

July 12, 2022

**Adriaan Riet**

# Modeling of the AGR 3/4 Experiments PIE



# 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)

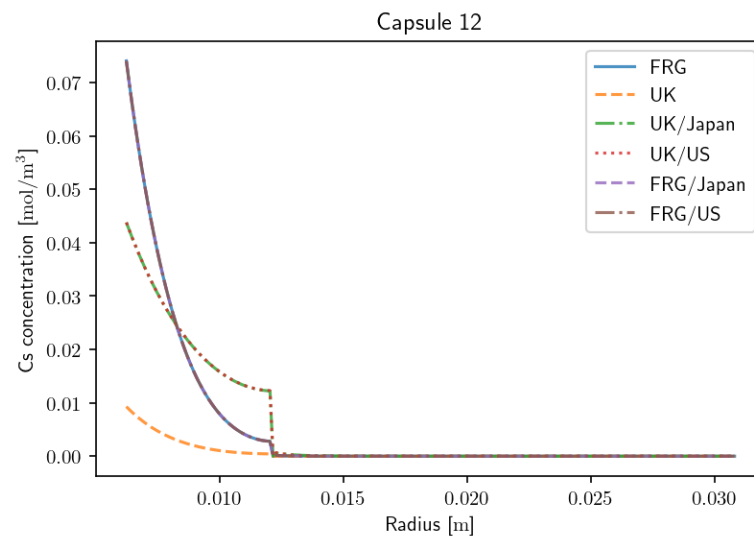
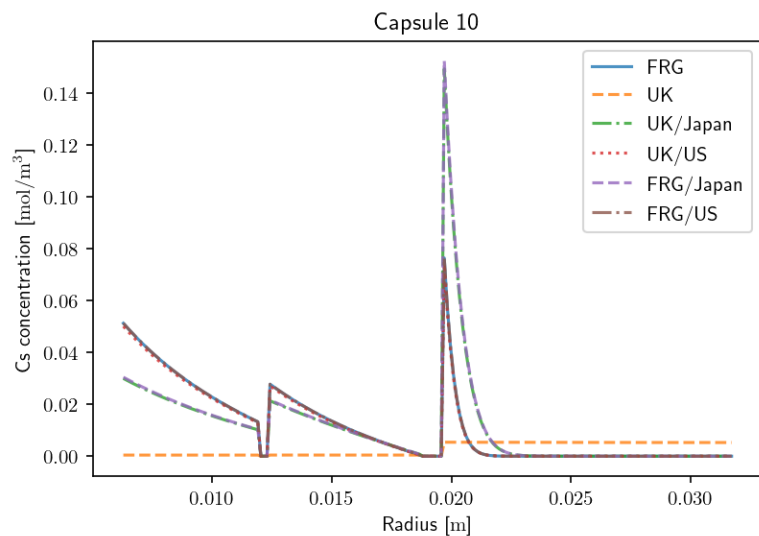
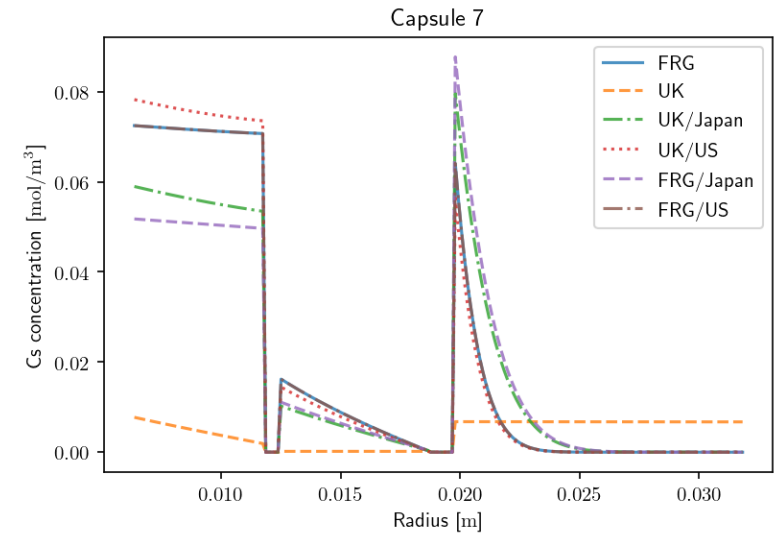
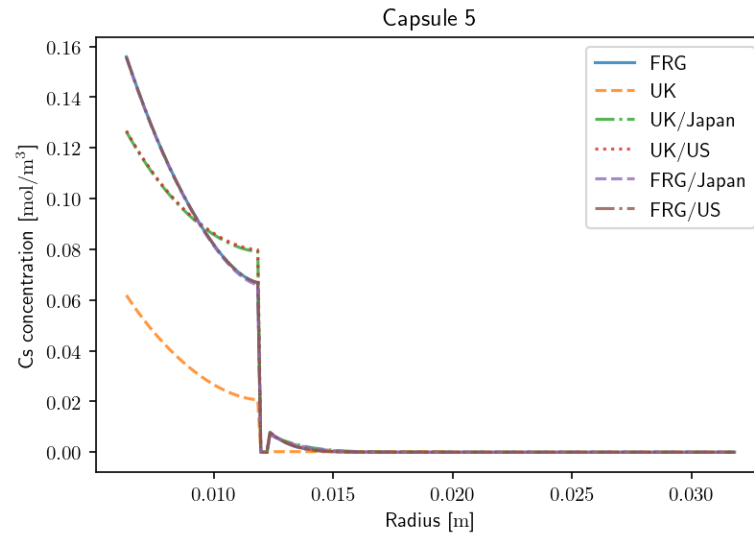
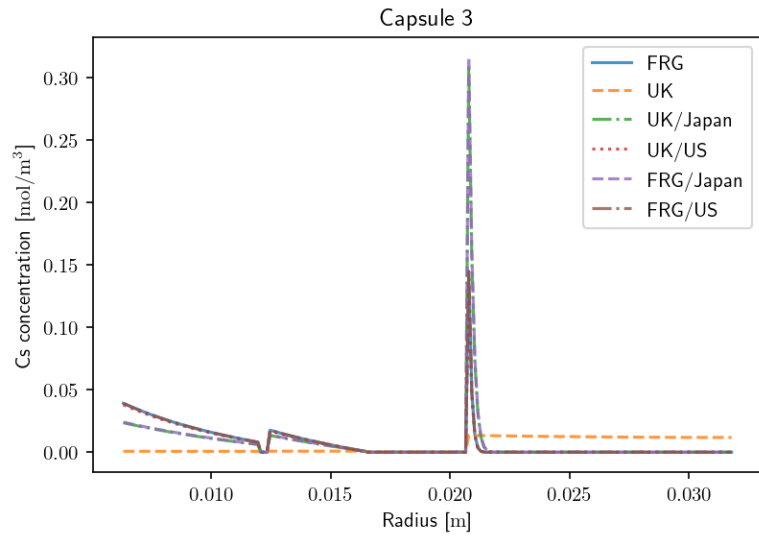
$$- T = \frac{\sum \left( D_0 \exp\left(-\frac{E_a}{RT(t)}\right) T(t) \Delta t \right)}{\sum \left( D_0 \exp\left(-\frac{E_a}{RT(t)}\right) \Delta t \right)}$$





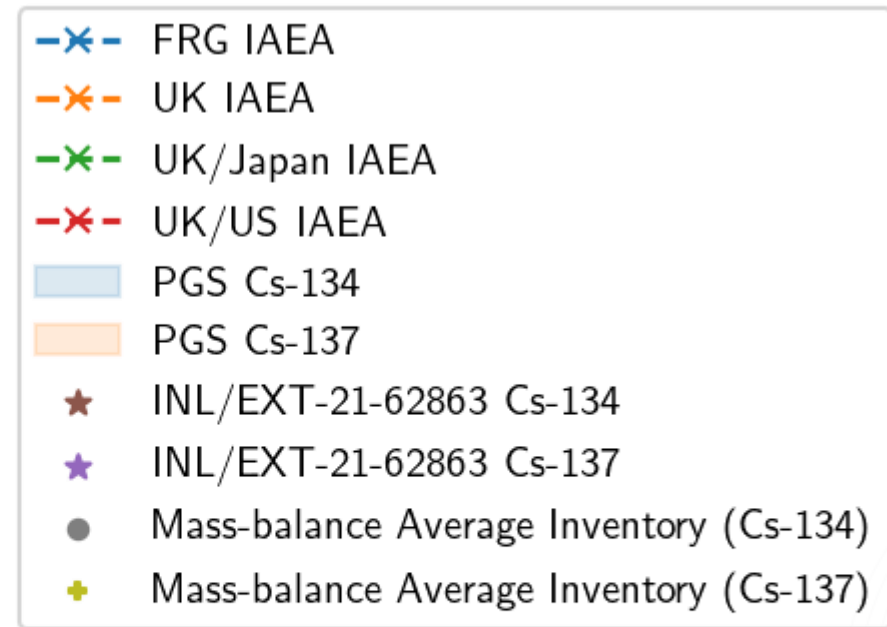
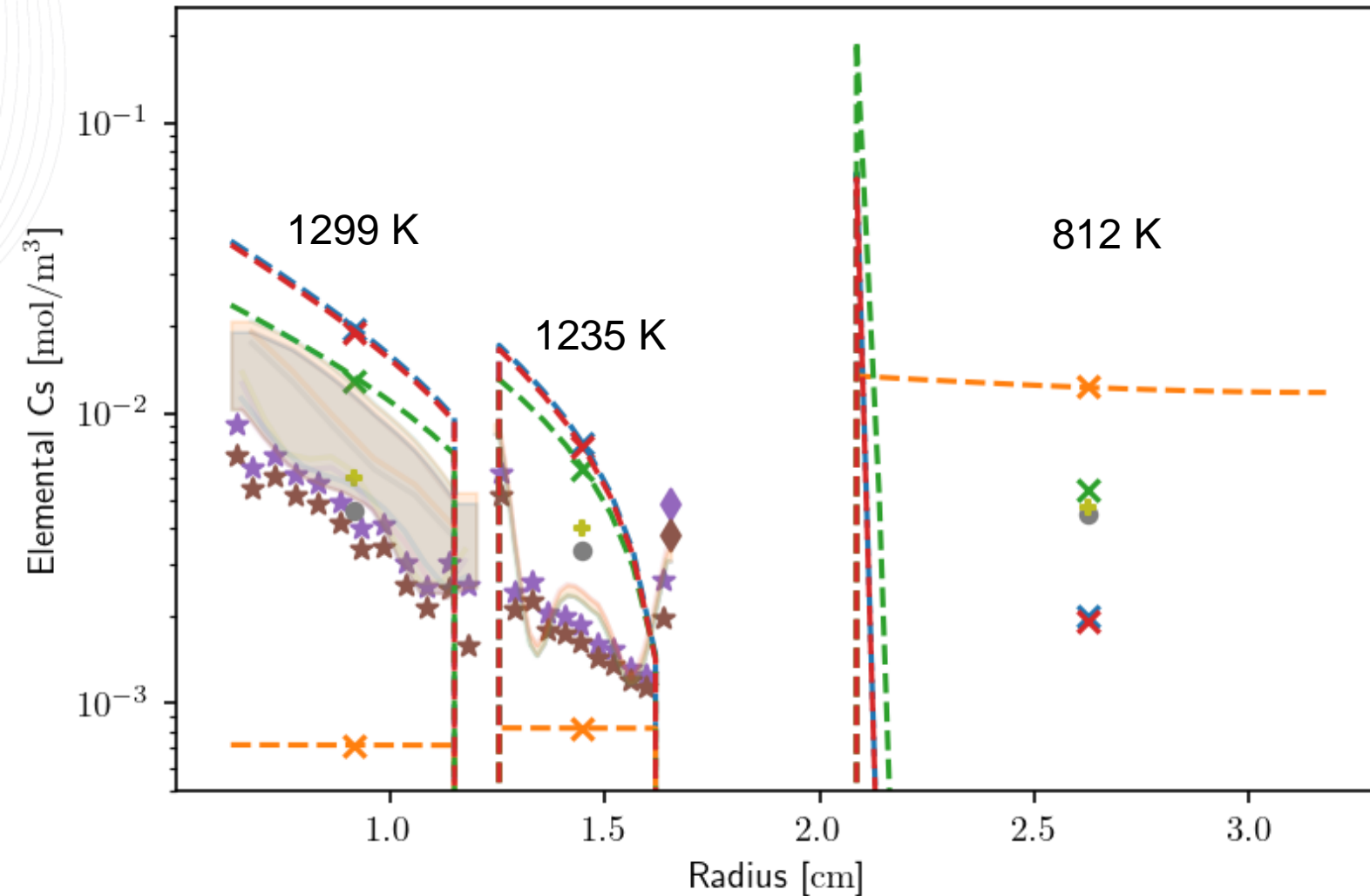
**Cesium**

# Modeled Concentration Profiles From Previous Literature Values

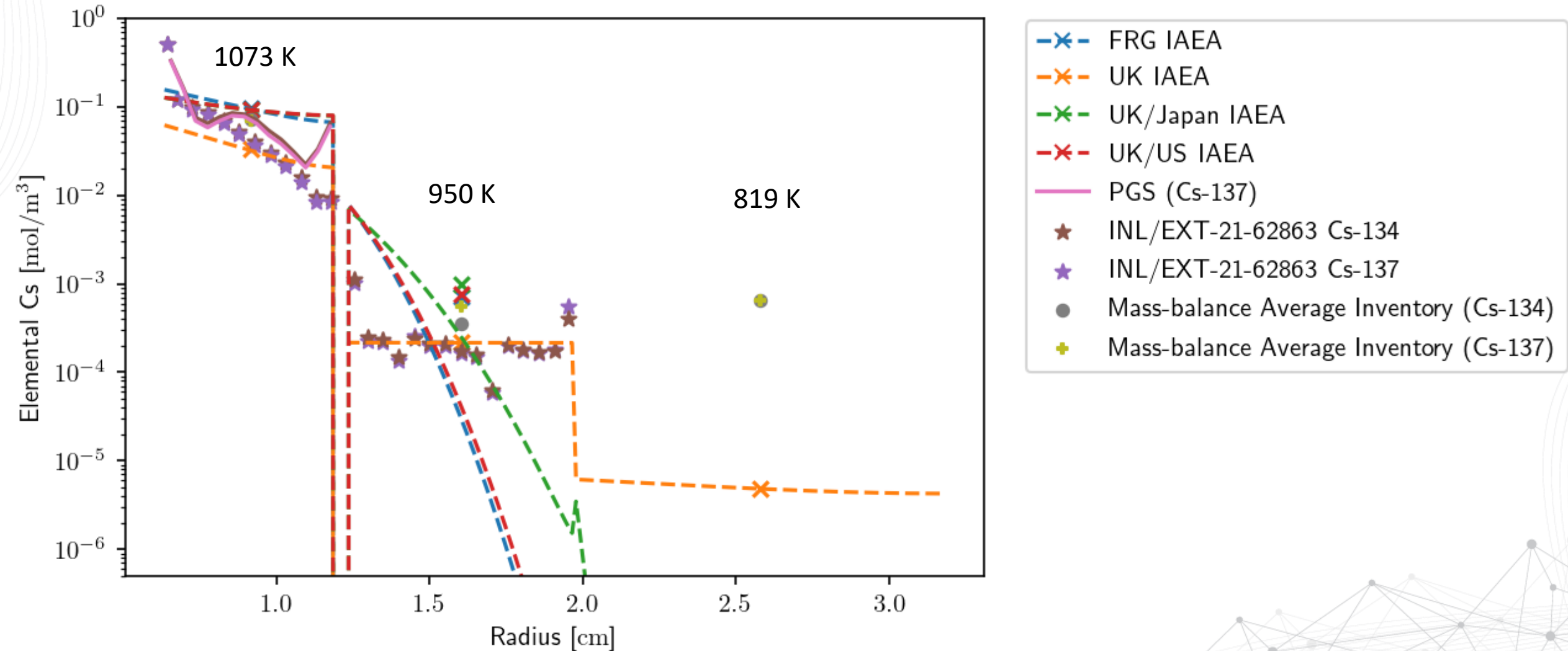


(IAEA TECDOC-978, 1997)

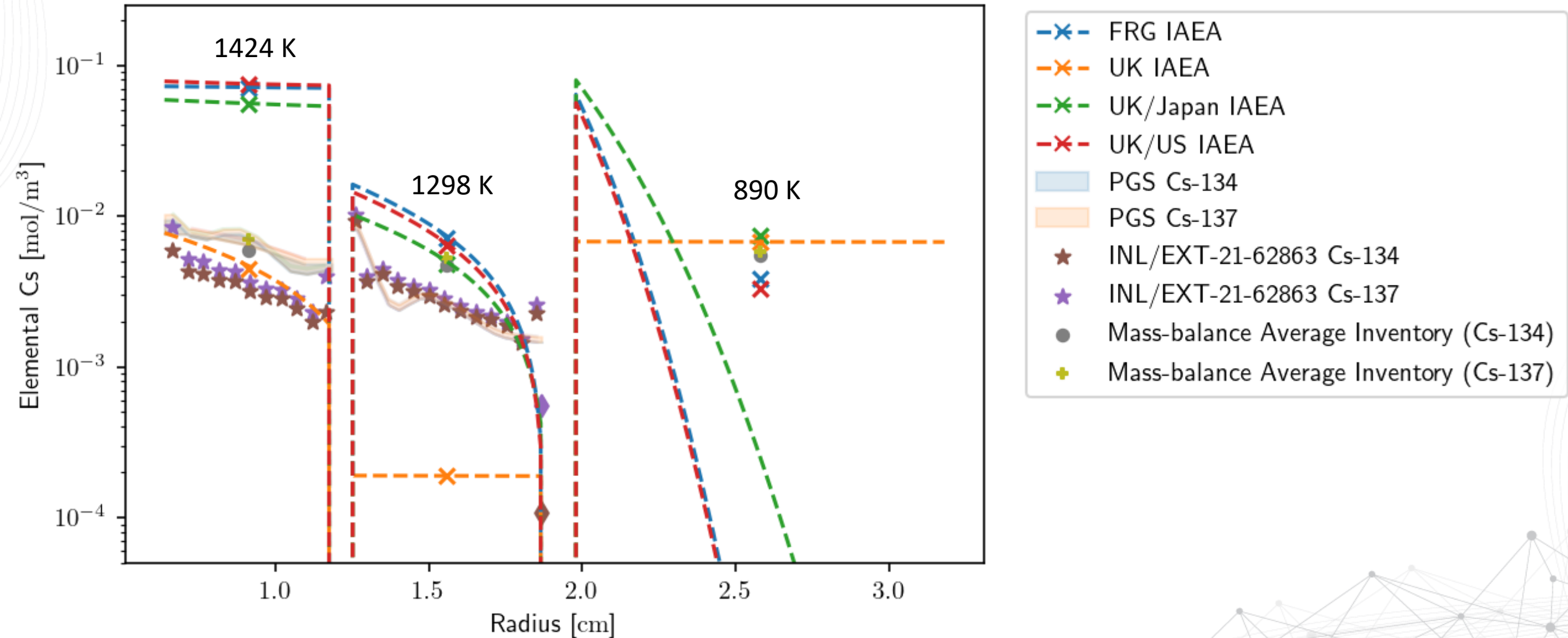
# Literature Parameters vs Measurements, Capsule 3



# Literature Parameters vs Measurements, Capsule 5

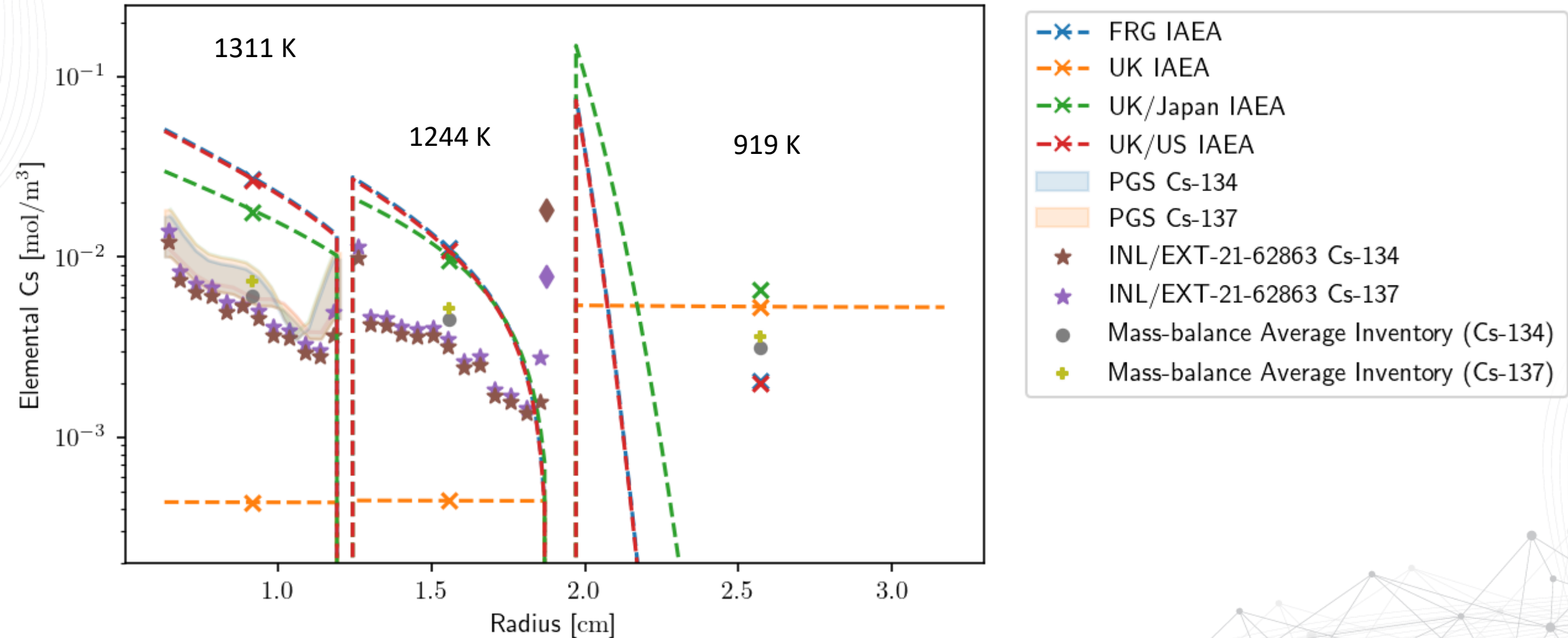


# Literature Parameters vs Measurements, Capsule 7

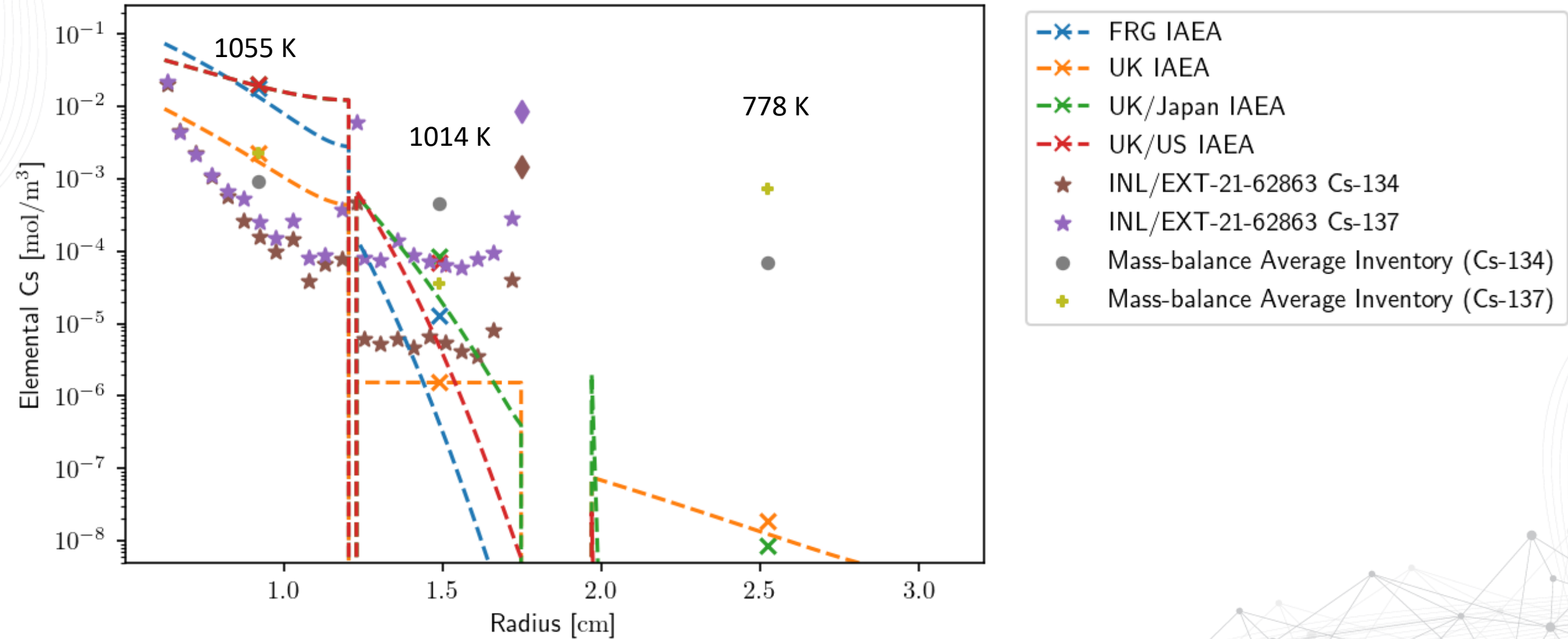




# Literature Parameters vs Measurements, Capsule 10



# Literature Parameters vs Measurements, Capsule 12





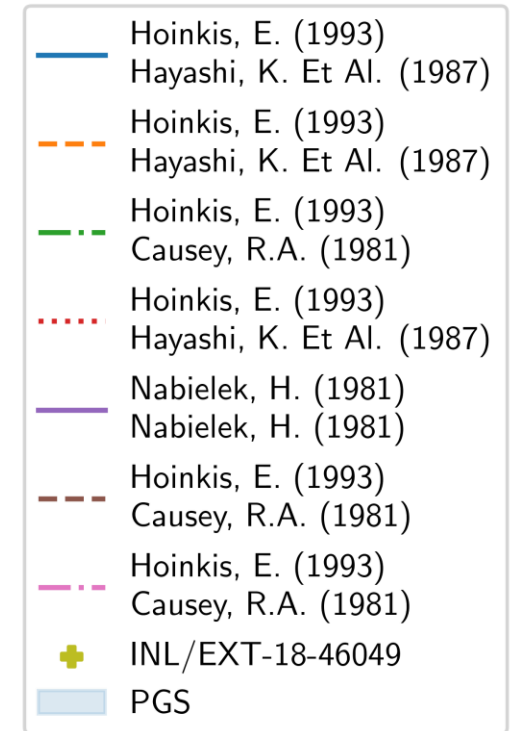
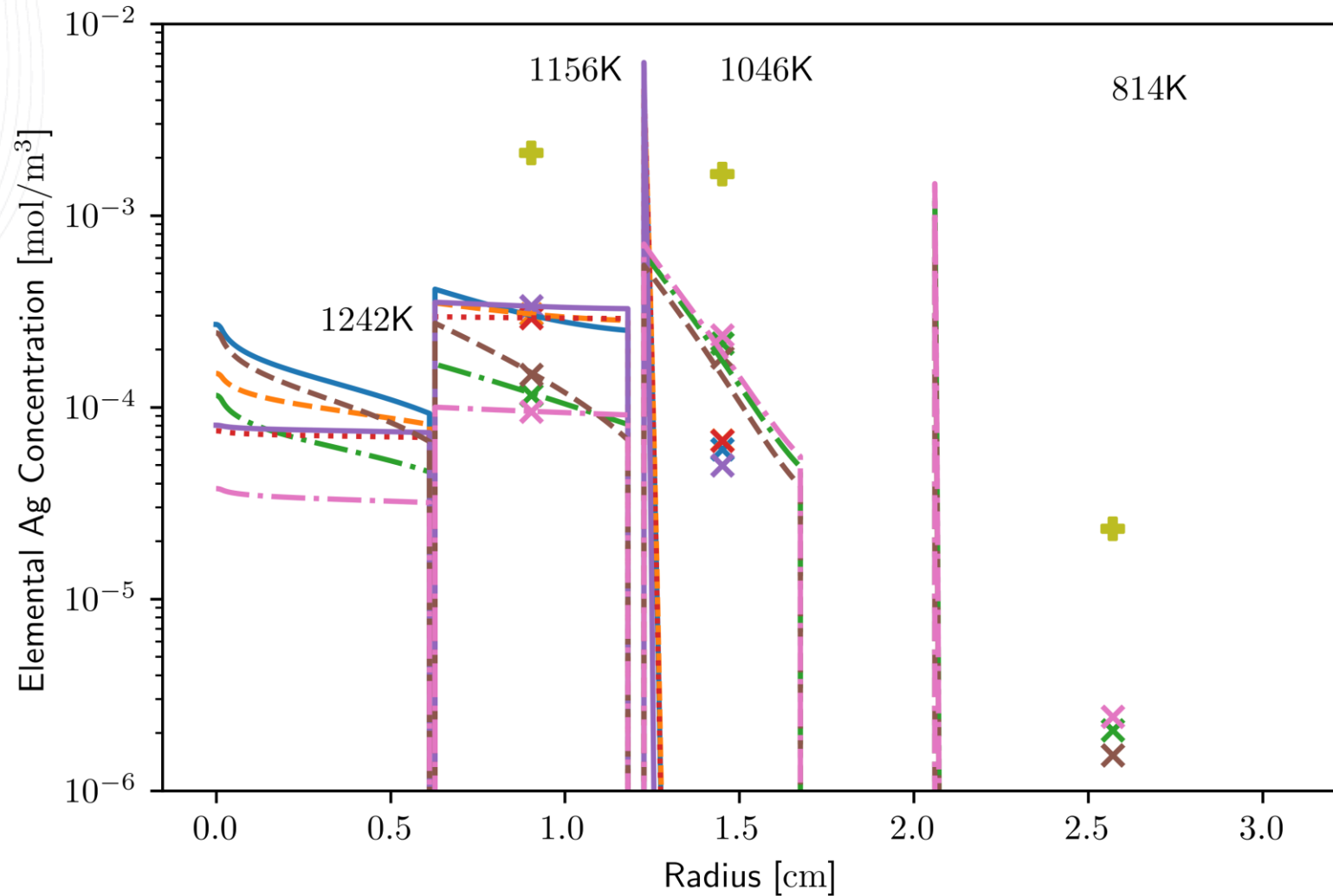
# Cesium - Summary

- 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
- There are indications of short-circuit transport

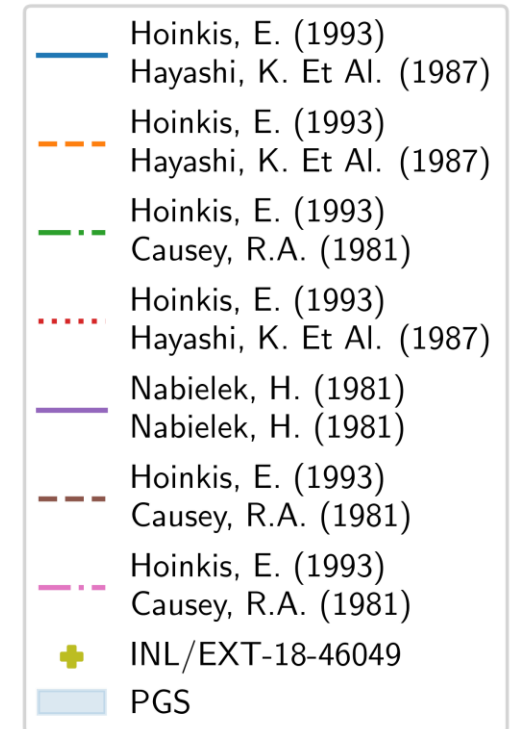
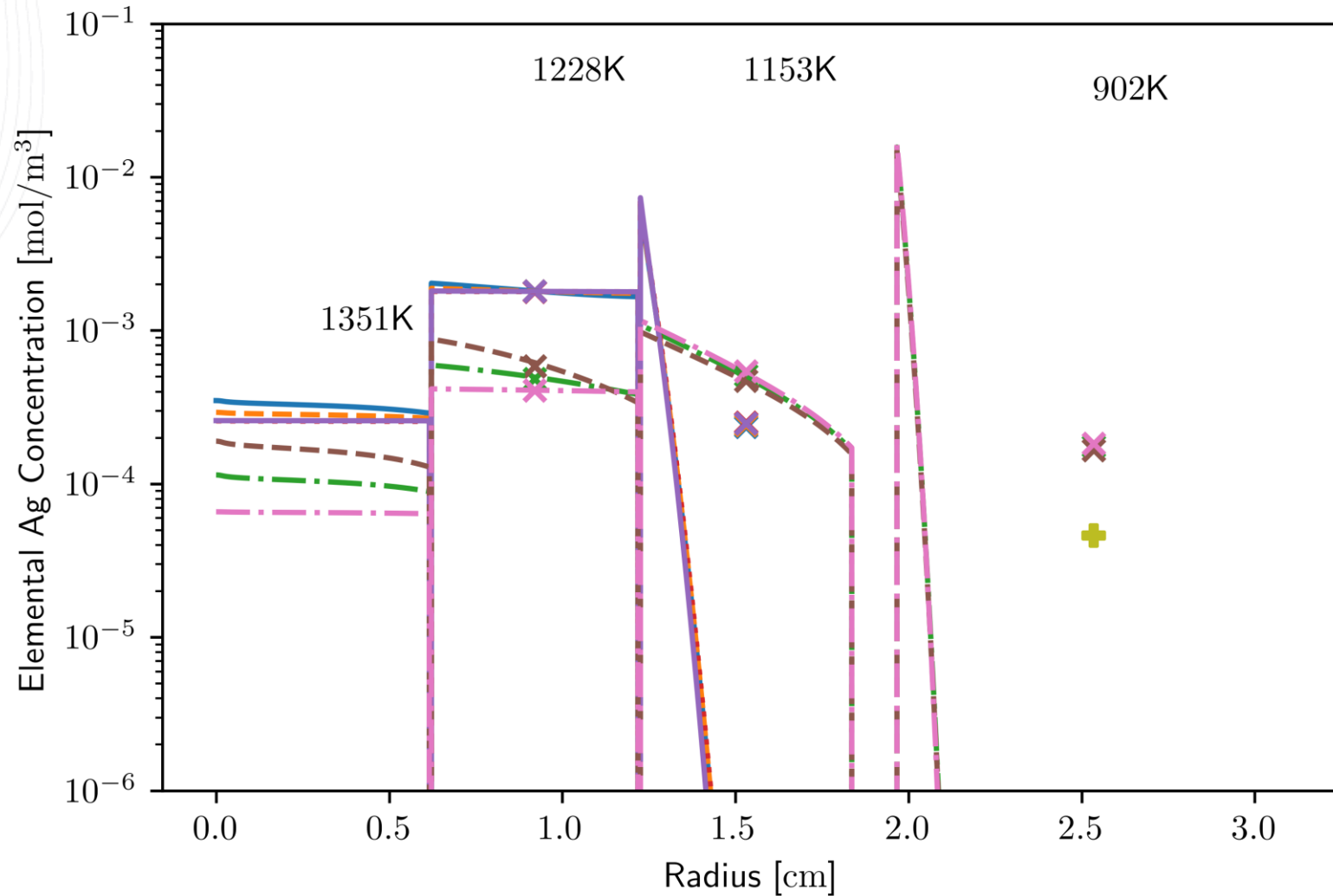


# Silver (Ag-110m)

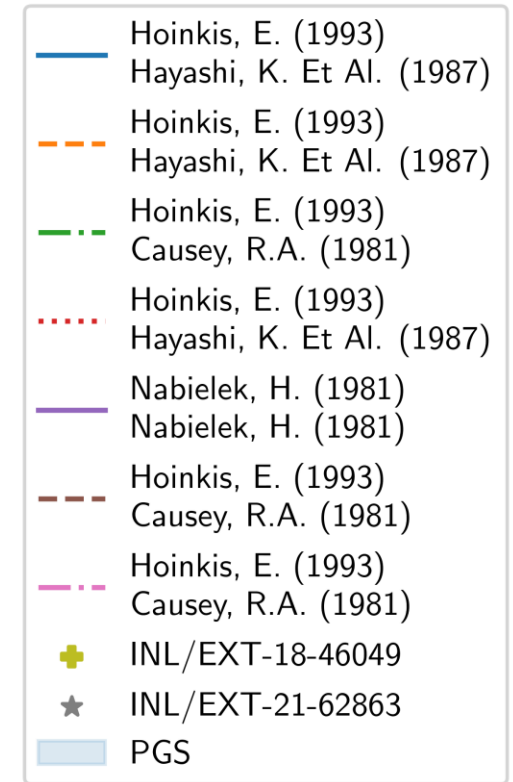
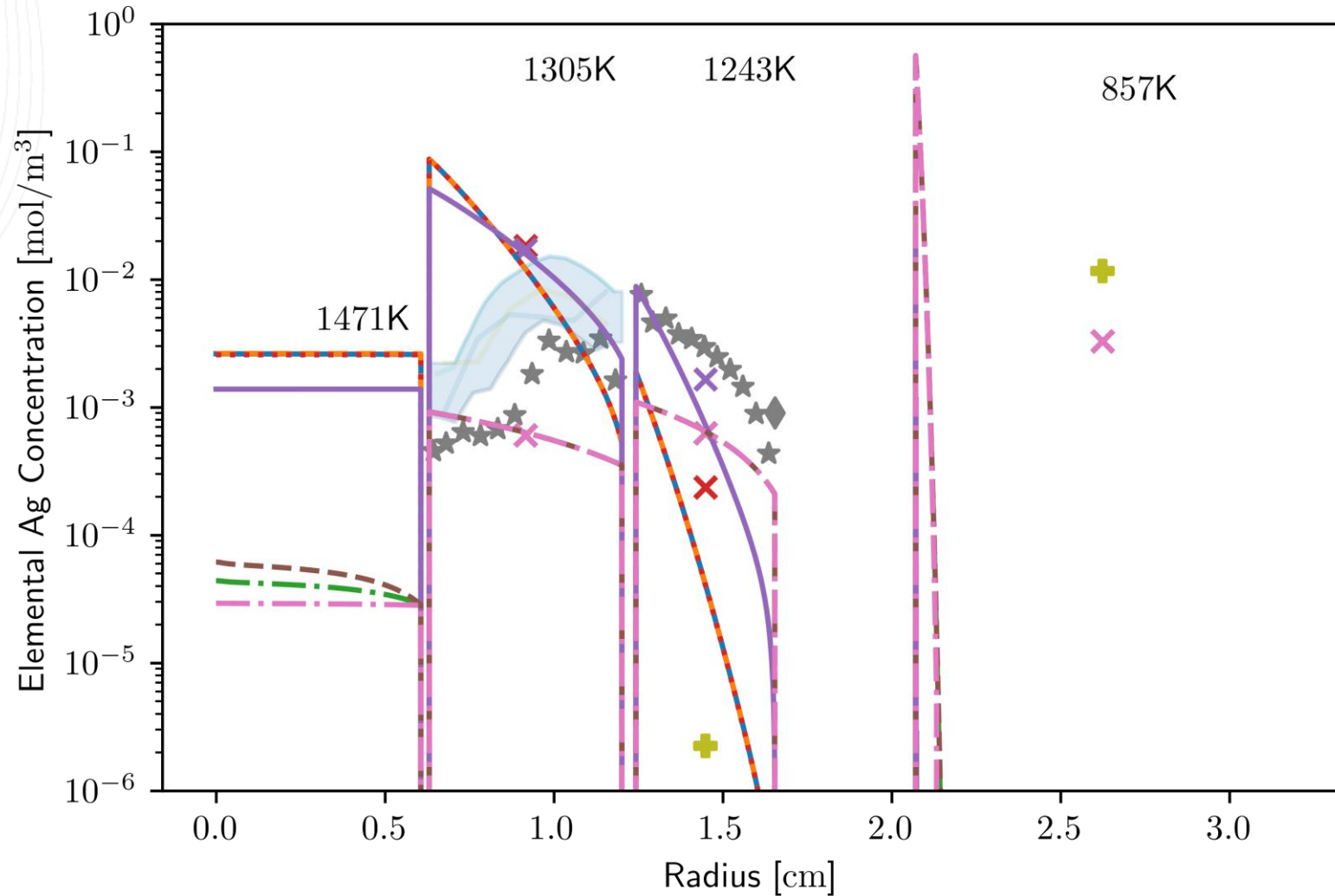
# Literature Parameters vs Measurements, Capsule 1



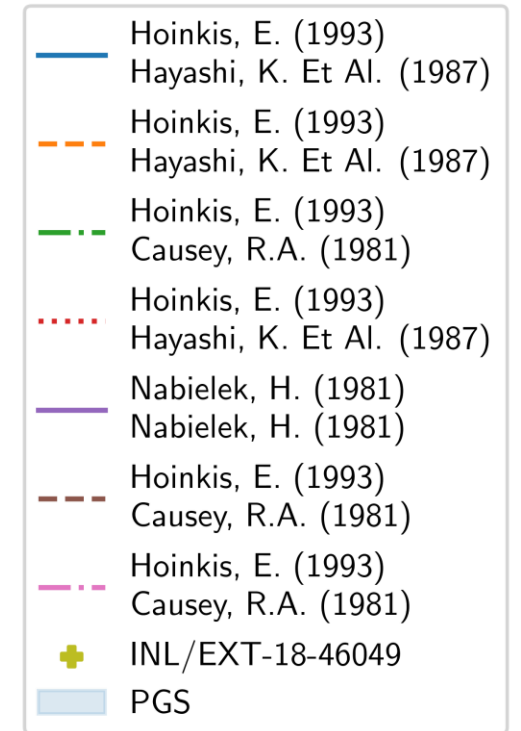
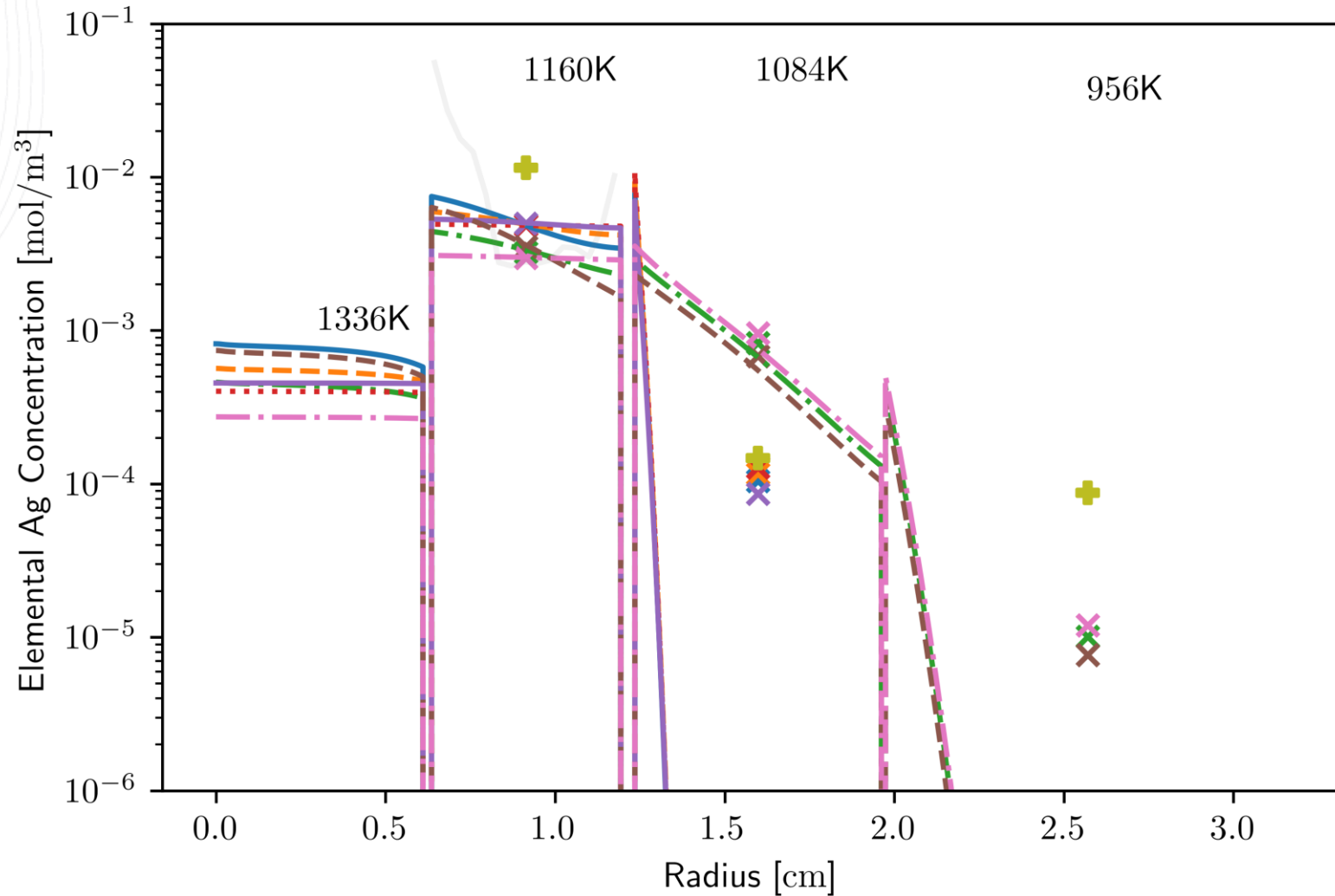
# Literature Parameters vs Measurements, Capsule 2



# Literature Parameters vs Measurements, Capsule 3

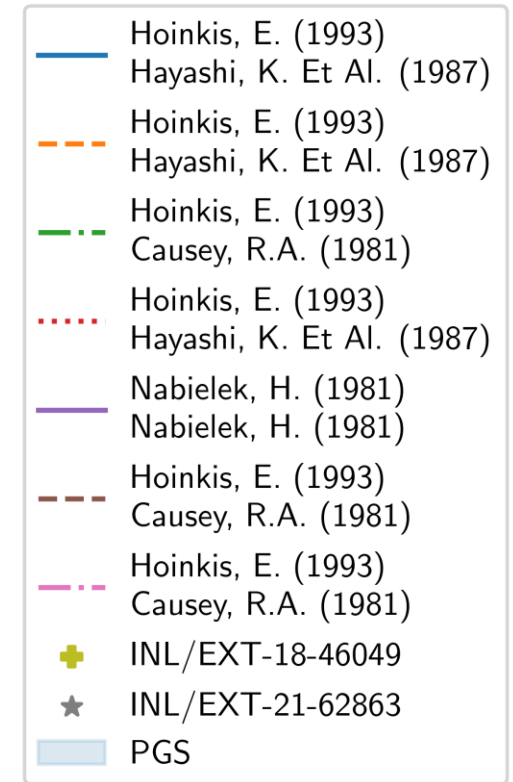
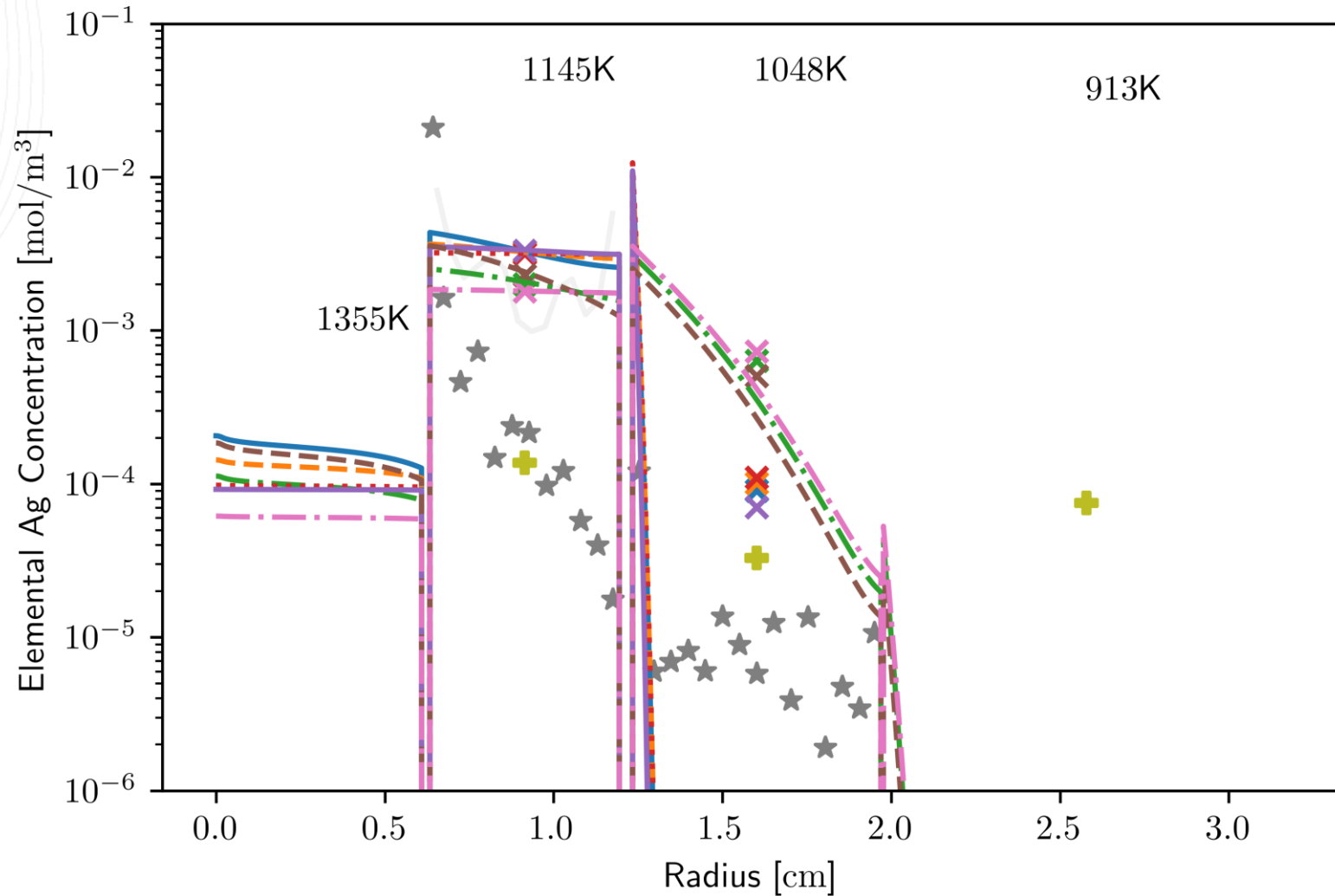


# Literature Parameters vs Measurements, Capsule 4

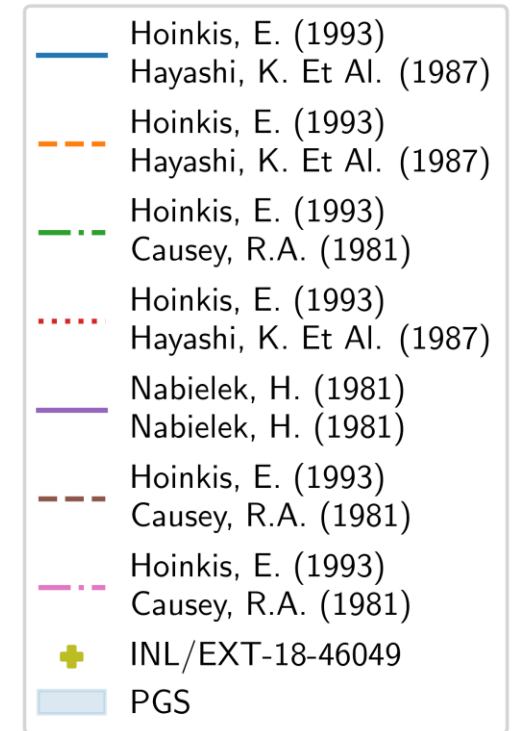
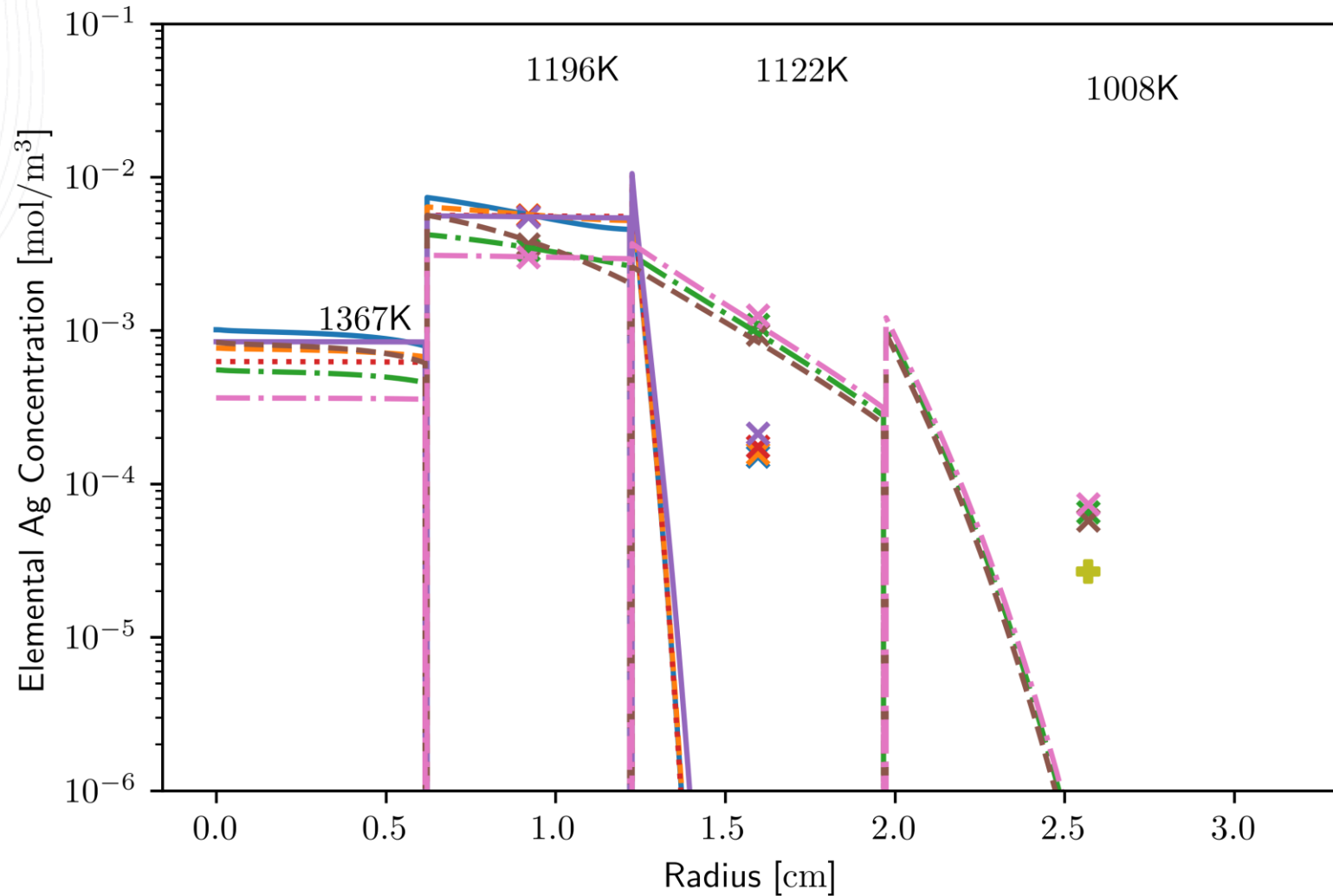




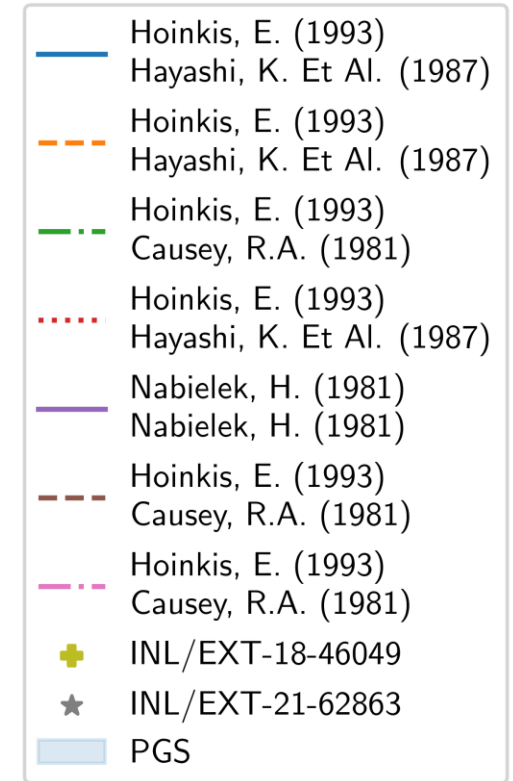
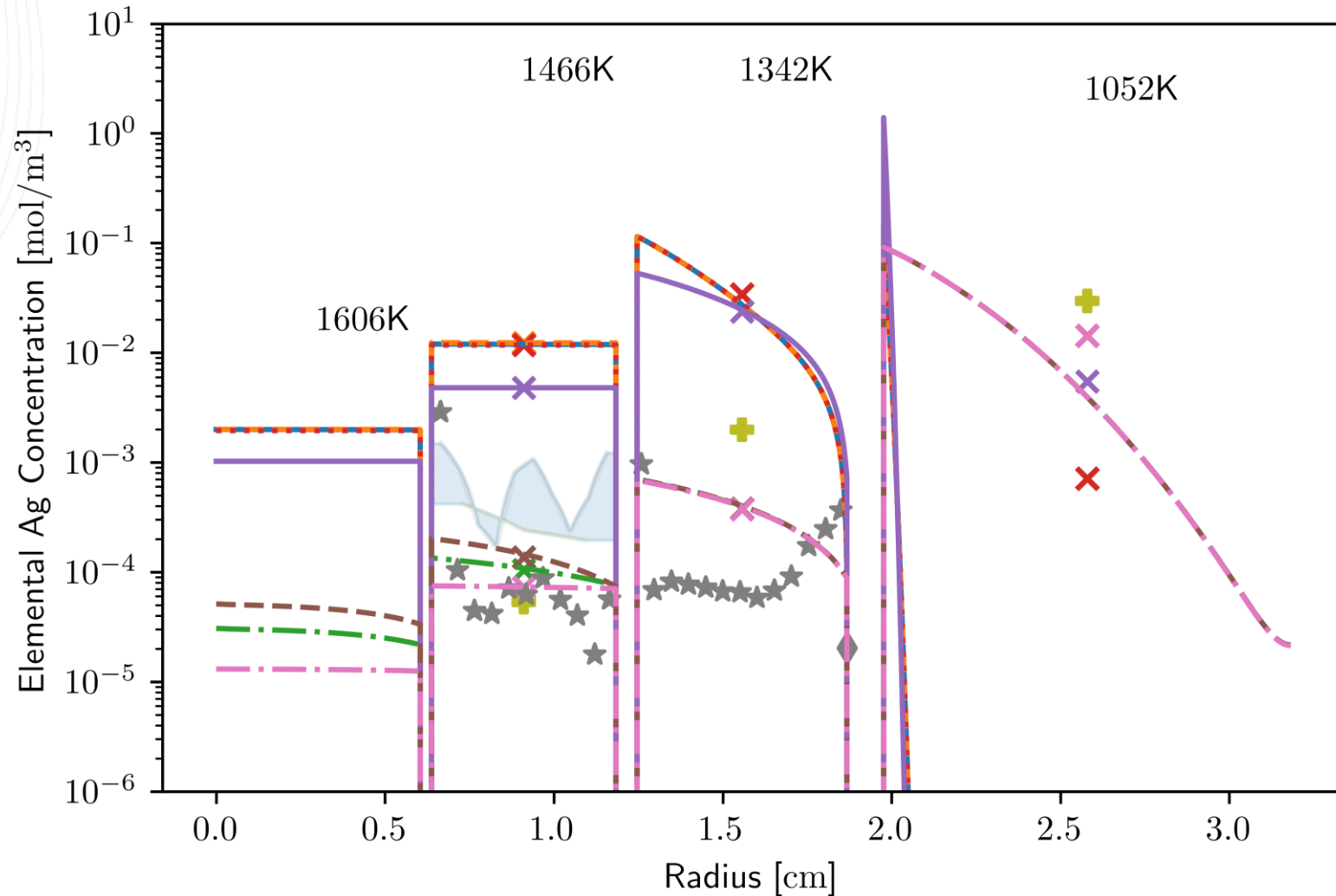
# Literature Parameters vs Measurements, Capsule 5



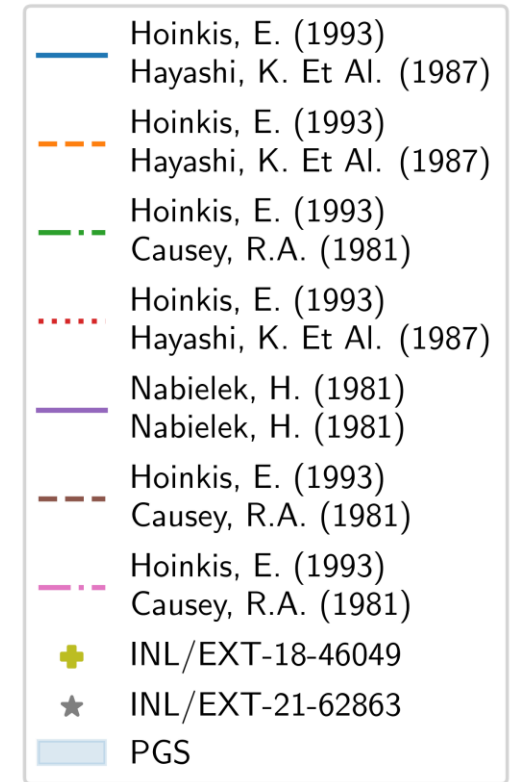
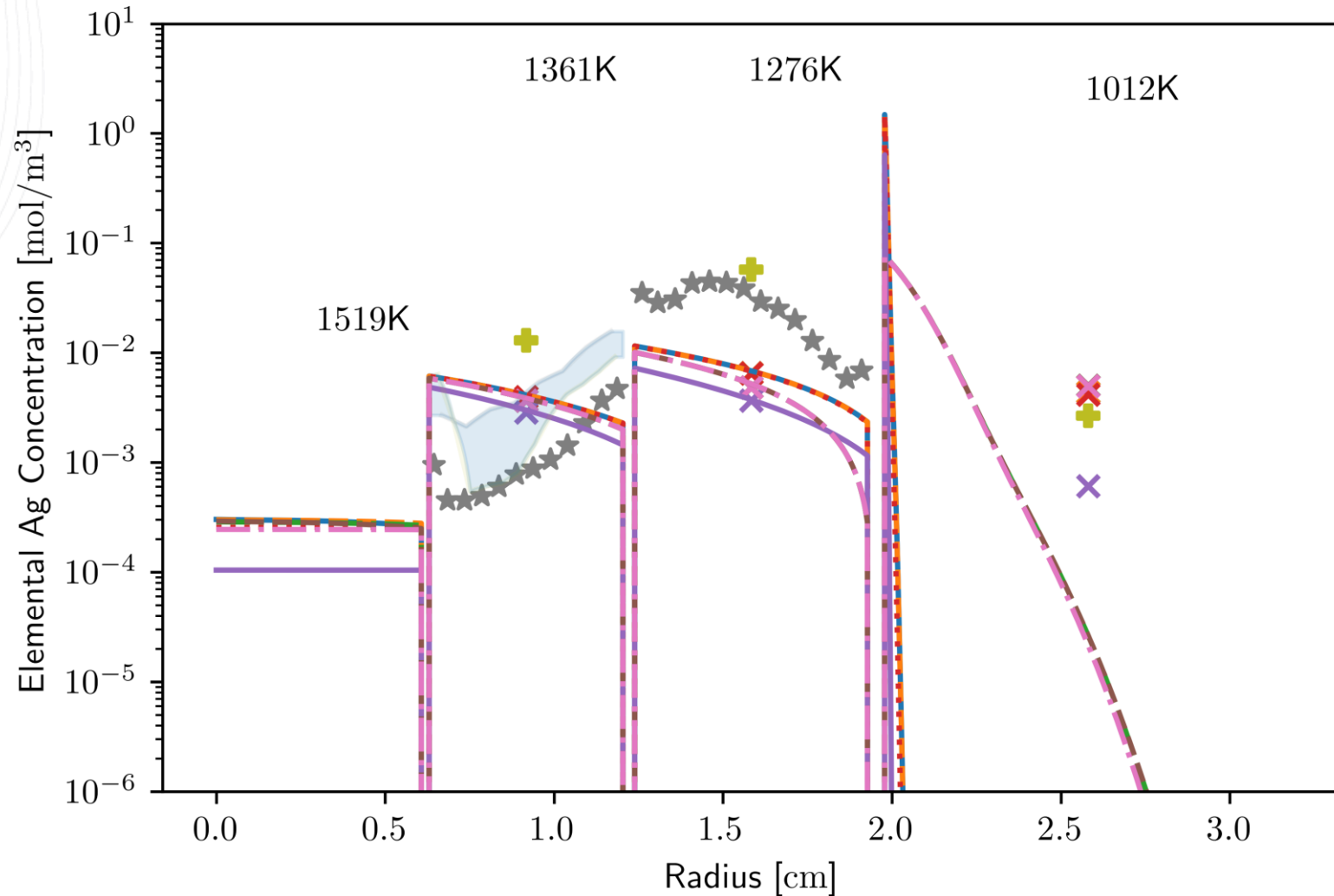
# Literature Parameters vs Measurements, Capsule 6



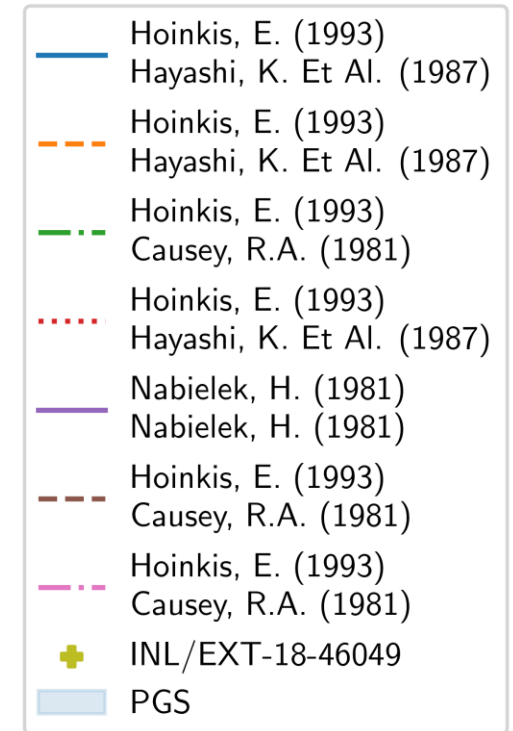
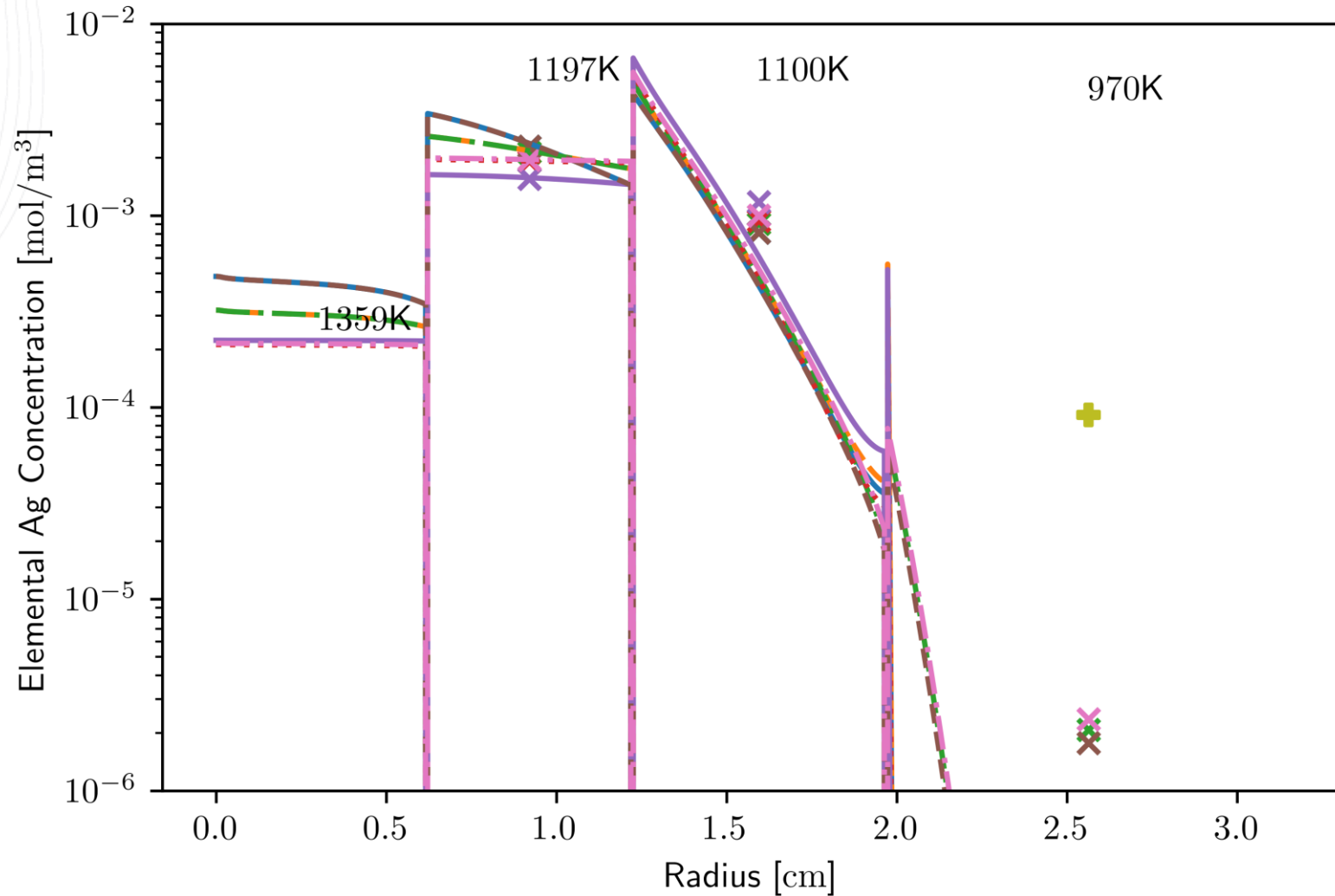
# Literature Parameters vs Measurements, Capsule 7



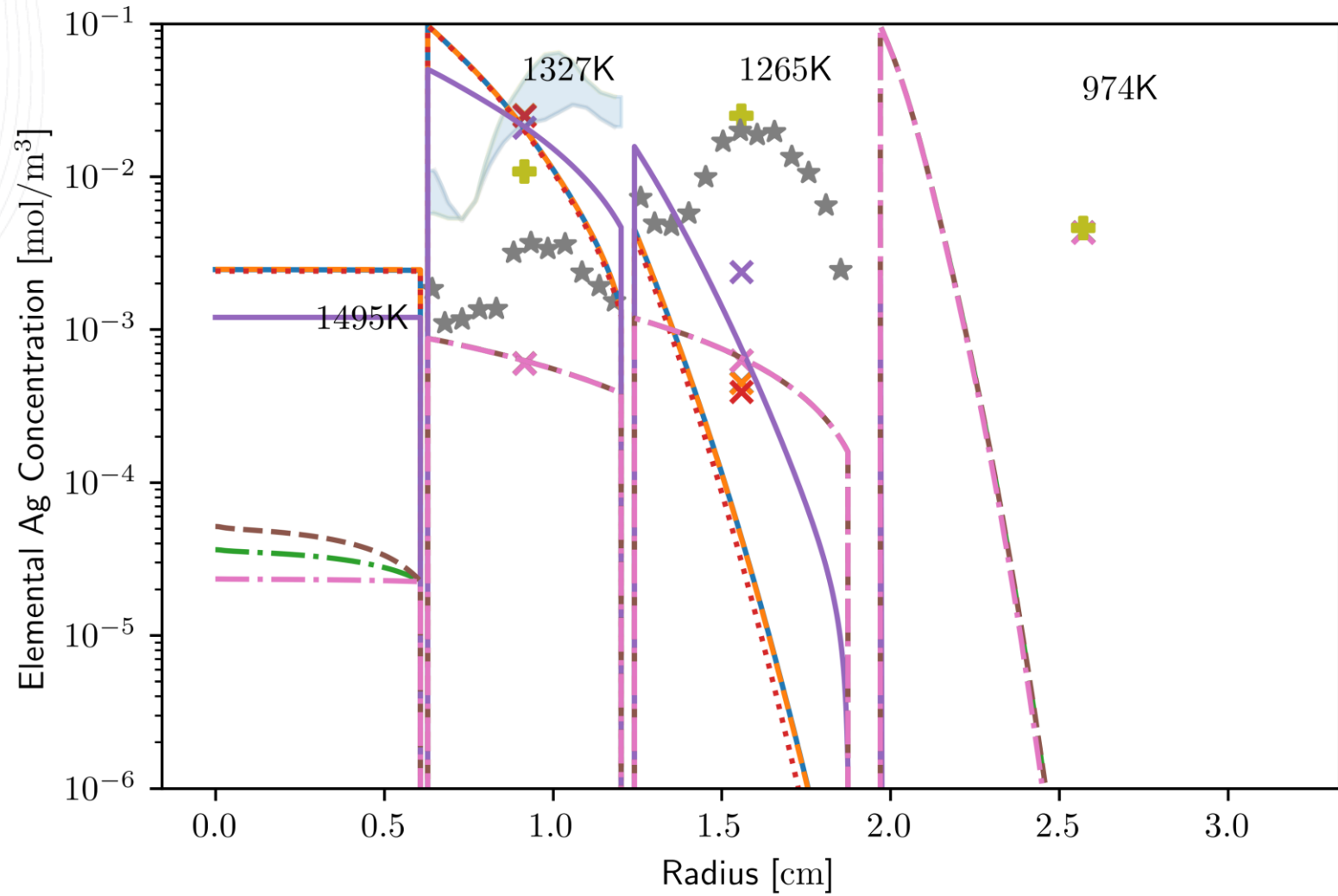
# Literature Parameters vs Measurements, Capsule 8



# Literature Parameters vs Measurements, Capsule 9

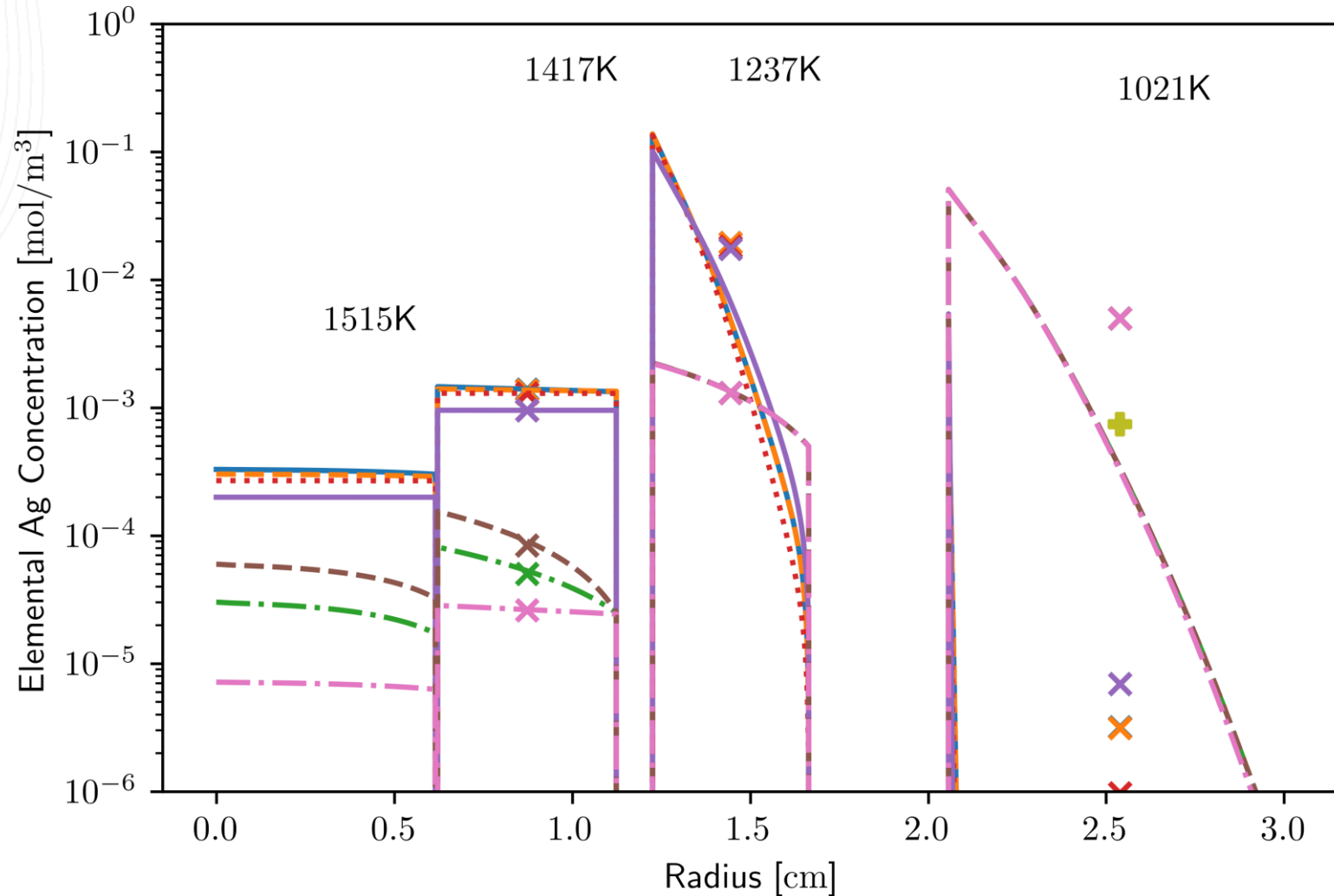


# Literature Parameters vs Measurements, Capsule 10



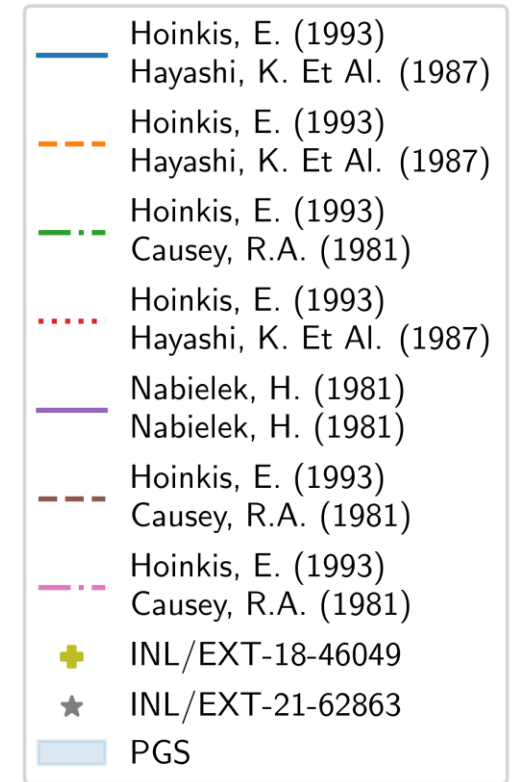
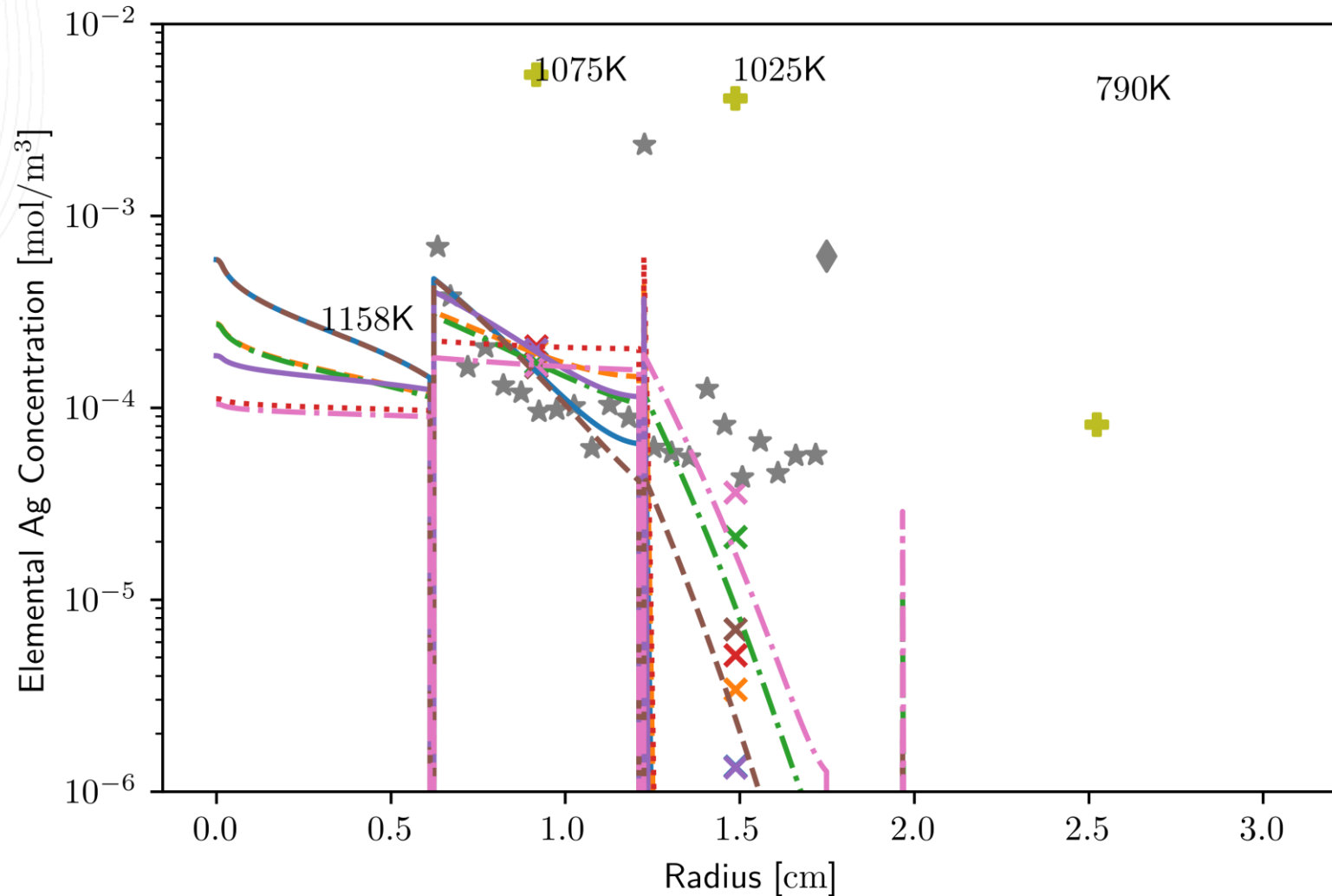
- Hoinkis, E. (1993)
- Hayashi, K. Et Al. (1987)
- - - Hoinkis, E. (1993)
- - - Hayashi, K. Et Al. (1987)
- . - . Hoinkis, E. (1993)
- . . - . Causey, R.A. (1981)
- · · Hoinkis, E. (1993)
- · · Hayashi, K. Et Al. (1987)
- Nabielek, H. (1981)
- Nabielek, H. (1981)
- - - Hoinkis, E. (1993)
- - - Causey, R.A. (1981)
- . - . Hoinkis, E. (1993)
- . - . Causey, R.A. (1981)
- + INL/EXT-18-46049
- ★ INL/EXT-21-62863
- PGS

# Literature Parameters vs Measurements, Capsule 11



- Hoinkis, E. (1993)
- Hayashi, K. Et Al. (1987)
- Hoinkis, E. (1993)
- Hayashi, K. Et Al. (1987)
- Hoinkis, E. (1993)
- Causey, R.A. (1981)
- Hoinkis, E. (1993)
- Hayashi, K. Et Al. (1987)
- Nabielek, H. (1981)
- Nabielek, H. (1981)
- Hoinkis, E. (1993)
- Causey, R.A. (1981)
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- Causey, R.A. (1981)
- INL/EXT-18-46049
- PGS

# Literature Parameters vs Measurements, Capsule 12







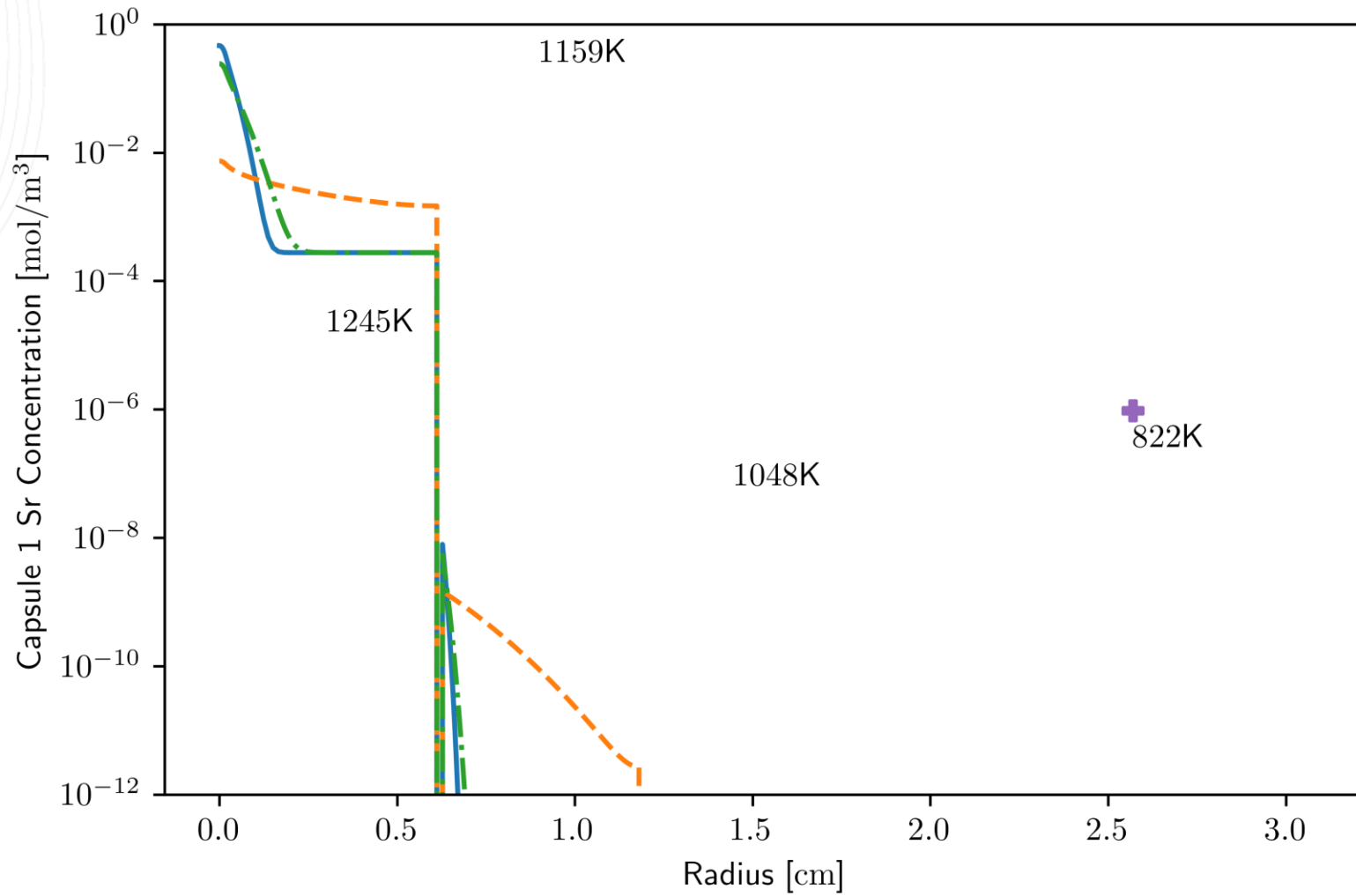
# Silver - Summary

- 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



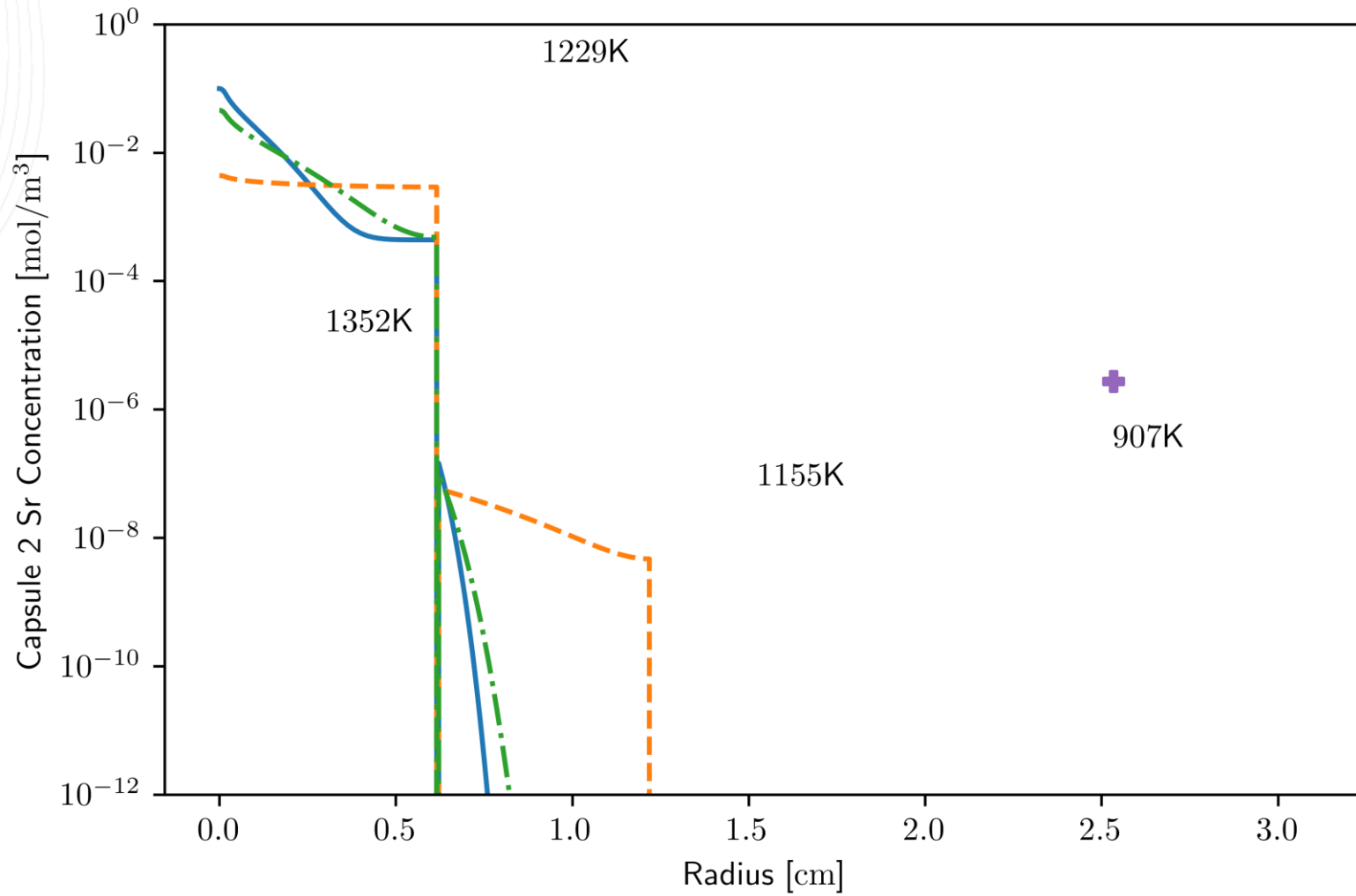
# Strontium

# Literature Parameters vs Measurements, Capsule 1

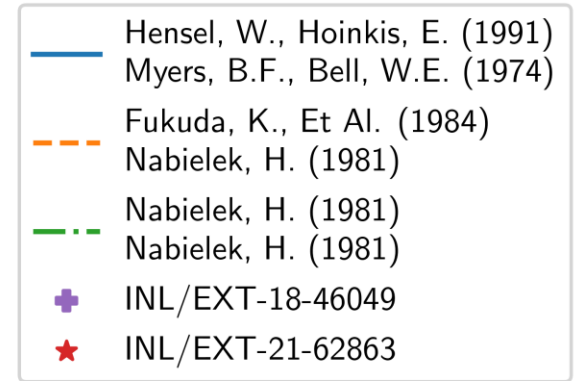
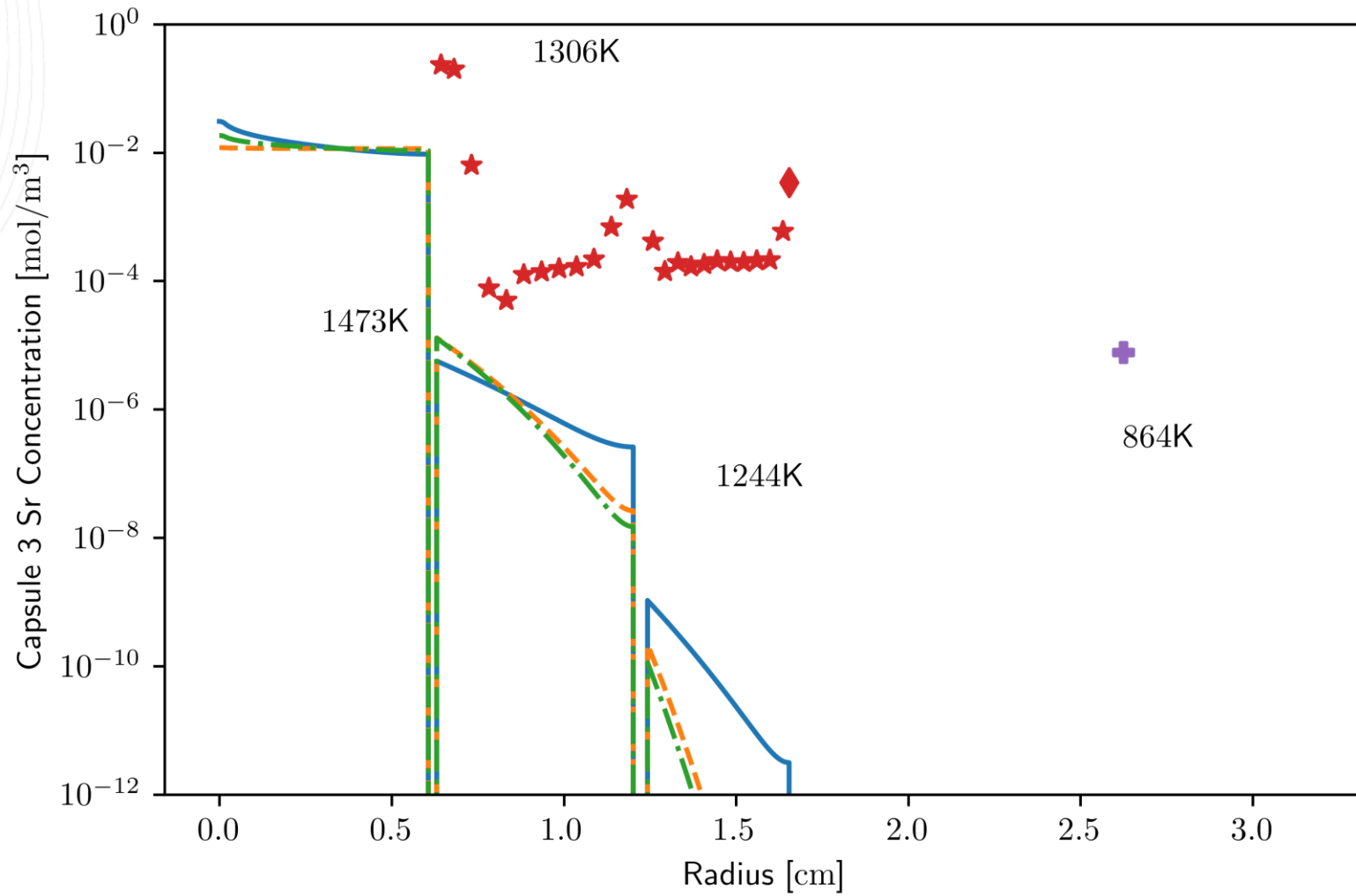


- Hensel, W., Hoinkis, E. (1991)
- Myers, B.F., Bell, W.E. (1974)
- - - Fukuda, K., Et Al. (1984)
- - - Nabielek, H. (1981)
- · - Nabielek, H. (1981)
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- + INL/EXT-18-46049

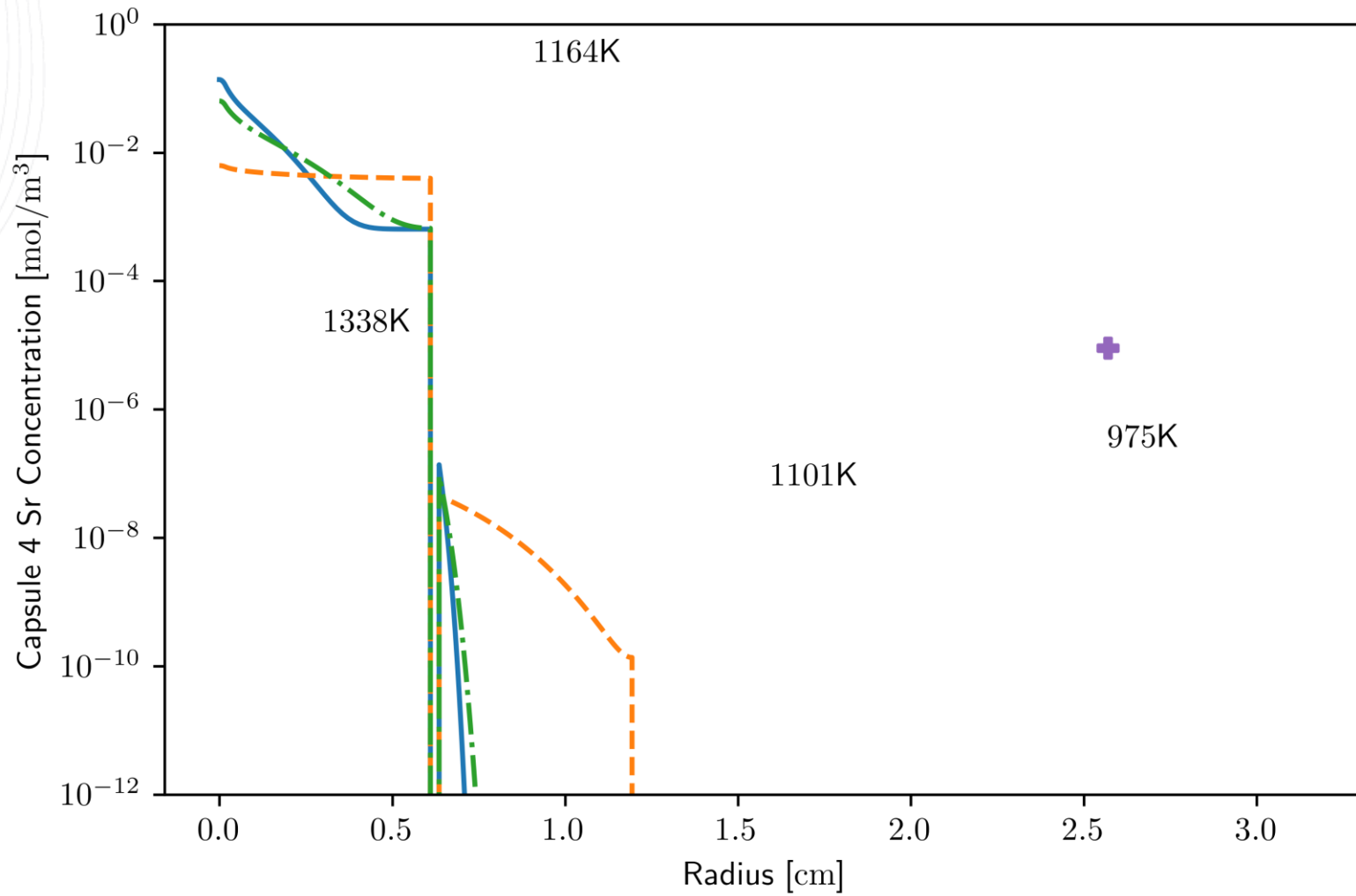
# Literature Parameters vs Measurements, Capsule 2



# Literature Parameters vs Measurements, Capsule 3

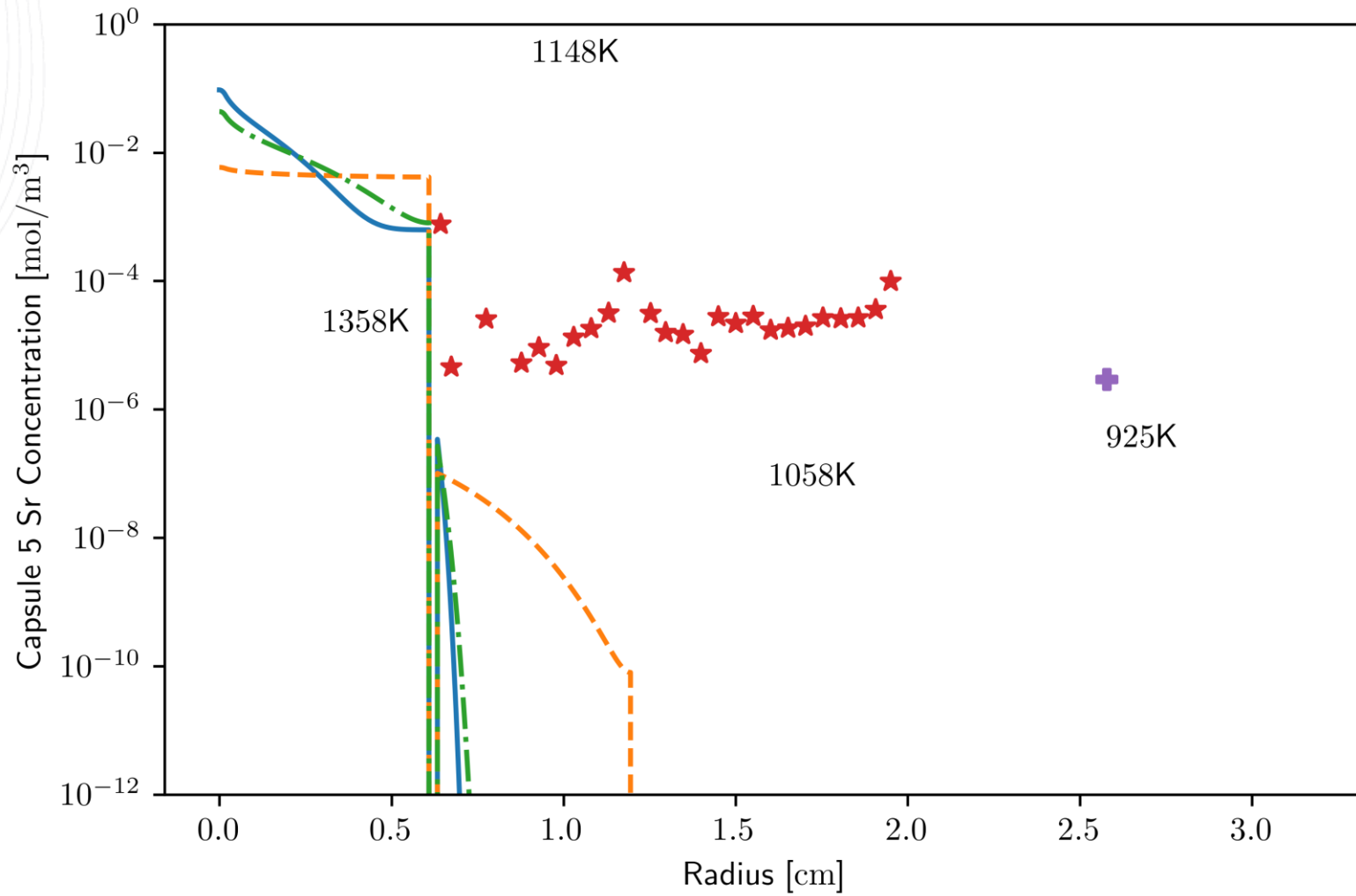


# Literature Parameters vs Measurements, Capsule 4



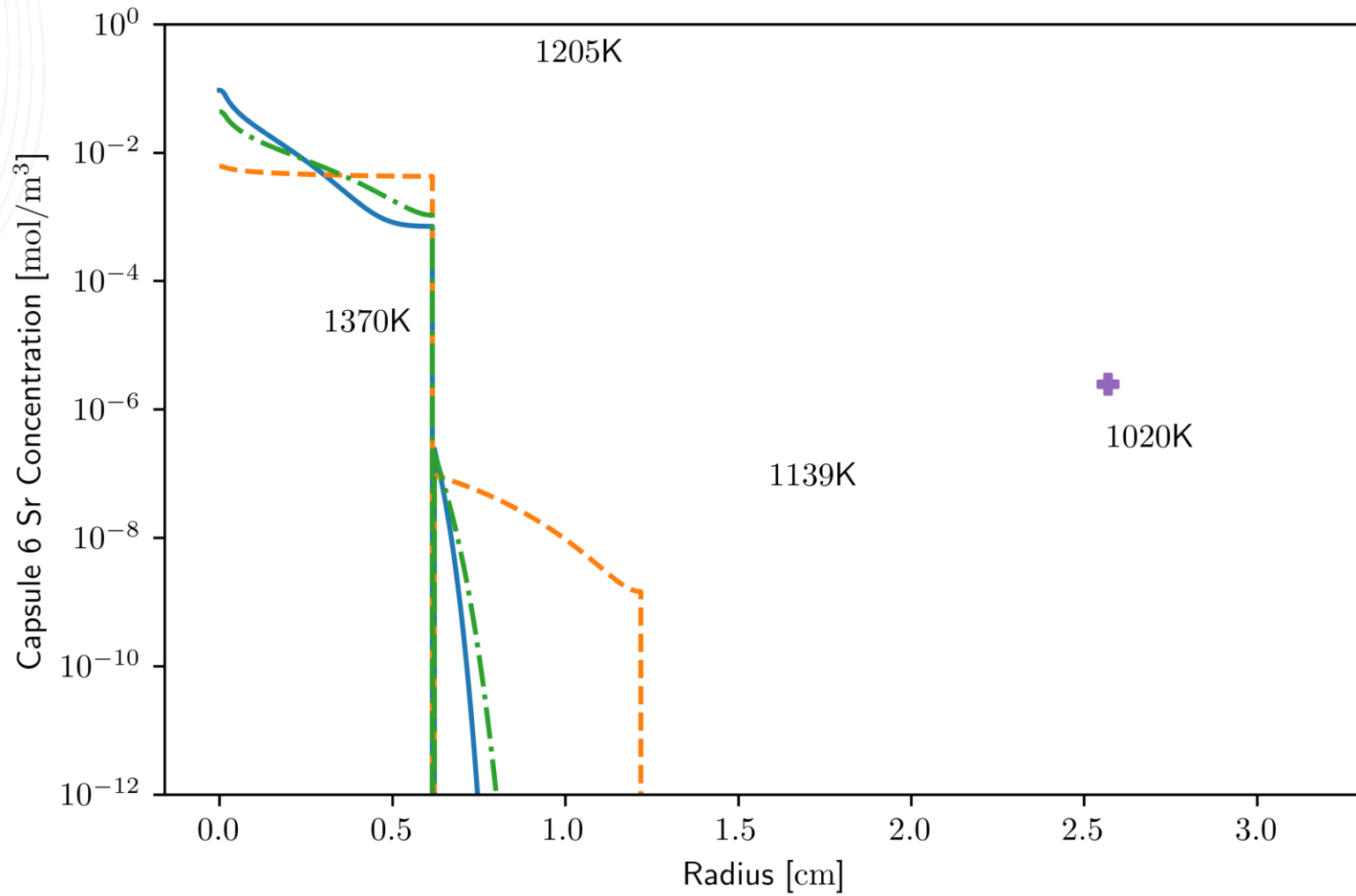
- Hensel, W., Hoinkis, E. (1991)
- Myers, B.F., Bell, W.E. (1974)
- - - Fukuda, K., Et Al. (1984)
- - - Nabielek, H. (1981)
- · - Nabielek, H. (1981)
- · - Nabielek, H. (1981)
- + INL/EXT-18-46049

# Literature Parameters vs Measurements, Capsule 5



- Hensel, W., Hoinkis, E. (1991)
- Myers, B.F., Bell, W.E. (1974)
- - - Fukuda, K., Et Al. (1984)
- · - Nabielek, H. (1981)
- · - Nabielek, H. (1981)
- + INL/EXT-18-46049
- ★ INL/EXT-21-62863

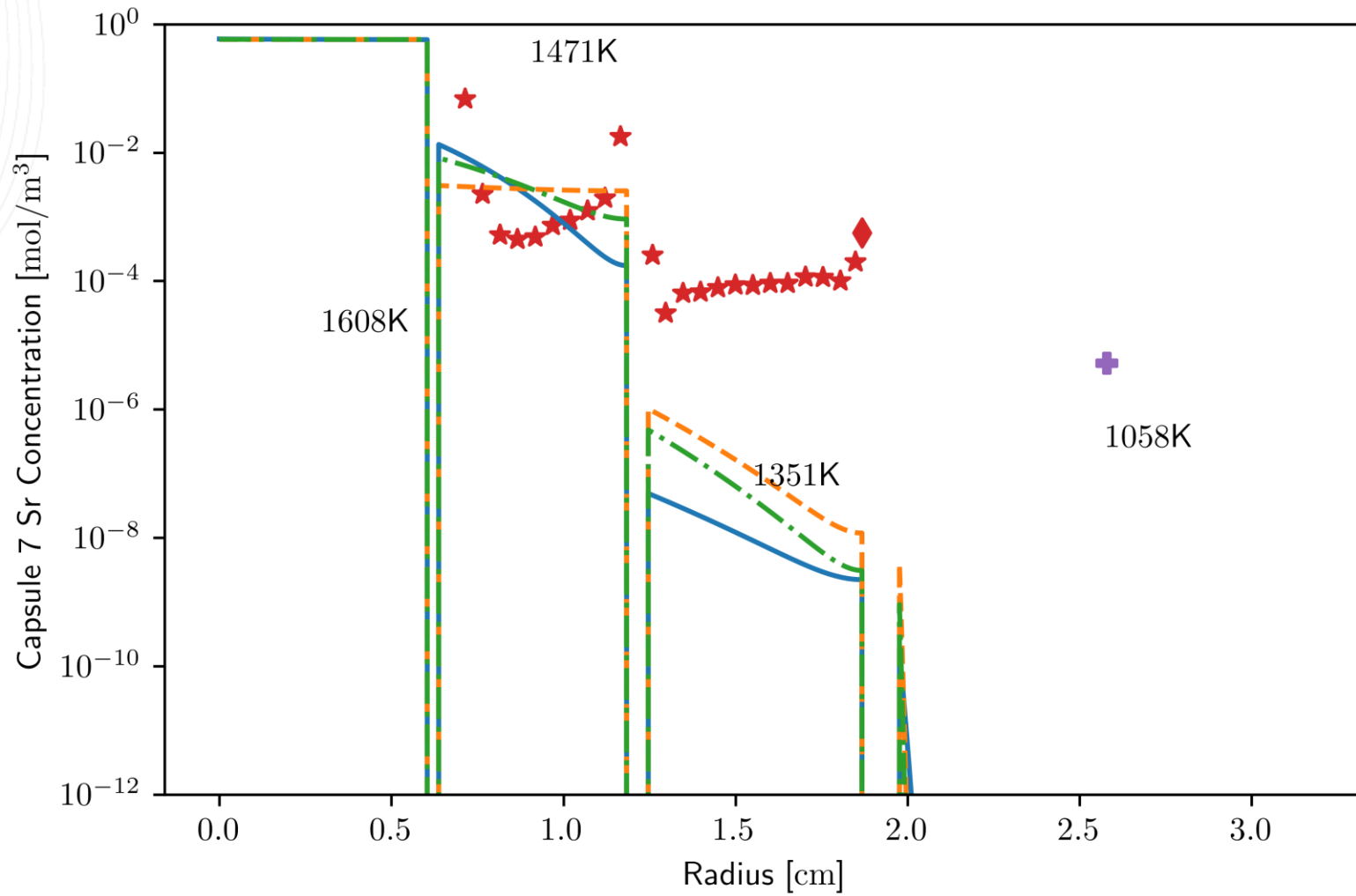
# Literature Parameters vs Measurements, Capsule 6



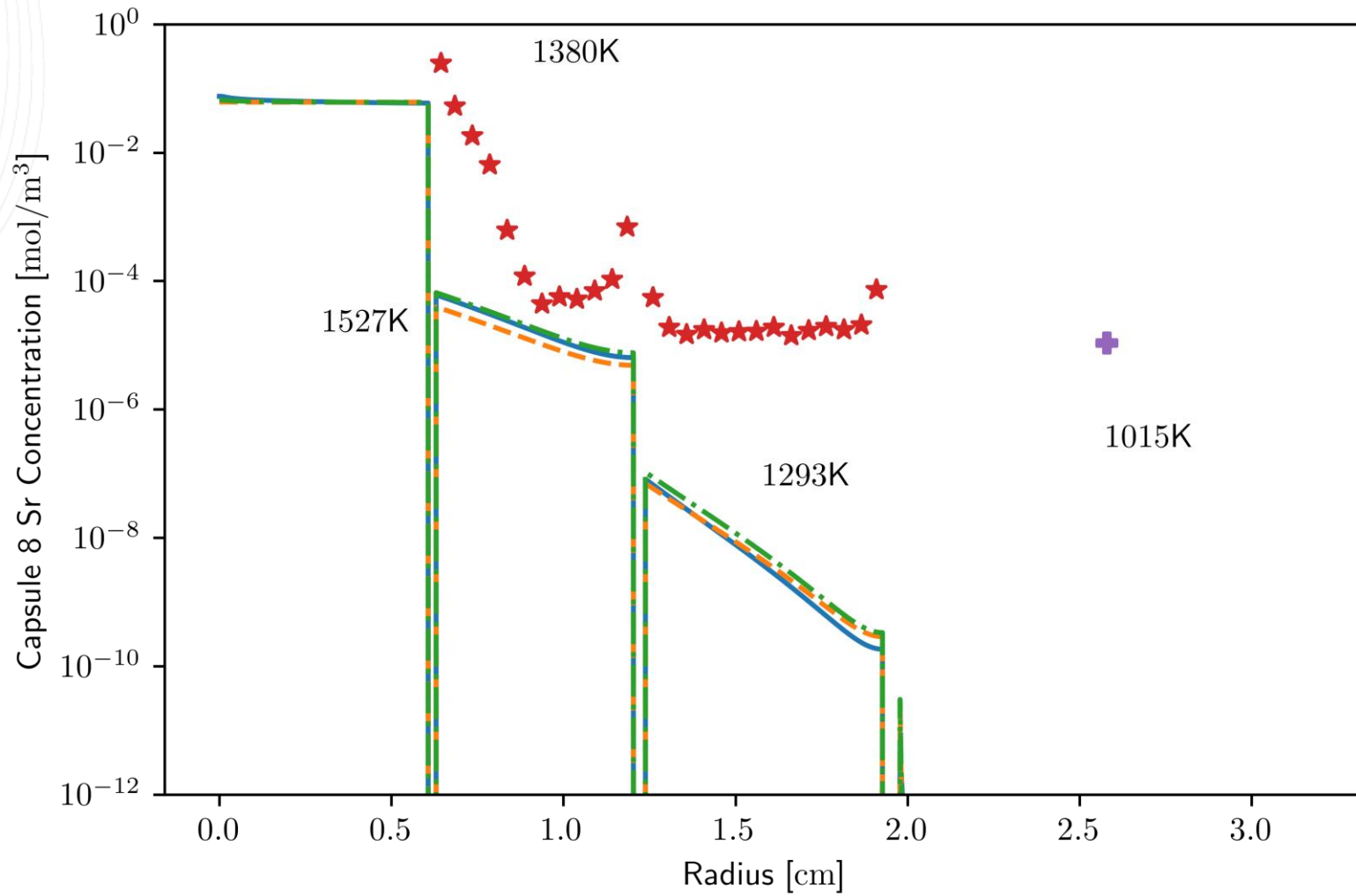
- Hensel, W., Hoinkis, E. (1991)
- Myers, B.F., Bell, W.E. (1974)
- - - Fukuda, K., Et Al. (1984)
- - - Nabielek, H. (1981)
- · - Nabielek, H. (1981)
- · - Nabielek, H. (1981)
- + INL/EXT-18-46049



# Literature Parameters vs Measurements, Capsule 7

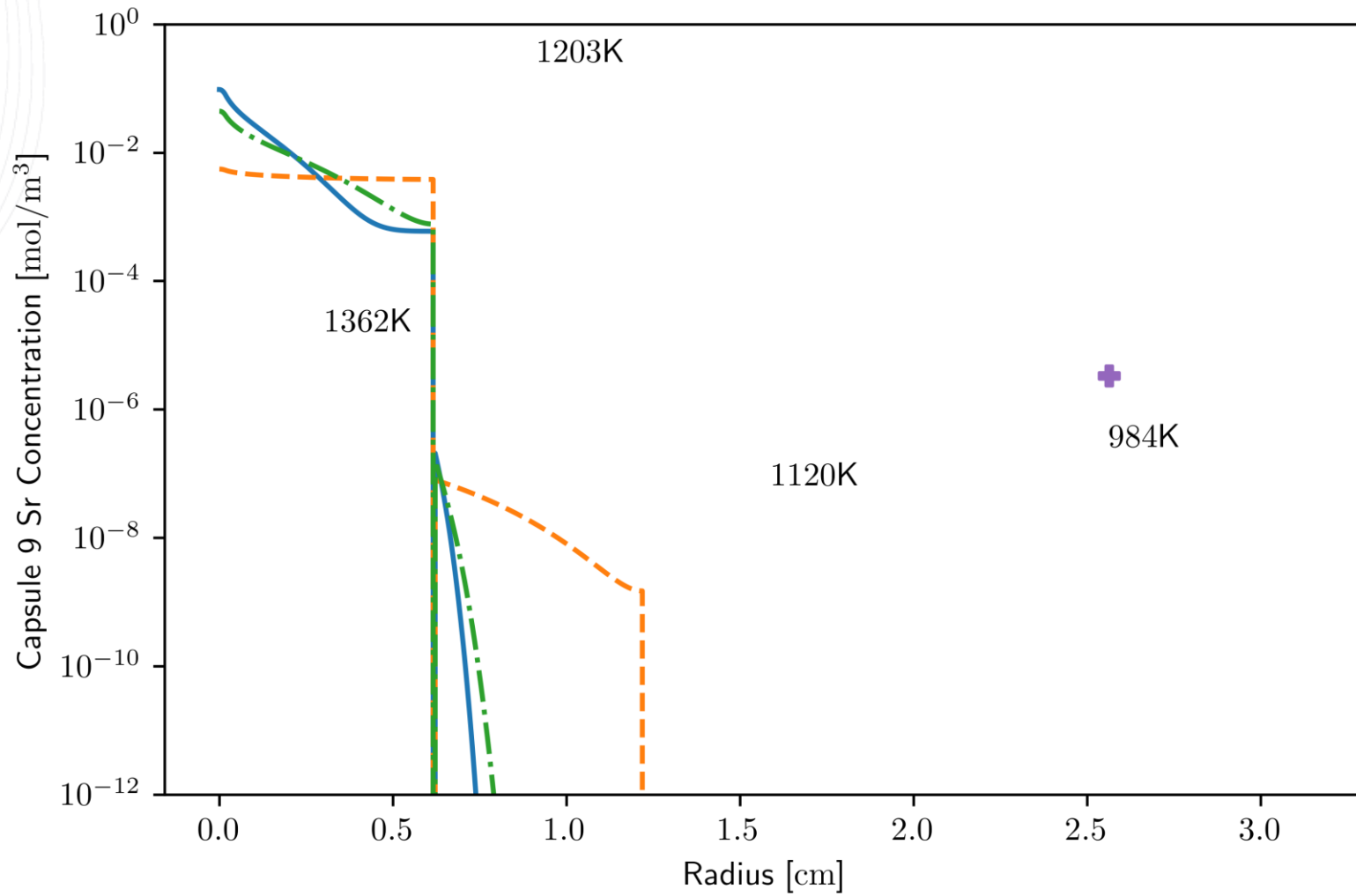


# Literature Parameters vs Measurements, Capsule 8



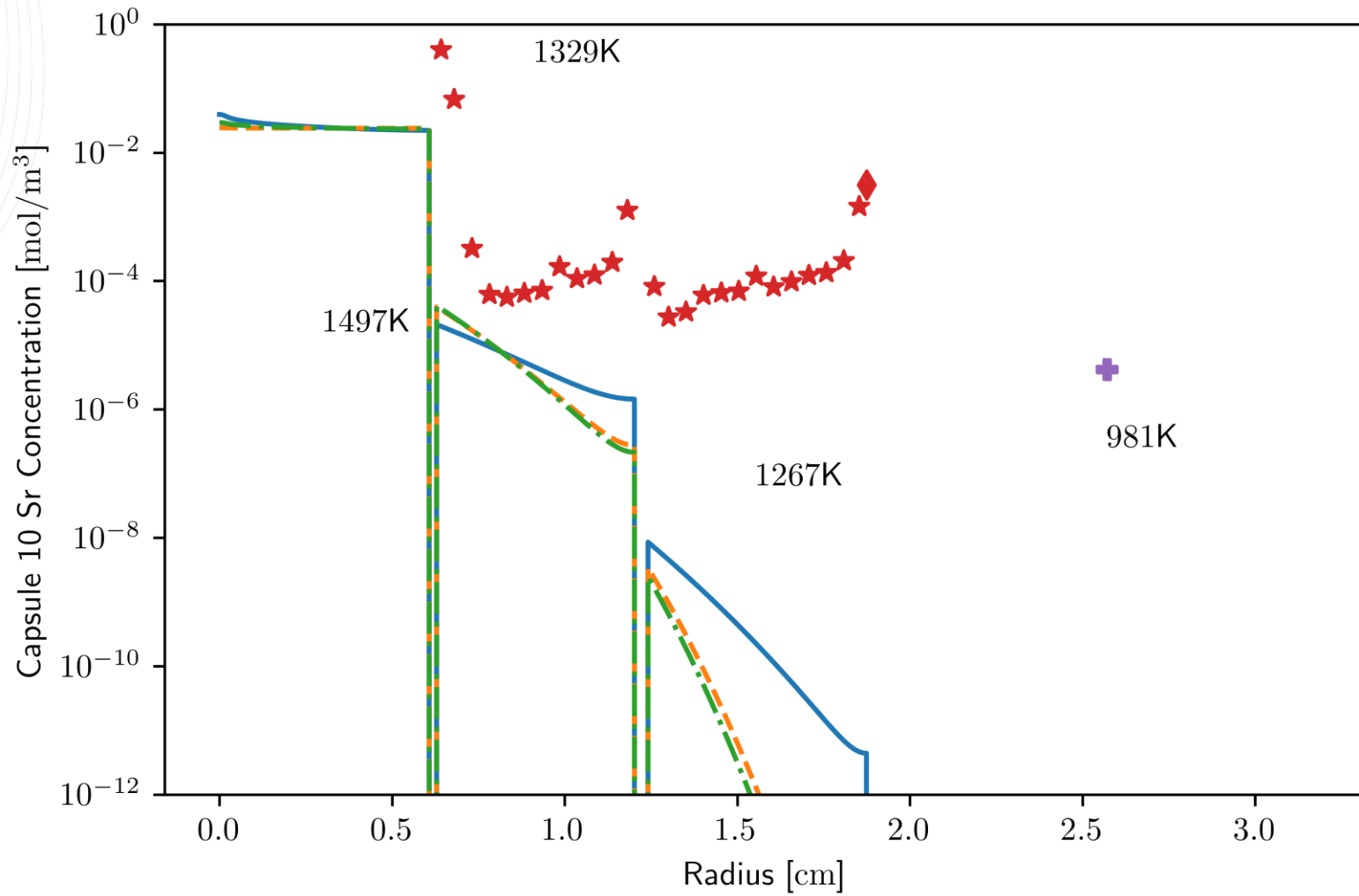
- Hensel, W., Hoinkis, E. (1991)
- Myers, B.F., Bell, W.E. (1974)
- - - Fukuda, K., Et Al. (1984)
- - - Nabielek, H. (1981)
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- + INL/EXT-18-46049
- \* INL/EXT-21-62863

# Literature Parameters vs Measurements, Capsule 9



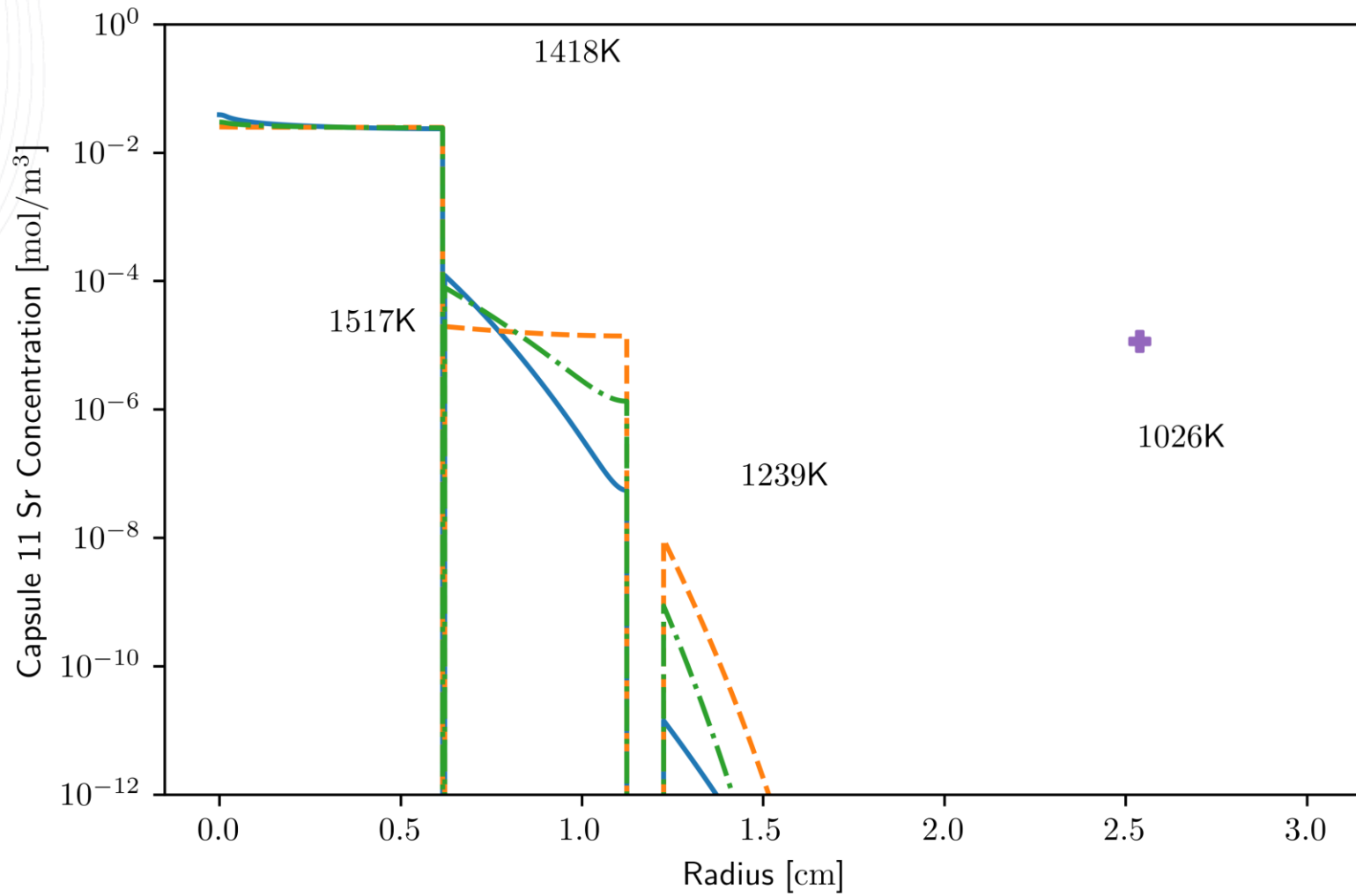
- Hensel, W., Hoinkis, E. (1991)
- Myers, B.F., Bell, W.E. (1974)
- - - Fukuda, K., Et Al. (1984)
- - - Nabielek, H. (1981)
- · - Nabielek, H. (1981)
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- + INL/EXT-18-46049

# Literature Parameters vs Measurements, Capsule 10

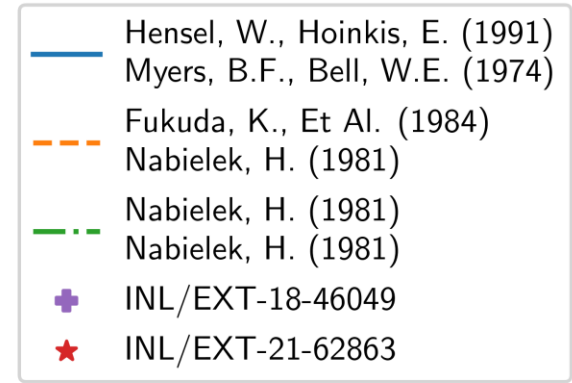
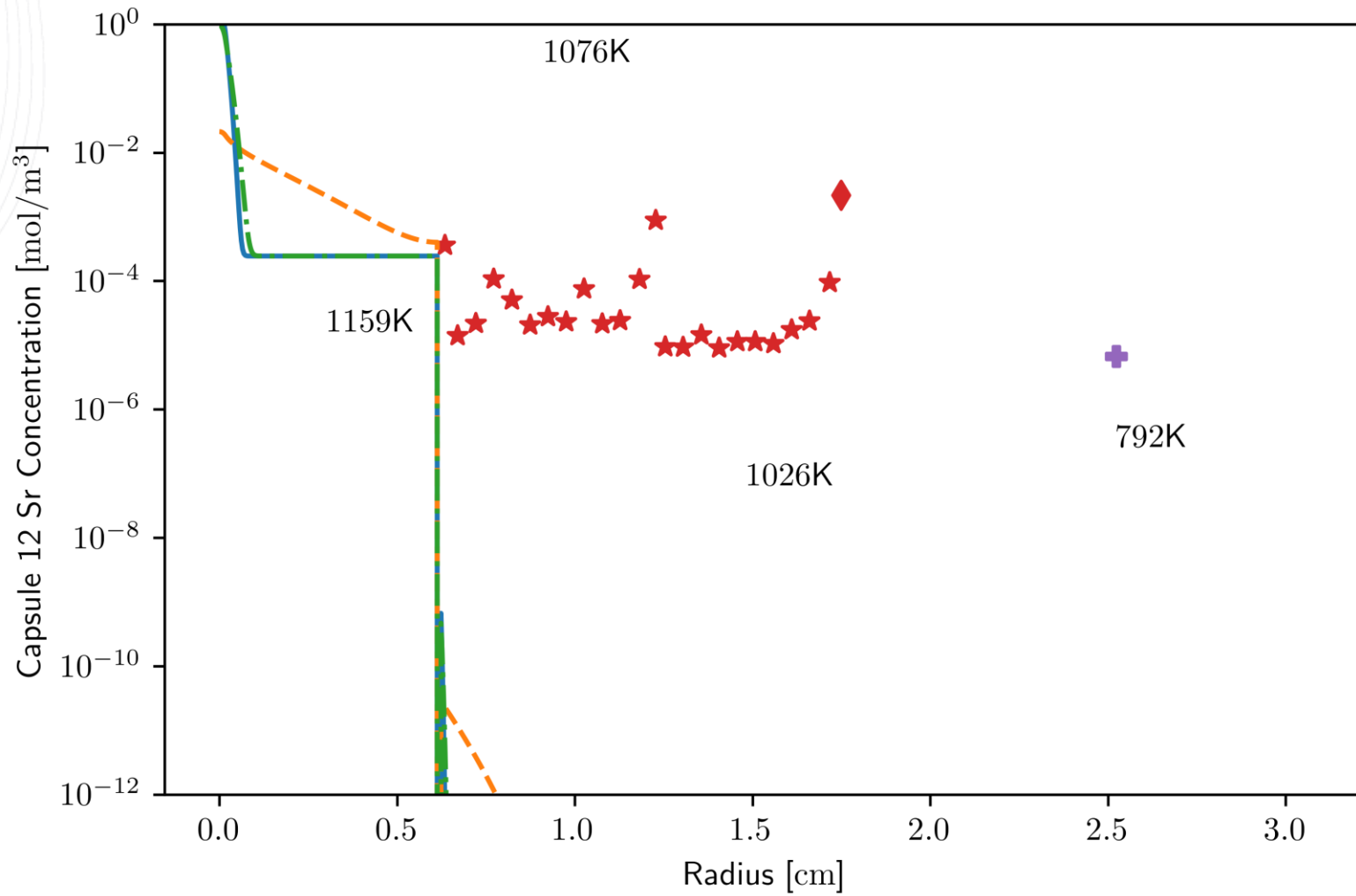


- Hensel, W., Hoinkis, E. (1991)
- Myers, B.F., Bell, W.E. (1974)
- - - Fukuda, K., Et Al. (1984)
- . - Nabielek, H. (1981)
- . - Nabielek, H. (1981)
- + INL/EXT-18-46049
- \* INL/EXT-21-62863

# 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