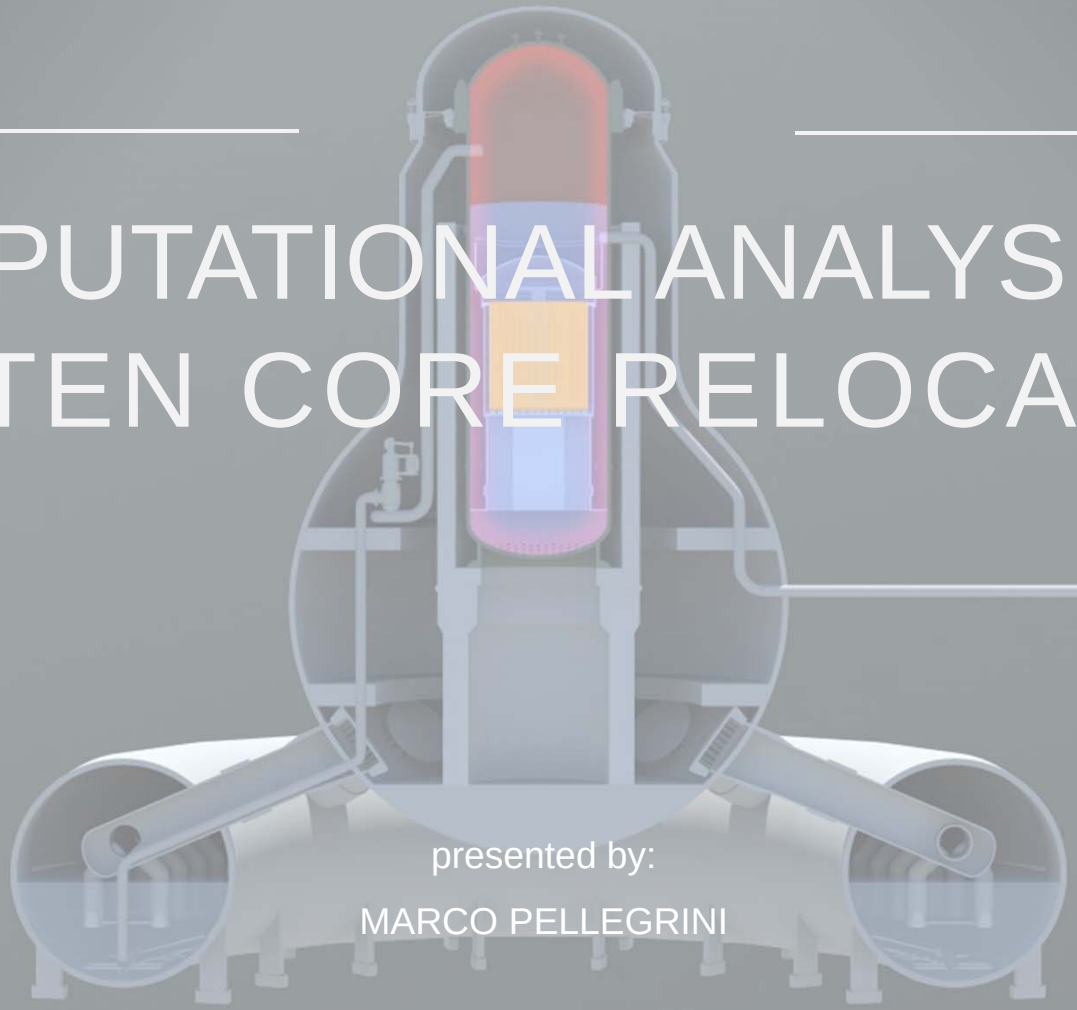
17 MAY , POLITECNICO DI MILANO, MILANO ITALY

# COMPUTATIONAL ANALYSIS OF MOLTEN CORE RELOCATION




presented by:

MARCO PELLEGRINI

The Institute of Applied Energy

AN ZEN

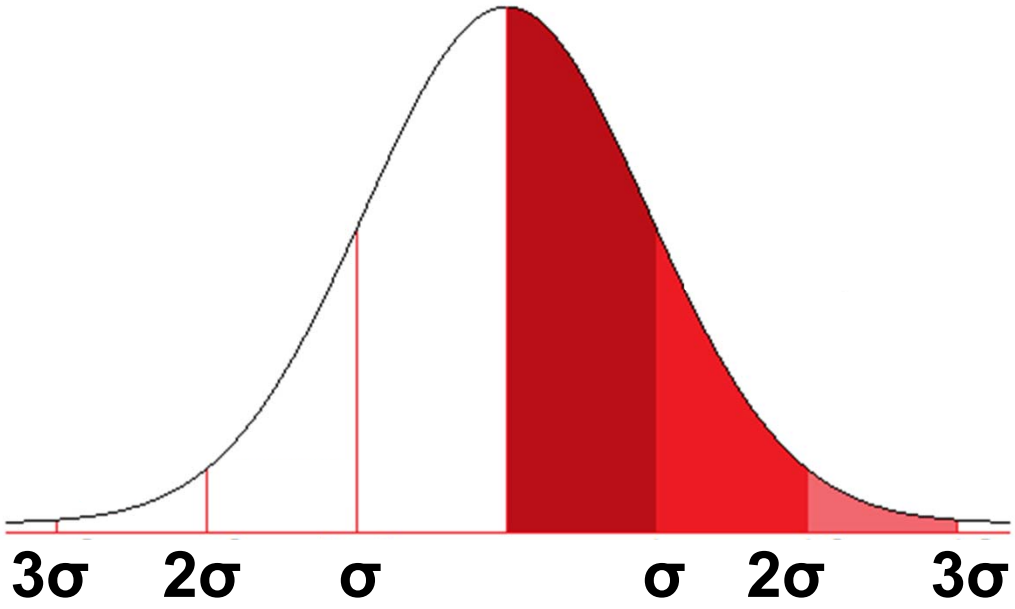
# 安全

safety

AN SHIN

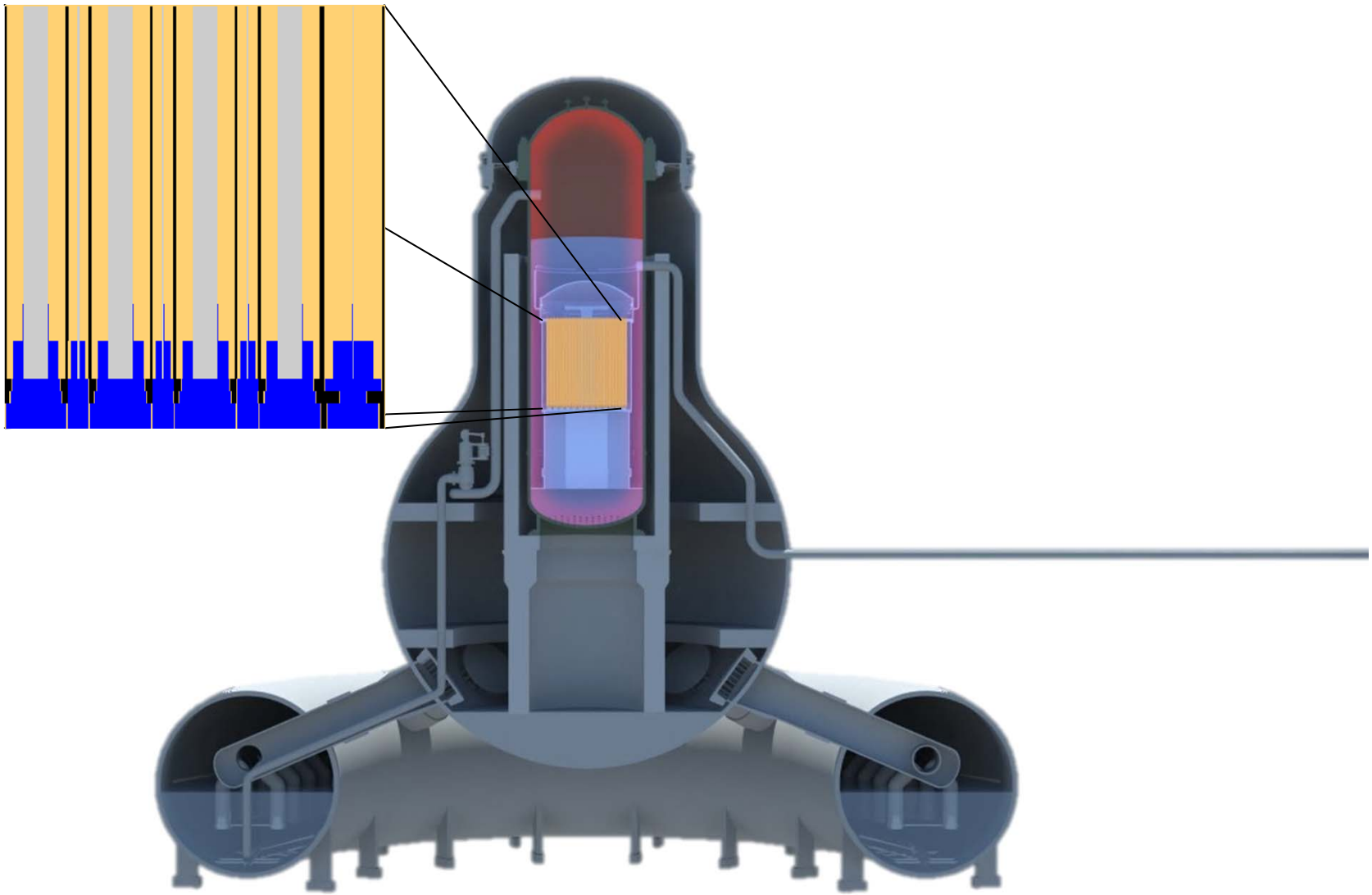
# 安心

peace of mind



# SAMPSON

## MOLTEN CORE RELOCATION ANALYSIS

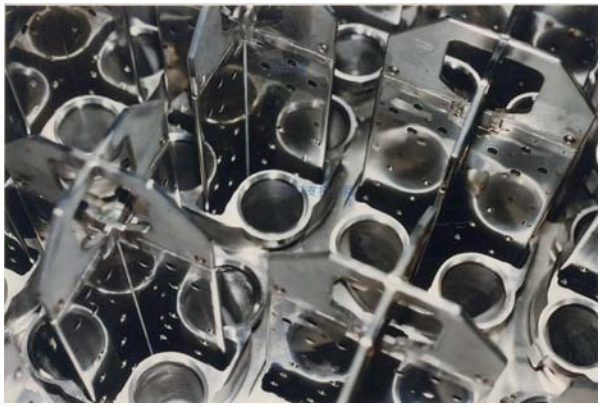


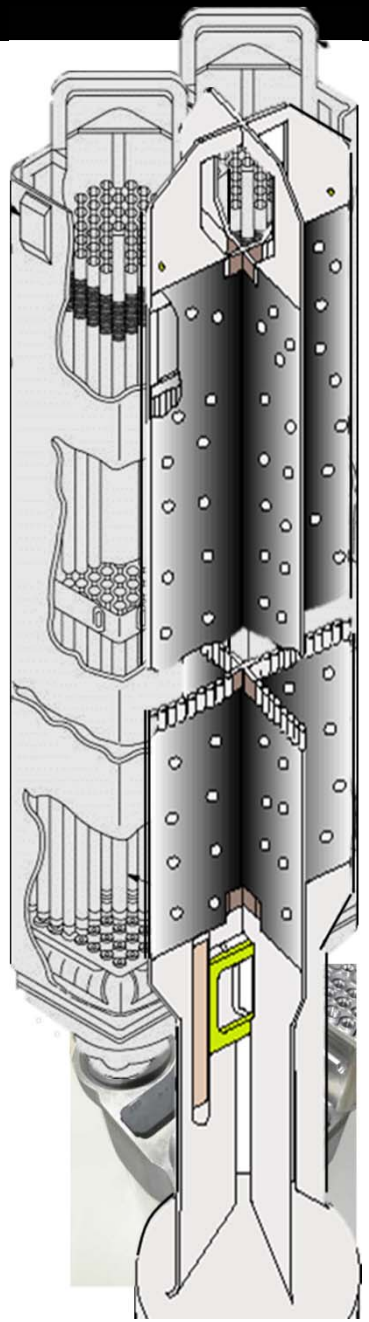
# CORE COMPONENTS

F U E L
ASSEMBLY

C O N T R O L
B L A D E

C O R E  P L A T E





F U E L
SUPPORT

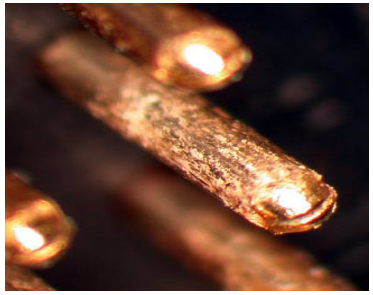
## BWR MATERIALS

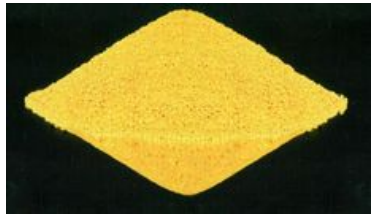
| | |
|---|---|
| SA# | 548 |
| $UO_2$ | ~120,000 kg |
| Zirconium | ~32,000 kg |
| Control Material | ~680 kg |
| $H_2$ potential | ~2000 kg |

# COMPLEXITY

## MULTI-PHASE

## MULTI-COMPONENTS



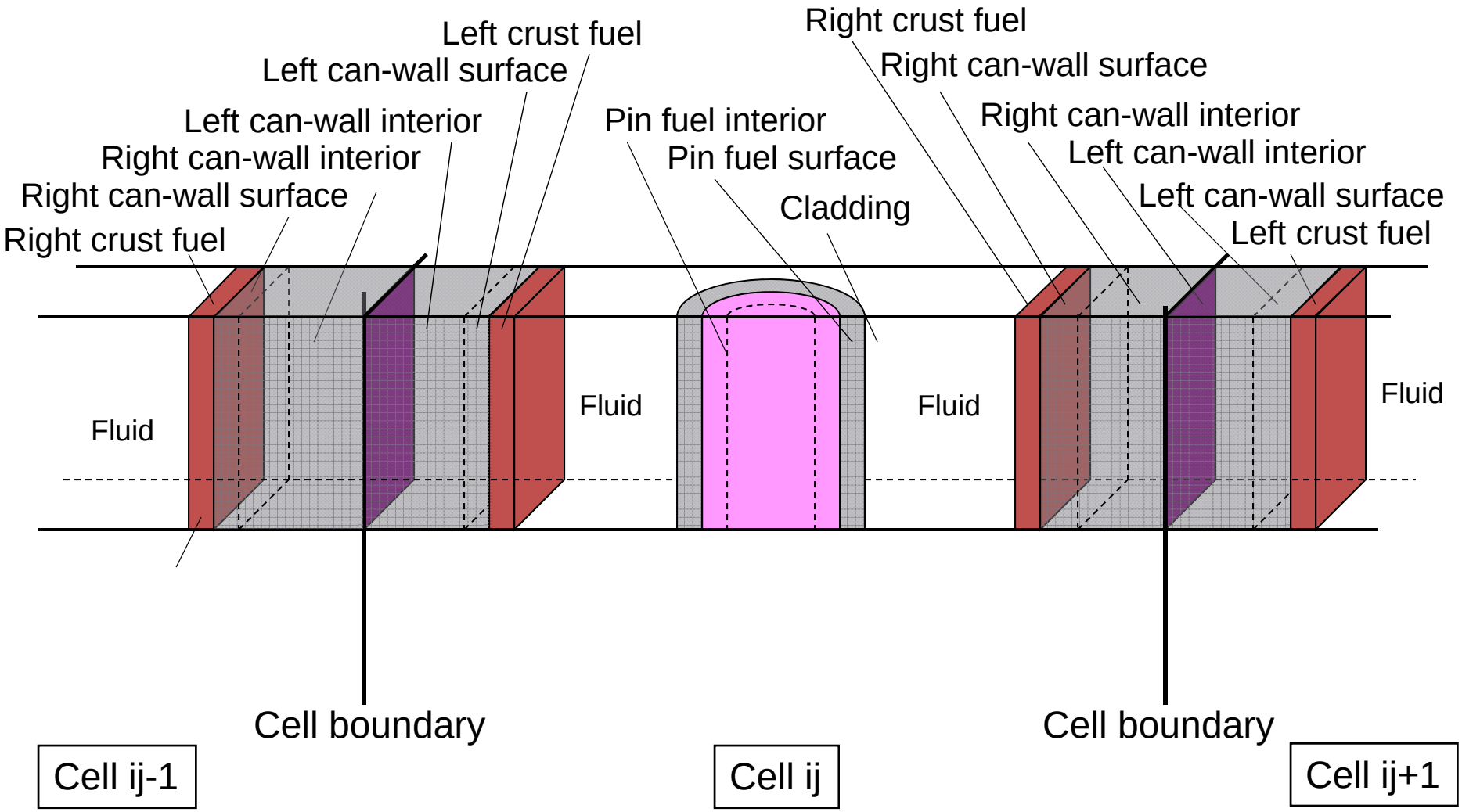


# CORE MAIN TEMPERATURES

TEMPERATURE [K]

| | |
|---|---|
| 3120 | $UO_2$ Melting |
| 2960 | $ZrO_2$ Melting |
| 2800 | $UO_2$- $ZrO_2$ Melting |
| 2720 | $B_4C$ Melting |
| 2500 | Eutectic melting |
| 2030 | Zr Melting |
| 1850 | Zr Oxidation |
| 1730 | SS melting |
| 1670 – 1500 | Eutectic interactions |
| 1420 | $B_4C$ – steel dissolution |
| 1300 | Zr Oxidation |
| 1200 | Clad burst |

# CORE SPACE DISCRETIZATION



# MCRA GOVERNING EQUATIONS

$$\frac{\partial \rho_{Lm}}{\partial t} + \nabla \cdot \left(\rho_{Lm} v_q\right) = \sum S_C$$

9 liquid + 6 gas

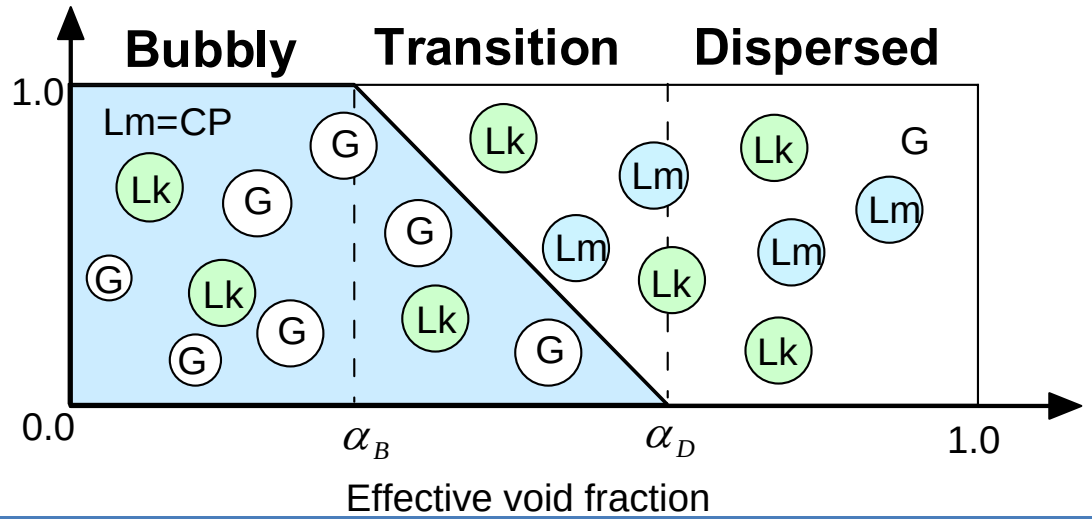
$$\frac{\partial \rho_{Lm} v_q}{\partial t} + \nabla \cdot \left(\rho_{Lm} v_q v_q\right) + \alpha_q \nabla p - \rho_q g = \sum S_m$$

2 liquid + 1 gas

$$\frac{\partial \rho e_{q_{Lm}}}{\partial t} + \nabla \cdot \left(\rho e_{q_{Lm}}\right) v_q + p\left[\frac{\partial \alpha_q}{\partial t} + \nabla \cdot \left(\alpha_{Lm} v_q\right)\right] = \sum S_e$$

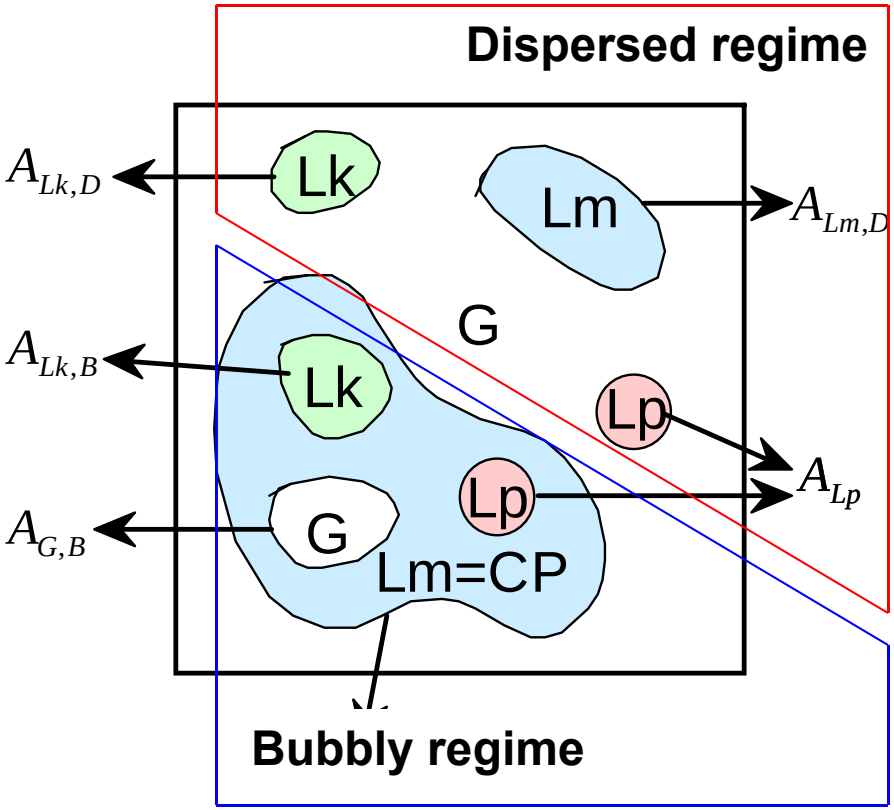
9 liquid + 6 gas

POOL FLOW REGIME

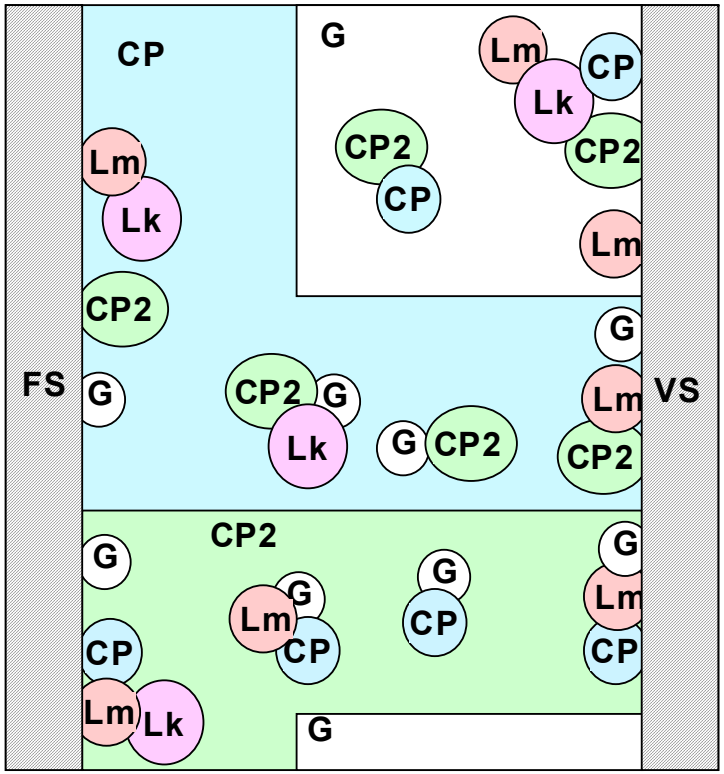


# MCRA MODELING

## INTERFACIAL CONTACT AREA



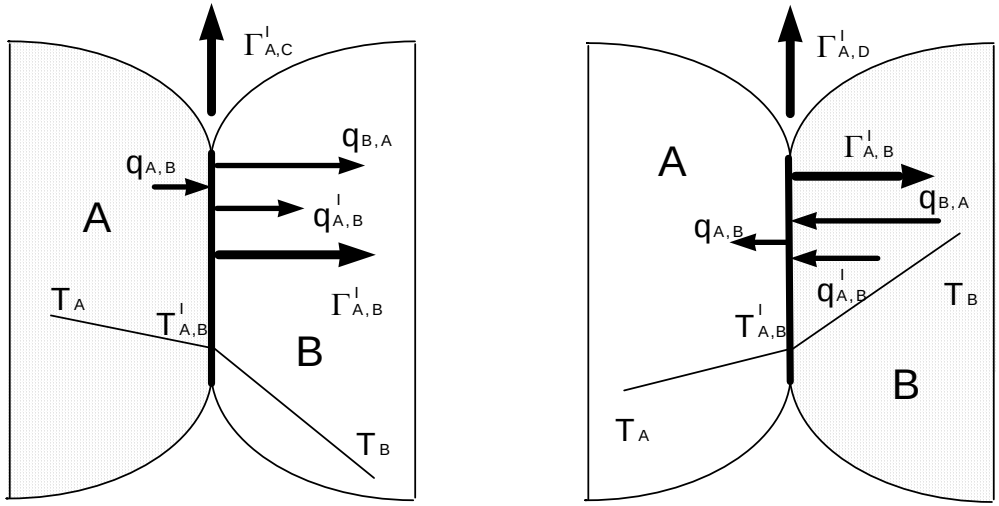

## BINARY CONTACT AREA
54 different correlations



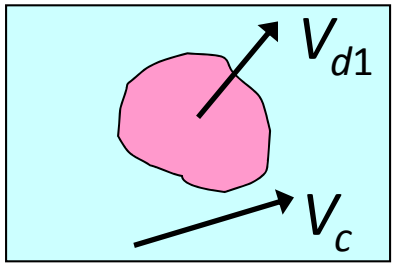

**Possible contact modes**

# MAIN MODELS

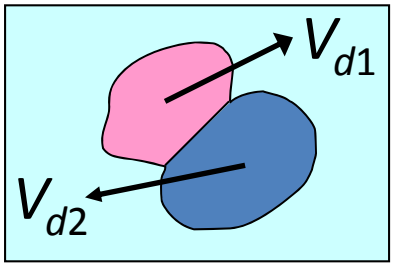
## HEAT AND MASS TRANSFER FUNCTIONS



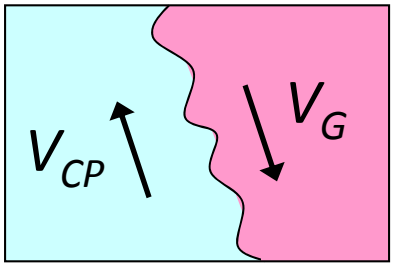

## MOMENTUM EXCHANGE FUNCTION




Continuous-Discontinuous




Discontinuous-Discontinuous

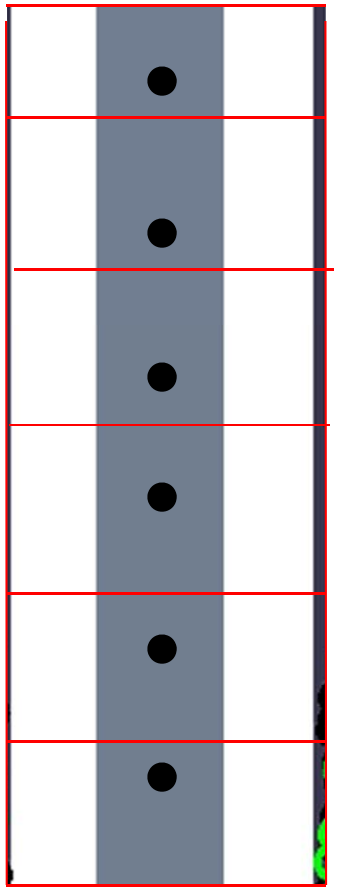



Continuous-Continuous

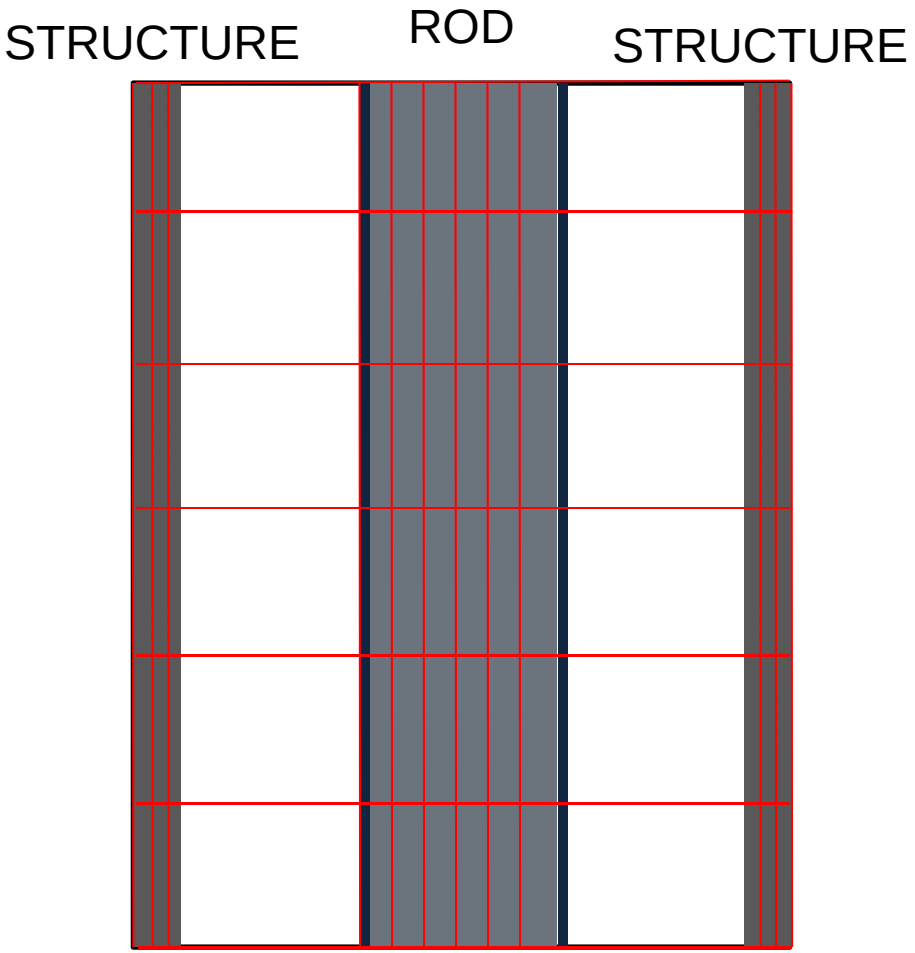
# COMPUTATIONAL DOMAIN



## FLUID DYNAMICS +STRUCTURE

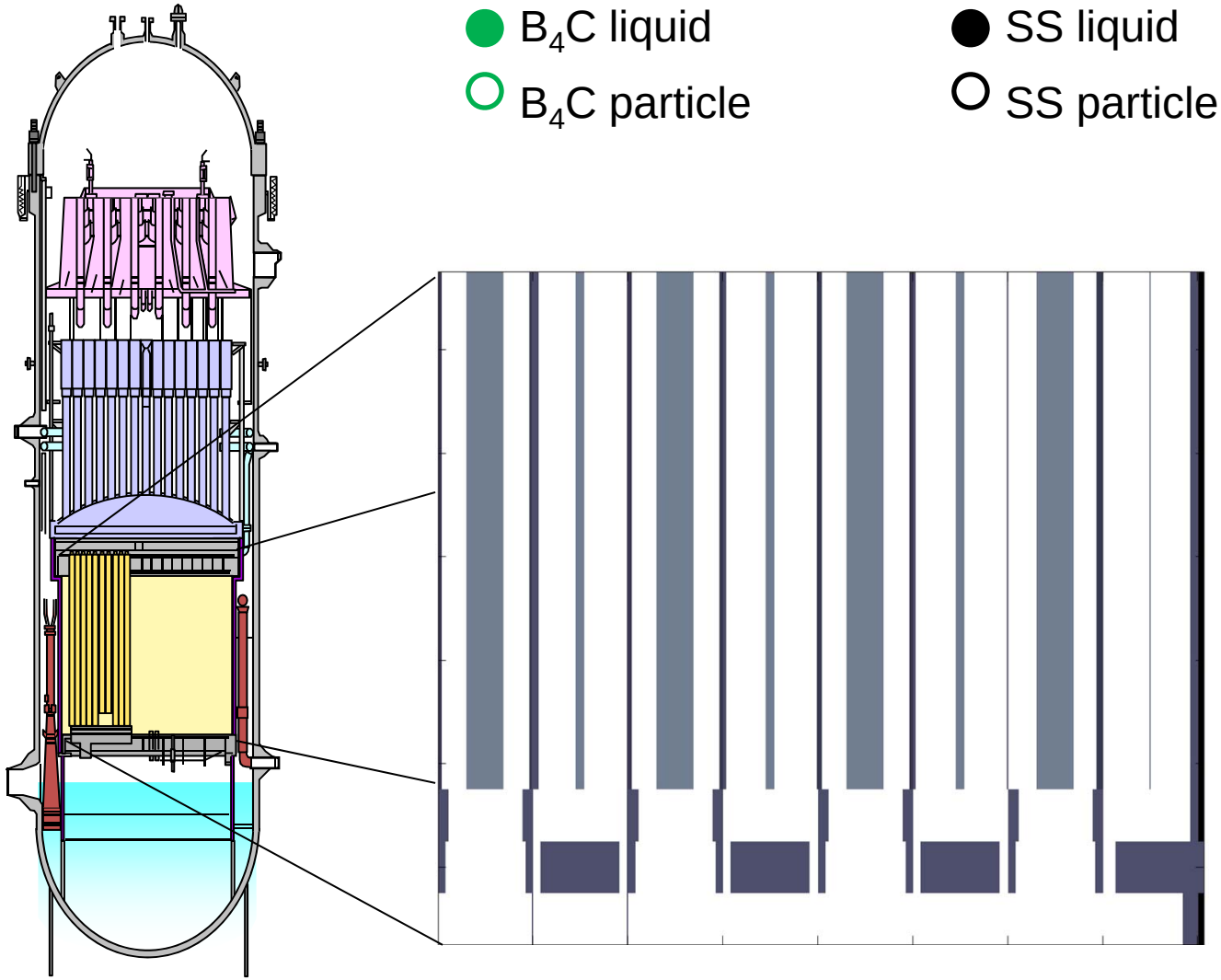


## STRUCTURE DOMAIN



# CONTROL ROD MELTING PROGRESSION

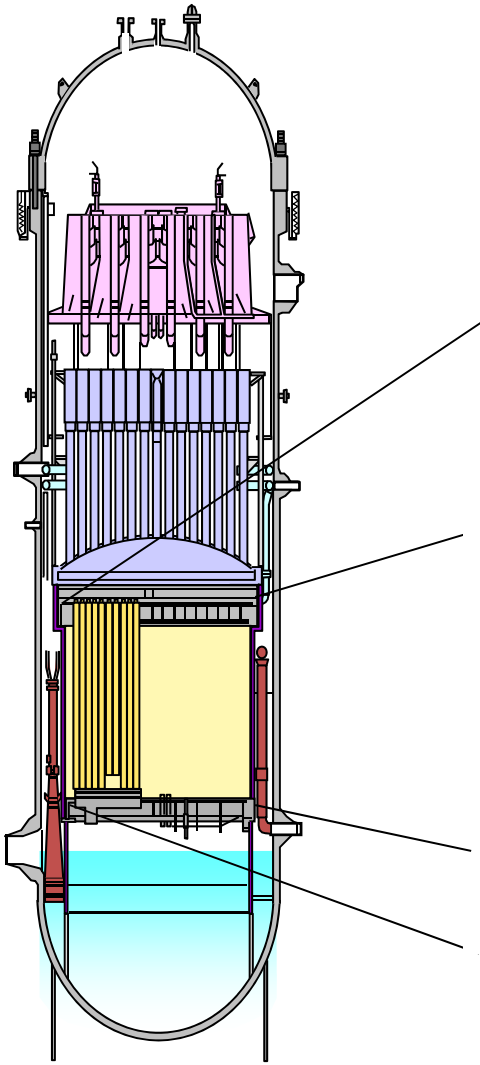
## SAMPSON/MCRA UNIT 3

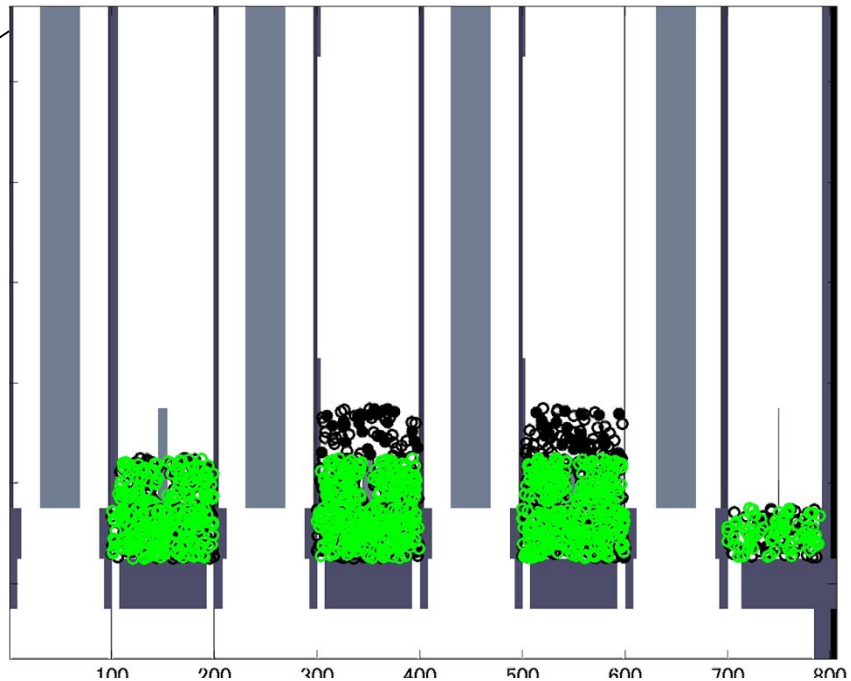


# FUEL ROD MELTING PROGRESSION

## SAMPSON/MCRA UNIT 3

- $B_4C$ liquid
- $B_4C$ particle
- $UO_2$ liquid
- $UO_2$ particle
- SS liquid
- SS particle
- Zr liquid
- Zr particle





# CONCLUSION

HOW CAN WE CREATE A PHYSICAL MODEL FROM SUCH AN EXPERIMENT?