Status of IFE Target Fabrication

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Presented by Dan Goodin at
the ARIES “E-Meeting”

October 17, 2001

Some recent IFE target fabrication/injection papers and publications

Target Fabrication	· **"Progress Toward Demonstrating IFE Target Fabrication and Injection", D. Goodin, et al. IFSA-2001 (Plenary Session Talk)** · **"Reducing the Costs of Targets for Inertial Fusion Energy", G. Besenbruch et al. IFSA-2001** · **"Target Injection and Fabrication Possibilities for Fast Ignitor IFE", R. Stephens, et al. IFSA-2001 (Invited Talk)** · **"Thermal Control Techniques for Improved DT Layering of Indirect Drive IFE Targets," J. Pulsifer et al. IFSA-2001** · **"Concepts for Fabrication of Inertial Fusion Energy Targets," Nobile, et al. *Fusion Technology,* Vol. 39, March 2001, 684.**
Target Injection	• **"Developing Target Injection and Tracking for Inertial Fusion Energy Power Plants", *Nuclear Fusion*, V41, No. 5, May 2001, 527.** • **"Developing the Basis for Target Injection and Tracking in Inertial Fusion Energy Power Plants", Goodin et al. Accepted for publication in *Fusion Engineering and Design*.** • **"Design of an Inertial Fusion Energy Target Tracking and Position Prediction System," Petzoldt et al. *Fusion Technology,* Vol. 39, March 2001, 678.**

.... Contributions and collaborations with people at GA, LANL, NRL, UCSD, LLNL, Schafer, SNL, and ORNL

“Critical issues” have been identified and agreed upon

Target fabrication critical issues

1) Ability to fabricate target capsules & hohlraums
2) Ability to fabricate them economically
3) Ability to fabricate, assemble, fill and layer at required rates

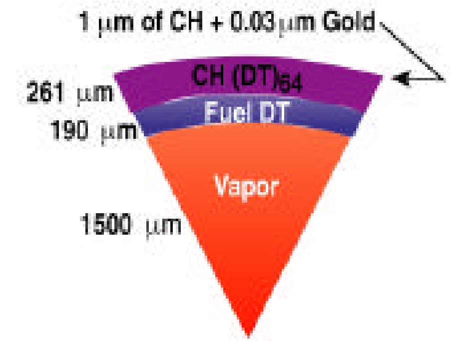
Power plant studies have concluded that $0.25 targets are needed - reduced from ~$2500 each for current targets

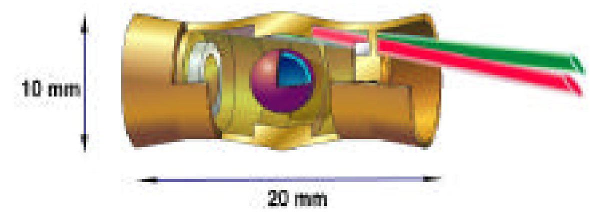
Target injection critical issues

4) Withstand acceleration during injection
5) Survive thermal environment
6) Accuracy and repeatability, tracking

A detailed experimental plan for target injection has been prepared - and is being carried out

NRL Radiation Preheat Target





LLNL Close-Coupled HI Target

“Baseline” targets

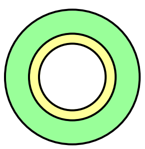
.... We are addressing issues for both laser and heavy-ion driven IFE targets

Overview of target designs and potential processes

Target Design | **Target Fabrication** → **Filling** → **Layering** → **Injection**

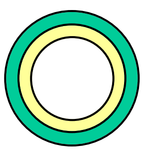
Rad. Preheat

- Foam shell microencapsulation
- Interfacial polycondensation
- Sputter-coating



Empty Outer Foam

- Foam shell microencapsulation
- Interfacial polycondensation
- *or* injection molding



Thick Capsule

- Microencapsulation
- *or*
- Coatings in a fluidized bed

Filling (Rad. Preheat, Empty Outer Foam, Thick Capsule): Permeation

Layering (Rad. Preheat, Empty Outer Foam, Thick Capsule): Cryogenic fluidized bed *or* In-sabot

Injection (all designs): Gas-gun *or* Electromagnetic

Dist. Radiator

- Microencapsulation +
- Foam Casting/Doping

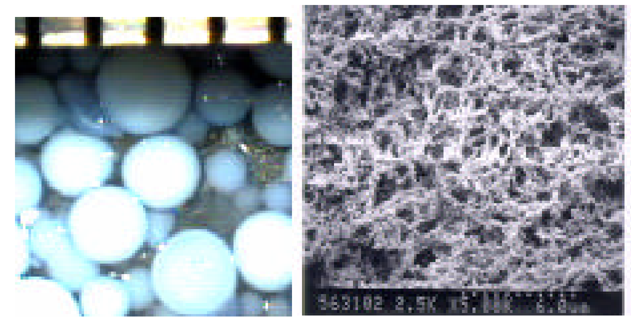
Filling: Permeation *or* liquid injection

Layering: Cryogenic fluidized bed *or* In-hohlraum

.... There are also other potential paths, but these are main focus

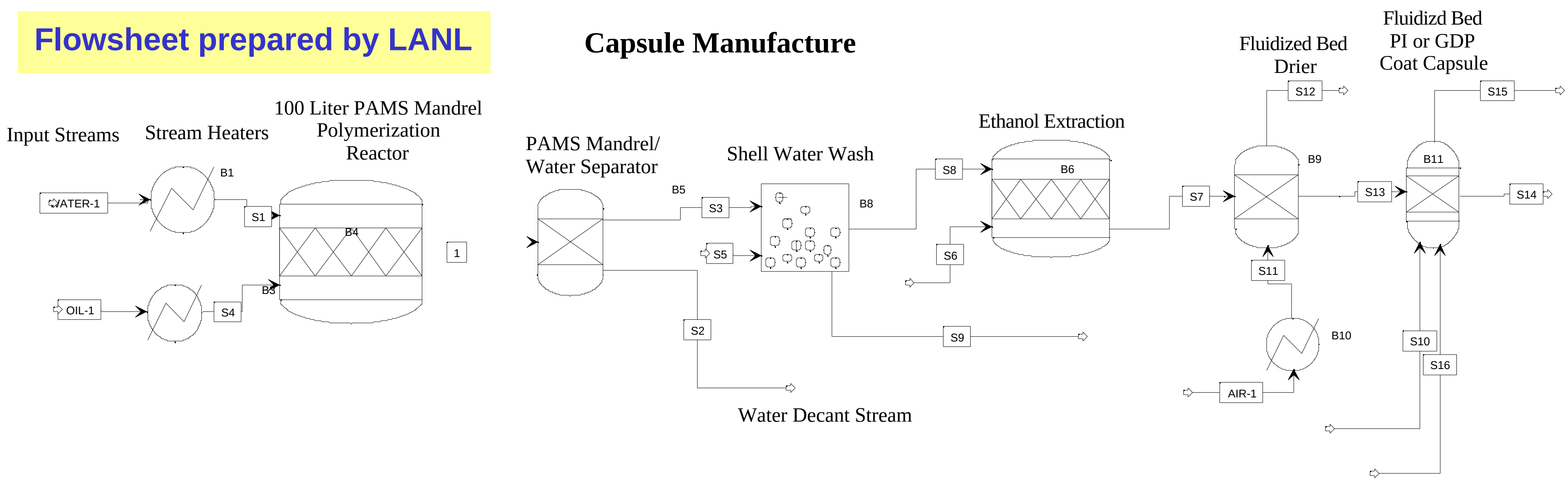
Microencapsulation studies for IFE are underway

- **DVB foam shells are being encapsulated at Schafer for the radiation preheat target**
  - **Density range of 10-250 mg/cc**
  - **Pores sizes down to ~1.6 μm at 10 mg/cc**
  - **Interfacial polymerization to make "seal" coat**
- **Direct microencapsulation of polymers**
- **Chemical process modeling and cost estimating**



DVB beads 10 mg/cc DVB
(D. Schroen)

Flowsheet prepared by LANL



.... Mass balance flowsheets are being prepared to evaluate scaleup of existing bench-scale processes

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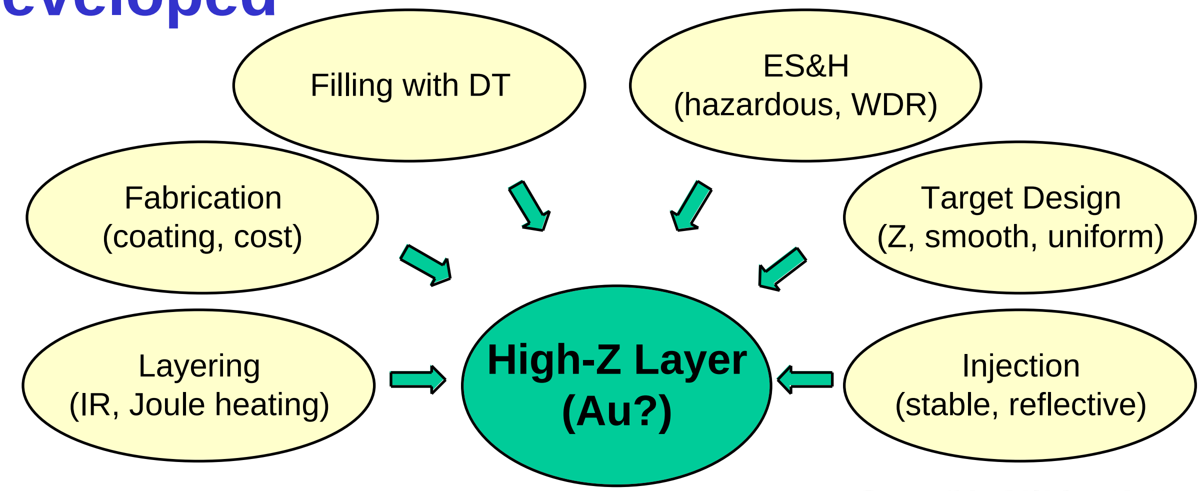
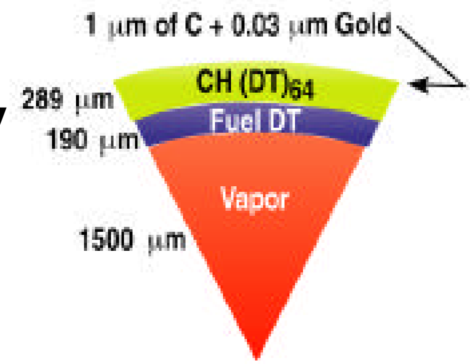
A successful high-Z layer for the radiation preheat target is being developed

Seemingly simple component has multi-disciplinary functions and requirements



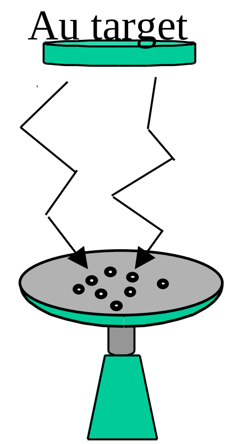
- **Gold was proposed first**
  - **Effective in design, easy to coat, high reflectivity**
- **Issue with gold is permeation rate during filling**
  - **Permeation through bulk gold is very slow**
  - **Experience → thin gold is actually hard to seal**



…. Some representative gold-coated flats and spheres have been fabricated and tested

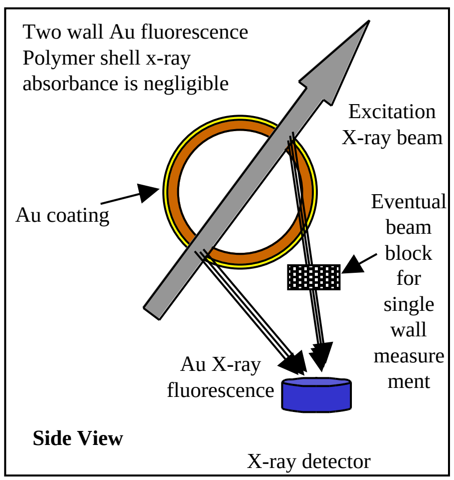
Gold layers were tested for required properties

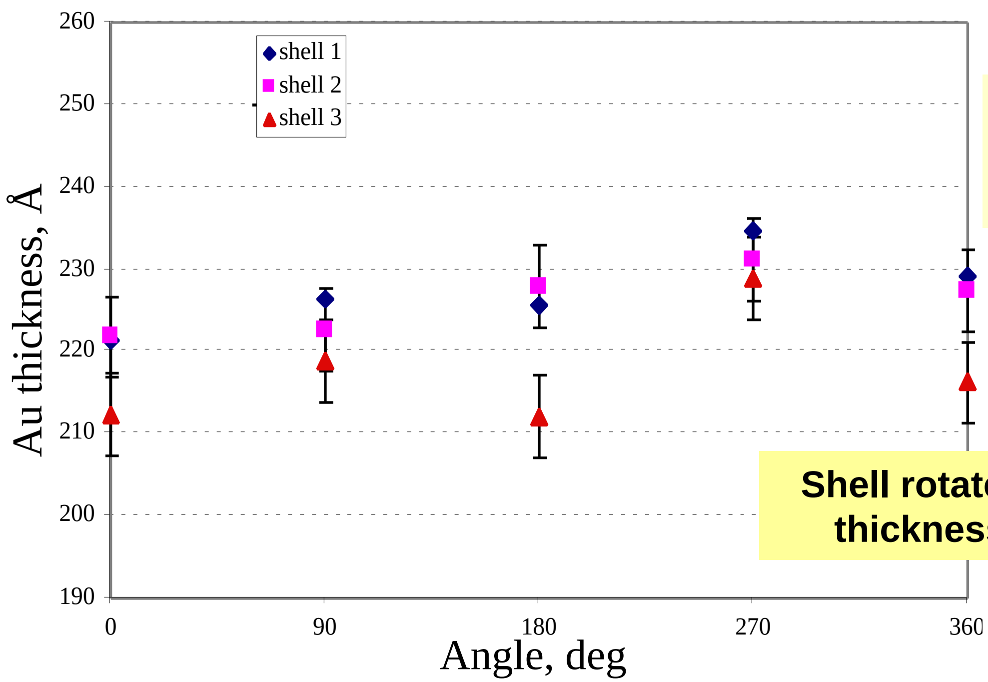
- Prepared 300-1200 Å gold coatings by sputter-coating (very smooth, good mass-production technique)
- Measured thickness and uniformity by XRF
- Gas permeation slowed by "only" a factor of ~8
  - Goal to minimize tritium inventory in Target Fab. Facility



Sputter-coating gold with bounce pan

XRF for thickness and uniformity





Shell rotated to examine thickness uniformity

…. Evaluate alternates in addition to the baseline

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Alternative high-Z materials may speed filling

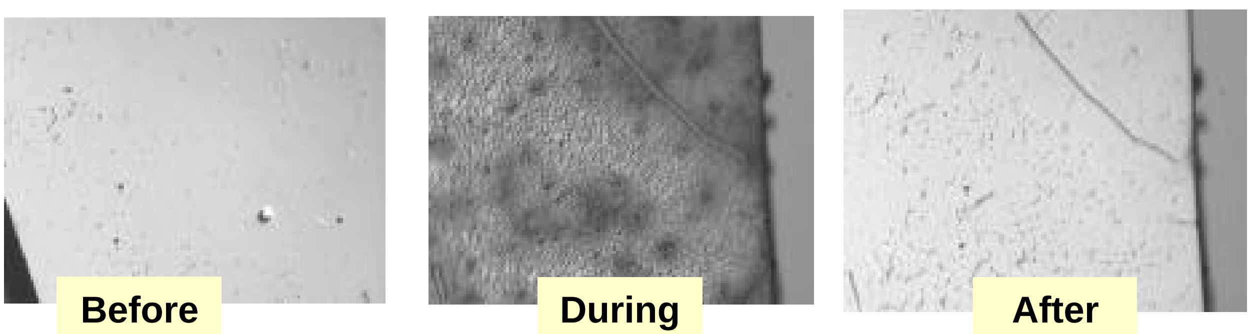
- Palladium is a well-known diffuser in tritium applications
- Target designers are finding Pd reduces the imprint
  - Permeation for hydrogen is very high
  - Reflectivity is lower but may be acceptable (~75% vs 95%)
- Concern for pure Pd is phase change (expansion) upon exposure to H_2 (often alloyed with Ag to reduce effect)
- Made some Pd flats and spheres for testing
  - Exposed flats on glass to H_2 - instant wrinkling
  - Exposed Pd-coated polymer sphere - no visible change

Fill Time @ 300K

Pd	4.4 hrs
Ta	50 days
Nb	6.6 yrs

0.047 atm ΔP
Calc. for bulk

390 Å Pd on Si, reaction to H_2 exposure

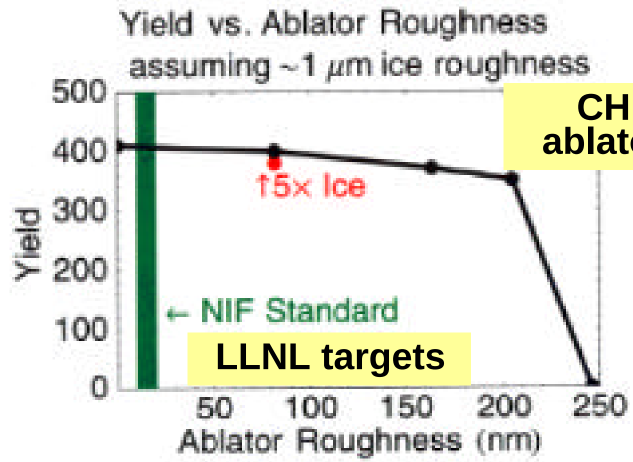


600 Å Pd on PAMS shell - before and after

…. Full test is to fill target, cool, and measure reflectivity at cryogenic temperatures!

Reduced requirements may allow less-precise processes

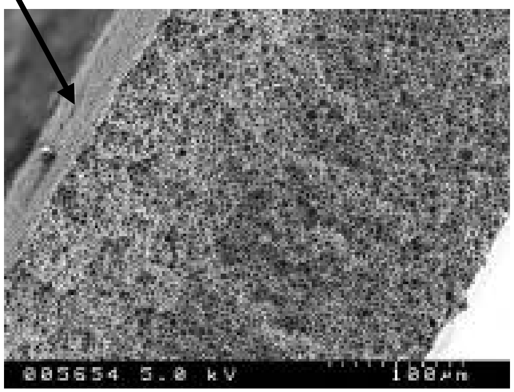
- **Recent results: High-yield capsules tolerate rougher surfaces than low-yield targets**
  - **Ablator 10-20X “NIF Standard” (10 to 20 nm)**
  - **Inner ice roughness 5-10X NIF (~1 μm)**



CH ablator

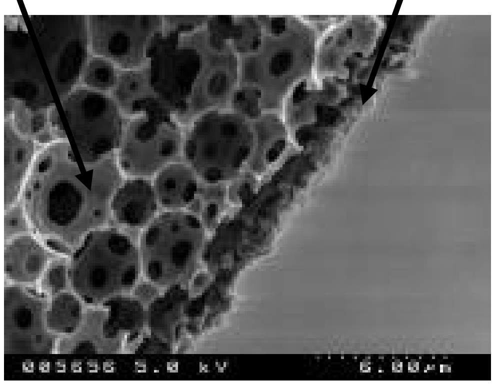
LLNL targets

“Partial” skin on foam hemishell exterior



Foam cross section

“Partial” skin



4 mm diameter hemishell ~100 mg/cc, 400 μm wall

Advantages

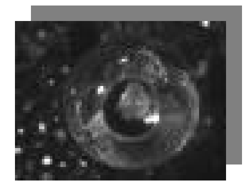
- **Simple process**
- **Reproducible process (each shell has same diameter and wall thickness)**

Status

- **Teflon mold made**
- **100 mg/cc foam shell**
- **Easy mold removal**
- **Defects at injection port and at equator**
- **Ongoing work**

Demonstration of mass layering with a room temperature surrogate instead of hydrogen

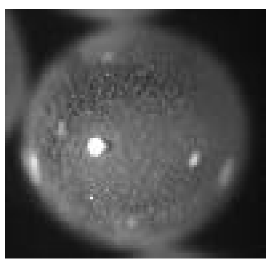
- Basic concept = use a more convenient surrogate to demonstrate fluidized bed layering and evaluate operating parameters
- Allows use of room temperature characterization equipment
- Prepared samples by microencapsulation and by injection



Filled thru hole and sealed

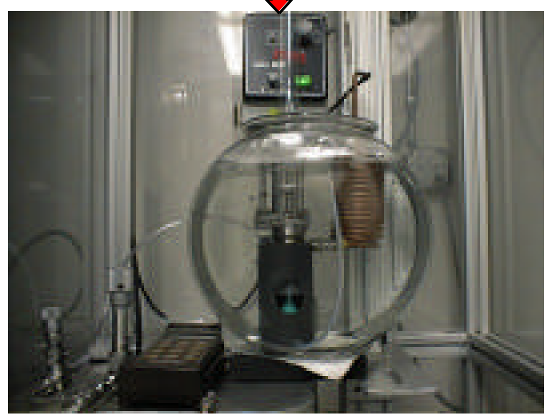
Before →

After →

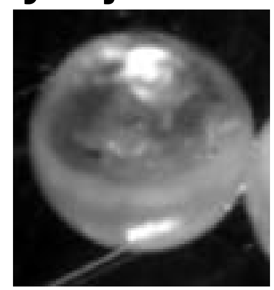


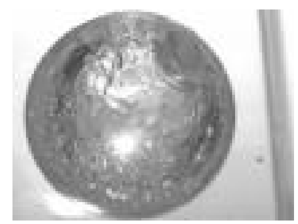
Oxalic acid

IR LAMP



Fluidized bed in water bath





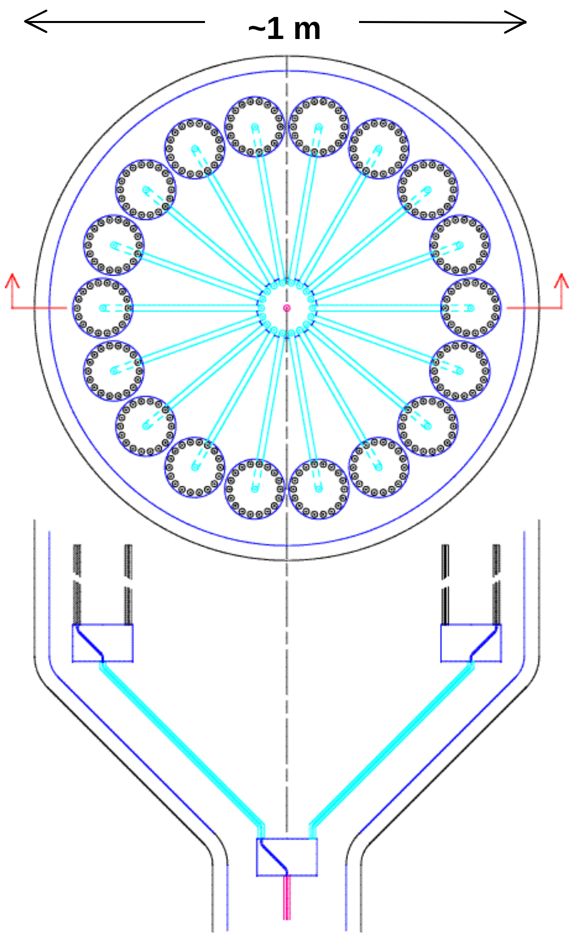
Neopentyl alcohol

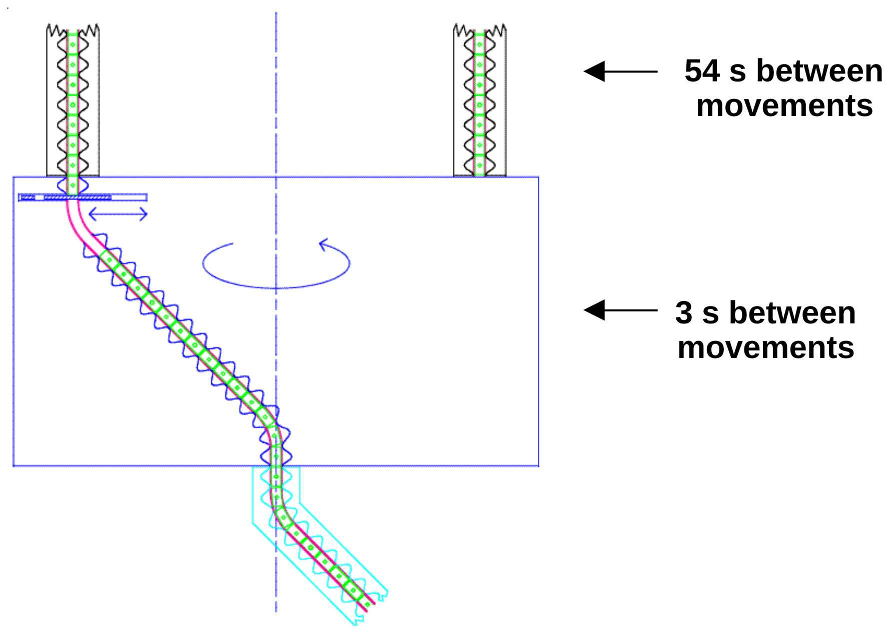
.... Proof-of-principle demonstration done, next step is to design a cryogenic fluidized bed system

Design calculations show equipment size for in-hohlraum layering is reasonable

Design Data

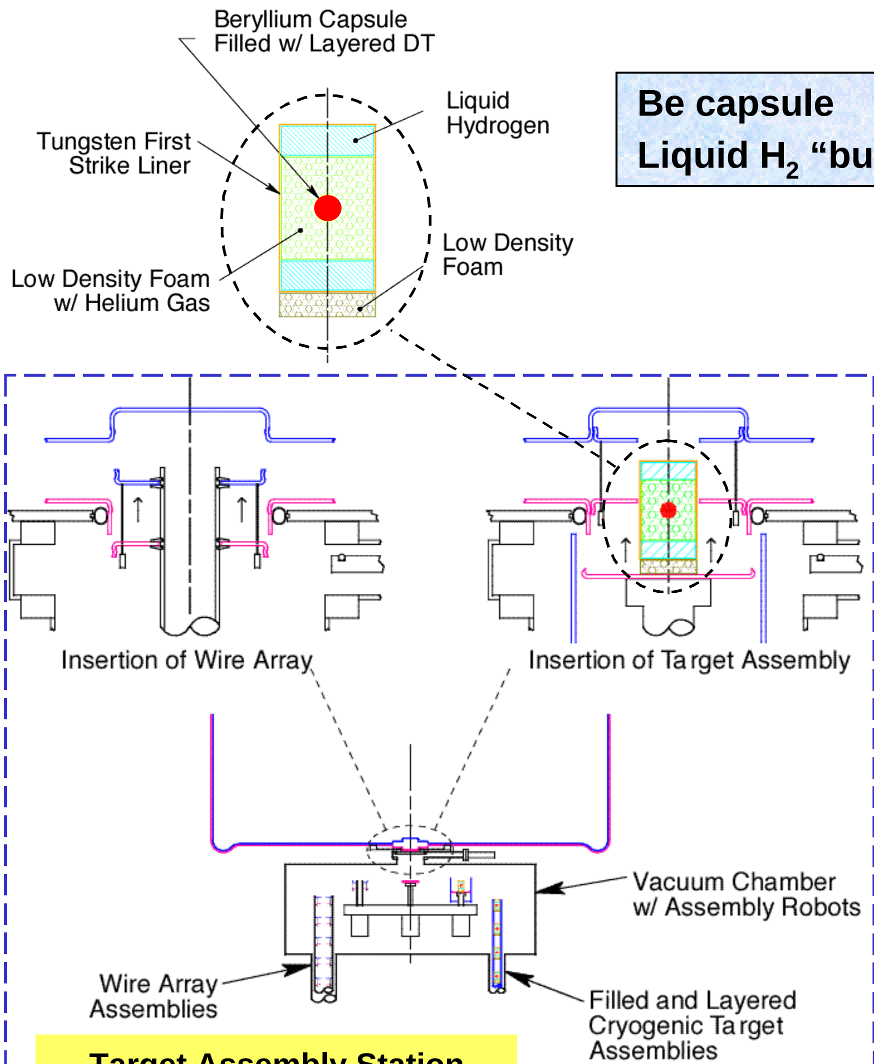
- 3 hr layering + 0.5 h backlog
- 18 rods per bundle
- 18 bundles total
- 75,600 hohlraums
- Total He cooling flow = 97 g/s





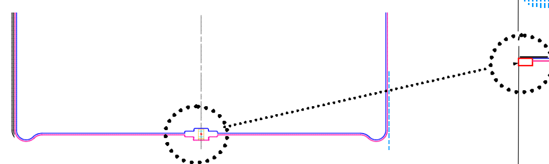
.... "In-hohlraum" layering can also apply to DD targets

With SNL and others, target systems for Z-pinch driven IFE are being developed

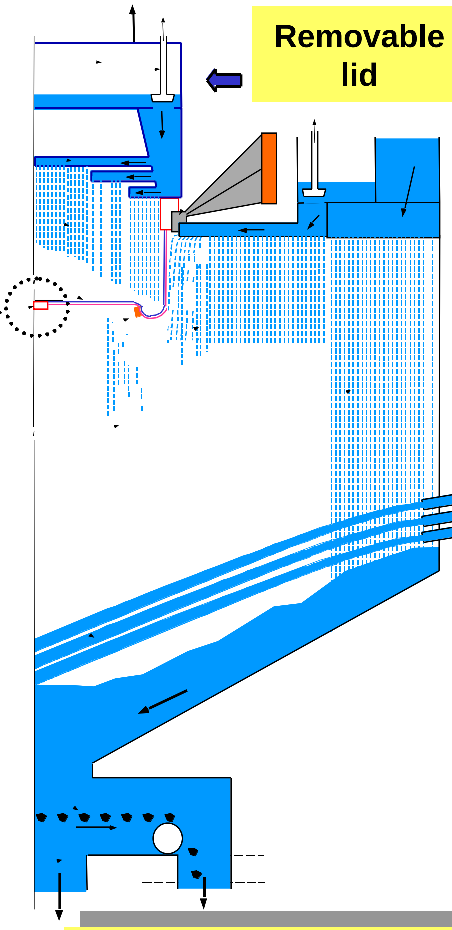


Target Assembly Station

Be capsule
Liquid H_2 "buffers"



Assembled RTL/target in transit



Removable lid

Flibe-protected ZFE chamber concept

Plant Design Data

Rep-rate = 0.1 Hz
Yield = 3 to 20 GJ
Power = ~1100 MW(e)

See ***"ZP-3, A Power Plant Utilizing Z-Pinch Fusion Technology", Rochau et al. IFSA2001***

.... Design concepts have been prepared indicating time frames for cryogenic target assembly and handling are feasible

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Summary and conclusions

Capsule Fabrication

- Materials fabrication technologies are now being defined
  - Exploratory R&D programs are underway - including experiments
  - Chemical process modeling and cost estimating is beginning
  - Industrial technologies for mass-production are being applied

Filling and Layering

- Filling models are available to guide the R&D programs
- Alternative approaches are being evaluated
- Initial design calculations are underway

Injection

- Methods for fueling of Z-pinch driven IFE devices are being developed

.... A significant development program for IFE target fabrication, filling, layering, and injection will be required