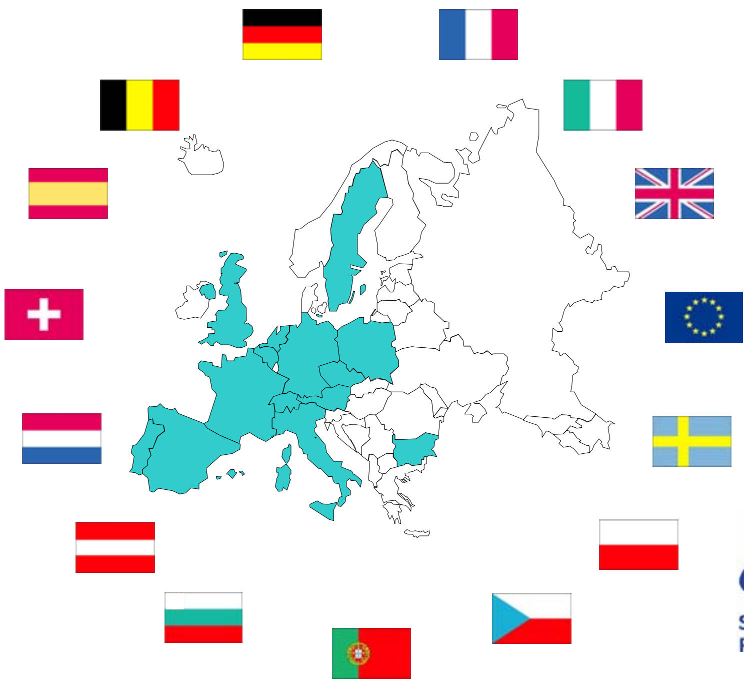
Nuclear Data for Transmutation NUDATRA (DM5 of IP-EUROTRANS)

EU Project: FI6W-CT-2004-516520



Enrique M. González
CIEMAT

SIXTH FRAMEWORK PROGRAMME

9th International Exchange Meeting on Actinide and Fission Product Partitioning and Transmutation NEA/OCDE

Nimes (France), September

Simulation is still and will continue to be for few years, the basis of the evaluation and extrapolation of performance, viability, cost and safety of the proposed transmutation devices.

Improvements on the simulation tools, programs and evaluated nuclear data libraries, are key elements to base our benefit/cost evaluations and to prepare a solid base for the definition of DEMO reactors that can provide the required validation before industrial deployment of transmuters.

NUDATRA is the Domain addressing this issue within EUROTRANS

Includes: Improvement of simulation programs and underlying models, Data measurement and evaluation, uncertainty propagation and sensitivity analysis

Device: Lead cooled ADS

Scope: Transmutation device and fuel cycle

Selection of activities initially based on relevance according to basic principles has been later confirmed by independent sensitivity analysis.
The viability in the FP6 time frame and the complementarities with others programs (in particular FP5) was important for the selection of measurements.

Nuclear data for Transmutation from the fuel cycle point of view

The isotopic composition of the equilibrium fuel, and correspondingly of the losses finally going to the storage, is defined by:

- The isotopic composition of the LWR wastes feed into the transmutation reactor
- the isotopes decay constants,
- the neutron flux intensity (reactor power) and,
- the effective cross sections of the activation reactions

Activation reaction Cross section	$\otimes$	Neutron flux Spectrum
(n,γ), (n,γ)* of actinides with		**elastic, inelastic,(n,2n),…**
(n,2n) +… half-live > 100d		**fuel matrix, Struct. Materials, coolant**

Transmutation takes place in a reactor: Critical or Subcritical (ADS)

Critical Reactors or ADS devoted to transmutation present new features:

In all cases

New fuels: ***High content on minor actinide*** and high mass Pu isotopes.

Very high Burn-up per irradiation cycle.

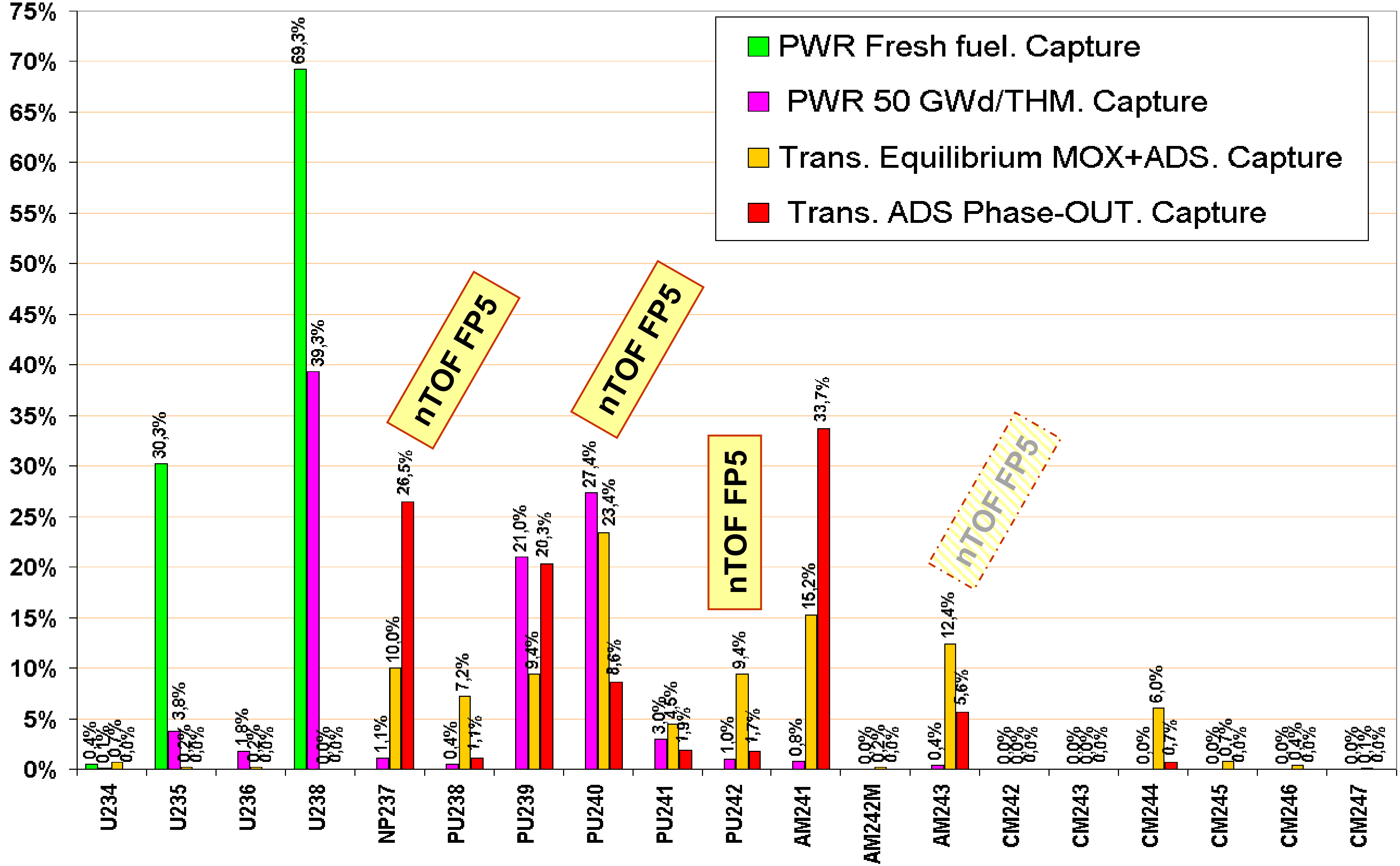
Most Frequently

Fast neutron flux spectrum.

Subcritical configurations + ***Spallation sources***

New Technologies: Coolant: Molten ***Lead or Pb/Bi***,
Fuel matrix: Inert matrix,..

Contributions to capture of present and transmutation fuels



Sensitivity analysis

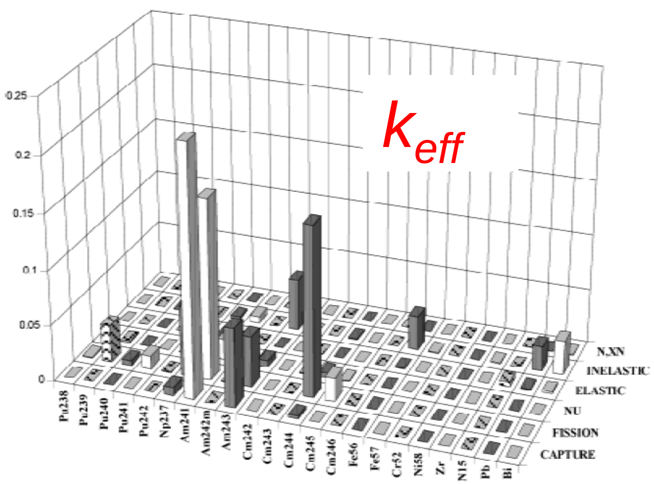
(from Impact of Nuclear Data Uncertainties on Transmutation of Actinides in Accelerator-Driven Assemblies, G. Aliberti et al., NSE **146**, 13–50 (2004))

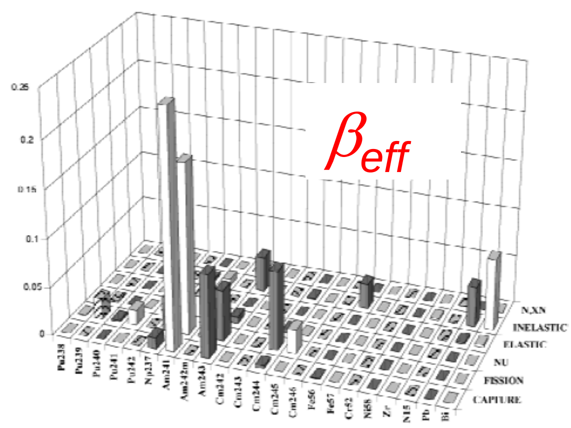
Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	$\sigma_{n,2n}$	Total[a]
^{238}Pu	0.01	0.11	0.02	—	—	—	0.11
^{239}Pu	0.04	0.51	0.11	—	0.04	—	0.53
^{240}Pu	0.05	0.18	0.05	—	0.02	—	0.19
^{241}Pu	0.04	0.30	0.03	—	0.01	—	0.31
^{242}Pu	0.01	0.05	0.02	—	0.01	—	0.06
^{237}Np	0.24	0.70	0.21	—	0.14	—	0.78
^{241}Am	1.32	1.12	0.38	—	0.22	—	1.79
^{242m}Am	0.01	0.09	0.03	—	0.01	—	0.10
^{243}Am	0.74	0.59	0.21	—	0.60	—	1.14
^{242}Cm	—	—	—	—	—	—	—
^{243}Cm	—	0.05	0.01	—	—	—	0.05
^{244}Cm	0.13	1.09	0.18	—	0.07	—	1.11
^{245}Cm	0.01	0.41	0.08	—	0.01	—	0.42
^{246}Cm	—	—	—	—	—	—	—
^{56}Fe	0.03	—	—	0.05	0.49	—	0.50
^{57}Fe	—	—	—	—	0.06	—	0.06
^{52}Cr	0.01	—	—	0.01	0.03	—	0.03
^{58}Ni	—	—	—	—	—	—	—
Zr	0.03	—	—	0.03	0.07	—	0.09
^{15}N	—	—	—	0.19	0.01	—	0.19
Pb	0.02	—	—	0.10	0.41	0.02	0.43
Bi	0.04	—	—	0.11	0.49	0.03	0.50
Total[a]	1.54	1.97	0.54	0.25	1.05	0.04	2.77

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	$\sigma_{n,2n}$	Total[a]
^{238}Pu	—	0.3	0.1	—	—	—	0.3
^{239}Pu	0.2	1.5	0.4	—	0.1	—	1.5
^{240}Pu	0.2	0.5	0.1	—	0.1	—	0.5
^{241}Pu	0.1	1.3	0.1	—	—	—	1.3
^{242}Pu	0.1	0.1	—	—	—	—	0.2
^{237}Np	1.1	1.9	0.6	—	0.6	—	2.3
^{241}Am	5.0	4.2	1.5	—	0.8	—	6.7
^{242m}Am	—	0.3	0.1	—	—	—	0.4
^{243}Am	2.9	2.3	0.8	—	1.9	—	4.3
^{242}Cm	—	—	—	—	—	—	—
^{243}Cm	—	0.2	—	—	—	—	0.2
^{244}Cm	0.6	2.9	0.5	—	0.3	—	3.0
^{245}Cm	—	1.6	0.3	—	—	—	1.6
^{246}Cm	—	—	—	—	—	—	—
^{56}Fe	0.1	—	—	0.1	1.6	—	1.6
^{57}Fe	—	—	—	—	0.1	—	0.1
^{52}Cr	—	—	—	—	0.1	—	0.1
^{58}Ni	—	—	—	—	—	—	—
Zr	0.1	—	—	0.1	0.4	—	0.5
^{15}N	—	—	—	0.4	—	—	0.4
Pb	0.1	—	—	0.4	2.0	0.1	2.1
Bi	0.2	—	—	0.5	2.7	0.2	2.8
Total[a]	5.9	6.4	2.0	0.8	4.4	0.2	10.0

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	$\sigma_{n,2n}$	Total[a]
^{238}Pu	0.01	0.08	0.02	—	—	—	0.08
^{239}Pu	0.04	0.37	0.09	—	0.02	—	0.39
^{240}Pu	0.04	0.10	0.03	—	0.01	—	0.12
^{241}Pu	0.03	0.26	0.03	—	—	—	0.26
^{242}Pu	0.01	0.03	0.01	—	—	—	0.03
^{237}Np	0.23	0.37	0.11	—	0.08	—	0.46
^{241}Am	1.18	0.48	0.17	—	0.12	—	1.29
^{242m}Am	0.01	0.08	0.02	—	—	—	0.08
^{243}Am	0.67	0.25	0.09	—	0.41	—	0.83
^{242}Cm	—	—	—	—	—	—	—
^{243}Cm	—	0.04	0.01	—	—	—	0.04
^{244}Cm	0.12	0.58	0.10	—	0.02	—	0.61
^{245}Cm	0.01	0.34	0.07	—	—	—	0.35
^{246}Cm	—	—	—	—	—	—	—
^{56}Fe	0.03	—	—	0.15	0.24	—	0.28
^{57}Fe	—	—	—	—	0.03	—	0.03
^{52}Cr	0.01	—	—	0.04	0.01	—	0.04
^{58}Ni	—	—	—	—	—	—	—
Zr	0.02	—	—	0.06	0.02	—	0.07
^{15}N	0.01	—	—	0.16	0.02	—	0.16
Pb	0.06	—	—	0.23	1.20	0.54	1.33
Bi	0.08	—	—	0.28	1.27	0.79	1.52
Total[a]	1.39	1.06	0.27	0.43	1.82	0.96	2.74

φ^*—Uncertainties by Isotope





Pb and Bi inelastic and (n,2n) also specially relevant for He, H production, reactivity loss during irradiation, and void coefficient.

Sensitivity analysis

(from Impact of Nuclear Data Uncertainties on Transmutation of Actinides in Accelerator-Driven Assemblies, G. Aliberti et al., NSE **146**, 13–50 (2004))

Isotope	Cross Section	Group[a]	Original Uncertainty (%)	Required Accuracy (%)	Isotope	Cross Section	Group[a]	Original Uncertainty (%)	Required Accuracy (%)
^{239}Pu	σ_{fiss}	4	6.5	3.4	^{244}Cm	σ_{fiss}	2	40	10.0
		5	4	3.1			3	40	8.5
^{241}Pu	σ_{fiss}	6	10	5.6			4	40	5.0
^{237}Np	σ_{fiss}	3	25	8.0	^{245}Cm	σ_{fiss}	5	30	9.7
		4	25	5.1			6	30	9.6
	ν	4	5	4.1	^{56}Fe	σ_{inel}	4	20	4.9
^{241}Am	σ_{cap}	4	40	7.5	^{15}N	σ_{el}	4	5	3.9
		5	40	5.5	Pb	σ_{inel}	1	40	20.4
		6	40	5.1			2	40	9.8
		7	20	5.9			3	40	10.6
		8	20	6.3			4	40	10.1
		9	20	6.9		$\sigma_{n,2n}$	1	100	21.5
	σ_{fiss}	2	20	5.6	Bi	σ_{inel}	1	40	18.8
		3	20	4.6			2	40	8.1
		4	20	3.9			3	40	9.3
	ν	3	5	3.8			4	40	14.0
		4	5	3.3		$\sigma_{n,2n}$	1	100	17.5
^{243}Am	σ_{cap}	4	40	10.4		σ_{dpa}	1	20	20.0
		5	40	5.5			2	20	12.0
		6	40	5.1			3	20	12.1
		7	20	5.9			4	20	8.8
		8	20	6.3			5	20	20.0
	σ_{fiss}	2	20	7.6			6	20	20.0
		3	20	6.2			7	20	10.9
		4	20	5.4		$\sigma_{(n,\alpha)}$	1	20	10.8
	σ_{inel}	3	50	12.6			2	20	20.0
		4	50	7.6		$\sigma_{(n,p)}$	1	20	15.1
		5	50	12.0			2	20	12.4
		6	50	12.2			3	20	20.0

Np239 Fission at nTOF in FP5

Am241 Fission at nTOF in FP5

Am243 capture

Am243 Fission at nTOF in FP5

Cm244 fission

Cm245 Fission at nTOF in FP5

Pb inelastic

Pb n,2n

Bi inelastic

Bi n,2n

Cross-Section Uncertainties and Required Uncertainty to Meet Integral Parameter Target Accuracy

NUDATRA project

Nuclear DAta for TRAnsmutation

DM5 of IP-EUROTRANS

General objective:

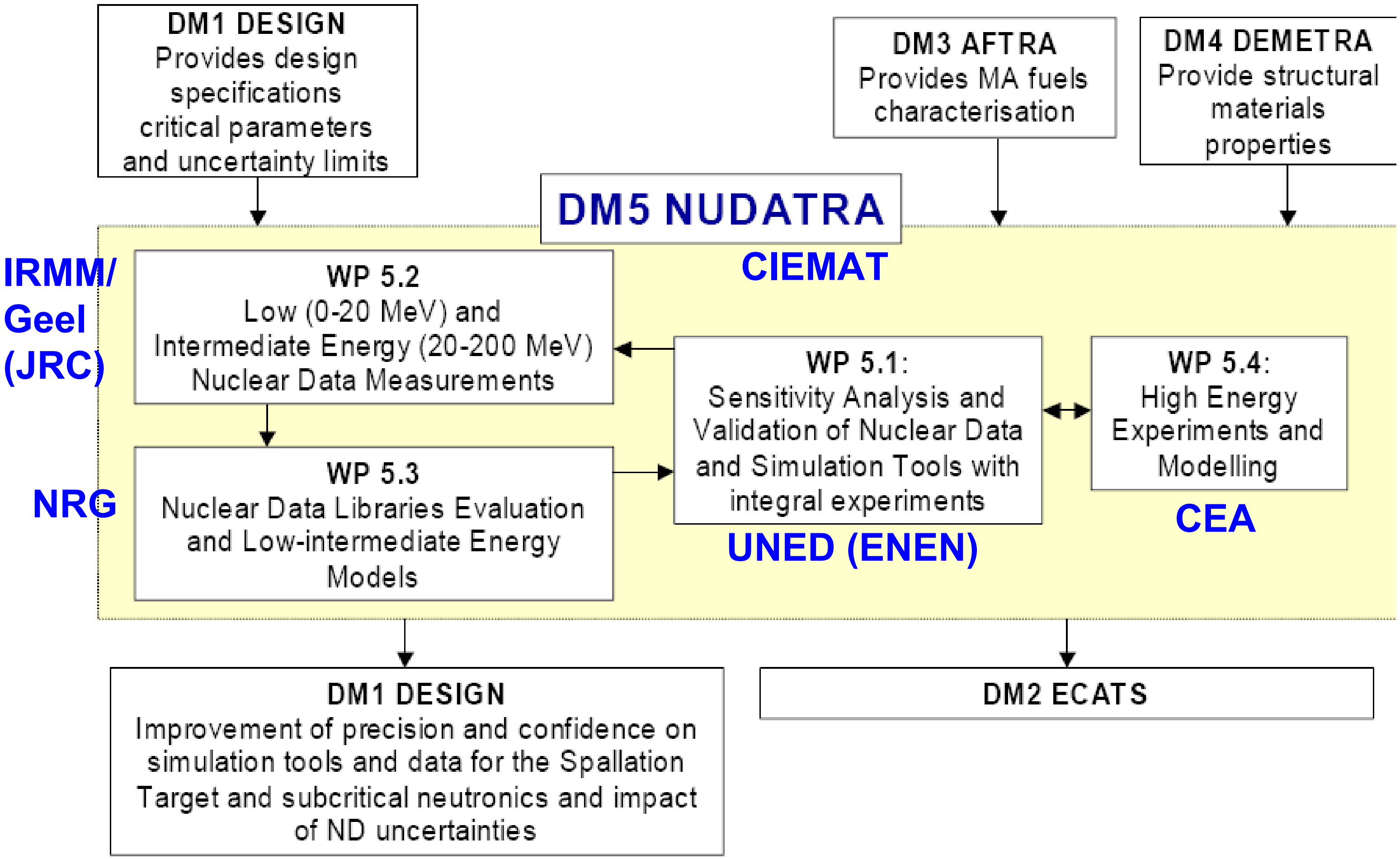
Improve nuclear data evaluated files and models which involves sensitivity analysis and validation of simulation tools, low and intermediate energy nuclear data measurements, nuclear data libraries evaluation at low and medium energies, and high energy experiments and modelling.

Participants: 13 Research Centers + 9 Universities

CEA (France), CIEMAT (Spain), CNRS (France), CSIC (Spain), FZJ (Germany), FZK (Germany), GSI (Germany), INFN (Italy), INRNE (Bulgaria), NRG (Netherlands), PSI (Switzerland), SCK-CEN (Belgium), JRC-Geel (EC)

Universities: AGH (Poland),TUW (Austria), KTH (Sweden), ULG (Belgium), UNED (Spain), USDC (Spain), USE (Spain), UU (Sweden), ZSR (Germany).

NUDATRA Organisation



NUDATRA Specific objectives

- **Pb-Bi cross sections: inelastic, (n,xn), Po production (B.R.)**
- **MA: Capture in ^{243}Am + Fission on ^{244}Cm**
- **TALYS improvements for MA evaluation and test on new Pb data**
- **High energy measurements: Gas (He) and Light Charged Particles production, Absolute Spallation product x-section**
- **High energy models improvement (INCL & ABLA)**
- **Sensitivity analysis of ETD fuel cycle**
- **New versions of transmutation simulation systems**

WP5.2 Low and intermediate energy nuclear data measurements:

Participants: FZK,CEA,CIEMAT,CNRS,CSIC, INFN, **JRC-Geel**, TUW,UU

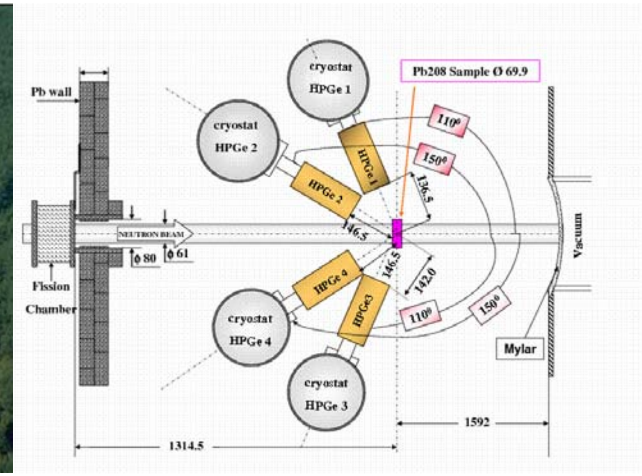
Task T5.2.1 Pb and Bi cross section and branching ratios

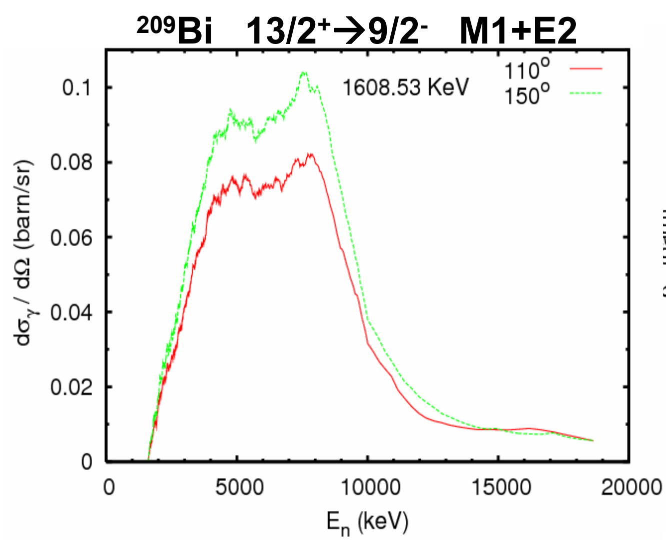
High resolution excitation functions for the inelastic scattering cross sections of Pb and Bi

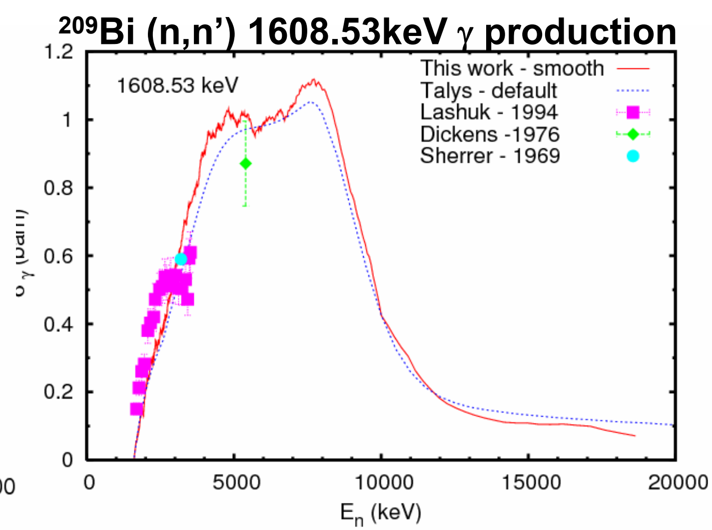
Critical to model correctly the ADS neutron spectra

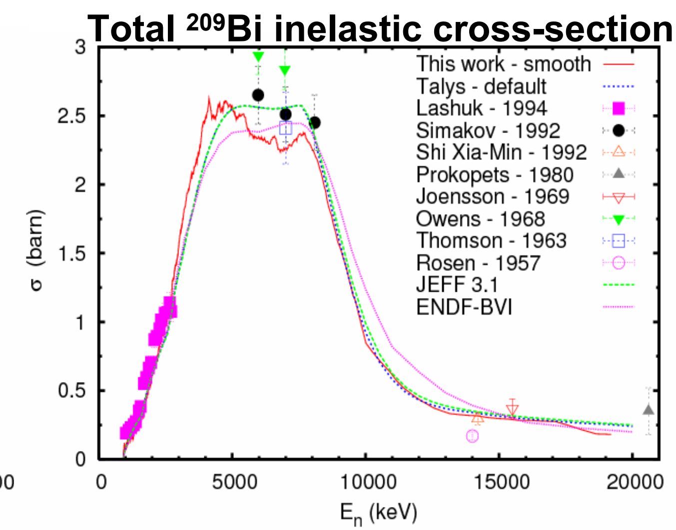
$^{206, 207, 208}Pb$ and ^{209}Bi, thr-20 MeV by (n,n'γ) at Gelina

Gamma-ray production cross sections are measured and total and level inelastic cross sections will be deduced



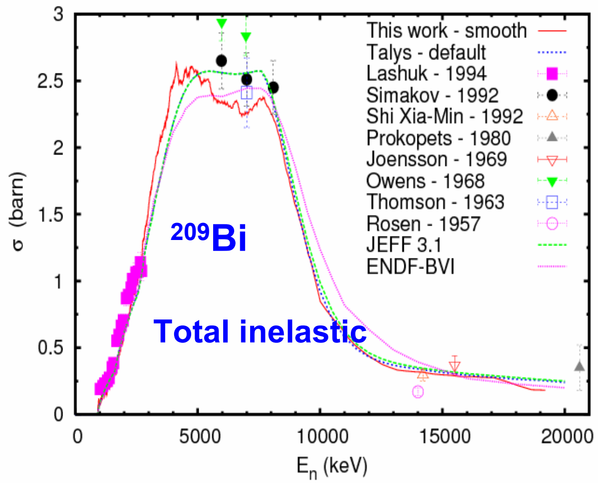


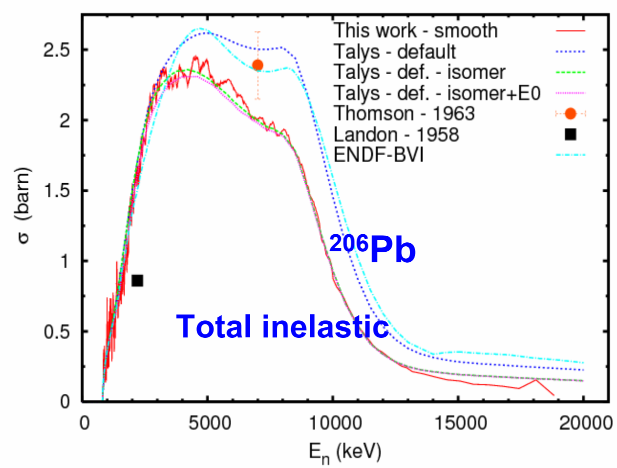




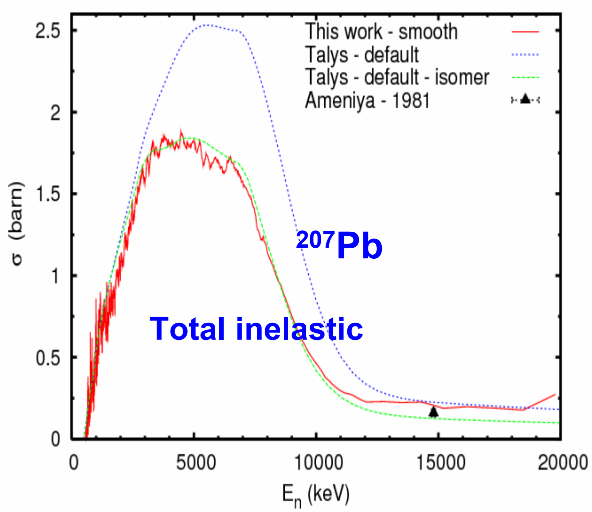
WP5.2 $^{206, 207, 208}$Pb and ^{209}Bi, thr-20 MeV by (n,n'γ) at Gelina

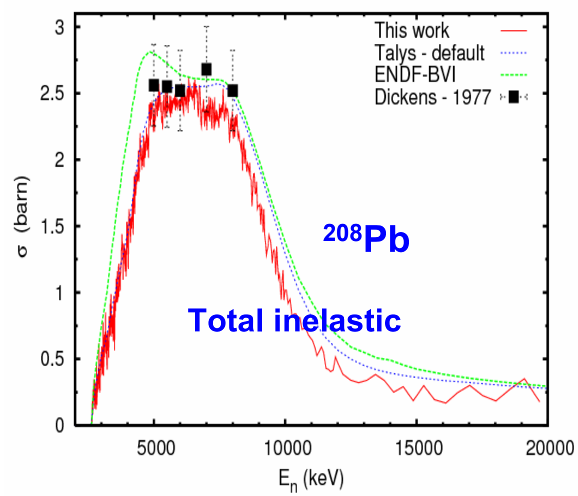
Data is already taken and analysis is progressing. First EXFOR files produced.

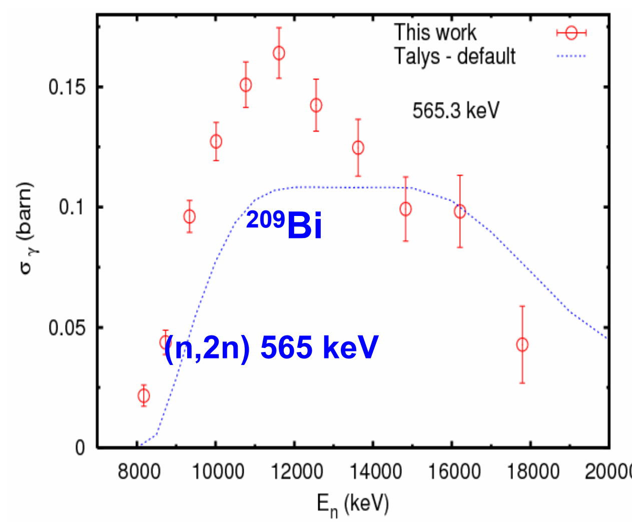




Nucleus	Reaction	Nbr. of observed γ-rays	E^{max} (MeV)
^{52}Cr	(n,n'γ)	12	3.77
	(n,2nγ)	2	1.16
^{209}Bi	(n,n'γ)	39	3.80
	(n,2nγ)	8	1.09
^{206}Pb	(n,n'γ)	23	3.56
	(n,2nγ)	2	0.70
^{207}Pb	(n,n'γ)	15	4.32
	(n,2nγ)	4	1.70
^{208}Pb	(n,n'γ)	29	5.56
	(n,2nγ)	5	3.22
	(n,3nγ)	1	0.80







WP5.2 Low and intermediate energy nuclear data measurements:

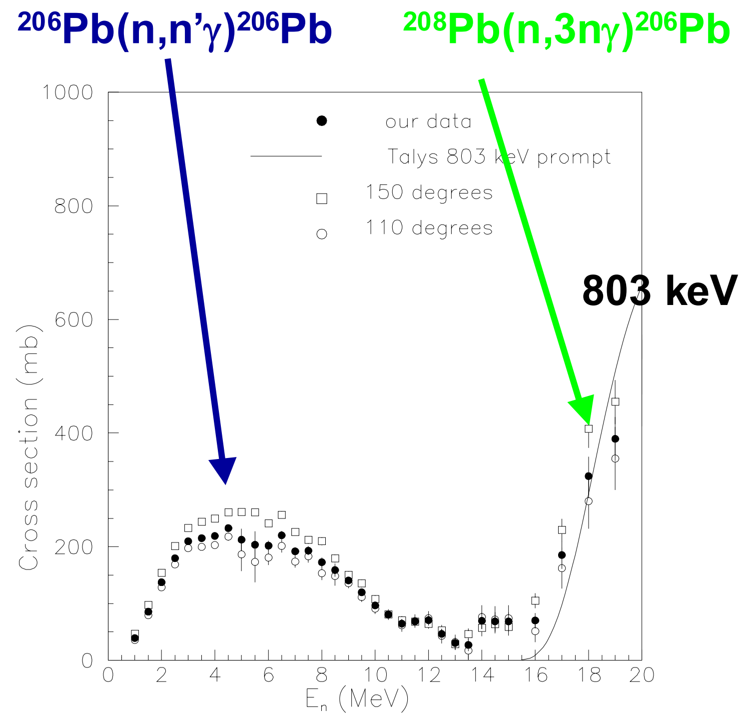
5.2.1.4 Measurements of Pb and Bi (n,xn) cross sections

^{206}Pb,^{209}Bi (n,xnγ)

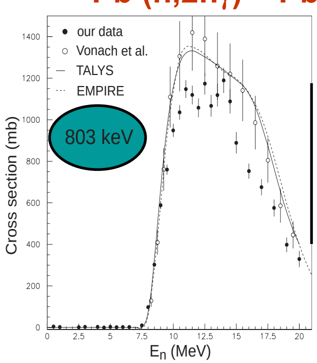
Effects on the neutron multiplication, the source importance and neutron spectra of ADS cooled with Pb/Bi or using Pb/Bi spallation target

Progress: Measurements performed and analysis ongoing for: ^{207}Pb(n,2n)^{206}Pb, ^{208}Pb(n,2n)^{207}Pb , ^{208}Pb(n,3n)^{206}Pb, ^{209}Bi (n,2n) ^{208}Bi

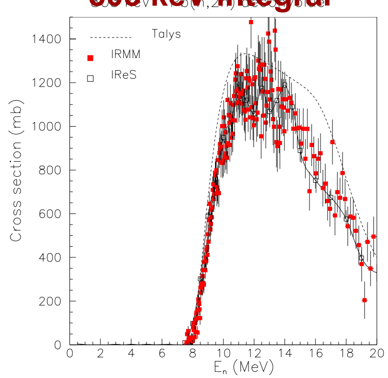
Online HPGe detectors at Gelina



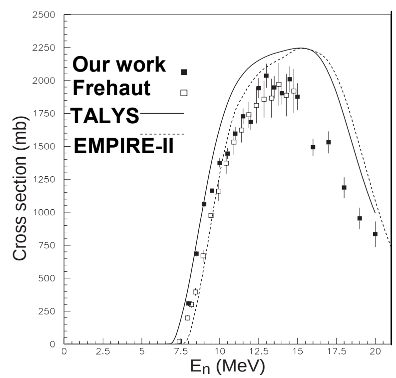
^{207}Pb (n,2nγ)^{206}Pb



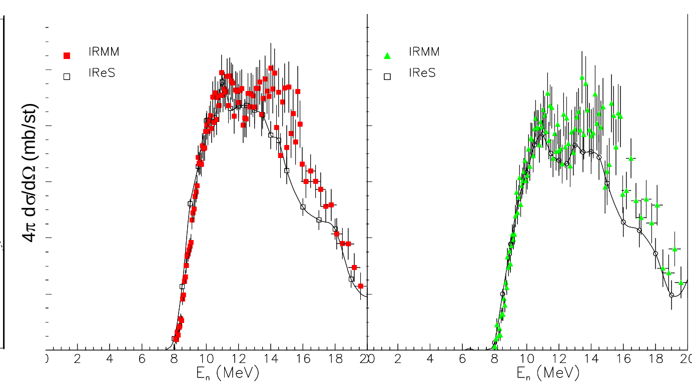
^{207}Pb (n,2n)
803 keV integral



^{207}Pb (n,2n)^{206}Pb Total



^{208}Pb (n,2n) 570 keV



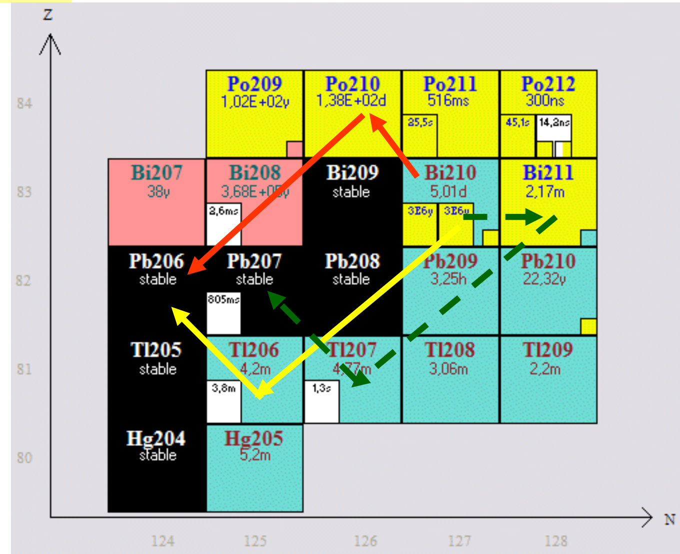
WP5.2 Low and intermediate energy nuclear data measurements:

Participants: FZK,CEA,CIEMAT,CNRS,CSIC, INFN, **JRC-Geel**, TUW,UU

Task T5.2.1 Pb and Bi cross section and branching ratios

Bi capture branching ratio ($^{209}Bi(n,\gamma)^{210m,g}Bi$)

Production of ^{210g}Bi is the mechanism leading to ^{210}Po production.
^{210m}Bi decay α to ^{206}Tl.
^{210}Po is one of the main ADS target and coolant activation concerns



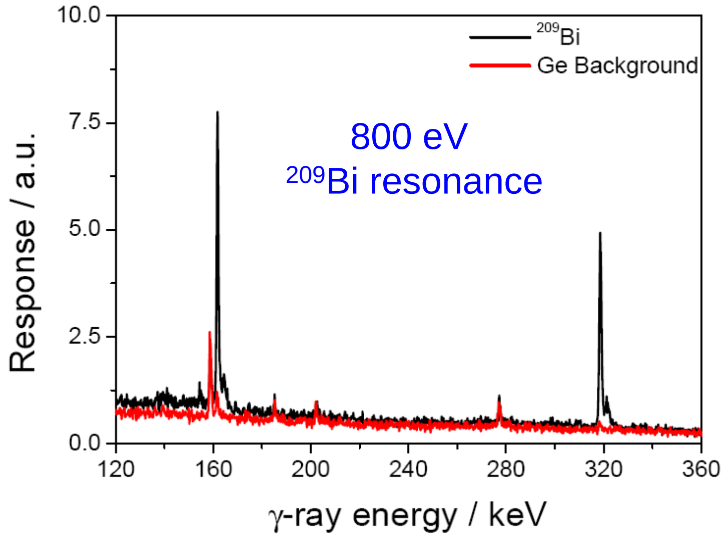
The time-of-flight technique will be used at Gelina

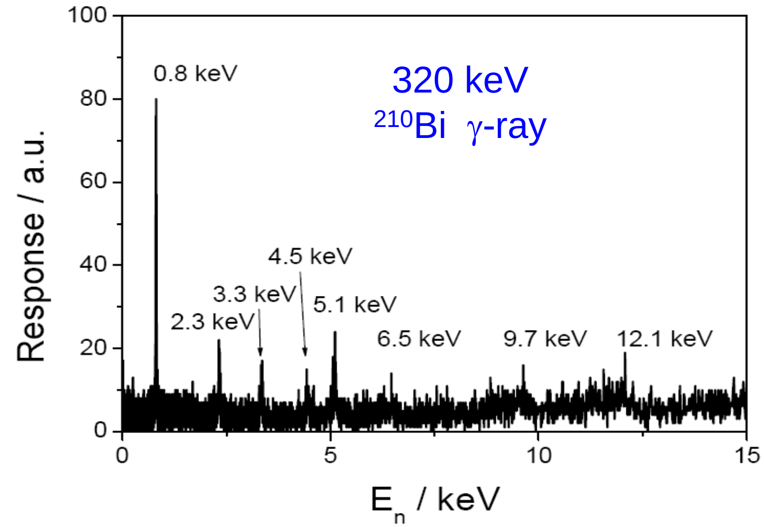
Two (3) HPGe detectors will be used to distinguish between capture events leading to the ground state and the meta-stable state

Compensation for γ angular dependence

Setup prepared and optimized,

Preliminary data presented at Physor 2006





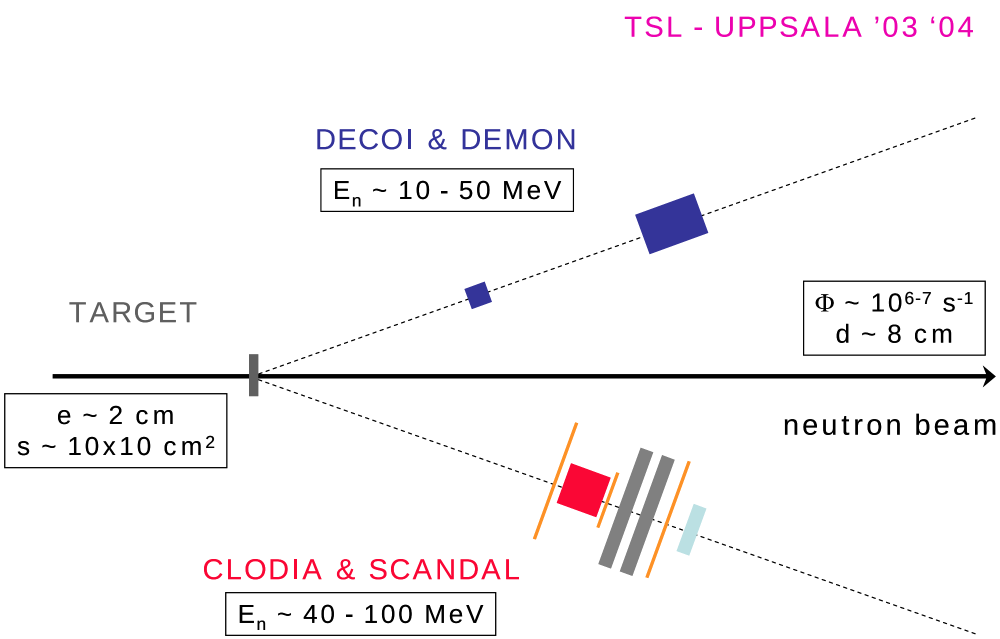
WP5.2 Low and intermediate energy nuclear data measurements:

5.2.1.3 Meas. of Pb (n, n'+X) cross section at 100 MeV

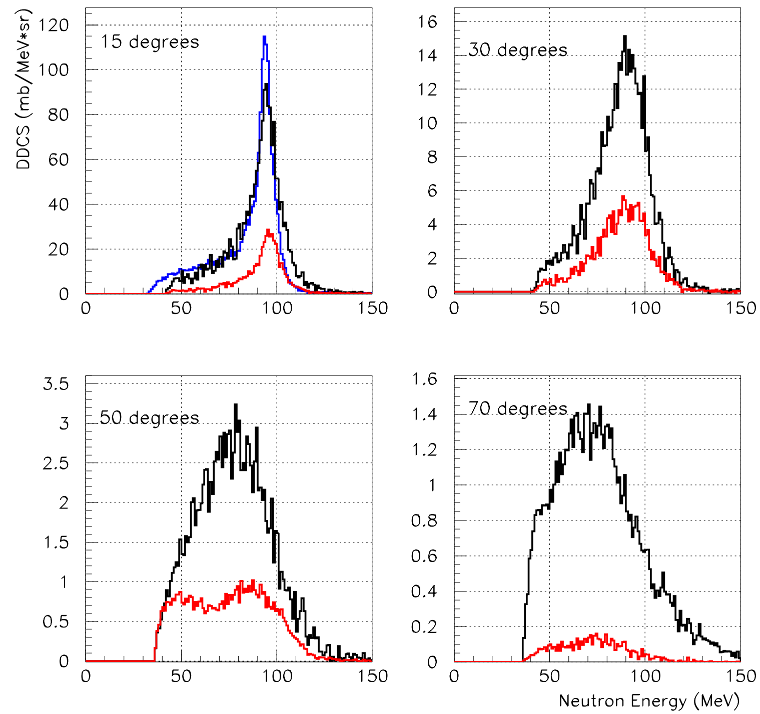
Non existing differential data required for Pb based ADS high energy neutron shielding calculations and spallation n multiplication

Pb (n,n'+X) at The Scandal facility at Uppsala

Setup optimization, preliminary analysis of 2003-2004 data.



Pb(n,xn) Uppsala '03
Uppsala '04
Fe(n,xn) Uppsala '04



Double Differential Cross Section
Fe, Pb (n,xn) @ 96 MeV – 15, 30, 50, 70°

WP5.2 Low and intermediate energy nuclear data measurements:

MA Capture and Fission cross sections

T5.2.2 MA capture cross sections ^{243}Am (n,γ) at nTOF-Ph2 (at CERN)

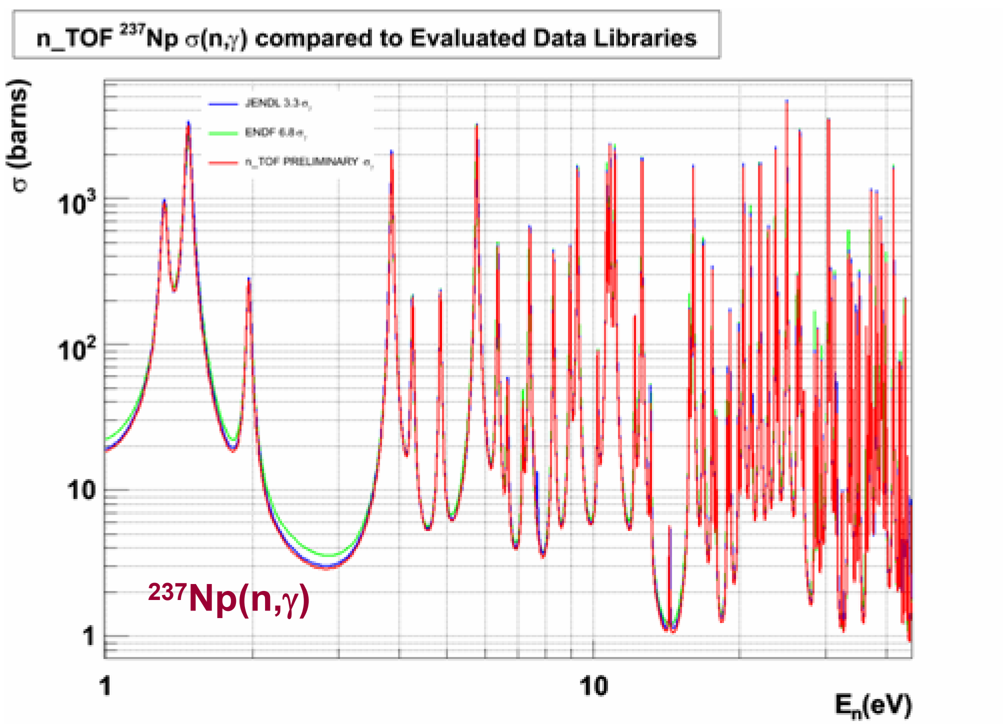
Transmutation of MA: ^{243}Am is the path to ^{244,245,246,247}Cm production

Time of flight + 4π TAC.

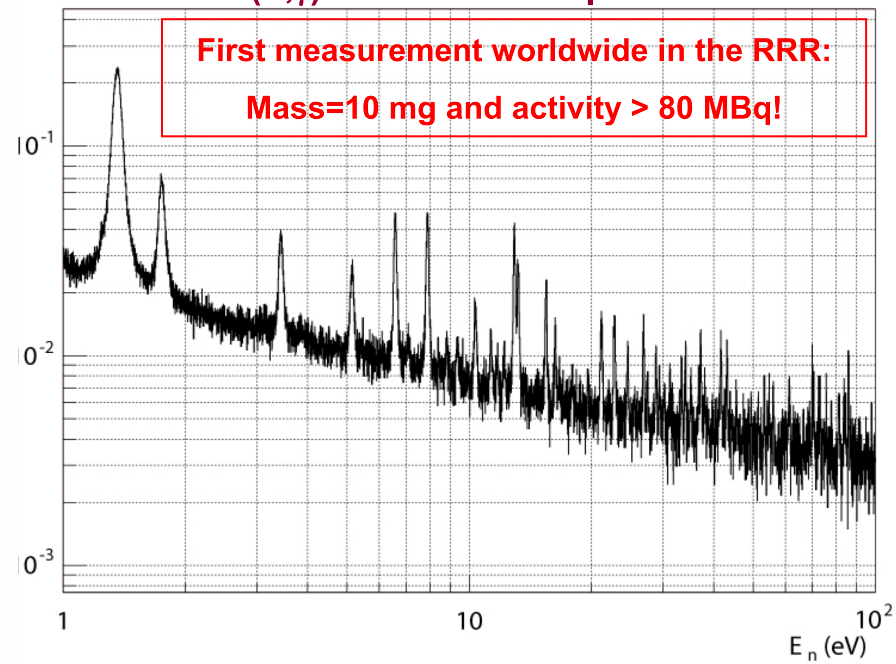
The methodology and setup tested in 2004 at the FP5 nTOF-ADS project.

Setup optimization, Preliminary analysis of 2004 data.

n_TOF_Ph2 proposal including ^{243}Am (n,γ) submitted+supported by CERN Res. Board.



Test ^{243}Am(n,γ) measurement performed in 2004



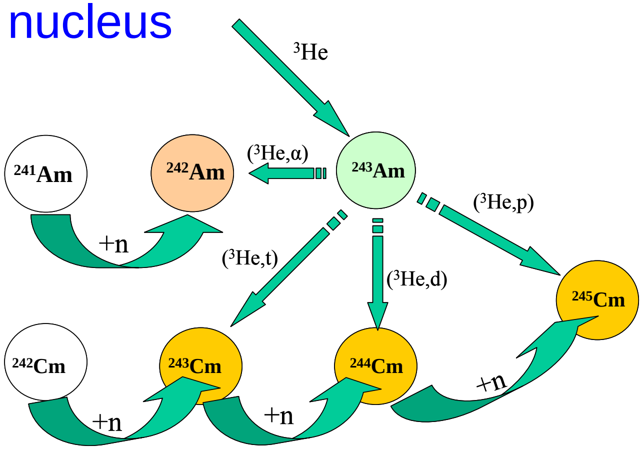
WP5.2 Low and intermediate energy nuclear data measurements:

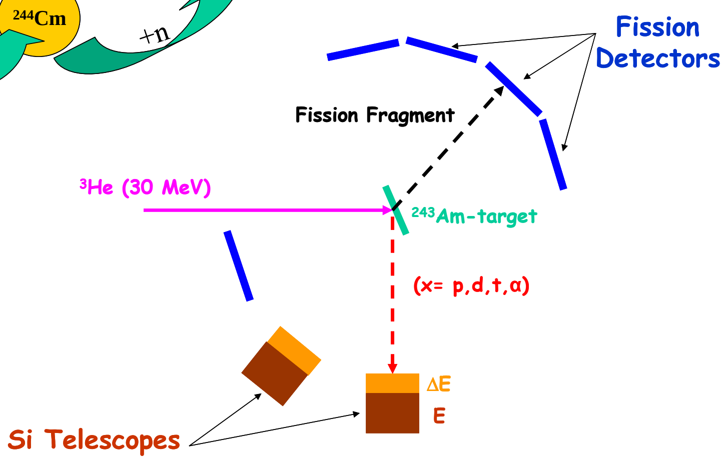
MA Capture and Fission cross sections

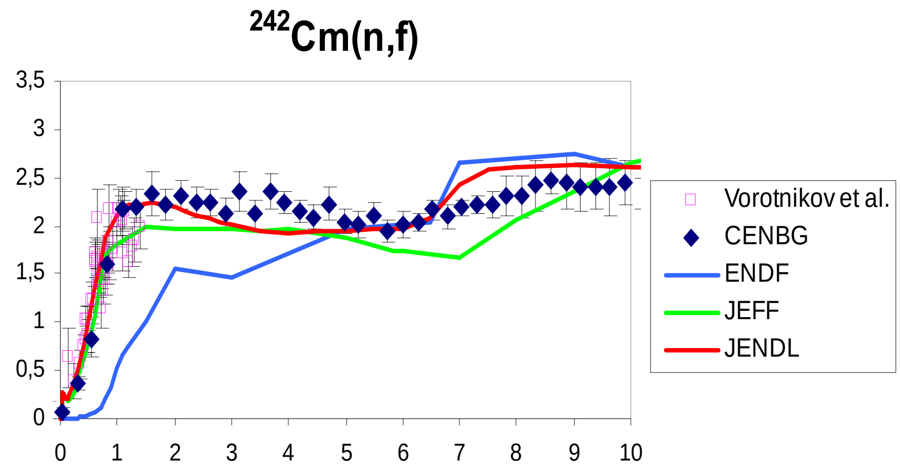
<u>T5.2.3 ^{244}Cm neutron induced fission cross section measurements</u>

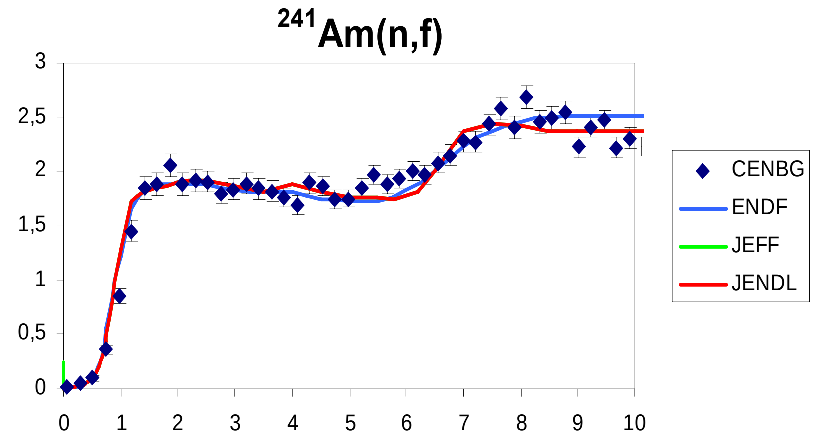
^{244}Cm(n,f) from ^{243}Am(^{3}He,pf)

Measurements of the transfer reactions ^{243}Am(^{3}He,pf) at Orsay + Evaluations and models for the formation of the composite nucleus









Setup optimization, First data taken.
^{241}Am(n,f) and ^{242}Cm(n,f) deduced

WP5.3 Nuclear data library evaluation and low and intermediate energy models

Participants: CEA,INRNE, **NRG**, TUW,USE

Measurements must be evaluated to become useful for simulations

Models can help to complete libraries many channels and isotopes without experimental data, above the resolved resonance region.

T5.3.1 Improvement of low and intermediate nuclear reaction models

Improvement of Nuclear model code TALYS: generalized superfluid model for level densities implemented and tested with U isotopes

Development of Methods to generate covariance data: 2 methods in good progress

T5.3.2 Evaluation of minor actinide data

Optical model, pre-equilibrium, compound nucleus and fission model parameters will be fine-tuned

Priority to Americium isotopes in the fast neutron range first test to ^{241}Am.

The resonance regions is also being analyzed

New isospin-dependent dispersive optical model potentials for actinides have been developed and and sent to publication

T5.3.3 Re-evaluation of data libraries for Pb and Bi

Using the data from the WP5.2 to complement the existing and FP5 data (nTOF,…),

First test already made with the new WP5.2 and CEA/BRC data from 7 to 14 MeV

WP5.3 Nuclear data library evaluation and low and intermediate energy models (NRG)

T5.3.3 Re-evaluation of data libraries for Pb and Bi

Using the data from the WP5.2 to complement the existing and FP5 data (nTOF,…),

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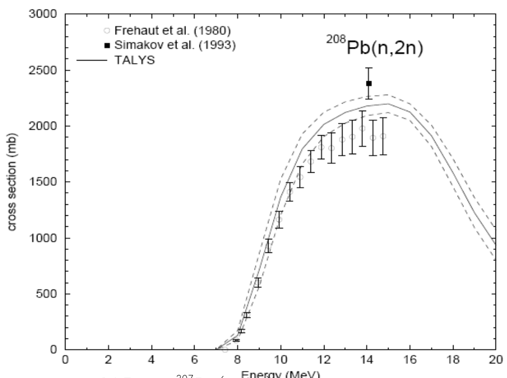
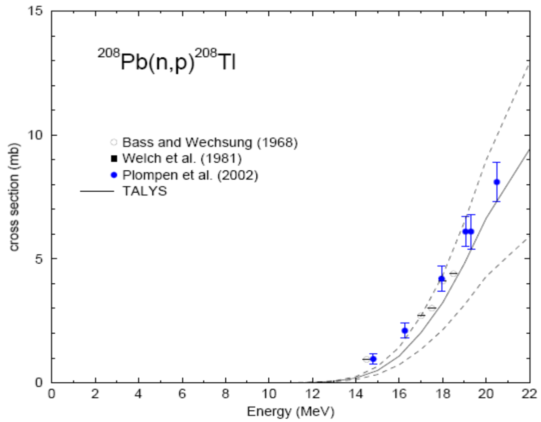
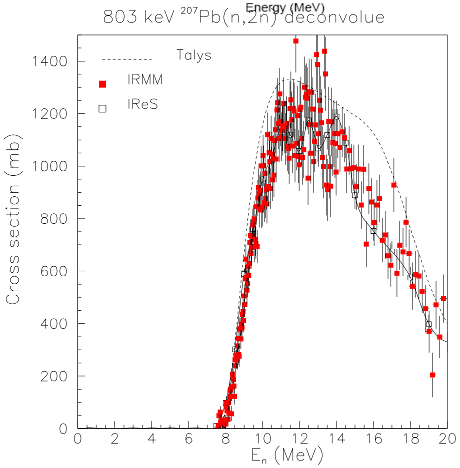
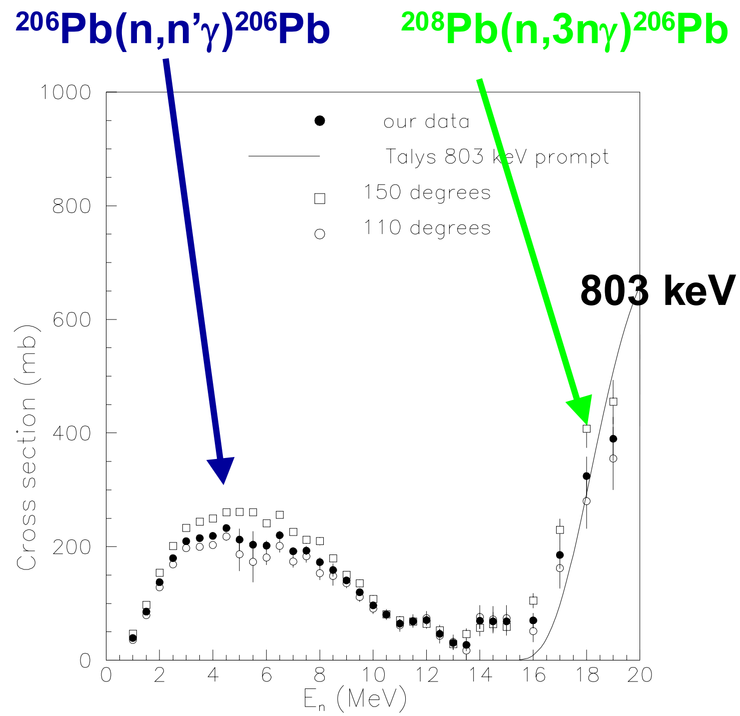






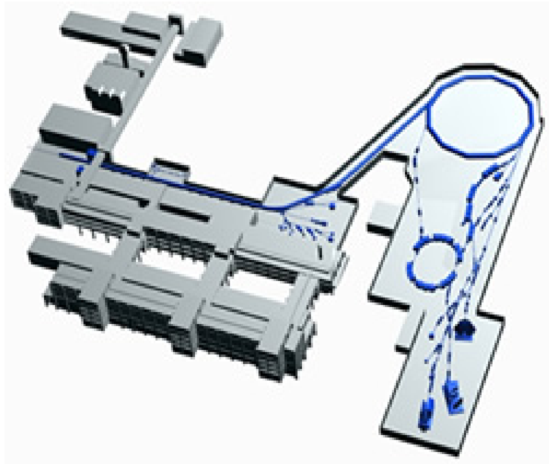
^{207}Pb (n,2n)
803 keV
integral



WP5.4 High energy experiments and modelling

Participants: **CEA**, FZJ, GSI, ULG, USDC, ZSR

The energy range (200-1000 MeV) specific of the ADS spallation target
Completing the experimental database of the HINDAS FP5 project (Very big progress on H.E. models but still some weak points)



GSI @ Darmstadt (Germany)

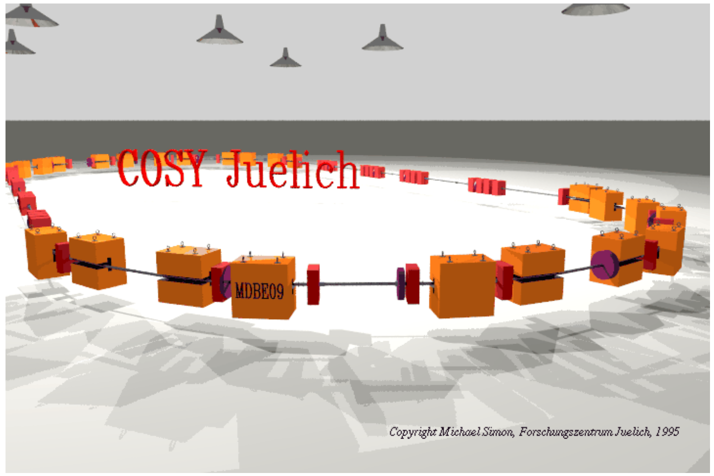
T5.4.1 High energy experiments for Radioactivity, chemical modification and damage assessment (USDC)

Total fission cross-section (200 MeV - 1 GeV) for Pb and W

Total fission cross sections in reactions induced by ^{208}Pb on ^{1}H and ^{2}H have been measured at 500 A MeV at GSI. Analysis is on progress.

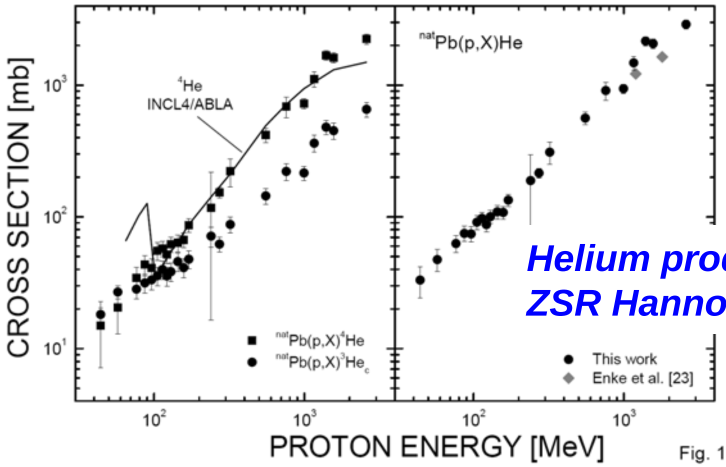
Production of long lived Intermediate mass fragments as ^{7}Be and ^{10}Be from Bi, W, Ni targets: 100-1000 MeV

Helium production in W or Ta and Fe or Ni, between E=100-800 MeV (NESSI/PISA experiment at FZJ)



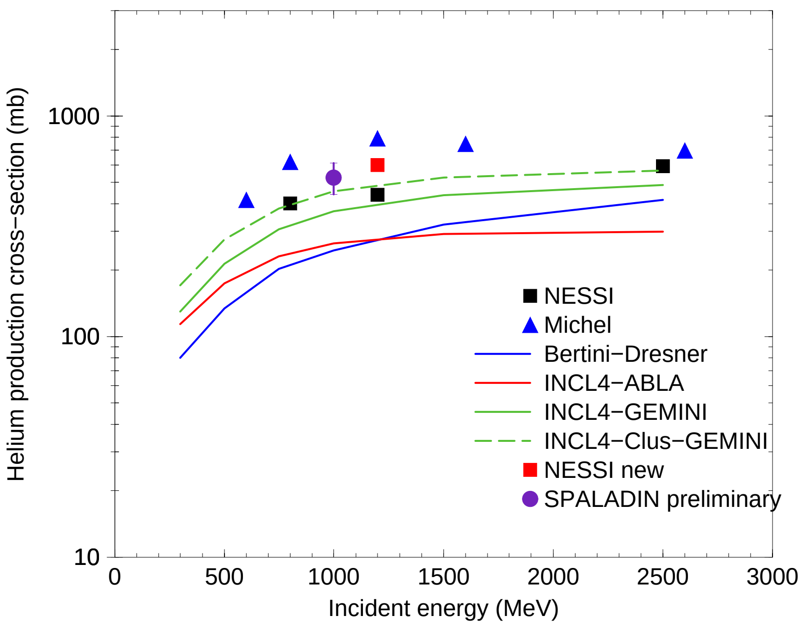
WP5.4 High energy experiments and modelling

He, LCP and Long-lived IMFs as $^{7}Be/^{10}Be$ production from selected targets measured at Hannover (ZSR) and NESSI+PISA

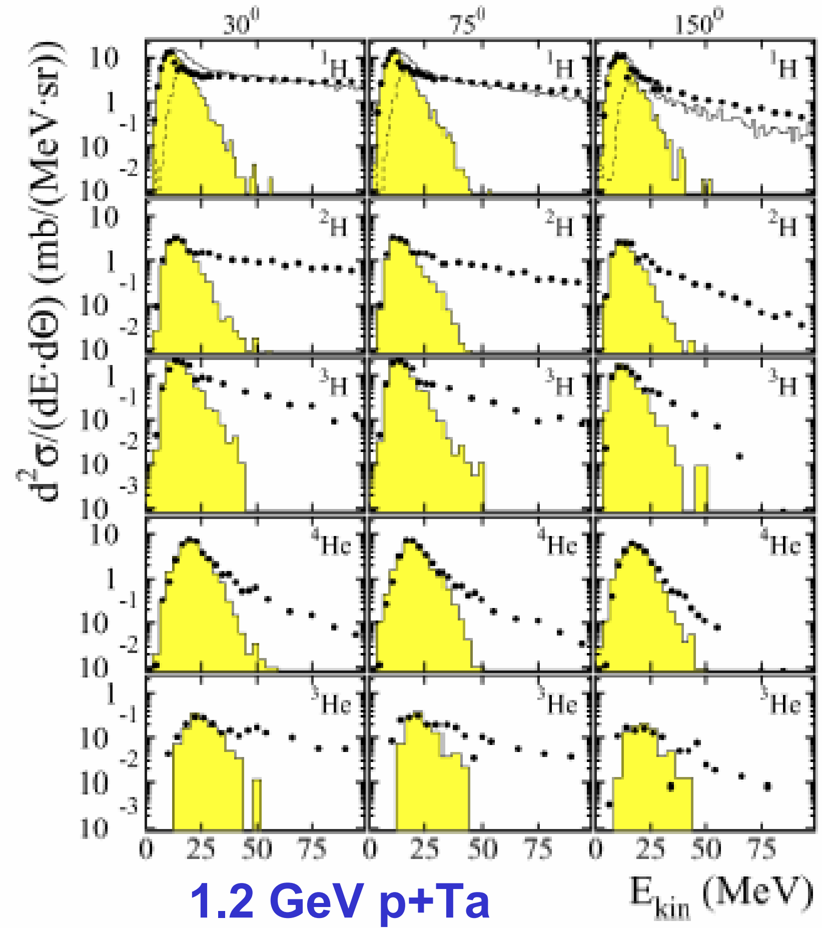


Helium production ZSR Hannover

p + Fe

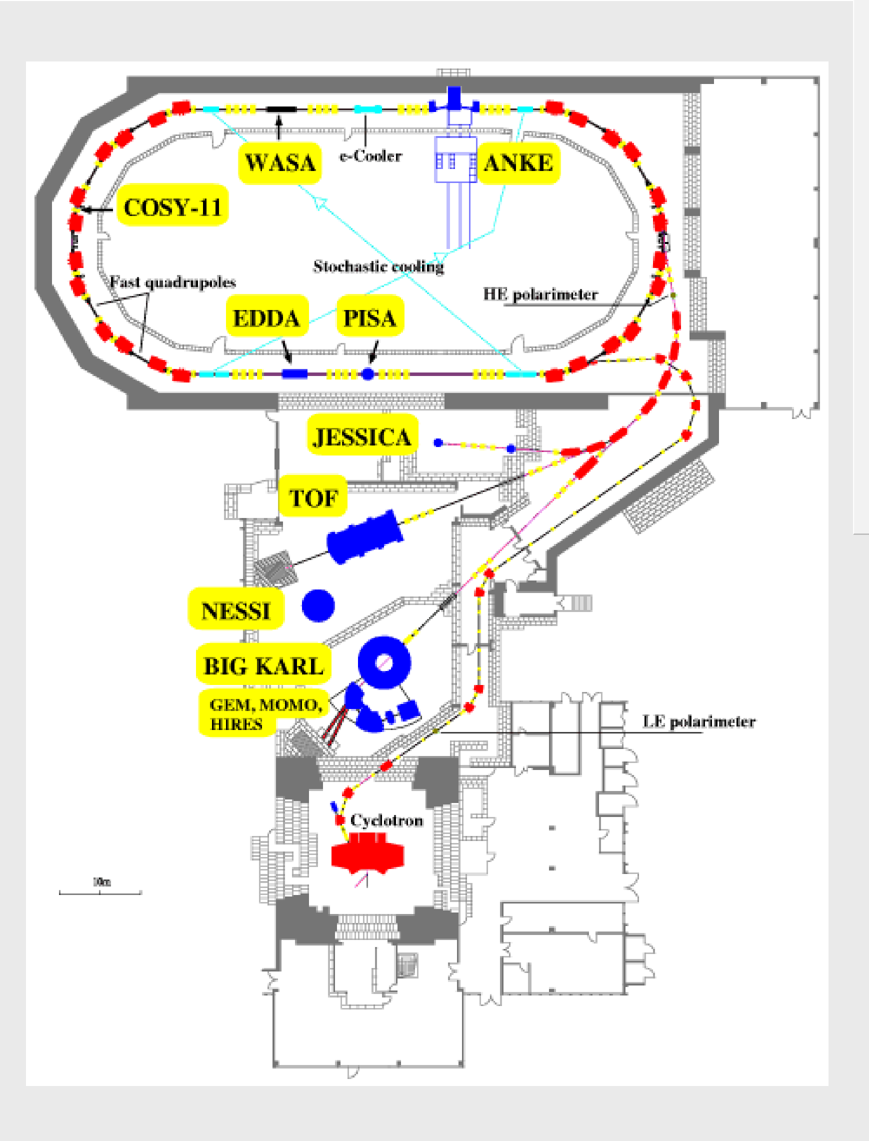


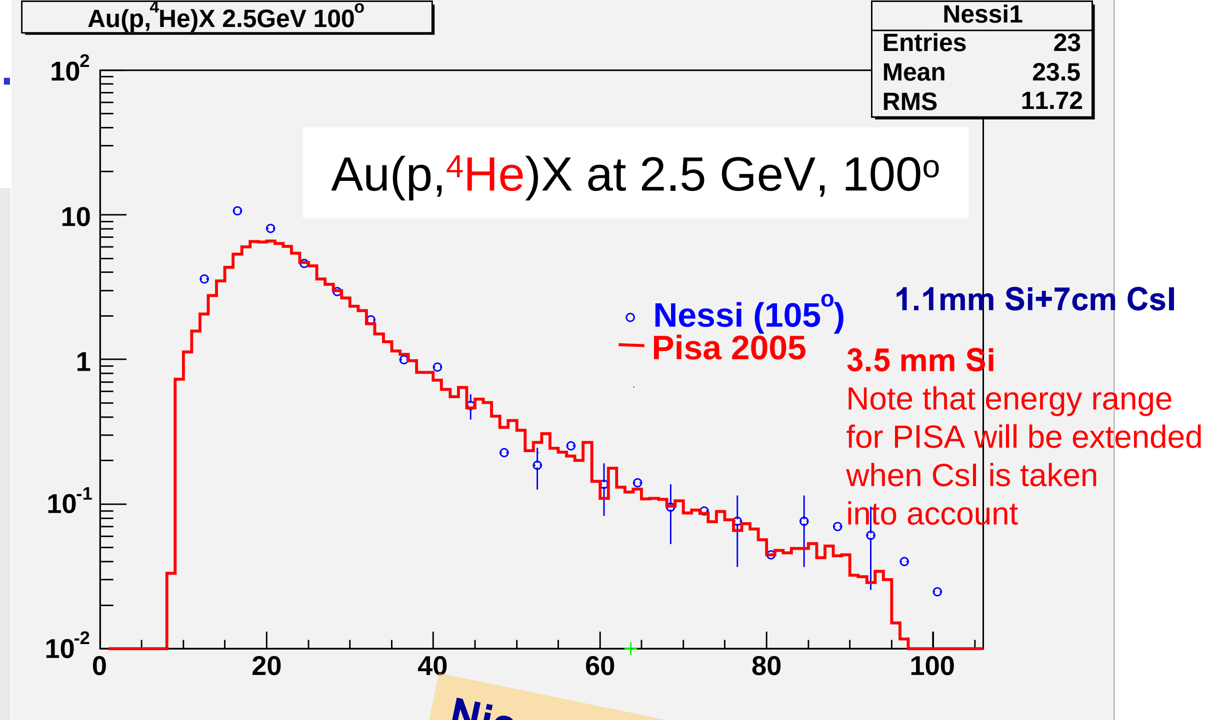
Comparison INCL4/ABLA with recent NESSI data



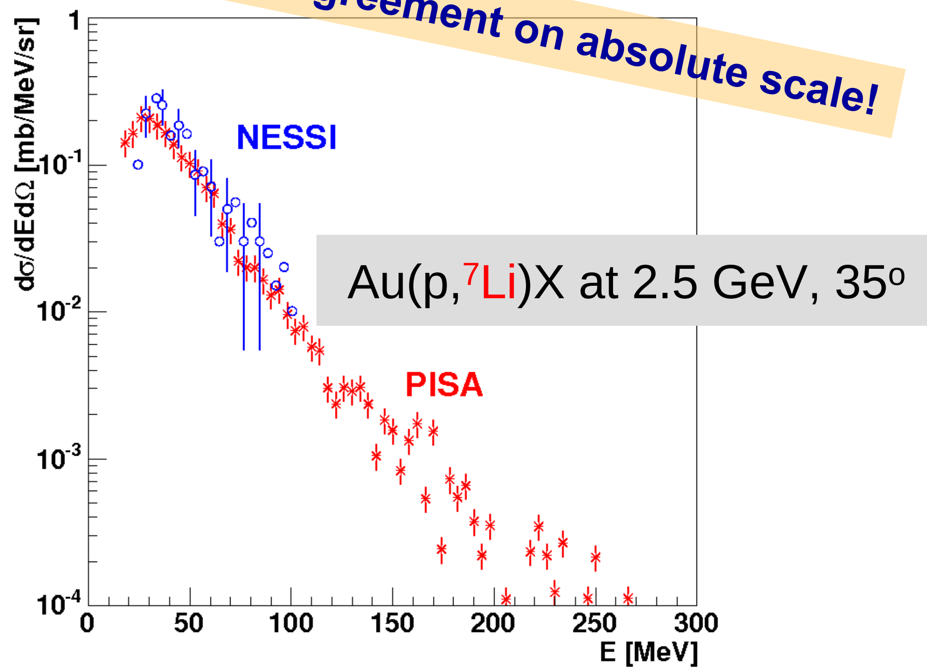
1.2 GeV p+Ta

Comparisons PISA / NESSI…





Nice agreement on absolute scale!

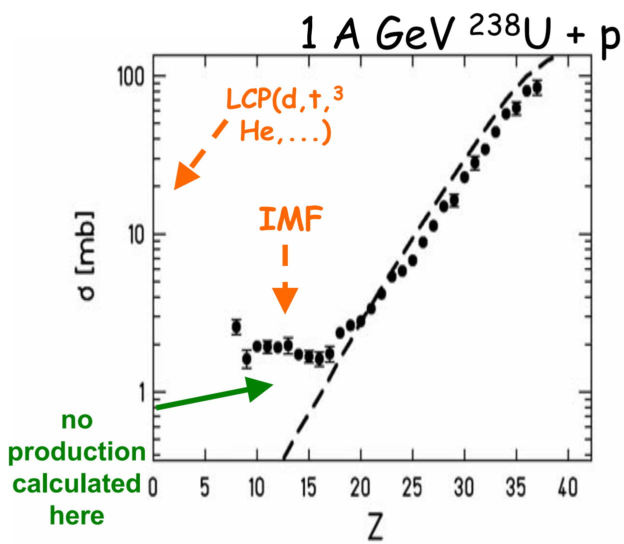


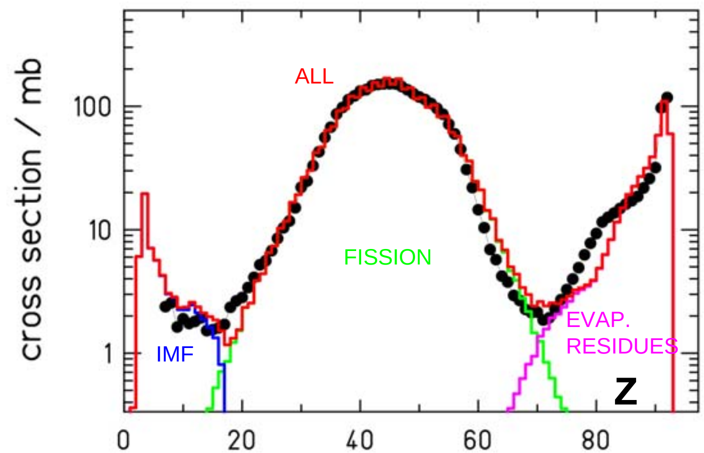
WP5.4 High energy experiments and modeling

<u>T5.4.2 High-energy nuclear model improvement: </u>Extension of INCL4 and ABLA

***INCL4**: Implementation of a dynamical coalescence model for cluster production (seems to correctly reproduce the production of high energy light clusters except $^4He/^3He$ ratio), Introduction of isospin- and energy-dependent average nucleon potentials, Improvements of pion dynamics (n multiplicity at very high energies)*

***ABLA**: Fission, Composite LCP, Intermediate Mass Fragments*





ABLA improvement on IMF emission

<u>T5.4.3 Quality assessment, validation and impact of the new models in ADS (ETD) simulations</u>

Implementation in High Energy transport codes (MCNPX)

Calculations of radiotoxicity, radioactivity due to residue production in the MEGAPIE. Calculations of DPA, chemical composition modifications, and activities in ETD with the new codes .

WP5.1 Sensitivity Analysis and Validation of Nuclear Data and Simulation Tools

Participants: FZK,CEA,CIEMAT,NRG,PSI,SCK,AGH,KTH,**UNED**

T5.1.1 and T5.1.2: Uncertainties propagation and Sensitivity analysis for the fuel Cycle

A list of topics for sensitivity evaluation of the transmutation ADS fuel Cycles had been proposed.

Wide review/compilation/comparison of uncertainties from the most recent activation data files, evaluated nuclear data files and bibliography proposals has been performed.

Proposals and tests of methodologies for the definition of covariance matrixes on nuclear data when not available.

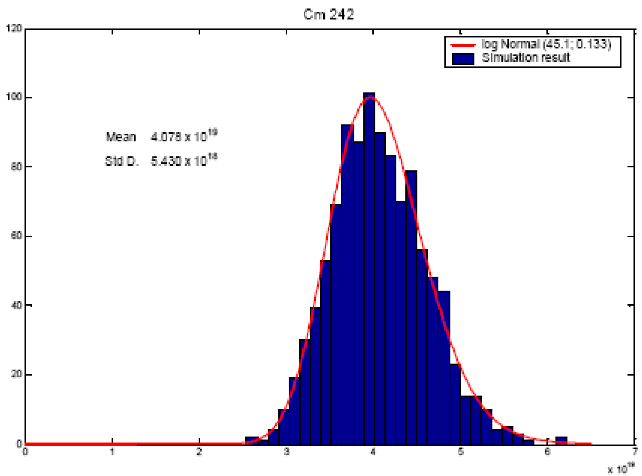
Review/Compilation, Processing and Analysis of Available Uncertainty Cross-Section Data

Complete list of materials with covariances of neutron cross section (FILE 33/40)

BROND-2.2	CENDL-2.1	ENDF/B-VI.8	ENDF/B-VIIb	IRDF90-2.0	IRDF2002	JEF-2.2	JEFF-3.1	JENDL-3.3
N. of MAT=3	N. of MAT=9	N.of MAT=44	N.of MAT=35	N. of MAT=37	N. of MAT=48	N. of MAT= 15	N. of MAT= 34	N. of MAT=20
C Au^{197} Pb	H^{2-3} O^{16} F^{19} Mn^{55} Fe^{56} U^{238} Pu^{240} Am^{241}	Li^{7} C F^{19} Na^{23} Si, $Si^{28-29-30}$ Ti^{46-48} V $Cr^{50-52-53-54}$ Mn^{55} $Fe^{54-56-57-58}$ Co^{59} $Ni^{58-60-61-62-64}$ Cu^{63-65} Y^{89} Nb^{93} In, In^{115} $Re^{185-187}$ Au^{197} $Pb^{206-207-208}$ Bi^{209} Th^{232} U^{238} $Pu^{240-242}$ Am^{241}	Li^{7} C F^{19} Na^{23} $Si^{28-29-30}$ Ti^{48} V $Cr^{50-52-53-54}$ Mn^{55} $Fe^{54-56-57-58}$ Co^{59} $Ni^{58-60-61-62-64}$ Cu^{63-65} $Re^{185-187}$ Au^{197} Pb^{208} Bi^{209} U^{238} $Pu^{240-242}$ Am^{241}	Li^{6} B^{10} F^{19} Na^{23} Mg^{24} Al^{27} P^{31} S^{32} Sc^{45} $Ti^{46-47-48}$ V Cr^{52} Mn^{55} $Fe^{54-56-58}$ Co^{59} Ni^{58-60} Cu^{63-65} Zn^{64} Y^{89} Zr^{90} Nb^{93} Rh^{103} Ag^{109} In^{115} I^{127} Au^{197} Th^{232} $U^{235-238}$ Np^{237} Pu^{239}	Li^{6}, B^{10}, F^{19}, Na^{23} Mg^{24}, Al^{27}, P^{31}, S^{32} Sc^{45} $Ti^{46-47-48-49}$ $Ti^{49}(n,x)Sc^{48}$ V^{51} Cr^{52} Mn^{55} $Fe^{54-56-58}$ Co^{59} Ni^{58-60} Cu^{63-65} Y^{89} Zn^{64} As^{75} Y^{89} Zr^{90} Nb^{93} Rh^{103} $Rh^{103}(n,n')Rh^{103m}$ Ag^{109} $Ag^{109}(n,g)Ag^{110M}$ In^{115} $In^{115}(n,n')In^{115m}$ I^{127} La^{139} Pr^{141} Tm^{169} Ta^{181} W^{186} Au^{197} Hg^{199} $Hg^{199}(n,n')Hg^{199M}$ Pb^{204} $Pb^{204}(n,n')Pb^{204m}$ Th^{232} $U^{235-238}$ Np^{237} Pu^{239} Am^{241}	H^{1} Li^{6-7} Be^{9} C Co^{59} $Ni^{58-60-61-62-64}$ Y^{89} Au^{197} $U^{235-238}$	H^{3} Be^{9} C F^{19} Si^{28} $Ti^{46-47-48-49-50}$ V $Cr^{50-52-53-54}$ Mn^{55} $Fe^{54-56-57-58}$ Co^{59} $Ni^{58-60-61-62-64}$ Cu^{63-65} Y^{89} Zr^{90} Nb^{93} $Re^{185-187}$ Au^{197}	H^{1} B^{10-11} O^{16} Na^{23} Ti^{48} V Cr^{52} Mn^{55} Fe^{56} Co^{59} Ni^{58-60} Zr^{90} $U^{233-235-238}$ $Pu^{239-240-241}$

LIBRARY	Nº of materials with covariance data	Nº of xs with covariance data (approx.)
BROND-2.2	3	35
CENDL-2.1	9	75
IRDF90-2.0	37	>100
IRDF2002	48	>100
ENDF/B-VI.8	44	400
ENDF/B-VIIb	35	>200
JEF-2.2	15	130
JEFF-3.1	34	400
JENDL-3.3	20	180

- Assessment of Uncertainties in the Calculation of Neutron Induced Reaction Cross-sections at Energies Above 0.1 MeV
- Proposals for Generation of Uncertainty Data
- Topics for Uncertainty Evaluation
- Progress in Defining Uncertainty Methodologies: Implementation and Proof of Principle for Practical Use

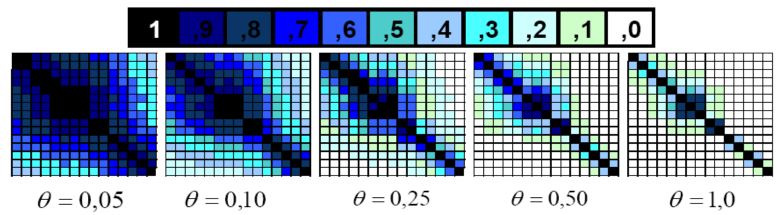


Histogram of the 1000 values of the ^{242}Cm concentration obtained by Monte Carlo Method. The red line is the lognormal density function

Sensitivity/ uncertainty analysis

+

Monte Carlo Method



	Initial $\times10^{20}$	Final $\times10^{20}$	Coefficient of variation of X_f (in %) No Correlation	θ 1	θ 0,5	θ 0,25	θ 0,10	θ 0,05	Palmiotti ´s Correlation
Pu 238	0,42300	1,23000	3,6	4,8	5,9	7,2	8,6	8,9	5,6
Am 241	8,08000	6,93000	1,3	1,7	2,1	2,8	3,2	3,3	2,0
Am 242	0,10900	0,15900	1,3	1,8	2,2	2,7	3,3	3,5	2,0
Am 243	5,83000	5,17000	0,2	0,2	0,2	0,3	0,3	0,3	0,3
Cm 242	0,00040	0,39800	8,7	11,3	14,0	18,0	21,1	21,6	13,5
Cm 244	2,37000	2,71000	0,6	0,8	0,9	0,9	1,1	1,1	0,9
Cm 245	0,31600	0,38500	2,4	3,3	3,8	4,7	5,5	5,6	3,6

WP5.1 Sensitivity Analysis and Validation of Nuclear Data and Simulation Tools

Improvement of Transmutation plants simulation programs

T5.1.3 Development and validation of simulation programs for transmutation plants:
MCB, EVOLCODE and KAPROS/KARBUS.

Updated versions of MCB, EVOLCODE.

EVOLCODE2:

Improved approximations on:

Energy dependence of Fission yields, Isomer production
Convolution method, Isotopes without transport x-sections
Different cross sections (T, library,…) at different cells
Increased number of isotopes for burnup (Spallat. prod.)

Improve coding, portability and bug fixes

Examples of benchmarks and applications

MCB:

New options: Normalization to proton intensity or total power
Improved fuel lattice handling, Spallation products included.

Bug fixes.

WP5.1 Sensitivity Analysis and Validation of Nuclear Data and Simulation Tools

Validation of Data, Models and programs

T5.1.4 Nuclear data and models validation for the spallation target (PSI):

Residual nuclei production in SINQ targets.

Measurements of absolute activities of residues (eg.: ^{194}Hg, ^{207}Bi) in spallation target models (Dubna, PSI).

Predefinition of spallation residues benchmarks based on Dubna data (IAEA).

T5.1.5 Minor actinide and Pb nuclear data validation in integral experiments (CIEMAT):

Fission cross section from MASURCA (Cadarache) experiments

^{240,241,242}Pu, ^{237}Np and ^{241,243}Am

First analysis done from MASURCA 1A' and 1B

Other Minor actinide and Pb nuclear data validation based on results from ISTC projects

Facilities: BFS, SAD, Yalina

Experiments completed and in *preparation*

Preparation/Definition of SAD and YALINA setups (but review might be needed after clarification of ECATS)

Conclusions and Outlook

Progress In the first year of NUDATRA

WP5.1: Development and validation of sensitivity analysis methodologies and collection of existing covariance information. Development of new versions of transmutation simulation codes (EVOLCODE2, MCB) + test of new/old codes KAPROS/ALEPH

WP5.2: Measurements of:

$^{206, 207, 208}$Pb and ^{209}Bi, thr-20 MeV by (n,n'γ) at Gelina

^{206}Pb,^{209}Bi (n,xnγ) two techniques at Gelina

Preparatory setups/analyses for ^{244}Cm(n,f) from ^{243}Am(^{3}He,pf), ^{243}Am (n,γ), Pb (n,xn') at 100 MeV, ^{209}Bi(n,γ)^{210m,g}Bi Branching Ratio.

WP5.3: Improvements of TALYS (low intermediate energy reactions modelling code used for evaluation) to be able to handle actinides

WP5.4: Measurements of He and Be production in high energy protons reactions at NESSI/PISA + prep. spallation @ GSI. Improvements on high energy reaction models INCL and ABLA

In the coming years:

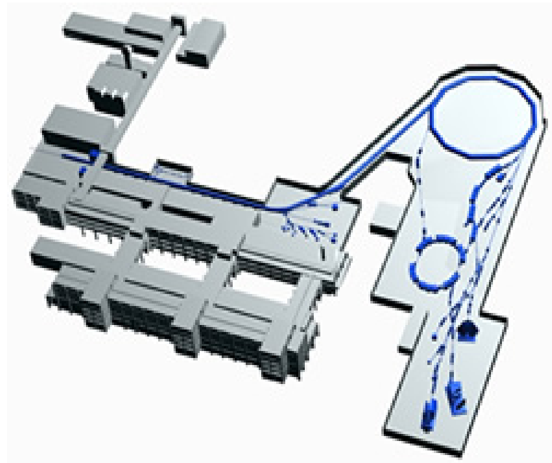
Complete evaluation of uncertainties for transmutation fuel cycles most relevant parameters & identification of additional data

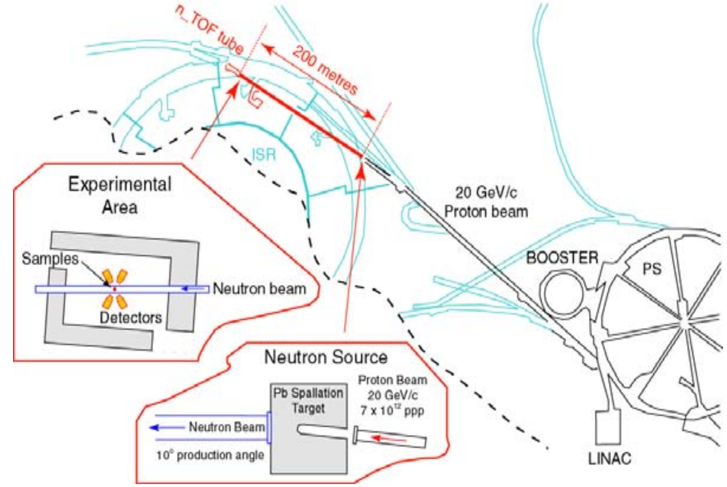
Completing the Pb and Bi data at low energies & Reliable Am and Cm data

Upgraded TALYS and model generated complete cross section and covariance libraries

Validated reliable high energy codes in MCNPX

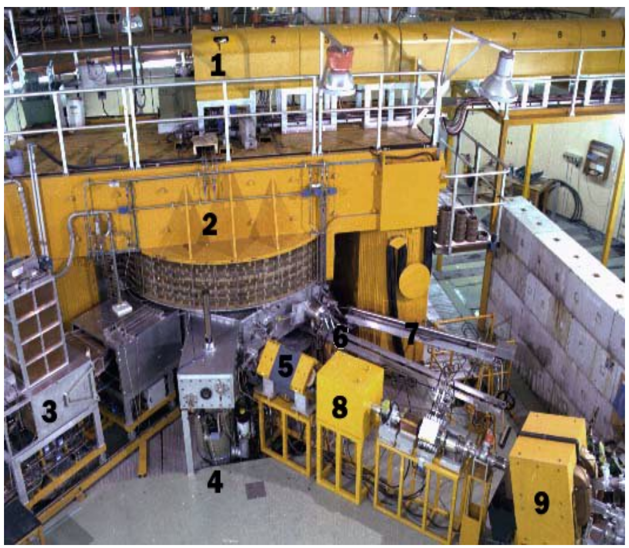
GSI @ Darmstadt (Germany)



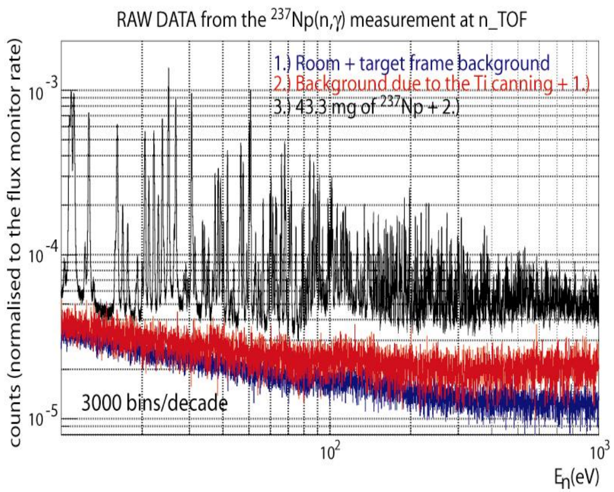


Gelina @ Geel (UE-Belgium)

nTOF @ CERN (Switzerland)



Cyclotron @ Uppsala (Sweden)



Neutron capture (n,γ) resonances in one actinide

and its TAS γ-calorimeter