Practices for Neutronic Design of RRs: Safety and Performances

M. BOYARD, P. PERE, L. CHABERT,
L. LAMOINE, T. BONACCORSI

Special thanks to Dieter COORS and Werner GYR from AREVA at Erlangen
for their involvement in our recent exchanges around reactor design

AREVA TA

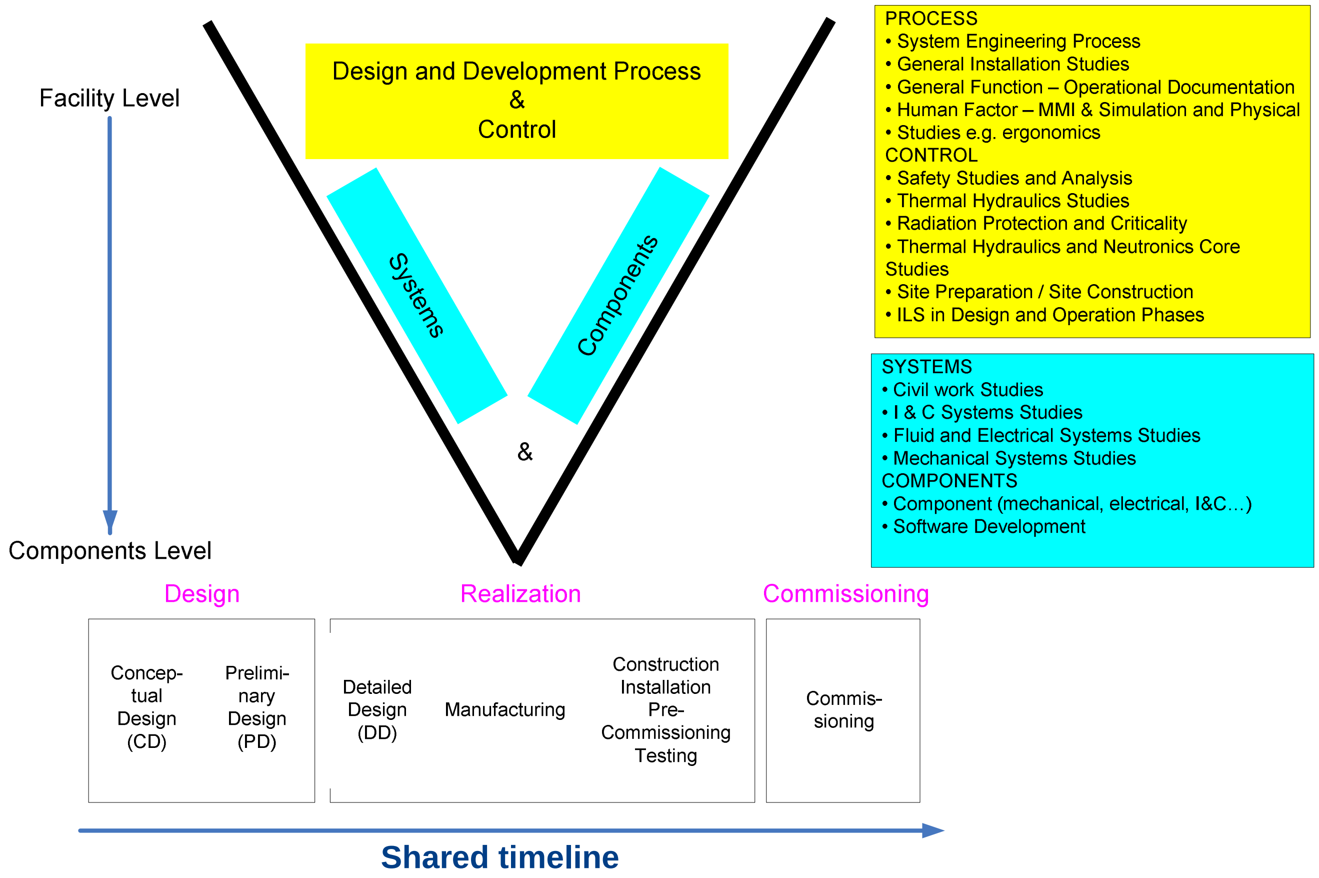
AREVA

Outline

- General process of design
- Safety organization
- Neutronic design process
- Focus on shutdown system
- Focus on neutronic calculation scheme
- People

General process of design (1/2)

- **Since the 1990's, AREVA TA has developed**
  - A consistent set of design processes (consistent with FD-X-50-410 standard)
  - A consistent set of technical instruction reports
  - An internal safety organization



A Design and Development Plan is tailored for each project & each phase

General process of design (2/2)

- **To summarize, the synchronization of design activities is based on:**
  - **A set of consistent design phases and Milestones to pace the design activities not only at plant level, but at system and component level too**
  - **The identification of the data exchanges between activities: input data expected and associated producer, and output data to be produced and associated user**

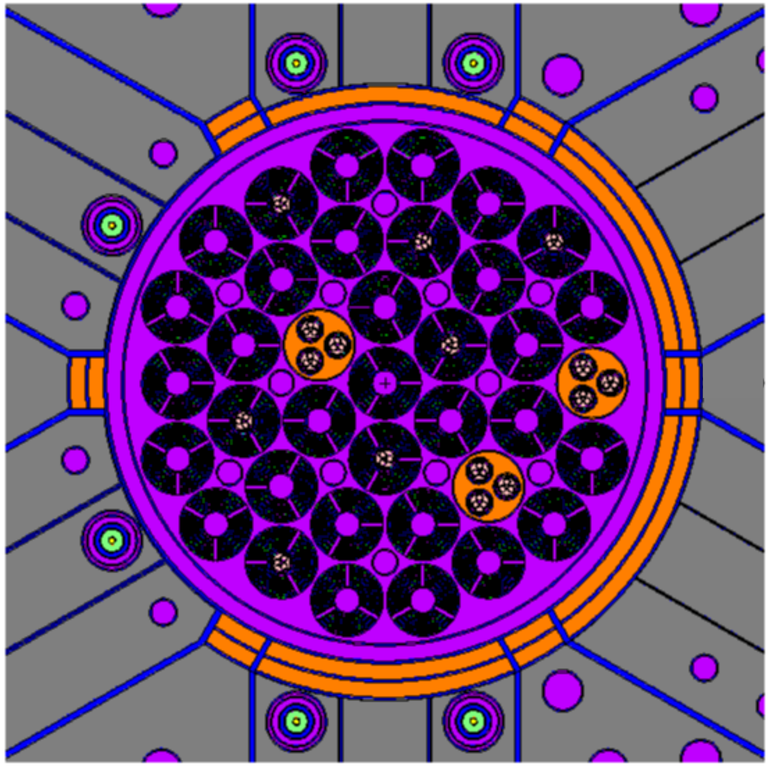
Safety organization

- **AREVA TA is the technical operator of some CEA facilities**
  - **Shutdown reactors : PAT, CAP-RNG**
  - **Reactor nearly in operation: RES (fuel and material irradiation tests, neutronic tests at power, component tests)**
  - **Zero-power reactor: AZUR (neutronic tests)**
  - **And other nuclear facilities: storage pools etc**
- **Research reactor projects benefit from the induced organization of safety**
  - **Internal Safety Committee (operators, technical experts etc): monthly committee gives safety advice and recommendations to the projects from a safety point of view**
  - **A Safety Project Engineer in each project and also safety engineers: for safety analysis and monitoring of the Safety Analysis Reports drafting**
  - **Engineers in thermal hydraulics, neutronics, mechanics, radiation protection etc for the safety assessments**

» That whole organization is fitted to ease the project safety activities, to ensure coherence between projects, not to make them heavy

Neutronic design process

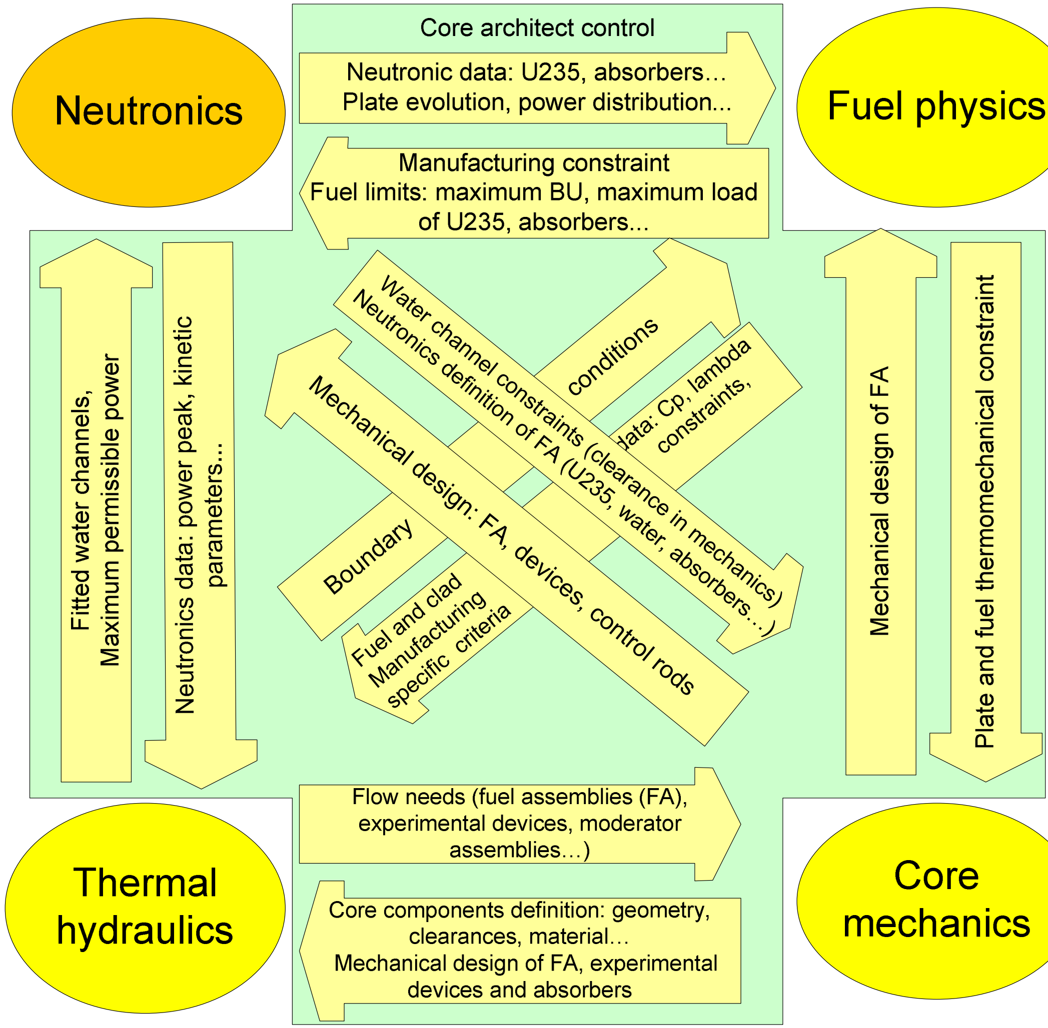
- **The core of a RR: a lot of constraints in a small volume**
  - **Experimental or production devices of all kind**
  - **Fuel**
  - **Moderator**
  - **Coolant**
  - **Neutron absorber**
  - **Reflector**
  - **Structures**
  - **Instrumentation for safety or experimental load**
- **Many technical interfaces and data exchanges**



Our guideline: to remain safe, simple and effective

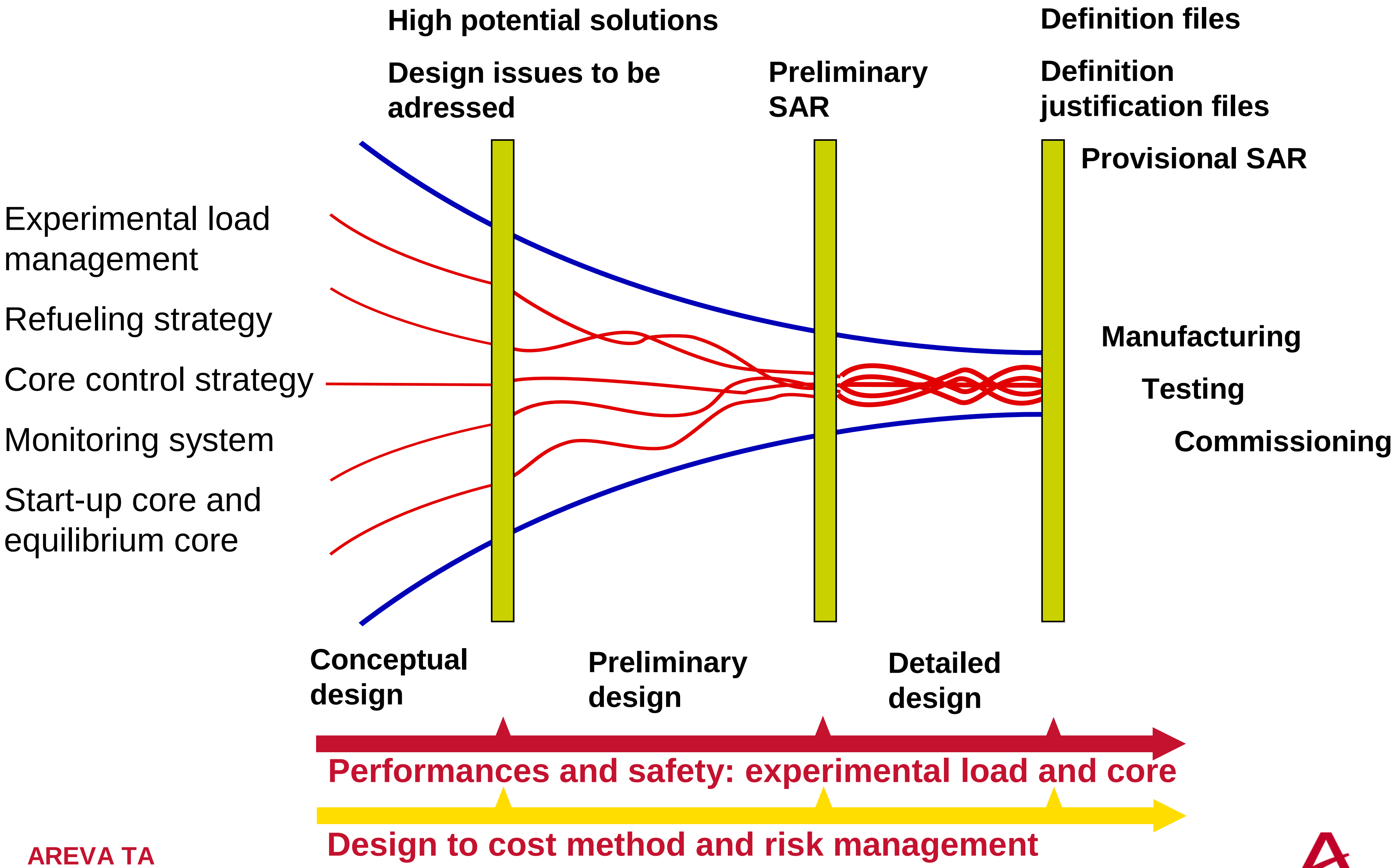
Main data exchanges

- **Management/control of main technical data**
  - ⇨ **Core architect responsibility**
  - ⇨ **Usually: core architect ≠ safety project engineer**



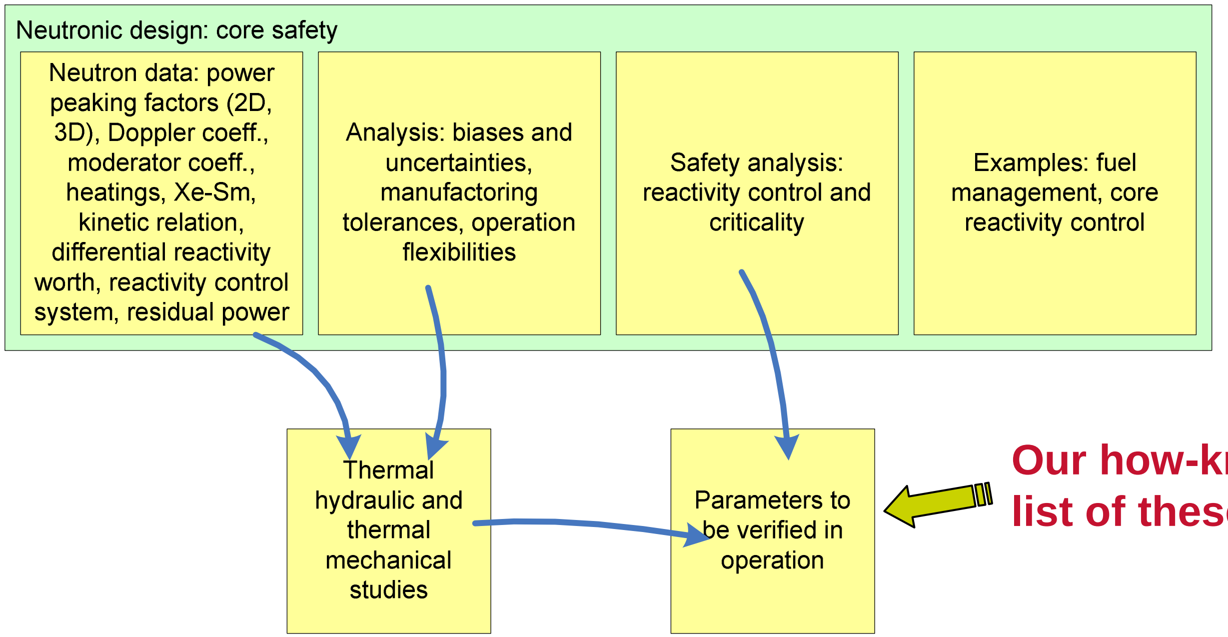
Core architect and Safety project Engineer are 2 key-functions for the core safety

Neutronic design



Preliminary and detailed design

- **A backbone: the core compliance approach to define and to take into account**
  - **Constraints of the fuel manufacturing and the tools for treatment of non compliances of fuel assemblies**
  - **Flexibilities offered to the operator: fuel management, experimental load management …**



Our how-know: a short list of these parameters

Examples of integration of experimental load

- **JHR kinetic relation**
  - **JHR experimental load can have fuel samples**
  - **Choice for delayed neutron fraction: whole allowance of power for the in-core devices come from Pu239 fissions ⇨ β – 33 pcm**
- **JHR power factor**
  - **A large number of various experimental load have been considered**
  - **But extra margin for 3D and 2D power factors has been defined to make easier the later modification of some of the devices**

The safety in operation for 40-50 years is improved by a sound initial design and these initial flexibilities

Focus on shutdown systems:
Basic principles for our design of RR

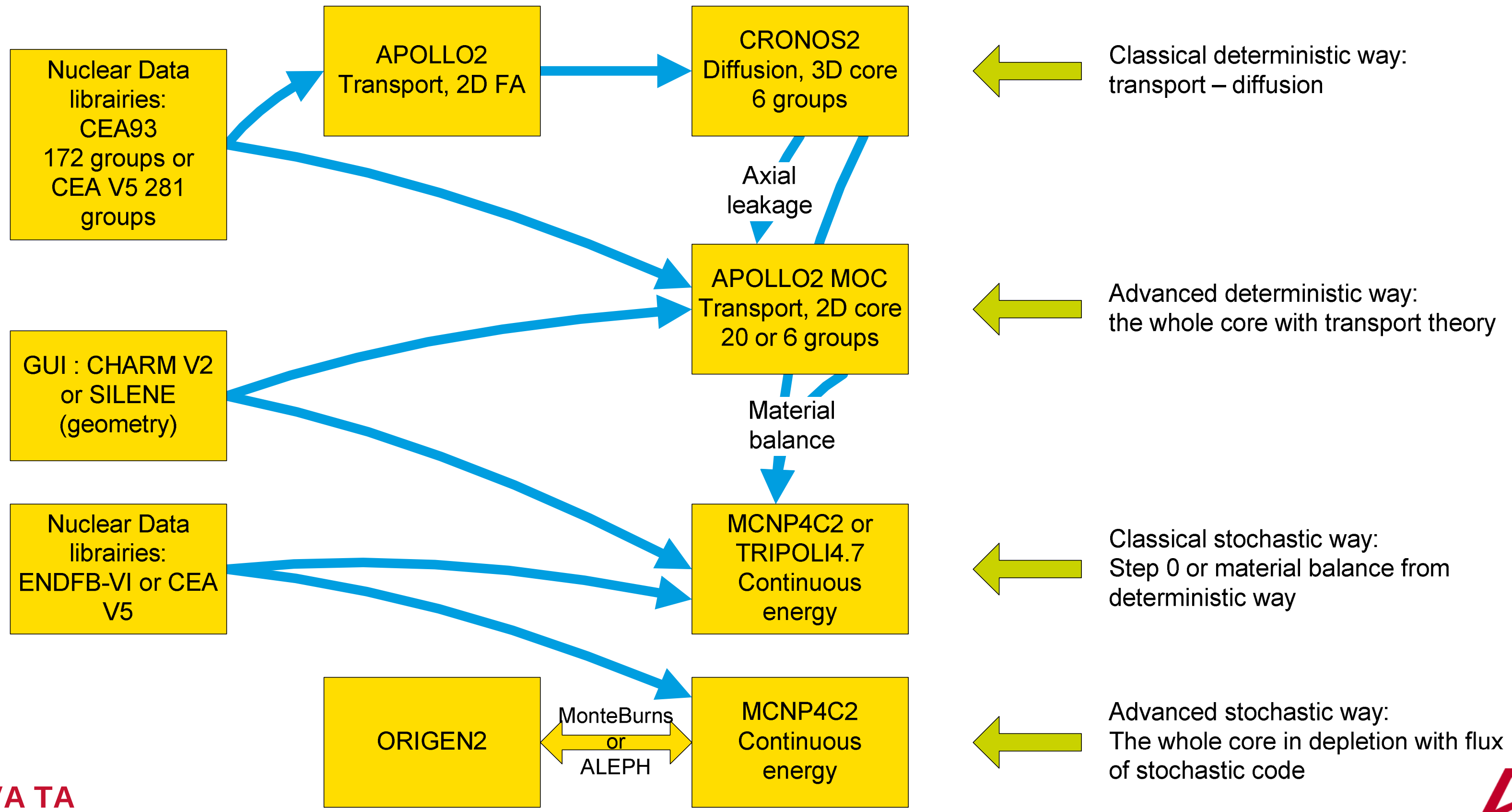
- **Usually, 2 automatic shutdown systems (NS-R-4)**
  - With the most complete possible separation between the 2 systems (analysis of common mode failure): from I&C to actuators
  - 2 different technologies
  - If possible, the both are for short, medium and long term
  - With the greatest flexibility for the experimental load
- **And another shutdown system (in fact provision for emergency planning management)**
  - Simple and robust design
  - Accessible from outside of the containment
  - Able to manage criticality in the first two confinement barriers
  - For the shutdown in the medium and long term
  - Not instantly operative to avoid spurious shutdown

Examples of shutdown systems: JHR

- **First shutdown system**
  - **4 drive mechanisms located in the crypt**
  - **Drive mechanisms allow bringing the absorber tubes to high position and then they step back**
  - ⇨ **No more mechanical bond between crypt and absorber**
  - ⇨ **Criterion: no core divergence by raising of the most reactive absorber**
- **Second shutdown system**
  - **Drive mechanisms located in the crypt**
  - **4 absorber tubes: ensuring control and preventive shutdown**
  - **19 shim absorber tubes for global effects of reactivity (fuel burn-up, modification of experimental load etc)**
- **Provision for emergency planning management**
  - **1 circuit: allowing to send soluble neutron poison in the reactor pool after dilution by batch: around -1000 pcm/batch for an 800 cubic meter pool**
  - **That system is consistent with the general water block design for the pools of the JHR**

Focus on neutronic current calculation scheme

- **That current scheme is used for Jules Horowitz reactor, R&D studies and other small and medium cores**
- **APOLLO, CRONOS, TRIPOLI, CEAV5 library, CHARM, SILENE and ALEPH: developed by CEA, IRSN and/or AREVA**



People

- The problem: to have the right people at the right moment in spite of a fluctuating RR market
- Our practice
  - Having a small group of engineers with good how-know of RR
  - Sensitization of a broader group of engineers to the RR core characteristics
  - R&D studies of new concepts of RRs to feed the technical skills
  - Development of related tools (general tools with specific functionalities for RR): AREVA framework for code activities
  - Varied careers at AREVA TA to widen the capabilities of people: neutron study, neutron tests (zero power reactor AZUR, RNG reactor then RES reactor etc), operation in other nuclear facilities, fuel manufacturing and other technical study
- AREVA TA's intermediate size in the broader AREVA group and our activities (from studies to nuclear reactor operation and dismantling) is facilitating this strategy

Concluding remarks

- This overview is focused on the neutronic core design and would require a supplement with the other technical aspects: in particular thermal hydraulics, mechanics and material physics
- However our purpose wasn't to be exhaustive nor to propose new safety rules but to present some of our practices for the neutronic core design, like the provision for emergency planning management
- It's just an example of our main guideline:
  - Having the right people and the right tools at the right moment
  - Improving the final safety of the reactor without sacrifice of experimental load performances or other economic performances
  - And also Keep It Simple and Safe

Thanks for your attention