

**PULSED X-RAYS FOR INTERVENTIONAL RADIOLOGY:
TEST ON ACTIVE PERSONNAL DOSEMETERS (APD)
EUROPEAN PROJECT FP7 ORAMED WP3**

par

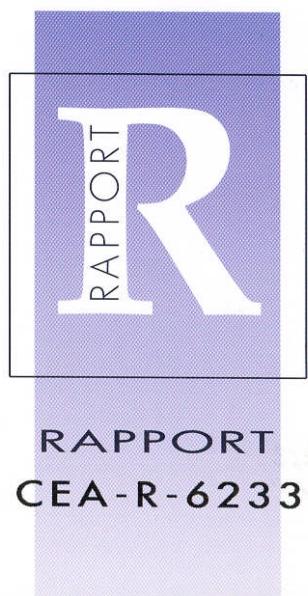
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**RAPPORT CEA-R-6233 – Marc DENOZIERE, Jean-Marc BORDY, Josiane DAURES,
Nelly LECERF**

«Rayons X pulses pour la radiologie interventionnelle : Tests sur Dosimètres Personnel Actifs»

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2009 - Commissariat à l'Énergie Atomique – France

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- Rapport CEA-R-6233 -

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- Novembre 2009 -

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M. Denozière, J.M. Bordy, J. Daures, N. Lecerf

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1	Introduction	4
2	Reference measurements	4
3	Irradiation of the APDs.....	7
3.1	APDs under test	7
3.2	Results.....	8
3.3	Discussion.....	8
4	Conclusion	20
	Bibliography	21

1 Introduction

This report presents the results of the tests performed on Active Personal Dosemeters (APD) to check their responses in pulsed X-ray beams used in interventional X-ray radiology. This work is one of the deliverable of ORAMED WP3, *Optimization of RAdiation protection for MEDical staff* is a collaborative project funded in 2008 within the 7th EU Framework Programme, Euratom Programme for Nuclear Research and training.

The response of seven APDs types was measured in terms of personal dose equivalent $H_p(10)$ for different pulsed X-ray width and dose rate.

2 Reference measurements

The beam quality is defined as follow :

- X-ray generator : GEHC PHASIX 80 in graphy mode and multi-pulsed mode
- High Voltage : 70 kV
- Total filtration : 4.5 mm Al + 0.2 mm Cu
- Half Value Layer : 5.17 mm Al
- Distance between X-rays source and reference point : 1 m
- Beam dimensions in reference plane: 30 x 30 cm

For multi-pulsed mode, the pulse width is 20 ms. The irradiation was done with 1 pulse per seconde (pps), 10 pps and 20 pps. The tube currents were 20 mA, 32 mA, 100 mA, 400 mA and 800 mA. The number of pulses over the irradiation time were of about 40 (1pps), 80 (10 pps) and 160 (20 pps).

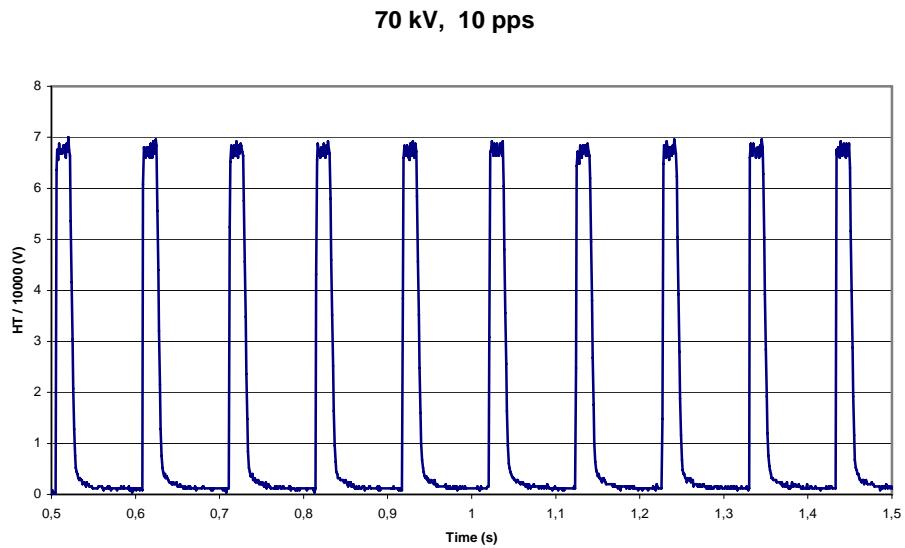


Figure 1 : Example of typical HV waveform in multi-pulses mode

For graphy mode the pulse duration was between 1 ms and 1000 ms and the tube current between 32 to 400 mA.

For determination of the reference Air-kerma values, the free air chamber MD03 LNHB primary standard was used. These values were determined accordingly to the LNHB method for establishing the air kerma reference for pulsed radiations [1].

The results are expressed in terms of :

- “mean Air-kerma per pulse” = Air-kerma integrated over the irradiation time divided by the number of pulses;

- mean “Air-kerma rate per pulse” = mean Air-kerma per pulse duration (*i.e.* 20 ms).

The beam was monitored with a parallel flat chamber (PTW 233612) placed behind the collimator in a shielding lead box in order to reduce the influence of the scattered component from the phantom (figure 2)

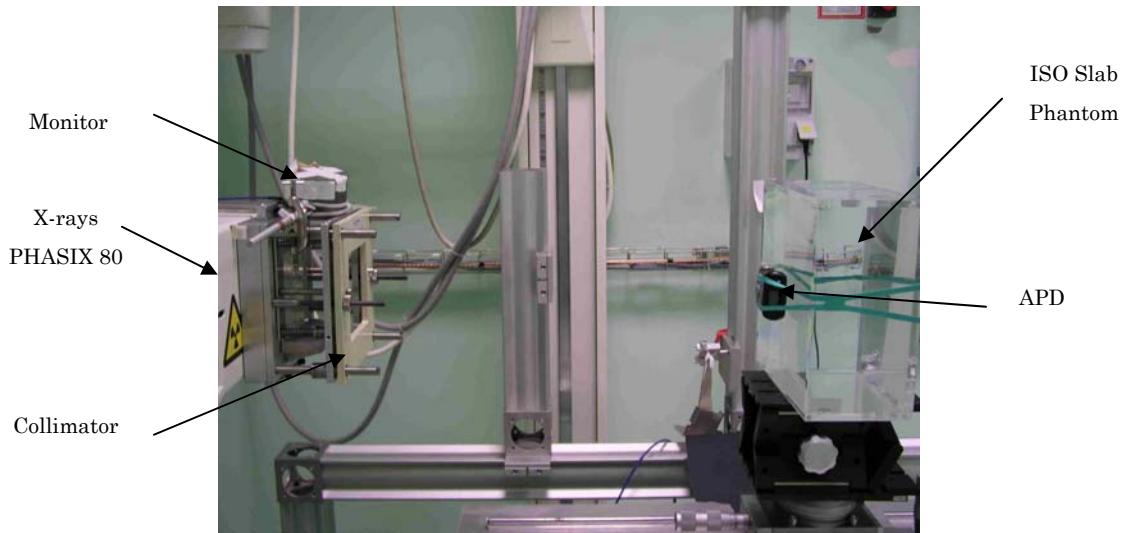


Figure 2 : experimental set up

The monitor was calibrated against the primary standard (free-air chamber).

Then this calibration coefficient N_{Kair} (in Gy/C) was used to measure air-kerma during APDs irradiations.

The dose equivalent $H_p(10)$ is calculated with conversion coefficient $H_p(10)/K_{air} = 1.65$ Sv/Gy calculated with the following equation :

$$H_p(10)/K_{air} = \frac{\sum h_K(E) \cdot \phi(E) \cdot dE}{\sum \phi(E) \cdot dE}$$

where $h_K(E)$ is the conversion coefficient at energy E, tabulated in [2] and $\phi(E)$ the fluence spectra of the incident beam calculated with Xcomp5 program [3].

The mean equivalent dose rates are given in table 1

pps	Current in X-ray tube (mA)	\dot{K}_{air} (Gy/h)	$\dot{H}_p(10)$ (Sv/h)
1	32	1.1	1.82
	100	4.1	6.77
10	20	0.75	1.24
	32	1.1	1.82
	100	4.1	6.77
	400	16	26.4
	800	33	54.5
20	32	1.1	1.82
	100	4.1	6.77

Table 1 : air-kerma rate and personal dose equivalent rate in multi-pulses mode

The relative standard uncertainty on air-kerma is 2.2%

The relative standard uncertainty on the conversion coefficient is 3.0 %.

Therefore the combined relative standard uncertainty on the dose equivalent is 3.7%.

3 Irradiation of the APDs

3.1 APDs under test

The Active Personal Dosemeters are presented in table 2. Two APD of each type were tested.

APD type	Serial number	Manufacturer
DMC 2000	374703L2; 374740L2	MGP Instruments
AT3509C	30434; 30433	Atomtex
EPD MK 2.3	00070388; 00070389	Siemens (?)
PM1621 A	61983 ;62002	Polimaster
DIS -1	270039 ; 270038	Rados
EDM III	2710977; 27104016	Panasonic
EDD 30	128999	Unfors

Table 2 : Active personal dosimeters under test

3.2 Results

The responses R_{APD} of the APDs are presented in tables 5a to 10b.

$R_{APD} = \text{reading of APDs} / H_p(10)$

The combined relative standard uncertainties on the response of the APDs are given in table 3.

APD	DMC 2000	AT3509 C	TEC MK2	PM1621 A	DIS -1	EDM III	EDD 30
$u(R)/R$ (%)	6	20	5	-	9	7	6

Table 3 relative uncertainties on APDs responses

3.3 Discussion

First of all, the capability to register a signal due to a pulsed radiation is linked to the time response of the detector itself (linked to the mobility of the charge carriers) and the time response of the electronic. Taking that in mind it is note surprising that the response of the Polimaster PM1621 A is zero for all configurations of pulsed X-ray beam, it is probably because the dosimeter is based on a Geiger-Muller detector which has a rather long time response.

In figures 3a to 9c are presented the mean of the responses of each type of ADP in muti-pulsed and single-pulsed modes.

A few general remarks can be drawn :

Past comparisons [4] have showed that when pulse width is larger than 1 s the response in pulsed and in continuous radiation field are similar. The results of this test confirm this tendency but a few comment can be done.

- When the dose rate is constant, the response increased with the number of pulses per second (see figures b except 8b).
- Whatever is the ADP (except for the PM1621 A), in multi-pulsed mode the responses at 10 and 20 pps are similar. The response at 1 pps is similar to response at 10 pps and in the graphy (single pulse) mode.
- Whatever is the ADP (except for the PM1621 A), in graphy mode, the response increased with the duration of the irradiation. Thus, when the irradiation time is 1000 ms, that is to say when - among the configuration used for this test – it is the closest to the continuous radiation fields, the response is similar to 10 pps multi-pulse mode.

These general behaviours suggest that these problems are probably due the response time of the dosimeter. For short pulses the dosimeter cannot record properly the entire pulse.

The work done within the CONRAD european program [5] has showed that, for many dosimeters, the response decrease when the dose increase. This result is confirmed here. For personal dose equivalent rates lower than 2 Sv/h the responses are, in general, close to the unity and fall down for higher dose rate. Looking at the curves where the response is plotted versus the means dose rate per pulse, it can be seen that, for the dose rate greater than 2 Sv/h, the response of ADPs decreases. This suggests some problems with the dead time correction, except for DIS-100. In table 4 the threshold of 40% of the maximum response is arbitrary chosen to qualify the maximum dose rate able to be measured by an ADP.

APD	DMC 2000	AT3509C	EPD MK2.3	PM1621 A	DIS - 100	EDM III	EDD30
Variation %	25-30	30 (from 10 to 20 pps ; no signal at 1pps)	~40(1.85Sv/h) ~25(6.8Sv/h)	Not applicable	~30	<10	~10(1.85Sv/h) ~40(6.8Sv/h)

Table 4 a : Effect of the frequency of the pulses (1 to 20 pps), percentage of variation on the response at constant dose rate

APD	DMC 2000	AT3509C	EPD MK2.3	PM1621 A	DIS -100	EDM III	EDD30
30%	~3	~1.8	~3.5	Not applicable	No threshold	~10	~6
40%	~4	~2.5	~4		up to 55 (30%)	~15	~7
50%	~5	~3.5	~7			~20	~10

Table 4b : Threshold in term of dose equivalent rate (Sv/h) for achieving a response higher than XX% of the maximum response

In addition to the former general remarks, it has to be mentioned that

- The DIS has a satisfactory response up to 55 Sv/h. This result is very good even if a large dispersion of the results is observed. It is probably due to the resolution of the reading (10 µSv). Indeed, the total dose equivalent received by the detector during the measurements was of about 80 mSv and as the annealing procedure of the detectors cannot be used between measurements, therefore one does not know which detector (among the three detectors which composed the DIS dosimeter) is used for measurements.

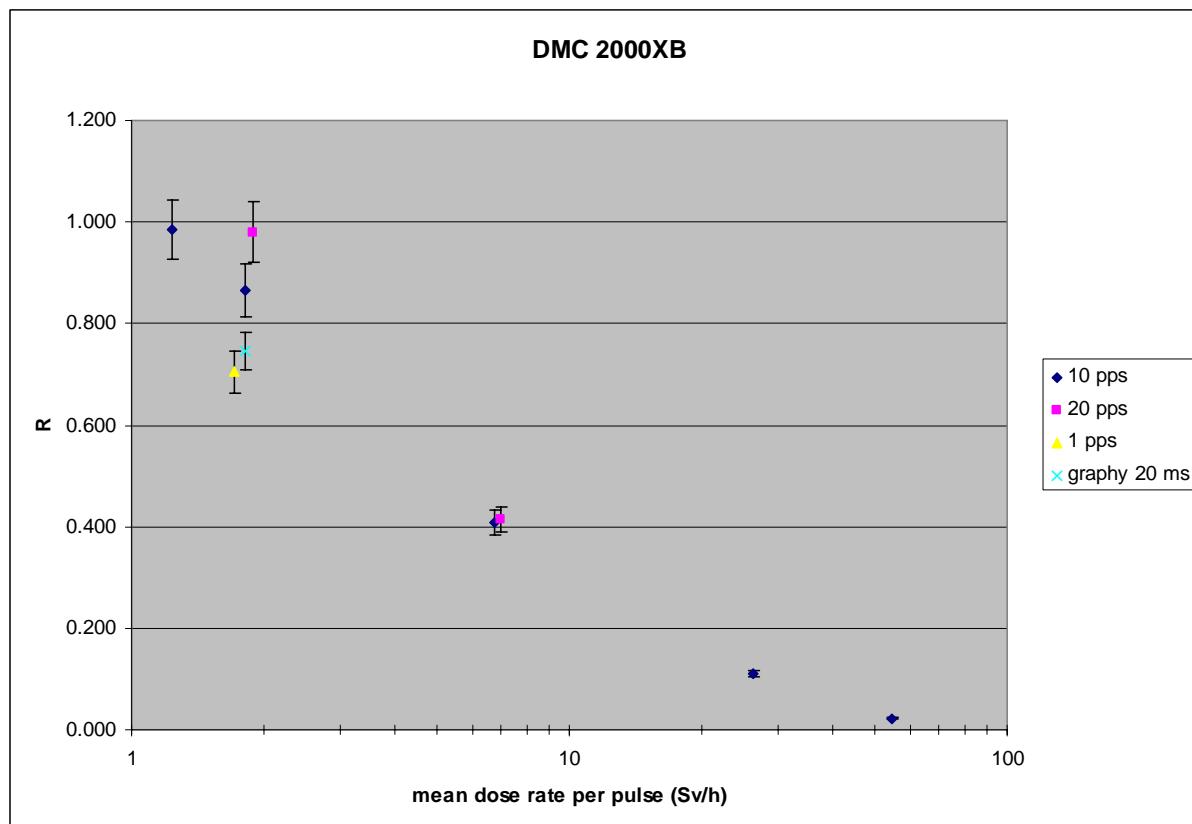


Figure 3a response of DMC 2000 XB in multi-pulsed mode

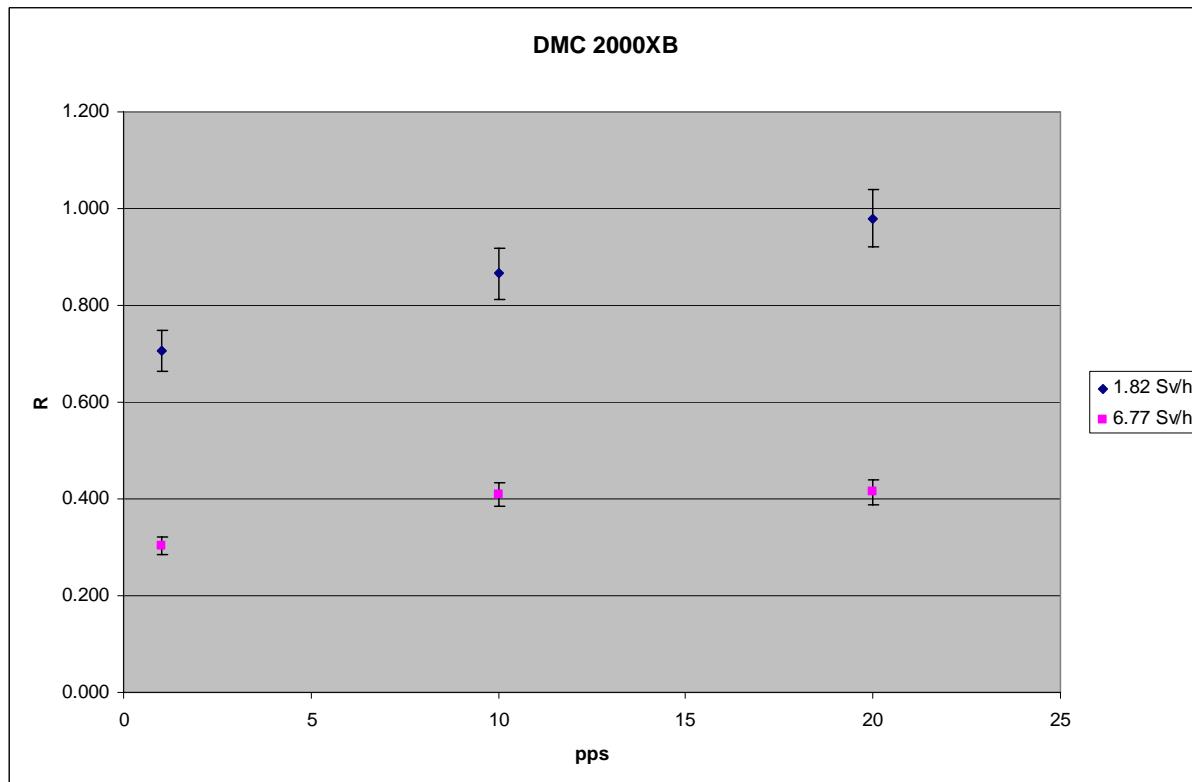


Figure 3b response of DMC 2000 XB in multi-pulsed mode vs pps

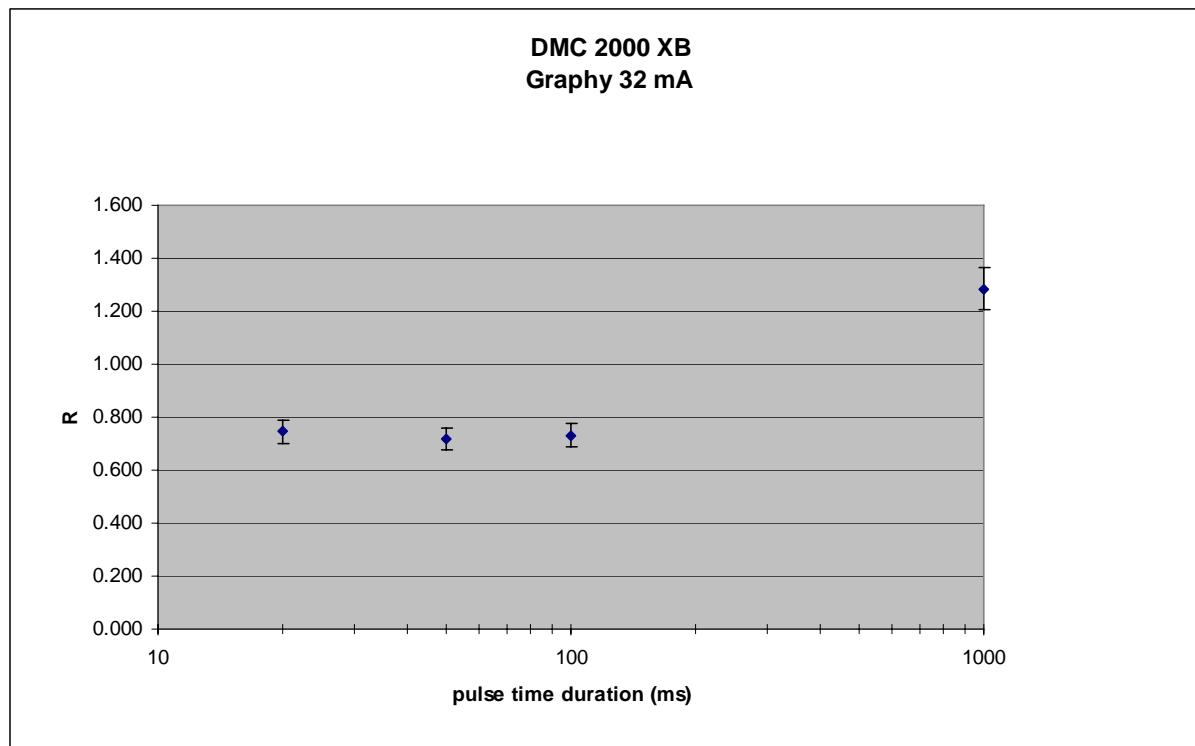


Figure 3c response of DMC 2000 XB in single pulsed mode

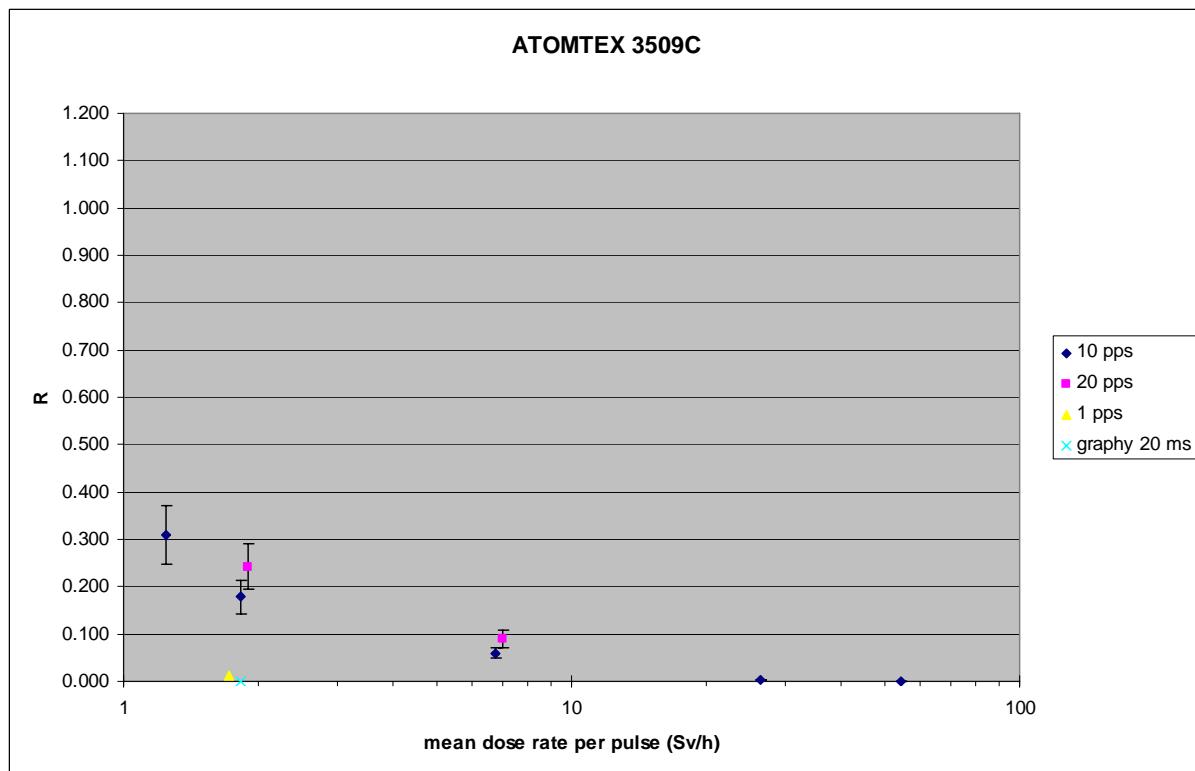


Figure 4a response of AT 3509 C in multi-pulsed mode

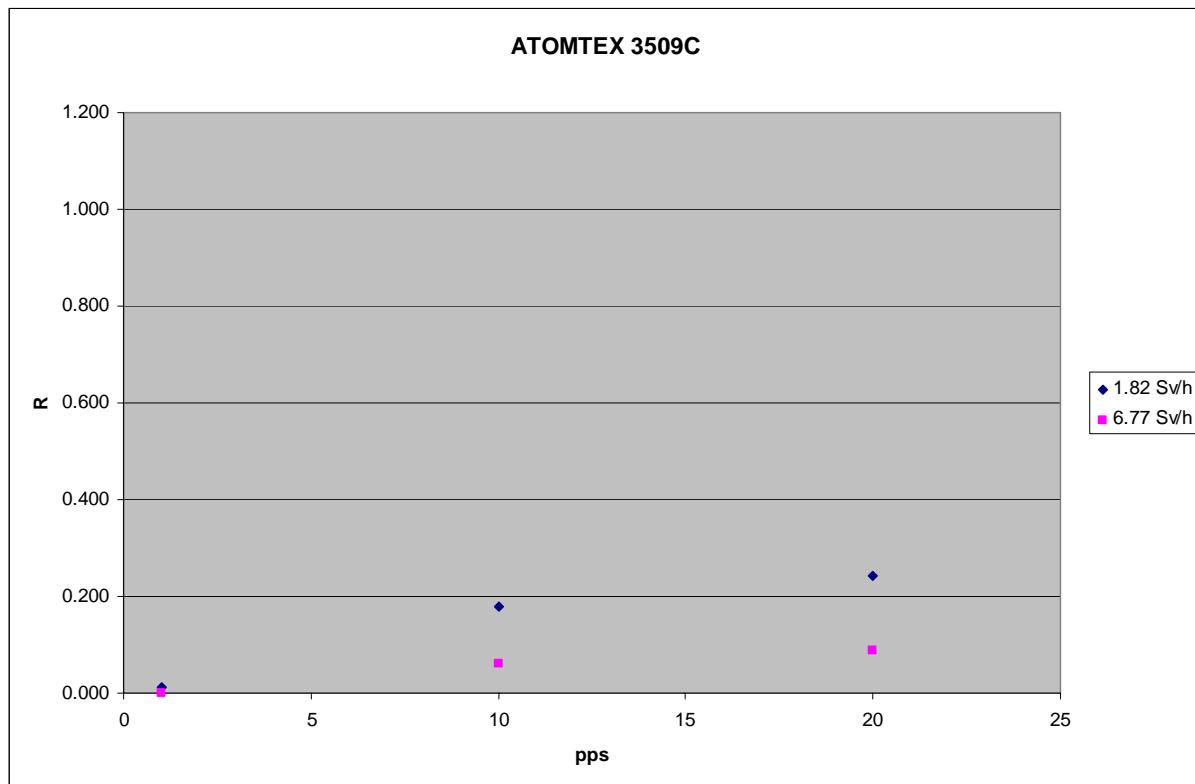


Figure 4b response of AT 3509 C in multi-pulsed mode vs pps

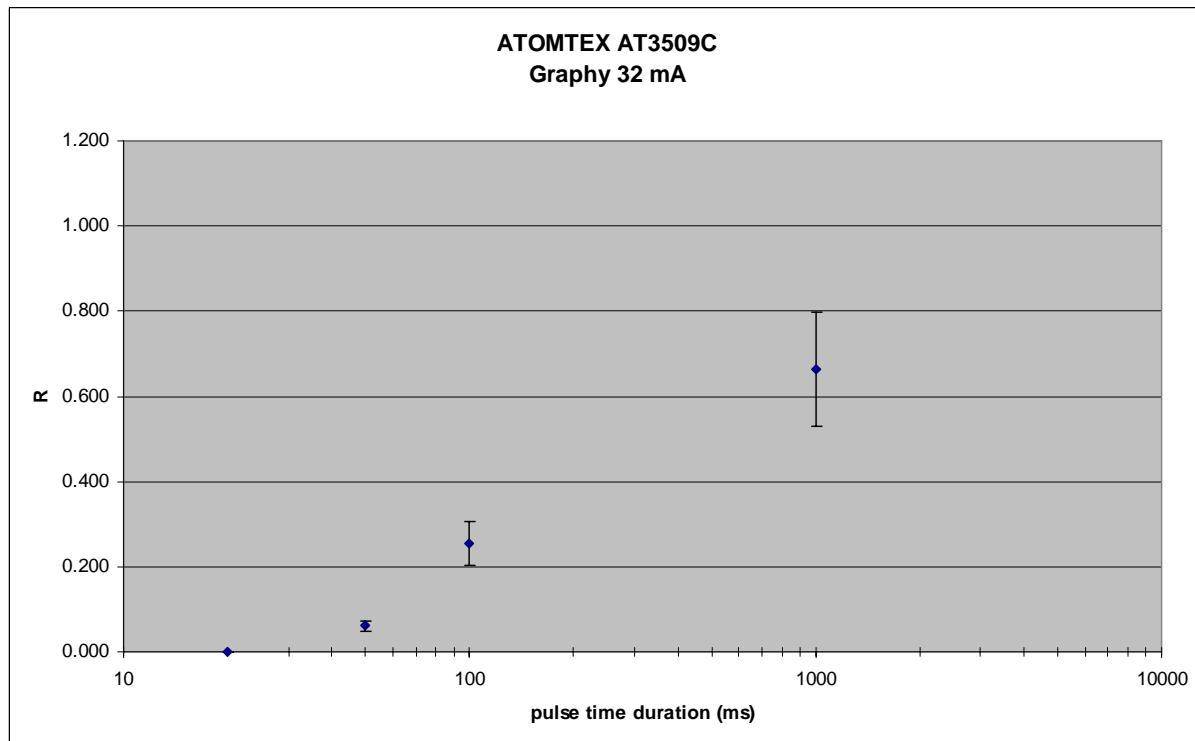


Figure 4c response of AT 3509 C in single-pulsed mode

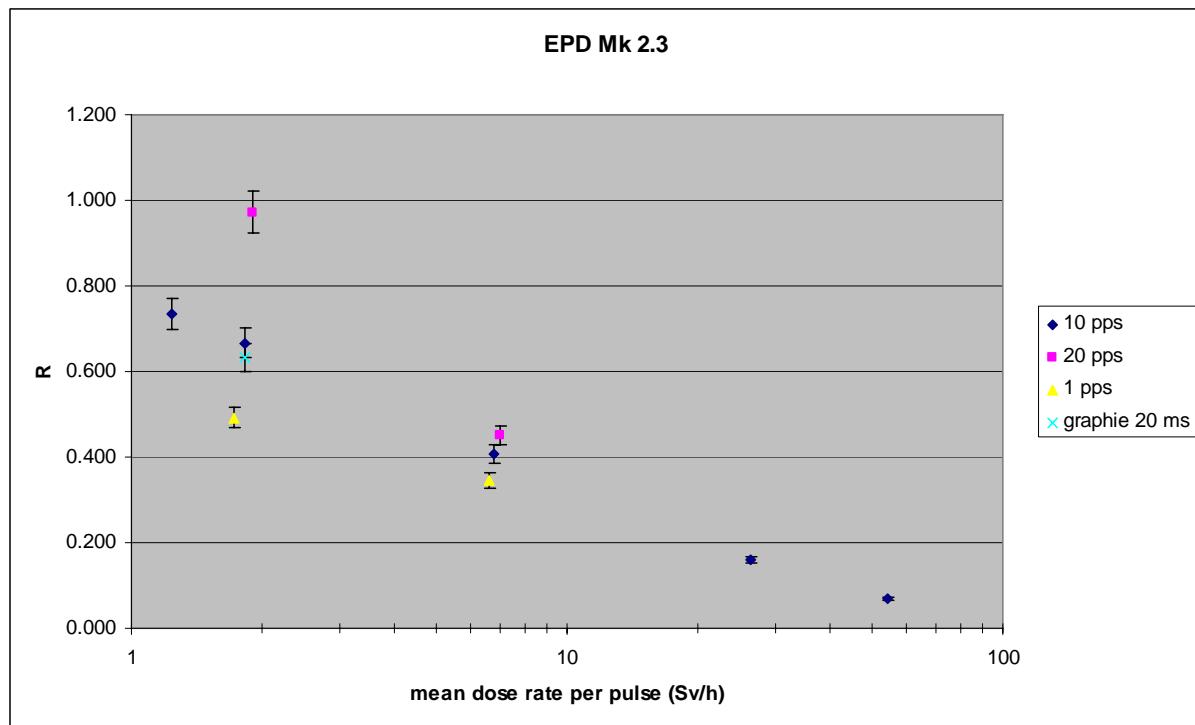


Figure 5a response of EPD MK 2.3 in multi-pulsed mode

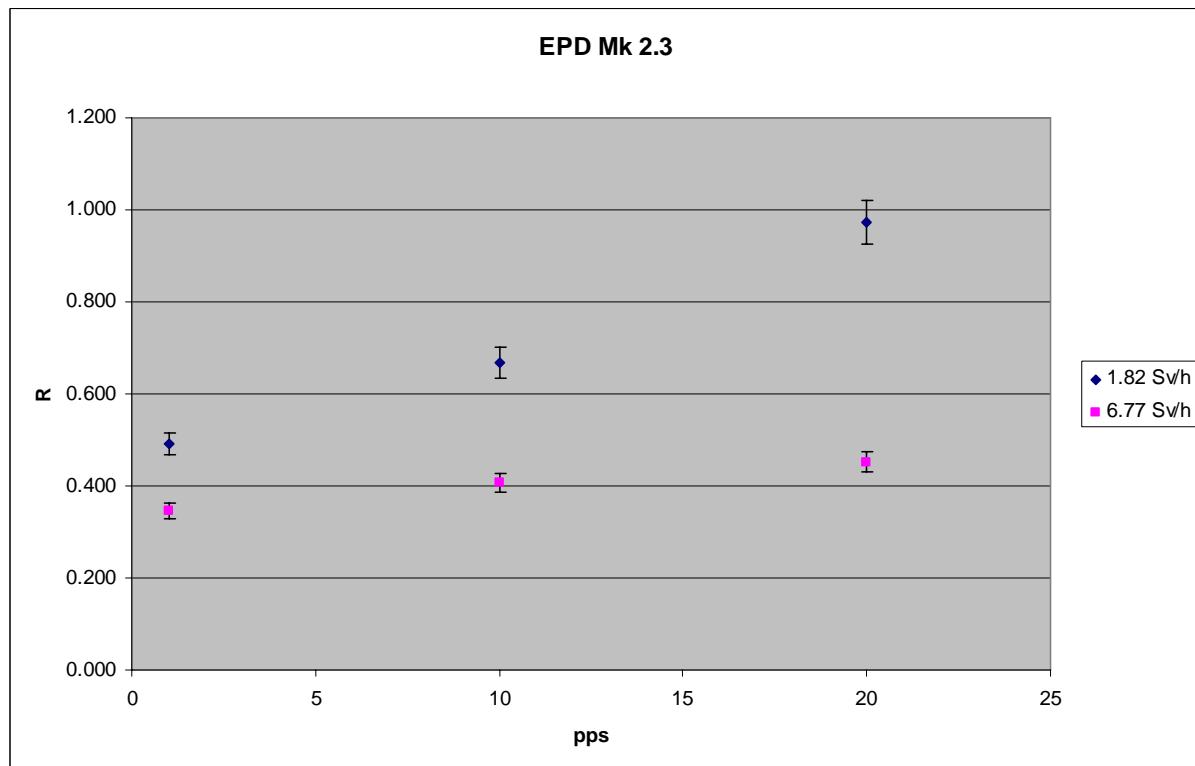


Figure 5b response of EPD MK 2.3 in multi-pulsed mode vs pps

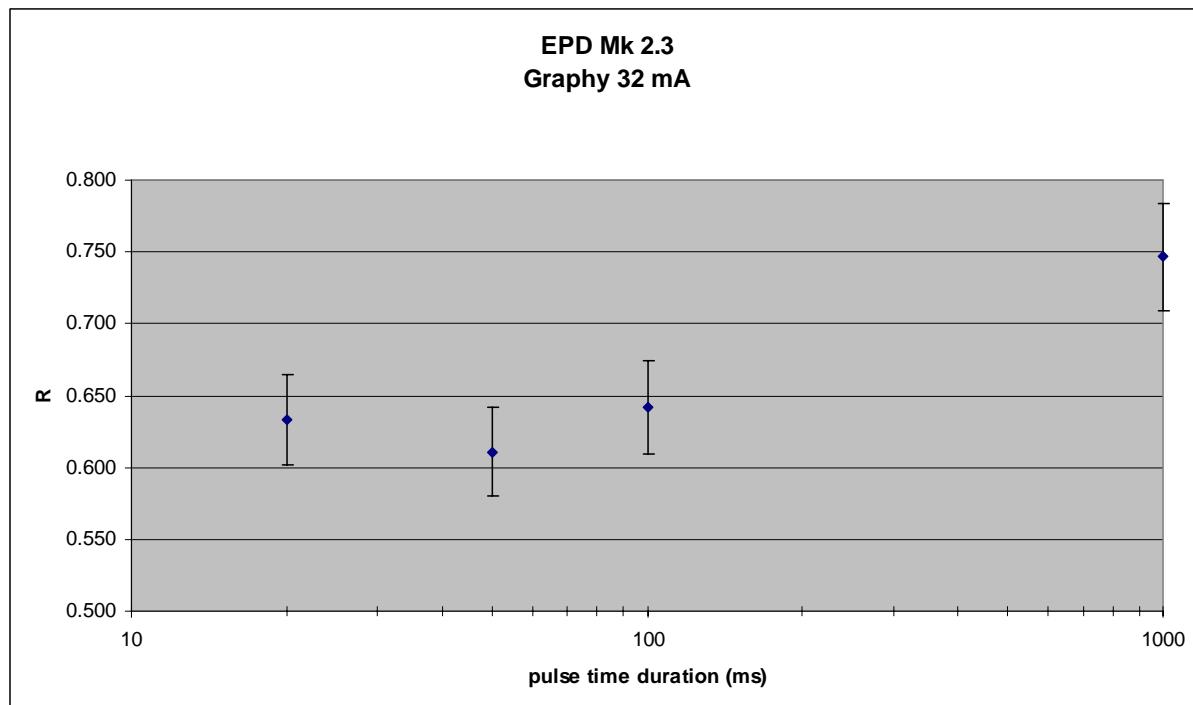


Figure 5c response of EPD MK 2.3 in single-pulsed mode

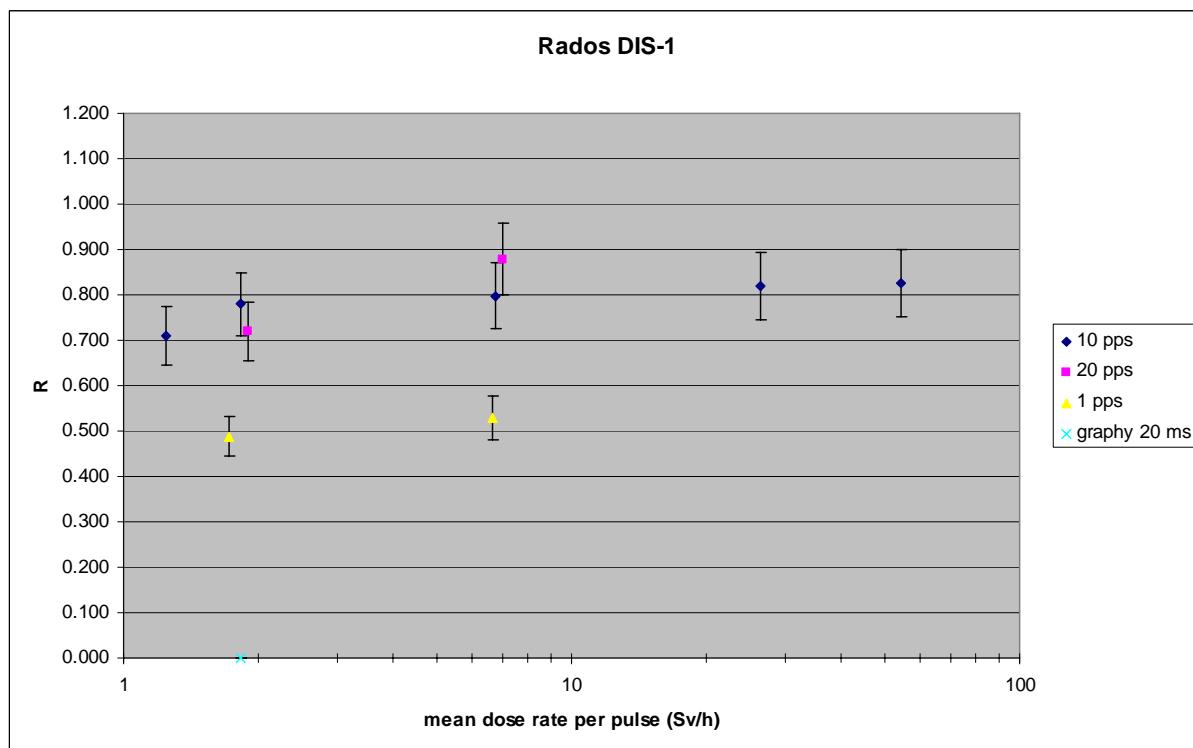


Figure 6a response of DIS-100 in multi-pulsed mode

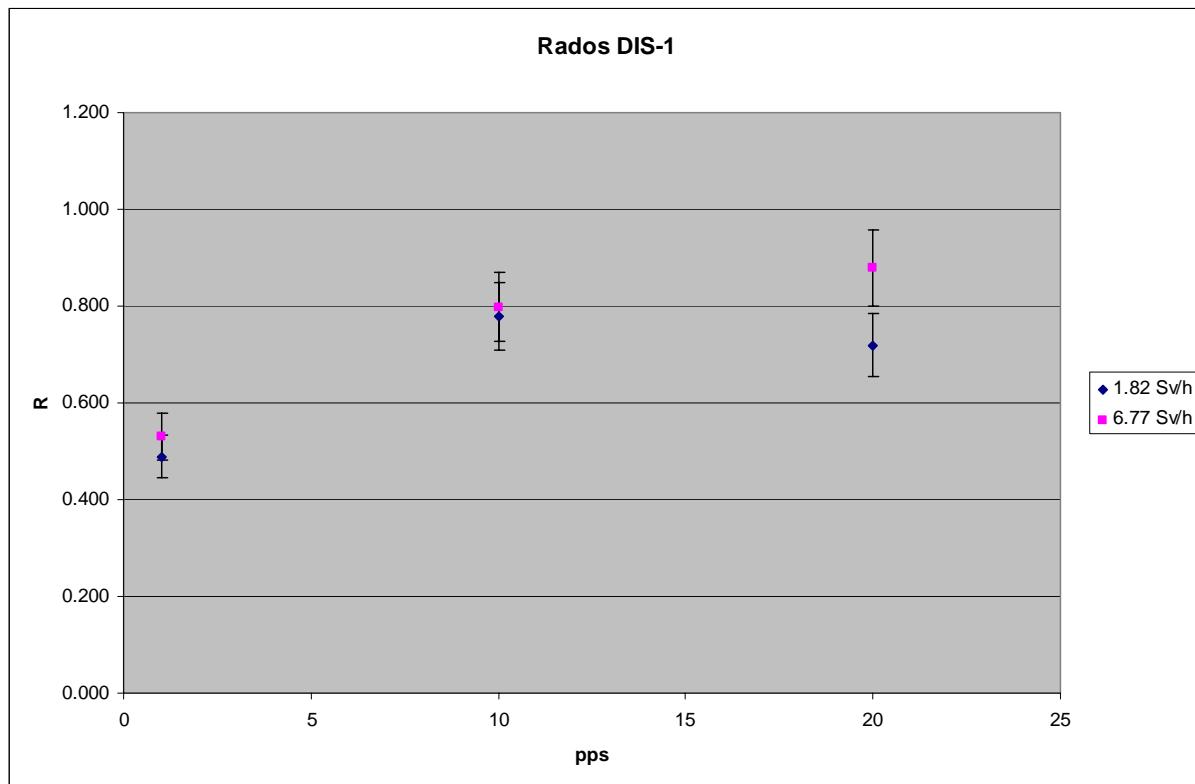


Figure 6b response of DIS-100 in multi-pulsed mode vs pps

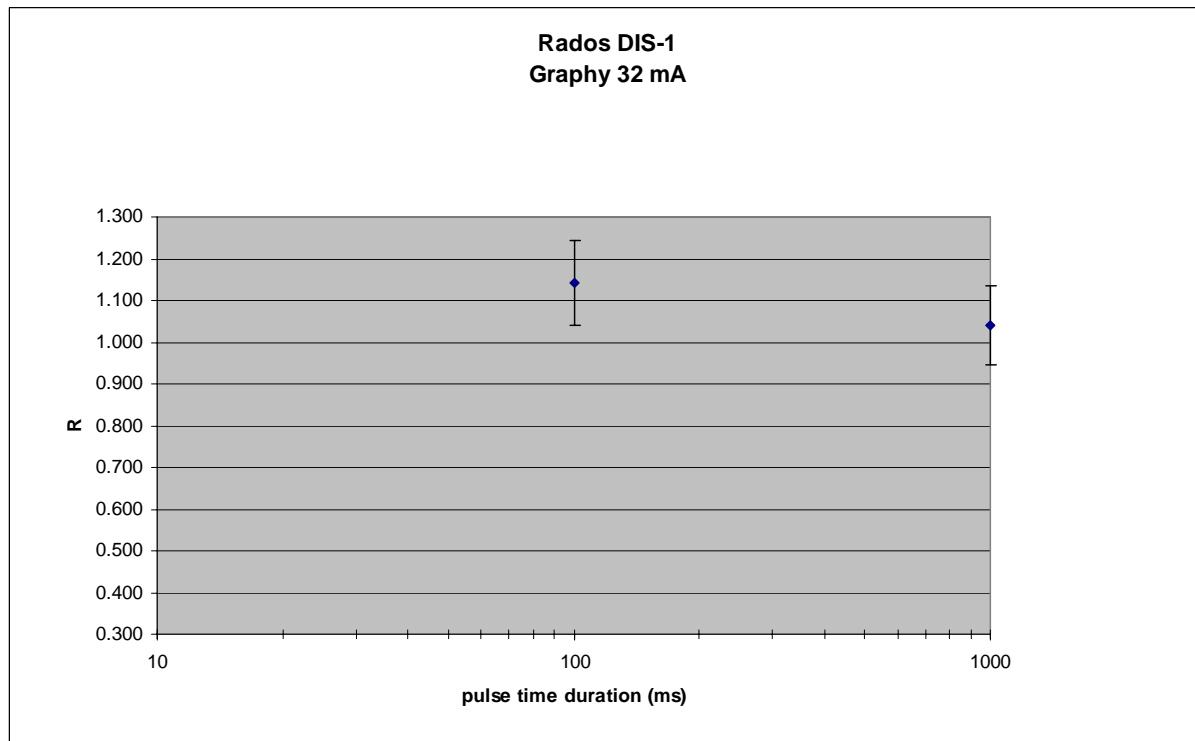


Figure 6c response of DIS-100 in single-pulsed mode

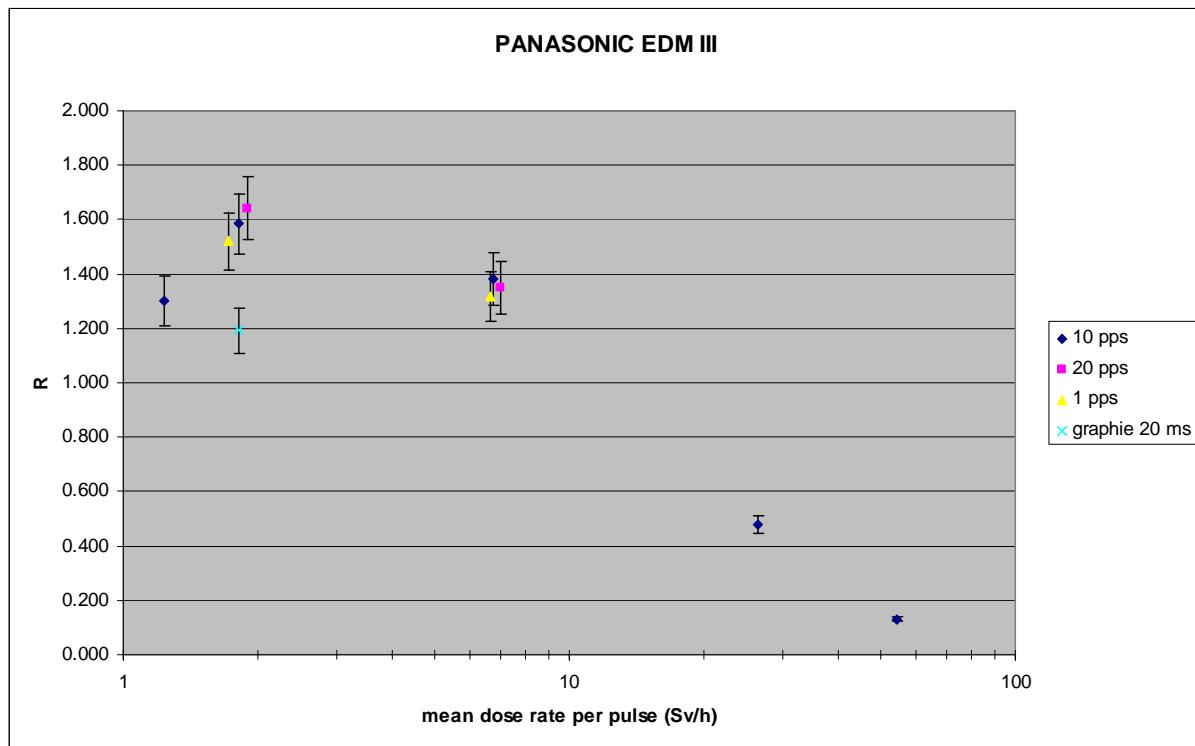


Figure 7a response of EDM III in multi-pulsed mode

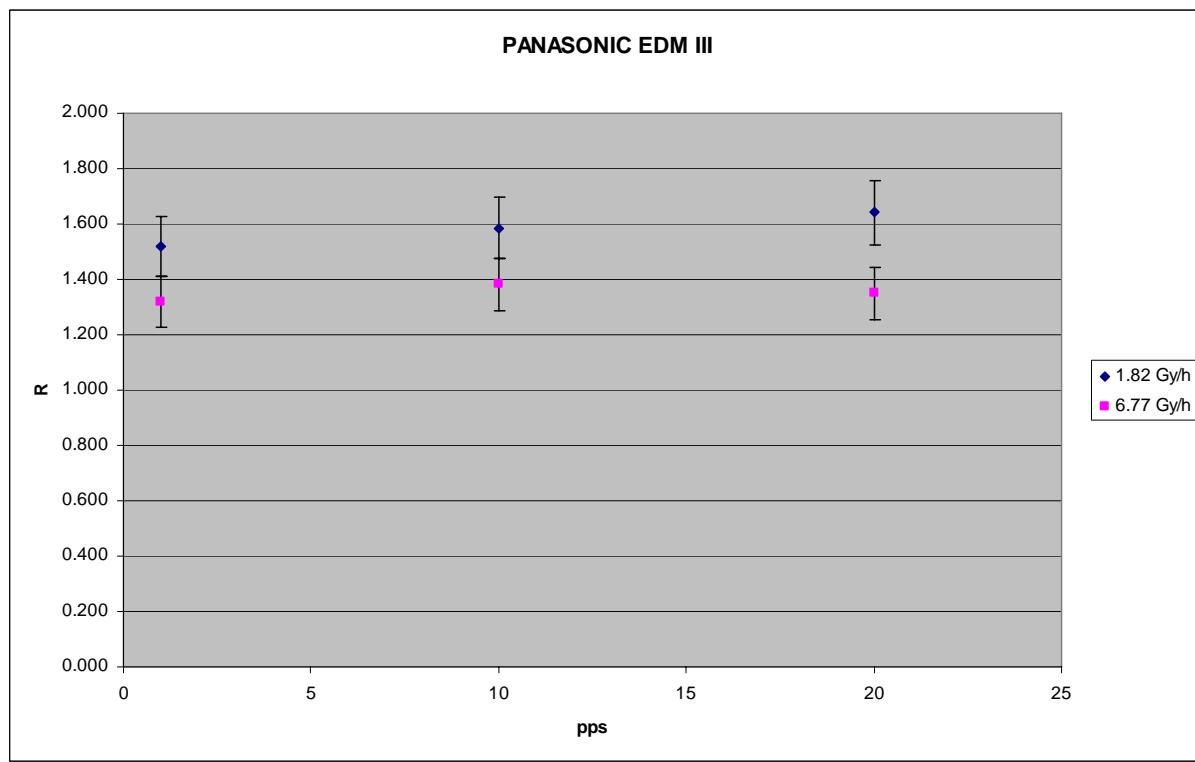


Figure 7b response of EDM III in multi-pulsed mode vs pps

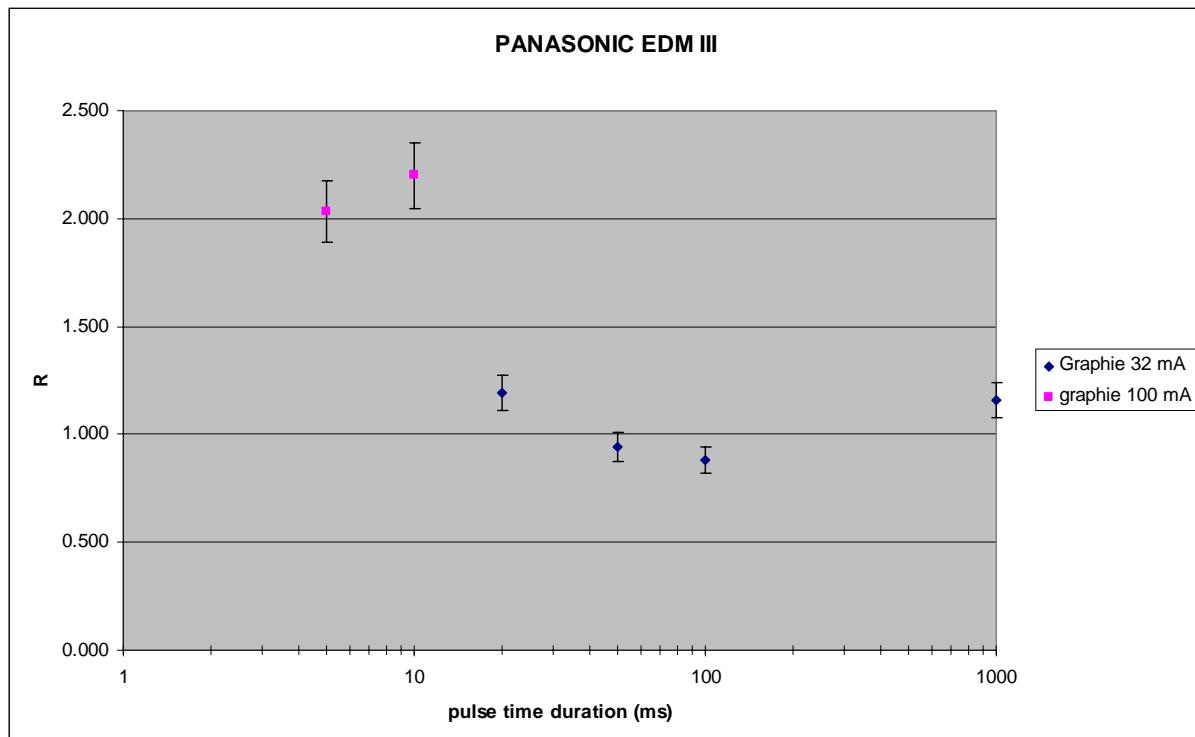


Figure 7b response of EDM III in single-pulsed mode

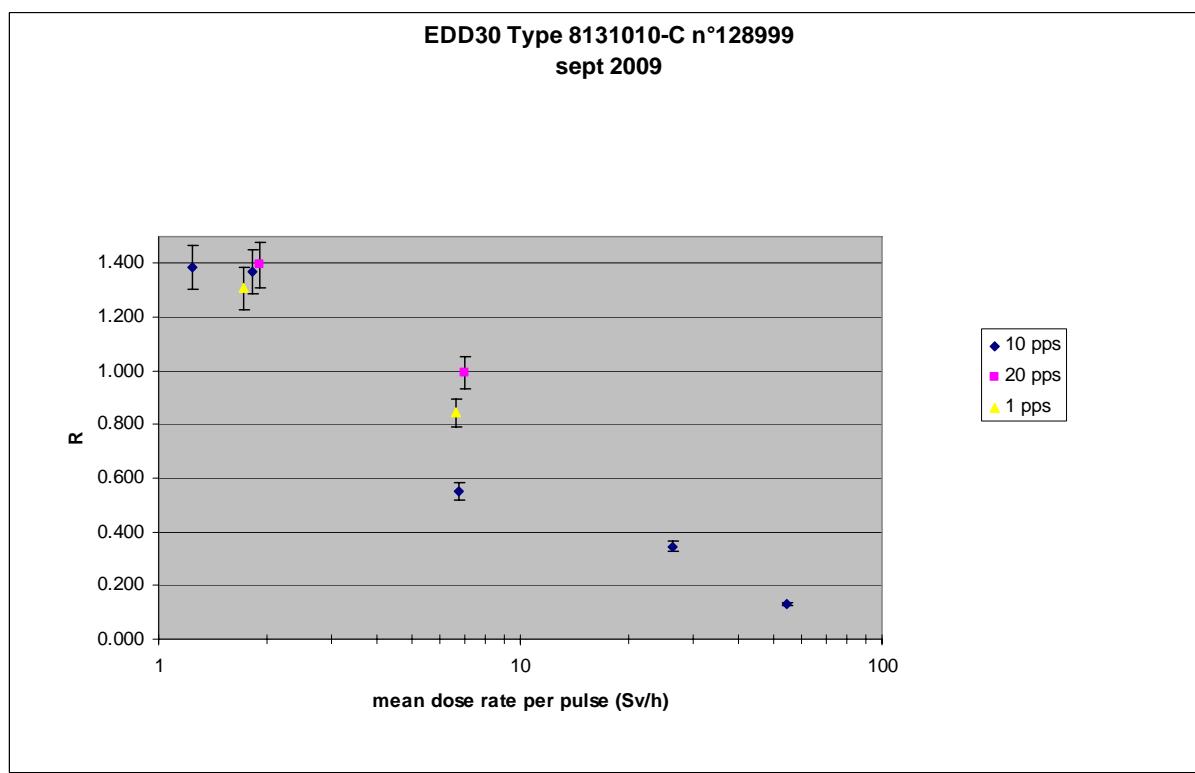


Figure 8a response of EDD30 in multi-pulsed mode

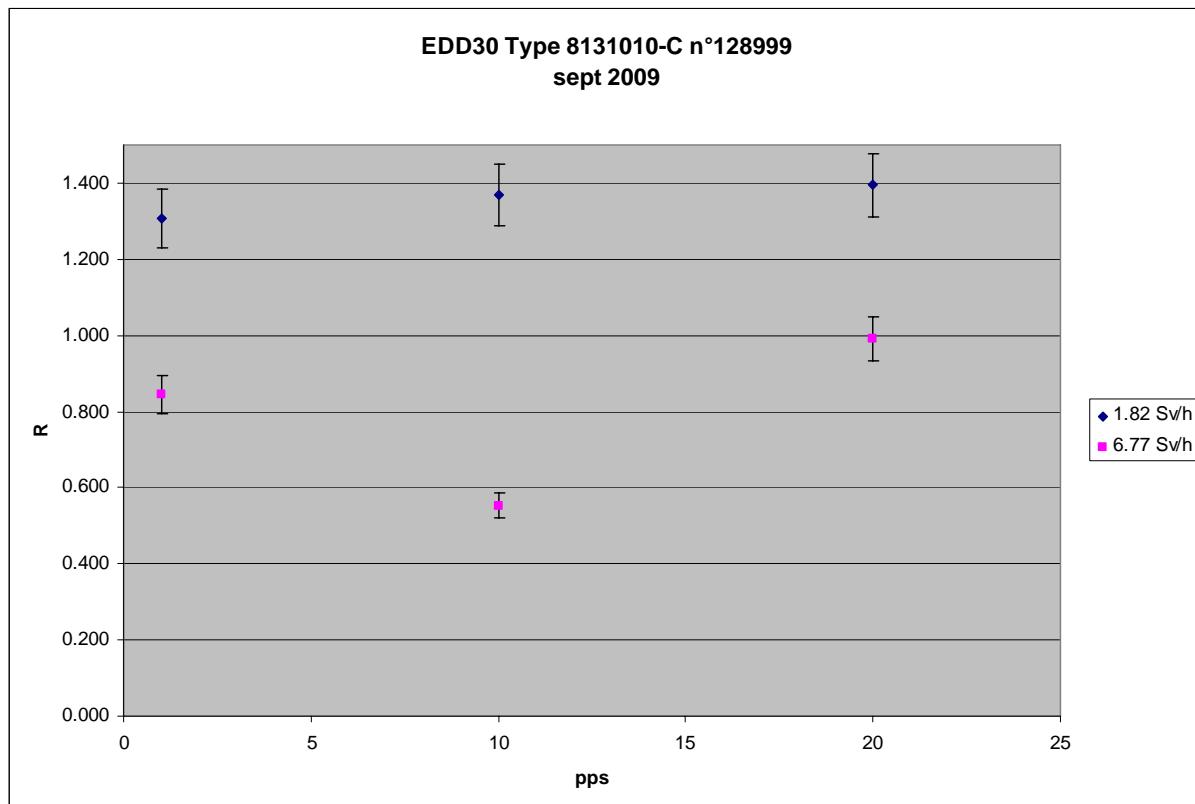


Figure 8b response of EDD30 in multi-pulsed mode vs pps

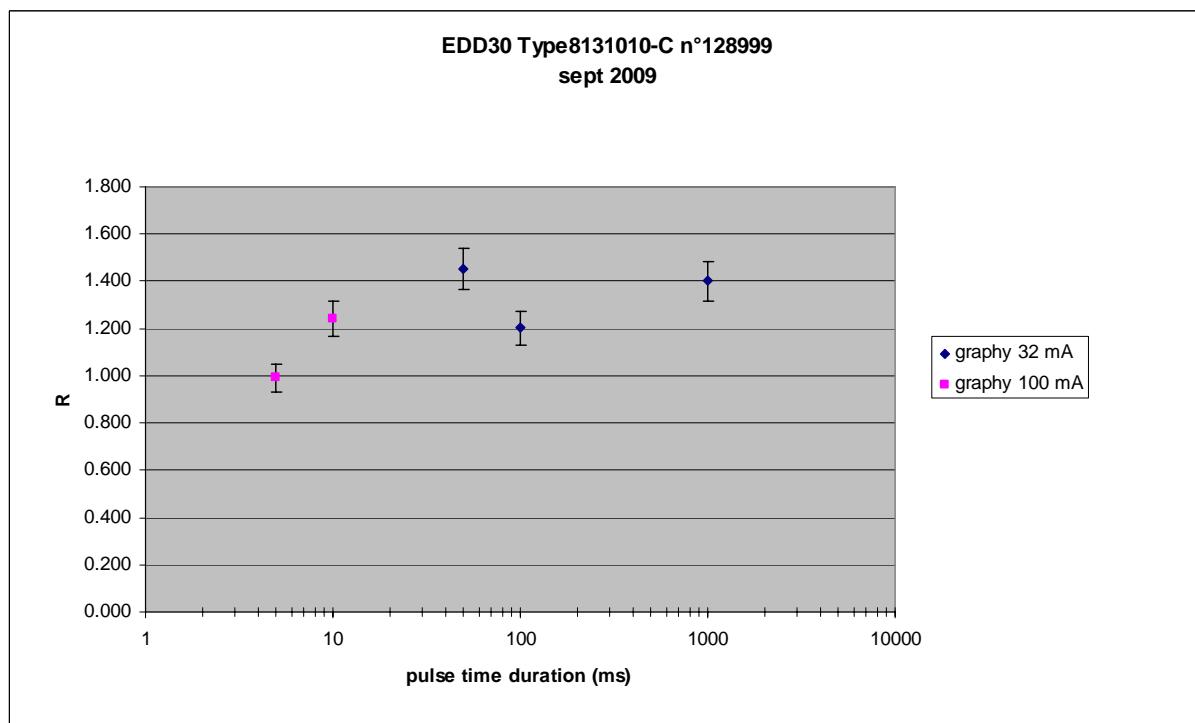


Figure 8c response of EDD30 in single-pulsed mode

4 Conclusion

The results are compatible with those achieved before [6]. The results show that it is important to add the tests in pulsed mode in Type-Test on APDs in IEC 61526 [7].

Except for Polimaster PM1621A, all APDs have silicon detector, then the difference of their responses is probably due to the time response of the electronics. The DIS has an “hybrid” technology between silicon and ionisation chamber which presents good results, on the other hand the procedure for annealing the detector is a constraint.

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- [1] Note technique LNHB 07/040 "Méthode DKRX1 : Etalonnage primaire d'un faisceau de RX basse et moyenne énergie en kerma et débit de kerma dans l'air", 2007.
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- [6] Intercomparison of Personal Dose Equivalent Measurements by Active Personal Dosimeters, Final Report of a joint IAEA-EURADOS Project, IAEA-TECDOC-1564, November 2007
- [7] International Standard, IEC 61526 (2005-02), Radiation protection instrumentation – Measurement of personal dose equivalents $H_p(10)$ and $H_p(0,07)$ for X, gamma, neutron and beta radiations – Direct reading personal dose equivalent meters and monitors

03/02/2009

DMC 2000 : N°374703L2

 $h_{pK}(10) = 1.65$ **Multi Pulses****10 pps**

mA	Nbr pulses	Reading (mSv)	Hp(10) (mSv)	R APD	mean R APD
20	80	0.509	0.521	0.977	0.985
	83	0.532	0.540	0.985	
	80	0.515	0.519	0.992	
32	83	0.753	0.847	0.889	0.884
	85	0.772	0.863	0.894	
	84	0.744	0.856	0.870	
100	85	1.130	2.492	0.454	0.455
	86	1.148	2.521	0.455	
	81	1.082	2.373	0.456	
400	82	0.839	8.200	0.102	0.099
	82	0.816	8.383	0.097	
	83	0.839	8.614	0.097	
800	79	0.487	22.133	0.022	0.022
	81	0.492	22.864	0.022	
	82	0.500	23.294	0.021	

20 pps

mA	Nbr pulses	Reading (mSv)	Hp(10) (mSv)	R APD	mean R APD
32	159	1.501	1.685	0.891	0.890
	160	1.501	1.687	0.890	
100	167	2.297	6.187	0.371	0.375
	167	2.336	6.174	0.378	

1 pps

mA	Nbr pulses	Reading (mSv)	Hp(10) (mSv)	R APD	mean R APD
32	40	0.289	0.442	0.654	0.653
	40	0.289	0.443	0.653	
	40	0.288	0.446	0.646	
	40	0.289	0.437	0.662	
	39	0.279	0.428	0.652	
100	40	0.412	1.505	0.274	0.276
	41	0.437	1.542	0.283	
	40	0.412	1.516	0.272	

Graphie

mA	Time (ms)	Reading (mSv)	Hp(10) (mSv)	R APD	mean R APD
32	20	0.007	0.010	0.702	0.688
		0.007	0.009	0.762	
		0.007	0.010	0.674	
		0.007	0.012	0.597	
		0.007	0.010	0.705	
	50	0.021	0.031	0.686	0.697
		0.020	0.029	0.699	
		0.021	0.027	0.768	
		0.020	0.030	0.669	
		0.019	0.029	0.664	
100	100	0.042	0.058	0.723	0.701
		0.040	0.054	0.738	
		0.035	0.057	0.615	
		0.040	0.060	0.671	
		0.041	0.054	0.758	
1000	1000	0.667	0.575	1.160	1.157
		0.544	0.573	0.950	
		0.909	0.574	1.584	
		0.648	0.578	1.122	
		0.558	0.577	0.967	

Table 5a : results of DMC 2000 N° 374703L2

03/02/2009 - 04/02/2009
 DMC2000 : N°374740L2

$h_{pk}(10) = 1.65 \text{ Sv/Gy}$

Multi Pulses

10 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
20	80	0.523	0.530	0.986	
	79	0.509	0.511	0.996	
	87	0.579	0.594	0.974	
32	81	0.695	0.828	0.839	0.846
	81	0.692	0.820	0.844	
	82	0.724	0.847	0.855	
100	80	1.070	2.948	0.363	0.361
	85	1.126	3.120	0.361	
	81	1.077	2.989	0.360	
400	79	0.901	7.138	0.126	0.120
	80	0.887	7.498	0.118	
	81	0.898	7.680	0.117	
800	79	0.494	21.664	0.023	0.023
	80	0.504	22.258	0.023	
	77	0.480	21.560	0.022	

20 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	148	1.610	1.496	1.076	1.070
	161	1.731	1.627	1.064	
100	159	2.617	5.832	0.449	0.453
	157	2.636	5.759	0.458	

1 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	41	0.342	0.445	0.769	0.757
	41	0.341	0.452	0.754	
	41	0.336	0.450	0.747	
100	39	0.479	1.471	0.326	0.332
	39	0.483	1.462	0.330	
	40	0.509	1.497	0.340	

Graphie

mA	Time (ms)	Reading (mSv)	$H_p(10)$ (mSv)	R APD	R APD moy
32	20	0.008	0.012	0.641	0.804
		0.008	0.012	0.653	
		0.008	0.008	1.010	
		0.008	0.010	0.836	
		0.007	0.008	0.881	
	50	0.021	0.031	0.682	0.738
		0.020	0.029	0.689	
		0.022	0.030	0.740	
		0.022	0.027	0.802	
		0.023	0.030	0.776	
	100	0.044	0.058	0.754	0.761
		0.038	0.058	0.652	
		0.045	0.057	0.793	
		0.045	0.056	0.799	
		0.044	0.055	0.806	
	1000	0.609	0.570	1.069	1.413
		0.937	0.574	1.632	
		1.021	0.573	1.782	
		0.673	0.575	1.170	
		0.813	0.575	1.413	

Table 5b : results of DMC 2000 N° 374740L2

05/02/2009
AT3509C : N°30434

$h_{pk}(10) = 1.65 \text{ Sv/Gy}$

Multi Pulses
10 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
20	86	0.235	0.563	0.418	0.407
	82	0.205	0.532	0.385	
	81	0.222	0.532	0.417	
32	80	0.213	0.808	0.264	0.272
	87	0.225	0.871	0.258	
	83	0.250	0.848	0.295	
100	84	0.210	2.572	0.082	0.082
	82	0.210	2.487	0.084	
	84	0.200	2.541	0.079	
400	87	0.040	8.780	0.005	0.005
	82	0.050	8.132	0.006	
	85	0.040	8.387	0.005	
800	86	0.000	23.554	0.000	0.000
	86	0.000	23.735	0.000	
	86	0.000	250.032	0.000	

20 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	162	0.625	1.676	0.373	0.356
	157	0.545	1.605	0.340	
100	158	0.600	4.962	0.121	0.132
	151	0.680	4.747	0.143	

1 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32		0.000	1.425	0.000	0.000
		0.000	0.000		
		0.000	0.000		
100		0.000	0.000	0.000	0.000
		0.000	0.000		
		0.000	0.000		

Graphie

mA	Time (ms)	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	20	0.000	0.011	0.000	0.000
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
	50	0.010	0.027	0.347	0.353
		0.009	0.028	0.332	
		0.009	0.027	0.342	
		0.010	0.029	0.337	
		0.010	0.024	0.405	
	100	0.021	0.056	0.373	0.365
		0.020	0.055	0.373	
		0.020	0.057	0.346	
		0.020	0.053	0.376	
		0.021	0.060	0.357	
	1000	0.152	0.575	0.264	0.887
		1.809	0.574	3.149	
		0.180	0.575	0.313	
		0.200	0.576	0.347	
		0.210	0.578	0.363	

Table 6a : results of AT3509C N°30434

05/02/2009
AT3509C : N°30433

$h_{\text{pk}}(10) = 1.65 \text{ Sv/Gy}$

Multi Pulses
10 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
20	81	0.153	0.540	0.284	0.280
	80	0.153	0.527	0.290	
	82	0.144	0.543	0.265	
32	85	0.150	0.875	0.172	0.176
	83	0.143	0.852	0.168	
	82	0.159	0.845	0.188	
100	83	0.158	3.058	0.052	0.051
	82	0.150	3.023	0.050	
	81	0.150	2.977	0.050	
400	82	0.000	12.231	0.000	0.000
	85	0.000	-0.009	0.000	
	84	0.000	-0.009	0.000	
800	86	0.000	24.981	0.000	0.000
	83	0.000	-0.009	0.000	
			-0.009	0.000	

20 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	163	0.370	1.678	0.221	0.222
	163	0.370	1.663	0.222	
100	162	0.420	5.950	0.071	0.074
	163	0.470	5.997	0.078	

1 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	39	0.000	0.436	0.000	0.000
		0.000	0.000		
		0.000	0.000		
100	40	0.000	1.522	0.000	0.000
		0.000	0.000		
		0.000	0.000		

Graphie

mA	Time (ms)	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	20	0.000	0.007	0.000	0.000
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
	50	0.007	0.028	0.252	0.101
		0.007	0.028	0.255	
		0.000	0.028	0.000	
		0.000	0.029	0.000	
			-0.009	0.000	
100	100	0.015	0.059	0.259	0.105
		0.015	0.058	0.264	
		0.000	0.053	0.000	
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
1000	1000	0.514	0.574	0.895	0.865
		1.146	0.570	2.010	
		0.180	0.569	0.316	
		0.110	0.570	0.193	
		0.520	0.570	0.913	

Table 6b : results of AT3509C N°30433

Multi Pulses

10 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
20	82	0.387	0.551	0.702	0.705
	86	0.402	0.567	0.709	
	83	0.390	0.554	0.704	
32	79	0.509	0.814	0.625	0.623
	79	0.506	0.812	0.623	
	80	0.512	0.823	0.622	
100	79	1.054	2.935	0.359	0.360
	84	1.121	3.115	0.360	
	84	1.121	3.106	0.361	
400	81	1.628	12.179	0.134	0.133
	81	1.629	12.191	0.134	
	82	1.641	12.366	0.133	
800	79	1.630	23.263	0.070	0.070
	83	1.700	24.351	0.070	
	85	1.730	24.721	0.070	

20 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	168	1.230	1.693	0.727	0.726
	169	1.240	1.707	0.726	
100	164	2.422	5.992	0.404	0.404
	162	2.407	5.963	0.404	

1 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	39	0.242	0.430	0.563	0.472
	39	0.243	0.428	0.567	
	39	0.240	0.430	0.558	
100	38	0.478	1.428	0.335	0.334
	40	0.506	1.512	0.335	
	39	0.494	1.480	0.334	

Graphie

mA	Time (ms)	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	20	0.006	0.008	0.792	0.624
		0.006	0.011	0.545	
		0.007	0.011	0.619	
		0.006	0.010	0.588	
		0.006	0.010	0.576	
	50	0.018	0.025	0.716	0.622
		0.016	0.026	0.613	
		0.017	0.027	0.628	
		0.018	0.031	0.574	
		0.017	0.029	0.580	
	100	0.035	0.054	0.643	0.627
		0.036	0.056	0.647	
		0.034	0.056	0.603	
		0.035	0.057	0.616	
		0.034	0.054	0.628	
	1000	0.435	0.576	0.755	0.751
		0.410	0.574	0.715	
		0.439	0.574	0.764	
		0.417	0.573	0.728	
		0.459	0.578	0.793	

Table 7a : results of EPD Mk 2.3 N°00070388

Multi Pulses

10 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
20	85	0.425	0.557	0.762	0.765
	81	0.404	0.533	0.758	
	83	0.414	0.535	0.774	
32	81	0.580	0.819	0.708	0.710
	87	0.634	0.900	0.705	
	87	0.650	0.906	0.718	
100	80	1.127	2.515	0.448	0.455
	81	1.145	2.507	0.457	
	82	1.141	2.477	0.461	
400	81	1.530	8.237	0.186	0.185
	82	1.547	8.383	0.185	
	79	1.493	8.144	0.183	
800	82	1.600	22.838	0.070	0.070
	80	1.570	22.423	0.070	
	83	1.630	23.136	0.070	

20 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	170	2.920	1.729	1.689	1.219
	159	1.200	1.603	0.749	
100	169	2.630	5.277	0.498	0.500
	174	2.850	5.686	0.501	

1 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	39	0.265	0.429	0.618	0.513
	39	0.262	0.424	0.617	
	39	0.260	0.437	0.595	
100	40	0.568	1.509	0.377	0.356
	39	0.522	1.465	0.356	
	39	0.496	1.482	0.335	

Graphie

mA	Time (ms)	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	20	0.007	0.010	0.729	0.643
		0.006	0.009	0.697	
		0.006	0.010	0.613	
		0.007	0.012	0.595	
		0.006	0.010	0.580	
	50	0.018	0.031	0.589	0.599
		0.018	0.029	0.622	
		0.018	0.030	0.607	
		0.017	0.031	0.557	
		0.018	0.029	0.622	
	100	0.037	0.056	0.655	0.656
		0.036	0.051	0.706	
		0.036	0.058	0.618	
		0.037	0.058	0.640	
		0.036	0.054	0.661	
	1000	0.412	0.575	0.716	0.742
		0.451	0.577	0.781	
		0.410	0.576	0.712	
		0.446	0.572	0.780	
		0.413	0.572	0.721	

Table 7b : results of EPD Mk 2.3 N°00070389

$$h_{pk}(10) = 1.65 \text{ Sv/Gy}$$

Multi Pulses

10 pps

mA	Nbr pulses	Reading (μSv)	Hp(10) (mSv)	R APD	mean R APD
20	82	0.040	0.555	0.000	0.000
	86	0.040	0.582	0.000	0.000
	81	0.050	0.546	0.000	0.000
32	83	0.030	0.848	0.000	0.000
	82	0.040	0.000	0.000	0.000
	81	0.030	0.000	0.000	0.000
100	85	0.030	3.138	0.000	0.000
	82	0.030	0.000	0.000	0.000
	82	0.030	0.000	0.000	0.000
400	82	0.020	12.272	0.000	0.000
		-0.430	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
800	83	0.050	24.341	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000

20 pps

mA	Nbr pulses	Reading (μSv)	Hp(10) (mSv)	R APD	mean R APD
32	163	0.110	1.683	0.000	0.000
	167	0.130	0.000	0.000	0.000
100	162	0.080	5.993	0.000	0.000
	174	0.090	0.000	0.000	0.000

1 pps

mA	Nbr pulses	Reading (μSv)	Hp(10) (mSv)	R APD	mean R APD
32	40	0.010	0.458	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
100	39	0.010	1.481	0.000	0.000
			0.000	0.000	0.000
		0.000	0.000	0.000	0.000

Graphie

mA	Time (ms)	Reading (μSv)	Hp(10) (mSv)	R APD	mean R APD
32	20	0.010	0.0000	0.0000	0.0000
			0.0000		
		0.000	0.0000		
		0.000	0.0000		
		0.000	0.0000		
	50	0.000	0.0000	0.0000	0.0000
		0.000	0.0000		
		0.000	0.0000		
		0.000	0.0000		
		0.000	0.0000		
	100	0.000	0.0000	0.0000	0.0000
		0.000	0.0000		
		0.000	0.0000		
		0.000	0.0000		
		0.000	0.0000		
	1000	0.000	0.0000	0.0000	0.0000
		0.000	0.0000		
		0.000	0.0000		
		0.000	0.0000		
		0.000	0.0000		

Table 8a : results of PM1621A N°61983

06/02/2009
POLYMASTER PM1621A : n°62002

$$h_{pk}(10) = 1.65 \text{ Sv/Gy}$$

Multi Pulses

10 pps

mA	Nbr pulses	Reading (μSv)	Hp(10) (mSv)	R APD	mean R APD
20		0.080	0.495	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
32		0.040	0.782	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
100		0.020	2.367	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
400		0.030	8.214	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
800		0.020	21.151	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000

20 pps

mA	Nbr pulses	Reading (μSv)	Hp(10) (mSv)	R APD	mean R APD
32		0.460	1.681	0.000	0.000
		0.000	0.000	0.000	0.000
100		0.120	16.140	0.000	0.000
		0.000	0.000	0.000	0.000

1 pps

mA	Nbr pulses	Reading (μSv)	Hp(10) (mSv)	R APD	mean R APD
32		0.020	0.434	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
100		0.010	1.204	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000

Graphie

mA	Time (ms)	Reading (μSv)	Hp(10) (mSv)	R APD	mean R APD
32	20	0.000	0.017	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
	50	0.000	0.034	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
	100	0.000	0.063	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
	1000	0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000

Table 8a : results of PM1621A N°62002

Multi Pulses
10 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
20	83	0.390	0.556	0.702	0.704
	81	0.350	0.529	0.662	
	81	0.400	0.534	0.749	
32	82	0.660	0.836	0.789	0.764
	84	0.620	0.867	0.715	
	78	0.650	0.825	0.787	
100	82	2.300	3.003	0.766	0.771
	83	2.370	3.070	0.772	
	84	2.410	3.104	0.776	
400	86	9.540	12.633	0.755	0.762
	82	9.370	12.425	0.754	
	83	9.760	12.573	0.776	
800	81	18.690	24.012	0.778	0.782
	83	19.360	24.630	0.786	
#VALEUR!					

20 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	158	1.270	1.645	0.772	0.771
	155	1.219	1.585	0.769	
100	153	4.710	5.594	0.842	0.840
	159	4.890	5.833	0.838	

1 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	39	0.190	0.438	0.434	0.640
	39	0.340	0.433	0.785	
	38	0.300	0.428	0.701	
100	39	1.180	1.462	0.807	0.772
	38	1.060	1.432	0.740	
	39	1.130	1.469	0.769	

Graphie

mA	Time (ms)	Reading (mSv)	$H_p(10)$ (mSv)	R APD	mean R APD
32	20	0.000	0.008	0.000	0.000
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
	50	0.000	0.030	0.000	0.000
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
		0.000	-0.009	0.000	
100	100	0.030	0.054	0.551	0.745
		0.040	0.056	0.709	
		0.050	0.058	0.857	
		0.050	0.054	0.925	
		0.040	0.059	0.682	
	1000	0.450	0.568	0.792	0.812
		0.510	0.571	0.893	
		0.430	0.566	0.760	
		0.470	0.569	0.826	
		0.450	0.571	0.788	

Table 9a : results of DIS 100 N°270039

Multi Pulses
10 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R/APD	mean R/APD
20	79	0.340	0.523	0.650	0.791
	81	0.470	0.528	0.890	
	83	0.450	0.541	0.833	
32	83	0.720	0.871	0.827	0.834
	80	0.680	0.820	0.829	
	83	0.720	0.851	0.846	
100	78	2.600	2.873	0.905	0.897
	84	2.750	3.104	0.886	
	84	2.790	3.101	0.900	
400	79	10.220	11.870	0.861	0.853
	80	10.200	12.010	0.849	
	80	10.160	11.991	0.847	
800	81	20.000	23.735	0.843	0.789
	80	17.260	23.466	0.736	
		#VALEUR!	-0.009		

20 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R/APD	mean R/APD
32	-	1.220	1.465	0.833	0.883
	-	1.480	1.586	0.933	
100	162	4.060	4.408	0.921	0.918
	166	4.210	4.603	0.915	

1 pps

mA	Nbr pulses	Reading (mSv)	$H_p(10)$ (mSv)	R/APD	mean R/APD
32	38	0.320	0.390	0.820	0.824
	39	0.310	0.393	0.790	
	39	0.330	0.382	0.863	
100	38	0.970	1.121	0.865	0.881
	39	1.020	1.144	0.892	
	38	0.960	1.083	0.887	

Graphie

mA	Time (ms)	Reading (mSv)	$H_p(10)$ (mSv)	R/APD	mean R/APD
32	20	0.010	0.008	1.232	1.232
		0.000	-0.009		
		0.000	-0.009		
		0.000	-0.009		
		0.000	-0.009		
	50	0.030	0.028	1.089	0.726
		0.010	0.028		
		0.000	-0.009		
		0.000	-0.009		
		0.000	-0.009		
	100	0.030	0.057	0.529	0.734
		0.040	0.055		
		0.040	0.057		
		0.040	0.052		
		0.050	0.053		
	1000	0.540	0.564	0.958	0.905
		0.510	0.560		
		0.450	0.564		
		0.540	0.568		
		0.510	0.563		

Table 9b : results of DIS 100 N°270038

10/02/2009
 Panasonic EDM III : N°2710977
 $h_{pk}(10) = 1.65 \text{ Sv/Gy}$

Multi Pulses

10 pps

mA	Nbr pulses	Reading (mSv)	H _p (10) (mSv)	RAPD	mean RAPD
20	81	0.616	0.486	1.268	1.289
	80	0.676	0.519	1.303	
	79	0.668	0.516	1.296	
32	85	1.279	0.858	1.490	1.577
	78	1.155	0.786	1.470	
	78	1.406	0.793	1.772	
100	76	3.645	2.773	1.314	1.464
	86	4.345	2.581	1.684	
	76	3.880	2.786	1.393	
400	87	6.410	13.808	0.464	0.464
	77	5.070	10.862	0.467	
	78	5.130	11.157	0.460	
800	79	2.560	23.043	0.111	0.109
	87	2.730	25.361	0.108	
	79	2.500	23.117	0.108	

20pps

mA	Nbr pulses	Reading (mSv)	H _p (10) (mSv)	RAPD	mean RAPD
32	159	2.750	1.635	1.682	1.685
	164	2.840	1.683	1.688	
100	161	8.240	5.930	1.390	1.393
	161	8.250	5.904	1.397	

1 pps

mA	Nbr pulses	Reading (mSv)	H _p (10) (mSv)	RAPD	mean RAPD
32	38	0.660	0.433	1.524	1.544
	38	0.660	0.424	1.556	
	38	0.670	0.432	1.552	
100	38	1.950	1.430	1.363	1.362
	40	2.040	1.504	1.356	
	38	2.010	1.472	1.365	

Graphie

mA	Time (ms)	Reading (mSv)	H _p (10) (mSv)	RAPD	mean RAPD
32	20	0.017	0.010	1.668	1.212
		0.017	0.008	2.238	
		0.017	0.008	2.157	
		0.000	0.009	0.000	
		0.000	0.009	0.000	
	50	0.045	0.024	1.880	1.054
		0.047	0.027	1.734	
		0.044	0.027	1.656	
		-0.009	0.000	0.000	
		0.000	-0.009	0.000	
	100	0.087	0.057	1.539	0.930
		0.086	0.054	1.595	
		0.085	0.056	1.516	
		-0.009	0.000	0.000	
		0.000	-0.009	0.000	
	1000	0.850	0.568	1.496	1.472
		0.840	0.572	1.468	
		0.840	0.575	1.461	
		0.840	0.572	1.467	
		0.840	0.572	1.468	

Table 10a : results of EDM III N°2710977

mA	Time (ms)	Reading (mSv)	Hp(10) (mSv)	R APD	Mean R APD
100	5	0.014	0.009	1.576	2.190
		0.014	0.006	2.477	
		0.014	0.006	2.517	
	10	0.027	0.014	1.877	1.912
		0.027	0.013	2.086	
		0.028	0.016	1.772	
400	1	0.001	0.003	0.313	0.057
		0.001	-0.002	-0.499	
		0.001	0.003	0.357	
	5	0.001	0.034	0.029	0.030
		0.001	0.033	0.030	
		0.001	0.034	0.029	
	10	0.015	0.075	0.200	0.200
	20	0.065	0.143	0.453	0.453

Table 10a : results of EDM III N°2710977 (continued)

Multi Pulses
10 pps

mA	Nbr pulses	Reading (mSv)	H _p (10) (mSv)	RAPD	RAPD moy
20	82	0.716	0.544	1.315	1.318
	80	0.696	0.526	1.323	
	81	0.699	0.531	1.316	
32	78	1.227	0.787	1.557	1.590
	82	1.367	0.837	1.632	
	86	1.387	0.877	1.582	
100	78	3.708	2.853	1.300	1.299
	77	3.661	2.815	1.300	
	78	3.700	2.854	1.297	
400	78	5.500	11.048	0.498	0.496
	79	5.560	11.245	0.494	
	76	5.360	10.809	0.496	
800	77	3.270	21.699	0.151	0.152
	77	3.270	21.697	0.151	
	76	3.290	21.381	0.154	

20pps

mA	Nbr pulses	Reading (mSv)	H _p (10) (mSv)	RAPD	RAPD moy
32	157	2.550	1.600	1.594	1.598
	157	2.590	1.616	1.602	
100	153	7.320	5.598	1.308	1.305
	151	7.170	5.505	1.302	

1 pps

mA	Nbr pulses	Résultat (mSv)	H _p (10) (mSv)	RAPD	RAPD moy
32	39	0.640	0.436	1.469	1.495
	39	0.640	0.425	1.507	
	39	0.660	0.437	1.509	
100	39	1.870	1.469	1.273	1.274
	38	1.840	1.441	1.277	
	39	1.870	1.471	1.271	

Graphie

mA	Time (ms)	Résultat (mSv)	H _p (10) (mSv)	RAPD	RAPD moy
32	20	0.013	0.006	2.256	1.174
		0.014	0.009	1.637	
		0.013	0.007	1.977	
		-0.009	0.000		
		-0.009	0.000		
	50	0.037	0.030	1.251	0.826
		0.038	0.025	1.512	
		0.037	0.027	1.369	
	100	0.078	0.057	1.363	0.832
		0.074	0.054	1.381	
		0.075	0.053	1.418	
	1000	0.800	0.574	1.395	0.848
		0.810	0.570	1.422	
		0.810	0.569	1.422	

Table 10b : results of EDM III N°27104016

mA	Time (ms)	Résultat (mSv)	Hp(10) (mSv)	R APD	mean R APD
100	5	0.012	0.009	1.300	1.870
		0.013	0.006	2.243	
		0.012	0.006	2.066	
	10	0.024	0.021	1.163	2.489
		0.026	0.014	1.839	
		0.025	0.006	4.464	
400	1	0.002	0.006	0.330	0.374
		0.002	0.006	0.363	
		0.002	0.005	0.428	
	5	0.019	0.034	0.566	0.587
		0.02	0.033	0.610	
		0.02	0.034	0.587	
	10	0.052	0.073	0.712	0.715
		0.052	0.072	0.721	
		0.051	0.072	0.711	
	20	0.105	0.146	0.719	0.712
		0.103	0.149	0.692	
		0.107	0.147	0.727	

Table 10b : results of EDM III N°27104016 (continued)

EDD30 n° 8131010-C n°128999

29/09/2009

 $h_{pK}(10) = 1.65$

Sv/Gy

Multi Pulses**10 pps**

mA	Nb pulses	Reading (mSv)	Hp(10) (mSv)	R APD	mean R APD
20	82	0.4685	0.3374	1.389	1.386
	79	0.4714	0.3402	1.386	
	80	0.5101	0.3686	1.384	
32	79	0.707	0.5111	1.383	1.368
	81	0.725	0.5357	1.353	
	83	0.74	0.5407	1.369	
100	79	2	1.5450	1.110	1.105
	81	1.758	1.5975	1.100	
	82	1.779	1.6096	1.105	
400	81	1.926	5.5453	0.347	0.346
	76	1.817	5.2792	0.344	
	82	1.959	5.6580	0.346	
800	78	1.928	14.7128	0.131	0.131
	80	1.978	15.1225	0.131	
	84	2	15.7449	0.132	

20 pps

mA	Nb pulses	Reading (mSv)	Hp(10) (mSv)	R APD	mean R APD
32	163	1.656	1.1775	1.406	1.394
	160	1.672	1.2097	1.382	
100	169	3.599	3.6378	0.989	0.991
	171	3.643	3.6677	0.993	

1 pps

mA	Nb pulses	Reading (mSv)	Hp(10) (mSv)	R APD	mean R APD
32	38	0.4157	0.3019	1.377	1.307
	38	0.4296	0.3096	1.388	
	39	0.4537	0.3918	1.158	
100	38	0.901	1.0139	0.889	0.843
	36	0.884	1.0580	0.836	
	39	0.912	1.1323	0.805	

Graphie

mA	time (ms)	Reading (mSv)	Hp(10) (mSv)	R APD	mean R APD
32	20	0.01029	0.0017	6.180	4.295
		0.01036	0.0000		
		0.01036	0.0043	2.409	
	50	0.02715	0.0180	1.510	1.452
		0.02707	0.0187	1.446	
		0.02687	0.0192	1.399	
	100	0.0539	0.0385	1.401	1.202
		0.054	0.0499	1.081	
		0.0538	0.0478	1.125	
	1000	0.536	0.3873	1.384	1.400
		0.5412	0.3863	1.401	
		0.55	0.3884	1.416	
100	5	0.008	0.0043	1.860	0.992
		0.008	0.0158	0.505	
		0.009	0.0147	0.613	
	10	0.016	0.0141	1.134	1.244
		0.015	0.0119	1.262	
		0.016	0.0120	1.337	

Table 13 : results of EDD30 N°81310010

ÉDITÉ PAR
LA DIRECTION DES SYSTÈMES
D'INFORMATION

CEA / SACLAY 91191 GIF-SUR-YVETTE CEDEX FRANCE