Linac Beam commissioning with EPID

Michael Barnes

Senior Medical Physics Specialist

Department of Radiation Oncology
Calvary Mater Newcastle

Address/ Locked Bag 7 , HUNTER REGIONAL MAIL CENTRE NSW 2310
Phone/ +61 2 4014 3627

Introduction

Todays talk will cover:

1. The advantages and disadvantages of EPID for beam commissioning

2. Commissioning philosophy to allow the use of EPIDs

3. Introducing the Pixel-Sensitivity-Map (PSM)

4. Overview of the literature on beam commissioning using EPID applications
    1. Acceptance tests
    2. Basic beam model verification
    3. Plan delivery type tests
    4. Electrons
    5. EPID performance

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Advantages and disadvantages of EPID as a detector for beam commissioning

Is EPID even worth considering?

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Advantages of EPID

- Primary Advantages:
  - Standardization
    - All modern linacs have an EPID
    - Common detector -> standardisation of methodology -> reduce errors
  - High Spatial Resolution two-dimensional measurement
    - Assessment of fluence. Possibly the best detector for this task.
- Secondary Advantages:
  - Large number of measurements with a single detector
  - Largely free of setup and user variability
    - Reproducible panel positioning
  - Digital data stored straight to a database (R&V)
  - Integrated with the linac
    - Potential for highly efficient workflows

Disadvantages of EPID

- Primary Disadvantage:
  - Non-water equivalence
    - Amorphous silicon panel means that dose cannot be measured directly
    - Work has been done with water equivalent EPIDs, which may solve this problem.

- Secondary Disadvantages:
  - Two-dimensional
    - Cannot easily directly measure in the depth direction
  - Integrated with the linac
    - Concerns about measurement independence

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Disadvantages of EPID

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  - Non-water equivalenc
    - Amorphous silicon pa measured directly
    - Work has been done v solve this problem.

A high DQE water-equivalent EPID employing an array of plastic-scintillating fibers for simultaneous imaging and dosimetry in radiotherapy

Samuel J. Blake,[a] and Zhangkai Cheng
Institute of Medical Physics, School of Physics, University of Sydney, Sydney, NSW 2006, Australia
Ingham Institute for Applied Medical Research, Sydney, NSW 2170, Australia

Aimee McNamara
Department of Radiation Oncology, Massachusetts General Hospital, Harvard Medical School, 30 Fruit St, Boston, MA 02114, USA

Minghui Lu
Varex Imaging Corporation, Santa Clara, CA 95054, USA

Philip Vial
Institute of Medical Physics, School of Physics, University of Sydney, Sydney, NSW 2006, Australia
Ingham Institute for Applied Medical Research, Sydney, NSW 2170, Australia
Department of Medical Physics, Liverpool and Macarthur Cancer Therapy Centers, NSW 2170, Australia

Zdenka Kuncic
Institute of Medical Physics, School of Physics, University of Sydney, Sydney, NSW 2006, Australia

- Secondary Disadvantages:
  - Two-dimensional
    - Cannot easily directly measure in the depth direction
  - Integrated with the linac
    - Concerns about measurement independence

Linac beam commissioning philosophy with EPID

Making the case for consensus data

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The case for consensus beam models

- Consider..

  – Traditional beam commissioning
    - measure beam model data and input into the TPS
    - Beam model specific to the local linac

  – As linac manufacturing improved linacs beams became more consistent
    - beam matching became a possibility
    - Standardised/consensus beam data was introduced as an option. Eg Varian Golden dataset

The case for consensus beam models

- Halcyon and Tomotherapy already mandate a standard beam model.
- There is growing evidence that the TrueBeam linac beams are highly consistent linac to linac
- This makes a standard beam model feasible.

Commissioning of the Varian TrueBeam linear accelerator: A multi-institutional study

Glide-Hurst C, Bellon M, Foster R, Altunbas C, Speiser M, Altman M, Westerly D, Wen N, Zhao B, Miften M, Chetty I, Solberg T.

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 14, NUMBER 1, 2013

Commissioning measurements for photon beam data on three TrueBeam linear accelerators, and comparison with Trilogy and Clinac 2100 linear accelerators

Gloria P. Beyer[a]
Medical Physics Services, LLC, Tampa, FL, USA and Medical Physics Services International Ltd., Cork, Ireland
gpbeyer@MedicalPhysicsServices.com

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Do the representative beam data for TrueBeam™ linear accelerators represent average data?

Yoshihiro Tanaka[1] | Hirokazu Mizuno[2] | Yuichi Akino[3] | Masaru Isono[4] | Norimasa Masai[5] | Toshijiro Yamamoto[6]

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EPID beam commissioning philosophy

- If we accept consensus data beam models
  - Commissioning becomes verification
  - Check that ones specific linac beams are not an unacceptable outlier from standard.
- Therefore,
  - we don't need water equivalent detectors
  - just detectors that are proven to be sensitive to clinically significant variation from the consensus data.
- EPID is the logical choice for such a detector
  - Standard model checked with a standard detector that is available on all linacs.
- With this philosophy acceptance testing and commissioning becomes blurred into essentially an extended Acceptance test procedure.
  - Accept the linac performance and Accept the beam model

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Introducing the Pixel-Sensitivity-Map (PSM)

How to retain dosimetric data in an EPID image

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The problem

- The flood field calibration
  - Corrects the image to provide a uniform image when exposed to a wide-open field
  - Good for IGRT, but bad for Dosimetry

- As well as detector non-uniformities it also corrects out beam non-uniformities (i.e. Beam horns), which we require for beam profile analysis.

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The solution

- Replace the flood field calibration with an alternate calibration that only corrects for the detector non-uniformities and retains the beam horns in the image.

- Such a calibration has been named the Pixel-Sensitivity-Map (PSM) and methods have been published on how to do this.

Correction of pixel sensitivity variation and off-axis response for amorphous silicon EPID dosimetry

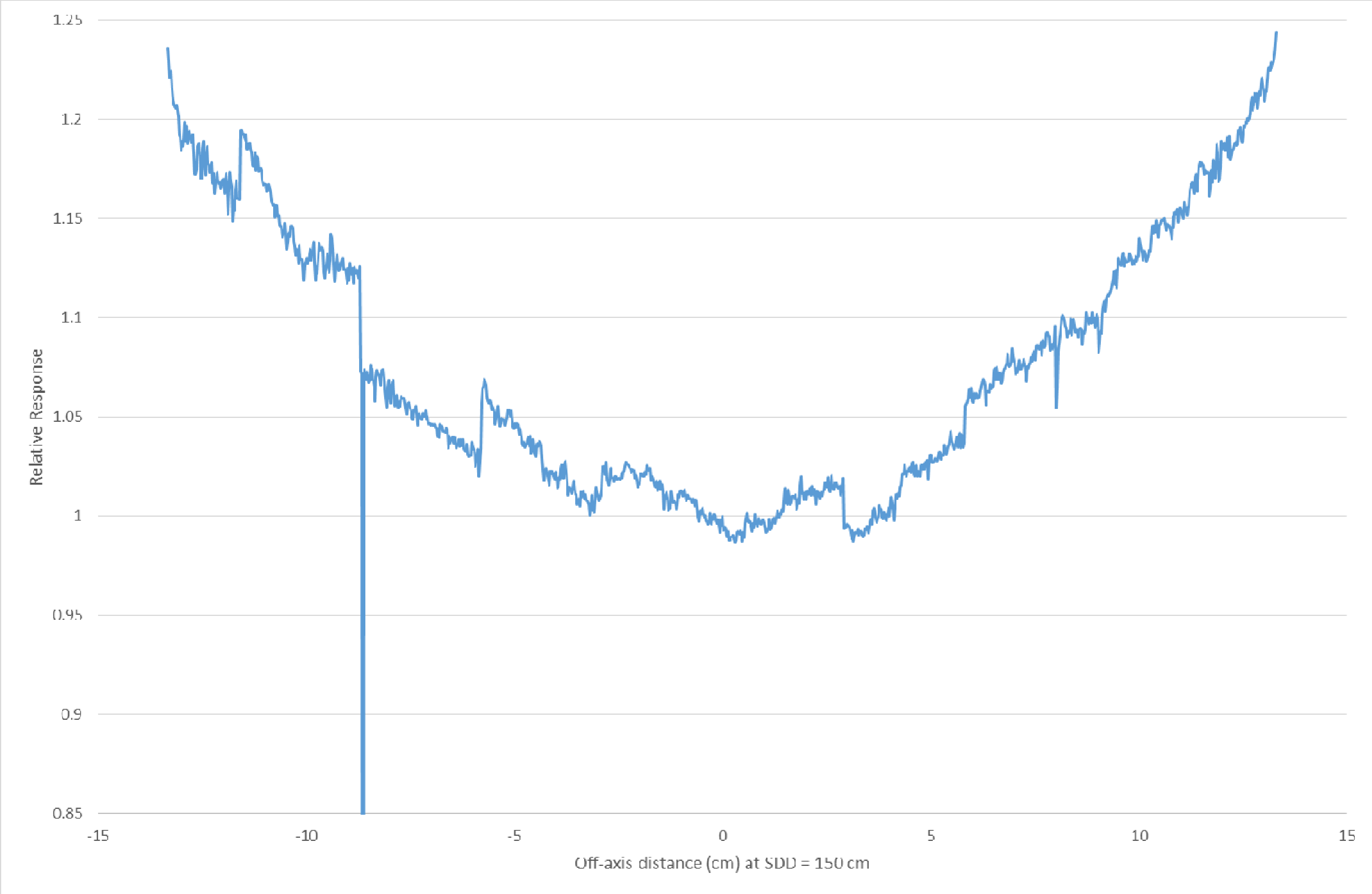
Peter B. Greer[a)]

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 14, NUMBER 6, 2013

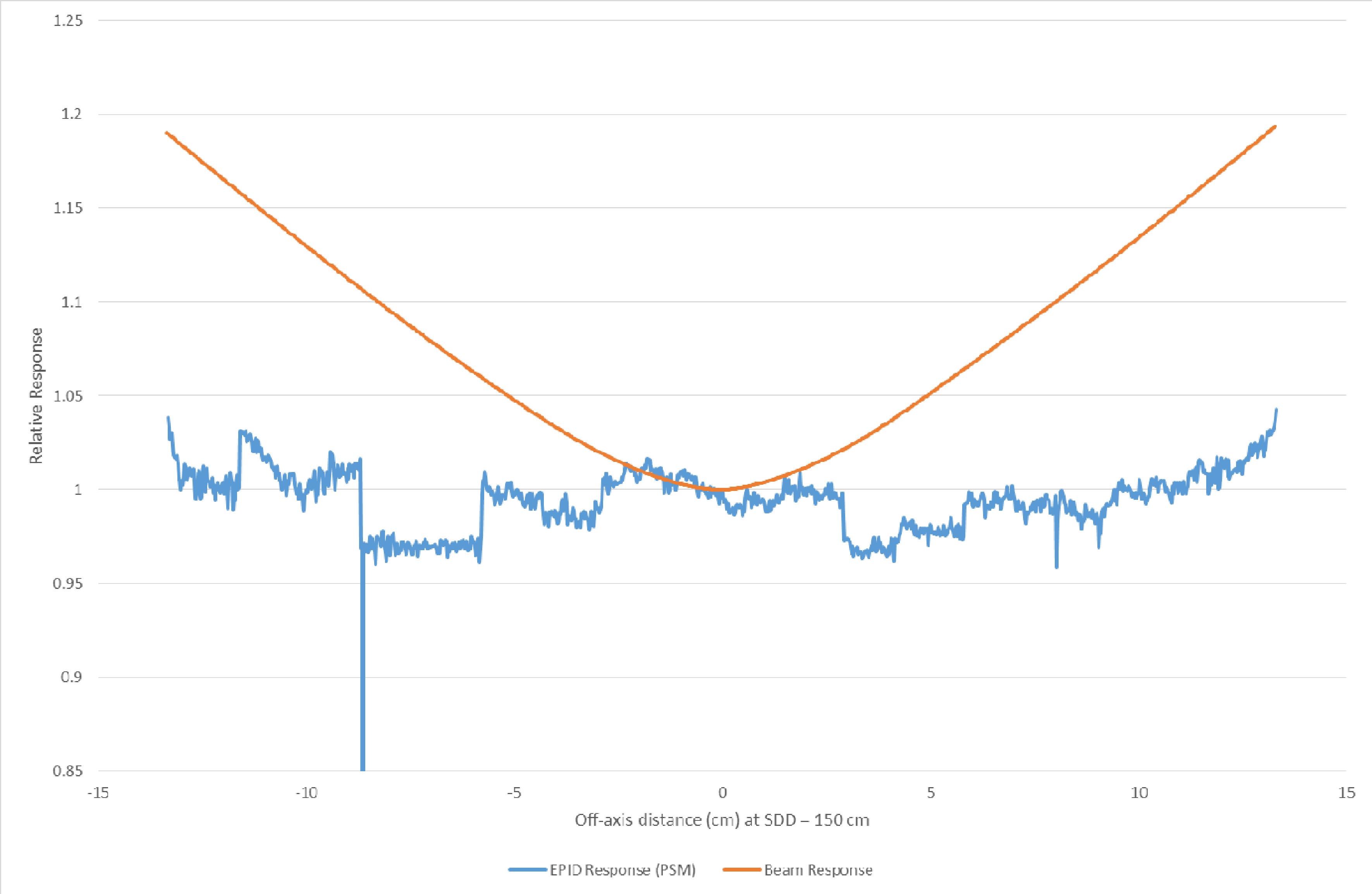
A new approach for the pixel map sensitivity (PMS) evaluation of an electronic portal imaging device (EPID)

Alberto Boriano,[1a] Francesco Lucio,[1] Elisa Calamia,[1] Elvio Russi,[1]
Flavio Marchetto[2]

Raw EPID Profile



Beam and EPID (PSM) Responses



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Beam model data verification with EPID: A quick literature review

Acceptance type tests:	Beam quality, beam steering
Basic beam model tests:	Output factors, profiles, MLC and Wedges
Plan delivery tests:	Fluence, overall process and plan delivery
Electrons:	Beam quality and profiles
EPID panel:	Consistency and stability

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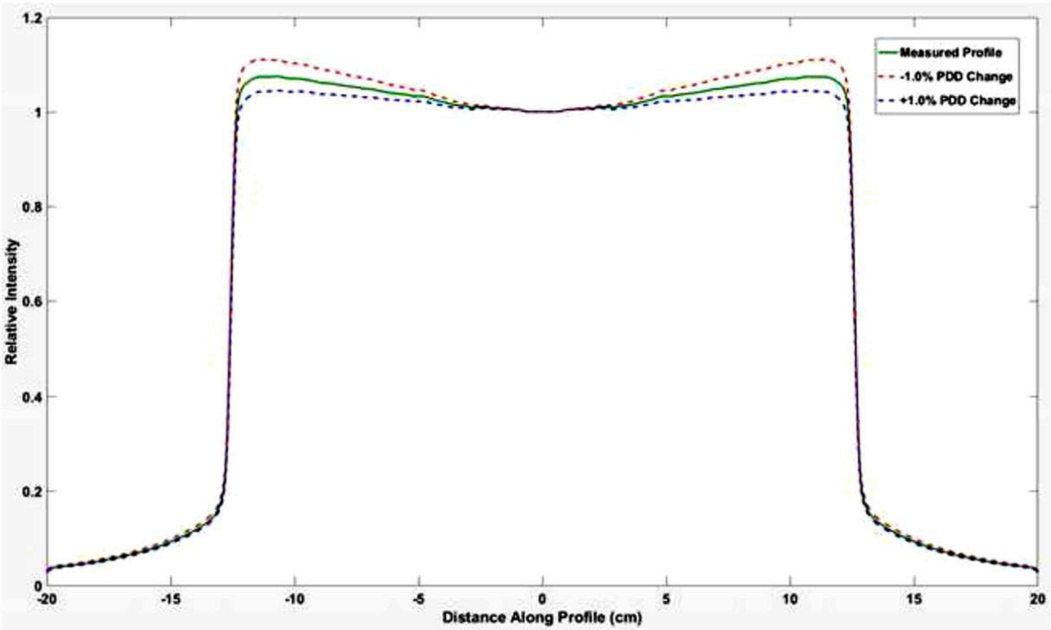
Acceptance tests: Beam Quality - Photons

Rapid Acceptance Testing of Modern Linac using On-board MV and kV Imaging Systems

Sridhar Yaddanapudi, Ph.D.[1,*,a)], Bin Cai, Ph.D.[1,*], Taylor Harry, M.S.[2], Steven Dolly, M.S.[1], Baozhou Sun, Ph.D.[1], Hua Li, Ph.D.[1], Keith Stinson, CMD[3], Camille Noel, Ph.D.[3], Lakshmi Santanam, Ph.D.[1], Todd Pawlicki, Ph.D.[2], Sasa Mutic, Ph.D.[1], S Murty Goddu, Ph.D.[1]



- Open field EPID images PSM corrected
- Flatness measured
- Beam energy was changed
  - Adjustment of the bend magnet shunt voltage until a 1% change in PDD10 was recorded (TG-142 tolerance).
- Flatness remeasured
- Therefore method is calibrated to TG-142
- Users can compare their measured flatness to see if it falls within this range.

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Acceptance tests: Beam Steering

A proposed method for linear accelerator photon beam steering using EPID

Michael P. Barnes[1,2,3] | Frederick W. Menk[3] | Bishnu P. Lamichhane[3] | Peter B. Greer[1,3]

- This paper provides methodology for beam angle and position steering using EPID.
  - PDDs -> Primarily influenced by beam energy
  - Dose profiles - > Primarily influenced by energy and beam steering.
  - Therefore -> By checking our energy and beam steering we have gone a long way towards assuring our PDDs and Dose profiles.
  - Profiles -> Spot check different field sizes with PSM-corrected EPID images.

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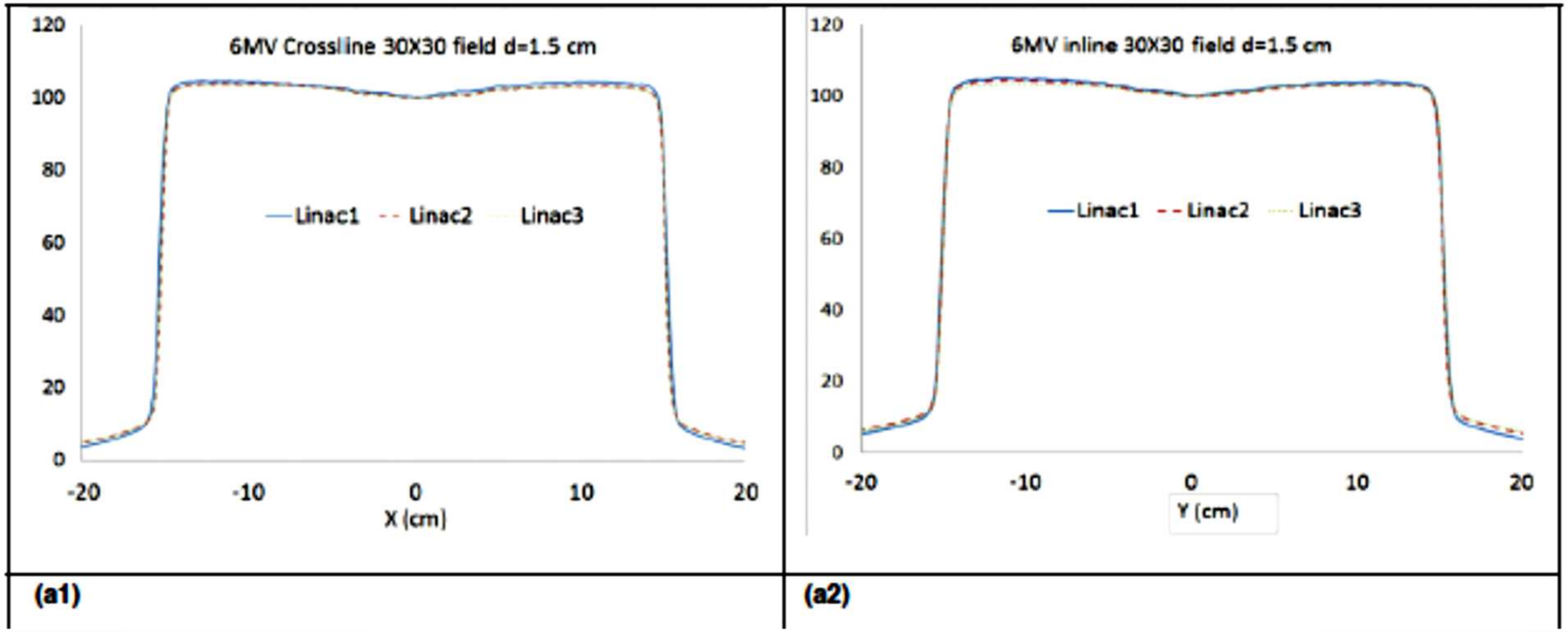
Basic beam model tests: Beam profiles

Normalize the response of EPID in pursuit of linear accelerator dosimetry standardization

Bin Cai[1] | S. Murty Goddu[1] | Sridhar Yaddanapudi[2] | Douglas Caruthers[1] | Jie Wen[3] | Camille Noel[4] | Sasa Mutic[1] | Baozhou Sun[1]



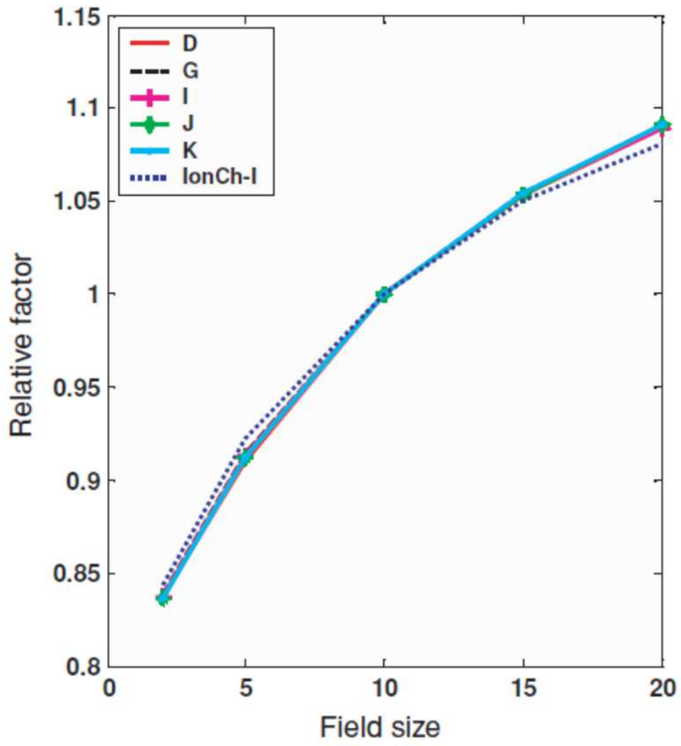
- Demonstrated: Beam matched linacs provide the same PSM corrected EPID profiles.
- Therefore for a range of field sizes users can compare their measured profiles against the consensus profiles

Basic beam model tests: Output factors - Varian

Assessment of dosimetrical performance in 11 Varian a-Si500 electronic portal imaging devices

Awusi Kavuma[1,2], Martin Glegg[1], Garry Currie[1] and Alex Elliott[1,2]

- Varian Beam matched linacs provide consistent EPID measured output factors.
- Therefore, consensus EPID output factors can be generated that users can compare their linac against
- Note: Plot is a little misleading as agreement with ion chamber diminishes at large field sizes.



Basic beam model tests: Output factors - Elekta

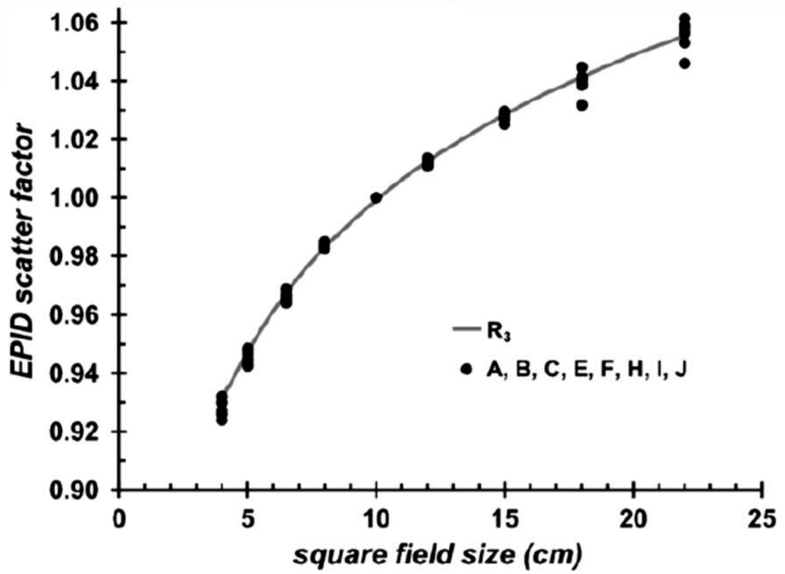
INSTITUTE OF PHYSICS PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY

Phys. Med. Biol. 51 (2006) 4189–4200 doi:10.1088/0031-9155/51/17/005

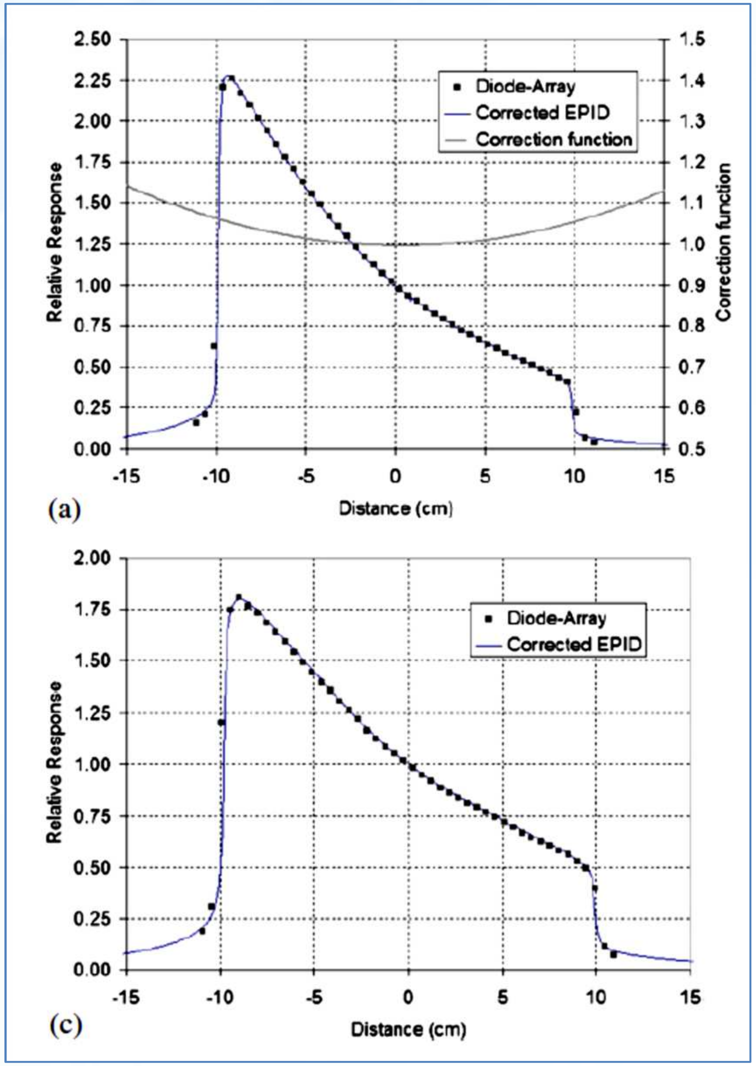
An intercomparison of 11 amorphous silicon EPIDs of the same type: implications for portal dosimetry

Peter Winkler and Dietmar Georg

- Similar results found for Elekta EPIDs.



Basic beam model tests: Wedges



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Phys. Med. Biol. 52 (2007) 1075–1087 doi:10.1088/0031-9155/52/4/014

Investigation of an amorphous silicon EPID for measurement and quality assurance of enhanced dynamic wedge

Peter B Greer[1,2] and Michael P Barnes[1,2]

- Wedge Profiles and Wedge factors can be measured with EPID too.
- Agreement with diode array if EPID is PSM corrected

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Basic beam model tests: MLC (transmission and DLG)

Automated EPID-based measurement of MLC leaf offset as a quality control tool

T A Ritter[1,2], B Schultz[3], M Barnes[4,5], R Popple[6], M Perez[7], K Farrey[8], G Kim[9] and J M Moran[2]

- DLG and MLC transmission have been measured using EPID in a number of publications
- This paper both compared EPID measured DLG and transmission across a wide number of linacs, but also demonstrated sensitivity as EPID results correlated with ion chamber results
- Again consensus EPID measured DLG and transmission can be determined which users can compare their linac against.

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Plan delivery type tests: 2D Fluence

The use of an aSi-based EPID for routine absolute dosimetric pre-treatment verification of dynamic IMRT fields

Ann Van Esch*, Tom Depuydt, Dominique Pierre Huyskens

- Use of EPID for 2D fluence checks is well established
  - Varians Portal Dosimetry and others.

- High spatial resolution = big advantage over other detector types.

- This allows dynamic field deliveries to be assessed compared to the plan, which is increasingly important in modern commissioning

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Plan delivery type tests: 2D Fluence

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JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 14, NUMBER 6, 2013

Optimized Varian aSi portal dosimetry: development of datasets for collective use

Ann Van Esch,[1,2a] Dominique P. Huyskens,[1,2] Lukas Hirschi,[3] Stefan Scheib,[4] and Christof Baltes[4]

- High spatial resolution = big advantage over other detector types.

- This allows dynamic field deliveries to be assessed compared to the plan, which is increasingly important in modern commissioning

- This paper developed a universal preconfigured Portal Dose Image Prediction (PDIP) datasets for Portal Dosimetry

- We could potentially all use the same model and compare our individual linac measured fluences against this consensus model.

Plan delivery types tests: Overall Process 3D dose distributions

- Back project EPID images into a virtual water phantom.
  - Calculate 3D dose distribution that can be compared against the plan.
- This allows plan delivery to be measured using EPID and compared to the TPS.
- This step is very important, but difficult to do without EPID unless one has specialist devices.

A remote EPID-based dosimetric TPS-planned audit of centers for clinical trials: outcomes and analysis of contributing factors

Narges Miri[1], Kimberley Legge[1], Kim Colyvas[1], Joerg Lehmann[1,2], Philip Vial[3,4], Alisha Moore[5], Monica Harris[5] and Peter B. Greer[1,2*]

Virtual EPID standard phantom audit (VESPA) for remote IMRT and VMAT credentialing

Narges Miri[1], Joerg Lehmann[1,2,3,5], Kimberley Legge[1], Philip Vial[4] and Peter B Greer[1,2]

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That’s all well and good for photons, but what about electrons?

Department of Radiation Oncology
Calvary Mater Newcastle
Address/ Locked Bag 7 , HUNTER REGIONAL MAIL CENTRE NSW 2310
Phone/ +61 2 4014 3627

Electrons - Profiles

Electron beam quality control using an amorphous silicon EPID

J. A. Beck[a] and G. J. Budgell
North Western Medical Physics, Christie Hospital NHS Foundation Trust, Withington, Manchester M20 4BX, United Kingdom

D. A. Roberts and P. M. Evans
Joint Department of Physics, Institute of Cancer Research, Royal Marsden NHS Foundation Trust, Downs Road Sutton, Surrey SM2 5PT, United Kingdom

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Normalize the response of EPID in pursuit of linear accelerator dosimetry standardization

Bin Cai[1] | S. Murty Goddu[1] | Sridhar Yaddanapudi[2] | Douglas Caruthers[1] | Jie Wen[3] | Camille Noel[4] | Sasa Mutic[1] | Baozhou Sun[1]

- Demonstrated for Elekta that EPID can be used for electron beam profile constancy,
  - However, this was done on flood field corrected images which potentially create systematic errors
- Demonstrated the PSM EPID calibration process works for electrons.

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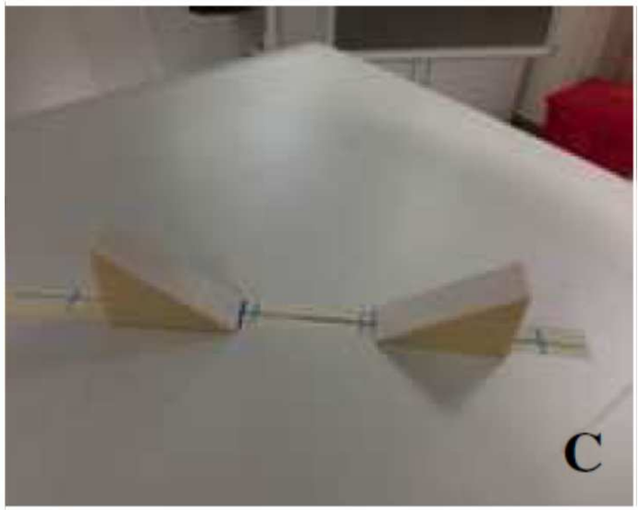
Electrons – Beam Quality

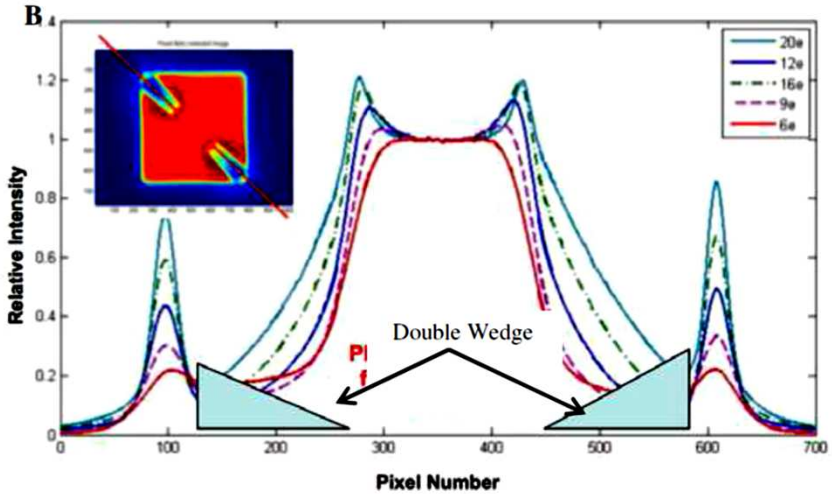
Rapid Acceptance Testing of Modern Linac using On-board MV and kV Imaging Systems

Sridhar Yaddanapudi, Ph.D.[1,*,a)], Bin Cai, Ph.D.[1,*], Taylor Harry, M.S.[2], Steven Dolly, M.S.[1], Baozhou Sun, Ph.D.[1], Hua Li, Ph.D.[1], Keith Stinson, CMD[3], Camille Noel, Ph.D.[3], Lakshmi Santanam, Ph.D.[1], Todd Pawlicki, Ph.D.[2], Sasa Mutic, Ph.D.[1], S Murty Goddu, Ph.D.[1]

- Electron beam energy check using EPID via profile changes when a double wedge phantom is imaged.

- Sensitivity was proven using adjustments to the bend magnet to the order of 1 mm in R50.





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Hold on, if we are all going to use EPID, don't we need to know that our EPIDs all respond consistently?

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EPID panel response consistency

- Studies demonstrate good consistency between EPID panels and long term constancy.
- Suggest: Include some EPID performance tests in the test suite.
- Consider: Benchmark the EPID against ion chamber for standard detector tests:
    - Eg Dose linearity, dose rate dependence, energy dependence etc

Normalize the response of EPID in pursuit of linear accelerator dosimetry standardization

Bin Cai[1] | S. Murty Goddu[1] | Sridhar Yaddanapudi[2] | Douglas Caruthers[1] | Jie Wen[3] | Camille Noel[4] | Sasa Mutic[1] | Baozhou Sun[1]

Australas Phys Eng Sci Med (2011) 34:459–466
DOI 10.1007/s13246-011-0106-0

SCIENTIFIC NOTE

Long-term two-dimensional pixel stability of EPIDs used for regular linear accelerator quality assurance

B. W. King · L. Clews · P. B. Greer

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Optimized Varian aSi portal dosimetry: development of datasets for collective use

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IOP Publishing — Physics in Medicine and Biology
Phys. Med. Biol. 53 (2008) 6893–6909 doi:10.1088/0031-9155/53/23/016

Assessment of dosimetrical performance in 11 Varian a-Si500 electronic portal imaging devices

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Institute of Physics Publishing — Physics in Medicine and Biology
Phys. Med. Biol. 51 (2006) 4189–4200 doi:10.1088/0031-9155/51/17/005

An intercomparison of 11 amorphous silicon EPIDs of the same type: implications for portal dosimetry

Peter Winkler and Dietmar Georg

Conclusion: Can we use EPID for linac beam commissioning?

- Ill leave that up to you to decide for yourself

- but, if…
  1. Linac beam consistency is proven
     - so we use consensus data
  2. EPID response consistency is proven.
  3. EPID sensitivity to beam variability is proven

- Then why not. I think there is a pathway here that Halcyon and Tomotherapy have already started down.

- However,
  – We will still need to do an ion chamber absolute calibration and benchmark our EPIDs.
  – More work required for electron beams

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Thank you

michael.barnes@calvarymater.org.au

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