White Paper

# Use of AutoTest BeamPro™ for rapid set-up of Photon and Electron Beams


## Abstract

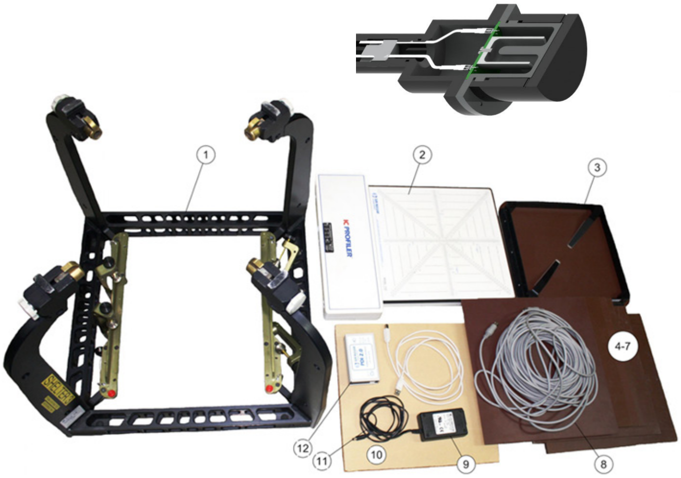
AutoTest BeamPro™ is a new tool designed for the service engineer. AutoTest BeamPro™ enables rapid and consistent set-up of an Elekta linac in preparation for the customer acceptance test. A 2-D panel array of ion chambers is used to provide a real-time beam profile and analysis capability resulting in significant time savings when compared to traditional water phantom based methods of beam set-up. Extensive factory testing, characterization and the provision of automatic self checking tools has resulted in a beam measuring system that quickly provides consistent machine set-ups. This paper briefly describes the intended use of the AutoTest BeamPro™ tool and explains how the rapid set up of a linac can be achieved.


ELEKTA

## Introduction

Use of AutoTest BeamPro™ in conjunction with the Sun Nuclear IC Profiler™ allows the service engineer to achieve a linac set-up in much less time than is possible with the sole use of a standard water phantom. The initial equipment set-up is much quicker and many sources of error are eliminated since the detector array is placed in a frame fixed to the linac head.[1]

Real time views of beam profiles while tuning the beam allow rapid confirmation of the factory specifications. Once the system has been set up using AutoTest BeamPro™, it is expected that customer beams may subsequently require only small adjustments using the customer's water phantom during acceptance.




| Item # | Description |
|---|---|
| 1 | Gantry mounting fixture |
| 2 | IC PROFILER™ |
| 3 | Electron wedge plate |
| 4 | Virtual water 3 mm, 2 off |
| 5 | Virtual water 5 mm |
| 6 | Virtual water 10 mm |
| 7 | Virtual water 20 mm |
| 8 | Cable, power data |
| 9 | PSU, 18V 24W |
| 10 | Acrylic backscatter plate 20 mm |
| 11 | Mains cable |
| 12 | Power data interface module |

Figure 1 & Table 1. AutoTest BeamPro™ kit components.

## X-Ray Beam Set-up

When using a water phantom X-Ray energy is set by adjusting beam parameters until the measured percentage dose at 10 cm depth ($D_{10}$) meets the required acceptance criteria. For example, the Elekta customer acceptance test specification requires that for a 6MV beam the relative dose measured at a depth of 10 cm should be 67.5% (±2%) when normalized to $D_{max}$. However, if the energy of the beam is varied by changing the bending magnet settings it will be observed that the flatness of the resulting beam changes significantly, even when the variation of the energy indicator ($D_{10}$) is still within tolerance.

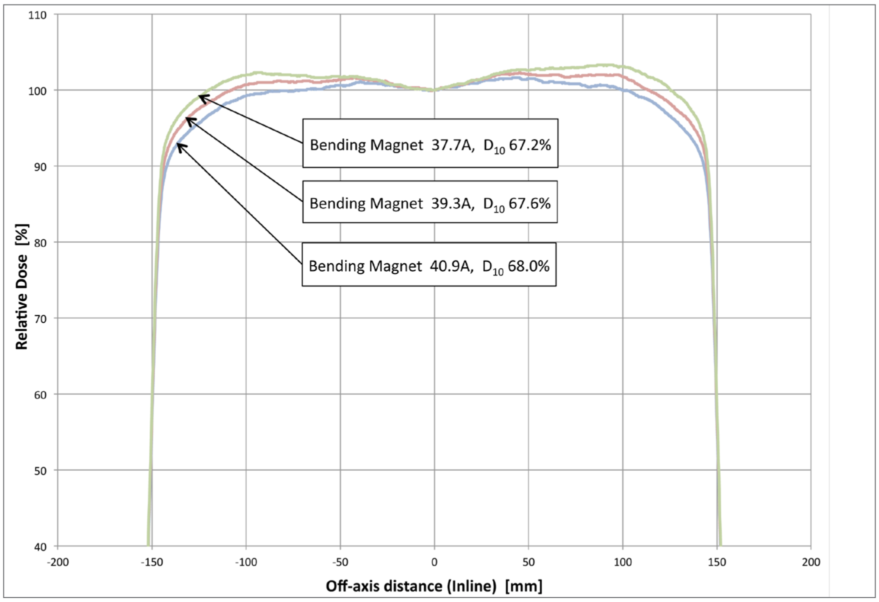



Figure 2. Effect of variation of X-Ray energy on flatness profile.

This is shown in Figure 2, where the changes in bending magnet setting produce a difference in $D_{10}$ dose value of less than 1%, whereas the resulting flatness changes by almost 2%. The flatness of the photon beam can therefore be used as a more sensitive indicator of changes to nominal beam energy than the traditional depth dose characteristic in water.[2]

This property is exploited in AutoTest BeamPro so that X-Ray energies and flatness can be set up quickly in real time by matching the observed profile to factory reference data for each particular beam.

## Electron Beam Set-up

Elekta specifications for electron beam energy are based on the R80 parameter, which is the depth of the distal 80% dose (normalized to $D_{max}$) measured in a water phantom under standard measurement conditions (see Figure 3).

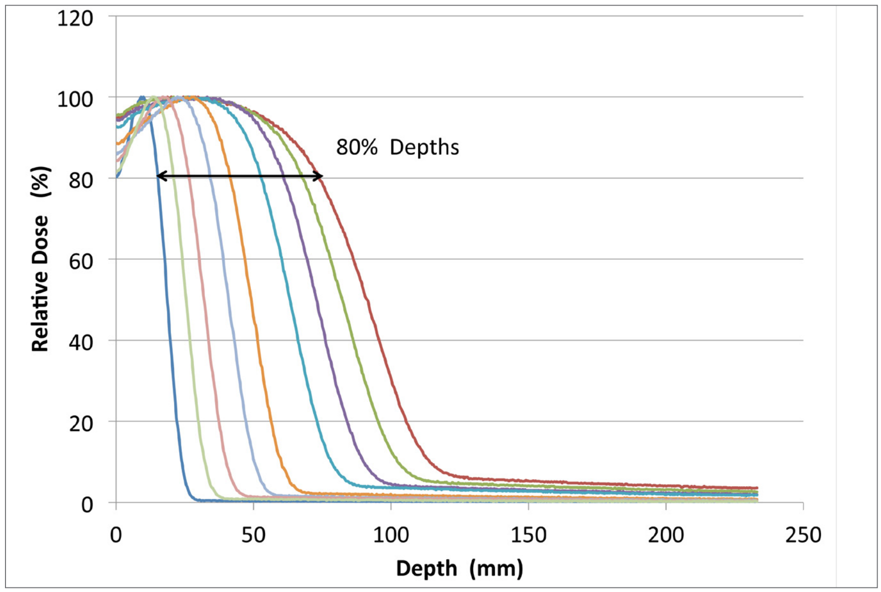



Figure 3. Electron Percentage Depth Dose Curves (4MeV to 22MeV electron energy). *For illustrative purposes only.*

Previous investigations in published literature have demonstrated that an indication of electron energy constancy can be obtained by using symmetrically positioned tapered wedges manufactured from a suitable material in conjunction with a 2-D diode or ion chamber array.[3, 4] Such a technique can be used with the Sun Nuclear IC Profiler™; the wedges modify the beam profiles to produce the characteristic curves shown in Figure 4.

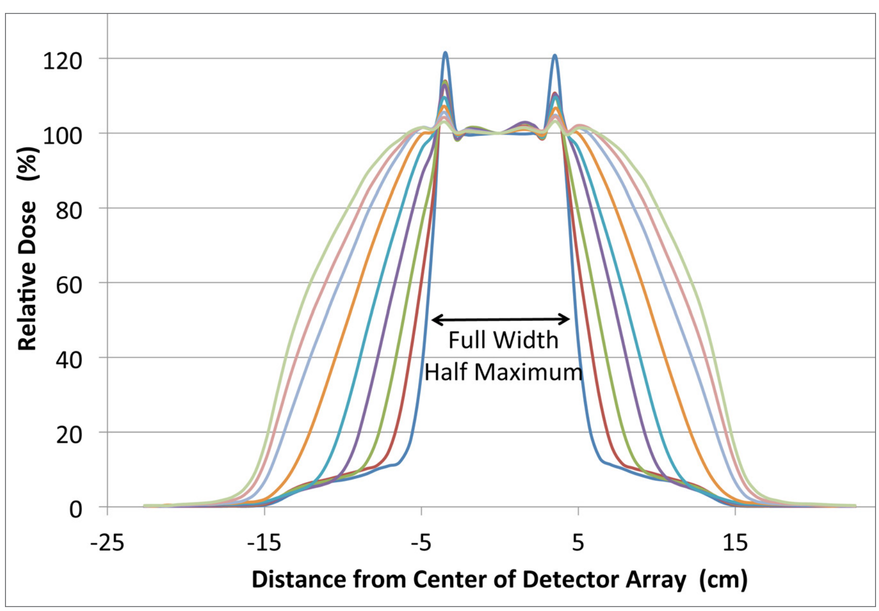



Figure 4. Profiles measured with an IC Profiler™ in combination with a pair of tapered wedges (4MeV to 22MeV electron energy) showing measurement of FWHM.

If the Full Widths at Half Maximum (FWHM or distance between the 50% dose points) of the profiles obtained in Figure 4 are plotted as a function of R80 as measured in a water phantom, a predictable relationship (see Figure 5) can be established between the FWHM (mm) and the electron energy (expressed by R80 in mm).

Tests have been performed on multiple IC Profiler panels, multiple pairs of tapered wedges and different linac systems in order to characterize this relationship such that it is now possible to use an IC Profiler to perform a rapid set-up of electron beam energies during the installation of a new Elekta linear accelerator.

Unlike X-ray flatness, electron beam flatness is relatively insensitive to small changes in energy and therefore if energies are set as described above, flatness specifications are usually met. However, the beam profile can still be adjusted and monitored in real-time using the IC Profiler with an appropriate amount of build-up, leaving only confirmation of final settings (e.g. auto-tracking diaphragm positions) during customer acceptance with a water phantom.

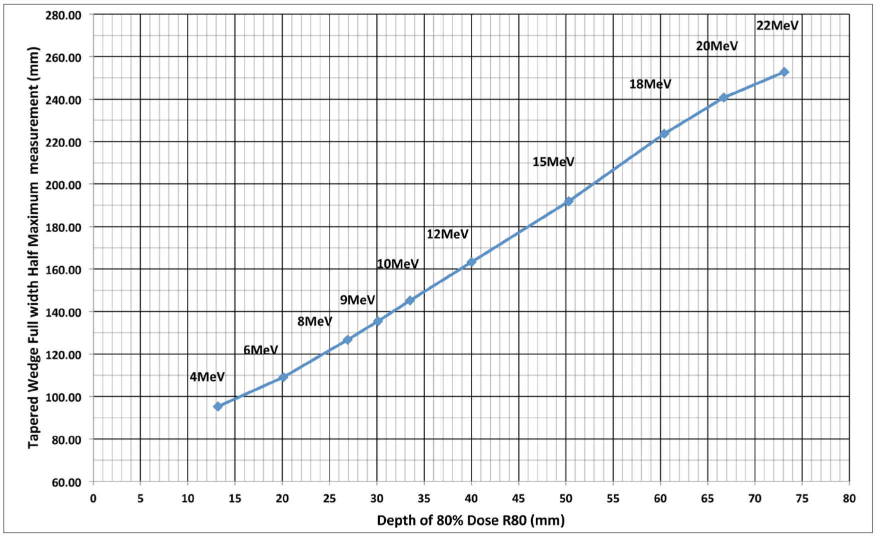



Figure 5. Depth of 80% dose vs. Full Width Half Maximum tapered wedge distance .

## Conclusion

AutoTest BeamPro™ makes use of widely available ion chamber array technology as an alternative to traditional water phantoms for preliminary system set-up. The system has the advantage of eliminating some of the user-dependent sources of inconsistency and provides beam profiles and analysis in real time thereby enabling very efficient tuning and set-up of the beams. AutoTest BeamPro™ therefore represents a major step forward in the ability to prepare systems for customer acceptance quickly and consistently.

## References


[1] Simon et al. (2010), “Characterization of a multi-axis ion chamber array”, Med. Phys. 37(11), 6101-6111

[2] Lovelock et al. (1995), “A Monte Carlo model of photon beams used in radiation therapy”, Med. Phys. 22(9), 1387-1394

[3] Wells et al. (2003), “Electron energy constancy verification using a double-wedge phantom”, JACMP Vol 4, No3, 204-208

[4] Speight et al. (2011) “Quality assurance of electron and photon beam energy using the BQ-Check phantom”, JACMP Vol 12, No2, 239-244





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