The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific
and Cultural Organization

International Atomic
Energy Agency

Workshop on
"Technology and Applications of Accelerator Driven Systems (ADS)"

17 - 28 October 2005

1677/7

Examples of ADS Design II:
The Energy Amplifier DEMO

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- ✓ LECTURE 1: Physics of Spallation and Sub-critical Cores, Fundamentals
  (Monday 17/10/05, 16:00 – 17:30)
- ✓ LECTURE 2: Nuclear Data & Methods for ADS Design I
  (Tuesday 18/10/03, 08:30 – 10:00)
- ✓ LECTURE 3: Nuclear Data & Methods for ADS Design II
  (Tuesday 18/10/03, 10:30 – 12:00)
- ✓ LECTURE 4: ADS Design Exercises I & II
  (Tuesday 18/10/03, 14:00 – 17:30)
- ✓ LECTURE 5: Examples of ADS Design I
  (Thursday 20/10/03, 08:30 – 10:00)
- ✓ **LECTURE 6: Examples of ADS Design II**
  (Thursday 20/10/03, 10:30 – 12:00)
- ✓ LECTURE 7: ADS Design Exercises III & IV
  (Thursday 20/10/03, 14:00 – 17:30)

Examples of ADS Design II : The Energy Amplifier DEMO

Y. Kadi
CERN, Switzerland

20 October 2005, ICTP, Trieste, Italy

SIMULATION OF THE ENERGY AMPLIFIER DEMONSTRATION FACILITY (EADF)

- Motivations
- Reference Configuration
- Global Neutronic Parameters
- Evolution of the Main Parameters with Burnup
- Minor Actinide Transmutation Studies

The Three Levels of ADS Validation

Three different levels of validation of an ADS can be specified:

- **First**, validation of the different component concepts, taken separately (accelerator, target, subcritical core, dedicated fuels and fuel processing methods). In Europe: The FEAT, TARC, MUSE & YALINA experimental programs and the MEGAPIE project are significant examples.

- Second, validation of the coupling of the different components in a significant environment, e.g. in terms of power of the global installation, using as far as possible existing critical reactors, to be adapted to the objectives.

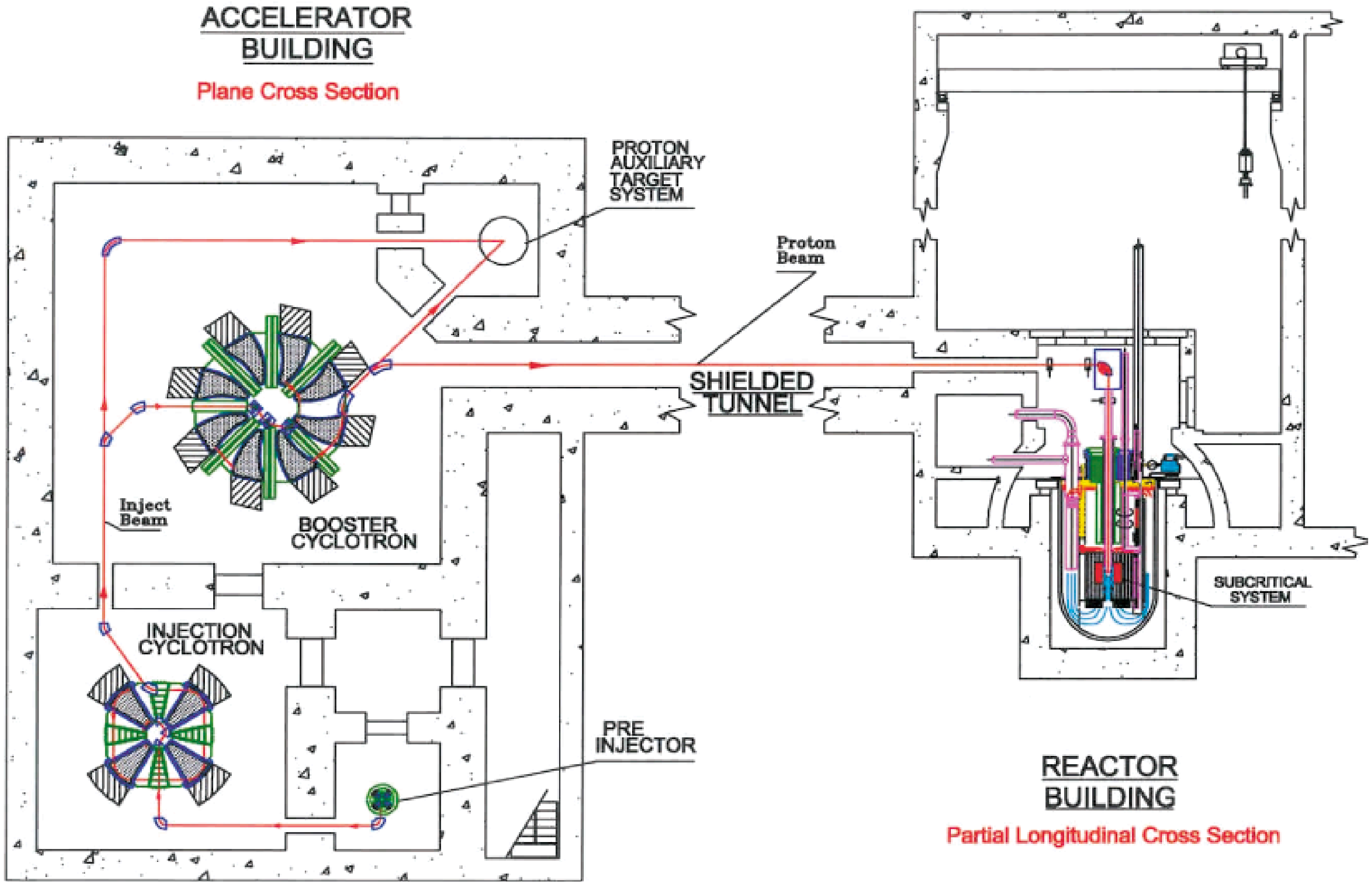
- **Third, validation in an installation explicitly designed for demonstration (e.g. the ADS installation described in the European roadmap established by the Technical Working Group, chaired by prof. Rubbia). This third step should evolve to a demonstration of transmutation fuels, after a first phase in which the subcritical core could be loaded with "standard" fuel.**

The key objective of the Energy Amplifier Demonstration Facility (EADF) is threefold:

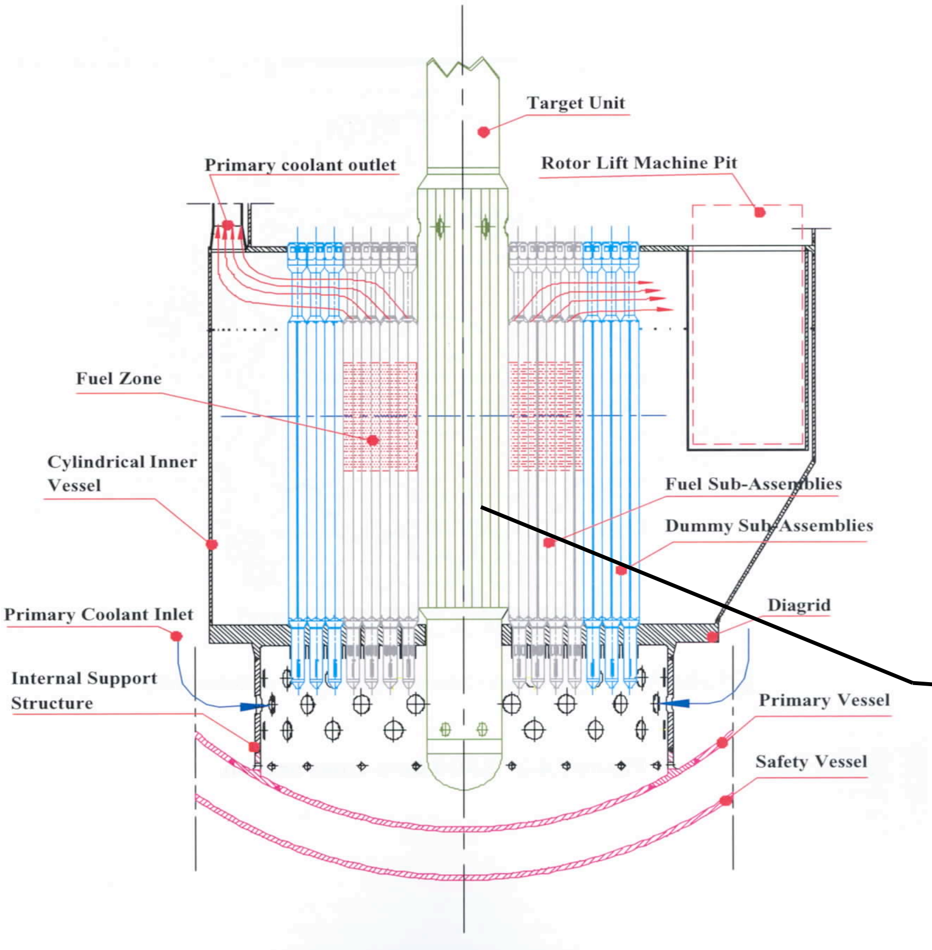
- Demonstrating the technical feasibility of a fast neutron operated Accelerator Driven System (ADS);
- Lead-Bismuth Eutectic coolant;
- Incineration of TRUs and LLFF while producing energy.

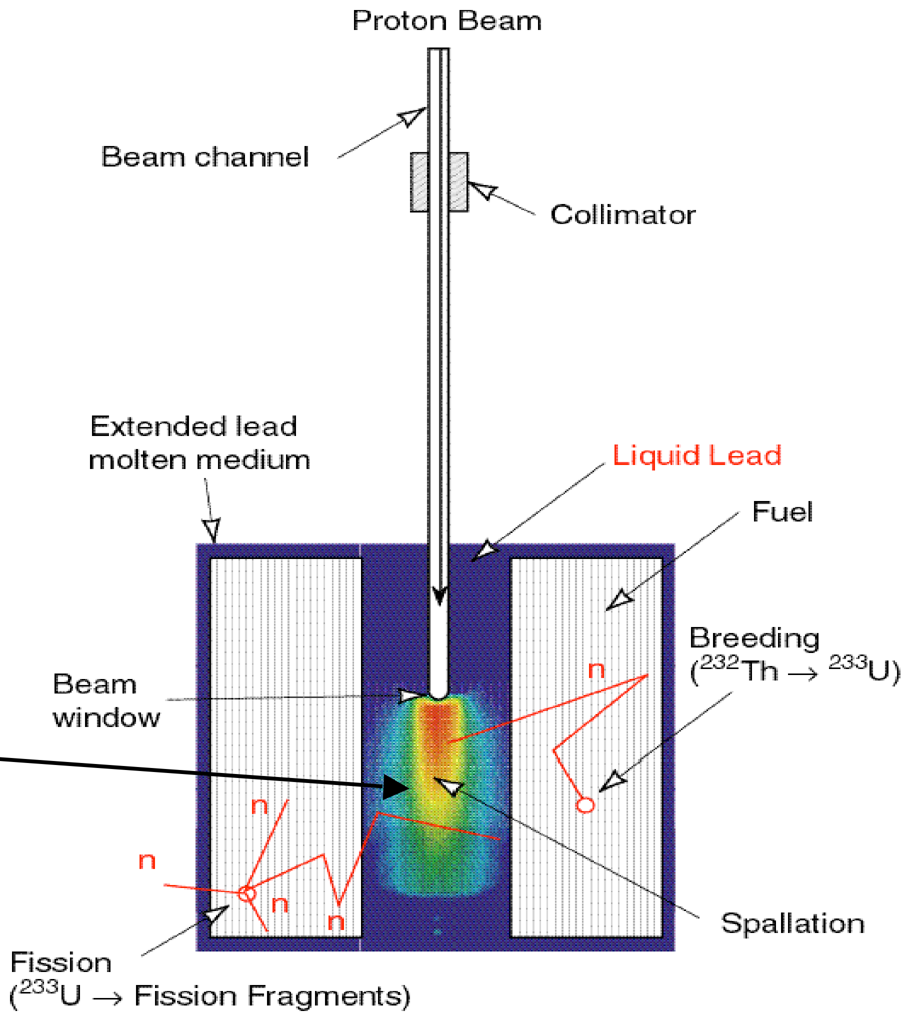
Ref.: ANSALDO Nucleare, EA-B0.00-1-200 – Rev. 0, January 1999.

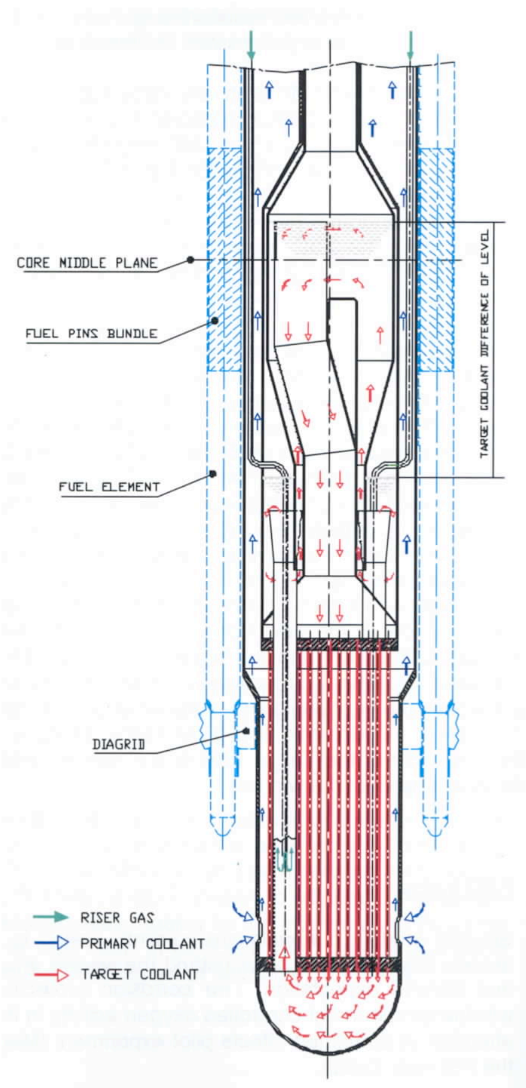
The EADF : *Plant Layout*

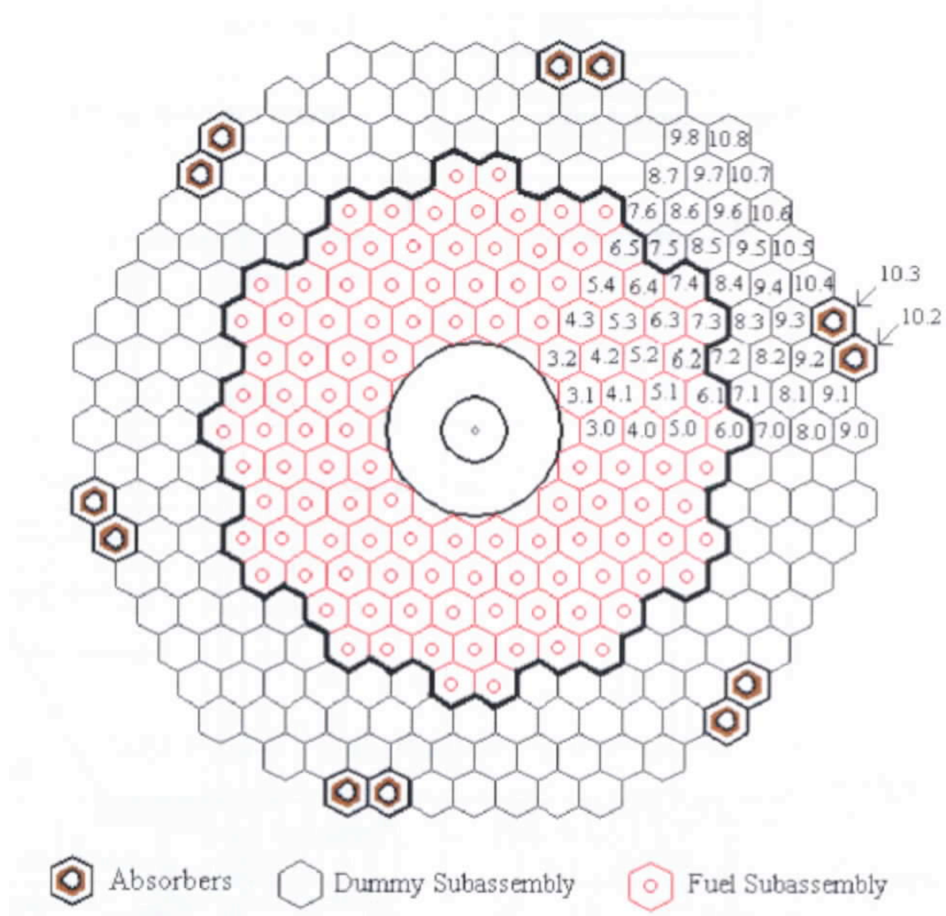


The EADF: *General Features*



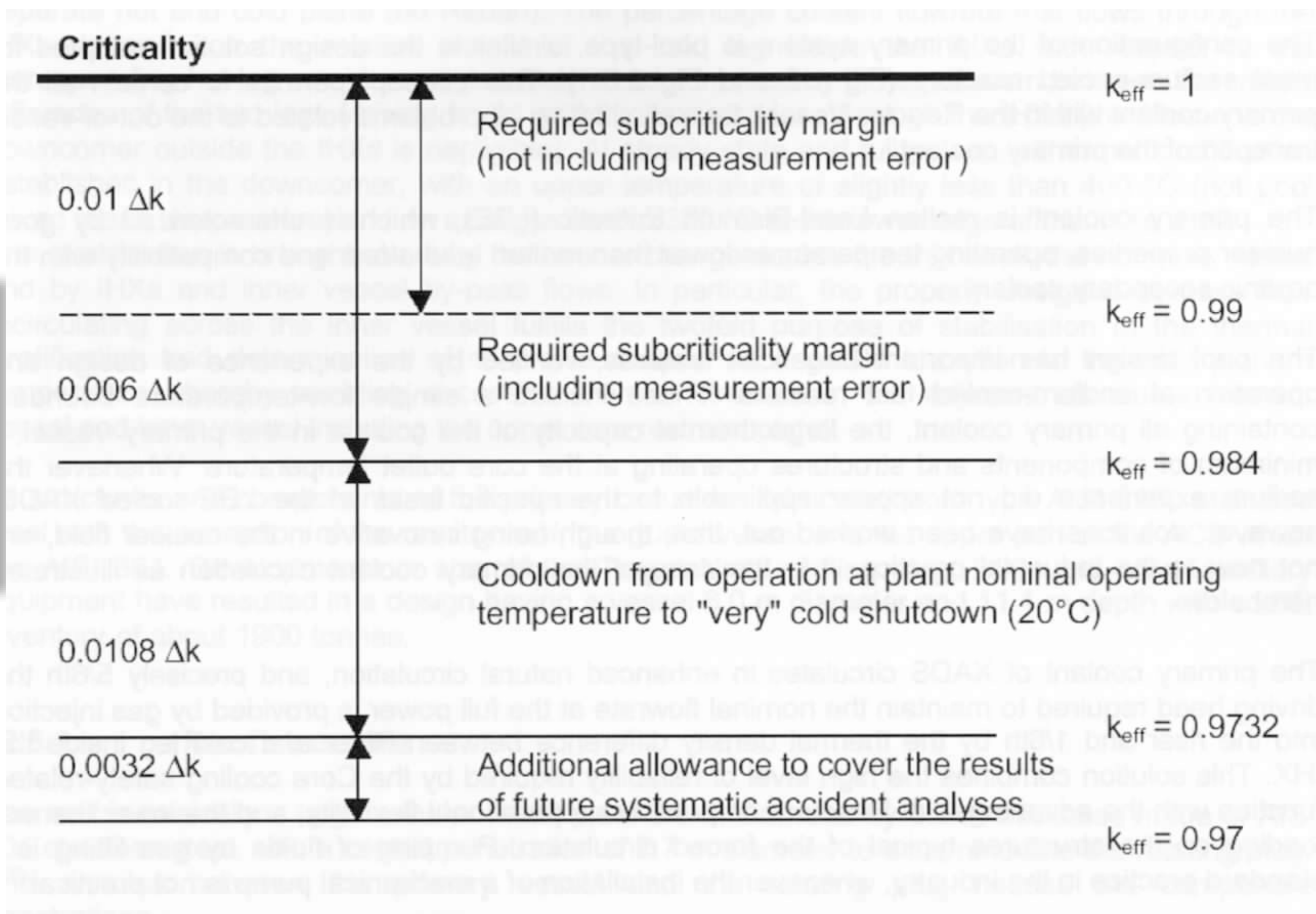



CORE MIDDLE PLANE
FUEL PINS BUNDLE
FUEL ELEMENT
DIAGRID
TARGET COOLANT DIFFERENCE OF LEVEL
RISER GAS
PRIMARY COOLANT
TARGET COOLANT


10.3
10.2
Absorbers
Dummy Subassembly
Fuel Subassembly

Determination of the sub-criticality level

⇨*Safety:* The sub-criticality ($k \approx 0.95 \div 0.98$) condition is guaranteed at all times.



Main parameters of the EADF reference configuration

Global Parameters	Symbol	EADF	EADF	Units
Initial fuel mixture	MOX	$(U\text{-}Pu)O_2$	$(Th\text{-}Pu)O_2$	
Initial fuel mass	m_{fuel}	3.793	3.793	ton
Initial Pu concentration	m_{Pu}/m_{fuel}	17.7	20.2	wt.%
Initial Fissile enrichment	$Pu^{39,41}$	14.7	16.9	wt.%
Thermal Power Output	P_{th}	80	80	MWatt
Proton Beam Energy	E_p	600	600	MeV
Spallation Neutron Yield	$N_{(n/p)}$	14.51 ± 0.10	14.51 ± 0.10	n/p
Net neutron multiplication	M	27.80 ± 0.56	26.74 ± 0.75	
Multiplication Coefficient	k=(M-1)/M	0.9640 ± 0.0007	0.9626 ± 0.0010	
Energetic Gain	G	42.73 ± 0.88	40.64 ± 1.19	
Gain coefficient	G_0	1.54	1.52	
Accelerator Current	I_p	3.20 ± 0.07	3.36 ± 0.10	mA
Core Power Distributions				
Av. fuel power density	P_{th}/V_{fuel}	255	258	W/cm^3
Av. core power density	P_{th}/V_{core}	55	56	W/cm^3
Radial peaking factor	P_{max}/P_{ave}	1.25	1.21	
Axial peaking factor	P_{max}/P_{ave}	1.18	1.14	

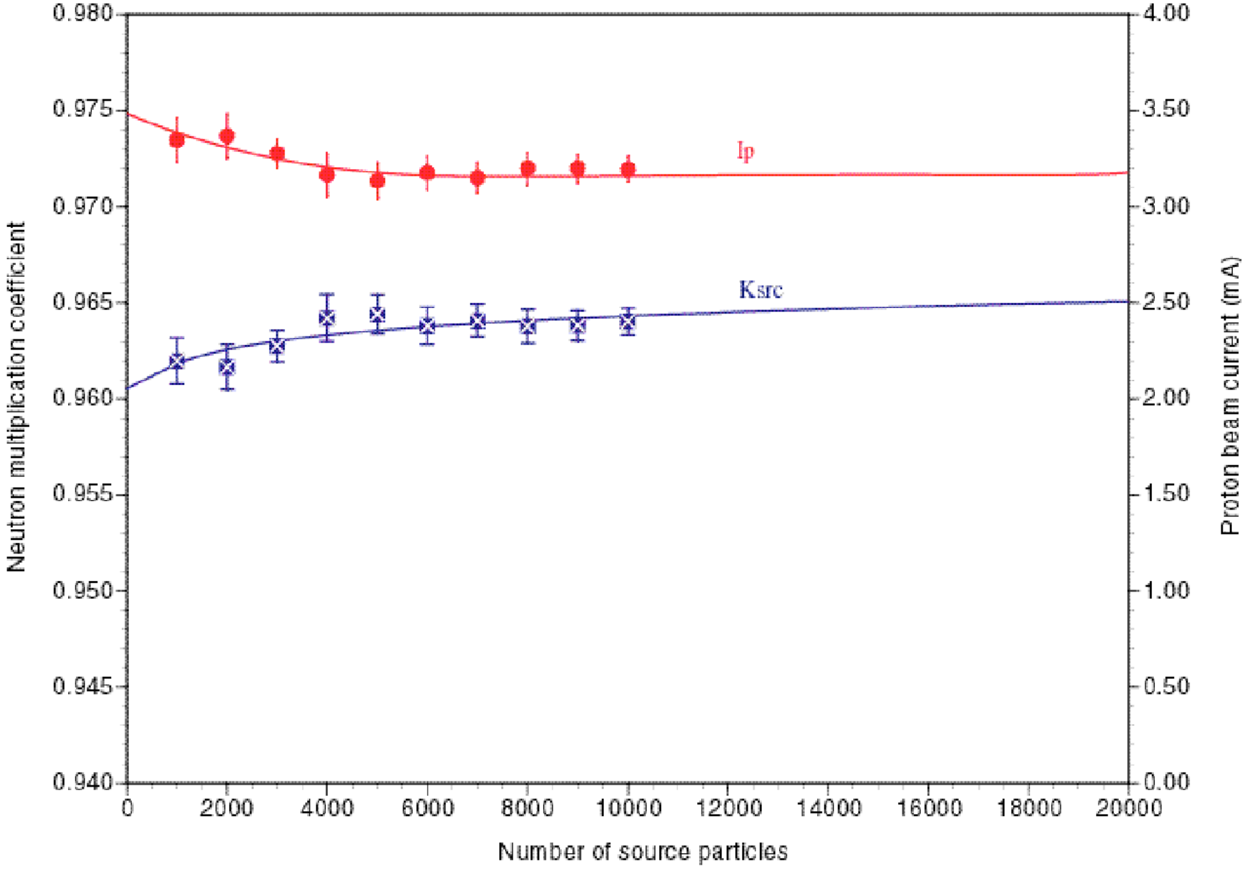
Statistical Fluctuations

Variation of the k_{src} multiplication coefficient and of the proton beam current as a function of the number of simulated primary protons

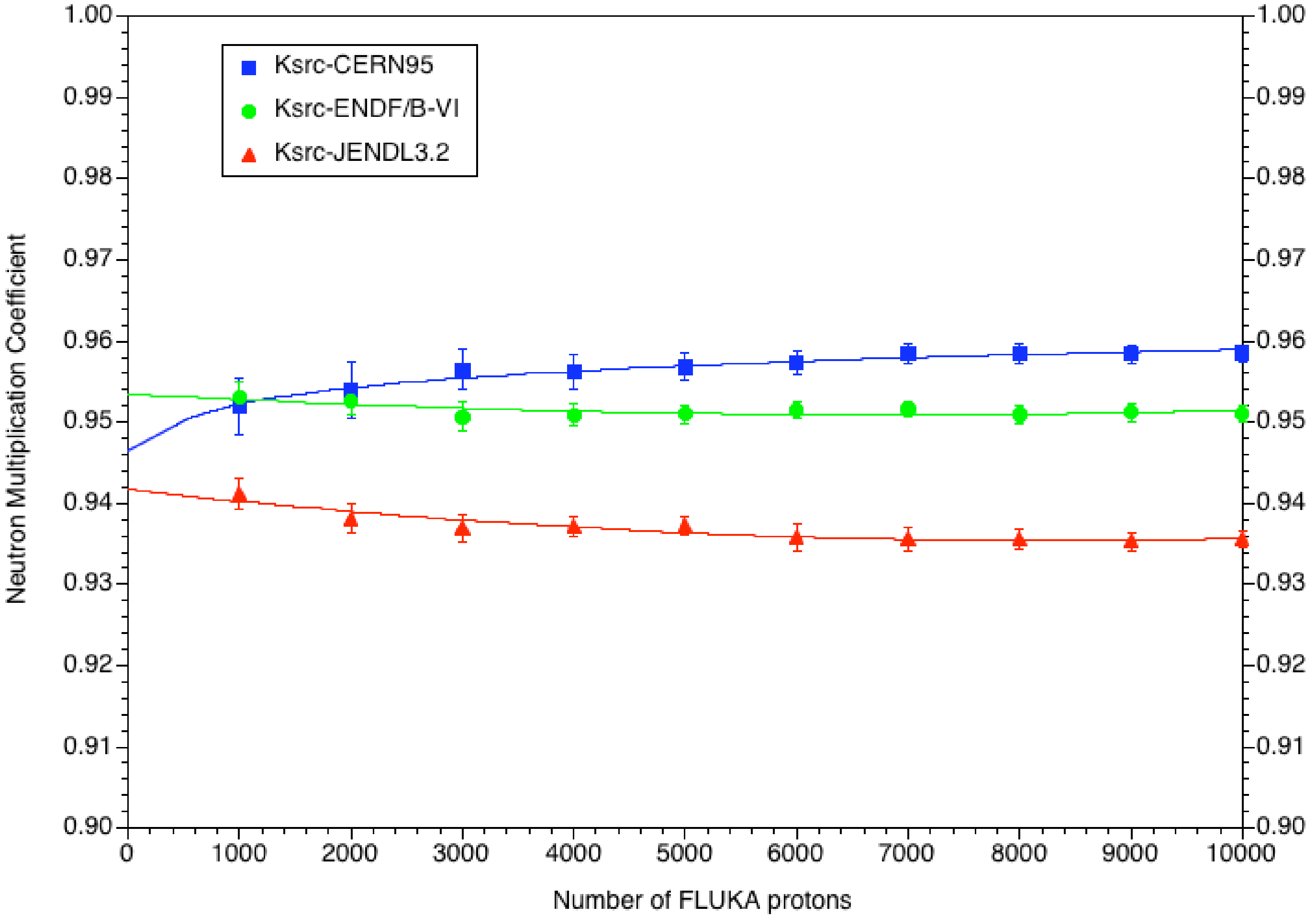
- ✓ *From the results of the convergence run, we can assume that the fission source spatial distribution, i.e. k_{src}, has achieved equilibrium after some $7x10^3$ primary protons have been transported.*

- ✓ *The very poor initial guess for the spatial distribution of fissions causes the first cycles estimates of k_{src} to be extremely low. This situation occurs because only a fraction of the spallation neutron source enters cells that contain fissionable material.*

$$\frac{\delta k}{1-k} = \frac{0.46}{\sqrt{N_p} \quad \sqrt{1-k}}$$

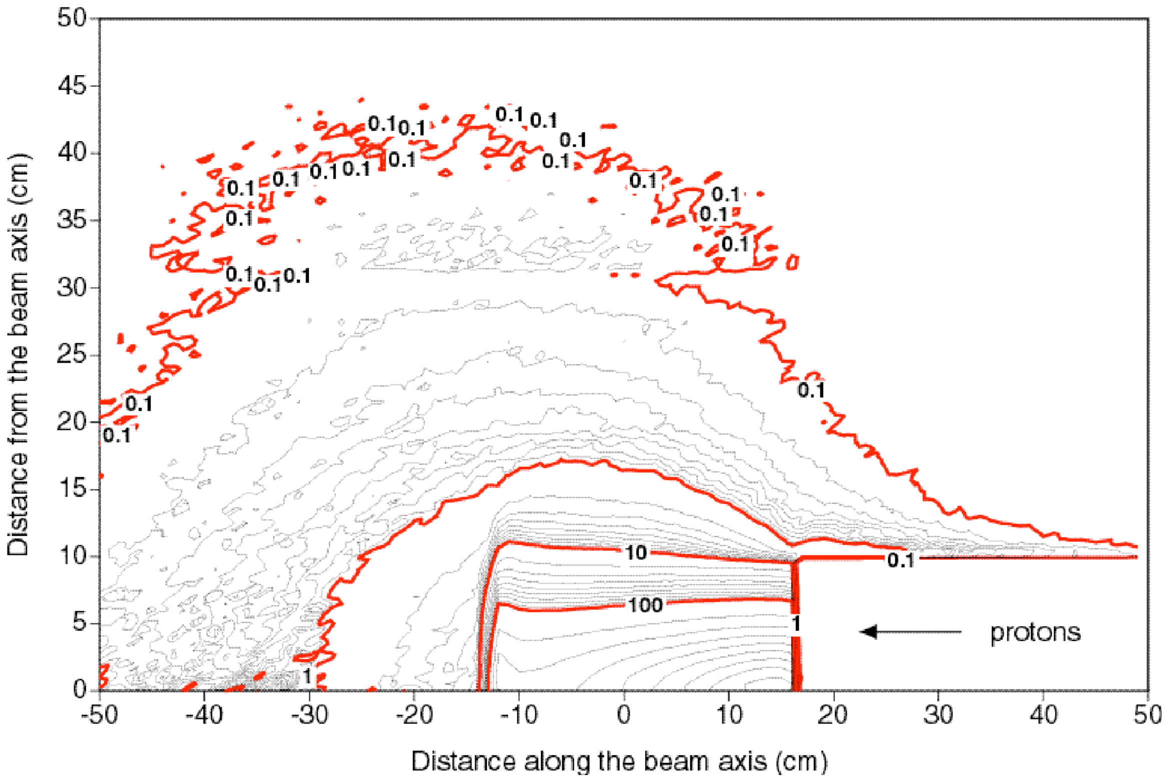


Convergence of the k_{src} multiplication coefficient for different neutron cross section data files



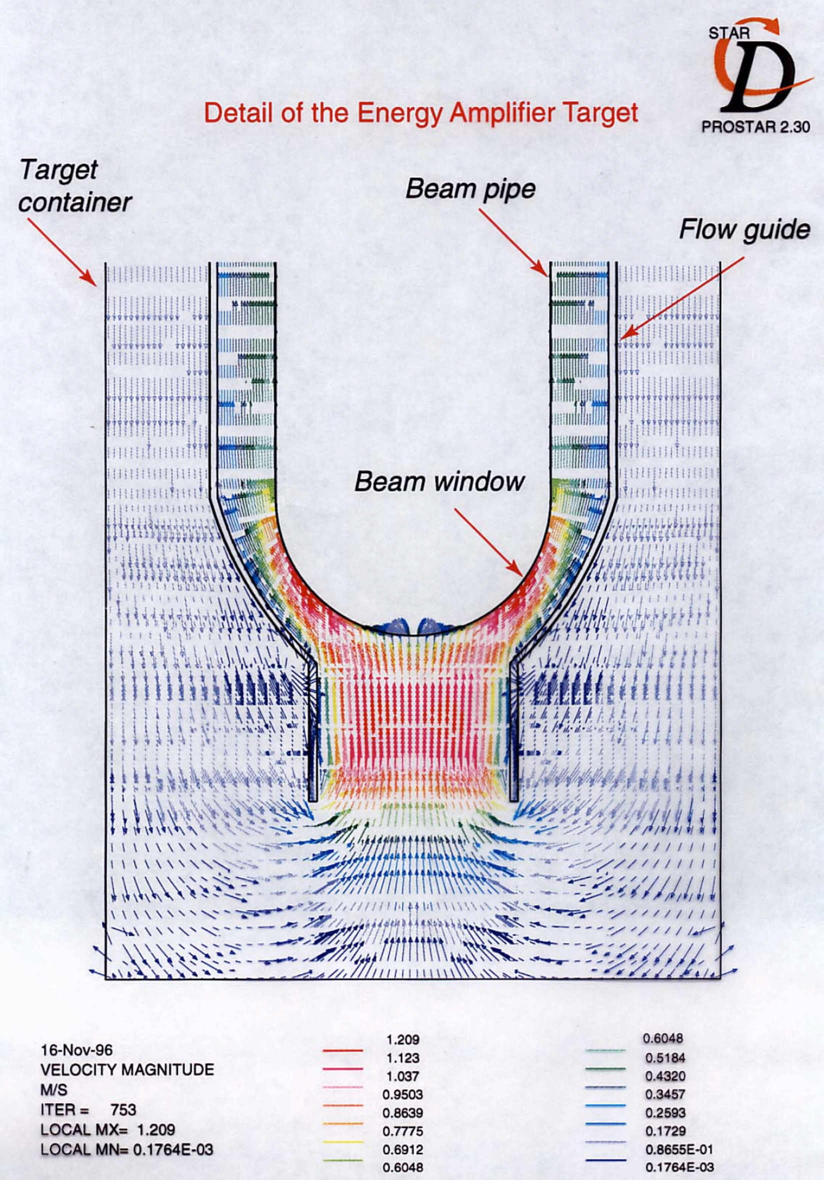
The EADF : *Beam-Target Interaction*

Power deposited (W/cm^3) by the 600 MeV, 3.2 mA proton beam impinging on the lead-bismuth eutectic spallation target



Total heat released: 1.45 MW (75% of Ep)
Ionization ~ 84%
EMF ~ 4%
Recoils + HF ~ 3%
Neutrons < 20MeV ~ 9%

The EADF: *Target thermo-hydraulics*



High temperature field

=>High coolant velocities

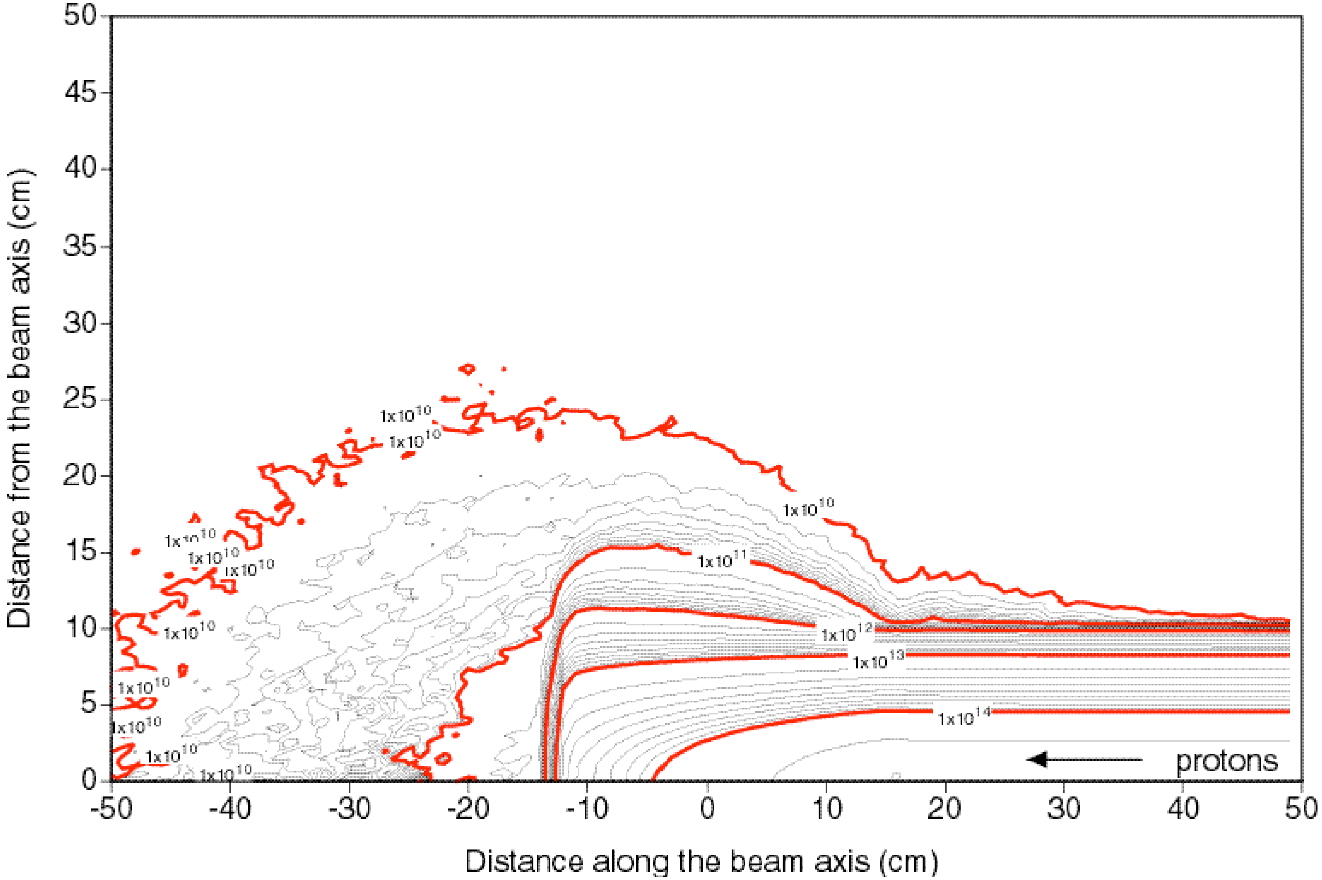
=>high turbulence, recirculation

=> High thermal stresses on the beam window

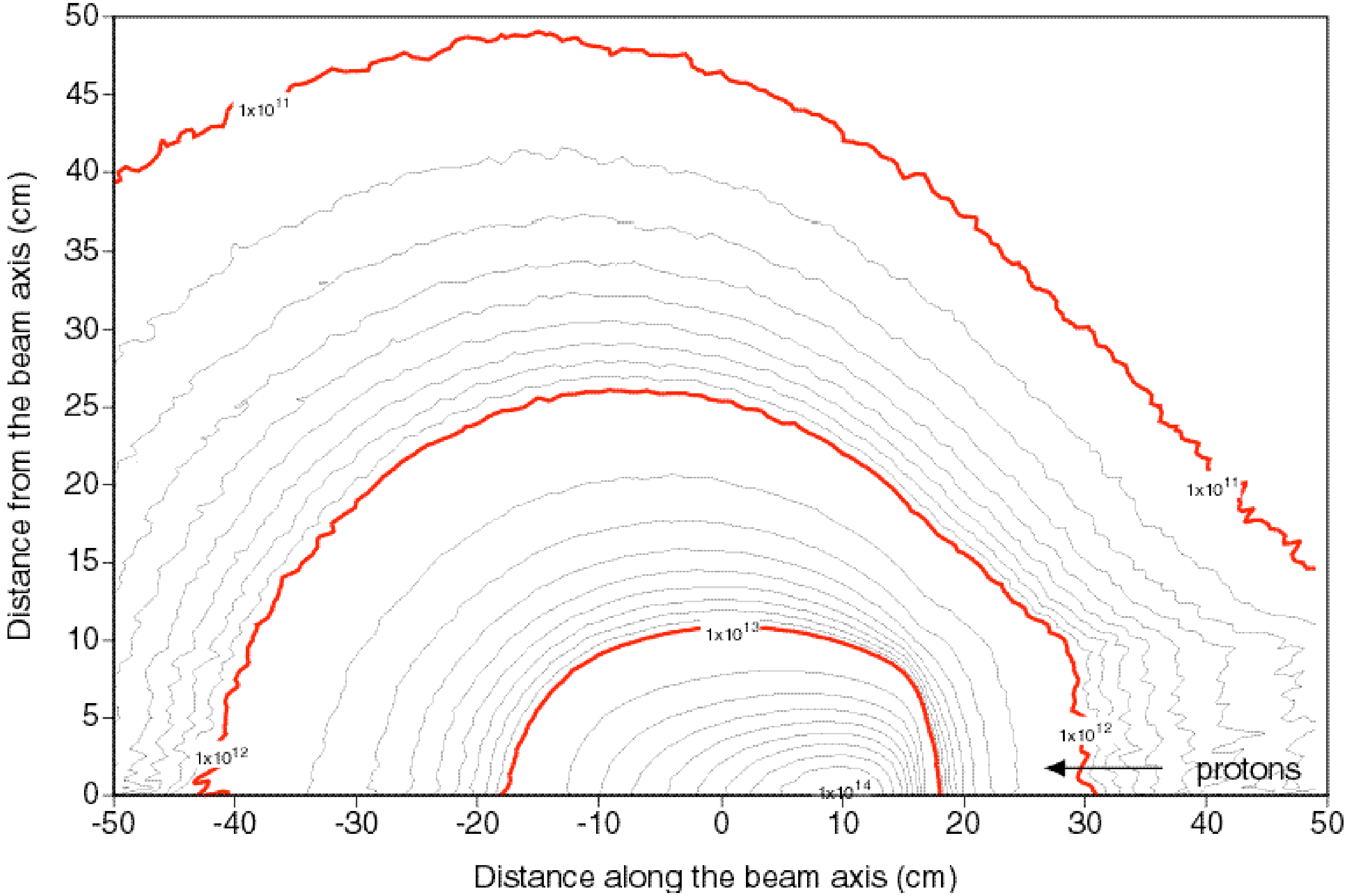
=> Windowless option

The EADF : *Beam-Target Interaction*

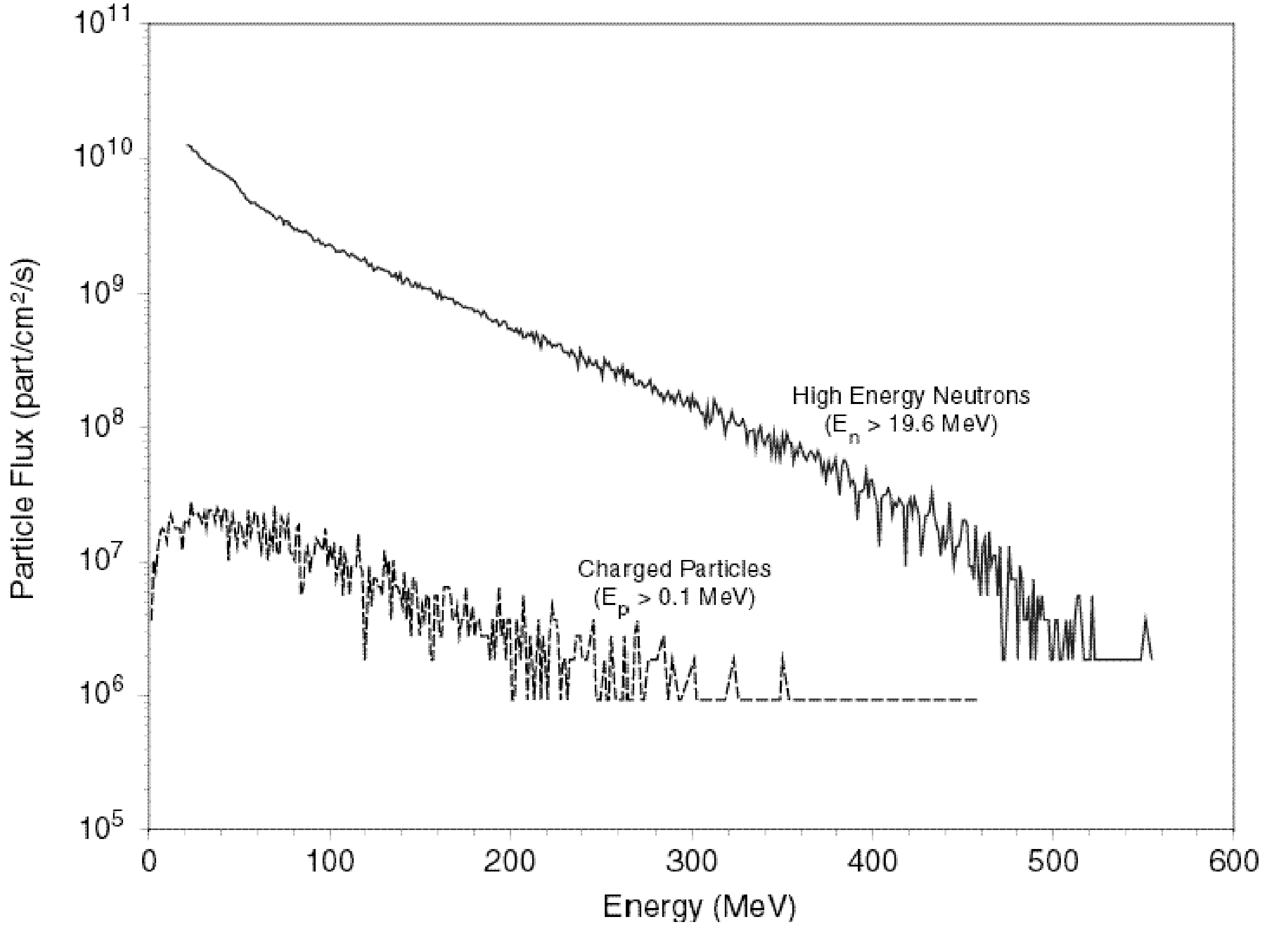
Charged particle fluence ($cm^{-2}.s^{-1}$) produced by the 600 MeV, 3.2 mA proton beam impinging on lead-bismuth eutectic.



High-energy neutron fluence ($cm^{-2}.s^{-1}$) produced by the 600 MeV, 3.2 mA proton beam impinging on lead-bismuth eutectic.



High-energy particle flux spectra at the exit of the spallation target unit (target containment vessel).



The EADF : *Radiation Damage*

Integrated flux, heating and damage of the spallation target unit internal structures, due to low-energy neutrons (LE) and high-energy particles (HE) as computed by EA-MC and FLUKA.

Region	Flux (part/cm^2.s)		Heat (W/cm^3)		DPA/year	
	HE	LE	HE	LE	HE	LE
Proton beam tube (HT-9 Steel)	$2.0x10^{13}$	$2.2x10^{13}$	$2.7x10^{-1}$	$9.4x10^{-2}$	$9.5x10^{-1}$	$5.5x10^{-2}$
Spallation target (LBE)	$1.7x10^{14}$	$5.9x10^{14}$	26	$5.2x10^{-1}$	8.0	1.6
Spallation target vessel (HT-9)	$4.1x10^{12}$	$1.3x10^{14}$	2.1	$4.9x10^{-1}$	$1.9x10^{-1}$	$4.3x10^{-1}$
Target unit containment vessel (HT-9)	$4.8x10^{11}$	$8.2x10^{13}$	$1.6x10^{-2}$	$2.6x10^{-1}$	$2.3x10^{-2}$	$2.3x10^{-1}$

Integrated flux, heating and damage in the reactor internal structures due to neutrons with energy below 20 MeV as computed by EA-MC.

Region	Flux (n/cm^2.s)	Heat (W/cm^3)	DPA/yr
Reactor roof	$7.0x10^{8}$	$3.7x10^{-6}$	$6.7x10^{-7}$
Reactor vessel	$1.2x10^{11}$	$2.9x10^{-3}$	$8.3x10^{-6}$
Safety vessel	$3.6x10^{10}$	$7.7x10^{-4}$	$2.5x10^{-6}$
Spallation target	$5.9x10^{14}$	0.515	1.566
Target vessel	$8.2x10^{13}$	0.263	0.230
Heat exchangers	$5.8x10^{11}$	$1.6x10^{-2}$	$1.5x10^{-4}$
HX secondary coolant	$7.2x10^{11}$	$2.3x10^{-4}$	$1.1x10^{-4}$
Core neutronic protection	$1.5x10^{13}$	0.184	$5.7x10^{-3}$
Av. fuel	$1.2x10^{14}$	260	0.772
Av. fuel cladding	$3.2x10^{13}$	0.098	0.141
Core radial reflector	$7.1x10^{13}$	0.327	0.146

The EADF : *Neutron Balance*

✓ The high-enrichment UPu MOX fuel, which contains a fissile concentration of about 20%, enables a very high fission-to-capture ratio, close to 0.95, to be achieved.

✓ Parasitic captures in the fuel core as well as in the entire device have been reduced to a minimum, i.e. 10 and 25% respectively.

✓ Half of the absorption reactions occuring in the lead-bismuth eutectic coolant are due to (n,Xn) reactions, which further increase the overall neutron multiplication in the system.

✓ Non-fission multiplicative processes account for more than 2% of the total non-elastic scattering reactions taking place in the EADF.

Neutron reaction inventory at several locations of the EADF

Neutron Absorption Inventory		Neutron Absorption Inventory	
Reactor vessel	0.33 %	Core upper reflector	5.49 %
Spallation target	1.96 %	Core radial reflector	2.04 %
Flow guides	0.14 %	Core lower reflector	6.91 %
Heat exchangers	0.80 %	Fuel core	72.63 %
Purification units	0.03 %	Primary coolant	6.83 %
Gas injection units	0.16 %	Escapes	0.16 %
Neutron shield	2.52 %	Total	100 %
Main Nuclear Reactions		**Main Nuclear Reactions**	
Capture	66.28 %	Others	0.43 %
Fission	30.95 %	Escapes	0.16 %
n,Xn	2.18 %	Total	100 %

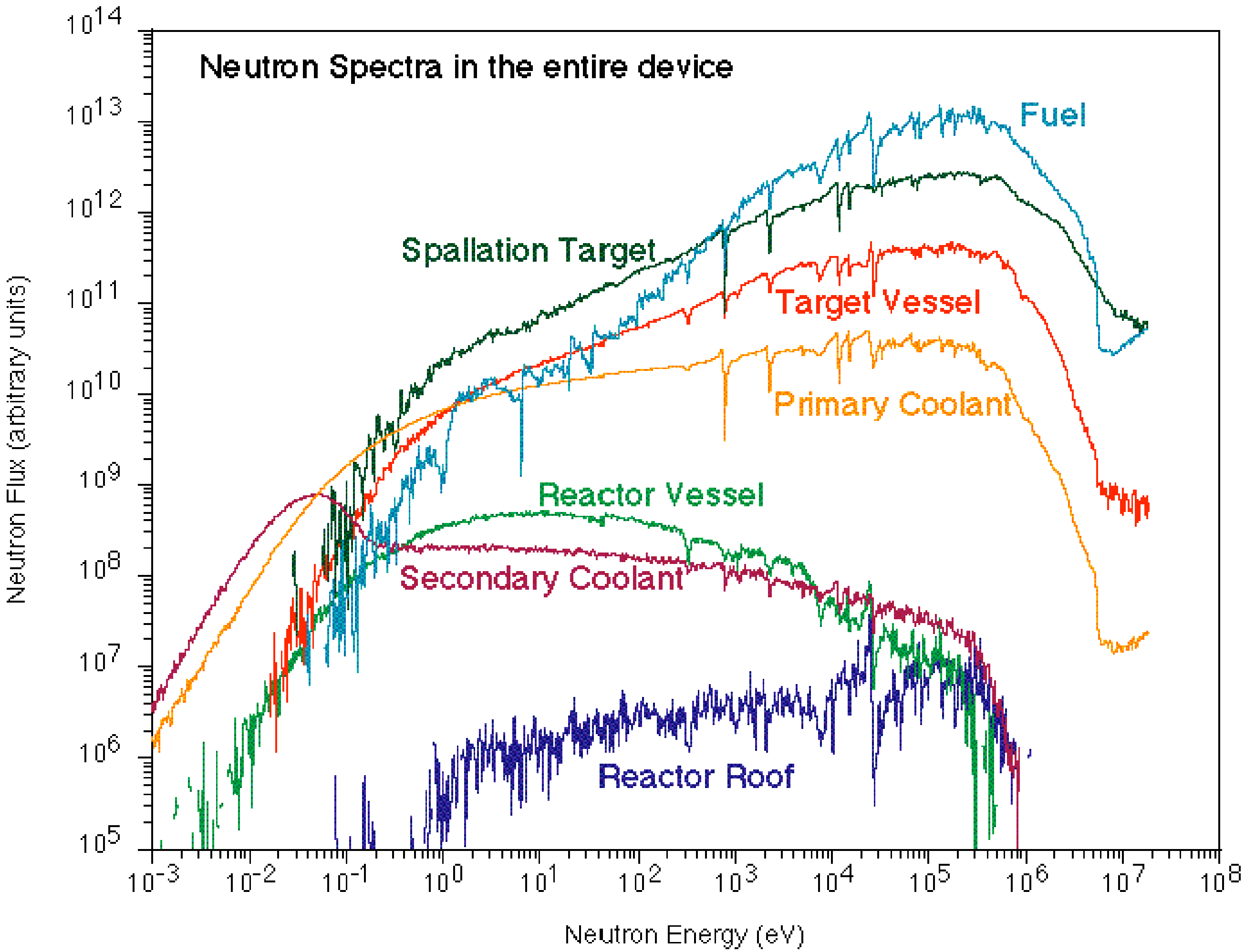
Neutron reaction inventory in the fuel core of the EADF

Neutron Absorption Inventory		Neutron Absorption Inventory	
MOX-Fuel	89.60 %	Sub-assembly wrapper	2.01 %
Cladding	3.83 %	Coolant	4.56 %
Main Nuclear Reactions		**Main Nuclear Reactions**	
Capture	54.44 %	n,Xn	2.40 %
Fission	42.61 %	Others	0.55 %

Neutronic characteristics of the sub-critical core

Neutron flux spectra at selected locations of the EADF

✓ Note the flat neutron spectrum in the primary coolant, where the dominating process is elastic scattering with very small lethargy variation



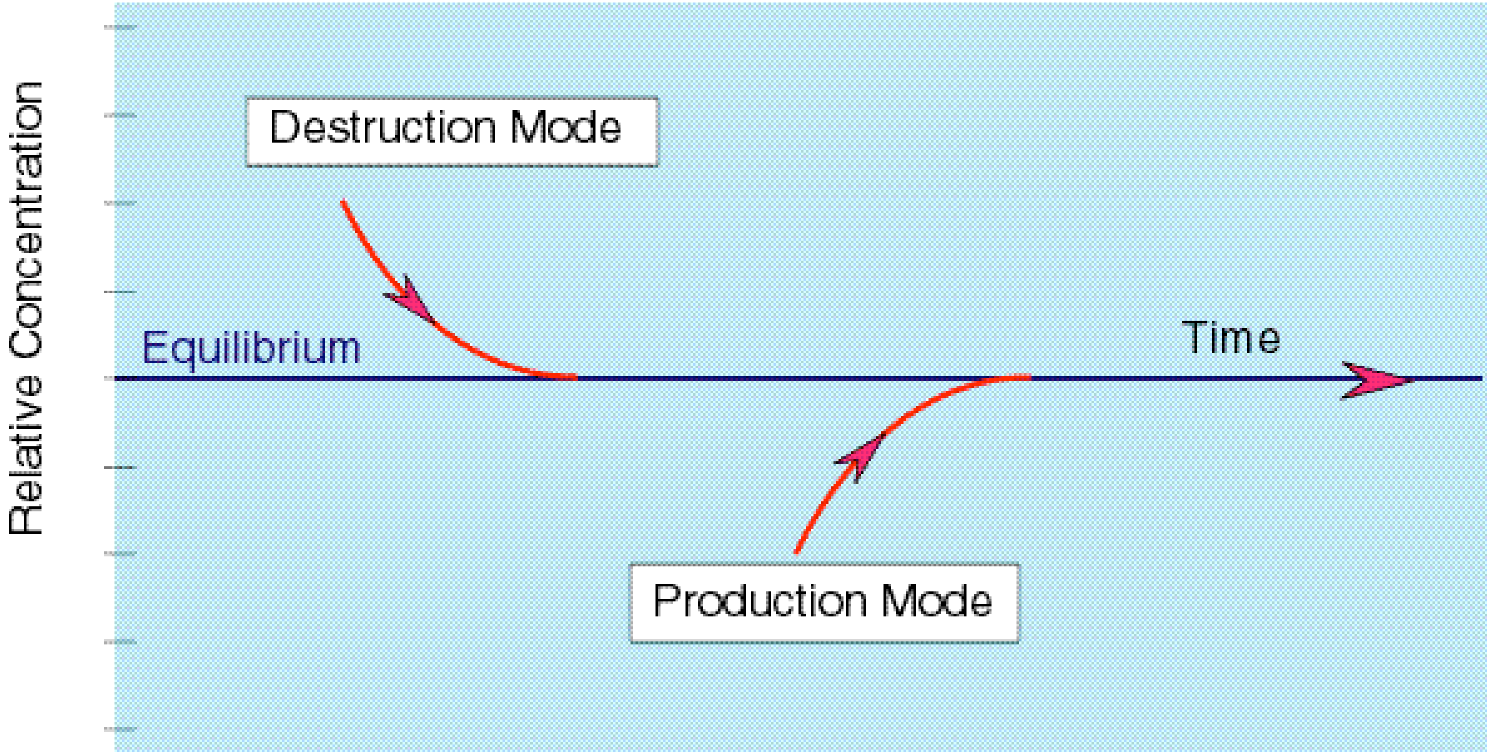
- The availability of an external neutron source (accelerator) and of fast neutrons (lead) allows the sustained operation of a sub-critical system with a lot of a flexibility in the choice of fuel.

- Pure Thorium does not fission, in practice, seeds are needed to start energy production:
  - Any fissionable material can be used (^{233}U, ^{235}U, ^{239}Pu or TRU)

- TRU's are destroyed by fission, a process which produces energy and makes the method economically attractive (TRU's still represent 40% of the energy delivered by the reactor which produced them).

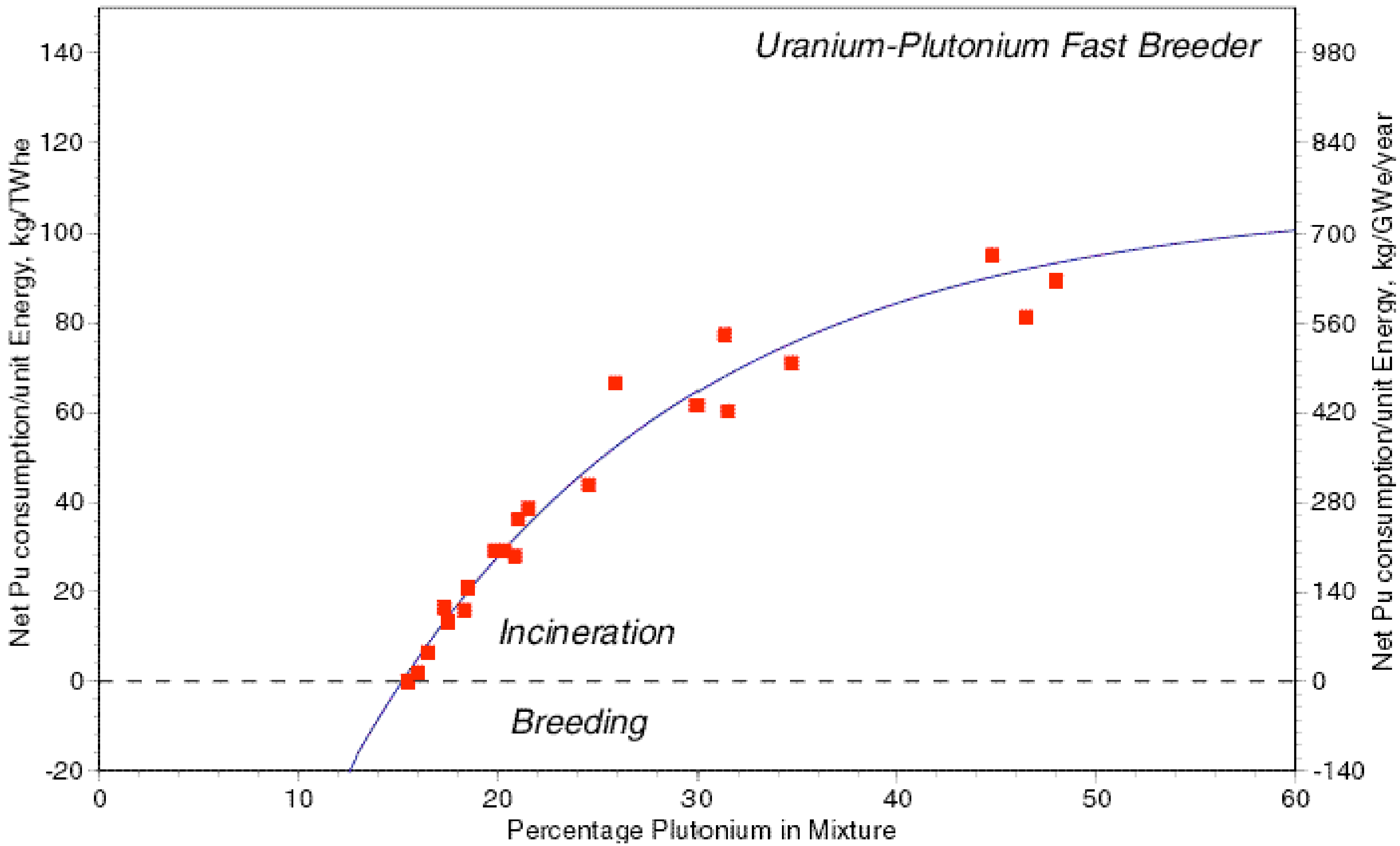
Principle of TRU destruction

- Fast Neutron Reactors (SPX) or even Accelerator-Driven Systems (EA) can operate either as a « breeder » (production mode) or as a « burner » (destruction mode) :

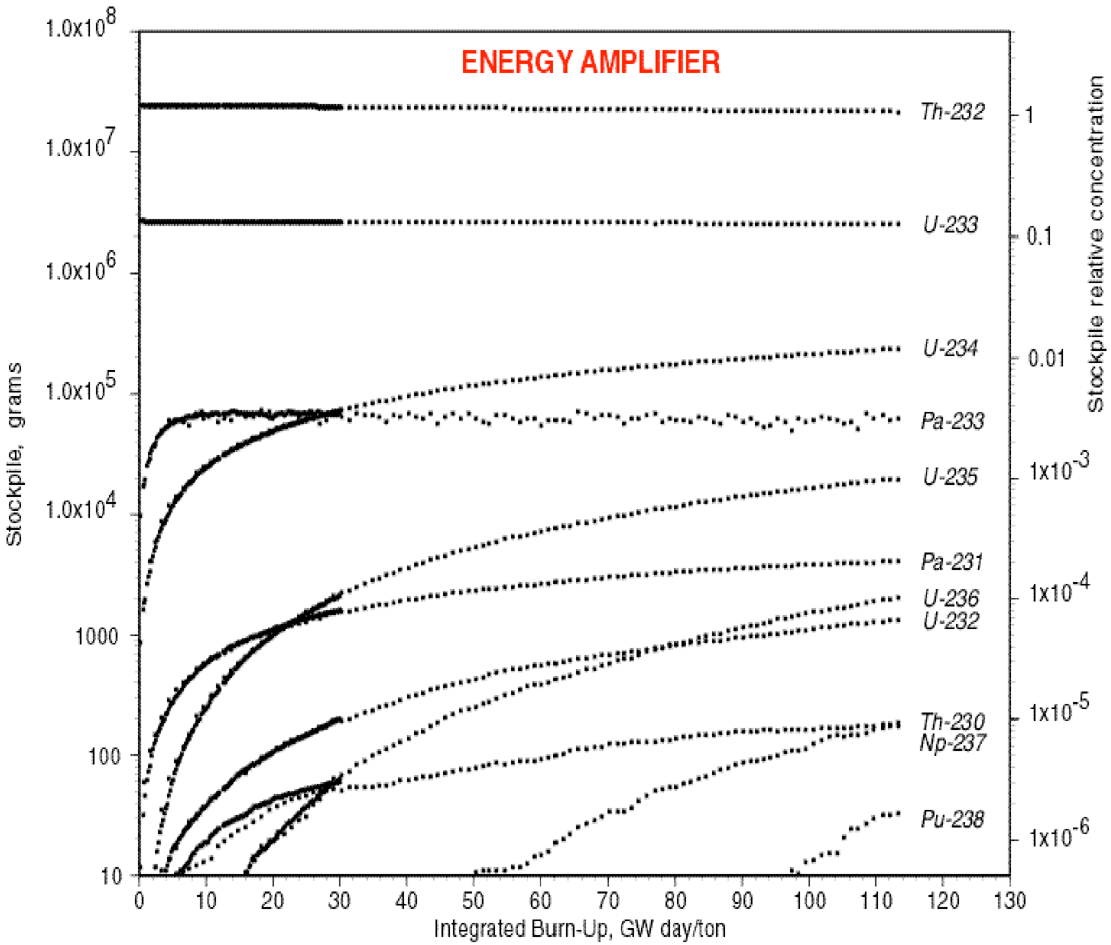


- It all depends on the concentration of the element of interest at a given time. For instance, an EA freshly loaded with pure ^{232}Th will be in the breeding mode for ^{233}U. This is explained by the simple fact that any system tends towards its equilibrium condition.

Plutonium incineration in fast neutron reactors



- Equilibrium concentrations are orders of magnitude lower than in a Uranium-plutonium based fuel

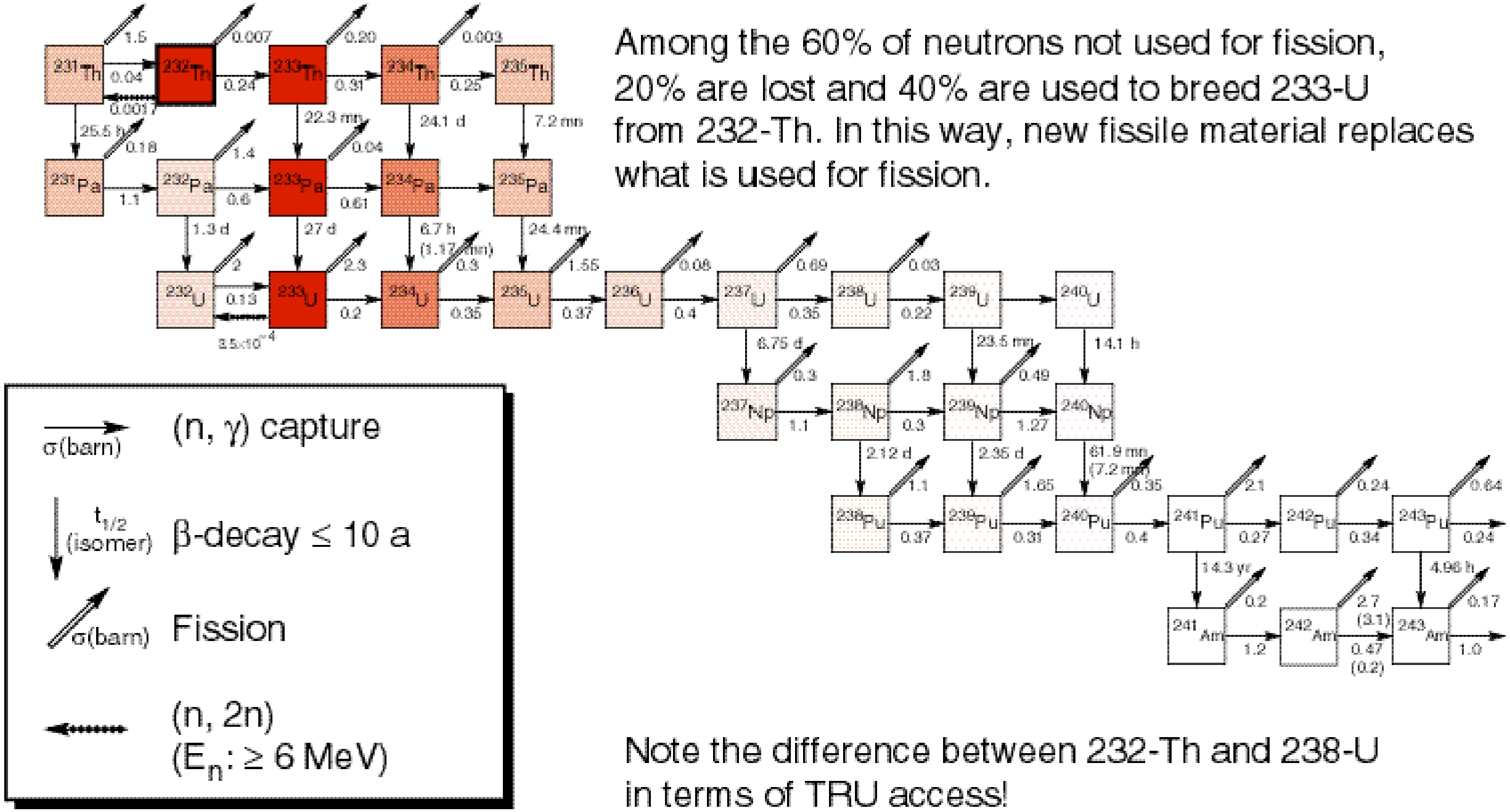


Elément	Limite asymptotique
^{232}Th	7,637 E-1
^{231}Pa	1,061 E-4
^{232}U	1,306 E-4
^{233}U	8,919 E-2
^{234}U	3,368 E-2
^{235}U	8,196 E-3
^{236}U	8,395 E-3
^{238}U	1,440 E-5
^{237}Np	2,168 E-3
^{238}Pu	1,958 E-3
^{239}Pu	6,374 E-4
^{240}Pu	3,703 E-4
^{241}Pu	7,034 E-5
^{242}Pu	4,572 E-5
^{241}Am	1,547 E-5
^{243}Am	1,372 E-5
^{244}Cm	1,303 E-5

CHOICE OF FUEL: Thorium [$^{232}ThO_2$ (+ $^{233}UO_2$)]

n + ^{232}Th(1.4×10^{10} a) → ^{233}Th(22.3 m) → ^{233}Pa(27 j) → ^{233}U(1.6×10^{5} a)

Among the 60% of neutrons not used for fission, 20% are lost and 40% are used to breed 233-U from 232-Th. In this way, new fissile material replaces what is used for fission.



Note the difference between 232-Th and 238-U in terms of TRU access!

The EADF : *Fuel Burnup*

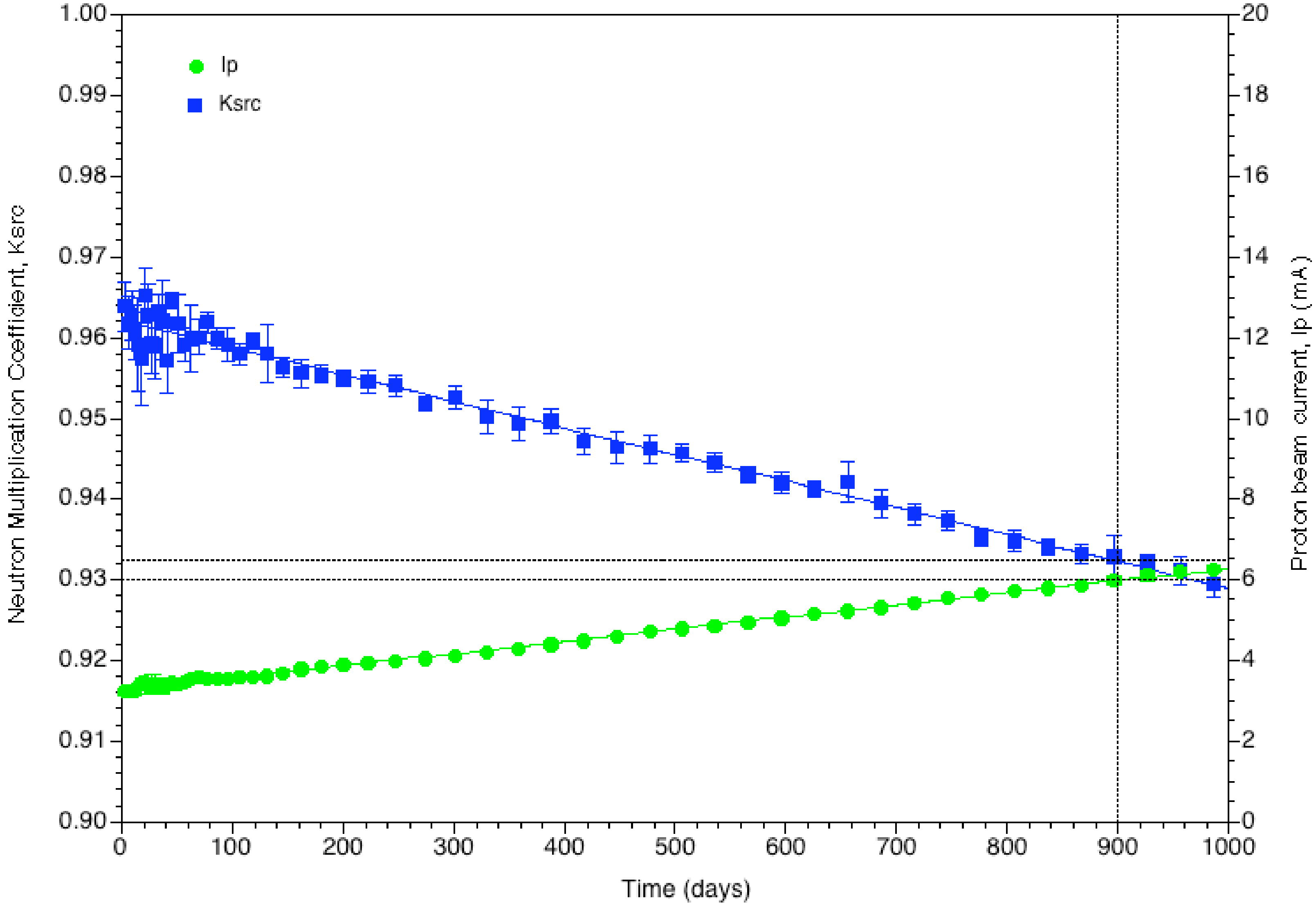
✓ We report the variation of the neutron multiplication coefficient after a fuel burnup of 20 GWd/t, that is 900 days of operation at 80 MW_{th}.

✓ During this period of operation the reactivity of the EADF drops by 2.94% in Δk, which is compensated by a factor two increase in the accelerator current to 6.0 mA in order to maintain a constant power output.

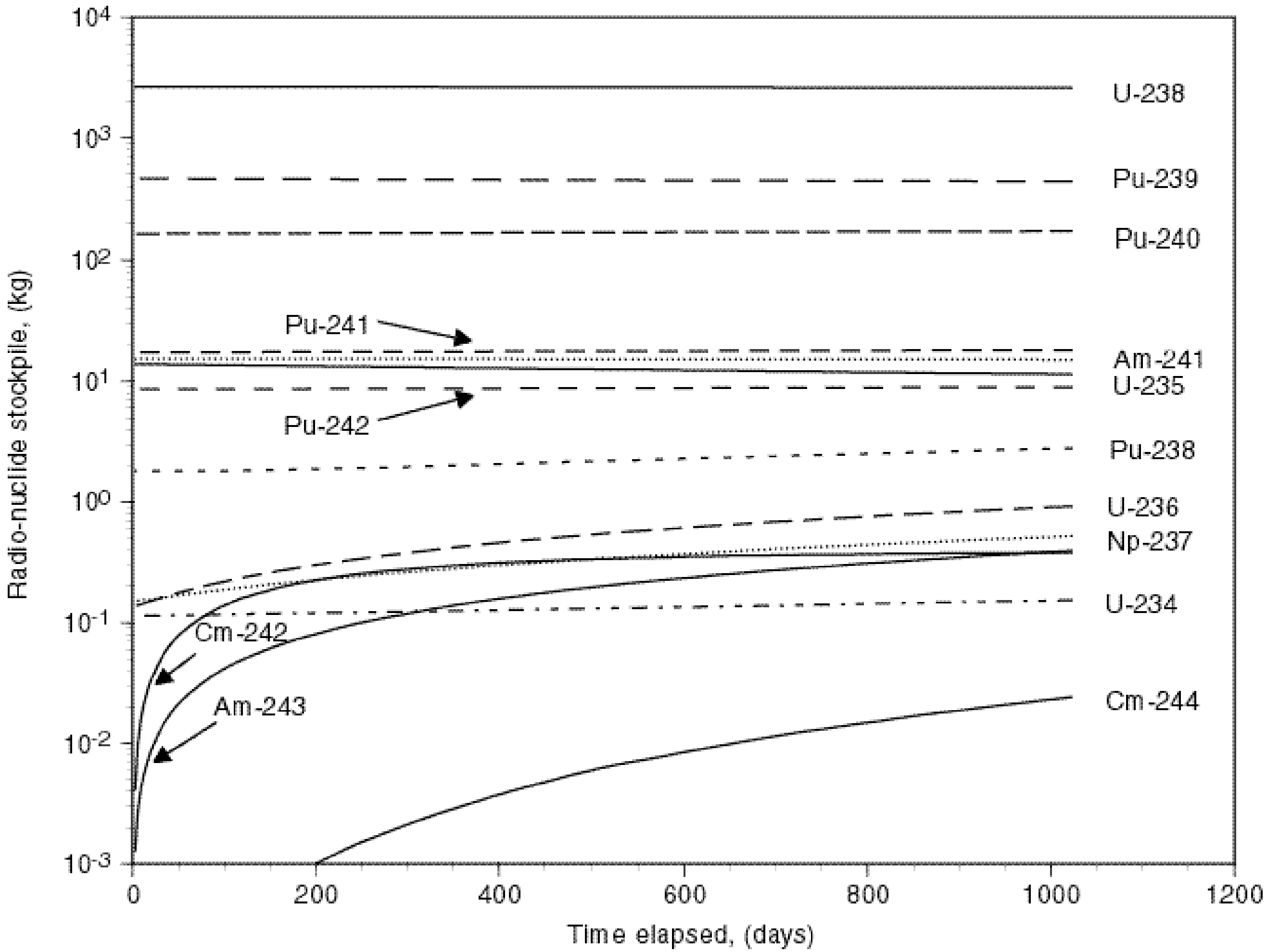
Main parameters of the EADF reference configuration after one burn-up cycle

Global Parameters	BOC	EOC	Units
Fuel mixture	$(U\text{-}Pu)O_2$	$(U\text{-}Pu)O_2$	
Fuel mass	3.793	3.723	ton
Pu concentration	17.7	16.3	wt.%
Fissile enrichment	14.7	14.3	wt.%
Fuel burnup	-	20	GWd/t
Cycle length	-	900	EFPD
Thermal Power Output	80	80	MWatt
Proton Beam Energy	600	600	MeV
Spallation Neutron Yield	14.51 ± 0.10	14.51 ± 0.10	n/p
Net neutron multiplication	27.80 ± 0.56	14.77 ± 0.65	
Multiplication Coefficient	0.9640 ± 0.0007	0.9323 ± 0.0011	
Energetic Gain	42.73 ± 0.88	21.27 ± 1.01	
Gain coefficient	1.54	1.44	
Accelerator Current	3.20 ± 0.07	6.00 ± 0.11	mA

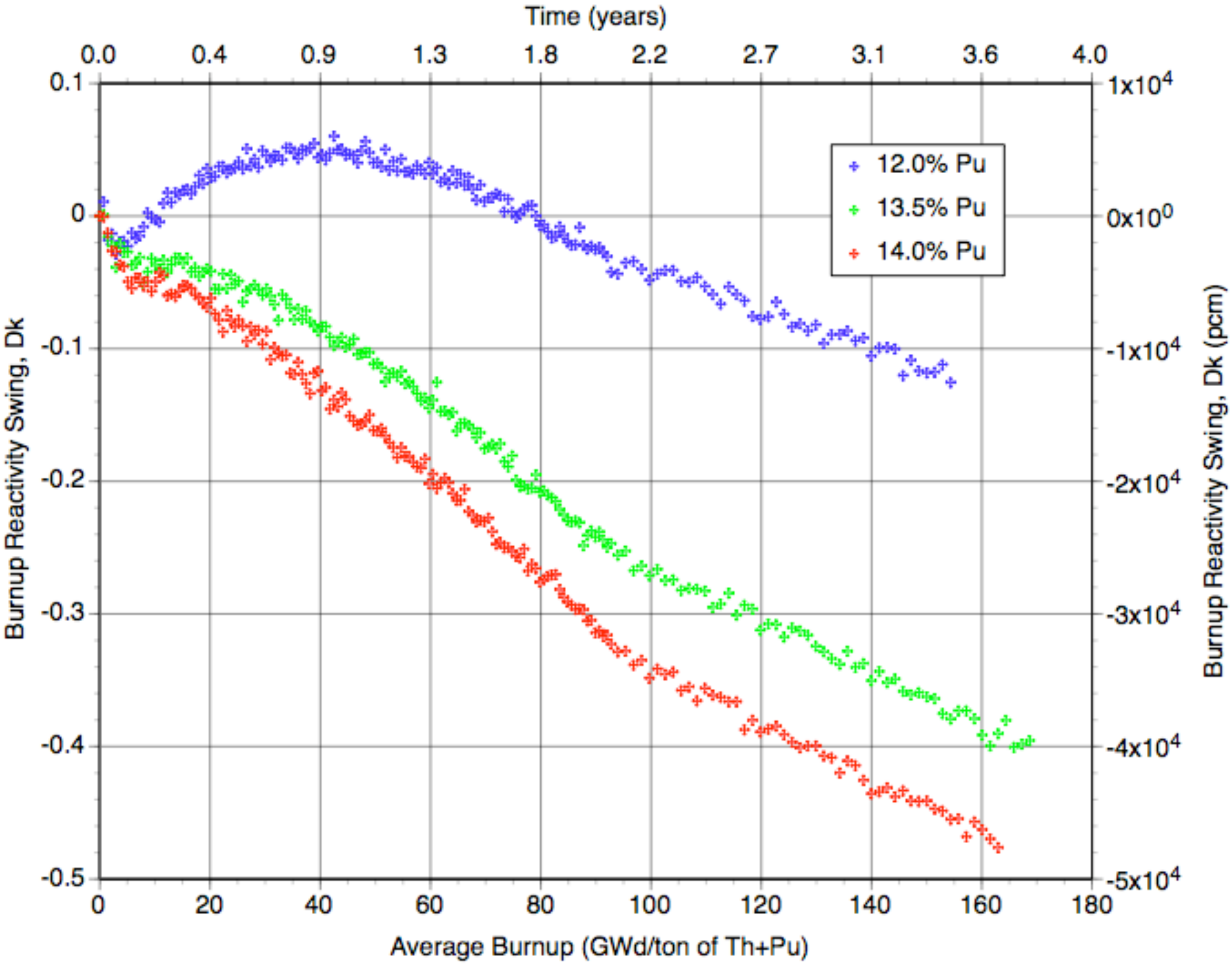
The EADF : *Evolution of the reactivity for UPu fuel*



Variation of the UPu MOX fuel composition is plotted as a function of time



The EADF : *Evolution of the reactivity for ThPu fuel*



Fission Fragments activity and toxicity after 1000 years of cool-down in a Secular Repository

(Values are given for 1 GWe ´ year)

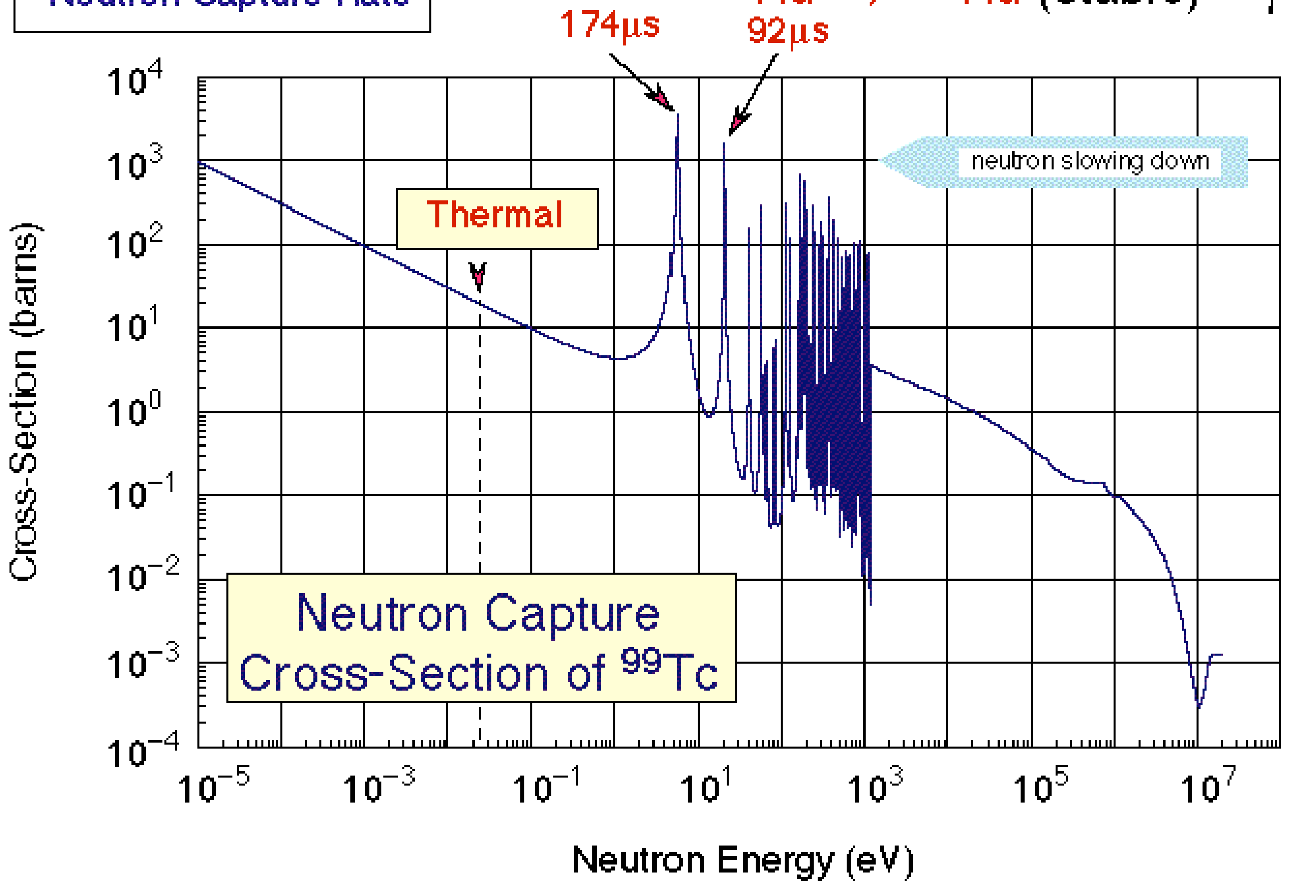
Radio-Isotope	Half-Life (years)	Mass (kg)	Activity @ 1000 yr (Ci)	Ingestive Toxicity (Sv) × 10^3	Dilution Class A (m^3)
^{129}I	1.57 x 10^7	8.09	1.43	19.58	178.47
^{99}Tc	2.11 x 10^5	16.61	284.29	27.67	947.65
^{126}Sn	1.0 x 10^5	1.187	33.79	3.20	9.65
^{135}Cs	2.3 x 10^6	34.12	39.32	9.87	39.32
^{93}Zr	1.53 x 10^6	26.11	65.64	2.38	18.75
^{79}Se	6.5 x 10^5	0.30	2.06	0.745	0.59

Principle of LLFP destruction

^{99}Tc ($t_{1/2}$ = 2.1×10^5 ans) + n → ^{100}Tc ($t_{1/2}$ = 15.8 s) + γ prompts (1)

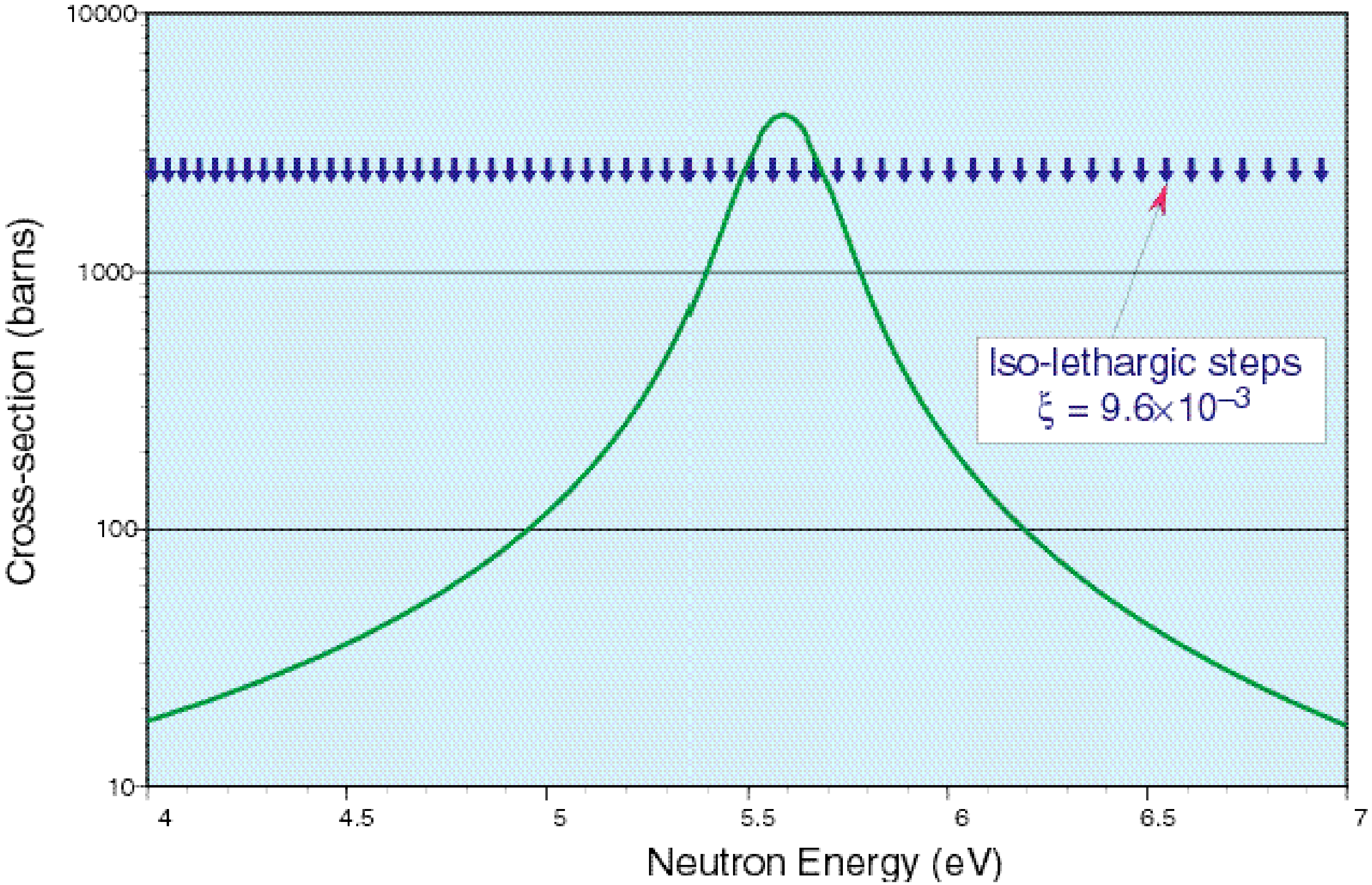
$^{100}Ru^*$ → ^{100}Ru (stable) + γ's (2)

ARC maximizes
Neutron Capture Rate



Adiabatic Resonance Crossing

Adiabatic Crossing of the 5.6 eV Resonance of ^{99}Tc



Neutronic Properties of Lead

- Unique properties of Lead from the point of view of neutronics:
  - Small capture probability ($\lambda_{mig.} \sim 1.2$ m);
  - High elastic collision probability ($\lambda_{el} \sim 3$ cm), independent of E_n
  - Small "Lethargy" kinematics of elastic collisions [below threshold for inelastic processes, (n, 2n), (n,3n), etc.]:

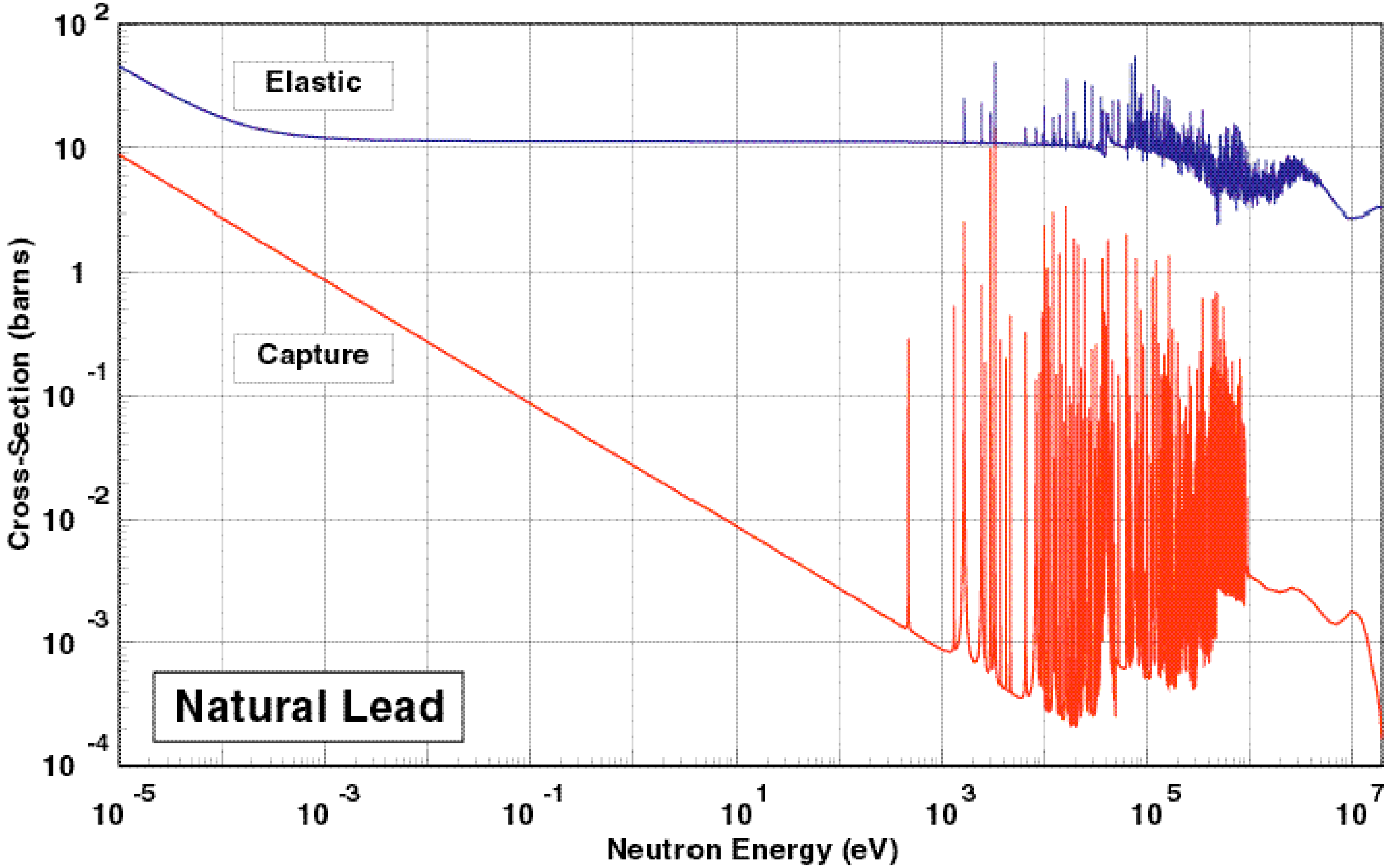
$$\frac{E_2}{E_1} = \frac{m_n^2 + m_{Pb}^2}{(m_n + m_{Pb})^2} + \frac{2 m_n m_{Pb} \mathrm{Cos}\theta}{(m_n + m_{Pb})^2} \approx 1 - \varepsilon$$

⇒ E_2 bounded: $\alpha E_1 \le E_2 \le E_1$; where:

$$\alpha \equiv \frac{(m_{Pb} - m_n)^2}{(m_{Pb} + m_n)^2} \approx 0.98; \quad (m_{Pb} \approx 207.2)$$

⇒ $\frac{E_2}{E_1}$ independent of energy and close to 1

Neutronic Properties of Lead (2)

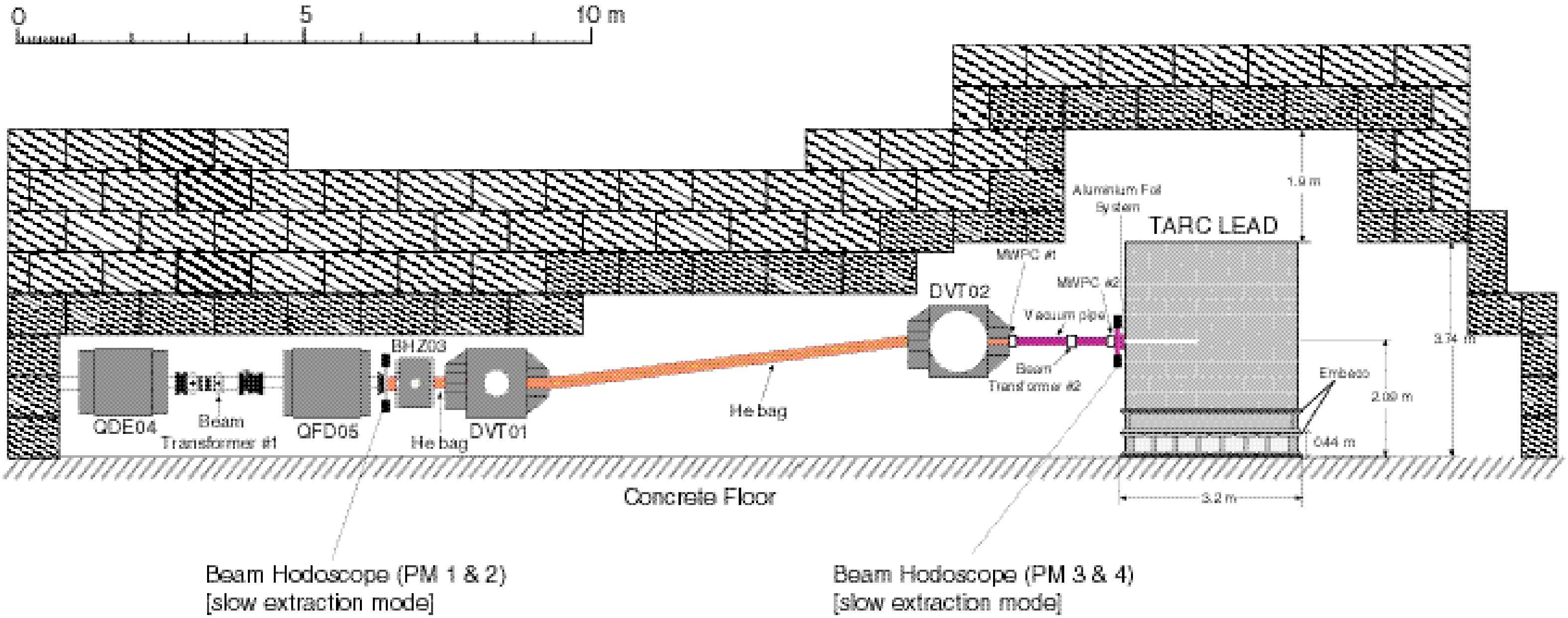


- Understanding the phenomenology of spallation neutrons in lead (neutron flux measurements by electronic detectors and by activation measurements, etc.)

- Direct test of Transmutation of Long-Lived Fission Fragments (^{99}Tc, ^{129}I) by Adiabatic Resonance Crossing

- Development & validation of appropriate simulation/computing tools

THE TARC EXPERIMENT

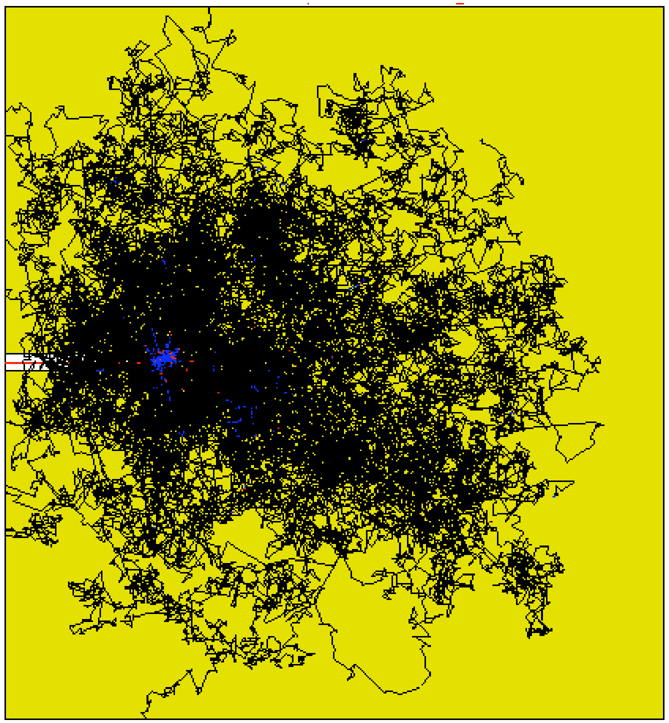


Side view of the TARC experimental area showing the details of the beam line. In the slow extraction mode the two station beam hodoscope is introduced in the beam line where indicated.

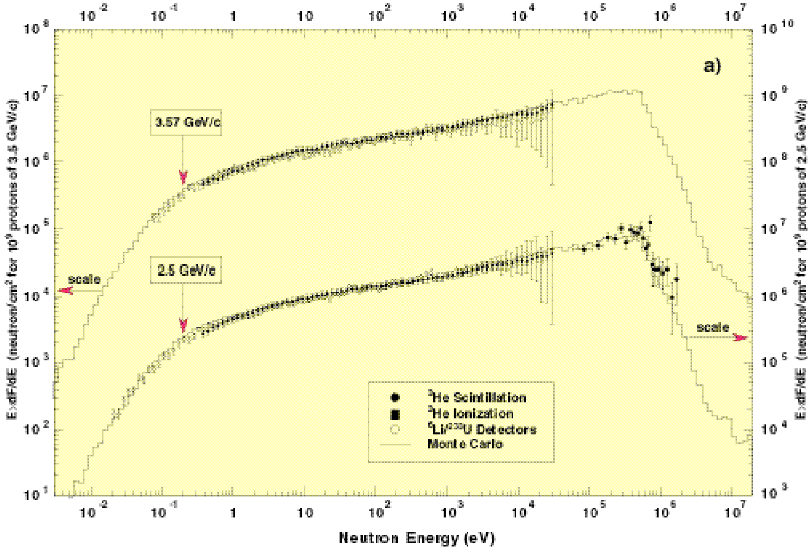
Experimental Setup (2)

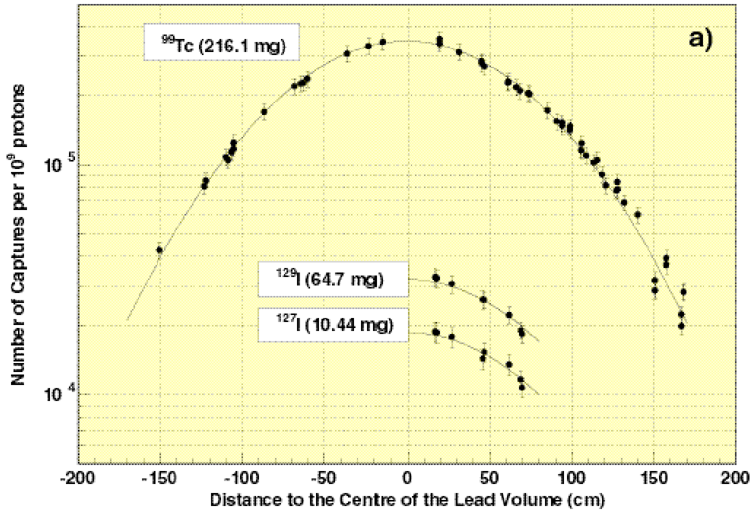
Simulation of neutrons produced by a single 3.5 GeV/c proton

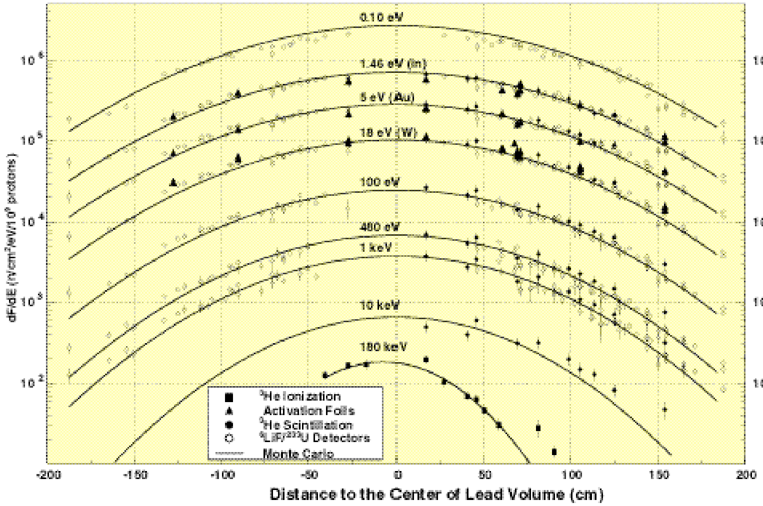
(147 neutrons produced, 55035 scattering)

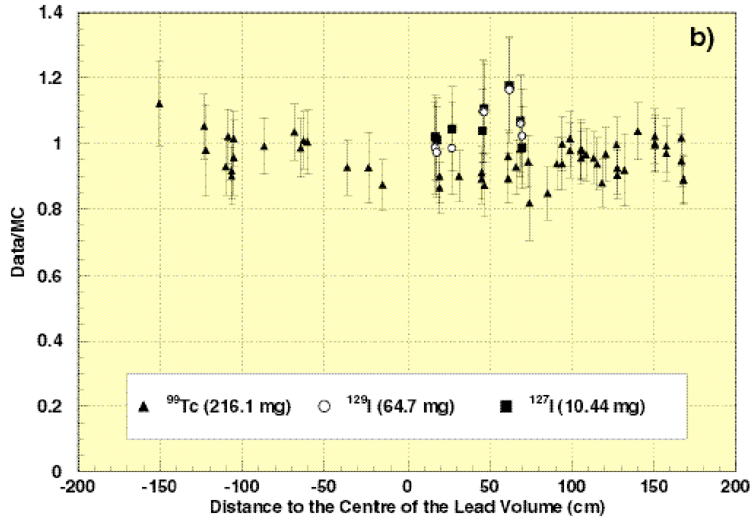


TARC Results

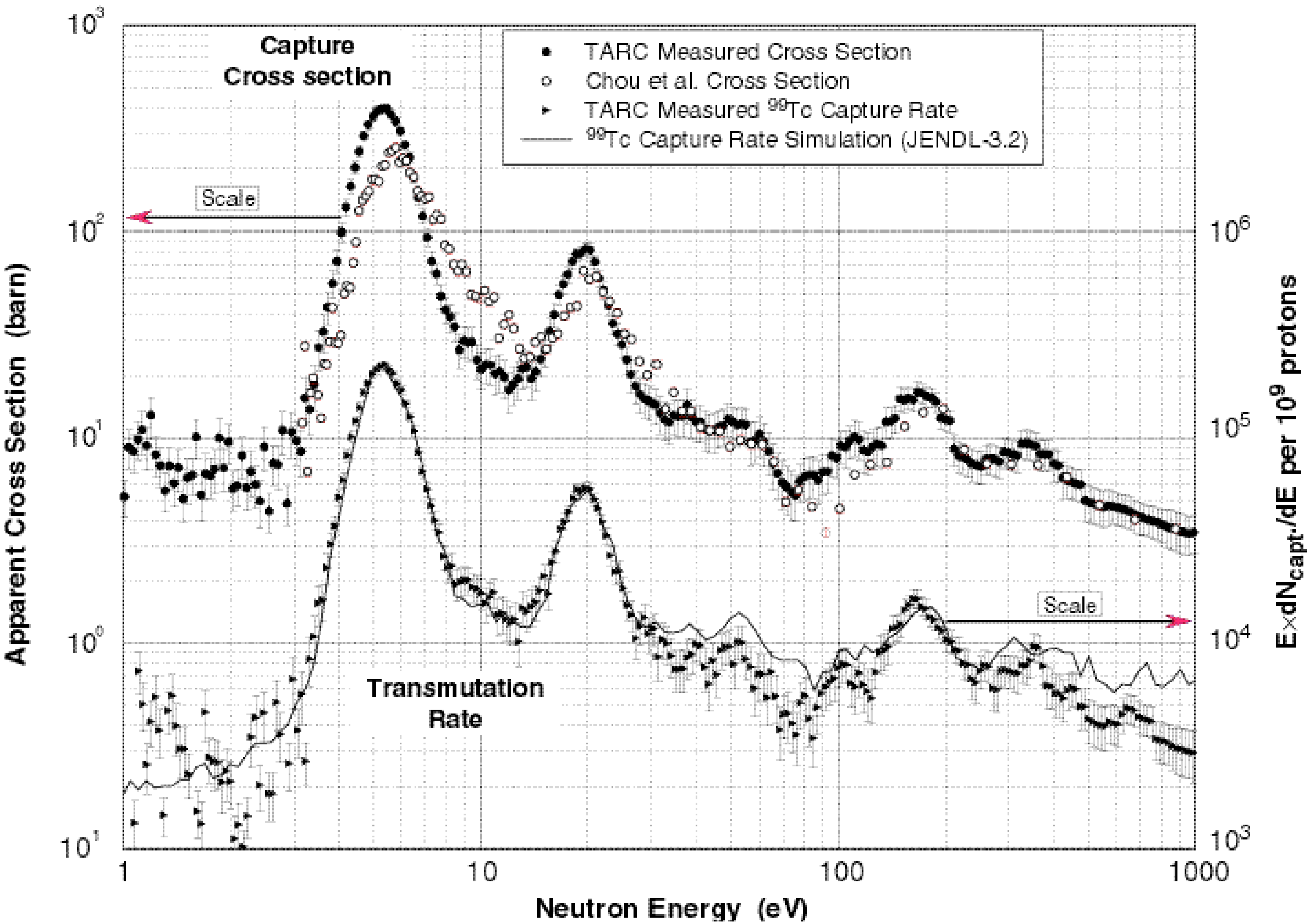




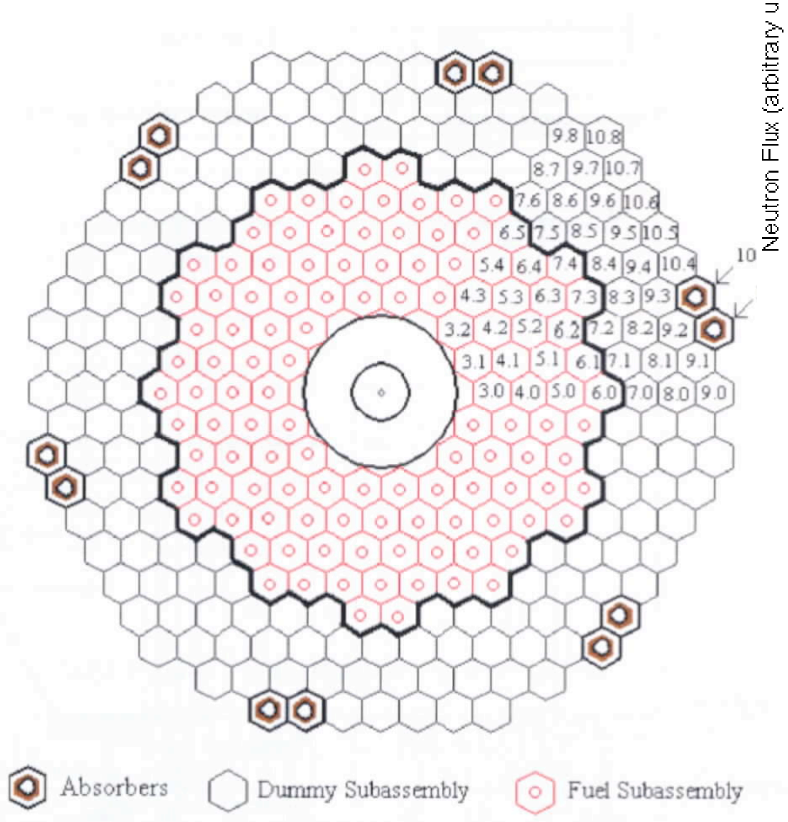


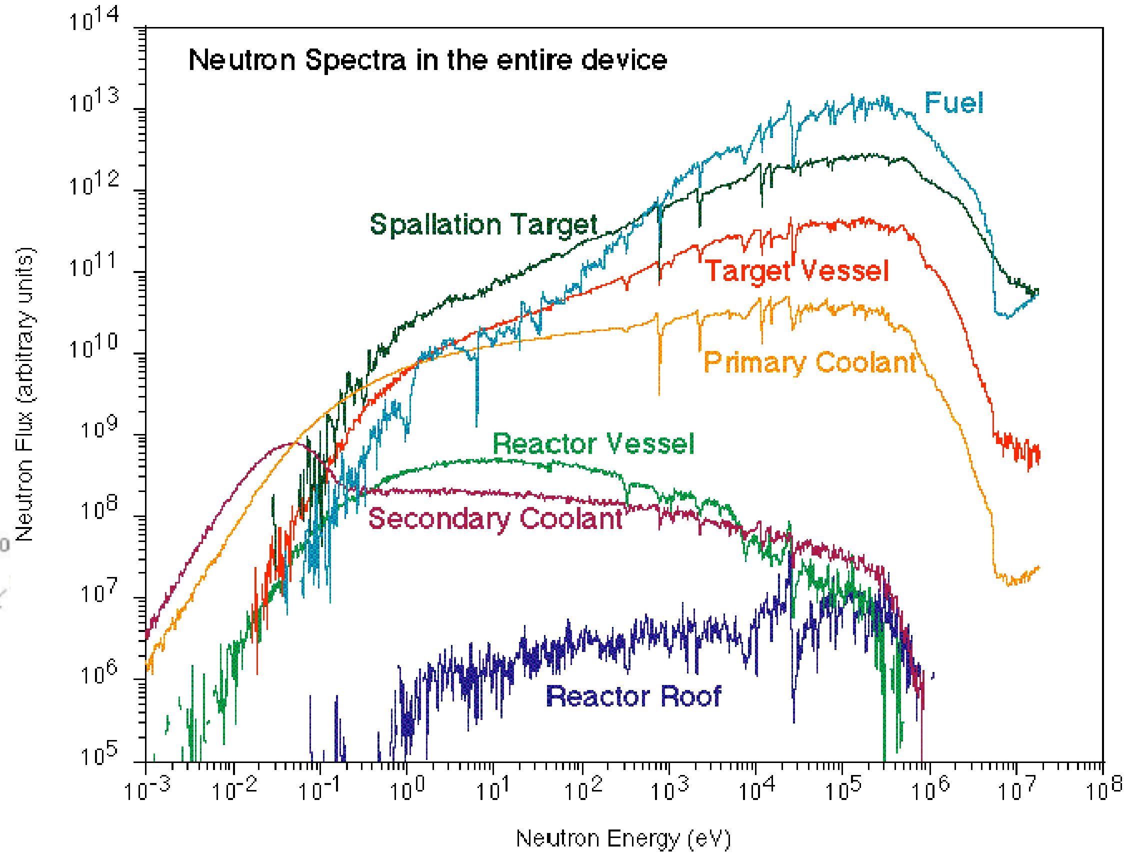


TARC Results (2)



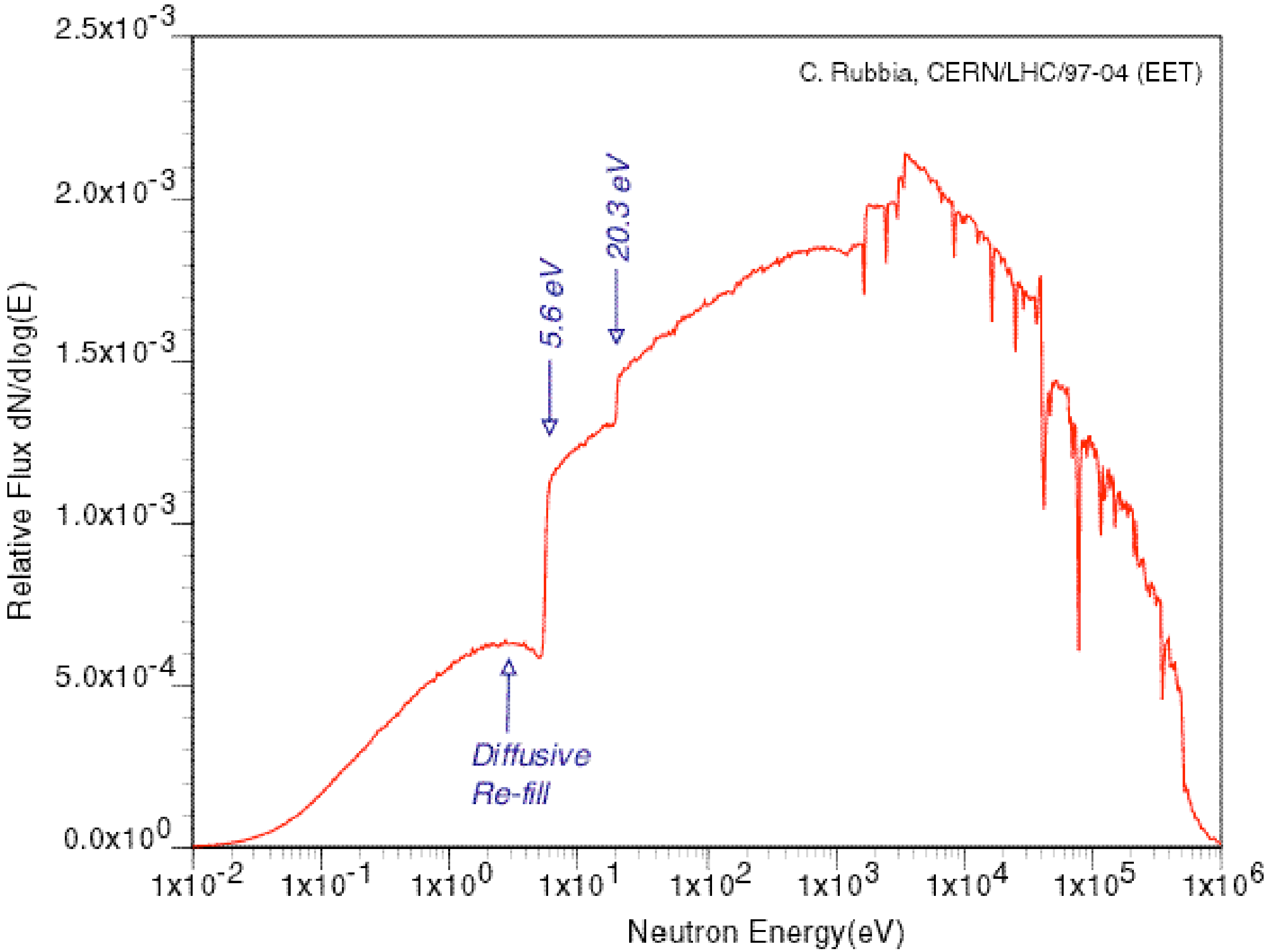
LLFP Incineration

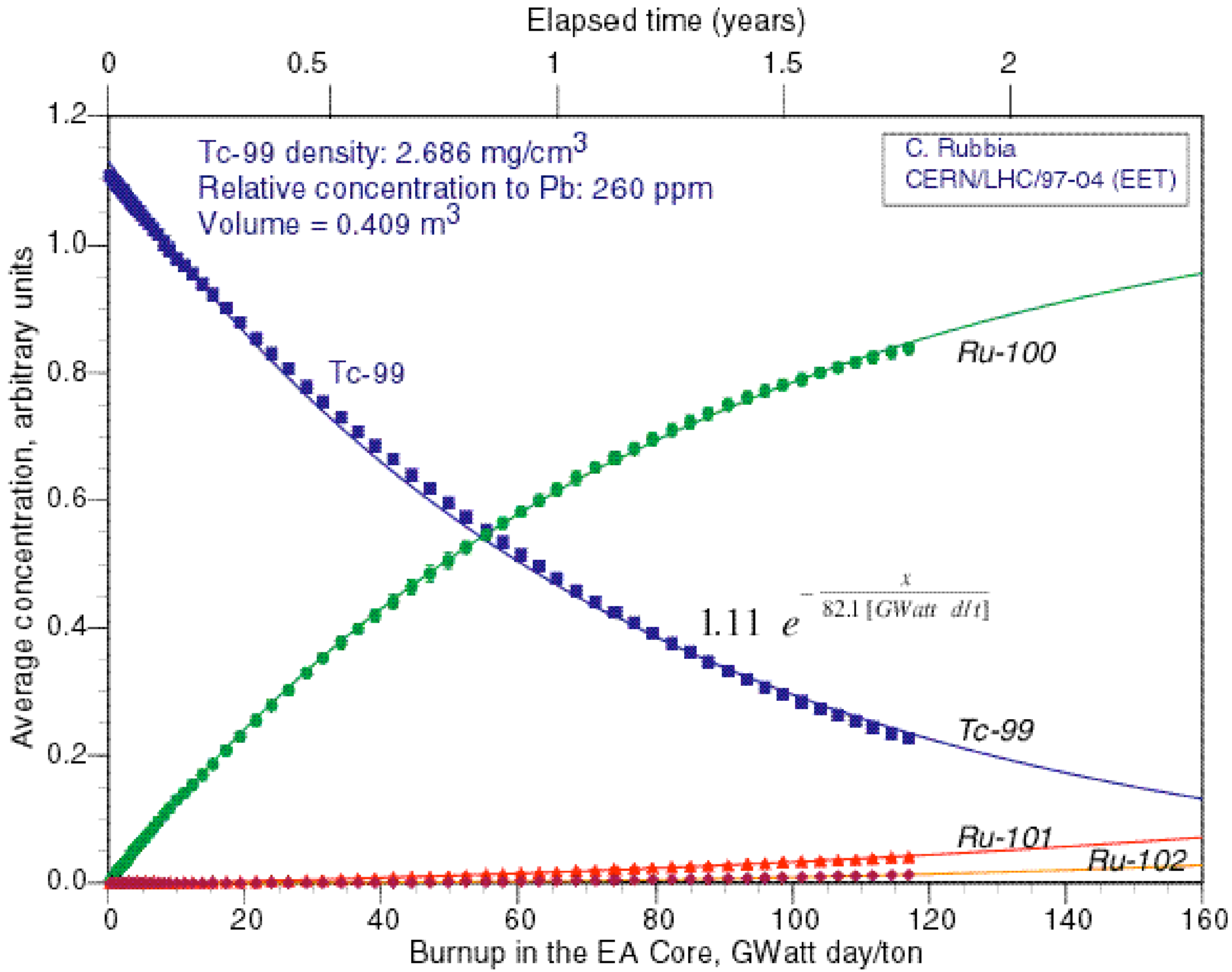




LLFP Incineration (2)

Monte Carlo simulation of the neutron fluence in the lead outside the Energy Amplifier core after introduction of 2.7 mg/cm^3 of ^{99}Tc.




Elapsed time (years)
0
0.5
1
1.5
2
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Average concentration, arbitrary units
Tc-99 density: 2.686 mg/cm3
Relative concentration to Pb: 260 ppm
Volume = 0.409 m3
C. Rubbia
CERN/LHC/97-04 (EET)
Tc-99
Ru-100
Tc-99
Ru-101
Ru-102
1.11 e^(−x / 82.1 [GWatt d/t])
0
20
40
60
80
100
120
140
160
Burnup in the EA Core, GWatt day/ton

The EADF : *Transmutation Rates*

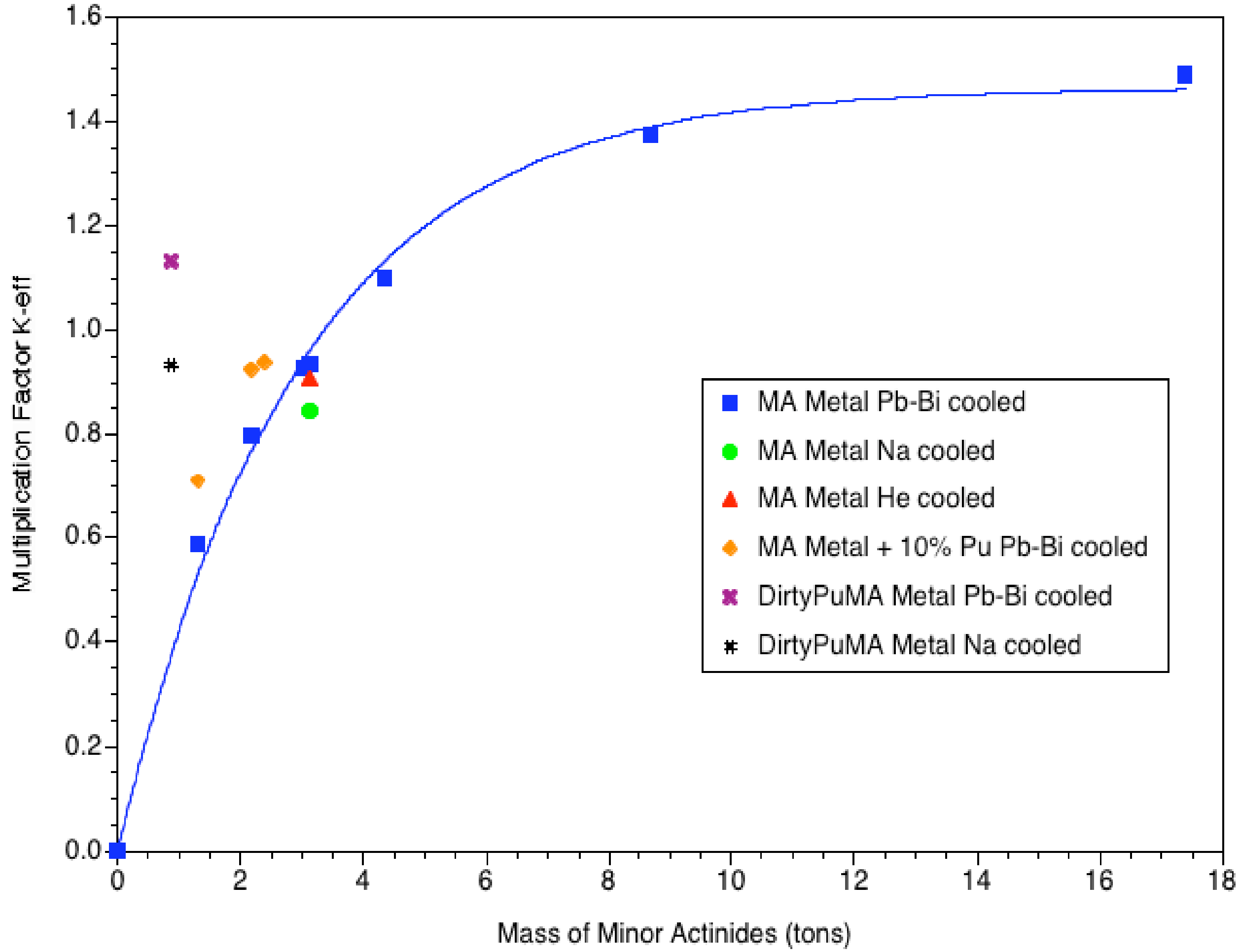
Plutonium incineration in ThPu based fuel is more efficient and settles to approximately 43 kg/TWh, namely 4 times what is produced by a standard PWR. The minor actinide production is very limited in this case.

Transmutation rates (kg/TW$_{th}$h) of plutonium and minor actinides and LLFPs

Nuclides	EADF (ThPuO2) ENDF/B-VI	EADF (UPuO2) ENDF/B-VI	EADF (UPuO2) JENDL-3.2	PWR (UO2)
^{233}U	+ 31.0			
Pu	– 42.8	– 7.39	– 5.55	+ 11.0
Np	+ 0.03	+ 0.25	+ 0.24	+ 0.57
Am	+ 0.24	+ 0.17	+ 0.14	+ 0.54
Cm	+ 0.007	+ 0.017	+ 0.020	+ 0.044
^{99}Tc prod	+ 0.99	+ 1.07	+1.22	+ 0.99
^{99}Tc trans	– 3.77	– 3.77		
^{129}I prod	+ 0.30	+ 0.31		+ 0.17
^{129}I trans	– 3.01	– 3.01		

Long-Lived Fission products incineration is made possible in a very efficient way through the use of the Adiabatic Resonance Crossing Method. Such a machine could in principle incinerate up to 4 times what is produced by a standard PWR.

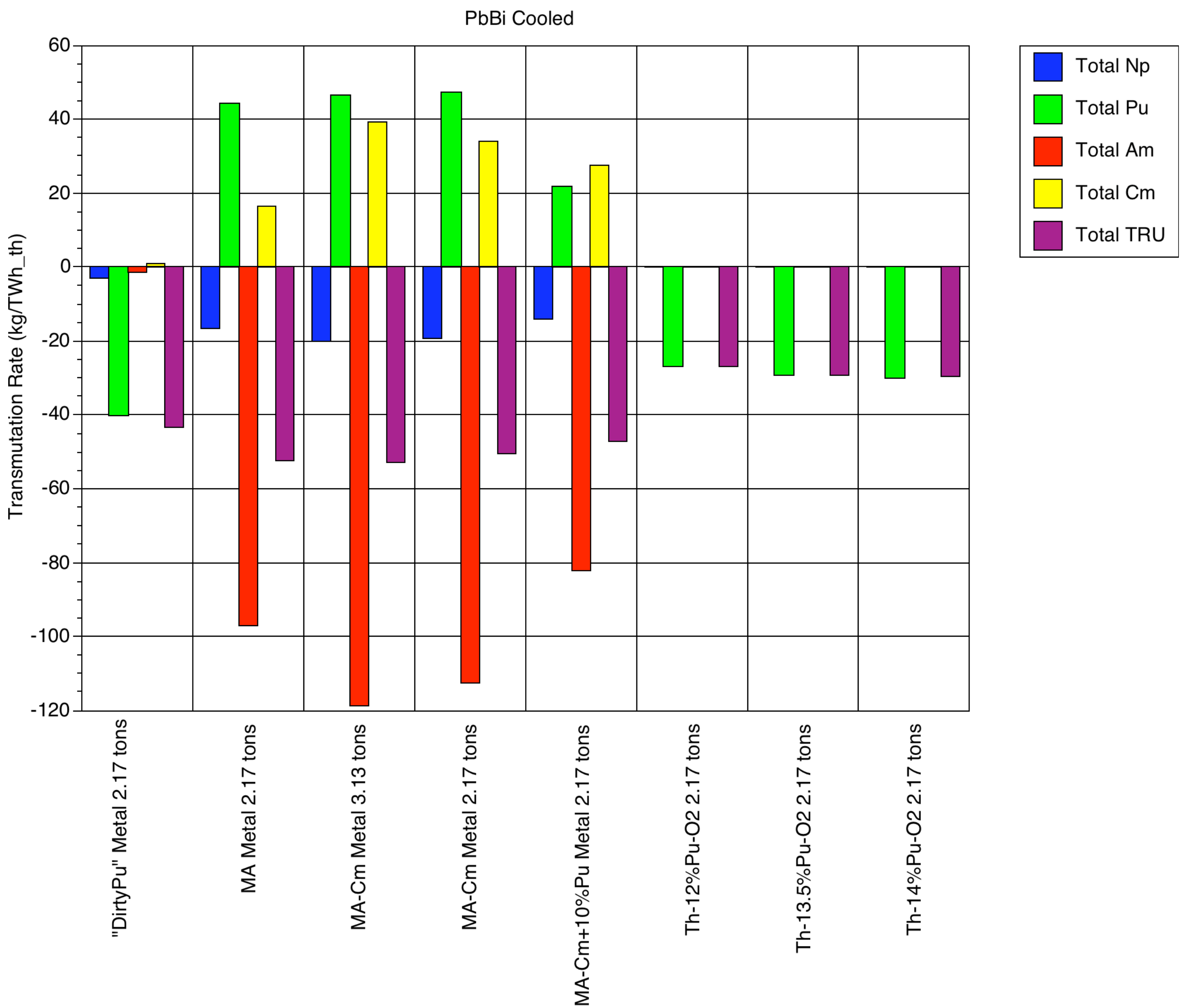
Minor Actinide transmutation is on the other hand very sensitive to the fuel type



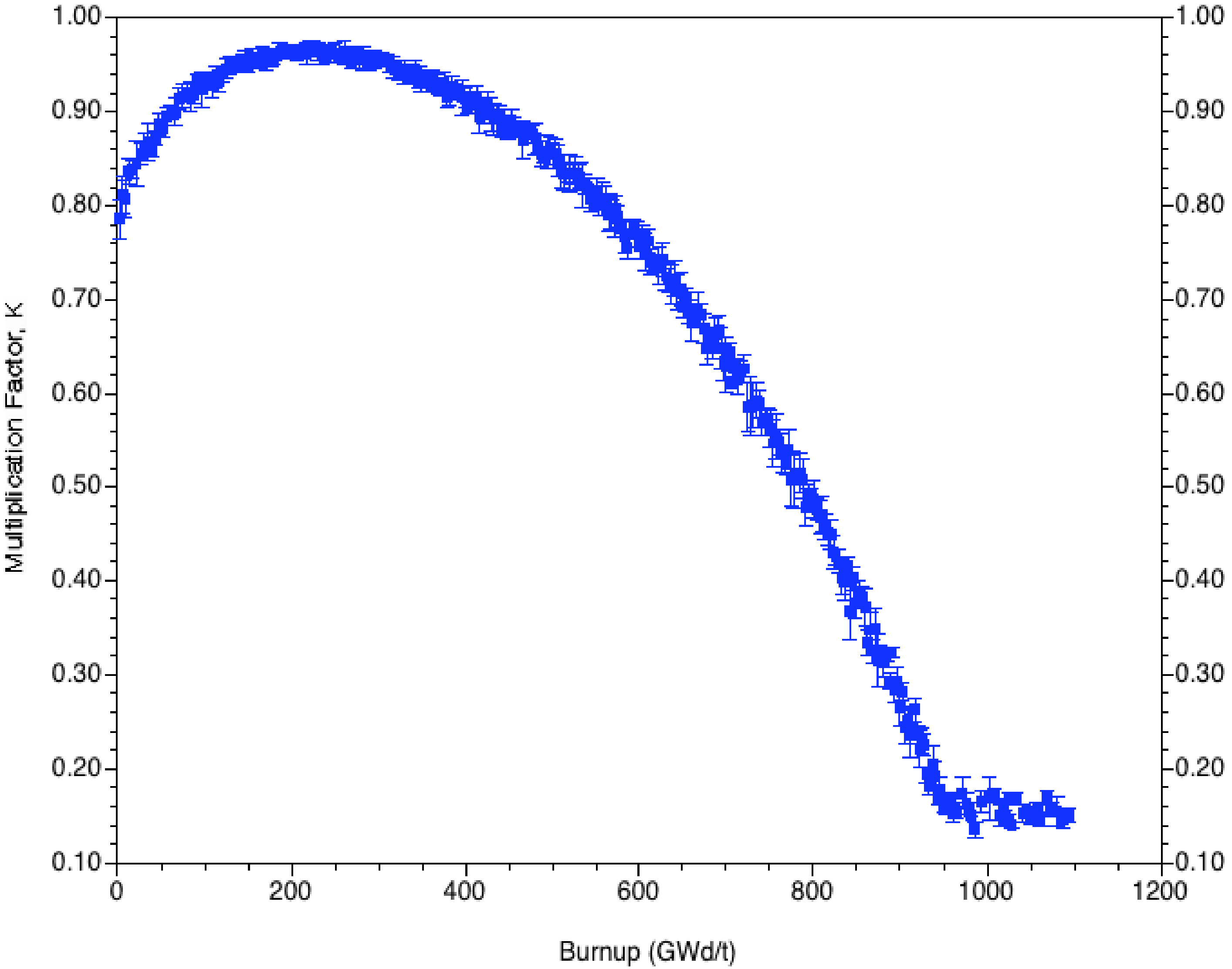
MA Transmutation Rates

Typical transmutation rates (~ 50 kg/TWh) using MA based fuels.

Doping with Pu will sensibly decrease the transmutation efficiency of such systems



The EADF : *Evolution of the reactivity for pure MA fuel*



Reactivity Coefficients

Configuration	Fuel	dk/(drho/rho)		dk/dT		Kinf
Na	MA-Metal	-15.2 e-2	NA	-1.02 e-5	OK	1.26
Na	MA-Oxide	-24.4 e-2	NA	+0.2 e-5	NA	1.08
Na	Pu+MA-Metal	+33.0 e-2	OK	+0.4 e-5	NA	2.68
Na	Pu+MA-Oxide	+4.5 e-2	OK	-1.0 e-5	OK	2.53
Pb-Bi	MA-Metal	-8.14 e-2	NA	+1.19 e-5	NA	1.30
Pb-Bi	MA-Oxide	-8.12 e-2	NA	-1.0 e-5	OK	1.08
Pb-Bi	Pu+MA Metal	+39.1 e-2	OK	+2.32 e-5	NA	2.37
Pb-Bi	Pu+MA Oxide	+2.27 e-2	OK	-0.7 e-5	OK	2.26

Conclusions

- Present accelerator technology can provide a suitable proton accelerator to drive new types of nuclear systems to destroy nuclear waste or to produce energy.
- The Energy Amplifier, based on physics principles well verified by dedicated experiments at CERN, is the result of an optimization made possible by the use of an innovative simulation code validated in these experiments (FEAT and TARC).
- An Energy Amplifier could destroy TRU through fission at about x4 the rate at which they are produced in LWRs. LLFF such as ^{129}I and ^{99}Tc could be transmuted into stable elements in a parasitic mode, around the EA core, making use of the ARC method.
- Next step: SAD ? MYRRHA ? Energy Amplifier DEMO ?

ADS Programs Worldwide

Project	Neutron Source	Core	Purpose
MUSE (France)	DT ($\sim 10^{10}$n/s)	Fast (< 1 kW)	Reactor physics of fast subcritical system
TRADE (Italy)	Proton (140 MeV) + Ta (40 kW)	Thermal (200 kW)	Demonstration of ADS with thermal feedback
TEF-P (Japan)	**Proton (600 MeV) + Pb-Bi (10W, $\sim 10^{12}$n/s)**	**Fast (< 1 kW)**	**Coupling of fast subcritical system with spallation source including MA fueled configuration**
SAD (Russia)	Proton (660 MeV) + Pb-Bi (1 kW)	Fast (20 kW)	Coupling of fast subcritical system with spallation source
MYRRHA (Belgium)	Proton (350 MeV) + Pb-Bi (1.75 MW)	Fast (35 MW)	Experimental ADS
MEGAPIE (Switzerland)	Proton (600 MeV) + Pb-Bi (1MW)	-----	Demonstration of 1MW target for short period
TEF-T (Japan)	**Proton (600 MeV) + Pb-Bi (200 kW)**	-----	**Dedicated facility for demonstration and accumulation of material data base for long term**
Reference ADS	Proton (≈ 1 GeV) + Pb-Bi (≈ 10 MW)	Fast (1500 MW)	Transmutation of MA and LLFP

LECTURES OUTLINE

- ✓ LECTURE 1: Physics of Spallation and Sub-critical Cores, Fundamentals
  (Monday 17/10/05, 16:00 – 17:30)
- ✓ LECTURE 2: Nuclear Data & Methods for ADS Design I
  (Tuesday 18/10/03, 08:30 – 10:00)
- ✓ LECTURE 3: Nuclear Data & Methods for ADS Design II
  (Tuesday 18/10/03, 10:30 – 12:00)
- ✓ LECTURE 4: ADS Design Exercises I & II
  (Tuesday 18/10/03, 14:00 – 17:30)
- ✓ LECTURE 5: Examples of ADS Design I
  (Thursday 20/10/03, 08:30 – 10:00)
- ✓ LECTURE 6: Examples of ADS Design II
  (Thursday 20/10/03, 10:30 – 12:00)
- ✓ **LECTURE 7: ADS Design Exercises III & IV**
  (Thursday 20/10/03, 14:00 – 17:30)

Exercises III & IV: Simulation Energy Amplifier Demonstration Facility, an 80 MW PbBi cooled fast neutron device setups using the FLUKA-EAMC code package, varying the sub-criticality in the nuclear data libraries.

Results:

- Neutron source importance (ksrc vs DD/DT vs Fiss vs Spall);
- Ksrc vs nuclear data
- Neutron interactions tables;
- Neutron flux and energy distributions.
- Transmutation rates (for minor actinides and long-lived fission products);