



Modeling of the AGR 3/4 PIE Experiments

July 2022

Changing the World's Energy Future

Adriaan Anthony Riet



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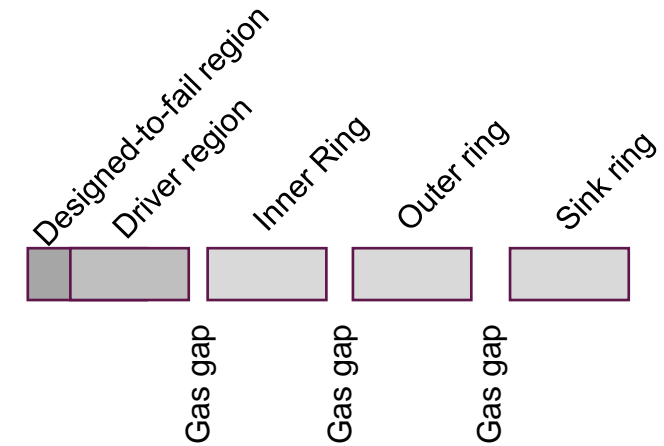
Introduction

- TRISO Fuel Accident Scenarios
 - Transport of Fission Products (FP) through modern nuclear-grade graphites is not well established
 - The AGR 3/4 experimental results need to be modeled to extract FP transport characteristics
 - A finite element model using graphite diffusivities from IAEA TECDOC-978 is compared against measured results

Finite Element Model

- Moose-based 1-D model
- Sorption modeled explicitly with the Freundlich sorption isotherm
- Time-dependent fission-product release
- Temperature at each interface set to a diffusion-weighted average of the time-dependent temperature at each interface (taking INL/MIS-15-35692 as a reference)

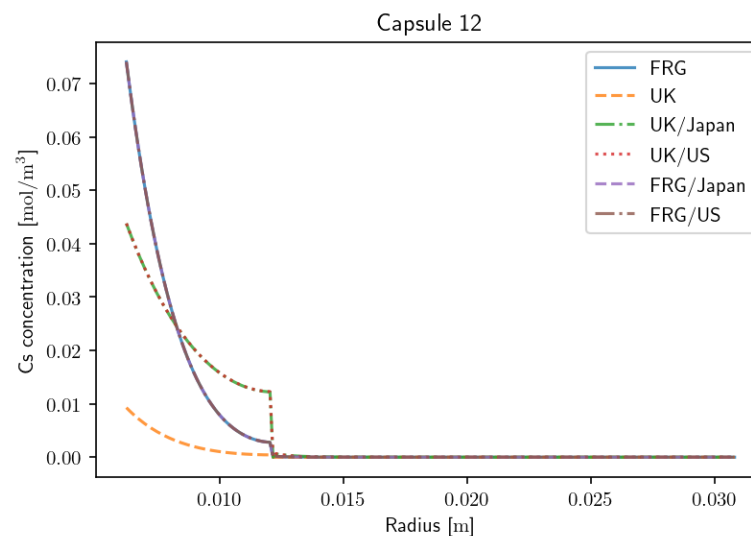
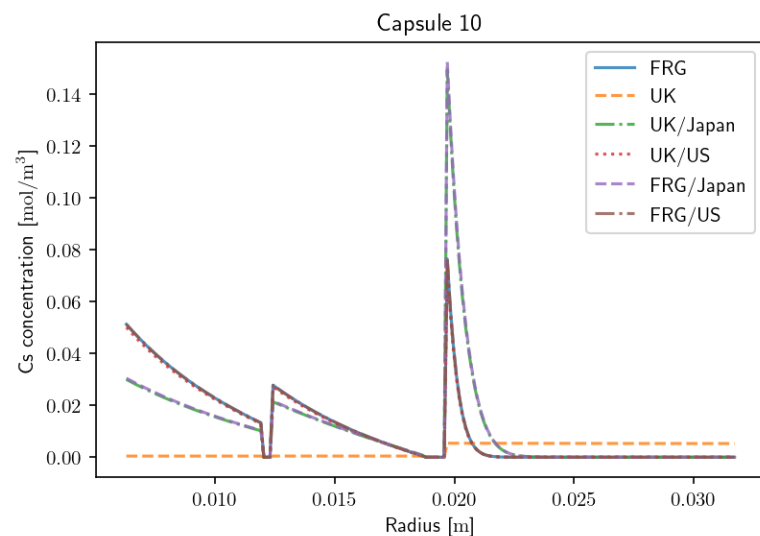
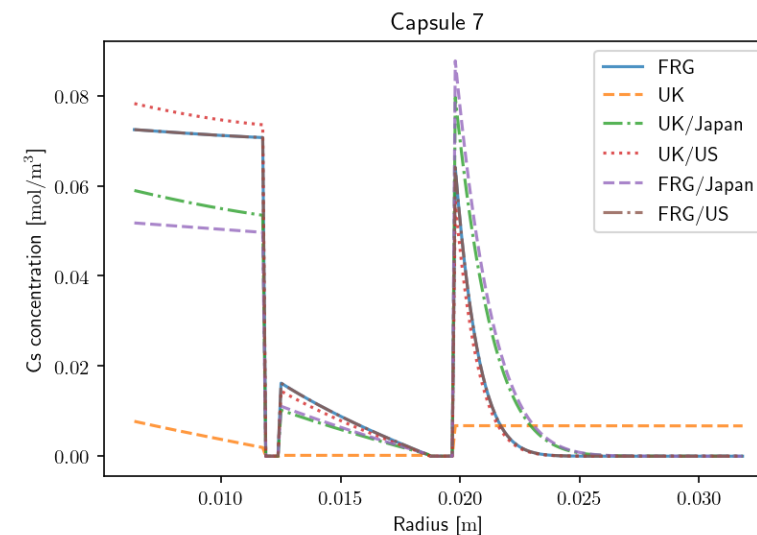
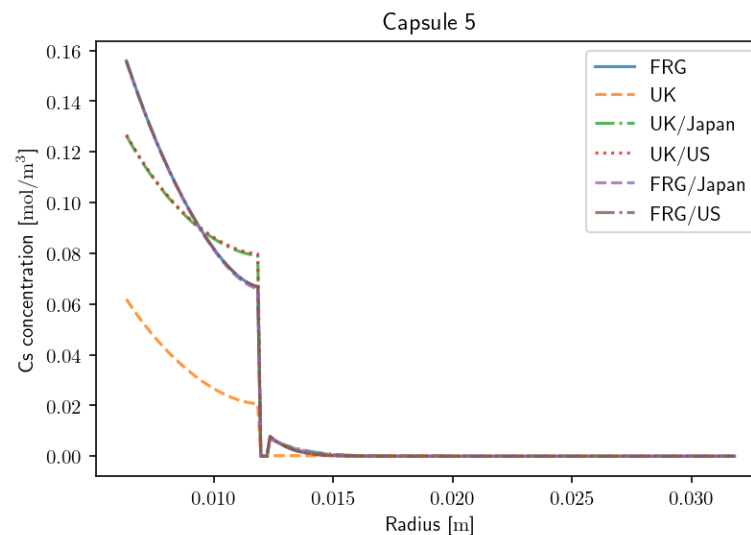
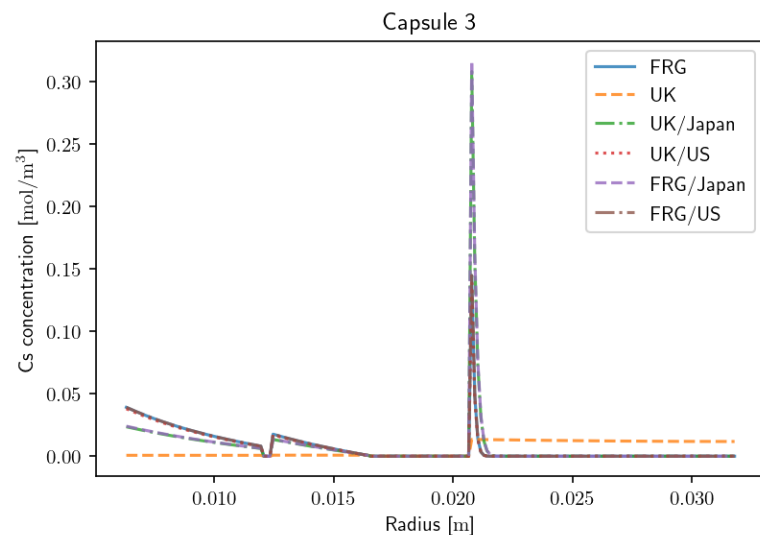
$$- T = \frac{\sum \left(D_0 \exp\left(-\frac{E_a}{RT(t)}\right) T(t) \Delta t \right)}{\sum \left(D_0 \exp\left(-\frac{E_a}{RT(t)}\right) \Delta t \right)}$$





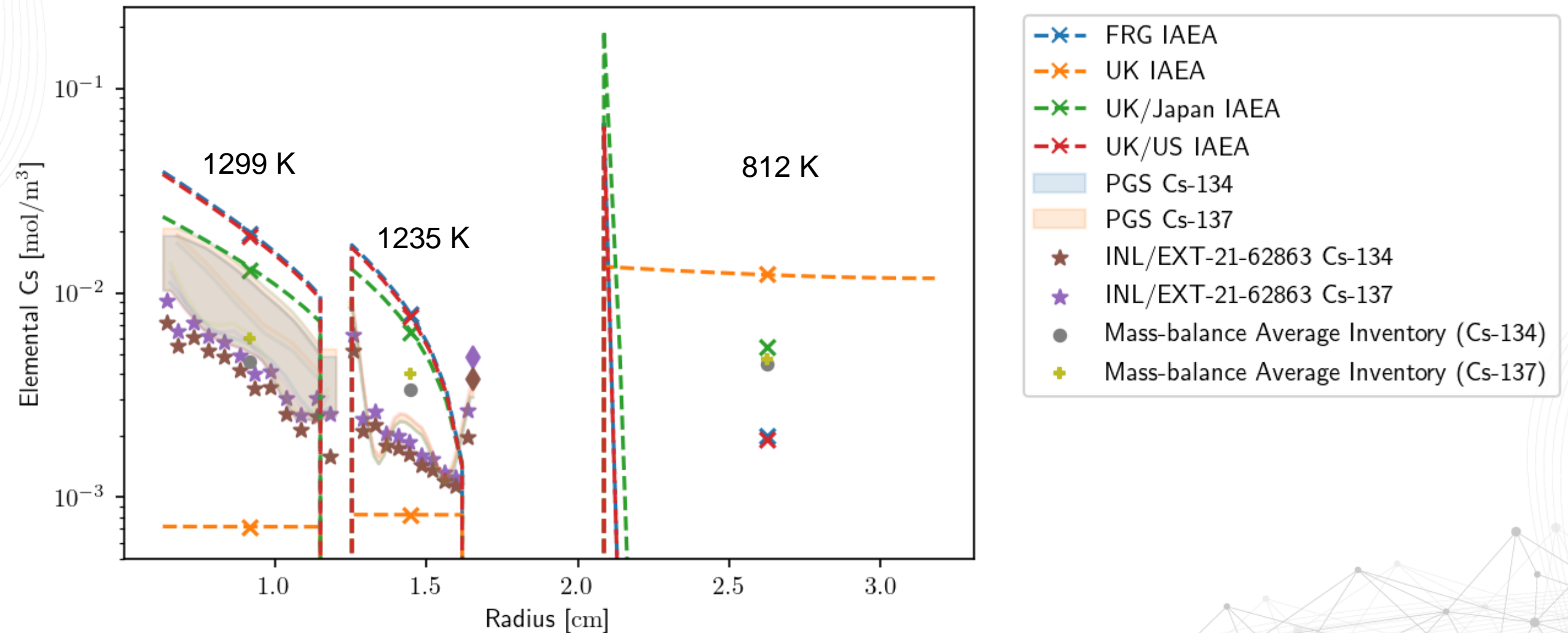
Cesium

Modeled Concentration Profiles From Previous Literature Values

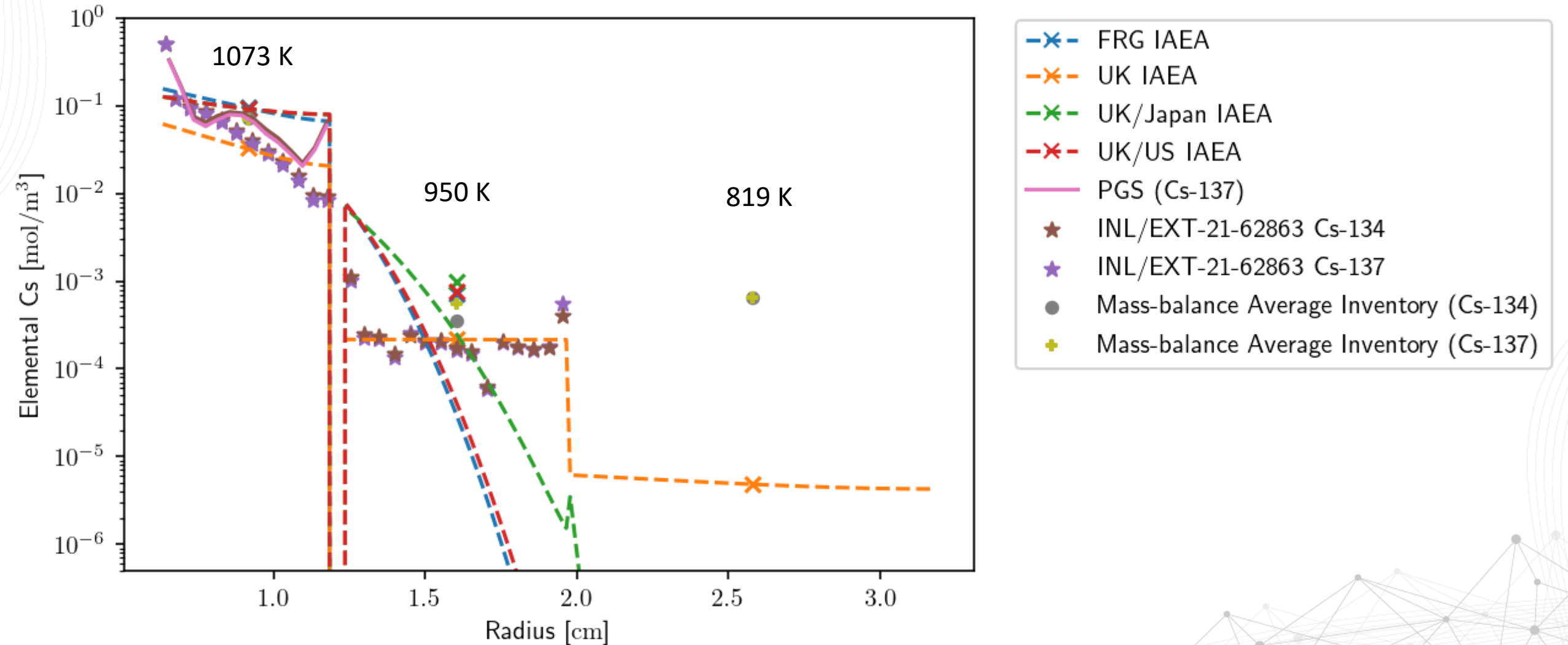


(IAEA TECDOC-978, 1997)

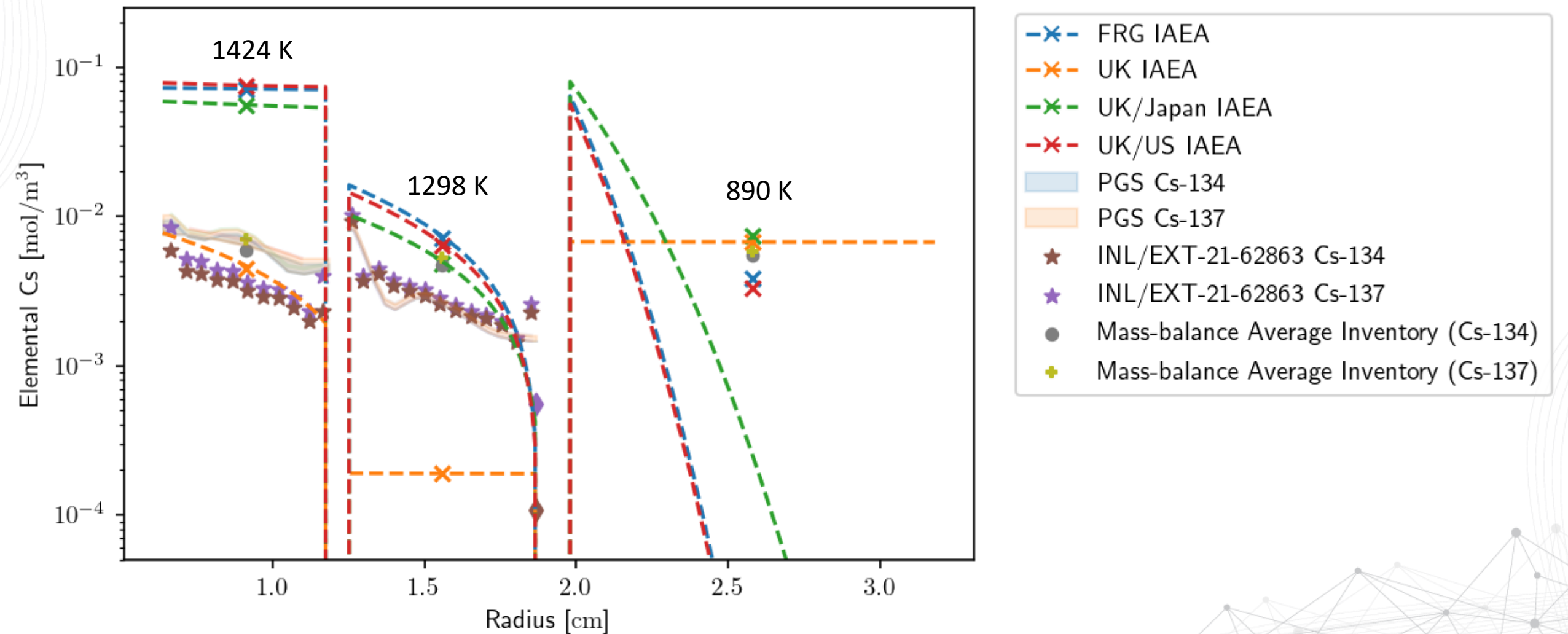
Literature Parameters vs Measurements, Capsule 3



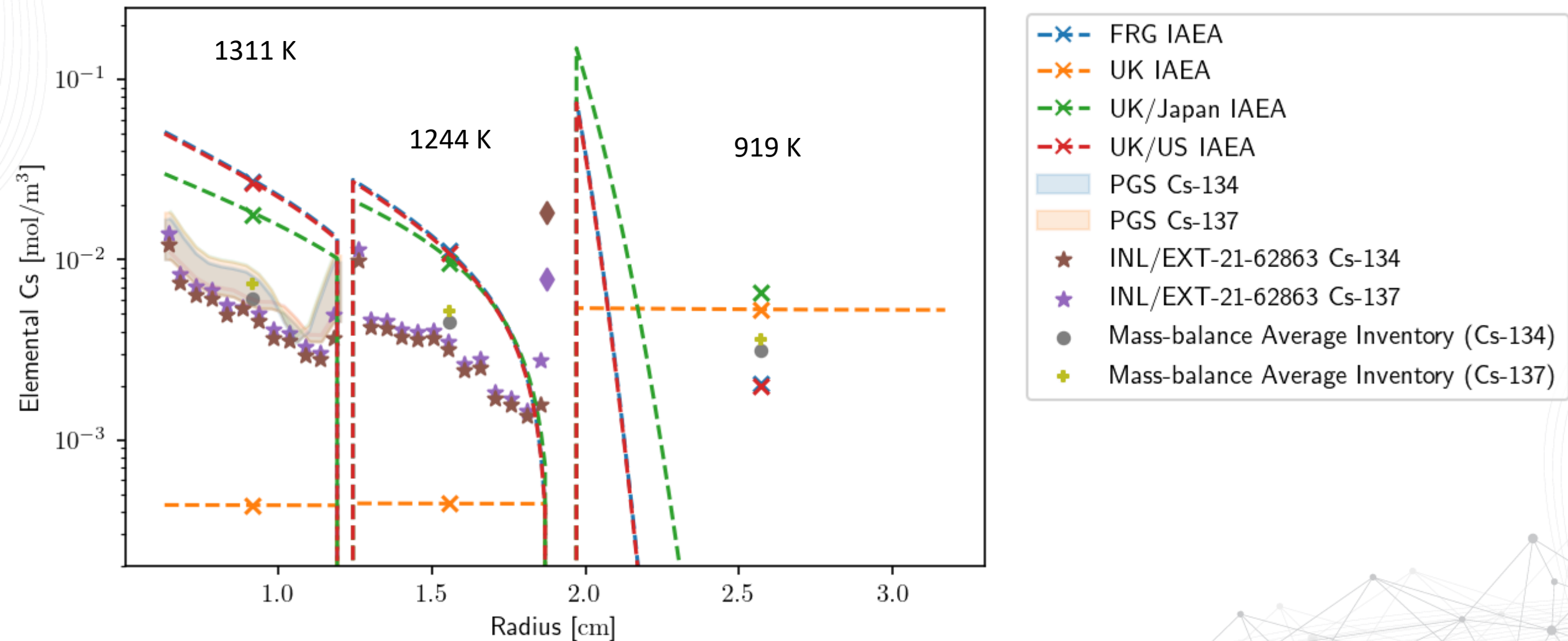
Literature Parameters vs Measurements, Capsule 5



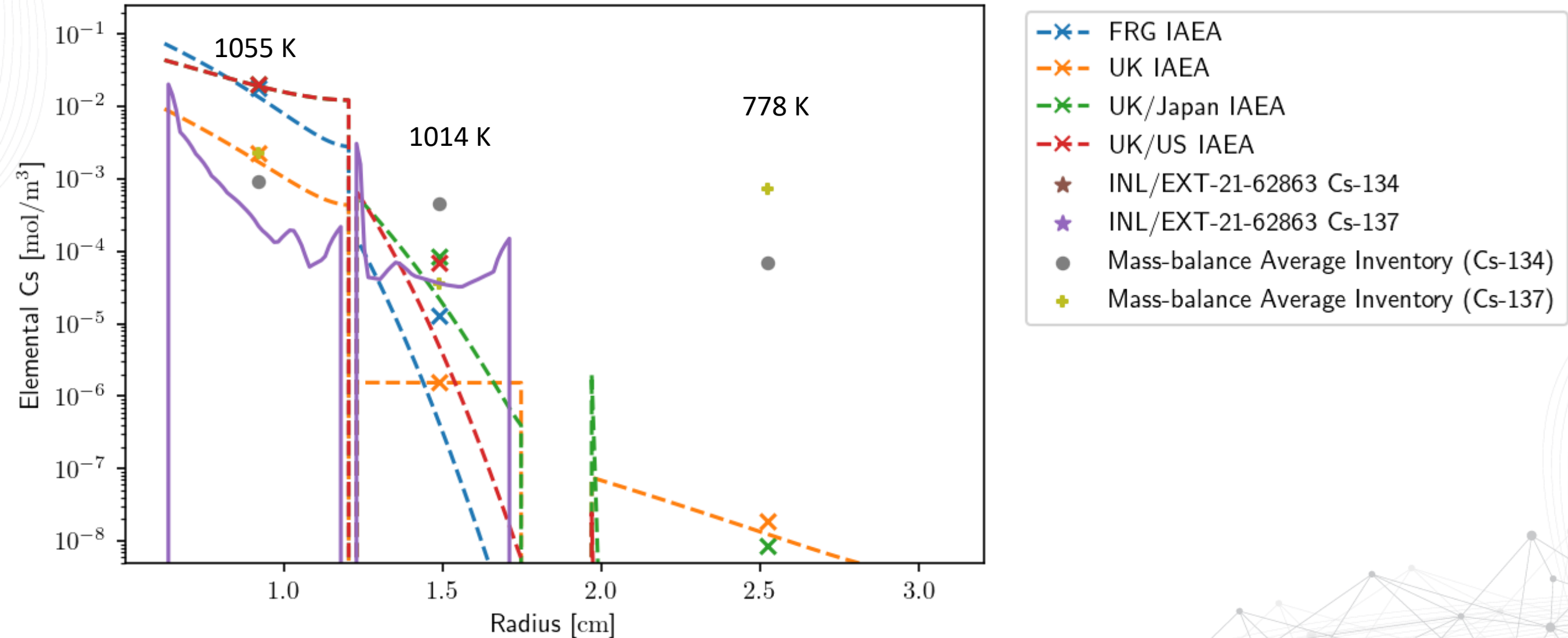
Literature Parameters vs Measurements, Capsule 7



Literature Parameters vs Measurements, Capsule 10



Literature Parameters vs Measurements, Capsule 12





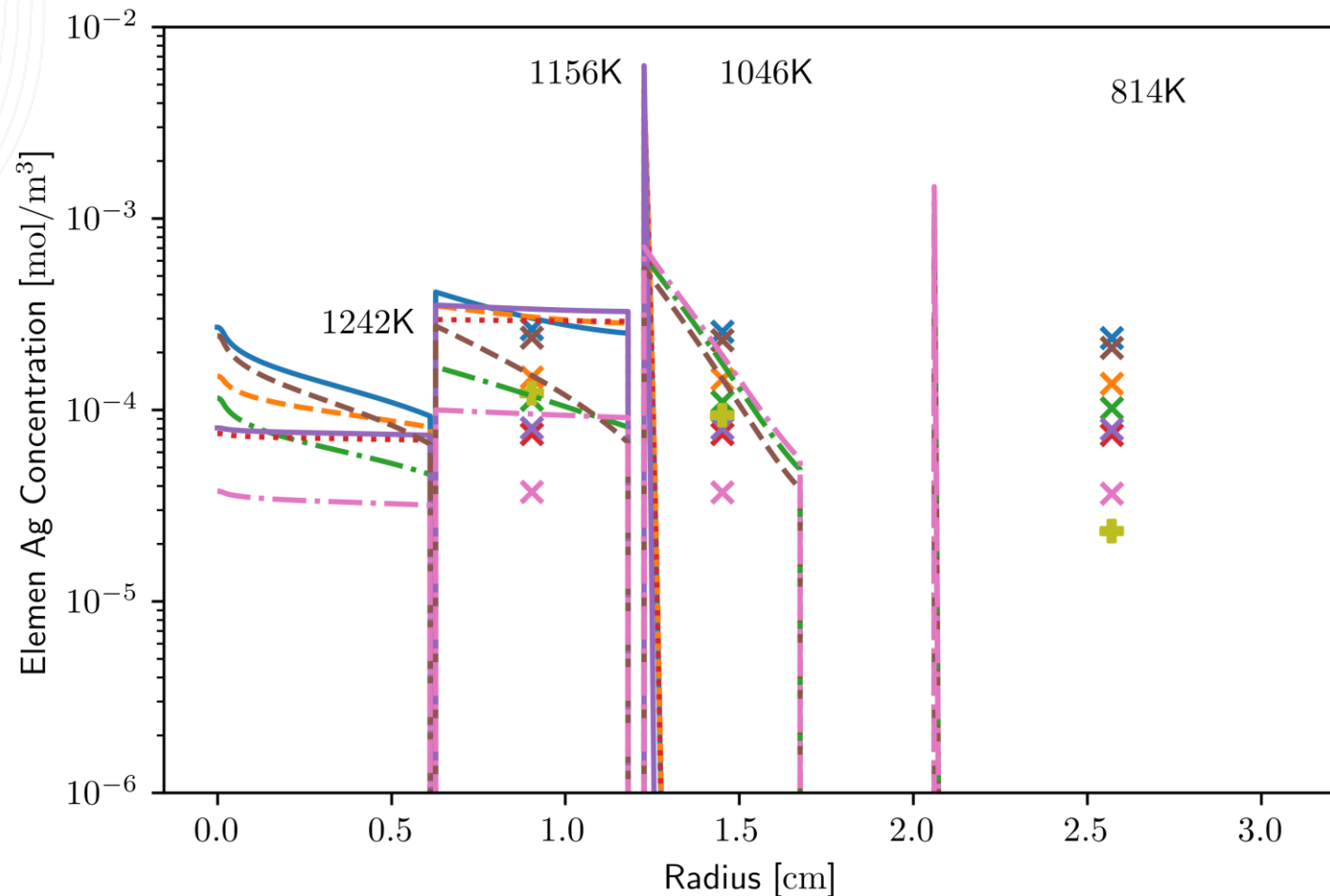
Cesium - Summary

- Observed diffusion of cesium through the rings can be explained by a diffusive transport model with the effective diffusivity in the range of historical literature values



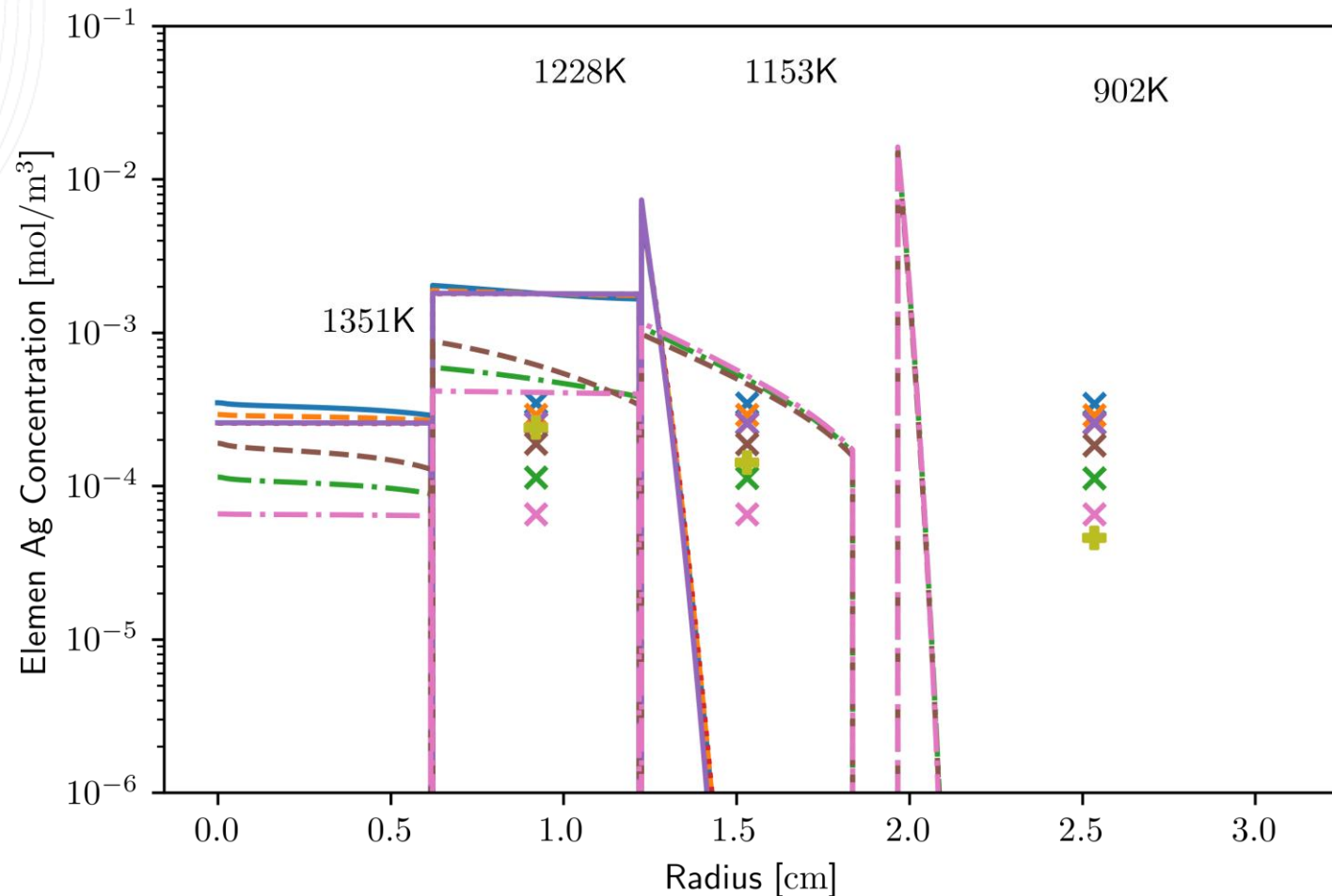
Silver (Ag-110m)

Literature Parameters vs Measurements, Capsule 1



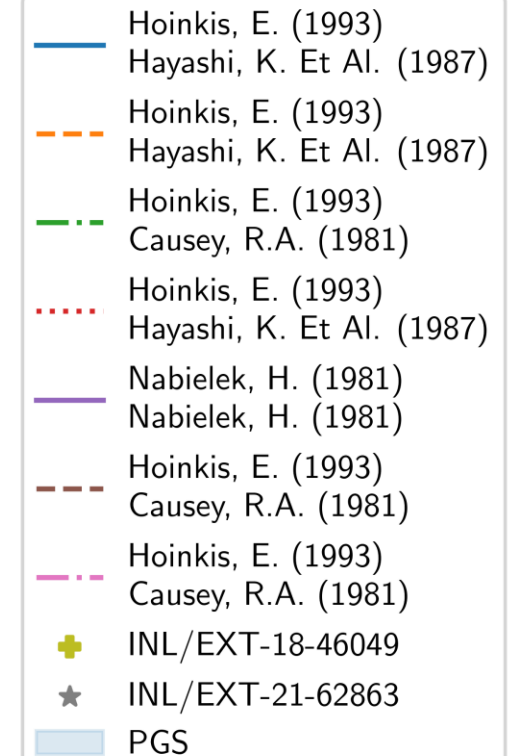
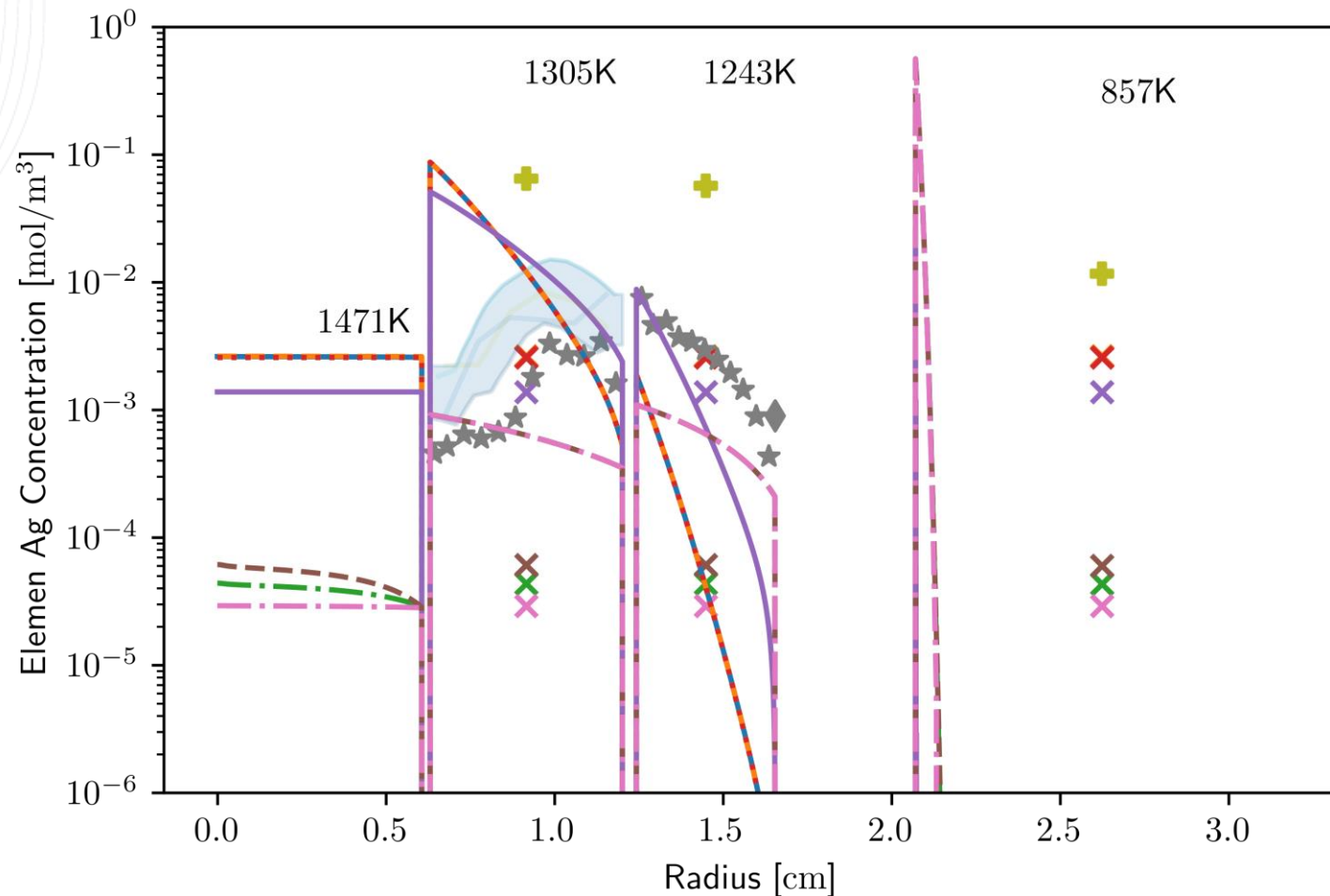
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- Causey, R.A. (1981)
- INL/EXT-18-46049
- PGS

Literature Parameters vs Measurements, Capsule 2

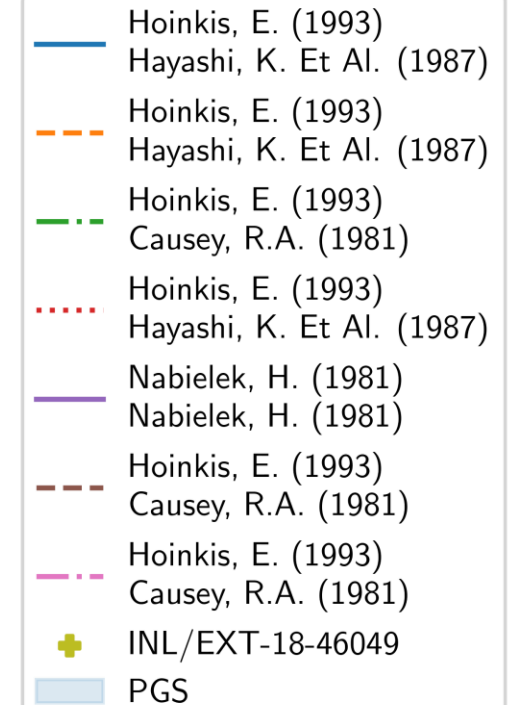
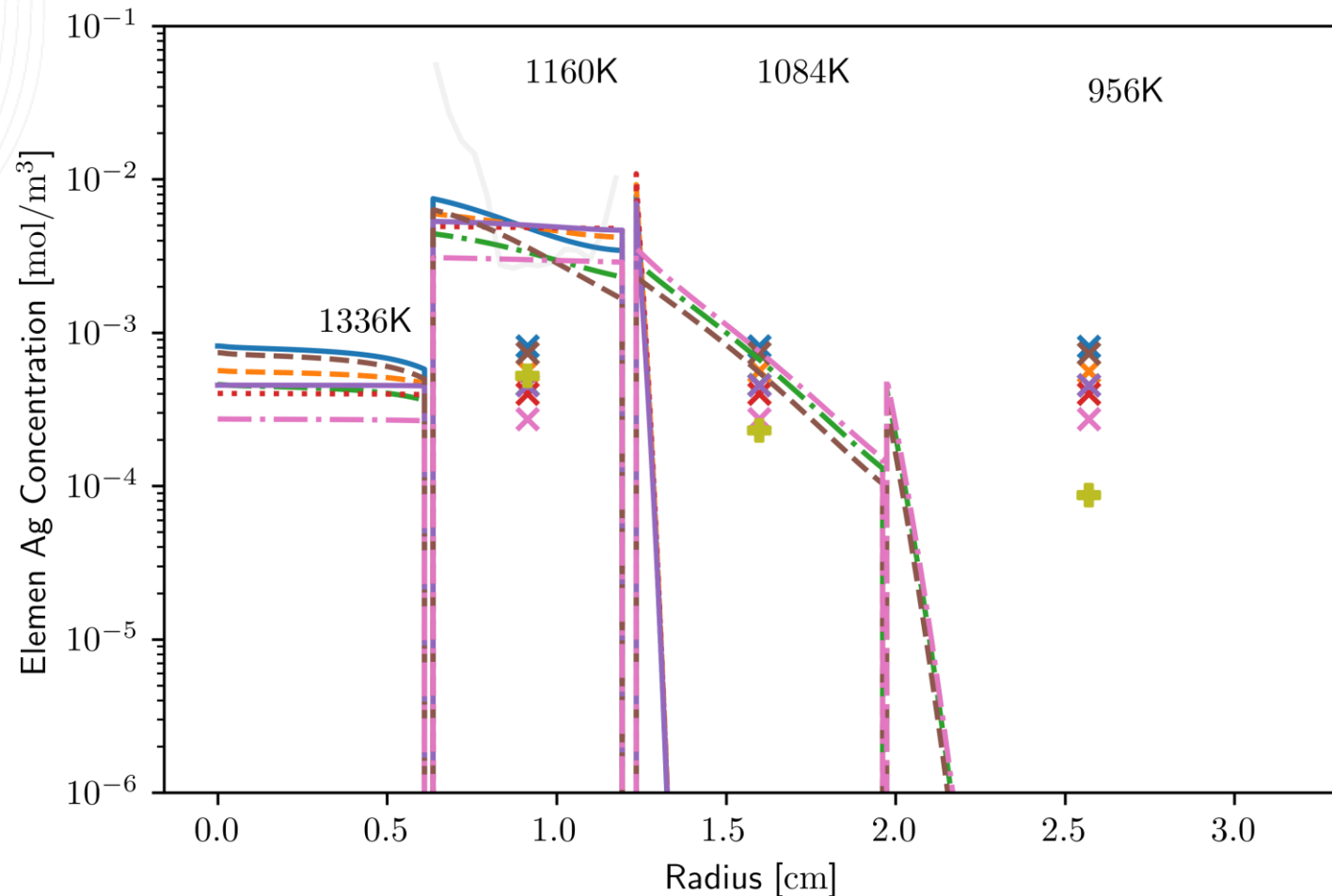


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- PGS

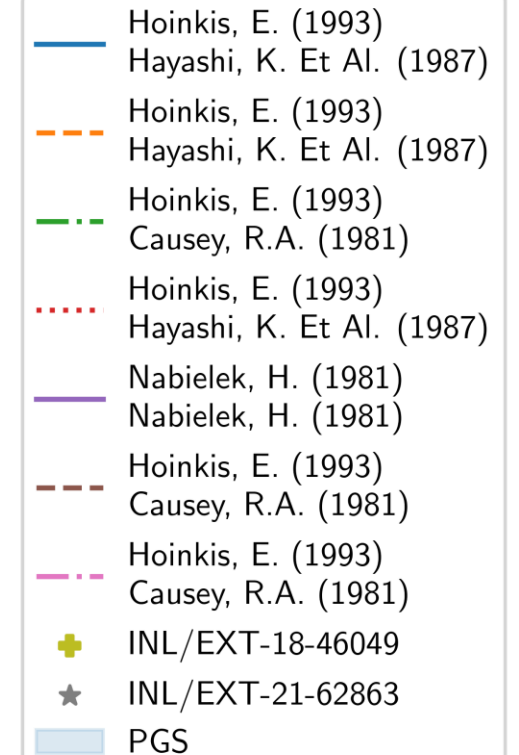
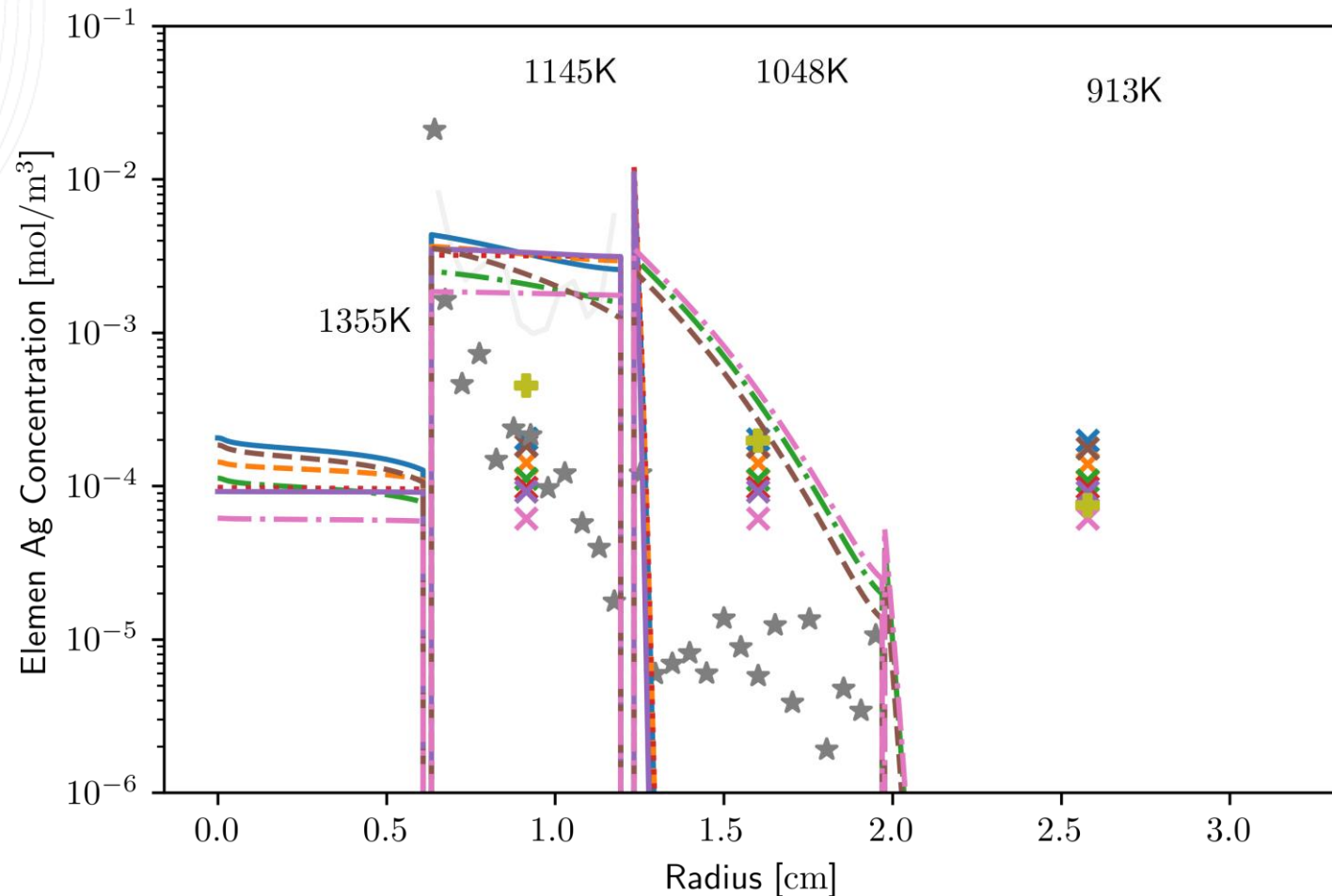
Literature Parameters vs Measurements, Capsule 3



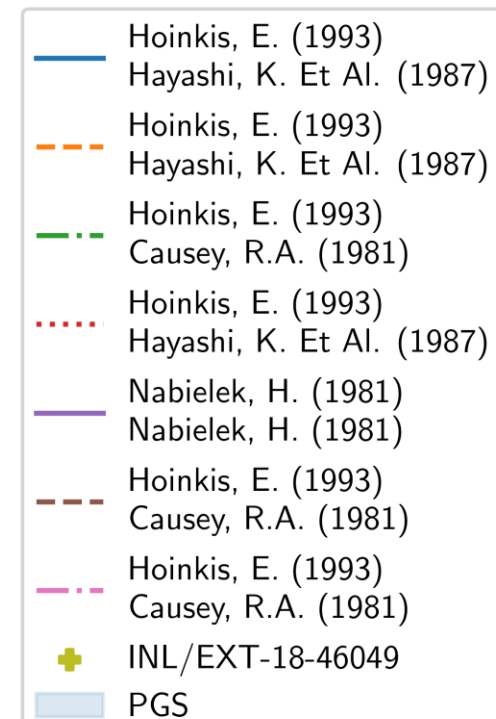
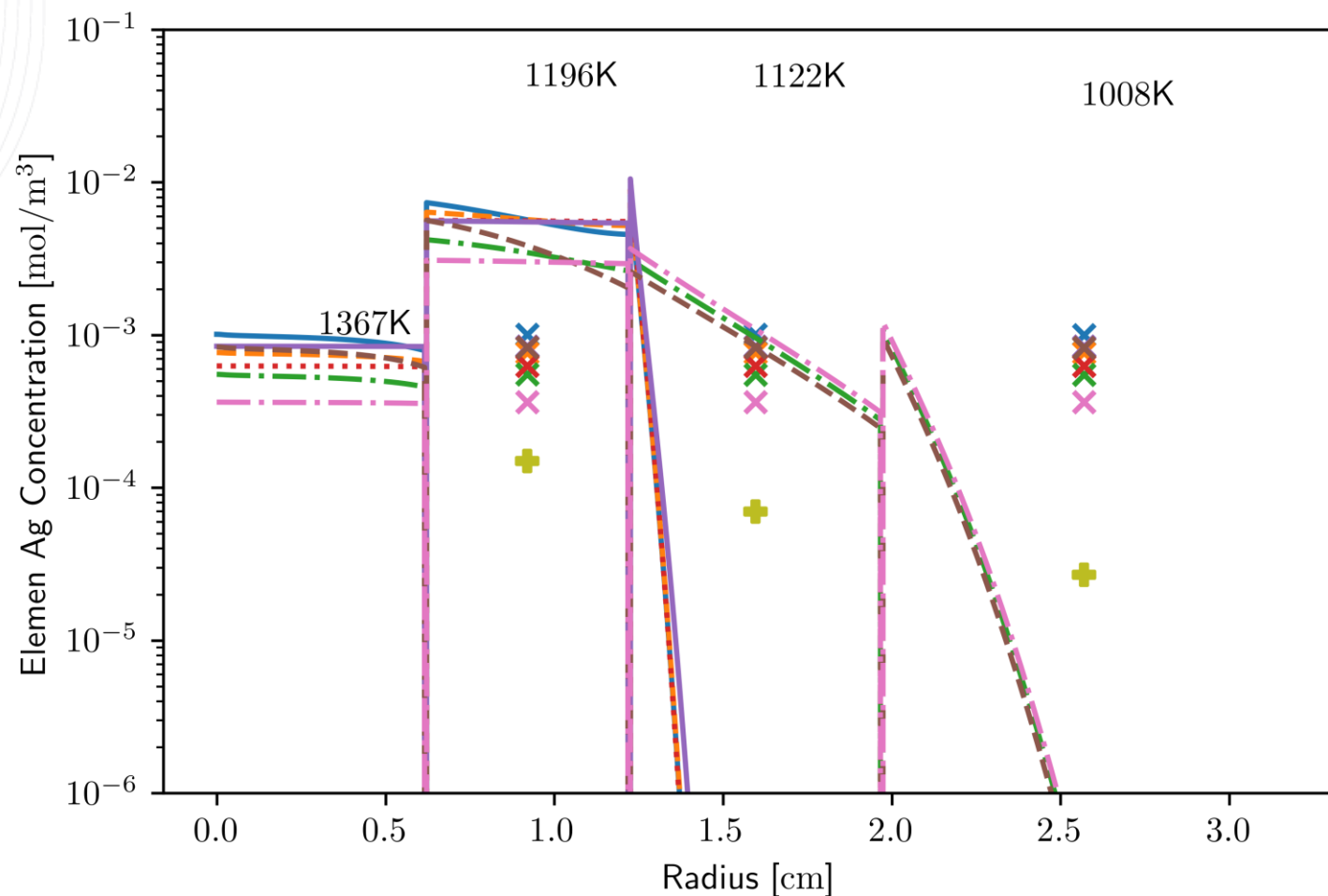
Literature Parameters vs Measurements, Capsule 4



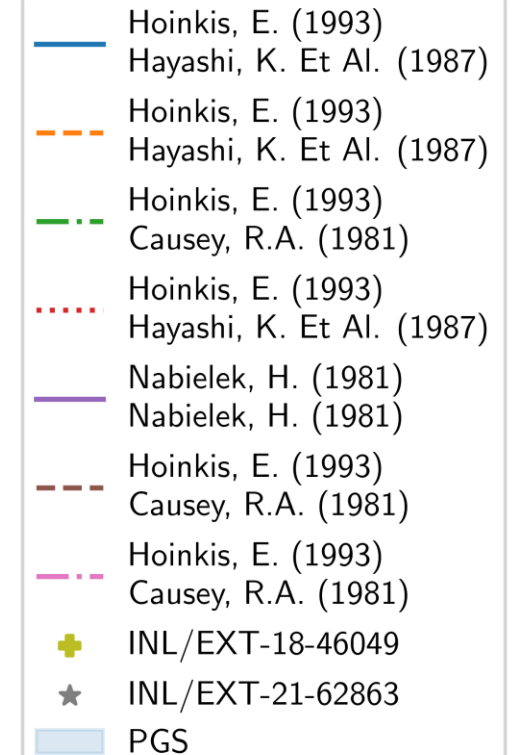
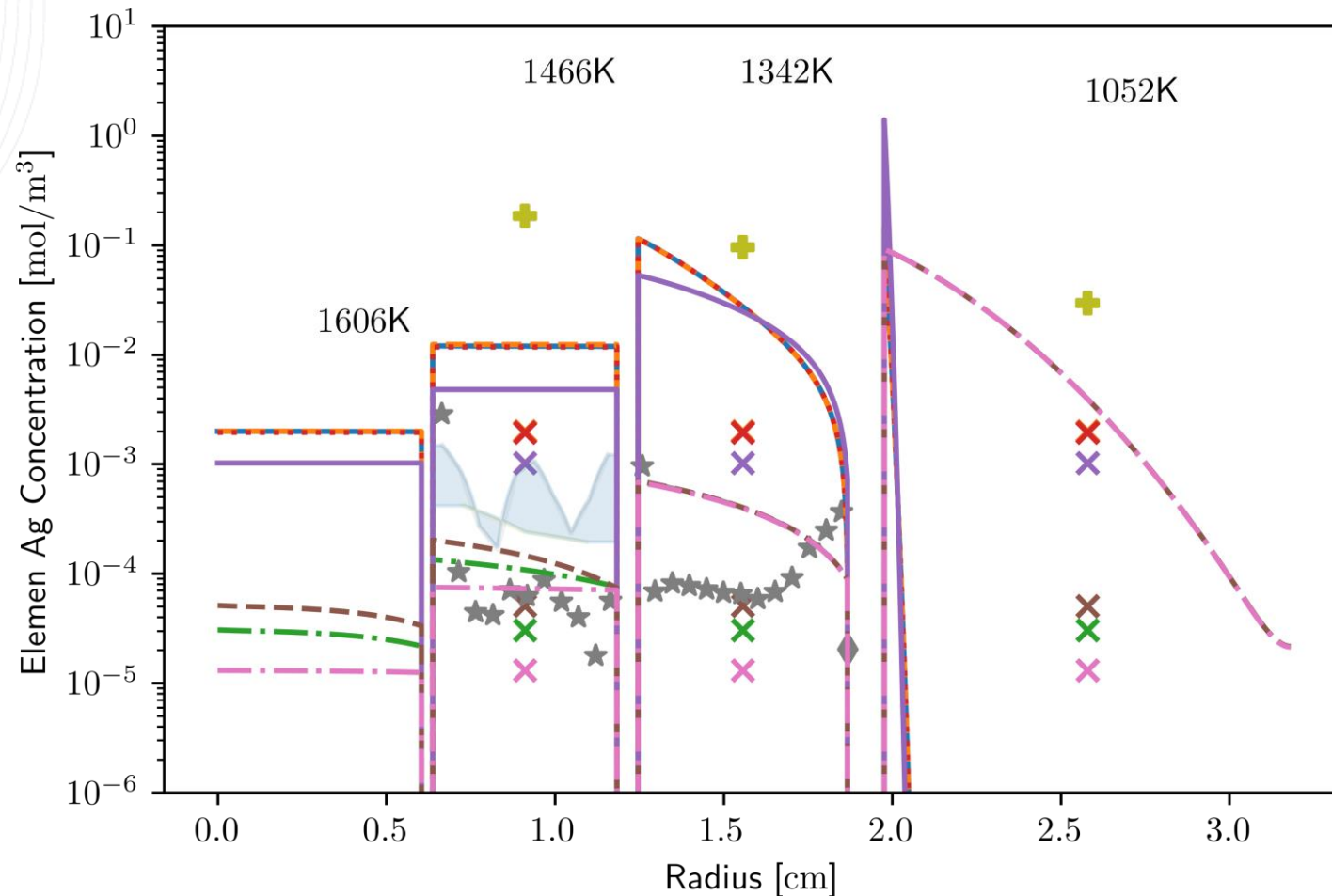
Literature Parameters vs Measurements, Capsule 5



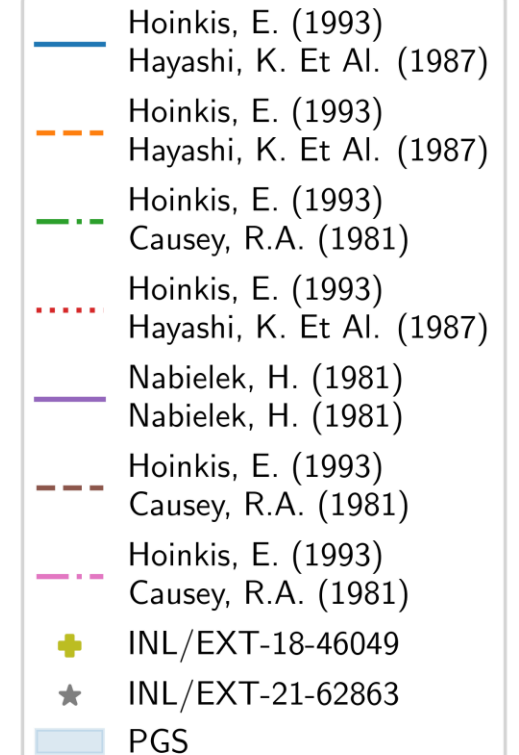
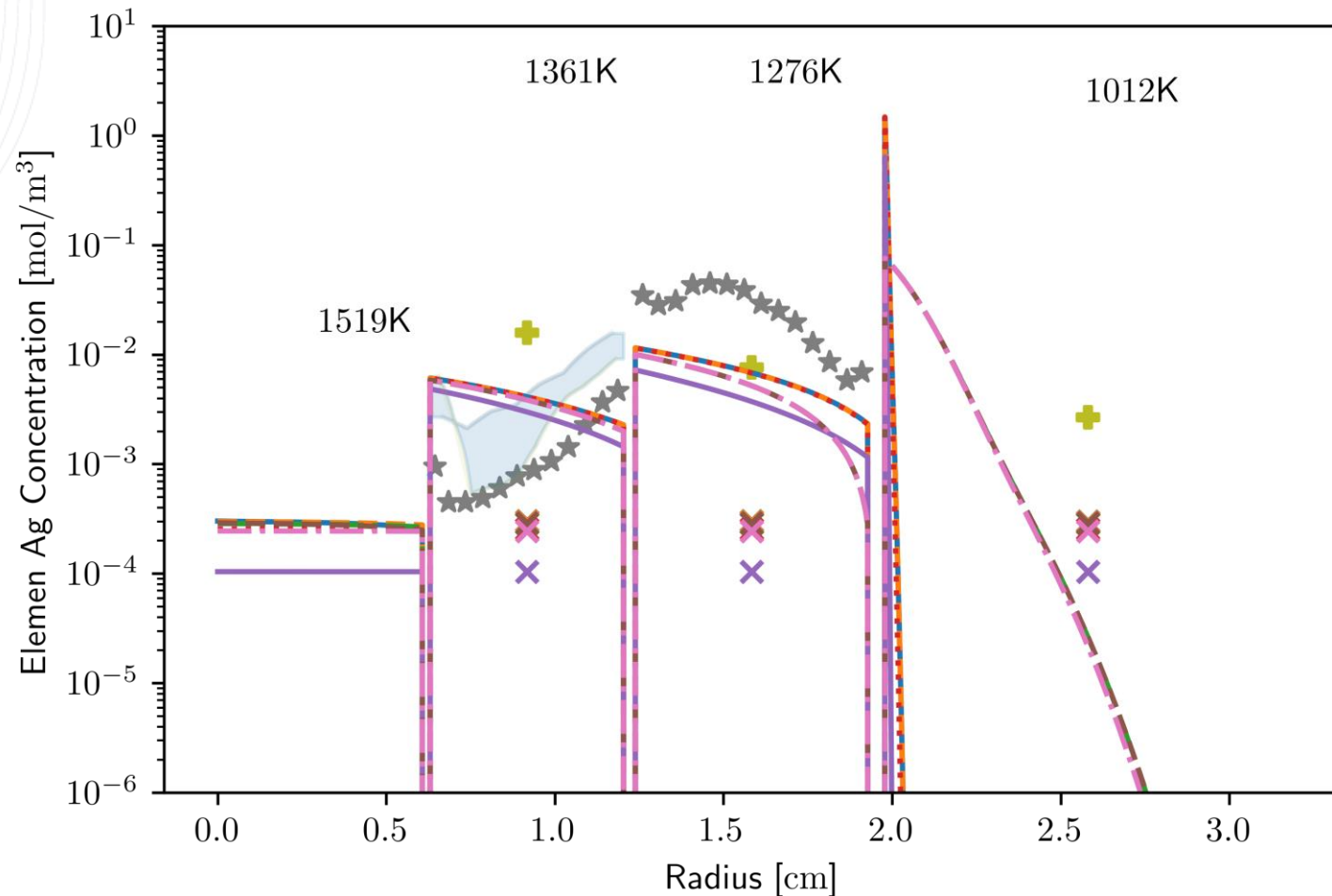
Literature Parameters vs Measurements, Capsule 6



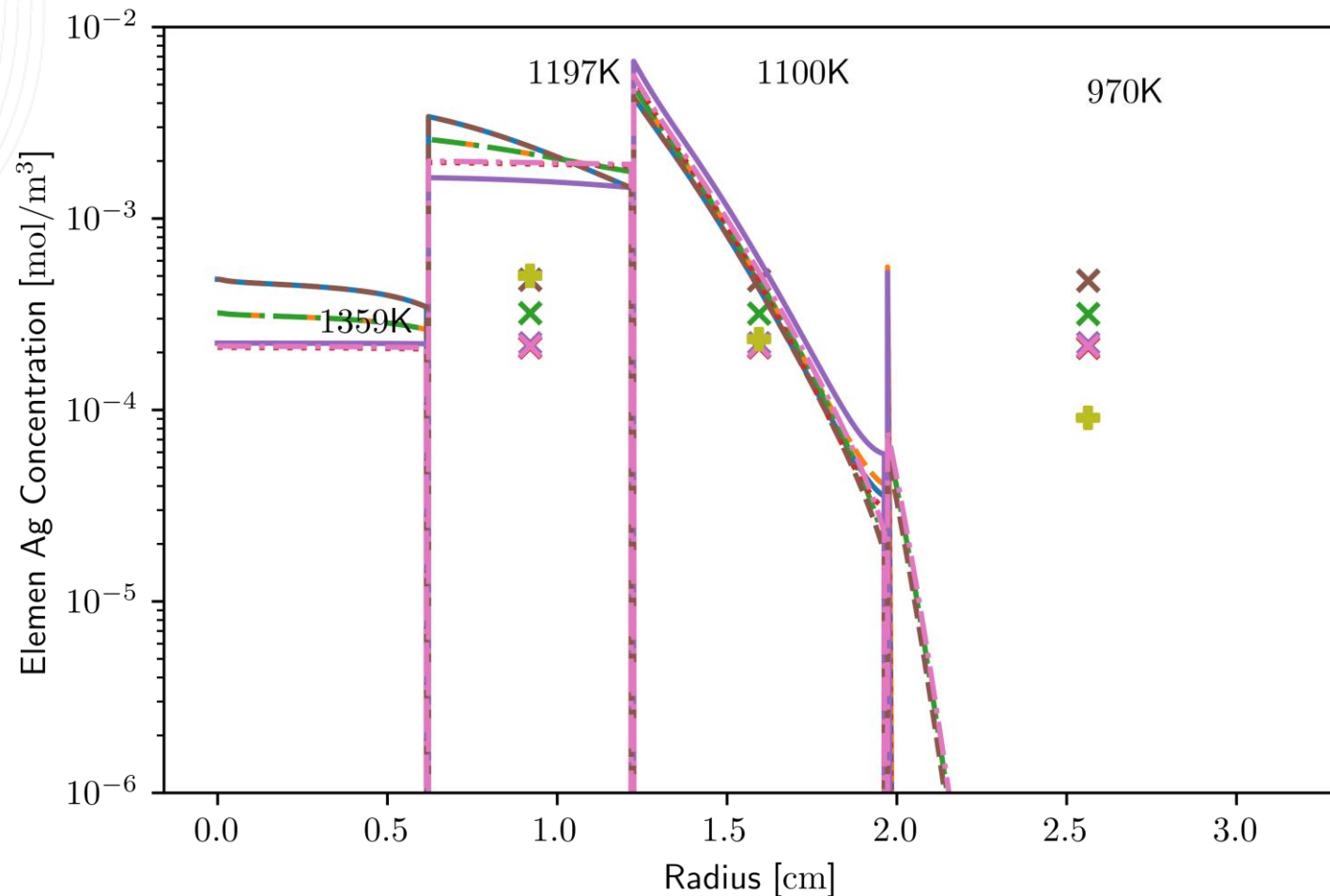
Literature Parameters vs Measurements, Capsule 7



Literature Parameters vs Measurements, Capsule 8

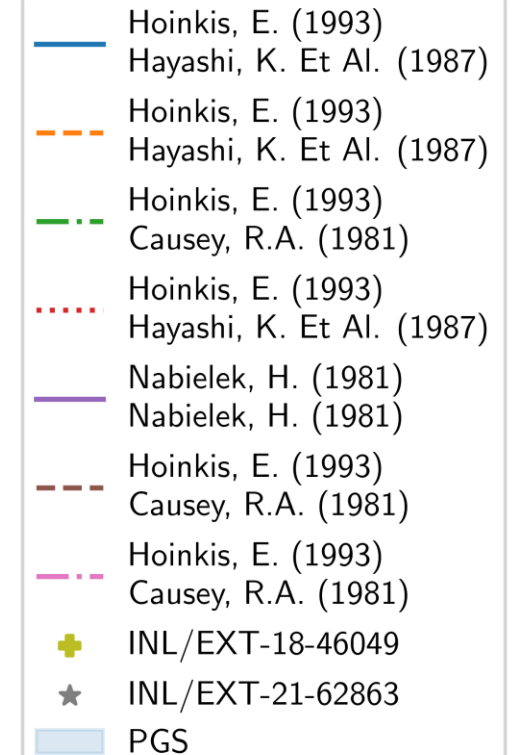
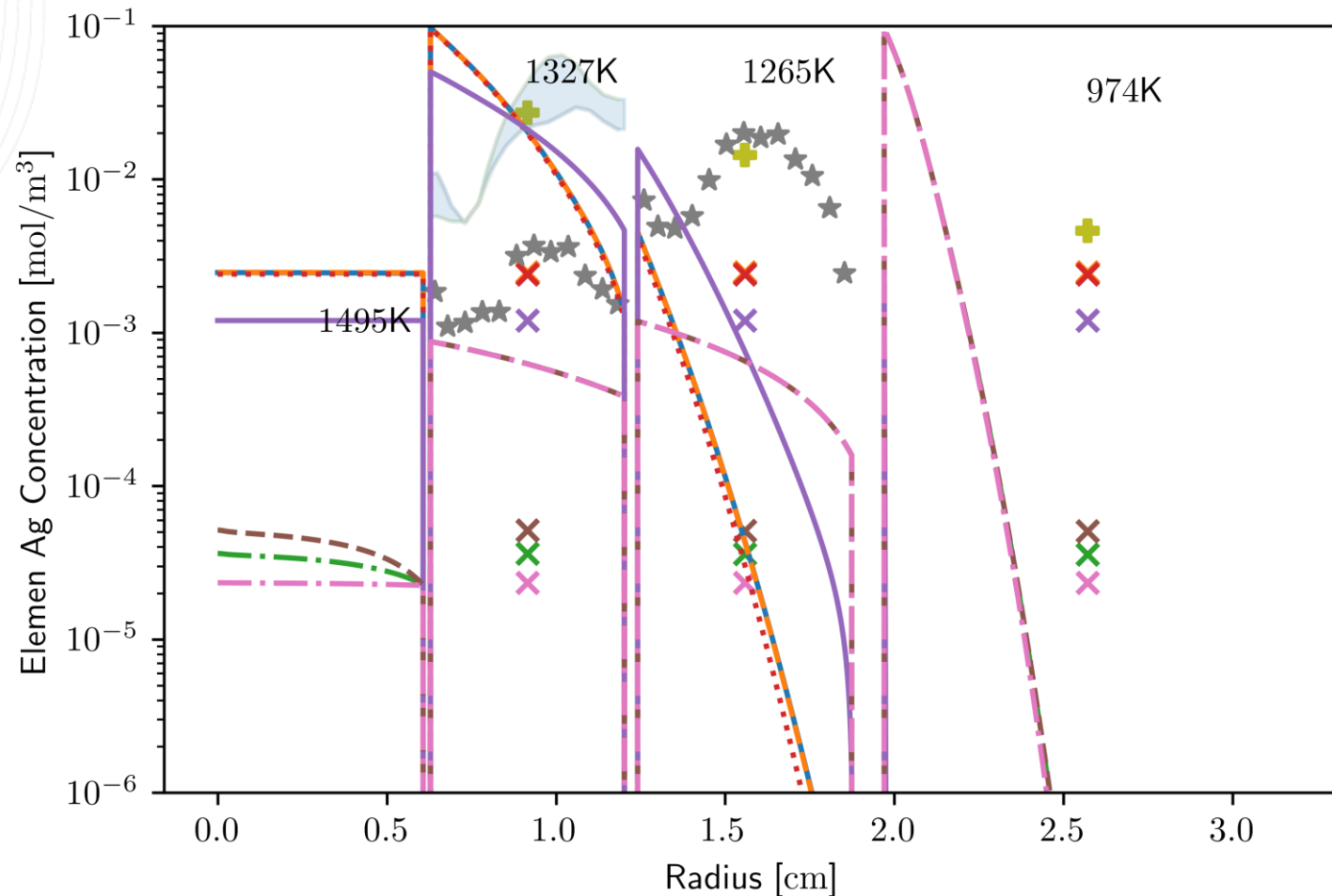


Literature Parameters vs Measurements, Capsule 9

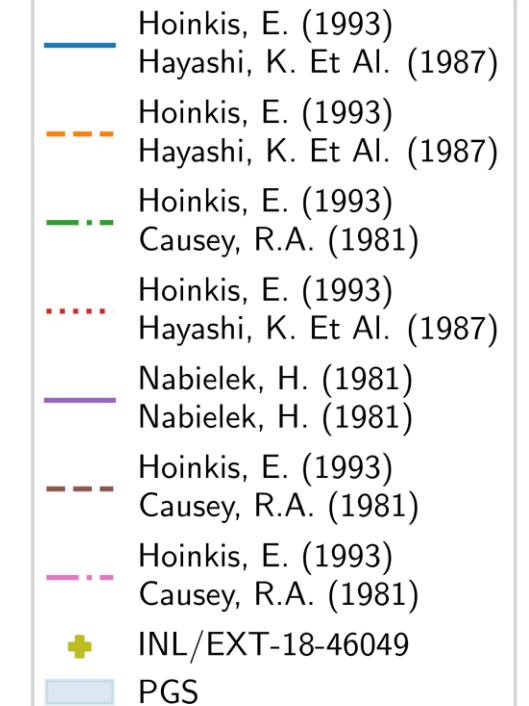
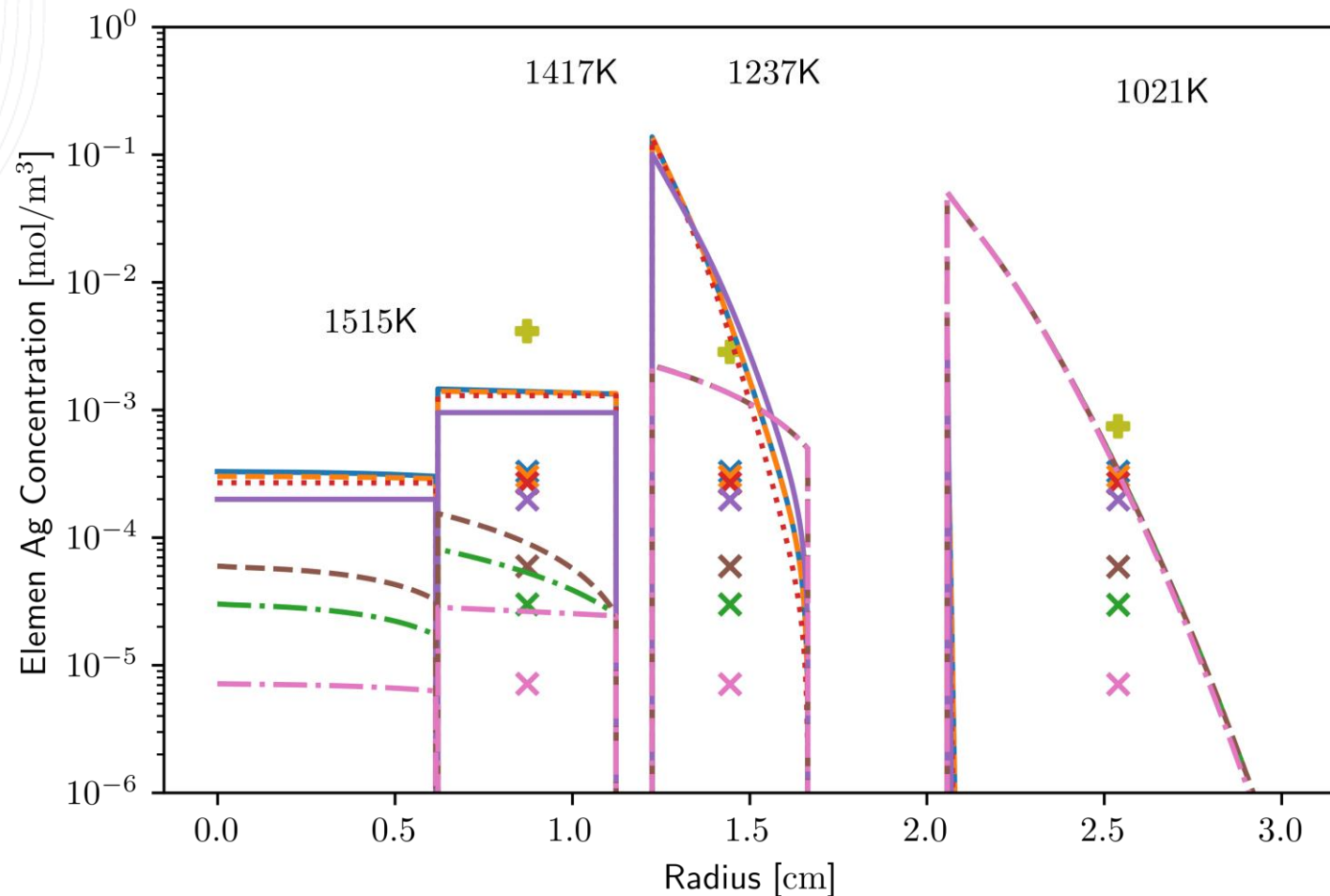


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- PGS

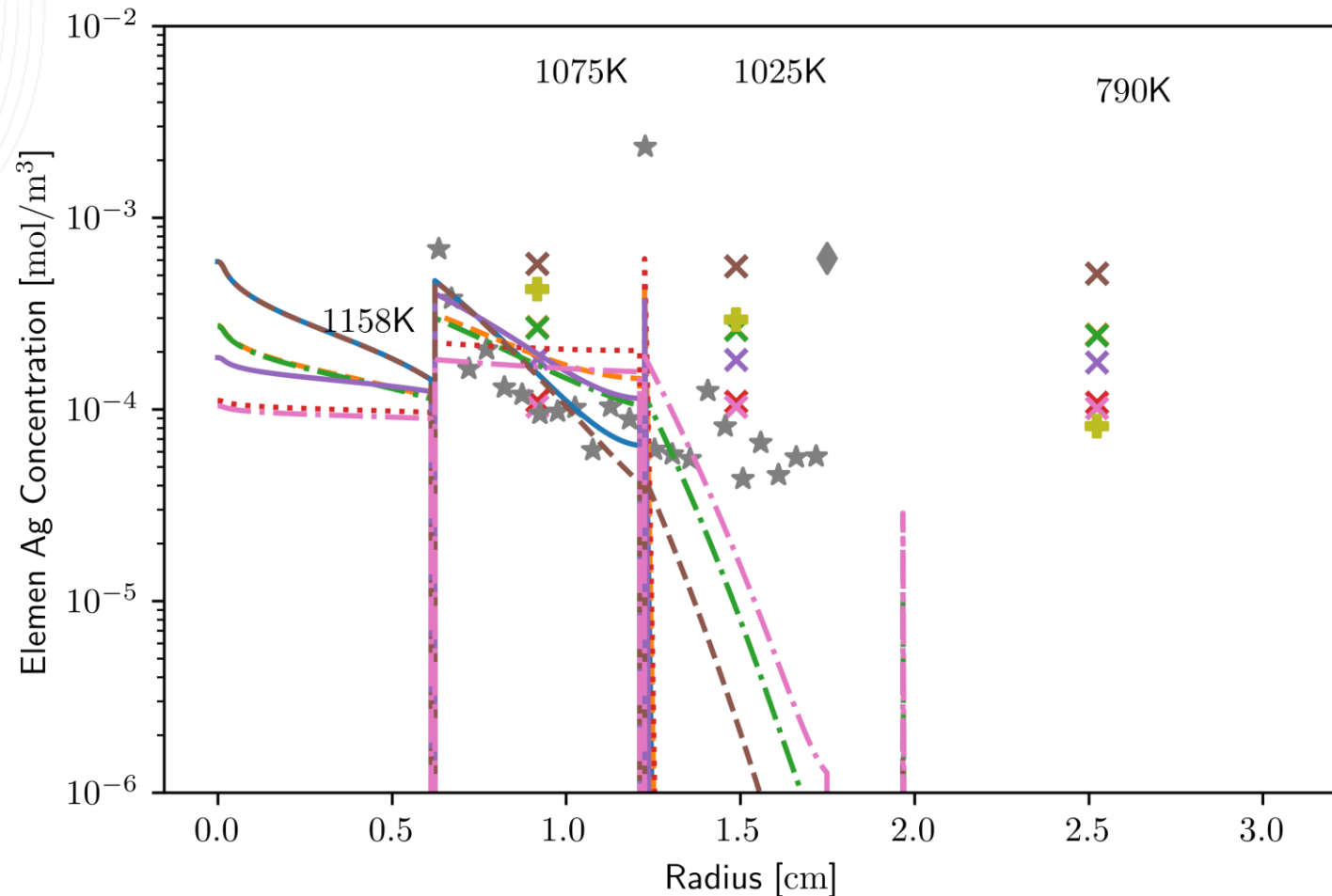
Literature Parameters vs Measurements, Capsule 10



Literature Parameters vs Measurements, Capsule 11



Literature Parameters vs Measurements, Capsule 12



- Hoinkis, E. (1993)
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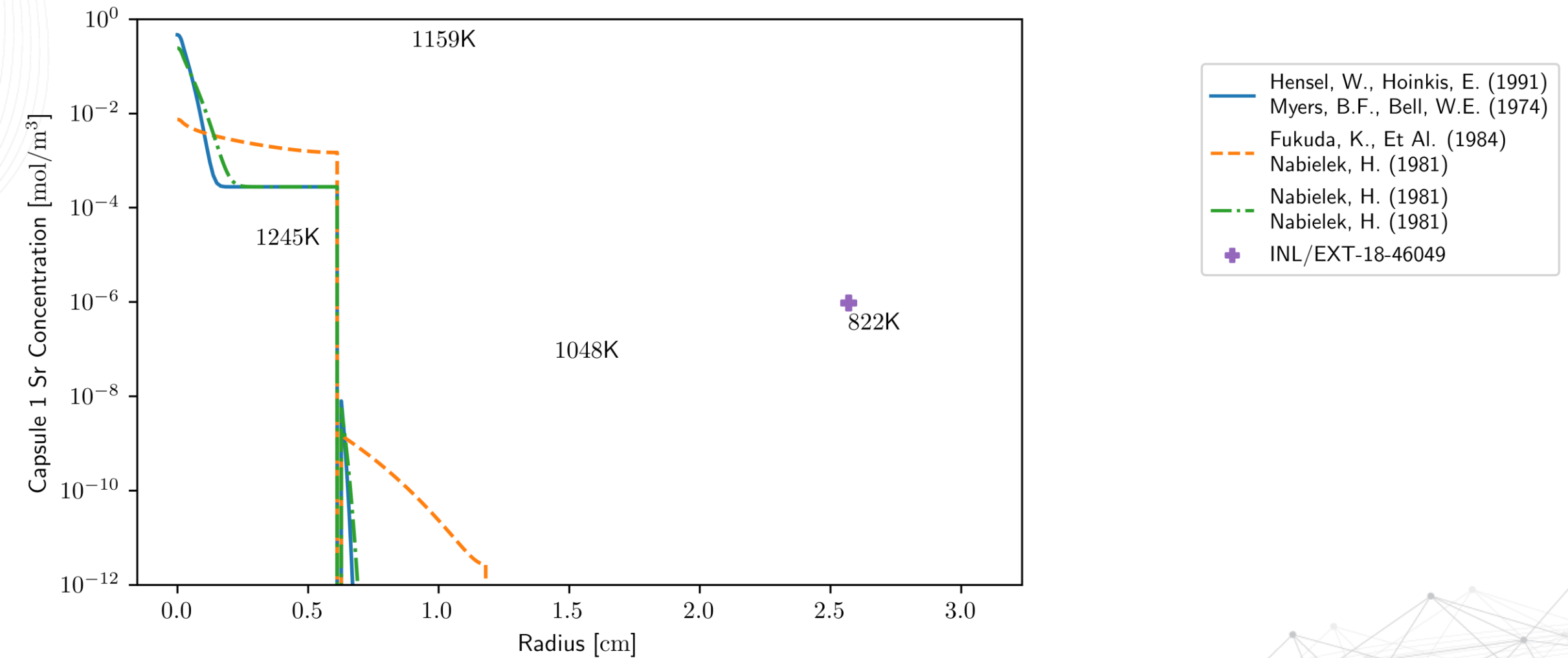
Silver - Summary

- Bulk silver transport can be mostly explained by an effective diffusivity in line with literature values
- Fitting to the observed concentration profiles will require more detailed modeling
 - Surface effects
 - Pore diffusion model

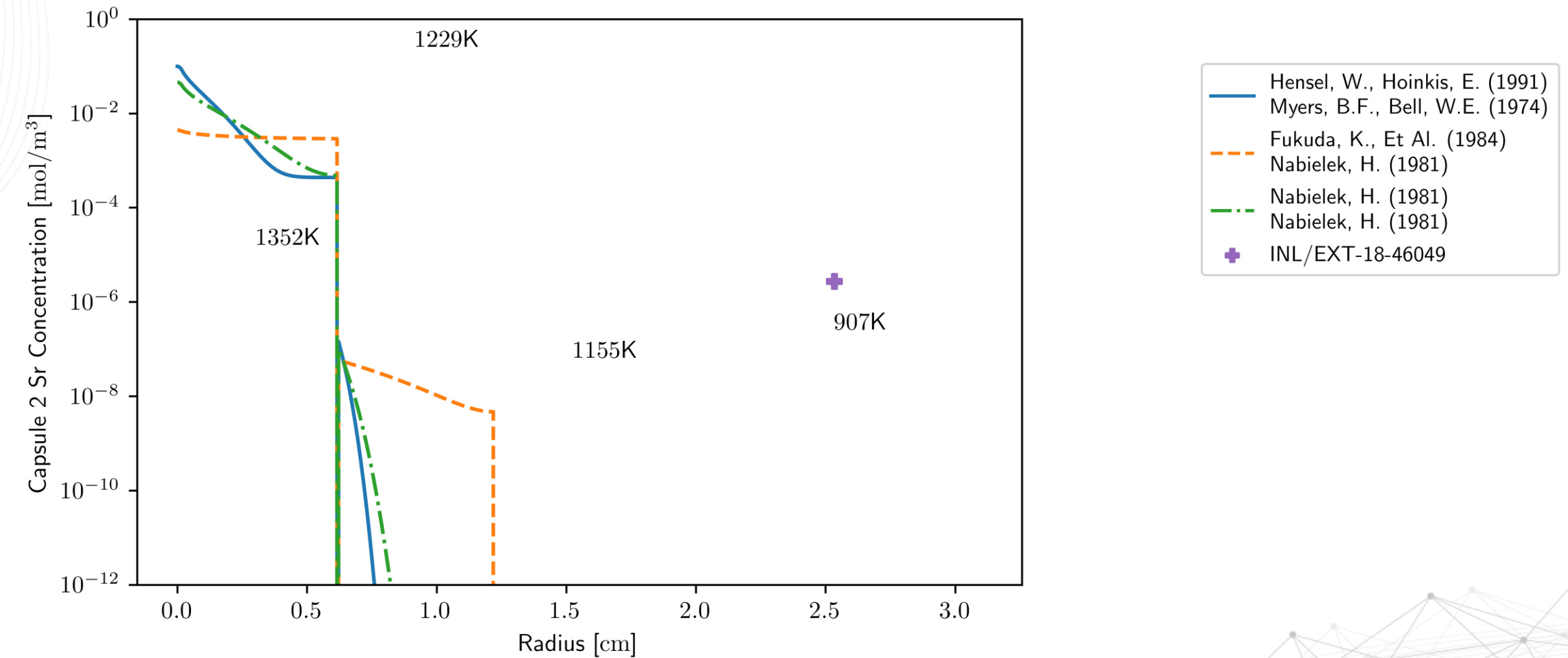


Strontium

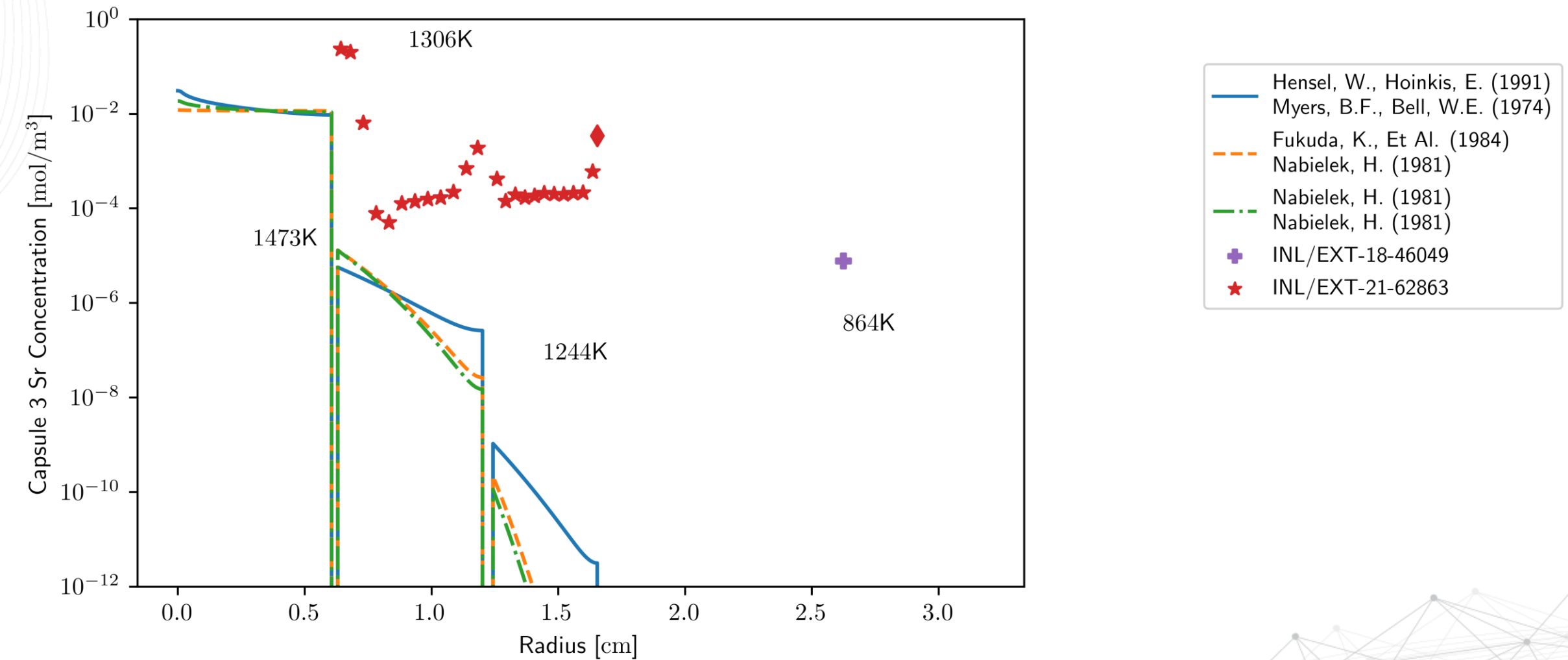
Literature Parameters vs Measurements, Capsule 1



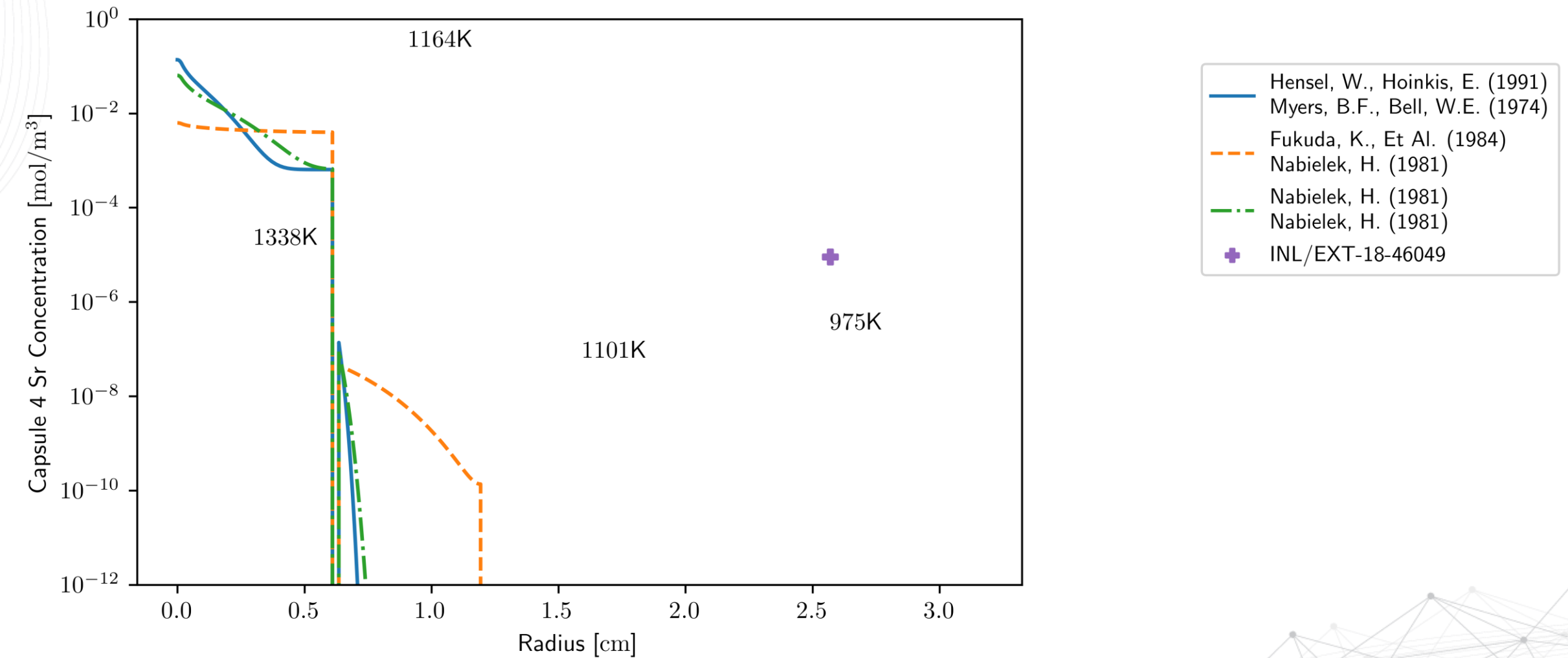
Literature Parameters vs Measurements, Capsule 2



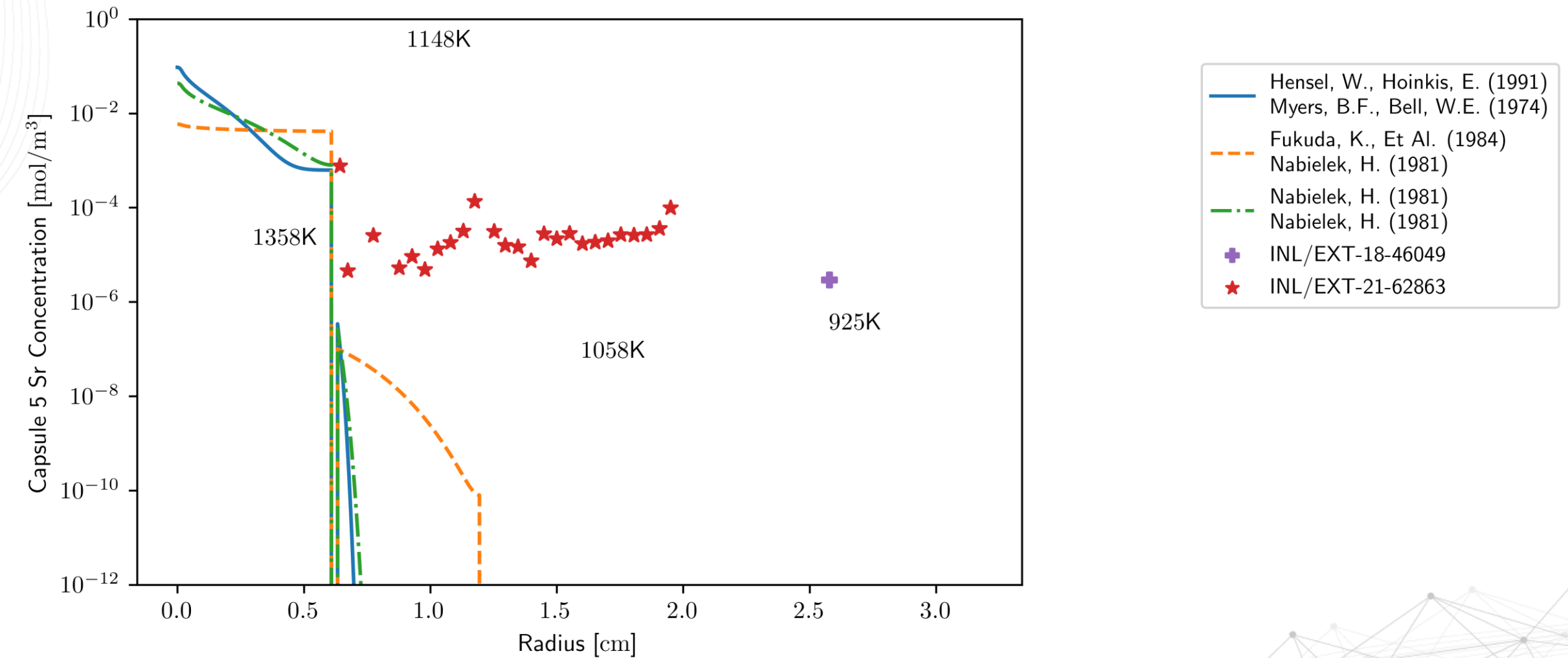
Literature Parameters vs Measurements, Capsule 3



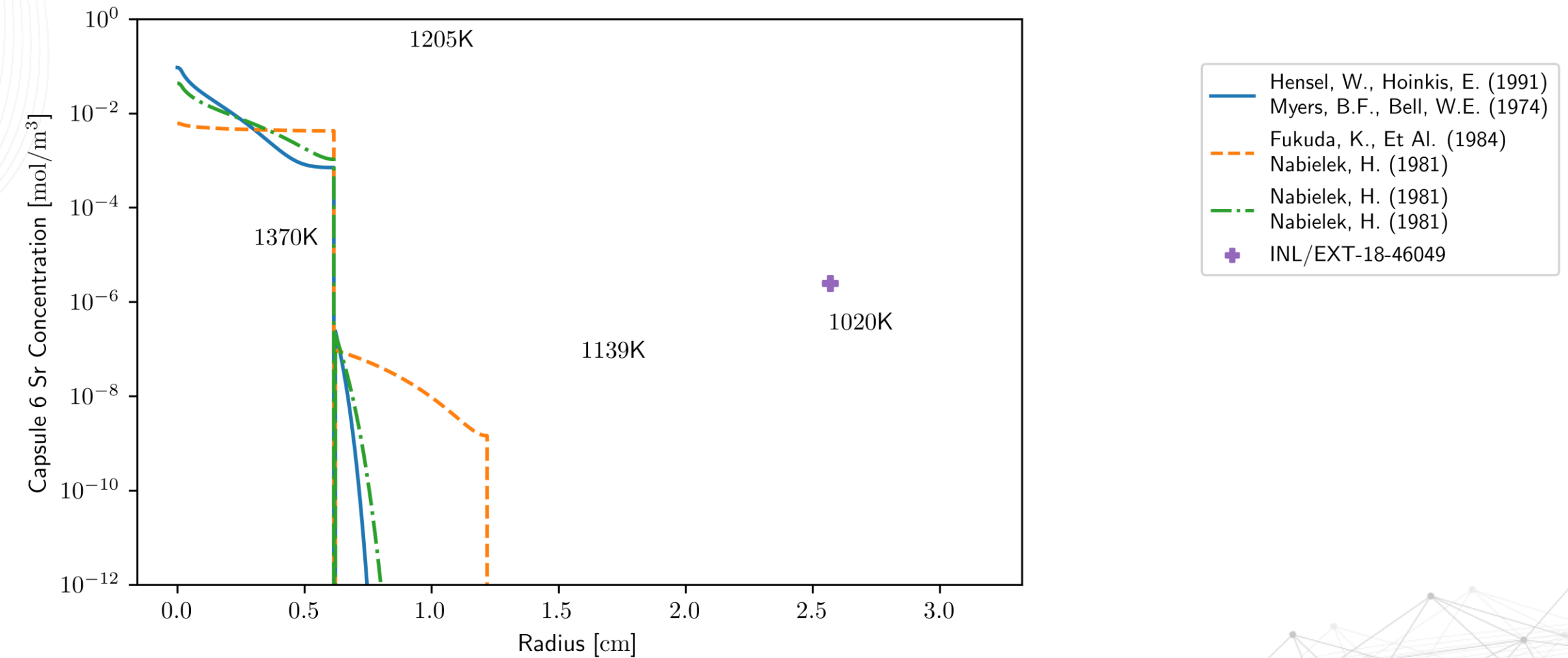
Literature Parameters vs Measurements, Capsule 4



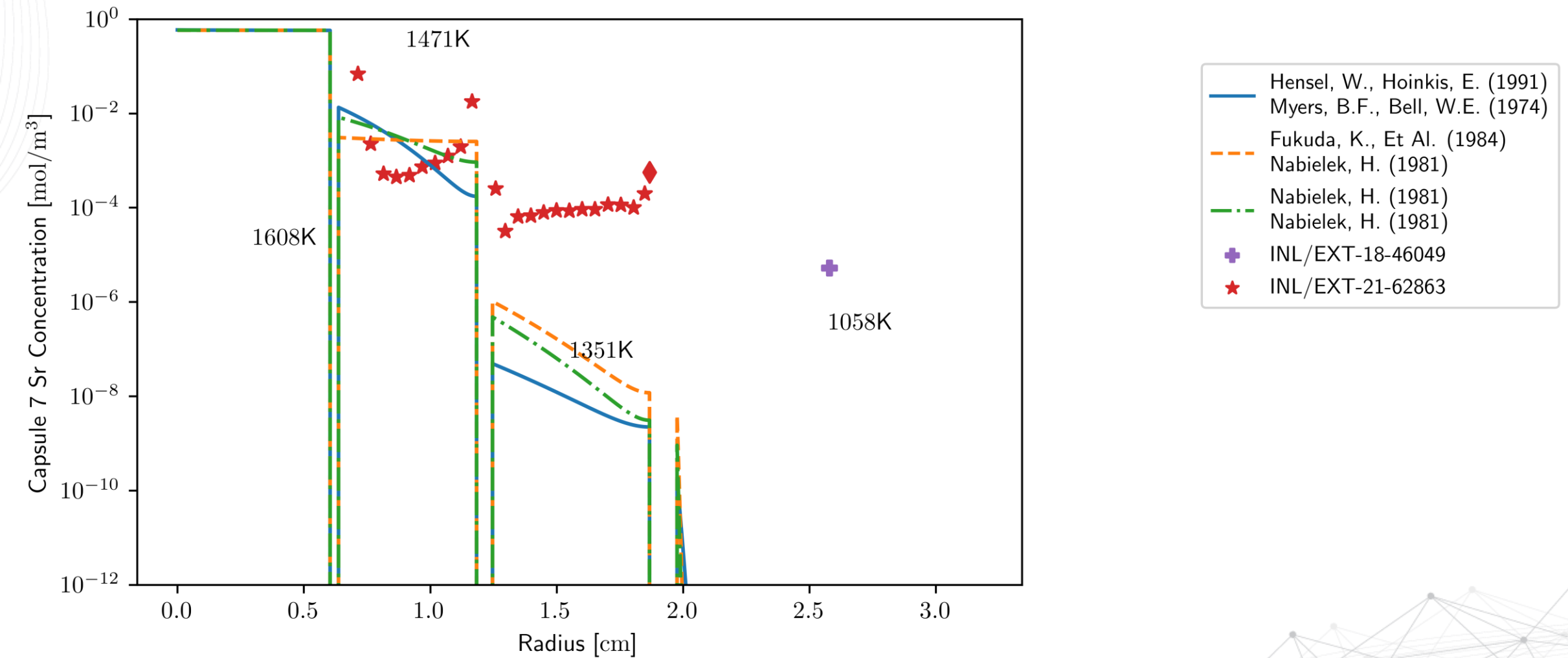
Literature Parameters vs Measurements, Capsule 5



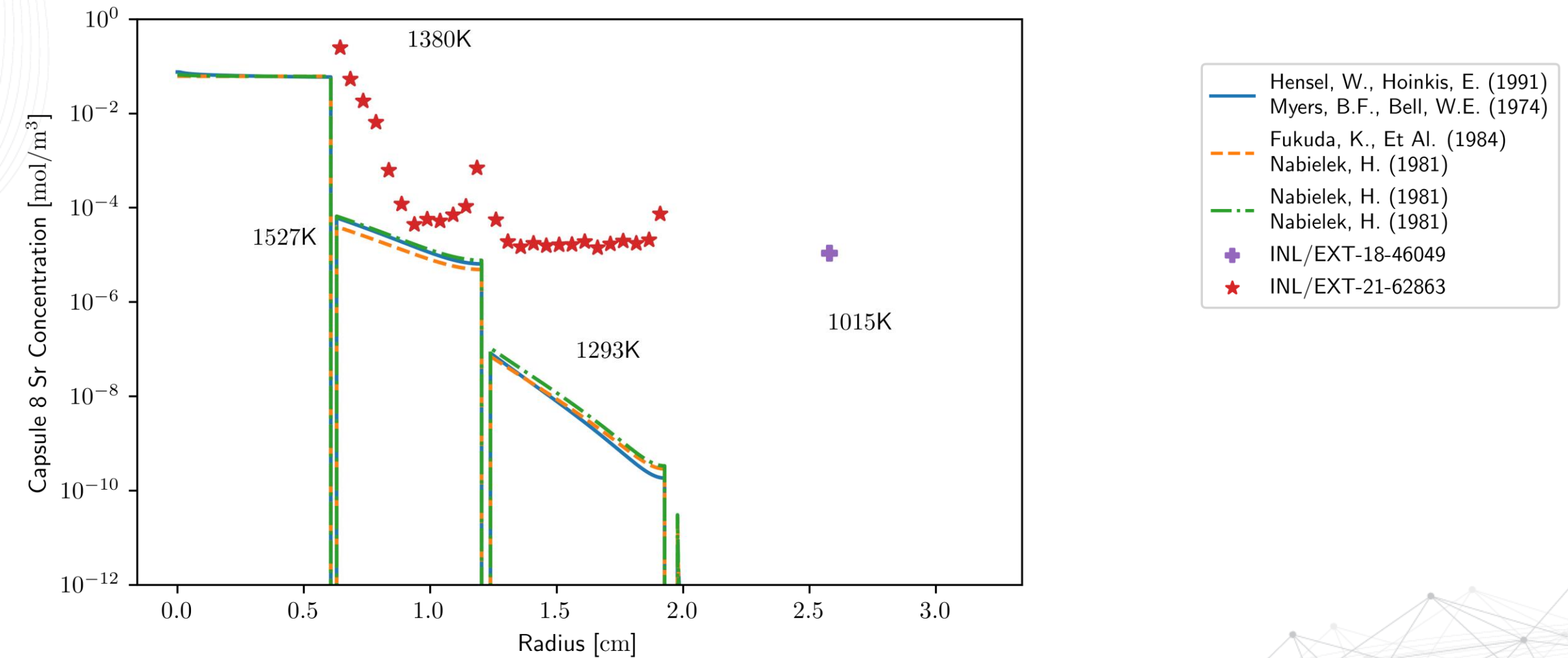
Literature Parameters vs Measurements, Capsule 6



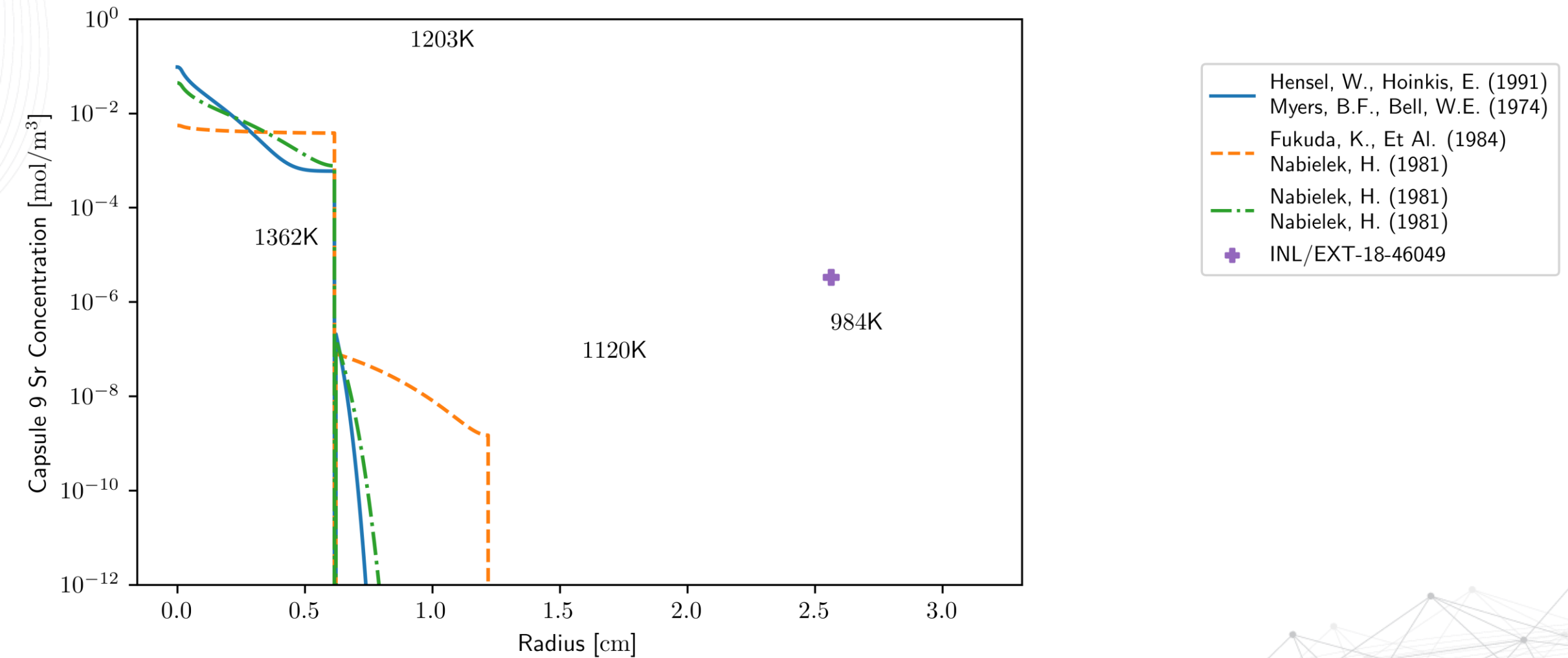
Literature Parameters vs Measurements, Capsule 7



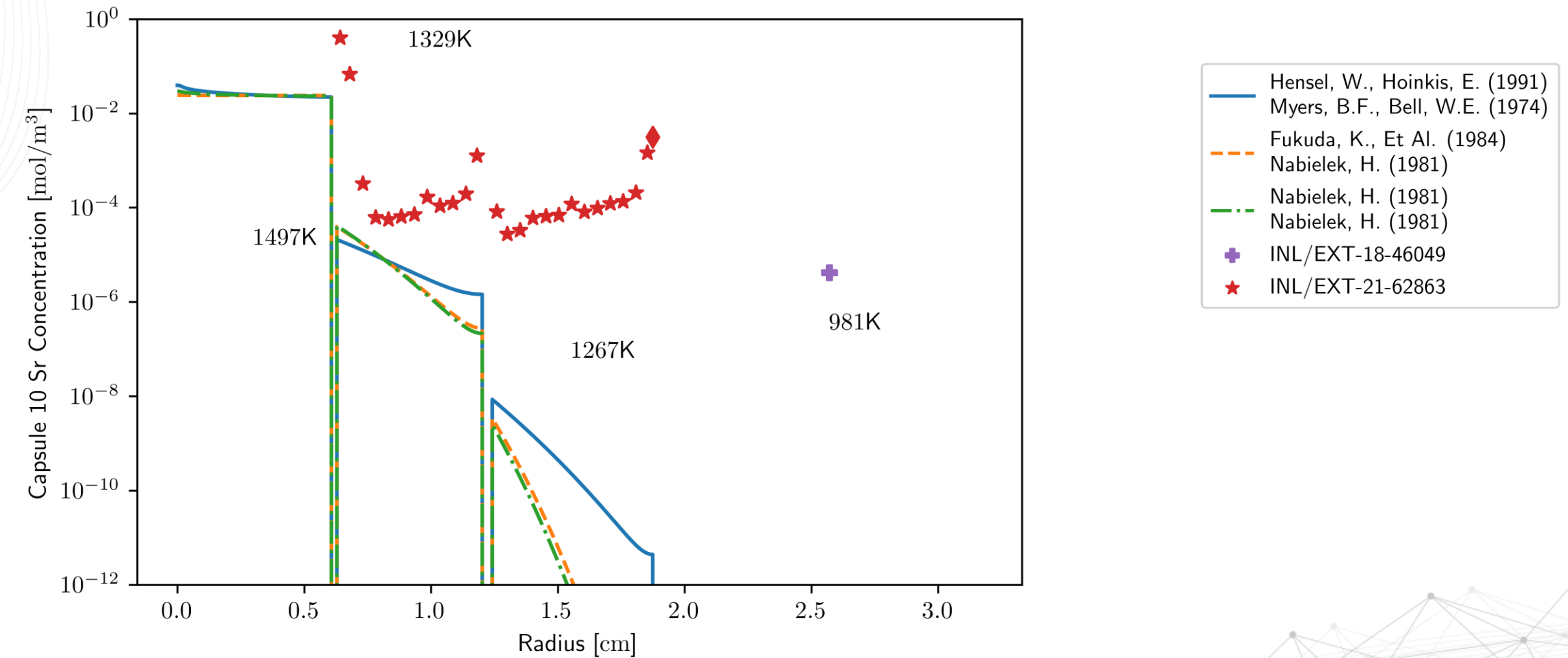
Literature Parameters vs Measurements, Capsule 8



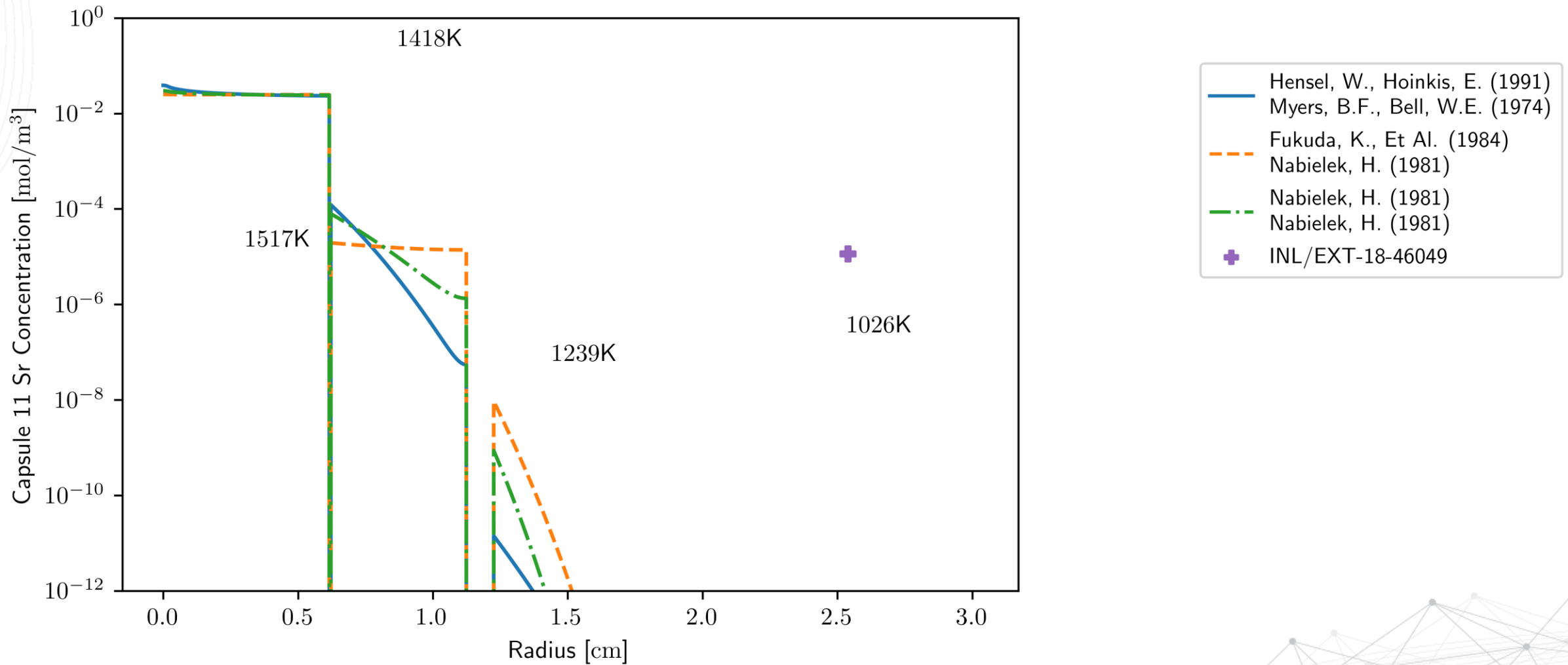
Literature Parameters vs Measurements, Capsule 9



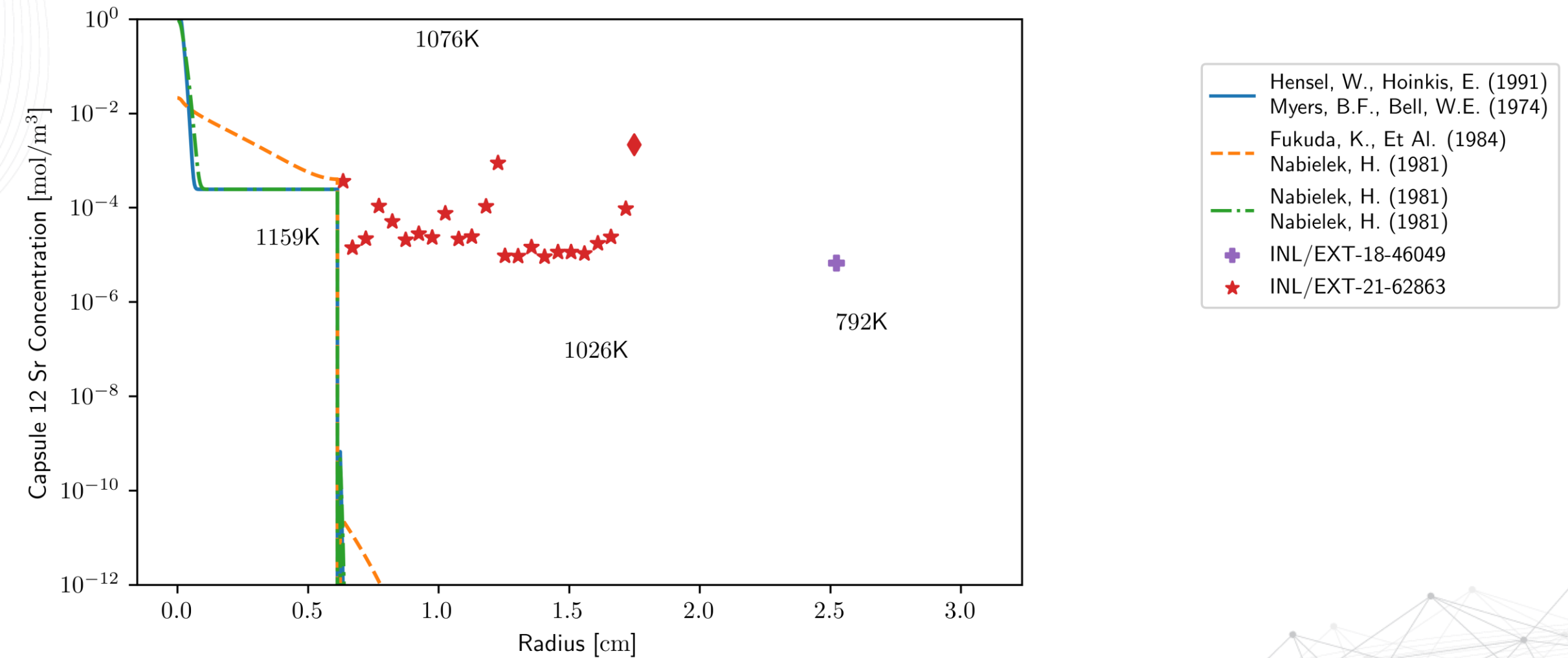
Literature Parameters vs Measurements, Capsule 10



Literature Parameters vs Measurements, Capsule 11



Literature Parameters vs Measurements, Capsule 12





Strontium - Summary

- Diffusion based on IAEA values strongly underpredicts total strontium transport under 1400 K
- Elevated outer surface concentrations suggest a short-circuit diffusion path *around* the rings



Ongoing Work (FY 23)

- Obtain recommended diffusion parameters for each isotope (and quantify uncertainty)
- Sensitivity analysis of isotherm parameters
- Compare Eu, Sr data

All capsules Sr

