# Recent Progress of Design & Development in IFMIF Activities

IFMIF International Team
presented by M. Sugimoto (JAERI)

# CONTRIBUTORS (1995-2003)

*From IFMIF Comprehensive Design Report (Jan. 2004)*

## EU

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## RF

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## USA

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# Introduction

## Mission

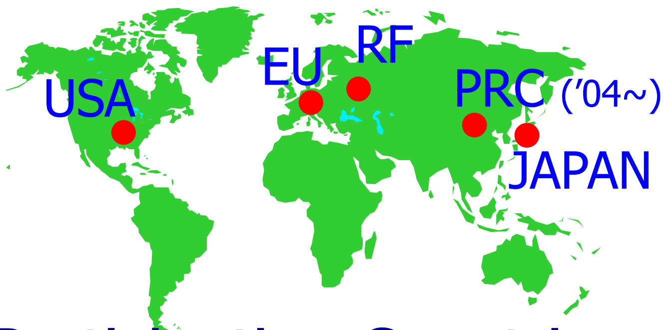
- **Qualification of candidate materials up to about full lifetime of anticipated use in a fusion DEMO reactor**
- Advanced material development for commercial reactors
- Calibration and validation of data generated from fission reactors and particle accelerators

**Accelerator-based D-Li neutron source was selected as IEA-Workshops consensus**

# Introduction (cont.)

## History

- IEA Fusion Materials collaboration (Annex II 1980~) since 1995 with a prehistory of FMIT (1978-1985)
- '95-'96: **C**onceptual **D**esign **A**ctivity phase
- '97-'98: **C**onceptual **D**esign **E**valuation phase
- '99: Cost reduction and staged deployment
- '00-'02: **K**ey **E**lement technology **P**hase
- '03-: Transition to next phase (**E**ngineering **V**alidation and **E**ngineering **D**esign **A**ctivity)
- Comprehensive Design Report (CDR) was published in Jan. 2004




Participating Countries

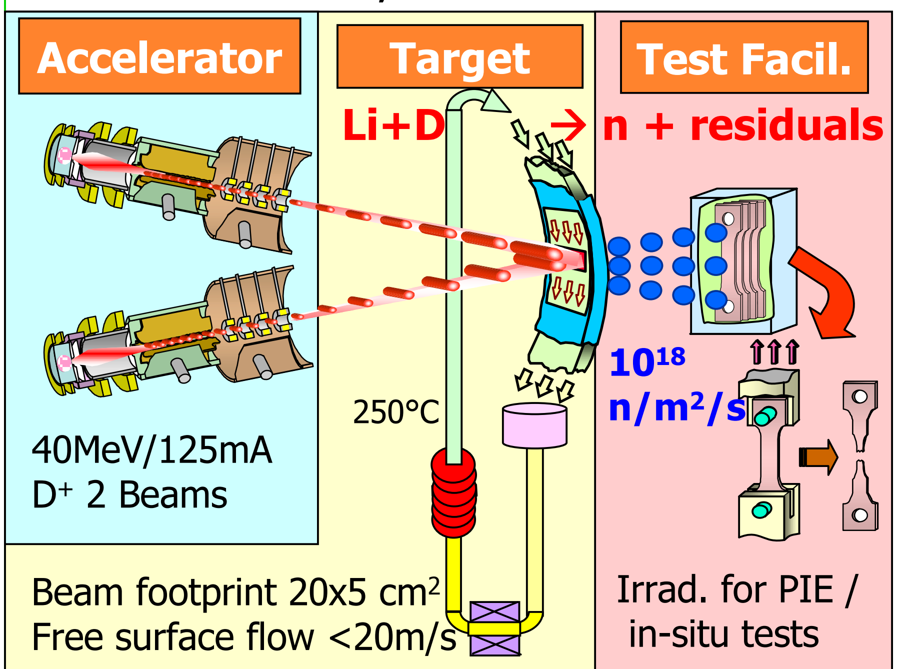
# System Requirements & Design

## Users Requirements:

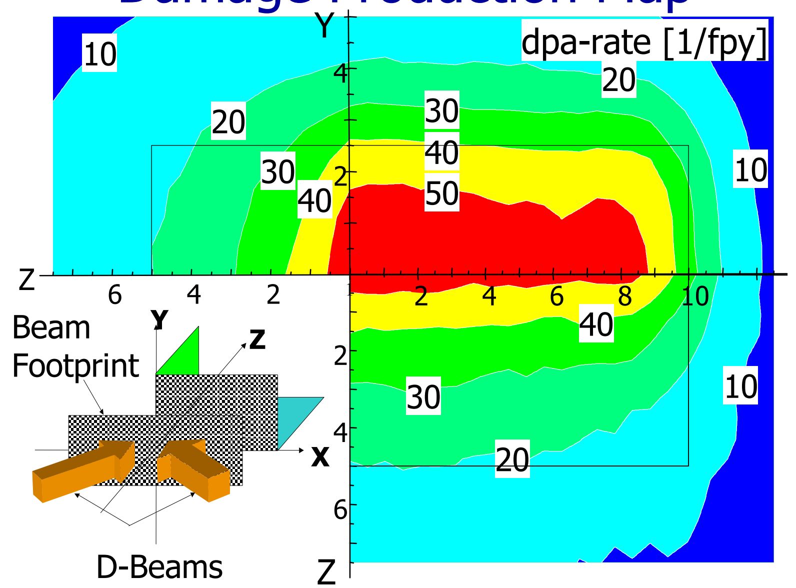
**Reduced activation first wall & blanket materials:**
**Ferritic-martensitic (ODS) steels 250-650°C**
**Vanadium alloys 350-650°C**
**SiC/SiC composites 600-1100°C**
(up to 150dpa)
**Refractory metals, Brazing materials & joints**
**Ceramic breeder, Neutron multipliers,**
**Ceramic insulators, etc.**

## System Requirements:

- Flux/Volume:
  High Flux Volume >20dpa/y, 0.5 ℓ;
  Medium Flux Vol. 1-20dpa/y, 6 ℓ;
  Low Flux Vol. 0.1-1dpa/y, 7.5 ℓ
- Availability: >70%

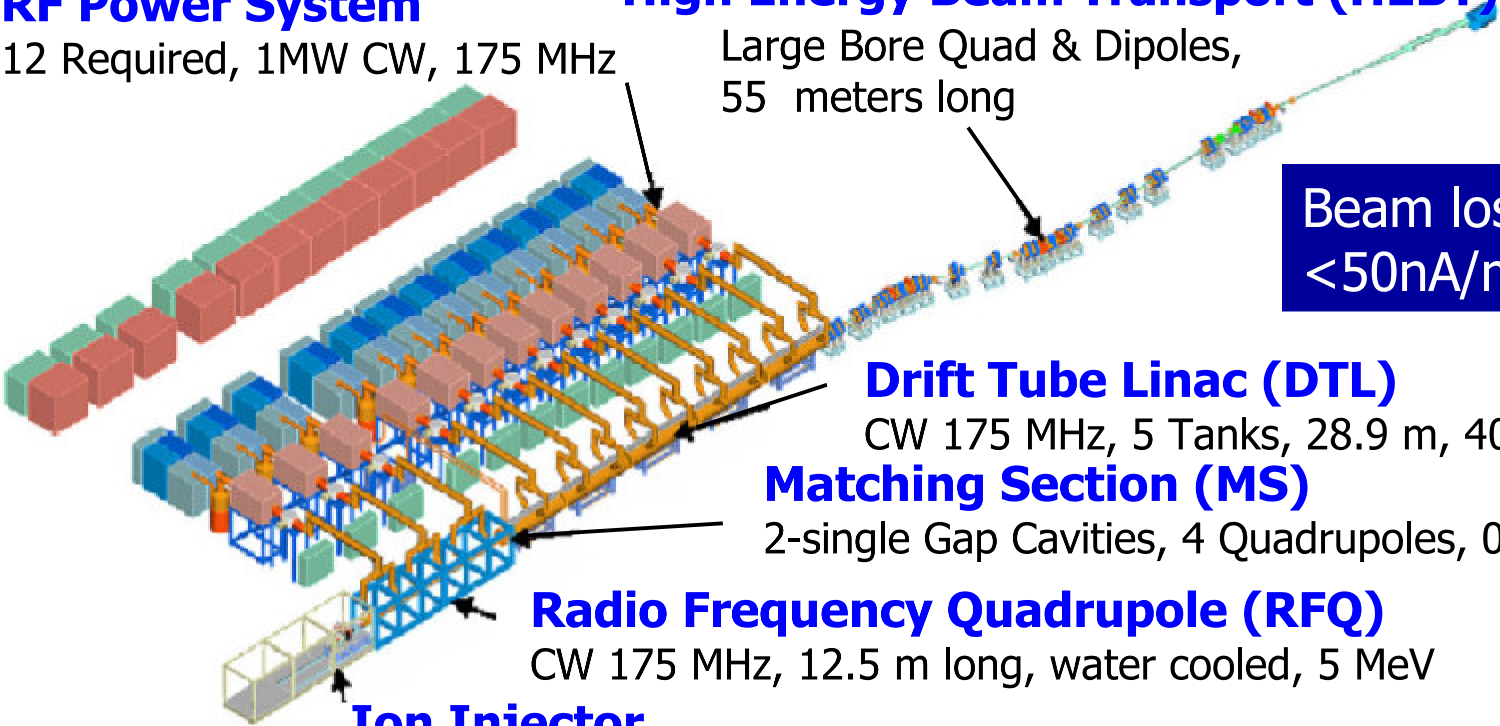



Damage Production Map



# Accelerator Facilities Design

Key Technology: Ion beam handling, RF cavity/control



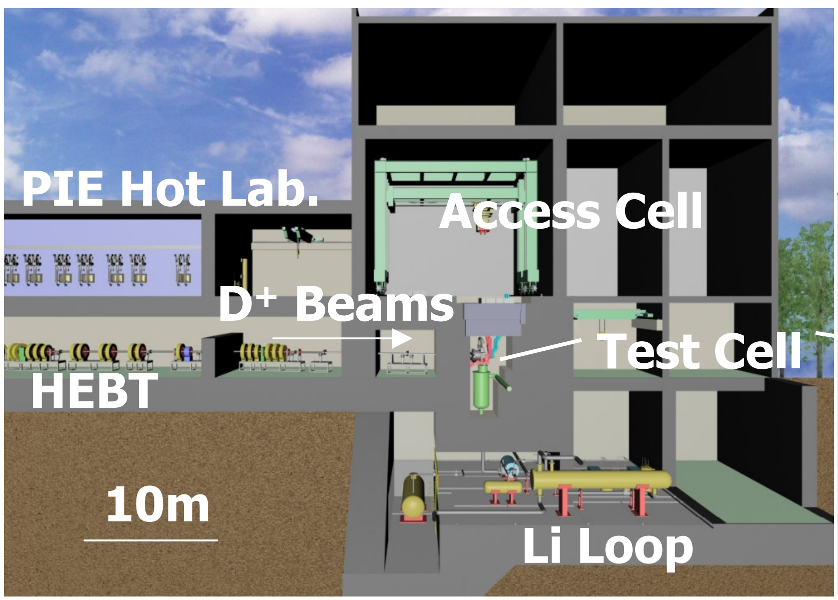

Beam loss criteria:
<50nA/m @ 40MeV

# Target & Test Facilities Design

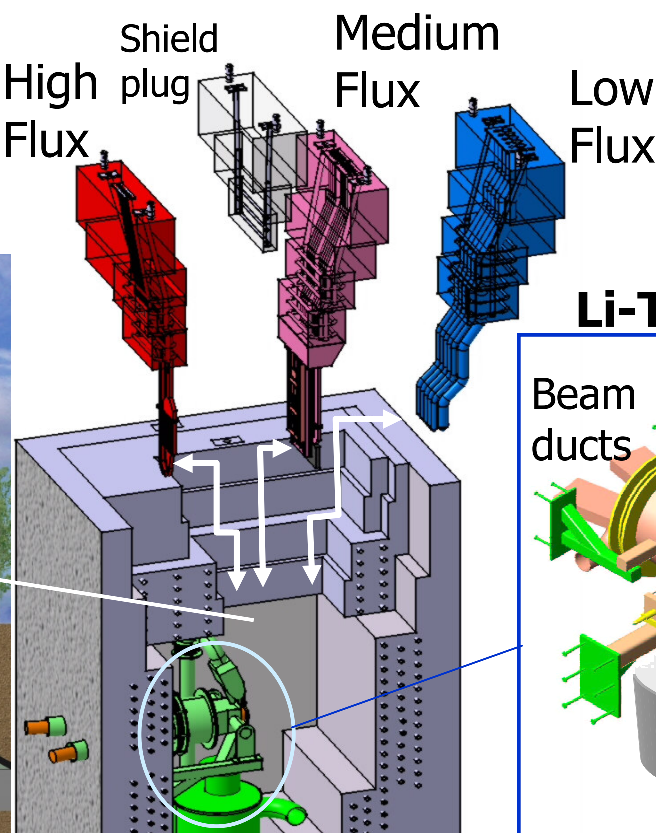
Key Technology: Liquid lithium handling, Irradiation temp. cont.

Li flow at beam target area:
10~20 m/s, 26cm w x 2.5cm thick.
Surface wave amp. <1mm,
Pressure at surface ~$10^{-3}$ Pa
Impurity control: < 10 wppm O,C,N

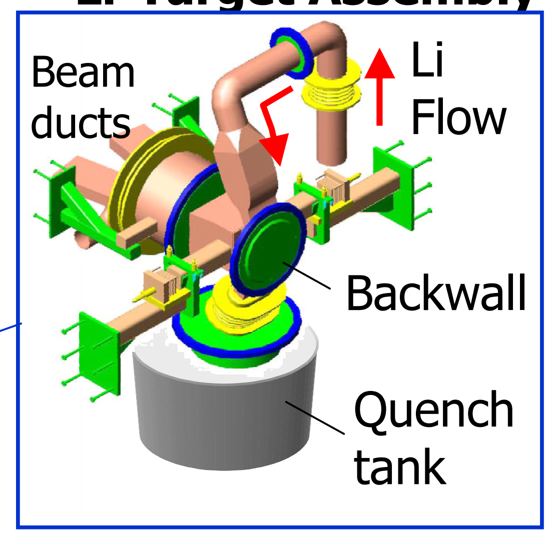
Guideline for irradiation temperature control:
±1.7% $T_{irrad}$




**Vertical Test Assemblies**




**Li-Target Assembly**



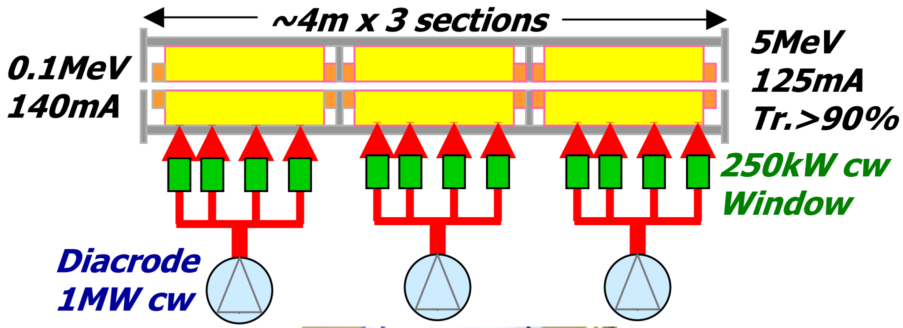
# Key Technology Development in ‘04

- Accelerator: $H_2^+$ extraction, RFQ drive loop, RFQ tuner (P-I-4), HEBT design, SC-CH cavity
- Target: Nitrogen getter, Li loop cavitation/surface wave, activation of Li impurities (P-I-22), Remote handling of backwall, erosion/corrosion test loops
- Test Facilities: High flux test module structure, Medium flux test module neutronics, Micro-fission chamber
- Design Integration: Availability analysis

# Accelerator

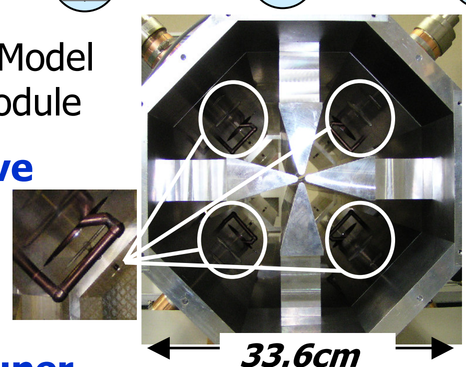
## RFQ: 175MHz coupled cavity, 4-vanes, NC

*S. Maebara (JAERI)*



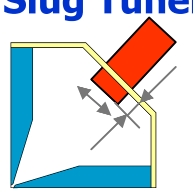

Al Cold Model
~4m module

**RF Drive Loop**

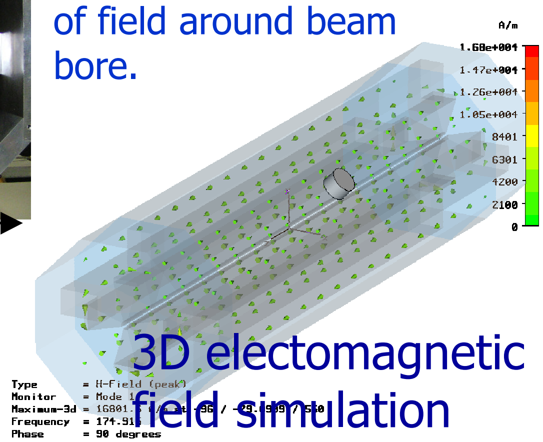



Multiple Drive Loops improve unformity of field around beam bore.

**Slug Tuner**



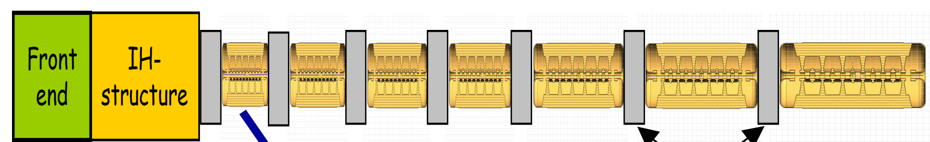
Tuning sensitivity & distortion effect to field are examined through simulation.

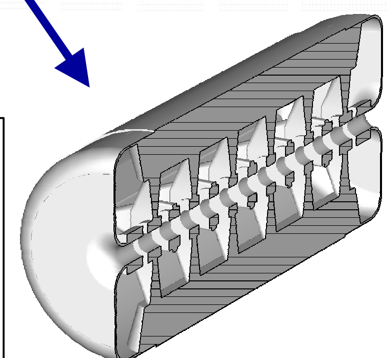


3D electomagnetic field simulation

## SC 175MHz CH(crossbar $H_{210}$)-cavity

*H. Podlech (IAP, Frankfurt U.)*



Triplet Q mag

$E_{in}$=5MeV/u
$E_{out}$=7.5MeV/u
$E_{acc}$=4MV/m
L=120cm

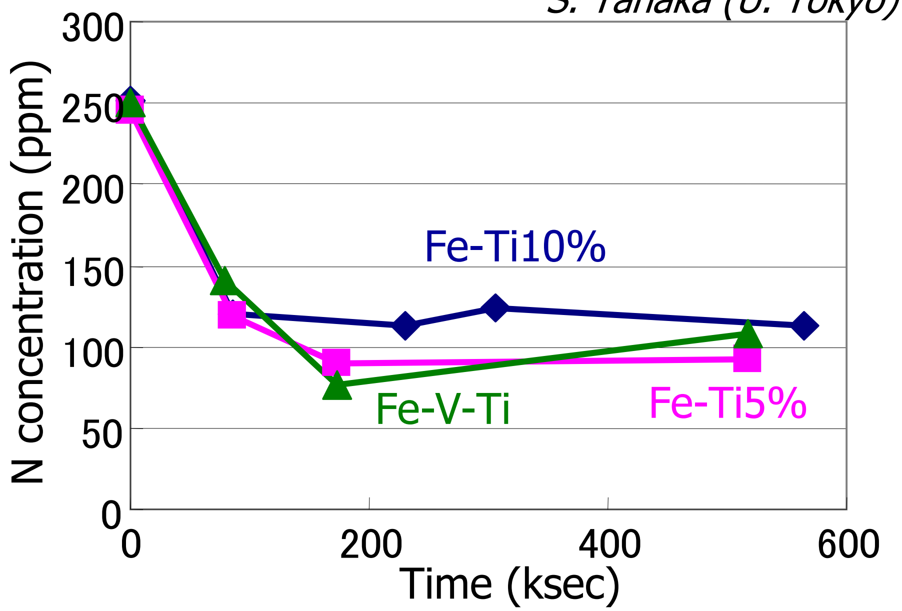
SC is alternative option to the reference design. Selection will be made at early EVEDA phase.

# Target

## Selection of nitrogen getter

(hot trap temp.~873K)

*S. Tanaka (U. Tokyo)*

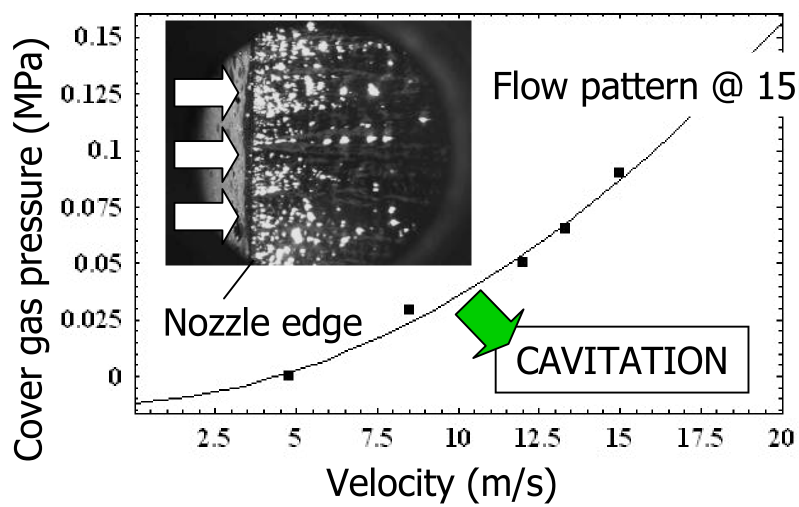



- V, Ti, Cr, V-Ti10% tested in KEP (>70ppm)
- Al soluble getter tried at IPPE (2-5ppm @ 623K)

## Cavitation property of Li-loop

(10cm w x 1cm thick.)

*H. Horiike (Osaka U.)*

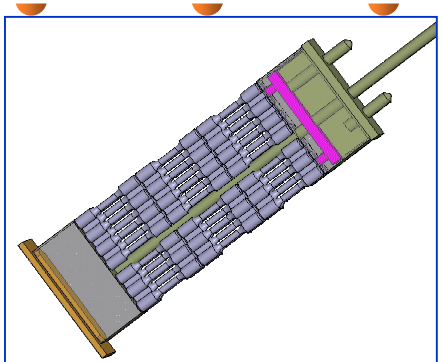



## Surface wave

- Wavelength ~1mm @ 8m/s
- Good agreement with Hassberger's results
- 30% larger than water with same geom.

# Test Facilities

## High Flux Test Module Structure – Precise control of irrad. temp.



*V. Heinzel (FZK)*

NaK (Na) bonding

3 heaters (top, middle, bottom)

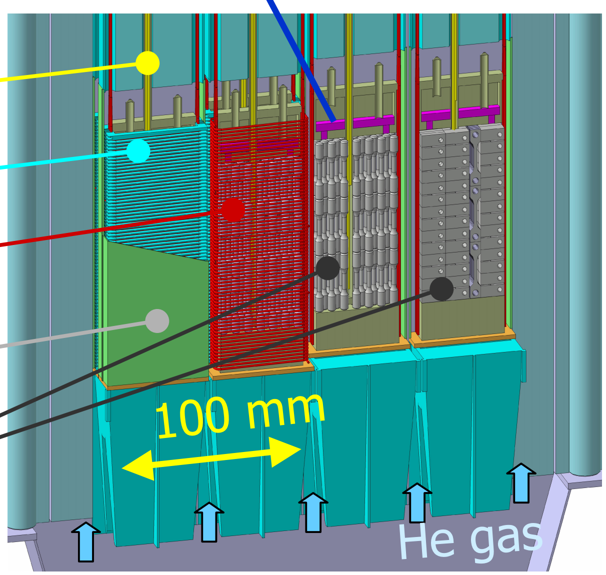
Thermo couples

Capsule

Ohmic heating

4x3 Rigs

700-1150 Specimens



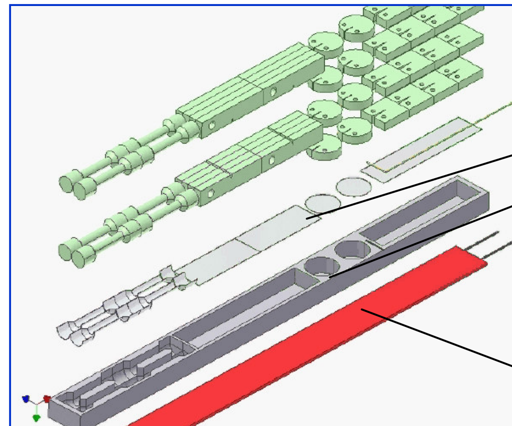

*A. Shimizu (Kyshu U.)*

He gas gap

metallic mesh

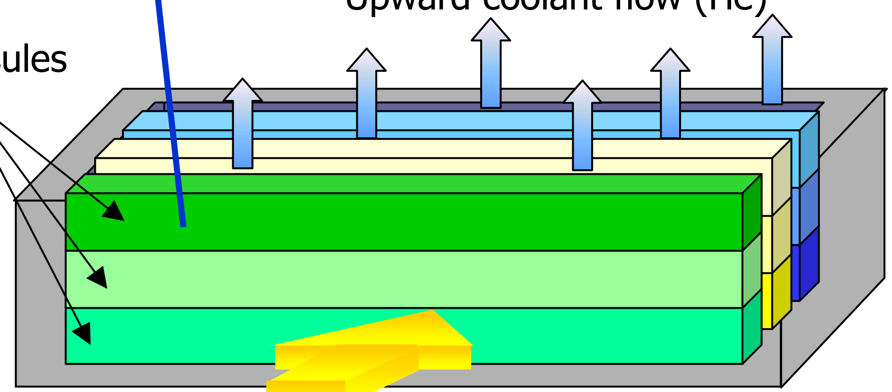
cast-type capsule (same material with test piece is preferred)

Panel heater



Upward coolant flow (He)

Capsules



neutron flux

# Availability Analysis

**Overall requirements: 70% online performance / year [6132h / 8760h]**

*I. Balan (FZK)*

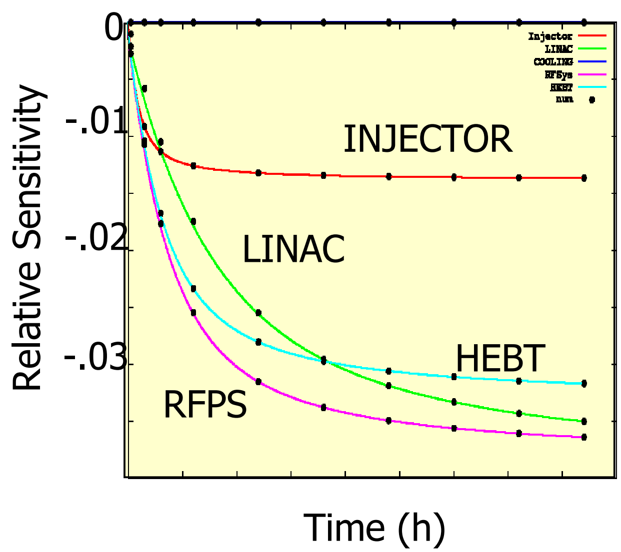
Availability allocation to subsystems:

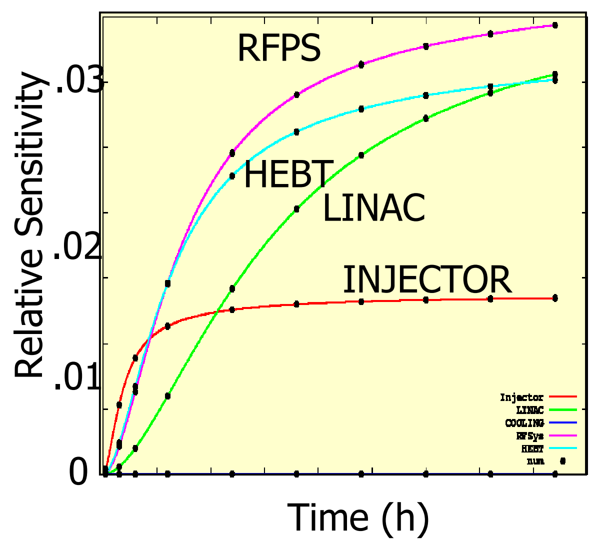
| | |
|---|---|
| - test facilities | 97.5% |
| - target facilities | 95.0% |
| - accelerator facilities | 88.0% |
| - conventional facilities | 99.5% |
| - CC & CI | 99.5% |
| Total availability | 80.7% |

Allowed downtime:
- scheduled maintenance: 1160h
  (1month(744h) / year + 8h / week (416h))
- unscheduled repairs: 1468h
  (random component failures)

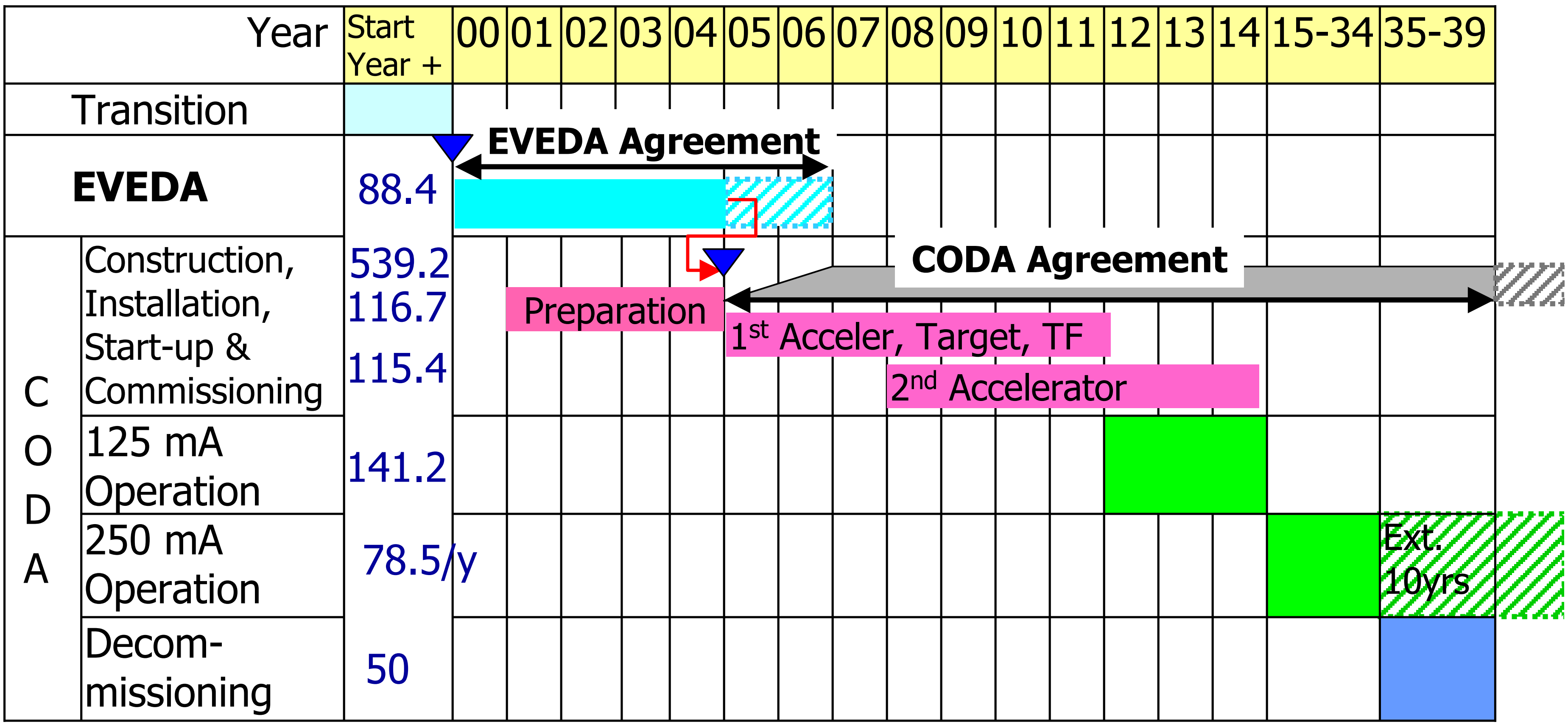
**Results of RAM analysis:**
**- mission-time 168h**
**- coupled Fault Tree/ Markov Chain**
**- sensitivity analysis**

$$R_2 = \frac{1}{T}\int_{t_0=0}^{t_f=T} P_1(t)dt \Rightarrow \left|\frac{\Delta R}{\Delta \alpha_i}\cdot\frac{\alpha_i^0}{R^0}\right|$$



# Schedule




Estimated Cost (2003 M$)

# Summary

- IFMIF activity under IEA collaboration completed KEP tasks and CDR in 01/2004.
- As the transition phase activity, extended data accumulation of KEP tasks and preparatory study for EVEDA were carried out in accelerator, target, and test facilities subsystems in 2004.
- Schedule in CDR describes start of 5~7 years EVEDA phase A.S.A.P. after establishing new Agreement to provide basis for making decision of IFMIF construction.