

Sixth Meeting of the Task Force on
**Shielding Aspects of Accelerators,
Targets and Irradiation Facilities**

10-12 April 2002
Stanford Linear Accelerator Center (SLAC)
Menlo Park, CA, USA

Jointly organised by

Organisation of Economic Co-operation and Development
Stanford Linear Accelerator Center (SLAC)
Radiation Safety Information Computational Center (RSICC)
Shielding Working Group of the Reactor Physics Committee of Japan

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

FOREWORD

Nuclear energy covers a field much wider than that of nuclear power. In fact, atomic and nuclear energy applications involve a large range of scientific and technological activities using a variety of machines and analysis techniques. Activities in this area have increased over the years and consequently the OECD/NEA Nuclear Science Committee sponsors an increasing amount of work in this domain.

One of these activities concerns “Shielding Aspects of Accelerators, Targets and Irradiation Facilities” (SATIF). A series of workshops have been held over the last decade: SATIF-1 was held on 28-29 April 1994 in Arlington, Texas; SATIF-2 on 12-13 October 1995 at CERN in Geneva, Switzerland; SATIF-3 on 12-13 May 1997 at Tohoku University in Sendai, Japan; SATIF-4 on 17-18 September 1998 in Knoxville, Tennessee, SATIF-5 on 17-21 July 2000 at OECD in Paris, France, and SATIF-6 was held from 10-12 April 2002 at the Stanford Linear Accelerator Center (SLAC), Menlo Park, California. SATIF-7 is scheduled for 17-18 May 2004 at ITN, Sacavem, Portugal and SATIF-8 is planned for 2006 in the Republic of Korea.

Each workshop is hosted by organisations having accelerator facilities and experts that enhance the interaction between local expertise and experts from the international community. SATIF-6 was held at the prestigious Stanford Linear Accelerator Center (SLAC) in California and the chairman of the workshop, Sayed H. Rokni, arranged visits to the different facilities. It also was an opportunity to become acquainted with the work being carried out on the Next Linear Collider (NLC). This powerful new instrument will provide a frontier facility for basic research on elementary particles. Stretching some 20 miles, it will smash electrons into their antimatter counterparts, creating exotic new particles from pure energy. Scientists expect research at this facility to answer fundamental questions about the behaviour of matter and the origins of the universe. It will involve the creativity of scientists and engineers from many nations in its design, construction and use.

SATIF-6 was jointly organised by the:

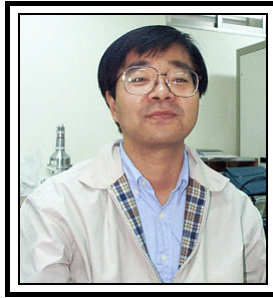
- OECD Nuclear Energy Agency;
- Stanford Linear Accelerator Center (SLAC);
- Radiation Safety Information Computational Center (RSICC);
- Shielding Working Group of the Reactor Physics Committee of Japan.

The current proceedings provide a summary of the discussions, decisions and conclusions as well as the text of the presentations made at the sixth SATIF meeting.

This text is published on the responsibility of the Secretary-General of the OECD. The views expressed do not necessarily correspond to those of the national authorities concerned.

Professor Kazuo Shin
(1950-2001)

Associate Professor
Nuclear Engineering Department, Kyoto University, Japan



*These proceedings are dedicated to the memory of our colleague,
who made major contributions to the progress of SATIF.*



Acknowledgements

Acknowledgements are due to the members of the SATIF-6 Technical Programme Committee: S. Rokni (SLAC, Chairman), A. Fassò (CERN), H. Hirayama (KEK), B.L. Kirk (RSICC), N. Mokhov (FNAL), T. Nakamura (U. Tohoku, Vice Chair), M. Silari (CERN), G. Stevenson, P. Vaz (ITN), L. Waters (LANL) and E. Sartori (OECD/NEA, Secretary), for their contribution in shaping the technical programme, and to all participants who contributed the valuable work and ideas described in these proceedings. Special thanks go to Amanda Costa for her dedication in editing these contributions and her efforts to improve the layout of the text.



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EXECUTIVE SUMMARY

Scope

The Expert Group on Shielding of Accelerators, Targets and Irradiation Facilities (SATIF) deals with multiple aspects related to the modelling and design of accelerator shielding systems including electron accelerators, proton accelerators, ion accelerators, spallation sources and several different types of facilities, such as synchrotron radiation facilities, very-high-energy radiation facilities, accelerator production of tritium and free electron lasers.

Objectives

Objectives of the SATIF-6 meeting include:

- 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;

Deliverables

Deliverables emerging from this meeting include:

- assessment of needs in experimental data for the validation of models and codes;
- organisation of shielding experiments;
- collection and compilation of experimental data sets;
- assessment of models, computer codes, parametrisations and techniques available for accelerator shielding design purposes;
- validation of computer codes and models available to perform particle transport simulation;
- organisation of international benchmark and intercomparison exercises;
- organisation of workshops and co-organisation of conferences relevant in the area of its scope and computing radiation dosimetry (e.g. QUADOS);
- publication of workshop proceedings;
- editing of an “Accelerator Shielding Handbook”;
- maintenance of SATIF listserver and archive of technical discussion between members.

SATIF-6 workshop

Introduction

The sixth SATIF workshop was hosted by the Stanford Linear Accelerator Center (SLAC), Menlo Park, California, USA. The objectives were to present and assess achievements on agreed actions agreed upon at the previous meeting held in Paris in 2000, and to discuss and recommend actions where a strong need is identified for further work in theoretical model development, experimental work and benchmarking for model validation.

The workshop was opened and the participants welcomed by the General Chair Sayed Rokni (SLAC Radiation Physics Group). He also called to mind the passing away of Professor Kazuo Shin of Kyoto University. This is a great loss to the SATIF group; Professor Shin contributed much to the success of the SATIF activities. It was agreed that the proceedings of SATIF-6 would be dedicated to him. The Chair then noted that Professor Nakamura was accompanied by five of his students, and commented that this is an effective means of transmitting know-how to the younger generation.

Professor Paterson, Associated Director for the Technical Division of SLAC also welcomed the participants to SLAC. He presented a brief history of SLAC, including the construction, 40 years ago, of what was at the time the world's largest linear accelerator. He continued in this vein, mentioning the SPEAR rings, the PEP-I and PEP-II double rings, the linear collider SLC, the establishment of a BIO-X satellite for structural molecular biology and finally the work being carried out on the Next Linear Collider. He then emphasised the importance of international collaboration in this area and at SLAC in particular.

Enrico Sartori welcomed participants on behalf of the OECD/NEA and thanked SLAC for hosting this workshop.

The workshop was attended by about 50 participants from 10 different countries, representing 26 organisations. Thirty-three (33) presentations were made, organised into six topical sessions:

- source term and related data – proton and ion accelerators and spallation source;
- measurements and calculations of induced radioactivity;
- benchmarking – calculations and results;
- dose and related issues;
- status of computer codes, cross-sections and shielding data libraries;
- shielding in medical accelerator applications (special topic).

The workshop was concluded with sessions on follow-up of past SATIF agreements and actions, and discussion/summary and future actions.

Specific actions agreed upon are:

- Collection of the different data produced on dose conversion coefficients, store them in comparative tables and make them available internationally through the NEA Data Bank, along with the descriptions of codes and methods used. This should help to resolve the remaining discrepancies.

- All authors of the major computer codes for accelerator shielding problems should be invited to the next SATIF meeting to present the latest features of codes, to discuss further needed developments and share new physics models and developments.
- The know-how and experience gathered by the SATIF group over recent years should be synthesised into a handbook – “Accelerator Shielding Handbook” – for the benefit of an increasingly larger community of accelerator shielders. No current handbook exists on this subject and, a strong need for it being expressed, its production was agreed upon. The editors of the handbook were designated among those SATIF members having editing experience. This should be prepared over a period of two years and be available in draft form for the next SATIF workshop. The chapters will cover: physics basics for accelerator shielding, facilities and their shielding and dosimetry approaches, simple fast methods for estimating orders of magnitude, existing state-of-the-art transport codes (MC and deterministic), data for accelerator shielding and experimental benchmark data.
- Sharing of modules for translating geometries for different radiation transport codes. This will reduce efforts in benchmarking and ensure that input to codes is coherent among different users.
- At the special session on shielding in medical accelerator applications it was concluded that medical accelerator physicists greatly benefit from SATIF activities, and as some of the medical-accelerator-related activities are equally of interest to SATIF, it was recommended that benchmarks of common interest to the two communities be carried out, in particular benchmarking of simplified methods that are more widely used in the medical area; standardisation of mazes for developing analytical tools was recommended. A general need for increased intercommunication between these fields was identified.
- Much progress was achieved as concerns the intercomparison of medium-energy neutron attenuation in iron and concrete. However, participants should provide further results in order to resolve discrepancies found for iron and the study should be extended up to 100 GeV to enable improved formulation of attenuation length trends at high energies. Also, results of appropriate experiments need to be selected to benchmark and verify the calculations and models.
- Newly developed codes for hadron transport, transport in complex ducts and cascades of particles have been developed. These should be acquired by the code centres for sharing among the community of experts.
- Additional (γ,n) data for accelerator shielding applications need to be collected and made available. Neutron shields are becoming increasingly important for electron accelerators as they increase in energy and power.
- The group has expressed interest in contributing to the EU Quality Assurance for Numerical Dosimetry (QUADOS) initiative.

The mandate of this expert group has been extended until 2005. As this group meets only every two years, a period judged as required for a consistent progress to be reported, it will seek a further extension of the mandate during the 2005 NSC meeting. In view of the number of large accelerator facilities in planning and under construction within the OECD area, the need for extended and improved databases, methods and codes in accelerator and target shielding is growing. Over the years, the radiation shielding community has benefited from the co-operation which takes place under the aegis

of SATIF, and the group has established itself as the international forum for addressing priority issues in this area. SATIF will contribute shared research results to emerging priority areas.

The seventh NSC meeting on Shielding Aspects of Accelerators, Targets and Irradiation Facilities (SATIF-7) will be hosted by ITN, Portugal from 17-18 May 2004 in connection with the ICRS10 and RPS-2004 conferences. The group organising these series of meetings should prepare a new draft mandate proposal for discussion at the NSC bureau meeting and subsequent decision at the next NSC meeting in June 2003.

Sponsors

This event was jointly organised by the:

- OECD Nuclear Energy Agency;
- Stanford Linear Accelerator Center (SLAC);
- Radiation Safety Information Computational Center (RSICC);
- Shielding Working Group of the Reactor Physics Committee of Japan.

Scientific Committee

The members of the Scientific Committee of SATIF-6 were:

| | |
|-------------------------------------|----------------------------------|
| A. Fassò (CERN) | E. Sartori (OECD/NEA, Secretary) |
| H. Hirayama (KEK) | M. Silari (CERN) |
| B. Kirk (RSICC) | G. Stevenson (CERN) |
| N. Mokhov (FNAL) | P. Vaz (ITN) |
| T. Nakamura (U. Tohoku, Vice Chair) | L. Waters (LANL) |
| S. Rokni (SLAC, Chair) | |

Executive Committee

The members of the Executive Committee, in charge of preparing the Technical Programme for SATIF-6 and submitting it to the Scientific Committee, were:

| | |
|-------------------------------------|----------------------------------|
| B. Kirk (RSICC) | E. Sartori (OECD/NEA, Secretary) |
| T. Nakamura (U. Tohoku, Vice Chair) | G. Stevenson (CERN) |
| S. Rokni (SLAC, Chair) | P. Vaz (ITN) |

Annex

SATIF-6 PROGRAMME

10-12 April 2002

Stanford Linear Accelerator Center

2575 Sand Hill Road, Menlo Park, CA 94025

General Chair: Sayed Rokni • General Vice-chair: Takashi Nakamura

Wednesday, 10 April

Registration

Introductory and welcome remarks (*Rokni, Paterson, Sartori*)

Session I: Source Term and Related Data – Proton and Ion Accelerators and Spallation Source

Chairs: T. Nakamura, A. Fassò

T. Nakamura, T. Kurosawa, T. Kato

Double-differential Thick Target Neutron Yields by Heavy Ions

H. Nakashima and ASTE Collaboration Team

Current Status on AGS Spallation Target Experiment

S. Teichmann, B. Amrein, J. Gerig, W. Hajdas, H. Temnitzer

Dose Rate Measurements behind Different Shielding for 250 MeV Protons on a Thick Copper Target

I. Koprivnikar, E. Schachinger

The Biological Shield of a High-intensity Spallation Source: A Monte Carlo Design Study

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Attenuation Curves in Concrete of Neutrons from 100-800 MeV per Nucleon He, C and Ne Ions

M. Silari and H. Vincke

The Effect of a Beam Loss at the PS/n_TOF Interface of the CERN PS Complex

C. Borcea, P. Cennini, A. Ferrari, Y. Kadi, V. Lacoste, E. Radermacher, C.

Rubbia, V. Vlachoudis, L. Zanini

Radioprotection and Shielding Aspects of nTOF Spallation Source

L. Heilbronn, H. Iwase, Y. Iwata, T. Nakamura, R. Ronningen, L. Townsend, Y. Tozawa
Neutron Production Measurements Relevant to Shielding for Space-related Activities

M. Brugger, G.R. Stevenson
The Radiological Situation in the NA60 Experiment

Thursday, 11 April

Session II: Measurements and Calculations of Induced Radioactivity

Chair: M. Silari

S.H. Rokni, A. Fassò, T. Gwise, J.C. Liu, S. Roesler, R. Sit
Comparison of Calculations and Measurements of Induced Activity of Different Materials at SLAC

H. Vincke, I. Brunner, M. Huhtinen
Production of Radioactive Isotopes in Al, Fe and Cu Samples by Stray Radiation Fields at a Proton Accelerator

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FLUKA Calculations of Radionuclides, Star and Neutron Fluence in Soil around the High-energy Electron and Proton Linear Accelerators

H. Yashima, H. Sugita, T. Nakamura, Y. Uwamino, S. Ito, A. Fukumura
Induced Radioactivities of Spallation Products by Various Projectile Ions

Session III: Benchmarking Calculations and Results

Chairs: H. Hirayama, R.E. Prael

H. Hirayama
Intercomparison of the Medium-energy Neutron Attenuation in Iron and Concrete (4)

D. Ridikas and P. Vertes
Code and Data Benchmarking with the New IAEA Photonuclear Data Library

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Benchmarking Codes for Proton Radiography Applications

S. Roesler, J.C. Liu, S.H. Rokni
Calculation of Neutron Time-of-flight and Energy Spectra behind Thick Shielding of an Electron Accelerator and Comparison to Experimental Data

S. Taniguchi, M. Sasaki, T. Nunomiya, H. Iwase, S. Yonai, T. Nakamura, S.H. Rokni, J.C. Liu, S. Roesler, K. Kase
Shielding Experiment of Neutrons through Concrete Outside the Beam Dump of 28.4 GeV Electron Linear Accelerator

N. Nakao, N.V.Mokhov, Y.Irie, K.Yamamoto, A.Drozhdin (Withdrawn)
Deep Penetration Calculation Along the Whole Ring Tunnel of JAERI-KEK
3 GeV Proton Synchrotron Using MARS Code

*T. Nunomiya, N. Nakao, P. Wright, T. Nakamura, E. Kim, T. Kurosawa,
S. Taniguchi, M. Sasaki, H. Iwase, Y. Uwamino, T. Shibata, S. Ito, D.R. Perry*
Deep Penetration of Neutrons Produced by 800 MeV Protons through Concrete and
Iron at ISIS

G. Maino, E. Menapace
Photonuclear Reaction Data Calculations by Algebraic Model Approach for
Radiation Shielding Purposes in the International Context

Session IV Dose and Related Issues

Chairs: M. Pelliccioni, A. Leuschner

M. Pelliccioni
Conversion Coefficients: An Addition to Existing Data

V. Mares, H. Schraube
The Effect of the Fluence-to-dose Conversion Coefficients Upon the Dose
Estimation to Cosmic Radiation

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Feasibility Study on an Active Neutron Dosimeter Based on Carbon Activation for
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Benchmark Calculation with Simple Phantom for Neutron Dosimetry (2)

P.K. Job, J. Alderman
Radiation Levels Experienced by the Insertion Devices of the Third-generation
Synchrotron Radiation Sources

General discussion on Sessions I-IV

Friday, 12 April

Session V: Status of Computer Codes, Cross-sections and Shielding Data Libraries

Chairs: H. Hunter, N. Mokhov

H.T. Hunter, B.L. Kirk, J.B. Mannes Schmidt, E. Sartori
Progress Report on the Available Analytical Tools for Accelerator Shielding
Analysis 2002

S.G. Mashnik, K.K. Gudima, A.J. Sierk
Merging the CEM2k and LAQGSM Codes with GEM2 to Describe Fission and
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Interaction of Ion Beams with Tissue-like Media with the Shield Transport Code

K. Hayashi, R. Tayama, H. Handa, K. Shin, H. Hirayama, H. Nakano,

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Analytical Method for Multi-scattered Neutron in Cavity Used in DUCT-III Code

H. Iwase, T. Kurosawa, T. Nakamura, N. Yoshizawa, J. Funabiki

Development of Heavy-ion Transport Monte Carlo Code

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Implementation of Xenon Capture Gammas in FLUKA for Background Calculations in a Transition Radiation Detector

N. Mokhov

Status of MARS Code

Session VI: Shielding in Medical Accelerator Applications

Chairs: J.C. Liu, P. Vaz

B. Mukherjee

Principle of Radiological Shielding of Medical Cyclotrons

W.D. Newhauser, U. Titt, D.T. Dexheimer

A Perspective on Shielding Design Methods for Future Proton Therapy Facilities

Discussions

Session VII: Follow-up of Past SATIF Agreements and Actions

Co-ordinators: A. Fassò, H. Hirayama, H. Hunter

Session VIII: Discussion/Summary and Future Actions

Co-ordinators: M. Silari, N. Mokhov, T. Nakamura, P. Vaz

Closing remarks (*Sartori, Rokni*)