Core Elements Improvements for Optimization of Radioisotopes Production in an MTR-type Core

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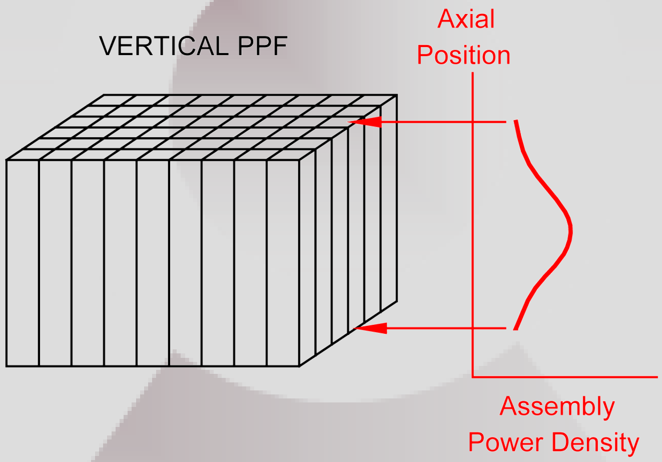
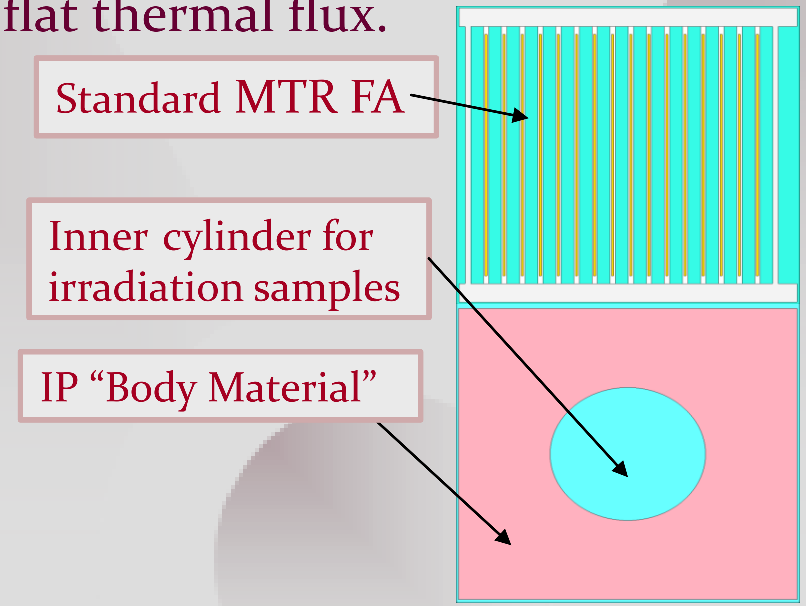
PART I: INTRODUCTION

- The primary purpose of Research Reactors is to provide a neutron source for research in natural sciences, industrial processing and nuclear medicine.
- The most common method for isotopes production is by the neutron activation process.
- Due to the cosine shape of the flux in every axis, the maximal flux length is located around the center of the active length of the Fuel Assembly (FA).
- This limited area of maximal flux makes the activation process of large or multiple samples less efficient.



PART II: THE OBJECTIVE OF THIS STUDY

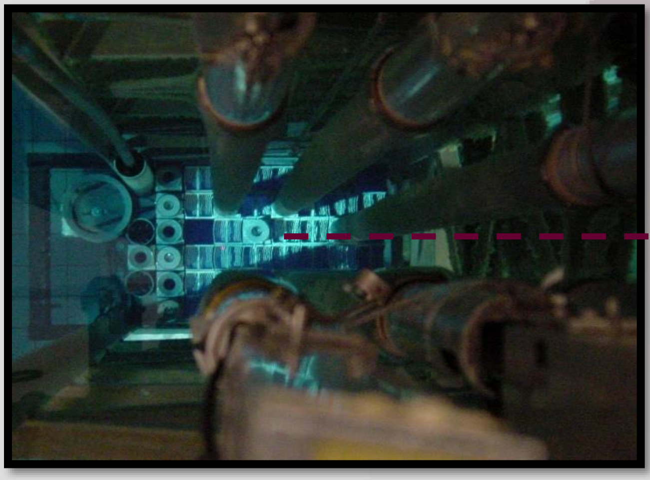
- Analyzing the main components in isotope production process in order to optimize the production by uniform and flat thermal flux.
- Re-design components:
  - Irradiation Position (IP) body material.
  - FA linear fuel distribution loading.
- Carry out a production rate comparison between MNR FA to the modified FA.

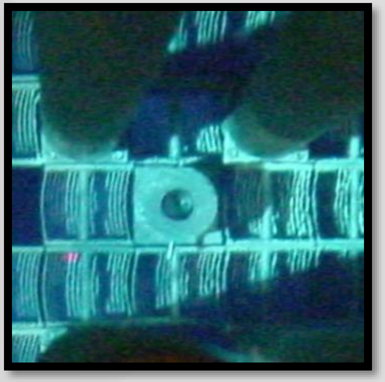


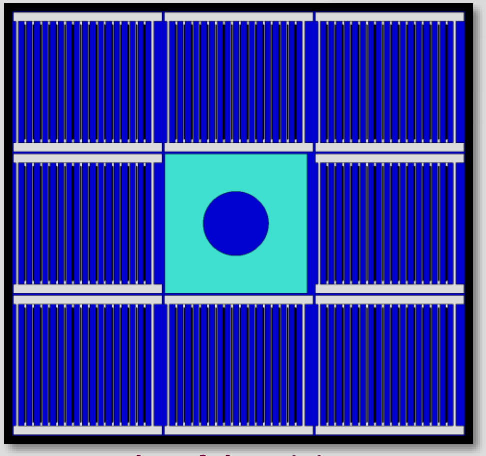
THE METHODOLOGY

- 3-D, Monta-Carlo Simulations of MTR fuel-type mini-core.
- The thermal flux, along the active length, of the inner cylinder was detected. The values were analysed and compared.

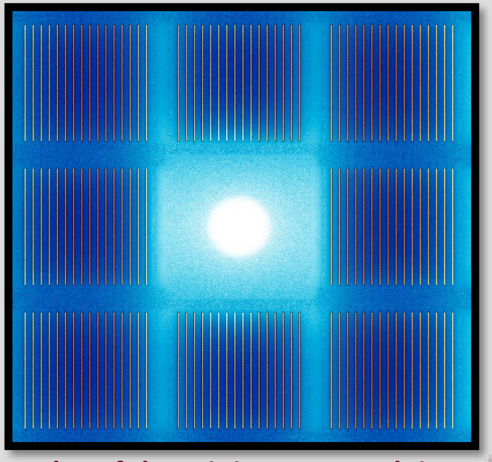
PART II: FLUX IMPROVEMENTS (1/4)



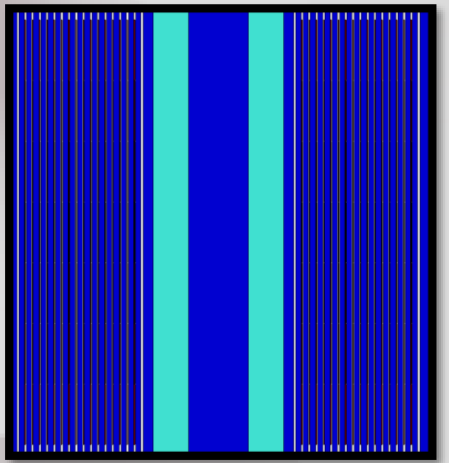




xy-plot of the mini-core.



xy-plot of the mini-core – mesh image.

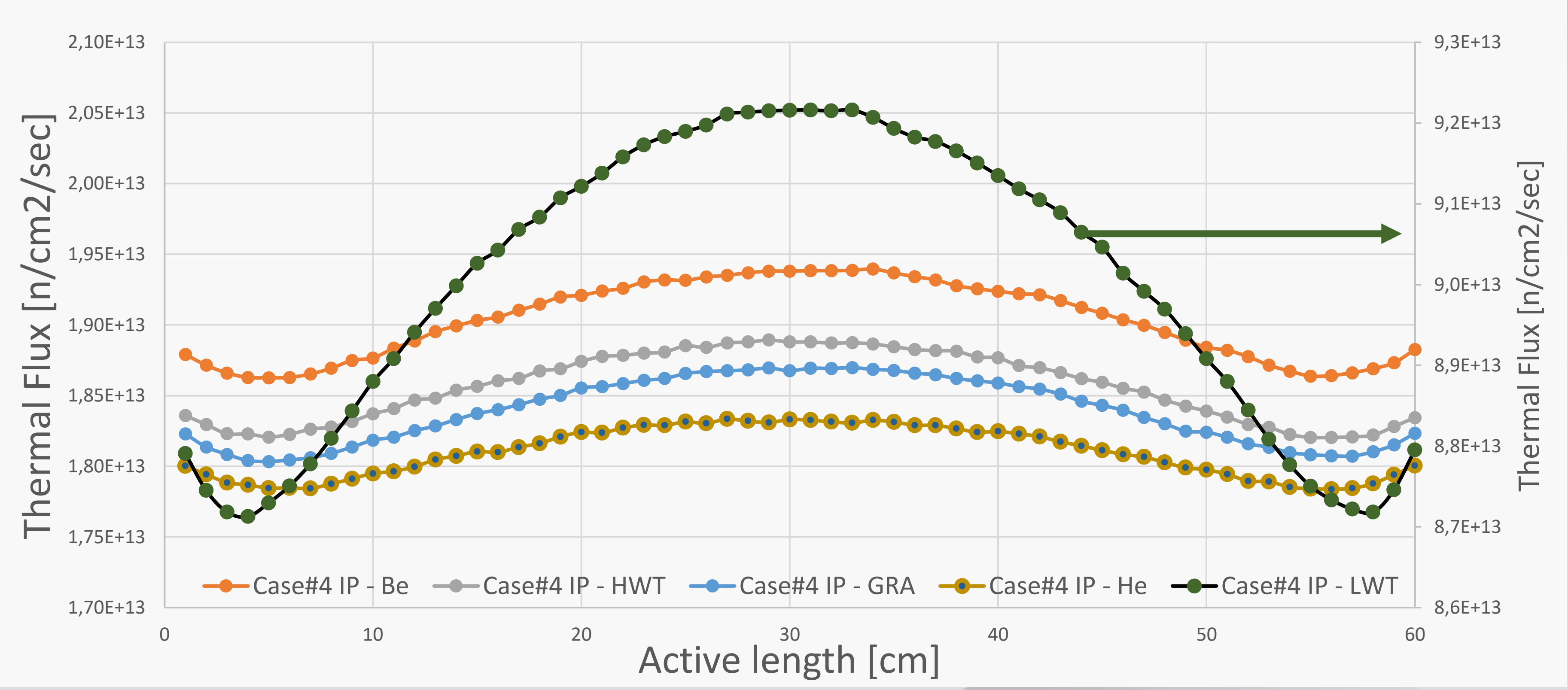


yz-plot

PART II: FLUX IMPROVEMENTS (1/4)

Changes in the IP body material

- Five principal materials simulated to analyse the change in flux shape.



PART II: FLUX IMPROVEMENTS

Changes in the linear atom density

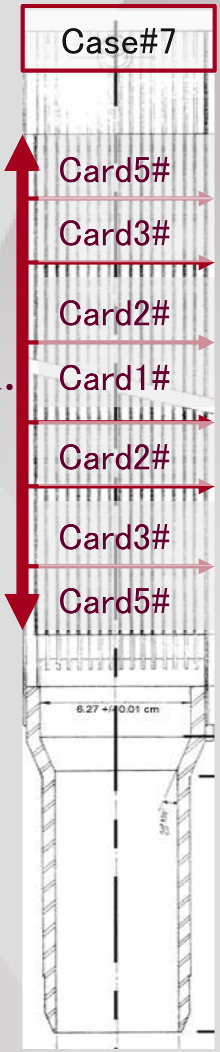
Card #	U^{235} mass in each plate [gr]	Total U^{235} mass in a FA [gr]	U^{235} density in a plate [gU^{235}/cc]	U density in a plate [gU/cc]	Thermal Conductivity [W*m/K]
1	14.0625	225	0.737	3.735	77.70
2	15.0000	240	0.786	3.984	66.39
3	15.9375	255	0.836	4.233	55.68
4	16.8750	270	0.885	4.482	45.81
5	17.8125	285	0.934	4.731	37.06
6	18.7500	300	0.983	4.980	29.81
7	19.6875	315	1.032	5.229	24.48
8	20.6250	330	1.081	5.478	21.60

- At very high loadings the aluminum ceases to play a significant role, and the thermal conductivity approaches that of the fuel ($15_{[W/mK]}$), which indicates stopping criteria for additional high density card.

PART II: FLUX IMPROVEMENTS

Changes in the linear atom density:

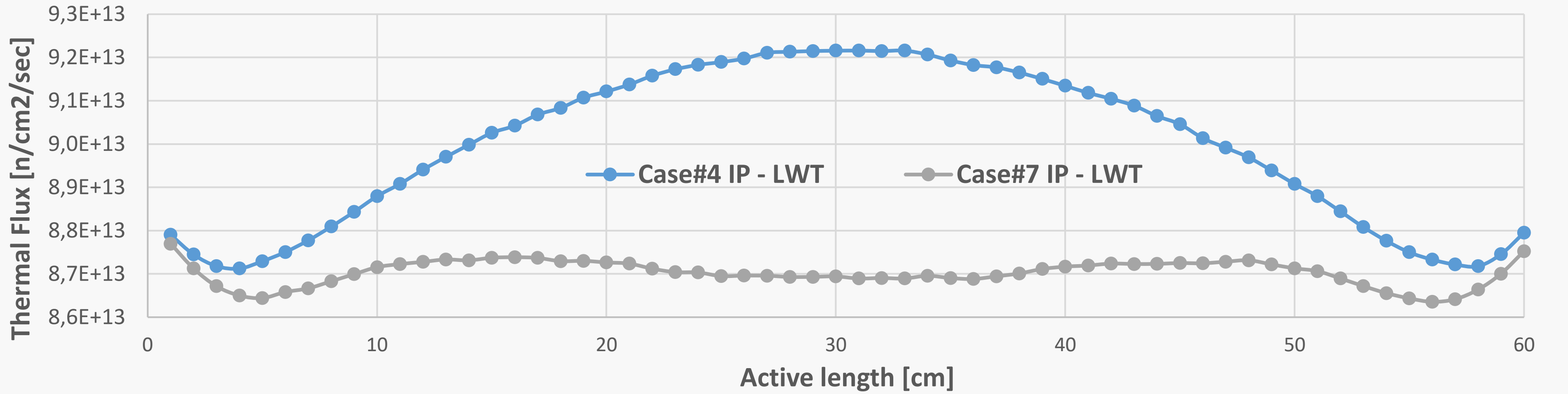
- Using the different loadings Cards, a new fuel (Case) was built.
- Each FA was split into seven sub segments (8.5714cm each).
- Eight different Cases were simulated. All analysed and compared.
- The most efficient cases, in terms of high and flat flux, were chosen.

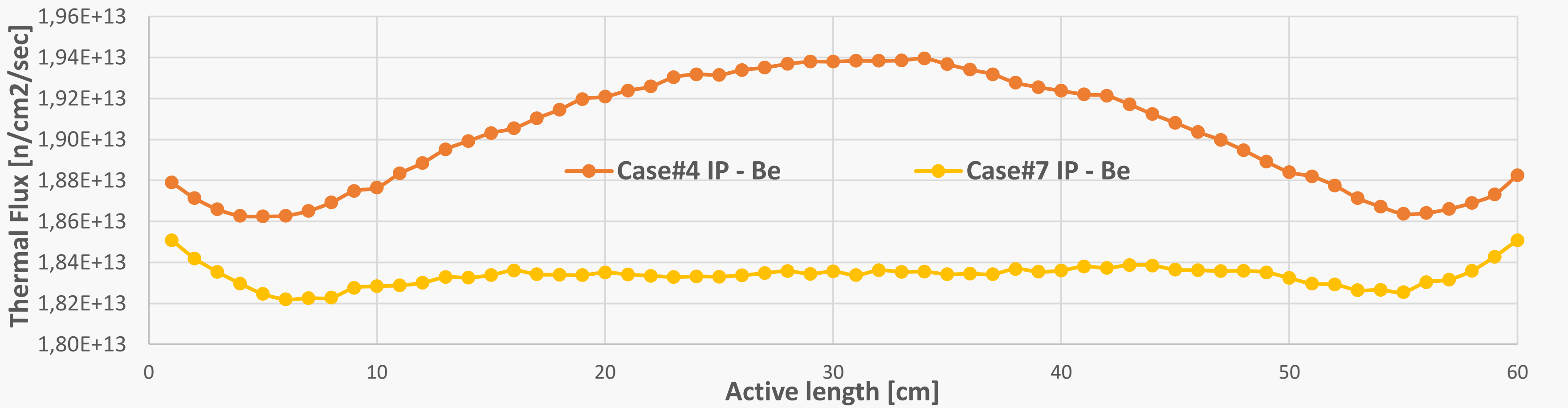


Sub-segment #	Fuel atom density [grU/cc]	Thermal Conductivity [w*m/K]	Fuel atom density [grU/cc]	Thermal Conductivity [w*m/K]
	Case #4 (MNR standard FA)		Case #7	
1	3.735	77.70	4.731	37.06
2	3.735	77.70	4.233	55.68
3	3.735	77.70	3.984	66.39
4	3.735	77.70	3.735	77.70
5	3.735	77.70	3.984	66.39
6	3.735	77.70	4.233	55.68
7	3.735	77.70	4.731	37.06

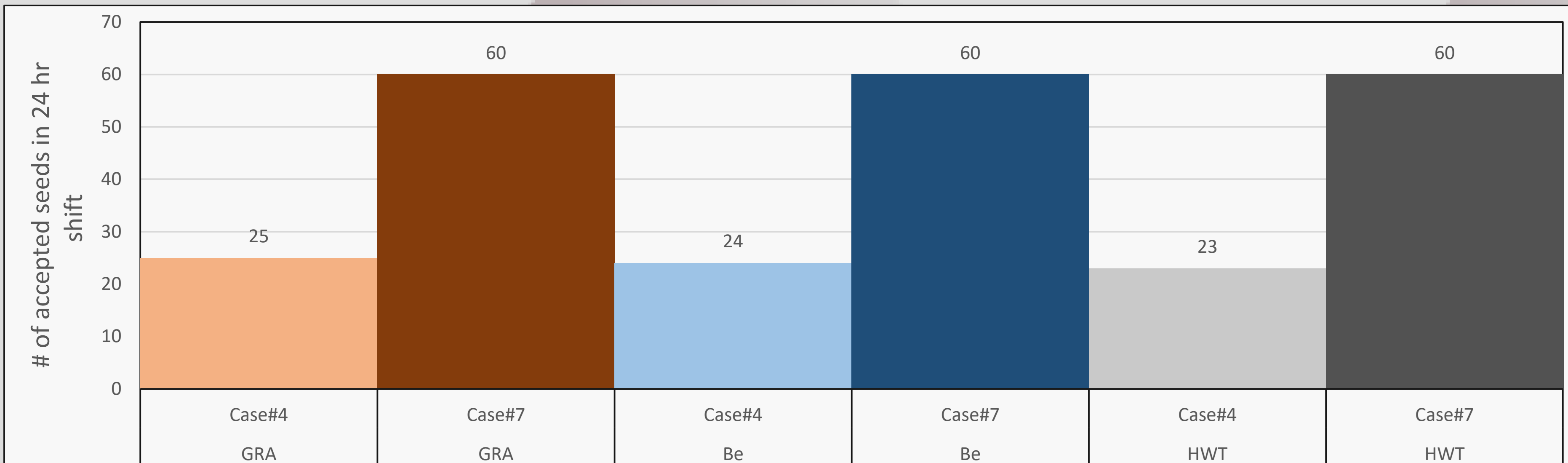
PART II: FLUX IMPROVEMENTS

Changes in the linear atom density and the IP body material:





PART III: PRODUCTION RATE COMPARISON



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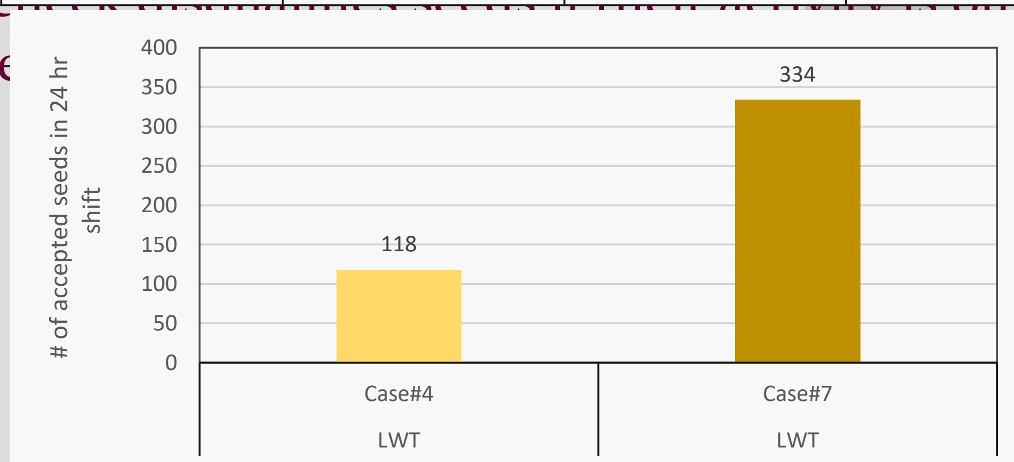
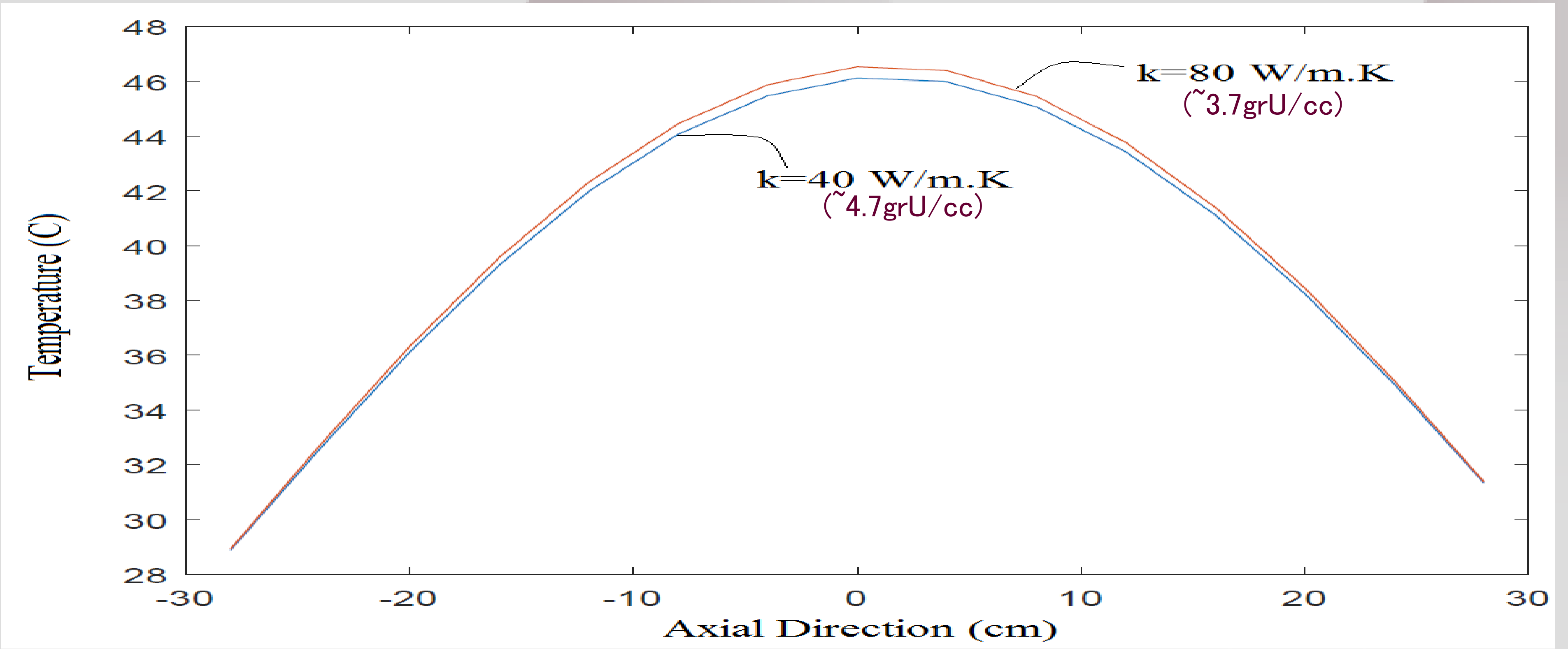


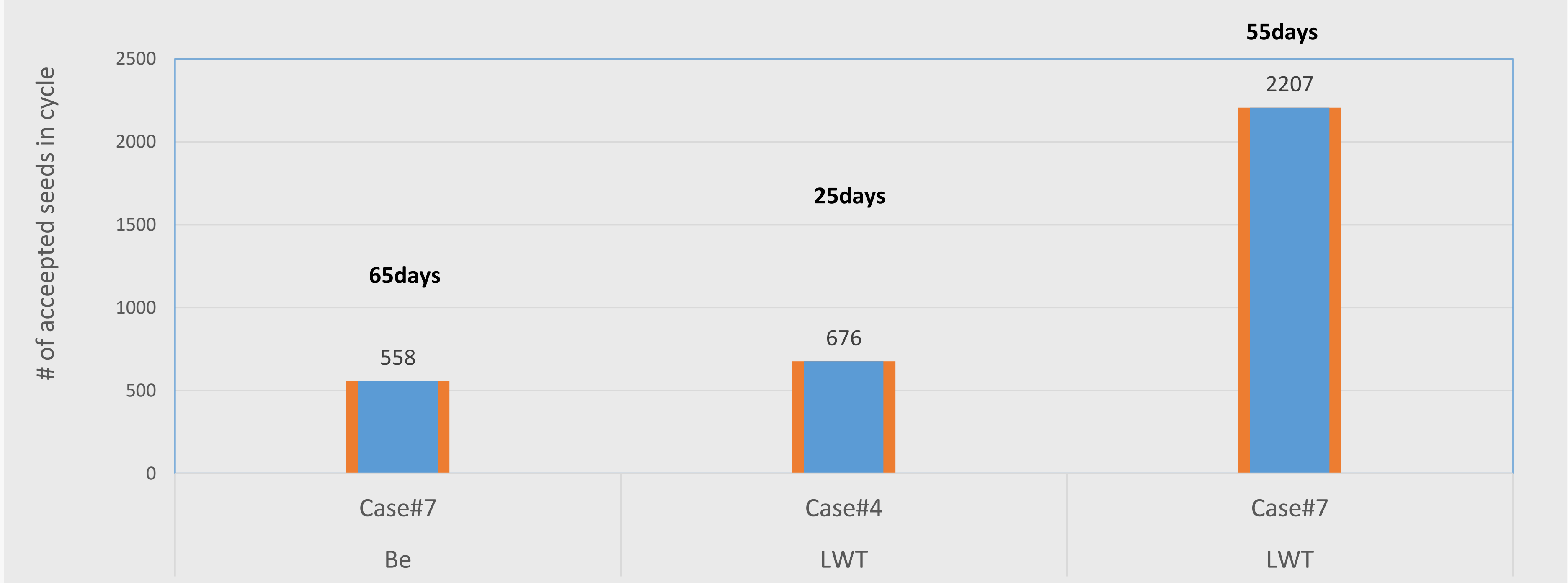
PART IV: THERMAL-HYDRAULIC CALCULATION



- Safety analysis calculations for Onset Nucleate Boiling and Pump Failure show no significant difference comparing to MNR standard FA calculations values.

PART IV: K_{EFF} AND BURNUP CALCULATIONS

- For reliable running, each simulation done with 50000 particles, 5000 active and 250 inactive cycles.
- The absolute error in the Keff was found to be <0.07mK and therefore neglected.



PART IV: SUMMARY AND CONCLUSIONS

- In this scoping study a new design of MTR FA analyse in order to optimize isotope production at MTR type RRs.
- Components impact:
  - IP body material changes the flux amplitude.
  - Linear fuel distribution changes the flux shape.
- In comparison a full cycle, by using the re-design models, the cycle length increases by 120% and the radioisotopes production increases by 230%
- Except LWT, no significant different found between the IP body materials, in terms of production rate and the K_{eff} .
- Thermal-Hydraulic calculations and a safety analysis for the selected cases shows safe operations comparing to an MNR safety analysis report.
- This new design can be cost effective in terms of radioisotopes production and fuel.

Questions?

THANK YOU!