



STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Nucleation and growth of lead oxide particles in liquid lead-bismuth eutectic



Nucleation and growth of lead oxide particles in liquid lead-bismuth eutectic

Kristof Gladinez

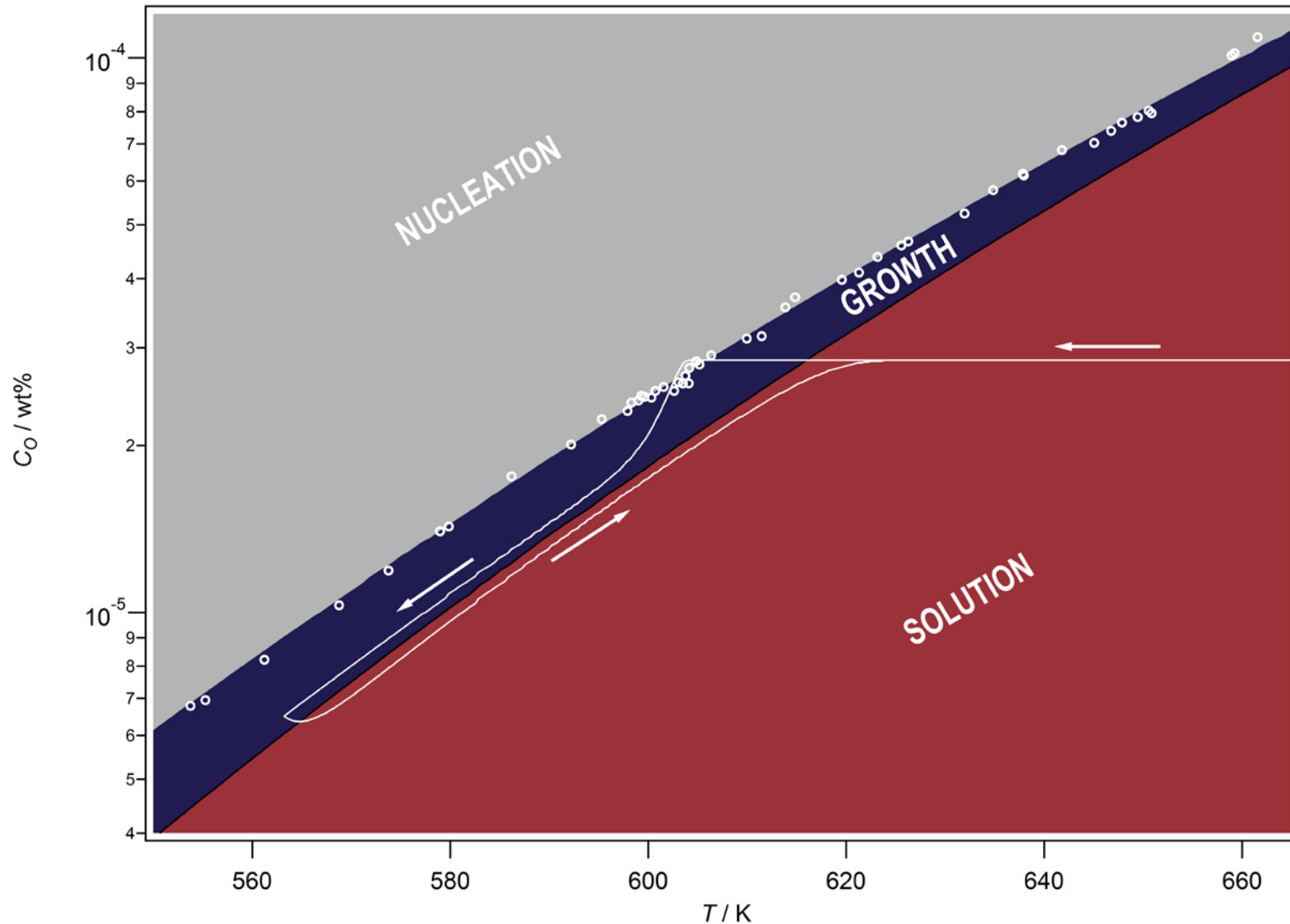
SCK•CEN – Ugent

Kristof.gladinez@sckcen.be

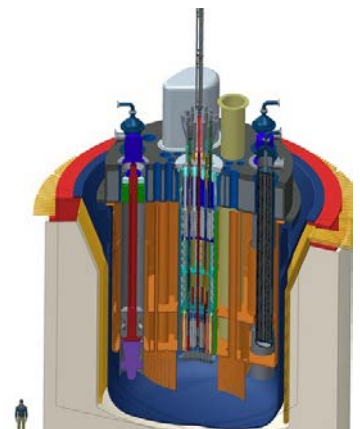


Gladinez, K., Rosseel, K., Lim, J., Marino, A., Heynderickx, G., & Aerts, A. (2017). Nucleation and growth of lead oxide particles in liquid lead-bismuth eutectic. *Physical Chemistry Chemical Physics*, 19(40), 27593-27602.

The formation and dissolution of lead oxide in lead-bismuth eutectic is studied to design and improve novel filtration techniques



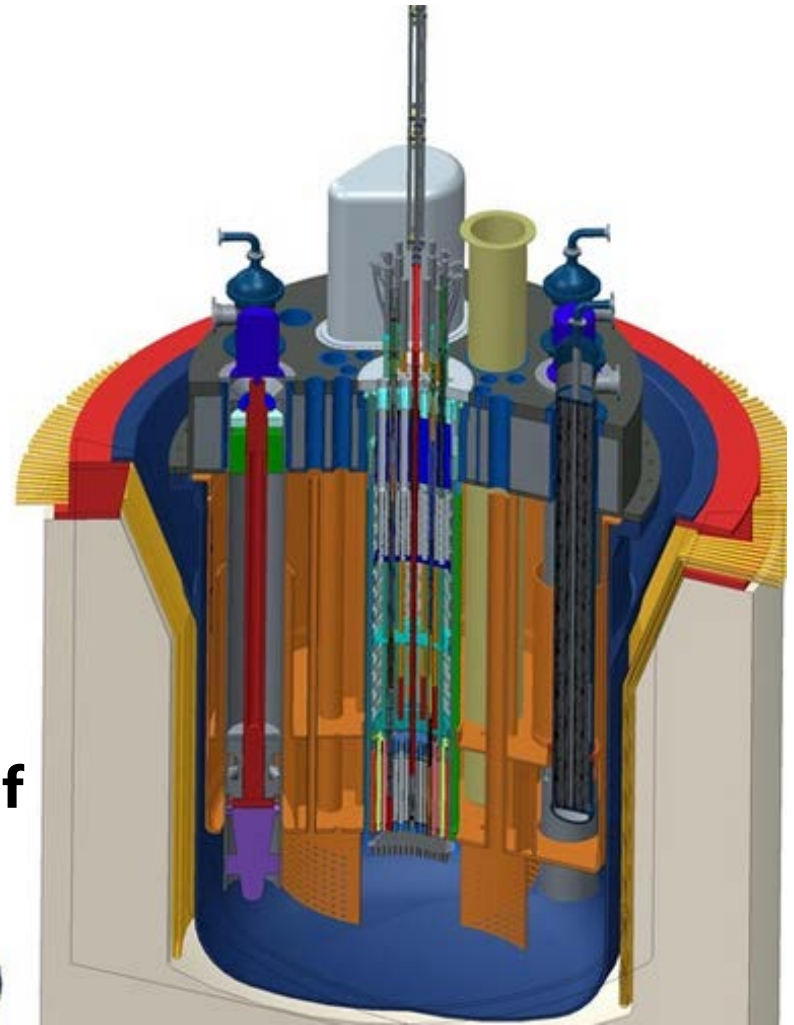
- MYRRHA at SCK•CEN
- Nucleation and growth of lead oxide
- Experimental treatment
- Theoretical description
- Results
- Relevance



MYRRHA @ SCK-CEN: an Accelerator-Driven System (ADS)

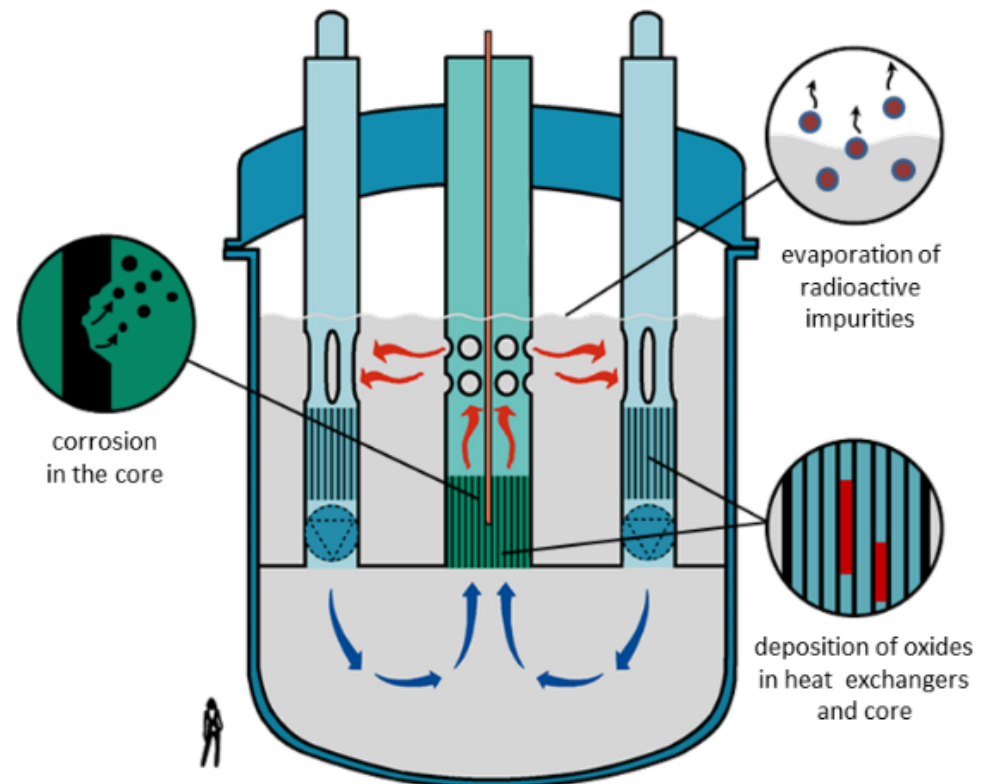
- Gen IV fast reactor
 - Technology demonstrator
 - Transmutation of radioactive waste
 - Subcritical core
- Lead-bismuth eutectic (LBE) coolant

LBE chemistry and oxygen control of prime importance



Oxygen in LBE: Why is this important?

- Due to its influence on
 - Corrosion of fuel cladding and structural steels
 - Evaporation of radionuclides
 - Liquid metal embrittlement
 - Plugging risk by coolant oxidation (PbO)



Nucleation and growth: winter edition

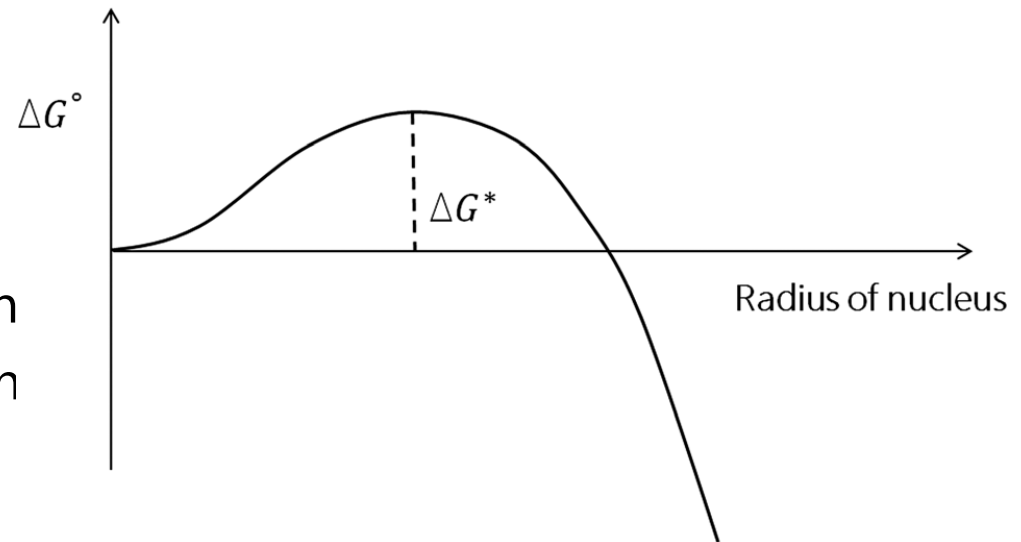


- **Water – Ice**

Homogeneous nucleation → Large nucleation barrier → supercooling (up to -35°C)

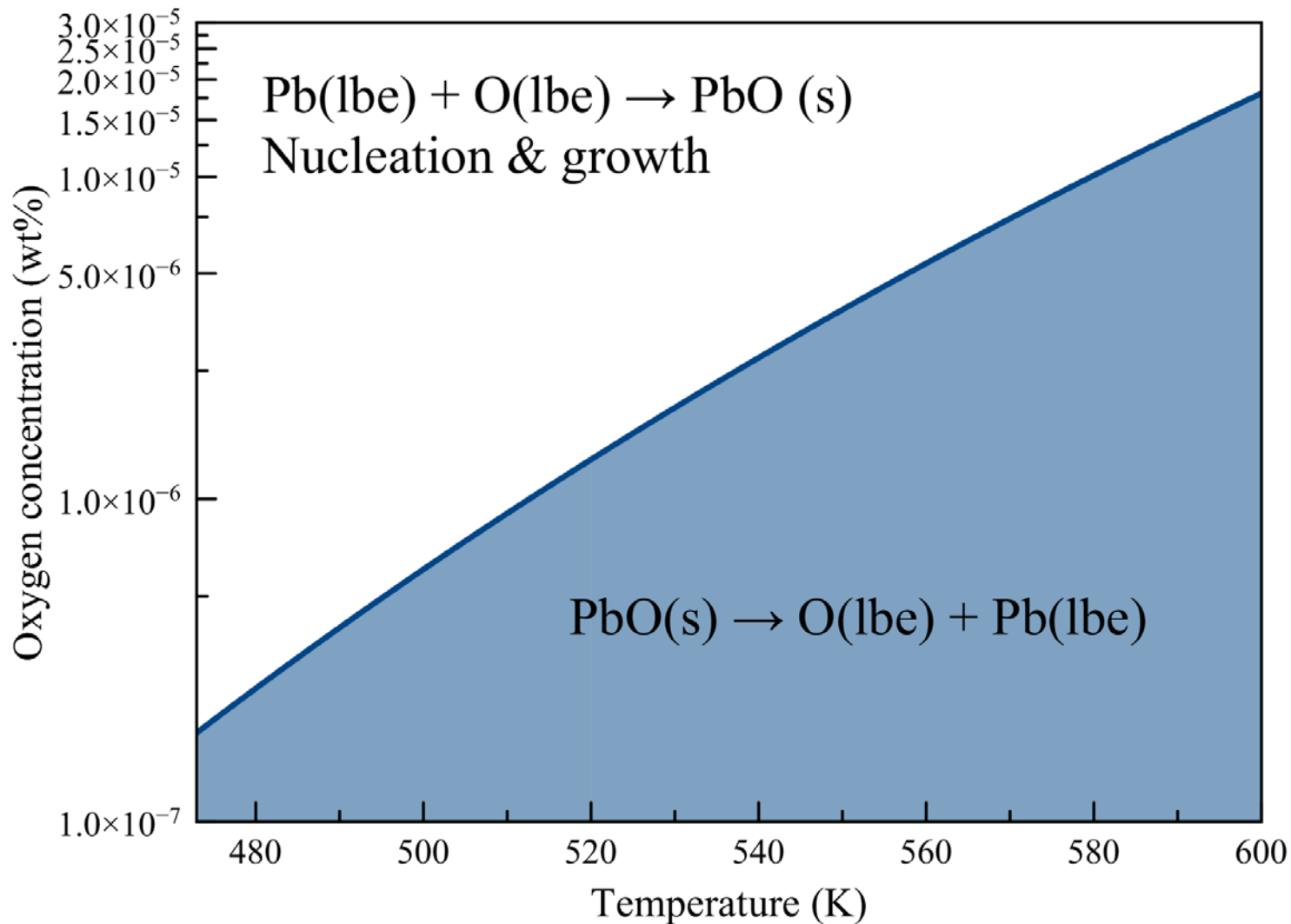
- **LBE – PbO**

- Nucleation barrier unknown
- Rate of nucleation unknown
- Crystal growth unknown



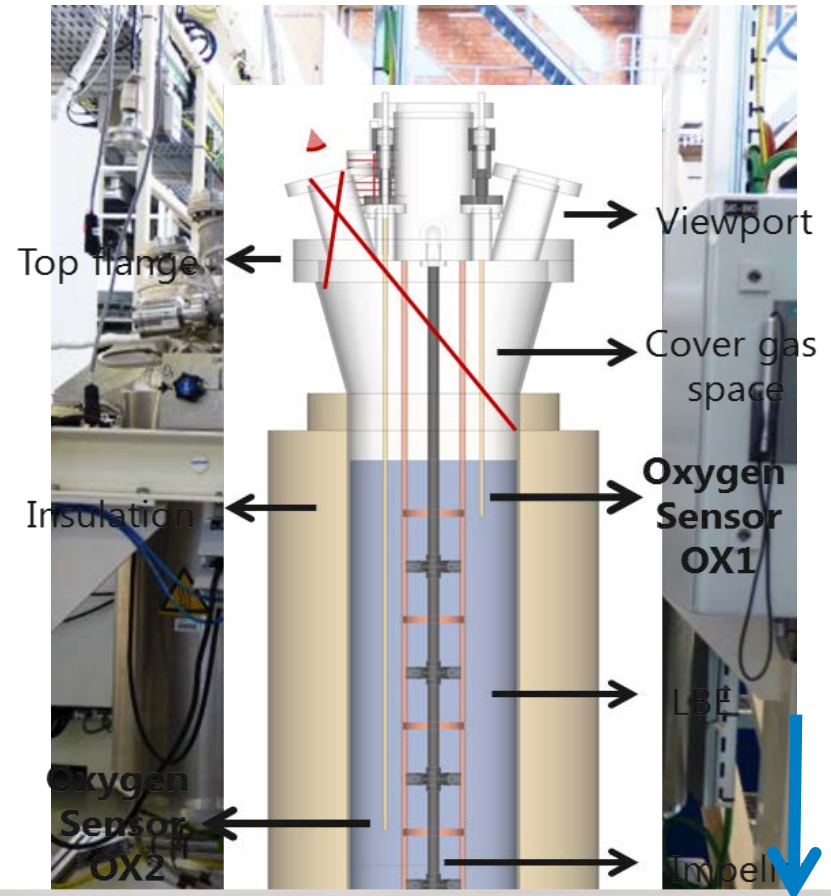
Impact, safety considerations of PbO in nuclear reactors cannot be judged ?

Lead oxide in Lead-bismuth eutectic: Oxygen saturation

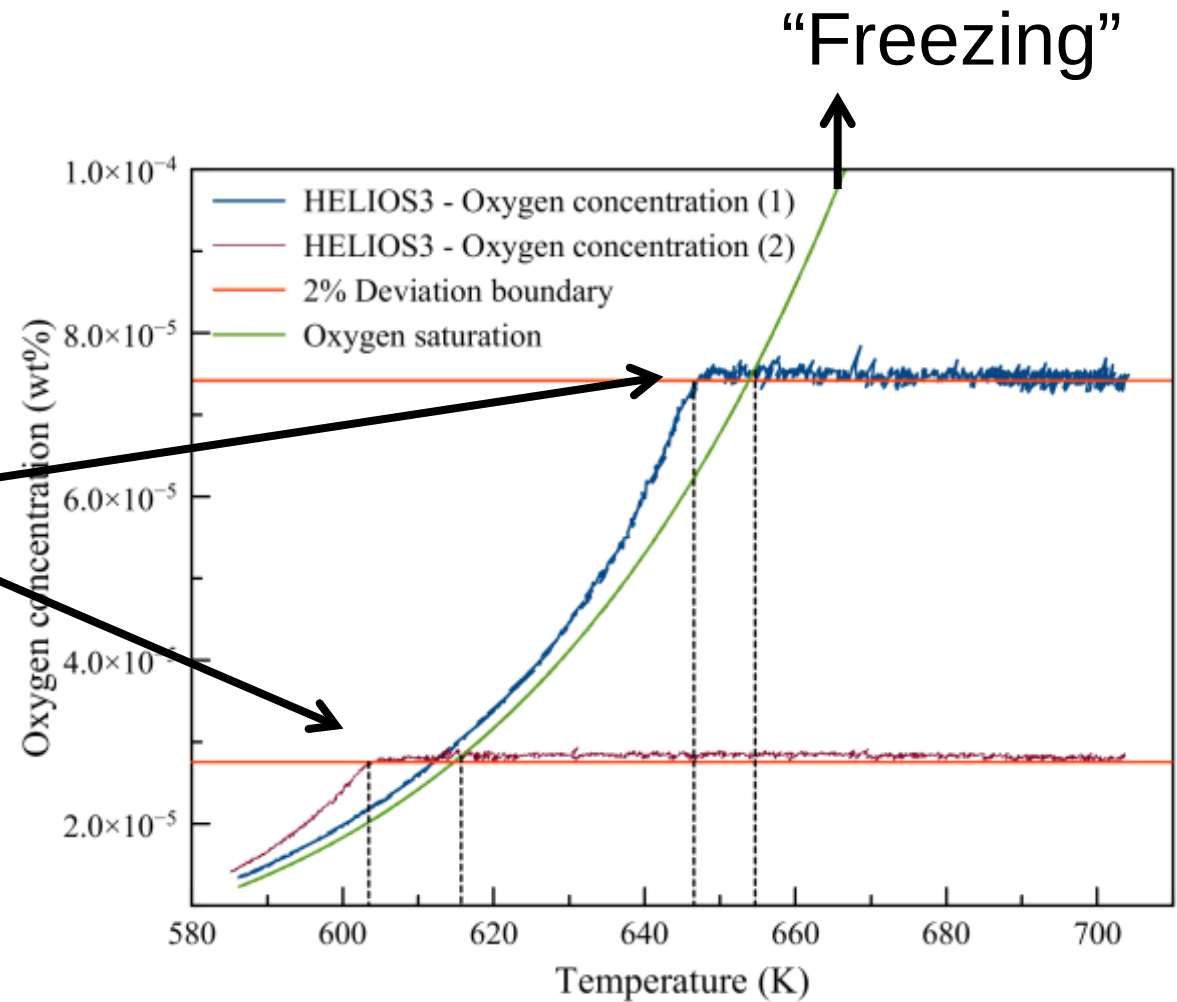


Nucleation of PbO in LBE

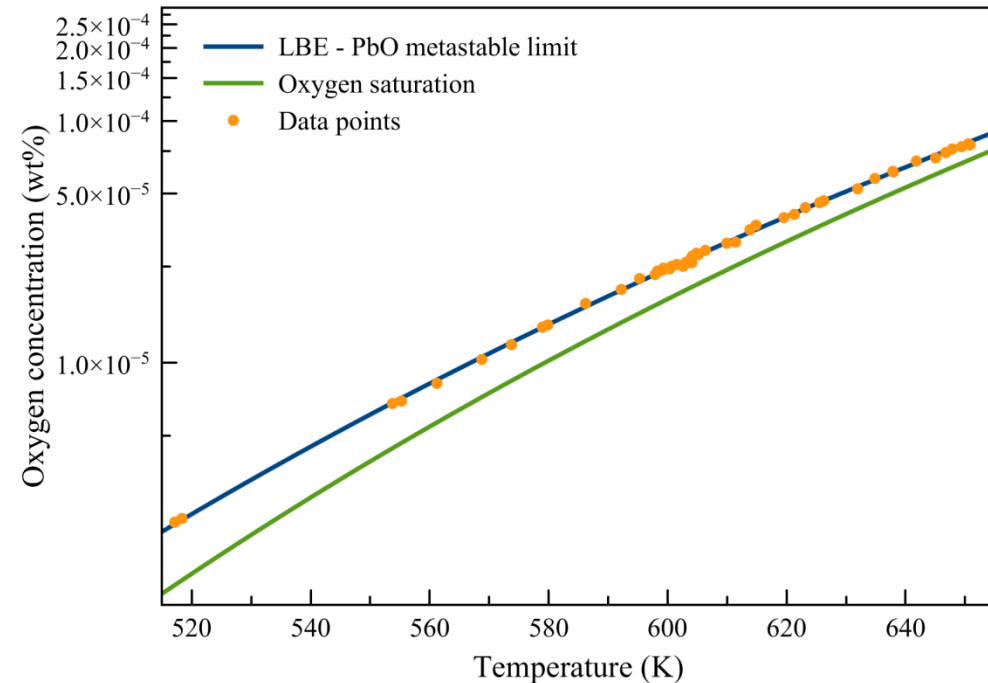
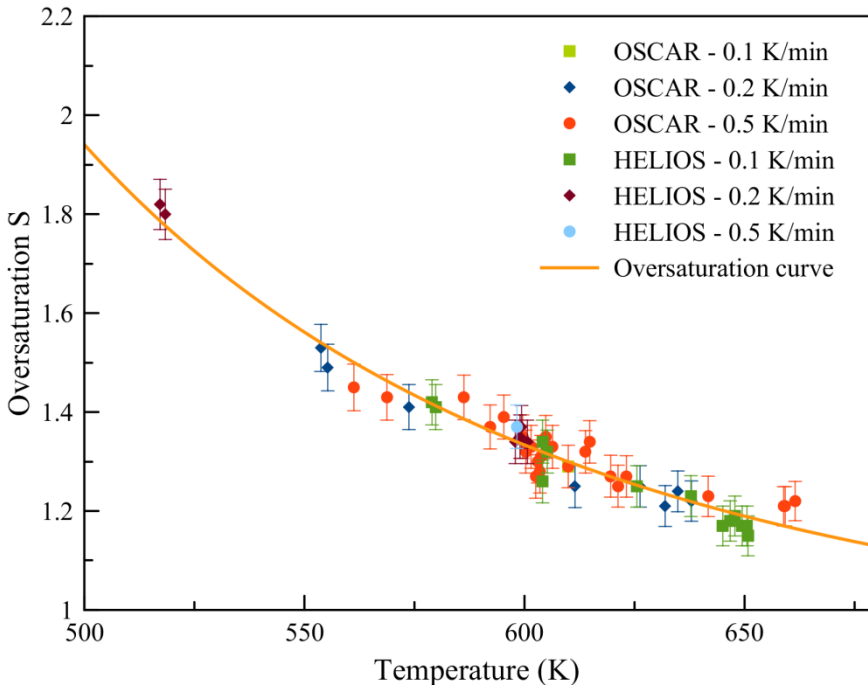
- HELIOSIII experiment
- Temperature cycling
 - fixed total oxygen concentration
- Oxygen concentration measurement



Nucleation **barrier** of PbO

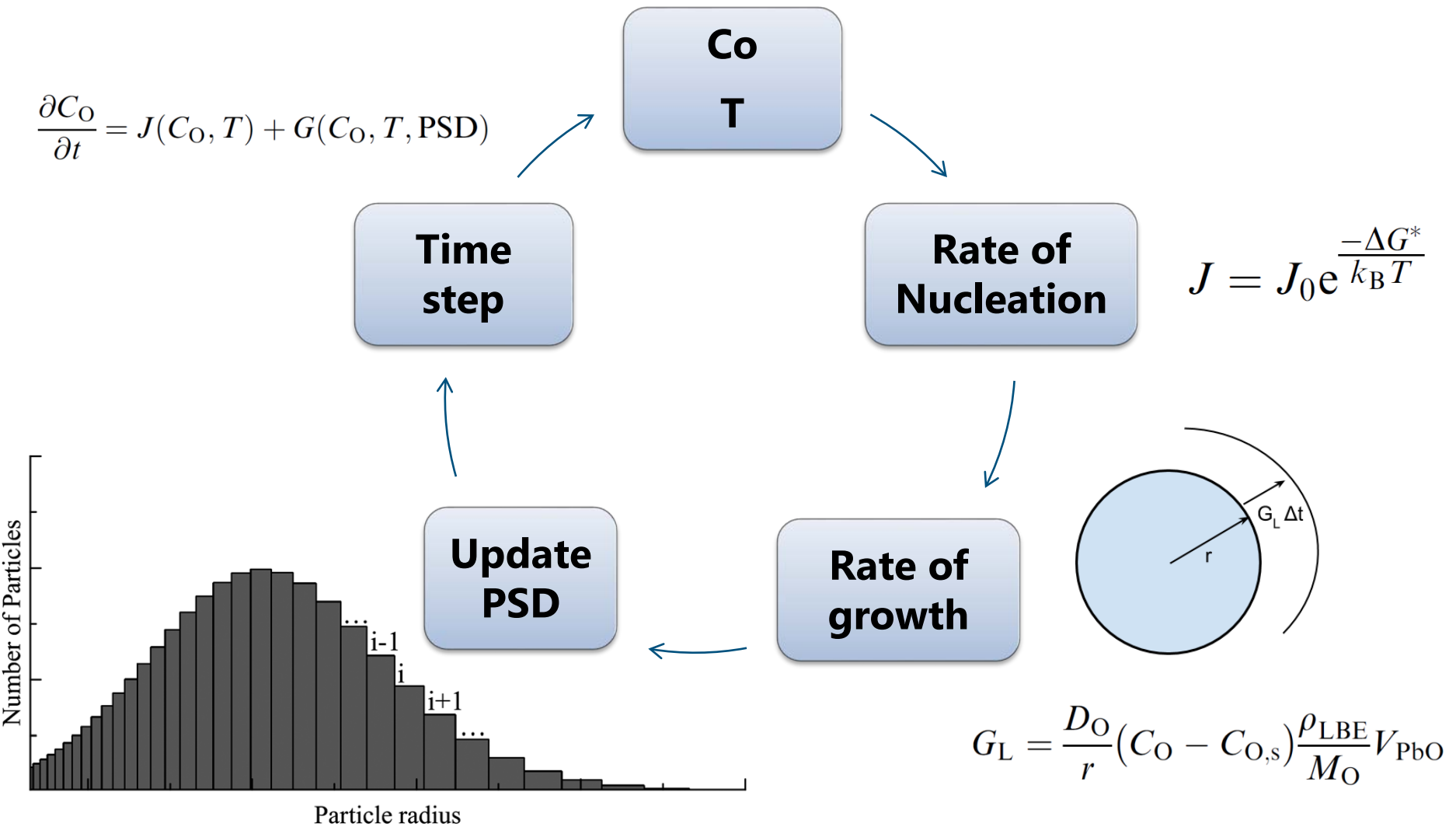


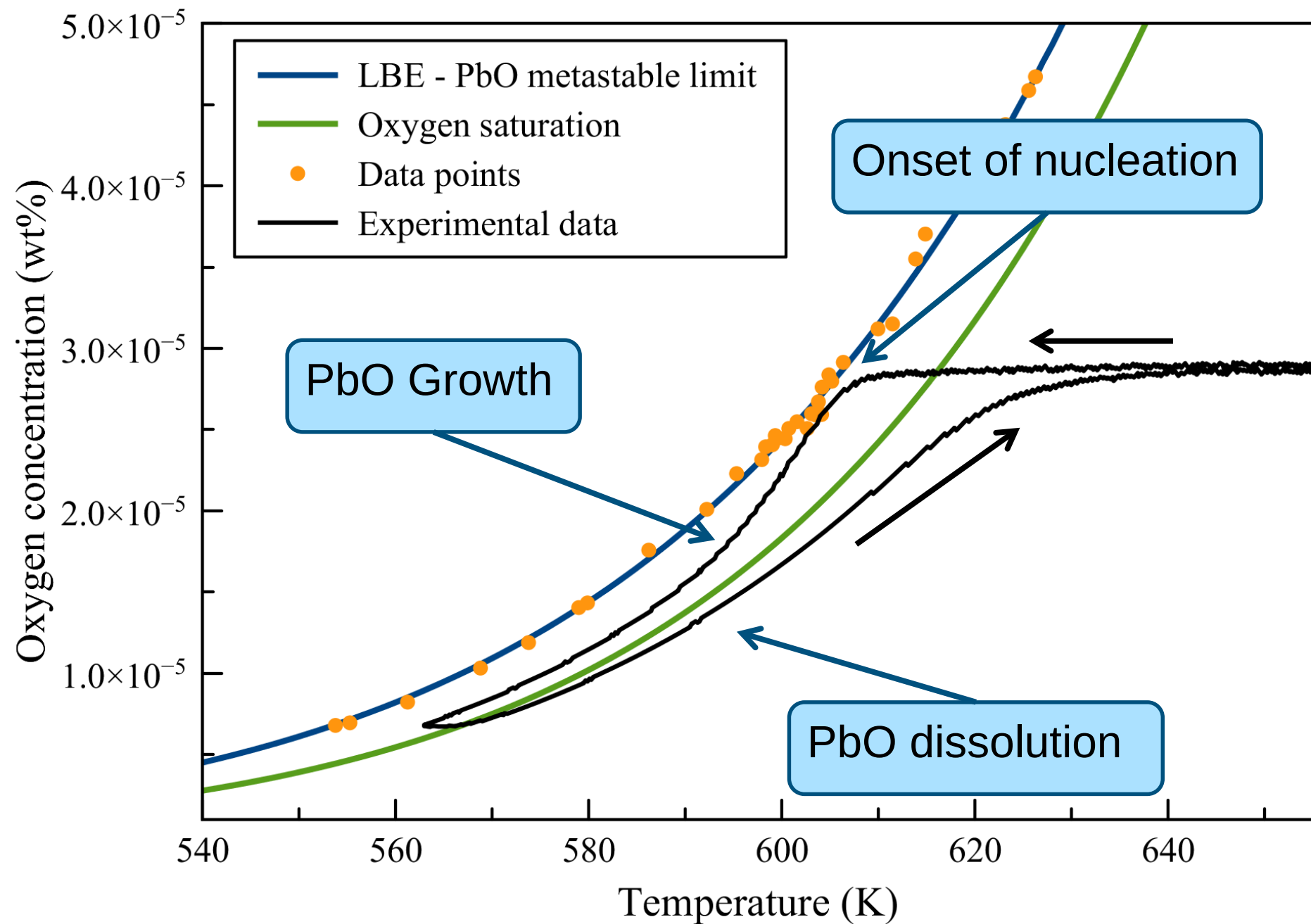
Nucleation barrier – Experimental campaign



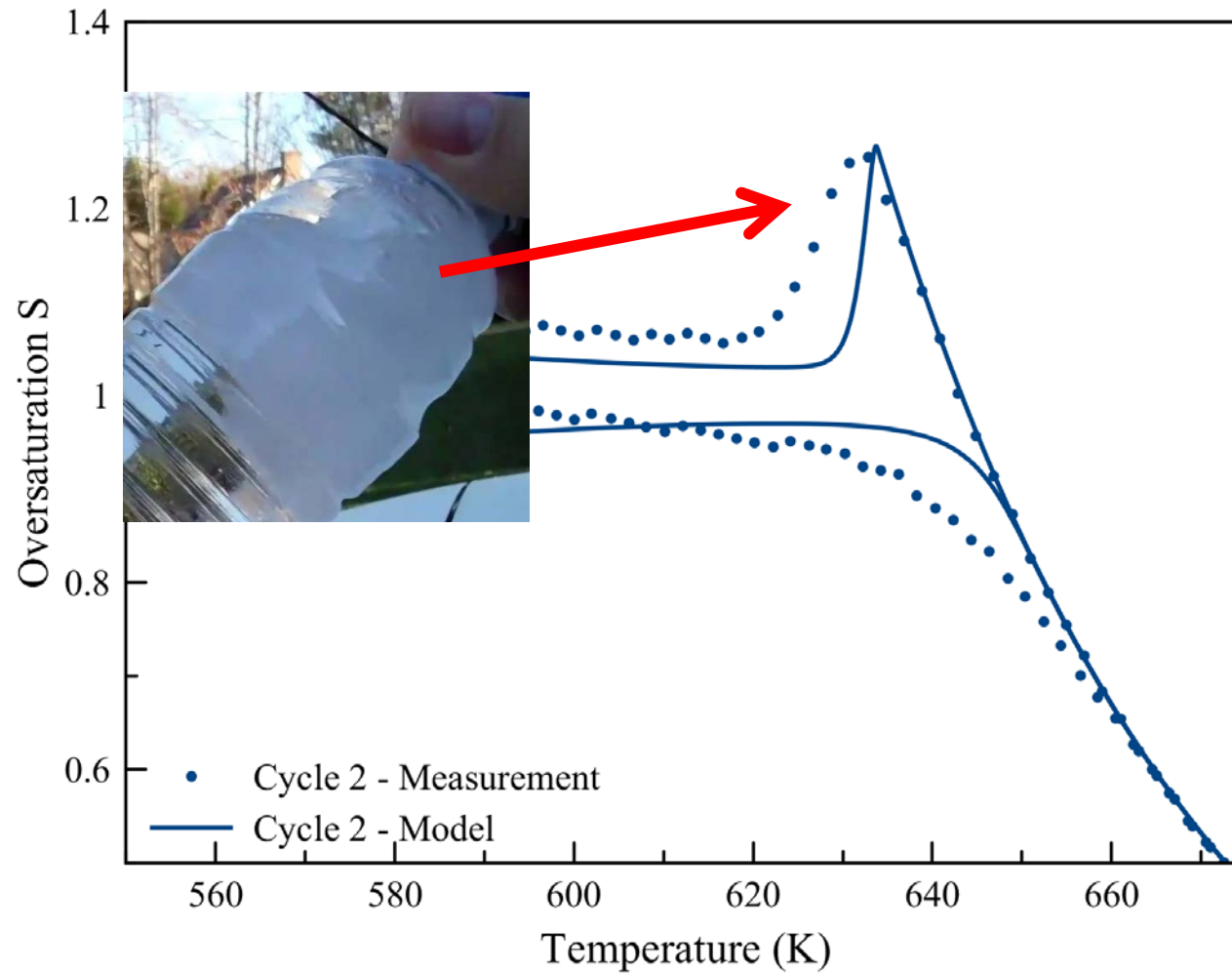
- Oversaturation $S = \frac{\text{Oxygen concentration}}{\text{saturation concentration}} = \frac{C_o}{C_{o,s}} = \text{'supercooling'}$
- Classical Nucleation Theory $\rightarrow$ Surface tension/Interfacial energy

Nucleation and growth: model development

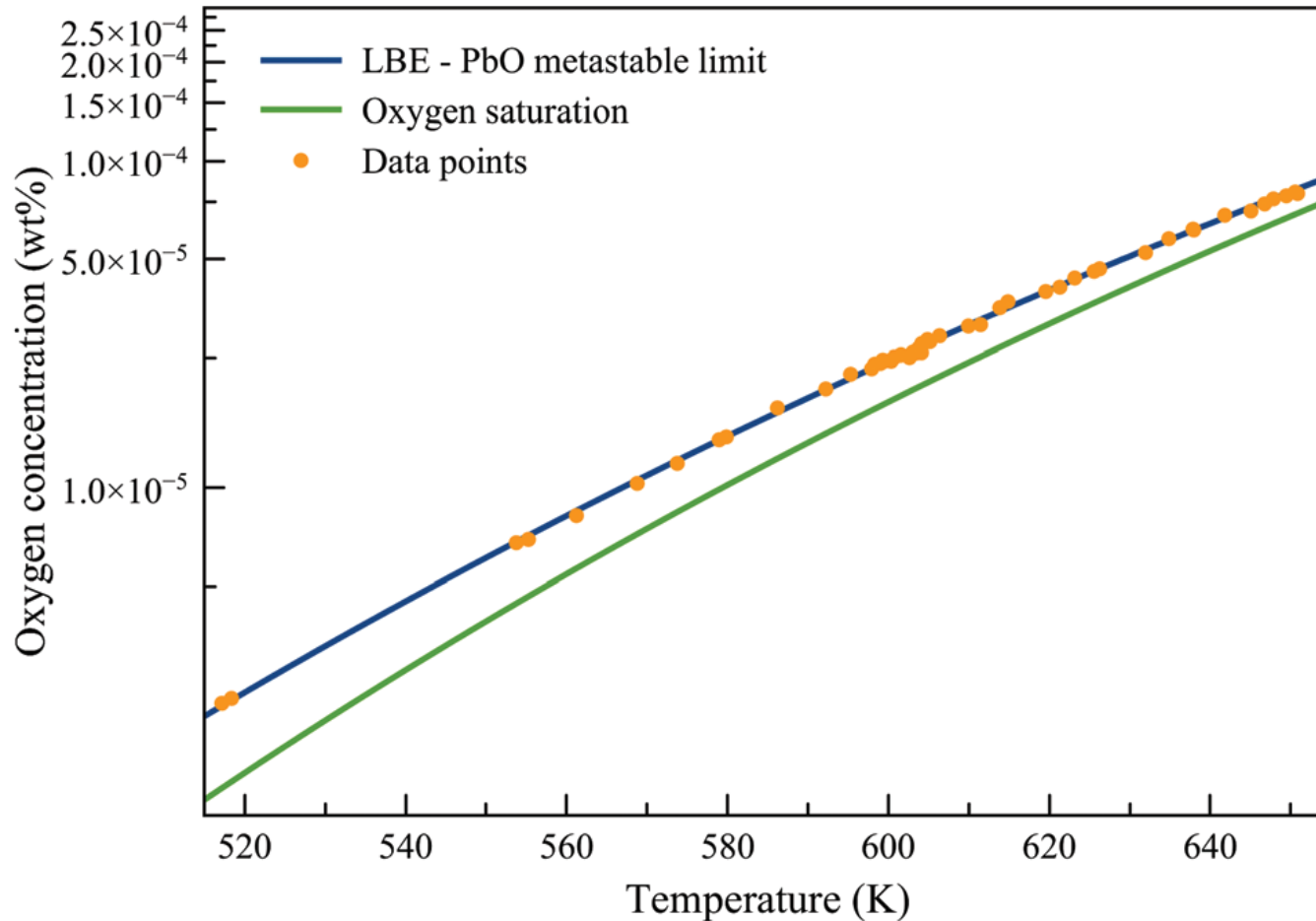




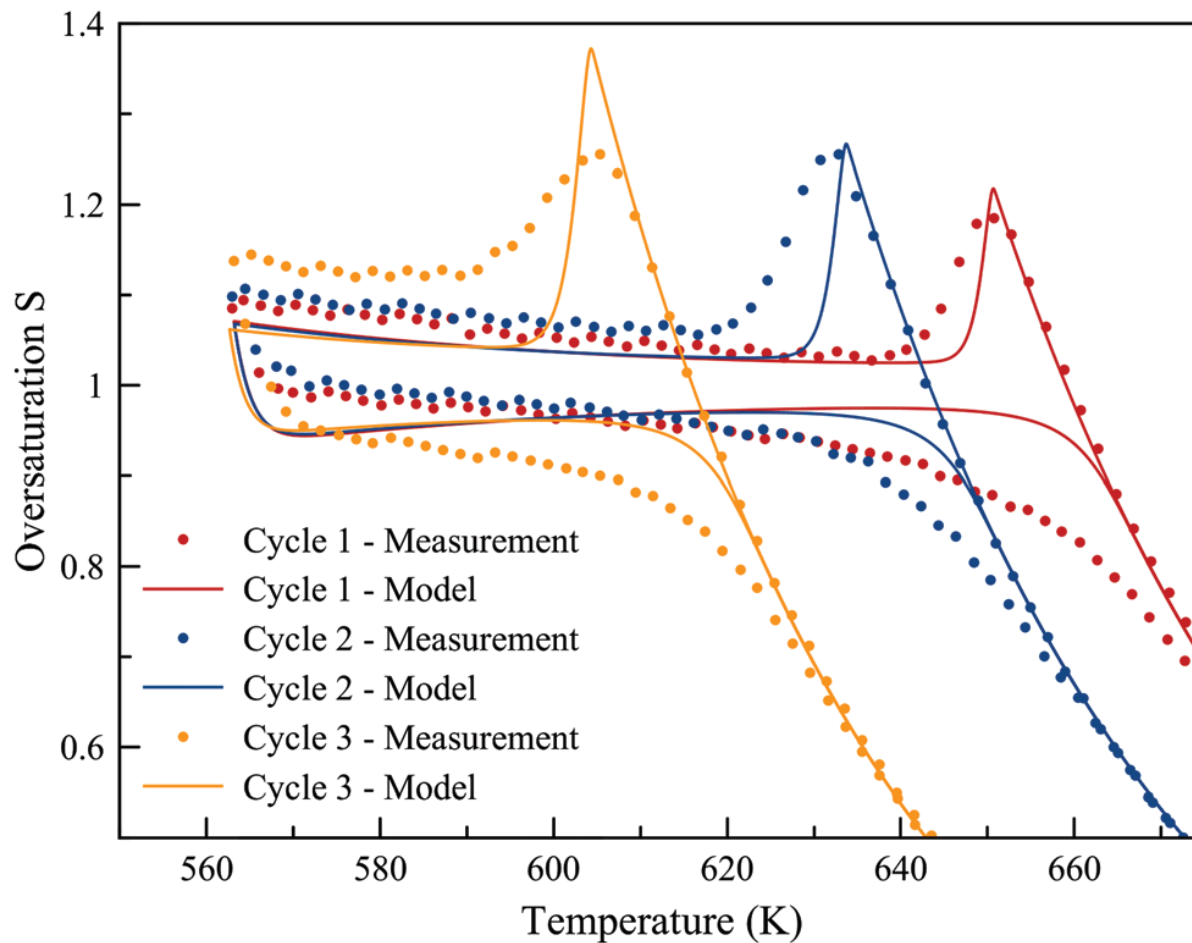
$$\frac{\partial C_O}{\partial t} = J(C_O, T) + G(C_O, T, \text{PSD})$$



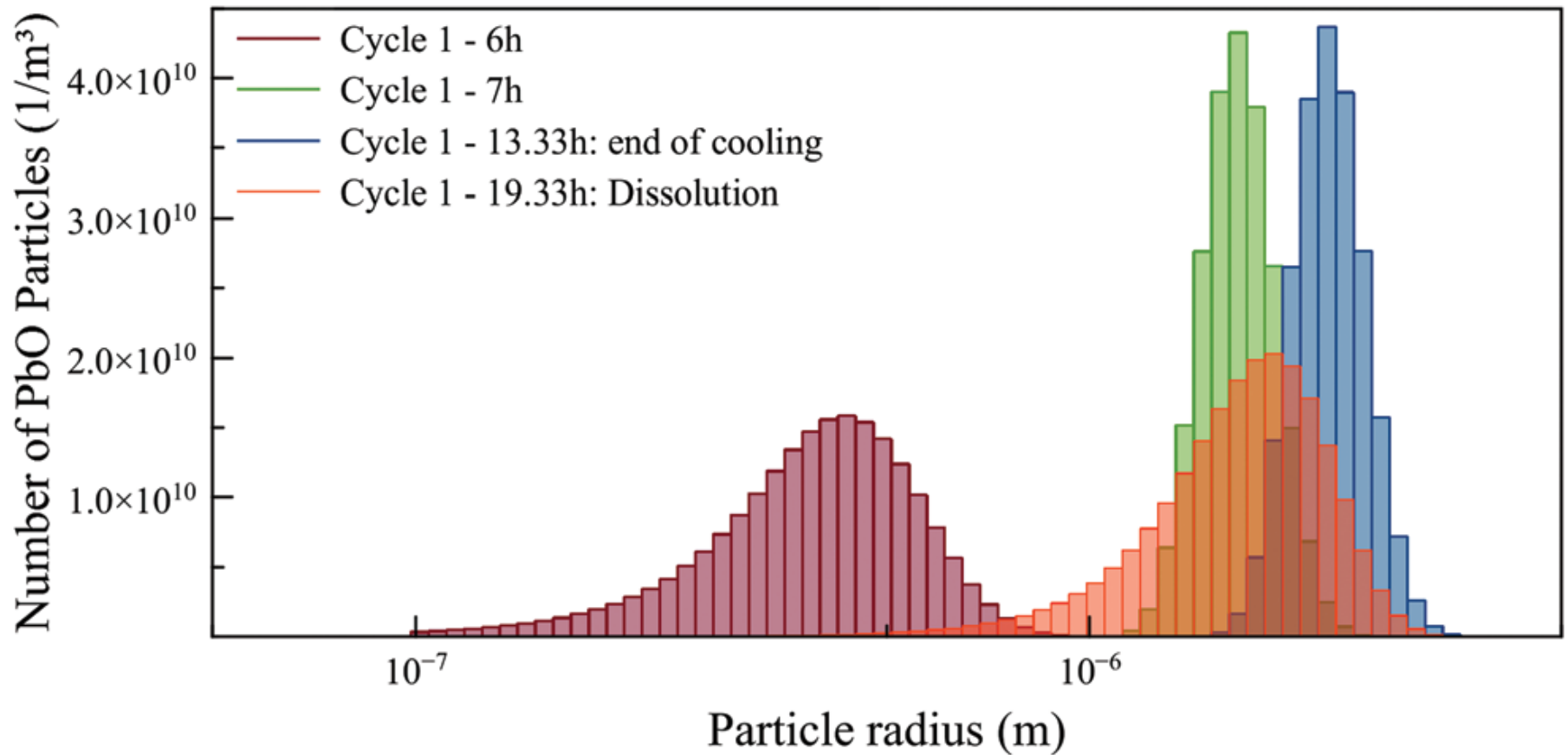
- 1. Measurement of metastable limit = onset of PbO formation



● 2. Model for PbO nucleation, growth and dissolution

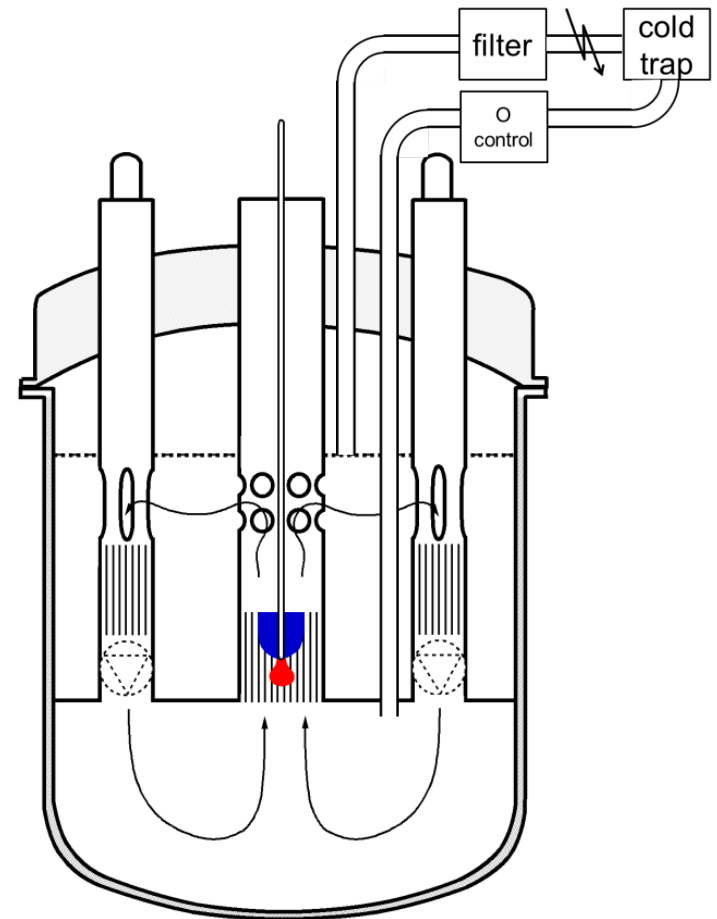
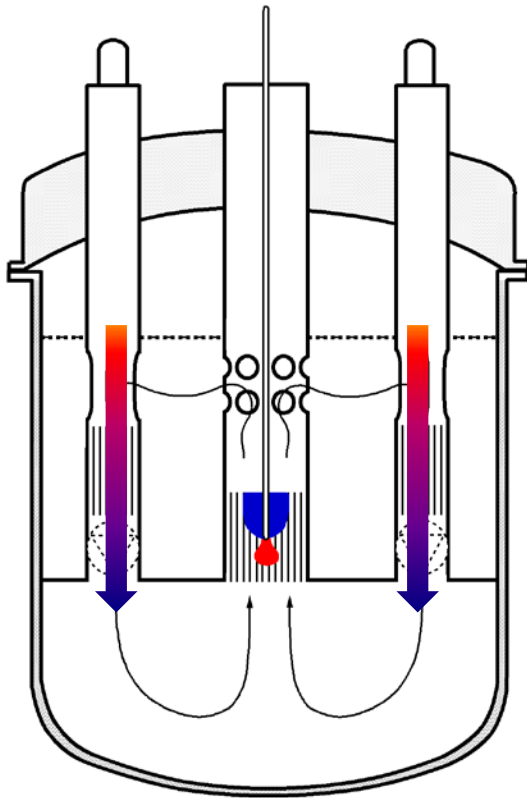


- 3. Particle size distribution prediction by model



Conclusion

- Lead and LBE cooled nuclear reactors need knowledge on PbO formation



Acknowledgements

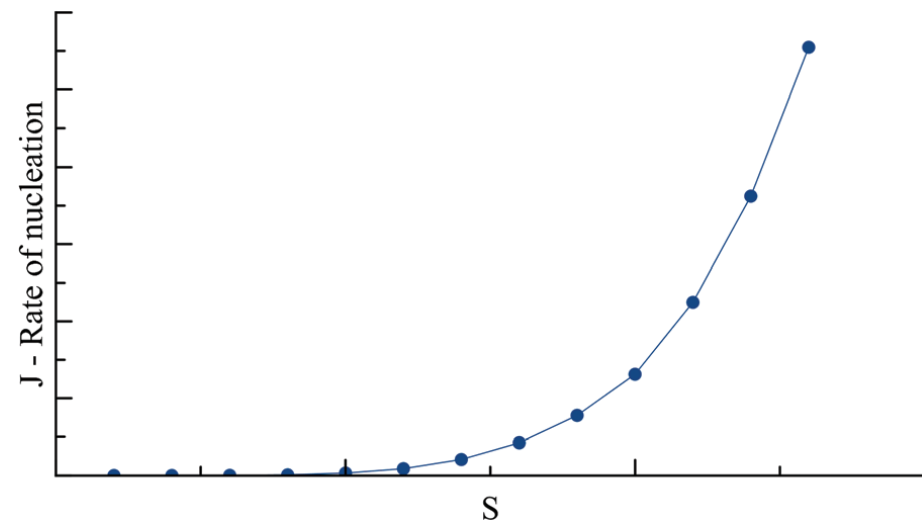
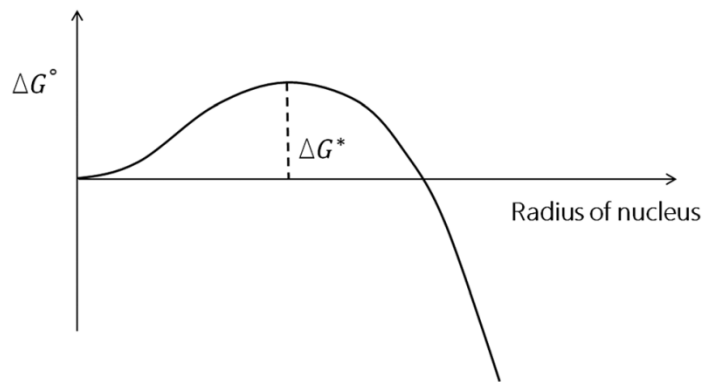
- Co-authors of the paper:

Gladinez, K., Rosseel, K., Lim, J., Marino, A., Heynderickx, G., & Aerts, A. (2017). Nucleation and growth of lead oxide particles in liquid lead-bismuth eutectic. *Physical Chemistry Chemical Physics*, 19(40), 27593-27602

- AVN for providing financial support in the framework of my PhD
- Belgian Government for funding of the MYRRHA programme
- BNS - YG

Classical Nucleation Theory

$$J = J_0 * e^{\frac{-\Delta G^*}{k_b T}} \text{ [nuclei/m}^3 \text{ s]}$$



$$\Delta G^* = \frac{16\pi\sigma^3}{3\Delta G_v^2}$$

$$J = 1 \Rightarrow \sigma = 0.1976 - 2.4075 * 10^{-4} T$$