

Test

Upper continental crust composition¹
⁴⁰Ca: 2.9% ; ³⁹K: 3.6%

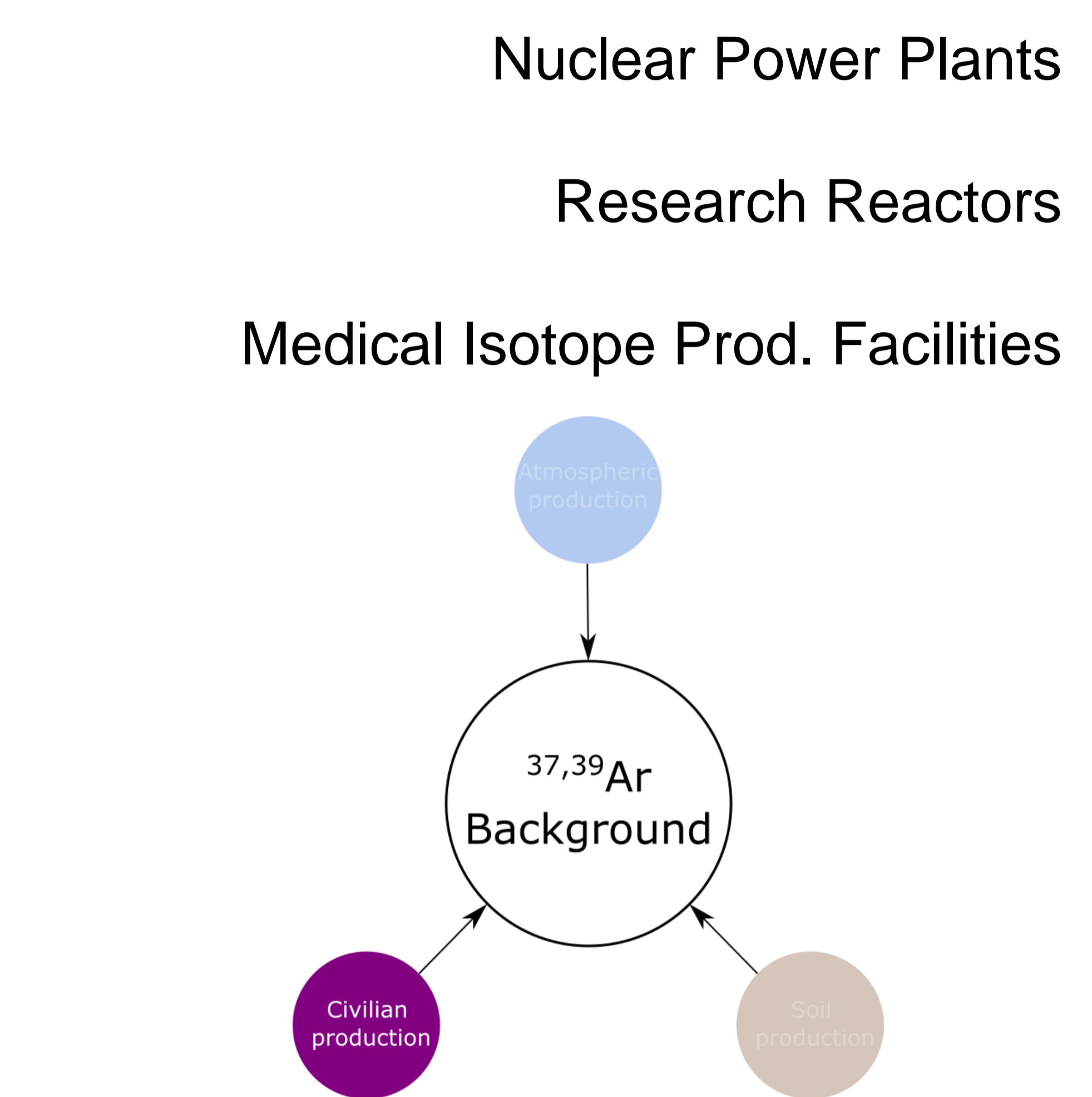
Projected Activity per kilotons of TNT²
³⁷Ar: ~10¹³ Bq ; ³⁹Ar: ~10¹² Bq

Study Case: The FRM-II Research Reactor

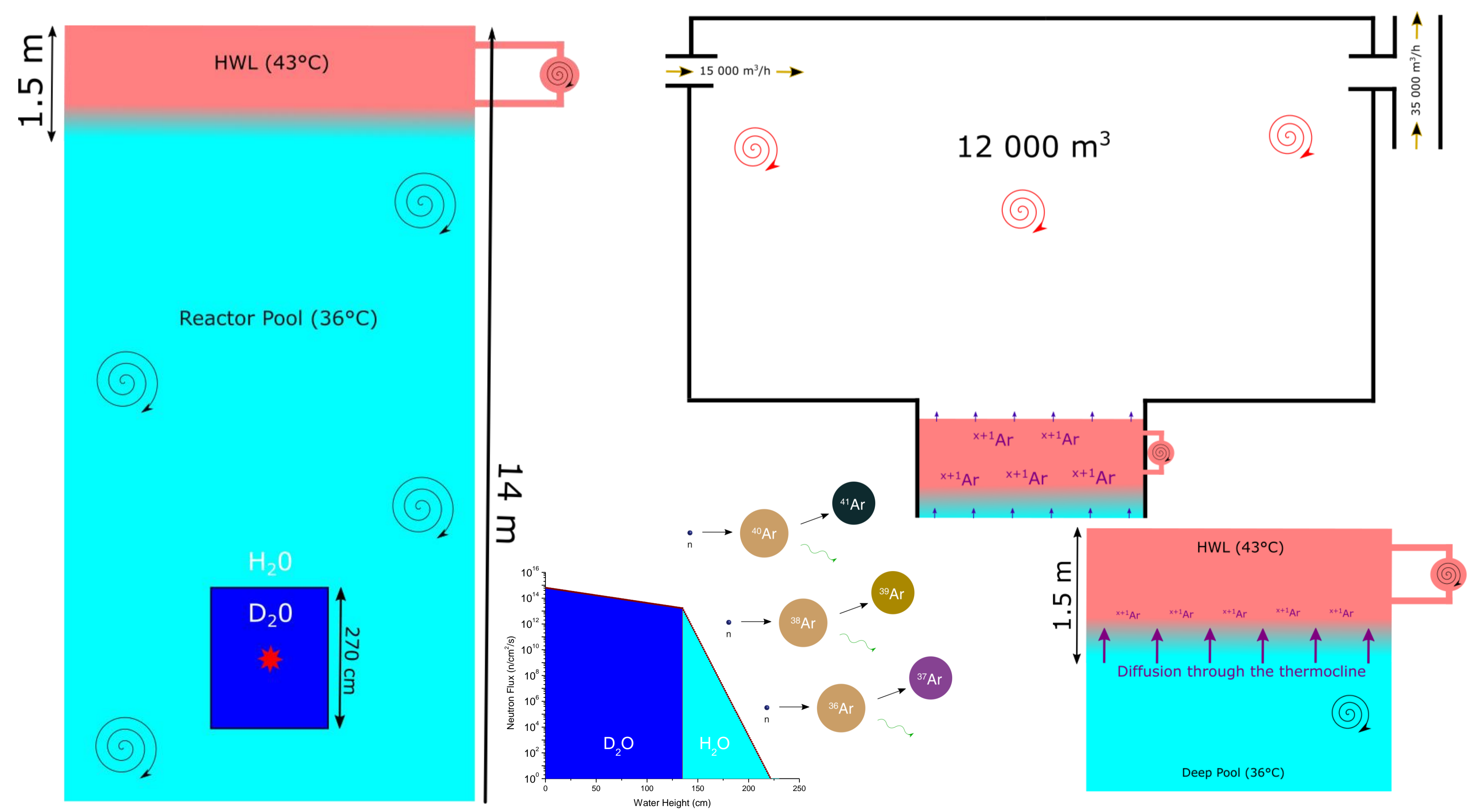
20 MWth; 93% ²³⁵U; 8·10¹⁴ n/cm²/s; D₂O moderator; H₂O coolant; 60 days cycle; 240 operating days; Located in Munich (Germany)

Objective: Characterization of ^{37,39}Ar

Background from Civilian sources

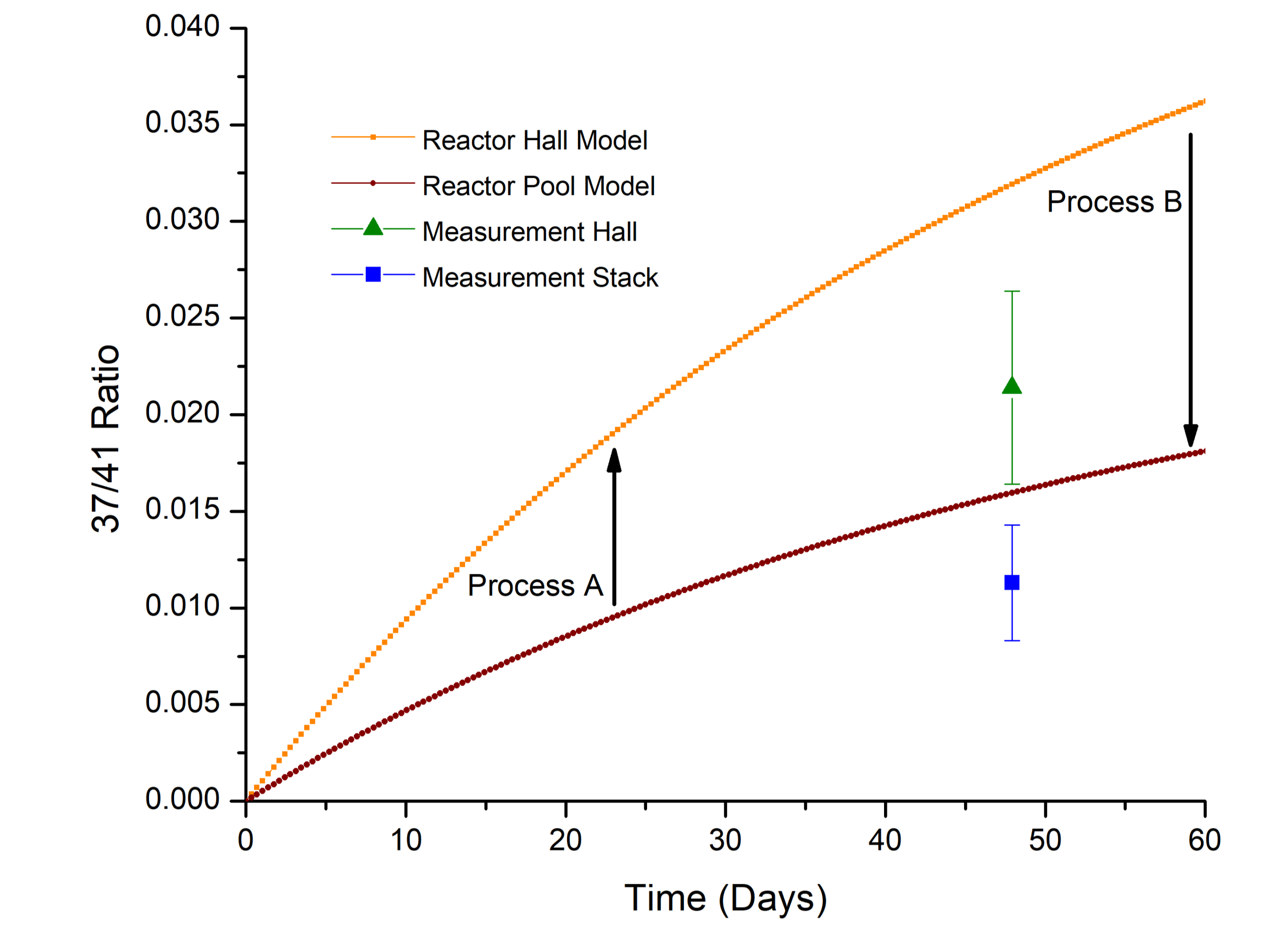


Modeling Argon Production Mechanism



Using ⁴¹Ar as a proxy

Ratio	Reactor Pool*	Reactor Hall	Reactor Stack
³⁷ / ₄₁ (x 10 ⁻³)	16.7	21.4 ± 0.05	11.3 ± 0.03



Discussions

Process A

- Diffusion through the thermocline
- With l the thermocline length

$$\propto \exp\left(-l/\Delta_i\right) \text{ with } \Delta_i = \sqrt{\frac{D}{\lambda_i}}$$

Process B

- With ν the ventilation mixing parameter

$$\propto \frac{\lambda_{37}}{\lambda_{37} + \nu} \text{ with } \nu < 10^{-6} \text{ s}^{-1}$$

Results for Activity Concentrations

Radionuclides	Reactor Stack (Bq/m ³)	Enrichment*	Release rate (Bq/h)
³⁷ Ar	38.7 ± 0.15	2.48·10 ⁴	2.66·10 ⁶
³⁹ Ar	0.132 ± 0.024	7.89	8.40·10 ³

Ratio	This Study	PWR ³	BWR ³
³⁷ / ₃₉	(2.93 ± 0.53)·10 ²	>1.6·10 ³	9·10 ²

*Atmospheric⁴ ³⁷Ar: 1.56·10⁻³ Bq/m³
 *Atmospheric⁴ ³⁹Ar: 1.67·10⁻² Bq/m³

Discussions

³⁷/₃₉ ratio ranging from 10² ~10³

$$R_{37/39}(t) < \frac{\lambda_{37}}{\lambda_{39}} = 2.81 \cdot 10^3$$

Conclusions

- ⁴¹Ar routing monitoring can be used to assess Ar-37 emission.
- The ratio ³⁷/₄₁ is affected by diffusion and removal through ventilation
- For nuclear facilities as well as for UNE the ³⁷/₃₉ ratio is a function of the decay constants
- ³⁹Ar can be use as a signature for legacy nuclear test sites

References

¹Rudnick, Roberta & Gao, Sally. (2003). Composition of the Continental Crust. Treatise Geochem 3:1-64, Treatise on Geochemistry, 3. 1-64, 10.1016/B0-08-043751-6/03016-4.
²C. F. Smith, Jr., UCRL-50635, "Project Gasbuggy Gas Quality Analysis and Evaluation Program Tabulation of Radiochemical and Chemical Analytical Results"
³Matuszek, J., Paperiello, C., Kunz, C. Reactor Contributions to Atmospheric Noble Gas Radioactivity Levels. in *Noble Gases* 360-364 (1973).
⁴Loosli, H.H., Oeschger, H., 1968. Detection of ³⁹Ar in atmospheric argon. *Earth and Planetary Science Letters* 5, 191-198.