Science and Technology of Inertial and Magnetic Fusion Energy

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UCLA Fusion Technology Program
(Prof. Mohamed Abdou)

UCLA

ITER

Test Program

- *UCLA leads US efforts*
- Definition of test program, international space allocation and device utilization
- Requirements on major device parameters

Nuclear Design

- Blanket tritium & thermal design and analysis
- Divertor design and analysis
- Shielding design for penetrations

Nuclear R&D

- Insulated duct MHD – experiments & modeling
- High heat flux compliant layers
- Thermal hydraulics: gap conductance, particle beds, purge flow characteristics

Neutronics

- US/JAERI collaboration on integral experiments and analysis

  UCLA leads the US effort
- Development of computational techniques; sensitivity/uncertainty analysis
- Radioactivity & decay heat experiments; measurement techniques for nuclear heating

VENUS

FNT Modeling, Analysis & Experiments ("The Base Program")

Solid Breeder Blankets

- Tritium transport in lithium ceramics & Be
- Innovative techniques for thermal control
- Thermomechanics experiments & models:**HiTeC, ICE, PBX**

Liquid Metal Components

- MHD models for thermal & fluid flow analysis of blankets
- Free surface film flows (divertor, HHFC)

Tritium Fuel Cycle

- Integral dynamic fuel cycle model
- Tritium extraction from liquid metals

TFTR Radioactivity and Shielding Exp'ts

Reactor Design Studies

- Prometheus
- MFE DEMO
- IFE Facilities and Technology R&D

UCLA Fusion Technology Program

- **Recognized internationally for being at the forefront of the world's effort on fusion technology.**

- **The Program is focused on:**
  1) Key Scientific issues and R&D for the technological feasibility and attractiveness of fusion energy.
  2) Education and Training of future scientists/engineers.

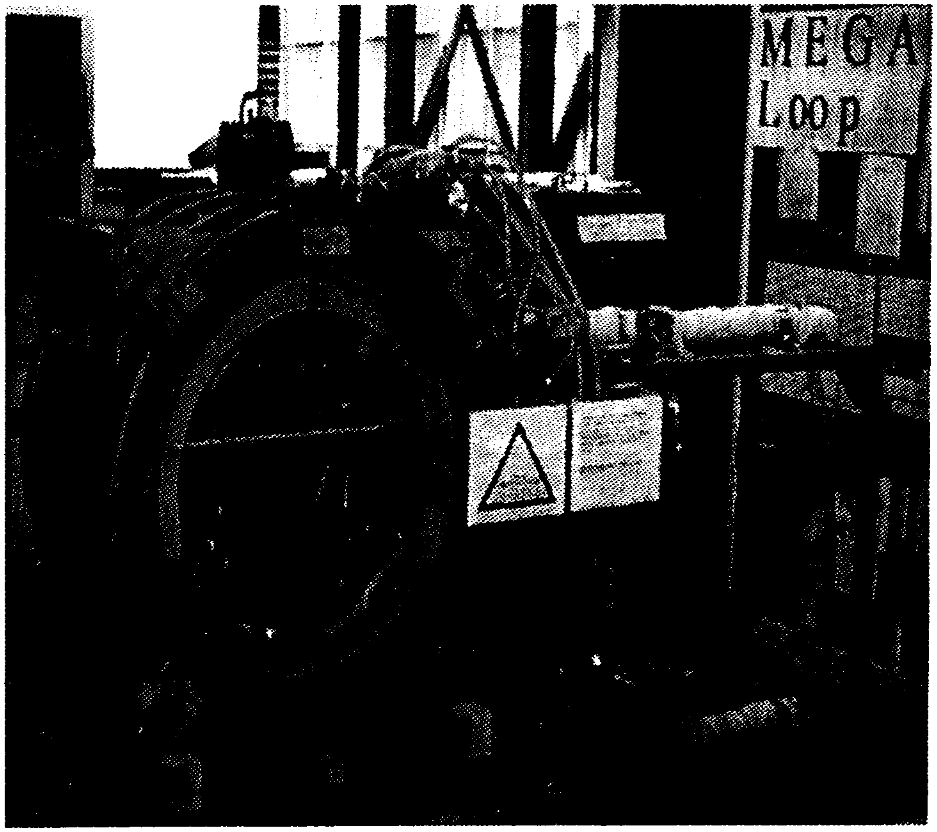
- **The Program includes:**
  1) Theory, modelling
  2) Experiments
  3) Analysis
  4) Innovative design

- **Key Elements:**
  - Blanket (Tritium Breeding and Energy Conversion)
  - Fuel Cycle
  - Divertor (Plasma Particle and Heat Removal and Impurity Control)
  - Design Studies

- **Strong Collaboration with others nationally and internationally.**

- **Integrated team of bright graduate students, faculty, and experienced research staff.**

MEGA Loop for Liquid Metal Magnetohydrodynamics Studies



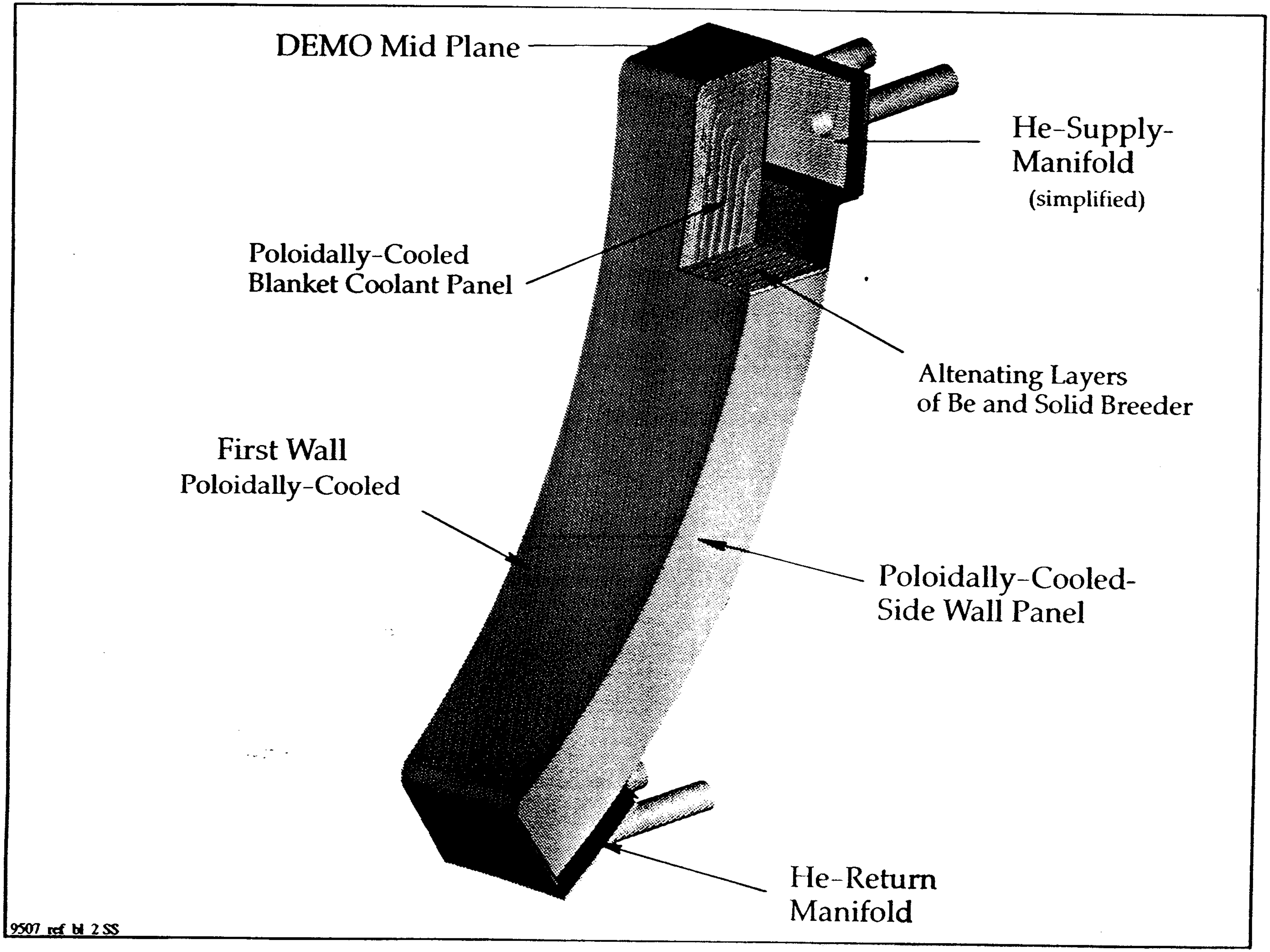
- Research on LM film flow behavior in fusion magetic fields
- Innovative concept for liquid metal divertor
- First wall candidate for Inertial Confinement Fusion Reactor

Loop Parameters

•Liquid Metal	Bi-Pb-In-Sn-Cd
•Melting Point	47 C
•Maximum Flow Rate	1.5 l/s
•Loop Volume	15 liters
•Pump Power	13 kW
•Maximum Field Strength	1.8 KG

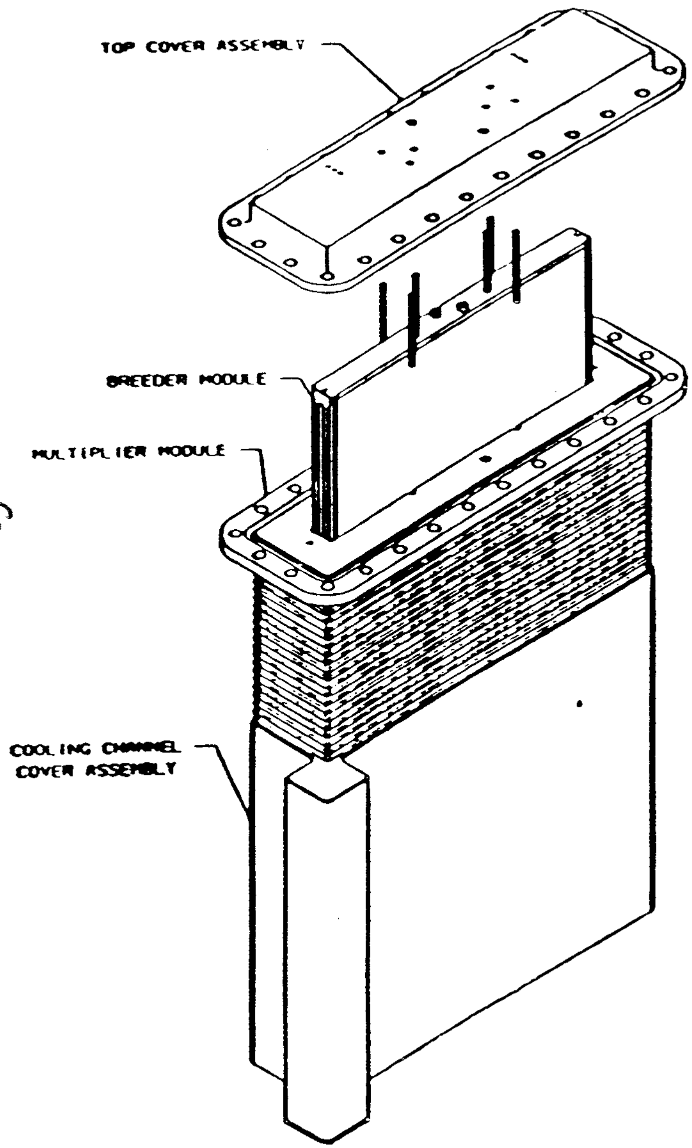
U.S. DEMO He-Cooled Solid Breeder Reference Blanket

View of One Lower First-Wall/Blanket Segment



UNICEX – Solid Breeder Unit Cell Thermomechanics

UCLA

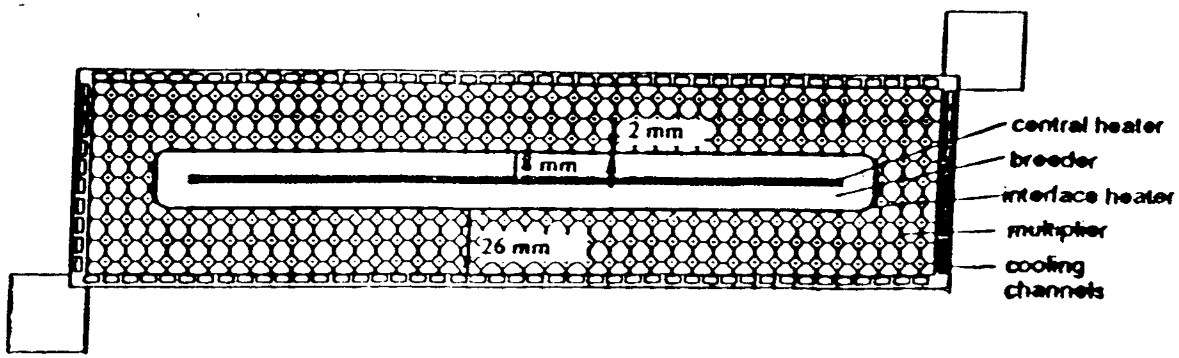


Purpose

- Demonstrate thermal control
- Generate empirical data
- Improve models and basic understanding

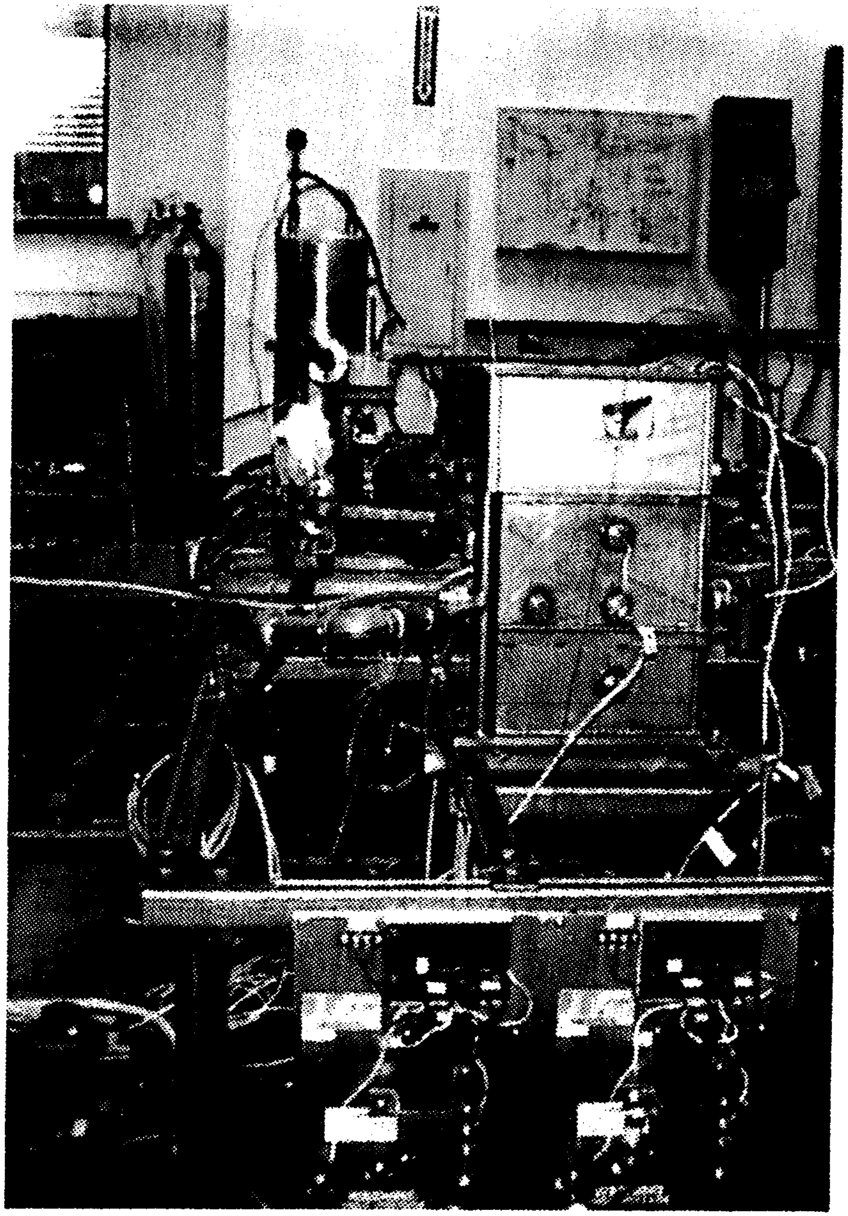
Key Features

- Prototypical materials
  - Li_2ZrO_3 bed
  - Be binary bed
- He & water coolants
- Breeder and multiplier purges
- Plate heaters at center and interfaces

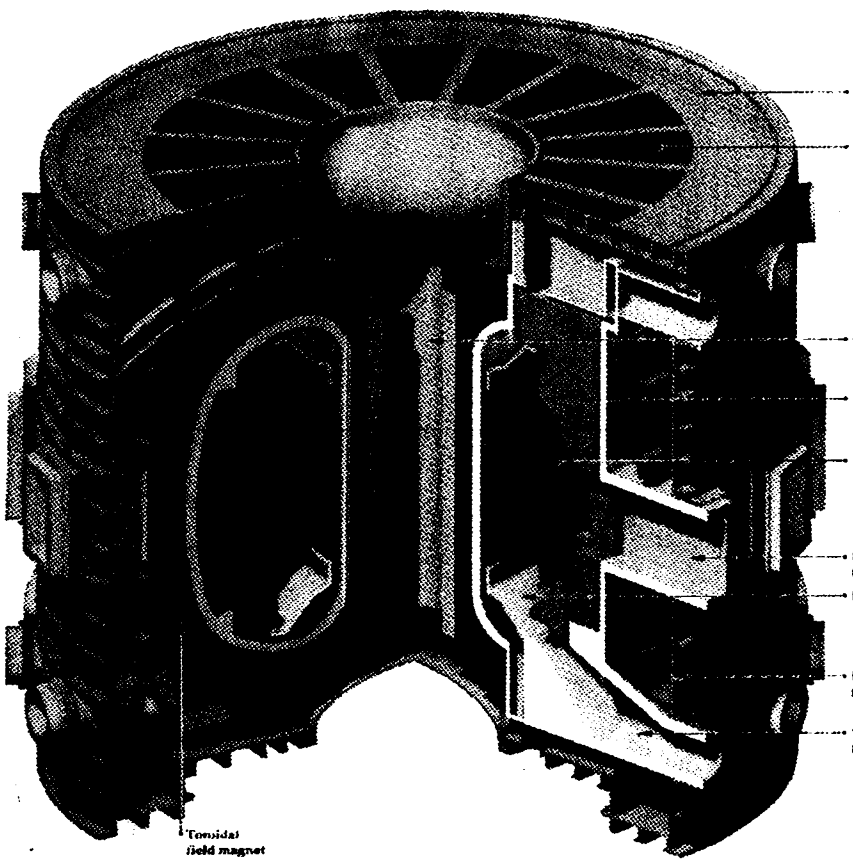


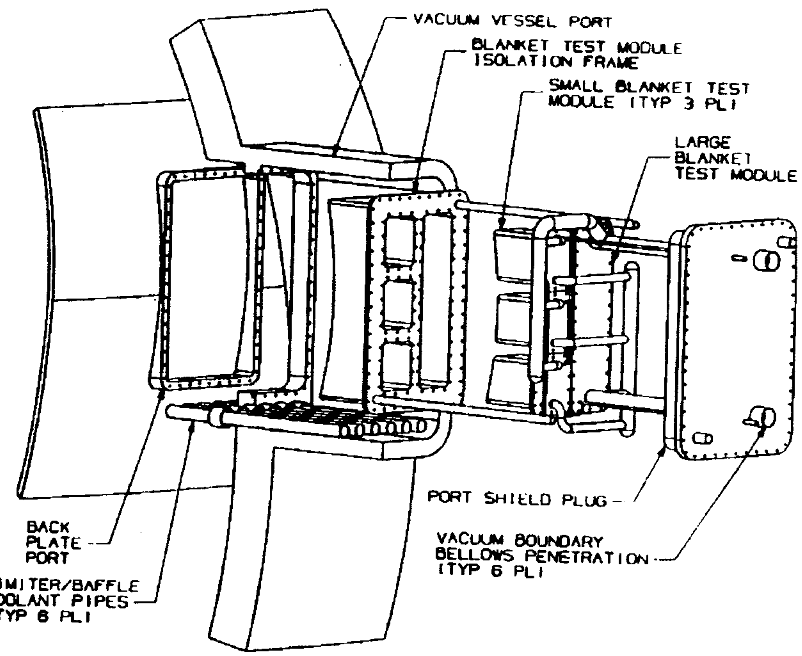
Solid Breeder Thermomechanics Laboratory

- Several experiments on thermomechanical interactions among the physical elements and environmental conditions of solid breeder blankets
- A series of unique experiments that have attracted international collaboration
- Joint collaboration with industry (Rockwell, MDA)
- Provide scientific and engineering data for ITER

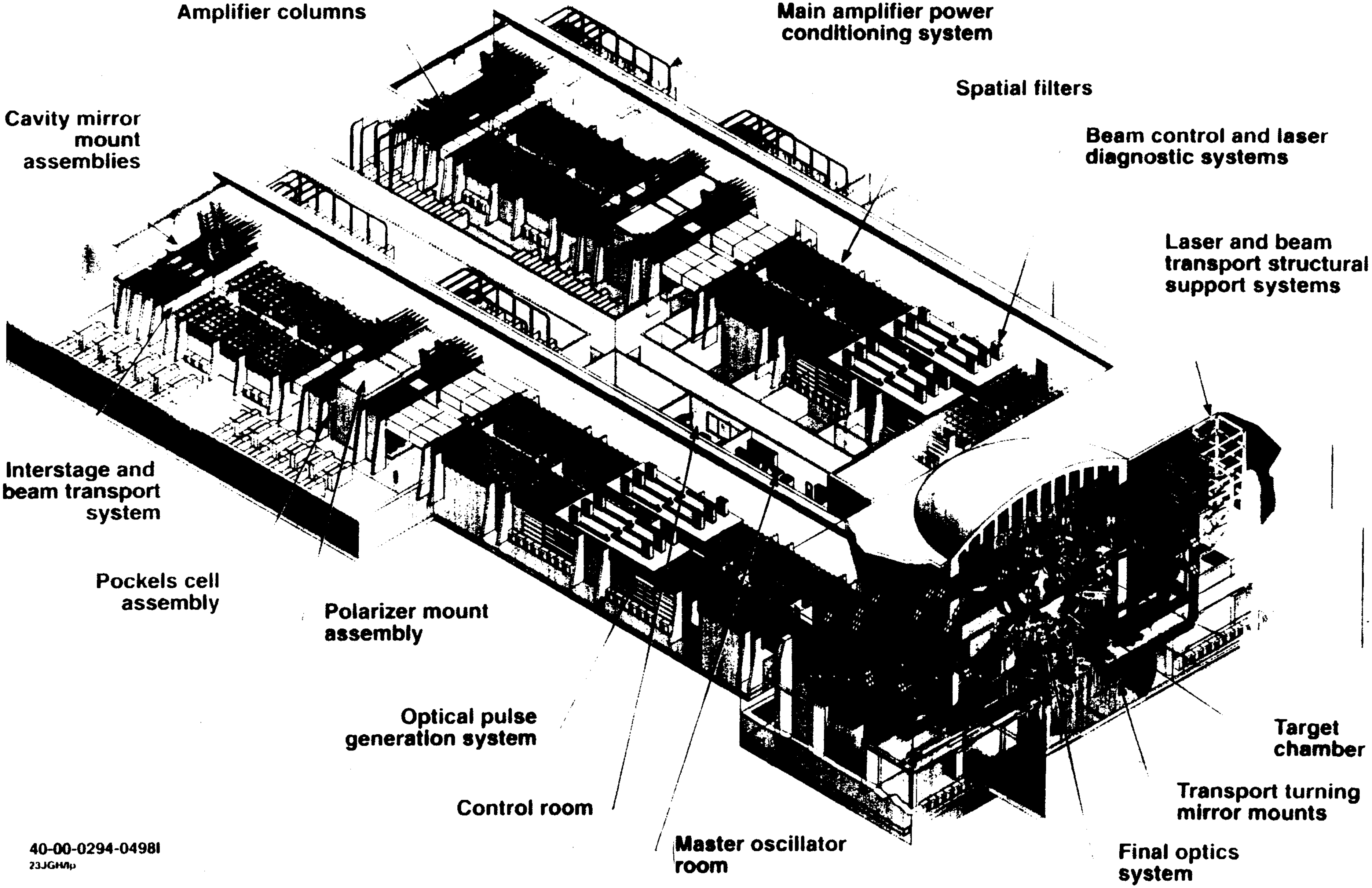


- **UCLA Leads Efforts on ITER Test Program**
  - Technical issue analysis; - Test article design; - Engineering scaling development
- **Industrial Affiliates Provide Support on ITER Test Blankets Engineering Integration in Key Areas:**
  - Remote handling;- Ancillary equipment; - Enginering interface and Test port design





The National Ignition Facility—192 Beam



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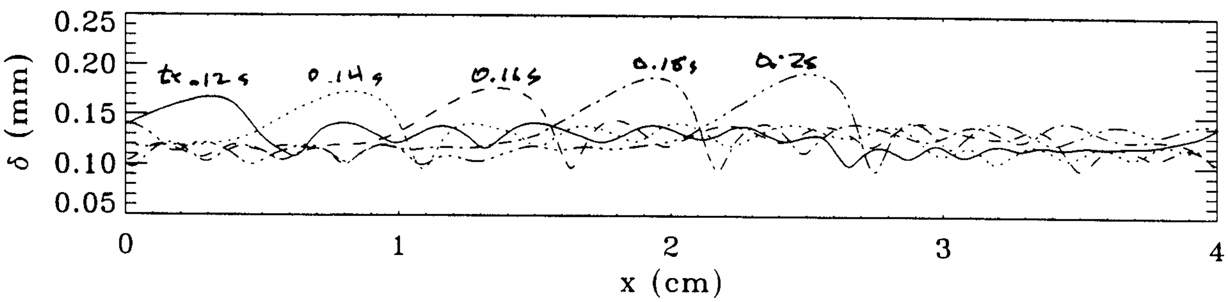
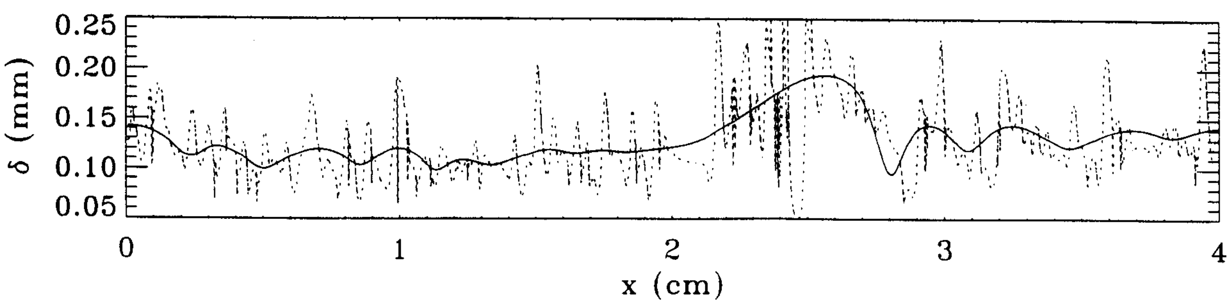
IFE First Wall Protection Modeling at UCLA

- Inertial jet flow on inverted surface
- Film flow stability and response to impulsive loading
  - isochoric heating
  - x-ray ablation impulse
- Shock propagation and effect in thin liquid film

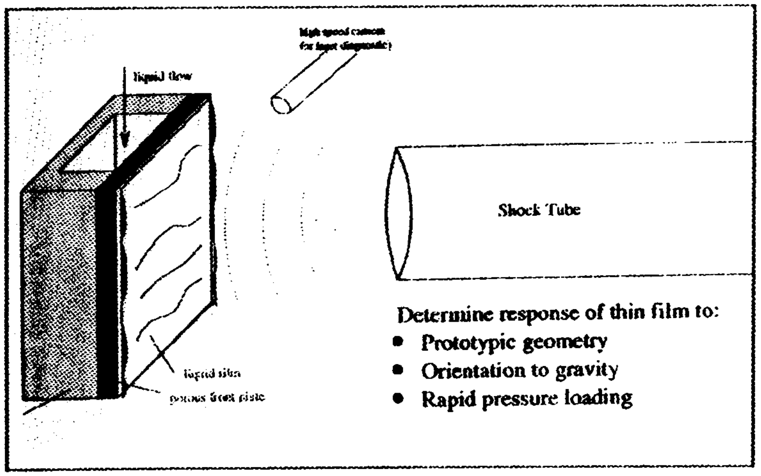


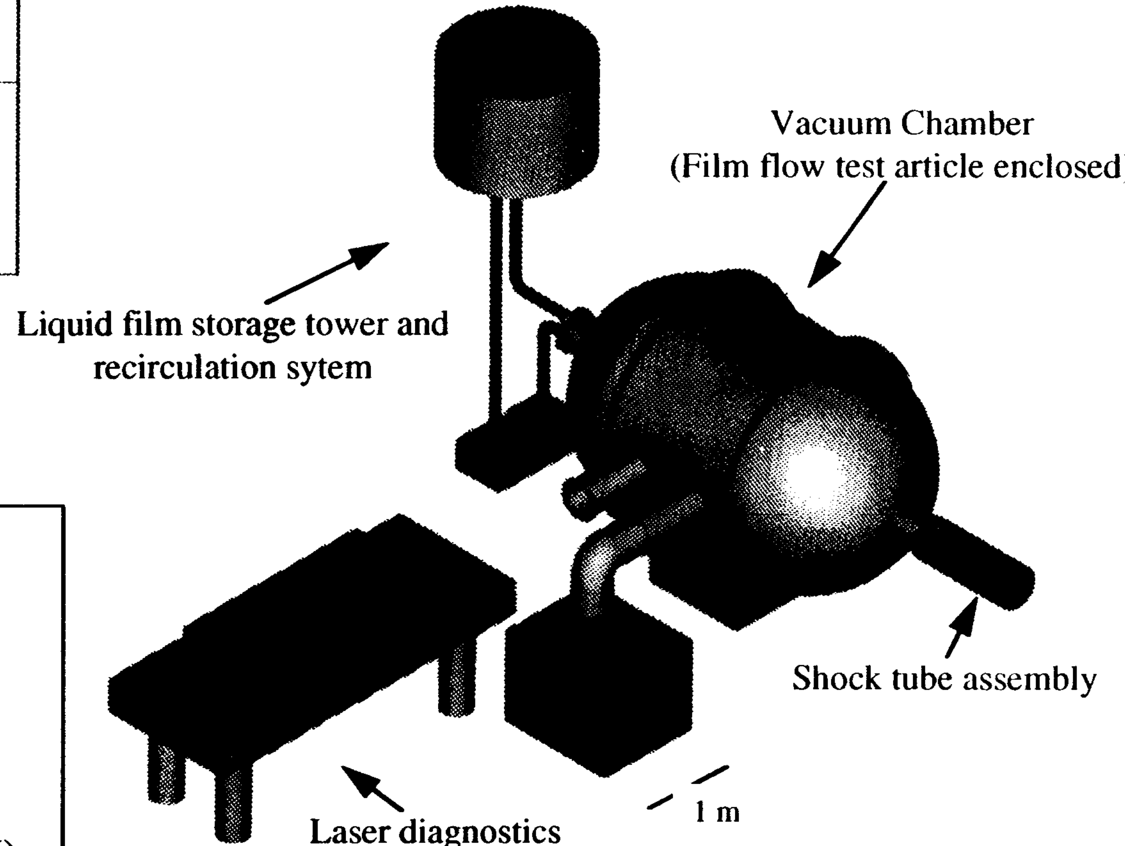
Vertical film flow at $Re = 200$ with periodic inlet conditions and no inflow through substrate. The solid line is a time $t = 0.12$ s with subsequent lines every 0.02 s



Vertical film flow at $t = 0.2$ s (solid) and $t = 0.20226$ s (dotted) with blast commencing at $t = 0.2$ s

Inertial Fusion Chamber Technology Test Stand





Facility Requirements

- Overhead crane
- Highbay area (> 18 feet)
- Floor space (~ 1500 sf)
- Cooling water (~ 300GPM)
- 480 VAC power (~ 400KW)

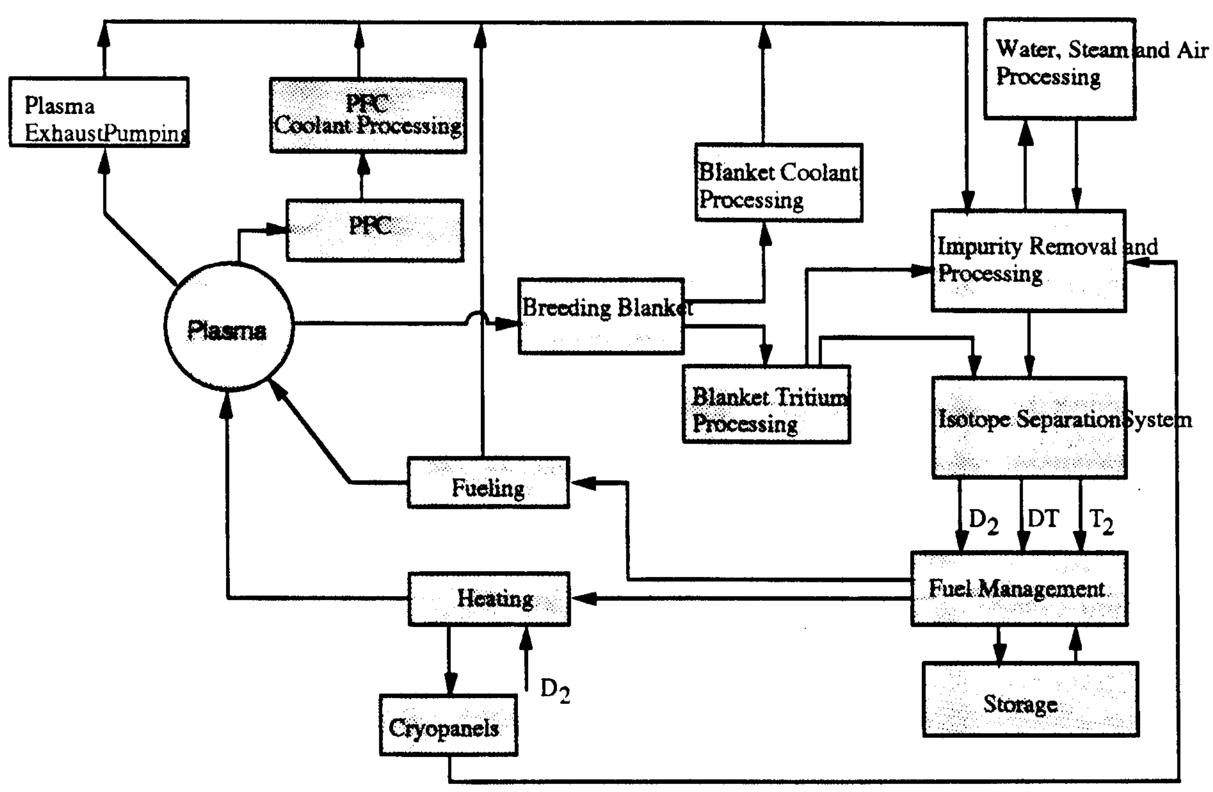
Dynamic Fuel Cycle Modeling

- Comprehensive dynamic modelling to determine the time-dependent tritium flow rates and inventories in the entire fusion system

- The model is now being used by ITER and the other organizations to:

  - evaluate whether the D-T cycle can be closed in a real engineering system (engineering feasibility of the DT cycle)

  - minimize tritium inventories in various components of the fusion system



Fuel Cycle Block Diagram

Fusion Neutronics R&D and Design Activities at UCLA

Nuclear Responses

- Tritium Production
- Nuclear Heating
- Inducted Activation and Decay Heat
- Shielding/Radiation Streaming

R&D

Elements

- Integral Experiments
- Experimental Techniques and Measuring Methods
- Code Development
- Basic Data measurements & Evaluation
- Basic data Processing and Working Libraries

Design

Participation in the Nuclear Design of Several Reactor Concepts

- ITER FW/Blanket/Shield
- IFE (Prometheus-L and Prometheus-H)
- VENUS

Objectives of the R&D Program

- Provide the Experimental Database Required for Approval and Licensing of the Device
- Verifcation of the Prediction Capabilities and Generation of Design Safety Factors
- Reduce High Cost Associated with Large Safety Factors Used to Compensate for Uncertainties

International

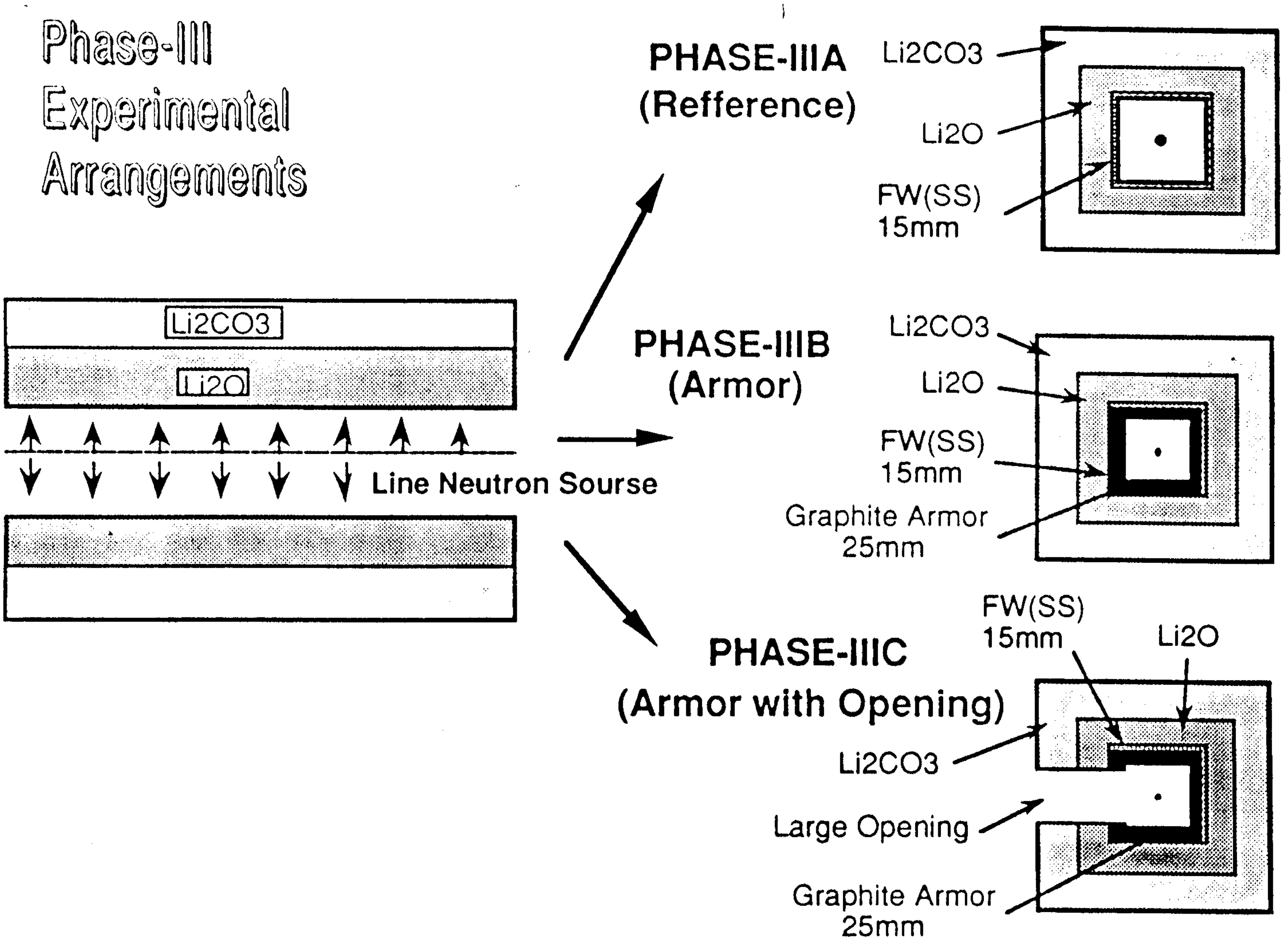
- USDOE/JAERI Collaborative Program
- ITER R&D

National

- TFTR
- NIF

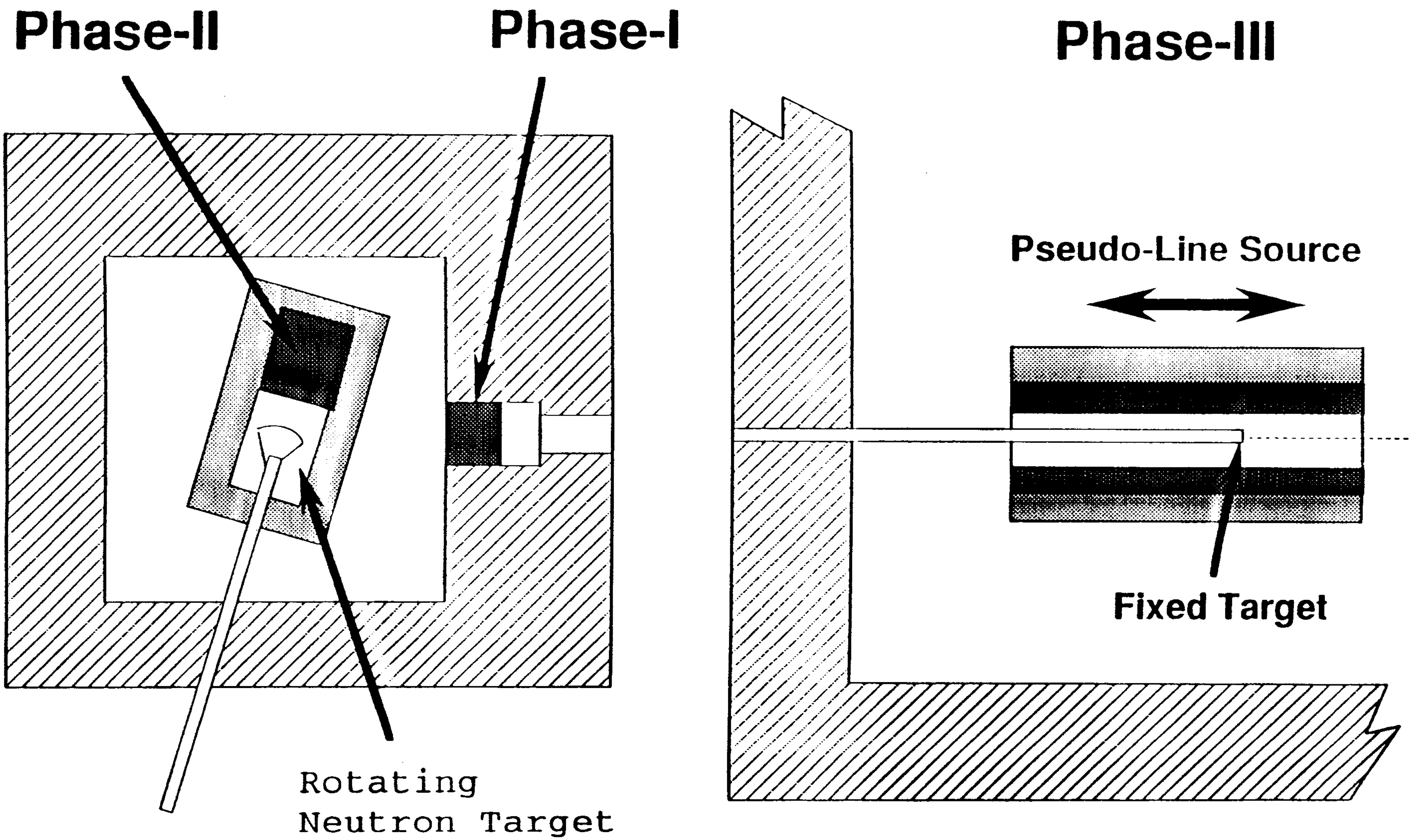
UCLA Collaboration with Japan on the World's Premier *Fusion Neutronics* Activities

Neutronics source surrounded by a mockup of a Fusion blanket



- Program includes experiments and analysis for tritium breeding, radioactivity, and nuclear heating
- Results are of critical importance to the feasibility and the attractiveness of fusion devices such as ITER

Concept of Experimental Arrangement



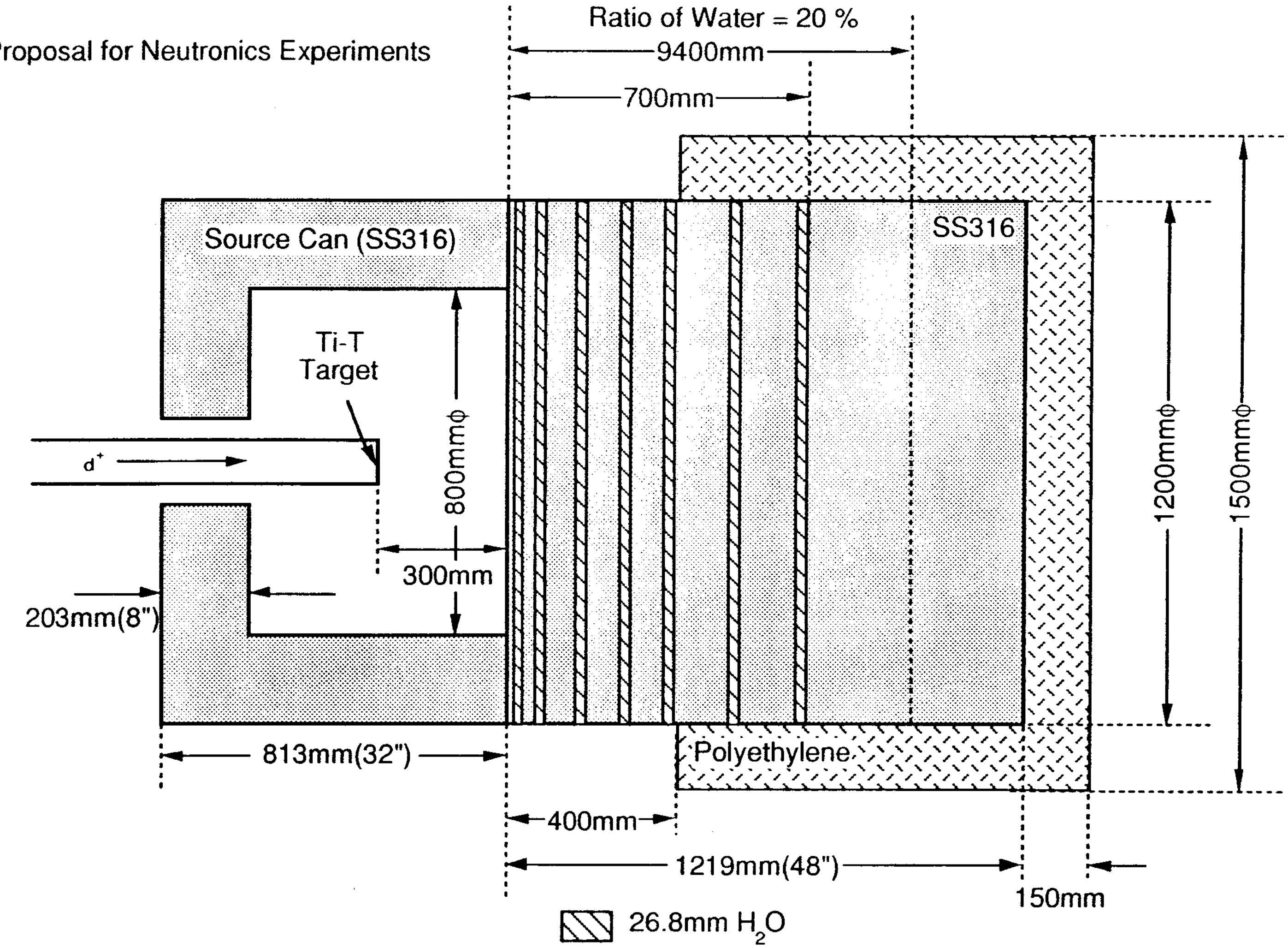
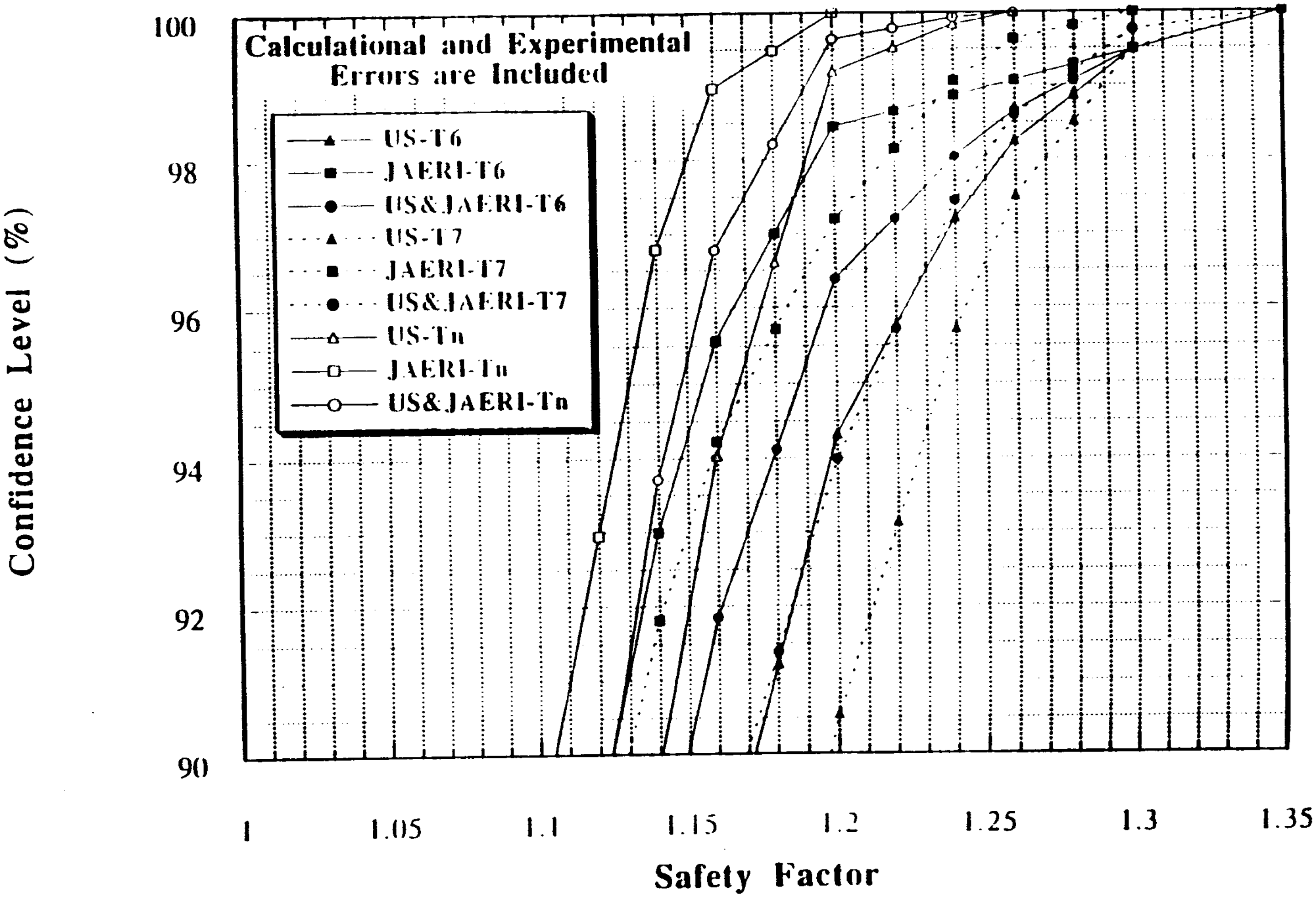


Fig. APP.IV.1 SS316/Water Experimental Assembly

Design Safety Factor Versus Confidence Level for Tritium Production Rate

- (Confidence Level for Calculations not to Exceed Measurements)



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Calculated-to-Experimental Values of Induced Radioactivity for Several Elements