STATUS AND RESULTS OF THE OECD BENCHMARK EXERCISE ON TMI-2 PLANT

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Outline

- Benchmark objectives
- Participants and codes
- Accident Scenarios
- Code results comparison
  - SBLOCA sequence and reflooding scenarios
  - SLB sequence and reflooding scenarios
- Conclusions

Benchmark objectives

- Gather information on the capability of the code/models to predict the key phenomena during reactor severe accident sequences by comparing the various results from several computer codes
- Simulate representative severe accident sequences with well defined boundary conditions up to different degree of in-vessel core melt progression:
  - Extend the analysis to molten core slumping into the lower plenum
  - Address core reflooding issue starting from different degree of core degradation
- Perform sensitivity studies on more important and uncertain key parameters and evaluate their impact on core melt progression

Schedule and links

Kick-off meeting	February 2011
Review meetings	2011 – 2013
Final meeting before preparation of the draft report	September 2013
Distribution of the final report	February 2014

- The project was linked with the WP5.4 “Corium and Debris Coolability – Bringing Research into Reactor Applications” of EU/SARNET2
- The activity has been carried out by a Group of Participants including members from WGAMA and SARNET2

Participants and codes

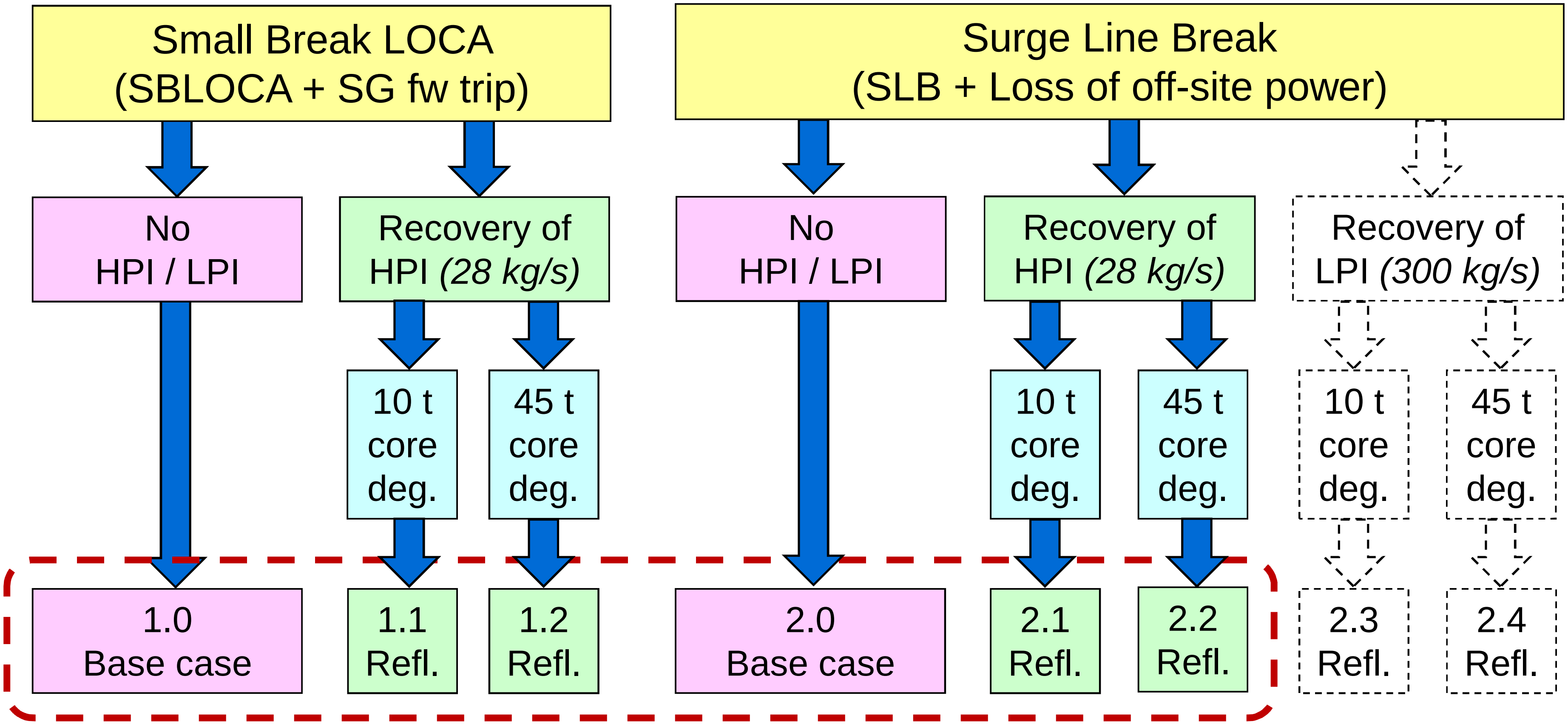
Participant	Country	Code
GRS	Germany	ATHLET-CD Mod 2.2 Cycle B
IKE		ATHLET-CD V2.2C
KIT		ASTEC V2.0R2p2 and MELCOR 1.8.6
RUB		ATHLET-CD V2.2A
ENEA	Italy	ASTEC V2.0R1p2
IRSN	France	ICARE/CATHARE V2.3rev1
IVS	Slovak Republic	ASTEC V2.0R2p2
INRNE	Bulgaria	ASTEC V2.0R2p2
Tractebel Engineering	Belgium	MELCOR 1.8.6
BARC	India	ASTEC V2.0R2p2
IBRAE-RAS	Russia	SOCRAT V3

- All participants were SARNET2 partners except IBRAE-RAS from Russia *(11 organizations, 8 countries)*

TMI-2 steady-state at nominal power

Parameter	Unit	Calculated values (range)	TMI-2 plant data
Reactor core power	MW	2772	2772
Pressurizer pressure	MPa	14.82 - 15.15	14.96
Hot leg temperature	K	589.3 - 594.8	591.15
Cold leg temperature	K	560.3 - 565.7	564.15
Primary loop flow rate	kg/s	8472 - 8888	8800
Pressurizer collapsed level	m	5.05 - 5.94	5.588
Total primary mass	kg	219830 - 225650	222808
SG secondary pressure	MPa	6.41 - 6.55	6.41
SG steam temperature	K	564.7 - 588.3	572.15
SG feed water flow rate	kg/s	701.8 - 791.0	761.1

Severe accident sequences



- 2 base case accident sequences + 4 reflooding scenarios starting from different core degradation conditions (10 and 45 tons of degraded core materials) have been calculated in the frame of SARNET2 *(until March 2013)*

SBLOCA sequence

INITIATING EVENT: Small break of 20 cm^2 in the hot leg of Loop A with simultaneous loss of SG main feed-water (t = 0 s)

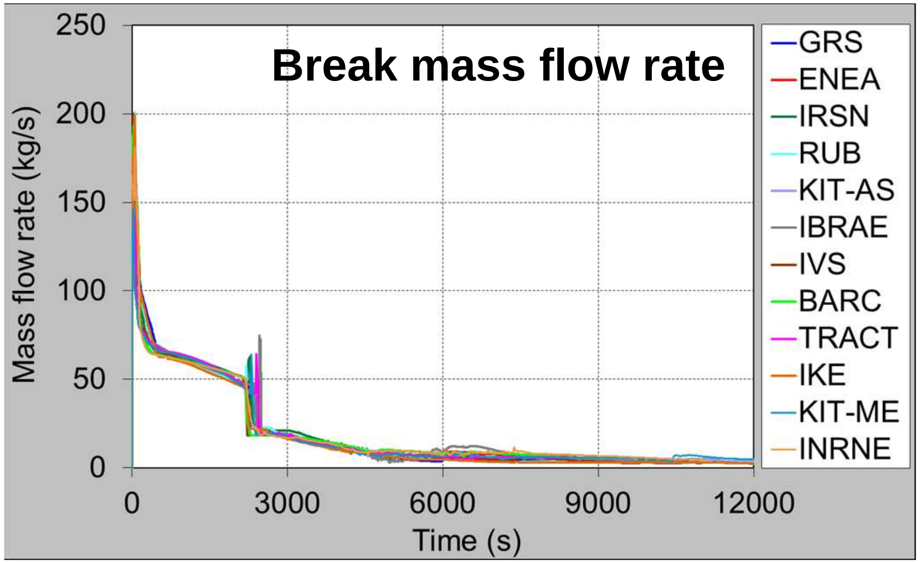
- Reactor scram on high pressure signal
- Auxiliary feed-water startup after 100 s → *Pressure (70 bar at 200 s) and level control (1 m at 200 s) on SG secondary side*
- Primary pump coastdown when primary coolant mass < 85 tons

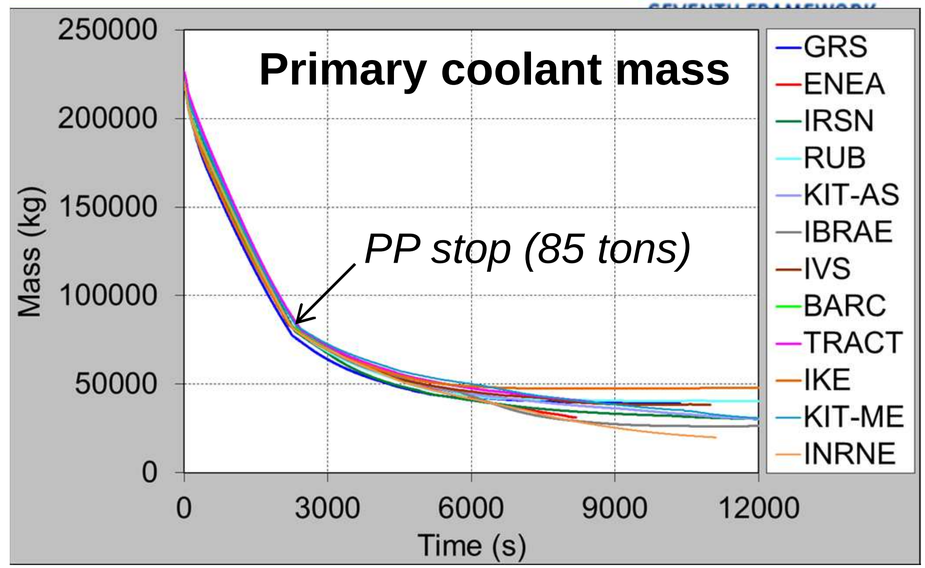
Boundary conditions: constant make-up flow rate = 3 kg/s – No letdown flow

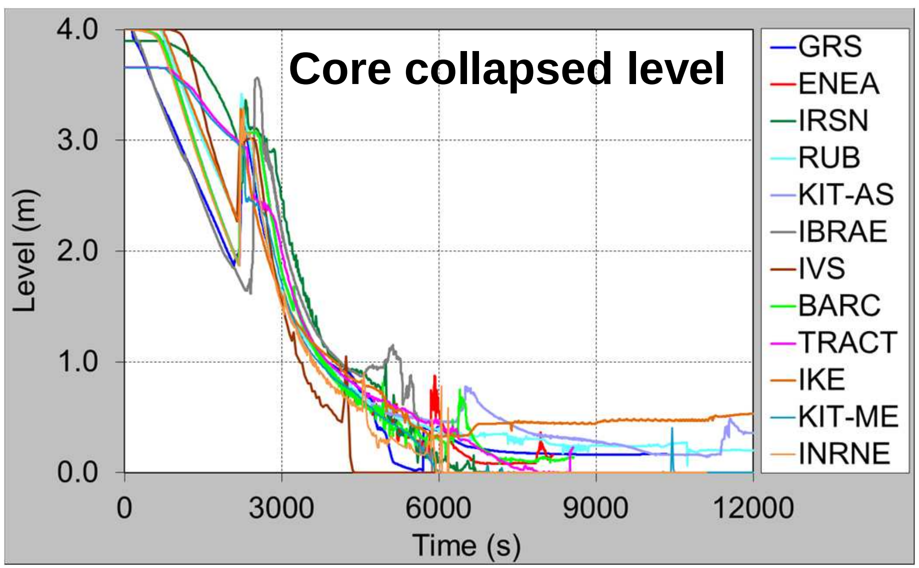
Base Case and Reflooding Scenarios:

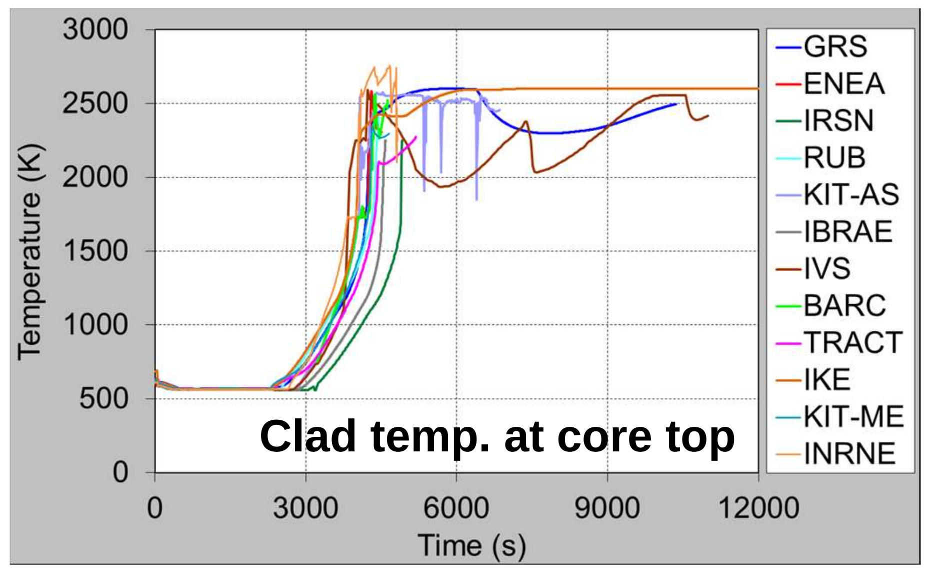
- Base case without reflooding (no HPI/LPI injection) → Free evolution of the transient until vessel failure
- Low flow rate reflooding of a slightly degraded core *(deg. mass M_D = 10 tons)*
- Low flow rate reflooding of a highly degraded core *(deg. mass M_D = 45 tons)*

SBLOCA: Base case without reflooding (1/2)

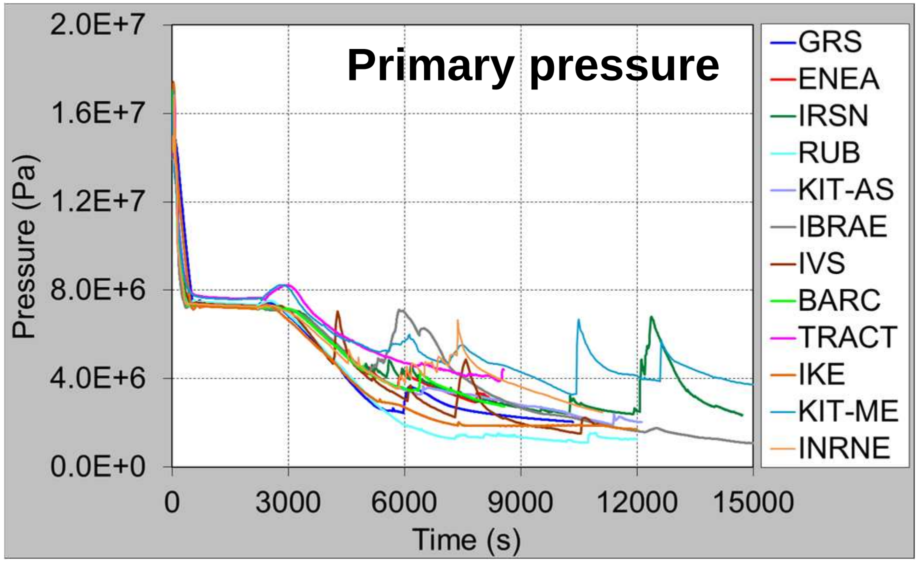


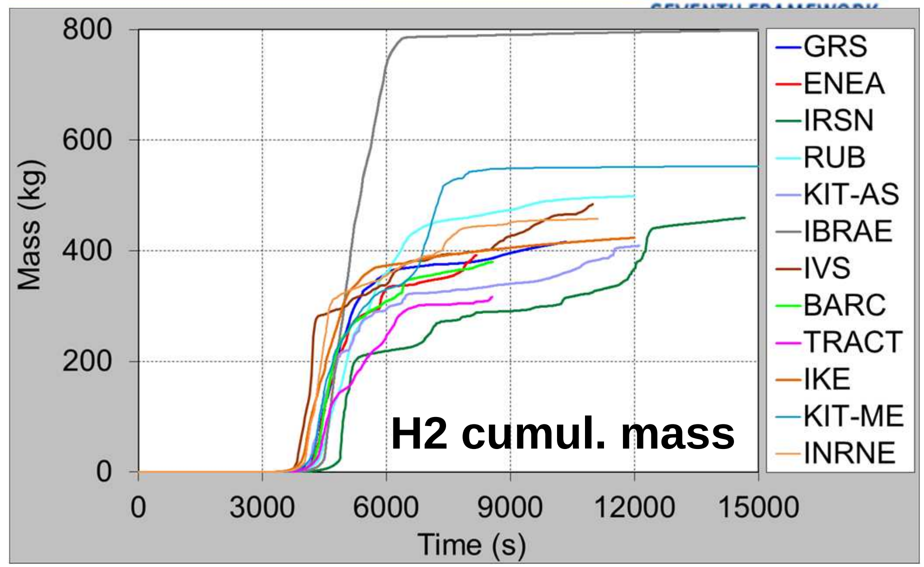


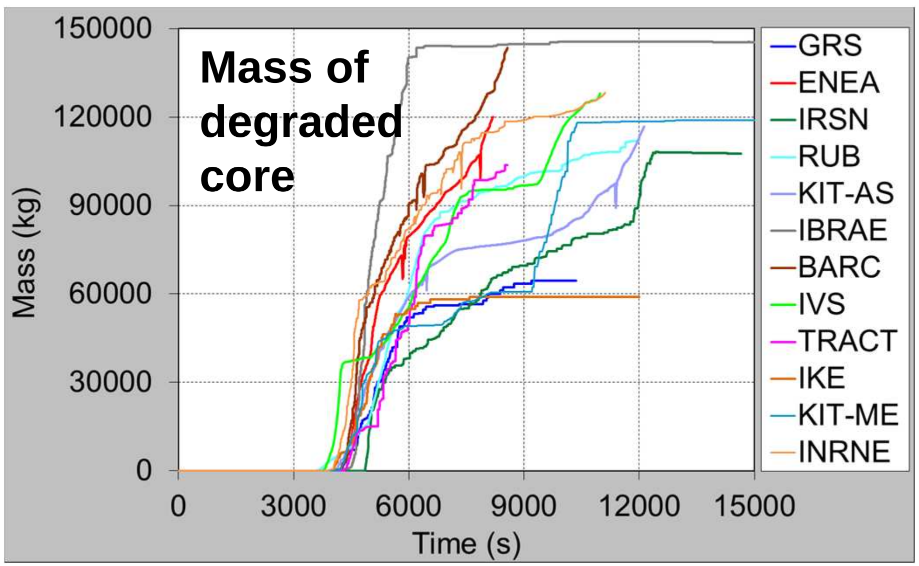


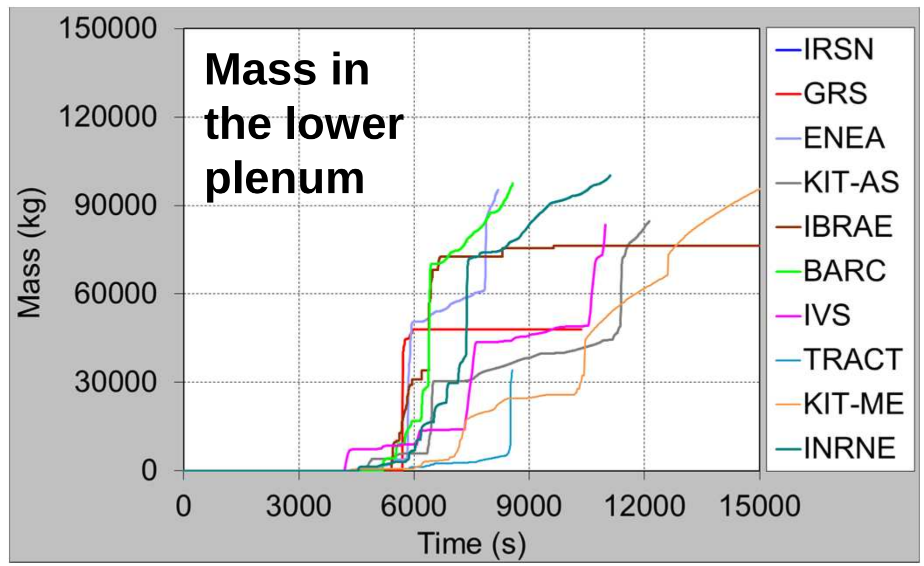


SBLOCA: Base case without reflooding (2/2)

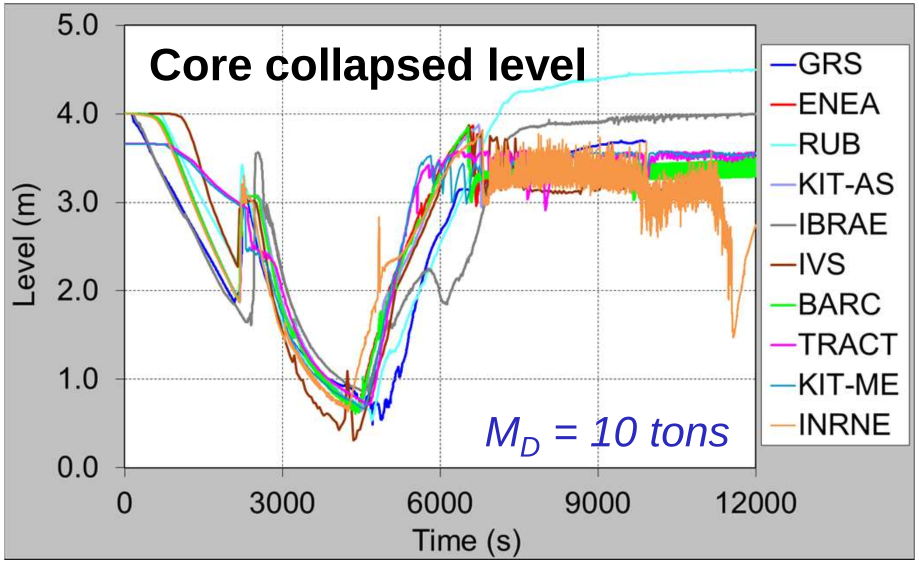


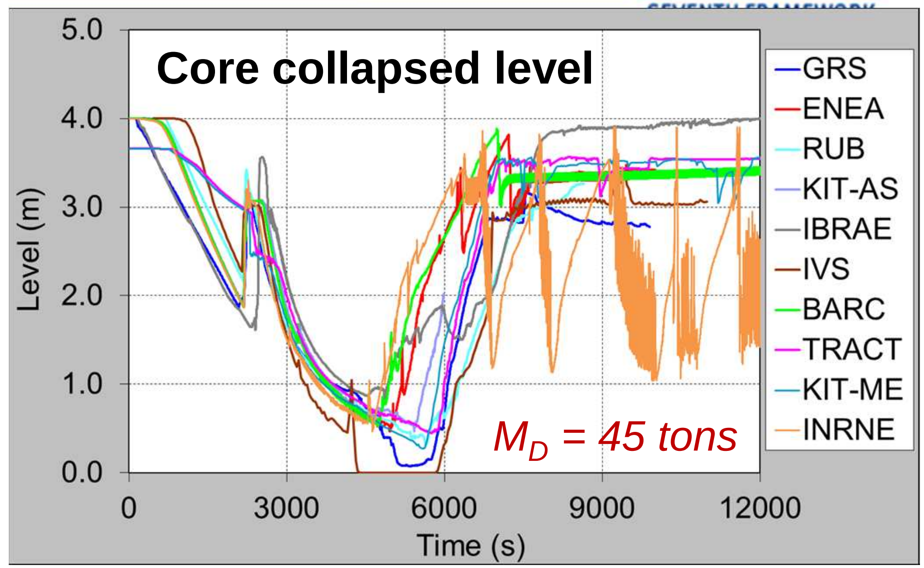


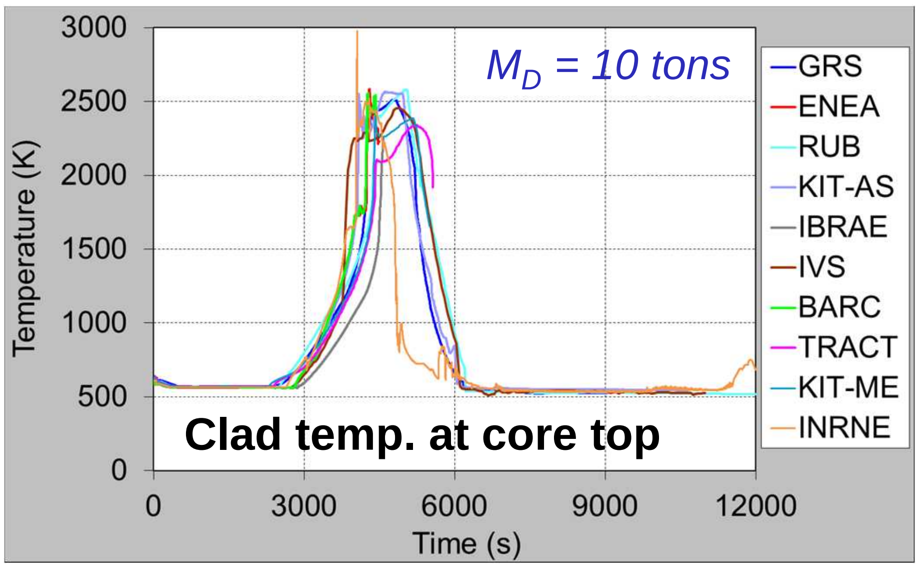


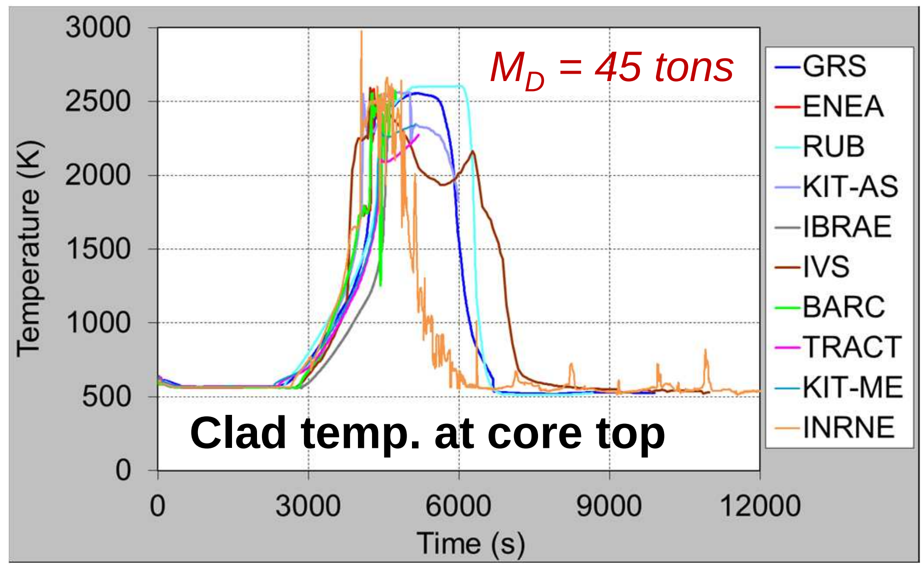


SBLOCA: Low flow rate reflooding (1/4)

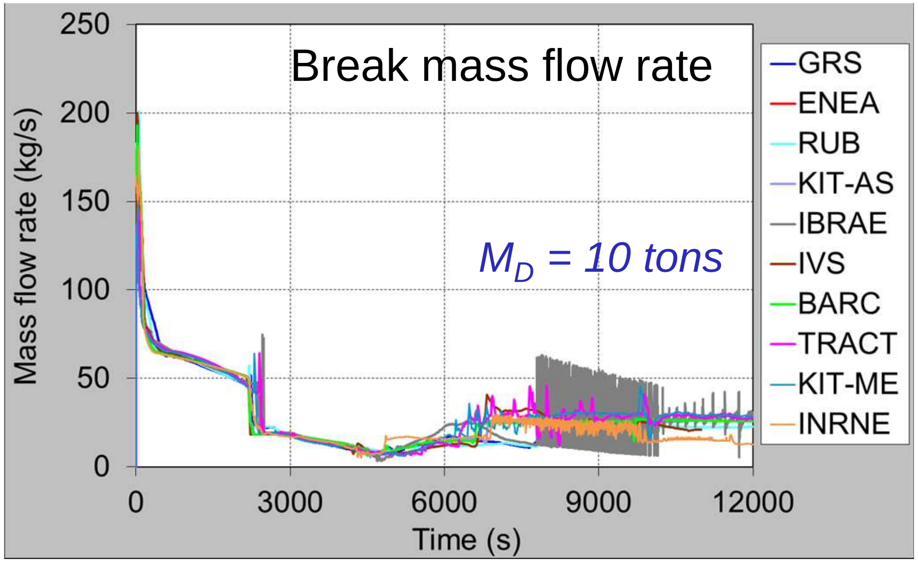


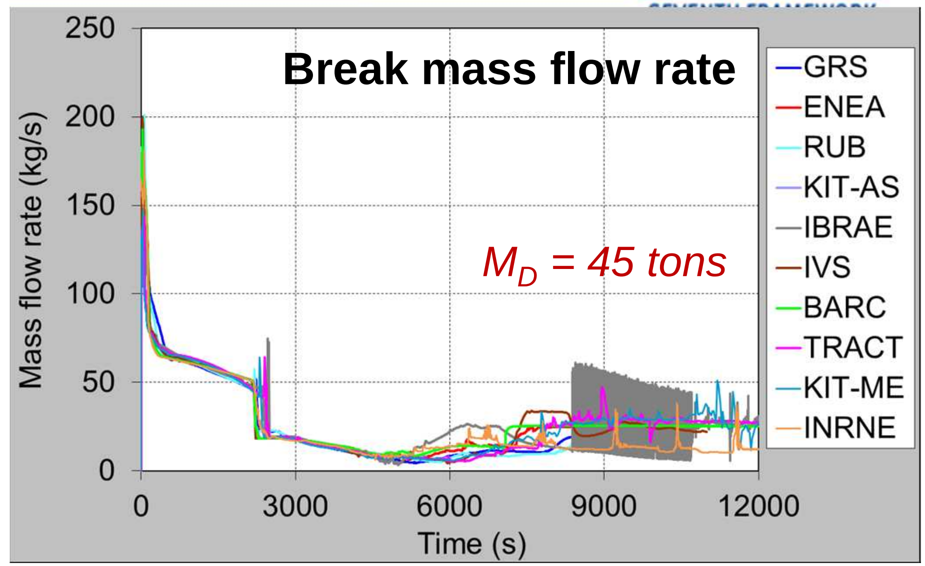


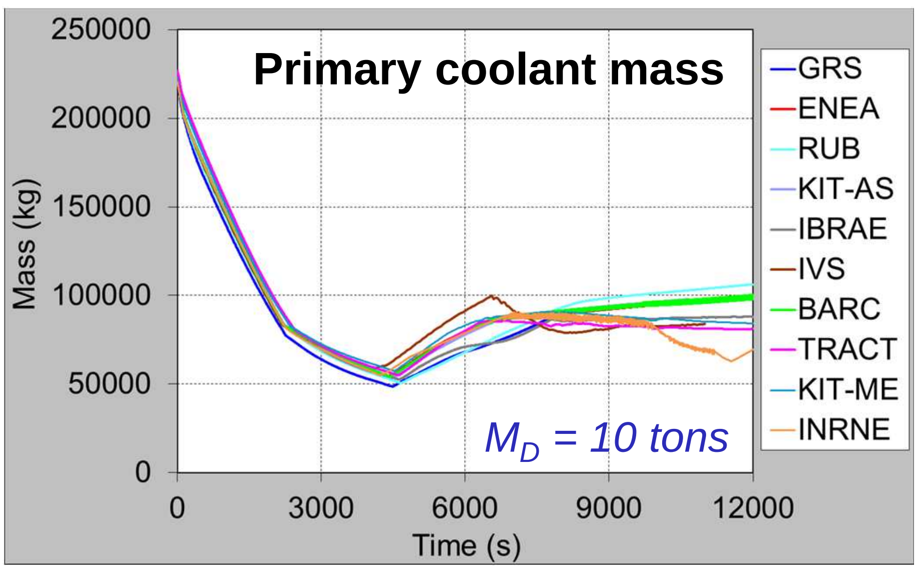


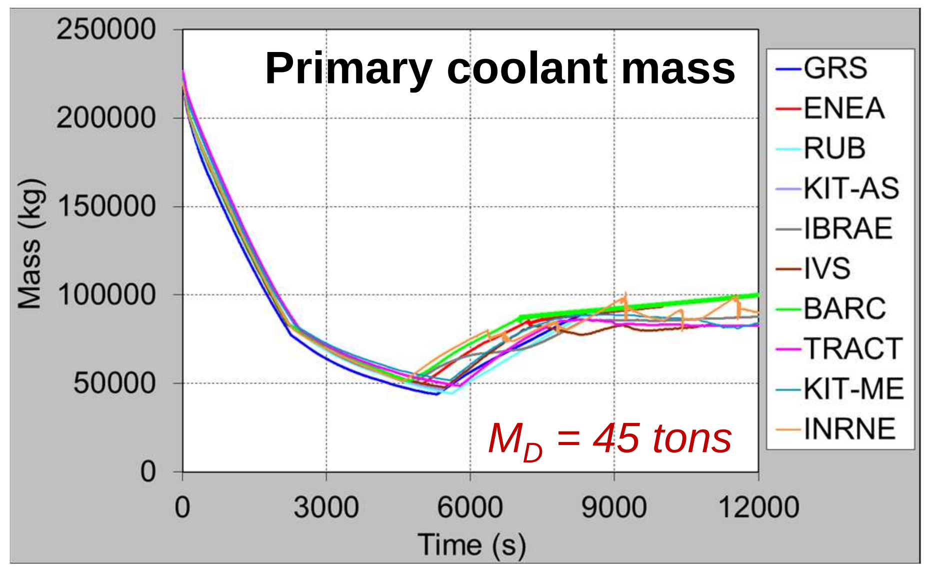


SBLOCA: Low flow rate reflooding (2/4)

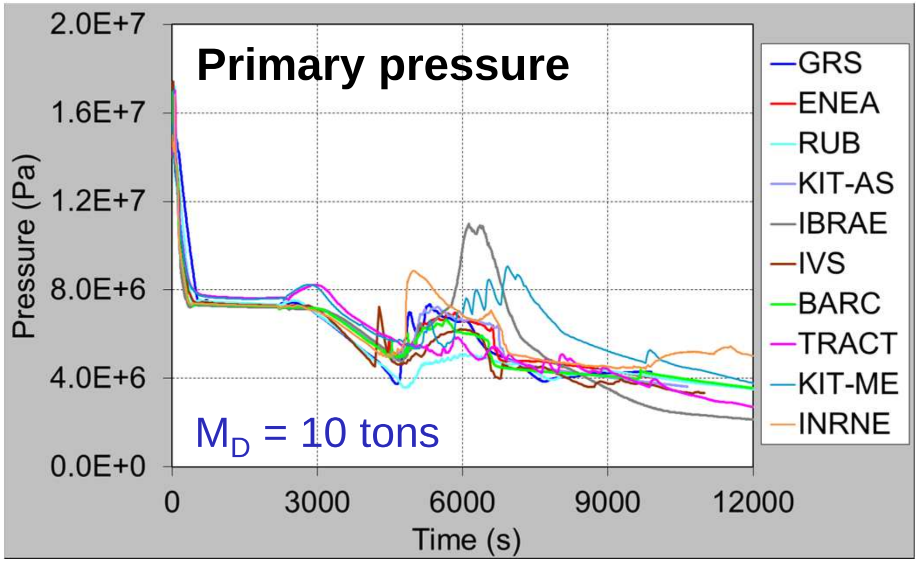


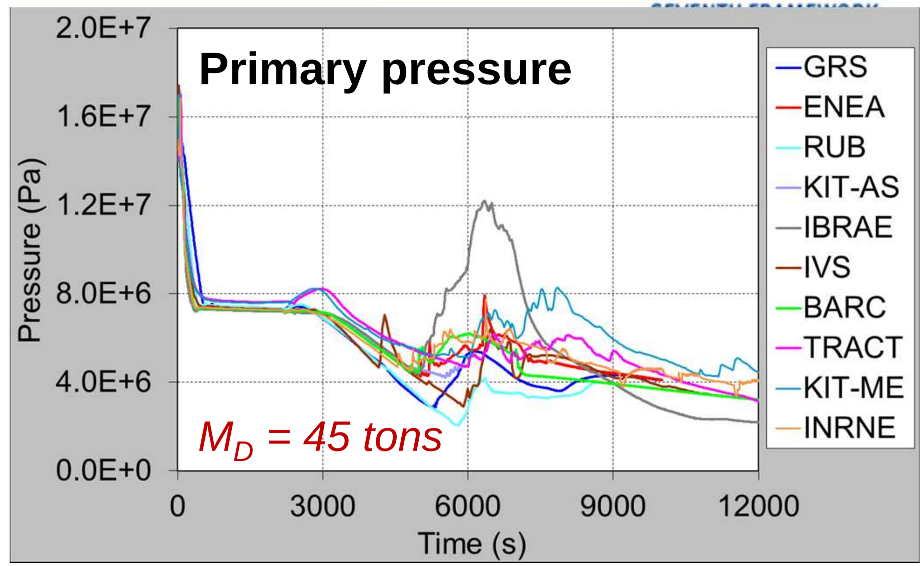


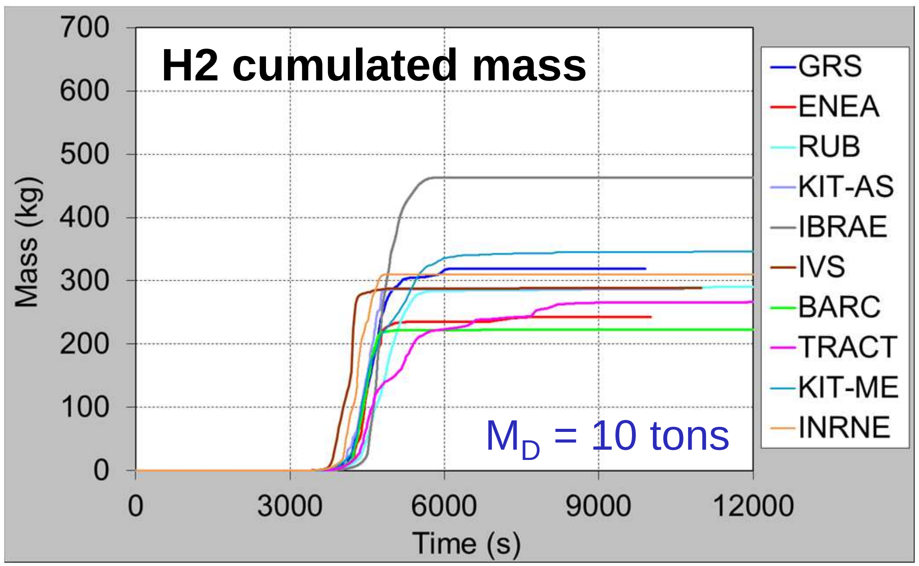


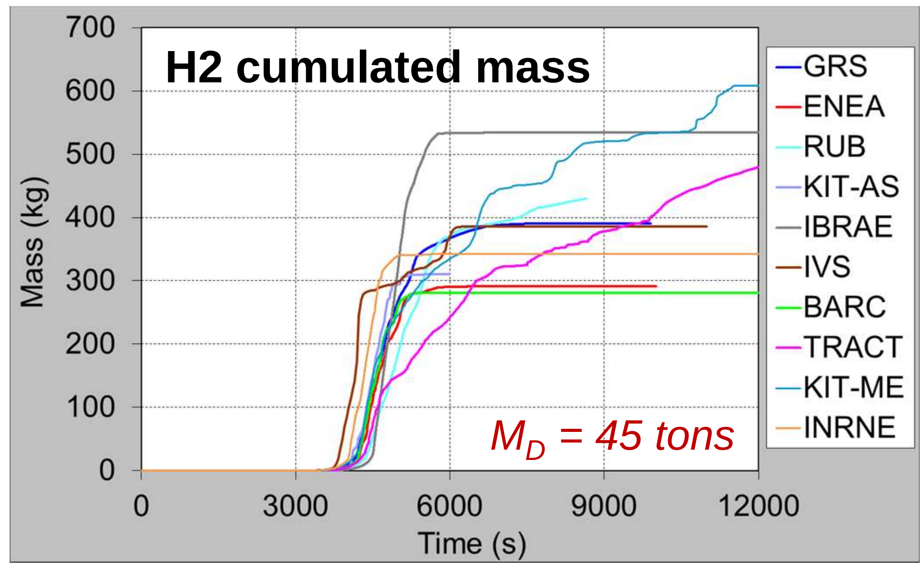


SBLOCA: Low flow rate reflooding (3/4)

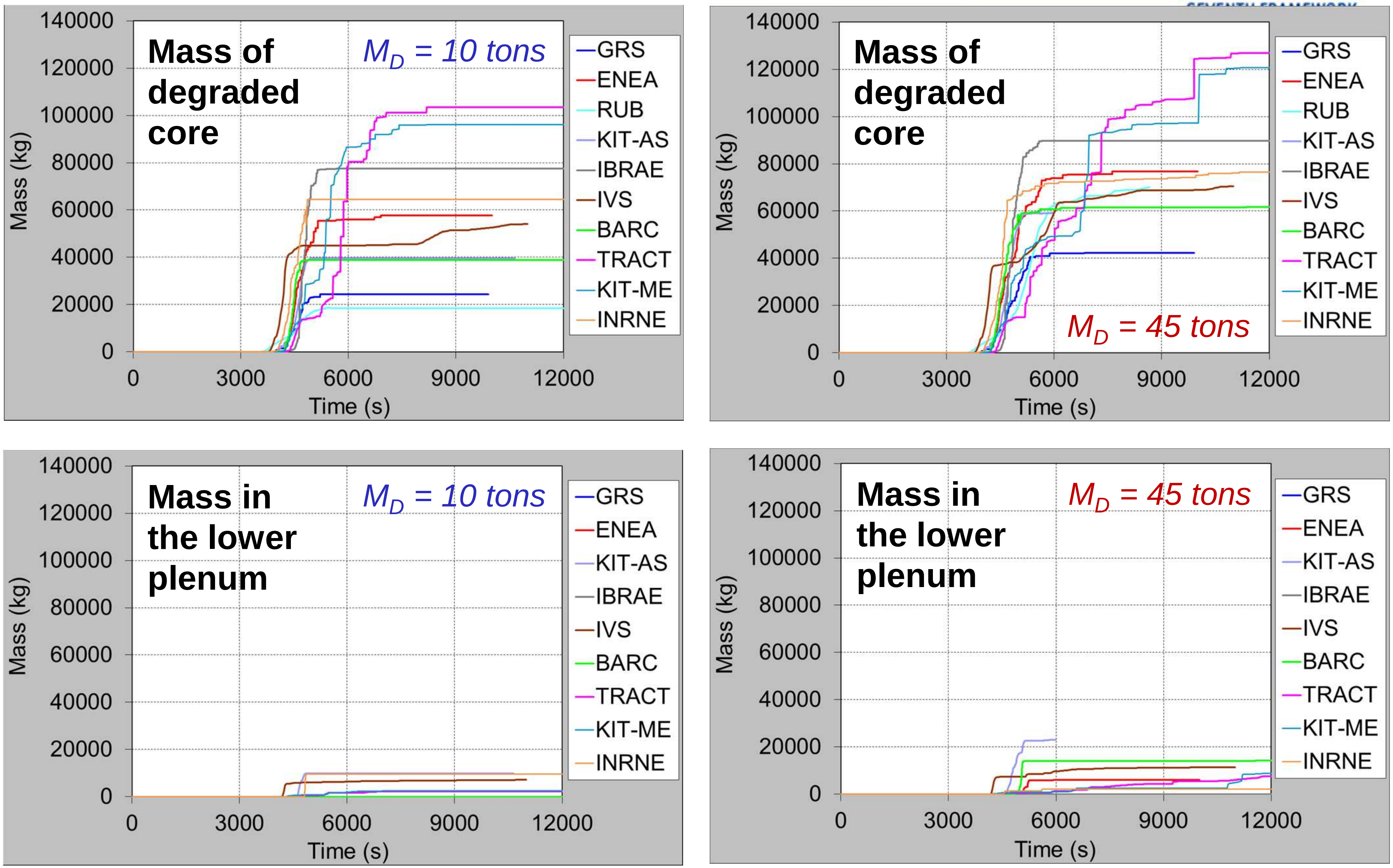








SBLOCA: Low flow rate reflooding (4/4)



SBLOCA results analysis

- Rather small uncertainties on thermal-hydraulic behavior of the plant until the onset of core uncovery and heat-up
- Most significant deviations are recorded after the onset of ceramic melting and core slumping in the lower plenum
- Large deviations in core degradation and hydrogen generation during reflooding. However, all codes agree in calculating more or less delayed stop of core melt progression, limited core slumping and no vessel failure in the late phase

SLB sequence

INITIATING EVENT: Surge Line Break with simultaneous loss of off-site power (SBO) at t = 0 s

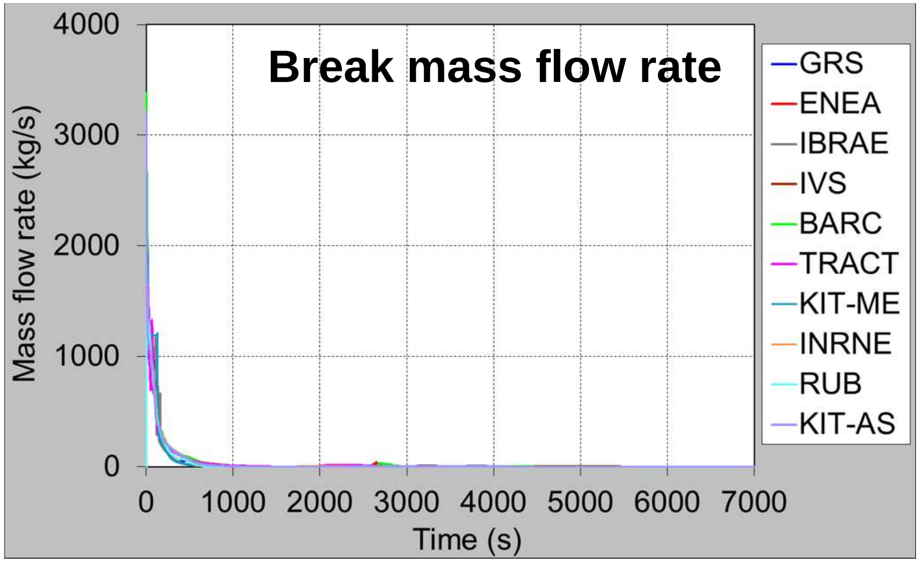
- Reactor scram , SG feed-water trip and primary pump coastdown at t = 0 s

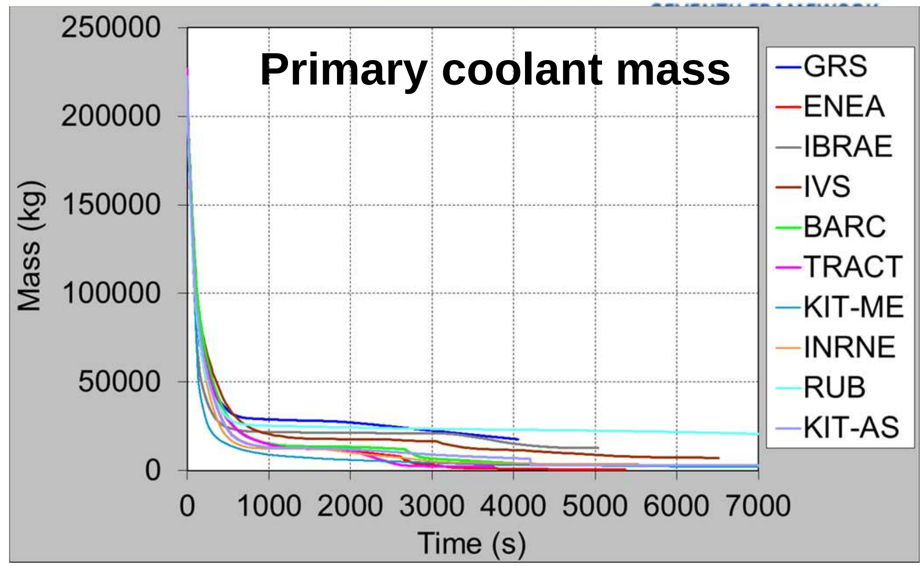
Boundary conditions: No auxiliary feed-water - No make-up flow – No letdown flow

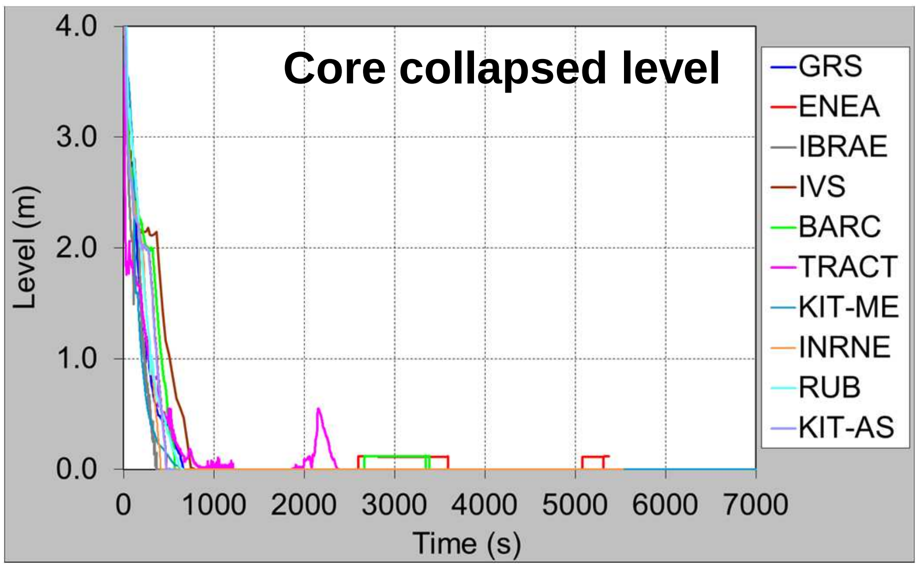
Base Case and Reflooding Scenarios:

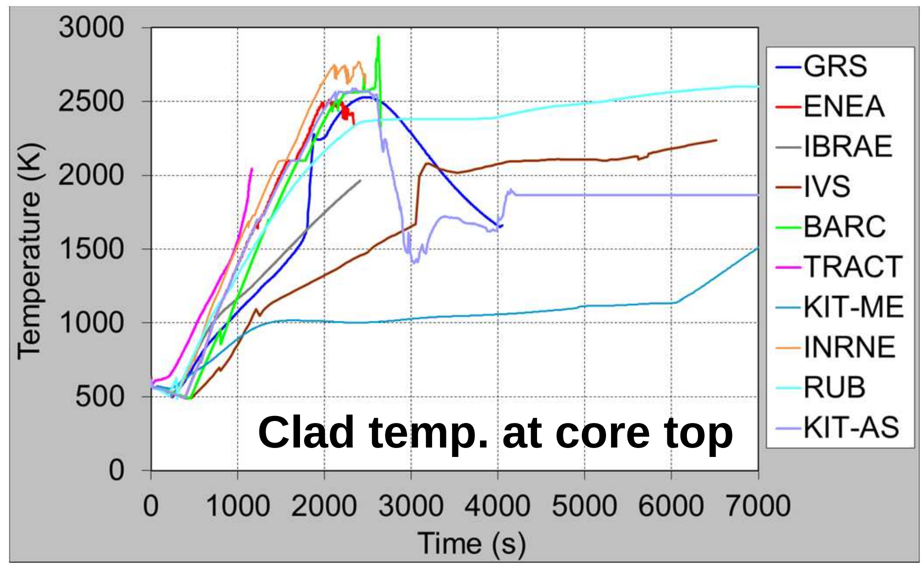
- Base case without reflooding (no HPI/LPI injection) → free evolution of the transient until vessel failure
- Low flow rate reflooding of a slightly degraded core *(deg. mass M_D = 10 tons)*
- Low flow rate reflooding of a highly degraded core *(deg. mass M_D = 45 tons)*

SLB: Base case without reflooding (1/2)

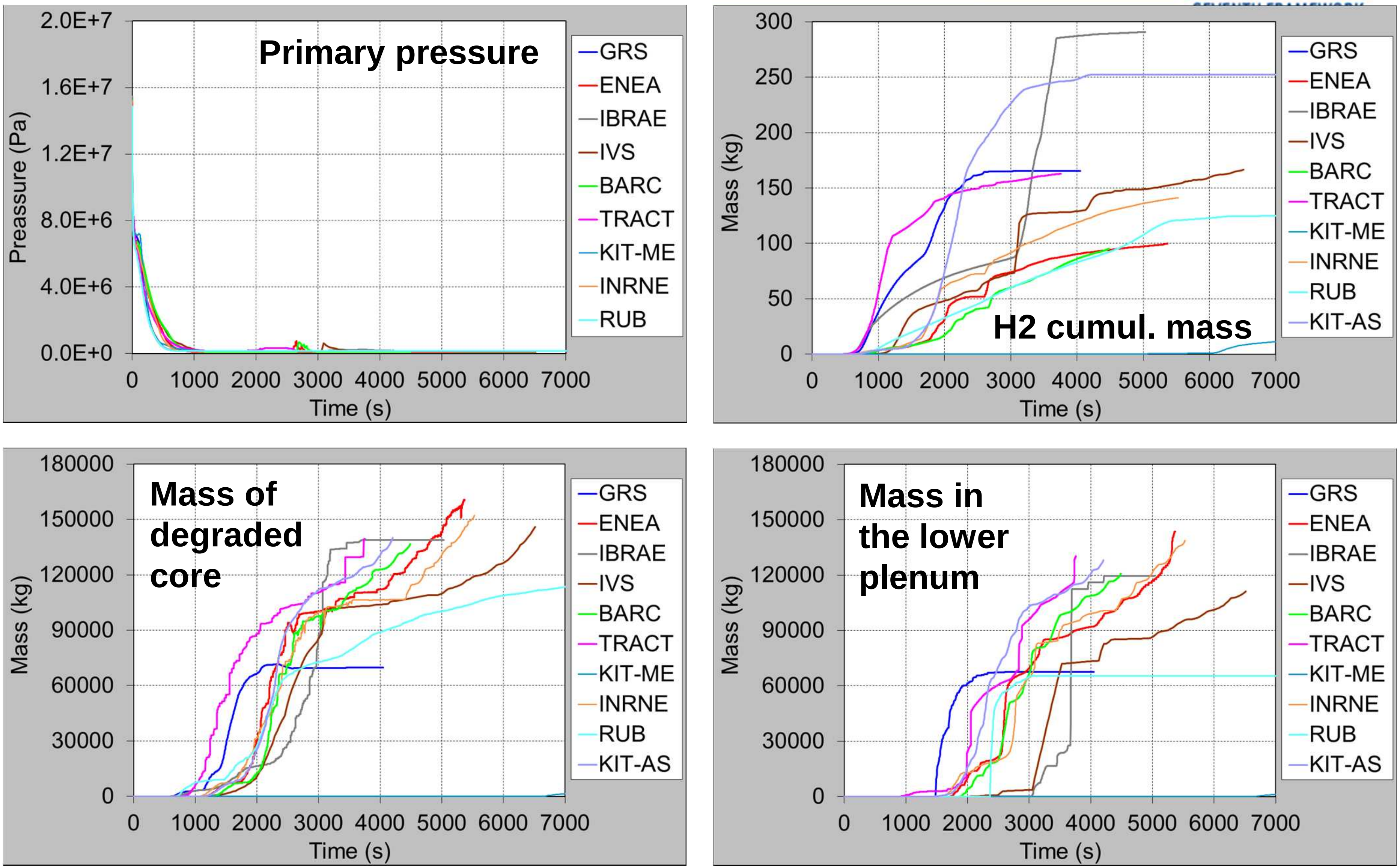




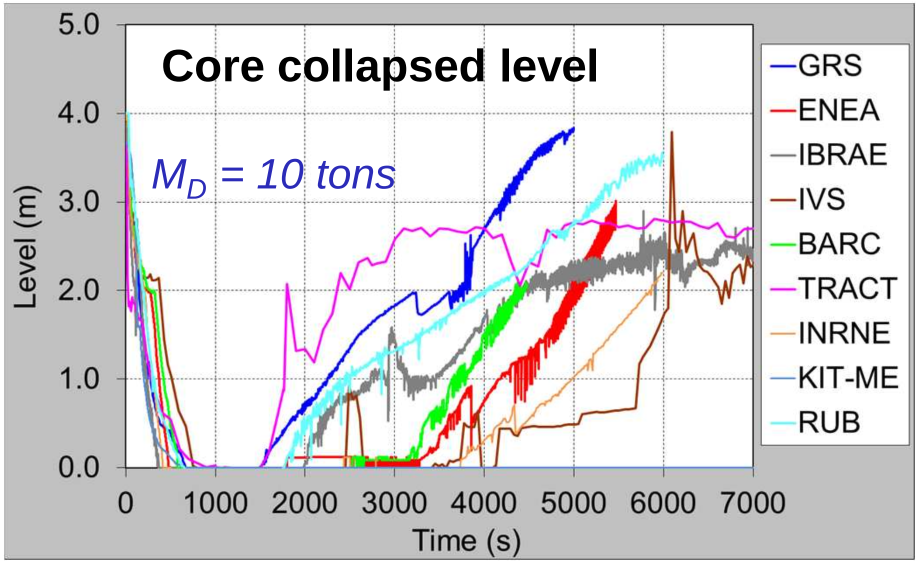


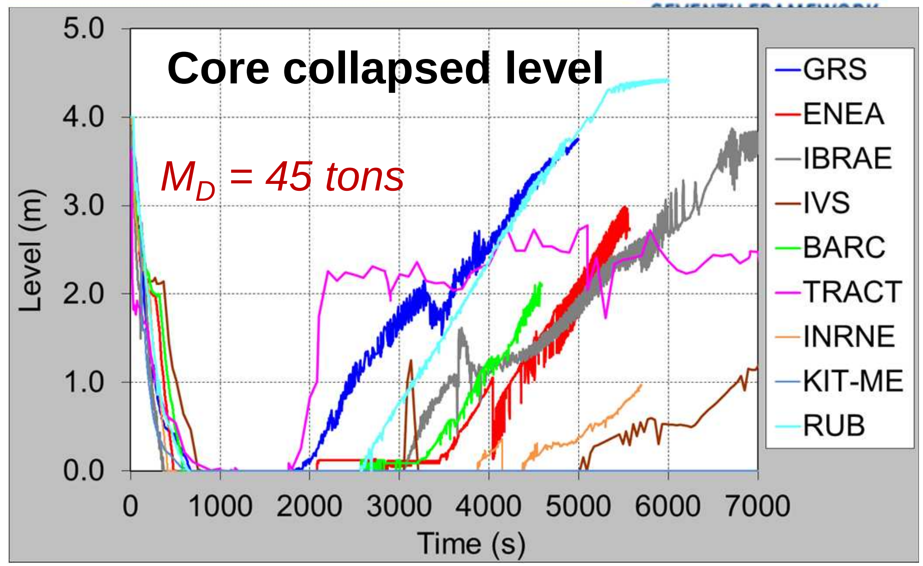


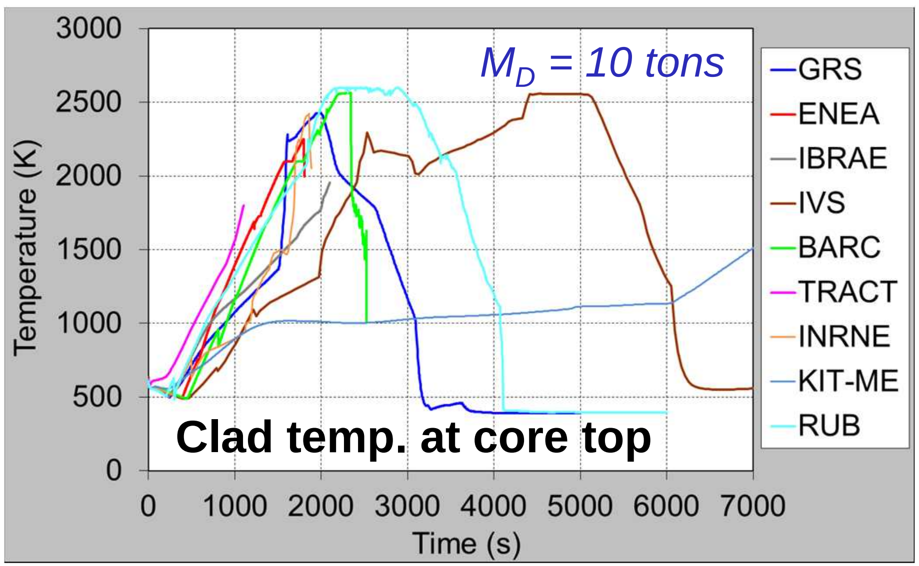
SLB: Base case without reflooding (2/2)

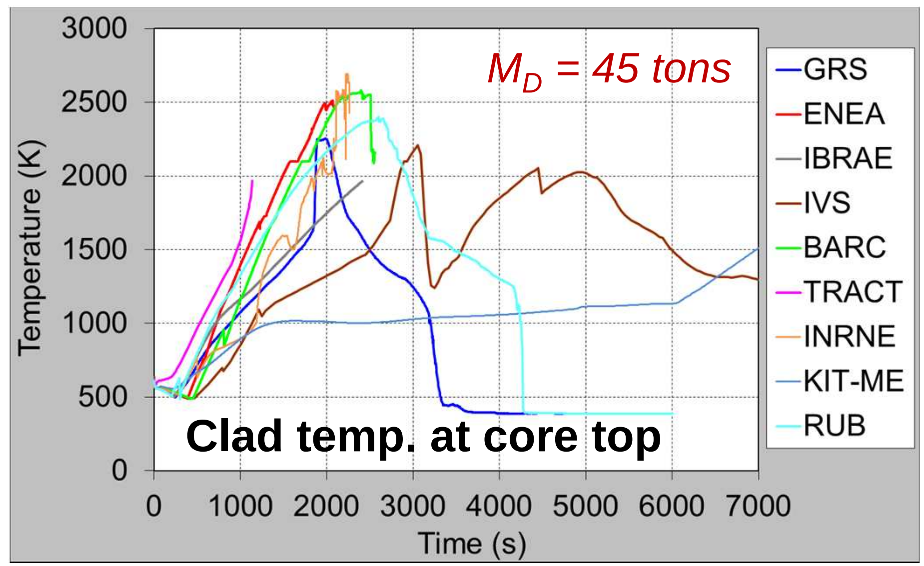


SLB: Low flow rate reflooding (1/4)

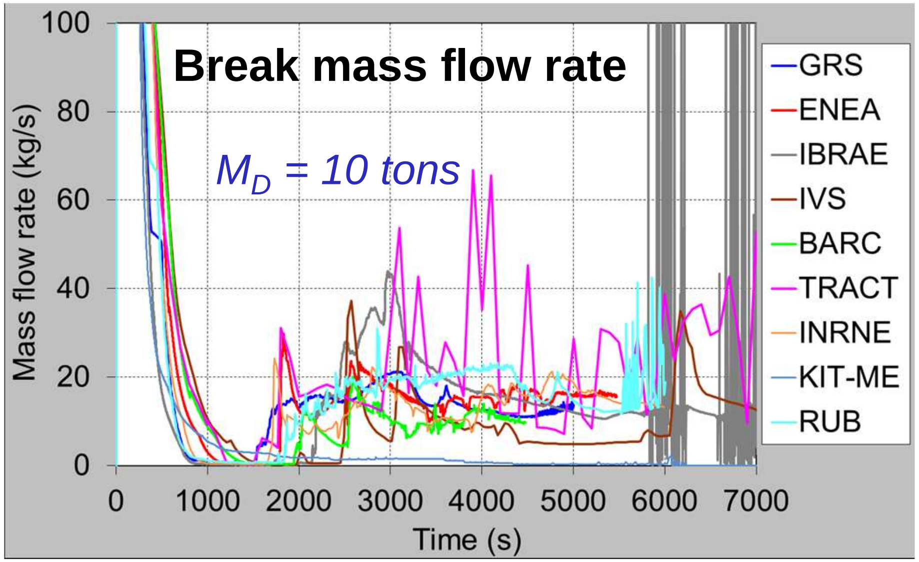


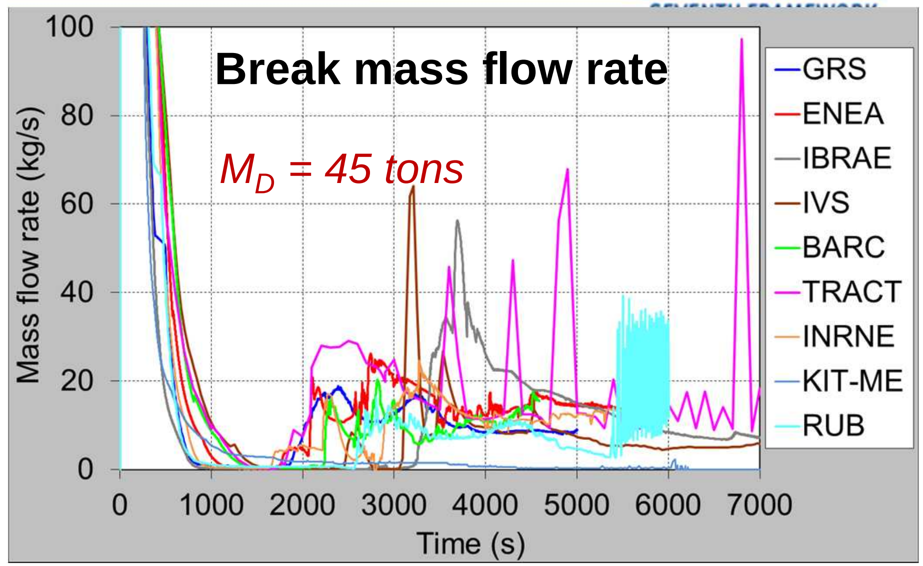


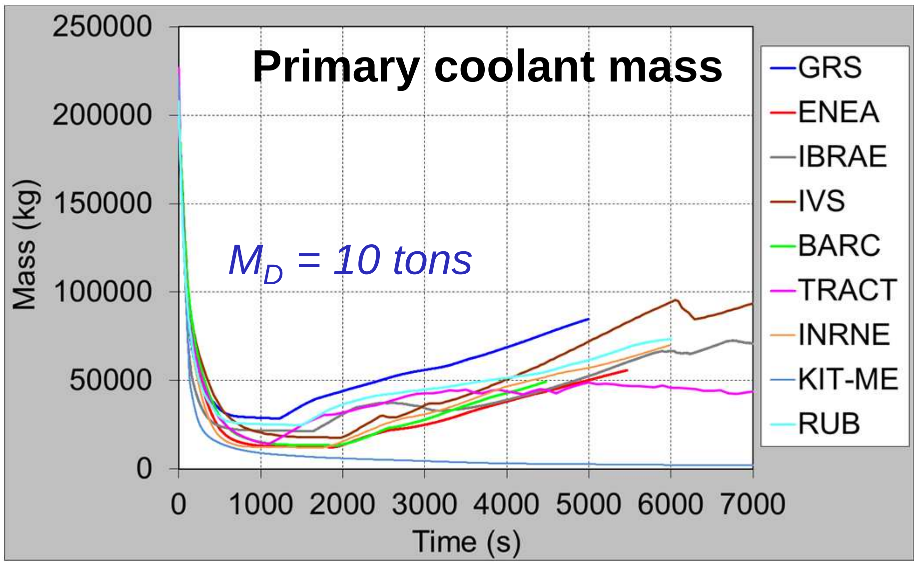


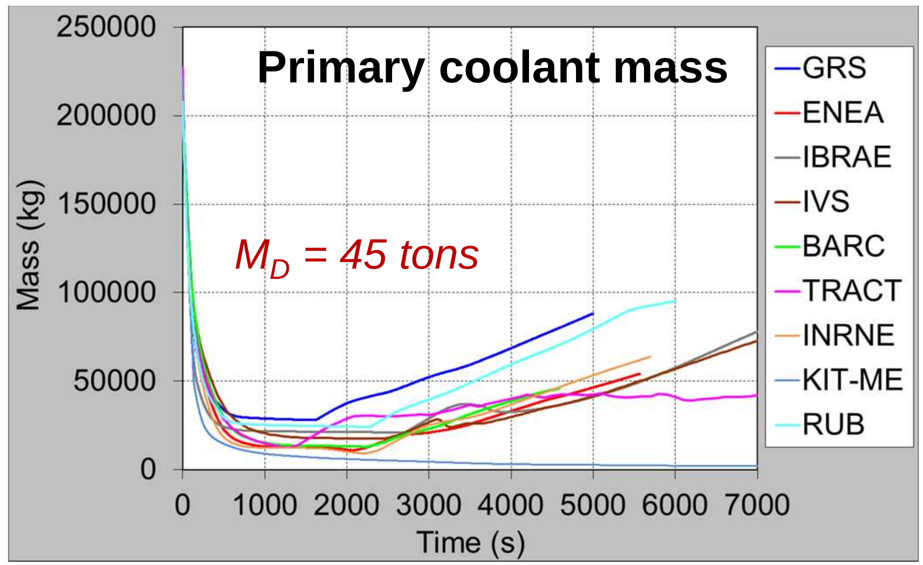


SLB: Low flow rate reflooding (2/4)

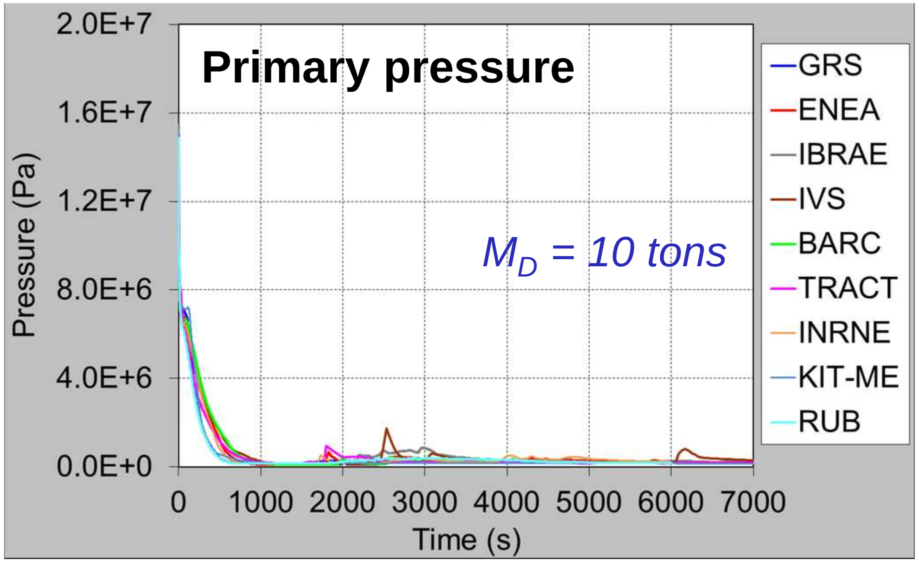


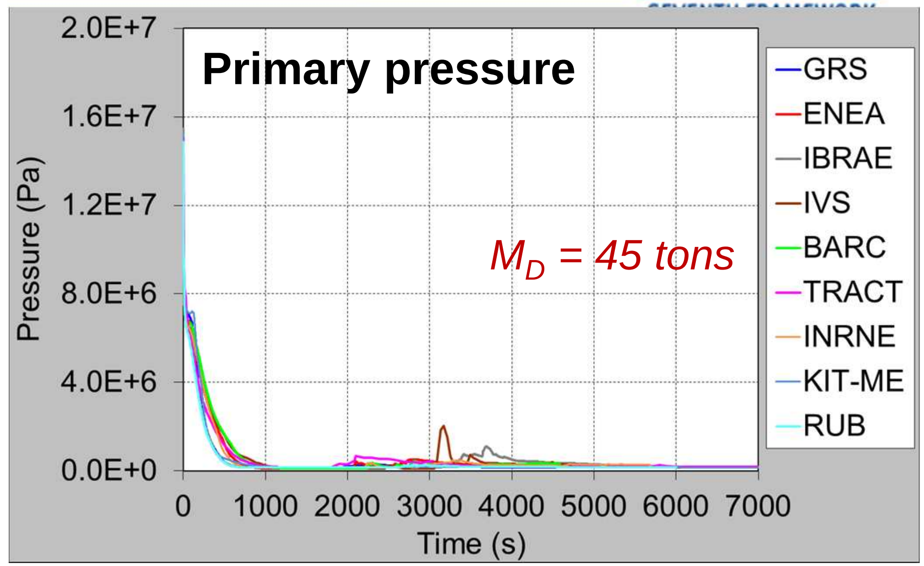


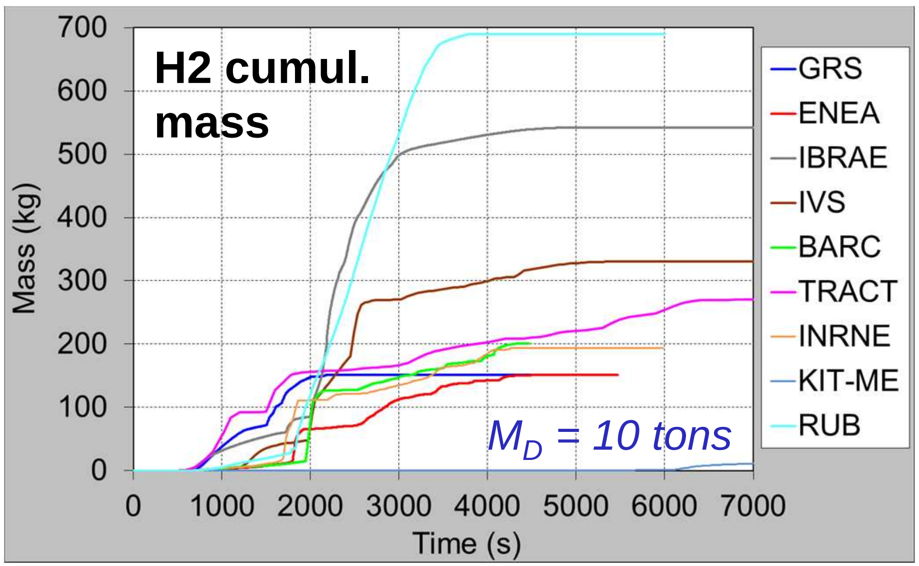


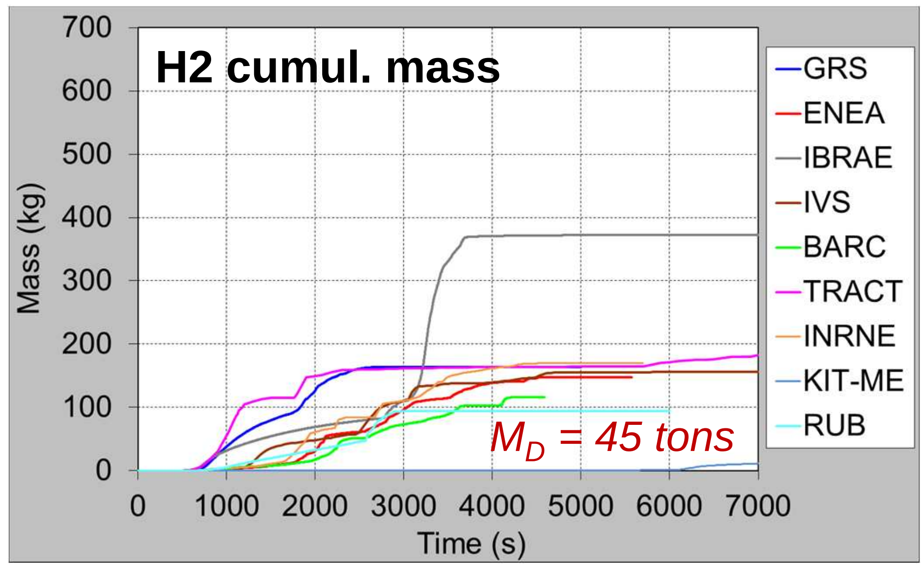


SLB: Low flow rate reflooding (3/4)

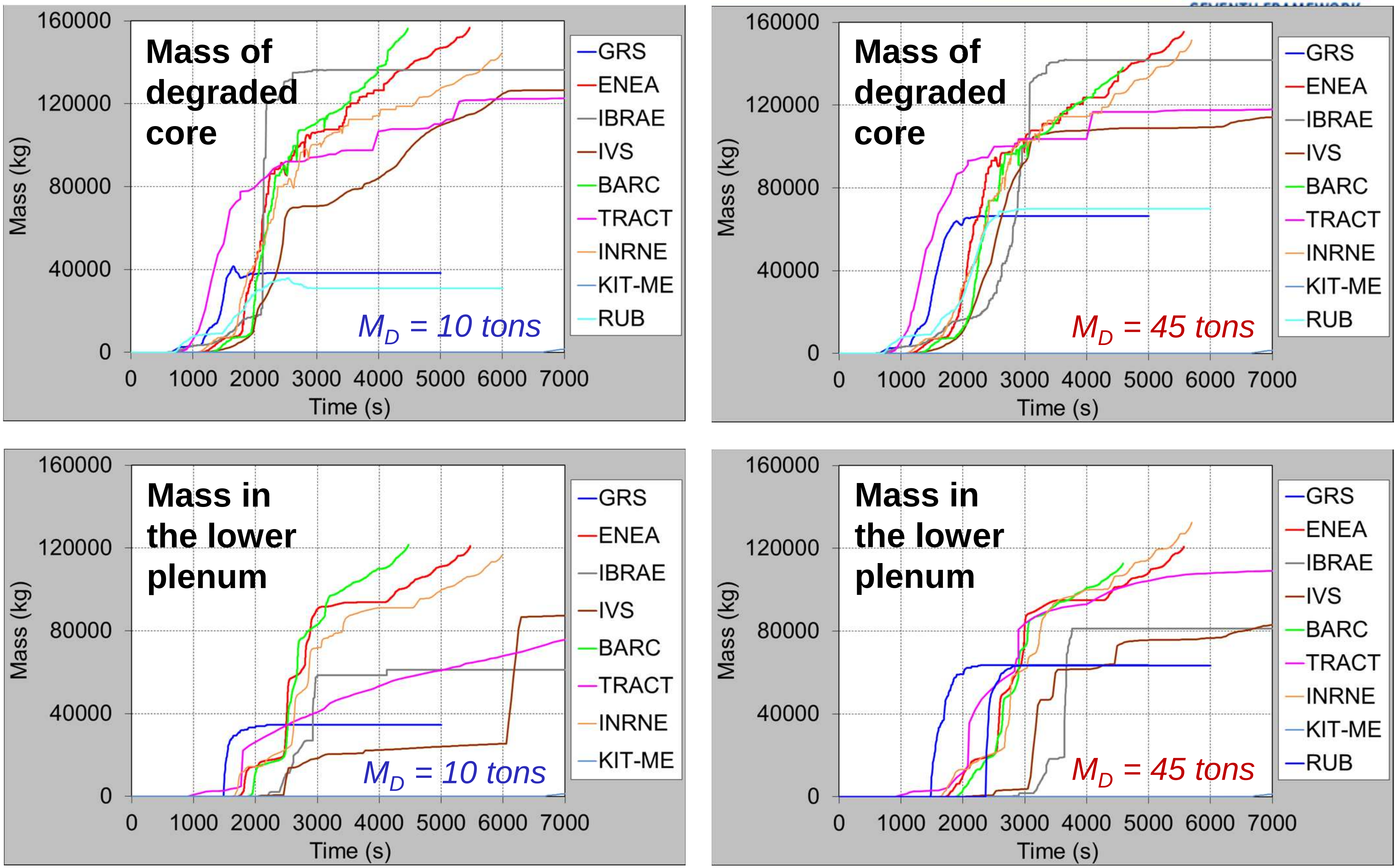








SLB: Low flow rate reflooding (4/4)



SLB results analysis

- Difference in steam starved conditions during oxidation seems to increase the uncertainties in core heat-up and H2 generation
- Lack of a residual water level in the core during the late degradation phase leads to largest deviations in spreading of core melt, core collapse and core slumping in the lower plenum
- Largest uncertainties during the low flow rate reflooding are introduced by the different time needed to fill-up the lower plenum and then to start effective core quenching → In most calculations core melt progression and material slumping into the lower plenum cannot be terminated, and then the vessel failure is not prevented

Conclusions (1/2)

- General robustness of the codes is confirmed → All codes were able to calculate the accident sequences up to the most severe degradation state and under degraded core reflooding conditions

- Thanks to the harmonization of initial steady-state and boundary conditions the uncertainties on plant thermal-hydraulic behavior were minimized, at least before significant core degradation takes place

- After significant core melting leading to fuel rod collapse, debris-molten pool spreading and core slumping the deviation in code results largely increases, primarily due to different degradation models used by the codes to simulate the late degradation phase

Conclusions (2/2)

- Some differences in plant-core discretization and core degradation parameters might contribute to increase the spread in code results → These effects are strictly connected with the user effect, and might be amplified by the degree of freedom left by the code developers in the selection of code input parameters
- Importance of code user guidelines is then strengthened, at least for reducing the difference between users of the same code. However, it appears from the benchmark exercise that the main reason for the extent of the results spread in not the user effect, but the difference in phenomenological modeling
- Uncertainties on the calculation of reflooding scenarios are still rather large, especially in case of later core reflooding