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Use of Existing High Enriched MOX Fuel in an Experimental ADS

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Outline of presentation:

- **Introduction**
- **Characterization of existing fuels in Europe**
- **Core configurations considered**
- **Burn-up investigations for a core with SNR-300 fuel**
- **Summary and outlook**

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Use of Existing High Enriched MOX Fuel in an Experimental ADS

Characterization of some existing fuels in Europe

- **Fuels considered:**
  - **SNR300 fuel from former fast reactor program in Germany**
  - **SUPERPHENIX (SPX) fuel from fast reactor program in France**
- **Both fuel assembly types contain two axial blanket zones with depleted UO2**
- **Fabrication periods for both fuels between 1978 and 1988**
- **Plutonium compositions comparable, Am^{241} seems not to be a major problem**
- **Use of both fuel types on assembly-, pin- and pellet- level seems feasible**
- **Because of the smaller core size, SNR300 fuel has higher fissile enrichment than SPX fuel**

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casing		fuel bundle	
form	hexagonal	number of fuel pins	166
pads distance	115.0 mm	number of structure pins	3
wrapper distance across flats	110.25 mm	spacers	14 grid spacers
wrapper thickness	2.6 mm	pitch/diameter	7.9/6.0 = 1.316
fuel pin			
outer cladding diameter	6.00 mm	fertile fuel length	2 x 400 mm
cladding thickness	0.38 mm	upper fission gas plenum length	43.0 mm
fissile fuel length	950.0 mm	lower fission gas plenum length	645.0 mm
pellet diameter	5.09 mm		

Main characteristics of the SNR-300 sub-assembly.

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isotope	mass of fuel isotopes per one FA for different fuel types, (g/FA)		
	C1_MAG	C1_LWR	C2_LWR
U^{234}	2.6	11.3	18.8
U^{235}	76.2	127.9	128.6
U^{236}	4.8	5.3	6.9
U^{238}	19848.5	19512.1	16755.3
Np^{237}	6.70	12.2	17.5
Pu^{238}	8.7	40.9	73.7
Pu^{239}	4921.8	4486.5	6219.7
Pu^{240}	1360.9	1638.2	2265.6
Pu^{241}	49.2	114.8	206.5
Pu^{242}	52.4	204.5	331.7
Am^{241}	197.3	393	616.4
Total fuel	26529.10	26546.70	26640.70
Pu_{-fi}+Am/HM	0.194816	0.188133	0.264355

SNR-300 material composition in the year 2010 for the three existing fuel types. The data corresponds to 166 fuel pins in one FA.

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casing		fuel bundle	
form	hexagonal	number of fuel pins	271
pads distance		number of structure pins	-
wrapper distance across flats	173 mm	spacers	14 grid spacers
wrapper thickness	4.6 mm	pitch/diameter	10.5/8.5=1.235
fuel pin			
outer cladding diameter	8.50 mm	fertile fuel length	2 x 300 mm
cladding thickness	0.565 mm	upper gas plenum length	Total 852 mm
fissile fuel length	1000.0 mm	lower gas plenum length	
pellet diameter	7.14 mm		

Main characteristics of the SPX sub-assembly.

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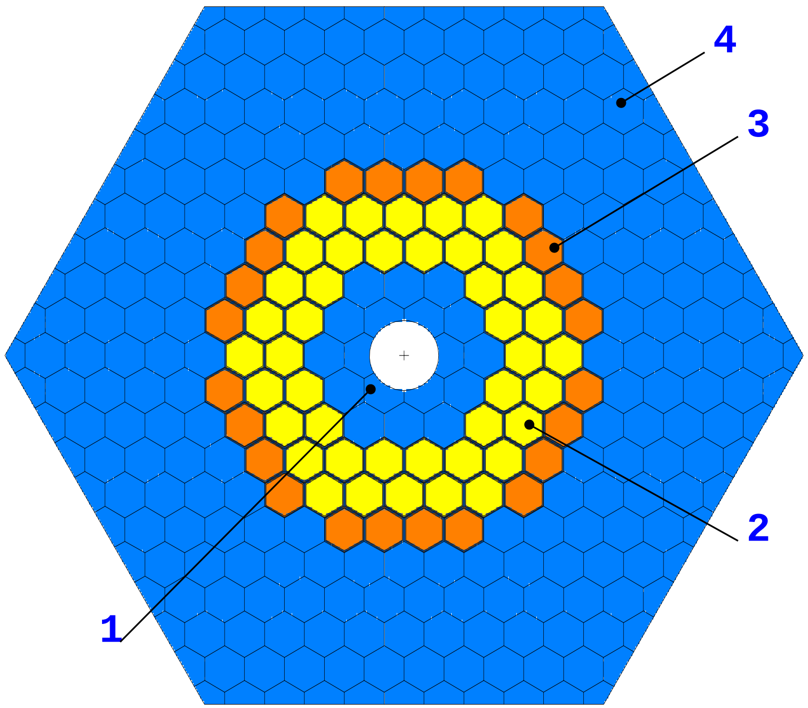
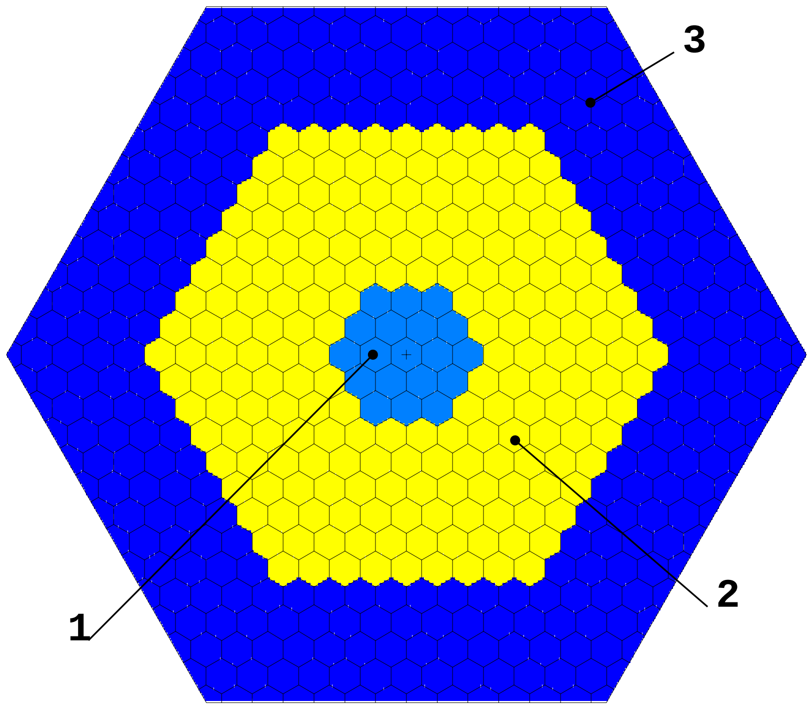
isotope	mass of fuel isotopes per one FA for different fuel types, (g/FA)			
	R1–inner core	R2–inner core	R1–external core	R2–external core
U^{234}	28.9	37.7	56.1	27.1
U^{235}	408.7	404.7	381.0	383.6
U^{236}	9.43	30.7	34.3	31.7
U^{238}	75407	75060	70930	70944.3
Np^{237}	17.5	21.1	29.9	22.5
Pu^{238}	136.8	178.1	255.8	128.0
Pu^{239}	9854.7	9842.7	11765.0	12733.5
Pu^{240}	3702.5	3792.0	4832.4	4596.3
Pu^{241}	394.1	508.2	658.7	542.2
Pu^{242}	533.2	720.4	1056.0	686.2
Am^{241}	913.0	1114.7	1554.0	1189.0
Total fuel	91406	91710	91553	91284
Pu_{fis} + Am	0.1221	0.1250	0.1527	0.1584

SPX Fuel element material composition in the year 2010 for the three existing fuel types. The data corresponds to 271 fuel pins in one FA.

Use of Existing High Enriched MOX Fuel in an Experimental ADS



. Reference SNR–300 core design. Low enriched C1_MAG assemblies (zone 2) are surrounded by high-enriched fuel assemblies of type C2_LWR (zone 3), reflector made of LBE-structure mixture (zone 4).



Core layout for the SPX fuel. Zone 1 – the target zone, represented by LBE mixed with structure material; zone 2 – most enriched SPX fuel in ANSALDO sub-assembly configuration; zone 3 – reflector, made of LBE - structure mixture

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Case		K_{eff}	
		TWODANT S8 12 groups	CITATION 12 groups
Cylinder	300 K	1.006	0.996
	1273 K	0.994	0.983
Hexahedral	300 K		0.994
	1273 K		0.981 4 meshes 0.983*)

*) source on, otherwise source off

SNR–300 fuel reference core results for K_{eff},

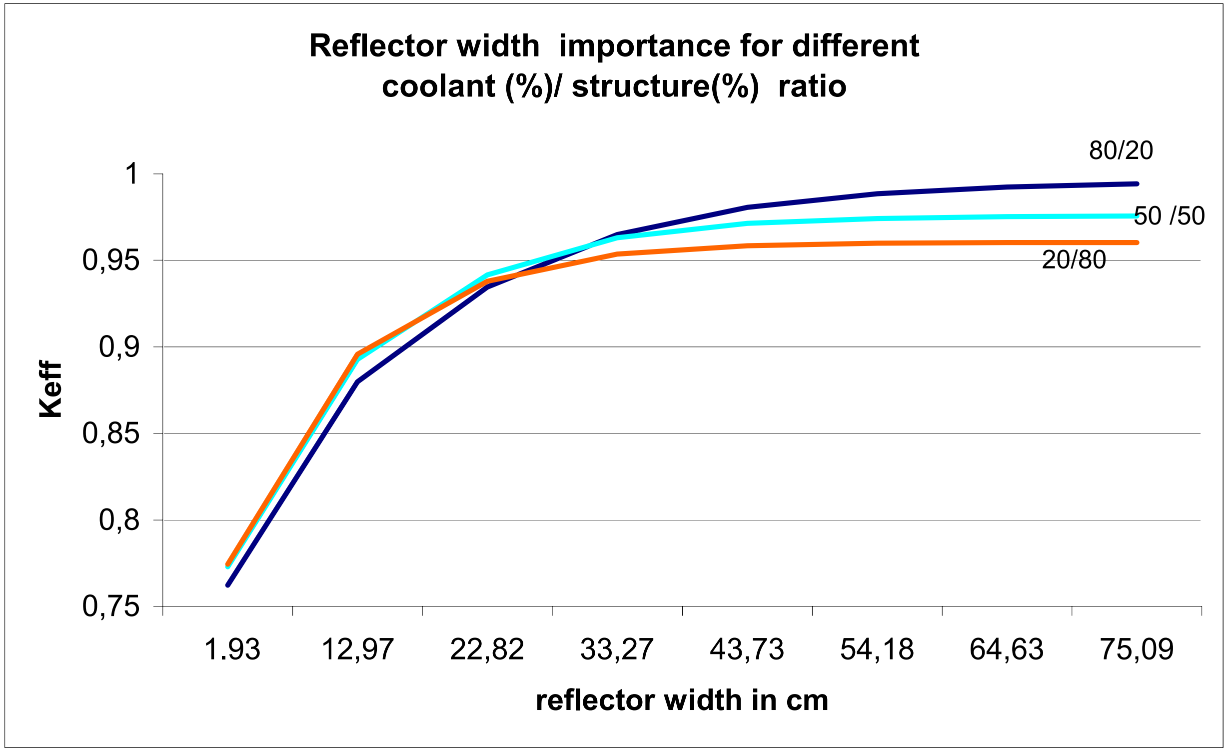
80% LBE and 20% structure material in the reflector and the central core (zones 1 and 4).

Use of Existing High Enriched MOX Fuel in an Experimental ADS

Coolant/structure fraction, %vol		K_{eff} for the „source off“ option
Target	reflector	
80/20	80/20	0.994
100/0	100/0	1.019
100/0	80/20	1.005
100/0	50/50	0.985
100/0	20/80	0.970

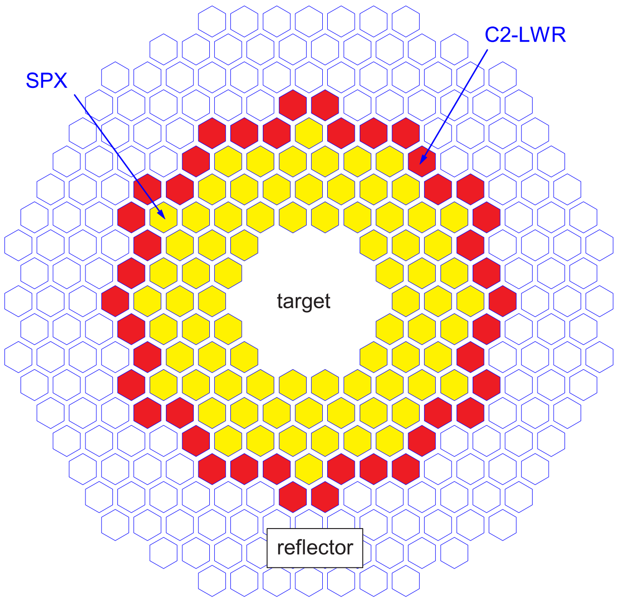
Influence of the structure material in the target and the reflector on K_{eff} in SNR300 core, calculated with cylindrical transport model of TWODANT at fuel temperature 1273 K.

Use of Existing High Enriched MOX Fuel in an Experimental ADS



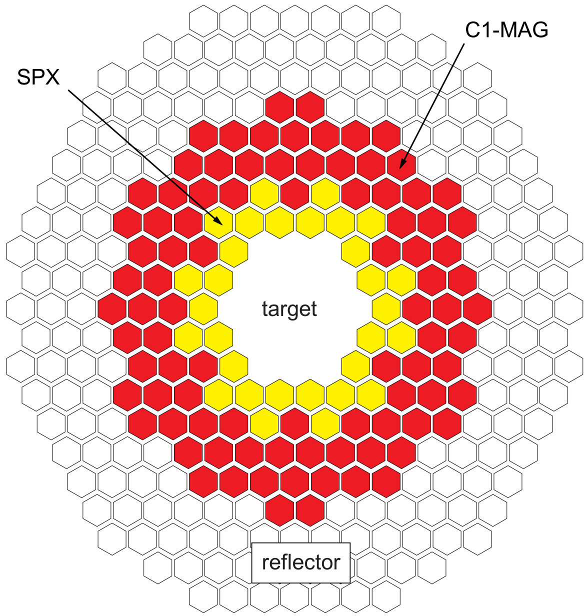
K_{eff} as a function of reflector thickness for the SNR300 core. Three coolant to structure volume ratios are considered for the reflector. The target region for all cases is represented by 80% of LBE and 20% of structure material. The fuel temperature is 1273 K.

Use of Existing High Enriched MOX Fuel in an Experimental ADS



Design A

ANSALDO core layout for the two enrichment option. The target zone, represented by LBE mixed with structure material; SPX – most enriched SPX fuel; C2_LWR – most enriched SNR fuel, reflector is represented by homogenized LBE and structure mixture



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Design B

ANSALDO core layout for the two enrichment option. The target zone, represented by LBE mixed with structure material; SPX – most enriched SPX fuel; C1_MAG – SNR fuel (with lower enrichment compared with C2_LWR), reflector is represented by homogenized LBE and structure mixture.

Use of Existing High Enriched MOX Fuel in an Experimental ADS

Core layout	Design A	Design B
Number of SPX assemblies	78	30
Number of C1_MAG SNR assemblies	------	90
Number of C2_LWR SNR assemblies	42	------
K_{eff}	0.9684	0.9717
Multiplicity with source on	0.9677	0.9722
Peak linear power (W/cm)	128.6	125.0
Mean linear power in SPX assembly (W/cm)	78.3	82.4
Mean linear power in C1_MAG assembly (W/cm)	------	89.7
Mean linear power in C2_LWR assembly (W/cm)	95.1	------

Summary of results for designs A and B for a 80MW$_{th}$ ANSALDO based XADS core design with mixed SNR300 and SPX fuel pellets.

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Burn-up investigations for an XADS core with SNR300 fuel

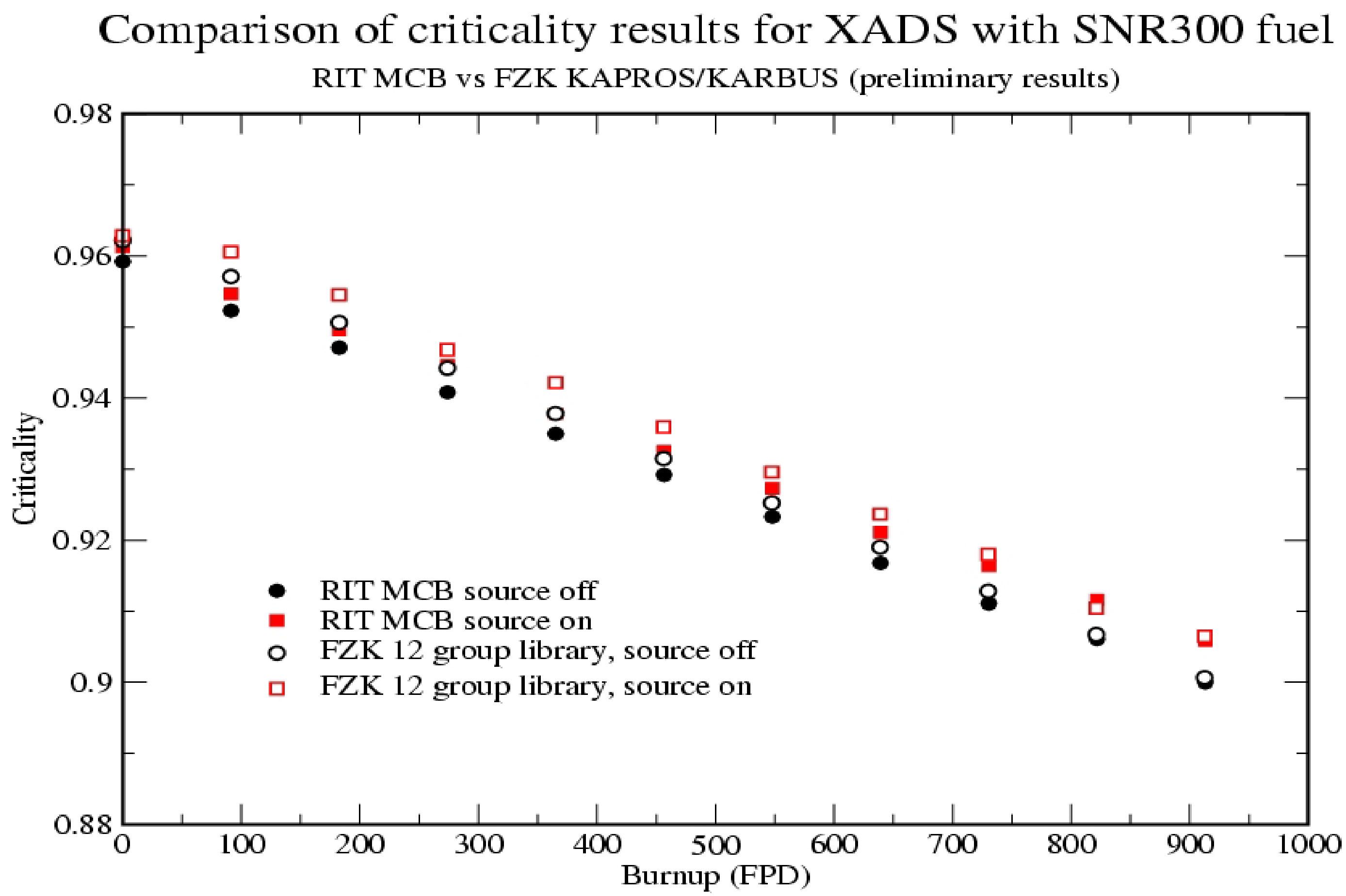
- **Applied calculation methods**
  - **Monte Carlo code MCB1C by RIT Stockholm**
  - **Deterministic multi-group code system KAPROS by FZK Karlsruhe**
- **Calculation model**
  - **Appropriate (R-Z) geometry in both calculation methods**
  - **Three radial and eight axial burn-up zones same in both methods**
  - **Mostly same JEF2.2 data base for cross section data**
  - **Detailed source from MCNPX calculation in Monte Carlo method, simplified constant source treatment in deterministic code**
- **Satisfactory agreement in preliminary results; reactivity loss 6..7 pcm/fpd**

Use of Existing High Enriched MOX Fuel in an Experimental ADS

Time[yr]	P [MW]	Src Str [1/s]	K_{eff}	K_s
BOL	80	3.04E+17	0.9592	0.9613
0.25	80	3.29E+17	0.9523	0.9547
0.50	80	3.71E+17	0.9471	0.9496
0.75	80	4.15E+17	0.9408	0.9446
1.00	80	4.58E+17	0.9350	0.9378
1.25	80	5.04E+17	0.9292	0.9325
1.50	80	5.54E+17	0.9233	0.9273
1.75	80	6.16E+17	0.9168	0.9211
2.00	80	6.43E+17	0.9111	0.9164
2.25	80	6.90E+17	0.9061	0.9116
2.50	80	7.48E+17	0.9000	0.9059
2.75	80	7.70E+17	0.8946	0.9014

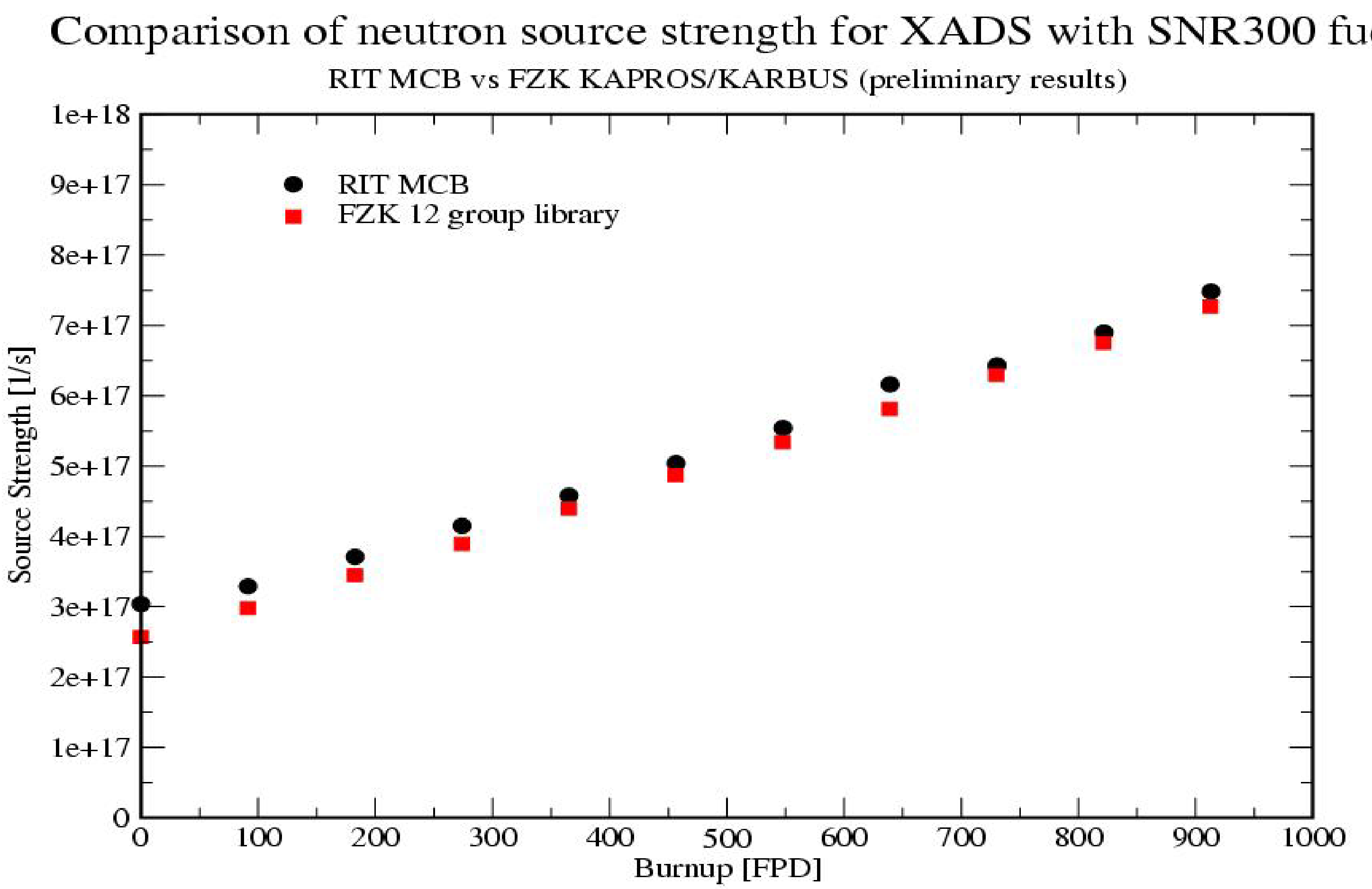
Summary of MCB1C results for LBE cooled XADS with SNR300 fuel

Use of Existing High Enriched MOX Fuel in an Experimental ADS



Comparison of RIT Monte Carlo and FZK deterministic results for burn up dependant criticality values for XADS with SNR300 fuel. Source on/off states are plotted.

Use of Existing High Enriched MOX Fuel in an Experimental ADS



Comparison of RIT Monte Carlo and FZK deterministic results for burn up dependant source strength for XADS with SNR300 fuel

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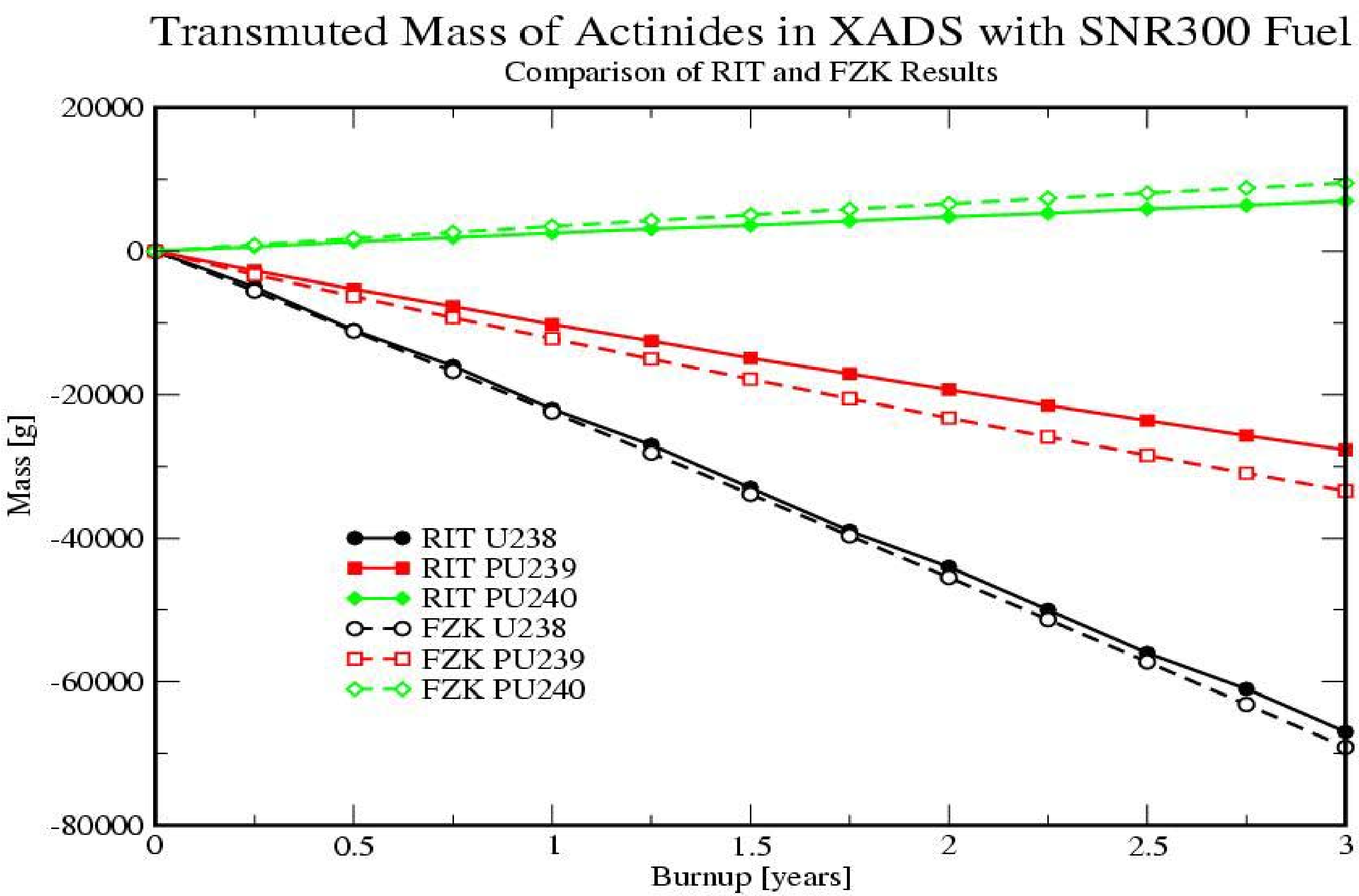

Comparison of RIT Monte Carlo and FZK deterministic results for burn up dependant mass change

Use of Existing High Enriched MOX Fuel in an Experimental ADS

Summary and outlook

- **Several options for the utilization of existing high enriched fuel from European fast reactor programs in an XADS core have been analyzed**
- **Use of slightly modified FA, of fuel pins and of fuel pellets are considered**
- **From neutron physics point of view, use of SNR300 FA is feasible**
- **Because of lower enrichments, use of SPX fuel leads to much larger cores**
- **If SPX fuel is to be used, the ANSALDO design for a 80 MW_{th} XADS core needs reprocessing and increasing of the fissile enrichment**
- **An interesting option could be the mixed application of pellets from SNR300 and from SPX fuel. The different pellet diameter of this fuel would require FA with same outer dimensions and also different lattice pitch**