EXECUTIVE SUMMARY OF THE FIFTH MEETING OF THE TASK FORCE ON SHIELDING ASPECTS OF ACCELERATORS, TARGETS AND IRRADIATION FACILITIES

Scope

The expert group deals with multiple aspects related to radiation safety, activation and shielding modelling and design of accelerator systems including electron, proton and ion accelerators, spallation sources and the following type of facilities: synchrotron radiation facilities, transmutation sources, accelerator-driven systems, free electron lasers, high power targets and dumps.

Objectives

The main objectives of the SATIF meetings are:

- To promote the exchange of information among scientists in this particular field.
- To identify areas in which international co-operation could be fruitful.
- To carry on a programme of work in order to achieve progress in specific priority areas.
- To encourage free access to computer codes sources and cross-section and integral experiments data, and making them available at information centres.

Background and past achievements

The first SATIF meeting (SATIF-1) took place in Arlington, Texas (USA) on 29-30 April 1994, the second meeting (SATIF-2) was held on 12-13 October 1995 at CERN (European Laboratory for Particles Physics) in Geneva, Switzerland, the third meeting took place on 12-13 May 1997 at Tohoku University (Sendai, Japan) and the fourth meeting was held in Knoxville, Tennessee (USA) on 17-18 September 1998.

As a consequence of the success of these conferences, the seventh meeting of the NEA Nuclear Science Committee, held on 29-30 May 1996, approved the establishment of a specific task force on shielding aspects of accelerators, targets and irradiation facilities. Consequently, the SATIF specialists meetings became regular meetings of this task force. Following the fourth meeting it was decided to organise SATIF meetings every two years.

It is generally recognised that the four SATIF meetings preceding SATIF-5 have fostered considerable and significant co-operative actions and efforts at the international level, in areas such as:

- *Basic data*: New measurements, compilation of existing neutron, proton, light ion and pion cross-section data in the intermediate energy range above a few dozens of MeV, forward bremsstrahlung yields from thick targets at energies above 100 MeV, photoproduction data (namely photonuclear cross-sections and photonuclear yields and angular distributions for all common elements at all energies), photo-pion yields and angular distributions at energies above 200 MeV, isotope production data, etc.

- *Nuclear models and computer codes in the intermediate energy range*: Code validation, intercomparison of codes, comparison between experimental data and predictions from existing computer codes implementing nuclear models.

- *Shielding experiments*: Measurements of forward and lateral attenuation of iron and concrete for proton and ion accelerators up to a few tens of GeV and as deep as possible, i.e. at least 5-6 meters, measurement of forward and lateral attenuation at electron accelerators.

- *Benchmark data*: Organisation of new benchmark exercises, compilation of existing benchmark data sets, etc.

- *Anthropomorphic computational models*: Compilation of existing models, phantom geometry and material compositions, evaluation of effective and organ doses.

- *Dose conversion coefficients for "high-energy" radiation*: Evaluation of fluence-to-effective dose conversion coefficients for high-energy radiation.

The last four SATIF meetings were held in conjunction with SARE (Simulating Accelerator Radiation Environment) meetings. The two meetings are complementary in their subject matter and the participants in both meetings are experts coming from different fields of science and technology. SATIF was originally designed as a forum of discussion and exchange of information in order to identify areas in which international co-operation is needed or needs to be strengthened. In the past, special attention has been paid to:

- The availability and compilation of experimental data for different applications.

- The organisation of international benchmark exercises.

- The availability of computer codes and data libraries for the use of the scientific community involved in various aspects related to accelerator shielding and applications.

- Identifying areas in which international co-operation can contribute to solve existing problems.

The presentations made at the successive SATIF meetings can generally be categorised according to the following topics:

- Data.

- Benchmarks.

- Computer codes and models.

- Facilities.

- Shielding techniques.
- Conversion coefficients.
- Code intercomparisons.
- Status of codes.

The fifth meeting – SATIF-5

The fifth meeting of the SATIF task force (SATIF-5) took place in Paris, France, at the OECD headquarters in the Château de la Muette, from 18-21 July 2000, and was jointly organised by:

- OECD Nuclear Energy Agency.
- Institut de Physique Nucléaire d'Orsay (IPNO).
- Radiation Safety Information Computational Centre (RSICC).
- Shielding Working Group of the Reactor Physics Committee of Japan.

Fifty-five specialists attended the meeting, among them physicists, engineers and technicians from laboratories, institutes, universities and industries in Belgium (Univ. Liège), France (CEA, GANIL, IN2P3), Germany (DESY, KFZ – Jülich, Hahn-Meitner Institute – Berlin, Univ. Hannover), Italy (INFN, ENEA), Japan (CYRIC, JAERI, KEK, RIKEN, Universities of Kyoto and Tohoku, Mitsubishi and Hitachi Corporations), USA (LANL, RSICC, SLAC, Georgia Institute of Technology), the Russian Federation (ITEP), Israel (Soreq Nuclear Data Centre), as well as representatives from international organisations (CERN, ESRF and OECD/NEA). The detailed list of participants is provided in Appendix 2.

The SATIF-5 meeting was preceded by the Workshop on Models and Codes for Spallation Neutron Sources, imbedded in the SARE-5 meeting, and organised on the same premises (please refer to Appendix 4 for a short summary of the workshop).

The SATIF-5 meeting was organised in seven sessions, each addressing different issues:

- *Session 1*: Proton and Ion Accelerators.
- *Session 2*: Electron Accelerators and Photon Sources.
- *Session 3*: High Intensity Medium Energy Accelerators.
- *Session 4*: Shielding Benchmark Calculations and Results.
- *Session 5*: Dosimetry and Dose Calculations.
- *Session 6*: Additional Topics.
- *Session 7*: Discussions and Future Actions.

A detailed agenda of the SATIF-5 meeting is provided in Appendix 1. Thirty-two papers were presented during the first six (topical) sessions. Highlights from the presentations performed and subjects discussed are as follows:

- Experimental data (reaction rates, residual product nuclei yield and neutron spectra) for 0.1-2.6 GeV protons impinging on different targets (Al, Mg, Na, Pb, W, Hg). This data is useful for future high-power proton accelerators. Status:
  - Data analysis still in progress.
  - Further measurements are planned.
  - Discrepancies between codes and measurements need to be reconciled.
  - Programme needs support.
- Neutron attenuation length and deep penetration experiments and benchmarks. Status:
  - Good progress has been accomplished.
  - Uncertainties on neutron attenuation lengths (for protons incident on concrete and iron) need to be resolved.
  - Need to understand differences in codes.
  - Extend neutron dose attenuation to tens of GeV to confirm asymptotic value.
- FLUKA calculations on hadron yields from high-energy electrons around thick targets and dose attenuation in concrete and resulting parameterisation is useful for electron accelerator shielding
- Beam loss scenarios for storage rings should be realistic and include Monte Carlo simulations and beam optics.
- Experimental measurements of neutron production from deuterons (up to 200 MeV) incident on Be, C and U targets show some discrepancies with calculations.
- Determination of high fission yields for future RNB facilities.
- Calculations and data presented for activation of soil, ground water, air, targets and cooling water. Status:
  - These data are relevant for personnel radiation safety and environmental impact.
  - In general there is less activation data available for electron machines than proton machines.
- Calculations for radiation damage to electronic components is important for future high-power machines.

- Benchmarking neutron dosimetry in simple phantoms:
  - Results indicate large discrepancies between codes.
  - Code experts need to resolve these differences.
  - Need for experiments on N and C targets to help reconcile differences.
- Completed collection of experimental data of neutron spectra and yield from thin and thick target bombardment with heavy ions up to 800 MeV/nucleon. Status:
  - This data is useful for benchmarking of future Monte Carlo codes that will deal with heavy ion transport (space research application, medical application, etc.).
- Several papers on dosimetry confirm that H*(10) is not always the best estimator of effective dose for both broad and narrow beams:
  - Comparisons were made between experiments and Monte Carlo calculations.
- Improvements of low-energy photon transport (keV) in EGS4 were verified with measurements between 20-40 keV. Status:
  - This data is very useful for synchrotron radiation facilities.
- Assessment of induced activity in accelerator structures is important for decommissioning efforts.
- Specific examples of application of Monte Carlo techniques in complex problems such as Atlas background and n_TOF experiments.
- Non-accelerator applications. They included:
  - Tokamak shielding aspects.
  - Neutron fluxes of high flux reactor.
- Computer codes for accelerator shielding design and modelling. Status:
  - Several of the major experts on intranuclear reactions (INC, evaporation, fissions) attended the meeting; however, the absence of experts on internuclear transport calculations was strongly felt.
  - Graphical interfaces between FLUKA and Autocad for geometry plotting and particle tracking appear promising to FLUKA users.
  - Duct-III code would facilitate design of ducts and labyrinths and therefore should be made available.

– Developments in codes should include:

⇒ Electron and photon transport (with polarisation) down to 0.1 keV (for light sources).

⇒ Reflectivity and refractivity of mirrors (for light sources).

⇒ Time dependence of radiation fields (for light sources).

⇒ Ion transport.

⇒ Residual nuclei decay mode for direct calculation of radiation exposure.

Discussion, proposals, conclusions

An extensive discussion took place during Session VII, with the following pre-established objectives:

- To review the progress achieved since the SATIF-4 meeting.
- To monitor the status of the agreed actions (on experiments, benchmark organisation, compilation of basic data, codes and methods) undertaken since then.
- To identify and initiate new co-operative actions.
- To improve common understanding of problems that have technical and safety significance.
- To review the current organisation of the SATIF meetings and to discuss the organisation of future meetings.
- To review the scope, objectives and deliverables of SATIF, in order to adjust them to the new needs expressed in the Member countries.
- To prepare and discuss a work programme for the next two years, which will be proposed for approval by the NSC together with the revised scope and objectives.

Follow-up of action items from SATIF-4

Progress was monitored on the following actions, decided at SATIF-4 (or earlier meetings):

- The BEEP benchmark (electron/photon transport benchmark, group chaired by A. Bielajew):
  - A paper reporting on low-energy photon results conducted at Japan in the framework of BEEP was presented at SATIF-5 by H. Hirayama.
  - A progress report by A. Bielajew is in preparation.
- Conversion coefficients, anthropomorphic computational models (group chaired by N. Yoshizawa):
  - Excellent progress has been obtained, four papers were presented during SATIF-5.

- Attenuation length (extension to other codes and to higher energies, group chaired by H. Hirayama):
  - Excellent progress has been achieved, three papers were presented during SATIF-5.
- Ground activation (work conducted at CERN):
  - A paper by H. Vincke was presented at SATIF-5 reporting on the results obtained so far.
- Deep penetration problems – different approaches (work by G. Stevenson and J. Bull).
  - No status report was presented.
- Compilation of photonuclear cross-sections (work by A Fassò):
  - No status report was presented.

Organisation of benchmark and intercomparison exercises

Results were presented on:

- The intercomparison of neutron transmission benchmark analysis for iron and concrete in TIARA and the intercomparison of the medium-energy neutron attenuation in these materials.
- The benchmark calculation with a simple phantom for neutron dosimetry.

It was decided to continue the collaborative work already undertaken, namely on:

- Conversion coefficients, anthropomorphic computational models (N. Yoshizawa).
- Attenuation length (H. Hirayama).

New benchmarks were proposed, discussed and accepted, as follows:

- Deep penetration shielding benchmarks (proposed by T. Nakamura):
  - *ISIS experiment*
    800 MeV – protons, 90°
    Materials: Concrete, iron
    Determination of λ values, neutron spectrum (Bonner ball, C- and Bi-activation)
  - *LANSCE/WNR experiment*
    800 MeV – protons, 90°
    Materials: Iron
    Determination of λ values
  - *HIMAC experiment* (proceeding now)
    400 MeV/nucleon – C on Cu target, 0°
    Materials: Neutron spectrum (NE-213, self TOF, Bi-activation) in concrete (2 m), iron (1 m).

- CERN experiment (proposed by M. Silari):
  - High energy mixed proton/pion beam on thick Cu target, complex shielding structure, FLUKA predictions and neutron spectral measurements.
- Activation cross-sections of neutrons (proposed by T. Nakamura – follow up by E. Menapace and S. Rokni):
  - Collection of data.
  - Data library above threshold especially for light nuclei in air, water and soil. Check for:
    - ⇒ LANL (what data is available?).
    - ⇒ MENDL (place it into information centres).
    - ⇒ Measurement.
- Residual nuclei production cross-section and reaction rates for high-energy (0.04-2.6 GeV) protons (proposed by Y. Titarenko, V. Batyaev, *et. al*.):
  - Experimental data from ITEP Moscow (Titarenko).
  - LANL calculations (Mashnik, Prael).
- Heavy ions (F. Clapier):
  - Neutron production from:
    - ⇒ Thick target (Data collection and compilation – HIMAC, Cecil, Heilbronn).
    - ⇒ Thin target (Cecil, RIKEN, HIMAC).

Follow-up of agreed actions

It was recognised that follow-up of agreed actions needs to become more effective. The follow-up should be made by the NEA Secretariat together with the co-ordinators assigned for specific activities or topics. In particular benchmarks should be distributed officially through the OECD/NEA to ensure an official status and strengthen participation. The setting up of specific listserver and web pages has been proposed as a tool to accomplish this.

Listserver and web pages

The following proposal for a listserver was submitted and accepted by the SATIF-5 participants:

- Address: satif@nea.fr.
- Members: all SATIF participants.
- Characteristics: Moderated (focussed, pertinent, of general interest to SATIF);web page with searchable archive of messages to be used to facilitate communication and follow-up actions

Further development of the web pages already existing has been discussed, in order to provide information on:

- Scope and objectives, deliverables.
- Membership and organisation.
- Next meeting and other relevant meetings.
- List of relevant publications or links to them.
- Summary records/actions.
- Downloading of benchmark specifications.
- Links to relevant web sites.
- Open questions/answers via notebook.

Computer codes and data libraries for shielding design and modelling

With regard to the state-of-the-art computer codes and data libraries available for use by scientists in the field of radiation shielding, an exhaustive and updated list of computer codes, data libraries and databases has been produced which is included in these proceedings. This compilation issued by RSICC in collaboration with the NEA Data Bank is a valuable reference for the community of users.

Among other actions decided upon at the discussion session were:

- To pursue the collection of experimental data sets available.
- To continue the activities on data compilations, giving particular emphasis to data availability for the user community.
- To further develop the activities on intercomparison exercises, between modelling methods (e.g. computer codes) available and experimental data.
- To encourage free access to computer codes sources and cross-section and integral experiments data, and making them available at information centres.

Future meetings of the SATIF task force

Concerning the organisation of future SATIF meetings, it was agreed by the majority of the SATIF participants that:

- Future SATIF meetings will typically last three days. They should contain, besides presentations of progress in work carried out at different research institution relevant to the scope of SATIF, specific sessions related to agreed collaborative work. During these it should be clarified, what has been achieved, what is in progress, what needs emerge for further work.

- A specific topical workshop addressing an issue of particular interest is organised in connection or embedded in SATIF meetings. The organisation of such topicals is under the responsibility of the Chair.

The next meeting (SATIF-6) is scheduled for September 2002 at SLAC, Stanford, CA, USA. The meeting will be held if possible in connection with the ANS RP&S Division Topical to be held in September 2002 in Santa Fe, NM, USA. A topical meeting embedded in SATIF-6, the topic of which is synchrotron radiation and free electron laser (FEL) light sources, has been proposed.

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Appendix 1

AGENDA

Tuesday, 18 July 2000

Welcome and opening remarks for the SATIF-5 meeting

Session I **Proton and Ion Accelerator**

Co-chairs: N. Ipe, M. Silari

V. Batyaev
Reaction Rates Inside and on the Surface of a 0.8 GeV Proton-Irradiated Thick W-Na Target

V. Batyaev
Neutron Spectra Generated in W and Na Targets by 0.8 GeV Proton Irradiation

Heinz Vincke
Production of Radioactive Isotopes in Molasse

T. Nakamura
Neutron Production from Thin and Thick Targets by High-Energy Heavy Ion Bombardment

N. Pauwels
Experimental and Calculated Neutrons Production by Deuterons Impinging on Be, C and U Thick Targets (200, 160, 80, 28, 20 and 17 MeV)

Y. Titarenko
Study of Residual Product Nuclide Yields in GeV Proton-Irradiated Thin ^{208}Pb and ^{nat}W Targets

Wednesday, 19 July 2000

Session II Electron Accelerator and Photon Sources

Co-chairs: T. Nakamura, N. Pauwels

Synchrotron Radiation Facilities

N. Ipe
The Linac Coherent Light Source

P. Bervkens
Shielding Issues Around the ESRF Storage Ring

High Energy Electron Machines

S. Rokni
Radiation Studies for the Personnel and Environment Protection for the Next Linear Collider Project

S. Roesler
Radiation Damage to Electronics in the Beam Tunnel of the Next Linear Collider

A. Leuschner
Calculation of Hadron Yields Around Thick Targets and Doses Behind Concrete Shielding of High-Energy Electron Accelerators

Session III High Intensity Medium Energy Accelerators

Co-chairs: D. Filges, H. Hirayama

D. Ridikas
High Intensity Fission Yields by the Use of the Flowing Lithium Target-Converter (Neutron Source)

V. Zhivun
Study of Residual Product Nuclide Yields in 0.1-1.6 GeV Proton-Irradiated Thin Hg Targets

V. Lacoste
Activation Studies and Radiation Safety for the n-TOF Experiment

C. Volant
Experimental Spallation Reaction Results

Thursday, 20 July 2000

Session IV Shielding Benchmark Calculations and Results

Co-chairs: P. Berkvens, L. Ulrici

Neutron Attenuation Length

H. Hirayama
Inter-Comparison of the Medium-Energy Neutron Attenuation in Iron and Concrete

Deep Penetration Experiment

Y. Sakamoto
Deep Penetration Calculations of Neutrons Up to 1.5 GeV

N. Nakao
Deep Penetration Experiment at ISIS

Neutron Dosimetry Benchmark

Y. Sakamoto
Benchmark Experiments of Absorbed Dose in a Slab Phantom for Several Tens MeV Neutrons at the TIARA Facility

N. Yoshizawa
Benchmark Calculation with Simple Phantom for Neutron Dosimetry

Electron-Photon Benchmark (BEEP)

H. Hirayama
Current Status of Low-Energy Photon Benchmark Experiments at KEK

Photon Neutron Production Benchmark

H. Vincke
Benchmarking of the Simulations of the Atlas Hall Background

Session V Dosimetry and Dose Calculations

Co-chairs: M. Pelliccioni, V. Batyaev

Dose Conversion Coefficients for "High-Energy" Radiations

Y. Sakamoto
Evaluation of Dose Conversion Coefficients for High Energy Radiation in Japan after SATIF-4

Anthropomorphic Computational Models

L. Ulrici
Effective Dose and Organ Doses Due to Gas Bremsstrahlung from Electron Storage Rings

Session VI Additional Topics

Co-chairs: B. Kirk, A. Leuschner

E. Sartori
Status of Computer Codes, cross-sections and Data Libraries for Accelerator Shield Modelling

H. Vincke
Flukacad/Pipsicad: Three-Dimensional Interfaces between Fluka and AutoCAD

H. Hirayama
Development of DUCT-III Code for Duct Streaming Calculation up to 3 GeV

D. Ridikas
On the Fuel Cycle and Neutron Fluxes of the High Flux Reactor at ILL Grenoble

S. Rollet
Shielding Aspects of a Tokamak Reaching Ignition

E. Menapace
Nuclear Data Evaluation by Model Calculations for Radiation Shielding Purposes in the Framework of the International Co-operation

Friday, 21 July 2000

Session VII Discussion Session

N. Ipe, M. Silari
Summary and Conclusions of the Meeting

Future Developments of SARE and SATIF

F. Clapier
Closing Remarks

Appendix 2

LIST OF PARTICIPANTS

AUSTRALIA

* MUKHERJEE, Bhaskar
ANSTO - Safety Division
PMB-1
MENAI, NSW 2234

Tel: +61 2 9717 3404
Fax: +61 2 9389 8444
Eml: mukherjee@ieee.org

BELGIUM

CUGNON, Joseph
Physics Department B5
University of Liege
B-4000 SART TILMAN LIÈGE

Tel: +32 43663601
Fax: +32 43663672
Eml: J.Cugnon@ulg.ac.be

FRANCE

CLAPIER, Francois
Ingenieur de Radioprotection
CNRS-IN2P3
Institut Physique Nucléaire
SPR
F-91406 ORSAY

Tel: +33 (1) 6915 7170
Fax: +33 (1) 6915 6470
Eml: clapier@ipno.in2p3.fr

DUARTE, Helder
CEA Bruyères-le-Châtel
BP 12
F-91191 BRUYÈRES-LE-CHÂTEL

Tel: +33 (1) 69 26 42 82
Fax: +33 (1) 69 26 70 63
Eml: duarte@bruyeres.cea.fr

DUCAUZE, Marie
CEA Bruyères-le-Châtel
BP 12
F-91680 BRUYÈRES-LE-CHÂTEL

Tel: +33 (1) 69 26 56 07
Fax: +33 (1) 69 26 70 63
Eml: ducauze@bruyeres.cea.fr

FREHAUT, Joel
Service de Physique Nucléaire
CEA/Bruyères-le Châtel
BP N° 12
F-91680 BRUYÈRES-LE-CHÂTEL

Tel: +33 (1) 69 26 47 23
Fax: +33 (1) 69 26 70 63
Eml: joel.frehaut@cea.fr

GALIN, Joel
GANIL
BP-5027
F-14076 CAEN Cedex 05
Tel: +33 (2) 31 45 45 74
Fax: +33 (2) 31 45 46 65
Eml: galin@ganil.fr

LERAY, Sylvie
CEA Saclay
DAPNIA/SPhN
F-91191 GIF-SUR-YVETTE Cedex
Tel: +33 (1) 69 08 83 61
Fax: +33 (1) 69 08 75 84
Eml: sleray@cea.fr

LETOURNEAU, Alain
GANIL
BP 5027
F-14076 CAEN Cedex 5
Tel: +33 (2) 31 45 45 49
Fax: +33 (2) 31 45 46 65
Eml: letourneau@ganil.fr

PAUWELS, Nicolas
CNRS-IN2P3
Institut Physique Nucléaire
SPR
F-91406 ORSAY
Tel: +33 (1) 69 15 62 67
Fax: +33 (1) 69 15 45 16
Eml: pauwels@ipno.in2p3.fr

RIDIKAS, Danas
CEA Saclay
DSM/DAPNIA/SPhN
F-91191 GIF-SUR-YVETTE Cedex
Tel: +33 (1) 69087847
Fax: +33 (1) 69087584
Eml: ridikas@cea.fr

TOCCOLI, Cecile
Commissariat a l'Énergie Atomique
DIF/DPTA/SPN
BP 12
F-91680 BRUYÈRES-LE-CHÂTEL
Tel: +33 (1) 69 26 49 92
Fax: +33 (1) 69 26 70 63
Eml: cecile.toccoli@cea.fr

VOLANT, Claude
DAPNIA/SPhN
CEA Saclay
F-91191 GIF-SUR-YVETTE Cedex
Tel: +33 (1) 69 08 55 85
Fax: +33 (1) 69 08 75 84
Eml: cvolant@cea.fr

GERMANY

FILGES, Detlef
Institut für Kernphysik
Forschungszentrum Jülich GmbH
D-52425 JÜLICH
Tel: +49 (2461) 61 5232
Fax: +49 (2461) 61 3930
Eml: d.filges@fz-juelich.de

GOLDENBAUM, F.
Institut für Kernphysik
Forschungszentrum Jülich GmbH
D-52425 JÜLICH
Tel: +49 (2461) 61 4250
Fax: +49 (2461) 61 3930
Eml: F.Goldenbaum@fz-juelich.de

HERBACH, Claus-Michael
Hahn-Meitner-Institute Berlin
Glienickerstr. 100
D-14109 BERLIN

Tel: +49 8062 2717
Fax: +49 8062 2293
Eml: herbach@hmi.de

HILSCHER, Dietrich
Hahn-Meitner-Institut Berlin
Glienickerstr. 100
D-14109 BERLIN

Tel: +49 8062 2718
Fax: +49 8062 2293
Eml: hilscher@hmi.de

JAHNKE, Ulrich
Hahn-Meitner-Institut Berlin
Glienicker str.100
D-14109 BERLIN

Tel: +49 8062 2727
Fax: +49 8062 2293
Eml: Jahnke@hmi.de

LEUSCHNER, Albrecht
Deutsches Elektronen-Synchrotron
DESY
Notkestrasse 85
D-22607 HAMBURG

Tel: +49 (0) 40 8998 2043
Fax: +49 (0) 40 8998 3282
Eml: Albrecht.Leuschner@desy.de

* MARES, Vladimir
GSF
Institute of Radiation Protection
Ingolstaedter Landstr. 1
D-85764 NEUHERBERG

Tel: +49 (89) 5996 838 or 3187 2652
Fax: +49 (89) 5996 840 or 3187 3323
Eml: mares@gsf.de

MICHEL, Rolf
Zentrum für Strahlenschutz
und Radiookologie der
Universitaet Hannover (ZSR)
Am Kleinen Felde 30
D-30167 HANNOVER

Tel: +49 (171) 644 2719
Fax: +49 (511) 762 3319
Eml: michel@mbox.zsr.uni-hannover.de

NEEF, Ralf D.
Institut für Kernphysik
Forschungszentrum Jülich GmbH
D-52425 JÜLICH

Tel: +49 (2461) 61 62 24
Fax: +49 (2461) 61 39 30
Eml: r.d.neef@fz-juelich.de

SCHAAL, Hartwig
Institut für Kernphysik
Forschungszentrum Jülich GmbH
D-52425 JÜLICH

Tel: +49 (2461) 61 4004
Fax: +49 (2461) 61 3930
Eml: h.schaal@fz-juelich.de

STERZENBACH, Guenter
Institut für Kernphysik
Forschungszentrum Jülich GmbH
D-52425 JÜLICH

Tel: +49 (2461) 61 4612
Fax: +49 (2461) 61 3930
Eml: G.Sterzenbach@fz-juelich.de

TICHTCHENKO, Vladimir
Hahn-Meitner-Institute Berlin
Glienickerstr. 100
D-14109 BERLIN
Tel: +49 8062 2717
Fax: +49 8062 2293
Eml: tichtchenko@hmi.de

WOHLMUTHER, M.
Institut für Kernphysik
Forschungszentrum Jülich GmbH
D-52425 JÜLICH
Tel: +49 (2461) 61 3415
Fax: +49 (2461) 61 3930
Eml: M.Wohlmuther@fz-juelich.de

ISRAEL

YARIV, Yair
Soreq Nuclear Research Centre
YAVNE 81800
Tel: +972 8 943 4789
Fax: +972 8 943 4157
Eml: Yariv@ndc.soreq.gov.il

ITALY

MENAPACE, Enzo
ENEA CRE Clementel
Applied Physics Division
via Don G. Fiammelli 2
I-40128 BOLOGNA
Tel: +39 051 60 98 239
Fax: +39 051 60 98 359
Eml: menapace@bologna.enea.it

PELLICCIONI, Maurizio
INFN
Laboratori Nazionali di Frascati
Casella Postale 56
I-00044 FRASCATI
Tel: +39 (06) 940 32246
Fax: +39 (06) 940 32364
Eml: maurizio.pelliccioni@lnf.infn.it

ROLLET, Sofia
CRE-ENEA
ENEA Fusion Division
via E. Fermi 27
00044 FRASCATI (Roma)
Tel: +39(0)6 94005825
Fax: +39(0)6 94005314
Eml: rollet@frascati.enea.it

ZAFIROPOULOS, Demetre
Head of Radiation Protection Service
INFN Laboratori Nazionali di Legnaro
via Romea, 4
35020 LEGNARO-PADOVA
Tel: +39 049 8068394
Fax: +39 049 8068889
Eml: zafiropoulos@lnl.infn.it

JAPAN

HAYASHI, Katsumi
Hitachi Engineering Company
3-2-1 Saiwai-cho
Hitachi-shi
IBARKI-KEN 317-0065
Tel: +81 (294) 21 7330
Fax: +81 (294) 23 6619
Eml: k_hayashi@psg.hitachi-hec.co.jp

HIRAYAMA, Hideo
KEK, High Energy Accelerator
Research Organisation
Oho 1-1
Tsukuba-shi
IBARKI-KEN 305-0801

Tel: +81 (298) 64 5489
Fax: +81 (298) 64 1993
Eml: hideo.hirayama@kek.jp

NAKAMURA, Takashi
Cyclotron and Radioisotope Centre
Tohoku University
Aramaki, Aoba, Aoba-ku
SENDAI 980-8578

Tel: +81 (22) 217 7805
Fax: +81 (22) 217 7809
Eml: nakamura@cyric.tohoku.ac.jp

NAKANE, Yoshihiro
Centre for Neutron Science
JAERI
Tokai-mura, Naka-gun
IBARKI-KEN 319-1195

Tel: +81 (29) 282 6329
Fax: +81 (29) 282 6496
Eml: nakane@shield4.tokai.jaeri.go.jp

NAKAO, Noriaki
KEK, High Energy Accelerator
Research Organisation
1-1 Oho, Tsukuba-shi
IBARKI-KEN 305-0801

Tel: +81 (298) 79 6004
Fax: +81 (298) 64 4051
Eml: noriaki.nakao@kek.jp

SAKAMOTO, Yukio
External Dosimetry Laboratory
Department of Health Physics
JAERI
Tokai-mura, Naka-gun
IBARKI-KEN 319-1195

Tel: +81 (29) 282 5803
Fax: +81 (29) 282 6063
Eml: sakamoto@frs.tokai.jaeri.go.jp

* SHIN, Kazuo
Dept. of Nuclear Engineering
Kyoto University
Yoshida
Sakyo-ku
KYOTO606-8501

Tel: +81 (75) 753 5825
Fax: +81 (75) 753 5845
Eml: shin@nucleng.kyoto-u.ac.jp

YOSHIZAWA, Nobuaki
Mitsubishi Research Institute
3-6, Otenachi 2-Chome
Chiyoda-ku
TOKYO, 100-8141

Tel: +81 (3) 3277 0772
Fax: +81 (3) 3277 3480
Eml: yoshizaw@mri.co.jp

THE NETHERLANDS

* KONING, Arjan
NRG Nuclear Research and
Consultancy Group
Building 34.333
Westerduinweg 3, P.O. Box 25
NL-1755 ZG PETTEN

Tel: +31 (224) 56 4051
Fax: +31 (224) 56 3490
Eml: koning@nrg-nl.com

RUSSIAN FEDERATION

BATYAEV, Vyacheslav F.
Institute for Theoretical and
Experimental Physics
B. Cheremushkinskaya 25
117259 MOSCOW

Tel: +7 (095) 123 6383
Fax: +7 (095) 127 0543
Eml: vfb@itep.ru

TITARENKO, Yuri
Institute for Theoretical and
Experimental Physics
B. Cheremushkinskaya 25
117259 MOSCOW

Tel: +7 095 123 6383
Fax: +7 095 127 0543
Eml: Yury.Titarenko@itep.ru

ZHIVUN, Valery M.
Institute for Theoretical and
Experimental Physics
B. Cheremunshkinskaya 25
117259 MOSCOW

Tel: +7 095 123 6383
Fax: +7 095 127 0543
Eml: zhivun@mail.ru

SLOVENIA

KODELI, Ivan
Institut Josef Stefan
Jamova 39
1000 LJUBLJANA

Tel: +386 (61) 188 5412
Fax: +386 (61) 161 2335
Eml: ivan.kodeli@ijs.si

UNITED STATES OF AMERICA

* HERTEL, Nolan E.
George Woodroof School of
Mechanical Engineering
Georgia Institute of Technology
900 Atlantic Dr.
ATLANTA, GA 30332-0405

Tel: +1 (404) 894 3601
Fax: +1 (404) 894 9325
Eml: nolan.hertel@me.gatech.edu

IPE, Nisy E.
SLAC
Radiation Physics Dept. MS-48
2575 Sand Hill Road
MENLO PARK, CA 94025

Tel: +1 (650) 926 4324
Fax: +1 (650) 926 3569
Eml: ipe@slac.stanford.edu

KIRK, Bernadette L.
Radiation Safety Information
Computational Center
Oak Ridge National Laboratory
Post Office Box 2008
OAK RIDGE, TN 37831-6362
Tel: +1 (865) 574 6176
Fax: +1 (865) 574 6182
Eml: blk@ornl.gov

MASHNIK, Stepan
Nuclear Physics Group, T-16
MS B283
Los Alamos National Laboratory
LOS ALAMOS, NM 87545
Tel: +1 (505) 667 9946
Fax: +1 (505) 667 1931
Eml: mashnik@t2y.lanl.gov

ROESLER, Stefan
SLAC
P.O. Box 4349, MS-48
STANFORD, CA 94309
Tel: +1 650 926 2048
Fax: +1 650 926 3569
Eml: sroesler@slac.stanford.edu

ROKNI, Sayed H.
Radiation Physics Department
SLAC
P.O.Box 4349, MS 48
STANFORD, CA 94309
Tel: +1 (650) 926 3544
Fax: +1 (650) 926 3569
Eml: rokni@slac.stanford.edu

SUTTON, Michele
Georgia Institute of Technology
Neely Nuclear Research Center
900 Atlantic Drive
ATLANTA, GA 30332-0425
Tel: +1 (404) 894 3600
Fax: +1 (404) 894 9325
Eml: sutton@nukeisit.gatech.edu

* WATERS, Laurie S.
MS H816
Los Alamos National Lab.
LOS ALAMOS, NM 87544
Tel: +1 (505) 665 4127
Fax: +1 (505) 667 7443
Eml: lsw@lanl.gov

INTERNATIONAL ORGANISATIONS

BERKVENS, Paul
ESRF, European Synchrotron
Radiation Facility
BP 220
6 rue Jules Horowitz
38043 GRENOBLE Cedex
Tel: +33 (4) 76 88 20 71
Fax: +33 (4) 76 88 24 18
Eml: berkvens@esrf.fr

SARTORI, Enrico
OECD/NEA Data Bank
Le Seine-Saint Germain
12 boulevard des Iles
F-92130 ISSY-LES-MOULINEAUX
Tel: +33 (1) 45 24 10 72/78
Fax: +33 (1) 45 24 11 10/28
Eml: sartori@nea.fr

VAZ, Pedro**
OECD/NEA Data Bank
Le Seine-Saint Germain
12 boulevard des Iles
F-92130 ISSY-LES-MOULINEAUX
Tel: +33 (1) 45 24 10 74
Fax: +33 (1) 45 24 11 10
Eml: vaz@nea.fr

* FERRARI, Alfredo
CERN – SL Division
Bldg. 864-2-D05
CH-1211 GENÈVE 23
Tel: +41 (22) 76 76119
Fax: +41 (22) 76 77555
Eml: alfredo.ferrari@cern.ch

KADI, YACINE
CERN
Emerging Energy Technologies
SL Division
CH-1211 GENÈVE 23
Tel: +41 (22) 7679569
Fax: +41 (22) 7677555
Eml: Yacine.Kadi@cern.ch

LACOSTE, Veronique
CERN
SL/EET Division
CH-1211 GENÈVE 23
Tel: +41 (22) 767 8165
Fax: +41 (22) 767 7555
Eml: veronique.lacoste@cern.ch

SILARI, Marco
CERN
TIS-RP
CH-1211 GENÈVE 23
Tel: +41 (22) 767 3937
Fax: +41 (22) 767 5700
Eml: marco.silari@cern.ch

ULRICI, Luisa
CERN
CH-1211 GENÈVE 23
Tel: +41 (22) 767 21 51
Fax: +41 (22) 767 57 00
Eml: Luisa.Ulrici@cern.ch

VINCKE, Heinz
CERN
CH-1211 GENÈVE 23
Tel: +41 (22) 767 8864
Fax: +41 (22) 767 9080
Eml: Heinz.Vincke@cern.ch

VINCKE, Helmut
CERN – EP Division
CH-1211 GENÈVE 23
Tel: +41 (22) 767 12 78
Fax: +41 (22) 767 12 20
Eml: Helmut.Vincke@cern.ch

** Regrets not being able to attend*

** *Current address:* Departamento de Fisica
Instituto Superior Tecnico
Av. Rovisco Pais
1049 LISBOA
Tel: +351 21 994 62 30
Fax: +351 21 994 10 39
Eml: pedrovaz@itn.pt

Appendix 3

EXPERT GROUP ON SHIELDING ASPECTS OF ACCELERATORS, TARGETS AND IRRADIATION FACILITIES (SATIF)*

Present chair:	F. Clapier (IPNO, France)
Next chair:	N. Ipe (SLAC, USA)
Members:	All NEA Member countries
Date of creation:	June 2000
Duration:	To 13th NSC meeting (2003)

Scope

The expert group deals with multiple aspects related to radiation safety, activation and shielding modelling and design of accelerator systems including electron-, proton-, ion-accelerators, spallation sources and the following type of facilities: synchrotron radiation facilities, transmutation sources, accelerator driven systems, free electron lasers, high power targets and dumps.

Objectives

- To promote the exchange of information among scientists within the defined scope.
- To identify areas in which international co-operation could be fruitful.
- To carry on a programme of work in order to achieve progress in specific agreed priority areas.
- To encourage free access to computer codes sources and cross-section and integral experiments data, and making them available at information centres.

Deliverables

- Assessment of needs in experimental data for the validation of models and codes.
- Assessment of needs for evaluated nuclear data and processed data libraries.
- Organisation of shielding experiments.

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* *Discussed at SATIF-5 (July 2000) and transmitted for endorsement to NSC.*

- Collection and compilation of experimental data sets.
- Assessment of models, computer codes, parameterisations and techniques available for accelerator shielding design purposes.
- Validation of computer codes and models available to perform particle transport simulation.
- Meeting at least once every two years and publication of proceedings.
- Reporting to the NEA Nuclear Science Committee.

Appendix 4

BRIEF SUMMARY OF THE WORKSHOP ON MODELS AND CODES FOR SPALLATION NEUTRON SOURCES*

The SARE-5 meeting officially started on Monday morning, 17 July 2000. François Clapier, co-organiser of both the SARE-5 and SATIF-5 meetings, welcomed the participants. Enrico Sartori and Pedro Vaz, of the OECD/NEA, represented the secretariat of the meeting.

The special topic of SARE-5 is "Models and Codes for Spallation Neutron Sources (SNS)". Detlef Filges of Germany, General Chair for SARE-5, gave the introduction. He briefly discussed the three major projects on SNS: the European Spallation Source (ESS), the US SNS, and the Japanese Spallation Source. The latter will start at 1 MW, as compared to 5 MW for the ESS. Filges said that there is a need to identify important processes in support of engineering design. Problems in spallation studies include the difficulty in estimating microscopic quantities from macroscopic quantities and also the difficulty in generating measured quantities from calculated ones. Major computer code systems used in spallation analysis are: CALOR (US/ORNL), HERMES (Germany), Lahet Code System (LCS) (US/LANL) and MCNPX (US/LANL). There is a great need to improve these codes so that they can handle higher energy transport for incident protons in the GeV range.

The first session covered experimental observations. C.M. Herbach of Hahn-Meitner-Institut, Germany, presented a comparison of calculations using three different codes: Intra Nuclear Cascade (INC) coupled with GEMINI, LAHET and HERMES. He compared measured observations against those computed by these three codes. Measured observations are for production cross-sections of neutrons and charged particles, carried out between 0.8 and 2.5 GeV. The measurements were done with the neutron scintillation tank and silicon (NESSI) ball detector in Jülich.

R. Michel of Hannover University presented excitation functions of residual nuclide production of light heavy ions and neutron double differential cross-sections. S. Leray of CEA Saclay showed results on neutron double-differential cross-sections measured at SATURNE Saclay on different thin and thick targets up to 1.6 GeV and on isotope production on Pb measured at GSI Darmstadt. Computer simulations were produced using LAHET (Bertini and ISABEL options), Liège INC and TIERCE including the different INC models Bertini, Cugnon or Isabel. Neutron data are rather well reproduced when using Cugnon INC model, however no single computer code can model the isotopic distributions correctly.

The next session covered Intra Nuclear Cascade (INC) models. Three INC models were presented: Liege INC, ISABEL and BRIC. J. Cugnon of the University of Liège, Belgium, discussed the Liège INC model. INC was developed for heavy ion collisions in 1980. INC continues to be developed, but is available through Cugnon.

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* *Held in Paris, France at the OECD headquarters in Château de la Muette on 17-18 July 2000, embedded in the SARE-5 meeting.*

Y. Yariv of Israel (Soreq Nuclear Research Centre) discussed his modifications to the ISABEL code – an INC model for hadrons. ISOBAR is a precursor of ISABEL. It calculates properties of single high-energy particles with a complex nucleus, using Monte Carlo simulations. The cascading of particles was discussed at length – particles are terminated when they leave the target or get below a certain energy cut-off. ISABEL is a generalisation to nucleus-nucleus collisions. A new version of ISABEL is available through Y. Yariv.

H. Duarte of CEA BRC discussed the BRIC 1.0 code. BRIC is a new INC code which calculates hadron nucleus reactions by Monte Carlo in the 150 MeV-1.5 GeV range. BRIC 1.0 results were compared with experiments and had good agreement.

F. Goldenbaum of FZ-Jülich discussed several nuclear transport models. HERMES and LCS were compared on neutron multiplicity distribution for 1.2 GeV on lead. The results were good for 2 cm, 15 cm and 35 cm. The agreement was still good for 2.5 GeV. The INC (Cugnon) code was then compared with LAHET (Bertini) and ISABEL using a gold target. These codes appear to be in agreement up to 400 MeV, but differ in the GeV range.

The latest developments in MCNPX were presented by S. Mashnik of LANL.

Y. Kadi of CERN then presented the Energy Amplifier Monte Carlo (EA-MC) code developed at CERN. EA-MC follows spallation neutrons generated by FLUKA-99. EA-MC keeps track of about 2 550 isotopes in a database. Of these isotopes, 393 have transport cross-sections.

A general summary of models used in accelerator-driven systems was presented by S. Mashnik.

A general discussion followed on Tuesday morning. The SARE-5 group felt that there is a need to concentrate on the following:

- Proton on mercury, lead, bismuth, iron and gold.
- Energy range $0.3 < E < 3$ GeV.
- For thin targets, double differential cross-sections.
- For thick targets, same as for thin plus distribution of residual nuclei.
- Provision of intermediate quantities from INC models.
- List of suggestions for experiments.
- Set up a web site to facilitate communication (Guenter Sterzenbach of Germany will do this).
- Keep these facilities in mind: LANSCE (800 MeV), Mol (350 MeV), ESS and SNS (1 GeV), JAERI/KEK (2-5 GeV).