IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

NRC / IRSN Meeting

RIA - French safety demonstration

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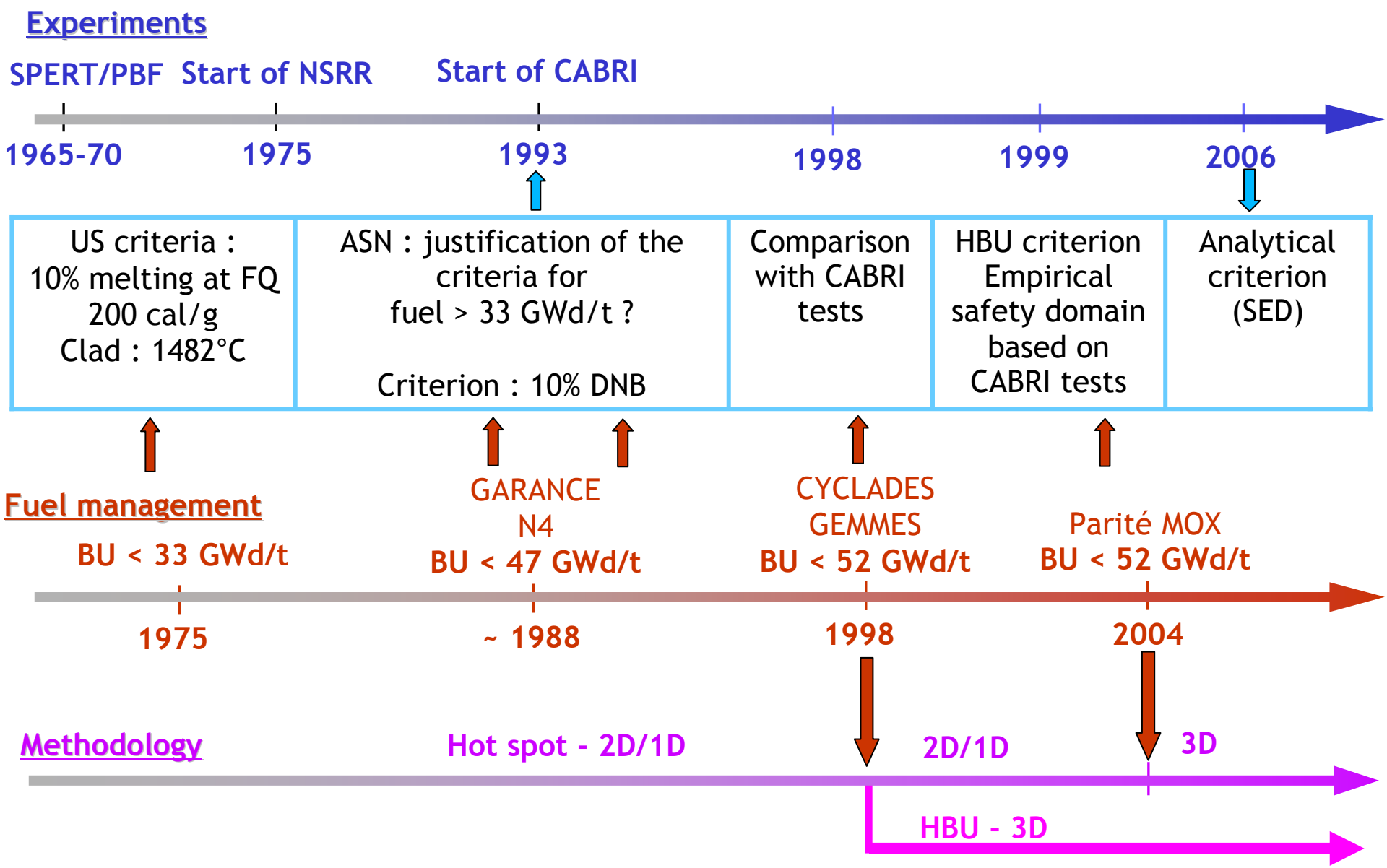
RIA - French safety demonstration

1. Main evolutions
2. Safety analysis at the original design
3. Main assumptions in the FSAR
4. High burnup calculations
5. 3D methodology
6. IRSN analysis

Main evolutions



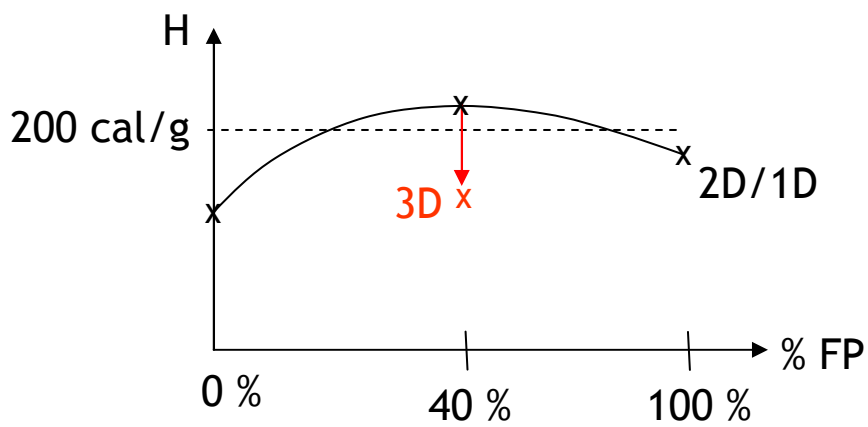
Safety analysis at the original design

- Based on the Westinghouse licence
- Decoupled methodology

Static calculations : 2D/1D
Kinetics : 1D
Fuel thermal transient

} *0% NP – 100% NP in the Safety Analysis Report*

Kinetics 3D (TWINKLE) } *Intermediate power level to complete the demonstration (not in the FSAR)*

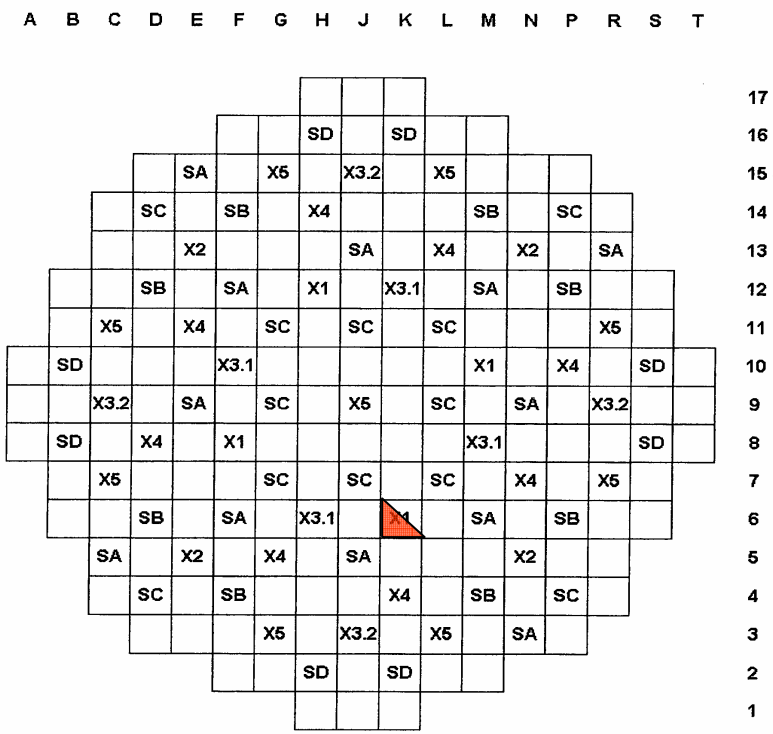


Main assumptions in the FSAR

Conservative values

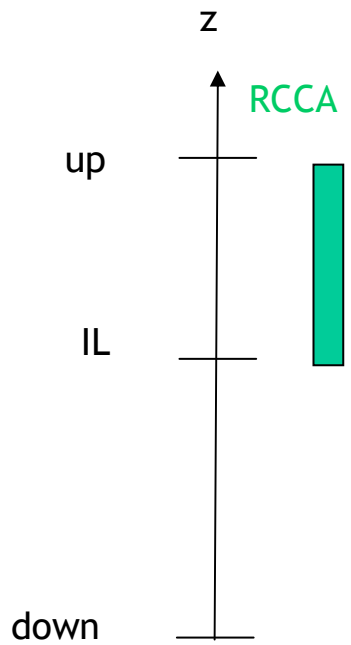
✓ *Maximal rod worth (Δρ)*

- *The worst considering their radial position*



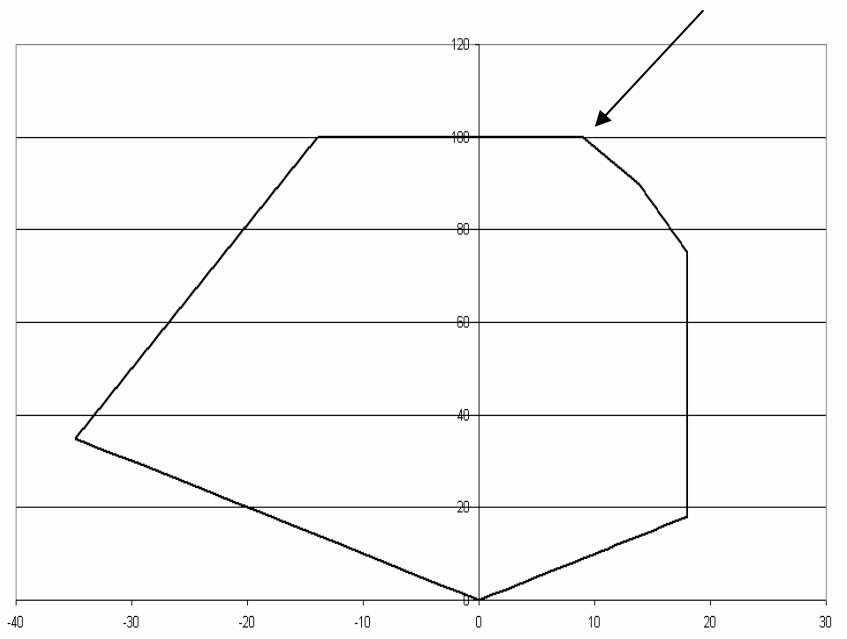
Main assumptions in the FSAR

- Conservative values
  - ✓ *Maximal rod worth (Δρ)*
    - *The worst considering their radial position*
    - *Insertion limit*



Main assumptions in the FSAR

- Conservative values
  - ✓ *Maximal rod worth (Δρ)*
    - *The worst considering their radial position*
    - *Insertion limit*
    - *Adverse axial power distribution*



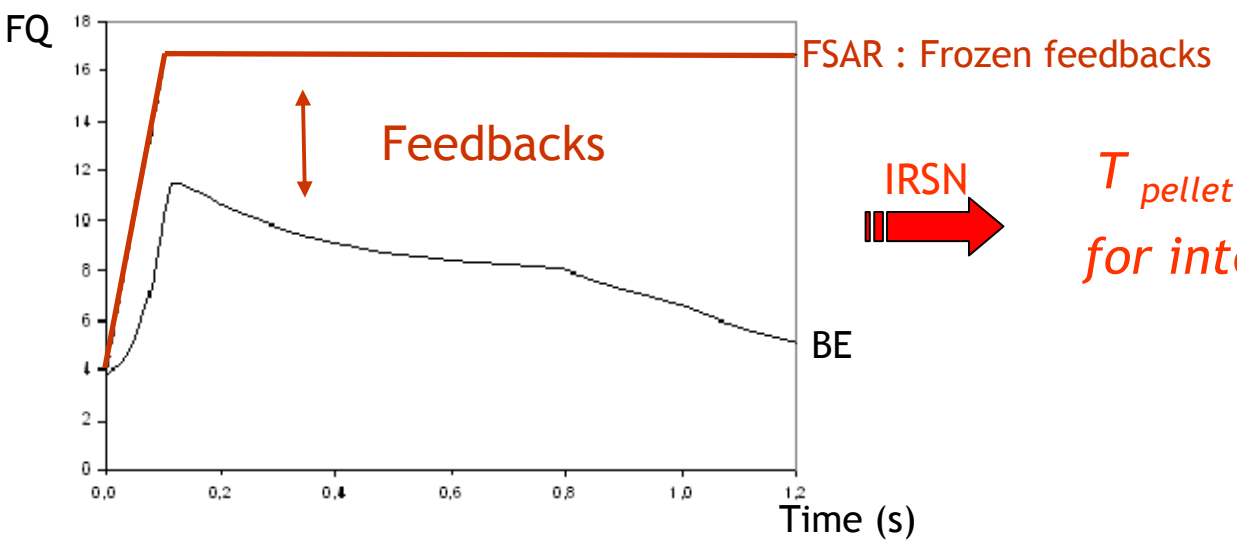
Main assumptions in the FSAR

- Conservative values
  - ✓ *Maximal rod worth ($\Delta\rho$)*
    - *The worst considering their radial position*
    - *Insertion limit*
    - *Adverse axial power distribution*
  - ✓ *Minimum delayed neutron fraction (βeff min)*
  - ✓ *Uncertainty on Doppler effect (minimum value)*

Main assumptions in the FSAR

Conservatism

- ✓ *Frozen feedbacks for calculations :*
  - *Rod worth*
  - *Hot spot factor*
- ✓ *Neutronic transient in 1D (radial effect not fully considered)*
- ✓ *Fuel thermal transient*
  - *frozen feedbacks for FQ evolution*



IRSN

$T_{pellet\ center}$ increase ≈ 400°C for intermediate power level

Main assumptions in the FSAR

- **Conservatism**
  - ✓ *Frozen feedbacks for calculations :*
    - *Rod worth*
    - *Hot spot factor*
  - ✓ *Neutronic transient in 1D (radial effect not fully considered)*
  - ✓ *Fuel thermal transient*
    - *frozen feedbacks for FQ evolution*
    - *DNB occurrence in initial conditions*

High Burnup calculations

CABRI database for HBU
(BU > 47 GWd/t)

⇩

Significant decrease of enthalpy limit
(order of magnitude : 80 – 100 cal/g)

⇩

Couldn't be checked with 2D/1D
methodology

⇩

Development of 3D kinetics methodology
for HBU safety demonstration

3D Methodology

- Decoupled methodology based on SCIENCE calculations

Neutronic static (SCIENCE)
rod worth, feedbacks

↓

Neutronic kinetics 3D (SCIENCE)

↓

Mean core nuclear power : $P_{nucl}(t)$
Hot spot factor : $F_Q(t)$
HBU peak factor : $F_Q^{HBU}(t)$

↓

Mean core thermal power : $P_{th}(t)$

↓

Fuel thermal transient
Conservative $F_Q(t)$ or $F_Q^{HBU}(t)$
DNB occurrence in initial conditions

DNB calculations (hot spot only)
Conservative $F_{\Delta H}$ with frozen feedbacks
Conservative Fuel Census Curve

3D methodology - IRSN analysis

Hot spot factor

- ✓ *Neutronic : minimization of hot spot factor to maximize the power transient*
- ✓ *Thermal : maximisation of hot spot factor to maximize the thermal parameters*

→ *Use of decoupled hot spot factor values between neutronic and thermal transient*

Uncertainties and penalties

- ✓ *Introduction of uncertainties and penalties on the main parameters (Δρ, Doppler) for the 3D calculations performed by modification on the cross-sections*

→ *Physical transient ?*

Δρ increase results in FQ increase not conservative for the power transient

3D methodology - IRSN analysis

Value of βeff and l* (1/v)

- ✓ *Radial distribution of βeff instead of an unique value whatever the assembly*
- ✓ *l* best-estimate*

→ *Impact of fuel management pattern*

Definition of the key parameters for reload safety analysis

- ✓ *FQ : neutronics one or thermal one or both ?*
- ✓ *Methodology to penalise rod worth and Doppler in 3D calculations*
- ✓ *βeff : mean value or distribution ?*
- ✓ *l* : key parameters ?*

→ *Updating of 3D Kinetics methodology by EDF for the EPR*