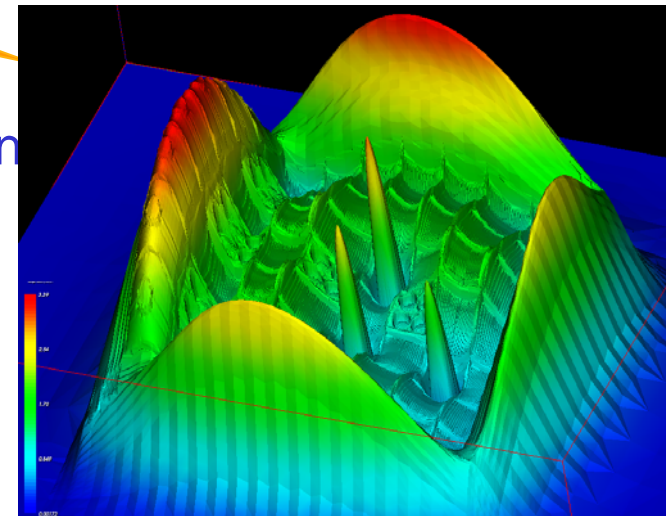# The ANUBIS scheme
used for safety assessment
and operations management
of the OSIRIS reactor
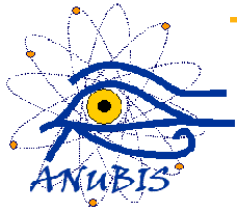
✓ Introduction:
  ➢ The OSIRIS reactor
  ➢ The project of ANUBIS calculation scheme

✓ Development of the scheme

✓ Validation

✓ Experimental validation

✓ Conclusion

The OSIRIS reactor: presentation

- OSIRIS is an experimental reactor located in Saclay (France)
- Open-core pool type light-water reactor, with a thermal power of 70 MW.
- Its first divergence was obtained in 1966

The core of the OSIRIS reactor is loaded with:

38 standard fuel elements
- It consists of 22 silicide plates
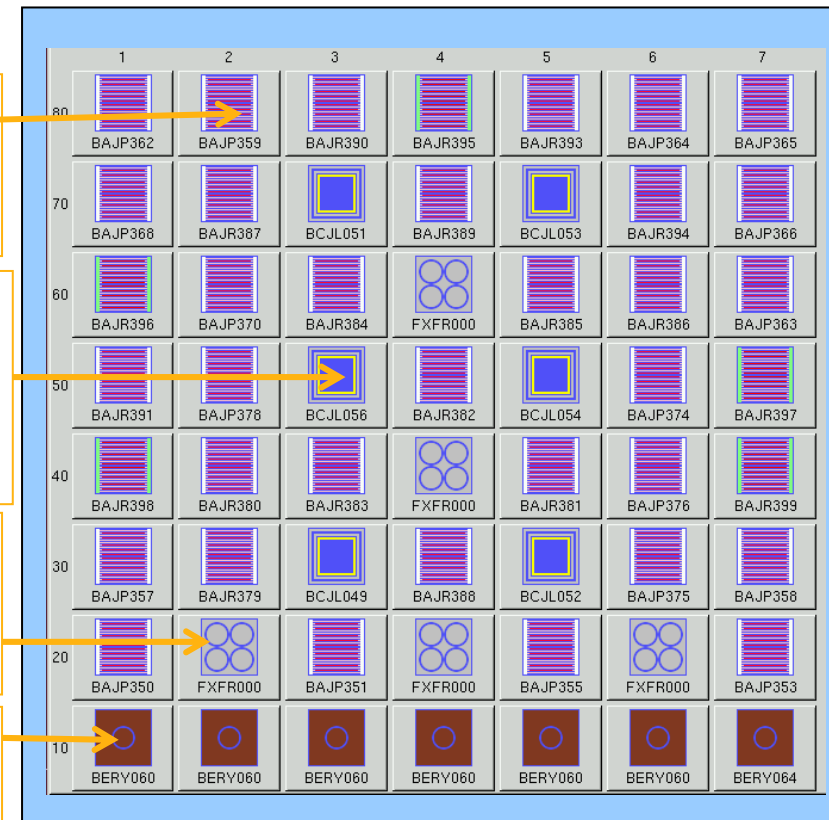- U_3Si_2Al alloy fuel enriched at 19.75%.

6 control elements
- 2 safety rods to ensure the emergency shutdown
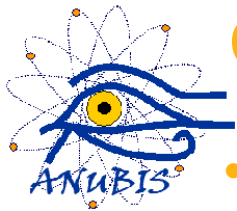- 4 to compensate the loss of reactivity during the cycle

5 experimental positions
- replaced by AG3 blocks when experiments are lacking

7 reflectors assemblies
- made of beryllium

|	1	2	3	4	5	6	7
80	BAJP362	BAJP359	BAJR390	BAJR395	BAJR393	BAJP364	BAJP365
70	BAJP368	BAJR387	BCJL051	BAJR389	BCJL053	BAJR394	BAJP366
60	BAJR396	BAJP370	BAJR384	FXFR000	BAJR385	BAJR386	BAJP363
50	BAJR391	BAJP378	BCJL056	BAJR382	BCJL054	BAJP374	BAJR397
40	BAJR398	BAJR380	BAJR383	FXFR000	BAJR381	BAJP376	BAJR399
30	BAJP357	BAJR379	BCJL049	BAJR388	BCJL052	BAJP375	BAJP358
20	BAJP350	FXFR000	BAJP351	FXFR000	BAJP355	FXFR000	BAJP353
10	BERY060	BERY060	BERY060	BERY060	BERY060	BERY060	BERY064

CONTEXT

- OSIRIS is a multi-purpose reactor, used for:
  - Technological irradiations for the nuclear plant: fuel improvement for PWR or fast reactor, vessels life time extension,
  - Production of radionuclide for medical applications
  - Doped silicon production

- Objective :
  - Extend the operating time to ensure the continuity of the programs until the JHR start-up in 2014 → convince the FNSA that safety requirements are guarantee

- Facilities :
  - Project dedicated to «OSIRIS renovation» :
    - Renovation of the infrastructures
    - Renovation of computational tools (→ ANUBIS scheme project)

      "**A**dvanced **NeU**tronics tools **B**ox for OSIR**IS**"
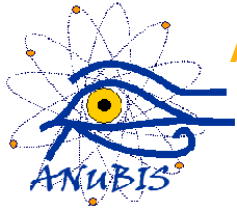
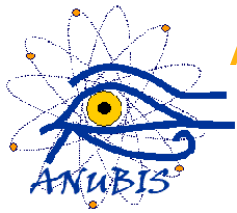# ANUBIS : main advantages of the new scheme

- **The actual scheme has some limitations**

  - ➤ Neutronics codes obsolescence (DAIXY)

  - ➤ Limitations for experimental interpretations and operations management
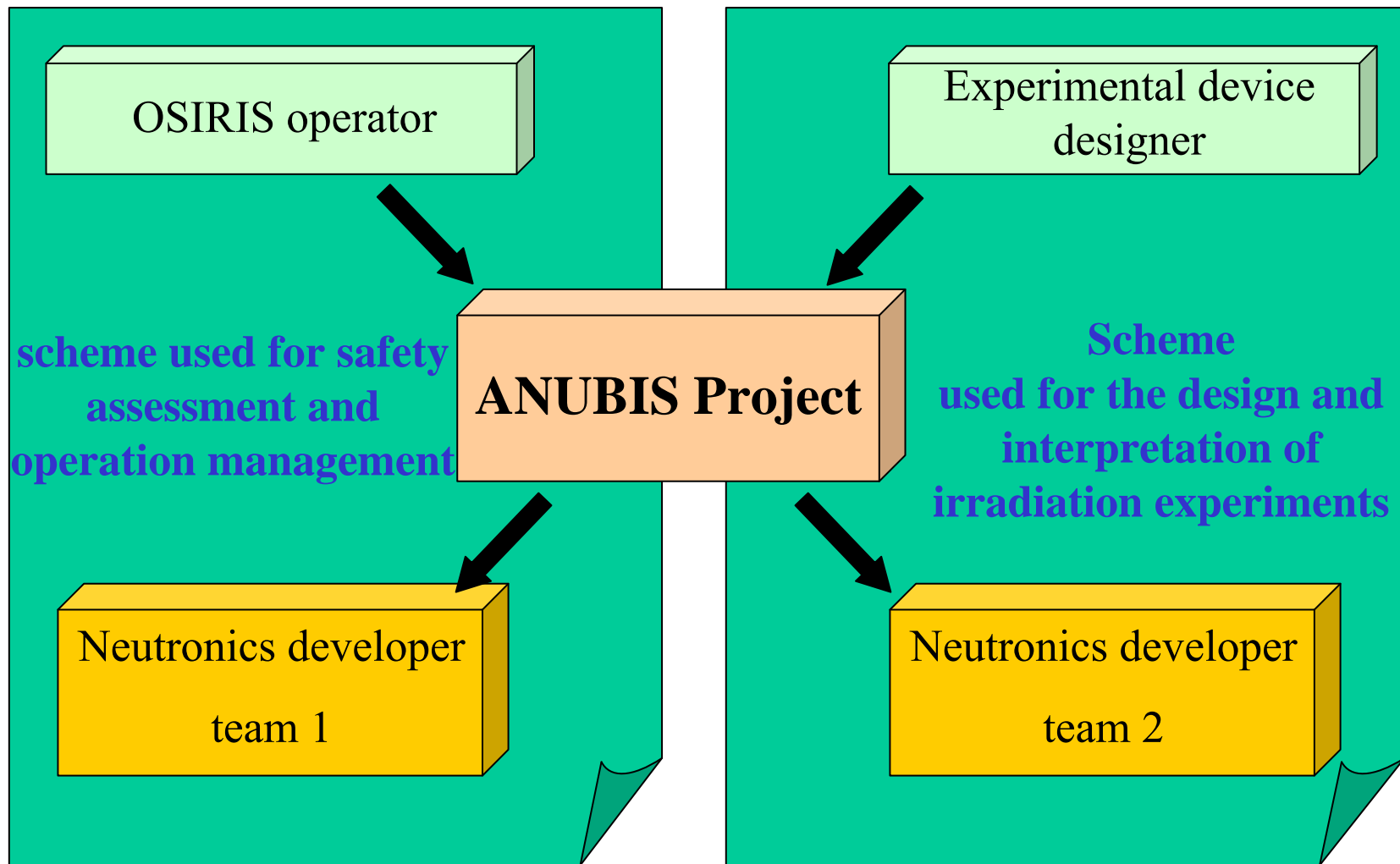
  - ➤ Low flexibility of the scheme

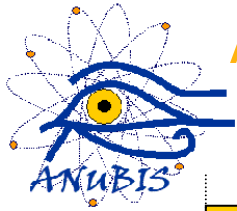- **The main contributions of the new scheme (ANUBIS)**

  - ➤ New generation's code (APOLLO2, CRONOS2) and nuclear data library (JEFF3.1)

  - ➤ 2D or 3D computation → flexibility in use (computing time / accuracy)

  - ➤ All the parameters needed for operations management and safety parameters checkout are calculated **with their uncertainties**
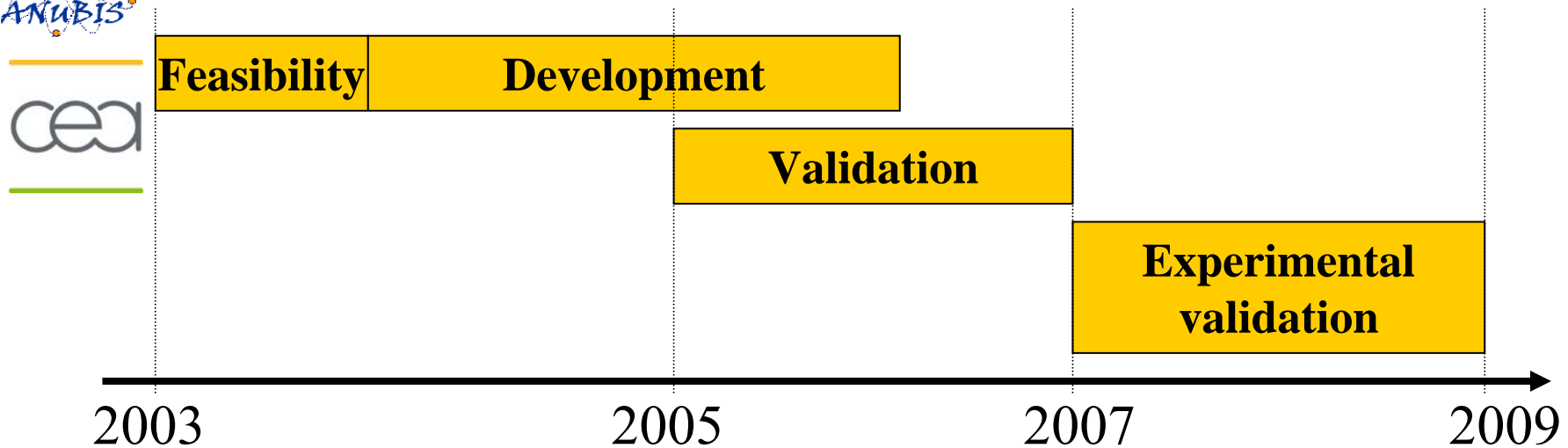
The ANUBIS project plans for the development of 2 calculation schemes :

```
┌─────────────────────────────────┐  ┌─────────────────────────────────┐
│                                 │  │                                 │
│      OSIRIS operator            │  │   Experimental device           │
│                                 │  │   designer                      │
│                                 │  │                                 │
│  scheme used for safety         │  │        Scheme                   │
│  assessment and         ANUBIS  │  │   used for the design and       │
│  operation management   Project │  │   interpretation of             │
│                                 │  │   irradiation experiments       │
│                                 │  │                                 │
│   Neutronics developer          │  │   Neutronics developer          │
│                                 │  │                                 │
│   team 1                        │  │   team 2                        │
└─────────────────────────────────┘  └─────────────────────────────────┘
```

scheme used for safety assessment and operation management

ANUBIS Project

Scheme used for the design and interpretation of irradiation experiments

OSIRIS operator

Experimental device designer

Neutronics developer team 1

Neutronics developer team 2

ANUBIS - PLANNING

Feasibility	Development		

Validation

Experimental validation

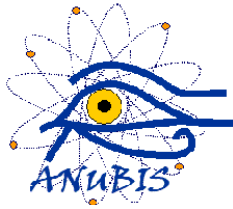2003   2005   2007   2009

Development
Physical and geometrical
models selection

Validation
Comparison to reference computation
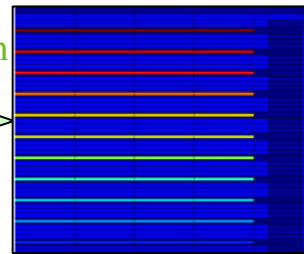• TRIPOLI4 MC (fresh fuel)
• APOLLO2 MOC (evolution)

Experimental validation

- Cell computation with APOLLO2 code (deterministic lattice code):
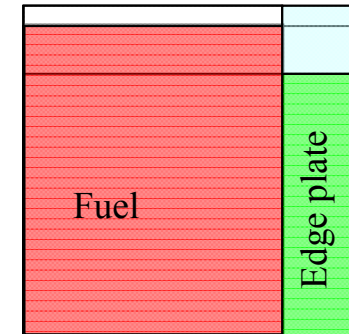 to calculate 1 simplified library (Σ,N) per assembly type

Example:

20g condensation

Homogeneisation –
6g condensation

Equivalent model

Fuel

Edge plate

Self-schielding
172g - 1D

Using self-schielded cross section
computation 20g & 2D exact geometry

6g library

- Core computation with CRONOS2 code (deterministic core code 2D/3D):
 use the simplified libraries in a specific irradiation load plan to improve the computing time

6g library(Σ, N)

Fuel

Control rod

reflector

Experimental device

Standard fuel

control rod

Experimental area

beryllium

Caisson

Pool
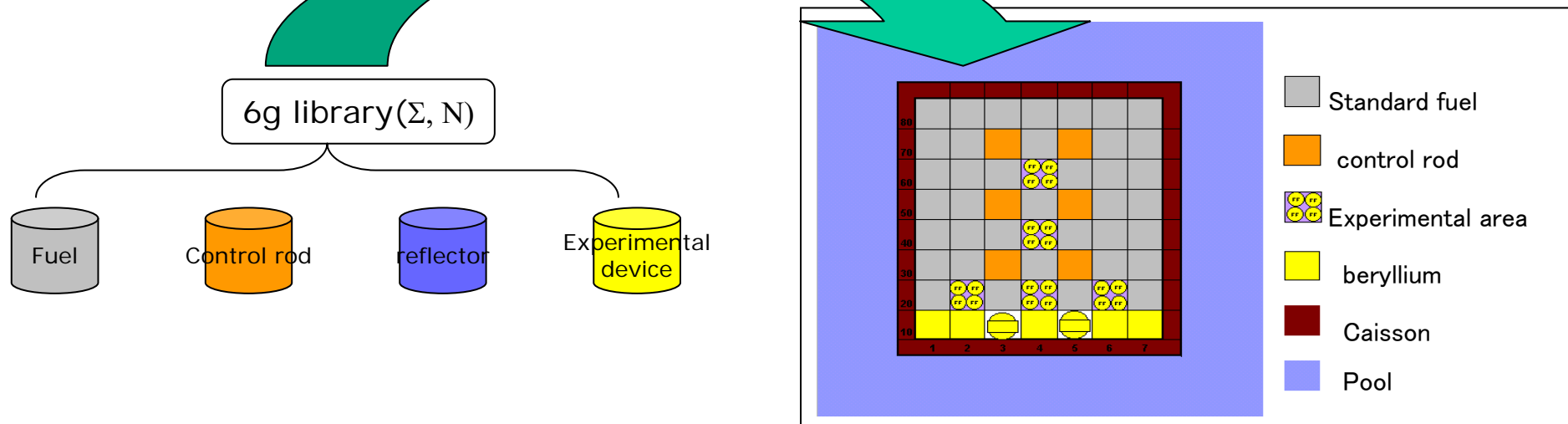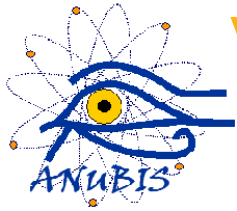
Validation: Comparison between ANUBIS and MC code

	Discrepancy
Reactivity Several configurations assessment (Control Rod, 2D/3D, experimental loading)	-300 pcm (2D) -500 pcm(3D)
Thermal Flux 2D & 3D for each kind of assembly: fuel, control rod, experimental device, beryllium	< 5%
Fast Flux 2D & 3D ➡ Fuel assemblies ➡ Beryllium block	< 5% 20%
Assembly Power	Often <1% Always < 3%
Peak power Always located in the same assembly and usually in the same plate	< 4%
Local Power (¼ plate)	6% (2σ)
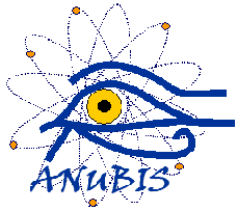
Validation of power distribution

(Example : configuration with all the control rods withdrawal)
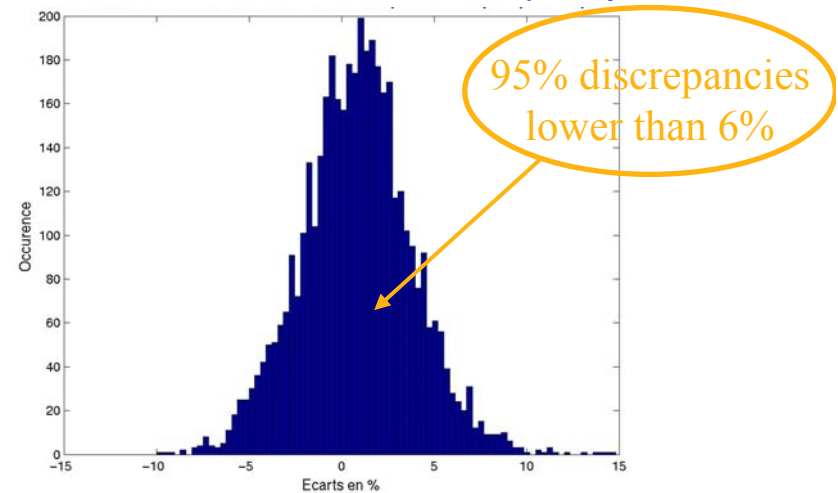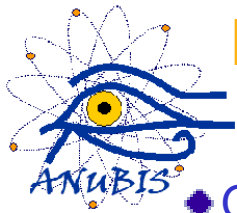
Power map ANUBIS
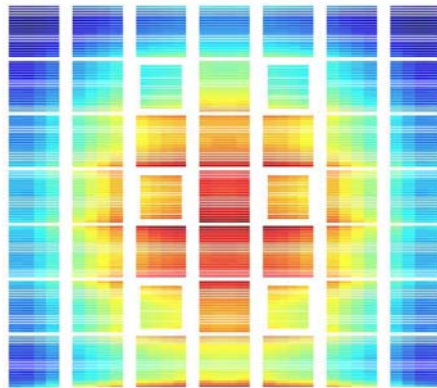
Power map TRIPOLI4
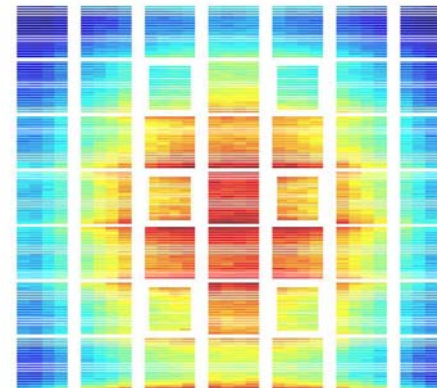
Discrepancy ANUBIS / TRIPOLI4
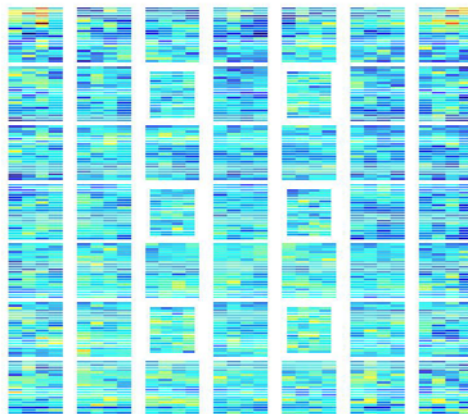
Statistic distribution of discrepancy

95% discrepancies lower than 6%

Successful validation (2D & 3D computations in any configurations)

Experimental validation

- Qualification based on experimental data bank:
  - Measurement in the ISIS mock-up identical to OSIRIS at low power (100 times lower)
  - The experimental critical position reported during an operating cycle in OSIRIS

- Performances computing
  - Reactivity BOL: ± 800 pcm
  - Reactivity EOL: ± 500 pcm
  - Control rod worth: ± 14%
  - Power distribution: ± 10%
  - Thermal and fast flux in
    - Fuel assemblies < ± 10%
    - Beryllium < ± 15 %

Theses performances respect the customer's requests for the assessment of safety and control parameters

Thermal Flux in OSIRIS - 3 control rods inserted
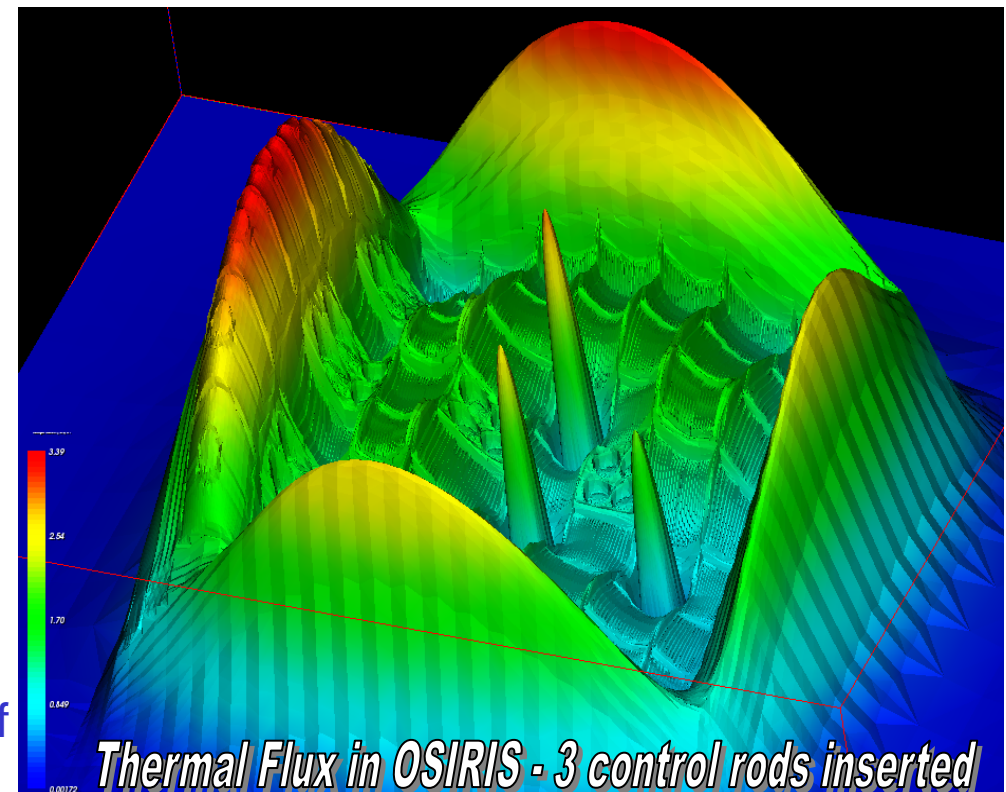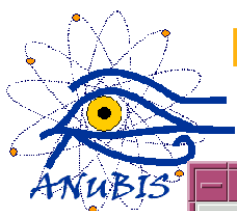
NEFTIS : a HMI developed and delivered to the plant operator

NEFTIS : fuel load tab
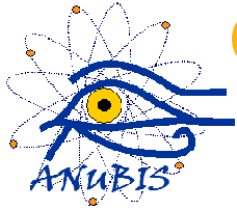

Reload= Drag&Drop

Assemblies databank
- Previous Cycle
- Pool
- New

Core at end of cycle

Reload for the next cycle

Assembly informations :
Name, ^{235}U mass, BU, Boron concentration...

Conclusion

Main steps

- ANUBIS developed for OSIRIS (and ISIS) reactor consists of 2 steps: scheme lattice (APOLLO2) and core computation (CRONOS2)
- ANUBIS has been validated by comparison to TRIPOLI4
- ANUBIS has been validated by comparison to experimental measurements
- At the moment, the plant operator takes over the scheme.

Main results

- The capability and the flexibility are increased compare to the previous scheme
- All the parameters needed for operations management and safety parameters checkout are calculated with their uncertainties
- The ergonomy is increased with the HMI Neftis