How to compensate the effects of ageing and fading in PADC detectors

POLITECNICO
MILANO 1863

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2° interconfronto internazionale radon in campo per sistemi di misura passivi: ambienti lavorativi e abitativi

On filed measurements:

- Several months of measurement duration
- Non controlled environmental parameters

The calibration factor measured in a reference facility
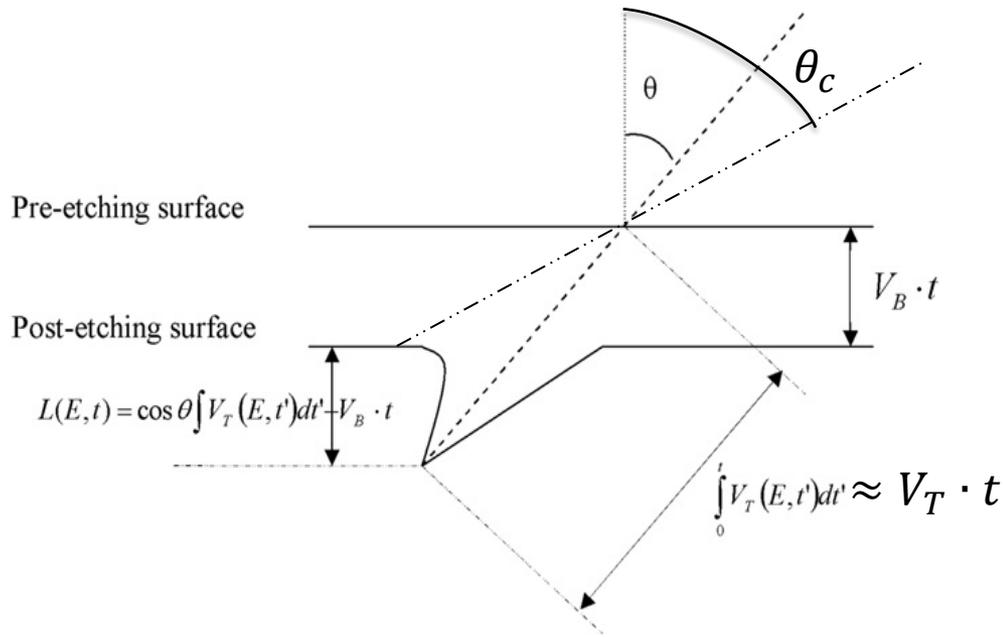1) High concentration
2) Short duration

Must be exported

To an on field measurement.
1) low concentration
2) Long duration

Theory – Limit angle
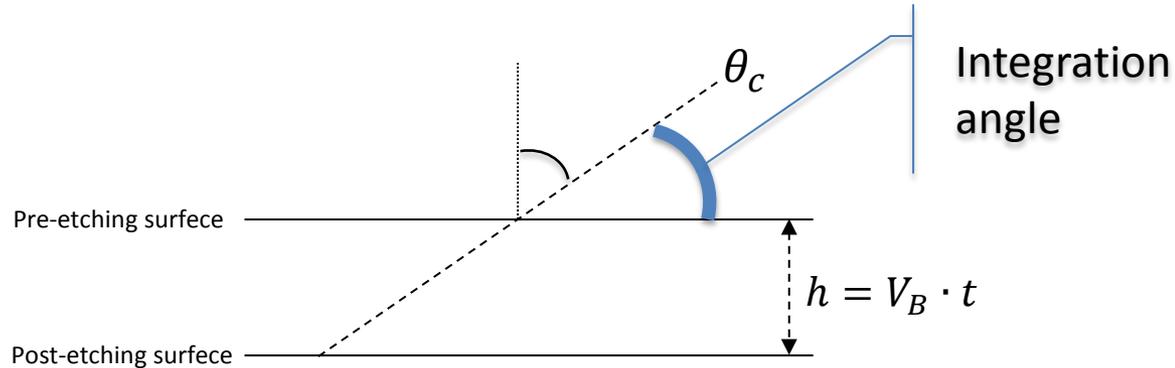

θ_c Limit angle

$$\int_0^t V_T(E,t')dt' \approx V_T \cdot t$$

$$c \quad \theta \int V_T(E,t')dt' - V_B \cdot t > 0 \implies \cos\theta \cdot V_T > V_B \qquad \cos\theta_c = \frac{V_B}{V_T} \implies \cos\theta_c = \frac{1}{V}$$

Criterion for track etching

$V = \frac{V_T}{V_B}$ Reduced track attack velocity

Theory – Assessment of the intrinsic efficiency

θ_c

Integration angle

Pre-etching surfece

Post-etching surfece

$h = V_B \cdot t$

Blind solid angle: integral between θ_c and π/2

$$\frac{1}{2\pi} \int_{\theta_C}^{\pi/2} 2\pi \cdot \sin\theta' \, d\theta' = \cos\theta_C$$

$$\epsilon = 1 - \cos\theta_c = 1 - \frac{1}{V}$$

Measurement of V: method of Cf-252

$$d = 2h\sqrt{\frac{V\sin\theta - 1}{V\sin\theta + 1}} \quad (1)$$

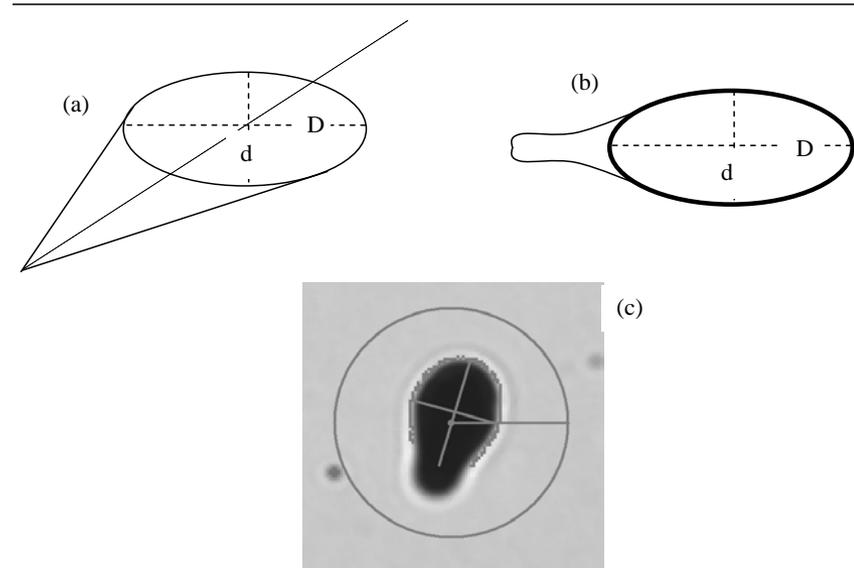$$D = 2h\frac{\sqrt{V^2 - 1}}{V\sin\theta + 1} \quad (2)$$

Figure 3 Simple example of an etched track (1), top view of the same track (2) and frame grab f a real track (3). See text for further explanation.

In tracks formed by fission fragments from ^{252}Cf, V>>1. Equation (1) can be approximated as:

$$d \approx 2 \cdot h$$

Detectors: TASLtrack

Detectors coming from a single batch have been divided in groups and subgrpups and irradiated in the reference radon chamber and with ^{252}Cf at POLIMI.
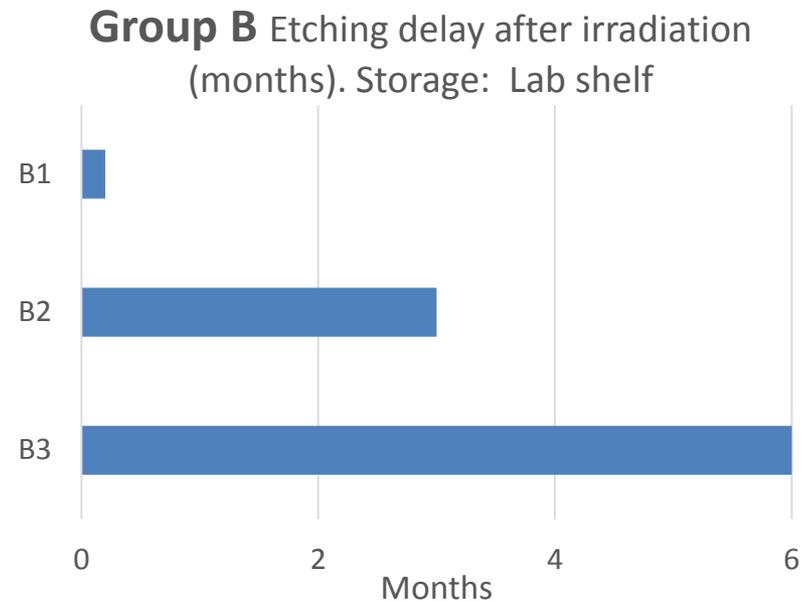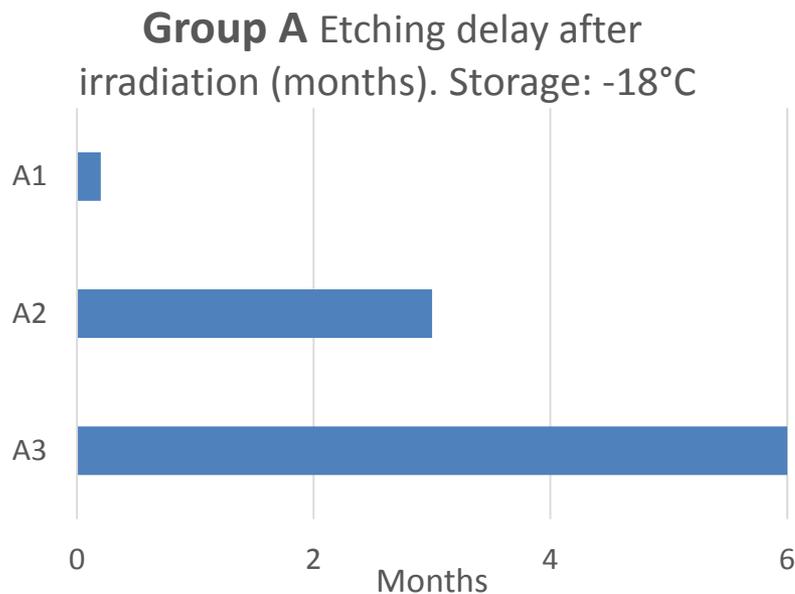
Etching has been done at MI.AM

Reading has been done with the Politrack at POLIMI

Fading and ageing test: material and methods

2 irradiation groups **(A, B) for fading analisys,** each group is divided in subgroups
Irradiated both to Radon and ^{252}Cf

Irradiation at time T=0

Group A Etching delay after irradiation (months). Storage: -18°C

Group B Etching delay after irradiation (months). Storage: Lab shelf

Fading and ageing test: material and methods

2 irradiation groups **(C, D) for ageing analisys**, each group is divided in subgroups

Batch reception at time T=0.   Delayed irradiation followed by an immediate etching
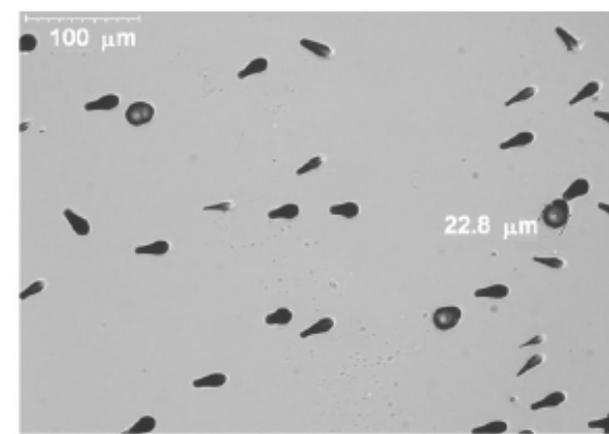

Group C delay after reception Storage: -18°C

Group D delay after reception. Storage: Lab shelf
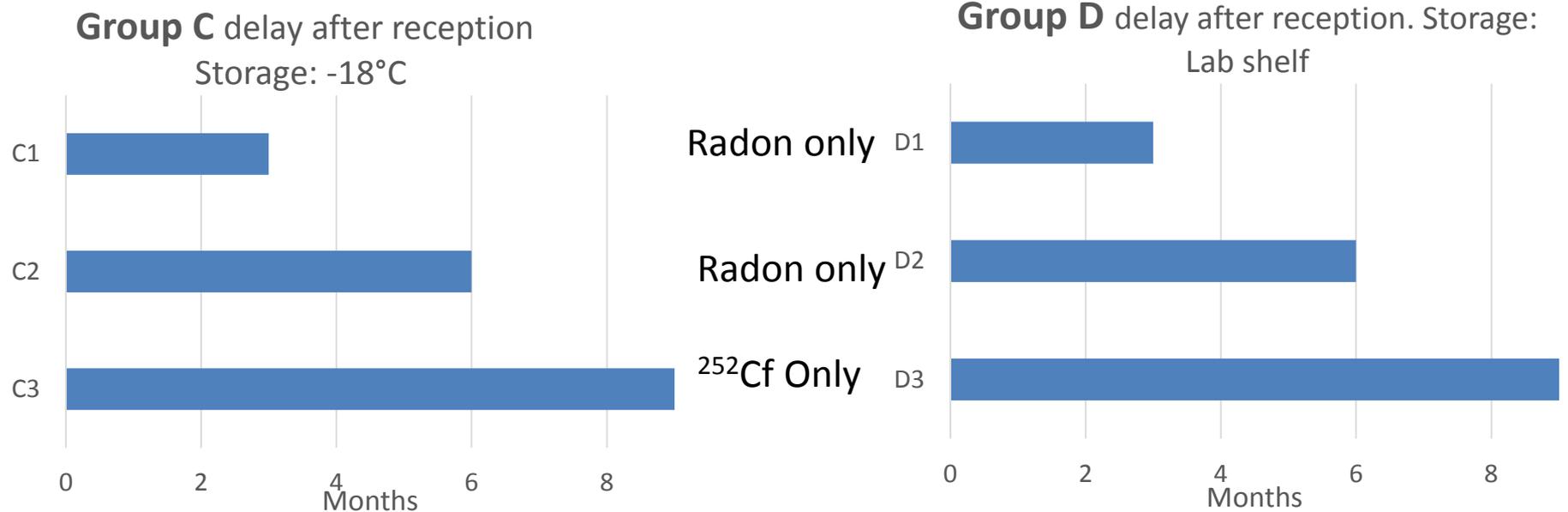
Fading
Politrack grabs:
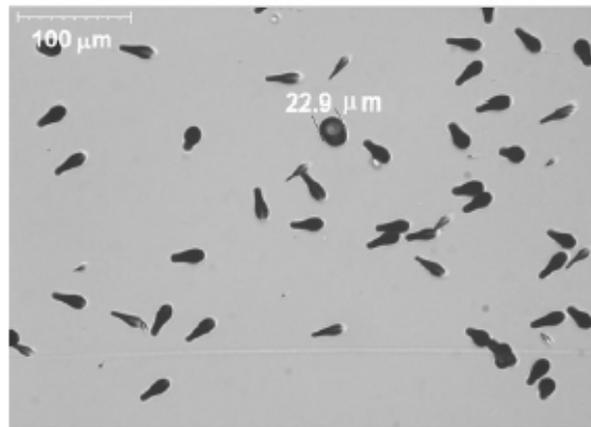
Alpha particle tracks are affected by fading, while fission fragment ones aren't.
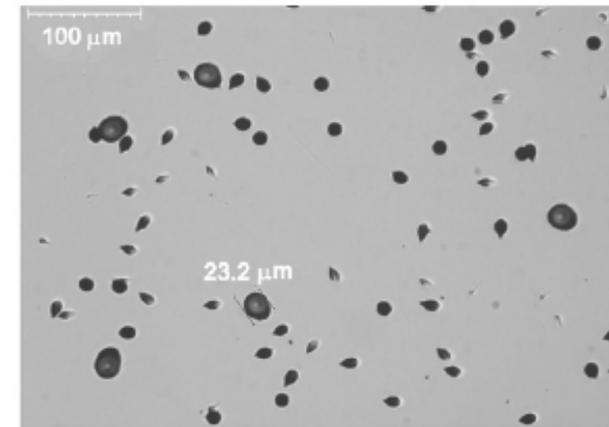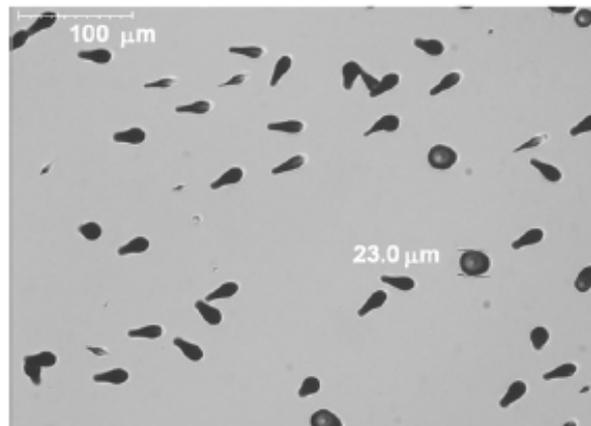
V_B remains constant
V_T decreases
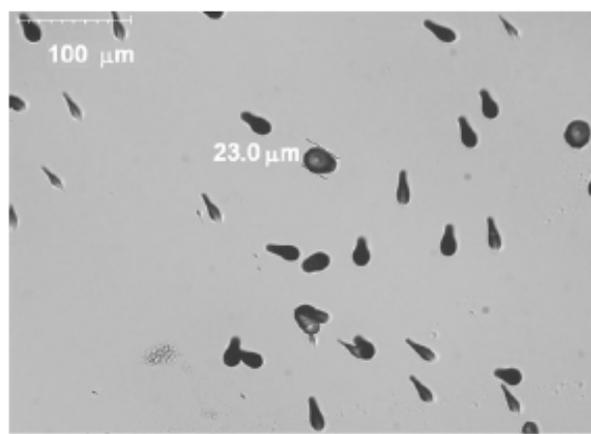
A1 Cf

B1 Cf

A2 Cf

B2 Cf

A3 Cf
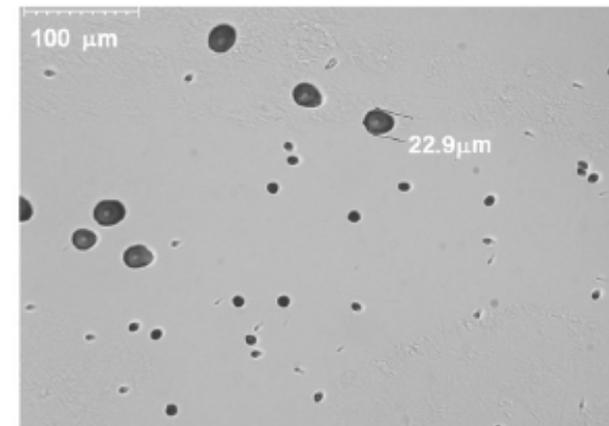
B3 Cf

Impact of ageing and fading

| Group	Subgroup	Without correction		
		Measured exposure value (kBq h m^{-3})	Difference %	Reference exposure value (kBq h m^{-3})
A	A1	1362	−2.1	1391
	A2	1430	2.8	1391
	A3	1403	0.9	1391
B	B1	1373	−1.3	1391
	B2	1105	−20.6	1391
	B3	749	−46.1	1391
C	C1	1464	0.6	1455
	C2	1296	0.6	1288
D	D1	1235	−15.1	1455
	D2	963	−25.2	1288

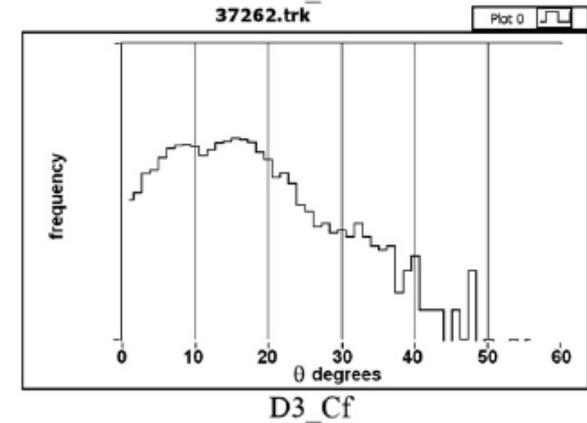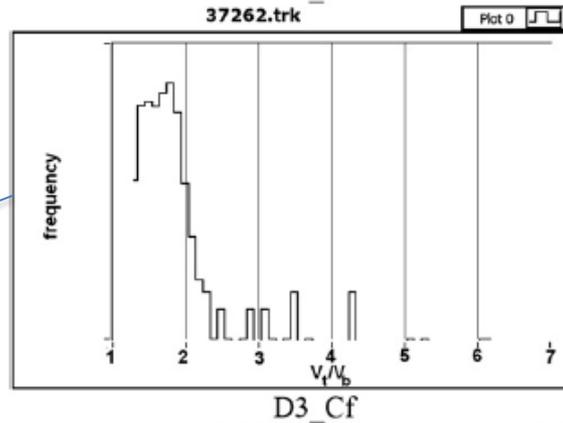**Fading** { A, B }

Ageing { C, D }

The impact on the sensitivity of fading, seems more severe than ageing
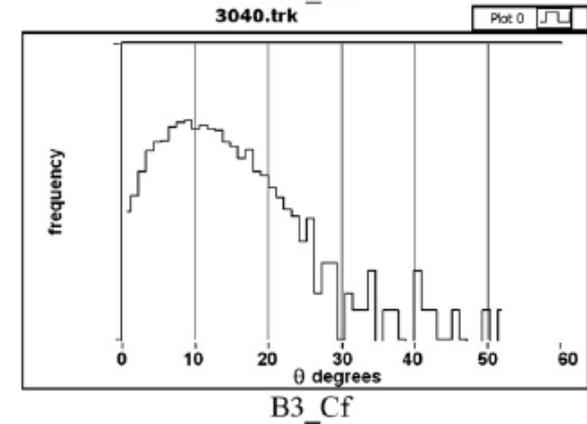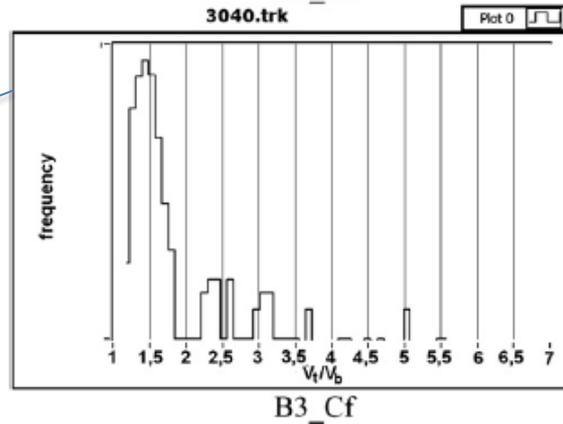
^{252} Cf V and angle distributions

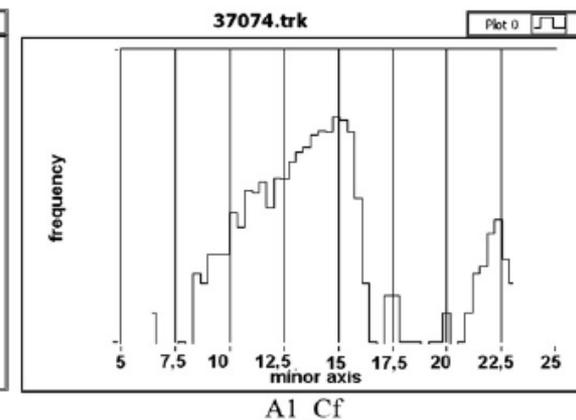Fridge 9 months ageing
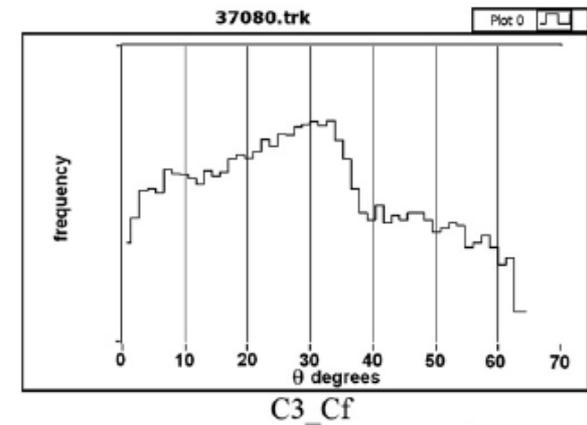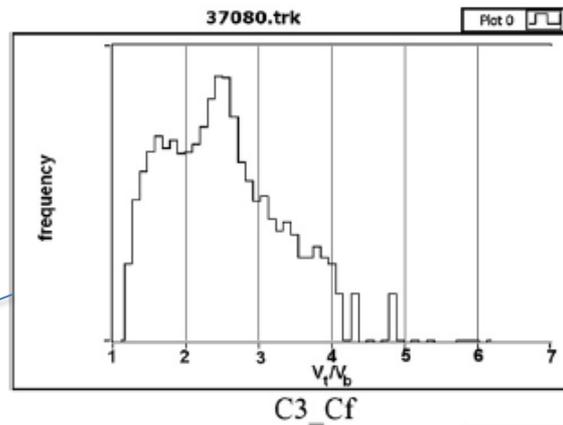
Shelf 9 months ageing

Shelf 6 months fading

^{252}Cf minor axis distributions

6 months fading

3 months fading

No fading

X axis in µm
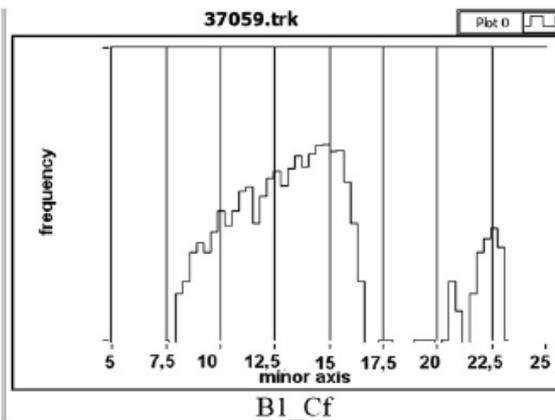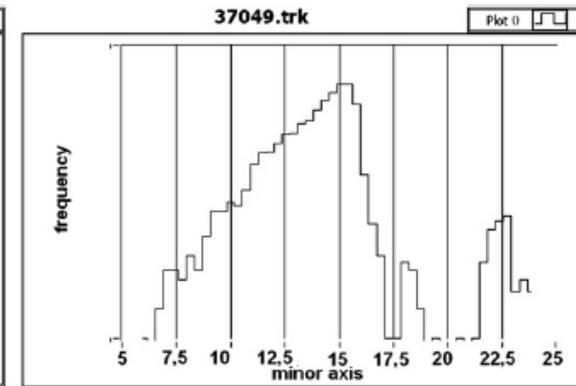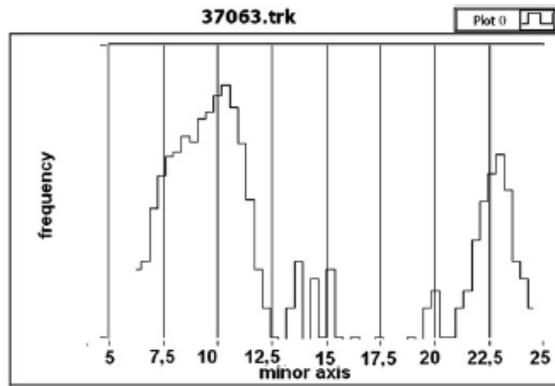
Fading/ageing compensation
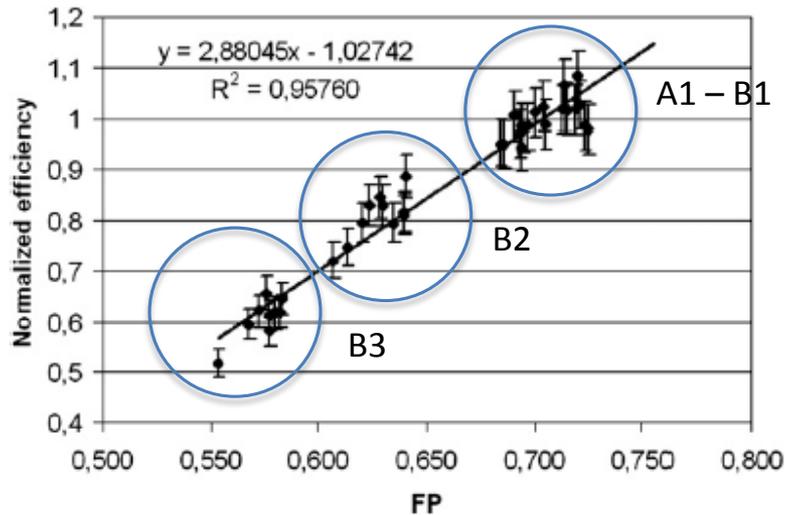
Fig. 4. Variation of the normalized efficiency $\varepsilon(n)$ vs the quantity $FP = 1 - 1/V_{90}$. V_{90} is the 90th percentile of the distribution of the quantity V measured on each detector.
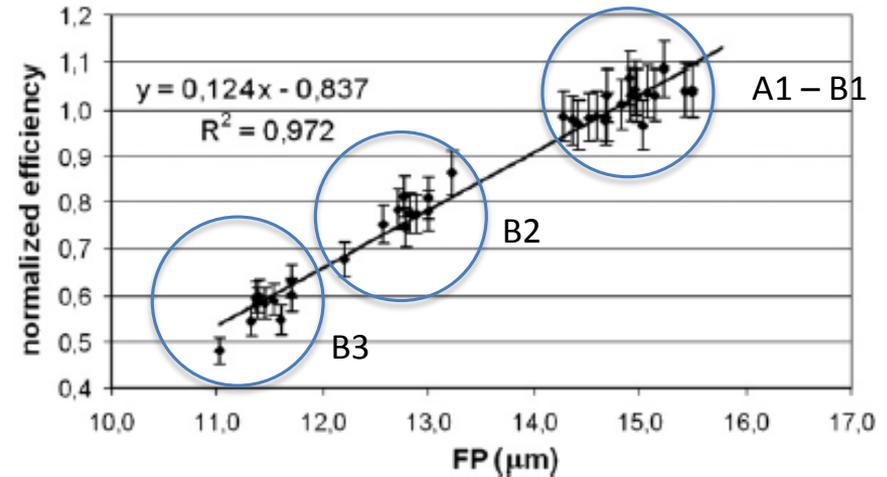
Fig. 5. Variation of the normalized efficiency $\varepsilon(n)$ vs the quantity FP. FP is the square root of the 90th percentile of the distribution of the tracks area measured on each detector.
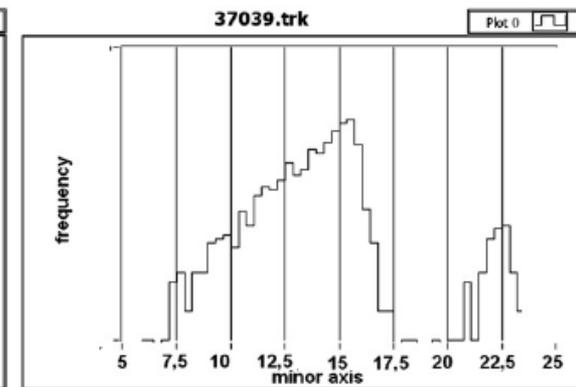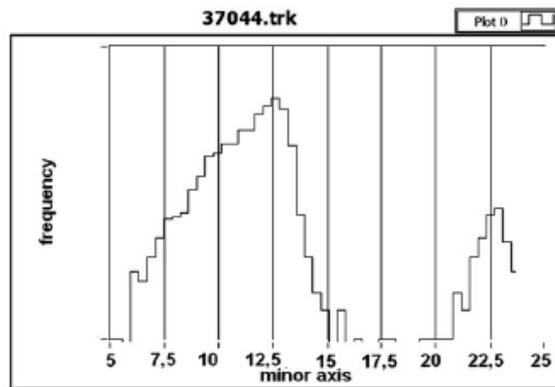
The normalized efficiency $\mathcal{E}$ is defined as the ratio between the efficiency measured for a specific group (B2 and B3) and the efficiency measured for the reference groups (A1 and B1)

Fading/ageing compensation

$$\exp\left(\text{FP}_{\text{ref}}\right) = \frac{\exp(\text{FP})}{1 - \beta\left(\text{FP} - \text{FP}_{\text{ref}}\right)} \qquad \beta = \frac{m}{m \times \text{FP}_{\text{ref}} + q}$$

FP_{ref} is the reference fading parameter, defined as the mean value of the fading parameters of the detectors (radon exposure) belonging to groups A1 and B1

Fading/ageing compensation

Group	Subgroup	Without correction		With correction		Reference exposure value (kBq h m^{-3})
		Measured exposure value (kBq h m^{-3})	Difference %	Measured exposure value (kBq h m^{-3})	Difference %	
A	A1	1362	−2.1	1390	0.0	1391
	A2	1430	2.8	1396	0.3	1391
	A3	1403	0.9	1400	0.6	1391
B	B1	1373	−1.3	1390	0.0	1391
	B2	1105	−20.6	1440	3.6	1391
	B3	749	−46.1	1332	−4.2	1391
C	C1	1464	0.6	1411	−3.0	1455
	C2	1296	0.6	1263	−1.9	1288
D	D1	1235	−15.1	1444	−0.8	1455
	D2	963	−25.2	1337	3.8	1288
E	E2	1597	−40.4	2650	−1.1	2679
F	F1	342	−16.6	377	−8.2	410
	F2	728	−21.0	886	−3.8	921

The reference exposure value is affected by uncertainty of 5% at a confidence level of 68%.

Conclusions

1) The fading/ageing is due to a reduction of V deriving from a reduction of V_T. V_B is not affected.
2) Fading and ageing can be handled in the same way.
3) The square root of the 90% percentile of the area distribution works very well as fading parameter.
4) The fading/ageing compensated exposure can be measured in a single scan of the plastic.

References

Caresana et al. *About ageing and fading of Cr-39 PADC track detectors used as air radon concentration measurement devices.* Radiat. Meas. 45 (2010) 183–189

Caresana et al. *Further studies on ageing and fading of CR39 PADC track detectors used as air radon concentration measurement devices* Radiat. Meas. 46 (2011) 1160–1167

Thanks for your attention