DE LA RECHERCHE À L'INDUSTRIE

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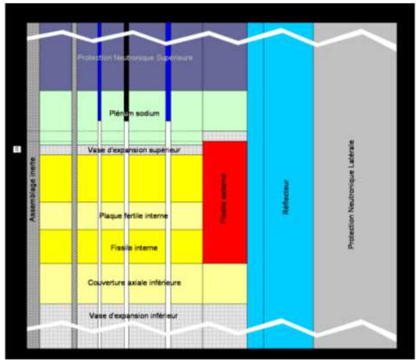
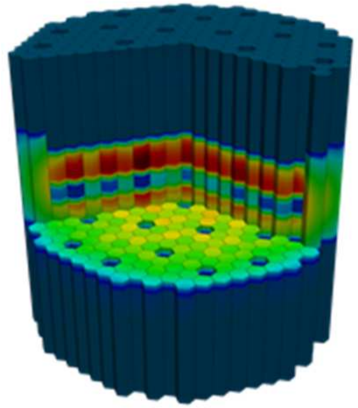
# APOLLO3® ROADMAP FOR A NEW GENERATION OF SIMULATION TOOLS DEVOTED TO THE NEUTRONIC CORE CALCULATION OF THE ASTRID PROTOTYPE



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# INTRODUCTION

- The neutronic specificities of the ASTRID FR (Advanced Sodium Technological Reactor for Industrial Demonstration) require improved tools with accuracies meeting the design team requirements, particularly for high safety level and a low Sodium Void Effect

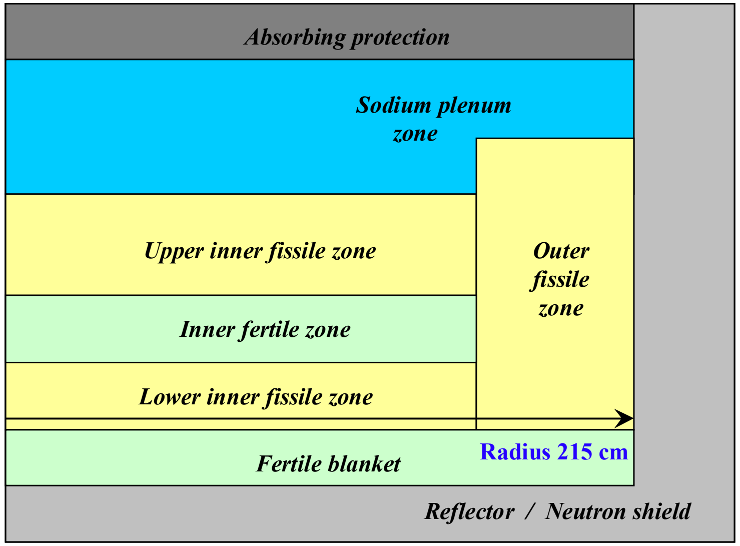
- CEA and its industrial partners have launched a large program for developing a new generation of simulation tools facing the challenges of multiphysics coupling and high-performance computing on massively parallel computers

- The new APOLLO3® code, will take over, after a commissioning period, the ERANOS2 code, currently used for ASTRID conceptual design. This code will take advantage of new numerical developments for neutronic core reactor calculations

- The transition is defined so as to meet the ASTRID development plans and will require the achievement of many tasks

# NEUTRONICS SPECIFICITIES OF ASTRID FEATURES

The current concept of the ASTRID core : CFV (low (reactivity) void effect)

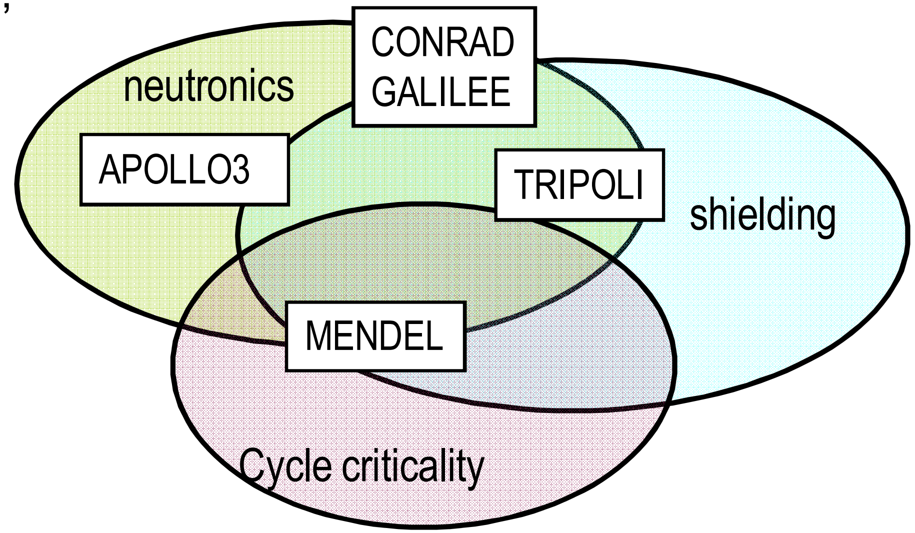



- Radial reflector instead of radial blanket
- Axial heterogeneity of the fuel with the inner fertile zone
- Na plenum in the upper part
  - this zone can be voided
  - followed by an absorbing zone
  - control rods have a large part of their absorption in this zone

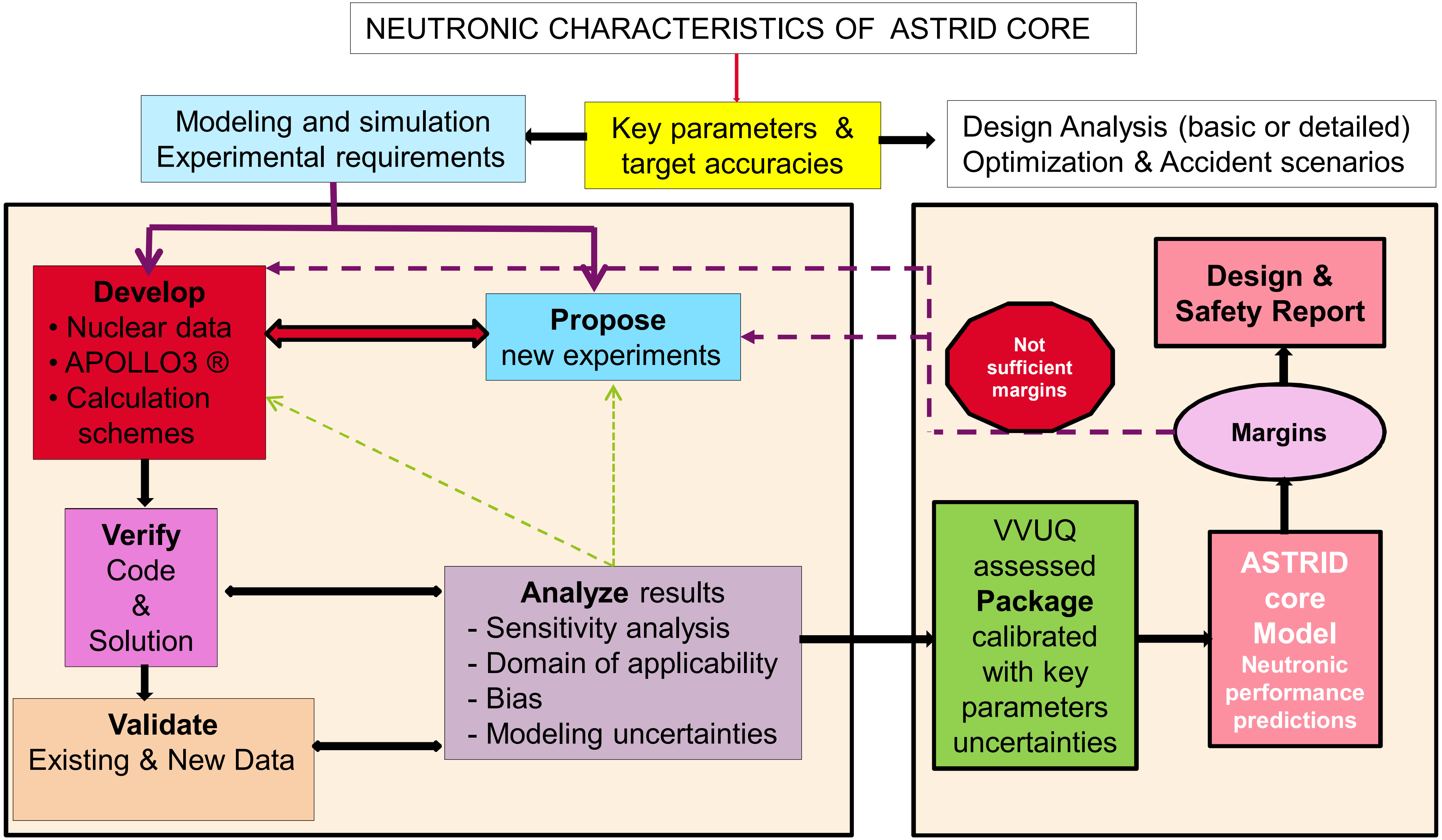
# THE APOLLO3 PLATFORM

- 3D deterministic multi-purpose code for any kind of reactor concepts
- Main guidelines leading its developments
  - Extended application domain : criticality, shielding for all kind of reactors (PWR, BWR, GFR, SFR, SCWR…)
  - Coupling through SALOME platform for multi-physics calculations (thermo-mechanics, thermal-hydraulics)
  - Uncertainties assessment with perturbation methods (internal library) and non-intrusive methods (URANIE platform)
- Ability to perform high performance computing

APOLLO3
part of the new CEA neutronic platform



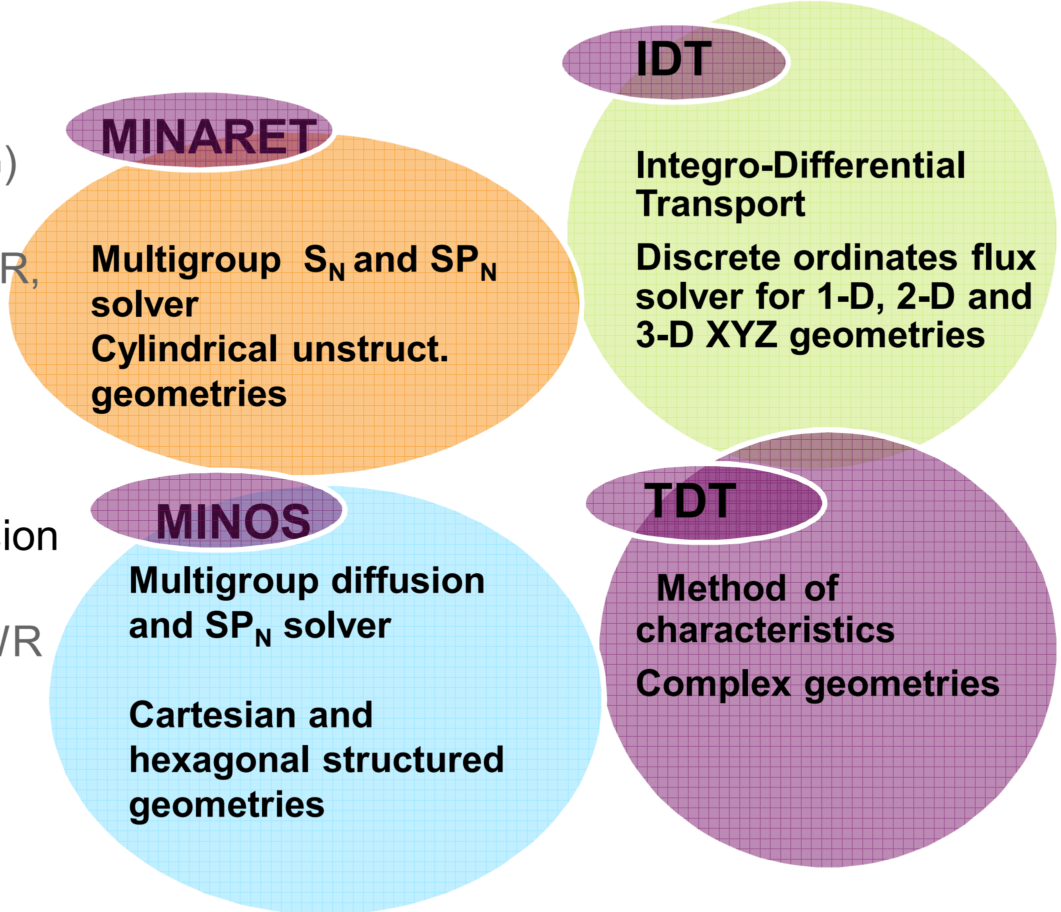
# THE VVUQ PROCESS DEVOTED TO ASTRID CORE CALCULATION



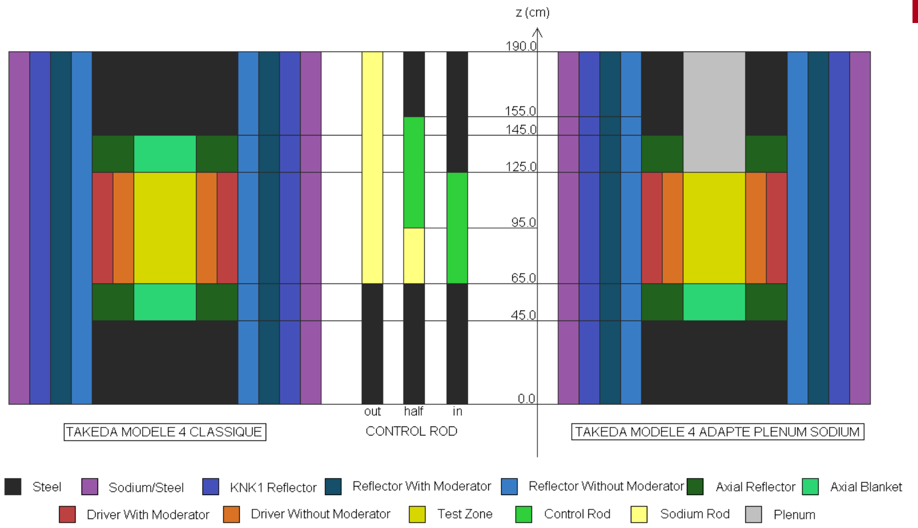
# V&V (1/3) : FIRST BENCHMARKS FOR SOLVER TESTS

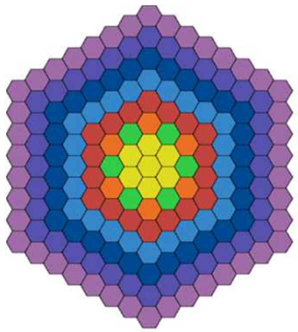
Objective : numeric validation of APOLLO3® solvers (IDT, TDT, Minos, Minaret) : comparison to Monte-Carlo reference calculations

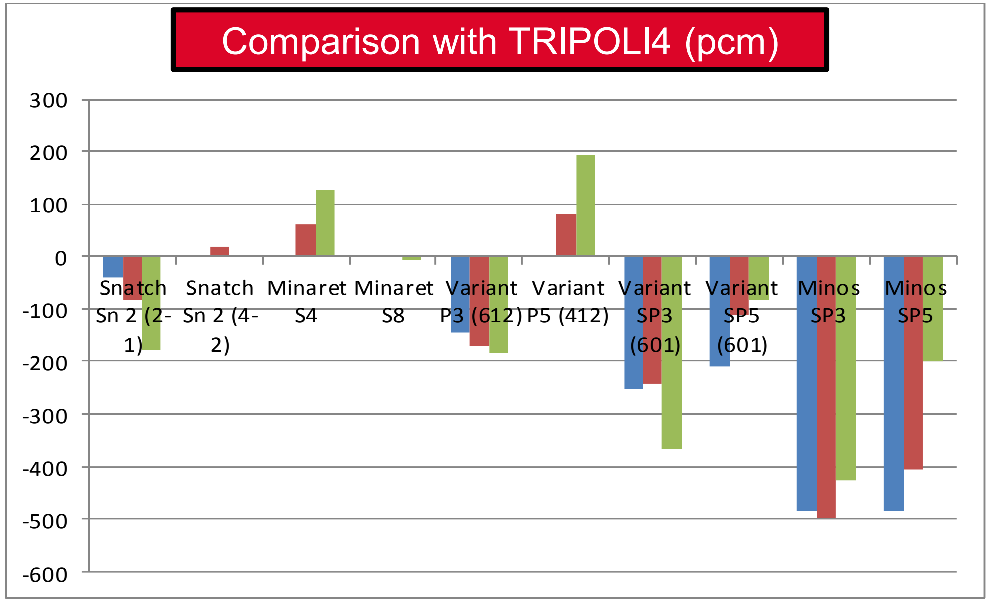
- Numeric convergence and TRIPOLI-4 comparison
  - Benchmark ZPR 1D (FR, ZPPR-3, 6 G)
  - Benchmark STEPANEK 2D (2x2, 1G)
  - Benchmarks TAKEDA 3D (PWR and FR, 10 configurations, 4 G)
  - Benchmark OECD C5 2D (cluster 2x2 UOx/MOx 2D heterogeneous, 7 G)
- Verification of solver chaining (non-regression test)
  - Homogeneous and heterogeneous PWR
  - SFR core
  - Submarine core



# V&V (2/3) : FIRST RESULTS FOR TAKEDA 4 BENCHMARK



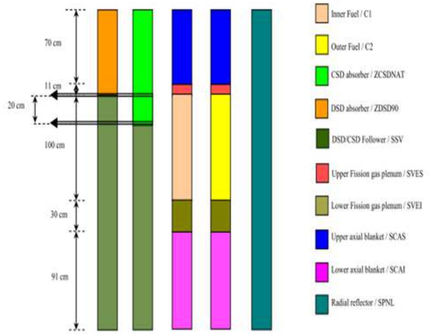


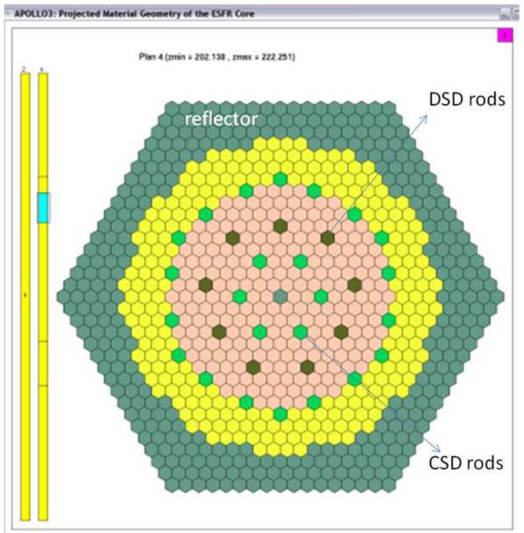

- SPn methods seem not enough accurate in this case
  - discrepancy MINOS/VARIANT
- MINARET very efficient but expensive in computation time
  - for reference calculation only ?
  - test acceleration and parallel calc.
- Pn method are maybe a good compromise but further investigations are needed

# V&V (3/3) : DEMONSTRATION OF SOLVERS CHAINING

Objective : check the implementation of the numerical developments for static and depletion analysis, kinetics and multi-physics coupling and high performance computing applied to sodium fast reactors

- MINOS and MINARET calculations for a SFR concept typical of a Generation IV, PHENIX and MASURCA configurations
  - Cross-sections have been provided by ECCO, the cell code of ERANOS2
  - Effective multiplication factor, breeding gain, spectrum hardness factor, Doppler and void effects and control rod worth have been calculated in both situations and have shown **the consistency of the implemented numerical methods**



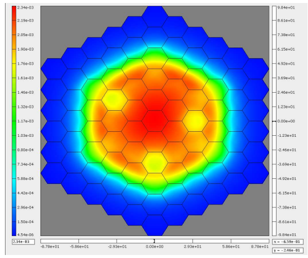



# DEVELOPMENT OF A SPECIFIC SFR DATA MODEL (1/2)

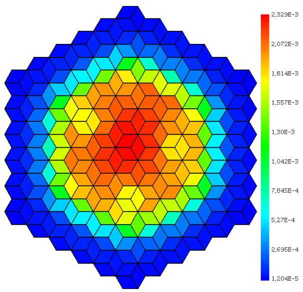
- Store data for SFR calculations in a ‘cupboard’ where you can easily access to your neutronic stuffs (such as flux, reaction rates, burnup or volumetric power)

- These objects do not depend on numerical solvers but only on the problem geometry This approach is particularly useful for the development of calculation schemes combining several numerical solvers

- A large set of functionalities has been defined to manipulate these objects (addition, subtraction, multiplication, cross product, cell integration, mesh projection, …) and enables us building complex procedures : core depletion, perturbation calculations, enrichment research, …



- Post-processing  without loosing any information
  - visualization of  continuous flux/rate 2D/3D
  - visualization of integrated flux/rate per mesh



# DEVELOPMENT OF A SPECIFIC SFR DATA MODEL (2/2)

- Objective : test and prepare the implementation of the SFR data model in the framework of APOLLO3®

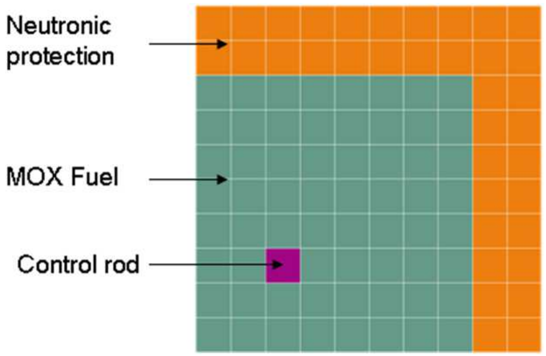
- Simple 2D benchmark, 400 physical meshes - 3 mediums – 33 groups energy – ECCO x-sections

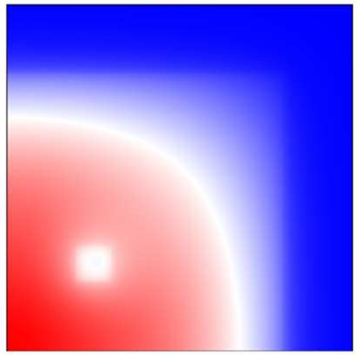
- Multi-solver (**Minos**, **Minaret**, IDT, TDT)

  **step 1** : Recovery of integrated scalar flux for physical meshes (MINOS, MINARET)

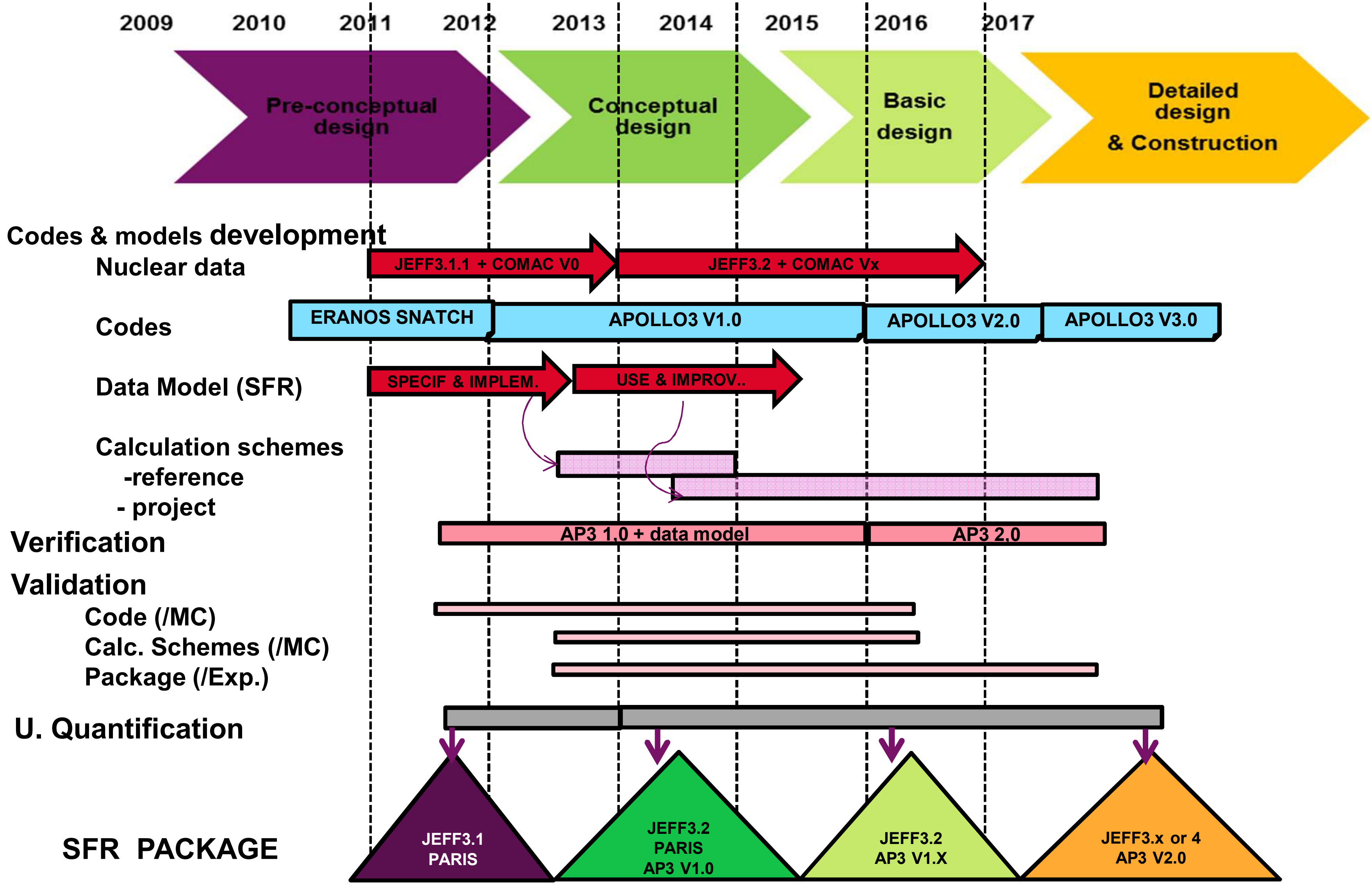
  **Step 2 :** Recovery of polynomial scalar flux for calculation meshes (MINARET)

  **Step 3 :** Recovery of integrated and polynomial angular fluxes for physical and calculation meshes



# ROADMAP FOR APOLLO3-ASTRID CALCULATIONS



Thank you for your attention

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