Development and manufacturing of special fission chambers for in-core measurement requirements in nuclear reactors

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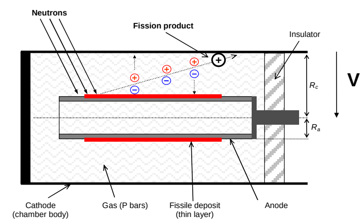
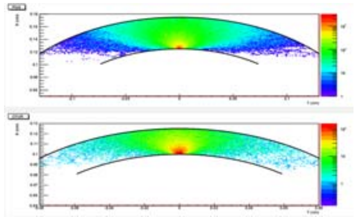
CEA Cadarache (France)

Presentation plan

1. **Overview : use and principle**
2. **Modeling and design**
3. **Manufacturing**
4. **CEA current developments**





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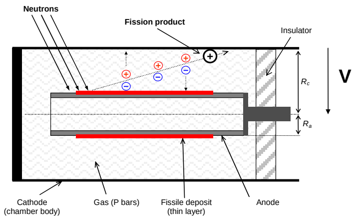
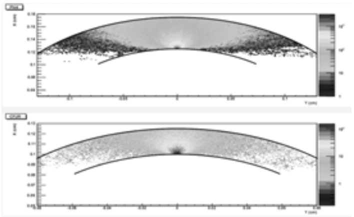




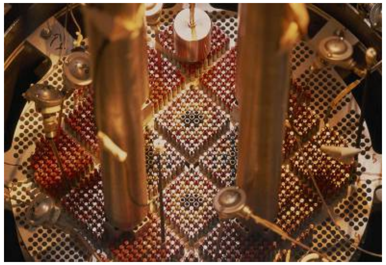
Fission chambers overview (1)

FC are well-known and widely used neutron detectors

- **Versatile detector** : various geometry and sizes, different isotopes, several operating modes
- Well adapted for reactors **incore monitoring** (among with SPND, thermocouple, gamma thermometer,…)

Often used in various reactors applications

- Power reactors : incore/excore flux monitoring
- Material Testing Reactors : experimental device instrumentation (thermal and fast neutrons measurements)
- Zero Power Reactors : neutronic measurements (reactivity measurements, spectrum studies…)
- Fusion reactors : flux monitoring (e.g. in blanket modules)



EOLE: zero power reactor facility (CEA, Cadarache)

Fission chambers overview (2)

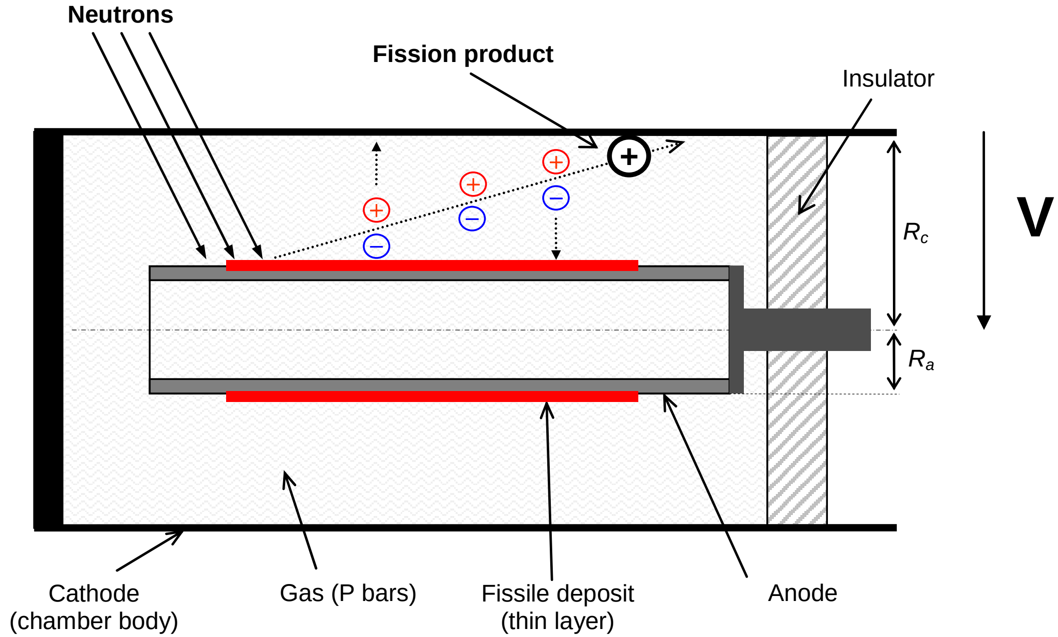
CEA develops miniature and sub-miniature FC for in core applications

- Several geometries (8mm, 4mm, 3mm, 1.5mm),
- Large choice of isotopes : ^{235}U, ^{233}U, ^{237}Np, ^{232}Th, ^{242}Pu,…
- Different gas and pressure,
- Integrated or stand alone cable.

Fission chambres are designed and manufactured at CEA Cadarache with the collaboration of PHOTONIS (FC parts) and Thermocoax (measurement cables)

A typical fission chamber

- Cylindrical geometry
- Fissile deposit on the anode
- Gas $Ar+4\%N_2$ @ 5 bars



Fission chambers principle (2)

Current signal is generated by secondary charges when fission products crosses the electrodes gap

- In normal conditions, signal *S* is proportionnal to fission rate *F*
- Factor *K* depends on technological parameters (gas, pressure, bias, operated mode)

$$S = K \times F$$

Fission rate *F* depends on the neutron flux φ (and spectrum) and depends on the fissile deposit composition

- Isotopes composition evolves with time (sometimes quickly)
- Neutrons energy spectrum must be well known

$$F(t) = \int_0^\infty \sum_{iso} N_{iso}(t)\,\sigma_{iso}(E)\,\varphi\big(E, T(t), t\big) \cdot dE$$

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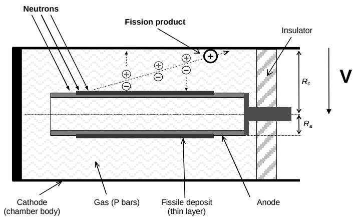
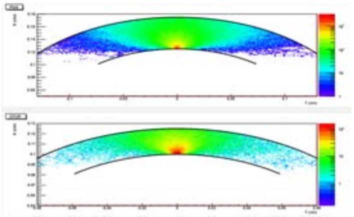
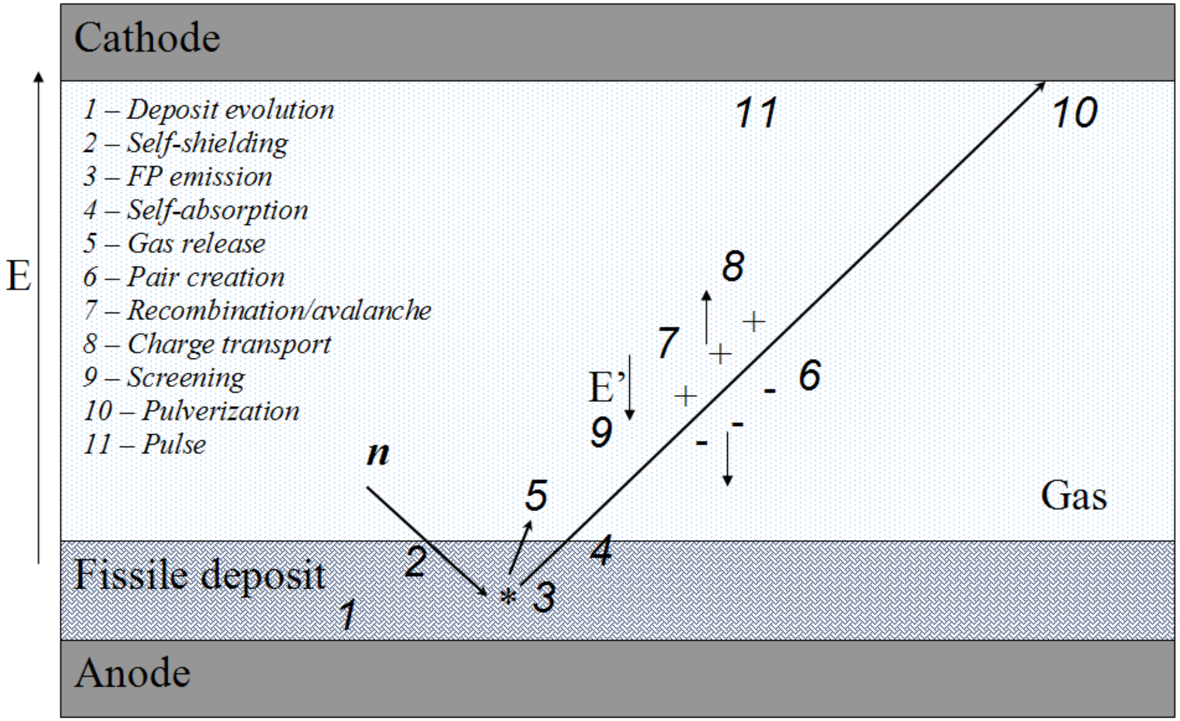




FC design is based on modeling tools used to :

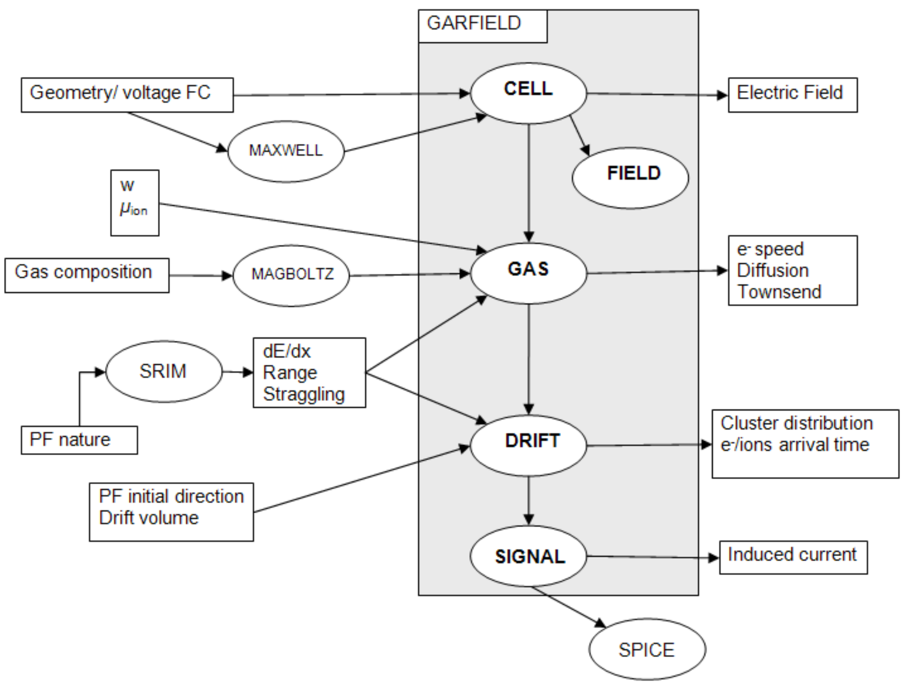
- Optimise FC technological parameters
- Help with detector calibration

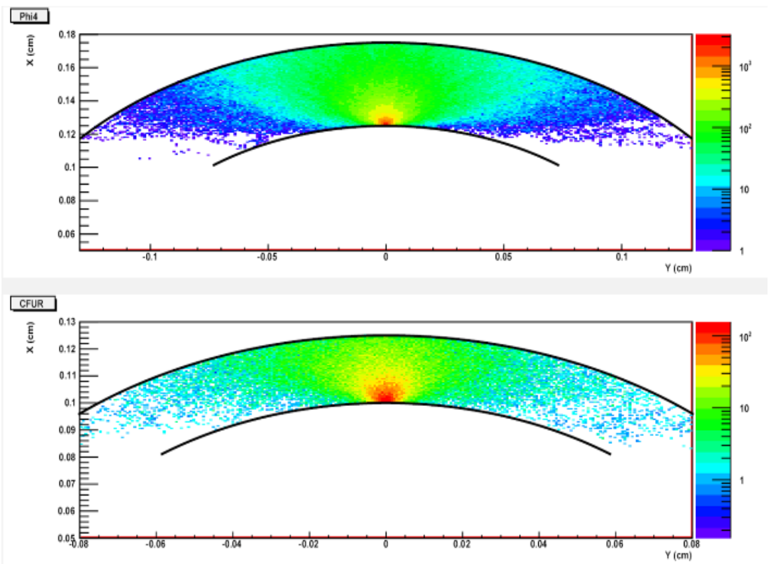
Signal generation in the ionization chamber is complex :



Ionization chamber modeling is based on the Garfield code

- Simulates the charges collection
- Gives the resulting current at the electrodes
- We also use third party tools :
  - SRIM models the ion-gas interaction,
  - MAGBOLTZ calculates electrons drift parameters in the gaz,
  - SPICE takes into account the preamplifier stage



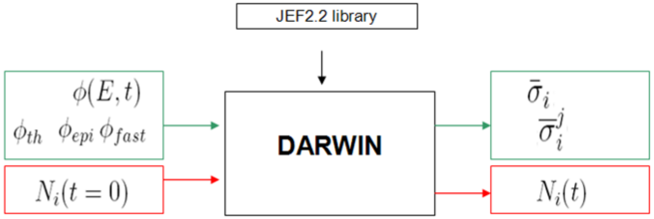


Charge density in the electrodes gap for two FC geometries

Fission chambers modeling and design (3)

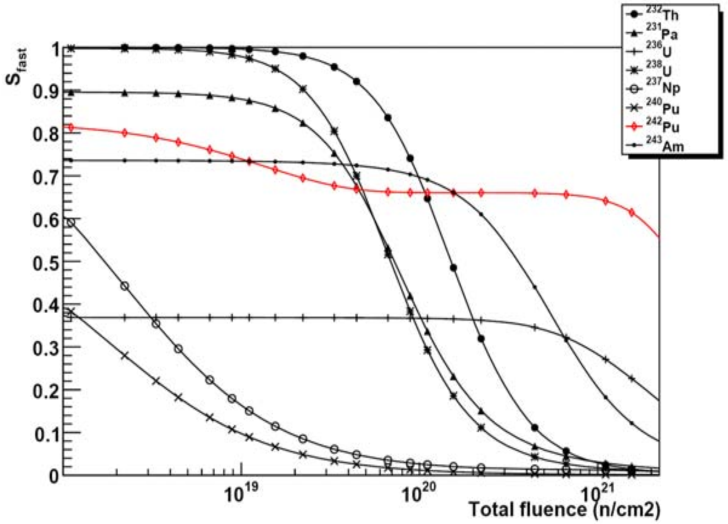
Fissile deposit modeling is based on DARWIN 2.2 code

- Calculates fissile deposit isotopic evolution over time
- Calculates total fission cross sections
- Needs neutron flux and spectrum



Helps you choose the best isotope candidate for a specific application

- E.g. ^{242}Pu for measuring fast neutrons in presence of a strong thermal component



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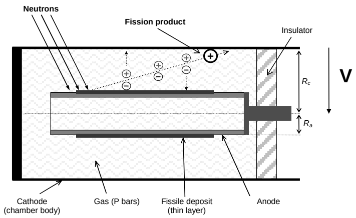
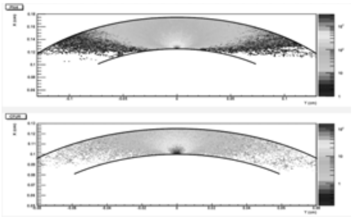
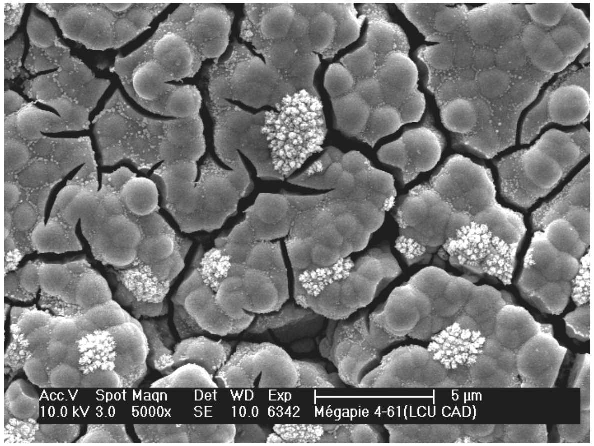




The CHICADE facility (CEA Cadarache) is authorized to produce and distribute special fission chambers with exotic fissile coating (^{237}Np, ^{239}Pu, ^{242}Pu, ^{232}Th,…)

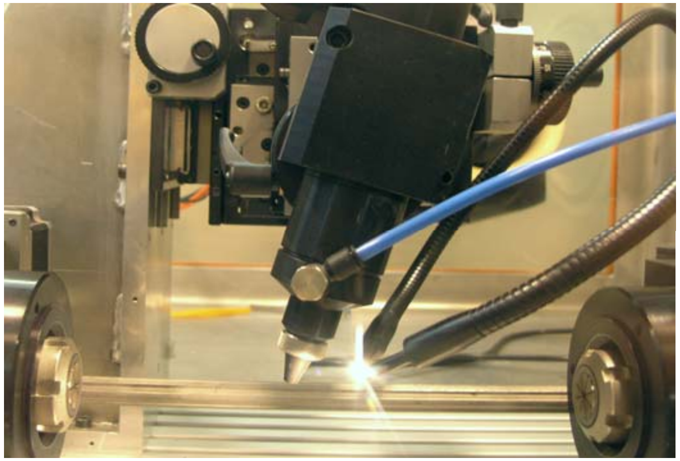
First step : Fissile material deposition

- Done with electro deposition in a dedicated glove-box,
- The deposit mass is not measured *in situ* but assessed afterwards,
- Isotopic composition is measured by mass spectroscopy (TIMS).



Second step : Detector assembly

- Fission chamber kits are provided by PHOTONIS (it includes chamber body, electrodes, insulator, etc.)
- TIG welding for large detectors (8mm and 4mm)
- Laser welding for small detectors (3mm and 1.5mm)



Third step : Filling gas

- High temperature heating
- Gas filling up (Ar, Ar+N_2 or other mixtures)

Last step : Post manufacturing tests

- Insulation resistance test (FC and cables)
- X irradiation (for gas pressure test)

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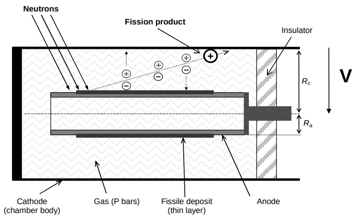
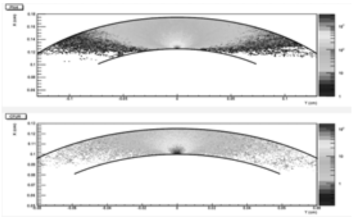




Online fast neutrons measurements in MTR : FNDS project

- Experimental device instrumentation : high thermal flux, high gamma field, high fluence (up to 10^{21}n/cm^2)
- Development in the framework of the Joint Instrumentation Lab CEA-SCK•CEN

Joint Instrumentation Laboratory

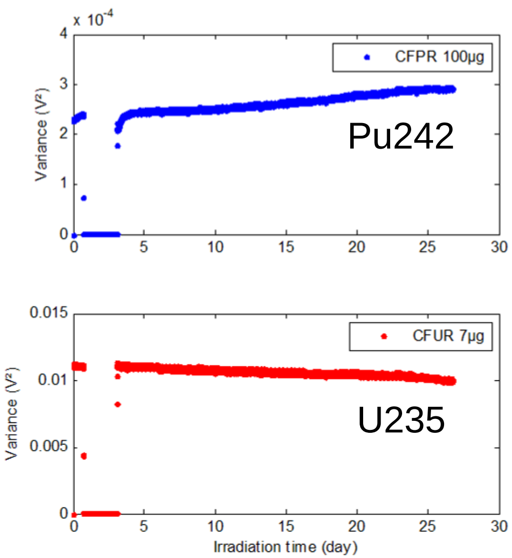
Projects main phases

- Development of a dedicated detector (^{242}Pu, 3mm, Ar+4%N_2, 5 bars)
- New data acquisition system operating in Campbell mode
- System has been qualified at BR2 reactor in 2009

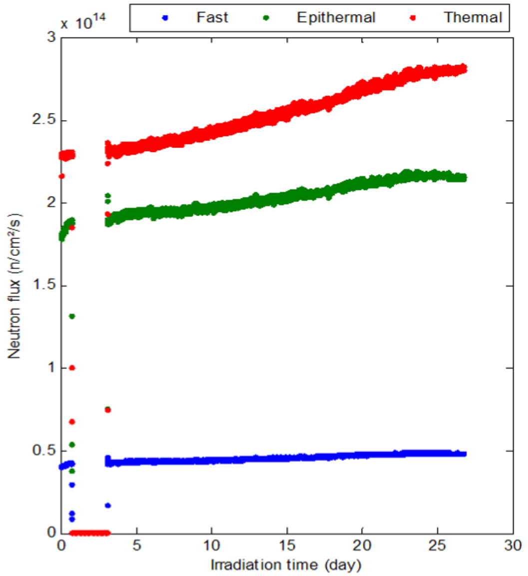
Current developments (2)

FNDS qualification : first results

- FICTIONS-8 experimental device : 14 FC (Pu242 and U235) operating in Campbell mode
- Irradiation during 2 reactor cycles (fluence ~8.10^{20} n/cm²)
- Online fast and thermal monitoring



Raw measurements



Flux estimations

Online analysis

Future developments

- Flux moniroring and safety for fast reactors (accident detection),
- Neutron noise measurements (core vibrations),
- Development of a versatile data acquisition system in Campbell mode (wide range measurement system).