UNIVERSIDAD DE TALCA

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INVESTIGATION OF INCINERATION RATE OF ^{241}AM, ^{243}AM AND ^{237}NP SPALLATION TARGETS USING A PROTON ACCELERATOR DRIVEN SYSTEM USING MCNPX CODE

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Nuclear waste


Mutation And cancer

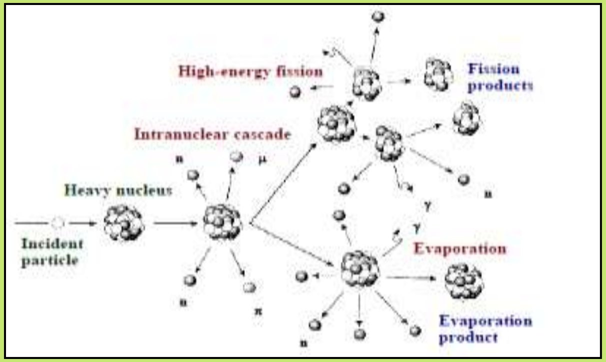

- In the world are 442 operating nuclear reactors

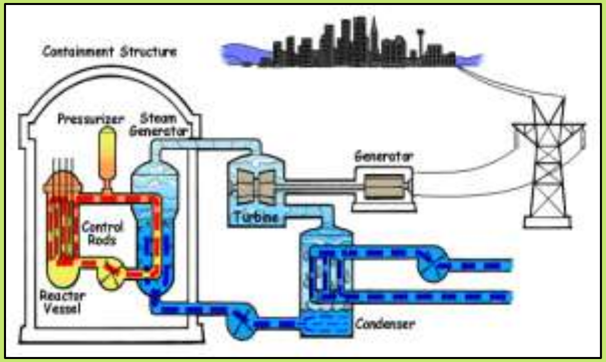
400,000 ton of waste produce annually: about 12,000 ton is high-level waste (HLW).

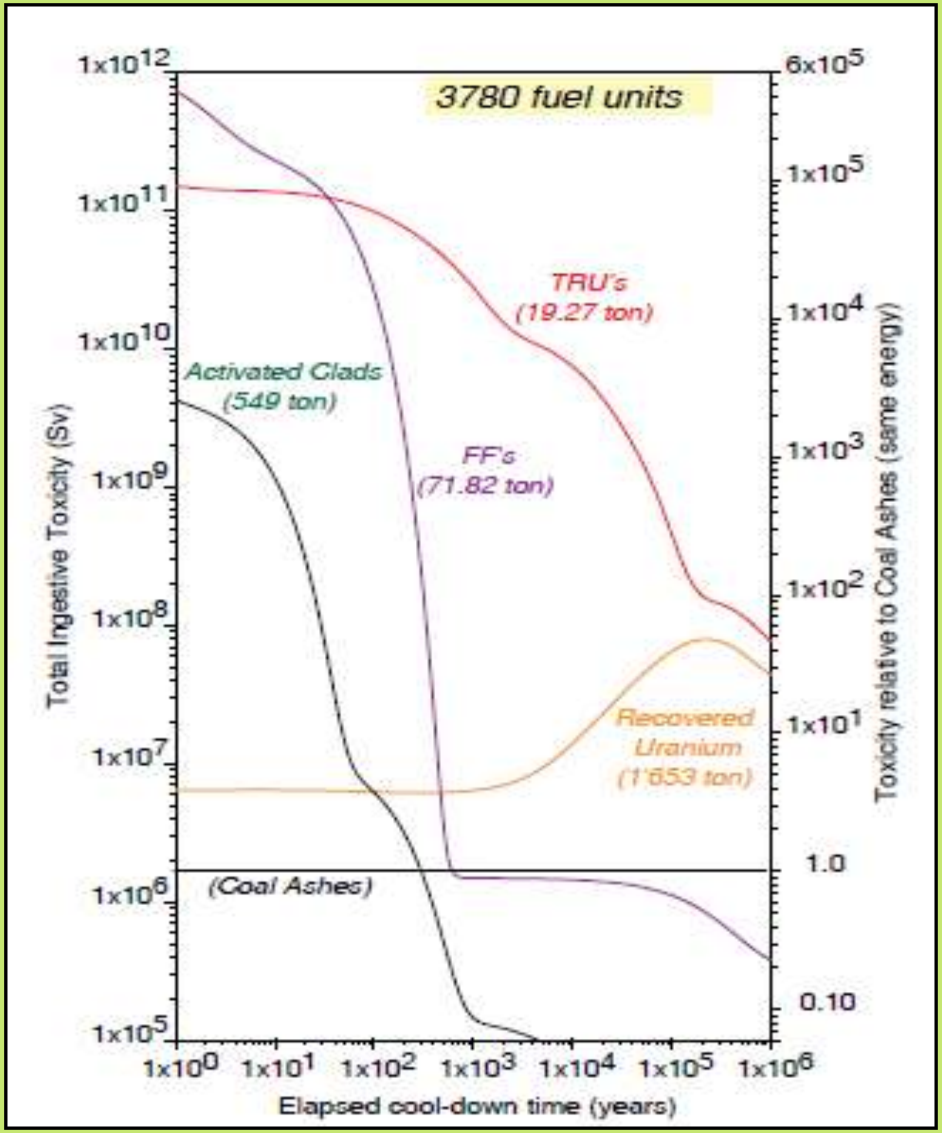
- **96% of this is U**
- **1% of this are actinides (TRU transuranics)**
- **3% other fission products**

The most radiotoxic elements

- Transuranic elements
- Fission products





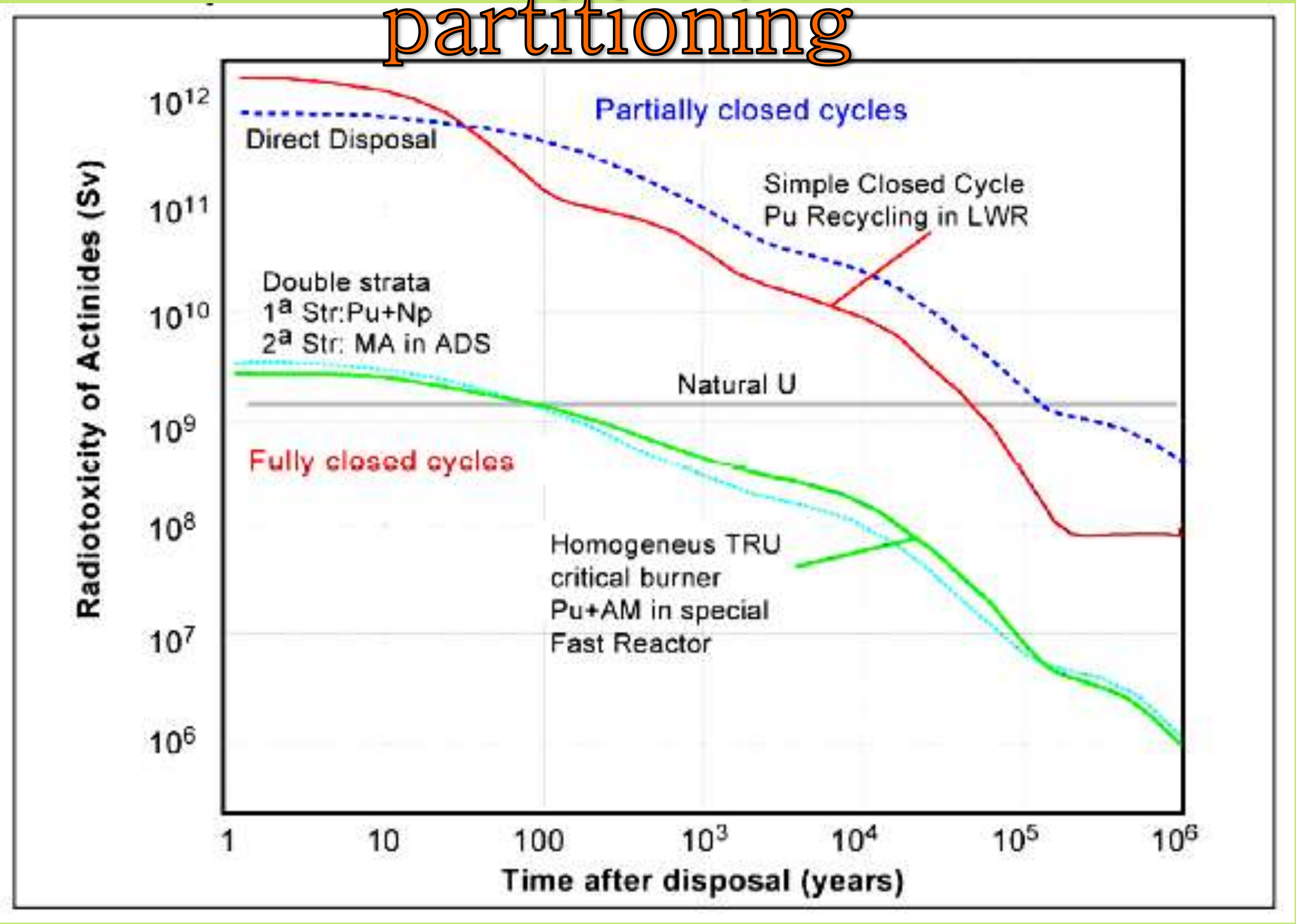


Nuclear waste disposal

- **Geological disposal of the UK's radioactive waste is circa 16.44 $ billion**

- **The value is 15 $ billion in U.S.**

Transmutation and partitioning



SNS cost

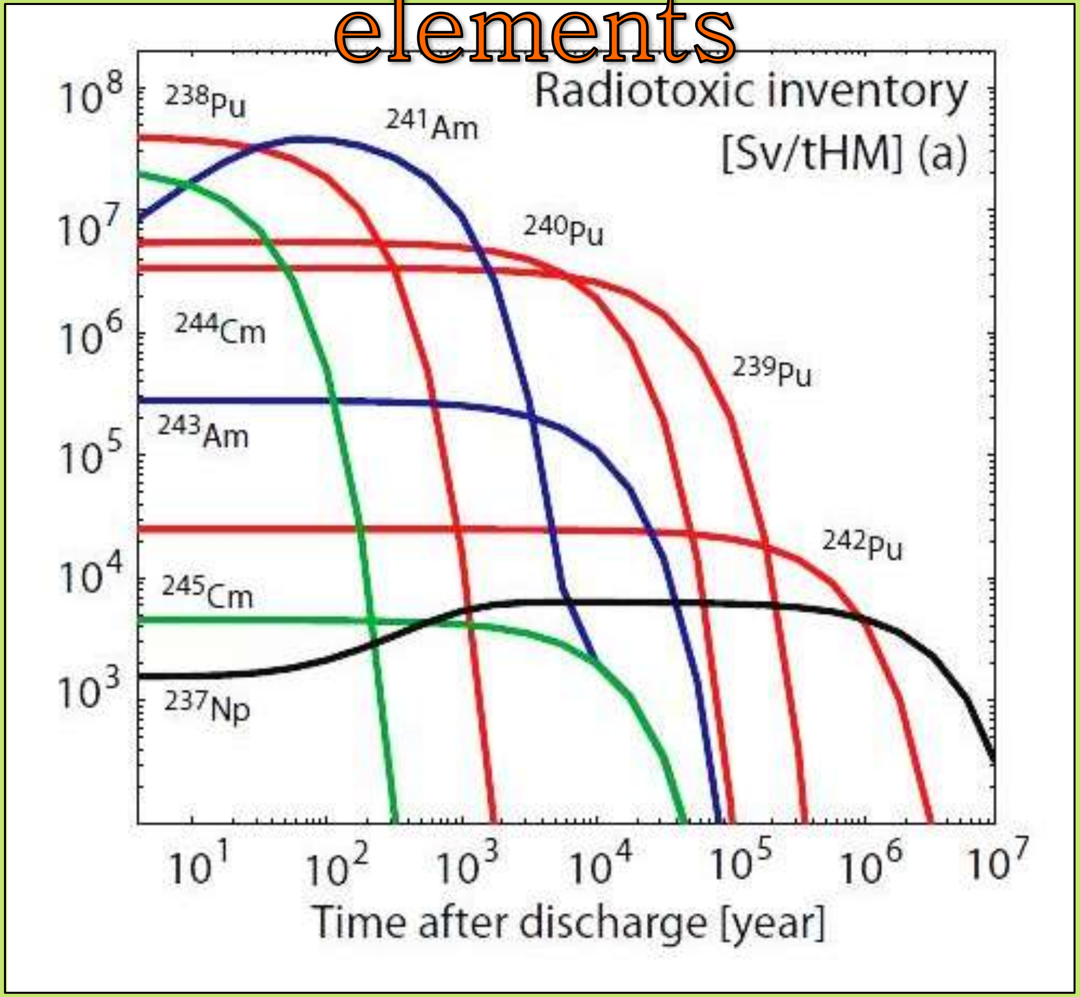
The total project cost of SNS was 1.4B$

Proton beam energy on target	1.0	GeV
Proton beam current on target	1.4	mA
Power on target	1.4	MW
Pulse repetition rate	60	Hz
Beam macropulse duty factor	6.0	%
Ave. current in macro-pulse	26	mA
H^- peak current front end >	38	mA
Chopper beam-on duty factor	68	%
RFQ output energy	2.5	MeV
FE + Linac length	335	m
DTL output energy	87	MeV
CCL output energy	185	MeV

SC linac output energy	1.0	GeV
HEBT length	170	m
Accumulator ring circ.	248	m
Ring fill time	1.0	m
Ring beam extraction gap	250	ns
RTBT length	150	m
Protons per pulse on target	1.5×10^{14}	
Proton pulse width on target	695	ns
Target material	Hg	

The most radiotoxic elements

- Pu
- Am
- Cm
- Np



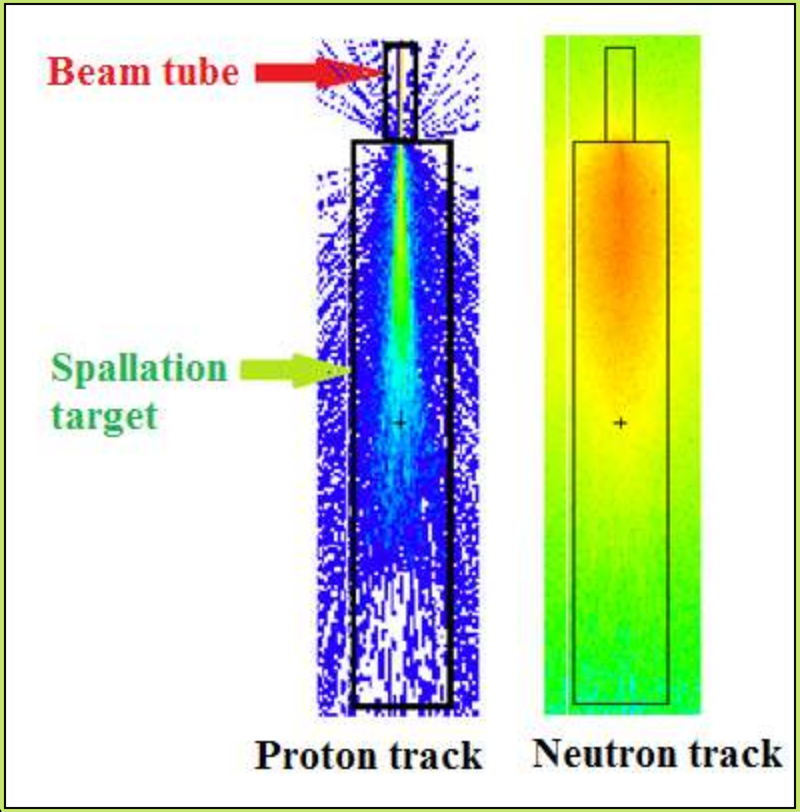
Objectives of this simulation work

Work proposal:

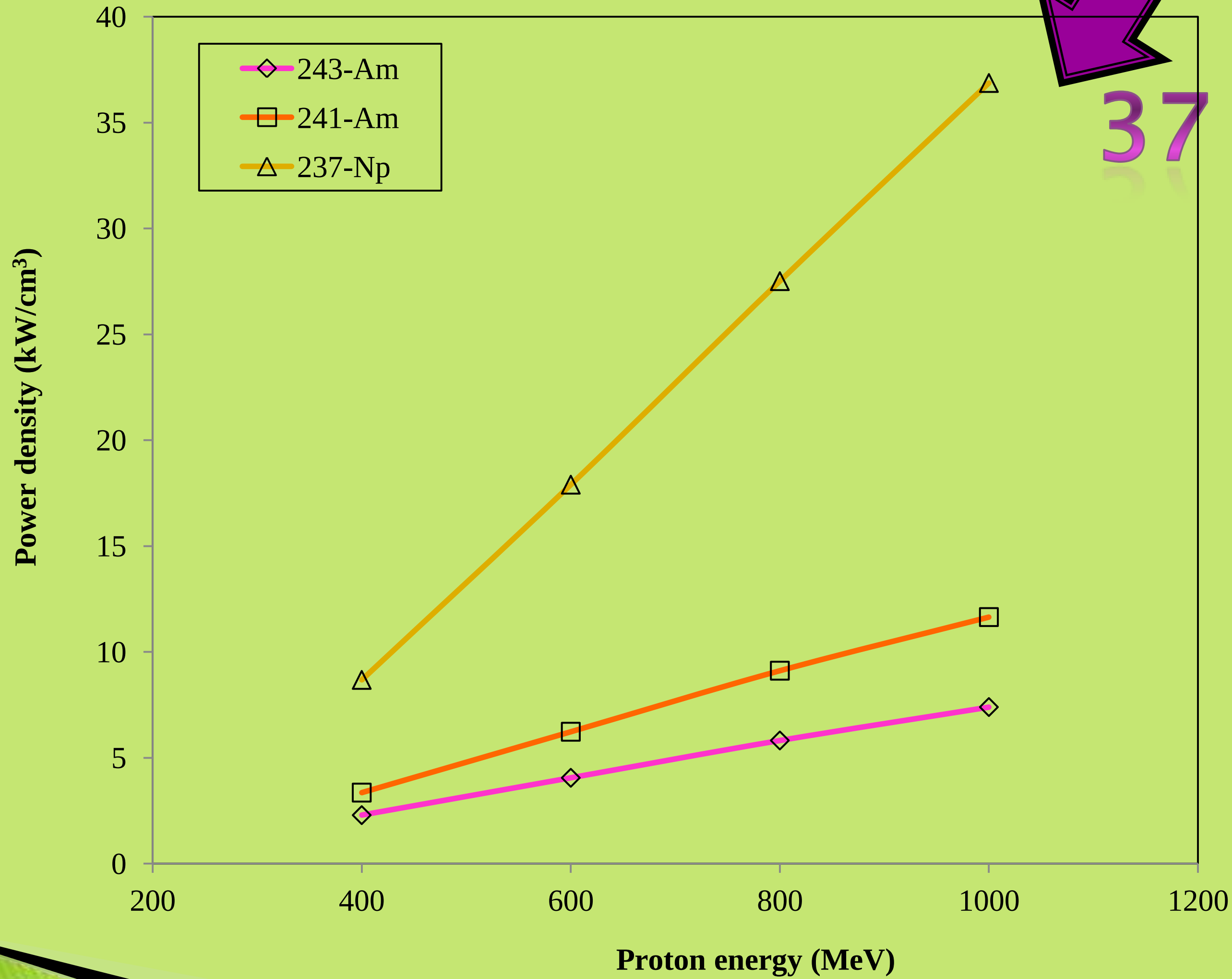
- Proton energies: 0.4, 0.6, 0.8 and 1 GeV
- Spallation targets: ^{241}Am, ^{243}Am and ^{237}Np
- Cylindrical target dimension 10×60 cm
- MCNPX 2.6.0 Monte Carlo-based code

Calculations:

- Escaped neutron yield from the spallation targets
- Neutron absorption rate
- Leaked neutron spectra from the spallation targets
- Heat deposition inside the spallation targets
- Radionuclide production inside the spallation targets
- Effective multiplication factor, delayed neutron fraction and effective delayed neutron fraction



Deposited heat



37 KW/CM³

SNS neutronic

Comparison of different physical and neutronic properties of spallation targets

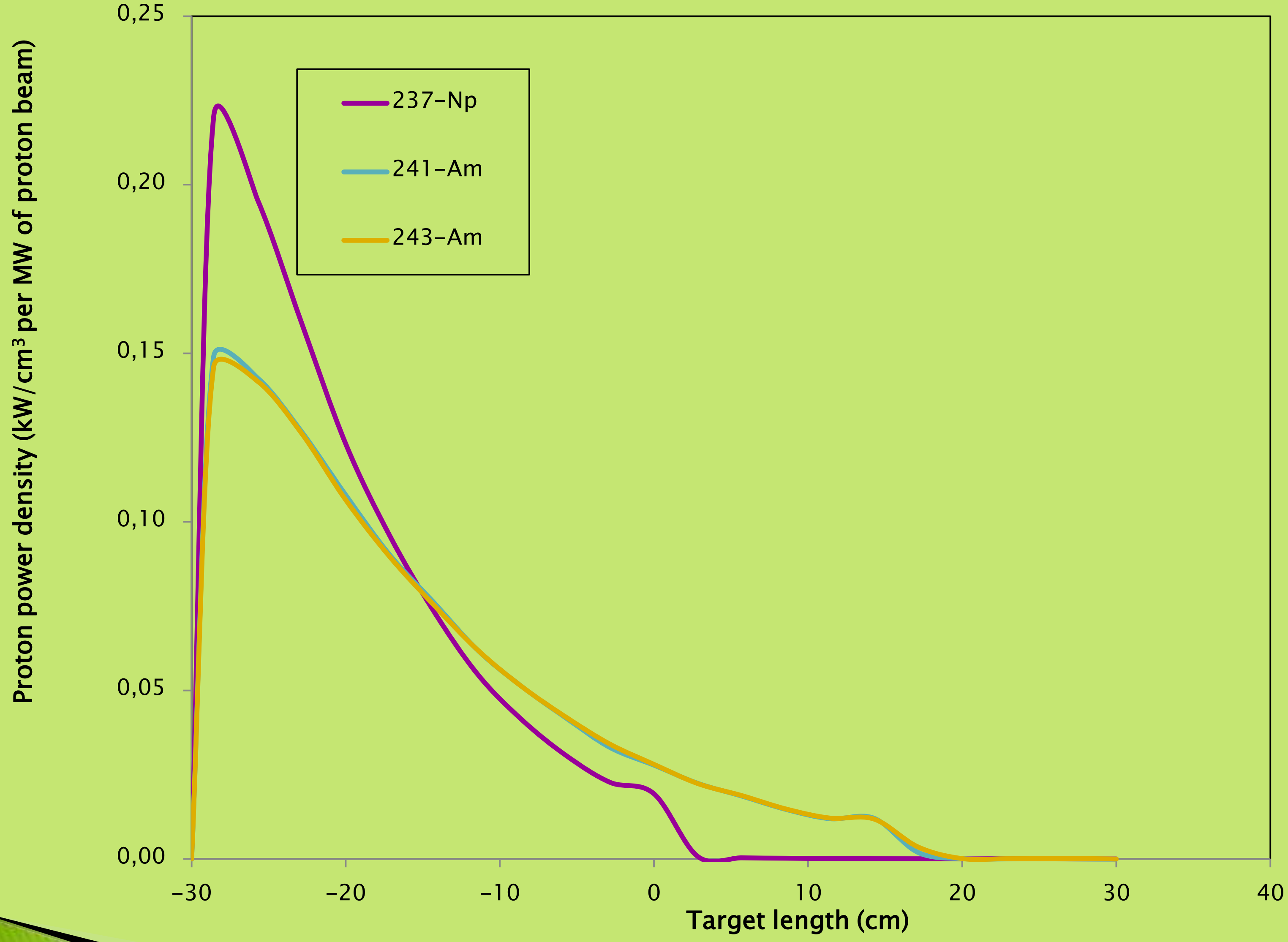
Target specifications	^{237}Np	^{241}Am	^{243}Am
Density ($\frac{g}{cm^3}$)	20.25	13.67	13.67
Melting point (˚C)	644	1176	1176
Boiling point (˚C)	4000	2011	2011
Termal conductivity ($\frac{W}{mK}$)	6	10	10
β (pcm)	194	214	190
β_{eff} (pcm)	75	231	182
Neutron per fission (ν)	3.00	3.67	3.87
k_{eff}	0.86213	0.76451	0.64974

SNS neutronic

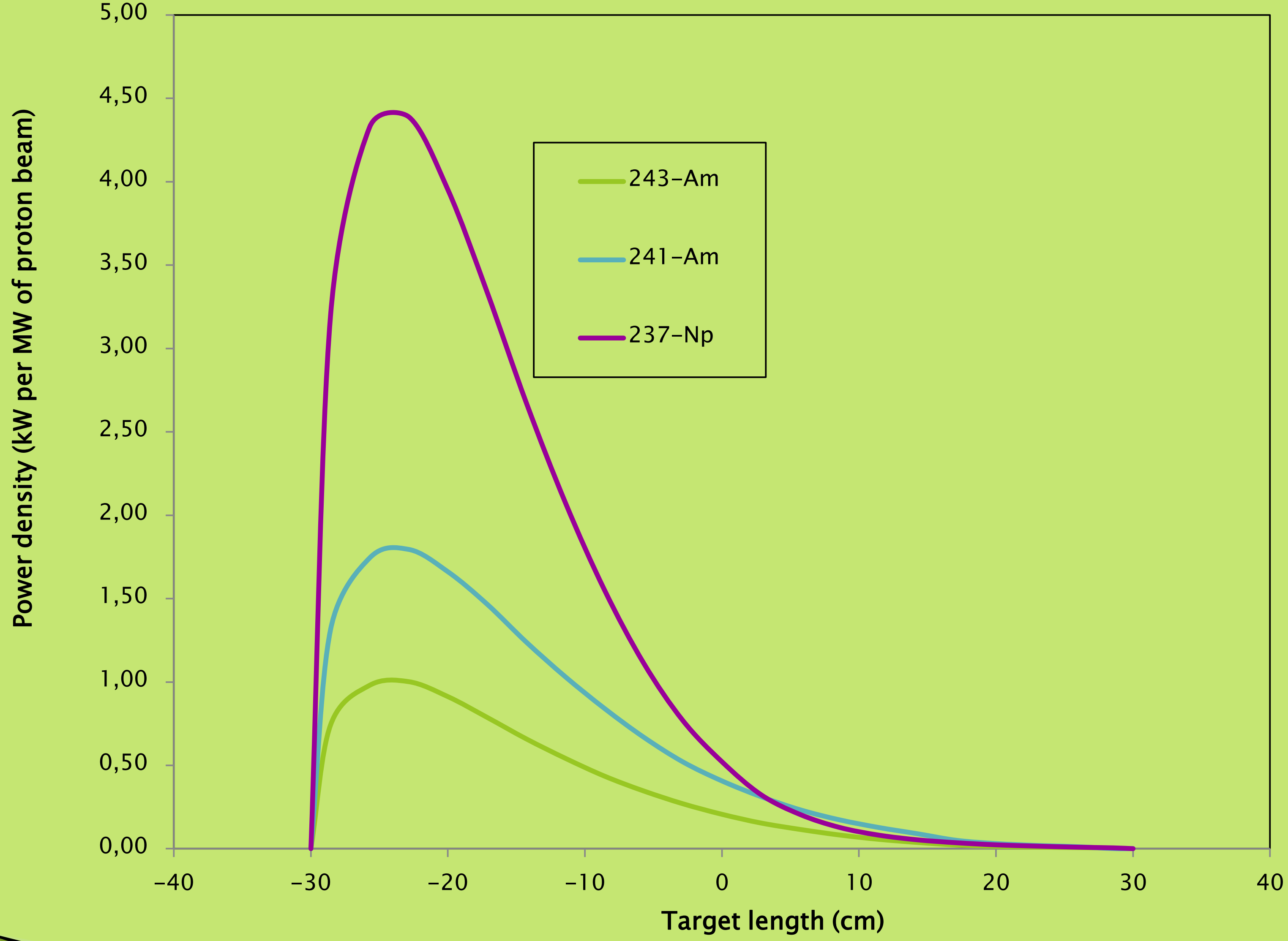
Comparison of different neutronic properties of spallation targets

Quantity	Energy (GeV)			
	0.4	0.6	0.8	1
^{237}Np				
(n,G) (#/s)	2.72E+16	5.77E+16	9.39E+16	1.23E+17
(n,f) (#/s)	8.74E+16	1.82E+17	2.97E+17	3.89E+17
Transmutation rate (kg/y)	1.423651	2.980534	4.850051	6.362937
Gas production (atom/y)	2.40E+08	3.47E+08	4.92E+08	6.48E+08
^{241}Am				
(n,G) (#/s)	1.15E+16	2.35E+16	3.59E+16	4.71E+16
(n,f) (#/s)	5.35E+16	1.08E+17	1.65E+17	2.16E+17
Transmutation rate (kg/y)	0.820617	1.661986	2.536969	3.326655
Gas production (atom/y)	2.39E+08	3.35E+08	4.59E+08	6.01E+08
^{243}Am				
(n,G) (#/s)	8.41E+15	1.68E+16	2.49E+16	3.25E+16
(n,f) (#/s)	2.73E+16	5.41E+16	8.09E+16	1.05E+17
Transmutation rate (kg/y)	0.451024	0.894867	1.335081	1.736473
Gas production (atom/y)	2.31E+08	3.24E+08	4.43E+08	5.77E+08

Thank you for your attention



Proton power density (kW/cm³ per MW of proton beam)
0,25
0,20
0,15
0,10
0,05
0,00
237-Np
241-Am
243-Am
-30
-20
-10
0
10
20
30
40
Target length (cm)



5,00
4,50
4,00
3,50
3,00
2,50
2,00
1,50
1,00
0,50
0,00
Power density (kW per MW of proton beam)
243-Am
241-Am
237-Np
-40
-30
-20
-10
0
10
20
30
40
Target length (cm)

Table 1- Energy range of neutron spectra leaked from the spallation targets.

Neutron energy	^{237}Np (%)	^{241}Am (%)	^{243}Am (%)
1e-04 MeV<En<1 MeV	4.47E+01	3.76E+01	4.43E+01
1 MeV<En<20 MeV	5.39E+01	6.06E+01	5.27E+01
20 MeV<En<1000 MeV	1.33E+00	1.88E+00	2.98E+00

Table 1
The composition of MA in the spent fuel of a light water reactor

Isotopes	Mass (kg/year) per unit PWR[a]
^{237}Np	15.1
^{238}Pu	16.1
^{239}Pu	205
^{240}Pu	120
^{241}Pu	72.7
^{242}Pu	41.6
^{241}Am	6
^{242m}Am	0.00793
^{243}Am	21.8
^{244}Cm	15.6
^{245}Cm	1.74

33 MWd/kg, 32.5% thermal efficiency, 150 days after discharge.
Nuclear Chemical Engineering (Manson et al., 1981, p. 370, Table 8.5).
[a] Pressurised-water reactor, fuel with plutonium recycle, 1000-Mwe reactor, 80% capacity factor.

reactors can become viable (Boczar et al., 2002a,b; Critoph, 1976; Jagannathan et al., 2001; Loewen et al., 2001). Other studies have investigated the utilization of LWR spent fuel in CANDU reactors mixed with thoria (ThO_2) (Şahin et al., 2004a,b).

A series of studies have been conducted on the Direct Use of spent Pressurized water reactor (PWR) fuel In CANDU reactors (DUPIC) by Korean researchers in a wide spectrum, which covered a wide spectrum of physical and technological aspects, including fuel management scenario and fuel performance (Choi et al., 1997).

In the present work, the neutronic analysis of a CANDU reactor with a mixed fuel made of thorium and MA is presented. The utilization of MA in combination with thorium has two main purposes. Firstly, it will enable the incineration of MA and so the reduction of the long living nuclear waste material. Furthermore, it will allow the

Table 1 Some important records of neutron targets so far been used at various spallation neutron facilities

Target	Proton Energy, MeV	Thermal Cycles	Total Protons, mA hrs	Peak Temperature, °C	Time-average beam current, μA	Relative Total Number of Fissions to U #5
ISIS U #1	780	—	92.4	—	30	0.31
ISIS U #2	800	40000	53.1	120	40	0.18
ISIS U #3	800	10389	174.9	130	65	0.59
ISIS U #4	800	4147	138.8	150	75	0.47
ISIS U #5	800	5074	295.6	165	90	1.00
ISIS U #6	800	2628	126.1	180	110	0.43
ISIS U #7	800	1805	107.2	215	125	0.36
ISIS U #8		Not Used			—	—
ISIS U #9	800	815	113.2		150	0.381
IPNS Depleted #1	450	89600	240.0	225	10 - 14	0.39
IPNS Enriched #1	450	28000	128.8	175	14 - 16	1.07
KENS U #1	500	~ 40000	~ 50	~ 120	~ 5	~ 0.1
ISIS Ta #1	800	73378	1751.6		170	3.80**
ISIS Ta #2*	800	21138	618.1		170	1.34**

* Still in use