

# Multipurpose real-time Flash IOERT dose detector

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**H.U.B**

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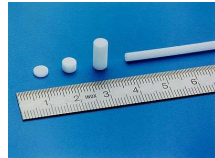


INTERNATIONAL SOCIETY of  
INTRAOERATIVE RADIATION THERAPY

7/11/2024

### Alanine Dosimeter

- ✓ Dose rate independent
- ✓ Linear response over large dose range
- ✗ Offline measure



### Thermoluminescent detector

- ✓ Dose rate independent
- ✓ Measurement usually limited to point
- ✗ Offline measure



### Radiochromic film

- ✓ Dose rate independent
- ✓ High Spatial resolution
- ✗ Offline measure



### Ionization chambers

- ✓ Direct-reading detector
- ✗ Dose rate dependant (use limit SSD 100)



### Diamant detector

- ✓ Direct-reading detector
- ✓ Adapted to relative dosimetry
- ✗ Very expensive



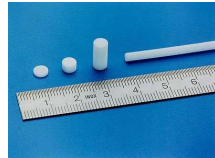
### Diode detector

- ✓ Direct-reading detector
- ✓ Not too expensive
- ✗ ??????



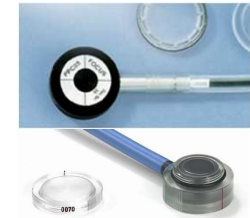
### Alanine Dosimeter

- ✓ Dose rate independent
- ✓ Linear response over large dose range
- ✗ Offline measure



### Ionization chambers

- ✓ Direct-reading detector
- ✗ Dose rate dependant (use with minimal 100cm SSD only)



### Thermoluminescent detector

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#### TLD 100 (10Gy max)



### Radiochromic film

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- ✓ High Spatial resolution
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#### EBT-XD (40Gy max)



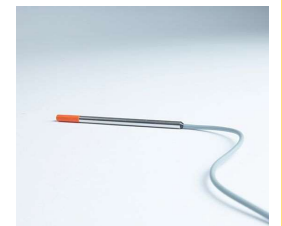
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## Elekta VersaHD accelerator



### Reference Beam

9MeV  
6Gy/min@Max  
SSD 100cm  
field 10cmx10cm  
400pulses/s(Hz) of 0,25mGy

Use to calibrate Film EBT-XD and TLD

## IntraOp Mobetron



### Conventional Mode

6MeV, 9MeV and 12MeV  
10Gy/min@Max  
SSD 50cm  
Applicator Diam. 4 to 10cm  
30pulses/s of 5,5mGy



console to select pulse  
width and frequency

### Flash Mode

6MeV and 9MeV  
SSD 50, 49, 40 or 23,3cm  
0,5, 1, 1,2, 2, 3 or 4us/pulse  
5, 10, 15, 30, 45, 60, 75, 90 or 120pulses/s(Hz)  
0,9 to 4Gy/pulse

eFlash pulse studied: 2us 90Hz 9MeV  
(used by researchers)

## Materials and Methods: applicators

### Intra-operative RT

SSD: 50cm



Diameters

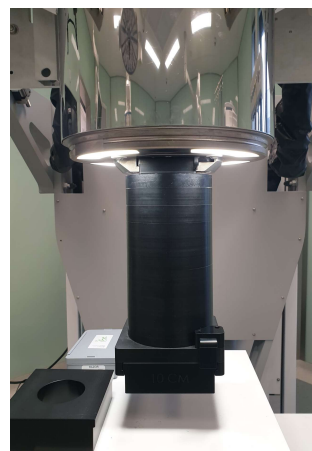
4-4.5-5-5.5-6-6.5-7...10cm

2us pulse dose

1.4Gy....0.9Gy

### Ultra-High Dose Rate (External RT with 5cm air gap)

SSD: 49cm



6-7-8-9-10cm

0.95Gy....1Gy

SSD: 40cm



2.5-3-3.5-4-4.5-5-6 cm

1.4Gy....1.8Gy

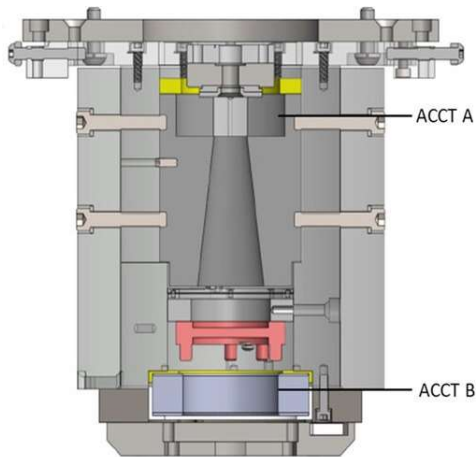
SSD: 23.3cm



2.5-3-3.5-4-4.5-5-6cm

4.1Gy....3.5Gy

## Two current transformers (upper and lower ACCT)



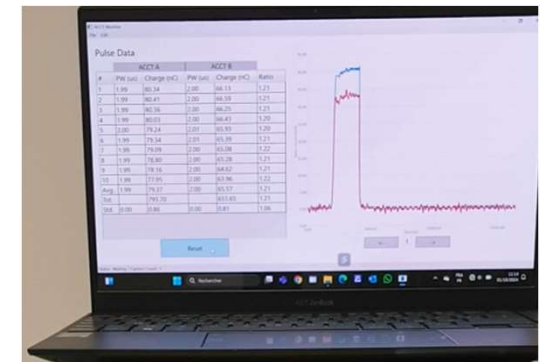
- Upper ACCT gives a very good image of the accelerator output at a fixed energy level.
- We don't use the Lower ACCT because its response is too influenced by the applicator.

## PicoScope (Pico Technology)

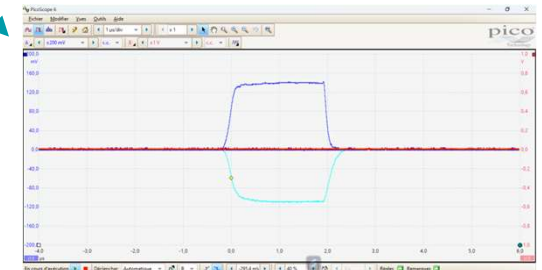
oscilloscope for measuring  
signals via a 50 ohm load



## Software to integrate ACCT (ACCT Monitor - IntraOp)



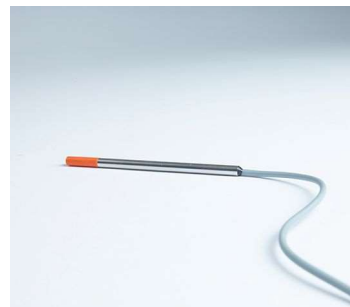
## Software to analyze signals (PicoScope)



Old in-vivo diodes (IBA)



Razor diode (IBA)



DPD3 in-vivo electrometer (IBA)

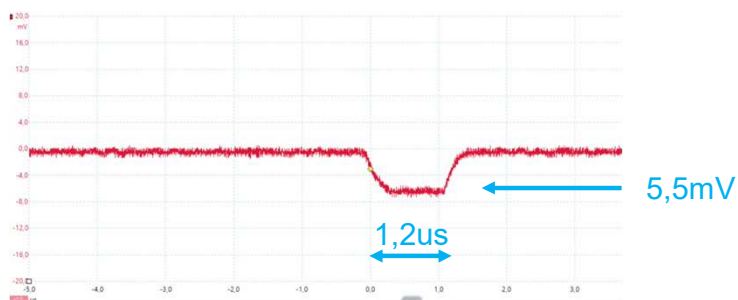


Dose-X electrometer (IBA)

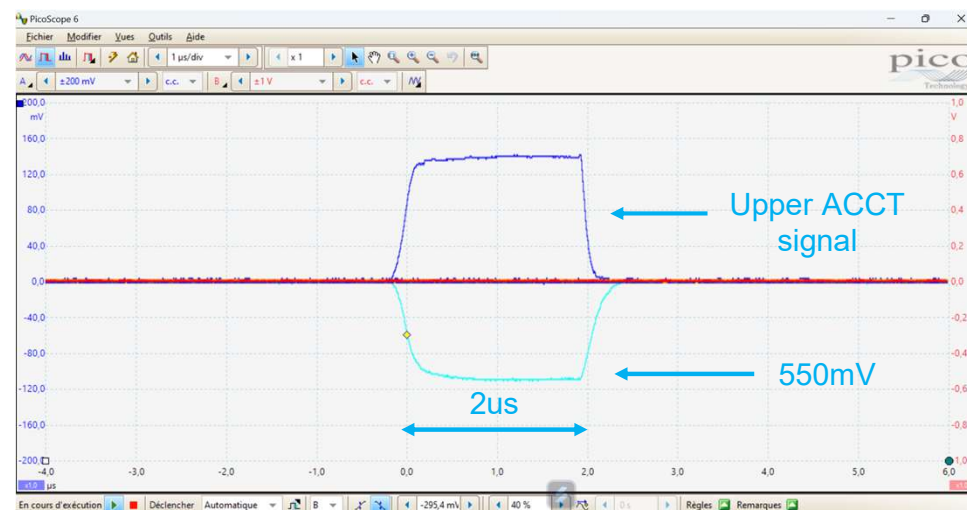


## Results: In-vivo Diode at SSD 50cm

### Conventional Pulse 9MeV 5.5mGy/pulse



### eFlash Pulse 9MeV 920mGy/pulse



The ratio of the areas of the 2 pulses corresponds to the dose ratio measured by film



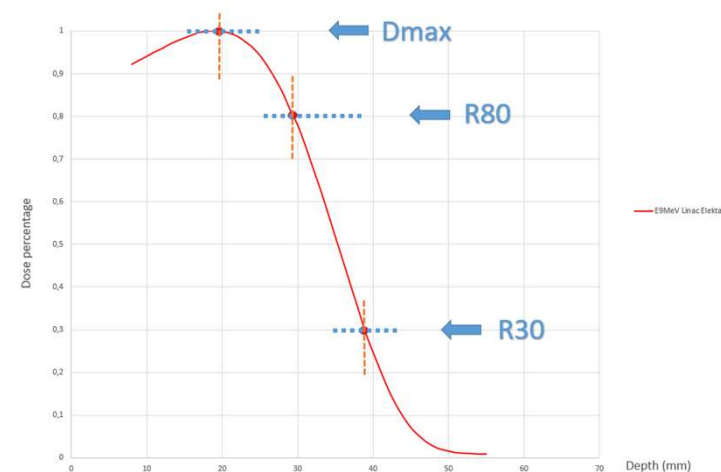
## Result: Electrometer choice

- Our PTW electrometers saturate (maximum current accepted too low) without Flash Adapter.
- Surprisingly, our old DPD3 in-vivo electrometer does not saturate . Therefore, we create a plastic phantom to control energy and dose at the same time with the three channels accessible.
- The control is based on IntraOp's acceptance test looking at R80 and R30 of the PDD

Beam Energy	Nominal Energy	Depth Dose: 80%	Depth Dose: 30%	X-Ray Contamination
6 UHDR	6 MeV	2.0 +/- 0.3 cm	< 3.0 cm	≤ 2%
9 UHDR	9 MeV	3.0 +/- 0.3 cm	< 4.3 cm	≤ 2%

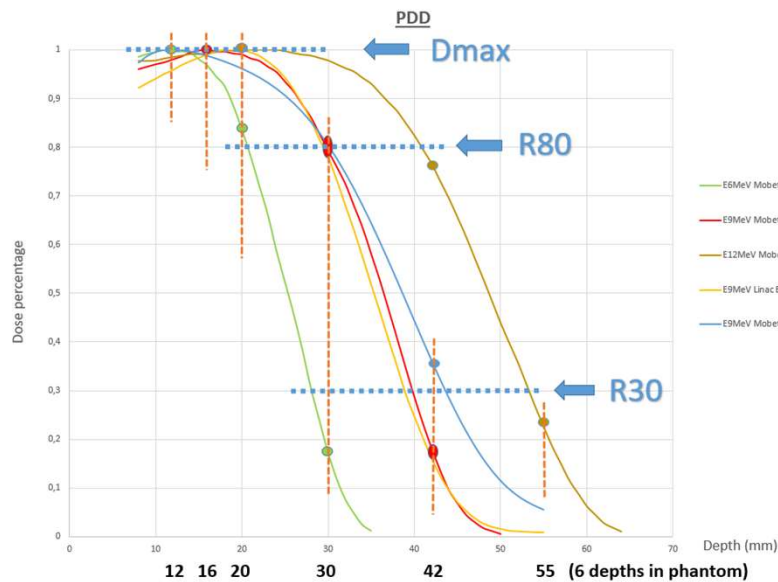
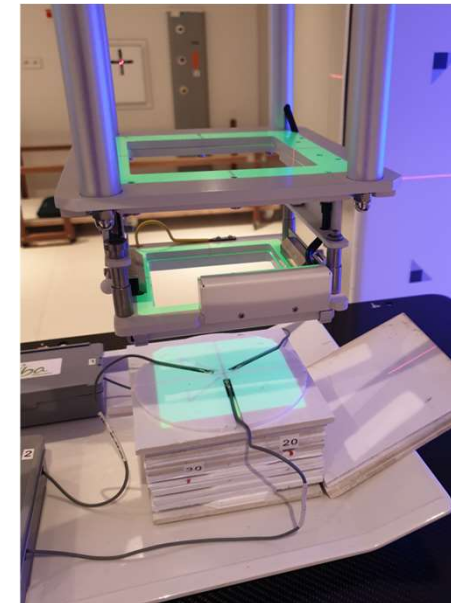
4.1 BEAM ENERGY						
Beam Energy Selection	Dmax (cm)	Dmax (typical) Informative	R80 (cm)	R80 (Limits)	R30 (cm)	R30 (Limits)
6 MeV		+/- 1,3 cm		2,0 +/- 0,2 cm		< 2,9 cm
9 MeV		+/- 1,9 cm		3,0 +/- 0,2 cm		< 4,2 cm
12 MeV		+/- 2,4 cm		4,0 +/- 0,2 cm		< 5,6 cm

- Disassembly and shaping of 3 diodes

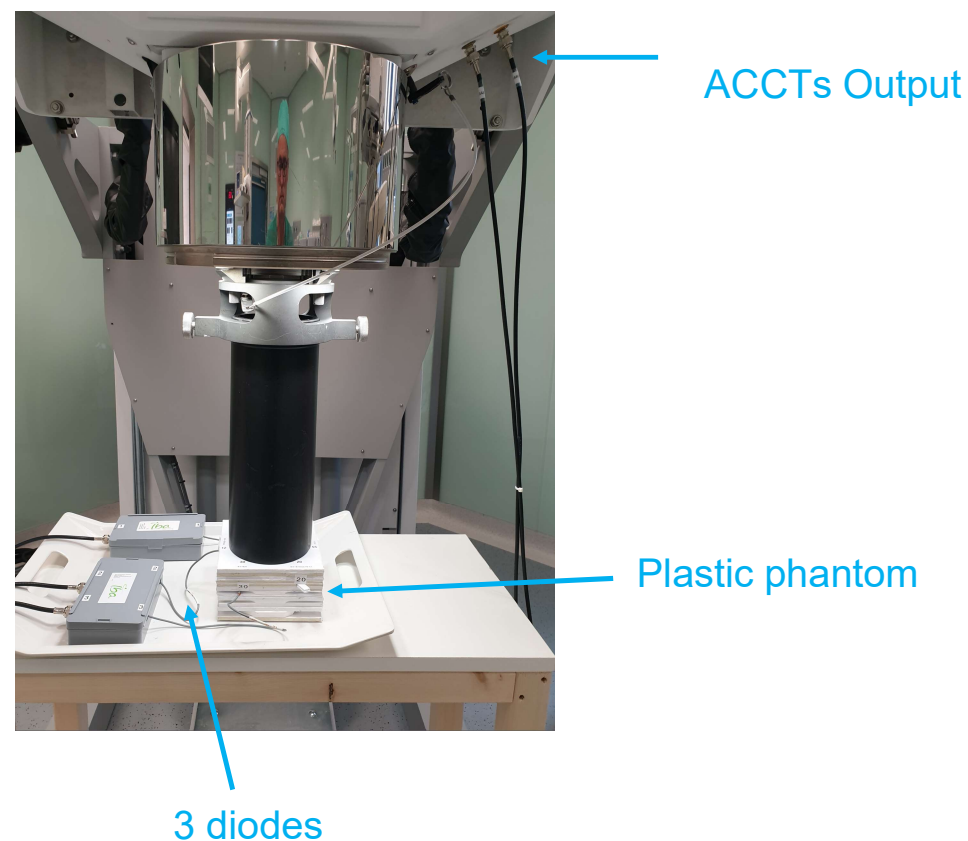
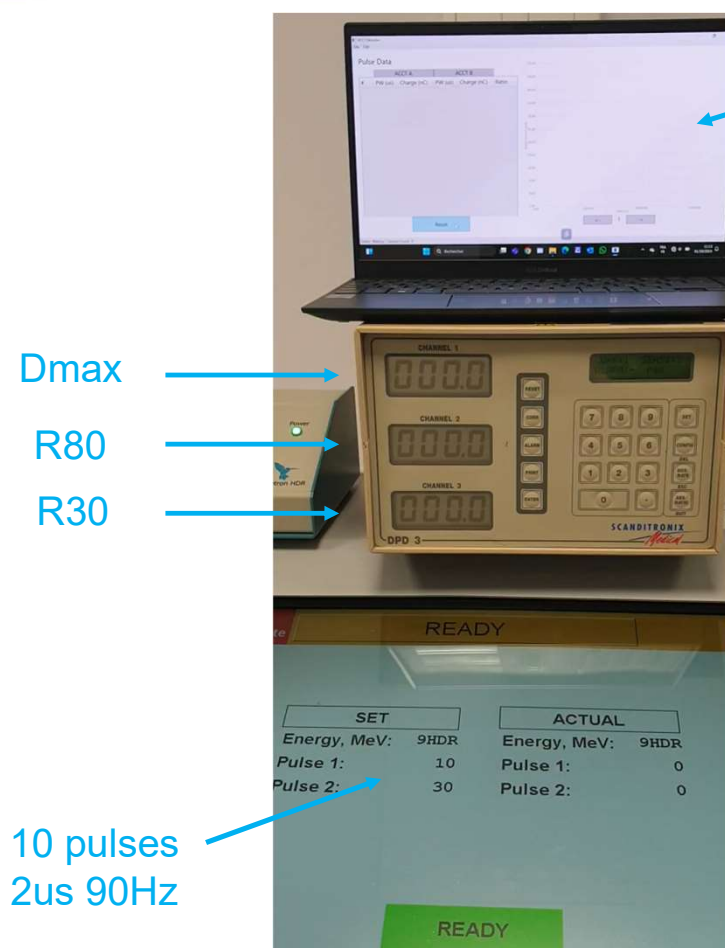


## Calibration of 3 diodes and electrometer

- Calibration of the 3 channels of the in-vivo electrometer on the Elekta accelerator in cGy @ Dmax of the conventional 9MeV beam.
- The plastic phantom is fitted with 6 entry points of different depths (12 16 20 30 42 55mm) to cover the maxima, R80 and R30 of all Mobetron conventional and Flash energies.



## Result: Demonstration



## Conclusions (In-vivo Diode)

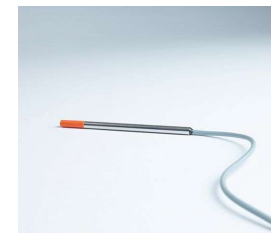
- Highly sensitive, in-vivo diodes can be used at distances of 49 and 50cm, but saturate at 40cm and above.
- In Flash mode, they overestimate the dose by around 4% compared with EBT-XD films.
- The plastic phantom allows extremely fast energy control and adjustment.
- It enabled us to observe and confirm a variation in energy with pulse width.

13	Date	D1	D2	D3	Upper	DoseD/p80nc
14	08-08-24	535,3	460,8	268,5	413,7	
15		597,5	486,2	241,1	483,7	
16		934,1	722,2	310,4	783,7	95,4
17		746,9	526,7	187,3	672,1	

R80	R30	
86,1%	50,2%	20P 0,5us
81,4%	40,4%	10P 1,2us
77,3%	33,2%	10P 2us
70,5%	25,1%	5P 4us

## Results: Razor Diode

- The Razor diode is 6 times less sensitive (4nC/Gy) than the in-vivo diode and does not saturate at SSD 40 and 23.3cm.
- In flash mode, it overestimates the dose by around 9% compared with EBT-XD films.
- The IBA electrometer (Dose X) in 'low' mode is able to correctly integrate the Razor diode signal at the highest achievable Mobetron dose rate (peak current up to 8mA),
- Thanks to the use of the Razor diode, essential information for eFlash dosimetry was easily observed and confirmed :
  - dose per pulse slightly dependent on number of pulses



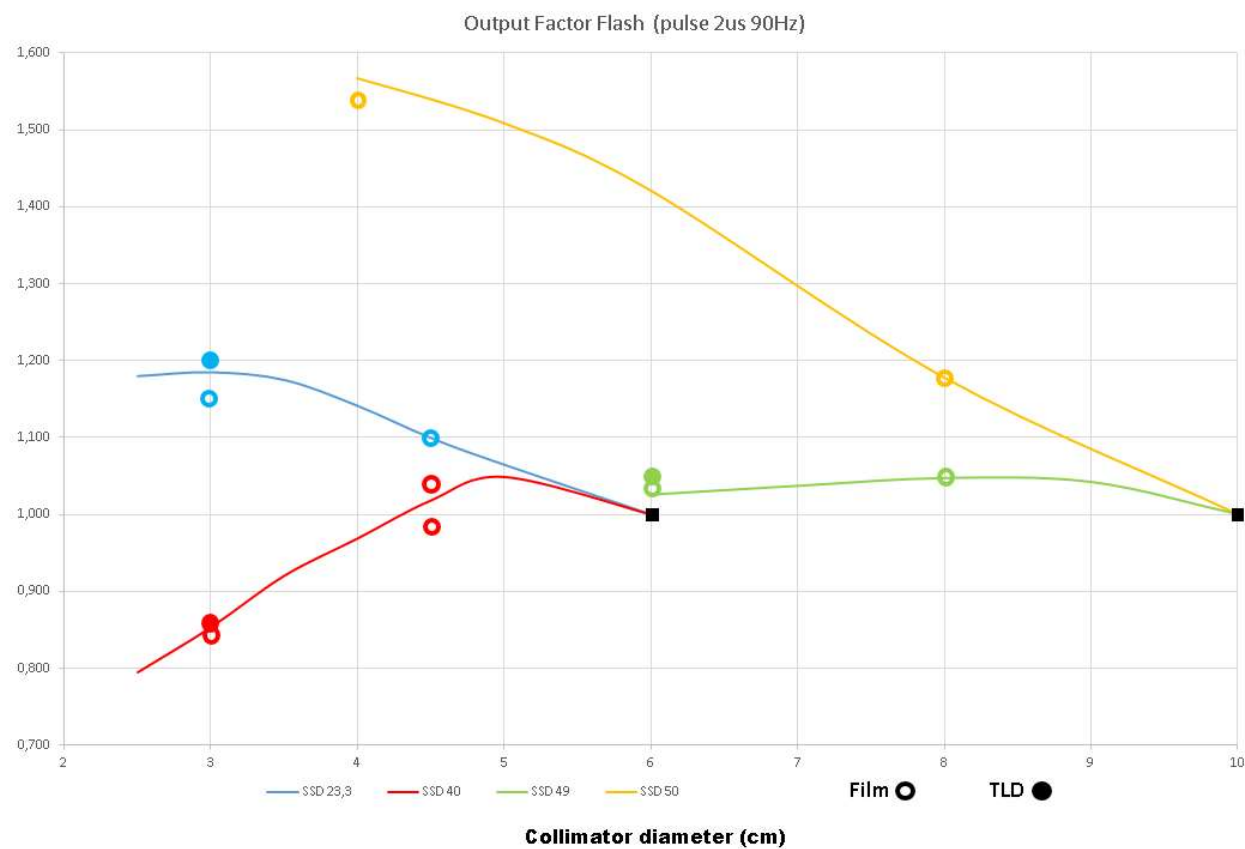
DSP50 90Hz 2us				
pulse number	Razor(nC)	ACCT up	nC/Pulse	nC Razor/nC Upper
2	7,38	161,7	3,69	0,0456
5	18,35	401,1	3,67	0,0457
10	36,54	795,1	3,65	0,0460
20	70,94	1557,1	3,55	0,0456
40	140,5	3086,7	3,51	0,0455



- dose per pulse also sensitive to frequency.

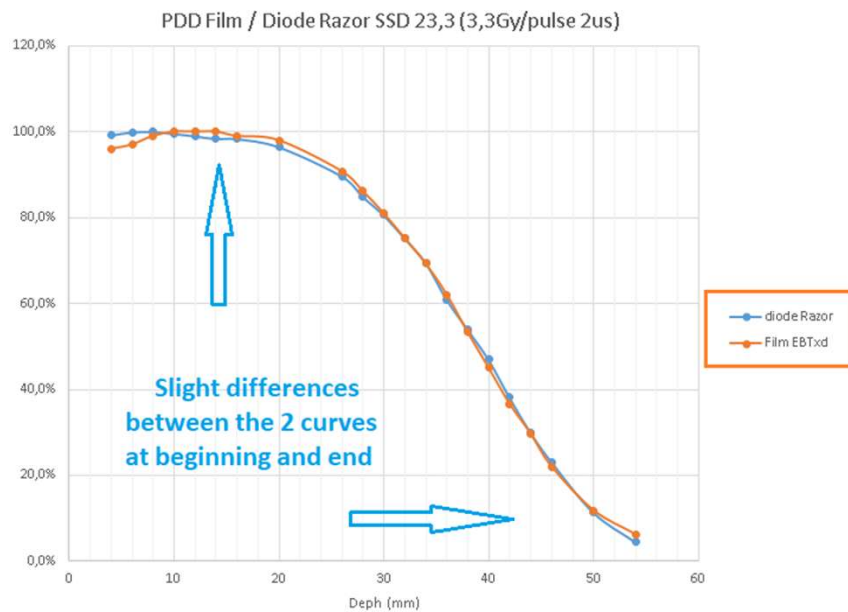
DSP50 10 Pulses 2us				
Frequency	Razor(nC)	ACCT up	nC/Pulse	nC Razor/nC Upper
5Hz	37,34	805,4	3,73	0,0464
10Hz	37,53	807,5	3,75	0,0465
30Hz	37,28	804	3,73	0,0464
60Hz	36,53	792,9	3,65	0,0461
90Hz	35,85	784,5	3,59	0,0457

# Output Factor with Razor Diode

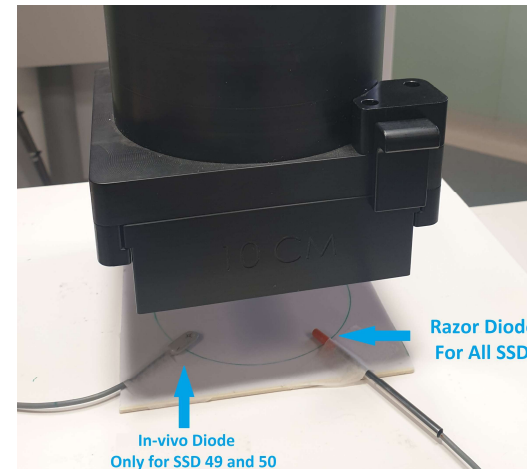


4 curves differently evolving

## PDD measurement



## Use as in-vivo diode

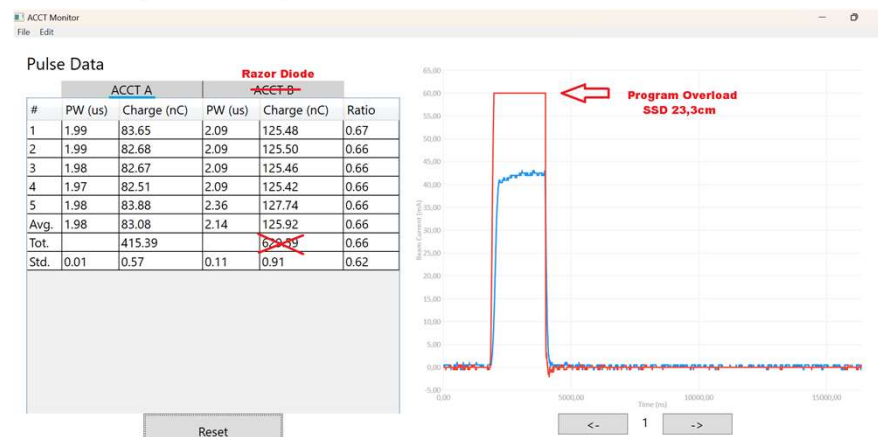
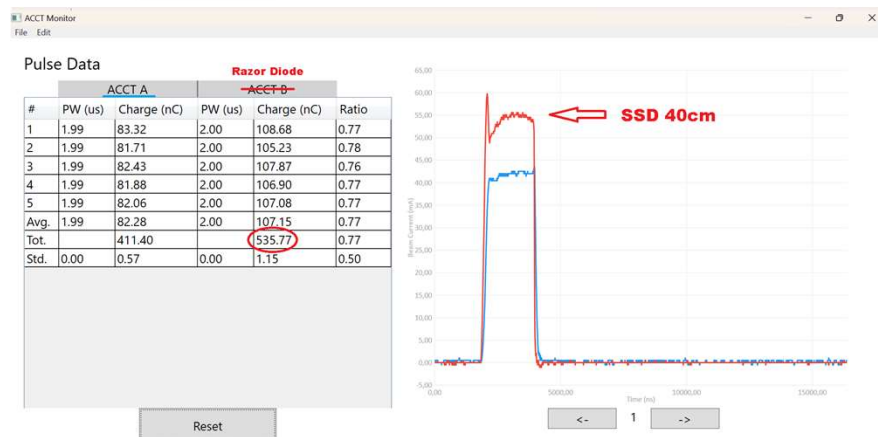


- 2% attenuation between radial and axial positions
- In-vivo diode as a secondary delivered dose check in case of a possible misreading of the Mobetron ACCT

- After 8000 Gy of exposure, we found no significant loss of sensitivity



## Replacement of ACCT Lower by Razor diode



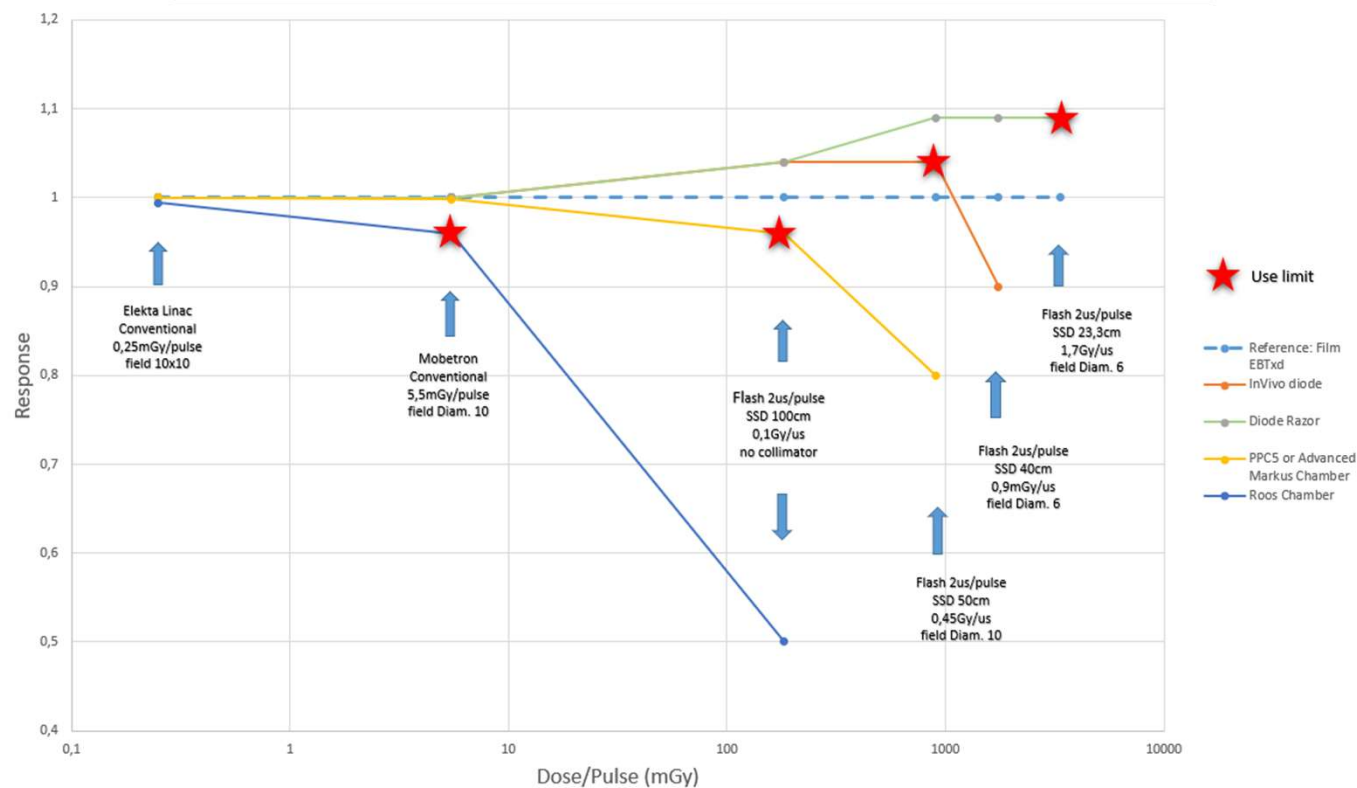


## Diode detector



- ✓ Direct-reading detector
- ✓ Highly reproducible
- ✓ Cost-effective detectors
- ✓ Dose control with correction factor
- ✓ Energy control and correction
- ✓ Relative dosimetry
- ✓ In-vivo detector
- ✗ Correction factor (overestimation in Flash mode)

Response of different detectors compared to EBTxd Films for different dose/pulse (9MeV)



*THANK YOU FOR  
YOUR ATTENTION*

