Energy: The Nuclear Perspective

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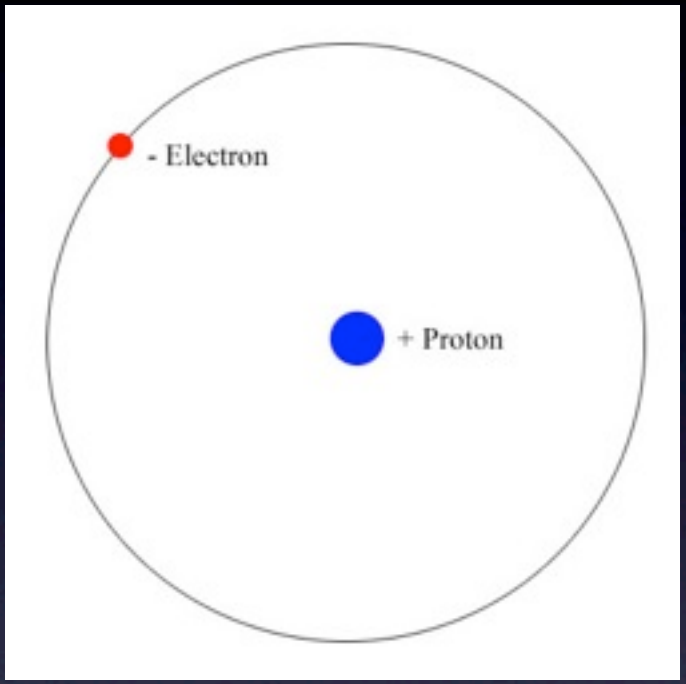
Nuclear Energy

- What makes nuclear energy different from other energies, such as fossil fuels like coal and oil?
- What is the physics of nuclear energy, and why do we wish to use it for energy production?
- Any questions you may have at the beginning of this lecture?

Chemical Energy Densities



Chemistry

$U = -e^2/r$

Distance ~ 10^{-10} m

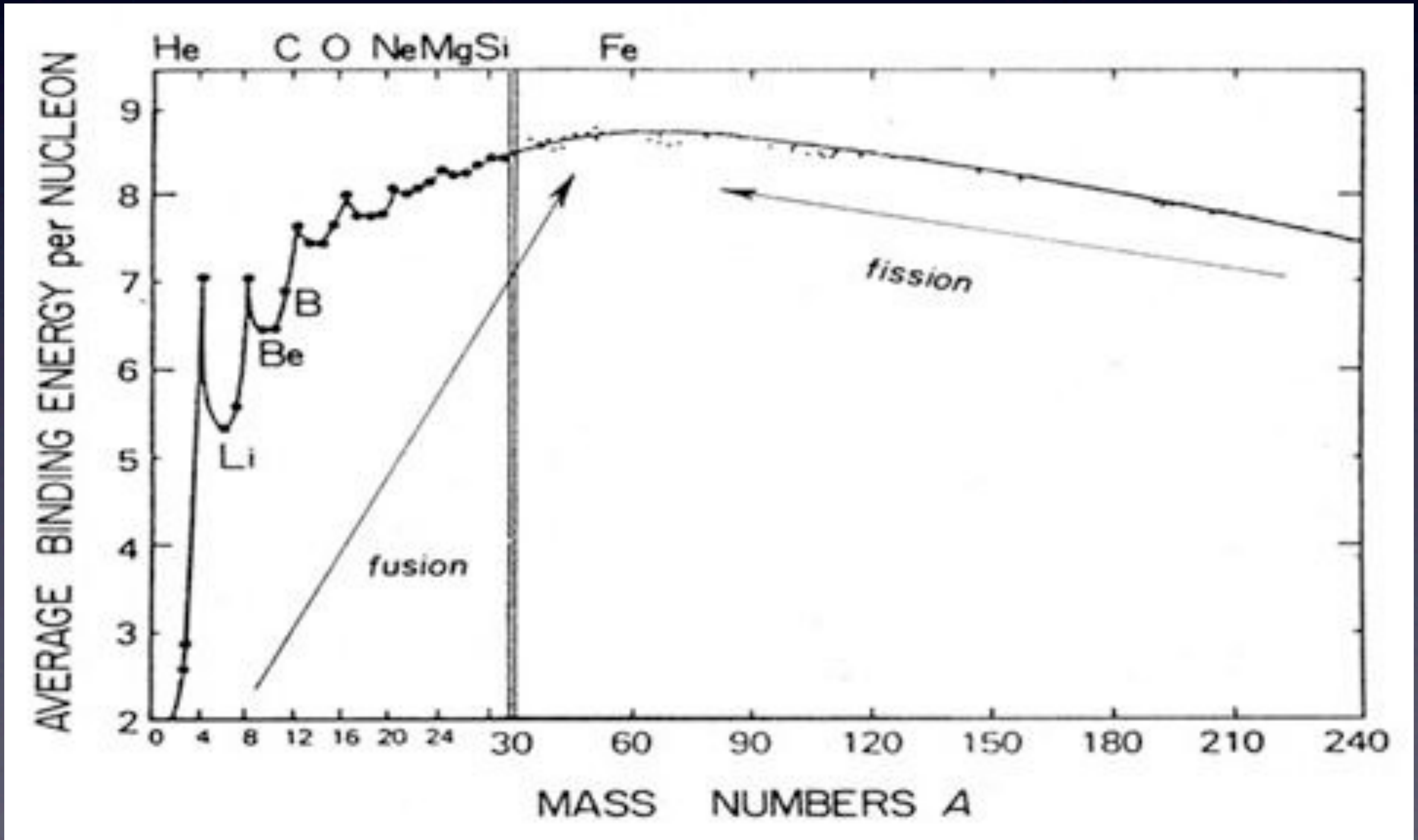
Order of Magnitude ~ eV

The maximum energy for any chemical reaction, which involves the rearrangement of electrons, is on the order of electron-volts.

Energy Density ~ 30-40 MJ/kg

$E = mc^2$

Energy-Mass equivalence tells us that mass is able to be "converted" into energy.



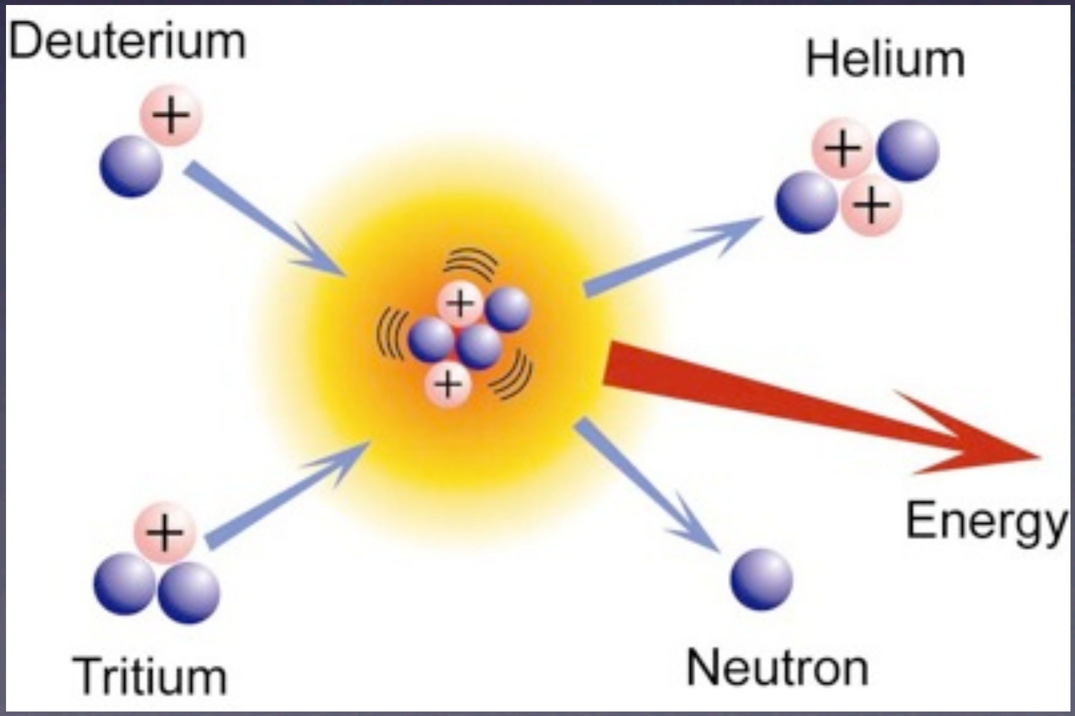
Nuclear Energy Densities

- *Fission:* The splitting of heavy nuclei, normally with the introduction of a thermalized neutron into U-235. ~ 88,000,000 MJ/kg
- *Thermonuclear Fusion:* Fusing of light nuclei, like heavy hydrogen deuterium and tritium, in an experimentally created stellar environment. ~576,000,000 MJ/kg

$$U = -e^2/r$$

Distance ~ 10^{-15} m

Order of Magnitude ~ MeV ! A million times greater than chemical reactions fundamentally.

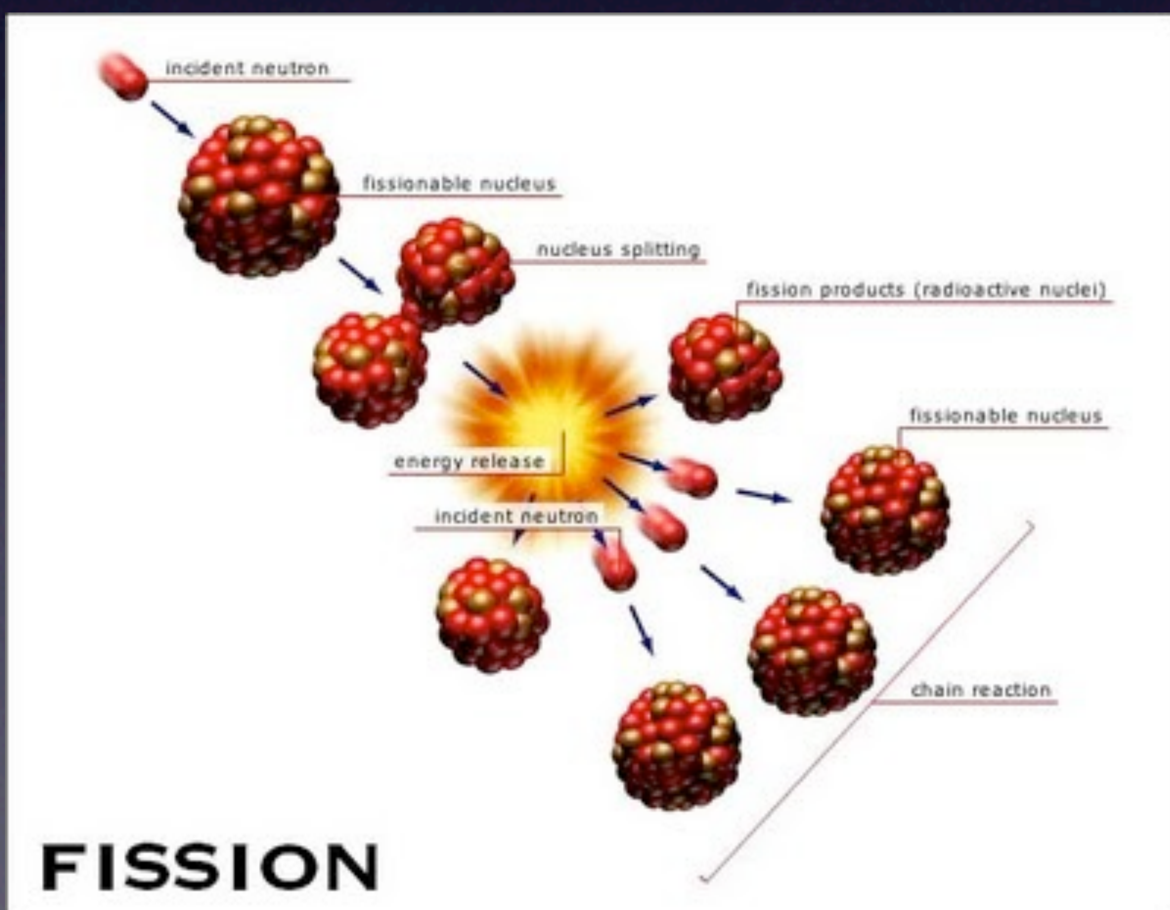


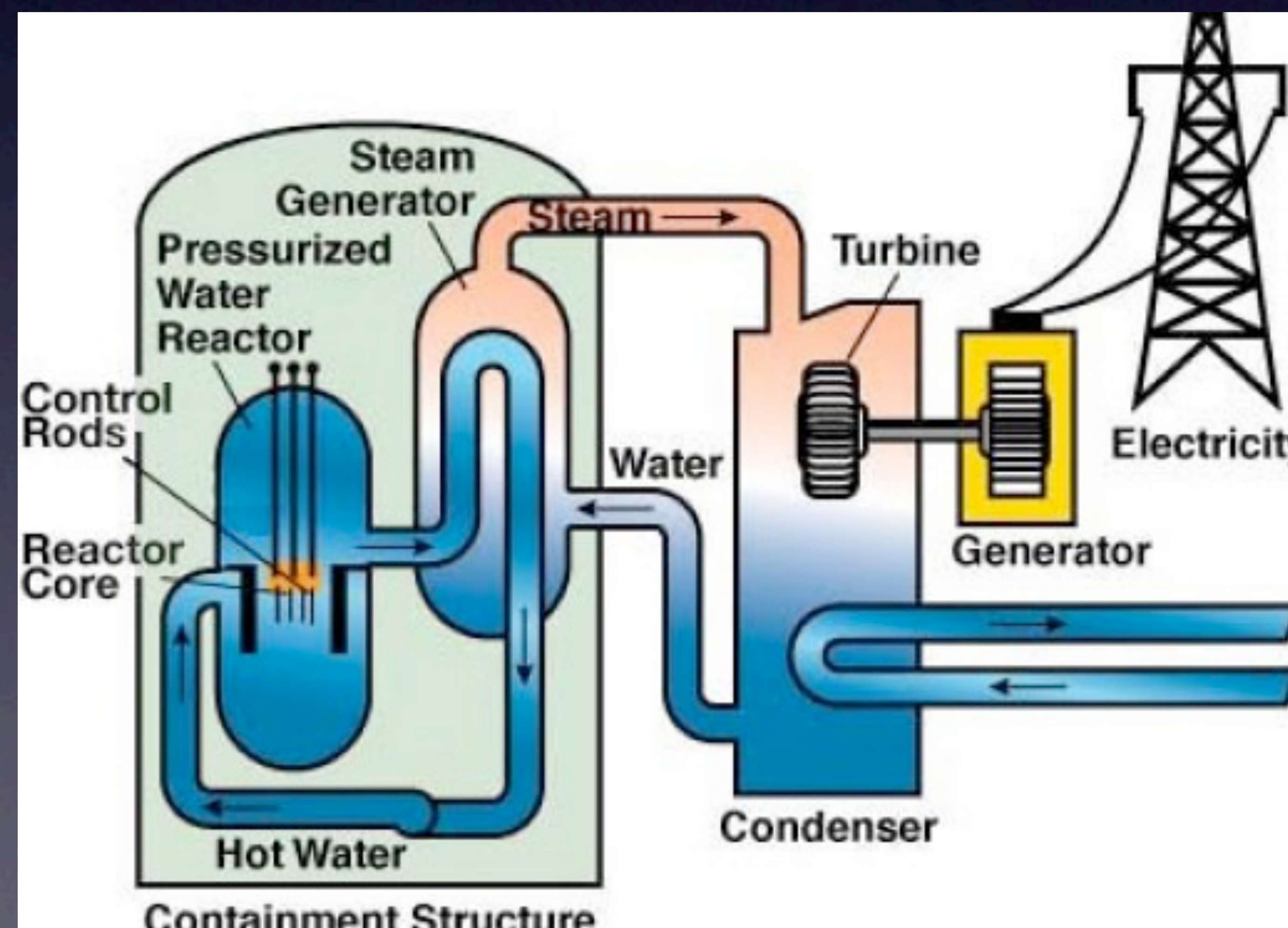
Huge Amounts of Energy

- Obviously, the amount of energy from nuclear reactions cannot be matched by any chemical reaction due to the fundamental length scales over which each interaction occurs.
- This large amount of energy, the plentiful amounts of fuel, and environmental considerations, are why we want to use it for energy production.

Fission Power Plants

- There are many fission power plants working around the world today, with some countries, like France, having roughly 80% of their energy coming from them.





Fission Safety

- Present reactors have many redundant passive safety features that form a negative feedback network, so that if something gets out of line, it drives the reactor to a lower power level and ultimate shutdown instead of a run away power increase, and meltdown.
- The storage of radioactive waste is still a long-term concern.

Fusion Power Plants?

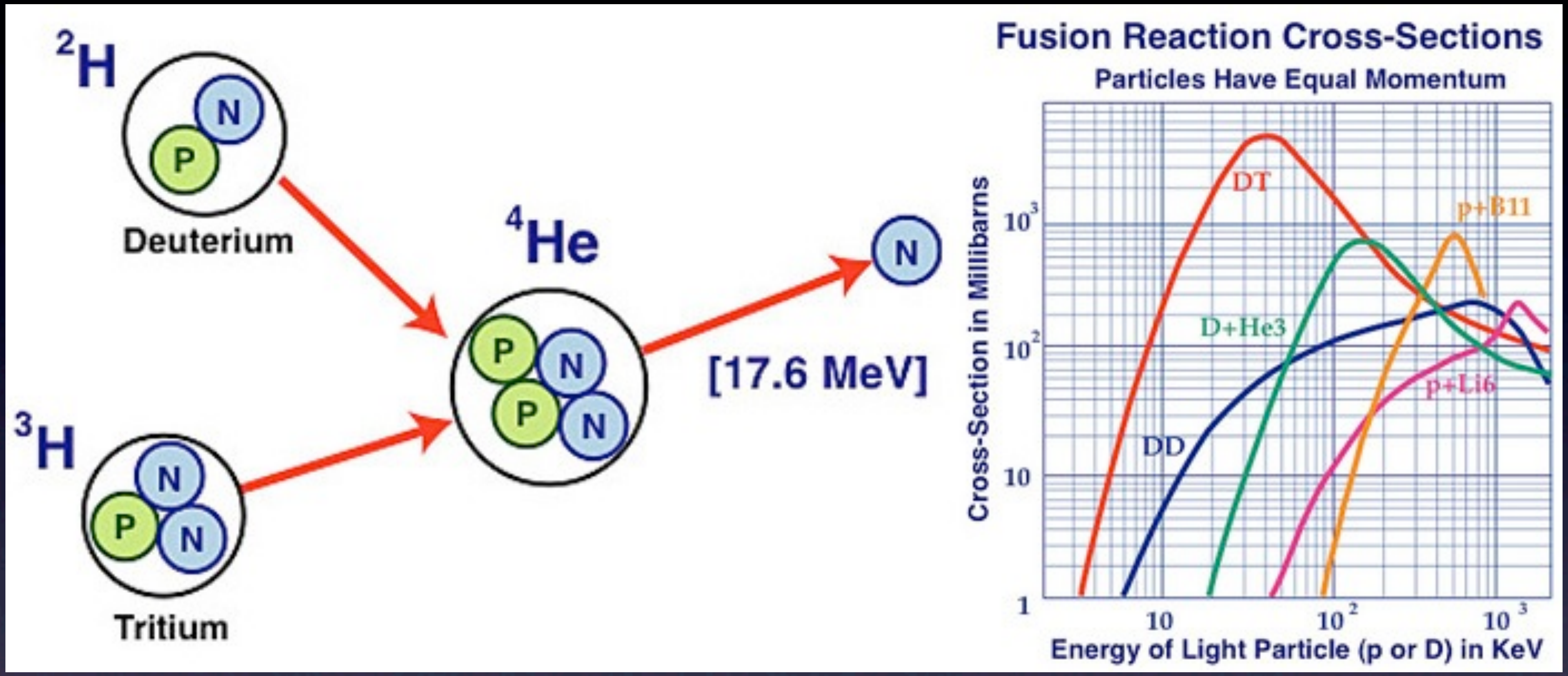
- There are no working commercial fusion power plants today, due to how much more complicated fusion is than fission to achieve here on Earth.
- Fission occurs at about room temperature with the right reactor set-up.
- Artificial (non-gravitational) fusion occurs at 100,000,000 degrees, in a complicated (and invisible) magnetic “bottle,” but first...

Plasmas!

- A plasma is a quasi-neutral gas of charged and neutral particles which exhibits collective behavior.
- Occurs at relatively high temperatures, around 160,000 K for hydrogen for example.
- Since plasmas consists of charged particles, magnetic fields can have an effect on the trajectories of these particles per the Lorentz Force.
- Magnetic fields will be used to confine particles in a plasma, which want to expand as fast as they can to regain thermodynamic equilibrium with their surroundings, so we can get a large enough fusion power density.

Natural Plasmas

Fusion Reactions

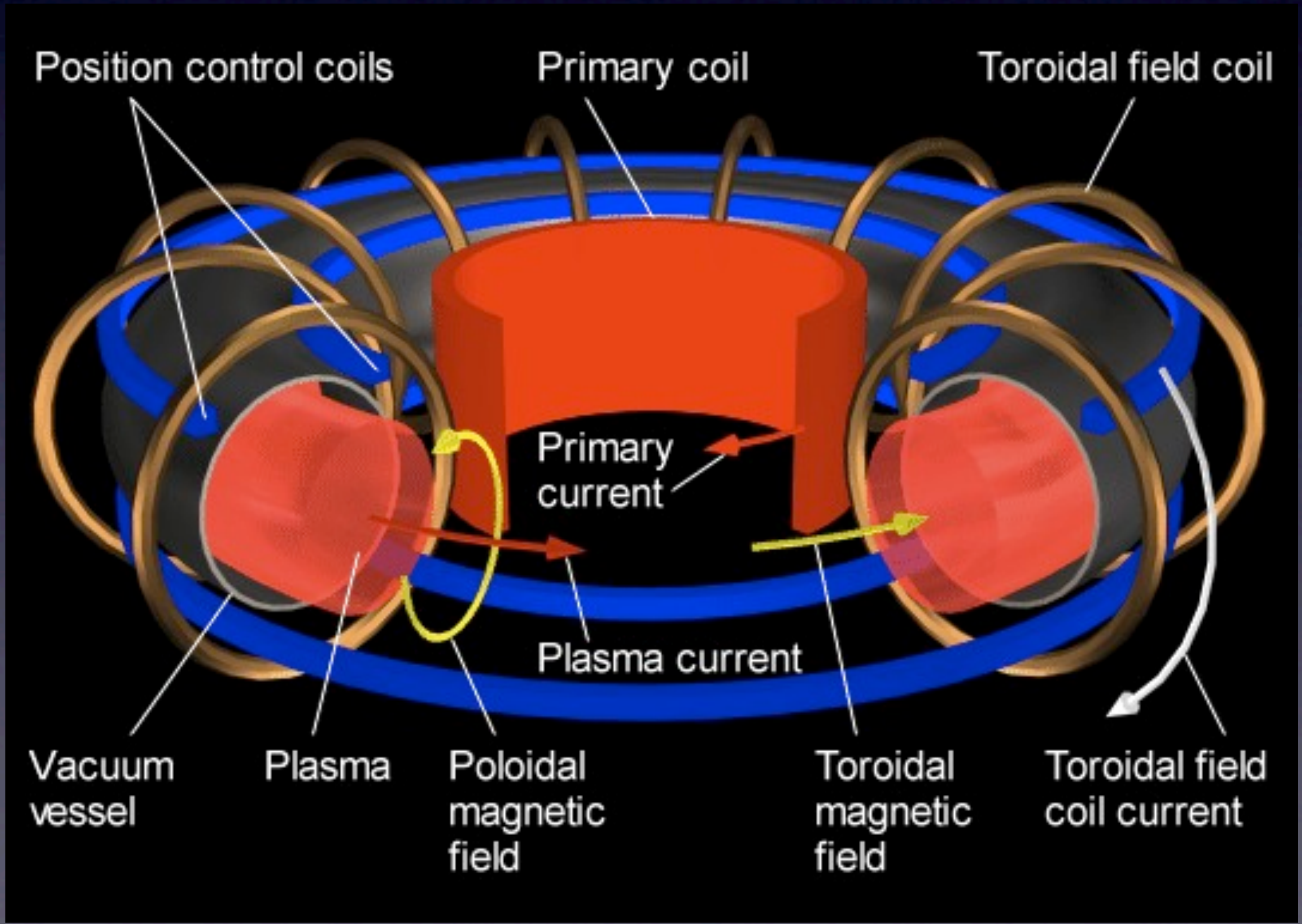


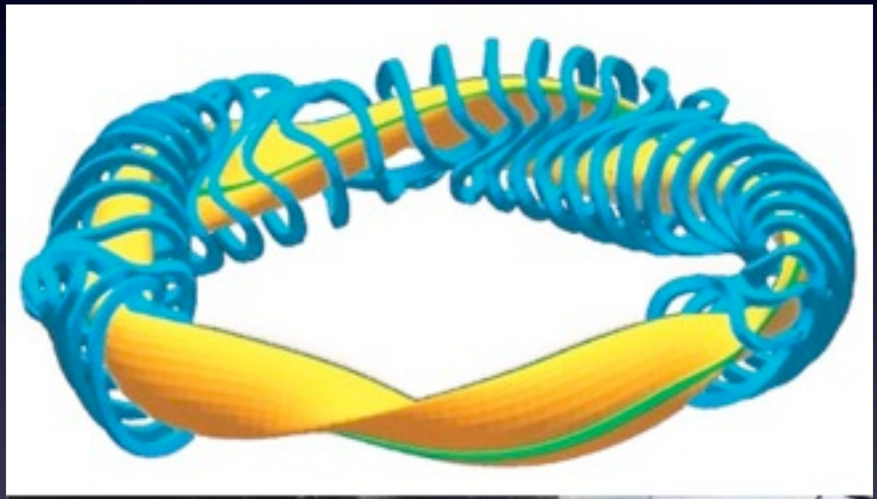
Requires high pressures ~ 5 atms, high temperatures ~ 100,000,000 K, and confinement t ~ 3-4 seconds.

Confinement

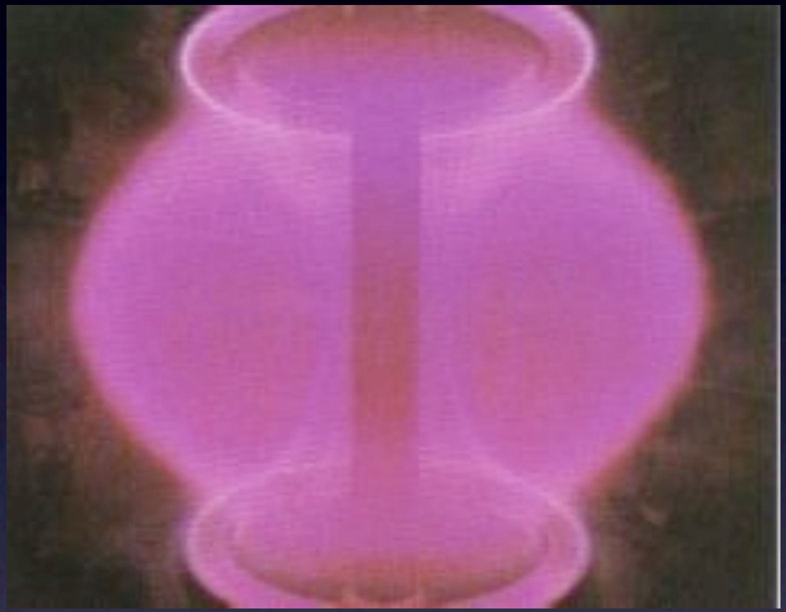
- Confinement is really the most dynamic area of study, which design is the best?

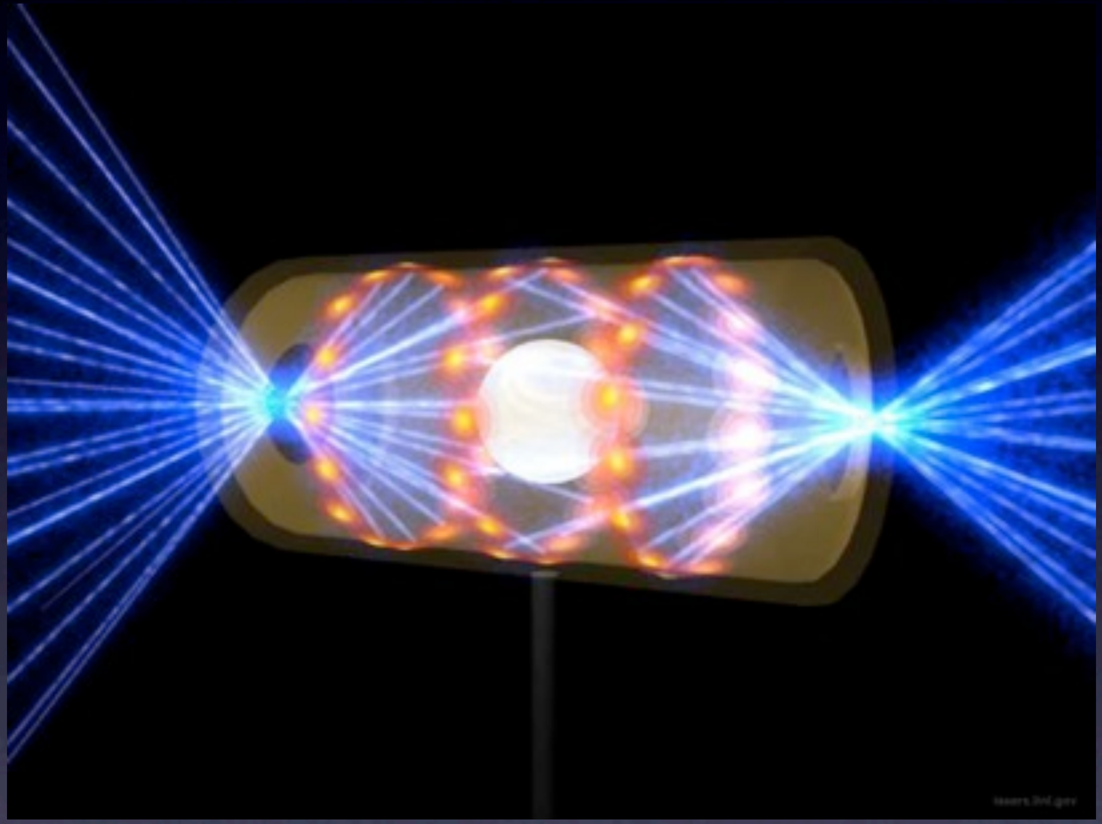
Magnetic Confinement Schemes

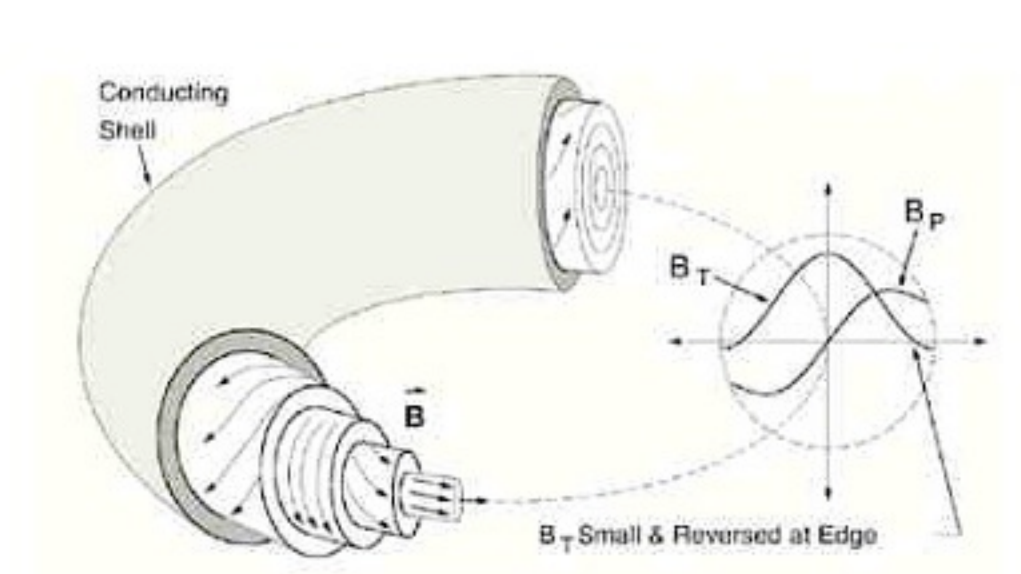




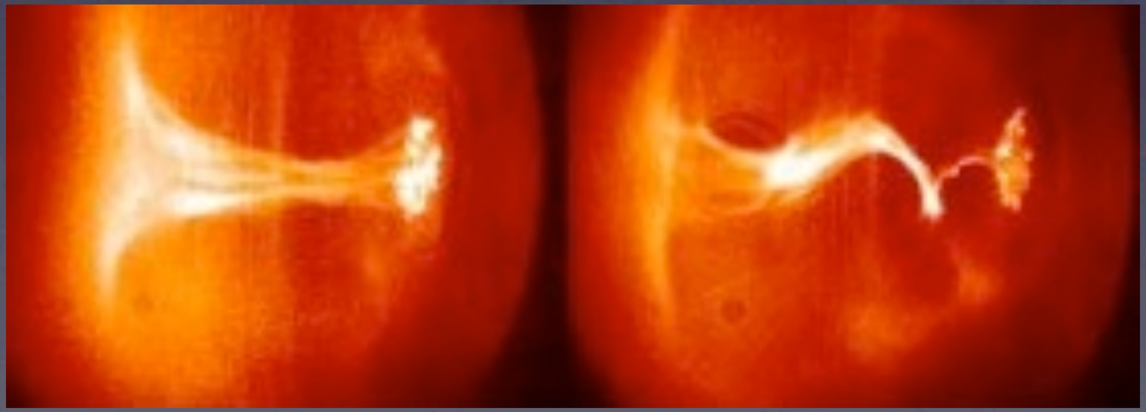
Other Confinement Schemes







Magnetic Field Structure of the RFP



Summary of Nuclear Energy

- Fission is currently the mode of nuclear energy production, and probably will be the dominate method throughout the next century. Plenty of fuel to use; storage of waste is still a problem, but no greenhouse problems.
- Fusion is a promising energy, though much work is left to be done before becoming an industry. ITER is presently the leading project in the world for magnetic confinement.