Preparation of Proton Irradiation System for Intercomparison Experiments of Luminescence Detectors (Proton-ICCHIBAN-2)

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on behalf of ICCHIBAN Working Group and Participants

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When you will drink Guinness Beer tonight, please say “Cheers, Prost, Na Zdrowie or Kanpai” for him.
Space-Intercomparison

SpaceIntecomparison-1 experiment
• Detectors were launched from Jan 29 - Apr 30, 2004 (91.5 days).
• 4 institutes were participated

SpaceIntecomparison-2 experiment
• Detectors were launched from May 15 - Oct 21, 2007. (160 days).
• 12 institutes participated.

SpaceIntecomparison-3 experiment
• Detectors was launched from May 2008 to Oct. 2008.
• 12 institutes have participated.
- CR-39 ICCHIBAN
  - To understand analysis methodologies of CR-39
    - Comparison of analysis methods of the SAME CR-39
    - Confirmation of angle dependencies of CR-39s

- Proton-ICCHIBAN (for Luminescence Detectors)
  - To understand responses of luminescence detectors for Low LET components
    - Construction of radiation field for low energy protons in NIRS
      Cyclotron
Luminescence Detector Efficiency in LET

ATI, Austria & DLR, Germany

OSU, USA
The Next Phase of ICCHIBAN Project

ICCHIBAN Phase-1

2002  2004  2006  2008  2009

HIMAC IC-1 ~ 8  LLUMC-IC  NSRL-IC  CERF-IC

Space-ICCHIBAN

Space-IC-1  Space-IC-2  Space-IC-3

ICCHIBAN Phase-2

CR-39 IC  Proton-IC
Ion beams used at past ICCHIBANs

H. Kitamura
Low LET beams

- Because of lack of comparison and calibration in low LET region, we will have intercomparison experiments in some facilities.

- In NIRS, there is a cyclotron which has capability to accelerate protons up to 80 MeV (LET is about 1keV/micron) and ICCHIBAN Working Group attempts to establish irradiation field in the cyclotron. Also, HIMAC and a medical accelerator of National Cancer Center in Kashiwa have high energy proton fields.

- Luminescence detectors like as TLD/OSLD will be irradiated in the proton fields.
Plan

- Objects: Luminescence detectors and other passive detectors. Simple active detectors (e.g. Liulin-4) can be discussed.

- Beams:
  - 70 MeV proton (0.95 keV/um) on Jan. 29th (Fri)
  - 30 MeV proton (1.86 keV/um) on Feb. 5th (Fri)
  - 235 MeV (0.40 keV/um) proton at National Cancer Center ???

- Beams in Future:
  - 40 (1.48 keV/um), 50 MeV (1.24 keV/um) proton
  - 100 MeV $^4$He (0.86 keV/micron)
  - 100 (0.72) ~ 150 MeV (0.54) proton in HIMAC
Specification of the NIRS-Cyclotron

- AVF Cyclotron
- Available Beams:
  - proton 5-80 MeV
  - Deuteron 10-55 MeV
  - $^3$He 18-147 MeV
  - $^4$He 20-110 MeV
  - Heavy ions …

- This cyclotron is used to produce radioisotopes for SPECT/PET mainly.
- It is usable for scientific experiments about one day per a week.
- Typical experiment time is from 11 am to 7 pm (8 hours).
NIRS-Cyclotron
Overall View

Exposed dose is measured by a calibrated Ion Chamber (Marcus).
Velocity of beam is measured by TOF detectors (2 plastic scint.).
Beam profile is measured beam a profile monitor (scint.).
Beam image on a luminescence plate
Stage for passive detectors

Beam Pipe

Beam Profile Monitor

XZ and Theta Stage
Standard Ion Chamber

PTW 23343 Marcus Chamber

- Nominal sensitive volume: 0.055 cm³
- Sensitive volume radius: 2.65mm, depth: 2mm
- Nominal response: 2nC/Gy
- Long-term stability: <1% per year
- Chamber voltage: 300 V nominal
- Polarity effect: < 1%
- Leakage current: < ±4fA

Keithley 6517A Electrometer

- Sensitive range: 10fC to 2uC
- 0.75fA p-p noise
- Built-in ±1kV voltage source
Scintillator Array

- 5 cm coverage
- 1.5 cm interval
- 1 x 1 cm² Scintillator
Beam Profile (proton 70 MeV) at C8

Measured by YU and HK at 20th June 2008
Modeling of Radiation Field (Analytical)

- Assumptions:
  - Gauss-distribution by the scatter.
  - Track of beam center is circle.
  - \( R \) : radius, \( \sigma \) : Sigma of Gaussian

\[
\Phi(x, y) = \int_0^{2\pi} \frac{A e^{-\frac{(x-R \cos(\theta))^2+(y-R \sin(\theta))^2}{2\sigma^2}}}{\sqrt{2\pi\sigma}} R \, d\theta
\]

\[
\Phi(r) = \frac{A}{\sqrt{2\pi\sigma}} e^{-\frac{r^2+R^2}{2\sigma^2}} L_0\left(\frac{Rr}{\sigma^2}\right)
\]

1st modified Bessel function

by H. Kitamura
NIRS-Cyclotron (5)
Fitted by “ROOT”

\[
\Phi(r) = \frac{A}{\sqrt{2\pi} \sigma} e^{-\frac{(r^2 + R^2)}{2\sigma^2}} \Re_0 \left( \frac{Rr}{\sigma^2} \right)
\]

X direction
• R = 37.4 (mm)
• \(\sigma = 23.7\) (mm)
• \(x_0 = 2.34\) (mm)

Y direction
• R = 35.3 (mm)
• \(\sigma = 23.9\) (mm)
• \(y_0 = 2.61\) (mm)

by H. Kitamura
Modeling of Radiation Field (Computed)

- $a = 38.5$ (mm)
- $b = 34.0$ (mm)
- $\sigma = 23.6$ (mm)
- $x_0 = 2.32$ (mm)
- $y_0 = 2.31$ (mm)

by H. Kitamura
National Cancer Center

Size
45 m x 35 m

Control Room
Gantry
Fixed Target
Horizontal Port

Cyclotron
Gantry

Sumitomo Industry
<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>2009</td>
<td>April-July</td>
<td>Tests to make wide beams.</td>
</tr>
<tr>
<td></td>
<td>September 10th</td>
<td>Announcement in this WRMISS</td>
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<tr>
<td>2010</td>
<td>Jan. 29th and Feb. 5th</td>
<td>ICCHIBAN Experiments at NIRS-Cyclotron</td>
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So, please send us your detectors by Jan. 15th (Fri), 2010.
Deadline of reports of the past ICCHIBAN is Dec. 31\textsuperscript{st}, 2009 for not only passive detectors but also active detectors.
In order to understand discrepancies in space intercomparison experiments, the new ICCHIBAN experiments for track detectors and luminescence detectors are started as ICCHIBAN experiments Phase-2.

ICCHIBAN Working Group is preparing irradiation field in the cyclotron in NIRS. Using HIMAC and other cancer therapy facilities, ICWC will have intercomparison experiments. ICWC welcome your participation of not only detectors but also yourself.

Also, it is possible to have intercomparison experiments for active detectors in future.
Acknowledgement

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- The members of ICCHIBAN Working Group; N. Yasuda, E. Benton, H. Kitamura, S. Kodaira, M. Hajek, T. Berger, V. Shurshakov, I. Jadrnickova.