Produced by University Communications

Tandem Mirror Materials Test Reactors of the Early 1980's

G. L. Kulcinski and J. F. Santarius

March 12, 2009

THE UNIVERSITY of WISCONSIN MADISON

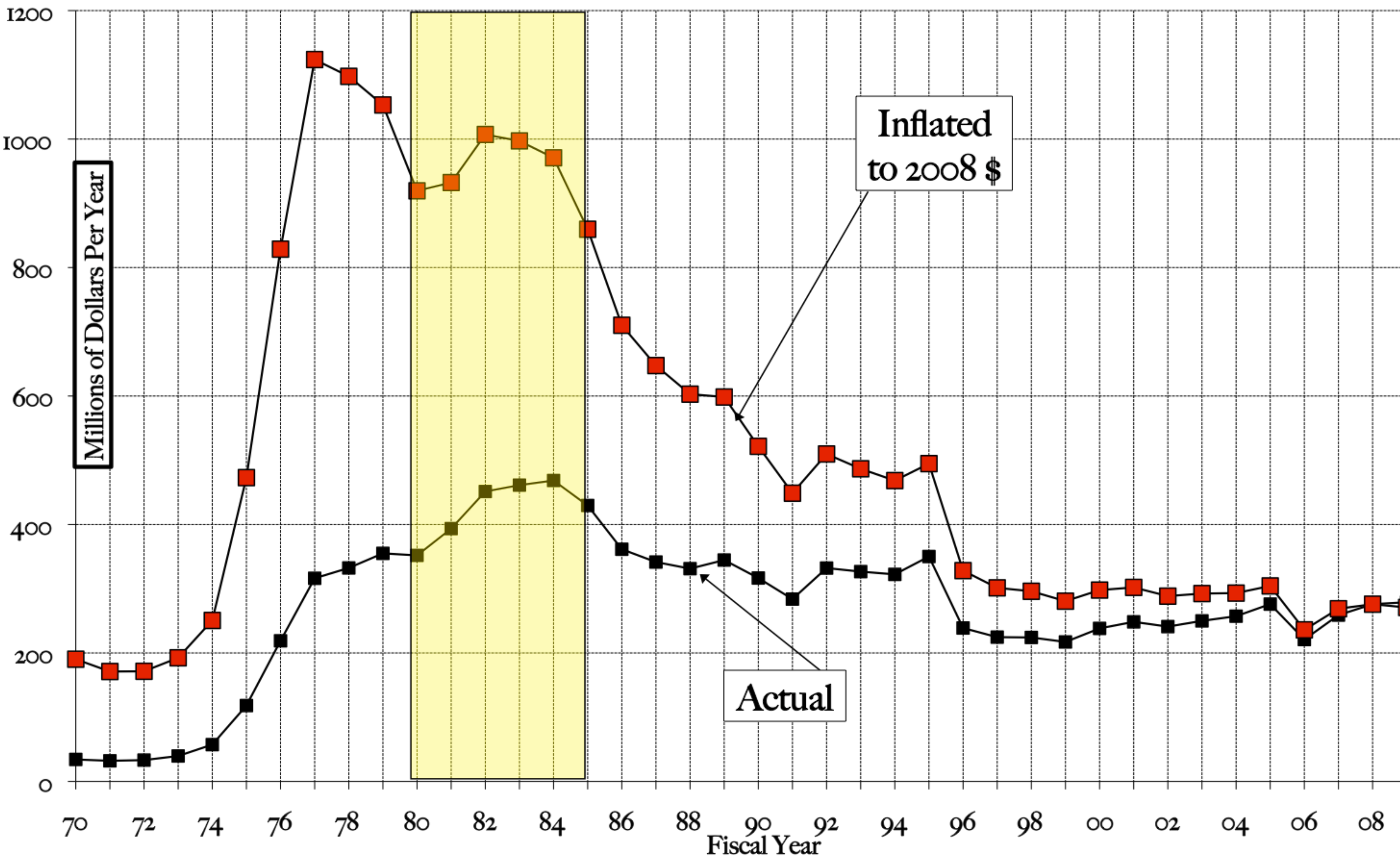
Items to Cover

- Overview of Mirror Materials/Components Test Reactors
- TASKA
- TDF
- TASKA-M
- Comparisons of Previous Designs
- Implications for Today

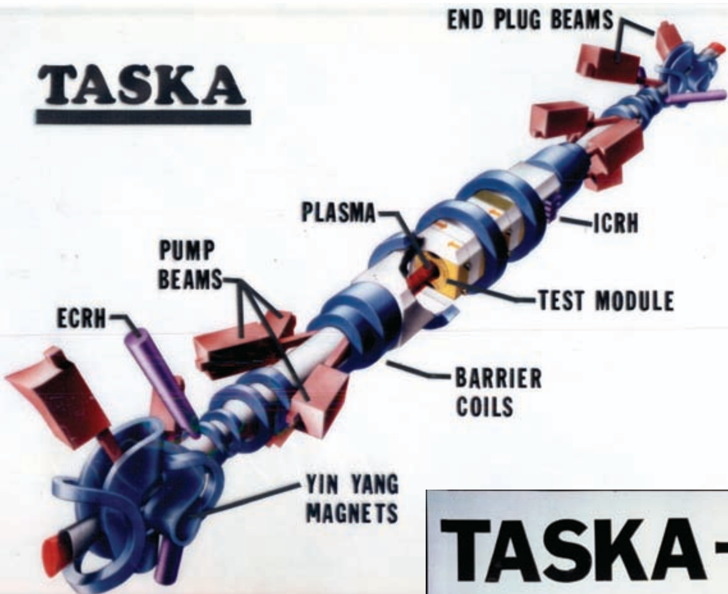
Environment in the Early to Mid 1980's For Fusion Technology

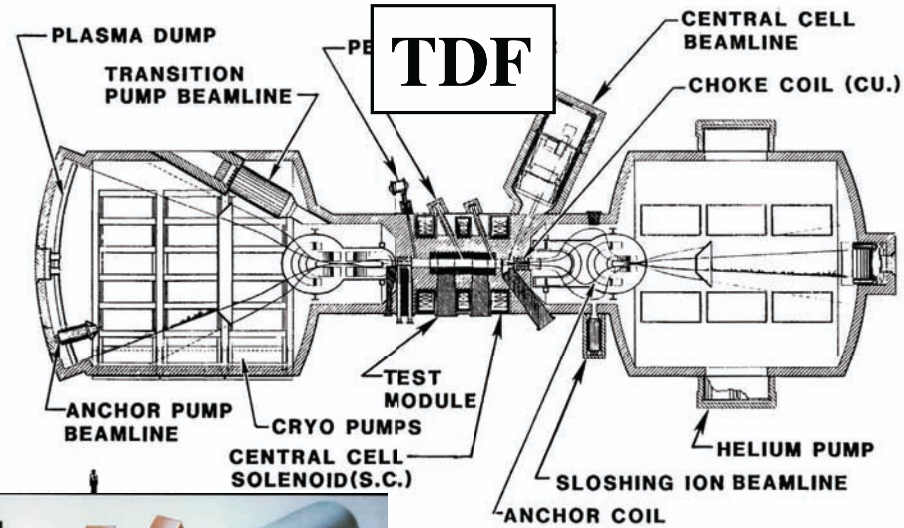
- Vibrant and aggressive fusion reactor design program in the U. S. (UWMAK series, Starfire, WITAMIR-1, HIBALL, MARS, etc.)
- Recognition by the fusion community that fusion materials could be the "Achilles Heel" of the Fusion Power Program.
- Ed Kintner the head of the DOE Fusion program (≈1978-1983) and a strong supporter of fusion materials work.
- Healthy Tandem Mirror program that is about to be killed (≈1986).

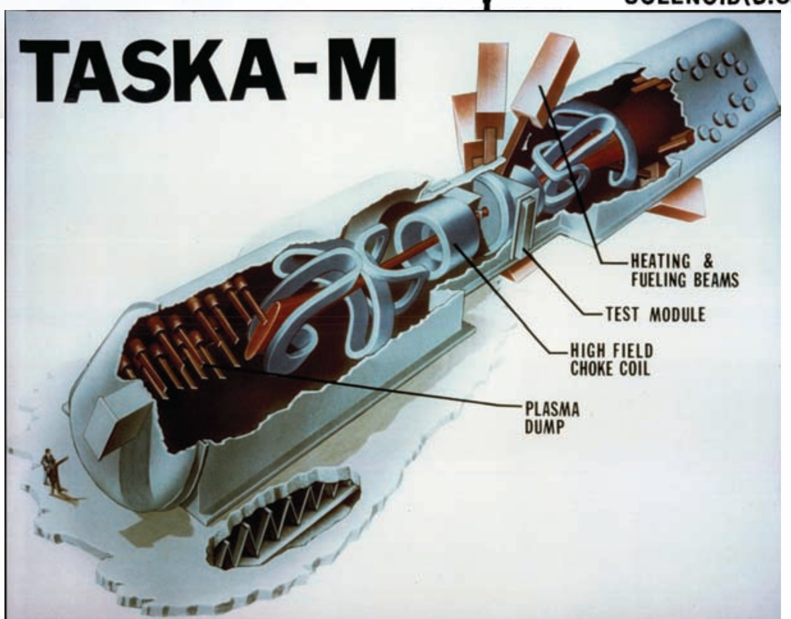
In the Early 1980's the Magnet Fusion Budget was Approaching $500 M in Then-Year Dollars (About $1 B in 2008 Dollars)



Three Early 80's Mirror Based Test Reactors Were Chosen for Comparison







Tandem Mirror Fusion Neutron Test Facilities in the Early '80's

	TASKA	TDF	TASKA-M
Year Published	1982	1983	1984
Team	UW, KfK, et al.	LLNL, FEDC, TRW, Grumman, UW, et al.	UW, KfK, et al.
Type	TM with separate thermal barrier & yin-yang plug cells	TM with combined thermal barrier and yin-yang plug cells	Axisymmetric central cell with sloshing ions plus yin-yang MHD anchors
Max n wall load	1.5 MW m^{-2}	1.4 MW m^{-2}	1.3 (0.6 ave.) MW m^{-2}
Test zone surf. A	7.8 m^2	~8 m^2	3.6 m^2
Fusion power	86 MW	20 MW	7 MW

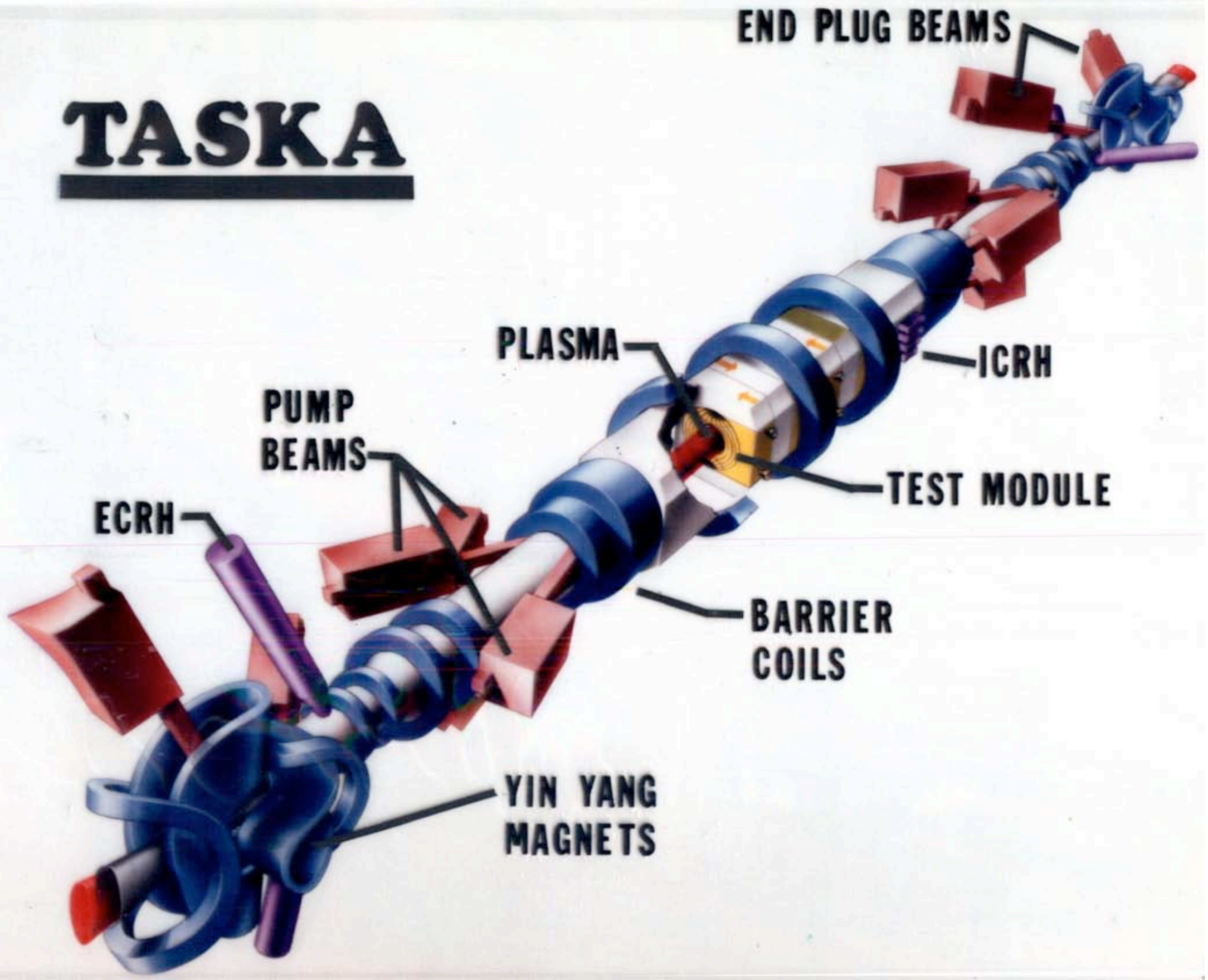
Tandem Mirror Fusion Neutron Test Facilities in the Early '80's (cont.)

	TASKA	TDF	TASKA-M
Input power	117 MW	51 MW	40 MW
Input systems	NB/ICRF/ ECRF	NB/ECRF	NB/ICRF
Total length	60 m	24 m	24 m
Max B field	20 T	15 T	17.5 T
β (n region)	0.5	0.24	0.30

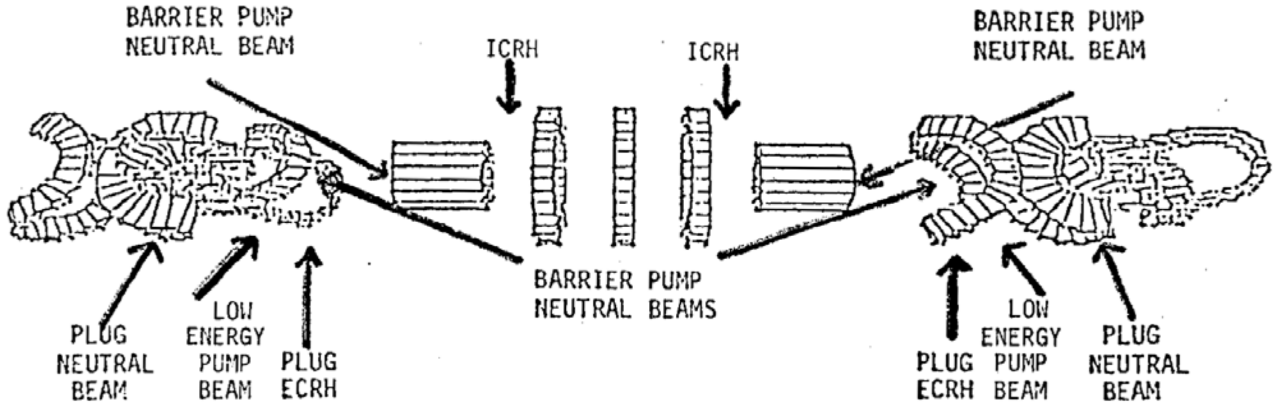
TASKA: Tandem Spiegelmaschine Karlsruhe

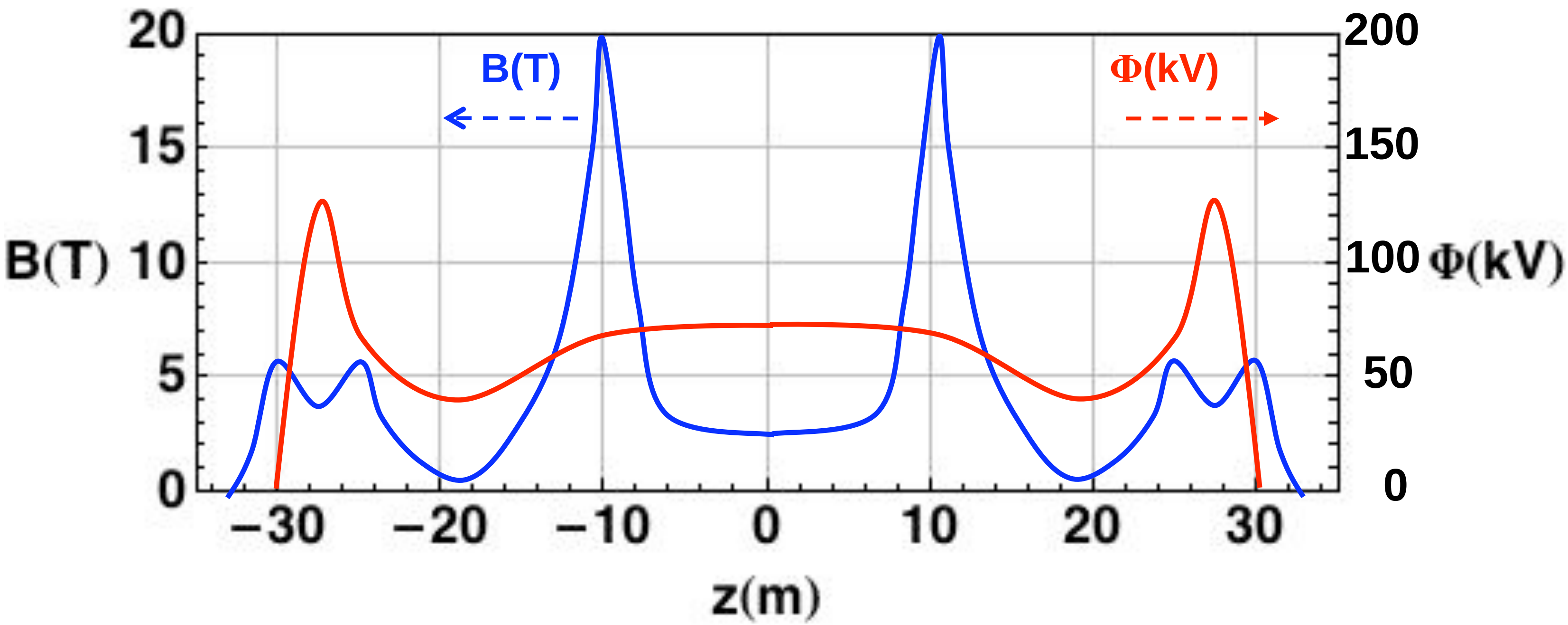
- When? 1981-2
- By Whom? UW-Madison, Kernforschungszentrum Karlsruhe, Interatom, Grumman, B&W, GA, HEDL, LLNL, Siemens
- Complete Publication: UWFDM-500/KfK 3311/1, June 1982
- http://fti.neep.wisc.edu/pdf/fdm500.pdf

TASKA:
Tandem Spiegelmaschine Karlsruhe



TASKA:
Tandem Spiegelmaschine Karlsruhe

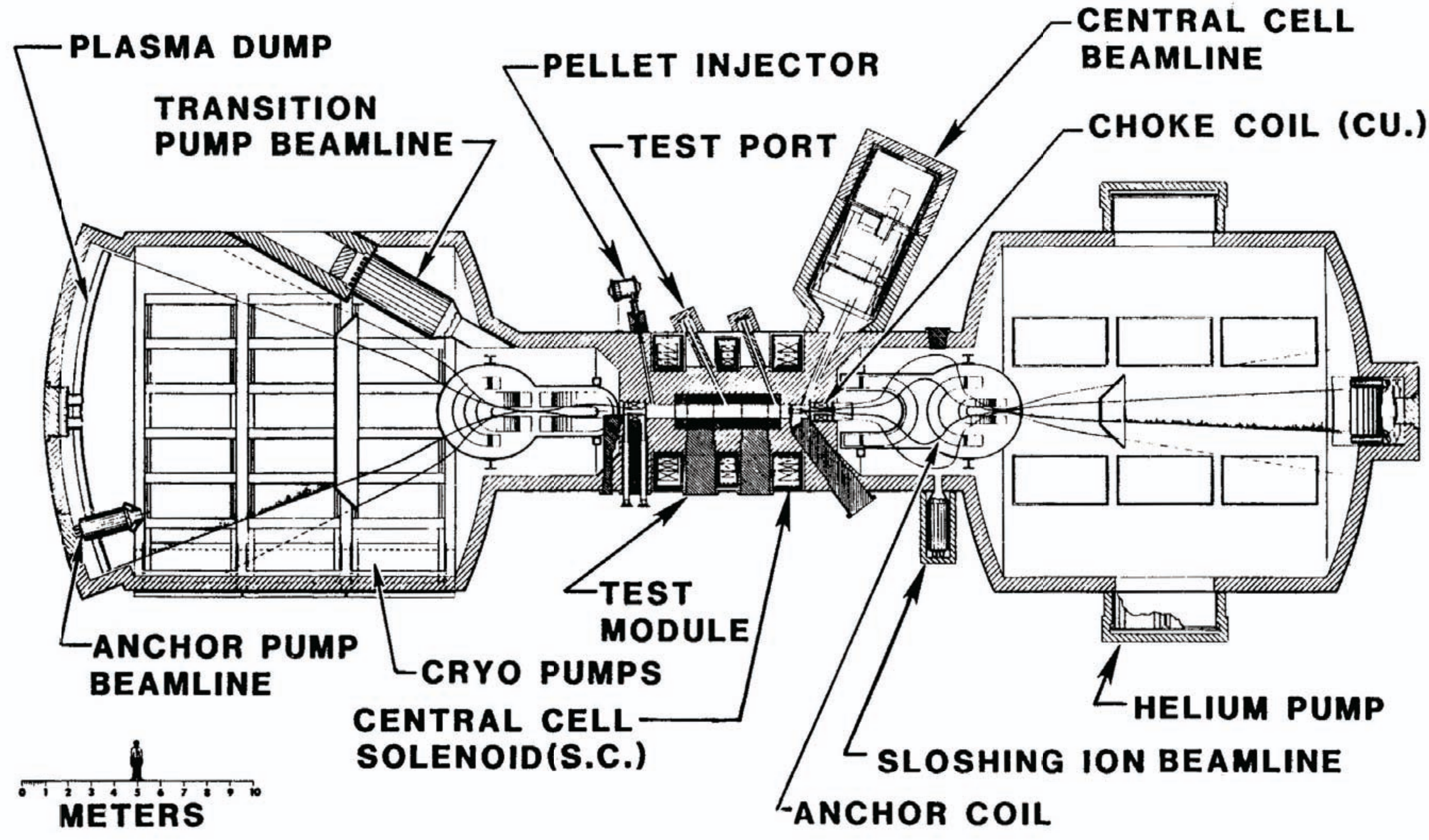




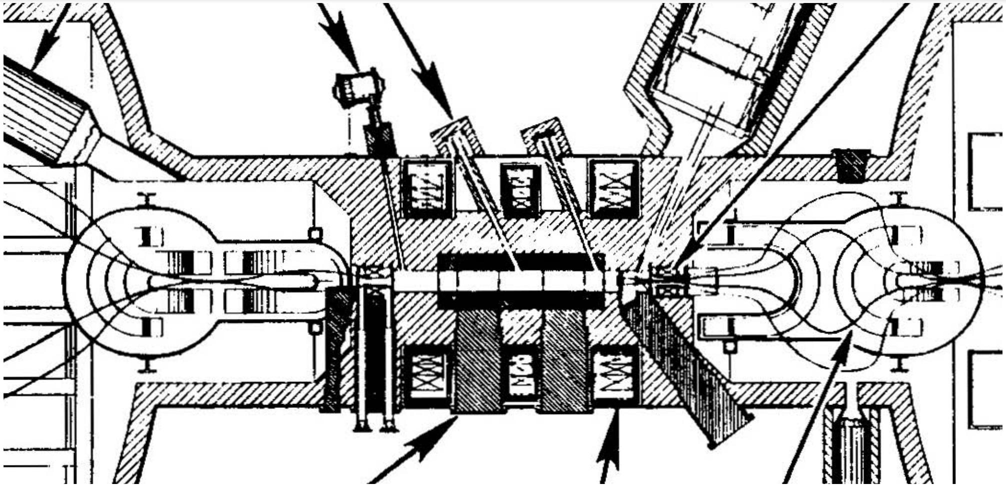
The TDF Study

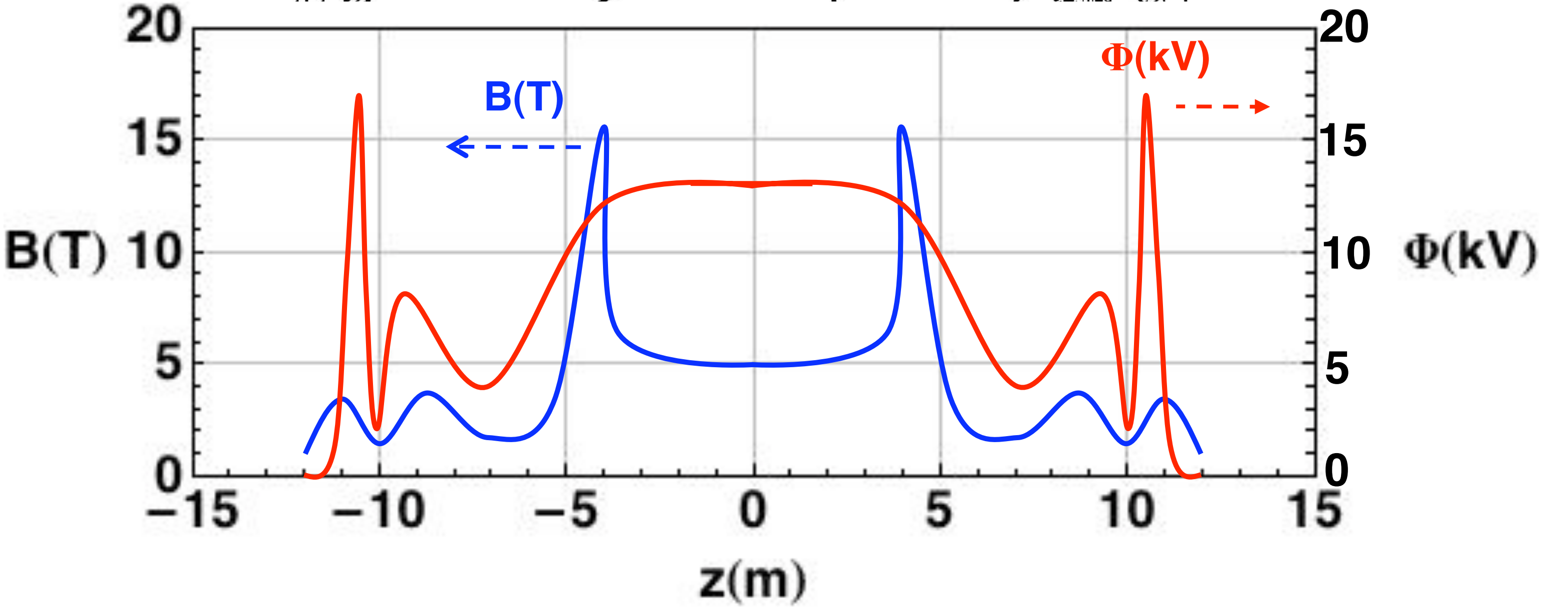
- When? 1982-3
- By Whom? LLNL, FEDC, TRW, General Dynamics, UW-Madison, Bechtel, SAIC, LANL, UCLA, MIT
- Complete Publication: UCID=19328, October, 1983

The TDF Study



TDF: Technology Demonstration Facility

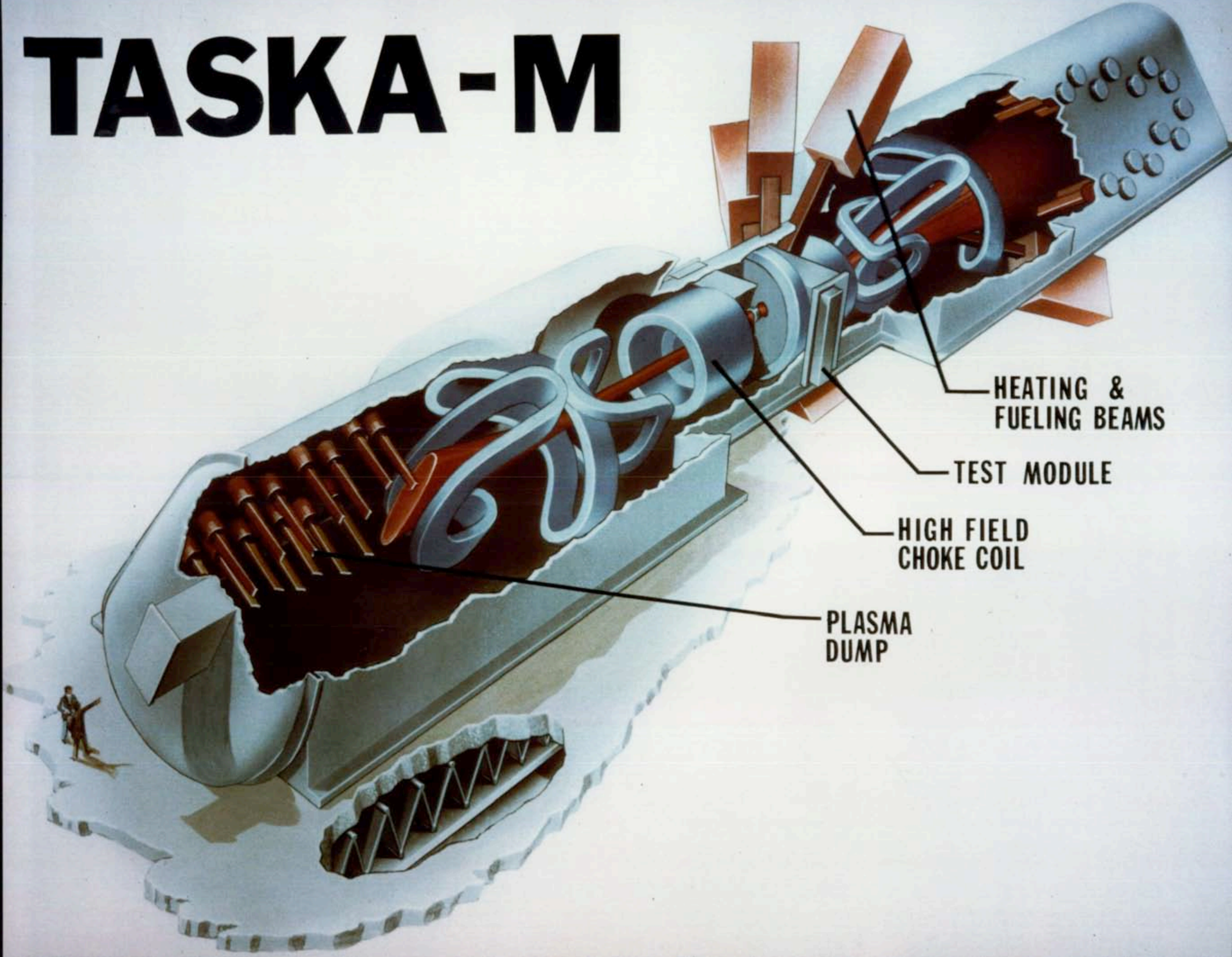




TASKA-M

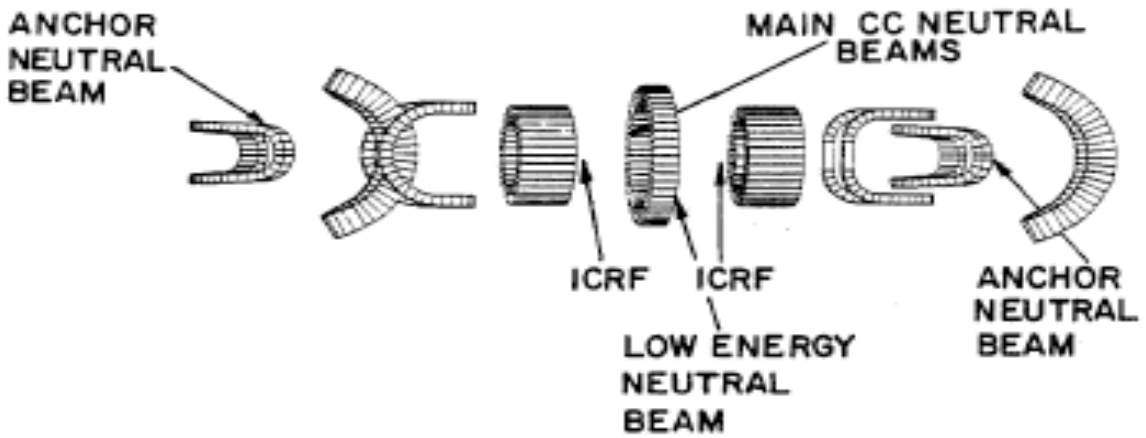
- When? 1983-84
- By Whom? UW-Madison, Kernforschungszentrum Karlsruhe, LLNL, HEDL, Univ of Karlsruhe, Univ. of Krakow,
- Complete Publication: UWFDM-600/KFK 3680, April 1984
- http://fti.neep.wisc.edu/pdf/fdm600.pdf

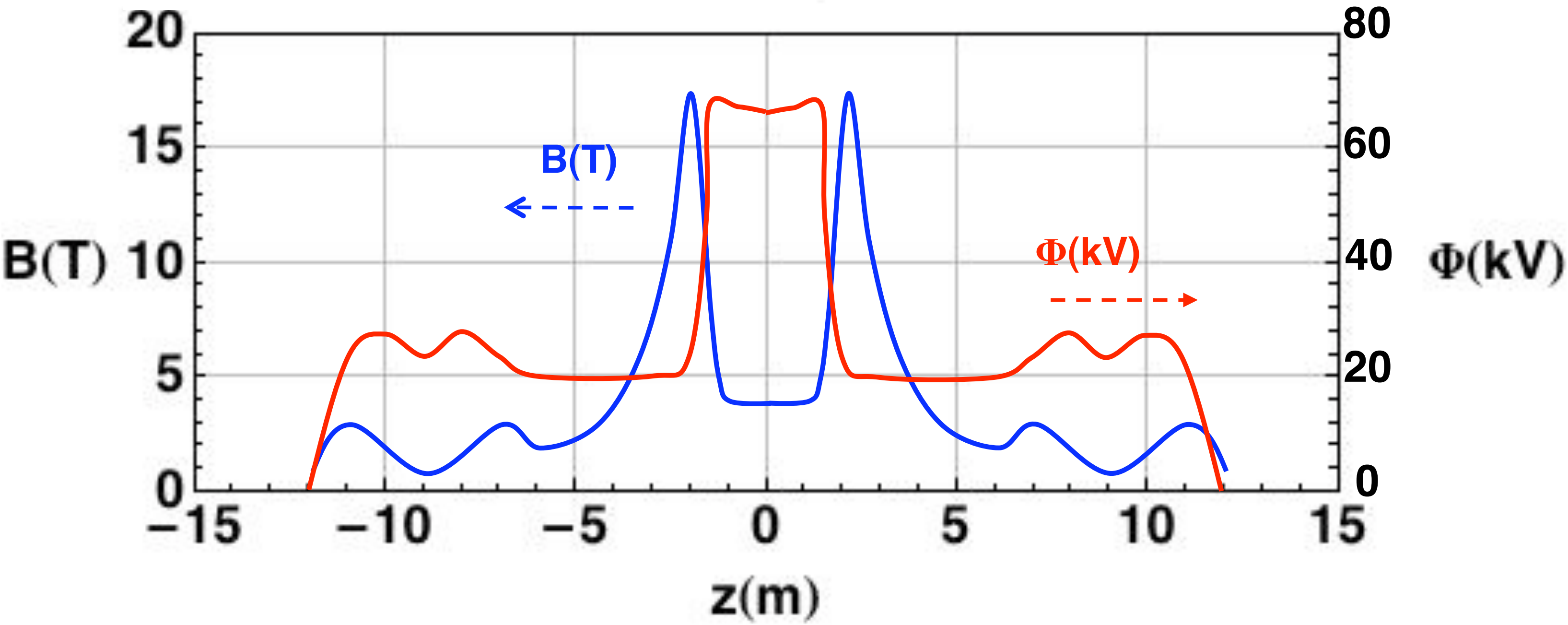
TASKA - M



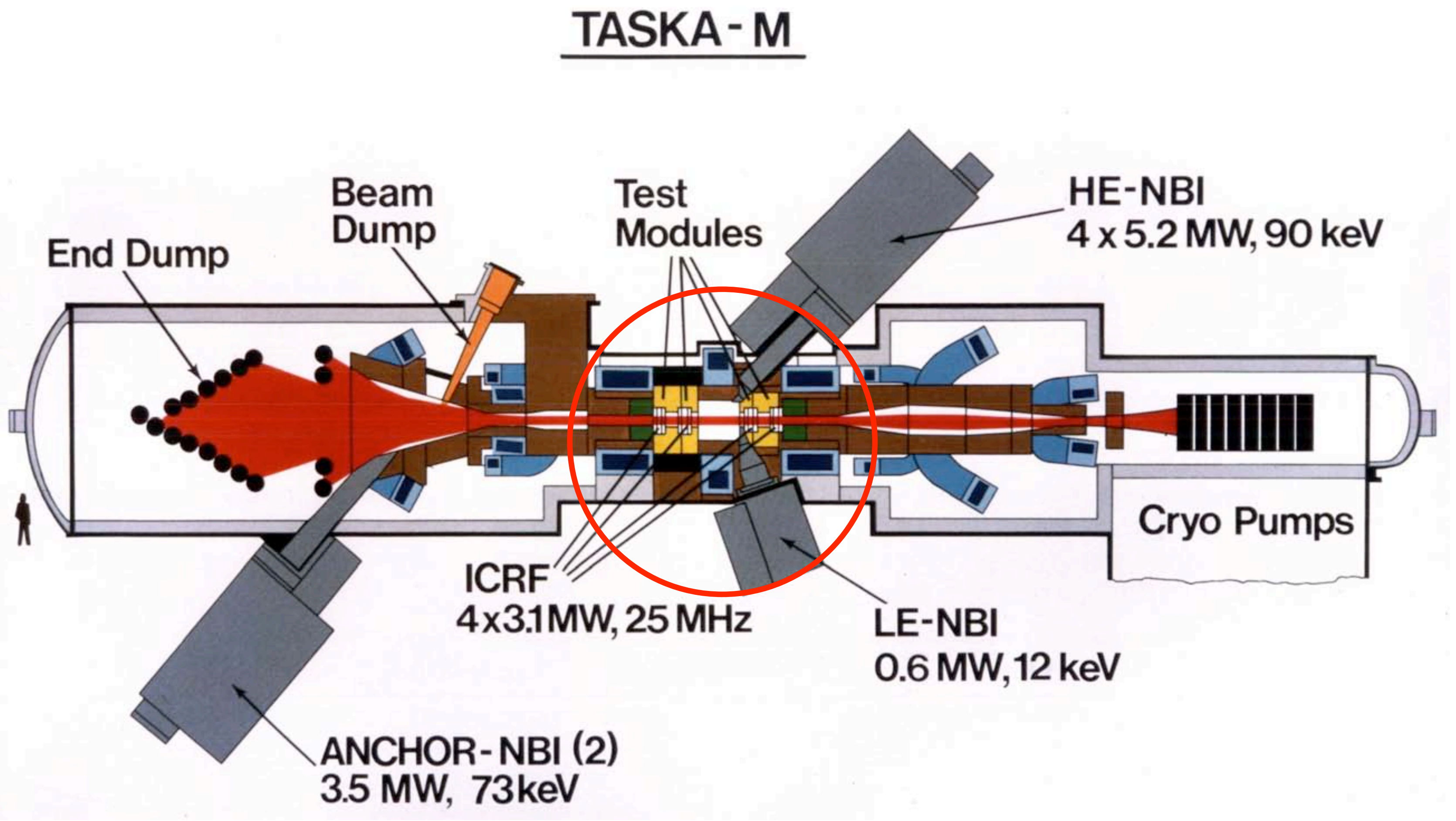
HEATING &
FUELING BEAMS
TEST MODULE
HIGH FIELD
CHOKE COIL
PLASMA
DUMP

TASKA-M

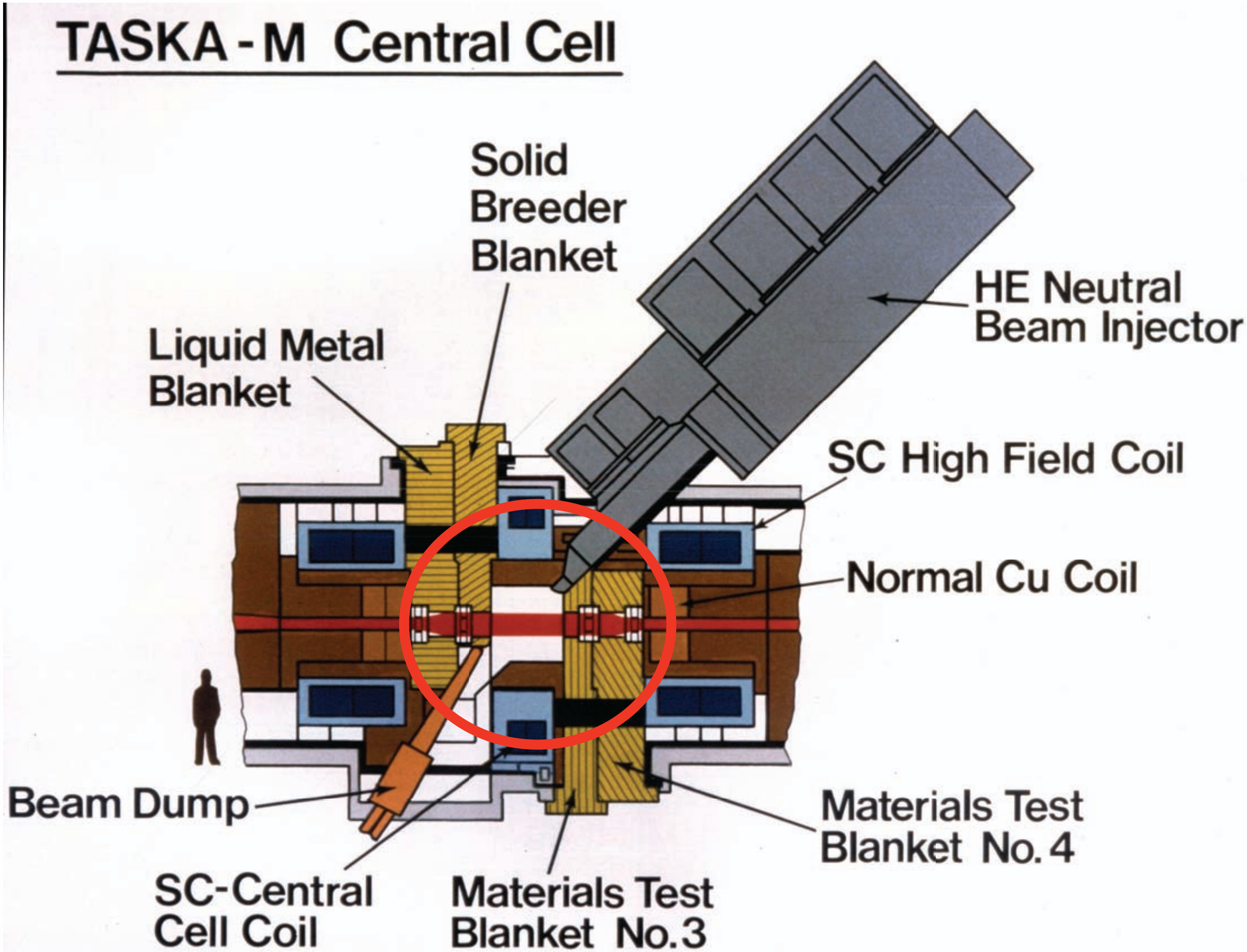

ANCHOR NEUTRAL BEAM
MAIN CC NEUTRAL BEAMS
ICRF
ICRF
LOW ENERGY NEUTRAL BEAM
ANCHOR NEUTRAL BEAM


B(T)
Φ(kV)
B(T)
Φ(kV)
z(m)
20
15
10
5
0
80
60
40
20
0
−15
−10
−5
0
5
10
15

TASKA-M
Optimized for Materials Testing

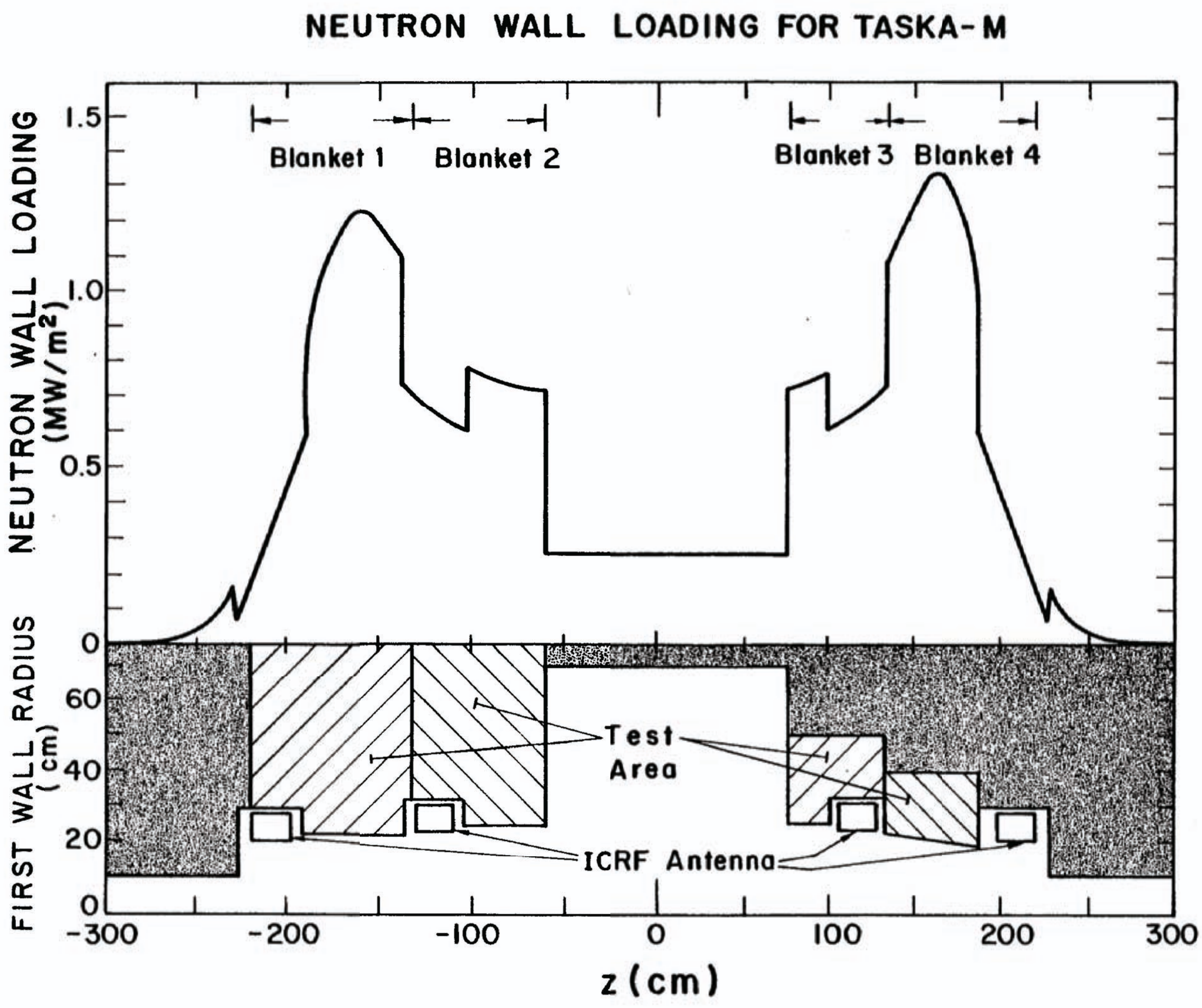


The TASKA-M Test Modules Make the Best Use of a Compact Neutron Source

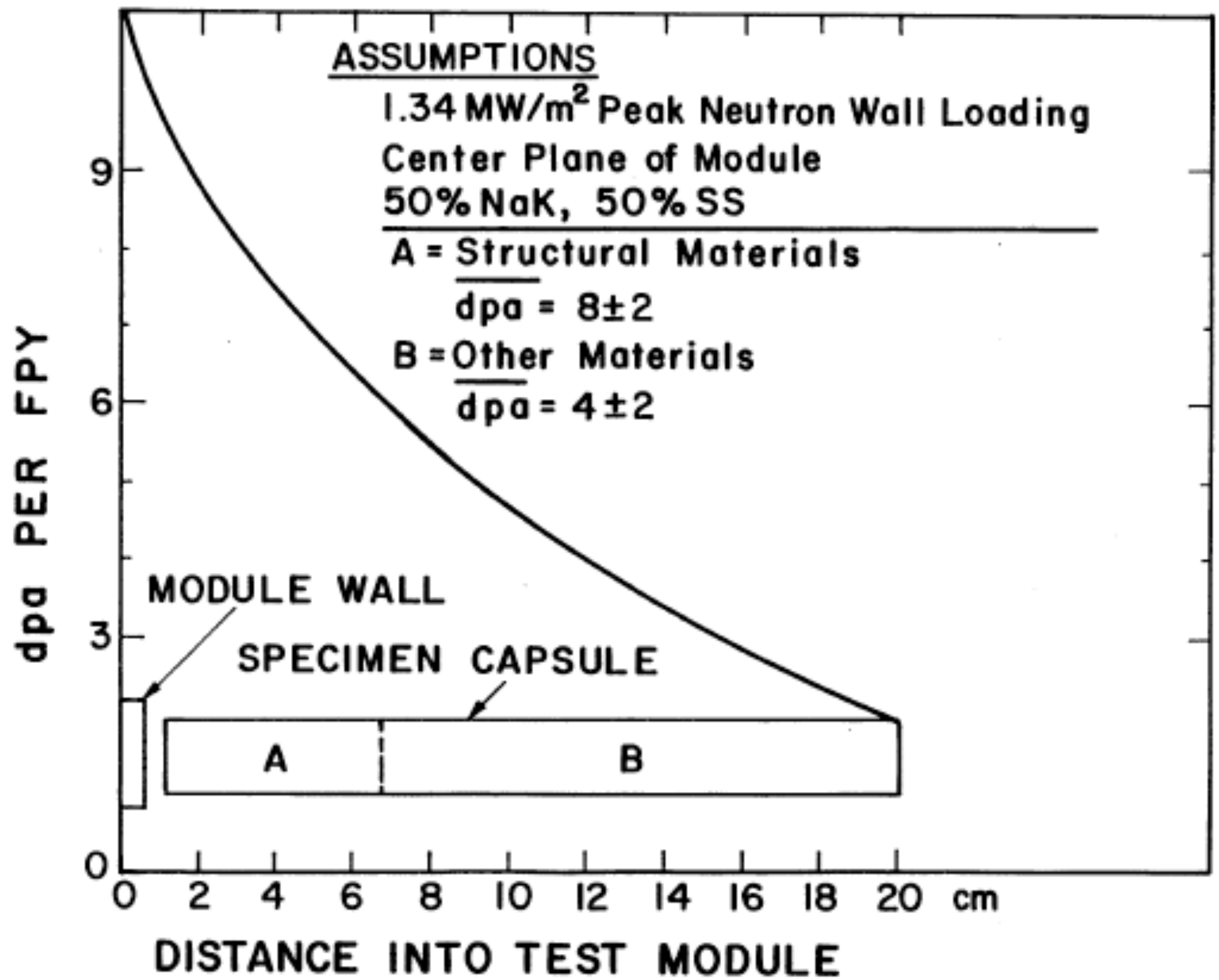


The Neutron Source Varies from 0.7 to Nearly 1.3 MW/m^2 in the Test Areas of TASKA-M

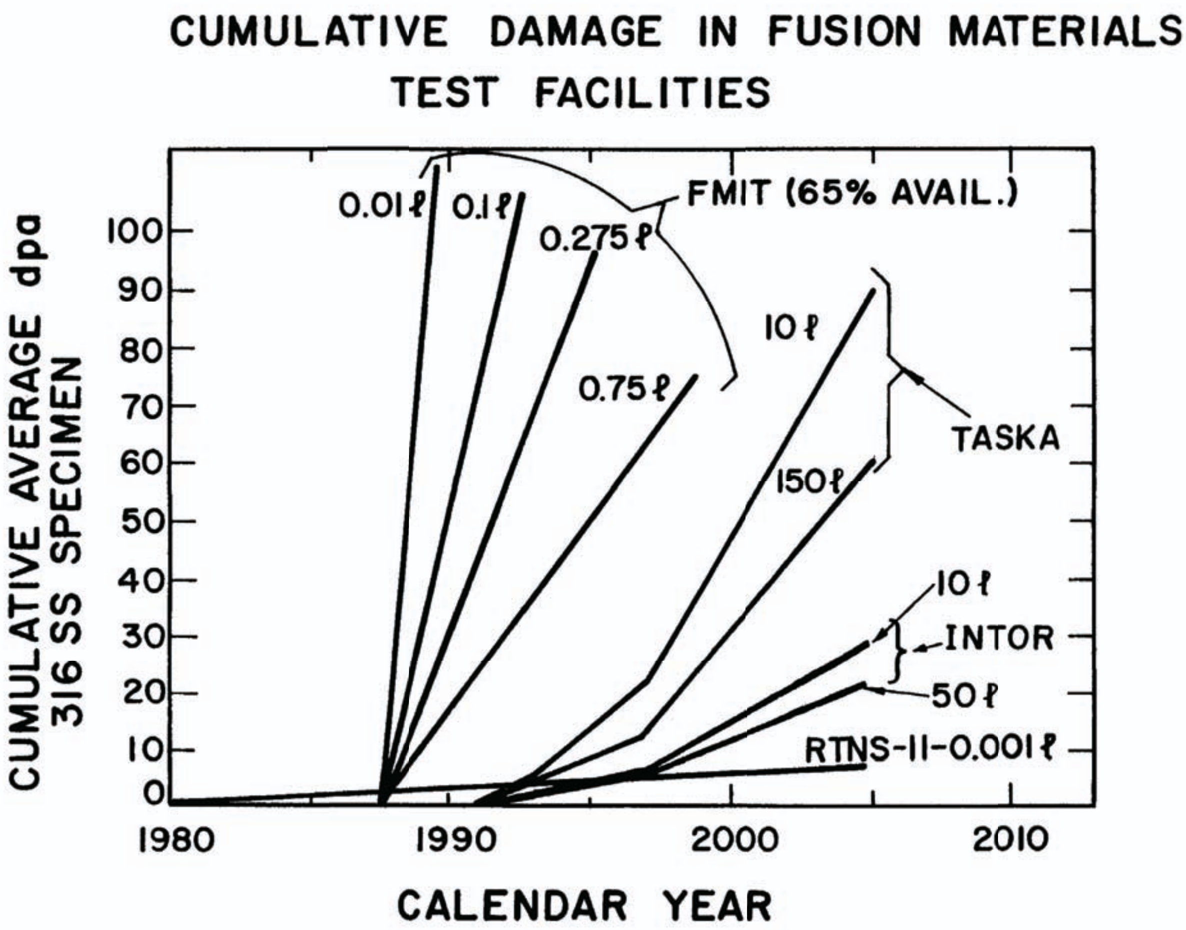
(Note that the removal of the central module reduces the damage gradient)



The Damage in TASKA-M Drops by a Factor of 5 in 20 cm From the First Wall



One Important Parameter in Materials Testing is the Volume Available for High Fluence Damage



Materials Test Capabilities

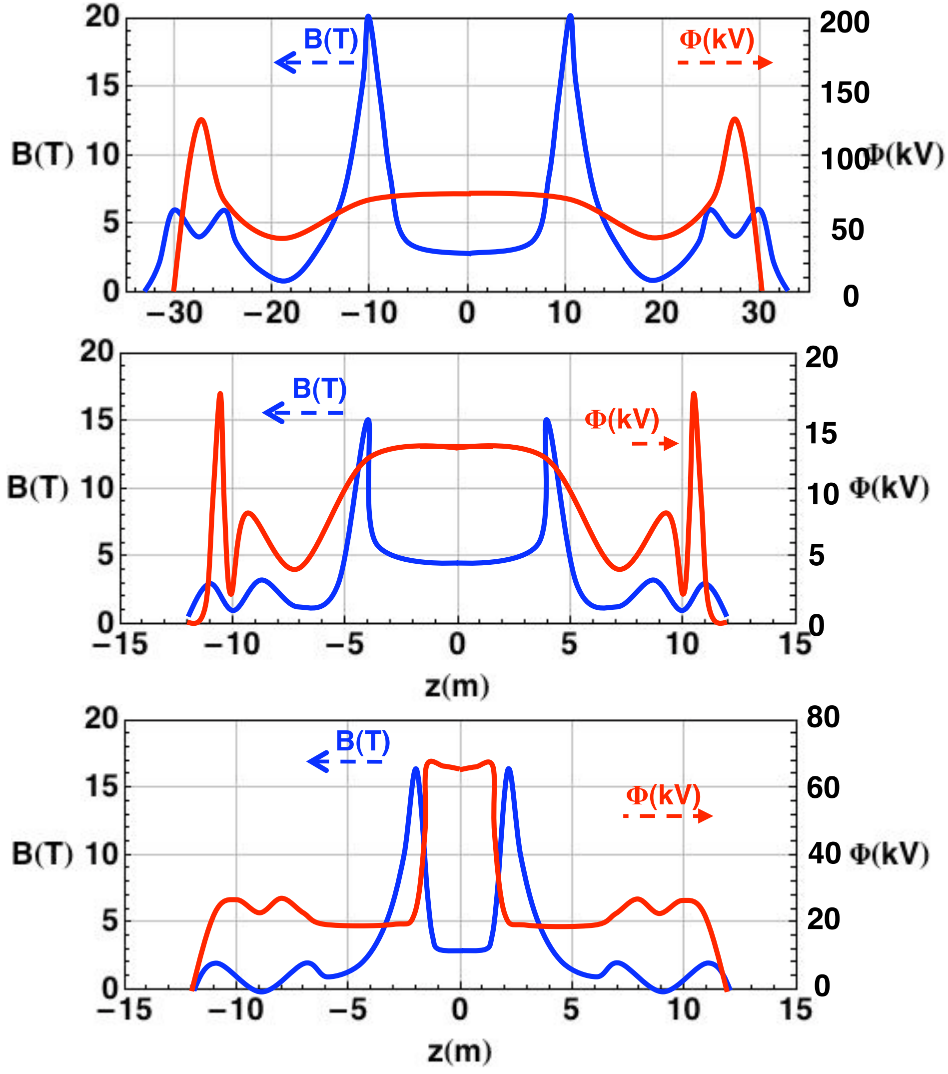
Facility	dpa-ℓ/FPY
TASKA	1,510
TASKA-M	530
INTOR	180
FMIT	5
RTNS-II	0.0003

TASKA, TDF, and TASKA-M Axial Profiles of Magnetic Field and Electrostatic Potential

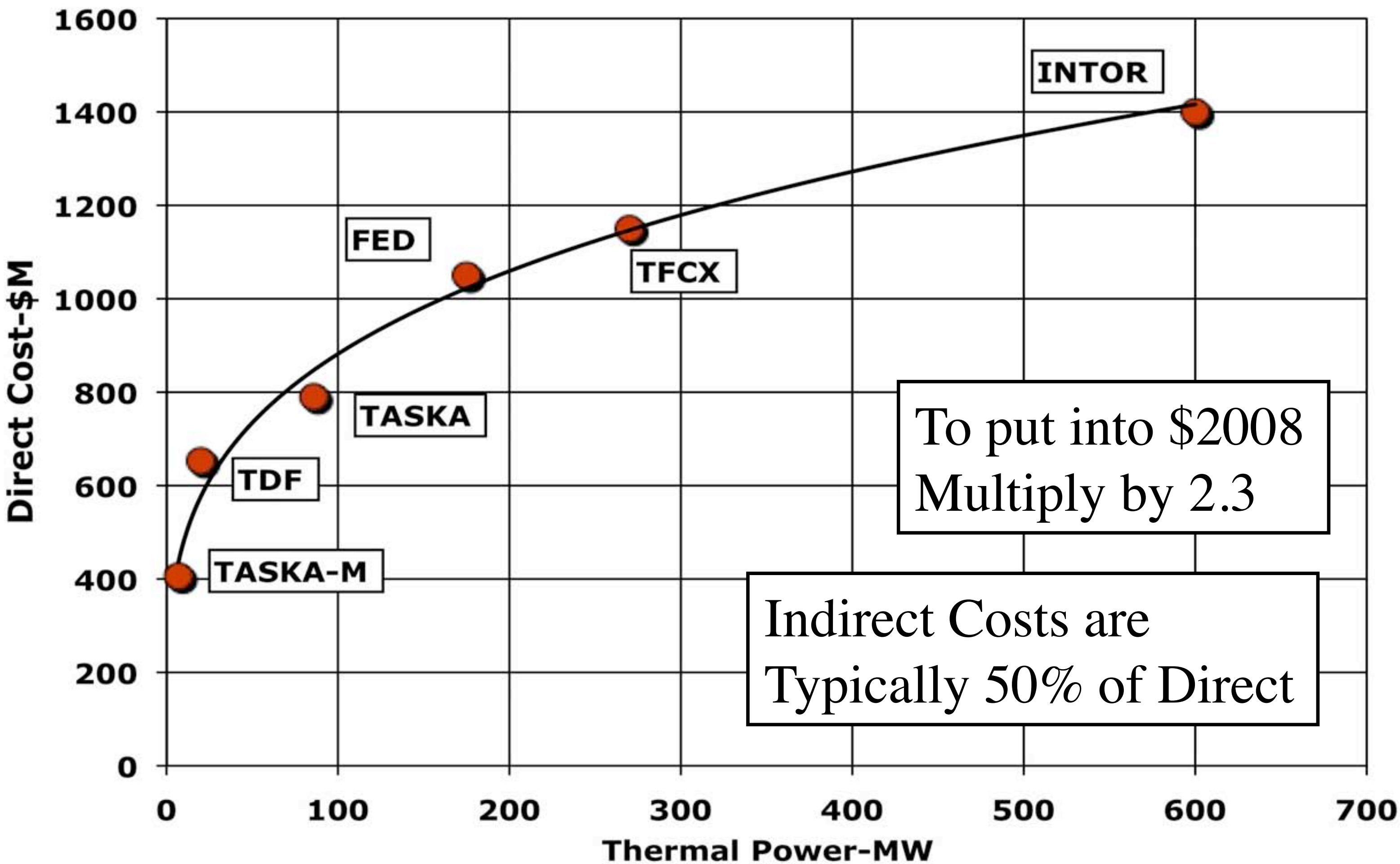
TASKA: TM with separate thermal barrier & yin-yang plug cells

TDF: TM with combined thermal barrier and yin-yang plug cells

TASKA-M: Axisymmetric central cell with sloshing ions plus yin-yang MHD anchors



Direct Cost of Materials Test Facilities in the Early 1980's is Consistent With Today's Estimates



To put into $2008
Multiply by 2.3

Indirect Costs are
Typically 50% of Direct

Comparison of TASKA-M and Proposed GDT Neutron Test Facilities

	TASKA-M	DTNS GDT-3*	DTNS SC*
Type	Axisymmetric mirror with sloshing ions plus yin-yang MHD anchor cells	GDT with sloshing ions, Cu insert in SC mirror coils	GDT with sloshing ions, superconducting mirror coils
Max n wall load	1.3 MW m^{-2}	2 MW m^{-2}	1.8 MW m^{-2}
Test zone area	3.6 m^2	1 m^2	~1 m^2 (?)
Fusion power	7 MW	~10 MW	2-3 MW
Input power	40 MW	30 MW (+30 MW for Cu insert coils)	47 MW
Input systems	NB/ICRF	NB	NB
Total length	24 m	~10 m (?)	10 m
Max B field	17.5 T	26 T	13 T
β (n region)	0.3	~0.6	~0.6

* From Bagryansky, et al., Fus. Eng. & Design **70**, 13 (2004).

Lessons Learned for Today

- Need for materials testing in 14 MeV spectrum has not changed, in fact it may be a show stopper in the development of fusion energy.
- Mirror-like test facilities do represent a viable solution given some serious physics and engineering attention.
- The community that knows most about the potential of Mirror –like DT reactors will not be around forever!

Questions?