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

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

MEXT

(Ministry of Education, Culture, Sports, Science and Technology)

Space-Intercomparison

SpaceIntecomparison-1 experiment

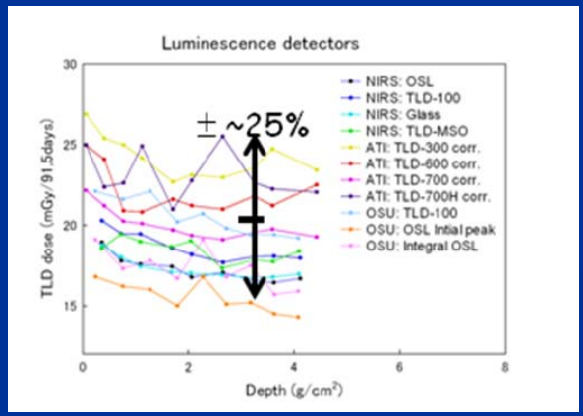
- Detectors were launched from Jan 29 - Apr 30, 2004 (91.5 days).
- 4 institutes were participated

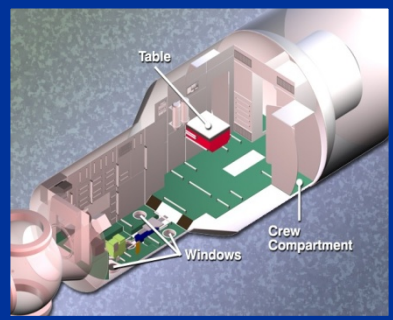
SpaceIntecomparison-2 experiment

- 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.





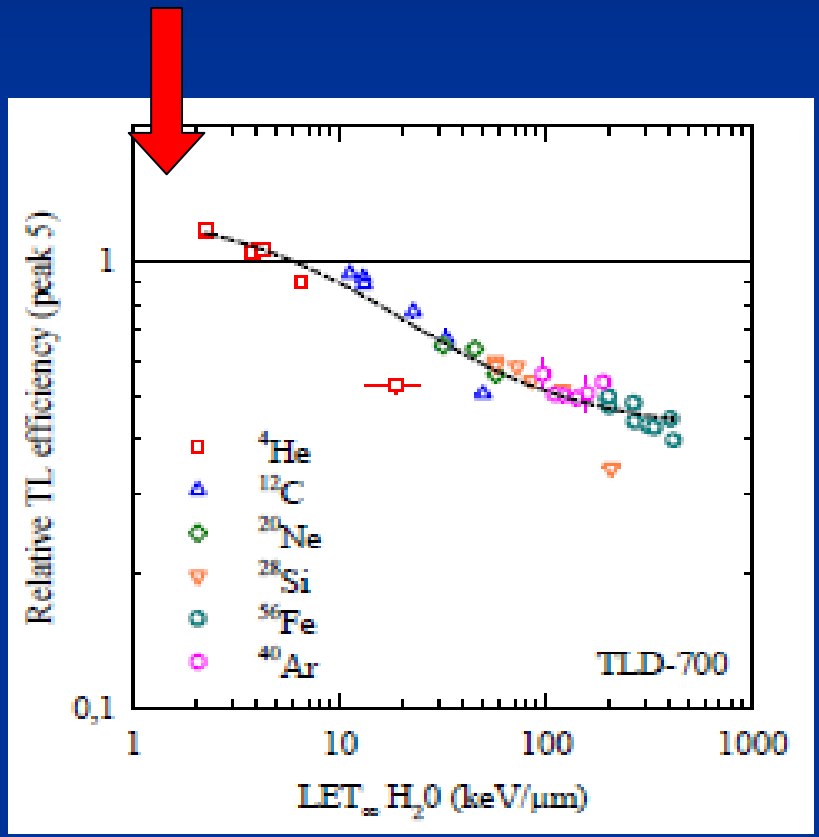
- CR-39 ICCHIBAN
  - To understand analysis methodologies of CR-39

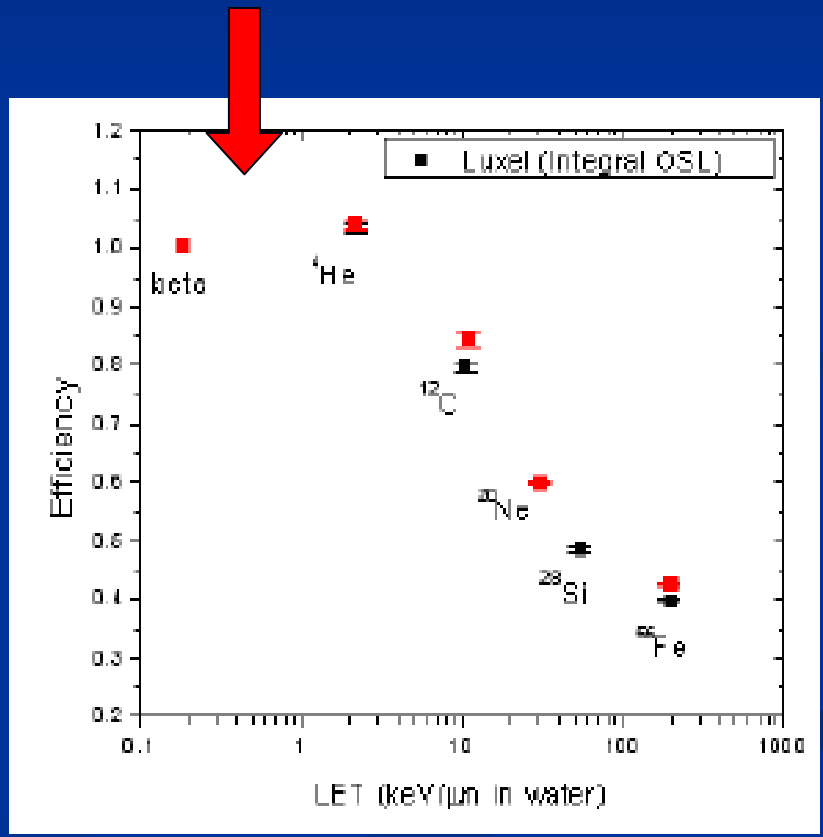
    - Comparison of analysis methods of the SAME CR-39
    - Confirmation of angle dependencies of CR-39s

- 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

2002 2004 2006 2008 2009

ICCHIBAN Phase-1

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

Space-ICCHIBAN

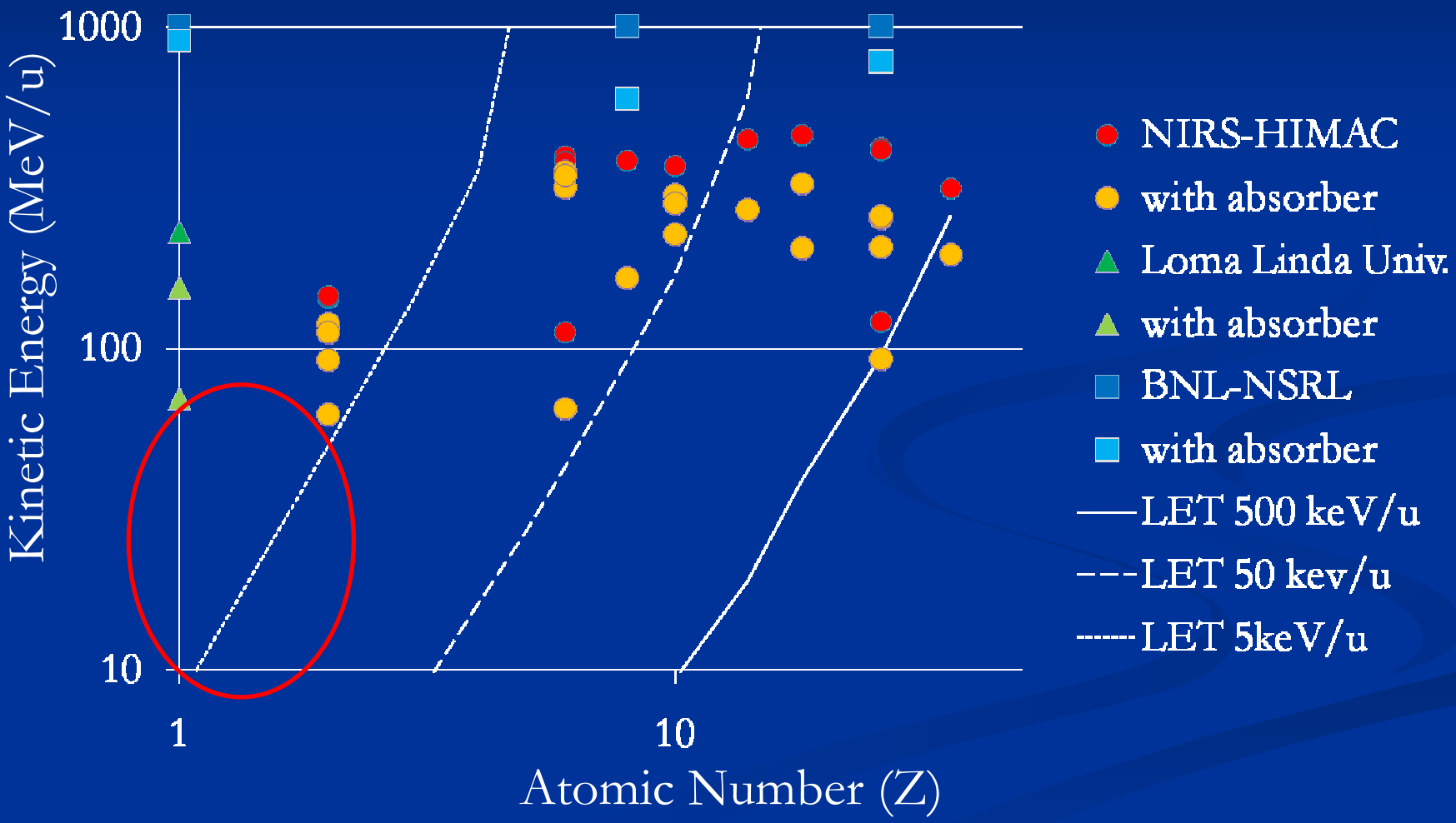
Space-IC-1 Space-IC-2 Space-IC-3

ICCHIBAN Phase-2

CR-39 IC

Proton-IC

Ion beams used at past ICCHIBANs



H.Kitamura

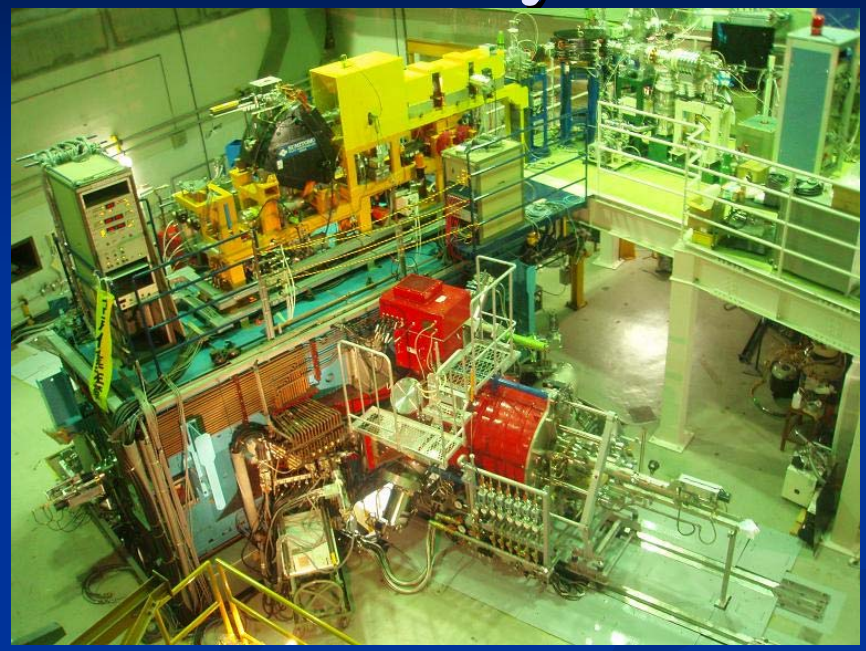
Low LET beams

- 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

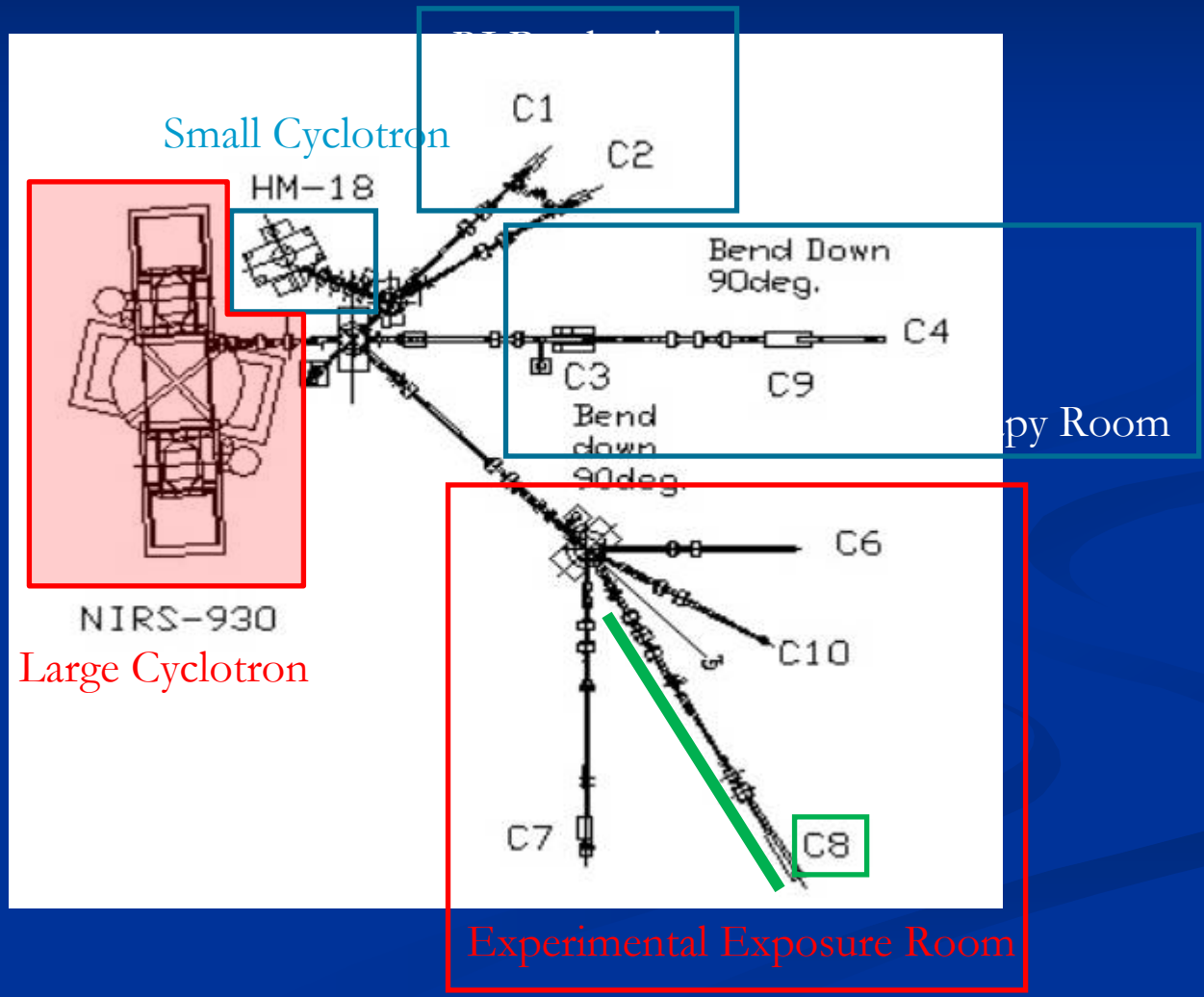
Specification of the NIRS-Cyclotron



- 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).

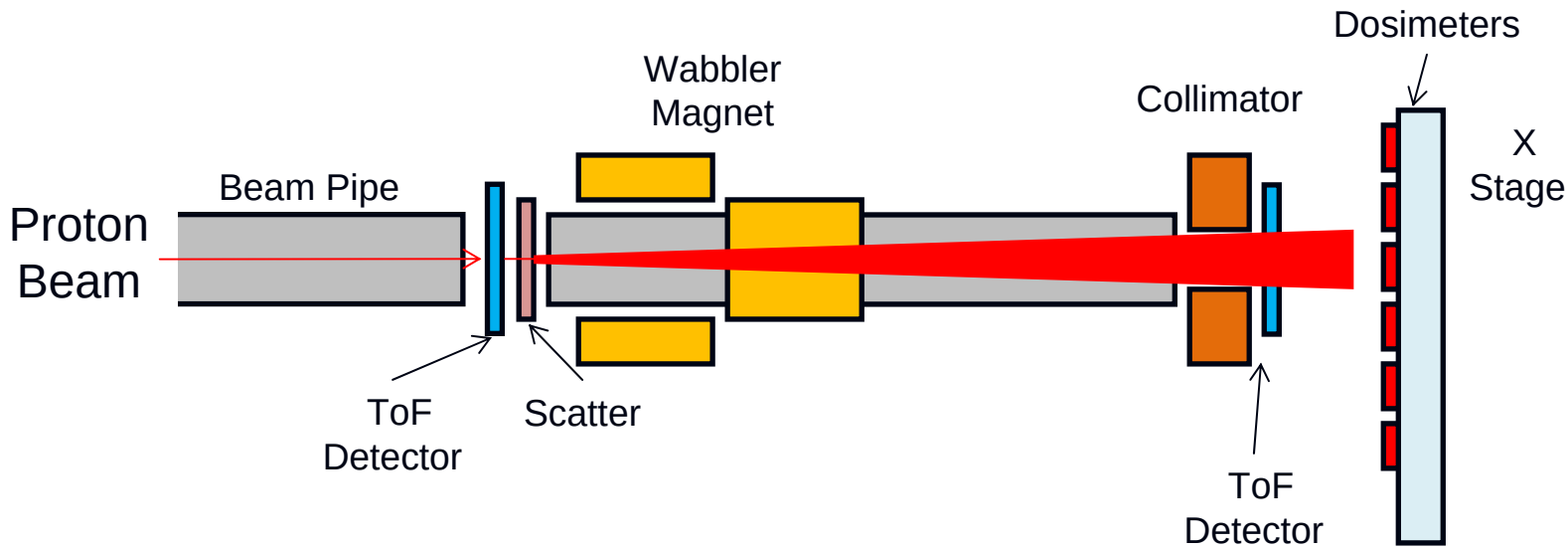
NIRS-Cyclotron
Overall View



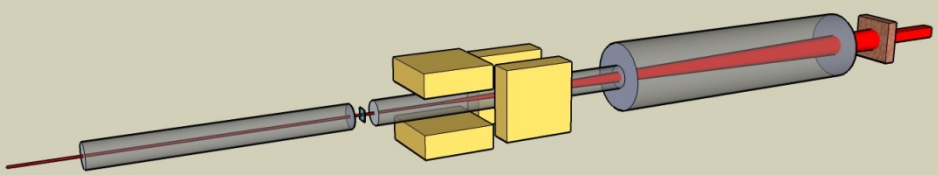
http://web.nirs.go.jp/HomePage/Jyuryushi/cyc/AVF930Character.htm

Preparation of Proton Field in NIRS Cyclotron

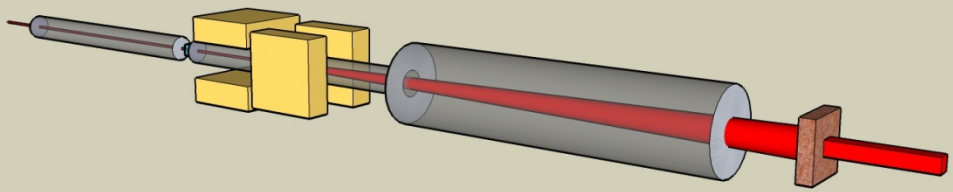
Proton : 10 ~ 70 MeV, He4 : 100 MeV, …

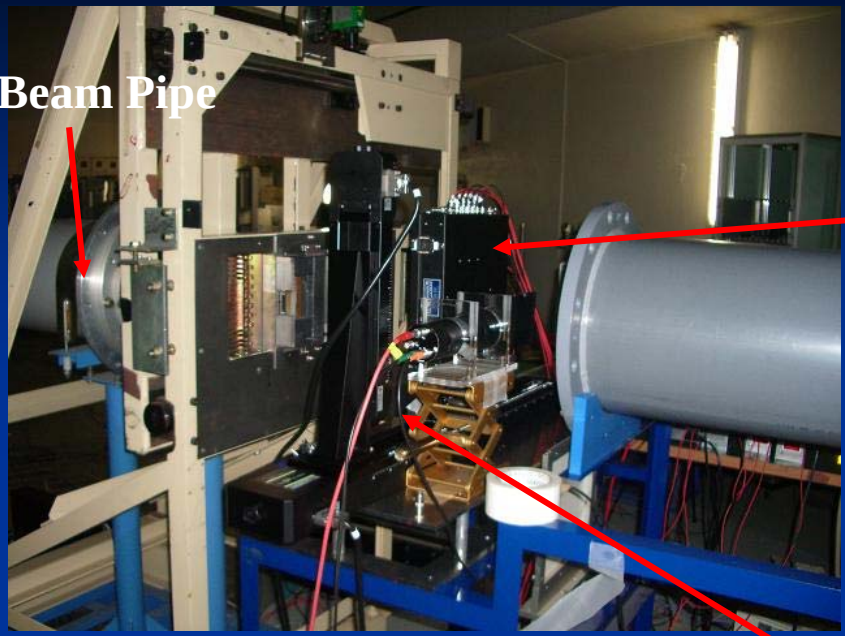


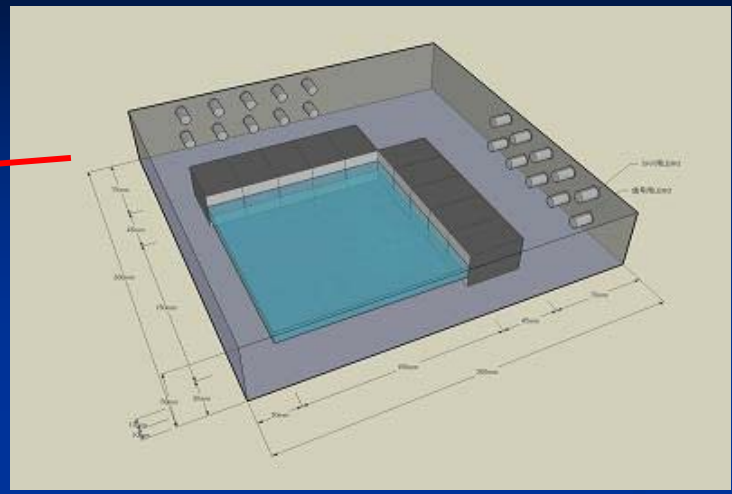
- Exposed dose is measured by a calibrated Ion Chamber (Marcus).
- Velocity of beam is measured by TOF detectors (2 plastic scint.).
- Beam profile is measured beam a profile monitor (scint.).



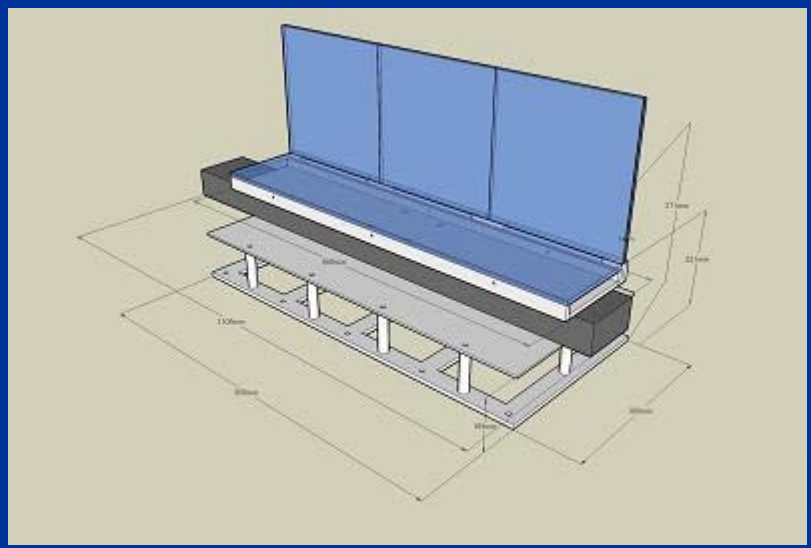
Beam image on a luminescence plate



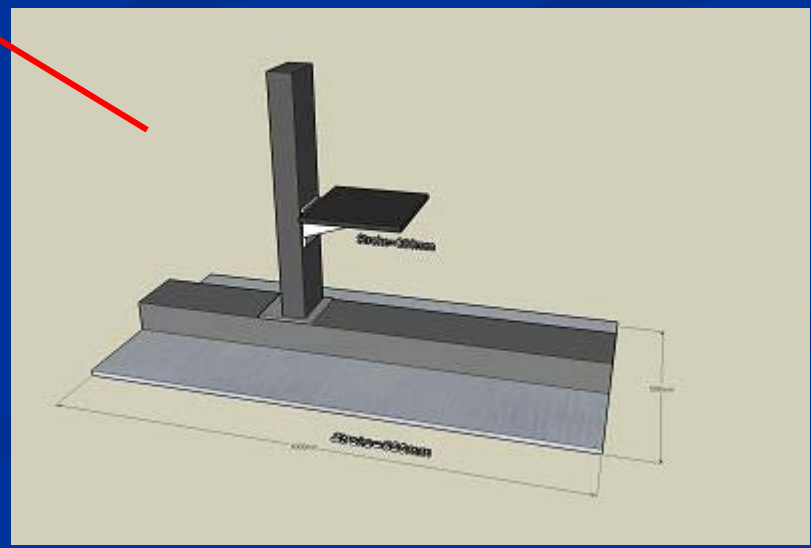




Beam Profile Monitor



Stage for passive detectors



XZ and Theta Stage

Standard Ion Chamber

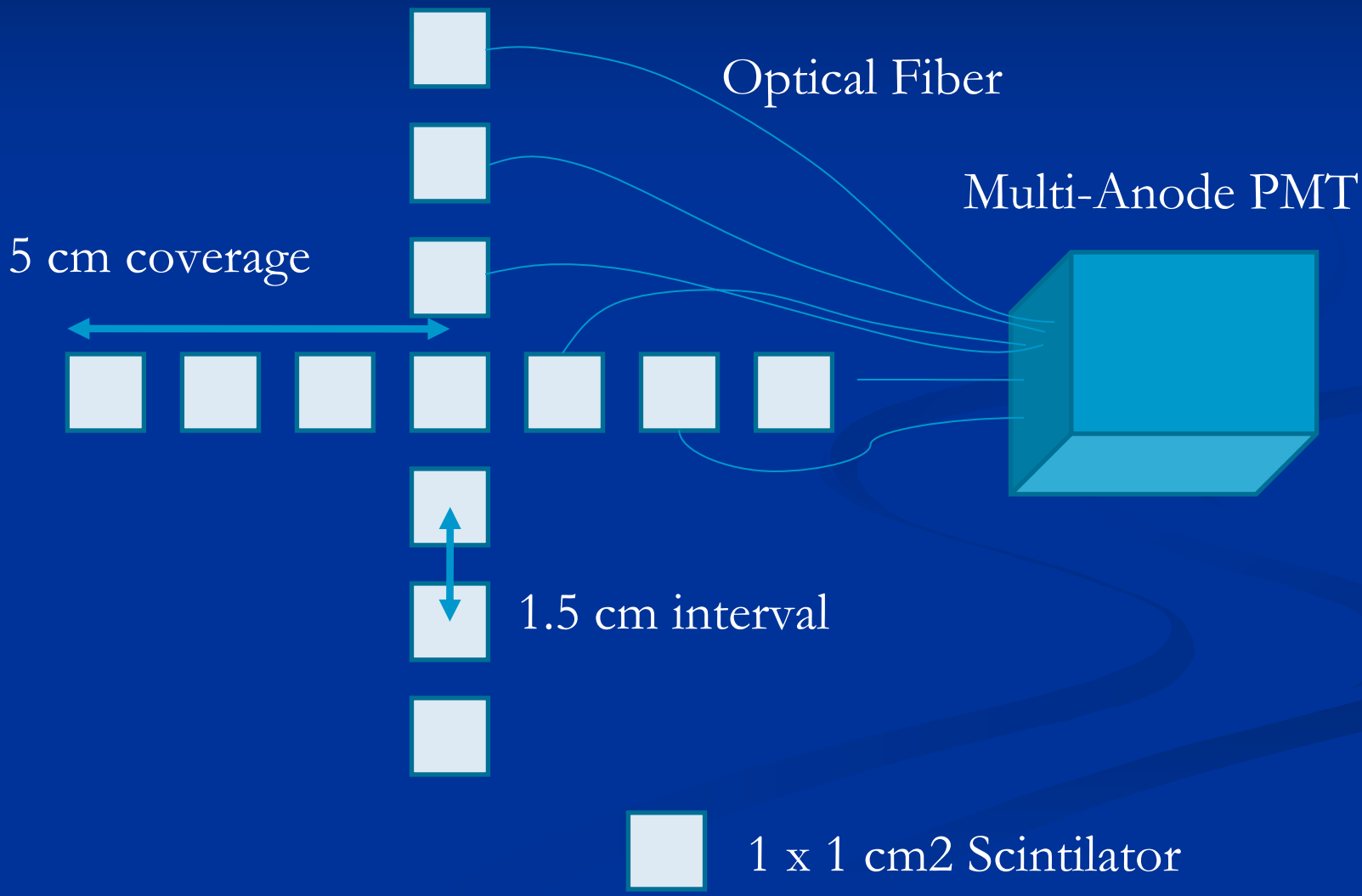
PTW 23343 Marcus Chamber

- Nominal sensitive volume : 0.055 cm^3
- 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

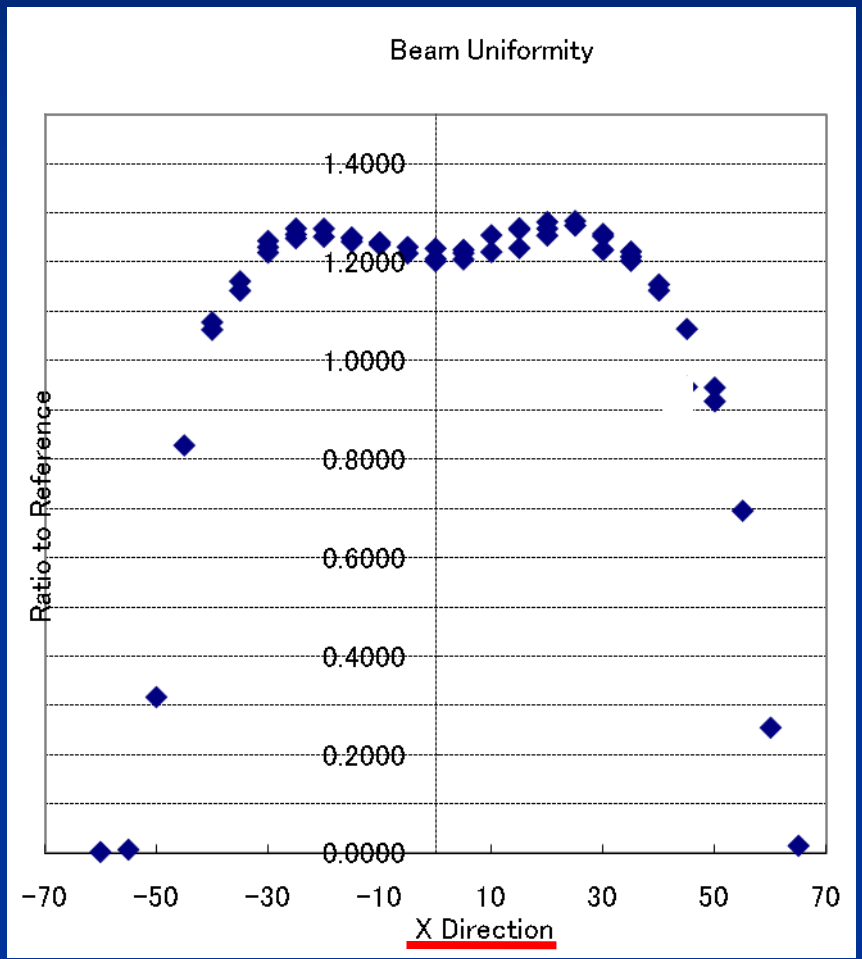
Keithley 6517A Electrometer

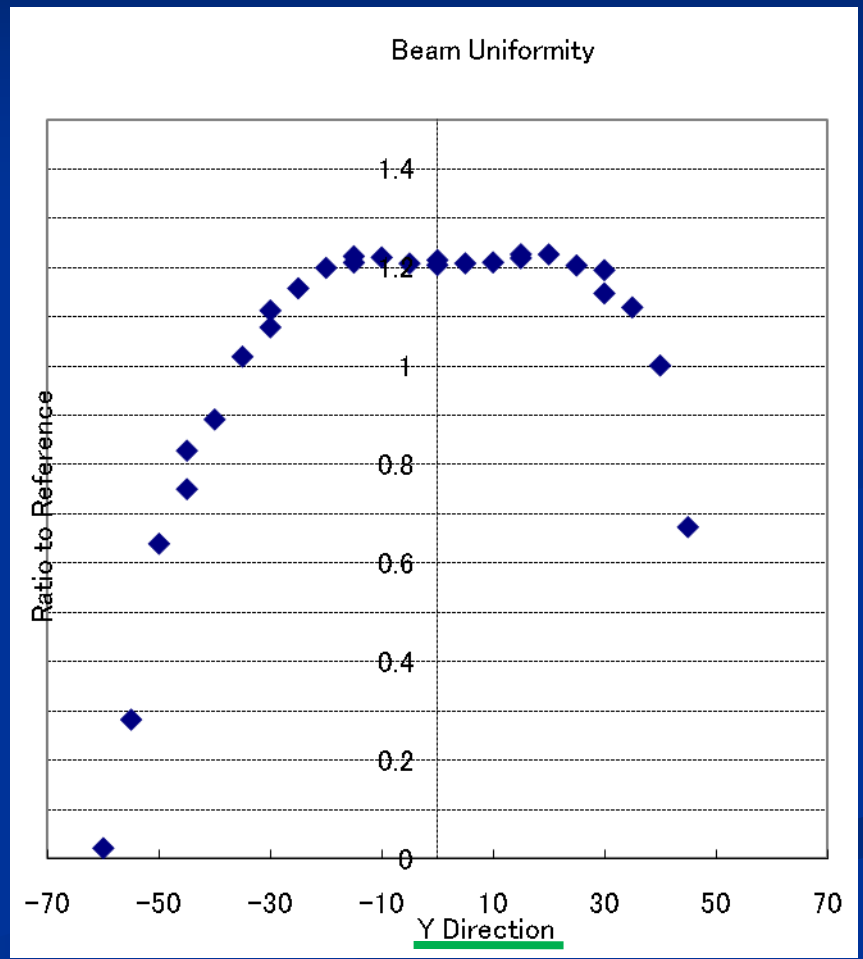
- Sensitive range : 10fC to 2uC
- 0.75fA p-p nioise
- Built-in +- 1kV voltage source

Scintillator Array



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, σ: Sigma of Gaussian

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

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

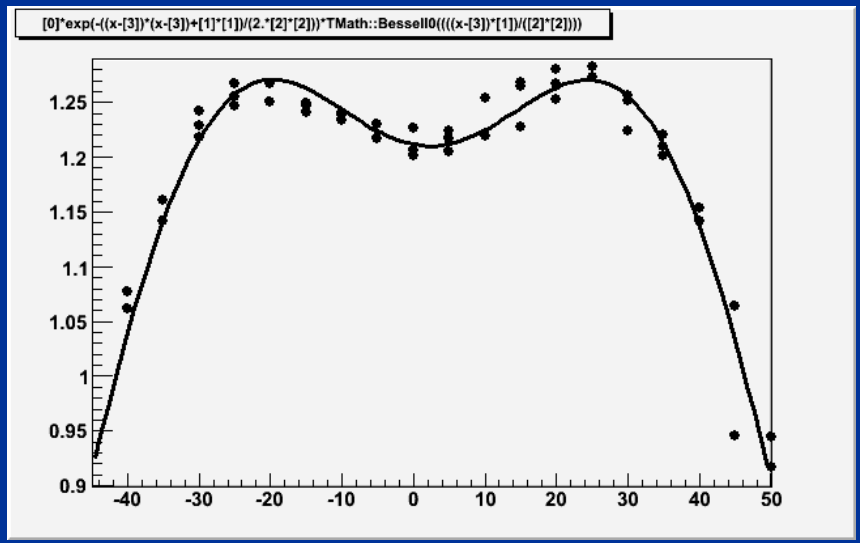
1st modified Bessel function

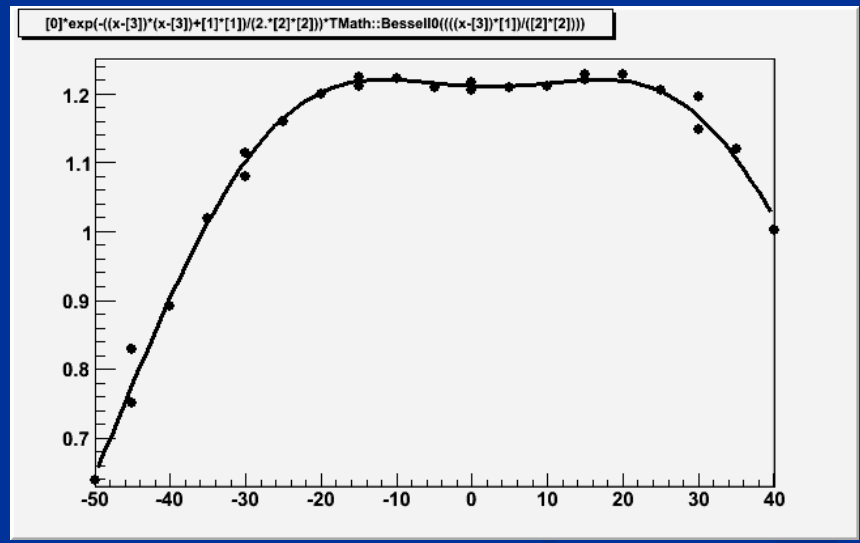
by H. Kitamura

NIRS-Cyclotron (5)

Fitted by "ROOT"

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





X direction

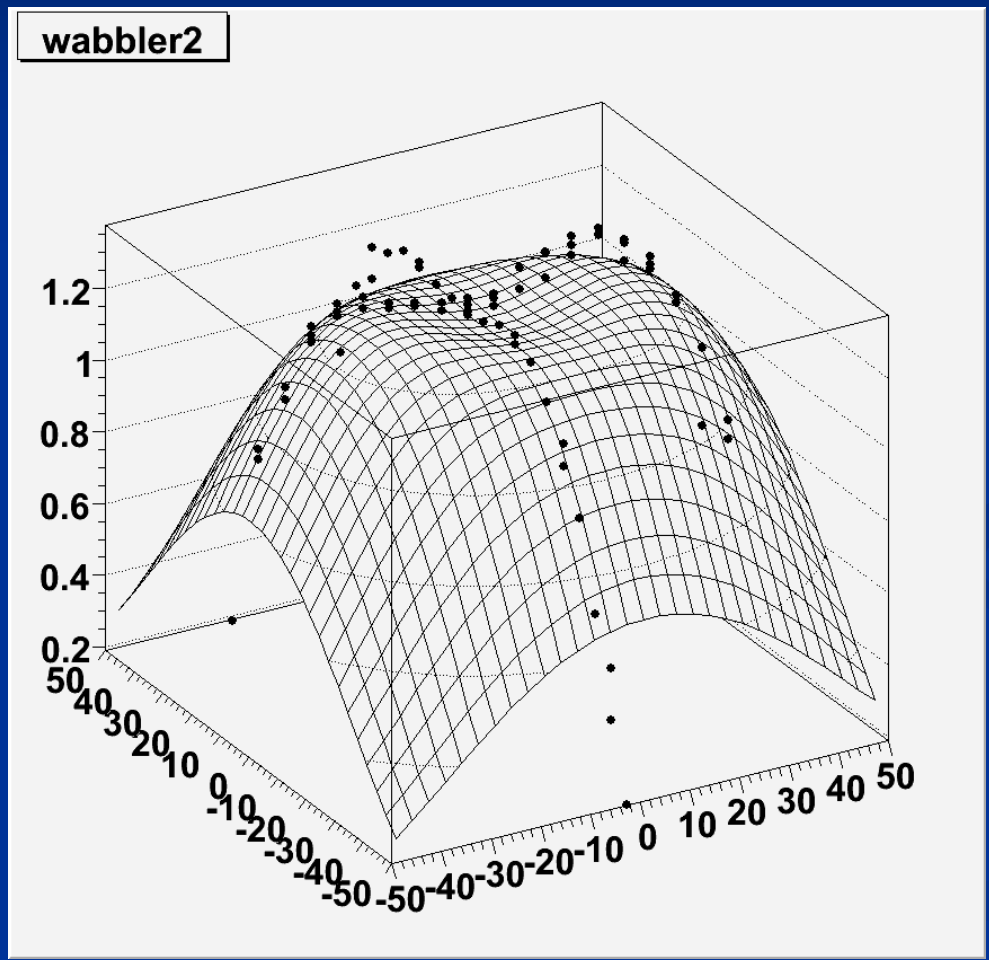
- R=37.4 (mm)
- σ=23.7 (mm)
- x0=2.34 (mm)

Y direction

- R= 35.3 (mm)
- σ= 23.9 (mm)
- y0=2.61 (mm)

by H. Kitamura

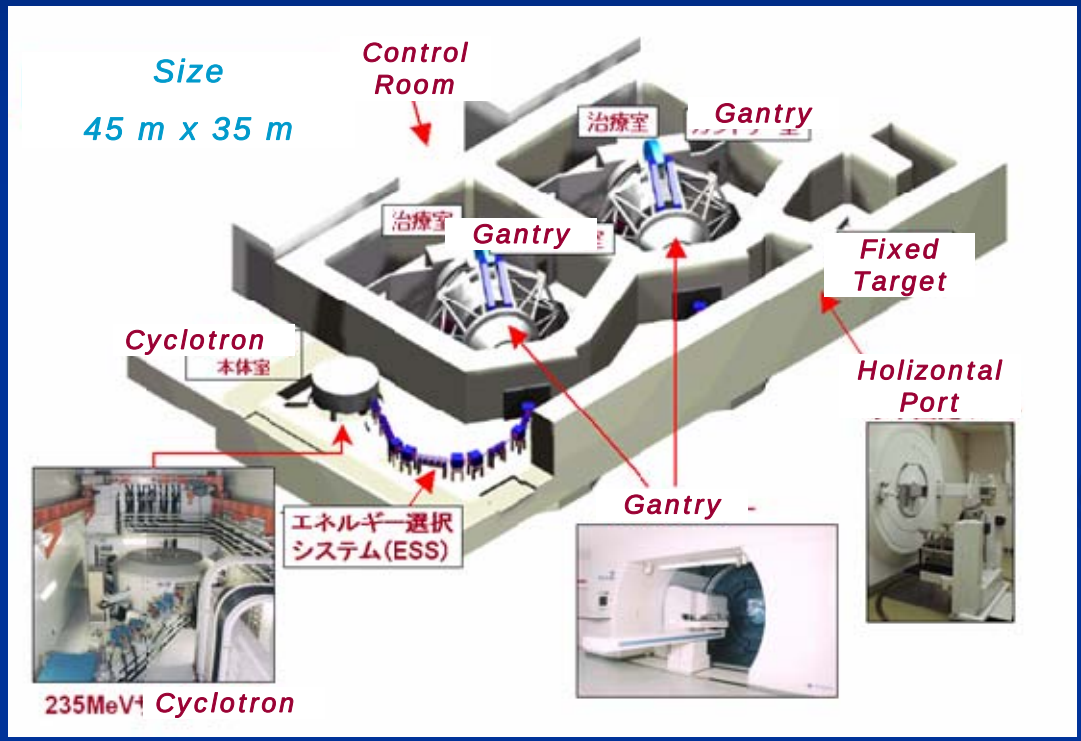
Modeling of Radiation Field (Computed)



- a=38.5 (mm)
- b=34.0 (mm)
- σ=23.6 (mm)
- x0=2.32 (mm)
- y0=2.31 (mm)

by H. Kitamura

National Cancer Center



Sumitomo Industry

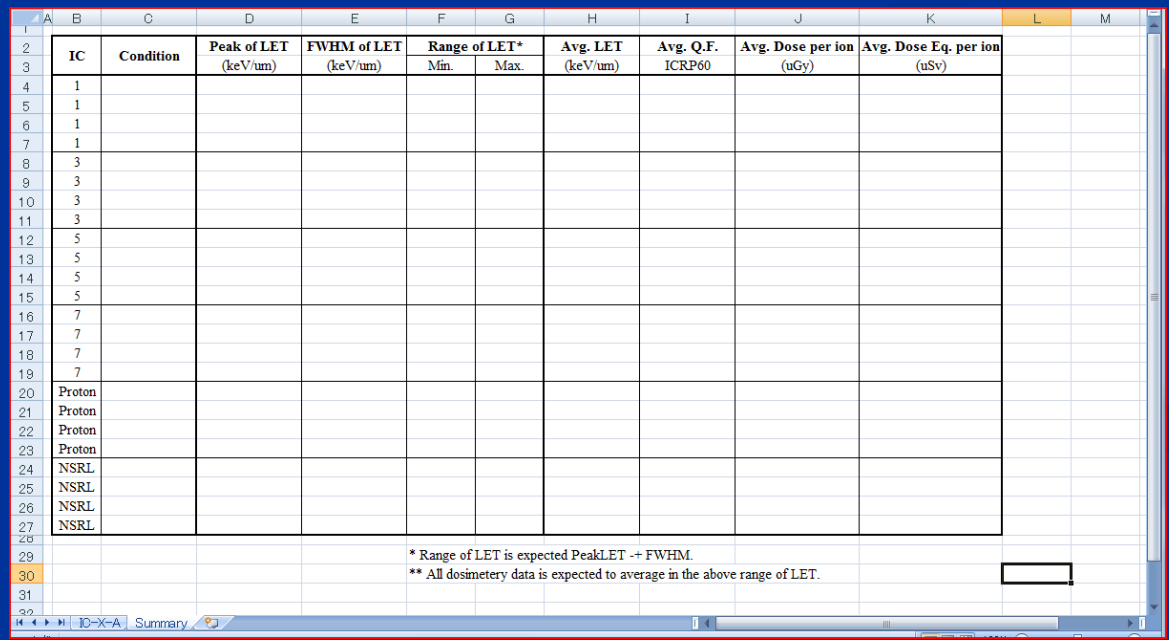
Time Schedule

Year	Month	
2009	April-July	Tests to make wide beams.
	September 10th	Announcement in this WRMISS
2010	Jan. 29th and Feb. 5th	ICCHIBAN Experiments at NIRS-Cyclotron

So, please send us your detectors by Jan. 15th (Fri), 2010.

Report of the Past IC

- Deadline of reports of the past ICCHIBAN is Dec. 31st, 2009 for not only passive detectors but also active detectors.



IC	Condition	Peak of LET (keV/um)	FWHM of LET (keV/um)	Range of LET* Min.	Range of LET* Max.	Avg. LET (keV/um)	Avg. Q.F. ICRP60	Avg. Dose per ion (uGy)	Avg. Dose Eq. per ion (uSv)
1									
1									
1									
1									
3									
3									
3									
3									
5									
5									
5									
5									
7									
7									
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Proton									
Proton									
Proton									
Proton									
NSRL									
NSRL									
NSRL									
NSRL									

* Range of LET is expected PeakLET -+ FWHM.
** All dosimetery data is expected to average in the above range of LET.

IC-X-A | Summary

Conclusion

- 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

- All staffs of NSRL, LLUMC, CERF and HIMAC accelerator facilities. All members in IBMP, Russia for space experiments.
- The participants of ICCHIBAN experiments from 21 institutions; YPI, ARCS, ATI, SCK-CEN, STIL-BAS, NPI, DLR, Kiel Univ., KFKI-AEKI, JAXA, NIRS, Waseda Univ., INP, IBMP, HPA, BNL, CARR, ERI, LBNL, NASA-JSC, OSU.
- The members of ICCHIBAN Working Group; N. Yasuda, E. Benton, H. Kitamura, S. Kodaira, M. Hajek, T. Berger, V. Shurshakov, I. Jadrnickova.