ICCHIBAN 2 & 4 & 6: NRPB Results

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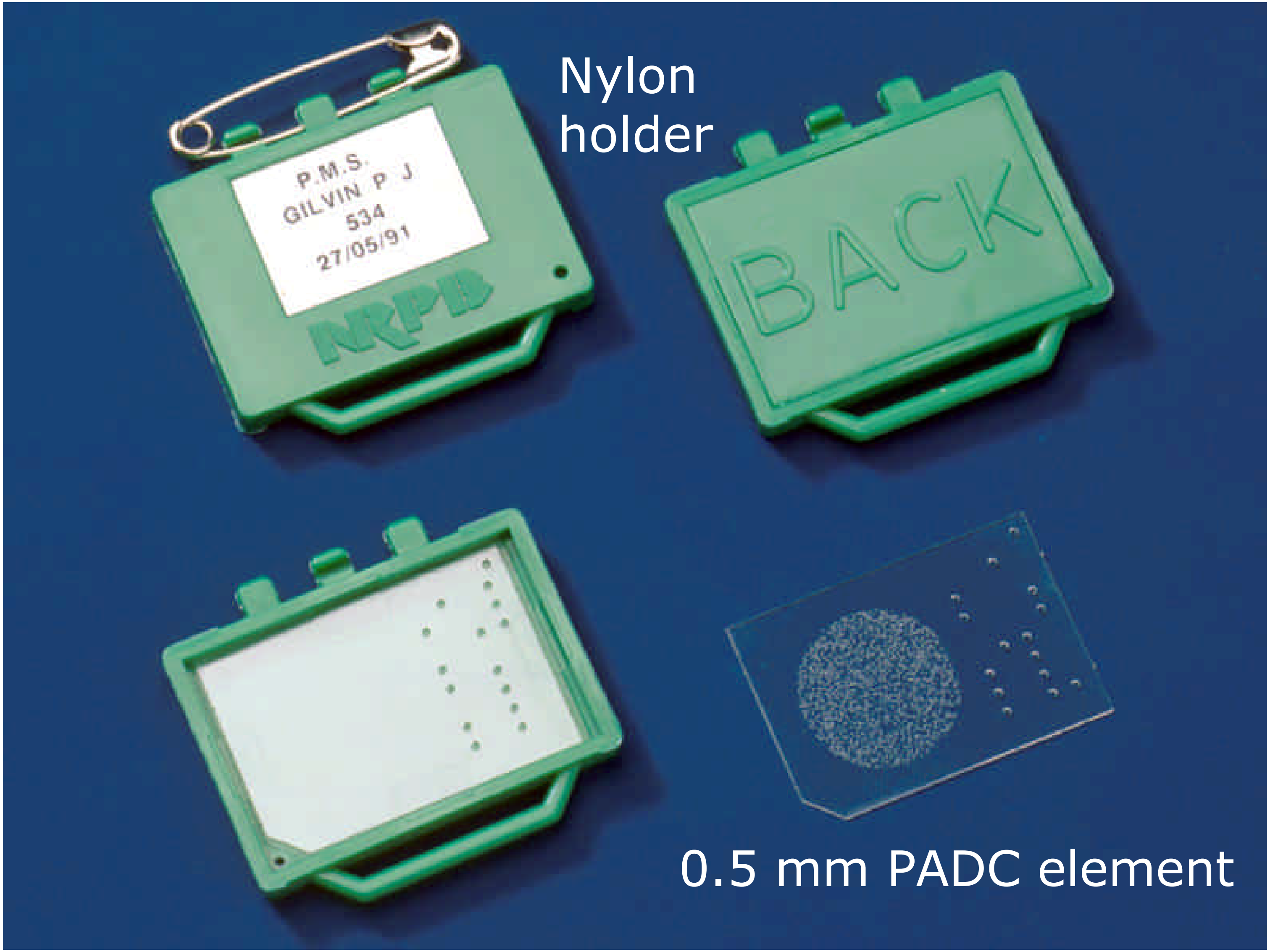
- Standard issue neutron dosemeters of simple design, processed using simple techniques developed for personal dosimetry, may be used to estimate the neutron component in spacecraft.
- Electrochemically etched pits in poly allyl diglycol carbonate (PADC or CR-39®) etched track detectors are identified and counted using fully automated read-out procedures.
- ICCHIBAN irradiations have allowed determination of the LET threshold of detection for the dosemeter and etch regime.


Nylon
holder
P.M.S.
GILVIN P J
534
27/05/91
NRPB
BACK
0.5 mm PADC element

Dosemeter Layout for Irradiation

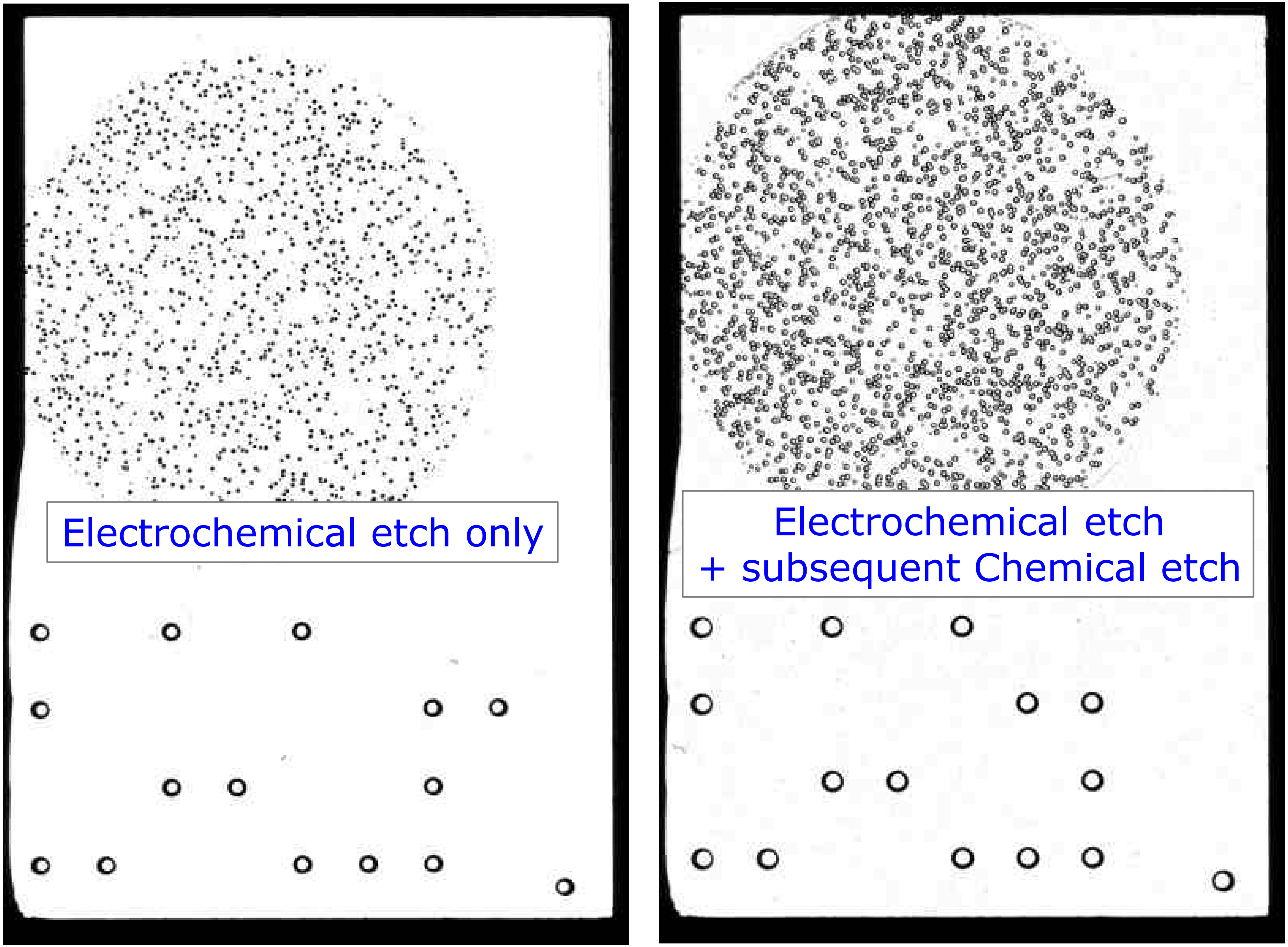
Processing Methods

Electrochemical etch - back face

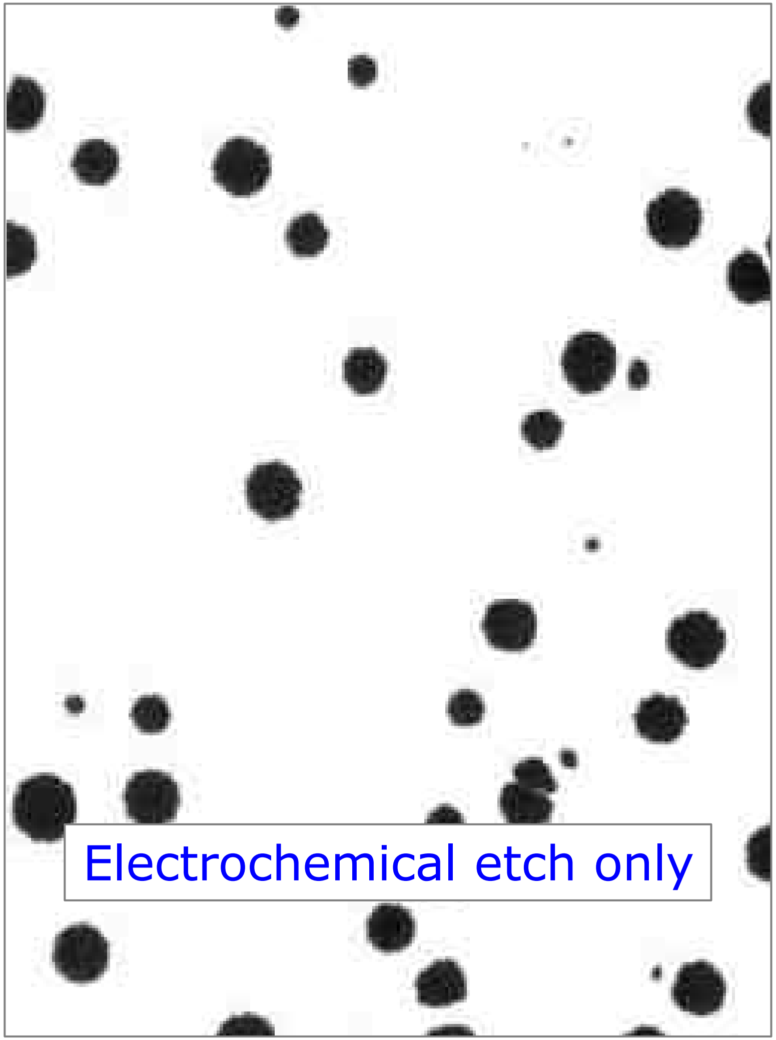
- 11.5 hours 20% NaOH at 40^0C followed contiguously
- by 8 hours 20% NaOH at 40^0C at 23.5 $kVcm^{-1}$

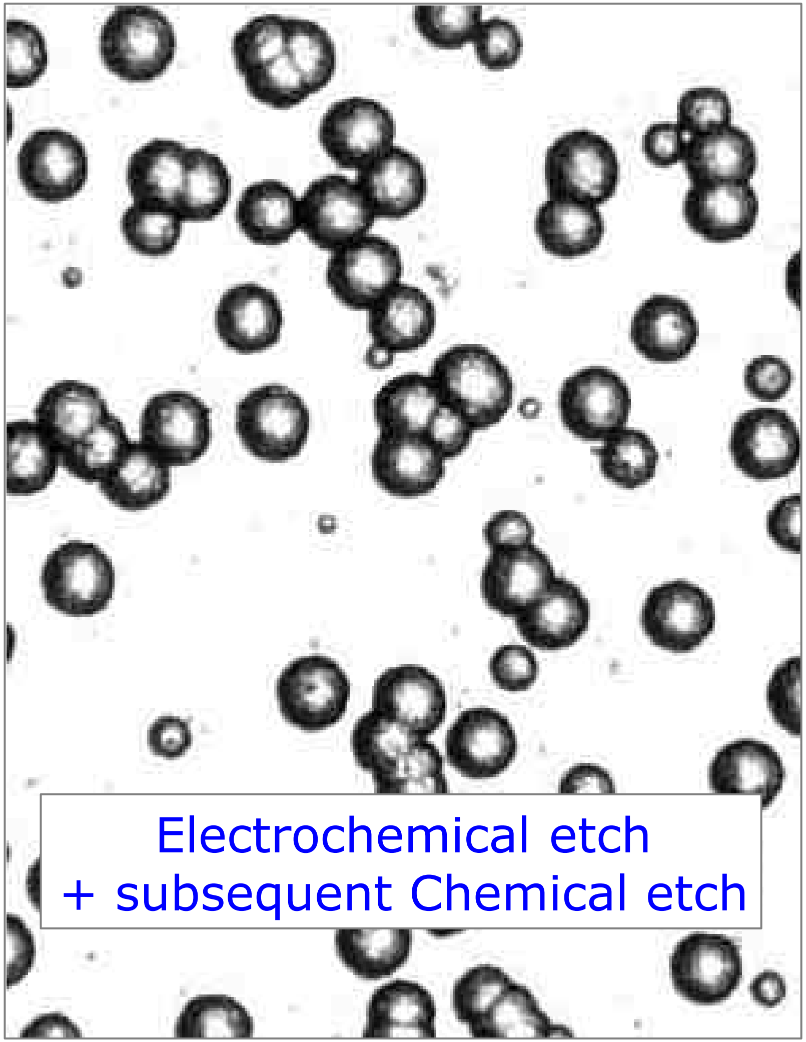
Subsequent Chemical etch - both faces

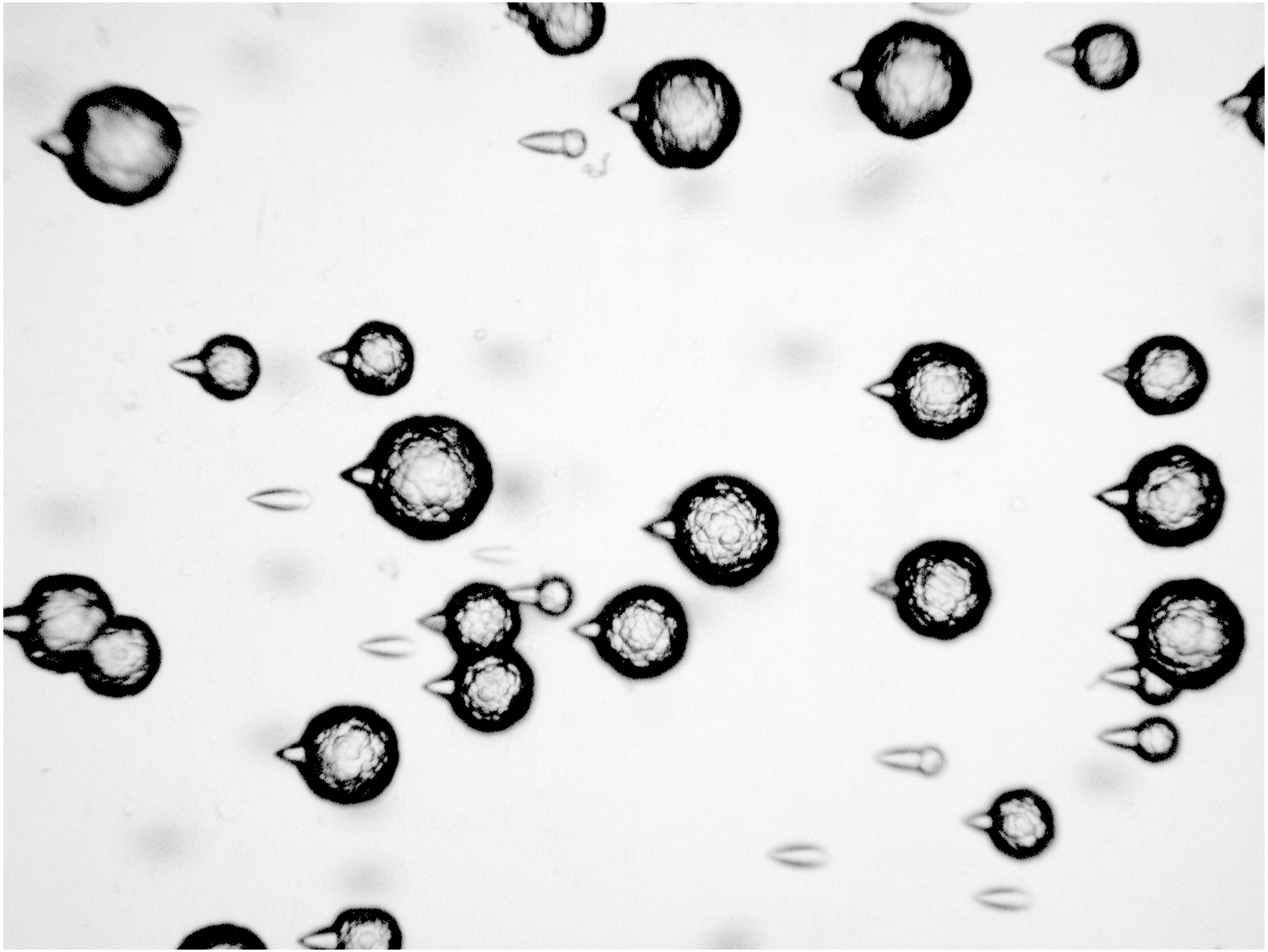
- 18 hours 20% NaOH at 80^0C


Electrochemical etch only
Electrochemical etch
+ subsequent Chemical etch

Comparison of Etch methods

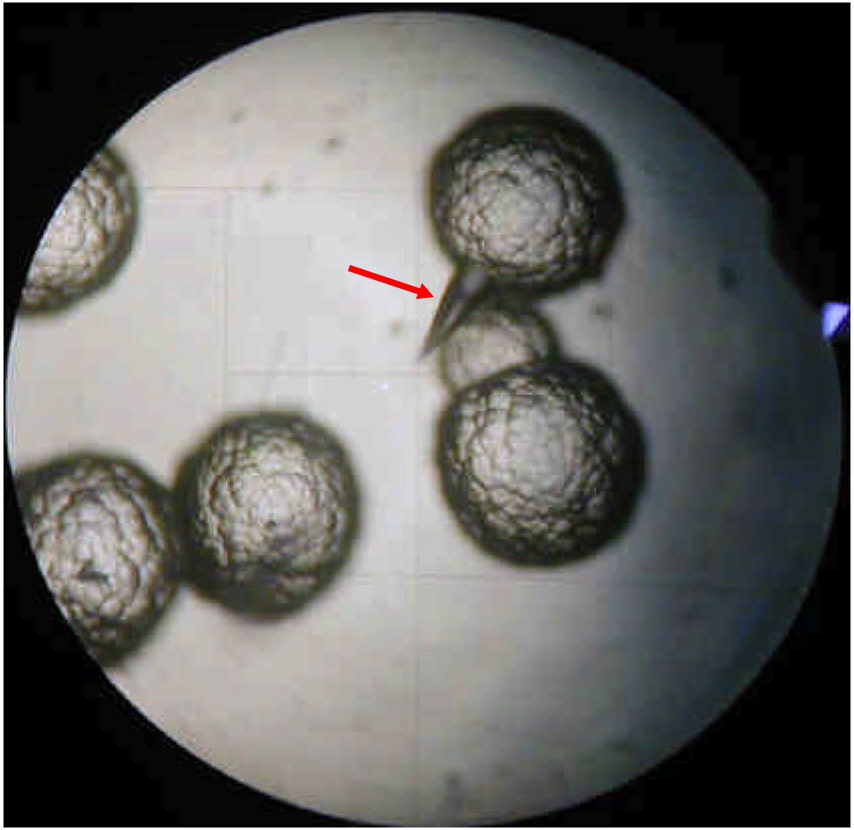




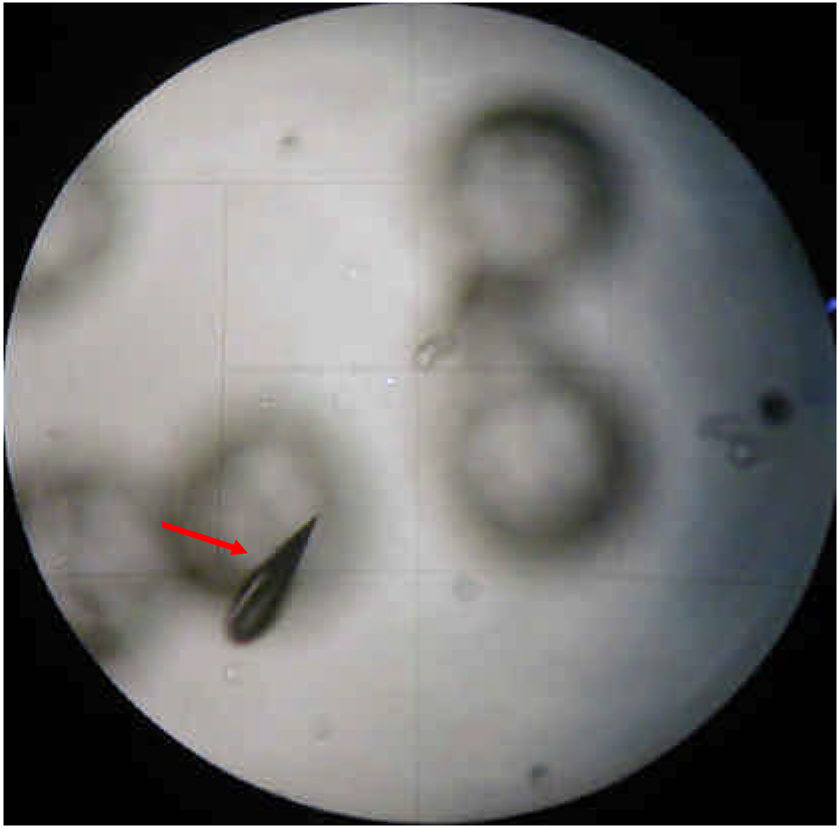


^{56}Fe 60º to normal incidence

NASA STS 105 - obvious HZE track

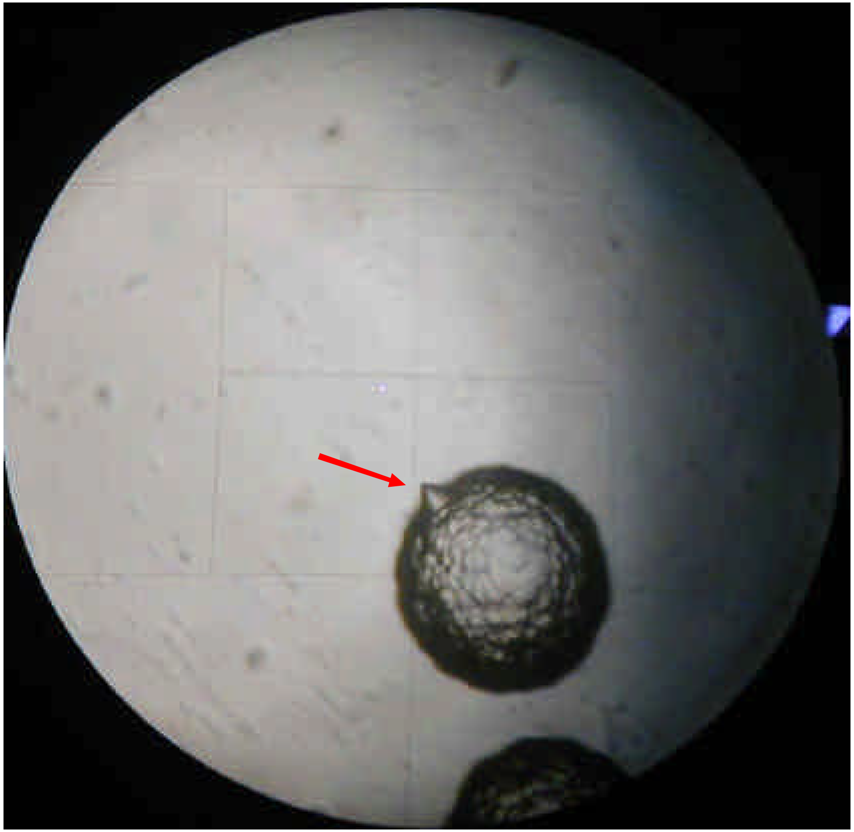


Back face



Front Face

NASA STS 105 - typical HZE track



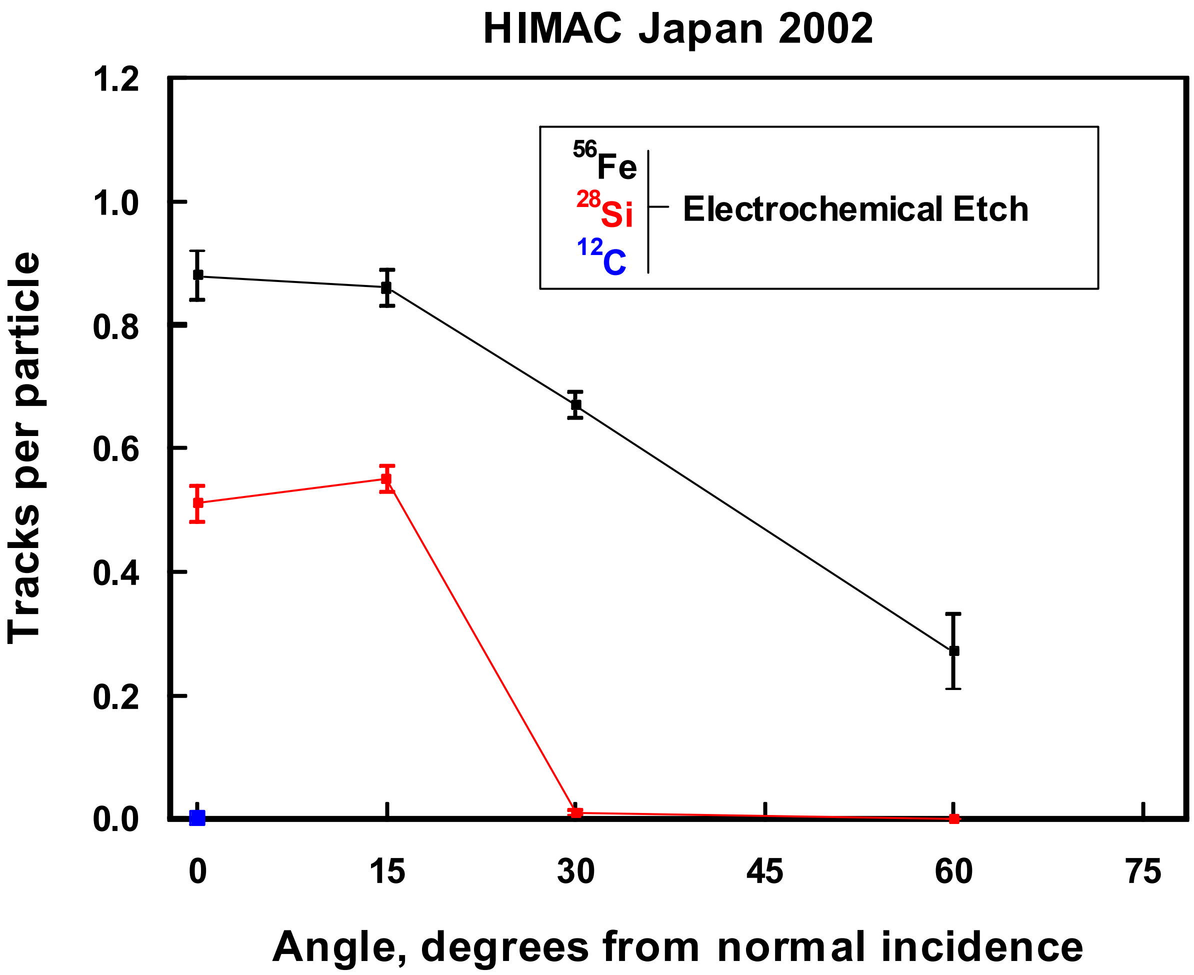
Back face

Front face

- PADC neutron personal dosemeter responds to neutrons plus neutron-like interactions of high-energy protons
- Only responds directly to protons of E_p < about 1 MeV
- Some response to heavier charged particles with LET_{200} > about 30 keV μm^{-1}, depending on particle type
- Can distinguish HZE electrochemically etched tracks by second chemical etch
- Preliminary measurements on NASA STS and ISS indicate that a correction of 20 to 30% is necessary to account for the detector HZE response.

ICCHIBAN-2 Irradiations

Angle dependence of response ICCHIBAN-2 data



Angle dependence of relative response: ICCHIBAN-2 data

	0º	15º	30º	60º	75º	ISO free air	ISO on body
^{56}Fe 464 MeV/n	0.90	0.85	0.70	0.30	0	30% to 40%	15% to 20%
^{28}Si 469 MeV/n	0.50	0.55	0.02	0	0	about 5%	about 2%

As well as helping to improve the neutron dose assessment the ICCHIBAN calibrations are also very useful to help understand a little bit better the response to HZE of our detector

Results of ICCHIBAN-4 Irradiations

Electrochemical etching- single detector charged particle results: ^{12}C 400 MeV/n

Particle/ Energy	Shielding condition	LET keV μm^{-1}	Dose mGy	Fluence cm^{-2}	Corrected Net Tracks [(a)] cm^{-2}		Note
					Det.1	Det.2	
^{12}C 400 MeV/n	zero	10.963	1	57000	8	1	(b)
	5 g cm^{-2} Al	?		?	9	11	(c)
	10 g cm^{-2} Al	?		?	21	14	(d)
	5 g cm^{-2} PMMA	?		?	19	15	(e)

(a) Observed number of tracks cm^{-2} after subtraction of background and corrected for non-linearity at high track density

(b) Not significantly different from background. Primary beam particles below LET threshold

(c), (d), (e) Primary beam particles below LET threshold. A few higher LET fragments? - some larger tracks

In subsequent figures, detector 1 is edged in orange, detector 2 in red.

Electrochemical etching- single detector charged particle results: ^{20}Ne 400 MeV/n

Particle/ Energy	Shielding condition	LET keV μm^{-1}	Dose mGy	Fluence cm^{-2}	Corrected Net Tracks [(a)] cm^{-2}		Note
					Det.1	Det.2	
^{20}Ne 400 MeV/n	zero	30.959	1	20200	690	23	(f)
	5 g cm^{-2} Al	?		?	225	1180	(g)
	10 g cm^{-2} Al	?		?	8390	5520	(h)
	5 g cm^{-2} PMMA	?		?	5000	7020	(i)

(f), (g) At LET threshold – some non-uniformity of response across/between detectors because of small differences in applied field strength during processing

(h), (i) Just on LET threshold – some non-uniformity of response

In subsequent figures, detector 1 is edged in orange, detector 2 in red

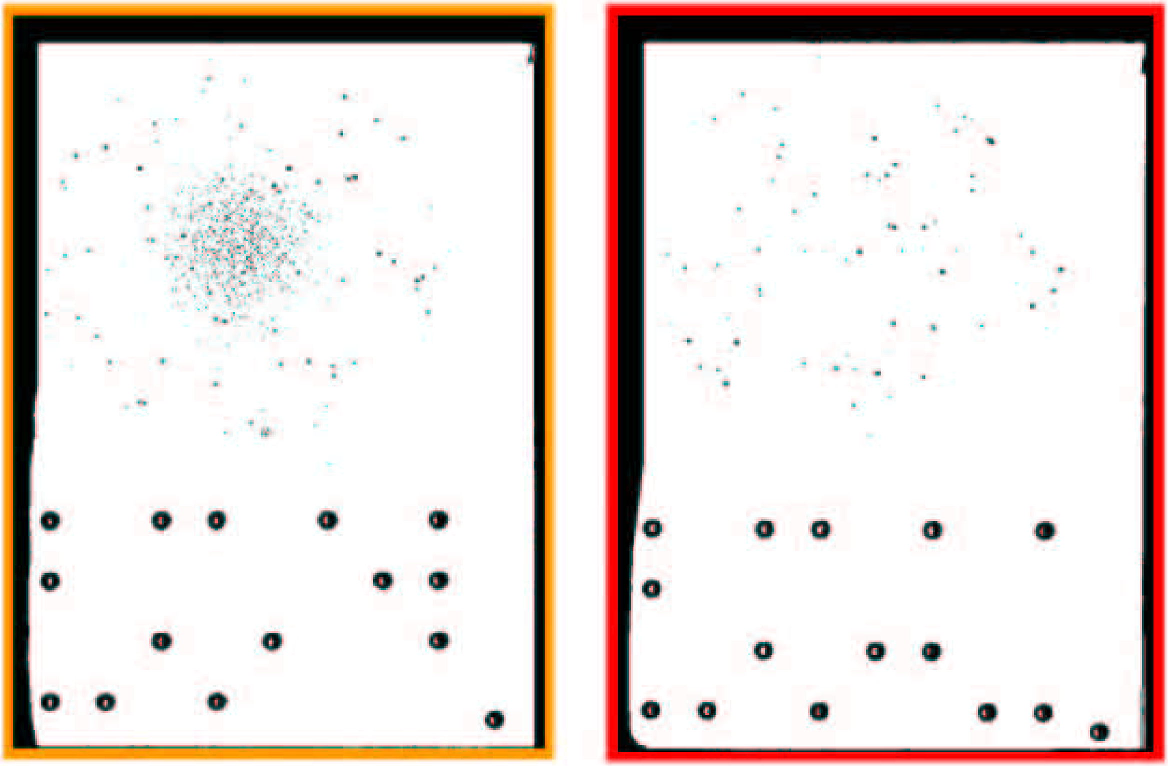
Electrochemical etching- single detector charged particle results: ^{56}Fe 500 MeV/n

Particle/ Energy	Shielding condition	LET keV μm^{-1}	Dose mGy	Fluence cm^{-2}	Corrected Net Tracks [a] cm^{-2}		Note
					Det.1	Det.2	
^{56}Fe 500 MeV/n	zero	~ 190	1	~3300	3980	3790	(j)
	5 g cm^{-2} Al	?		?	3420	3440	(k)
	10 g cm^{-2} Al	?		?	380	360	(l)
	5 g cm^{-2} PMMA	?		?	3640	3570	(m)

(j), (k) Above threshold, 100% detection efficiency
(l) Beyond Bragg peak- some fragments plus a few secondary neutrons?
(m) Above threshold, 100% detection efficiency

In subsequent figures, detector 1 is edged in orange, detector 2 in red

482 microns 520 microns

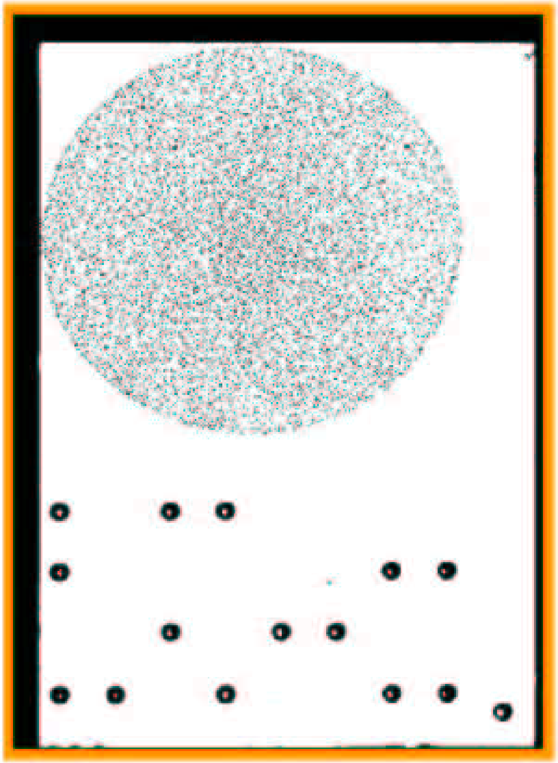
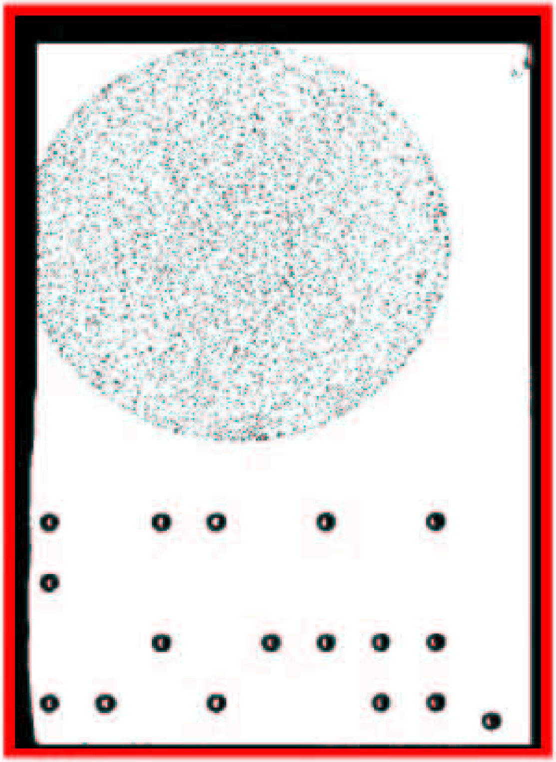


Ne pack 1	1mGy		
Condition	mono		
ID	Dtr	Tracks	Net Corr Tracks
33	D109284	1105	1220
71	D109201	66	40

513 microns

502 microns

Ne pack 2	1mGy		
Condition	5g Al		
ID	Dtr	Tracks	Net Corr Tracks
59	D109214	406	397
64	D109232	1744	2093

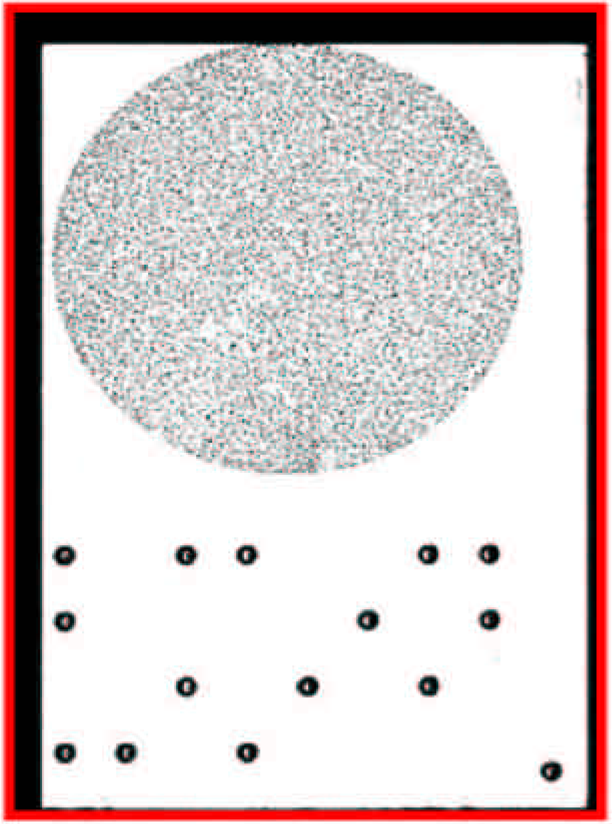
506 microns	516 microns
	

Ne pack 3	1mGy
Condition	10g Al

ID	Dtr	Tracks	Net Corr Tracks
13	D109225	6704	14818
54	D109203	5250	9750

485 microns

500 microns



Ne pack 4	1mGy
Condition	5g H_2O

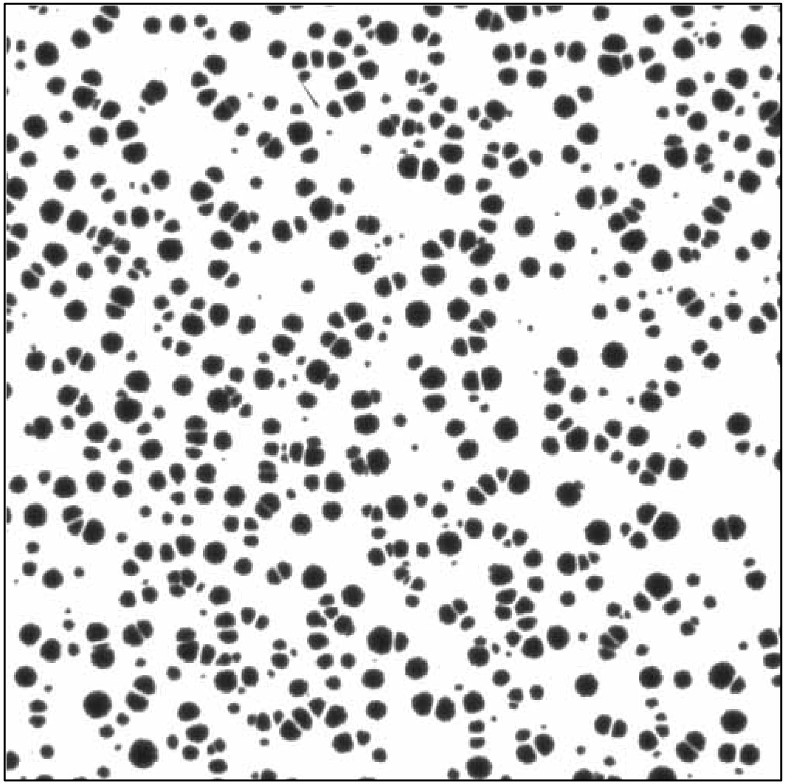
ID	Dtr	Tracks	Net Corr Tracks
37	D109260	4943	8841
52	D109240	6057	12400

Results of
ICCHIBAN-6 Irradiations

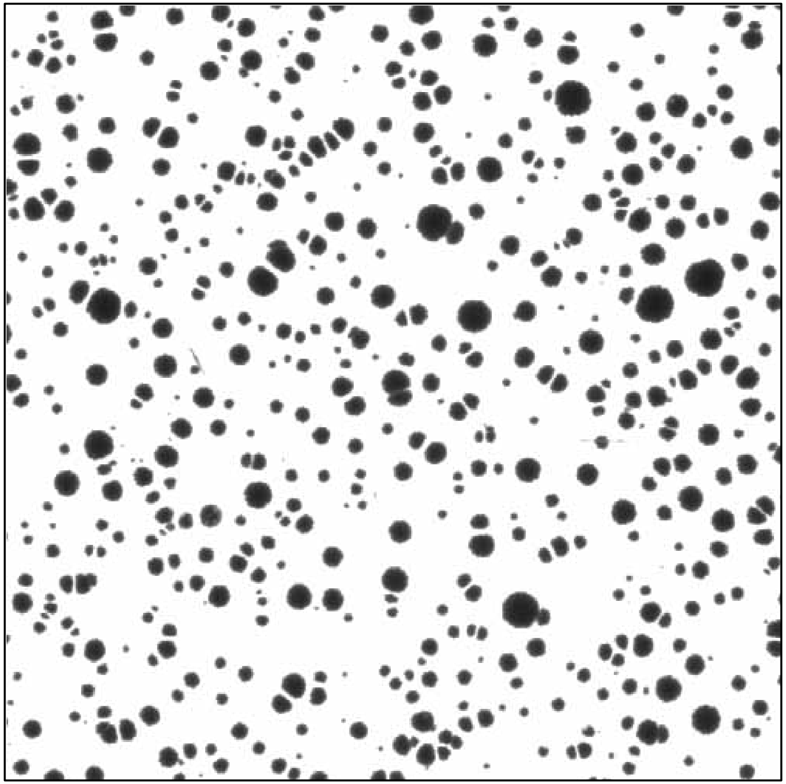
Electrochemical etching ICCHIBAN-6 charged particle results

Particle/ Energy	Shielding condition	LET keV μm^{-1}	Nominal Fluence cm^{-2}	Corrected net tracks cm^{-2} for several detectors Det.1	Det.2	Det.3
^{12}C 135 MeV/n	Bare Beam	21.2	5000	5	2	19
	PMMA absorber	?	5000	3691	3256	3017
^{40}Ar 500 MeV/n	Bare Beam	89.3	5000	4489	4993	4858
	PMMA absorber	?	5000	2990	3053	3119
^{84}Kr 400 MeV/n	Bare Beam	397	5000	3375	3337	3326
	PMMA absorber	?	5000	3135	3026	3176

ICCHIBAN 6: ^{12}C 135 MeV/n through PMMA

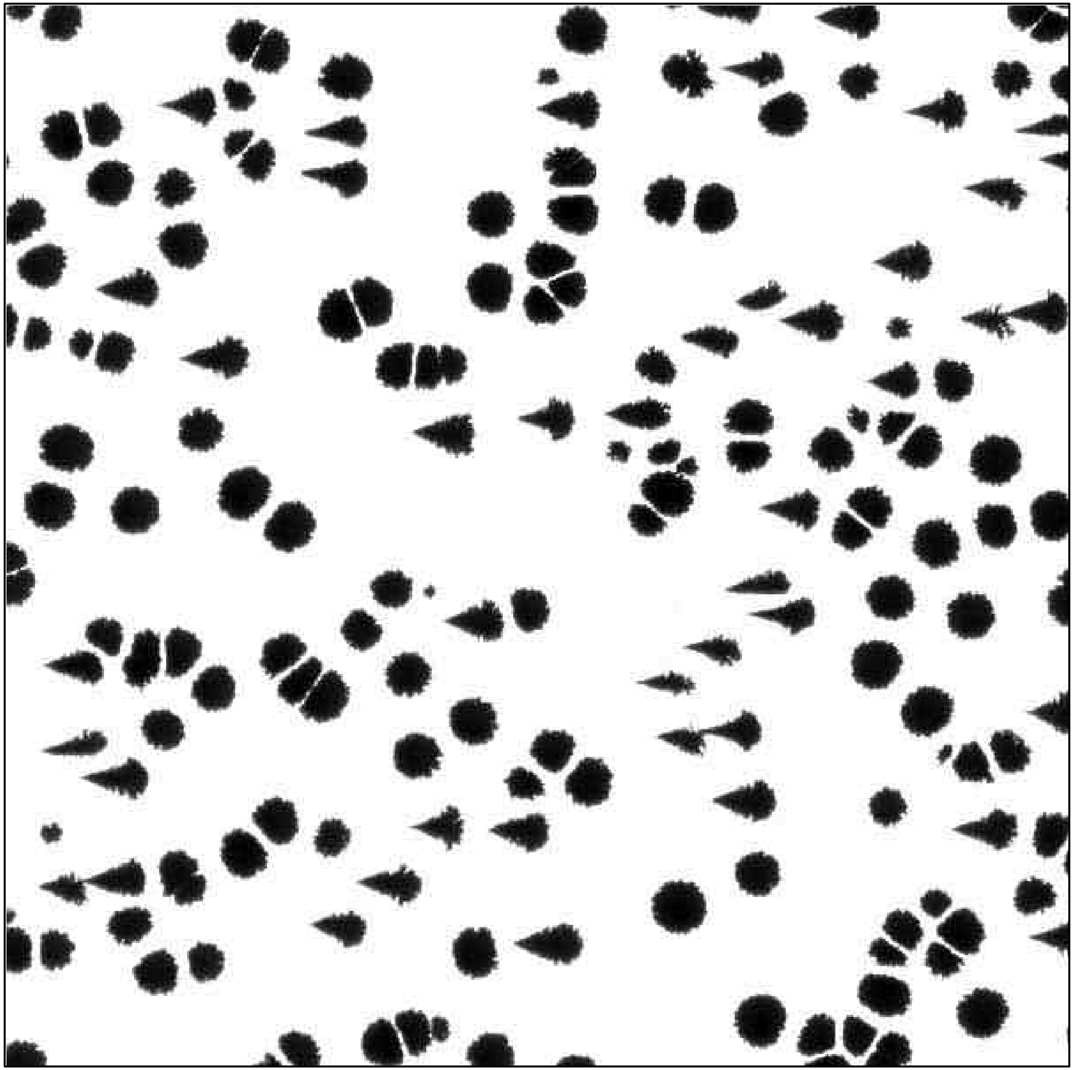


Detector 2 (511 μm)



Detector 3 (542 μm)

ICCHIBAN-6 Blind # 5



SUMMARY

- Efficiency of detection of charged particles highly dependent on particle type, energy and angle of incidence - results in low isotropic response for the electrochemical etch method used

- For neutron dose assessment the HZE response of the detector is not a problem as long as it can be subtracted

- A subsequent chemical etch is performed which identifies HZE tracks and removes unwanted HZE component from neutron dose assessment

ACKNOWLEDGEMENTS

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