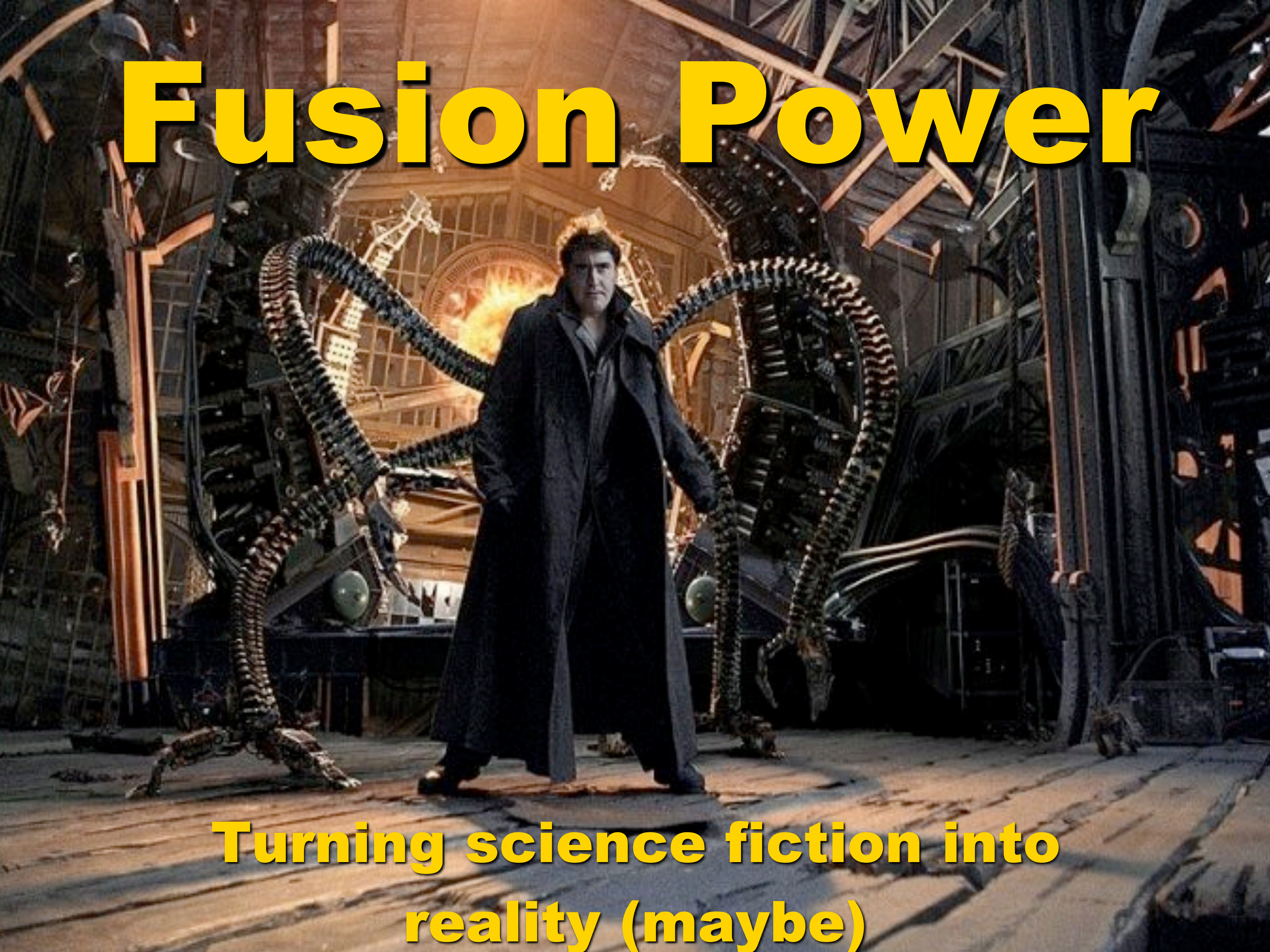
Fusion Power



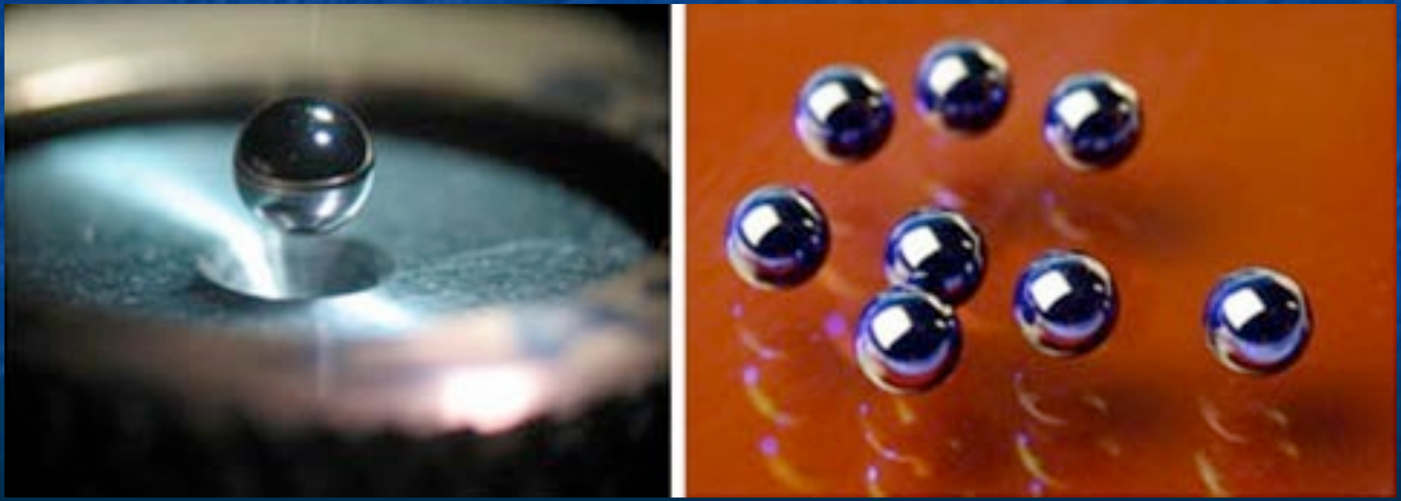
Turning science fiction into reality (maybe)

Last Time

- Current research facilities capable of producing fusion reactions
  - NIF (USA), HiPER (Europe)
  - Ignition expected within the decade
  - Not designed for power generation
    - Constant fuel injection
    - Neutron capture/control
    - Durability to sustain decades of neutron flux and extreme heat

Questions

- How do you contain the sphere before attempted ignition? Is this energy efficient?
  - Capsules: "light or low-atomic-number elements that perform well as "rocket fuels" when ablated by the X-rays in the hohlraum[1]"
  - Filled with D/T gas

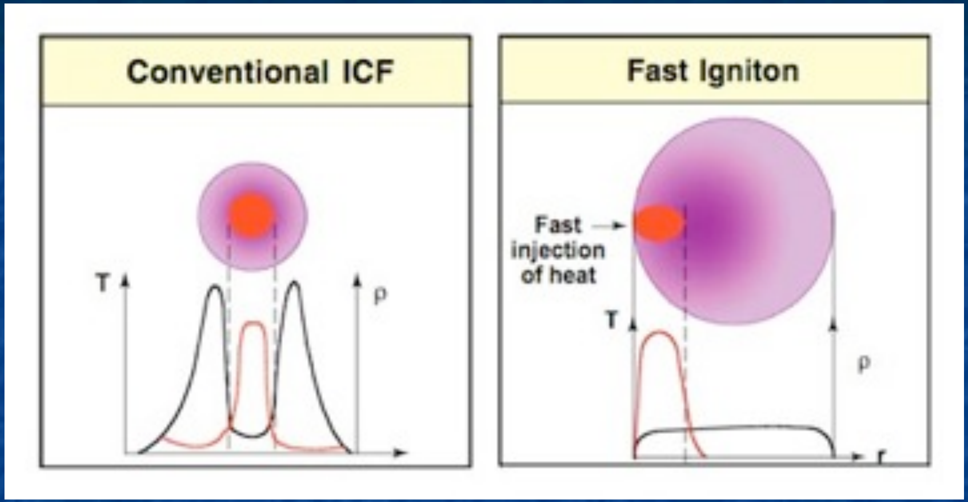


[1] https://lasers.llnl.gov/programs/nic/target_fabrication.php

- Is fusion, if we achieved it, significantly more dangerous than fission in terms of radioactive emissions?
  - No; this is why we continue to pursue it
  - Products:
    - Helium (stable, escapes earth's atmosphere)
    - Tritium (radioactive, but we use it as more fuel)
    - Neutrons (not safe, but we convert them to energy)
    - No "useless" radioactive materials
  - Proposed reactor designs involve the gradual production of radioactive isotopes in the target chamber and cooling materials
    - This occurs in fission plants too – associated with neutron flux & moderation

- How do you gather the output energy from a fusion reaction and make it useful?
  - The energy is contained in neutrons
  - You must make the neutrons hit something (it should not be your million dollar optics)
  - This generates heat
  - Heat is converted to electrical energy just like an ordinary coal/fission plant
  - Ideally, Make new fuel AND generate energy

- Slow ignition vs. fast ignition
  - Analogous to diesel vs. gas engines
  - "Fast" is fast b/c the pulses are shorter



https://lasers.llnl.gov/science_technology/fusion_science/fast_ignition.php

http://www.hiper-laser.org/fusion/storyboard.asp

- Currently is there any way of beginning fusion that seems more viable than any of the others?
  - Magnetic and inertial are still the frontrunners
  - Much of the research applies to both methods
  - Both present significant technological challenges
  - "The scale of the energy problem is such that multiple solutions are demanded. There is great potential for knowledge exchange between the two projects in areas such as material research, diagnostics and the underlying science[2]."

[2] http://www.hiper-laser.org/keyfacts/KeyFacts.asp

- Could fusion cause a disaster on the scale of Chernobyl?
  - Not with our current fusion schemes
  - NO CRITICAL MASS FUEL = NO MELTDOWN
  - Worst case: release of X-rays, tritium, heat, radioactive elements after reactor failure
  - No thermonuclear explosion

http://www.personal.psu.edu/ozz100/300pxChernobyl_Disaster.jpg

Generating fusion energy

- Pros
  - Zero carbon, no radioactive waste
  - ~1 part/6000 ocean water is "heavy"
  - Tritium could be produced by a functioning plant
  - Theoretical energy outputs are comparable w/ other major power sources
  - Possibility for fusion/fission hybrid reactors
- Cons
  - Will require extensive, expensive research
  - Plants would be expensive to build, hard to engineer
  - Tritium production depends on lithium reserves
  - High maintenance components – regular replacement of central parts needed.
  - Won't solve the immediate climate/energy crisis

Generating fusion energy

- Requirements
  - Laser system capable of firing at a constant rate for an extended period of time
  - A "blanket" that must
    - Absorb neutrons and extract thermal energy from them
    - Absorb neutrons and "breed" tritium
    - Protect the optics and electronics from neutrons, heat & radiation
  - Fuel injection system (as fast as the laser system)
  - Fuel production facility that can keep up with fuel consumption
  - Traditional heat → electricity facility such as a steam turbine
  - Durability and reliability of every component

Proposed Fusion Power Plants - LIFE

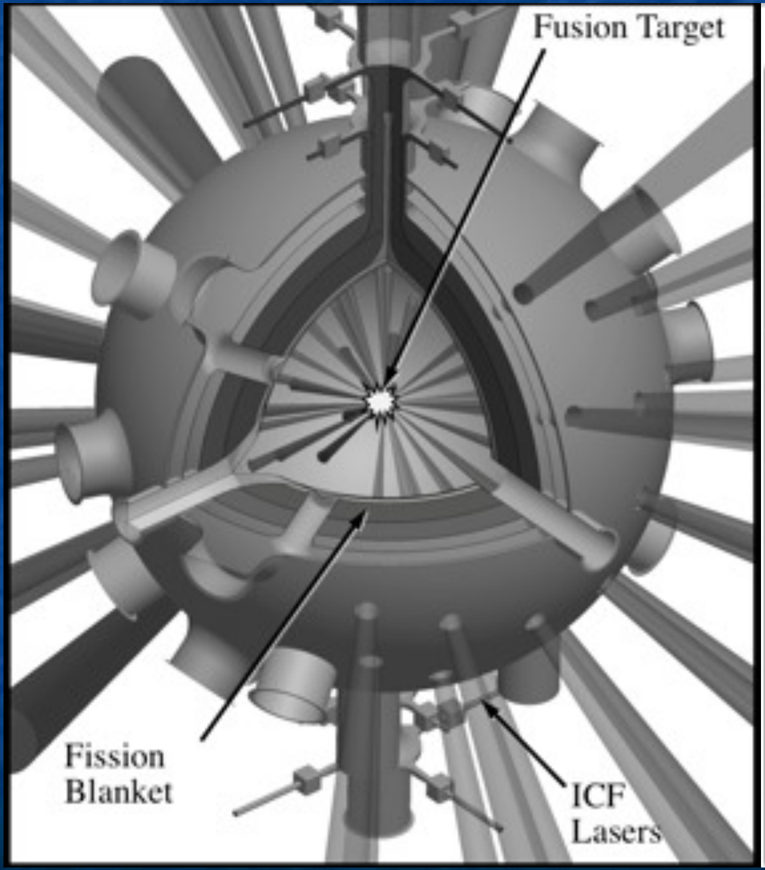
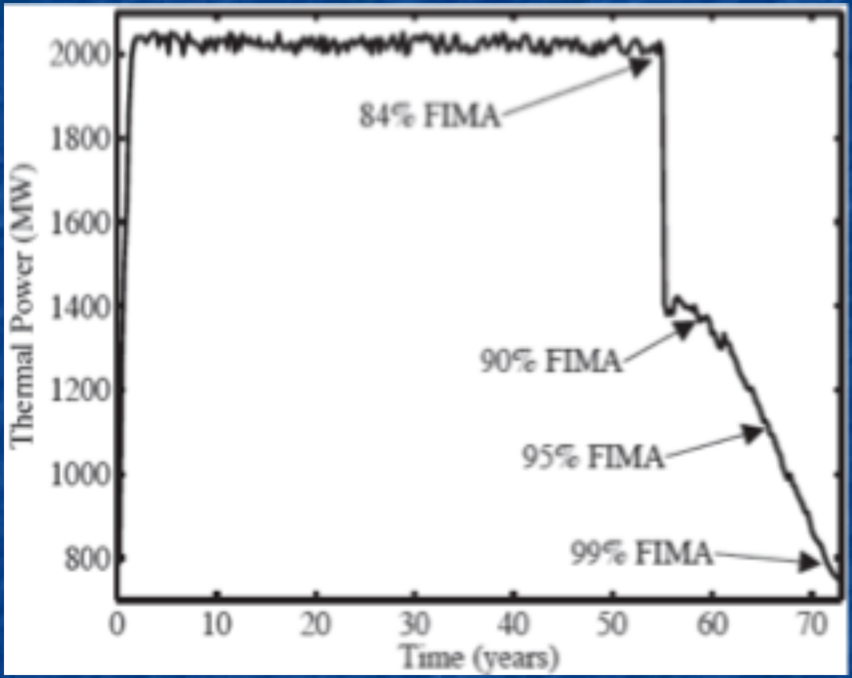


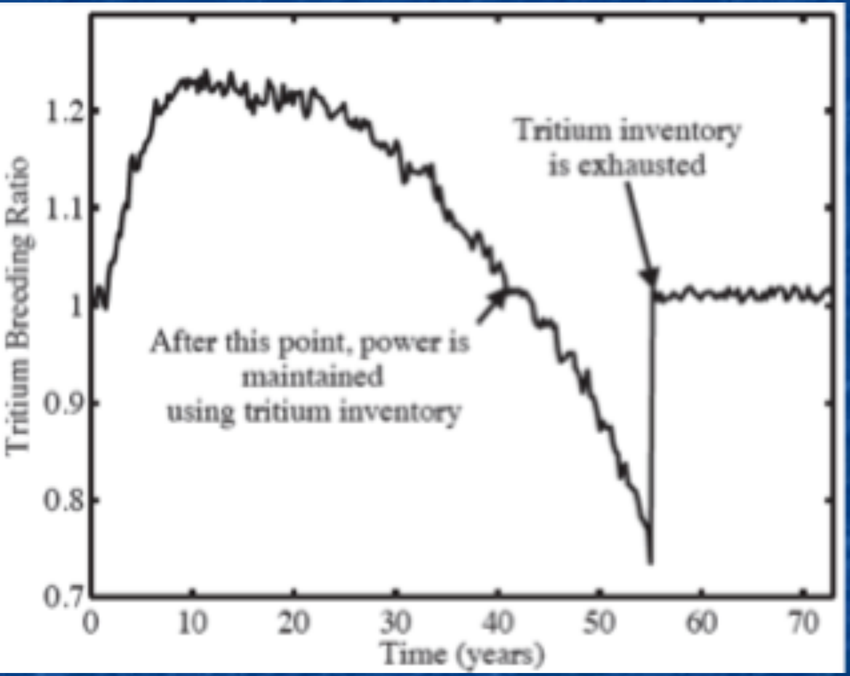
TABLE II. Key LIFE design parameters

Item	Value
Thermal Power (MWt)	2000
First wall coolant	$Li_{17}Pb_{83}$
Fusion yield (MWt)	500
Fission blanket DU mass (kg)	40,000
Primary coolant	flibe
First wall inner radius (m)	2.5
TRISO packing fraction (%)	30
Pebble packing fraction (%)	60
Be multiplier thickness (cm)	16
Fission blanket thickness (cm)	86
Graphite reflector thickness (cm)	75

https://e-reports-ext.llnl.gov/pdf/366991.pdf

Proposed Fusion Power Plants - LIFE

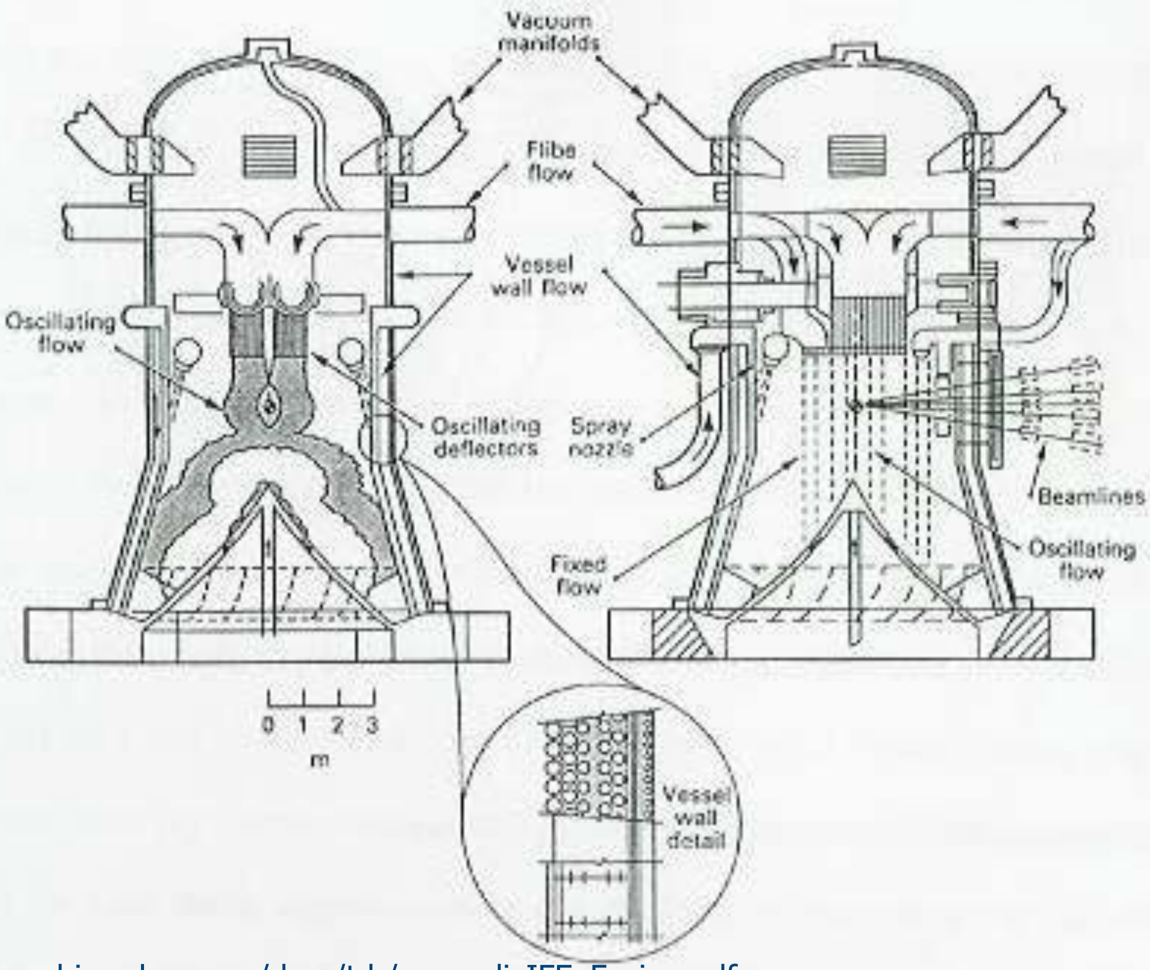




"This design produces 2000 MWt of power for over 50 years using a fuel loading of 40 MT. Fuel enrichment and reprocessing are not required. Early results show promise for this system with limitations being driven by self-sufficient tritium production."[3]

[3] https://e-reports-ext.llnl.gov/pdf/366991.pdf

Proposed Fusion Power Plants – HYLIFE-II



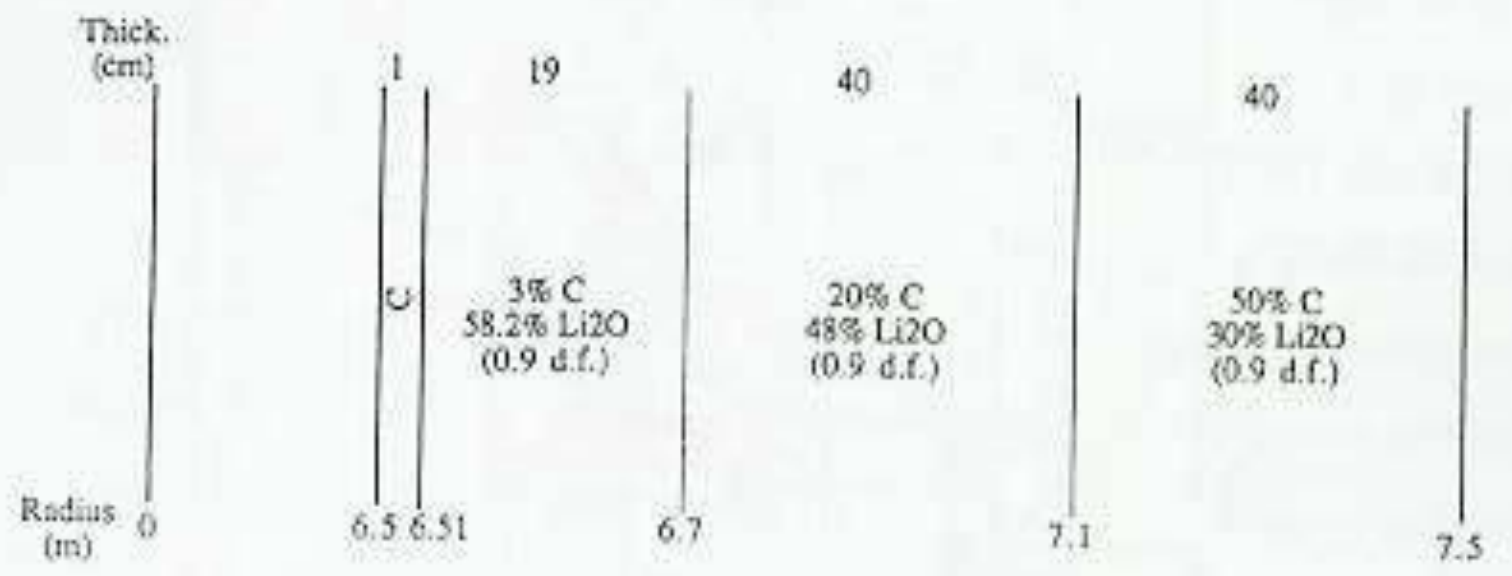
http://www.hiper-laser.org/docs/tdr/appendixIFE_Fusion.pdf

Proposed Fusion Power Plants – HYLIFE-II

- Similar to LIFE fission hybrid, but no fission
- Flibe used as T producer, neutron absorber; actually injected into target chamber
- Modeled for both 1GW and 2GW net electrical power output
- 6-7Hz repetition needed
- Proposed to use heavy ion driver, not lasers

Propuestas centrales de fusión- ¡Sombrero!

- KrF laser driven
- Xe gas layer before blanket
- Blanket of LiO_2 and carbon/carbon composite



http://www.hiper-laser.org/docs/tdr/appendixIFE_Fusion.pdf

Plant parameters	**SOMBRERO**	**HYLIFE-II**
Driver	KrF laser	Heavy-ion beams
Driver energy (MJ)	3.4	5
Driver efficiency (%)	7.5	35.0
Type of target	Direct drive	Indirect-drive
Target gain	118	70
Target yield (MJ)	400	350
Rep-rate (Hz)	6.7	6.0
Energy multiplication	1.08	1.18
Chamber material	C/C composites	SS304
Breeding material	Li_2O particles	Flibe
Breeding ratio	1.25	1.17
Fusion power (MW)	2677	2100
Thermal power (MW)	2891	2500
Cycle efficiency (%)	47	43
Gross electric power (MWe)	1359	1075
Driver power (MWe)	304	85
Auxiliary power (%)	55	50
Net electric power (%)	1000	940

http://www.hiper-laser.org/docs/tdr/appendixIFE_Fusion.pdf

Conclusions

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