Australian Government

Australian Radiation Protection and Nuclear Safety Agency

Response of Active Electronic Radiation Monitors in Pulsed X-ray Beams from Linacs

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Introduction

- Radiation protection when using linear accelerators (linacs) requires monitoring instruments which can measure high dose rates from scattered radiation from the beams.
- The beams are pulsed, with frequency of the pulses typically in the range 50-400 Hz.
- The beam pulse widths are of the order of 1 µs, which is much less than the period between pulses of 2.5-20ms.
- In order to accurately measure the dose rate from the scattered beam, the monitoring instruments must be able to cope with the intense peak dose rate present during these beam pulses.

Dead-time considerations

- If the monitoring instruments have dead-time of 1 µs or more, there can only be one count recorded per pulse.
- GM tubes typically have 100-300 µs dead-time, so are unsuitable for measuring the high dose rate during linac beam pulses.
- Passive dosimeters such as TLD badges do not suffer from dead-time effects, but the results are not available until after the wearing period has expired and the badges have been processed.
- Active semiconductor dosimeters such as PIN diodes also have dead-time and have been found to be deficient in pulsed radiation fields.

Previous work

Deficiencies of Active Electronic Radiation Protection Dosemeters in Pulsed Fields, U. Ankerhold, O. Hupe and P. Ambrosi,

Radiation Protection Dosimetry (2009) Vol. 135, No. 3 p149.

Summary

- They investigated the performance of active dosimeters in pulsed radiation fields of T_{pulse} = 40 ms (Diagnostic X-ray unit , single pulse) and T_{pulse} = 50 ns (X-ray flash unit, freq = 29 Hz), with dose rates of 4 mSv/s and 36 Sv/s respectively. The tested dosimeters included a GM tube and a semi-conductor PIN diode.
- They found that the active dosimeters completely failed to record the correct dose.
- The doses recorded by the active dosimeters ranged from 0-5% of the reference dose.

Present investigation

- Since linacs have a low beam pulse width of only 1 µs, we wanted to test various active electronic monitors in scattered beam from our 6 MV, 10MV and 18MV beams.
- Active electronic dosimeters tested:

1) a pressurized high volume ionization chamber (Victoreen 451P)

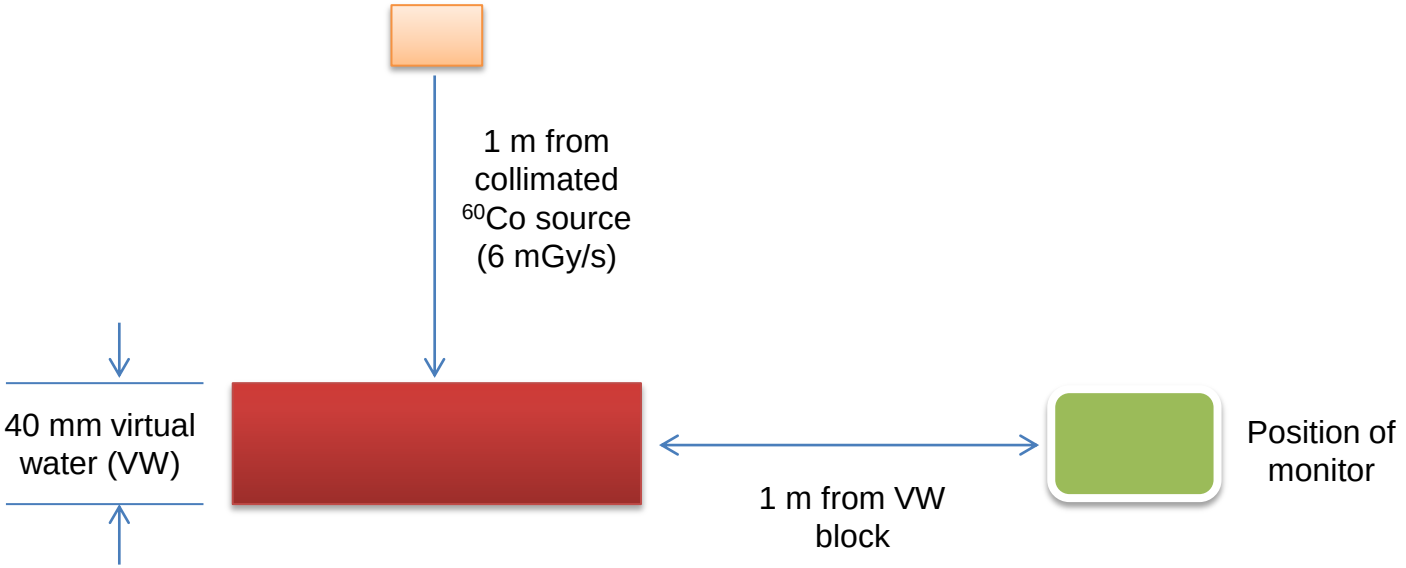
2) 3 semi-conductor PIN diodes

3) 3 energy-compensated GM tube monitors

As a reference monitor a Farmer-type graphite thimble ionization chamber model NE2571 was used. The charge from this chamber was collected using an electrometer. This was chosen as reference chamber, as it is unaffected by dead-time effects and the response is well known at these beam energies of 6MV, 10MV and 18MV.

Preliminary calibration tests

- As a preliminary check of the calibrations of the monitors, measurements were made under reference conditions in a scattered beam from a ^{60}Co teletherapy source of strength 94 TBq.



^{60}Co calibration tests

Instrument	Measured dose rate (mSv/h)	
	1 m from VW	Outside teletherapy room, ~4 m from VW
Pressurized high-volume ionization chamber	8.7	0.014
PIN Diode (1)	7.6	0.008
PIN Diode (2)	6.8	0.009
PIN Diode (3)	7.4	0.009
GM tube (1)	9.2	0.011
GM tube (2)	9.1	0.009
GM tube (3)	overload	0.009

Linac measurements

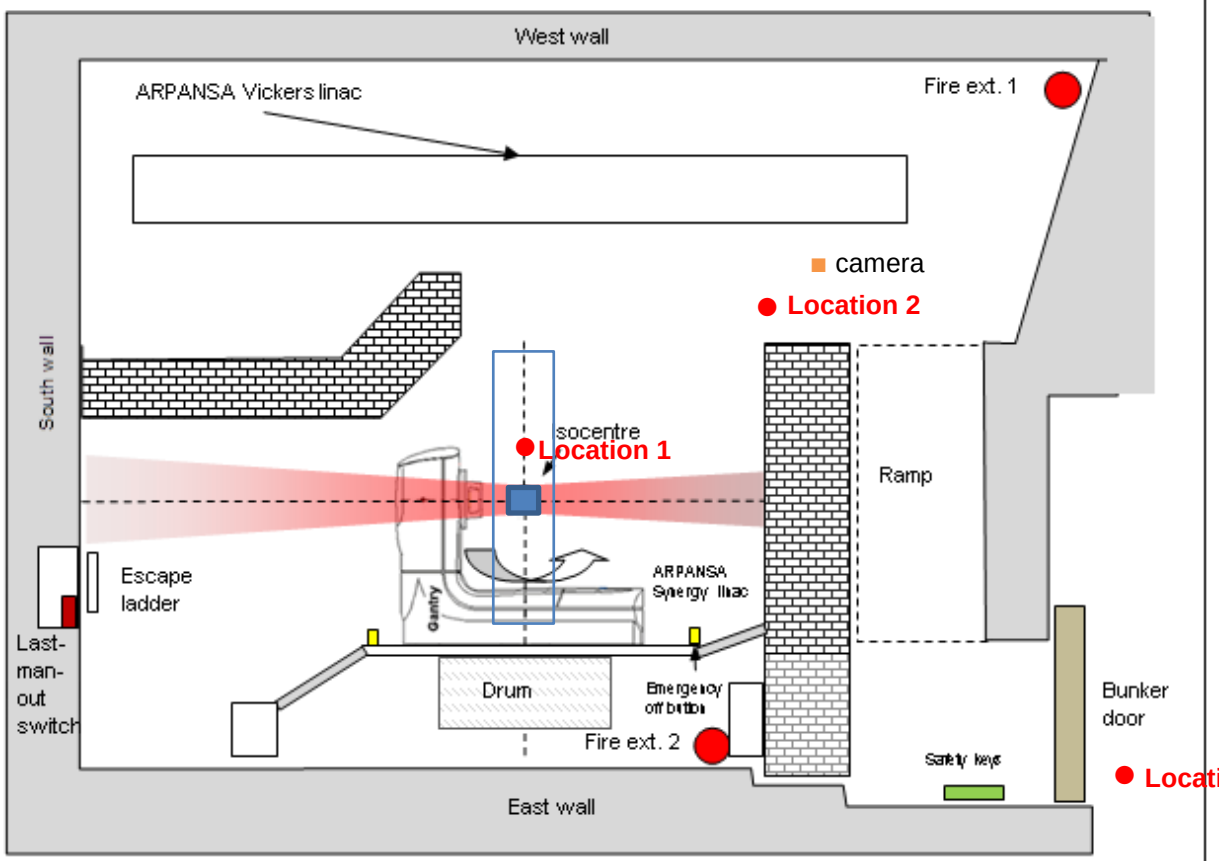


Figure 1. Lower level (bunker) floor plan

Location 1 = 0.67 m from the beam isocentre

Location 2 = 6.0 m from the beam isocentre, unshielded

Location 3 = 10 m from the beam isocentre behind concrete wall

The scattering medium, 90 mm of virtual water

Linac results – 6 MV and 200 MU/min

Instrument	Measured dose rate (mSv/h)		
	Position 1 0.67 m from VW	Position 2 6.0 m from VW	Position 3 10 m from VW (behind concrete)
Farmer-type reference chamber NE2571	44	N/A	N/A
Pressurized high-volume IC	44	0.94	0.0034
PIN Diode (2)	1.4	0.99	-
GM tube (2)	0.12	0.12	0.0053
GM tube (3)	0.05	0.05	0.0050

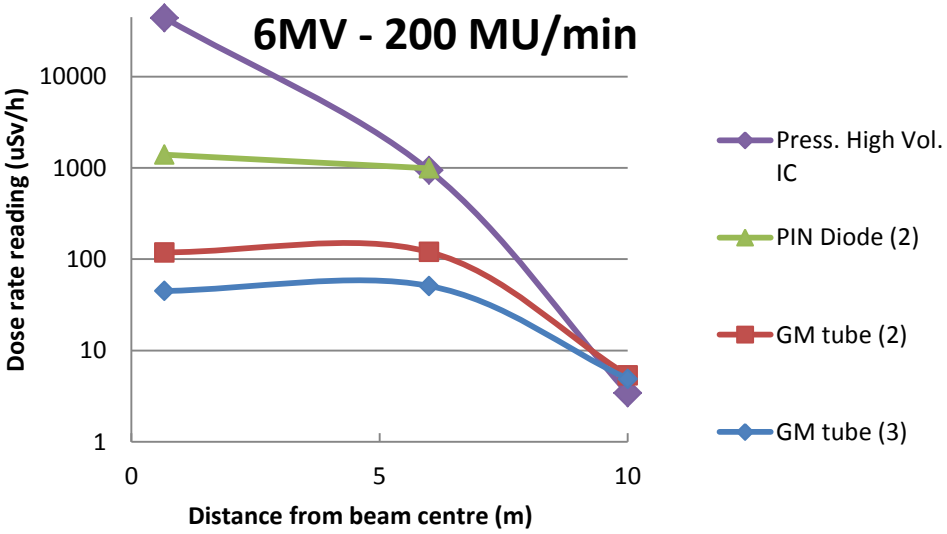
Linac results – 10 MV and 200 MU/min

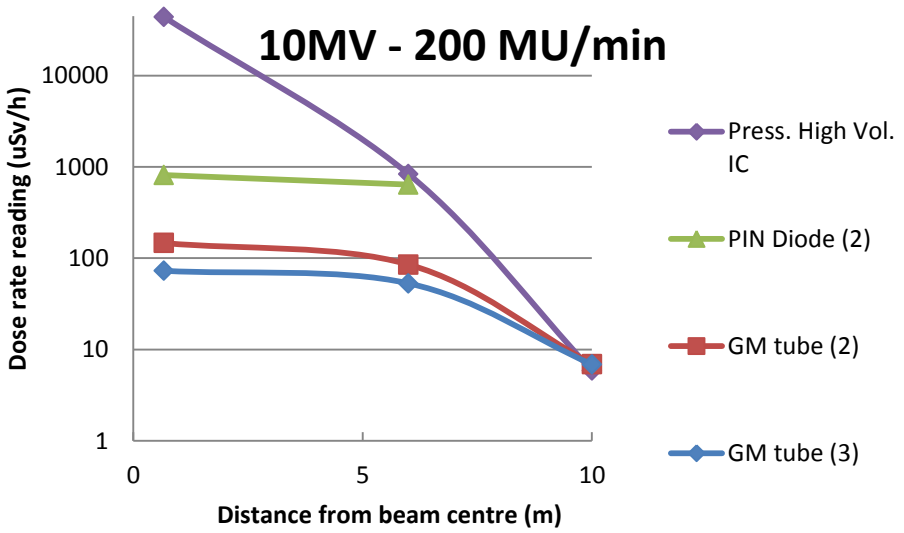
Instrument	Measured dose rate (mSv/h)		
	Position 1 0.67 m from VW	Position 2 6.0 m from VW	Position 3 10 m from VW (behind concrete)
Farmer-type reference chamber NE2571	44	N/A	N/A
Pressurized high-volume IC	44	0.84	0.0059
PIN Diode (2)	0.81	0.64	-
GM tube (2)	0.15	0.085	0.0069
GM tube (3)	0.073	0.053	0.0069

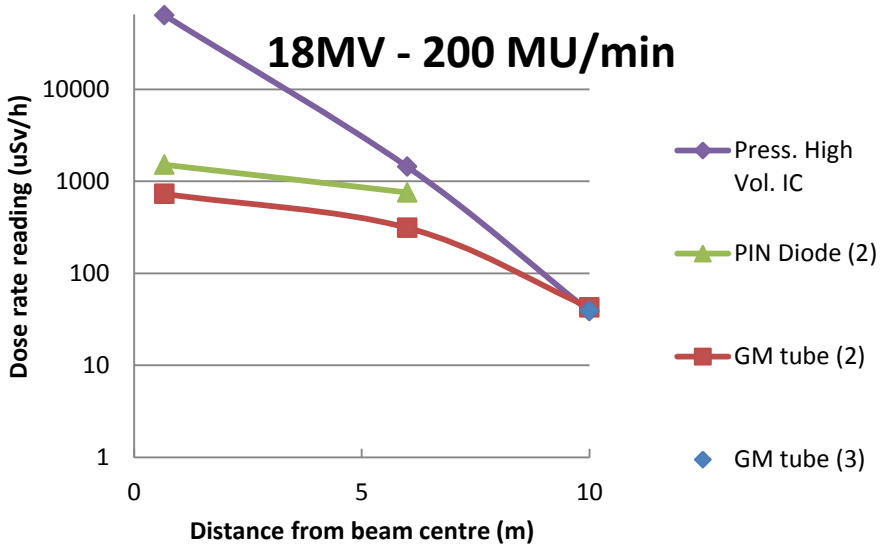
Linac results – 18 MV and 200 MU/min

Instrument	Measured dose rate (mSv/h)		
	Position 1 0.67 m from VW	Position 2 6.0 m from VW	Position 3 10 m from VW (behind concrete)
Farmer-type reference chamber NE2571	69	N/A	N/A
Pressurized high-volume IC	64	1.4	0.039
PIN Diode (2)	1.5	0.76	-
GM tube (2)	0.73	0.31	0.043
GM tube (3)	overload	overload	0.039

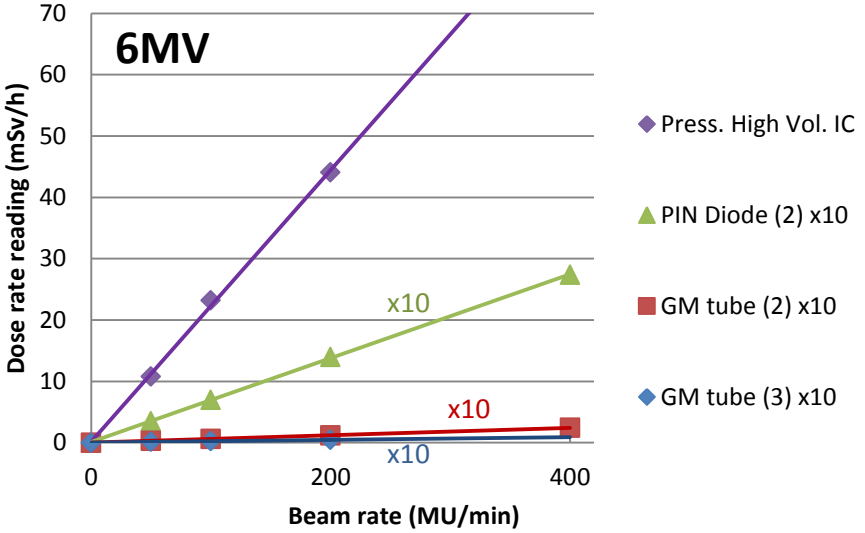
Dependence on position of monitors

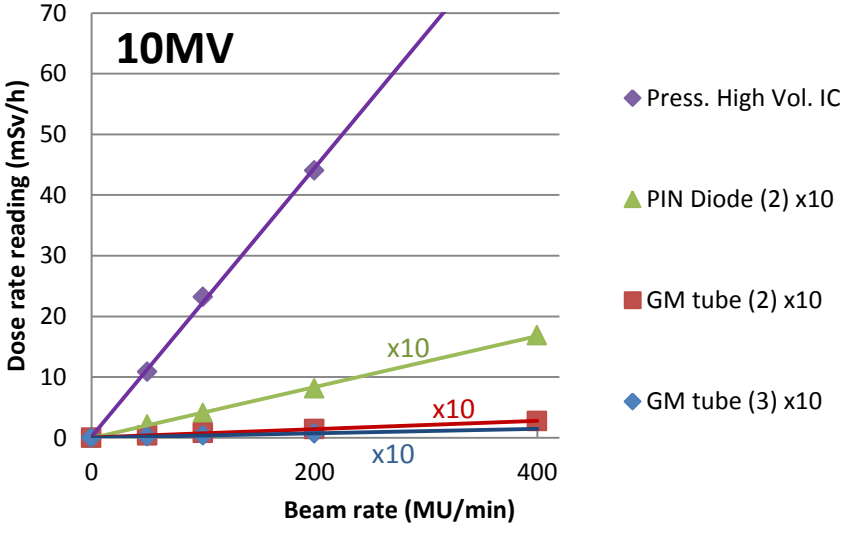


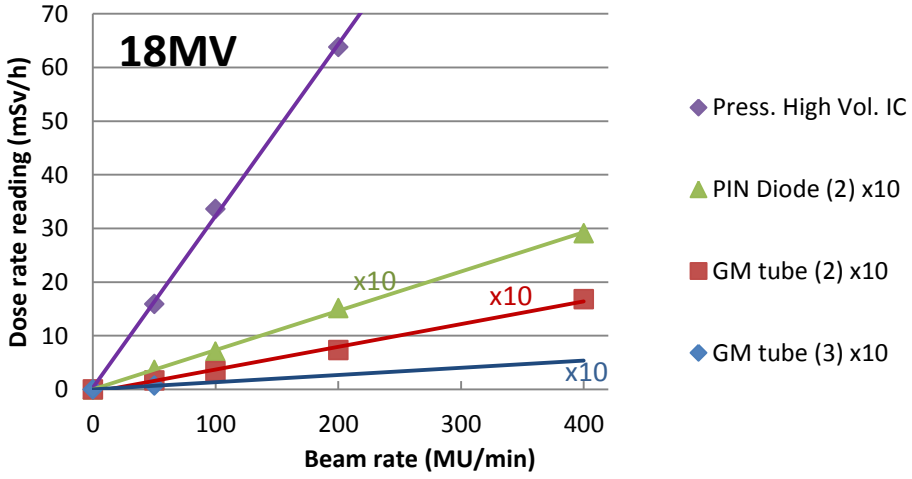




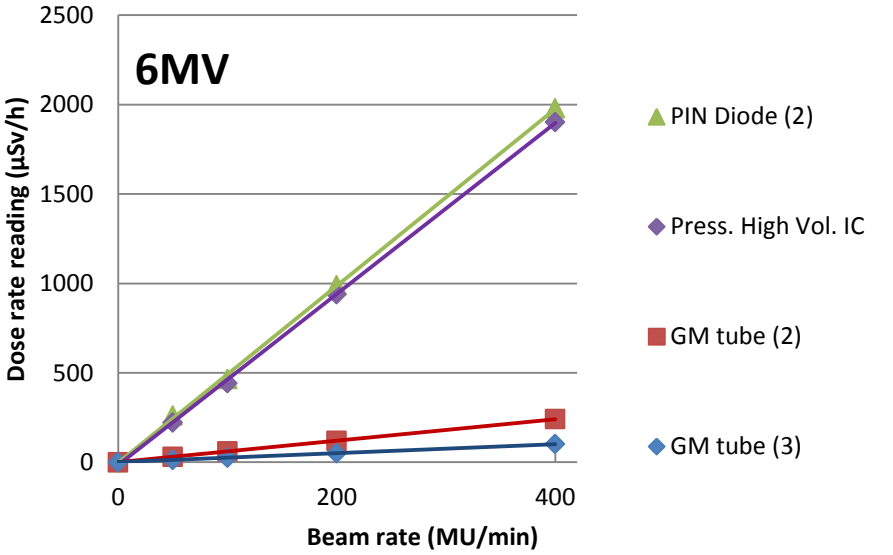
Beam rate dependence – Position 1, 0.67 m from beam isocentre

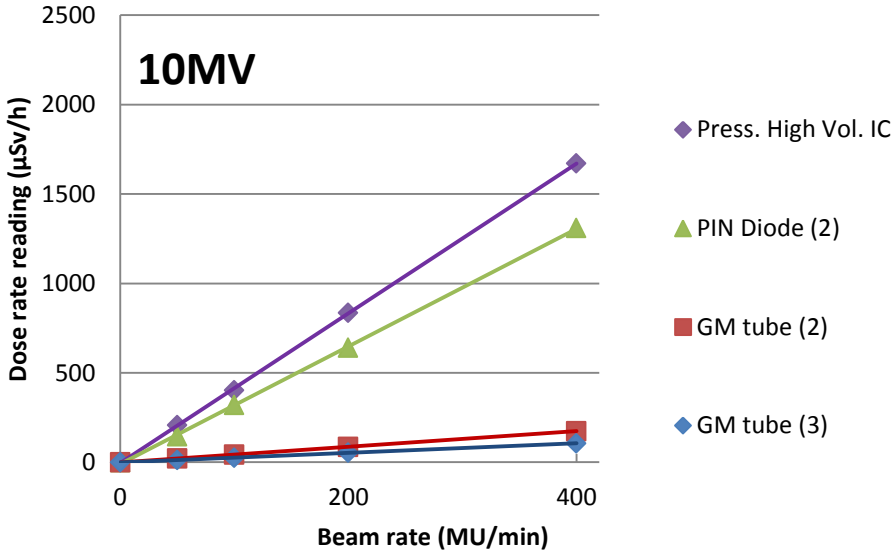


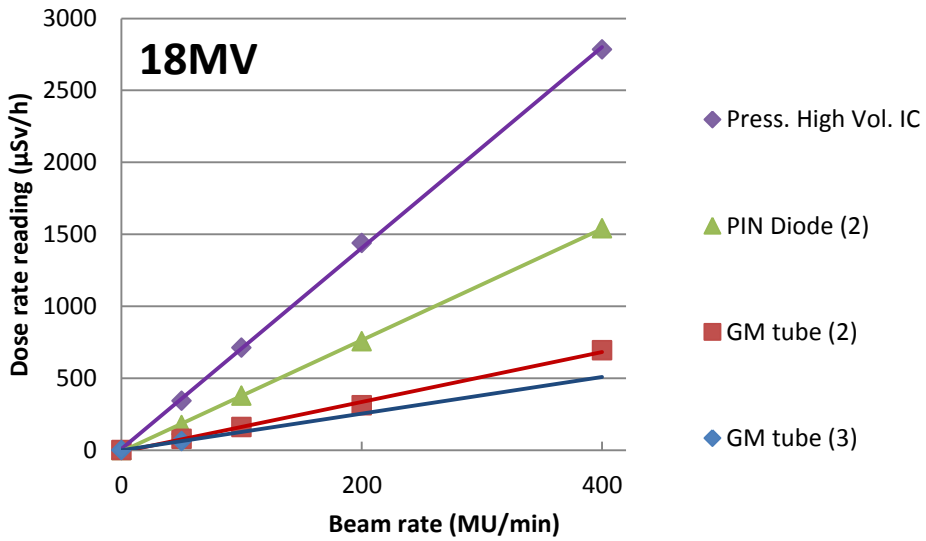




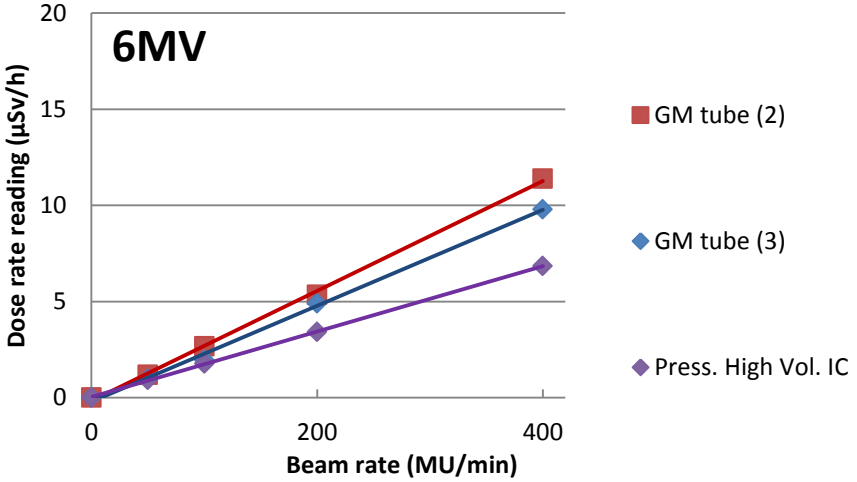
Beam rate dependence – Position 2, 6.0 m from beam isocentre

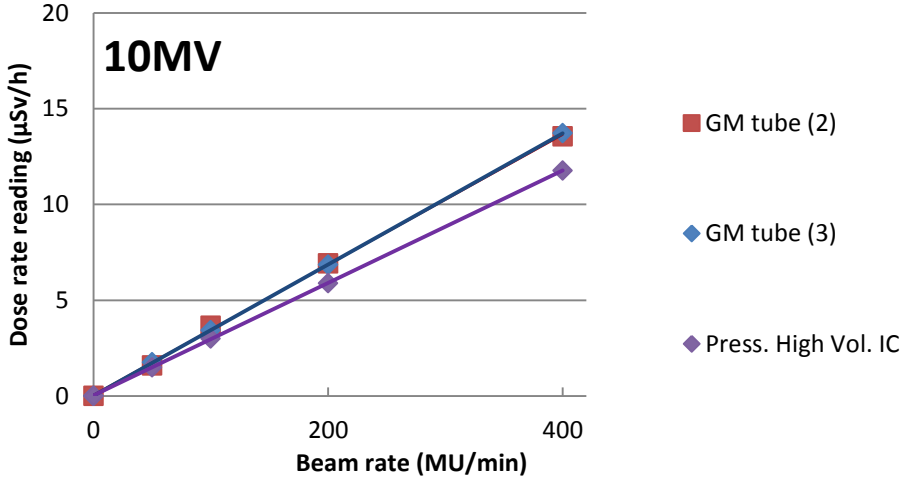


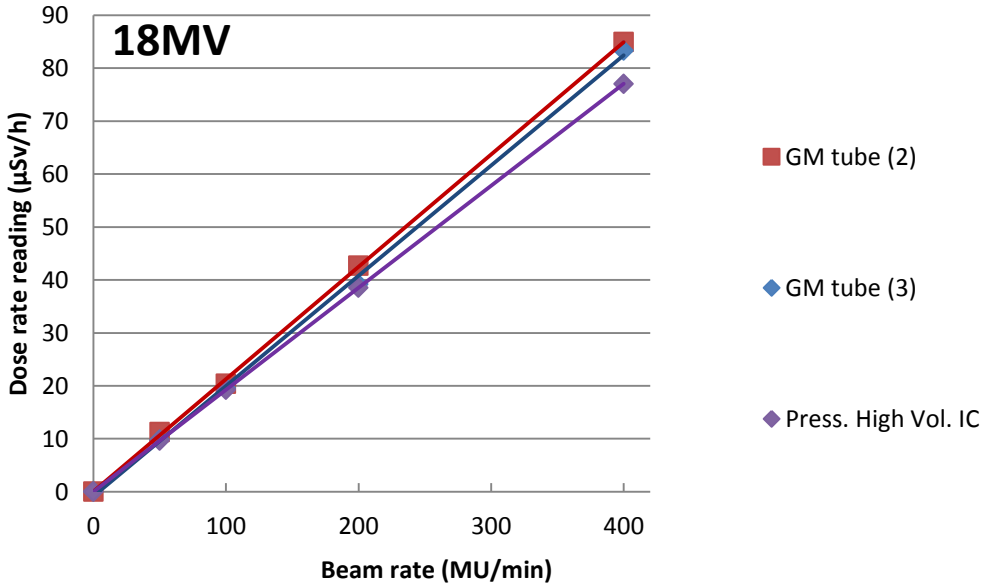




Beam rate dependence – Position 3, 10 m from VW (behind concrete)







Conclusions

1. All monitors agree (within uncertainties) for measurements in the ^{60}Co continuous beam of scattered gamma radiation.
2. Of the monitors tested against the reference monitor, only the pressurized high-volume ionization chamber responds correctly at the high dose rate locations inside the linac room.
3. All the monitors have a linear beam rate dependence, but in the case of the PIN diode and GM tube monitors the linearity is based on the number of pulses per second rather than dose per beam pulse.
4. At distances from 0.67- 6 metres, the PIN diode and GM tube monitors fail to respond correctly to the high dose rates present.
5. The PIN diode monitors start to reliably record the true dose rate at distances of around 6 metres from the beam (for 6MV), and for 10 MV & 18 MV a bit further than 6 metres.
6. Outside the linac room, where the dose rate is lower (~1-90 µSv/h), the active electronic monitors accurately record the dose rate present despite the pulsed beam.

Recommendations

1) For general monitoring inside a linac room, GM tubes and PIN diode active electronic dosimeters should not be used as they will generally not respond correctly to the high dose rates present.
2) Outside a linac room, where shielding is good and dose rates are much lower, GM tubes and PIN diode active electronic dosimeters can be used to accurately measure the dose rates.
3) A pressurised high volume ionization chamber will be a good choice of monitor to have available for use, as it will accurately measure the dose, whether it is used inside or outside of a linac room.
4) TLD badges will also accurately measure the dose whether used inside or outside of a linac room and should be worn as well as any active electronic dosimeter that is being used.

QUESTIONS?