Response of a PADC Neutron Personal Dosemeter to HZE: ICCHIBAN-4 Results

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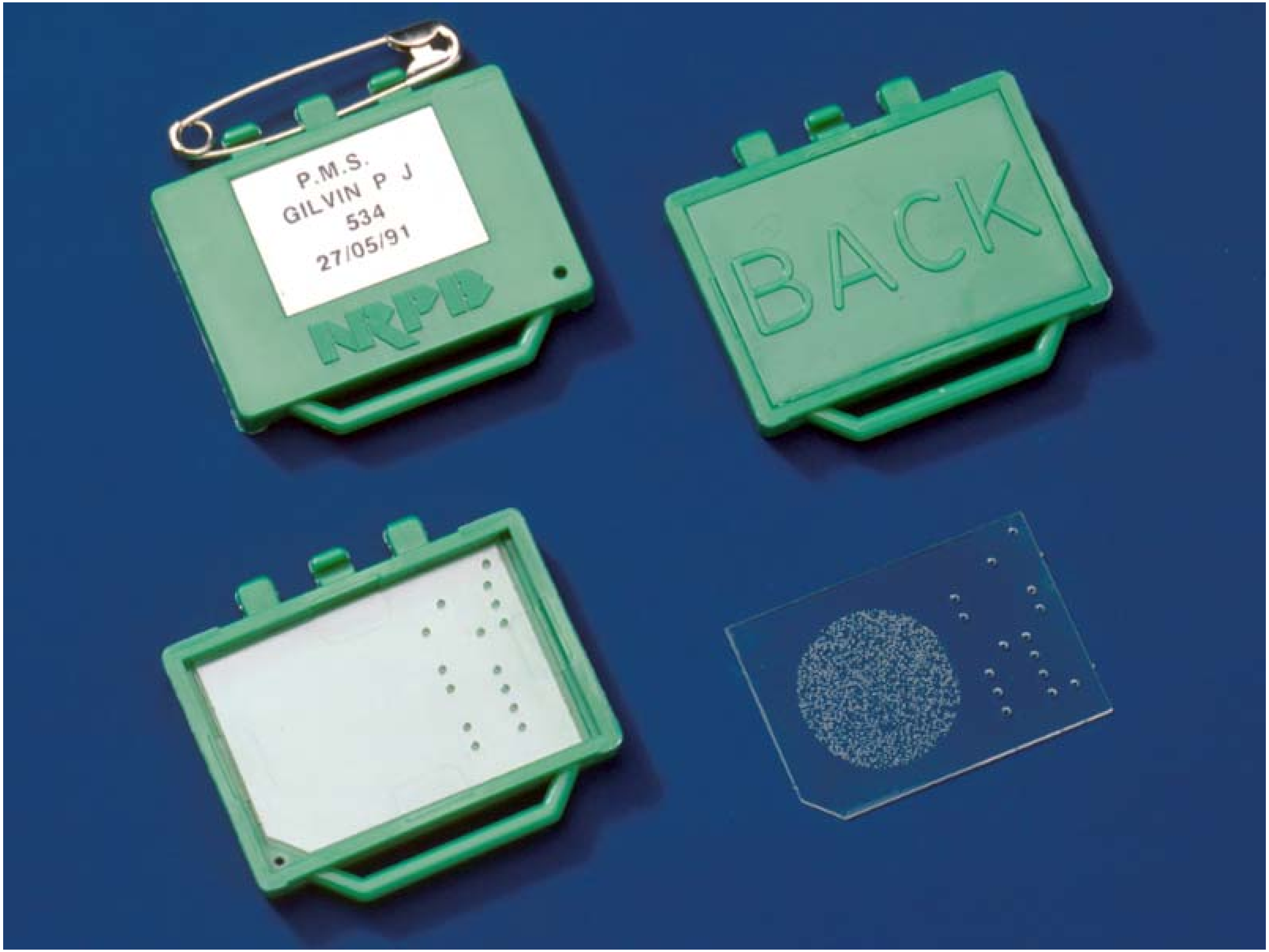
Personal neutron dosemeters of simple design, processed using simple techniques developed for personal dosimetry, may be used to estimate this neutron component. Electrochemically etched pits in poly allyl diglycol carbonate (PADC or CR-39®) etched track detectors are identified and counted using fully automated read-out procedures.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BACK

The tracks observed will be produced not only by secondary charged particles from interactions of the neutron component of the radiation field, but also in part by the proton and energetic heavy charged particle components of the radiation field at the location of the dosemeter, leading to an over-estimate of the neutron component. The efficiency of the etch and read procedures is very dependent on particle type, energy and angle of incidence.

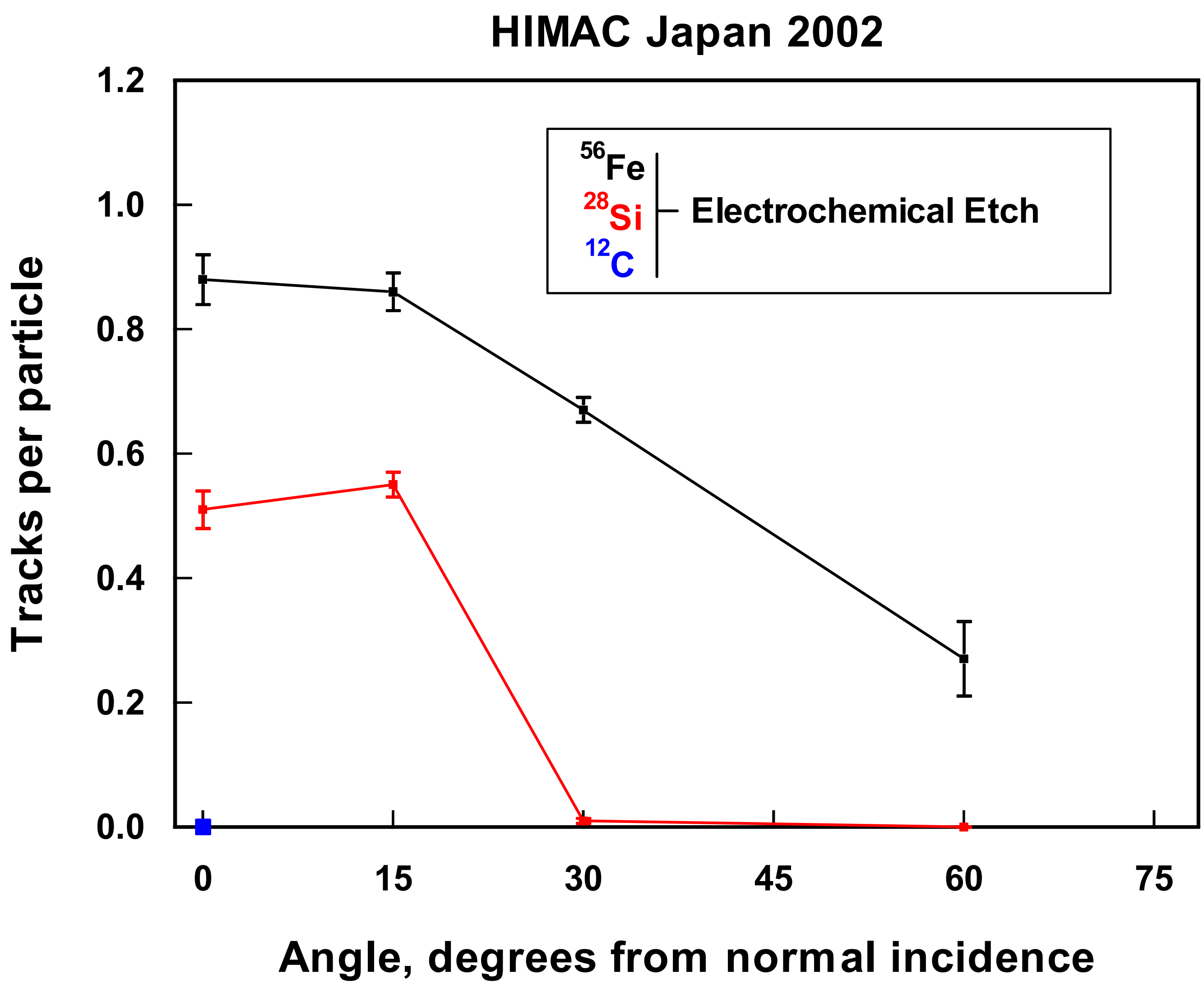
For the etch regime employed, the combination of high LET threshold (there is little response below a restricted LET_{200} in PADC of about 30 keV μm^{-1}), and poor angle dependence of response to high-energy charged particles (HZE), results in a much reduced overall response of the neutron dosimeter to the HZE component of the field in spacecraft and no response to protons of energy greater than about 1 MeV at the surface to be etched.

Preliminary measurements indicate that for examples of the HZE component of the radiation fields in spacecraft, a correction of 5 to 10% is necessary to account for the detector HZE response.

Alternatively, an additional chemical etch can be carried out which allows discrimination.

- 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 LET_{200} > about 30 keV μm^{-1}, depending on particle type
- Can generally distinguish HZE electrochemically etched tracks by second chemical etch

Figure showing results for ICCHIBAN-2



Charged particle angle dependence of relative response: ICCHIBAN-2 data

	0º	15º	30º	60º	75º	Forward 2π (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%

Results of
ICCHIBAN-4 Irradiations

Measurements at HIMAC/ICCHIBAN-4 with the NRPB PADC Dosemeter

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 $kVcm^{-1}$

Chemical etch - both faces

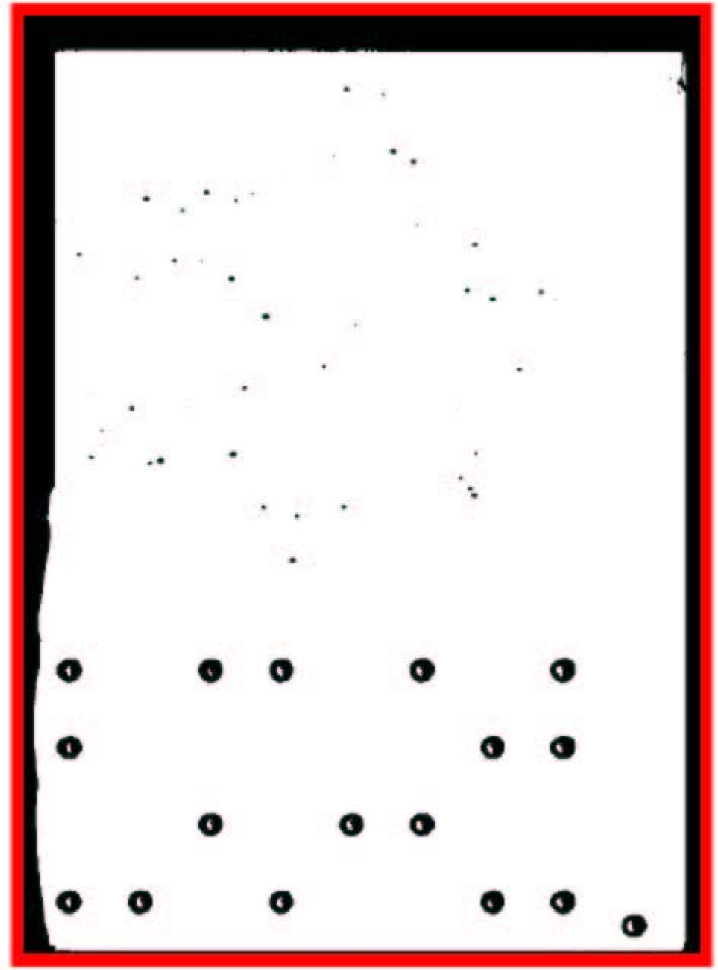
18 hours 20% NaOH at 80^0C –only ECE results available at present time

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

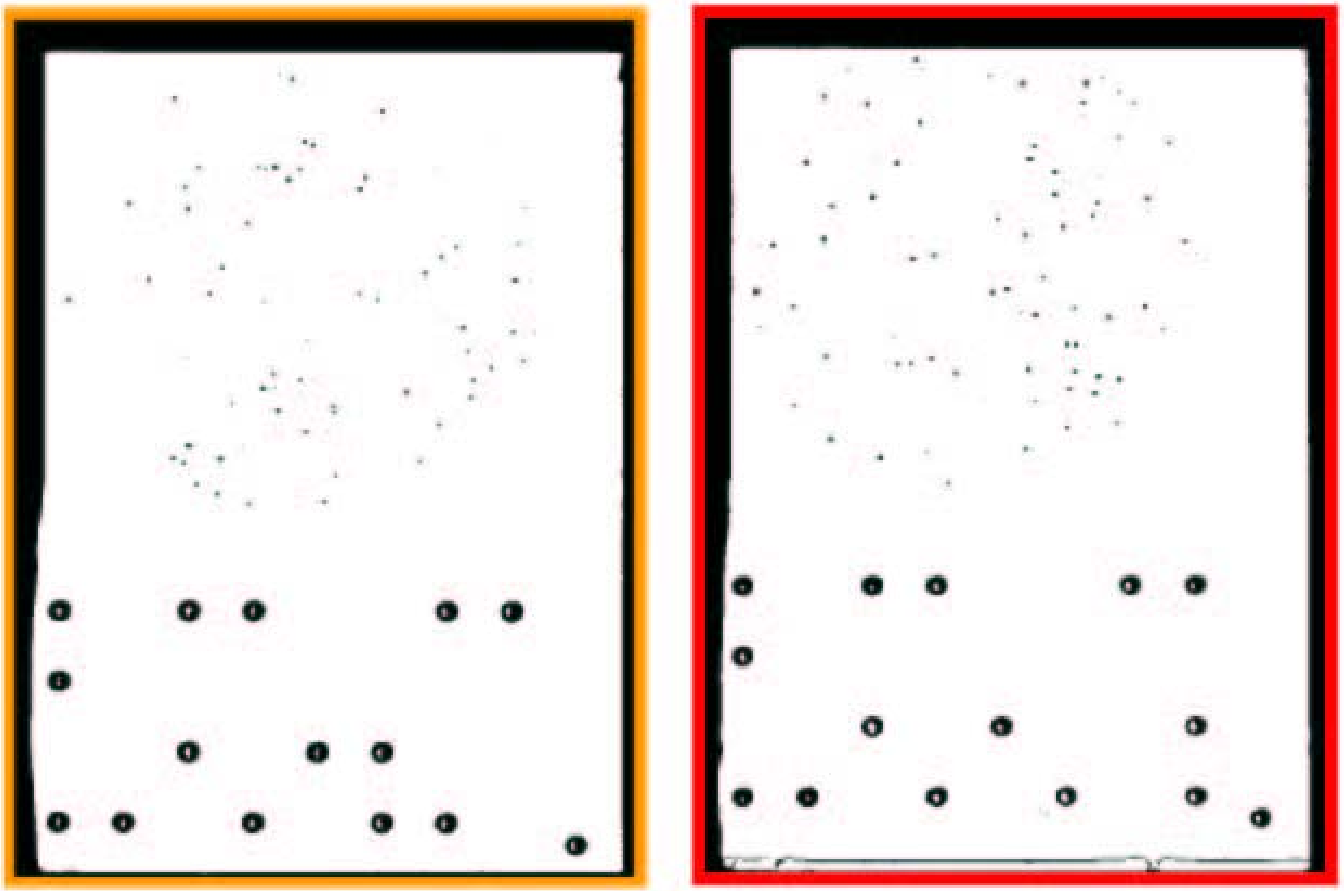
Particle/ Energy	Shielding condition	LET keV μm^{-1}	Dose mGy	Fluence cm^{-2}	Corrected Net Tracks [a] cm^{-2}		Note
					Det.1	Det.2	
^{12}C 400 MeV/n	zero	10.963	1	57000	8	1	(b)
	5 g cm^{-2} Al	?		?	9	11	(c)
	10 g cm^{-2} Al	?		?	21	14	(d)
	5 g cm^{-2} PMMA	?		?	19	15	(e)

(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

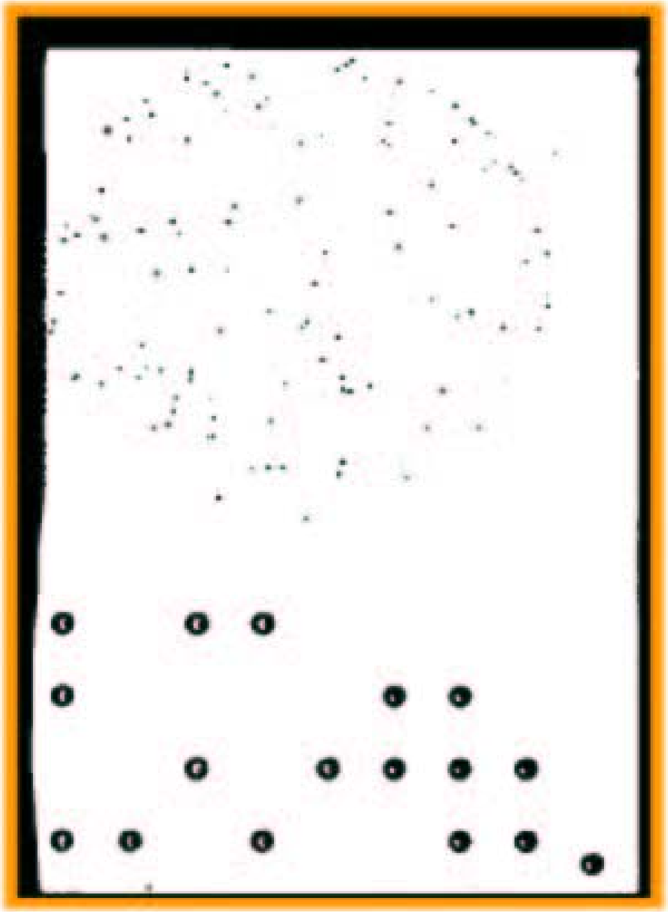
In subsequent figures, detector 1 is edged in orange, detector 2 in red.

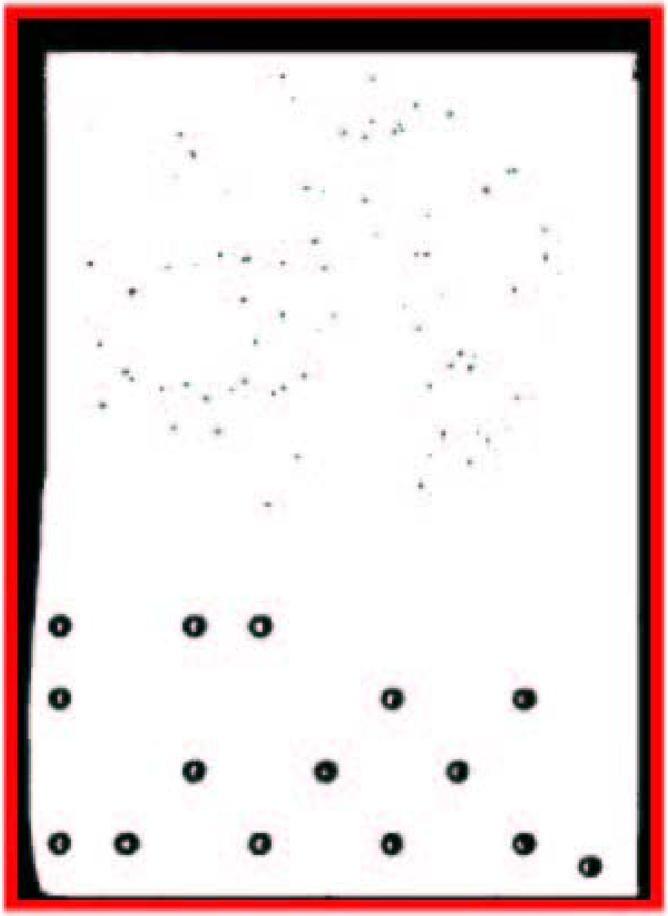
 

C pack 1	1mGy		
Condition	mono		
ID	Dtr	Tracks	Net Corr Tracks
24	D109235	41	15
41	D109205	28	2

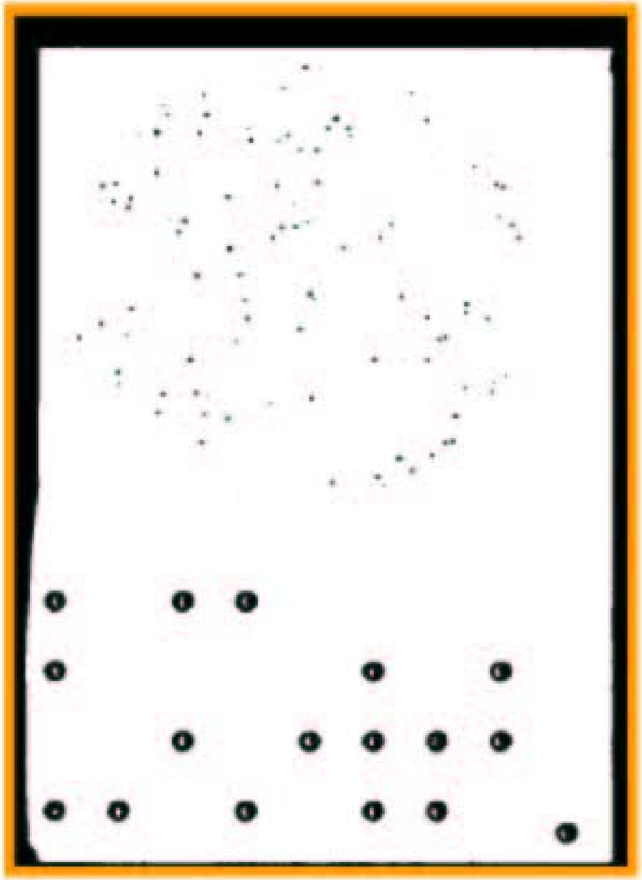


C pack 2	1mGy		
Condition	5g Al		
ID	Dtr	Tracks	Net Corr Tracks
6	D109239	42	16
35	D109218	46	20





C pack 3	1mGy		
Condition	10g Al		
ID	Dtr	Tracks	Net Corr Tracks
21	D109267	63	37
40	D109252	50	24



C pack 4	1mGy		
Condition	5g H2O		
ID	Dtr	Tracks	Net Corr Tracks
1	D109273	59	33
34	D109290	52	26

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

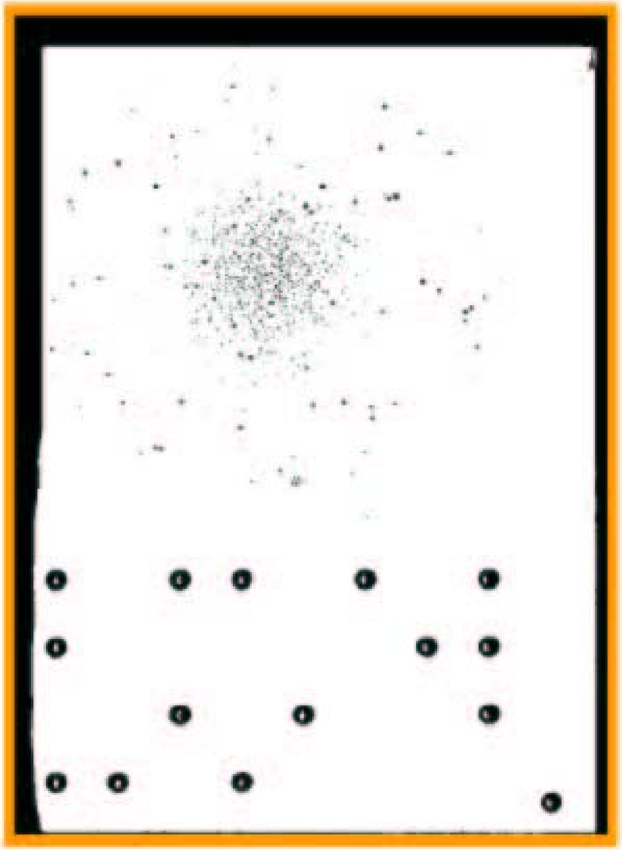
Particle/ Energy	Shielding condition	LET keV μm^{-1}	Dose mGy	Fluence cm^{-2}	Corrected Net Tracks [a] cm^{-2}		Note
					Det.1	Det.2	
^{20}Ne 400 MeV/n	zero	30.959	1	20200	690	23	(f)
	5 g cm^{-2} Al	?		?	225	1180	(g)
	10 g cm^{-2} Al	?		?	8390	5520	(h)
	5 g cm^{-2} PMMA	?		?	5000	7020	(i)

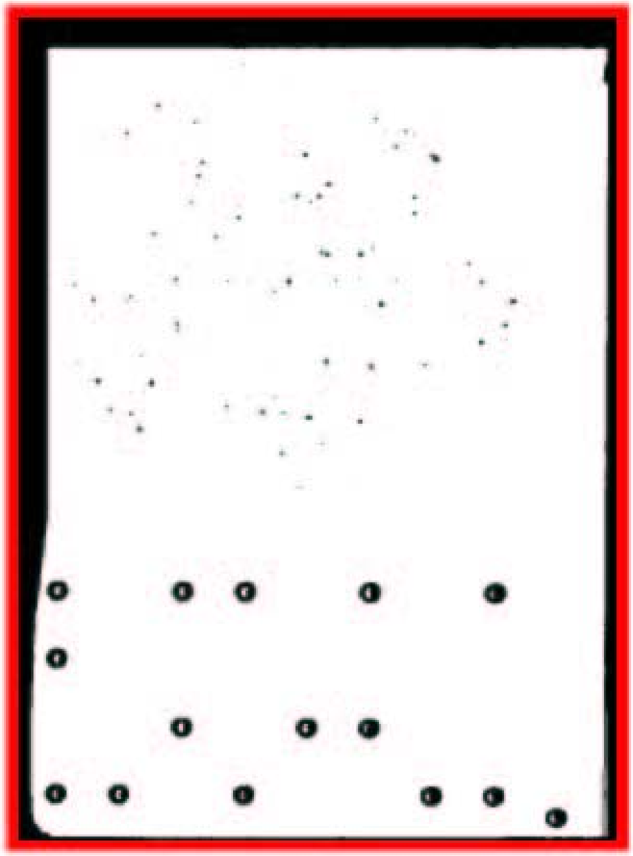
(f), (g) At LET threshold – some non-uniformity of response across/between detectors because of small
differences in applied field strength during processing
(h), (i) Just on LET threshold – some non-uniformity of response

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

482 microns

520 microns

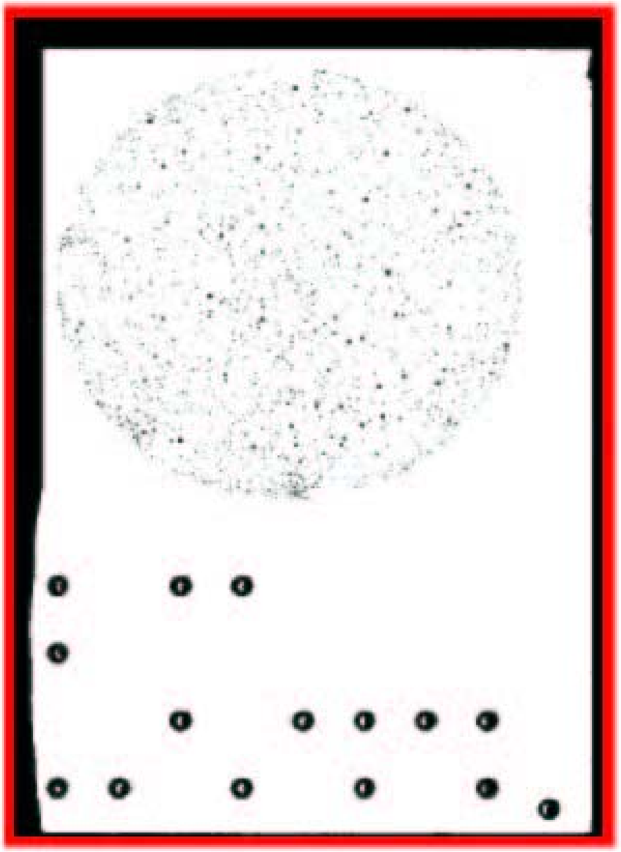




Ne pack 1	1mGy		
Condition	mono		
ID	Dtr	Tracks	Net Corr Tracks
33	D109284	1105	1220
71	D109201	66	40

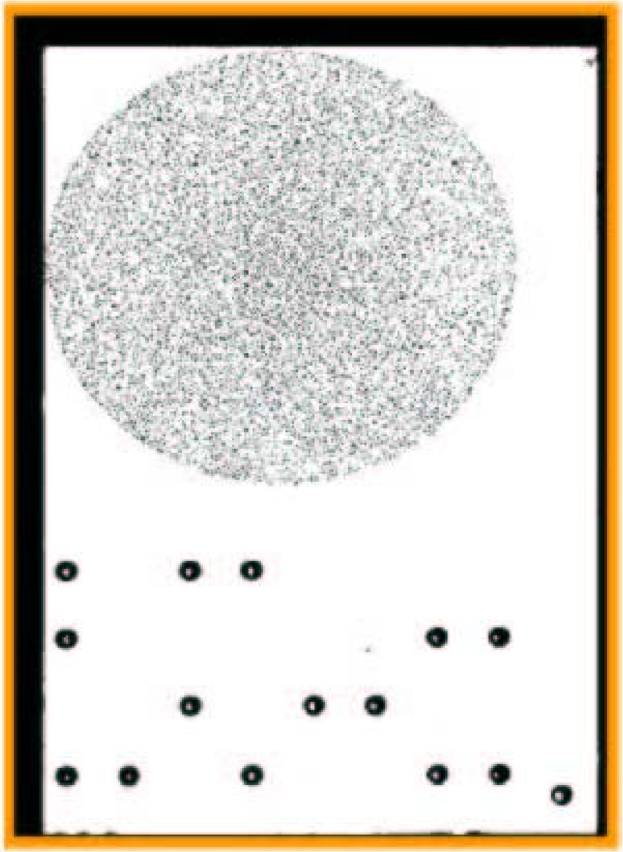
513 microns

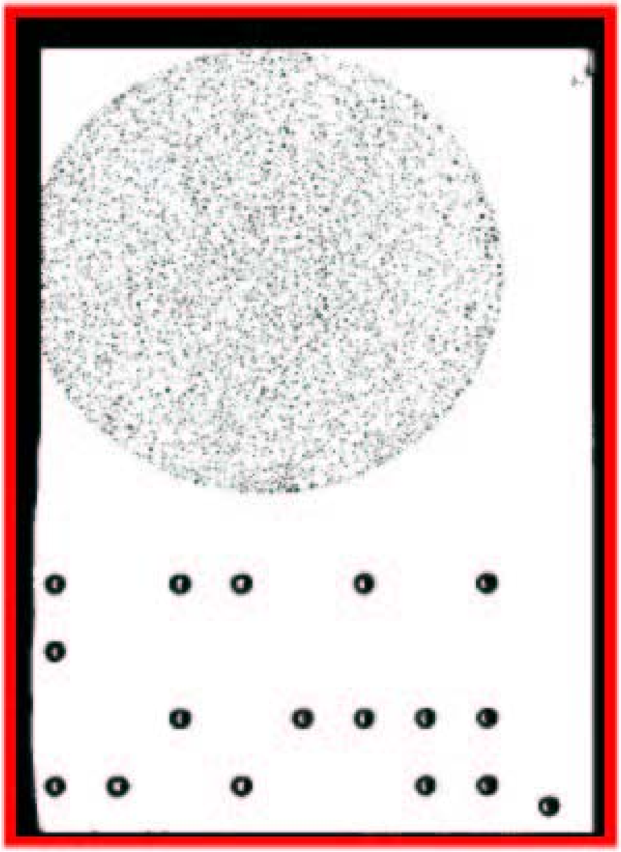
502 microns



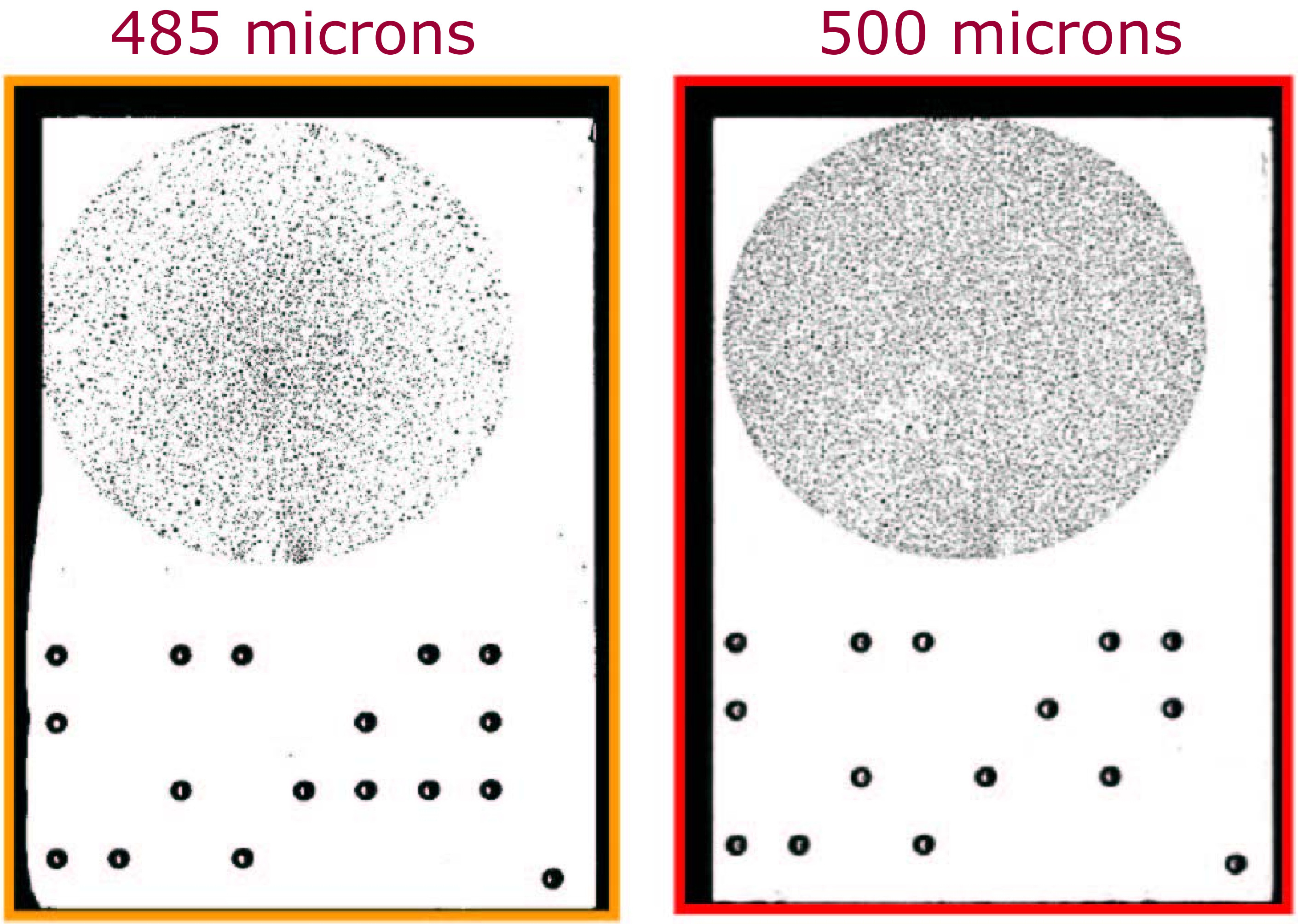
Ne pack 2	1mGy		
Condition	5g Al		
ID	Dtr	Tracks	Net Corr Tracks
59	D109214	406	397
64	D109232	1744	2093

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



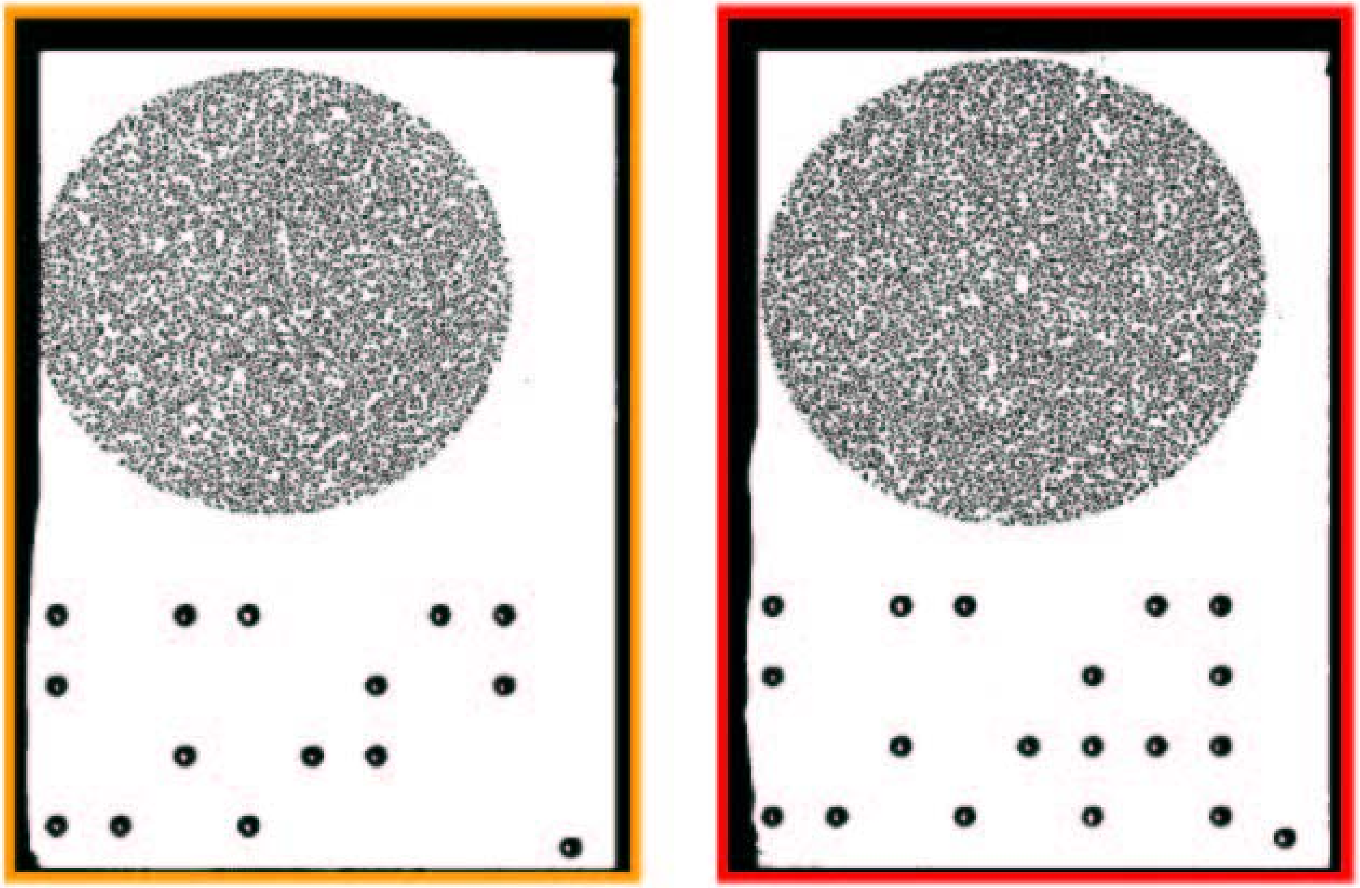
Ne pack 4	1mGy		
Condition	5g H_2O		
ID	Dtr	Tracks	Net Corr Tracks
37	D109260	4943	8841
52	D109240	6057	12400

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

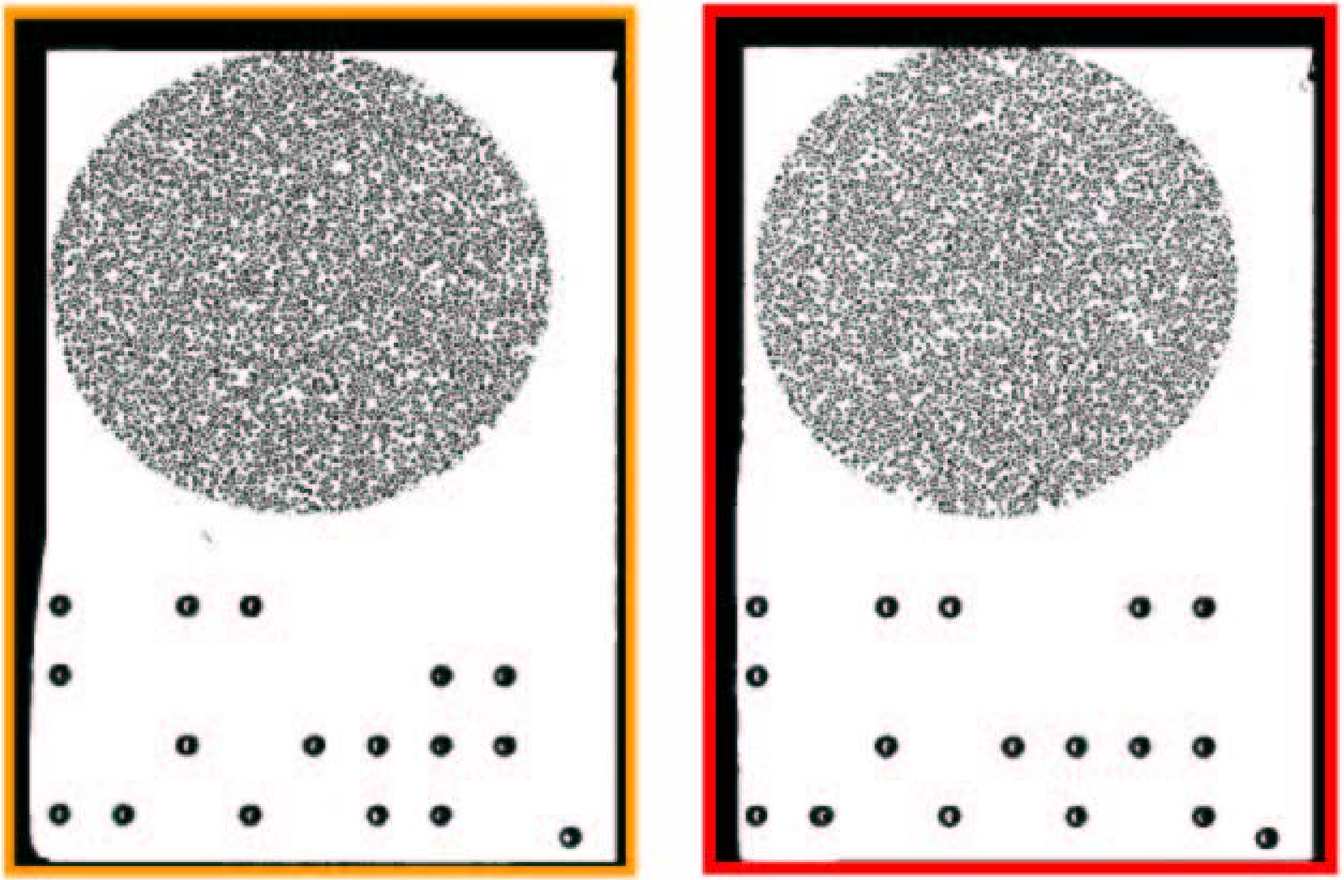
Particle/ Energy	Shielding condition	LET keV μm^{-1}	Dose mGy	Fluence cm^{-2}	Corrected Net Tracks [a] cm^{-2}		Note
					Det.1	Det.2	
^{56}Fe 500 MeV/n	zero	~ 190	1	~3300	3980	3790	(j)
	5 g cm^{-2} Al	?		?	3420	3440	(k)
	10 g cm^{-2} Al	?		?	380	360	(l)
	5 g cm^{-2} PMMA	?		?	3640	3570	(m)

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

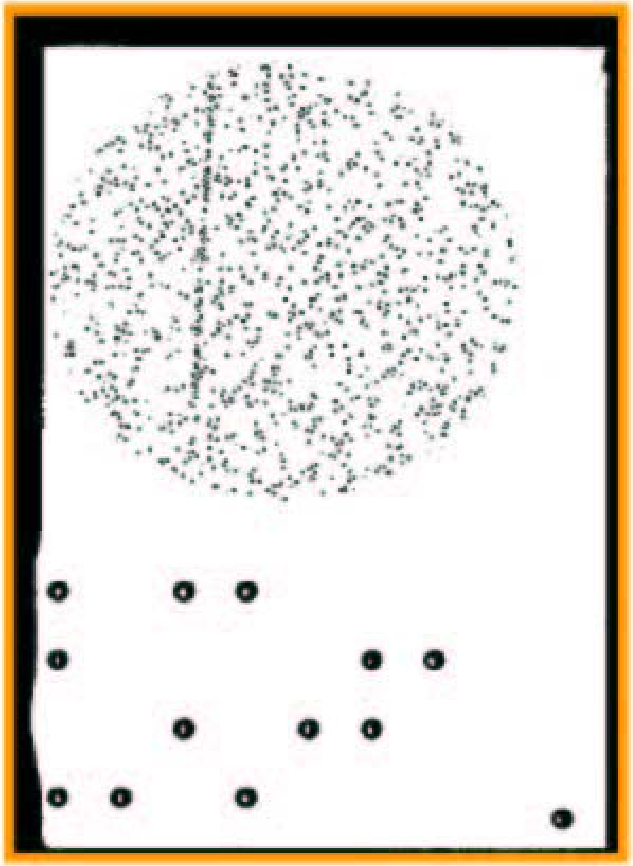
In subsequent figures, detector 1 is edged in orange, detector 2 in red

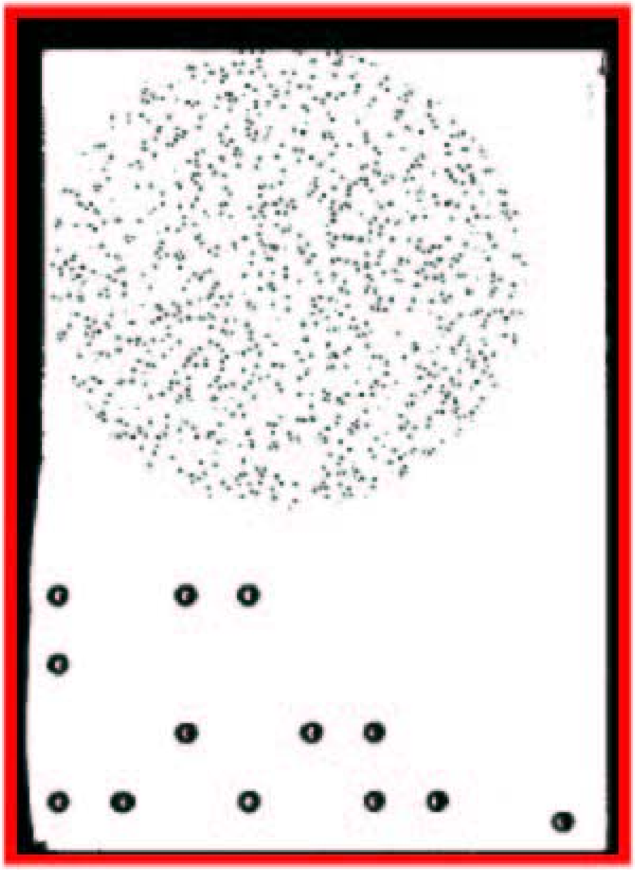


Fe pack 1	1mGy		
Condition	mono		
ID	Dtr	Tracks	Net Corr Tracks
16	D109268	4271	7032
72	D109270	4138	6702

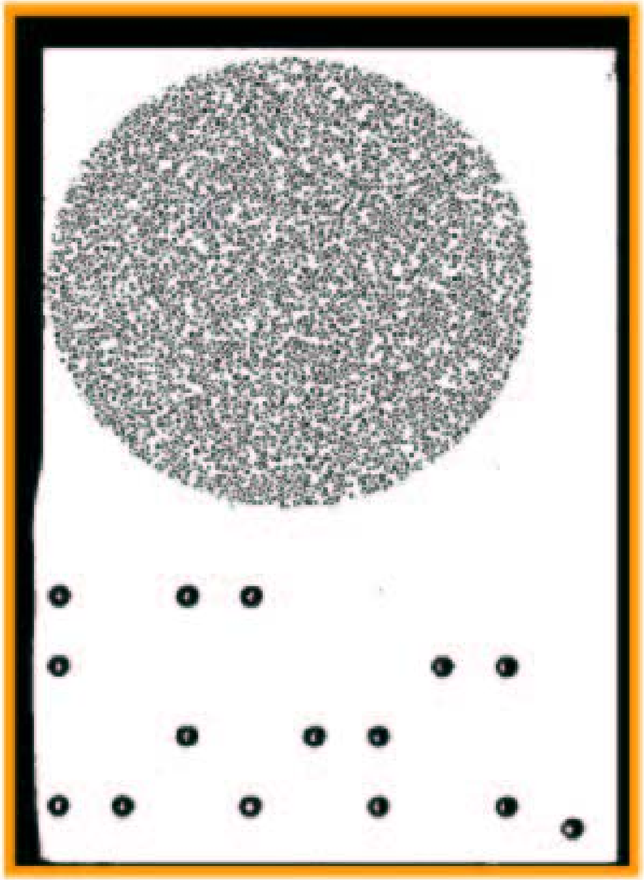


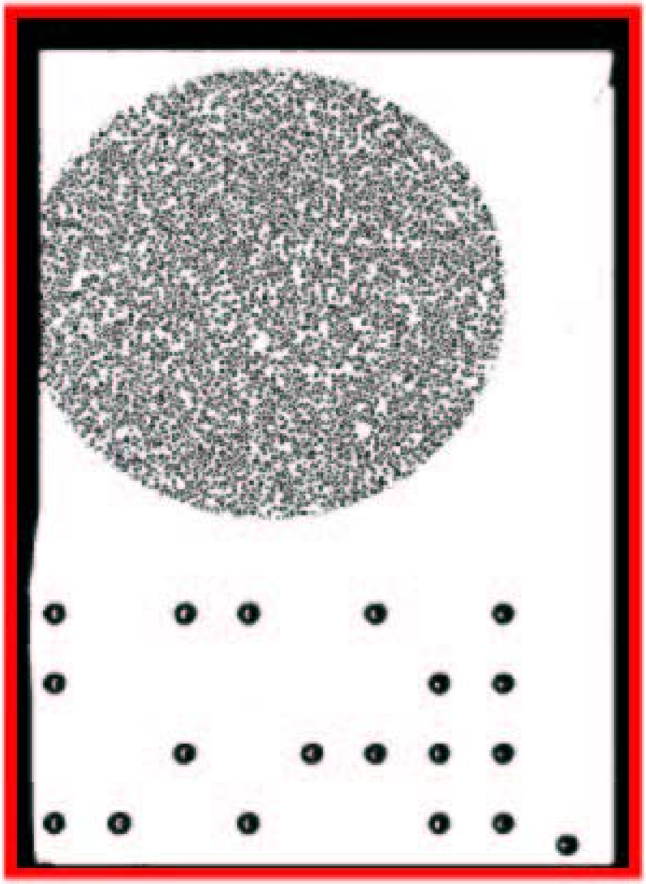
Fe pack 2	1mGy		
Condition	5g Al		
ID	Dtr	Tracks	Net Corr Tracks
30	D109237	3864	6048
58	D109230	3878	6081





Fe pack 3	1mGy		
Condition	10g Al		
ID	Dtr	Tracks	Net Corr Tracks
4	D109264	656	677
36	D109231	621	637



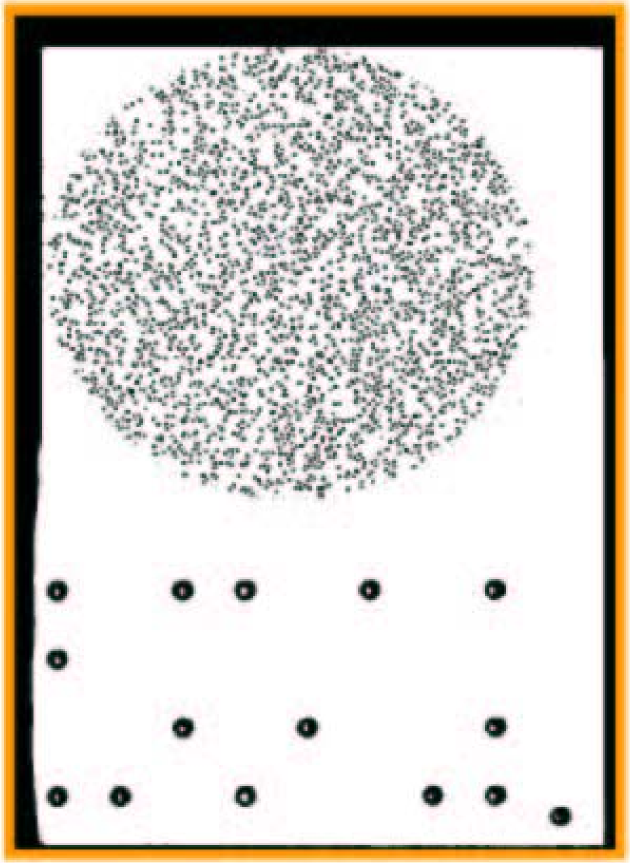
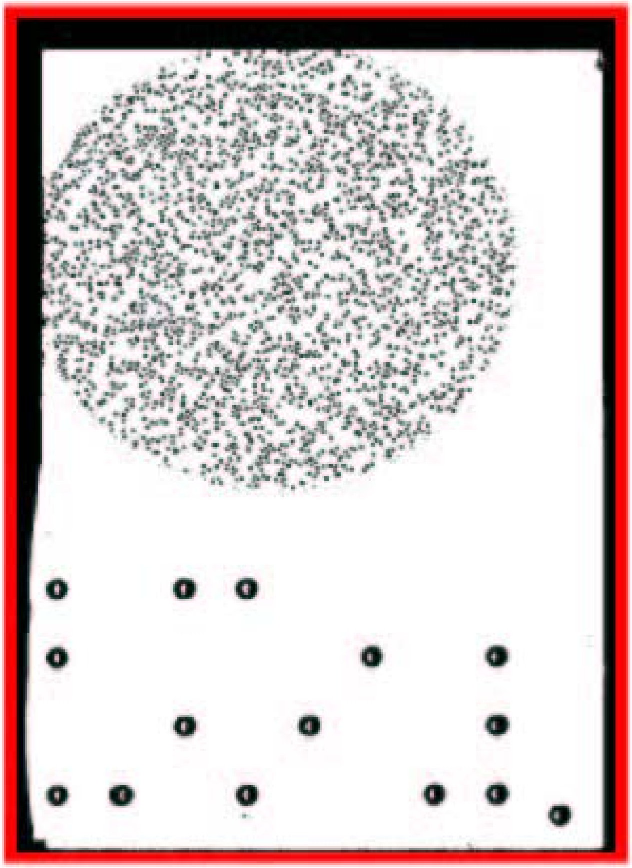


Fe pack 4	1mGy		
Condition	5g H_2O		
ID	Dtr	Tracks	Net Corr Tracks
39	D109234	4029	6438
61	D109207	3974	6306

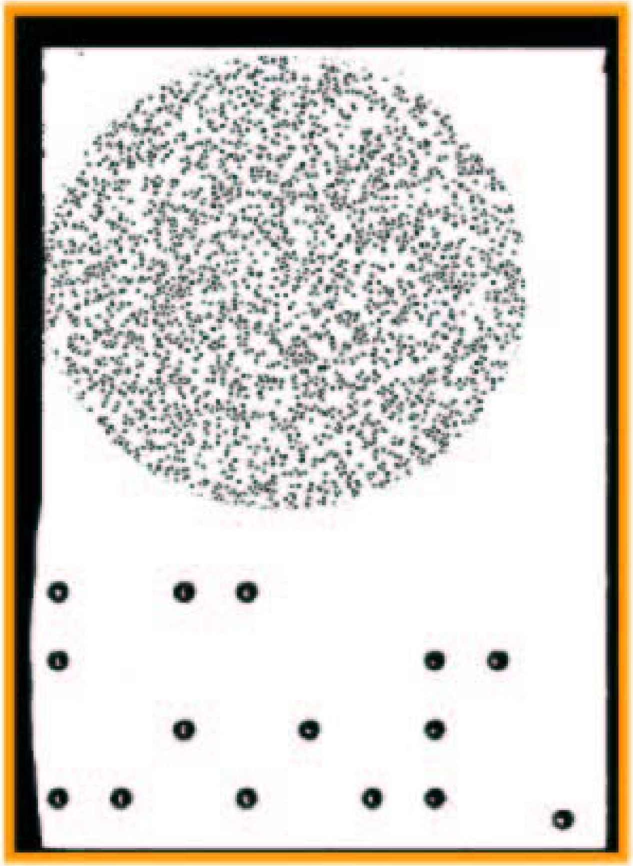
Electrochemical etching- single detector charged particle results: 'blind' irradiations

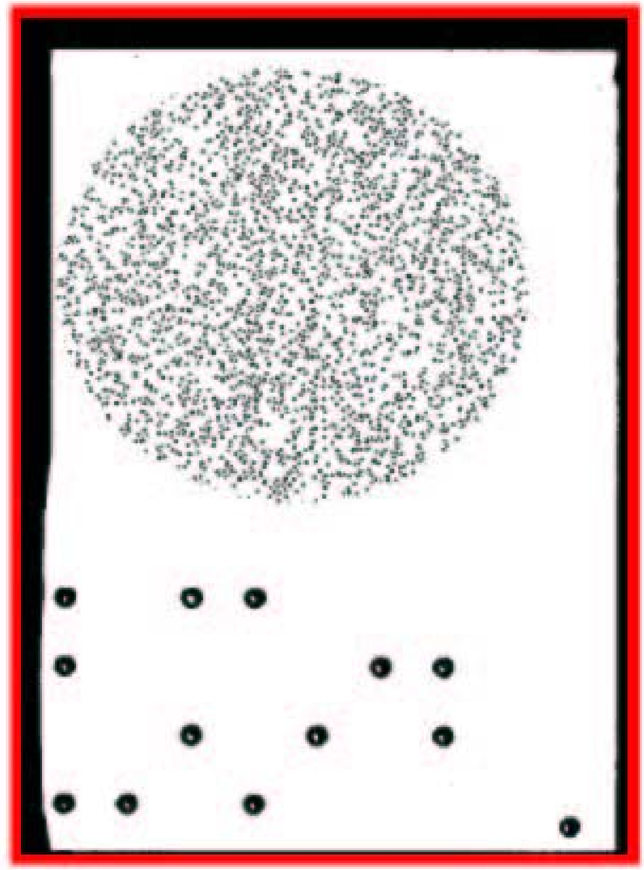
Particle/ Energy	Shielding condition	LET keV μm^{-1}	Dose mGy	Fluence cm^{-2}	Corrected Net Tracks [a] cm^{-2}		Note
					Det.1	Det.2	
'Blind' 4	?	?	?	?	1040	990	
'Blind' 6	?	?	?	?	1040	1080	
'Blind' 7	?	?	?	?	3460	3580	

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

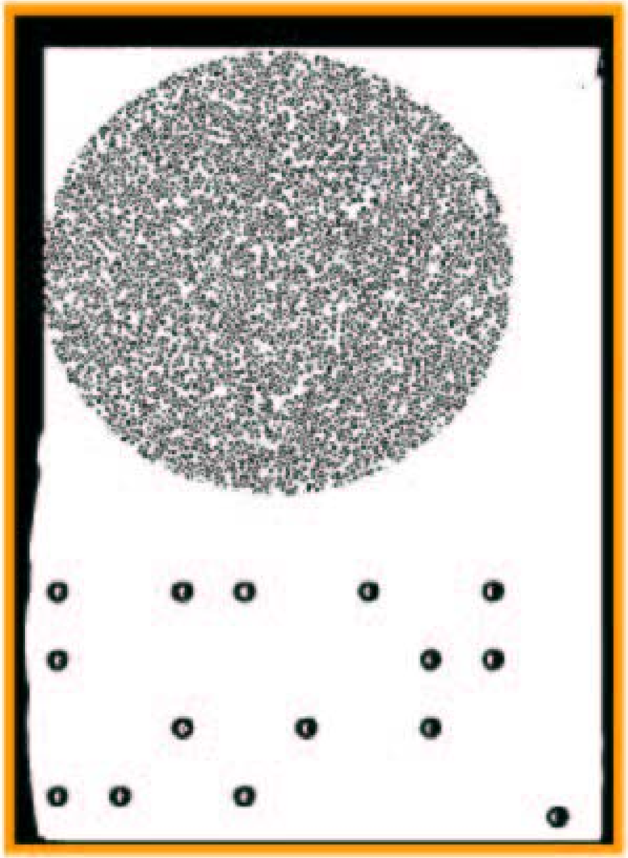
 

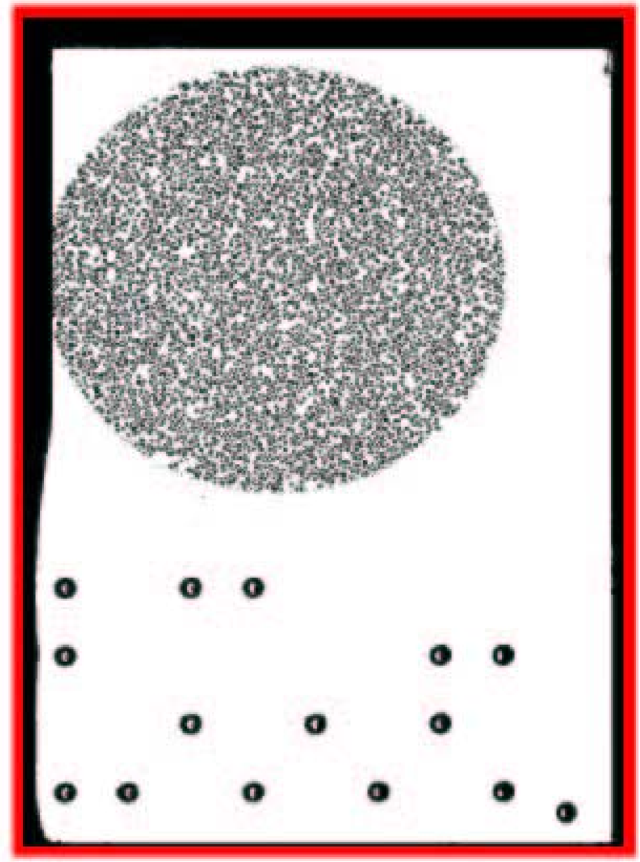
Blind Pack 1			
Condition	Blind 4		
ID	Dtr	Tracks	Net Corr Tracks
9	D109281	1565	1836
48	D109241	1506	1753





Blind Pack 2			
Condition	Blind 6		
ID	Dtr	Tracks	Net Corr Tracks
20	D109217	1566	1837
56	D109246	1617	1909





Blind Pack 3			
Condition	Blind 7		
ID	Dtr	Tracks	Net Corr Tracks
10	D109286	3892	6114
77	D109216	3980	6321

Electrochemical etching- single detector charged particle full results

Particle/ Energy	Shielding condition	LET keV μm^{-1}	Dose mGy	Fluence cm^{-2}	Corrected Net Tracks [(a)] cm^{-2}	
^{12}C 400 MeV/n	zero	10.963	1	57000	8	1
	5 g cm^{-2} Al	?		?	9	11
	10 g cm^{-2} Al	?		?	21	14
	5 g cm^{-2} PMMA	?		?	19	15
^{20}Ne 400 MeV/n	zero	30.959	1	20200	690	23
	5 g cm^{-2} Al	?		?	225	1180
	10 g cm^{-2} Al	?		?	8390	5520
	5 g cm^{-2} PMMA	?		?	5000	7020
^{56}Fe 500 MeV/n	zero	~ 190	1	~3300	3980	3790
	5 g cm^{-2} Al	?		?	3420	3440
	10 g cm^{-2} Al	?		?	380	360
	5 g cm^{-2} PMMA	?		?	3640	3570
'Blind' 4		?	?	?	1040	990
'Blind' 6		?	?	?	1040	1080
'Blind' 7		?	?	?	3460	3580

ACKNOWLEDGEMENTS

The authors should like to thank Yukio Uchihori, N Yasuda, Eric Benton and their colleagues at NIRS.