Nuclear data at n_TOF for fundamental science and technological applications

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CIEMAT, on behalf of the n_TOF Collaboration

Workshop on Applications of High Intensity Proton Accelerators

Fermilab

20-X-2009

INTRODUCTION

New problems, New concepts, New materials or New procedures will need dedicated experimental validation.

The first step should be done in basic experiments at specialized experimental reactors that allow to identify and separate the different Phys/Chem phenomena: *E.g. Monitoring reactivity in ADS*

Today there are many problems where it is possible to perform high precision computer simulation. This applies in particular to neutronics, shielding and other core physics problems when nuclear data is accurate enough.

In this way, simulations can optimize and enhance the value of those experiments and even reduce the number of experiments needed

Today, high precision simulation is often cheaper and faster than the actual experiments, and normally provides much more details of the process – But it needs accurate basic (nuclear) data and always needs some experimental validation of its absolute accuracy.

The important role of simulation and basic data is in the SRA of SNETP

Some possible (new) roles of high precision simulations include:

Optimization of experiment (at any scale) planning

- Significant results will be obtained?
- Experimental setup/devices are appropriated
- Progress vs state of the art / Conclusive results ?

Exploitation (substitution) of experim. results and operational experience

- Understanding available data
- Interpolation of experimental results
- Exploration of interest for difficult/expensive possibilities before exper.
- Estimation of results for presently unreachable conditions

Guiding decision making

- Choices in early phases of the projects
- Choices with limited (expensive) experimental information

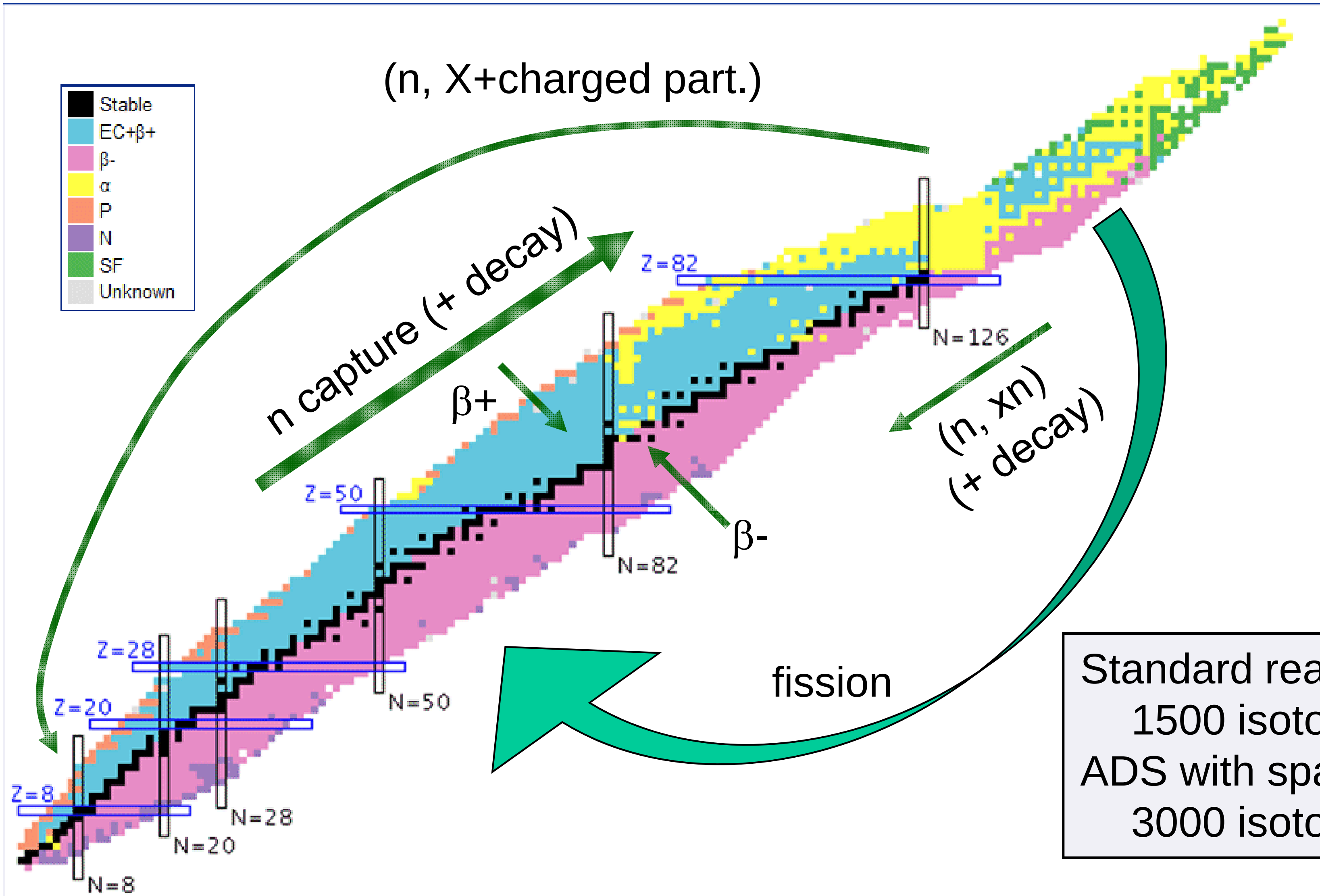
  E.g. ***SNETP Choices of alternative systems in 2012***

Education and Training

Accurate nuclear data an selected basic (neutronic) experiments are key pieces to reduce uncertainties and increase confidence for safety and design

Main reactions in a nuclear reactor or transmutation device

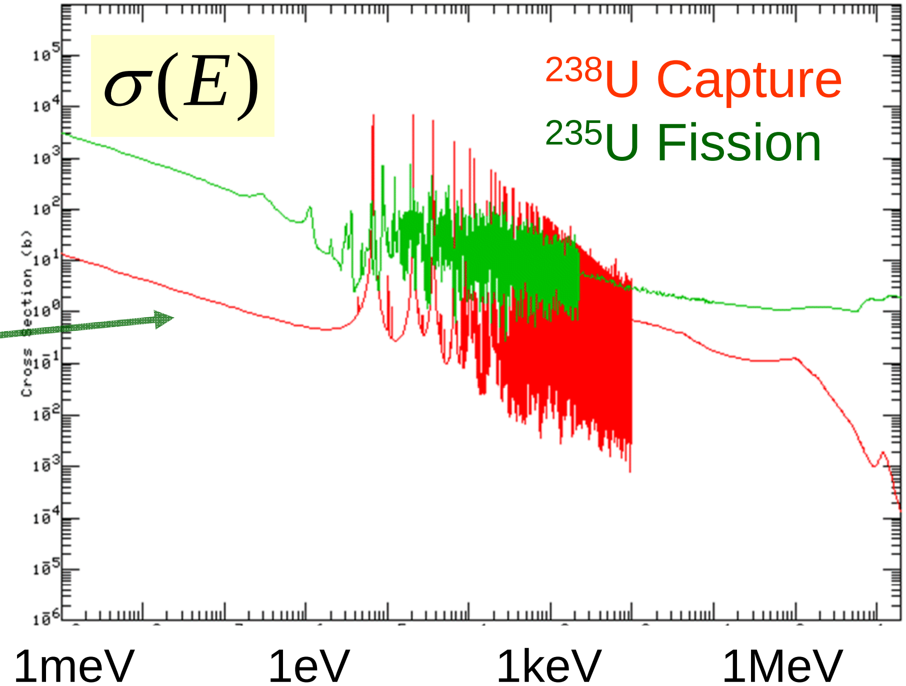
- n- induced fission (energy + wastes)
- neutron capture (activation + breeding)
- elastic and inelastic neutron scattering
- radioactive decay
- (n,xn), (n, charged particle), …



Standard reactor 1500 isotopes
ADS with spallation 3000 isotopes

$$Rate = \int n\,\sigma(E)\varphi(E)\,dE$$

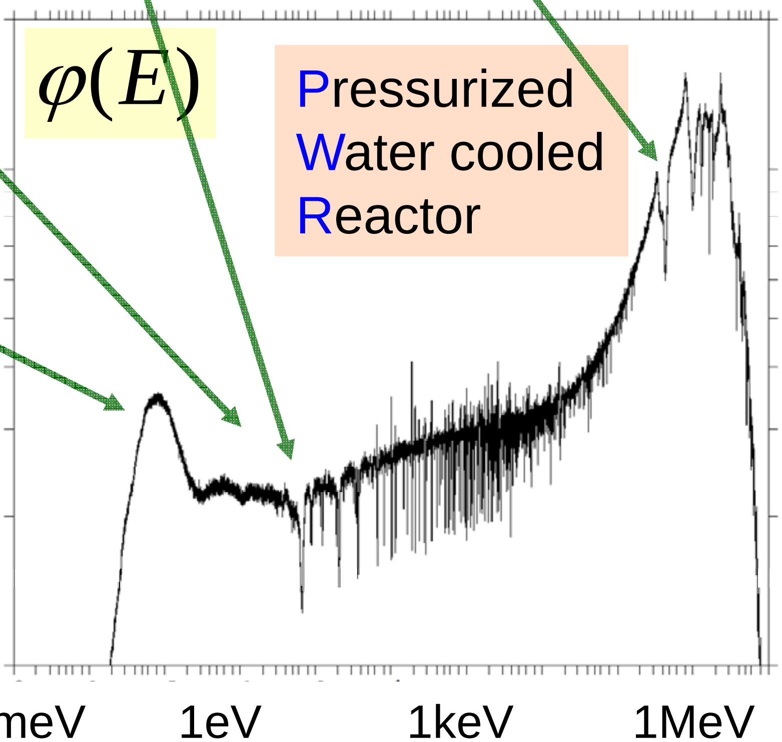
- n- induced fission
- neutron capture

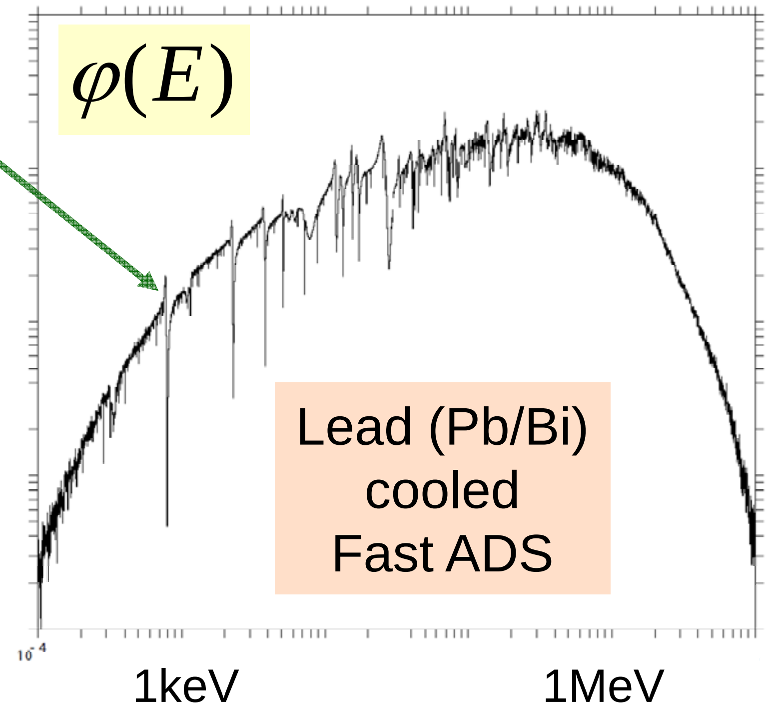


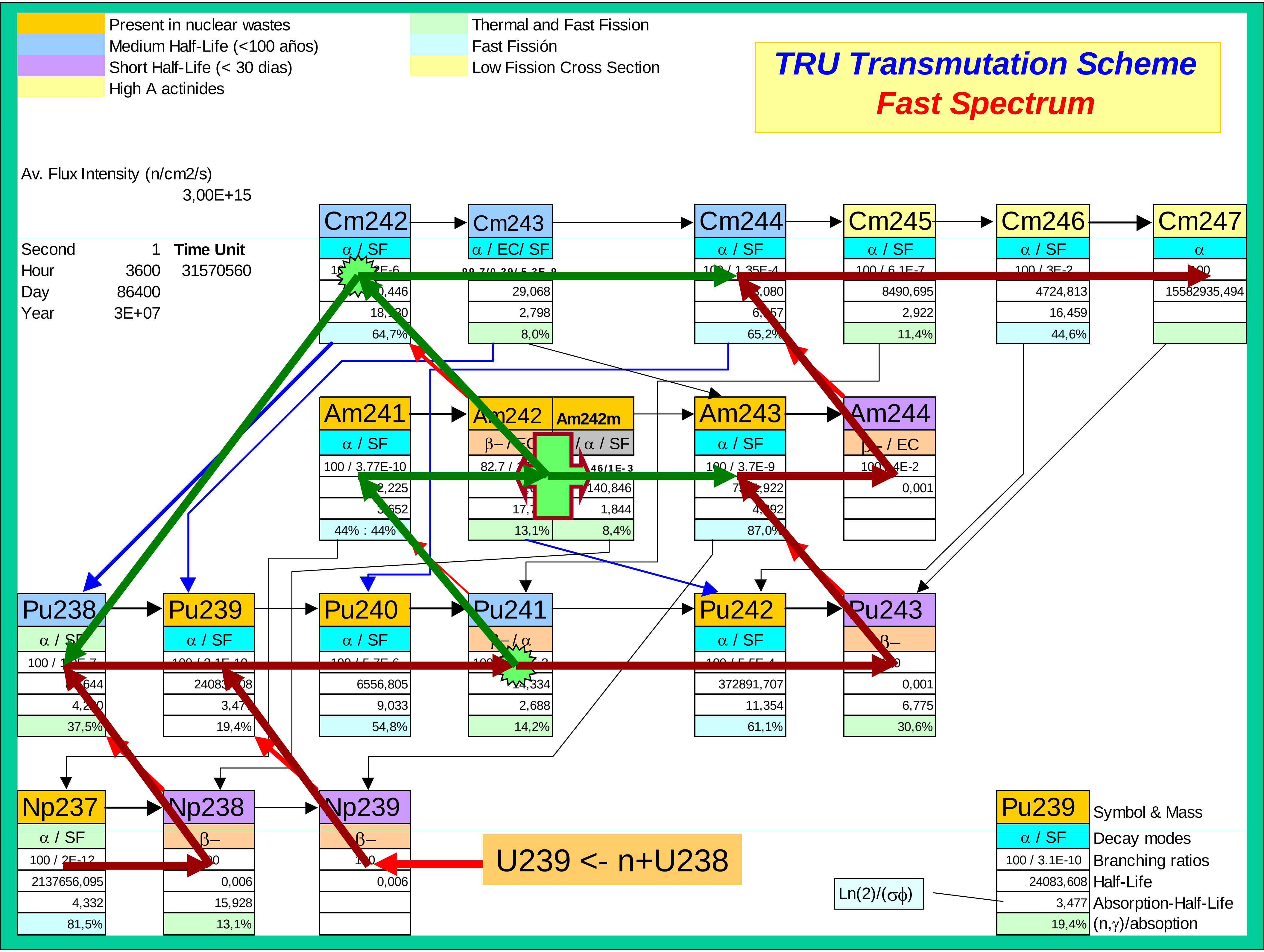
- elastic and inelastic neutron scattering

Resonances (absorption, elastic, inelastic,…)

Thermalization, Moderation







Present in nuclear wastes
Medium Half-Life (<100 años)
Short Half-Life (< 30 dias)
High A actinides
Thermal and Fast Fission
Fast Fissión
Low Fission Cross Section
TRU Transmutation Scheme
Fast Spectrum
Av. Flux Intensity (n/cm2/s)
3,00E+15
Second 1 Time Unit
Hour 3600 31570560
Day 86400
Year 3E+07
Cm242
α / SF
64,7%
Cm243
α / EC/ SF
29,068
2,798
8,0%
Cm244
α / SF
65,2%
Cm245
α / SF
100 / 6.1E-7
8490,695
2,922
11,4%
Cm246
α / SF
100 / 3E-2
4724,813
16,459
44,6%
Cm247
α
15582935,494
Am241
α / SF
100 / 3.77E-10
44% : 44%
Am242
Am242m
α / SF
17,
13,1%
140,846
1,844
8,4%
Am243
α / SF
87,0%
Am244
β– / EC
0,001
Pu238
37,5%
Pu239
α / SF
19,4%
Pu240
α / SF
6556,805
9,033
54,8%
Pu241
14,334
2,688
14,2%
Pu242
α / SF
372891,707
11,354
61,1%
Pu243
β–
0,001
6,775
30,6%
Np237
α / SF
100 / 2E-12
2137656,095
4,332
81,5%
Np238
β–
0,006
15,928
13,1%
Np239
β–
0,006
U239 <- n+U238
Ln(2)/(σϕ)
Pu239
α / SF
100 / 3.1E-10
24083,608
3,477
19,4%
Symbol & Mass
Decay modes
Branching ratios
Half-Life
Absorption-Half-Life
(n,γ)/absoption

Steps to identify data needs

- All technologies can profit from better data:
  Gen II, Gen III(+), Gen IV and P&T
- Industrial, Exp. Reactors and Fuel Cycle
- **Identify relevant parameters and target precision** and priorities on those parameters

End Users Group
Designers, Builders and Utilities.
Strategic choices.
Simulation tools
Internat. Coop/ NEA / IAEA

- Identify present uncetainties
- **Identify relevant basic data**:
  Isotopes, reactions, energy range

Uncertainty evaluation (M.C., Linear Deriv.)
Sensitivity analysis

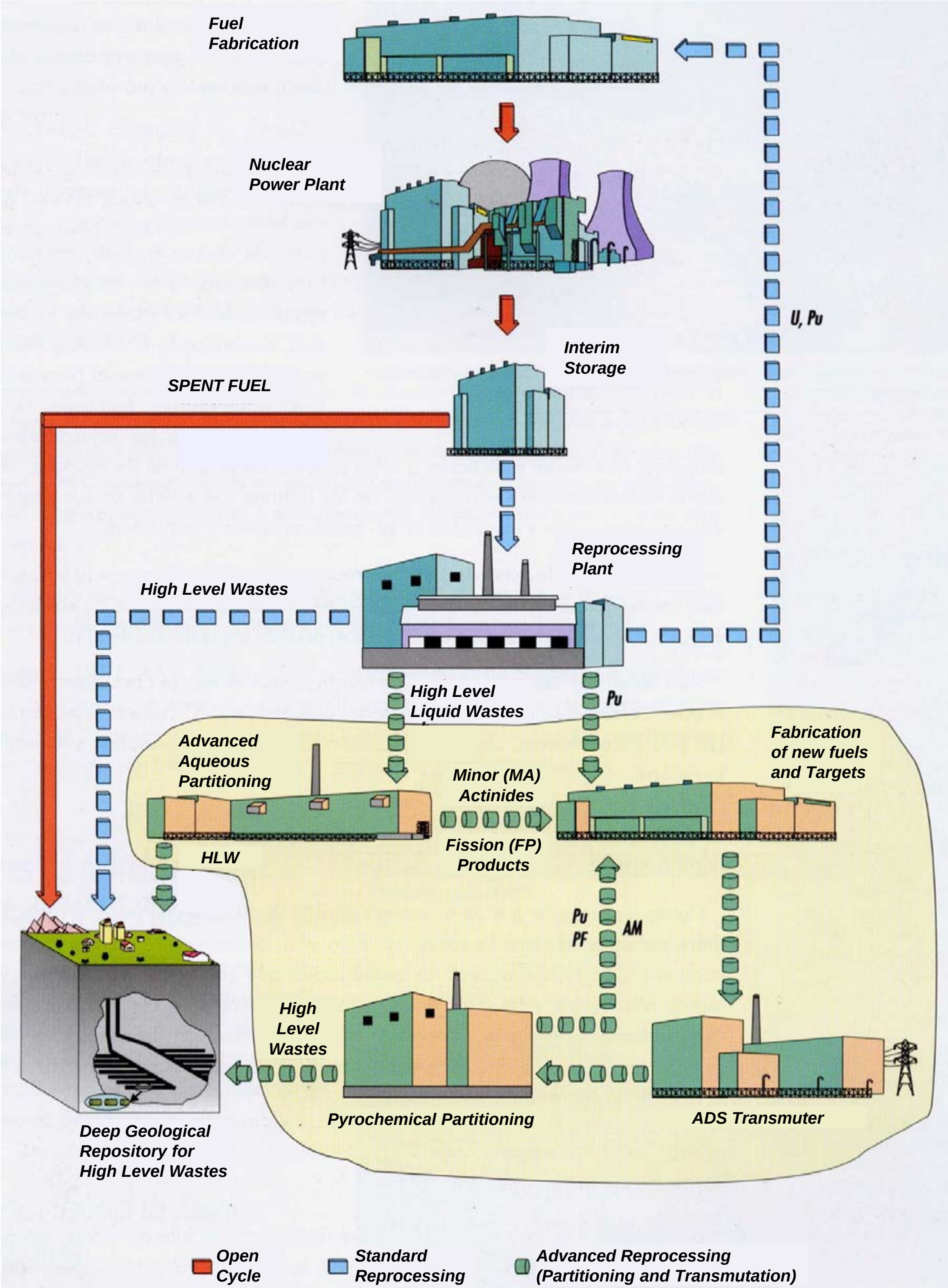
Required precision for the data
Priorities for different data

Estimate Experimental feasibility and timely availability of experim. facilities

Global optimization and **evaluation of required measurements / evaluations and needed accuracies**

Need for complete and reliable uncertainties and correlations.

Coordinate needs from different technologies/fuel cycle
Reevaluation of priorities and accuracies



Reactors: **(Δ<0.5%)**

Performance: Reaction rates, Power distribution, Flux, Energy Spectrum

Safety: Criticality, Feedbacks, Reactivity coeffs, Damage, Shielding

Waste: Isotopic evolution, activation

Storage, Reprocessing and Fabrication plants: (Δ<5%-10%)

Isotopic composition !!!

Radioactivity, Neutron emissions, Decay Heat,

Proliferation interest

Storage, Reprocessing and Fabrication plants: **(Δ<5%-10%)**

Isotopic composition !!!

Radioactivity, Neutron emissions, Decay Heat,

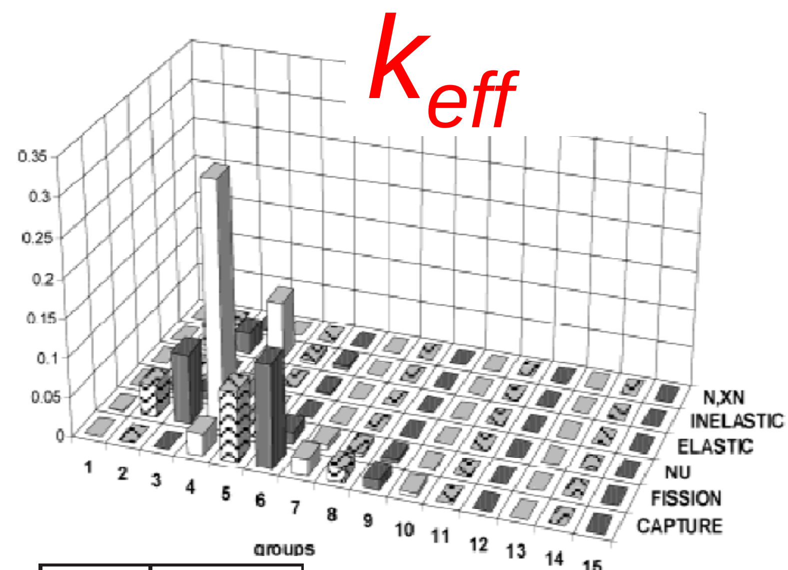
Proliferation interest

Radiotoxicity and Dose to Public and Environment

Effective capacity

Sensitivity analysis – ADS for Transmutation

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	$\boxed{1.32}$	$\boxed{1.12}$	0.38	—	0.22	—	1.79
^{242m}Am	0.01	0.09	0.03	—	0.01	—	0.10
^{243}Am	$\boxed{0.74}$	0.59	0.21	—	0.60	—	1.14
^{242}Cm	—	—	—	—	—	—	—
^{243}Cm	—	0.05	0.01	—	—	—	0.05
^{244}Cm	0.13	$\boxed{1.09}$	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	$\boxed{0.41}$	0.02	0.43
Bi	0.04	—	—	0.11	$\boxed{0.49}$	0.03	0.50
Total[a]	1.54	1.97	0.54	0.25	1.05	0.04	2.77



Group	(MeV)[a]
1	19.6
2	6.07
3	2.23
4	1.35
5	4.98e−1[c]
6	1.83e−1
7	6.74e−2
8	2.48e−2
9	9.12e−3
10	2.04e−3
11	4.54e−4
12	2.26e−5
13	4.00e−6
14	5.40e−7
15	1.00e−7

(from G. Aliberti et al., NSE 146, 13–50, 2004)

a) Upper limit of the group

NEA/WPEC-26.

One possible optimization for target accuracy for innovative systems using recent covariance data evaluations (BOLNA).
M. Salvatores and R. Jacqmin (Eds), NEA/WPEC-26.
ISBN 978-92-64-99053-1

Similar tables for each present or proposed future reactor

Still serious dependence on the reactor and fuel models and on the transmutation model (homogeneous) can slightly modify the target accuracy and details on the priority order

Table 30. ADMAB: uncertainty reduction requirements needed to meet integral parameter target accuracies

Isotope	Cross-Section	Energy range	Uncertainty (%) Initial	Required $\lambda=1$	Required $\lambda\neq1$ [a]
Pu238	σ_{fiss}	6.07 - 0.498 MeV	20	3	3
	ν	1.35 - 0. 183 MeV	7	3	3
Pu239	σ_{capt}	498 - 2.03 keV	12	4	3
	σ_{inel}	6.07 - 0.498 MeV	25	5	6
Pu240	σ_{capt}	183 - 67.4 keV	14	6	6
	σ_{fiss}	2.23 - 0.498 MeV	6	2	2
	ν	1.35 - 0.498 MeV	4	2	2
Pu241	σ_{capt}	1.35 - 0. 183 MeV	20	7	7
	σ_{fiss}	6.07 MeV-22.6 eV	15	2	2
Pu242	σ_{capt}	24.8 - 9.12 keV	35	10	10
	σ_{fiss}	6.07 - 0.498 MeV	20	4	4
Np237	σ_{capt}	498 - 0.454 keV	6	3	3
	σ_{fiss}	6.07 - 0.183 MeV	8	2	2
	σ_{inel}	2.23 – 0.183 MeV	25	5	6
Am241	σ_{capt}	1.35 MeV- 0.454 keV	8	2	2
	σ_{fiss}	6.07 – 0.183 MeV	10	1	1
	ν	6.07 - 1.35 MeV	2	1	1
	σ_{inel}	6.07 – 0.183 MeV	25	4	5
Am242m	σ_{fiss}	1.35 MeV- 9.12 keV	17	5	5
Am243	σ_{capt}	1.35 MeV- 0.454 keV	10	2	2
	σ_{fiss}	6.07 - 0.498 MeV	10	2	2
	σ_{inel}	6.07 MeV- 24.8 keV	40	2	3
Cm242	σ_{fiss}	6.07 MeV- 67.4 keV	55	26	26
Cm243	σ_{fiss}	1.35 MeV- 67.4 keV	50	8	8
Cm244	σ_{capt}	498 -9.12 keV	20	6	6
	σ_{fiss}	6.07 MeV- 67.4 keV	45	2	2
	ν	6.07 – 0.183 MeV	10	1	1
Cm245	σ_{fiss}	6.07 MeV- 0.454 keV	45	3	3
Fe56	σ_{capt}	183 - 0.454 keV	12	5	3
	σ_{inel}	6.07 - 0.498 MeV	20	2	2
Zr90	σ_{inel}	6.07 - 2.23 MeV	18	3	4
N15	σ_{el}	2.23 MeV - 67.4 keV	5	1	1
Pb	σ_{capt}	9.12 - 2.03 keV	20	20	14
	σ_{inel}	6.07 - 2.23 MeV	12	3	4
Bi209	σ_{inel}	2.23 - 0.498 MeV	34	3	3

[a] See Table 24 for $\lambda\neq1$, case A

Important isotopes for Transmutation Fuel Cycles: The multi-recycling point of view

Report of the Numerical results from the Evaluation of the nuclear data sensitivities, Priority list and table of required accuracies for nuclear data. E. Gonzalez-Romero (Ed), NUDATRA Deliverable D5.11 from IP-Eurotrans

Isotopes	Uncertainty in the abundance % Burnup (GWd/t) 150	500	800	Important for:			
^{234}U	4.6	16.1	32.4	T	DH		
^{235}U	13.1	18.4	15.5	T			
^{236}U	1.8	7.6	12.6	T			
^{237}Np	6.3	23.7	28.1	T			
^{238}Pu	4.3	10.8	19.3	T	DH		R
^{239}Pu	4.6	12.9	17.8	T	DH		R
^{240}Pu	2.0	7.0	14.4	T	DH		R
^{241}Pu	8.2	14.7	17.0	T			
^{242}Pu	2.1	7.9	16.2	T	DH		R
^{241}Am	7.2	20.7	26.0	T	DH		R
^{242m}Am	12.8	28.6	34.4	T			
^{243}Am	6.6	15.6	20.2	T	DH		R
^{242}Cm	10.7	7.7	15.6	T	DH		
^{243}Cm	23.3	32.6	35.7				
^{244}Cm	6.0	13.3	19.1	T	DH	N	R
^{245}Cm	13.3	18.8	16.3	T	DH		R
^{246}Cm	7.5	21.7	31.5	T	DH	N	R
^{247}Cm	15.4	27.2	31.6	T			
^{248}Cm	6.4	19.8	31.4			N	
^{250}Cf	31.9	28.9	36.9			N	
^{252}Cf	52.4	46.1	48.9			N	

T= Transmutation efficiency
DH= Decay Heat load
N = Neutron emission
R = Radiotoxicity

Identifying and setting priorities of Nuclear data for applications: An international endeavor

- Applications set the problems to be analyzed and the required accuracies for the simulation.
- Detailed uncertainty and covariance propagation to evaluate the accuracy.
- Sensitivity analysis identify the relevance of each data for each isotope/reaction/energy on the most significant parameters
- Linear Optimization with expert assessment of “cost” (experimental difficulties) to set priorities

Efforts coordinated by dedicated expert groups of NEA/OECD, IAEA, and dedicated EU framework programs

EU support and demand for nuclear data measurements:

- Clear and repeated demand from the Nuclear Waste community, Sustainability of Nuclear Energy (Resources, Safety, Waste) by EU Framework Program calls:
  - FP5: nTOF_ND_ADS (*start of n_TOF facility at CERN*)
  - FP6: NUDATRA (inside EUROTRANS),
  - FP6: EFNUDAT (Transnat. Access) + CANDIDE (Roadmap for ND)
  - FP7: ANDES proposal to WP2009
- Collaboration with other measurements at USA, Japan, Russia.

One EU call on Nuclear Data for each FP (FP5-FP7),
n_TOF measurements in all of them

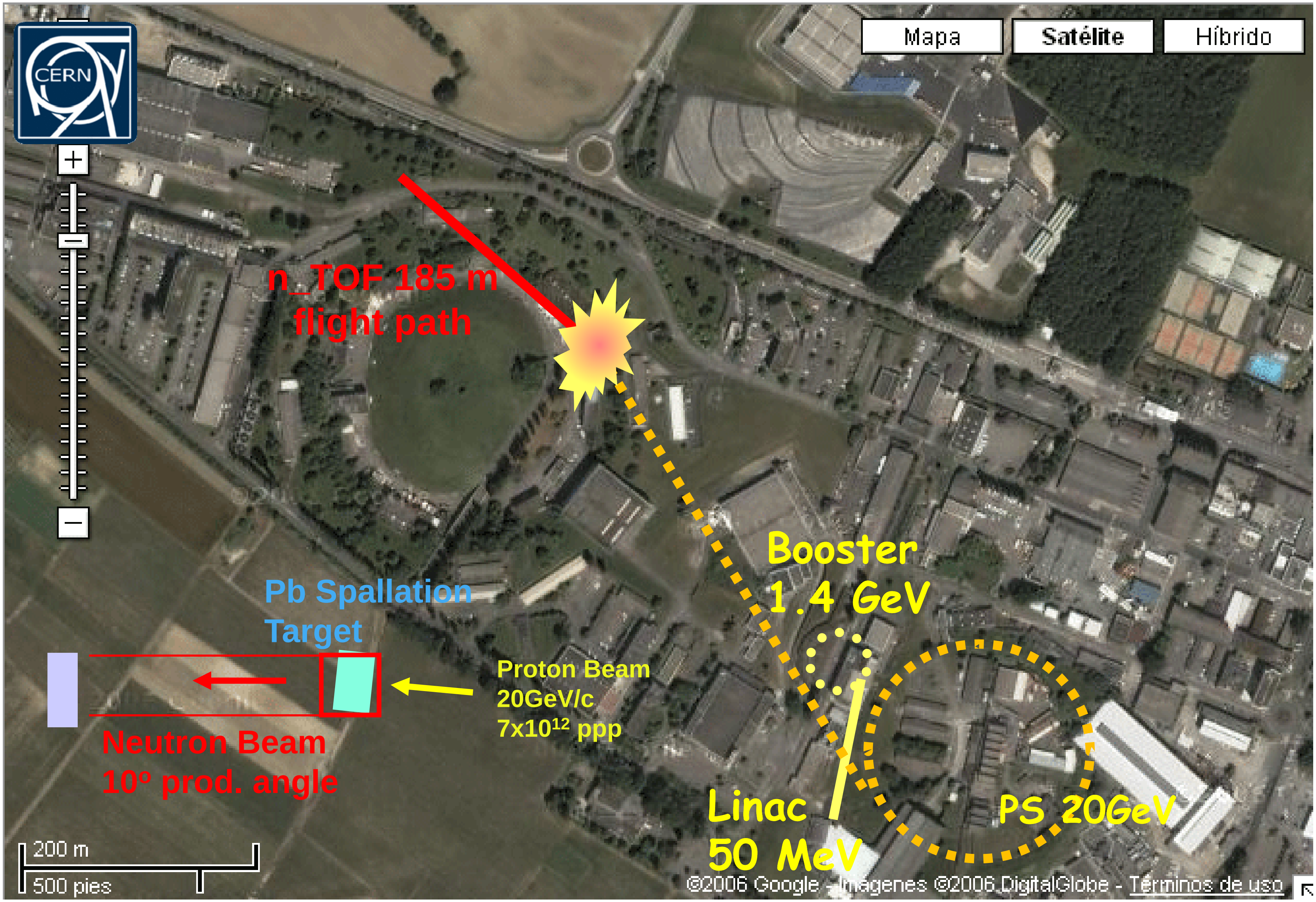
n_TOF Collaboration

A group of 23 institutions from 14 countries (today)
(A, D, Ch, Cz, E, F, I, Gr, P, Po, Ro, India, Jp, Ru)
working together from 1998 to measure
Precision Neutron cross sections for
- Nuclear Astrophysics
- Sustainable Nuclear Technologies
- Basics Physics

using the neutron time of flight facility at CERN

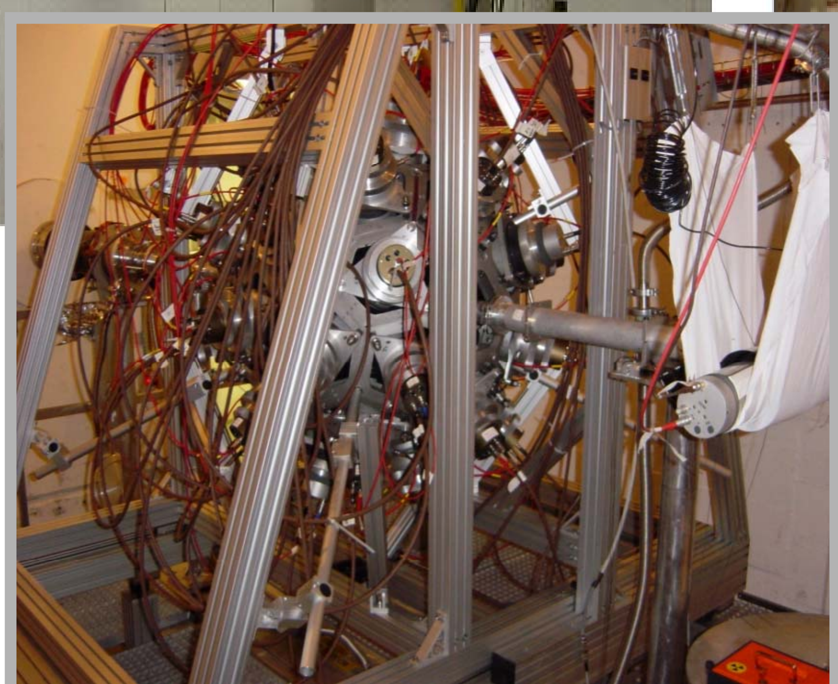
A nice social experiment of joining communities that discovered that most cross section needs and interesting measurements were common and that now share resources (shifts, detectors, analysis…) and results for each single measurement at CERN.

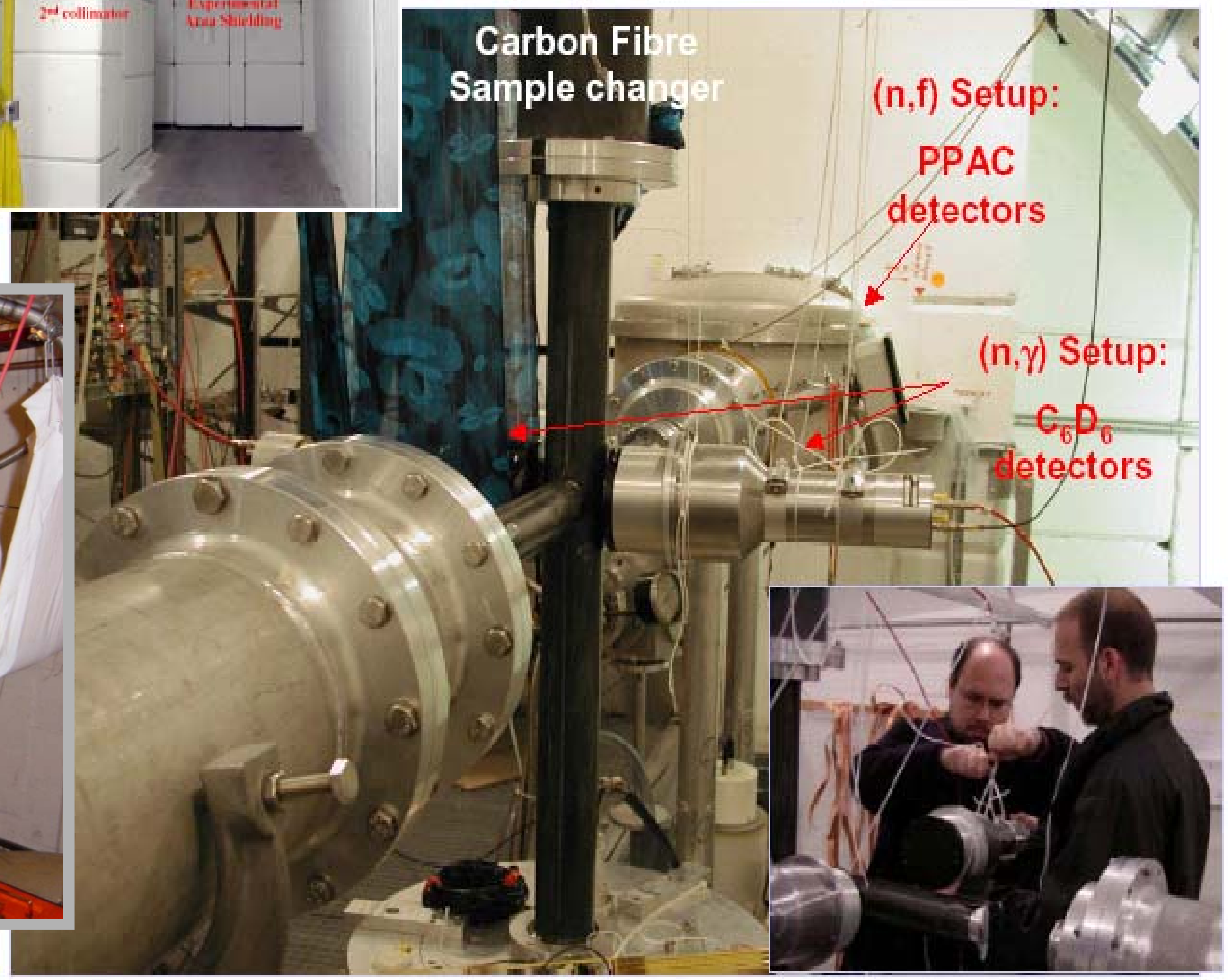
2000: A Google view of n_TOF



2001: The real world from inside

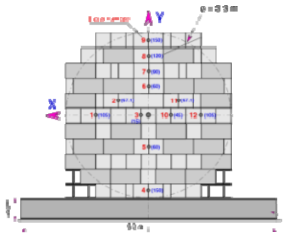
- n_TOF commissioned in 2001-2002





www.cern.ch/n_TOF

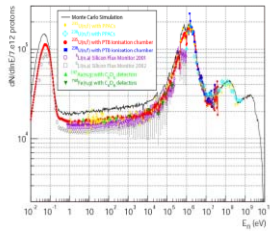
n_TOF timeline



1995-1997 **TARC** experiment

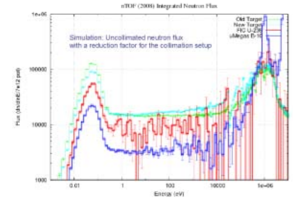
May 1998 **Feasibility** CERN/LHC/98-02+Add

2000 **Commissioning**



2008 **New Target** construction

May 2009 **Commissioning**

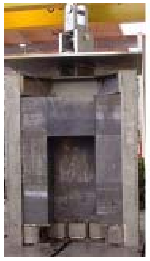


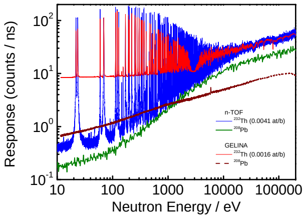
1996 **2009**

1997 **Concept** by C.Rubbia CERN/ET/Int. Note 97-19

Aug 1998 **Proposal** submitted

1999 **Construction** started





2001-2004 **Phase I**
Isotopes
Capture: 25
Fission: 11
Papers: 21
Proc.: 51
Doc: 150

2004-2007 **Problem** Investigation

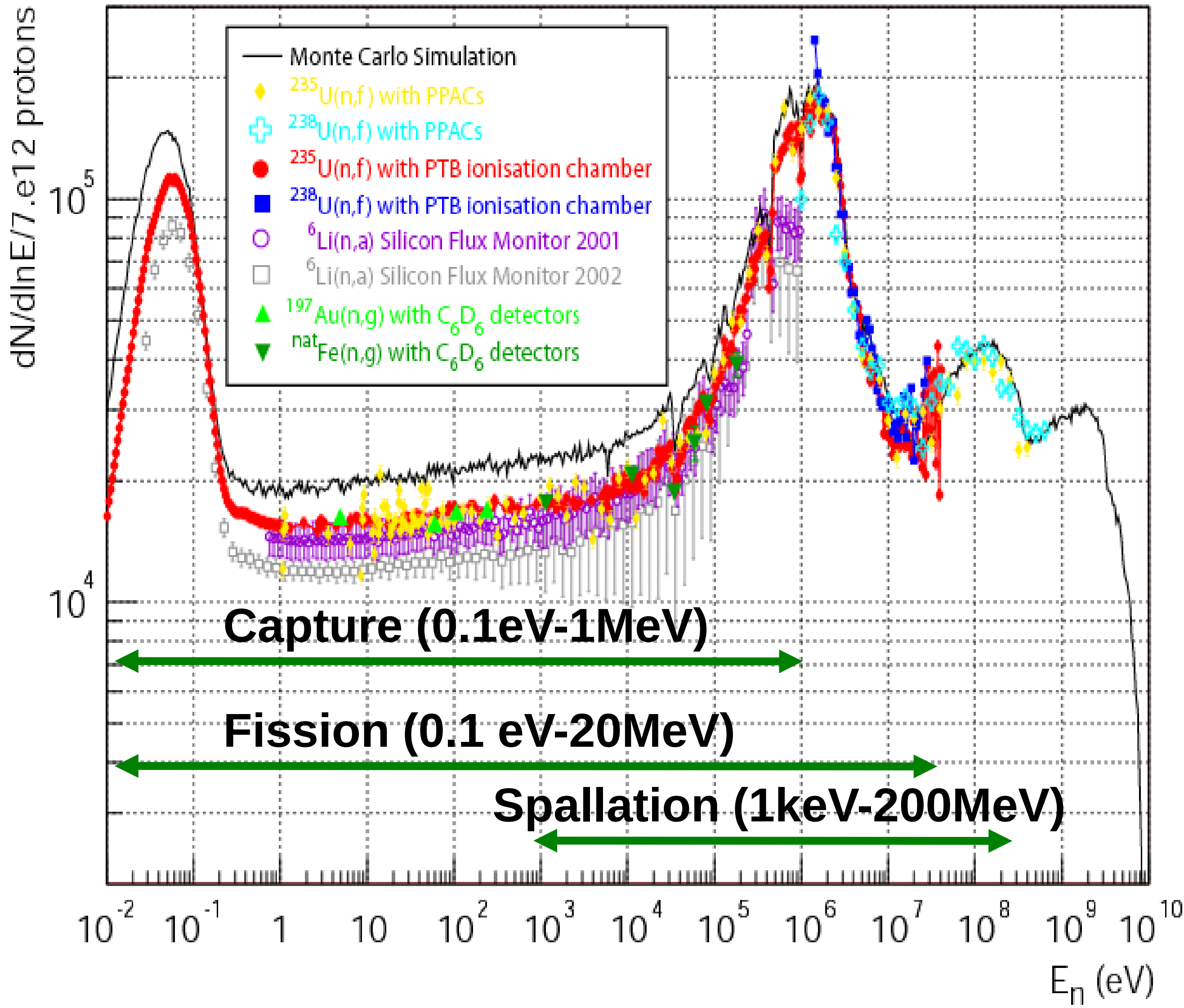
2009 **Phase II**

2010 **Upgrades:**
Borated-H_2O
Second Line
Class-A

n_TOF beam characteristics

- Wide energy range
- High instantaneous n- flux
- High resolution
- Low ambient background
- Low repetition frequency
- Favorable duty cycle for radioactive samples.

2^{nd} collimator ϕ=1.8 cm (capture mode)



The neutron fluence in EAR-1

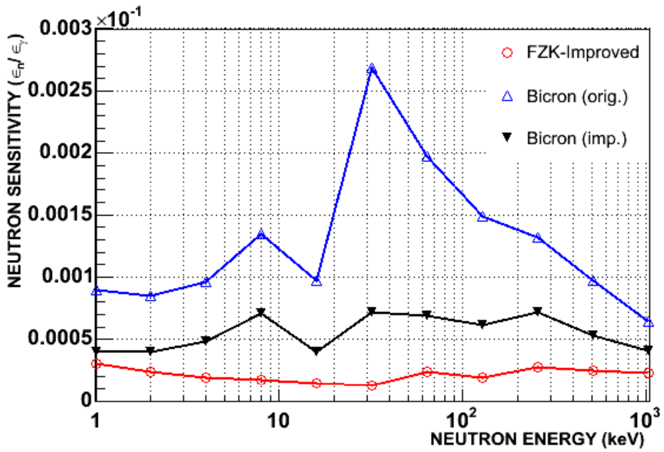
Energy range	Uncollimated [n/pulse/cm2]	Capture mode [n/pulse]	Fission mode [n/pulse]
< 1 eV	**2.0E+05**	**3.1E+05**	**2.0E+06**
1 eV - 10 eV	2.7E+04	4.5E+04	2.9E+05
10 eV - 100 eV	2.9E+04	4.7E+04	3.1E+05
100 eV - 1000 eV	3.0E+04	5.1E+04	3.3E+05
1 eV - 1 keV	**8.6E+04**	**1.4E+05**	**9.3E+05**
1 keV - 10 keV	3.2E+04	5.4E+04	3.6E+05
10 keV - 100 keV	3.9E+04	7.1E+04	4.7E+05
100 keV - 1000 keV	1.1E+05	2.3E+05	1.5E+06
1 keV - 1 MeV	**1.8E+05**	**3.5E+05**	**2.3E+06**
1 MeV - 10 MeV	8.3E+04	2.4E+05	1.7E+06
10 MeV - 100 MeV	2.8E+04	7.2E+04	5.1E+05
> 100 MeV	4.4E+04	1.2E+05	5.6E+05
1 MeV - > 100 MeV	**1.6E+05**	**4.4E+05**	**2.7E+06**
Total	**6.2E+05**	**1.2E+06**	**8.0E+06**

Note: 1 pulse is 7E+12 protons. Collimated fluence (fission and capture modes) is integrated over the beam surface.

One of the best worldwide facilities for radioactive samples: Complementary to GELINA (EU JRC-IRMM@Geel, Belgium)

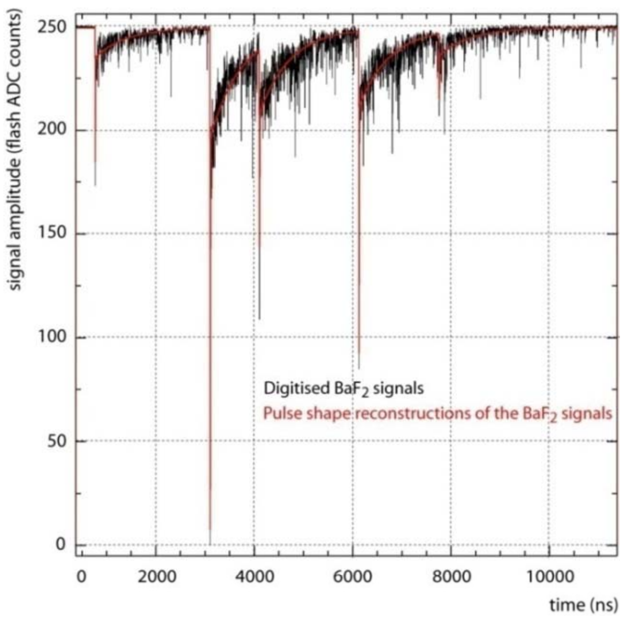
n_TOF: Advanced DAQ and detectors

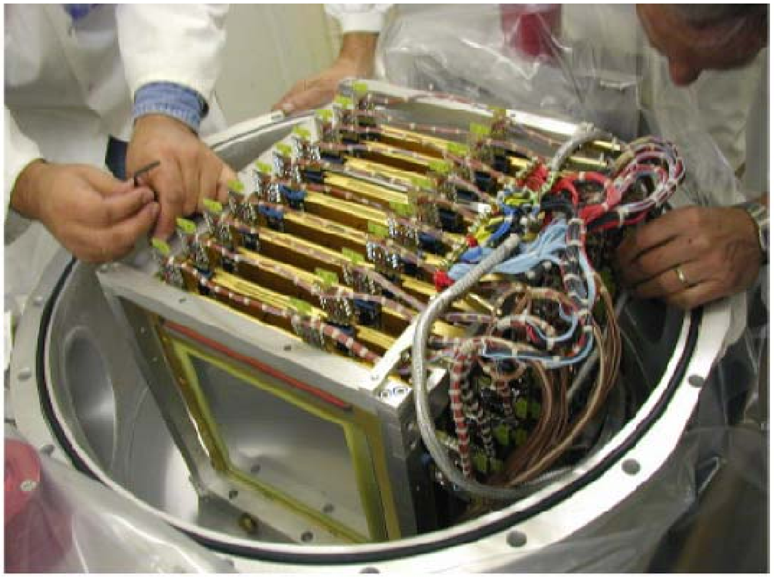
+ Precision simulations (Geant4, MCNPX, Fluka): Utilization and Validation



Low n-sensitivity capture detectors

Total Absorption Segmented Calorimeter





First FADC DAQ for T.o.F facilities

Fission detector reconstructing F.F. trajectories

n_TOF experiments
2000-2004 measurements

Capture

^{151}Sm

^{204,206,207,208}Pb, ^{209}Bi

^{232}Th

^{24,25,26}Mg

^{90,91,92,94,96}Zr, ^{93}Zr

^{139}La

^{186,187,188}Os

^{233,234}U

^{237}Np, ^{240}Pu, ^{243}Am

Fission

^{233,234,235,236,238}U

^{232}Th

^{209}Bi

^{241,243}Am,

Sensitivity analysis

NSE 146, 13–50 (2004))

NEA/WPEC-26 (2008)

NUDATRA Deliverable D5.11 of IP-Eurotrans (2009)

Other types of reactor & cycles (Th-U, PWR)

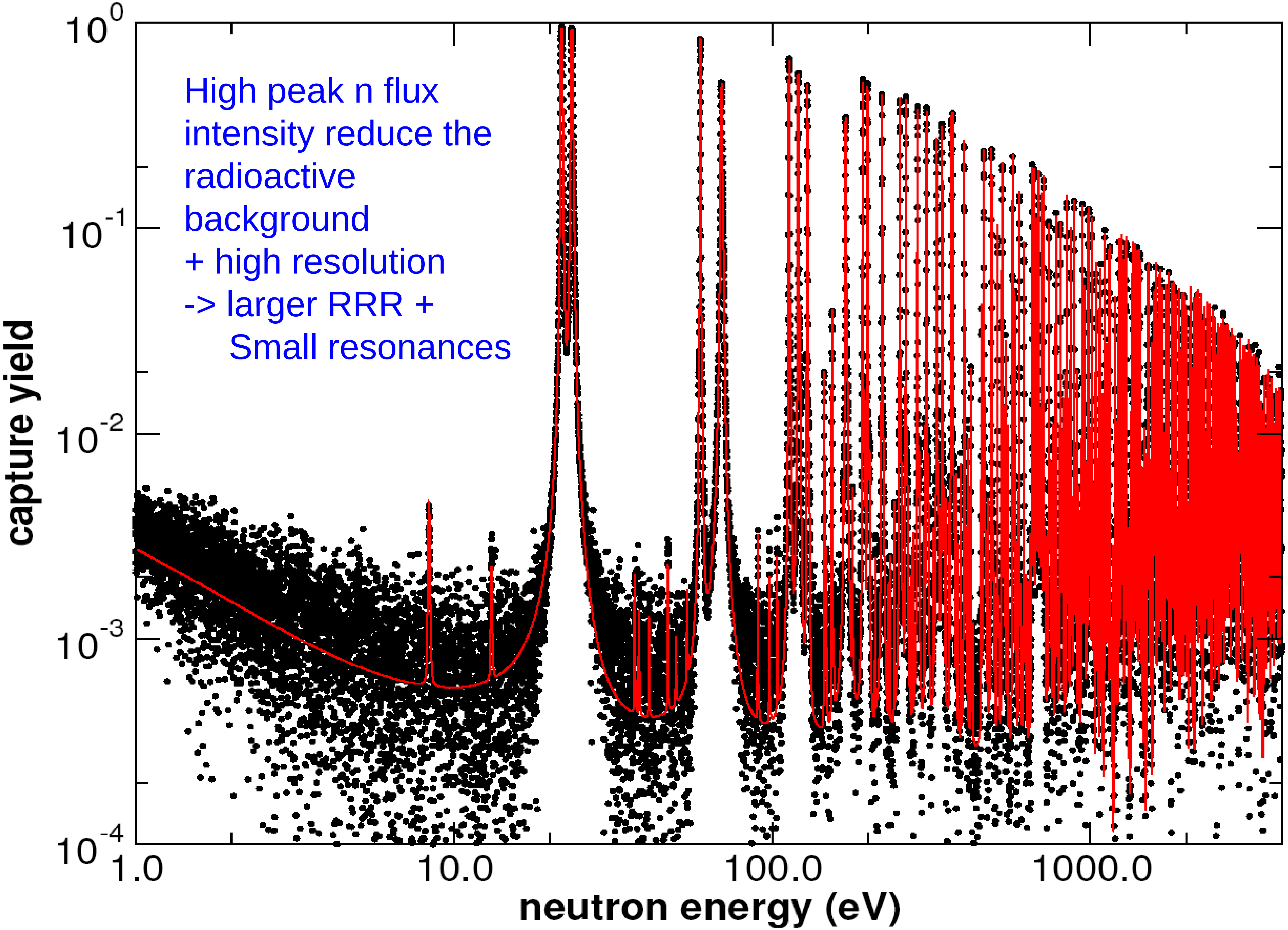
Challenge for the first n_TOF campaign:
- To improve the quality of previous measurements
- Demonstrate feasibility of challenging isotopes

All data first published then stored in the EXFOR database

n_TOF measurements are designed to obtain the maximum information for basic nuclear physics

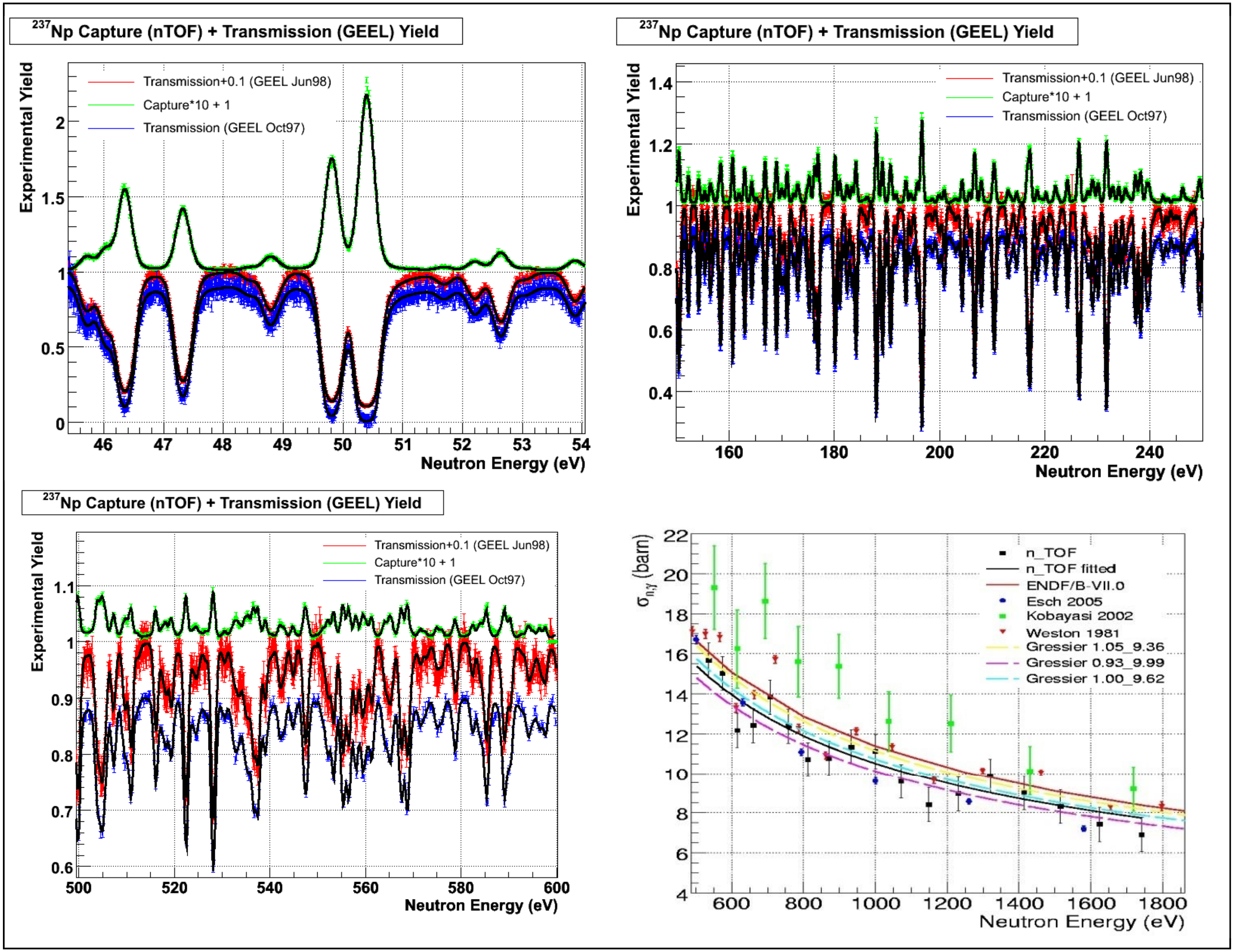
- **Nuclear structure models**
  - Improving the accuracy and statistical information from resolved resonances (RR)
    - Extending the RR region
    - Level densities and criteria for the estimation of missed resonances
  - Photon Strength functions from the TAC
  - Direct vs. compound nuclei mechanism
  - Measurements in closed-shell nuclei and light nuclei (Pb, Mg,…)
- **Fission: towards a better understanding of the process**
  - High resolution measurements over large energy ranges in the same setup
  - FF kinetic energy and angular distributions determination
  - Fissile (^{233}U, ^{235}U, ^{245}Cm) and Fissionable isotopes (^{234}U, ^{232}Th, …)
  - Sub-threshold, direct and multiple chance fission
  - Fine structures in the fission barriers (outer fission barrier and hyper-deformation of the fission potential)
- **Basic reactions**
  - n-n scattering by ^{2}H(n,np)n
  - (n, l.c.p.) reactions (l.c.p. = light charged particles like p, α, ^{3}H, Li,…)

High resolution low backgr. of radioactive samples: ^{232}Th by C_6D_6



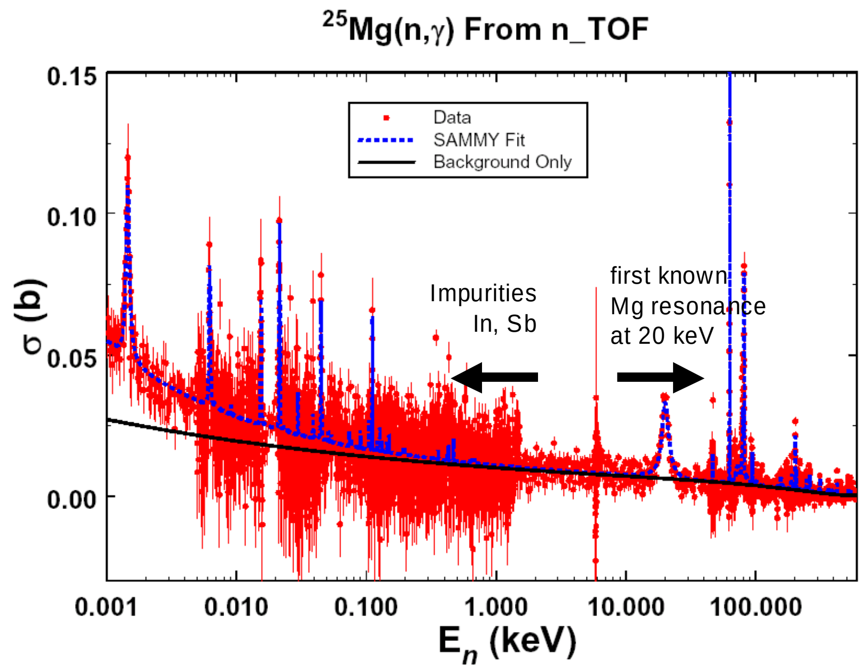
High resolution low backgr. of radioactive samples: ^{237}Np TAC

n_TOF capture
+
GELINA transmission
=
One of the best measur. made at Europe.

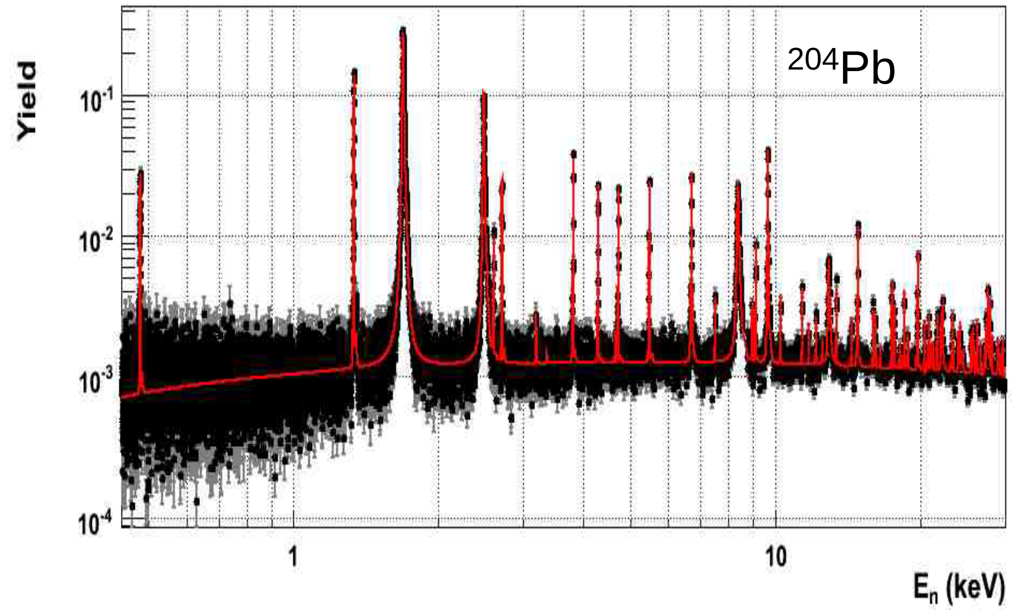


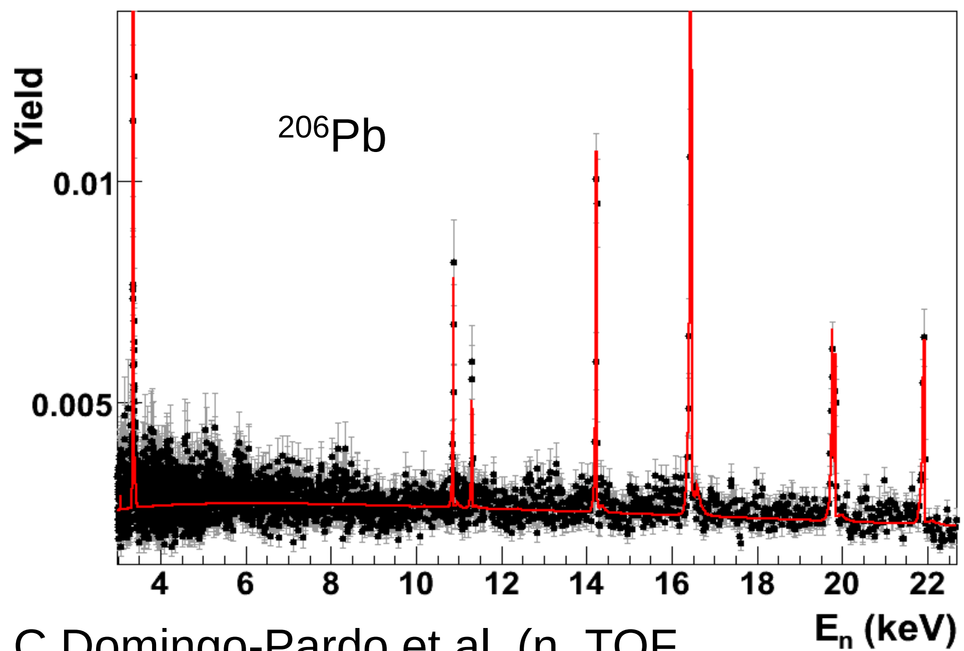
C. Guerrero et al. (n_TOF Collaboration), Proc. Int. Conf. Nuc. Data for Sci. and Tech. 2007, Nice.

High resolution low capture cross section samples: C_6D_6 + TAC



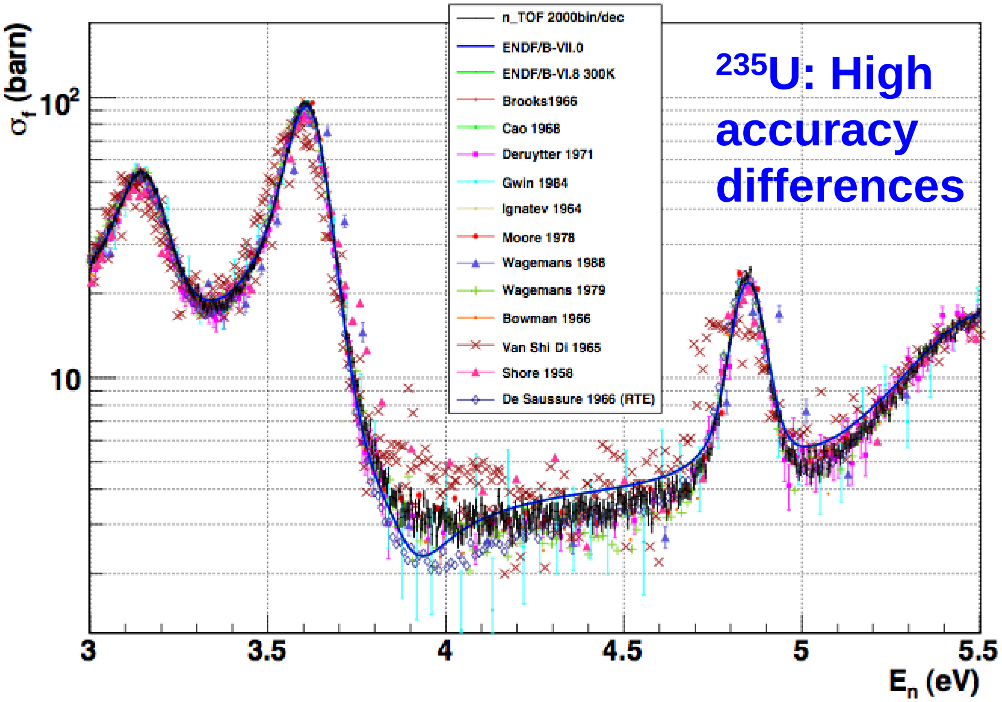
M.Heil (FZK), Nuclei in the Cosmos IX, Geneva 2005

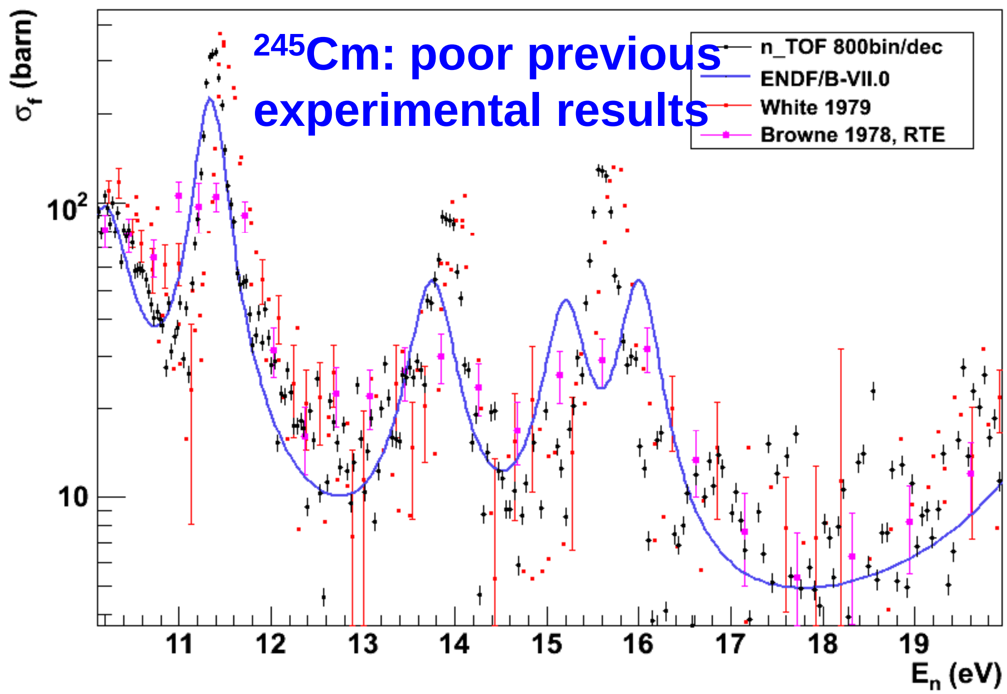


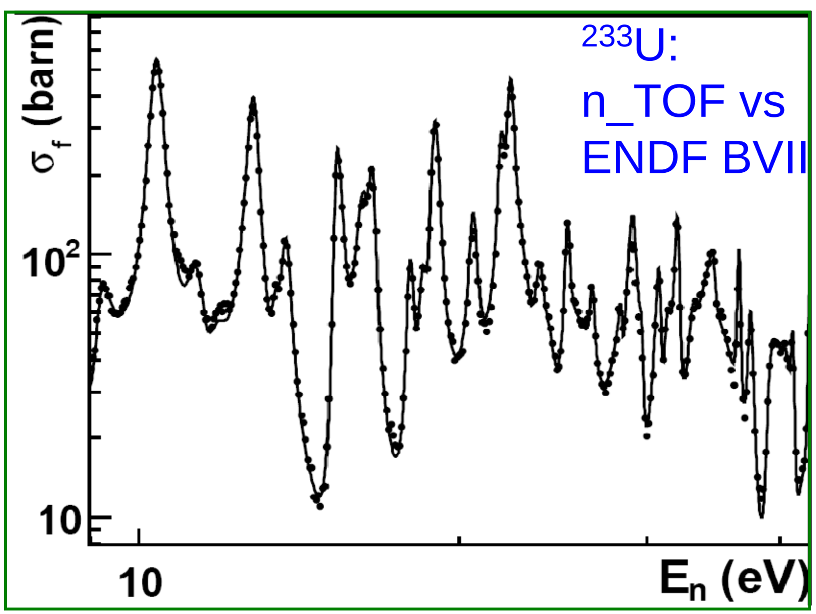


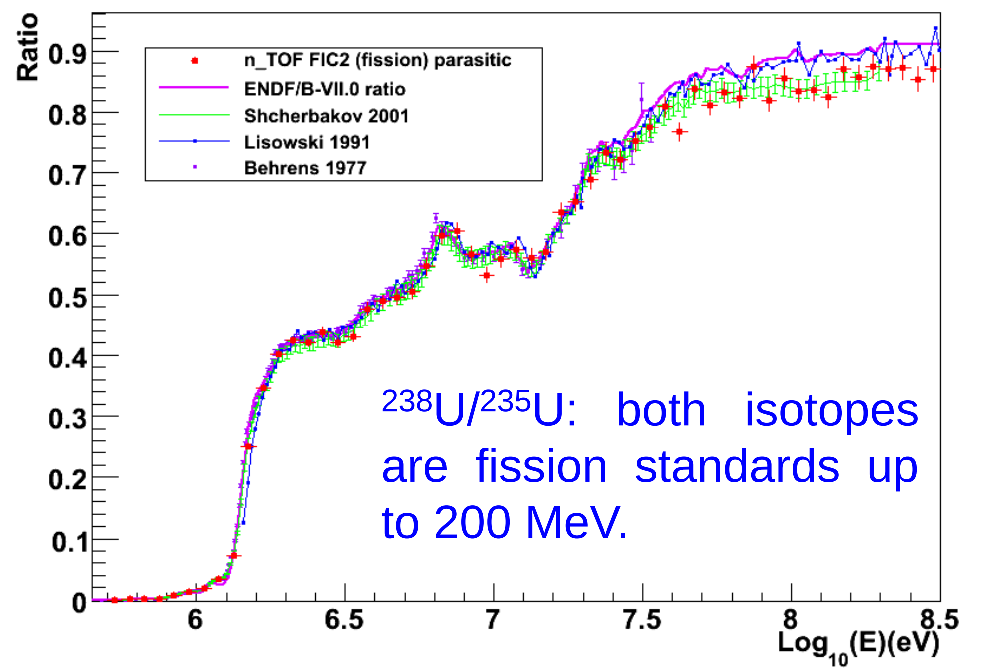
C.Domingo-Pardo et al. (n_TOF Collaboration), Phys. Rev. C 74/75, 2006/7

High resolution and large energy range accurate fission data



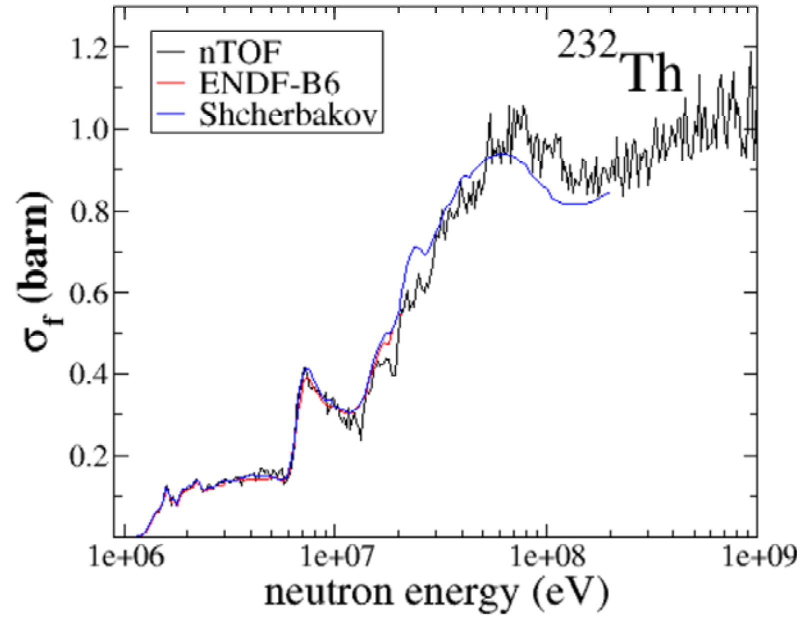


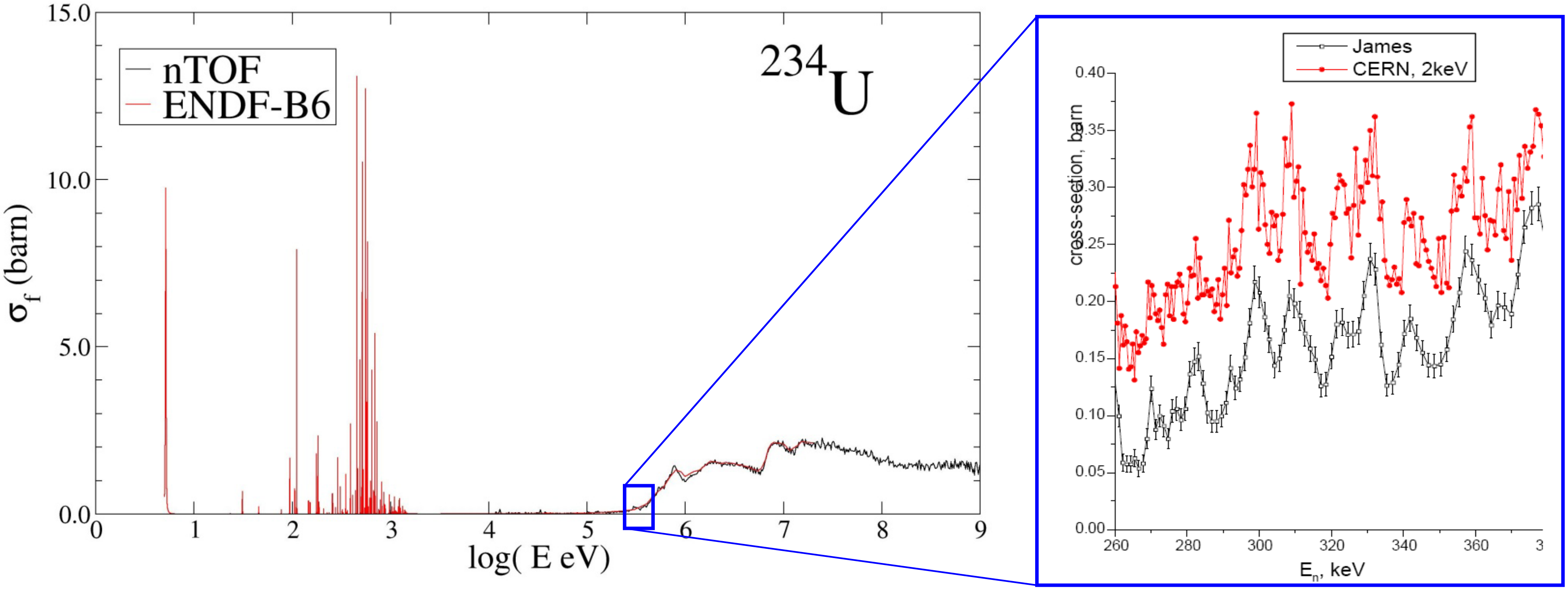




High resolution and large energy range accurate fission data

Fine structures in the fission barriers (outer fission barrier and hyper-deformation of the fission potential)





n_TOF_ph2 experiments
Current program

Reaching required accuracy indicated by the sensitivity analysis : (5-10%) M.A. and (2%-5%) for main isotopes.

Capture

Stable Isotopes:

Mo, Bi: Materials for fuel matrix (Mo) and coolant (Bi)

Fe, Ni, Zn, ^{79}Se: Structural materials

^{234,236,238}U, ^{231}Pa: Th/U fuel cycle

^{239,240,242}Pu, ^{241,243}Am, ^{245}Cm: transmutation of minor actinides

Fission

^{231}Pa, ^{234,235,236,238}U : Safety and sustainability of nuclear energy

^{241}Pu, ^{241,243}Am, ^{244}Cm, ^{245}Cm : transmutation of minor actinides

^{234}U: study of vibrational resonances below the barrier

Other

n-n scattering by ^{2}H(n,np)n

(n, lcp) (lcp = light charged particles like p, α, ^{3}H, Li,…)

Sensitivity analysis

NEA/WPEC-26 (2008)

NUDATRA Deliverable D5.11 of IP-Eurotrans (2009)

Other types of reactor & cycles (Th-U, PWR)

n_TOF_ph2 experiments

Main upgrades from n_TOF

- New target, target cooling station and ventilation system (improving safety and reliability)
- New fission detectors to measure more physical magnitudes (angle, kinetic energy)
- New capture samples design for the calorimeter with lower beam scattered background
- The possibility to have independent moderator and cooling circuits:
    - Moderation by borated water to reduce in-beam γ background.

Further upgrades ahead:

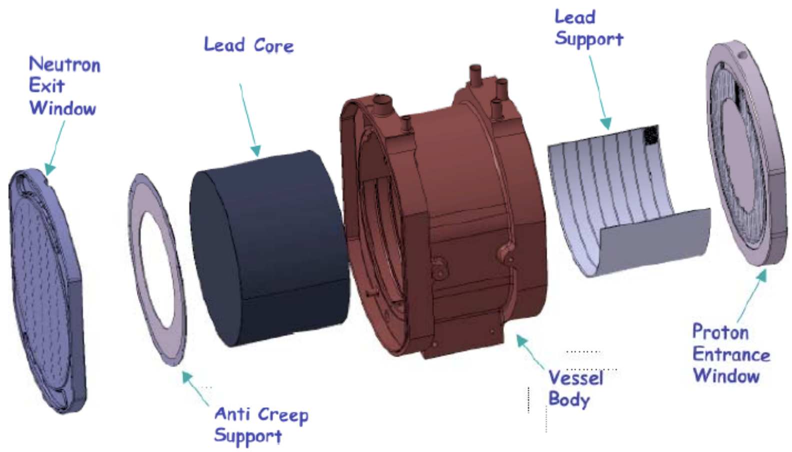
- convert EAR1 to Class A/B Rad. Laboratory
- Building a new short flight path and the associated experimental area EAR2 (also expected to be Class A Rad. Laboratory)

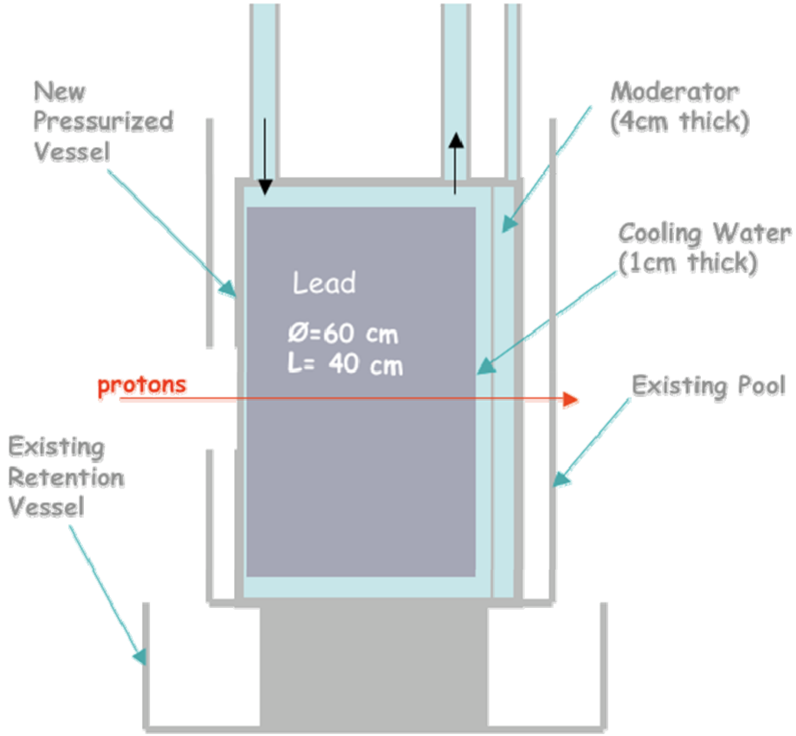
Most measurements proposed before can be done with the facility as it is (3 first upgrades), however some fission targets are conditioned by R.P. rules and will require to upgrade the Experimental Area to a Class A/B Rad. Laboratory.

The 2008 Upgrade

- Design and build of new spallation target and pit lay-out
- New cooling station
- New ventilation system
- Additional shielding and radio-protection actions
- Updated detectors and DAQ

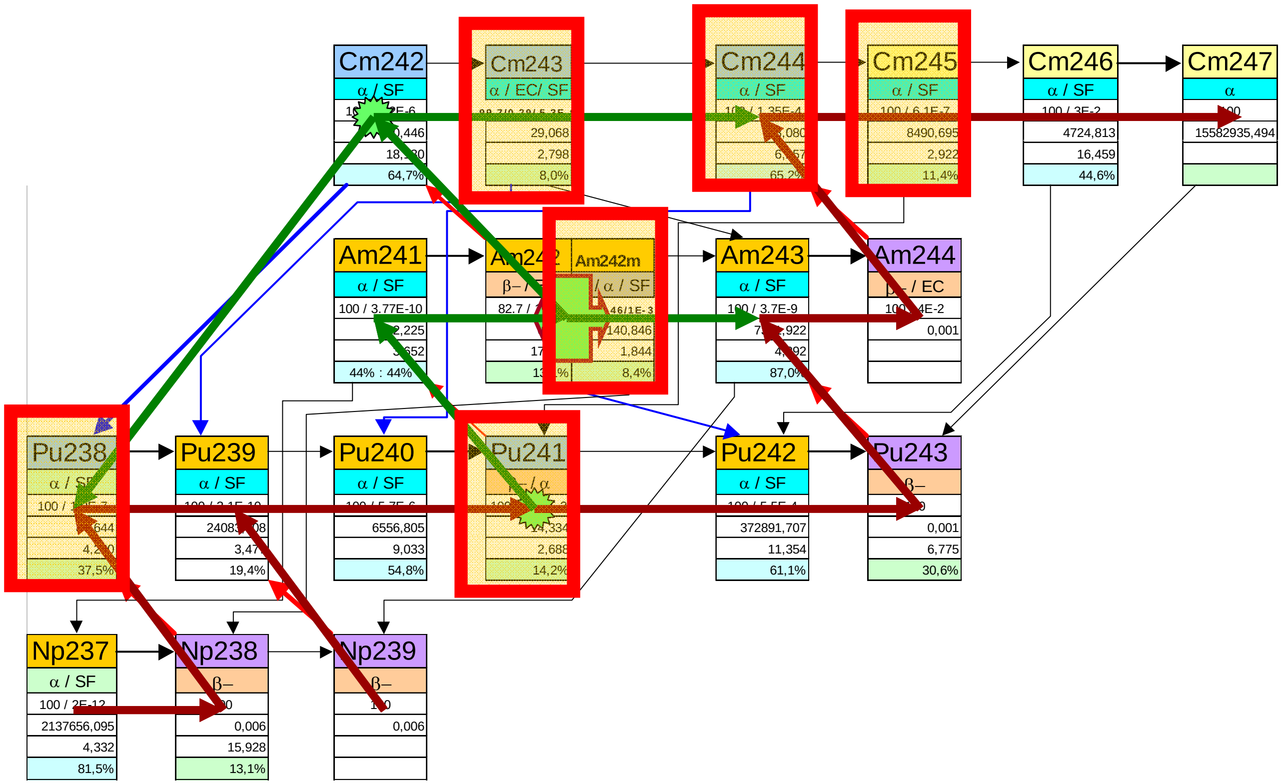
New spallation target





The next frontier: n_TOF @ EAR2

Actinides with very short half life (10-200 yr): ^{238,241}**Pu**, ^{242m}**Am**, ^{243,244}**Cm**



- These isotopes are key steps for the nuclear waste breeding, but their radioactivity makes their measurement very difficult.
- Very low mass samples (<<1 mg): to reduce the radioactivity induced background and to be compatible with R.P. rules.
- Same conditions allow very rare materials (even deposits from rad beams ISOLDE?), and materials of very low cross section:

^{90}Sr, ^{79}Se, ^{126}Sn, ^{147}Pm, ^{135}Cs: long lived FF

The next frontier: n_TOF @ EAR2

(1) Radioactivity background
- High brightness (peak flux intensity) and low duty cycle
- Shorter flight path 1/10 -> 10-100 times larger flux (EAR2)

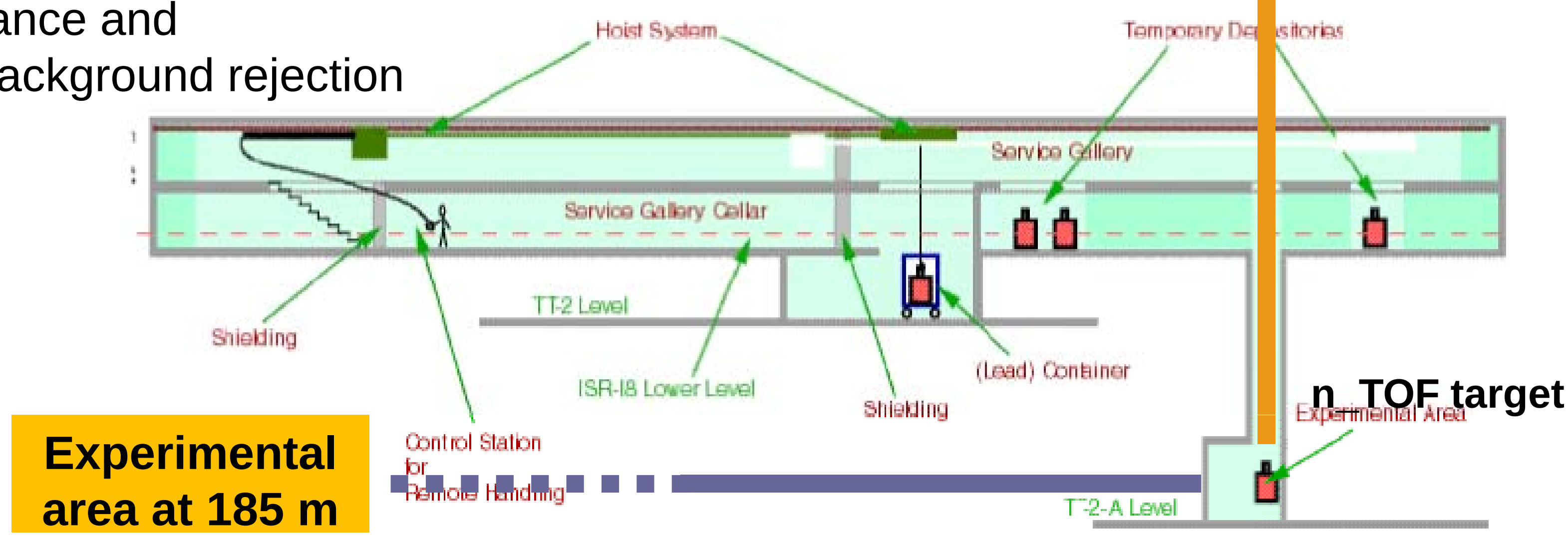
(2) Scattered beam background
- Very thin sample support no encapsulation
  Class A laboratory (EAR2)
- Distance from samples to walls (EAR2)

(3) Background vs. Detectors
- Low neutron sensitivity of detectors
- Improved background rejection by detectors

(4) In beam background
- Large angle of neutron and proton lines (EAR2)
- Optimized moderator

(5) Ambient background
- Walls distance and
- detector background rejection

New experimental area at 20 m



E. Gonzalez: Nuclear data

Summary and conclusions

- n_TOF @ CERN is a first class neutron Time Of Flight facility
- It is specially well suited for radioactive materials, samples of rare materials or low cross section.
- Excellent facility for measuring neutron capture and fission cross sections and the most needed cross sections identified for nuclear applications (nuclear waste minimization). Sustained support from the EU framework programs.
- The measurements provide very relevant parameters to improve the understanding and physics models of nuclides and reactions.
- Combined with high performance detectors and DAQ allows to perform high accuracy cross section measurements.
- The n_TOF potentiality was proved by successful operation from 2000 to 2004
- The current campaign, with improved setup, will allow to fully exploit its possibilities to fulfill the request of the highest priority nuclear data needs
- There are plans to enhance the performance with an additional short flight path and EAR2 that will allow to open a new frontier of sample masses, short lived isotopes and accurate measurements