WPEC/SG-46 nuclear data target accuracies
MYRRHA

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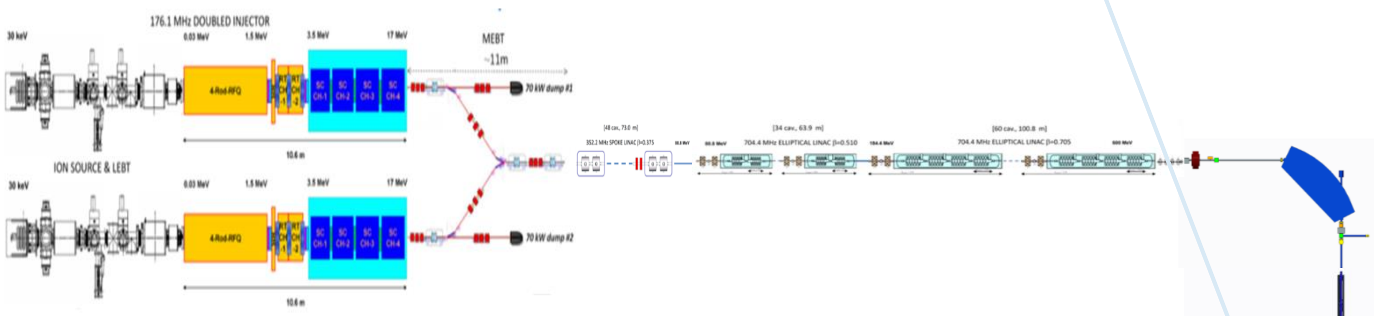
MYRRHA = Accelerator Driven System (ADS)

Construction of Accelerator-Driven System (ADS) consisting of

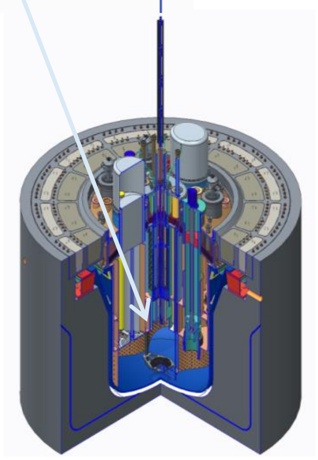
- A 600 MeV – 2,5 mA to 4,0 mA proton linear accelerator
- A spallation target/source
- A Lead-Bismuth Eutectic (LBE) cooled reactor able to operate in subcritical & critical mode

Accelerator	
particles	protons
beam energy	600 MeV
beam current	2.4 to 4 mA

Target	
main reaction	spallation
output	$2{\cdot}10^{17}$ n/s
material	LBE (coolant)

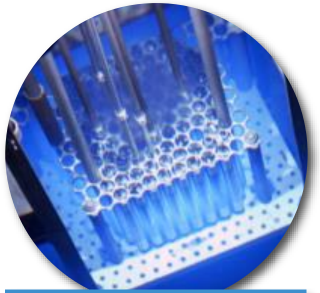


Reactor	
power	65 to 100 MW_{th}
k_{eff}	0.95
spectrum	fast
coolant	LBE



Source: SCK CEN MYRRHA Project Team

MYRRHA application portfolio



Fission GEN IV

Fusion

Spent Nuclear Fuel

Multipurpose
h**Y**brid
Research
Reactor for
High-tech
Applications

Fundamental research

Radio-isotopes

Small Modular Reactor

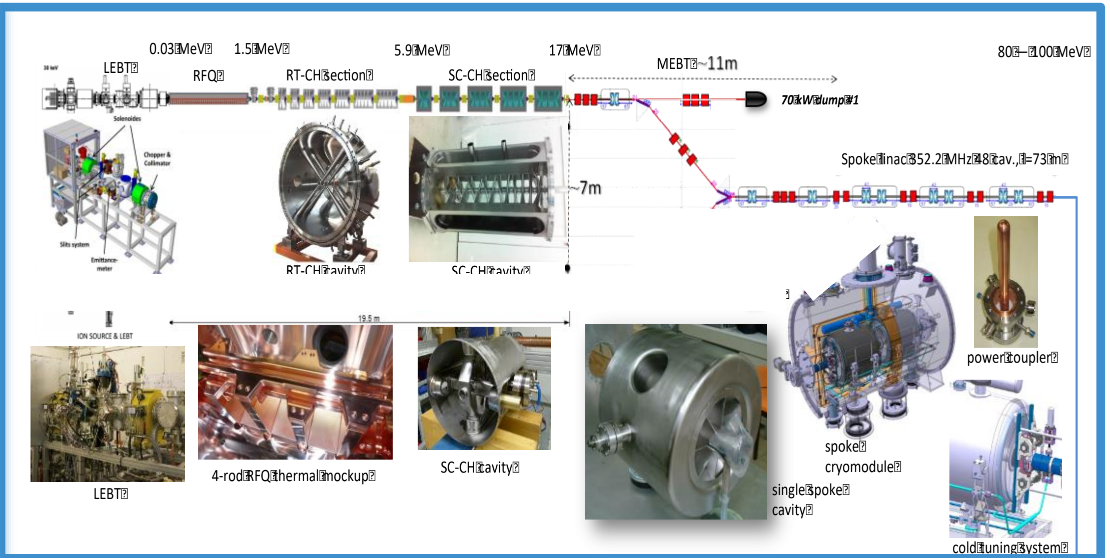
Source: SCK CEN MYRRHA Project Team

MYRRHA’s phased implementation strategy

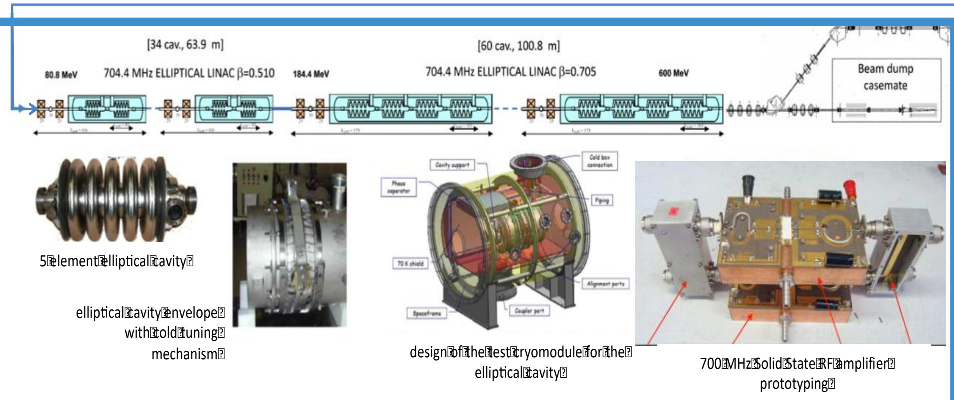
Benefits of phased approach:

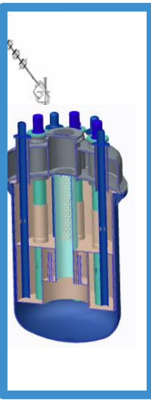
- Reducing technical risk
- Spreading investment cost
- First R&D facility available in Mol end of 2026

Phase 1 – 100 MeV



Phase 2 – 600 MeV

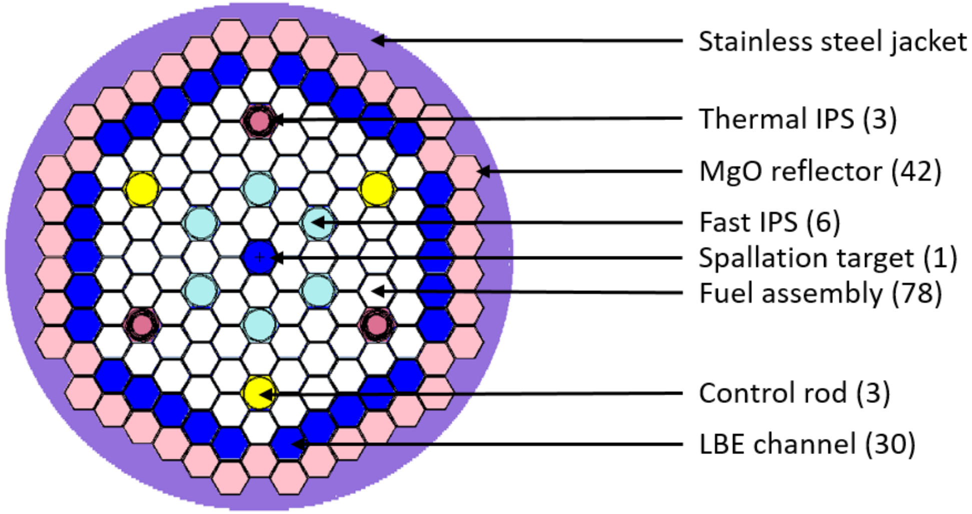


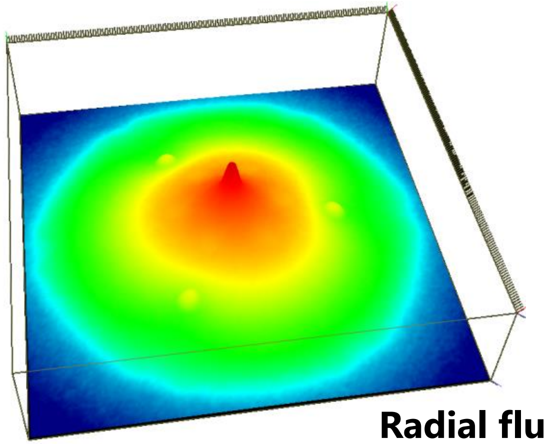


Phase 3 – Reactor

New MYRRHA core design revision v1.8

- Focus on the subcritical core
- Operation by control rods instead of by the beam to reduce thermal stresses on the beam window
- Lower operating temperatures
  - $T_{clad}|_{peak}$=400 ^{0}C
- Reduced core size
  - $\sim 20\ cm$ smaller core diameter
- Relaxed limits on radiation damage on the core barrel
  - 10 dpa in 10 calendar years

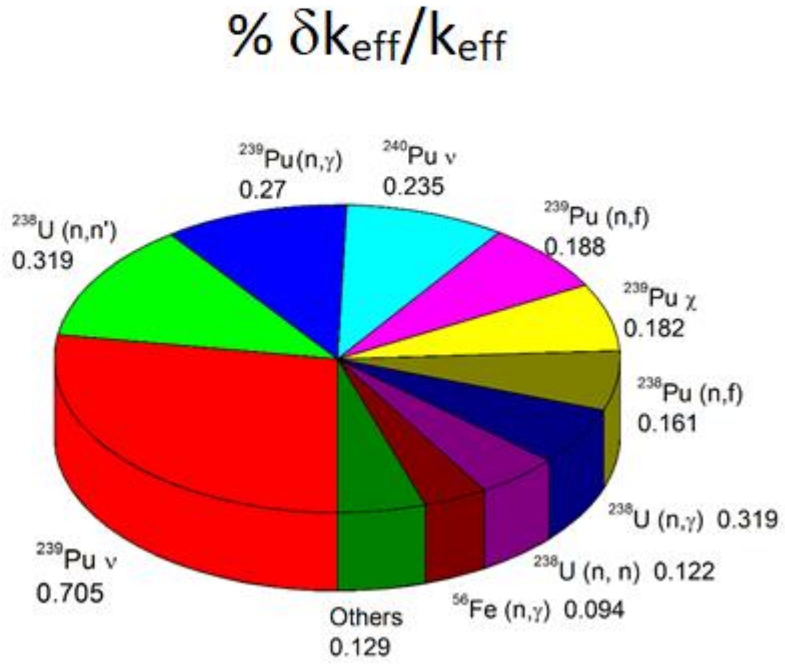




Radial flux distribution

Criticality uncertainties (results of CHANDA)

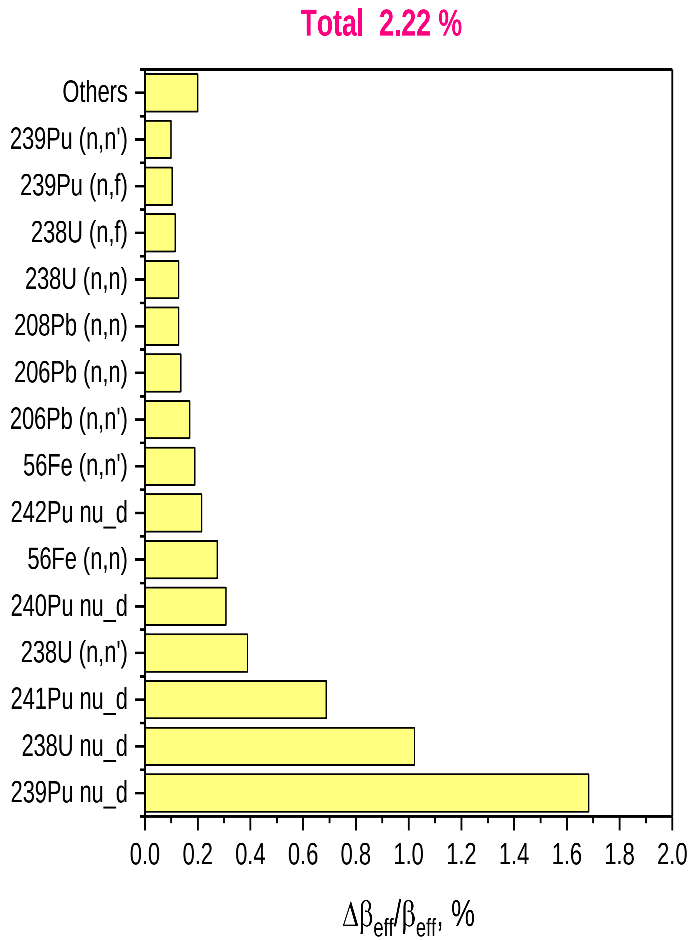
K_{eff} uncertainty



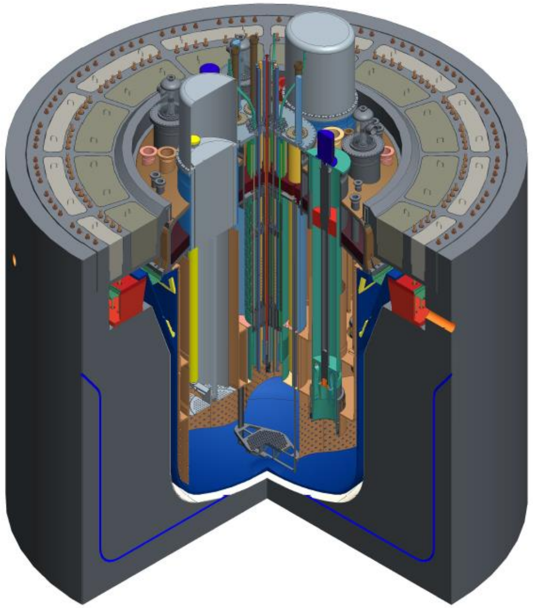
Total $\frac{\delta k_{eff}}{k_{eff}} = 0.945\% \sim 1000$ pcm

Target accuracy : $\frac{\delta k_{eff}}{k_{eff}} \sim 300\ pcm$ ($<\beta_{eff}$)

β_{eff} uncertainty



Priority list

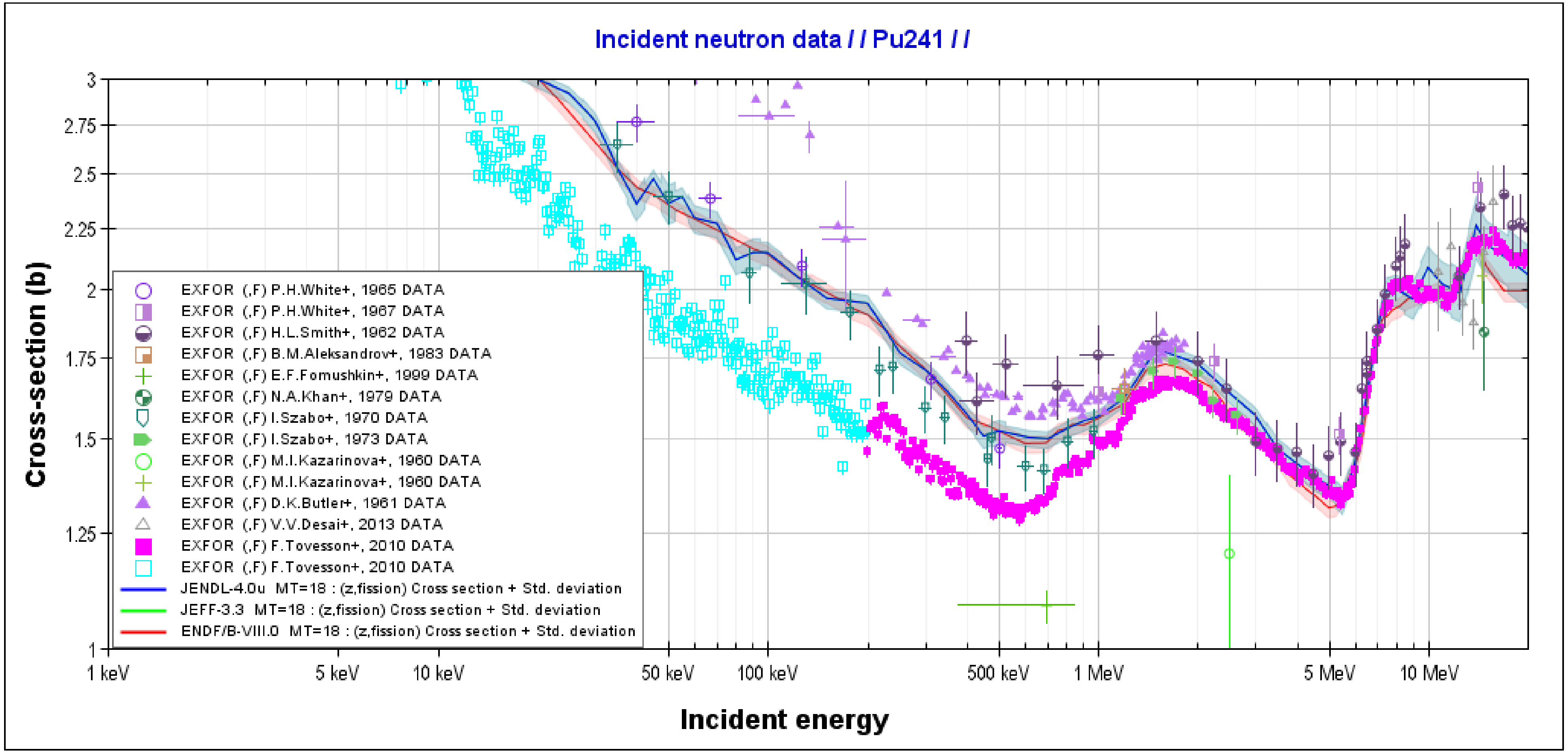


Increase of confidence by improving the uncertainties is needed for

- ^{239}Pu: (n,γ) both in resonance and fast energy region, (n,f) fast, χ and $\bar{\upsilon}$ fast
- ^{238}U: (n,n') fast, (n,γ) resonance and fast, (n,n) resonance and fast
- ^{240}Pu: $\bar{\upsilon}$ fast
- ^{238}Pu: (n,f) both resonance and fast
- ^{56}Fe: (n,γ) both resonance and fast

Special attention to ^{209}Bi (n,γ) and (n,n'), ^{208}Pb (n,n) and (n,n') and ^{235}U, (n,f) and (n,γ) due to flexibility of providing neutron spectrum in various core regions

Challenges: Pu-241 example



MYRRHA Performance and TAR

Besides criticality safety of MYRRHA ADS, let's have a look on the performance (and burnup)- key parameter here is power (proportional to number of fissions)

$$P \approx \frac{IQ_f S}{(1-k_{eff})}$$

$I = beam\ current$

$Q_f = average\ energy\ release\ per\ fission$

$S = number\ of\ neutrons\ source\ to\ fission\ (per\ incident\ proton)$

- S has uncertainty at level of 10% [Ann. Nucl. En. 120 (2018) 207-218] –no proton/neutron data files from Pb and Bi @600 MeV
- Target uncertainty on k_{eff} should be such that does not significantly increase total uncertainty on the power.
- For example, taking k_{eff} = 0.95 and S=10 n/p:

$\Delta k_{eff}/k_{eff}$, %	$\Delta P/P$, %
1	22.3
0.5	14.1
0.3	11.7
0.2	10.8

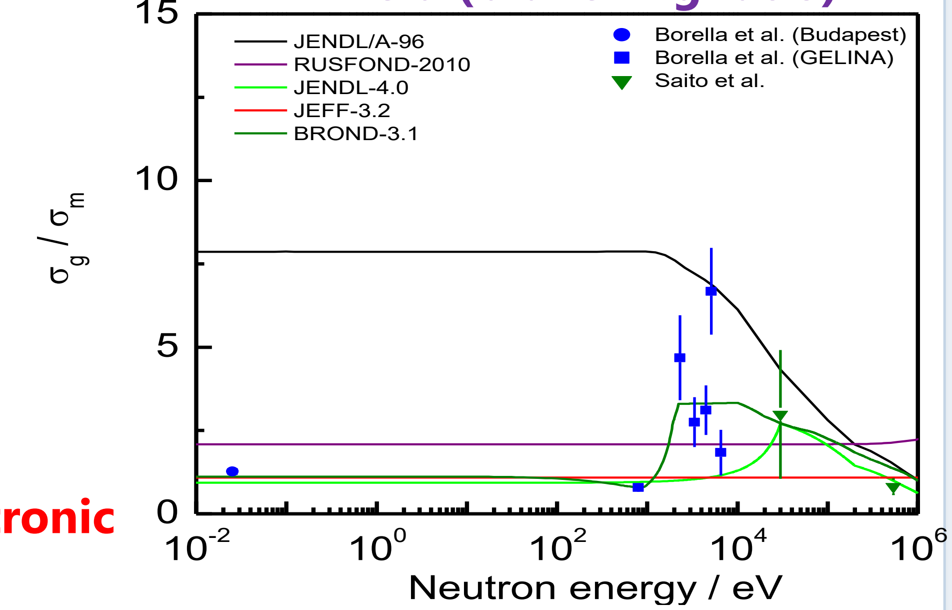
- Current target requirements of 0.3% $\boldsymbol{\Delta k_{eff}/k_{eff}}$ **seem OK for MYRRHA also from the viewpoint of performance and burnup**

Source:

Polonium-210 in MYRRHA

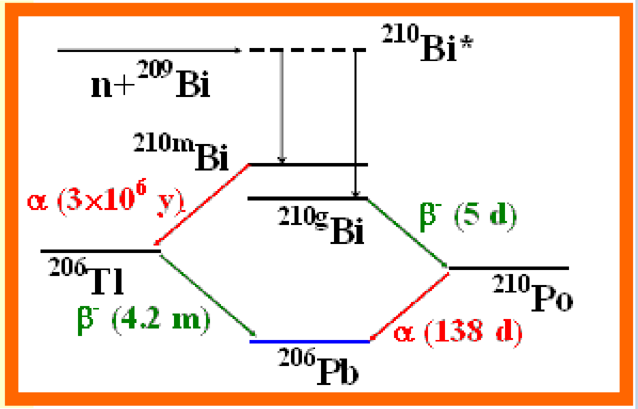
- Produced by neutron capture
- Assuming no release, during 1 irradiation cycle 5.5e+4 TBq of ^{210}Po is produced from ~7600 ton of LBE (´~ 350 g)
- Decay heat: 48 kW of LBE pool
- Normal operation: partially migrates in cover gas
- Failures or leaks: evaporation in contact with ambient air, formation of highly volatile species in presence of moistures and/or hydrogen

Yield (branching ratio)



Accurate prediction of ^{210}Po production by neutronic codes is needed

- New entry added to the NEA HPRL
- Experimental programme to measure BR and total neutron capture (JRC and SCK CEN)
- First measurements in 2019 at J-PARC/ANNRI (Japan)
- Neutron transmission and capture measurements at GELINA (JRC) in 2020



Conclusions

- For criticality safety, we need to reduce the keff uncertainty from ~1000 to 300 pcm (< 1 β_{eff})
- For shielding design for MINERVA, reliable proton-induced data, especially for light nuclides, are required
- For waste management, one of key points is accurate prediction of Po-210 production: an experimental programme has been launched with ultimate goal to produce new JEFF evaluation for Bi-209
- Research continues within SANDA
  - WP5.1 homogenized core model for v1.8

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