Minor Actinides Burnup Enhancement in the European Sodium Fast Reactor through Moderator Material Addition

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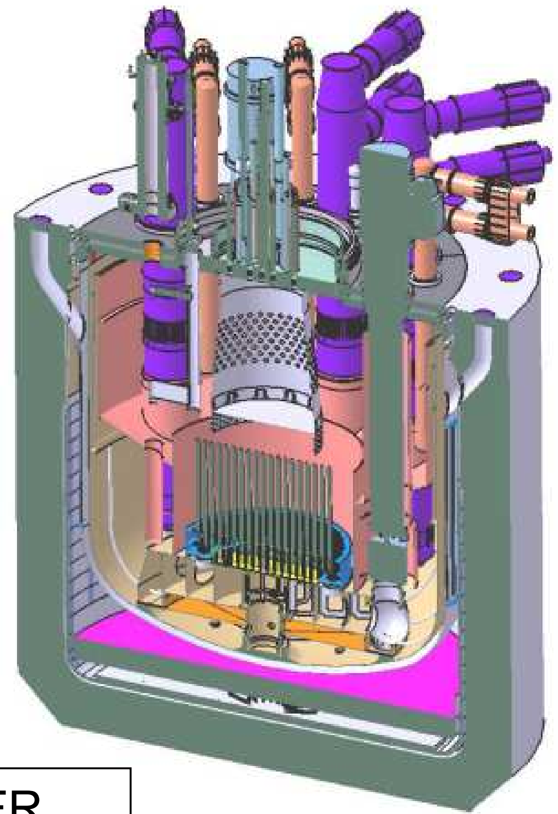
Framework

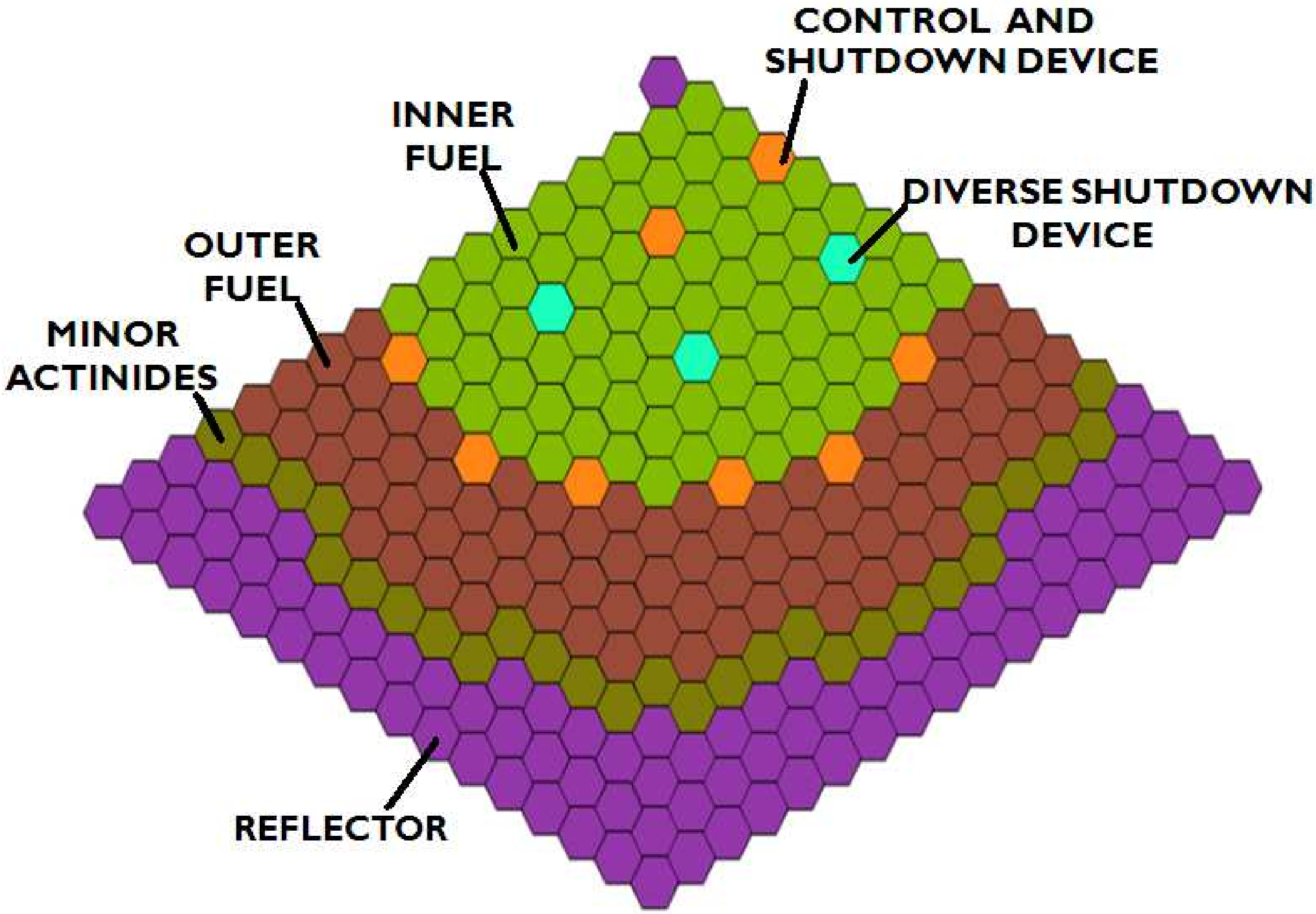
- Scientific and Technical Cooperation Agreement signed by CNEA and CEA on July 2010.

- CEA transferred ERANOS 2.2 code.



ESFR

ESFR core



Fuel → $(U,Pu)O_2$ MA → $(U,Am)O_2$

Minor Actinides Consumption

$$C(\Delta t) = m_{(t=0)}(1 - e^{-\phi\sigma\Delta t})$$

- C(Δt): minor actinide mass consumed
- m(t=0): initial mass loaded
- ϕ : mean neutron flux
- σ: mean effective absorption cross section

Minor Actinides Consumption

σ is very sensitive to the neutron espectrum

→ Add small amounts of moderator materials in MA subassembly

↓ It will increase σ locally

↓ It will increase C(t)

← **Moderating Materials:**

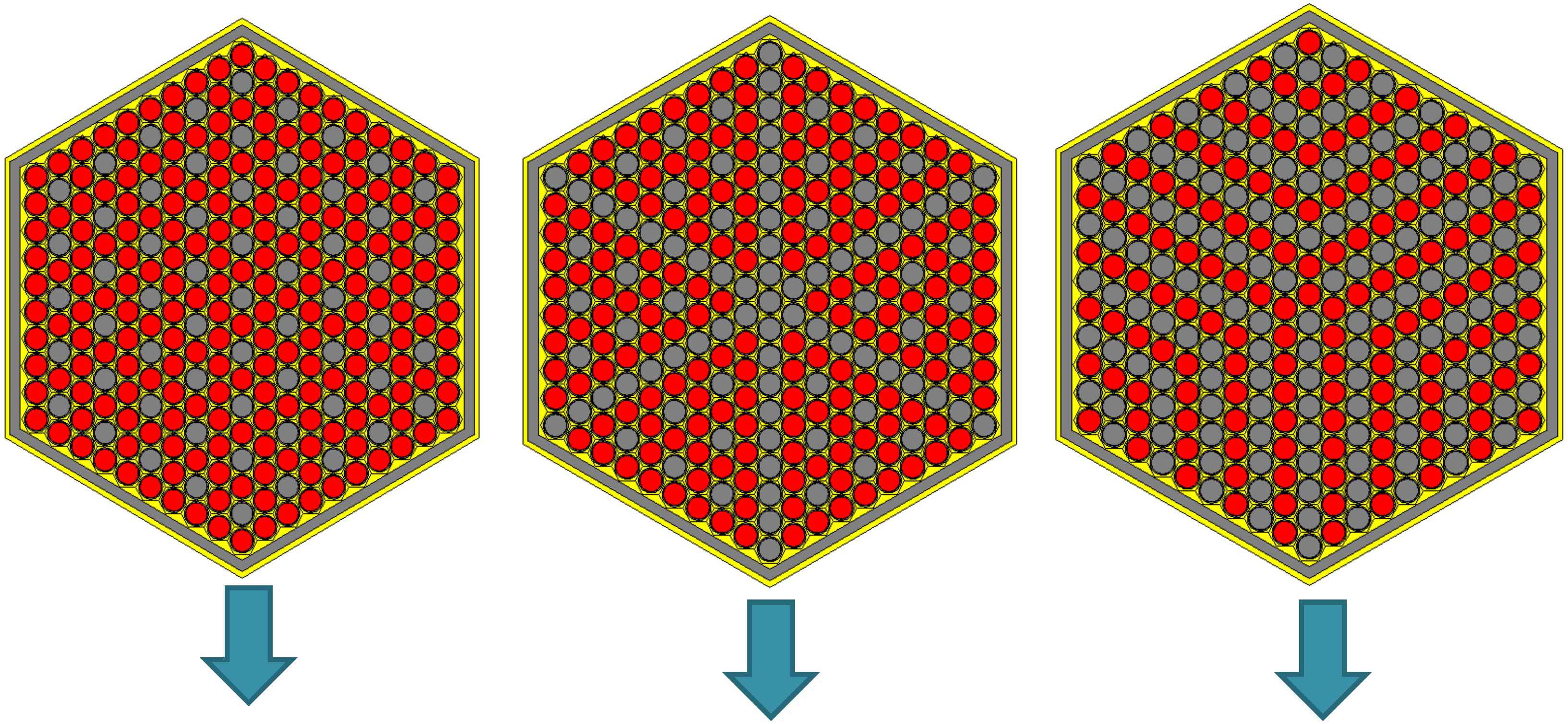
ZrH_2
SiC
BeO
LiO_2
MgO
$MgAl_2O_4$
TiC
ZrC

Minor Actinides Subassemblies

- MA subassemblies contain 271 pins
- The AmO_2 content in the $(U,Am)O_2$ mixture is 10% mass fraction
- The composition of Am is 80% mass fraction of ^{241}Am and 20 % mass fraction of ^{243}Am
- Some of these pins were replaced by other identical ones containing pellets of moderating materials

Minor Actinides Consumption

Three different configurations were studied



61 moderator pins	91 moderator pins	135 moderator pins

Minor Actinides Consumption

- The cell calculation was performed using the module ECCO of ERANOS 2.2 and the libraries JEFF 3.1.
- The core calculation was performed using the code ERANOS 2.2.
- The core calculations were performed on the basis of a full three-dimensional geometrical description and the diffusion theory.
- The evolution with burn up was performed in 6 calculation steps, with 5 time periods in between, of 410 efp days each, and a power level of the whole core of 3600 MWth.
- The mass balance was calculated in order to know the amount of minor actinides consumed after 2050 efp days.

Results

Comparison of moderating materials with 61 moderator pins

Initial masses: 909.97 kg of ^{241}Am
227.49 kg of ^{243}Am

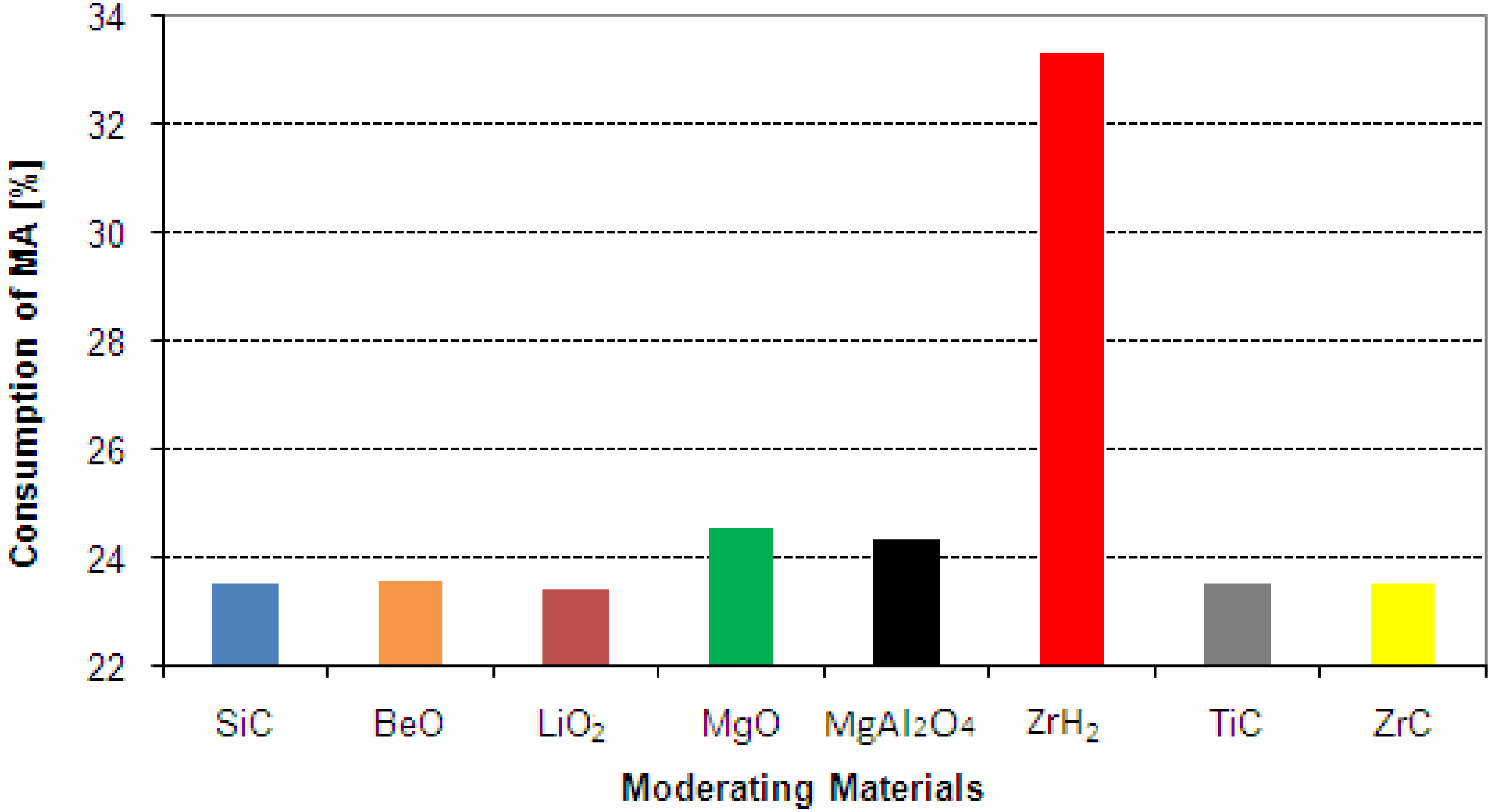
$$\text{Consumption of MA } [\%] = 100 \, x \, \frac{\text{consumed mass}\,(^{241}Am + ^{243}Am)}{\text{initial mass}\,(^{241}Am + ^{243}Am)}$$

Moderating materials	Consumption of ^{241}Am [Kg]	Consumption of ^{243}Am [Kg]	Consumption of MA [%]
SiC	220.57	46.97	23.52
BeO	220.95	47.18	23.57
LiO_2	219.94	46.83	23.45
MgO	230.07	49.25	24.56
$MgAl_2O_4$	228.27	48.83	24.36
ZrH_2	310.38	68.55	33.31
TiC	220.81	47.03	23.55
ZrC	220.77	47.02	23.54

Results

Comparison of moderating materials with 61 moderator pins

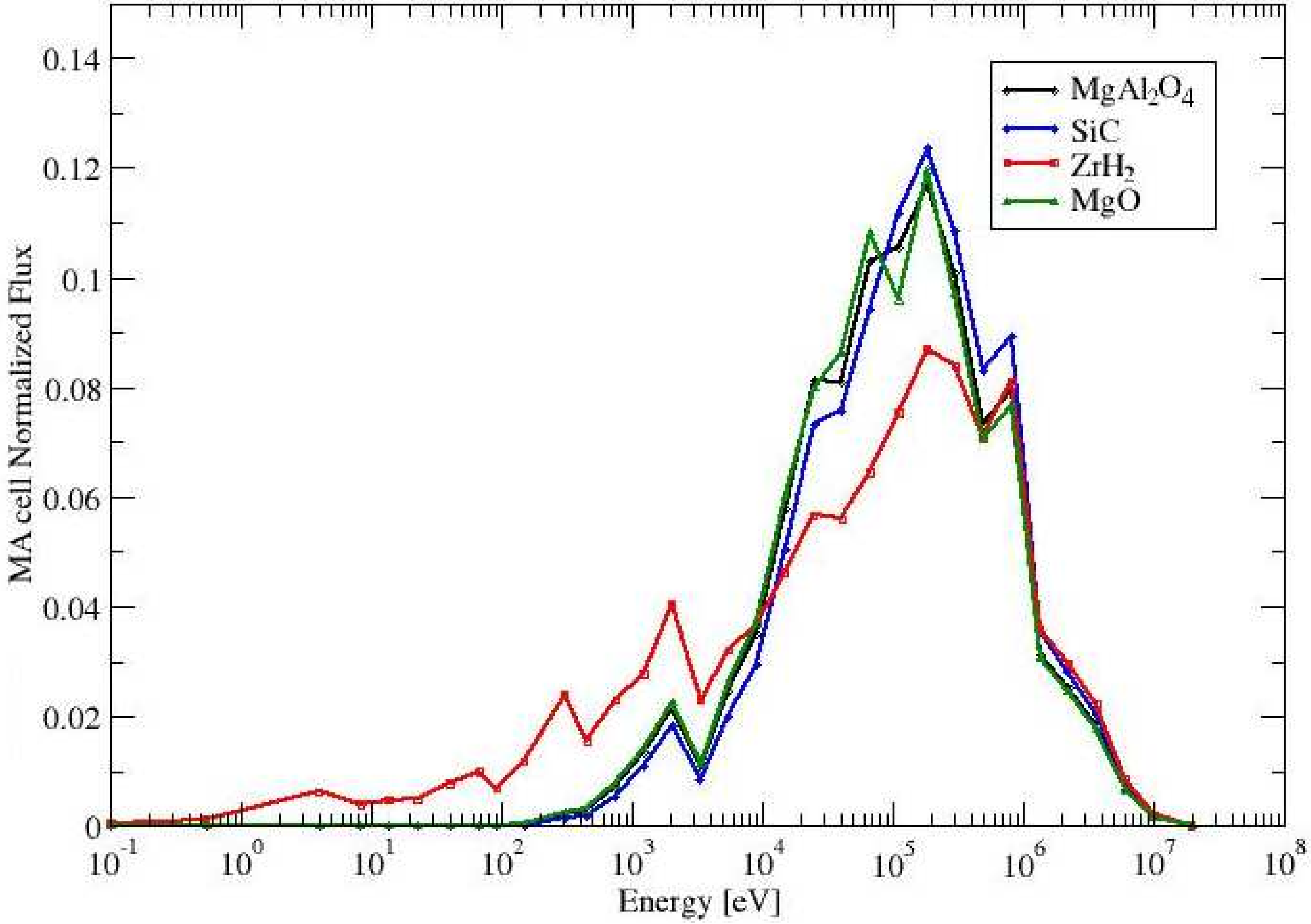
$$Consumption\ of\ MA\ [\%] = 100\,x\,\frac{consumed\ \ mass\,({}^{241}Am + {}^{243}Am)}{initial\ \ mass\,({}^{241}Am + {}^{243}Am)}$$



Results

Comparison of moderating materials with 61 moderator pins

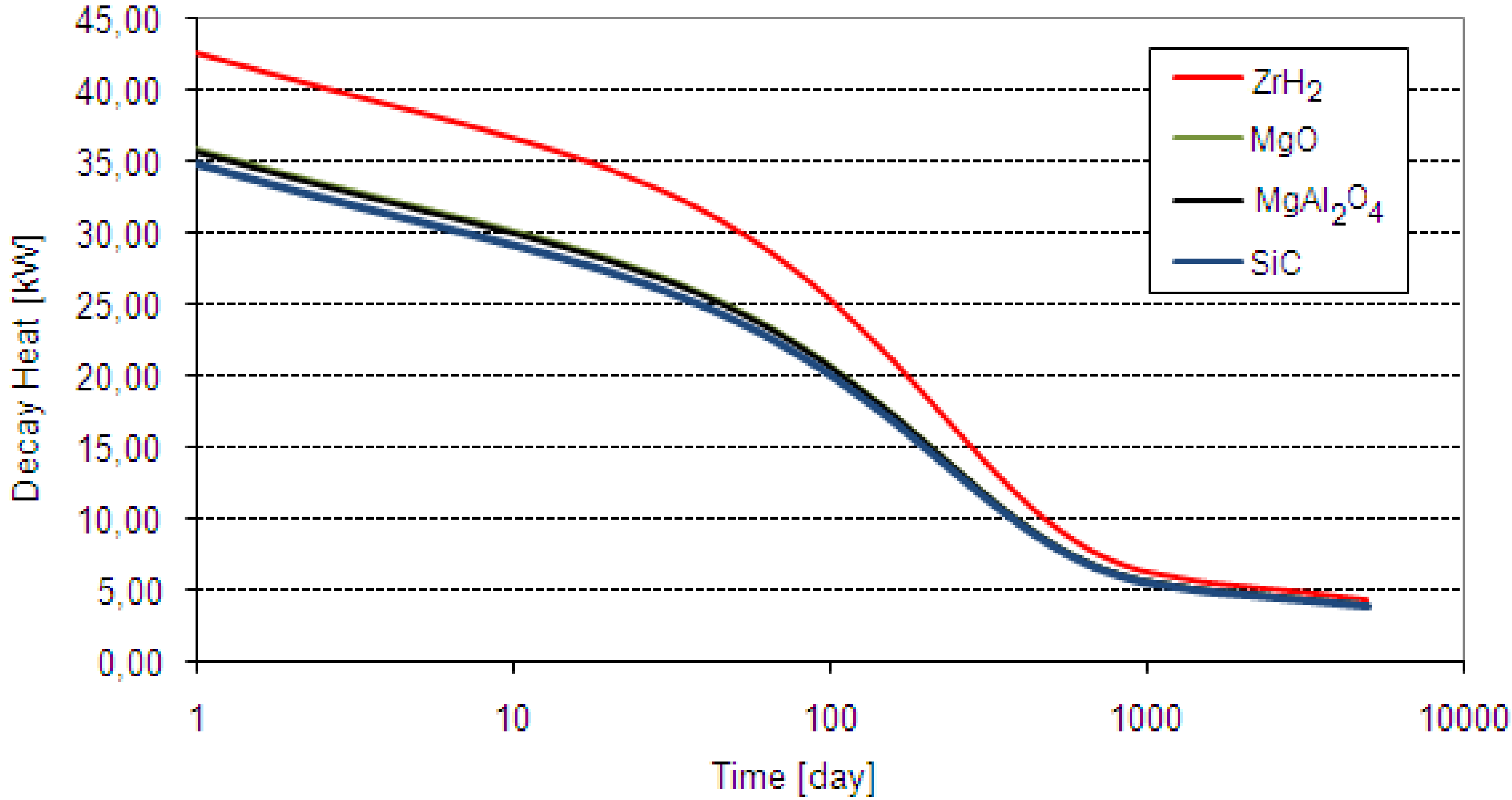
Neutron Spectrum



Results

Comparison of moderating materials with 61 moderator pins

Decay heat generated by ^{242}Cm, ^{244}Cm and ^{238}Pu

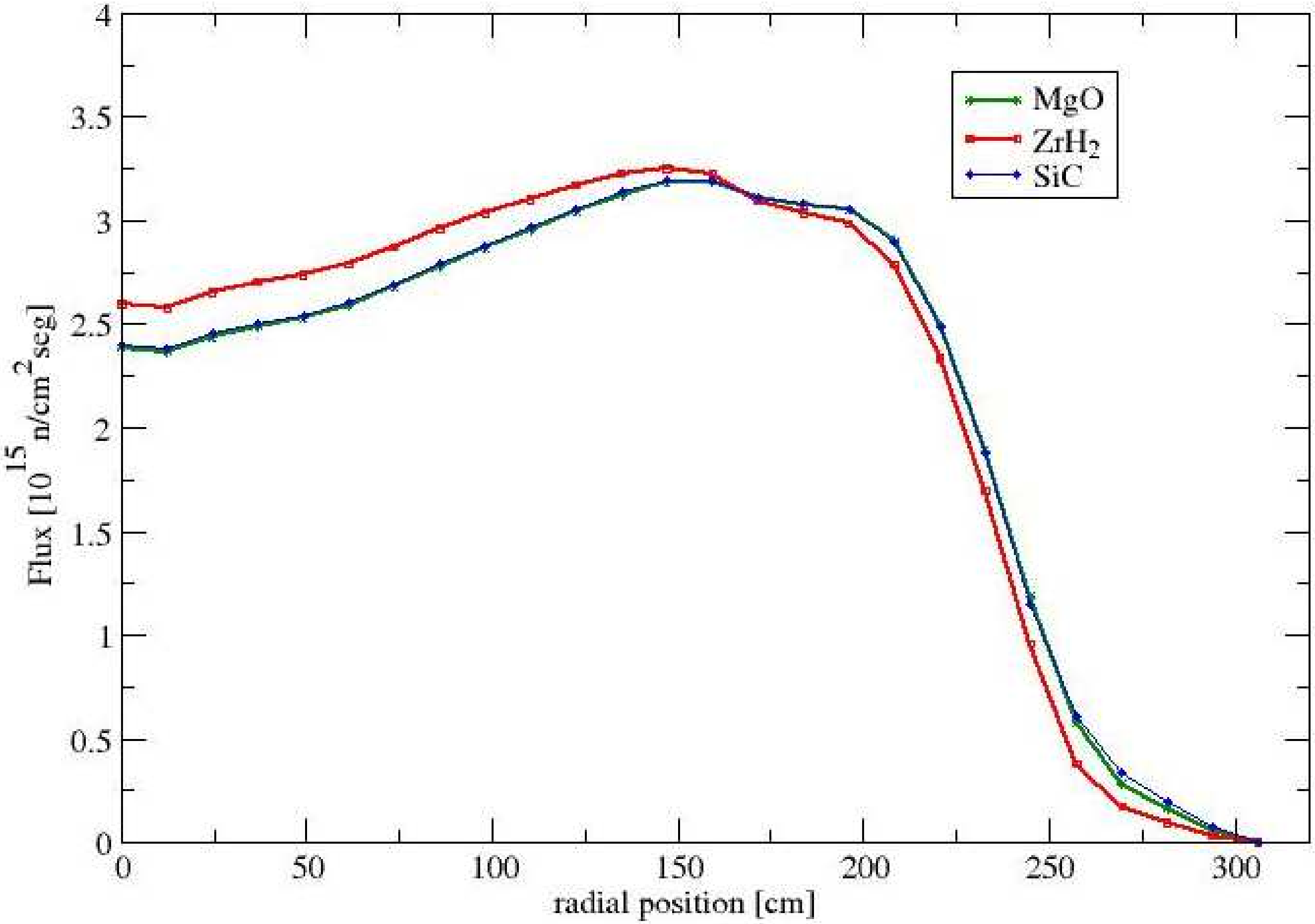


Results

Comparison of moderating materials with 61 moderator pins

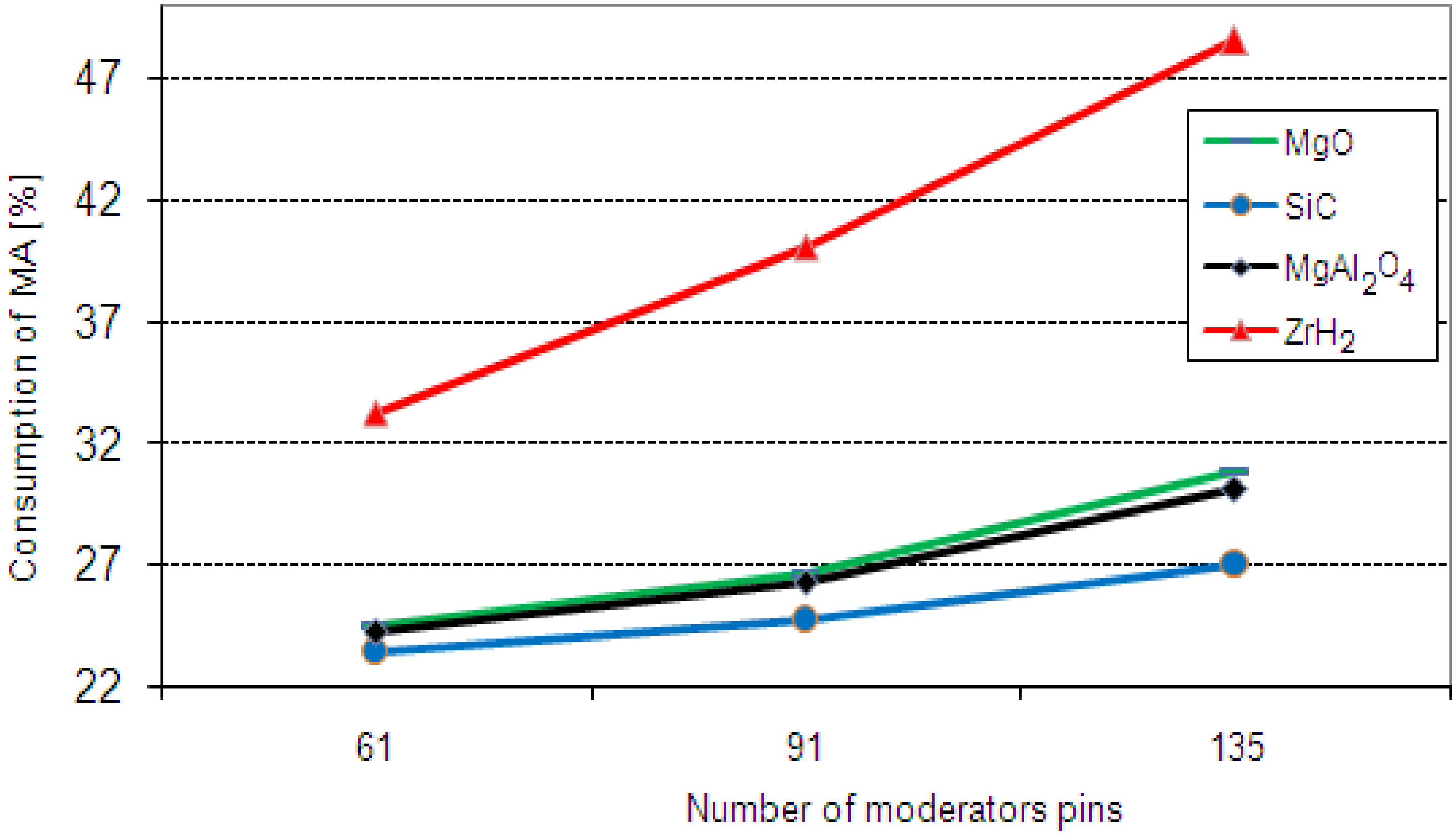
Total neutron flux as a function of the radial position

(Height of 150 cm - End of life)



Results

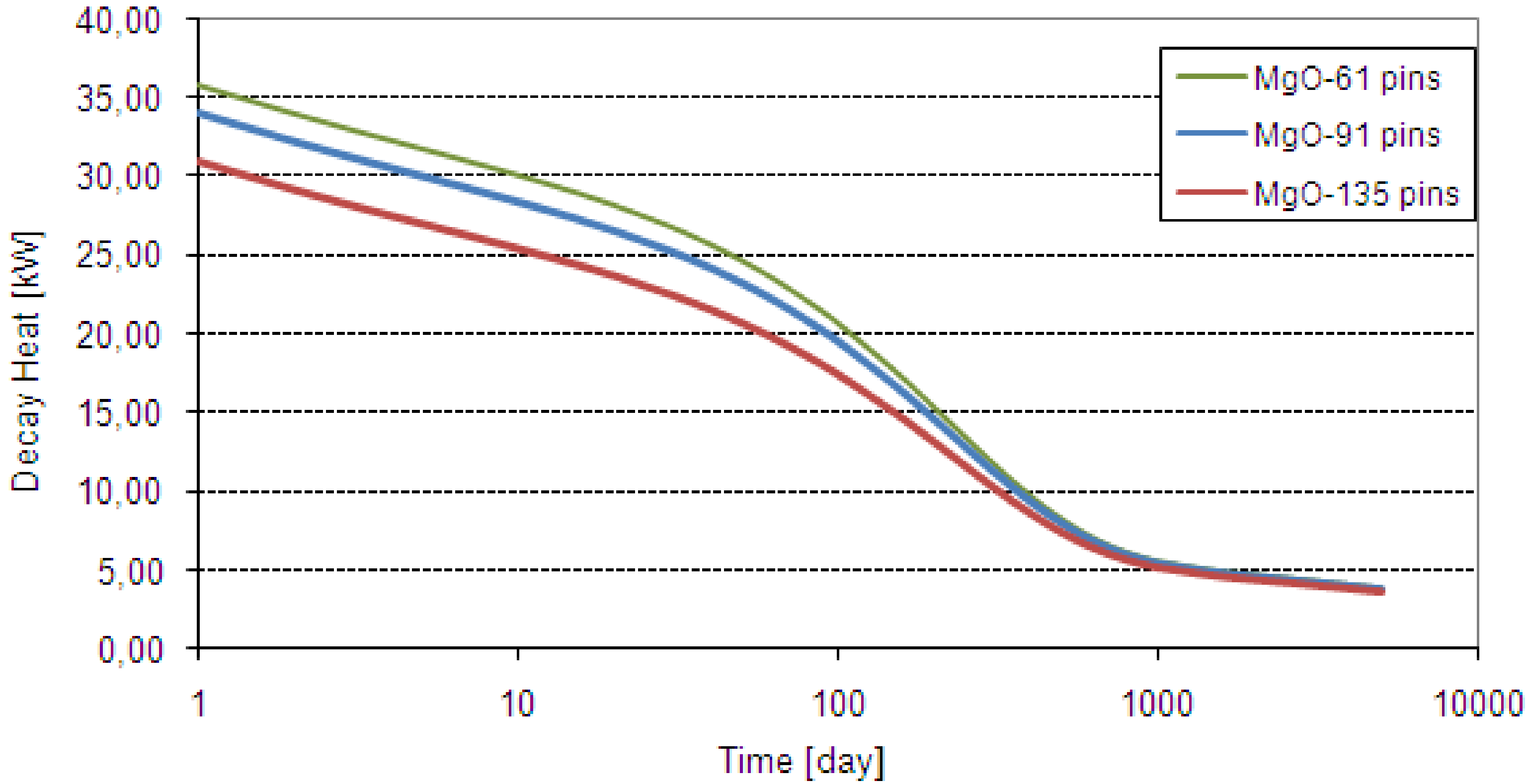
Minor Actinides Consumption vs. Number of moderator pins



Results

Minor Actinides Consumption vs. Number of moderator pins

Decay heat generated with MgO as moderator



Results

Minor Actinides Consumption vs. Number of moderator pins

MgO as moderator

Moderating materials	Initial mass of MA [Kg]	Consumed mass of MA [Kg]	Consumption of MA [%]
Without moderator pins	1467.87	312.13	21.26
61 pins with MgO	1137.46	279.32	24.56
91 pins with MgO	974.94	260.40	26.71
135 pins with MgO	736.65	227.22	30.85

Conclusions

- ZrH_2 was the best moderator material, followed by MgO and $MgAl_2O_4$
- When the number of moderator pins is increased:
  - the percentage of minor actinides consumed increases,
  - the total mass consumed of minor actinides decreases,
  - the decay heat generated decreases,
  - the neutron flux in the reactor varies very little.

Perspectives

- For future studies it would be possible to evaluate the use of other materials with resonances in the scattering cross section in the fast range that would improve the results obtained with Mg.
- It would be necessary to consider how to add moderator material without changing the initial mass of minor actinides. E.g., adding the moderator at the periphery of the minor actinide elements.

Thank you very much
for your attention !

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