Application of ATHENA/RELAP to Fusion Loss-of-cooling Accidents

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INEEL

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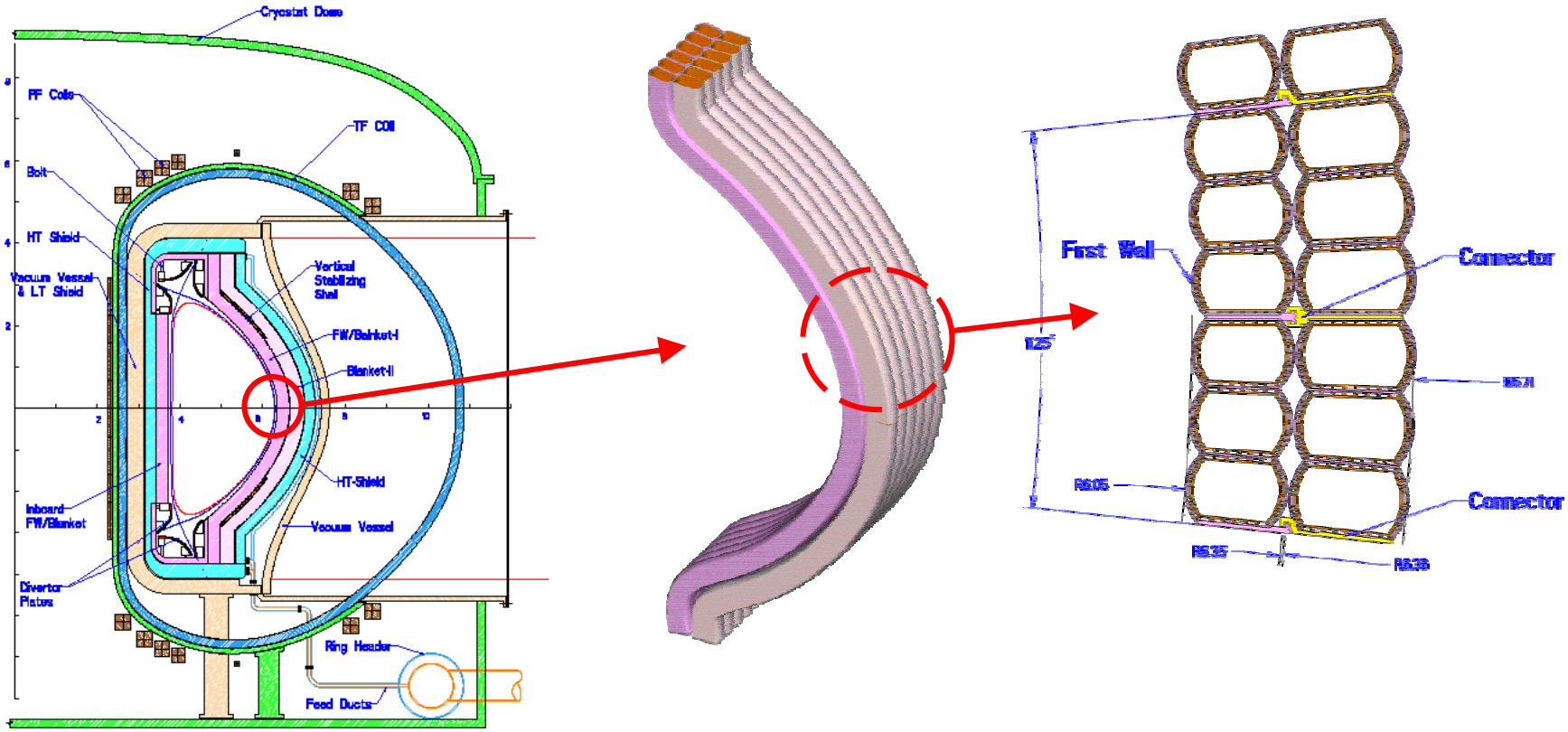
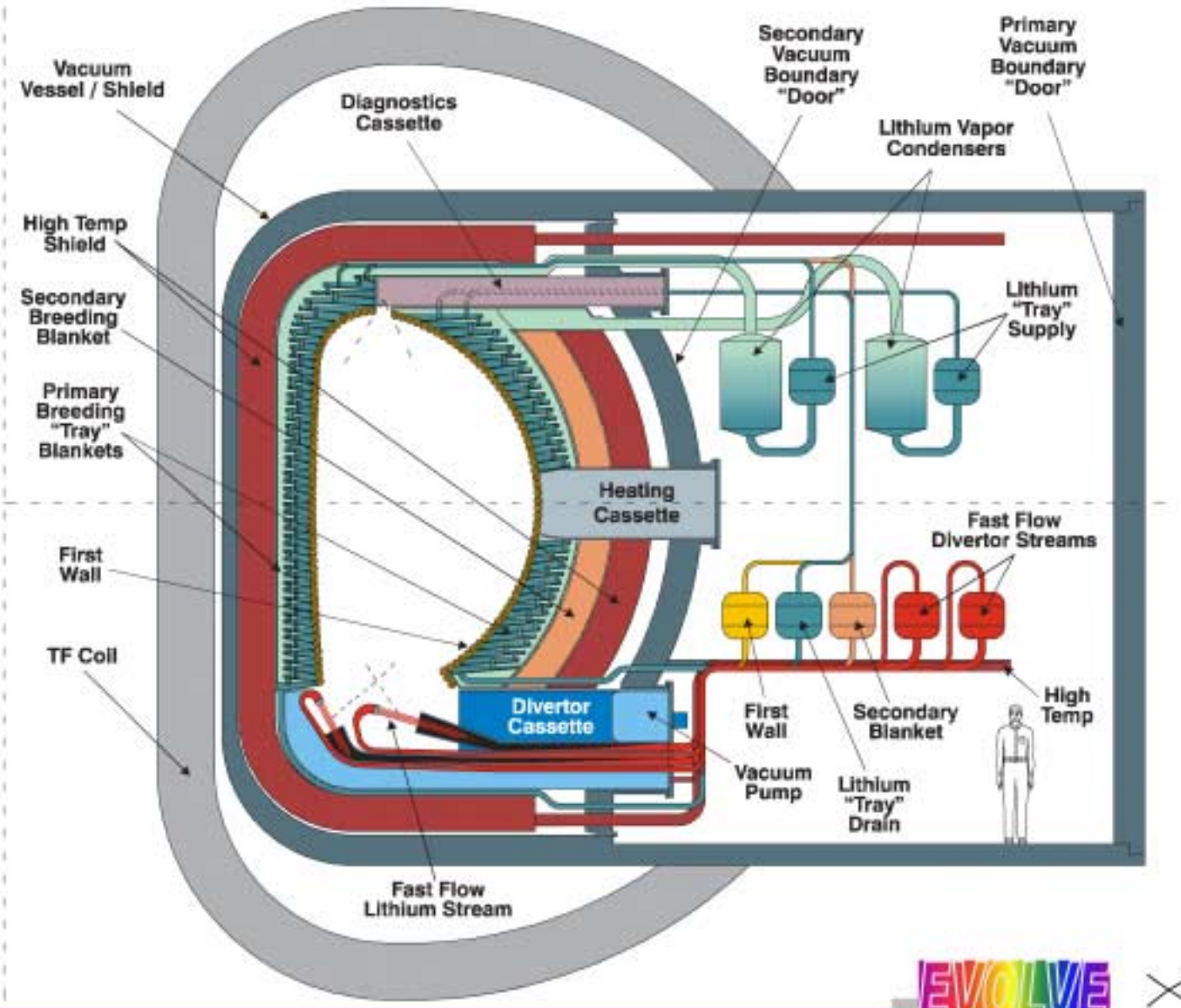
PRESENTATION OUTLINE

- Overview of proposed fusion reactor designs
- Code capabilities for fusion loss-of-cooling accidents
- ITER LOCA experience
- Code comparison with fusion specific LOCA experiments
- Conclusions

Cross-sectional View of ARIES-AT $Li_{17}Pb_{83}$ Self-cooled Fusion Reactor Design

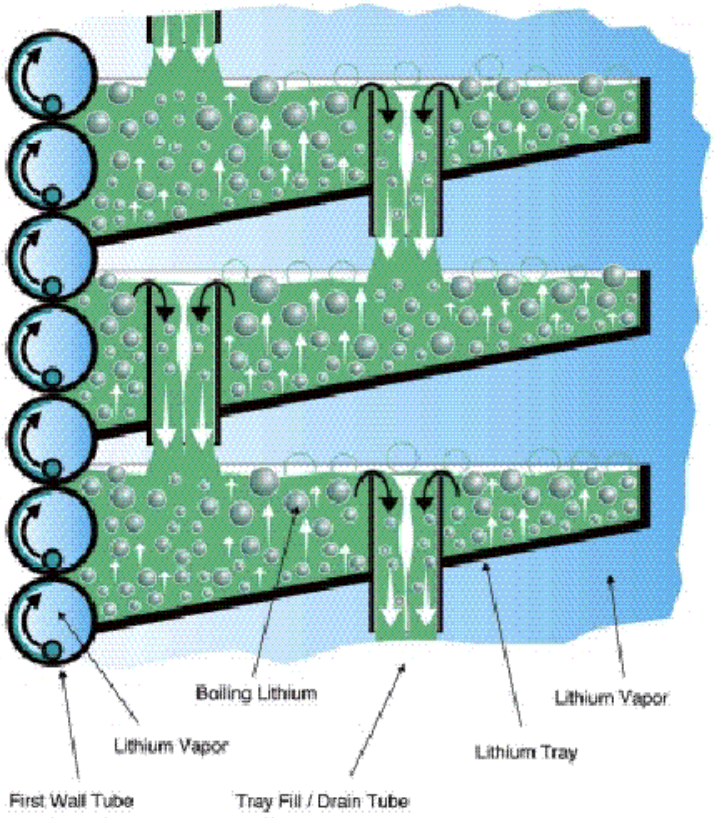


EVOLVE Configuration



EVOLVE

Schematic of EVOLVE First Wall Tubes and Blanket Trays



EVOLVE

REQUIRED CODE CAPABILITES

- Fluids other than water (cryogens to liquid metals)
- Heat transfer for high heat flux (up to 20 MW/m^2), single side heating components
- Accurate pressurization and critical flow predictions for ingress of coolant into a vacuum environment
- MHD pressure drop predictions for liquid metal coolants
- Coolant freezing

ATHENA a MODIFIED RELAP5-3D

ATHENA (Advanced Thermal Hydraulic Energy Network Analyzer)

A major difference between the two codes is the number of fluids which can be modeled by ATHENA

Water	• Potassium	• Heavy water	• Lithium-Lead
Helium	• Hydrogen	• Sodium	• Nitrogen
Lithium	• Lead-Bismuth	• Sodium-Potassium	• Flibe

Liquid metal MHD pressure drop & convective heat transfer correlations

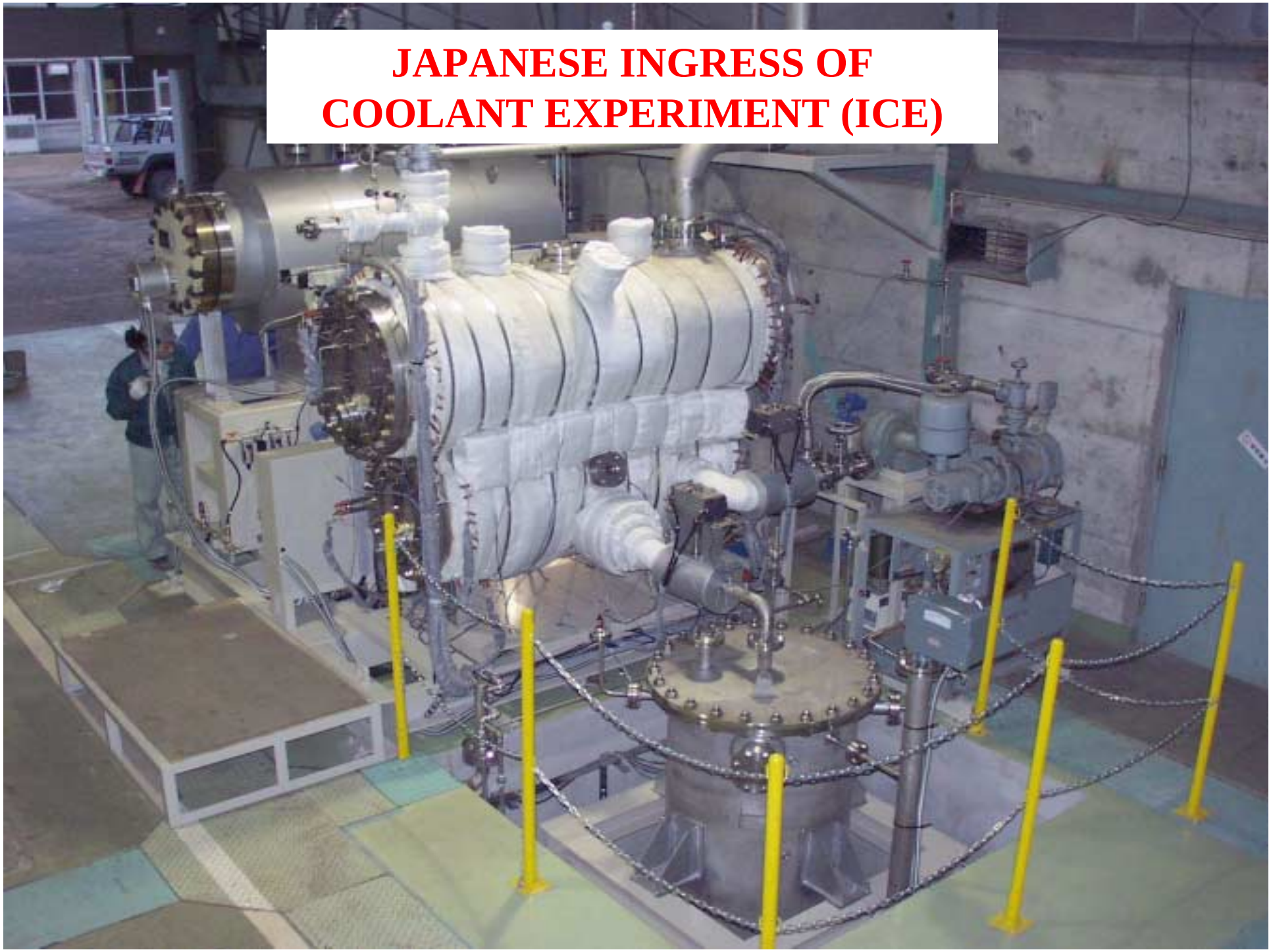
High heat flux heat transfer correlations for one-sided heat loads

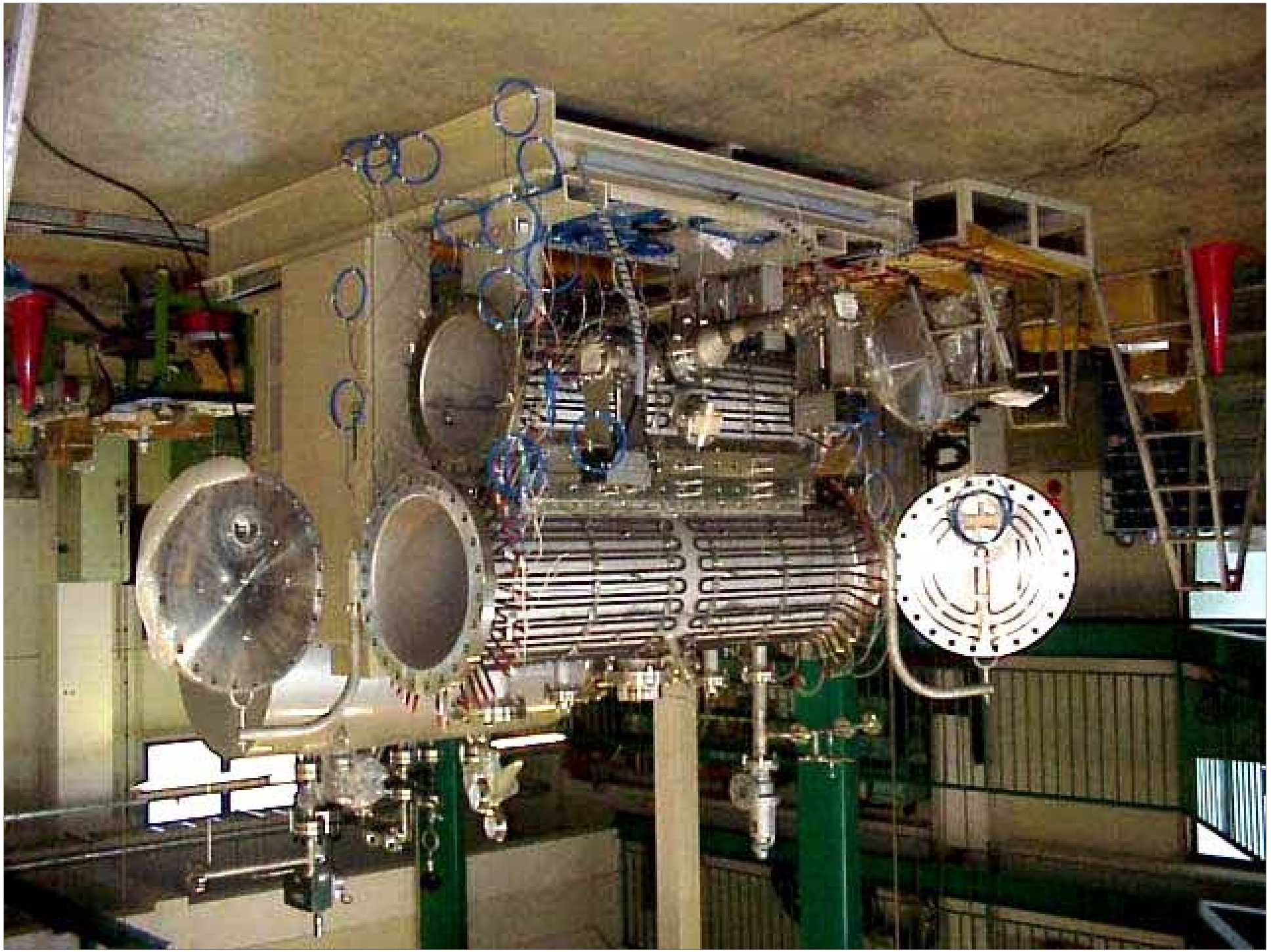
Extensively used by the EU HT in ITER divertor, blanket and vacuum vessel loss-of-cooling analyses (stand alone and as part of ISAS)

ITER EXPERIENCE WITH LOCAs

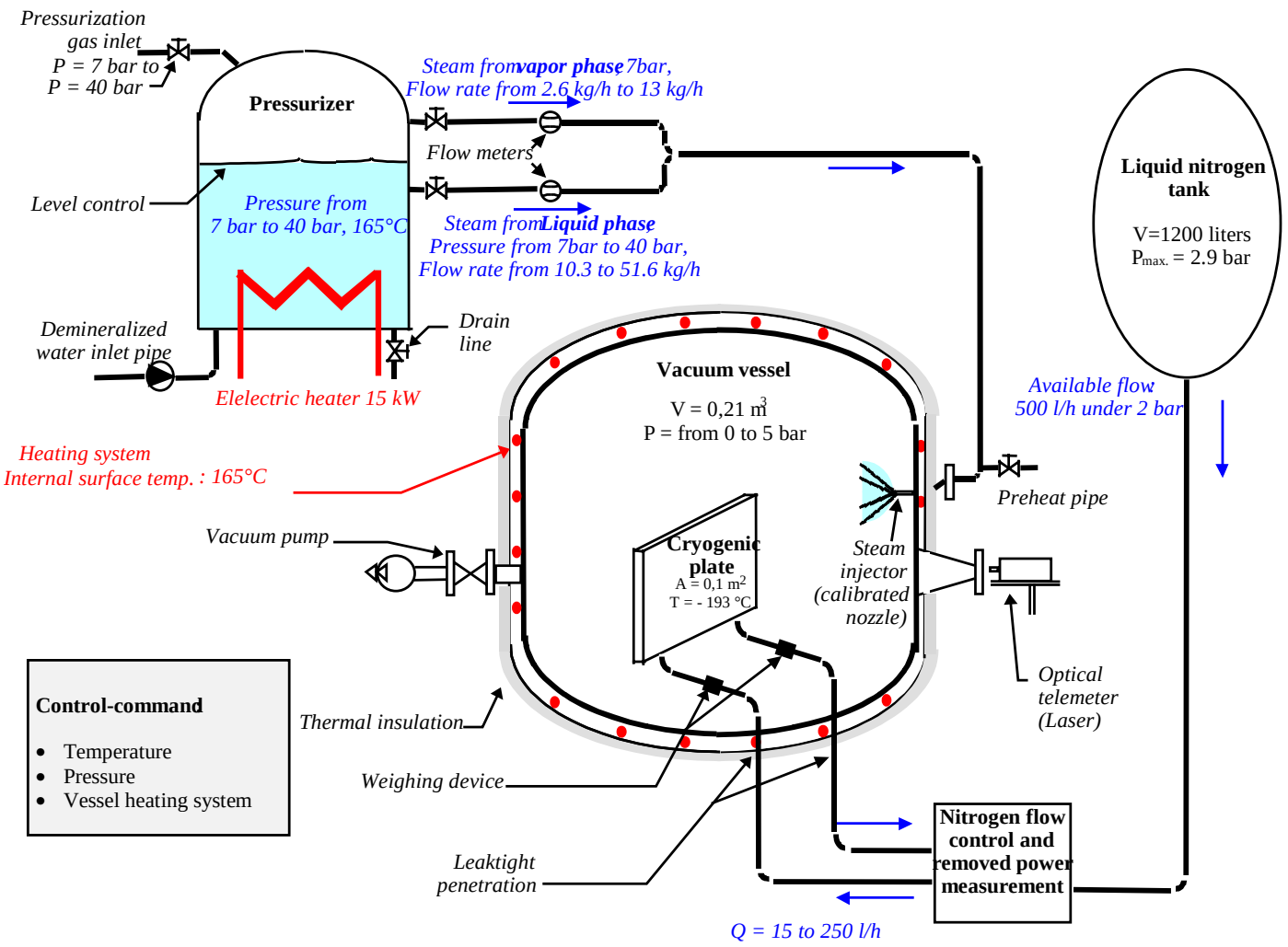
- Design basis LOCA required suppression system to meet 500 kPa vacuum vessel (VV) design limit
- Predicted maximum pressure of 380 kPa in 21 seconds, with suppression system opening at 200 kPa
- Safety issue is mobilization of activated tungsten dust and tritium in VV, no release during DBA
- Beyond design basis LOCA was a small break with an assumed VV breach (bypass event), release did not exceed non-evacuation goal of 1 Rem at the site boundary
- Results sensitive to two-phase choked flow and heat transfer models

JAPANESE INGRESS OF COOLANT EXPERIMENT (ICE)





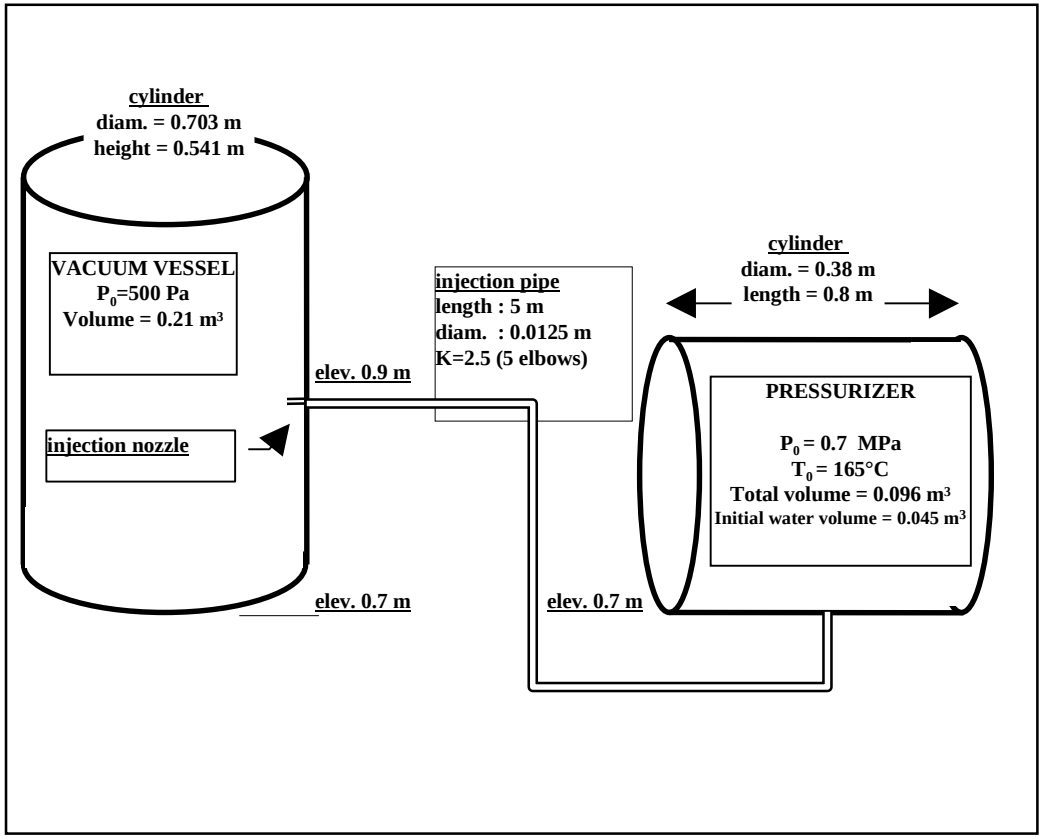
FRENCH EVITA EXPERIMENT



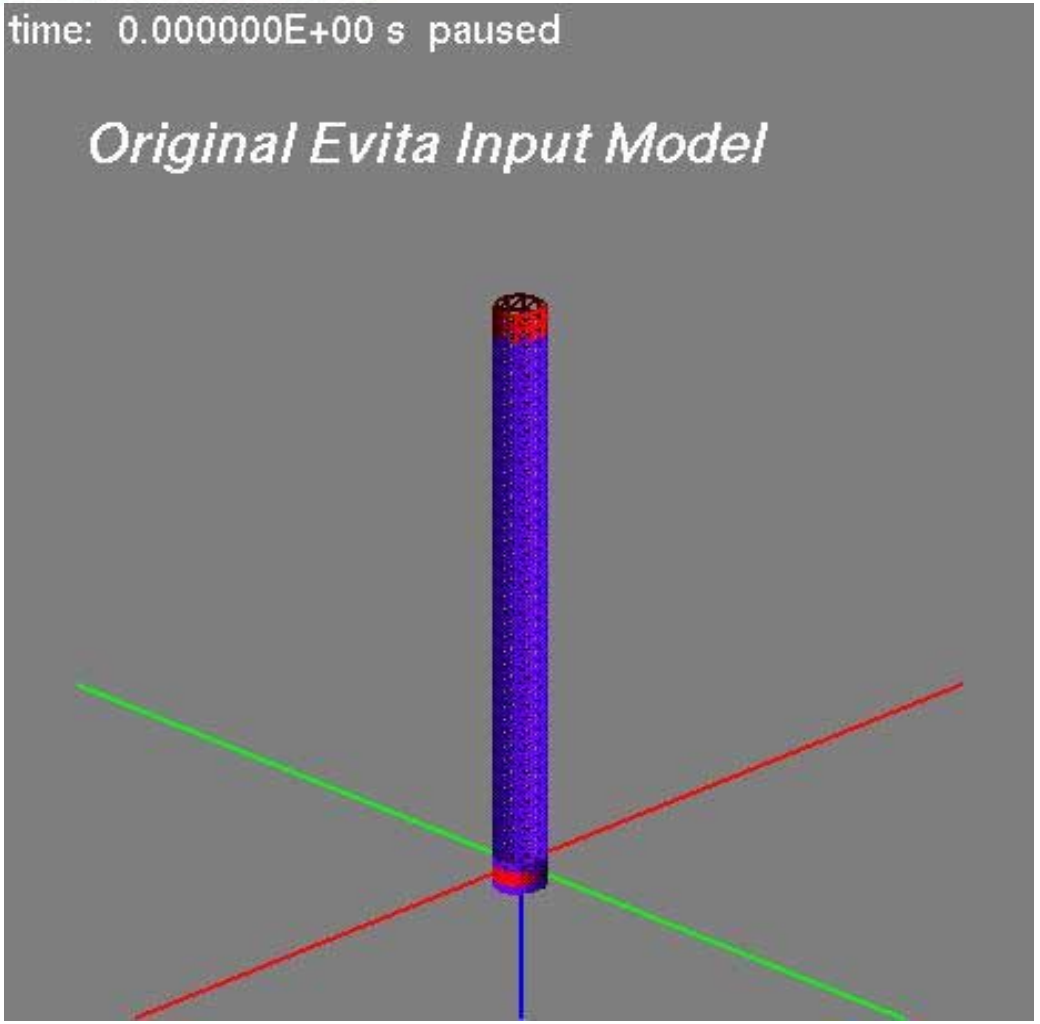
Pre-test Calculations Modelling of the EVITA Facility

European Colleague's Experience

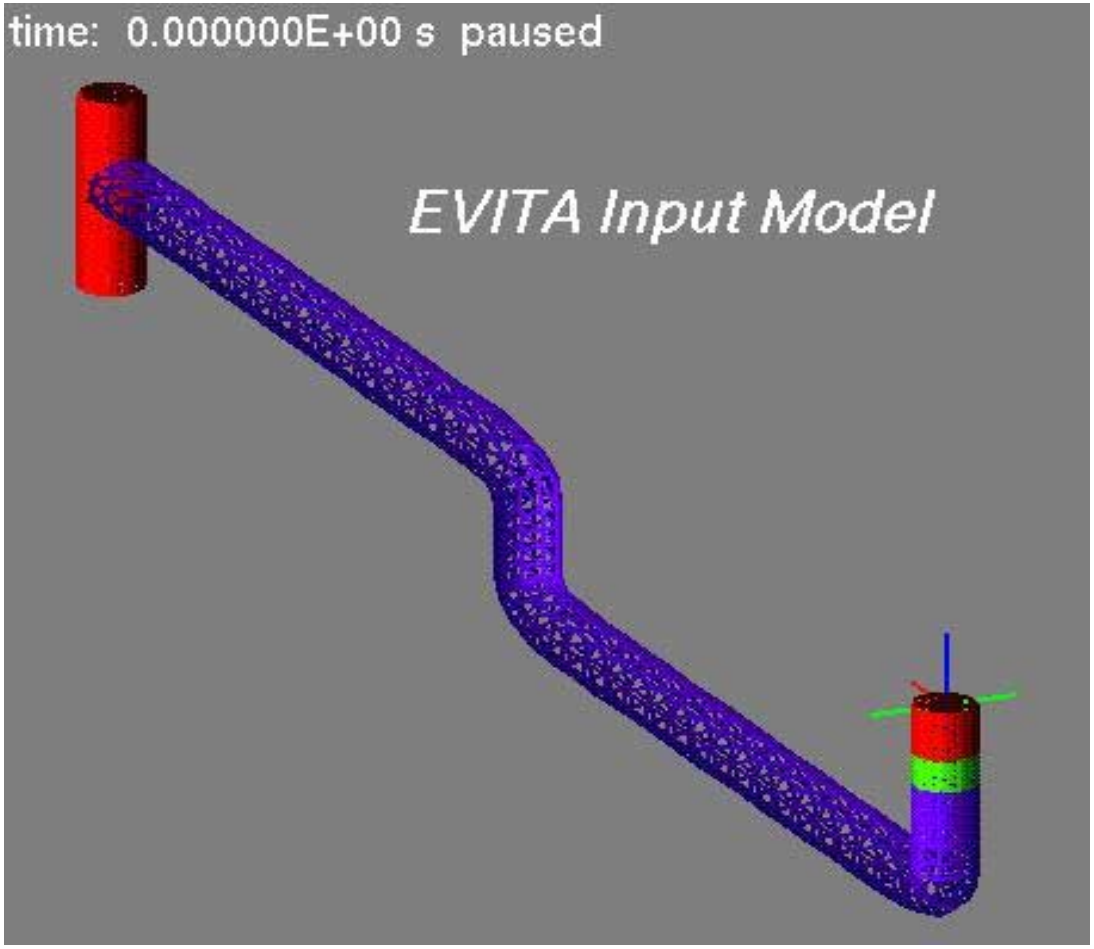
Dear Brad, according to our discussion in Cadarache relating to the benchmark case5 results (I send you in attachment the description) there was one point that it seemed to influence my low flow rate from the break: it was very little (1.8 g/s) compared with those obtained by the other colleagues (Melcor 70 g/s, Relap 15 g/s, Consen and Trac 7 g/s) and it was mainly steam.



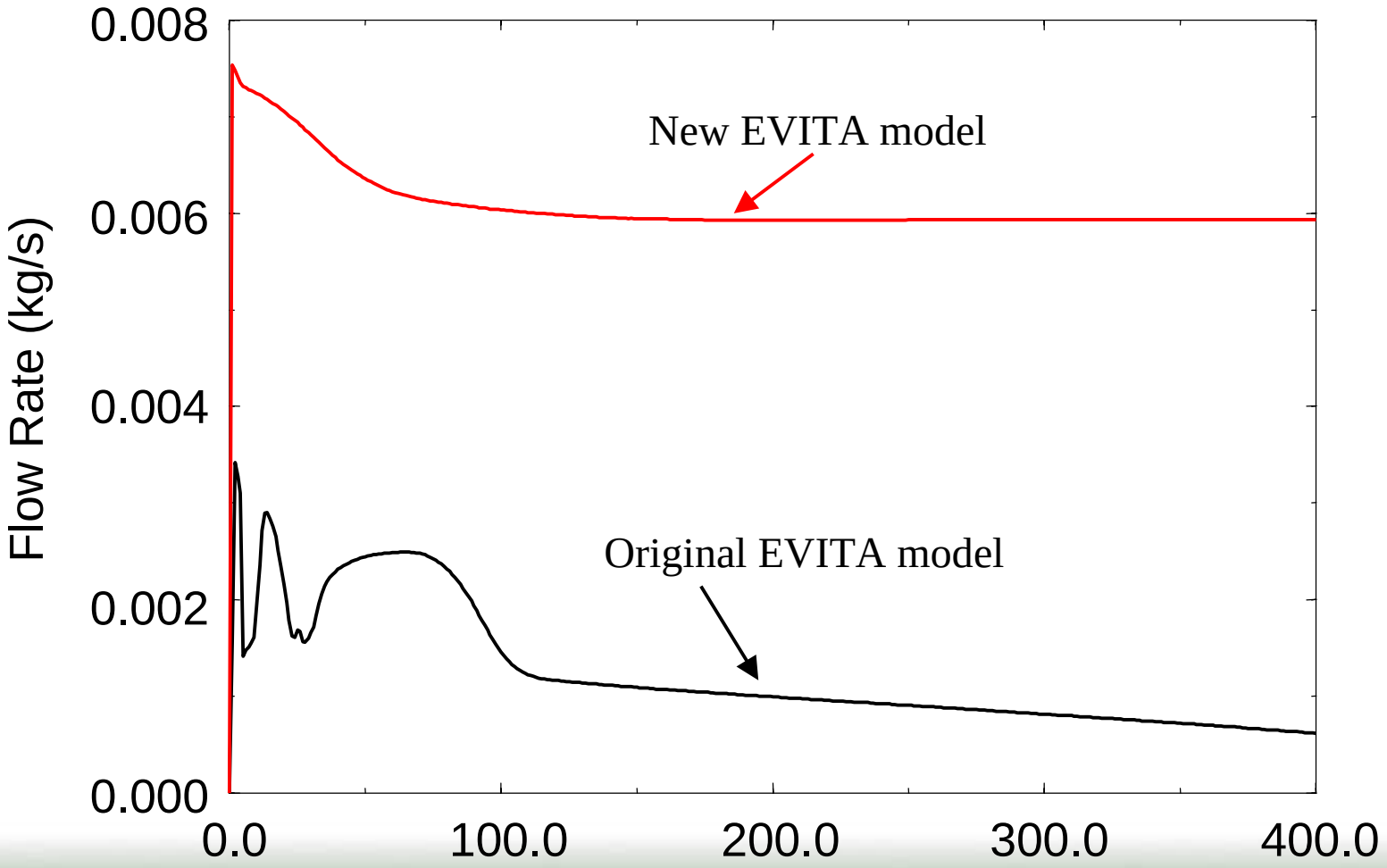
Colleague's Model Viewed with GUI



Model elevation and orientation problems fix



EVITA INJECTION FLOW COMPARISON



CONCLUSIONS

- ATHENA has been developed for fusion LOCA, and has be successfully used in the ITER international design study
- Code comparison with data from ICE and EVITA presently underway with large spread in code predictions
- New GUI feature for ATHENA makes life easier
- Results of code validation will be presented at next IRUG meeting