AC2-2025: Overview and Future Strategy

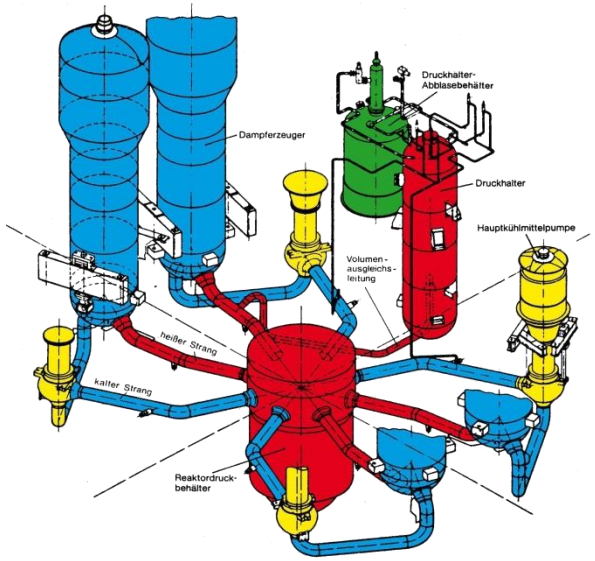
AC2 User Meeting 2025, Cologne, Fabian Weyermann

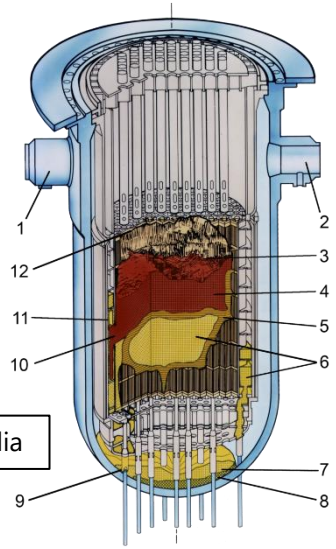
Content of this talk

The code package AC² 2025

- Content of the release AC² 2025
- New Features of
  - ATHLET
  - ATHLET-CD
  - COCOSYS
  - NuT
- Future Strategy

What is AC²?

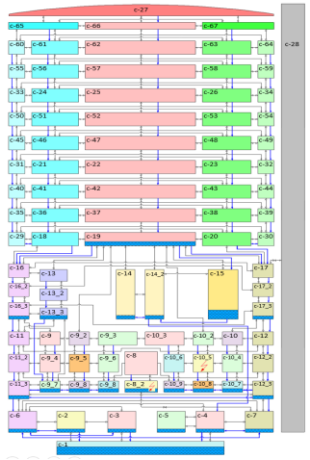




From: 11), Wikipedia

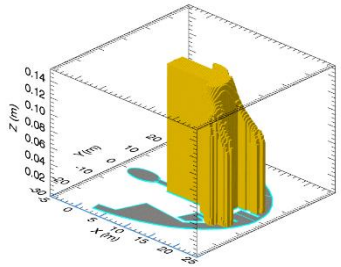
AC²= ATHLET + ATHLET-CD + COCOSYS

ATHLET
Cooling System
- Thermohydraulics
- Neutron kinetics
- I&C



Mass and Energy Transfer

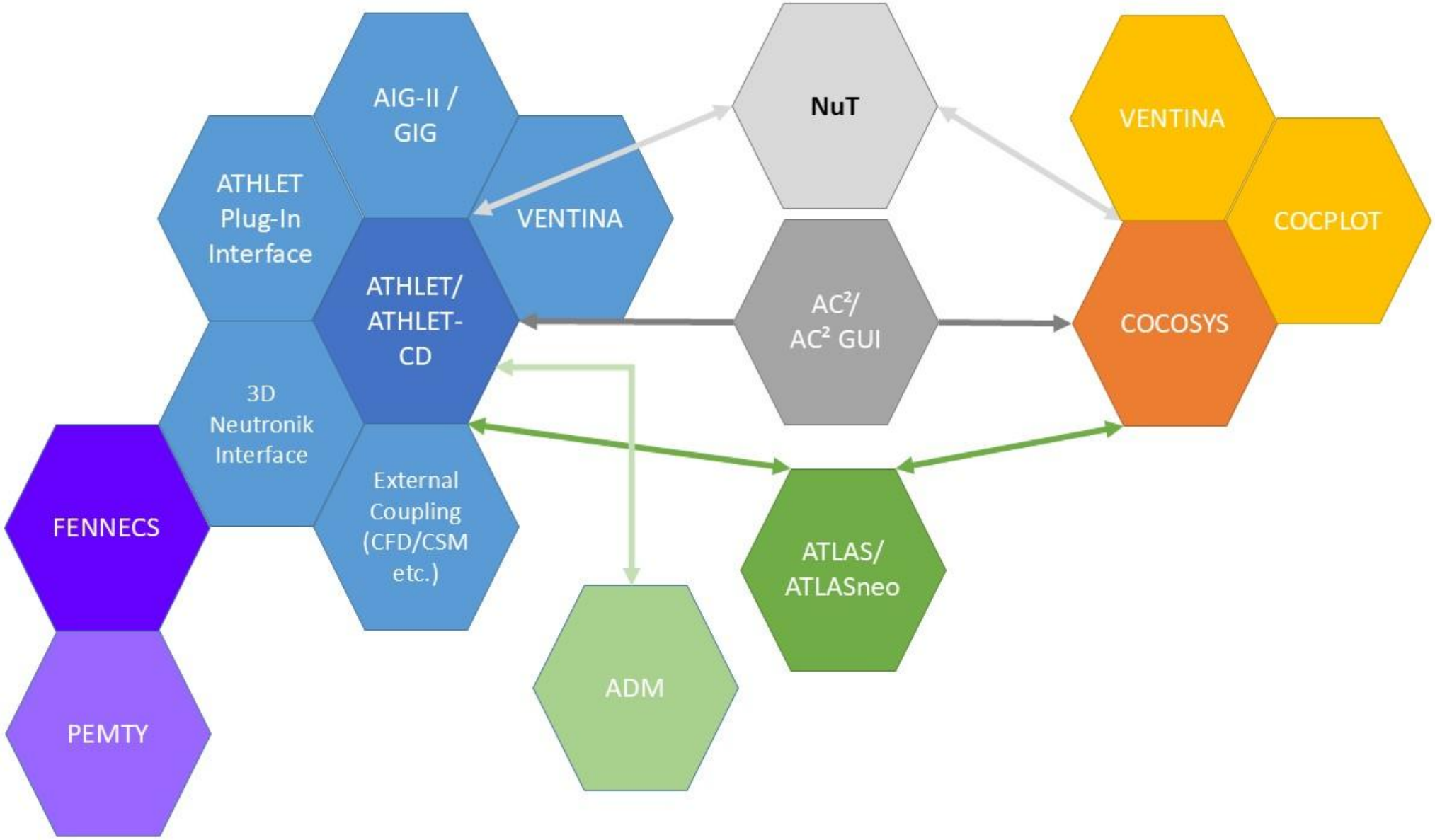
COCOSYS
Containment
- Fission products
- Hydrogen
- Core Melt



Hydrogen, Fission Products

ATHLET-CD
Core Degradation
- Hydrogen
- PV failure

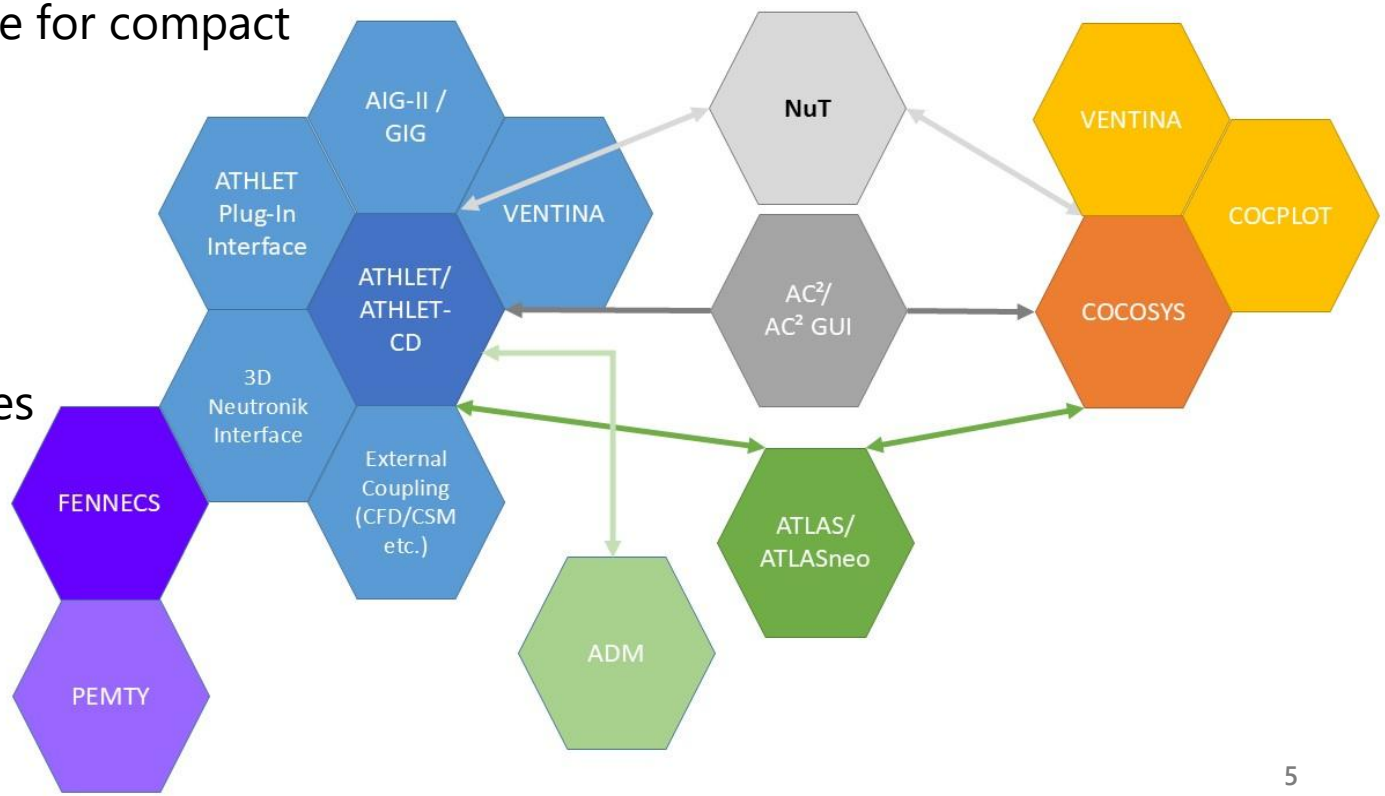
AC² 2025: Content of the Distribution



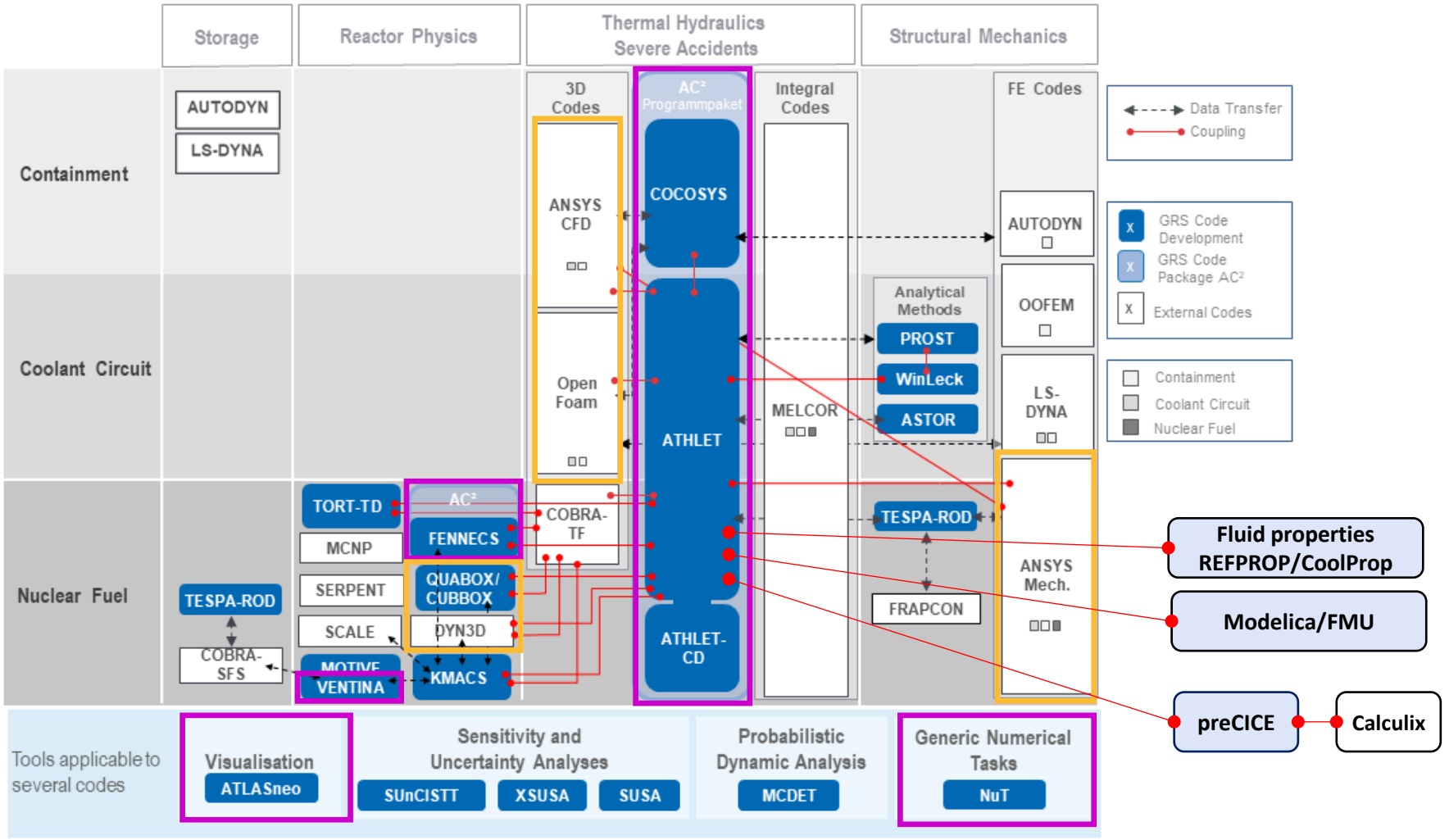
AC² 2025: Content of the Distribution

In addition to the AC² (**ATHLET**, **ATHLET-CD**, **COCOSYS**) code, **AC² 2025** package will contain:

- **ATLASneo/ATLAS** for visualisation of simulation results and interactive control
- **ADM** (ATHLET Design Modeler) for graphical generation of **ATHLET/CD** models
- **FENNECS**: 3D-Neutronic-Diffusion Code for compact cores
- **PEMTY**: Grid generator for **FENNECS**
- **New: VENTINA:** inventory calculation
- **Coupling Interfaces** to CFD/CSM-Codes
- **Plug-In templates** for User-models
- Tools für **ATHLET** und **COCOSYS**
- Sample inputs

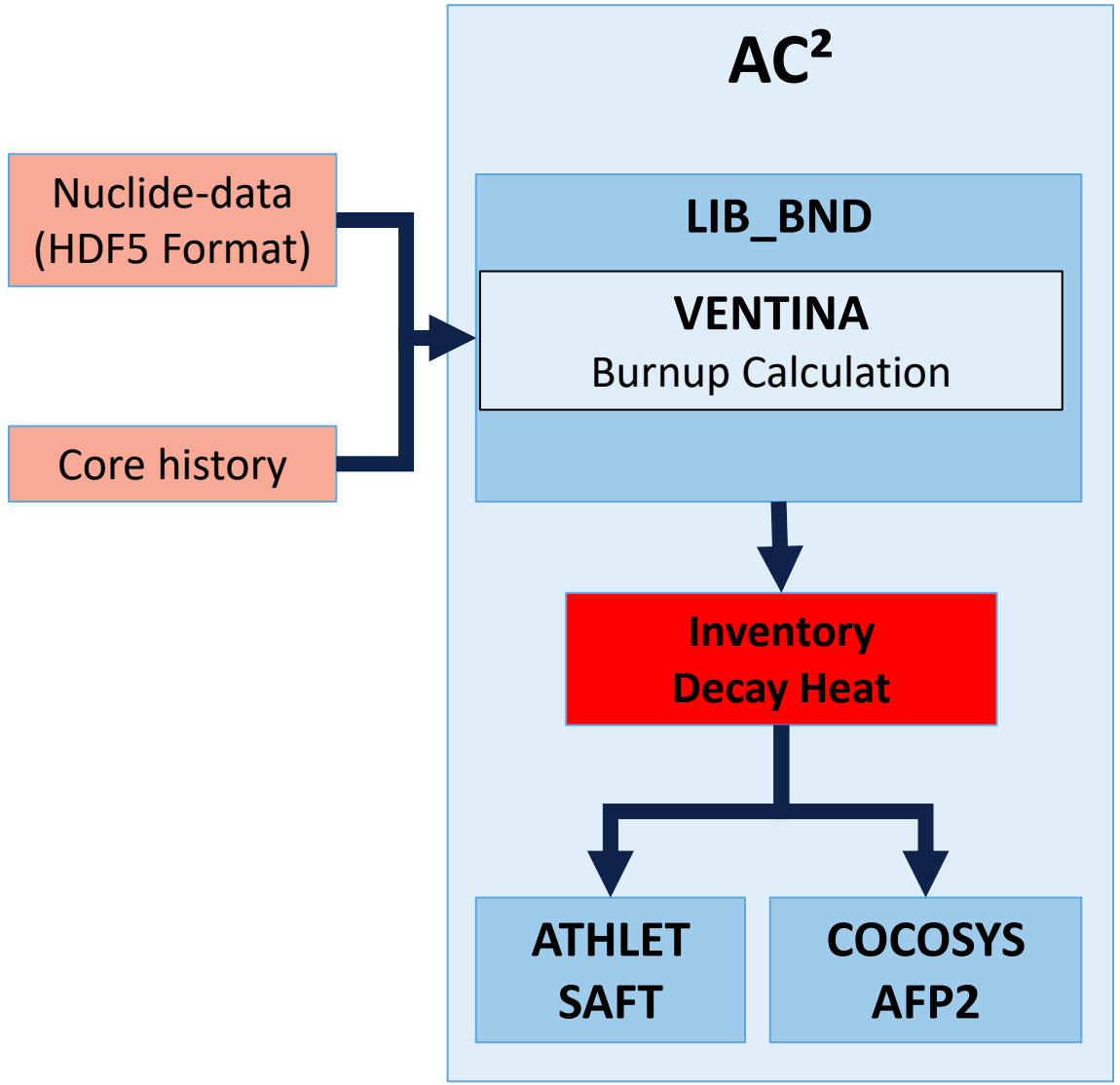


AC² 2025 within the GRS simulation chain



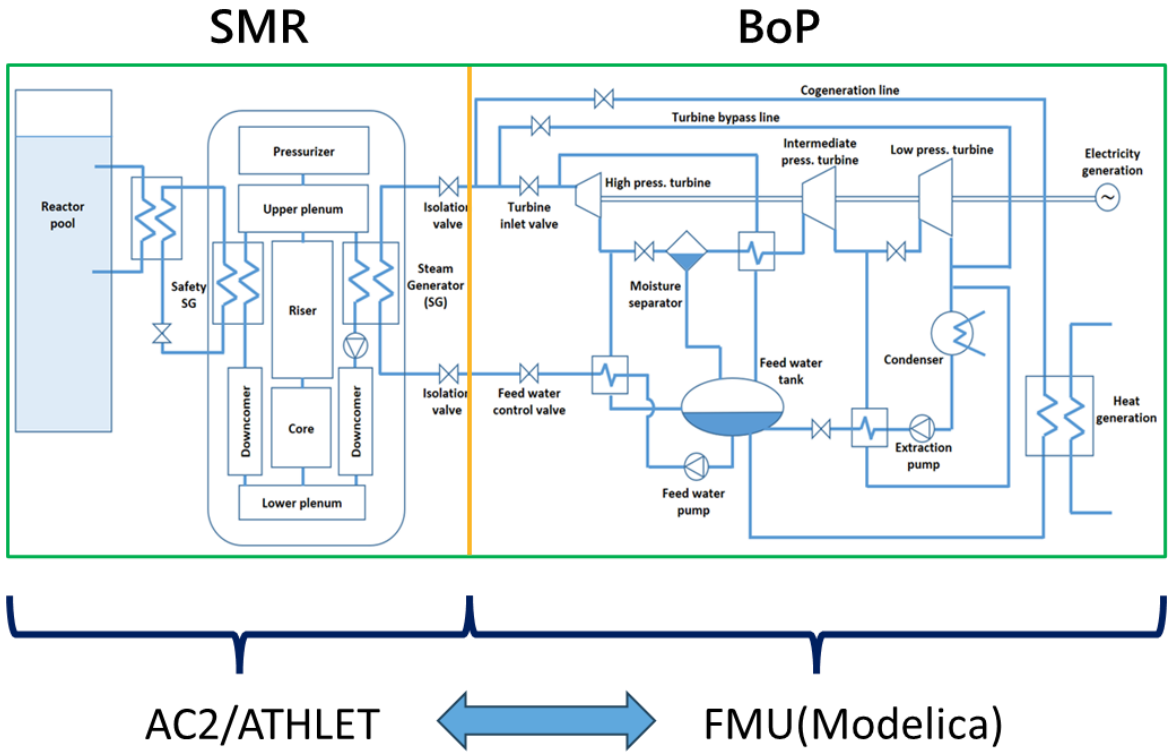
Inventory and decay calculation: Ventina

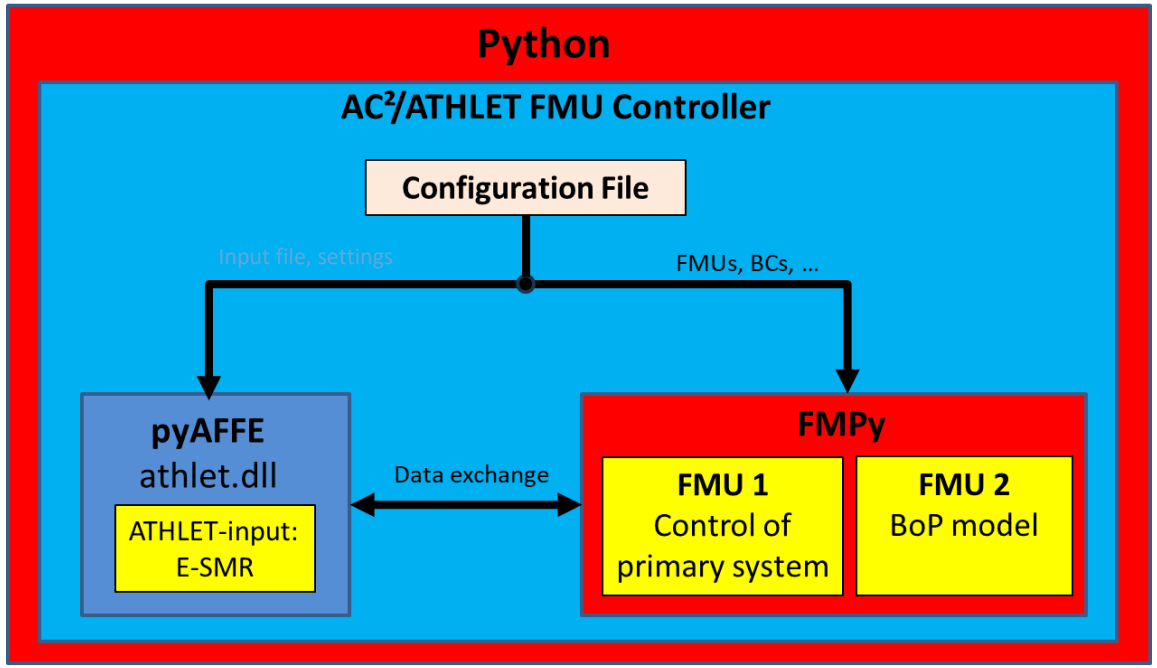
- Calculates inventory based on:
  - Irradiation history / Target burnup
- Currently assumes a 18x18 PWR fuel assembly
- More assembly types in development (research reactor FE)
- Considers 1348 isotopes and their decays
- Alpha/Beta/Gamma radiation
- Not fully validated, for testing!



New Features ATHLET (1): FMU Controller

- FMU: Functional Mock up Unit:
  - Simulation Model generated by arbitrary Software (Dymola, Simulink, OpenModelica,…)

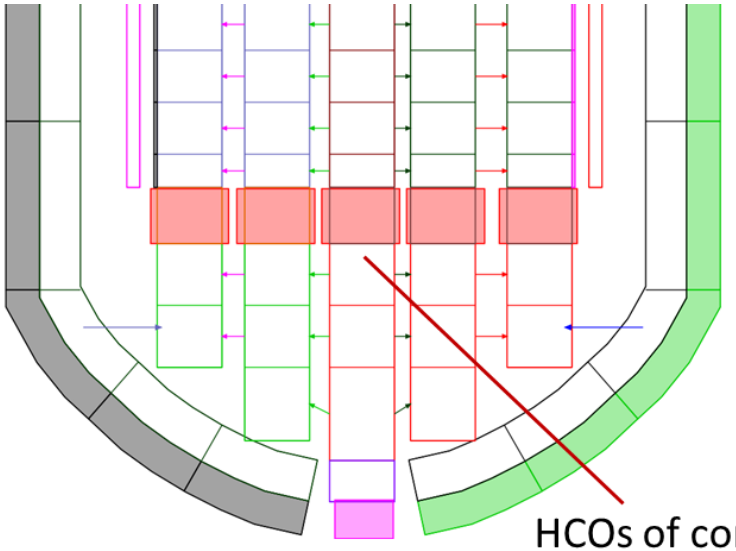


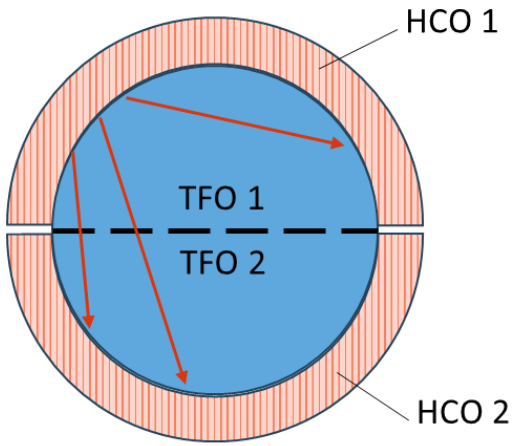


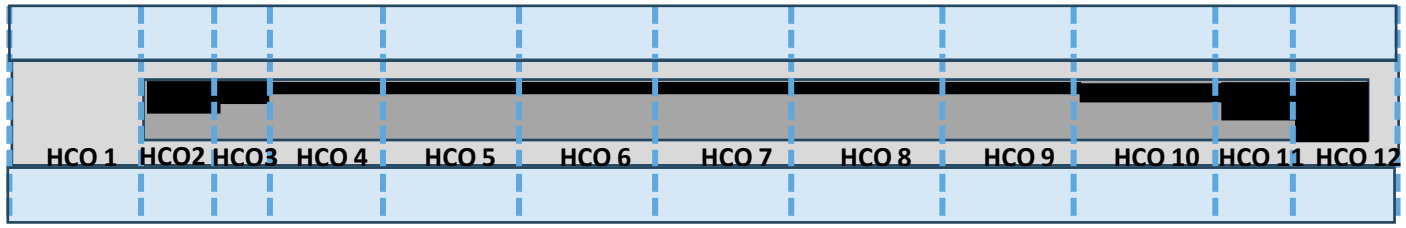
- Python based Controller to run coupled simulations ATHLET – FMU
- Handles Co-Simulation FMUs
- In development for COCOSYS

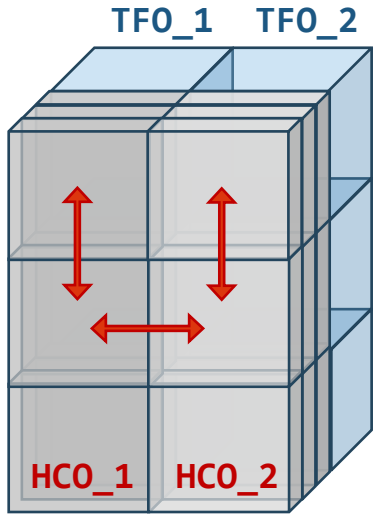
New Features ATHLET (2)

- New HCO type "**horizontal plate**"
- HCOs may consist of more than three material zones
- Simulation of **3D Heat Conduction** in Structures
- Extended Thermal Radiation Model
- Improvements of HECU Module for **Helically Coiled HTEX**



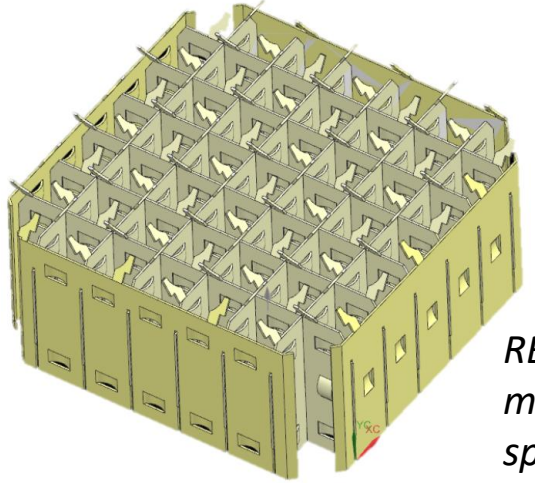




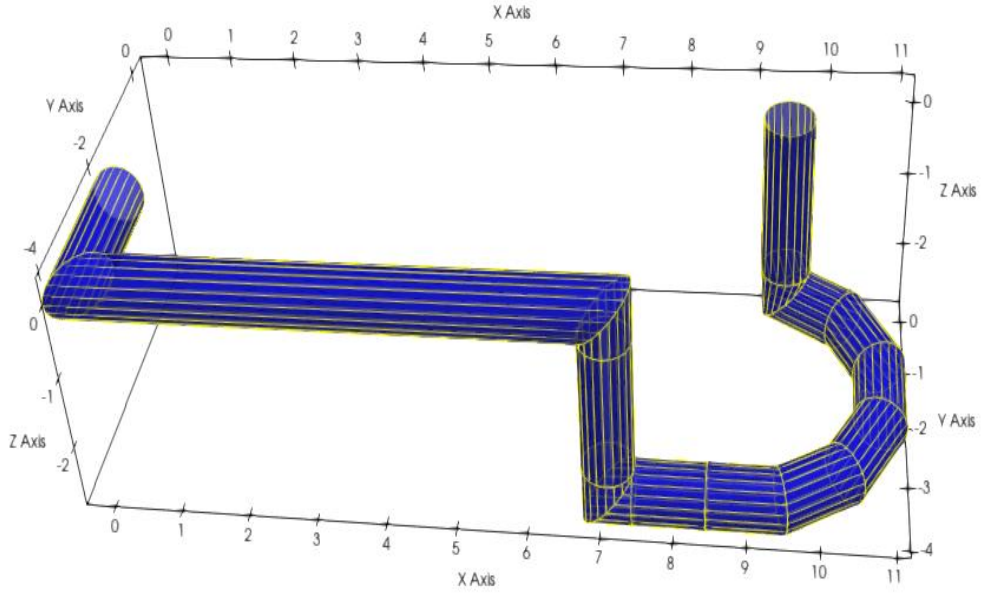


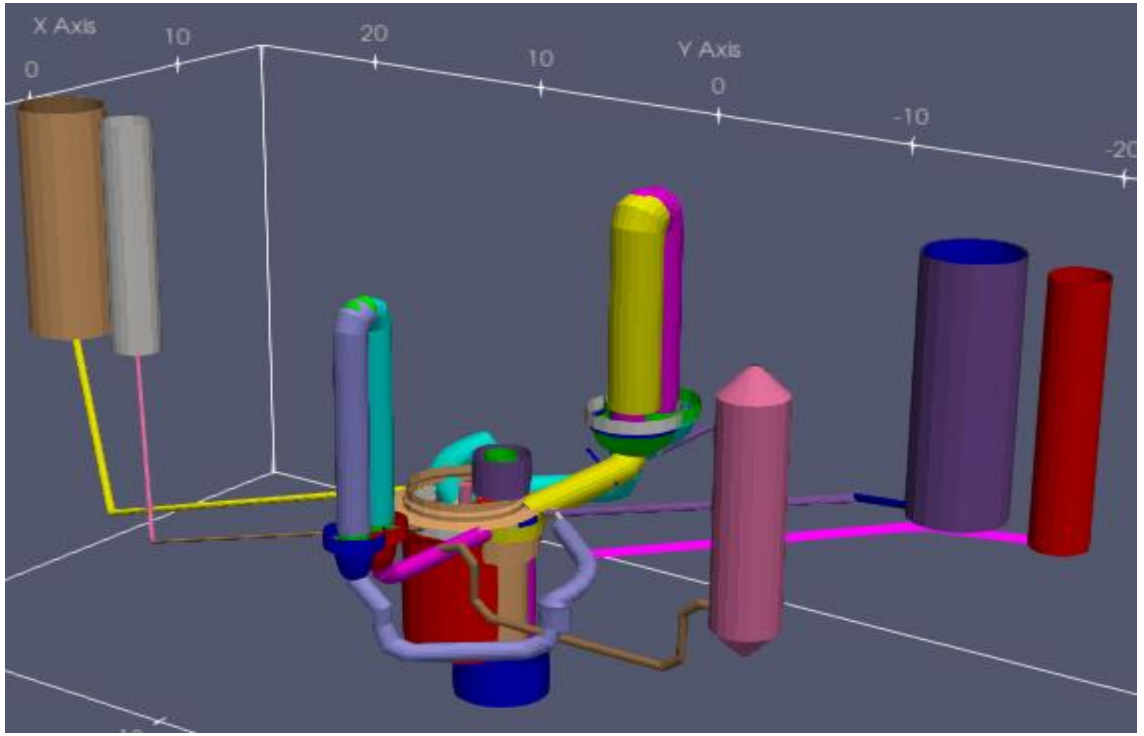
New Features ATHLET (3)

- Extended Spacer Grid Model for Rod Bundles
- Extended Plug-ins for User-provided HTC and CHF Correlations
- New Input and Output Options: 3D Data



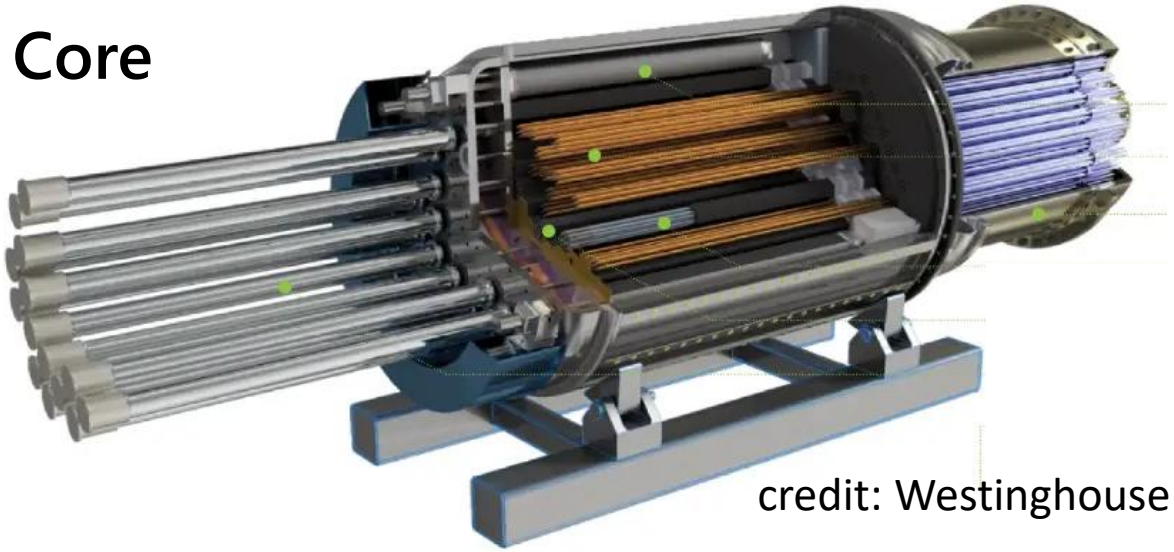
RBHT mixing vane spacer grid



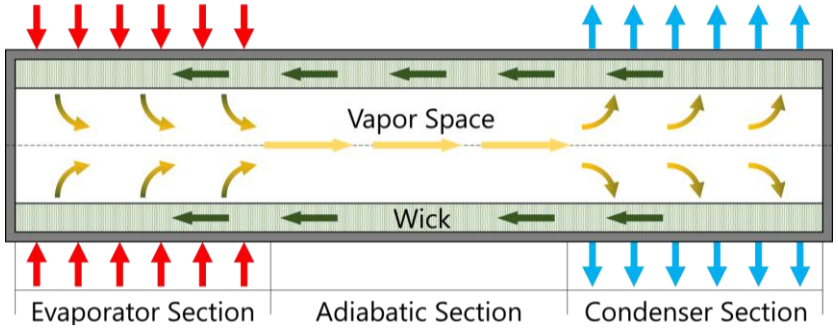


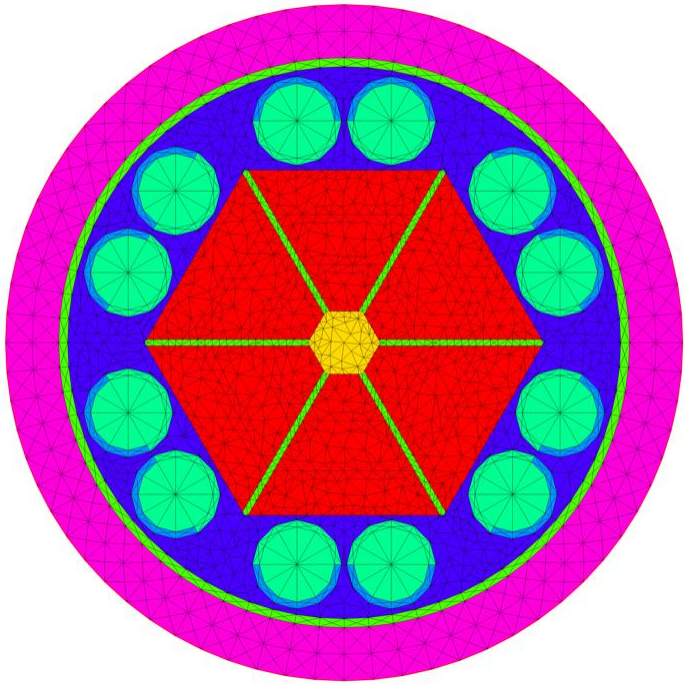
Simulation of MMRs: Heat Pipes and Core

- **Liquid metal heat pipe-cooled MMR** (eVinci, SPR, …)
- Development of ATHLET for MMR safety analysis
- New ATHLET “Heat Pipe” – Module
- FENNECS: Improvements for MMR cores



credit: Westinghouse



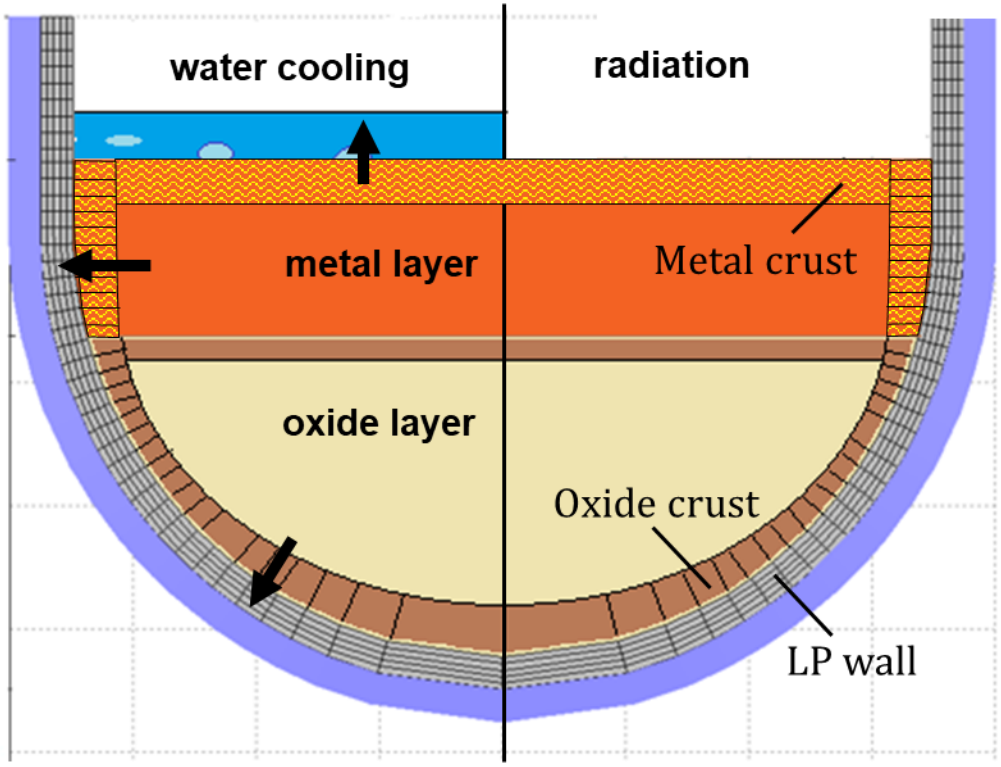


Integration of ATHLET-CD into ATHLET (ongoing)

- **Goals:**
  - Simplify development of **ATHLET-CD** input starting from **ATHLET** input
  - Harmonization with **ATHLET**
  - Extending **ATHLET** with severe accident simulation capabilities
- **Status: ATHLET-CD modules available in ATHLET:**
  - **VENTINA** for initial **inventory calculation** and decay of isotopes
  - **FPREL** and **SAFT** for release, transport and deposition of **radionuclides** in LWR
  - **THEMEC** for fuel **rod behavior**, ballooning, and feedback on thermal-hydraulics
  - Enables **severe accident** scenario simulation until/without core degradation

New Features ATHLET-CD

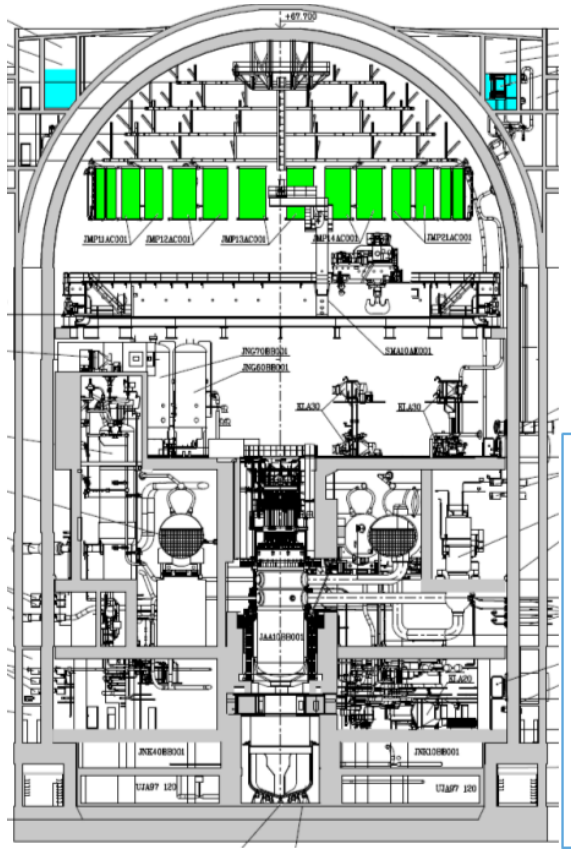
- Improvements in the lower plenum module **AIDA**
  - Modelling of upper and sideward metal layer **crust formation**
  - New correlation for **sideward heat transfer** from metal layer (*Chawla-Chan*)
  - New correlation for heat transfer between **oxide crust** and **metal layer** (*COPRA based*)
  - New heat flux distribution factor to model **shallow lower plenum** geometries (VVER, SMR, etc.)



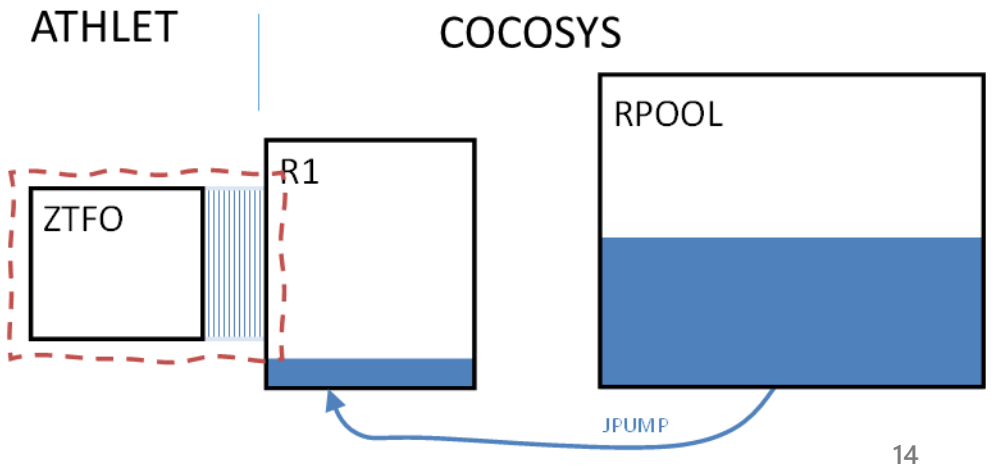
Modelling scheme of AIDA

New Features COCOSYS (1)

- Simulation of **stratified atmospheric conditions** along vertical building condensers with **GEKO** model
- Consideration of segmented structures coupled to **ATHLET**
- Improvements and new features in **THY**:
  - **Heat transfer coefficient** calculations (film boiling, nucleate boiling, free convection,regime-change)
  - Extended simulation of **building condensers**
  - Coupling **ATHLET-COCOSYS** structures
  - …



/ENS 17/ ENSREG stress test report - Belarus

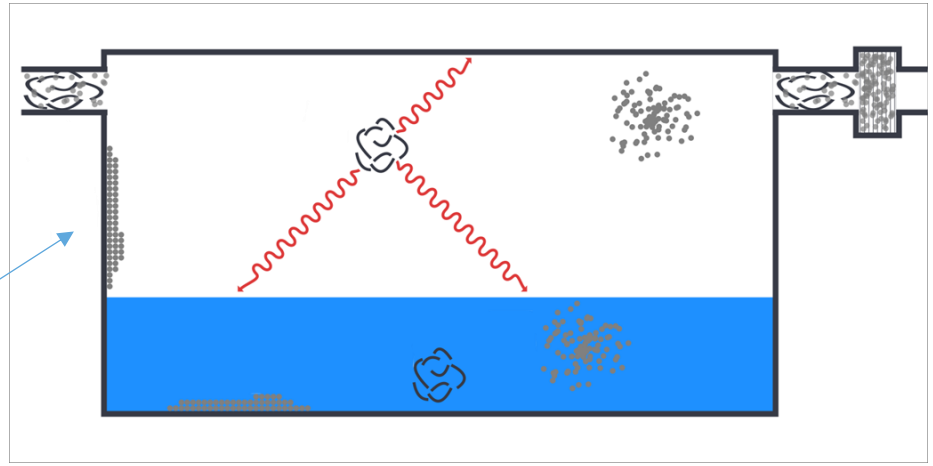


New Features COCOSYS (2)

Model improvements and new features in **AFP** & **AFP2**

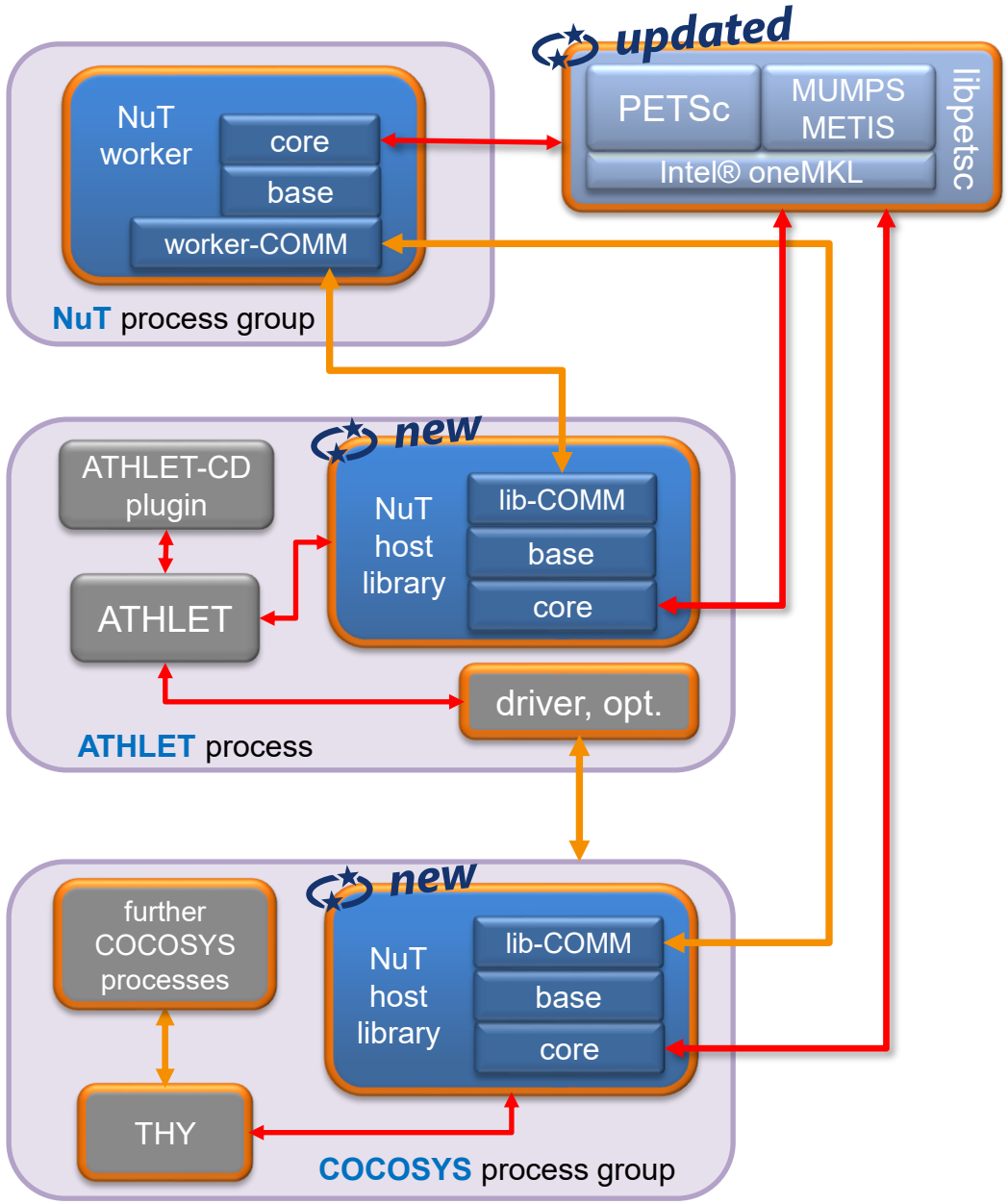
- Simulation of isotope behaviour in COCOSYS when coupled in AC²:
  - New: ATHLET+ & COCOSYS/AFP2 → VENTINA
- Improvement of AFP/AFP2 interface with COCOSYS driver, enhancing numerical performance, particularly for volume condensation

- Simple autocatalytic recombiners (CATALY_SIM)
- **AFP2** extended for dry and wet resuspension processes
- New concept of CsI aerosol decomposition model



NuT: What's new in AC² 2025

- Introduction of **local use** of **NuT**
  - resides within the host process, i.e., **single processor use**, and **NuT** worker not required
  - **ideal for** parallel execution of different calculations, e.g., **uncertainty analysis**
  - no more plugin but **still optional** for time-integration
- Application of **NuT** local in
  - **ATHLET**'s **HECU** module
  - **Ventina** (nuclide inventory)



Strategy for Future Developments (1)

- **Main topics of on-going ATHLET code development**
  - Extended **flow regime maps** for flows across diabatic walls
    - Improved prediction of heat exchangers of passive safety systems
    - Distribution of wall heat flow to phases
    - Consideration of post-CHF conditions
  - Closure laws for **interfacial transfers** at low pressure, e.g. for research reactors
  - Further **integration** of **ATHLET** and **ATHLET-CD**
- Improvements for **non-LWR designs**
  - Use **cooperation** with external developers

Strategy for Future Developments (2)

- **Two main paths for "ATHLET-CD" development**
  - **Current ATHLET-CD:**
    - Mostly lower plenum related developments
    - Bugfixes, quality of life, stability and performance improvements
  - **ATHLET+:**
    - Future of severe accident simulation within **AC²**
    - Up until melting most relevant phenomena covered
    - **Melt related** phenomena
    - Improvements for research reactors
    - **Non-LWR severe accident** phenomena: **collaboration** with external developers

Strategy for Future Developments (3)

- **Main topics of on-going COCOSYS code development**
  - Water film behaviour on structures due to external containment cooling
  - Hydrogen deflagration at low oxygen concentrations & impact of CO
  - User guidelines and improvements for simulation of water pools
  - Integration of advanced knowledge on iodine chemistry
  - Further improvements in numerical methods in modules (AFP2, …)
- **Include TESPA-ROD into AC² Distribution**
  - More realistic temperature, Strain and Pressure Analysis of a fuel rod
  - fuel rod behaviour under various accident conditions, normal operation as well as long-term storage condition
- Postprocessing: 2D-result graphics within ATLASneo

Acknowledgements

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