Preliminary Results of Proton ICCHIBAN Experiments

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(5) Institute of Atomic and Subatomic Physics, Vienna University of Technology, Vienna, Austria

(6) Nuclear Physics Institute, Prague, Czech Republic

(7) Chalmers University of Technology, Gothen-burg, Sweden

Contents

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ICCHIBAN Projects

- WRMISS
  - The objective of the workshop was to elaborate an optimal set of instruments for radiation protection issues and to develop and agree on methodologies so that data from these instruments can be compared and properly interpreted. (excerpt from 3rd WRMISS recommendation)
- Intercalibration campaigns
  - During the 4th WRMISS in Farnborough, all participants agreed that it is necessary to establish a process for calibration and intercomparison of space radiation dosimeters. (http://wrmiss.org)
- Ground-base inter-comparison experiments using accelerators
  - The first exposures were perfomed with heavy ion beams; several 100 MeV/nucleon He to Xe at the HIMAC to intercompare radiation instruments designed for use in space as part of a newly initiated. We call this project as InterComparison for Cosmic-ray with Heavy Ion Beams At HIMAC (ICCHIBAN) project.
  - The experiments have been spread to other facilities (BNL-NSRL, CERN-CERF, LLUMC and NCCHE) on the framework of the ICCHIBAN project.
  - Intercmparisons of detectors on ISS also have been performed as BRADOS, Space-ICCHIBAN and Matroshka-R.

ICCHIBAN Project

一番

(InterComparison for Cosmic-ray with Heavy Ion Beams At NIRS)

NASA-JSC, JAXA, IBMP, DLR, … 13 countries, 21 institutes

- 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.
- Compare response and sensitivity of various space radiation monitoring instruments. Aid in reconciling differences in measurements made by various radiation instruments during space flight.
- Establish and characterize a heavy ion "reference standard" against which space radiation instruments can be calibrated.

http://www.nirs.go.jp/ENG/rd/1ban/index.html

2nd and 3rd Proton ICCHIBAN

- To understand responses of detectors for <u>Low LET</u> components
  - Main objects: TLD, OSL, glass, etc.
  - To expose detectors with same conditions, the ICWG (ICCHIBAN Working Group) prepared “Standard Packages”.
  - Construction of radiation field for low LET particles at accelerators.

Standard package

2nd and 3rd Proton ICCHIBAN

- 2nd Proton ICCHIBAN (PI-2)
  - proton 70 MeV (Jan.29th 2010) @ NIRS-Cyclotron
  - Proton 40 MeV (Feb. 5th 2010) @ NIRS-Cyclotron

    http://www.wrmiss.org/workshops/fifteenth/Uchihori.pdf
- 3rd Proton ICCHIBAN (PI-3)
  - proton 30 MeV (Feb. 4th 2011) @NIRS-Cyclotron
  - proton 235 MeV (Feb. 7th 2011) @ NCCHE-Cyclotron

    http://wrmiss.org/workshops/sixteenth/Kitamura.pdf
- Covered LET(in water): 0.45 – 2 keV/μm

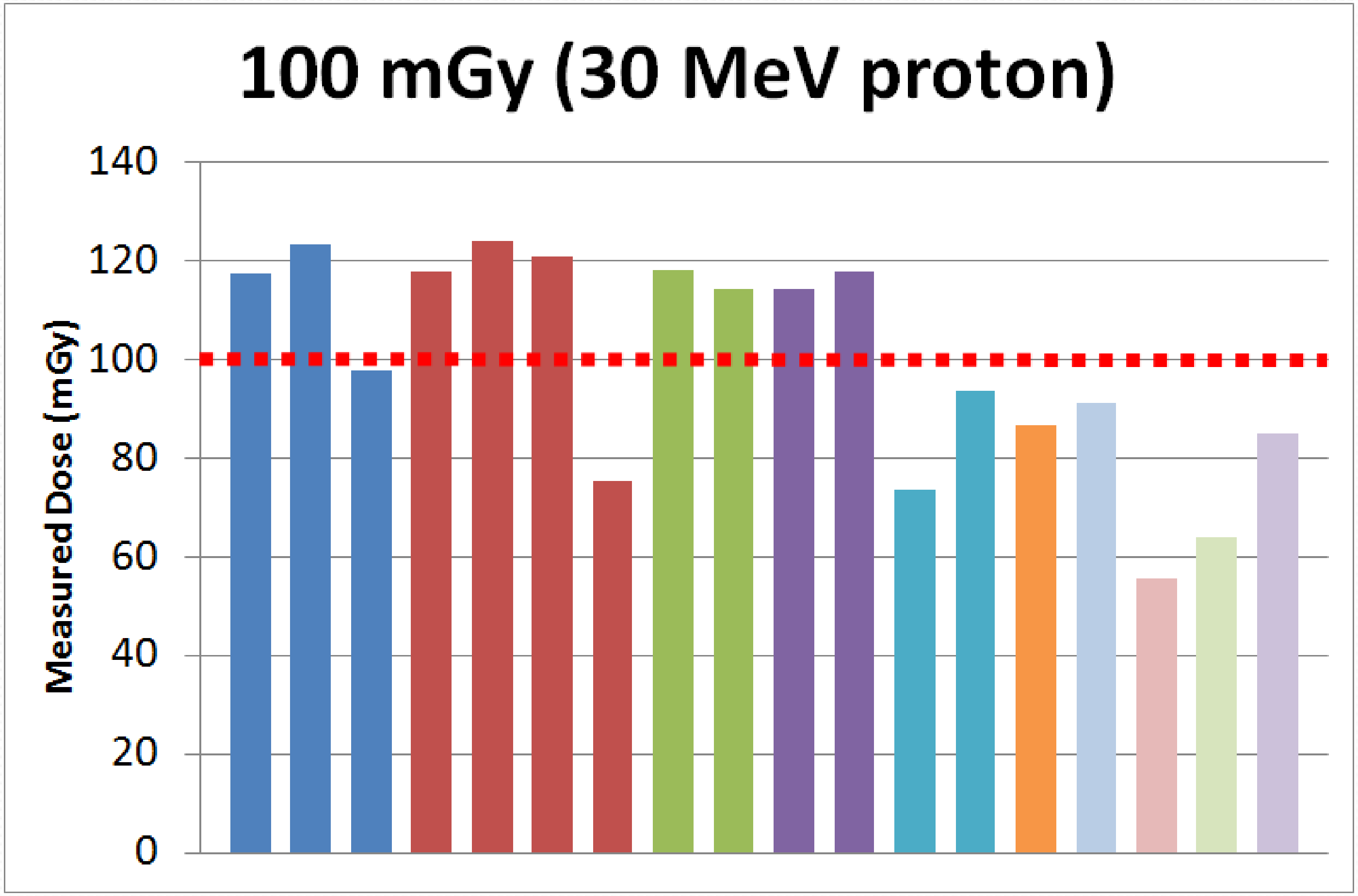
Exposure List

	30 MeV	40 MeV	70 MeV	235 MeV
Energy (MeV)	26	36	69	210
LET(keV/µm)	2.1	1.5	0.97	0.45
Linear	1 mGy	1 mGy	1 mGy	-
	10 mGy	10 mGy	10 mGy	10 mGy (16 mGy)
	50 mGy	50 mGy	50 mGy	50 mGy (80 mGy)
	100 mGy	100 mGy	100 mGy	100 mGy (160 mGy)
	-	-	-	300 mGy (480 mGy)
Aluminum Plate	50 mGy with 1 mm	50 mGy with 3 mmt	50 mGy with 5 mm	-

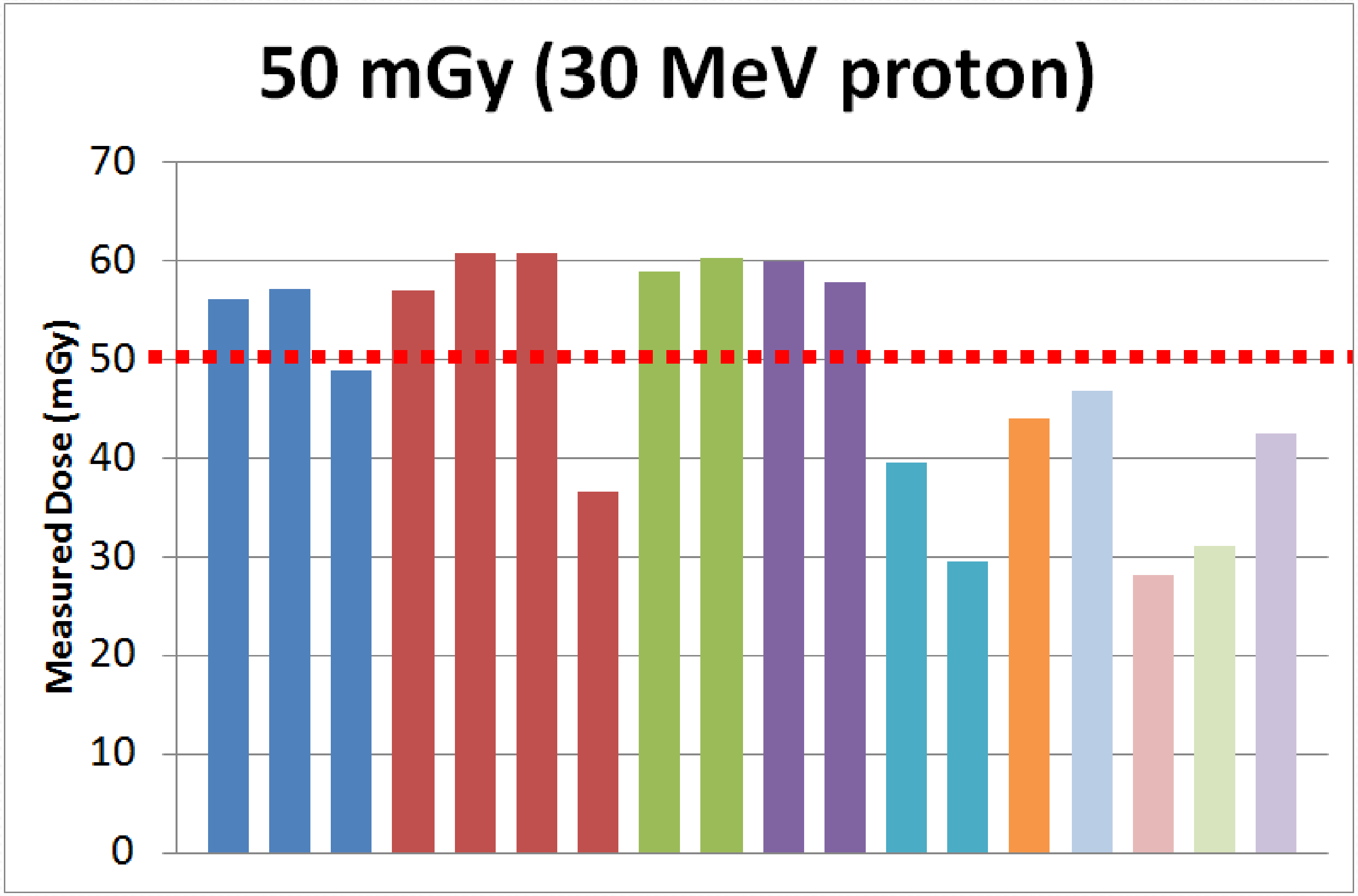
Comparisons of detectors on 3rd Proton ICCHIBAN

- 30 MeV proton beam
- 235 MeV proton beam
  - Failed to evaluate absolute exposed doses.

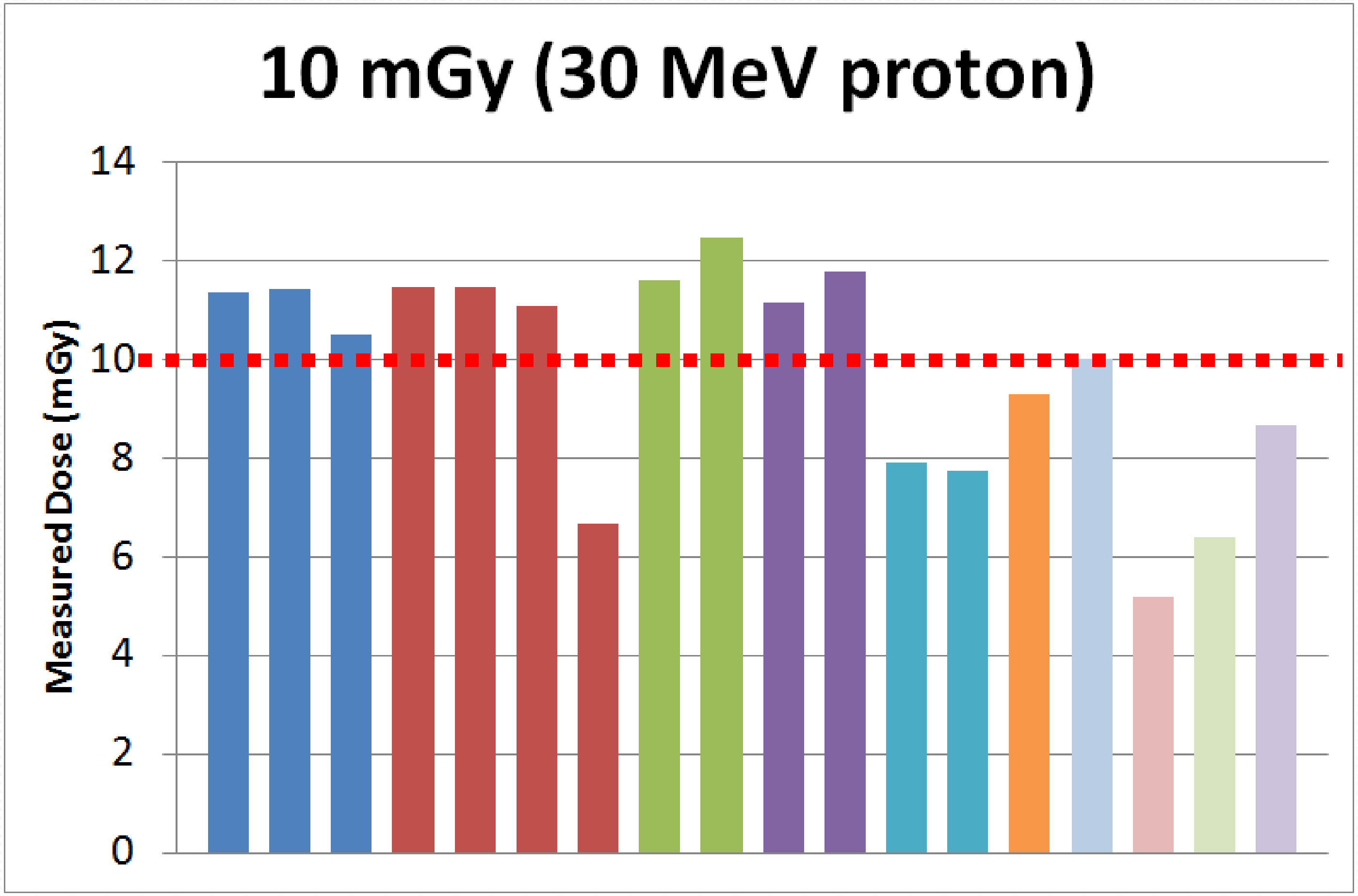
30 MeV proton beam



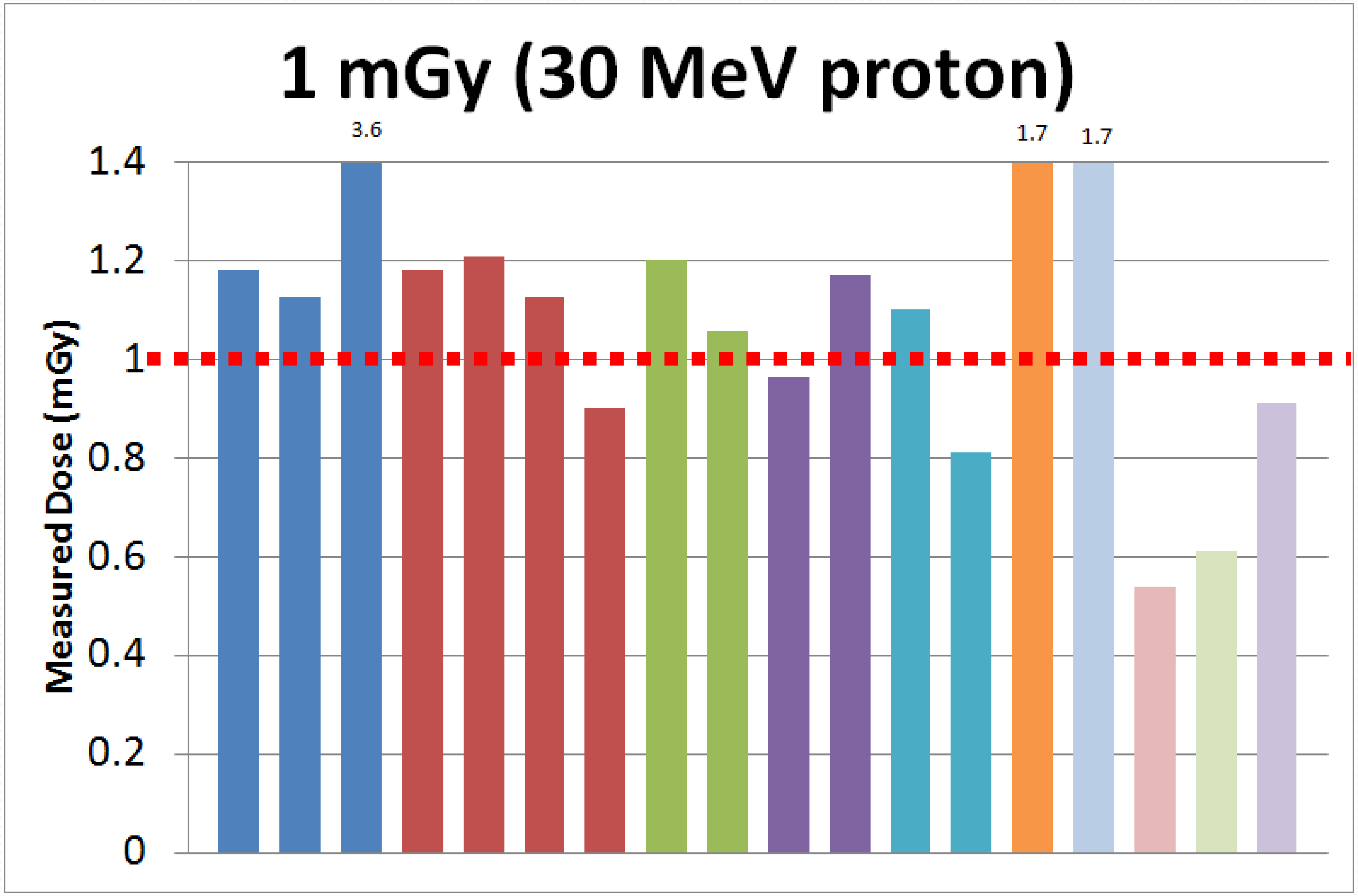
30 MeV proton beam



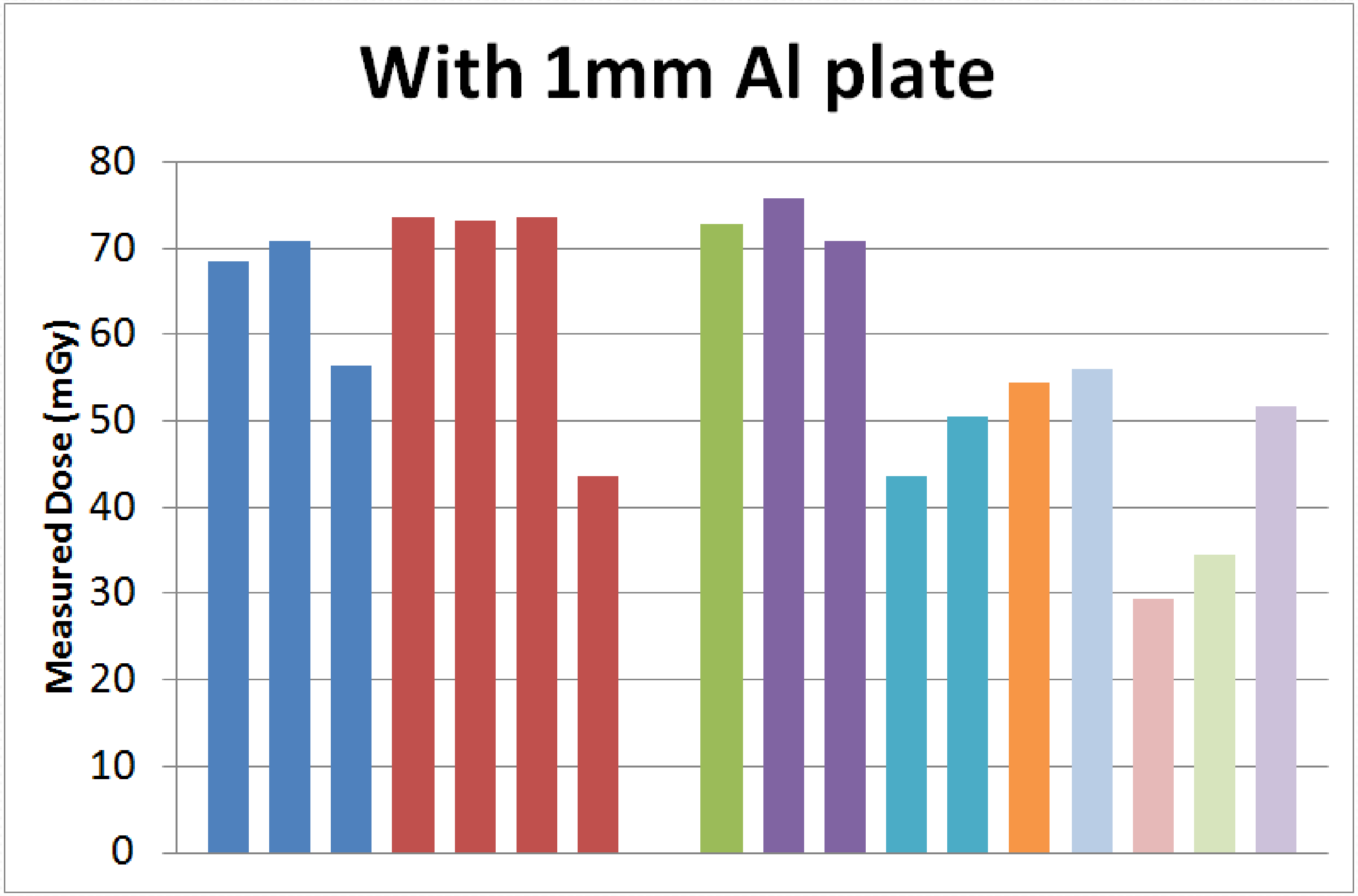
30 MeV proton beam



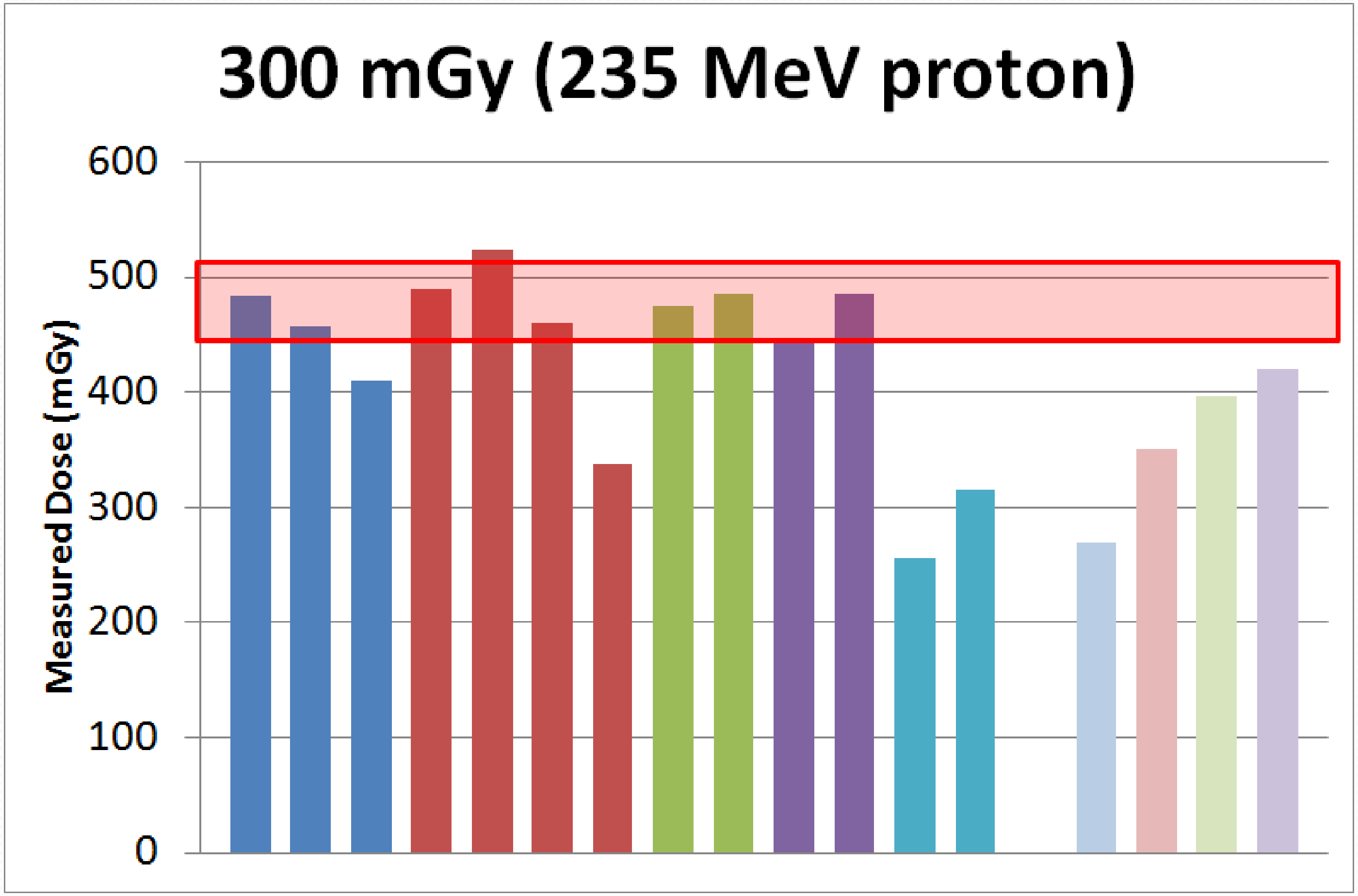
30 MeV proton beam



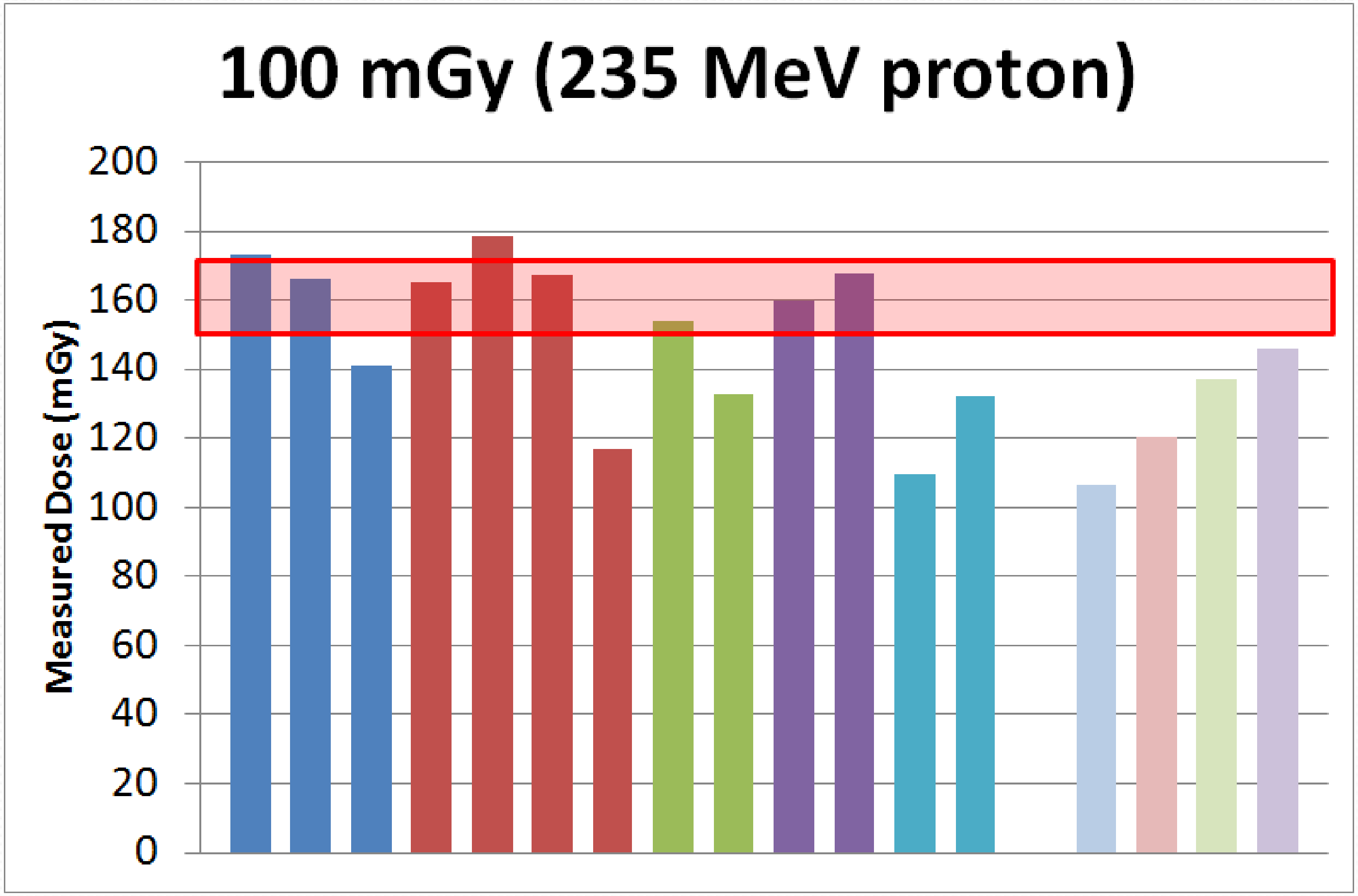
30 MeV proton beam



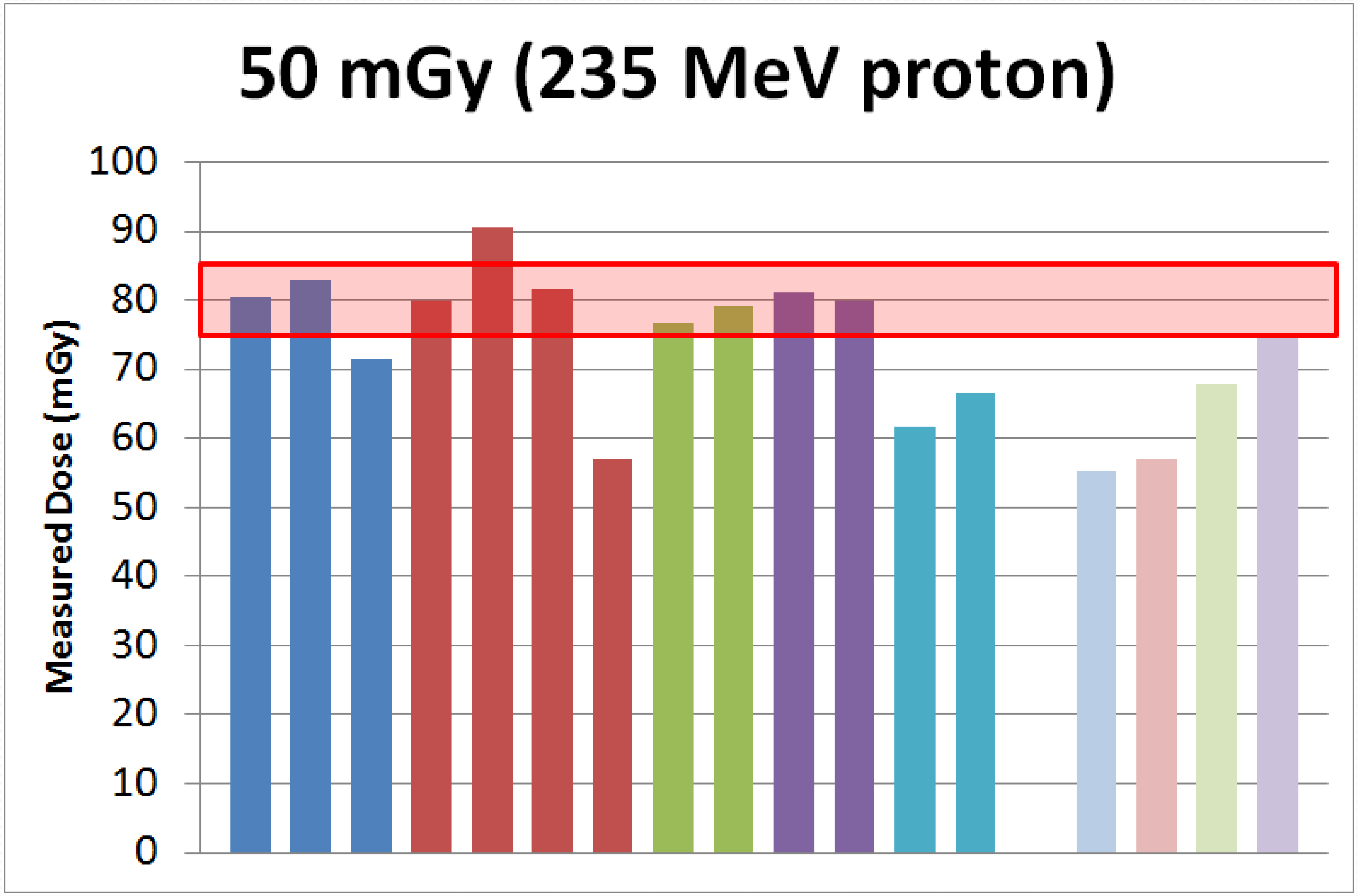
235 MeV proton beam



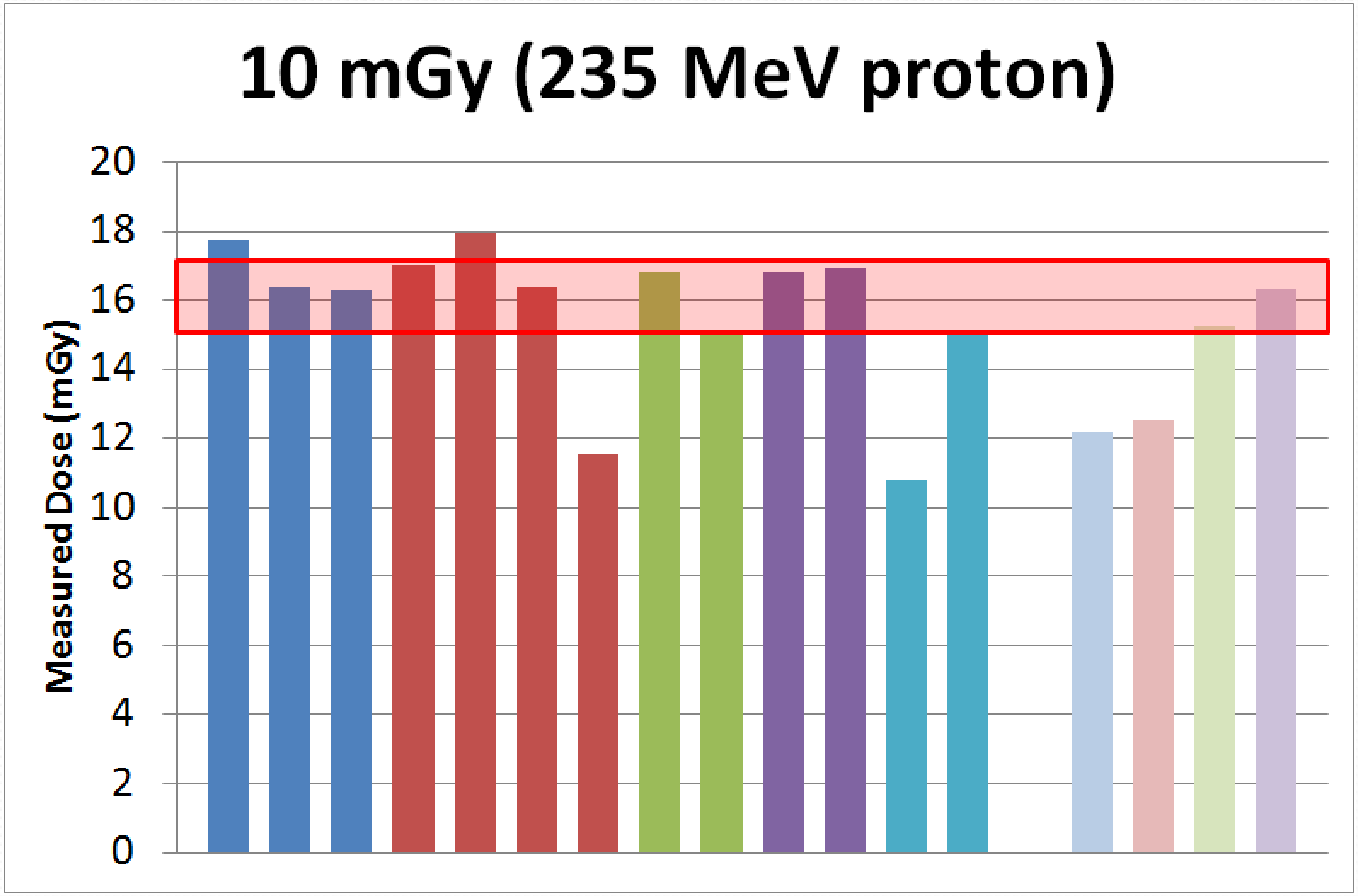
235 MeV proton beam



235 MeV proton beam



235 MeV proton beam



Summary of 3rd Proton ICCHIBAN

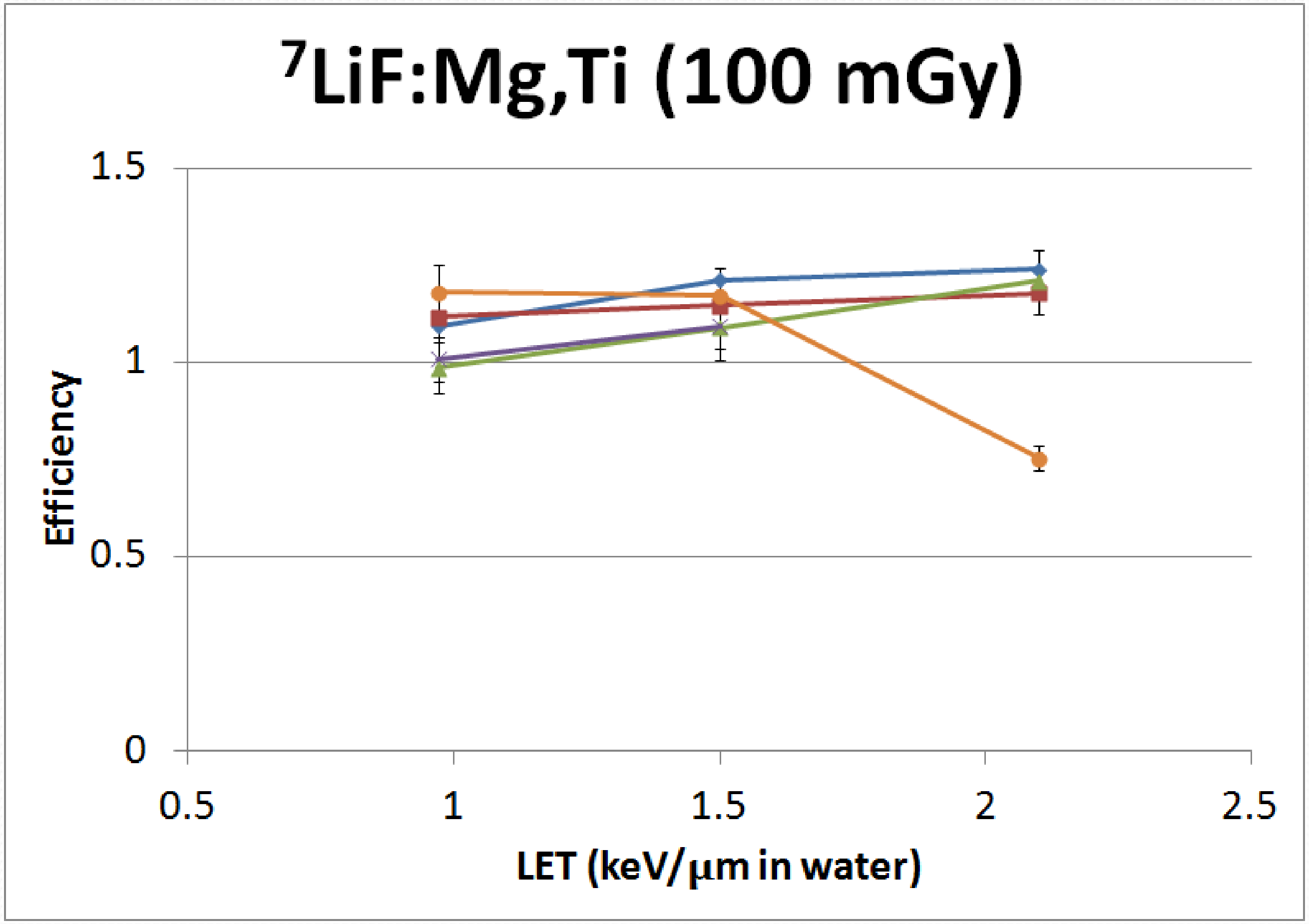
- The measured doses for 30 MeV proton (26 MeV in real value) are relative to the exposed doses in the region of 10 to 100 mGy.
- Exposures of 1 mGy (30 MeV) might be not controlled well because of the accuracy of the Ion Chamber to monitor low dose-rate beams, and the measured value also have problems such as subtraction of background.
- The dose dependences for 235 MeV proton (210 MeV in real value) are relative to the exposed doses in the region of 16 to 480 mGy, too.

Preliminary Result

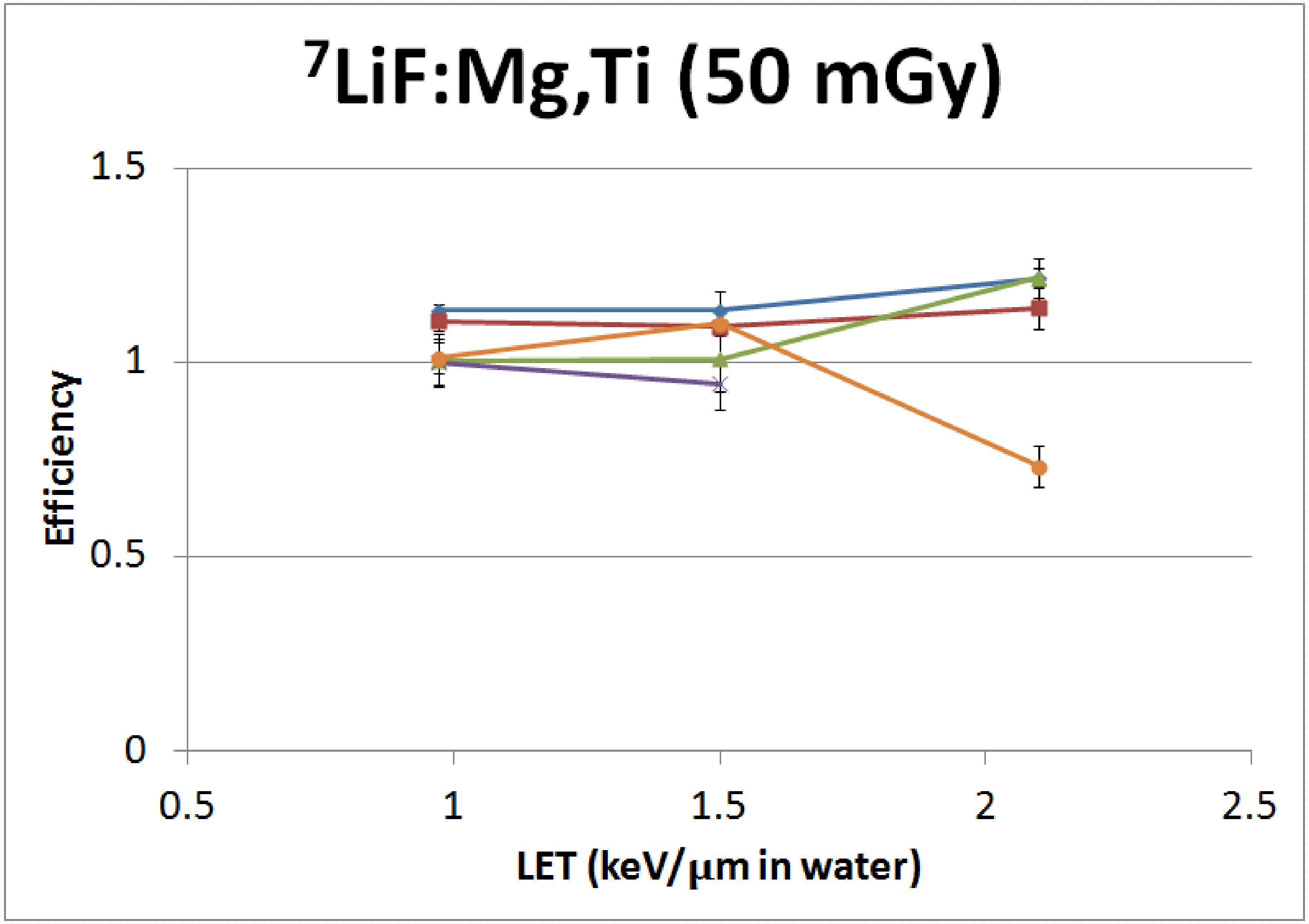
TL-Efficiencies in 0.97 – 2.1 keV/μm

(30, 40 and 70 MeV proton beam. 235 MeV beam is excluded.)

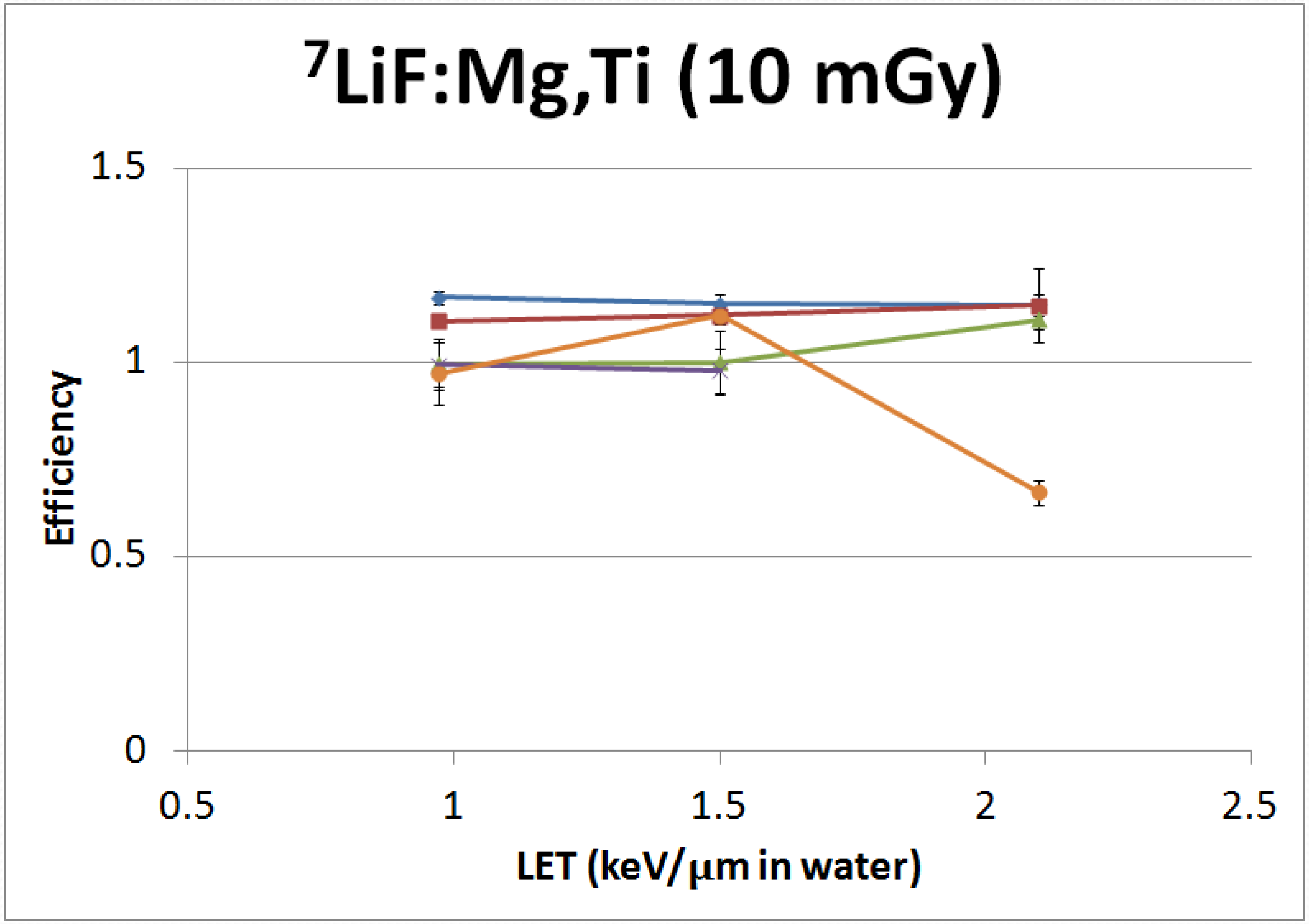
TLD ($^7LiF:Mg,Ti$)



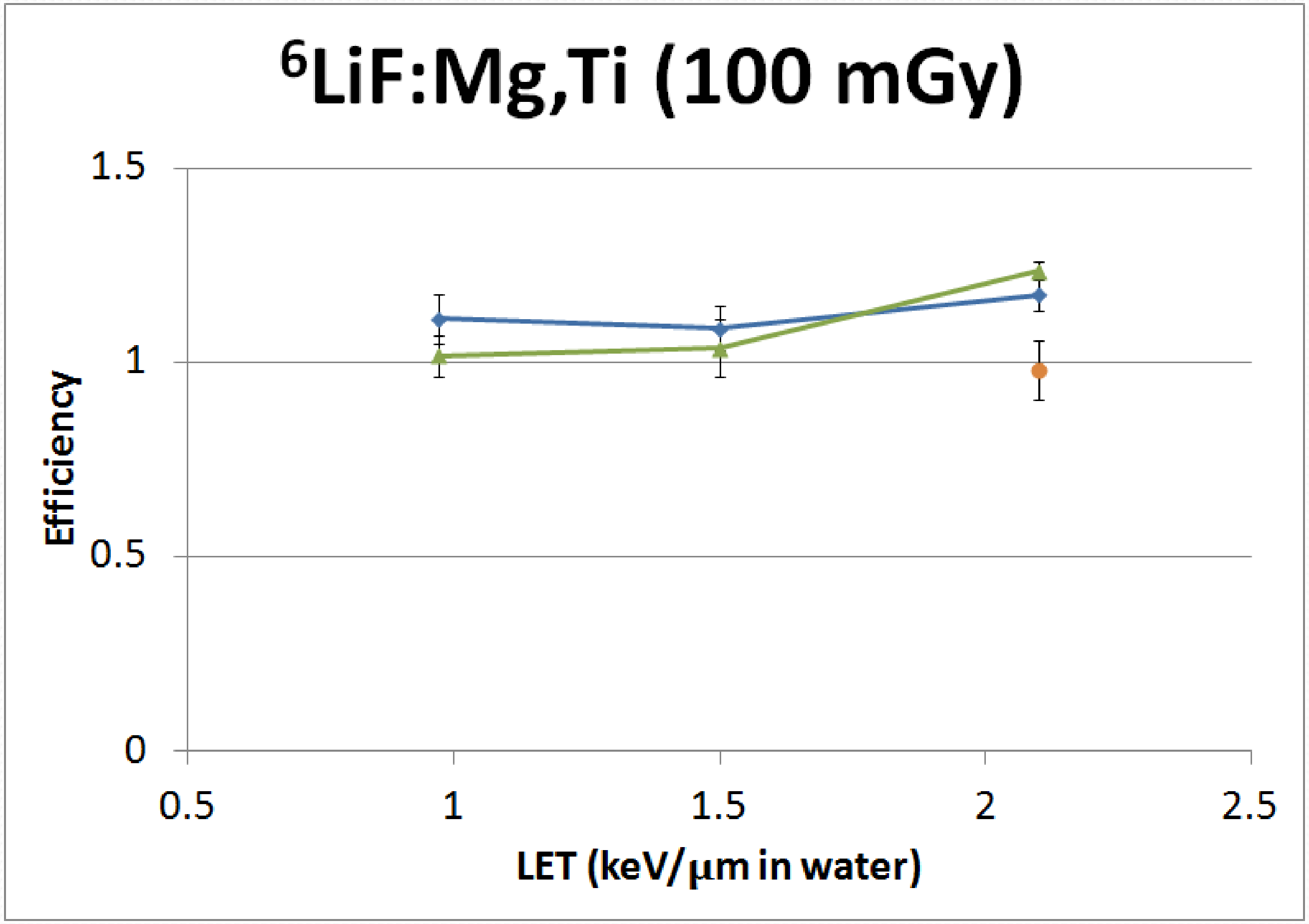
TLD (^{7}LiF:Mg,Ti)



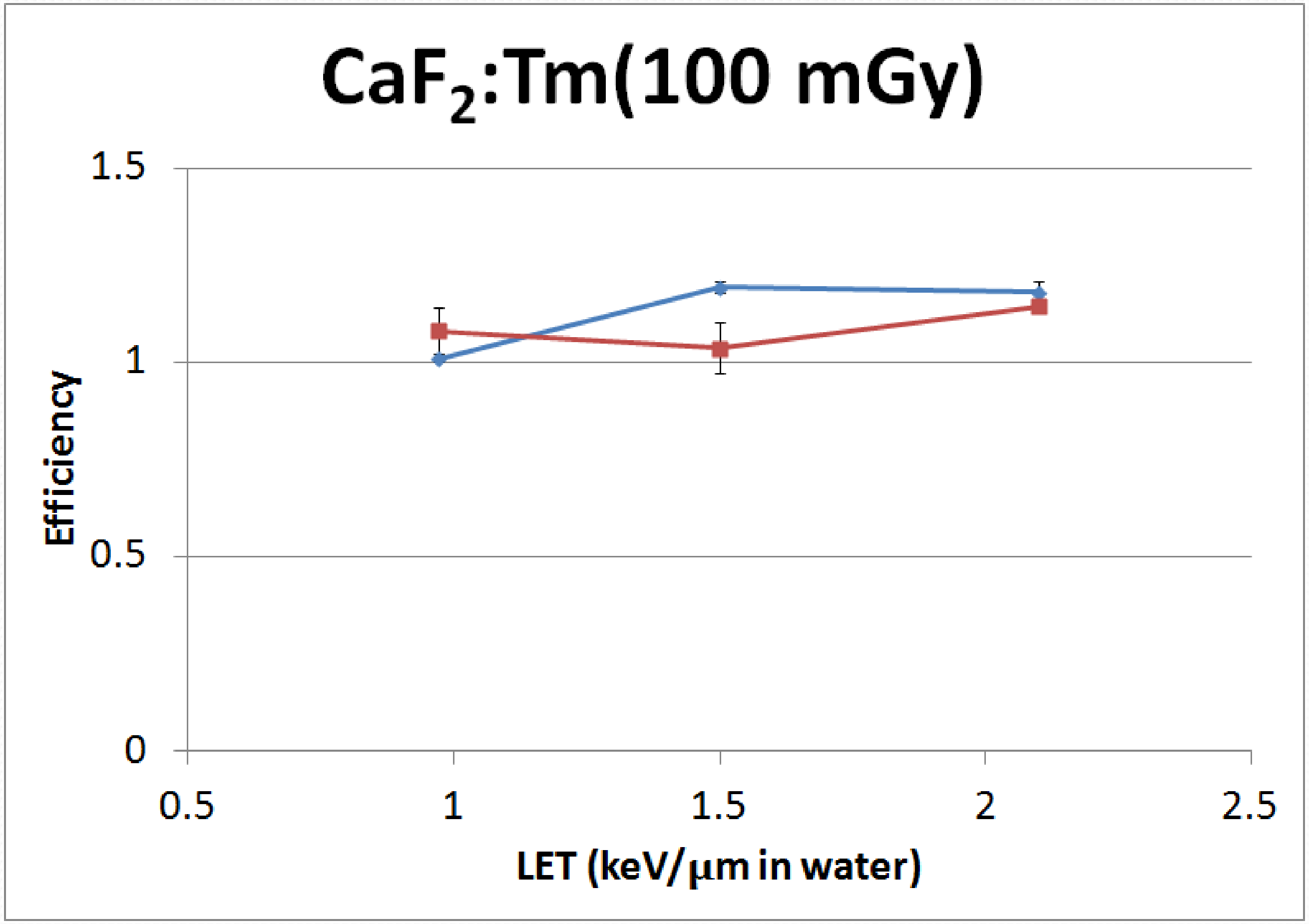
TLD (^{7}LiF:Mg,Ti)



TLD (^{6}LiF:Mg,Ti)

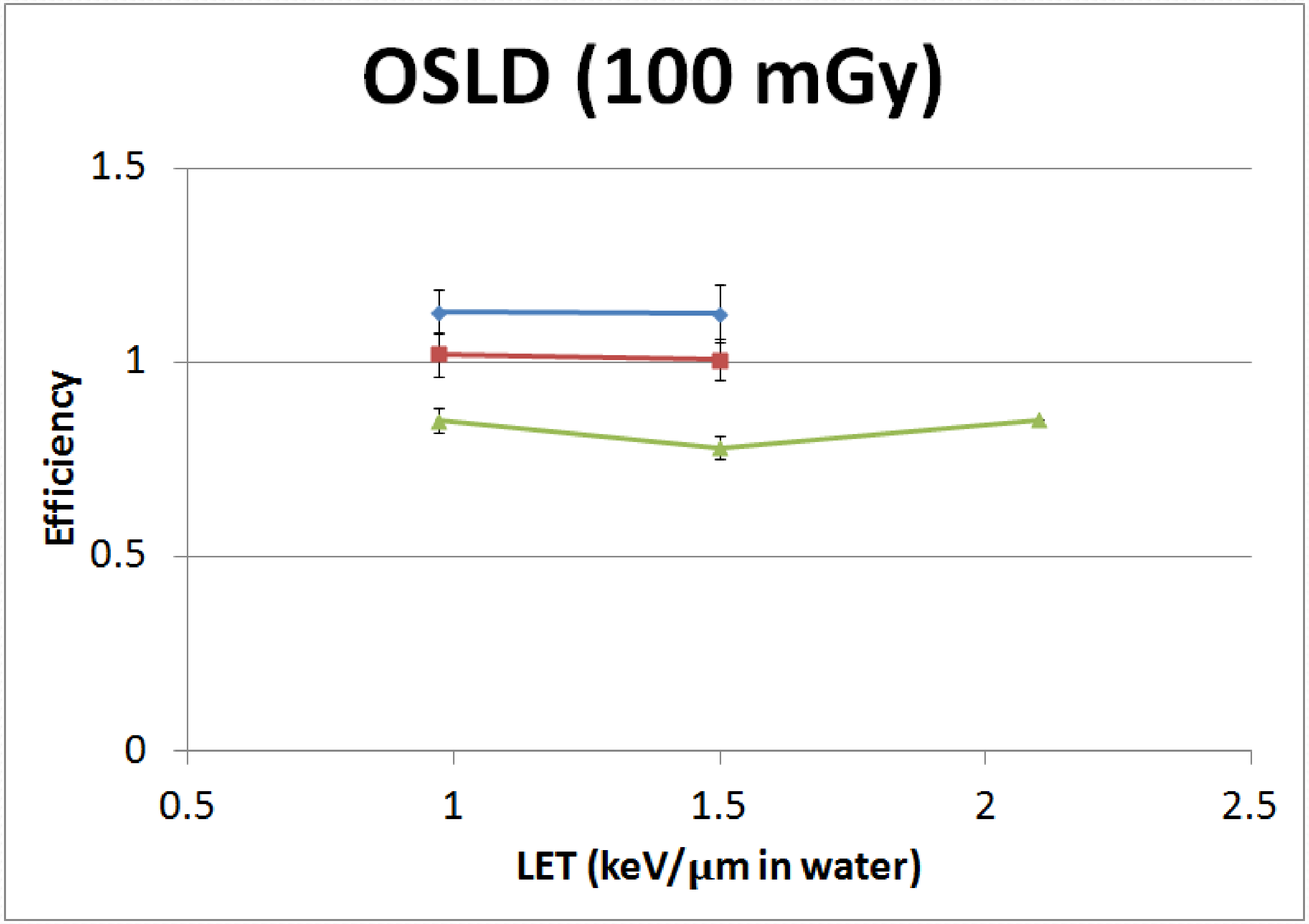


TLD (CaF_2:Tm)



CaF2:Tm(100 mGy)
1.5
1
0.5
0
Efficiency
0.5
1
1.5
2
2.5
LET (keV/μm in water)

OSLD



Summary of PI-2 and -3

- Luminescence efficiencies are almost constant in 1-2 keV/um LET region.
- But, some detectors showed slight increases in luminescence efficiencies with LET increasing.
  - Because of the shorter range of 30 MeV proton beam, thickness of detectors should be considered to calculate the exposed doses.
  - The ICWG should check the real thickness of the standard packages and the time variation of the calibrated ion chamber to evaluate the beam monitor.

Next Experiments

- Plan of 4^{th} Proton ICCHIBAN
  - Proton 80 MeV (77MeV, 0.90 keV/μm)
  - NIRS-Cyclotron
  - January 31st, 2013
  - Object: TLD,OSLD, Glass, etc.

- Future plan (Not fixed)
  - Proton 160/230 MeV
  - ^{4}He 150 MeV/u

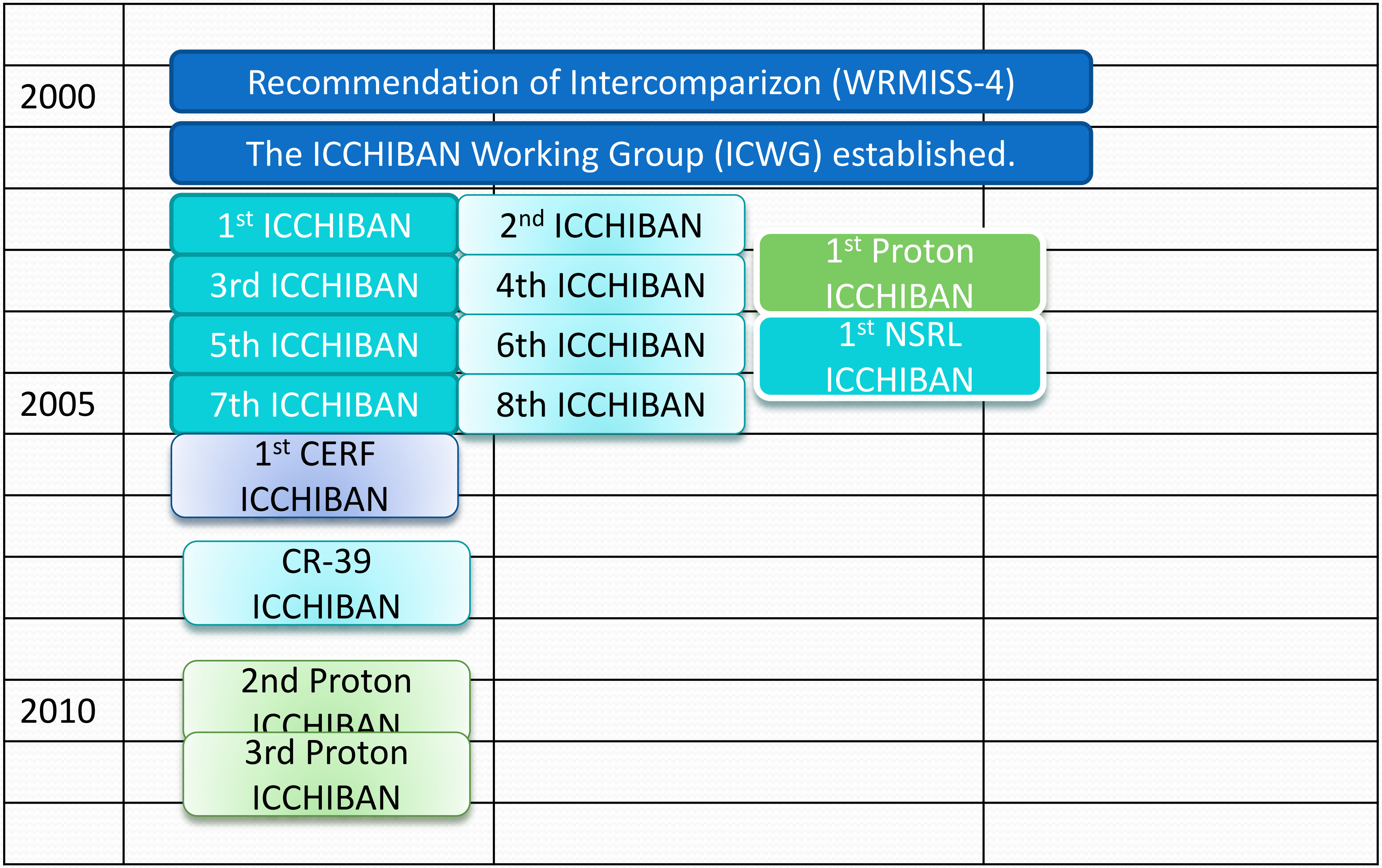
Acknowledgement

- Staffs of the NIRS-Cyclotron facility
- Dr. Teiji Nishio and stuffs of the cyclotron in National Cancer Center Hospital East

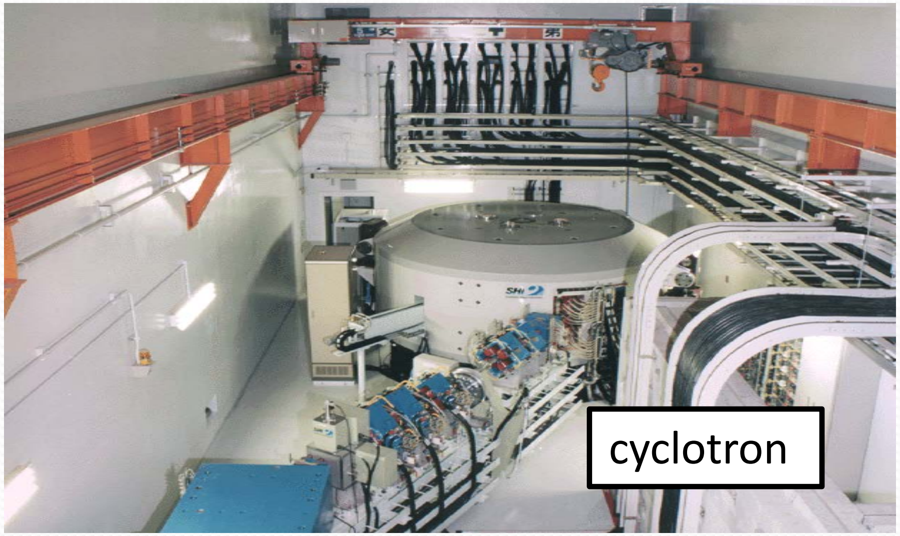
Thank you for your attention.

Back pockets

Brief History of ICCHIBAN Project



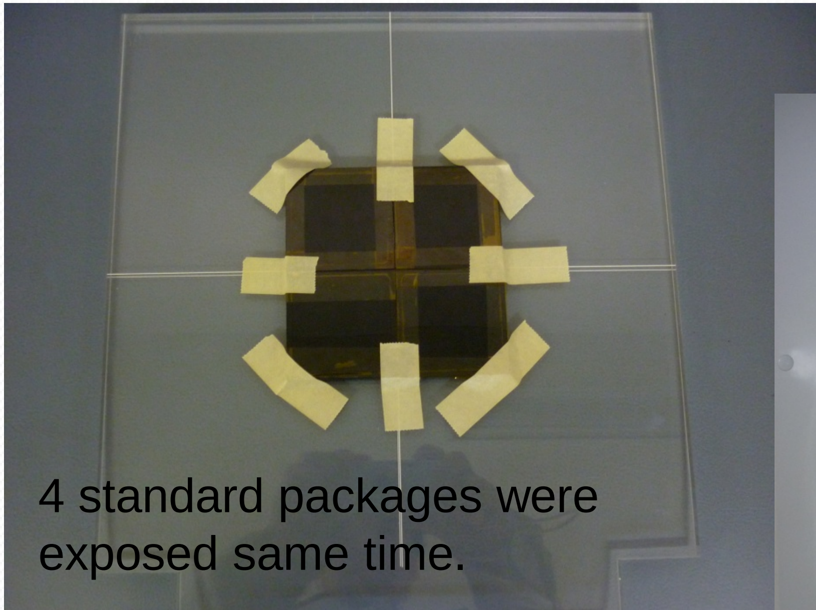
National Cancer Center Hospital East (NCCHE) Cyclotron

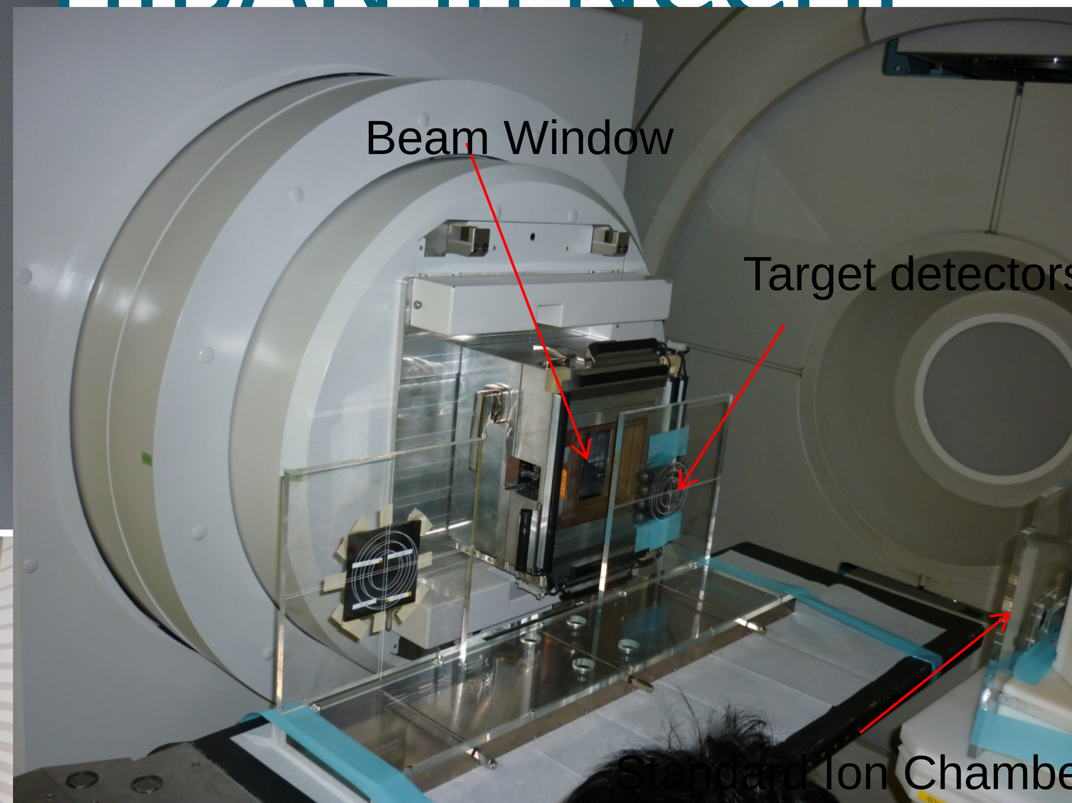


- Place: Kashiwa-City, Japan
- Establish: April 1997
- Purpose: Cancer Therapy
- http://www.ncc.go.jp/en/ncce/about/hospital_e.html

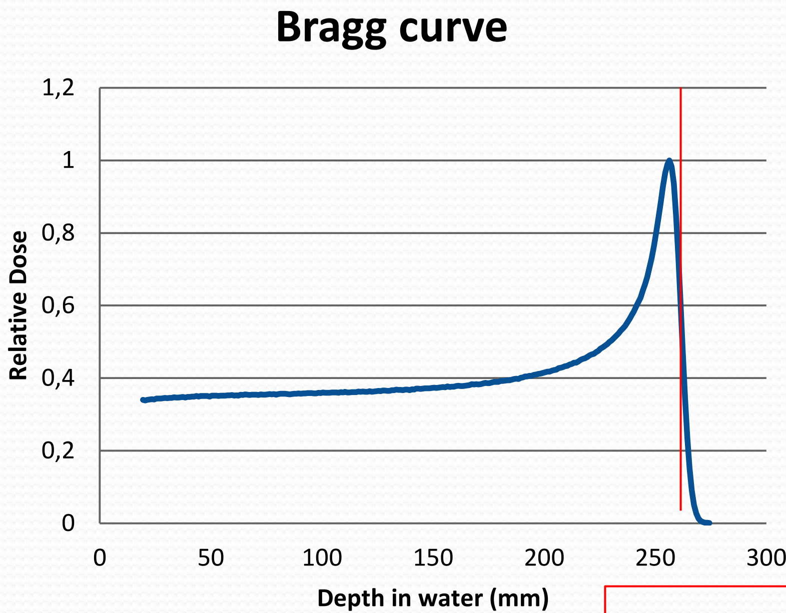
- Type: AVF-Cyclotron
- Beam: Proton 235 MeV
- http://www.shi.co.jp/quantum/eng/product/proton/proton.html

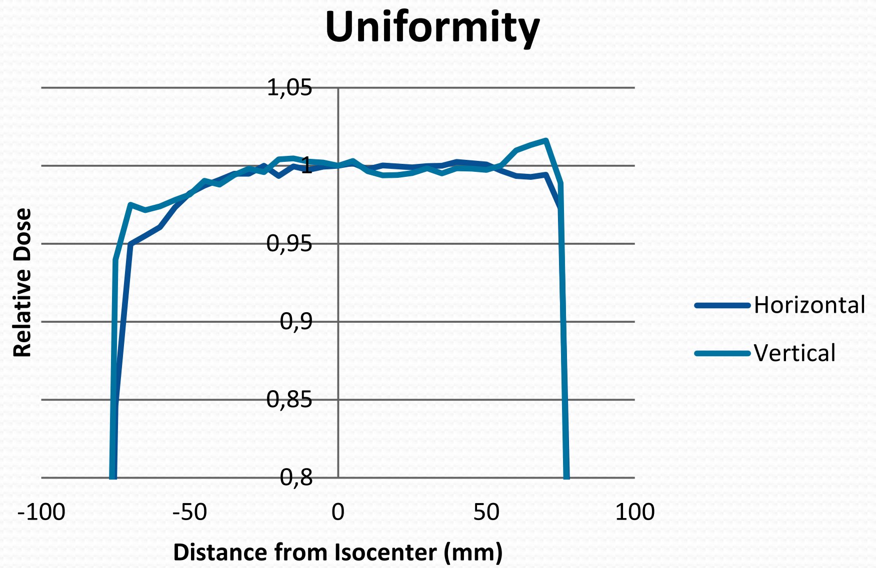
HIBAN in NCCHF





Characteristic of 235 MeV beam





range
262mm

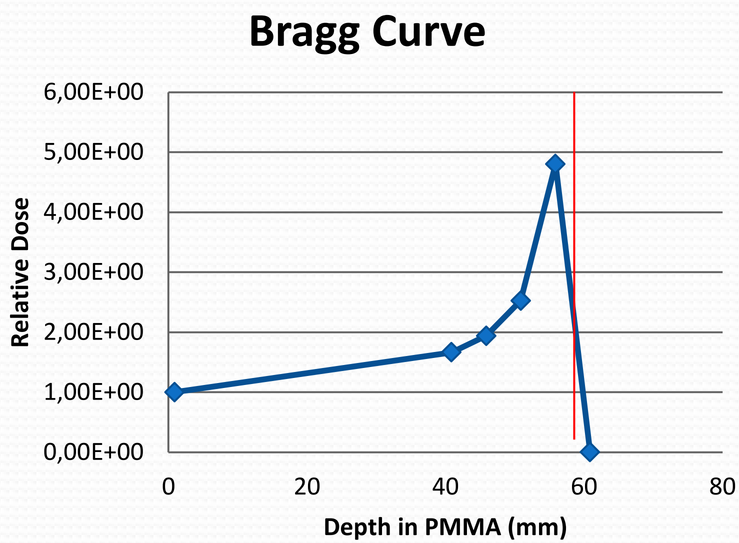
Energy: 203 MeV
LET in water: 0.45 keV/μm
(SRIM 2008)

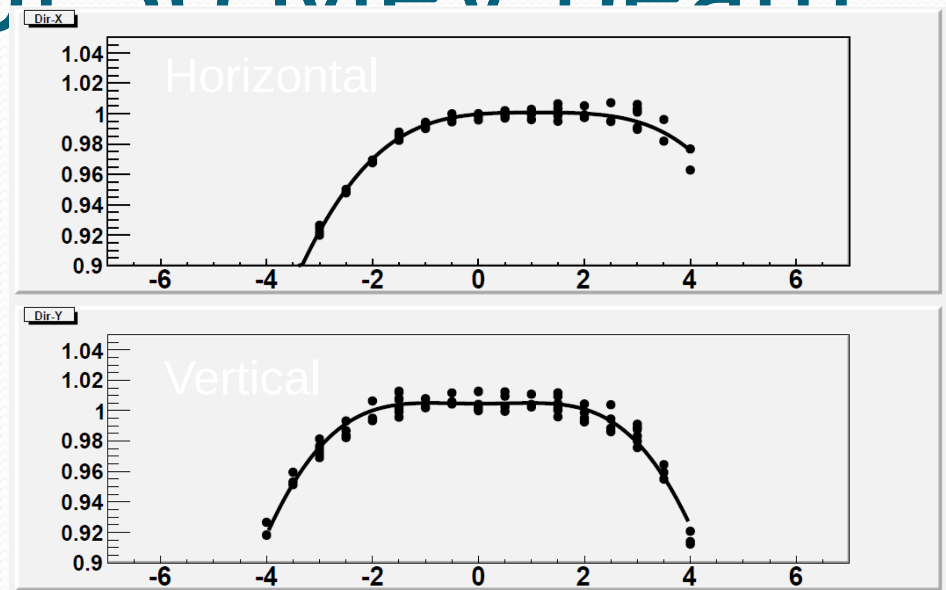
Uniformity: ±5%
within 140 mm diameter

Exposures of proton 235 MeV beam in the NCCHE cyclotron

- Result from range measurement, energy of the beam is 203 MeV, not 235 MeV. #But, I use 235 MeV in this presentation.
- This is the first trial for the NCCHE cyclotron to be used as “reference field”.
  - Exposed doses are almost 80% for nominal doses and have large errors because the nominal doses are smaller than the typical clinical doses.
  - We will evaluate the exposed dose, again.

Characteristic of 30 MeV beam





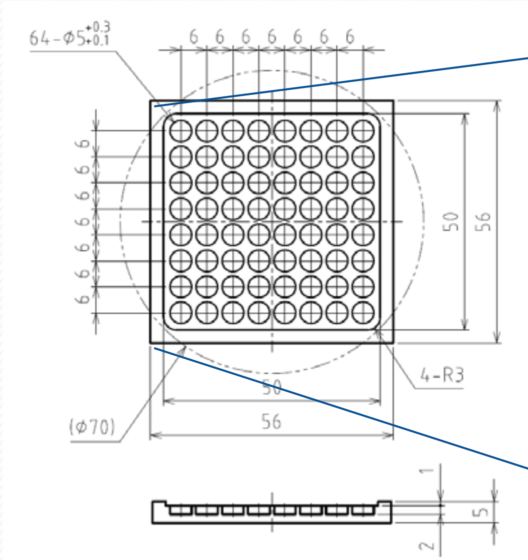
range
5.8 mm

Energy: 26 MeV
LET in water: 2.1 keV/μm
(SRIM 2008)

Uniformity: ±5%
within 70 mm diameter

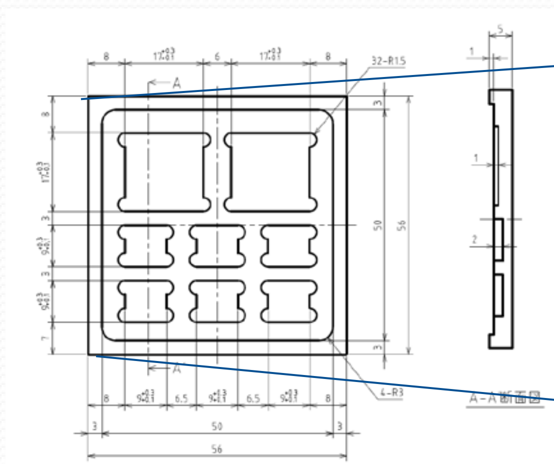
Relative exposed dose* for 30MeV proton at position of the standard packages

Type A Package



0.956	0.973	0.981	0.986	0.987	0.987	0.984	0.978
0.974	0.985	0.992	0.994	0.995	0.995	0.994	0.990
0.983	0.992	0.997	0.998	0.999	0.999	0.998	0.996
0.987	0.996	0.999	1.000	1.000	1.000	1.000	0.998
0.987	0.996	0.999	1.000	1.000	1.000	1.000	0.998
0.983	0.993	0.997	0.998	0.998	0.998	0.998	0.995
0.973	0.985	0.991	0.994	0.994	0.994	0.992	0.988
0.957	0.972	0.980	0.984	0.986	0.985	0.982	0.976

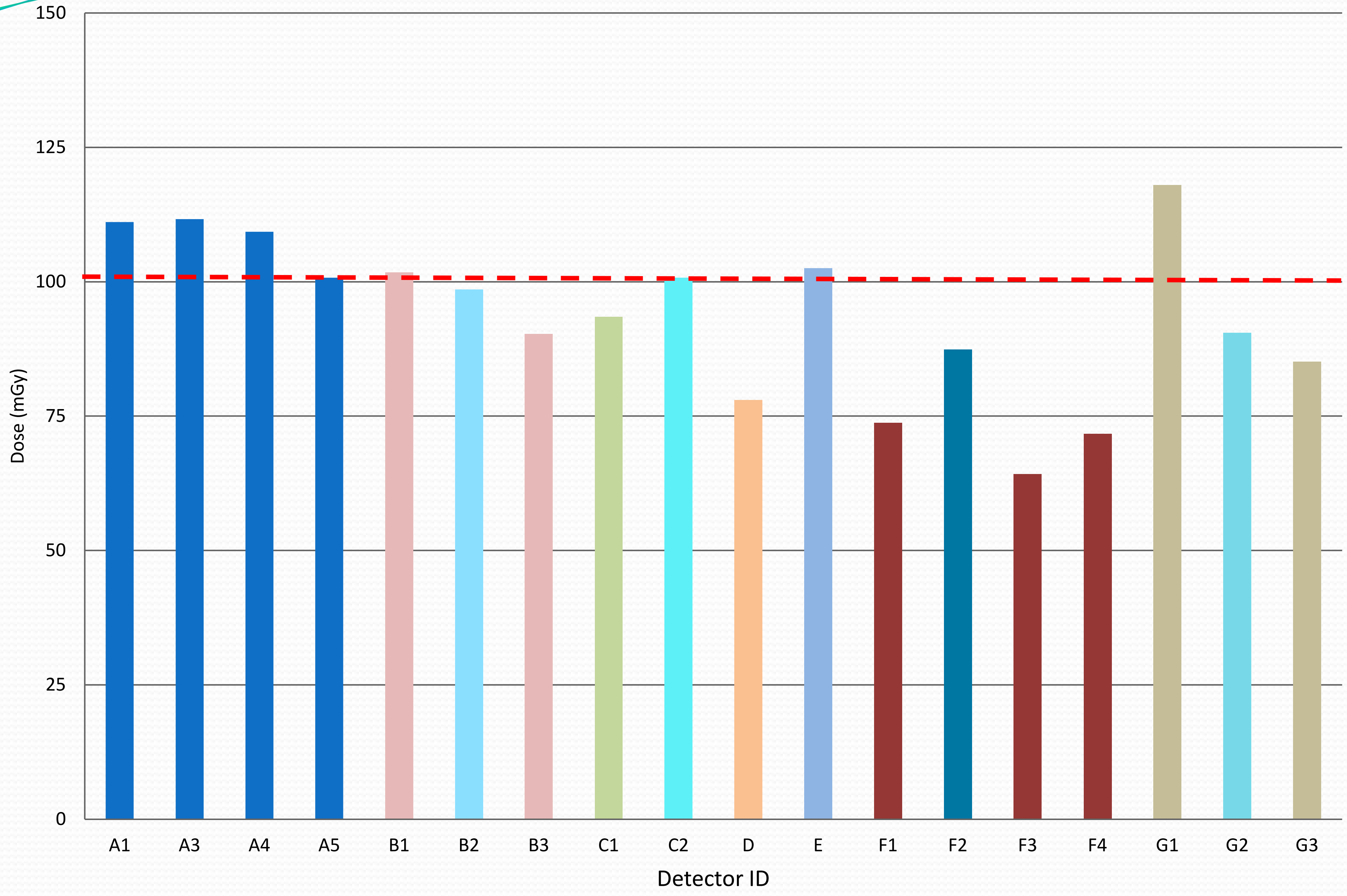
Type C Package



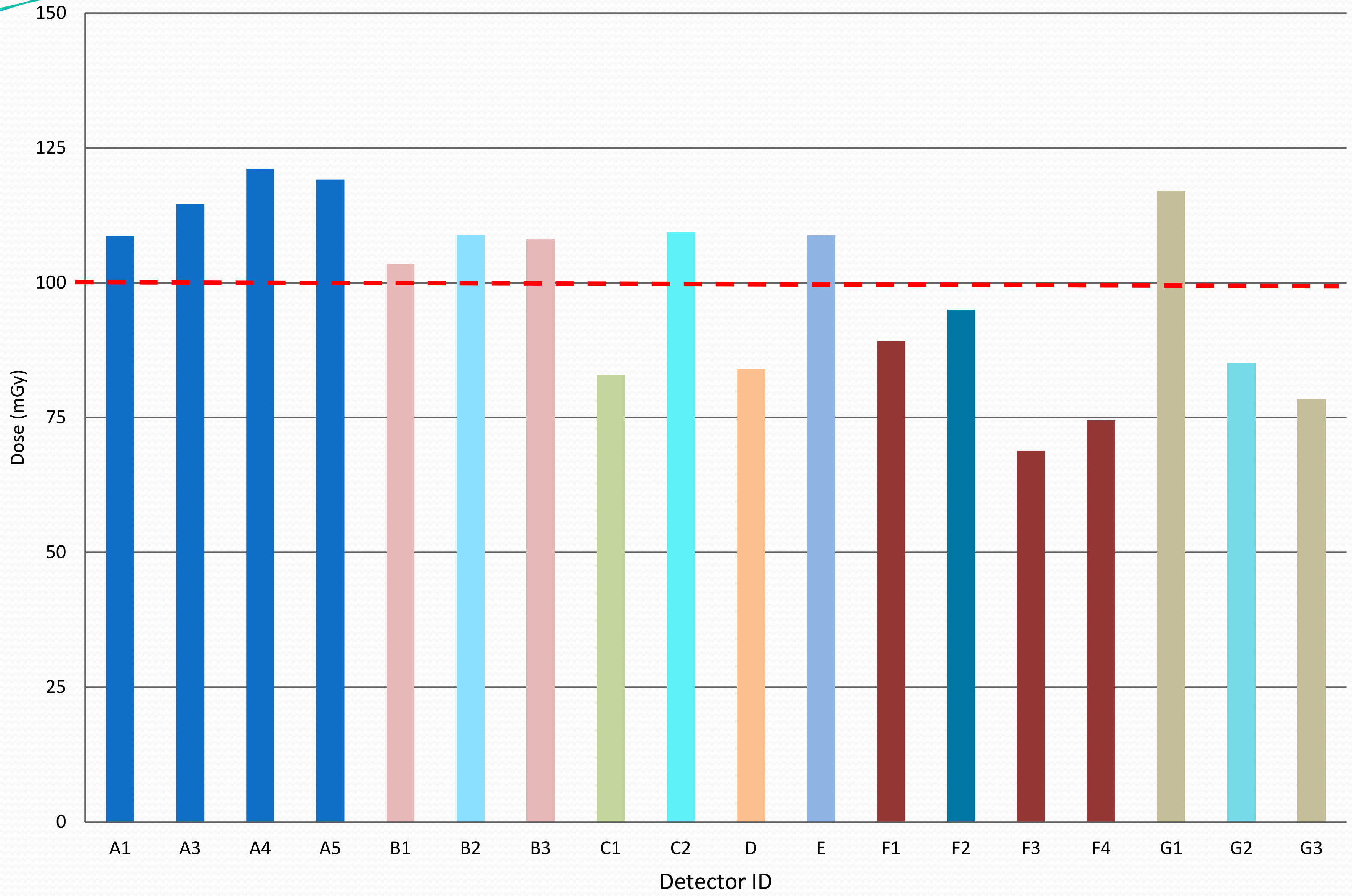
0.990	0.996	
0.991	0.999	0.999
0.976	0.990	0.990

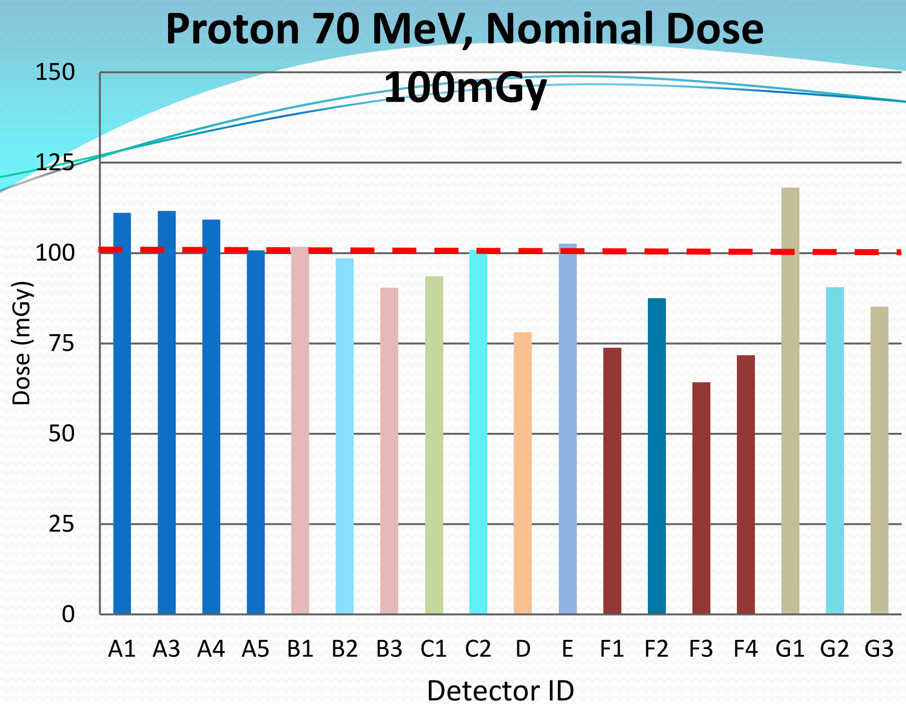
* Not available for 235 MeV proton beam

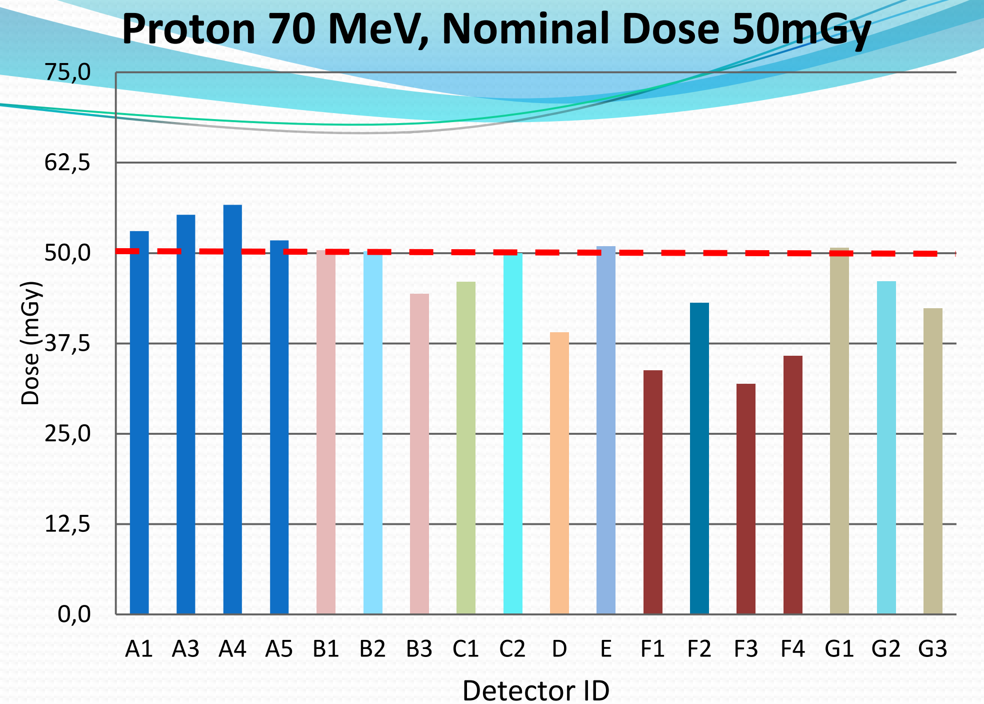
Proton 70 MeV, Nominal Dose 100mGy

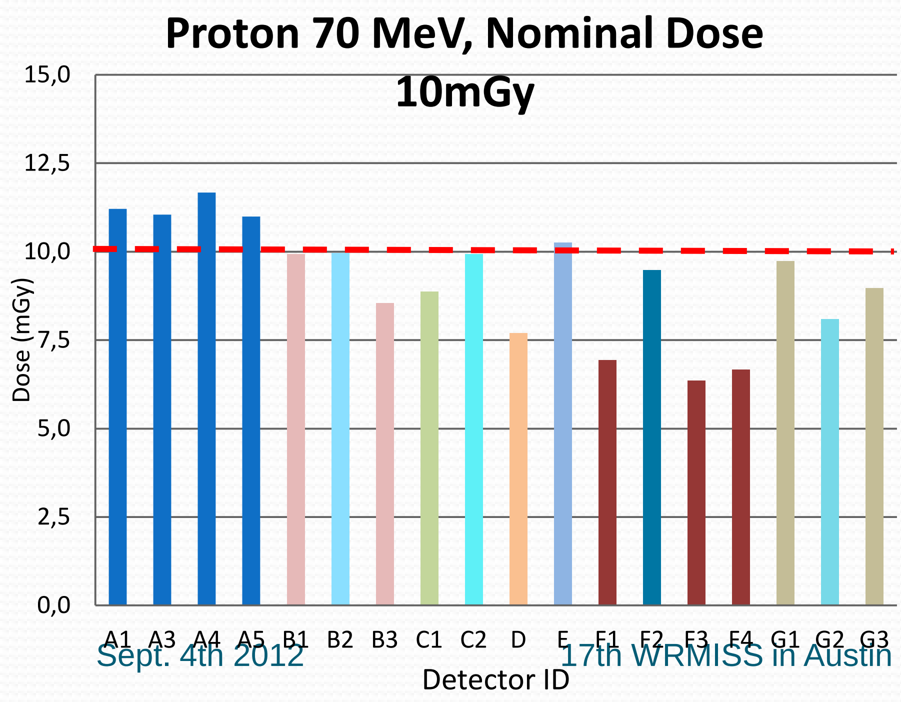


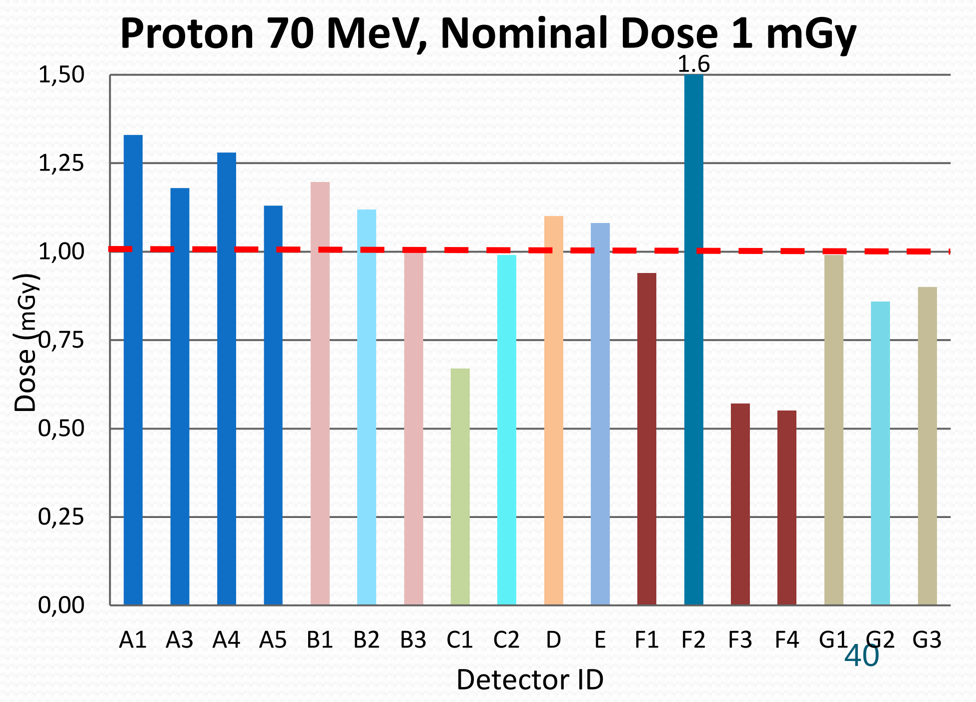
Proton 40 MeV, Nominal Dose 100mGy



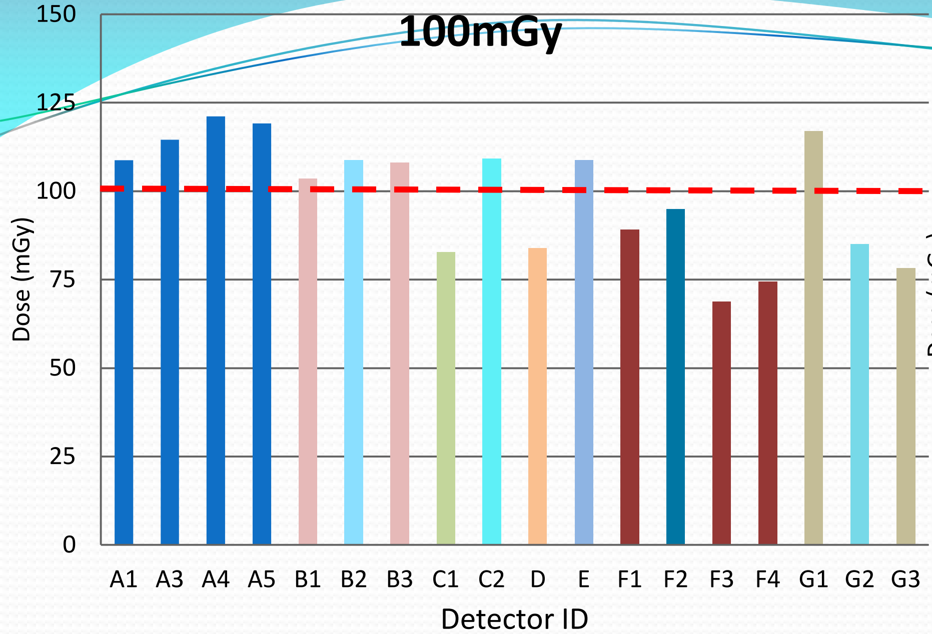

Proton 70 MeV, Nominal Dose 100mGy
150
125
100
75
50
25
0
Dose (mGy)
A1 A3 A4 A5 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID


Proton 70 MeV, Nominal Dose 50mGy
75,0
62,5
50,0
37,5
25,0
12,5
0,0
Dose (mGy)
A1 A3 A4 A5 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID

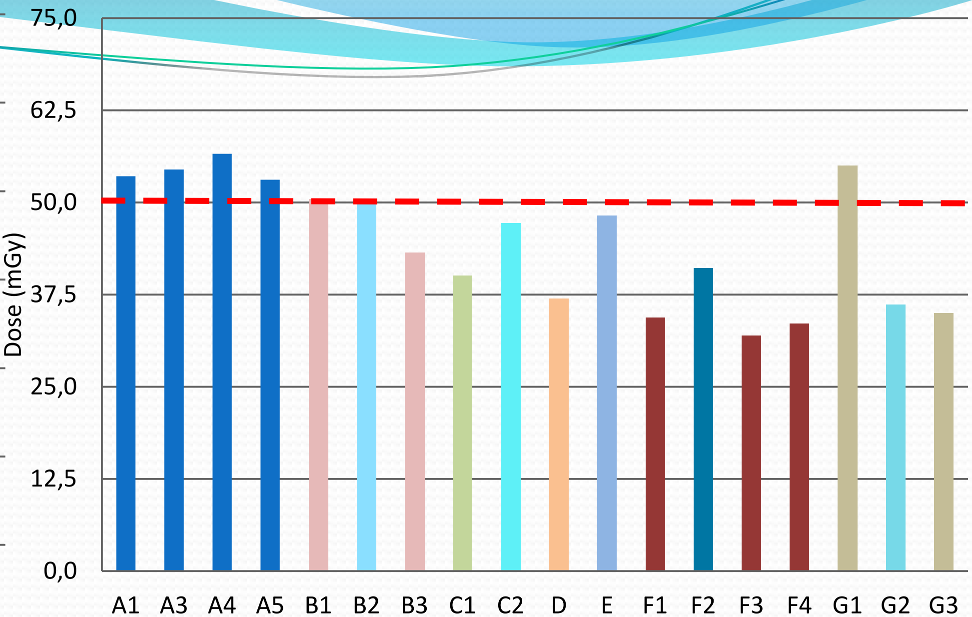

Proton 70 MeV, Nominal Dose 10mGy
15,0
12,5
10,0
7,5
5,0
2,5
0,0
Dose (mGy)
A1 A3 A4 A5 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID


Proton 70 MeV, Nominal Dose 1 mGy
1.6
1,50
1,25
1,00
0,75
0,50
0,25
0,00
Dose (mGy)
A1 A3 A4 A5 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID

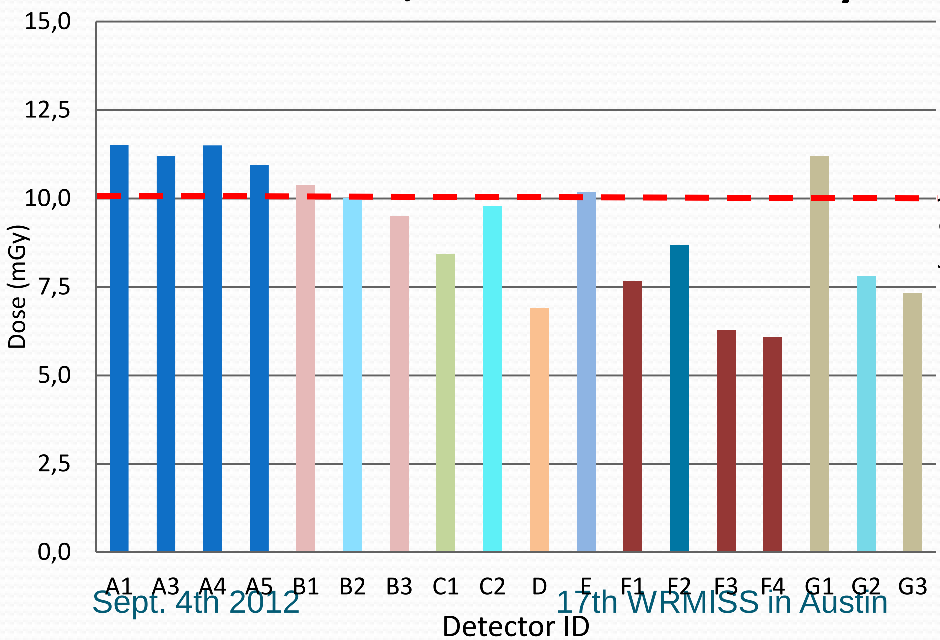
Proton 40 MeV, Nominal Dose 100mGy



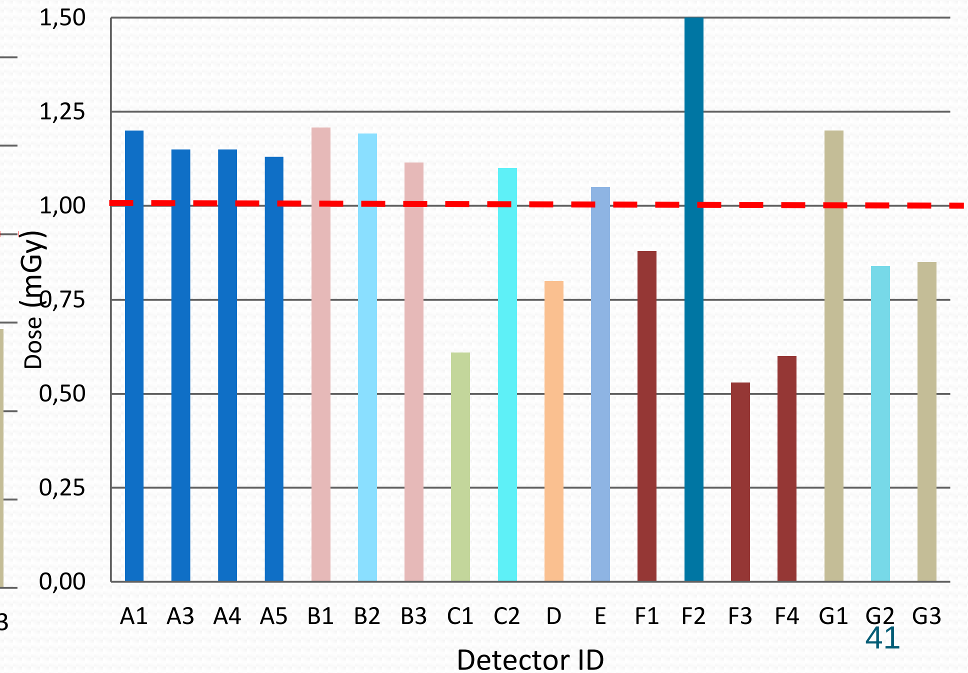
Proton 40 MeV, Nominal Dose 50mGy

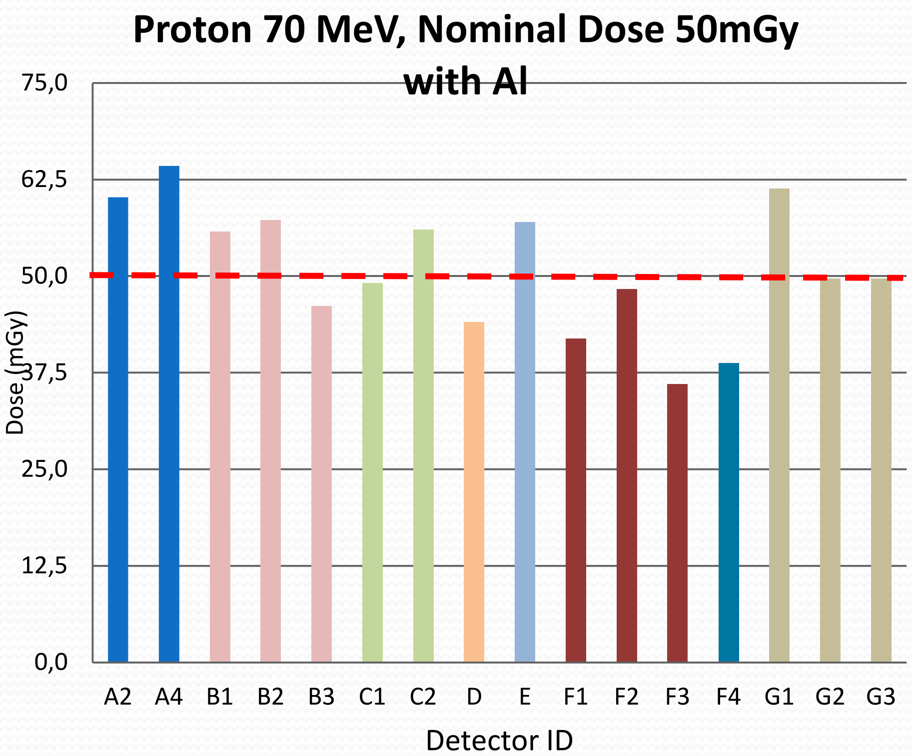


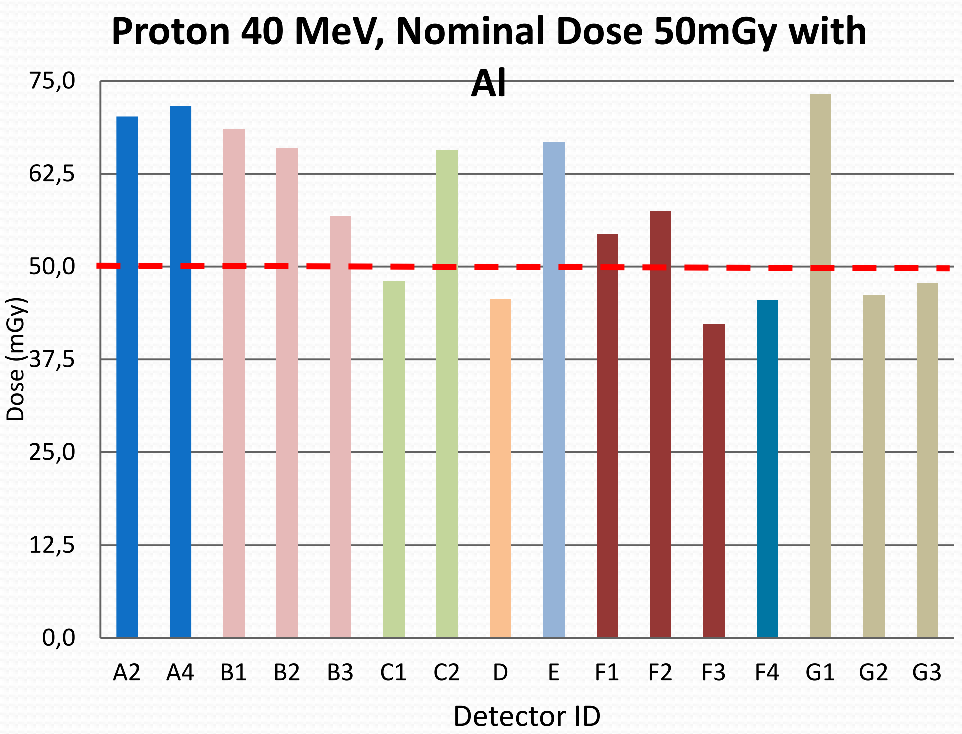
Proton 40 MeV, Nominal Dose 10mGy

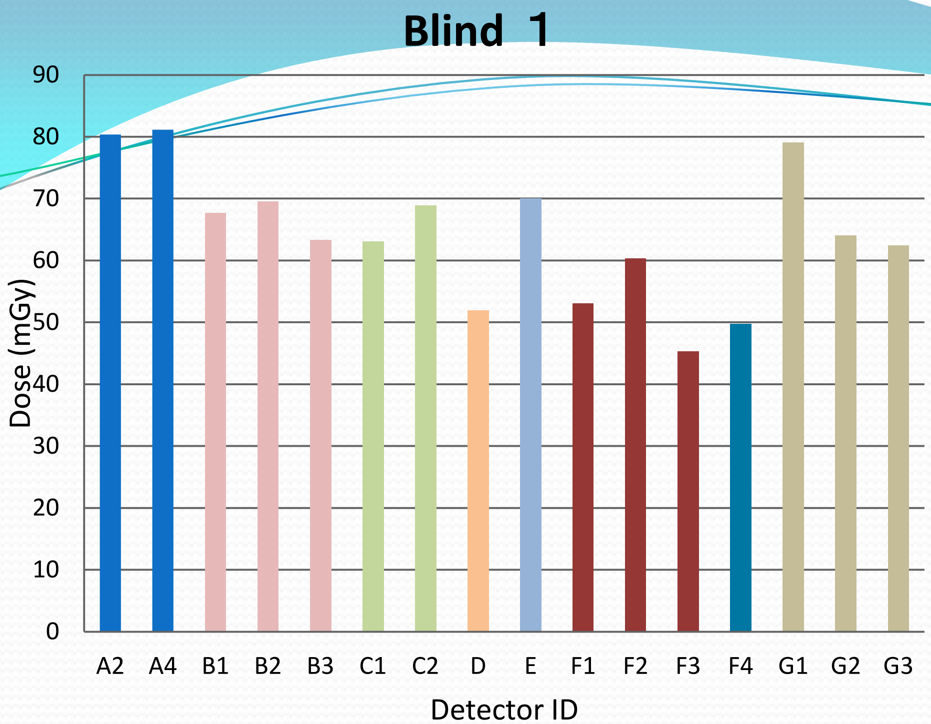


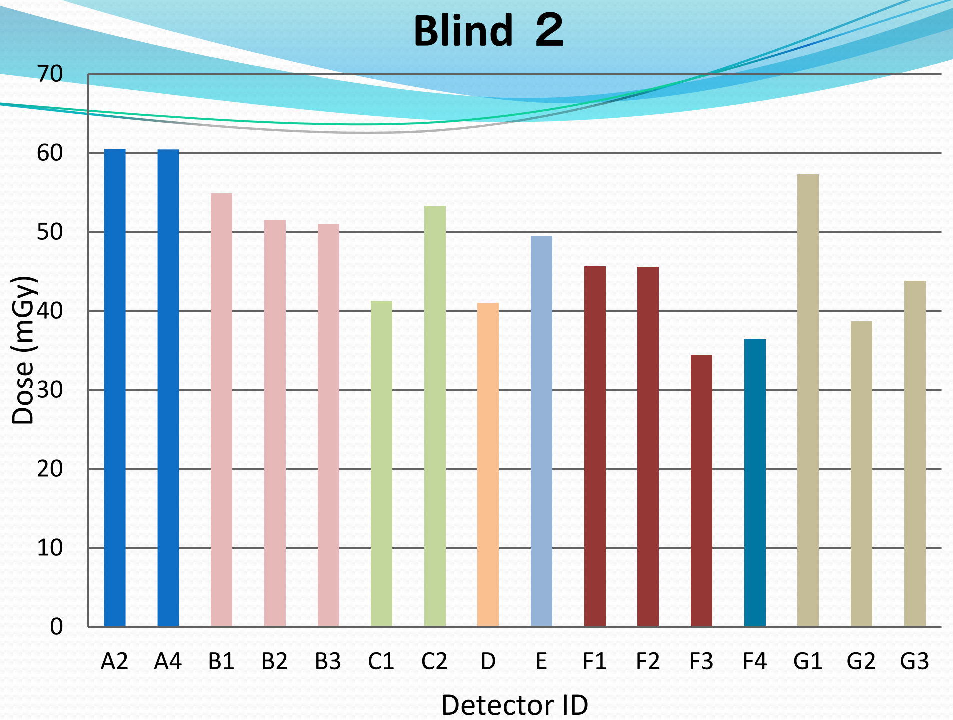
Proton 40 MeV, Nominal Dose 1mGy

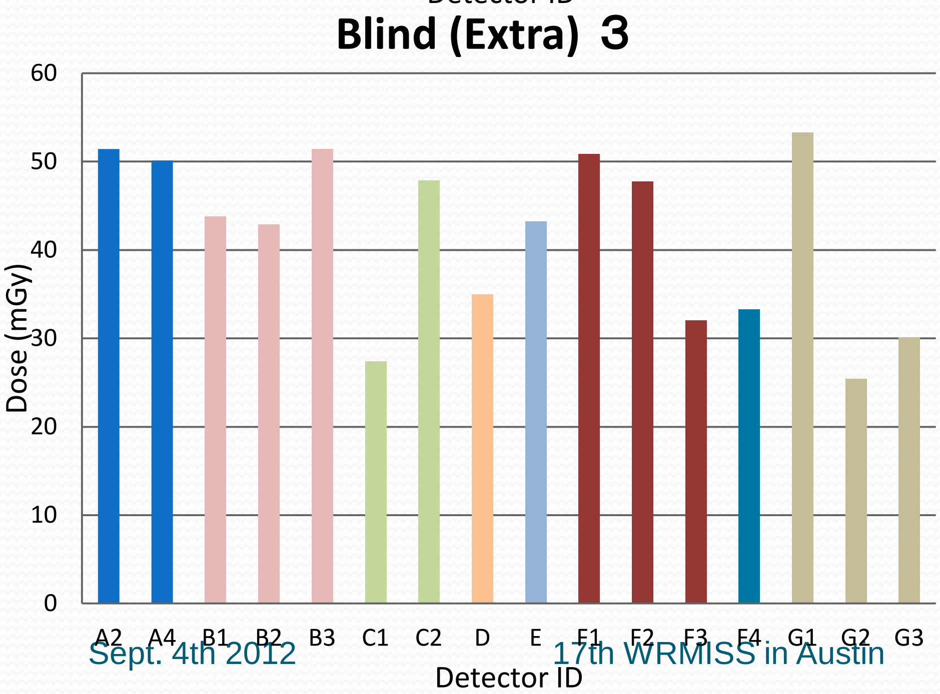


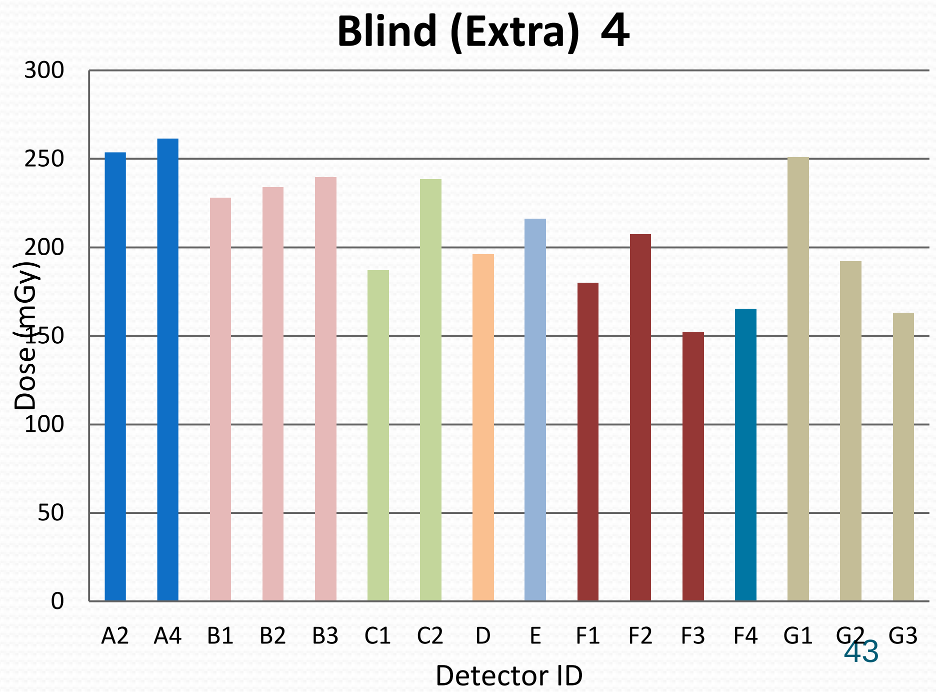

Proton 70 MeV, Nominal Dose 50mGy with Al
75,0
62,5
50,0
37,5
25,0
12,5
0,0
Dose (mGy)
A2 A4 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID


Proton 40 MeV, Nominal Dose 50mGy with Al
75,0
62,5
50,0
37,5
25,0
12,5
0,0
Dose (mGy)
A2 A4 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID

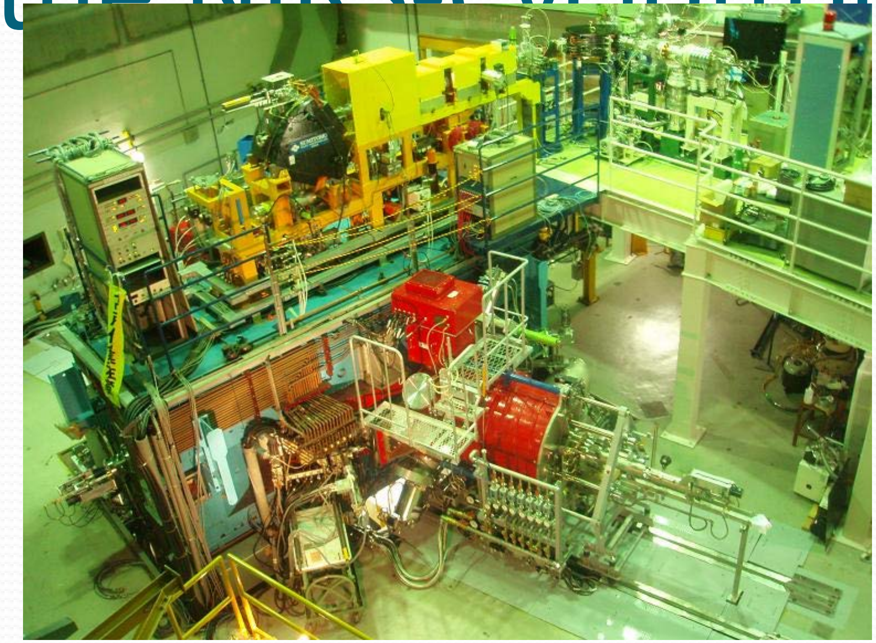

Blind 1
90
80
70
60
50
40
30
20
10
0
Dose (mGy)
A2 A4 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID


Blind 2
70
60
50
40
30
20
10
0
Dose (mGy)
A2 A4 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID


Blind (Extra) 3
60
50
40
30
20
10
0
Dose (mGy)
A2 A4 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID


Blind (Extra) 4
300
250
200
150
100
50
0
Dose (mGy)
A2 A4 B1 B2 B3 C1 C2 D E F1 F2 F3 F4 G1 G2 G3
Detector ID

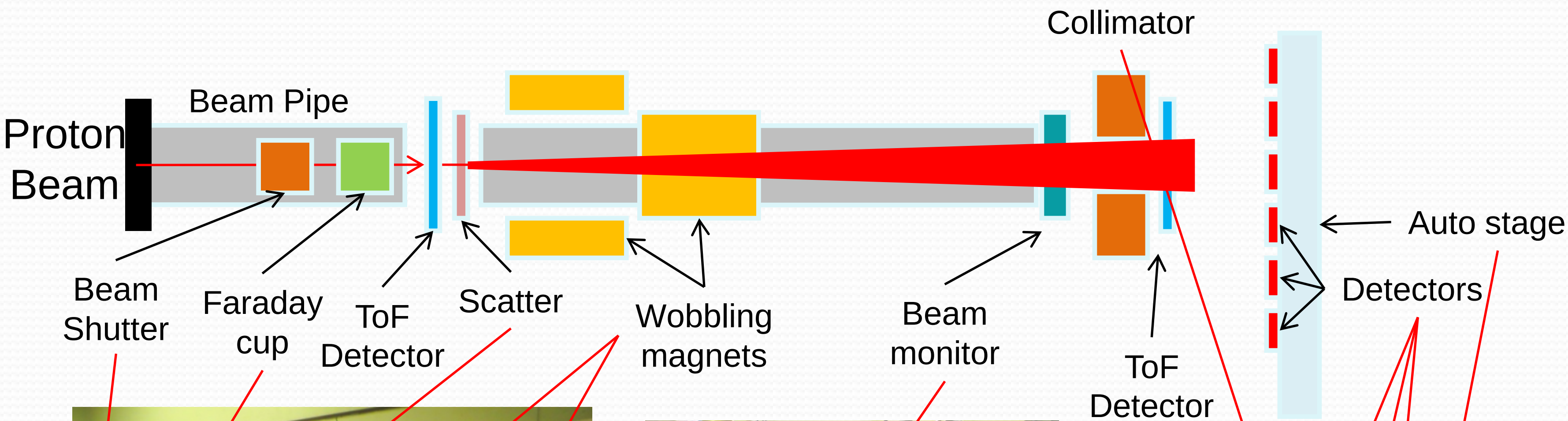
Specification of the NIRS-Cyclotron

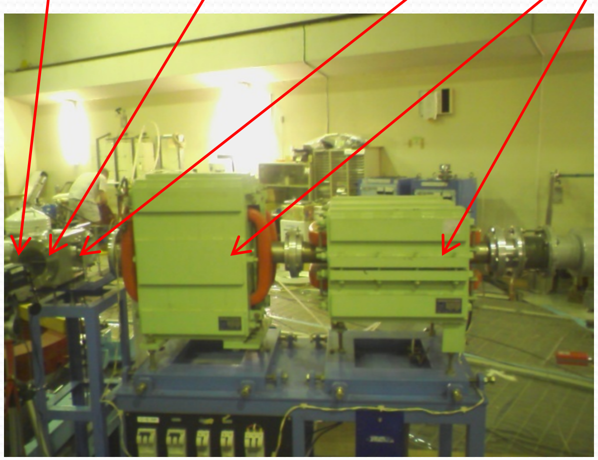


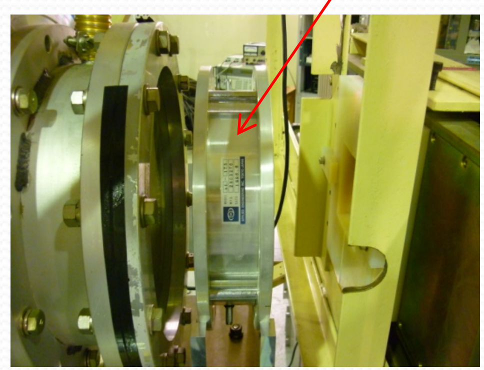
- Type: AVF Cyclotron
- Beams:
  - proton 5-80 MeV
  - deuteron 10-55 MeV
  - ^{3}He 18-147 MeV
  - ^{4}He 20-110 MeV
  - Heavy ions …

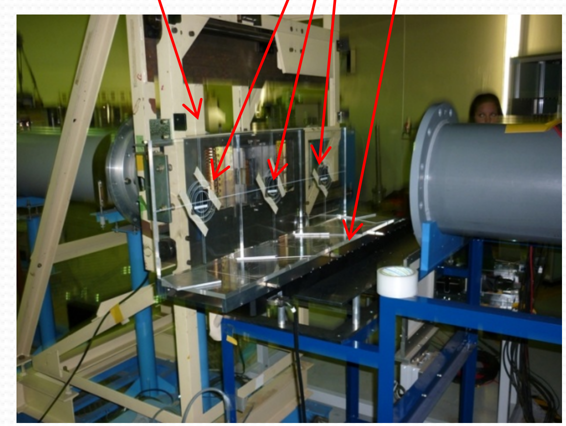
- This cyclotron is used to produce radioisotopes for SPECT/PET mainly.
- It is usable for scientific experiments about one day per a week.
- Typical experiment time is from 11 am to 7 pm (8 hours).

Reference Radiation Field (C-8 course)









Beam monitor is an ionizing chamber with 17cm diameter aperture.

List of Participants

1	Armenia	YPI (Yerevan Physics Institute, Yerevan)
2	Austria	ATI (Atomic Institute of the Austrian Universities, Vienna)
3	Belgium	SCK-CEN (Belgian Nuclear Research Center, Mol)
4	Czech Rep.	NPI (Nuclear Physics Institute, Prague)
5	Germany	DLR (German Aerospace Center, Cologne)
6	Greece	AUT (Aristotle University of Thessaloniki)
7	Hungary	KFKI AEKI (KFKI Atomic Energy Research Institute, Budapest)
8	Japan	JAXA (Japan Aerospace Exploration Agency, Tsukuba)
9	Japan	NIRS (National Institute of Radiological Sciences, Chiba)
10	Poland	IFJ (Institute of Nuclear Physics, Krakow)
11	Russia	IMBP (Institute of Biomedical Problems, Moscow)
12	USA	Eril Research Inc. (Stilwater)
13	USA	NASA-JSC (NASA Johnson Space Center, Houston)
14	USA	Oklahoma State University (Stilwater)

Exposure list (PI-2)

- Proton 70 MeV
  - 1mGy, 10 mGy, 50 mGy, 100 mGy
  - 50 mGy with 5 mmt aluminum
- Proton 40 MeV
  - 1mGy, 10 mGy, 50 mGu, 100 mGy
  - 50 mGy with 3 mmt Alminum
- Blind
  - #1 70 mGy Proton 70 MeV
  - #2 50 mGy ^{4}He 2.2keV/u
  - Extra #3 52 mGy ^{12}C 11 keV/µm,
  - Extra #4 200 mGy Proton 40 MeV,
    20 mGy ^{12}C 11 keV/µm, 10 mGy ^{28}Si 55 keV/µm

Exposure List (Blind)

	package	
2^{nd} Proton ICCHIBAN	#1	70 mGy Proton 70 MeV
	#2	50 mGy ^{4}He 2.2keV/μm
	#3	52 mGy ^{12}C 11 keV/μm
	#4	200 mGy Proton 40 MeV, 20 mGy ^{12}C 11 keV/μm, 10 mGy ^{28}Si 55 keV/μm
3^{rd} Proton ICCHIBAN	#1	50 mGy Proton 30 MeV with 1mmt Al
	#2	200 mGy Proton 30 MeV with 1mmt Al
	#3	100 mGy Proton 30 MeV with 1mmt Al 200mGy Proton 235 MeV
	#4	