Atelier FrenchTeam-MSFR 02/02/2017

CALCULS D'ECHAUFFEMENT GAMMA

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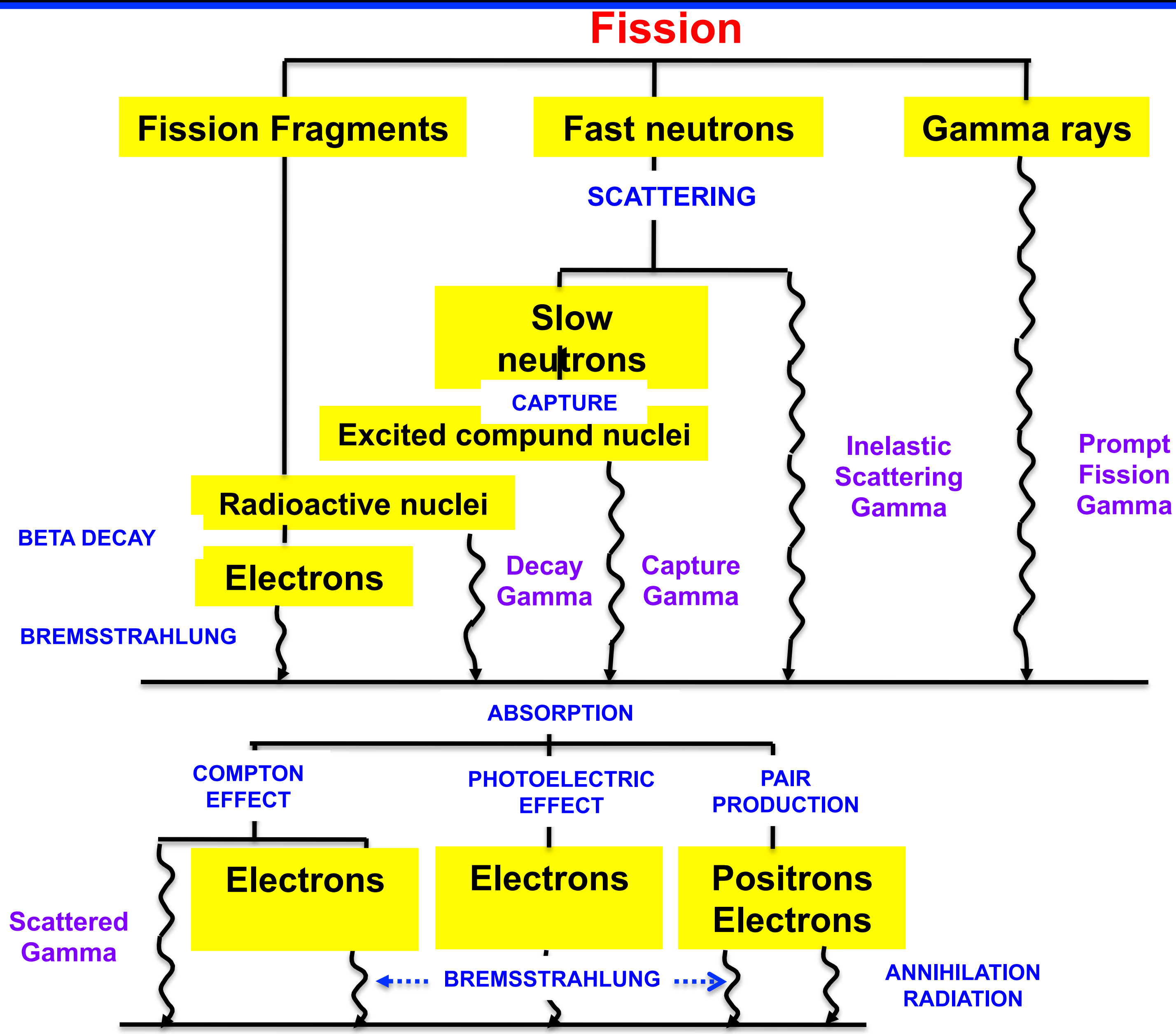
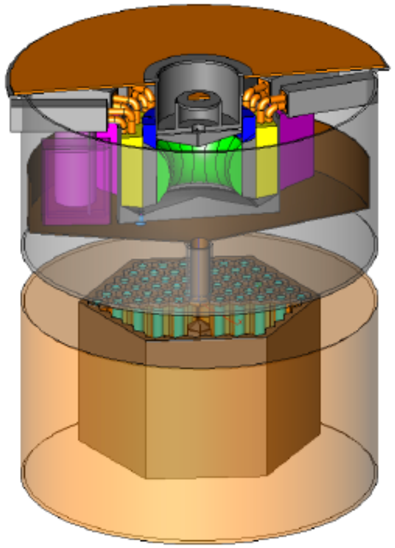
Plan

- Problématique:
  - Source de γ dans les réacteurs
  - Cas du réservoir de vidange du MSFR
- Fuel Evolution et Transport
  - Codes envisagés : MURE & MCNP6
  - Travaux déjà réalisés à SUBATECH
- Réservoir de vidange:
  - Travail réalisé
  - Perspectives

Source de γ dans les réacteurs



Réservoir de vidange du MSFR



Problématique:

- Puissance résiduelle au niveau du réservoir de vidange

- Rayonnement γ: mode transfert d'énergie important

Volume occupé par sel combustible faible / volume total

➔ **Evaluer quantité de chaleur déposée hors sel combustible**

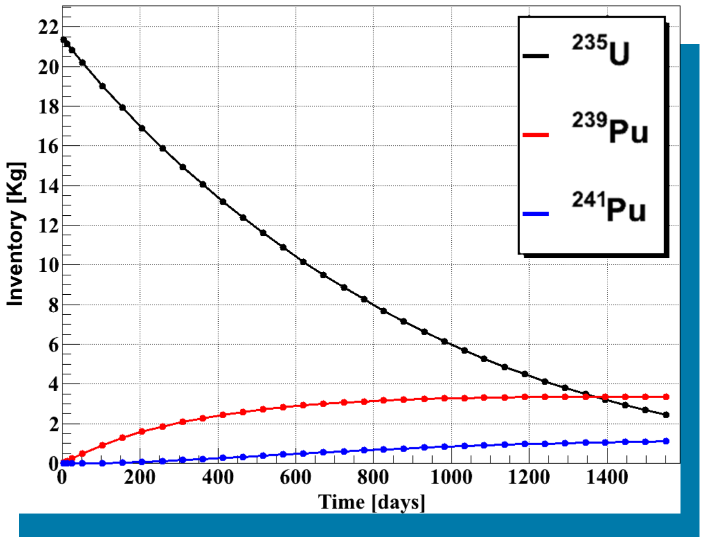
Méthode:

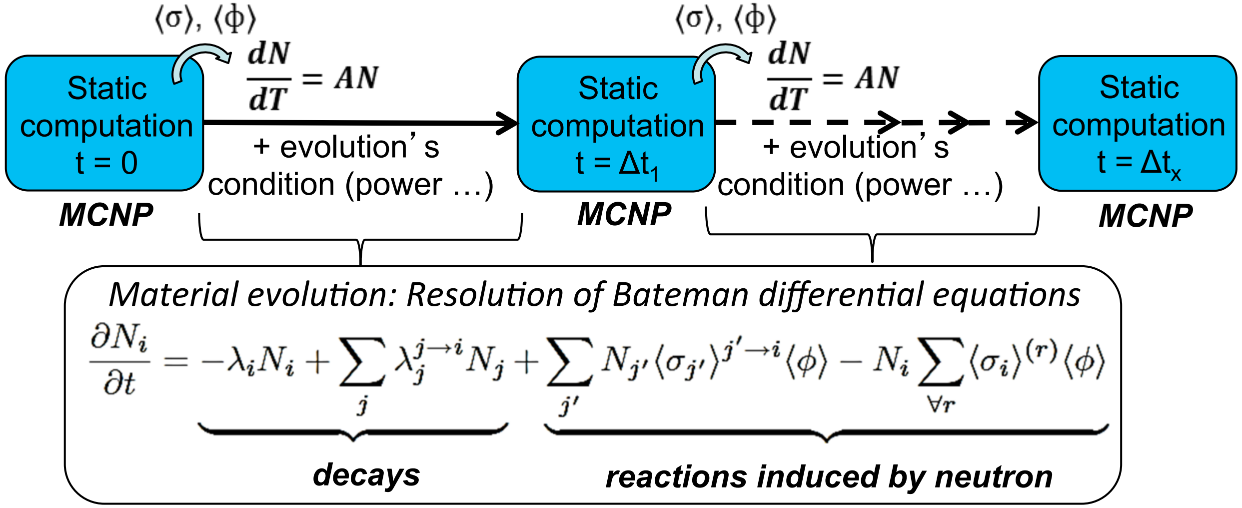
- **Calcul spectre γ en fct du temps** après l'arrêt des fissions avec code Monte-Carlo **MURE (MCNP Utility for Reactor Evolution)**

- **Transport** des γ dans le réservoir de vidange avec code Monte Carlo **MCNP6**

MURE

- The MURE Code (MCNP Utility for Reactor Evolution) :
  - ✓ C++ interface to the Monte Carlo code MCNP (static particle transport code)
  - ✓ Developped by CNRS laboratories: IPNO and LPSC
  - ✓ Open source code available @ NEA: http://www.oecd-nea.org/tools/abstract/detail/nea-1845
  - ✓ Adapted by SUBATECH for antineutrinos experiments and on-going for decay heat
    ===> all β^- and γ decays emitters followed at each time step





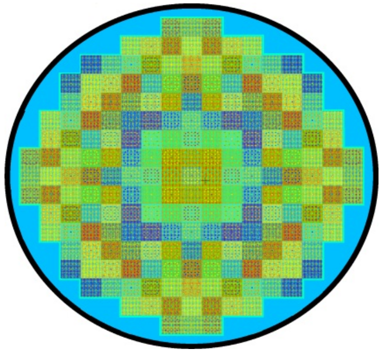
- Outputs provided: keff, neutron flux, reactions rates, inventories

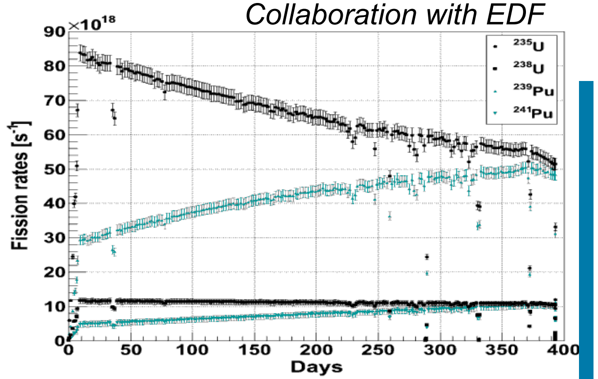
O. Méplan et al. ENC Proceedings (2005)
MURE, MCNP utility for reactor evolution (2009), O. Meplan. Tech. Rep. LPSC 0912 and IPNO-09-01 (2009)

Simulations de Réacteurs avec MURE @SUBATECH

French N4 PWR full core: Double Chooz:

A. Onillon's PhD Thesis 2014
Collaboration with EDF





The first simulation of a realistic case: the Chooz reactors with a detailed full core model following the operation history of the reactor + estimate of the associated systematic errors

- **Expertise développée à SUBATECH sur des concepts de réacteurs très différents**

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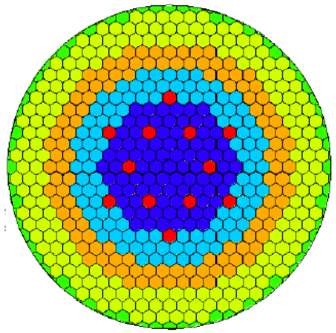
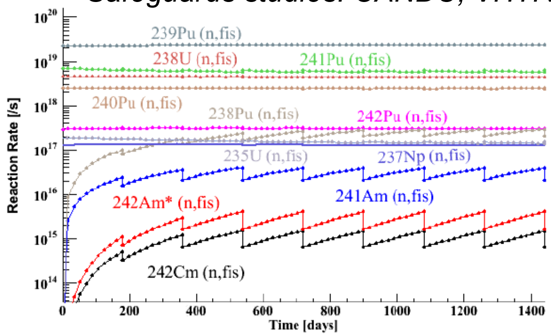
Na-Fast Breeder:

S. Cormon's PhD Thesis 2012
Safeguards studies: CANDU, VHTR, RNR



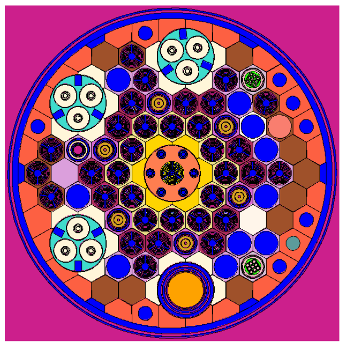


See also T. Shiba, M. Fallot et al. Reactor Simulations for Safeguards with the MURE Code, Symposium on International Safeguards, IAEA 2014.

BR2 Reactor@Mol

L. Giot, M. Fallot
S. Kalcheva

under development
collaboration with BR2 reactor group @ SCK-CEN



- **twisted hyperboloid bundle**
- **^{235}U enrichment 93 wt%**

BR2 Core *Fuel element*

- **For the SoLid exp. ($\bar{\nu}$ sterile, safeguards)**
- **Very complex geometry, MURE adapted to read an external MCNP file**

L. Giot et al., RRFM 2015 and references therein
S. Kalcheva et al., M&C 2017 and references t…

Choix de MCNP6.1.1 pour transport Gamma

- **Depuis 2012, @Los Alamos**
  beaucoup de développements pour transport des photons
- **Possibilité transport photons/électrons en même temps**
- **Adapté au transport des gamma dans un réacteur**

- K and L shell Fluorescence

- Compton scattering

- Photoelectric effect is modeled as analog absorption + possible K and L shell fluorescence

- Pair production

- Thomson scattering, also called coherent scattering

- Rayleigh scattering taken into account from MCNPX 2.7c

- Delayed Gamma

- Photofission

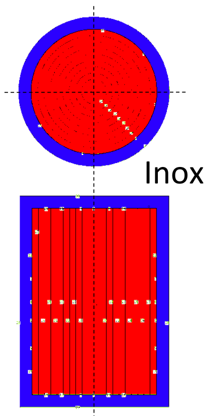
- Bremsstrahlung: Thick Target approximation or Electrons transport

- Photonuclear reactions

Fuel évolution et transport gamma @ SUBATECH

Transport/storage of wastes

L. Giot, 2012-2013
Chaire industrielle matériaux DAHER

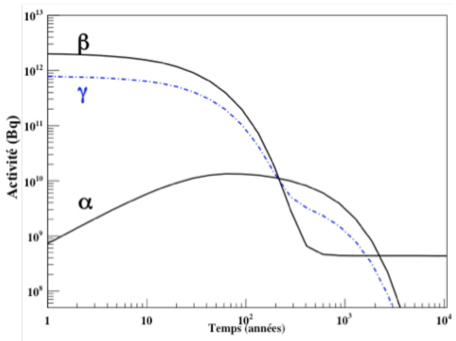


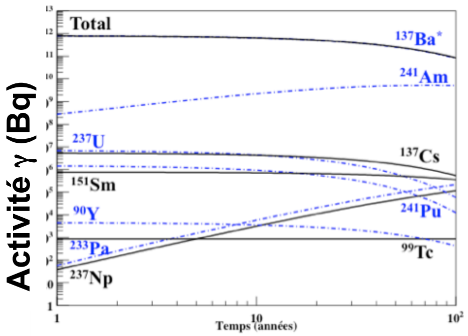
F2-3-05 container of bituminized muds

- Ex: Colis de déchets nucléaires, MA-VL

- MURE/CHARS used to compute α,β,γ activities as a function of the cooling time and associated decay energy spectra

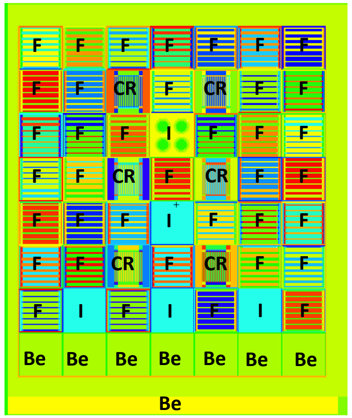
➯ **Calcul des termes sources pour transport puis calcul dpa**





Osiris Reactor@Saclay

V. M. Bui's PhD Thesis 2012



- Fuel inventories as function of operation history

- Simulation to propagate gamma from the core behind the concrete walls detailed understanding of different processes involved, optimization of simulation

F: Fuel I: Irradiation cells CR: Control rods

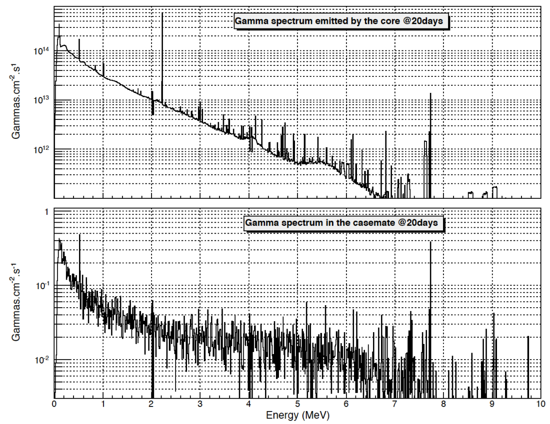


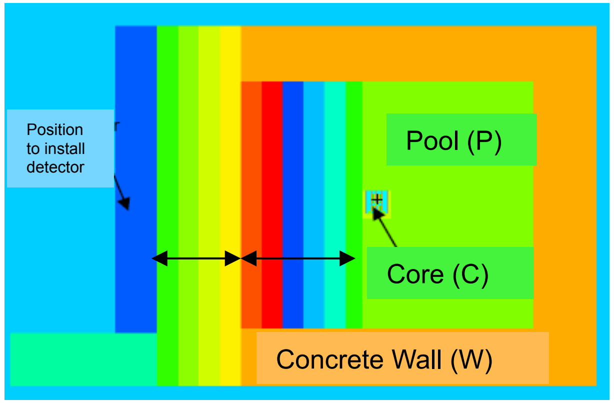
FIG. 8. Gamma spectra computed with MURE for a reactor fuel composition at the equilibrium after 20 days in the core (upper panel) and in the casemate (lower panel).

V.M. Bui, L. Giot, M. Fallot et al., Antineutrino emission and gamma background characteristics from a thermal research reactor arXiv 1602.07522

Exemple: Gamma background simulation @OSIRIS

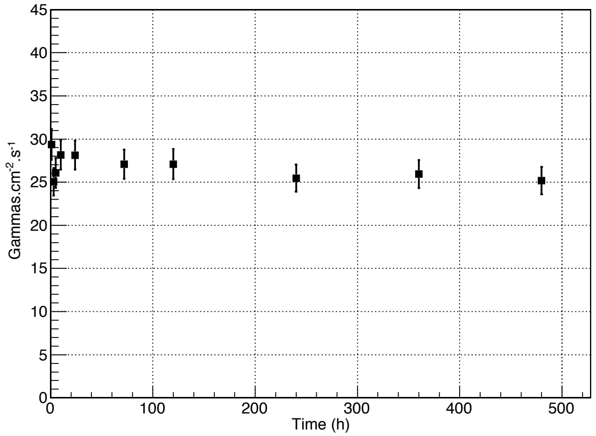
- **Aim to understand the origin of gamma rays:** **location: core, pool, concrete and production process and how they induce accidental and correlated background in antineutrino detector**

- **Simulation: MURE Geometry + n/γ transport with MCNPX2.7d**



- ***Reference simulation: default MCNPX options***
- ***From this reference, we "allowed" each time only 1 extra physic process, ex: bremsstr., delayed γ, photonuclear reactions***
- ***Core alone, C+P or C+P+W***
- ***Around 80 simulations performed***

- **Gamma Flux rate in the detector casemate, computed with a fuel at the equilibrium from our refueling scenario**



⇒ Gamma flux in a 10m^2 detector calculated to 2.5 MHz

✓ **Measured Gamma Flux ~ 5MHz**

V.M. Bui, L. Giot, M. Fallot et al., Antineutrino emission and gamma background characteristics from a thermal research reactor arXiv 1602.07522

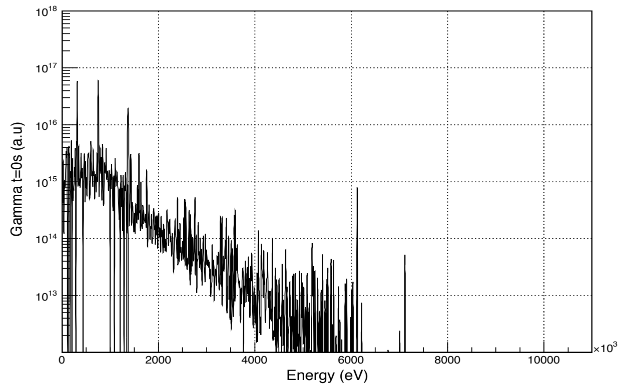
Réservoir de vidange du MSFR

<u>Travail Réalisé</u> avec (à partir sept 2016)

Evolution du combustible

- Comparaison avec REM (LPSC) sur des inventaires
- Spectres γ en énergie pour différents pas en temps

  (termes sources pour le transport)



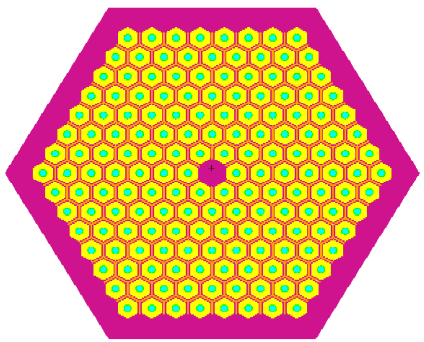
Exemple de spectre gamma

Géométrie du réservoir de vidange

- d'après fichier SERPENT(D. Gerardin)

<u>Perspectives 2017</u> : stagiaire M1

- Comparaison calculs de criticité SERPENT vs MURE validation géométrie
- **Transport γ dans géométrie -> calcul échauffement**
- **Analyse détaillée γ produits**



Section transverse du réservoir de vidange (MURE)

Merci de votre attention

Groupe S.E.N @SUBATECH

BACKUP

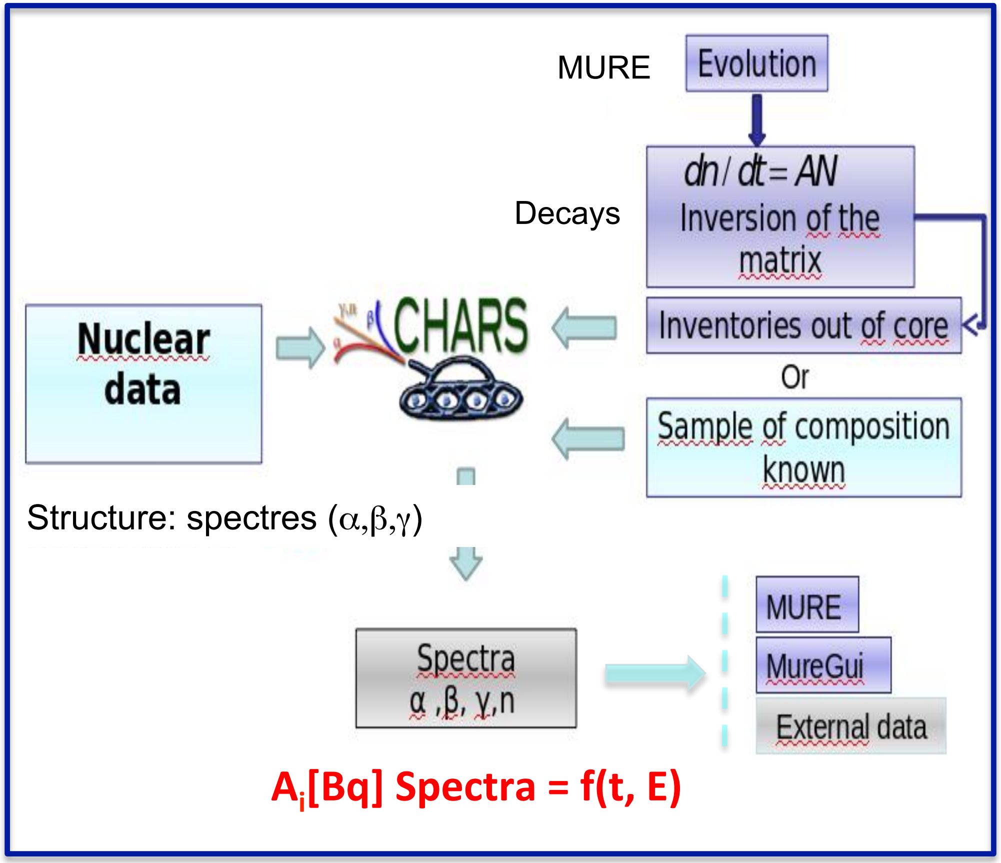
CHARS: utilisé ici simplement comme interface graphique

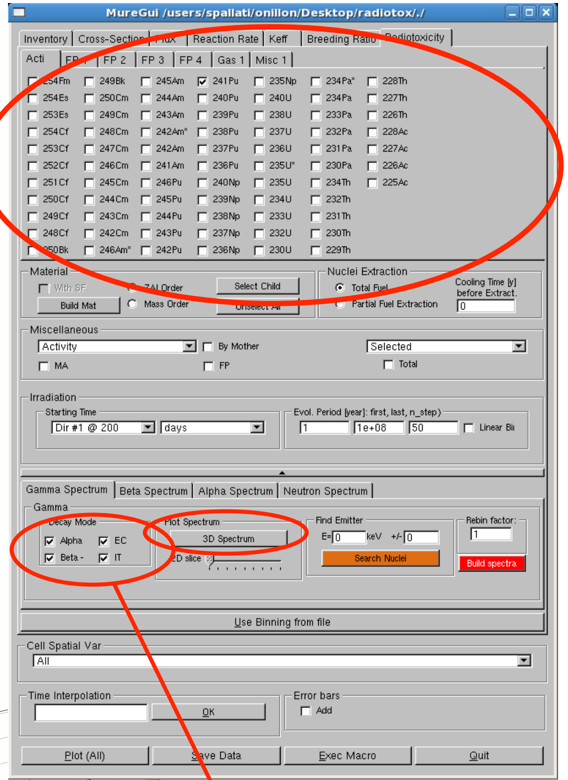
Coupled to the MURE code:

- produces spent fuel composition info for any geometry
- generates α,β,γ,n spectra for any spent fuel

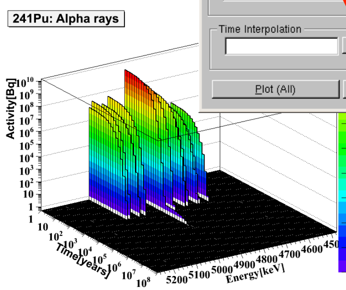
Coupled to Graphical User Interface MureGui

- Access to data generated during the fuel evolution
  Fluxes, Decay spectra, Inventories, Reaction Rates





Nuclei to be chosen



Production process

B. Leniau's PHD Thesis, IPNO, 2013

B. Leniau et al., Prog. In Nucl. Science and Technology, Vol. 4 (2014) 134