TAGS and related measurements in India: Immediate- and longer-term plans

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on behalf of the nuclear data committee in India

Nuclear data centre and TAGS status in India

- A nuclear data committee has been formed 2 years back to look into the scope and feasibility of opening a data centre in India.
- NDC meets at least 3-4 times a year to discuss various issues.
- One of the focused areas for the data centre activities would be the decay heat calculations for the U-Th fuel cycle.
- In a recent meeting held at the Bhabha Atomic Research Centre (BARC), Mumbai on 31st December 2008, the importance of TAGS measurement and its feasibility in India has been discussed.

Meeting on 31st Dec 2008

The following were present:

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- **The need to conduct TAGS measurements in India have been strongly felt in view of the ongoing research activities on AHWR in India.**
- **Scientists from various institutes (Manipal University; BARC, Mumbai, VECC, Kolkata) have shown interest for such measurements who has expertise in γ spectroscopy measurements.**
- **The available facilities in India needs to be augmented while the new facilities those are coming up needs to be used effectively.**
- **The need to have strong collaboration with international laboratories having TAGS measurement facilities has been emphasized.**
- **We are interested to take responsibility of a few nuclei to be decided by the IAEA with possibility of conducting the experiments at other labs until the set up is build in India**

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RADIO-TOXICITY OF SPENT FUEL OF THE ADVANCED HEAVY WATER REACTOR

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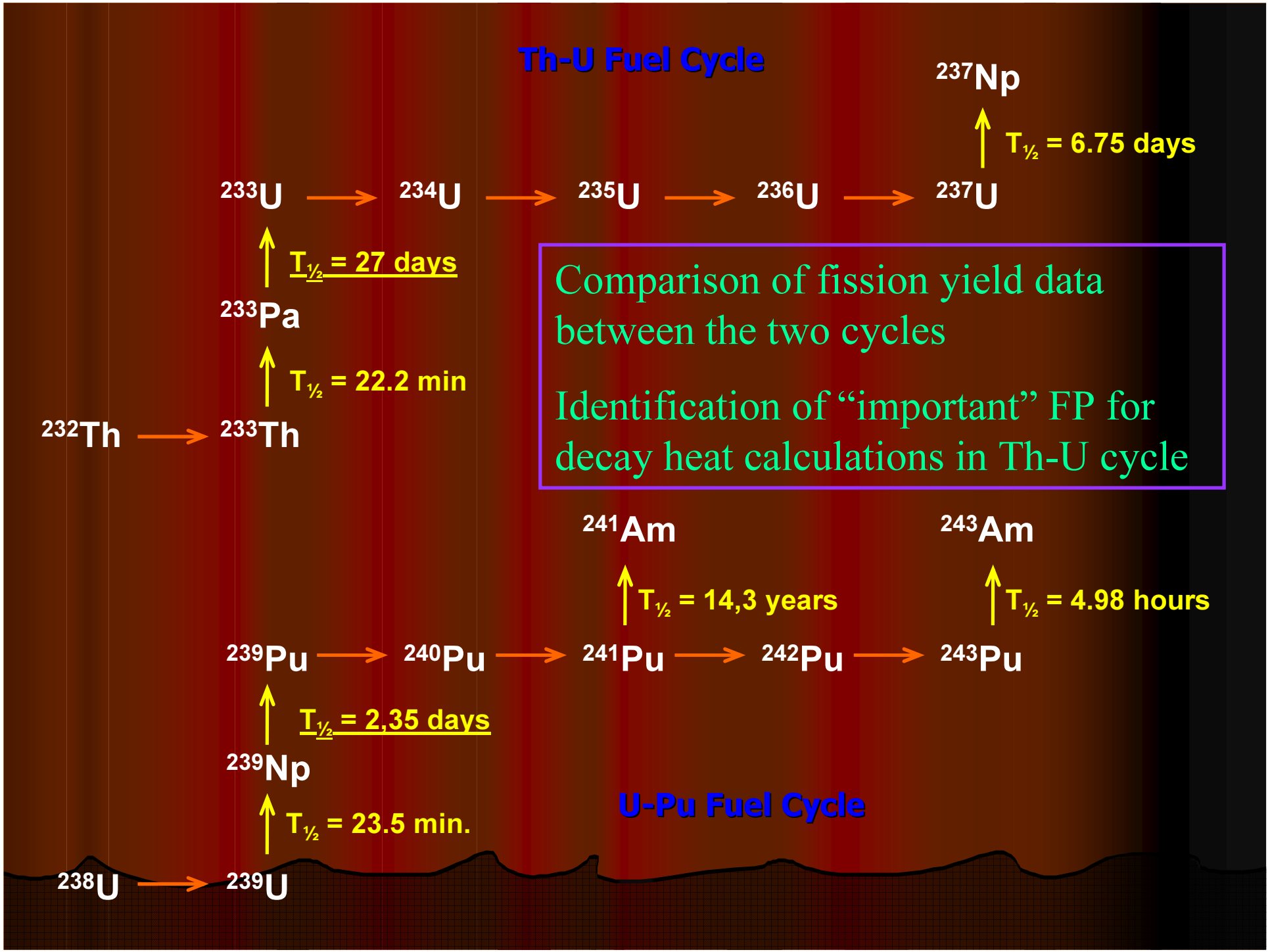
Abstract

The Advanced Heavy Water Reactor (AHWR) is a new power reactor concept being developed at Bhabha Atomic Research Centre, Mumbai. The reactor retains many desirable features of the existing Pressurised Heavy Water Reactor (PHWR), while incorporating new, advanced safety features. The reactor aims to **utilize the vast thorium resources** available in India. The reactor core will use plutonium as the makeup fuel, while breeding 233U in situ. On account of this unique combination of fuel materials, the operational characteristics of the fuel as determined by its **radioactivity, decay heat and radio-toxicity are being viewed with great interest**. The **radio-toxicity** of the fuel is **extremely high** to start with, being about 104 times that of the fresh natural U fuel used in a PHWR, and continues to remain relatively high during operation and subsequent cooling. A unique feature of this fuel is the peak observed in its radio-toxicity at about 105 years of decay cooling. The delayed increase in fuel toxicity has been traced primarily to a build up of 229Th, 230Th and 226Ra. This phenomenon has been observed earlier for thorium-based fuels and is confirmed for the AHWR fuel. **This paper presents radio-toxicity data for AHWR spent fuel up to a period of million years.**


Th-U Fuel Cycle
^{237}Np
$T_{½}$ = 6.75 days
^{233}U → ^{234}U → ^{235}U → ^{236}U → ^{237}U
$T_{½}$ = 27 days
^{233}Pa
$T_{½}$ = 22.2 min
^{232}Th → ^{233}Th
Comparison of fission yield data between the two cycles
Identification of "important" FP for decay heat calculations in Th-U cycle
^{241}Am
^{243}Am
$T_{½}$ = 14,3 years
$T_{½}$ = 4.98 hours
^{239}Pu → ^{240}Pu → ^{241}Pu → ^{242}Pu → ^{243}Pu
$T_{½}$ = 2,35 days
^{239}Np
$T_{½}$ = 23.5 min.
U-Pu Fuel Cycle
^{238}U → ^{239}U

Comparison of the fission yields of the few radio-toxic fission products in the U^{233}, U^{235} and Pu^{239} fission

ORIGEN 2 code

ENDF-BV data

Highlighted ones are important from decay heat point of view (larger fractional decay heat values suggested by ORIGEN 2).

Nuclide	U-233	Pu-239	U-235	$T_{1/2}$
Sn-126	**1.63E-01**	**1.10E-01**	**1.88E-02**	**$2.3\ 10^5$ y**
Sb-126M	7.76E-03	3.02E-03	3.71E-04	19.2 m
Sb-126	**7.75E-03**	**3.03E-03**	**8.54E-04**	**12.4 d**
I-129	2.16E-03	1.91E-04	4.32E-05	$1.6\ 10^7$ y
Sn-121	2.71E-05	8.18E-05	6.64E-06	27.0 h
Sm-151	8.37E-05	2.54E-05	3.89E-06	90 y
Eu-152	2.03E-07	4.76E-08	3.29E-09	13.5 y
Eu-153	6.15E-04	1.85E-06	6.55E-05	stable
Eu-154	**3.75E-05**	**3.35E-05**	**1.65E-06**	**8.6 y**
Cs-135	1.05E-02	4.17E-03	8.33E-04	$2.3\ 10^6$ y
Ba-137M	**6.87E-03**	**1.50E-03**	**2.51E-04**	**2.55 m**
Cd-113M	2.34E-07	1.07E-06	1.42E-08	14.1 y
Tc-99	**8.63E-06**	**6.25E-06**	**1.64E-05**	**$2.1\ 10^5$ y**
Nb-93M	2.73E-07	2.44E-07	9.69E-09	16.1 y
Nb-94	1.29E-05	8.56E-06	4.46E-07	$2.0\ 10^4$ y
Y-90	**2.25E-04**	**1.15E-04**	**2.25E-04**	**64.1 h**
Sr-90	**1.66E-01**	**7.89E-02**	**2.86E-02**	**28.9 y**
Kr-85	**2.15E-02**	**6.94E-03**	**2.31E-03**	**3916.8 d**
Zr-93	2.58E-03	1.96E-03	2.38E-04	41.6 s
Nb-93	2.73E-07	2.44E-07	9.10E-09	stable
Pr-143	**1.52E-04**	**9.28E-06**	**2.79E-06**	**13.6 d**
La-141	1.76E-01	3.90E-02	1.96E-02	3.9 h
Ce-143	9.18E-02	1.31E-02	3.06E-02	33.0 h

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Short term goal

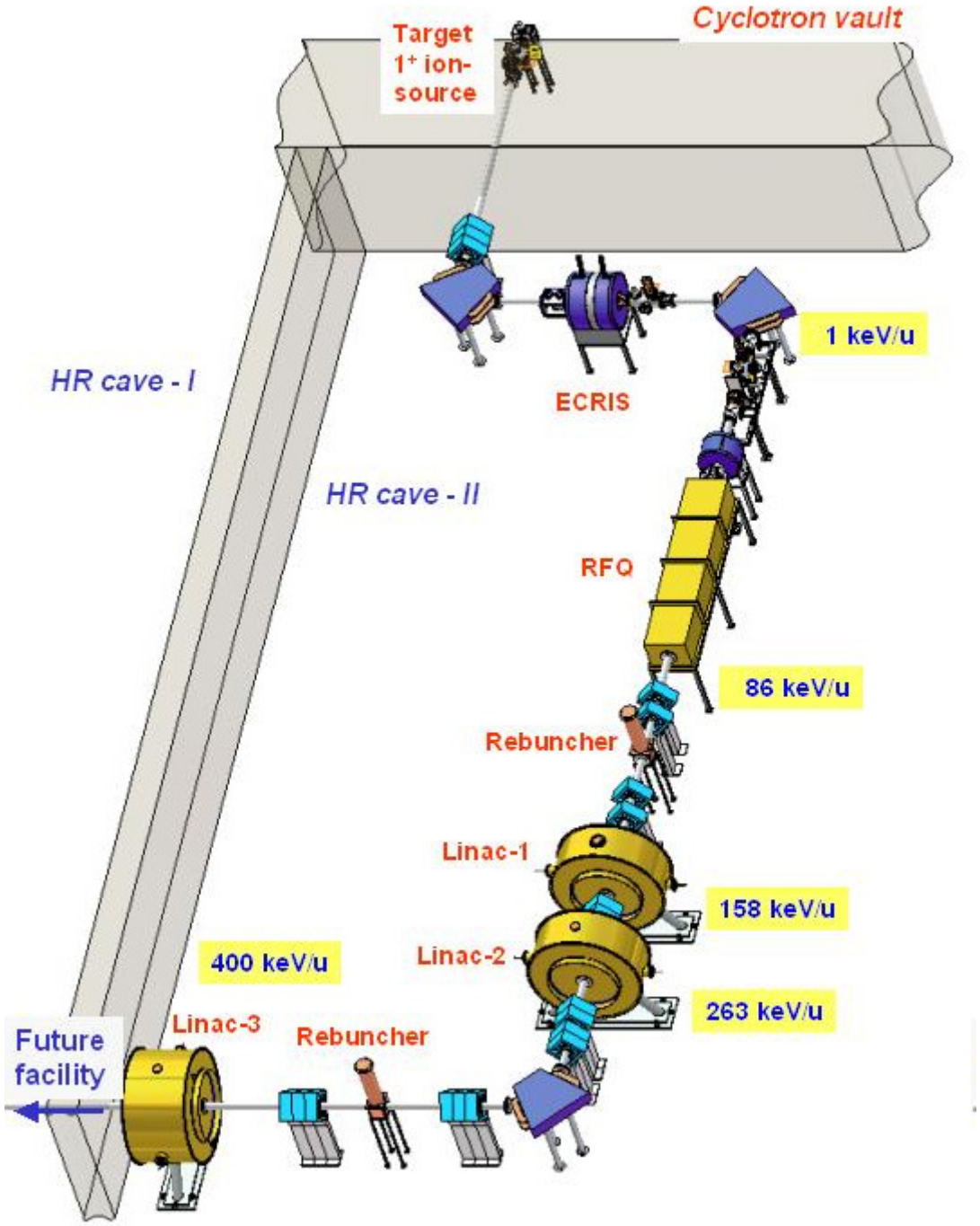
- Precise identification of the key nuclei contributing to the decay heat in the Th-U fuel cycle.
- Identification of nuclei for which TAGS measurements are needed for that and study the feasibility of their production and measurement in India.
- Active Participation in similar measurements elsewhere and collaboration with the experts in the field to gain experience.

Facilities at VECC, Kolkata

- Room temperature AVF cyclotron capable of delivering protons and alpha beams up to about 20 MeV and 60 MeV respectively. This may be used to produce and study some of the important nuclei listed e.g using $(\alpha,X)\gamma$ reaction.
- A low energy (up to few 100 keV/A) RIB facility (ISOL type) is coming up.
- A K=500 superconducting cyclotron capable of delivering heavy ion beams of up to about 60 MeV/A is coming up shortly.
- A set up for high resolution gamma ray spectroscopy including segmented LEPS detectors exist. A He-jet system exists which has been used earlier to study the cross section of fission products. There is a plan to procure a large NaI detector for TAGS measurement.
- BaF2 array (160 detectors)
- New facilities coming up: neutron array (TOF and multiplicity), DSSD based charged particle array.

VECC RIB

ISOL type



Conclusions

- **Nuclear data Centre of India is coming up.**
- **One of the main activity of the NDCI would be the calculations of decay heat related to Th-U fuel cycle and TAGS measurement.**
- **There are interest, need and resources to set up a facility for the TAGS measurements in India.**
- **The short term goal is to identify the nuclei of interest for the TAGS measurement and to collaborate with the experts in the field not only to gain experience but take responsibility of studying a few nuclei.**
- **In the long term we plan to set up a TAGS measurement facility in India preferably based at VECC, Kolkata.**