TECNICHE DI RADIOTERAPIA AL SENO CON RAGGI X MONOCROMATICI

G. Mettivier

Medical Physics Research Laboratory, Dip. Fisica 'Ettore Pancini', UNINA

SR^{3}T

Synchrotron **R**adiation **R**otational **R**adio**T**herapy breast cancer

(INFN project – 2018/2020)

G. Mettivier

AIM OF PROJECT

To propose and investigate an **innovative therapeutic approach for breast cancer therapy** which combines kilovoltage external beam **rotational radiotherapy** using **synchrotron radiation**, the use of **contrast and radiosensitizing agents**, image guidance via pre-treatment and within-treatment **computed tomography scans for precise tumor localization** and patient repositioning, showing its potential with respect to currently available conventional and experimental radiotherapy techniques for breast cancer.

BRIEF HISTORY

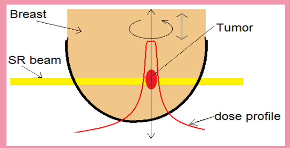
PRELUDE (PRIN)

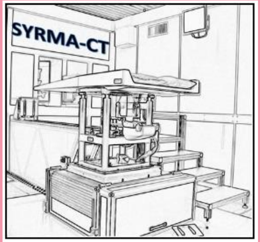
X Ray tube

Syncrotron Source

SYRA3 (COST)

SR^{3}T





Breast-CT

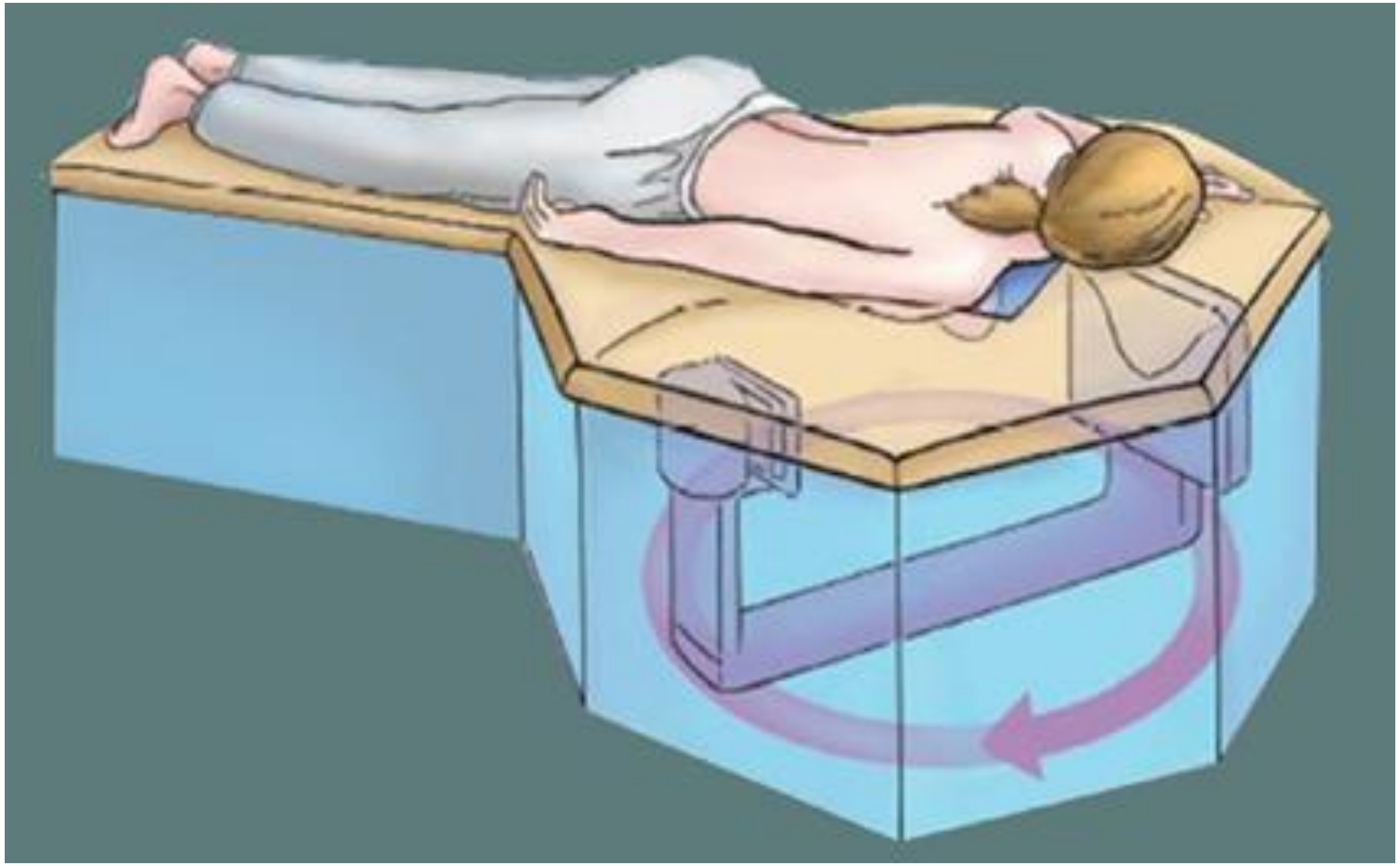
bct

SYRMA3D

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

YEAR

BREAST CT



J. Boone U.C. Davis Medical Center

BRIEF HISTORY

PRELUDE (PRIN)

X Ray tube

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bct

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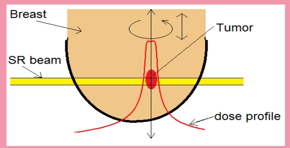

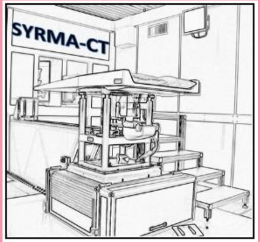

SYRMA3D

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

YEAR

BREAST CT

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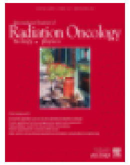
ELSEVIER

International Journal of Radiation Oncology*Biology*Physics

Volume 84, Issue 2, 1 October 2012, Pages 533-539



Physics Contribution

Kilovoltage Rotational External Beam Radiotherapy on a Breast Computed Tomography Platform: A Feasibility Study

Nicolas D. Prionas Ph.D. *, Sarah E. McKenney B.S. *, Robin L. Stern Ph.D. †, John M. Boone Ph.D. *

Show more

https://doi.org/10.1016/j.ijrobp.2011.12.042

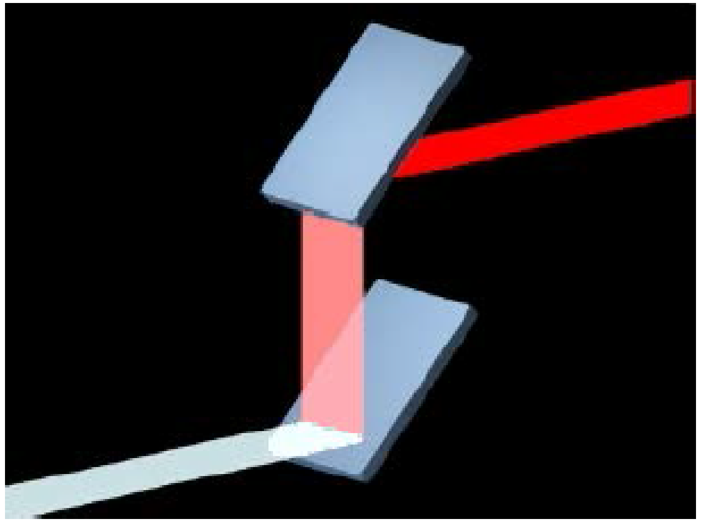
Purpose

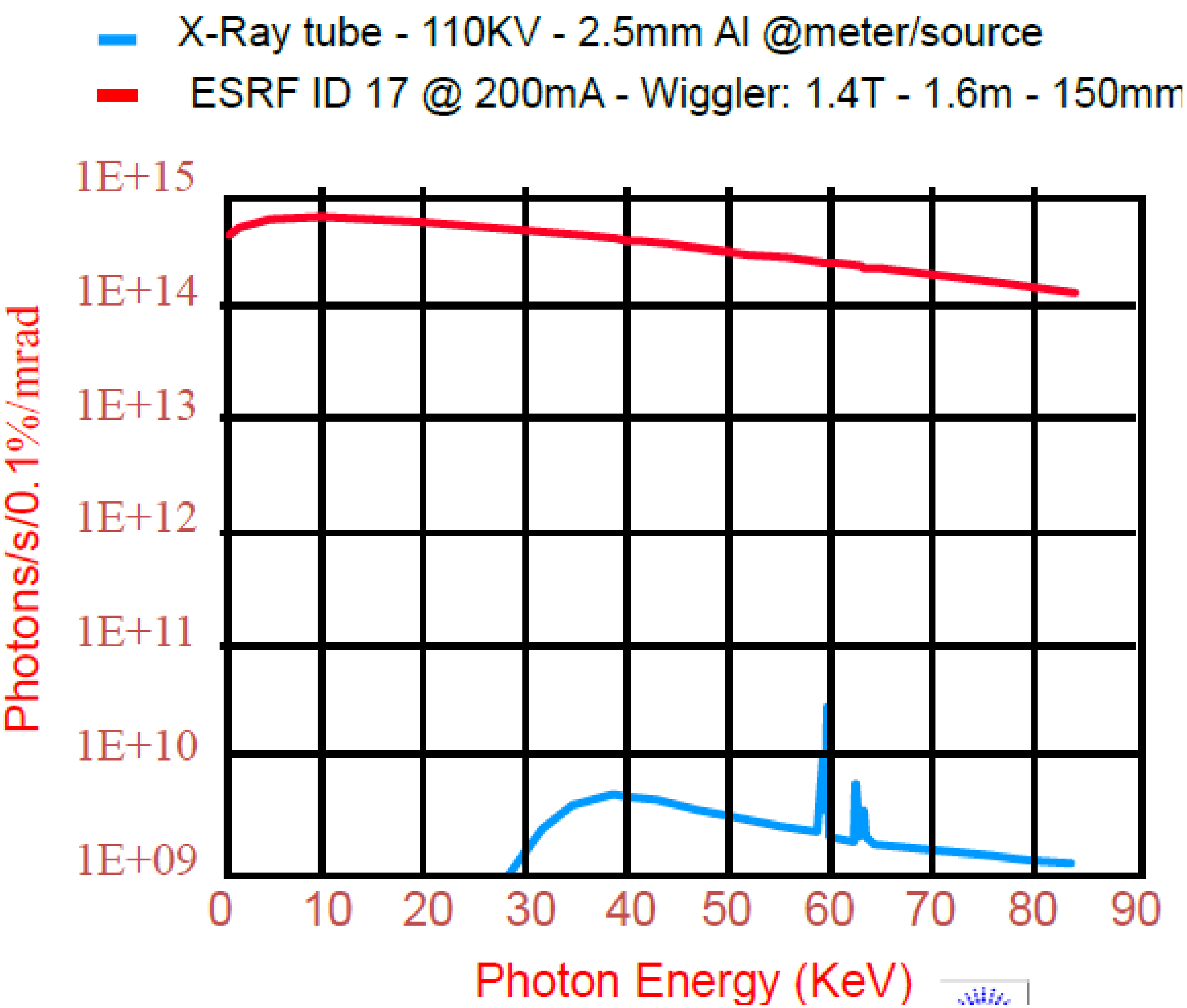
To demonstrate the feasibility of a dedicated breast computed tomography (bCT) platform to deliver rotational kilovoltage (kV) external beam radiotherapy (RT) for partial breast irradiation, whole breast irradiation, and dose painting.

Methods and Materials

Rotational kV-external beam RT using the geometry of a prototype bCT platform was evaluated using a Monte Carlo simulator. A point source emitting 178 keV photons (approximating a 320-kVp spectrum with 4-mm copper filtration) was rotated around a 14-cm voxelized polyethylene disk (0.1 cm tall) or cylinder (9 cm tall) to simulate primary and

SYNCHROTRON RADIOTHERAPY





2016-2017

- Marzo 2015: MASR Conference
- Dicembre 2015: Sottomissione proposal ad ESRF ed AS (accettati)
- Aprile 2016: Lettera di intenti Australian Synchrotron
- Giugno 2016: Lettera di intenti ESRF
- Giugno 2016: Turno di misure presso AS
- Luglio 2016: Turno di misure presso ESRF
- Settembre 2016: Oral contribution ad ECMP
- Luglio 2017: Invito dal Canadian Light Source per proposal congiunto (2 anni)
- Agosto 2017: turno di misure presso AS

- Di Lillo et al., "*Towards breast cancer rotational radiotheraphy with synchrotron radiation* ", in stampa su EJMP-Physica Medica
- Di Lillo et al, "*Synchrotron radiation external beam rotational radiotherapy of breast cancer: proof of principle*", sottomesso a JSR
- Di Lillo et al, "*Monte Carlo and Analytical simulations of dose distribution in Synchrotron radiation rotational radiotherapy of breast cancer: an experimental phantom study*" , contributo ad MCMA

BREAST CT

Physica Medica 41 (2017) 20–25

Contents lists available at ScienceDirect

Physica Medica

journal homepage: http://www.physicamedica.com

Original paper

Towards breast cancer rotational radiotherapy with synchrotron radiation ☆

Francesca Di Lillo, Giovanni Mettivier *, Antonio Sarno, Roberta Castriconi [1], Paolo Russo

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INFN, Sezione di Napoli, Napoli, Italy

ARTICLE INFO

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ABSTRACT

Purpose: We performed the first investigations, via measurements and Monte Carlo simulations on phantoms, of the feasibility of a new technique for synchrotron radiation rotational radiotherapy for breast cancer (SR^3T).

Methods: A Monte Carlo (MC) code based on Geant4 toolkit was developed in order to simulate the irradiation with the SR^3T technique and to evaluate the skin sparing effect in terms of centre-to-periphery dose ratio at different energies in the range 60–175 keV. Preliminary measurements were performed at the Australian Synchrotron facility. Radial dose profiles in a 14-cm diameter polyethylene phantom were measured with a 100-mm pencil ionization chamber for different beam sizes and compared with the results of MC simulations. Finally, the dose painting feasibility was demonstrated with measurements with EBT3 radiochromic films in a phantom and collimating the SR beam at 1.5 cm in the horizontal direction.

Results: MC simulations showed that the SR^3T technique assures a tumour-to-skin absorbed dose ratio from about 7:1 (at 60 keV photon energy) to about 10:1 (at 175 keV), sufficient for skin sparing during radiotherapy. The comparison between the results of MC simulations and measurements showed an agreement within 5%. Two off-centre foci were irradiated shifting the rotation centre in the horizontal direction.

Conclusions: The SR^3T technique permits to obtain different dose distributions in the target with multiple rotations and can be guided via synchrotron radiation breast computed tomography imaging, in propagation based phase-contrast conditions. Use of contrast agents like iodinated solutions or gold nanoparticles for dose enhancement (DE-SR^3T) is foreseen and will be investigated in future work.

SYNCHROTRON IRRADIATION TECHNIQUES

SYNCHROTRON RADIOTHERAPY

Physica Medica 31 (2015) 568–583

Contents lists available at ScienceDirect

Physica Medica

journal homepage: http://www.physicamedica.com

Medical physics aspects of the synchrotron radiation therapies: Microbeam radiation therapy (MRT) and synchrotron stereotactic radiotherapy (SSRT)

Elke Bräuer-Krisch [a, *], Jean-Francois Adam [b], Enver Alagoz [c], Stefan Bartzsch [d], Jeff Crosbie [e], Carlos DeWagter [f], Andrew Dipuglia [g], Mattia Donzelli [a], Simon Doran [h], Pauline Fournier [a, g], John Kalef-Ezra [i], Angela Kock [j], Michael Lerch [g], Ciara McErlean [h], Uwe Oelfke [d], Pawel Olko [k], Marco Petasecca [g], Marco Povoli [l], Anatoly Rosenfeld [g], Erik A. Siegbahn [m], Dan Sporea [n], Bjarne Stugu [o]

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[b] INSERM, Grenoble, France
[c] University of Bergen Department of Physics and Technology, PB 7803 5020, Norway
[d] The Institute of Cancer Research, 15 Cotswold Rd, Sutton SM2 5NG, United Kingdom
[e] RMIT University, Melbourne, VIC, 3001, Australia
[f] Ghent University Hospital, 9000 Gent, Belgium
[g] Centre for Medical Radiation Physics, University of Wollongong, Northfields Ave, NSW, Australia
[h] CRUK Cancer Imaging Centre, Institute of Cancer Research, 15 Cotswold Rd, Sutton Surrey, UK
[i] Medical Physics Laboratory, University of Ioannina, 451.10, Ioannina, Greece
[j] Sintef Minalab, Gaustadalléen 23C, 0373, Oslo, Norway
[k] Institute of Nuclear Physics PAN, Radzikowskiego 152, 31-342, Krawkow, Poland
[l] University of Oslo, Department of Physics, 0316, Oslo, Norway
[m] Department of Oncolgy-Pathology, Karolinska Institutet, S-177176, Stockholm, Sweden
[n] National Institute for Laser, Plasma and Radiation Physics, Magurele, RO-077125, Romania
[o] University of Bergen, Department of Physics and Technology, PB 7803, 5020, Bergen, Norway

A R T I C L E I N F O

Article history:
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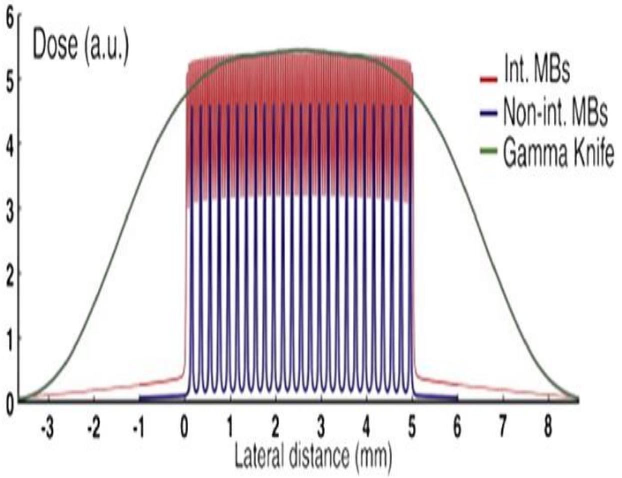
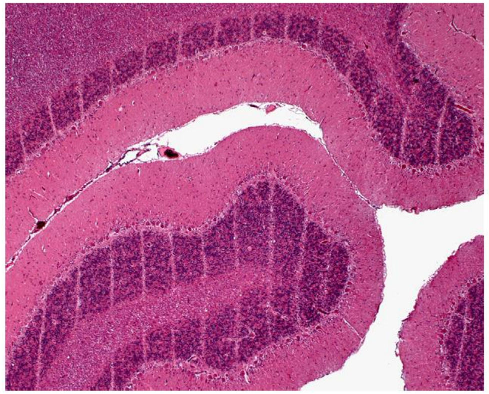
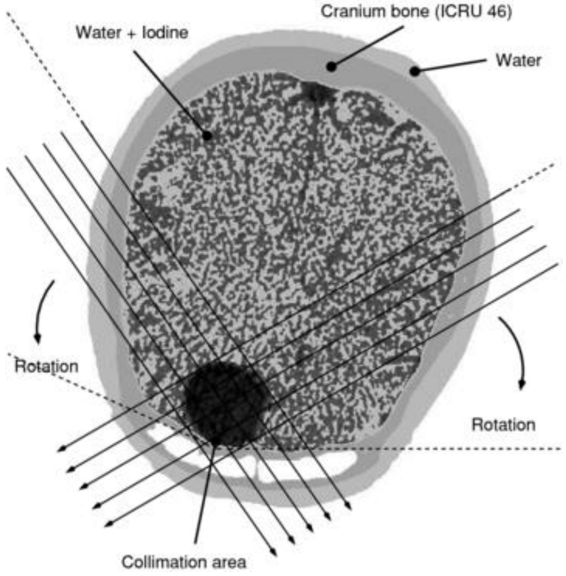
27 April 2015
Accepted 28 April 2015

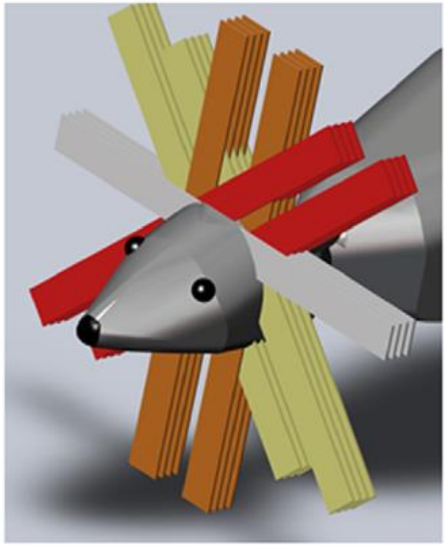
A B S T R A C T

Stereotactic Synchrotron Radiotherapy (SSRT) and Microbeam Radiation Therapy (MRT) are both novel approaches to treat brain tumor and potentially other tumors using synchrotron radiation. Although the techniques differ by their principles, SSRT and MRT share certain common aspects with the possibility of combining their advantages in the future. For MRT, the technique uses highly collimated, quasi-parallel arrays of X-ray microbeams between 50 and 600 keV. Important features of

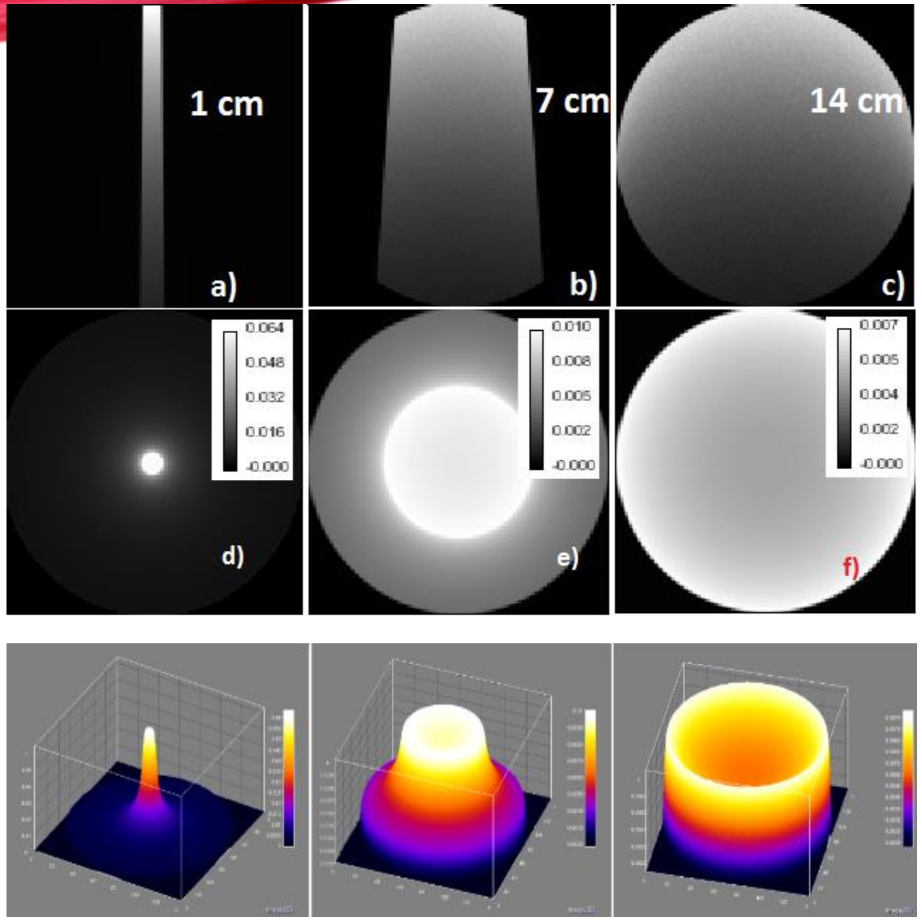




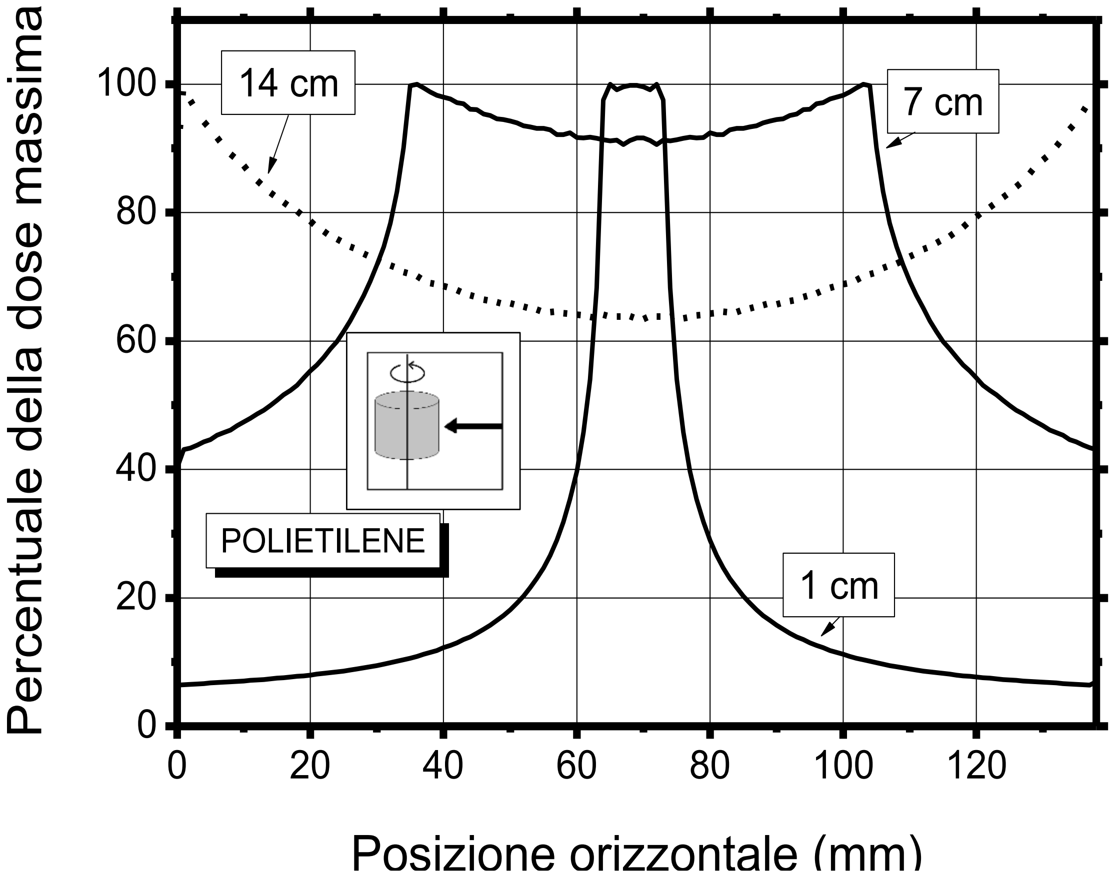




ROTATIONAL RADIOTHERAPY
W/ ORTHOVOLTAGE X-RAY TUBE

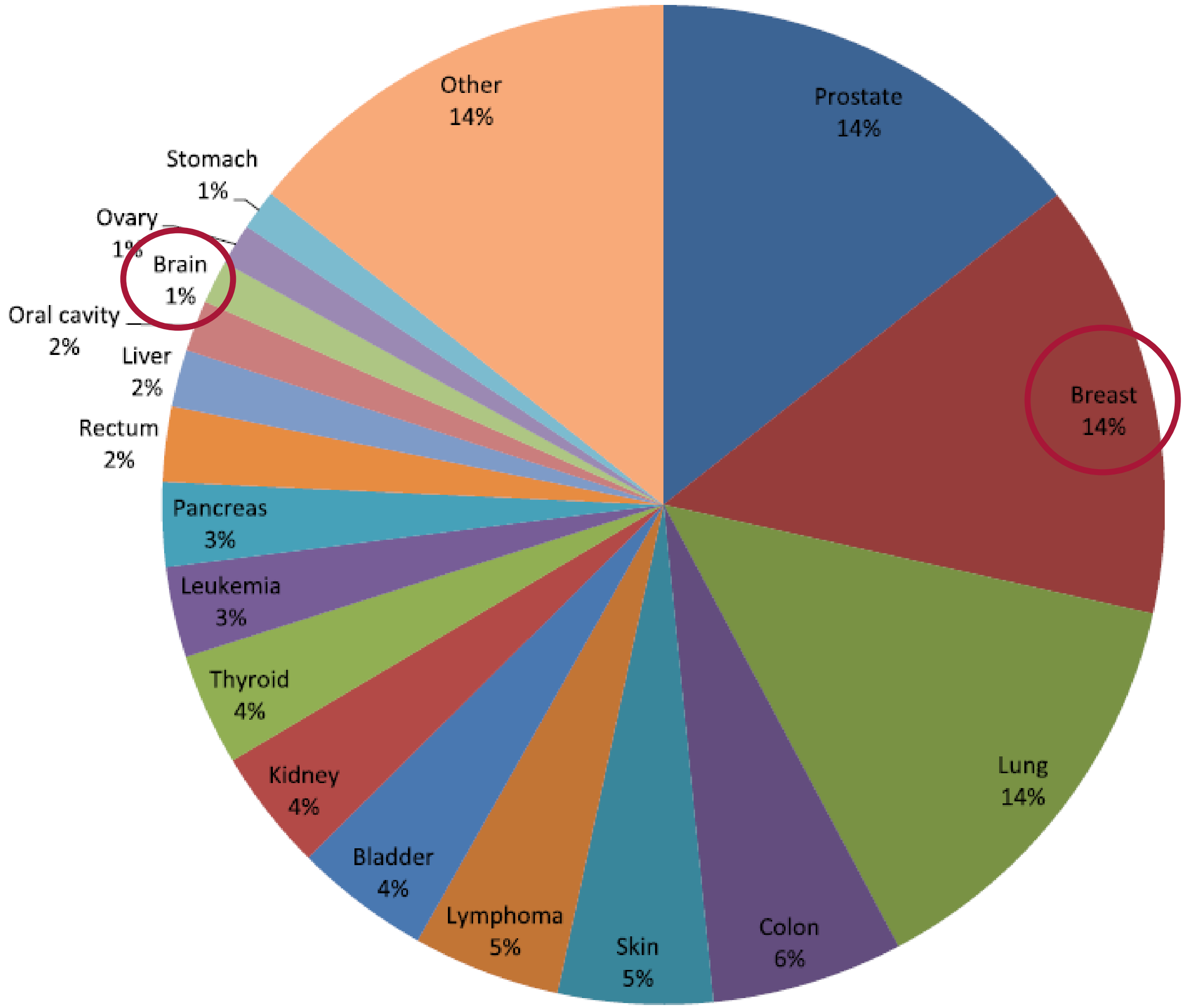


1. Quando il fascio è stretto (1 cm) **la dose al bordo è meno del 10% di quella al centro**.
2. Quando il fantoccio è totalmente irraggiato (14 cm) il massimo della dose è al bordo ed **il profilo è a forma di coppa**



- **Energia**: 178 keV
- **Dimensioni fantoccio**: 14 cm diametro 9 cm altezza
- **Materiale**: polietilene
- **Collimazioni fascio: 1, 7, 14 cm in direzione x**

Cancer 2013 USA



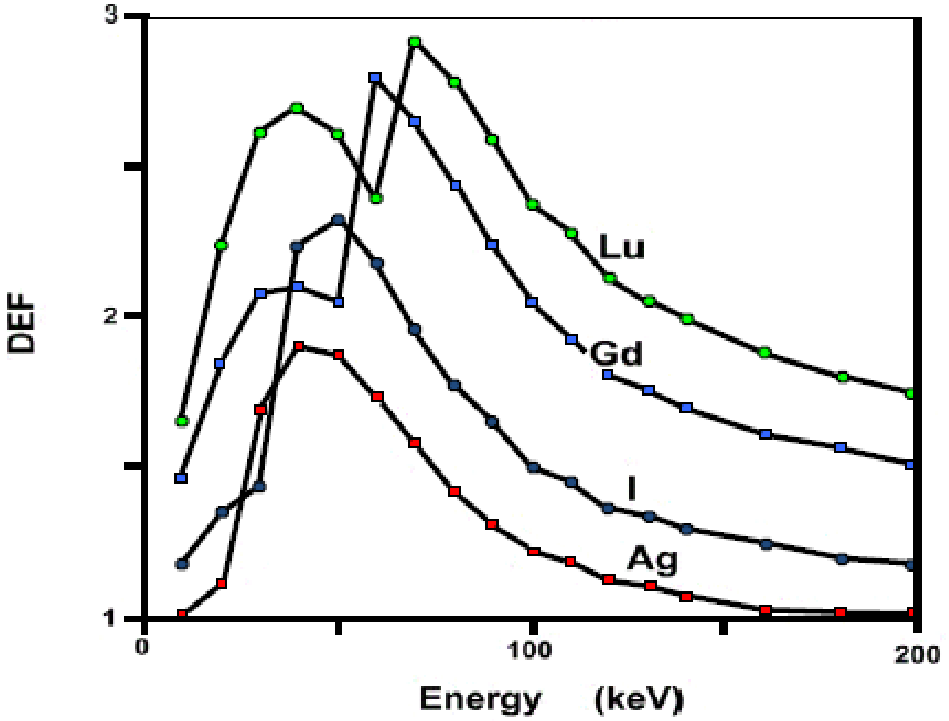
OBIETTIVI

- Applicazione di questa tecnica al breast tumor
- Ottimizzazione energia e geometria per sparing skin effect
- Confronto con la tecnica tradizionale

DOSE ENHANCEMENT EFFECT

DOSE ENHANCEMENT EFFECT

- Radiation dose enhancement in tumors with iodine, Mello et al., **Med. Phys. 10, 75 (1983)**
- Calculation of radiation dose enhancement factors for dose enhancement therapy of brain tumors, Solberg et al., **Phys. Med. Biol. 37, 439-443, (1992)**



DEF vs. photon energy for equimolar concentrations of Ag, I, Gd, and Lu equal to that of 5 mg/ml Ag.

Amos NORMAN -MASR 2001-GRENOBLE

SYNCHROTRON SOURCE FOR CT THERAPY

Synchrotron Radiation CT-Therapy ● J.-F. ADAM *et al.*

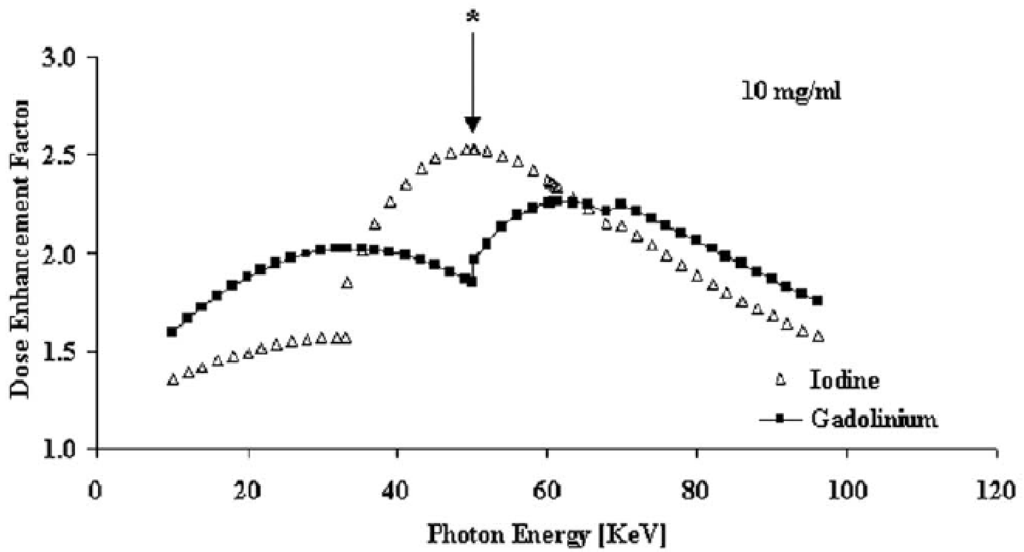


Fig. 4. Dose enhancement factor (DEF) curves computed with Eq. 4, as a function of energy for two different elements (iodine and gadolinium) at identical concentrations (10 mg/mL). The arrow points out the maximal DEF for iodine (50 keV).

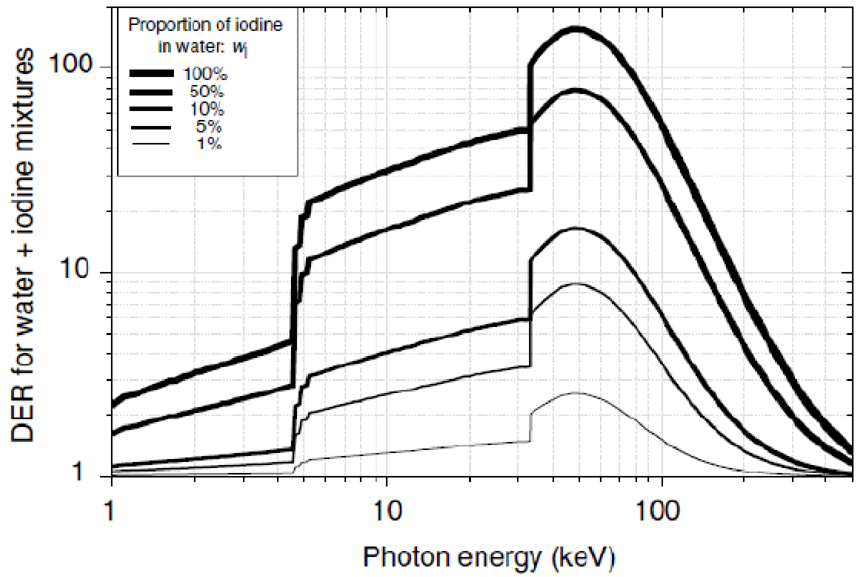


Figure 1 Energy dependence of the theoretical dose-enhancement ratio for several iodine aqueous mixtures (from bottom to top, the mass proportion of iodine in water, w_I is ranging from 0.01 to 1).

Corde S., *et al*. Synchrotron radiation-based experimental determination of the optimal energy for cell radiotoxicity enhancement following photoelectric effect on stable iodinated compounds. *British Journal of Cancer* (2004) 91, 544 – 551

OBIETTIVI

- Studio del mezzo (nanoparticelle?) e sua concentrazione per dose enhancement effect
- Misura dell'effetto biologico
- Confronto con la tecnica tradizionale
- Phase contrast imaging con mezzo contrasto

DOSIMETRY

DOSIMETRIA

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Physics in Medicine & Biology

PAPER • FEATURED ARTICLE

Glandular dose in breast computed tomography with synchrotron radiation

G Mettivier[1,2,6], C Fedon[3,4,6], F Di Lillo[1,2], R Longo[3,4], A Sarno[1,2], G Tromba[5] and P Russo[1,2]

Published 18 December 2015 • © 2016 Institute of Physics and Engineering in Medicine

Physics in Medicine & Biology, Volume 61, Number 2

Article PDF

Figures References Citations

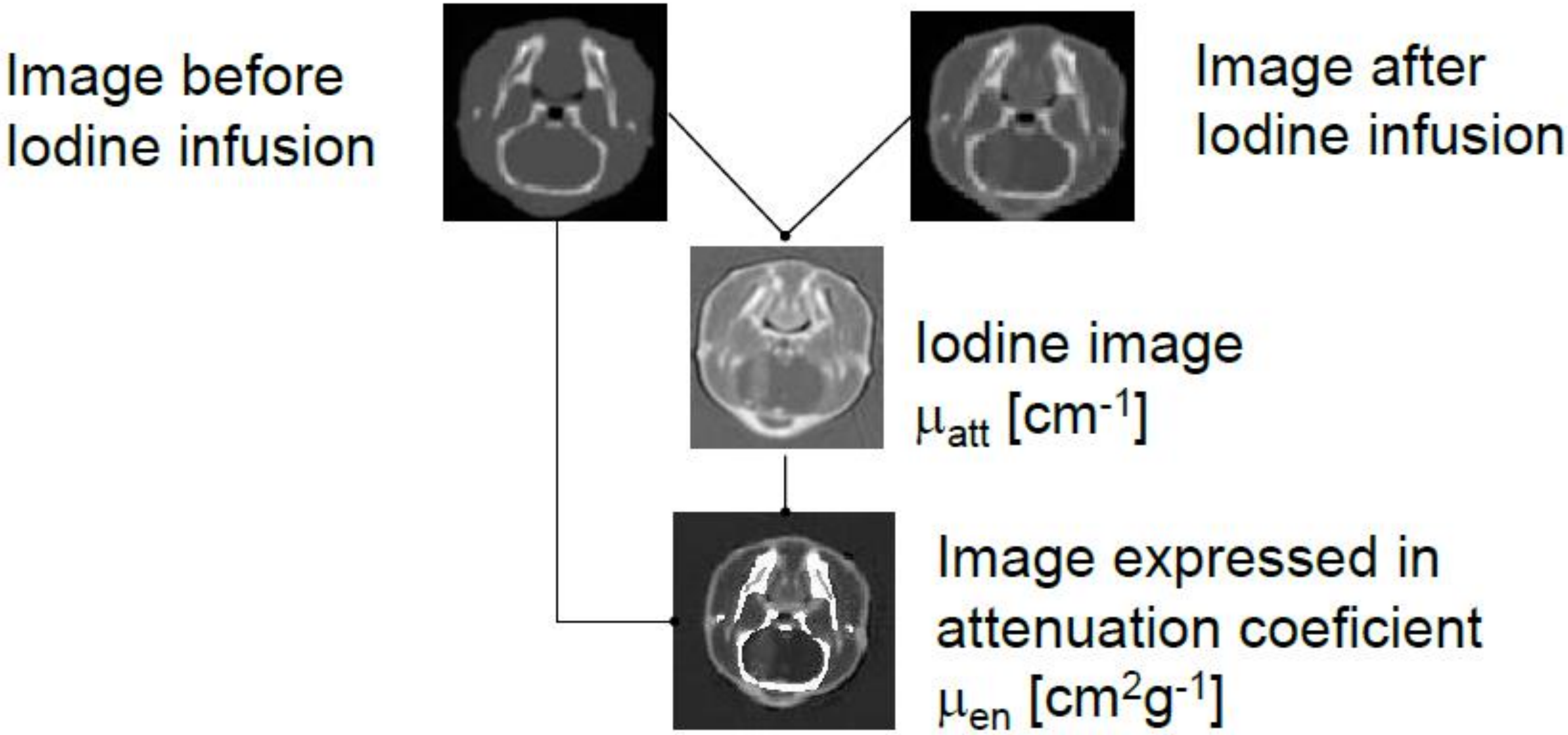
An erratum for this article has been published in 2016 *Phys. Med. Biol.* **61** 2970

+ Article information

Abstract

The purpose of this work is to provide an evaluation of the mean glandular dose (MGD) for breast computed tomography (CT) with synchrotron radiation in an axial scanning configuration with a

DOSE COMPUTATION



$$Dose[Gy] = \Phi_0 \cdot \exp(-\mu_{att} x) \cdot \mathrm{E} \cdot \left(\frac{\mu_{en}}{\rho}\right)$$

OBIETTIVI

- Applicazione metodi MC per valutazione dose
- Misura dell'effetto biologico

ASPETTANDO SR^{3}T (2018)

2016-2017

- Giugno 2016: Turno di misure presso AS
- Luglio 2016: Turno di misure presso ESRF
- Settembre 2016: Oral contribution ad ECMP
- Luglio 2017: Turno di misure presso AS
- Marzo 2018: Turno di misure presso ESRF
- Giugno 2018: turno di misure presso Canadian Light Source

- Di Lillo et al., "*Towards breast cancer rotational radiotheraphy with synchrotron radiation* ", in stampa su EJMP-Physica Medica
- Di Lillo et al, "*Synchrotron radiation external beam rotational radiotherapy of breast cancer: proof of principle*", sottomesso a JSR
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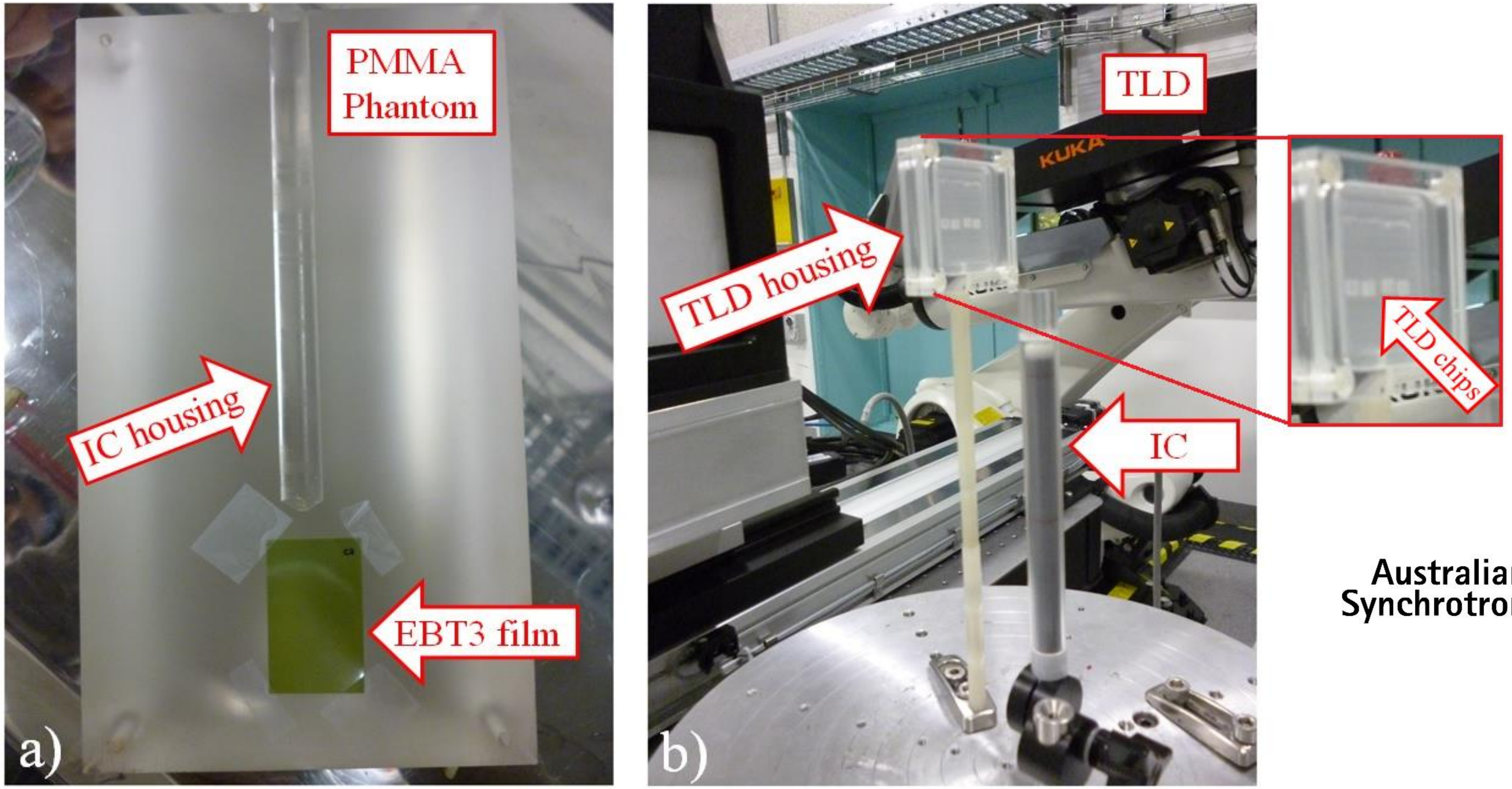
PRIME MISURE



Australian Synchrotron

Photo of the midplane face of the two halves cylindrical PMMA phantom containing a cavity for the ionization chamber and with the EBT3 film in place (a); Setup for TLD irradiation (b): four TLD chips inserted in the PMMA housing and 100-mm pencil ionization chamber (IC) placed along the vertical direction. The inset shows the four chips in place in the housing.

PRIME MISURE

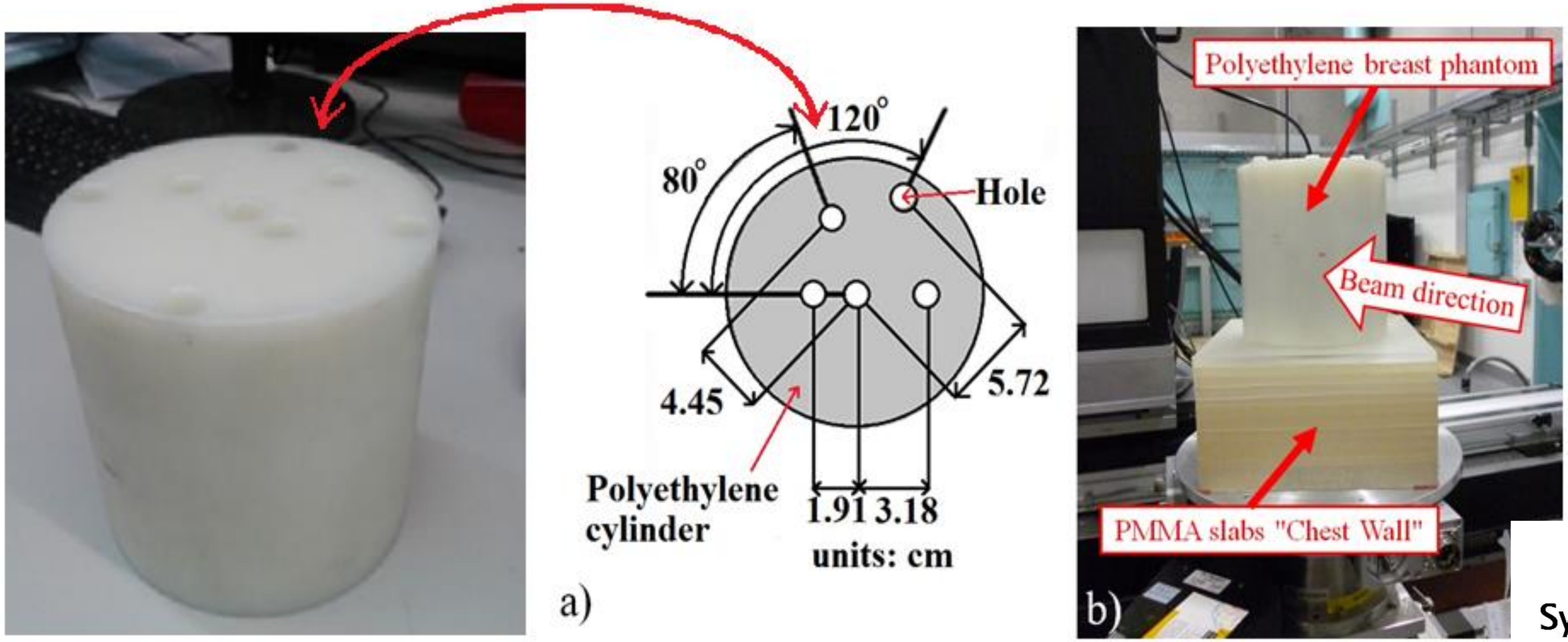
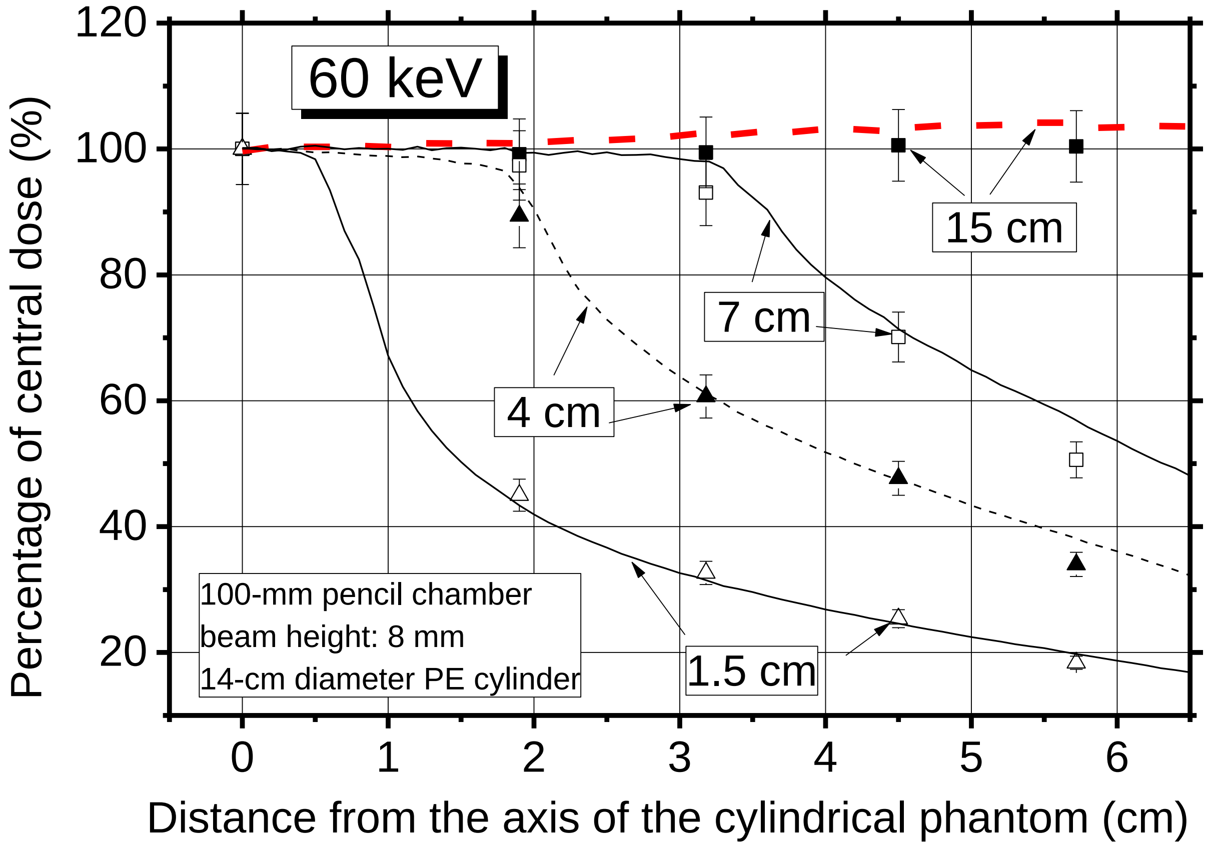


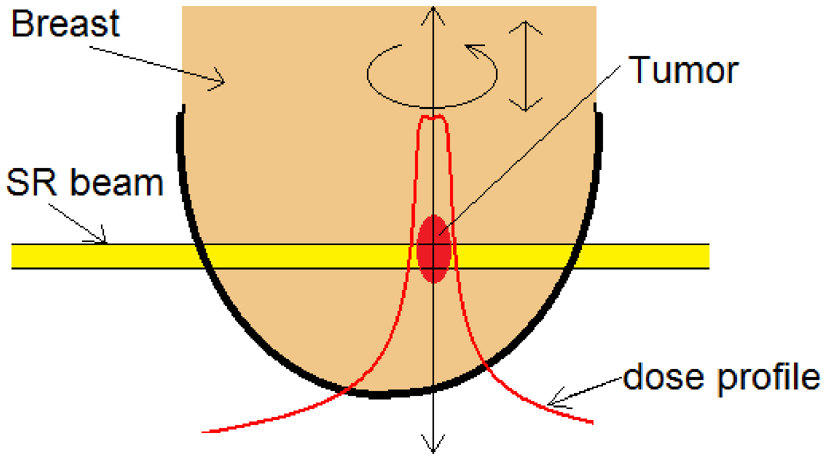
Photo and scheme of the polyethylene cylindrical phantom with five cylindrical holes at various radial distances for hosting a 100-mm long ion chamber (a). Experimental setup for radial dose profile measurement, in this image the IC is positioned in the central hole of the phantom (b).

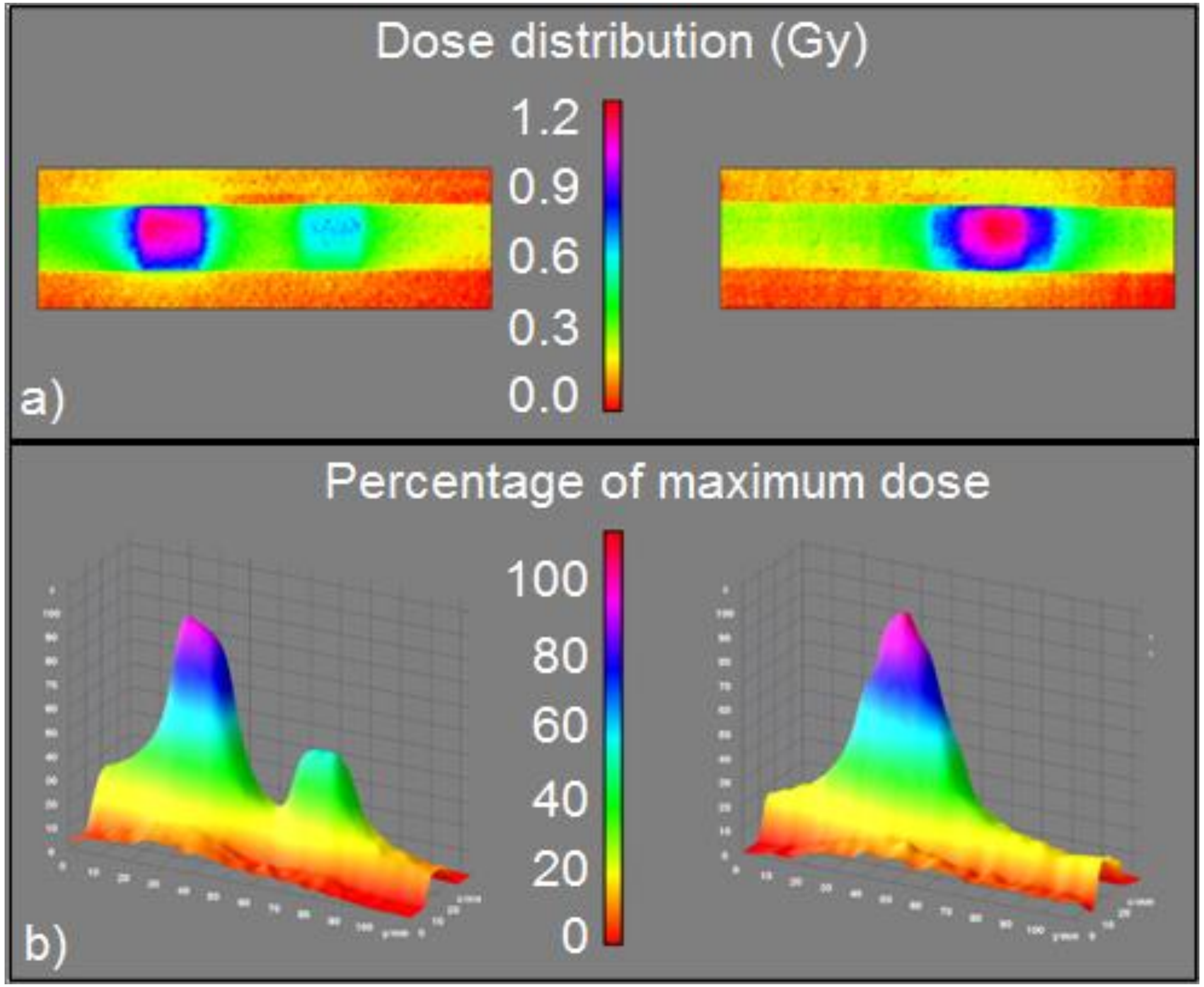
PRIME MISURE



Comparison between the measured (symbols) and simulated (lines) relative air kerma in a 14-cm diameter polyethylene cylindrical phantom for beam width of 1.5, 4, 7 and 15 cm. For the MC simulation, the dose distribution was evaluated by integrating the dose along 100 mm in the direction of the cylinder axis.

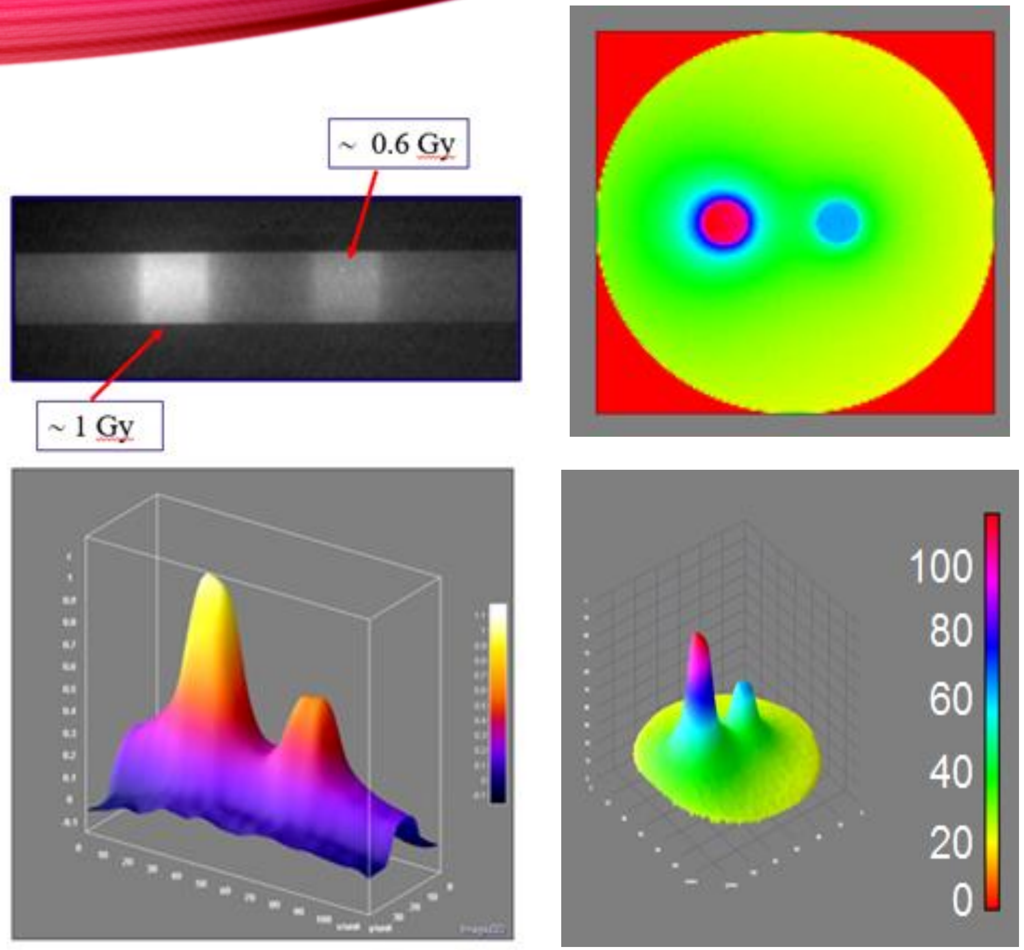
PRIME MISURE

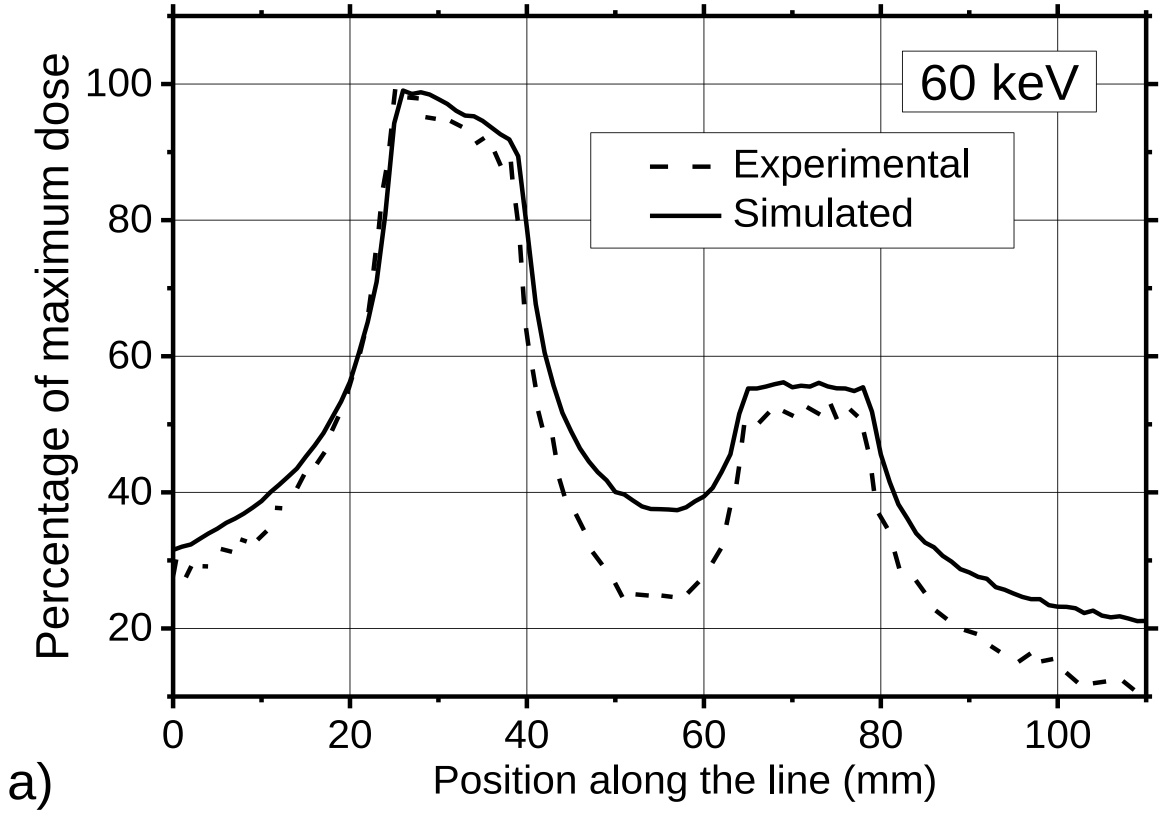




Australian Synchrotron

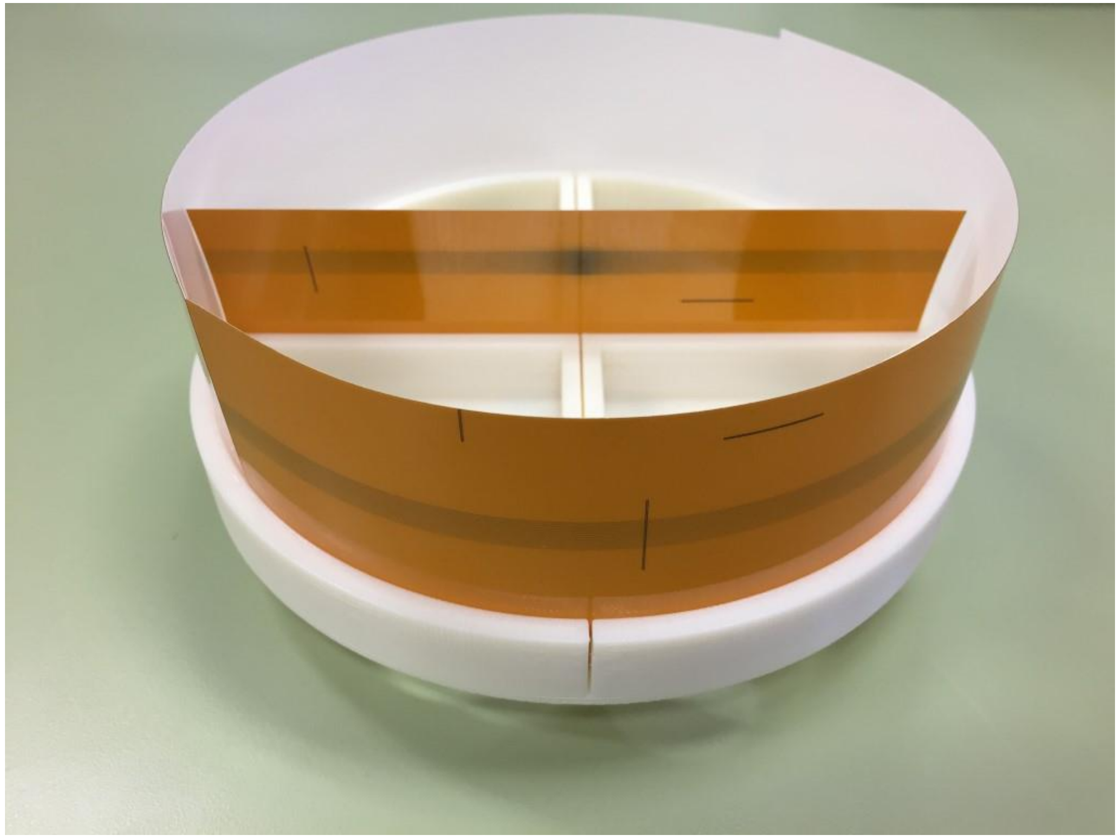
PRIME MISURE

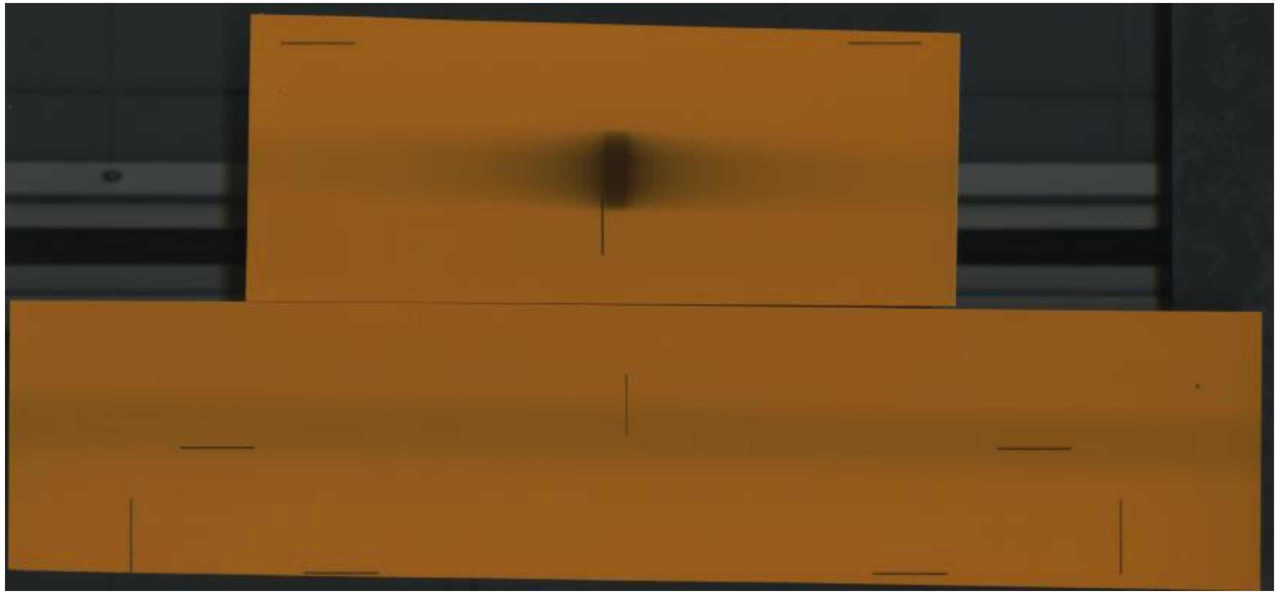




Dose distributions (a) evaluated with radiochromic film EBT3 at midplane in a 14-cm diameter PMMA phantom and (b) surface plot of percentage of maximum dose: two off-center foci. The dose distribution was obtained with two full rotations of the phantom with displaced axis of rotation and different target doses.

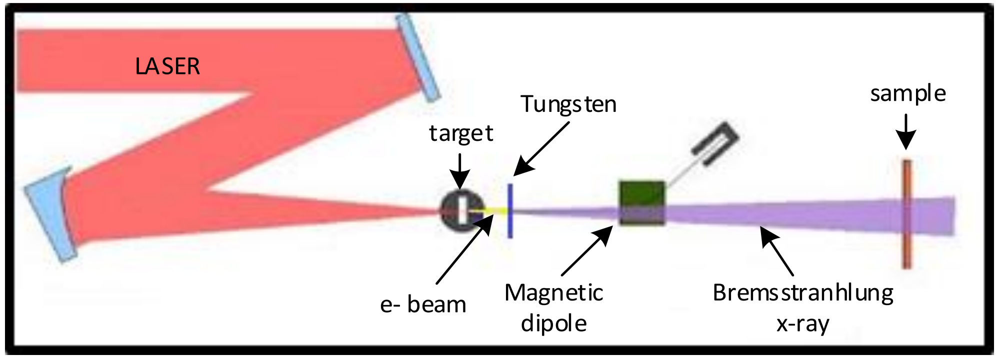
SPIRAL MICRO-BEAM RADIATION THERAPY

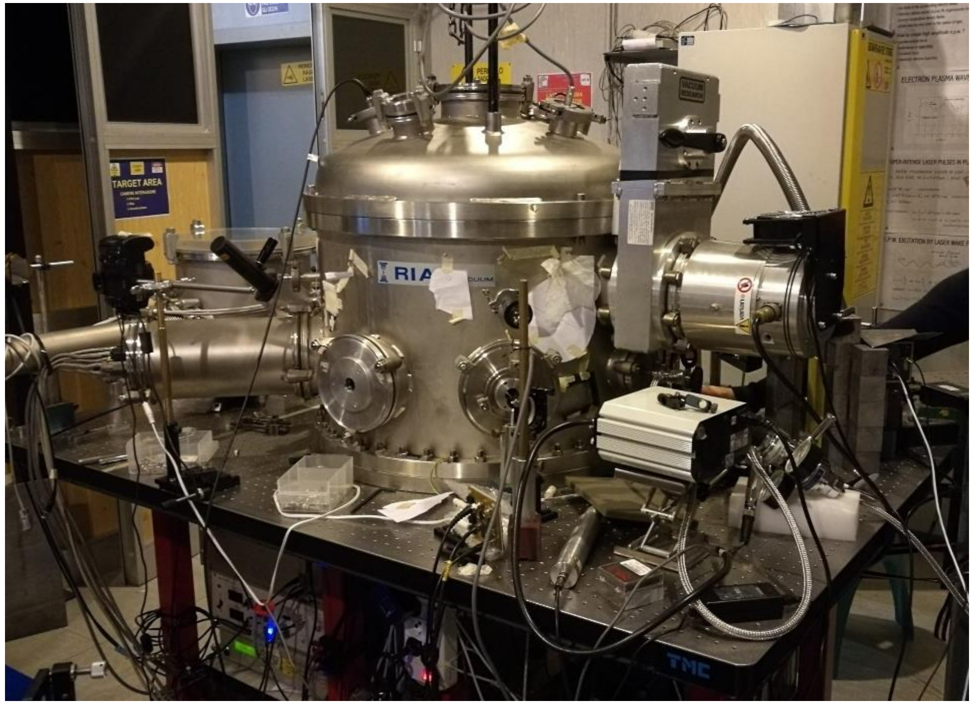




Canadian Light Source
Centre canadien de rayonnement synchrotron

PRIN 2015: CLINICALY COMPATIBLE TOOL FOR ADVANCED TRANSLATIONAL RESEARCH WITH ULTRASHORT AND ULTRAINTENSE X-RAY PULSES

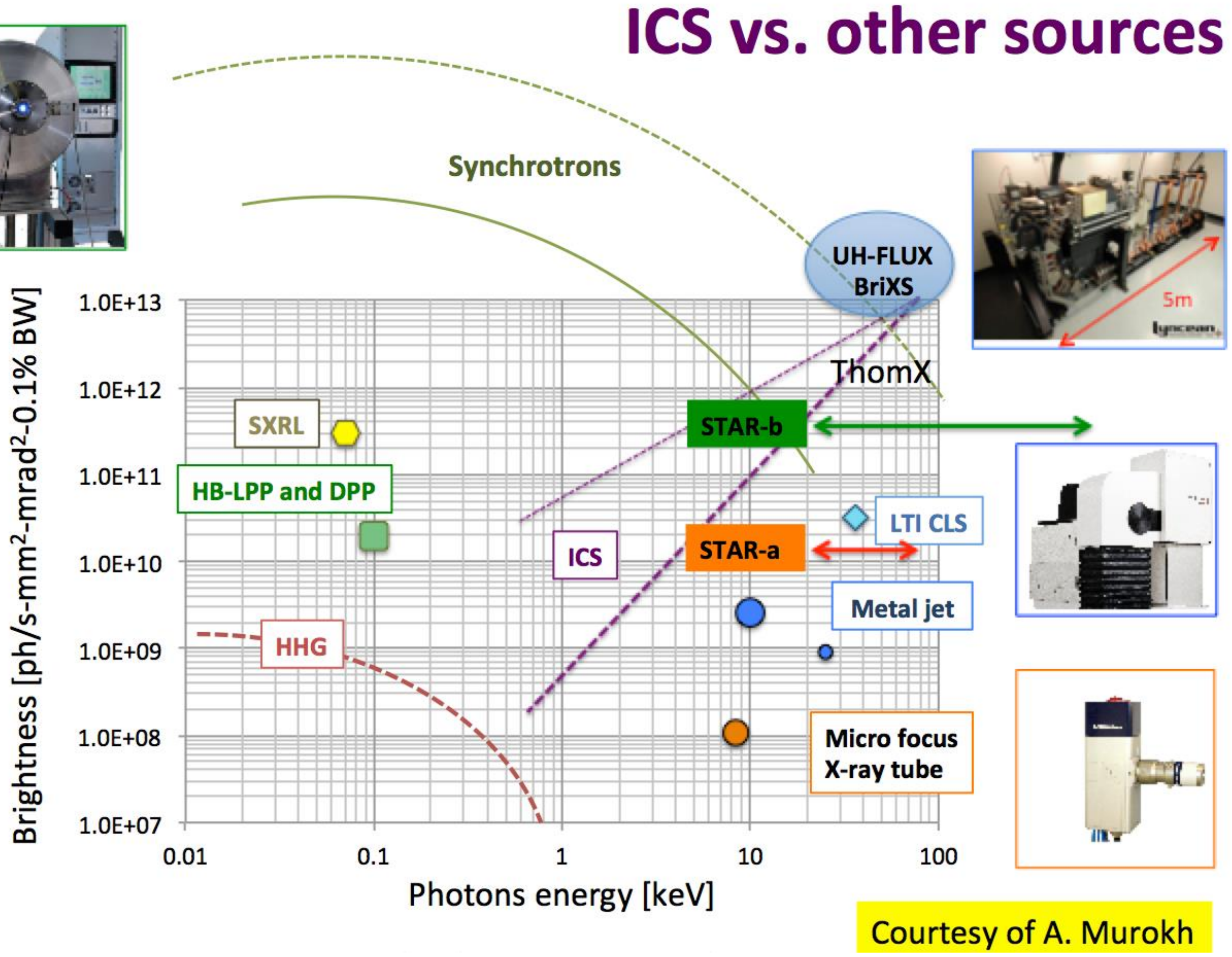




MARIX

Caratteristiche sorgente
Compton mono-chromatic X-ray beam
Energy: 30 -150 keV
Flux: 10^{13} photons/s

Phase	X-Ray photon energy (keV)	X-ray flux (ph/s)	
0	20-90	10^{11}	
1	20-90	10^{12}	4 years
2	20-200	10^{15}	2-3 years



Vantaggi
Compact source
Disponibilità di una sorgente

Da Studiare
Fascio divergente
dosimetria

MEDICAL PHYSICS RESEARCH LABORATORY

Prof. Paolo Russo
Professore Ordinario

Prof. Giovanni Mettivier
Ricercatore
Coordinatore gruppo V – INFN Napoli

Dr Antonio Sarno
INFN Post Doc

Dr Francesca Di Lillo
Dottoranda

Grazie per l'attenzione

Canadian Light Source
Centre canadien de rayonnement synchrotron

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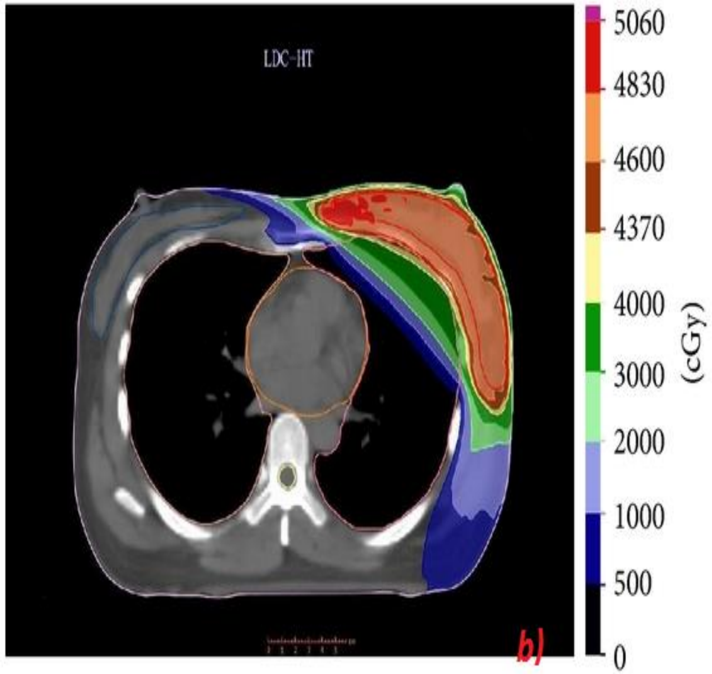
The European Synchrotron

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

OSPEDALE SAN RAFFAELE

RADIOTERAPIA CONVENZIONALE



a) Utilizzo di acceleratori lineari al megavoltaggio (LINAC) e 2 fasci incidenti lateralmente nel seno

b) Distribuzione di dose risultante e problematica legata allo "skin sparing" ed alla salvaguardia degli altri organi come il cuore (la attuale EBRT deposita sulla pelle fino al 40% della dose al tumore ≈ 20 Gy)