SENSITIVITY ANALYSIS OF NUCLEAR DATA ON KEFF FOR GRAPHITE MODERATED INNOVATIVE REACTORS

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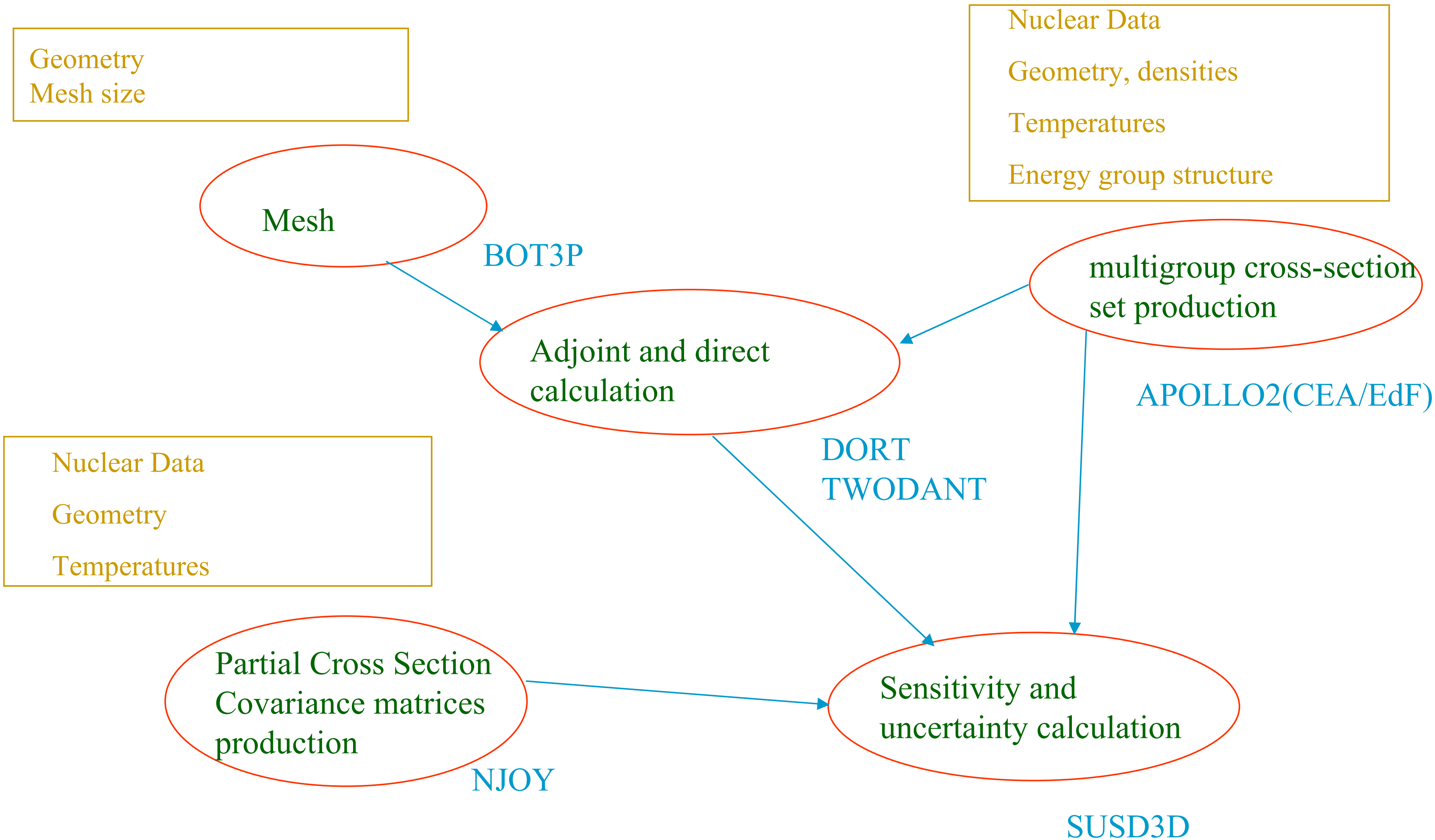
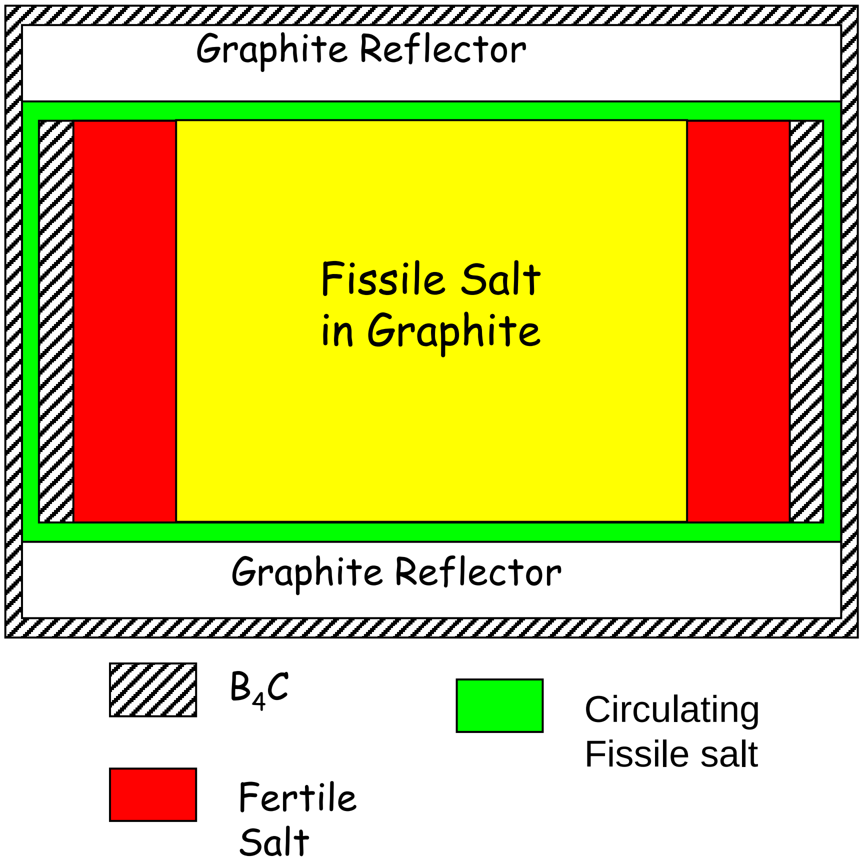
First Order Perturbation theory application





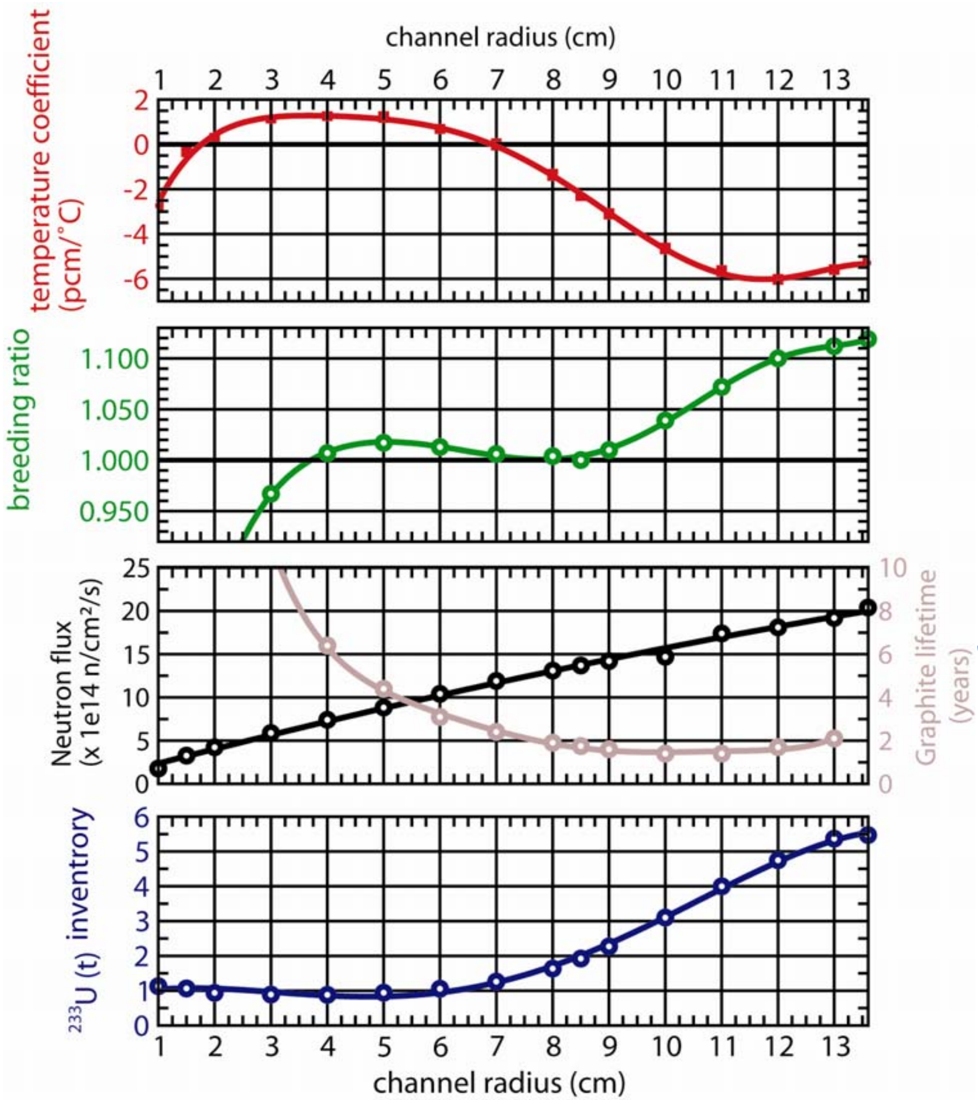
Evolution of Molten Salt Breeder Reactor concept toward fuel chemistry simplification

2 salts zones (1 fissile and 1 fertile) with different enrichment/moderation ratio :

- Temperature coef<0
- Neutron balance optimized

Densities :

- Fuel at equilibrium
- FP concentrations and enrichment depend on fuel chemistry



Thorium cycle advantages :

- *Breeding*
- *Minimum waste production*
- *Low fissile inventory*

But competitions between:

Breeding+Graphite lifetime

<->temperature coefficient

'Reference ' chosen :

Radius = 8,5 cm

Integrated sensitivity comparison

Isotope	reaction	Deterministic method(%/%)	stochastic method(%/%)
C	(n,elas)	0,340	0,310
U235	(n,gamma)	-0,020	-0,019
	(n,fission)	0,037	0,044
	Nu total	0,093	0,099
U234	(n,gamma)	-0,138	-0,058
Pa233	(n,gamma)	-0,015	-0,013
U233	(n,gamma)	-0,080	-0,068
	(n,fission)	0,336	0,385
	Nu total	0,875	0,883
Th232	(n,gamma)	-0,379	-0,371

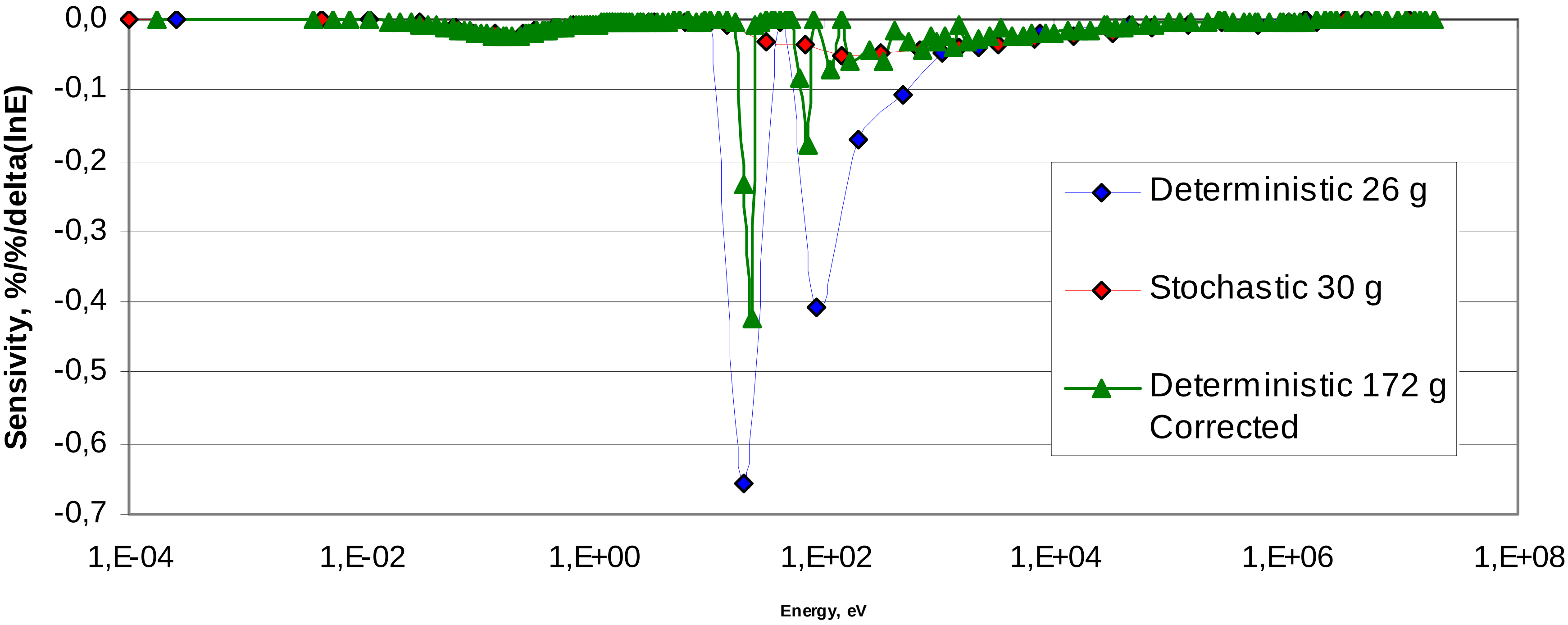
Direct calculation results :

0,1% change of Th density gives 0,26%/%

1% change of Th density gives 0,29%/%

3% change of Th density gives 0,29%/%

Th 232 Capture Sensitivity Profile



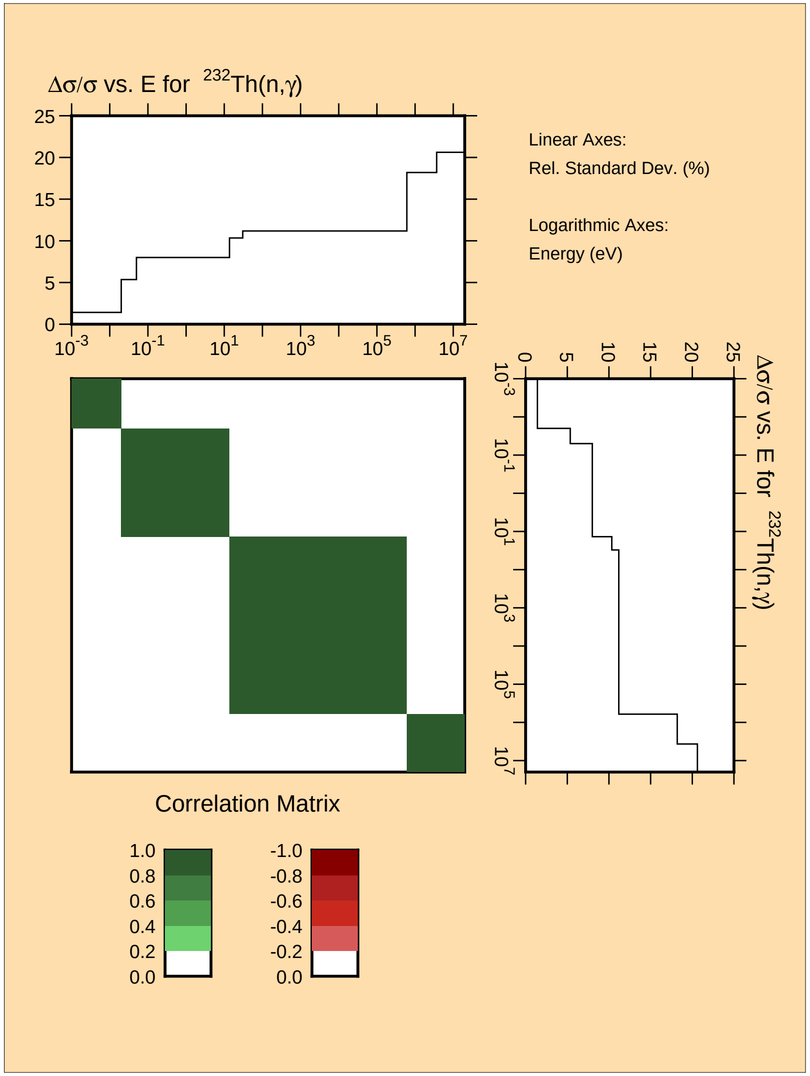
Th 232 cross section uncertainties

available Th232 evaluations : rather old
~1977(ENDFB6)->1985
modif : JEFF3.0 (JENDL3.2) 1993
Available Th232 uncertainties last :
one unique source : 1977 ENDF evaluation
shared by ENDFB6, IRDF90v2, JEFF3.0
~10% uncertainty in the resolved
resonance energy range, diagonal covariance matrice.

New measurements :n-TOF(CERN), IRMM (Geel, Belgium) 3-5% precision-> new evaluations.

JEFF3.1 available in march 2005

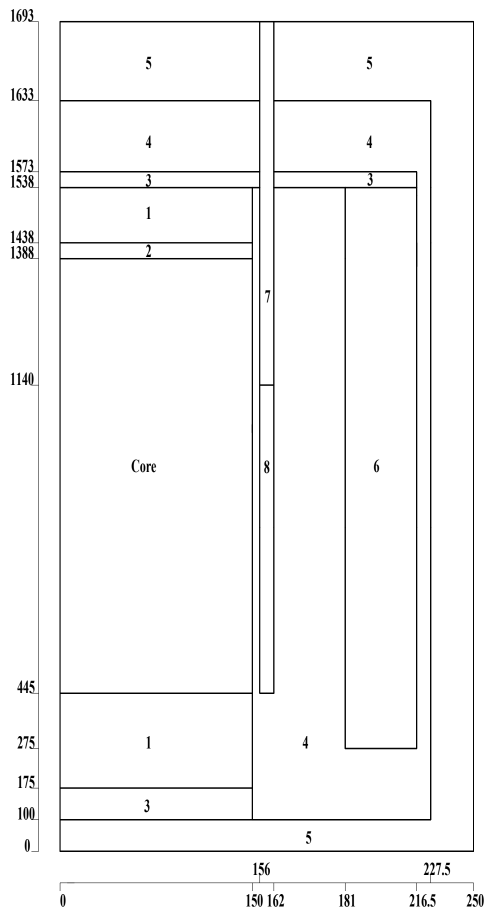
When new uncertainty evaluation can be expected?..



Uncertainty analysis

Isotope	reaction	Sensitivity(%/%)	Uncertainty (pcm)	uncertainty source
C	(n,elas)	3,40E-01	35	JEF2.2
U235	(n,gamma)	-1,98E-02	42	JENDL3.2
	fission	3,67E-02	27	
	Nutotal	9,30E-02	30	
U233	(n,gamma)	-8,03E-02	27	JENDL3.3
	fission	3,36E-01	227	
	Nu	8,75E-01	186	
Th232	(n,gamma)	-3,79E-01	3891	ENDFB6
	fission	2,83E-02	34	IRDF90v2
	Nu	3,20E-02	0	JEFF3.0

OECD/NEA HTR Benchmark



Number	Region	Number	Region
1	Reflector 1	5	Carbon Layer Surrounding System
2	Void	6	Reflector + Coolant Channels
3	Void + Graphite	7	Reflector + Control Rods
4	Reflector 2	8	Reflector 3

Cell calculations and core calculations with various fuels at 2 temperatures.

Good agreement between participants (Deterministic and stochastic)

But for VSOP solution for Pu core calculations : -4000 pcm.

Pu240 capture cross section suspected.

26 g sensitivity analysis

Material	Reaction	Sensitivity(%/%)
Pu239	Nu total	8,20E-01
	(n,fission)	3,55E-01
	(n,γ)	-2,82E-01
Pu240	(n,γ)	-4,72E-01
Pu241	Nu total	1,79E-01
	(n,fission)	8,21E-02
	(n,γ)	-3,56E-02
Pu242	(n,γ)	-1,87E-02
Carbon	elastic	1,59E-01
	(n,γ)	-1,32E-02

VSOP discrepency investigation

Reaction	1g XS relative difference	26g Integrated sensitivity (%/%)	Expected impact (pcm)
Pu239 fission	0,28%		
Pu242 Capture	21%		
Pu240 Capture	15%		

VSOP discrepency investigation

Reaction	1g XS relative difference	26g Integrated sensitivity (%/%)	Expected impact (pcm)
Pu239 fission	0,28%	0,355	
Pu242 Capture	-21%	-0,0187	
Pu240 Capture	15%	-0,472	

VSOP discrepency investigation

Reaction	1g XS relative difference	26g Integrated sensitivity (%/%)	Expected impact (pcm)
Pu239 fission	0,28%	0,355	+100
Pu242 Capture	-21%	-0,0187	+400
Pu240 Capture	15%	-0,472	-7000

Uncertainty analysis

Material	Reaction	Uncertainty(pcm) JENDL/alternative source
PU239	Nu total	65
	(n,fission)	1280/90(IRDF90)
	(n,γ)	750
Pu240	(n,γ)	375
Pu241	Nu total	52
	(n,fission)	39
	(n,γ)	55
Carbon	elastic	46(ENDFB5)
	(n,γ)	79(ENDFB5)
Total		1556/405

Conclusion (1)

- Whatever the concept, most sensitive reactions are:
  - Neutron yelds
  - Fission and capture reaction for fissile material
  - Capture reaction on fertile material
  - Scattering reaction on moderator
- Sensitivity of thermal treatement for carbon in graphite very important but not evaluated.
- Importance of Pu240 capture cross section confirmed for HTR discrepancy.

Conclusion(2)

- Uncertainty due to nuclear data are:
  - >1% for TMSR, Thorium capture is by far the main contributor.
  - About 1% for HTR benchmark. Main contributors are Pu240 capture and Pu239 cross sections and neutron yelds.
- Keff uncertainty is not the real problem :it *will* be equal to 1! But design margins have to be taken to cope with this uncertainty : U233 density and inventory for TMSR (with side effect on safety coefficients and breeding?) and number of pebble for pebble bed HTR or another parameter able to control reactivity swing.
- These analyses are limited by the amount of nuclear data uncertainty information. Almost no information is available for nuclides with mass>241, or Th232, even though they will be massively loaded in next generation reactors…