Ex-vessel Fuel Coolant Interaction Experiment in the DISCO Facility

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Motivation

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- Experiment in the DISCO facility, similar to those made for Direct Containment Heating (DCH), but with **water in the pit**, that would give **data for the validation of the codes** in geometrical situation closer to the reactor ones than all other available data

- No triggered steam explosion, only premixing stage is investigated (but possibility of spontaneous explosion)

Relevance for SARNET2

- Ex-vessel Fuel Coolant Interaction (WP 7.1) and debris formation (WP 5.3) are two high-priority issues of SARNET2. Despite the importance of these issues, only a few experimental data are available for the qualification of codes.

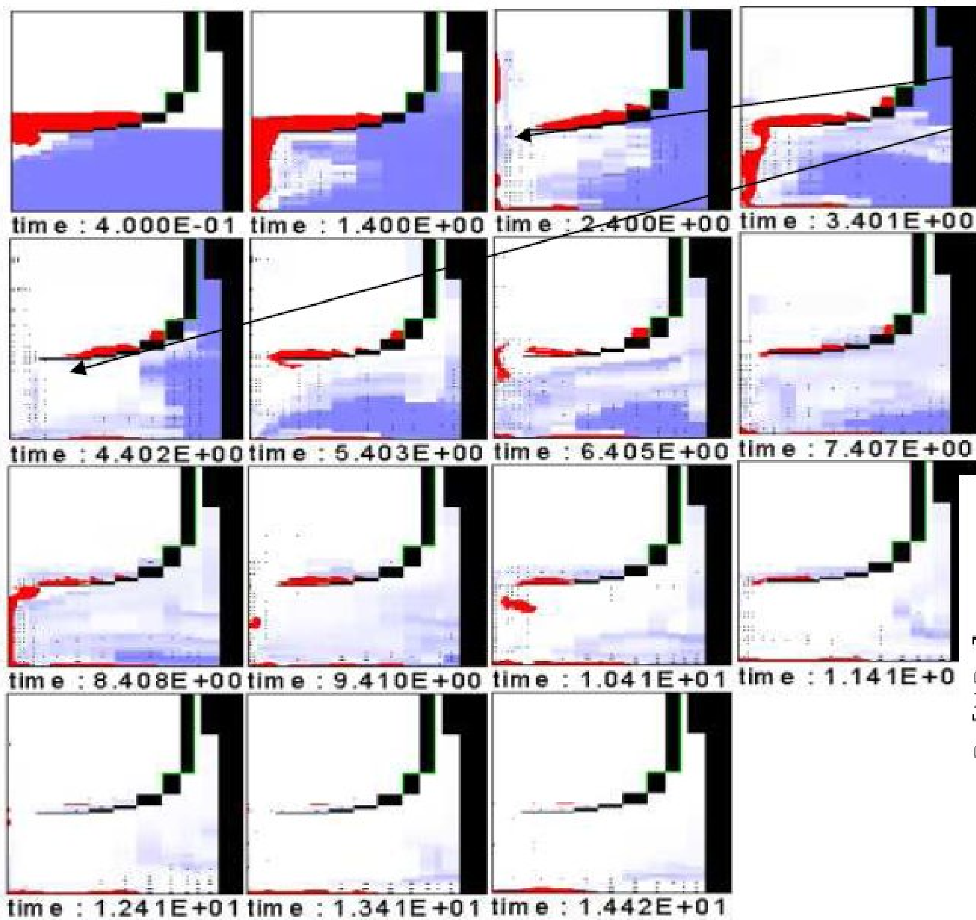
Available experimental data limited

- Database for premixing modeling assessment for application of ex-vessel situation is very limited
  - Water subcooling (~50 K)
  - High temperature
  - High density
  - No way to assess the behavior with existing database
  - FARO L31 (ISPRA): 100 kg UO_2/ZrO_2 (gravity driven)
  - TROI-VISU (KAERI, SERENA): 15 kg UO_2/ZrO_2 (gravity driven)

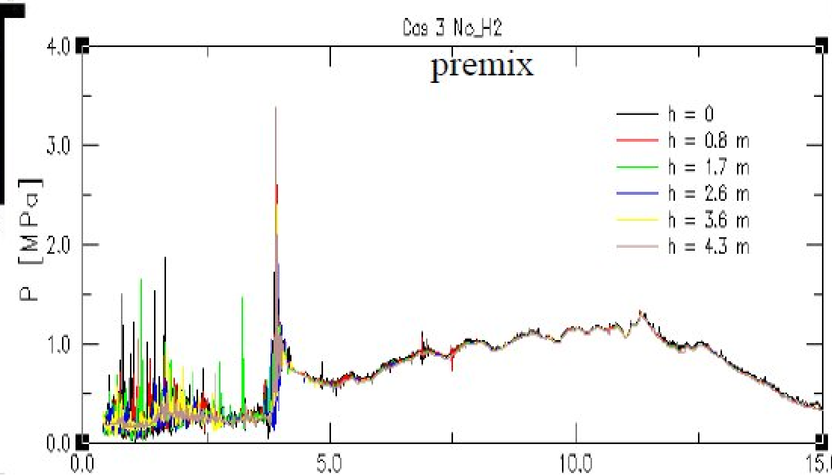
- ***Behavior is not as expected from "classical" FCI experiments***
  - Jet fragmentation with small fragments compared to TROI or FARO, even at low melt vessel pressure
  - Due to water inertia and small flow area around vessel
    - No escape for pressure
    - Vapor film around the jet is unstable
- ***Purpose is to check the code evaluation of fragmentation in more "reactor-like" configuration***

Reason for experiment: evaluation of ex-vessel FCI in PWR's at IRSN with MC3D

Vessel pressure [b]	2
Breach diameter [m]	0.7
Sub-cooling [K]	50
Water height [m]	4
Corium Super-heat	200



- 2 typical behaviors:
  - Ppit > Pvessel then strong potential interaction
  - High tendency to sweep out water and large part of melt



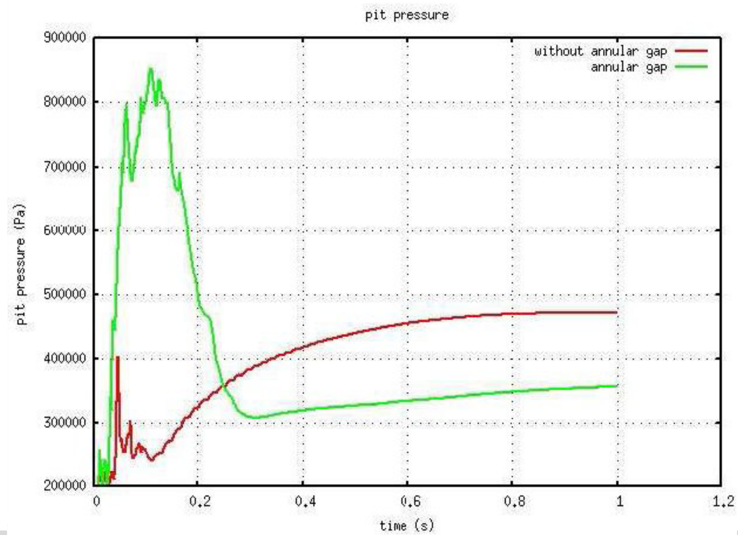
Major issues addressed in the experiment

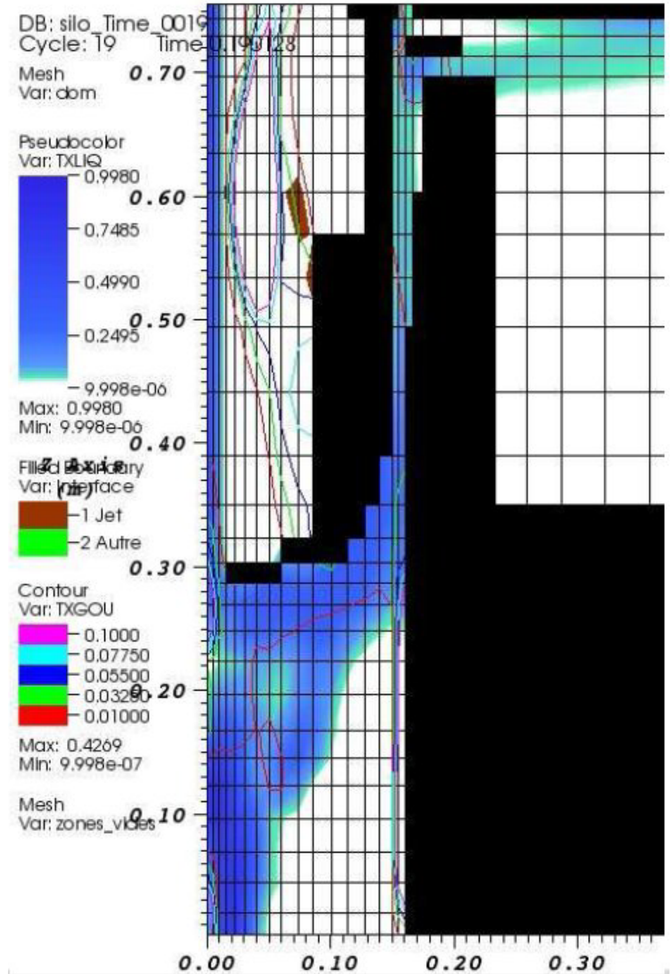
- Investigating the fragmentation processes and subsequent phenomena occurring consecutively to the break of the vessel and melt ejection

- Information will be useful for several SARNET2 WPs:
  - Melt fragmentation processes for high velocity melt jets through a precise analysis of the size of the debris found (WP7.1, WP5.3)
  - Pressurization of the pit and containment during the mixing (WP7.1)
  - Debris bed characteristics important for coolability:
    shape, porosity, debris size distribution (WP5.3)
  - Melt and water dispersion out of the pit during the process:
    initial conditions for MCCI (WP6)
  - Oxidation of the iron to be compared with cases without water:
    impact of water on DCH (WP7.1)
  - Hydrogen production and potential impact of water for combustion (WP7.2)

IRSN pre-test analysis for standard DISCO P'4 2D geometry

- Calculations with rough mesh
- Strong interaction in most cases
  due to Pit pressure > Vessel pressure
- Water + melt flow back into the vessel
- Not possible to pour all the corium
- Weakest interaction for larger annular section
- But very fast dispersion of melt

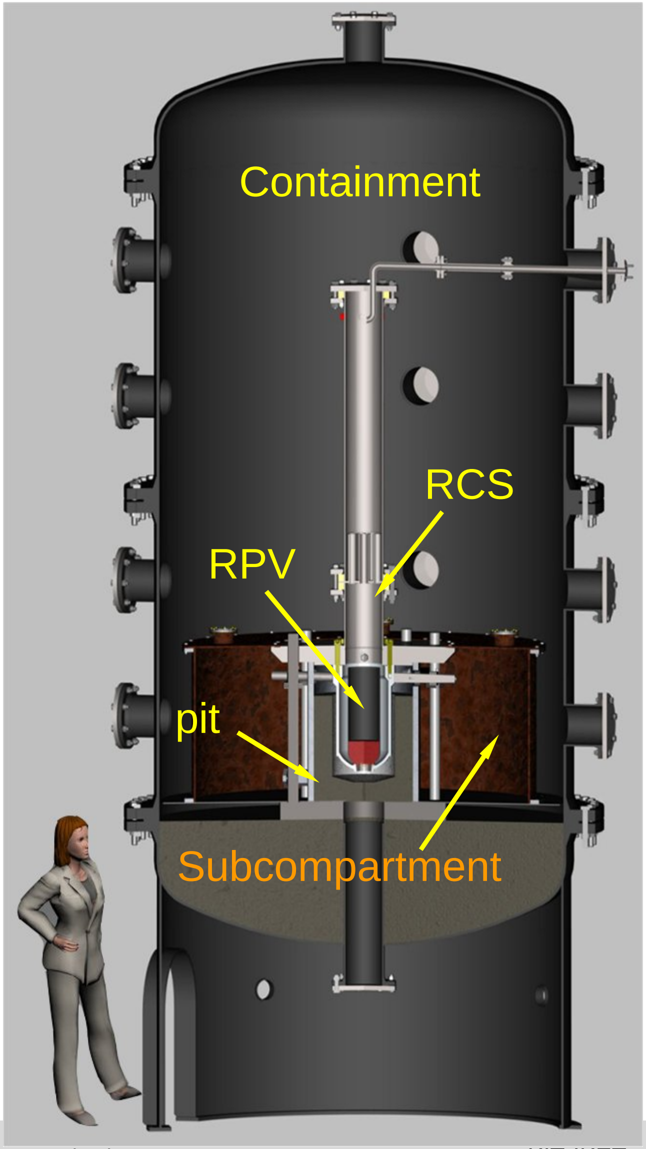




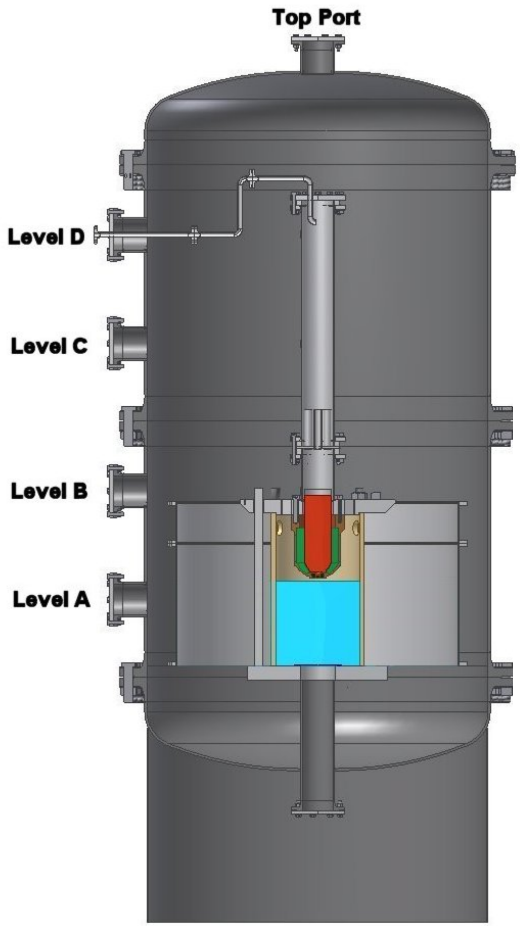
DISCO Test Facility

- **Tests with**
  - Scale 1:18 (EPR)
  - Iron-alumina melt (2400 K)
  - Steam (10-20 bar)
  - Air-steam-hydrogen atmosphere
  - Production and combustion of hydrogen

- **Measurements of**
  - Pressures (15)
  - Gas temperatures (22)
  - Hydrogen production and combustion (gas samples)
  - Melt dispersal fractions
  - Video cameras (4)



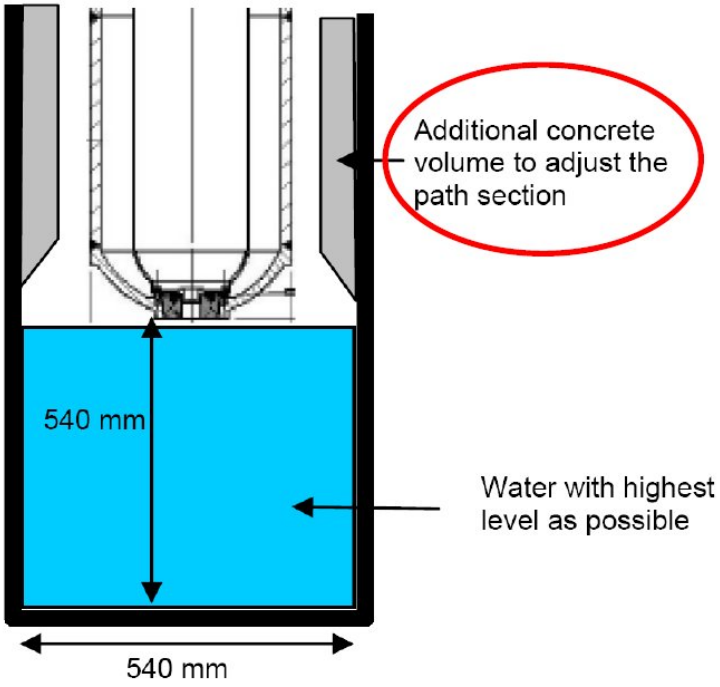
Design of the DISCO-FCI experiment



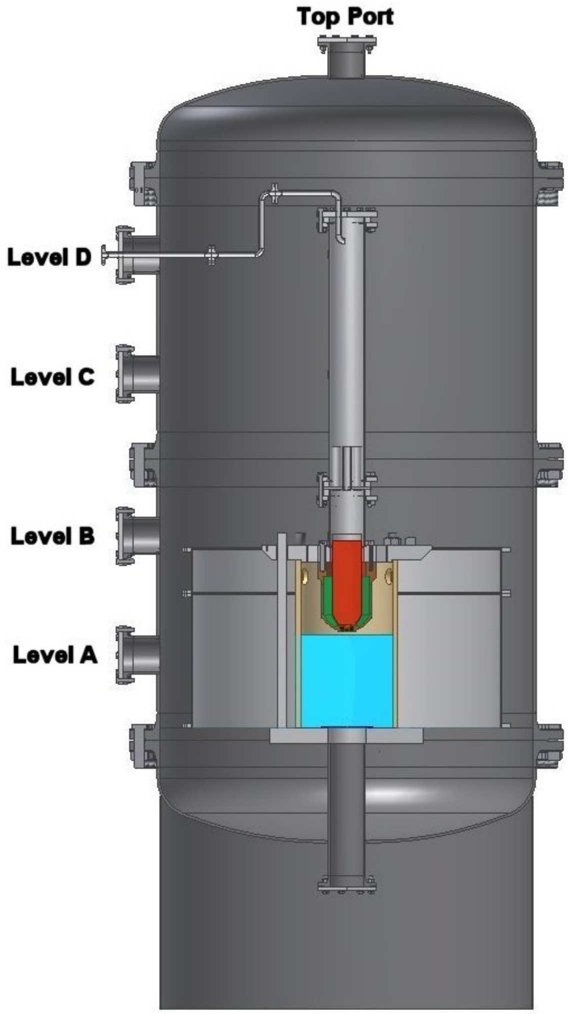
$V_{melt} = 0.0026\ m^3$

$V_{water} = 0.125\ m^3$

$V_w/V_m = 48$



Geometry



No specific reference to a particular reactor, so simplifications for code calculations and analysis

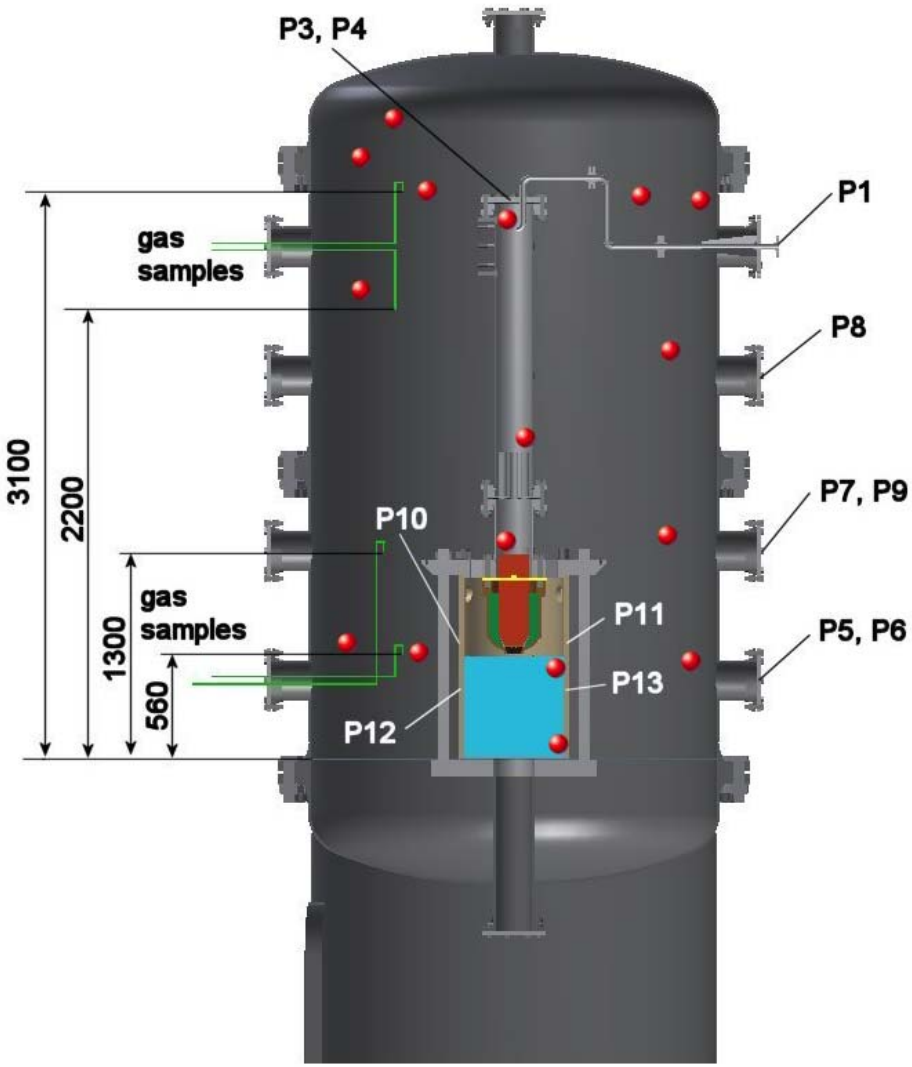
- Symmetric reactor pit, no access: 2D calculations
- Subcompartment without cover plates
- Reactor pit circumferential exits (8) without main cooling lines
- Open flow paths from pit to containment
- Height and diameter of the water pool in the cavity both as high as possible to limit scaling effects: 540 mm
- Distance between lower edge of the RPV and water level: 20 mm
- Temperature of the water: 85 °C

Geometry and initial conditions

CON: Volume	m³	13,88
CON: Height	m	4.5
CON: Diameter	m	2.17
Cavity: Volume	m²	0.2034
Cavity: Height	m	0.984
Cavity: Diameter	m	0.540
Flow nozzles (8x cut out area)	m²	0.0603
Flow area into con. (8 holes)	m²	0.0688

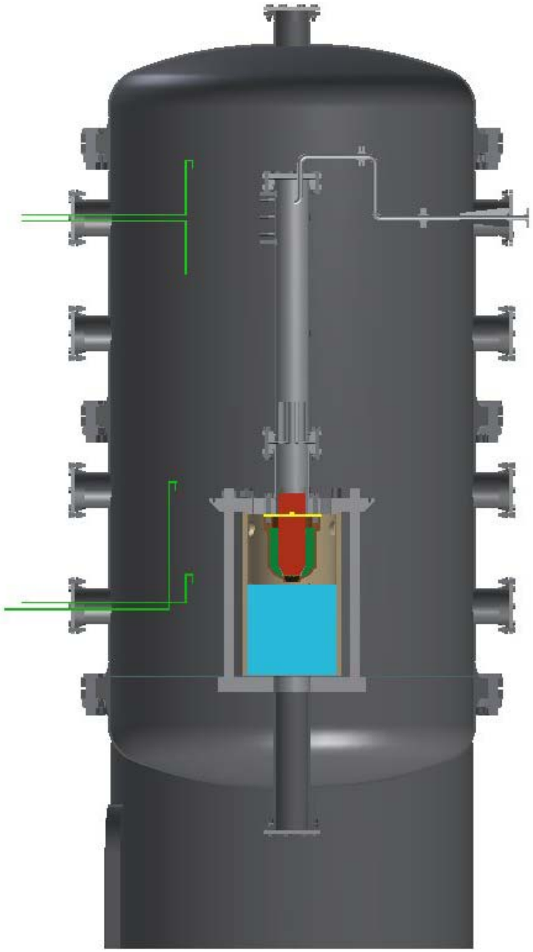
CON: Pressure	MPa	0.2
CON: Temperature	°C	100
CON: Atmosphere	-	Air/Steam
RPV: Breach diameter	mm	30
RPV: Driving pressure	MPa	0.6
RPV: Amount of thermite	kg	10.64
Water pool	l / °C	125 / 85

Facility instrumentation



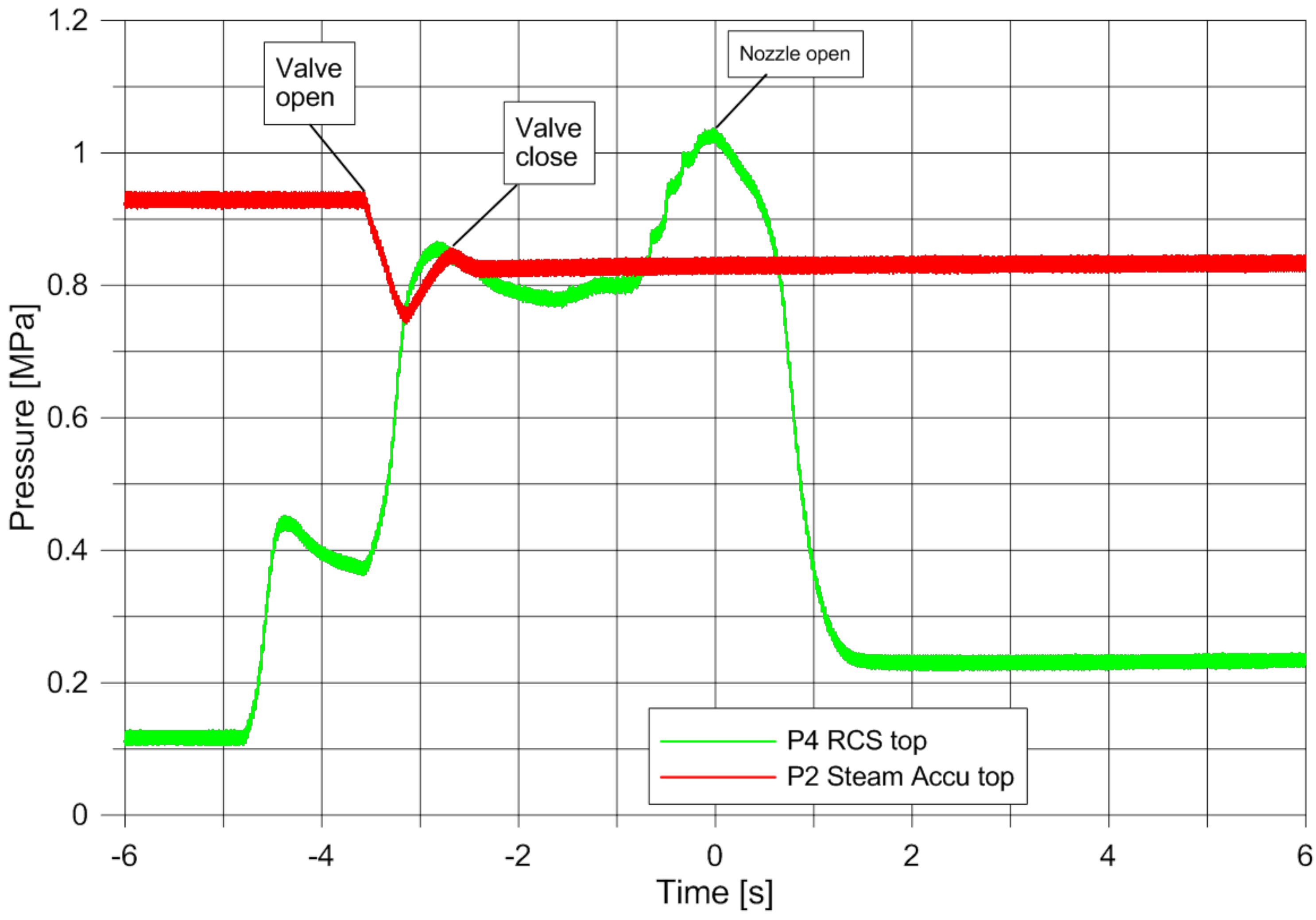
- 5 pressure transducers at reactor pit, sampling rate >2 kHz
- 3 transducers below water level, range: 1.7, 3.5, 30 MPa
- 2 transducers above water level, range: 3.5, 3.5 MPa
- Thermocouples in containment, subcompartment, RCS and RPV
- Pre and post test analysis of gas samples in containment
- Collecting of the melt debris and sieve analysis

Test procedure

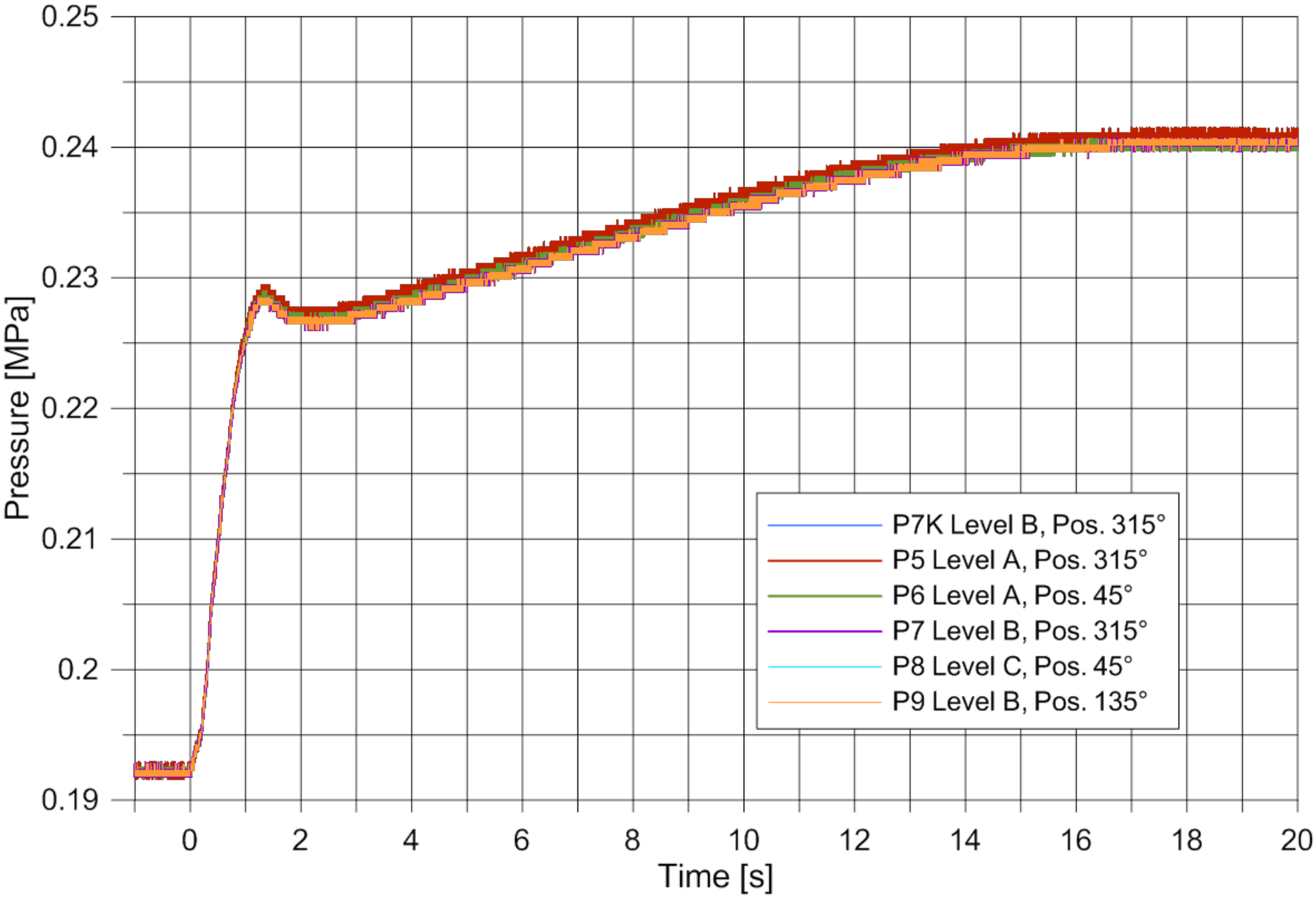


- Containment (steam, press, temp)
- Loading steam accumulator
- Water pool
- Gas sample
- Ignition (trigger: temp, press)
- Steam valve open (1 s)
- Melt plug (brass)
- Discharge of melt
  - increase temp, press
  - hydrogen burning
- Gas sample
- Collecting of particles

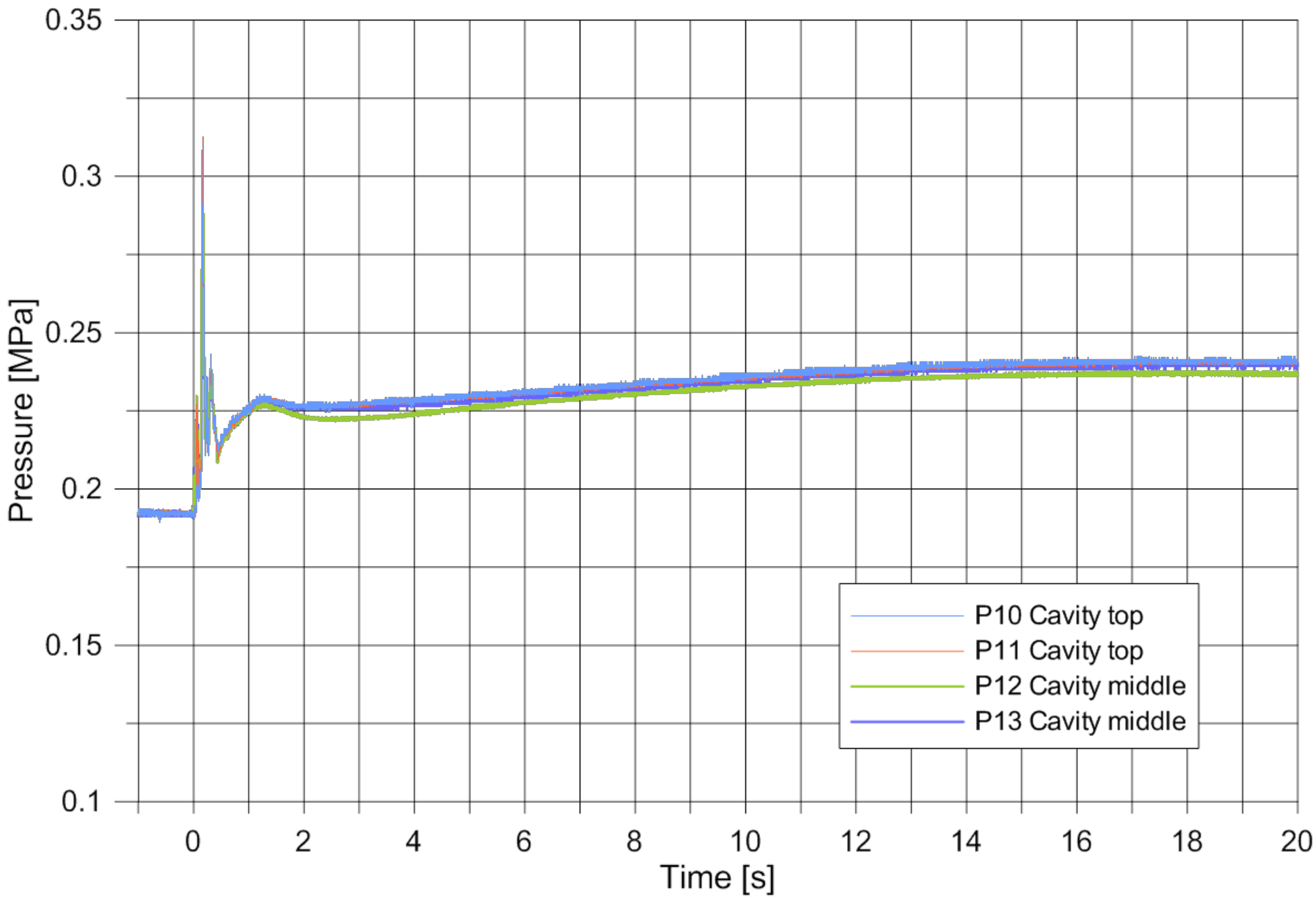
Pressures Steam Accumulator and RPV



Pressures Containment



Pressures Cavity



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Pressures Cavity (short time line)

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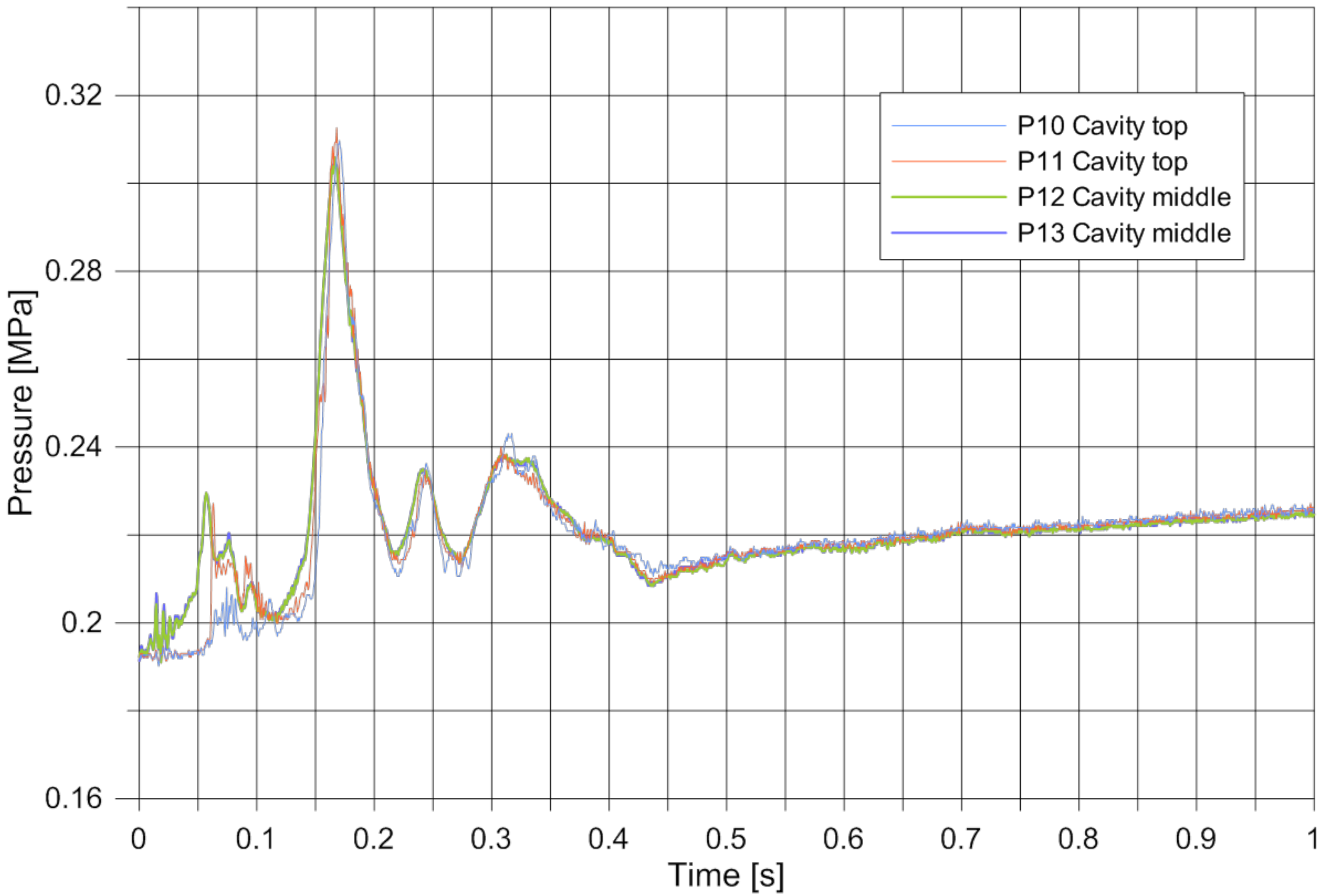
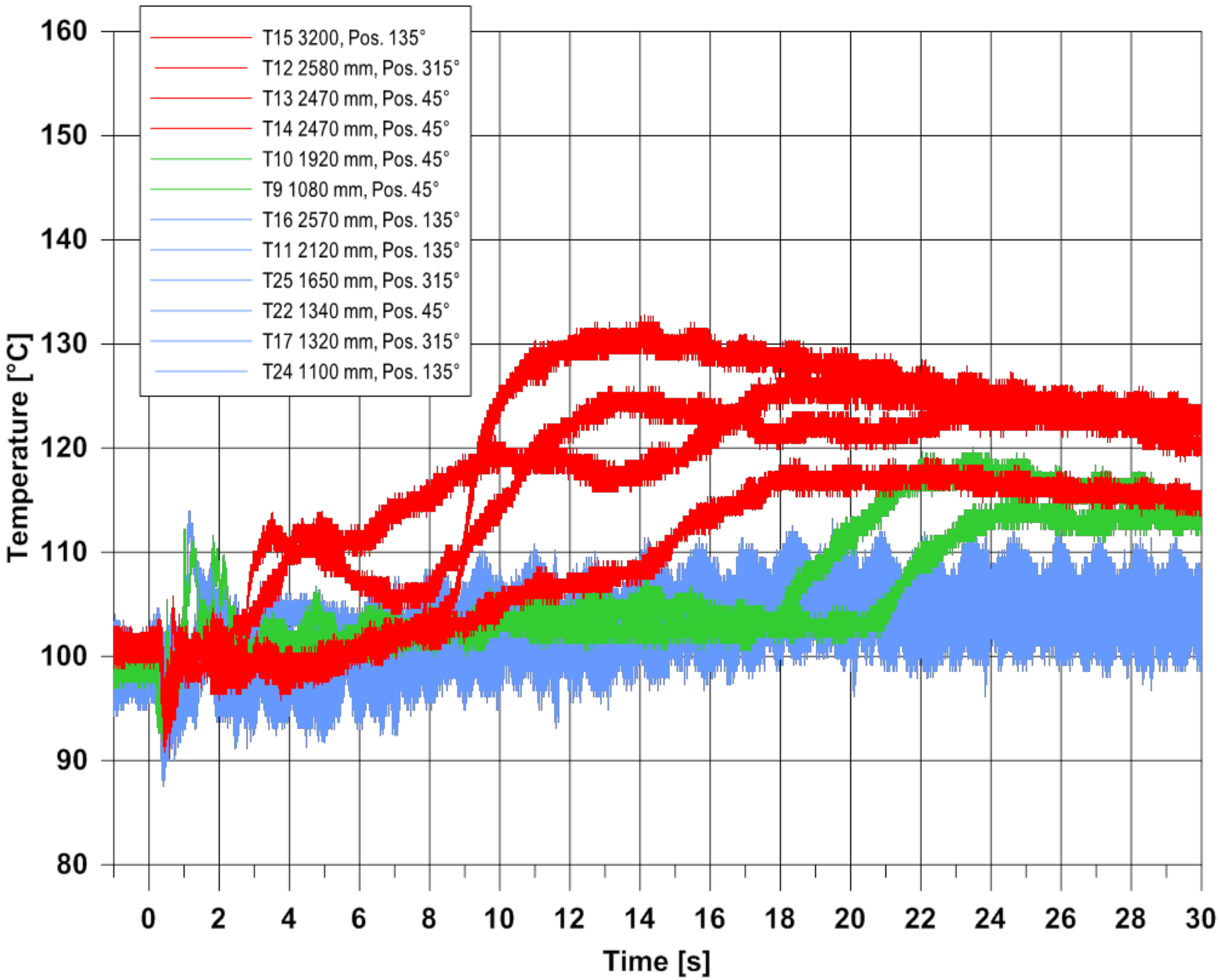
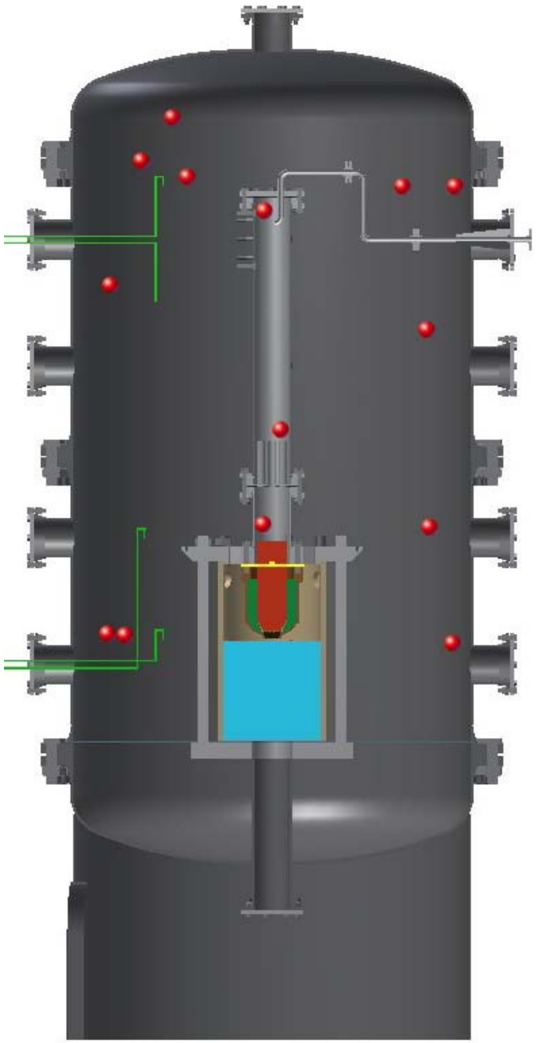
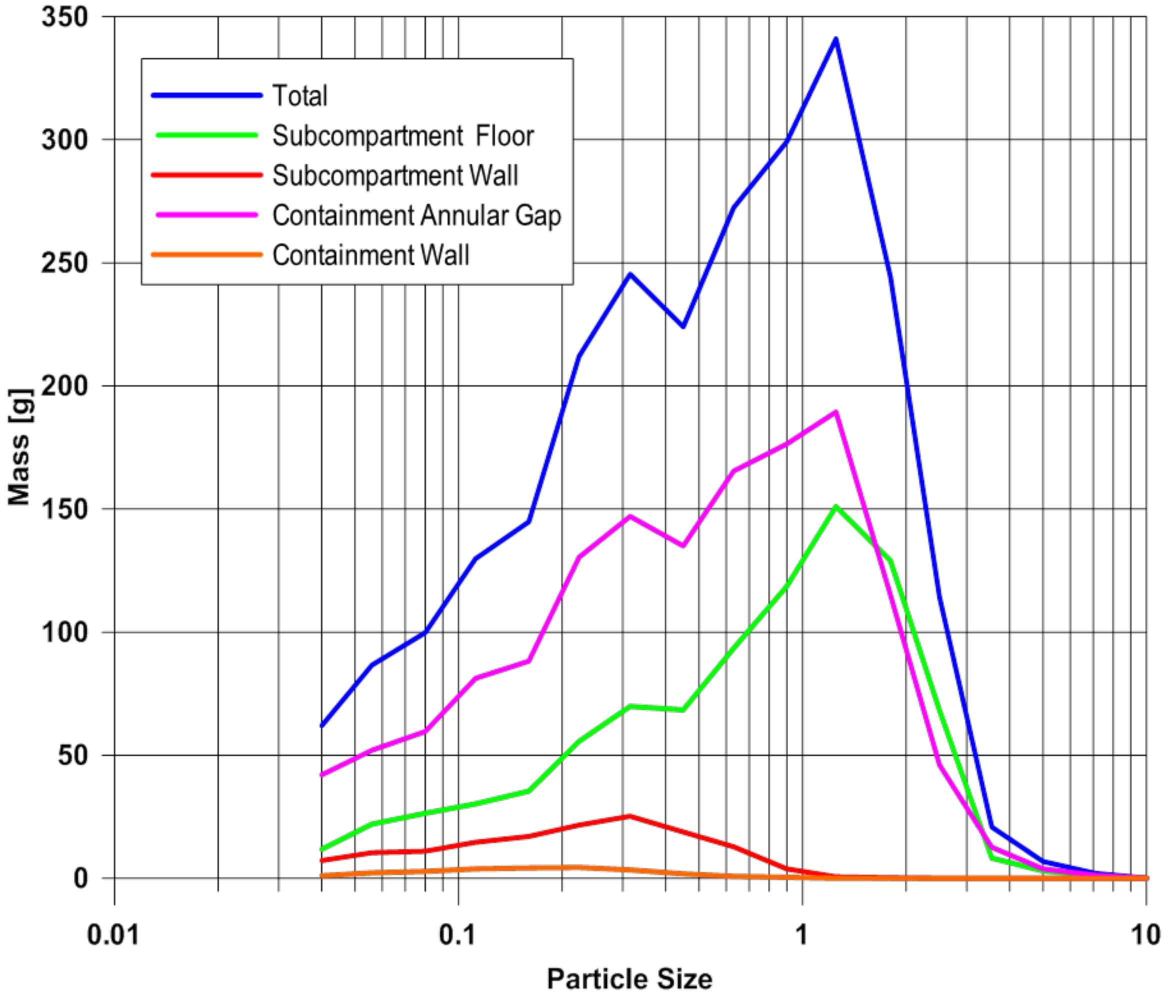


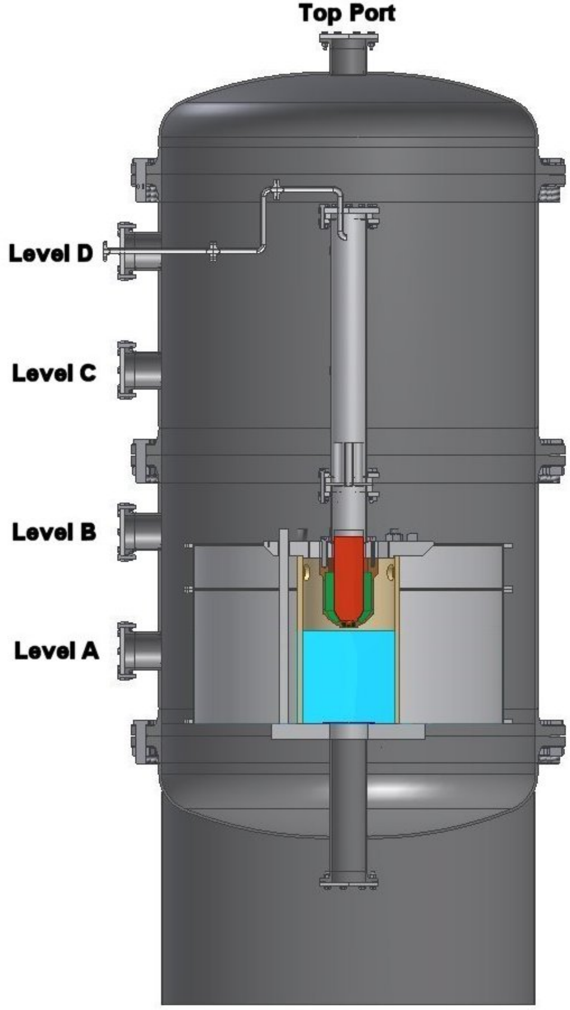
Temperature Containment





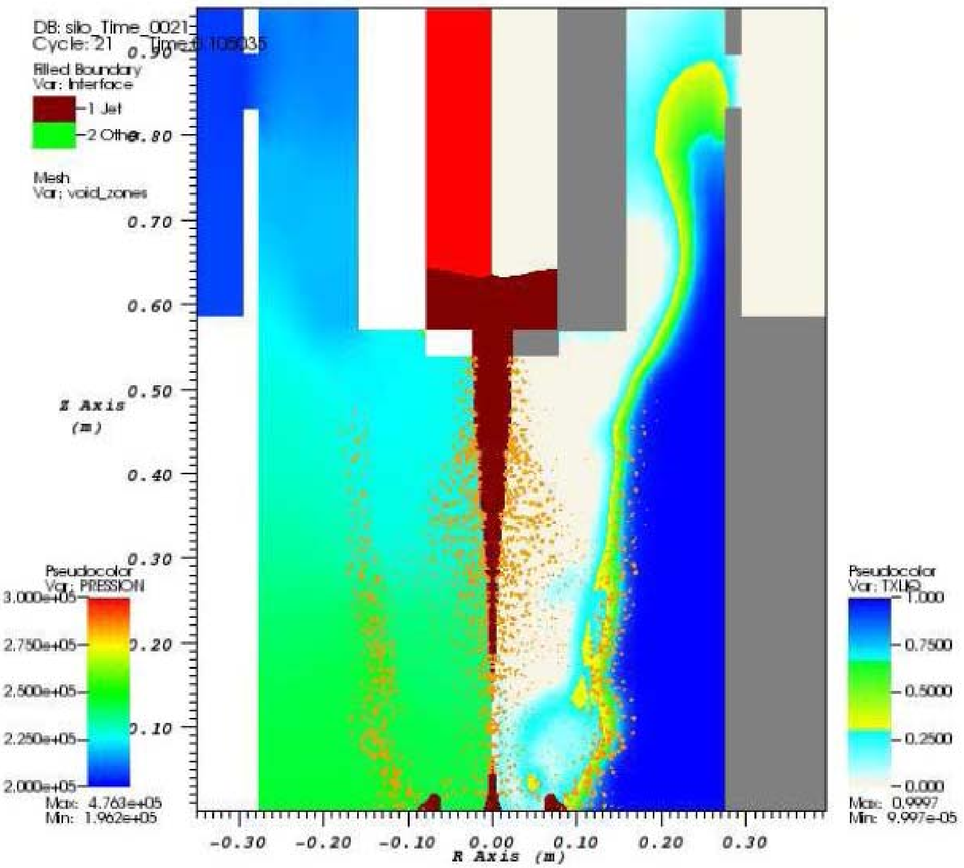
Analysis of generated particles (distribution)





IRSN preliminary post-test analysis

- Simplified vessel geometry but refined mesh
  - o High sensitivity of jet fragmentation when water contacts the jet
    - Important work of analysis
    - Some 2D sloshing effect
    - 3D to be investigated
  - o Generally pressure in the pit reaches vessel pressure
    - Strong interaction



Conclusions

- The experiment addresses SARP high priority issues
- No experiment is known with pressure driven melt ejection in reactor geometry at accident conditions
- Bridges the gap between DCH and ex-vessel FCI issues
- Data will be used for code qualification
- Analysis in the frame of SARNET2 WP7.1 and WP5.3 through post-test calculations
  - MC3D (IRSN, CEA, …)
  - JEMI (IKE Stuttgart)