PARAMETRIC ANALYSIS OF AN FFHR FOR WASTE TRANSMUTATION

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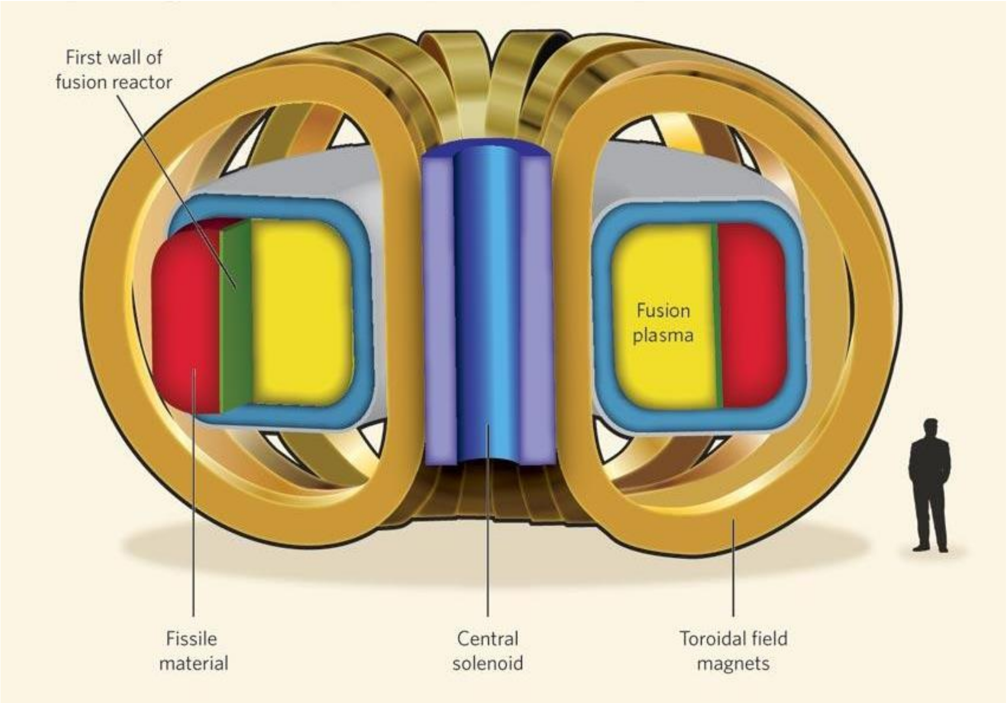
The fusion hybrid

Fusion Fission Hybrid Reactors (FFHR) result from the coupling of Fusion reactors and a subcritical Fission reactors.

They could be multipurpose machines and operate in various nuclear related fields:

- Energy generation
- Tritium Breeding
- Fuel breeding
- **Waste Transmutation**
- Any other irradiation activity

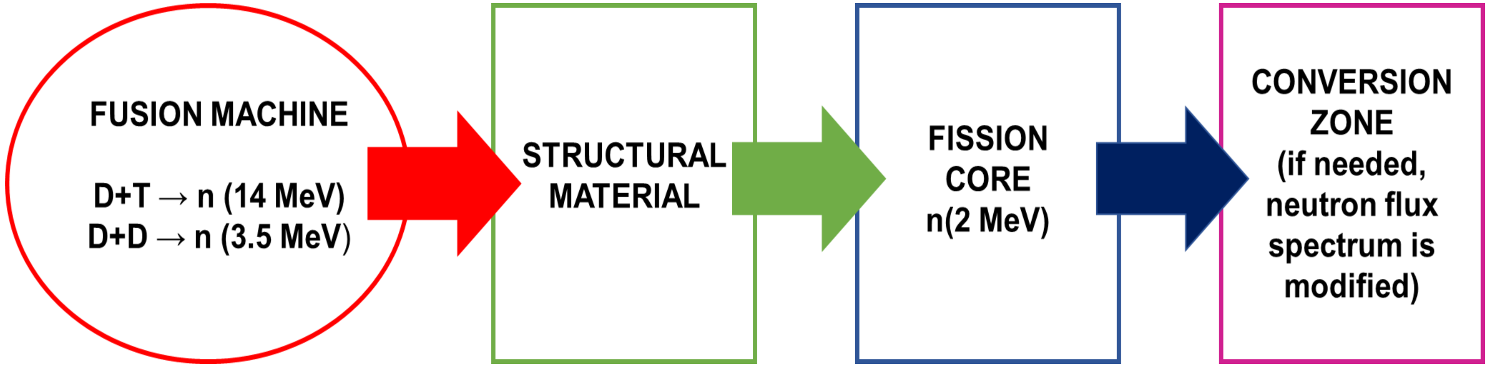


A need for optimization

The large availability of designs for fusion and fission machines makes the choice of devices to couple quite chaotic. Lots of FFHR concepts presented in the literature are often based on attempts or collaborations. The consequence is the coupling of fusion and fission technologies without real optimization.

A parametric analysis is proposed for an approach to a possible design optimization strategy

Neutron production scheme in an FFHR



EXAMPLE: let us suppose that k_{eff} is 0.97 (M = 33.3), that the neutron flux on the first wall of the fusion device is $5 \cdot 10^{12}$ n cm^{-2} s^{-1} and that no neutron is lost on the path to the fission blanket. Then, the neutron flux inside the blanket is of the order of $1.7 \cdot 10^{14}$ n cm^{-2} s^{-1}

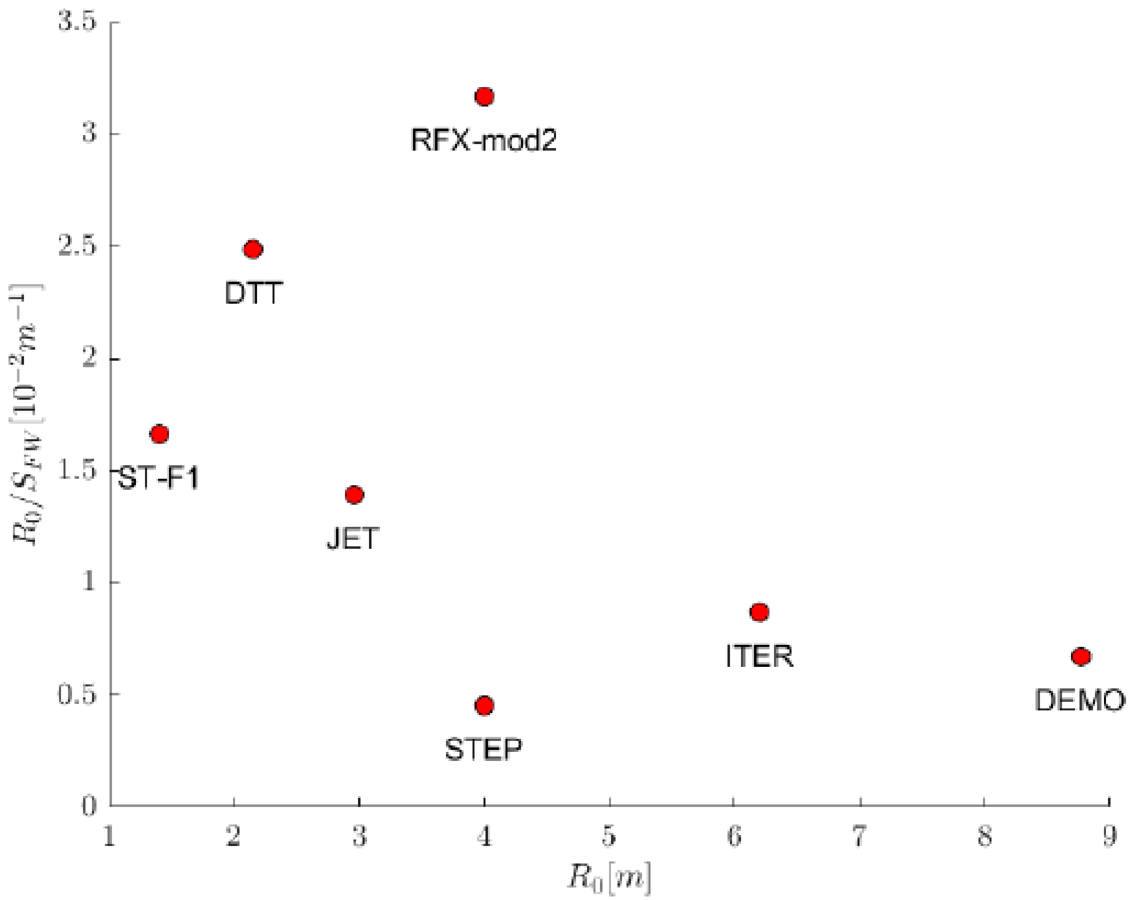
A proposal for a figure of merit

For a fusion machine: $$Q = \frac{P_{FUS}}{P_{EXT}}$$

For a FFHR (Bethe's idea): $$Q_{HYBR} = \frac{\sum_{i=1}^{n} P_i}{P_{EXT}} = Q + N_b \frac{\sum_{i=2}^{n} P_i}{P_{EXT}}$$

Toroidal machines, ring neutron source: $$Q_{HYBR} \approx \boxed{\frac{Q \cdot R_0 \cdot f_1}{S_{FW} \cdot f_{\Theta}}} \sum_{i=2}^{n} C_i$$

Figure of merit

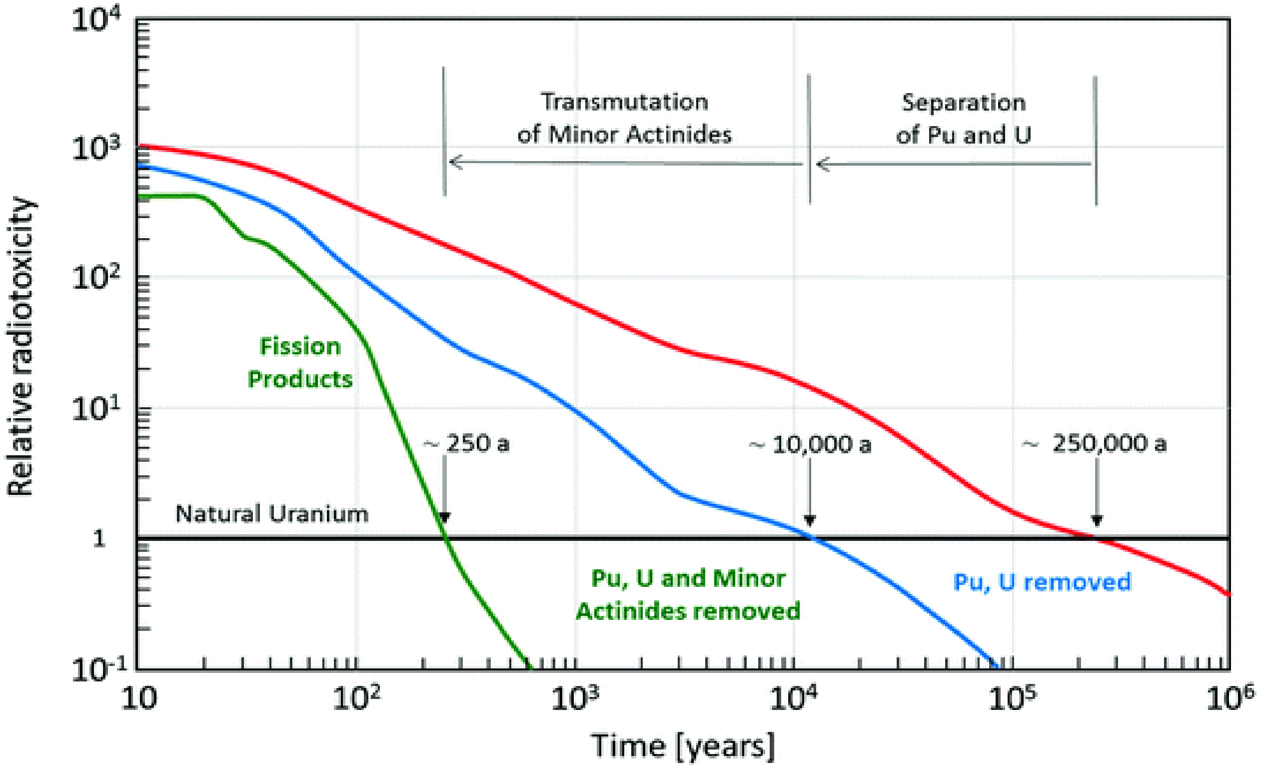


REF: Parametrical Choice of the Optimized Fusion System for a FFHR, S. Murgo et al., Energies, 2024

Waste transmutation

Nuclear waste (say fission products and actinides), could be irradiated and «burn» in nuclear reactors to:

- Reduce storage time before disposal
- Allow the recycling of used nuclear fuel



Waste transmutation

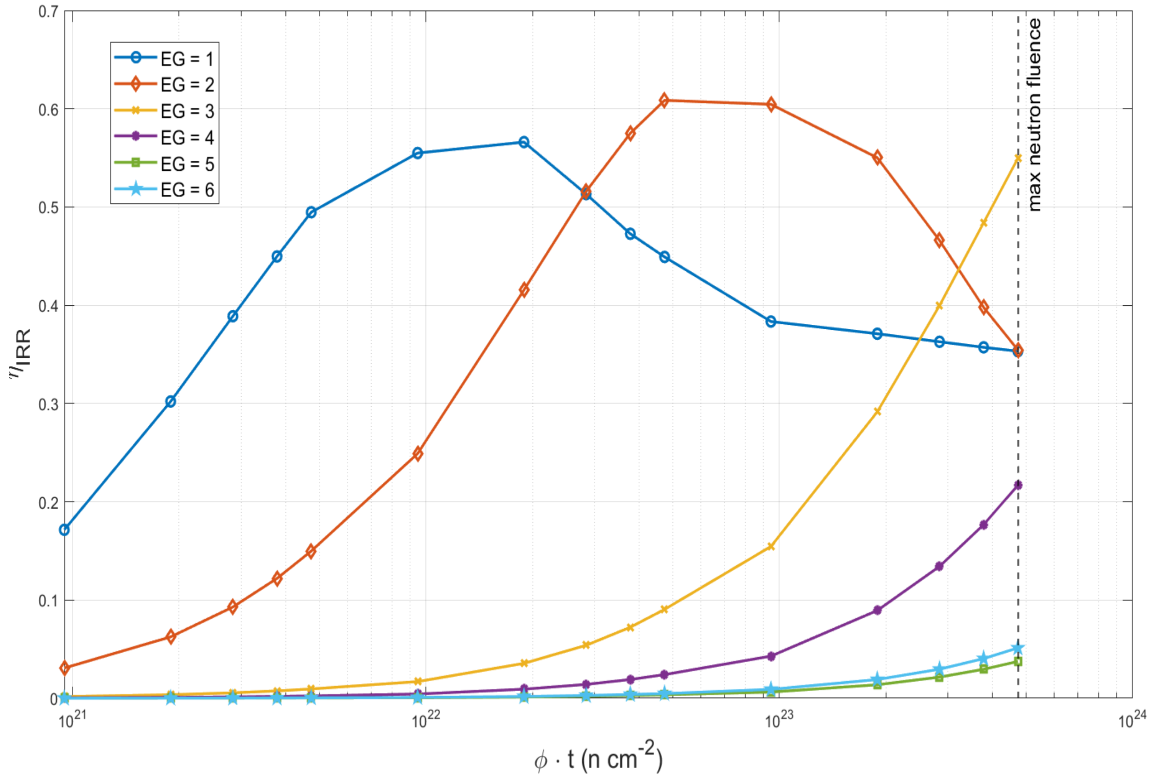
In order to study the evolution of nuclear waste subjected to neutron flux irradiation, we defined a waste target and a discretization of neutron spectrum (six groups). Then we simulated the irradiation of the target with monoenergetic fluxes of various intensity (one run for each group and intensity)

Isotope	Mass (%)
Np-237	39.7
Am-241	34.3
Am-242	0.1
Am-243	16.2
Cm-243	0.05
Cm-244	8.68
Cm-245	0.868

Energy Group	Energy Range (eV)	Neutron Energy Spectrum
EG 1	0 - 3.06E+00	Thermal
EG 2	3.06E+00 - 3.71E+03	Epithermal
EG 3	3.71E+03 - 1.43E+05	Moderately Fast
EG 4	1.43E+05 - 8.20E+05	Fast
EG 5	8.20E+05 - 4.50E+06	Very Fast
EG 6	4.50E+06 - 2.00E+07	Very Fast (Fusion source)

$$\eta_{IRR}(\Phi, EG, t) = 1 - \frac{m_{MA}(\Phi, EG, t)}{m_{MA}(t=0)} - \left(1 - \frac{m_{MA}(t)}{m_{MA}(t=0)}\right)$$

DECAY



The main effect of neutron irradiation is the conversion of Neptunium and Americium to Plutonium

Low thermal neutron fluences may be beneficial as also LOMBT is slightly reduced

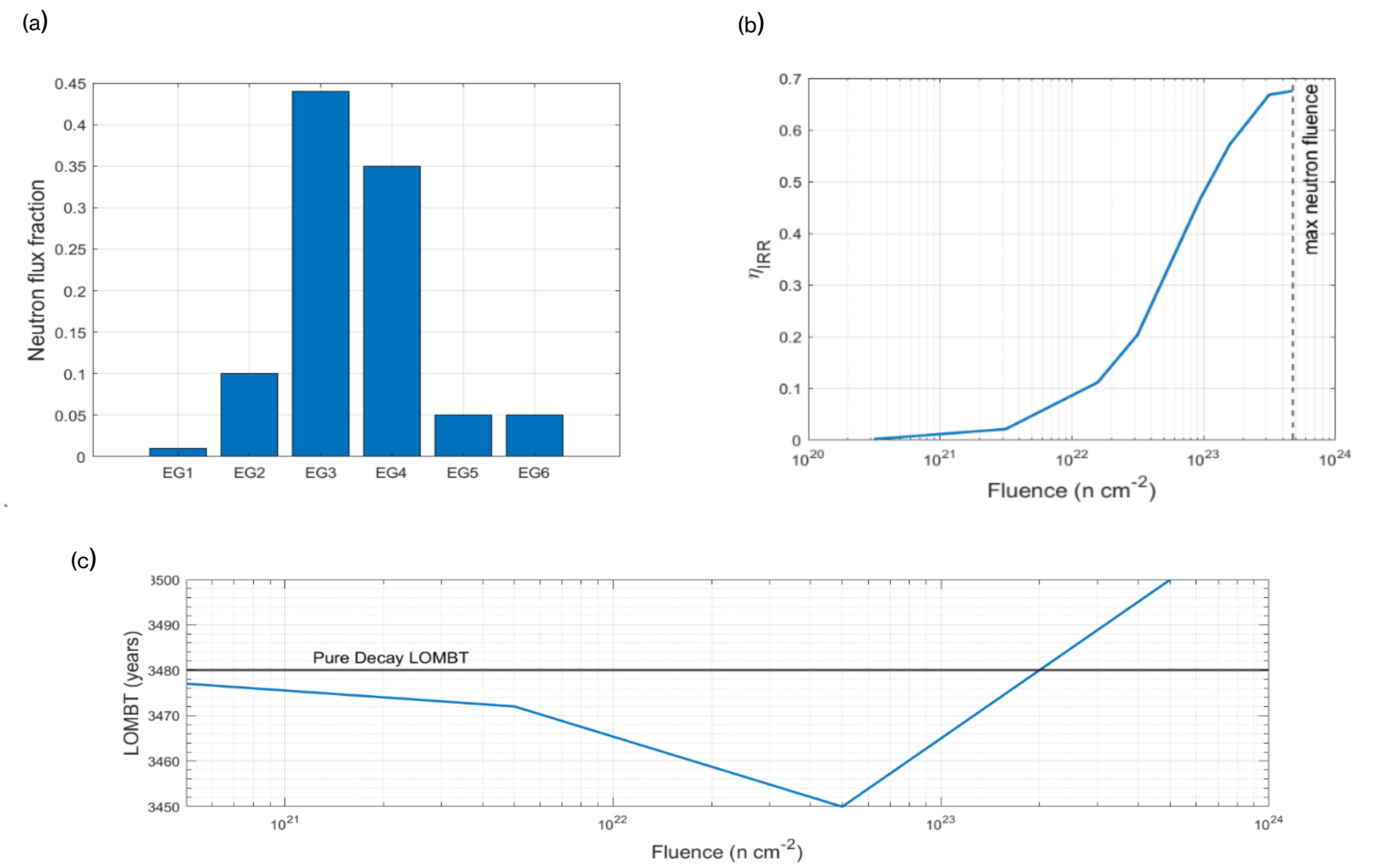


Fig. 5.1: a) Neutron flux energy spectrum for the tested scenario; **b)** Irradiation conversion efficiency as a function of the neutron flux for the tested scenario; **c)** LOMBT as a function of fluence for the tested scenario (t = 15 years)

CONCLUSIONS

- A parameter for Fusion neutron source has been proposed
- Fusion machines with smaller minor radii may be interesting as neutron sources for FFHR since they required lower Q-values.
- Waste transmutation could be obtain via actinides conversion to plutonium: actinides burning via fission seem impossible due to high neutron fluence requirements
- Low thermal (or medium energy) neutron fluences may be benificial for repository time reduction