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**EXECUTIVE SUMMARY OF THE THIRD MEETING OF THE  
TASK FORCE ON SHIELDING ASPECTS OF ACCELERATORS,  
TARGETS AND IRRADIATION FACILITIES (SATIF)**

**Held at Tohoku University, Sendai, Japan  
12th and 13th May 1997**

**58963**

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**English text only**

**Executive Summary**  
**of the Third Meeting of the Task Force on**  
**Shielding Aspects of Accelerators, Targets and Irradiation Facilities**  
**(SATIF)**

**Held at Tohoku University (Sendai, Japan)**

**on 12th and 13th May 1997**

**Jointly organised by:**

**The OECD / NEA**  
**The Radiation Safety Information Computational Center (U.S.A.)**  
**The Shielding Working Group of the Reactor Physics Committee of Japan**  
**Tohoku University (Sendai, Japan)**

## **Third Meeting of the Task Force on Shielding Aspects of Accelerators, Targets and Irradiation Facilities (SATIF)**

### **Executive Summary**

The main objectives of the SATIF meetings are:

- to promote the exchange of information among scientists in this particular field,
- to identify areas where international co-operation can be fruitful and
- to carry on a programme of work in order to achieve progress in specific priority areas

The first meeting of SATIF (SATIF-1) took place in Arlington, Texas (U.S.A.) from 29-30 April 1994, and the second meeting (SATIF-2) was held from 12-13 October 1995 at CERN (European Laboratory for Particles Physics) in Geneva, Switzerland.

In the meantime, the seventh meeting of the NEA Nuclear Science Committee, held on 29th and 30th May 1996, approved the setting up of a specific Task Force on Shielding Aspects of Accelerators, Targets and Irradiation Facilities. As a consequence, the specialists meetings of SATIF became regular meetings of this Task Force.

The third Specialists' Meeting on Shielding Aspects of Accelerators Targets and Irradiation Facilities (SATIF-3) took place from 12-13 May 1997 in Sendai, Japan. It has been jointly organised by:

- the OECD Nuclear Energy Agency
- the Shielding Working Group of the Reactor Physics Committee of Japan
- the Radiation Safety Information Computational Center of the U.S.A., and
- Tohoku University

About fifty specialists attended the meeting, including physicists, engineers and technicians from laboratories, institutes, universities and industries in France (IN2P3), Germany (DESY, KFA Jülich, University of Munich), Italy (INFN, ENEA, LNGS), Sweden (University of Uppsala), Japan (JAERI, KEK, RIKEN, INS, Universities of Tokyo and Kyoto, Mitsubishi, Hitachi), U.S.A. (ANL, CEBAF, Fermilab, LANL, RSICC and SLAC) and the Russian Federation (IHEP) as well as representatives from international organisations (OECD/NEA and CERN).

The meeting was organised in six Sessions on the following topics:

**Session 1: Source Term and Related Data - Electron Accelerator**

- |                |   |
|----------------|---|
| Subsession 1-1 | Gas Bremsstrahlung and Narrow Beam Dosimetry  |
| Subsession 1-2 | Photoneutron and Photopion - DDX and Spectrum |

**Session 2: Source Term and Related Data - Proton and Ion Accelerator**

- |                |   |
|----------------|---|
| Subsession 2-1 | Thin Target Yield Measurements and Compilation  |
| Subsession 2-2 | Thick Target Yield Measurements and Compilation |
| Subsession 2-3 | Spallation Neutron Source Facility              |

**Session 3: Shielding**

- |                |   |
|----------------|---|
| Subsession 3-1 | Shielding Benchmark Problem - Review of Analysis    |
| Subsession 3-2 | Attenuation Length - Definition and Intercomparison |
| Subsession 3-3 | Shielding Experiments and Compilation               |

**Session 4: Miscellaneous Topics**

- |                |   |
|----------------|---|
| Subsession 4-1 | Neutron Facility for Shielding Experiments and Detector Calibration |
| Subsession 4-2 | Dosimetry and Instrumentation                                       |
| Subsession 4-3 | Activation  |
| Subsession 4-4 | Dose Conversion Coefficients and Anthropomorphic Phantom            |

**Session 5: Present Status of Computer Codes and Cross Section and Shielding Data Libraries**

- |                |   |
|----------------|---|
| Subsession 5-1 | Current Status of Computer Codes and Data sets for Accelerator Shielding Analysis |
| Subsession 5-2 | A Standard for Shielding Calculations   |

**Session 6: Discussions and Future Actions**

About 24 papers have been presented at the meeting. An extensive discussion took place during the Session 6, with the following objectives:

- to review the progress achieved since the SATIF-2 Meeting held at CERN the 12-13 October 1995,
- to monitor the status of the agreed actions (on experiments, 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

It was generally recognised that substantial developments took place during this period and that significant progress has been achieved. However, in order to achieve further progress it was felt by the participants that substantial efforts should be developed and actions undertaken in several areas concerning:

- 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, photopion 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);
- New or better measurements of many activation detector excitation functions (in particular C-11 production by neutrons and pions in the energy range above 100 MeV and Bi production);
- Benchmark data (development of new benchmark exercises, further compilation of existing benchmark data sets, etc.);
- Anthropomorphic computational models (compilation of existing models, phantom geometries and material compositions, dosimetric studies, etc.).

In the next section, a detailed list of the actions decided at the SATIF-3 Meeting is provided. Taking each of the presentations at SATIF-3, actions to be undertaken or continued and which concern the corresponding subject and/or related topics are listed as specific items; the names of those designated at the SATIF-3 Meeting, to perform the monitoring and follow up of the work are indicated. The listed actions reflect and incorporate the assessment, made by the SATIF-3 participants, of the status of the actions undertaken since the SATIF-2 Meeting.

As can be seen in the relevant items, two important topics proposed by Japan which will be followed-up at the SATIF-4 meeting concern:

- i) Shielding benchmark calculations and
- ii) Attenuation length calculations

These areas will greatly benefit from the definition of new experiments and by undertaking new international intercomparison exercises.

The high quality of the SATIF-3 meeting and its excellent organisation would not have been possible without the work of the Local Organising Committee and its Chairman Prof. T. Nakamura, and the continuous help of Dr. N. Yoshizawa.

Acknowledgements are also due to the members of the Scientific Committee of SATIF-3 (F. Clapier, A. Fassò, A. Ferrari, T. Gabriel, H. Hirayama, N. Ipe, B. Kirk, N. Mokhov, T. Nakamura, E. Sartori and L. Waters) for their contribution in shaping the technical programme.

## **NEW OR CONTINUED ACTIONS DECIDED AT SATIF-3**

### **GAS BREMSTHALUNG AND NARROW BEAM DOSIMETRY**

- ◆ **Narrow Beam Dosimetry - Organ and Effective Doses estimated between 1 MeV and 1 GeV (M. Pelliccioni)**
  - Include more organs in the computations
  - Include more energies in the calculations
  - Extend energy range of the computations
  - Determine how adequately average doses over organs describe Narrow Beam Effects
  - Co-ordinate effort to push official bodies (e.g. ICRP) to include Narrow Beams issues
  - Define a new quantity and agree on how to score it
- ◆ **Gas Bremsstrahlung Measurements performed at APS (P.K. Job)**
  - Compare with calculation

### **PHOTONEUTRON AND PHOTOPION DATA**

- ◆ **Nuclear Data Evaluation for the JENDL Photonuclear Data File (T. Fukahori)**
  - Make data available
  - How to handle targets for which data are not available ?

Need for experimental data to build confidence in predicting spectra and angular distributions:

- SLAC/KEK Collaboration has finalised a proposal
- CEBAF is building detectors

N. Ipe, A. Fasso, S. Ban and P. Degtyarenko are involved in the different aspects

- ◆ **Giant Dipole Resonance Photonuclear Cross-Sections (A. Fasso)**
  - Check energy regions near threshold
  - Redo calculations with new version of PEANUT/FLUKA
  - Complete data with parametrization for missing nuclei
  - Extend to heavier nuclei - **requesting support from NEA**
- ◆ **PICA95 Code (C.Y. Fu)**
  - Make code available
  - Make gamma and pion cross-section data available

- Comparison PICA95 and CEM95

- Photopion Yields and angular distributions are needed for  $E > 200$  MeV
- More generally, there is a lack of available data for double differential cross-sections of pion emission

**THIN TARGET  
(MEASUREMENTS AND COMPILATIONS)**

- ◆ **EXFOR Database (P. Vaz)**
  - Make access to data more user-friendly
  - Include database from LBL

**THICK TARGET  
(MEASUREMENTS, COMPILATIONS AND NEEDS)**

- ◆ **Thick Target Yield Measurements at TIARA, KEK, HIMAC (K. Shin)**  
(Several measurements have been carried out)
  - Benchmark new version of QMD Model with measured data
  - Continue experiments at HIMAC
  - Need data for Deuterons and He-3
- ◆ **Spallation Sources (D. Filges, L. Charlton, H. Ikeda)**
  - Data urgently needed for materials damage, gas production (H, He) for structural materials and lifetime limitations
  - Verification of cross-sections and nuclear models used for Mercury
  - Residual nuclei distributions for residual radioactivity, afterheat and Transmutation atom generation in target and structure materials, including recoiling nuclei in radiation damage
  - Verification of calculated integral and differential neutron flux density and secondary particle distribution from an engineered target-moderator-reflector system
  - Planned experiments - material irradiation at SING, LAMPF, Jülich
  - Multiplicity, energy deposition, charged particle production on thin and thick targets at Cosy - Jülich
  - Mercury target neutron performance and stress investigations at the AGS (BNL)

**Data needed for RAD damage by photons (magnets)**



<b>SHIELDING</b> <b>(EXPERIMENTS, FACILITIES, BENCHMARKS AND INTERCOMPARISONS)</b>
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◆ **Shielding Benchmark - Neutron Transmission for Iron and Concrete, for low, intermediate and high energy proton machines (Y. Nakane & K. Hayashi)**

- Perform new benchmark experiments:
  - 1) 43 MeV and 68 MeV through Iron and Concrete shields (TIARA, JAERI)
  - 2) 230 MeV protons through concrete shields (Loma Linda)
  - 3) 500 MeV protons through iron beam stop and concrete shields (KEK)
  - 4) 1.5 -24 GeV protons through concrete shields (AGS,BNL)
  - 5) 12 GeV protons through concrete shields (PS-CERN, KEK)
  - 6) 24 GeV protons through iron beam dump (PS-CERN)

The following questions need further discussion:

- Add FLUKA results to problem 1 in summary ?
- Add 200 MeV benchmark problem ?
- Add  $E > 400$  MeV results to intercomparisons to find asymptotic value of  $\lambda(E)$  ?
- Study total and low energy neutron dose equivalent - attenuation in Iron separately ?
- Study  $\lambda_D(E)$  for incident protons ?
- Add results of analytical (especially asymptotic) considerations to the intercomparisons?

Collaboration between code users and code developers is recommended before results are released
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◆ **Attenuation lengths (H. Hirayama)**

- Comparisons between codes
- Comparison of Iron cross-sections
- Detailed comparison of neutron spectrum
- Comparison at higher energies
- Comparison for neutrons produced by high energy protons

<b>Need definition of attenuation length</b>
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◆ **Shielding Experiments at TIARA and ISIS - Dose Equivalent Rates Behind Concrete for Target Irradiated by 0.05-10 GeV Proton Beams (Y. Sakamoto)**

- Need deeper bulk shielding experiments at intermediate and high energy (neutrons) to verify shielding codes for accelerator facility design

Plans exist to perform experiments at $E > 1$ GeV at KEK and AGS, BNL
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- ◆ **Neutron Facility for Shielding Experiment and Detector Calibration (T. Nakamura)**
  - Calibration and response measurements of various neutron detectors
  - Neutron scattering cross-section measurements
  - Charged particle production cross-section measurements
  - Neutron spectral and dose distribution in several media
  - Thin and Thick target neutron yields by heavy ions
  
- ◆ **CERN-CEC High Energy Reference Field Facility (M. Silari)**
  - Beam time available in 1998-1999. Participants encouraged to make use of this opportunity
  - Shielding configuration of Radiation Dump

<b>MISCELLANEOUS</b>
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- ◆ **Response Functions of Bonner Spectrometer in High Energy Neutron Fields (V. Mares)**
  - Perform simulations with MCNPX (LAHET-MCNP code merger) as soon as it will be released
  - Add another high energy channel
  
- ◆ **Energy Response of Tissue Equivalent Proportional Counter for Neutrons of E > 20 MeV (E. Gelfand)**
  - Make instrument response functions and instrument design details available
  
- ◆ **Test of Activation Detectors as Neutron Spectrometer (6-140 MeV) (F. Clapier)**
  - Continue experimental work
  
- ◆ **Computer Version of Handbook on Radionuclide Production Cross-Section at Intermediate Energies (N. Sobolevski)**
  - Make computer version available (limited subset)

<b>CONVERSION COEFFICIENTS</b>
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- ◆ **Conversion Coefficients for High Energy Radiation (M. Pelliccioni)**
  - Include photonuclear reactions
  - Provide results for pion calculations
  - Liaison ICRP-ICRU
  - Propose new operational quantity since ambient dose equivalent is not appropriate for high energies

◆ **Conversion Coefficients for High Energy Particles (S. Iwai)**

- Compile report including conversion coefficients for various anthropomorphic computational models and radiation types at high energies
- Appoint working group (L. Waters, S. Iwai, M. Pelliccioni, V. Mares) which will submit a proposal to ICRP

<b>COMPUTER CODES AND DATA SETS FOR SHIELDING ANALYSIS</b>
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◆ **Current Status of Computer Codes and Data Sets for Accelerator Shielding Analysis (B.Kirk, E. Sartori, P. Vaz)**

- NEA/RSICC take a proactive role in exchanging information on new codes etc, with SATIF participants
- Continue work at RSICC and NEA/DB on the SINBAD database to include additional shielding benchmark experimental data sets

<b>Participants to inform NEA/RSICC on availability of codes and data</b>
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<b>ANTHROPOMORPHIC DATA</b>
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◆ **Collection of anthropomorphic data for dosimetry studies (E. Sartori, V. Mares)**

- Cooperate with R. Loesch, developer of the database being implemented at DOE
- Get information on the code MRIPP

◆ **GSF anthropomorphic computational models (V. Mares)**

- Make anthropomorphic computational models (often erroneously called "phantoms") available

Mares will contact authors
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## **Looking into the future...**

The technological applications of accelerators, targets and irradiation facilities cover a wide range of domains, from basic research to Accelerator Based Transmutation, Material Science or Medicine.

The analysis and solution of shielding problems related to the development and operation of accelerators, targets and irradiation facilities involves the understanding of the physics of the interactions of different particles (neutrons, protons, electrons, photons, pions, light and heavy ions) in an energy range spanning over several orders of magnitude.

The community of participants in the Meetings of SATIF includes physicists, engineers and technicians coming from different fields of Science and Technology. Given the increasing number of facilities in operation, under construction, being commissioned or being planned, their diversity (proton accelerators, electron accelerators, spallation sources, radioactive nuclear beams, etc.) and the increasing complexity of the associated shielding problems, this community feels that an effective follow-through process will be necessary in order to make sure substantial progress is achieved, ensuring that a sound technical basis is established for proper licensing and operation of these facilities.

In this context, it was requested that the NEA strengthen its role of co-ordinating the collection and dissemination of experimental or evaluated data, computer programs, benchmark data sets and exercises. It was felt that an effective follow-up of the recommendations performed and actions undertaken in the different areas and fields concerned, could only benefit from the NEA role of providing secretariat and organisational support and assistance to the members of the Task Force and to their activities. In this framework, a specific follow-through process co-ordinated by the NEA has been established to monitor regularly the progress achieved and to collect and make available relevant information (data sets , computer codes, etc.) newly released.

Finally, it was decided to hold the next meeting of SATIF (SATIF-4) either at Knoxville, Tennessee, U.S.A., probably on 12th and 13th November, 1998, or after the ANS Topical Meeting on Accelerator Applications (AccApp '98) which will take place in Gatlinburgh Tennessee, U.S.A., from 20-23 September 1998, and to assign the Local Organisation responsibility to the Oak Ridge National Laboratory (ORNL).

**ANNEX 1**

NEA/NSC/DOC(97)3  
Revision 1  
30 April 1997

**ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT**

**NUCLEAR ENERGY AGENCY**

Nuclear Science Committee

Third Specialists' Meeting on

SHIELDING ASPECTS OF ACCELERATORS, TARGETS AND IRRADIATION FACILITIES

(SATIF3)

**PROGRAMME**

12th and 13th May, 1997

Tohoku University, Sendai, Japan

Aoba Memorial Hall  
(AOBA KINEN KAIKAN)

jointly organised by

the OECD/NEA,

the Shielding Working Group of the Reactor Physics Committee of Japan

the Radiation Safety Information Computational Center

and the Tohoku University

May 12 (Monday)

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9:00-9:30 Registration

9:30-9:40 Welcome Address [10] T.Nakamura

9:40-9:50 Chairperson T.Nakamura

Opening Remark [10] S.Matsuura

9:50-11:00 Session 1. Source Term and Related Data - Electron Accelerator  
Chairpersons A.Ferrari  
H.Hirayama

1-1 Gas Bremsstrahlung and Narrow Beam Dosimetry

1-1-1 Some Preliminary Results about Narrow Beam  
Dosimetry [15+5] M.Pelliccioni

1-1-2 Measurement of Gas Bremsstrahlung from Insertion  
Device Beamlines of the Advanced Photon Source [15+5] P.K.Job

1-2 Photoneutron and Photopion - DDX and Spectrum

1-2-1 Status of Nuclear Data Evaluation for JENDL  
Photonuclear Data File [15+5] T.Fukahori

11:00-11:20 Coffee Break

11:20-12:00 Session 1.(continued)

1-2-2 PICA95: An Intranuclear-Cascade Code for 25-MeV  
to 3.5-GeV Photon-Induced Nuclear Reactions [15+5] C.Y.Fu

1-2-3 Total Giant Resonance Photonuclear Cross Sections  
for Light Nuclei: A Database for the FLUKA Monte  
Carlo Transport Code [15+5] A.Fassò

12:00-12:30 Session 2. Source Term and Related Data  
- Proton and Ion Accelerator  
Chairpersons L.A.Charlton  
K.Shin

2-1 Thin Target Yield Measurements and Compilation

2-1-1 Summary of Compiled Experimental Data from  
Intermediate Energy Neutron and Proton  
Interactions with Different Nuclides  
(EXFOR Data Base) [15+5] P. Vaz

12:30-13:30 Lunch

13:30-15:00

Session 2 (continued)

2-2 Thick Target Yield Measurements and Compilation

2-2-1 Thick Target Yield Measurements in TIARA, KEK and HIMAC [15+5] K. Shin

2-3 Topics - Spallation Neutron Source Facility

2-3-1 Radiation Physics of High Power Spallation Targets,  
State-the-Art of Simulation Methods and  
Experiments [15+5] D.Filges2-3-2 Overview of the National Spallation Neutron  
Source [15+5] L.A.Charlton2-3-3 Overview of the Spallation Neutron Source  
Project in JHP [15+5] H.Ikeda

15:00-15:20

Session 3. Shielding

Chairpersons N.Mokhov  
K.Hayashi

3-1 Shielding Benchmark Problem - Review of Analysis

3-1-1 Intercomparison of Neutron Transmission Benchmark  
Analyses for Iron and Concrete Shields in Low,  
Intermediate and High Energy Proton Accelerator  
Facilities [15+5] Y.Nakane

15:20-15:40 Coffee Break

15:40-16:50

Session 3 (continued)

3-2 Attenuation Length - Definition and Intercomparison

3-2-1 Definition and Intercomparison of Attenuation  
Length [15+5] H.Hirayama

3-3 Shielding Experiments and Compilation

3-3-1 Bulk Shielding Experiments at TIARA and ISIS [15+5] Y.Sakamoto

3-3-2 Equivalent Dose Rate behind Concrete Shielding of  
Target Irradiated by 0.05 - 10 GeV Proton Beams [15+5] E.Gelfand

16:50-17:30

Session 4. Miscellaneous Topics (1)

4-1 Neutron Facility for Shielding Experiment and  
Detector CalibrationChairpersons L.Waters  
Y.Uwamino4-1-1 Neutron Facility for Shielding and Cross Section  
Experiment in JAPAN [15+5] T.Nakamura4-1-2 Recent Results at The CERN-CEC High Energy  
Reference Field Facility [15+5] M.Silari18:00-20:00 Reception at Aoba Memorial Hall  
sponsored by JAERI





**ANNEX 2****LIST OF PARTICIPANTS**

3rd Specialists' Meeting on Shielding Aspect of  
Accelerators, Targets and Irradiation Facilities

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12-13 May 1997

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