



# Introduction to Small Field Dosimetry

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# TECHNICAL DIFFICULTIES



# PLEASE STAND BY

# Disclaimer

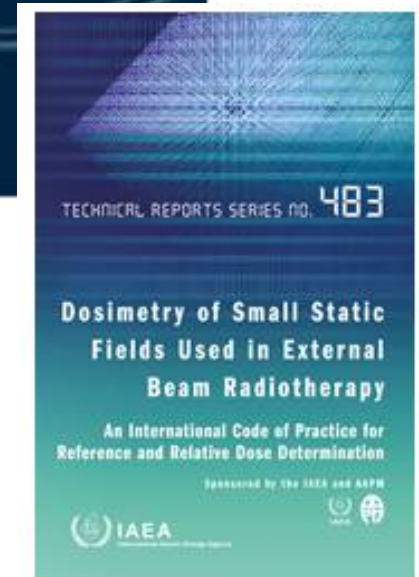
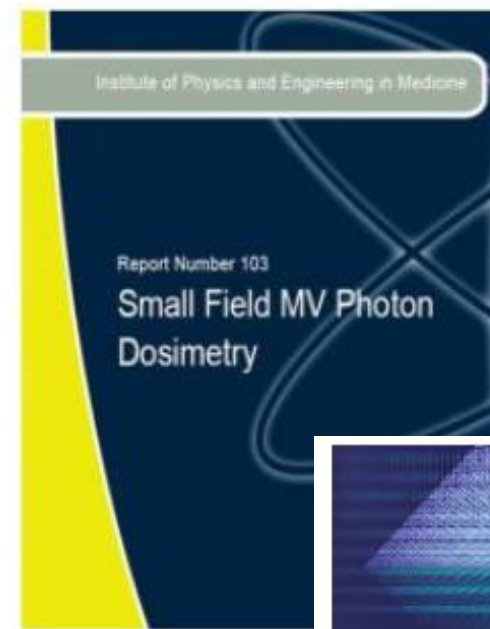


- Small-field dosimetry is a huge and complex subject
- This is a basic introduction to some of the issues surrounding small field dosimetry
- Not a set of “how-to” instructions
- Small field measurement errors have led to clinical incidents e.g. Hopital de Rangueil in Toulouse, France (2006-7)

Report concerning the radiotherapy incident at the university hospital centre (CHU) in Toulouse – Rangueil Hospital. ASN – Autorité de Sûreté Nucléaire (2007)

# Sources of Guidance

- IPEM Report 103: Small Field MV Photon Dosimetry
- IAEA Report 483: Dosimetry of Small Static Fields Used in External Beam Radiotherapy
- AAPM TG-155: Small fields and non-equilibrium condition photon beam dosimetry (in review)

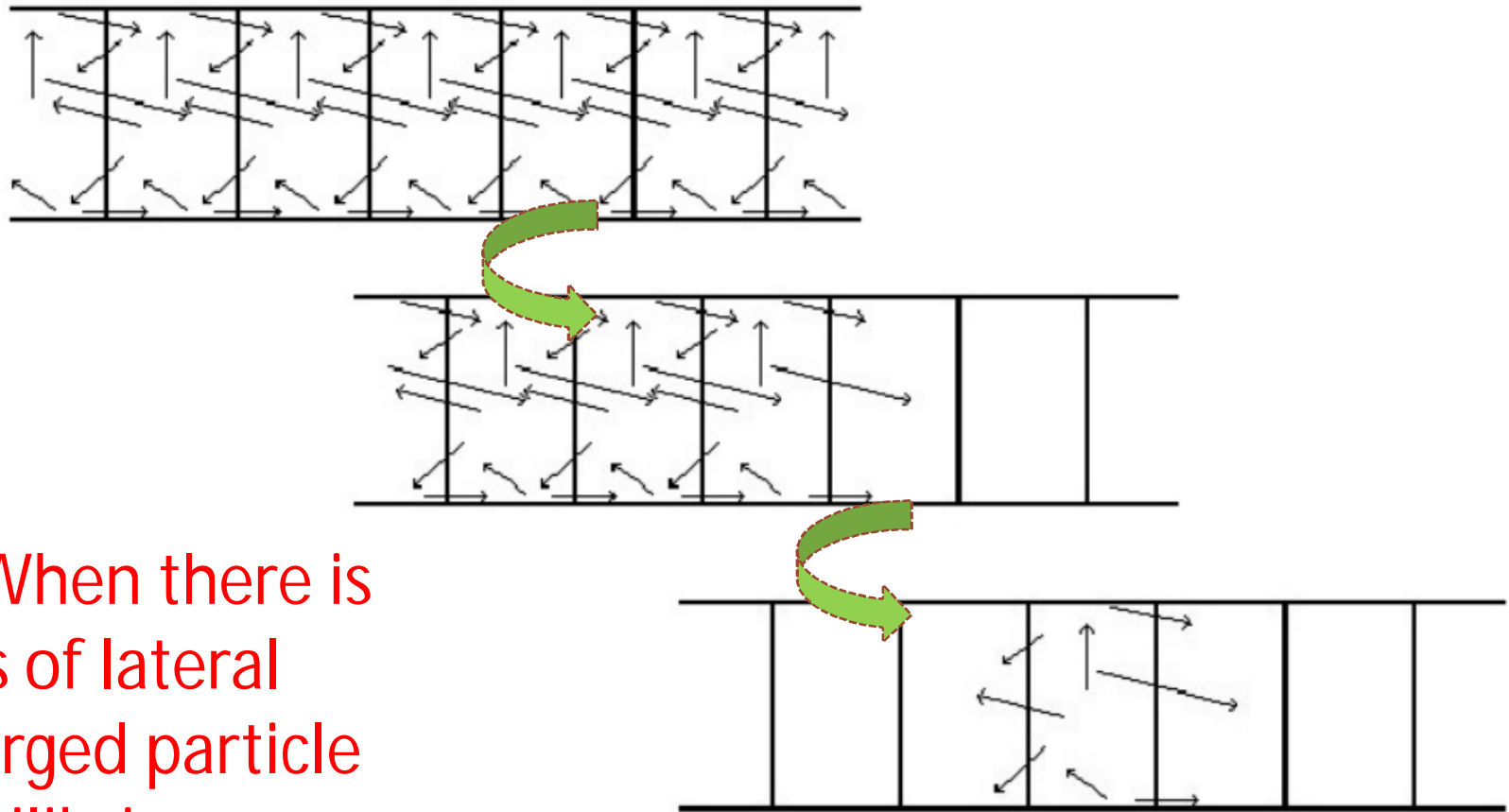


# Overview



- When is a field “small”?
- Differences between small and large fields
- Choice of detector for small field dosimetry
- Audit

# When is a Field “Small”?



1. When there is  
loss of lateral  
charged particle  
equilibrium

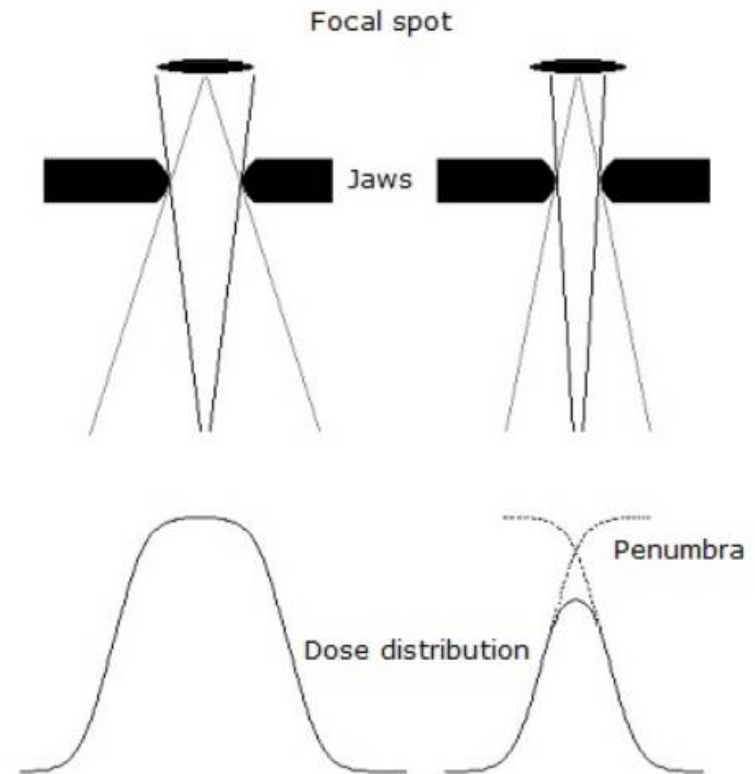
# When is a Field “Small”?



2. When there is partial occlusion of the primary source



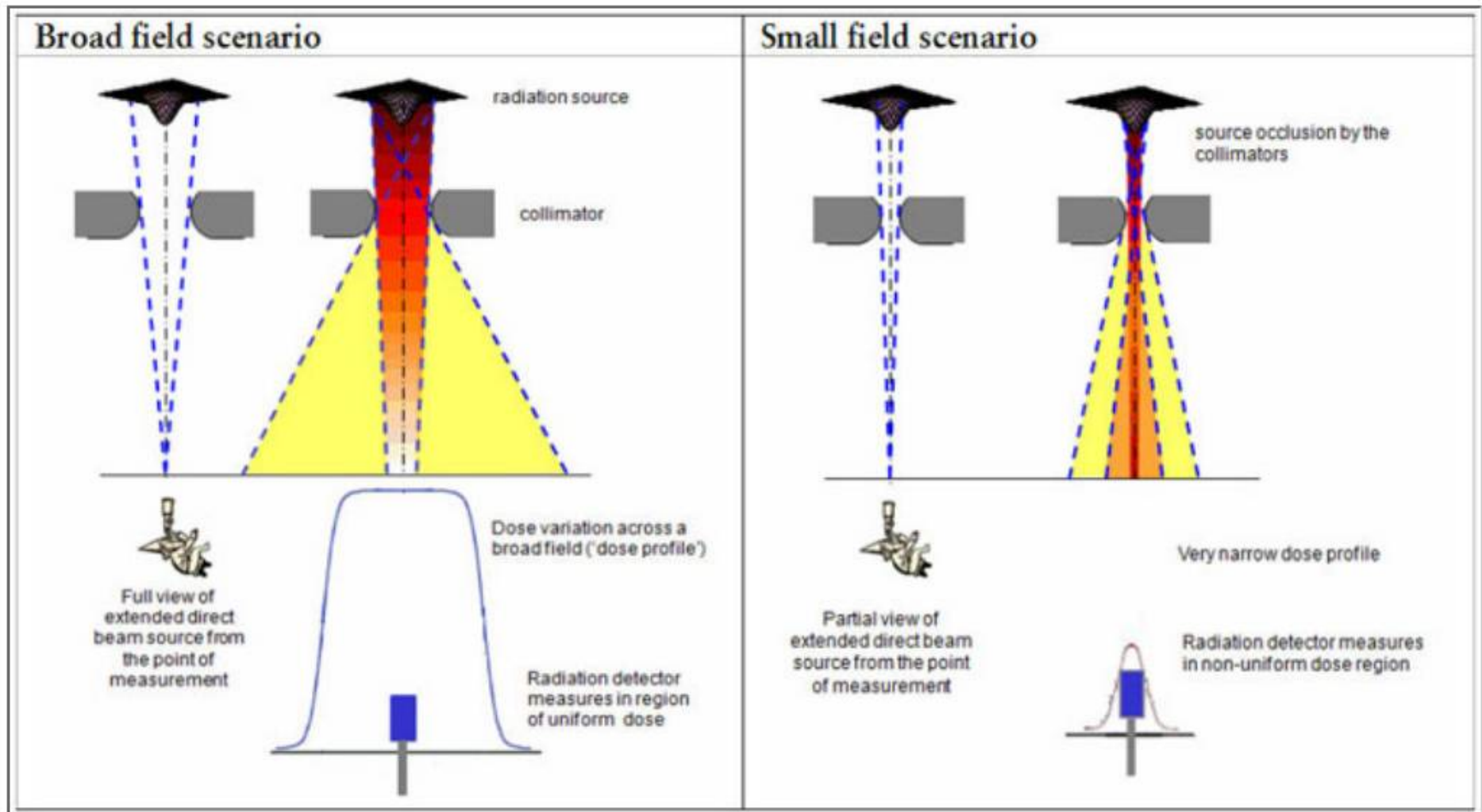
Leading to a marked reduction in output factor



Source occlusion alters the shape of the profile when the field is narrower than twice the penumbral width.

Image from Scott *et al.* 2009

# When is a Field “Small”?



Aspradakis, M and Byrne, J. Small field dosimetry: challenges and progress (2011).  
medicalphysicsweb.org



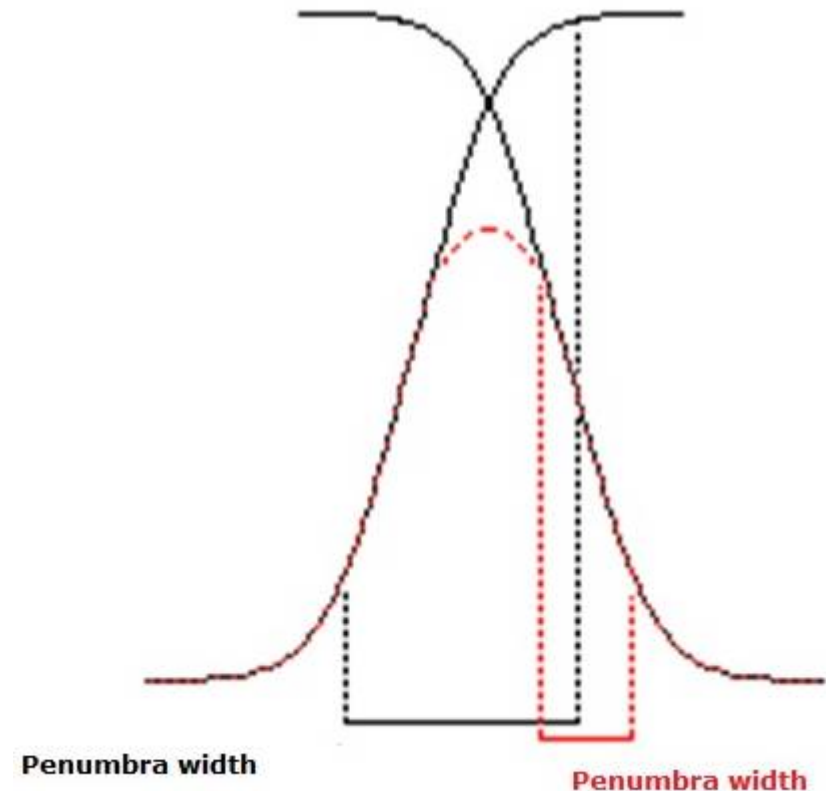
# When is a Field “Small”?



Source occlusion also alters the shape of the profile



Steeper fall off in the penumbra (80% - 20%) for small fields



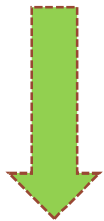
Source occlusion alters the shape of the profile when the field is narrower than twice the penumbral width.

Image from Scott *et al.* 2009

# When is a Field "Small"?



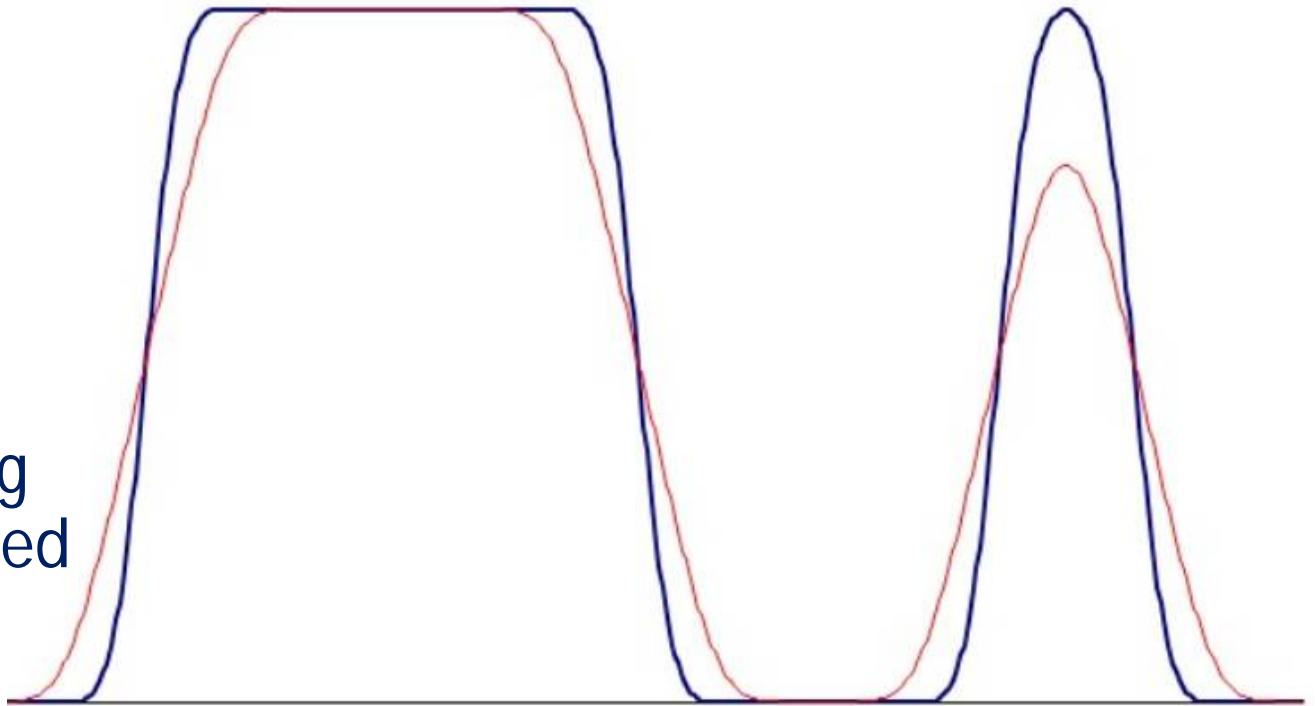
3. When the detector size is too large relative to size of the field



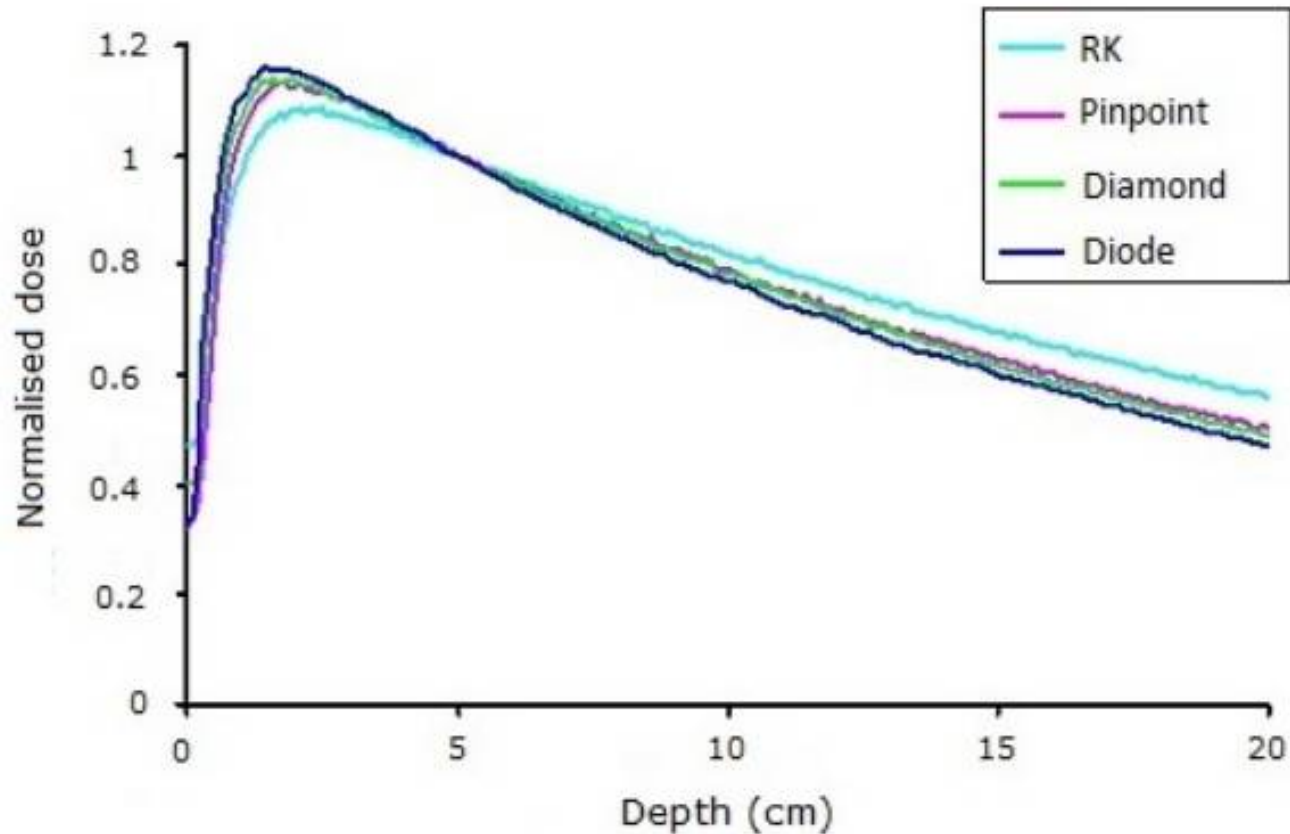
Volume averaging leads to broadened penumbra and reduced dose on CAX

Blue = true dose profile

Red = measured dose profile



# When is a Field “Small”?



RK ionisation chamber: 0.4 cm diameter, 1 cm length

Pinpoint ionisation chamber: 0.3 cm diameter, 0.3 cm length

Diamond detector: 0.3 cm diameter, 0.02 cm thick

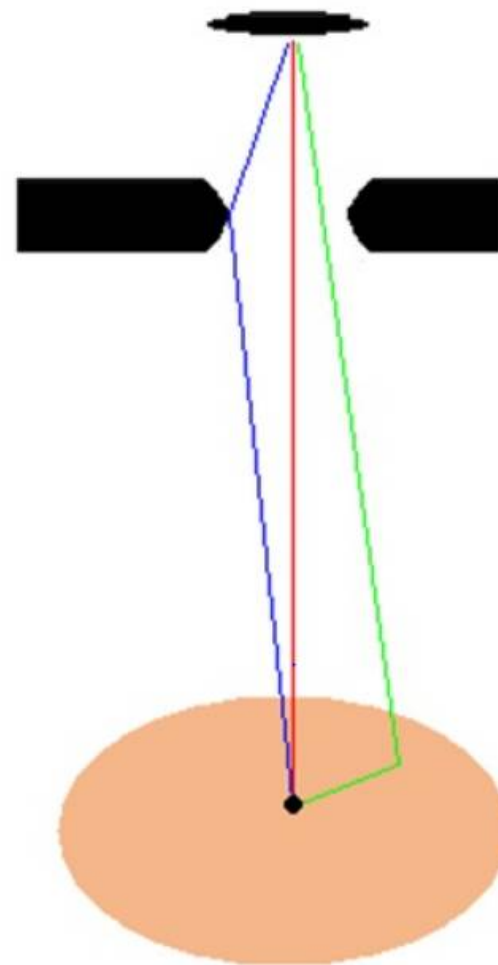
Photon diode: 0.25 cm diameter, 0.5 mm thick

Depth-dose curves for 0.5 cm x 0.5 cm field




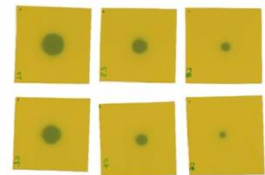
# Choice of Detector: Energy Dependence



- Change in photon spectrum – average energy increases as the beam gets smaller
- Use energy-dependent detectors with caution
- Consider daisy-chaining measurements from an intermediate field size (e.g. 3 cm) to a 10 cm field

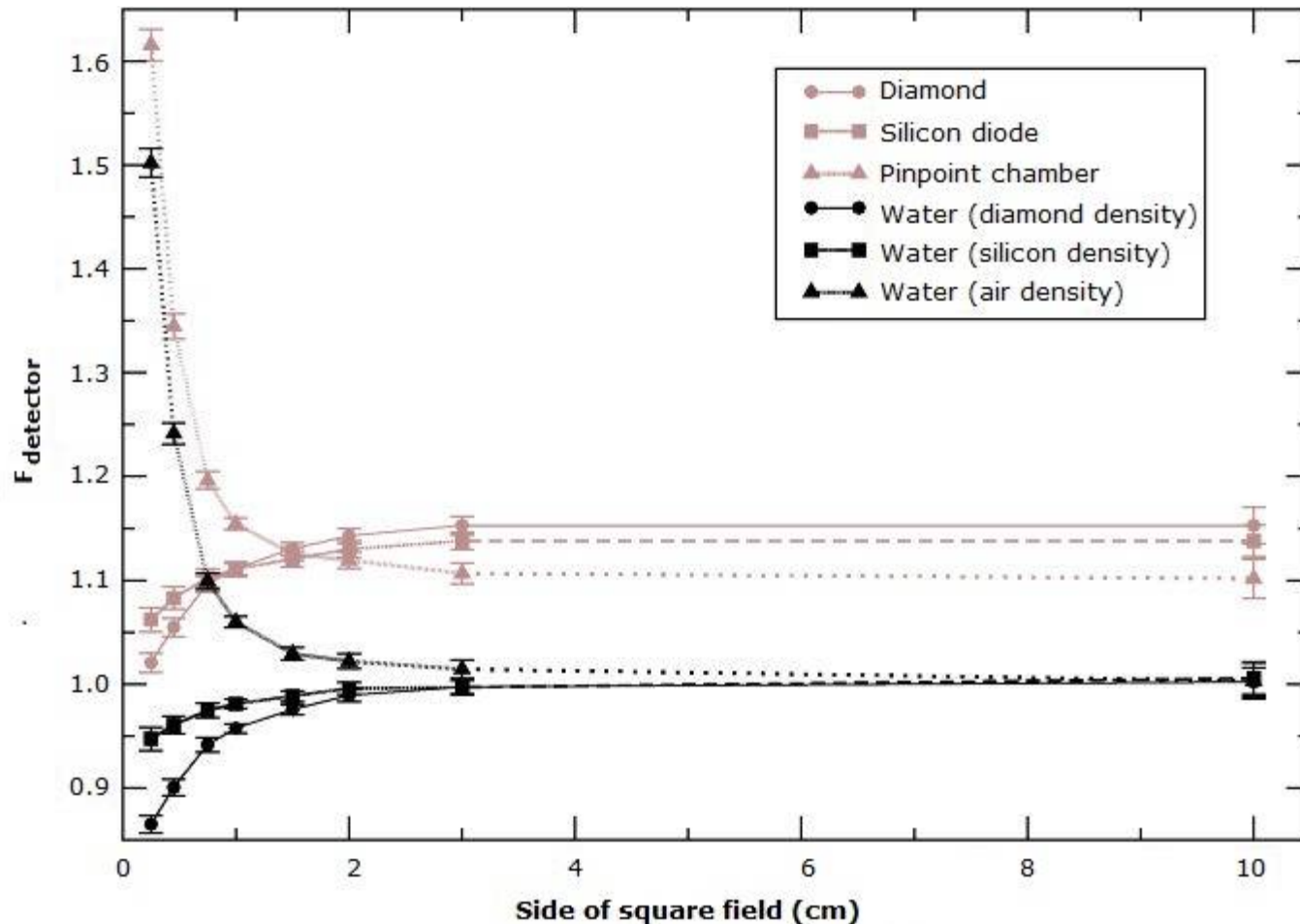


# There is No Ideal Detector...

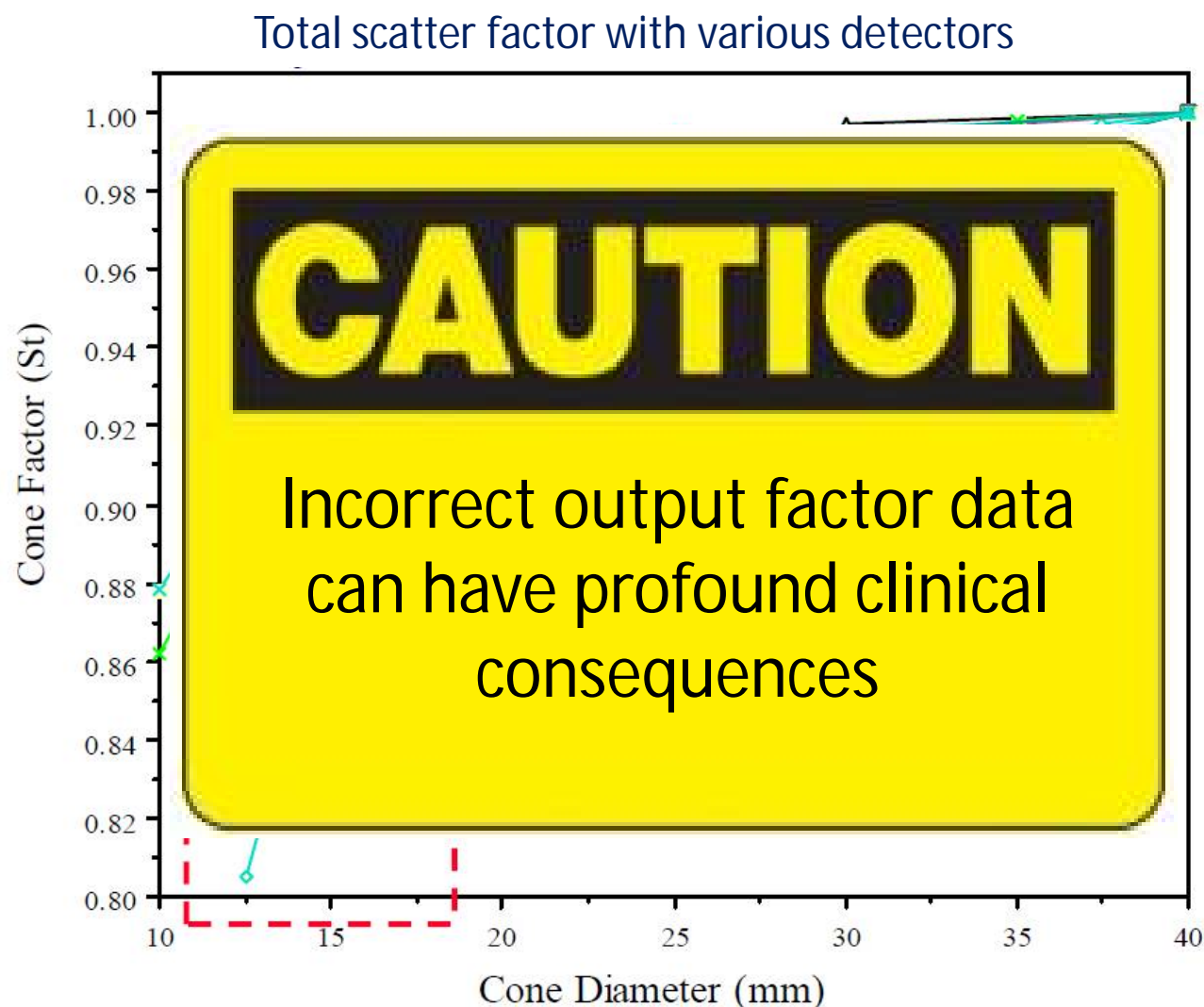
Detector	Advantages	Disadvantages
Small-volume ionisation chamber e.g. pinpoint 	Easy to calibrate (to traceable primary standard) Well-known energy response Often directionally independent response and resolution	Not suitable for very small fields (~2 cm) Insensitive / subject to noise
Stereotactic (small, unshielded) diode 	Highly sensitive, low noise Sensitive volume 0.3 mm <sup>3</sup> (PTW SFD) Suitable up to 10 cm x 10 cm	Potential angular dependence Energy dependence (silicon not tissue equivalent)
Diamond 	Good tissue equivalence – minimal energy dependence Suitable up to 40 cm x 40 cm Sensitive volume 0.004 mm <sup>3</sup> (PTW microDiamond)	Possible dose-rate dependency May require irradiation to a high dose (~10 Gy) before each fraction Directional dependence
GafChromic Film 	Potentially infinite resolution Requirement for positional accuracy reduced	Result is not instant Response depends on time to read-out and orientation in scanner Cannot be reused - expensive

# Detector Issues: Perturbation

Monte-Carlo modelled variation in  $F_{\text{detector}}$  (ratio of dose-to-water to dose-to-detector in water) with field size for 3 different detectors



# Choice of Detector: Output Factor



# Choice of Detector: Recommendations



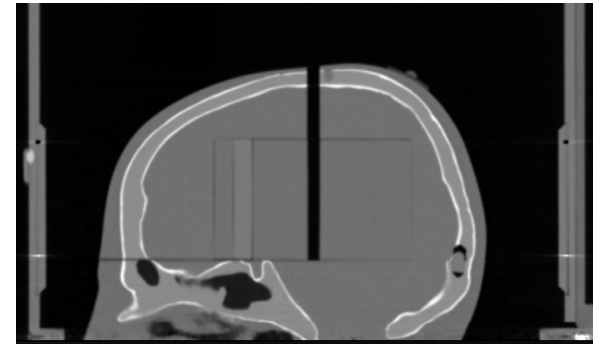
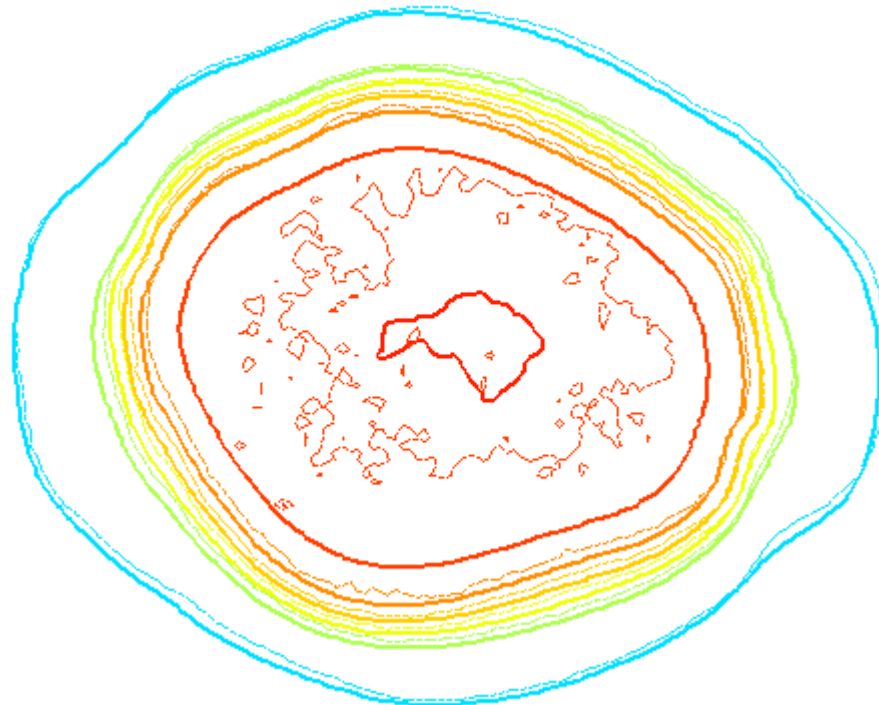
1. Fully characterise your detectors - they may not behave identically to others of the same model
2. Use as small a detector as you can whilst maintaining a good SNR
  - Volume averaging
  - Perturbation
3. Corroborate your measurements:
  - Repeat with same equipment (geometrical inaccuracies)
  - Repeat with different equipment (suitability of detectors)
  - Compare to other centres' data or golden data
  - Arrange an external audit for all new techniques



# End-to-End Dosimetric Accuracy

Dosimetric end-to-end testing is essential - relative (shown here) and absolute measurements

Isodose level (Gy)
5
8
9
10
11
12
12.5



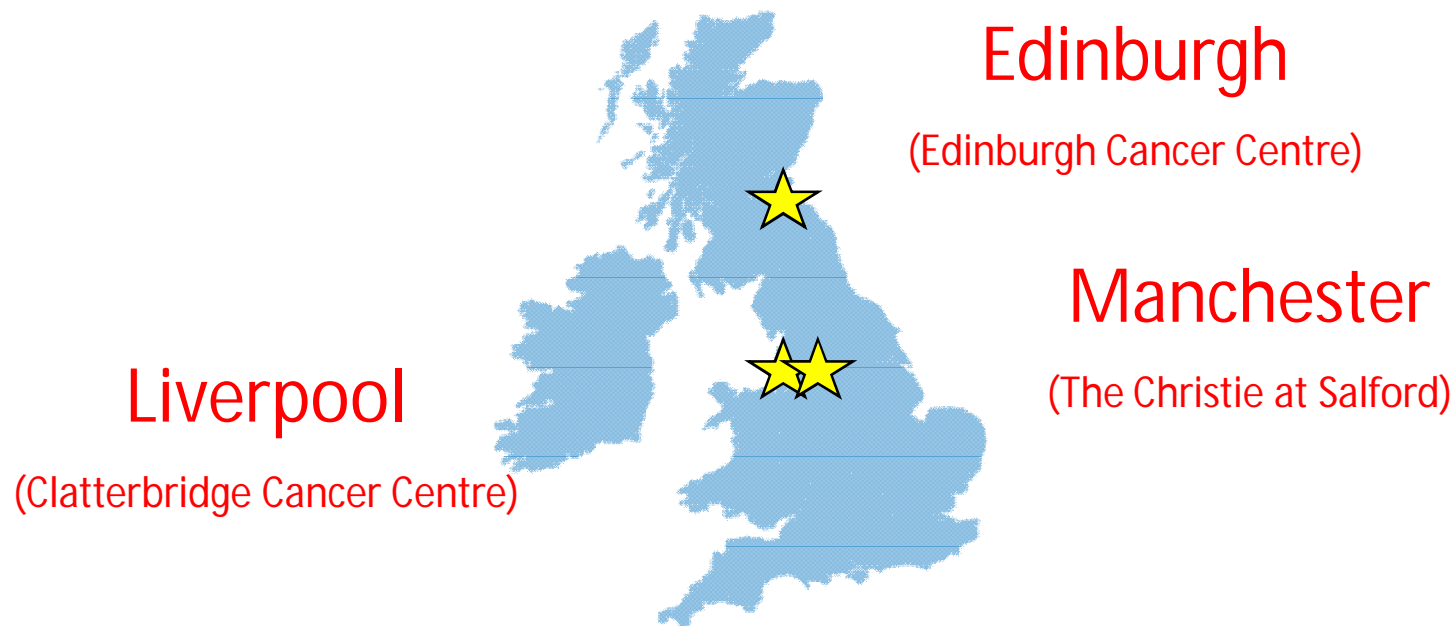


# Audit & Corroboration of Data

# The Novalis Triangle



- In 2011, three centres installed the UK's first Novalis Tx's (Varian specialist stereotactic linac)



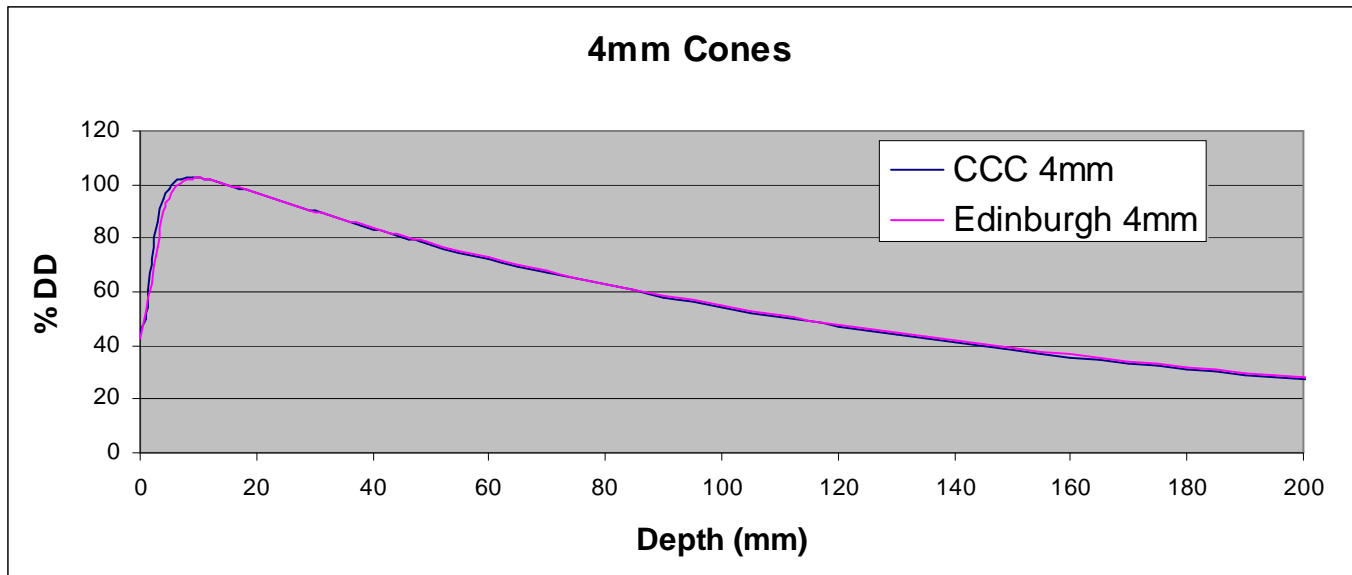
# Novalis Triangle Comparison



- Bolt-on circular collimator arcs – 4 mm - 15 mm diameter
- Ideal for small, spherical lesions but introduce dosimetric challenges
- Opportunity to share experience and directly compare independent data



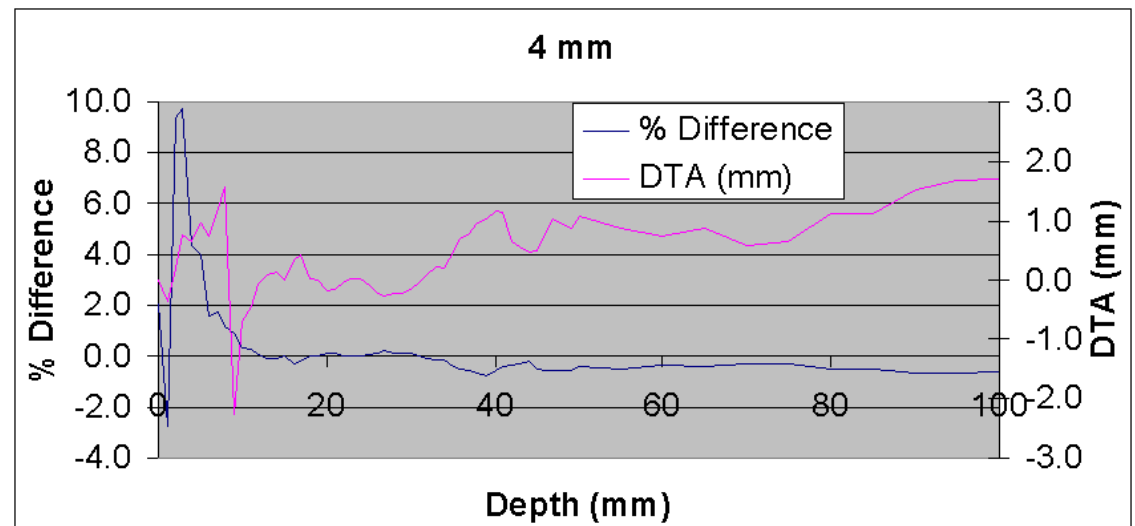
# PDD 6MVSRS – Liverpool vs. Edinburgh



Normalised to  
15 mm and  
unsmoothed.

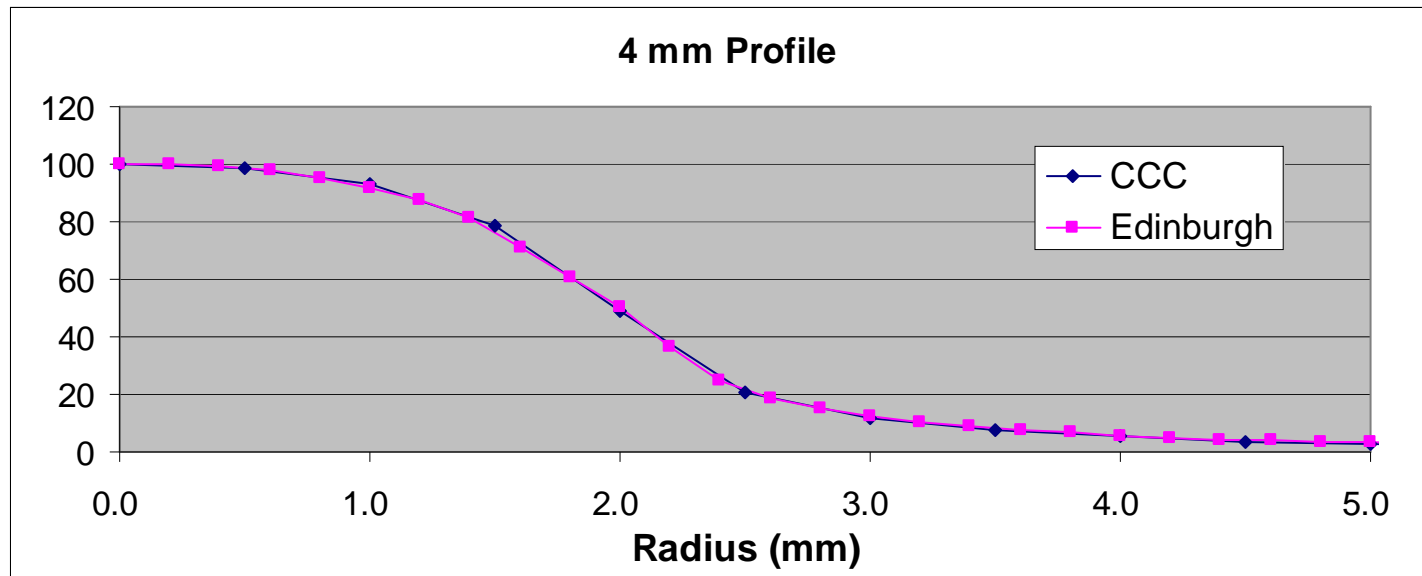
Agreement good for all diameters:

- DTA in build-up region < 2 mm
- % difference beyond Dmax is < 1 %



Presented by Martyn Gilmore  
at ICPM, Brighton, UK 2013

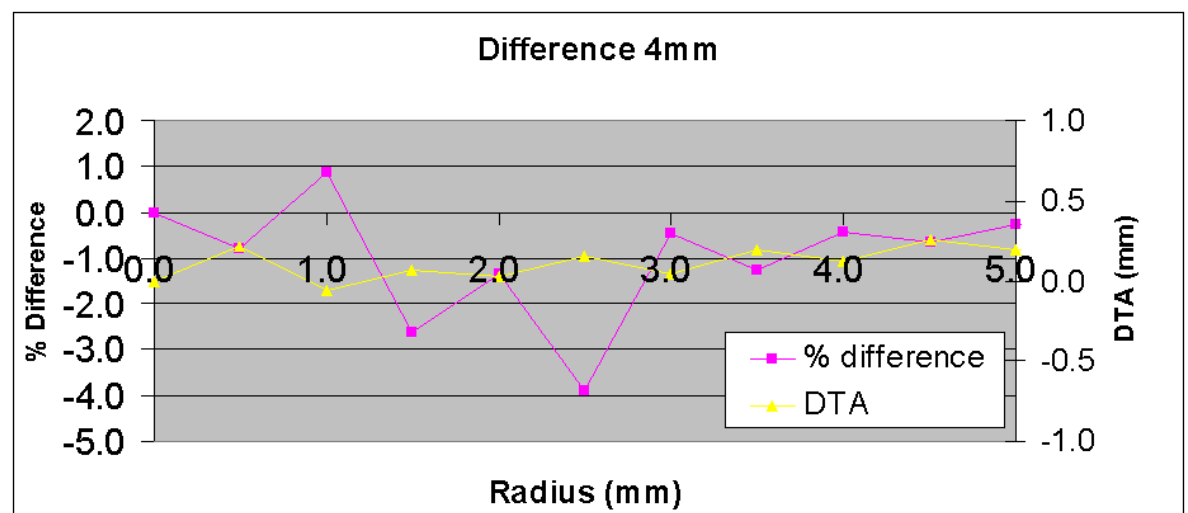
# Profiles 6MVSRS – Liverpool vs. Edinburgh



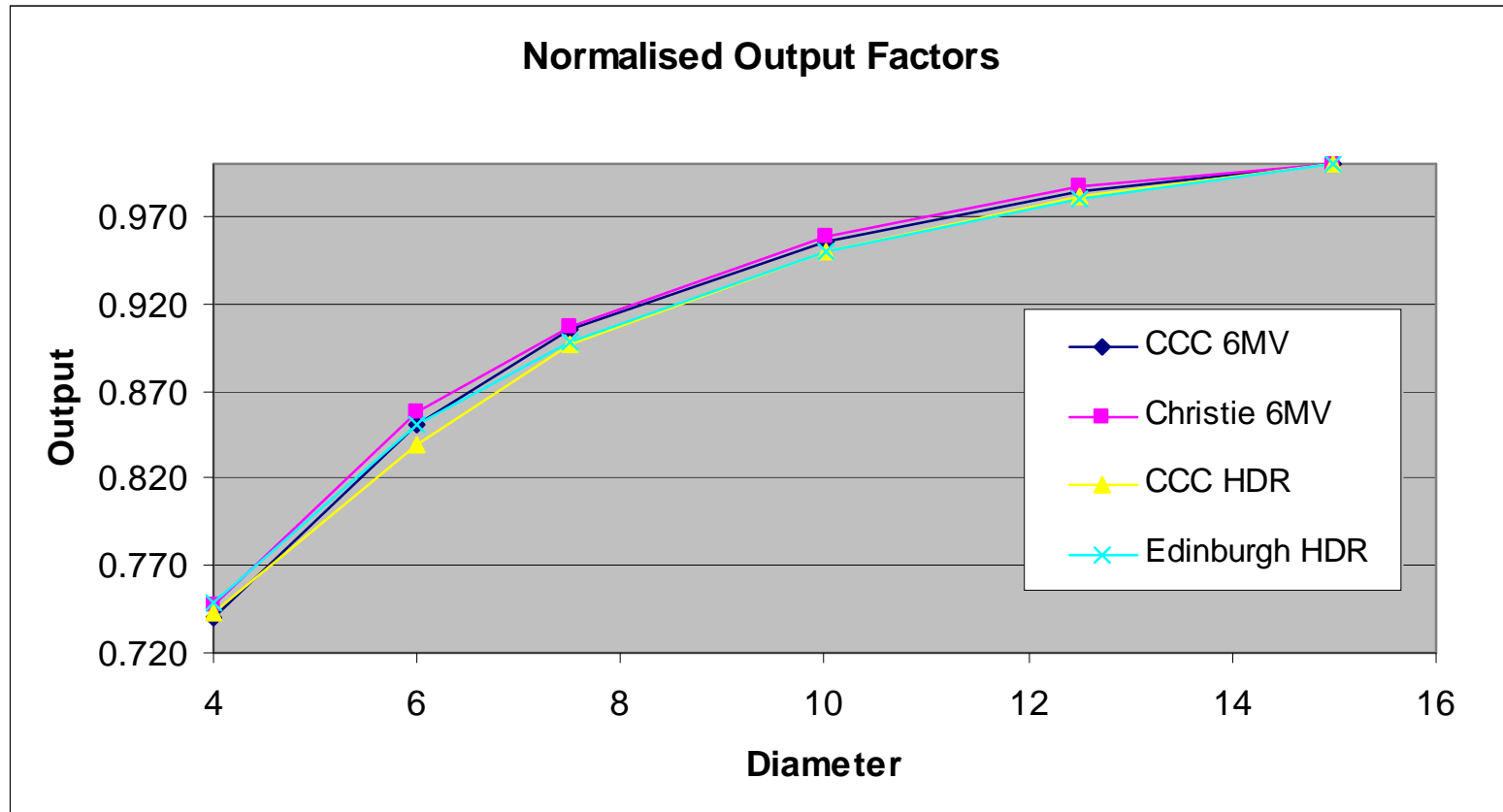
Profiles show good agreement for all diameters

- % difference in central region < 2 %
- DTA in penumbra < 0.2mm

Presented by Martyn Gilmore  
at ICPM, Brighton, UK 2013



# Output Factors Comparison



# Initial Report on Cranial SRS audit

*A collaboration between:*

Royal Surrey County Hospital   
NHS Foundation Trust

Portsmouth Hospitals   
NHS Trust

   
National Physical Laboratory Radiotherapy Trials Quality Assurance

**Centre:** Clatterbridge Cancer Centre

**Delivery Platform / Planning system:** Varian Linac / iPlan

**Technique / Energy:** Non-coplanar static fields / 6MV SRS mode

**Date of visit:** 20<sup>th</sup> January 2016

**Local Hospital Staff:** Laura Howard

**Auditors:** Alexis Dimitriadis & Jonathan Lee

**Alanine pellets processed and checked by:** Clare Gouldstone & David Crossley – NPL

**Report compiled by:** Alexis Dimitriadis

**Report checked by:** Catharine Clark

Location	Pellet No.*	Measured (cGy)	Output Corrected (cGy)	Predicted (cGy)	Relative difference with output corrected (%)
Target	2336.1	2185.1	2146.5	2143.0	0.2%
	2336.2	2167.6	2129.3	2113.0	0.8%
	2336.3	2137.5	2009.7	2087.0	0.6%
	2336.4	2105.8	2068.6	2041.0	1.4%
Mean of all pellets		2149.0	2111.0	2096.0	0.7%

\*pellet 1 at the superior end of the holder; pellet 4 at the inferior end of the holder.



# Warning



- Even the best data can produce poor results if they are not used correctly by the treatment planning system
- Ensure you understand your planning system
- Treatment planning system beam data errors affect ALL patients
- Use your beam model to verify a number of non-standard fields
- Is there a minimum field size that you can safely use?
- Dosimetric end-to-end testing should be part of commissioning and routine QA

# Any Questions?

