INL/MIS-22-67890-Revision-1

Modeling of the AGR 3/4 PIE Experiments

July 2022

Adriaan Anthony Riet

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Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

July 12, 2022

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Modeling of the AGR 3/4 PIE Experiments

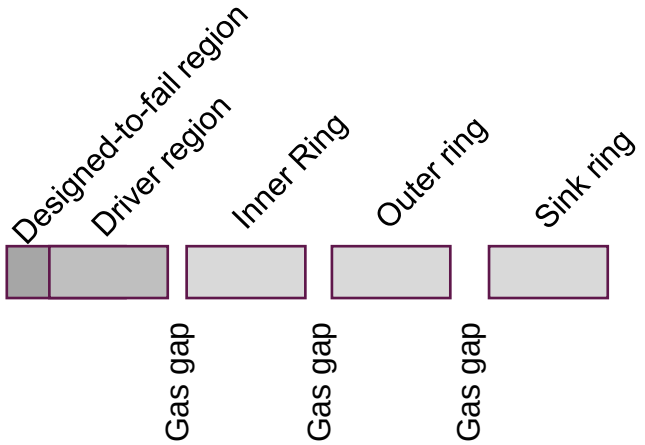
ART Advanced Reactor Technologies
GAS-COOLED REACTORS

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

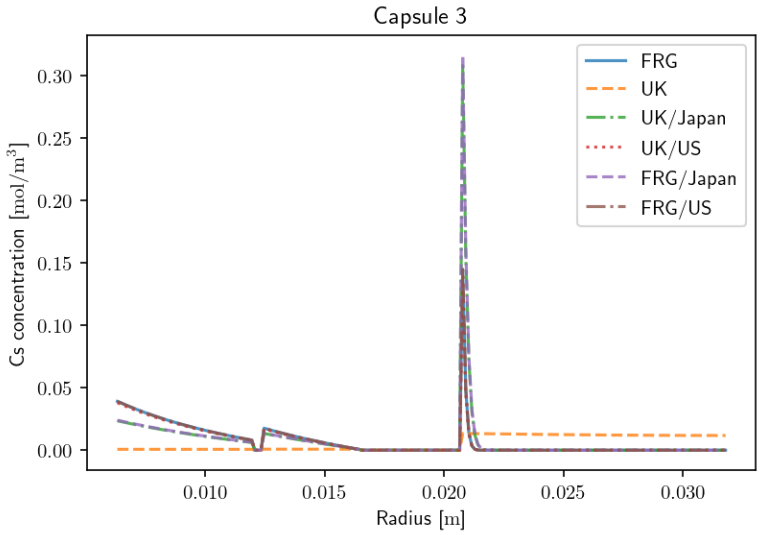
Finite Element Model

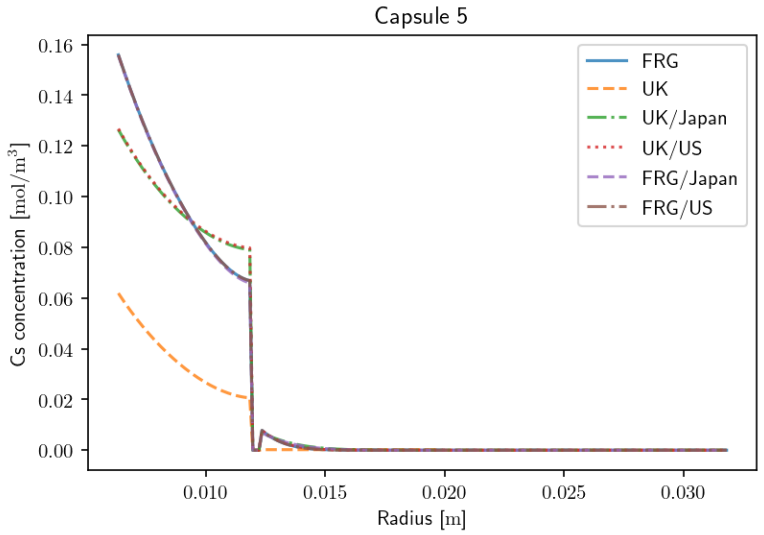
- Moose-based 1-D model
- Sorption modeled explicitly with the Freundlich sorption isotherm
- Time-dependent fission-product release
- Temperature at each interface set to a diffusion-weighted average of the time-dependent temperature at each interface (taking INL/MIS-15-35692 as a reference)
  - $T = \frac{\sum\left(D_0 \exp\left(-\frac{E_a}{RT(t)}\right)T(t)\Delta t\right)}{\sum\left(D_0 \exp\left(-\frac{E_a}{RT(t)}\right)\Delta t\right)}$

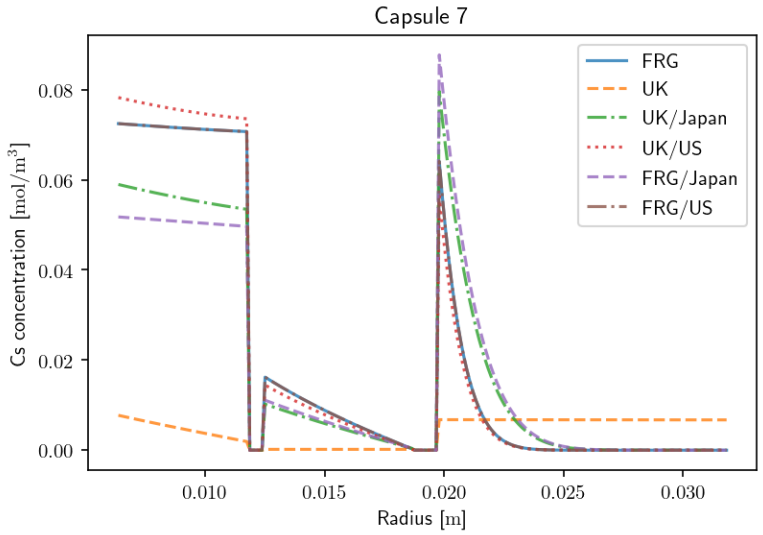


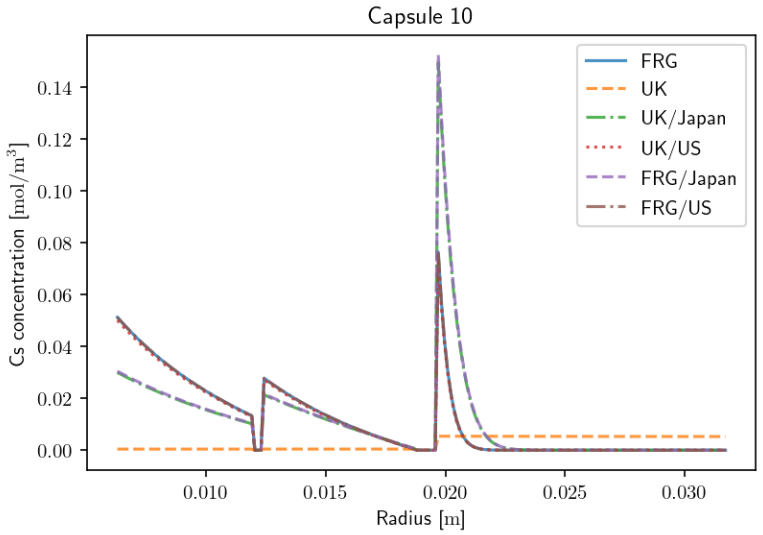
Cesium

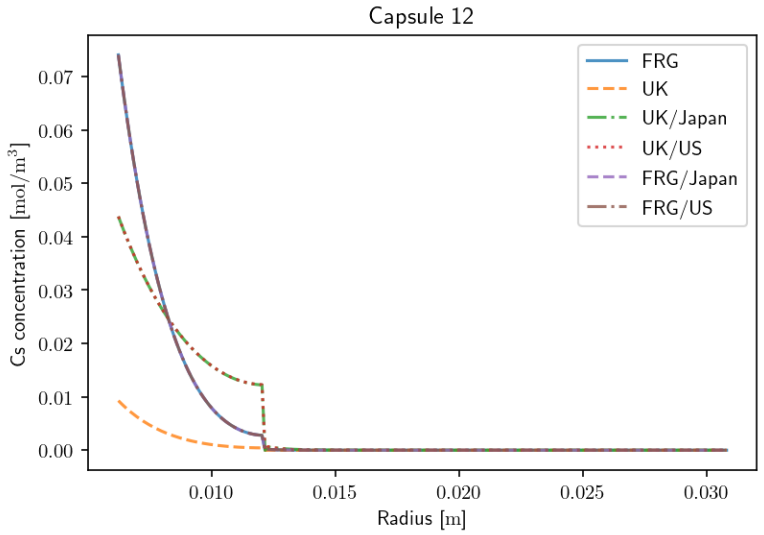
Modeled Concentration Profiles From Previous Literature Values





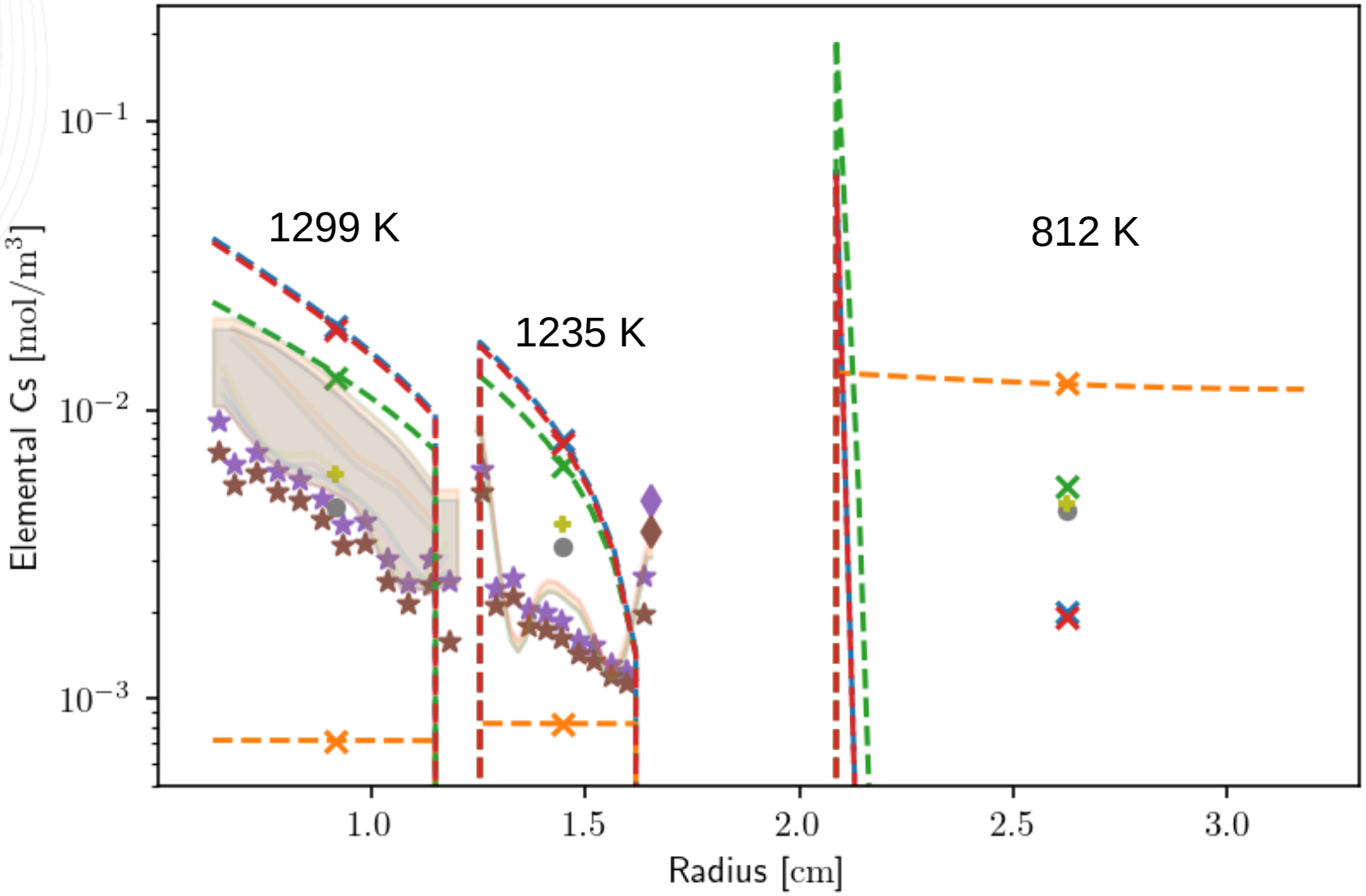


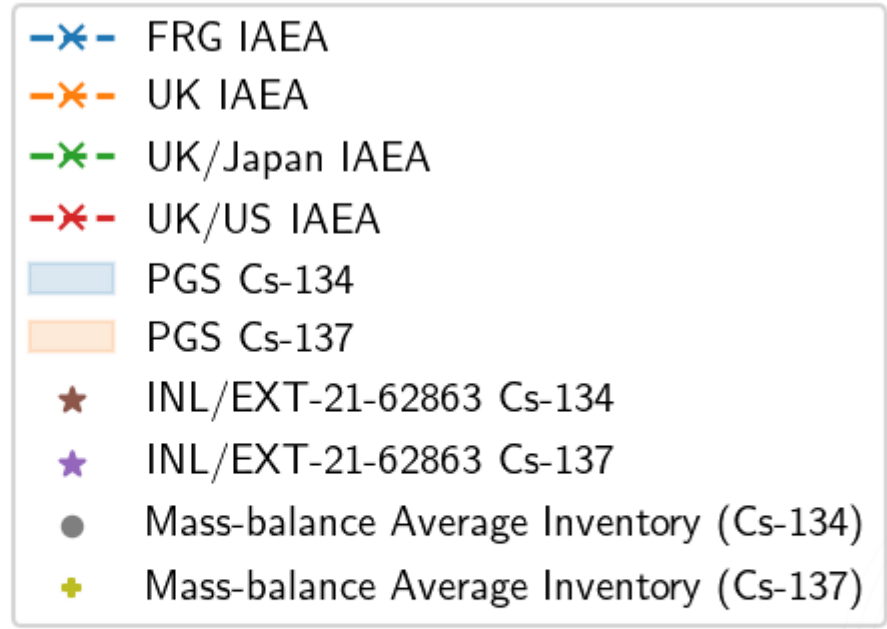




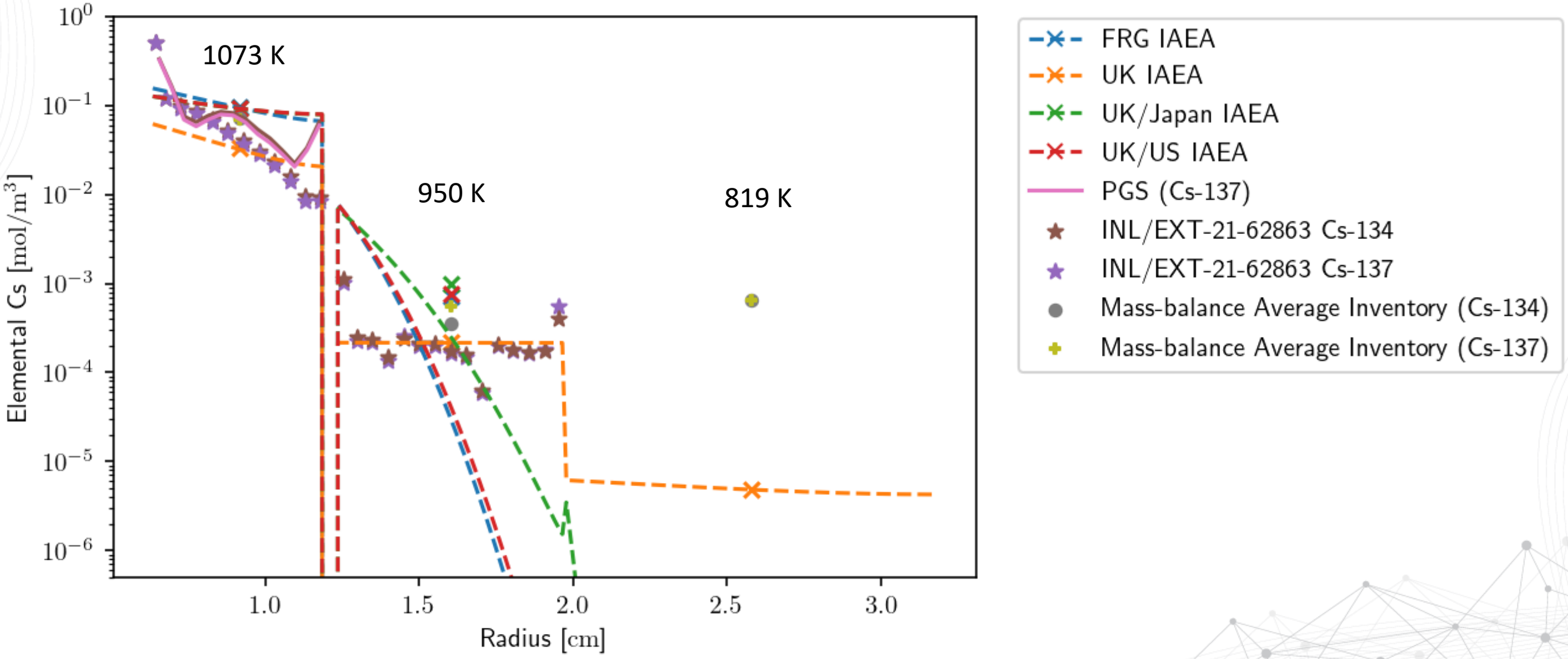
(IAEA TECDOC-978, 1997)

Literature Parameters vs Measurements, Capsule 3

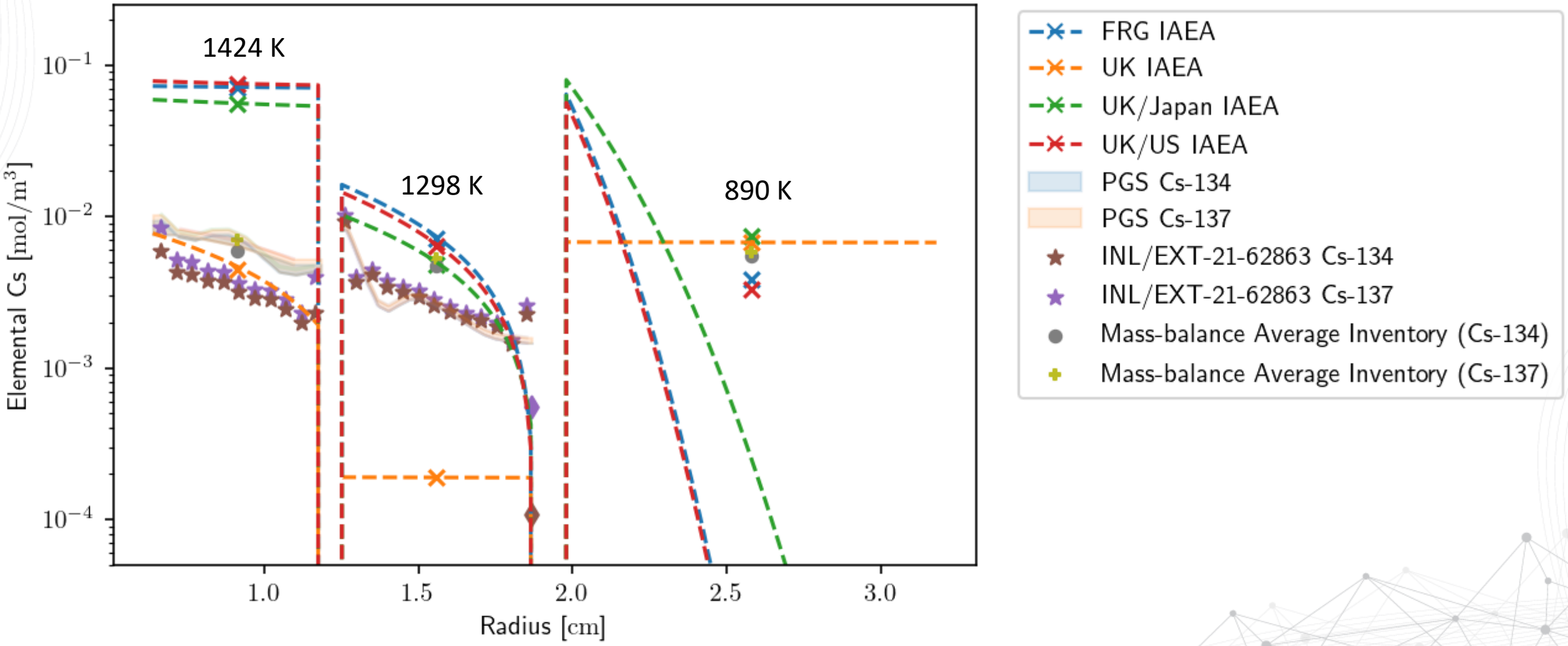




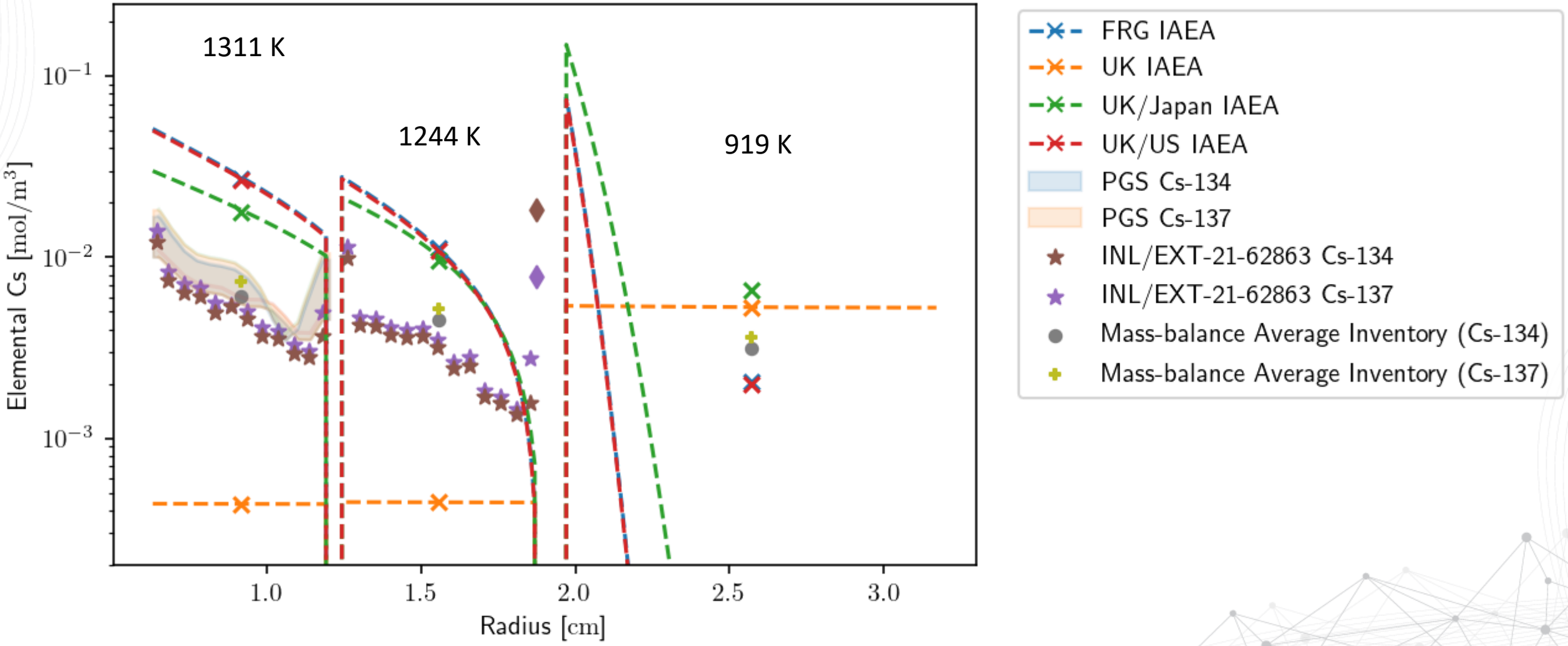
Literature Parameters vs Measurements, Capsule 5



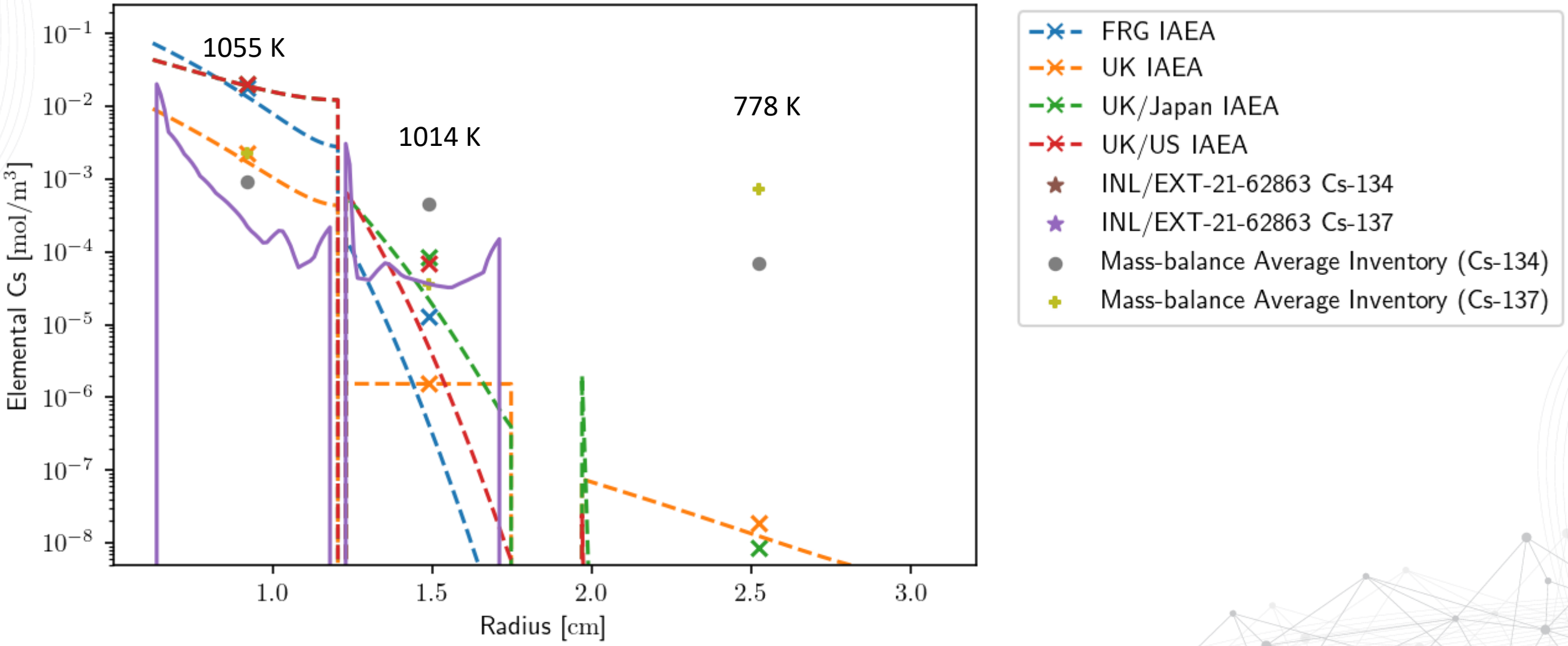
Literature Parameters vs Measurements, Capsule 7



Literature Parameters vs Measurements, Capsule 10



Literature Parameters vs Measurements, Capsule 12

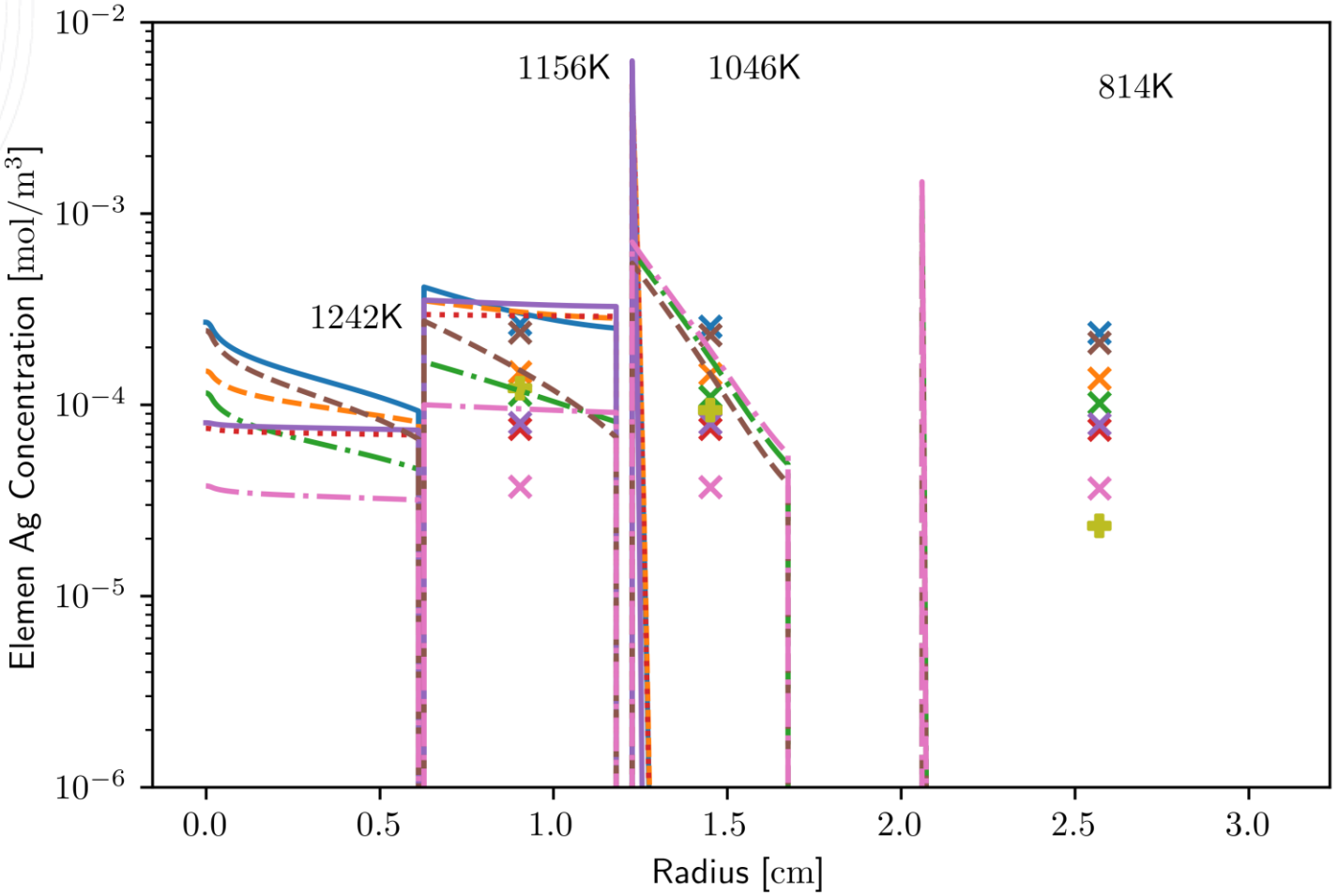


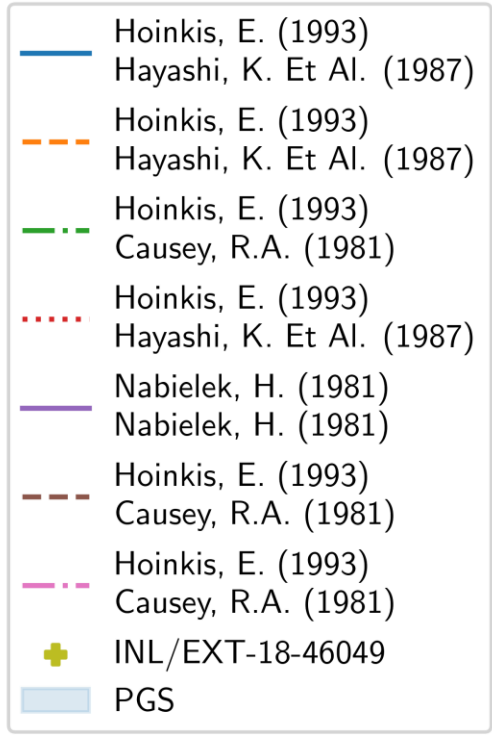
Cesium - Summary

- 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

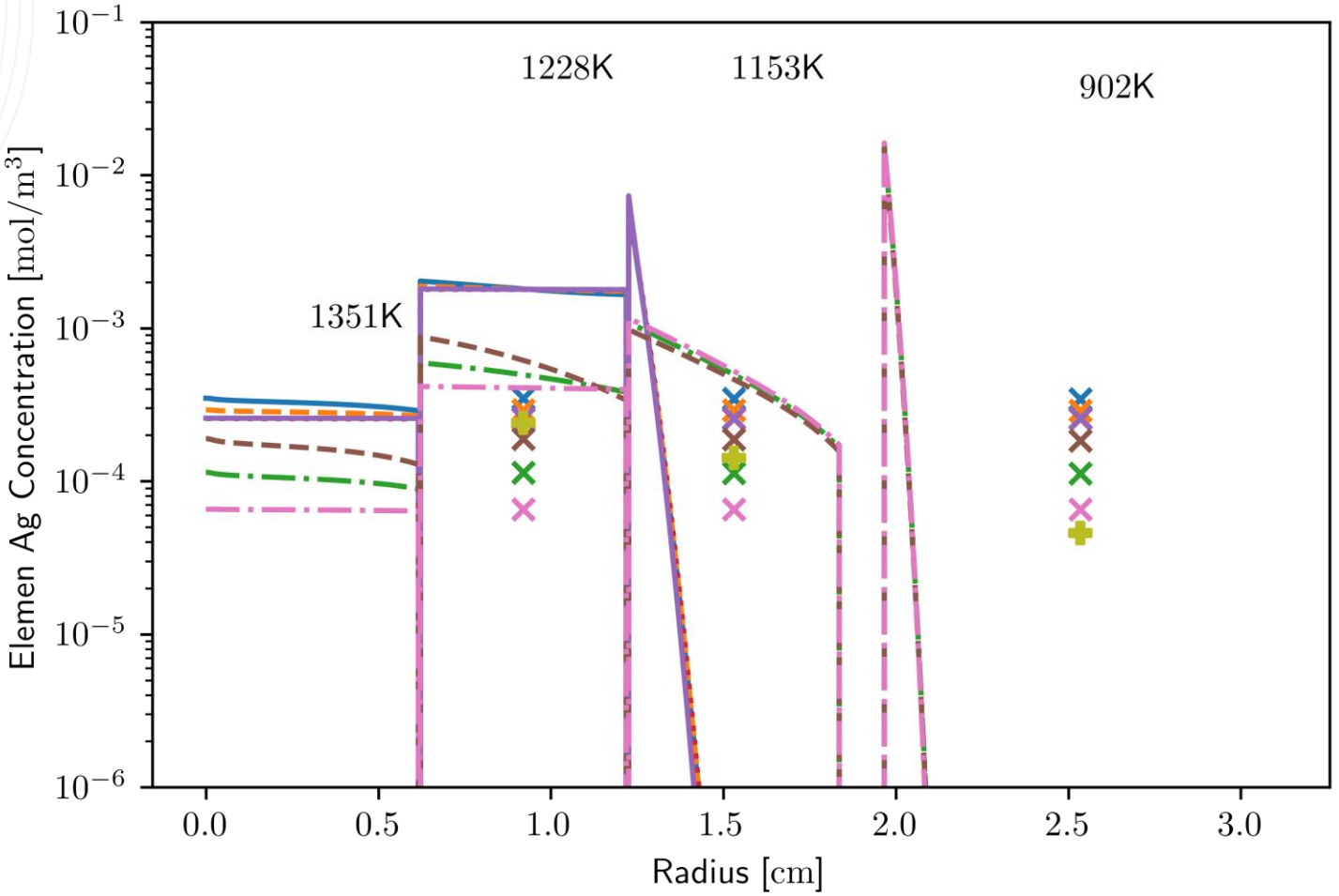
Silver (Ag-110m)

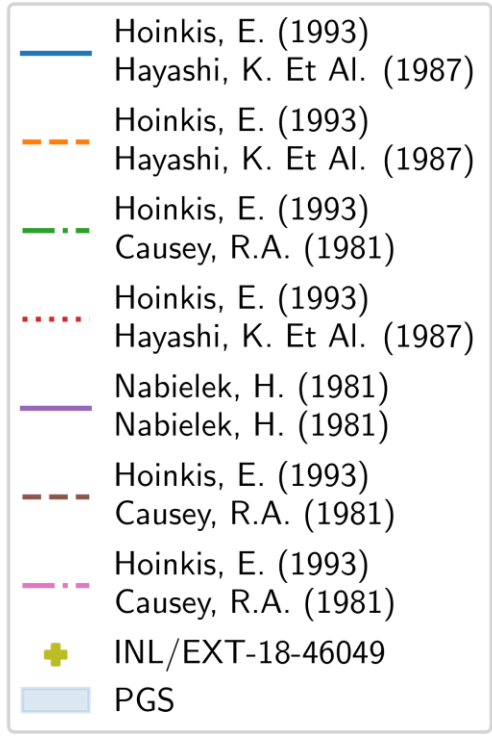
Literature Parameters vs Measurements, Capsule 1



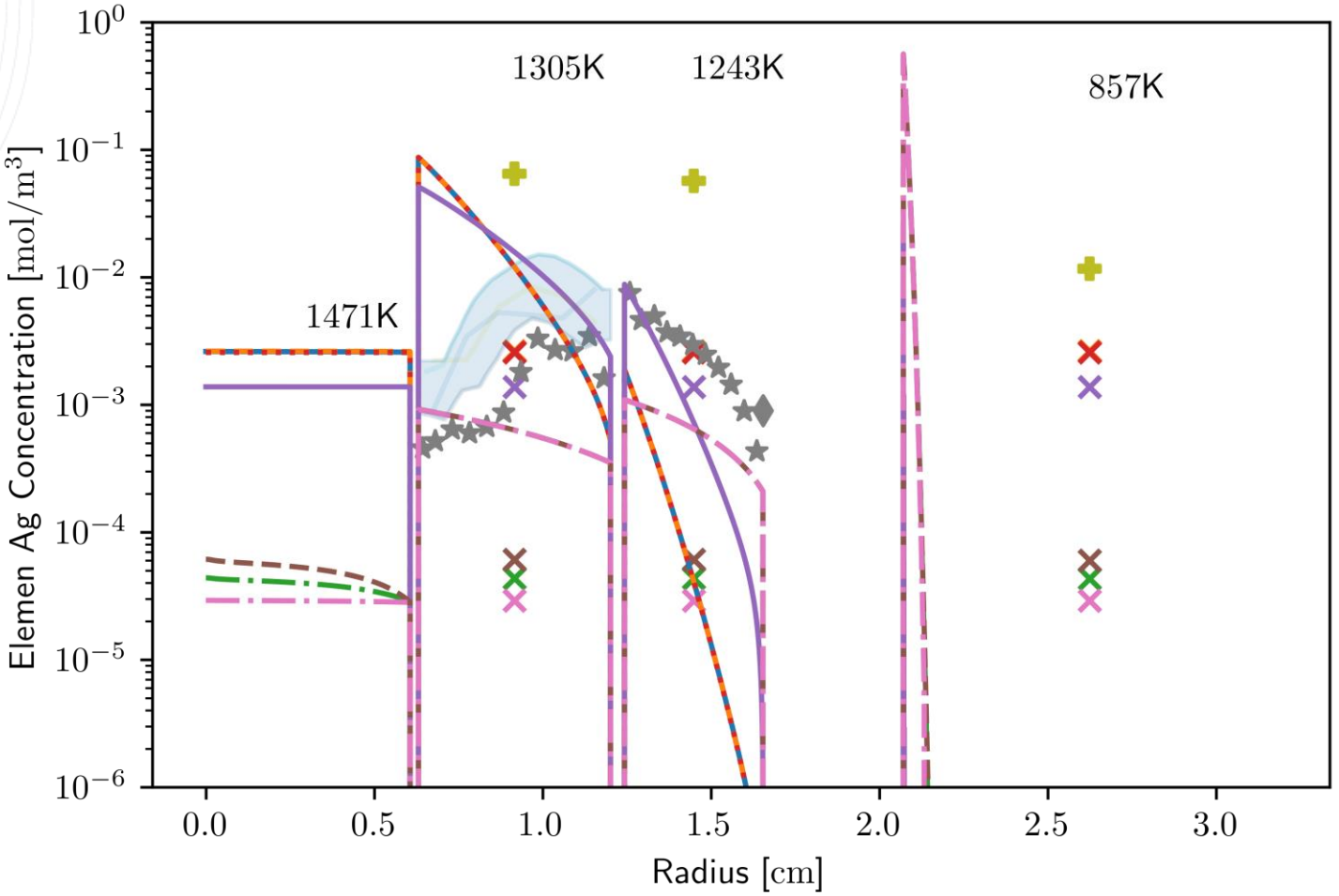


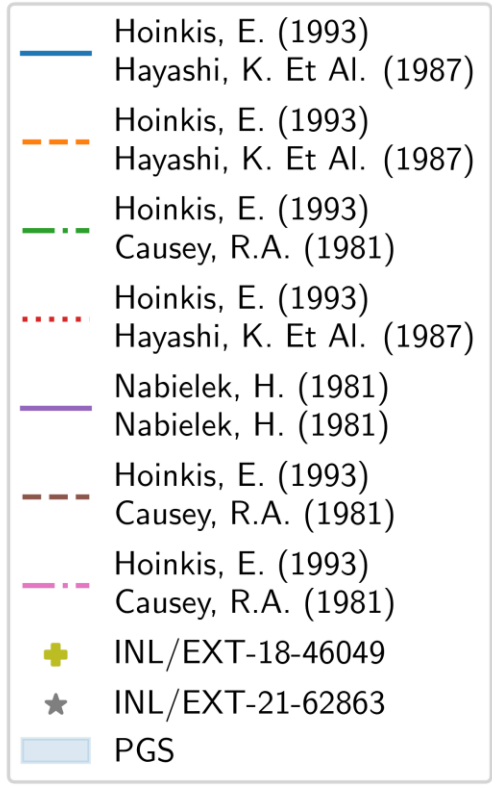
Literature Parameters vs Measurements, Capsule 2



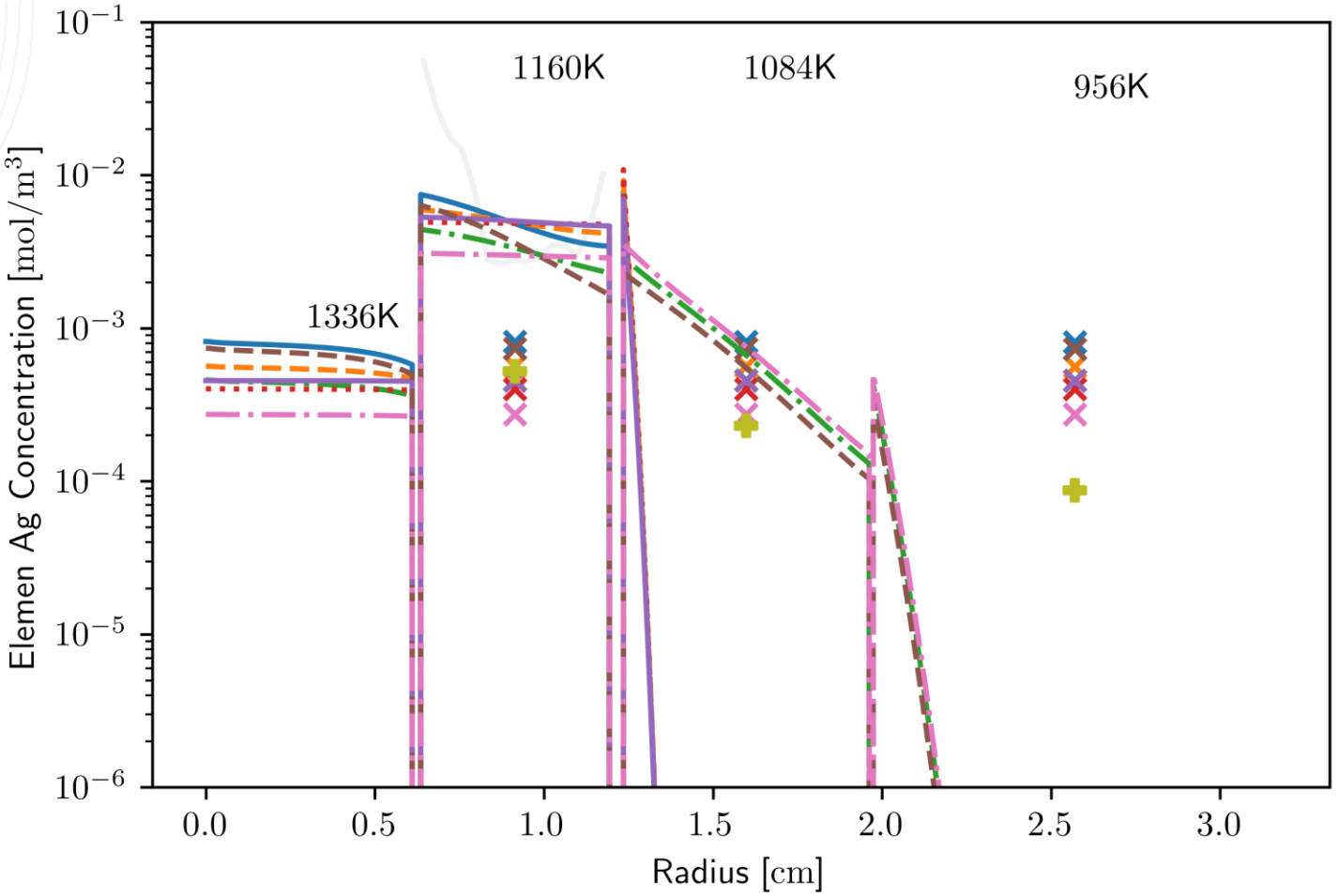


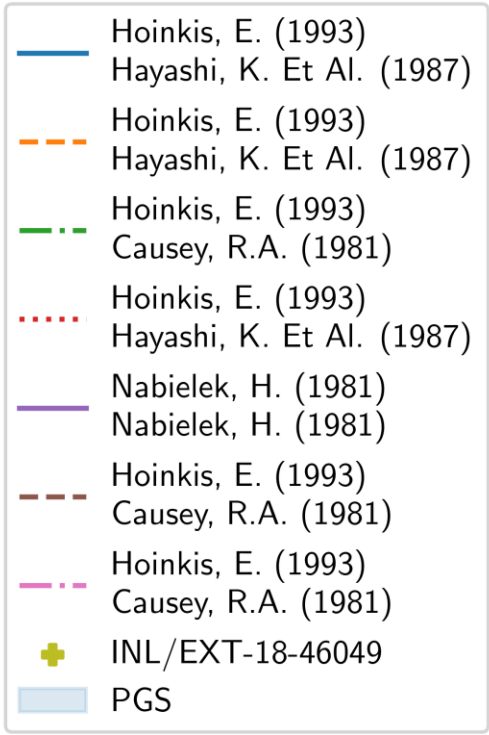
Literature Parameters vs Measurements, Capsule 3



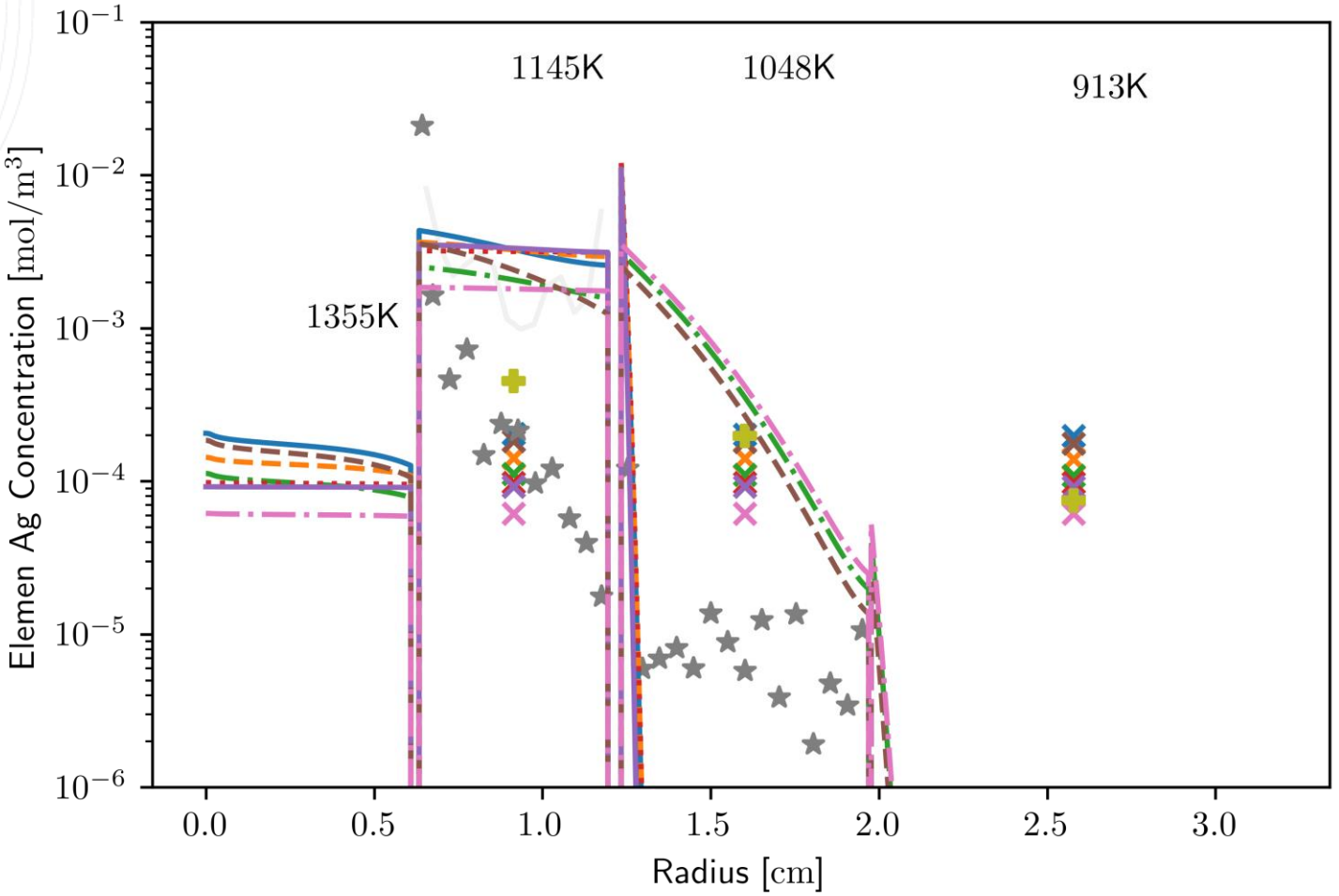


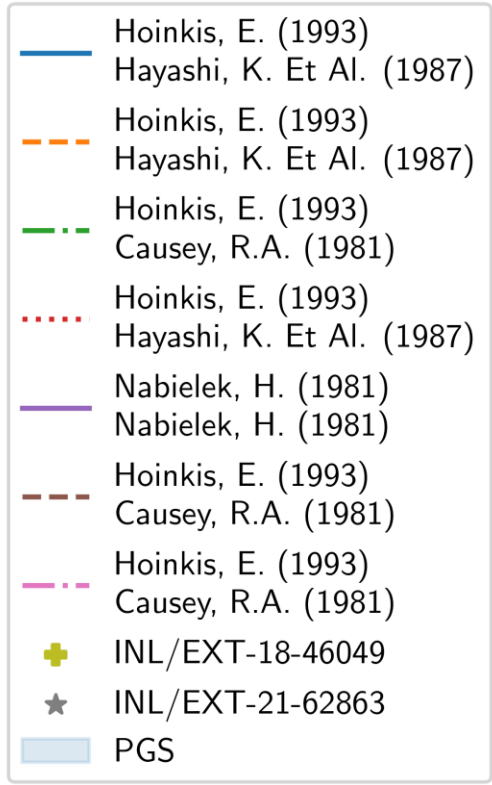
Literature Parameters vs Measurements, Capsule 4



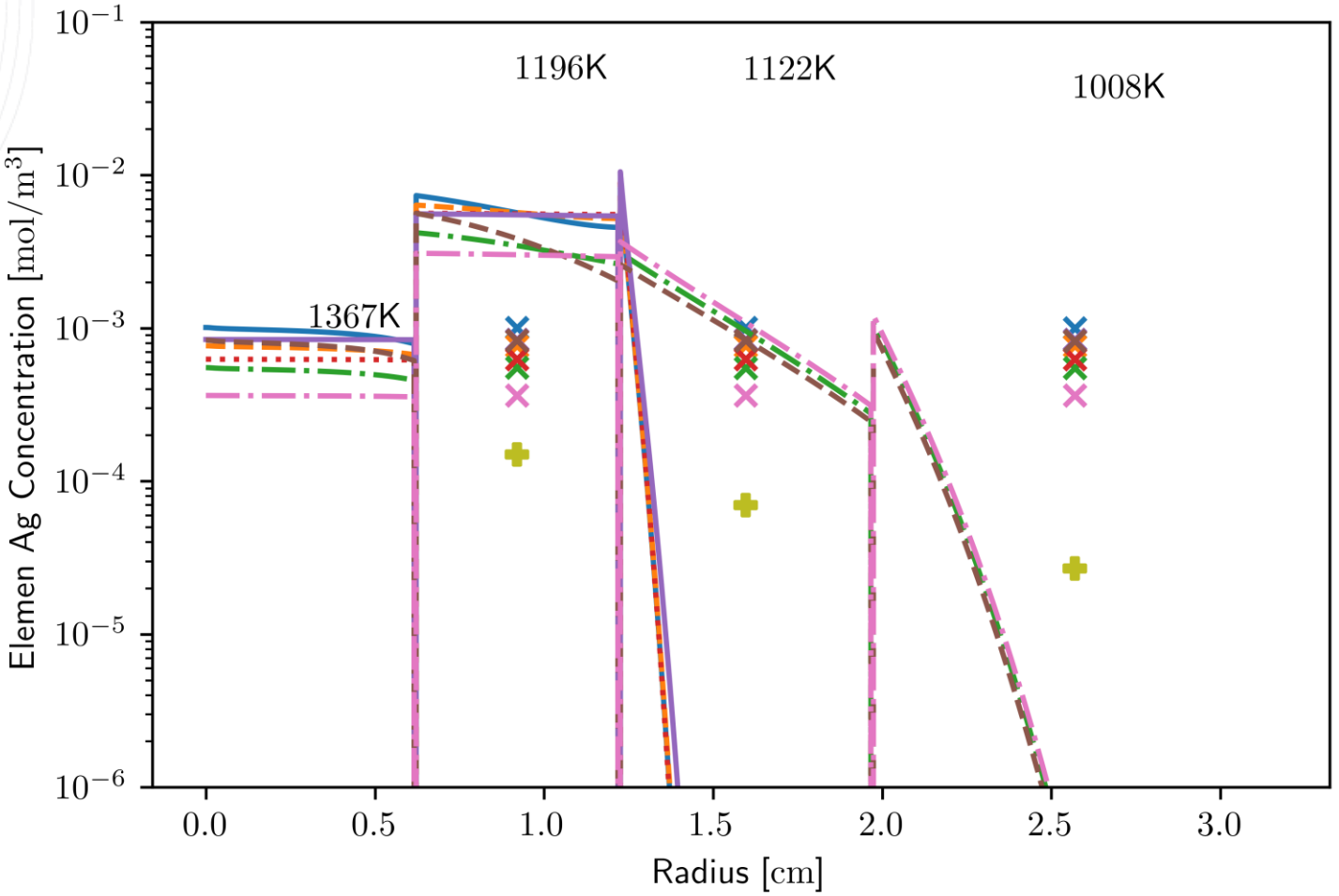


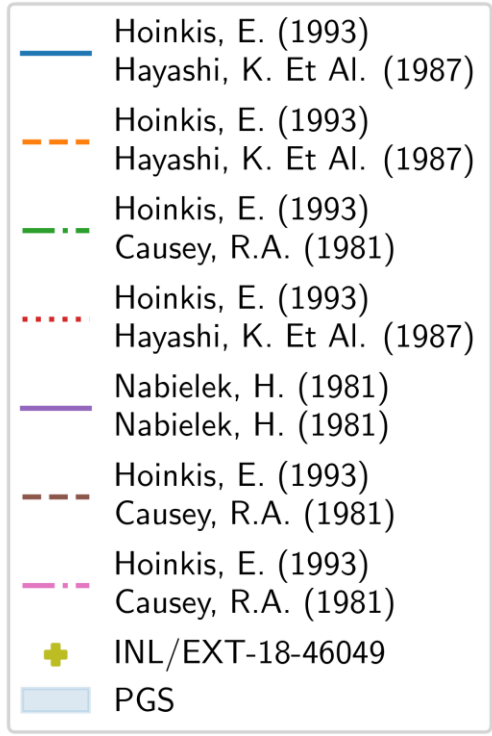
Literature Parameters vs Measurements, Capsule 5



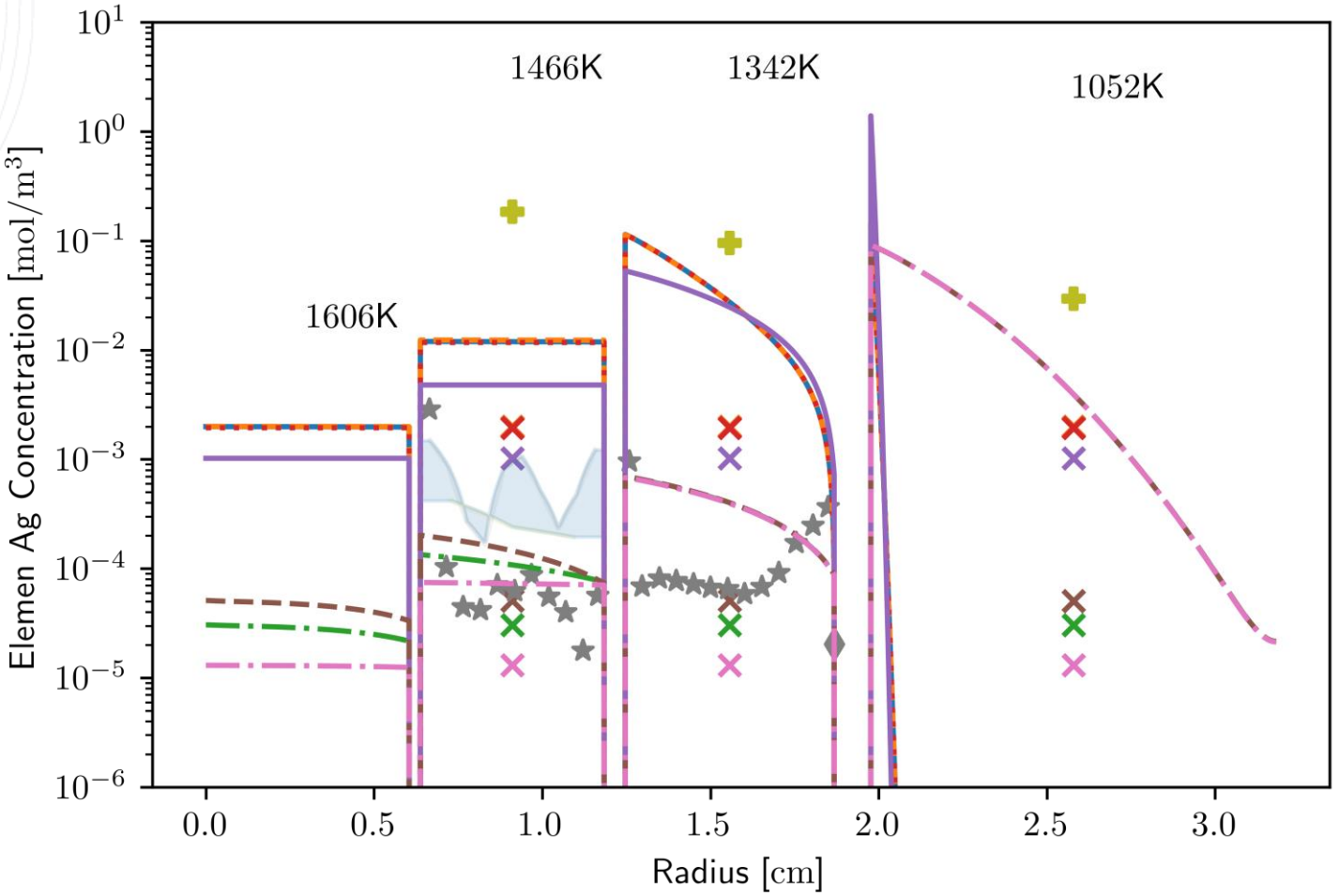


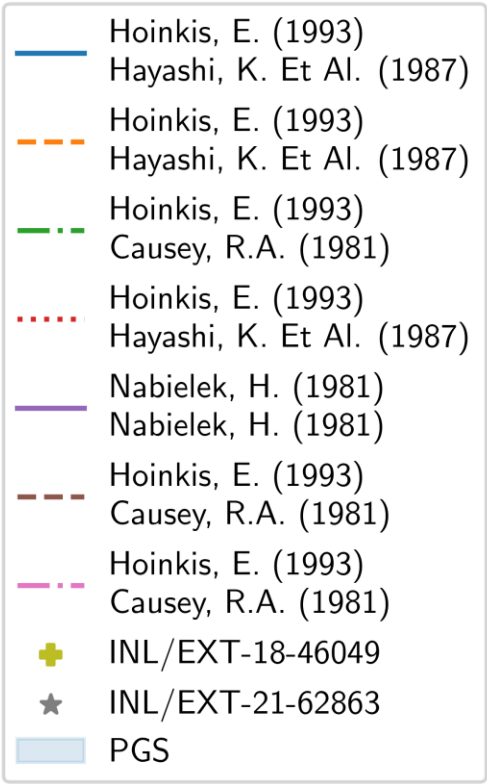
Literature Parameters vs Measurements, Capsule 6



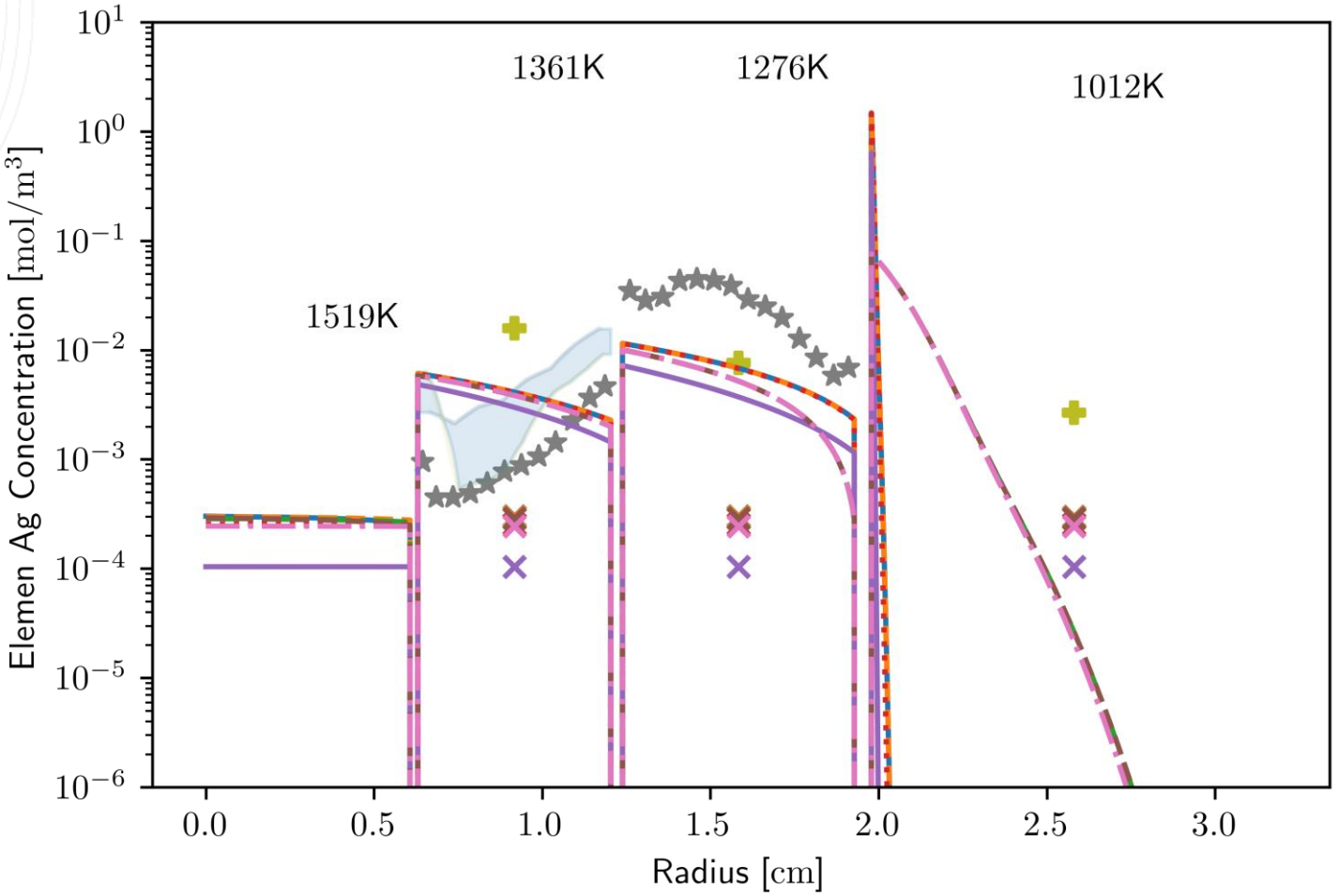


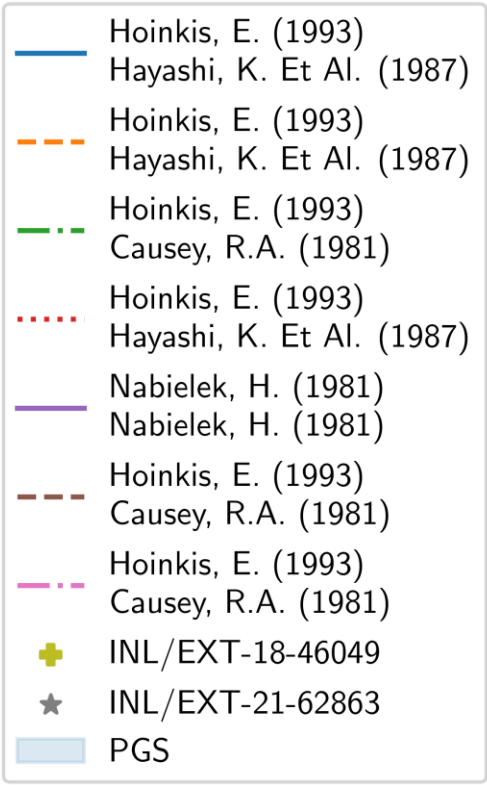
Literature Parameters vs Measurements, Capsule 7



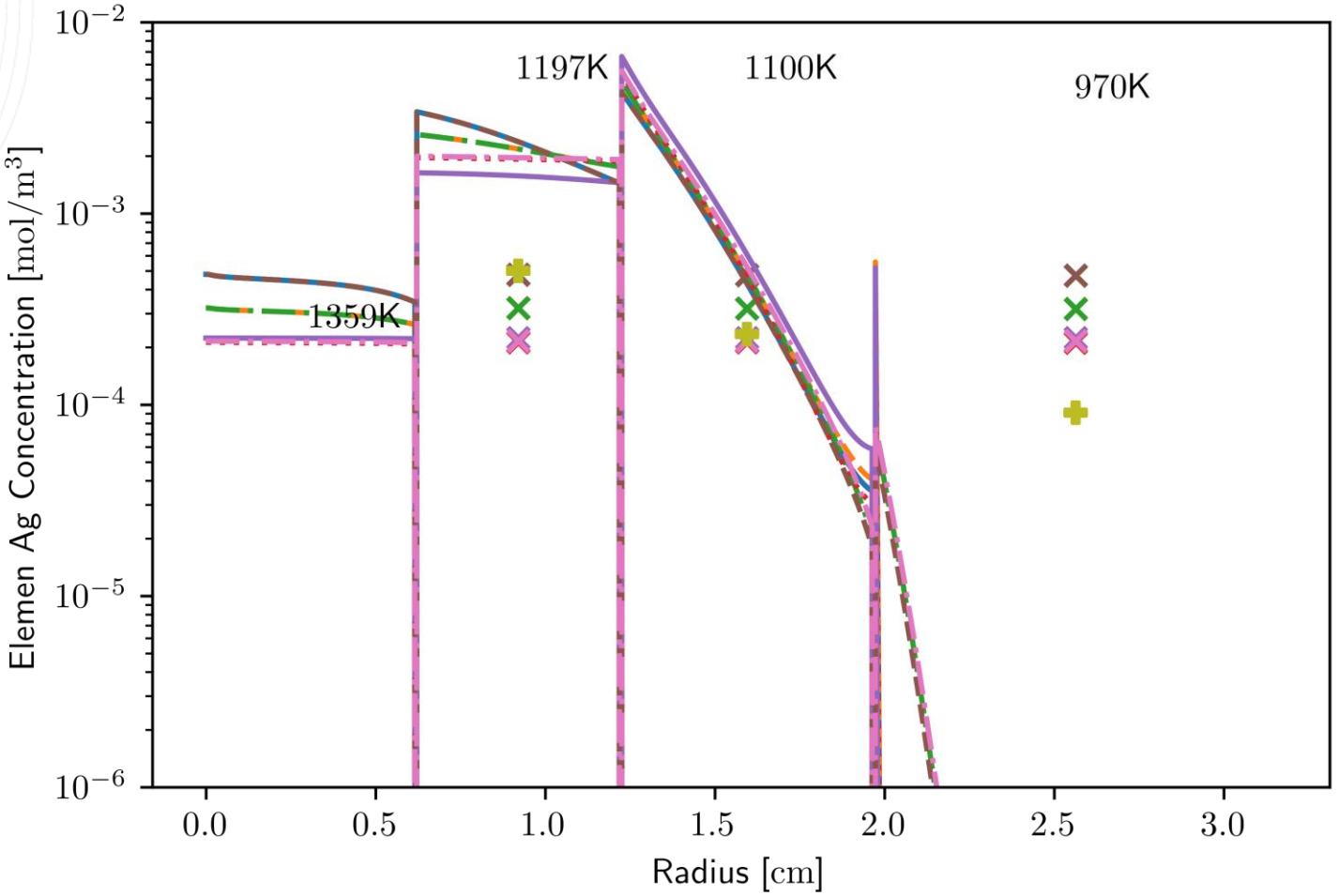


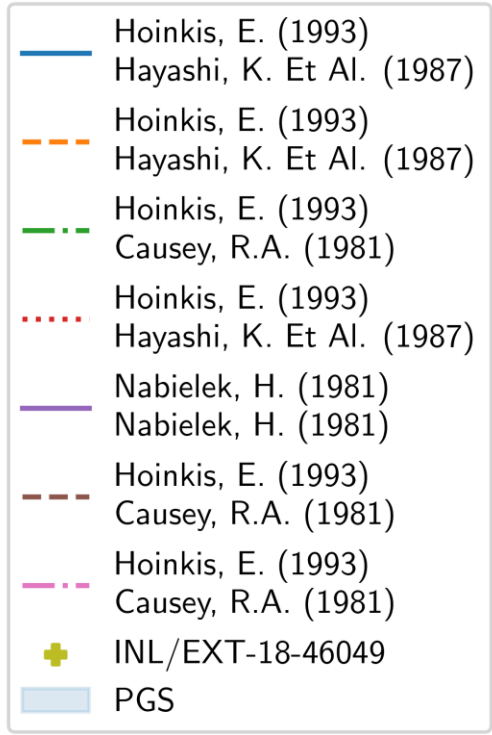
Literature Parameters vs Measurements, Capsule 8



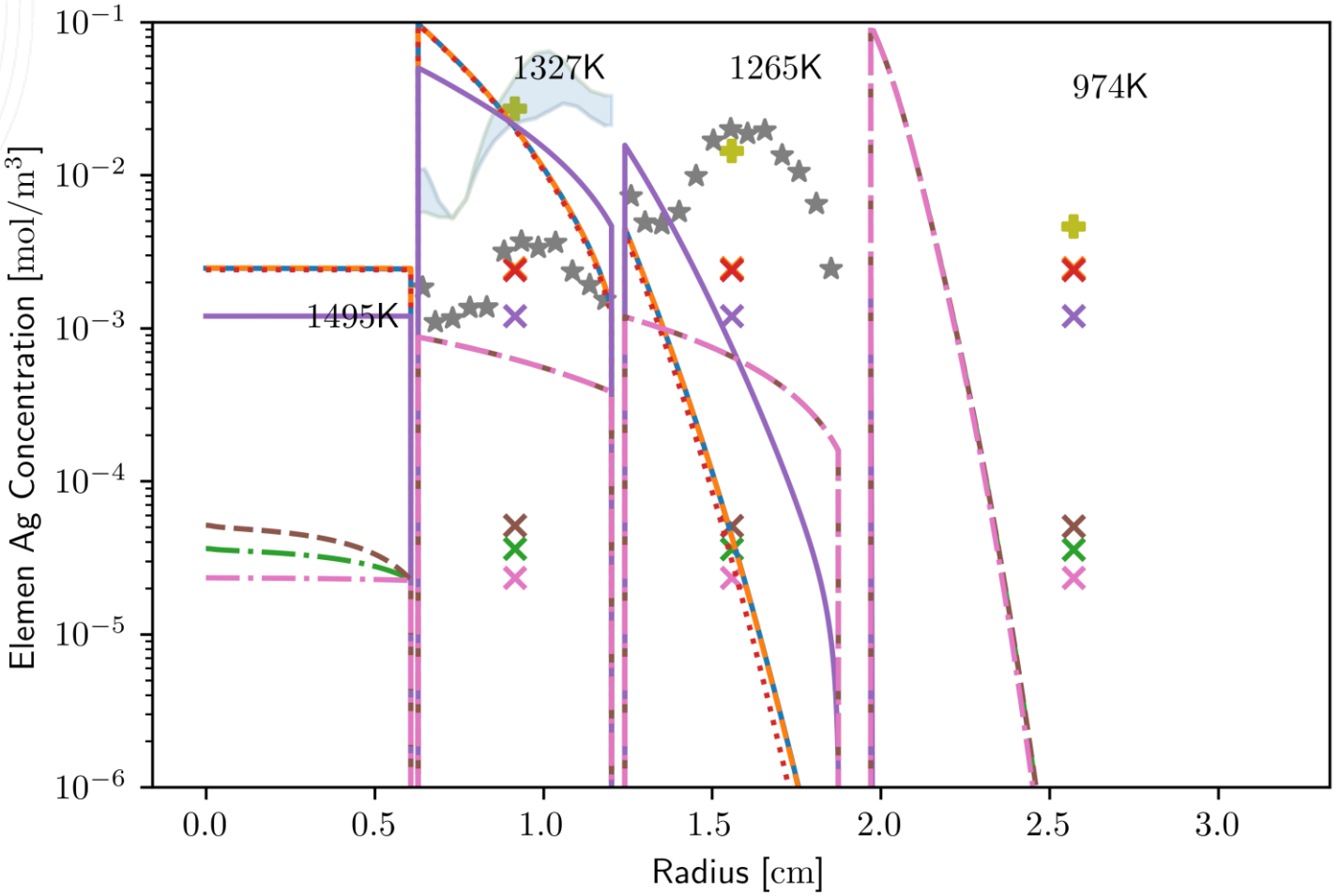


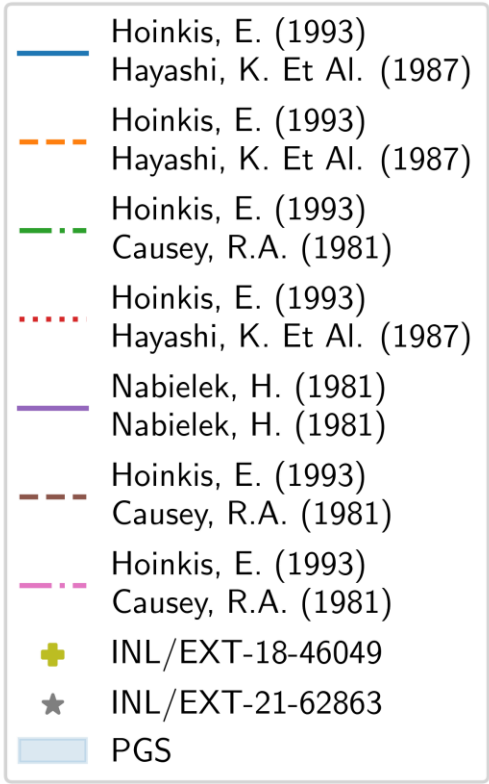
Literature Parameters vs Measurements, Capsule 9



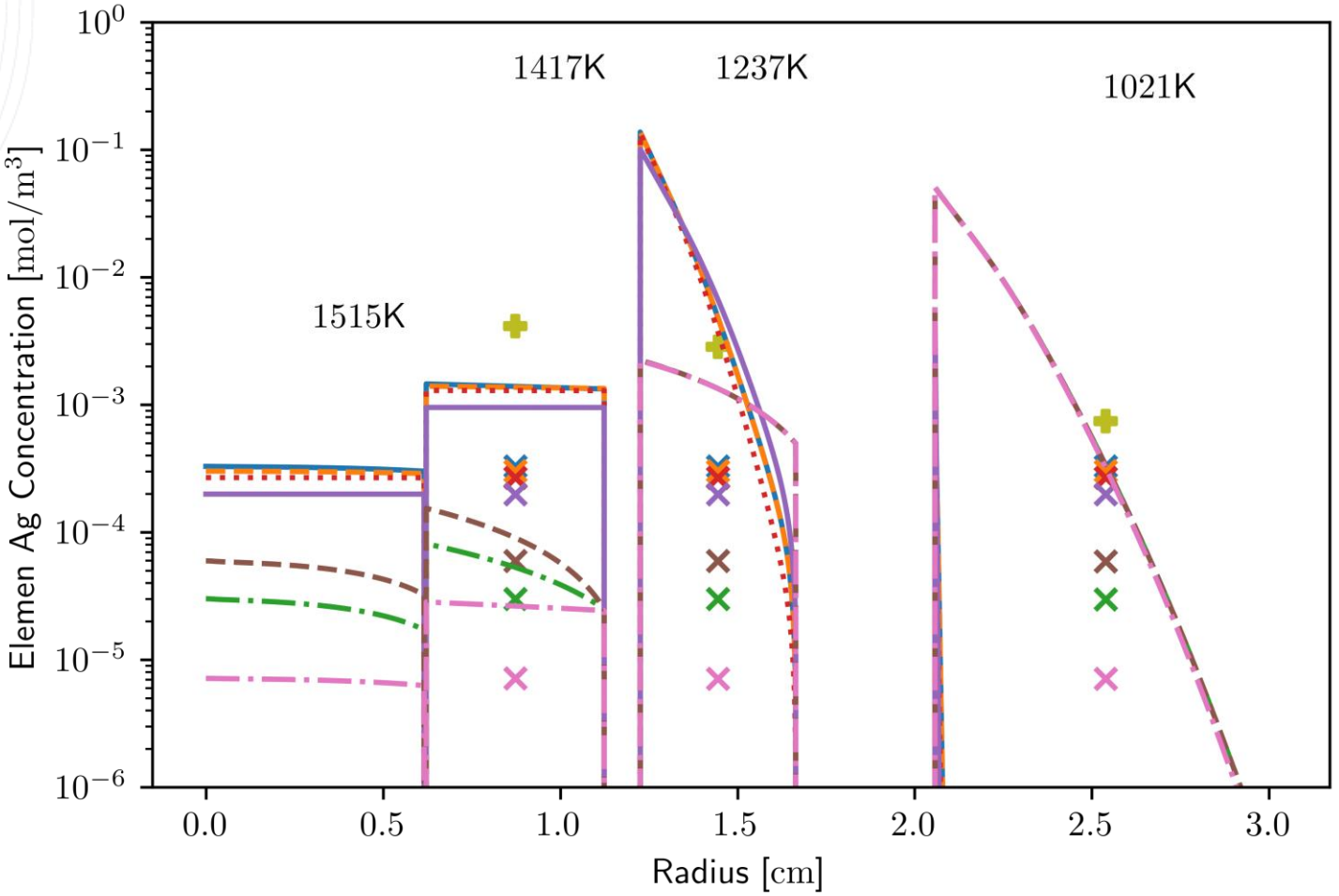


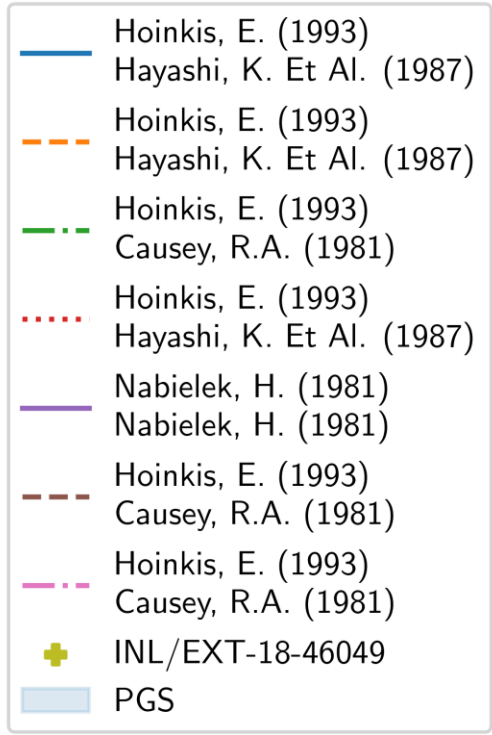
Literature Parameters vs Measurements, Capsule 10



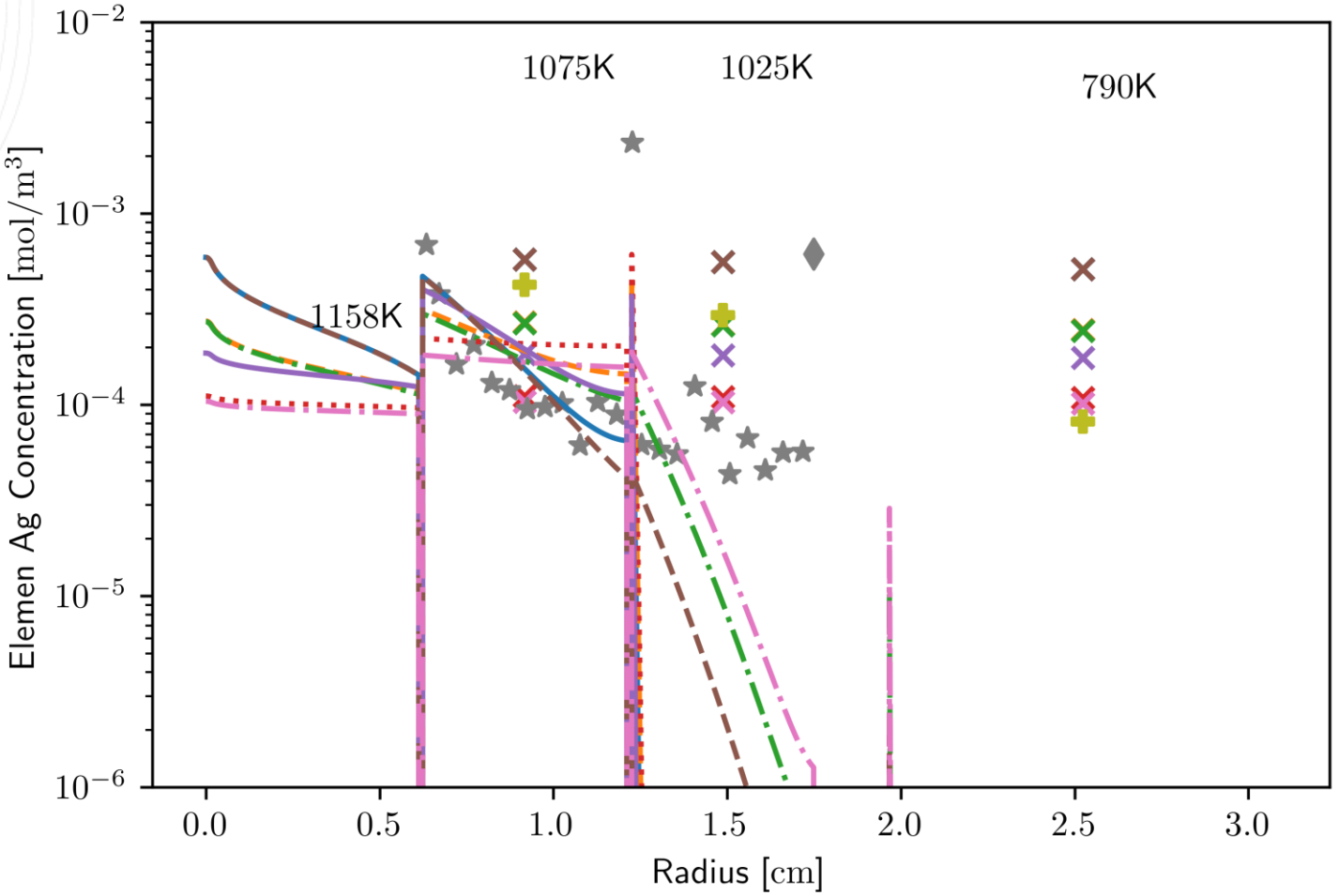


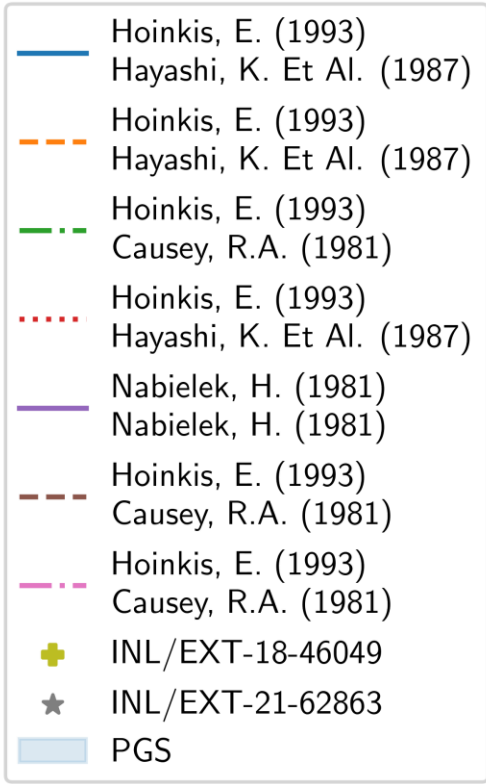
Literature Parameters vs Measurements, Capsule 11





Literature Parameters vs Measurements, Capsule 12



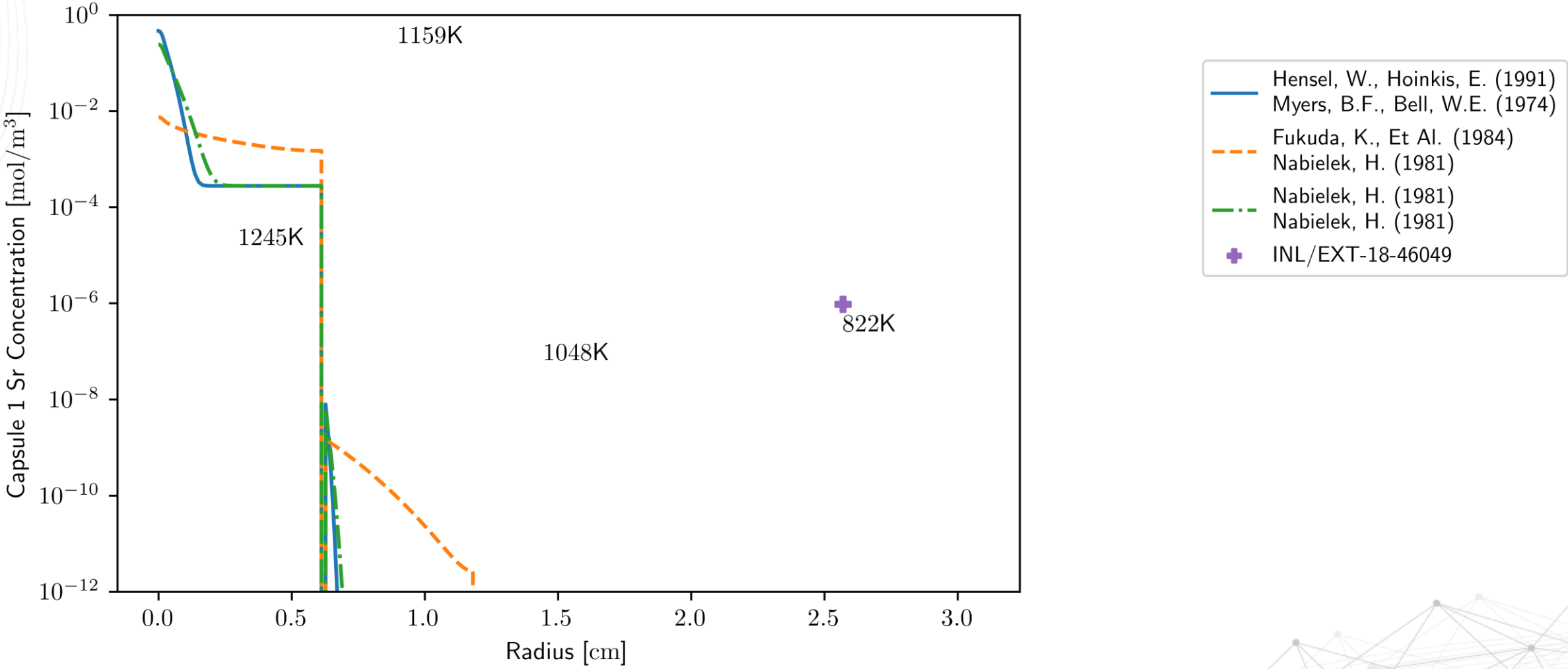


Silver - Summary

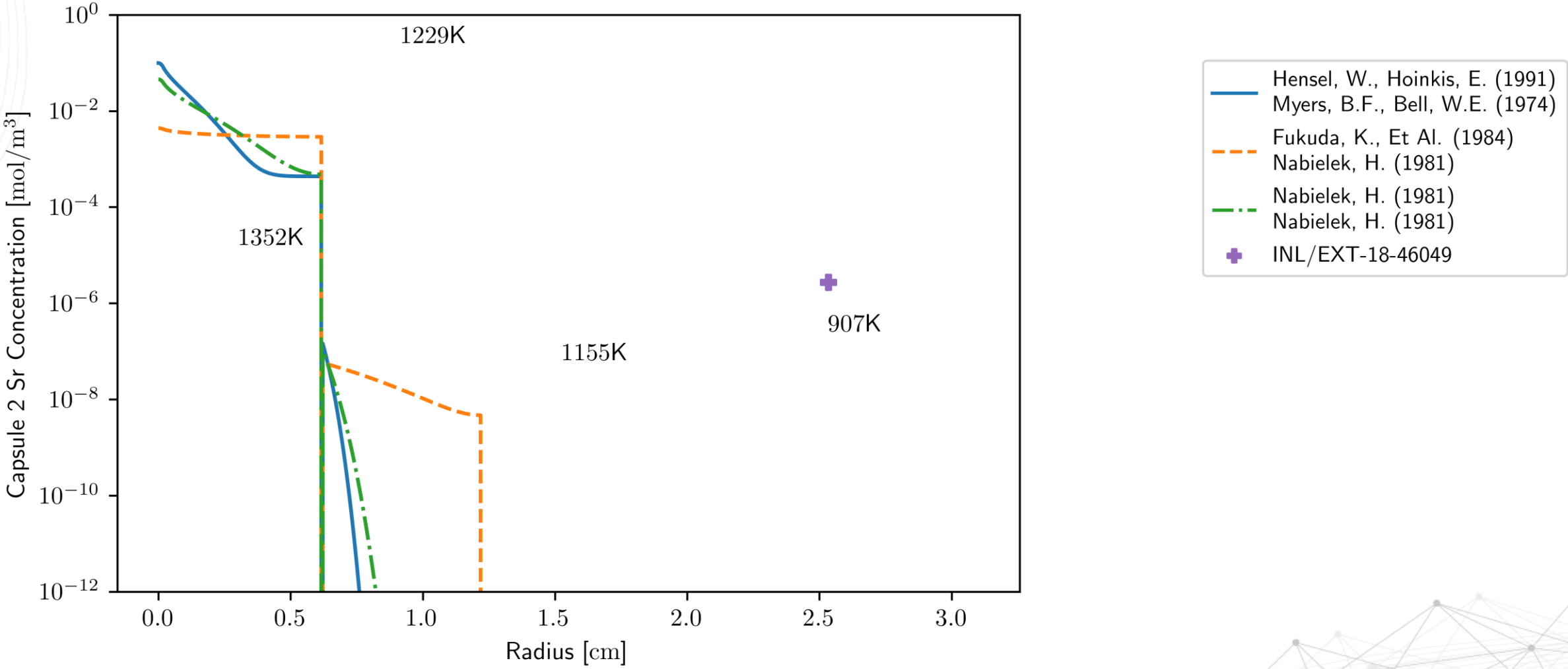
- Bulk silver transport can be mostly explained by an effective diffusivity in line with literature values
- Fitting to the observed concentration profiles will require more detailed modeling
  - Surface effects
  - Pore diffusion model

Strontium

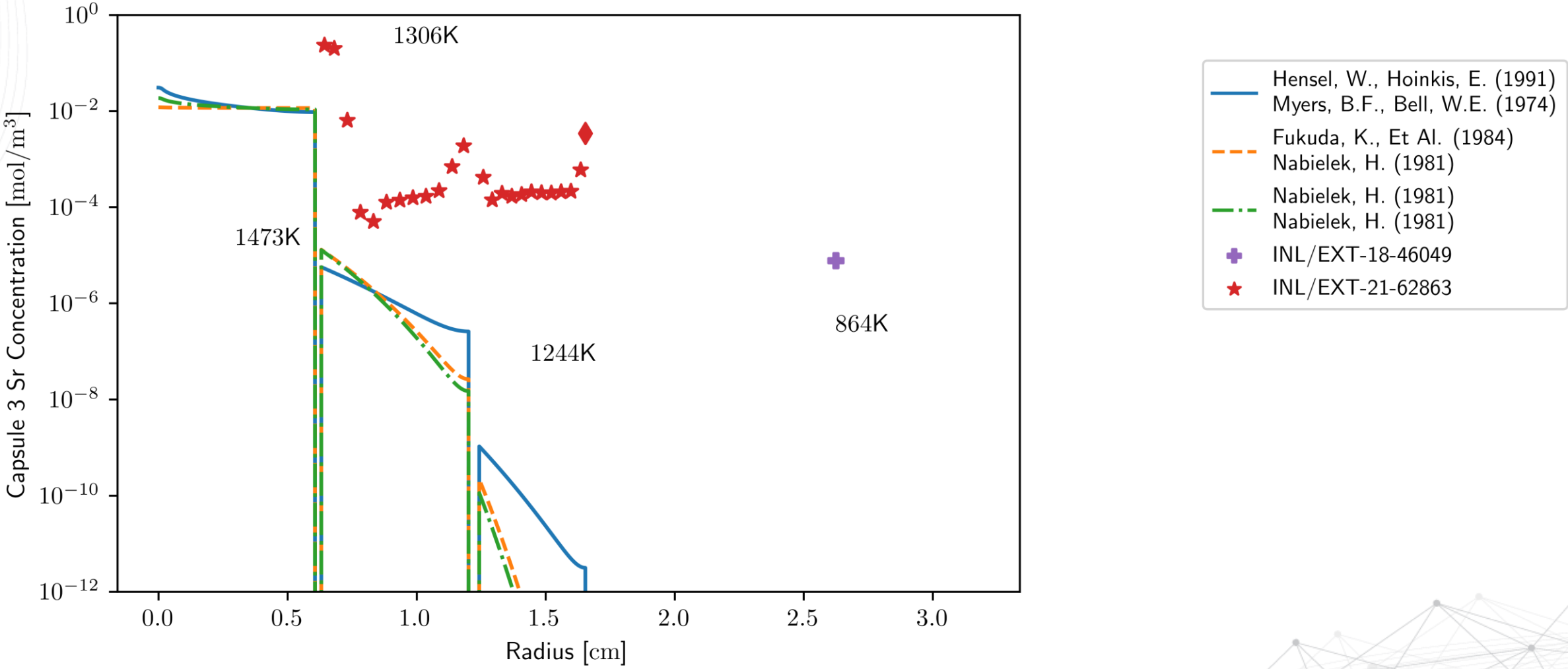
Literature Parameters vs Measurements, Capsule 1



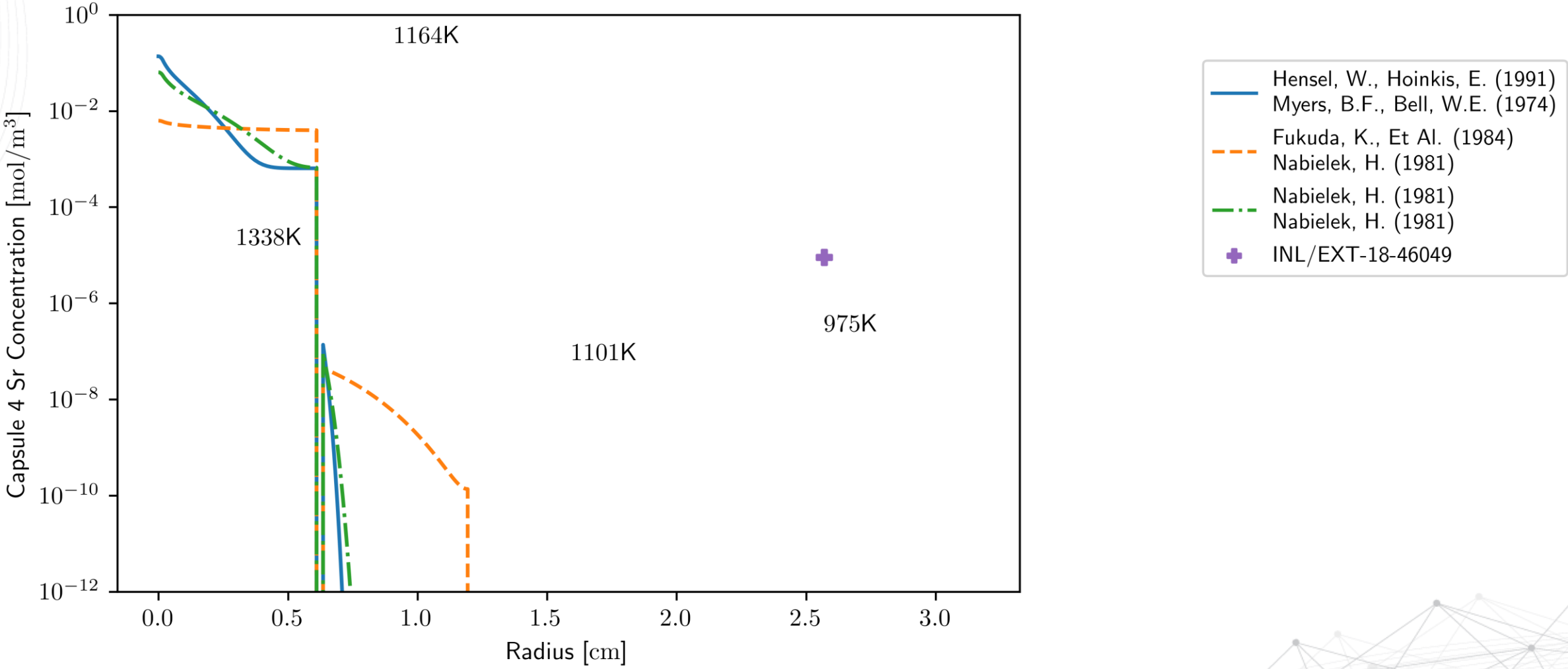
Literature Parameters vs Measurements, Capsule 2



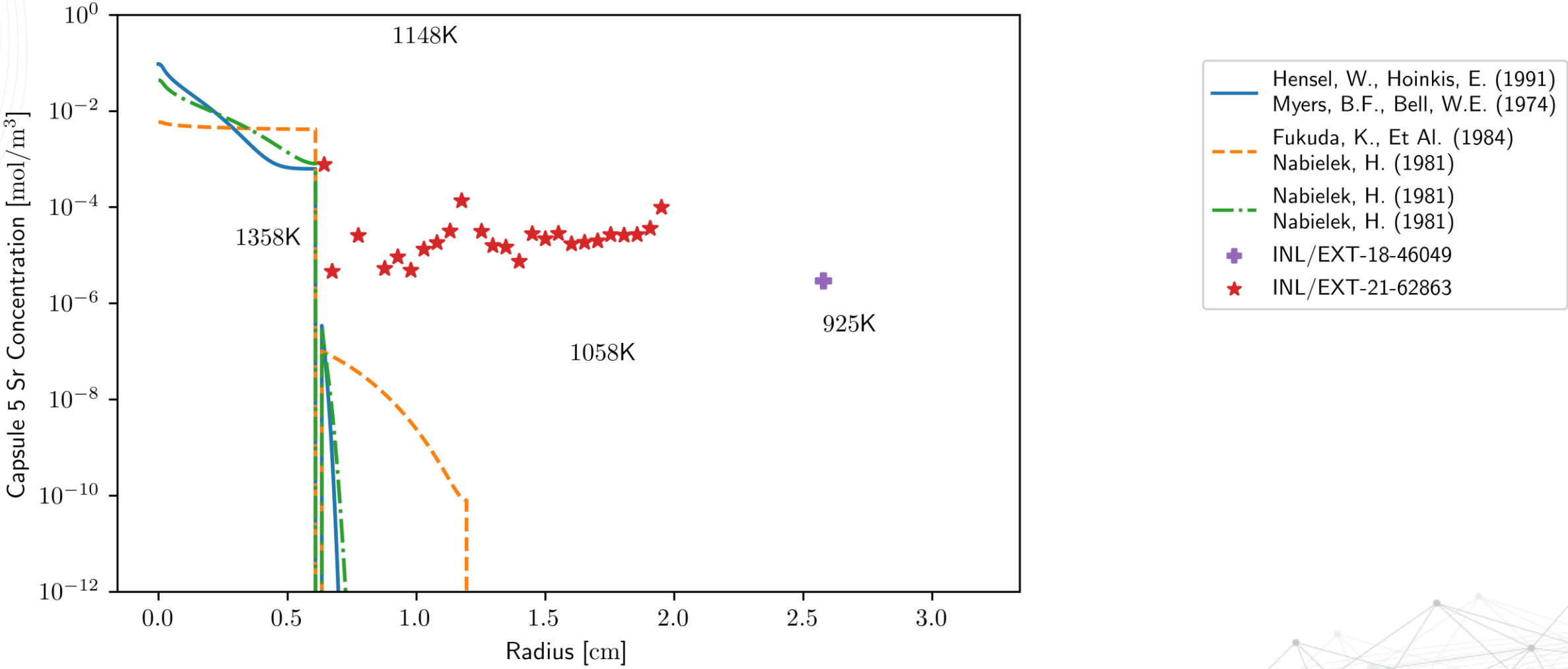
Literature Parameters vs Measurements, Capsule 3



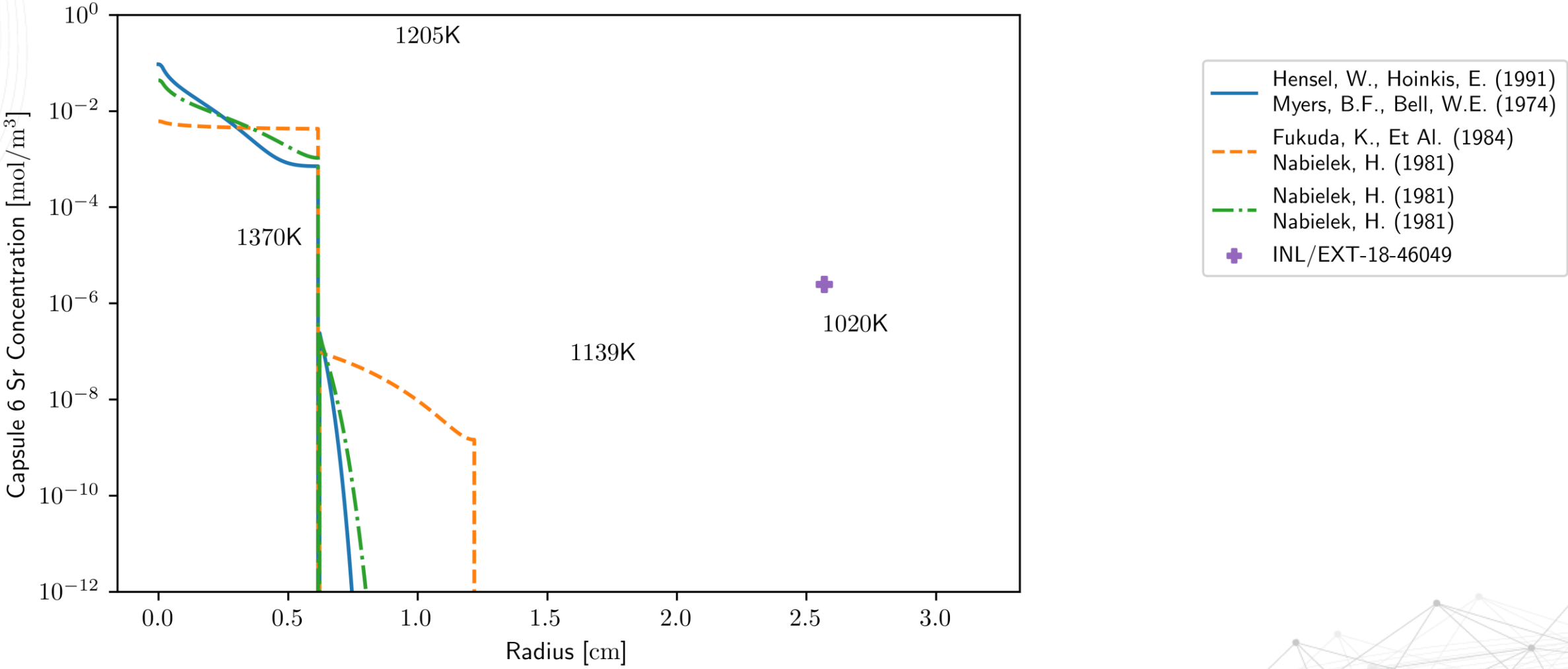
Literature Parameters vs Measurements, Capsule 4



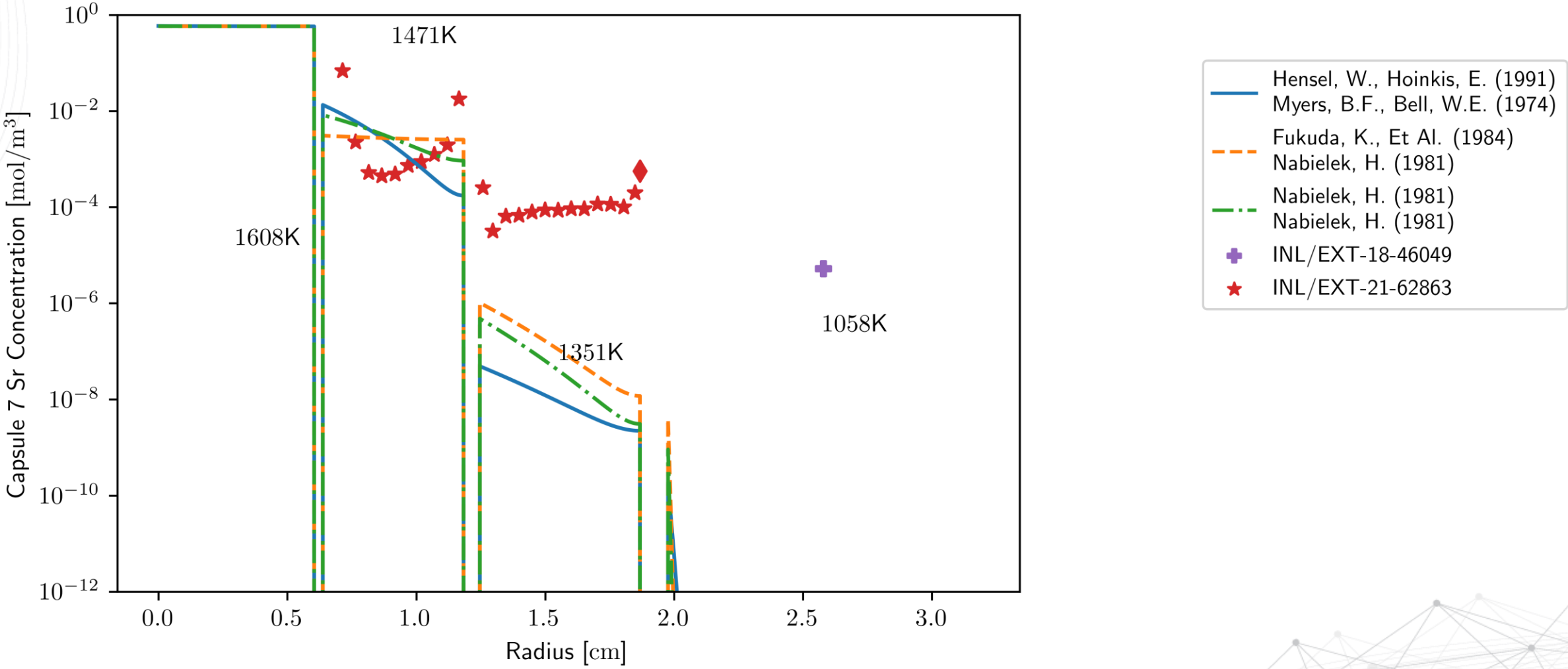
Literature Parameters vs Measurements, Capsule 5



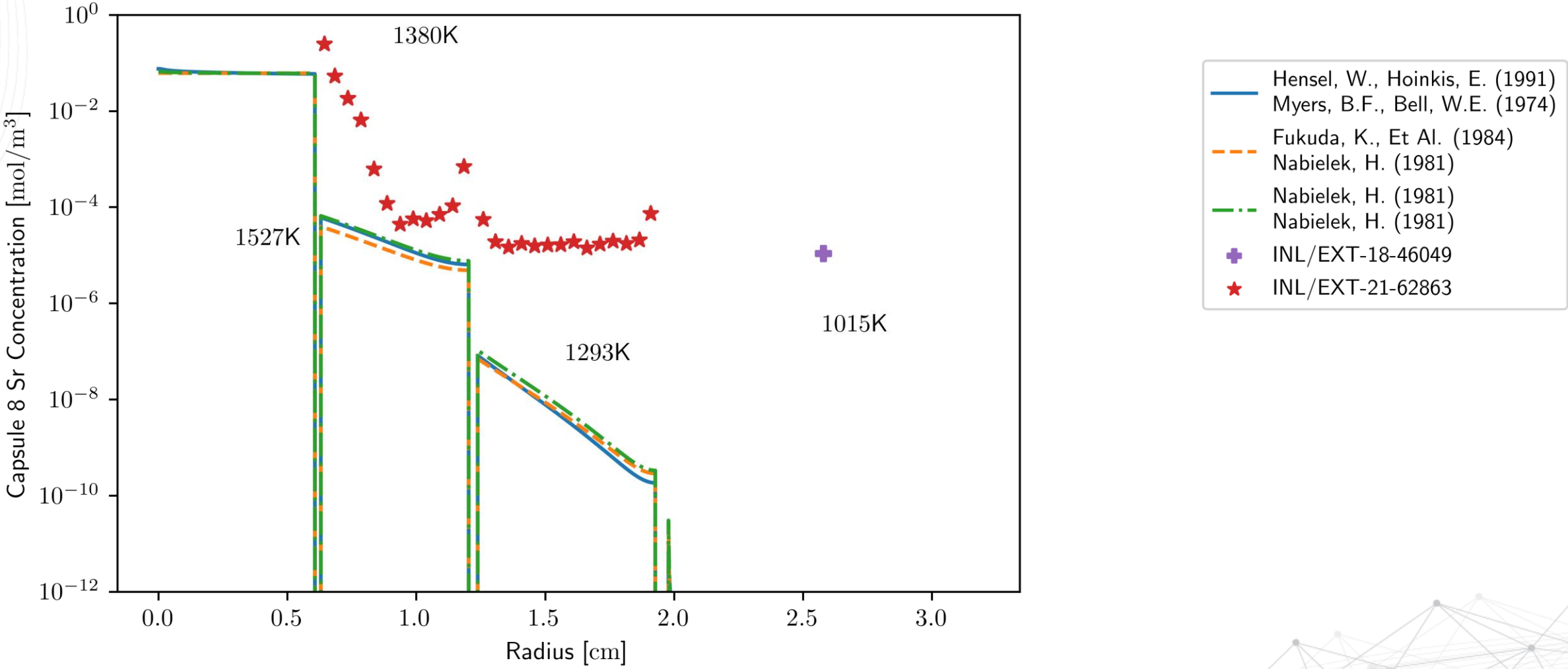
Literature Parameters vs Measurements, Capsule 6



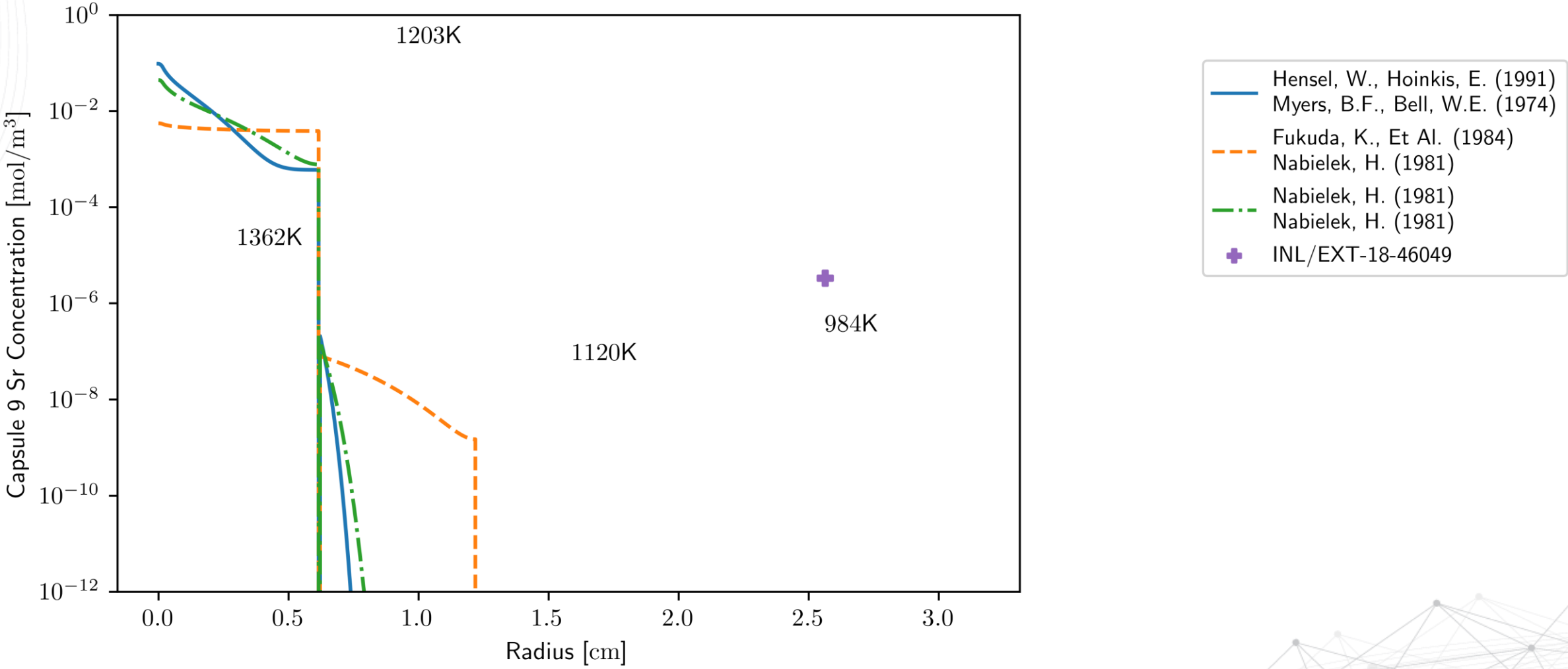
Literature Parameters vs Measurements, Capsule 7



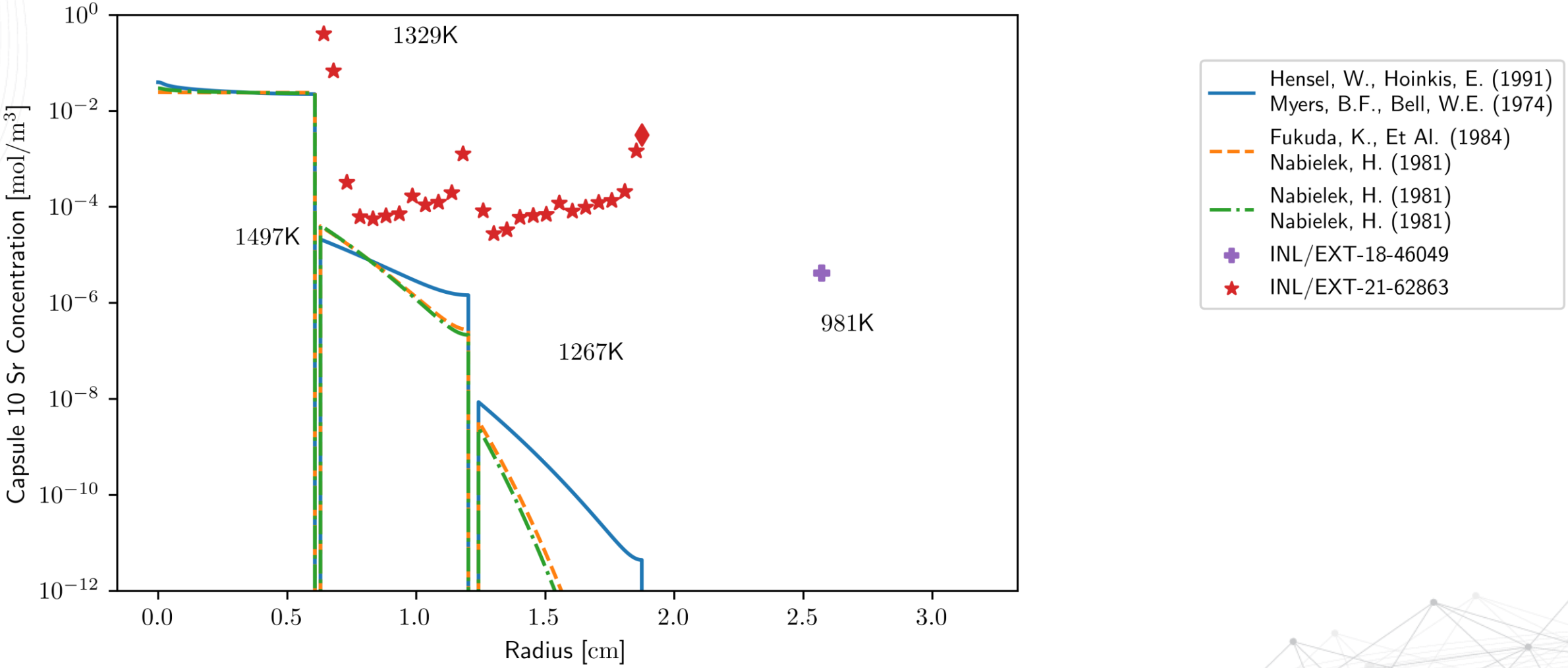
Literature Parameters vs Measurements, Capsule 8



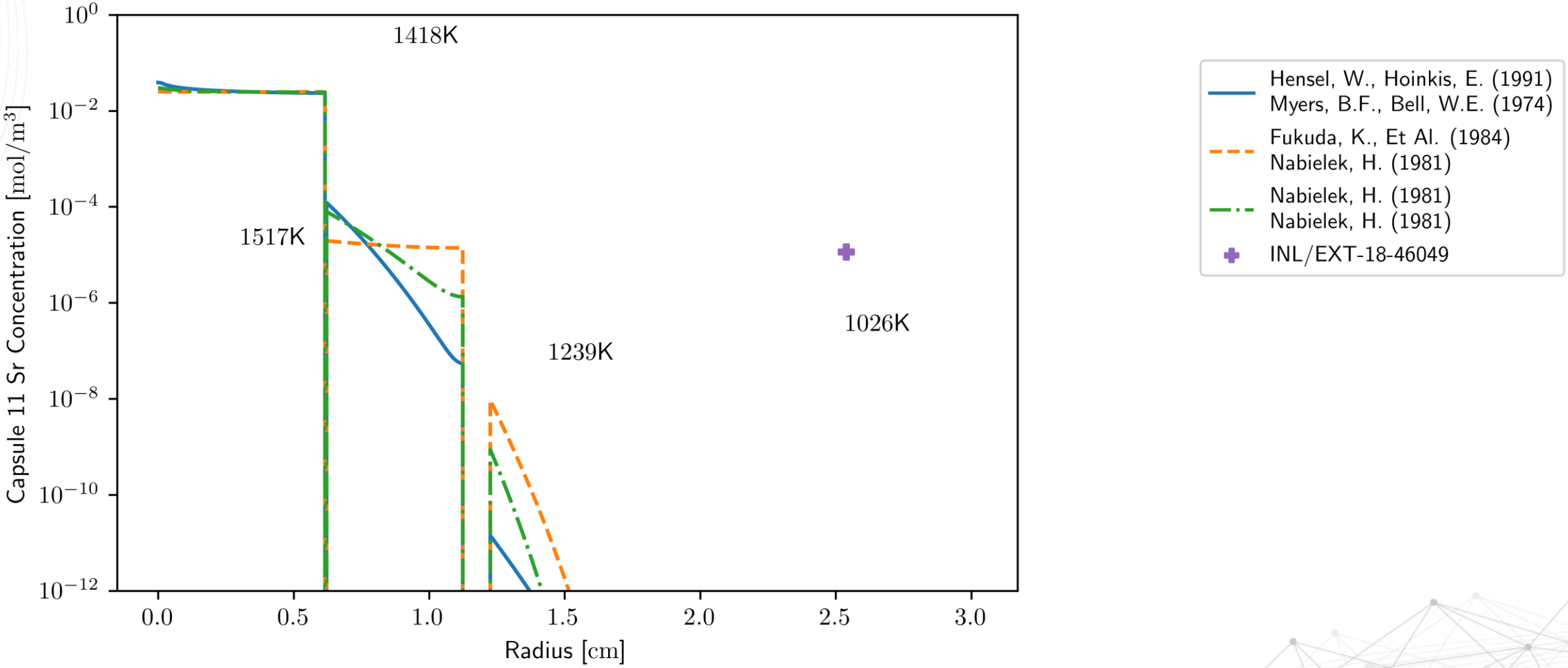
Literature Parameters vs Measurements, Capsule 9



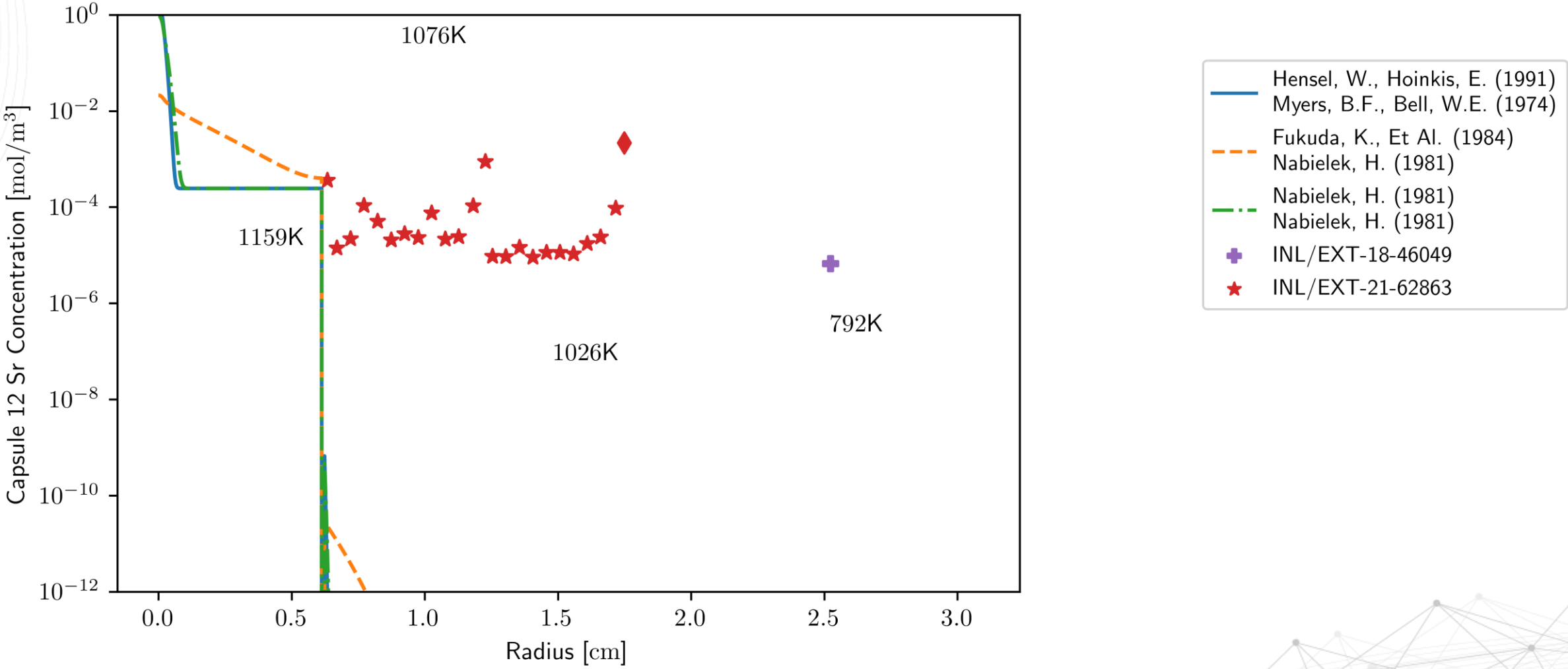
Literature Parameters vs Measurements, Capsule 10



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