Comparison of Results from the ICCHIBAN-4 Experiment and Current Status of the Proton ICCHIBAN and ICCHIBAN-6 Experiments

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Eric Benton (Eril Research, Inc.), Yukio Uchihori, Nakahiro Yasuda (NIRS, Japan) & Jack Miller (LBNL) on behalf of the ICCHIBAN Working Group and ICCHIBAN Participants

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Eril Research, Inc.

8 September 2004

Overview of ICCHIBAN Experiments for Passive Detectors

ICCHIBAN-3, May 2003:	150 MeV/n He 400 MeV/n C 400 MeV/n Ne 500 MeV/n Fe
Proton ICCHIBAN, Sept 2003:	70-250 MeV protons
ICCHIBAN-6, May 2004:	135 MeV/n C 500 MeV/n Ar 400 MeV/n Kr
NSRL ICCHIBAN, Sept 2004:	1 GeV protons 1 GeV/n O 1 GeV/n Fe

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ICCHIBAN-4: Participants

Institution	Investigators	Country	Detectors
ATI	T. Berger*, M. Hajek* & N. Vana	Austria	TLD-600 (^{6}LiF:Mg, Ti), TLD-700 (^{7}LiF:Mg, Ti) CR-39 PNTD
CARR	B. B. Gersey*, R. Wilkins*	USA	TEPC
ERI	E. R. Benton*, A. L. Frank & E. V. Benton	USA	CR-39 PNTD, TLD-700 (^{7}LiF:Mg, Ti)
IMBP	Yu. Akatov* & V. Shurshakov	Russia	TLD-100 (LiF:Mg,Ti), CR-39 PNTD, Biomarker Seeds
INP	P. Bilski & T. Horwacik	Poland	TLD-100 (LiF:Mg,Ti), LiF:Mg,Cu,P TLD, LiF:Mg,Ti, CR-39 PNTD
KFKI AEKI	S. Deme, I. Apathy & T. Pazmandi	Hungary	Pille TLD System ($CaSO_4$:Dy)
NASA JSC	E. Semones	USA	TLD-100 (LiF:Mg,Ti), TLD-300 (CaF_2:Tm), TLD-600 (^{6}LiF:Mg, Ti), TLD-700 (^{7}LiF:Mg, Ti)
NIRS	Y. Uchihori*, H. Kitamura* & N. Yasuda*	Japan	Luilin-4J MDU
NRPB	D. Bartlett L. Hager	UK	PADC PNTD
JAXA/KEK	H. Tawara*, A. Nagamatsu* & M. Masukawa	Japan	MSO TLD (Mg_2SiO_4:Tb), CR-39 PNTD
NPI	F. Spurny & K. Turek	Czech Rep.	CR-39 PNTD, Melinex/Bi PNTD, Al_2O_3:C TLD, Al-P Glass
OSU	S.W.S. McKeever, R. Gaza*, & E. G. Yukihara	USA	Al_2O_3:C OSL, Luxel Al_2O_3 OSL, Al_2O_3:C TLD, TLD-100 (LiF:Mg,Ti)

*Present at HIMAC

ICCHIBAN-4: Passive Detectors

- 10 Laboratories in 8 countries (not including Liulin-4J & TEPC).
- Two basic types of detectors (with a few exceptions): TLDs (including OSL) and CR-39 PNTDs.
- Much variation within each detector type:
  - TLDs: LiF most common, but all three forms of LiF (TLD-100, TLD-600, TLD-700) were used. Other types of TLD also used included CaF_2:Tm, Mg_2SiO_4:Tb, $CaSO_4$:Dy & Al_2O_3:C.
  - CR-39 PNTDs included both standard chemical etch and electrochemical etch.
  - Other detectors included Biomarker Seeds (IMBP) and Aluminum Phosphate glass (NPI).

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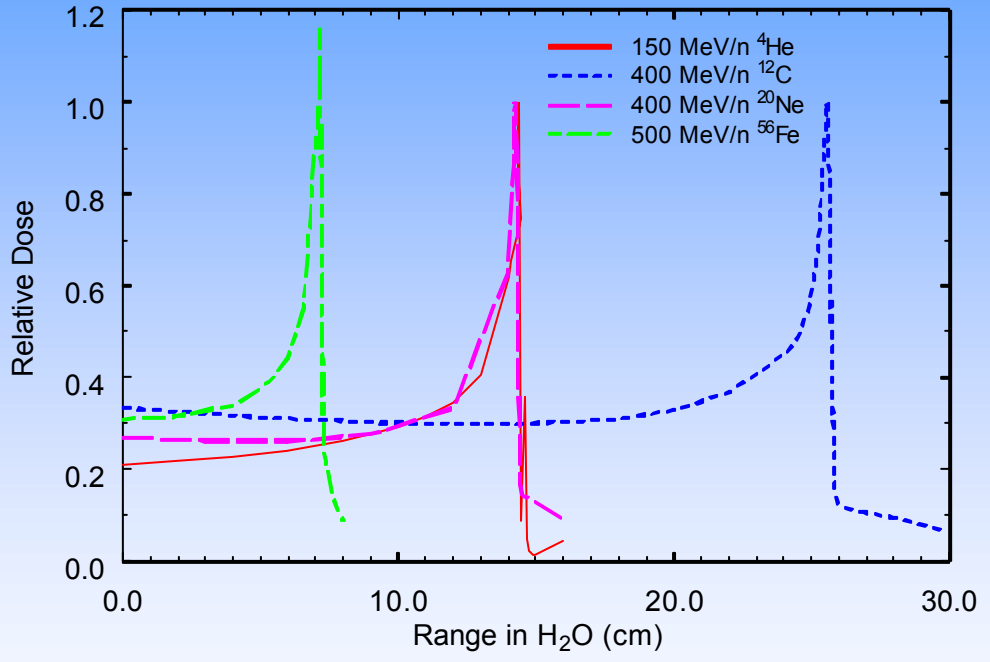
ICCHIBAN-4: Heavy Ion Bragg Curves



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ICCHIBAN-4: Heavy Ions

Date	Ion	Nominal Energy (MeV/n)	Actual Energy (MeV/n)	Range in H_2O (cm)	$LET_\infty H_2O$ (keV/μm)
24/05/03	^{4}He	150	142.3	14.52	2.27
19/05/03	^{12}C	400	392.2	26.56	11.13
21/05/03	^{20}Ne	490	381.5	15.24	31.34
29/05/03	^{56}Fe	500	415.8	7.26	203.0

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ICCHIBAN-4: Exposures

- Calibration Exposure: 10 mGy for each ion/energy.
- Fragmentation: 10 mGy for each ion/energy
  - 5 g/cm^2 Al;
  - 10 g/cm^2 Al;
  - 5 g/cm^2 H_2O Equivalent acrylic (PMMA).
- Blind Exposures:
  - 8 detectors exposed.
  - participants not given any *a priori* knowledge of exposure composition.

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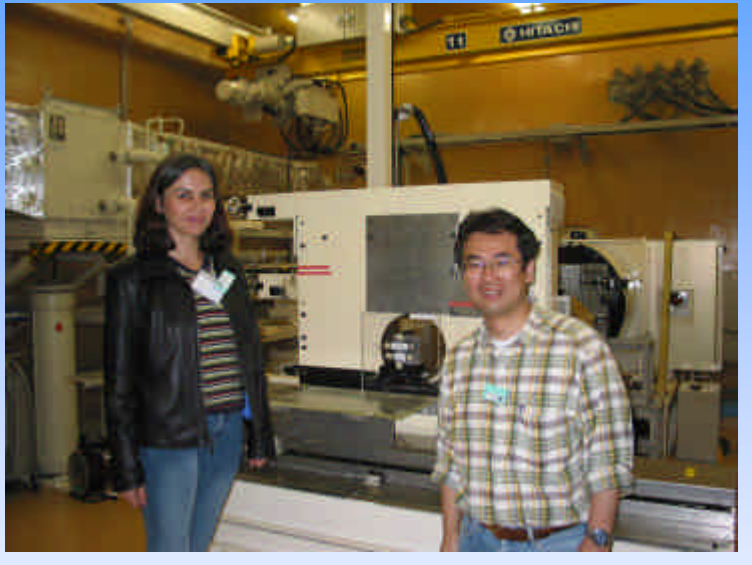
ICCHIBAN-4: Preparation of Detectors



- All Exposures carried out in HIMAC “BIO” room.
- Beam spot: ~10 cm diameter.
- Passive detector packages taped onto acrylic plates.

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ICCHIBAN-4: Reporting of Results

- Each participant was asked to submit a written report documenting their results…or at least to send me their data.
- Intercomparison limited because:
  - Received Results from only 7 out of 10 passive detector laboratories.
  - Not all labs participated in all exposures (usually due to limitations of their detectors).
  - Not all labs provided identical dosimeter packages for each exposure.
  - Not all labs provided values of standard deviation or uncertainty with their results.

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ICCHIBAN-4: Blind Exposures

	^{60}Co γ-rays	^{137}Cs γ-rays	^{4}He	^{12}C	^{20}Ne	^{56}Fe
1. ^{60}Co γ-rays	25 mGy					
2. ^{137}Cs γ-rays		25 mGy				
3. Helium			25 mGy			
4. Space Simulation	10 mGy		1 mGy	1000 cm^{-2}	1000 cm^{-2}	1000 cm^{-2}
5. Equal Dose	2 mGy		2 mGy	2 mGy	2 mGy	2 mGy
6. CR-39 Equal Fluence				1000 cm^{-2}	1000 cm^{-2}	1000 cm^{-2}
7. 5 g/cm^2 Al						1 mGy
8. Carbon				25 mGy		

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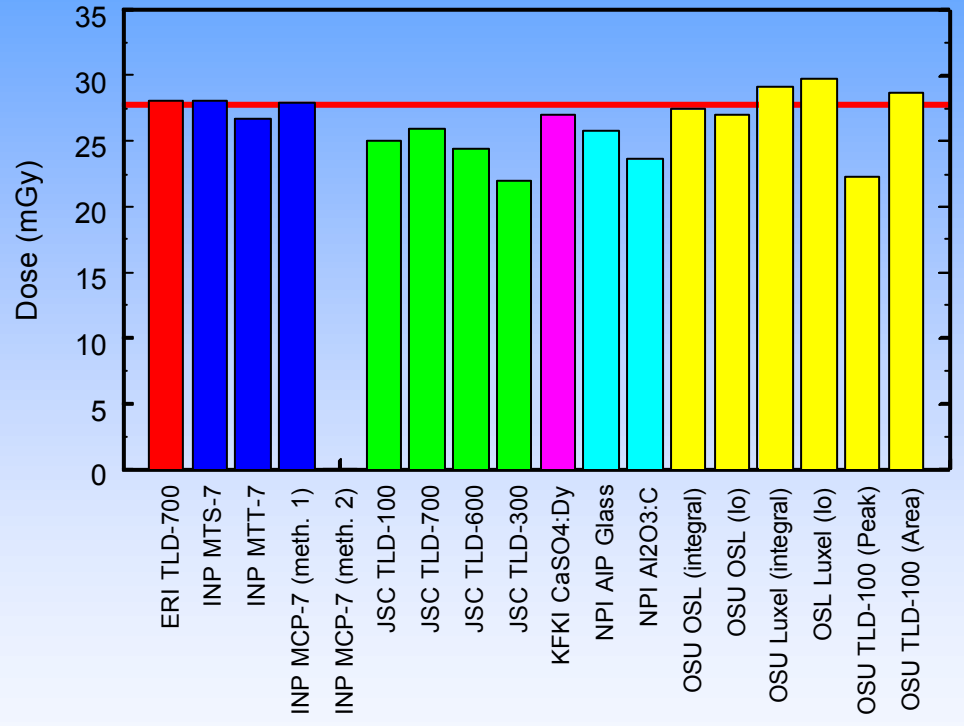
ICCHIBAN-4: Blind No. 1 TLD/OSL

27.8 mGy ^{60}Co γ-rays



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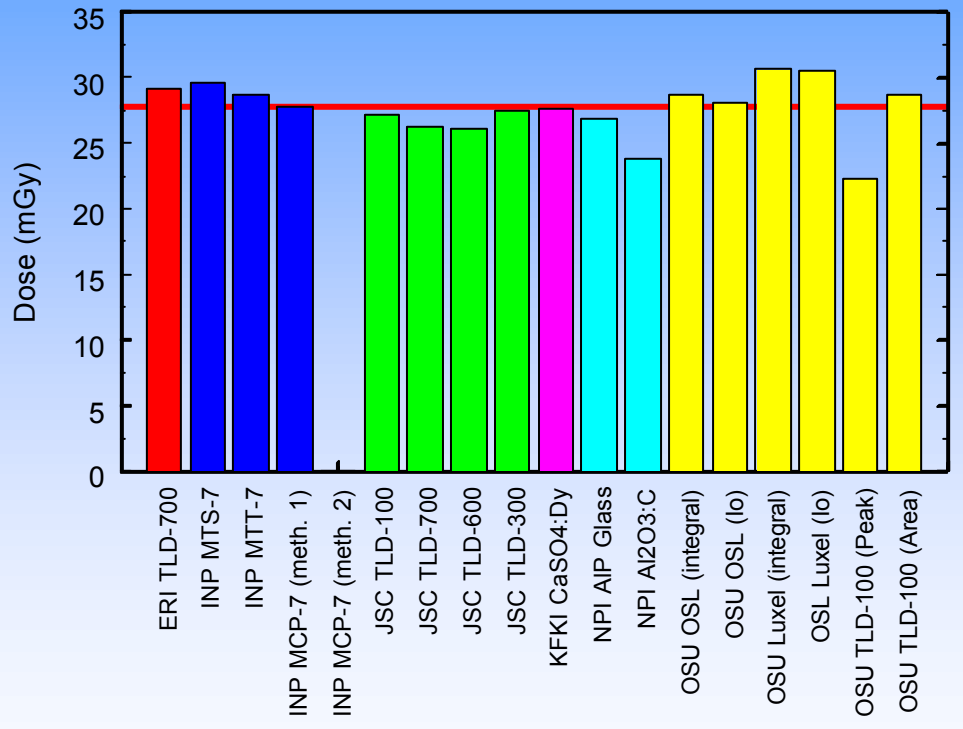
ICCHIBAN-4: Blind No. 2 TLD/OSL

27.8 mGy ^{137}Cs γ-rays



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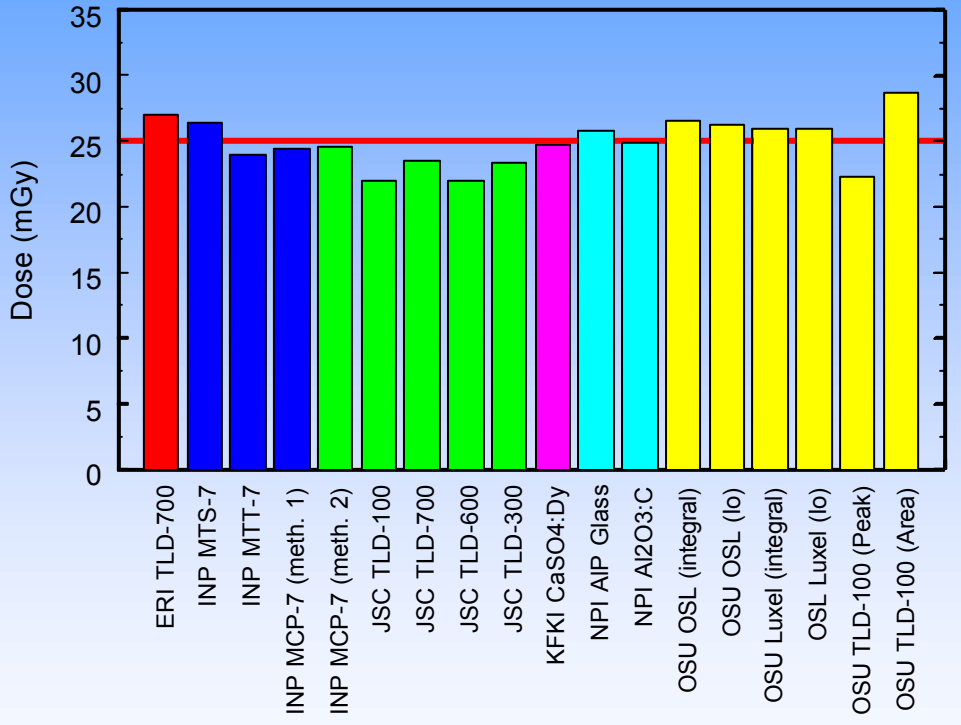
ICCHIBAN-4: Blind No. 3 TLD/OSL

25 mGy 150 MeV/n ^{4}He



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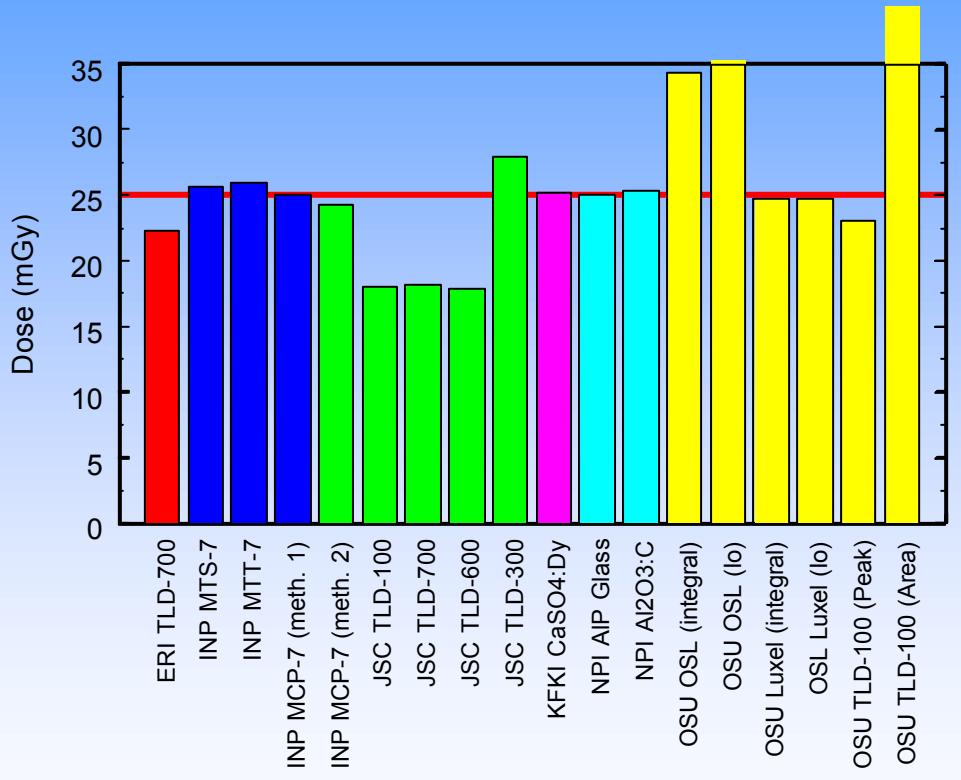
ICCHIBAN-4: Blind No. 8 TLD/OSL

25 mGy 400 MeV/n ^{12}C



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ICCHIBAN-4: ~25 mGy Results

- Good agreement between different detectors and between detectors and nominal dose for all four sources.
- Background contamination (airport x-ray screening exposure) was problem for ERI and JSC.
- As seen in past, some detectors showed higher than nominal dose for 150 MeV/n ^{4}He.
- Results for ^{12}C exposure were worst, but not always as expected. Sometimes higher than nominal dose measured.

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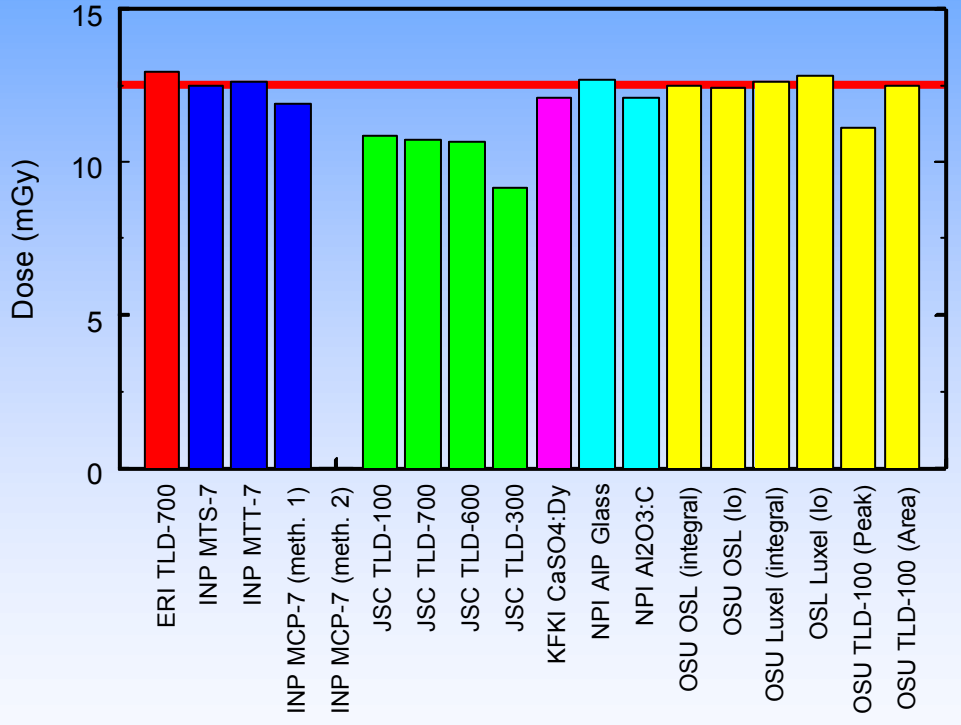
ICCHIBAN-4: Blind No. 4 TLD/OSL

Space Simulation



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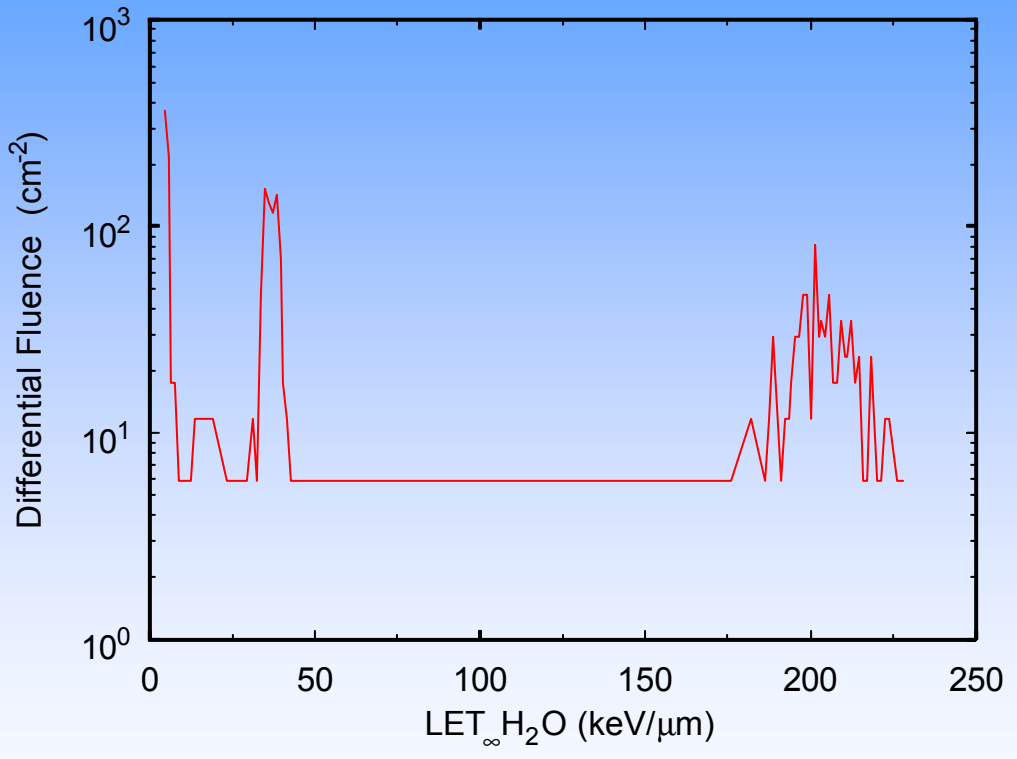
ICCHIBAN-4: Blind 4 CR-39 PNTD

ERI Differential LET Fluence Spectrum



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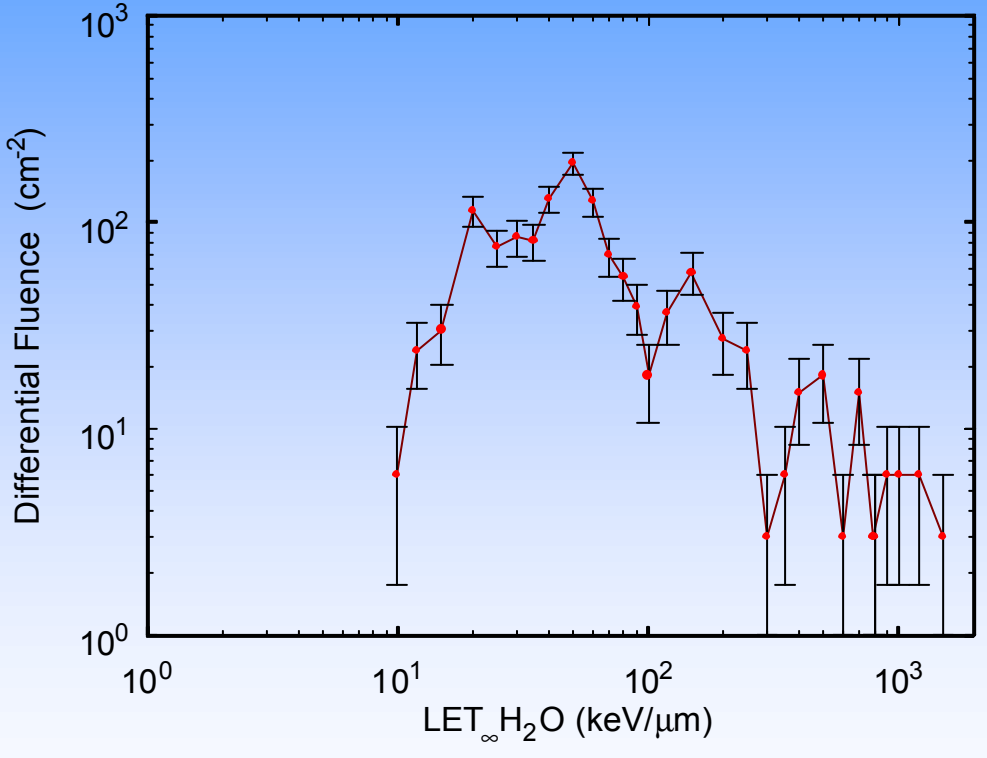
ICCHIBAN-4: Blind 3 CR-39 PNTD

ERI Differential LET Fluence Spectrum



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ICCHIBAN-4: Blind CR-39 PNTD Results

- No lab (except ERI) provided LET spectrum.
- Other labs that used CR-39 PNTD counted fluences of ^{12}C, ^{20}Ne and ^{56}Fe exposure, assigned an LET to each ion, then computed Dose and Dose Equivalent.

  …you can't do that with a space-exposed detector.
- With Exception of Blind 3, all tracks were circular, making analsyis unrealistically easy.
- No participant (except ERI) provided Dose and Dose Equivalent from combined TLD+CR-39.

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ICCHIBAN-4: Conclusions

- Received reports/results from only 7 of 10 participants.
- TLD performance improved - close agreement with nominal dose.
- No Dose Equivalent data from TLDs, e.g. using HTR method.
- CR-39 PNTD not analyzed in realistic way – results maybe useful to individual labs, but not for purposes of intercomparison.
- We request reports from all participants so that we can carry out the intercomparison and write the final report.

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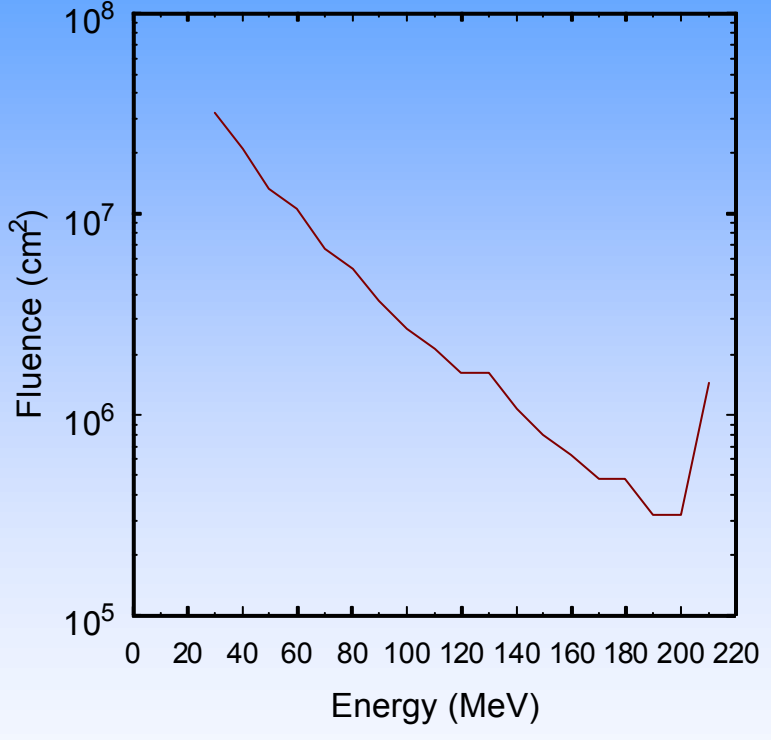
Proton ICCHIBAN: SPE Simulation



Energy (MeV)	LET (keV/μm)	Fluence (cm^2)	Dose (mGy)
30	1.67	3.20×10^7	85.56
40	1.35	2.13×10^7	46.27
50	1.15	1.33×10^7	24.65
60	1.01	1.07×10^7	17.31
70	0.91	6.67×10^6	9.68
80	0.82	5.33×10^6	7.04
90	0.76	3.73×10^6	4.53
100	0.71	2.67×10^6	3.02
110	0.66	2.13×10^6	2.27
120	0.62	1.60×10^6	1.59
130	0.59	1.60×10^6	1.51
140	0.56	1.07×10^6	0.96
150	0.53	8.00×10^6	0.68
160	0.51	6.40×10^6	0.52
170	0.49	4.80×10^5	0.38
180	0.47	4.80×10^5	0.36
190	0.46	3.20×10^5	0.23
200	0.44	3.20×10^5	0.23
210	0.43	1.44×10^5	0.99
Total:		1.07×10^8	207.78

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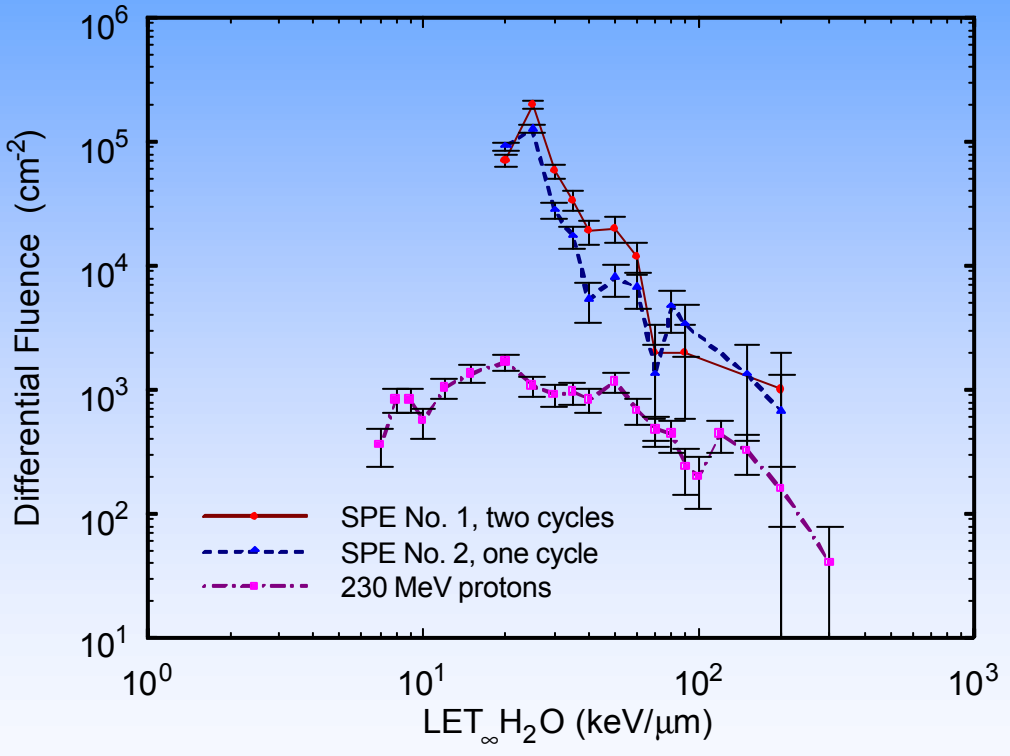
Proton ICCHIBAN: CR-39 PNTD

ERI Differential LET Fluence Spectrum



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Proton ICCHIBAN: ERI TLD Results

Exposure	Dose (mGy)
SPE #1 (two cycles)	322 ± 10
SPE #2 (one cycle)	153 ± 5
230 MeV #1 (25 mGy)	127.3 ± 7.3
230 MeV #2 (100 mGy)	497 ± 15
230 MeV #3 (500 mGy)	13.9 ± 0.4
155 MeV #1 (25 mGy)	27.5 ± 0.8
155 MeV #2 (100 mGy)	64.1 ± 1.9
155 MeV #3 (500 mGy)	320 ± 10
70 MeV #1 (25 mGy)	7.29 ± 0.22
70 MeV #2 (100 mGy)	65.8 ± 2.0
70 MeV #3 (500 mGy)	131 ± 4

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Proton ICCHIBAN

- No useful dosimetry data from Loma Linda.
- Comparison of Relative Doses may be useful.
- Tracks from Proton-induced target fragmentation is one way to simulate “isotropic” exposure in CR-39 for intecomparison purposes.
- Is there interest in repeating Proton ICCHIBAN and SPE simulation?
- Given problems with Loma Linda dosimetry, should we still publish a report for the Proton ICCHIBAN experiment?

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Proton ICCHIBAN and ICCHIBAN-6

- Participants currently analyzing results from Sept. 2003 Proton ICCHIBAN and June 2004 ICCHIBAN-6 experiments.
- Given problems with Proton ICCHIBAN, should we publish a report?
- For ICCHIBAN-6, made exposures to 135 MeV/n ^{12}C, 500 MeV/n ^{40}Ar and 400 MeV/n ^{84}Kr.
- Will report on results of intercomparison for Proton-ICCHIBAN, ICCHIBAN-6 and NSRL ICCHIBAN experiments at WRMISS-10 next year.

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NSRL ICCHIBAN Experiment

- NASA Space Radiation Laboratory (NSRL), Brookhaven National Laboratory
- Protons to Gold, 200 MeV/n to 3 GeV/n
- September 25-27, 2004
- 1 GeV protons, 1 GeV/n ^{16}O, 1 GeV/n ^{56}Fe
- Both active and passive detectors
- Blind exposures for passive detectors

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Deep Space Test Bed (DSTB) ICCHIBAN

- 2-3 week exposure aboard circumpolar Antarctic Balloon.
- 4-5 g/cm^2 atmospheric overburden.
- “Deep Space” GCR environment.
- Possible to expose a large compliment of passive detectors.
- Active detectors will include TEPC, Liulin-4 MDU.
- http://sd.msfc.nasa.gov/cosmicray/DSTB/DSTB.htm

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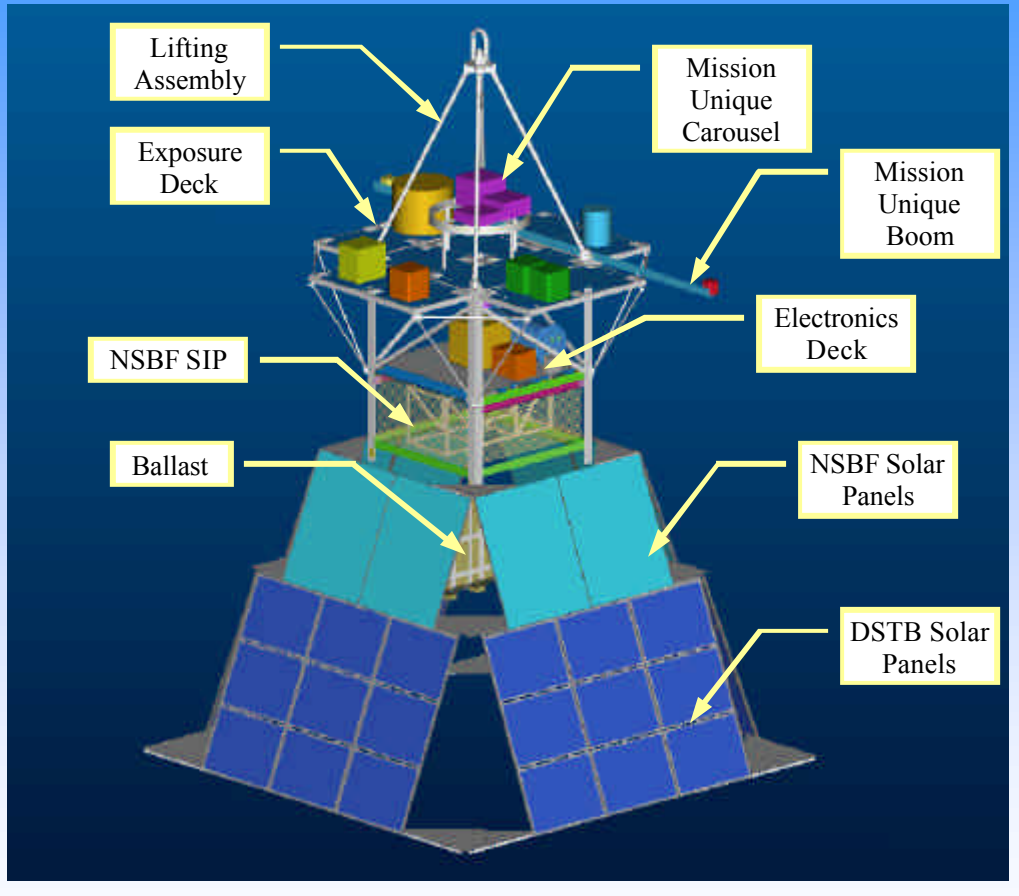
DSTB Facility



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