Brief results from the MATROSHKA/Space Intercomparison 2 and ongoing experiments to resolve differences in CR-39 PNTD measurements

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Intercomparison experiments as ICCHIBAN project

Space

MATROSHKA-R/SI2
- Comparison of data from TLD and CR-39
[Data correction]

Shuttle ICCHIBAN
- Comparison of CR-39 data using USF-4
[Exposed in Space Shuttle]

MATROSHKA-R/SI3
- Comparison of data from TLD and CR-39
[will be returned at the end of 2008]

CR-39 ICCHIBAN
- Comparison of data from CR-39
  - Baseline detector (USF-4)
  - CR-39 detector from participants
[will be returned at the end of 2008]

Ground(HIMAC)

Data correction for previous ICCHIBAN
- Preparation of database
[announced by Hisashi]

CR-39 ICCHIBAN
- Calibration using 6 ions
- Dip angle dependence for track registration sensitivity
[distributing CR-39s]

Preliminary results
MATROSHKA-R/Space Intercomparison (SI-2)

Nakahiro, Iva, Yukio, Hisashi, Eric,
Thomas, Michael with SI2 participants

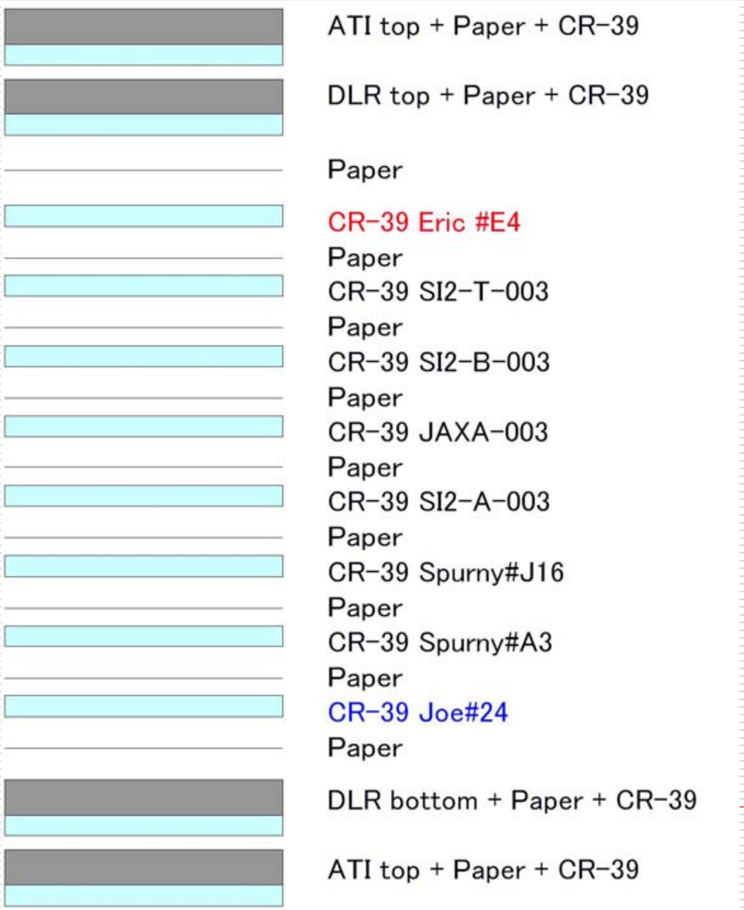
Participants
(Responsible person for this experiment)

Michael Hajek, *Atomic Institute of the Austrian Universities (ATI), Austria*
Frantisek Spurny, *Nuclear Physics Institute (NPI), Czech Academy of Sciences, Czech Republic*
Pawel Bilski, *Institute of Nuclear Physics (INP), Poland*
Eric Benton, *Oklahoma State University (OSU), USA*
Joe K. Palfalvi, *Atomic Energy Research Institute of the Hungarian Academy of Sciences (HAS), Hungary*
Aida Akopova, *Yerevan Physics Institute (YPI), Armenia*
Filip Vanhavere, *SCK-CEN, Belgian Nuclear Research Centre (SCK-CEN), Belgian*
Thomas Berger, *German Aerospace Center (DLR), Germany*
Edward Semones, *NASA, Johnson Space Center (JSC), USA*
Aiko Nagamatsu, *Japan Aerospace Exploration Agency (JAXA), Japan*
Yury Akatov, *State Scientific Center, Institute for Biomedical, Problems (IBMP), Russia*
Nakahiro Yasuda, *National Institute of Radiological Sciences (NIRS), Japan*

* *Aida*
* *JAXA*

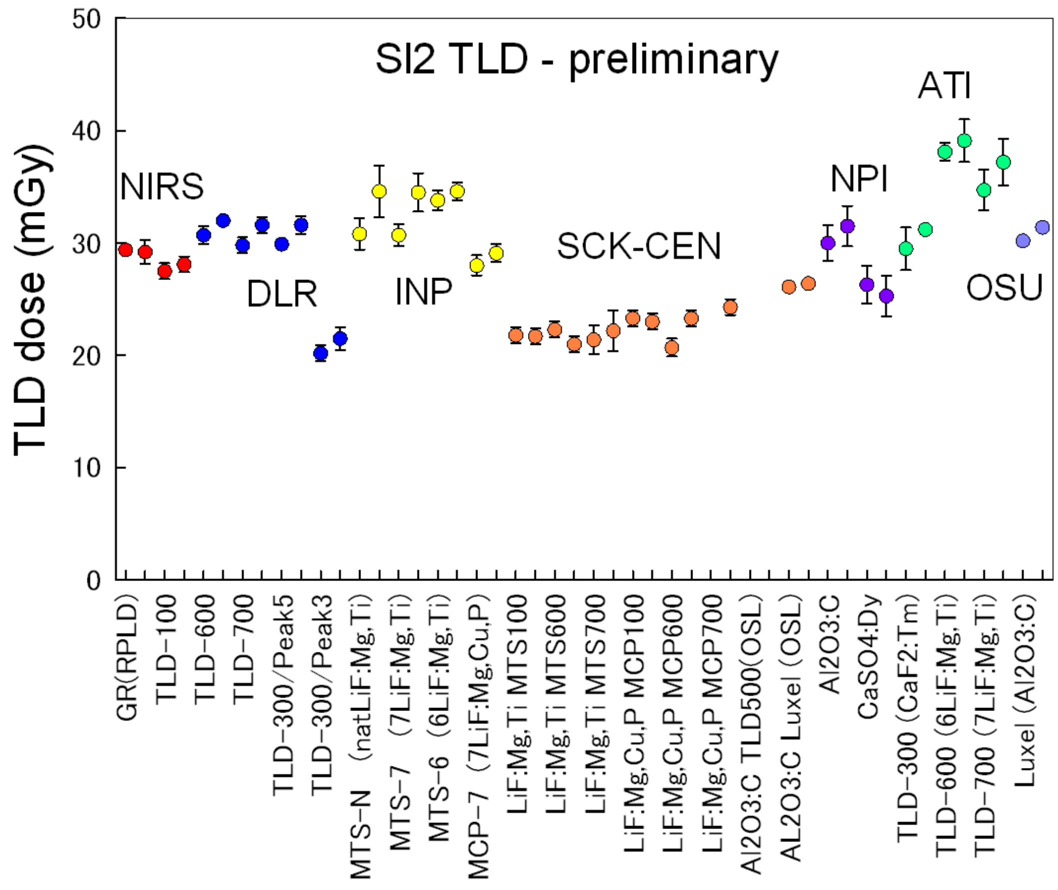
Detector component and experimental conditions

Example of detector stack



Exposure duration: 163 days
(12 May 2007 – 22 Oct 2007)
Start with Progress M-360.
Landing with Soyuz TMA 10

Results of TLDs



$$28.4^{+37\%}_{-27\%} \text{ mGy}$$

Where come from uncertainties for CR-39 measurement?

- Material (Threshold, Incident angle dependence …)
- Etching conditions (short and long etch combined or not)
- Homogeneity of irradiation
- Selection of etch pit to be measured
- Human dependences (skills and experiences)

- Correction (critical angle, dip angle dependence…)
- Calculation method

1) LET calculation (calibration)

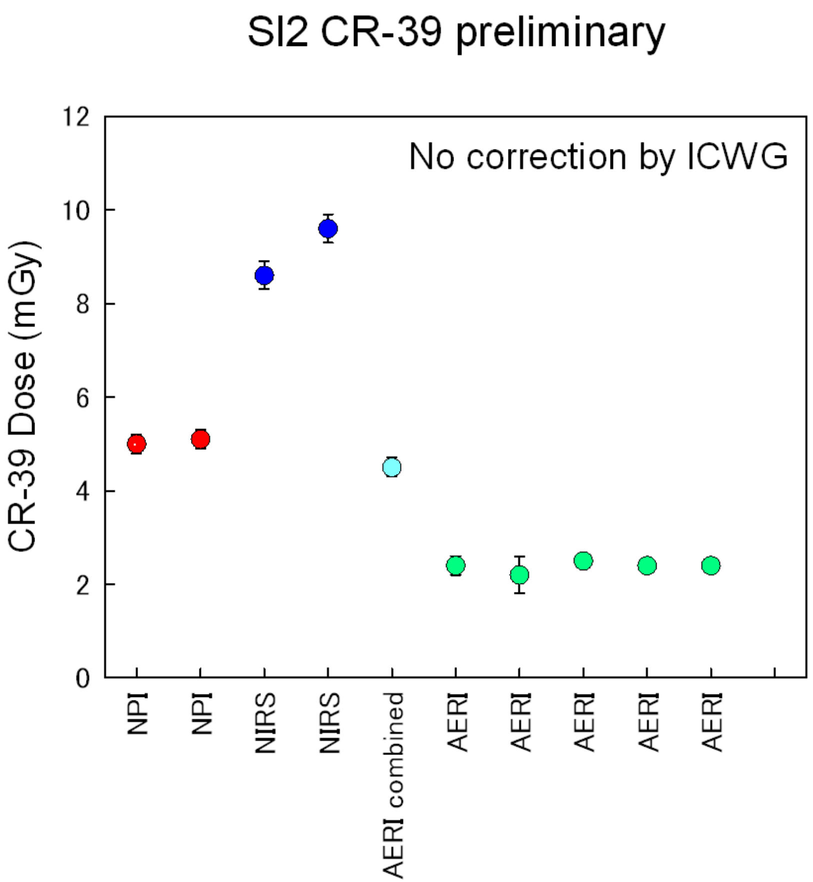
2) Critical angle correction

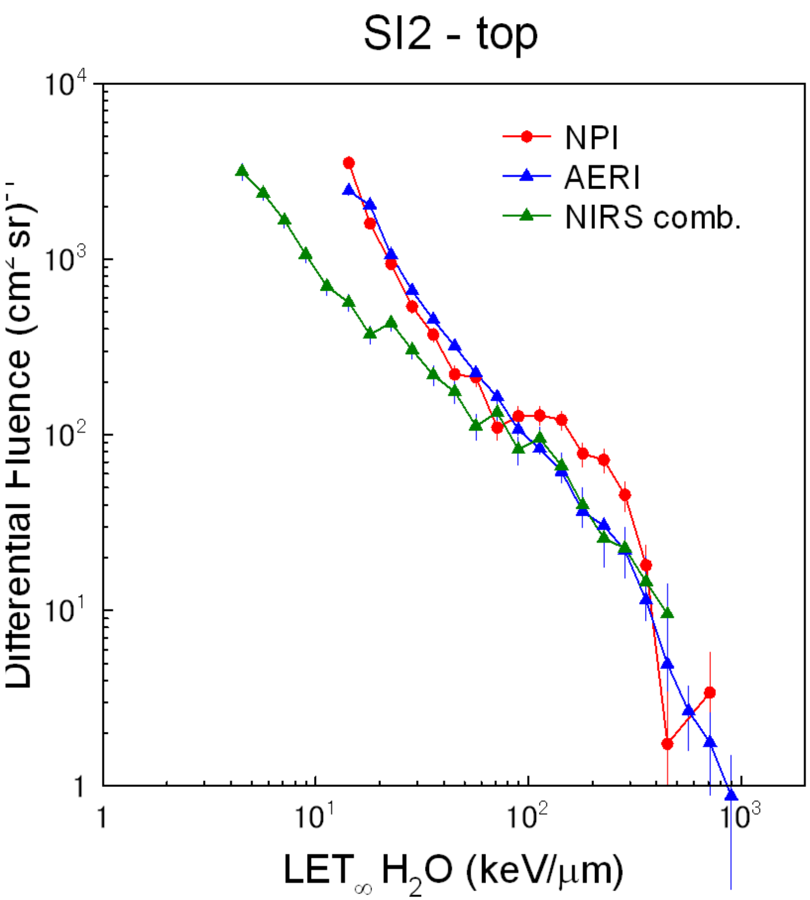
3) Dip angle correction   TO Japanese TD-1 detector

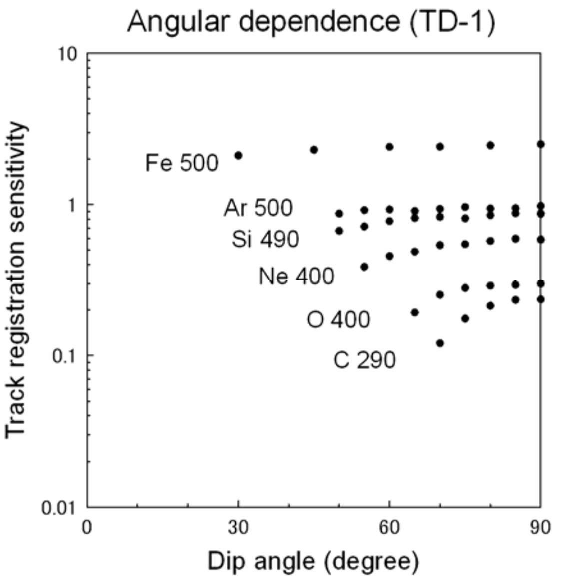
4) Dose and dose equivalent calculation

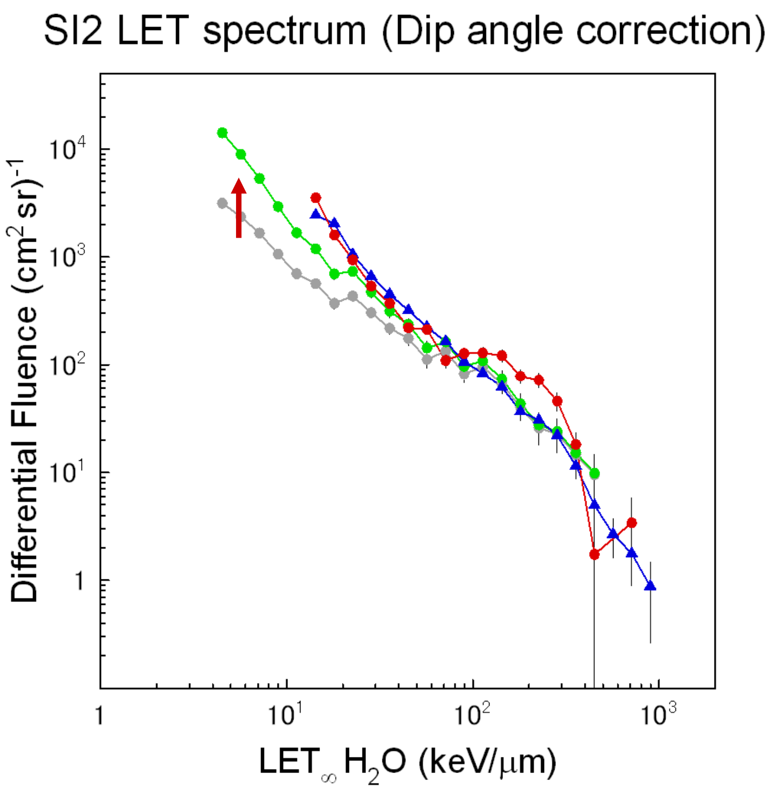
A) No control by ICWG
B) Applied the same calculation after LET spectrometry by participants

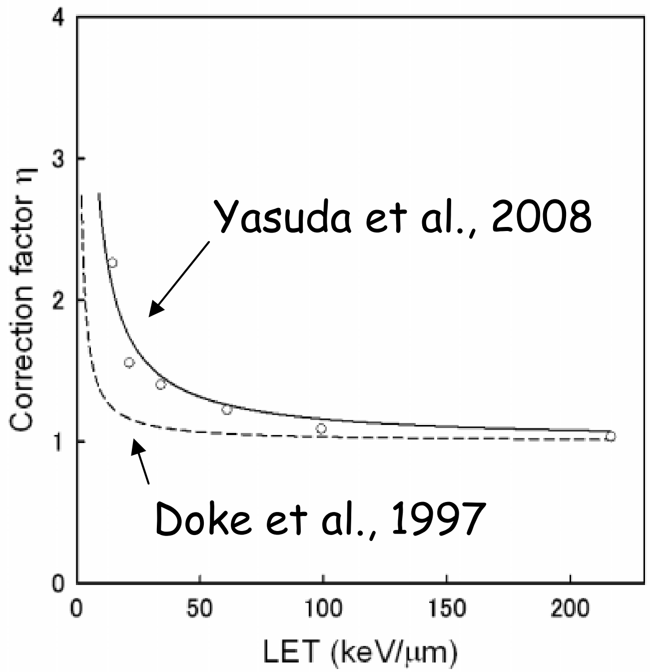
Results of CR-39 PNTDs A






Angular dependence (TD-1)
Track registration sensitivity
Dip angle (degree)
Fe 500
Ar 500
Si 490
Ne 400
O 400
C 290
10
1
0.1
0.01
0
30
60
90


SI2 LET spectrum (Dip angle correction)
Differential Fluence $(cm^2 sr)^{-1}$
$LET_\infty H_2O$ (keV/μm)
10^4
10^3
10^2
10^1
1
1
10^1
10^2
10^3


Correction factor η
LET (keV/μm)
Yasuda et al., 2008
Doke et al., 1997
4
3
2
1
0
0
50
100
150
200

LET Spectrum Formulas

Differential Fluence

$$\frac{d\Phi}{dLET} = (2\pi A\cos^2\delta_c)^{-1}\frac{dN}{dLET}$$

Integral Fluence

$$\Phi(LET_i \geq LET_x) = \sum_{i=\max}^{x}\frac{N_i}{W_i}$$

Integral Dose

$$D(LET_i \geq LET_x) = \frac{4\pi \cdot 1.602\times 10^{-9}}{\rho}\sum_{i=\max}^{x}\frac{N_i LET_i}{W_i}$$

Integral
Dose Equivalent

$$H(LET_i \geq LET_x) = \frac{4\pi \cdot 1.602\times 10^{-9}}{\rho}\sum_{i=\max}^{x}\frac{N_i LET_i Q_i}{W_i}$$

Comparison of CR-39 results (applied the same calculation) B

$5.1^{+37\%}_{-27\%}$ mGy $54.5^{+23\%}_{-15\%}$ mSv

LET >= 10 keV/um	AERI	NPI	NIRS
Dose [mGy]	4.6 ± 0.1	7.0 ± 0.2	3.7 ± 0.2
Dose equivalent [mSv]	50.4 ± 1.1	66.8 ± 2.8	46.3 ± 2.8

LET >= 16 keV/um	AERI	NPI	NIRS
Dose [mGy]	3.9 ± 0.1	4.1 ± 0.1	2.9 ± 0.1
Dose equivalent [mSv]	48.7 ± 1.1	61.8 ± 2.8	45.0 ± 2.8

$3.6^{+14\%}_{-19\%}$ mGy $51.8^{+19\%}_{-13\%}$ mSv

CR-39 ICCHIBAN - Ground

CR-39 ICCHIBAN ground - participants

Institute	Trademark	Label (WG)
NIRS	HARZLAS TD-1	NIRS T A – O
	BARYOTRAK	NIRS B A – O
	TT-S	NIRS S A – O
OSU	USF-4	OSU A – O
JSC	USF-4	JSC A – O
DLR	USF-4	DLR A – O
NPI	Page	NPI PAGE A – O
	Tastrak	NPI TAS A – O
	HARZLAS TD-1	NPI TD-1 A – O
	USF-4	NPI ATP A – O
INP	Tastrak	IFJ A – O
JAXA	HARZLAS TD-1	JAXA A – O
AERI	Tastrak	HIMAC A – O

- 8 institutions
- 6 types of CR-39 PNTD
- 13 combinations for materials/methods

HARZLAS TD-1	(3)
BRYOTRAK	(1)
TT-S	(1)
USF4	(4)
Page	(1)
Tastrak	(3)

CR-39 ICCHIBAN ground - Calibration curve

Calibration #1

C290, Ne400, Si490, Ar500, Fe 500, Kr400 without filter

All ion irradiated to one CR-39 for each type. (1 sheet)

500 ions/cm^2 x 6 ions

Calibration #2

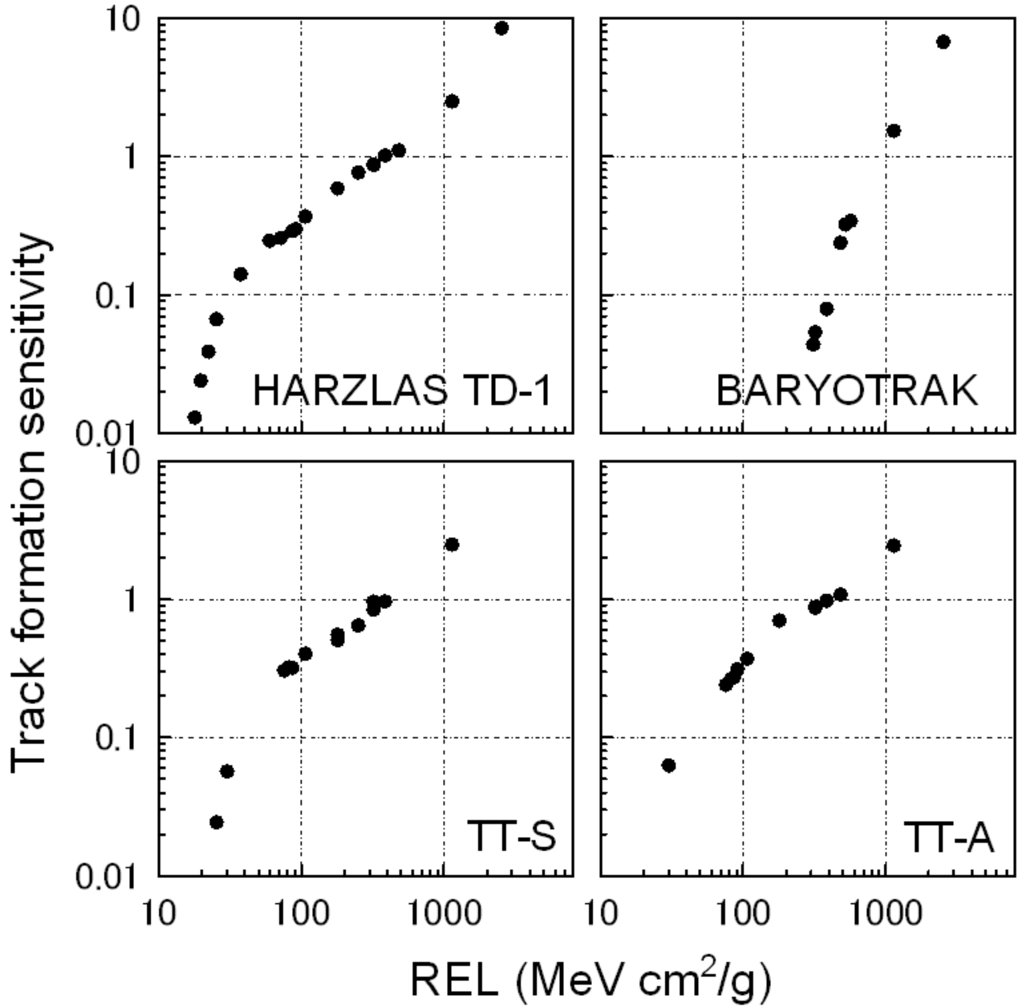
C290, Ne400, Si490, Ar500, Fe 500, Kr400 with filters

For each ion, 3 (BF=0, x, xx mm) energies were selected and irradiated to one CR-39 detector. (6 sheets)

Irradiation conditions

	BF	Range	E	LET
	(mm)	(mm)	(MeV/n)	(KeV/um)
C290	0.00	150.64	275.2	13.1
	95.03		154.0	18.9
	129.81		88.6	28.4
Ne400	0.00	145.68	370.1	31.2
	65.59		250.2	38.9
	105.44		172.6	49.3
Si490	0.00	138.51	445.7	56.8
	60.95		311.6	68.0
	96.80		215.5	84.6
Ar500	0.00	122.75	462.2	95.5
	52.26		327.5	113.1
	98.62		173.4	166.7
Fe500	0.00	74.36	418.3	197.6
	30.05		303.9	232.9
	56.70		175.8	325.9

Kr400 is not listed here

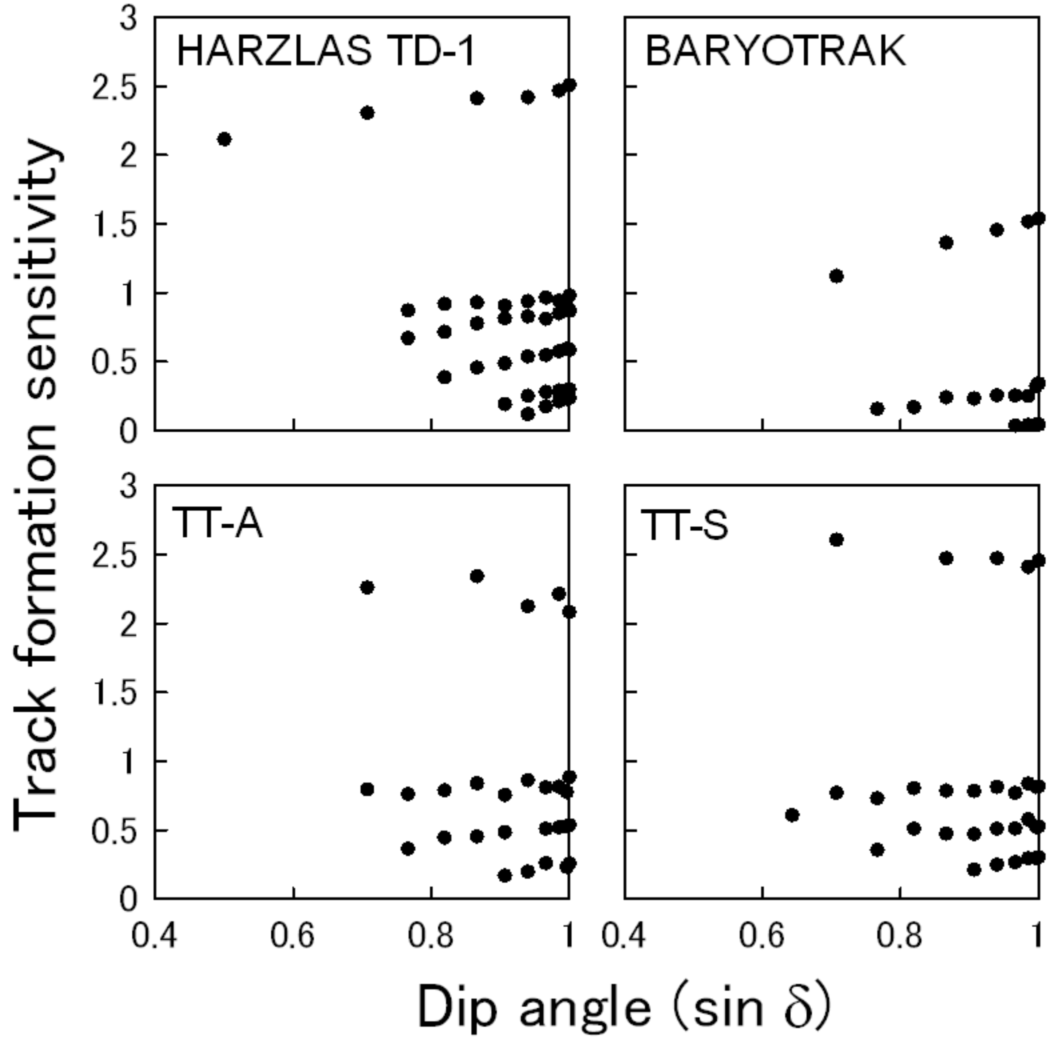


Track formation sensitivity
REL (MeV cm²/g)
HARZLAS TD-1
BARYOTRAK
TT-S
TT-A
10
1
0.1
0.01
10
100
1000

CR-39 ICCHIBAN ground – Angular dependence

Calibration #3:

C290	90°85°80°	
Ne400	90°80°70°60°	90°85°75°65°
Si490	90°80°70°60°50°	90°85°75°65°
Ar500	90°80°70°60°50°	90°55°45°
Fe 500	90°70°50°	90°80°60°40°
Kr400	90°75°60°45°30°	


HARZLAS TD-1
BARYOTRAK
TT-A
TT-S
Track formation sensitivity
Dip angle (sin δ)
0
0.5
1
1.5
2
2.5
3
0.4
0.6
0.8
1

Strategy and schedule

1) We will distribute irradiated CR-39 detectors during WRMISS.
2) We will send "baseline CR-39 detector" to participants.
   Baseline detector will be etched by ICWG.
3) We hope to collect all information within half year.

Deadline: The end of March 2008.

4) All the calibration data will be a base information to clarify uncertainties of CR-39 analysis.
5) Based on these data, we will compare the results from CR-39 ICCHIBAN in space.

CR-39 ICCHIBAN - Space

Participants

Nakahiro Yasuda, National Institute of Radiological Sciences (**NIRS**), Japan
Eric Benton, Oklahoma State University (**OSU**), USA
Thomas Berger, German Aerospace Center (**DLR**), Germany
Frantisek Spurny, Nuclear Physics Institute (**NPI**), Czech Republic
Pawel Bilski, Institute of Nuclear Physics (**INP**), Poland
Aiko Nagamatsu, Japan Aerospace Exploration Agency (**JAXA**), Japan
Joe K. Palfalvi, Atomic Energy Research Institute (**AERI**), Hungary
Edward Semones, Johnson Space Center (**JSC**) NASA, USA

Institute	Label	Trademark	Company	Thickness
NIRS	IC3	HARZLAS TD-1	Fukuvi Chemical Industry	0.9 mm
	IC3	BARYOTRAK	Fukuvi Chemical Industry	0.9 mm
	TTS	TT-S		0.9 mm
OSU	OSU	USF-4	American Technical Plastics	0.6 mm
JSC	JSC	USF-4	American Technical Plastics	0.6 mm
DLR	DLR ICC	USF-4	American Technical Plastics	0.6 mm
NPI	NPI ASCR ICCHIBAN CR-39 PAGE	Page	Page Mouldings Ltd	0.5 mm
	NPI ASCR ICCHIBAN CR-39 ATP	USF-4	American Technical Plastics	0.6 mm
	NPI ASCR ICCHIBAN CR-39 TD-1	HARZLAS TD-1	Fukuvi Chemical Industry	0.9 mm
	NPI ASCR ICCHIBAN CR-39 TASTRAK	Tastrak	Track Analysis Systems Ltd, Bristol, UK	0.5 mm
INP	Spc-ICC IFJ	Tastrak	Track Analysis Systems Ltd, Bristol, UK	1 mm
JAXA	CR39ICCHI-JAXA	HARZLAS TD-1	Fukuvi Chemical Industry	0.9 mm
AERI	ICCH	Tastrak	Track Analysis Systems Ltd, Bristol, UK	3 mm

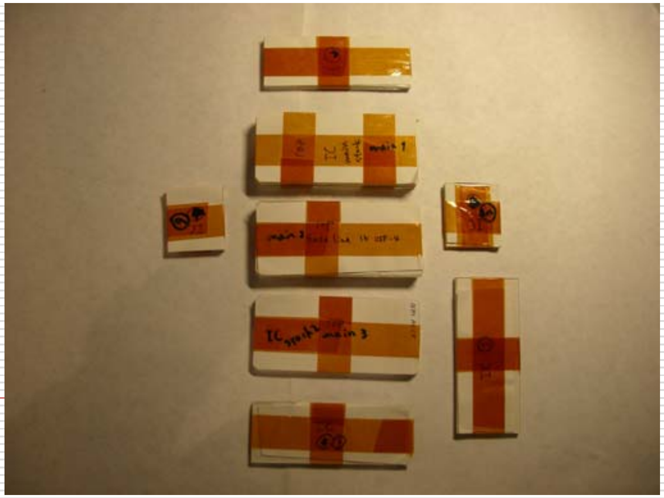
Purposes

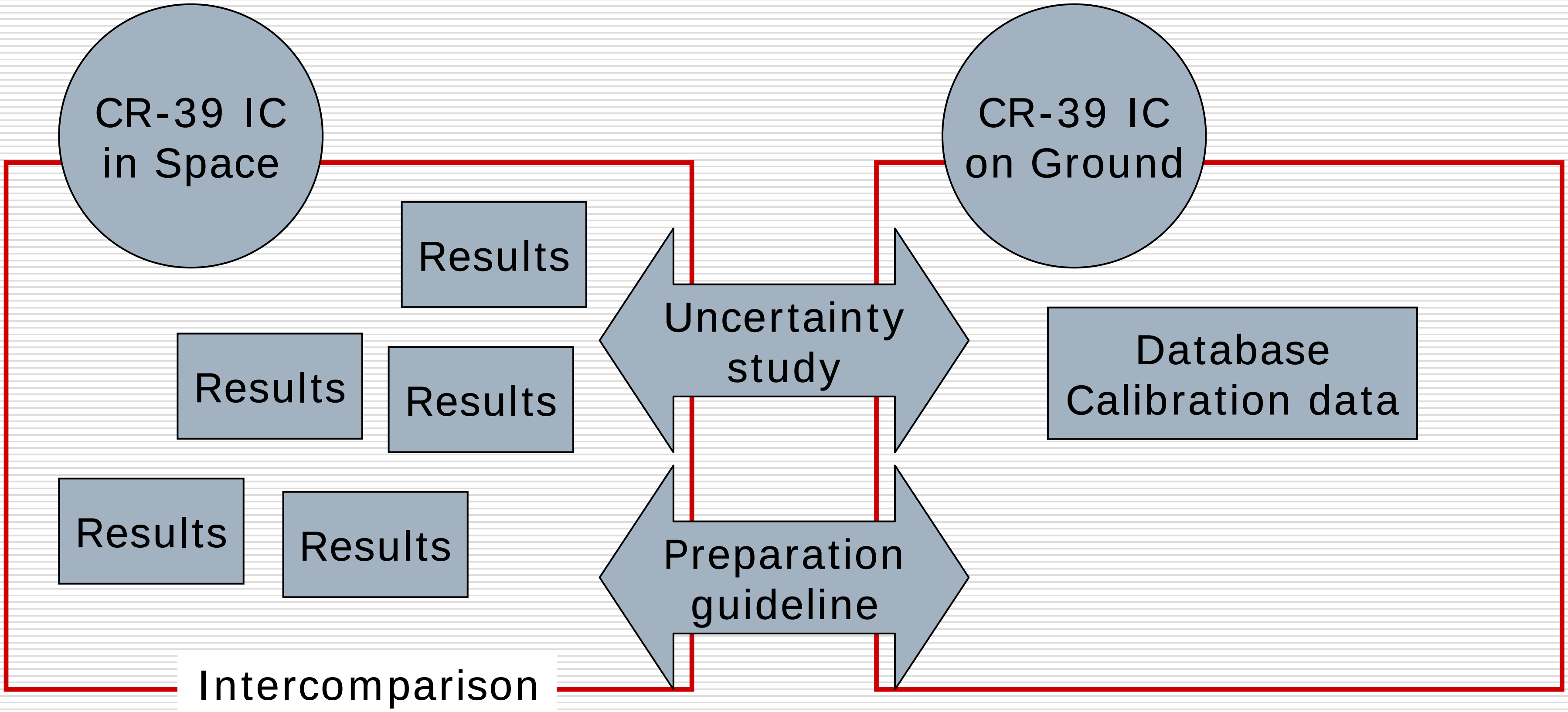
- Wall detector components

- Main stacks
  1. Stacks for all kinds of material

     Intercomparison for each material/methodology
  2. Baseline detector stack

     Intercomparison for methodology




CR-39 IC in Space
Results
Results
Results
Results
Results
Uncertainty study
Preparation guideline
CR-39 IC on Ground
Database Calibration data
Intercomparison

Where come from uncertainties for CR-39 measurement?

For CR-39 ICCHIBAN, Shuttle ICCHIBAN and SI3

- Material
  will be used also baseline detector
- Etching conditions (short and long etch combined or not)
  will be calibrated for all conditions in CR-39 IC ground
- Homogeneity of irradiation
  will be verified by ICWG
- Selection of etch pit to be measured
  will be announced a tentative guide line
- Human dependences (skills and experiences)
  will be verified by NIRS method
- Correction (critical angle, dip angle dependence, fading …)
- Calculation method
  will be controlled by ICWG

Pilot test to clarify the uncertainties

Captured all image to be measured

- Material
  HARZLAS TD-1

- Etching conditions
  multi etching 4, 8, 12, 16, 20 ,24 hrs
- Homogeneity of irradiation
  the different positions were measured on one detector surface
- Selection of etch pit to be measured
  Comparison of cone shaped and cone shaped + over etched
- Human dependences (skills and experiences)
  Comparison of 2 person's results / 1 person tried 2 times
- Correction
  Critical angle only
- Calculation method
  Applying common calculation

Intercomparison experiments as ICCHIBAN project

Space

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[Data correction]

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[Exposed in Space Shuttle]

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Ground(HIMAC)

Data correction for previous ICCHIBAN
- Preparation of database
[announced by Hisashi]

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- Dip angle dependence for track registration sensitivity
[distributing CR-39s]