Intercalibration of Space Radiation Monitors with Heavy Ion Beams

InterComparison for Cosmic-ray with Heavy Ion Beams At NIRS

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and
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Objectives of ICCHIBAN

- Establish and characterize a heavy ion “reference standard” against which space radiation instruments can be calibrated.
- Determine the response of space radiation dosimeters to heavy ions of charge and energy similar to that found in the galactic cosmic radiation (GCR) spectrum.
- Aid in reconciling differences in measurements made by various radiation instruments during space flight.
• Opportunity for two or three runs per year.

• 1\textsuperscript{st} ICCHIBAN: active detectors, shake down run

• 2\textsuperscript{nd} ICCHIBAN: passive detectors

• Participants/Detectors not included in first two runs will have opportunity later.
NIRS HIMAC (Heavy Ion Medical Accelerator in Chiba) ISRL

Available Ions
p, He, C, Ne, Si, Ar, Fe, Kr, Xe, …

Energies
125〜800MeV/u

Linear Accelerator
Synchrotron 2 Rings
About 1000 patients had treatment in HIMAC.
Operation of HIMAC

- During day time on week day, HIMAC ion beams are used for the treatment of patients.

- During night time on week day or day time on weekend, they are used for the biology and physics experiments.

<table>
<thead>
<tr>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
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<tbody>
<tr>
<td>day</td>
<td>night</td>
<td>day</td>
<td>night</td>
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<td>night</td>
<td>day</td>
</tr>
</tbody>
</table>

- Physics and Biology Experiments are available.

- **Orange**: Treatment
- **Teal**: Maintenance
- **Gray**: No Service
• Treatment Rooms for Patient --- 3 rooms  
  (Upper & Lower Ring)

• A Biological Experiment Room (BIO)  
  (Upper Ring)

• Physics Experiment Rooms  
  – Direct Beam Courses --- 2 courses (PH1, PH2)  
  – Secondary Beam Courses --- 2 courses (SB2, SB3)  
  (Lower Ring)
• Yukio Uchihori (Project Coordinator), NIRS, Japan
• Kazunobu Fujitaka (Chair), NIRS, Japan
• Nakahiro Yasuda (Deputy Project Coordinator), NIRS, Japan
• Eric Benton (Deputy Project Coordinator), Eril Research, USA
• Tadayoshi Doke, Waseda University, Japan
• Hisashi Kitamura, NIRS, Japan
• Tatsumi Koi, NIRS, Japan
• Masashi Takada, NIRS, Japan
• Cary Zeitlin, LBNL, USA
Organizing Committee of WRMISS Intercomparison

- Guenther Reitz (Chair), German Aerospace Center (DLR), Germany
- Kazunobu Fujitaka, National Institute of Radiological Sciences (NIRS), Japan
- Jack Miller, Lawrence Berkeley National Laboratory, USA
- Thomas Borak (Liaison with WG), Colorado State University, USA
- Rudolf Beaujean, University of Kiel, Germany
<table>
<thead>
<tr>
<th>Participants</th>
<th>Nation</th>
<th>Detector Name</th>
<th>Detector Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. Doke</td>
<td>Japan</td>
<td>RRMD-III</td>
<td>Silicon Stack Detector</td>
</tr>
<tr>
<td>R. Beaujean &amp; G. Reitz</td>
<td>German</td>
<td>DOSTEL</td>
<td>Silicon Stack Detector</td>
</tr>
<tr>
<td>JSC, NASA</td>
<td>USA</td>
<td>TEPC + CPDS</td>
<td>TEPC + Silicon&amp;CU</td>
</tr>
<tr>
<td>Y. Uchihori</td>
<td>Japan</td>
<td>Liulin-4J</td>
<td>Mobile Si Dosimeter</td>
</tr>
<tr>
<td>E. Benton</td>
<td>USA</td>
<td>CR-39 + TLD</td>
<td>CR-39 + TLD</td>
</tr>
<tr>
<td>C. Zeitlin &amp; J. Miller</td>
<td>USA</td>
<td>Grand Base Detectors</td>
<td>Silicon Stack Detector</td>
</tr>
<tr>
<td>Date</td>
<td>Day</td>
<td>Time</td>
<td>Group</td>
</tr>
<tr>
<td>----------</td>
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</tr>
<tr>
<td>Feb. 10</td>
<td>Sun</td>
<td>20:00~7:00</td>
<td>1\textsuperscript{st} Group</td>
</tr>
<tr>
<td>Feb. 11</td>
<td>Mon</td>
<td>20:00~7:00</td>
<td>2\textsuperscript{nd} Group</td>
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<tr>
<td>Feb. 12</td>
<td>Tue</td>
<td>20:00~7:00</td>
<td>1\textsuperscript{st} Group</td>
</tr>
<tr>
<td>Feb. 13</td>
<td>Wed</td>
<td>20:00~7:00</td>
<td>2\textsuperscript{nd} Group</td>
</tr>
</tbody>
</table>
Requirement for Participants after Experiments

- LET or \( y \) Distribution
- Mean Quality Factors
- Dose (to Tissue) per \( 10^6 \) Particles
- Dose Equivalent per \( 10^6 \) Particles
- To be determined
HIMAC Committee realized importance of our project and approved 4 nights ~ 40 hours for 1st ICCHIBAN runs.

- 2 nights for Carbon (400MeV/u) and 2 nights for Iron (400MeV/u) are available.

- Beam intensity will be tuned $3 \times 10^2$ particles per spill. 1 spill every 3.3 sec. Spill distribution is about 0.7 sec.

- The beam spot will be tuned as 20 mm diameter circles.
Beam Characteristics to be provided to participants

- Actual Beam Energy at Detector
- Geometric Beam Profile (We can provide position of each particle.)
- Time Structure of Beam
- Fluence and Average Beam Intensity
• Single Spill Profile --- ZnS Fluorescence Sheet + Video Camera
• Average Beam Profile --- CR-39
• Real Time Beam Profile --- PSD
• Beam Intensity --- Plastic Scintillation Counter
• Total Beam Energy --- Silicon Stack
**NIRS**

**Trigger System**

![Diagram of a trigger system](image-url)
Dosimeters will be irradiated for direct beam after transmitting a thin scintillation counter. The scintillation counter will count the beam intensity and give trigger signal for the dosimeter if required.

Detectors can be rotated with the Theta stage and it will be irradiated with several incident angles.
NIRS Flow Chart of ICCHIBAN Exposure ISRL
# Time Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>Sep. 12, 2001</td>
<td>6th WRMISS Workshop at Oxford</td>
</tr>
<tr>
<td>Oct. 15, 2001</td>
<td>2nd Circular</td>
</tr>
<tr>
<td>Nov. 30, 2001</td>
<td>Procedure for Radiation Control, Visiting Researcher and Hotel reservation</td>
</tr>
<tr>
<td>Feb. 10-13, 2002</td>
<td>1st ICCHIBAN Experiment</td>
</tr>
<tr>
<td>Apr. 30, 2002</td>
<td>Preliminary Report of data</td>
</tr>
<tr>
<td>May, 2002</td>
<td>2nd ICCHIBAN Experiments (For Passive Detectors)</td>
</tr>
<tr>
<td>Jun. 15, 2002</td>
<td>Suggestions for next accelerator run, (i.e. ions, energy, dates)</td>
</tr>
<tr>
<td>(End, 2002)</td>
<td>3rd ICCHIBAN Experiment</td>
</tr>
</tbody>
</table>

will continue for two more years
2nd ICCHIBAN Experiments

- 2nd ICCHIBAN Experiment will be held on May 2002 and it will be concentrated with “Passive Detectors”. These exposures will be done in “Biology Room (BIO)”.

- Possibility to include “unknown ions” (blind exposures) in addition to “known ions”.

- Participants with passive detectors need not attend in person (send detectors to ICCHIBAN WG).
• Aug. 8th, 2001
• Iron 500 MeV/u
• Intensity $\sim 10^{3-6}$ particles per spill
• Beam Profile $\sim$ 2cm circle

• Detectors
  – Silicon stack detector
  – CR-39
  – Liulin-4J
NIRS PSD Position Resolution ISRL
CR-39 and PSD

Scanning region

40 mm

10 mm

CR-39

PSD

NIRS ISRL

CR-39, Fragments of Fe(500) at Pre-ICCHIBAN
• We hope this project will succeed and it will contribute to our understanding of space radiation instruments.

• We are eager for your participation to ICCHIBAN.

• If you have interest in ICCHIBAN, please contact me (uchihori@nirs.go.jp).
\[ N \, d\nu \, dx = \frac{2\pi e^2 z^2}{\hbar^2} \left( 1 - \frac{1}{n^2 \beta^2} \right) d\nu \, dx \]

\[ \cos(\theta_{\lambda}) = \frac{1}{n_{\lambda} \beta} \]

N: Number of Photons
\nu: Frequency of Light
z: Charge of Particle
\beta: Velocity of Particle (v/c)
n: Refractive Index
**NIRS**

RICH Setup  

**ISRL**

SC : Scintillation Counter  
PSD : Position Sensitive Si Detector  
MAPMT : Multi-Anode Photo-Multiplier Tube
Velocity Distributions Observed by RICH for Si beam. Both results for 405MeV/u and 395MeV/u are shown.

~0.2%
Liulin-4J

30 - 70 MeV Proton Beam

Beam Pipe

MDU

Computer Controlled XZ Stage and Theta Stage

10cm

MDU

Beam Pipe

XY-Theta Stage
GEANT4

Estimated Deposited Energy in keV

Y = X * 0.0123

Alpha particles

Protons

Experiment
Simulation

Deposited Energy in MeV

Number of Events

Estimated Deposited Energy in keV

ADC Channels

MDU-1
MDU-2
MDU-3
MDU-4

Exposure Angle
0 deg
45 deg
60 deg

Y = X * 0.0123

Alpha particles

Protons

Exposure Angle
0 deg
45 deg
60 deg
Artificial diamond detector is developed with collaboration with Kanagawa Univ., Japan.

Diamond has characters which is radiation hardness, low noise and tissue equivalent.

The energy resolution of diamond detector is corresponding to surface barrier silicon detector.

Because of tissue equivalent, diamond detector will be used as radiation protection monitor.
Phoswich Neutron Detector

By Masashi Takada
Scintillation Fiber Detector

By Tatsumi Koi