# Ex-vessel LOCA for the European HCPB TBM system using the pedigreed MELCOR182 for fusion

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# Outline

- Pedigreed MELCOR182 for fusion

- HCPB TBM and HCS

- Ex-vessel LOCA
  - Accidental sequence
  - MELCOR model for helium blow-down
  - MELCOR 3D-model for ½ BU

- MELCOR results & open issues

# Pedigreed MELCOR182 for fusion

- The version is modified by INL for ITER purposes*:
  - chemical oxidation reactions of steam with Be, C and W,
  - extension of water properties below its triple point temperature for Loss Of Coolant Accidents (LOCAs) into cryostats,
  - the cryogenic He or air as the primary fluid,
  - convective boiling,
  - HTO transport,
  - enclosure radiant heat transfer.

- In 2010 input deck limited to 9999 lines were extended, but the limitation for CV, FL, CF and TF (999) is not changed.

*Merrill B.J., Modifications to the MELCOR code for application in fusion accident analyses, Fusion Engineering and Design 51-52, 2000.*

# HCPB TBM and the combined HCS

## Vertical TBM box
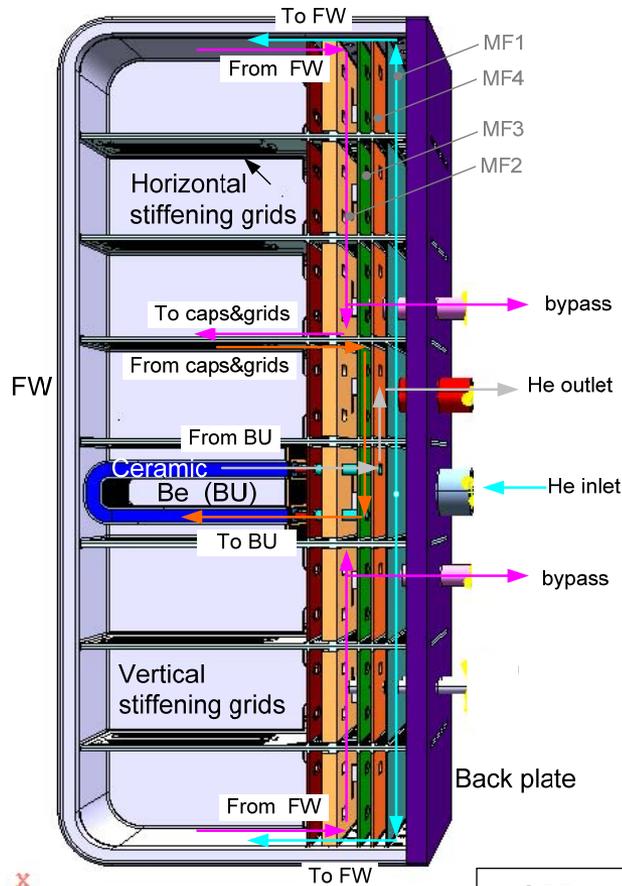


## HCS and results at steady state (RELAP5-3D)



Mass flow rate $\dot{m}$ (kg/s)
Temperature $T$ (°C)
Pressure $p$ (MPa)
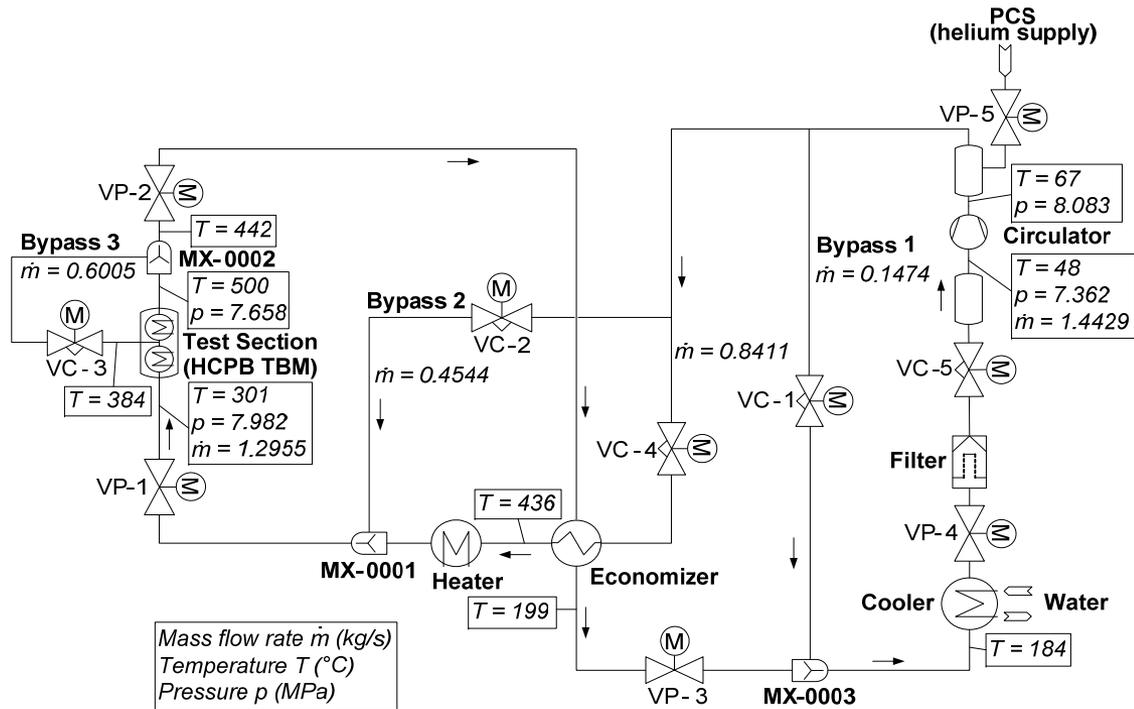
## Ex-vessel LOCA is assumed at the steady state

| | |
|---|---|
| HCPB: Helium Cooled Pebble Bed | FW: First Wall |
| TBM: Test Blanket Module | BU: Breeder Unit |
| HCS: He Cooling System | MF: Manifold |
| PCS: Pressure Control System | MX: Mixer |

# Accidental sequence



HCPB TBM & HCS (Steady state) — RELAP5-3D

Ex-vessel LOCA inside port cell

Helium blow-down (HCPB TBM & HCS) — MELCOR

Active plasma shutdown — yes

fast plasma shutdown (3s) — yes

Plasma disruption (1s)

Failures of ITER FW & TBM FW — no → T behavior — ANSYS

yes → Be-steam reaction (TBM box)

T behavior & H2 production — MELCOR

$$Be + H_2O \rightarrow BeO + H_2 \quad -370 KJ/mol, \quad T > 300°C$$
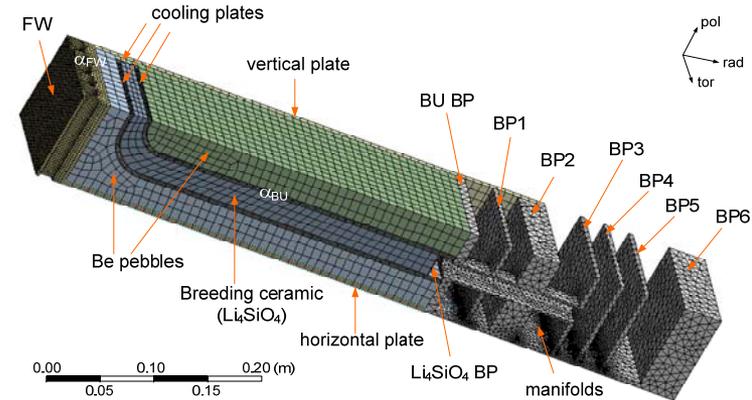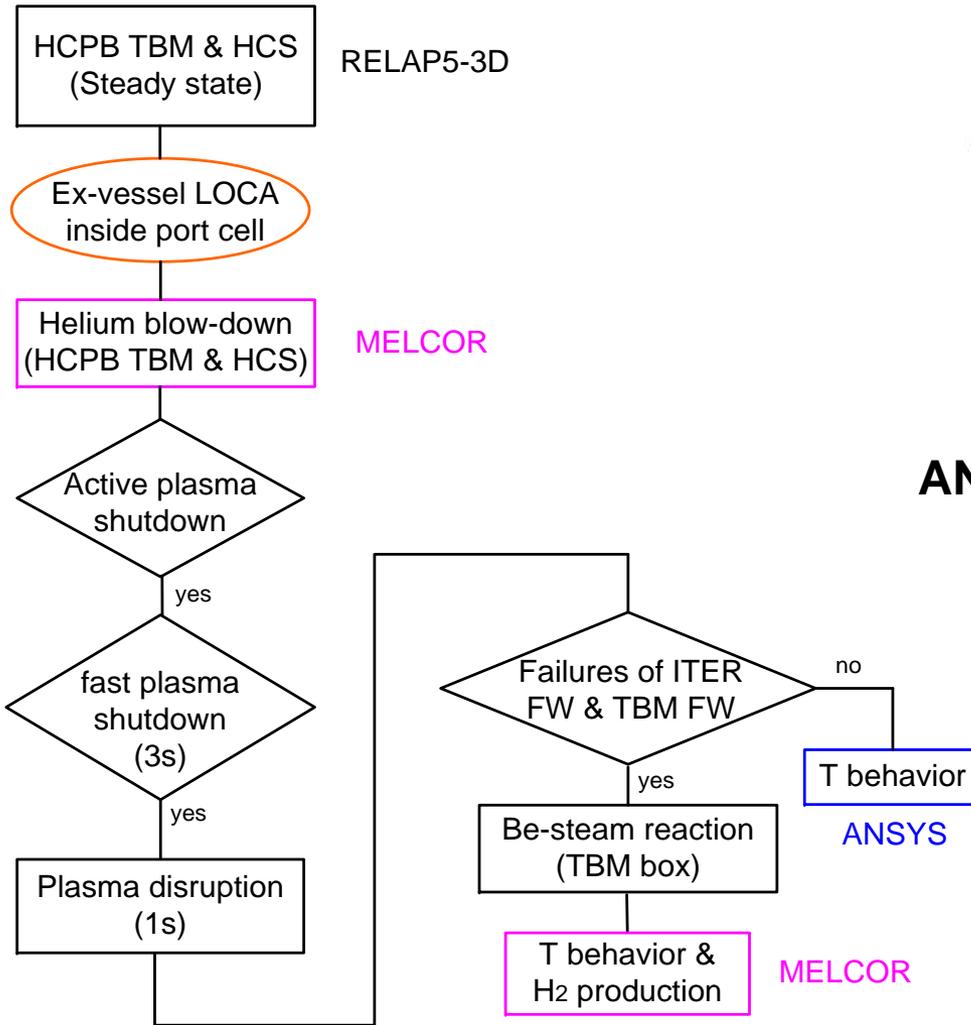


**ANSYS 3D-model of the TBM with ¼ BU**

Labels: FW, cooling plates, vertical plate, $\alpha_{FW}$, BU BP, BP1, BP2, BP3, BP4, BP5, BP6, $\alpha_{BU}$, Be pebbles, Breeding ceramic (Li$_4$SiO$_4$), horizontal plate, Li$_4$SiO$_4$ BP, manifolds, pol, rad, tor

Scale: 0.00  0.05  0.10  0.15  0.20 (m)



ANSYS calculation

Temperature (°C) vs time (s), legend: FW
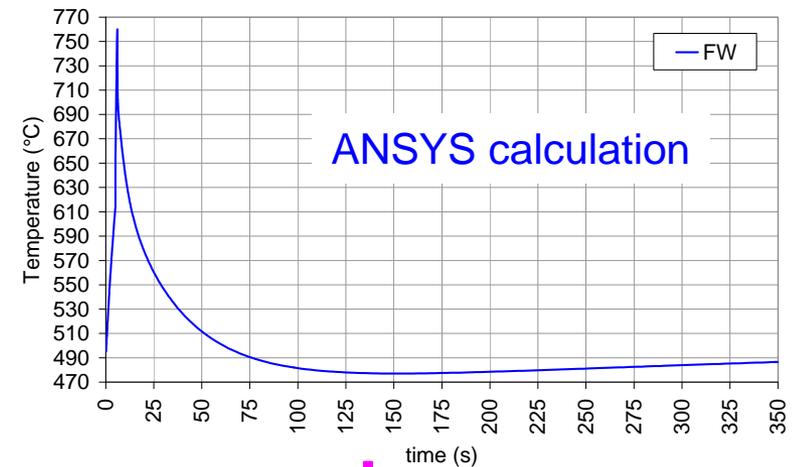
*ANSYS-temperatures after the plasma disruption are MELCOR initial temperatures.*
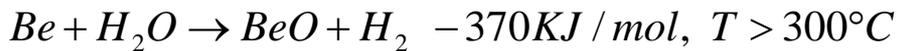
# Helium blow-down inside port cell



## MELCOR nodalization for the HCS and HCPB TBM
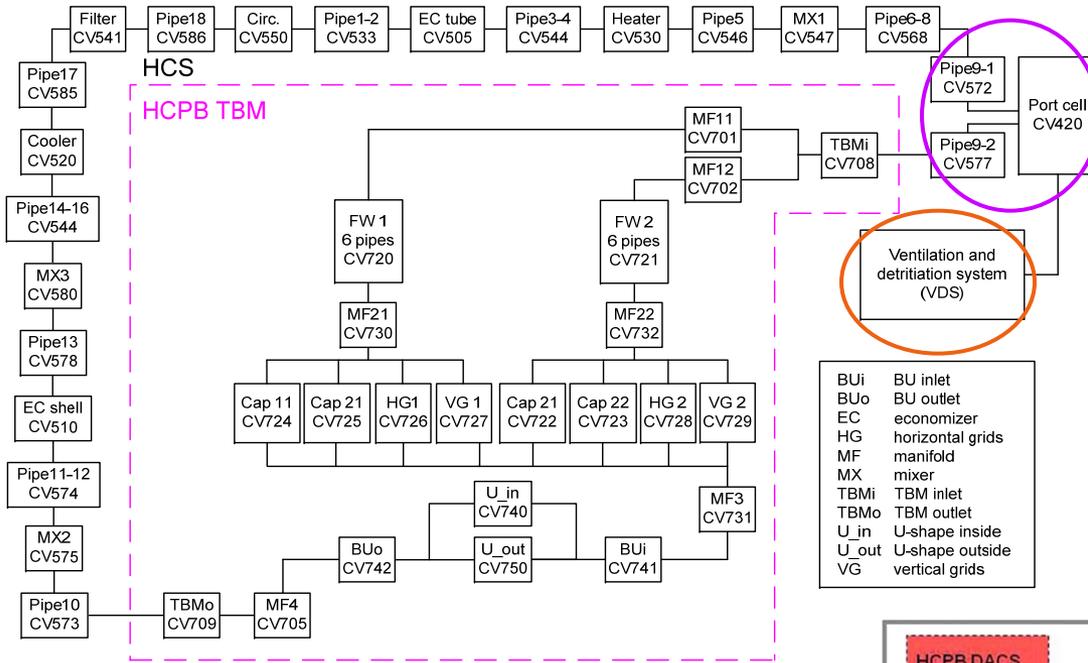
## Location of the port cell & HCPB TBM *

*Boccaccini L.V. et al., Present status of the conceptual design of the EU test blanket systems, Fusion Engineering and Design 86(2011) 478-483.*

CVCS: Chemical and Volume Control Systems
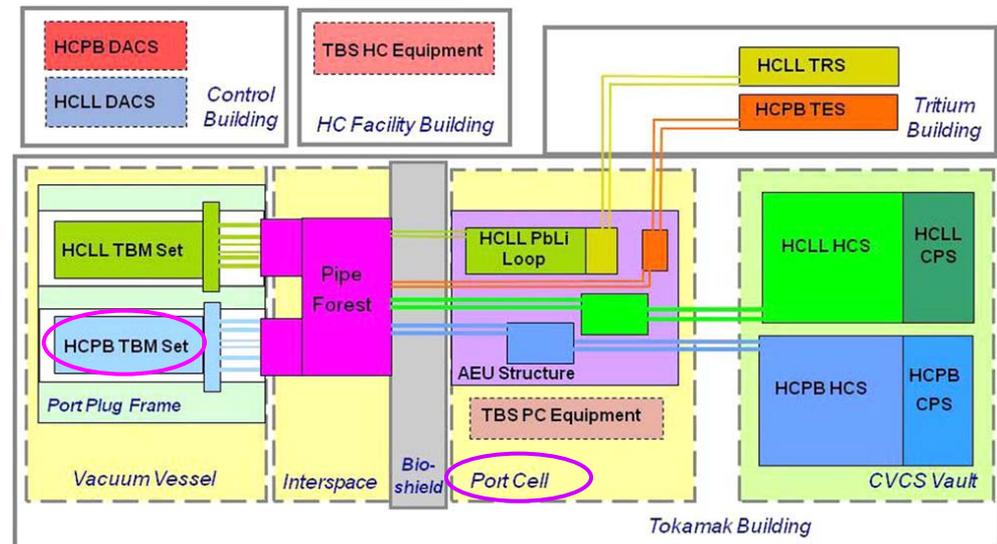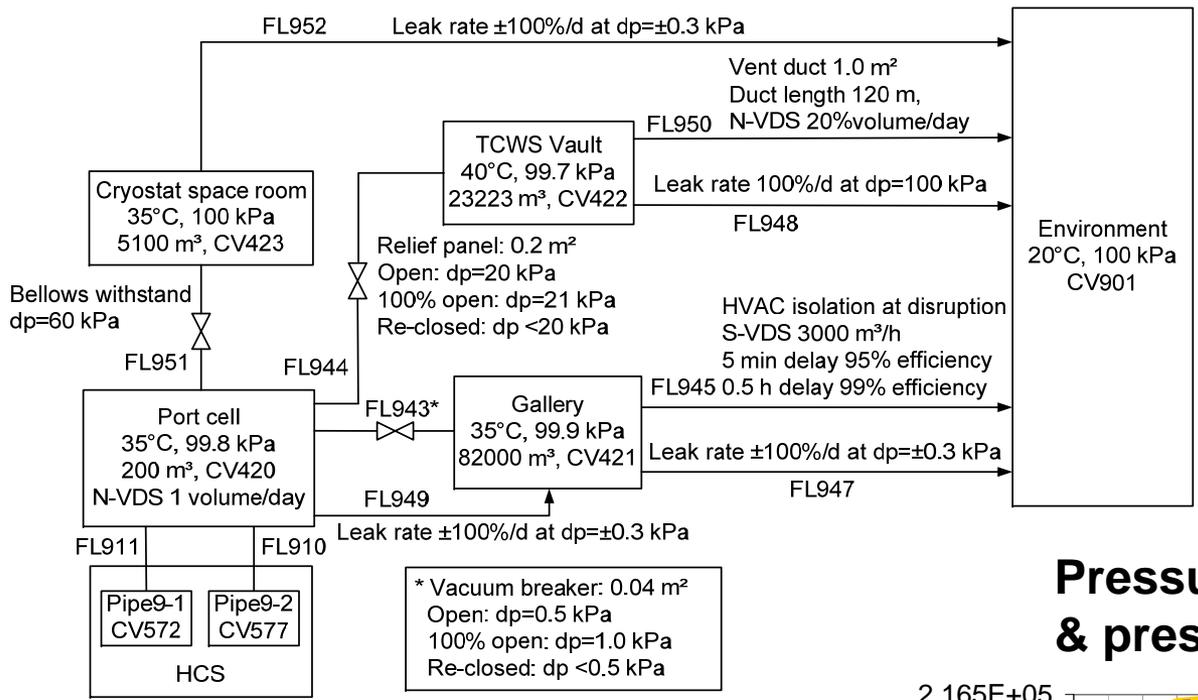
**MELCOR nodalization for the VDS**

**Pressure behavior inside port cell & pressure drop of the system**
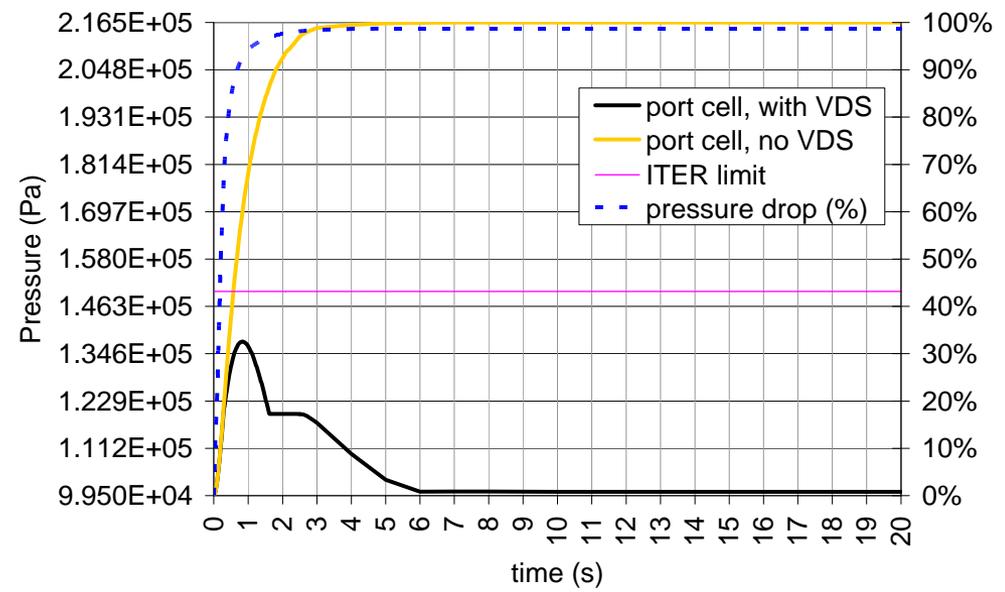
# Beryllium–steam reaction in the long term
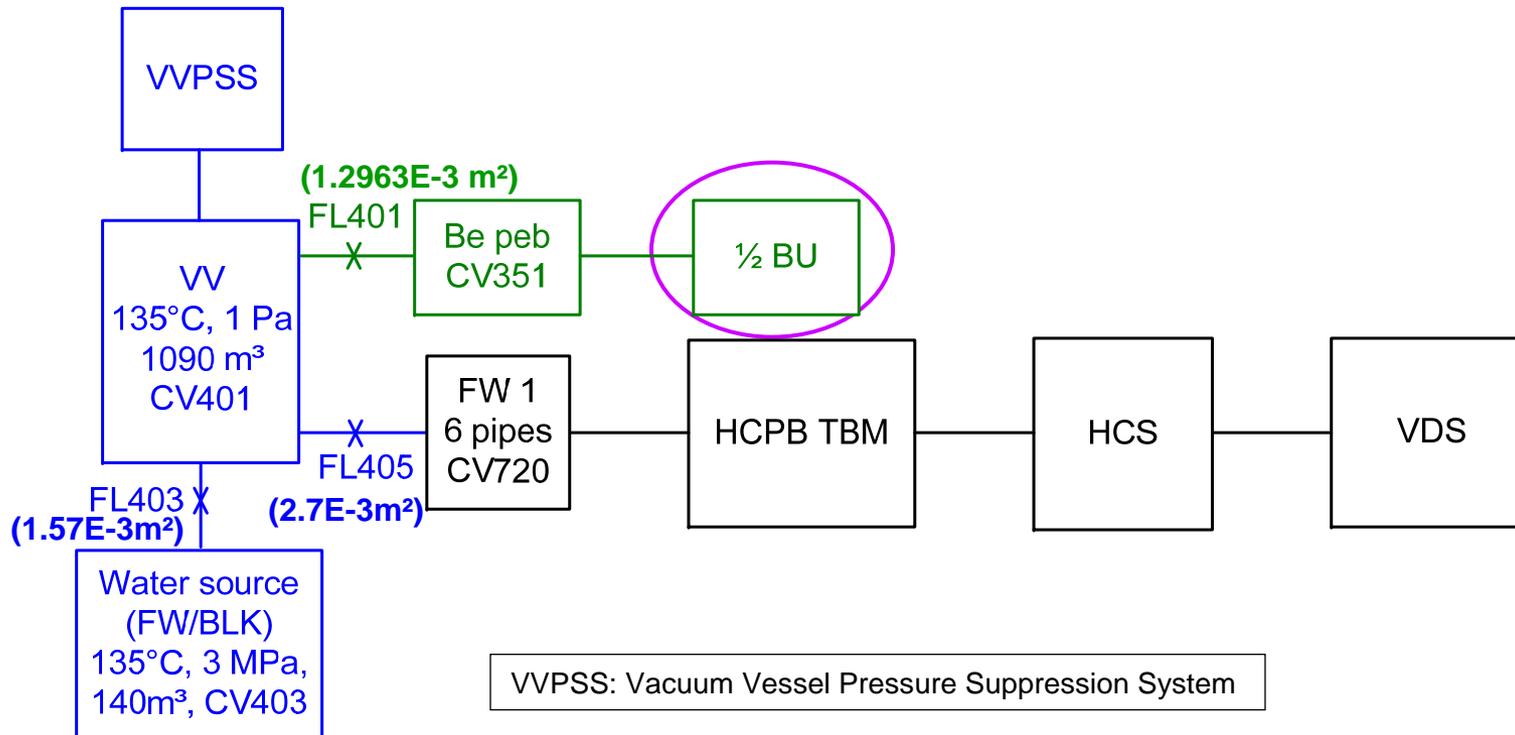


**MELCOR modelling for failures of ITER FW & TBM FW**

# MELCOR 3D-model for ½ BU
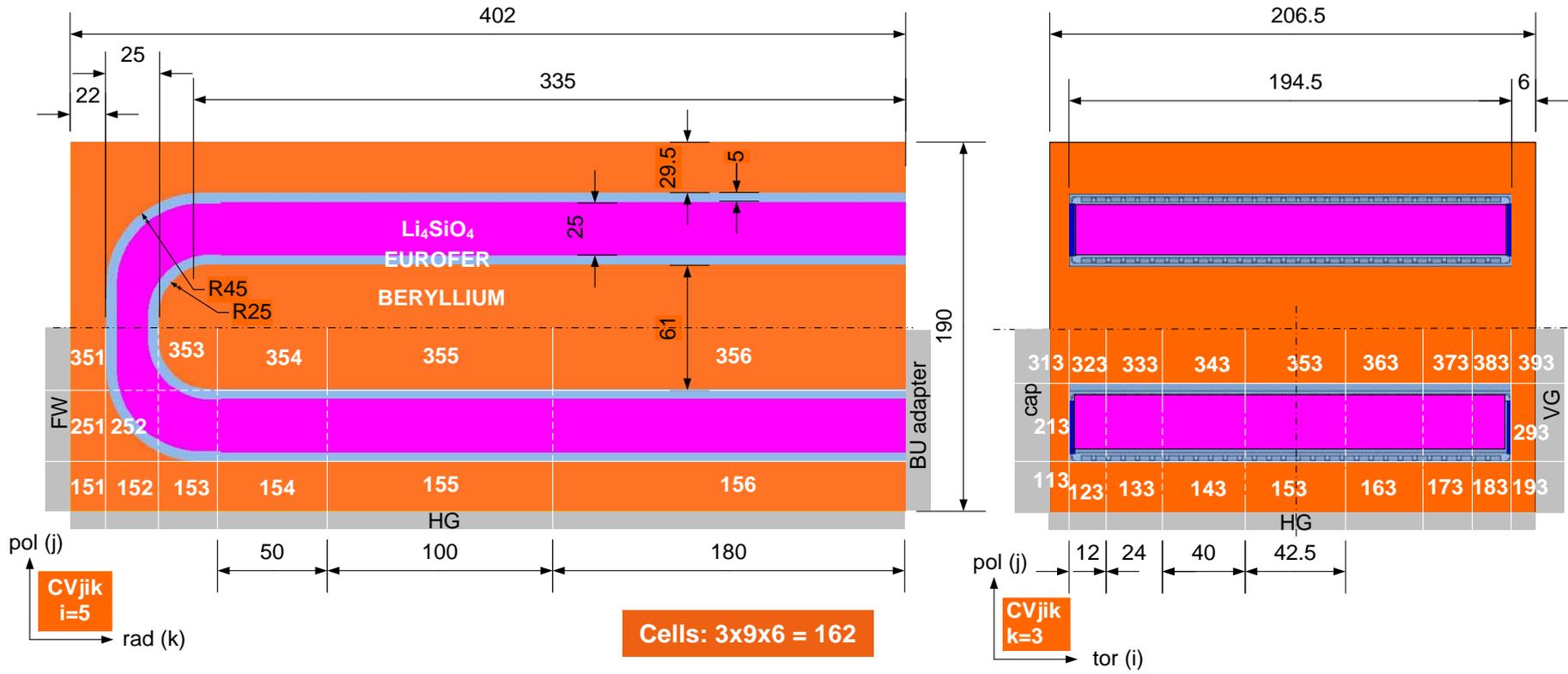


- modeling for 1 pebble $d_{1peb}$ = 1 mm, HSMULT = $N_{peb}$.

- thermal conduction between adjacent cells by modeling the heat conducted from one cell to be received by a HS in the adjacent cell in the given direction.

- internal power source: decay heat as table function ~ time.

- radiation: gray-gas-a, emissivity 0.65.

# MELCOR simulations

**Failures of ITER FW & TBM FW to the VV**
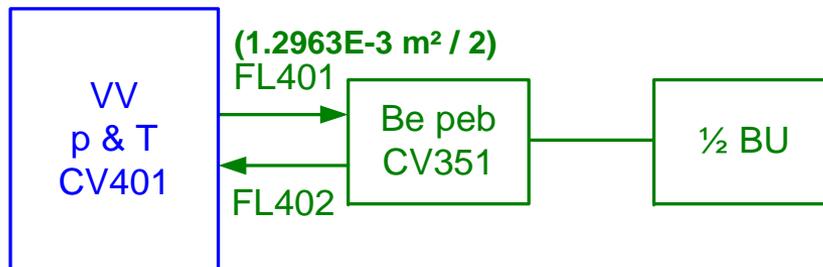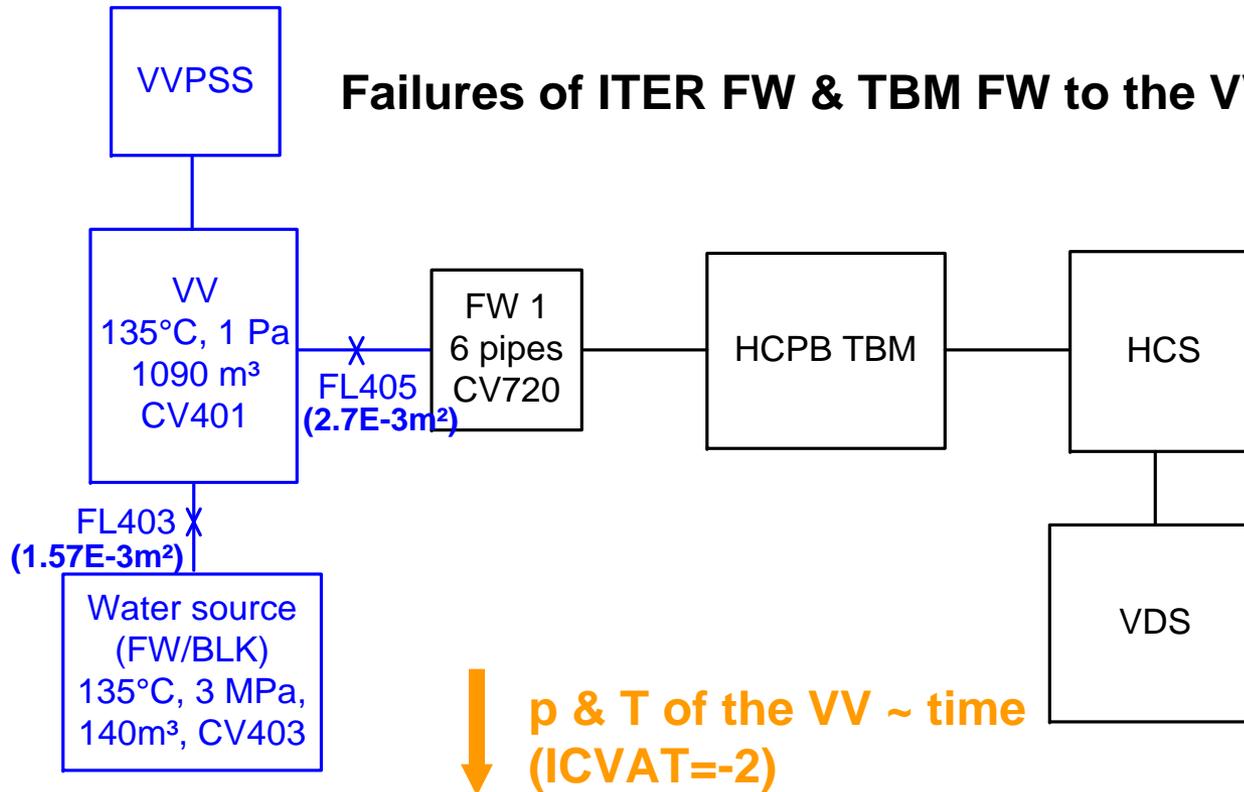


**Failure of TBM FW to the beryllium pebble bed**

# MELCOR results in the long term
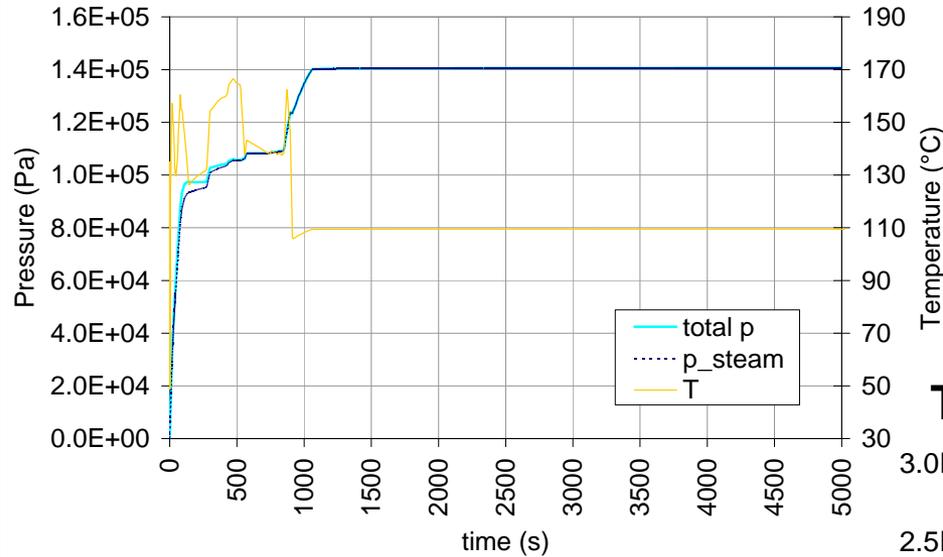


**Pressure and temperature behavior in the VV**

**Temperature behavior and H$_2$ production**
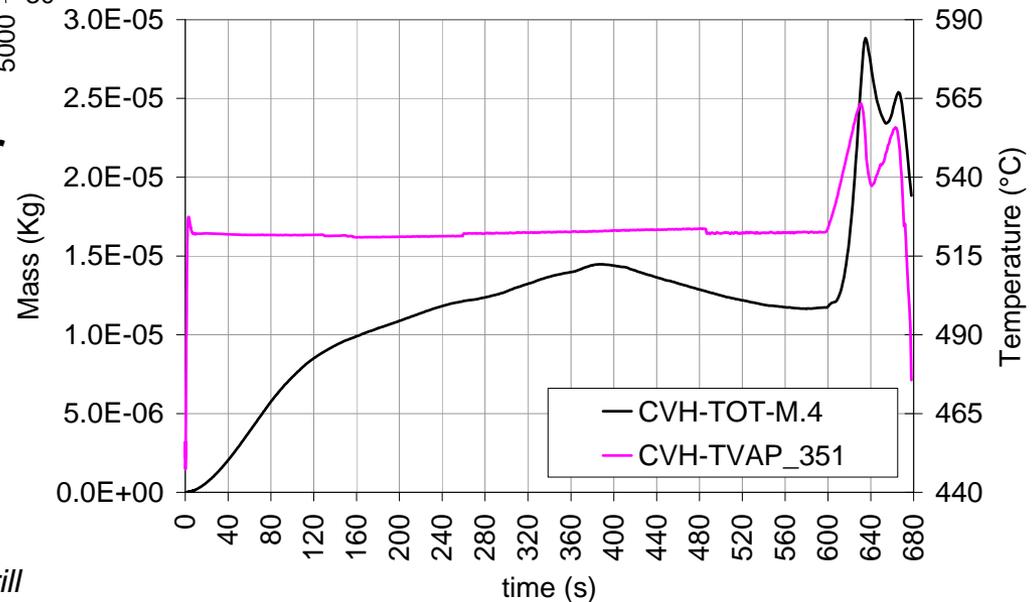


*H$_2$-results for the first 400s are shown in [1] Jin X., Merrill B.J., Boccaccini L.V., Preliminary safety analysis of ex-vessel LOCA for the European HCPB TBM system, Fusion Engineering and Design, in press.*

*t = 6.335626E+02   DT(CVH) = 1.241800E-05*
*CPU = 1.469860E+07 = 170 days*

# Open issues

- Helium is treated as noncondensible gas.

- CVH-TOT-M.4 cannot show the total $H_2$ production of the system because p&T of the VV are specialized as a function of time.

- Round-off error due to the single precision of the version 1.8.2

- limitation for CV, FL, CF and TF (999).

**Updated MELCOR version for fusion is needed !**

4th EMUG                X. Jin                Institute of Neutron Physics and Reactor Technology (INR)