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Brief MELCOR uncertainty and sensitivity analysis

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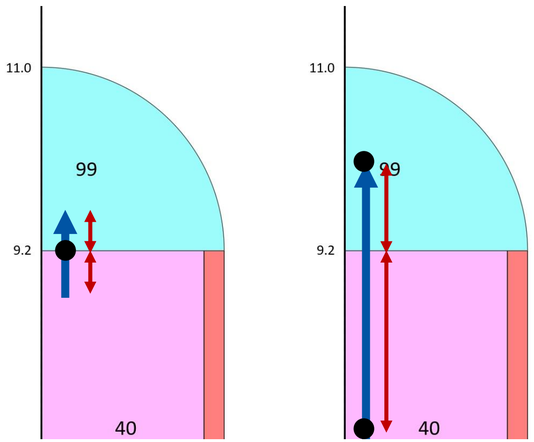
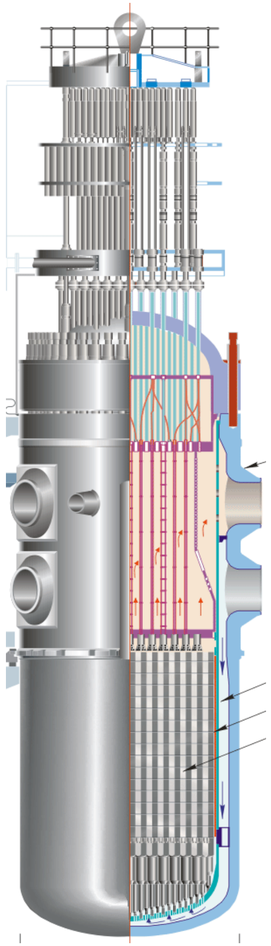
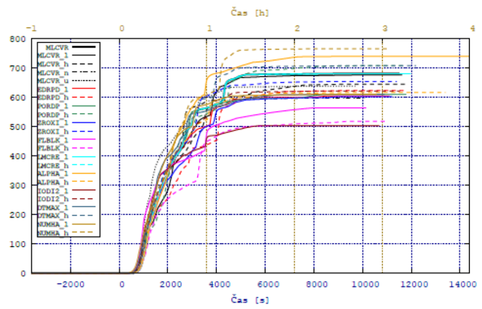
UJV Group
PEOPLE | INNOVATION | TECHNOLOGY

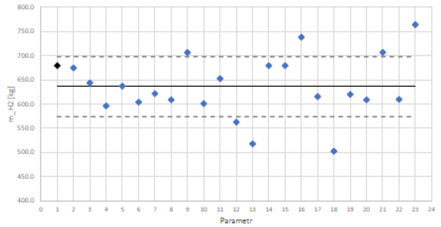
OUTLINE

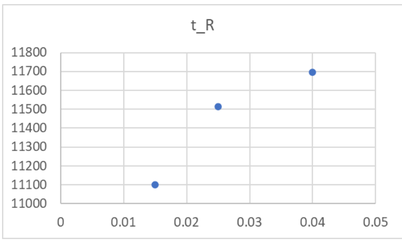
1. MELCOR sensitivity to uncertain parameters
   - Very simple UQ for VVER-1000
     - Focus on ~**10** parameters, separately changed
2. Water leveling in RPV
   - 2 different approaches of FL definition:
     1. FL elevations at interfaces of stacked CVs
     2. FLs connecting CV centers

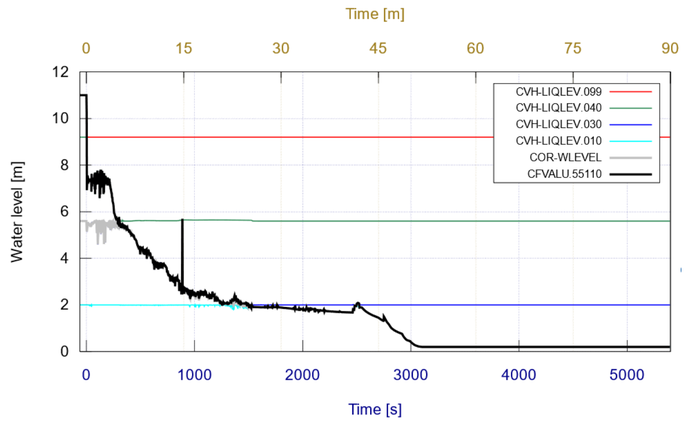












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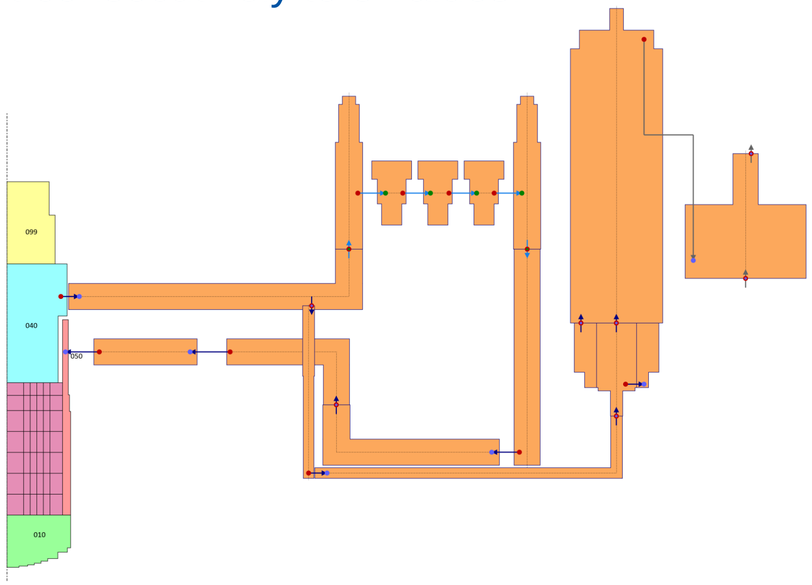
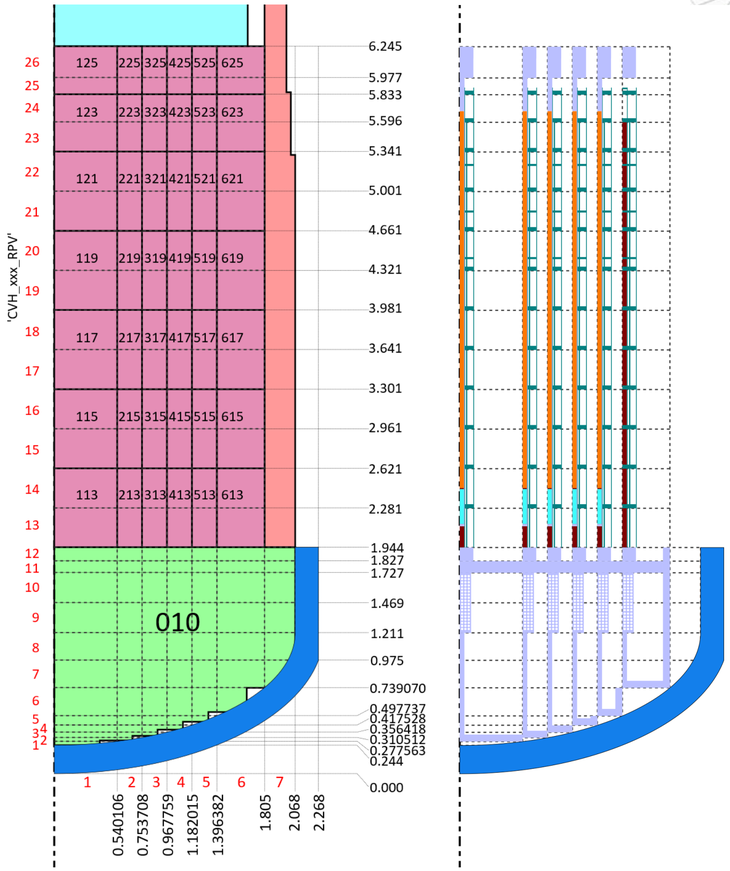
UQ

SIMPLIFIED APPROACH

- 10 uncertain parameters from:
  1. *Numerics*
  2. *Models‘ settings*
  3. *Boundary conditions*
- Each of the 10 parameters separately examined (*no LHC sampling!*), setting it consecutively to 3 values:
  1. ***Base (best-estimate)***
  2. ***Decreased***
  3. ***Increased***
- FOMs:
  1. $t_{RPV\text{-}failure}$
  2. H_2
  3. XE_{CTMT}
  4. CS_{CTMT}
  5. $I2_{CTMT}$
  6. CSI_{CTMT}
- Where meaningful, Pearson correlation coefficient was evaluated



- VVER-1000
- Guillotine LOCA + SBO
- Only in-vessel phenomena studied

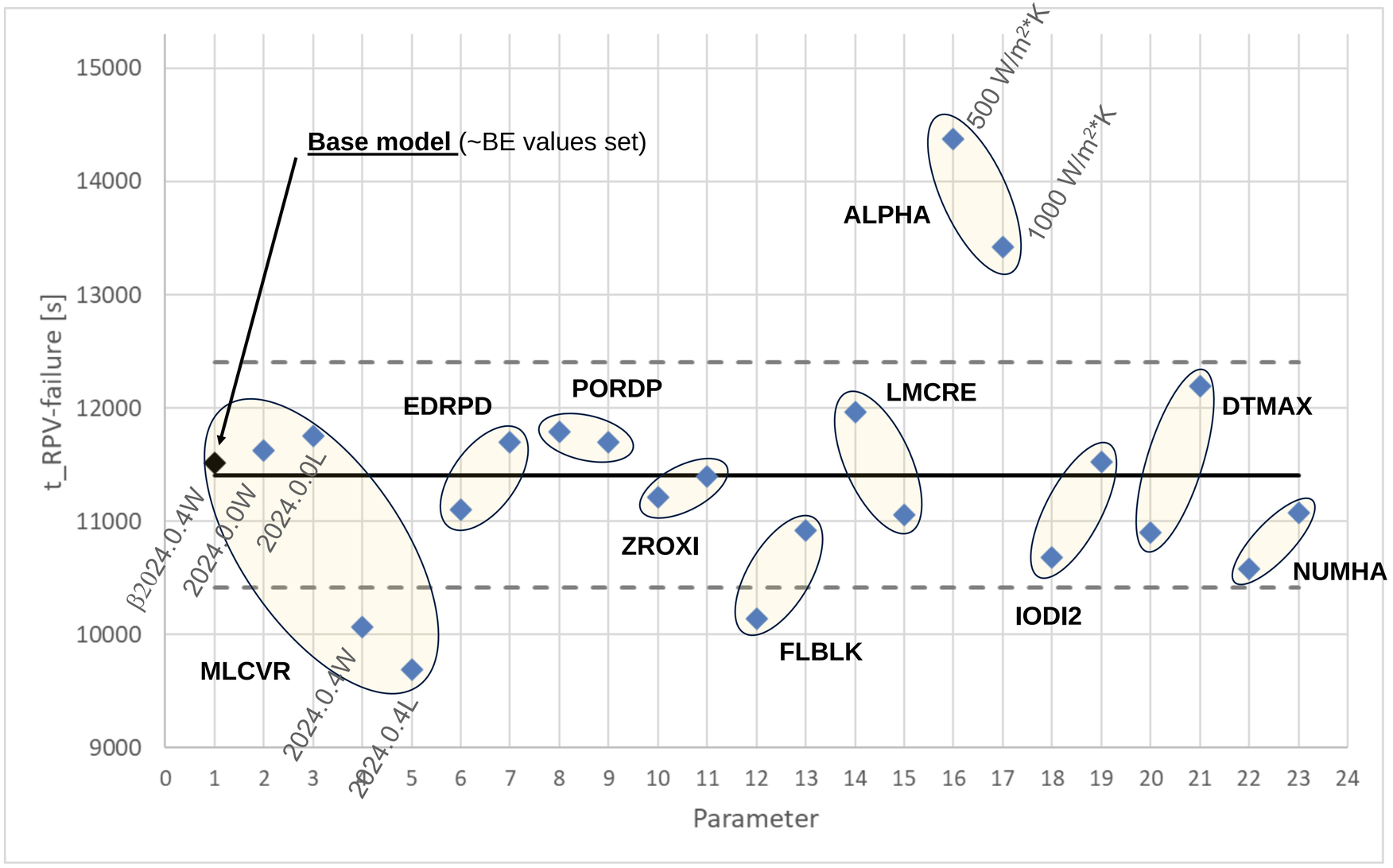


VARIED PARAMETERS

Base model (~BE values set)

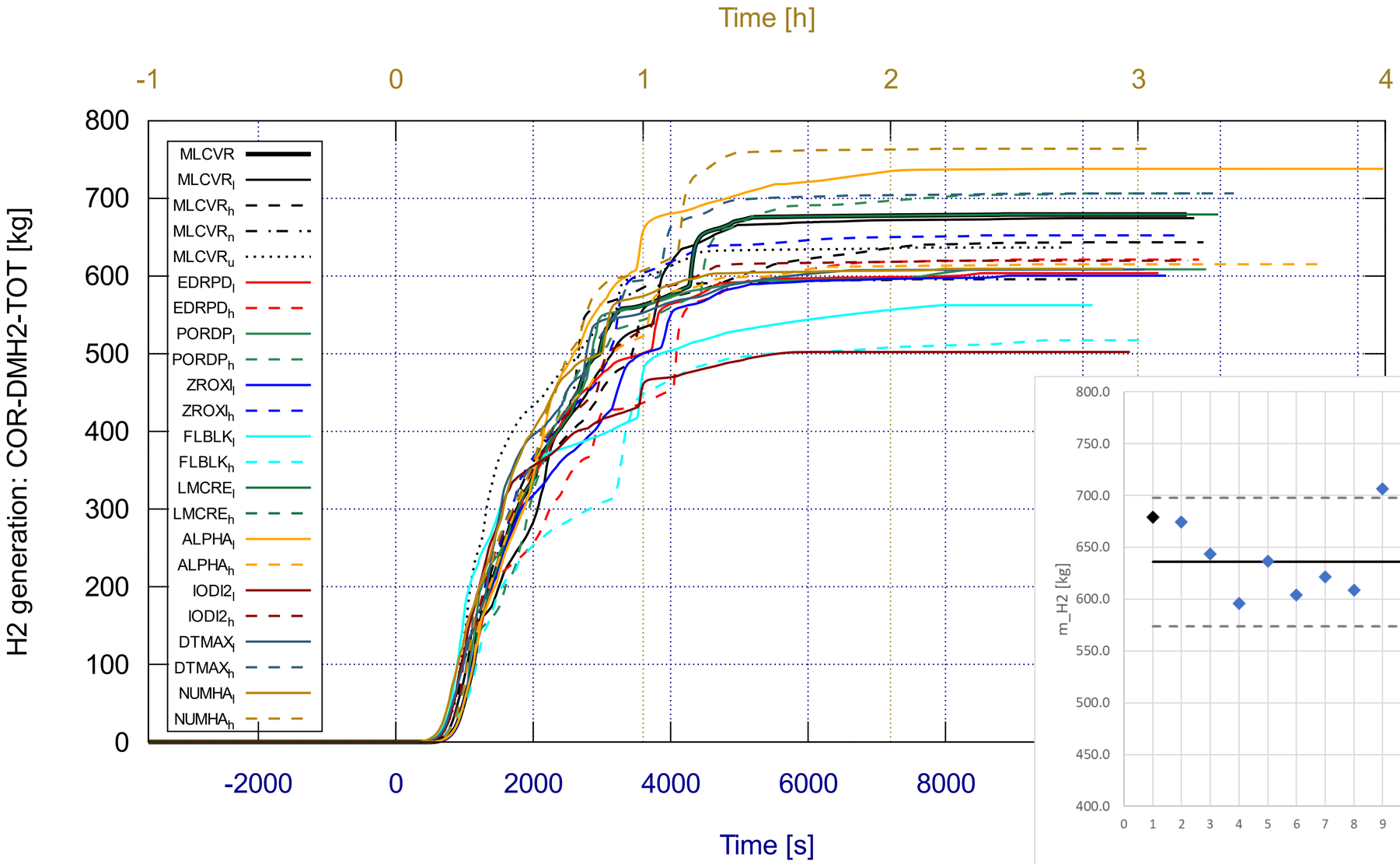
#	Parameter	Interpretation	Type	Base	"Decreased"	"Increased"	Alternative_1	Alternative_2
1	**MLCVR**	MELCOR version; [-]	NUMERICS	**β-r2024.0.4 W**	r2024.0.0 W	r2024.0.0 L	r2024.0.4 W	r2024.0.4 L
2	**EDRPD**	Debris hydraulic diameter, [m]	MODEL	**0.025**	0.015	0.04		
3	**PORDP**	Debris porosity, [-]	MODEL	**0.5**	0.4	0.6	0.4	
4	**ZROXI**	Zr oxidation correlation; [various]	BC	**A_l=29.6** **B_l=16820** **A_h=87.9** **B_h=16610** **T_l=1853** **T_h=1873**	A_l=159 B_l=19150 A_h=98.25 B_h=17290 T_l=1773 T_h=1773.1	A_l=30.802 B_l=16970 A_h=4297 B_h=23270 T_l=1800 T_h=1800.1		
5	**FLBLK**	FL blockages induced by COR, [-]	MODEL	**FL_r13_RPV_12-14**	No blockages	FL_r13_RPV_12-13 FL_r15_RPV_14-15 FL_r17_RPV_16-17 FL_r19_RPV_18-19 FL_r21_RPV_20-21 FL_r23_RPV_22-23 FL_r25_RPV_24-25		
6	**LMCRE**	Larson-Miller creep model parameters, [various]	BC	**A=-9373** **B=101562** **C=22.276** **D=0.18**	A=-4725 B=48120 C=7.042 D=0.18	A=-5335 B=62291.3 C=16.44 D=0.18		
7	**ALPHA**	HTC between PD/MP1,2 <=> LH, [W/(m^2*K)]	MODEL	**"MODEL"**	500	1000		
8	**IODI2**	Ratio of iodine in I2 class, [%]	BC	**1.56**	CSI <= CS & I2	3		
9	**DTMAX**	Δt_{max}, [s]	NUMERICS	**0.05**	0.001	1		
10	**NUMHA**	# of available HAs, [-]	BC	**4**	2	3	2	

TIME OF RPV FAILURE

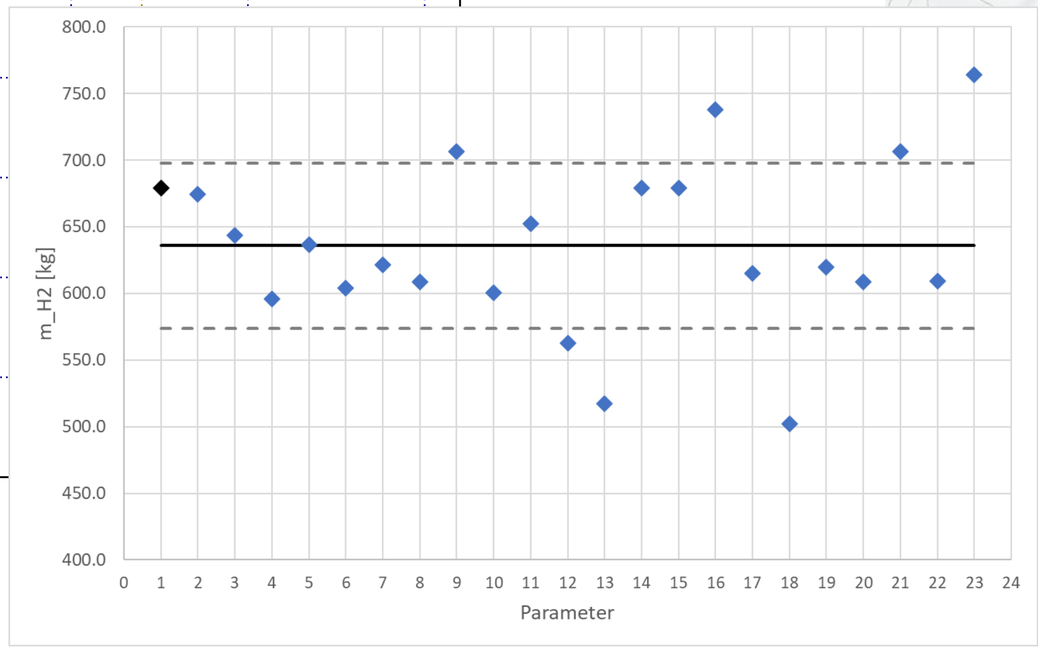


μ=11409 s
σ=993 s

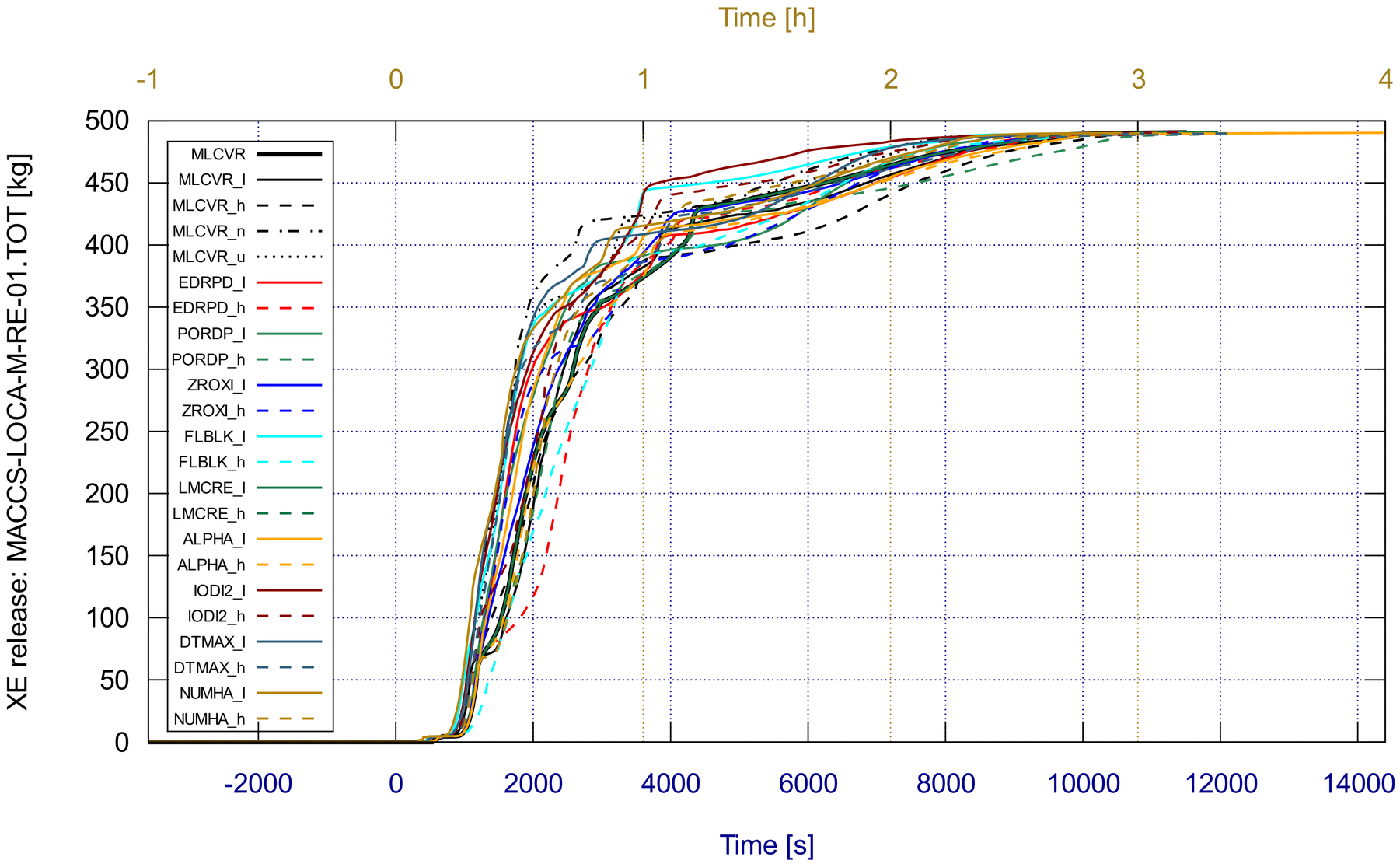
HYDROGEN PRODUCTION



μ=636 kg
σ=62 kg

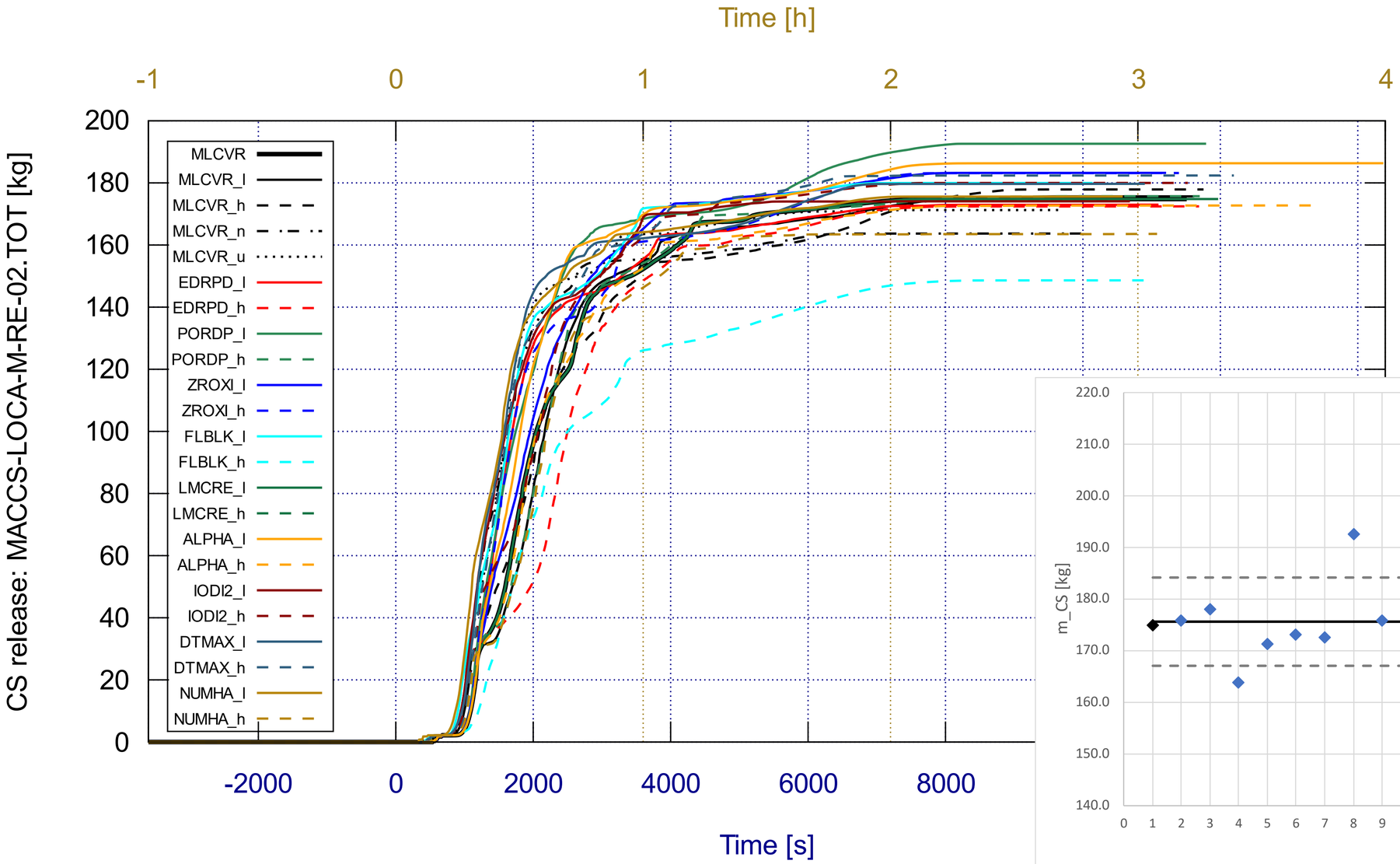


XE RELEASE INTO CTMT

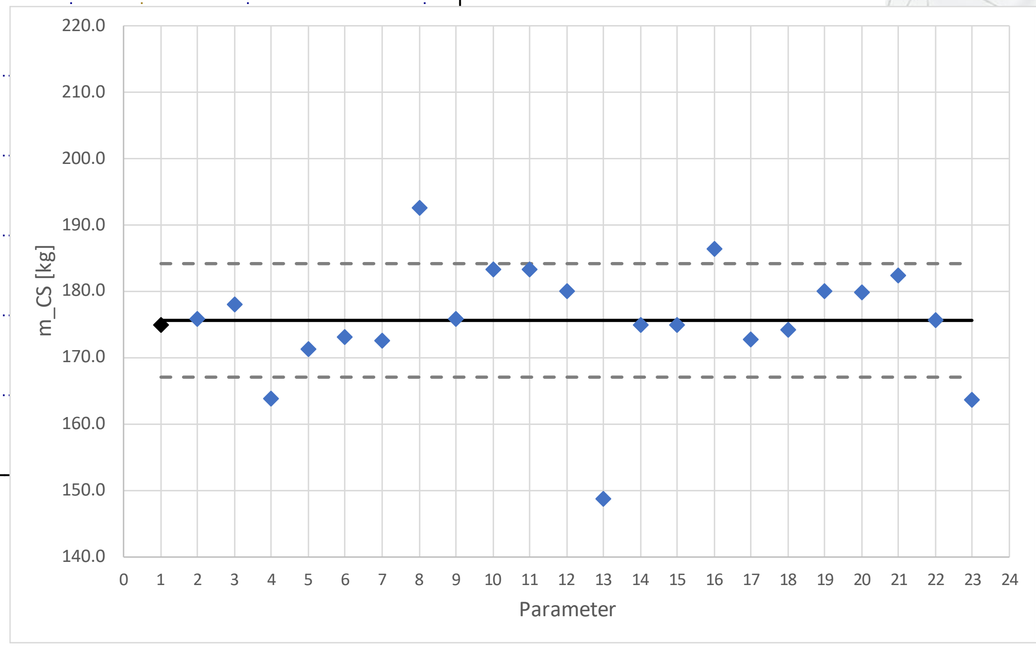


μ=490 kg
σ=0.5 kg

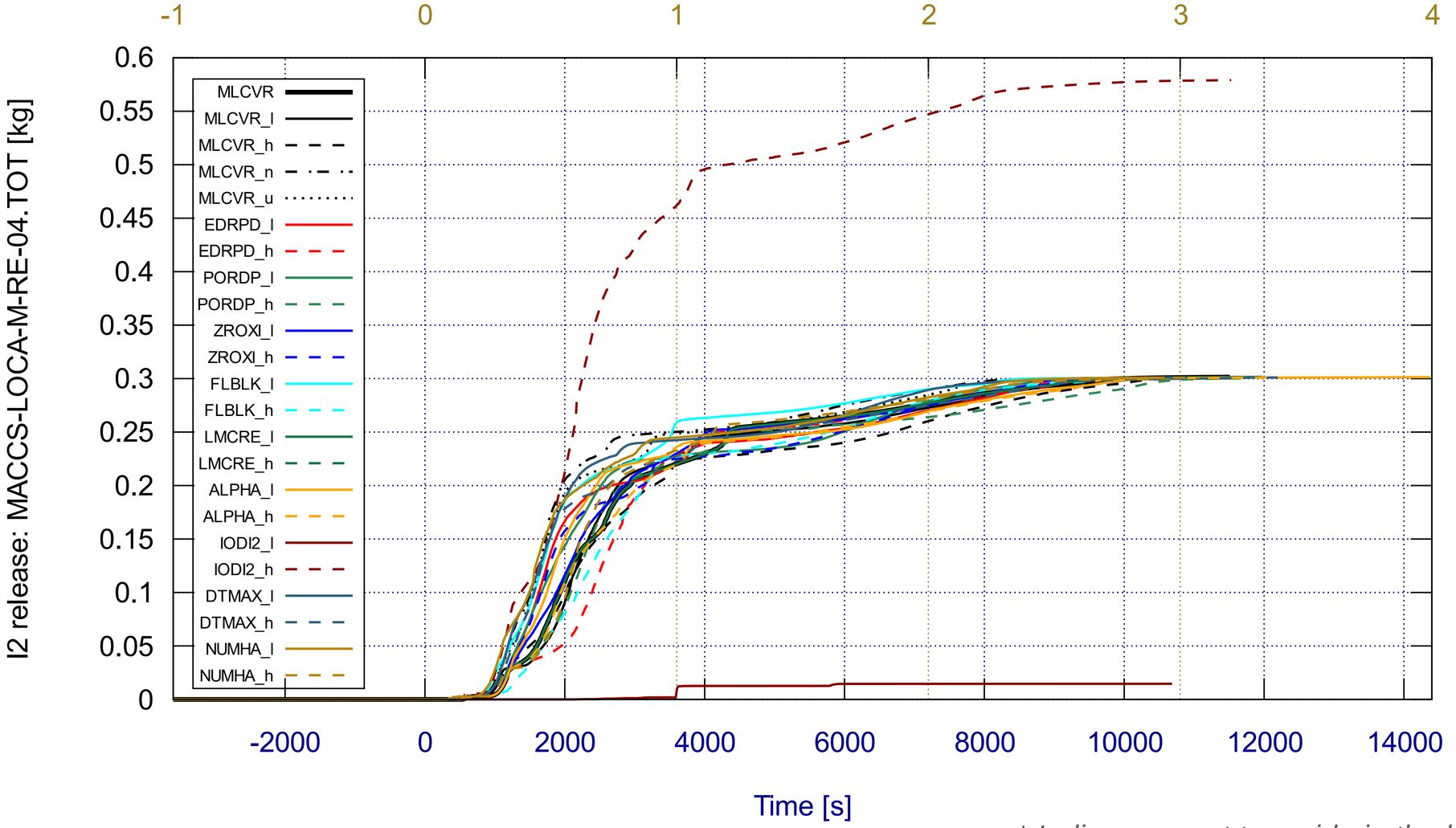
CS RELEASE INTO CTMT



μ=175 kg
σ=8.5 kg

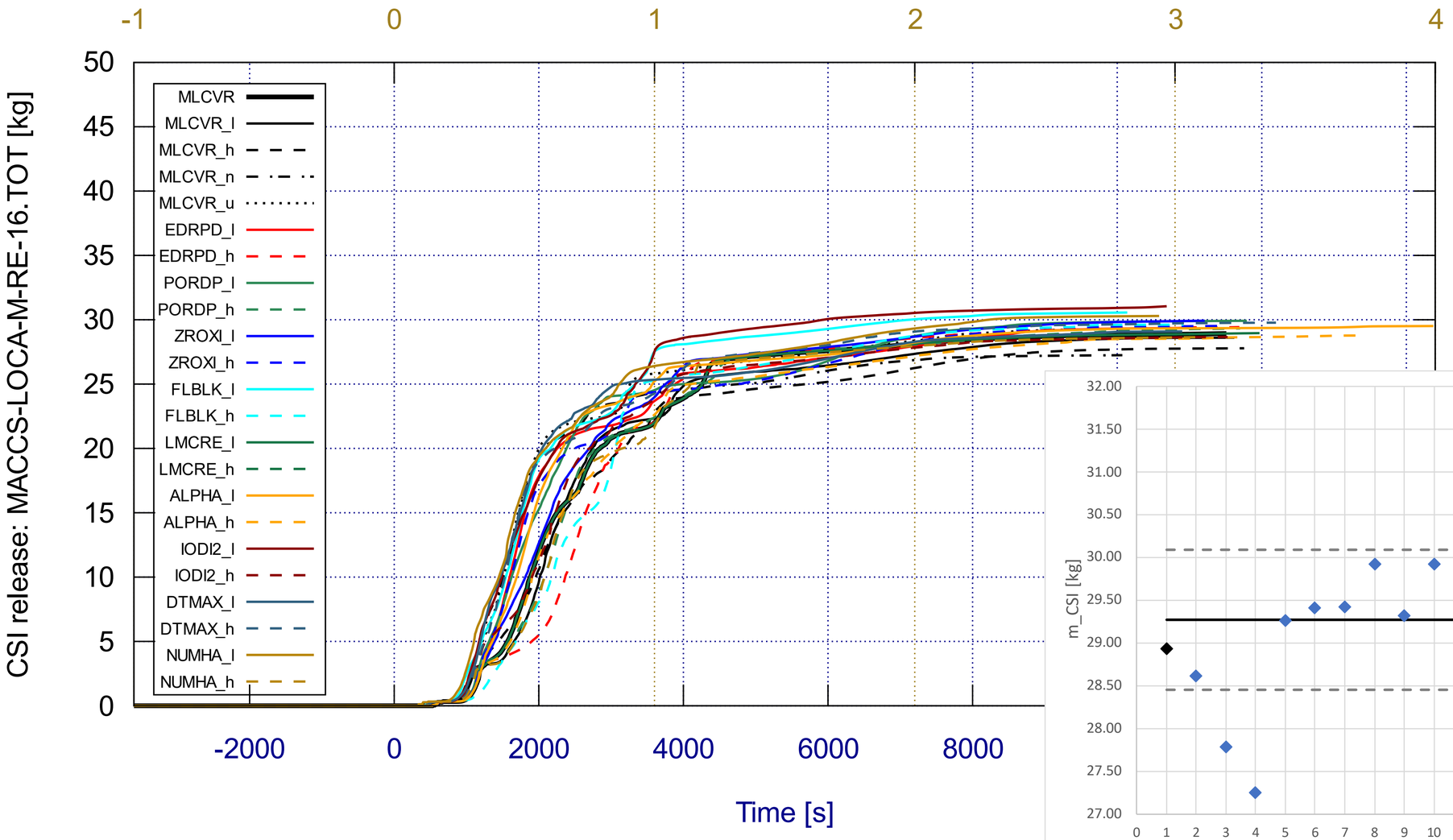


I2 RELEASE INTO CTMT

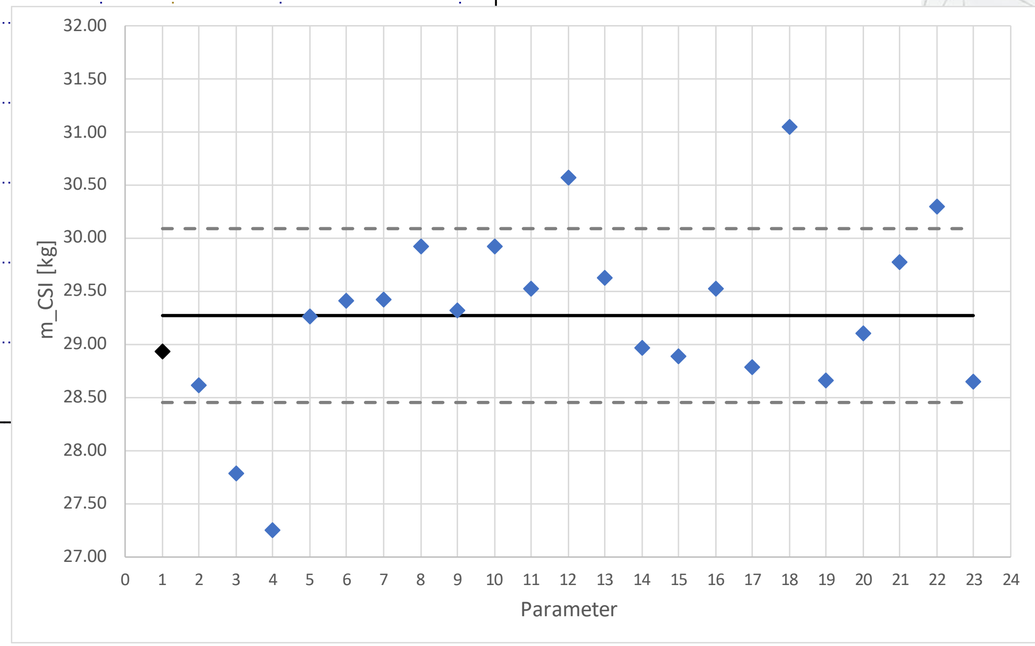


** Iodine was set to reside in the halogens (I2) class at a firm fraction 1.5 % (CsI creation suppresed)*

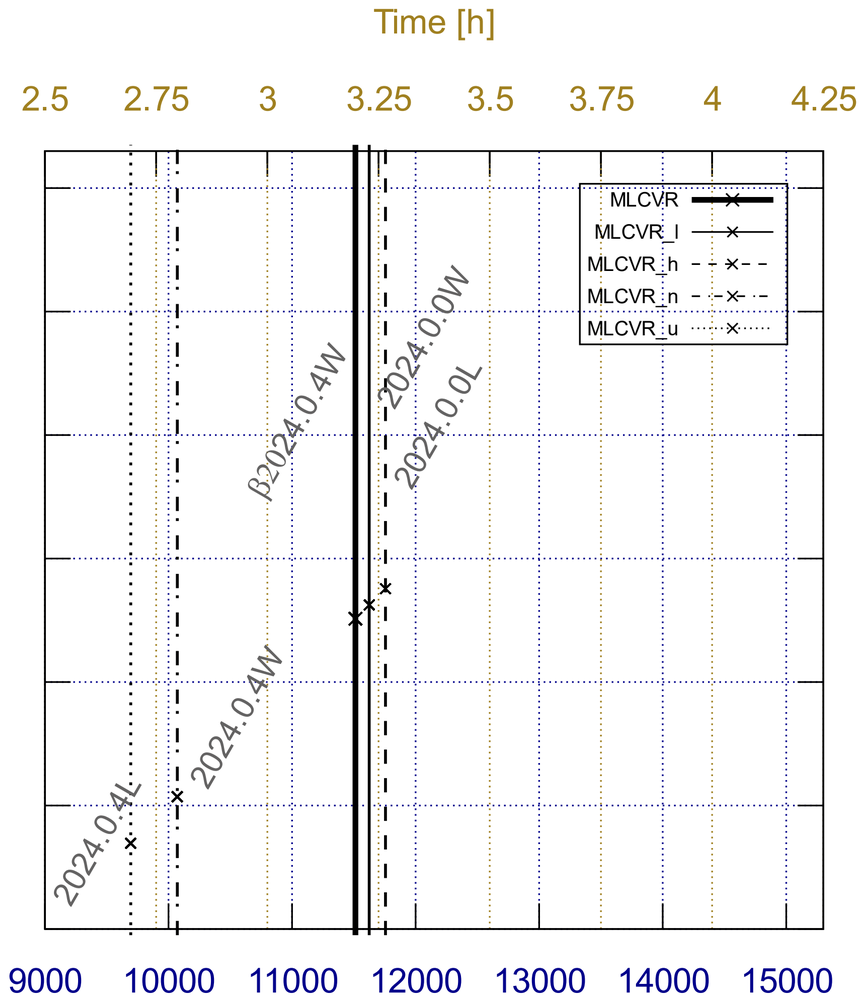
CSI RELEASE INTO CTMT



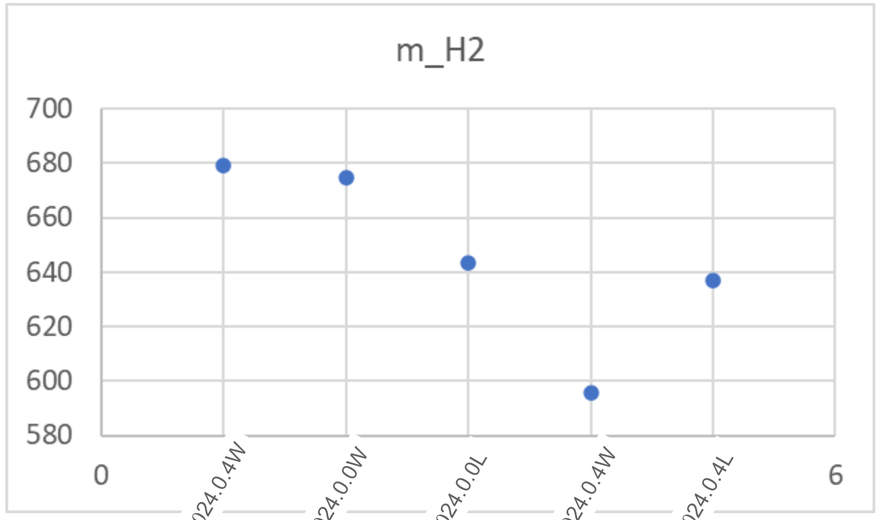
μ=29.3 kg
σ=0.8 kg

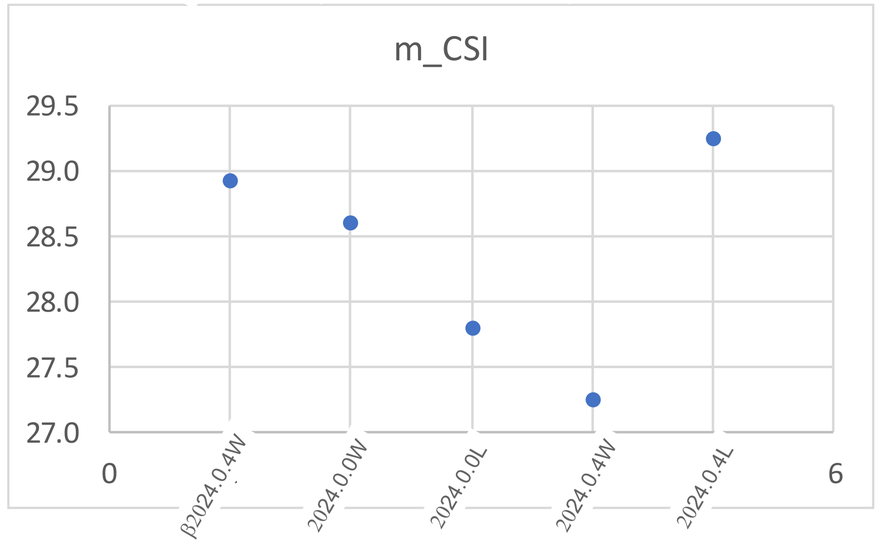


EXAMPLE: MELCOR VERSION

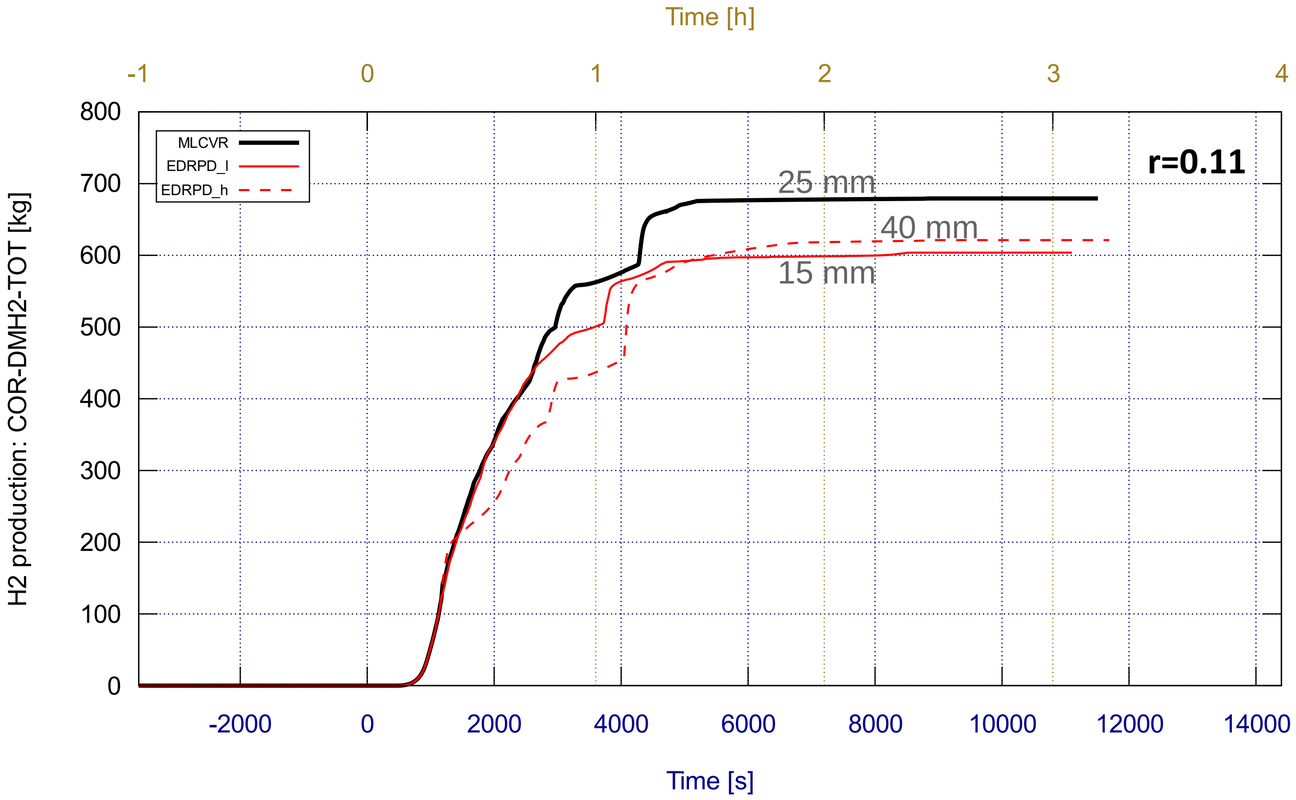


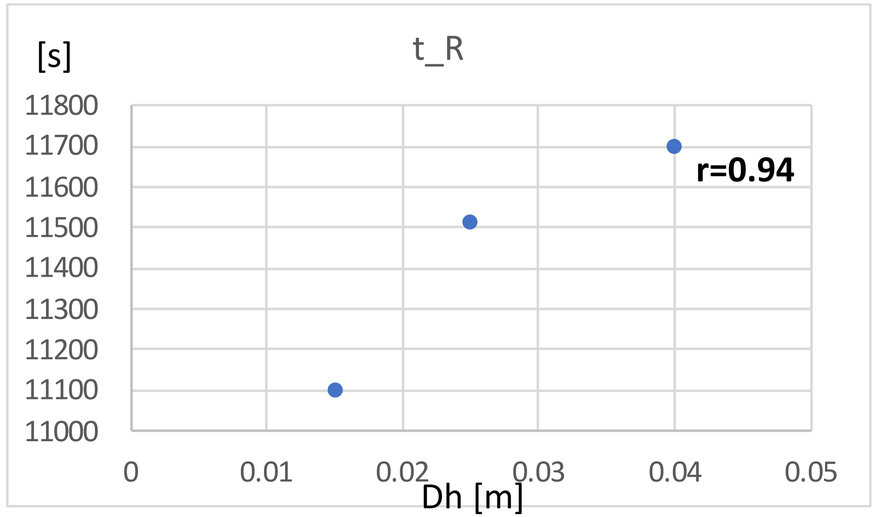
RPV failure time: t_R [s]

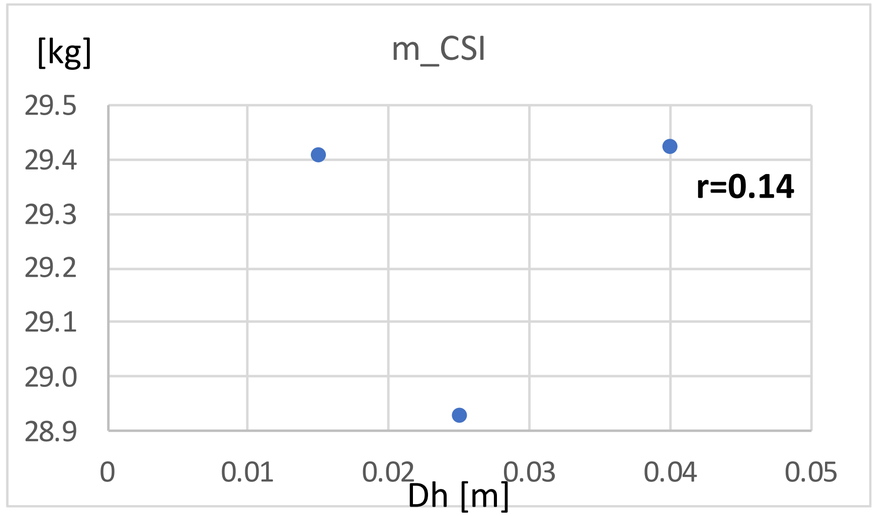




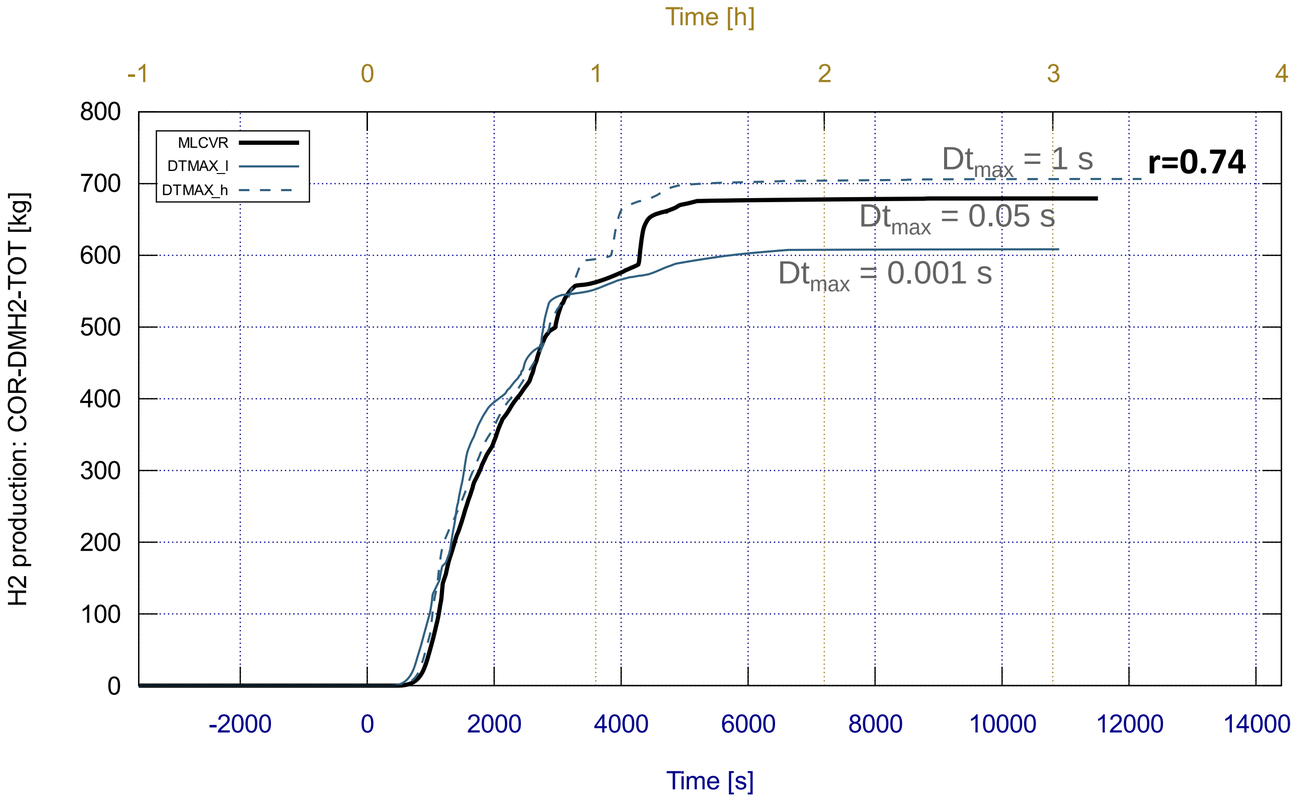
EXAMPLE: DEBRIS HYDRAULIC DIAMETER

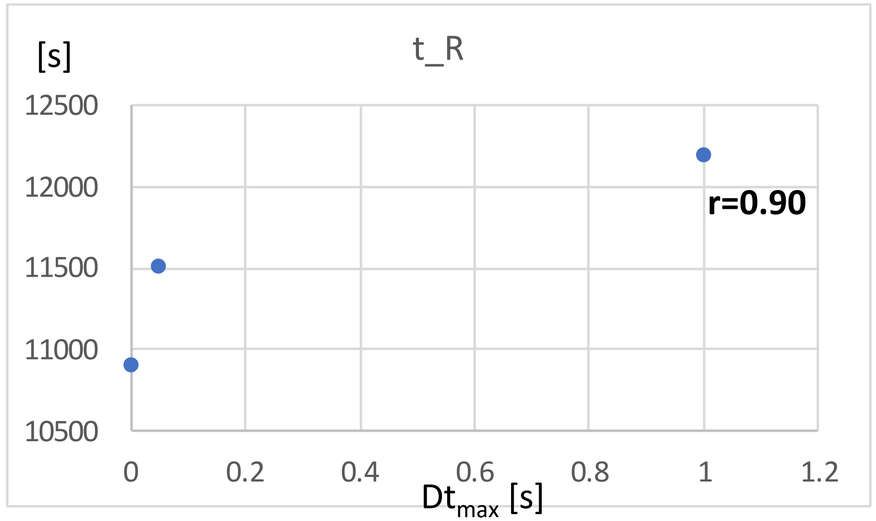


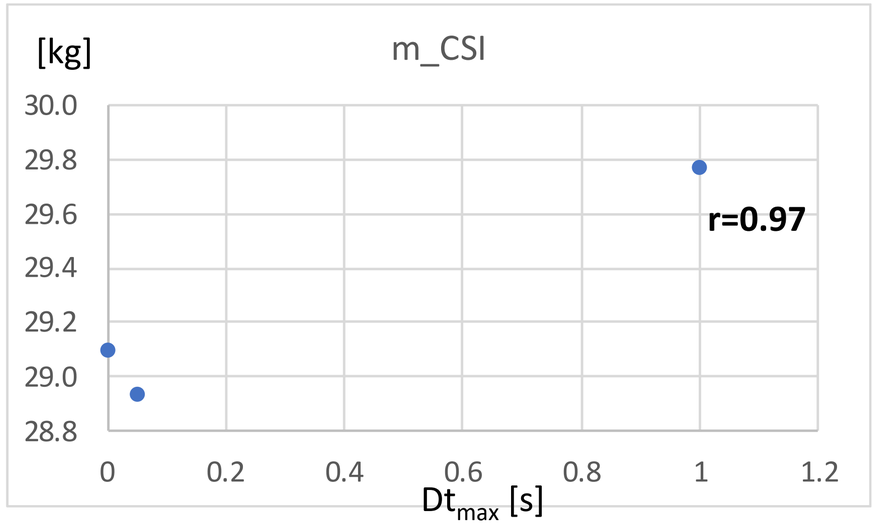




EXAMPLE: MAXIMUM ALLOWED TIME-STEP







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WATER LEVELING

RELATIVE ELEVATIONS

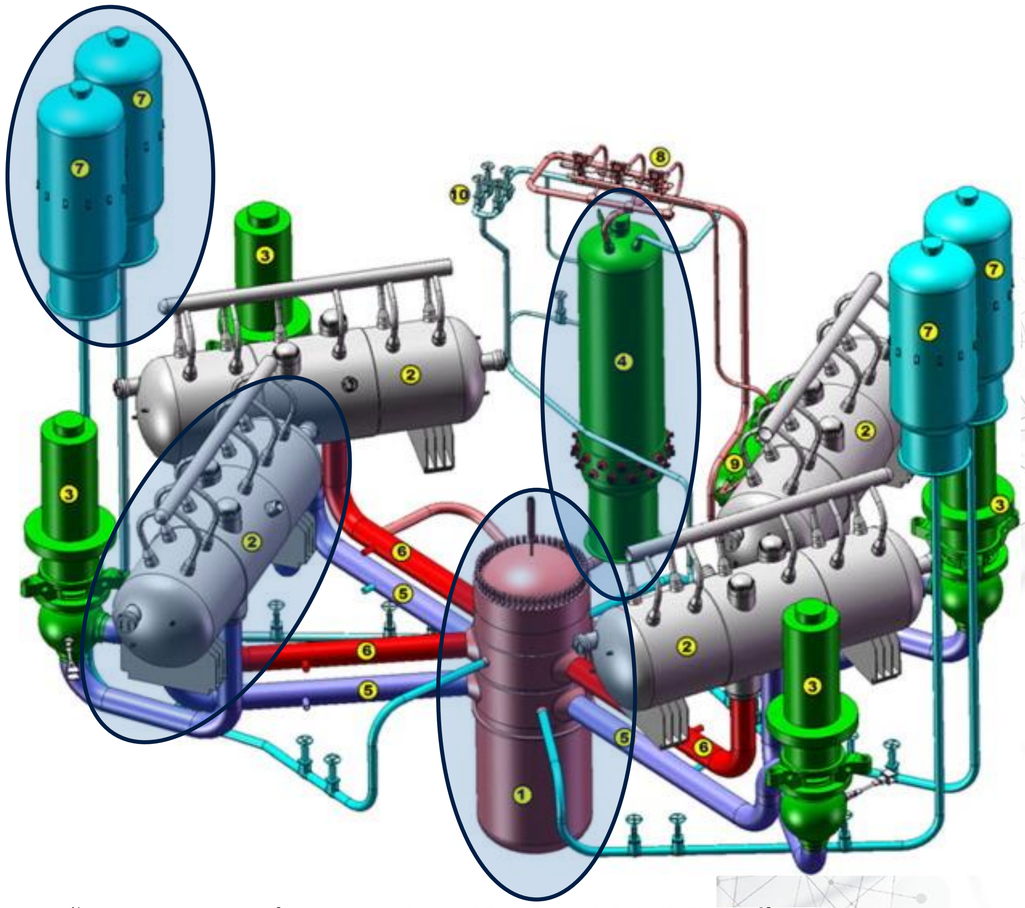
- More useful to track water elevations within a component
  - Can be done using CFs (EQUALS, ADD, FORMULA, …):

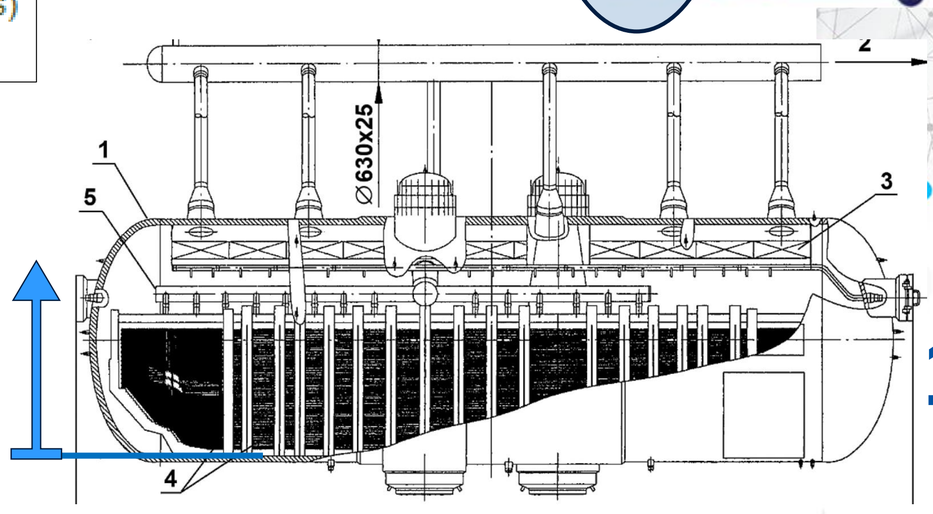
```
CF_ID     'LW-SCSG1P1'     4511     'FORMULA'
CF_SAI    1.0 0.0   2.55276
CF_FORMULA   2          (WLEV-BOTT)
1          WLEV          CVH-LIQLEV('CVH_511')
2          BOTT          11.257
```

  - However, for RPV, COR-WLEVEL is not a CF-argument!!!

COR-WLEVEL	Water level in COR package (channel volumes) (Units = m, default =ON)

  - Thus, a CF was written to track water level within the RPV (in the innermost channel of the core) – see next slide:



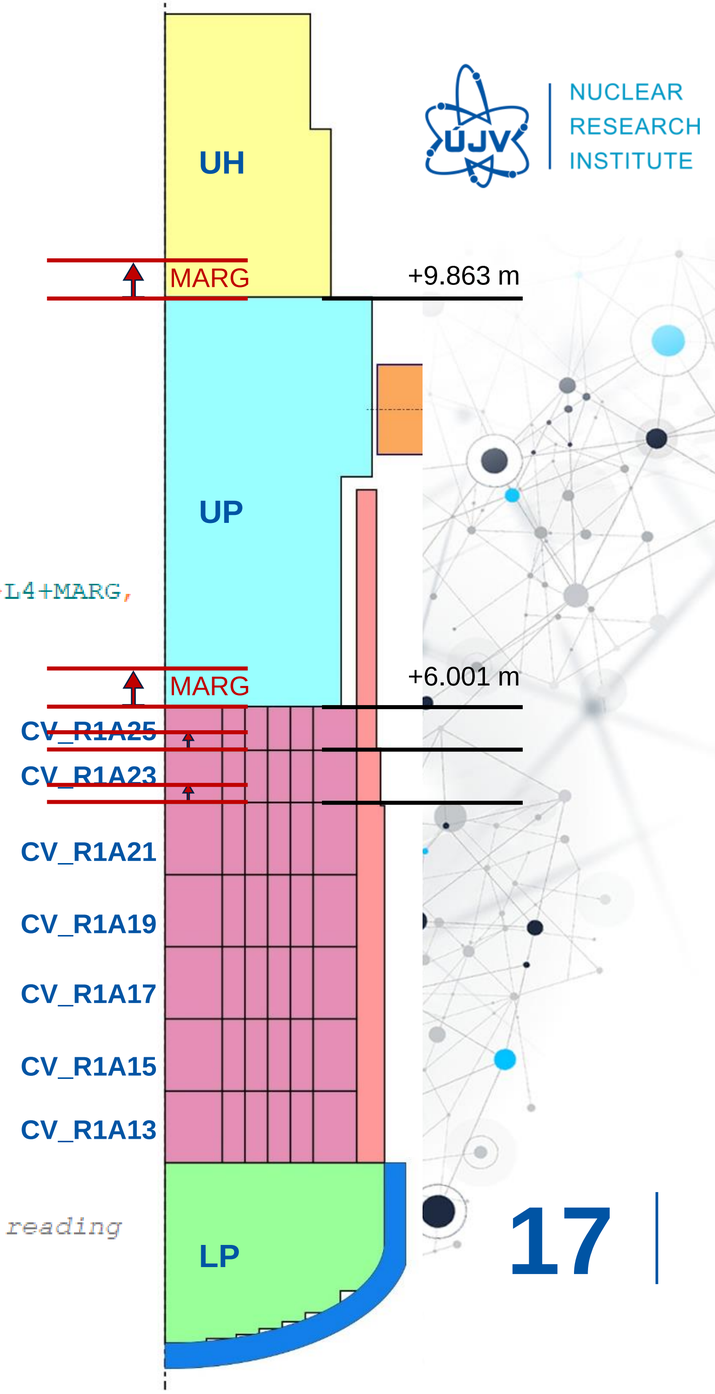


NESTED ‚L-A-IFTE‘ CONDITIONS

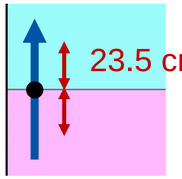
```
CF_ID    'LW-UH'      4099     'FORMULA'
CF_SAI   1.0 0.0   12.533
CF_FORMULA  2         (WLEV-BOTT)
1         WLEV         CVH-LIQLEV('CVH_099')
2         BOTT         0.244
```

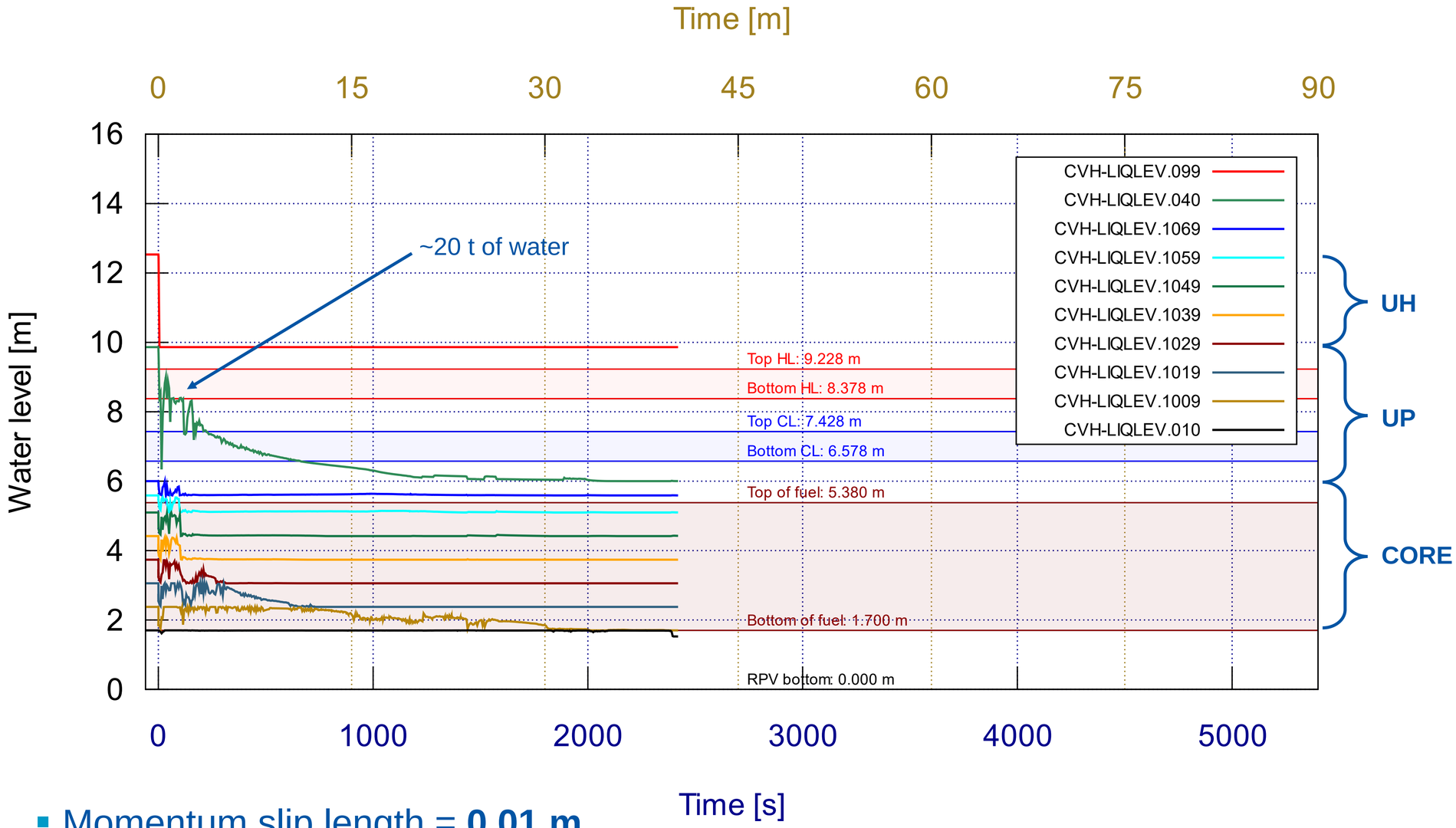
```
CF_ID    'LW-RPV'     4110     'FORMULA'
CF_SAI   1.0 0.0   12.533
CF_FORMULA  20        L-A-IFTE(LW1>L1+MARG,LW1,L-A-IFTE(LW2>L2+MARG,LW2,L-A-IFTE(LW3>L3+MARG,LW3,L-A-IFTE(LW4>L4+MARG,
1             LW1          CF-VALU('LW-UH')
2             L1           9.863                    ! UH bottom elevation plus 1 cm margin
3             LW2          CF-VALU('LW-UP')
4             L2           6.001                    ! UP vessel bottom elevation plus 1 cm margin
5             LW3          CF-VALU('LW-R1A25')
6             L3           5.589                    ! Core 25th axial level bottom elevation
7             LW4          CF-VALU('LW-R1A23')
8             L4           5.097                    ! Core 23rd axial level bottom elevation
9             LW5          CF-VALU('LW-R1A21')
10            L5           4.417                    ! Core 21st axial level bottom elevation
11            LW6          CF-VALU('LW-R1A19')
12            L6           3.737                    ! Core 19th axial level bottom elevation
13            LW7          CF-VALU('LW-R1A17')
14            L7           3.057                    ! Core 17th axial level bottom elevation
15            LW8          CF-VALU('LW-R1A15')
16            L8           2.377                    ! Core 15th axial level bottom elevation
17            LW9          CF-VALU('LW-R1A13')
18            L9           1.70                     ! Core 13th axial level bottom elevation
19            LW10         CF-VALU('LW-LP')
20            MARG         0.01                     ! Margin for upper volume minimum water level to switch for reading
```

1 cm



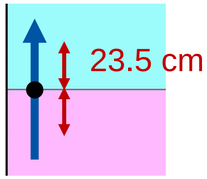
WATER LEVELS (G-LOCA)

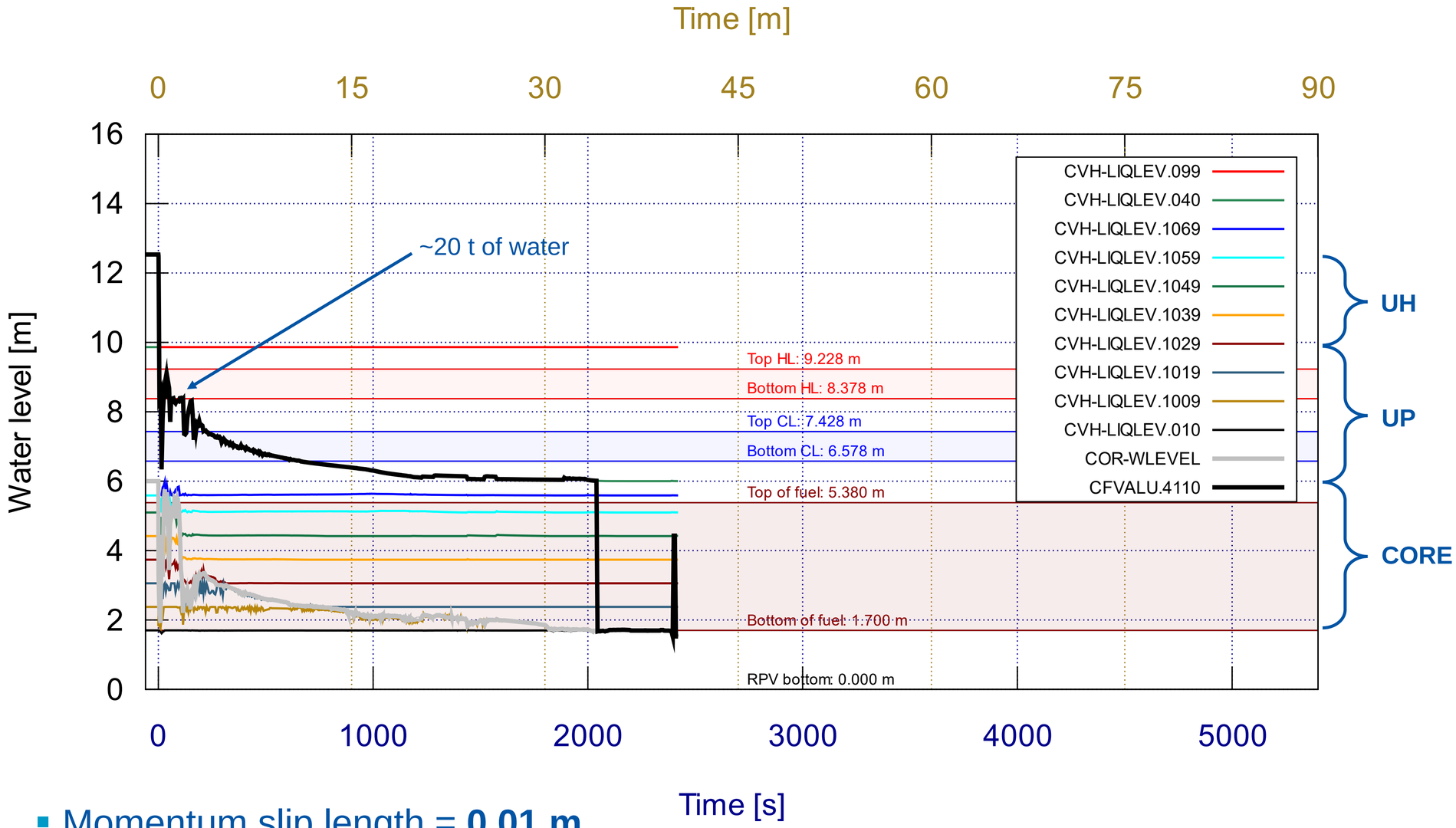




- Momentum slip length = **0.01 m**

CALCULATED WATER LEVEL (G-LOCA)





- Momentum slip length = **0.01 m**

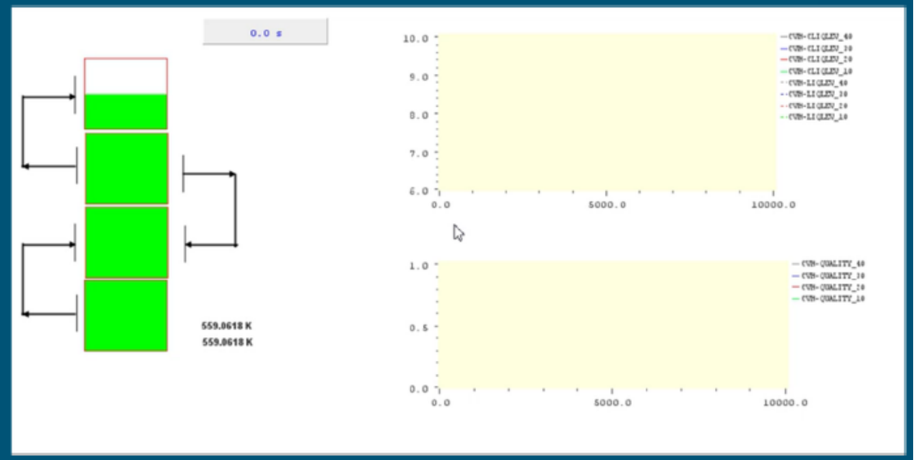
RECOMMENDATION (EMUG 2023)

27

CVH Modeling – User Choice of Junction Elevations and Opening Heights for Vertically Stacked CVs

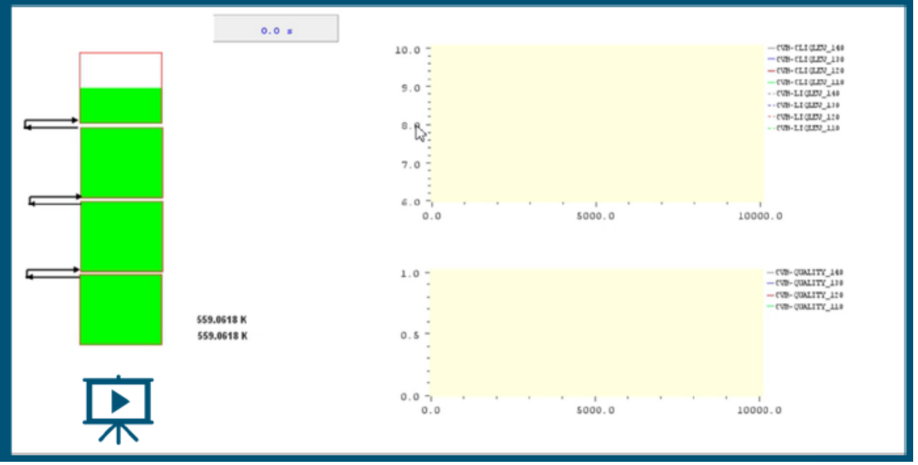
Setting FP junction elevation to midpoint of CV more representative of forced flow boiling

- Leads to layering of pool and atmosphere
- MELCOR lacks a flow regime map



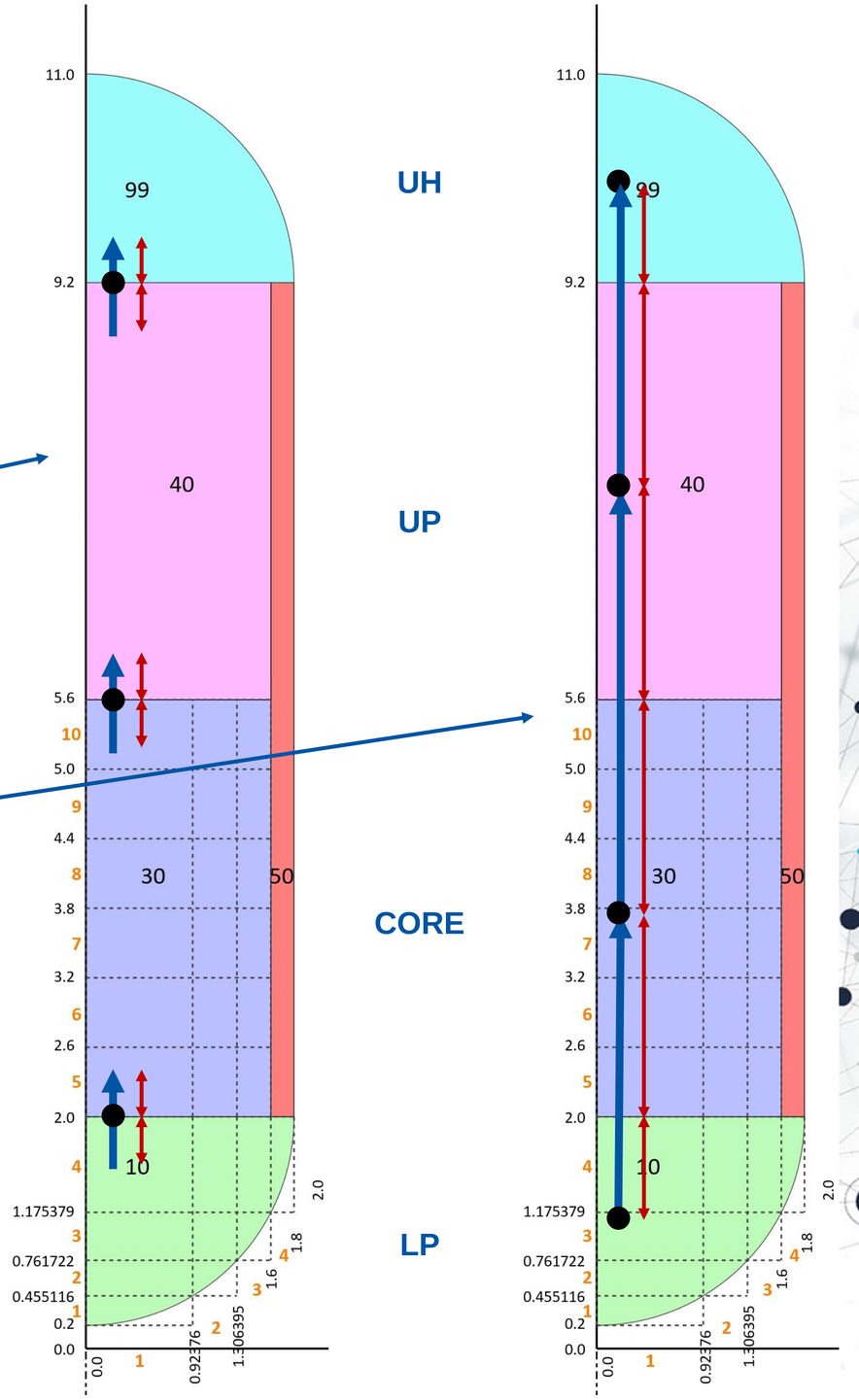
Setting FP Junction Elevation to top/bottom elevation is more representative of quiescent boiling

- Eliminates layering of pool/atmosphere



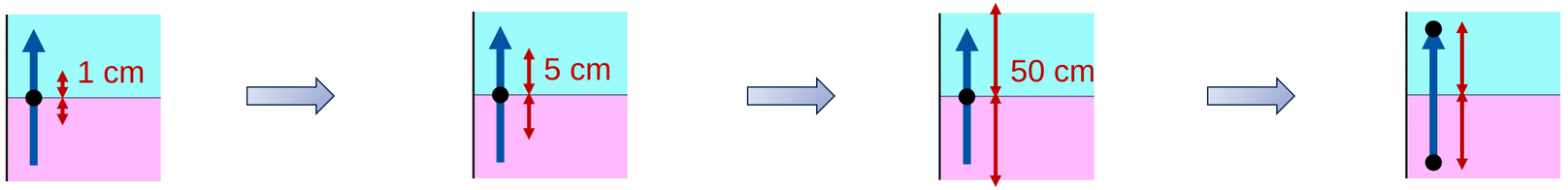
SIMPLE PWR MODEL TESTING

- 4 sets of FL definitions:
  - FLs at the CV‘s interfaces:
    1. FLHGTT/F=**1 cm**
    2. FLHGTT/F= **5 cm**
    3. FLHGTT/F= **50 cm**
  - FL from CVs‘ center to center:
    1. FLHGTT/F=**half of CV height**
- 2 scenarios:
  - Medium Break (Ø100 mm) LOCA – Cold Leg
  - Large Break (Ø346 mm) LOCA – Cold Leg
- CF (L-A-IFTE) written for water elevation

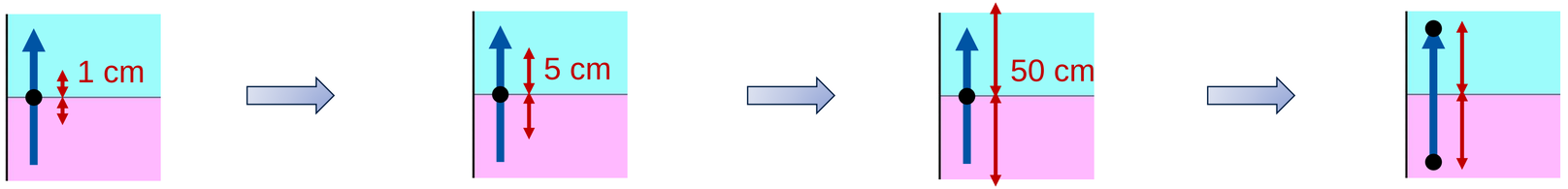


RESULTS PRESENTATION

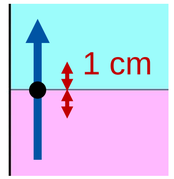
1. MB LOCA



2. LB LOCA



MBLOCA: FLHGT*=1 CM (ELEVATIONS)



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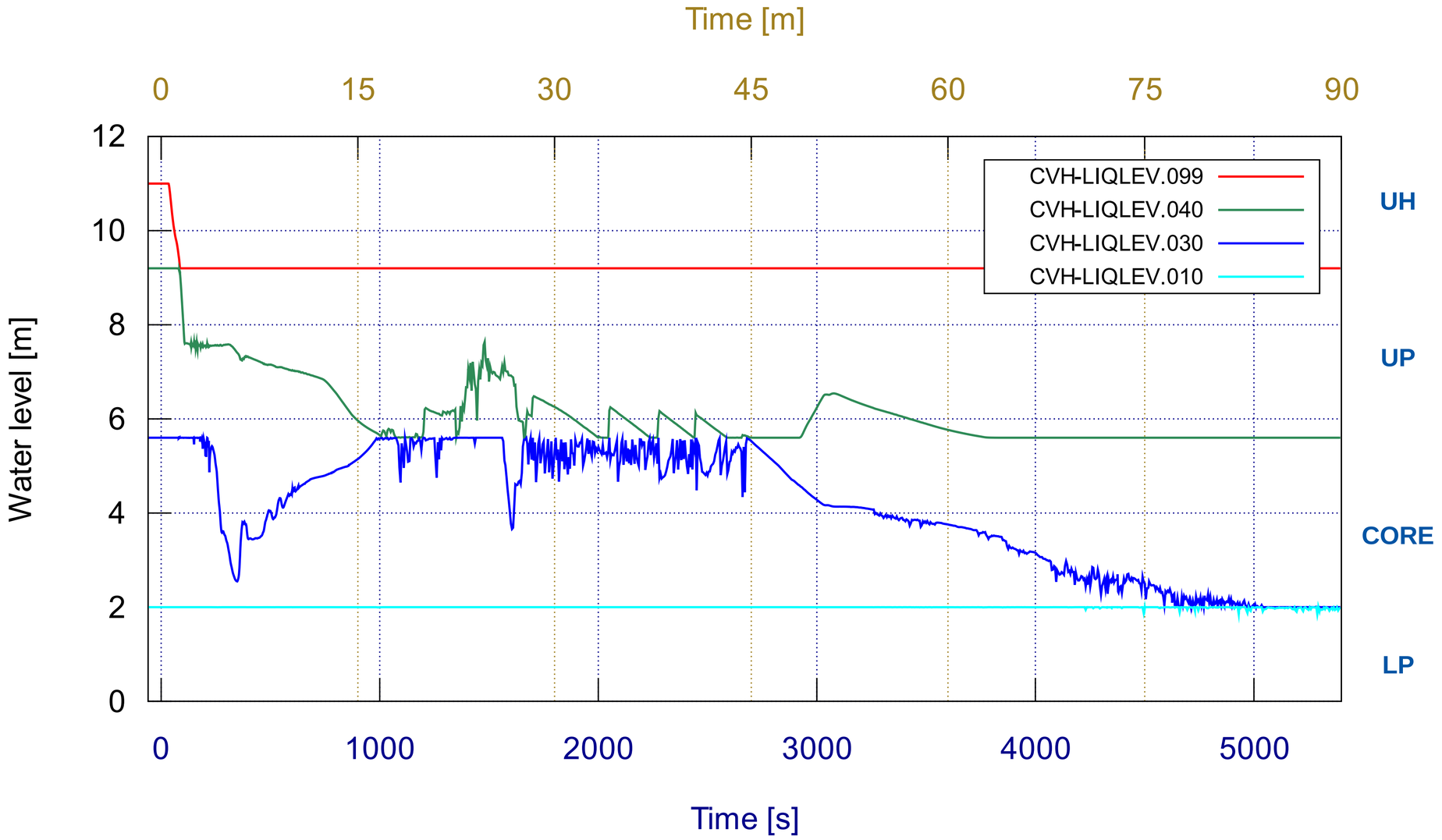
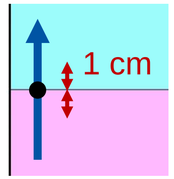


MBLOCA: FLHGT*=1 CM (FUNCTION)



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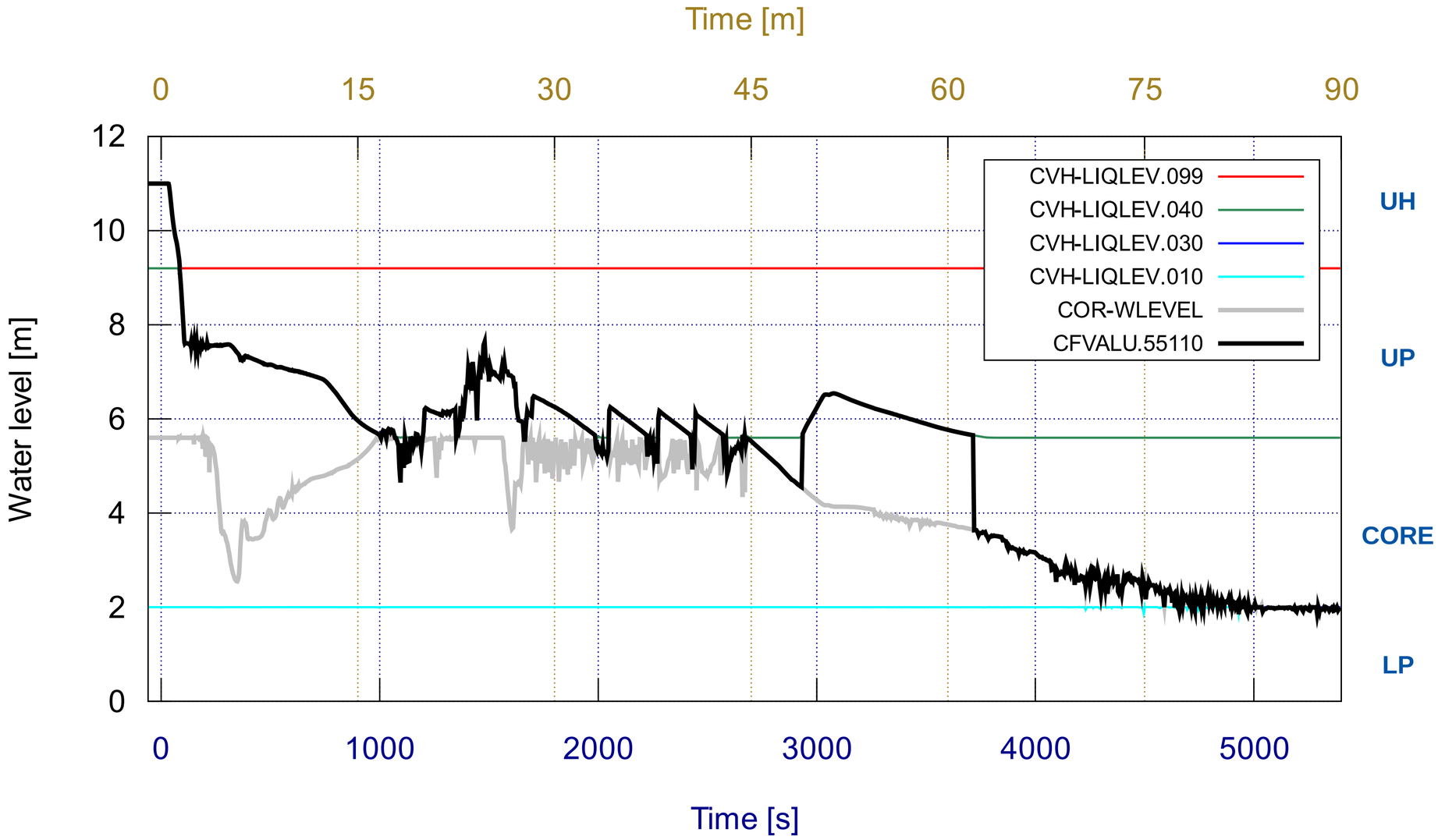
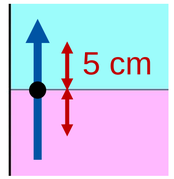


MBLOCA: FLHGT*=5 CM (ELEVATIONS)



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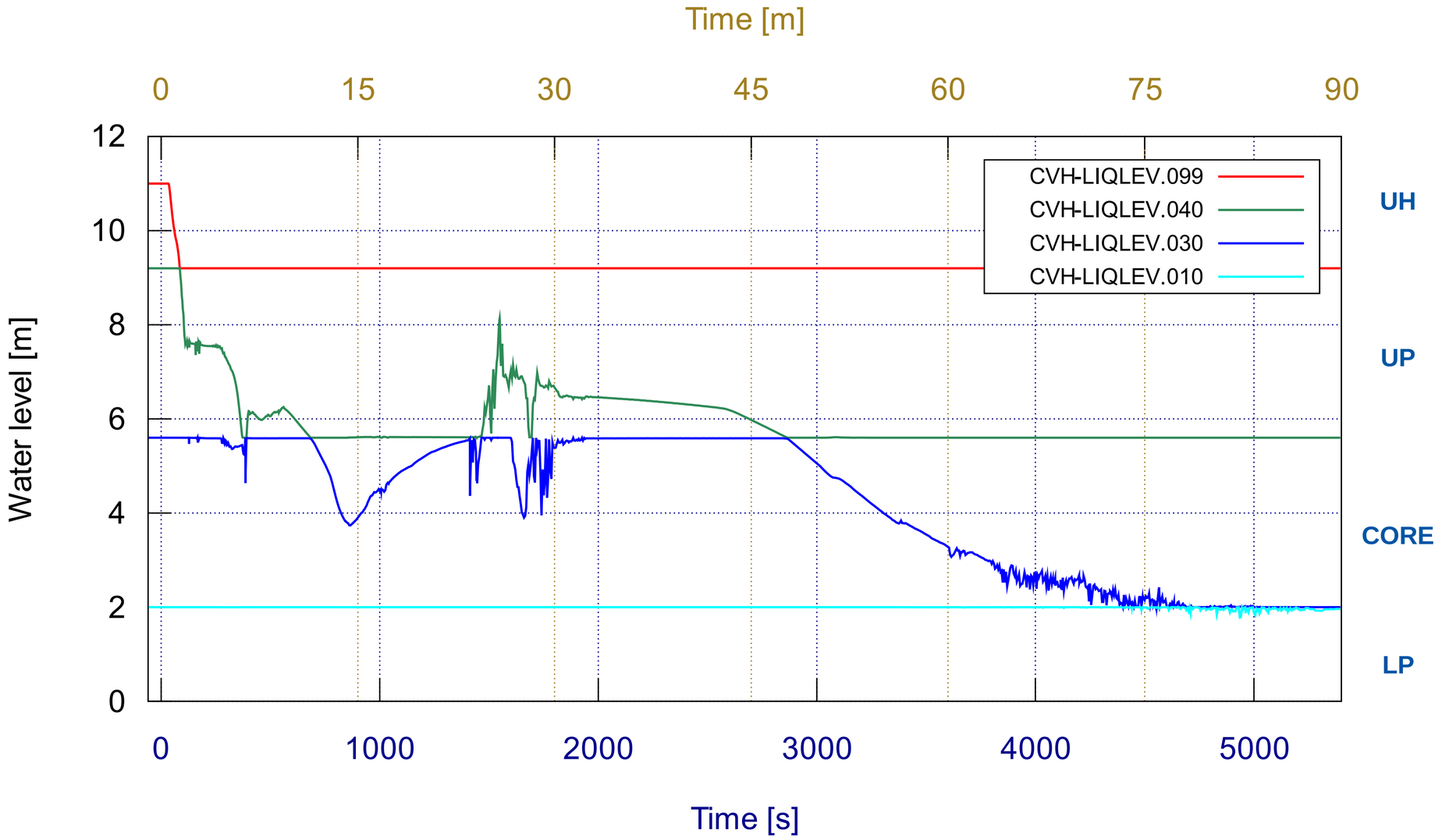
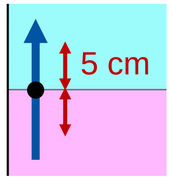


MBLOCA: FLHGT*=5 CM (FUNCTION)



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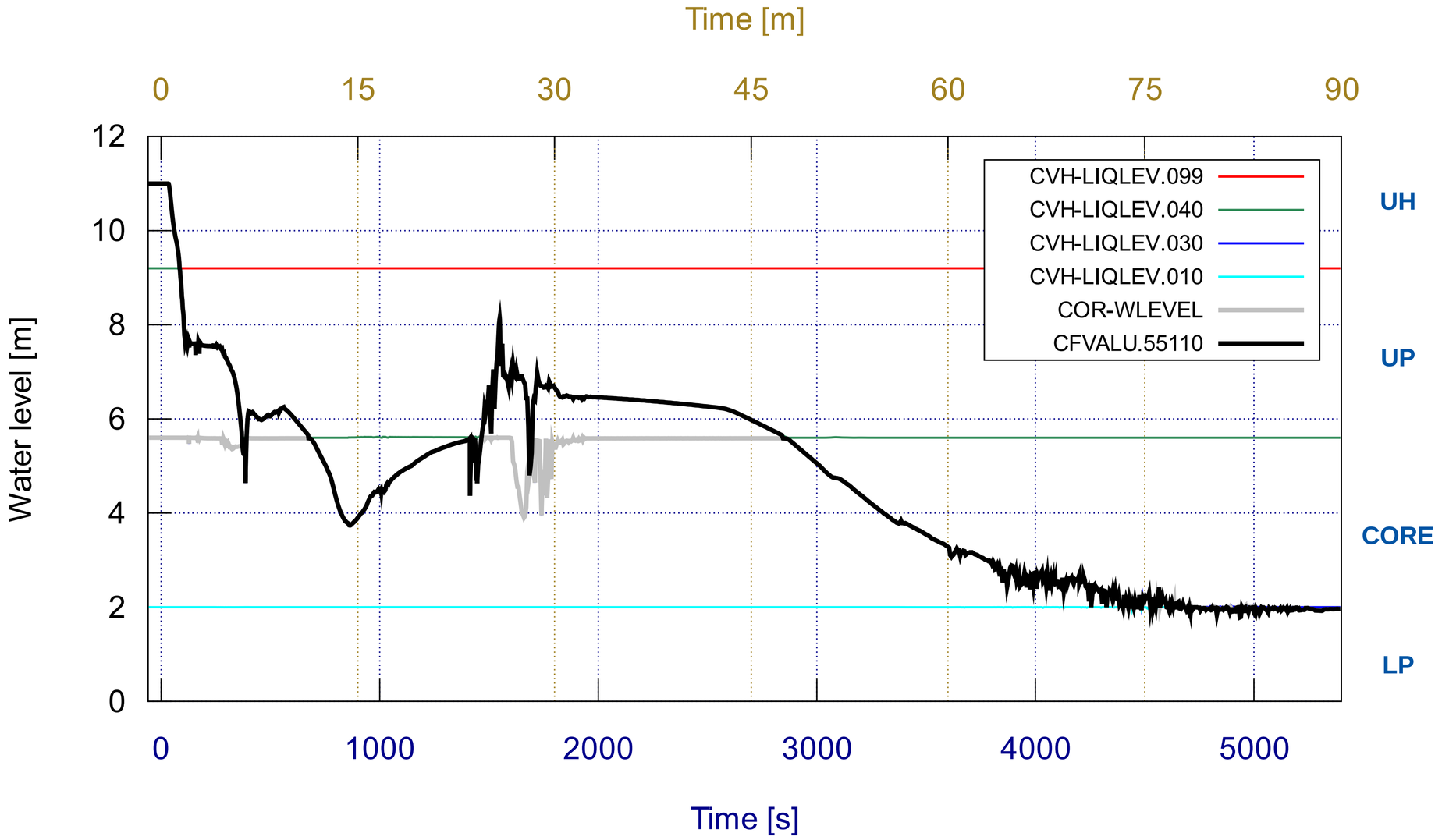
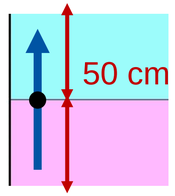


MBLOCA: FLHGT*=50 CM (ELEVATIONS)



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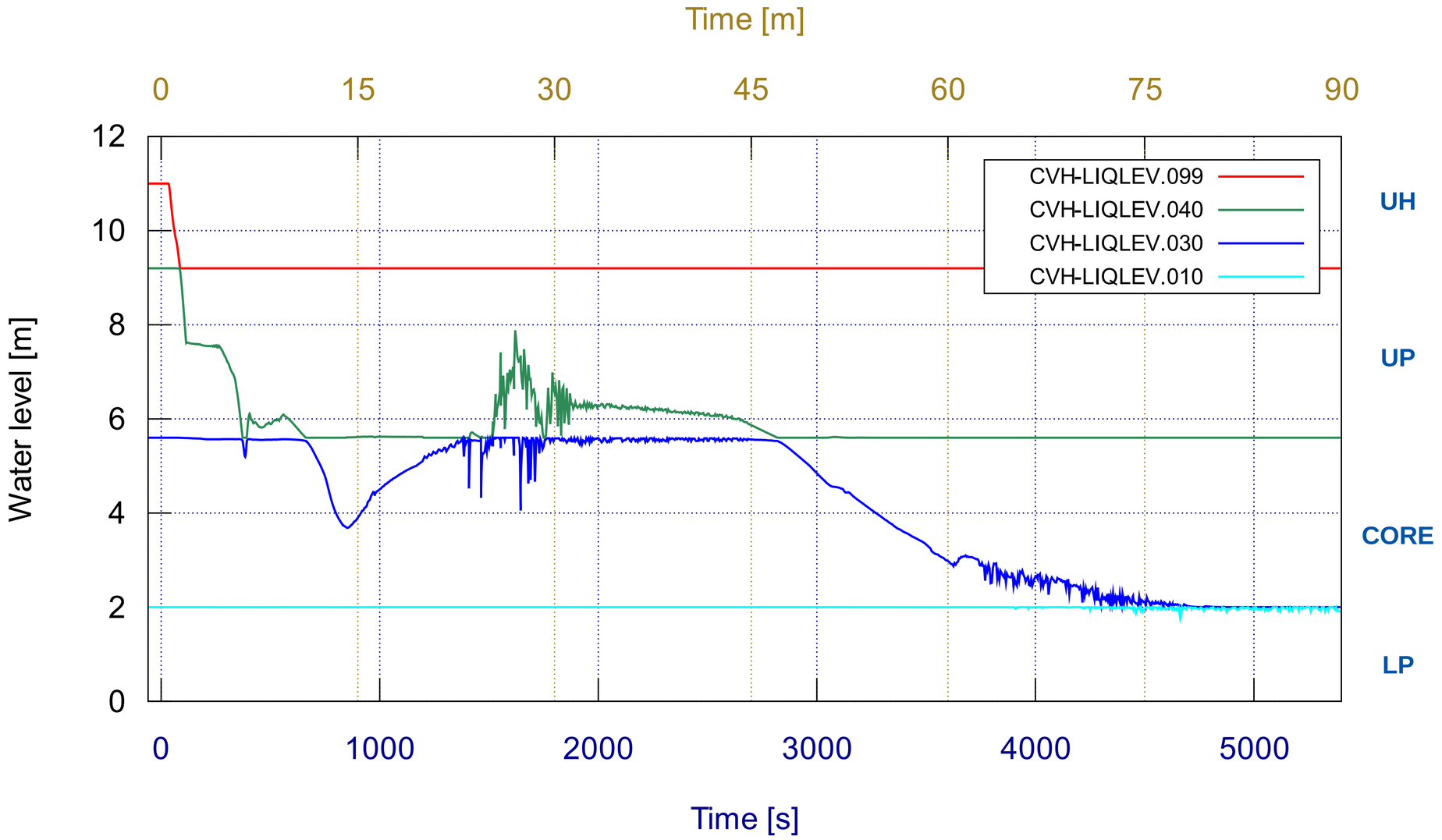
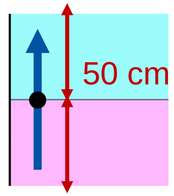


MBLOCA: FLHGT*=50 CM (FUNCTION)



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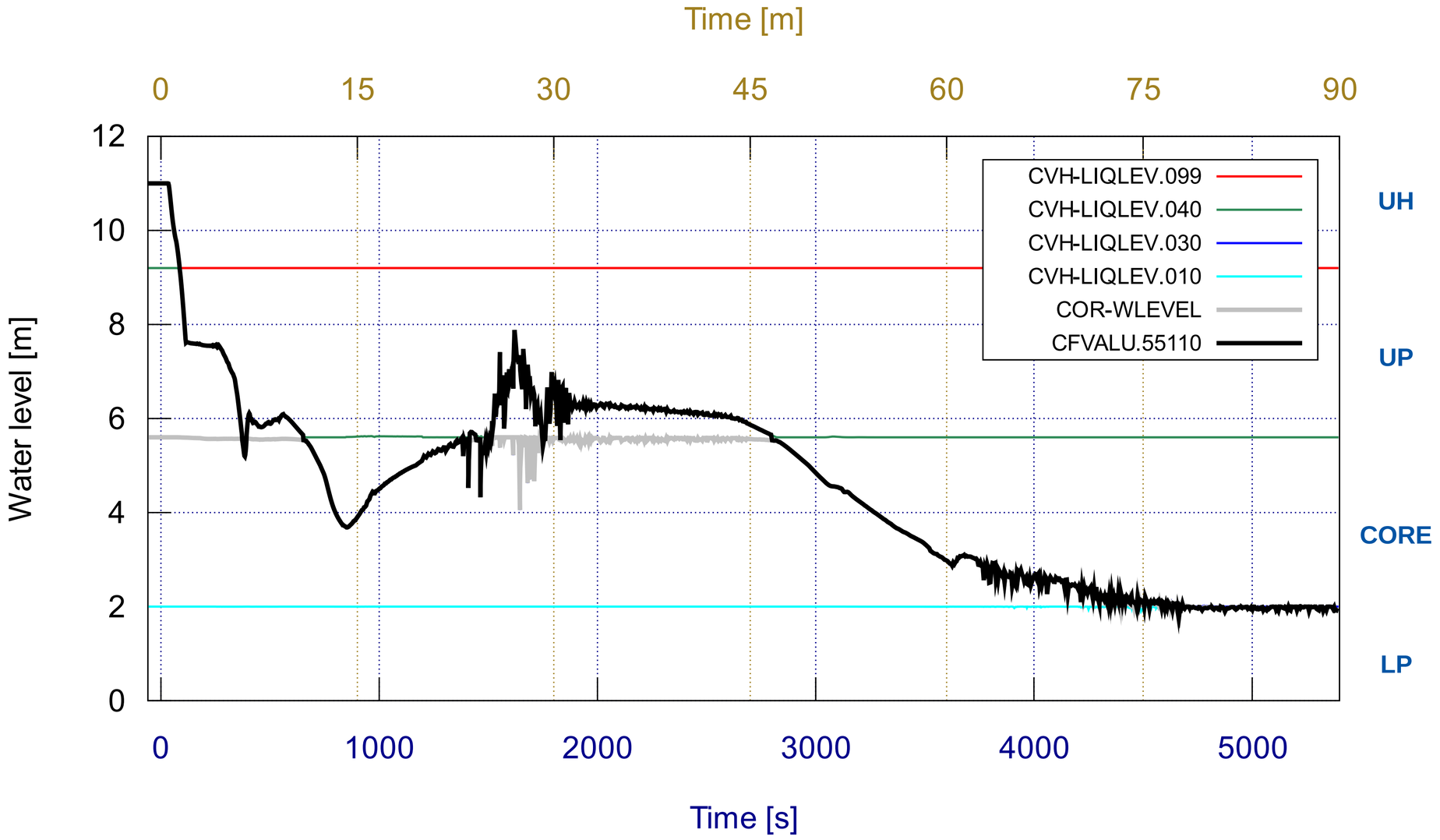
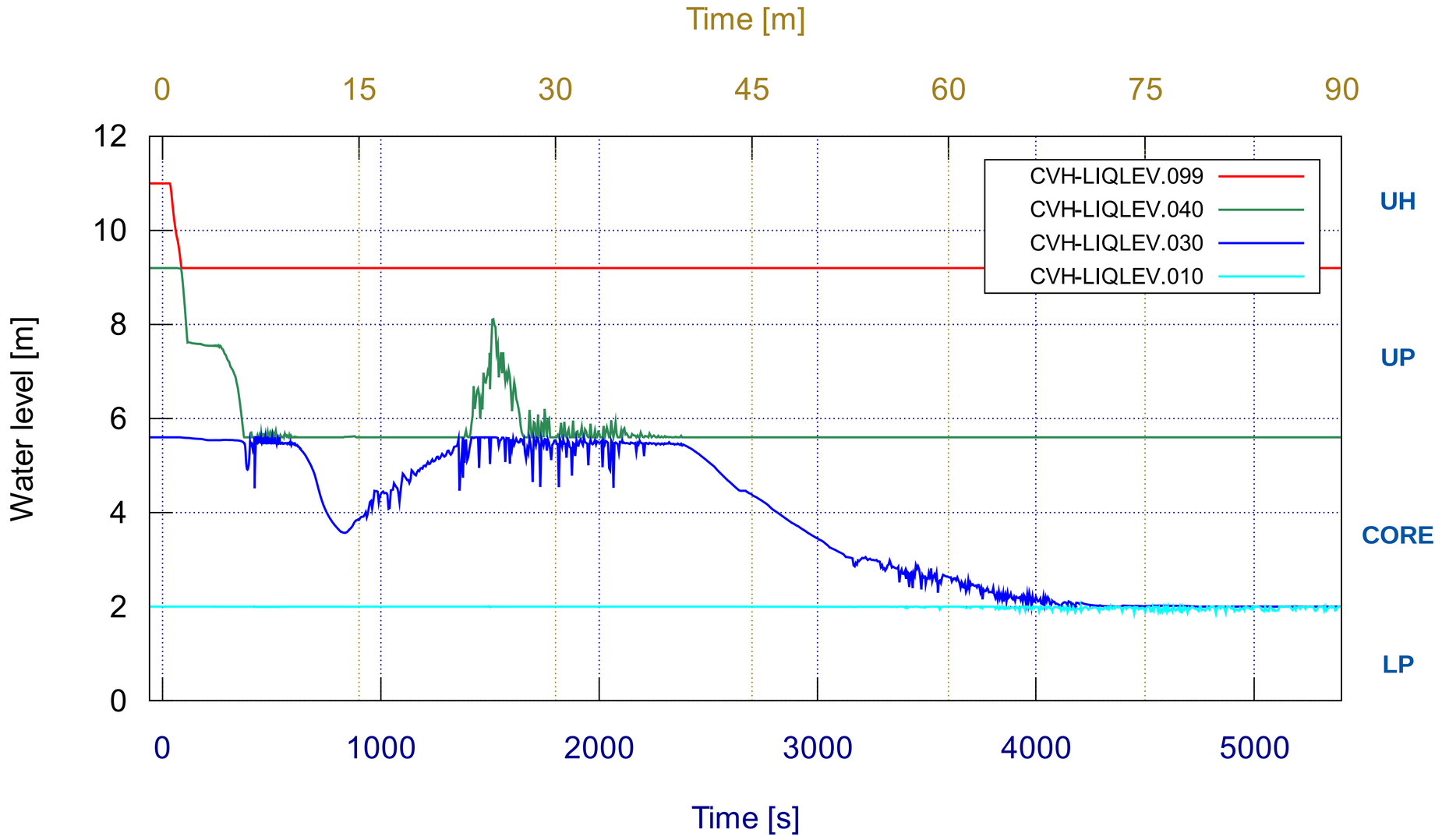
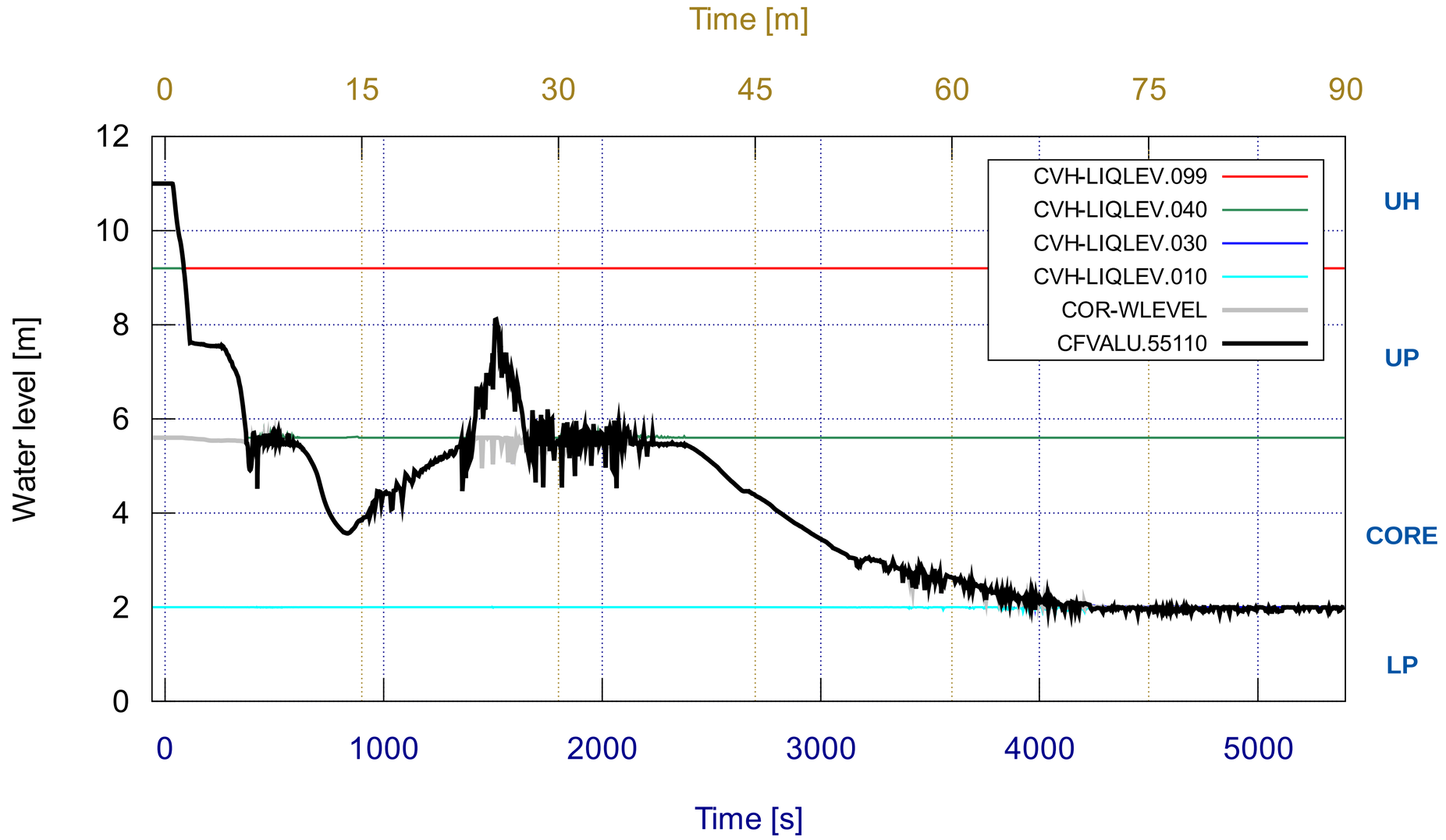


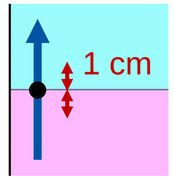
MBLOCA: CENTERS (ELEVATIONS)



MBLOCA: CENTERS (FUNCTION)



LBLOCA: FLHGT*=1 CM (ELEVATIONS)



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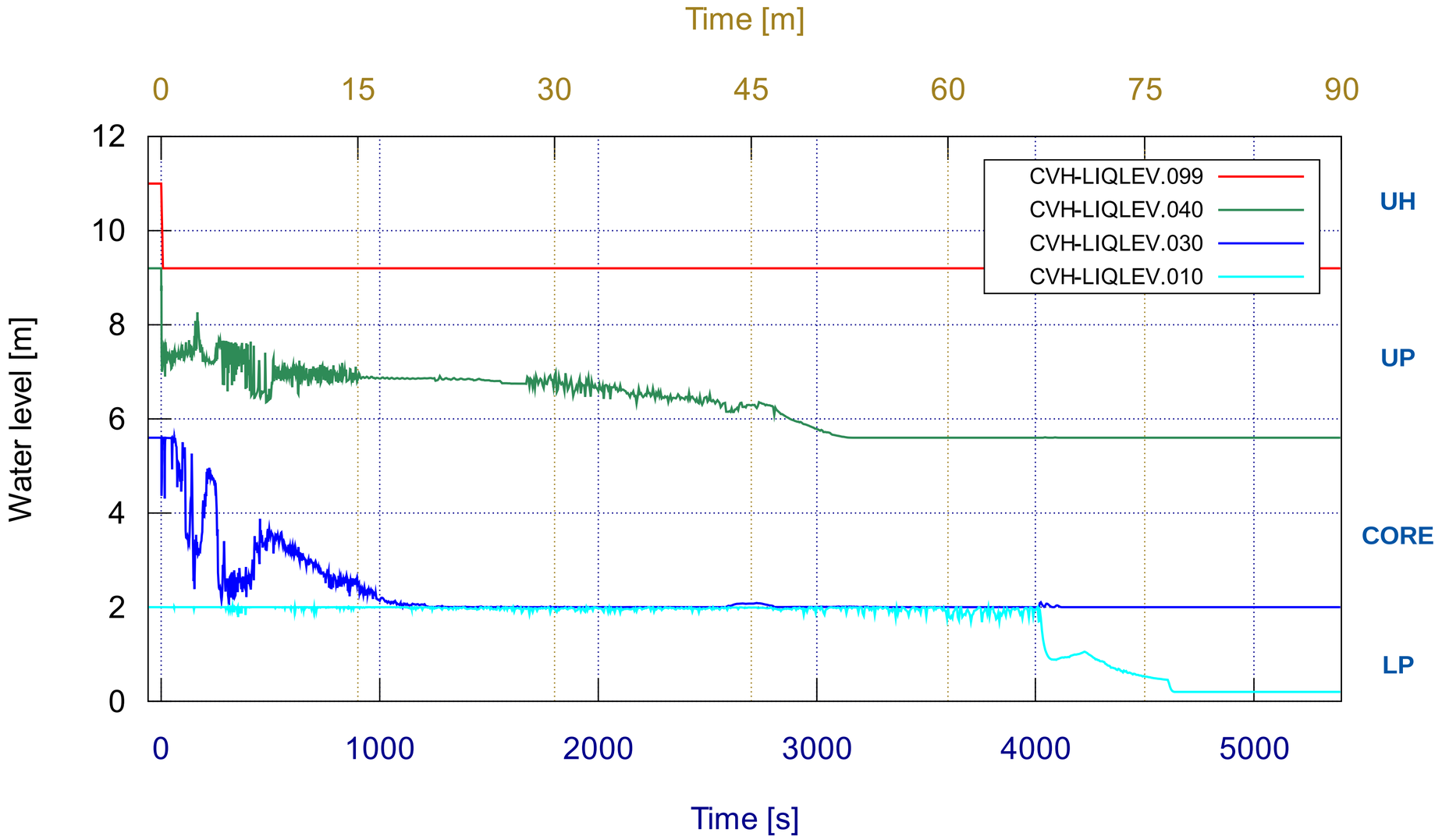
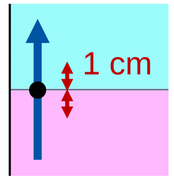


LBLOCA: FLHGT*=1 CM (FUNCTION)



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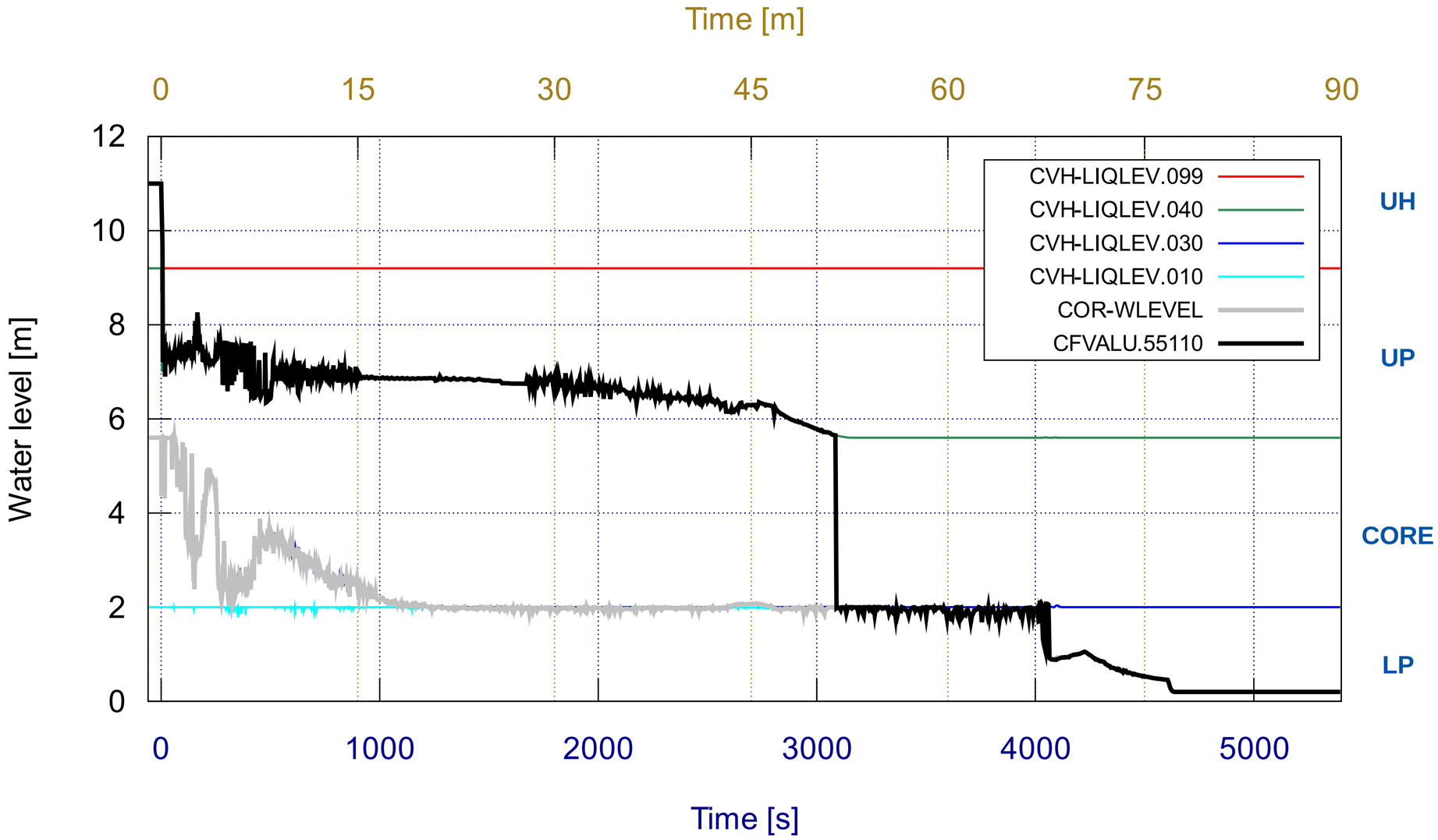
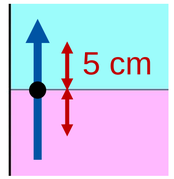


LBLOCA: FLHGT*=5 CM (ELEVATIONS)



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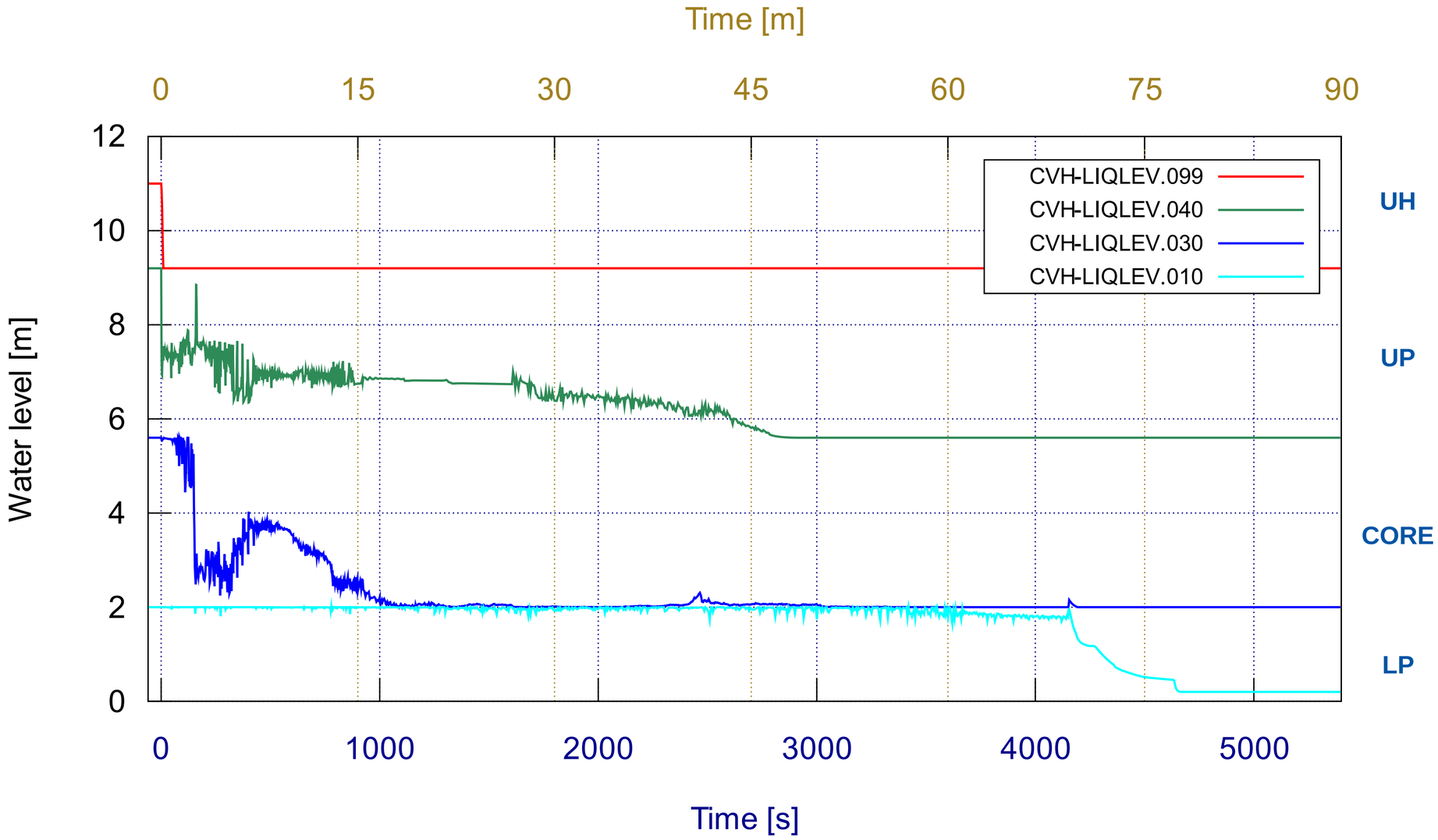
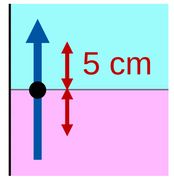


LBLOCA: FLHGT*=5 CM (FUNCTION)



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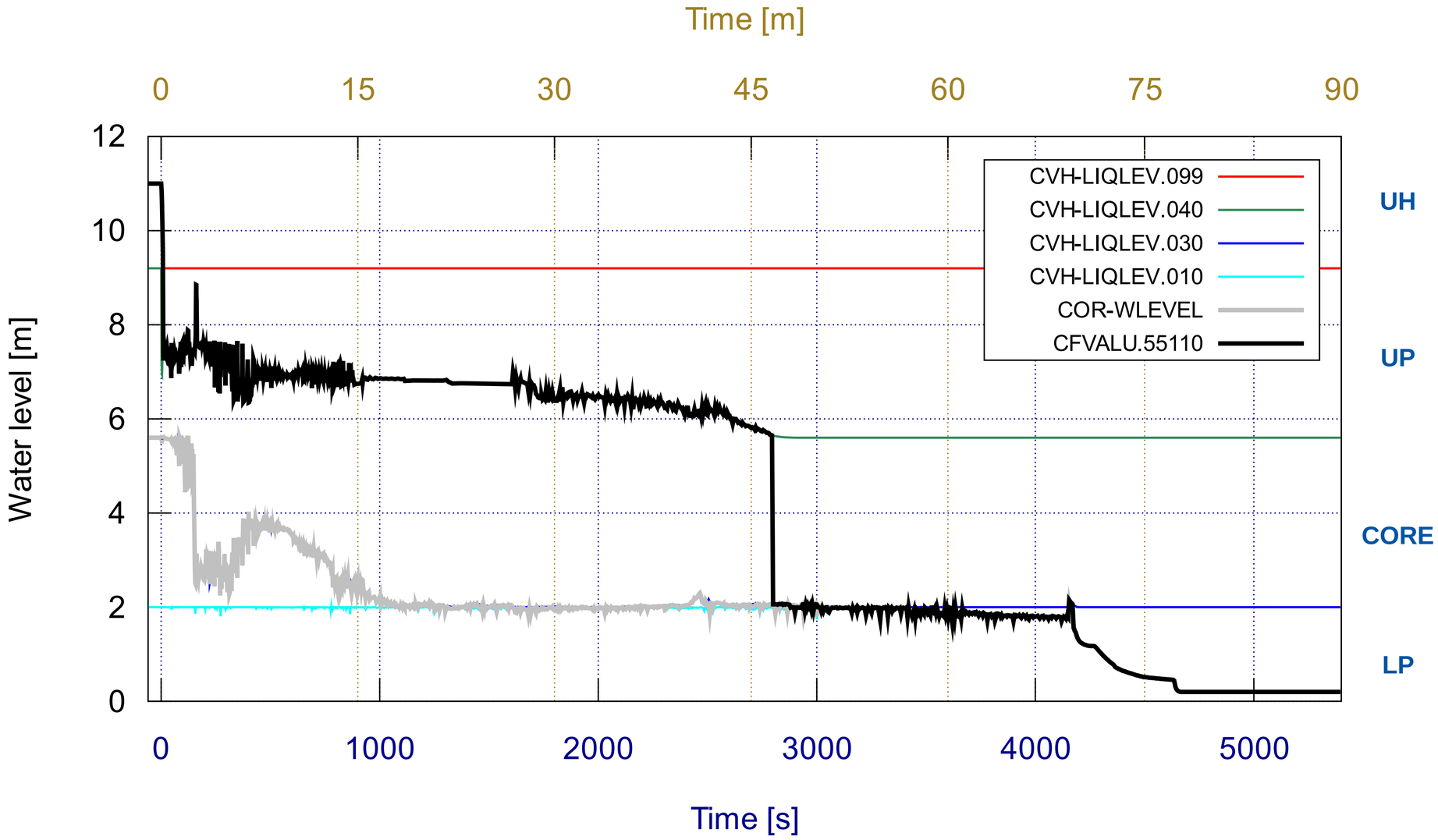
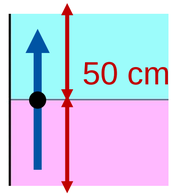


LBLOCA: FLHGT*=50 CM (ELEVATIONS)



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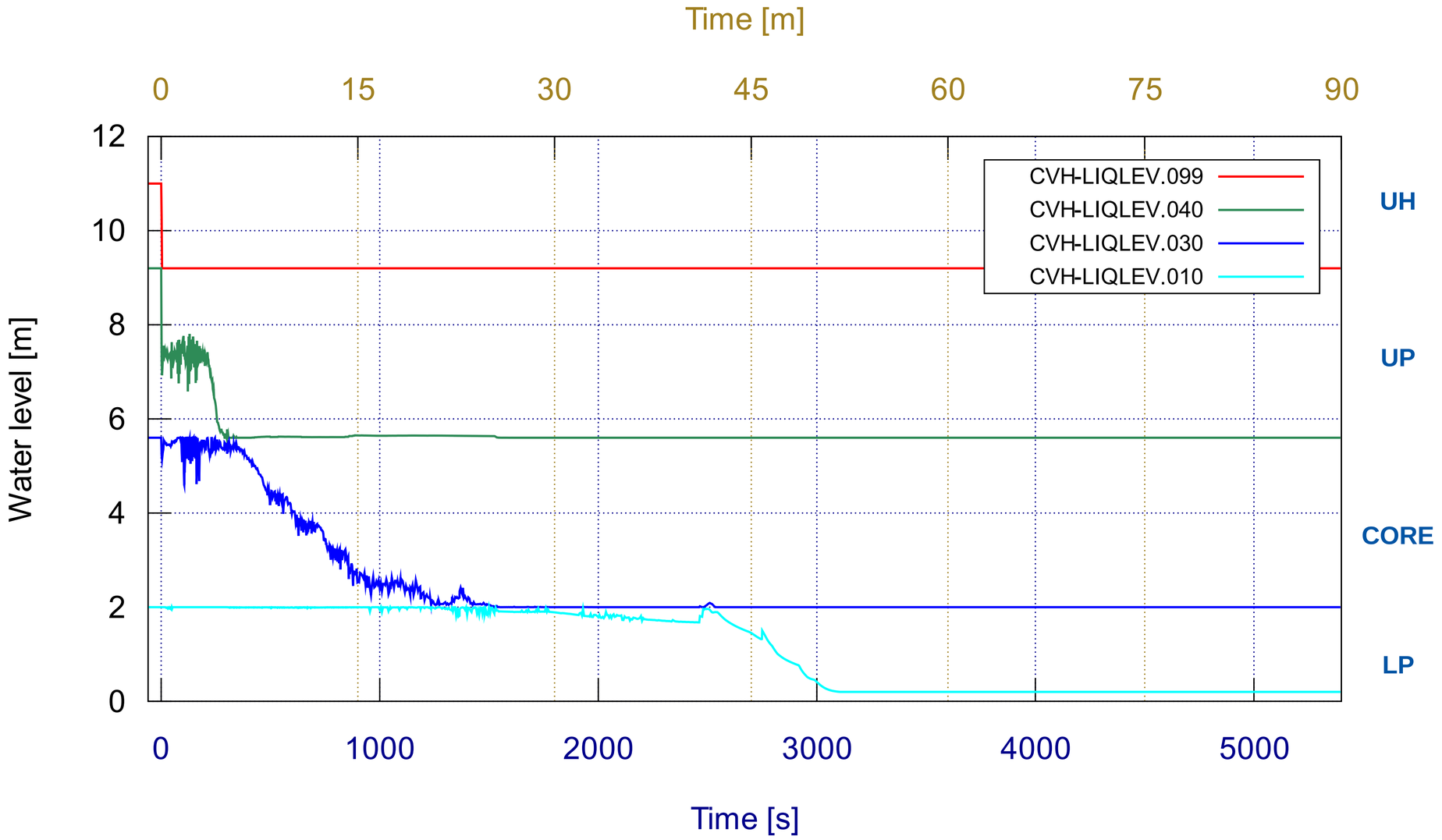
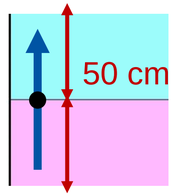


LBLOCA: FLHGT*=50 CM (FUNCTION)



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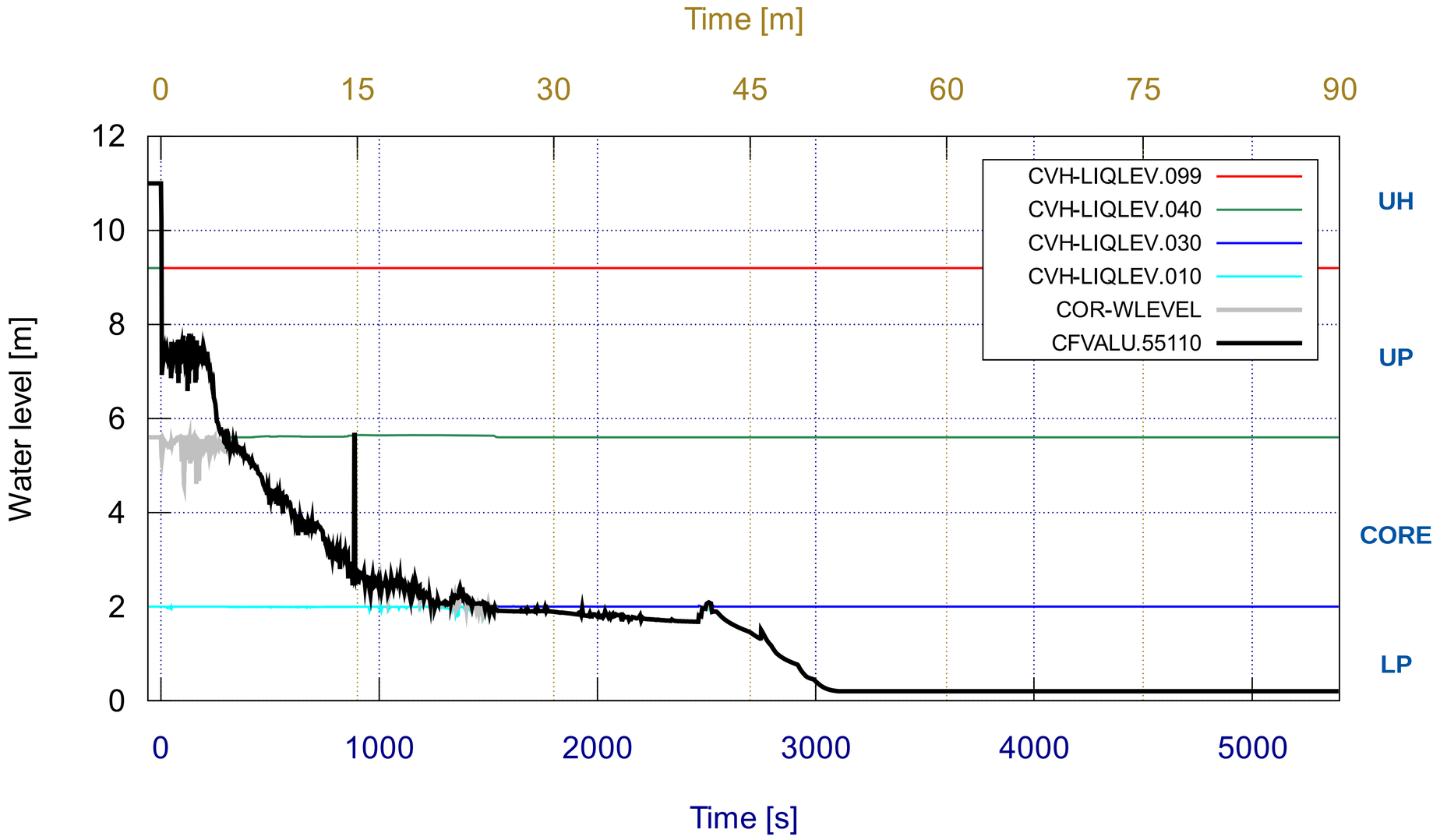
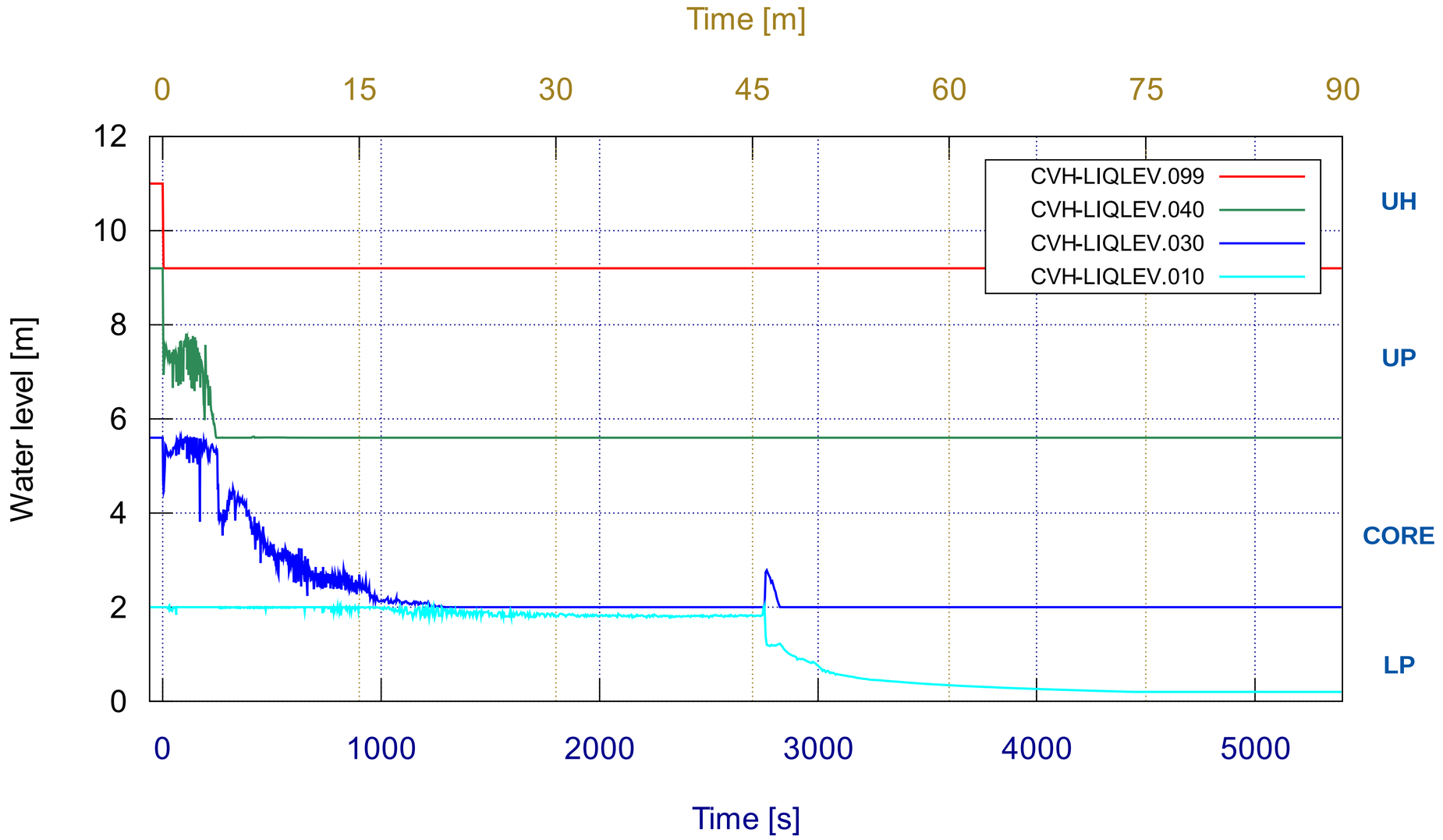
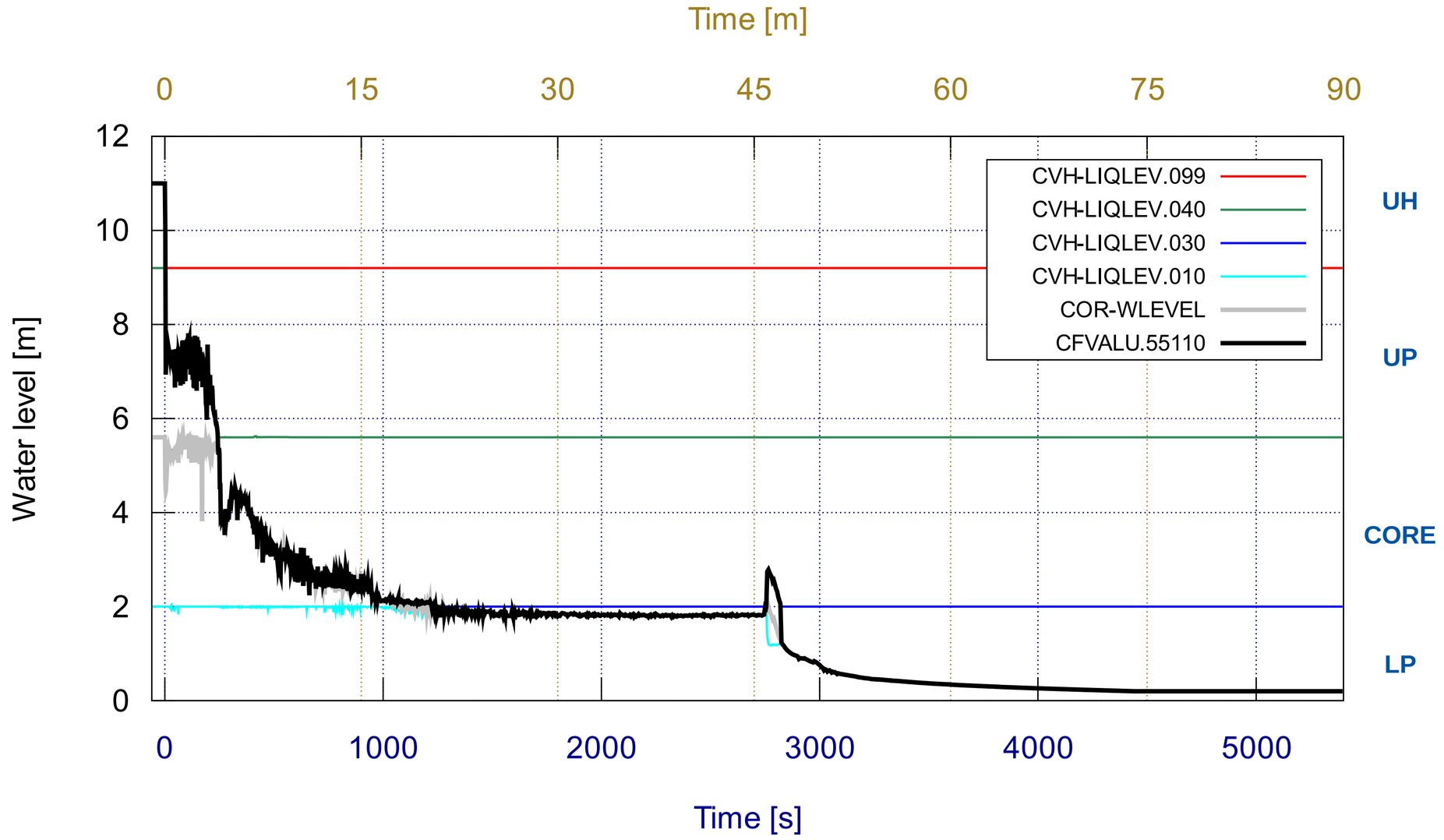


LBLOCA: CENTERS (ELEVATIONS)



LBLOCA: CENTERS (FUNCTION)



CONCLUSIONS

1. Uncertainty quantification

- Strong sensitivity of MELCOR to *numerics-related* parameters & uncertain *model parameters* settings
  - Non-monotonous behavior was often observed (weak correlation)
- => UaSA shall be always performed

2. Water leveling in the RPV

- It seems that setting FLs‘ elevations to CVs‘ interfaces or CVs‘ centers yields slightly different, but correct and comparable results
  - Provided that opening heights are wide enough
  - *Larger* breaks require *larger* opening heights