Minutes of the

Second Meeting of the SAD/YALINA-B Steering Committee (SC)

JIPNR Minsk, Stepanov' Institute of Physics, 13 July 2004

1) The Chairman of the CEG ISTC Projects ADS and Transmutation, W. Gudowski, and the Chairman of the SC, C. Broeders, welcomed the participants of the 2nd SC meeting. Both strongly pointed out the importance of the current meeting in view of the problems in EC IP EUROTRANS DM2 with TRADE-PLUS confirmation by ENEA. A. Stanculescu, representant of IAEA, introduced the IAEA CRP on "Analytical and Experimental Benchmark Analyses of Accelerator Driven Systems". A. Stanculescu was appointed secretary of the meeting in charge, along with C. Broeders, of preparing the minutes. A "Short Mission Report" for the meeting of the Chairman can be found in Appendix 1.
2) The proposed agenda was accepted (Appendix 2).
3) The list of participants is given in Appendix 3.
4) The minutes of the 1. SC meeting were accepted.
5) The list of actions was discussed accordingly to the comments of the Chairman in the original text (Appendix 4). All actions are closed.
6) V. Shvetsov presented the latest information about the cost assessment for the SAD project (Appendix 5). The estimated full costs based on JINR data amount 432 MRoubles, being equivalent to approximately 12 MEuro. The cost estimates and possible solutions for funding were discussed in detail, see Appendix 1.
7) H.A. Abderrahim presented the view of SCK-CEN "What to do for making SAD attractive?" (Appendix 6)
8) After lunch S. Chigrinov presented the status of the YALINA project (Appendix 7). Main focus of the presentation was on the proposed YALINA-Booster (YALINA-B) experiment and its relation to SAD. It was highlighted that in YALINA-B, the neutron spectrum in the booster zone, as well as the neutron lifetime were very close to those in SAD. Moreover, time responses are similar (e.g., response of ^{235}U fission rate to the source pulse). YALINA-B and SAD have a high degree of synergy, since the YALINA-B experiment is expected to provide valuable results that will feed into and help define the SAD scientific programme.
9) F. Mellier presented the main outcomes of the MUSE project (Appendix 8)
10) H.A. Abderrahim presented the project MYRRHA as proposal for the prototype XT-ADS in the EC ADS framework programs (Appendix 9). The question was raised, whether a prototype ADS with power level between 20-100 kW and 50 MW should be recommended, e.g. by revival of an earlier proposal for such experiment in Troitsk.
11) A. Polanski presented a neutron physics feasibility study for enhancing the SAD power from 20 up to 100 kW (Appendix 10). The alternative options, increase of proton beam power or increase of sub-criticality level were discussed in some detail (see Appendix 1).
12) G. Domanska presented calculations of the activity induced in the SAD assembly materials (Appendix 11). It was recommended to initiate a new benchmark on the basis of these investigation (see Appendix 1 for more details).

13) V. Shvetsov presented the current time-schedule for the SAD project. He agreed that the time schedule to have a SAD set-up in 2008, ready for first physics experiments, is ambitious, but reachable if no funding delay occurs. The most critical part seems to be the fuel fabrication at MAYAK, due to the restricted capabilities of production lines. Special efforts are already initiated to do the fuel fabrication as effective as possible.
14) The SC meeting agreed on recommendations and action plan, as given in Appendix 1.
15) Next meeting: it is planned to hold the Third SC Meeting on 27 and 28 June 2005 in Dubna, Russia.

16) Appendices

Appendix 1: Short Mission Report by Chairman

C.H.M. Broeders, FZK/IRS/NR 08.2.2005

Final Draft

Short Mission Report SAD/YALINA-B 2. SCM Minsk, 24-25 January 2005

During the meeting a number of key issues have been discussed:

1) Costs and Funding Models

Status of cost estimates and of funding alternatives were presented by the Project Manager (PM) V. Shvetsov, and discussed by all participants in the meeting. A summary of the extensive discussions during and after the presentation is as follows:

1) Final cost estimate will be issued within a few weeks
2) Basically, there are two funding alternatives:
   a) Full JINR/Russia funding model ("full cost model")
   b) Three (or more)-partner funding model, with ISTC being one of the partners. In this case, ISTC funds, being direct grants to the service provider, are 2 – 3 times more effective (compared to the "full cost model") when used to cover the salary costs.
3) Based on the "full cost model", approx. 432 MRoubles is estimated for the current proposal, being equivalent to approx. 12 MEuro.
4) The final cost estimate will be established in terms of a "partnership programme". In this model, ISTC funding would go towards covering the salaries, and it is expected that, on this basis, the final project cost estimate will be approx. 6 MEuro.
5) The SC is aware that even this funding costs of 6 MEuro can hardly be provided by JINR and ISTC alone in the 3 years required to build the SAD facility up to the status "Ready for Physics Experiments". The conclusion is that the realization of the SAD facility according to the technical specifications (see below) requires at least another funding partner.
6) JINR Dubna higher management has already started discussions aiming at finding additional funding sources. A possibility being investigated is in-kind contributions from JINR member countries. Another avenue being pursued is to contact various parties involved in innovative research in the Dubna region (Dubna is one of the 4 Russian cities announced by the Russian President as bases for development of the innovative technologies).
7) The SC recognizes that the required reorganisation of IP EUROTRANS DM2 (due to the withdrawal of the TRADE-PLUS experiment), is an unique opportunity to integrate the SAD experiment more directly in EC activities in the area of experimental verification of concepts for incineration of long-lived nuclear waste by ADS, specifically as support to the creation of XT-ADS, intended to be realized at the Mol (B) site.
8) Therefore, the SC recommends to IP-EUROTRANS to integrate the SAD project in the DM2 new proposal, subject to the SAD project team delivering within two weeks a detailed time line (including critical points and contingencies) and a cost assessment, based on this time line, for the realization of the SAD facility. These documents will be submitted, along with

the summary of convincing technical arguments, to the IP-EUROTRANS PCC in view of their decision finding.

9) The SC emphasises that the Joint Institute for Nuclear Research (JINR), the host organization of the SAD project, constitutes a natural bridge for stronger scientific cooperation between the EC and Russia, since it is an international intergovernmental organization, founded by 18 member-countries, including EC members (Czech Republic, Poland) and EC candidates (Bulgaria, Romania)..

2) Time schedules

The ISTC #2267 project SAD Phase I is progressing according to schedule.Phase II can follow on schedule if funding is assured in time. Because of the current high conversion rate Euro-Rouble, the funding for the current Phase I enables financing the project in Dubna until the end of the year 2005. The SAD Project Manager agrees that the time schedule to have a SAD set-up in 2008, ready for first physics experiments, is ambitious, but reachable if no funding delay occurs. The most critical part seems to be the fuel fabrication at MAYAK, due to the restricted capabilities of production lines. Special efforts are already initiated to do the fuel fabrication as effective as possible.

3) Licensing

1) As Russian licensing rules have to be applied, all support for licensing must be approved by Russian authorities. This may require that the experimental support for licensing is performed inside Russia.
2) Proposed start-up experiments for SAD in an additional ISTC project at BFS, Obninsk, have to be carefully assessed, especially in view of costs and funding.
3) Fast and reliable determination of the sub-criticality level in SAD is a key issue for the SAD licensing procedure.

4) Aspects of know-how preservation

Preservation of know-how in nuclear engineering is a general need and recognized by the EC as a main objective of IP EUROTRAN DM2. In this context, the participation of young students, researchers and engineers to relevant experiments has a high priority. The tradition of JINR Dubna and the quality of the SAD experiment is a very good basis to satisfy these objectives in the proposed projects.

As part of the SAD project, irradiation tests for the SAD target are on-going. The analysis of these experiments will be used for benchmarking codes, involving young people from participating parties.

5) Technical issues

1) It is recognized that the YALINA support for SAD may contribute essentially to the realisation of the SAD experiment.
2) The SAD experiment can support a number of significant licensing issues for the XT-ADS Pb-Bi cooled facility (see below “SC conclusions”).
3) More detailed information about cooling systems for target and core of SAD will be sent to the Chairman of the SC within a few days.

4) The need for experiments with power reactivity feedbacks has to be assessed carefully, especially in view of licensing of the XT-ADS where such experiments can be completed during the commissioning phase.
5) The possibilities to increase the power level of SAD from the current design value of 20 kW have been discussed in some detail on the basis of a nuclear physics assessment:
   a) Increase of target power
   The PHASOTRON proton accelerator can currently deliver up to 2.5 kW beam power. In the current design the maximum target power is 1 kW, as temperatures in the lead target reach close to melting values. Since it is foreseen in the SAD experimental program to investigate different target materials, a Tungsten target that can handle up to 2 kW could be considered at a later stage..
   b) *Increase of core criticality*
   The sub-criticality level of SAD core can be easily increased from 0.95 to 0.97-0.98 by increasing of the number of fuel assemblies from 133 to 141. Russian licensing rules allow sub-critical experiments without control rods (like current SAD design) if the maximum criticality value does not exceed 0.98. SAD accident analyses have been performed (e.g., water ingress in experimental channels) for the current design, confirming compliance with the Russian regulatory limits imposed on an experimental facility without control rods. However, for short experimental periods (days, few weeks?), increasing the sub-criticality level up to 0.98 could be allowed, subject to the approval by Russian regulatory organizations of the corresponding safety assessment report.
   c) *Increase of system power*
   In conclusion: based on maximum target power of 2 kW and on sub-criticality level slightly below 0.98, the SAD experiment could be run for specific experiments at a level of about 100 kW, if these conditions are shown to be useful. Cooling aspects at this power level must be assessed carefully. The project manager will distribute the information about the current coolant system design within a few days. The SAD designer pointed out that one should take into account that operation at 100 kW level will require drastic reconstruction of the cooling system including choice of the coolant and equipment.

6) SC conclusions

The SAD/YALINA Steering Committee has reviewed the progress on both projects during its meeting held in Minsk (BY), Jan. 24-25, 2005, paying particular attention to examine the relevance of these projects to the FP6 EUROTRANS integrated project.

The conclusions of the Steering Committee are summarized below:

1. The SAD project as planned today has considerable technical/scientific appeal as a preliminary step for an XT-ADS scale facility.
2. The coupling of a 600 MeV proton accelerator to a MOX based fast sub-critical core, with lead reflector, through a solid Pb target is very representative of the final objective of building a XT-ADS Pb-Bi cooled facility.
3. The high energy protons of the PHASOTRON will allow to have the high energy neutron tail that will be very determining in optimising both the lateral

and the axial shielding of XT-ADS, and therefore have a positive impact on the cost of an XT-ADS scale facility.

4. The present SAD design has been established according to a very conservative approach in terms of safety, in order to ensure its license-ability within a reasonable time frame. According to the experience accumulated until now by the SAD project team, the contacts with the Russian safety authorities are very positive. Keeping K_{eff} below 0.98 does exclude the need of any control or safety rods. Therefore, the SAD experiment has been designed for a K_{eff} value of 0.95, leaving 3000 pcm margin to the maximum allowable K_{eff} value. However, configurations with K_{eff} up to 0.98, are allowed for experiments of limited duration and subject to approval of special safety assessments by the Russian regulatory organizations.
5. The increase of the total power of the SAD experiment from 25 kW up to 100 kW has been examined following both the proton current intensity increase (from 1 kW to 2 kW) and the core size increase (from 133 fuel assemblies to 141) routes.
6. The SC members concluded during the Minsk meeting that the very modest thermal feedback effects achieved through the envisioned power increase do not justify pursuing this option that would jeopardize the time schedule of the project. The SC meeting noted that following a strict SAD schedule is a key issue for the time planning of XT-ADS and IP-EUROTRANS. Therefore it is recommended to keep the SAD power unchanged at approximately 20 kW. Moreover, the SC meeting noted that several proposals had been presented in previous SAD meetings for different methods to simulate fast reactivity variations that would allow to study ADS dynamics, including the simulation of thermal feedback effects.
7. The SC members agreed on the DM2 IP-EUROTRANS initial objectives given in the table below that would be met by the SAD project:

Objective	SAD
1) Coupling proton beam-spallation target - core at sizable power	+ Correct proton energy, + Good spallation target materials, but small target size
2) Stable operation	- OK
3) Startup / Shutdown	+ (un)loading reactivity variations simulation
4) Reactivity monitoring	+ Fast system + Large lead reflector
5) Dynamic behavior/feedbacks	+ Simulated feedbacks. Different feedback source
6) Response to beam trips	+ Simulated feedback
7) ADS licensing issues	- First step of coupling
8) Core power vs. proton current	-
9) Shielding of high energy neutrons	+ Correct proton energy + Lead shield
10) Beam transport line	+ High proton energy

8. The Conclusion of this assessment and recommendation is that IP-EUROTRANS become partner of the SAD project and integrate it in the DM2 new proposal subject to the SAD project team delivering by mid-February a detailed time line (including critical points and contingencies) and a cost assessment, based on this time line, for the realization of the SAD facility, and submit it to the EUROTRANS PCC for consideration.

7) SC action plan

Action plan from the 2-nd SAD/YALINA SC meeting

1) SAD short term actions
   a) Project time schedule with identified critical paths and milestones of special importance for EUROTRANS: 10 Feb. 2005 with 1-st draft distributed by Feb.6: responsible V. S.
   b) Cost assessment, linked to the TS, exploring ISTC funding and ISTC-channeling and “Russian template”: 10 Feb. 2005 with 1-st draft distributed by Feb.6: responsible V. S.
   c) Cost assessment should be prepared according to the timeline with well defined parts for salary, design work, equipment manufacturing and construction work: responsible V. S.
   d) Template for the cost assessment will be kindly provided by H.A.A. by Jan.28 2005: responsible H.A.A.
   e) The document “White Paper”, summarizing the objectives and the most important deliverables of the SAD. First draft to be prepared by Jan.31. This document will contribute to development of the “comparison table”/C.B./, which is the separate document, first circulation by Feb 1: final draft - Feb. 8 2005 responsible: C.B.&V.S.
   f) The additional funding options are to be explored for example: USA or Japan support for physical security system of SAD/V.S./, collaborators cofunding/SC members/, Japan and/or USA through ISTC/W.G, C.B. &V.S./.
2) SAD management prepares request to ISTC executive director for current project prolongation caused by exchange rate effect till the end of 2005.
3) SAD management prepares the ISTC application for the Phase II as a prolongation of the SAD project for the second GB meeting of 2005.
4) Recommendation from the SC to the EUROTRANS committee on the SAD experiment: Jan 31, responsible: SC members
5) SAD management prepares annual report on ISTC project #2267 with description of the SAD design by the end of Feb. 2005.
6) YALINA actions
   a) Formal proposal for continuation of the YALINA experiment. The proposal should have strong synergy components with SAD: by the Feb. 15 2005, responsible S.Ch., V.S. & C.B.
   b) Calibration of the YALINA detectors at MOL facility. Yu. Pepelyshev from SAD team participates this activity.: by June 30 2005, responsible: S.Ch. & H.A.A.
7) General actions
   a) The Polish group from UMM prepares benchmark on SAD target induced activity.: first input by the end of Feb. 2005, responsible: G.D. with intensive consulting needed from C.B.&E.G.
   b) The SAD/YALINA collaborators create a group of young students/researchers/engineers to join experimental work on YALINA and SAD. The seed of this group already exists.
   c) SAD/YALINA collaborators to submit proposals for Research agreements and Research contracts to IAEA for the CRP “ …ADS benchmarking… ”.: by the end of Feb. 2005.

Appendix 2: Agenda

SAD/YALINA-B Steering Committee Second Meeting January 24-25, 2005

Place: Stepanov' Institute of Physics, prospekt Skoriny, 68, Minsk

Monday, January 24

9:00 – 9:15 Opening of the 2. SAD/YALINA-B SC Meeting, Approval of the Agenda

- Welcome by S. Zhdanok (National Academy of Sciences of Belarus)
- W. Gudowski (Chairman CEG ISTC Projects ADS and Transmutation)
- L. Tocheny (ISTC)
- A. Stanculescu (IAEA)
- C. Broeders (Chairman SAD/YALINA-B Steering Committee)

9:15 – 9:30 Approval of the Minutes of first SC Meeting in Dubna – C. Broeders

9:30 – 9:50 Review and discussion of Action Plan of first SC Meeting – C. Broeders

9:50 – 13:00 Review of current projects:

9:50 – 11:00 Report on SAD status and progress, V. Shvetsov and others

With particular emphasis on:

- Cost assessment and uncertainties of the cost assessment
- Timelines for the project realisation assuming ensured funding on an agreed level
- Possible visible showstoppers: assessment of licensing problems, priorities of the Institute etc.
- A plan for an extensive foreign participation; potential, logistic and possible difficulties (EUROTRANS participants)
- A sketch of planning and establishing a working group for SAD instrumentation support
- Possible synergy with other on-going and planned ISTC projects

11:00 – 11:20 Coffee/Tea break

11:20 – 11:50 Supporting experiments for SAD licensing at BFS – A. Lopatkin

11:50 – 12:30 Report on YALINA status and planning.

YALINA as support experiment to SAD – S. Chigrinov

12:30 – 13:00 Identification and discussion of critical issues of ongoing projects – all

13:00 – 14:15 LUNCH

14:15 – 16.15 Synthesis with other international projects

14:15 – 14:45 MUSE project , F. Mellier, P. Fougeras

14:45 – 15:15 MYRRHA project , Aït Abderrahim Hamid

15:15 – 15:45 TRADE project , S. Monti

15:45 – 16:15 RACE project , Y. Kadi

16:15 – 16:45 Coffee/Tea break

16:45 – 17:30 Discussion of future experimental programs,

e.g. assessment of possibilities to perform dynamics experiments – Polanski, Gudowski, Broeders, SAD-team

17:30 Adjourn

19:00 Dinner

Tuesday, 25 January

8.30 – 12.00 Visit to Sosny – YALINA-B

12:30 – 14:00 Lunch

14:15 – 15:00 Organizational Issues + buffer time for continuation of Monday's program

15:00 – 16:00 A detailed Action plan for SAD project for coming 3 years – V. Shvetsov

16:00 – 16:20 Coffee/Tea time

16:20 – 17:00 Working/Action plan for supporting SAD experiments

17:00 – 17:30 Action plan SAD-YALINA Steering Committee,

date and place next meeting

17:30 Adjourn

19:00 Dinner

Appendix 3: List of participants

«SAD-YALINA-B, 24 25 January 2005, Minsk

No.	Surname	Institute	Country
1	Monti Stefano *	ENEA	Italy
2	Aït Abderrahim Hamid	SCK.CEN	Belgium
3	Waclaw Gudowski	RIT	Sweden
4	Mellier Frederic	CEA	France
5	Broeders Cornelis	FZK	Germany
6	Stanculescu Alexander	IAEA	Austria
8	Lev Tocheny *	ISTC	Russia
9	Valery Shvetsov	JINR	Russia
10	Kadi Yacine *	CERN	Switzerland
11	Gonzalez Romero Enrique Miguel	CIEMAT	Spain
12.	Mikhail Vorontsov	ГСПИ	Russia
13	Anatoly Bobolev	МАЯК	Russia
14	Igor Tret'yakov	НИКИЭТ	Russia
15	Alexander Lopatkin	НИКИЭТ	Russia
16	Igor Golovnin	ВНИИНМ	Russia
17	Yurij Ivanov	ВНИИНМ	Russia
18	Sergey Elsukov	Mayak	Russia
19	Sergey Chigrinov	JIPNR-Sosny	Belarus
20	Hanna Kiyavitskaya	JIPNR-Sosny	Belarus
21	Anatoly Khilmanovich	Stepanov' IP	Belarus
22	Boris Martsinkevich	Stepanov' IP	Belarus
23	Ivan Serafimovich	JIPNR-Sosny	Belarus
24	Victor Burnos	JIPNR-Sosny	Belarus
25	Christina Rutkovskaya	JIPNR-Sosny	Belarus
26	Yurij Fokov	JIPNR-Sosny	Belarus
27	Andrey Fokov	JIPNR-Sosny	Belarus
28	Fougeras Philippe	CEA	France
29	Vyacheslav Kuvshinov	JIPNR-Sosny	Belarus
30	Edvard Rudak	Stepanov' IP	Belarus
31	Nikolaj Shumejko	High energy Physics Institute	Belarus

32	Marcin Szuta	Atomic power institute	Poland
33	Grazhina Domanska	TU	Poland
34	Alexander Polanski	TU, JINR	Poland, Russia
35	Milan Pesic	“Vinca”	Serbia
36	Lachesar Kostov	Nuclear Research and Nuclear Energy Institute	Bolgaria
37	Kurochkin Yurij	Stepanov’ IP	Belarus
38	Vladimir Kudryashov	Stepanov’ IP	Belarus
39	Dmitrij Shelkovuj	Stepanov’ IP	Belarus
40	Sergey Yanush	Stepanov’ IP	Belarus
41	Dmitry Olijnikov	Stepanov’ IP	Belarus
42	Tamara Korbut	Stepanov’ IP	Belarus

Appendix 4: Commented list of actions from SC Meeting 1

Action Plan from Minutes of the First Meeting of the SAD/YALINA-B Steering Committee (SC) JINR Dubna, Frank Laboratory, 13 July 2004

11) The SC meeting agreed on the following action plan:

a) <u>SAD design</u>

- Diameter of the beam inlet hole: within 2 weeks, CIEMAT and SAD project manager will quantify expected variations of the neutron importance in the system as a function of the beam position. Responsible E. Gonzalez, V. Shvetsov Actions initiated, results?
- Actuators for experimental channels: it was agreed to consider in the design one fast (1 m/s) and two slow actuators in all the three experimental core channels. Responsible for changes in the design: A. Lopatkin and V. Shvetsov Actions initiated, results?
- NIKIET will provide by middle of September 2004 the precise information about the role of high energy neutrons for the power distribution in the sub-critical core. Responsible: A. Lopatkin Actions pending?
- By middle of September, the SAD designer team requests confirmation that the neutron generator to be used during SAD start-up fits into the experimental channel: action on CIEMAT and ITEP. Responsible: E. Gonzalez, Y. Titarenko in contact with V. Shetsov Actions initiated, fixation of results?
- It must be ensured that design provision is made for separate temperature and flow rate measurements in the target coolant, and in the core coolant. These measurements must be provided with sufficient accuracy in two temperature ranges, i.e., low and nominal: action on the SAD project manager. Resp. V. Shvetsov Actions pending?
- It was agreed that construction details fixing the 28 KW system power without freedom to enhance it at a later stage should be avoided: action on the SAD project manager. Resp. V. Shvetsov Actions pending?
- The CEG will initiate the dialog with IPPE and ITEP on the possibility of using existing and/or proposed ISTC projects to support the licensing of SAD. The action will be taken after request from the designer (NIKIET). Responsible A. Lopatkin and W. Gudowski Actions initiated, new ISTC proposal: status, recommendations?

b) Radiation shielding

- **By end of July, the SAD project manager will provide the input data needed for the optimization studies of the shielding of the SAD core. Responsible V. Shvetsov** Actions OK
- **By end of July, the SAD project manager will provide the input data needed for dose rate calculations in the SAD building and its surroundings. KTH (with CIEMAT and UMM support) is making the commitment to perform these calculations. Responsible – V. Shvetsov in collaboration with W. Gudowski, E. Gonzalez and S. Taczanowski** Actions OK, documentation of results?

c) General issues

- **The SAD Web Site will be online with open and restricted areas by the end of July; links to ISTC and to other relevant P&T sites will be made available. Responsible – V. Shvetsov** Actions OK
- **The final version of the SAD leaflet will be available by the end of July and will be distributed as Word file for comments. Responsible V. Shvetsov, feedback from C. Broeders, W. Gudowski, E. Gonzalez, F. Mellier** Actions OK
- **KTH will discuss with US responsible persons the possibility of the SAD Russian design groups using of MCNPX. Responsible – W. Gudowski and A.Polanski** Actions pending?
- **The foreign collaborators (KTH, CIEMAT, FZK, and UMM) agree to perform necessary MCNPX design calculations. At JINR, this action will be coordinated by Aleksander Polanski (responsible)** Actions initiated, documentation of results?
- **The SAD and YALINA project managers are urged to keep close contact in order to increase synergy between the two projects. Responsible – V. Shvetsov and S. Chigrinov** Actions pending?
- **The YALINA project manager will provide a leaflet for the YALINA project by the middle of September. Resp. S. Chigrinov** Actions initiated, first version distributed

12) The SC members agreed to record, in addition to the action plan, the following general conclusions as the outcome of the first SC Meeting:

- **By the end of December 2004, the SAD project manager will provide a cost assessment for the SAD construction. Resp. V. Shevstsov.** **Status OK?**
- **The issue of final disposal of SAD activated structures was raised; an action was put on the SAD project manager to initiate preliminary discussions on this subject with the appropriate persons at JINR. Resp. V. Shevstsov** **Actions pending?**
- **The SC expects strong commitment on the side of JINR for the construction and operation of the SAD facility, and asks the SAD project manager to convey this message to the JINR management. Resp. V. Shevstsov and C. Broeders** **Status OK?**
- **The SC took note that the IAEA Coordinated Research Project (CRP) on analytical and experimental benchmark analyses of sub-critical systems driven by an external neutron source was approved by the Agency. The CRP will start in 2005. The SC acknowledged that both projects, SAD and YALINA, would greatly benefit from the participation in this CRP. Forms for research agreement and contract proposals were distributed by the IAEA representative in the SC, and the participants were encouraged to submit proposals for participation in the CRP. Resp. A. Stanculescu** **Status OK?**
- **The SC acknowledges that SAD fuel manufacture was initiated, and that no cliff-edges were encountered at this stage of the fuel manufacturing process. The SC also took note of the fact that the fuel assembly grids will be manufactured at JINR.**

Appendix 5: SAD Presentation by V. Shvetsov

SAD cost assessment

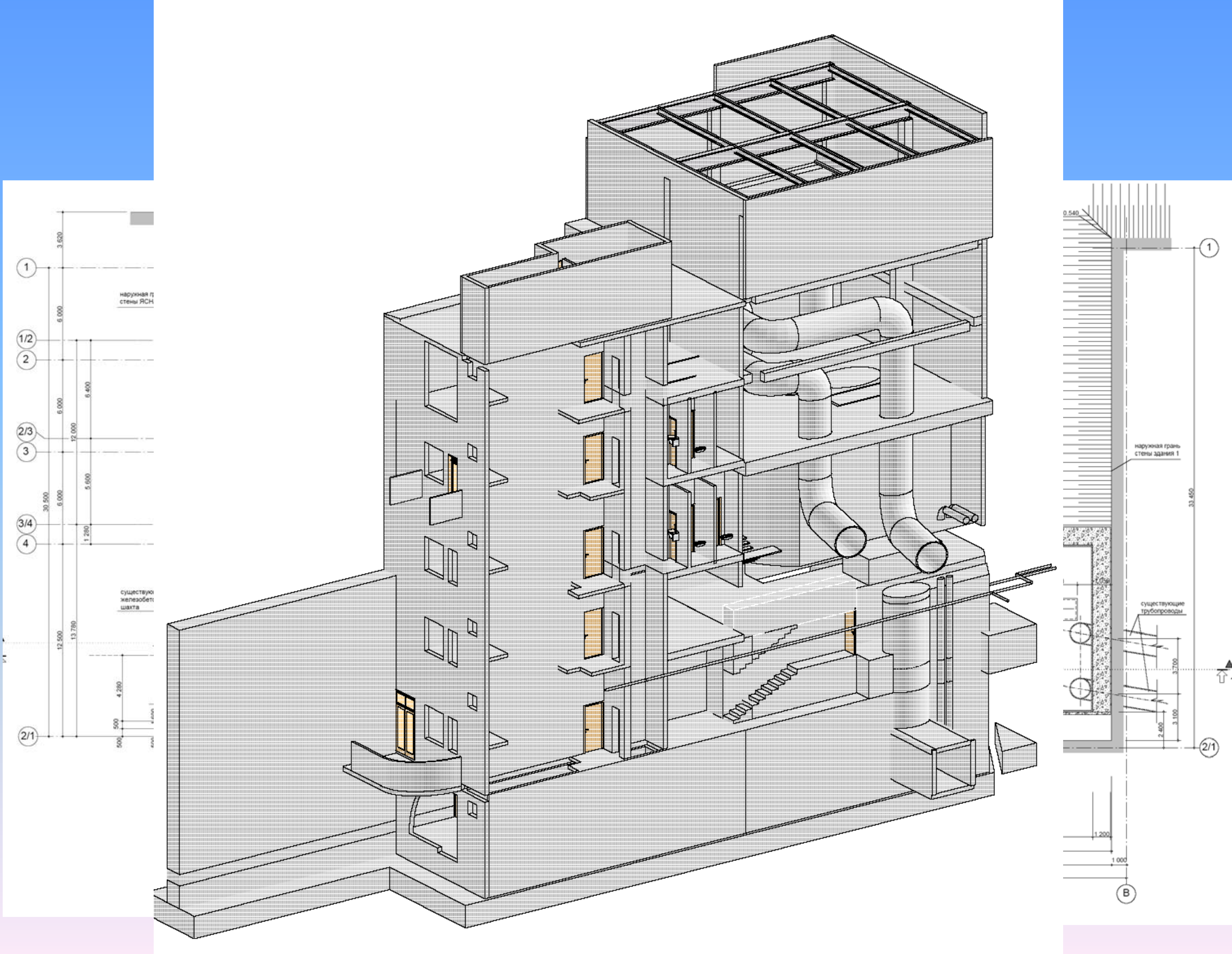
Second SAD/YALINA-B SC meeting

Minsk, Jan. 24-25, 2005

V. Shvetsov, I. Golovnin, M. Vorontsov, I. Tretyakov, B. Ryabov,

SAD facility main components

- **Building**
  - **Construction work**
  - **Optional equipment**
  - **Equipment assembling**
  - **Physical security**
- **Core**
  - **R&D**
  - **Manufacturing of the optional equipment**
  - **Installation work**
  - **Balancing and commissioning**
- **Fuel**
- **Beam line**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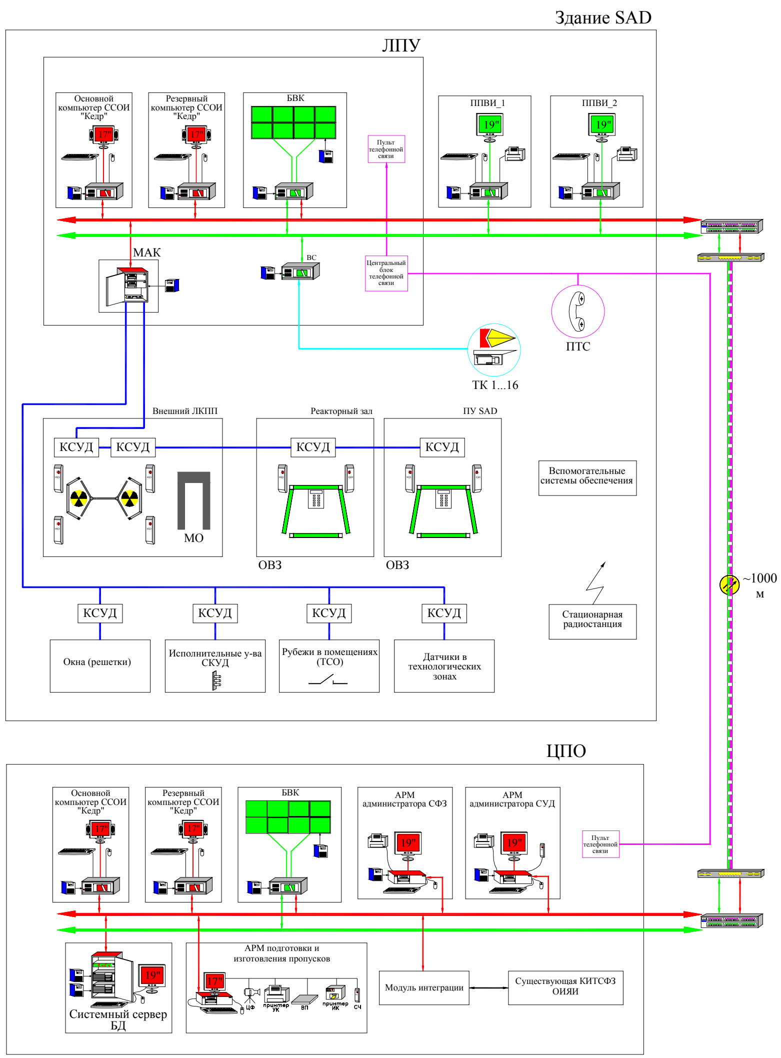
Physical security

Структурная схема КИТСФЗ объекта SAD



Условные обозначения:

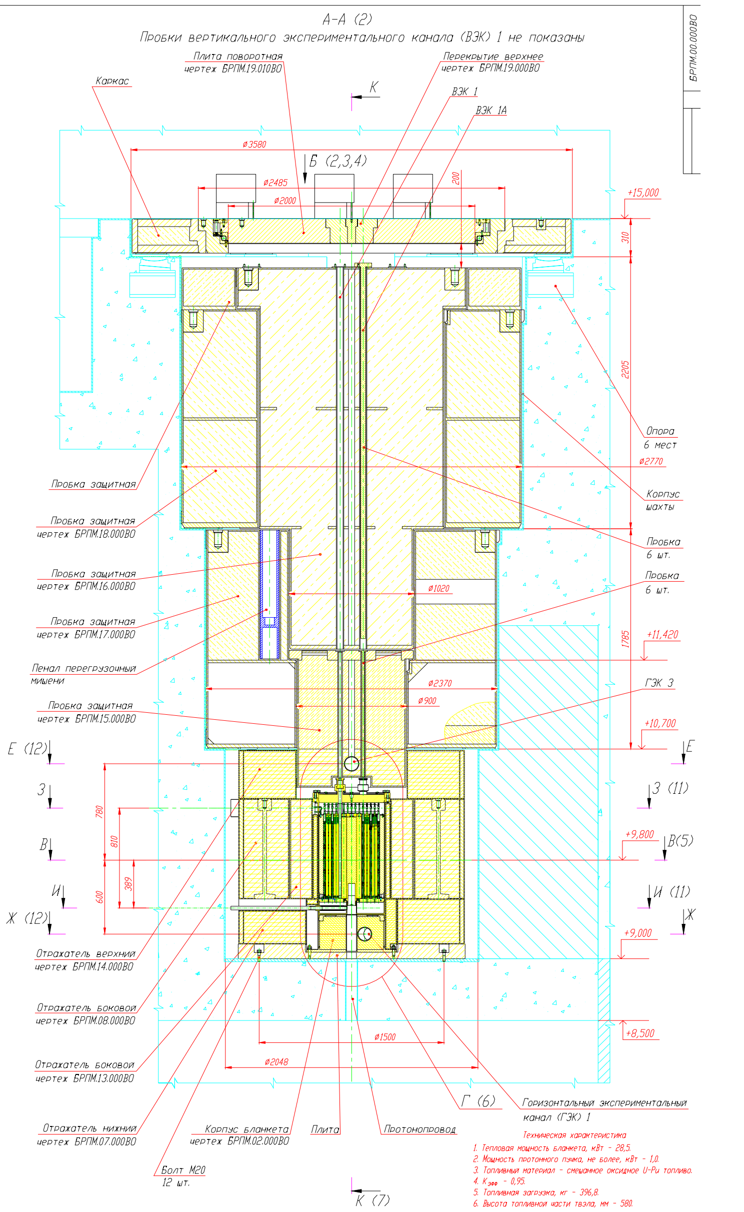
Обозначение	Название
	- Стационарные телекамеры
	- мультимедийный ж/к монитор 17" (ССОИ "Кедр")
	- ж/к монитор 19" (СЦТ)
	- системный блок в офисном исполнении (ССОИ "Кедр")
	- системный блок в промышленном исполнении (ССОИ "Кедр")
	- системный блок в промышленном исполнении (СТН)
	- маятниковая дверь-шлюз
	- источник бесперебойного питания
	- принтер лазерный ч/б
	- кодонаборное устройство
	- считыватель
	- устройство преграждающее управляемое двухпроходное (турникет)
	- магистральный контроллер системы контроля управления доступом
	- весовая платформа
	- принтер для изготовления идентификационных карточек
	- цифровой фотоапарат
	- сетевой коммутатор
	- оптическая панель
	- прожектор
	- радиационный монитор
	- металлообнаружитель

Сокращения:

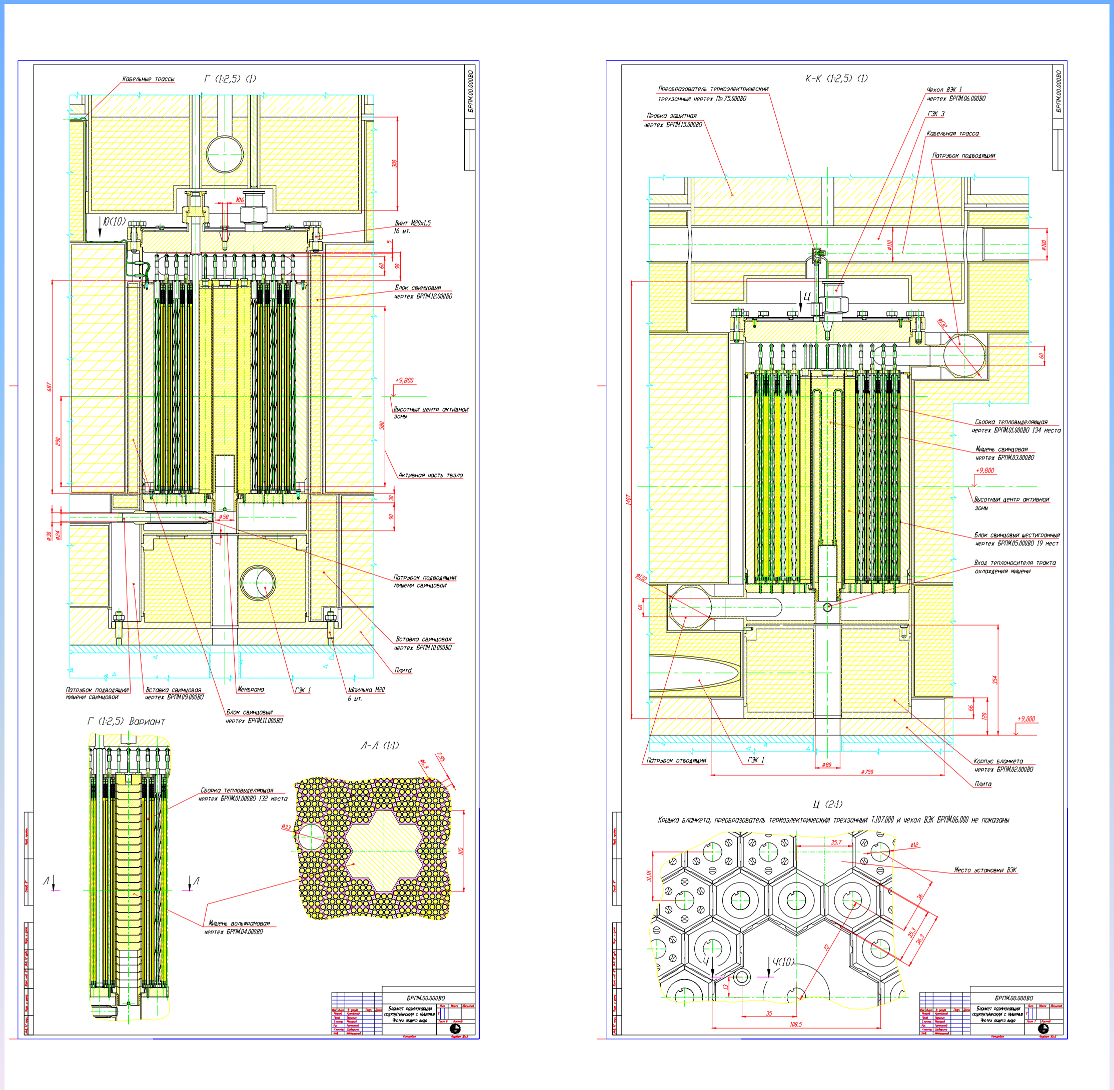
БВК - блок видеоконтроля
ВС - видеосервер
ППВИ - пункт просмотра видеоинформации
КСУД - контроллер средств управления доступом
ПТС - периметровая телефонная связь
МО - металлообнаружетель

eting, M

Core



А-А (2)
Пробки вертикального экспериментального канала (ВЭК) 1 не показаны
Плита поворотная чертеж БРПМ.19.010ВО
Перекрытие верхнее чертеж БРПМ.19.000ВО
Каркас
ВЭК 1
ВЭК 1А
Б (2,3,4)
Опора 6 мест
Корпус шахты
Пробка 6 шт.
Пробка 6 шт.
ГЭК 3
Пробка защитная
Пробка защитная чертеж БРПМ.18.000ВО
Пробка защитная чертеж БРПМ.16.000ВО
Пробка защитная чертеж БРПМ.17.000ВО
Пенал перегрузочный мишени
Пробка защитная чертеж БРПМ.15.000ВО
Отражатель верхний чертеж БРПМ.14.000ВО
Отражатель боковой чертеж БРПМ.08.000ВО
Отражатель боковой чертеж БРПМ.13.000ВО
Отражатель нижний чертеж БРПМ.07.000ВО
Корпус бланкета чертеж БРПМ.02.000ВО
Плита
Протонопровод
Болт М20 12 шт.
Горизонтальный экспериментальный канал (ГЭК) 1
Г (6)
К (7)
Техническая характеристика
1. Тепловая мощность бланкета, кВт - 28,5.
2. Мощность протонного пучка, не более, кВт - 1,0.
3. Топливный материал - смешанное оксидное U-Pu топливо.
4. Kэфф - 0,95.
5. Топливная загрузка, кг - 396,8.
6. Высота топливной части твэла, мм - 580.



Г (1:2,5) (1)
К-К (1:2,5) (1)
Г (1:2,5) Вариант
Л-Л (1:1)
Ц (2:1)
БРПМ.00.000ВО

Fuel

Дробление брикетов

Beam line

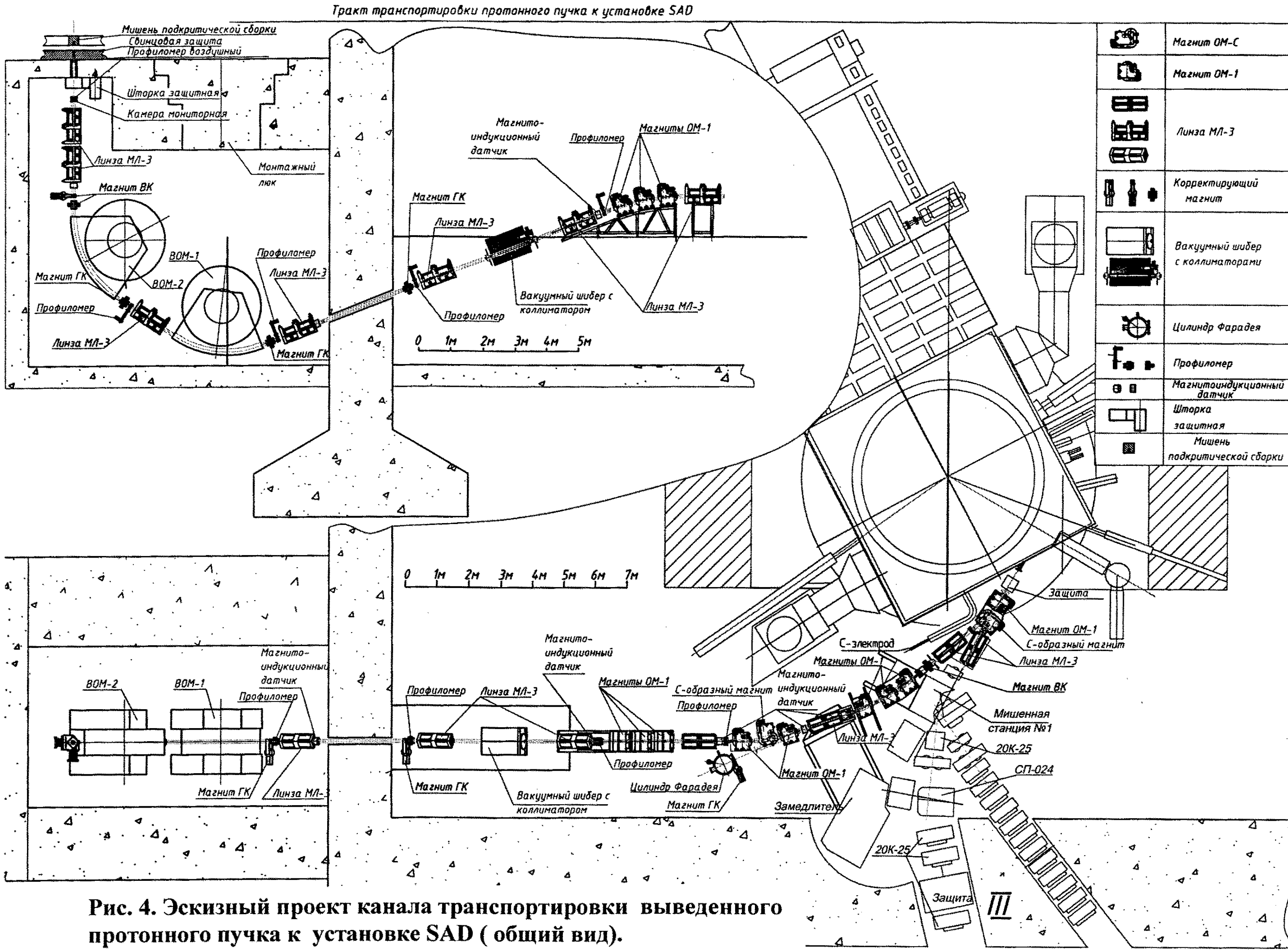


Рис. 4. Эскизный проект канала транспортировки выведенного протонного пучка к установке SAD (общий вид).

Cost assessment

Cost in roubles of 2004

- **Core: 92 Mr**
- **Beamline: 24.23 Mr**
- **Construction works: 93.6 Mr**
- **Equipment for fuel storage: 25.32 Mr**
- **Cooling systems: 16.99 Mr**
- **Fuel elements tightness control system: 5.07 Mr**
- **Fuel (3000 FE) 41.82 Mr**
- **Physical security system: 40.63 Mr**
- **Radiation control system: 16.84 Mr**
- **……………………………………………..**
- **……………………………………………..**
- **………………………………………………..**

Cost assessment

TOTAL COST: 432.045 Mr

- ……………………………………………

Appendix 6: View of SCK-CEN to make SAD attractive
by H.A. Abderrahim

SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

What to do for making SAD Attractive

To be worked out by SAD project team
with help from the Steering Committee members

Actions

- Make a convincing time planning with a classical steps succession:
  - **Conceptual design**
    - to my opinion completed
    - having defined correctly the objective of SAD, this is not yet fully accomplished
  - **Period : 2nd half of 2005**
    - Components design, production, QC/QA and cost assessment
    - Definition of needed R&D Program in support for the realization of the components or assessing the contingencies
    - Preparation of the Preliminary Safety assessment report

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CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Actions

- **Period : 2006**
  - Detailed Engineering design of SAD
  - Identify the eventual show stoppers and address them through the appropriate R&D
- **Period : 2007 ?**
  - Construction in one year is this realistic in a 6 months frozen country ?
- **Period : 2008**
  - Commissioning of SAD
  - Start of the experimental program (Core physics, reactivity effects, shielding experiments for fast neutrons,…

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CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

We have to pay attention to :

- Costing through the ISTC funding route
- Think about time and cost contingencies
- We have to separate the needed work and thus consequently the costs for the different steps (in time) and not for the different components because that what determine the needed cash flow

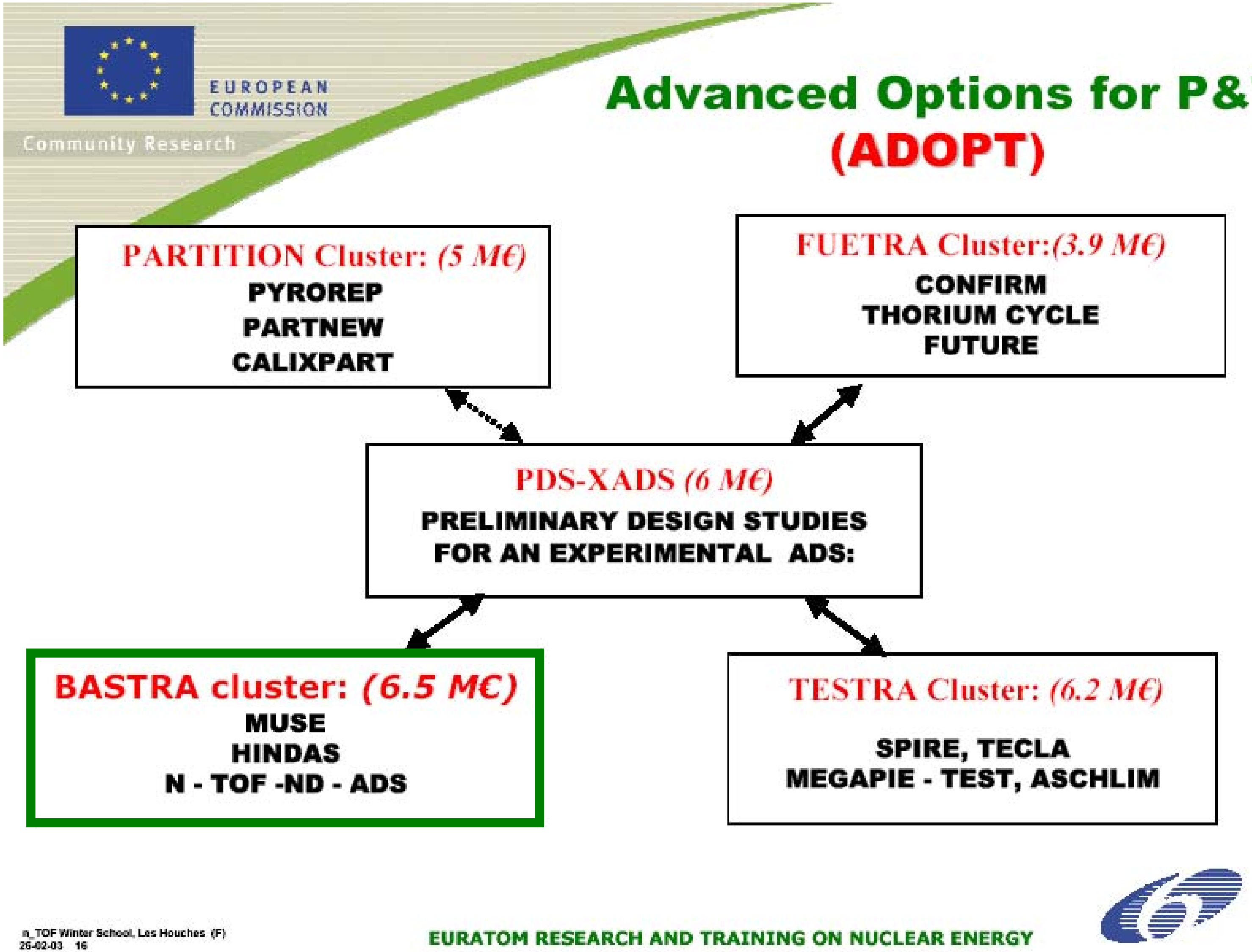
Appendix7: YALINA presentation S. Chigrinov

Appendix 8: Presentation MUSE Project by F. Mellier

Overview and Highlights of Results from the MUSE project

Frédéric Mellier (CEA/DEN/CAD/DER/SPEX/LPE)
fmellier@cea.fr

On behalf of the MUSE collaboration


EUROPEAN
COMMISSION
Community Research
Advanced Options for P&T
(ADOPT)
PARTITION Cluster: (5 M€)
PYROREP
PARTNEW
CALIXPART
FUETRA Cluster:(3.9 M€)
CONFIRM
THORIUM CYCLE
FUTURE
PDS-XADS (6 M€)
PRELIMINARY DESIGN STUDIES
FOR AN EXPERIMENTAL ADS:
BASTRA cluster: (6.5 M€)
MUSE
HINDAS
N - TOF -ND - ADS
TESTRA Cluster: (6.2 M€)
SPIRE, TECLA
MEGAPIE - TEST, ASCHLIM
n_TOF Winter School, Les Houches (F)
26-02-03 16
EURATOM RESEARCH AND TRAINING ON NUCLEAR ENERGY

The MUSE collaboration

- Partners of the EURATOM 5th FP - MUSE Contract n°FIKW-CT-2000-00063

- CEA	Commissariat à l'énergie atomique, France
- SCK•CEN	Belgian Nuclear Research Center, Belgium
- CNRS/IN2P3/LPSC	Université Joseph Fourier, Grenoble 1, France
- FZK	Forshungszentrum Karlsruhe GmbH, Germany
- FZJ	Forshungszentrum Jülich GmbH,Germany
- BNFL	British Nuclear Fuels plc, Great Britain
- ENEA	Ente per le Nuove technologie, l'Energie e l'Ambiente, Italy
- NRG	Nuclear Research consultancy Group, The Netherlands
- DUT	Delft University of Technology, The Netherlands
- CIEMAT	Centro de Investigaciones Energeticas, Medio Ambiantales y Technologicas, Spain
- KTH	Kungliga Tekniska Hogskolan, Sweden
- CTH	Chalmers University of Technology, Sweden
- AGH/UST	University of Mining and Metallurgy, Poland

- **PSI** and **DOE** (bilateral collaborations with CEA)

Objectives of the MUSE Project

- Three main objectives

1. Improve the understanding of the behaviour of a subcritical core driven by an external neutron source
   => extensive characterization of the cores

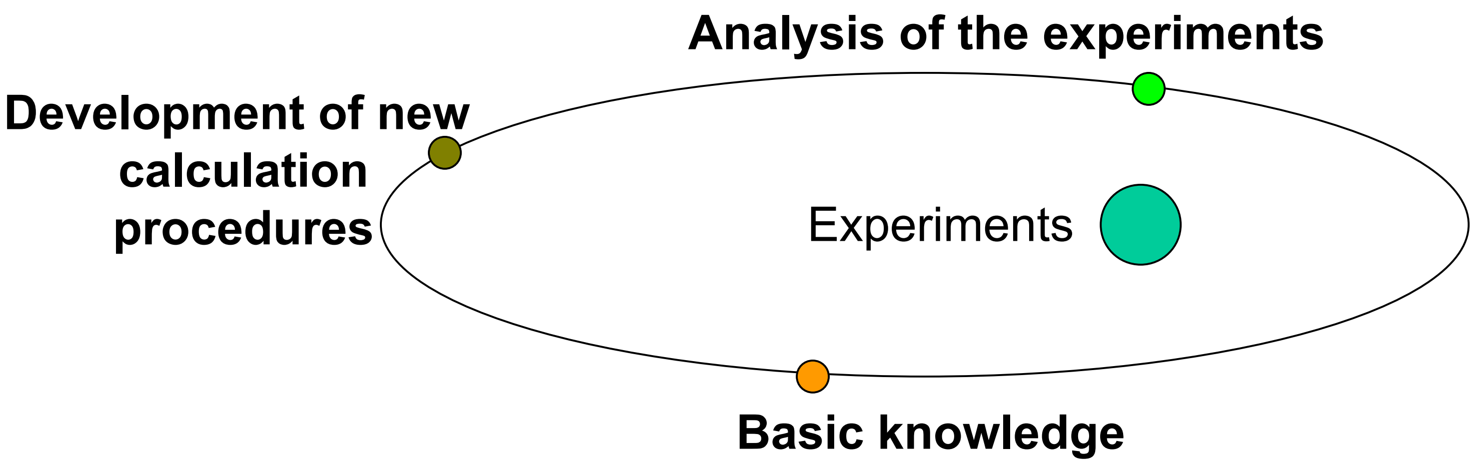
2. Contribute to the development of experimental techniques for the control and the monitoring of a future ADS
   => numerous experimental techniques and analysis methods tested, various configurations,

3. To participate to the definition of reference tools (data, codes, biases, uncertainties) for the prediction of ADS neutronic features
   => separate analysis of the experiments,
   a calculation benchmark under the auspices of OECD/NEA

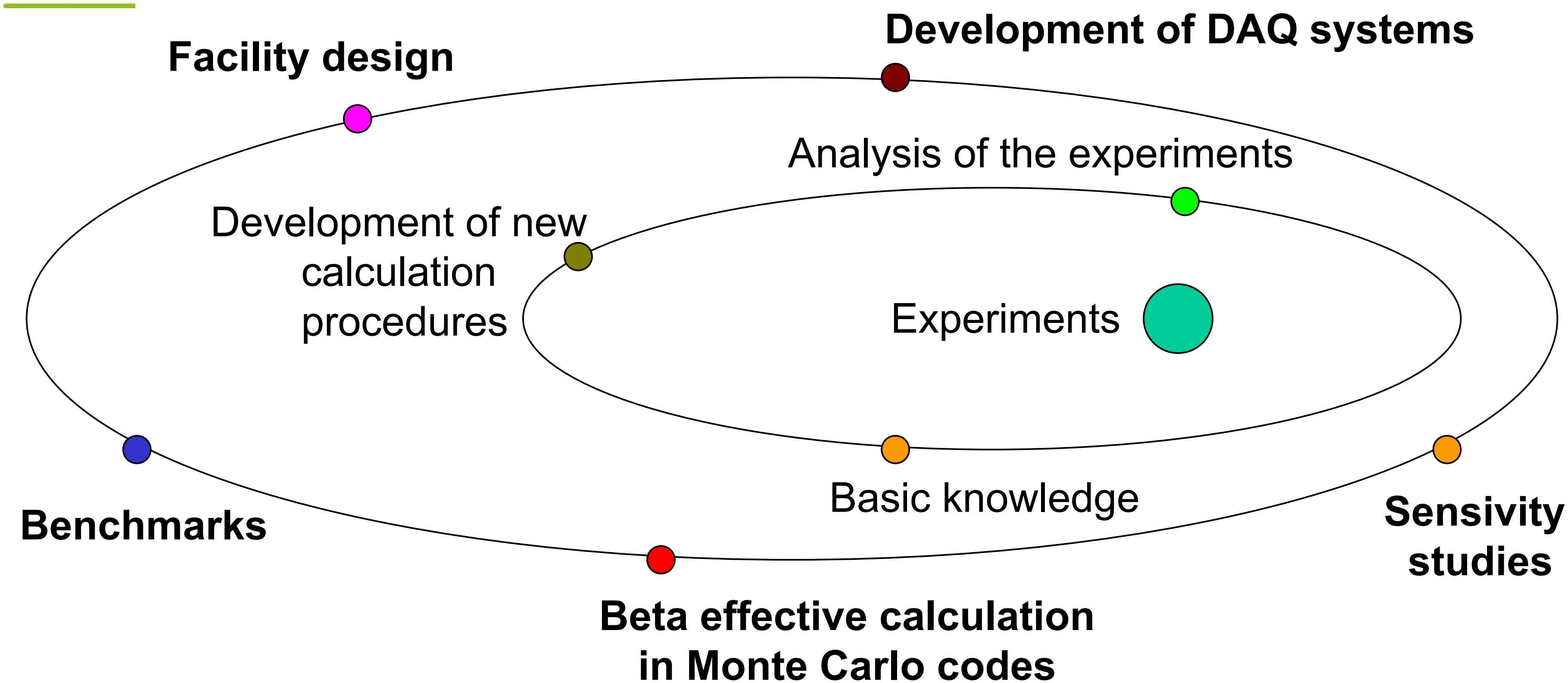
Activities conducted within the MUSE project

Experiments

Activities conducted within the MUSE project



Activities conducted within the MUSE project



Experimental programs

Preliminary studies concerning spallation sources, spallation targets and subcritical cores can be disconnected

Characterisation of subcritical cores driven by an external neutron source

The MUSE-4 experiments

Measurement of the subcriticality

Characterisation of spallation targets bombarded by a 660 Mev proton beam

The PRE SAD experiments

Assessment of possibilities to measure the subcriticality

Feedback for future experiments (TRADE, SAD, …)

The MUSE program series

- MUSE 1 (1995) & MUSE 2 (1996) :

  very short test experiments (≈-1700 pcm)
  ^{252}Cf source in the center of the core, S=7.6 10^7 n/s
  demonstration of the feasibility of neutronic measurements

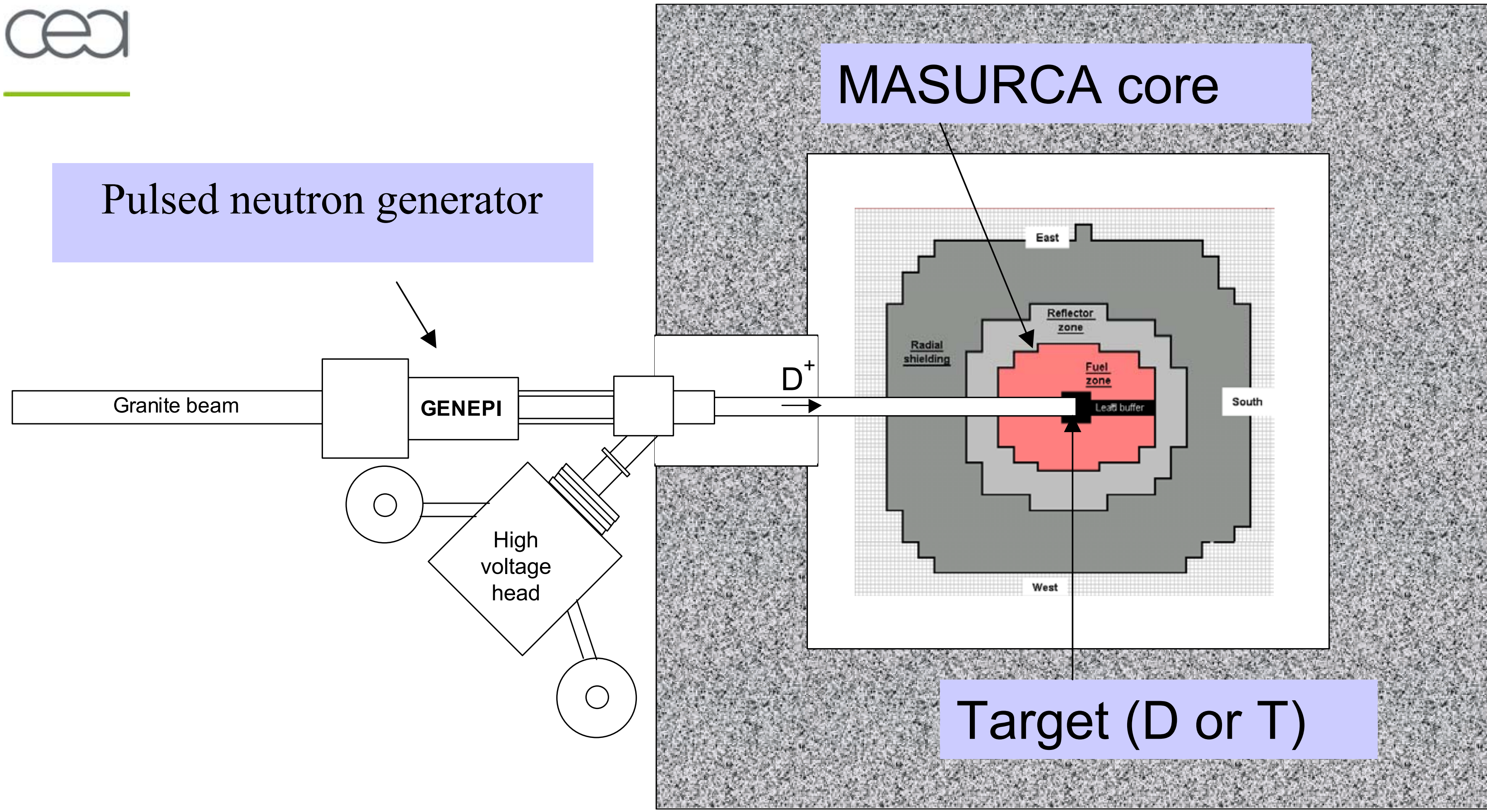
- MUSE 3 (1998) :

  three months
  commercial neutron generator (14 Mev neutrons), S=3 10^8 n/s
  four configurations (critical, -500 pcm, -1000 pcm, -1500 pcm)
  two buffers tested (sodium and pure lead)
  in-depth analysis very difficult, experimental biases

⇓

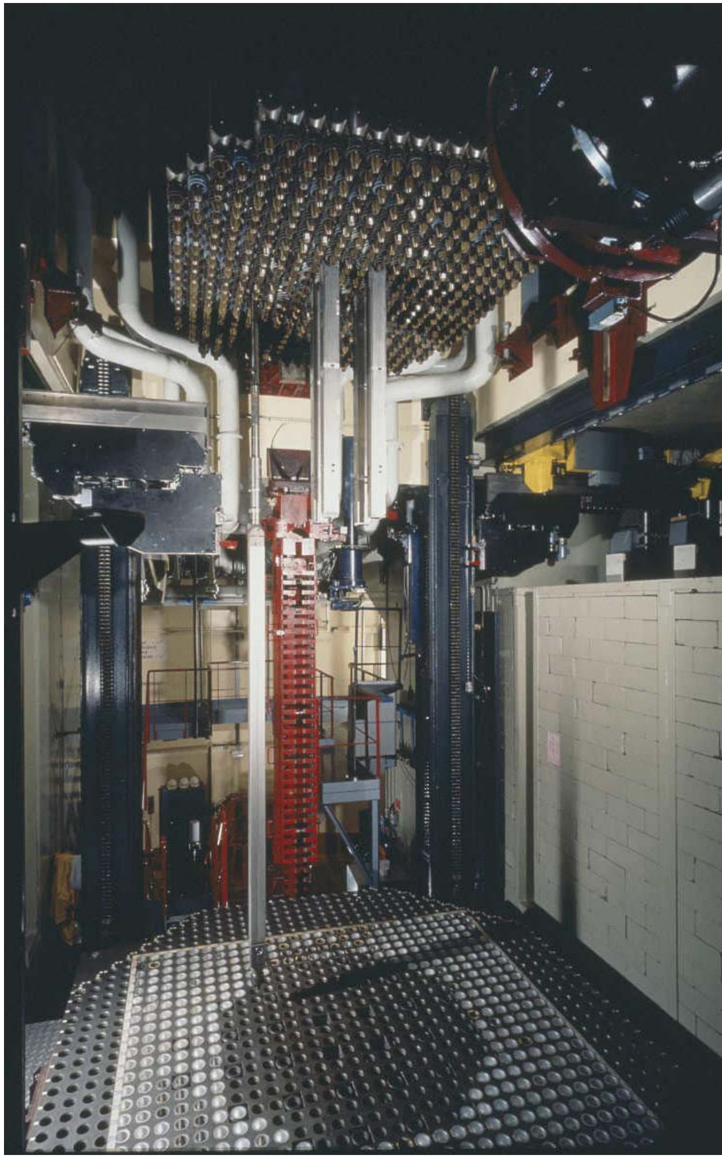
Recommendations and
specifications for a intense external source
Proposal of MUSE 4 experiments

The MUSE-4 experimental set-up

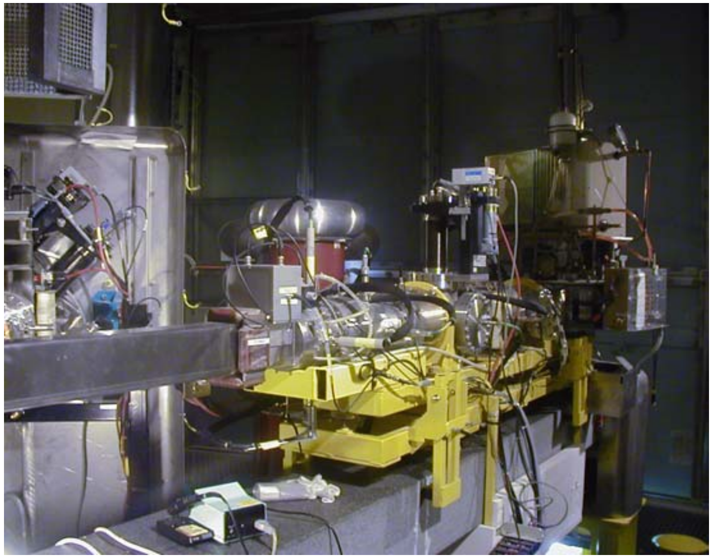


The MASURCA facility

- Maximum power : 5 kW
- Airflow cooled system
- Reference critical mock-up for the fast neutron reactor program till the 1990's
- Experiments within the frame of Transmutation since 1995
  - Support of irradiations in moderated spectra in PHENIX (COSMO program)
  - Support of research on ADS since 2000 (MUSE-4 program)



The GENEPI neutron generator



Specially designed and built for this program

Pulsed source (some hertz to 5 kHz)

Very short pulse duration (<1μs) – very fast intensity decrease

Set-up at MASURCA : February ➔ June 2000

Deuterium target => 1.2 10^{8} n/s (f=4 kHz)

Fresh tritium target => **1.3 10^{10}** n/s (f=4 kHz)

Experiment schedule

- Three large phases

1st phase : October 2000 ➔ February 2002

- Preparation of the experiments, safety measurements

2nd phase : March 2002 ➔ September 2002

-Full characterization of the reference critical configuration

3rd phase- October 2002 ➔ July 2004

- Studies of subcritical configurations

SC0, Na $k_{eff} \approx 0.994$	- November 2002 ➔ March 2003
SC2, Na $k_{eff} \approx 0.97$	- April 2003 ➔ July 2003
SC3, Na $k_{eff} \approx 0.954$	- September 2003 ➔ November 2003
SC3, Na-Pb, $k_{eff} \approx 0.954$	- June 2004 ➔ July 2004

Experiment schedule

- Main events

- **9 January 2001**:
  first criticality of the MUSE-4 reference configuration

- **19 September 2001** :
  authorization to couple MASURCA and GENEPI

- **13 November 2001** :
  authorisation to perform experimental program in the three successive MUSE-4 subcritical configurations

- **27 November 2001** :
  first coupling of the accelerator with the reactor all safety rods up

- **October 2002-November 2003** : Study of the subcritical configurations

- **19 February 2004** :
  authorisation to perform experimental program on the partial lead MUSE-4 subcritical configuration

- **2 August 2004** : End of the experimental program

Characteristics of the main MUSE-4 core configurations

PR down

Configuration	Total number of equivalent fuel cells	Reactivity - in dollars	Reactivity - in pcm 1$ = 334 pcm	Target	Period	Maximum power with GENEPI ON
Reference	1125	**-0.25**	-83 ± 5	-	March-September 2002	-
SC0	1108	**-1.9**	-621 ± 37	**D**	November-December 2002	**<10 W**
				T	January-March 2002	**<50 W**
SC2	1006	**-8,7**	-2911 ± 187	**T**	April-June 2003	**<10 W**
	1004	**-9,1**	-3037 ± 195	**T**	May-June 2003	**<10 W**
				D	July 2003	**<2W**
SC3	972	**-13.6**	-4534 ± 292	**T**	September-November 2003	**<5 W**
SC3 Lead (partially)	972	**~-11.2**	~-3841	**T**	June-July 2004	**<5 W**

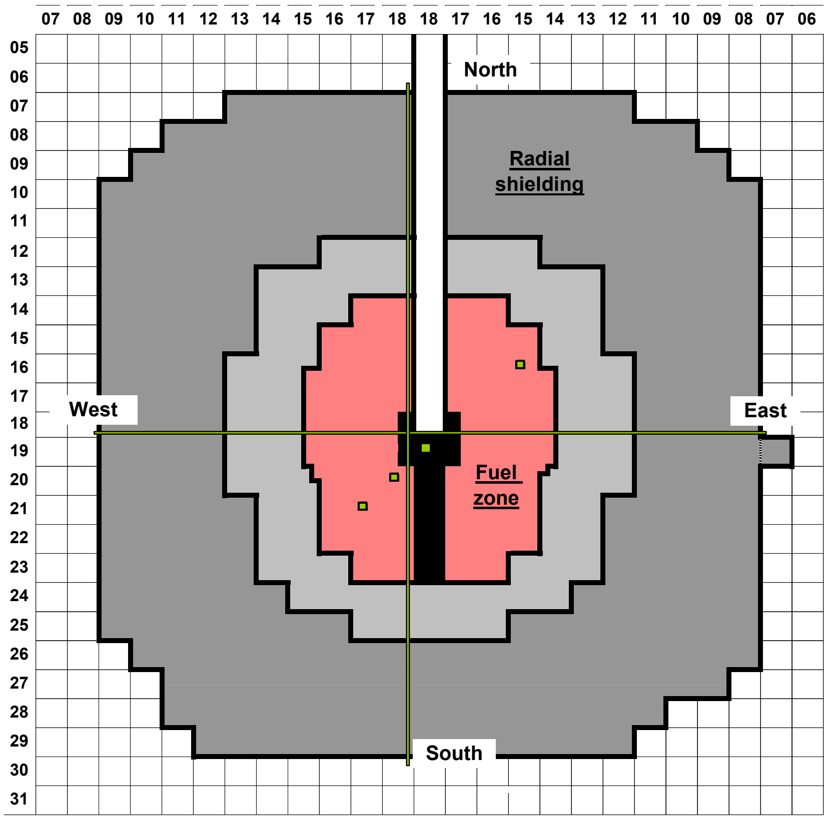
Experimental program

		Configuration														
		Reference		SC0				SC2			SC3			SC3+		
	Coolant	Sodium												Sodium + Lead		
	State	Critical	Subcritical													
	External neutron source	-	^{252}Cf	-	D target	T target	^{252}Cf	-	D target	T target	-	T target	^{252}Cf	-	T target	^{252}Cf
Characterisation measurement	Critical mass	X														
	Rod drop	X														
	Fission rate relative distribution	X			X	X				X		X			X	
	Spectral indices (miniatures FC)	X				X				X		X			X	
	Spectral indices (foil irradiations)	X			X	X				X						
	Importance relative distribution		X				X						X			X
	β_{eff}, β_{eff}/Λ (CPSD method)	X														
	β_{eff}, β_{eff}/Λ (source modulation method)					X				X		X			X	
Reactivity measurement	Source jerk						X						X			X
	Pulsed neutron source				X	X			X	X		X			X	
	Noise methods	X		X	X	X	X	X	X	X	X	X	X	X	X	X

Characterisation of the reference critical core

Goal : code validation in a reference critical configuration

Determination of initial biases (due to new heterogeneities, independent of the external sources)



Fission rate relative distribution

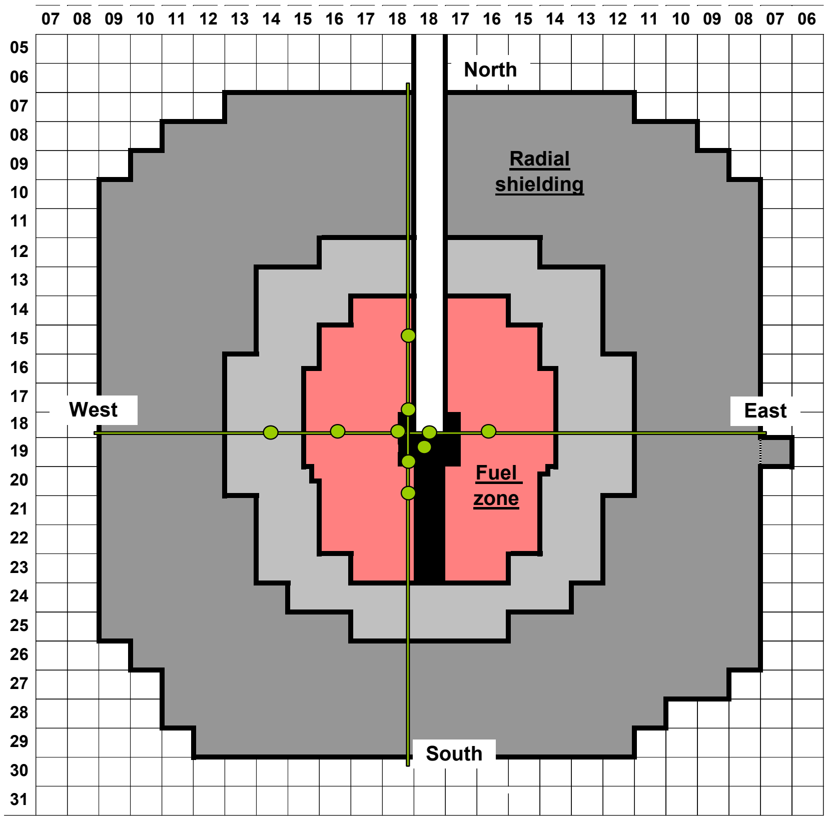
- 6 directions
- for a large set of fissile isotopes (^{232}Th , ^{233}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{243}Am)

=> ~70 fission rate traverses

Characterisation of the reference critical core

Goal : code validation in a reference critical configuration

Determination of initial biases (due to new heterogeneities, independent of the external sources)



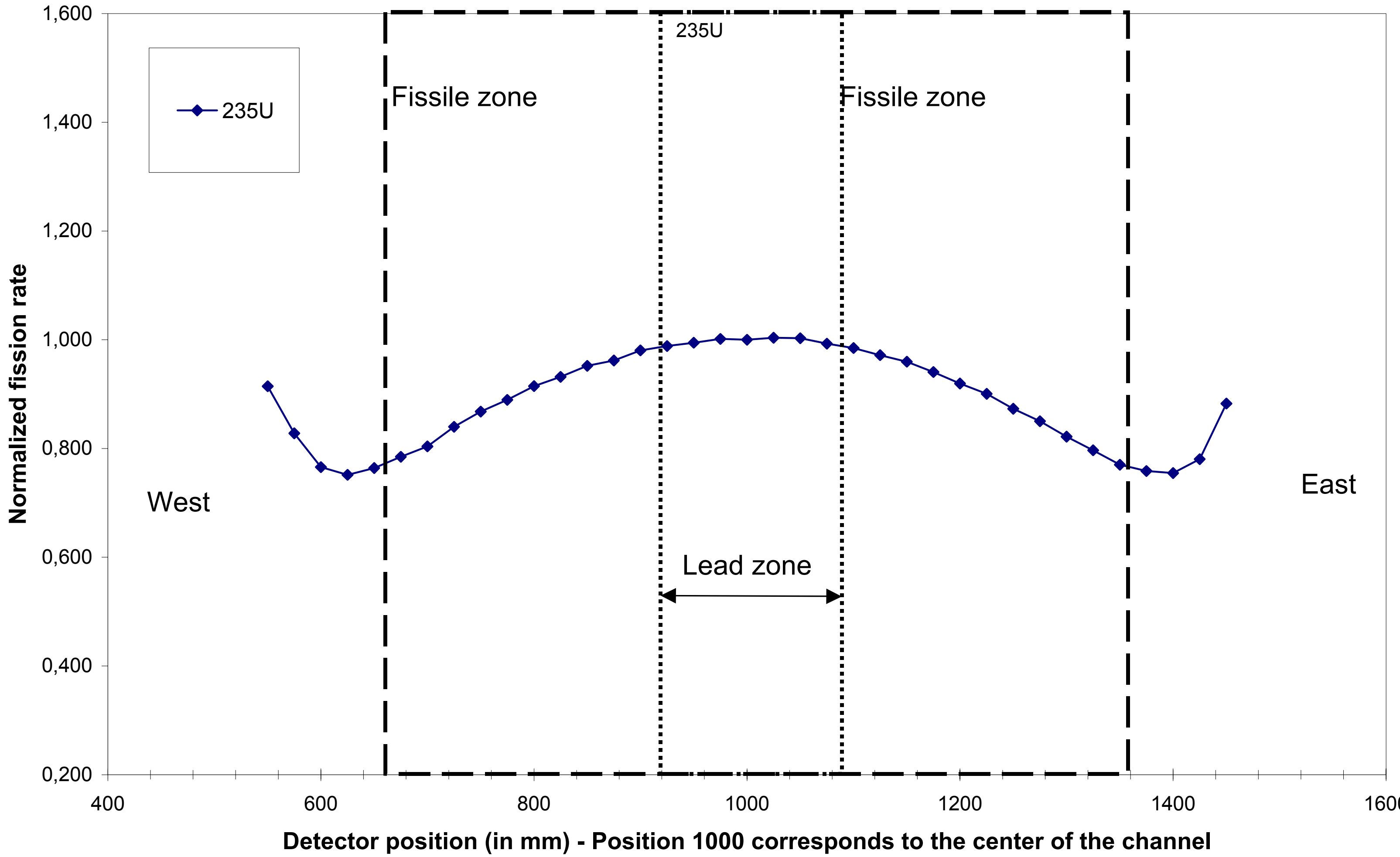
Spectral indices

- in positions of interest

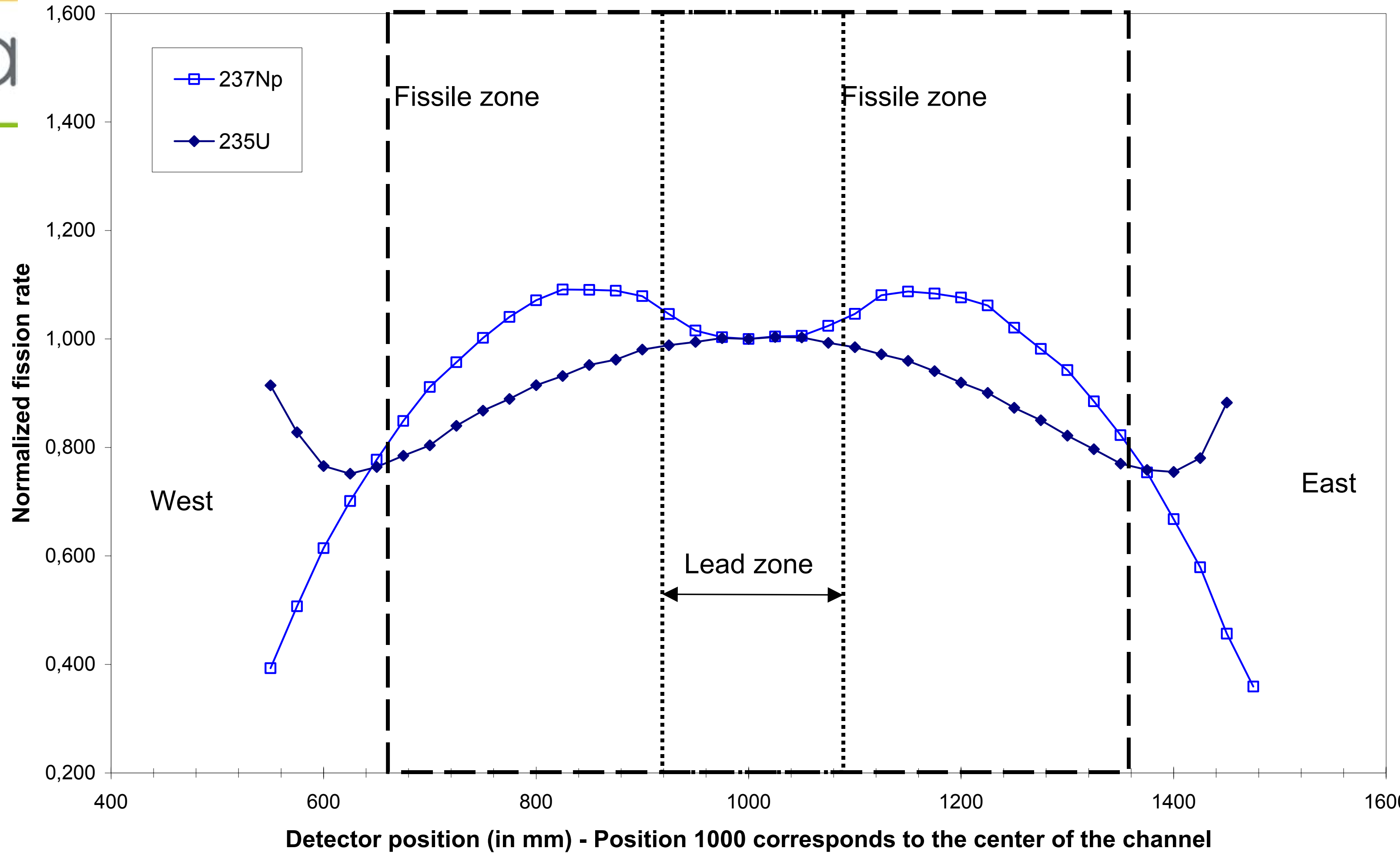
- for a large set of fissile isotopes (^{232}Th , ^{233}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{243}Am) and non fissile isotopes **(some with high threshold reactions)**

=> ~200 spectral indices

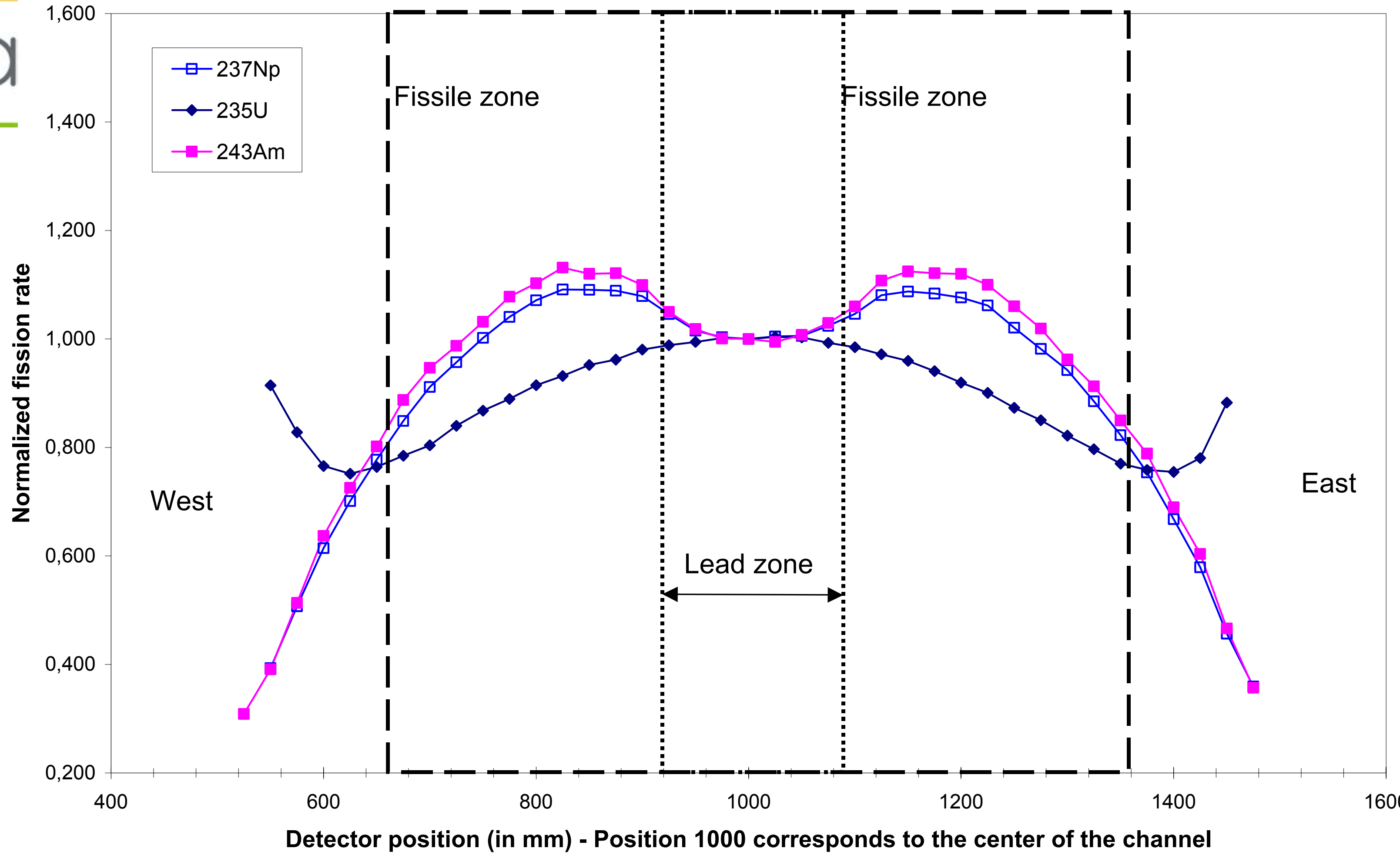
Characterisation of the reference critical core



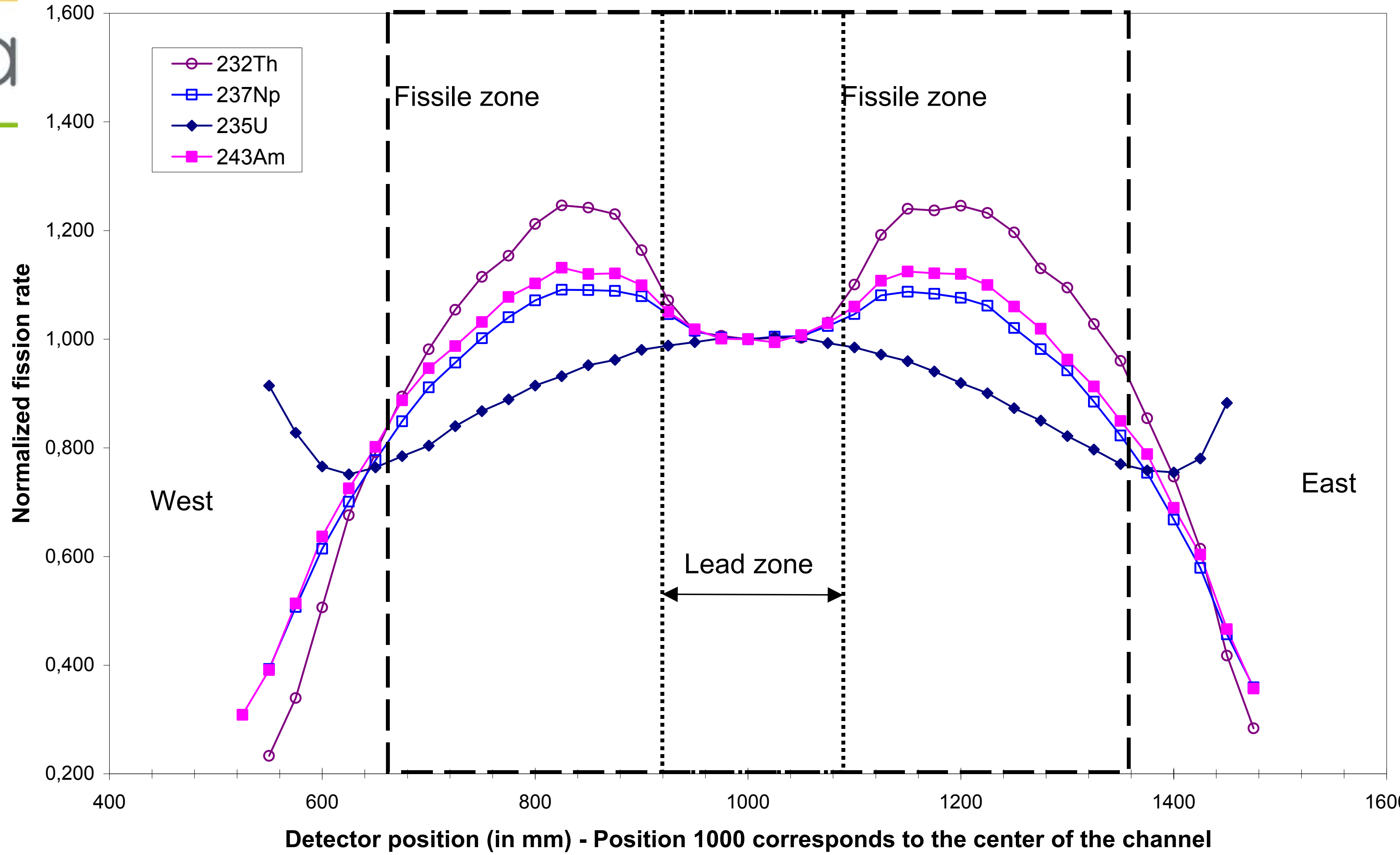
Characterisation of the reference critical core



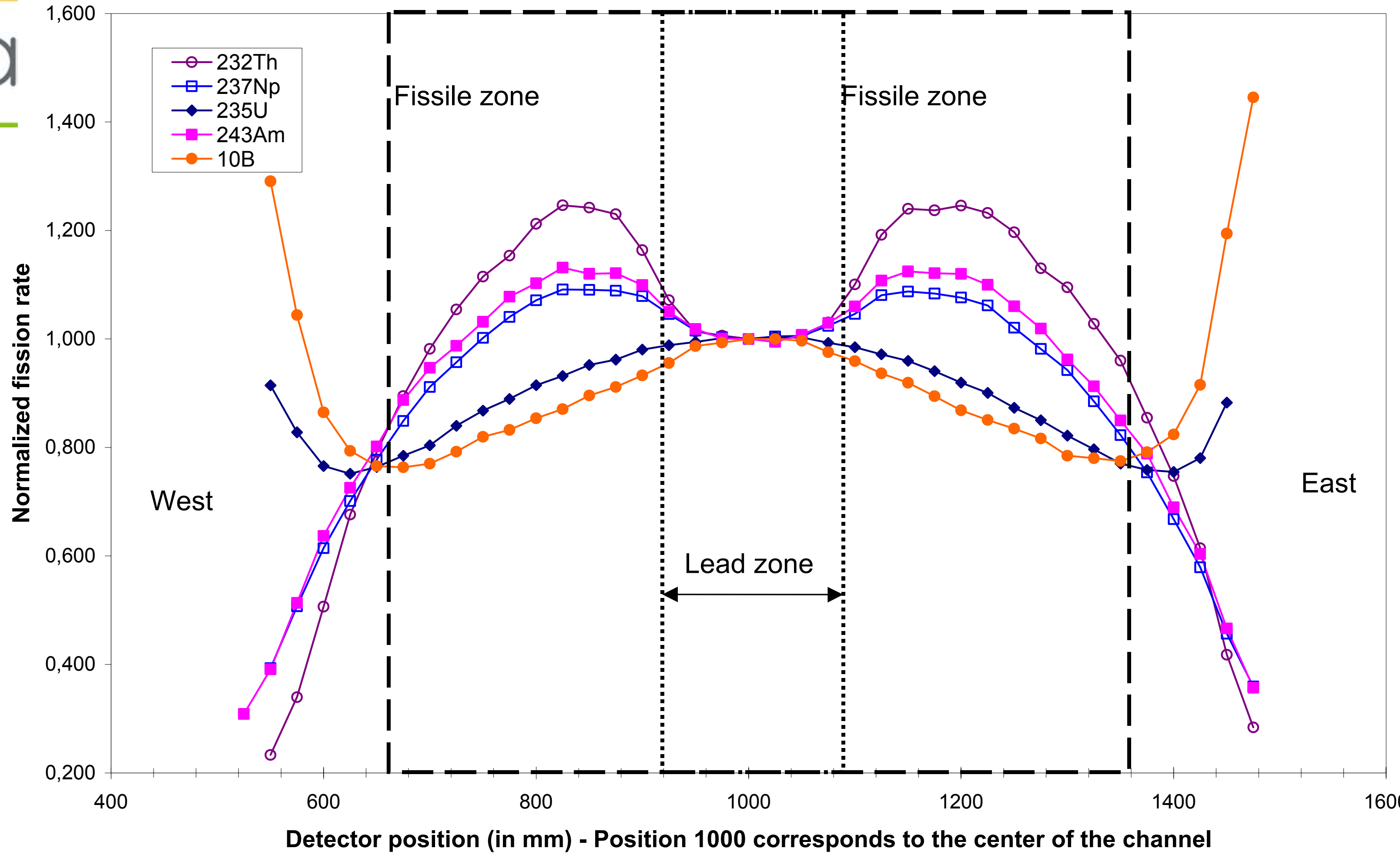
Characterisation of the reference critical core



Characterisation of the reference critical core



Characterisation of the reference critical core



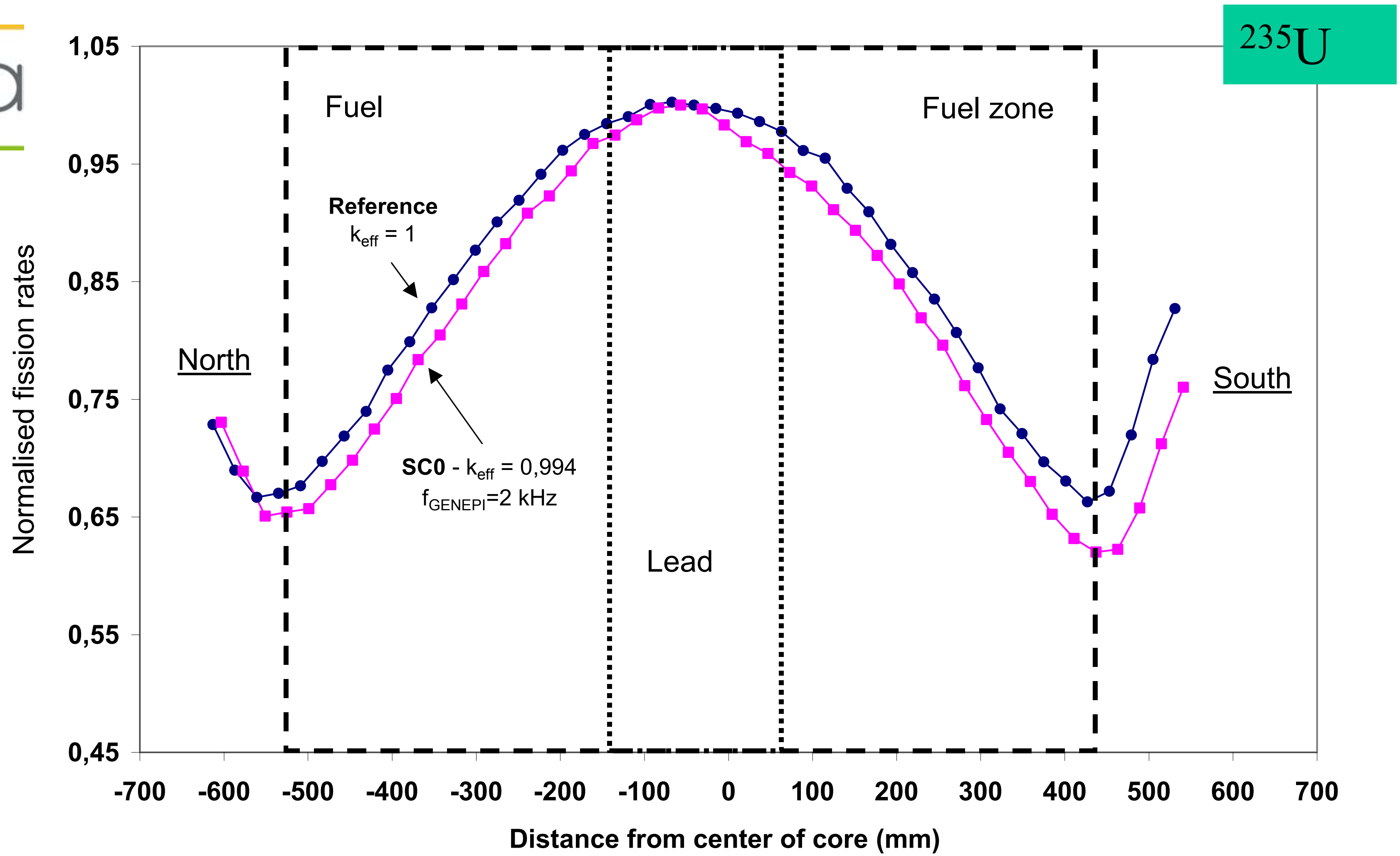
Characterisation of the subcritical cores

- Less measurements have been performed because of :
  - the limitation of the duration of the measurements
  - the intensity of the external source (lower than expected)
  - the deposit mass of fissile fission chambers (designed for critical experiments)
  - the priority was given to reactivity measurements.

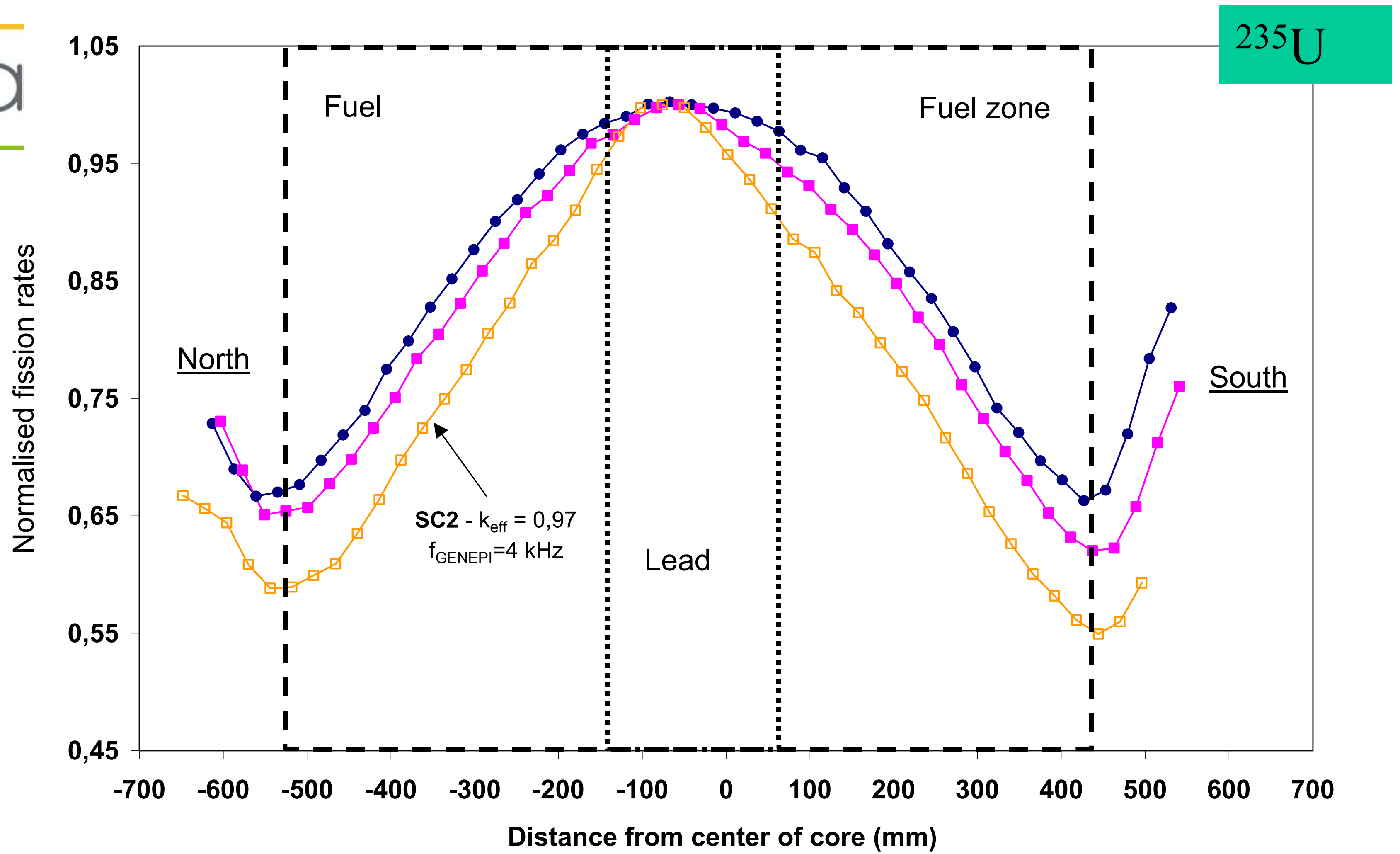
		Critical	SC0	SC2	SC3	SC3 Pb
^{235}U	N/S	X	X	X	X	X
	E/W	X		X	X	X
	E19-18	X		X		

		Critical	SC0	SC2	SC3	SC3 Pb
^{238}U	N/S					
	E/W	X	X			
	E19-18					

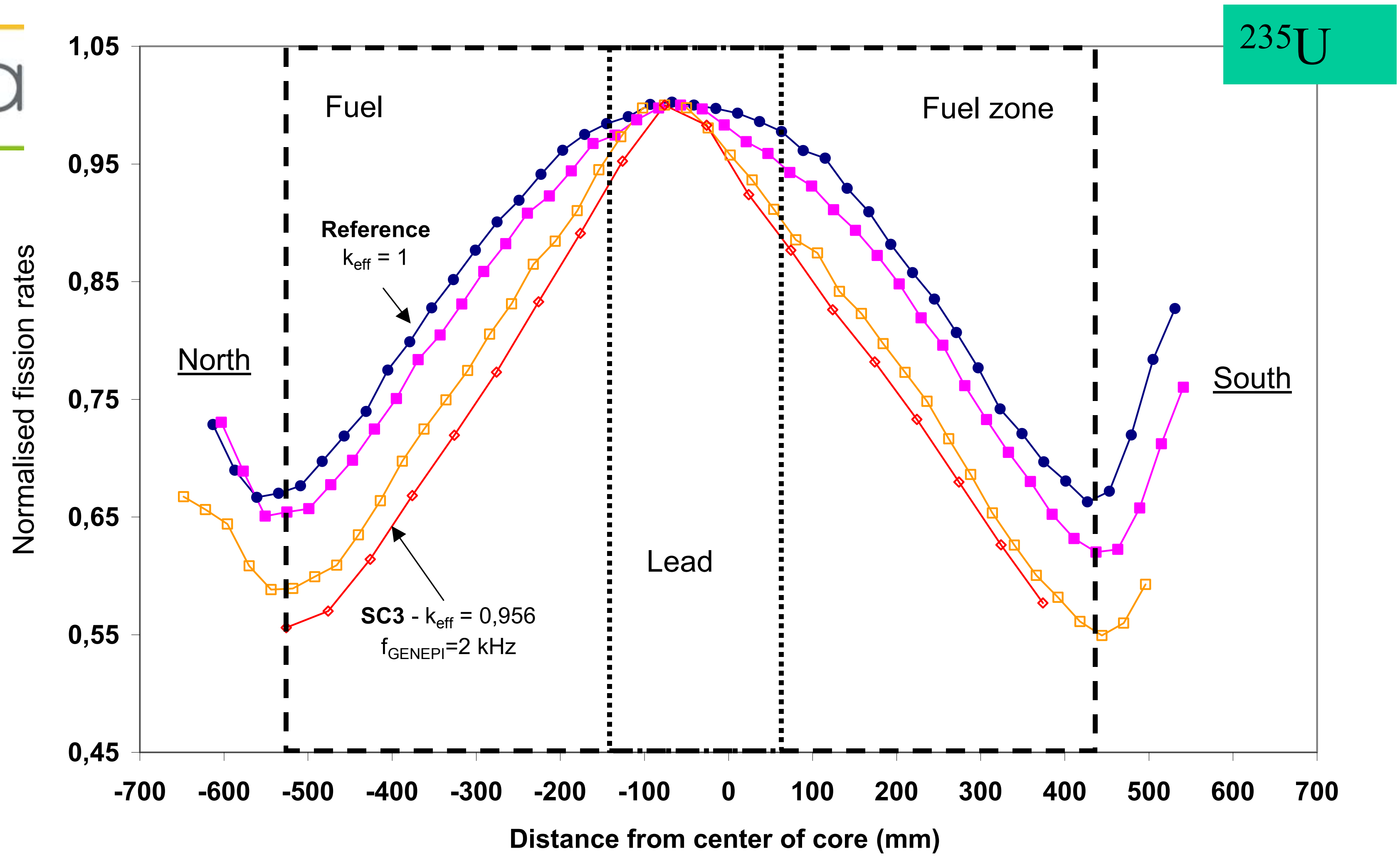
Characterisation of the subcritical cores



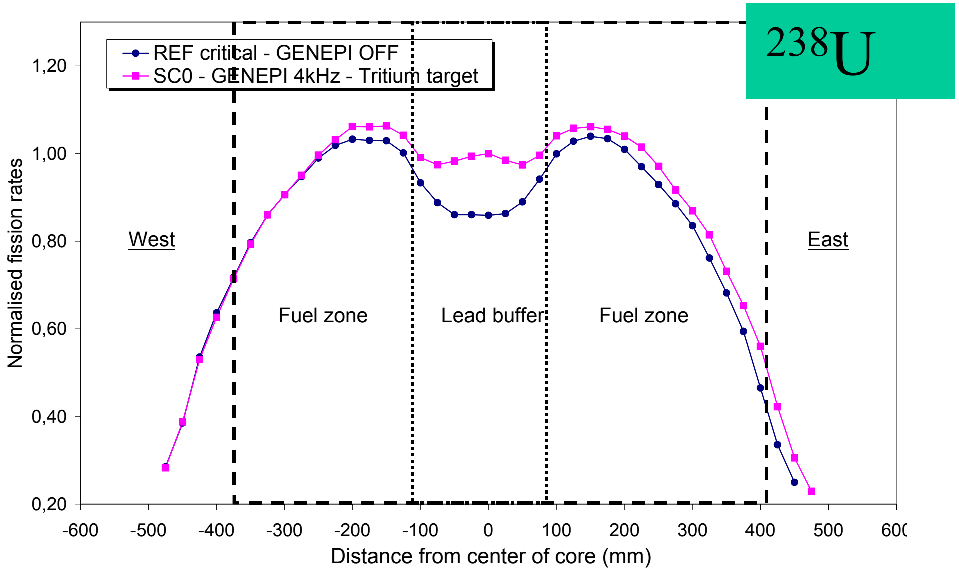
Characterisation of the subcritical cores



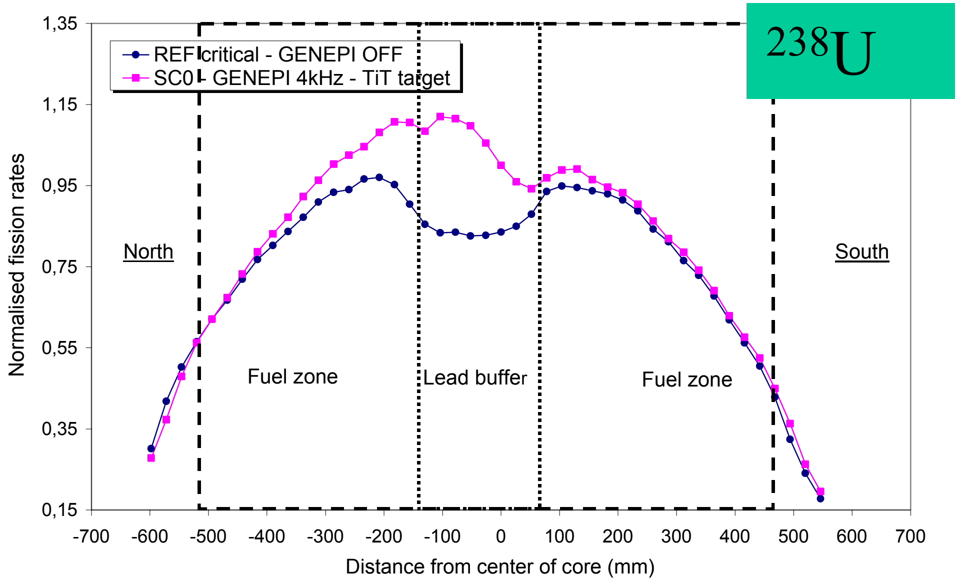
Characterisation of the subcritical cores



Characterisation of the subcritical cores



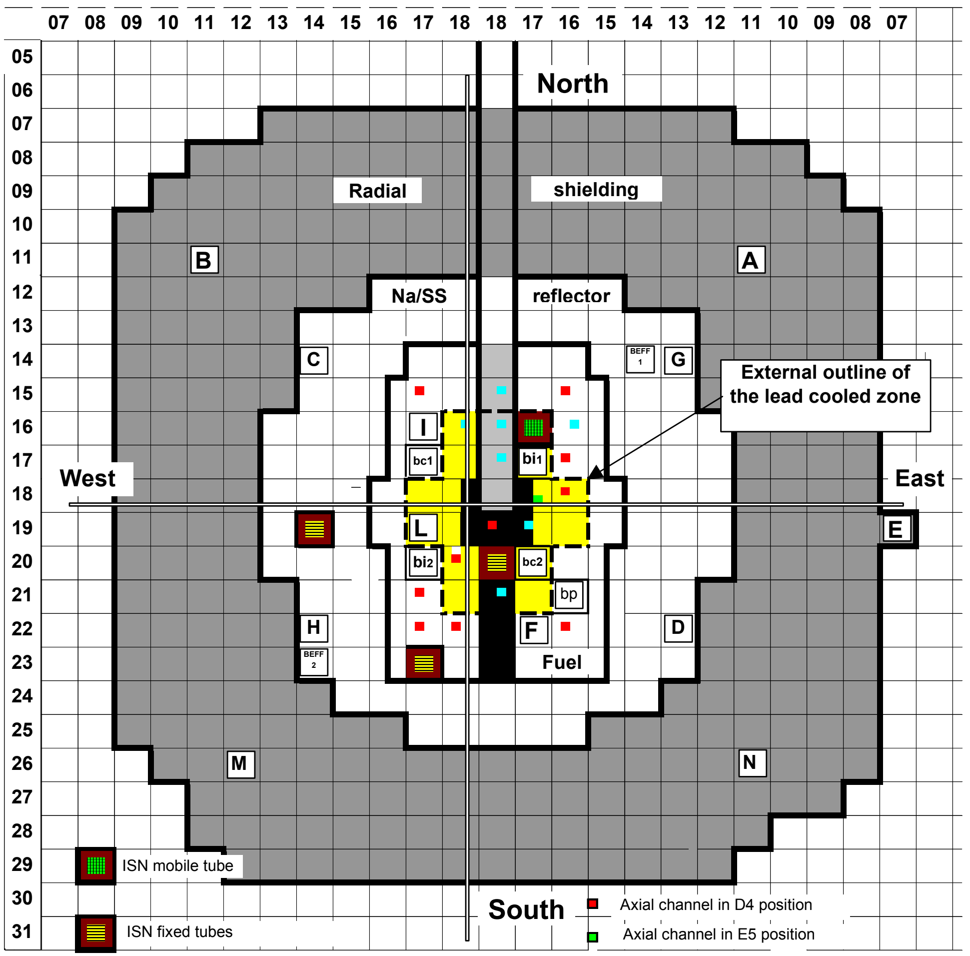
- Effect of 14 Mev neutron provided by the Tritium target

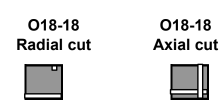


- Dissymmetry in the North/South channel

Characterisation of the subcritical cores

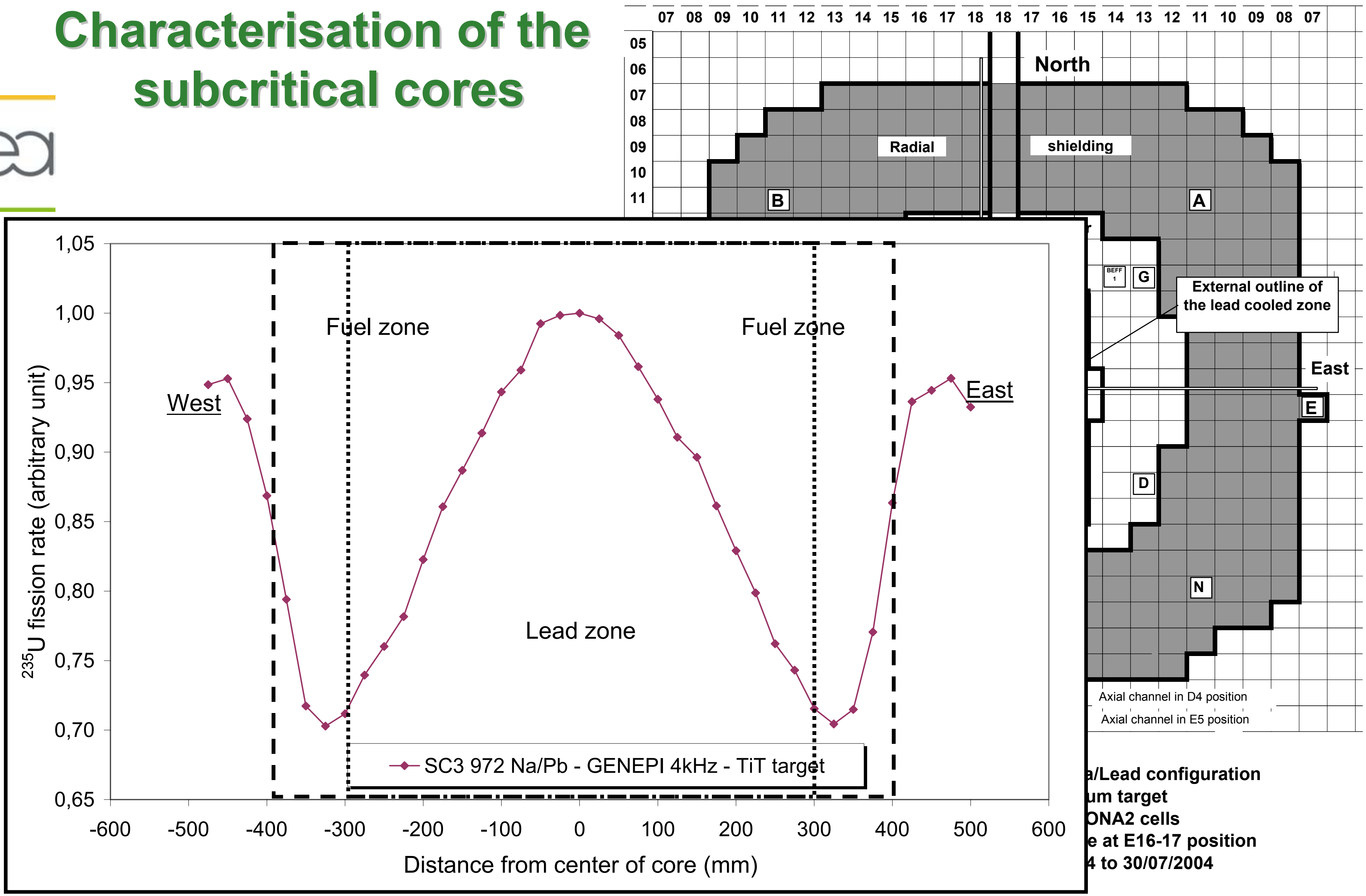
- Sodium removed from one third of the fissile tubes and changed by lead
- Last configuration of the program
- Reactivity effect due to the change sodium ➔ lead ≈ **+2,4 $**





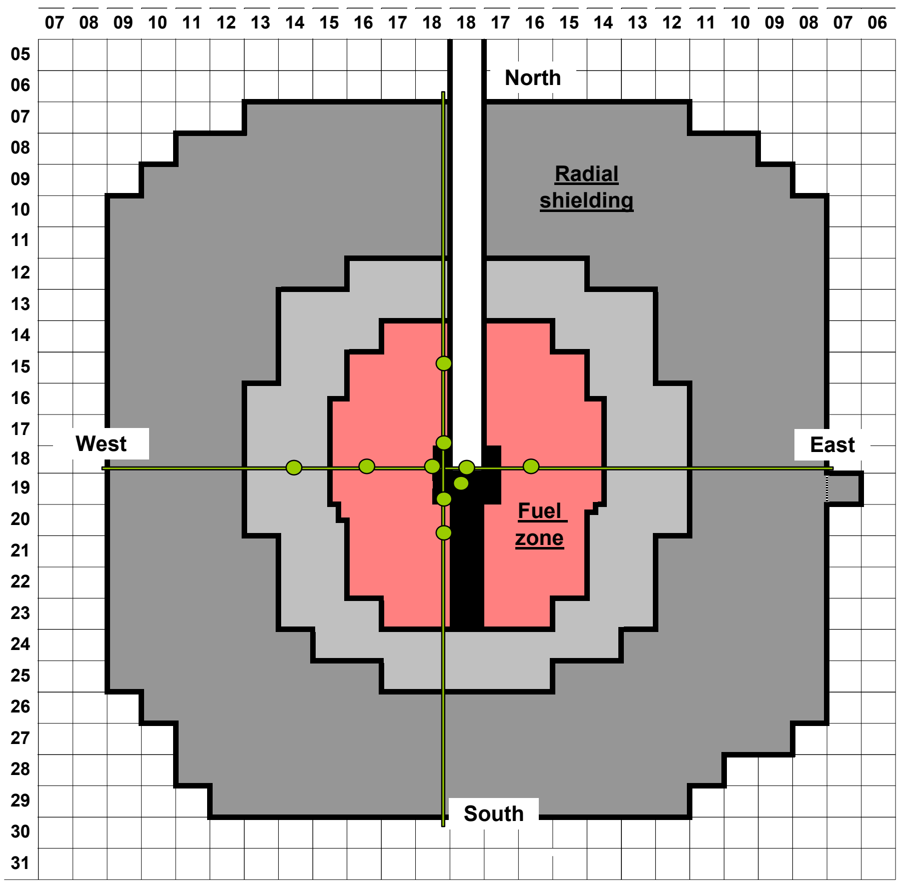
MUSE-4 SC3 Na/Lead configuration
Tritium target
972 ZONA2 cells
Mobile ISN tube at E16-17 position
07/06/2004 to 30/07/2004

Characterisation of the subcritical cores



Characterisation of the subcritical cores

Spectral indices by foil activation



G1

Reaction	Threshold [MeV]
In^{115}(n,g)	-
Co^{59}(n,g)	-
Th^{232}(n,g)	-
Zn^{64}(n,g)	-
Au^{197}(n,g)	-
U^{235}(n,fis)	-
Np^{237}(n,g)	-

G2

Reaction	Threshold [MeV]
Np^{237}(n,fis)	0.7
Th^{232}(n,fis)	~1
In^{115}(n,n')	1.2
Th^{232}(n,fis)	1.3
Co^{59}(n,p)	2.0
Ni^{58}(n,p)	2.8
Zn^{64}(n,p)	2.8
Fe^{54}(n,p)	3.1

G3

Reaction	Threshold [MeV]
Fe^{56}(n,p)	6.0
Mg^{24}(n,p)	6.8
Pb^{204}(n,2n)	~7
Th^{232}(n,2n)	~7
Al^{27}(n,a)	7.2
Nb^{93}(n,2n)	11.0
V^{51}(n,α)	11.5
Ni^{58}(n,2n)	13.5

Configuration	Target	Number of irradiations
Reference	-	5
SC0	D	2
SC0	T	4
SC2	T	2

~350 samples irradiated

Characterisation of the reference critical core

Simulations of the experiments

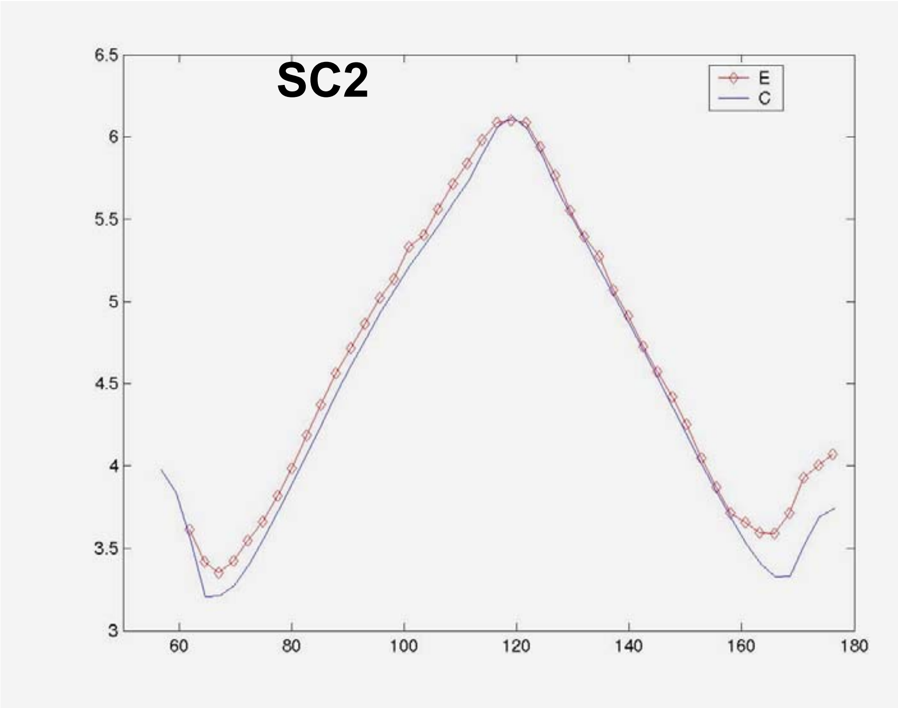
Important moderation effect in lead well reproduced by both ERANOS and Monte-Carlo codes (but always the standard problem at the fuel/reflector interface)

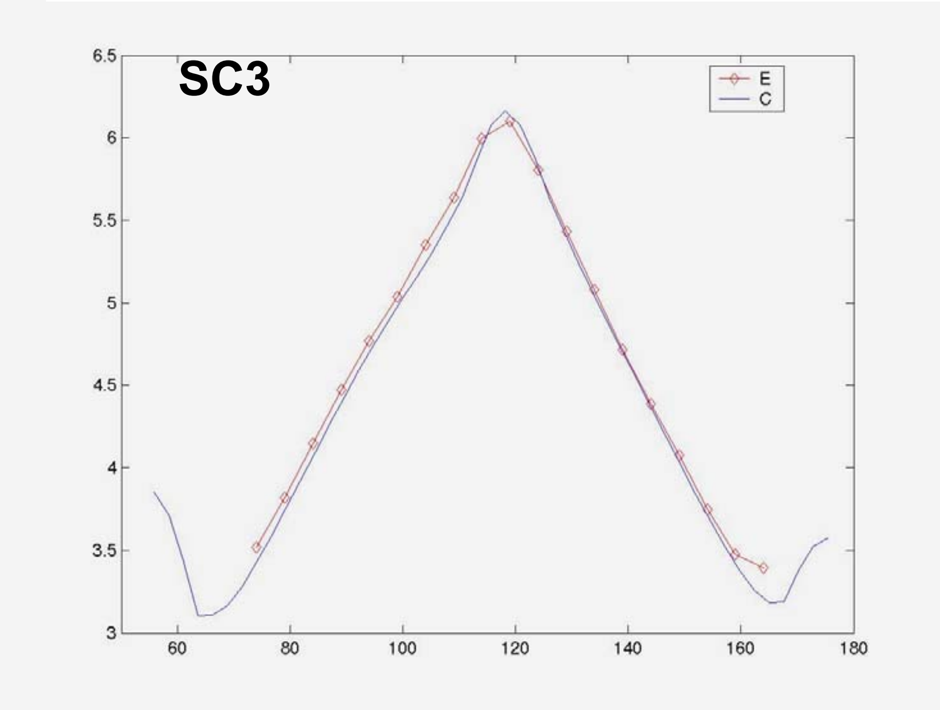
Very satisfactory agreement for all parameters

Characterisation of the subcritical cores

Simulations of the experiments

^{235}U fission rate distribution



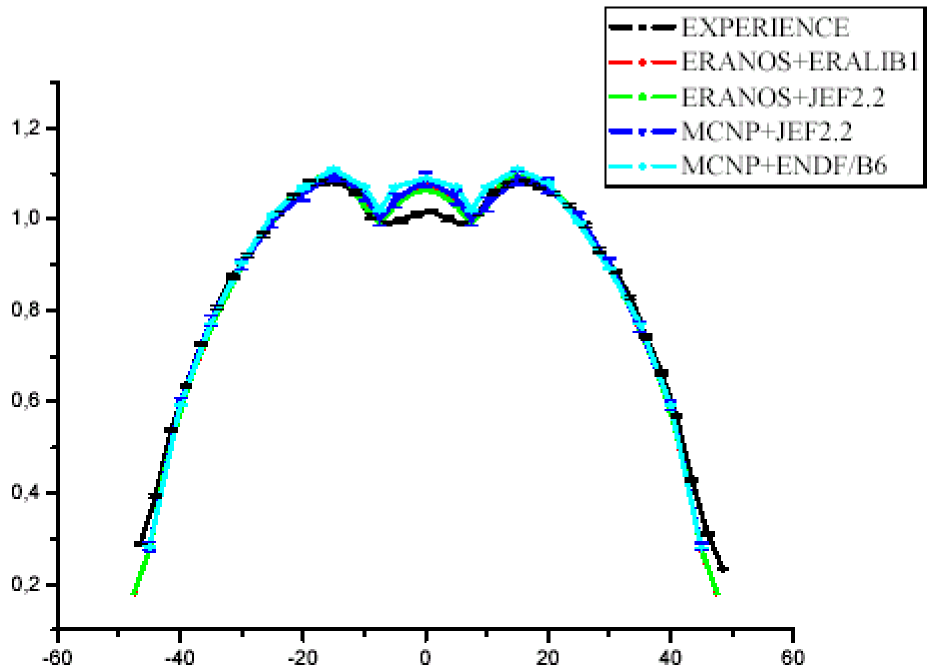


Good agreement (usual problem in the reflector)

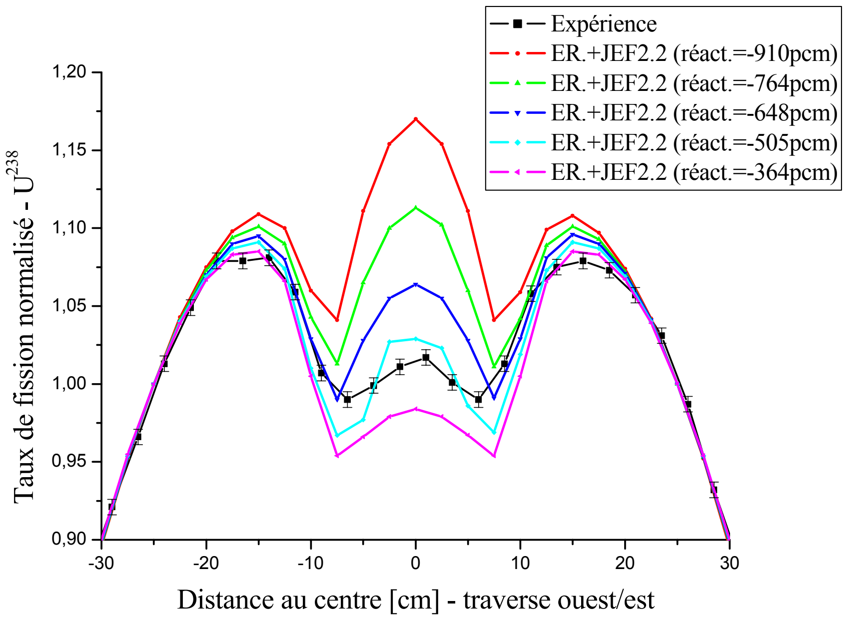
Characterisation of the subcritical cores

Simulations of the experiments

^{238}U fission rate distribution

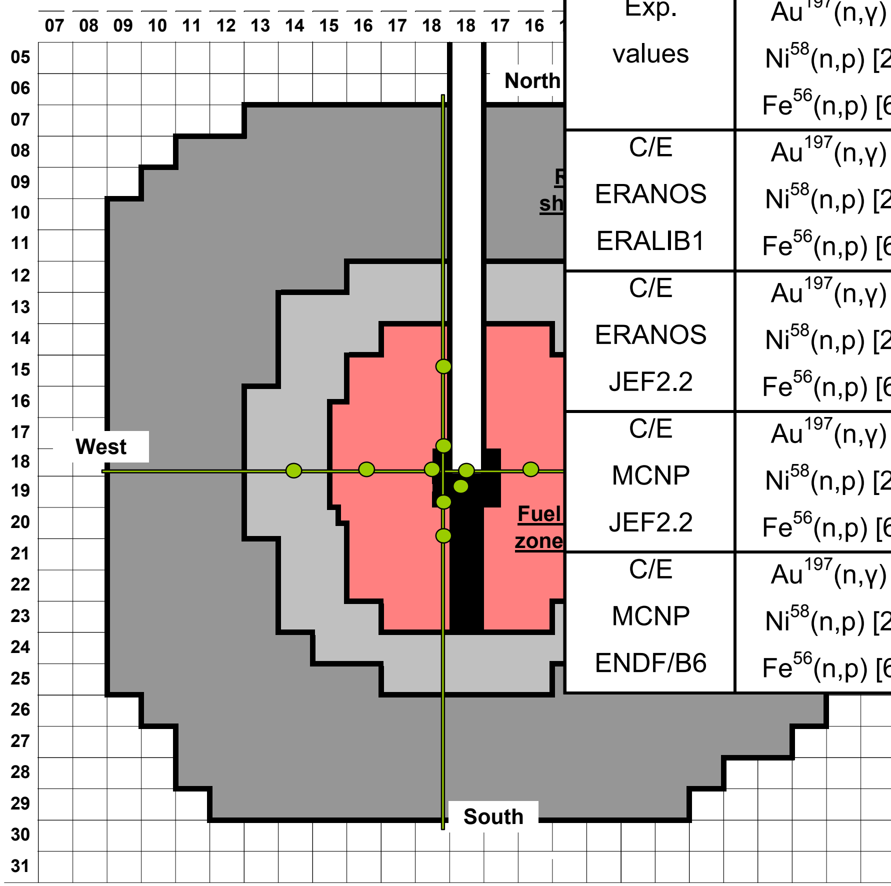


- Sensitivity, of relative distribution in the lead zone, to reactivity level



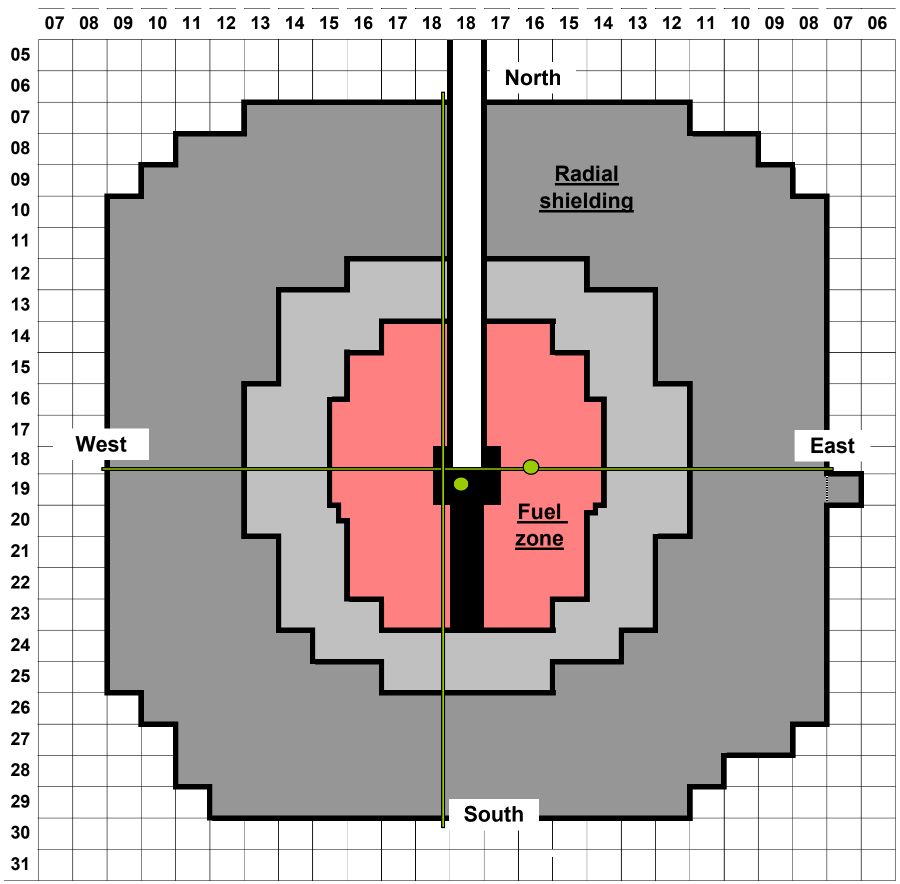
Characterisation of the subcritical cores

Methods & data	Reaction [Threshold in MeV]	2/1 C/E	3/1 C/E	4/1 C/E	5/1 C/E	6/1 C/E
Exp. values	$Au^{197}(n,\gamma)$ [-]	1.22±0.03	1.16±0.03	1.17±0.02	1.05±0.02	0.92±0.02
	$Ni^{58}(n,p)$ [2.8]	0.52±0.01	0.74±0.01	0.74±0.01	0.81±0.01	0.71±0.01
	$Fe^{56}(n,p)$ [6.0]	0.38±0.01	0.68±0.01	0.64±0.01	0.75±0.02	0.72±0.02
C/E ERANOS ERALIB1	$Au^{197}(n,\gamma)$ [-]	0.98	0.98	0.95	0.99	0.99
	$Ni^{58}(n,p)$ [2.8]	0.94	0.93	1.09	1.02	0.96
	$Fe^{56}(n,p)$ [6.0]	0.93	0.88	1.15	1.04	0.92
C/E ERANOS JEF2.2	$Au^{197}(n,\gamma)$ [-]	0.98	0.98	0.95	0.99	0.99
	$Ni^{58}(n,p)$ [2.8]	0.94	0.93	1.09	1.03	0.96
	$Fe^{56}(n,p)$ [6.0]	0.94	0.88	1.15	1.04	0.92
C/E MCNP JEF2.2	$Au^{197}(n,\gamma)$ [-]	0.99	1.00	0.95	0.99	0.97
	$Ni^{58}(n,p)$ [2.8]	0.84	0.95	1.02	1.04	0.98
	$Fe^{56}(n,p)$ [6.0]	0.49	0.81	0.98	1.00	0.92
C/E MCNP ENDF/B6	$Au^{197}(n,\gamma)$ [-]	1.01	0.98	0.96	1.00	0.98
	$Ni^{58}(n,p)$ [2.8]	0.92	0.99	1.07	1.05	1.00
	$Fe^{56}(n,p)$ [6.0]	0.92	0.93	1.09	1.08	0.95



Good agreement for all isotopes with non threshold reactions

Characterisation of the subcritical cores



		2/1	
Reaction	Threshold in Mev	Critical	SC2 - T target
Au^{197}(n,g)	-	1,22	1,23
In^{115}(n,n')	1,2	0,74	1,06
Ni^{58}(n,p)	2,8	0,52	1,14
Fe^{56}(n,p)	6,0	0,38	9,41

	Ratio 2/1 - Critical configuration		
Methods & data	Average C/E (%)		
	G1	G2	G3
MCNP - ENDF/B6v2	0,1	-8,8	-14,2
ERANOS - ERALIB	-3,8	-6,8	-9,8

	Ratio 2/1 - SC2 subcritical configuration		
Methods & data	Average C/E (%)		
	G1	G2	G3
MCNP - ENDF/B6v2	4	-3,5	-43
ERANOS - ERALIB	-1	-2,5	-32

Need for testing a dosimetric library

Analysis of characterisation measurements Conclusions

• Good agreement for critical measurement. Discrepancies in the lead zone are less than 5%.

• For ^{235}U fission rate traverses, good agreement also for subcritical measurements

• Larger discrepancies for ^{238}U threshold fission. Analysis demonstrated the sensitivity :

- to the location of the source
- to the reactivity level (tuning of the reactivity is necessary but … modifies the neutron balance !)

• Poor agreement for spectral indices with fission chambers but the analysis is complex owing to specific measurement conditions. More analysis on-going.

• Some analyses should be performed using a dosimetric library

The MUSE-4 benchmark

- Benchmark on computer simulations of MASURCA critical and subcritical experiments
- Initiated in the frame of MUSE then managed by the OECD/NEA
- 3 steps :
  - Critical - COSMO (a MASURCA past program)
  - Critical - MUSE 1112 cells
  - Subcritical - MUSE 976 cells
- Static and dynamic parameters compared
- 16 participants calculated standard static parameters and provided, for some parameters, up to 34 solutions
- Several MC and deterministic codes, 3 libraries (JEF2.2, ENDFB6, JENDL3.2) and a number of variants were used

The MUSE-4 benchmark - Main conclusions

-k_{eff} simulated with an uncertainty of ~500 pcm (dispersion ~2000 pcm)

- Reactivity change between crirical and subcritical configurations better predicted (uncertainty ~200 pcm)

-β_{eff} calculated with an uncertainty between 10% and 40%. Scatter results ~20%.

- Large discrepancies for the average power with the pulsed source (close to 40%)

- Only 10 solutions for the time evolution of the neutron flux after a short pulse. Large differences explained by the different reactivity estimated on each calculation.

- Need for additional exercises in order to investigate the external fast neutron propagation within the multiplying media and thermalization in large nearly transparent reflectors

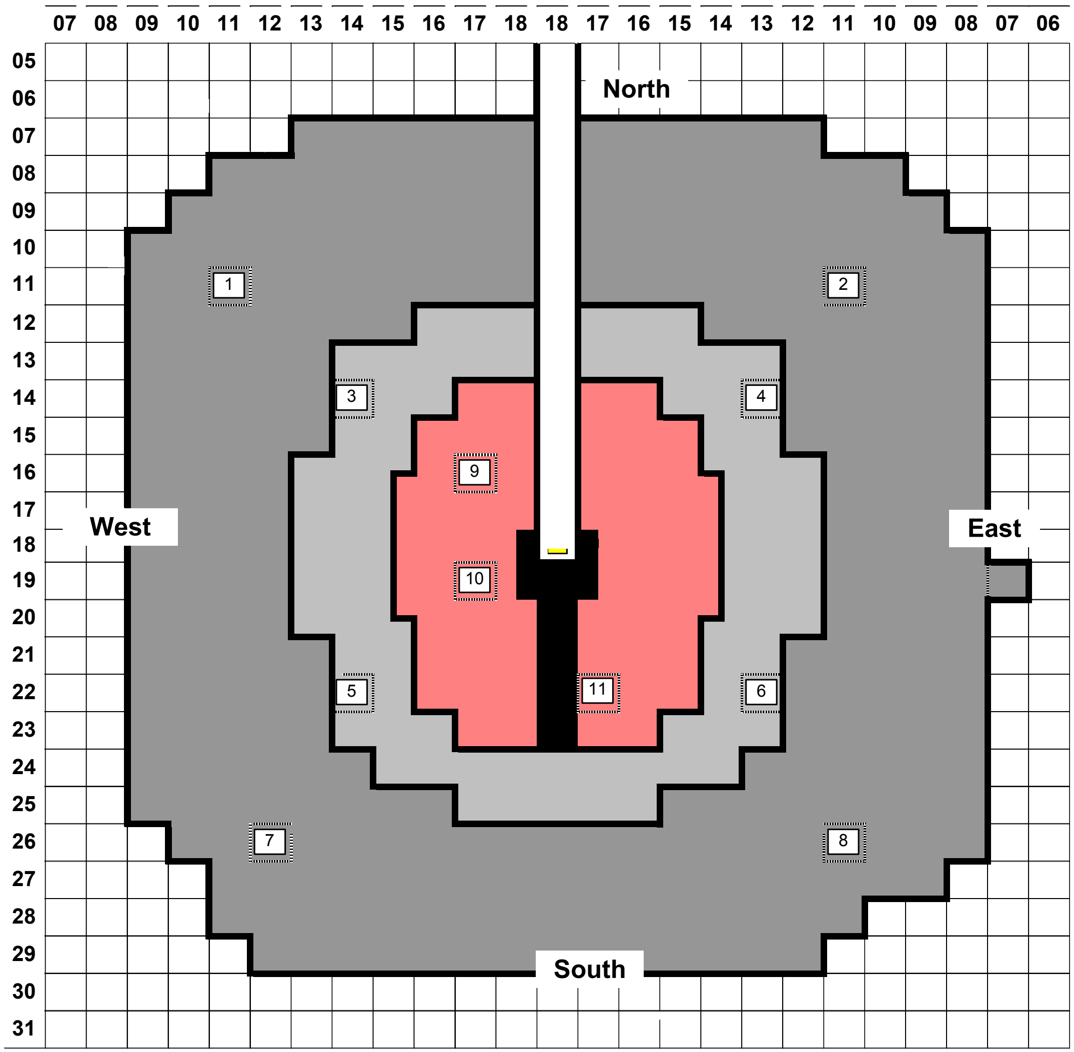
Measurement of the subcriticality

<table>
<tr><th>Type of source</th><th colspan="2">Analysis method</th><th>Experimental parameter</th><th>Calculated parameters used</th></tr>
<tr><td rowspan="4">Intrinsic source</td><td colspan="2">Reference method</td><td>$\rho_{\$} = \rho/\beta_{eff}$</td><td>Kinetic parameters (α_i, λ_i) + MSM factors</td></tr>
<tr><td colspan="2">Rossi-α method</td><td rowspan="3">$\alpha_p = (\beta_{eff}-\rho)/\Lambda$</td><td></td></tr>
<tr><td colspan="2">Feynman-α method</td><td></td></tr>
<tr><td colspan="2">APSD and CPSD methods</td><td></td></tr>
<tr><td rowspan="2">^{252}Cf external source</td><td colspan="2">Rossi-α method</td><td>α_p</td><td></td></tr>
<tr><td colspan="2">Source jerk method</td><td>$\rho_{\$}$</td><td>Kinetic parameters (α_i, λ_i)</td></tr>
<tr><td rowspan="8">Pulsed neutron source (neutrons of 2,7 Mev or 14 Mev)</td><td rowspan="3">PNS technique</td><td>Area method</td><td>$\rho_{\$}$</td><td></td></tr>
<tr><td>Slope fit method</td><td>α_p</td><td></td></tr>
<tr><td>k_p method</td><td>$k_p = (1-\beta_{eff})/(1-\rho)$</td><td>P($\tau$) distribution</td></tr>
<tr><td colspan="2">Rossi-α method</td><td rowspan="4">α_p</td><td></td></tr>
<tr><td rowspan="2">Feynman-α method</td><td>Deterministic way</td><td></td></tr>
<tr><td>Stochastic way</td><td></td></tr>
<tr><td colspan="2">APSD and CPSD methods</td><td></td></tr>
<tr><td colspan="2">Source modulation method</td><td>$\rho_{\$}$</td><td></td></tr>
</table>

Experimental devices

11 fixed monitors with fissile deposits in the range

(10 mg, 1g)



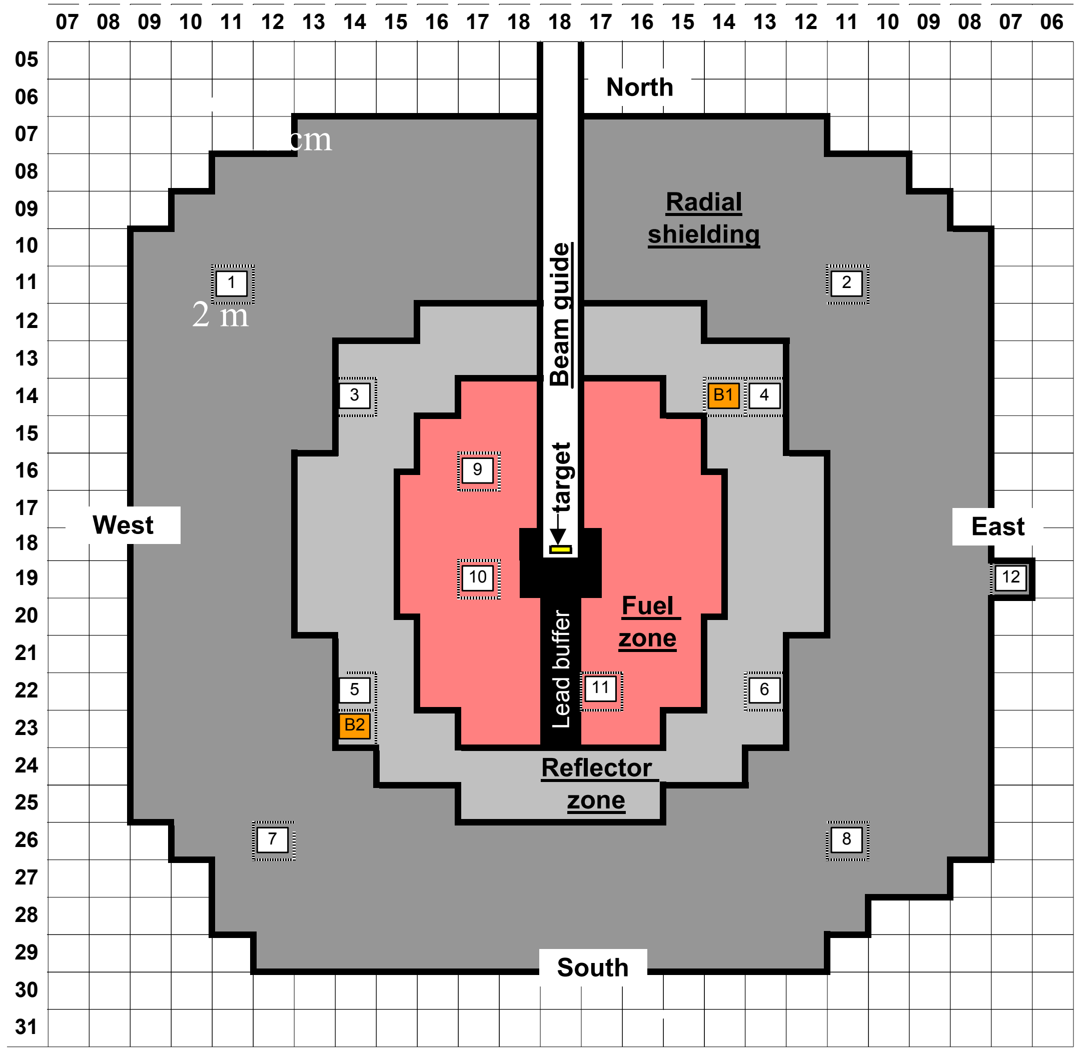
Experimental devices

11 fixed monitors with fissile deposits in the range

(10 mg, 1g)

+ two chambers with high efficiency

(~4,5 g of ^{235}U)



Experimental devices

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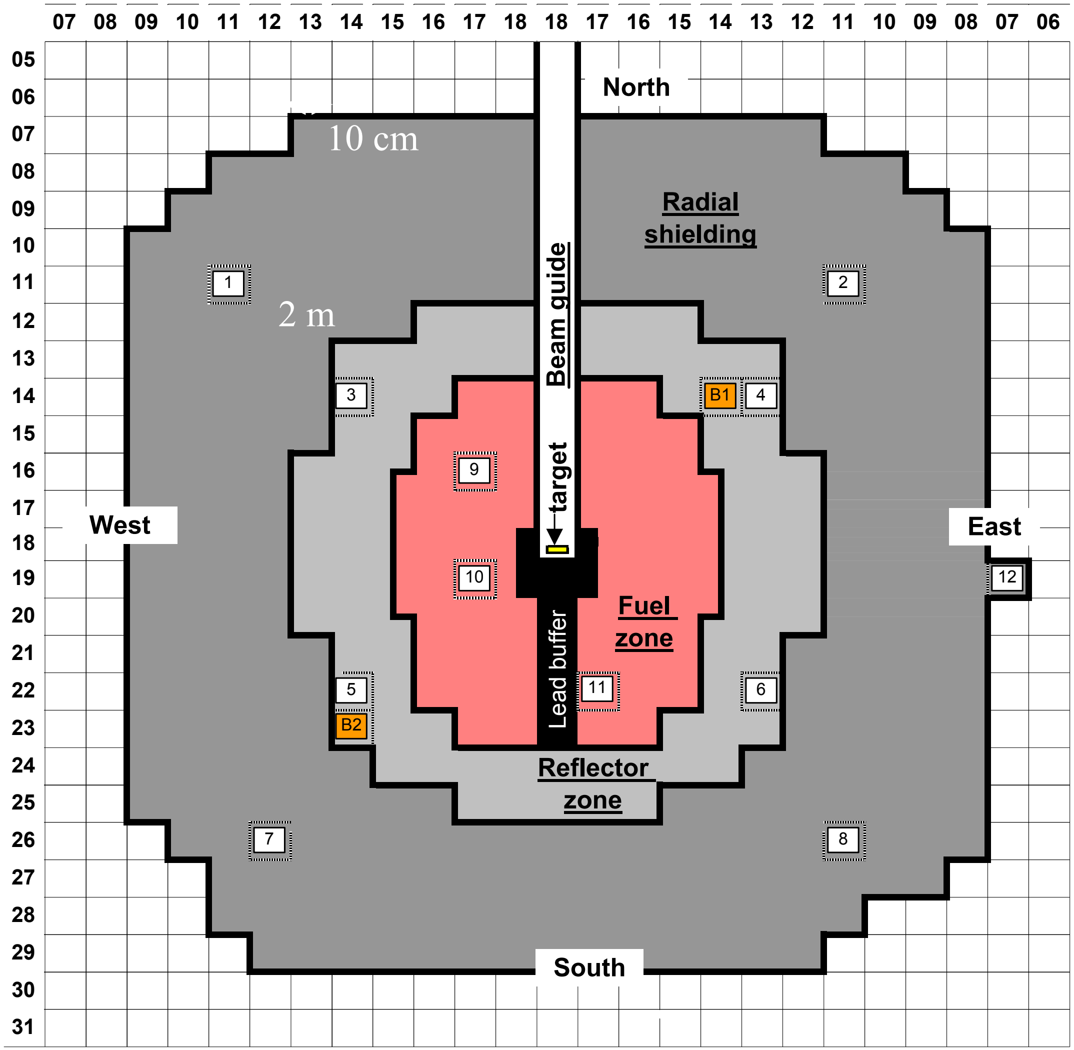


New DAQ systems

- All events are dated (for all detectors) with a precision of 100 ns (12.5 ns minimum)
- GENEPI triggers are also dated

=> Allow reduced histograms and then various analysis with a single measurement

Reference Method

- Rod-drop + MSM method is the reference method for critical reactors (mainly used to determine the reactivity worth of control rods – set-up in PHENIX, SUPERPHENIX, MASURCA, EOLE, MINERVE, AZUR, PHEBUS)
- The MSM method allows to take into account the changes of the detector efficiency and the modification of the source
- Knowing one reference reactivity level (ρ_{ref},$T_{ref}^{detector}$), one can deduce the reactivity of any subcritical configuration :

$$\rho=\rho_{ref.}\frac{T_{ref.}^{detector}}{T^{detector}}f_{MSM}$$

- The MSM factor f_{msm} is equivalent to the ratio (ε.S/ ε_{ref}.S_{ref}). It is calculated :

$$f_{MSM}=\frac{\rho\, T^{detector}}{\rho_{ref.}\, T_{ref.}^{detector}}$$

Reference Method

- Calculations were performed using the ERANOS 2.0 code system
- Since the MSM factors depend closely from the reactivity scale, we adjust the fission spectrum so that the reactivity calculated for the reference configuration with 1125 cells is equal to the measured value (–83 pcm or –24,9 cents). This adjustment is kept for all the calculations.

		MSM factors (%)			
Position	Zone	SC0 1108	SC2 1006	SC2 1004	SC3 972
W16-17	Core	-1%	-3%	-4%	-6%
W19-17	Core	-2%	-4%	-5%	-6%
E22-17	Core	-3%	-4%	-8%	-2%
E22-16	Core	-3%	-3%	-6%	-3%
W14-14	Reflector	-1%	-7%	-7%	-12%
E14-13	Reflector	-1%	-5%	-6%	-11%
W22-14	Reflector	-4%	-6%	-8%	-7%
E22-13	Reflector	-3%	-6%	-9%	-7%
W11-11	Shielding	-1%	-13%	-13%	-17%
E11-11	Shielding	-1%	-12%	-13%	-17%
W26-13	Shielding	-5%	-13%	-15%	-11%
E26-11	Shielding	-4%	-13%	-15%	-10%

Reference Method

		F	I	L	M	N	Average (in cents)	Average (in pcm)	Number of detectors
SC0 1108 (October 21, 2002)	ASM reactivity (cents		-188	-191	-192	-187	-190	-634	4
	MSM reactivity (cents)		-186	-187	-190	-181	-186	-621	
	C/E (Tref/Tpert)		1,00	0,97	0,97	0,98			
SC2 1006 (March 26, 2003) (no ISN mobile tube)		F		L	M	N			4
	ASM reactivity (cents	-900		-925	-858	-961	-911	-3043	
	MSM reactivity (cents)	-886		-892	-794	-914	-871	-2911	
	C/E (Tref/Tpert)	1,01		0,97	1,00	0,92			
SC2 1004 (May 14, 2003) (ISN mobile tube in E21-17)		F		L	M	N			4
	ASM reactivity (cents	-988		-971	-915	-1009	-971	-3242	
	MSM reactivity (cents)	-935		-926	-842	-934	-909	-3037	
	C/E (Tref/Tpert)	0,94		0,96	0,98	0,90			
SC3 972 (November 19, 2003) (ISN mobile tube in E21-17)		F		L					2
	ASM reactivity (cents	-1381		-1443			-1412	-4716	
	MSM reactivity (cents)	-1355		-1360			-1358	-4534	
	C/E (Tref/Tpert)	1,02		0,94					

Uncertainties (1σ) :

Reference reactivity level in $: 4.4%
Counts : 1%
MSM factors : 3%
Evolution of the delayed neutron fraction : 2%
Delayed neutron fraction : 2%

		Standard deviation	
		Reactivity in dollars	Reactivity in pcm
ASM method	SC0	4.7%	5.1%
	SC2, SC3	5.3%	5.7%
MSM method	SC0	5.6%	5.9%
	SC2, SC3	6.1%	6.4%

Noise methods with intrinsic source or ^{252}Cf source

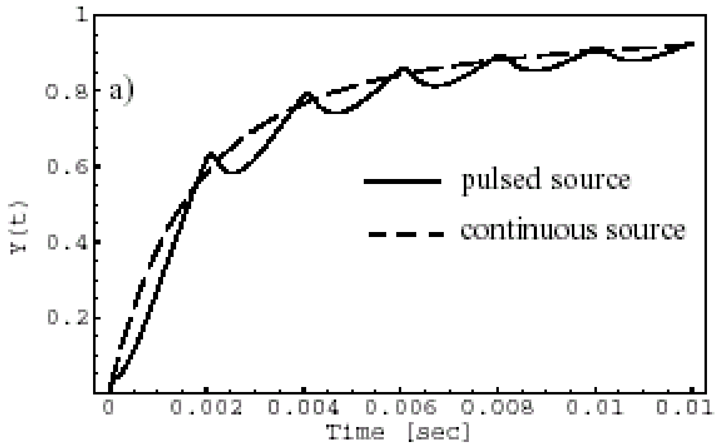
- Rossi-alpha and Feynman-alpha methods with the intrinsic source pointed out that for small subcritical levels (<1$) the alpha decay constant can be derived with an uncertainty of about 10%.
- When deeper subcritical levels were investigated, the statistics are strongly deteriorated in the extraction valuable information becomes difficult.
- The recording of auto- and cross-power spectral density at even small subcritical levels with a continuous intrinsic driving source based on the sampling of the detector current is impossible due to strongly reduced flux level.
- The determination of the kinetic parameters Λ and β_{eff} can be achieved with the Rossi-alpha method or the CPSD technique when the subcritical facility is driven by the intrinsic source for subcritical levels smaller than 1$.

Noise methods with pulsed source

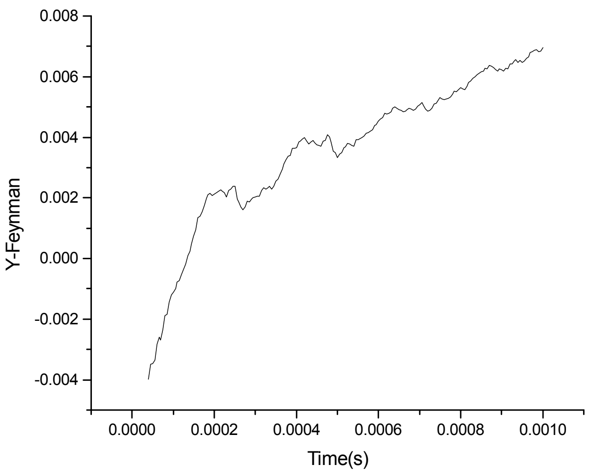
- Feynman formula has been derived for a system driven by a pulsed source.

Case 1 : synchronised pulses (deterministic)

Theory



Measurement (4,5kHz) – ρ=-550 pcm

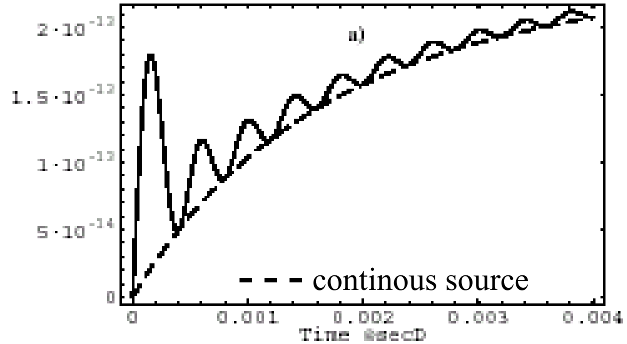


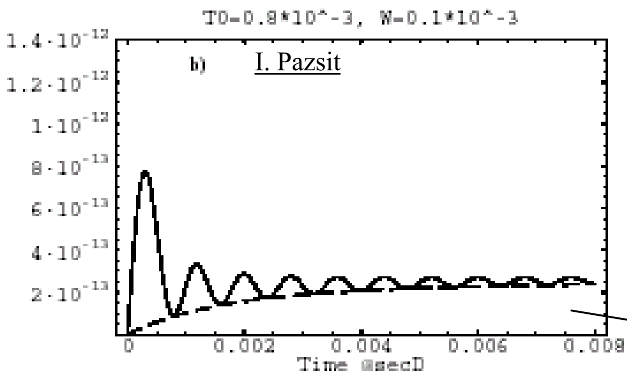
Qualitative agreement

Noise methods with pulsed source

Case 2 : Non synchronised pulses (stochastic)

$$Y = \frac{\sigma}{\mu} - 1 = p_1 \left(1 - \frac{1 - \exp(-\alpha\tau)}{\alpha\tau}\right) + \frac{p_2}{\tau} \sin^2 \frac{2\pi\tau}{T_p}$$

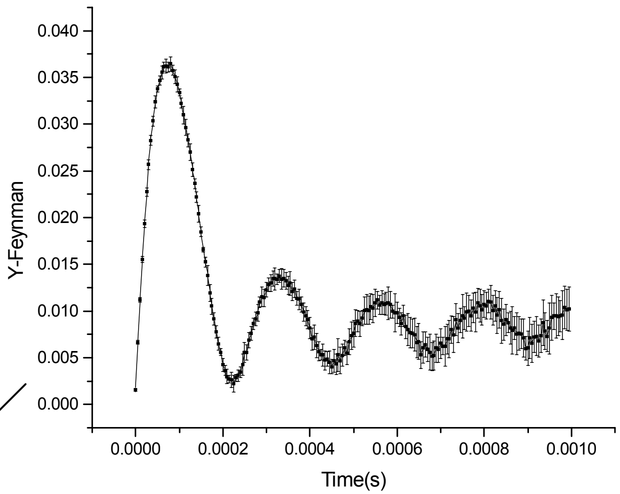




Theory

Qualitative agreement

Measurement (4,5kHz) – ρ=-550 pcm



Theory and Analysis of the Feynman-a Method for Deterministically and Randomly Pulsed Neutron Sources

I. Paszit, M. Ceder

Nuclear Science and Engineering, Vol. 148 (2004), p. 67-78

Noise methods with pulsed source

- Even for SC0 configuration , only qualitative results could be obtained using Feynman-a and APSD and CPSD methods

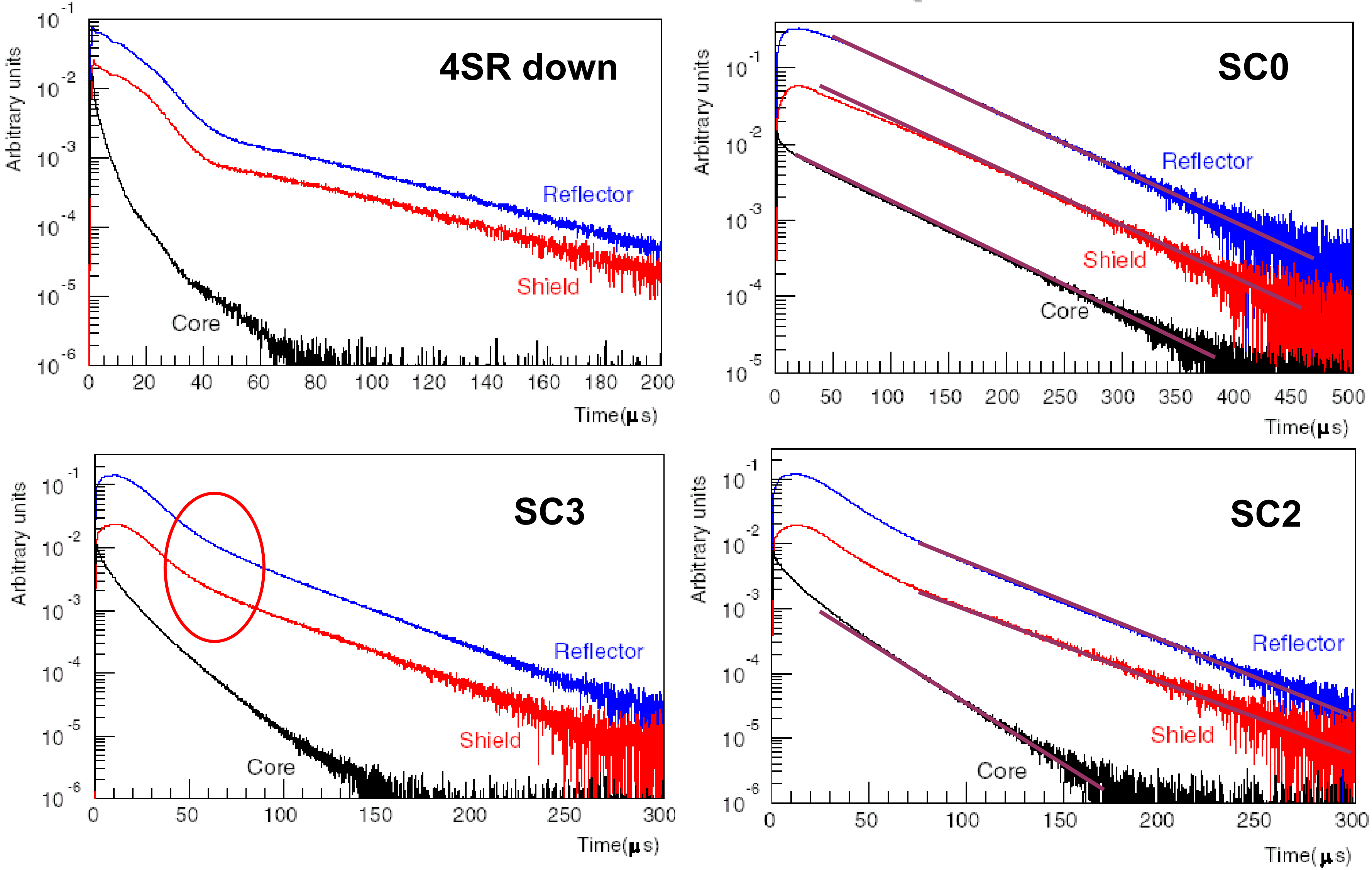
- Results could be obtained only with Rossi-a and using the area method

$$A = \frac{1}{\rho_\$ + 1}\left(\frac{2\rho_\$ + 1}{\rho_\$ + 1}\right)$$

Longer measurements than PNS

Heuristic derivation of the Rossi-alpha formula for a pulsed neutron source
P. Baeten
Annals of Nuclear Energy, Vol. 31 (1), 43-53 (2003)

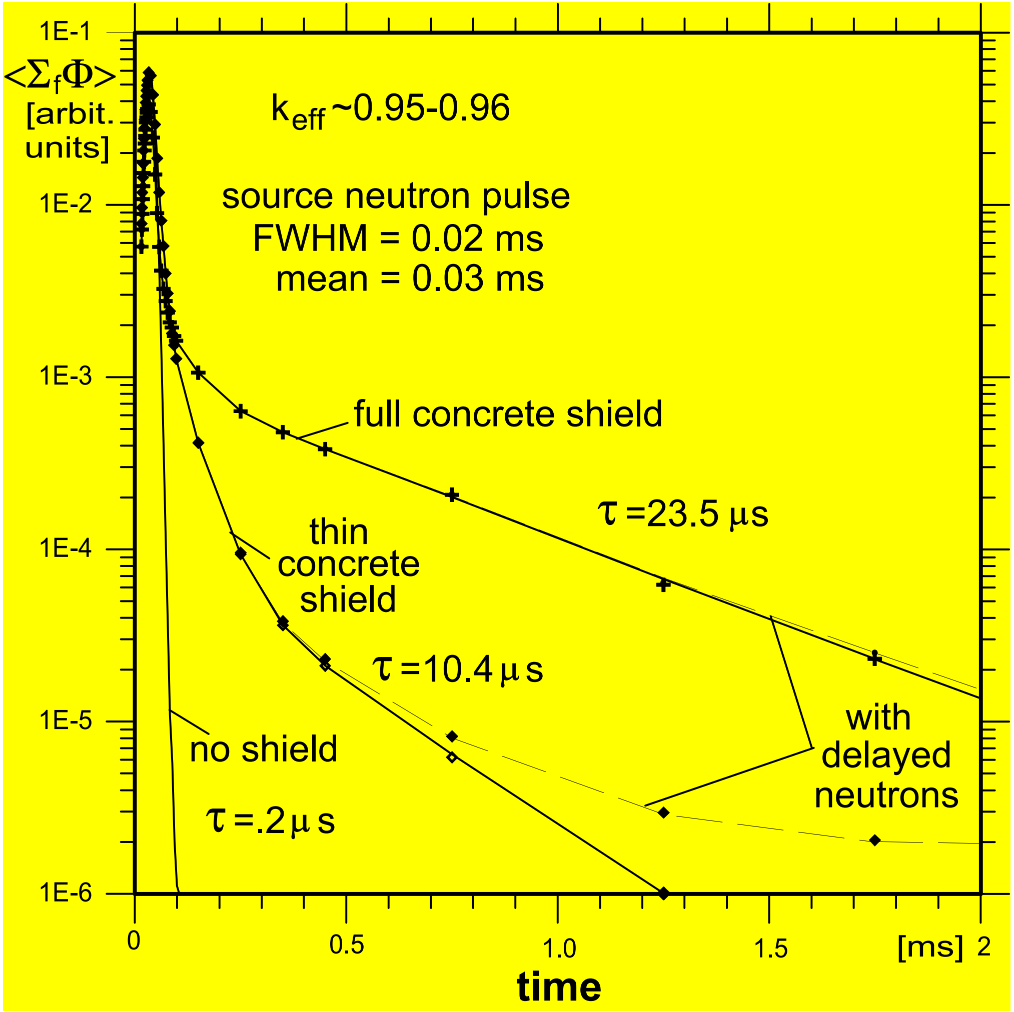
Pulsed source technique



Effect of the reflector and shileding on neutron flux decreasing

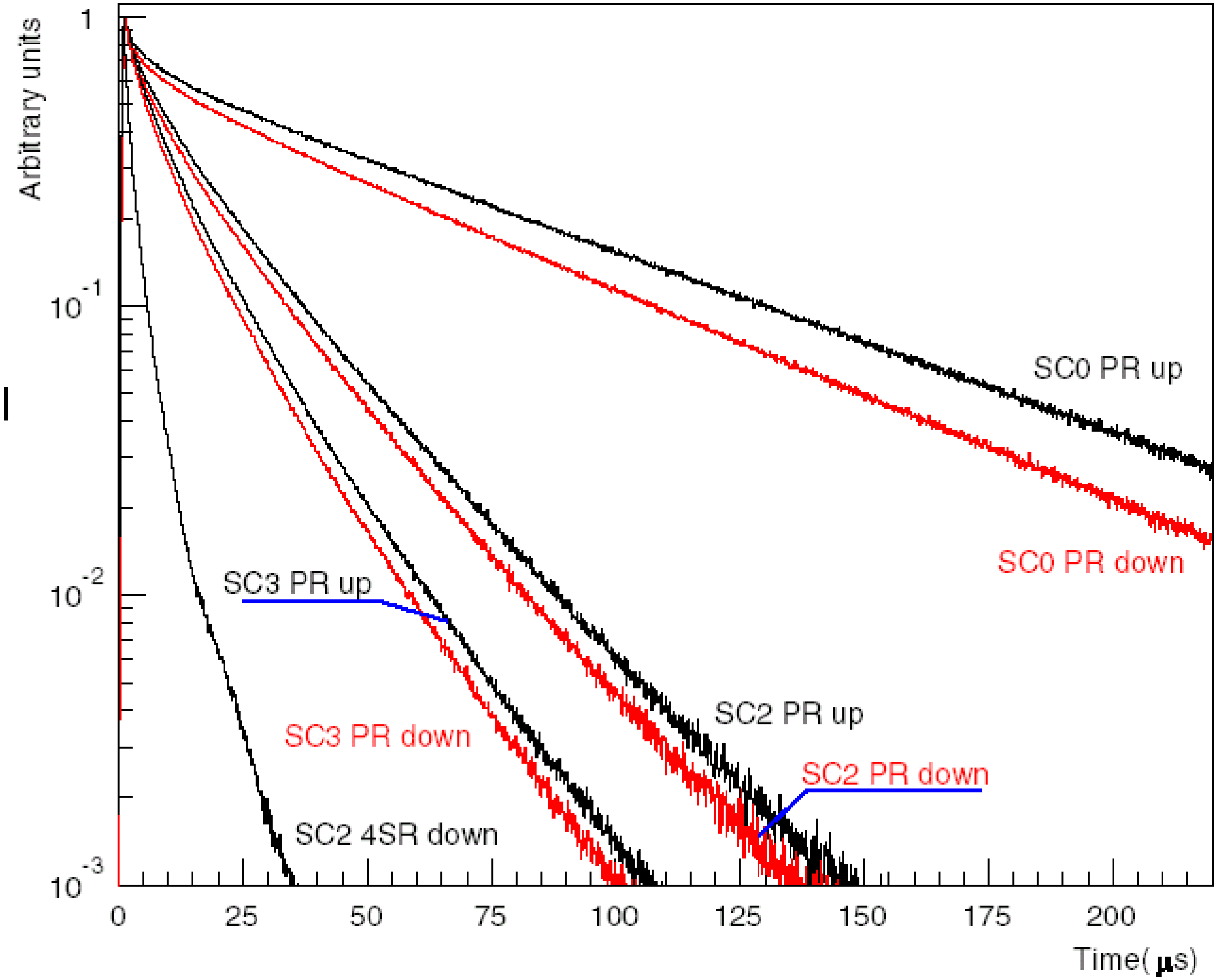
The neutron field behaviour in the system proves dependent on the properties of the shield.

These properties affect the possibilities and conditions of planned measurements of the system parameters on the basis of the neutron pulse decay.



Pulsed Neutron Source technique

Using a single exponential fit, small reactivity changes less than 60 pcm could be detected



PNS analysis - Slope method

- Point kinetics valid for slight subcritical model and for all detectors

- For deep subcritical state :

  - large effect due to the reflector (also pointed out during the SAD design activities)

  - two advanced models have been used both based on the Avery theory

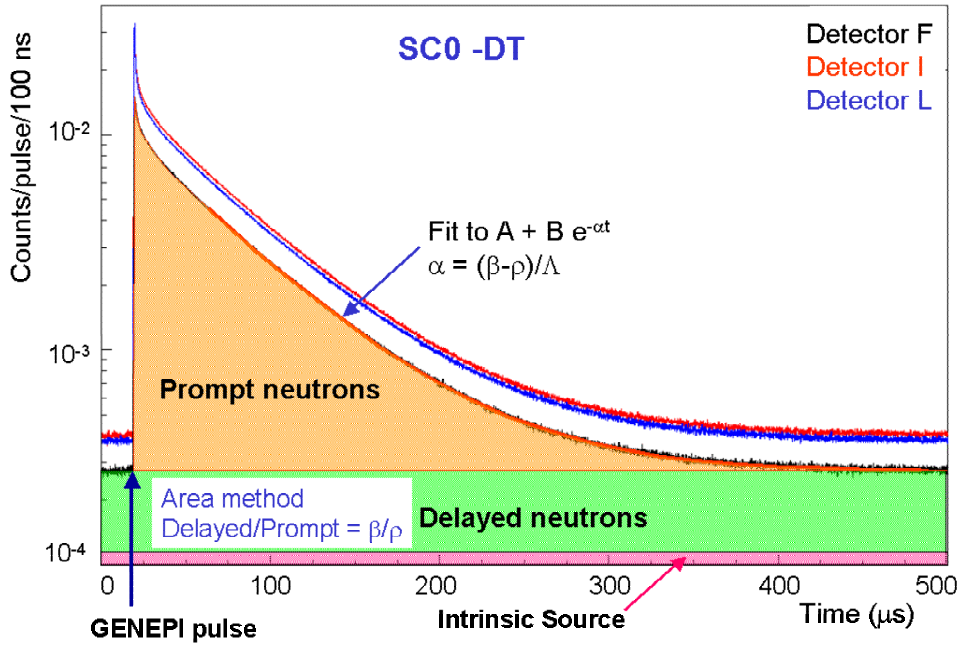
    √ a two region model

    √ a three region and three energy group model linked with a specific fitting procedure

  - in any case, analysis is very delicate (results obtained depend on the fitting interval)

PNS analysis - Area method

• Analysis is based on point kinetics model



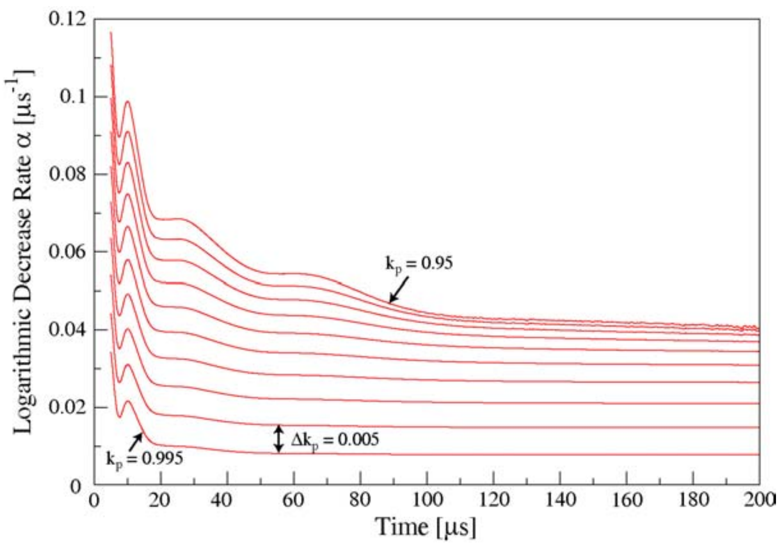
• Very easy analysis (integral analysis)

• Sensitive to small changes of reactivity

PNS analysis - k prompt method

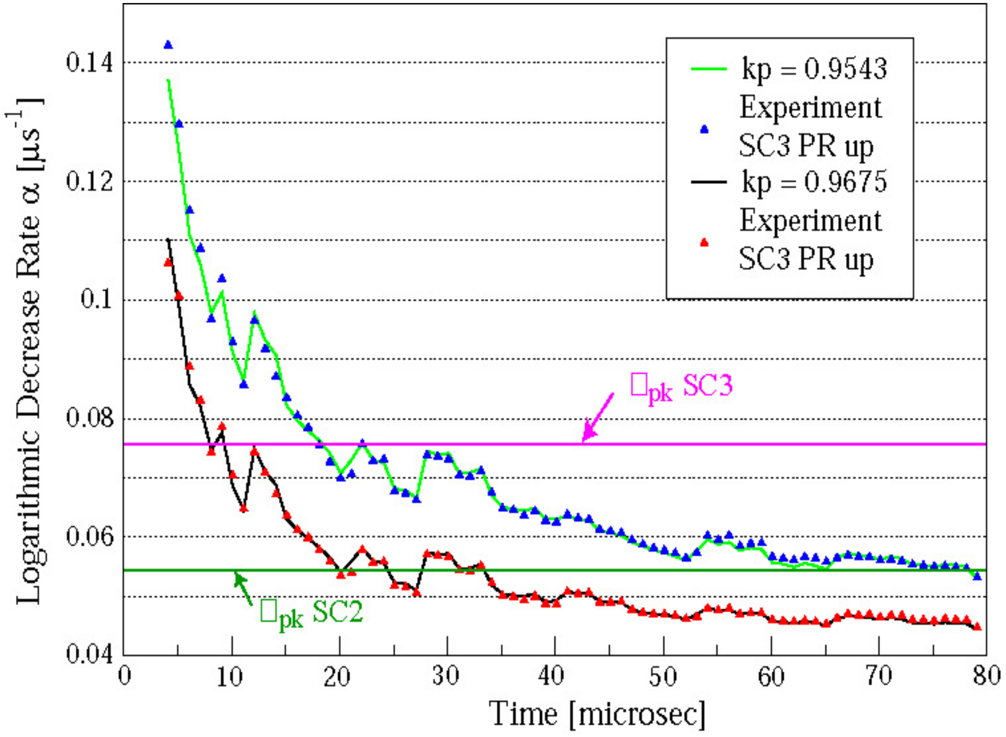
- The prompt neutron decay is not constant
- The parameter considered is the time distribution $P(\tau)$ which represents the probability for a neutron to give birth to a new one as a function of the time elapsed since its birth. $P(\tau)$ easily obtained by Monte Carlo simulations.
- The number of neutron in the core at any time for any k_p value (k_p=keff(1-β)) writes : $N(t) = k_p P(t)+k_p^2 * P(t)*P(t)+K_p^3*P(t)*P(tp)*P(t)+ \ldots.$
- The decrease rate $\alpha_{kp}(t)$ can then be calculated for different k_p values from the logarithmic derivative

$$\alpha_{kp}(t) = \frac{1}{N}\frac{dN}{dt}$$



PNS analysis - k prompt method

These different functions $\alpha_{kp}(t)$ can then be compared with the one obtained from the experimental N(t) distribution. The one which fits best the experiment determines the k_p value of the reactor.



Analysis of dynamics measurement

• Development of new calculation procedures to correct results from area method and source-jerk method

- based on a static approach and steady state calculations
- one correction by detectors

• Corrections more complex to assess for slope method

- based on dynamic calculations
- very long to have good statistics in reflector

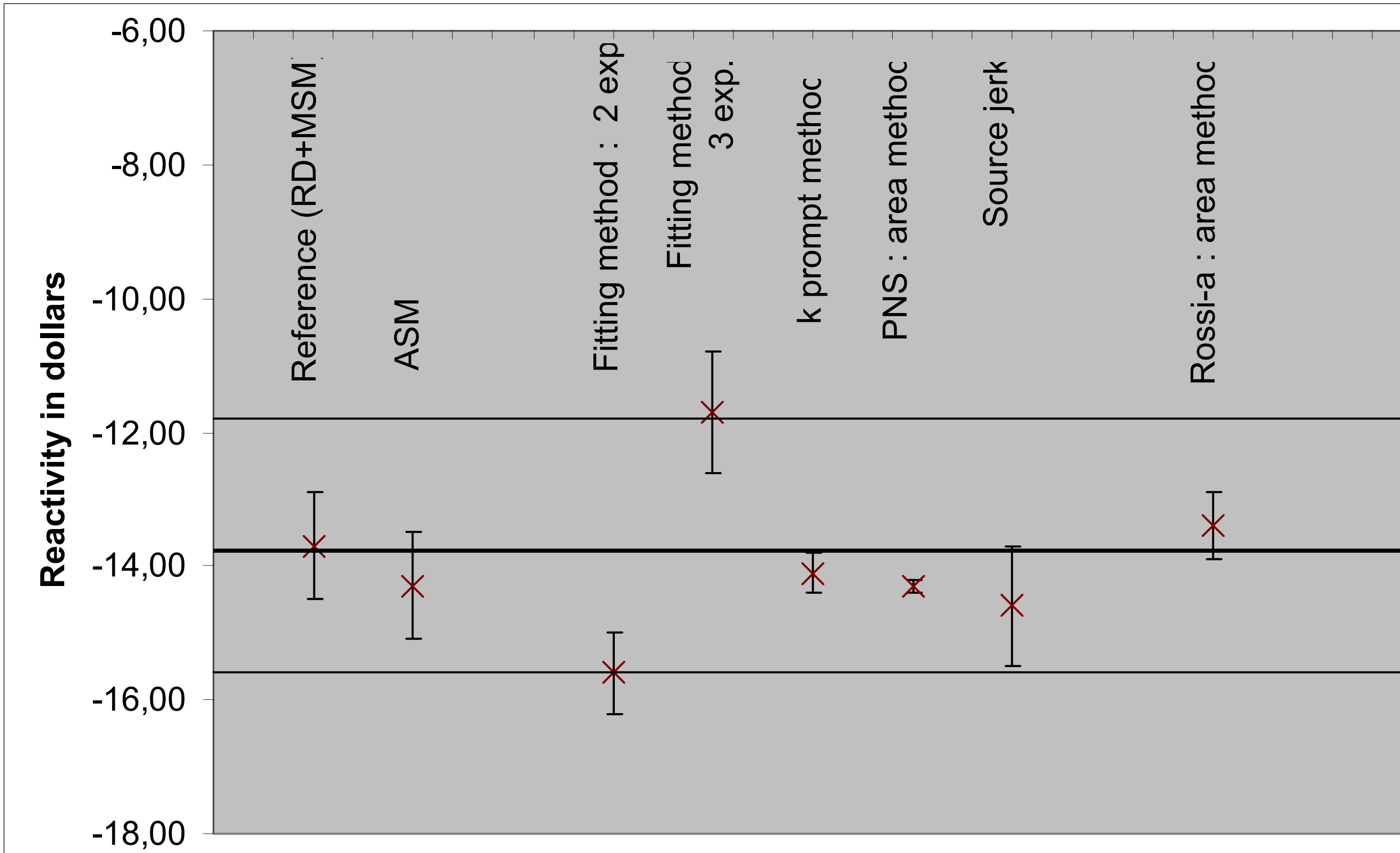
• Beta effective calculation in MCNP4C (more accurate than actual estimators and faster)

Calculating the effective delayed neutron fraction with Monte Carlo
R. Klein Meulekamp, S.C. van der Marck
Submitted to Nuclear Science and Engineering (September 2003)

Synthesis of the measurements

	Coolant	Reference (rod-drop-MSM)	Rod drop + ASM	PNS - Fitting method			PNS - k prompt method	PNS - Area method	Source jerk	Source modulation	Rossi-a
				Point kinetics	*2 regions model*	*3 regions, 3 energy group model*					
SC0 1108 cells	Na	**-1.86**	**-1,90**	**-1,90**			**-2,20**	**-2,03**	**-1,92**	**-2,18**	**-2,04**
SC2 1006 cells	Na	**-8,7**	**-9,1**			**-8,7**		**-9,2**			**-8,8**
SC2 1004 cells	Na	**-9,1**	**-9.7**				**-9,7**			**-9,7**	
SC3 972 cells	Na	**-13,7**	**-14,3**		**-15,6**	**-11,7**	**-14,1**	**-14,3**	**-14,6**		**-13,4**
SC3 972 cells	Na/Lead	-	**-11,2**		**-14,5**						**-11,8**

Measurement of the subcriticality



Techniques for the reactivity monitoring

	Calibration at zero-power	On line measurement	Intermediate cross checking	Comment
Reference method				Calculations needed No critical state in an ADS
MSA				
PNS - Area method	**X** (pulsed neutron source needed)			
PNS - Slope method	**X** (pulsed neutron source needed or accelerator with repetitive beam trip structure)		**X** (if repetitive beam trip structure is used, measurement time = a few minutes)	
PNS - k prompt method				Calculations needed
Source jerk by ^{252}Cf or similar	**X** ?			Repeated measurements needed
Source modulation	**X**			PNS with high and low frequencies (unlikely to be achieved in an ADS)
Noise method with intrinsic source				Poor statistics
Feynman-a method with pulsed neutron source				Model and analysis complex
Rossi-a method with pulsed neutron source	**X**			
CPSD with pulsed neutron source				Filtering needed

Proposals for the reactivity monitoring

- None method tested within the MUSE program seems fit for use for on line measurement. Current-to-flux technique could be the most suitable technique (no calculations needed, well known technology, good relative accuracy) and should be tested within the TRADE-Plus experiments.

- On the other hand, several techniques could be applied for calibration at zero power. Most promising require a pulsed neutron source. Area method is the best candidate because of its simplicity.

- For intermediate cross checking, fitting method seems to be the most suitable technique. It should require that a repetitive beam trip structure is used. It should need a few minutes to allow a measurement.

The PRE-SAD experiments

Three mains activities were carried on **AGH-UST (formerly UMM) Cracow team** within the frame of SAD and MUSE projects

- Calculations for examining the influence of core, reflector and shielding parameters of the SAD versions on its exploitation and experimental properties, testing the applicability of different methods of subcriticality determination.

- Measurements of radioactivity generated in the spallation target and its surroundings, in order to improve the prediction on the build-up of long-lived radioactivity and composition changes in the targets

- Development of the methodology for neutron spectrum and dose rate measurements for the energy range above 20 MeV.

The PRE-SAD experiments

- proton energy : 659 ± 0.6 MeV

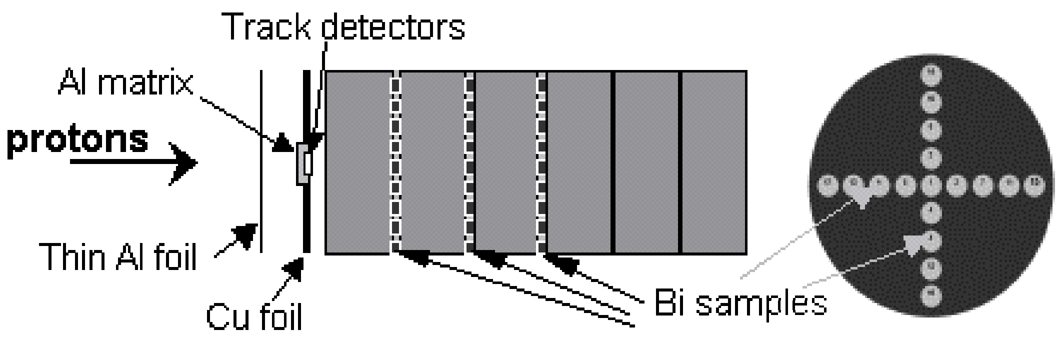
- nominal intensity ~ 10^{13} p/s (reduced to ~ 10^{10} p/s for these experiments)

- irradiation times : 8-10h

Five series of experiments performed from

June 2000 to October 2004

The PRE-SAD experiments



- The experiments consisted of :

 - irradiation of lead targets,

 - irradiation of samples of Bi and main isotopes present in construction materials (Mg, Al, Cr, Mn, Nb, ….) inside and on the surface of the targets

 - measurement of generated radioactivity,

 - measurement of production and distribution of radionuclides inside the spallation targets

General conclusions

• The MUSE-4 experiments allowed to operate with success a subcritical fast neutron reactor coupled to an intense neutron external source on a long duration and in various configurations. From this point of view, this program constitutes a first convincing demonstration of the functioning principle of an ADS.

• Experimental database in subcritical have been extended. Part of these data should contribute to the validation of nuclear data of MA and lead.

• A good agreement were found between calculations and measures for non threshold reactions. On the other hand, analysis showed that calculations of threshold reactions are very sensitive to the reactivity level in particular. Extra investigations and sensitivity studies are necessary to perform a full in-depth analysis and to take into account experimental conditions that sometimes were enough complex (decreasing of the external source, beam losses, synchronization of some repeated measurements, count losses).

General conclusions

• Several experimental techniques and numerous analysis methods have been used for subcritical level measurements and provided an exciting experimental data base. New knowledges, new calculations possibilities in the area of « kinetics model » and « analysis methods for reactivity measurement » allowed to improve our understanding of the experimental results.

• Some methods seems to be able to be used for cross checking of the reactivity during the reactor operating but none for on line measurements. Investigations must be continued in order to determinate reliable corrections factors to apply to the results of PNS area method and slope method.

• Last, MUSE-4 experiments allowed to gain experience and provided important lessons as concerns the supervision of subcritical experiments. This feedback already benefited to the on-going PRE-TRADE experiments.

THE END …

Appendix 9: Presentation MYRRHA Project by H.A. Abderrahim

MYRRHA in the European Frame

H. Aït Abderrahim

on behalf of the MYRRHA Team and Support

haitabde@sckcen.be

Summary

- Introduction
- MYRRHA Progress at a Glance
- MYRRHA R&D Programme
- MYRRHA Collaboration Network
- European Frame and Perspective
- Conclusion

Introduction (1)

- SCK•CEN core competencies: design, realisation and operation of large nuclear research facilities (BR1, BR2, BR3, VENUS reactors, Pu-Lab, LHMA Hot cells, HADES URL for waste Mgt).
- BR2, a 100 MW MTR, is arriving to an age of 45 years, like other major MTRs in Europe (OSIRIS, HFR, R2).
- the RJH (F) project a thermal spectrum MTR is the only planned testing reactor for the moment and **MYRRHA** would be the natural **fast spectrum** complementary facility.
- This will put **Europe in a strategic position towards its energy independence for both support of Gen. III and development of Gen. IV reactors**.

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Introduction (2)

- SCK•CEN and IBA have been associated to develop the ADONIS project during the 1995-97 period. A ~1.5 MW ADS with 0.15 to 0.3 MW low energy proton beam power (1 to 2 mA * 150 MeV) for Radioisotopes production
- Ad-hoc Scientific Committee recommended to extended the fields of applications:
  - to material and fuel research,
  - to P&T studies,
  - to system integration for helping ADS demonstration
- Therefore we migrated in 1997 from ADONIS to MYRRHA as a Multipurpose R&D facility able to replace BR2 and being able to be the first step for ADS demo facility.

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Introduction (3)

- Europe : 35% of electricity from nuclear energy
- produces about 2500 t/y of used fuel: 25 t (Pu), 3.5 t (MAs: Np, Am, Cm) and 3 t (LLFPs).
- social and environmental satisfactory solution is needed for the waste problem
- During the period 1997-98, TWG tri-lateral group (It, Fr, Sp) under chairmanship of Carlo Rubbia was working at the development of preliminary design of an XADS.
- In 1999, this group has been enlarged to become ETWG, and Belgium joined and participated to the European Roadmap for ADS for P&T (April 2001).
- In November 2001, MYRRHA is integrated in the FP5 PDS-XADS
- We are also willing to serve as a IRRADIATION FACILITY for FUSION and Gen.IV material research & development

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MYRRHA Applications catalogue

MYRRHA

MYRRHA is intended to be:

- A full step ADS demo facility
- A P&T testing facility
- A flexible irradiation testing facility in replacement of the SCKŸCEN MTR BR2 (100 MW)
- An attractive fast spectrum testing facility in Europe, beyond 2010 complementary to RJH (F)
- An attractive tool for education and training of young scientists and engineers
- A medical radioisotope production facility

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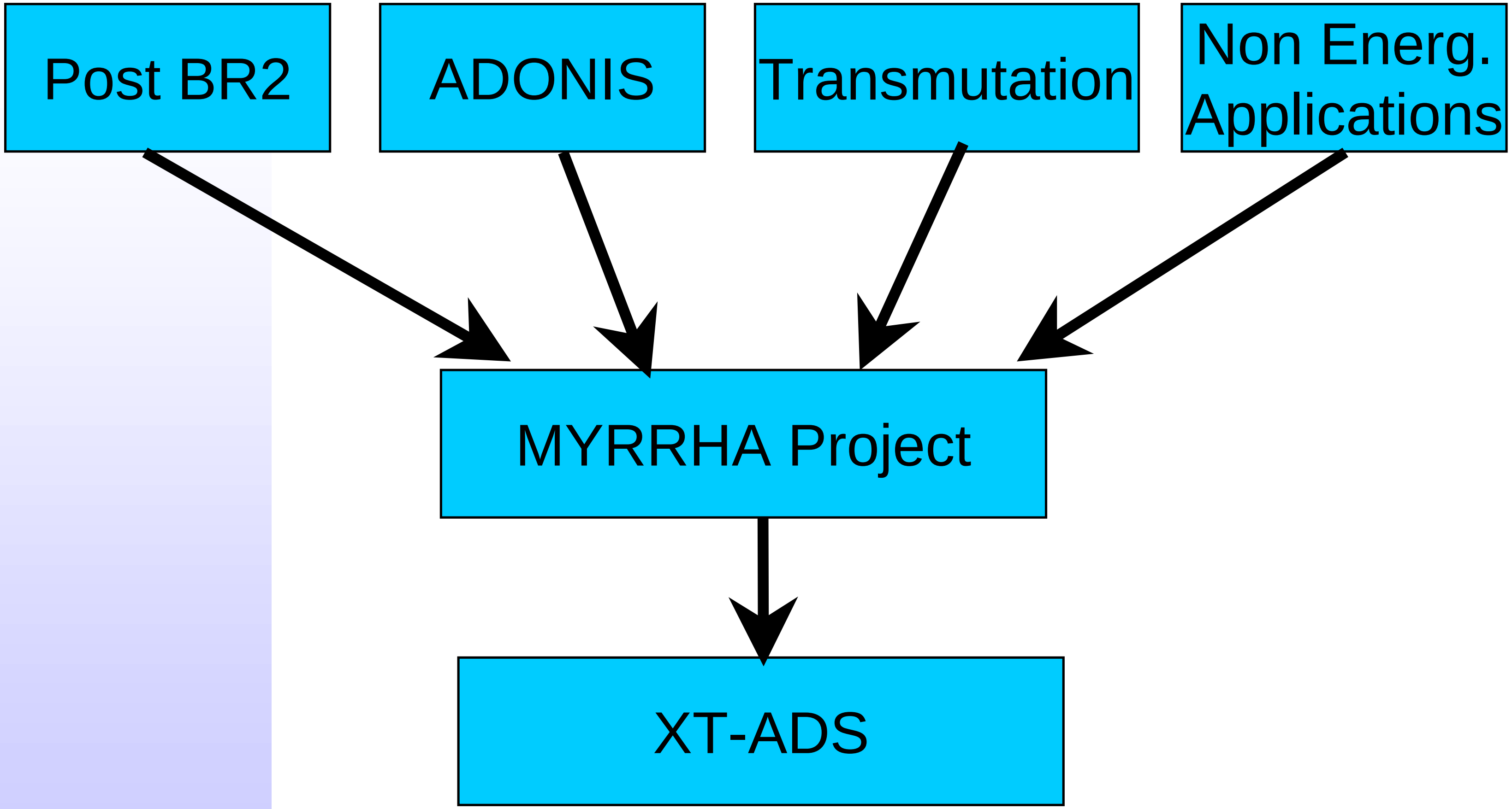
MYRRHA Genesis & Evolution



MYRRHA Progress at a Glance
1995-97 : ADONIS

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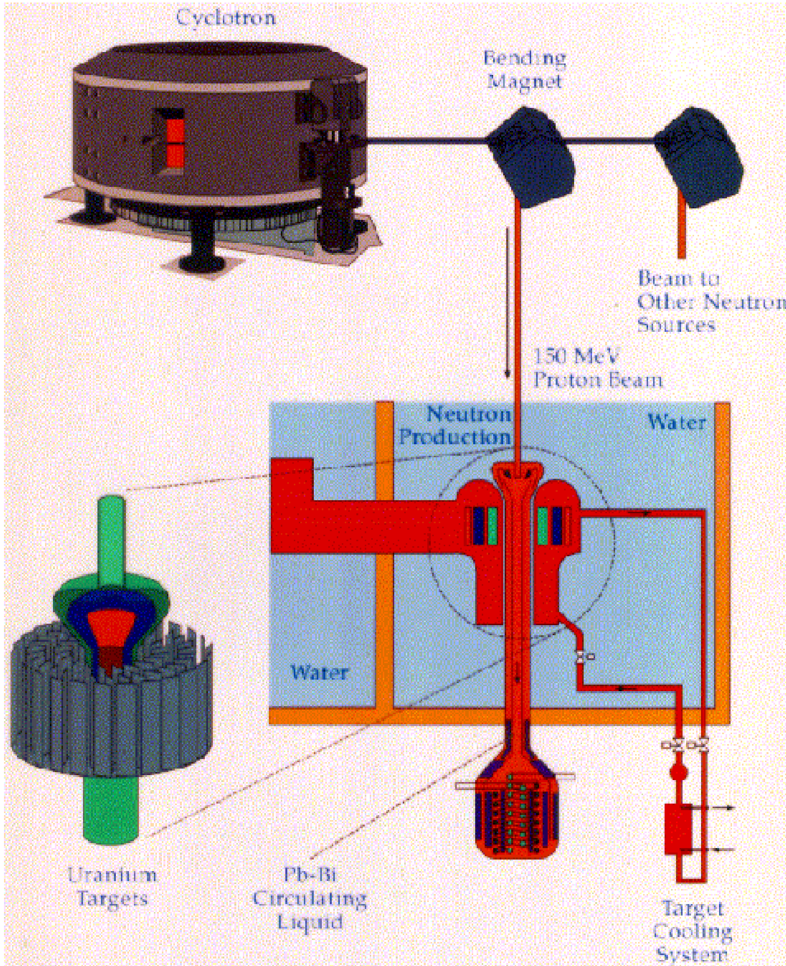
***Cyclotron** (nominal values):*

- *Accelerated: H^-; Extracted: H^+*
- *E_p=150 MeV; I_p = 2 mA*
- *Typical total P_e = 600 kW*
- *Dim.: 7 x 2.5 m; weight 500 tons*

Sub-Critical Assembly:

- *Use of HEU or LEU*
- *k_{eff} < 0.93*
- *Thermal fluxes: ca. 3-4 10^{14} n/cm².s*



MYRRHA Progress at a Glance
1998: Conceptual ideas

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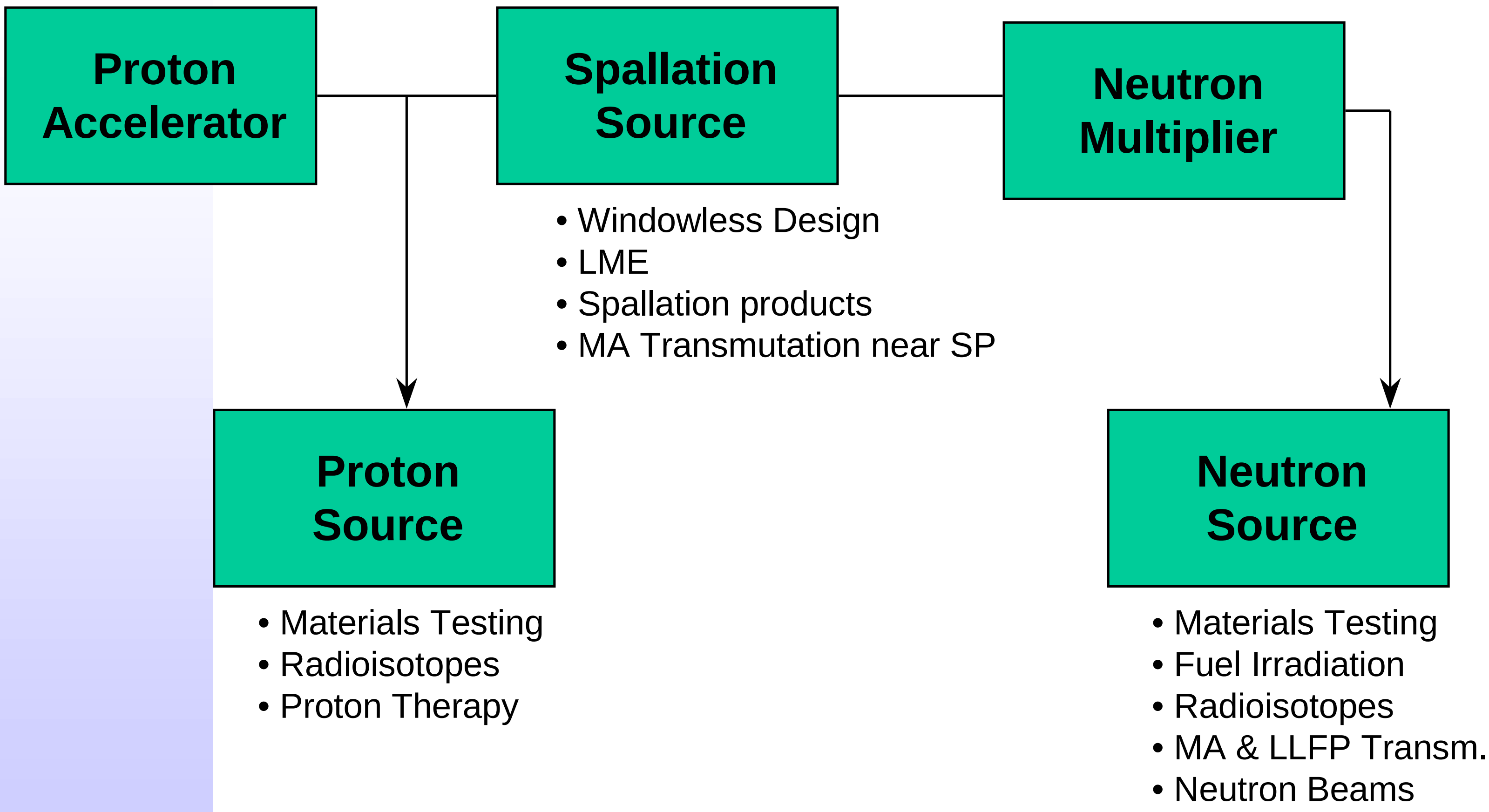

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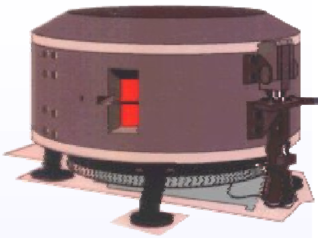
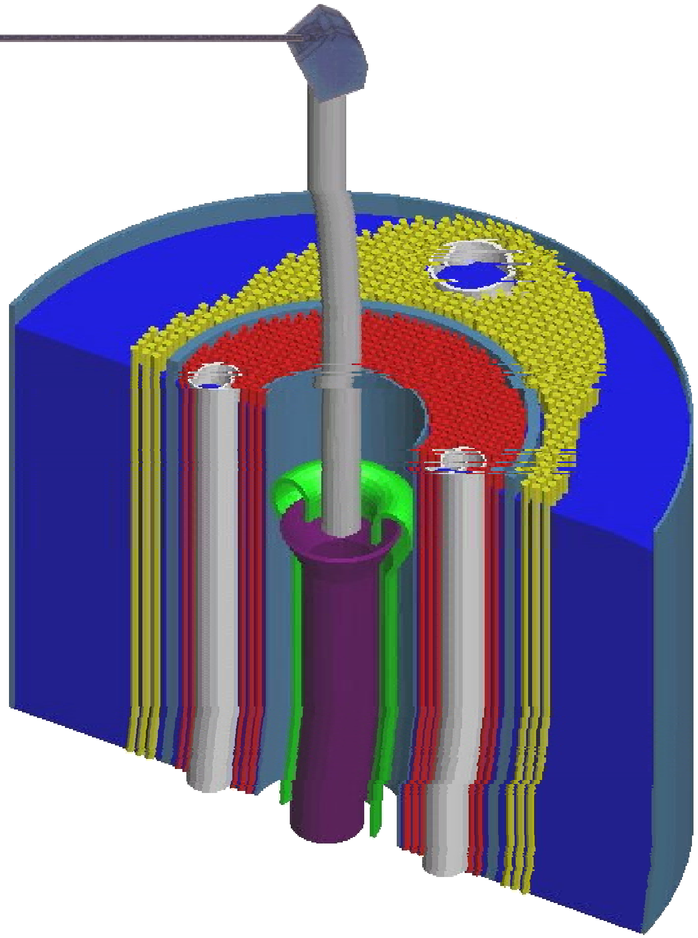
MYRRHA Progress at a Glance
1998-99: Fast + Thermal Cores



Cyclotron :

- Ep = 350 MeV
- Ip = 2 mA
- H+ accelerated
- 6 Sectors



ADS :

Spallation Source:

- Pb-Bi liquid target
- Window less design

Sub-critical core :

- Fast zone
- Thermal zone
- ∅ = 1 m
- Active height = 50 cm
- $0.85 < K_{eff} < 0.95$

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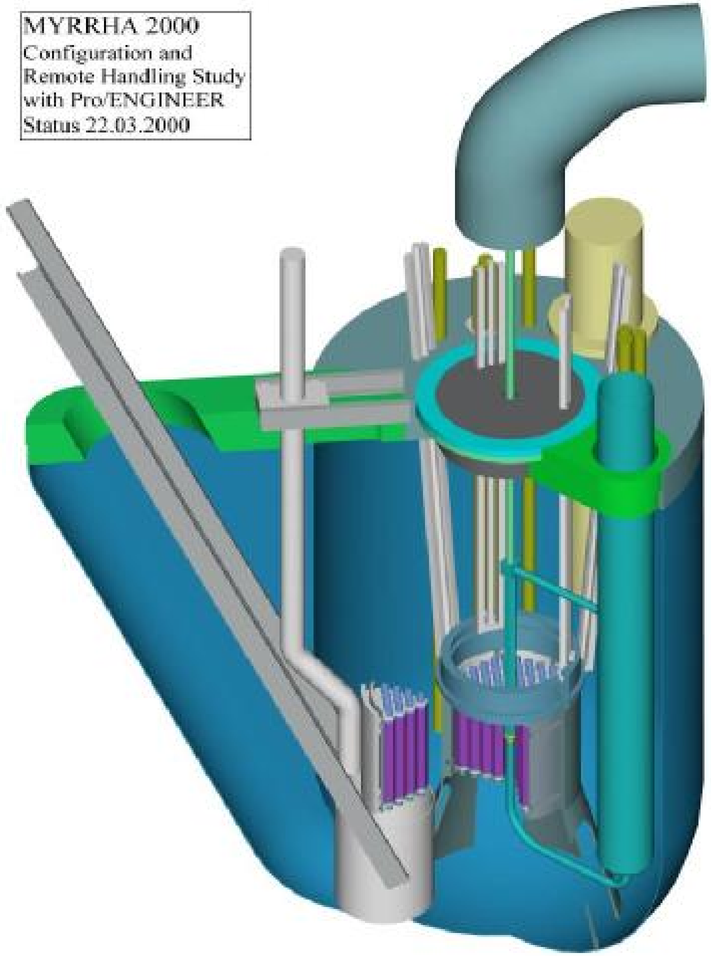
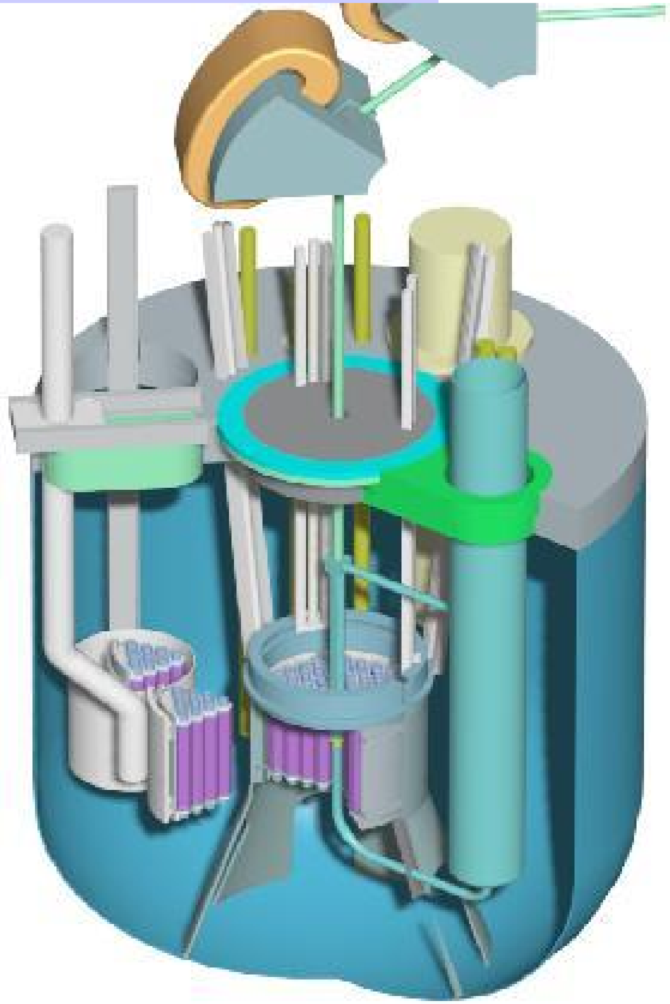
MYRRHA Progress at a Glance 03.2000: Fast Core (sectors)



MYRRHA Progress at a Glance
10.2000: Fast Core (sectors II)



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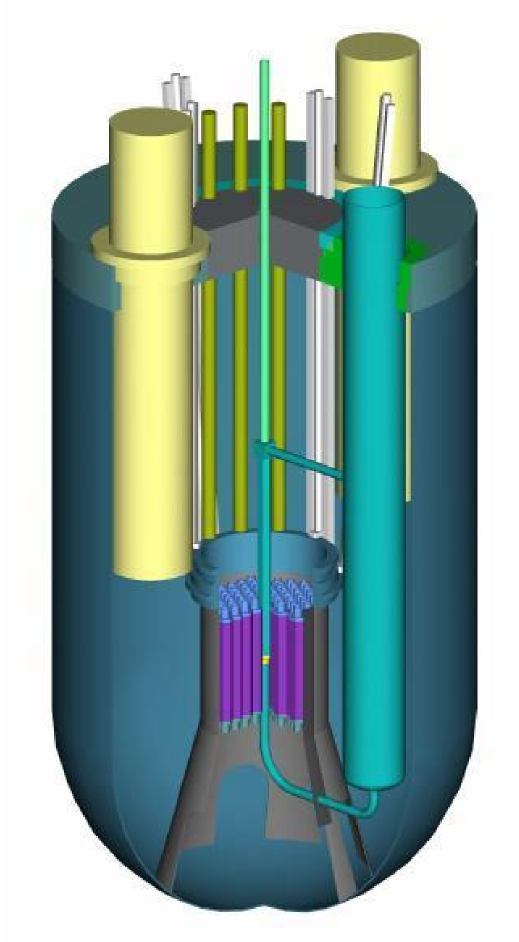
MYRRHA Progress at a Glance 11.2000: Fast Core (sectors III)



MYRRHA Progress at a Glance 2001-2002: Experimental Fac.

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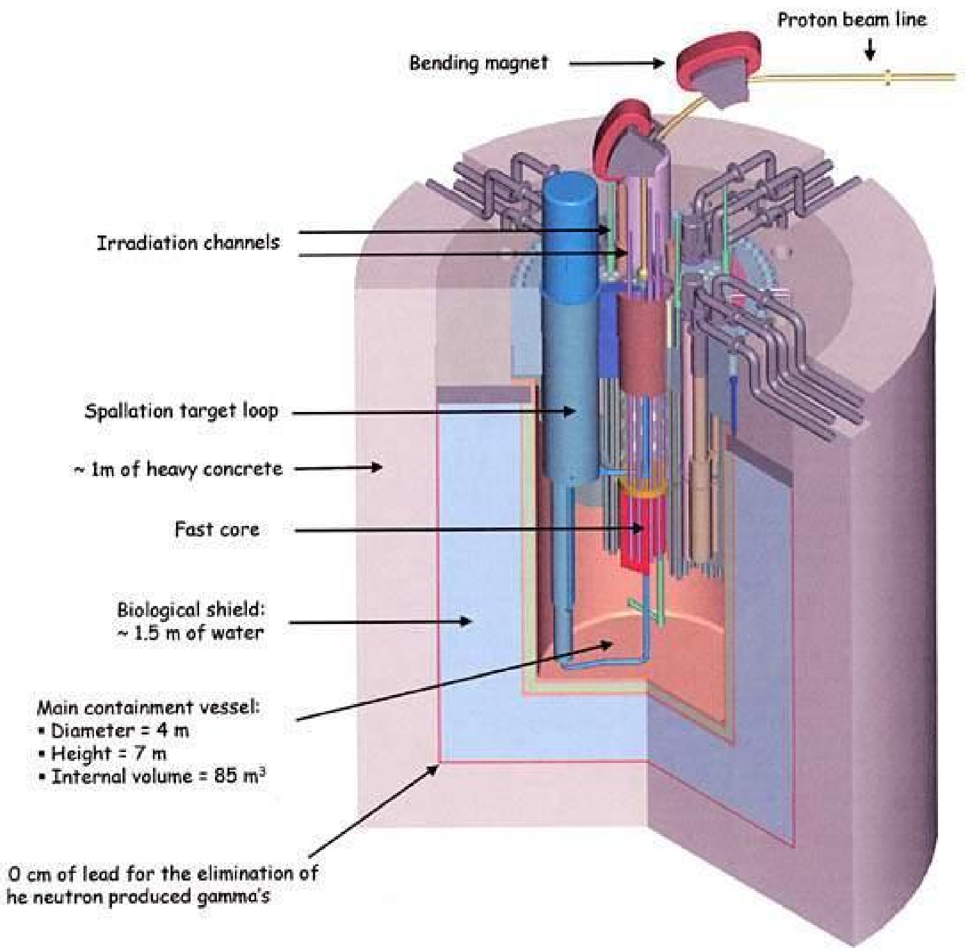

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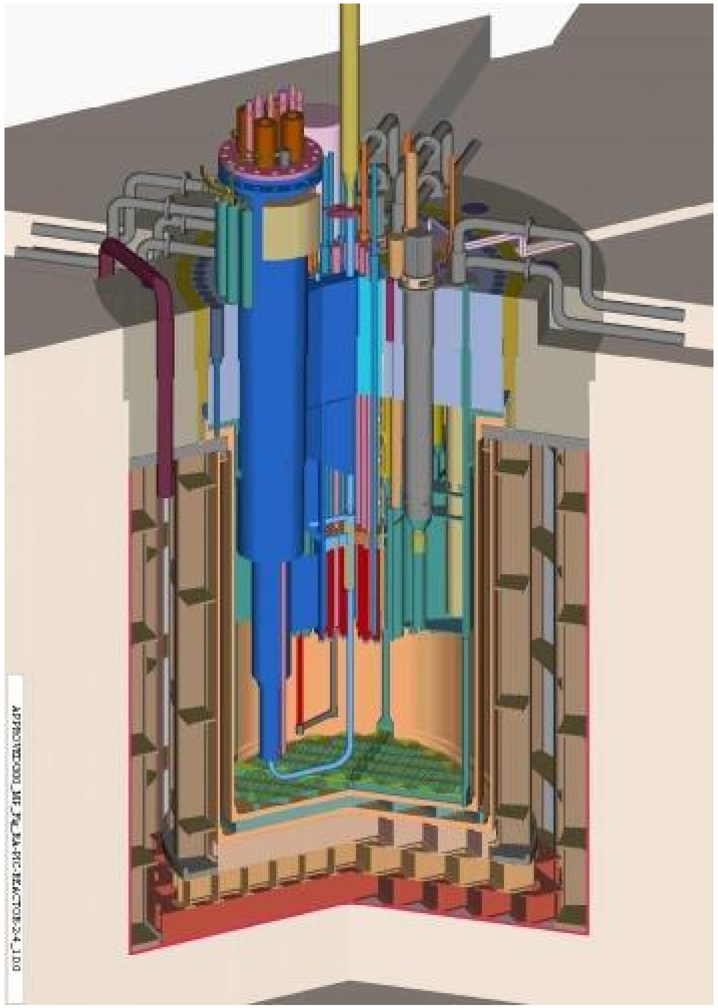
MYRRHA Progress at a Glance End.2002: Experimental Fac.



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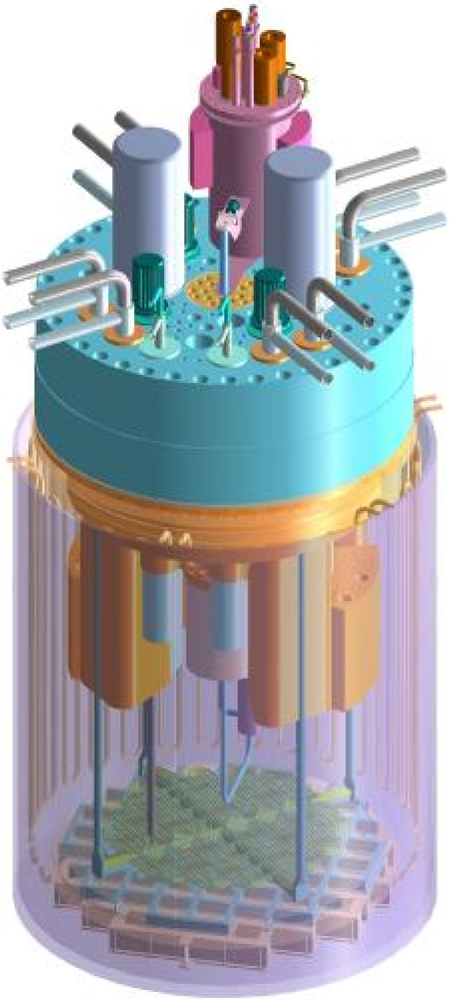
MYRRHA Progress at a Glance
End.2004: Experimental Fac.



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Robotics of MYRRHA in action

MYRRHA

- **Extraction of the spallation target loop and parking it in the maintenance pit**

Robotics of MYRRHA in action

- **Déployment of the IVRM :**
  - Ø **To retrieve a miss-alined fuel assembly**
  - Ø **To inspect a duct of the spallation loop**

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MYRRHA R&D Programme

- **Since the beginning of the MYRRHA project, we decided to accompany the project by a comprehensive support R&D programme including:**
  - **Windowless spallation target thermal-hydraulic design.**
  - **Vacuum Interface compatibility,**
  - **LBE technology: Po migration, visibility under LBE through ultrasonic cameras,**
  - **Material Corrosion & erosion and their mitigation,**
  - **LBE conditioning and monitoring,**
  - **Material embrittlement due to irradiation and LME,**
  - **MOX fuel qualification under LBE and irradiation up to high targeted burn up (100 MWd/t) and high dpa (100) and also under representative transient conditions,**
  - **Instrumentation development: O2-meters (< 200°C), HLM free surface monitoring, sub-criticality monitoring, ultrasonic visualisation**
  - **Robotics : development of a robot arm to be deployed under LBE for testing and qualification**

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MYRRHA Collaboration Network

- **IBA**, Belgium: cyclotron design and/or Intermediate energy section of the LINAC (normal conducting);
- **ENEA**, Italy: spallation source thermal-hydraulics design, core dynamics, TRADE;
- **UCL**, Belgium: spallation source design water experiment, CFD modelling, Advanced CFD development;
- **FZR**, Germany: instrumentation for the spallation target;
- **FZK**, Germany: windowless spallation source testing with Pb-Bi in KALLA, Material Corrosion studies, Neutronics of sub-critical systems;
- **NRG**, The Netherlands: Spallation Source CFD modelling and system safety assessment;

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MYRRHA Collaboration Network

- **CEA**, France: subcritical core design, MUSE experiments;
- **CNRS/IN2P3**, France: LINAC development and components design, Windowless Spallation Target design, T91 structural material research, sub-critical core physics,
- **PSI**, Switzerland: basic spallation data, MEGAPIE;
- **IPUL**, Latvia: windowless spallation source testing with Hg,
- **Belgonucléaire**, Belgium: MOX Fuel manufacturer fuel pin and assembly design, fuel loading policy and fuel procurement;
- **CIEMAT**, Spain: Neutronic core design;
- **KTH**, Sweden: development and validation on basis of experimental results of adapted burn up codes for ADS,
- **IPPE**, Russia: design of the MYRRHA sub-critical reactor;

MYRRHA Collaboration Network

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- **Suez-Tractebel,** Belgium: confinement building and auxiliary systems, Safety analysis studies.
- **OTL**, UK: Remote Handling & Robotics design and development;
- **USI_KU**, Lithuania: development of US sensors operational under LBE and aggressive radiation environment, development of associated visualisation camera and signal treatment;
- **AFCN and AVN**, Belgium: Licensing authorities
- Contacts that may lead to additional collaborations exist with:
  - ISTC: JINR-Dubna, Russia, YALINA-Minsk, Belarus
  - DoE and LANL; USA
  - JAERI, Japan

European Frame and Perspective

- SCK-CEN has clearly declared within the FP6 IP_EUROTRANS its intention to open the MYRRHA characteristics to fit the objectives of the XT-ADS
- Mol is a candidate site for hosting the XT-ADS
- The XT-ADS can be seen as a first step contribution towards a European regional fuel cycle scenario
- The XT-ADS should be holding the characteristics of a fast spectrum irradiation facility for the addressing the next generation energy concepts
- Such a system should be deployed around 2015 to be in-line with the SCK-CEN objectives and the P&T community

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Ongoing effort for ADS at Mol

- **SCK-CEN has started an ADS activity in 1994 through ADONIS project for ^{99}Mo production,**
- **Since 1997 it moved its activity towards the design of a small scale experimental ADS MYRRHA intended to be an ADS concept demonstration and a fast spectrum irradiation facility,**
- **In 2001 MYRRHA has been integrated in the FP5 PDS-XADS as one of the XADS to be studied,**
- **At the end of 2002, SCK-CEN mgt answered positively a request of the European P&T community to open the MYRRHA parameters to suit its requirements without jeopardising completely the initial objectives**

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Ongoing effort for ADS at Mol

MYRRHA

- **At the end of PDS-XADS, MYRRHA is coming to pre-design completion with a potential to contribute as a starting point to XT-ADS**
- **The Topical Day of Nov.23, 2004 in Mol gave a reviewing of the achievements of MYRRHA, in the light of the on-going effort at European level, that is:**
  - **MYRRHA design has the requested performances**
  - **The LBE Spallation target design efforts in Europe (Window and Windowless) will lead to the XT-ADS target**
  - **The ADS accelerator R&D effort is well focussed on the beam reliability that is a key issue for ADS application**
  - **The Material research and HLM technology are addressed at European scale giving confidence that key issues for XT-ADS can be answered in due time**
  - **Safety of ADS systems has drastically progressed during the 3 last years thanks to the European effort in the frame of PDS-XADS**

Roadmap of an XT-ADS at Mol

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MYRRHA

- 2005-2008 FP6 : EUROTRANS Period
  - Advanced Pre-design File of XT-ADS
  - Potential show stoppers in Basic Technological research (material, HLM technology, instrumentation) should be answered
  - Key Accelerator components will be demonstrated
  - Spallation module hydraulic design will be accomplished
  - Realise a coupling of the ADS components at realistic power
- Beyond FP6, Besides the technical issues addressed above, Funding of the project should have been addressed to enter from then on an Multi-lateral Integrated Project structure
  - **Phase 1: 2009-2011**
    - Detailed Engineering design and Mol site preparation
    - Reactor components testing (IHX, PP, Fuel Assembly,…)
    - Spallation module testing under beam
    - Licensing procedure
  - **Phase-2 : 2012-2016**
    - Construction at Mol : 3 to 4 years
    - 2 years for commissioning
    - **Full power operation**

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Conclusion: a little drawing is better than a long speech…we are in 2014

MYRRHA

Appendix 10: Presentation neutron physics feasibility study for enhancing SAD power by A. Polanski

Possible extension of experimental program

Increase of system power to maximum 100 kW

A.Polanski, C. Broeders ,W.Gudowski, S. Petrochenkov.

SAD parameters modeling.

1. Energy release in SAD elements .
2. Calculations of the neutron fields in experimental channels.
3. Calculations of the SAD biological shielding.
4. Conclusions.

Computer Codes and Models for Calculations

MCNPX

- Cross sections:
  parameterized fits for hadron-hadron interactions Tabulated data plus parameterized fits for hadron-nucleus interactions – BARPOL.DAT

- Models:
- Energy between 0.02 and 2.5 GeV:
  the Bertini intranuclear cascade (INC) model,
- the ABLA evaporation model,
- the Fermi breakup model.

Low-energy neutrons :

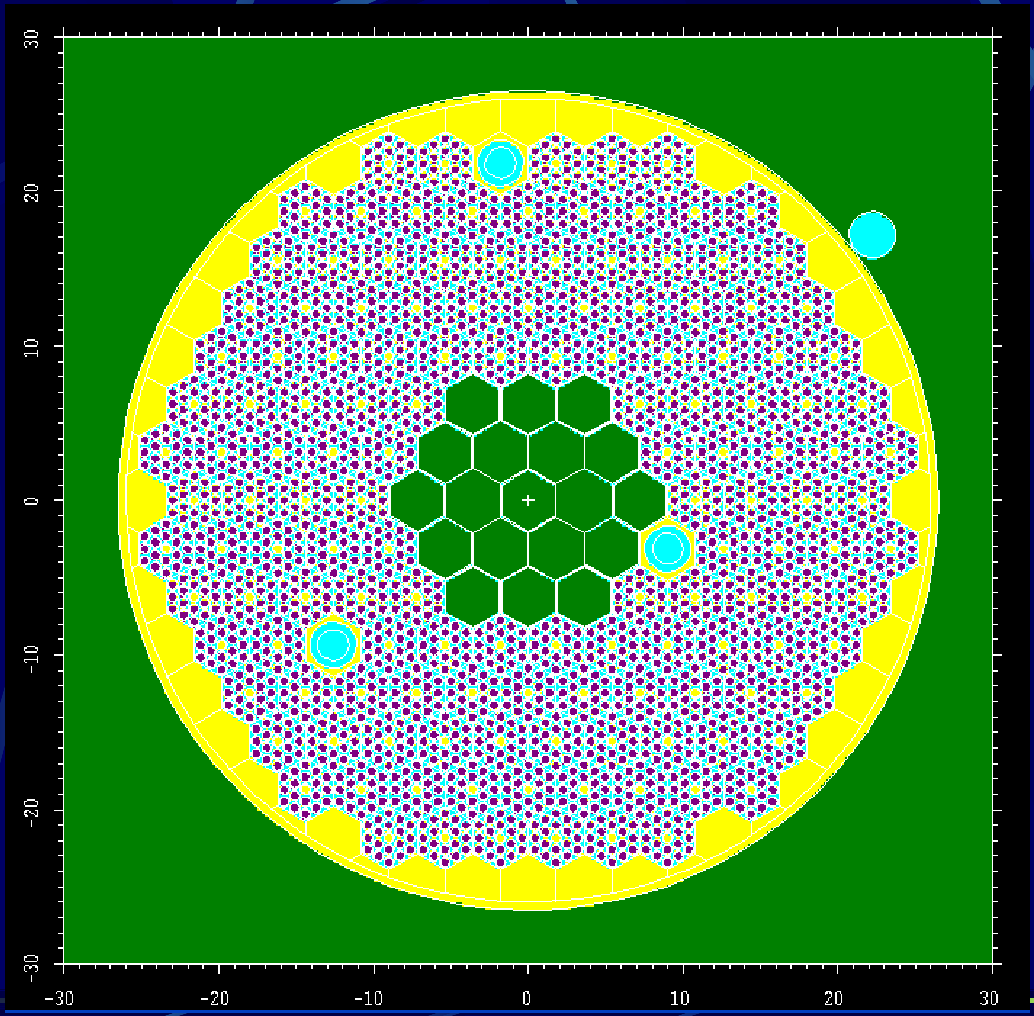
- Cross sections
- The ENDF6 format points cross sections
- transport of coupled neutral- and charged-particles below 150 MeV based on nuclear data evaluations.
- Transport: standard with photon and fission neutron generation.

- **Scoring**
- Track-length fluence by region.

Increase of system power

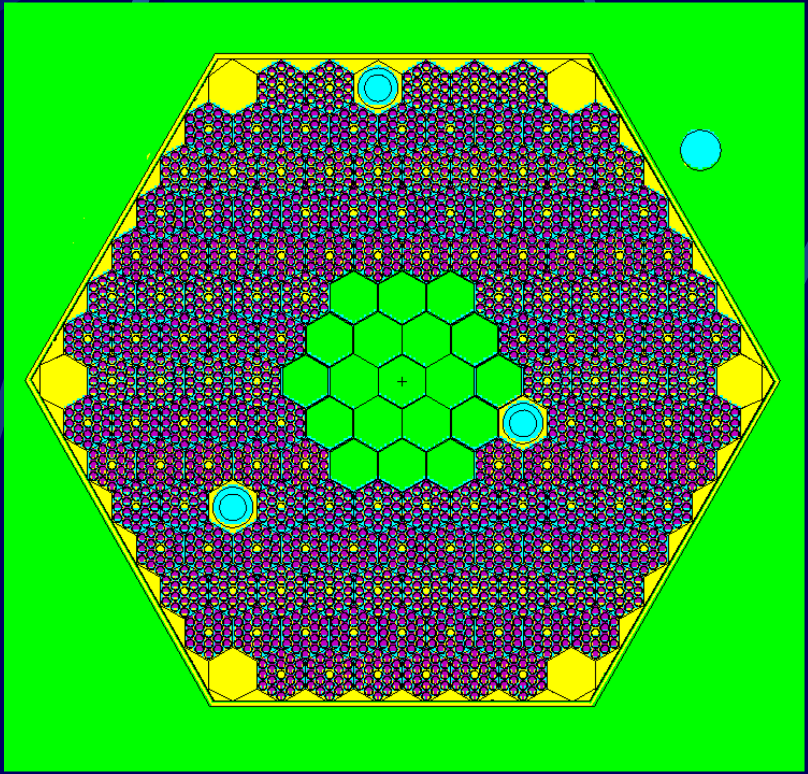
Beam power	1.0 kW - 2 kW
K_{eff}	0.95 – 0.98
Fission power	25 - 100 kW
Number of fuel element assemblies	133-141
Number of dummy of element assemblies	6
Weight of loaded fuel	400 - 424 kg

Cross-section of the Subcritical core



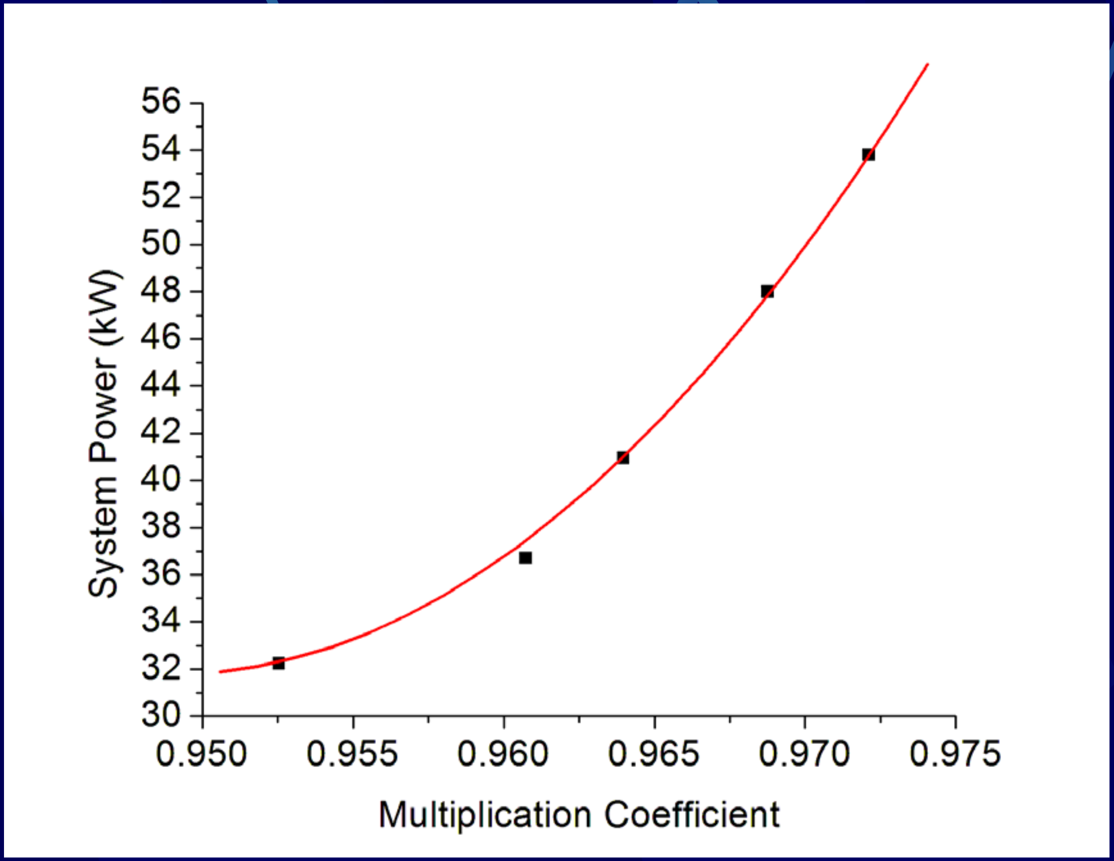
- Number of fuel batches in the active core = 141
- K-eff = 0.9721 (0.0006)
- System power = 53.8 kW for beam 1 kW
- System power = 107 kW for beam 2 kW

Geometry of SAD CORE

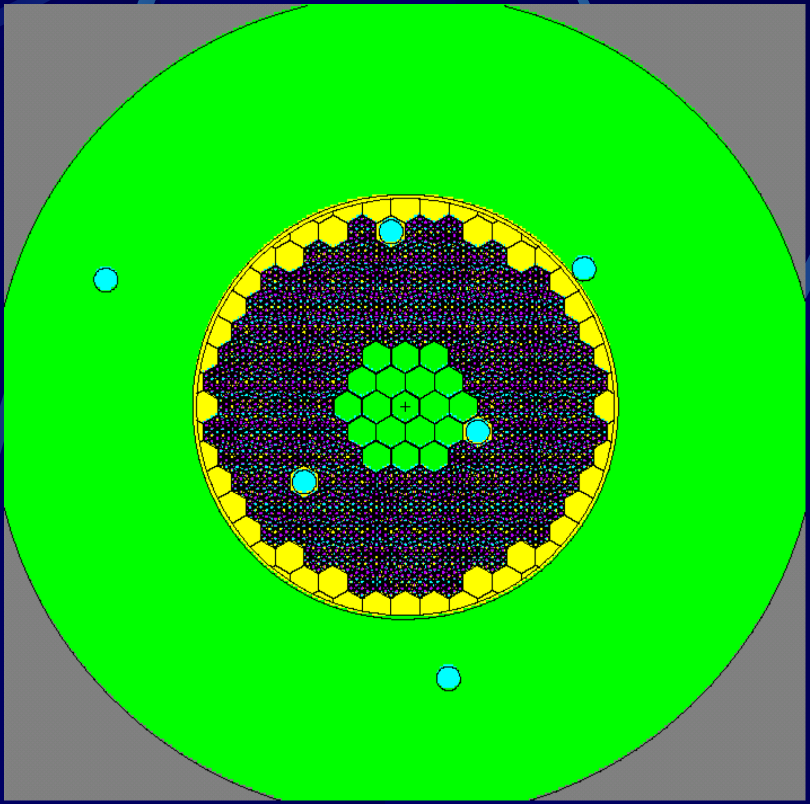


- Number of fuel batches in the active core = 141
- Number of empty batches in the active core = 6

System Power vs Multiplication Koefficient for 1 kW Beam Power

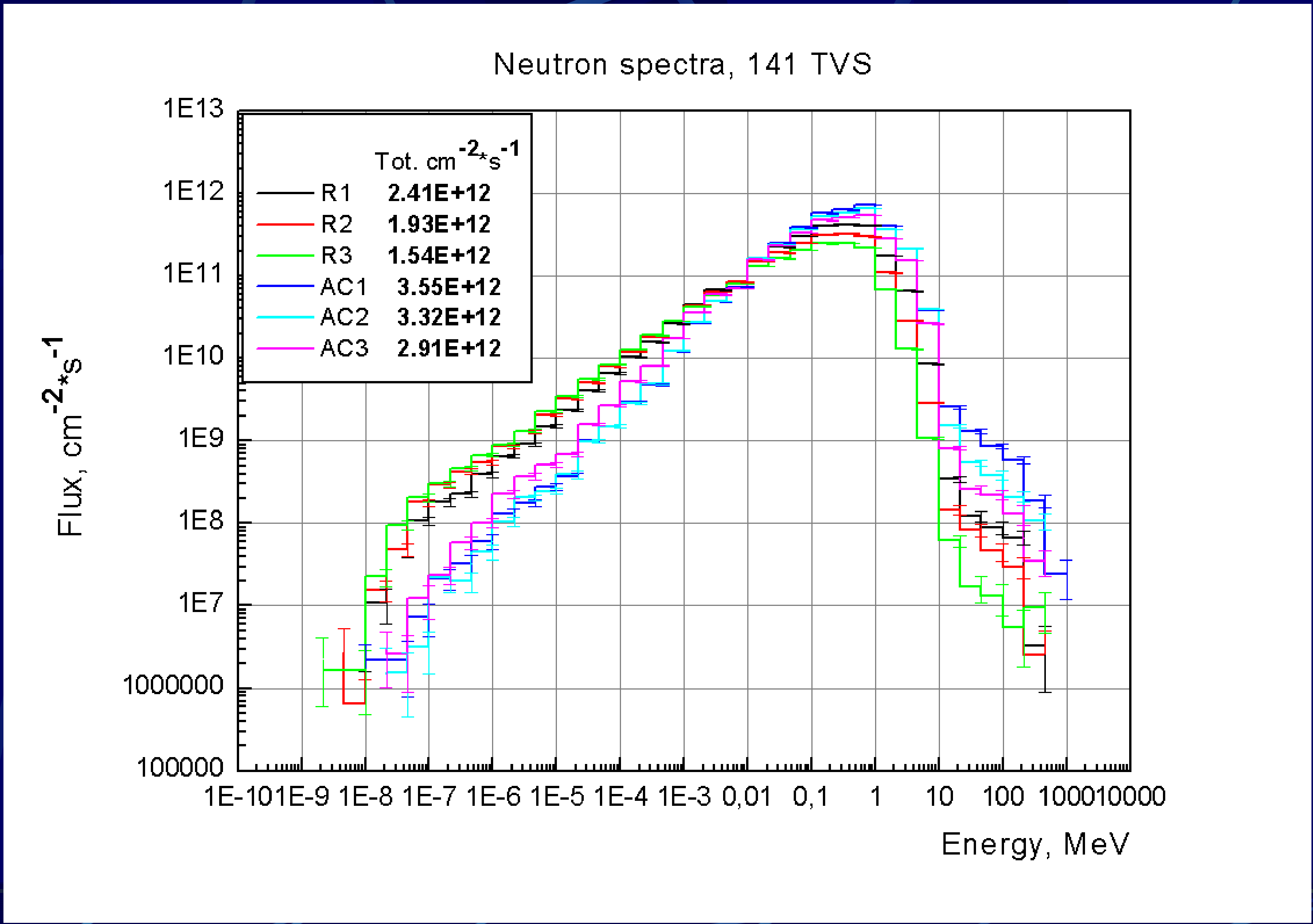


Calculations of the neutron fields in experimental channels.

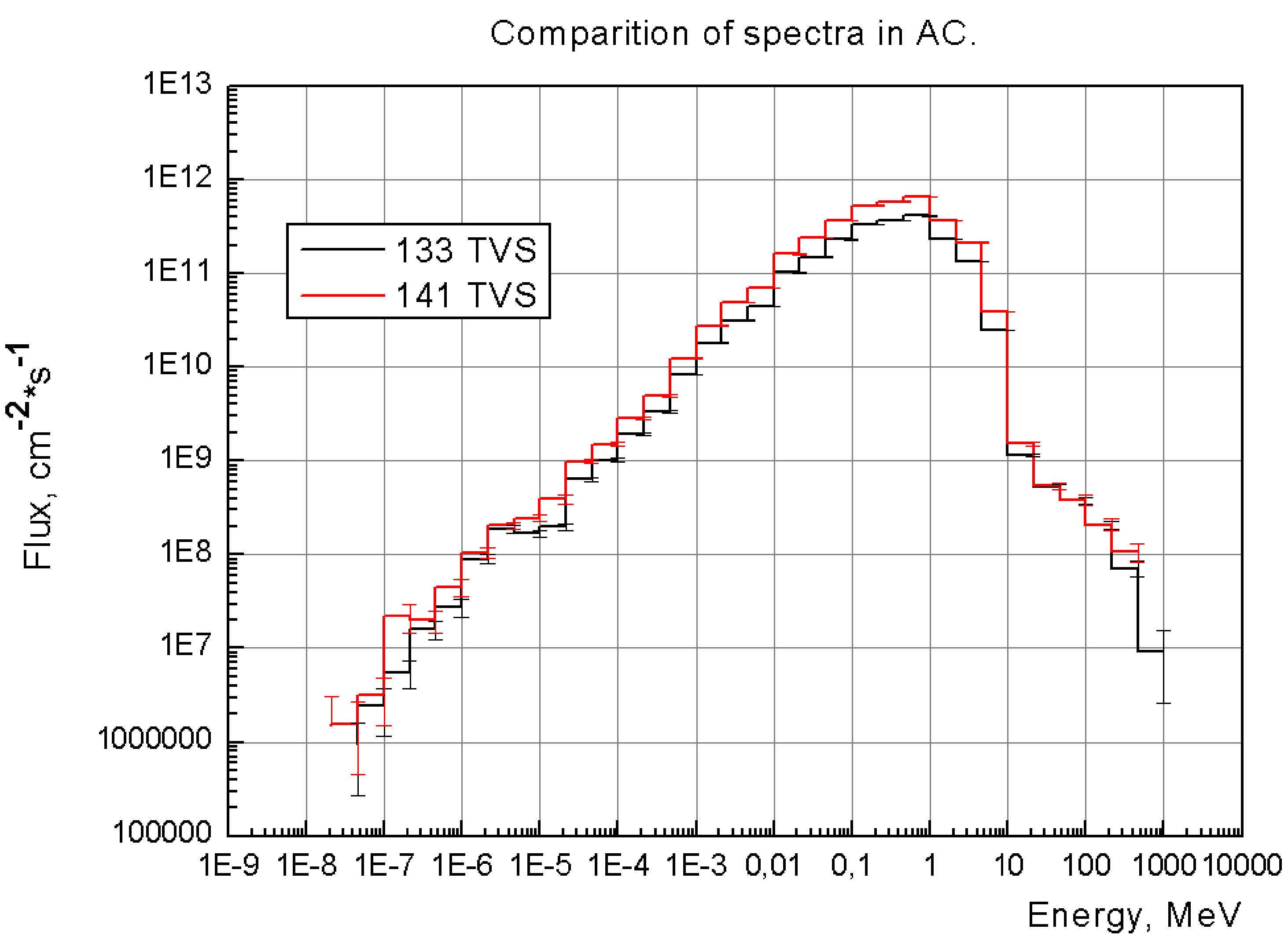


- K-eff = 0.952   133 TVS
- K-eff = 0.972   141 TVS

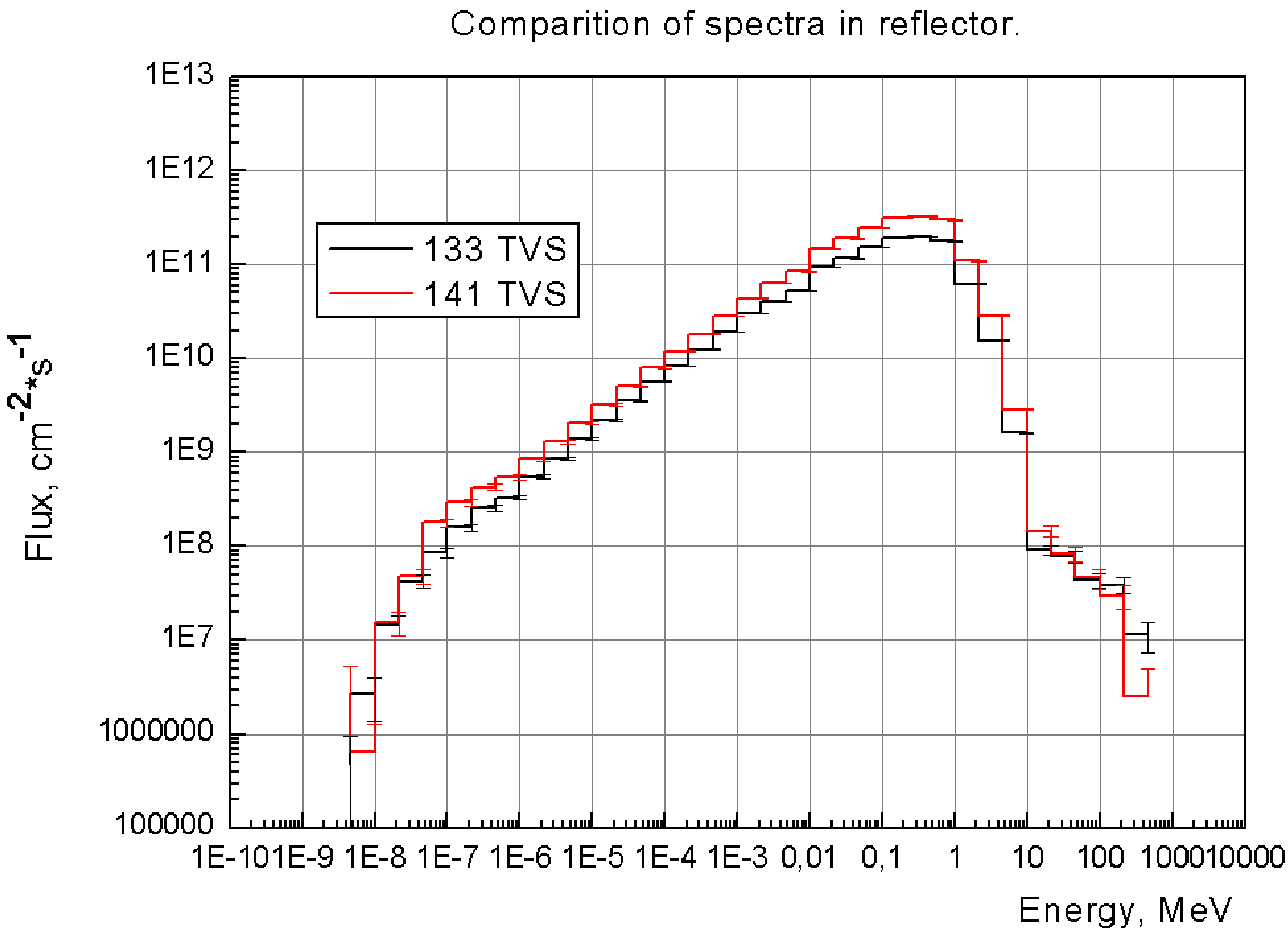
- Channels in active core:
- AC1, AC2, AC3
- Channels in reflector:
- R1, R2, R3



Neutron spectra, 141 TVS
Tot. cm-2*s-1
R1 2.41E+12
R2 1.93E+12
R3 1.54E+12
AC1 3.55E+12
AC2 3.32E+12
AC3 2.91E+12
Flux, cm-2*s-1
1E13
1E12
1E11
1E10
1E9
1E8
1E7
1000000
100000
1E-10 1E-9 1E-8 1E-7 1E-6 1E-5 1E-4 1E-3 0,01 0,1 1 10 100 1000 10000
Energy, MeV



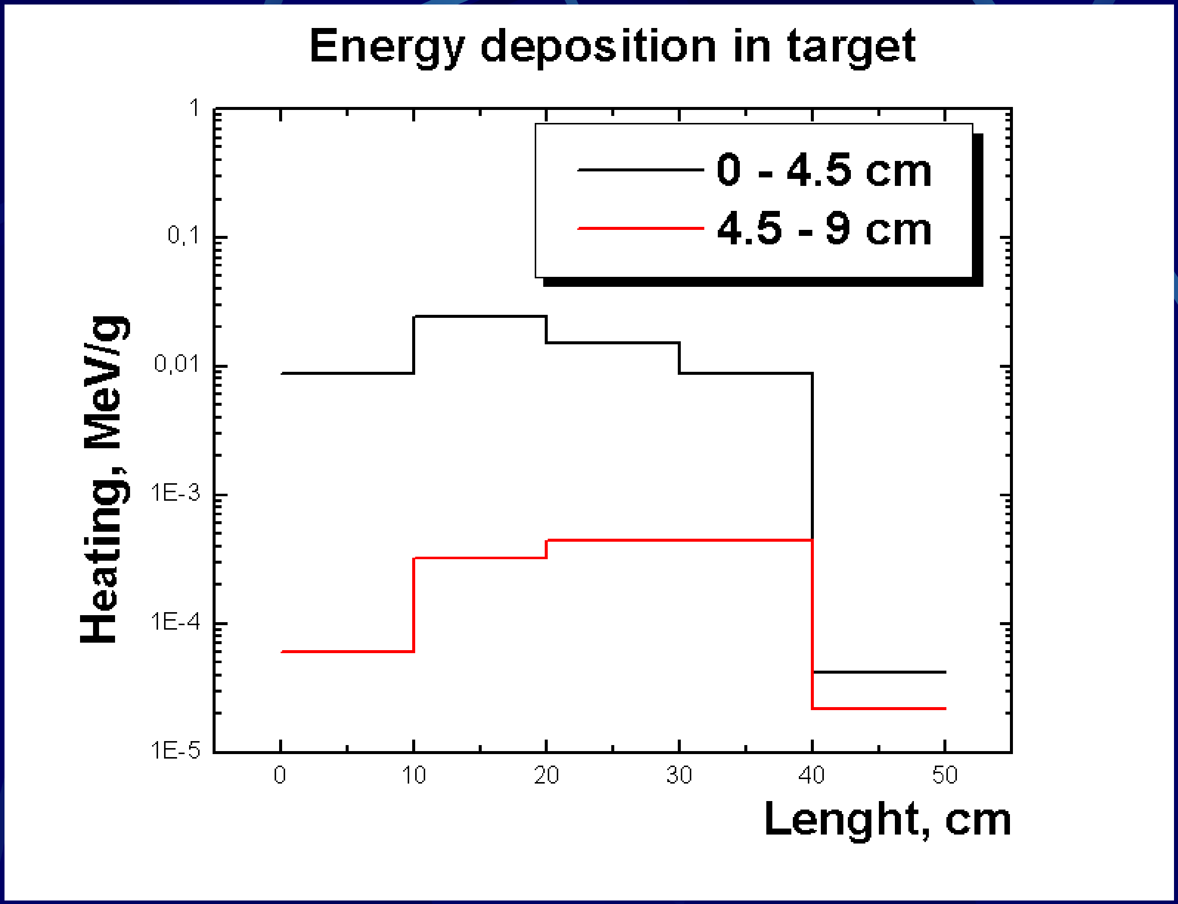
Comparition of spectra in AC.
133 TVS
141 TVS
Flux, cm^{-2}*s^{-1}
Energy, MeV
1E13
1E12
1E11
1E10
1E9
1E8
1E7
1000000
100000
1E-9
1E-8
1E-7
1E-6
1E-5
1E-4
1E-3
0,01
0,1
1
10
100
1000
10000

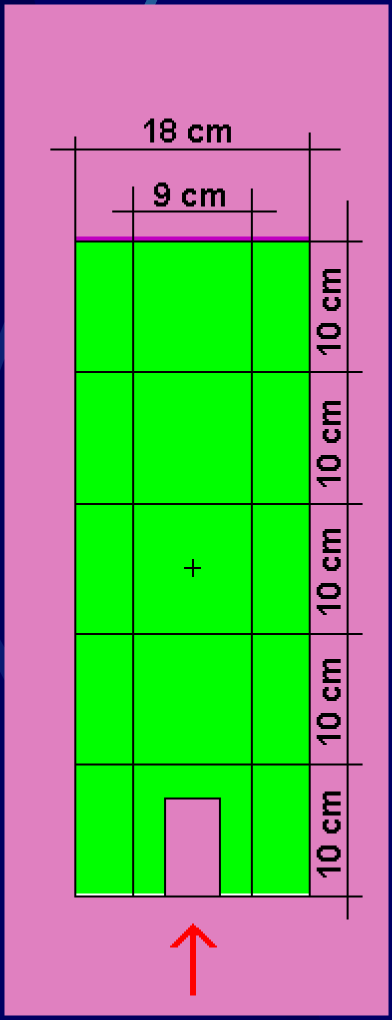

Comparition of spectra in reflector.
133 TVS
141 TVS
1E13
1E12
1E11
1E10
1E9
1E8
1E7
1000000
100000
Flux, cm-2*s-1
1E-10 1E-9 1E-8 1E-7 1E-6 1E-5 1E-4 1E-3 0,01 0,1 1 10 100 1000 10000
Energy, MeV

Summary Table

	Total flux in channels , $cm^{-2} * s^{-1}$ Beam power 1kW	
	Keff=0.952	Keff=0.972
AC1	2.26E+12	3.55E+12
AC2	2.09E+12	3.32E+12
AC3	1.80E+12	2.91E+12
R1	1.50E+12	2.41E+12
R2	1.19E+12	1.93E+12
R3	9.66E+11	1.54E+12

Energy deposition in 2 kW target

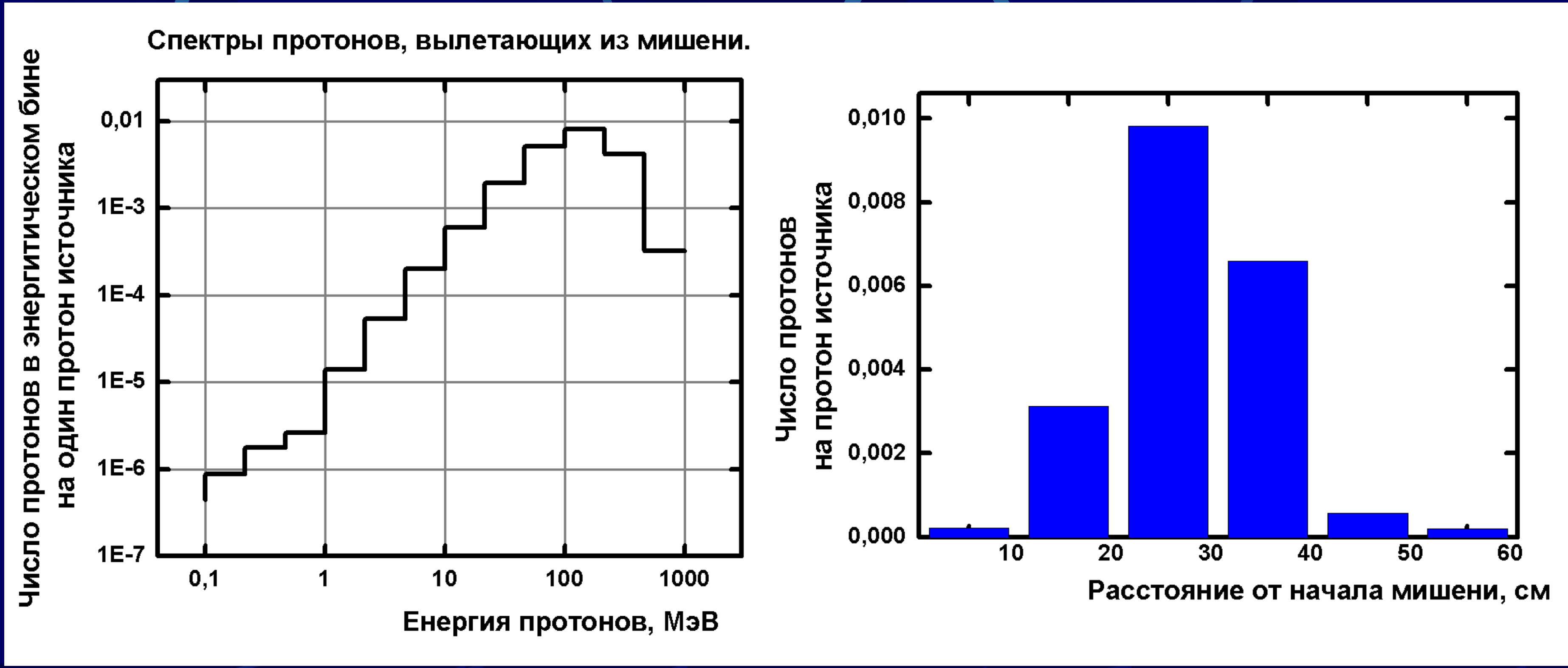




Total energy deposition in target is ~1.4 kW

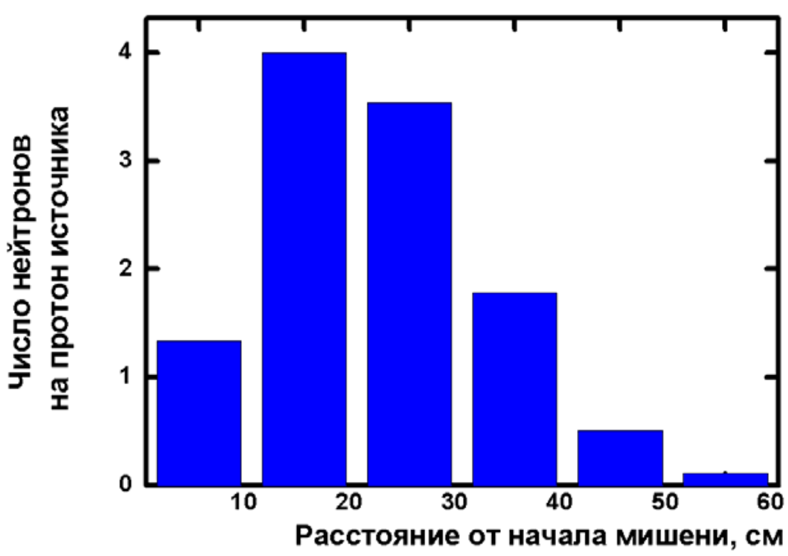
Protons Leaking the spallation Target

Total : 2.1781e+11 s^{-1}



Neutron Leaking from the spallation Target

Total : 1.23e+14 s^{-1}



Maximum flux in chanels

Beam power	1kW	2kW
Keff=0.952	2.26E+12	4.52E+12
Keff=0.972	3.55E+12	7.10E+12

Power of the System

Beam power	1kW	2kW
Keff=0.952	32 kW	64 kW
Keff=0.972	52 kW	104 kW

Calculations of the SAD biological shielding.

Beam power System power	1kW 52 kW	2kW 104 kW
Under assembly	40 μSv/h	80 μSv/h
In control room	<0.5 μSv/h	<1 μSv/h

Conclusion

<u>Extension of experimental program</u>

for study of the power and flux for:

- **Different keff in range 0.95-0.98**
- **Different beam power in rage 1-2 kW**

Appendix 11: Presentation calculations for activity induced in SAD assembly materials by G. Domanska

CALCULATIONS OF THE ACTIVITY INDUCED IN THE SAD ASSEMBLY MATERIALS

/preliminary results/

G. Domańska, J. Cetnar, W. Pohorecki, S.Taczanowski, J. Janczyszyn, K. Morstin

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AGH Univ. of Science & Technology
Cracow 30 059, Poland

e-mail: domanska@novell.ftj.agh.edu.pl

PRESENTATION OVERVIEW

Computing Tools

Calculations of Induced Radioactivity
and Neutron Spectra

Conclusions

Computing Tools :

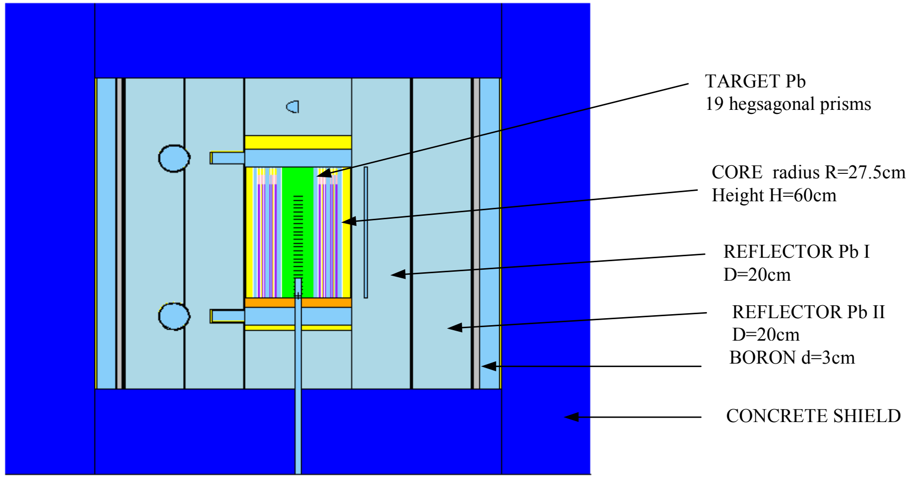
Transmutation Code:
MCB

Transport Calculation Code
MCNPX2.5e
Library: endf602, endf-vi et al.

FISPACT2003

Library EAF2003

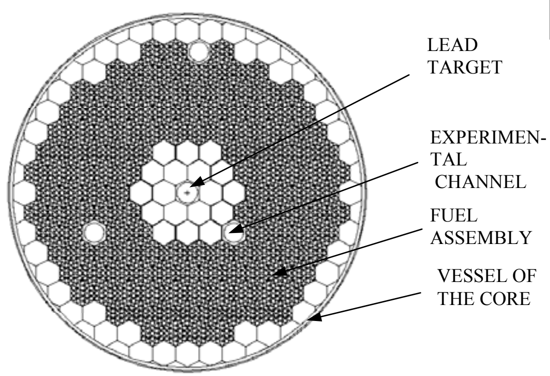
GEOMETRY OF **SAD** /NIKIET PROJECT/



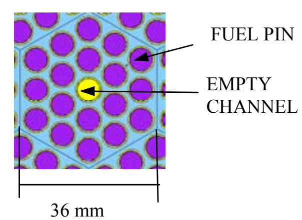
ACTIVE CORE

MOX FUEL: 29.5 % PuO_2 (95% ^{239}Pu,)
(0.4% ^{235}U)

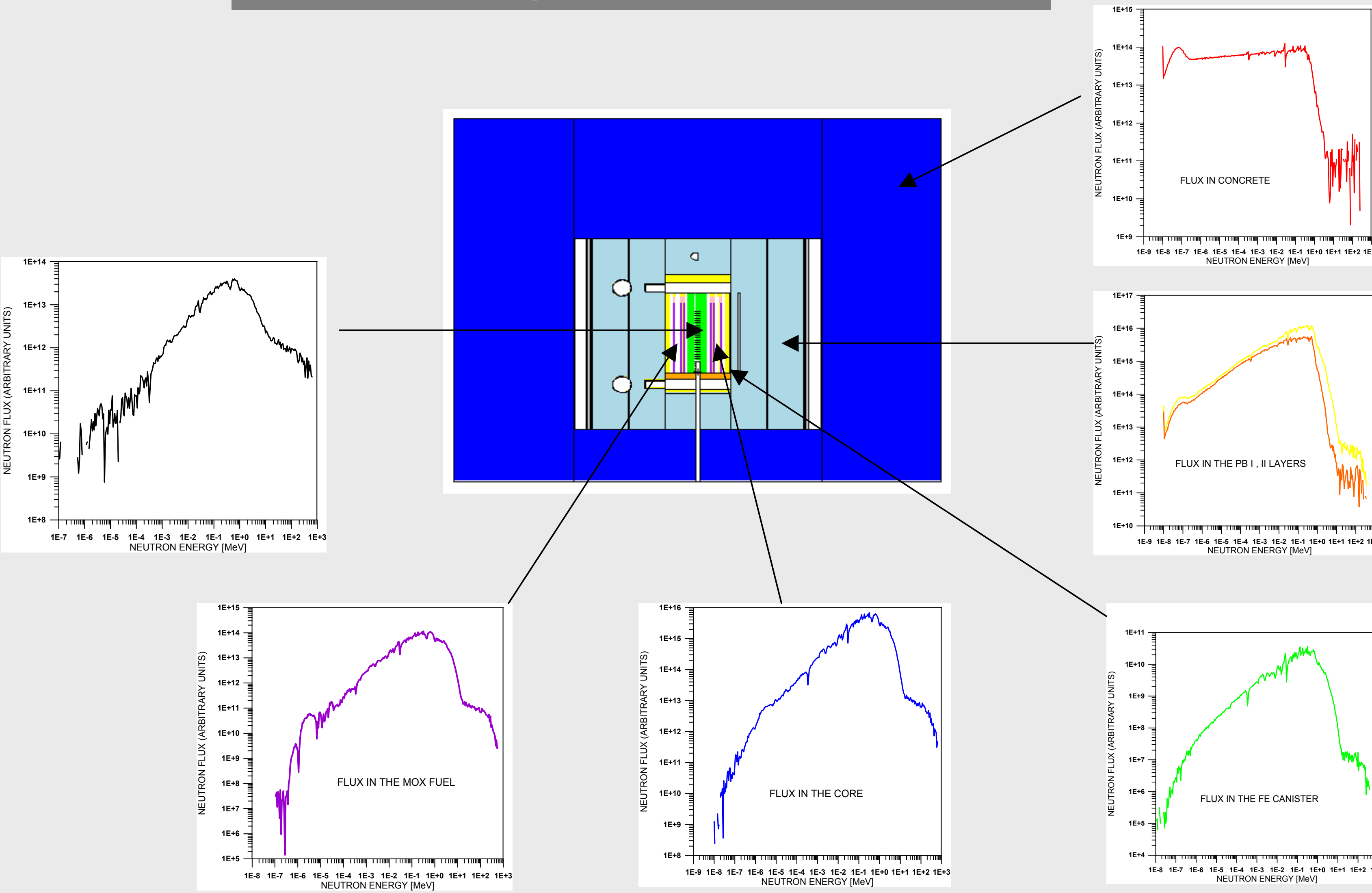
Fuel density 10.4 g/cm^3
Height 58cm



FUEL ELEMENT

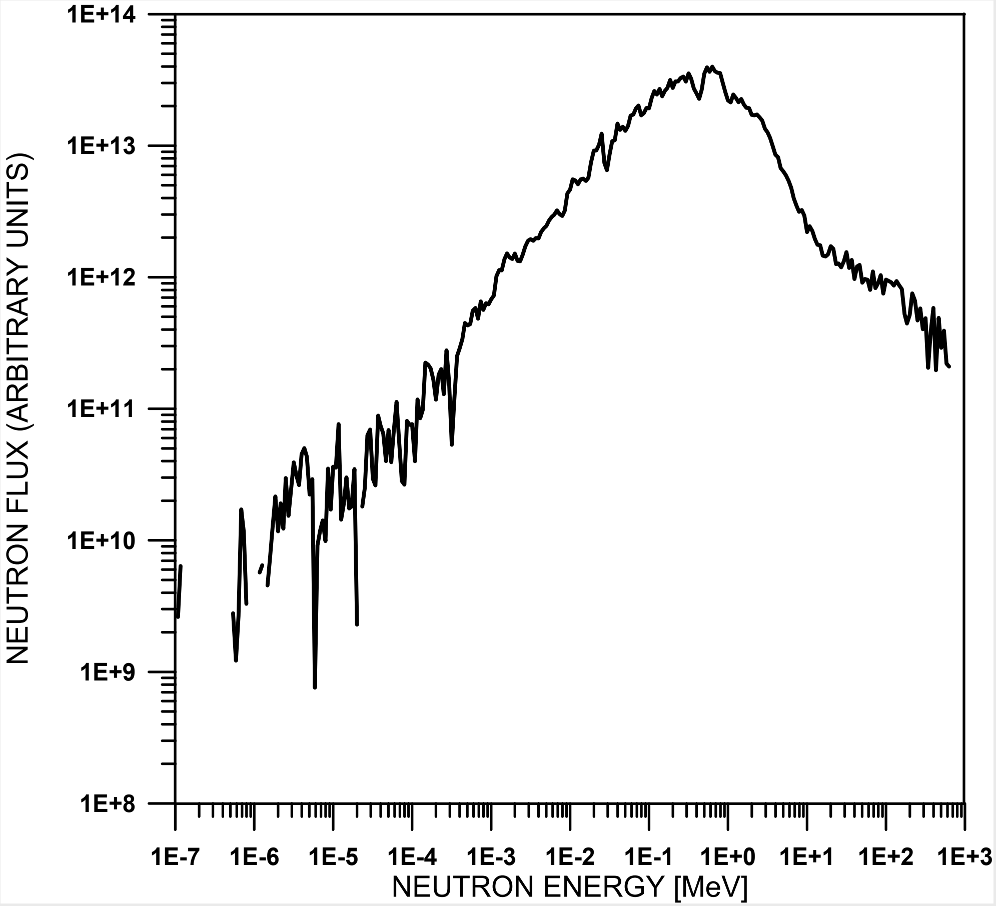


Neutron spectra in the SAD

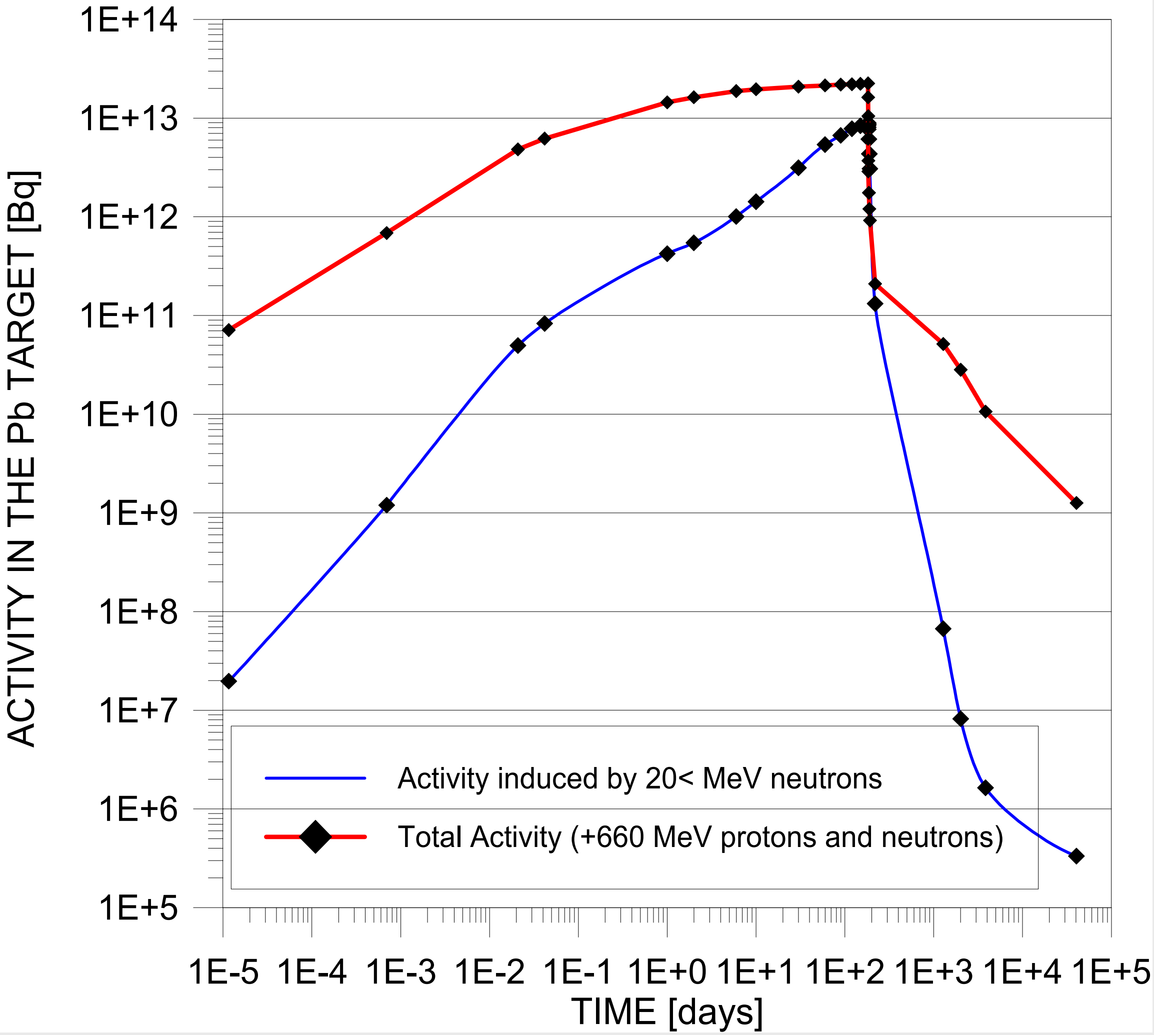


Faculty of Physics & Applied Computer Science
AGH University of Science & Technology
Cracow, PL

Neutron Spectrum in the Target



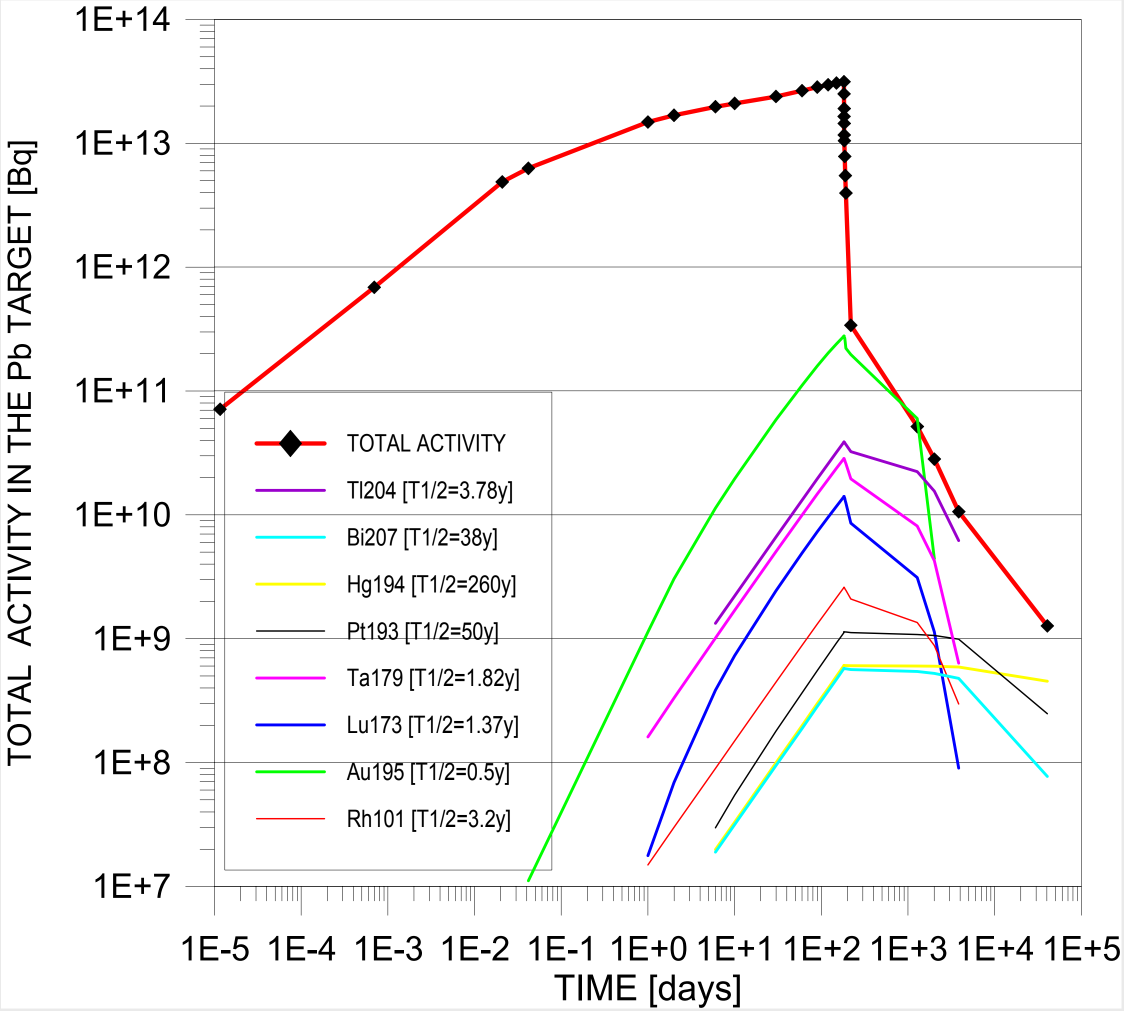
Comparison Target Activity - Total and induced by <20 MeV neutrons



Proton beam 2 μA
Irradiation time 05y

Mass of the Pb target
1.1e5 g

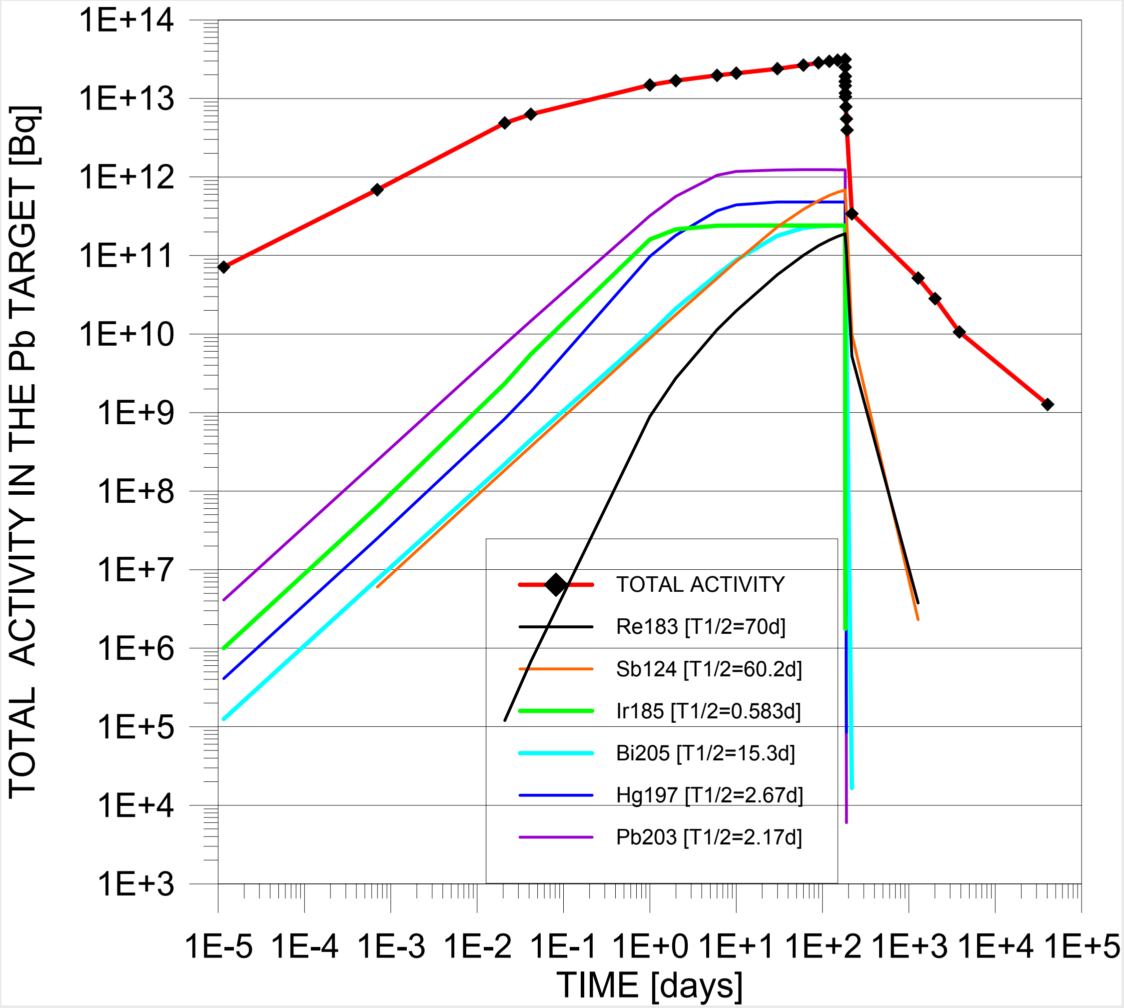
Total activity and activity of long lived nuclides in the Pb target vs. time



Proton beam 2 μA
Irradiation time 05y

Mass of the Pb target
1.1e5 g

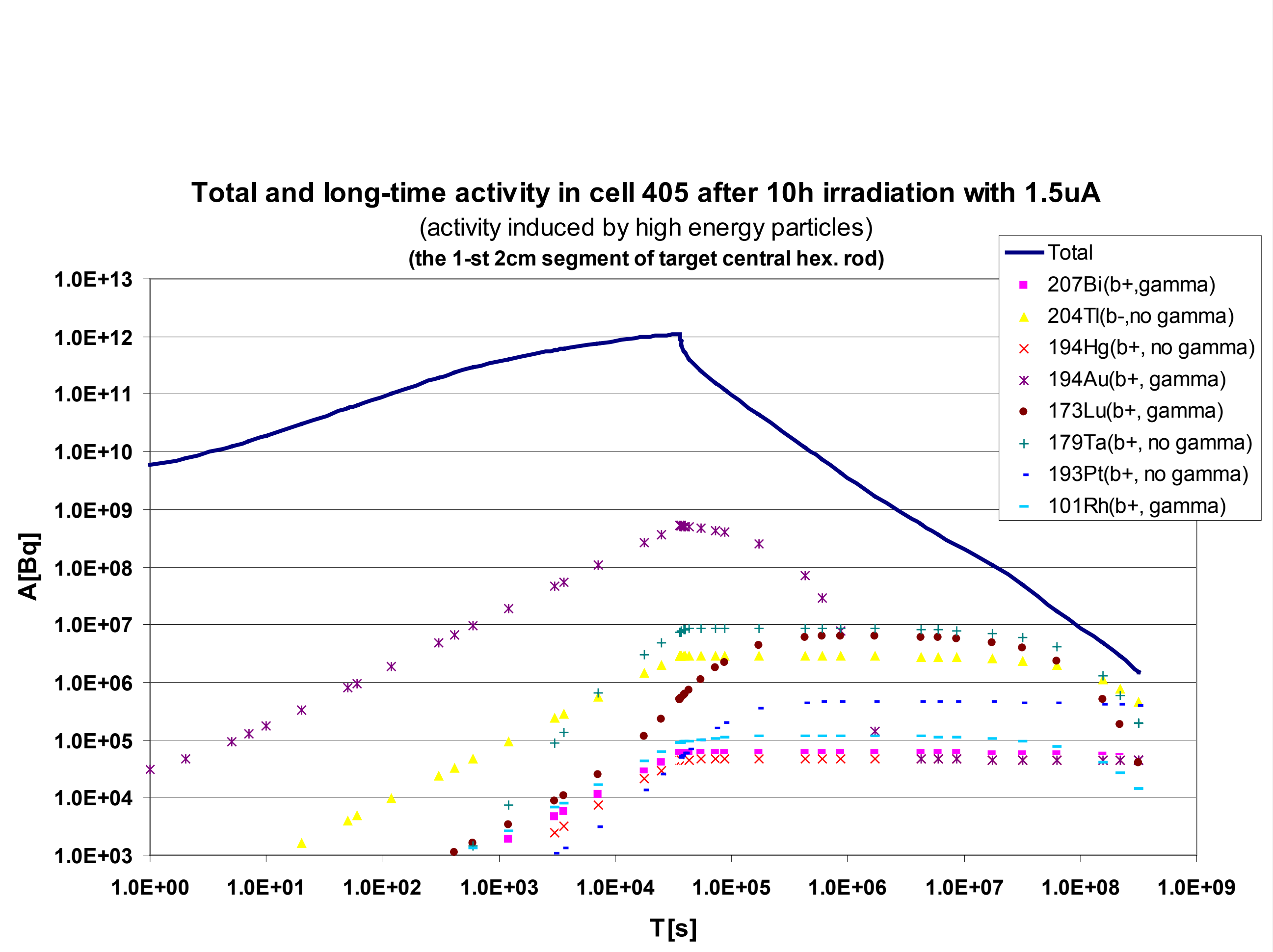
Total activity and activity of dominant nuclides in the Pb target vs. time

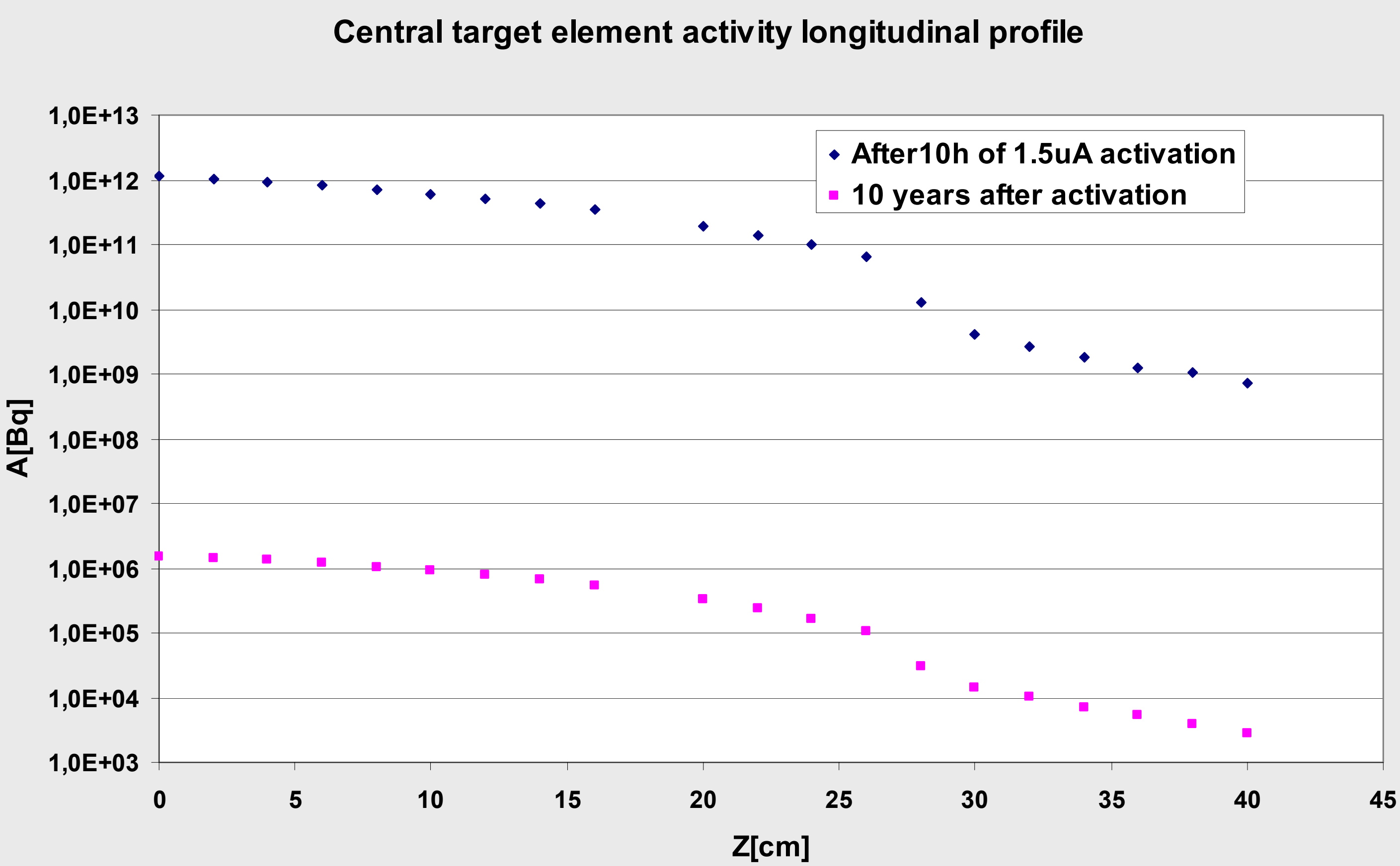


Proton beam 2 μA
Irradiation time 05y

Mass of the Pb target
1.1e5 g

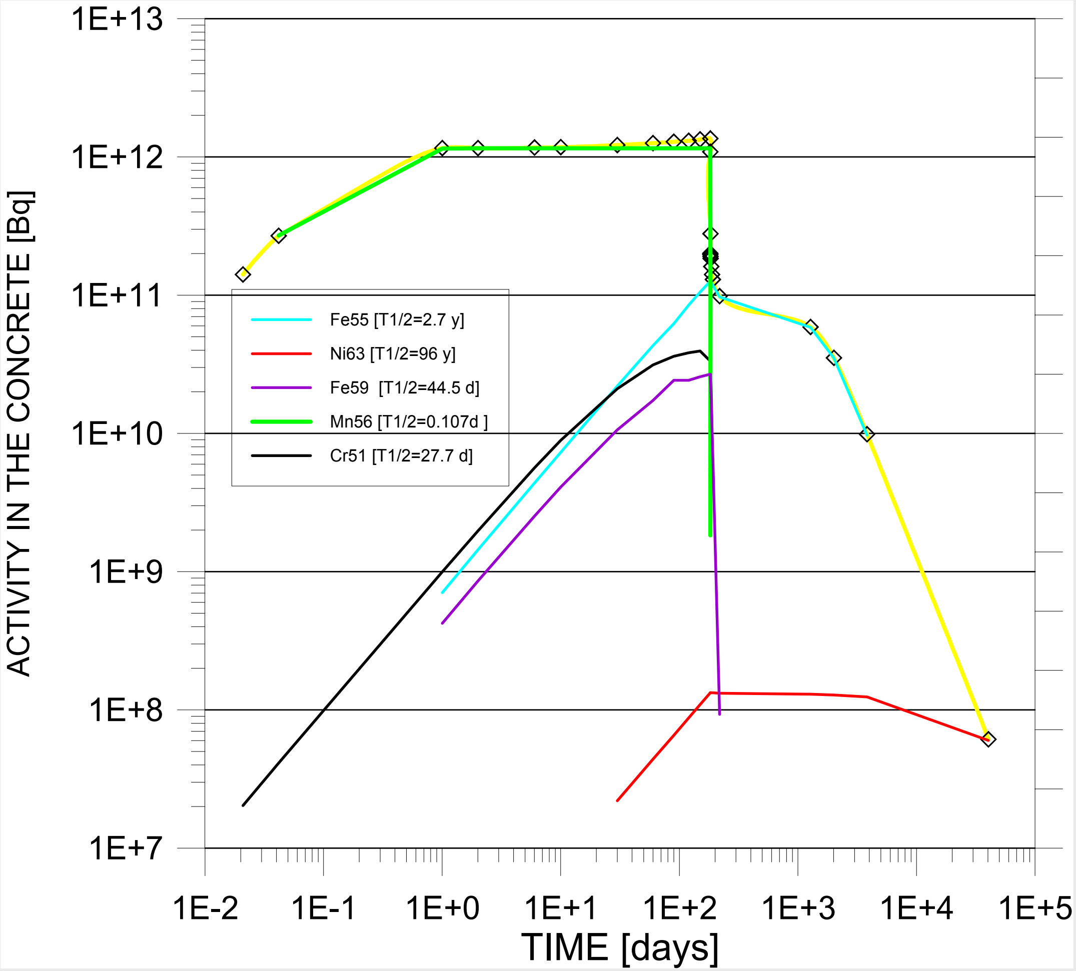
Total activity and activity of long lived nuclides in the Pb target vs. time /10h activation/





Central target element activity longitudinal profile
1,0E+13
1,0E+12
1,0E+11
1,0E+10
1,0E+09
1,0E+08
1,0E+07
1,0E+06
1,0E+05
1,0E+04
1,0E+03
A[Bq]
0
5
10
15
20
25
30
35
40
45
Z[cm]
After10h of 1.5uA activation
10 years after activation

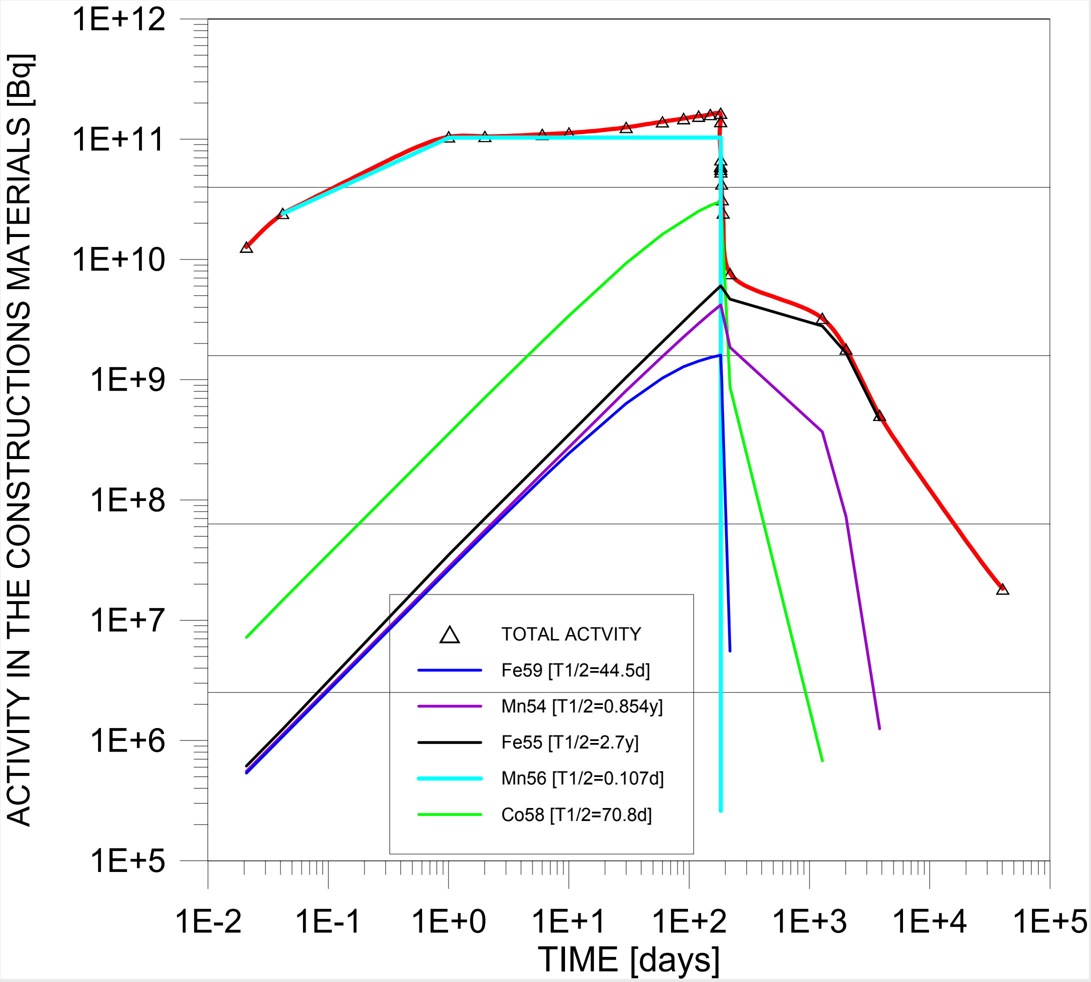
Total activity in the concrete vs. time



Proton beam 2 μA
Irradiation time 05y

Mass of the concrete
8.64e6 g

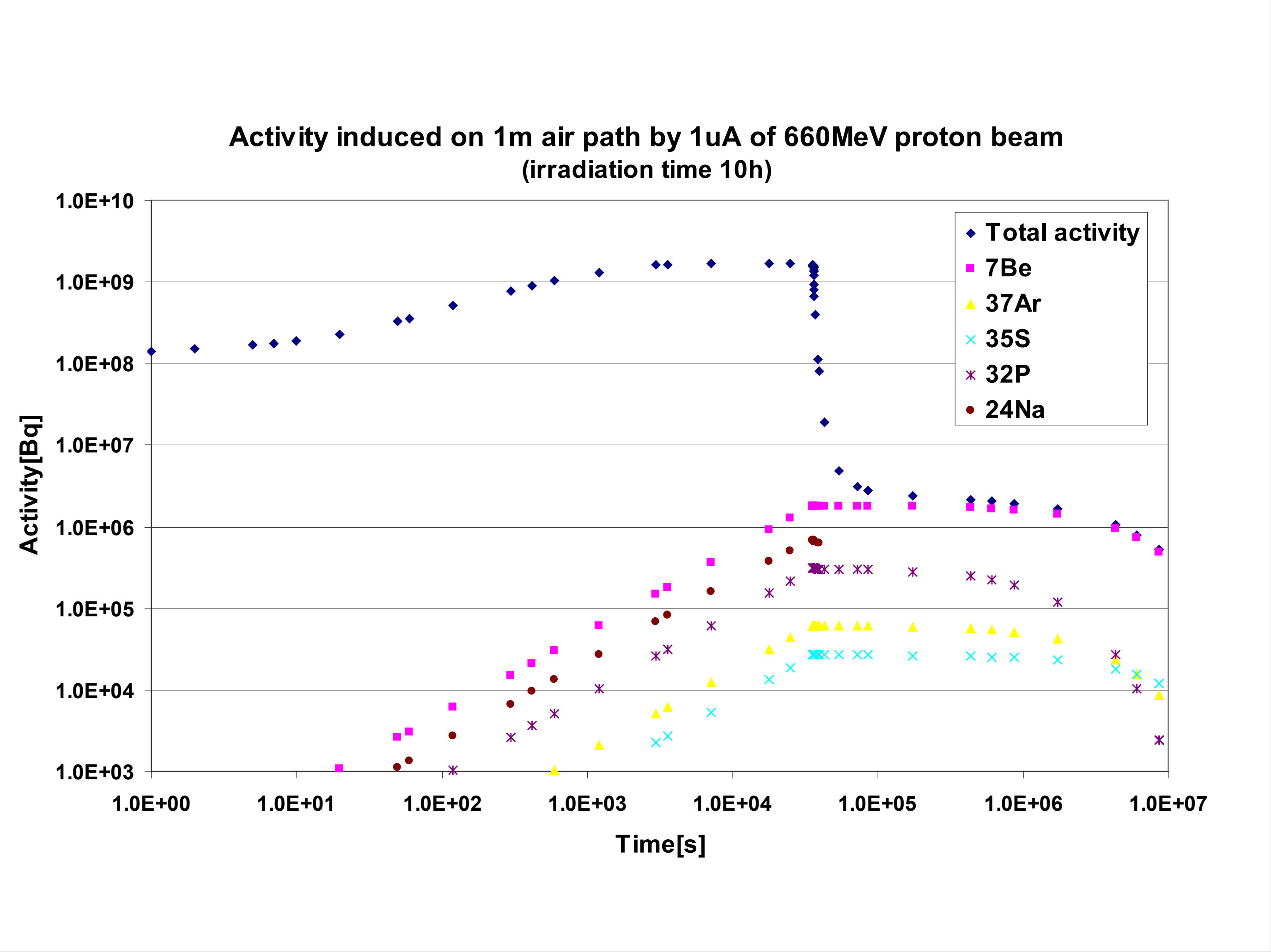
Total activity in the constructions materials vs. time

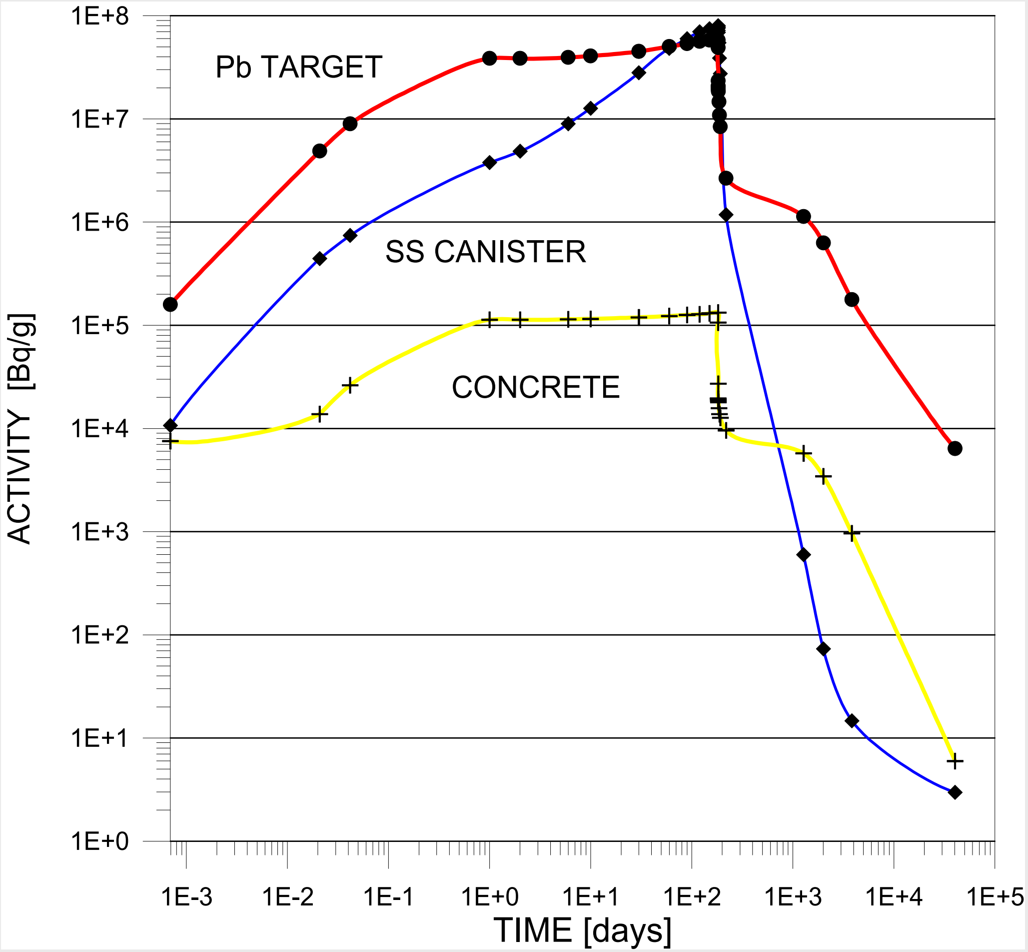


Proton beam 2 μA
Irradiation time 05y

Mass of the canister
4.34e4 g

Air activation by protons vs. time





Proton beam 2 μA
Irradiation time 05y

Measured and calculated activities of the whole Pb target in Bq (for 2,63E14 p)

	EXP	BerAbl	Berdef	CunAbl	CunDre	CEM	Isadef	IsaDre	FLUKA
^{60}Co	148 ± 6	75	71	89	89	69	68	73	55.8
^{65}Zn	274 ± 8	238	469	212	183	558	225	450	213
^{83}Rb	3543 ± 165	1742	1516	2100	2226	1785	1890	1312	2414
^{85}Sr	1644 ± 85	1092	960	1320	1312	1269	1241	832	1473
^{88}Y	6052 ± 154	2708	2748	3202	3267	3394	3226	2540	4395
^{95}Zr	5071 ± 58	4514	2869	8074	8460	2865	6408	2909	6105
^{102m}Rh	905 ± 39	543	342	686	723	328	690	332	696
^{110m}Ag	3458 ± 92	1508	1352	2539	2589	650	2050	819	2030
^{121m}Te	1582 ± 44	1003	1226	1428	1341	899	1238	1125	855
^{173}Lu	6640 ± 119	9457	12329	3618	3628	6859	6218	8835	459
^{175}Hf	13354 ± 447	15182	17589	6921	6837	11878	10719	13747	1294
^{183}Re	32946 ± 828	51093	53687	33566	33843	46747	45199	50259	18305
^{185}Os	63771 ± 890	80910	73100	56692	56730	76220	74830	72310	32559
^{194}Au	435 ± 41	470	423	462	461	557	501	458	582
^{203}Hg	4480 ± 33	5830	5736	7144	7165	2168	4527	4522	3045
^{207}Bi	825 ± 18	878	1167	971	975	1379	1537	1824	966

C/E for the whole Pb target

		Exp.	Uncert.	BerAbl	Berdef	CunAbl	CunDre	CEM	Isadef	IsaDre	FLUKA
fission products	^{60}Co	148	6	0.50	0.48	0.60	0.60	0.46	0.46	0.50	0.38
	^{65}Zn	274	8	0.87	1.71	0.77	0.67	2.04	0.82	1.64	0.78
	^{83}Rb	3540	170	0.49	0.43	0.59	0.63	0.50	0.53	0.37	0.68
	^{85}Sr	1640	85	0.67	0.59	0.80	0.80	0.77	0.76	0.51	**0.90**
	^{88}Y	6050	160	0.45	0.45	0.53	0.54	0.56	0.53	0.42	0.73
	^{95}Zr	5070	58	0.89	0.57	1.59	1.67	0.57	1.26	0.57	1.20
	^{102m}Rh	905	39	0.60	0.38	0.76	0.80	0.36	0.76	0.37	0.77
	^{110m}Ag	3460	92	0.44	0.39	0.73	0.75	0.19	0.59	0.24	0.59
	^{121m}Te	1580	44	0.63	0.78	**0.90**	0.85	0.57	0.78	0.71	0.54
spallation prod.	^{173}Lu	6640	120	1.42	1.86	0.54	0.55	**1.03**	**0.94**	1.33	0.07
	^{175}Hf	13350	450	1.14	1.32	0.52	0.51	0.89	0.80	**1.03**	0.10
	^{183}Re	32950	830	1.55	1.63	**1.02**	**1.03**	1.42	1.37	1.53	0.56
	^{185}Os	63770	890	1.27	1.15	0.89	0.89	1.20	1.17	1.13	0.51
	^{194}Au	435	41	**1.08**	**0.97**	**1.06**	**1.06**	1.28	1.15	**1.05**	1.34
	^{203}Hg	4480	33	1.30	1.28	1.59	1.60	0.48	**1.01**	**1.01**	0.68
p,xn	^{207}Bi	825	18	**1.06**	1.41	1.18	1.18	1.67	1.86	2.21	1.17

(black) < 10%   10% < (grey) < 20%

CONCLUSIONS

The radioactivity induced in the materials of SAD is acceptable.

No significant activation of long lived nuclides was obtained.

Short lived activation of air by protons should by studiet.