

30 May - 3 June 2022  
Lyon, France

# Towards an Optimized Management of Accidents

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10<sup>th</sup> European Commission Conference on EURATOM Research and Training in Safety of Reactor Systems  
30 May - 3 June 2022 | Lyon, France

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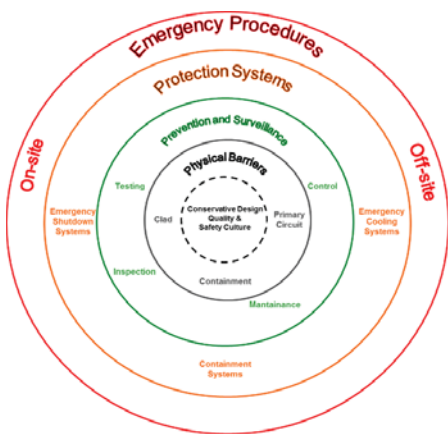
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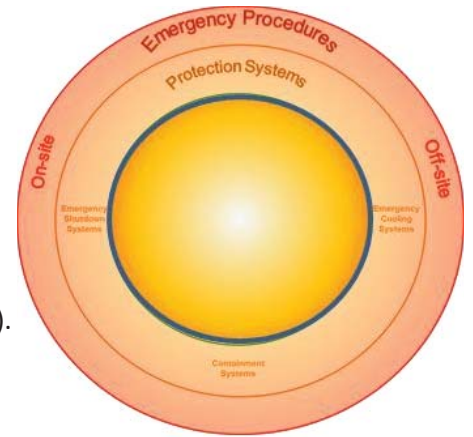
# Motivation

- Research on accidents: Deep-down in the roots of the DiD concept.



(Herranz, 2021)

- Safety systems – Performance (passive!).
- Analytical tools – From BE to BEPU (AM!).
- Containment – Combustion risk (AM!)



- EURATOM commitment to research on Nuclear Power Plants safety!

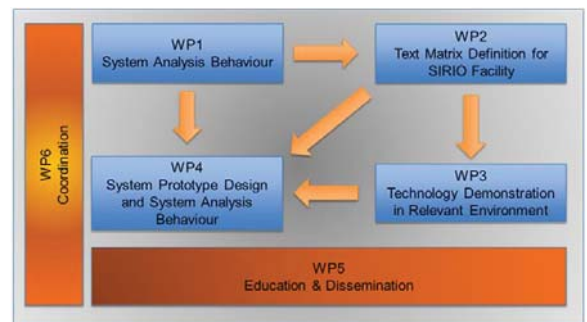


# The PIACE Project

## Overview

- Passive Isolation Condenser (PIACE). H2020 GA n° 847715 (400 p-m).
- **Aim:** To demonstrate the feasibility of a **passive** innovative Decay Heat Removal (DHR) system.
  - Design assessment
  - Feasibility testing (SIRIO facility)

(LW & LMRs)



- **Extension:** 2019 – 2022.

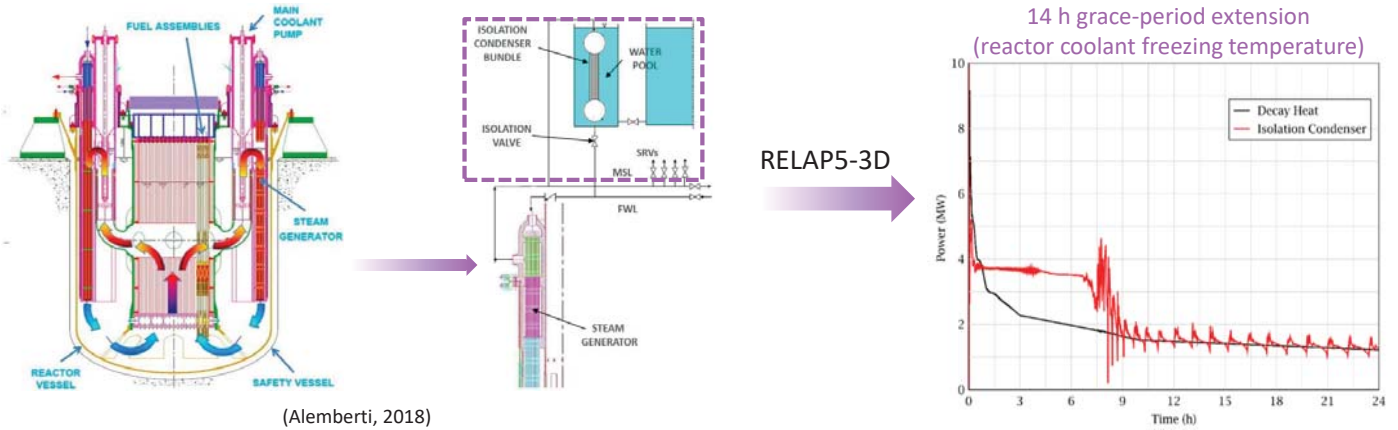
- **Partners:** ANN, EAI, **ENEA**, GEN ENERGIJA, JSI, RATEN, SCK-CEN, SIET, SINTEC, TRACTEBEL, UPM



# The PIACE Project

## Preliminary Results

- LMRs (ALFRED, 200 MW<sub>th</sub>) – A PLOOP (Protected Loss Of Offsite Power)



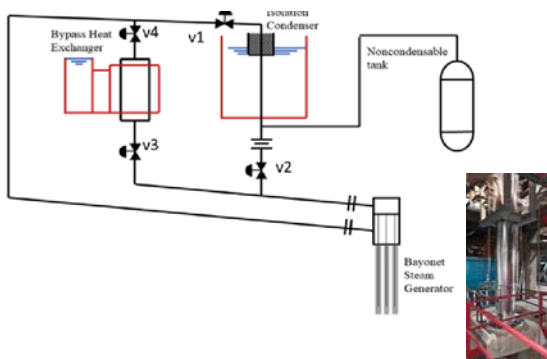
- Other transients modeled for MHYRRA, PWR (2000 MW<sub>th</sub>), ESBWR, ...



# The PIACE Project

## Preliminary Results

- Testing in SIRIO facility



SIRIO facility upgrading needs and test matrix of each reactor technology

LFR, PWR and BWR are selected for test campaign

	LFR (SIRIO as it is)	ADS		PWR		BWR		PHWR	
		Proposal 1	Proposal 2	Proposal 1	Proposal 2	Proposal 1	Proposal 2	Proposal 1	Proposal 2
Layout & components modifications required	None	Direct connection of the non-condensable tank to the HX upper header		Heat transfer surface of HX increased by a factor 1.82	Heat transfer surface of HX increased by a factor 1.82	Extra vessel on Steam line. 6" x 5,86 m	None	Modification of the diameters of the most piping of the loop	
Operation parameters									
Power [kW]	55	28.3	3.25	55	55	55	110	30	55
Pressure primary circuit [bar]	180	16.0	16.0	60	60	72.52	72.52	46	46
Pressure gas tank [bar]	110	12	12	50	50	50	69	30	30
Water inventory [kg]	38	38	50.7	38	38	57.1	57.1	38	38

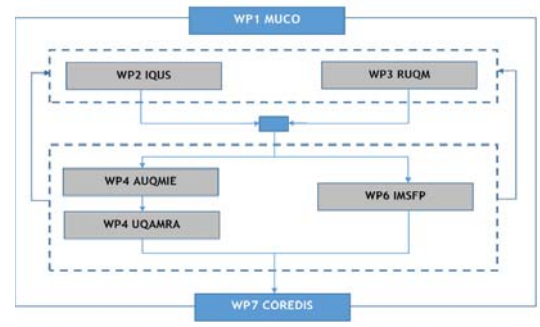
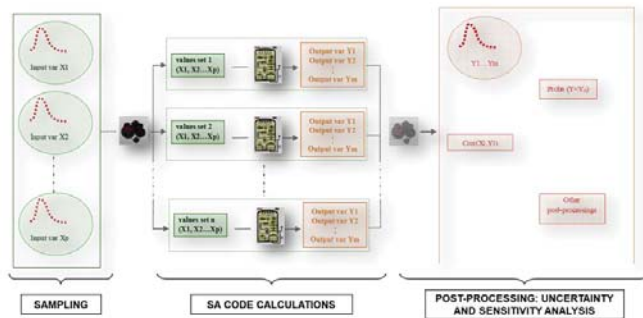
- The test campaign on LFR Technology already ongoing.



# The MUSA Project

## Overview

- Management and Uncertainties of Severe Accidents. H2020 GA n° 847441 (625 p-m).
- **Aim:** To quantify uncertainties in SA codes' predictions, AM included (FOM: Source Term).



- **Extension:** 2019 – 2023.
- **Partners:** Bel V, CEA, **CIEMAT**, CNPRI, CNCS, ENEA, Energorisk, EPRI, Framatome, GRS, INRNE, IRSN, JAEA, JACOBS, JRC, KAERI, KIT, LEI, LGI, NINE, PSI, SSTC, Tractebel, TUS, UNIPI, UNIRM1, USNRC, VMU, VTT



# The MUSA Project

## Preliminary Results

- On input-deck uncertainties

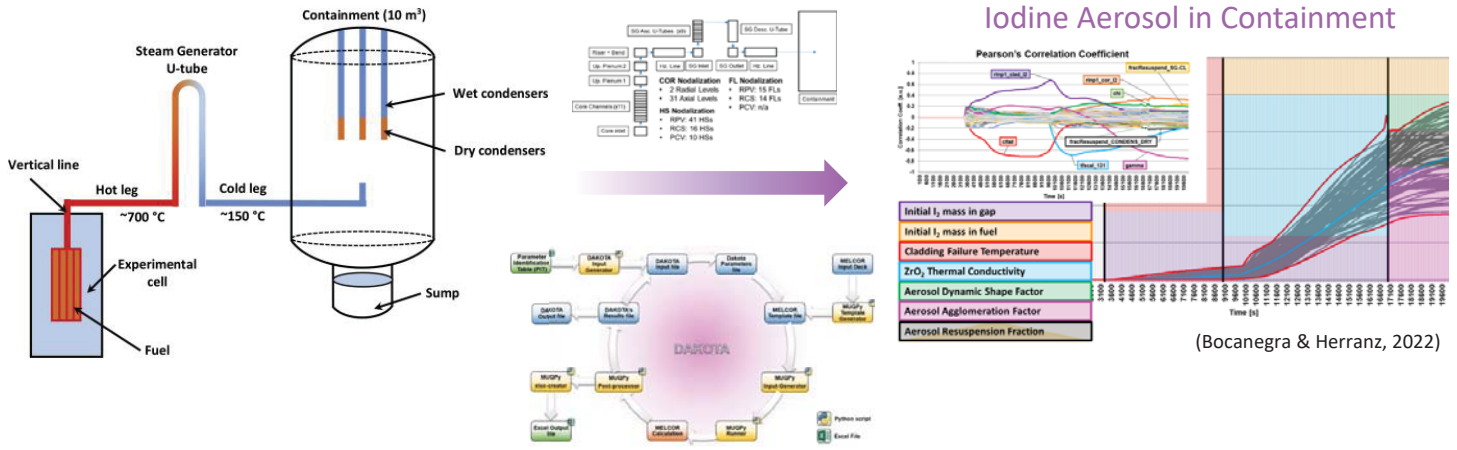
Phenomena	Uncertain Parameter	reference value	lower bound	upper bound	pdf	reference	
Sedimentation	Gas viscosity [kg/ms]	1.0 / NA	-5% / NA	+5% / NA	Uniform	Expert Judgment	
	Gas temperature [K]	N/A	N/A	N/A	N/A	N/A	
	Gas pressure [Pa]	1.55E+07 / NA	-1.5% / NA	+1.5% / NA	Normal	Expert Judgment	
	Gas mean free path	N/A	N/A	N/A	N/A	N/A	
	Particle diameter Lower Bound [m]	0,000000011		0,00000001	0,0000002	Triangular	1986 Helton et al. "Uncertainty and Sensitivity Analysis of a Model for Multicomponent Aerosol Dynamics"; 2009 NEA/CSNI "State-of-the-Art Report on Nuclear Aerosols"
	Particle diameter Upper Bound [m]	0,000199		0,000005	0,00002	Triangular	1986 Helton et al. "Uncertainty and Sensitivity Analysis of a Model for Multicomponent Aerosol Dynamics"; 2009 NEA/CSNI "State-of-the-Art Report on Nuclear Aerosols"
	Slip factor (default = 1.257)		1,257		1,14	1,28	Triangular 1990 D. J. Rader "Momentum slip correction factor for small particles in nine common gases"; MELCOR Default; Expert judgment (pdf)



# The MUSA Project

## Preliminary Results

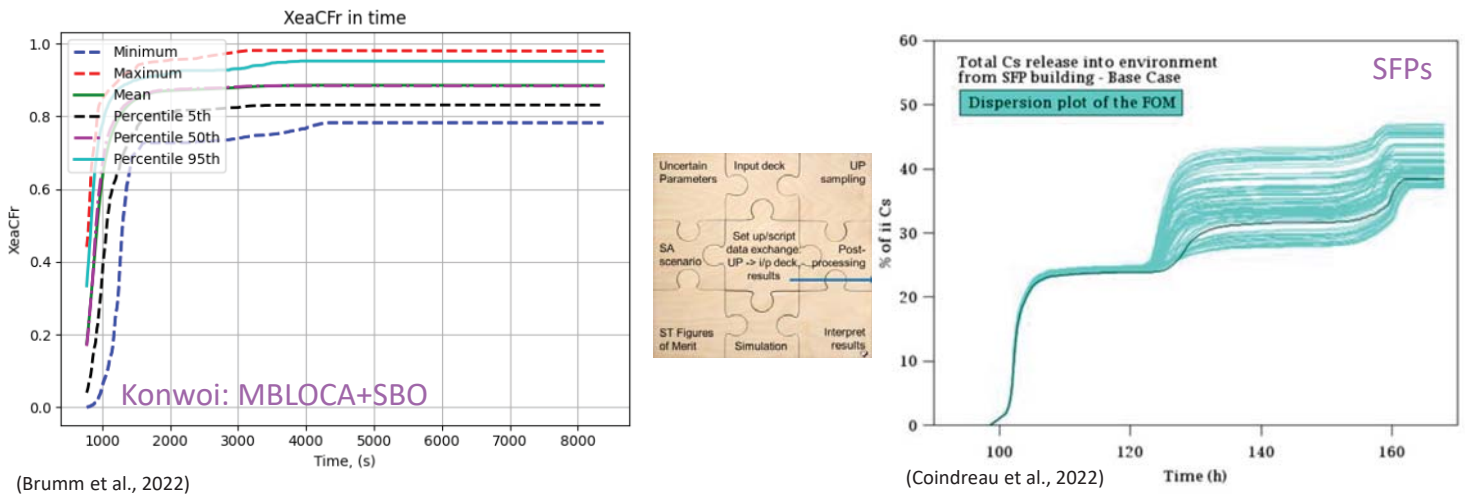
- On PHEBUS-FPT1 modeling



# The MUSA Project

## Preliminary Results

- On Reactor & SFP calculations



# The AMHYCO Project

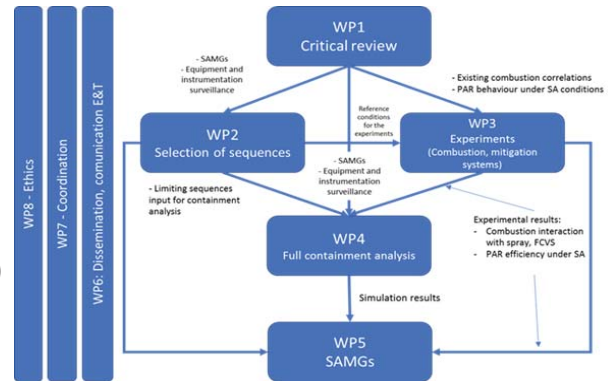
## Overview

- Towards an Enhanced AM of the H<sub>2</sub>/CO Combustion Risk (AMHYCO).  
H2020 GA n° 847715 (490 p-m).

- **Aim:** To further minimize the threat posed by combustible gases by SAMGs.

- Methodologies for containment analyses.
- Experiments on unexplored domains.

(PWR-W; -K; -V)



- **Extension:** 2020 – 2024

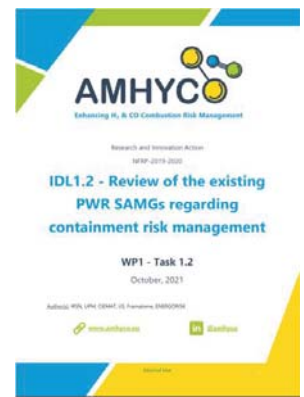
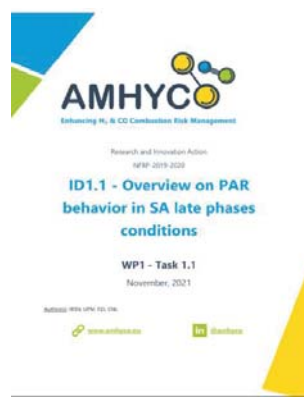
- **Partners:** CIEMAT, CNL, CNRS, ENERGORISK, FRAMATOME, FZJ, IJS, IRSN, LGI, NRG, RUHR, **UPM**.



# The AMHYCO Project

## Preliminary Results

- **Critical review of the current status (completed & embedded in D1.1)**



- Efforts in survivability under SA

- Unclear transition H<sub>2</sub>-CO recomb. regimes.
- CO poisoning; T,P; Pt vs. Pd; deactivation

- P<sub>0</sub> to be investigated.
- H<sub>2</sub>O y CO<sub>2</sub> effect (P>1 bar)

- Mitigation means designed JUST in-vessel
- No monitoring of CO in containment

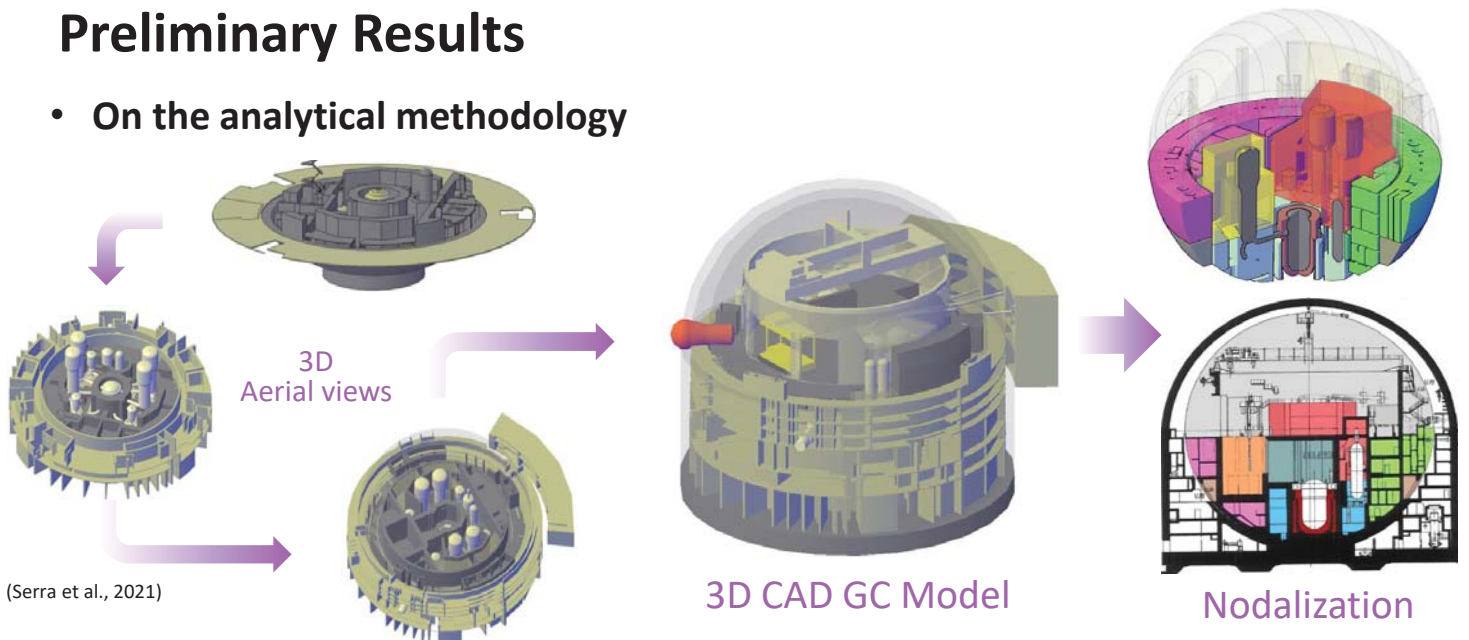




# The AMHYCO Project

## Preliminary Results

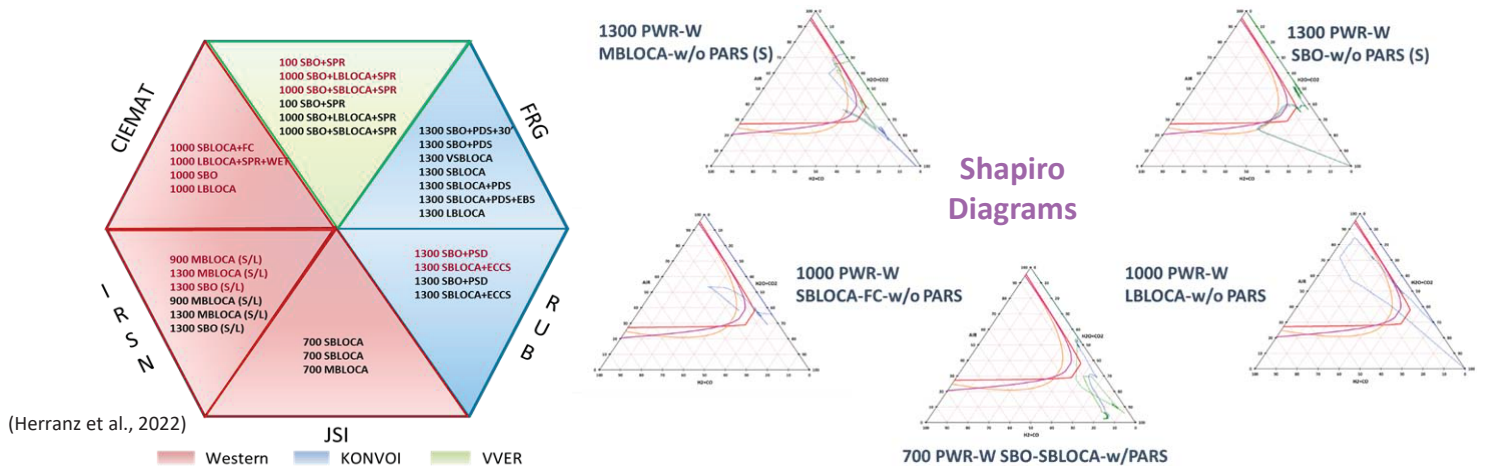
- On the analytical methodology



# The AMHYCO Project

## Preliminary Results

- Accident sequences DB already simulated.



# Final Remarks

**Accurate  
Risk Assessments**

**Robust  
Accident Management**



**Reliable & Efficient  
Safeguards**



# Final Remarks

- **PIACE:** On the demonstration of an innovative, technology-independent DHR system.  
**Challenges:** applicability; scalability; testing.
- **MUSA:** On the uncertainty quantification of SA predictions.  
**Challenges:** Systematic analytical methodology; data analysis.
- **AMHYCO:** On the optimization of SAMGs to handle combustion risk in SA.  
**Challenges:** Systematic analytical methodology; testing; assimilation.





# Thank you for your attention!

## Acknowledgements

The authors are indebted to their project partners, who have been doing an extraordinary job under truly adverse circumstances, and to the EC for approving, supporting and monitoring these projects.



## ERMSAR 2024

- ERMSAR 2022 - KIT, Karlsruhe - An astonishing success!
- ERMSAR 2024 - KTH, Stockholm (Sweden) <https://www.kth.se/en>
- Rooms available in the main campus or AlbaNova University <https://www.albanova.se/>
- Mid-May, 2024 currently considered (3 full days).

