



Calibration of RADFETs for the Component Technology Test-Bed (CTTB) of the Alphasat spacecraft radiation Environment and Effects Facility (AEEF)

ESA/16403/10/NL/SFe

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PRELIMINARY

Study of the variation of the RADFET voltage threshold shift, V_{ths} , as function of the dose, for different temperatures, and assessment of potential long-term annealing effects.

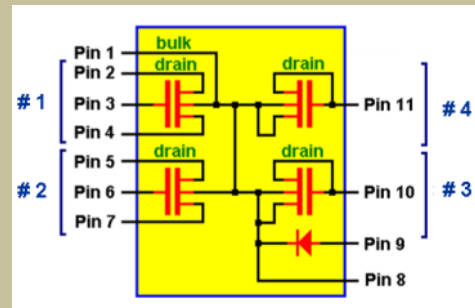
- Characterization of 18* RADFET 02-400nm IMPL units, manufactured by Tyndall National Institute (Ireland).
- Production batch of the flight lot to be assembled in the boards of the CTTB of the ALPHASAT spacecraft radiation Environment and Effects Facility (AEEF)
- Each RADFET package contains 4 RADFETS:

R#1 : 300/50 standard

R#2: 690/15 standard

R#3 : 300/50 passivated

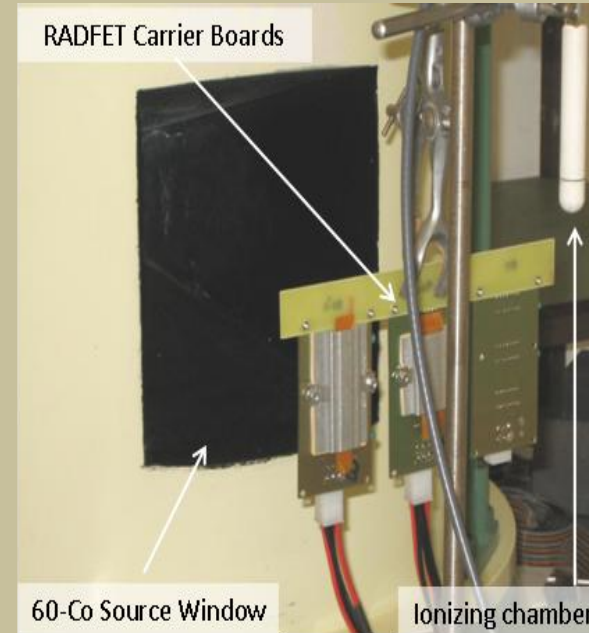
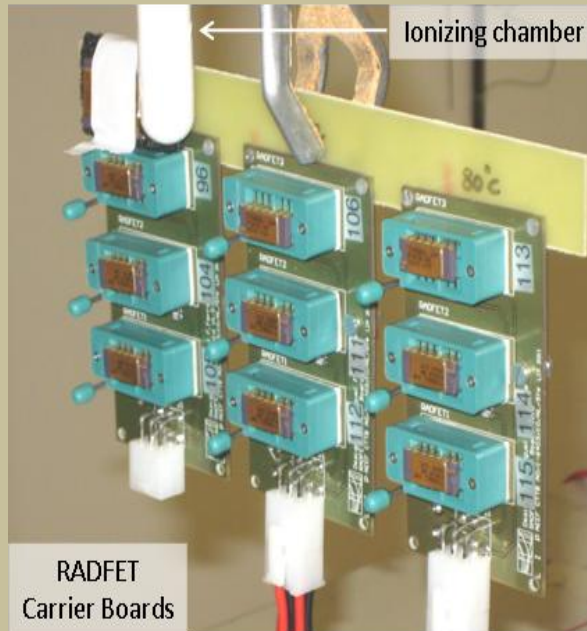
R#4: 690/15 passivated



* 20 packages in the batch: 1 malfunctioning /1 kept for reference

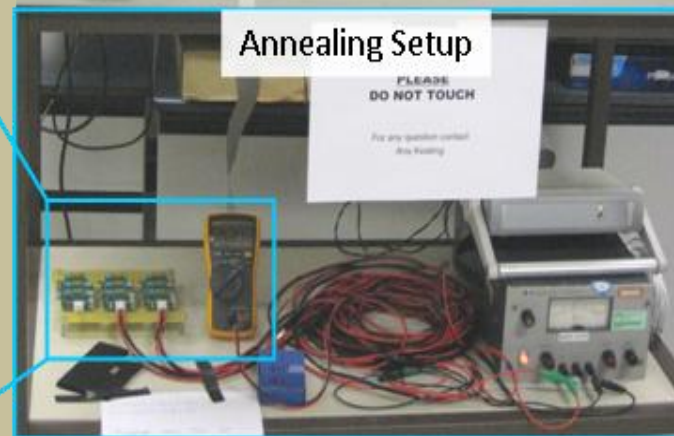
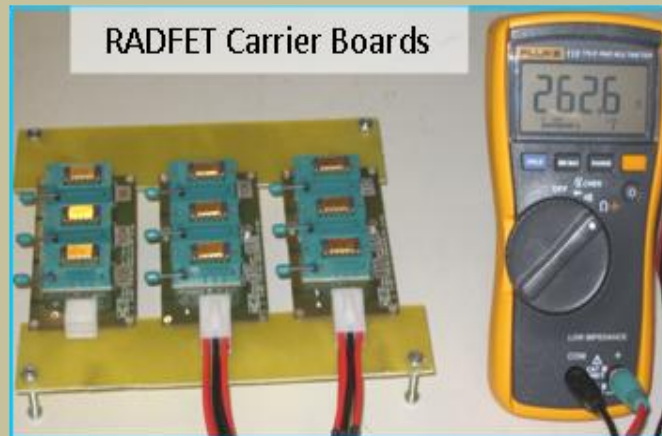
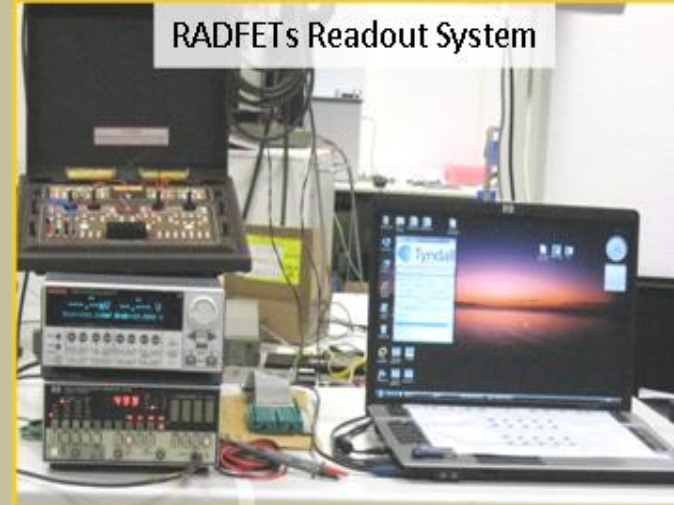
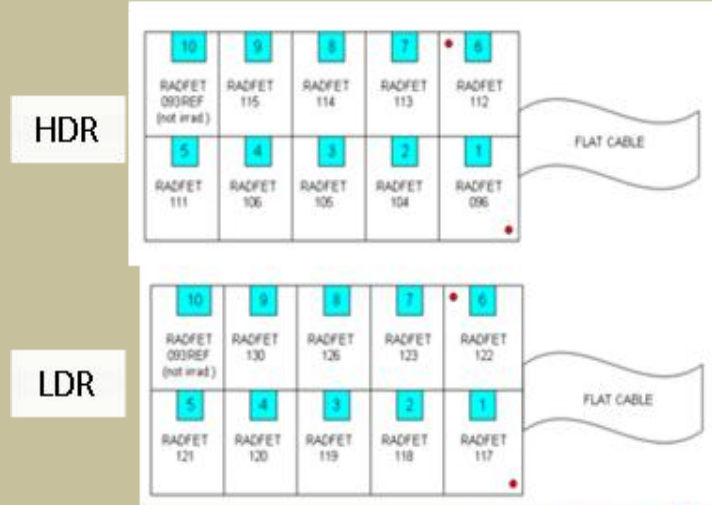
RADFET Carrier Boards

dedicated board developed and produced at LIP to provide a stable thermal environment.



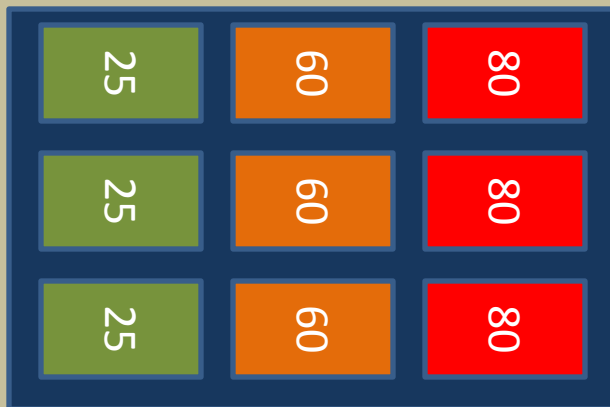
- guarantee that a packages are correctly grounded
- 3 RADFET packages/board at a specific temperature by means of a self-regulated PTC heater (20W/60°C and 30W/80°C)
- 2 PT100 Class B Thin Film Temperature sensors to monitor temperature during the irradiation

Measurement setup

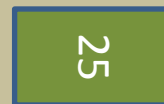
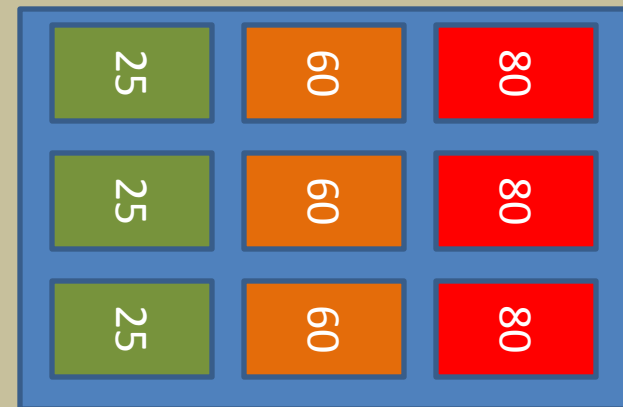


The RADFETS were irradiated at the ESA/ESTEC Cobalt-60 facility, up to a total dose of 50 krad.*

HDR : High Dose Rate
 5000 rad/hour : total 50 krad
 10 hours: 19 April 2011



LDR: Low Dose Rate
 36 rad/hour : total 58 krad
 63 days: 20 April - 22 June 2011

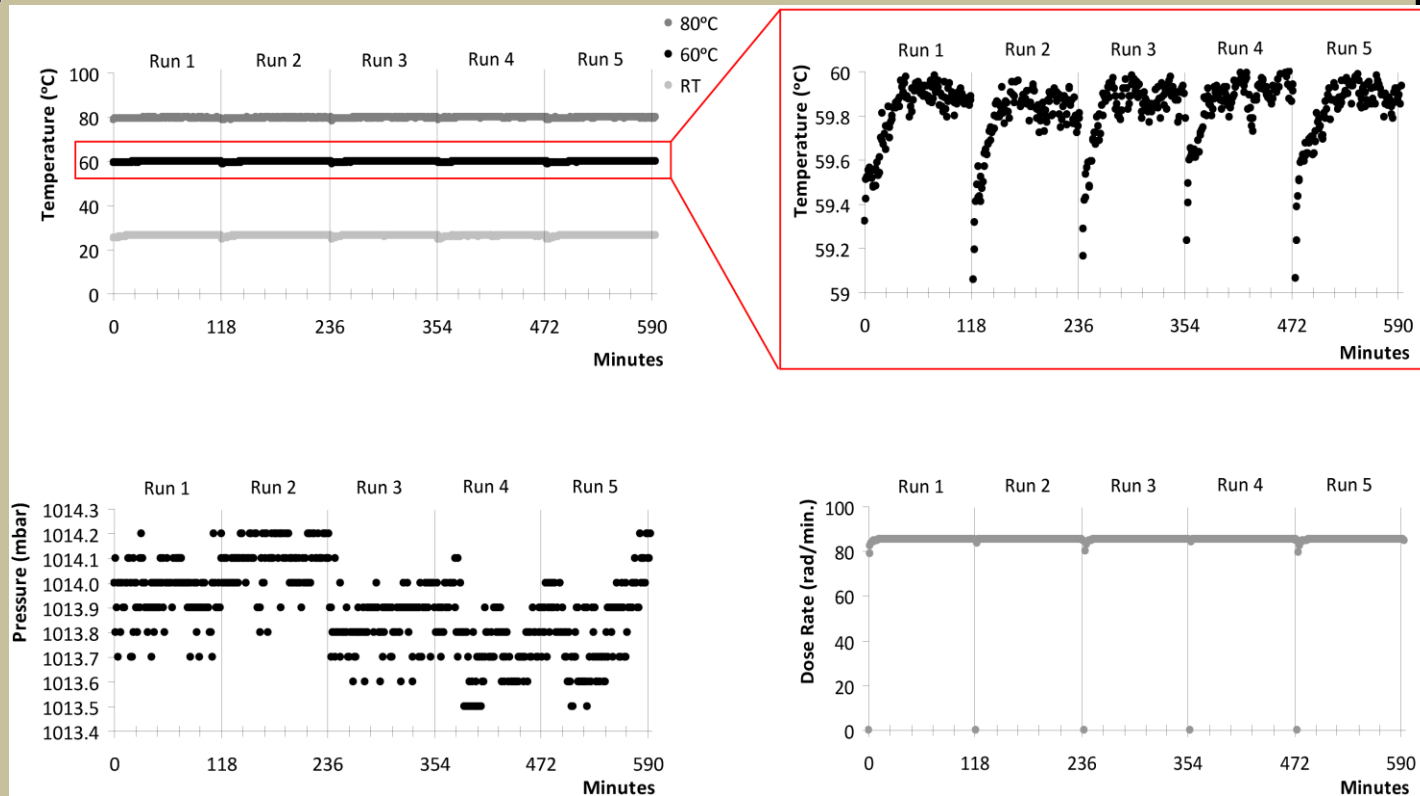


reference

Procedure:

In 10 krad irradiation steps, the threshold voltage of each the RADFET was measured by applying a constant current of 10 μ A and measuring the source-drain voltage.

* In Water: Dose in Si: ~20% less



Temperature, pressure and dose rate logging data recorded in the RADFET boards, during the five irradiation runs for the HDR regime. The temperatures were stabilized at $59.8^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ and $79.9^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ for 5 runs of 2 hours each.

the thermal heaters in the RADFET carrier boards show an excellent stability with $\Delta T \sim 0.2^{\circ}\text{C}$ with the exception of the first minutes at the start of each 10 kRadrun for which the cooled RADFET packages were returning from the RADFET measurement setup and re-placed in the RADFET carrier boards. The mismatch of temperatures created a maximum shift of the temperature of the board of about 1°C .

$$V_{th_shift}(t) = V_{th}(t) - V_{th}(t=0)$$

The voltage threshold shift is calculated with respect to the threshold voltage reference values measured before irradiation.

Model* :

$$V_{th_shift}(t) = a \text{ Dose}^b$$

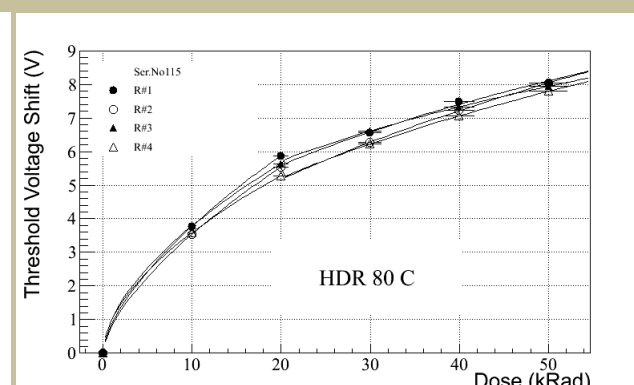
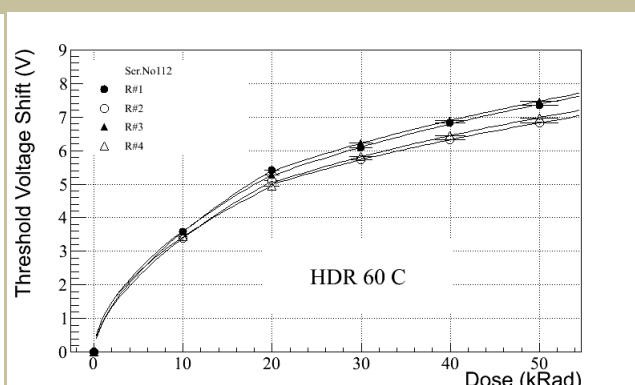
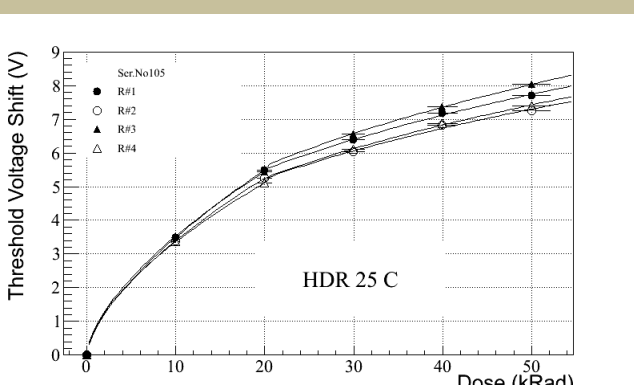
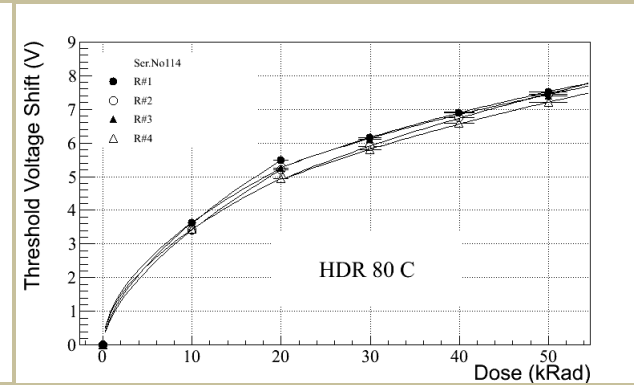
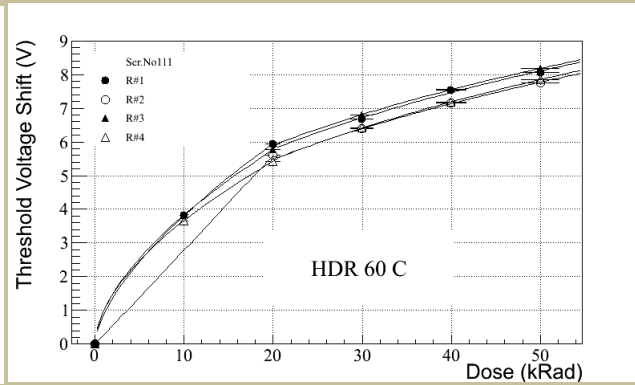
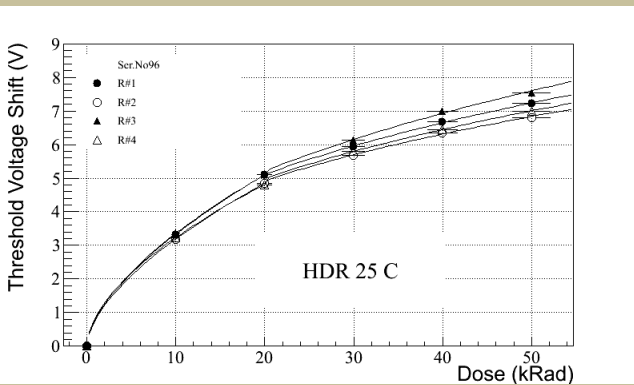
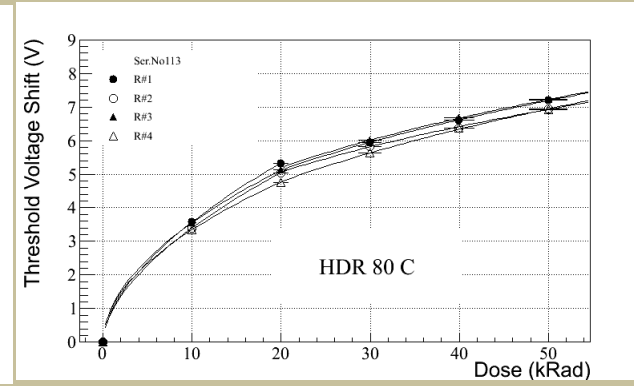
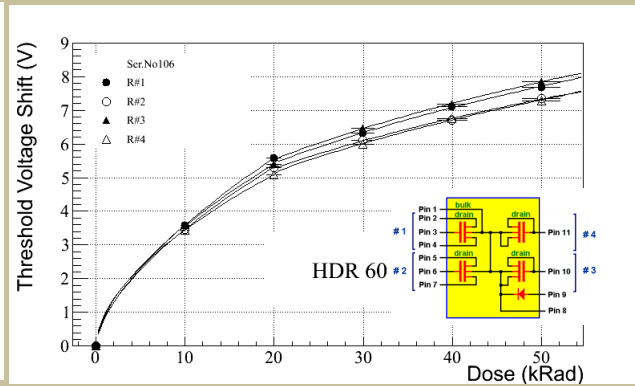
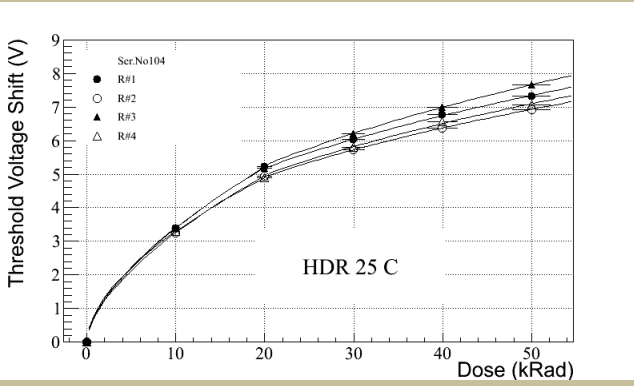
Procedure:

- fits of the $V_{th}(t)$ were performed on data for accumulated doses 0-20 krad and 20-50 krad.
- average values of the fit parameters (a,b) were derived for each of the 4 RADFET types and for the 3 irradiation temperatures

Error on dose : 4.2%

Error on V_{th} : taken from RMS of measurements of the reference RADFET (1%)

*A. Holmes-Siedle et al. IEEE, 2007 and L. Ruckman et al. IEEE, 2006 and S. Stanic et al., NIM A 2005:

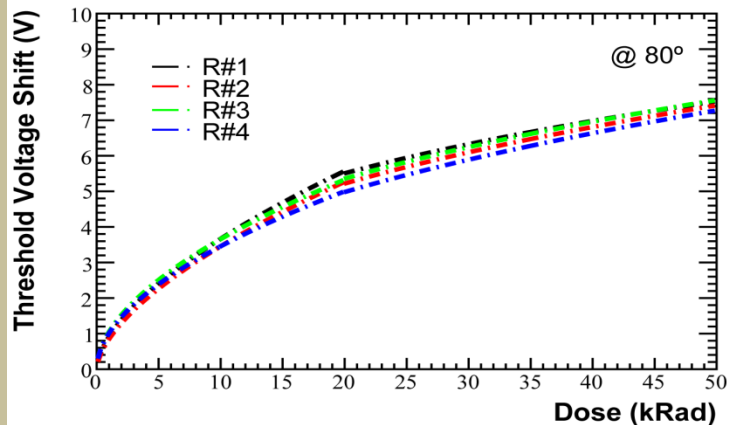
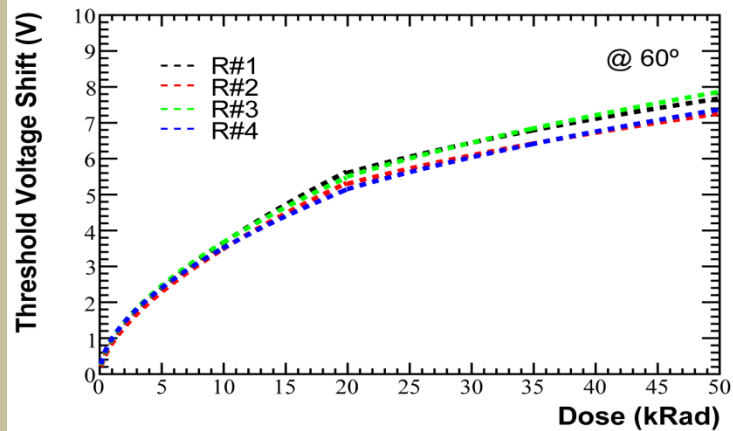
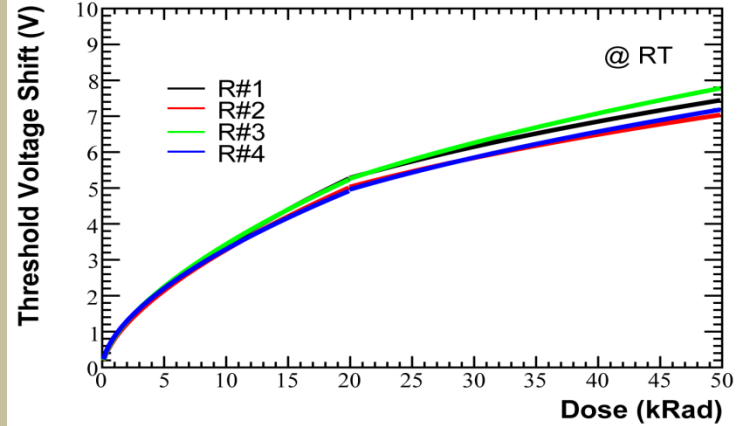


HDR Irradiation										
Calibration factors										
T	Package ID	RF	from 0 krad to 20 krad				from 20 krad to 50 krad			
			a1	Error(a1)	b1	Error(b1)	a2	Error(a2)	b2	Error(b2)
RT	96	#1	0,804	0,115	0,617	0,053	1,633	0,271	0,381	0,045
		#2	0,790	0,116	0,606	0,054	1,691	0,350	0,357	0,056
		#3	0,834	0,116	0,605	0,052	1,514	0,267	0,412	0,048
		#4	0,864	0,129	0,573	0,056	1,645	0,336	0,400	0,056
	104	#1	0,804	0,116	0,624	0,054	1,653	0,274	0,371	0,045
		#2	0,803	0,127	0,608	0,059	1,606	0,268	0,371	0,058
		#3	0,839	0,117	0,609	0,052	1,543	0,268	0,410	0,047
		#4	0,890	0,132	0,569	0,055	1,557	0,268	0,388	0,057
	105	#1	0,768	0,116	0,657	0,057	1,704	0,259	0,371	0,044
		#2	0,787	0,129	0,634	0,061	1,704	0,269	0,363	0,057
		#3	0,837	0,120	0,625	0,054	1,730	0,269	0,392	0,045
		#4	0,833	0,129	0,606	0,058	1,704	0,352	0,376	0,056
60°C	106	#1	0,826	0,122	0,638	0,055	1,709	0,287	0,384	0,045
		#2	0,844	0,135	0,614	0,061	1,768	0,371	0,361	0,057
		#3	0,905	0,124	0,593	0,051	1,775	0,287	0,380	0,044
		#4	0,944	0,139	0,583	0,057	1,651	0,343	0,380	0,057
	111	#1	0,870	0,129	0,644	0,055	1,920	0,310	0,368	0,044
		#2	0,274	0,921	0,208	1,124	1,746	0,374	0,382	0,058
		#3	0,986	0,133	0,590	0,051	2,015	0,308	0,358	0,042
		#4	0,995	0,135	0,566	0,055	1,669	0,355	0,396	0,058
	112	#1	0,896	0,125	0,601	0,052	1,726	0,280	0,371	0,044
		#2	0,877	0,135	0,588	0,058	1,785	0,361	0,343	0,055
		#3	1,007	0,128	0,553	0,048	1,836	0,280	0,359	0,042
		#4	0,922	0,143	0,526	0,052	1,728	0,345	0,357	0,054
80°C	113	#1	0,912	0,126	0,578	0,050	1,685	0,271	0,371	0,044
		#2	0,912	0,138	0,571	0,057	1,812	0,366	0,343	0,055
		#3	1,051	0,128	0,529	0,045	1,773	0,271	0,359	0,042
		#4	1,031	0,141	0,511	0,051	1,406	0,305	0,408	0,059
	114	#1	0,906	0,126	0,602	0,052	1,645	0,277	0,388	0,046
		#2	0,837	0,133	0,611	0,060	1,248	0,298	0,457	0,065
		#3	1,067	0,130	0,532	0,046	1,708	0,276	0,376	0,044
		#4	1,013	0,142	0,530	0,053	1,380	0,306	0,423	0,060
	115	#1	0,869	0,128	0,638	0,055	1,653	0,293	0,407	0,048
		#2	0,795	0,132	0,649	0,062	1,208	0,300	0,485	0,068
		#3	1,009	0,133	0,575	0,049	1,967	0,299	0,357	0,041
		#4	0,987	0,144	0,560	0,055	1,400	0,318	0,439	0,062

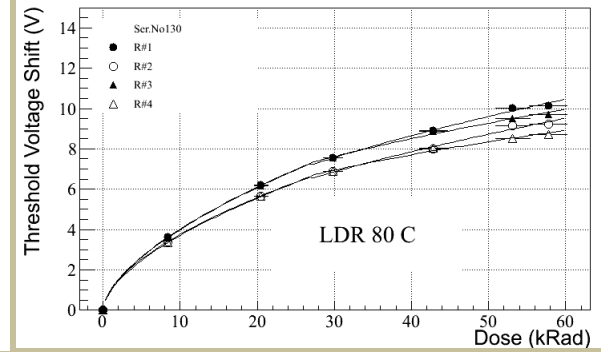
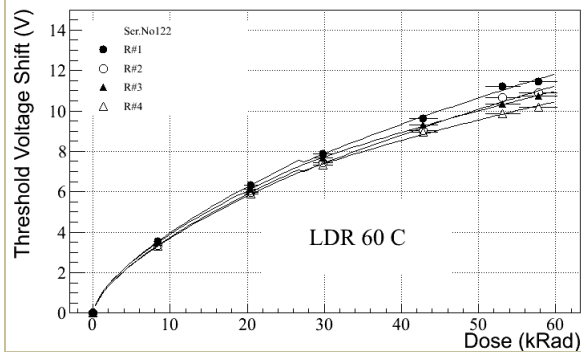
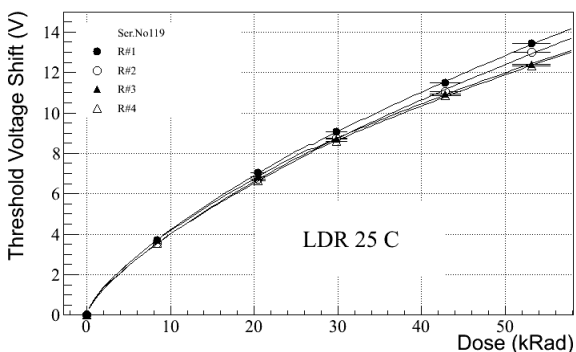
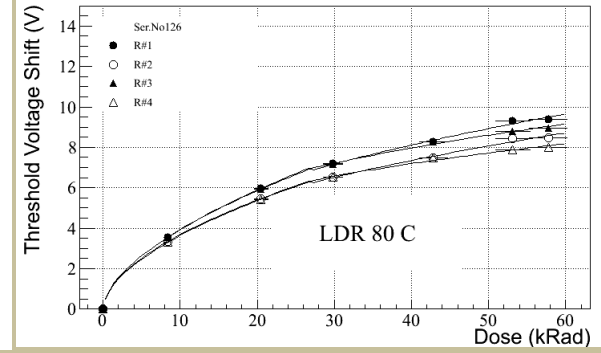
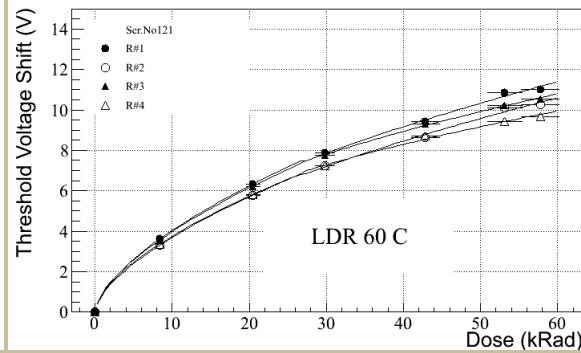
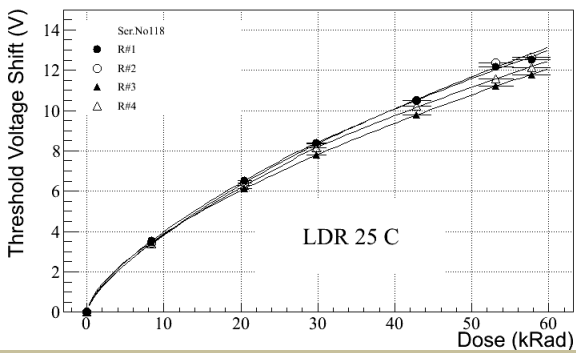
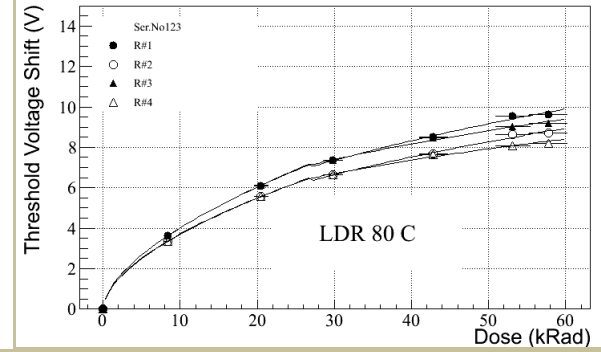
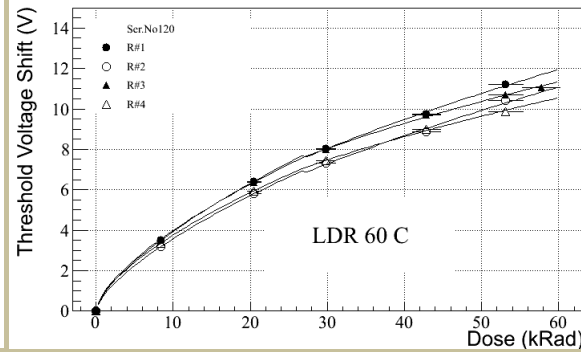
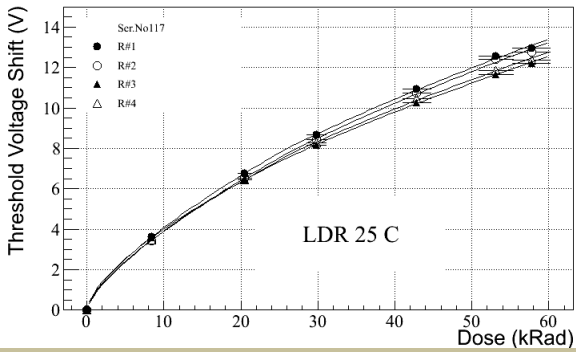
PRELIMINARY

HDR

Expected threshold voltage shift as function of dose for RADFETs R#1, R#2, R#3 and R#4 at 25°C, 60°C and 80°C, using mean parameters a and b for the 4 different RADFETS and temperatures.



LDR Irradiation results

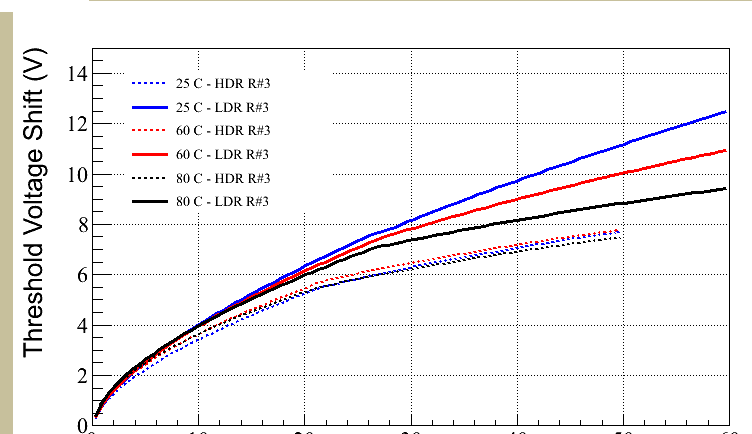
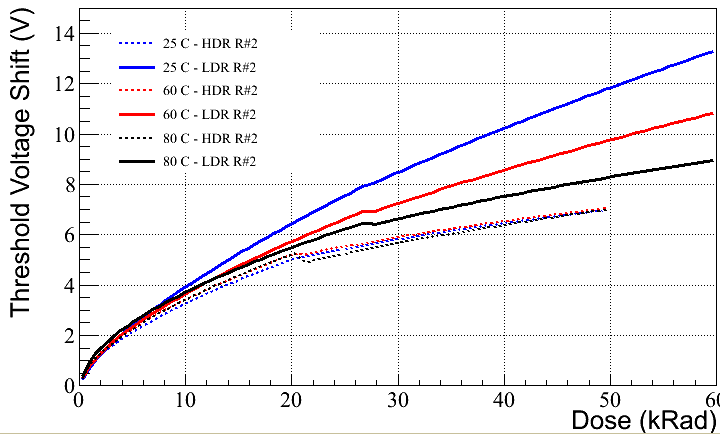
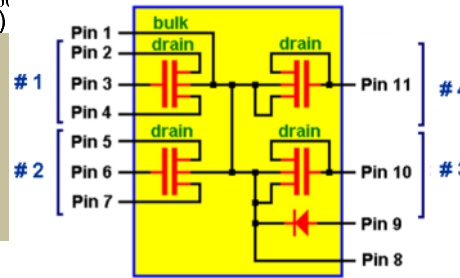
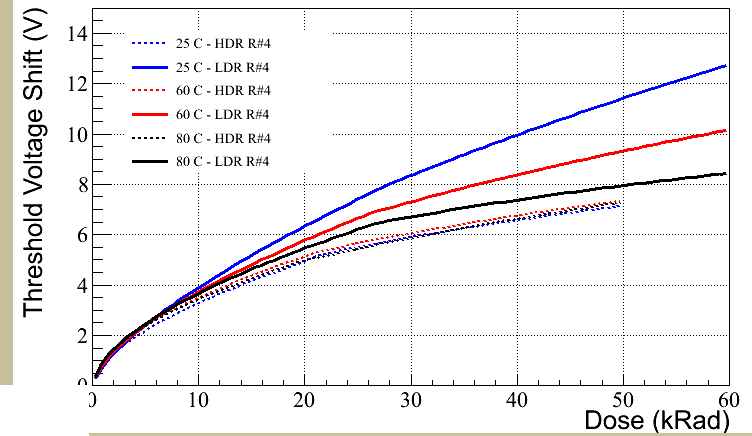
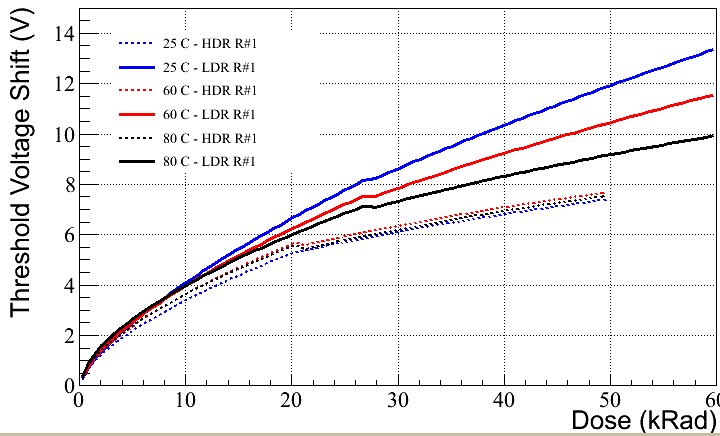


LDR Irradiation Calibration factors										
T	Package ID	RF	0 krad to 20 krad				20 krad to 60 krad			
			a1	Error(a1)	b1	Error(b1)	a2	Error(a2)	b2	Error(b2)
RT	117	#1	0,81	0,10	0,70	0,05	1,06	0,21	0,62	0,05
		#2	0,75	0,10	0,72	0,05	0,97	0,21	0,64	0,06
		#3	0,88	0,10	0,66	0,04	1,02	0,20	0,61	0,05
		#4	0,78	0,10	0,70	0,05	1,04	0,21	0,61	0,05
	118	#1	0,82	0,10	0,69	0,05	1,00	0,20	0,63	0,05
		#2	0,76	0,10	0,71	0,05	0,91	0,20	0,63	0,06
		#3	0,91	0,10	0,63	0,04	0,92	0,18	0,63	0,05
		#4	0,78	0,10	0,69	0,05	1,04	0,21	0,61	0,05
	119	#1	0,81	0,10	0,71	0,05	0,97	0,21	0,68	0,07
		#2	0,77	0,10	0,72	0,05	0,86	0,23	0,68	0,07
		#3	0,85	0,10	0,69	0,05	1,09	0,25	0,61	0,06
		#4	0,78	0,10	0,71	0,05	1,04	0,25	0,62	0,07
60°C	120	#1	0,83	0,10	0,68	0,04	1,07	0,25	0,57	0,06
		#2	0,76	0,09	0,67	0,05	0,92	0,22	0,61	0,07
		#3	0,89	0,10	0,67	0,04	1,49	0,23	0,50	0,04
		#4	0,86	0,10	0,67	0,04	1,38	0,28	0,50	0,05
	121	#1	0,95	0,11	0,63	0,04	1,28	0,22	0,53	0,04
		#2	0,87	0,10	0,63	0,04	1,09	0,20	0,56	0,05
		#3	0,94	0,10	0,62	0,04	1,60	0,23	0,47	0,04
		#4	0,92	0,10	0,61	0,04	1,59	0,24	0,45	0,04
	122	#1	0,88	0,10	0,65	0,04	1,08	0,20	0,59	0,05
		#2	0,84	0,10	0,65	0,05	0,96	0,19	0,60	0,05
		#3	0,95	0,10	0,63	0,04	1,38	0,22	0,51	0,04
		#4	0,84	0,10	0,64	0,04	1,35	0,22	0,50	0,04
80°C	123	#1	1,00	0,11	0,59	0,04	1,71	0,24	0,43	0,04
		#2	1,01	0,11	0,57	0,04	1,55	0,24	0,43	0,04
		#3	1,03	0,11	0,59	0,04	2,27	0,25	0,35	0,03
		#4	0,98	0,10	0,57	0,04	2,20	0,26	0,33	0,03
	126	#1	1,03	0,11	0,58	0,04	1,68	0,23	0,43	0,04
		#2	1,03	0,11	0,55	0,04	1,56	0,23	0,42	0,04
		#3	1,04	0,10	0,58	0,04	2,24	0,24	0,34	0,03
		#4	1,00	0,10	0,56	0,04	2,25	0,26	0,32	0,03
	130	#1	1,01	0,11	0,60	0,04	1,54	0,23	0,47	0,04
		#2	1,01	0,11	0,57	0,04	1,38	0,23	0,47	0,04
		#3	0,99	0,10	0,61	0,04	2,05	0,25	0,39	0,03
		#4	0,96	0,10	0,59	0,04	2,04	0,26	0,36	0,03

PRELIMINARY

LDR vs HDR

$$V_{th_shift}(t) = a \text{ Dose}^b$$



HDR calibration factors

Preliminary results

HDR Irradiation Calibration factors									
T	R F	from 0 krad to 20 krad				from 20 krad to 50 krad			
		a1	Error(a1)	b1	Error(b1)	a2	Error(a2)	b2	Error(b2)
25	# 1	0,79	0,07	0,63	0,03	1,69	0,16	0,38	0,03
60		0,86	0,07	0,63	0,03	1,78	0,17	0,37	0,03
80		0,91	0,07	0,60	0,03	1,66	0,16	0,39	0,03
25	# 2	0,79	0,07	0,61	0,03	1,68	0,20	0,36	0,03
60		0,86	0,10	0,60	0,04	1,79	0,26	0,35	0,04
80		0,85	0,08	0,61	0,03	1,37	0,18	0,42	0,04
25	# 3	0,84	0,07	0,61	0,03	1,59	0,16	0,40	0,03
60		0,96	0,07	0,58	0,03	1,87	0,17	0,37	0,02
80		1,04	0,08	0,54	0,03	1,81	0,16	0,36	0,02
25	# 4	0,86	0,08	0,58	0,03	1,63	0,20	0,38	0,03
60		0,99	0,08	0,55	0,03	1,68	0,20	0,38	0,03
80		1,01	0,08	0,53	0,03	1,40	0,18	0,42	0,03

LDR calibration factors

Preliminary results

LDR Irradiation Calibration factors									
T	RF	from 0 krad to 20 krad				from 20 krad to 60 krad			
		a1 (V)	Error(a1)	b1	Error(b1)	a2 (V)	Error(a2)	b2	Error(b2)
25	#1	0,81	0,06	0,70	0,03	0,99	0,12	0,64	0,03
60		0,88	0,06	0,65	0,03	1,16	0,13	0,56	0,03
80		1,03	0,06	0,59	0,02	1,64	0,13	0,44	0,02
25	#2	0,76	0,06	0,71	0,03	0,91	0,12	0,65	0,03
60		0,82	0,06	0,65	0,03	0,99	0,12	0,58	0,03
80		1,01	0,06	0,56	0,02	1,49	0,13	0,44	0,02
25	#3	0,88	0,06	0,66	0,03	0,99	0,12	0,62	0,03
60		0,91	0,06	0,64	0,02	1,48	0,13	0,49	0,02
80		1,02	0,06	0,59	0,02	2,19	0,14	0,36	0,02
25	#4	0,78	0,06	0,70	0,03	1,04	0,13	0,61	0,03
60		0,87	0,06	0,63	0,03	1,44	0,14	0,48	0,03
80		0,98	0,06	0,57	0,02	2,16	0,15	0,33	0,02



Annealing



276/211 days for LDR/HDR irradiated samples

Model:

V_{ths} should decrease exponentially with time, reaching a minimum V_{ths_{end}} value.

(V_{ths_{end}}=0 : complete recovery)

$$V_{ths}(t) = V_{ths_{end}} + V_0 \exp(-t/\tau)$$

Procedure:

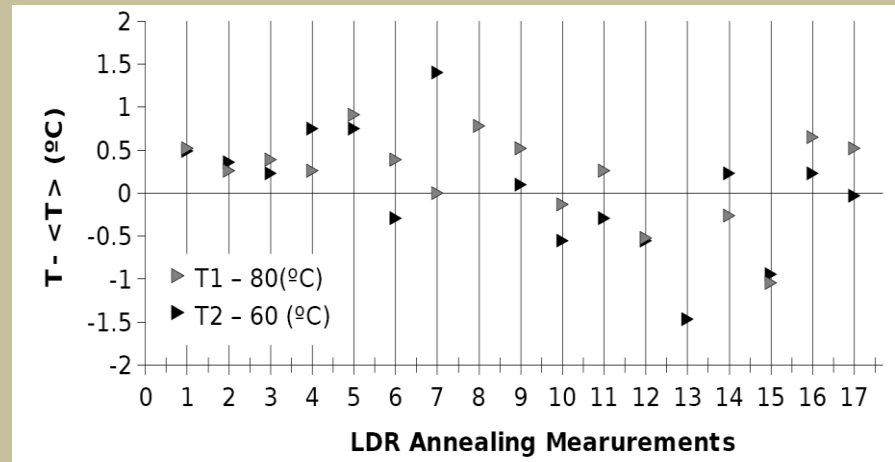
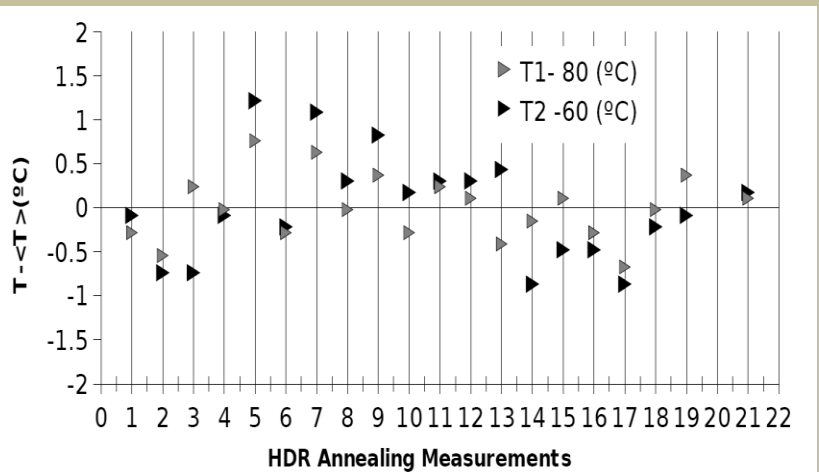
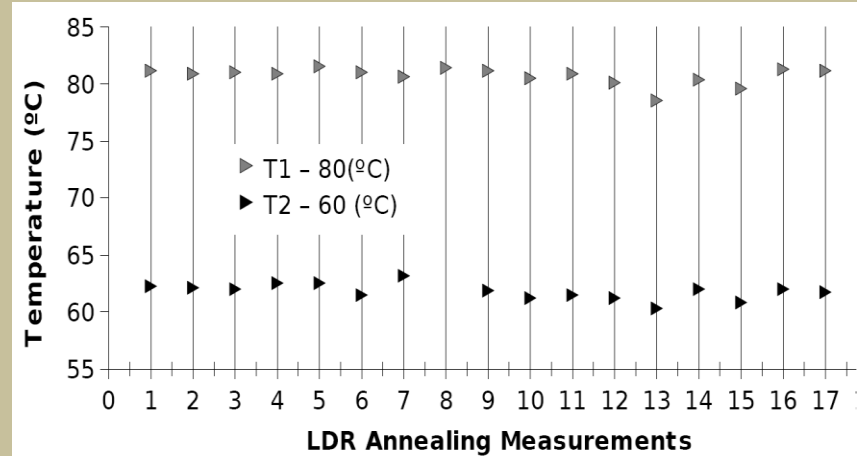
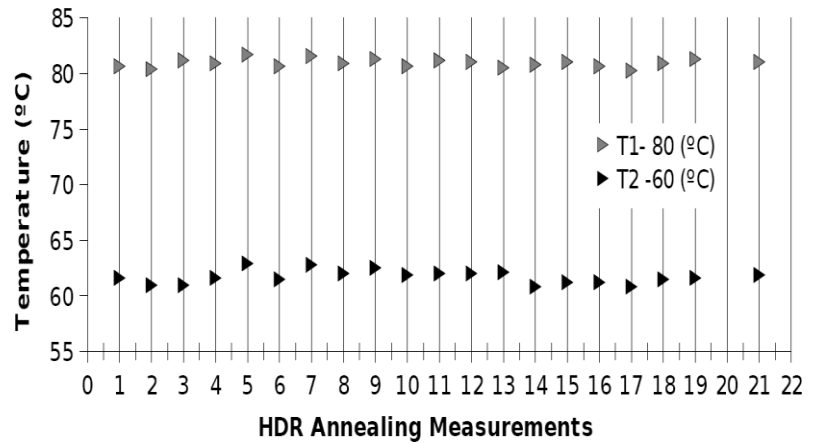
- fits of the V_{ths} annealing model were performed on data and fit parameters were derived.

Error on time: 0.5 h

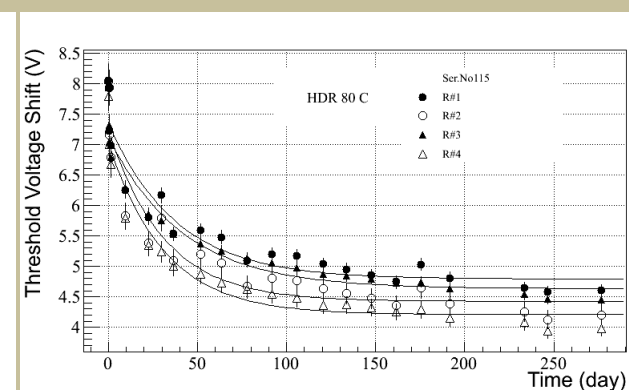
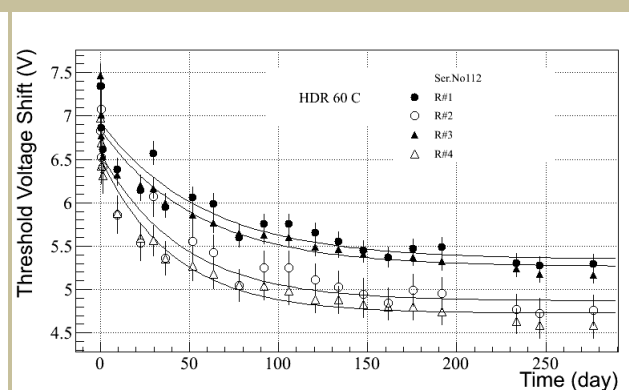
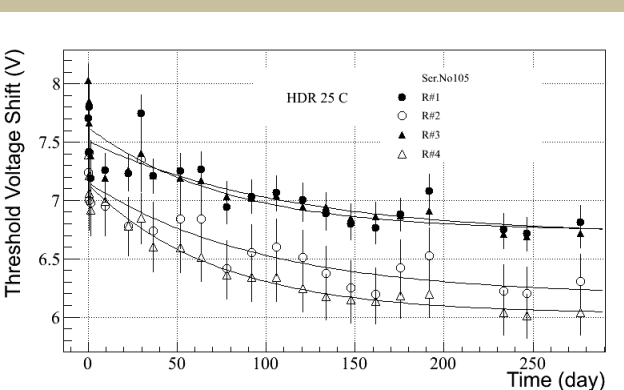
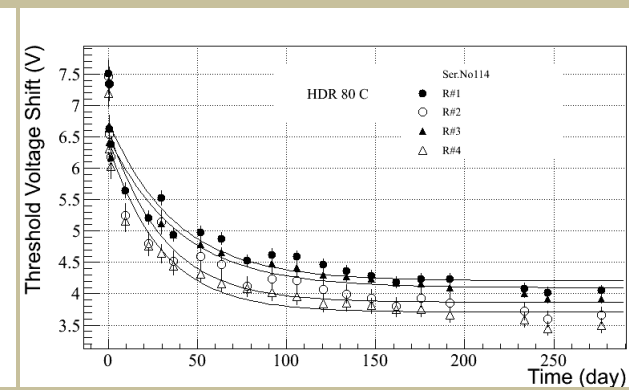
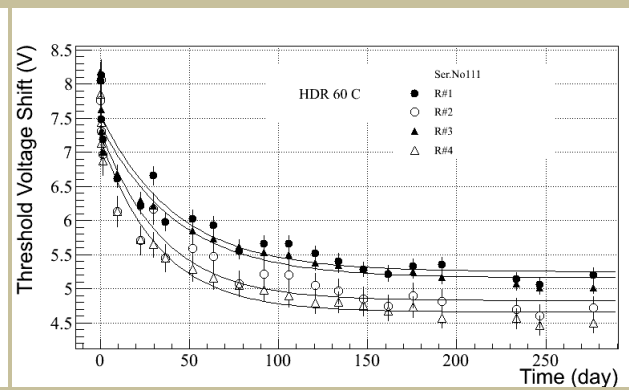
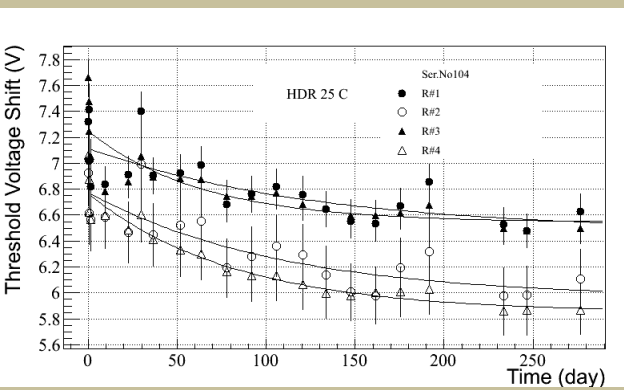
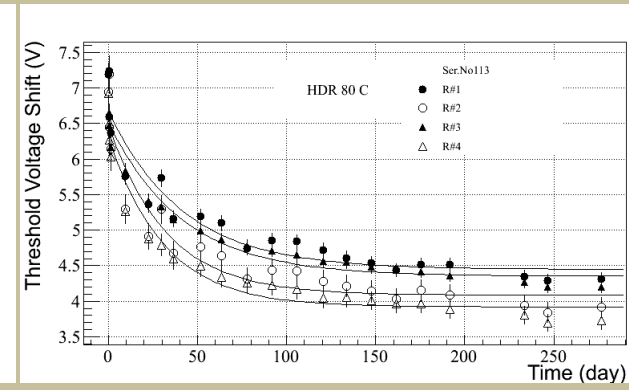
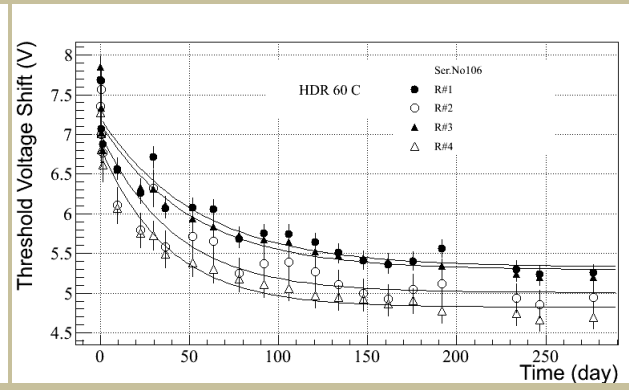
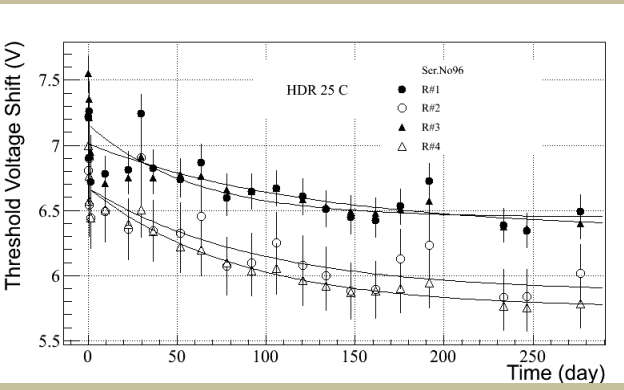
Error on V_{ths}:

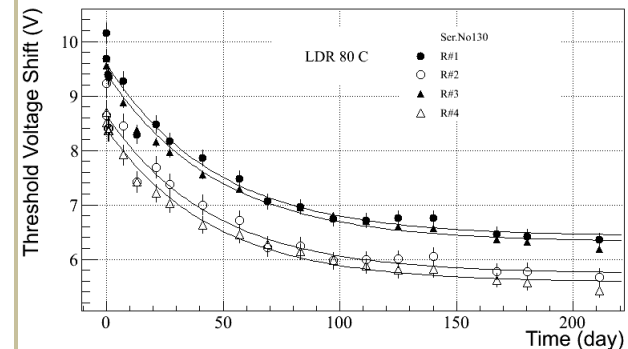
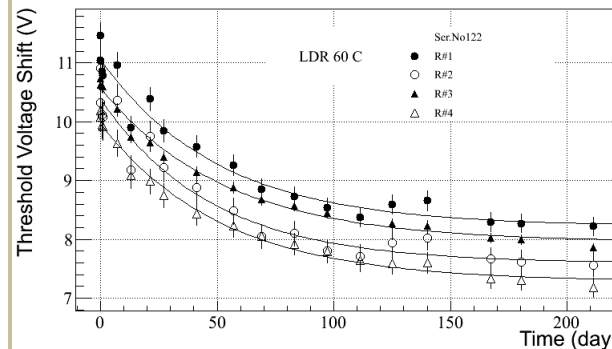
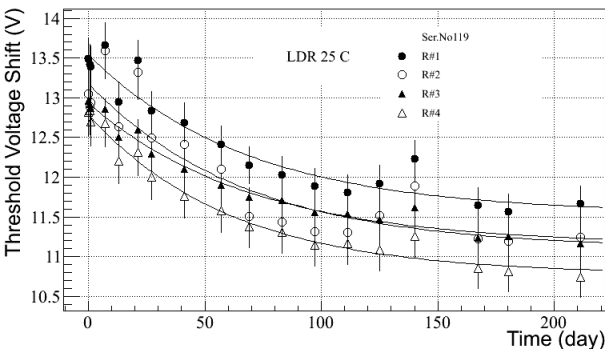
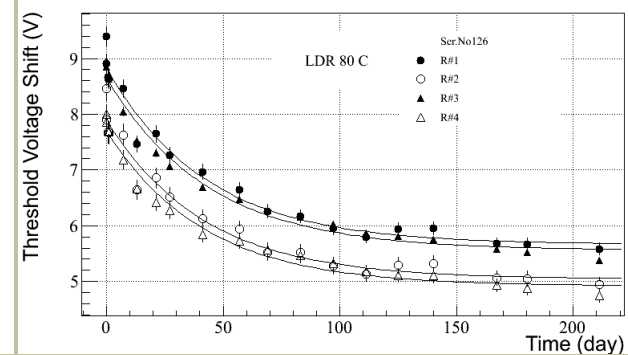
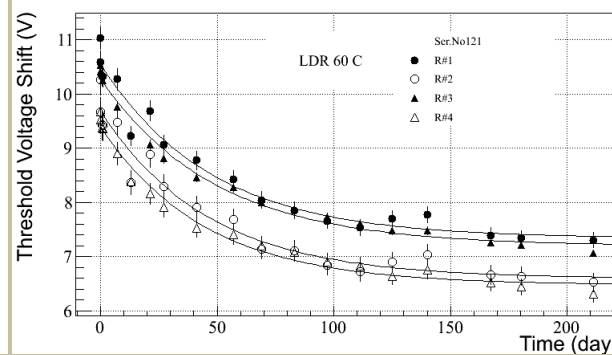
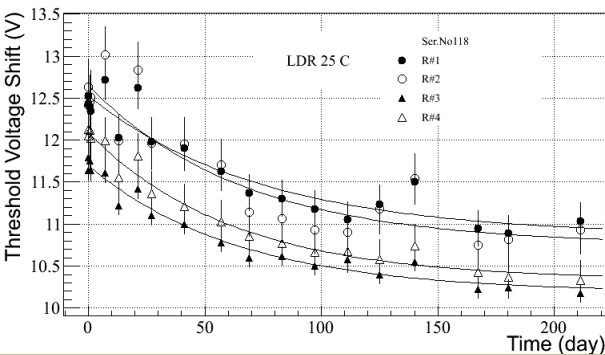
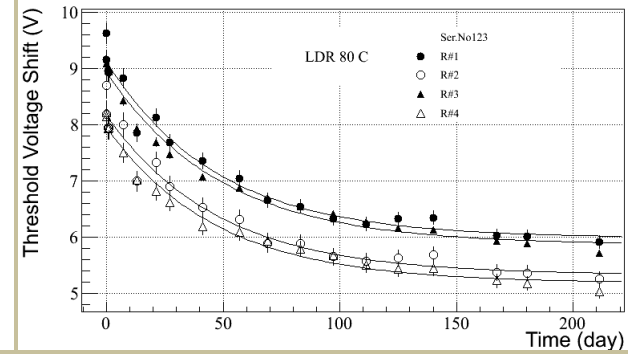
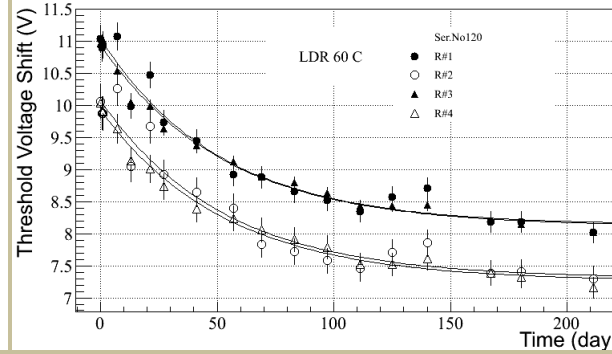
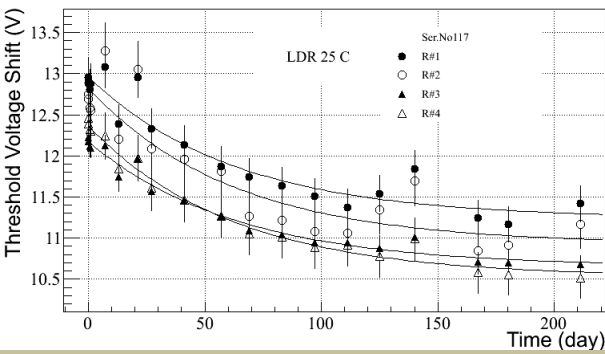
maximum fluctuation between neighbour measurements of the reference package.

Temperature control

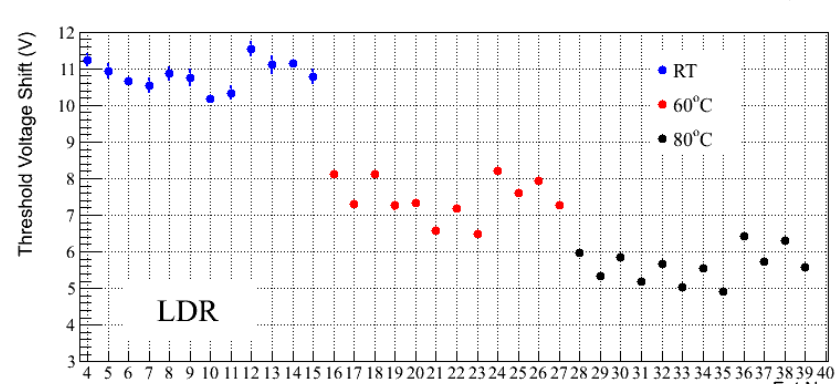
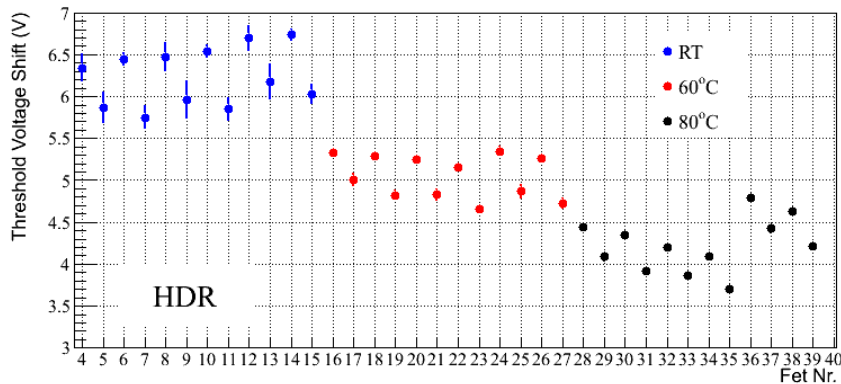
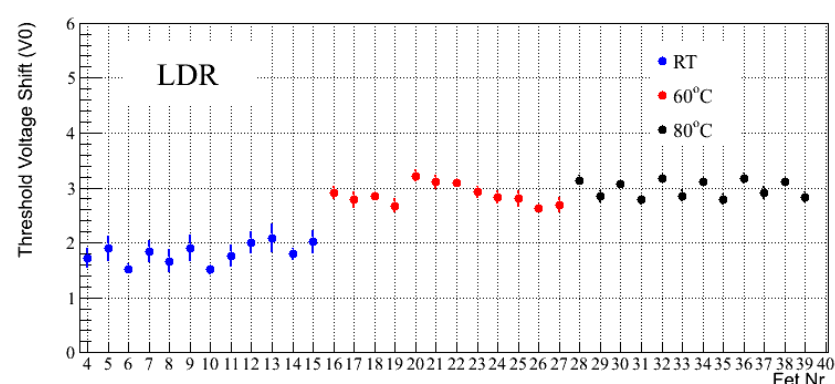
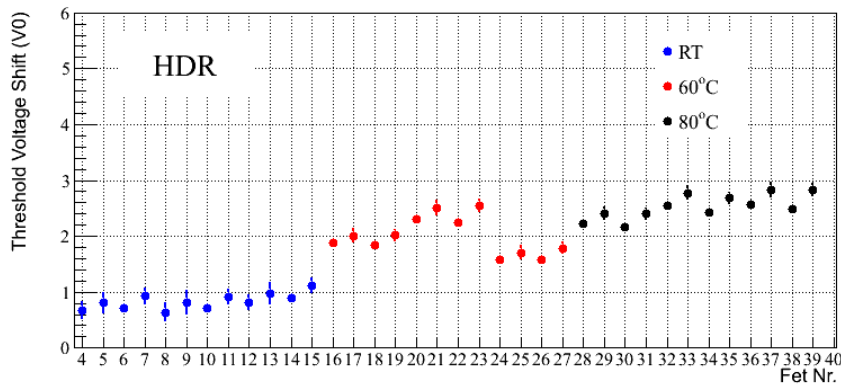
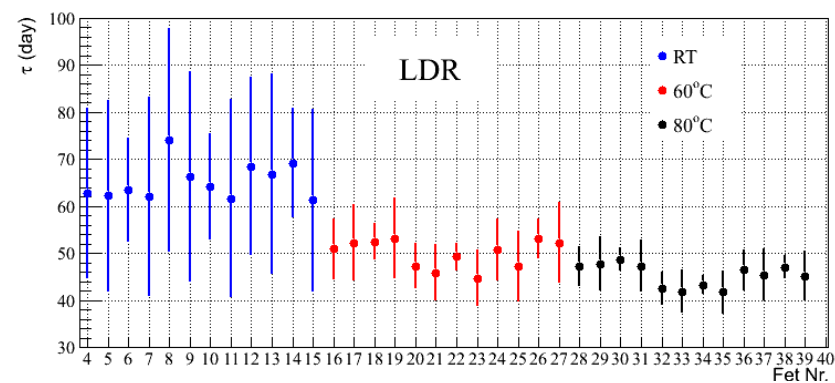
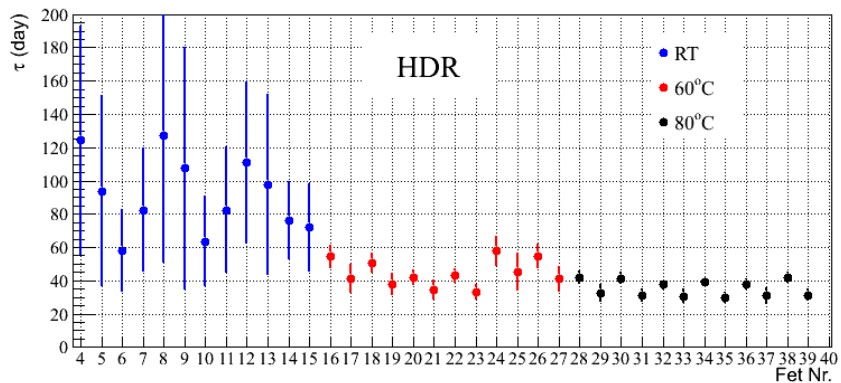


Room temperature: 21 ± 1 °C





$$V_{ths}(t) = V_{ths_{end}} + V_0 \exp(-t/\tau)$$





Outlook



Preliminary results

- A calibration test campaign of RADFET dosimeters was conducted at the ESA/ESTEC Cobalt-60 facility.
- Irradiation runs were performed at three distinct temperatures: 25°C (room temperature), 60°C, and 80°C and at high and low dose rates, up to 50 krad and 57.7 krad respectively.
- After the irradiation runs, each RADFET sample underwent annealing during 276/211 days (LDR/HDR irradiated samples).
- The voltage threshold shift values for the 72 irradiated RADFET devices in the 18 packages were measured during irradiation and annealing and the corresponding calibration curves were derived.