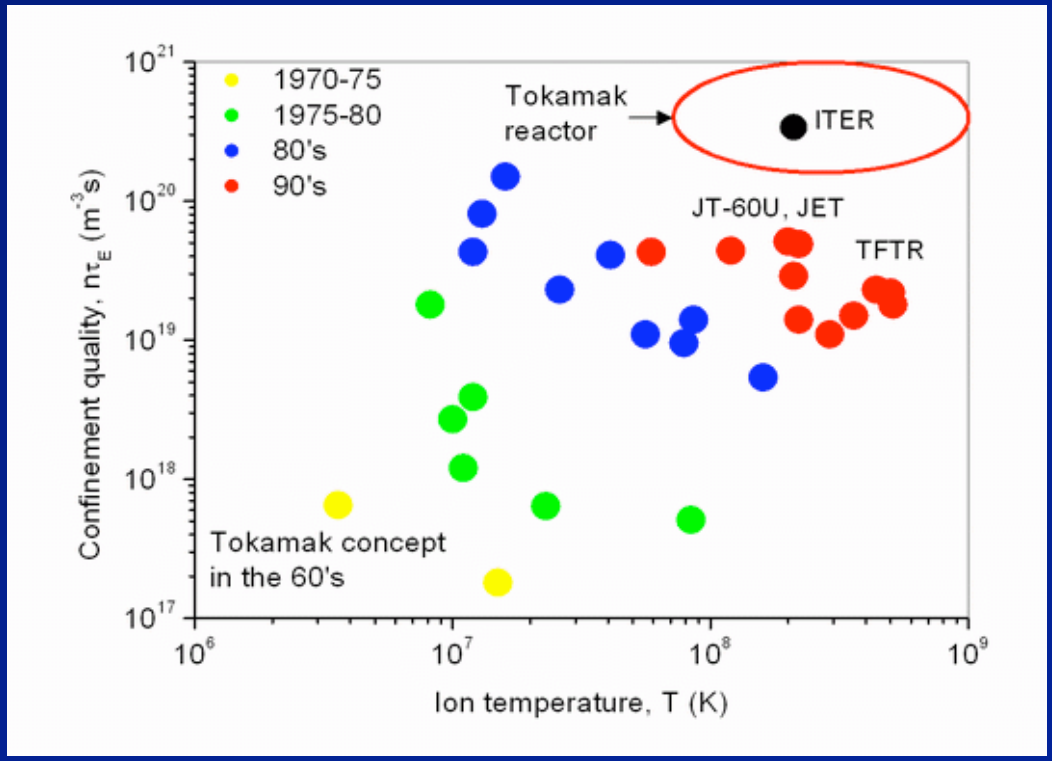
Plasma temperature needed to meet Lawson Criterion

History of tokamaks approaching Lawson Criterion



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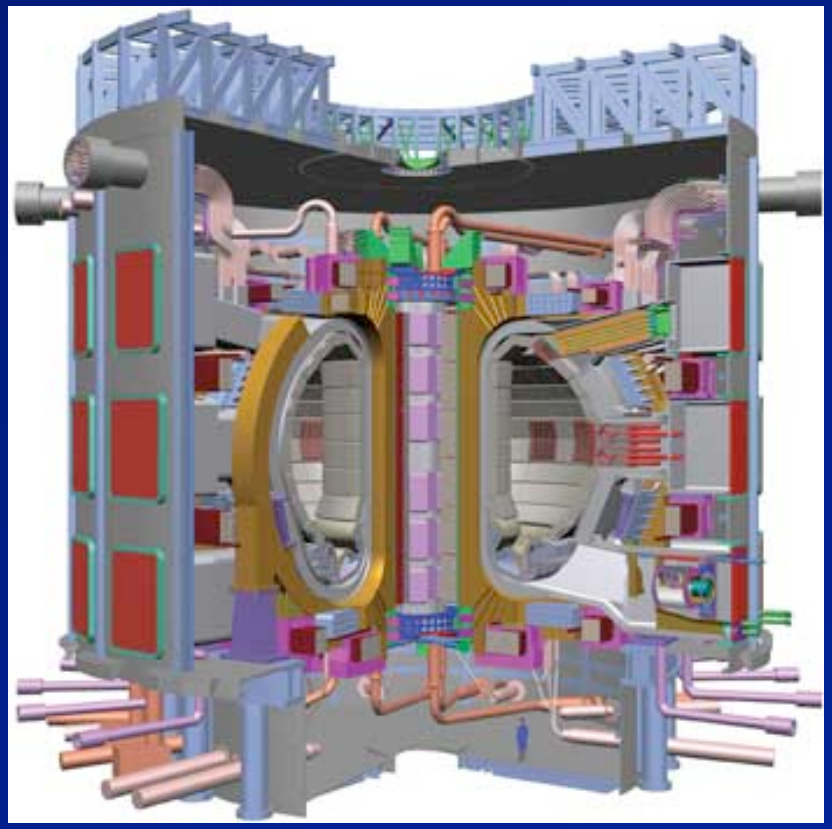
Found at http://www.plasma.inpe.br/LAP_Portal/LAP_Site/Figures/Progress_in_Fusion.gif

Some Difficulties:

- Ability to contain such high temperatures
- Higher T requires more initial power, making it more difficult to reach break-even
- Wall collisions create wave disruptions in the plasma resulting in turbulent transport and more energy loss

ITER

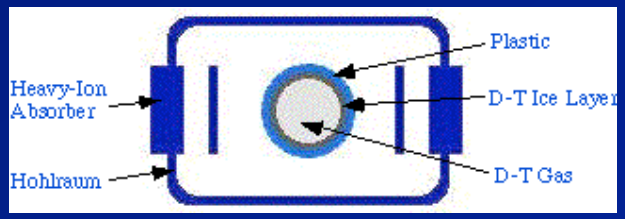
Expected to achieve ignition and steady-state reaction in a toroidal confinement

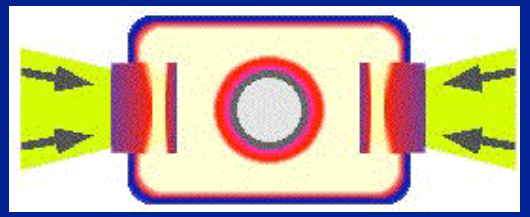


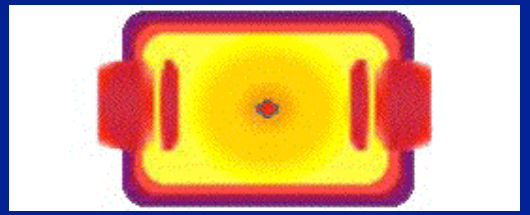
Courtesy of ITER.

Inertial Confinement Ignition

National Ignition Facility







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http://www.llnl.gov/nif/

Courtesy of Per F. Peterson, 1998.

Courtesy of Lawrence Livermore National Laboratory.

The Physics of Plasmas. Boyd, T.J.M., J.J. Sanderson. Cambridge University Press, Cambridge, UK, 2003.

Nuclear Power - fusion. Fowler, T. Kenneth. Reviews of Modern Physics, Vol. 71 No. 2. 1999.

Course Notes: 22.611 Dr. Ian Hutchinson, Massachusetts Institute of Technology, Spring 2003.

http://other.nrl.navy.mil/EnergyOptions/PFP_Dean/PFP_Dean.pdf

http://www.jet.efda.org/pages/faqs

Wikipedia. http://en.wikipedia.org. Lawson Criterion, Fusion Energy Gain Factor.

http://oldwww.cfn.ist.utl.pt/port/expofusao/lawson.gif

http://www.nationmaster.com/wikimir/images/upload.wikimedia.org/wikipedia/en/thumb/8/8c/Teller-Ulam_device.png/360px-Teller-Ulam_device.png

http://upload.wikimedia.org/wikipedia/commons/thumb/6/68/DT_ntauE.svg/250px-DT_ntauE.svg.png

http://www.plasma.inpe.br/LAP_Portal/LAP_Site/Figures/Power_Flow.gif

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