# Comments on Current and Planned Neutron Sources and Fusion Materials Development Strategy

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IEA Workshop on Spallation-based Neutron Sources for Fusion Materials Irradiation Studies

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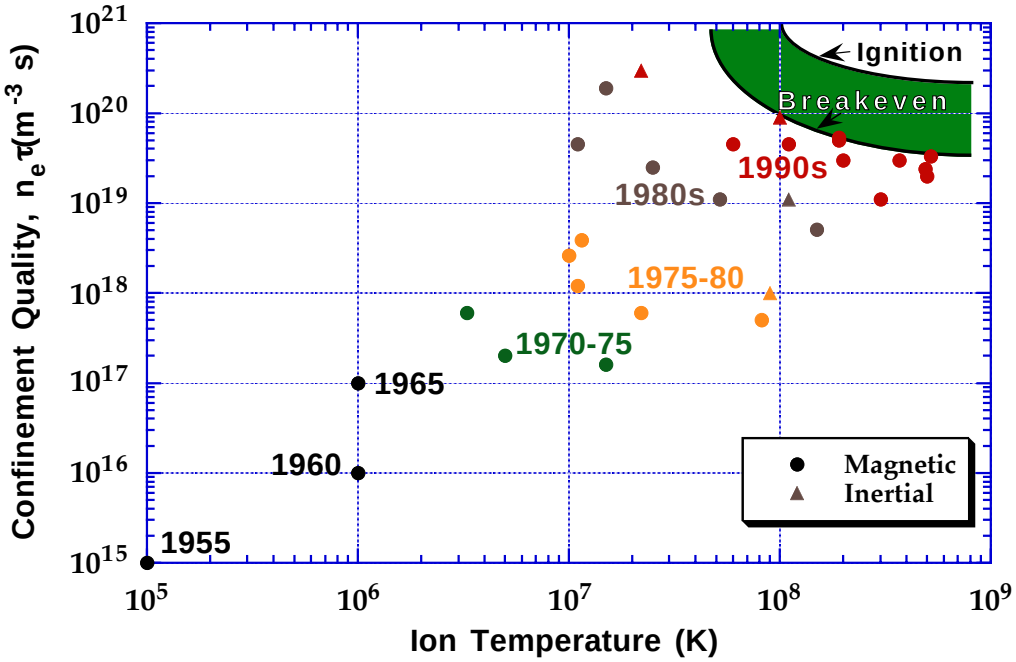
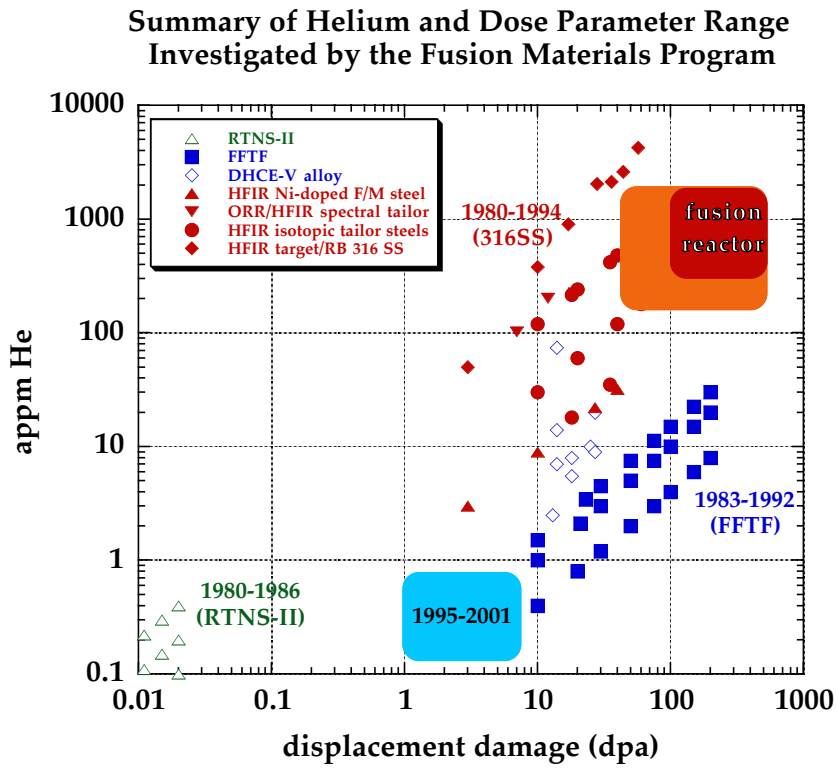
# Fusion materials research must rely heavily on modeling and surrogate experiments due to inaccessibility of fusion-relevant operating regime

- Extrapolation from currently available parameter space to fusion regime is much larger for fusion materials than for plasma physics program
- An intense neutron source such as IFMIF is needed to develop fusion structural materials



# Overview of Fission, Spallation, and d-Li Neutron Sources for Fusion Materials R&D

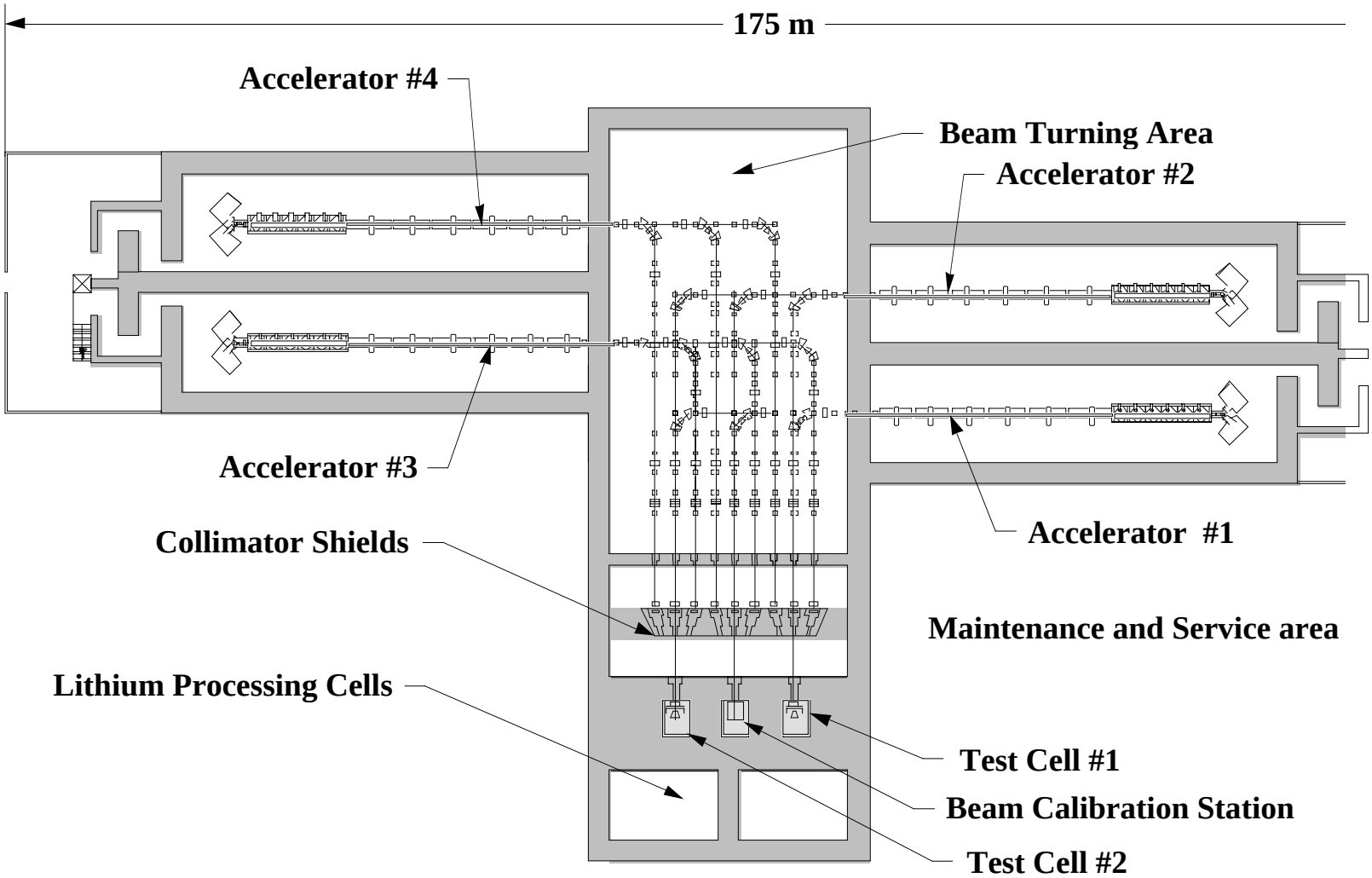
| Neutron Source | Advantages | Disadvantages |
|---|---|---|
| Fission Reactors | Well-characterized spectra<br>Allows medium-high damage regimes to be investigated in bulk specimens<br>Operating funds provided by multiple users (non-fusion) | Low He/dpa ratio |
| Spallation | Allows high-He irradiation conditions to be explored<br>Operating costs may be largely provided by non-fusion agencies | Not designed for materials irradiations (physics/ neutron scattering facility)<br>He/dpa,H/dpa ratio too high<br>Pulsed irradiation; requires detailed analysis |
| D-Li | Correct He/dpa ratio, etc.<br>Dedicated materials irradiation facility | Operating funds completely provided by fusion |

# Historical fusion materials neutron source summary

- **A fusion materials test facility is still not available**
  - **demanded several times by**
    **Fusion Materials Community and high ranking advisory boards**
    - **Cottrell Blue Ribbon Panel, 1983**
    - **Amelincks Senior Advisory Committee, 1986**
- **Under IEA coordination (1989 - 1994)**
  - **An Accelerator-based D-Li neutron source fulfils all requirements within a realistic time scale**
- **Implementing Agreement of the IEA on IFMIF**
  - **Conceptual Design Activity (CDA) 1995-1996**
  - **Conceptual Design Evaluation (CDE) 1997-1998**
  - **Evaluation of key issues and cost reduction 1999 .....**

**Ehrlich et al. ICFRM9 1999**

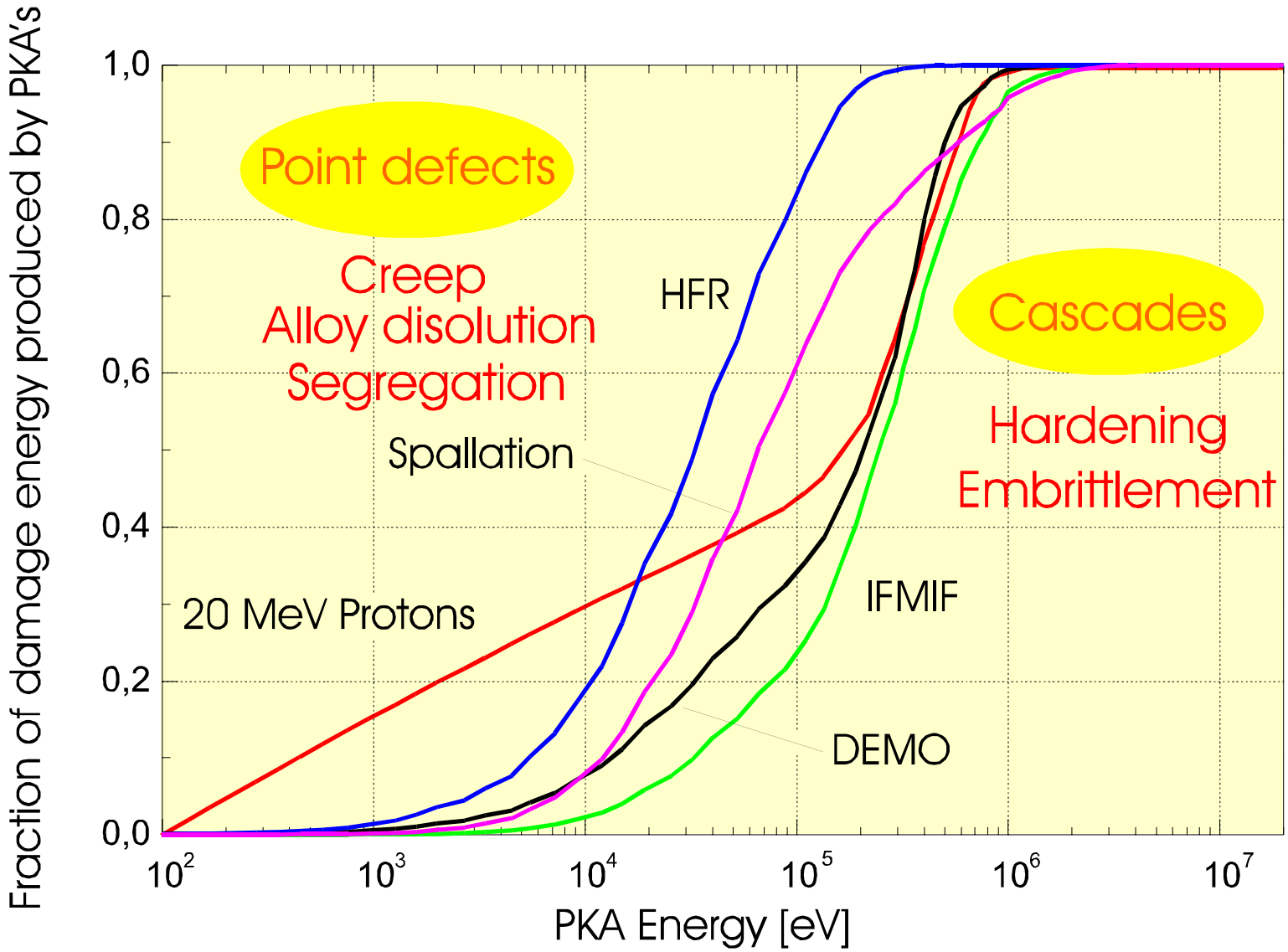
# Original IFMIF configuration (2 test cells, 2+2 accelerators)




**IFMIF CDA report 1996**

**IFMIF Expanded Configuration**

# IFMIF provides correct PKA spectrum for fusion materials

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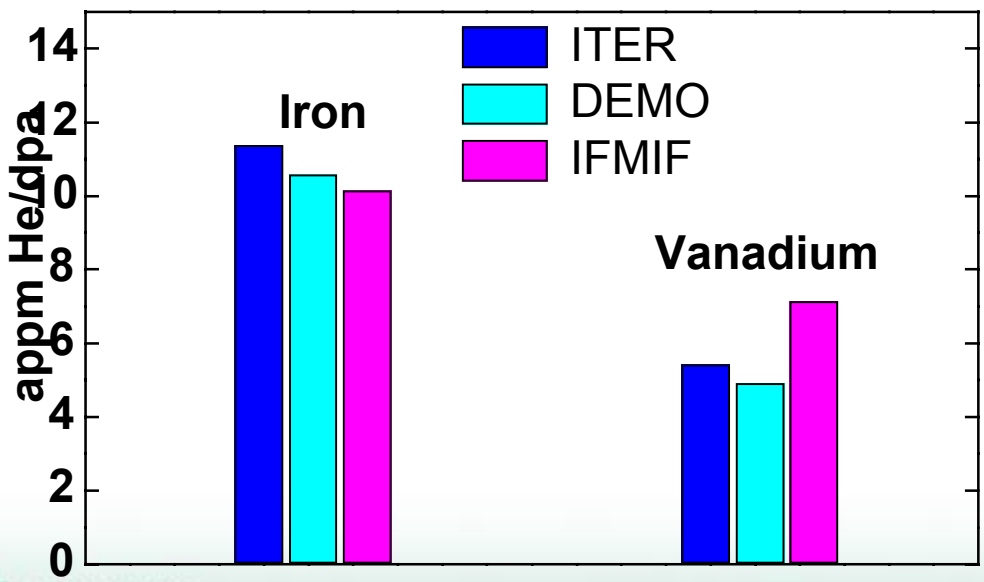
# IFMIF provides correct neutron spectrum for fusion materials

SPECTER calculations for damage and transmutation products using First Wall spectra provided by 3D Monte Carlo calculations

| | ITER | | | DEMO | | |
|---|---|---|---|---|---|---|
| MWy/m$^2$ | damage (dpa) | He (appm) | H (appm) | damage (dpa) | He (appm) | H (appm) |
| Fe | 20 | 228 | 890 | 17 | 180 | 709 |
| Cr | 20 | 361 | 905 | 18 | 282 | 722 |
| Ni | 21 | 790 | 3994 | 19 | 634 | 3222 |
| V | 21 | 114 | 477 | 18 | 89 | 374 |
| Be | 6.9 | 6510 | 98 | 6.9 | 5424 | 76 |
| C | 9.4 | 4302 | 1.2 | 9.2 | 3371 | 0.9 |
| Si | 27 | 860 | 1912 | 24 | 692 | 1524 |

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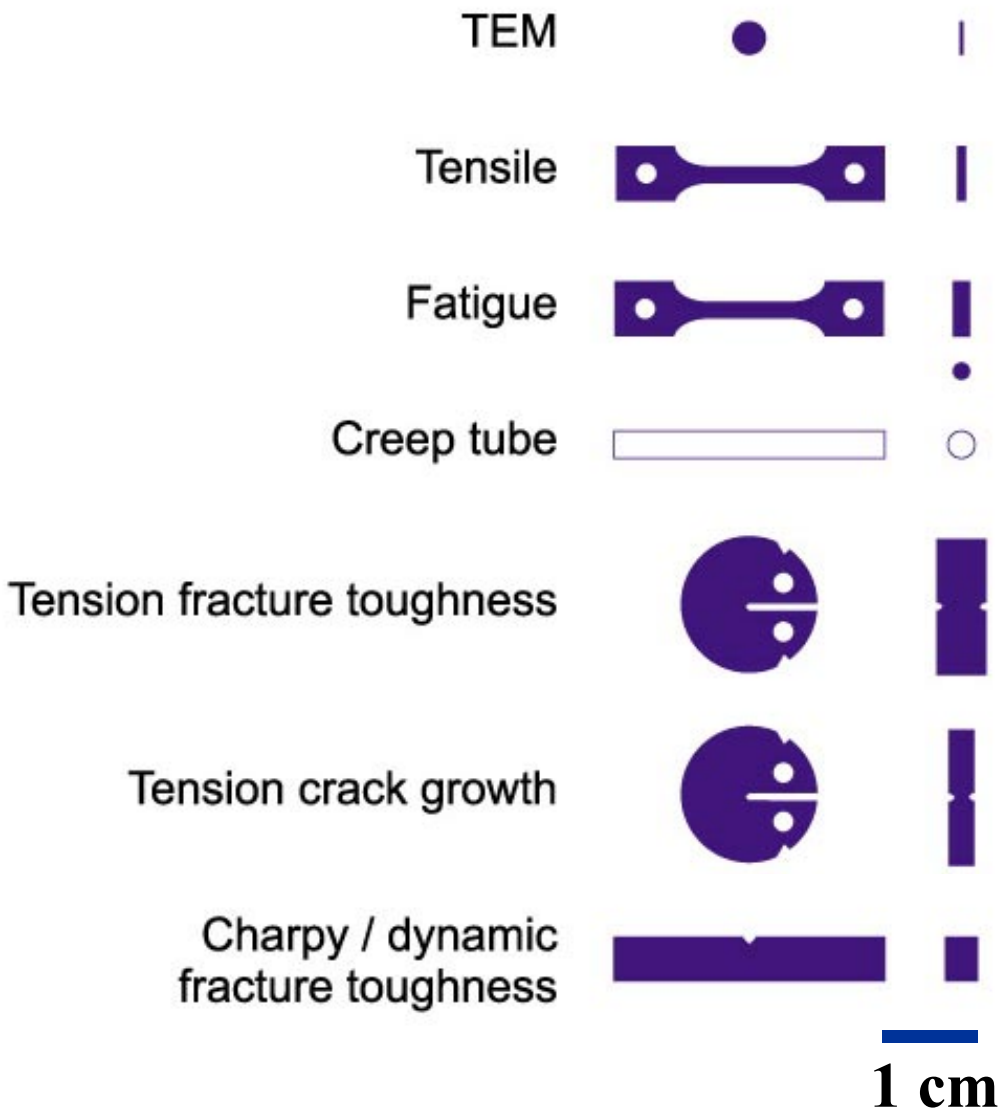
## Validated Miniaturized Specimens Enable Engineering Data to be Obtained from Small Irradiation Volumes (currently used in extensive fission reactor studies)



# IFMIF provides capability of accelerated radiation effects testing of structural materials in a fusion-relevant neutron spectrum

- ~0.5 liter volume with >2 MW/m$^2$ equivalent neutron flux (~5x20x5 cm$^3$)
  - ~0.1 liter volume with >5.5 MW/m$^2$
  - (note: typical current fission reactor irradiation capsule volumes are 0.013 to 0.1 liters)
- Strawman specimen matrices indicate that 600-1000 mechanical property specimens (and >>1000 TEM specimens) can be accommodated in 0.5 liter high flux region
- Irradiation to 15-20 MW-a/m$^2$ of a complete set of mechanical property specimens of two materials at 3 to 4 different temperatures could be accomplished in 4 years in the $\geq$5.5 MW/m$^2$ flux regions of IFMIF
- Medium and low-flux regions of IFMIF (<2 MW/m$^2$) are earmarked for in-situ creep fatigue tests, ceramic breeder irradiation studies, diagnostic component irradiations, etc.

## Strategy for Deployment of IFMIF vs. other major technology irradiation test beds

- Acquisition of the fundamental constitutive properties of irradiated materials is essential for the analysis of the performance of irradiated components
- Development of materials will likely require several iterations of materials irradiation & alloy modification (requiring >15-20 years to develop and qualify materials)
- IFMIF should be deployed in advance of a plasma technology test bed (strong interactions between users of each facility are essential)