Design-Phase Probabilistic Risk Assessment for the International Fusion Materials Irradiation Facility

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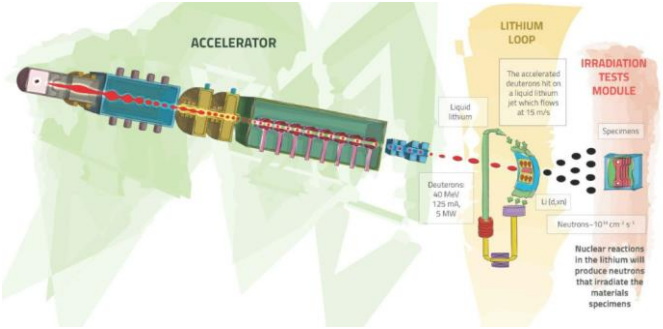
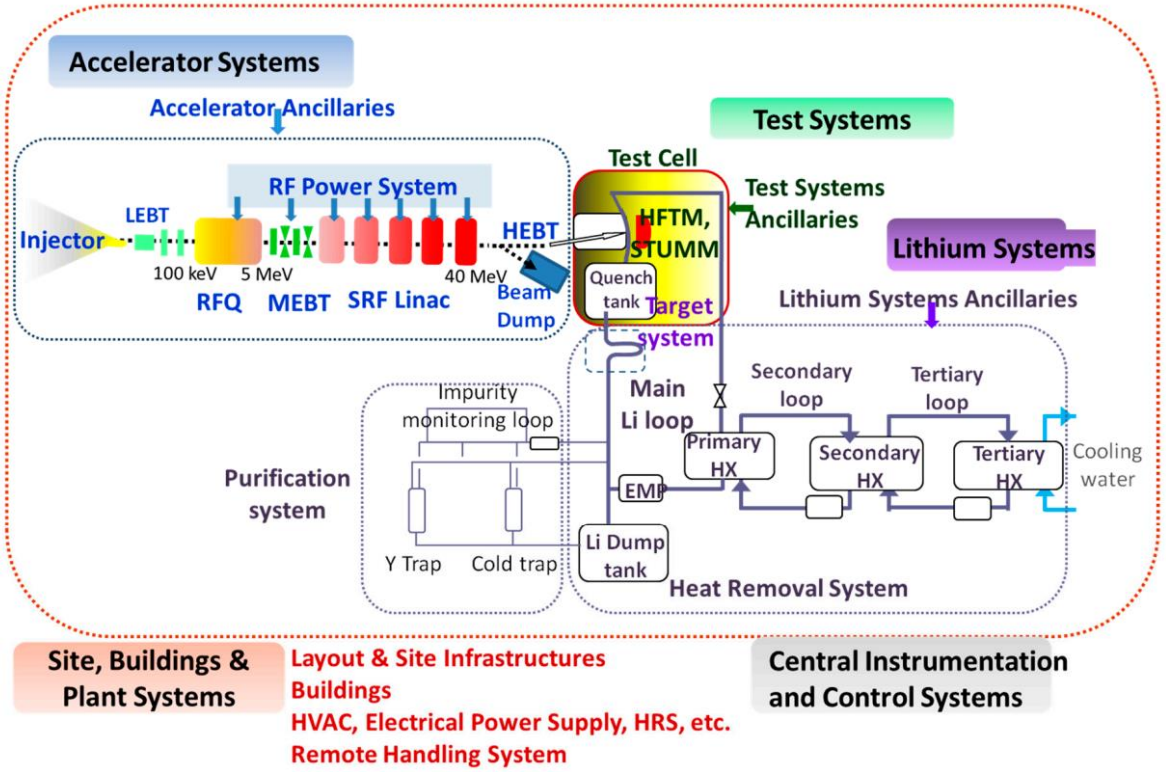
Introduction to the IFMIF-DONES facility

- IFMIF-DONES = International Fusion Materials Irradiation Facility – DEMO Oriented Neutron Energy Source
- Testing of the suitability of materials for fusion plant conditions
- Deuteron beam directed through a lithium target
  - Neutron flux for the irradiation of materials
  - Radioactive tritium and activation products also produced
- After 15 years of design, the construction expected to start in the near future
  - WPENS project funded by EUROfusion



https://ifmif-dones.es/dones-program/dones-facility/

Plant configuration

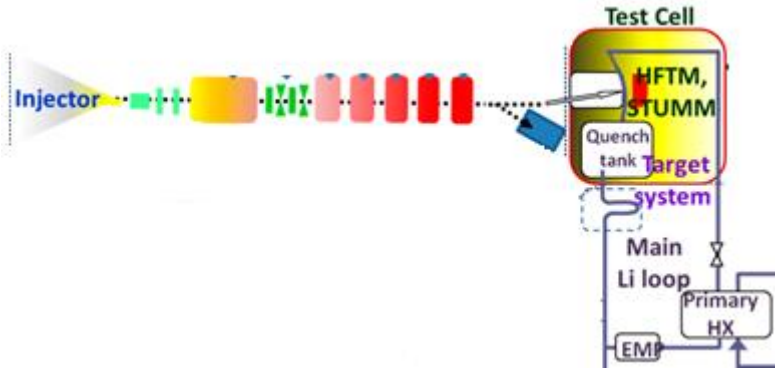


- Service gas system
  - Inerting of rooms where lithium can leak to
- Heating, ventilation and air conditioning (HVAC) system
  - Isolates rooms with radioactive leaks
- Heat rejection system
  - The heat sink with cooling towers
- Beam shutdown system

F. Martin-Fuertes, M.E. Garcia, P. Fernandez, A. Cortes, G. D'Ovidio, E. Fernandez, T. Pinna, M.T. Porfiri, U. Fischer, F. Ogando, F. Mota, Y. Qiu, A. Helminen, S. Potempski, E. Gallego, A. Ibarra, "Integration of Safety in IFMIF-DONES design", Safety, Vol. 5(4), p. 74, 2019

Accident scenarios

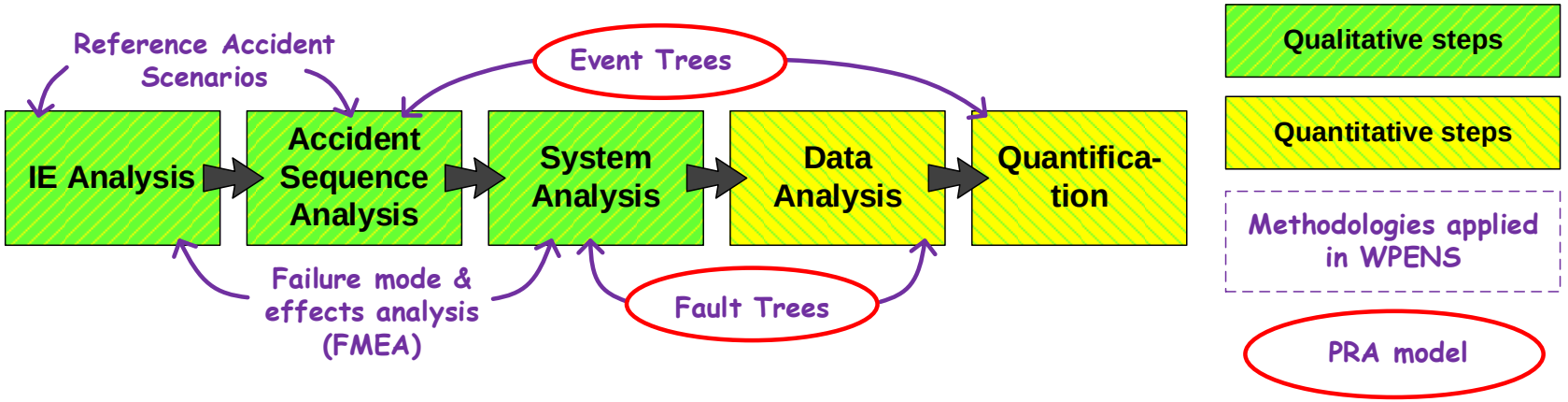
- Loss of lithium flow
  - If the beam is not promptly shutdown, it breaks the back-plate of the target system, test modules and the back-wall of the test cell
  - Release of large amounts of activation products



- Lithium fire
  - Possible e.g. if lithium leaks from the piping system
  - Only if inerting fails
  - Release of tritium

- Loss of cooling of the high flux test module (HFTM)
  - If the beam is not shut down in 15 minutes, rupture could occur
  - Release of large amounts of activation products

Probabilistic risk assessment approach



Challenges

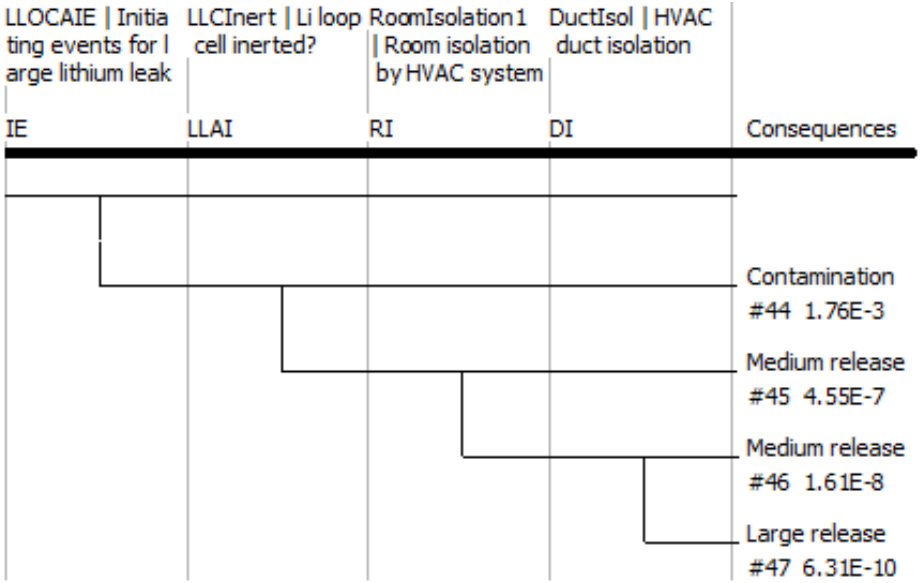
- First of its kind facility
  - New systems, components and accident scenarios
- Evolving design
  - Design details missing
  - Accident scenarios not well defined
- There are still significant uncertainties related to accident sequence modelling

Event trees

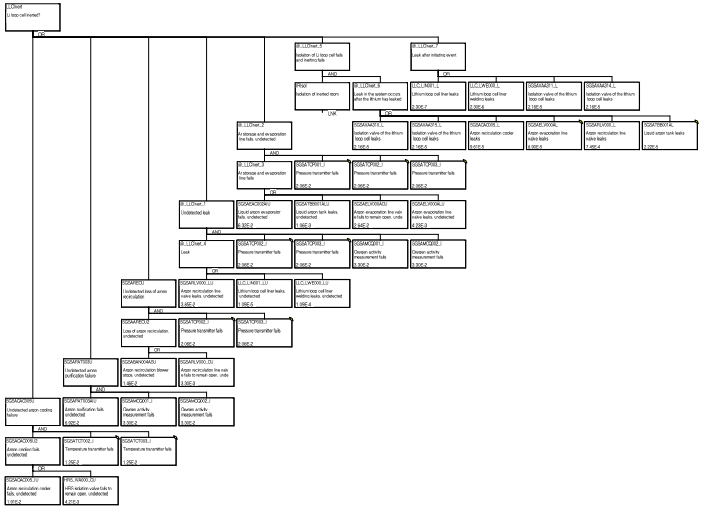
Event tree	Worst consequence
Large lithium leak to the lithium loop cell	Large release
Small lithium leak to the lithium loop area	Medium release
Lithium leak to the test cell	Medium release
Loss of lithium flow at target	Large release
Loss of cooling of lithium	Large release
Loss of HFTM cooling	Large release
Air ingress in beam duct	Large release?
Water in beam duct	Large release?

Large release: > 100 TBq
Medium release: 1-100 TBq

Event tree for large lithium leak



Fault tree for lithium loop cell inerting



Preliminary results

- The results are still quite uncertain
- Dominating scenarios are loss of lithium flow and loss of cooling of lithium
  - Beam breaks through the test cell within a minute if the beam shutdown fails
    - However, this may be a conservative assumption
  - Very high reliability of fast beam shutdown is required
- Other scenarios have significantly smaller risk

Conclusions

- Design-phase PRA for IFMIF-DONES
  - 8 event trees
  - Fault trees for safety functions

- Preliminary quantifications with data from fusion and fission applications
  - Loss of lithium flow with failed beam shutdown is the most important scenario
  - Uncertainties are still large
    - Related to damage that the beam can cause, source terms and beam shutdown design