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Corium Properties & Accident Scenarios: Preliminary Insights

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CIEMAT

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Background

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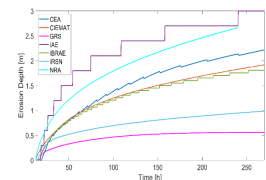
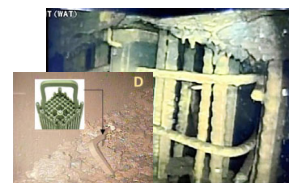
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Background

Motivation

- SA ex-vessel phase might jeopardize containment integrity:
 - Penetration of basemat (& attack to pedestal walls).
 - Over-pressurization.
 - High energetic combustion.
- Fukushima observations, far from “expectations”.
- Codes major discrepancies in the long run.
- Intl. projects on ex-vessel corium (ROSAU; **COPS**; ...).
- BEPU in SA ... is phasing UQ an option?
- Mobility support to SEAKNOT PIRT.




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Background


Objectives & Scope



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- Investigate the influence of corium properties on the containment scenario during the ex-vessel phase:
 - Cavity erosion
 - Gas composition
 - Pressure
- PWR “dry cavity” (MCCI).
- BEPU approach (MELCOR + in-house Python scripts)


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Scenario



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Accident Scenario

- 1000 MWe W-PWR.
- Unmitigated SBO.
- Dry cavity
- Corium pool: 80% of oxides; 20% metals.
- Total mass of corium: 135 tons
- Limestone concrete
- Initial conditions (26400 sec = 7.3h):

Pressure Pa	T atm K	Relative Humidity	Molar fraction H2
2.66E5	457.95	0.102	0.08

SPECIES	Limestone aggregate/common sand concrete (mass%)
SiO ₂	35.80
TiO ₂	0.18
MnO	0.03
MgO	0.48
CaO	31.30
Na ₂ O	0.082
K ₂ O	1.22
Fe ₂ O ₃	1.44
Al ₂ O ₃	3.60
Cr ₂ O ₃	0.014
CO ₂	21.15
H ₂ O chem	2.00
CaCO ₃	-
Ca-OH-2	-
H ₂ O vap	2.70

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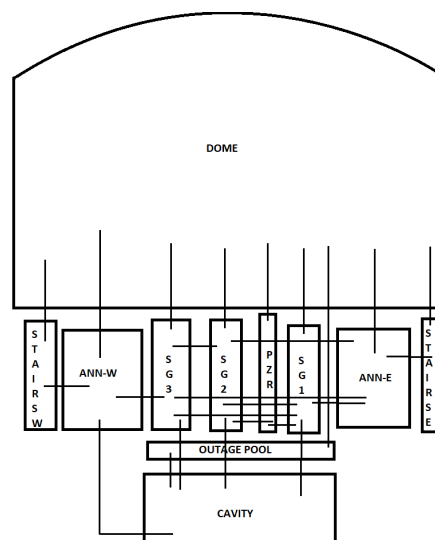
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MELCOR modelling

- MELCOR 2.2 2025.0.
- Single layer debris pool.
- Independent containment analysis.
- Ex-vessel phase (20 – 180 ks).

CV	% of volume	% surface
Cavity	1.26%	3.90%
SG-1	2.40%	9.42%
SG-2	2.80%	9.66%
SG-3	3.11%	11.09%
ANN-E	5.39%	17.62%
ANN-W	5.64%	20.43%
PRZ	0.67%	5.32%
STAIRS-E	0.18%	0.64%
STAIRS-W	0.36%	2.13%
OUTAGE-POOL	1.92%	2.17%
DOVE	76.26%	17.62%



Total CVs volume = 61293 m3
Total area = 25120.3 m2

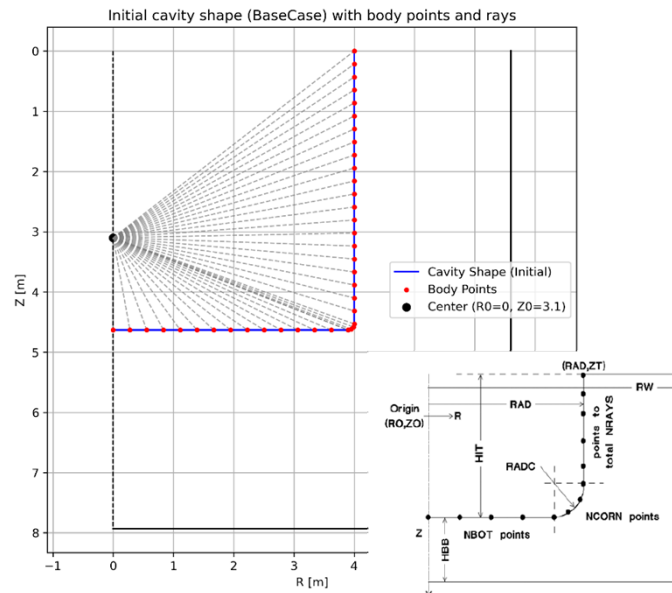
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Cavity modelling

- # rays = 40
- $(R0, Z0) = (0, 3.1)$
- # BOT=15
- # CORN=2
- HBB=3.3m
- HIT=4.6m RAD=4m



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Corium Properties

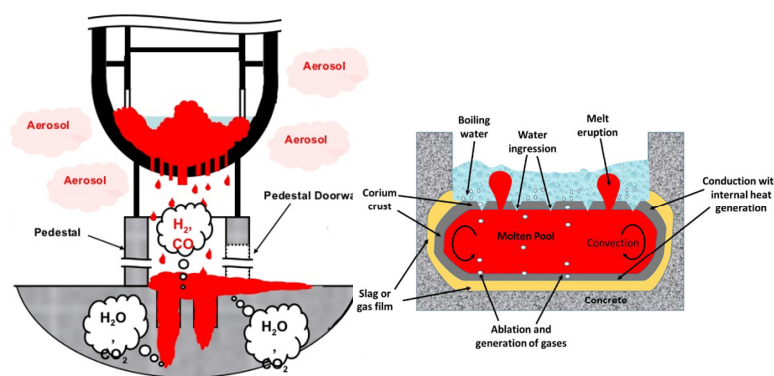
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Identification

- Conductivity k
- Viscosity μ
- Density ρ
- Specific heat c_p
- Emissivity ε

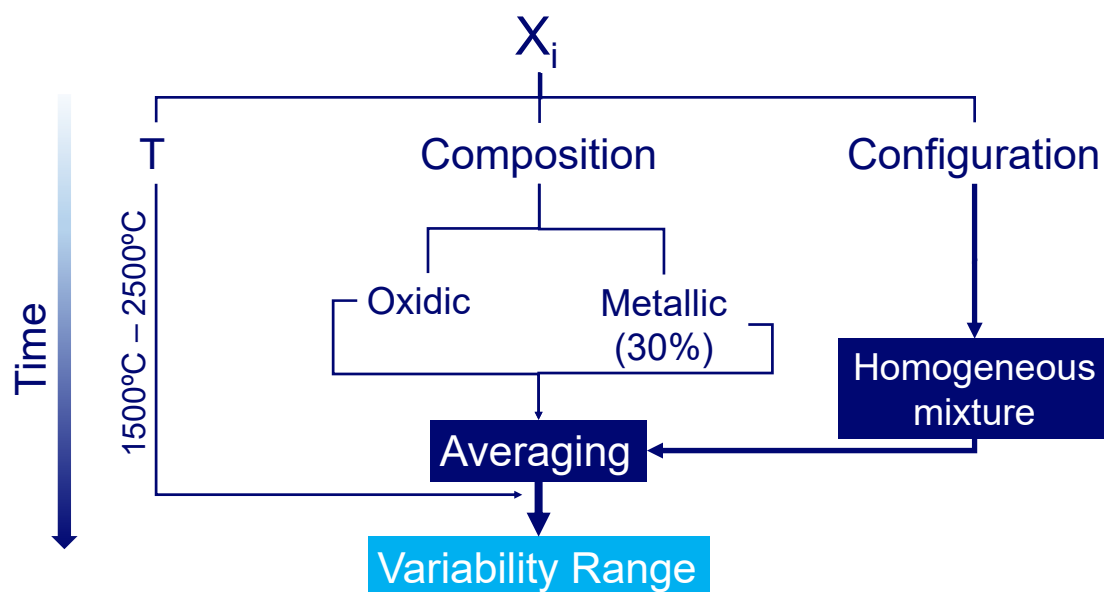


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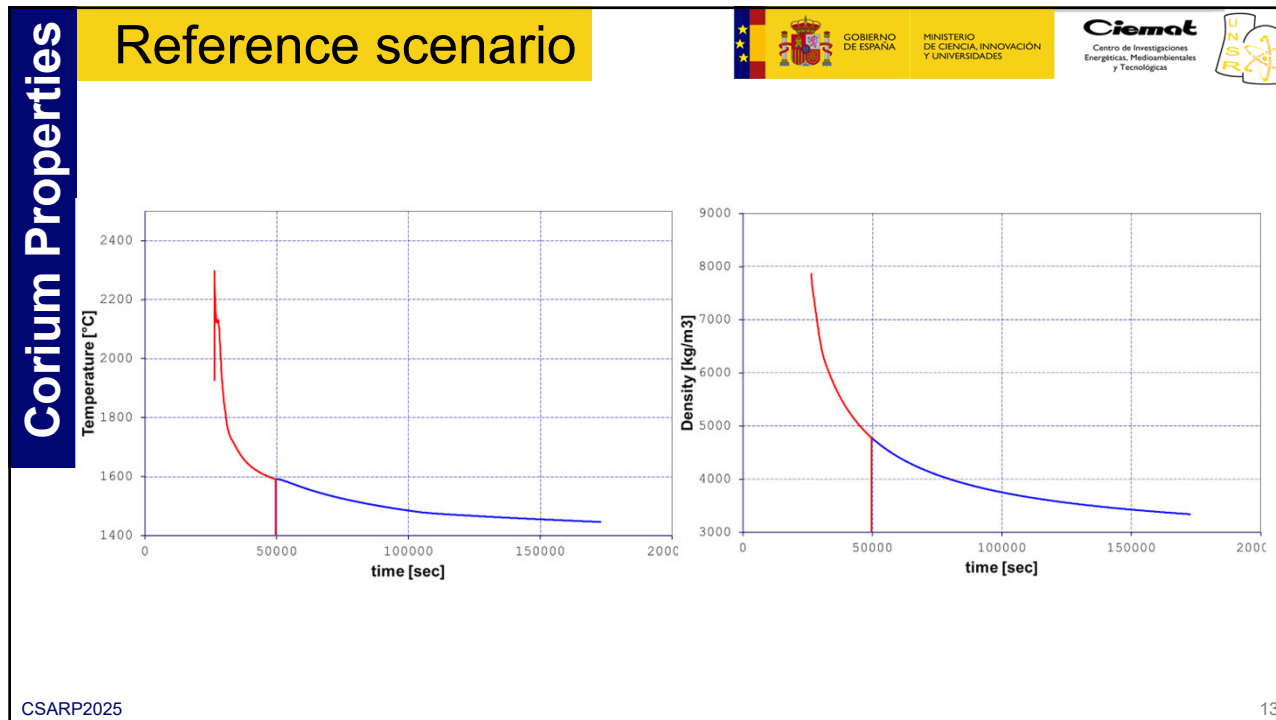
Influencing factors



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Corium Properties

Properties ranges

	Averaging method	Unit of measurement	Lower bound	Upper bound
μ	Molar fraction	kg/ms	0.1	10
k	Molar fraction	W/mK	1	10
c_p	Mass fraction	J/kgK	500	1500
ρ	Mass fraction	kg/m ³	3000	9000
ϵ	Molar fraction	-	0.5	1

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BEPU

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BEPU

Ranges Adaptation

- MELCOR v.2.2 2025.0 allows using multipliers M (Thanks Brad!)

Corium property	Range of the multiplier M
μ	0.5 – 1.5
k	0.85 – 2.5
ε	-
c_p	0.83 – 1.2
ρ	0.9 – 1.9

- “OAT” sensitivity

- No influence
- Little influence
- Big influence

	Pressure in the dome	Erosion	H2/CO produced in the cavity
μ	●	●	●
k	●	●	●
ε	●	●	●
c_p	●	●	●
ρ	●	●	●

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Methodology

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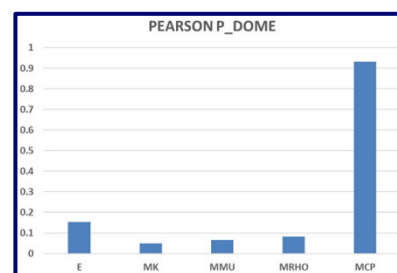
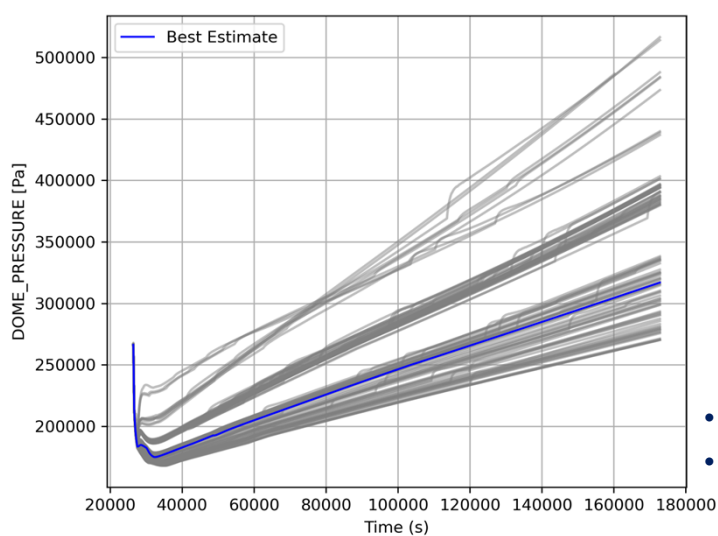

- 95/95 Wilks approach (100 cases run).
- SRS used to sample properties ranges.
- Uniform probability density function assumed.
- In-house Python scripts to manage outputs.

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Results: Pressure

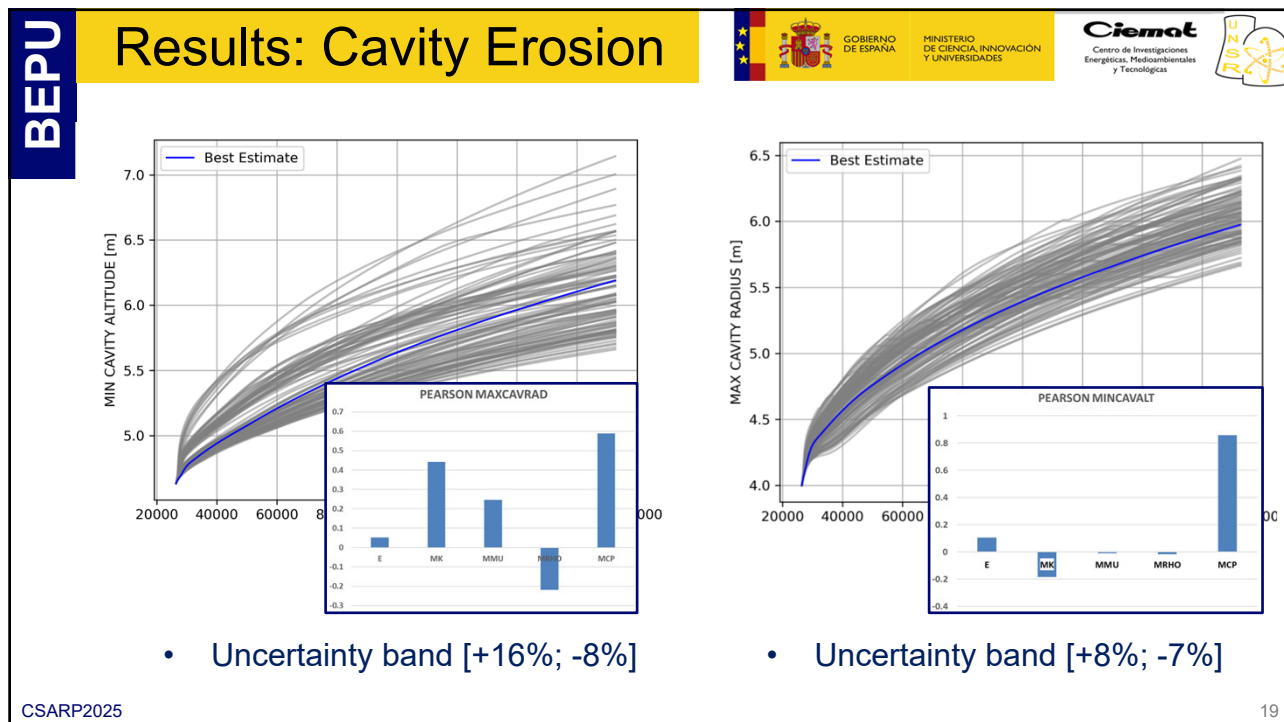
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- Bifurcations! (ongoing work).
- Uncertainty band [+60%; -16%]

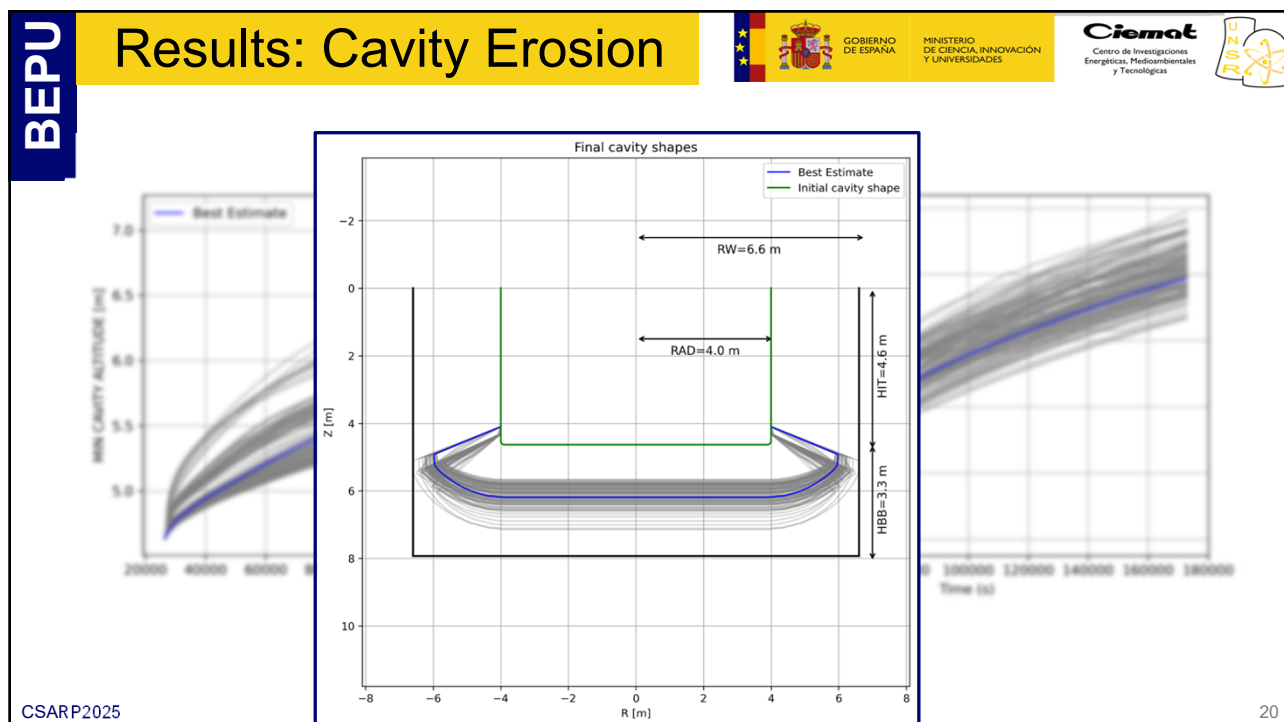
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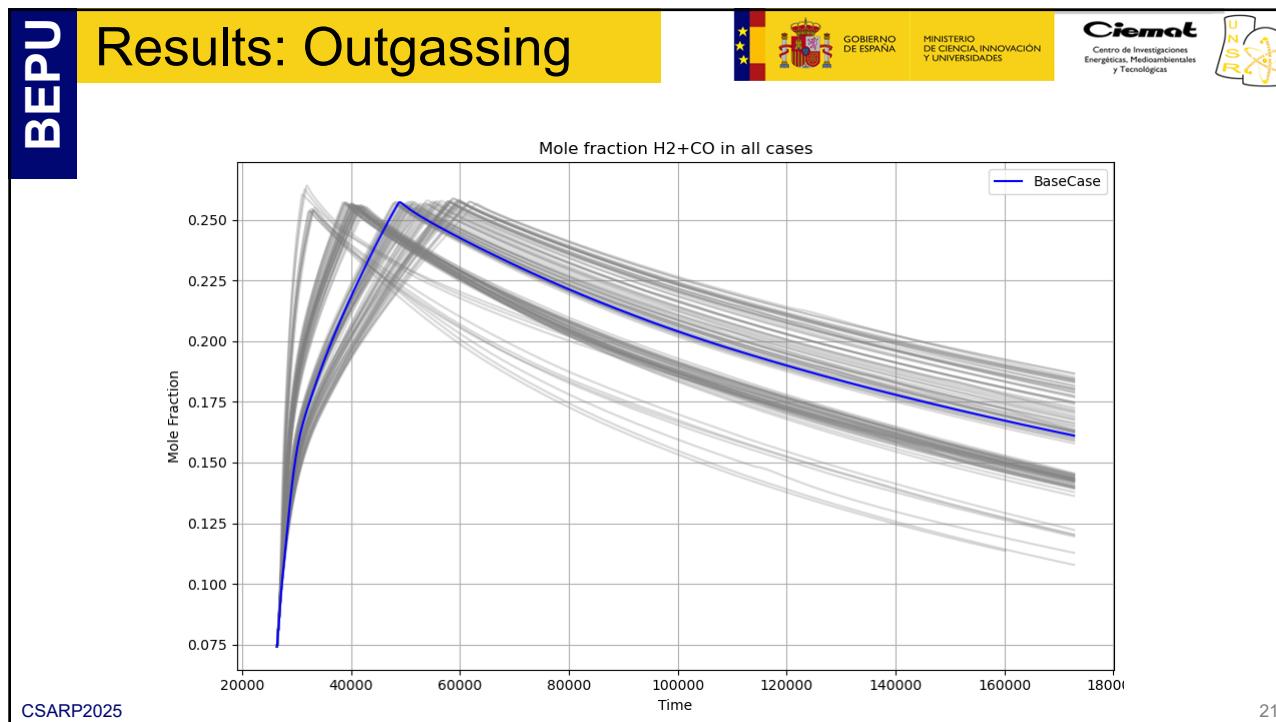
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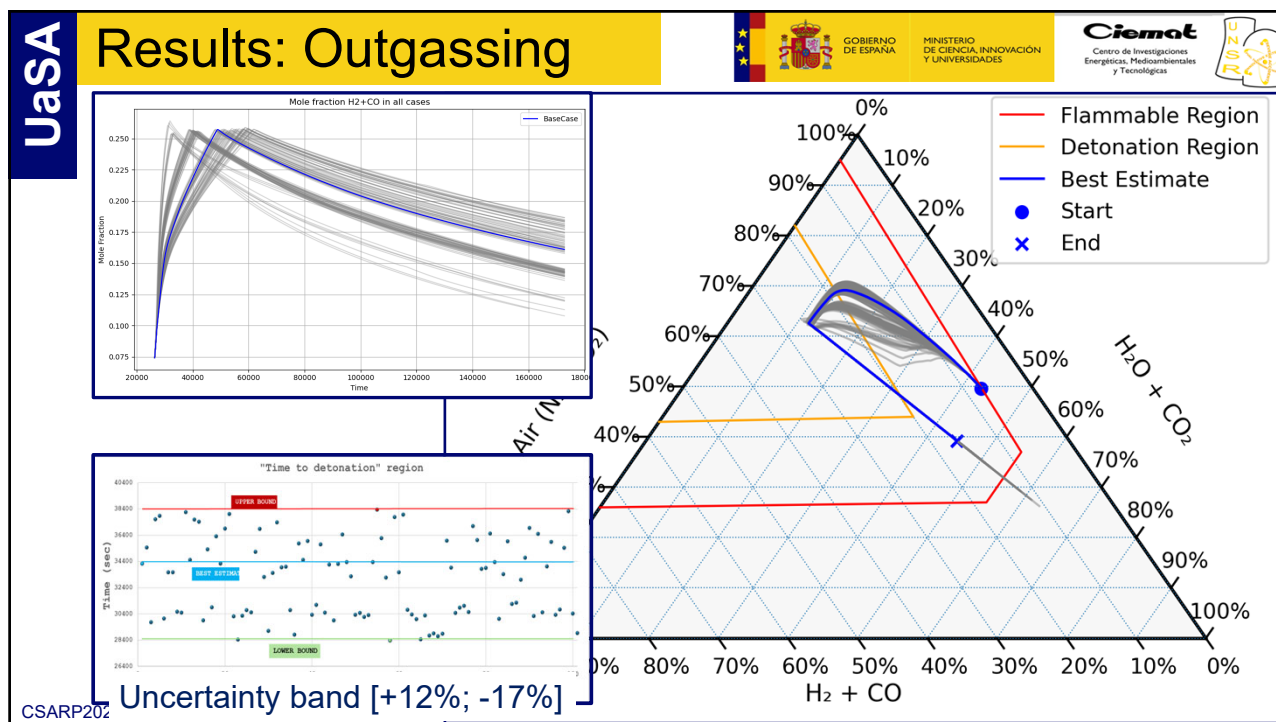
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Preliminary Insights

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Preliminary Insights

- **A methodology** proposed to explore the relevance of corium properties on SA containment scenario in the ex-V phase.
- **Major hypos** made to set the basis of the BEPU analysis.
- A “**small/moderate**” **effect of uncertainties in corium properties on erosion & combustion risk** found.
- **Containment pressure significantly affected**, though.
- **Specific heat uncertainties** a big player!

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Future Steps

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Future Steps


- To consolidate the results (sensitivity to assumptions).
- To extend to other scenarios (BWRs; Fukushima).

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Thank you for your attention!



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