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TRANSMUTATION OF HIGH LEVEL WASTES IN A FUSION-DRIVEN TRANSMUTER (FDT)

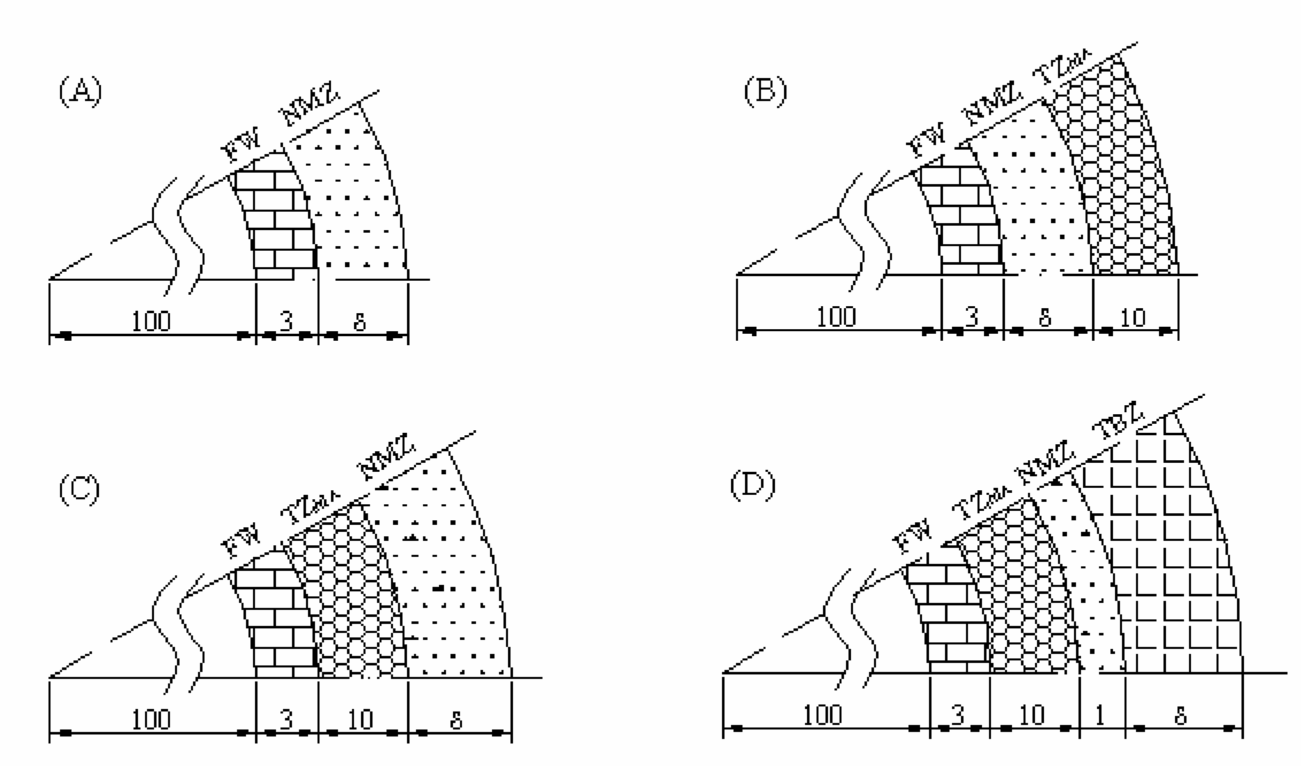
Nesrin DEMİR*, Gamze GENÇ, Hüseyin YAPICI
* Erciyes University, Faculty of Engineering,
Department of Mechanical Engineering KAYSERİ, TURKEY
nkayatas@erciyes.edu.tr

The Purpose of This Study

We investigate the transmutations of both the minor actinides (MAs: ^{237}Np, ^{241}Am, ^{243}Am and ^{244}Cm) and the long-lived fission products (LLFPs: ^{99}Tc, ^{129}I and ^{135}Cs), discharged from high burn-up PWR-MOX spent fuel, in a fusion-driven transmuter (FDT) and the effects of the MA and LLFP volume fractions on their transmutations.

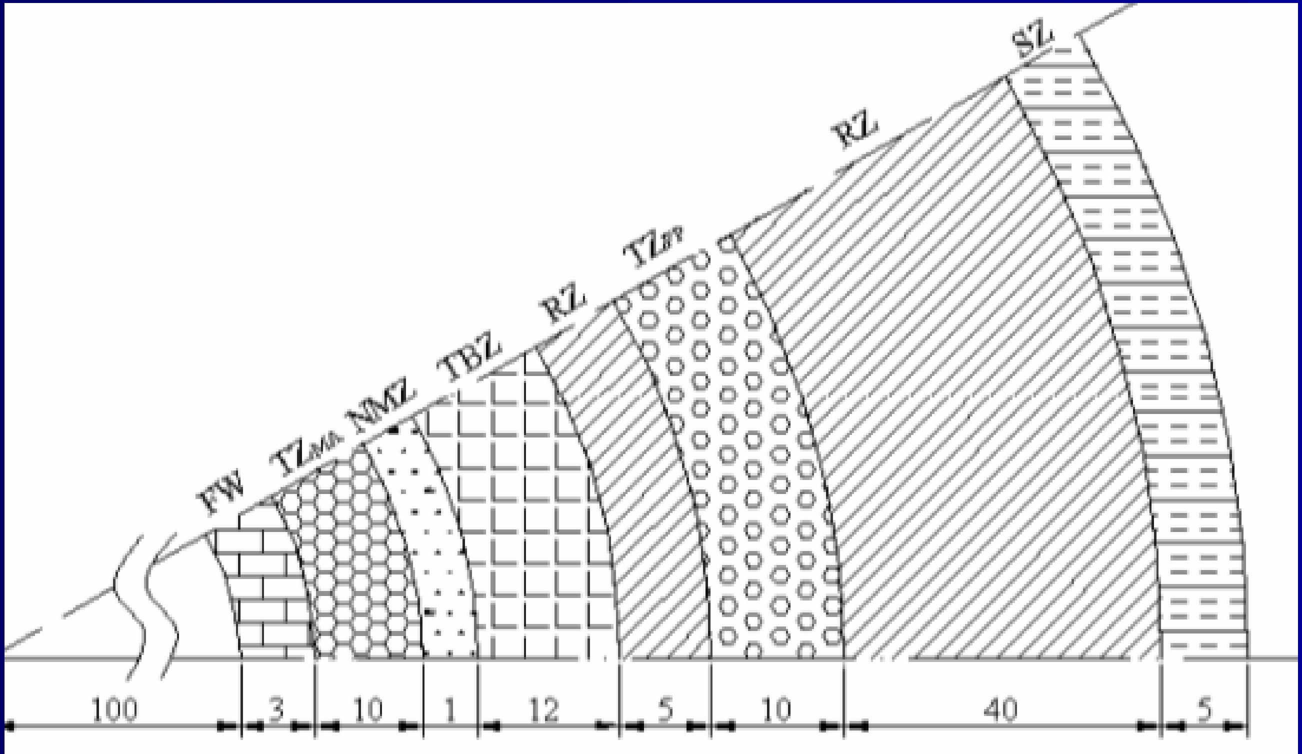
BLANKET CONFIGURATION

Horizontal cross-sectional views of blanket conceptual designs for a fusion-driven transmuter



BLANKET GEOMETRY

The improved blanket, FW: first wall, TZ_{MA}: MA transmutation zone, NMZ: neutron multiplier zone, TBZ: tritium breeding zone, RZ:reflector zone,TZ_{FP}: LLFP transmutation zone, and SZ: shielding zone.

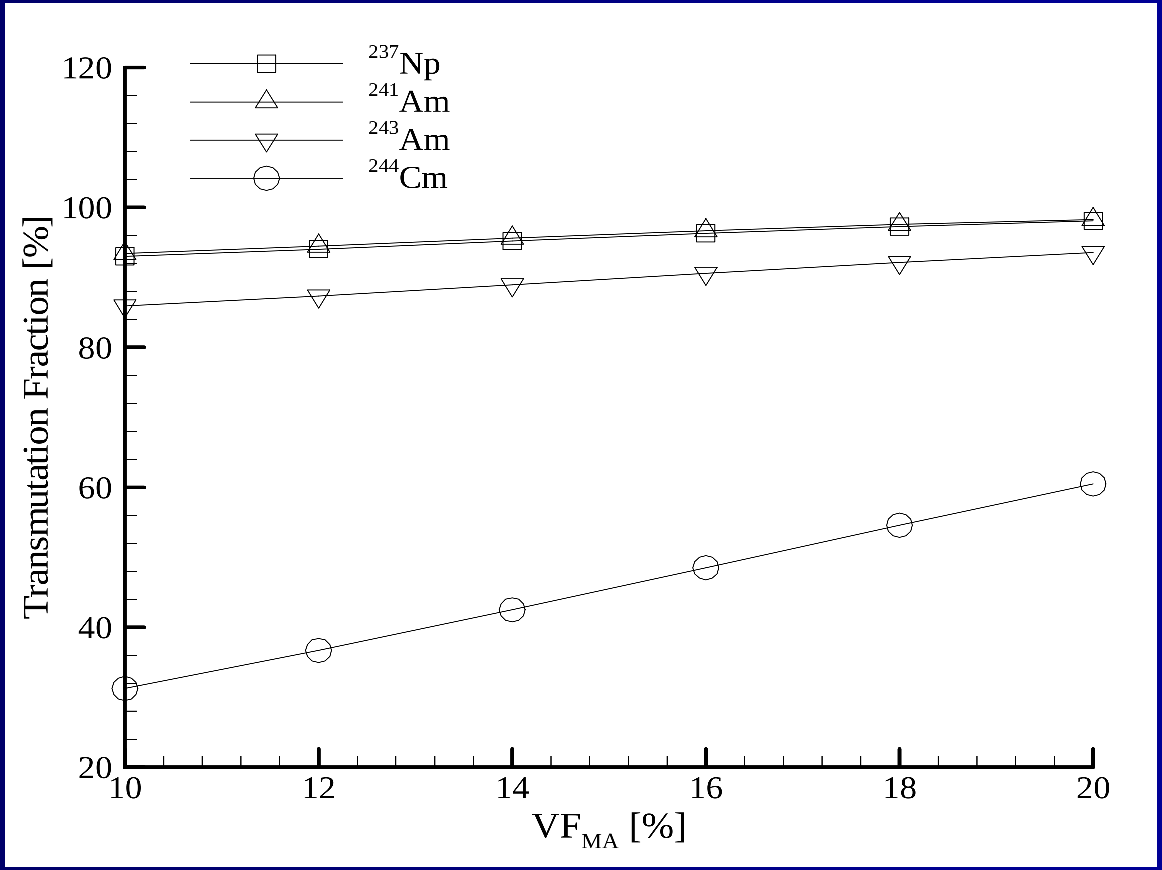


CALCULATION METHOD

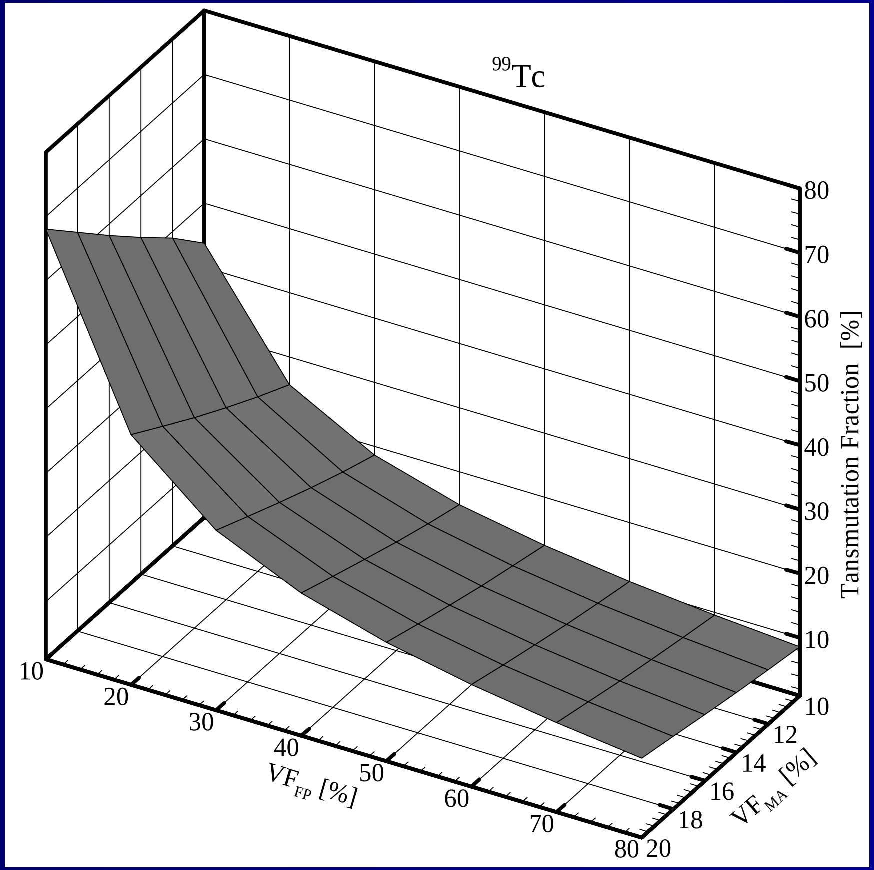
The neutronic calculations per D–T fusion neutron have been performed for a cylindrical one-dimensional geometry by solving the Boltzmann transport equation with the help of the neutron transport code XSDRNPM/SCALE4.4a and the 238 energy groups neutron transport and activity cross-section data library. The calculations of the time dependent atomic densities of the isotopes have been performed for an operation period (OP) of up to 10 years by 75% plant factor (η) under a neutron wall load (P) of 5 MW/m^2.

NUMERICAL RESULTS

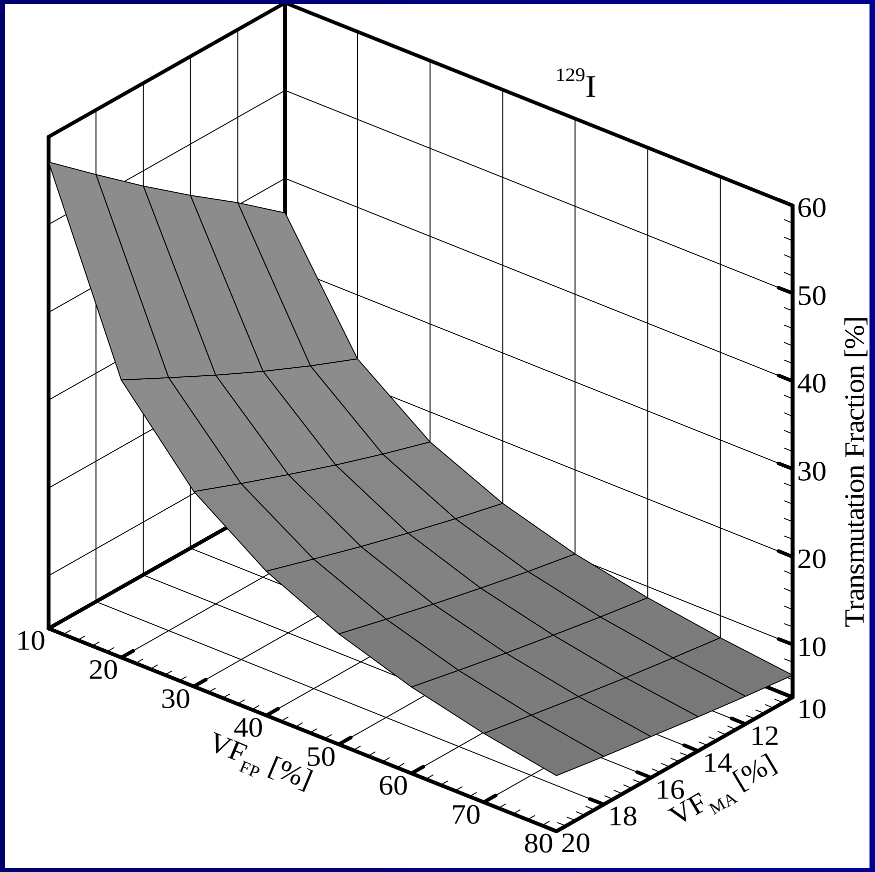
Variations of the transmutation fractions of the MAs with the MA volume fraction



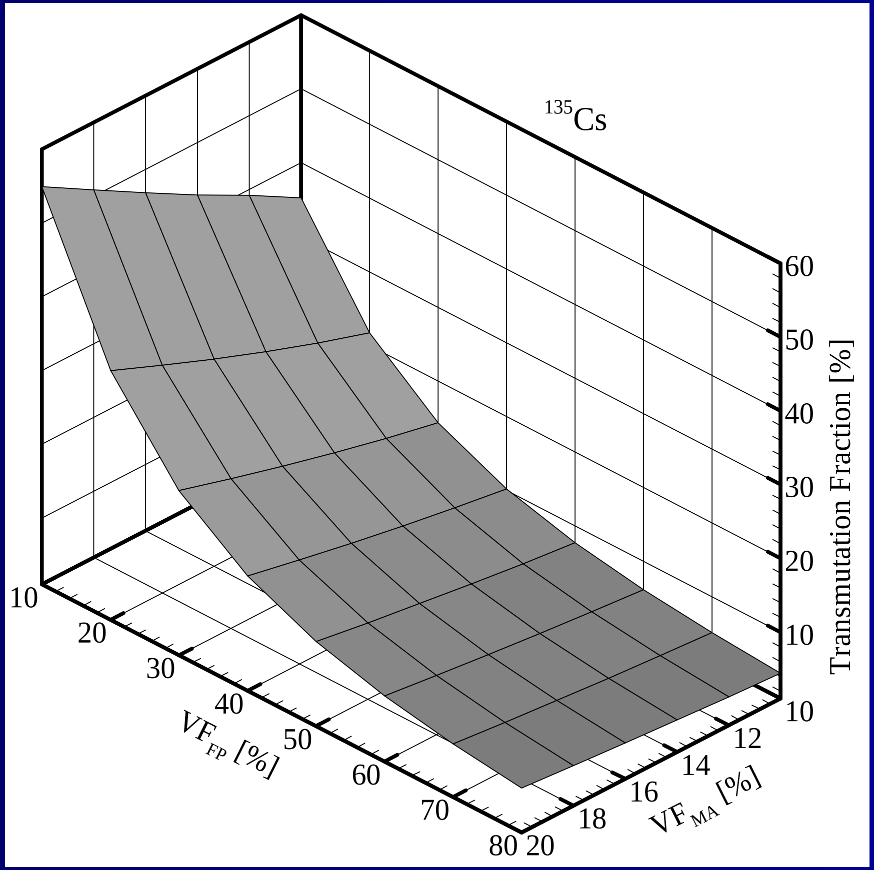
Variation of the transmutation fraction of ^{99}Tc with the MA and LLFP volume fractions



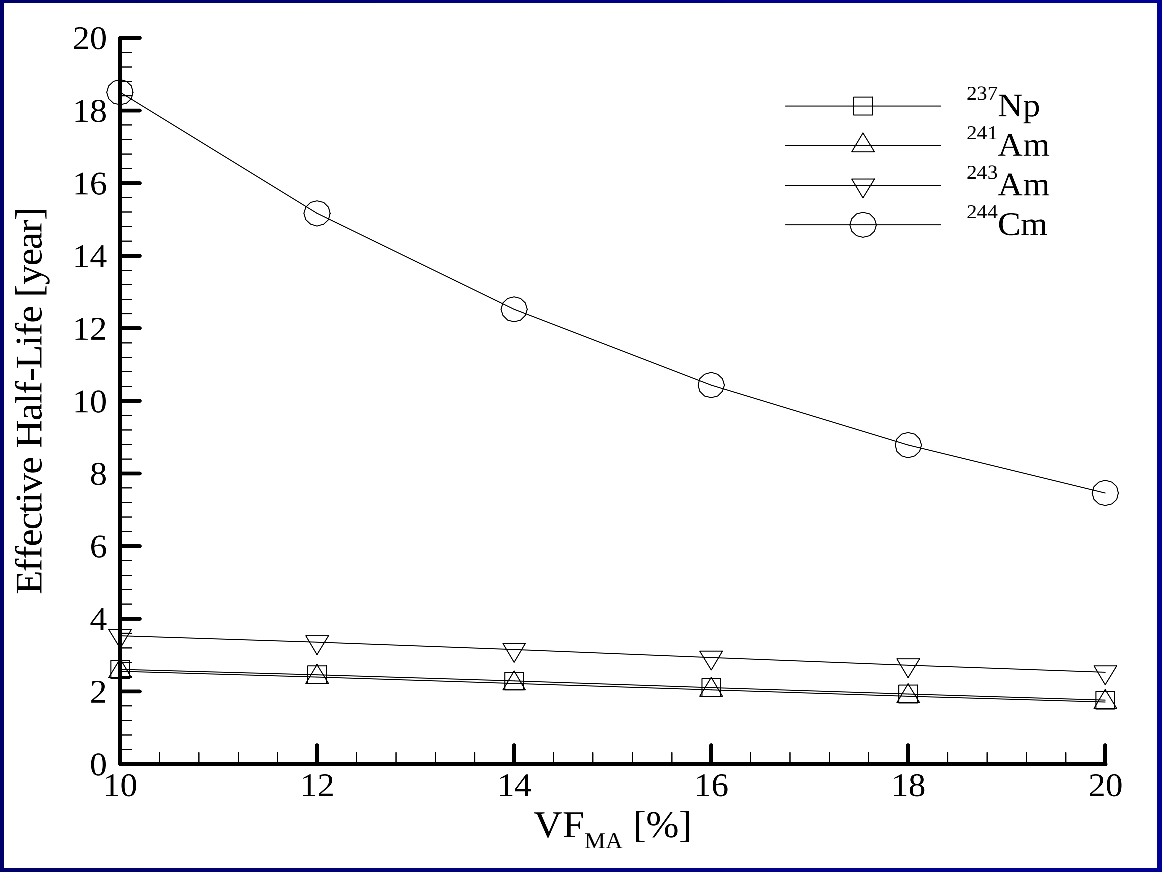
Variation of the transmutation fraction of ^{129}I with the MA and LLFP volume fractions



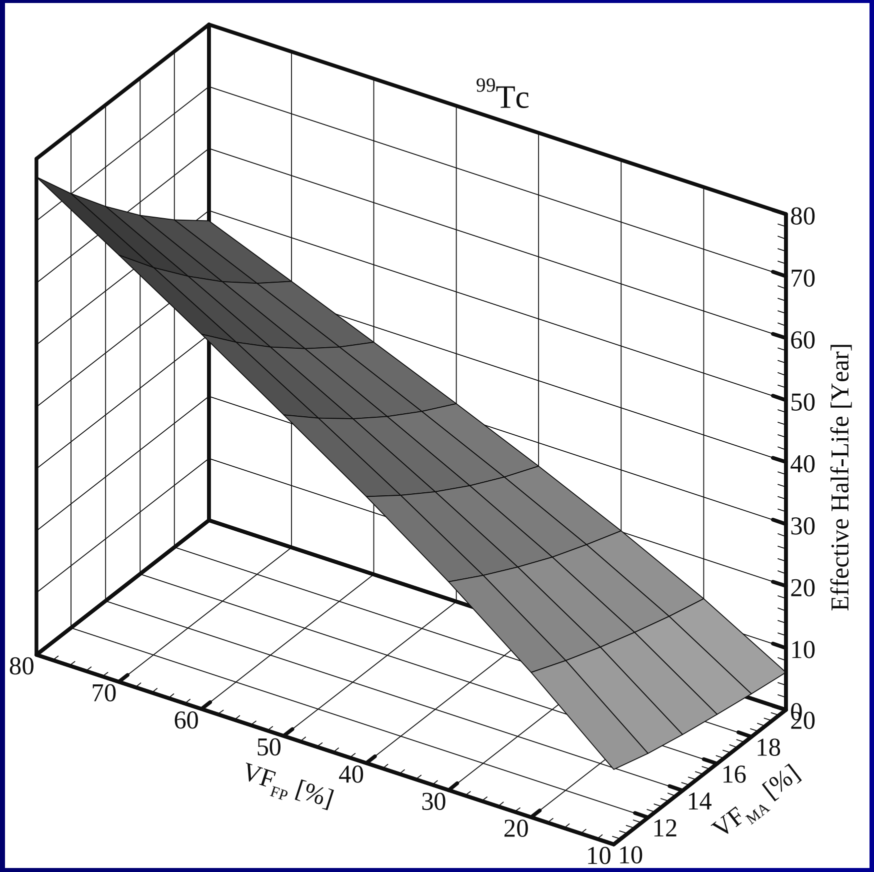
Variation of the transmutation fraction of ^{135}Cs with the MA and LLFP volume fractions



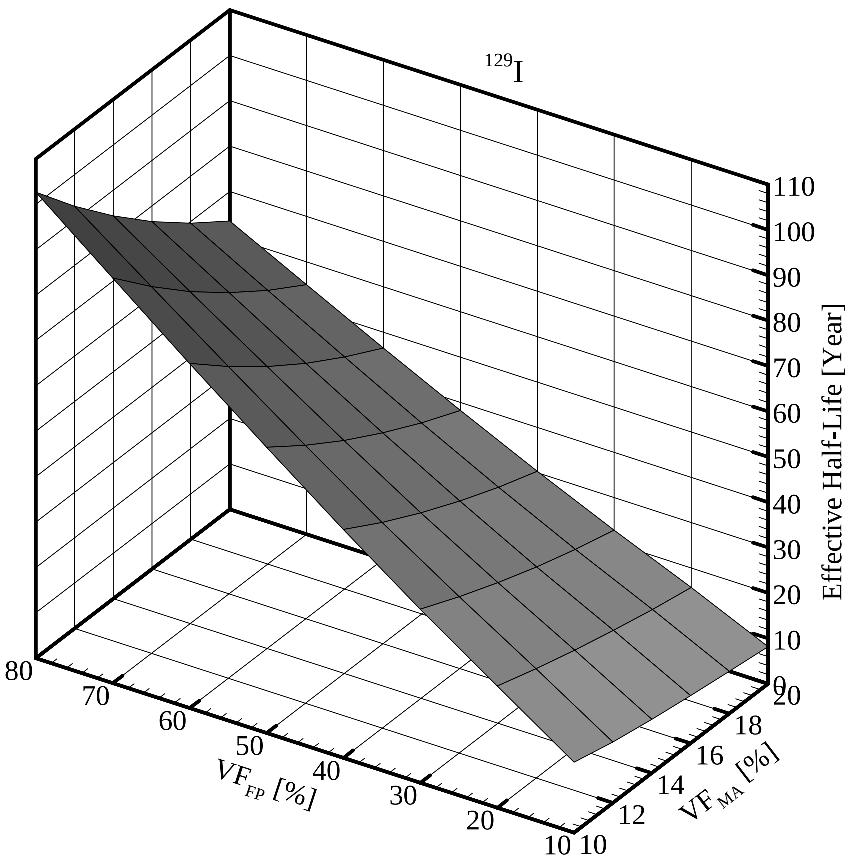
Variations of the effective half lives of the MAs with the MA volume fraction



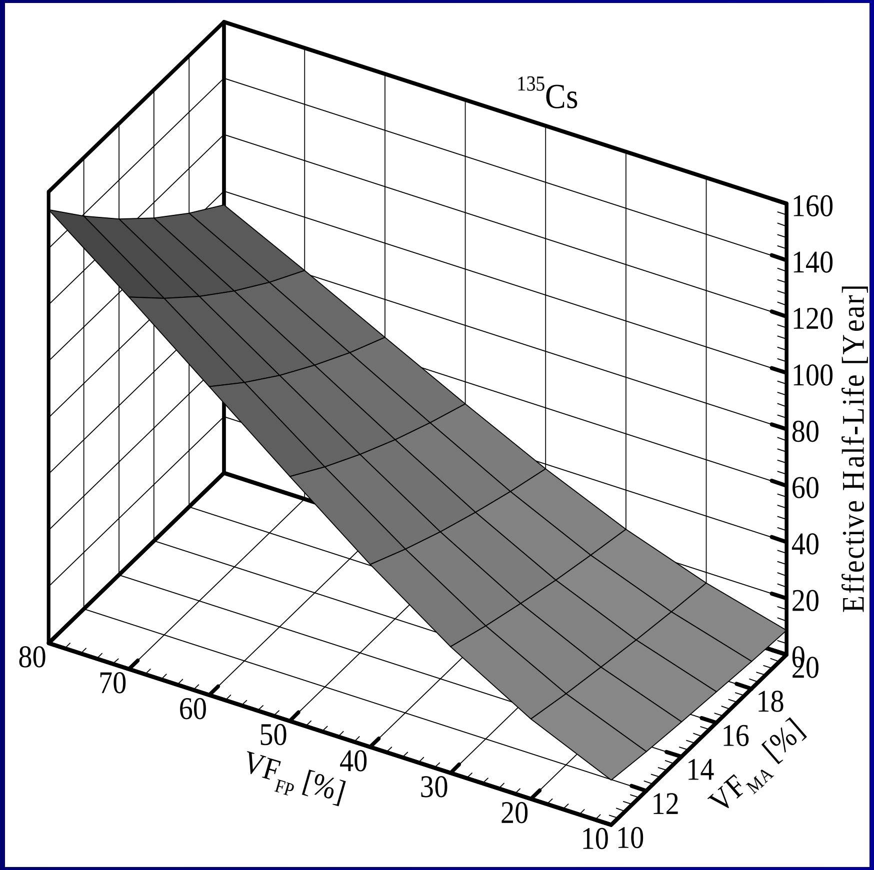
Variation of the effective half life of ^{99}Tc with the MA and LLFP volume fractions



Variation of the effective half life of ^{129}I with the MA and LLFP volume fractions



Variation of the effective half life of ^{135}Cs with the MA and LLFP volume fractions



Neutronic performance of the blanket

The blanket energy multiplication factor (M) is one of the main parameters in a fusion-driven reactor, is defined as the ratio of the total amount of nuclear energy release in the blanket to the incident fusion neutron energy.

$$M = \frac{R_F \cdot E_f + 4.784 \cdot T_6 - 2.467 \cdot T_7 + 14.1}{14.1}$$

The peak-to-average fission power density ratio (Γ) is a measure of spatial non-uniform fission energy density that must be reduced to 1.0 for obtaining a flat fission power density.

$$\Gamma = \frac{(R_F D)_{\max}}{R_F / V_{MA}}$$

Neutronic data per D-T fusion neutron in the overall blanket

VF_{MA} [%]	10	12	14	16	18	20
M	6.3	7.9	9.7	11.8	14.3	17.3
Γ	1.080	1.070	1.068	1.065	1.067	1.064

CONCLUSIONS

- The transmutation fractions of the MAs increase quasi-linearly depending on the MA volume fraction.

- The transmutation fractions of LLFPs decrease quasi-linearly with the increase of VF_{FP} and these values increase with the increase of VF_{MA}. The ^{99}Tc among the LLFP nuclides has the highest transmutation fraction.

- The rise of MA fraction (from 10% to 20%) decreases the effective half-lives of the MAs.
- The effective half lives of LLFPs increase quasi-linearly with the increase of VFFP and these values decrease with the increase of VFMA.
- In all volume fraction cases, the blanket can provide enough tritium for its own fusion driver.

THANK YOU