1st meeting

of the CLUSTER for BAsic StUDIES FOR TRANSMUTATION

1st BASTRA meeting

DECEMBER 5, 2001

CERN, GENEVA, SWITZERLAND

VOLUME II

First meeting of the Basic Studies for Transmutation
BASTRA Cluster
HINDAS / n_TOF-ND-ADS / MUSE / ISTC / OECD-NEA

Date: **Wednesday 5 December 2001**; *Place:* **CERN, Geneva, Switzerland**

BUILDING: 864 (Lab 2; Prevessin/F)

Chairman: V. Bhatnagar; Co-chairman: P. Pavlopoulos

08:30	**Welcome, Introduction and Approval of the agenda**	**V. Bhatnagar**
08:50	**Presentation of the HINDAS Project (10'')**	**J.-P. Meulders**
	Experimental program from 20MeV to 200MeV (20")	**N. Olsson**
	Experimental program from 200 MeV to 2 GeV (20")	**K.H. Schmidt**
	Theoretical program (20")	**J. Cugnon**
10:05	*Coffee Break*	
10:25	**Presentation of the n_TOF-ND-ADS Project** (15")	**P. Pavlopoulos**
	The CERN Neutron TOF Beam (15")	**A. Zanini**
	Experimental Set-up & Preliminary Results (20")	**E. Gonzalez**
	Required Precision and Priority List of Elements (10")	**Y. Kadi**
	ND Evaluation & Modelling (15")	**H. Leeb**
11:40	**Presentation of the MUSE Project**	**R. Soule + W. Gudowski**
12:15	**Presentation from the Nuclear Data bank NEA/OCDE (Paris)** The Route from Experiment to Evaluation	**M. Kellett**
12:50	*Lunch*	
14:00	**Presentation of the n_TOF ND Evaluation Network**	**W. Furman**
14:15	**Presentation of the ISTC projects on Nuclear Data**	**15'' each**
	#B70: Transmutation of LLFP and MA in a Sub-critical Assembly Driven by a Neutron Generator	**S. Chigrinov**
	#1309: p- and n-induced X-sections of Pb and Neighbouring Nuclei in 20-200 MeV Region	**N. Olsson + S. Yavshits**
	#1372: Radiochemical and Activation Analysis of LL Nuclear Waste Transmutation in FR and Accelerators	**Y. Shubin**
	#1971 : n-Induced Fission X-section of Pu240, AM243 and W in the Range of 1-200 MeV	**A. Laptev**
	#2002 : Yields of Residual Products in Thin Pb and Bi Targets by 40-2600 MeV Protons	**V. Batyaev**
15:30	*Coffee Break*	
15:50	***Discussion on the needs of nuclear data studies for ADS and coverage by FP5 and other projects***	**Animated by P. Pavlopoulos**
17:30	***Actions to be taken***	
18:00	**Close of the meeting**	

List of participants BASTRA Kick-off meeting at CERN, December 5, 2001

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EXECUTIVE SUMMARY (Short Minutes)

Extract from Ved Bhatnagar's Mission report (internal)

The meeting proceeded with brief presentations of the three projects: HINDAS, n_TOF_ND_ADS and MUSE. In each case, the co-ordinators briefly outlined the objectives and scope of the work to be carried out in their projects followed by presentations made by work package leaders on the tasks that they are responsible for. Presentations were also made by 5 ISTC projects in this area including the one from Nuclear Data Centre at NEA. The aim of the discussion during and after the presentations was to highlight the issues that are of importance for nuclear data needs for an ADS and in particular the ones that are not being addressed in the presently running FP5 projects.

The main points of the discussion can be summarised as follows (Partially based on the slide that Noulis Pavlopoulos presented in the discussion)

- The Commission's initiative of clustering of related FP5 projects and facilitating exchange of information was highly appreciated. It was more so for the BASTRA cluster as not only the FP5 projects but also the ISTC related projects and OECD/NEA participation made the meeting more valuable.

- The nuclear (cross section) data bank at NEA/OECD is dealing with all kinds of cross section data, for all kinds of isotopes, in all energy ranges and for all kinds of applications. This has lead to a mammoth job which is becoming somewhat unwieldy and puts people off.

- It was suggested that the BASTRA cluster focus on the specific needs of nuclear cross section data for Accelerator Driven Systems for P&T. This implies reiterating (some information is already available from NEA) and listing the (Z,A) of the isotopes, nuclear reaction mechanisms and the energy range for which this data is required.

- There is a need to review and take stock of the situation of the data that already exist, the data that is being acquired and planned during the present FP5 and other projects on nuclear data. This would culminate in defining properly the future needs and efforts required in this direction. A sub group is proposed to be set up to work it out and for reporting (see below).

- It was suggested that the input data should have to be filtered by a quality control system (or criteria) before it is accepted for dissemination via the Nuclear Data for ADS (NUDADS) databank (name coined by myself!) possibly managed by NEA/OECD. The quality control parameters should be defined and may include $\Delta E/E$, precision, completeness parameters etc.

- There should be more complete horizontal activities relating to interactions between authors of different theoretical models including transport codes so that they can sort out the reasons for discrepancies among different evaluations that are accepted in the dedicated ADS database. In this context, source codes should be made available to other with due care of IPRs.

- There should be collaborative efforts so that specialists in certain areas or those implementing specialised techniques may also perform tests or measurements on samples coming from other institutions.

- Efforts should be made via financing of the fellowships such as Marie Curie or others so that young scientists are attracted to the field of nuclear data evaluation as veteran scientists become unavailable through natural wastage.

- It is proposed to establish several subgroups (2 or 3 persons each) which will report back to the cluster chairman on certain specific topics such as: (a) ADS designers' requirements for the nuclear data, (b) Sensitivity studies on nuclear cross section data, (c) Overlap of work being done at FP5 and ISTC projects in nuclear data, (d) Theoretical models etc.

The next meeting of the cluster is informally proposed (to be confirmed) to take place in Uppsala, Sweden on 13/14 September 2002 together with the progress meeting of HINDAS project.

Background Reduction in n_TOF

Luca Zanini (EET Group, CERN) for the n_TOF Collaboration

The problem of the background

Measurements performed at the n_TOF facility until June 2001 showed that the background for capture measurements was about two orders of magnitude higher than tolerable.

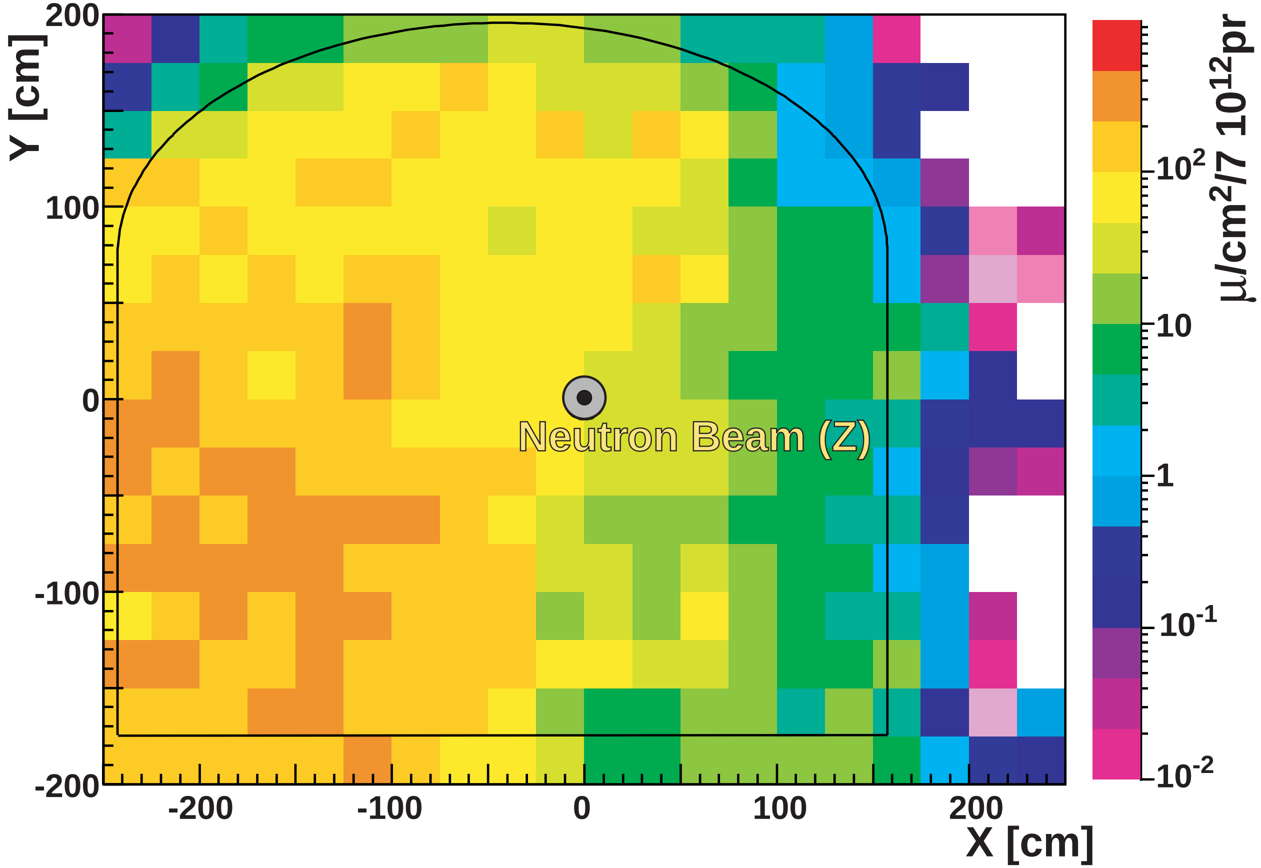
The following features had been observed:

- a strong asymmetry in the n_TOF measuring station
- the presence of a *short* and a *fast* component
- an intense prompt pulse also outside the beam

An extensive study, consisting in simulations and experimental work, was therefore undertaken with the following purposes:

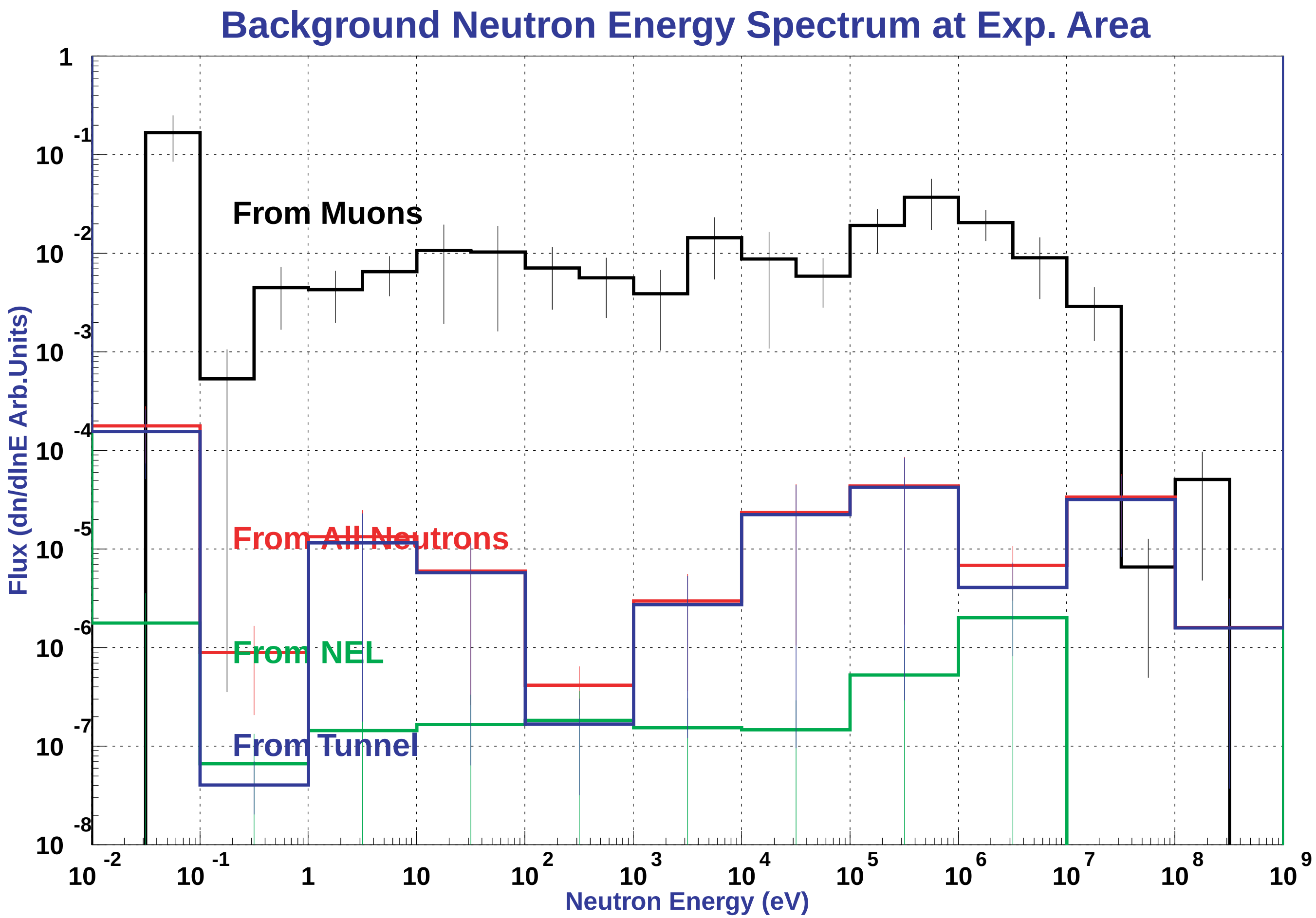
- determine the origin of the background
- find a way to reduce it!

Simulated muon fluence



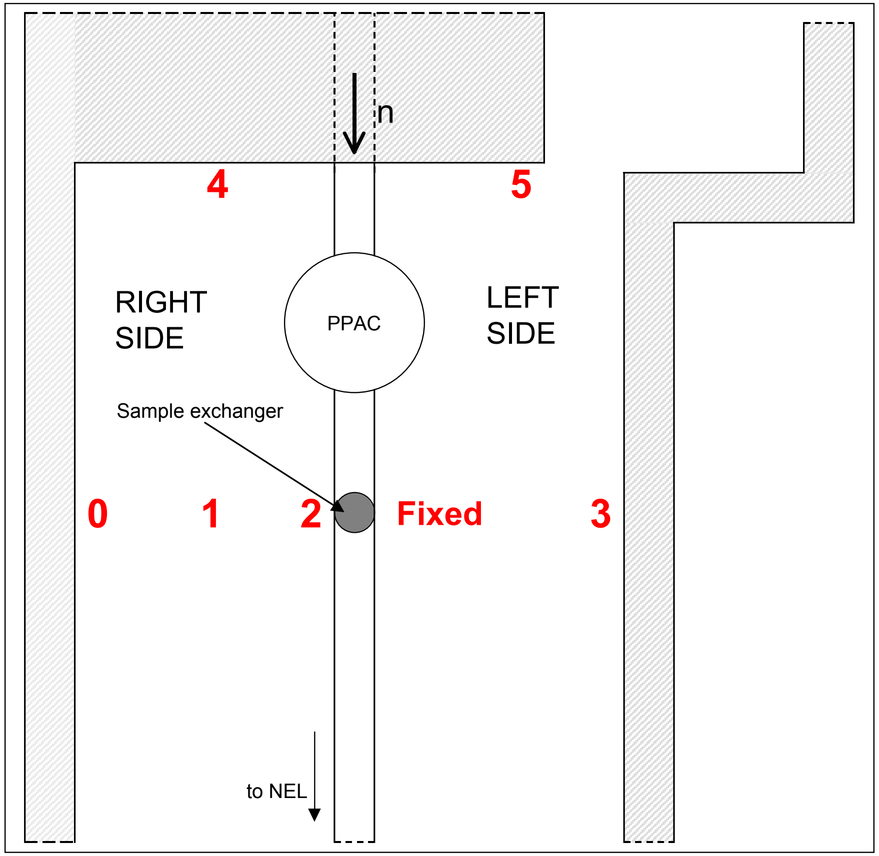
Simulated muon fluence at the entrance of the exp. station per 7 10^{12} protons.

Simulated neutron energy spectrum



Background neutron entries split into different sources

Measurements

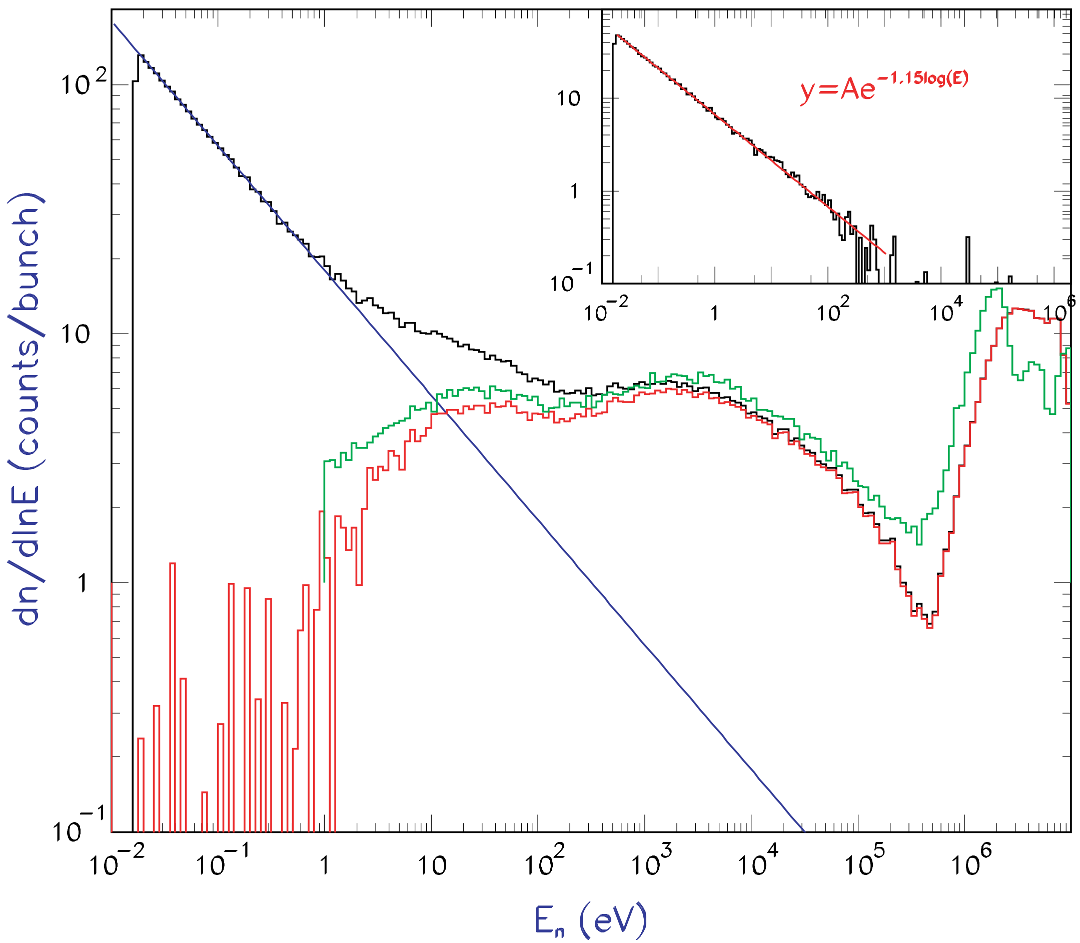


<u>Detectors used:</u>

For γ-ray measurement:
- C6D6 scintillation counters
- HPGe counter

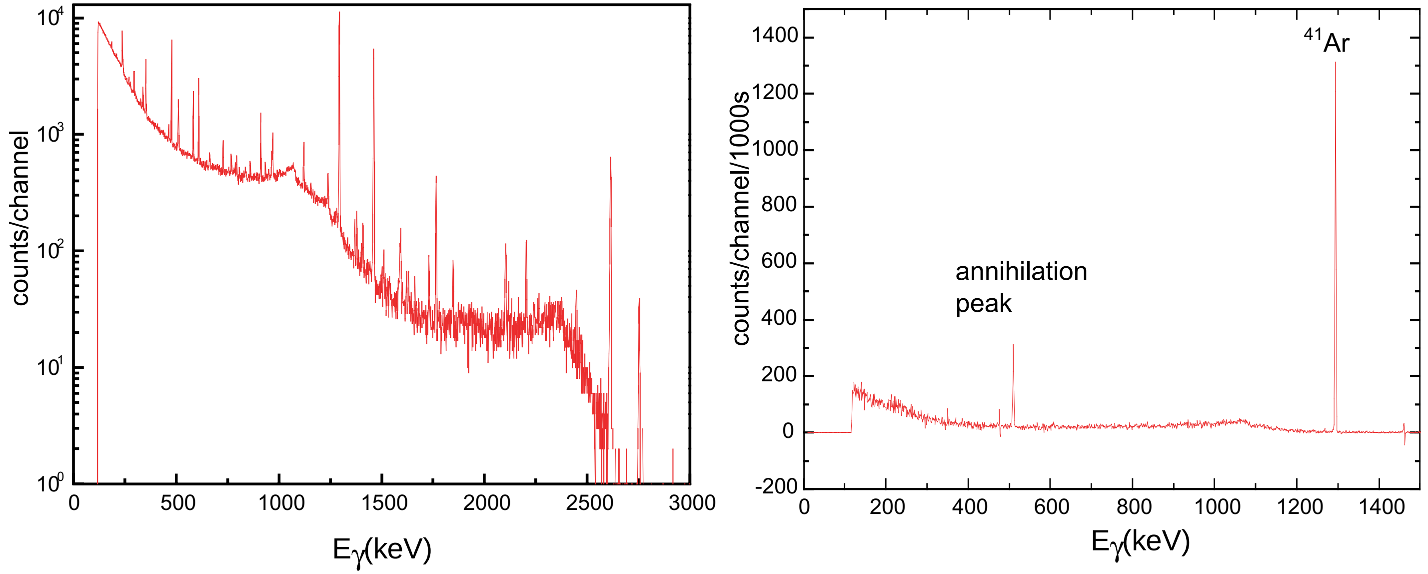
For neutrons:
- ^{3}He proportional counter

C6D6 raw spectrum



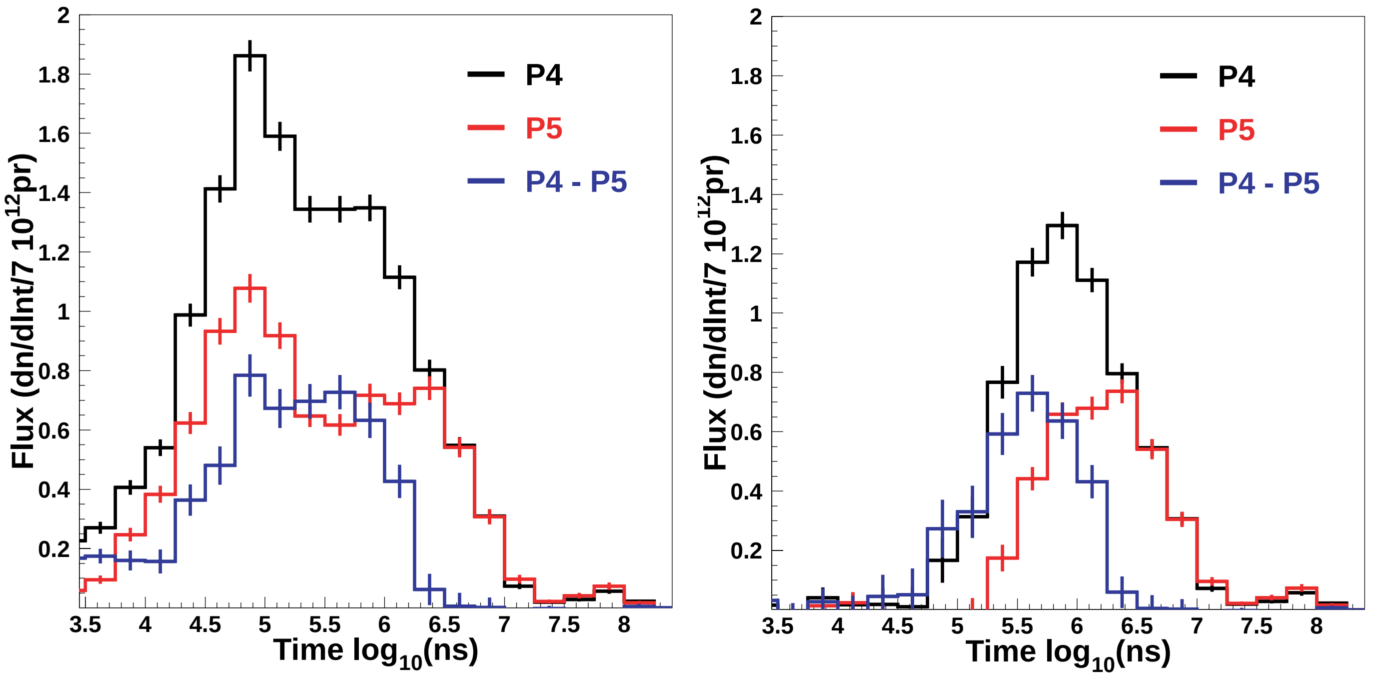
Typical C6D6 raw spectrum. Black: total spectrum; blue: activation component; red: after activation subtraction; green: previous measurements (May, nTOF DAQ)

(Air) activation: Ge spectra



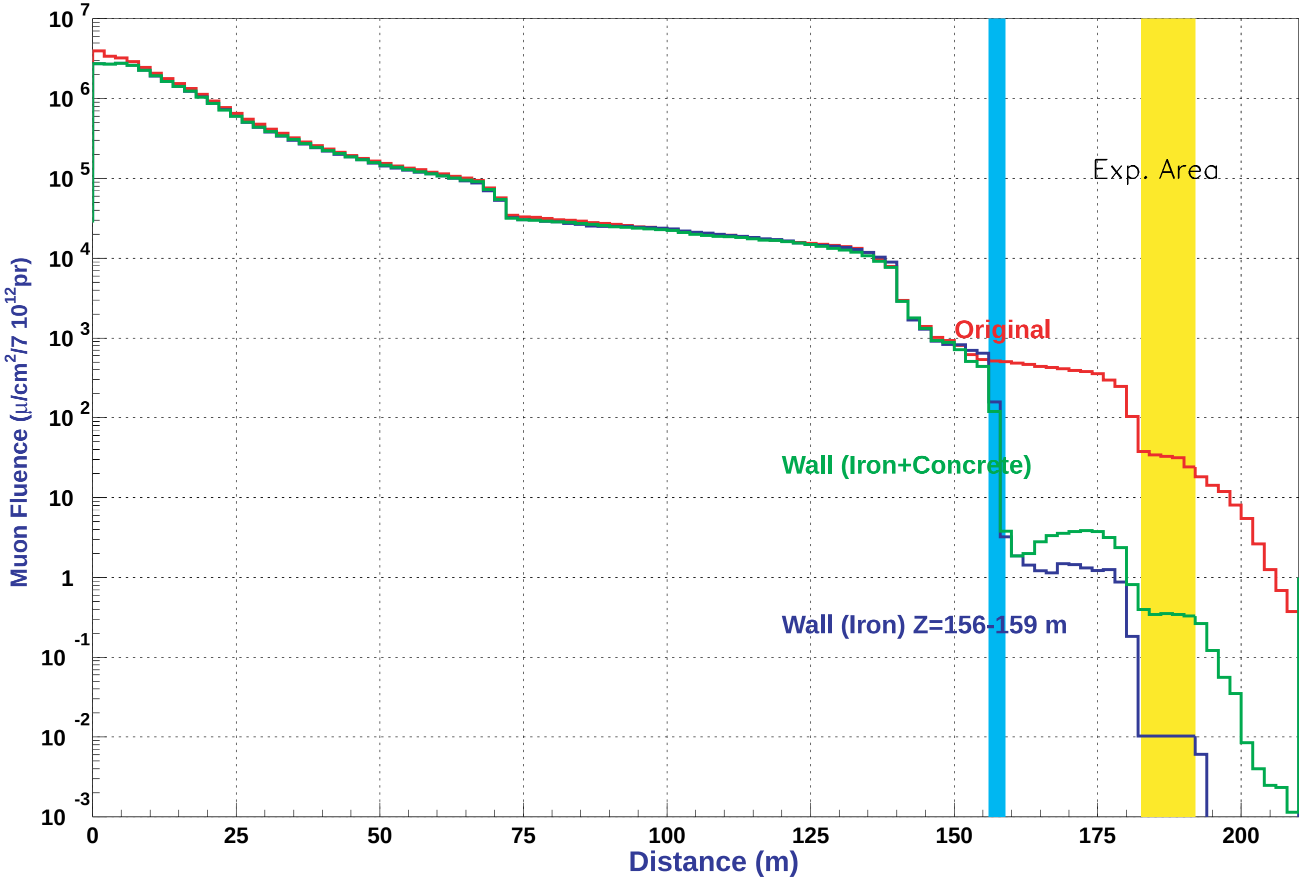
Gamma spectrum (HPGe detector) 3.5 hours after beam stop (left), and background-subtracted (right).

Asymmetry: neutrons (^{3}He + 81 mm poly sphere with or w/o Cd)



Left-right asymmetry measured with the ^{3}He detector in position 4 (black) and 5 (red) and their difference (blue): with the 81 mm diameter poly sphere (left) and the thermal part only (right, obtained by the difference without and with Cadmium)

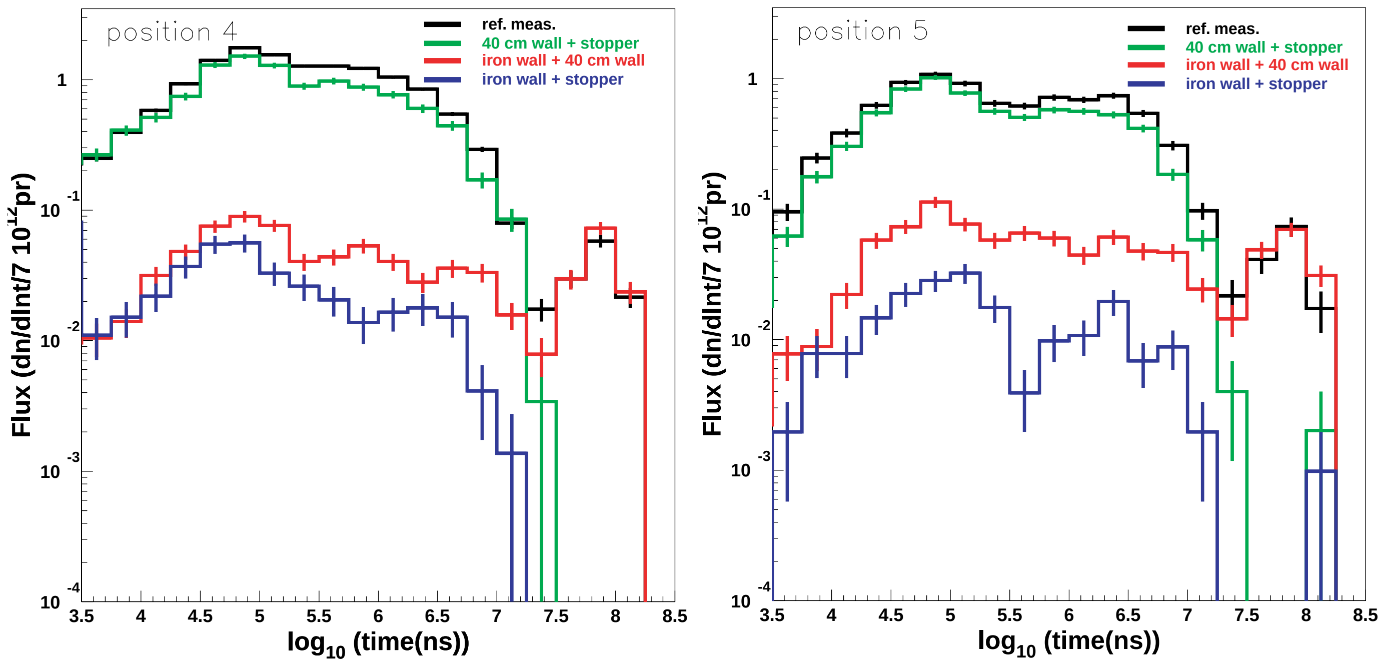
Effect of the iron shielding on the background from simulations



Simulated average muon flux as a function of the distance from the lead target for a standard pulse of 7×10^{12} protons. Red: configuration without iron shielding. green : iron shielding with concrete base. Blue: shielding entirely of iron.

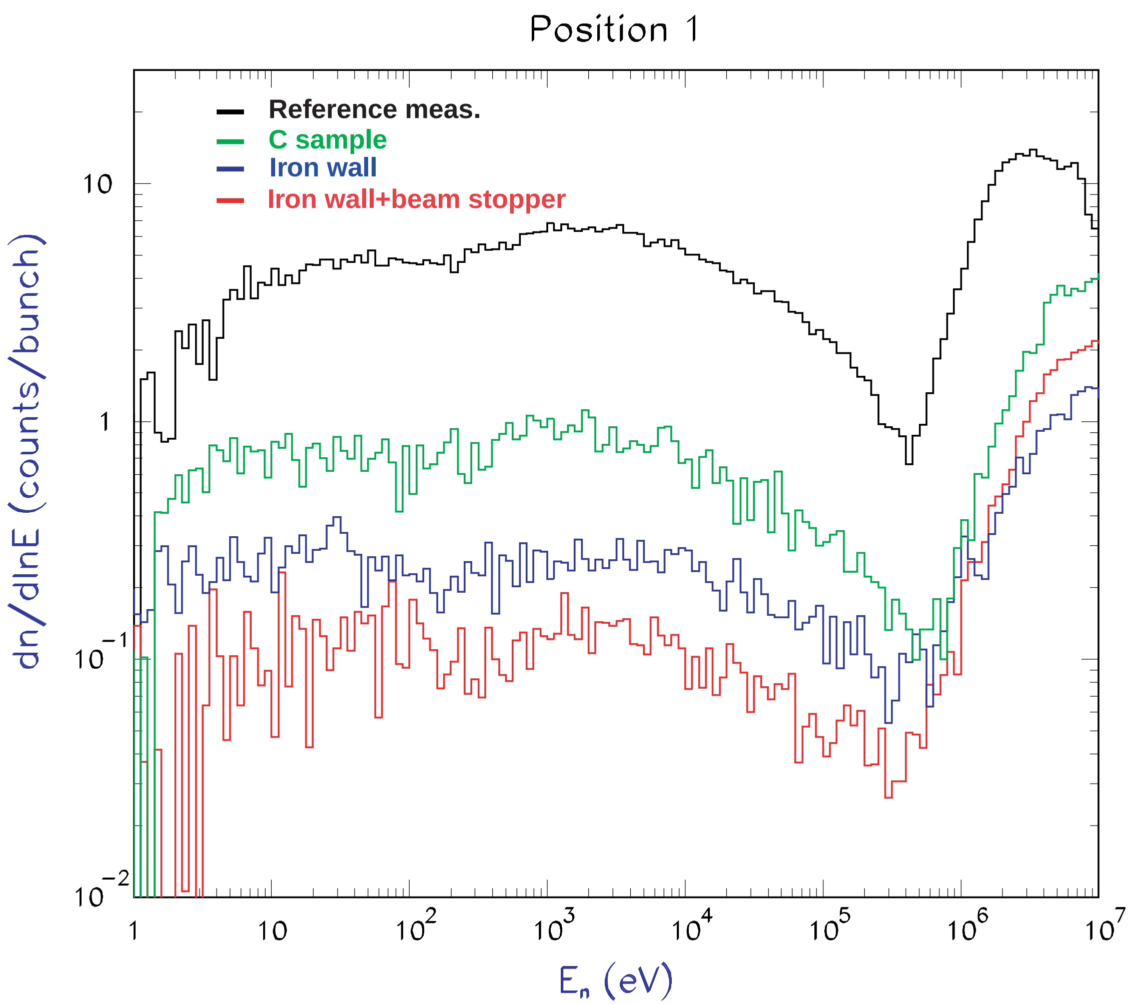
Provisional (October 2001) muon wall layout: picture

Summary results: ^{3}He



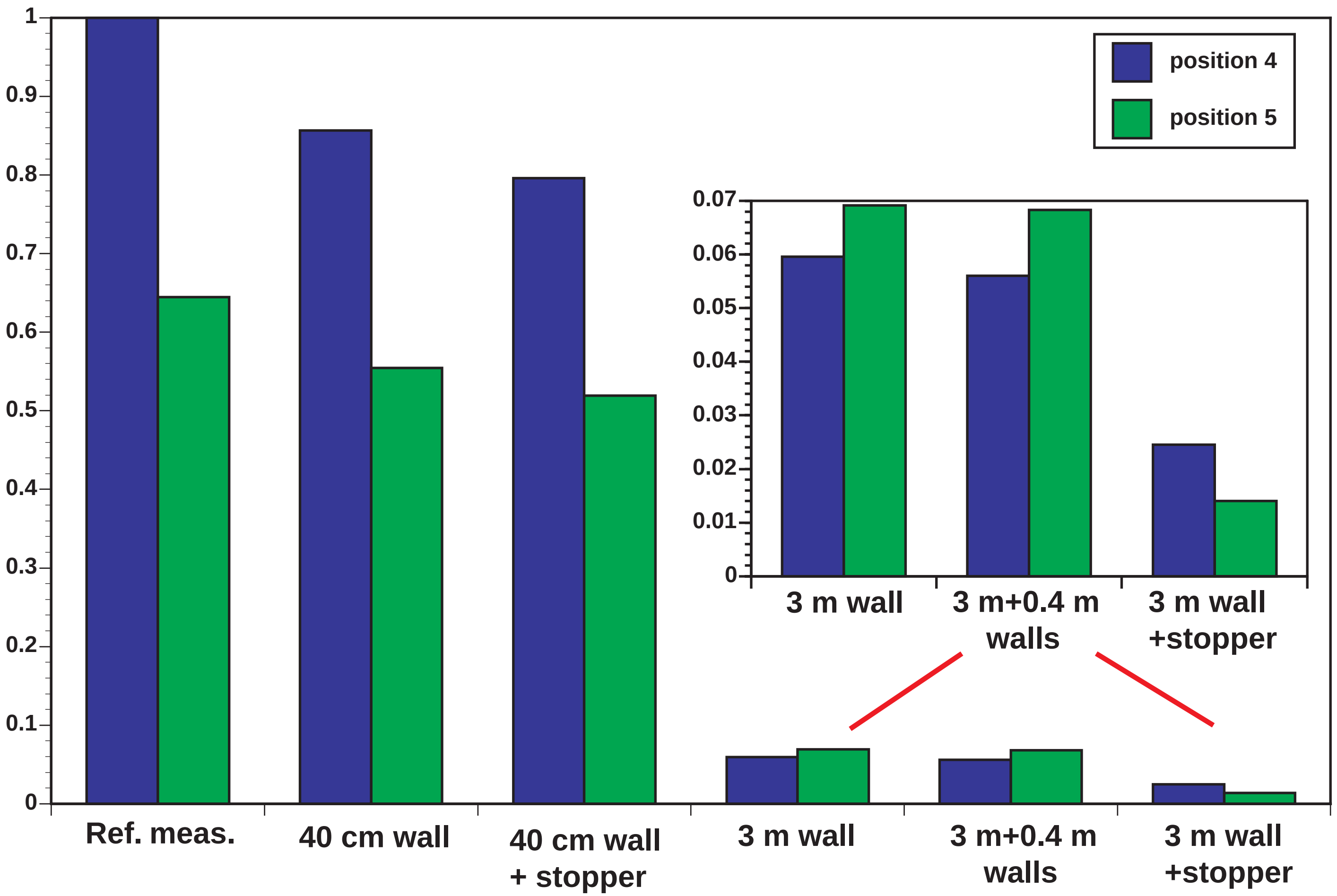
^{3}He detector+poly (81 mm): reference measurement (black), with extra 40 cm shielding (green), with the muon wall and the beam stopper (blue) and with the muon wall + 40 cm extra shielding (red)

Summary results: C6D6



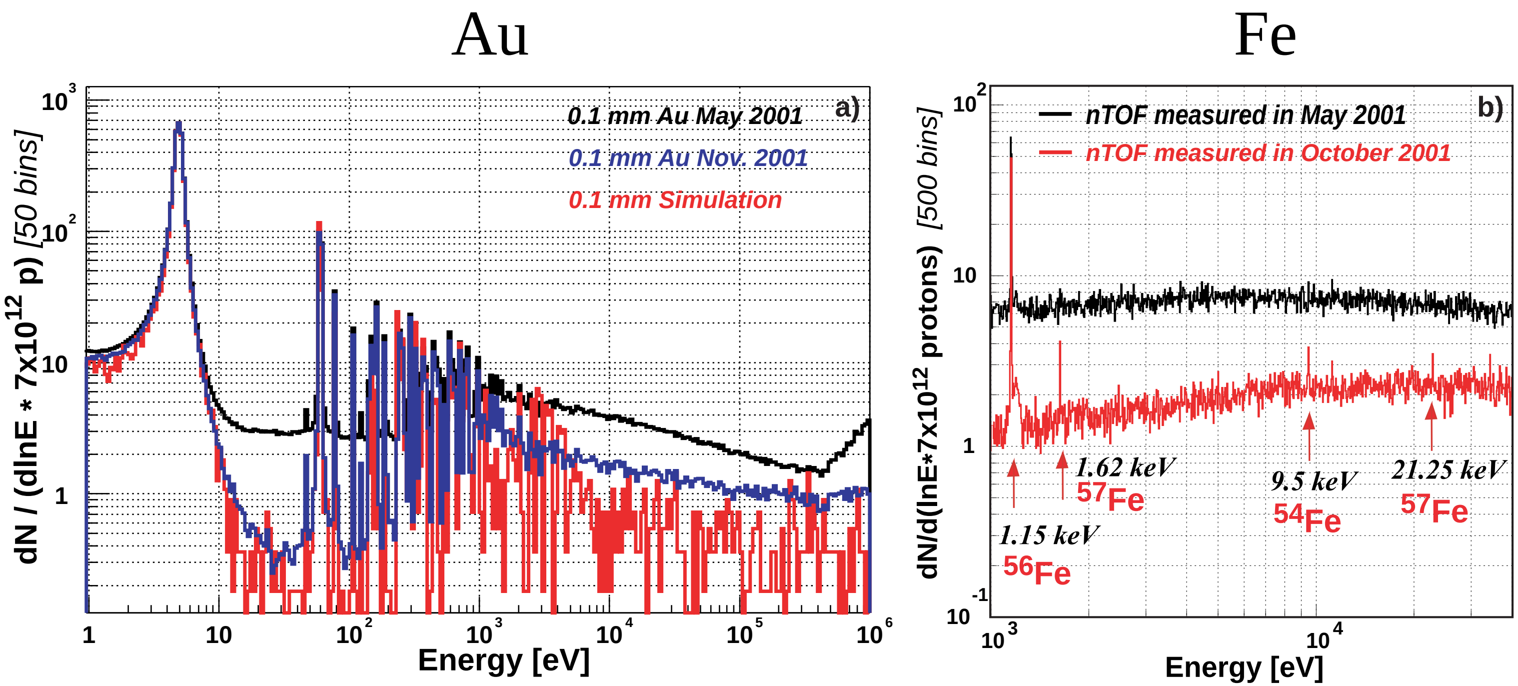
C6D6 raw spectra (activation subtracted) before (black), and after the iron wall installation (red: beam stopper in, blue: beam stopper out, green: 6.35 mm C sample in).

Global summary : ^{3}He



Global summary of the ^{3}He + poly (81 mm) measurements (cts/10^{12}p)

Measurements of Au and Fe resonances



Left: Count rate measured with a C_6D_6 detector for a 0.1-mm Au sample, right: with a 1.5-mm Fe sample. The raw neutron capture spectra obtained in the May/June campaign (black histogram) are compared with the results obtained after the installation of the 3.2 m iron wall in the secondary area. The simulation spectrum is also shown in the case of gold.

Conclusions

- After the installation of the 3.2 m iron shielding the reduction factor of the "muon" component of the background is about 30 for both neutrons and photons

- The beam-related background is now the largest contribution to the slow component of the background

- The sample-associated background is now visible, as well as the effect of the sweeping magnet

- Neutron-capture measurements with Au and Fe samples show that the peak-to-ratio value has substantially increased. The experimental program will greatly benefit from the improvement of the background level, and it will be possible to perform most of the measurements in a reasonable time.

An improvement of the shielding will be performed during the winter shutdown by mounting a wall made completely of iron. This will further reduce the muon-related background. The beam-related background could be reduced by ex. lining the experimental area with borated polyethylene.

The n_TOF Experimental Set-up & Preliminary Results

E. González on behalf of the **n_TOF collaboration**.

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Presentation Scheme

Detectors installation and tests
Measured beam characteristics
Commissioning of (cross section) detectors
Background levels ?

Detectors installation and tests: ***Beam monitors***

Si - ^{6}Li detectors: Beam intensity and energy dependence (En < 1MeV). Based on the in beam $^{6}Li(n,\alpha)^{3}H$ reaction observed by off-beam Si detectors. Good operation, large improvements on the signal over noise during data taking runs.

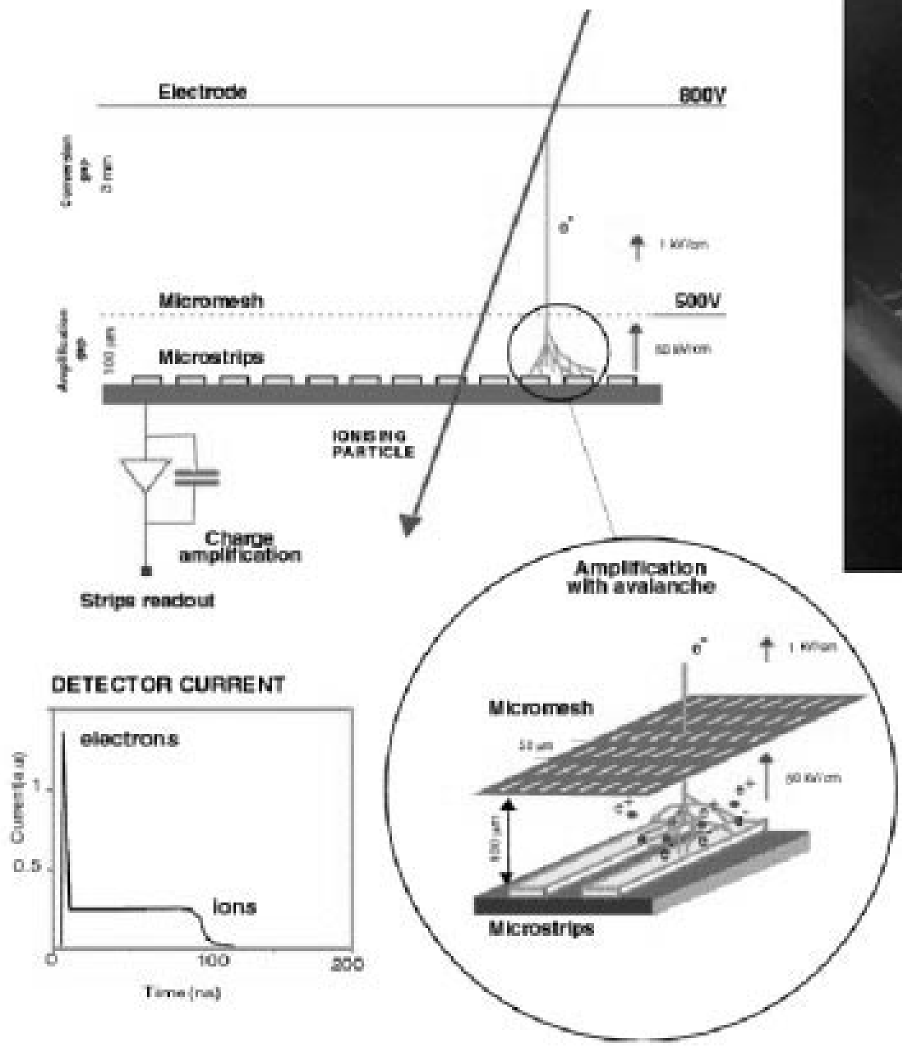
PPAC – ^{235}U, ^{238}U, ^{209}Bi: Beam intensity and energy dependence (En<250 MeV). Based on the fission of the targets and the Parallel Plate Avalanche Chambers. Multi-layer very fast (1ns) wire chambers with identification of fission from other reactions (id of the 2 FF). Good operation. Needs large conversion targets.

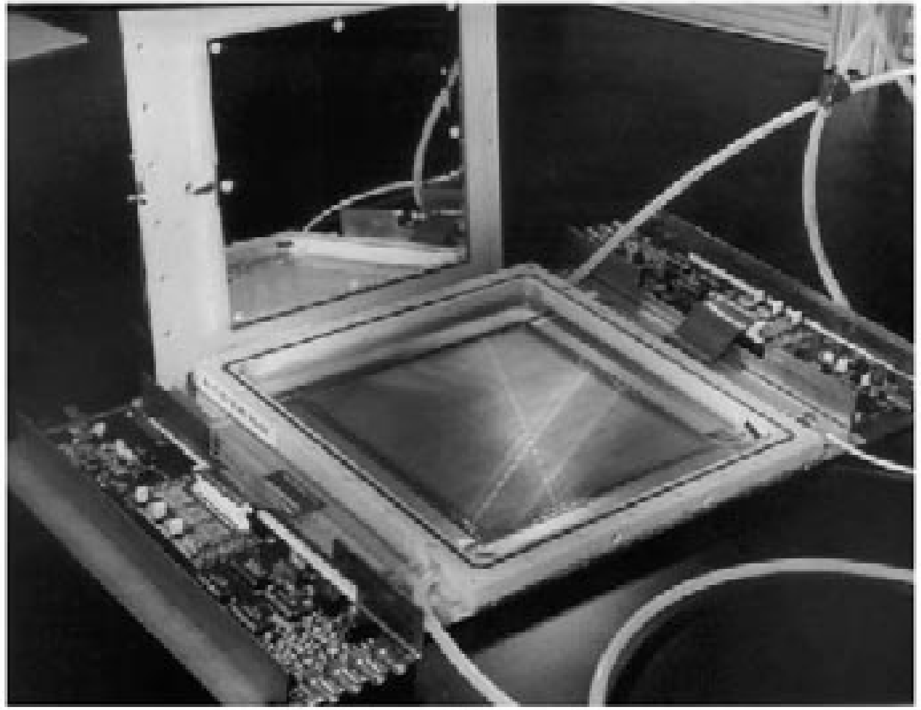
Micromegas - ^{6}Li: Geometrical beam profile as a function of neutron energy (En<100 MeV potentially). Based on the $^{6}Li(n,\alpha)^{3}H$ reaction and in the proton and other gas nuclei recoils as neutron converters and a micromegas (small drift chamber + micro-holes multiplication + multystrip charge collection) as segmented charge particle detector. Tested with several Gas mixtures (Ar-CH_4 and He). Excellent performance, improved electronics installed.

BF_3 – Polyethylene (long detectors) : Monitoring of the Beam intensity and beam position in a shot by shot basis. Placed and the end of the neutron beam line, the polyethylene reduces the back-scattering background and provide approximate energy independent detection efficiency (long counter). Weighted average beam position obtained by relative counting of 3 BF_3 detectors placed in star.

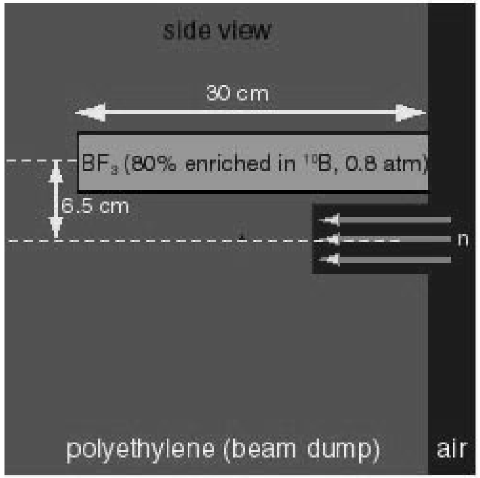
Integral detectors (TLD, CR-39, Au activation): Provide absolute calibration at 4.9 eV (Au), about 0.5 eV (Cd-covered ^{6}Li-^{7}Li TLD and Cd-covered ^{6}Li+CR-39) and above 1MeV (CR-39 with Polyethylene converter) and profile information integrated over long periods of runs.

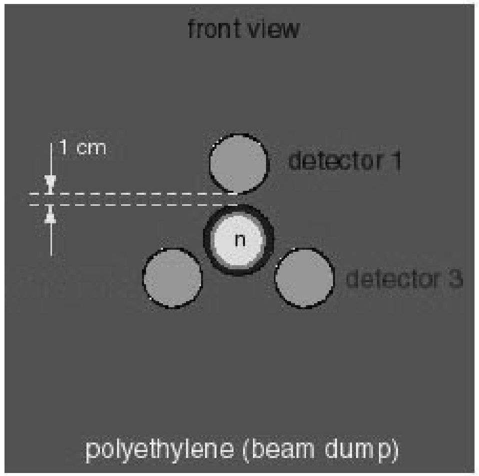
Micromegas detector





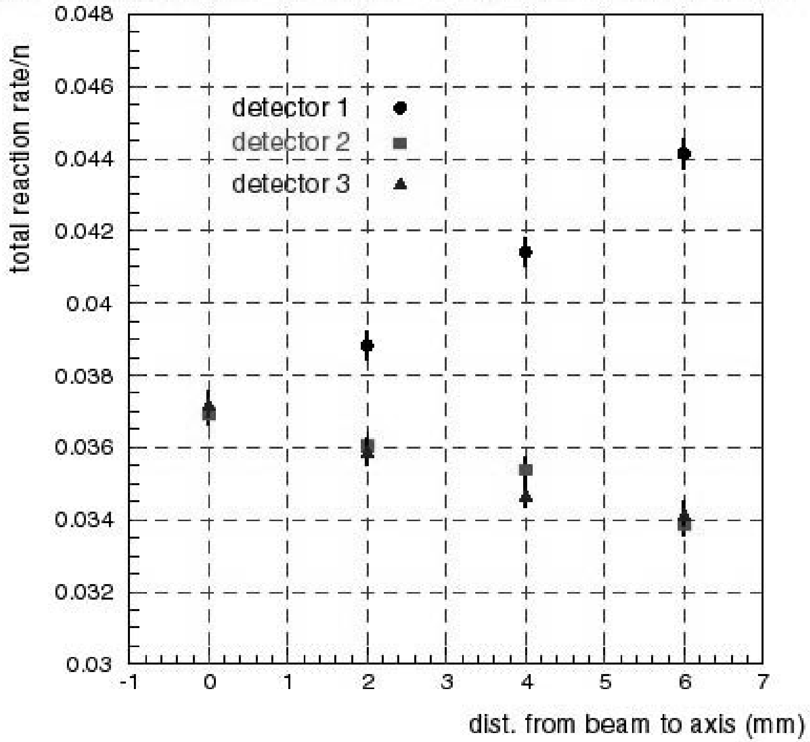
Neutron escape line, intensity and position monitoring BF_3 detectors





Position sensitive array of 3 long counters

Variations in the reaction rate as a function of the beam displacement (n_TOF neutron energy spectrum up to 20 MeV)



Daniel Cano-Ott, n_TOF collaboration meeting, July 13th-15th

Detectors installation and tests: ***Reaction products detectors (X-sections)***

C_6D_6: Capture detector of low efficiency and low neutron sensitivity (En<500 keV). Needs weighting functions to evaluate reaction rate from counting rate. 4 commercial (BICRON) detectors modified by the collaboration and 2 newly designed (FZK) detector used (lower neutron sensitivity). Good performance for equivalent neutron energies below 1 MeV.

BaF_2: Individual crystals of the proposed Total Absorption Calorimeter . Large size very high efficiency. Needs reduction of its sensitivity to very fast particles (n, γ and charged). CeF_3 crystals provide much faster response and reduce the effects of the sensitivity to fast particles. More test time and developing foreseen.

HPGe: Used to detect well identified prompt γ lines for the (n,xn) reaction. First test with the Ge in the experimental area. More tests time foreseen.

PPAC: Already explained as beam monitor. When different targets are used they will provide the fission cross section of the target isotope from the measured neutron fluence. Allow to reach several hundred MeV neutron energies (few ns after γ arrival time).

DAQ and data preprocessing : FADC very large memory recording. Full event (zero suppressed) recorded on tape with 1-2 ns resolution. Huge data production and computing requirements for data reduction. Parallelized data path. Large effort affecting all the measurements.

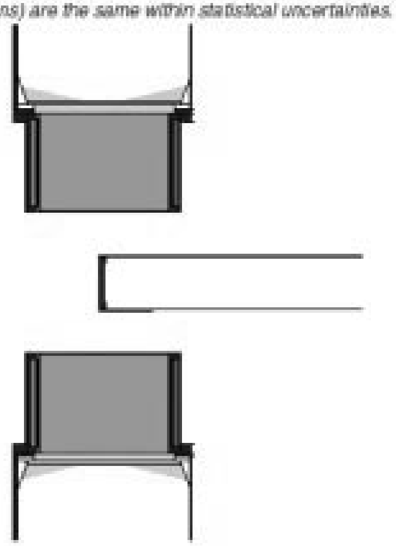
Data taking periods: April 13, April 21, April 28th-June 11th, some additional tests on October 2001.

C_6D_6 photon detector

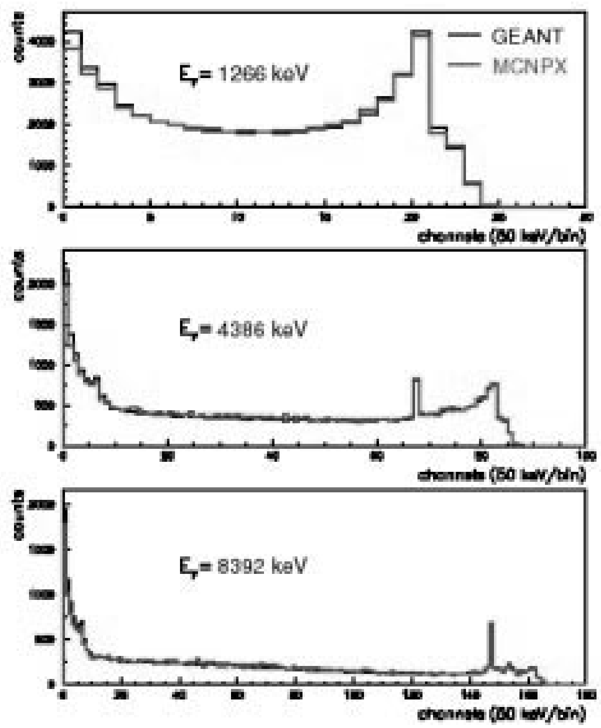
Simulation (MCNPX) of C_6D_6 detectors

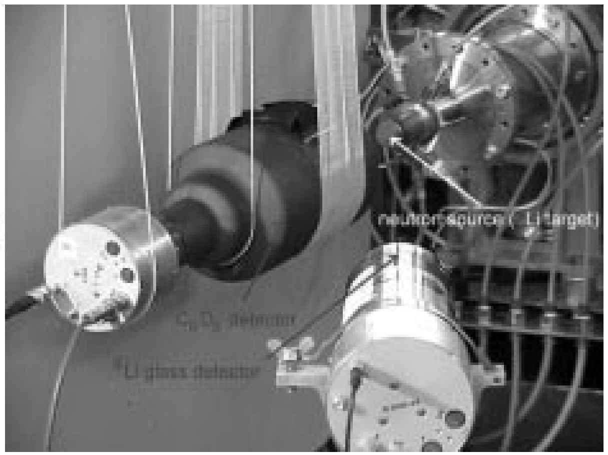
I. Weighting functions

Monte Carlo simulations of the C_6D_6 γ-ray responses with MCNPX lead to the same results as GEANT (J.L. Tain et al. MC-group web page). The same geometry of the (p,γ) measurements done by Corvi et al. was used. The MCNPX and GEANT γ-ray responses (i.e. the derived weighting functions) are the same within statistical uncertainties.



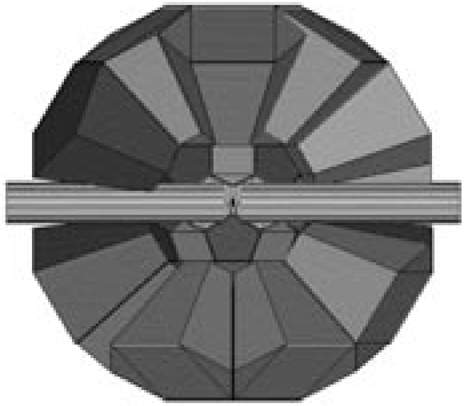
γ-ray spectra for different energies





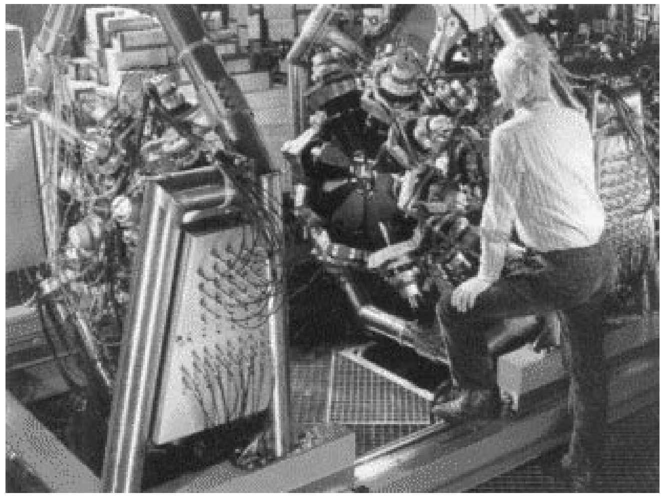
High performance, 4π or total absorption γ Calorimeter

Capture measurements of Highly radioactive of fissionable isotopes are nearly impossible with C_6D_6 detectors and require a Total Absorption Calorimeter.



Advantages of TAS compared to C_6D_6 detectors:

- Discrimination between capture events and other sources of γ's (Radioactive decay, background, etc..) by measuring the total cascade energy.
- Better control of systematic : No need of weighting function or similar corrections. The tails of the total energy absorption allow to estimate the efficiency and contamination.
- Higher absolute event efficiency: Improvements by a factor 5 to 10 in absolute efficiency.
- Separation of Capture from Fission events by γ multiplicity.



Design inspired by the existing BaF_2 calorimeter

CeF_3 being investigated (faster and same n sensitivity)

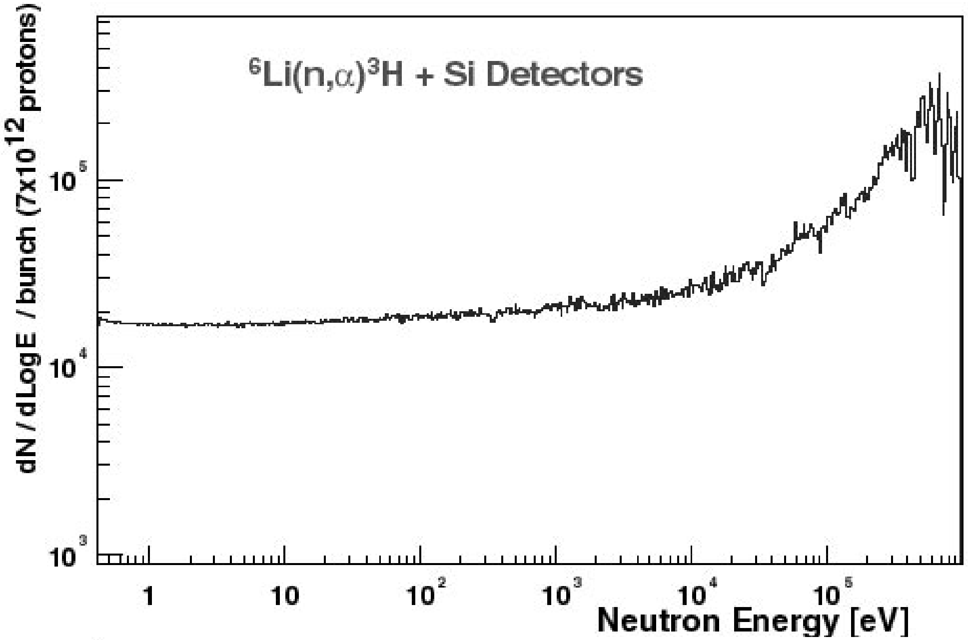
Slightly different shape to adapt to the beam pipe

Measured beam characteristics: Beam intensity

$^{6}Li(n,\alpha)^{3}H$ in beam observed by 4 off beam
Si detectors (inside a vacuum chamber).

Both α and ^{3}H, can be observed. The data from ^{3}H present less systematic effects.

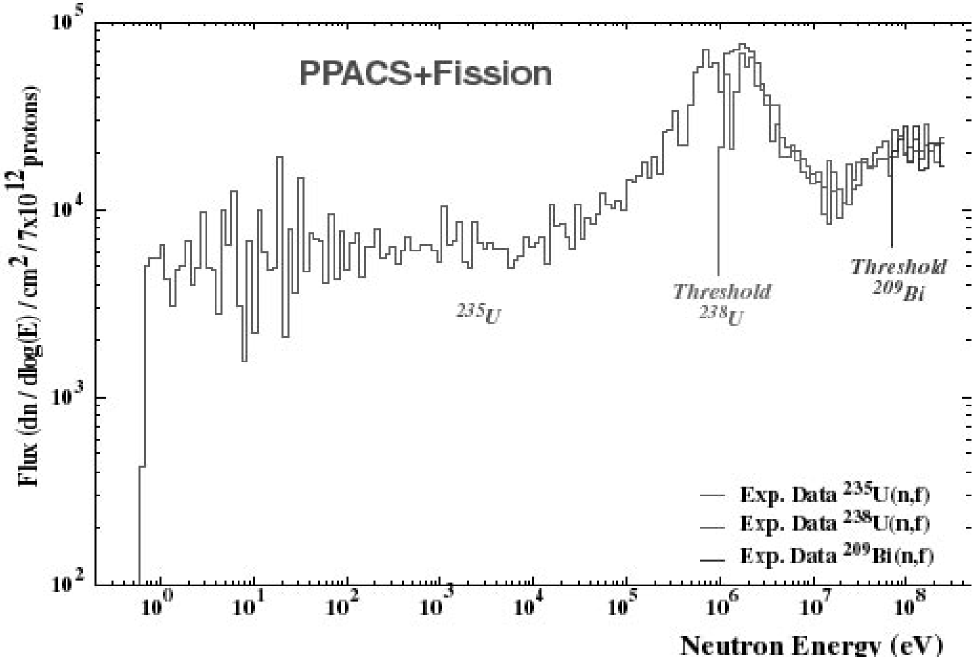
Excellent agreement with Montecarlo on the value and on the energy dependence !



In beam PPACs observing fission on 3 simultaneous samples: ^{235}U, ^{238}U, ^{209}Bi.

General good agreement, some discrepancies at high energies still under evaluation.

Possibility to measure fission from 0.1 eV up to 300 MeV simultaneously !!



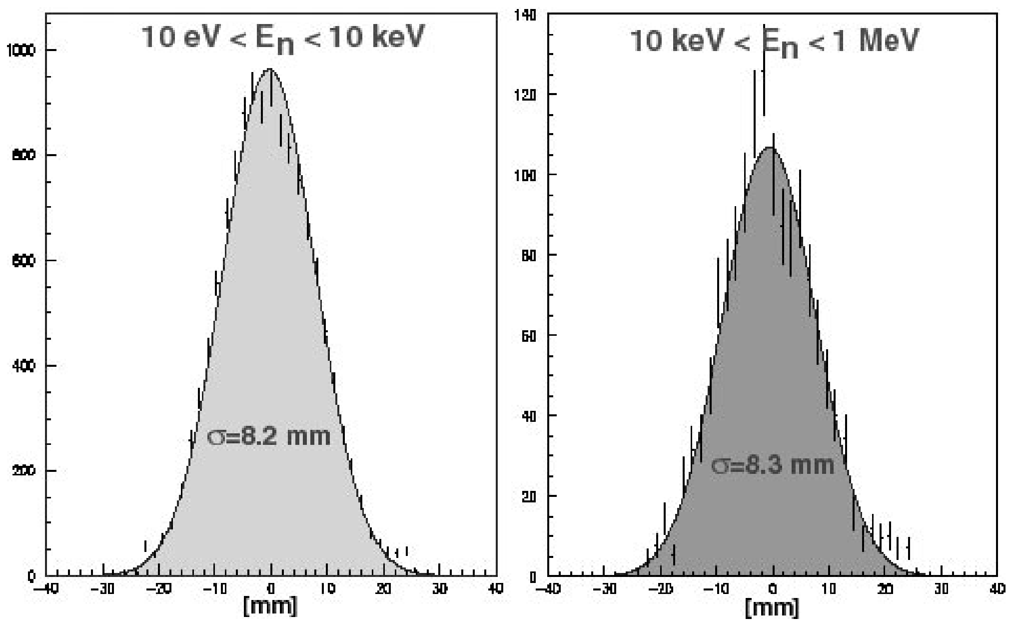
Measured beam characteristics: Beam profile

Vertical beam profiles measured by the Micromegas detector in a region dominated by the $^{6}Li(n,\alpha)^{3}H$ reaction.

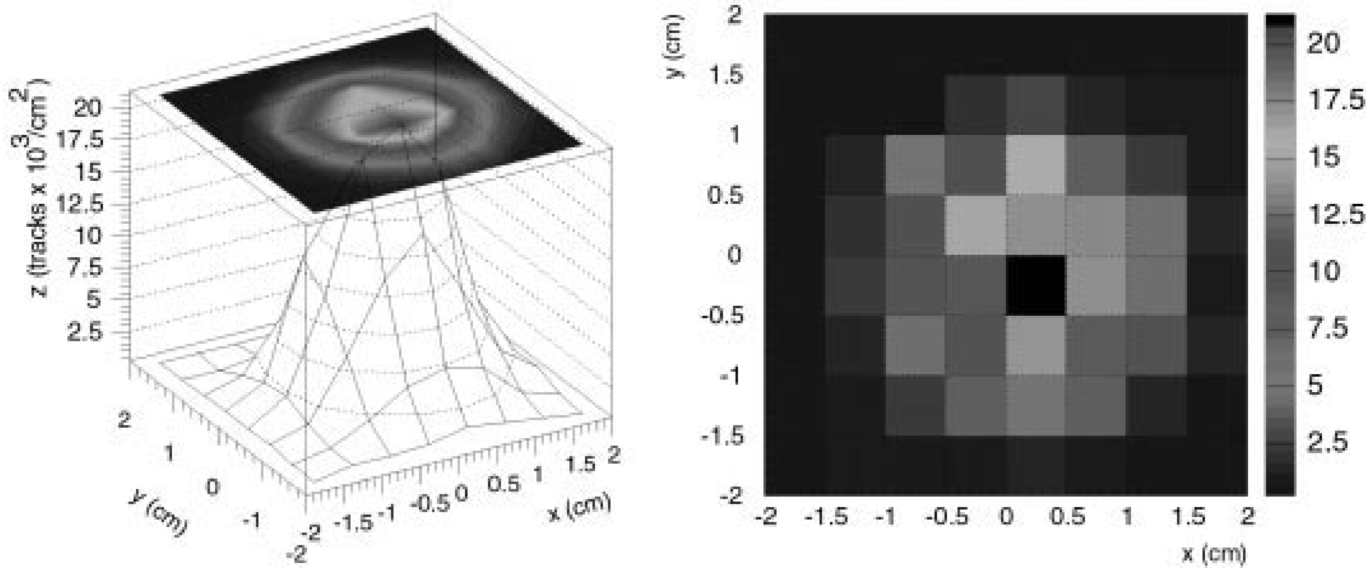
Excellent agreement with MC based estimations.

Note: Micromegas is at longer distance from the source than the samples, and the beam divergence needs to be corrected.

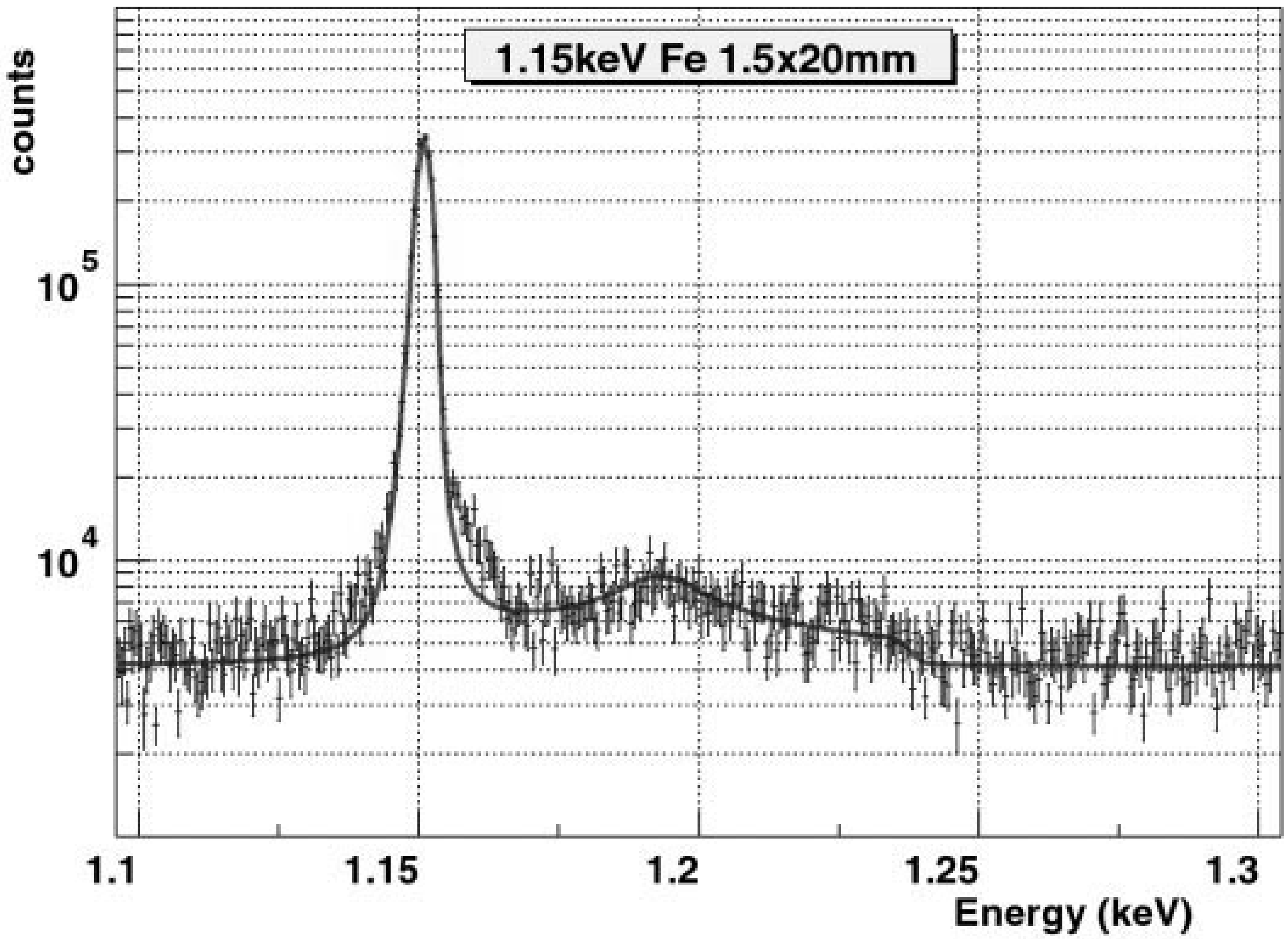
2D beam profile at neutron energies close to 1 eV measured by CR39 with a ^{6}Li converter all coverd by a Cd foil (to exclude low energy neutrons En<0.5 eV).



CR-39 covered with Cd at the end of Sample Exchanger



Measured beam characteristics: Energy resolution.



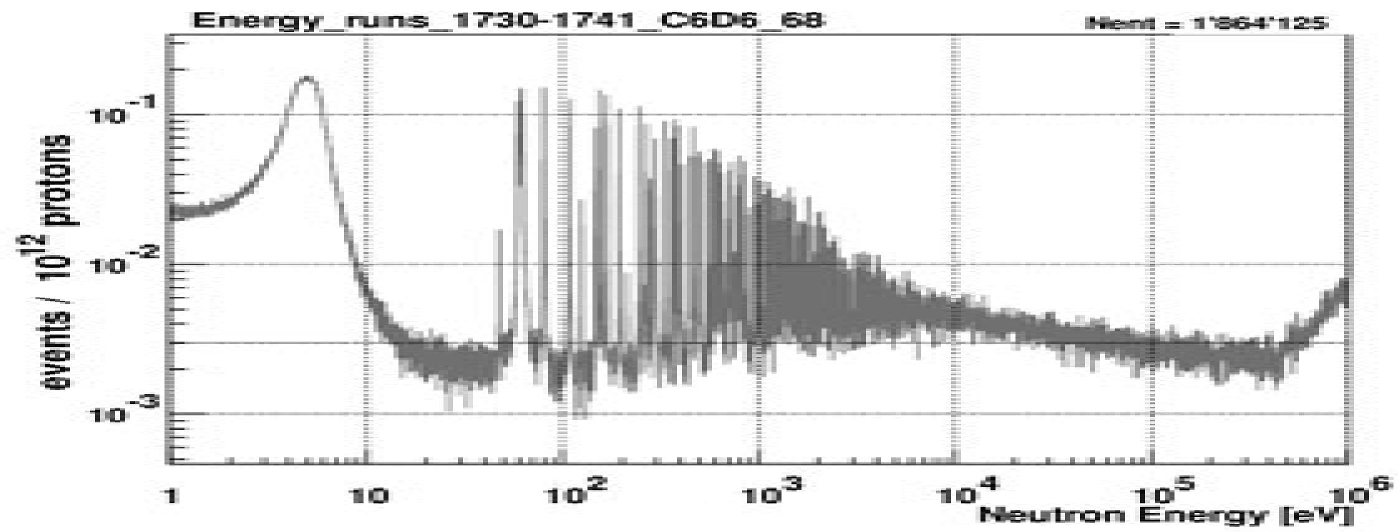
Weighted capture spectra and SAMMY fit for the 1.15 keV Fe resonance peak

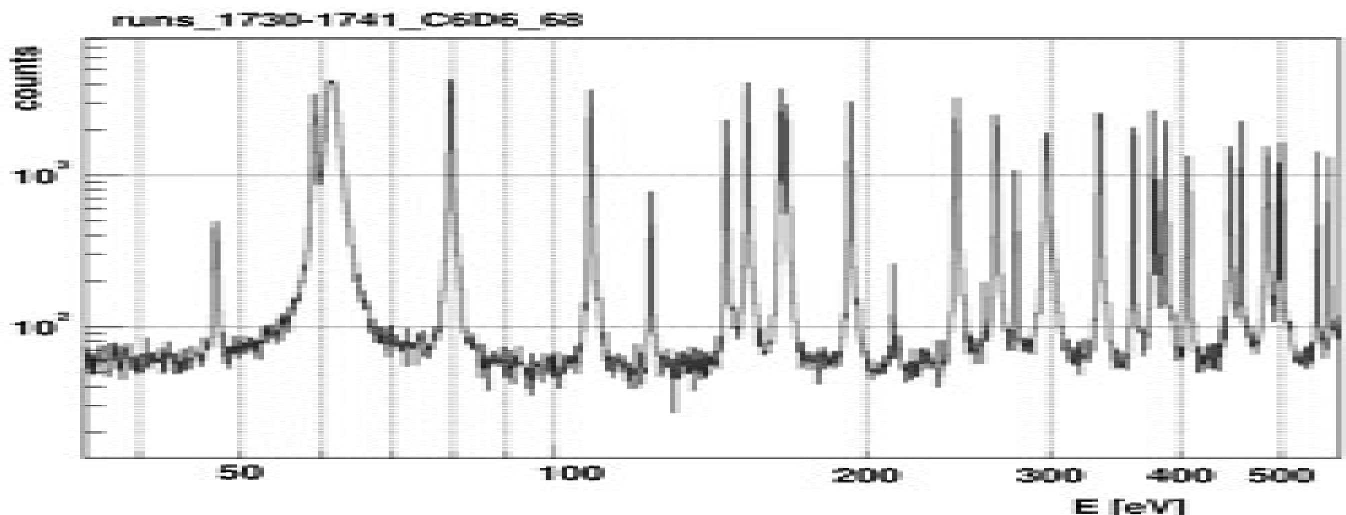
The energy resolution of the n_TOF installation has not been determined yet, however the measurements of the 1.15 keV Fe capture resonance, show a 4 eV FWHM width. The continuous line shows the resonance fit with the SAMMY program including the effects of the Doppler broadening, the C_6D_6 weighting functions and the Monte Carlo simulated n_TOF resolution function. From this fitting we estimate that less than 1 eV (0.1% FWHM) can be attributed to the n_TOF resolution function.

Commissioning of Cross section detectors: Capture Detectors C_6D_6.

Samples of well known cross section (Au, Ag and Fe) had been measured.

- Time to energy calibration
- Energy resolution
- Sensitivity to γ from inelastic and neutron interactions
- Background in the measurements.

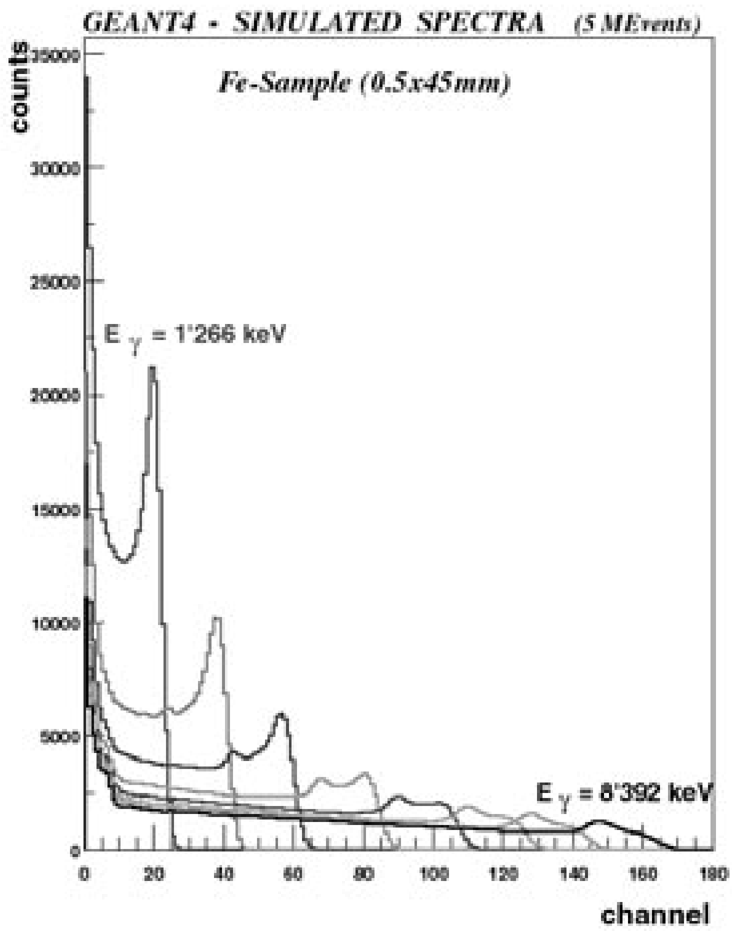


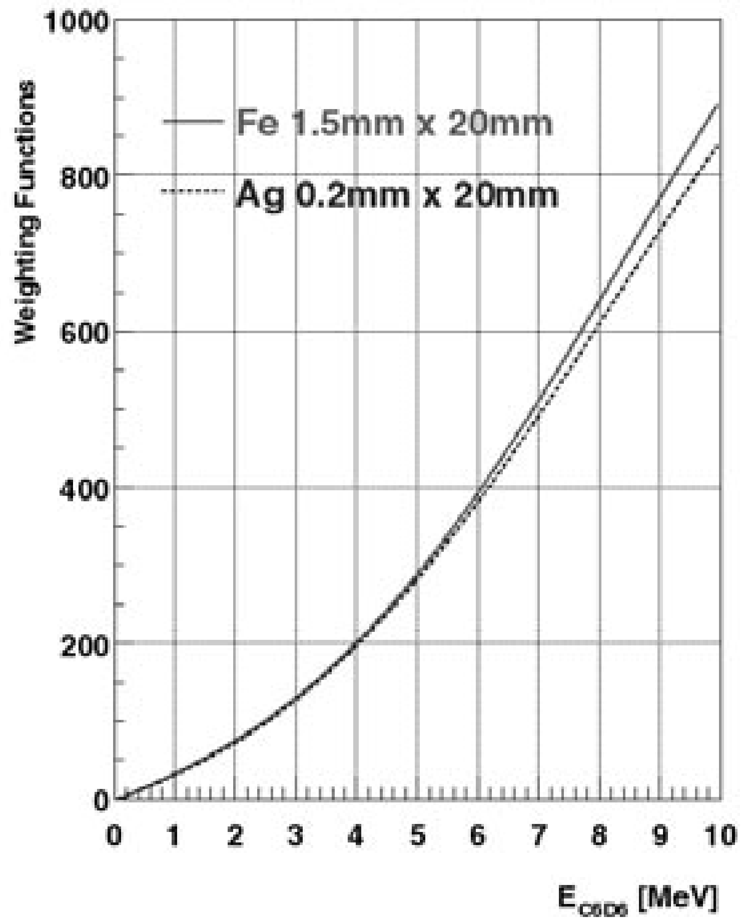


Raw neutron capture spectra from a typical run with a 1 mm thick ^{197}Au sample, measured by the C_6D_6 detectors and a zoom around the 200 eV region.

Commissioning of Capture Detectors C_6D_6. Response and Weighting Functions.

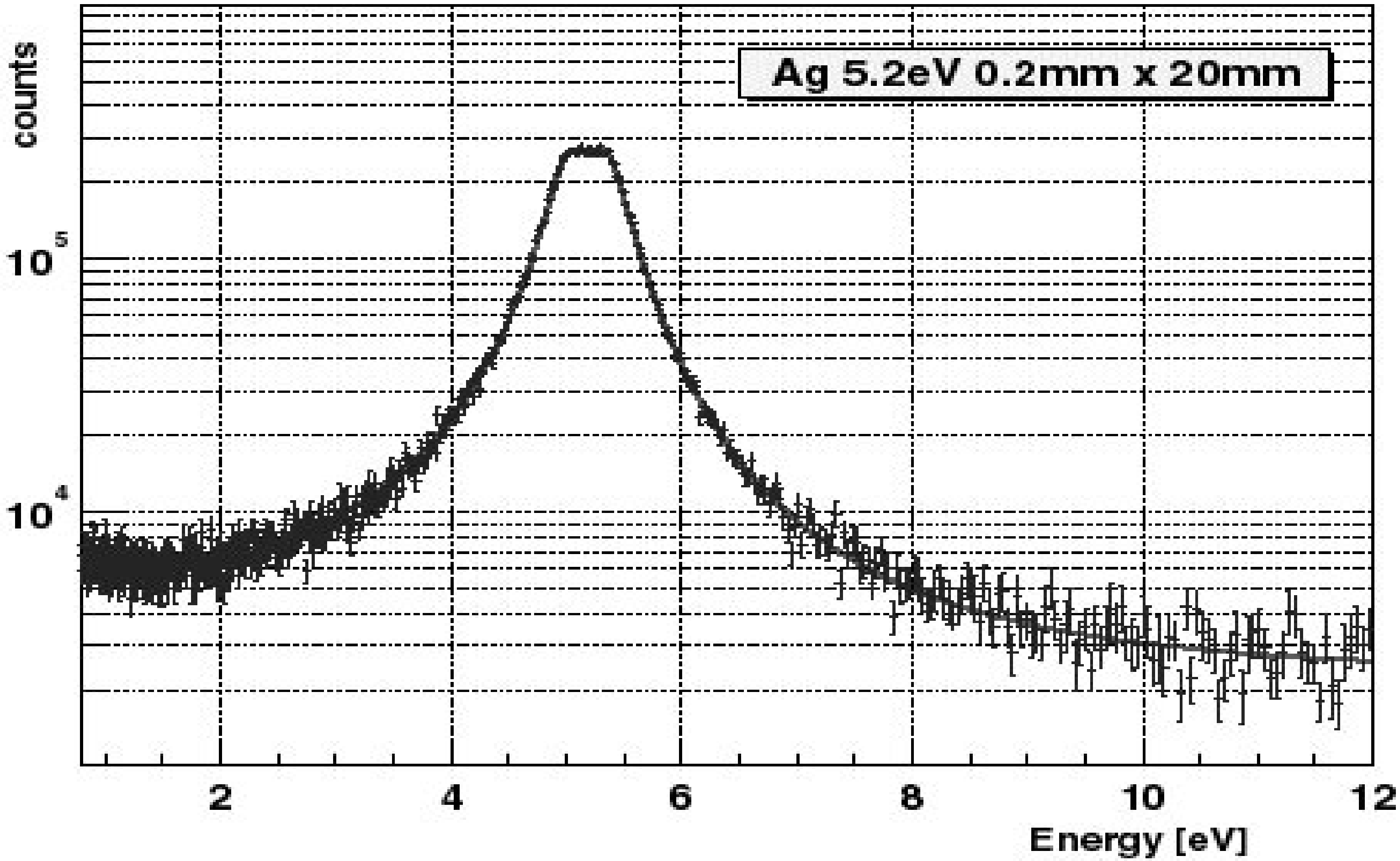
In order to extract the capture reaction rate from the spectra of raw C_6D_6 detector signals, each signal has to be weighted in such a way that the resulting photon detection efficiency is proportional to its energy. In this way the cascade detection efficiency becomes proportional to the known cascade energy and independent of the cascade path of each individual event.





Example of the simulated gamma-ray C_6D_6 detectors response functions and of the deduced weighting functions.

Commissioning of Capture Detectors C_6D_6. Response and Weighting Functions.



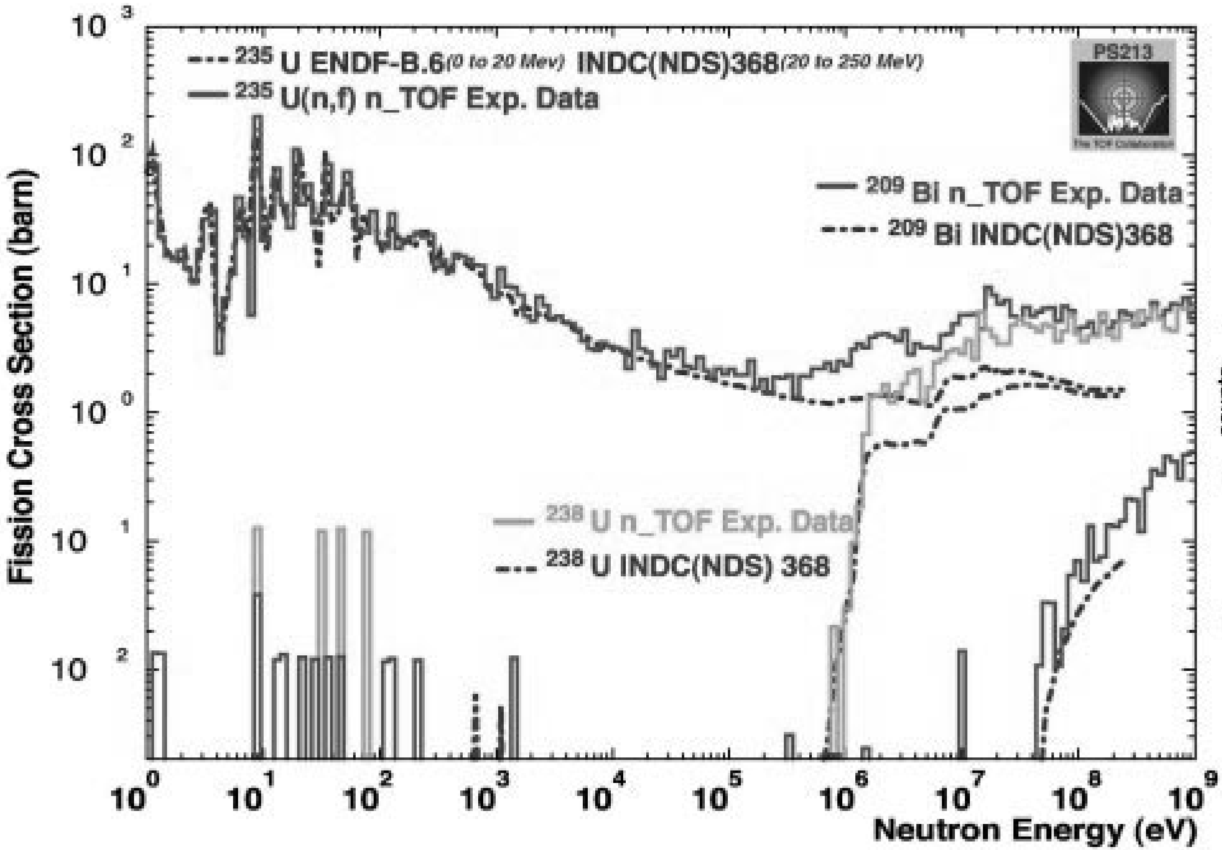
Weight capture spectra and SAMMY fit for the Ag main resonance peak.

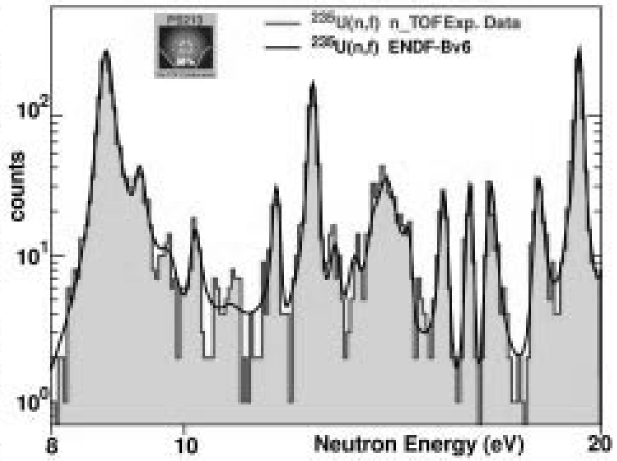
Commissioning of Cross section detectors: Fission Detectors PPACS.

The PPAC fission detectors have been tested with isotopes of “standard” cross sections. The performance of these detectors has been studied analyzing the obtained data as a cross section measurement with the MC simulated fluence (instead of measuring this fluence).

Good agreement on the thresholds for fission and the opening energies for (n,nf) and (n,2nf) channels. Reproduction of database values within a factor 2 over 9 orders of magnitude (flux).

Good separation of the resonance peaks a low energies.

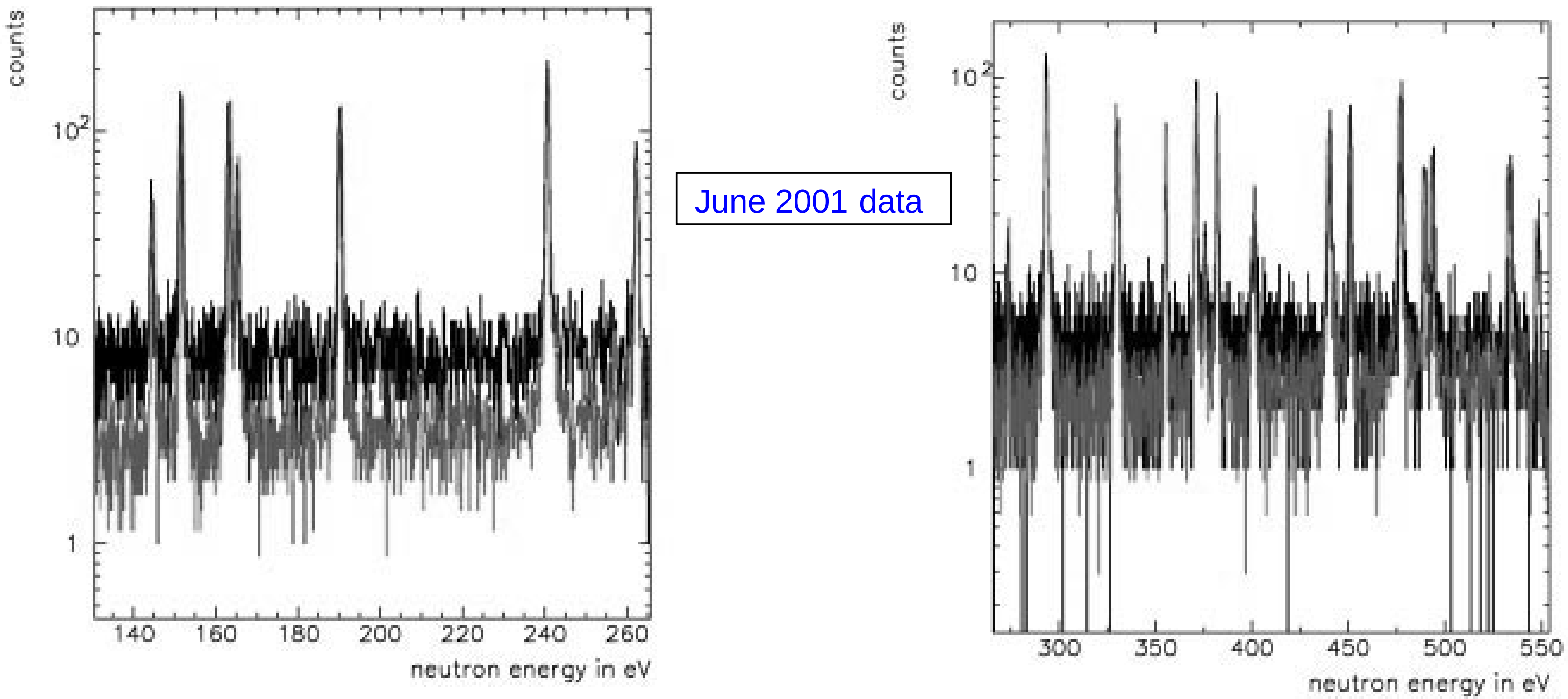




Comparisons between experimental data for ^{235}U, ^{238}U and ^{209}Bi and the evaluated cross sections

Background levels

The capture measurements show important amounts of ambient background in the experimental area. The level of background is similar to typical values in other installations (ORELA,IRMM), however the characteristics of nTOF should allow to reach better background conditions.

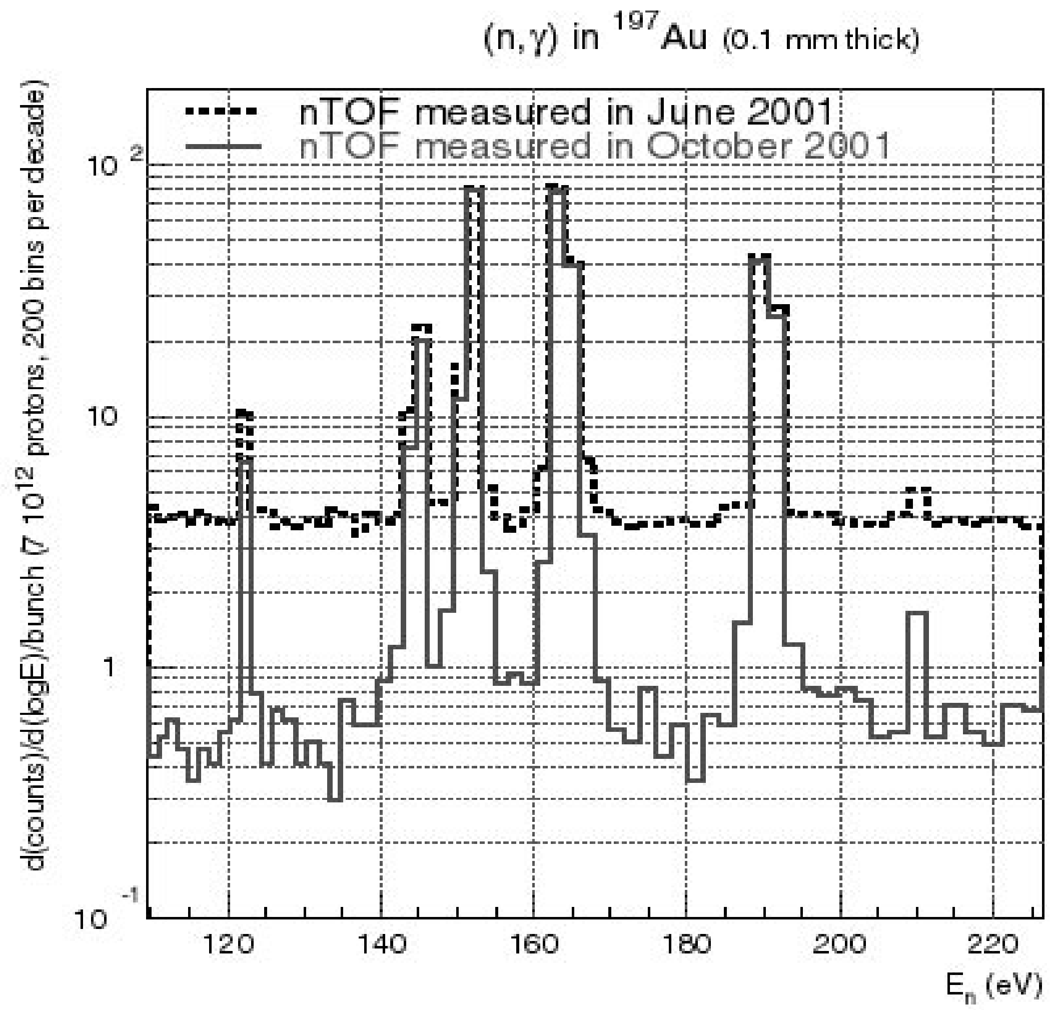


Different sections of a Au spectrum measured at n_TOF (red) compared to a corresponding spectrum taken at ORELA (black). Since the sample thickness were different the n_TOF background has to be multiplied by 2.

Detailed MC simulations allowed to identify the insufficient shielding in the nTOF tunnel as one large source of fast neutron and charge particle backgrounds. In addition the simulations have shown that these neutrons, after moderation and capture in the experimental area walls, could generate the observed backgrounds.

Background levels

A program for progressive reduction of the experimental area ambient background including additional measurements is in progress at CERN. The latest measurements (end of October 2001) show already a factor 10 reduction on the background. Additional actions are being considered for further background reduction.



Required Precision and Priority List of Elements

Marcus DAHLFORS[1,2], Yacine KADI[2]

[1]*Department of Radiation Sciences, Uppsala University, 75121 Uppsala, Sweden*
[2]*Emerging Energy Technologies, CERN, 1211 Geneva, Switzerland*

1st meeting of the BASTRA Cluster, Dec. 5, 2001, CERN

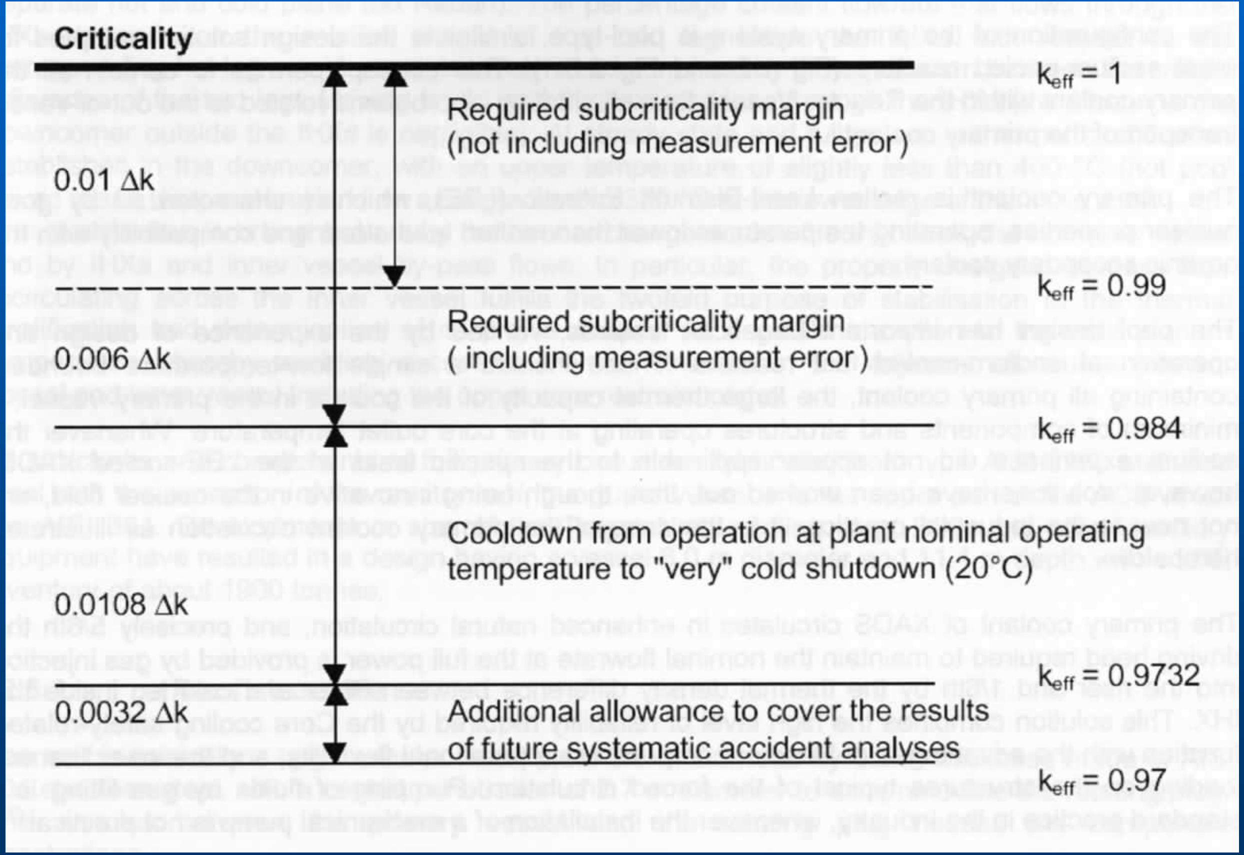
Introduction

- **Better knowledge of nuclear data to validate calculational models ⇒ insight on uncertainties associated with integral parameters that characterize a particular core**

- **For ADS, minimisation of uncertainty in Δρ/cycle essential ⇒ determines margins**
  - **at *k* ≈ 0.98, ± 2% uncertainty in Δρ/cycle has serious consequences on safety analysis and accelerator current requirements**

Introduction

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



Introduction

- **Also need to validate:**
  - **Neutron flux distributions and competition of different modes (source and higher harmonics)**
  - **Importance of source neutrons with respect to fission neutrons**
  - **Effect of buffer medium around spallation source**
  - **Kinematics of sub-critical cores**

Principal Requirements for ADS Technology

- **Structural materials and coolant:**
  - **Inelastic scattering and (n,xn) in Fe, Cr, Ni, Pb, Bi and W (± 5% to ± 10%)**
- **Fission products:**
  - **Capture XS of Tc-99, I-129, Xe-131, Cs-133, Cs-135, Sm-149, Sm-151 (typically ± 10%)**
- **Primary actinides:**
  - **Capture XS of Th-232, U-233, U-235, Pu-isotopes in the energy range 1 eV to 500 keV (typically ± 10%)**
  - **Inelastic scattering of Th-232 and U-238 (± 5%), Pu-239 (± 10%), Pu-240 (± 20%)**

Principal Requirements for ADS Technology

- **Primary actinides (continued):**
  - Fission XS of Th-232 and U-238 above 500 keV (typically ± 10%), U-233, U-235, Pu-239, Pu-241 in the energy range 1 eV to a few MeV (± 1% to ± 5%)
  - Fission product yields for mass chains 92 to 140 in U-233, U-235 and Pu-239
  - Delayed neutron yields for Th-232 and U-238 (± 3%), Pu-isotopes (± 3% to ± 7%), Np-237 and Am-241 (± 5%)
- **Minor actinides:**
  - Capture, fission, inelastic scattering, (n,2n), fission neutron spectra, delayed neutron yields, fission product yields and spontaneous fission half-lives for Np-237, Pu-238, Am-241, Am-243, Cm-244 (typically ± 10%)

XS Data Effect

Neutron cross section data effect in k_{src}

	JAR-95	ENDF/B-VI	JENDL-3.2
$UPuO_2$	0.96403	0.95883	0.93937
error	±0.00070	±0.00094	±0.00106
$\Delta k/k$ [pcm]		–539	–2558
$ThPuO_2$	0.96260	0.94945	0.94526
error	±0.00102	±0.00109	±0.00088
$\Delta k/k$ [pcm]		–1366	–1801

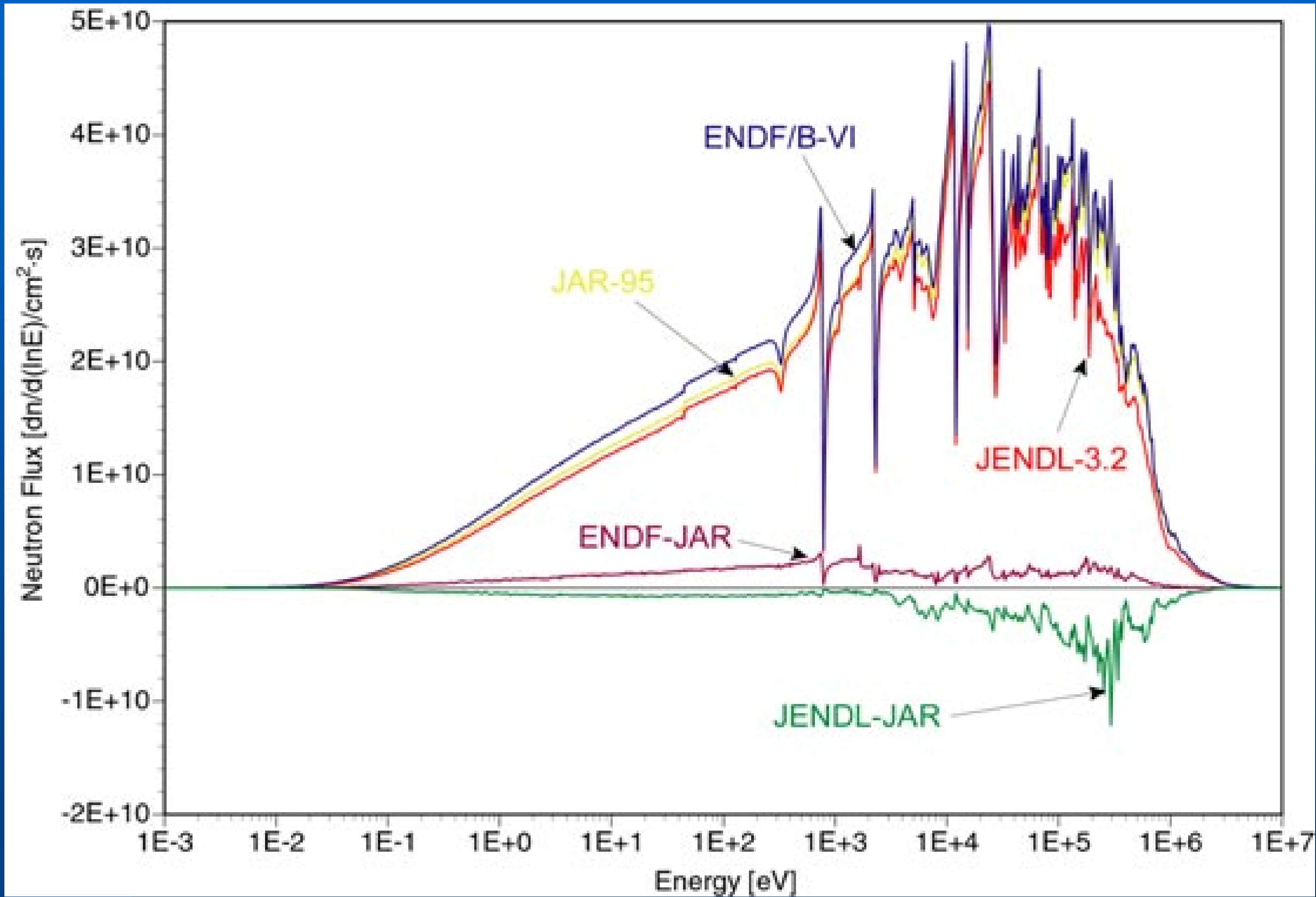
Neutron Balance (Device)

- U-Pu and Th-Pu fuel types show similar trends in library differences
- JAR-95 compilation taken as reference
- Differences for JENDL-3.2:
  - 2-4% excess for capture in fuels, coolant and cladding
  - 2-4% deficit for fission in fuels, (n,xn) in coolant
  - 25-30% deficit for (n,xn) in cladding
- Differences for ENDF/B-VI:
  - 0.5-2% excess for capture in fuels and cladding
  - Around 4% deficit for capture in coolant
  - 0.5-2% deficit for fission in fuels
  - Around 6% excess for (n,xn) in coolant
  - 1.5-2.5% excess for (n,xn) in cladding

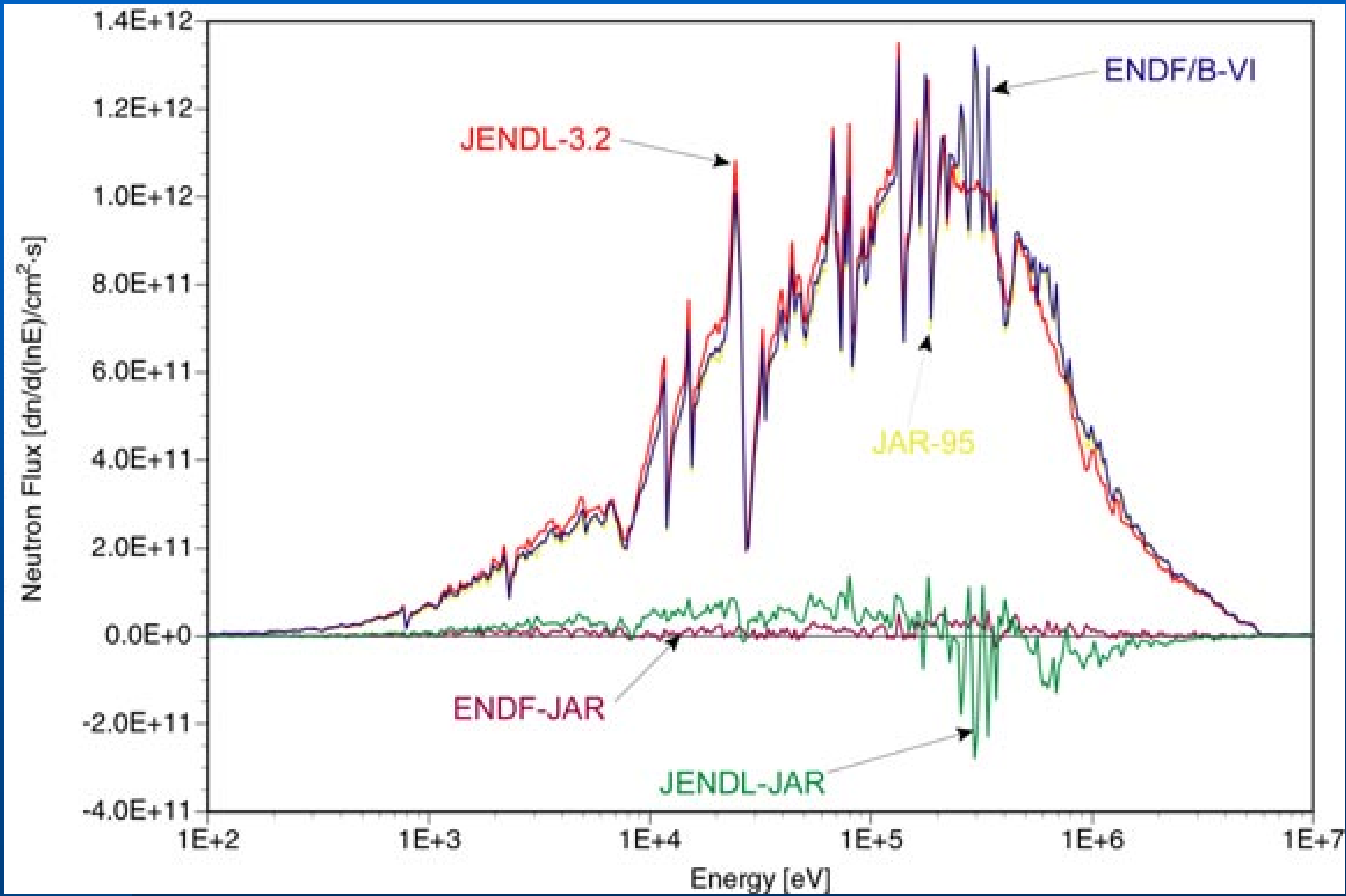
Neutron Balance (Fuel)

- **Fission to capture ratio:**
  - U fuel: JAR 0.92, JENDL 0.85, ENDF 0.91
  - Th fuel: JAR 0.88, JENDL 0.83, ENDF 0.84
- **Differences for JENDL-3.2:**
  - Capture:
    - 1.5% excess in ^{235}U, ^{238}U
    - 4% excess in ^{239}Pu
    - 10% excess in ^{240}Pu
    - 15-25% excess in ^{241}Pu
  - Fission:
    - 11% deficit in ^{238}U
    - 9% deficit in ^{232}Th
    - 12-16% deficit in ^{240}Pu
    - 2.5-4% deficit in ^{241}Pu

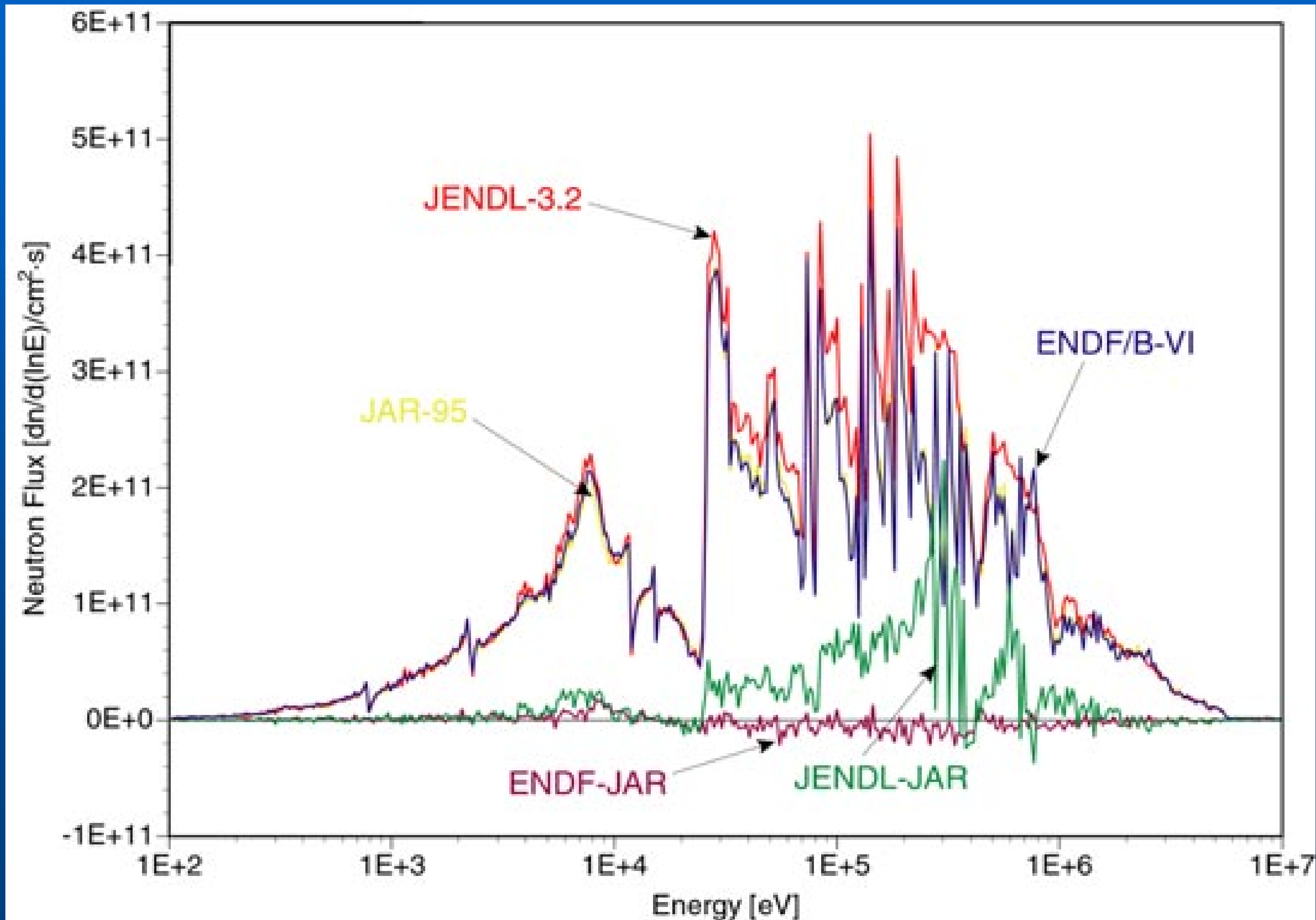
Spectrum Effect, Coolant



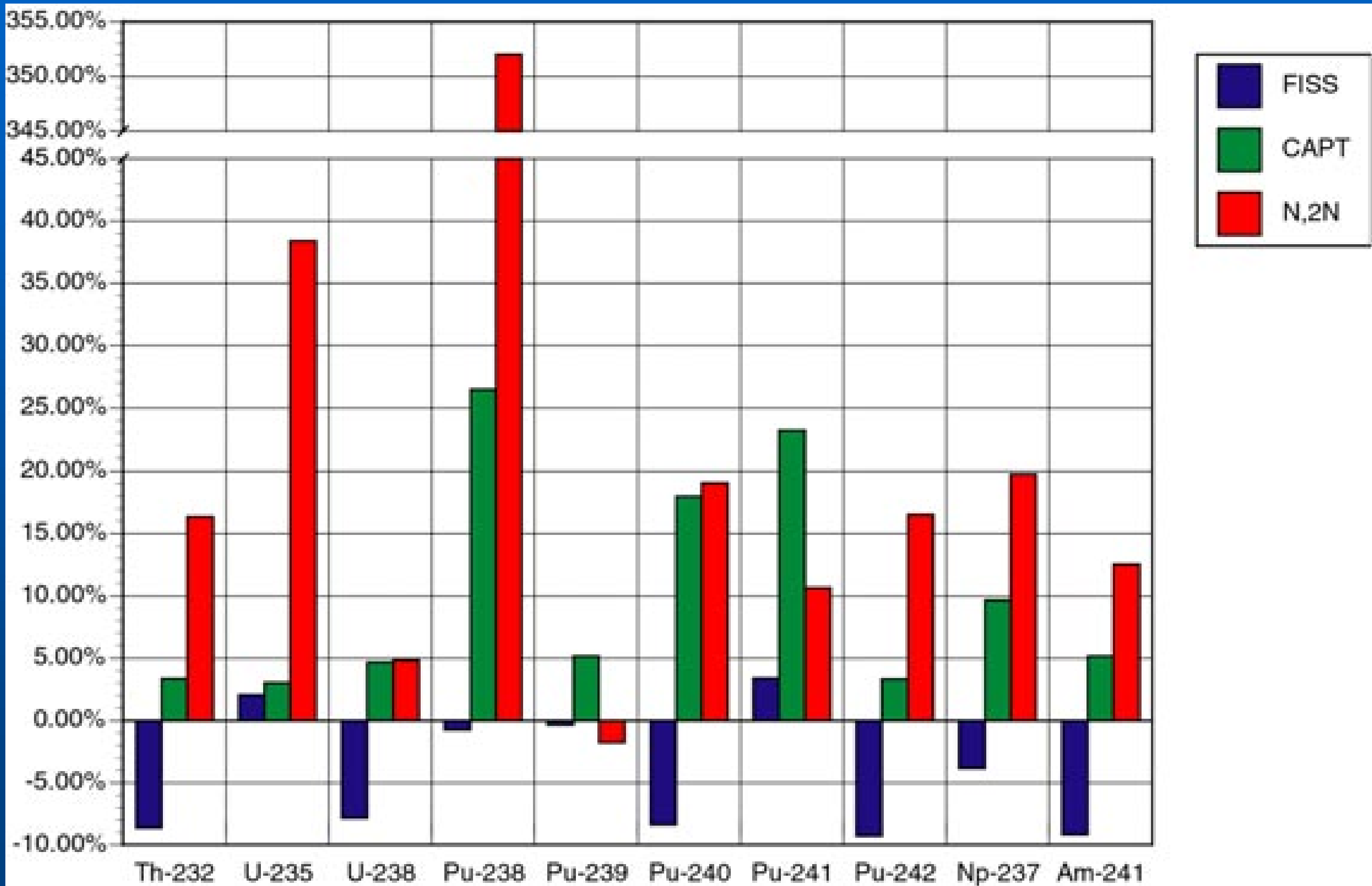
Spectrum Effect, Fuel



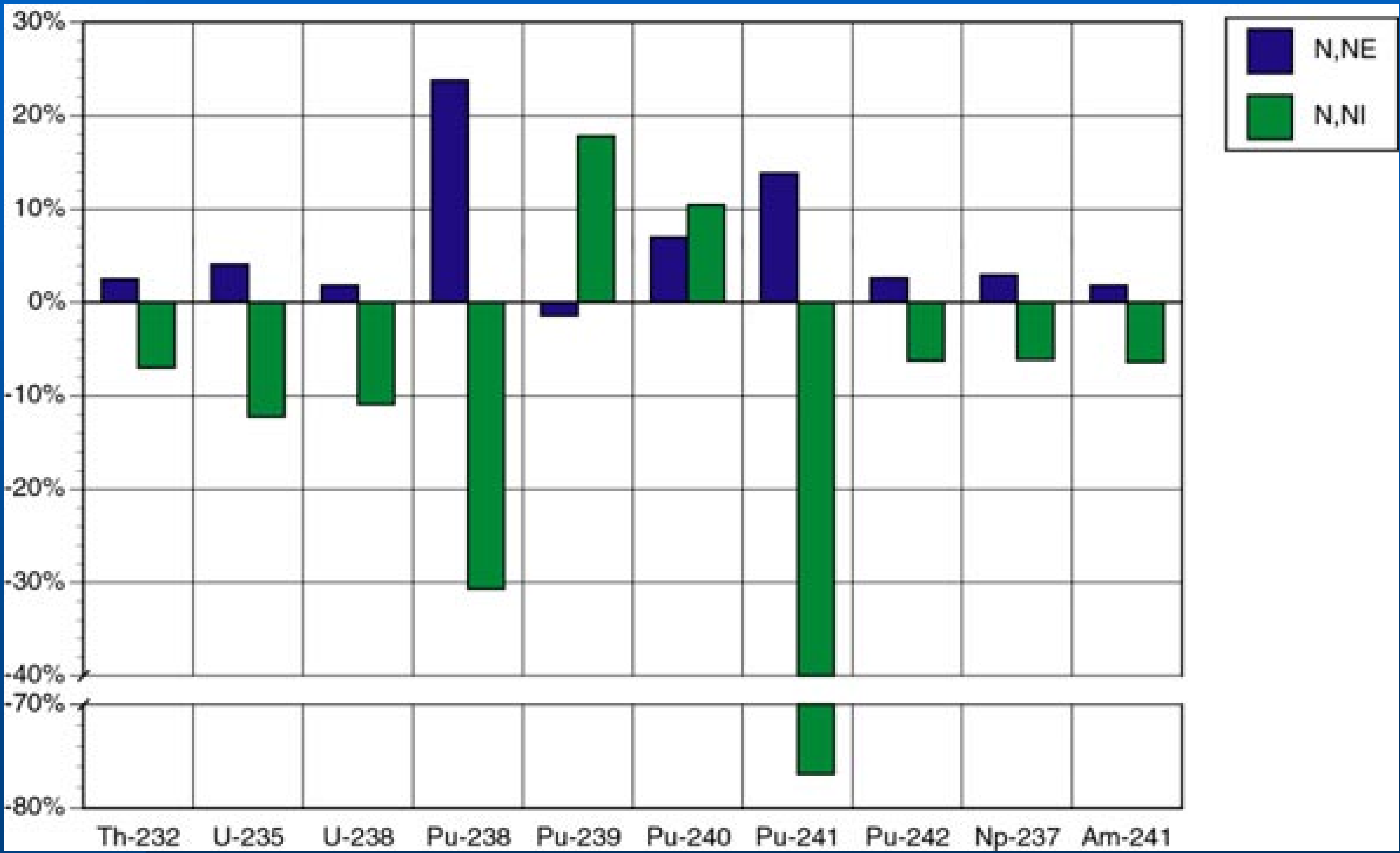
Spectrum Effect, Cladding



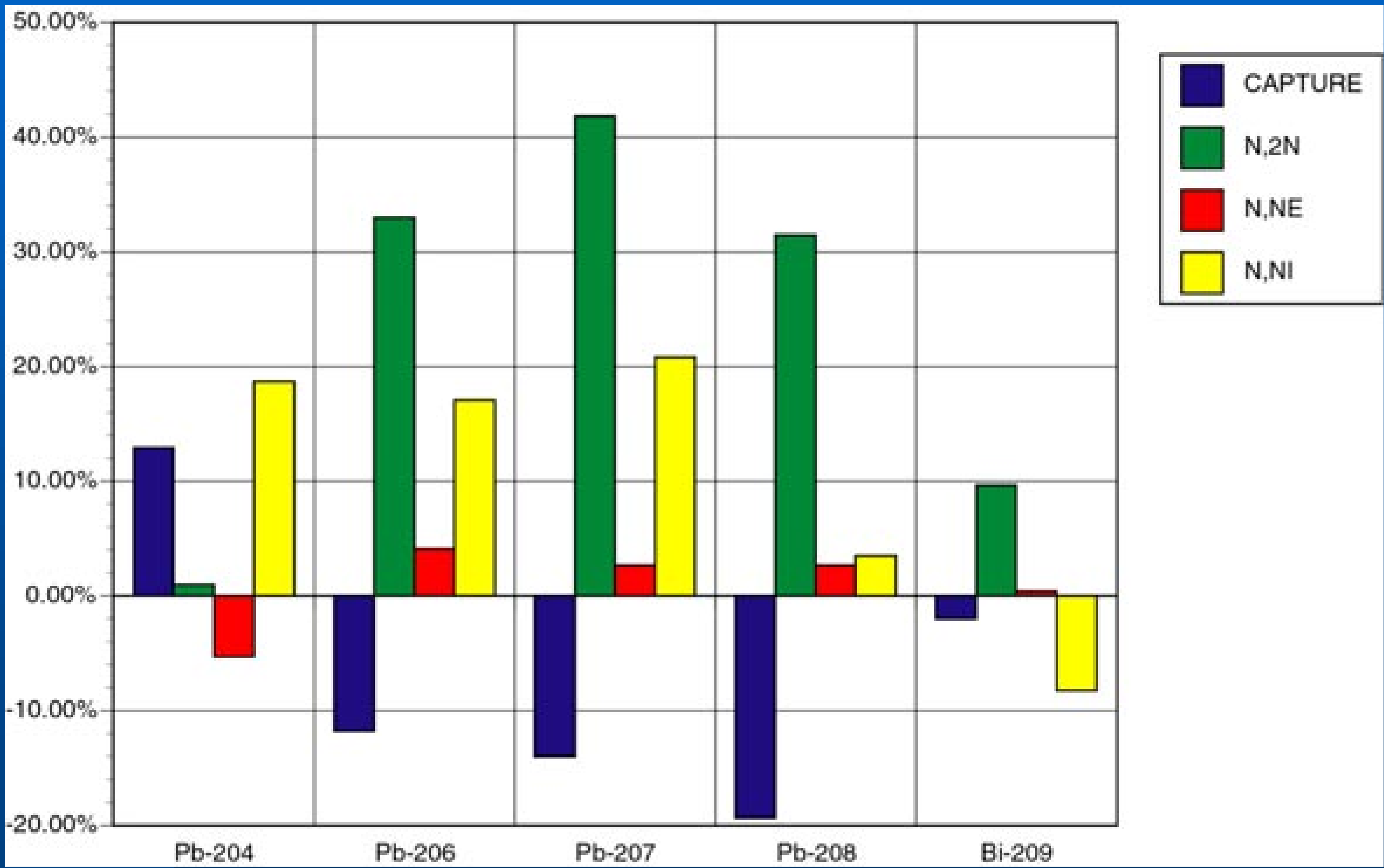
Comparison of 1-group XS



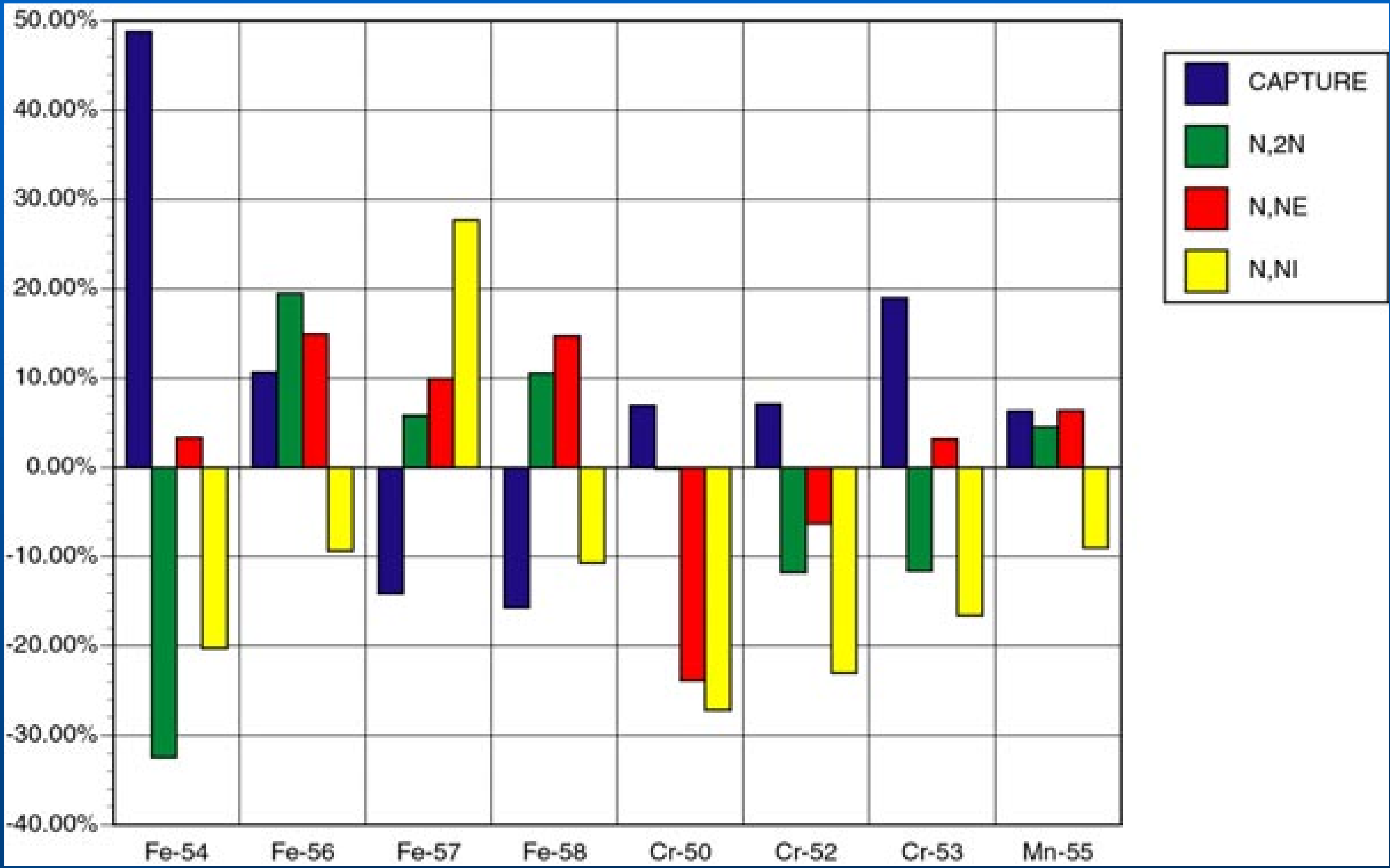
Comparison of 1-group XS



Comparison of 1-group XS



Comparison of 1-group XS



Conclusions

- Discrepancies of 2000 pcm in k_{src} for different nuclear data libraries
- Spectrum effects were seen for JENDL
- In the fuel materials, improved XS determination needed for
  - fission in ^{232}Th, ^{238}U, ^{240}Pu and ^{242}Pu
  - capture in ^{238}Pu, ^{240}Pu and ^{241}Pu
  - (n,xn) in most nuclides (even ^{235}U)
  - elastic scattering in ^{238}Pu and ^{241}Pu
  - inelastic scattering in ^{238}Pu, ^{239}Pu, ^{240}Pu and ^{241}Pu

Conclusions

- **In the coolant materials, improved XS determination needed for capture, (n,xn) and inelastic XS for the Pb isotopes**

- **In the cladding materials, improved XS determination needed for Fe isotopes, particularly ^{54}Fe (relative abundance 5.8%) has badly determined XS**

- **Analysis with a sensitivity-uncertainty code utilising XS data covariance files foreseen (deterministic code must be used)**

1^{st}BASTRA Cluster Meeting
CERN, Genf, 5. 12. 2001

nTOF-ND-ADS
Nuclear Data Evaluation and Modelling

H. Leeb[1] on behalf of the nTOF Collaboration
Atominstitut der Österreichischen Universitäten, Vienna University of Technology, Vienna, Austria

ABSTRACT

The nTOF-project aims at a measurement campaign of neutron cross sections relevant for transmutation, the design of ADS and the use of the Thorium-Uranium cycle. It is an important part of the EC-project to make these new data accessible to the user community as soon as possible. In order to reach this goal two activities are foreseen within the EC-project: (1) provide measured cross section in EXFOR format for direct inclusion into the world wide nuclear data banks; (2) generate evaluated files (which also include the new cross section data) for part of the isotopes and reactions by nTOF related evaluators. For both good links to the Nuclear Data Centres (NEA and IAEA) are required.

In order to perform this work a nTOF-Theory Group has been set up which is formed of members of the nTOF Collaboration and of external *Associated Experts*. Until recently the activities of the nTOF Theory Group have been focused on preparatory works, i.e. define the evaluation strategy, identify the research challenges and building up links to the nuclear data centres. In addition a first preliminary evaluation of ^{233}Pa, an isotope in the Thorium-Uranium cycle for which no measurements are planned at nTOF, has been performed by Russian members of the nTOF Collaboration.

The capture, fission, (n,xn) and total cross sections measured at nTOF will be prepared in formats suitable for the inclusion into the international data banks. The evaluation of part of these data will be a major task of the nTOF Theory group. It is the general strategy to perform evaluations by standard procedures and established codes. The choice of codes depends strongly on the energy range considered; emphasis will be given to microscopic descriptions in order to allow for reliable inter- and extrapolations to experimentally non accessible reactions. An important aspect of the nTOF-project is the planned inclusion of covariance matrices which will allow reliable estimates of uncertainties for key quantities in technical systems. In this context effort will be put on the study how to provide reasonable covariance matrices for cross sections only obtained via modelling procedures. Apart from this important issue several research challenges have been identified. These might be studied in connection with specific reactions, but no systematic code development is planned within the nTOF project.

Within the project time complete evaluations can only be performed for those isotopes where fully analysed and released data are available before mid of 2003. Taking into account the present measurement plan for 2002, capture and fission cross sections for several isotopes can be expected to be available and can be evaluated. Because of the present time schedule, evaluations for actinides cannot be expected within the running time of the EC project.

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nTOF-ND-ADS
NUCLEAR DATA EVALUATION AND MODELLING

H. Leeb (Vienna)
on behalf of the nTOF Collaboration

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OBJECTIVES and TASKS

Objectives:

The nTOF Project aims at a measurement campaign of neutron reaction cross sections related to transmutation, the ADS and the Thorium-Uranium cycle.

- **to make these high precision data accessible to the user (via data banks NEA, IAEA) as soon as possible.**
- **Evaluated files including the new cross section data should be generated for part of the isotopes**

Tasks:

- Providing measured cross sections in EXFOR for inclusion in the world wide data banks as early as possible. Link to international organisations (NEA, IAEA)
- Standard Evaluations and modelling procedures of part of the isotopes including the measured cross sections at nTOF
- Development of improved evaluation and modelling procedures on a microscopic basis to allow more reliable inter- and extrapolations.

nTOF THEORY GROUP

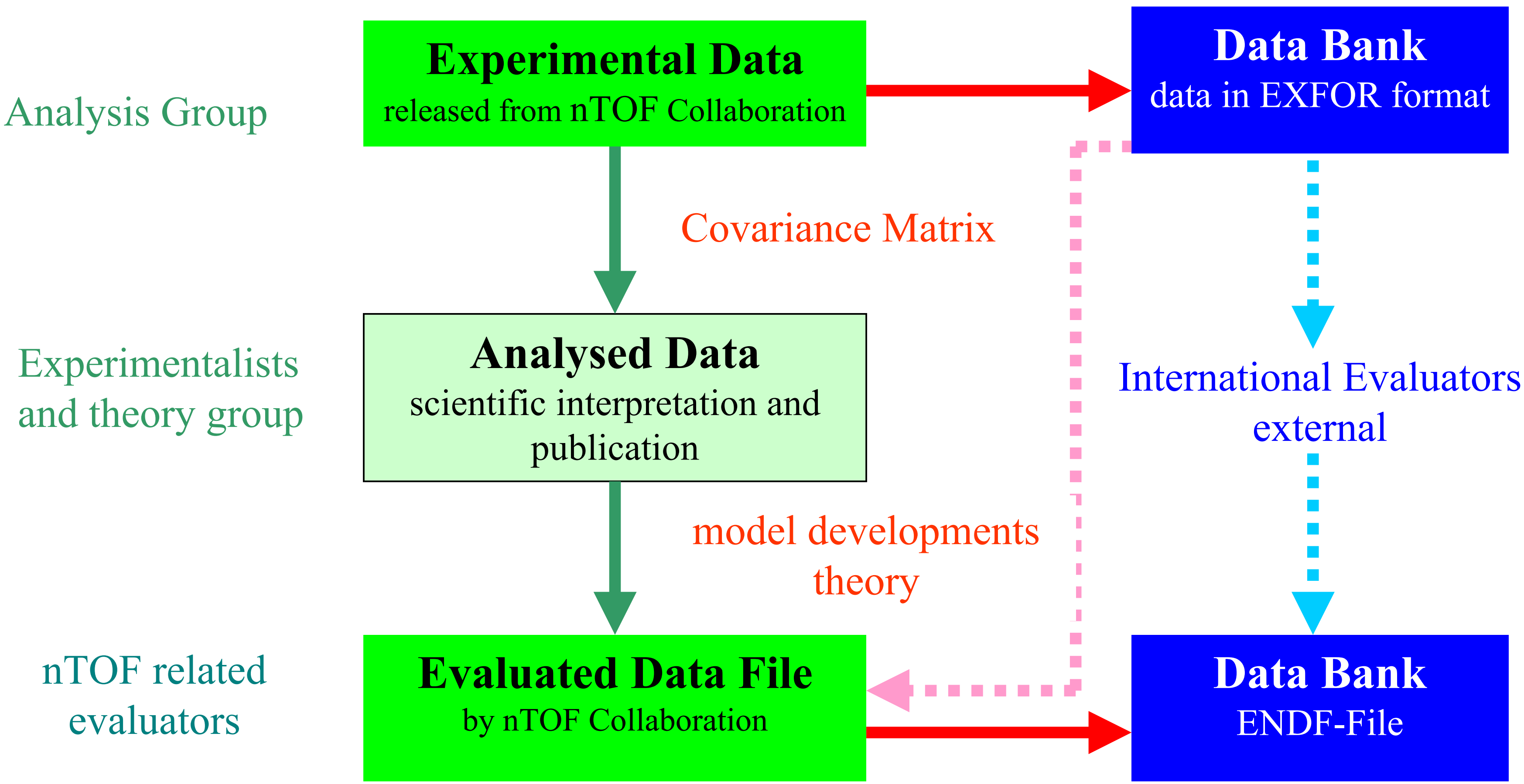
Members:

- **nTOF members:** Univ. Basel, ENEA Bologna, JINR Dubna, IPPE Obninsk, Univ. Sevilla, Atominstitut Wien
- **Associated experts:** CEA Bruyeres-le-Chatel, Univ. Lisbon, IRRM Minsk, Univ. Surrey

Activities so far:

- nTOF-Theory Group Meetings: CERN(31.1.2000), Bologna (3.6.2000), Paris (13/14. 3. 2001)
- Define Evaluation Strategy and identify Research Challenges
- Establish relations with NEA/OECD (Paris) and IAEA (Vienna)
- Planning of the evaluation schedule and modelling procedures
- First preliminary evaluation of ^{233}Pa

NUCLEAR DATA TREATMENT



EVALUATION STRATEGY

Models: Use of microscopic descriptions as far as possible

Uncertainties: Provide covariances as far as possible

Energy range: nTOF will provide (n,γ), (n,f) (n,xn) and some total cross sections in the energy range between 1eV and 250 MeV. Therefore evaluations in the resolved resonance range, the unresolved resonance range and at intermediate energies should be made.

Codes: Use standard codes for the evaluation procedure. We will make extensive use of standard codes distributed by NEA, e.g. SAMMY, GLUCS, STAPRE-code system, ECIS, EMPIRE-II, TALYS etc.

Timing: Within the project time complete evaluations can only be performed for those isotopes where fully analysed and released data are available before mid of 2003. All others will only be transferred into EXFOR format to be available for the data banks.

RESEARCH CHALLENGES

Several **open scientific problems** have been identified which should be considered in order to allow for more reliable inter- and extrapolation of not available or not measurable quantities

- Consistent analysis of overlapping resonances
- Level densities at high excitations
- Improved description of fission
- Onset of precompound reactions (especially for capture reactions)
- Improvements of multi-step direct reaction theory

- inclusion of evaluations resulting from modelling into a consistent covariance analysis

nTOF PROGRAMME

mono-energetic beams, evaluation

Evaluations

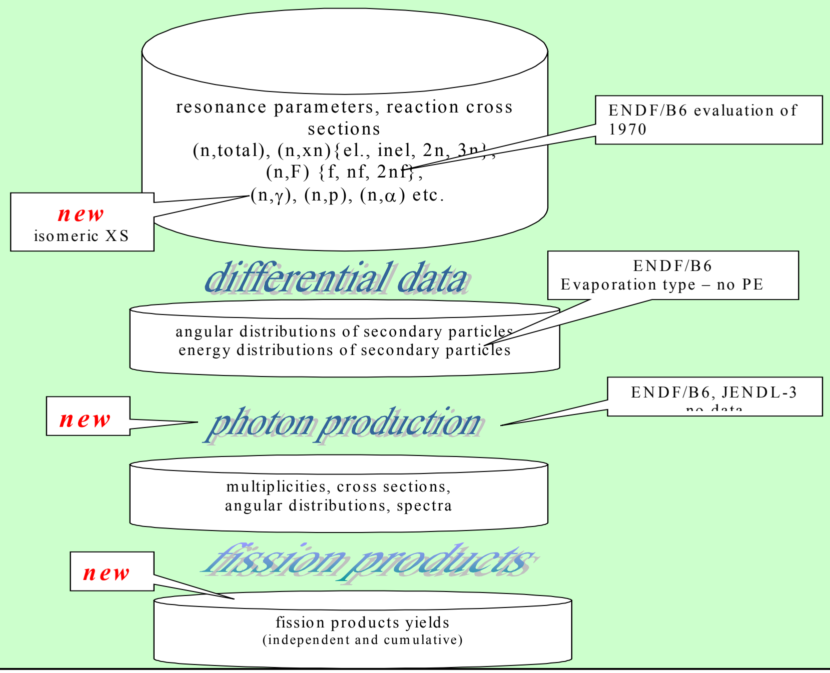
Within the EC-project nTOF-ND-ADS, evaluations by nTOF related evaluators including the results obtained at CERN can only be performed for part of the isotopes:

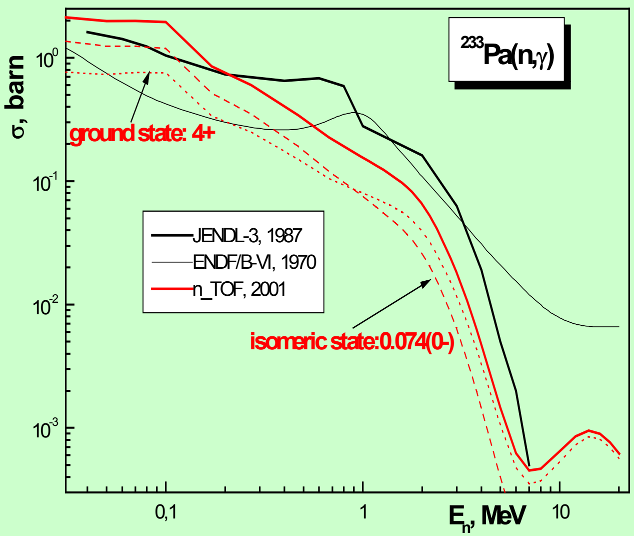
^{151}Sm, ^{204,206,207}Pb, (^{208}Pb, ^{209}Bi), ^{231}Pa, ^{232}Th, ^{233}U, ^{234}U, ^{236}U

Transfer to EXFOR format is foreseen for the cross sections obtained in all other measurements.

EVALUATION OF ^{233}Pa
by nTOF-ND Evaluation Network

The evaluation performed by the Obninsk-Dubna group takes into account new capture data, new photo production data and new data on fission product yields.





Capture cross sections.

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PS213

The TOF Collaboration

CONCLUSION

Making use of the unique properties of the nTOF facility at CERN the nTOF project will produce many high quality cross section data, specifically for very active isotopes, which should be accessible to the users as soon as possible.

Although the nTOF project will make all efforts to generate evaluated data files for several isotopes, a major effort of the Nuclear data community is required for the proper inclusion of the new data in evaluations.

FIFTH FRAMEWORK PROGRAMME

THE MUSE EXPERIMENTS

EC Contract: FIKW – CT – 2000 - 00063

R. SOULE CEA Cadarache

List of participants

CEA Cadarache, France (Coordinator)
CEN/SCK Mol, Belgium
University Joseph Fourier, Grenoble, France
FZK, Karlsruhe, Germany
FZJ, Julich, Germany
BNFL, Warrington, UK
ENEA, Roma, Italy
NRG, Petten, The Netherlands
TUDT.IRI, Delft, The Netherlands
CIEMAT, Madrid, Spain,
KTH, Stockholm, Sweden
Assistant contractors:
Chalmers UT, Goeteborg, Sweden
University of mining and metallurgy, Krakow, Poland

OBJECTIVES

1- Definition of an experimental data set for developing a reference calculation route
(including: - recommended nuclear data,
- recommended calculational tools,
- and recommended residual uncertainties)

to optimise both the multiplying sub critical media
and the shielding
of a future industrial accelerator driven system.

2- Definition, validation and recommendation of experimental techniques allowing the subcriticality determination of the system in operation.

METHODOLOGY (1)

1- Experimental program in the MASURCA facility using the coupling of the « ad hoc » GENEPI accelerator and multiplying subcritical media loaded in the MASURCA facility,

➤ 3 Work Packages

2- Experimental program performed at DUBNA (Russia): the SAD experiments, based on the use of the 660 MeV protons accelerator and on the creation of a subcritical assembly

➤ 1 global Work Package

METHODOLOGY (2)

MUSE experiments

WP1: Preparation of the MUSE experiments

- Definition of the experimental core configurations
- Elaboration of the experimental safety report
- Definition of the unique physical data set describing the physical and geometrical arrangements of the configurations

WP2: MUSE experimental program

- Definition of the experiments and of the experimental needs and conditions
- Performance of the experiments
- Common publication of the experimental conditions and results
- Definition of a unique experimental data set (experimental conditions, techniques and results + associated uncertainties

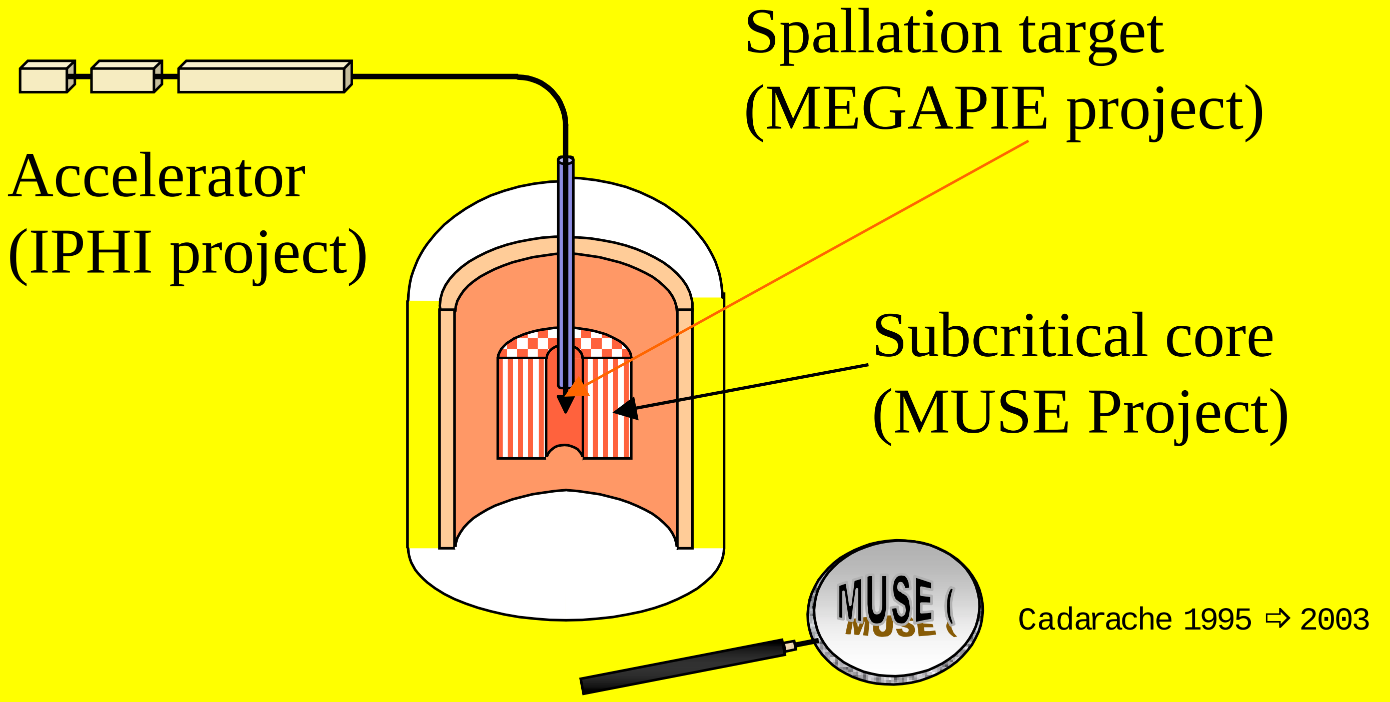
METHODOLOGY (2)

MUSE experiments

WP3: Analysis of the MUSE experiments and final report(s)

- Separate analysis of the experiments (different tools and nuclear data)
- Inter-comparison of all the separate analyses and trends determination
- Common publication(s) of the analysis results and trends
- Definition of a recommended validated calculation route for the neutronic predictions of sub-critical systems

METHODOLOGY (3)

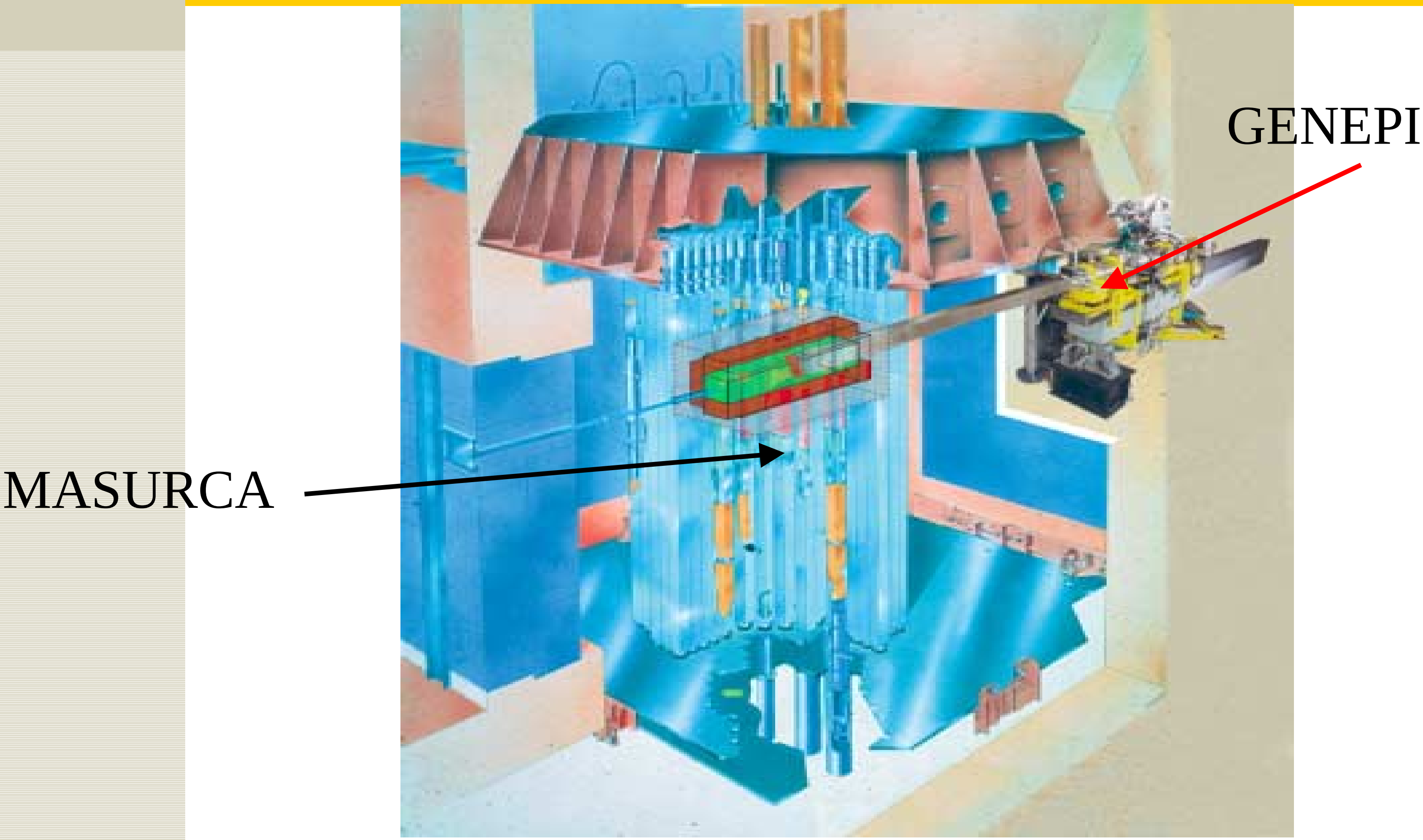


Studies concerning spallation source, spallation target and sub-critical core can be disconnected

➔ **parametric studies of different sub critical configurations**

(compositions, geometries, reactivities, external sources types and locations)

The MASURCA – GENEPI Coupling



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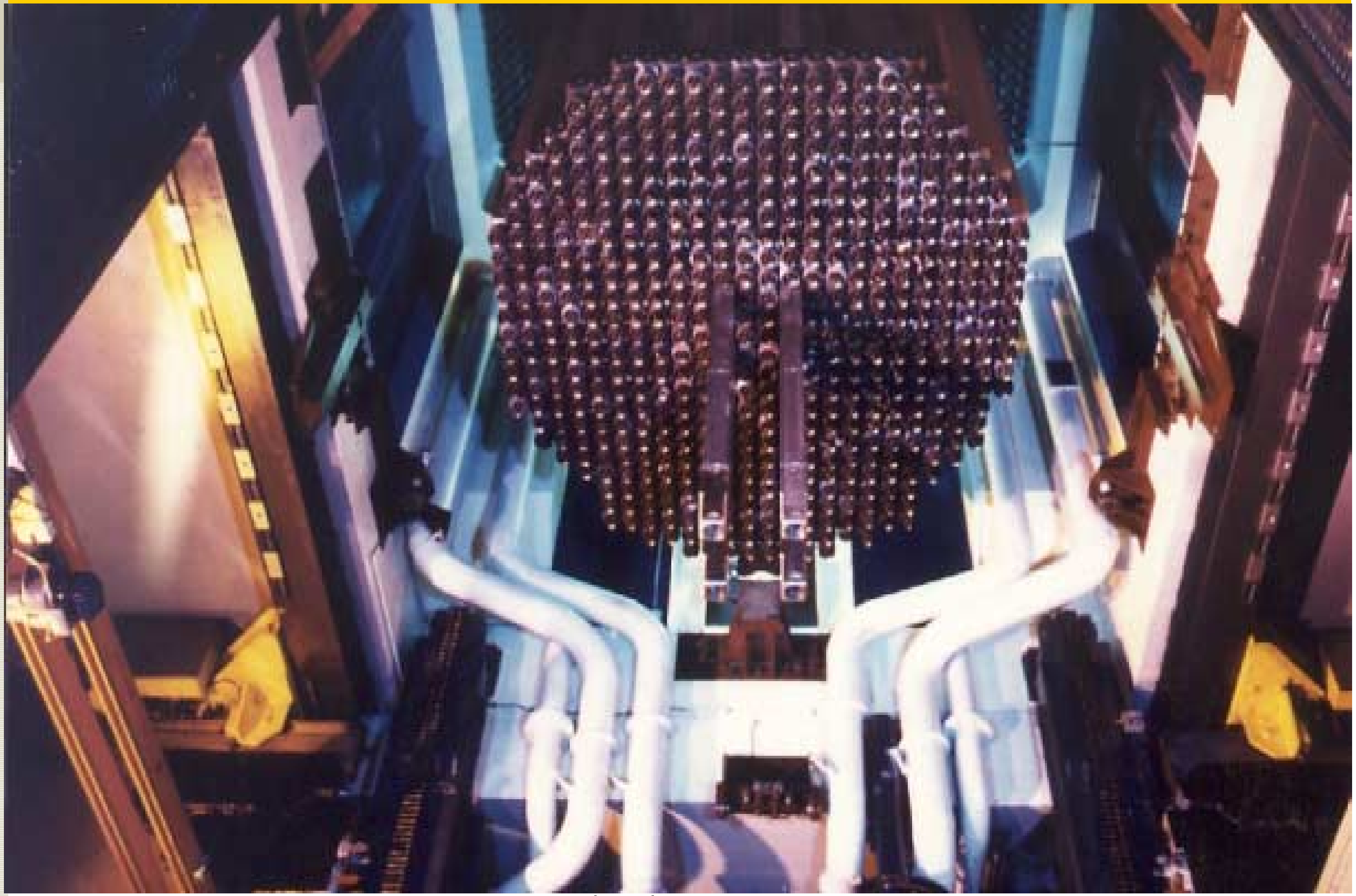
The MASURCA facility



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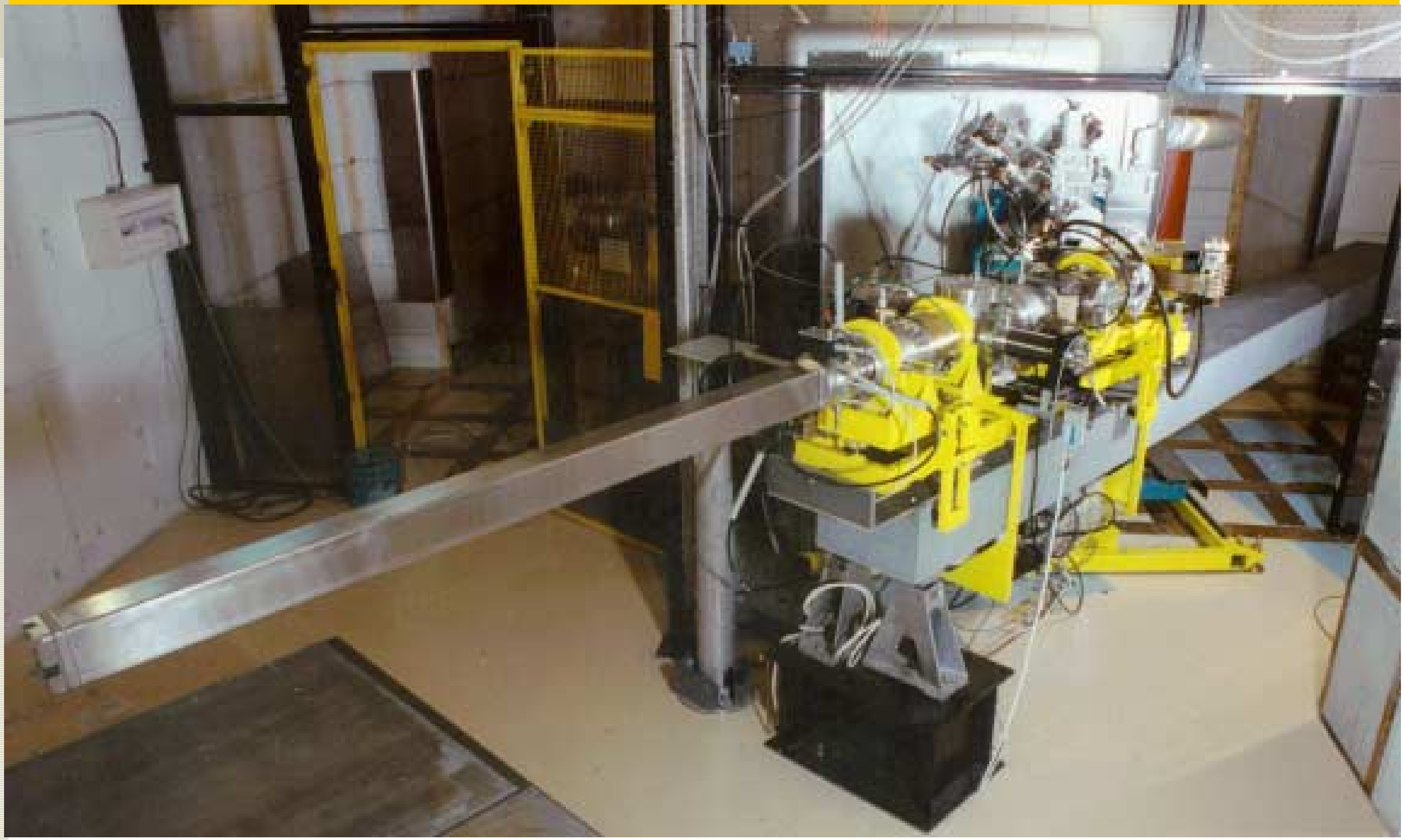
The GENEPI Accelerator



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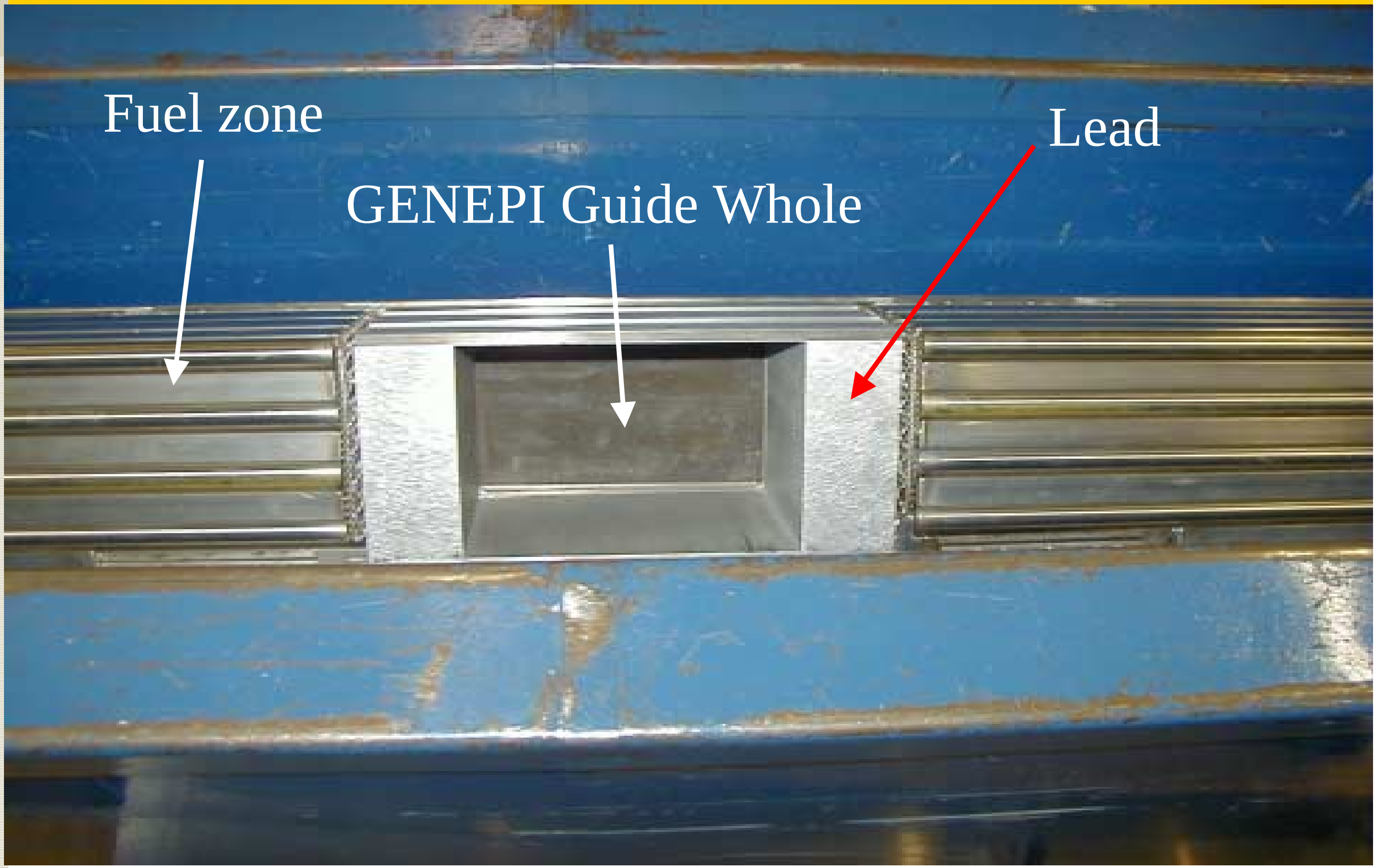
Some characteristics of the GENEPI accelerator

Beam Energy	140 to 240 keV
Peak current	50 mA
Repetition rate	10 to 5000 Hz
Minimum pulse duration	700 nanosecond
Mean beam current	Less than 200µA (for a duty cycle of 5000 Hz)
Spot size	Diameter ≈ 20mm
Pulses reproducibility	Fluctuations at 1%

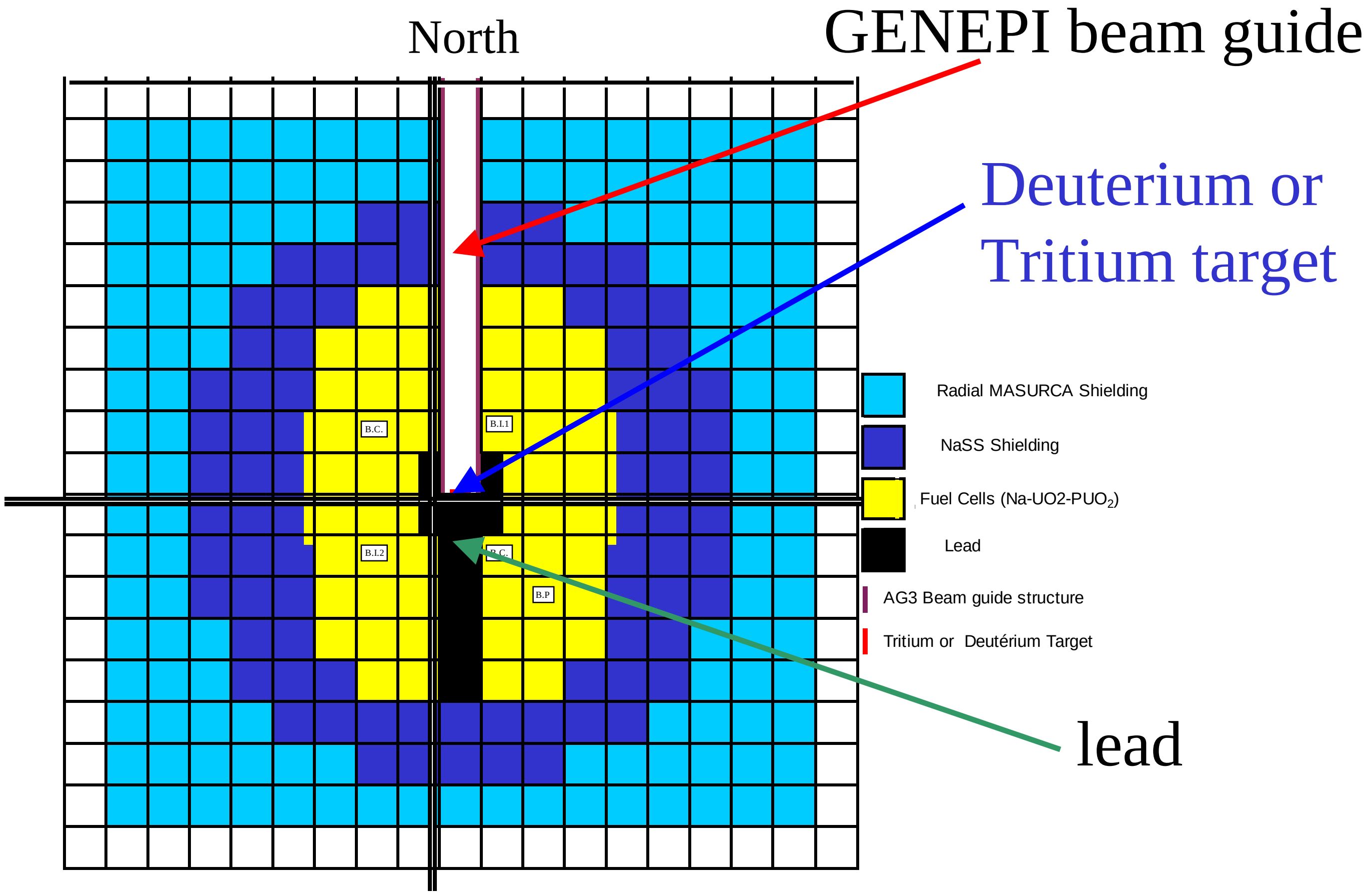
Neutron sources from GENEPI

Targets characteristics	Nuclear Reactions	Neutrons/s
Deuterium in 1 mg/cm2 Ti deposit (30 mm diameter)	D(d,n)^{3}He E_n ~ 2,7 MeV	# 8.0 10^{07}
Tritium in Ti deposit with 10 Ci	T(d,n)^{4}He E_n ~ 14 MeV	1.5 to 4.5 10^{10}

Special MASURCA tubes for coupling

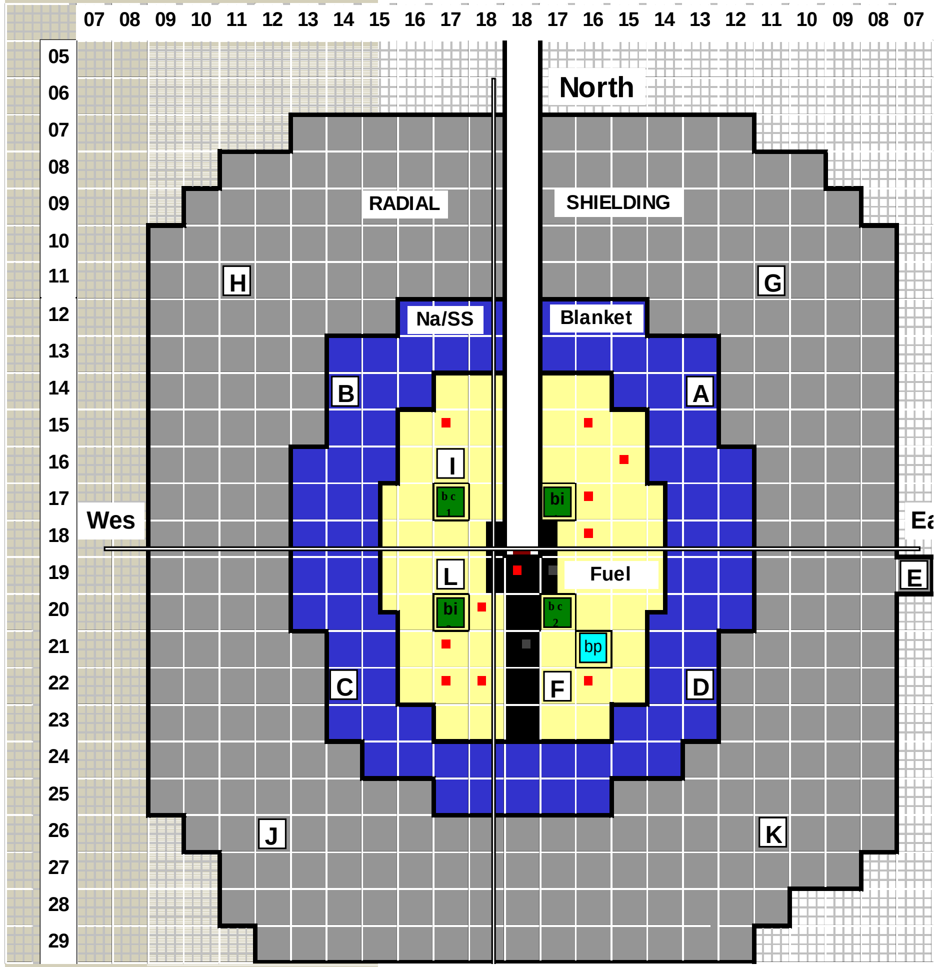


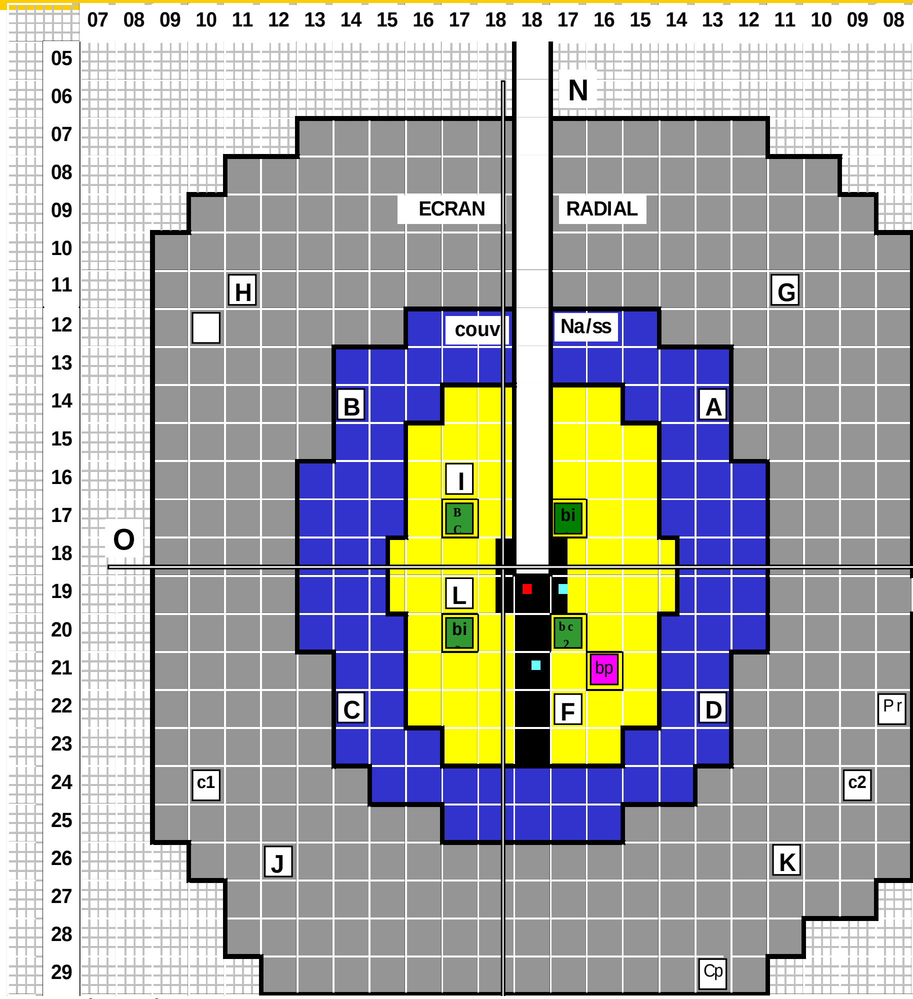
XY Loading of the MUSE-4 Reference configuration



XY cut of the MUSE-4 reference critical configuration at the core mid-plane

XY Loading of the MUSE-4 ref and SC1 configurations





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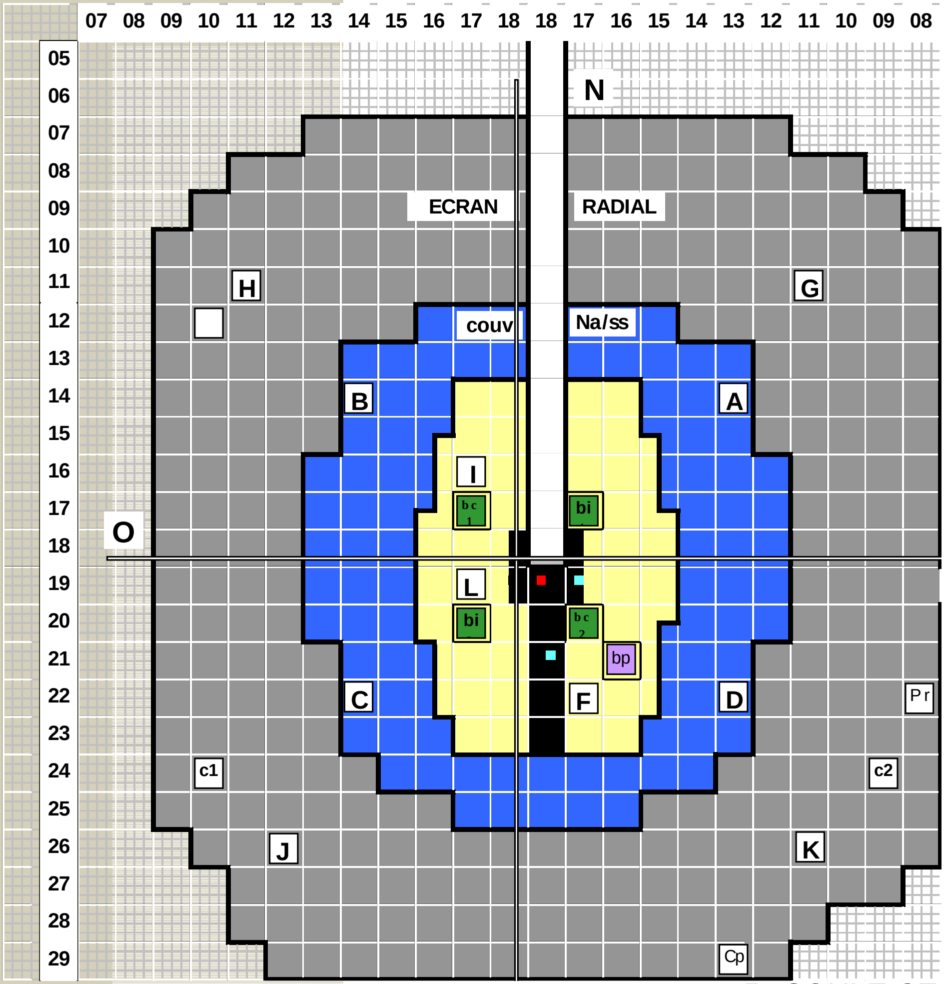
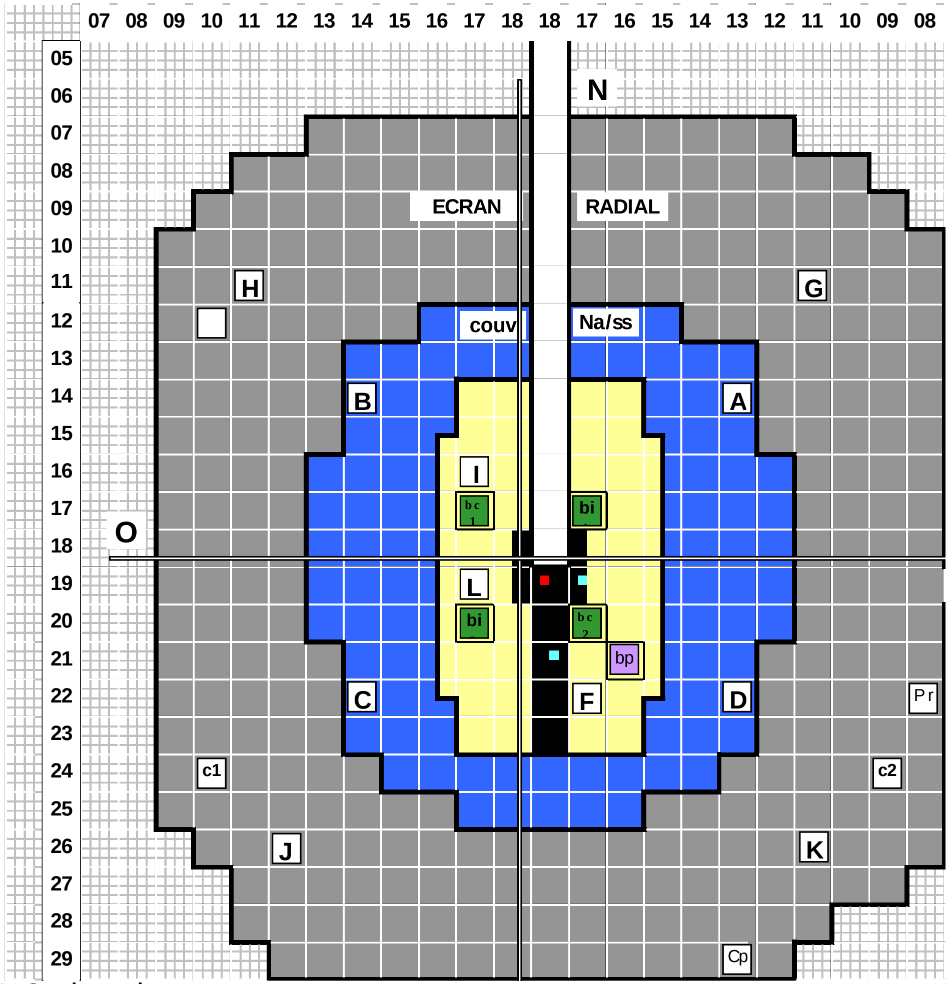
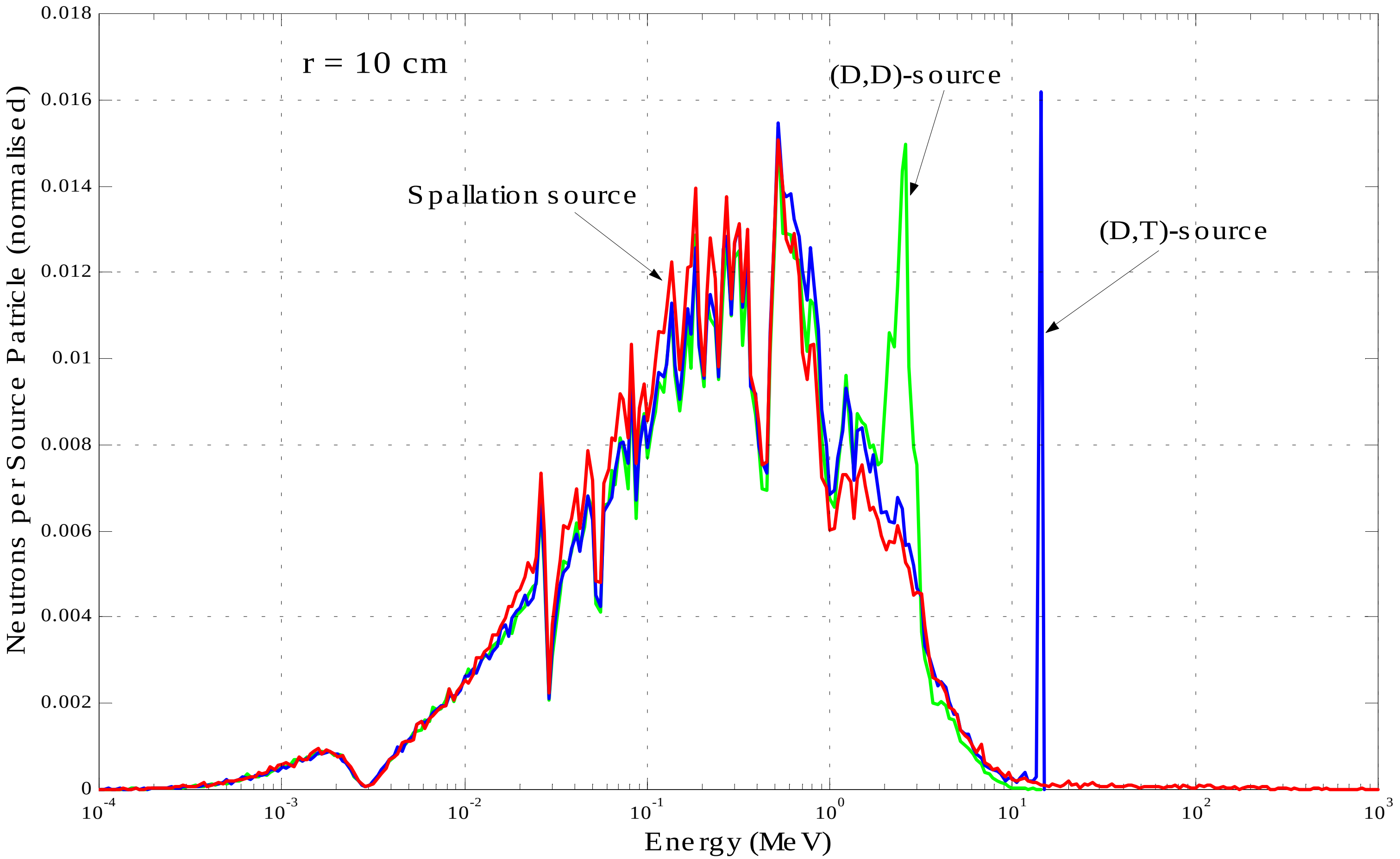
XY Loading of the MUSE-4 SC2 and SC3 configurations





GENEPI Sources Representativity (1)

The Neutron Spectra at the interface between lead and fuel



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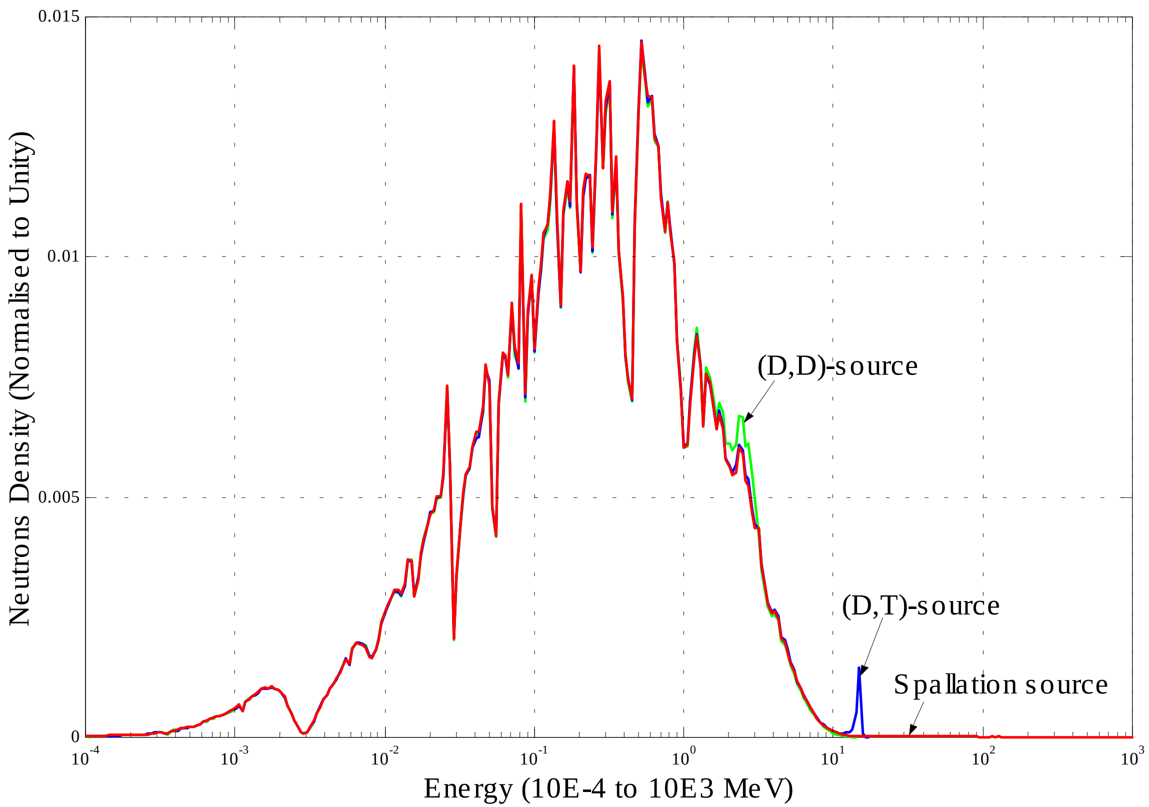
GENEPI Sources Representativity (2)

The Neutron Spectra in the Fuel



The presence of the sources almost forgotten in the fuel!

GENEPI Sources Representativity (3)
The φ* parameter

$$\varphi^* = \frac{\text{Average Importance of Source Neutrons}}{\text{Average Importance of Fission Neutrons}} = \frac{\dfrac{<\phi_0^*, S>}{<S>}}{\dfrac{<\phi_0^*, \boldsymbol{F}\phi_S>}{<\boldsymbol{F}\phi_S>}}$$

$$\Rightarrow$$

$$\varphi^* = \left(\frac{1}{k_{eff}} - 1\right) \cdot \frac{<\boldsymbol{F}\phi_S>}{<S>}$$

GENEPI Sources Representativity (4)
The φ* parameter

MCNP, MCNPX

ENDF/B-VI.4

- *(d,d)*-source: $\varphi^* \sim 1.35$
- *(d,t)*-source: $\varphi^* \sim 2.15$
- Spallation source: $\varphi^* \sim 2.25$

(Average Fission Neutron: $\varphi^* \sim 1.0$)

The fraction of high-energy neutrons (17% with $E_n > 20$ MeV) in the spallation source, contribute for 50 % to the total number of fission neutrons produced in the core.

MUSE - 4 CONFIGURATIONS

Four configurations with different sub criticality worths:

REF	SC1	SC2	SC3
0 $ (0 pcm)	-1.5 $ (-500 pcm)	-10 $ (-3000 pcm)	-17$ (-5000 pcm)

These configurations are scheduled as follows:

Conf.	REF	SC1			SC2		SC3		SC3	SC2
GENEPI status/target	OFF	OFF	(d,d)	(d,t)	OFF	(d,t)	OFF	(d,t)	(d,d)	(d,d)

For spatial coupling studies, SC1 and SC2 will also be made asymmetrical using safety rod motion.

MUSE - 4 experimental program

	REF	SC1					SC2				SC3		SC3	SC2
		OFF		(d,d)	(d,t)		OFF		(d,t)		OFF	(d,t)	(d,d)	(d,d)
		SYM	ASY		SYM	ASY	SYM	ASY	SYM	ASY				
Operating														
Rod worth	X	X					X				X			X
Monitor calibration	X	X					X				X			X
Reactor calibration	X	X					X				X			X
Chamber inter-calibration	X													
GENEPI monitoring				X	X									
Target control study				X	X				X			X	X	X
Statics														
Source multiplication	X	X					X				X			
Radial traverses	X			X	X	X			X	X		X	X	X
Axial traverses	X			X	X	X			X	X		X	X	X
Spectrum indices	X								X					X
Foil activation	X			X	X				X			X	X	
He-3 spectrum				X	X				X			X	X	X
Cf-252 source importance		X	X					X			X			
GENEPI source importance				X	X	X			X	X		X	X	X
Dynamics														
Reactor noise	X	X												
Transfer function				X	X				X			X	X	X
Frequency modulation				X	X				X			X	X	X
Pulsed source methods				X	X	X			X	X		X	X	X
Rossi- & Feynman-α methods	X	X		X	X		X		X		X	X	X	X

Some key dates

a – 9th January 2001: First divergence of the MUSE-4 Reference Configuration

b – 27th May 2001: Safety authorisation for the experimental program in the MUSE-4 reference configuration

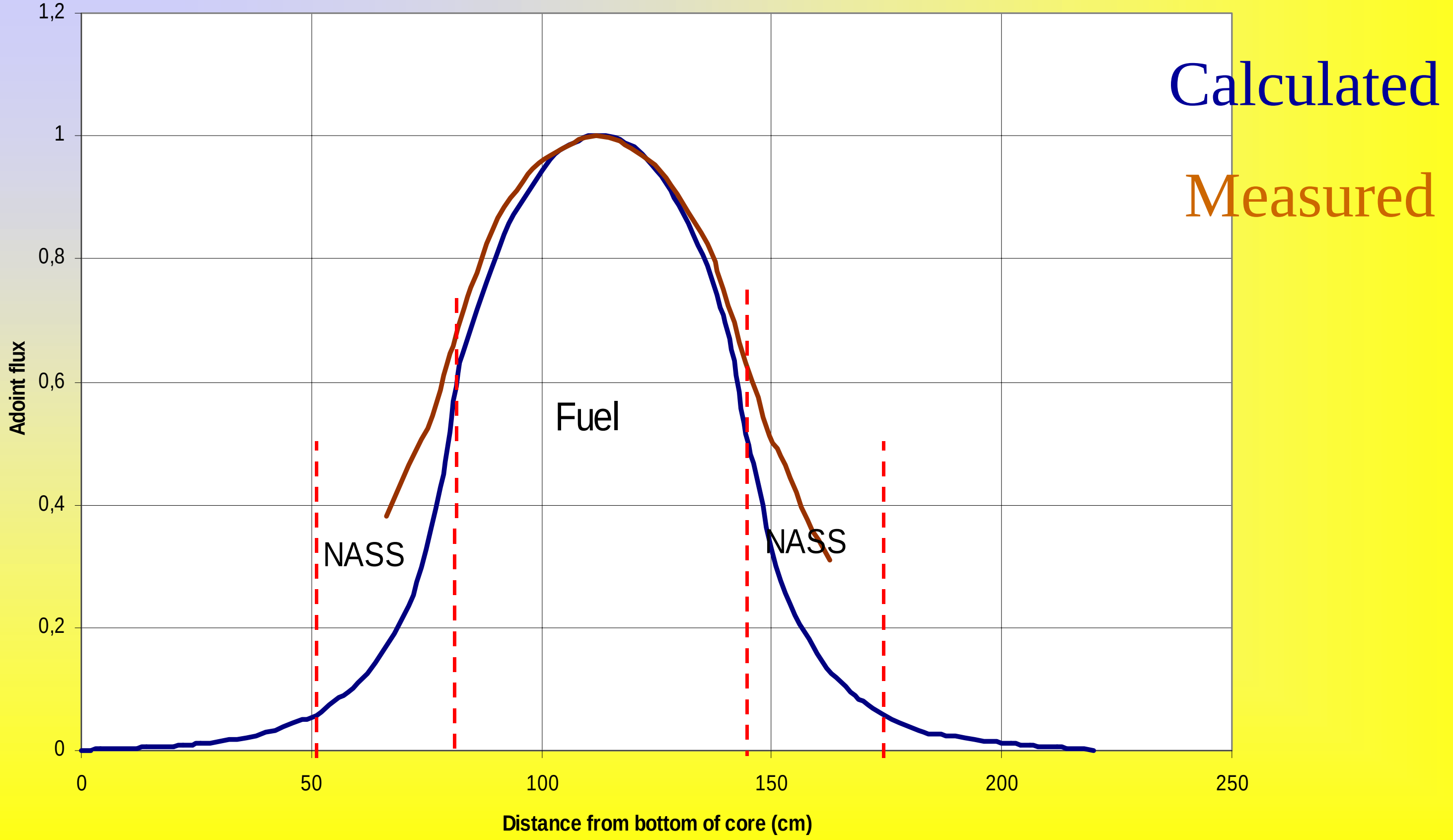
c – 19th September 2001: Safety authorisation for the GENEPI-MASURCA coupling

d – 15th October 2001 : Safety autorisation for the sub-critical experiments

e – 27th November 2001: First coupling:
MASURCA – 569 pcm
GENEPI: (d,d) source, 5kHz

Some preliminary experimental results

Measured and Calculated Adjoint flux in W22-17



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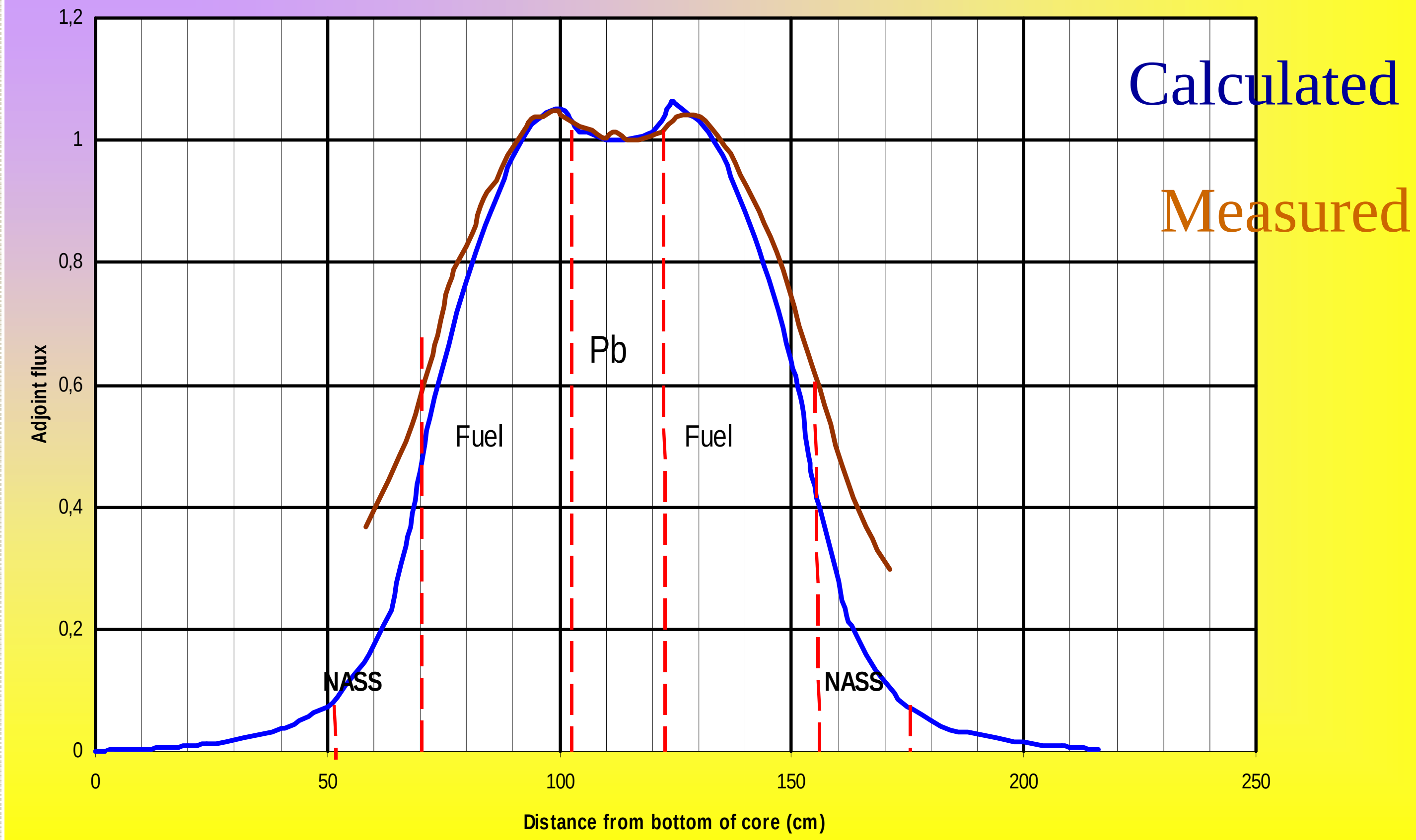
Some preliminary experimental results (2)

Measured and Calculated Adjoint flux in E19-18



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Some preliminary experimental results (3)

Feynman-α experiment (without GENEPI)

This neutron-noise technique was applied in the MUSE-reference core at two subcriticality levels, -70 pcm and -20 pcm, very close to criticality.

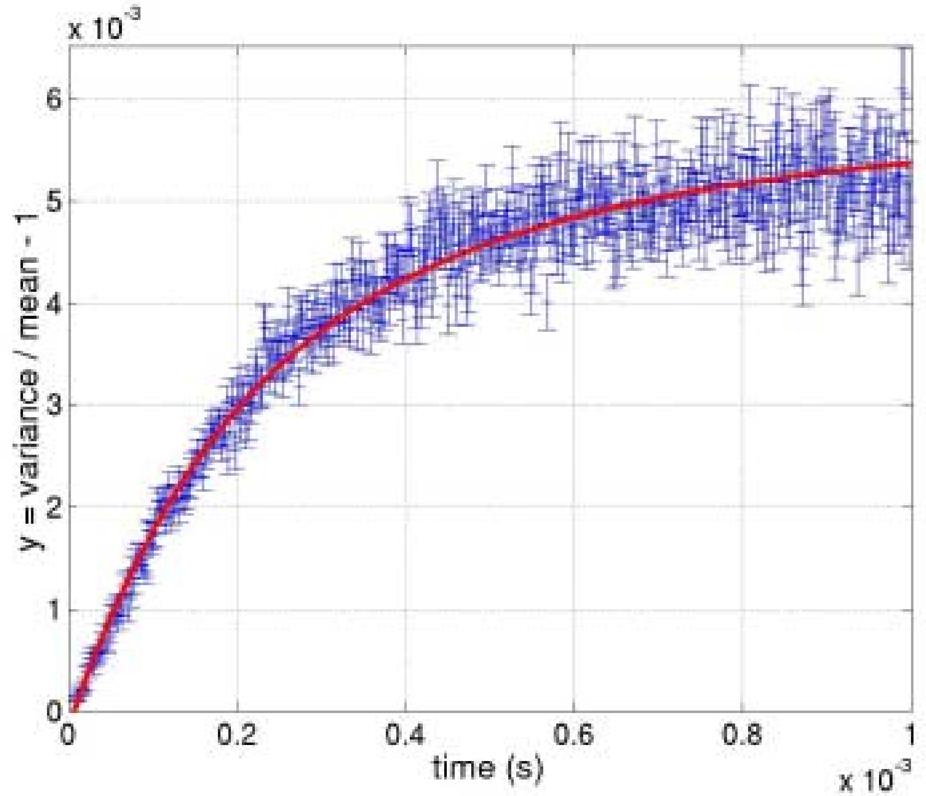
Neutron detectors:

- 4 U5-fission chambers in the reflector
- 2 U5-fission chambers in the shielding

→ *6 neutron-input channels*

Some preliminary experimental results (4)

The analysis is in progress: owing to a low detector efficiency, the signal-to-noise ratio is somewhat low.



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The prompt-neutron decay constant α can be thus inferred:

$$\alpha = 7761 \pm 270$$

with 95% confidence bounds and a correlation coefficient of 0.996.

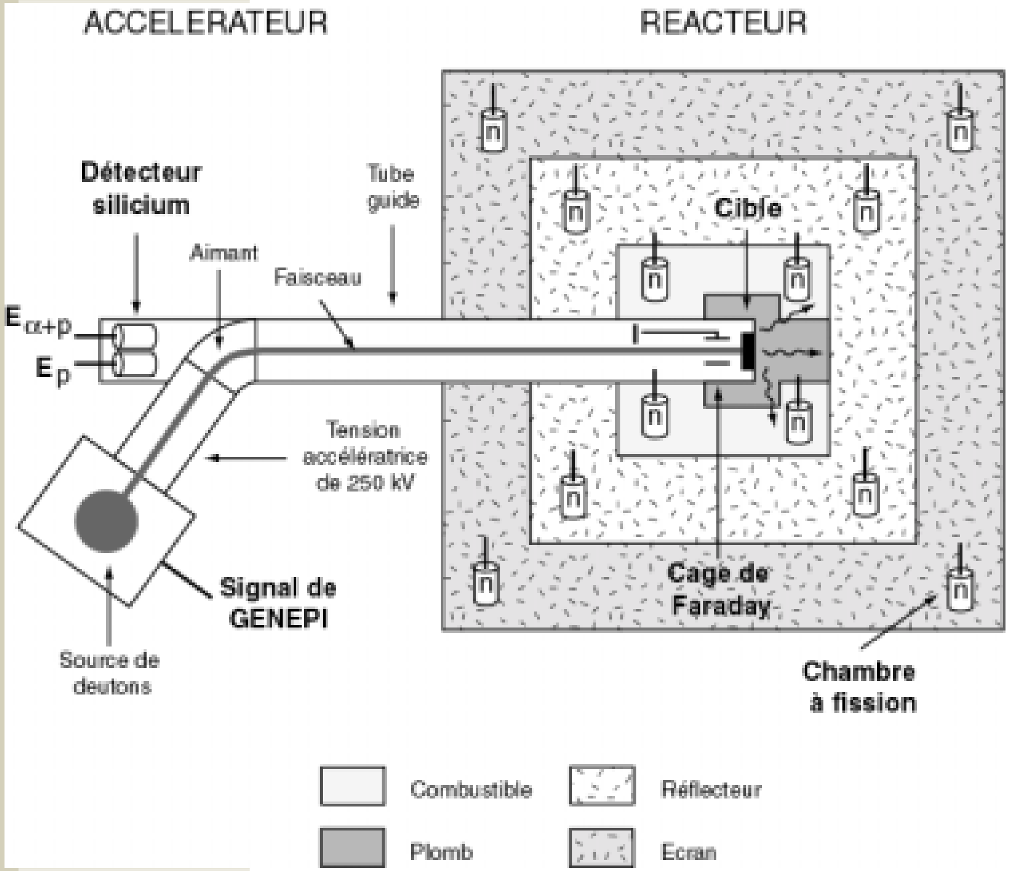
A first application

Definition of an international calculation exercise based on MUSE-4 configurations:

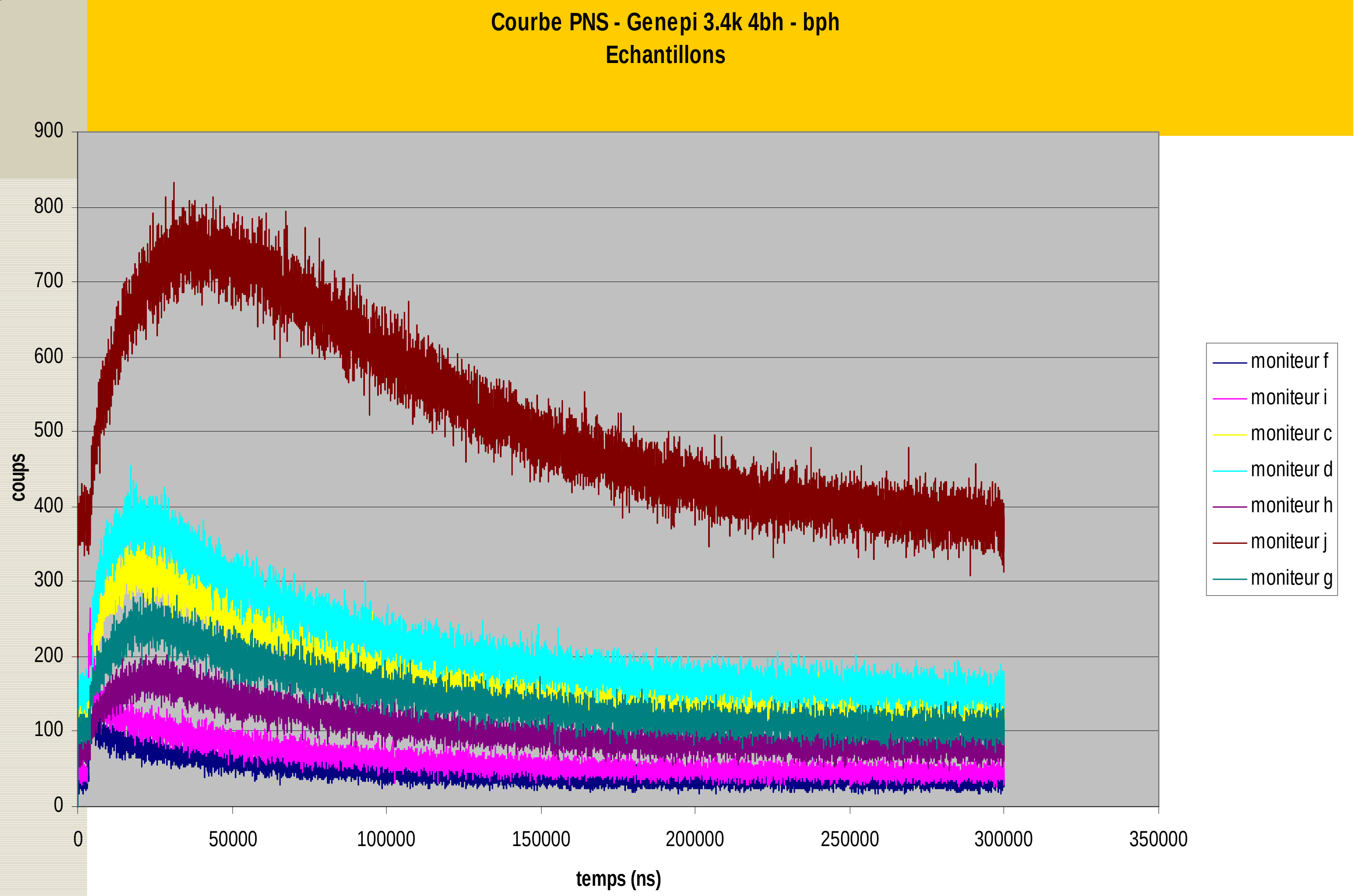
Benchmark on computer simulation of MASURCA critical and subcritical experiments
CEA-CIEMAT
Under the auspices of the OECD/NEA (distributed this week)

3 configurations:
- a clean critical core
- the MUSE-4 reference type configuration
- a largely sub-critical MUSE-4 type configuration with external sources

DITER – Datation neutronIque TEmps-Réel



- MUSE Program
- Neutron detection system coupled to the GENEPI monitoring
- One experimental run, several analyses



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