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Overview of Chamber and Power Plant Designs for IFE

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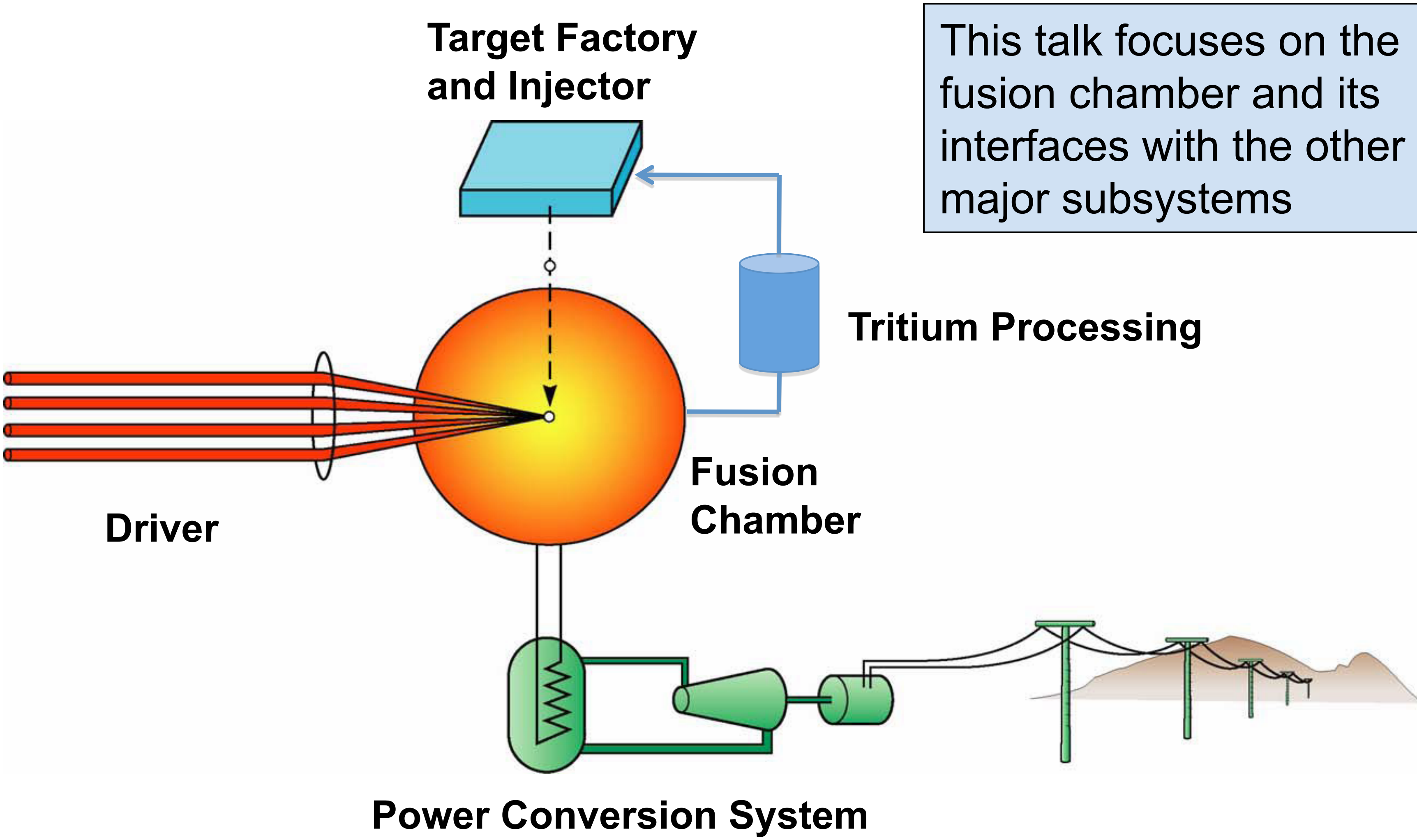
Outline

- Introduction and basic requirements
- Example chamber designs
- Comments on R&D needs and synergy with MFE
- Additional resources/references

Introduction and Basics Requirements

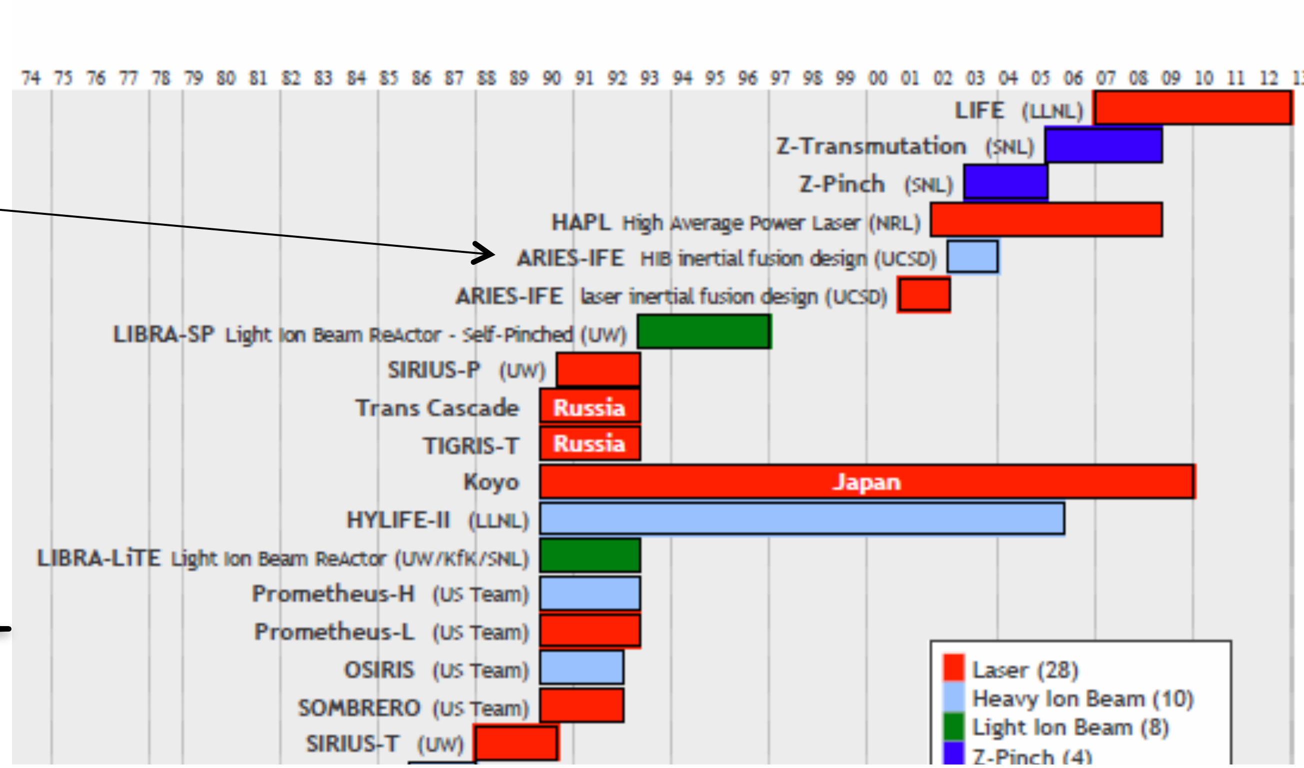
Major elements of an IFE power plant are illustrated here

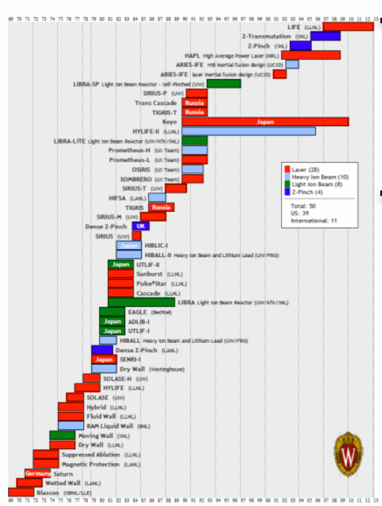
This talk focuses on the fusion chamber and its interfaces with the other major subsystems



There have been >50 IFE chamber design concepts and power plant studies over the last 35 years

Robust Point Design (HIF)
HIF-VNL
(2001-2003)





I will review some of the more complete integrated design studies to illustrate different approaches for various driver/target combinations.

L. El-Guebaly, "Basic Concepts of Thermonuclear Fusion." Wiley Encyclopedia of Energy. Volume 1: Nuclear Energy, Jay Lehr, Editor-in-Chief, Steven B. Krivit, Senior Editor, to be published in 2011, (ISBN 9780470894392)

The ultimate objectives in the design of an IFE power plant are:

1. Produce and deliver reliable and economically competitive electric power
   – Key factors that impact economics are capital costs (direct + indirect), fuel costs, operation and maintenance (O&M) costs, and availability.
2. Operate in a safe and environmentally acceptable manner
   – Key factors that impact S&E are choice of materials, chamber and building design, tritium inventory, design of tritium processing systems (e.g., controlling vulnerable inventory)

If these can be accomplished, the plant should be
- attractive to end users
- licensable
- publically acceptable

The top level chamber requirements include aspects of basic concept feasibility and overall system attractiveness

Requirements related to feasibility:

- Establish (and repeatedly reestablish) chamber conditions to allow target injection (or placement in the case of Z-IFE), beam propagation and engagement (or energy delivery) to the specifications needed for ignition and high gain (IFE unique).

- Protect the first wall from pulsed, short-ranged target emissions (x-rays, ion and debris), e.g., from intense thermal spikes and ion damage, or design the FW to accommodate these threats (IFE unique).

- Capture and transfer power to power conversion system (all fusion).

- Breed, recover and recycle tritium to provide a self-sustained fuel cycle (all fusion).

The top level chamber requirements … (cont.)

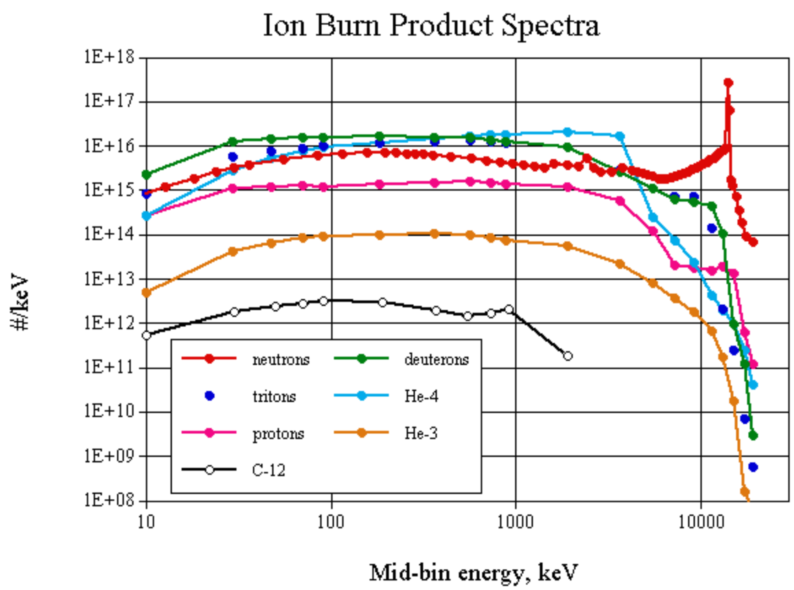
Requirements related to attractiveness and acceptability (all fusion):

- Operate at temperatures that are high-enough for efficient power conversion
- Configure the system for ease of maintenance to allow high availability
- Design for safe operation and minimal environmental impact (system configuration and selection of materials).

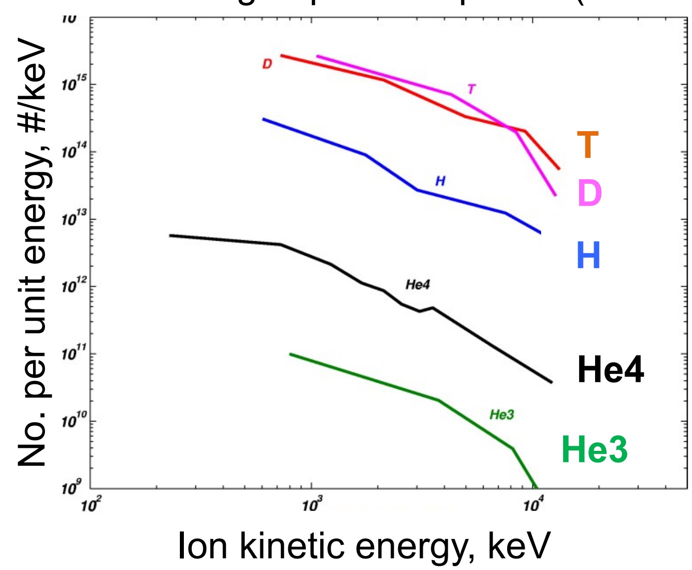
All these must be met in a self-consistent, integrated manner.

Target emissions and resulting threats to chamber components depend on target type/design

In addition to high energy (~14 MeV) neutrons, IFE targets emit a combination of x-rays, ions (fusion alphas and ionized target materials) and debris



Fast burn charged particle spectra (LLNL ID)



Direct drive energy split:
2% x-rays
28% ions
70% neutrons

Indirect drive energy split:
25% x-rays
6% ions
69% neutrons

 http://www-ferp.ucsd.edu/ARIES/WDOCS/ARIES-IFE/SPECTRA

Example Chamber Designs

We typically classify IFE chamber designs in three categories

- Dry-wall
  - Gas protected
  - Magnetically protected
  - Engineered surface
- Wetted-wall
- Thick-liquid-wall

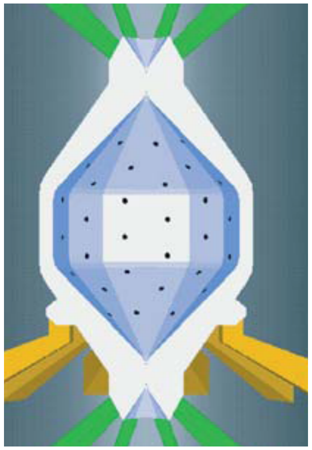
Seven chamber designs that will be discussed

Name	Driver	Target	Type
Sombrero	Laser (KrF)	DD	Dry-wall / gas protected
HAPL	Laser (DPSSL and KrF)	DD	Dry-wall / magnetic deflection or engineered W surface
LIFE	Laser (DPSSL)	ID	Dry-wall / gas protected
Osiris	Heavy ion	ID	Wetted-wall
Koyo-F	Laser (DPSSL)	DD FI	Wetted-wall
HYLIFE-II	Heavy ion	ID	Thick-liquid-wall
Z-IFE	Pulsed power	ID	Thick-liquid-wall

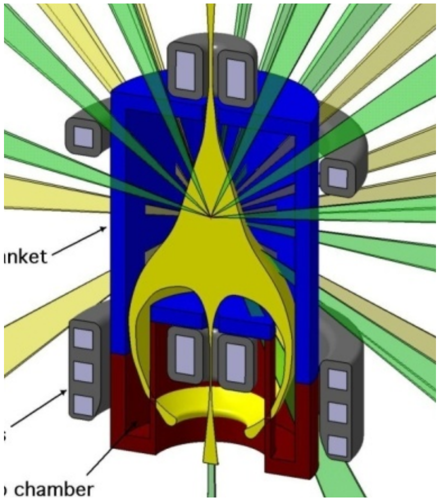
DD = Direct-drive
ID = Indirect-drive
FI = Fast ignition

Three dry-wall chamber examples will be discussed

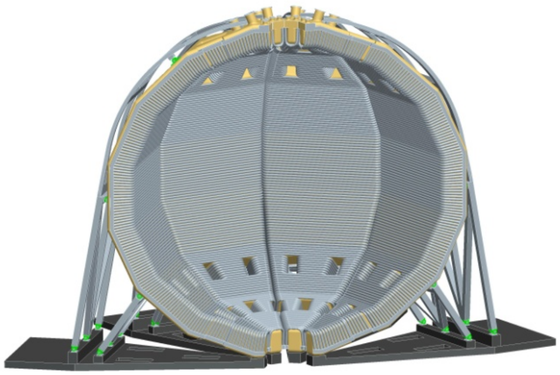
- Sombrero (1990-92)
- High Average Power Laser (HAPL) program design (2002-08)
- Laser Inertial Fusion Energy (LIFE) design (2007 – present)



Sombrero



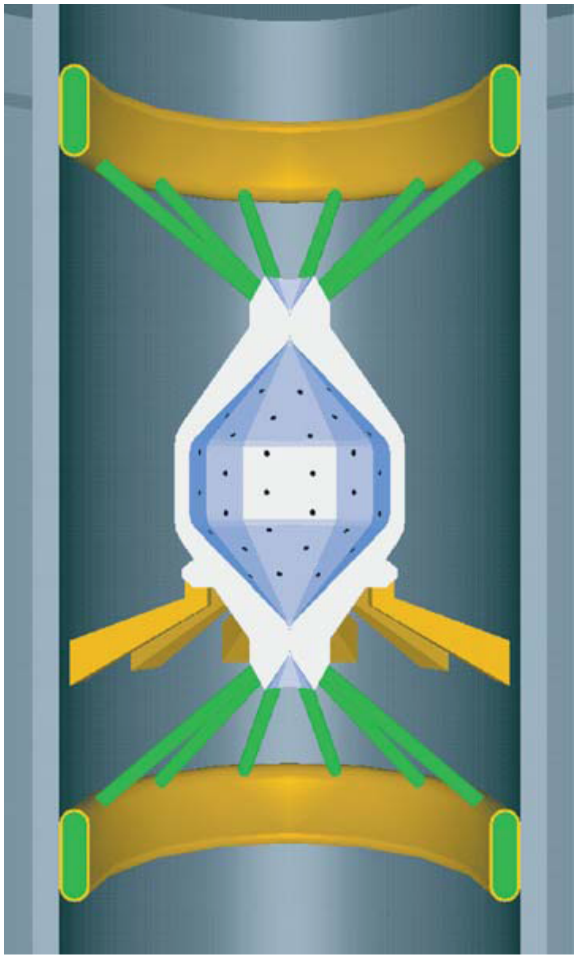
HAPL



LIFE

Not shown to Scale!

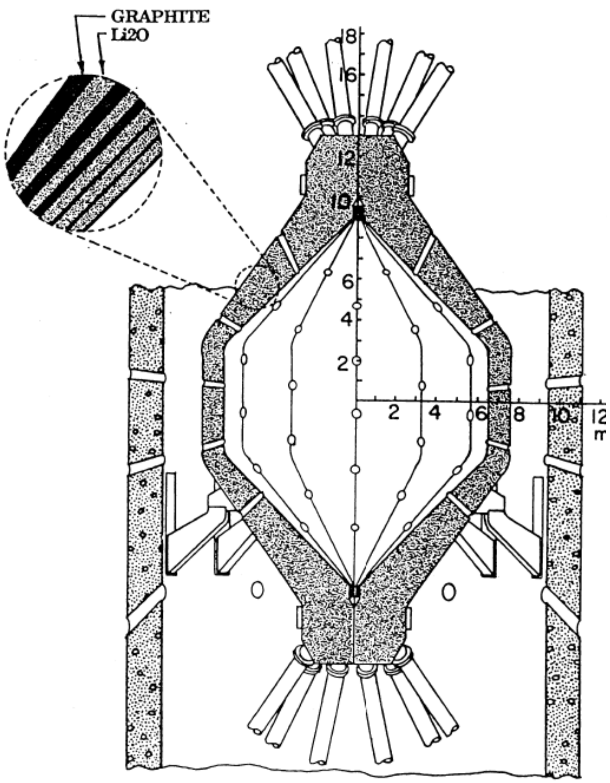
Sombrero was part of a DOE-funded IFE power plant study in the early 1990's



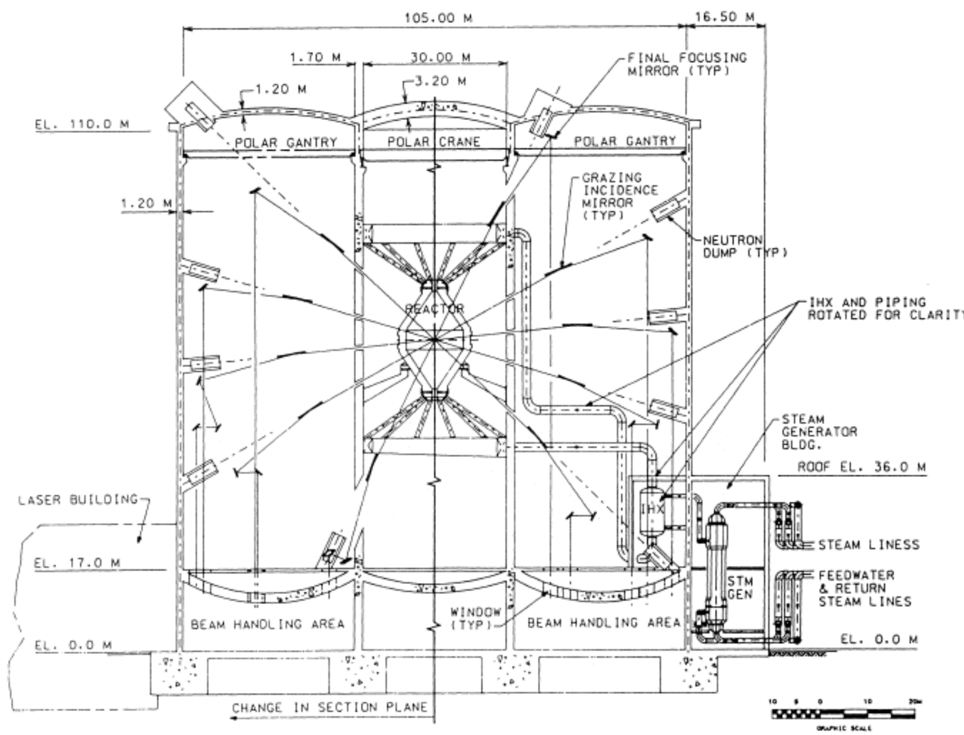
- Based on KrF laser
- Direct-drive targets
- Low pressure (~0.5 torr), high-Z gas (Xe) protects first wall from short-ranged target emissions
- Low activation structures (C/C composites)
- Flowing Li_2O granules serves as breeder and coolant

W.R. Meier, et al., "OSIRIS and SOMBRERO Inertial Confinement Fusion Power Plant Designs," DOE/ER/54100-1 (1992)

Sombrero chamber was located at the center of a large vacuum building



Cross section of chamber
FW radius = 6.5 m



Sombrero confinement/vacuum building
110 m high x 105 m dia.

Key design parameters for SOMBRERO

	SOMBRERO
Driver	
Driver Energy (MJ)	3.4
Rep-Rate (Hz)	6.7
Driver Efficiency (%)	7.5
Target	
Type	Direct Drive
Target Gain	118
Yield (MJ)	400
Chamber Design	
First Wall Material	4-D C/C Composite
X-ray and Debris Protection	3.25 torr-m of Xe
First Wall Radius, m	6.5
Estimated First Wall Life (fpy)	5
Breeding Material	Li_2O Granules
Tritium Breeding Ratio	1.25
Power Conversion System	
Primary Coolant	He w/ Li_2O granules
Intermediate Coolant	Lead
Secondary Coolant	Water / Steam
Power Conversion Eff. (%)	47

Sombrero proposed some innovative design features

- Advanced materials (C/C composite structures) for high temperature operation and low activation.
- Chamber was segmented into independent parts to improve maintainability and enhance availability.
- Solid breeder was circulated as primary coolant minimizing need for leak tight blanket structures.
- Vacuum boundary was separate from the chamber; the confinement building was the vacuum barrier.

Toward the end of the study we discovered a serious flaw – target heating was excessively high with the proposed gas density needed for first wall protection. There was no follow-up study to address this issue due to lack of funding.

HAPL study was carried out from 2001-2008

Background info relevant to chamber design:

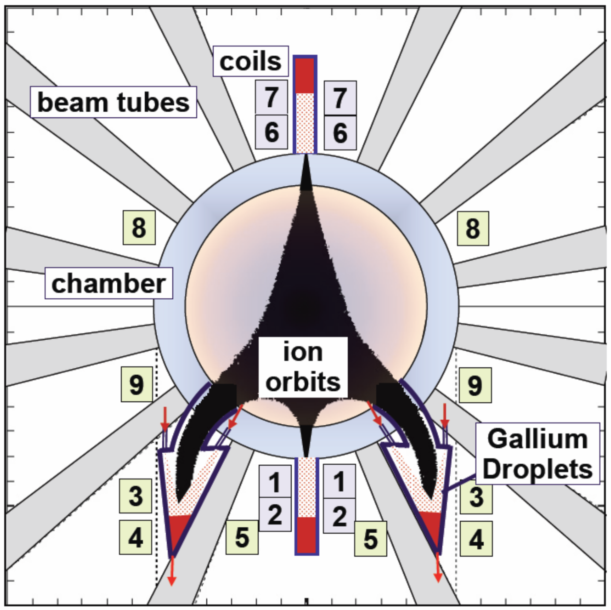
- HAPL focused on laser-driven (KrF and DPSSL), direct-drive targets
- Initially evaluated gas protection, but this caused unacceptable target heating during injection
- Removing gas resulted in severe ion damage to the W-armored steel first wall
- By the end of the project (2008), the design called for either
  - magnetic deflection of ions to liquid-film heat dumps outside the main chamber
  - engineered W first wall surface to address ion implantation issue

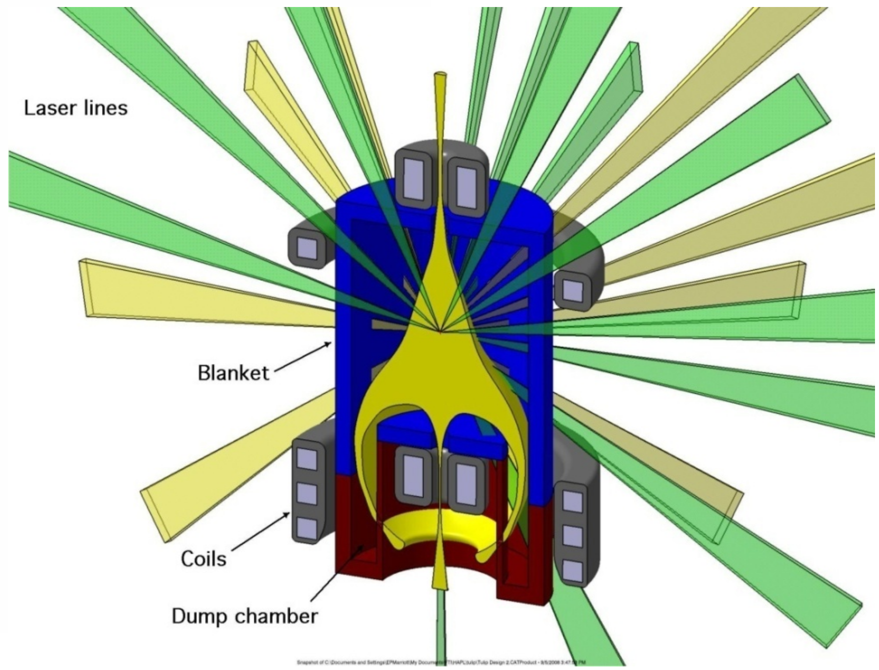
Project meeting presentations can be found at:
http://aries.ucsd.edu/HAPL/MEETINGS/

One version of the magnetic protection concept used liquid metal sprays to absorb ion energy

An example of a Magnetic Intervention Chamber

Ions deflected downward by magnetic fields
Ion energy absorbed in Gallium Rain Ion Dissipaters™





J. Sethian, 2009 SOFE talk
http://fire.pppl.gov/sofe09_sethian.pdf

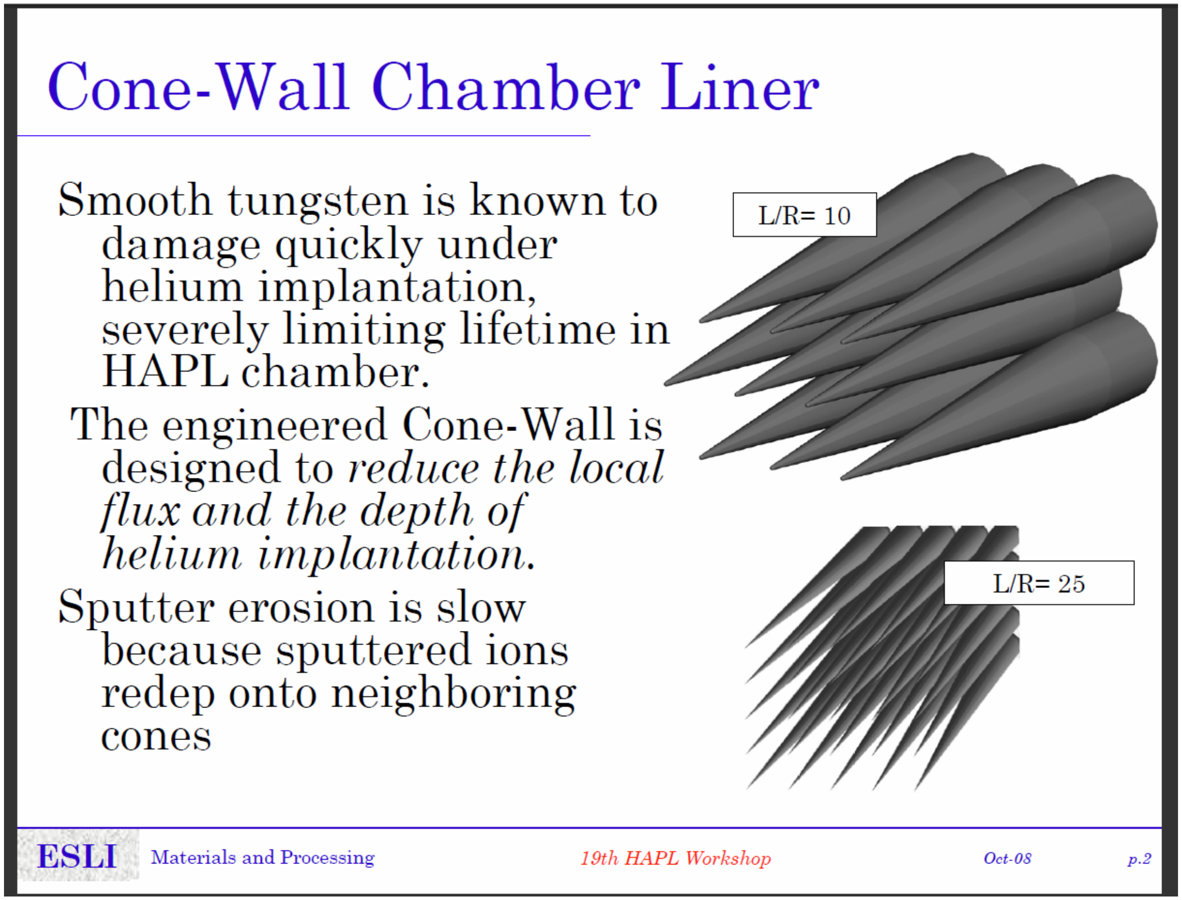
FW radius = 4.5 m

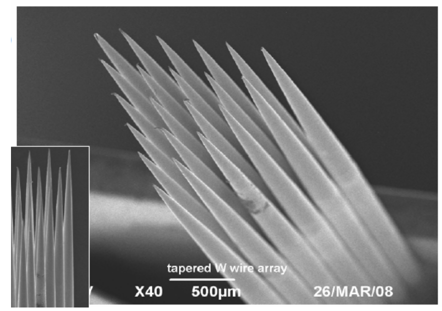
R. Raffray (UCSD) HAPL presentation, U. Wisc. (Oct. 22-23, 2008)

Features of the magnetically protected chamber

- Low electrical conductivity SiC_f /SiC composite first wall and blanket structure (required for dissipating the magnetic energy resistively)
- Designed for nominal 370 MJ yield targets at 5 Hz
- Considered two breeder options; Both had good TBR (~1.2)
- PbLi
- Molten salt (Li_2BeF_4 – flibe) with additional Be multiplier layer
- Used intermediate (flibe) heat transfer loop for T control
- Used a Brayton power conversion cycle for high efficiency
- Began evaluation of remote maintenance approach toward end of study

Another option to deal with ion threat is an engineered first wall

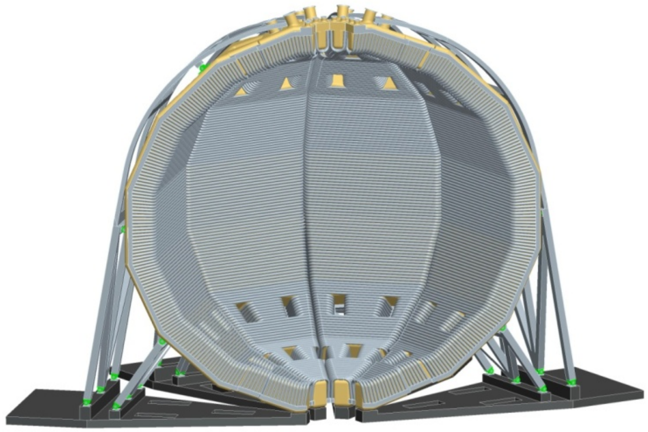




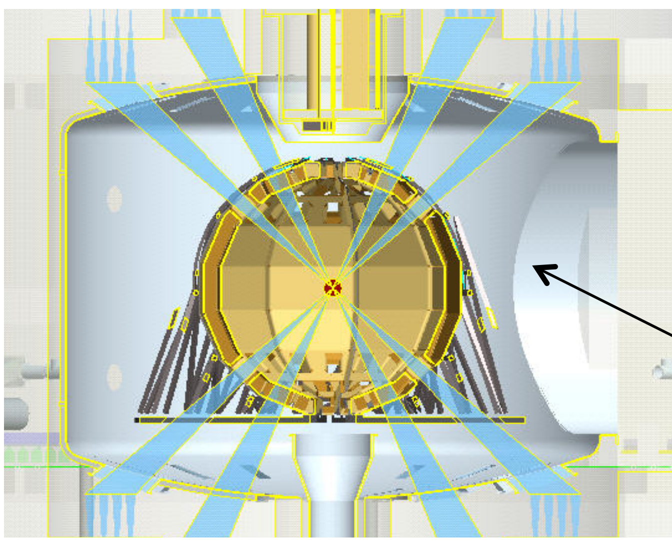
Test specimen

19th HAPL Workshop (Madison, WI) Oct 22-23, 2008
T R Knowles, Y R Yamaki, G J Price, M H Douglas
Energy Science Laboratories, Inc. (San Diego, CA)

The LLNL LIFE project uses a gas-protected dry-wall chamber



FW radius = 6 m

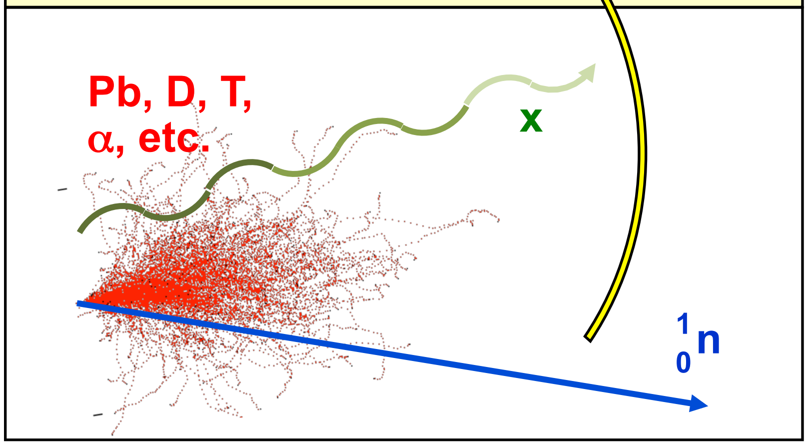


- Designed for indirect-drive targets with NIF illumination geometry
- First wall is made of 10 cm diameter, steel tubes with 1 mm thick walls
- Fabricate from available steel
- FW radius ~6 m
- Uses gas protection to stop ions and reduce peak temperature spike on steel first wall to an acceptable level
- <1% clearing between shots
- Liquid Li is the coolant and tritium breeder

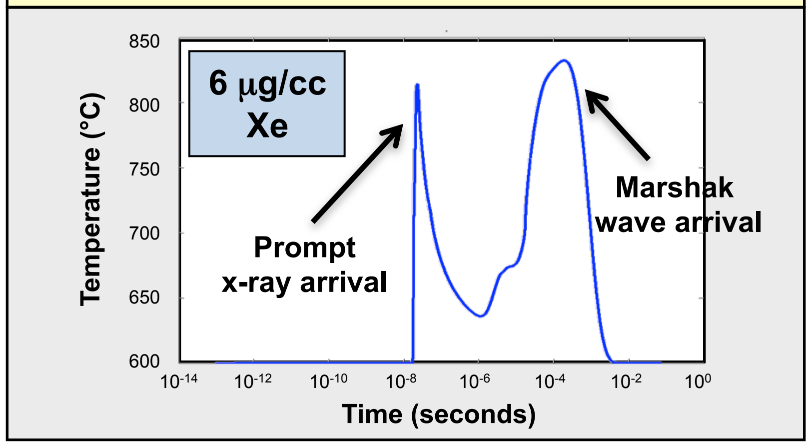
Chamber is enclosed within a larger vacuum vessel.

Chamber gas used to reduce the ion and thermal threats to the wall; still allows beam propagation

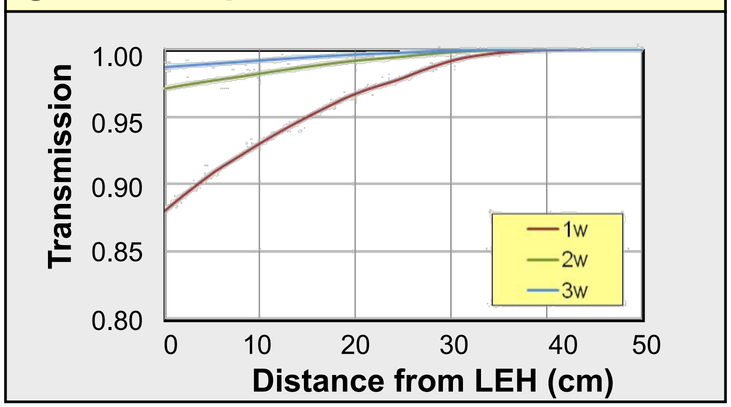
Target output includes ions, x-rays and neutrons



~ 10 kg of Xe gas reduces chamber size from >30 m to only 6 m radius



Laser beam propagation through hot gas is acceptable



J. Latkowski, LLNL

Key design features for LIFE

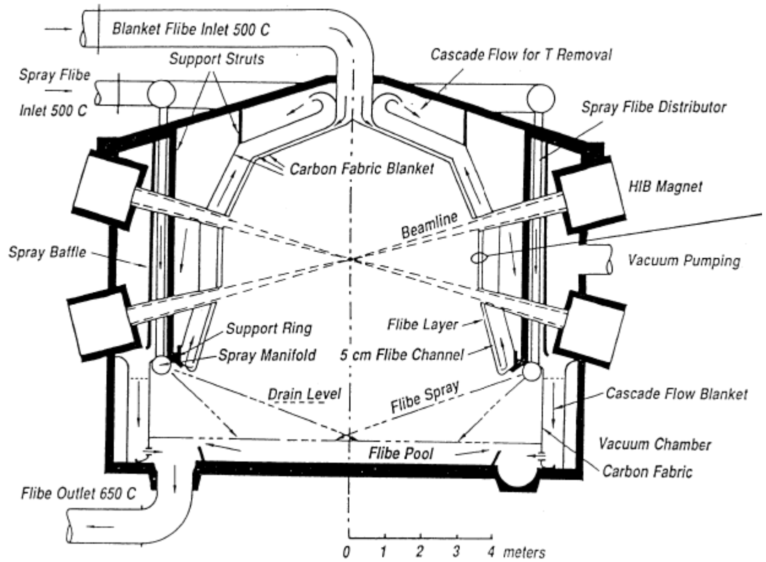
- Chamber is not the vacuum barrier; it sits within a larger vacuum vessel
- Lower target yield (~130 MJ) and higher pulse repetition rate (16 Hz) than other IFE approaches
- Segmented chamber for ease of maintenance
- Li coolant outlet at 750C is coupled to a supercritical steam cycle giving ~50% power conversion efficiency
- High potential tritium breeding ratio (1.4); Excess T could be used as fuel to start-up new fusion power plants.
- Tritium breeding can be traded for higher blanket gain (optimizes at ~1.25-1.3). Possible load following.
- Proposed T recovery system (from Li) designed to obtain a very low T inventory in the Li coolant (< 50 g) for enhanced safety

Typical LIFE parameters for 1000 MWe net power

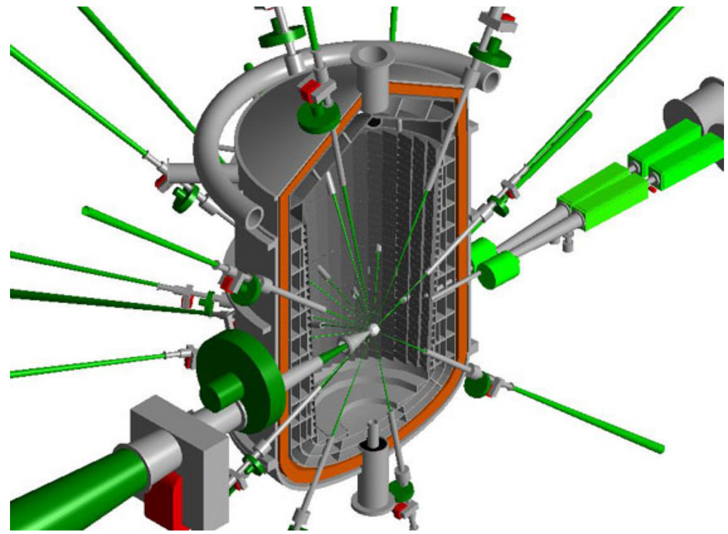
Parameter	
Laser energy (MJ)	2.2
Target yield (MJ)	125
Rep-rate (Hz)	16
Fusion power (MW)	1970
Thermal power (MW)	2570
Conversion efficiency (%)	49
Gross electric power (MWe)	1250
First wall radius (m)	6
Neutron wall load (MW/m^2)	~ 3 MW/m^2
First wall	ODS-FS
First wall protection	Xe at 6 $\mu g/cc$

Several papers recently submitted to Fusion Science and Technology as part of TOFE 2010 proceedings. Preprints available from LLNL.

Two examples of wetted-wall chamber designs are briefly reviewed



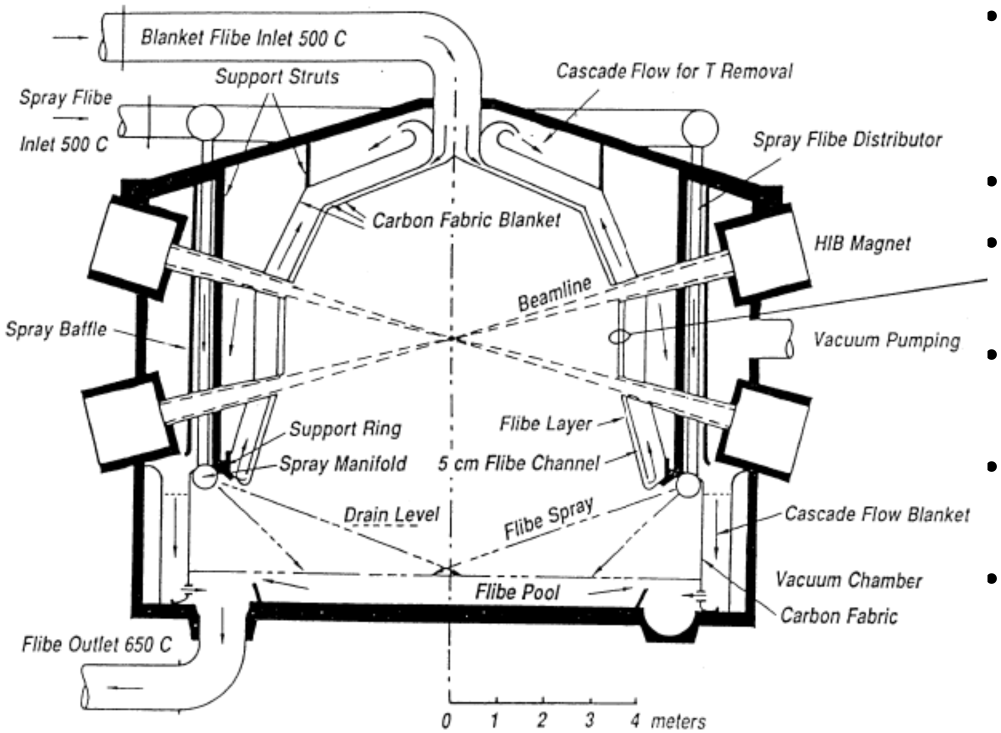
Osiris



Koyo-F

Not shown to scale

Osiris was a wetted-wall design for heavy ion fusion (HIF)



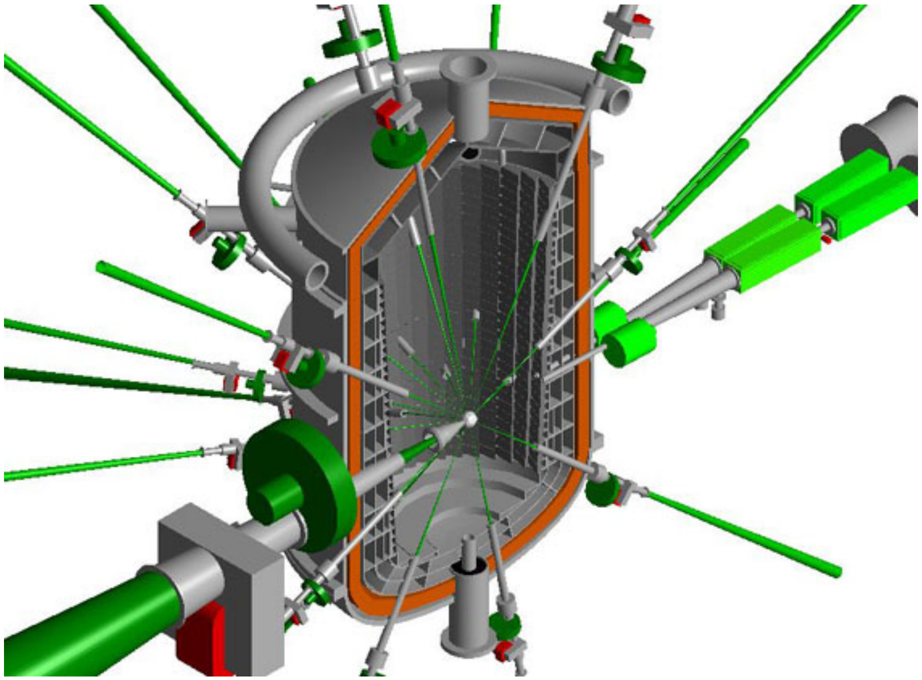
Cross section of Osiris chamber
FW (fabric) radius = 3.5 m

- Indirect drive targets
- Molten salt (flibe) breeder/coolant contained within a flexible C fabric blanket (T_{max} = 650C)
- Thin liquid layer covers inner surface
- Liquid sprays to enhance post-shot condensation
- Fabric FW/blanket easily replaceable for ease of maintenance
- Liquid Pb intermediate loop for tritium control (T_{max} 600C)
- Supercritical pressure, double reheat steam cycle gave 45% conversion efficiency
- Compact power core building

Key design parameters for Osiris

	Osiris
Driver	
Driver Energy (MJ)	5.0
Rep-Rate (Hz)	4.6
Driver Efficiency (%)	28.2
Target	
Type	Indirect Drive
Target Gain	86.5
Yield (MJ)	432
Chamber Design	
First Wall Material	Woven Graphite Fabric
X-ray and Debris Protection	Liquid Flibe
First Wall Radius, m	3.5
Estimated First Wall Life (fpy)	1.8
Breeding Material	Molten Flibe
Tritium Breeding Ratio	1.24
Power Conversion System	
Primary Coolant	Flibe
Intermediate Coolant	Lead
Secondary Coolant	Water / Steam
Power Conversion Eff. (%)	45

KOYO-F design uses a thin liquid metal (PbLi) flow to protect the first wall



Cut-away view of Koyo chamber
FW radius = 3 m

From T. Norimatsu (ILE-Osaka) presentation to TITAN workshop, UCSD (Feb. 10-11, 2009).

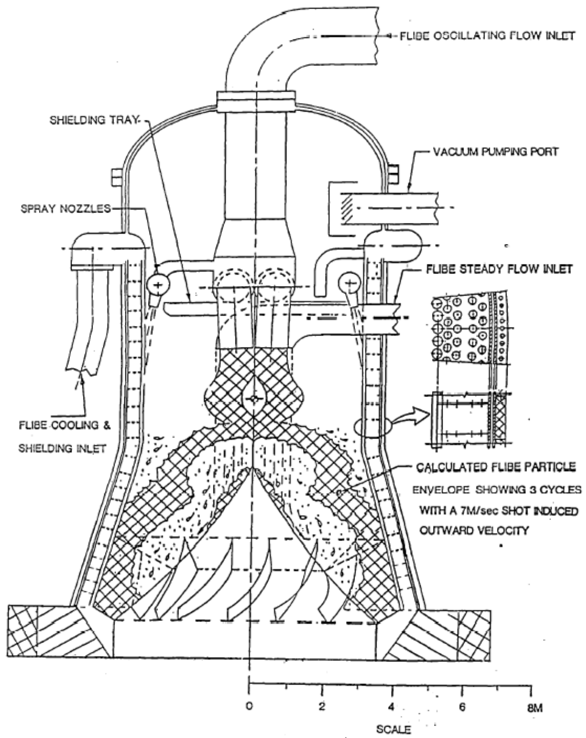
- Direct drive, fast-ignition targets
- $Li_{17}Pb_{83}$ coolant / breeder
- SiC First wall and blanket
- Ferritic steel outer vessel wall
- Fusion yield = 200 MJ
- Rep-rate per chamber = 4 Hz
- Thermal output = 916 MW
- Chamber size (inner/outer/high) = 3m / 5m / 14m
- Peak neutron load = 5.6 MW/m^2
- Solid angle of beam ports < 5%
- Tritium breeding ratio = 1.3
- Cascading flow has short re-establishment distance
- Modeling and experiments on flow configuration and heating, vaporization and condensation

KOYO-F fast ignition IFE plant parameters

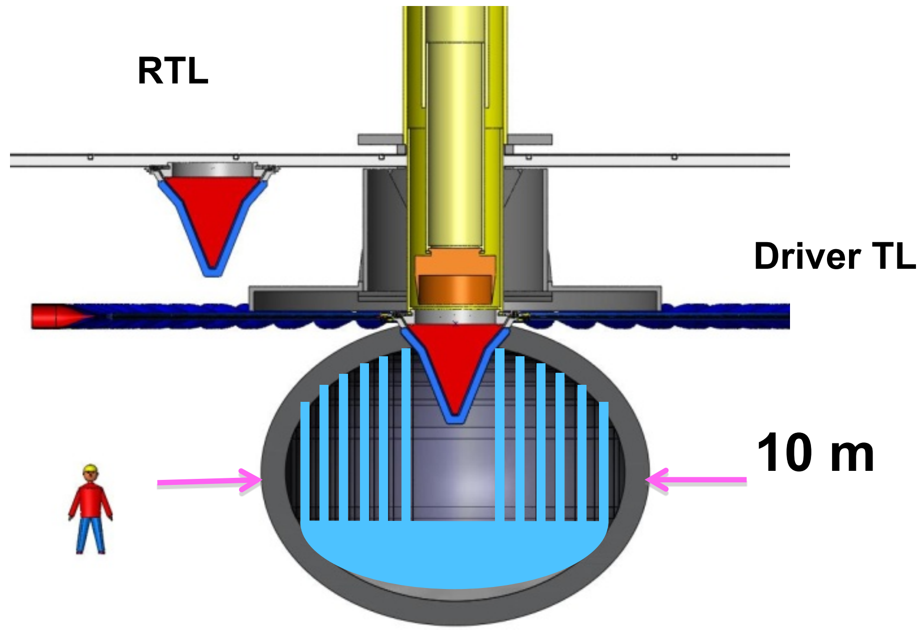
TABLE II Basic design parameters for the power plant KOYO-F

Net electric output	1283 MWe (320 MWe x 4)
Electric output from one module	320 MWe
Target gain	167
Fusion Yield	200 MJ
Laser energy/Beam number	1.2 MJ（Compression=1.1MJ/32beams, Heating=100kJ 1beam）
Laser material／Rep-rate	Cooled Yb:YAG ceramics at 150～220K /16 Hz
Chamber structure/Rep-rate at module	Cascade-type, free-fall liquid LiPb wall/4 Hz
Fusion power from a module	800 MWth
Blanket gain	1.2（design goal）
Total thermal output from a module	916 MWth
Total thermal output from a plant	3664 MWth (916 MWth x 4)
Heat-electricity conversion efficiency	41.5 %（LiPb Temperature 500℃）
Gross electric output	1519 MWe
Laser efficiencies	13.1% (compression), 5.4% (heating)、Total 11.8%（including cooling power）
Recirculating power for laser	164 MWe（1.2 MJ x 16 Hz / 0.118）
Net electric output/efficiency	1283 MWe(1519 MWe - 164 MWe - 72 MWe Aux.)/32.7%

Thick liquid wall designs proposed for HIF and Z-IFE



HYLIFE-II
(used in Robust Point Design)

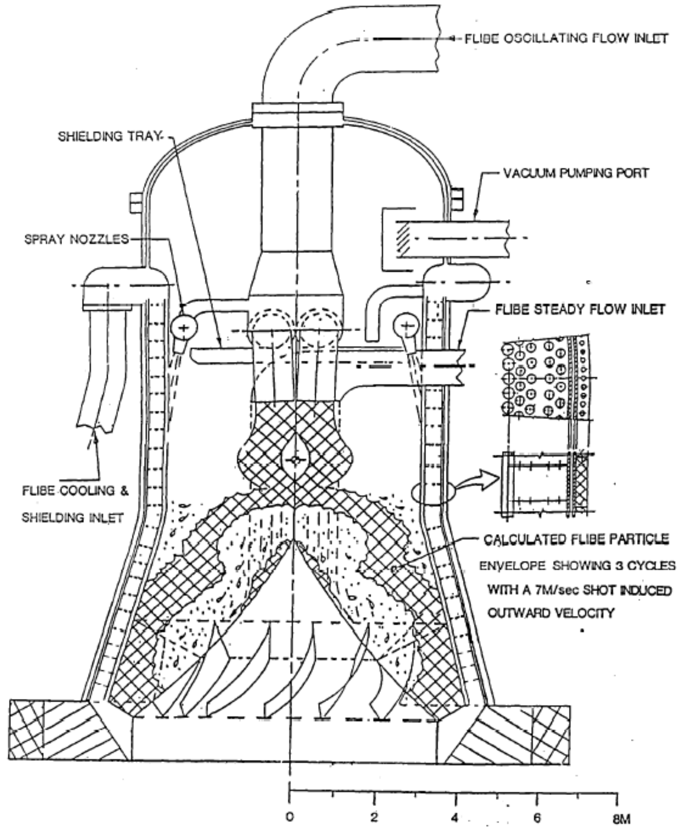


Z-IFE

General features and potential advantages of TLW chamber designs

- A neutronically thick region (~50-100 cm) of liquid protect structures from x-rays, ions, debris **and neutrons**
  - Early concepts proposed Li; HYLIFE and Z-IFE propose molten salt
- Reduces neutron damage rate by ~10x
  - No need for a high intensity 14-MeV neutron test facility to develop first wall materials
  - Estimated chamber lifetime of 30-40 years improves availability
- Spaced jets absorb shock from fusion blast
  - Compatible with high yield targets in compact chambers
- Flowing jets can be designed to clear the chamber

HYLIFE-II is a thick liquid wall chamber design for heavy ion fusion (HIF)



Cross section of HYLIFE-II chamber
FW radius = 3 m

- Indirect drive targets, multi-beam induction linac driver
- Liquid is molten salt – flibe or flinabe
- Effective shielding thickness is 56 cm
- Chamber is lifetime component
- Oscillating jets dynamically clear droplets near target (clear path for next pulse).
- Allowed compact chamber, short beam propagation distance
- High temperature molten salt coolant gave good thermal efficiency (44%)
- Final focus magnets shielded from neutrons and predicted to be lifetime components

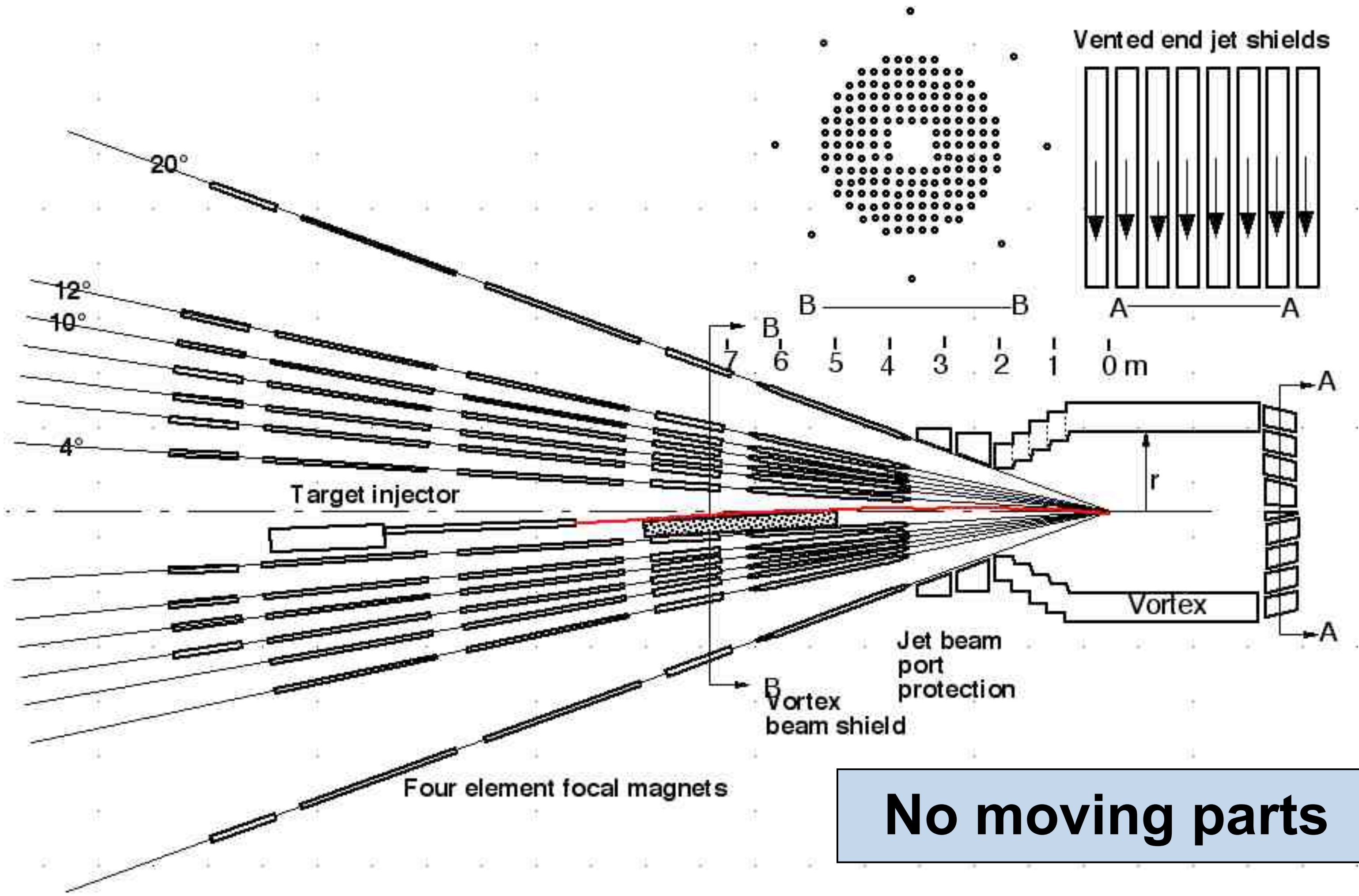
Ref. - S.S Yu et al., *Fusion Science and Technology,* **44**, No.2, 266 (2003).

Key design parameters for the Robust Point Design (RPD)

Driver energy, MJ	7.0
Target gain	57
Target yield, MJ	400
Pulse rep-rate, Hz	6.0
Fusion power, MW	2400
Thermal power, MWt	2832
Conversion efficiency, %	44
Gross electric power, MWe	1246
Auxiliary power, MWe	50
Pumping power, MWe	27
Driver efficiency, %	38
Driver power, MWe	110
Net electric power, MWe	1058

RPB was an self-consistent, integrated power plant design for HIF based on the HYLIFE-II thick-liquid wall chamber.

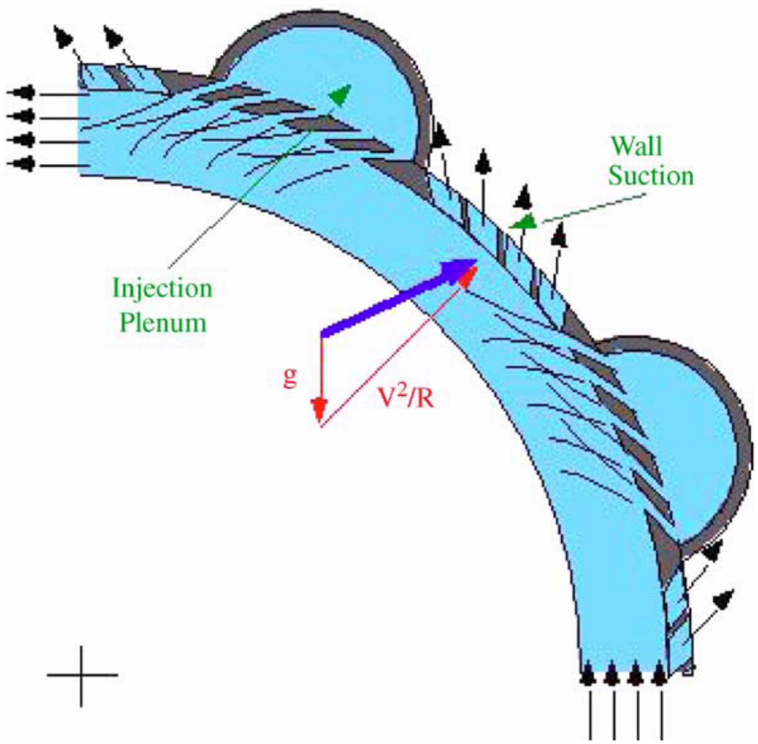
Liquid jets and a vortex chamber protect solid structures for the life of the plant

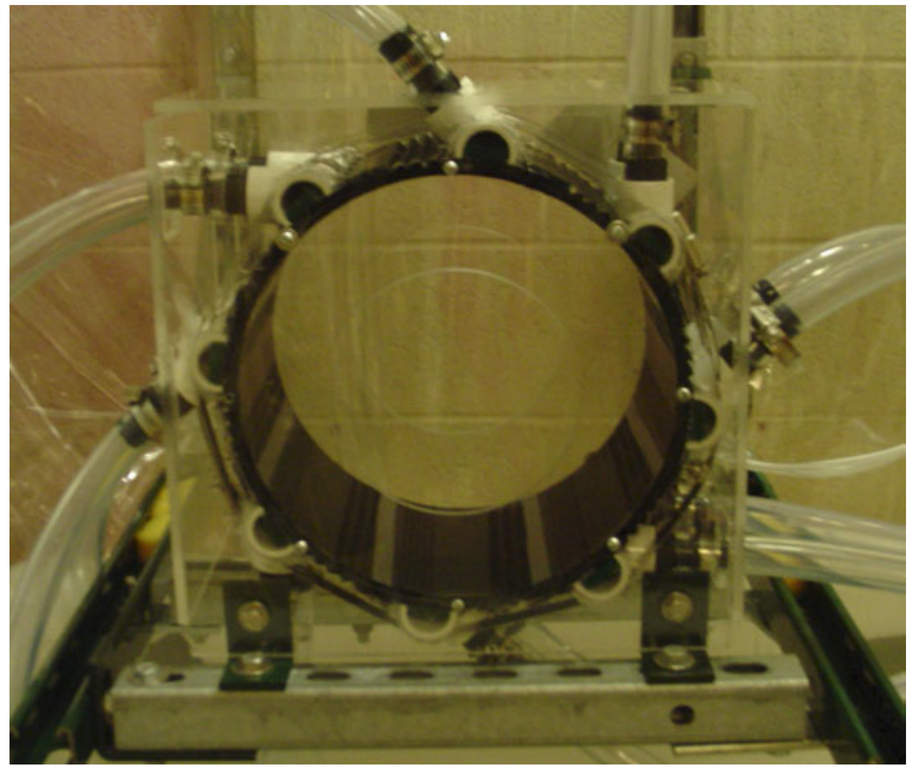


No moving parts

Ralph Moir Dec. 6, 2010

UC Berkeley worked on modeling and experiments in support of vortex chamber concept

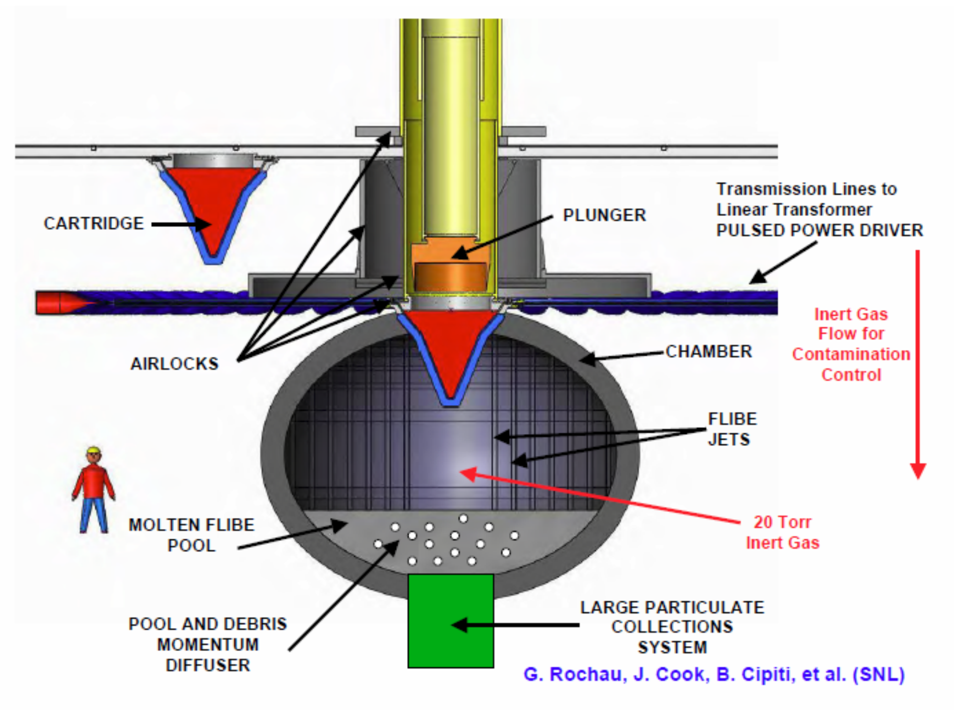




Per F. Peterson, Philippe M. Bardet, Christophe S. Debonnel, Grant T. Fukuda, Justin Freeman, Boris F. Supiot

Votex chamber exp
Dia. = 20 cm?

Z-IFE also proposed a TLW chamber



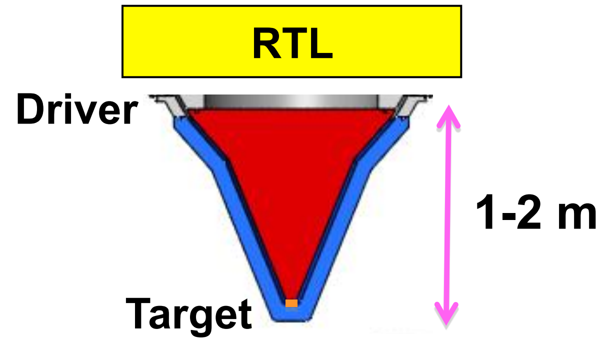
Cross section of Z-IFE chamber
FW radius = 4-5 m

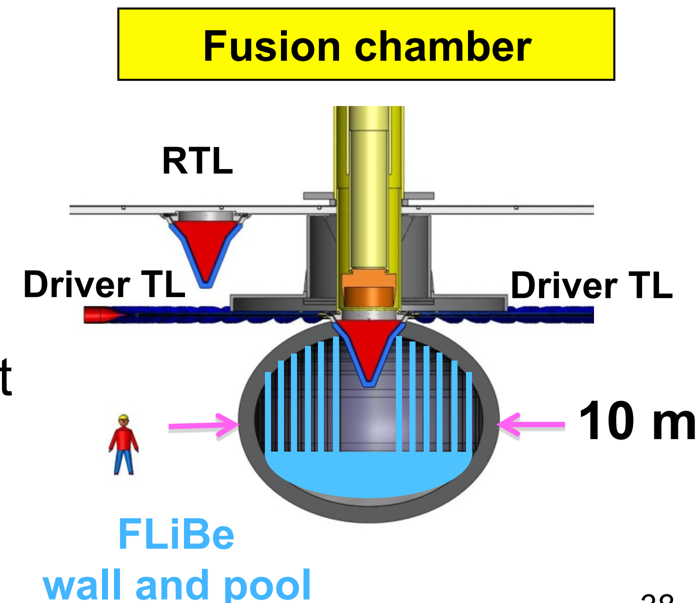
- Indirect drive targets, pulse power driver
- Replaceable Transmission Line (RTL) robotically placed each shot
- Liquid jets absorb blast and target/ RTL debris (can also add gas fill)
- Molten salt (flibe) coolant / breeder
- For low rep-rate, high yield systems, flibe acts as a thermal medium storing the heat (heat capacity)
- Higher yield (~3 GJ), lower rep-rate (~0.1 Hz) per chamber than other IFE designs
- 40 year wall life, 10-20 FPY for components near RTL
- 10 chambers per 1 GWe power plant
  - share RTL/target factory
  - improved plant availability
- SNL now considering single-chamber plants

Craig Olson at IFE Workshop (2007)
http://ifeworkshop/proceedings.html

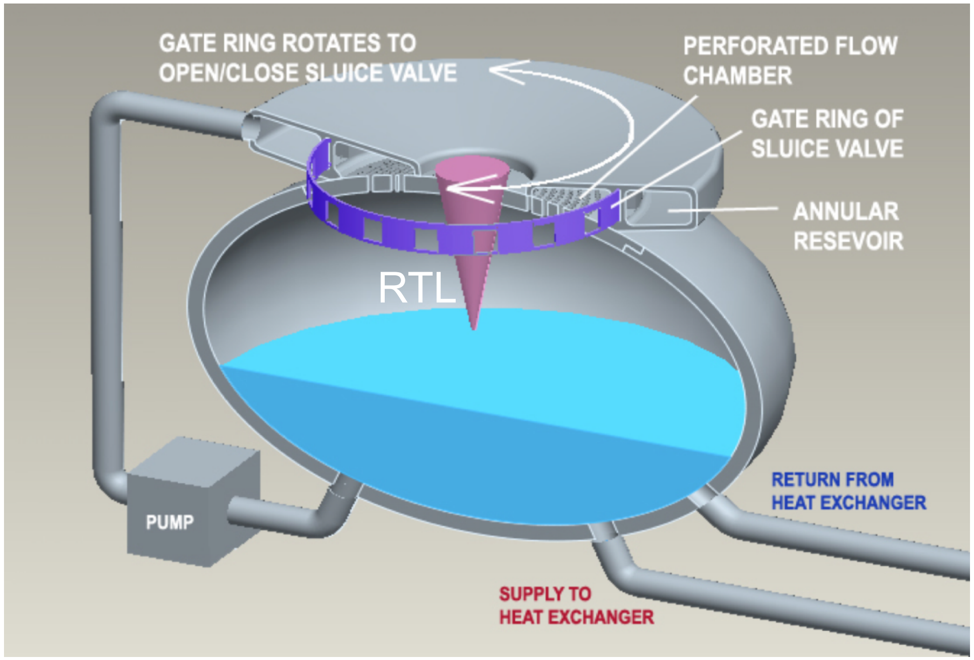
Z-IFE approach features large yields and low repetition rates as a path for IFE

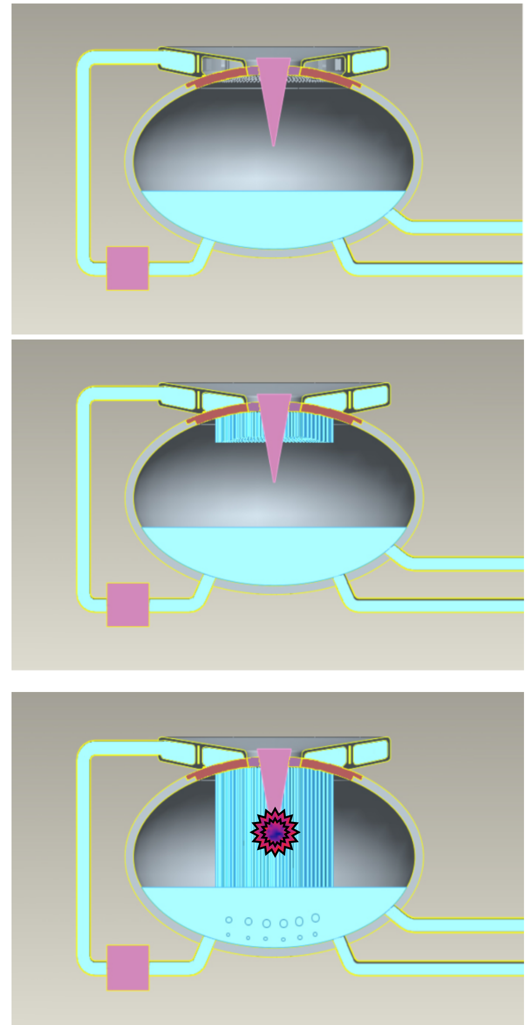
- **Recyclable Transmission Lines (RTL) directly connects driver to target repetitively**
  - Mass produced by on hand technology (stamping or casting)
  - Economic at lower rep-rate and higher yield
  - Can be shaped to shield driver direct-line-of-sight
- **High Yields**
  - Low rep-rate (> 0.1 Hz)
  - Compatible with high pulsed power driver energy to the load (10 MJ)
  - Thick liquid walls made possible by RTL
  - RTL provides coupling of driver and target even with chamber debris from previous event; chamber clearing not required





Gated/pulsed flow proposed to reduce pumping power requirement of TLW





- 1-m thick equivalent flibe layer
- 30% void fraction
- Total number of flibe jets = 562
- Designs considered flibe or LiPb working fluid
- Li and LiSn should also be considered

L. El-Guebaly *et al.*, UWFDM-1283 (2006)

Summary of chamber designs reviewed

Name	Driver	Target	Type
Sombrero	Laser (KrF)	DD	Dry-wall / gas protected
HAPL	Laser (DPSSL and KrF)	DD	Dry-wall / magnetic deflection or engineered W surface
LIFE	Laser (DPSSL)	ID	Dry-wall / gas protected
Osiris	Heavy ion	ID	Wetted-wall
Koyo-F	Laser (DPSSL)	DD FI	Wetted-wall
HYLIFE-II	Heavy ion	ID	Thick-liquid-wall
Z-IFE	Pulsed power	ID	Thick-liquid-wall

DD = Direct-drive
ID = Indirect-drive
FI = Fast ignition

IFE separability allows flexibility in chamber design for enhance performance and attractiveness

- Design to minimize critical functions of most highly damage components (e.g., FW does not have to be a vacuum wall)
- Design to be insensitive to component life-time (e.g. rapidly replaceable components as in LIFE)
- Design to significantly reduce neutron damage and activation rates
- Design choices can improve maintenance and reliability.
  - Separation of chamber/vacuum function improves access
  - Blanket can be segmented into more easily maintainable parts
  - TLWs to give very long lived structural life, with goal of avoiding the need for chamber replacement

Comments on R&D Needs

Key aspects/issues that any chamber R&D plan must address

1. **Target delivery** – Chamber environment (residual gases, vapor, turbulence, liquids, etc.) must accommodate reliable, precision target injection (or insertion) in a manner that does not degrade the integrity of the target (at the specified rep-rate).
2. **Drive energy delivery** – Chamber must accommodate reliable, precision delivery of drive energy to the target in a manner that meets target physics requirements for ignition and gain (at rep-rate).
3. **Single shot effects** – Need method to assure survival of chamber first wall from single shot effects (x-rays, ions, pulsed heating, mechanical loads).
4. **Long-term effects** – FW and chamber structures must withstand various degrading threats (neutrons, ions, corrosion, T/M fatigue, etc.) for a time long enough that the plant availability is not significantly impacted. Understanding failure mechanisms and rates and developing techniques for rapid repair/replacement are needed.
5. **Power conversion** – Demonstrate ability of remove chamber power and drive a power conversion system in a safe (e.g., T confinement) and efficient manner.

Key aspects/issues that any R&D plan must address (cont.)

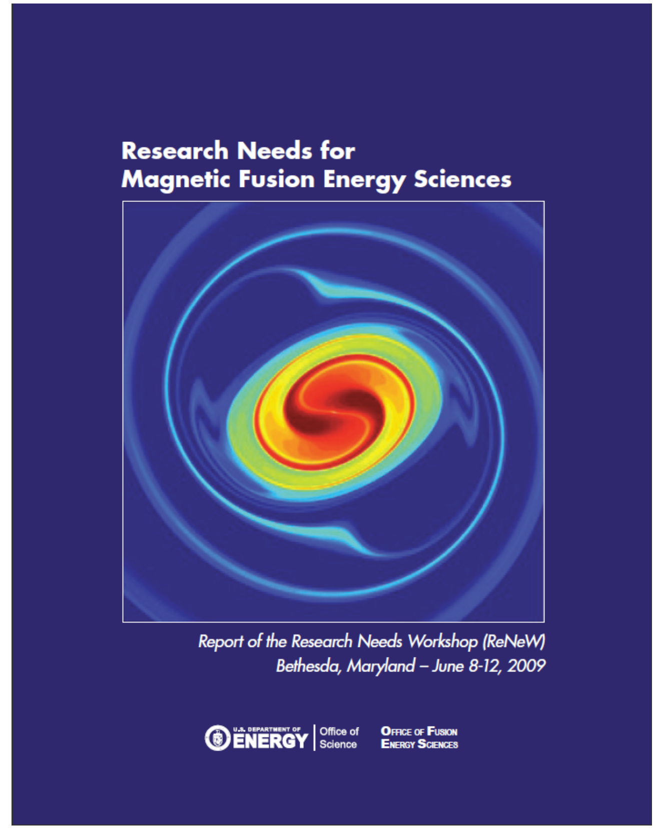
6. **Fuel cycle** – Demonstrate ability to close the fusion fuel cycle with adequate tritium breeding, T recovery from breeder and vacuum system, and refueling systems.
7. **Safety** – Accomplish the above in a manner that the plant can be shown to operate in a safe manner in normal conditions and postulated accident scenarios; typically dominated by T control.
8. **Environmental impacts** – Accomplish the above in a manner that long-term environmental effects are acceptable (ideally low activation waste and/or recyclable materials).
9. **Integrated designs** – Develop integrated designs that not only meet the technical criteria but also meet end-user criteria of good economics (capital, fuel cycle and O&M costs and availability), high reliability and high availability.

Bonus point:

Not part of the chamber, but not to be forgotten is the need to protect final focusing elements (or RTL placement equipment) from target threats to the degree needed for long-term operation.

Synergy with MFE

- DOE's Fusion Energy Sciences (FES) completed a Research Needs Workshop (ReNeW) report that included a comprehensive evaluation of requirements under the heading of "Harnessing Fusion Power" (one of five workshop Themes)
- This Theme addressed the topics of
  - Fuel Cycle
  - Power Extraction
  - Materials
  - Safety and Environment
  - Reliability, Availability, Maintainability, Inspectability (RAMI)
- The report is being used to help define R&D in the coming decade and has set the stage for the current Fusion Pathways Study



IFE needs its own fusion chamber technology R&D program

- Some of the R&D in proposed MFE nuclear science and technology programs should be applicable to IFE (e.g., S&E, basic material science, RAMI systems)
- But this can not be a substitute for a dedicated IFE chamber technology program since there are many unique aspects that won't translate
  - different material choices (e.g., MFE in US is not considering Li of flibe breeders)
  - pulsed effects with IFE
  - system integration issues

Additional comments on fusion materials

All fusion concepts seek structural materials that are:

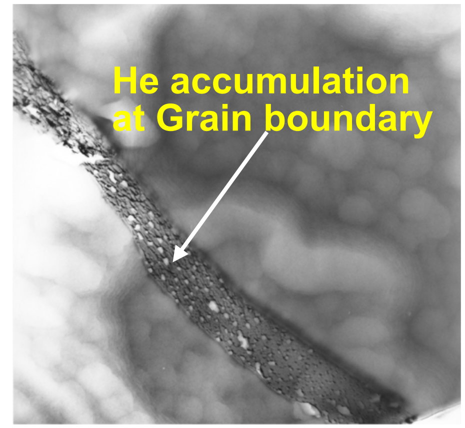
- Good thermal mechanical properties
- Fabricable (forming, welding, etc)
- Compatible with selected coolant/breeder
- High temperature capable
- Low activation
- Radiation damage resistant
- Available/affordable
- Maintainable (e.g., rewelding if needed)

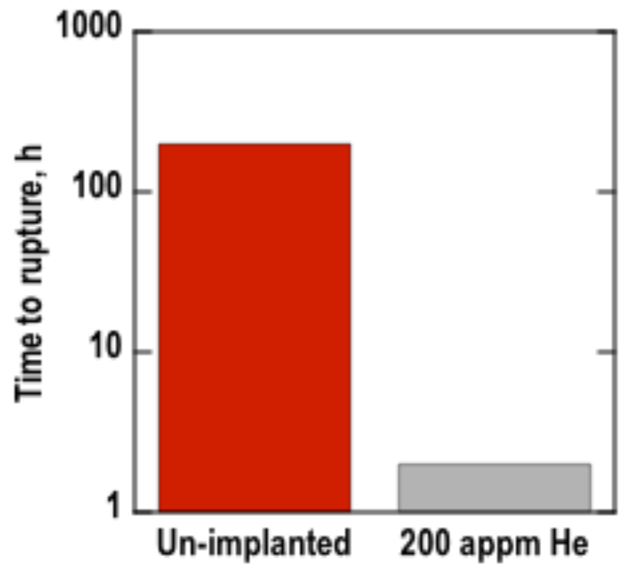
Issue of radiation damage due to high energy fusion neutrons is commonly viewed as the most serious challenge for fusion in general. Dealing with short-range threat is equally important for IFE.

Radiation damage is a serious issue

- Fusion spectrum leads to high energy transmutations in steel that produce H and He ions via (n,p) and (n,α), in addition to displacement damage measured in displacements per atom (dpa)
- Fusion spectrum results in He/dpa ratios about 10x higher than fission reactor spectrum, so material response is different
- The community has been developing more radiation damage resistant steels, e.g., oxide dispersion strengthened (ODS)
- A combination of detailed modeling and experiments are needed

(TLW design created to address this issue)





Schroeder & Batfalsky, 1983

R. Kurtz et al., “Scientific & Technical Challenges for Development of Materials for Fusion’” Briefing to FES (12/09)

How to obtain the needed radiation damage data to build fusion chambers?

- Accelerator sources of high E neutrons (e.g., IFMIF, LANSCE, etc.)
- Ion simulations (triple beam facility) on micro samples
- Bootstrap by building an average power fusion facility capable of testing materials and components; options include
  - Dedicated component test facility
  - Testing as part of commissioning a power plant
- Clearly the longer the life the better, but there are approaches that can be advanced without 200 dpa materials being proven first (e.g., TLW chambers, chambers with very rapid maintenance schemes)

Integrated R&D plan must include chamber and other fusion technology components

- It is essential to conduct integrated R&D that carefully considers and evaluates the driver/target/chamber/power plant interfaces, resulting design and performance trade-offs, and attractiveness of the product to end-users
- There is danger in a program that develops subsystems independently. e.g., choosing materials to optimize target physics performance without considering the impact on chamber conditions, tritium recovery processes, safety, etc.
- If we want to progress, we need to start developing the fusion chamber technology and begin integrating subsystems as part of a self-consistent power plant design. (Don’t we have enough paper studies?)

Conclusions

Chamber designs

- A wide variety of IFE chamber and power plant concepts have been proposed and developed to different levels of detail.
- These illustrate different approaches to meeting fundamental technical requirements and attractiveness characteristics
- Designs show significant flexibility in approaching the objectives

R&D Needs

- Issues and R&D needs can be classified in a generic manner, but detailed plans will depend on the specifics of the proposed design
- There is some degree of interchangeability between MFE and IFE, but it is not sufficient to meet IFE needs
- IFE fusion chamber and BOP technology must be developed in concert with target physics, target technology and drivers. It should be a significant component of the R&D portfolio, not an afterthought.

Additional Resources / References

Selected Resources / References

- **Sombrero and Osiris**

  Fusion Technol., **121,** 1547 (1992). Several Papers

  Meier, W R., "Osiris And Sombrero Inertial Fusion Power Plant Designs - Summary, Conclusions, and Recommendations," *Fusion Eng. and Design*, **25,** 145-157 (1994)

- **High Average Power Laser Program**

  J. Sethian et al., "An overview of the development of the first wall and other principal components of a laser fusion power plant," Journal of Nuclear Materials 347 (2005) 161–177

  http://aries.ucsd.edu/HAPL/

  http://fire.pppl.gov/sofe09_sethian.pdf

- **LIFE**

  *M. Dunne et al., "*Laser Inertial Fusion Energy (LIFE) – Overview and Path to Delivery," to be published *Fusion Science and Technology* (Proceedings 2010 ANS Technology of Fusion Energy (TOFE) meeting).

  Several other papers in the same issue (preprints available from Mike Dunne, LLNL).

Selected Resources / References

- **HYLIFE-II and Robust Point Design**

  R.W. Moir et al., "HYLIFE-II: A Molten-salt Inertial Fusion Energy Power Plant Design – Tinal Report," *Fusion Tech*., **25** , 5 (1994)
  S.S Yu et al., *Fusion Science and Technology,* **44**, No.2, 266 (2003)
  Several other papers in the same issue

- **Z-IFE**

  "Z-Inertial Fusion Energy: Power Plant Final Report FY 2006" SANDIA REPORT
  SAND2006-7148 Unlimited Release Printed October 2006

- **ARIES IFE**

  http://www-ferp.ucsd.edu/ARIES/DOCS/bib.shtml#ARIES-IFE
  Fusion Science and Technology, **46** (2004) several papers

- **IFE Science and Technology Strategic Planning Workshop**
  (San Ramon, CA, April 2007)
  http://ifeworkshop.llnl.gov

- **MFE ReNeW report**

http://www.science.doe.gov/ofes/ReNeW_report_press.pdf

Questions?

Thank you!