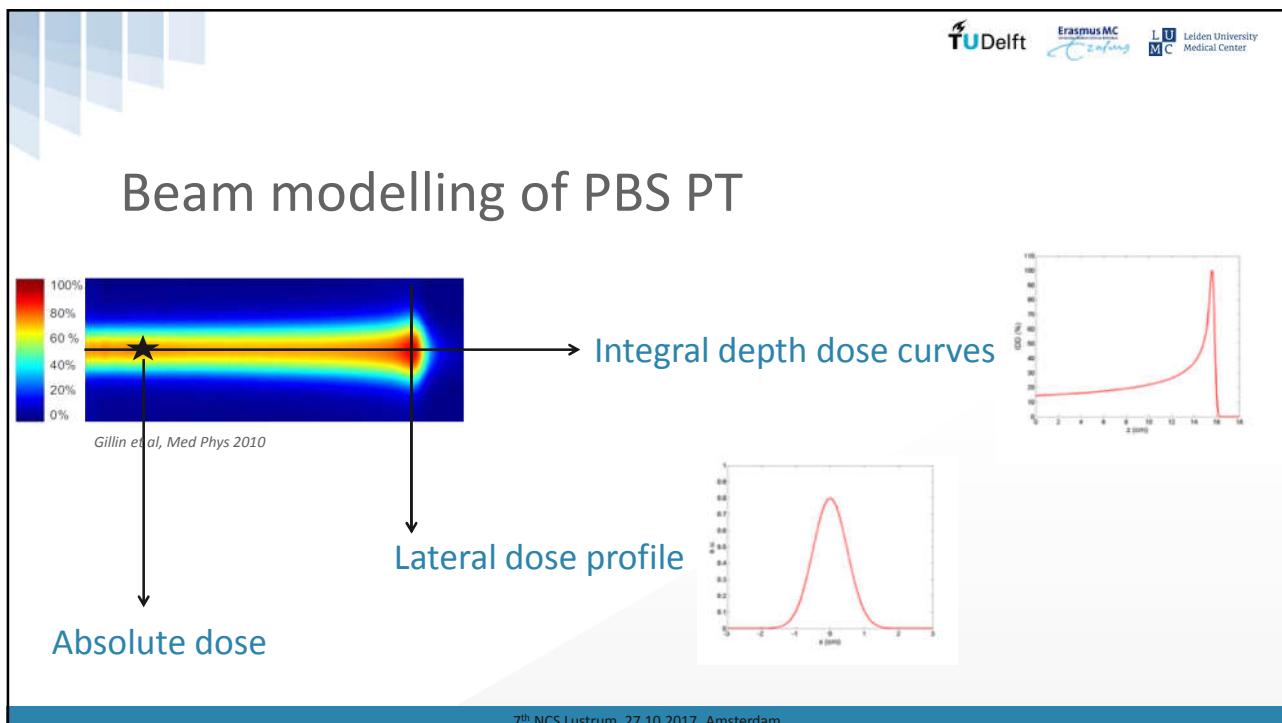
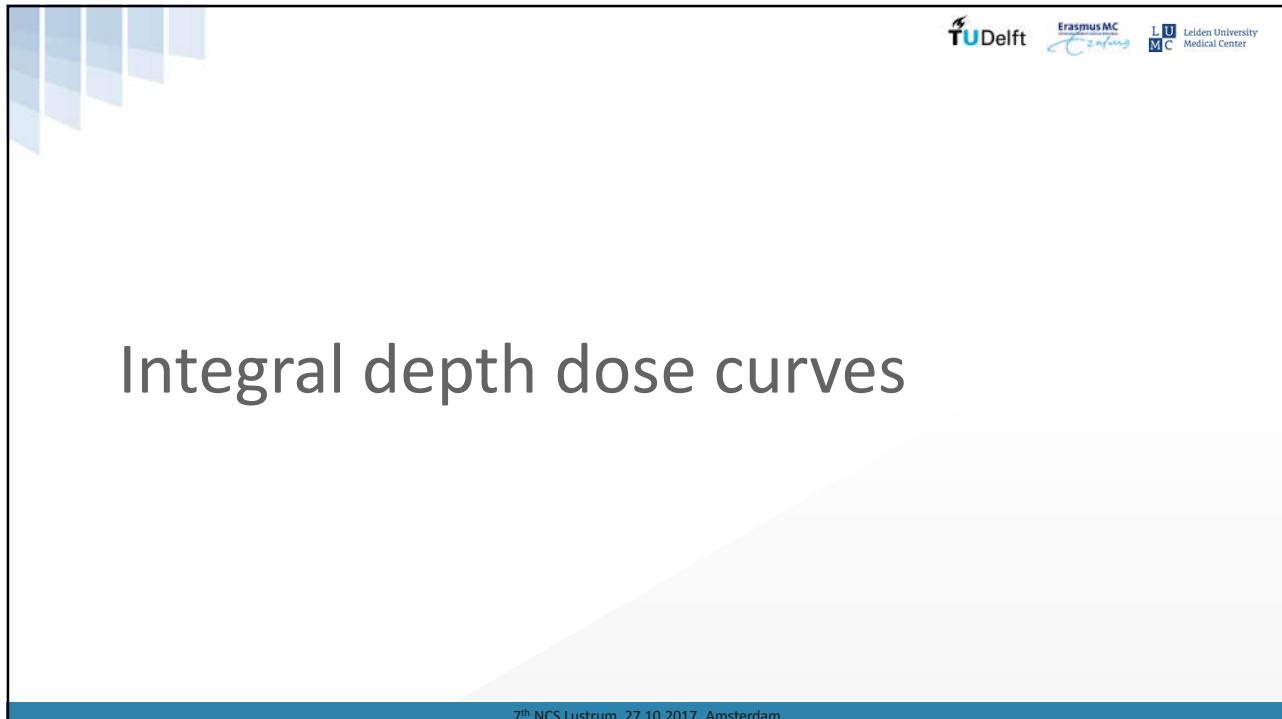


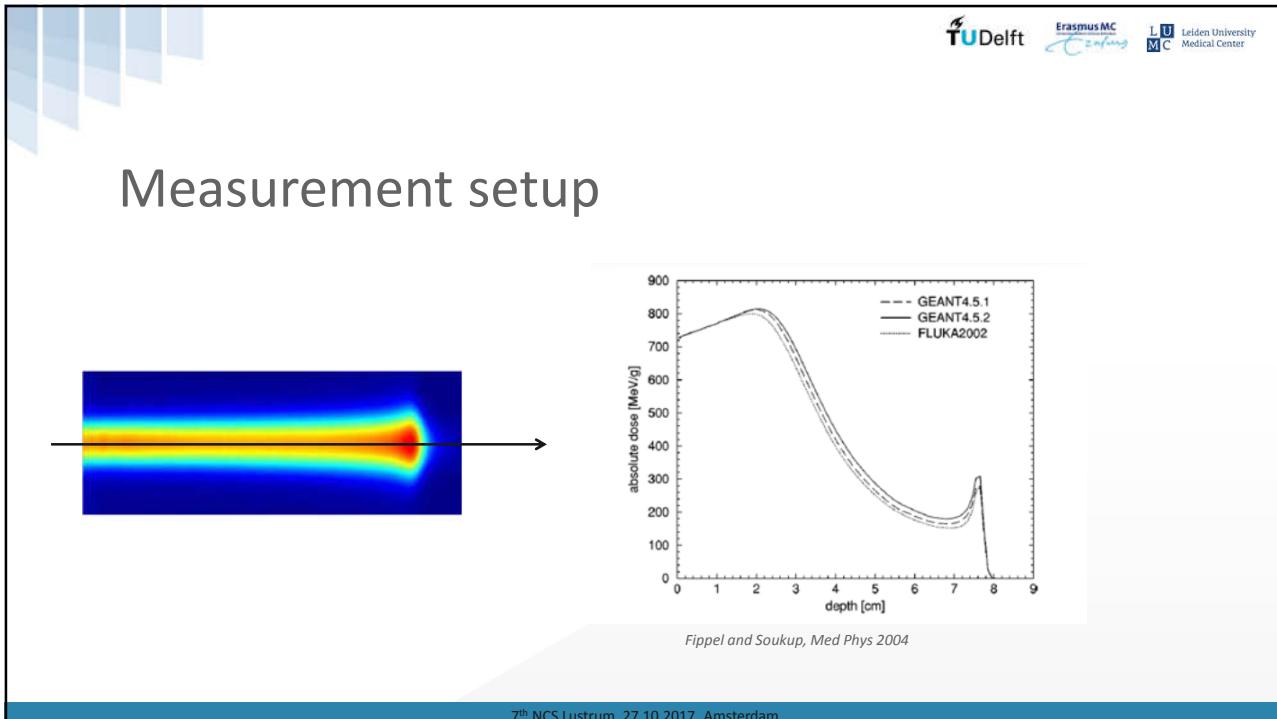
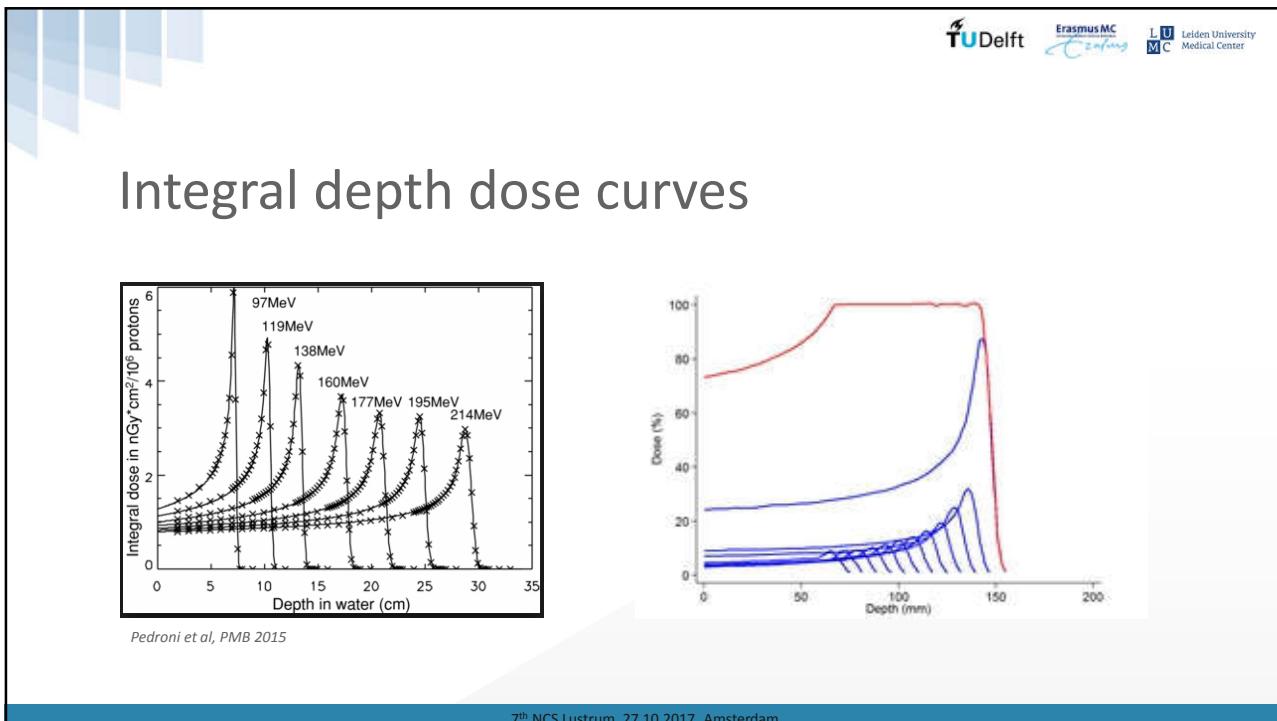
Relative dosimetry for scanned pencil beam proton therapy

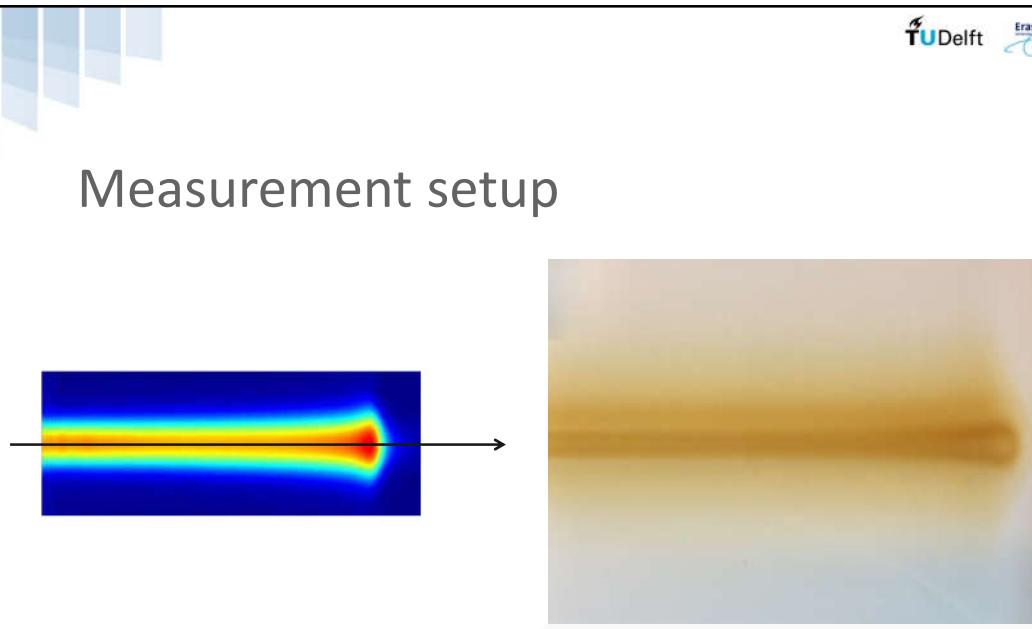
Petra Trnková

Outline

- Relative dosimetry:
 - Integral depth dose measurements
 - Phase space definition
- NCS subcommittee for proton therapy

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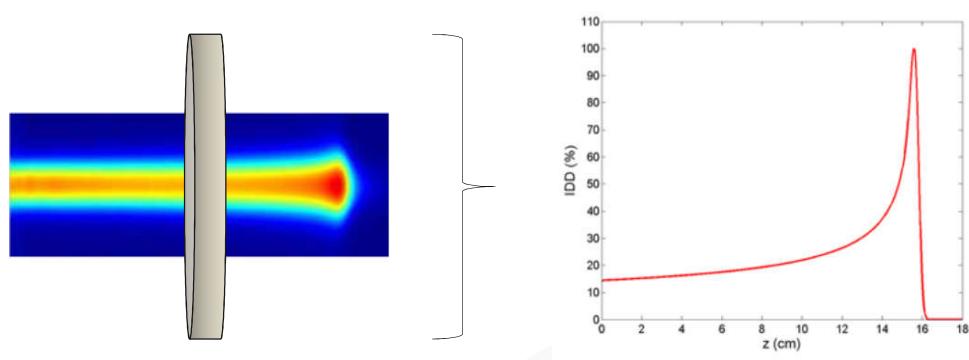




The figure shows a measurement setup. On the left, a schematic diagram illustrates a beam passing through a lens, represented by a vertical rectangle, and then diverging. An arrow points from this schematic to a photograph on the right. The photograph shows a beam of light diverging from a point source, with the divergence angle increasing as it moves away from the source.

Courtesy of Ethan Cascio and Martijn Engelsman

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The figure shows a measurement setup. On the left, a schematic diagram illustrates a beam passing through a lens and then diverging. A bracket indicates the divergence angle. To the right is a graph showing the intensity distribution (ID) in percent versus distance z in centimeters. The curve starts at approximately 15% at $z = 0$, remains relatively flat until $z \approx 10$, and then rises sharply to a peak of about 100% at $z \approx 15.5$, before dropping back to near zero at $z \approx 17$.

Courtesy of Carles Gomà

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Bragg peak chambers



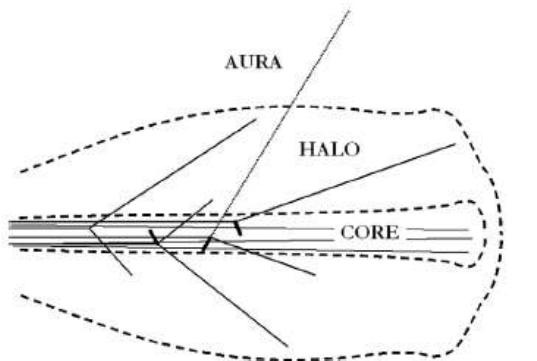
PTW Bragg Peak Chamber 34070
Diameter 8.16 cm



IBA Stingray
Diameter 12 cm

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Nuclear halo



Gottschalk et al, PMB 2015

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Absolute measurement of the entire halo

BEAM MONITOR $96.8 \times$

CURRENT INTEGRATOR 10 pC/count

PRESCALER $+ 16,000$

$6.45 \times 10^6 \text{ p / MU}$

Keithley 6512

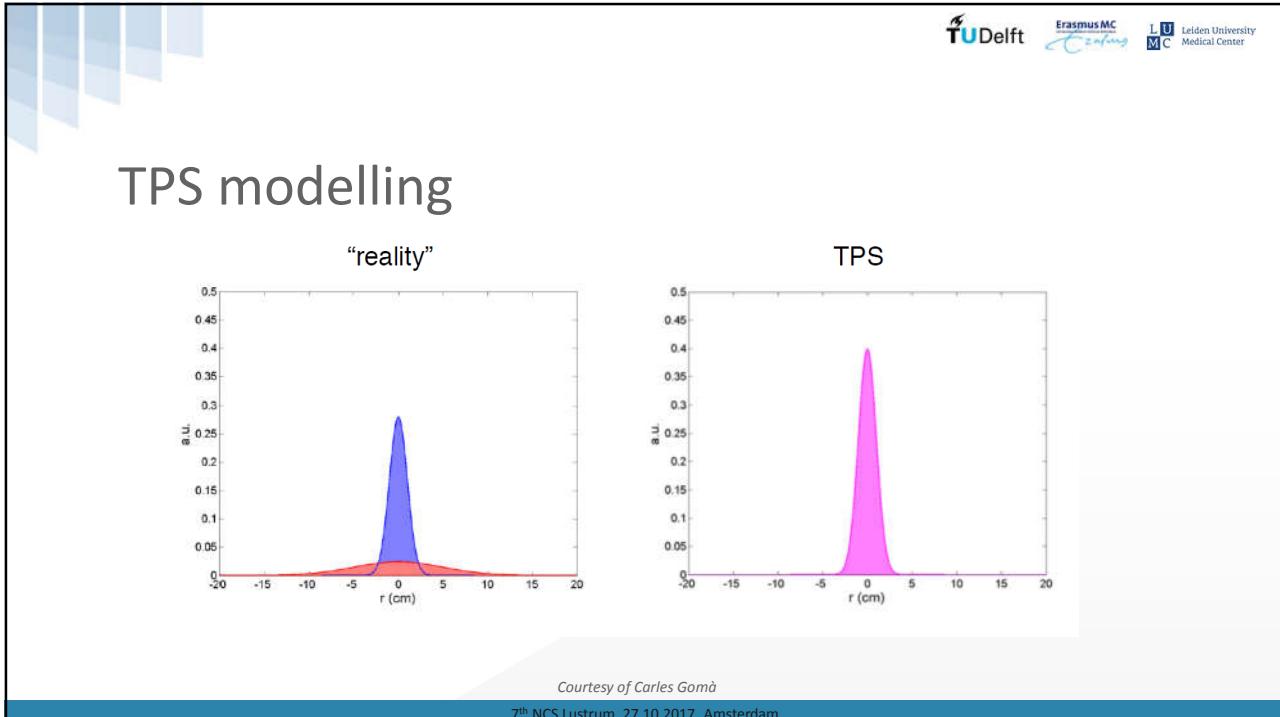
5.1415

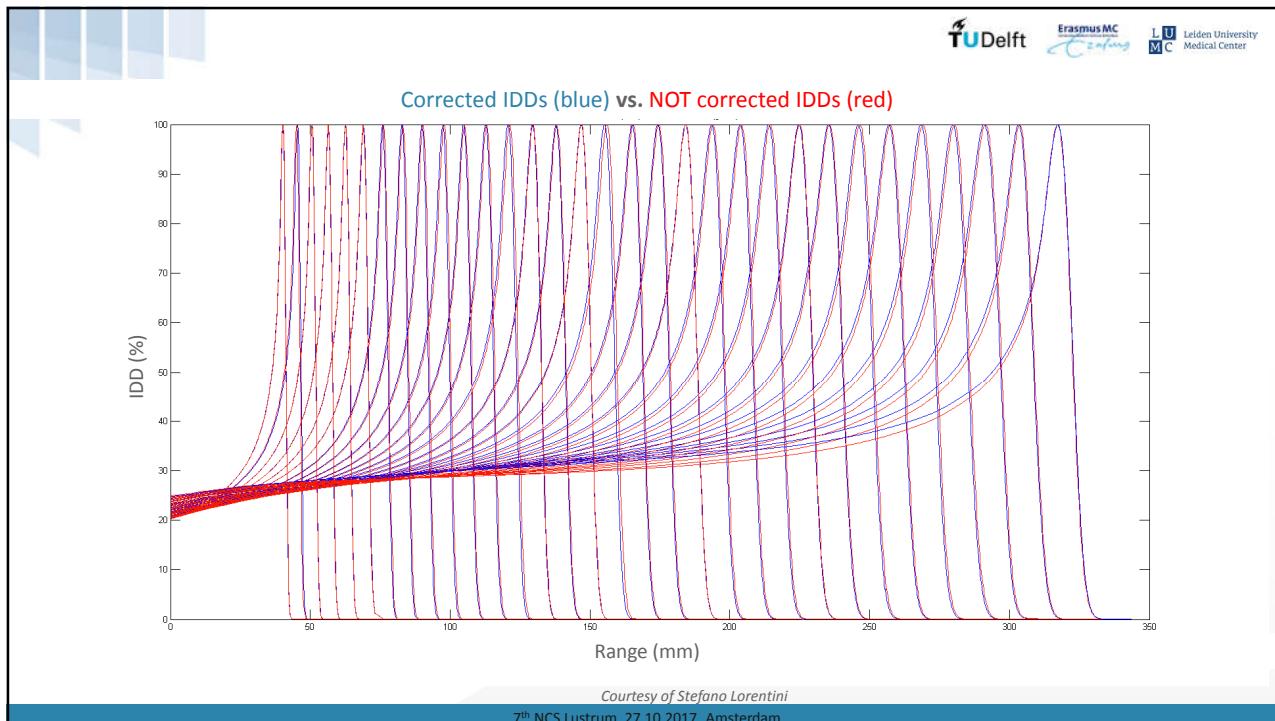
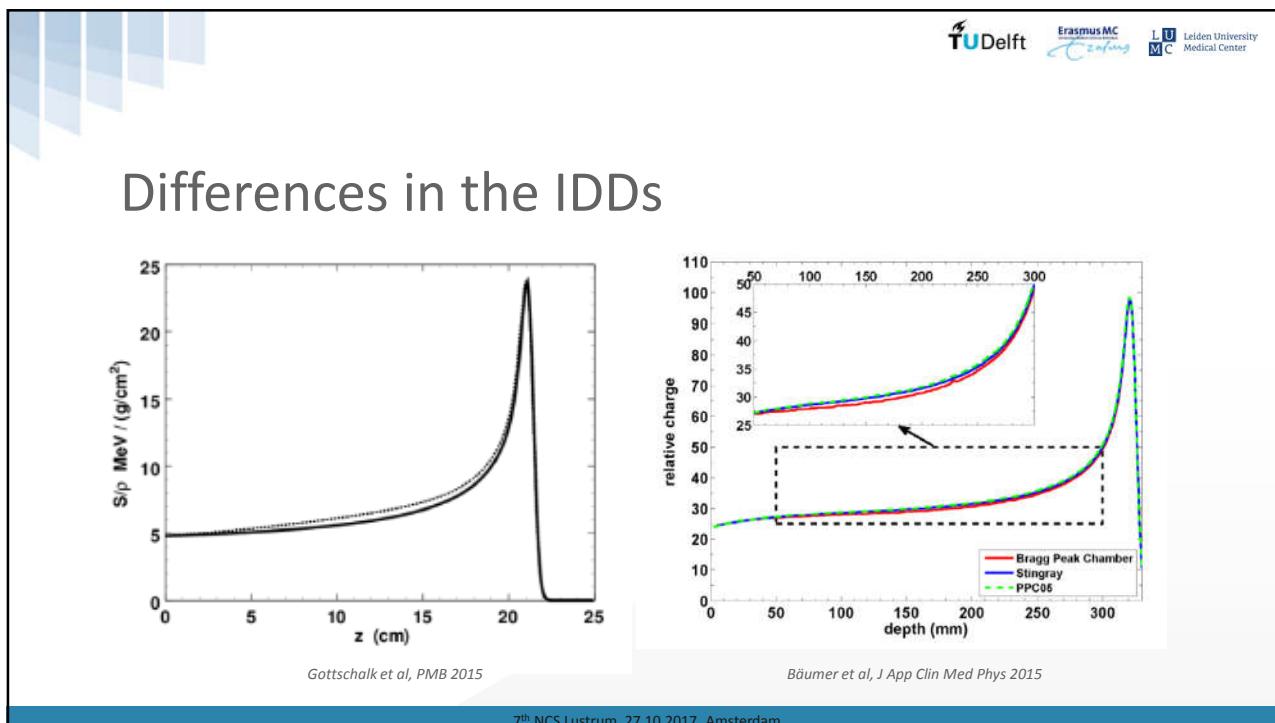
Exradin T1

O

PRESET BEAM ON/OFF

Gottschalk et al, PMB 2015

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How to correct?

- Monte Carlo simulations (Fippel& Soukup, Med Phys 2004)
- Analytical calculations (Pedroni, PMB 2005)
- Experimental correction (Anand, MedPhys 2012)
- Golden beam data approach (Classie, PMB 2012)

- Create large Bragg peak chambers

- **Note:** RayStation 6 corrects during the beam modelling

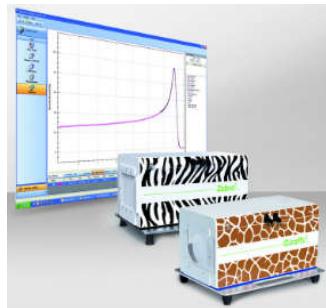
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Other measurement devices

- Multi-layer ionization chambers (MLIC)
 - IBA Zebra: 180 independent chambers
 - IBA Giraffe: 180 independent chamber
 - De.Tec.Tor Cube: max 128 independent chambers
- Water column with a reference and measurement chamber
 - PTW Peakfinder: scanning range 35 cm

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MLIC



IBA Zebra: \varnothing 2.5 cm

IBA Giraffe: \varnothing 8.16 cm



De.Tec.Tor CUBE: $12.7 \times 12.7 \text{ cm}^2$

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PTW Peakfinder

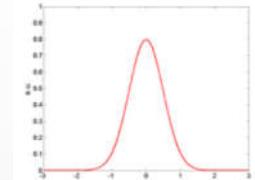
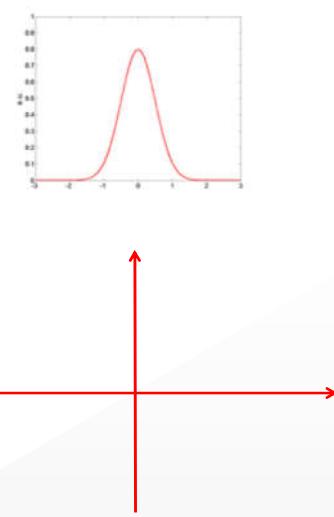
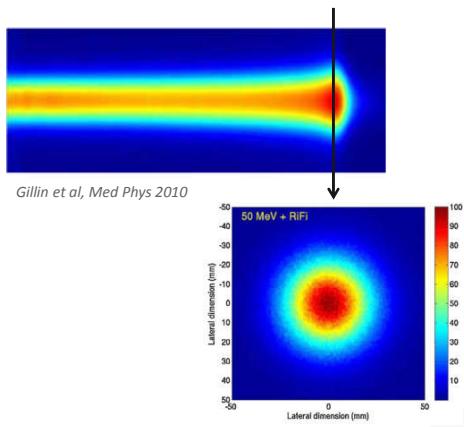


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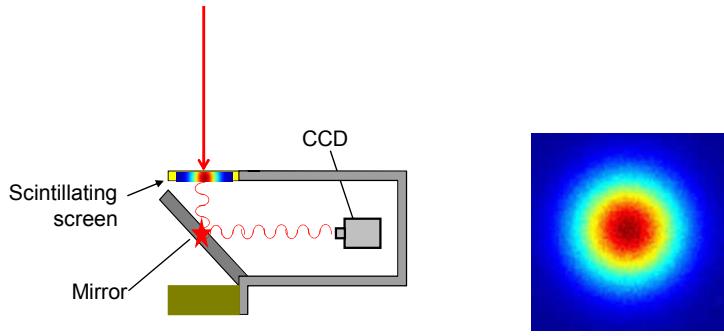
Phase space definition

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Lateral dose profile



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The diagram illustrates a measurement setup for imaging. A red arrow points from the top towards a scintillating screen. The screen is positioned behind a mirror, which reflects the light onto a CCD camera. To the right of the setup is a heatmap showing a central bright region with concentric rings of decreasing intensity, representing the resulting image.

Scintillating screen
Mirror
CCD

Measurement setup

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The section displays three types of scintillation screens and detectors:

- IBA Lynx:** A large, rectangular scintillating screen with a built-in monitor showing a grid pattern.
- XRV-4000:** A blue detector unit with a black front panel labeled "XRV-4000". The Logos Systems logo is visible at the bottom.
- XRV-124:** A smaller, dark detector unit with a conical front end, also featuring the Logos Systems logo.

Scintillation screens

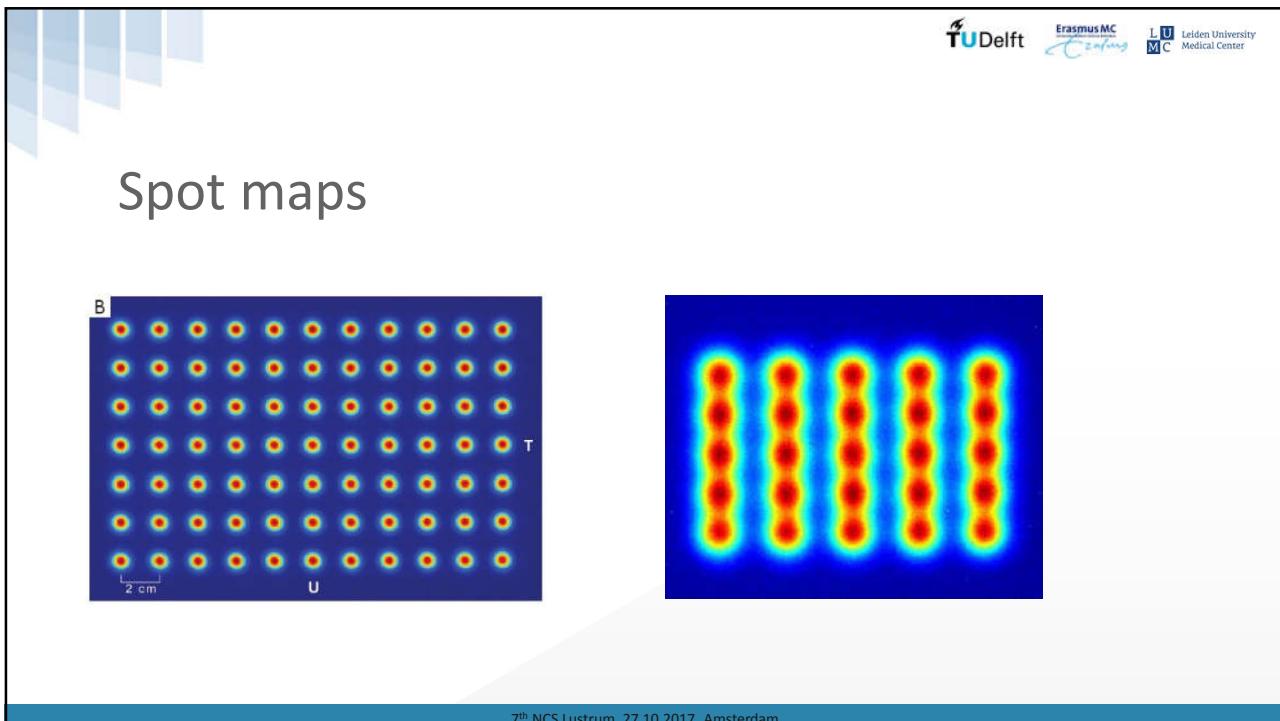
IBA Lynx

XRV-4000

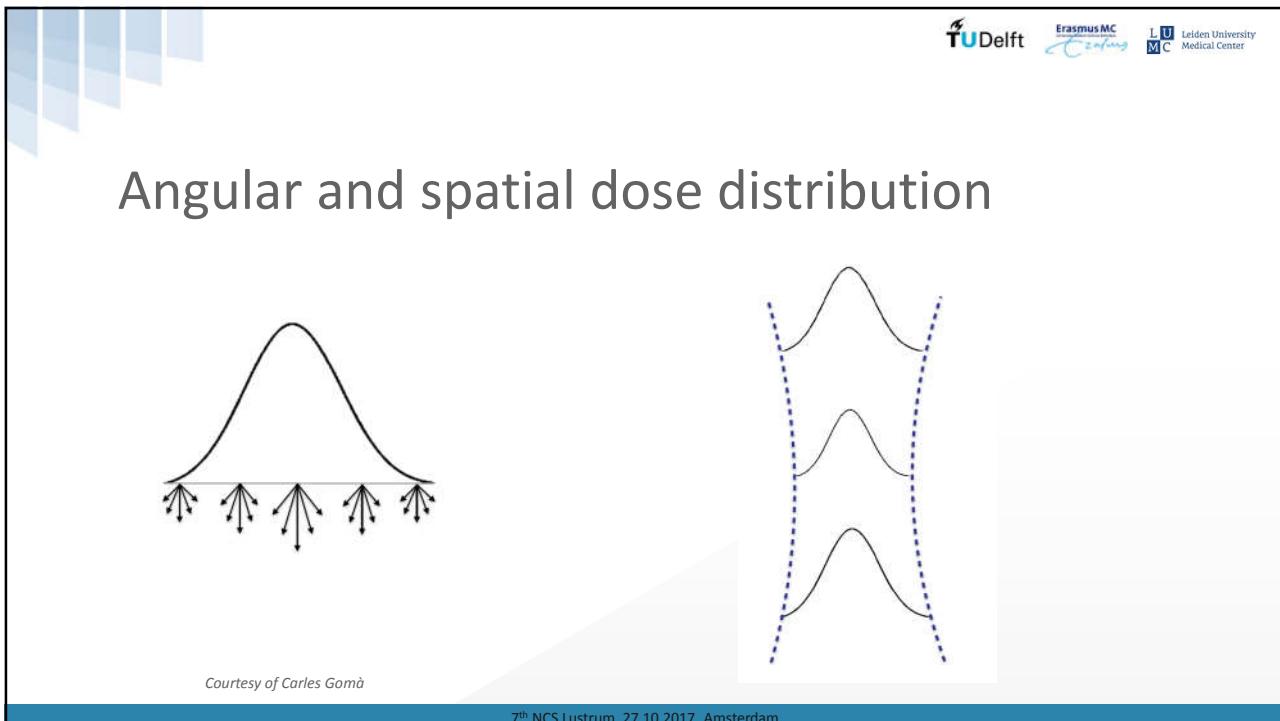
XRV-124

Logos Systems

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Courtesy of Carles Gomà

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The diagram illustrates the relationship between the angular and spatial dose distributions. On the left, a schematic shows a black trapezoidal source emitting a blue cone-shaped beam downwards. A vertical blue arrow labeled z_1 indicates the distance from the source to the point where the beam begins to spread. On the right, a graph plots dose distribution against distance z . A red horizontal line represents the angular dose distribution, which is a single broad peak centered at z_1 . Two dashed blue lines represent the spatial dose distributions at different angles, showing narrower peaks that are shifted towards the source ($z=0$) as the angle increases.

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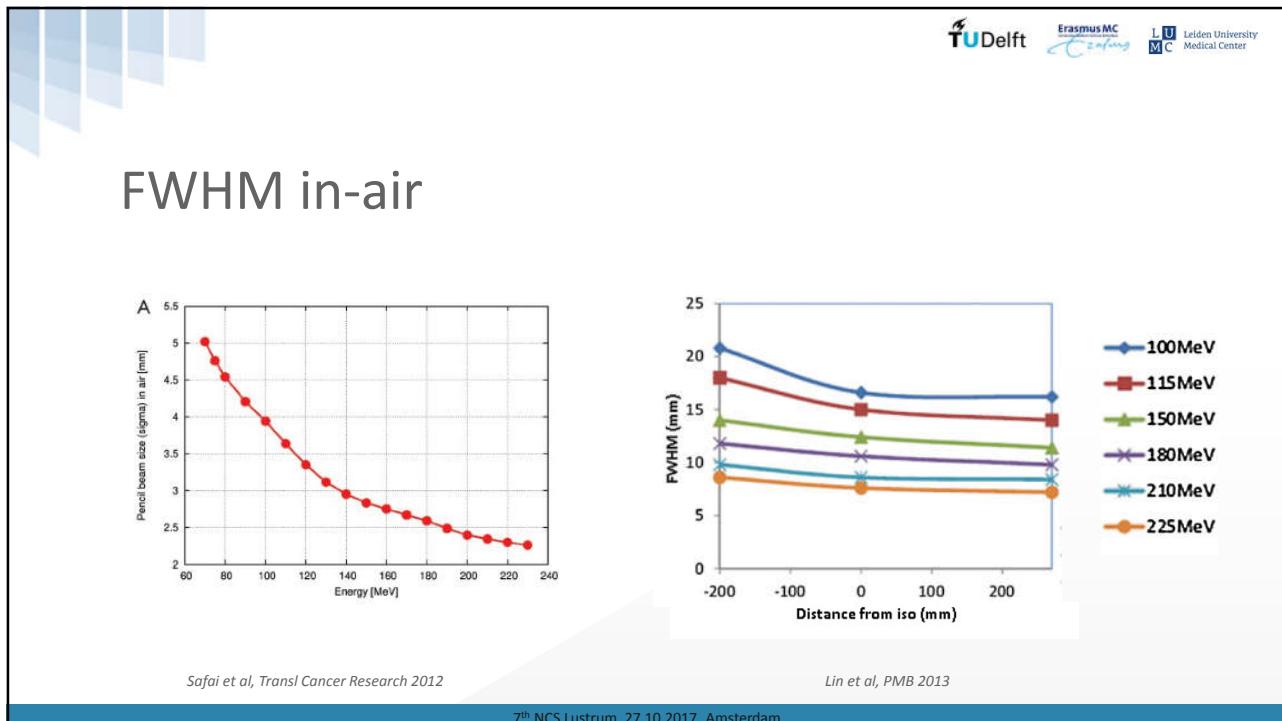
The diagram illustrates the relationship between the angular and spatial dose distributions. On the left, a schematic shows a black trapezoidal source emitting a blue cone-shaped beam downwards. A vertical blue arrow labeled z_2 indicates the distance from the source to the point where the beam begins to spread. On the right, a graph plots dose distribution against distance z . Two red horizontal lines represent the angular dose distributions at two different depths z_2 and z_1 . Two dashed blue lines represent the spatial dose distributions at these angles, showing narrower peaks that are shifted towards the source ($z=0$) as the angle increases. The peak at z_2 is higher than the peak at z_1 .

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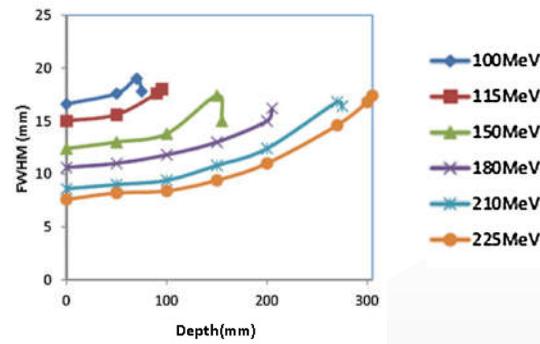
Angular and spatial dose distribution

TU Delft Erasmus MC Leiden University Medical Center

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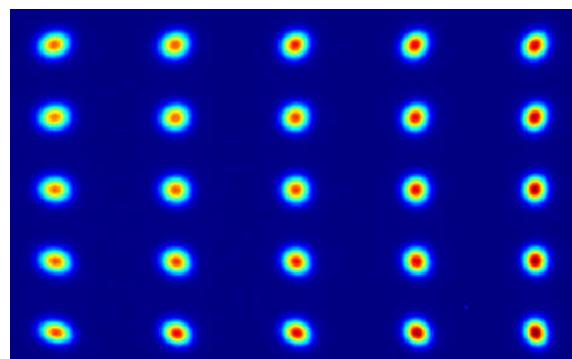
FWHM in water



Lin et al, PMB 2013

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Spot symmetry and ellipticity



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Alternative devices

- Films
- Strip chambers
- Silicon detectors

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NCS subcommittee for proton therapy

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NCS subcommittee for proton therapy

- <http://radiationdosimetry.org/ncs/protontherapy>
- First meeting: 5.9.2016
- Topics to be covered:
 - Reference dosimetry
 - Single pencil beam specific characteristics
 - Time and space dependent dosimetry
 - Neutron contamination
 - Characteristics of the dosimetry equipment

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Members

Jacco de Pooter (VSL, **representative NCS board**)
 Carles Gomà (UZ Leuven)
 Steven Habraken (ErasmusMC)
 Arturs Meijers (UMCG, **secretary**)
 Severine Rossomme (UC Louvain)
 Marco Schippers (UMCG / PSI, **advisor**)
 Enrica Seravalli (UMCU)
 Petra Trnková (HollandPTC, **chair**)
 Paul van Beers (HollandPTC)
 Marc-Jan van Goethem (UMCG)
 Frank Verhaegen (MAASTRO)
 Gloria Vilches Freixas (MAASTRO)

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Thank you for your attention!



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