Breast CT with Synchrotron Radiation: Dosimetric Approach

*Christian **FEDON** - SYRMA-CT collaboration*

Università degli Studi di Trieste – Dipartimento di Fisica
INFN – Trieste

SYRMA-CT Project

The aim is to realize the first clinical study of Breast Computed Tomography with Synchrotron Radiation.

The project involved several institutions:

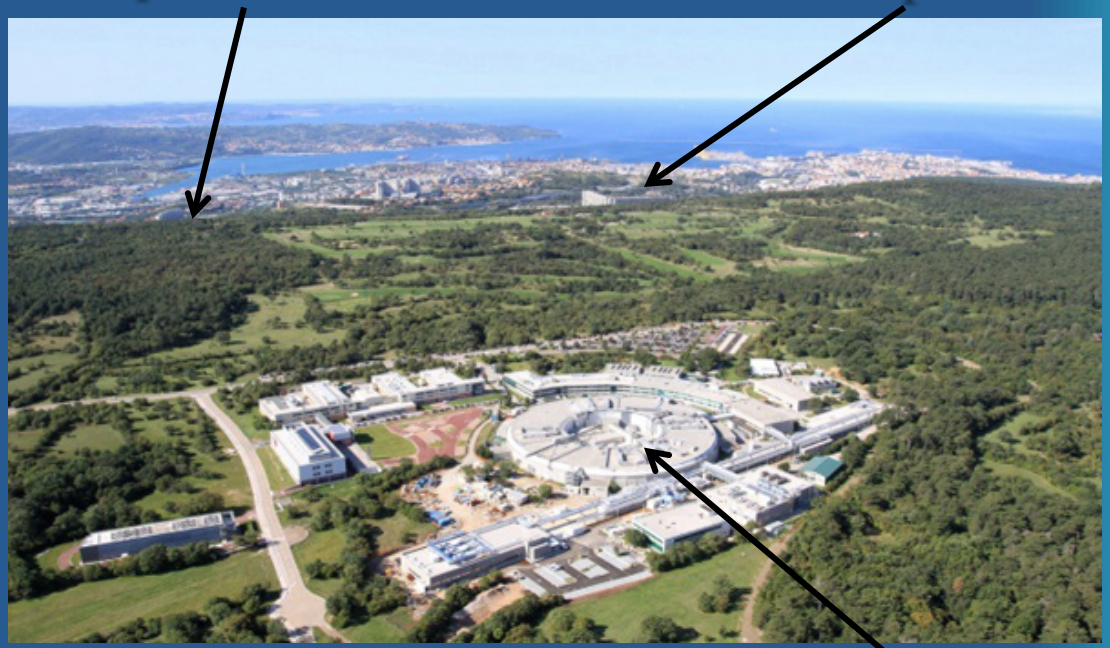
INFN Istituto Nazionale di Fisica Nucleare

Bologna
Cagliari, Sassari
Napoli
Pisa

Università degli Studi di Napoli Federico II

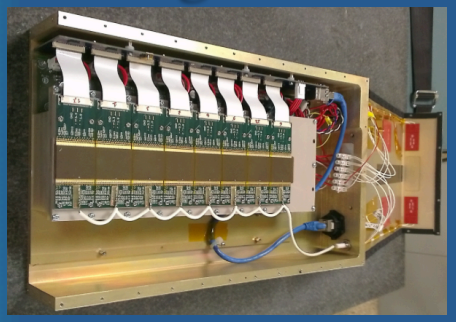
Università di Pisa

PiXirad Imaging Counters s.r.l.

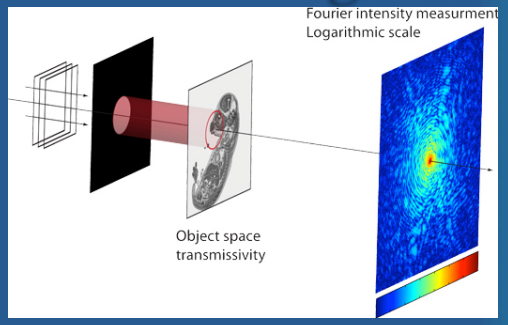


SYRMA-CT

Single Photon Counting Detector



State of the art for CT reconstruction algorithms

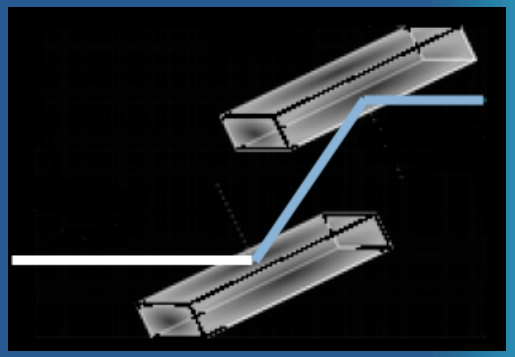


Facility upgrade

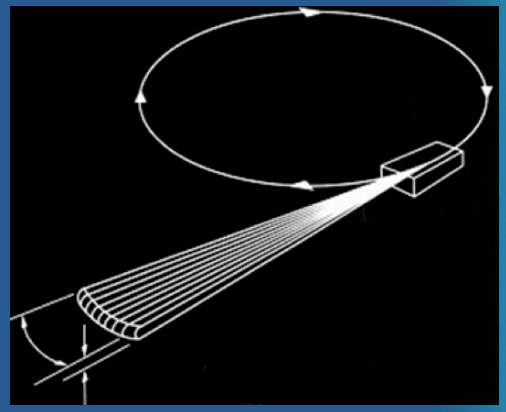
Dosimetric upgrade

Characteristics of Synchrotron Radiation

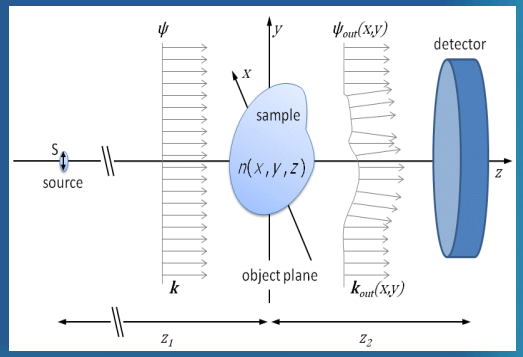
- High x-ray intensity on a broad energy (10 – 40 keV)
- Tunable monochromatic beam



- Laminar beam geometry
- The images are acquired by scanning the object



- Small source size and large source-to-sample distance
- Free space propagation phase imaging



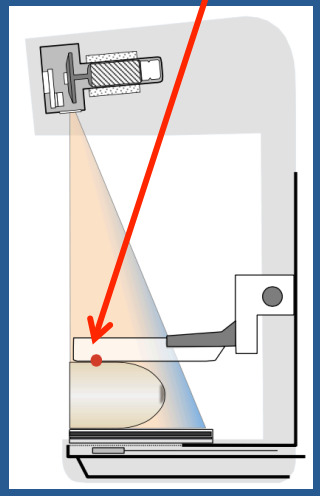
Dosimetric Quantities

The Breast-CT combines two techniques

Mammography

The key quantity is the
Mean Glandular Dose (MGD)

$$MGD = DgN \cdot ESAK$$

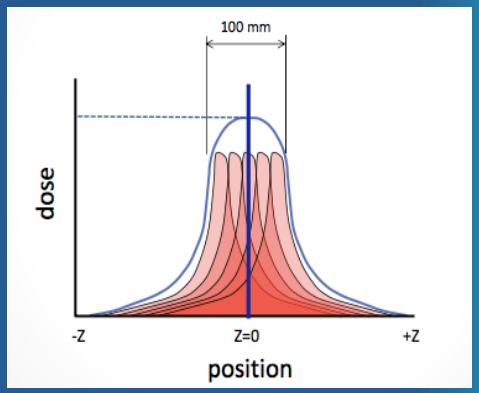


Monte Carlo Simulation

Computed Tomography

Computer Tomography
Dose Index (CTDI)

$$CTDI_{100} = \frac{1}{nT}\int_{-50mm}^{50mm} D(z)\, dz$$



Useful for characterization

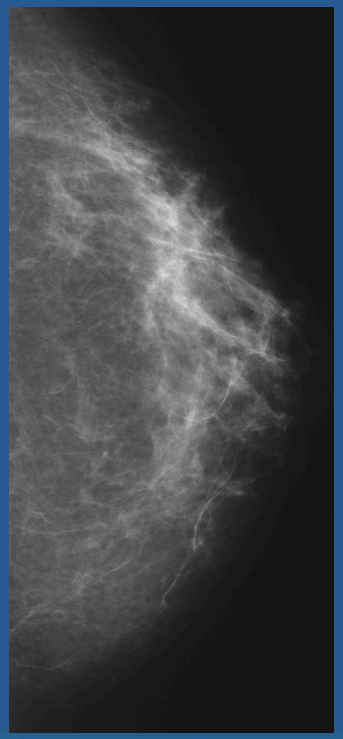
Monte Carlo Code

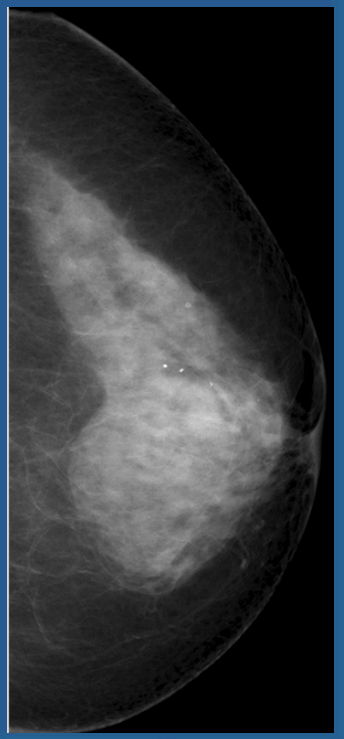
A specific Monte Carlo code has been developed to estimate the DgN coefficients using **GEANT4**

The dose was calculated as follows:

$$MGD = \frac{E_g \cdot G_{factor}}{mass \cdot f_g}$$

$$DgN = \frac{MGD}{ESAK}$$





Literature Validation

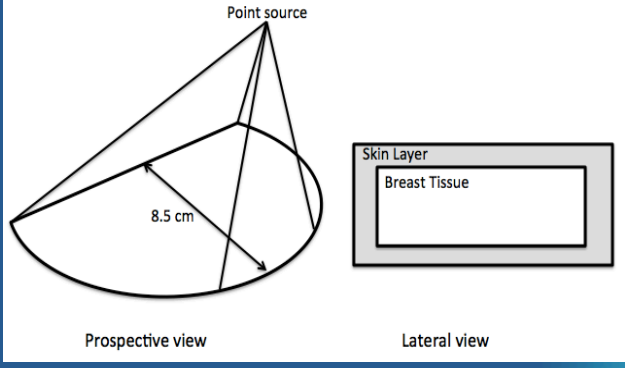
A validation of the code was performed against published works

Normalized glandular dose (DgN) coefficients for arbitrary x-ray spectra in mammography: Computer-fit values of Monte Carlo derived data

John M. Boone[a)]
Department of Radiology, University of California, Davis, Sacramento, California 95817

(Received 1 November 2001; accepted for publication 28 February 2002; published 19 April 2002)

Cone Beam Irradiation field
Semi-Cylindrical Breast shape



A comprehensive analysis of DgN_{CT} coefficients for pendant-geometry cone-beam breast computed tomography

J. M. Boone[a)]
Department of Radiology, U.C. Davis Medical Center, 4701 X Street, X-ray Imaging Laboratory and Department of Biomedical Engineering, Sacramento, California 95817

N. Shah
Department of Radiology, U.C. Davis Medical Center, 4701 X Street, X-ray Imaging Laboratory, Sacramento, California 95817

T. R. Nelson
Department of Radiology, University of California, San Diego, California 92037

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Cylindrical Breast shape

Radiation dose in breast CT imaging with monochromatic x-rays: simulation study of the influence of energy, composition and thickness

A Mittone[1,2], A Bravin[3] and P Coan[1,2]

[1] Department of Physics, Ludwig Maximilians University, Garching D-85748, Germany
[2] Department of Clinical Radiology, Ludwig Maximilians University, Munich D-81377, Germany
[3] European Synchrotron Radiation Facility (ESRF), Grenoble F-38043, France

E-mail: alberto.mittone@physik.uni-muenchen.de

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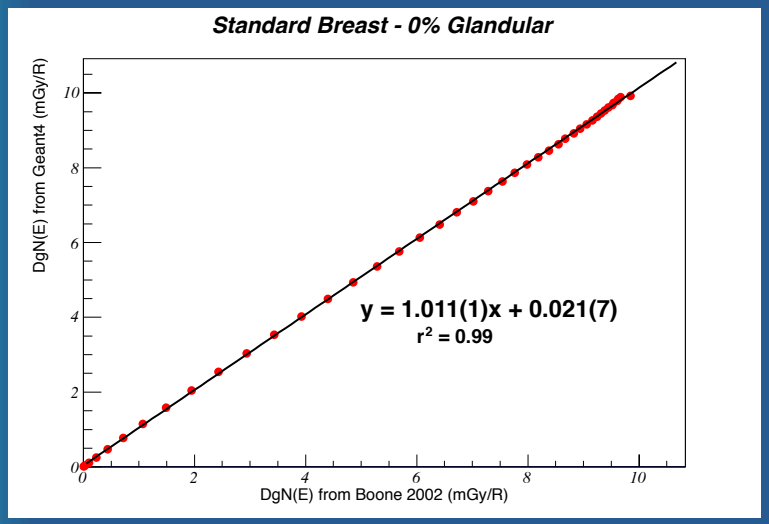
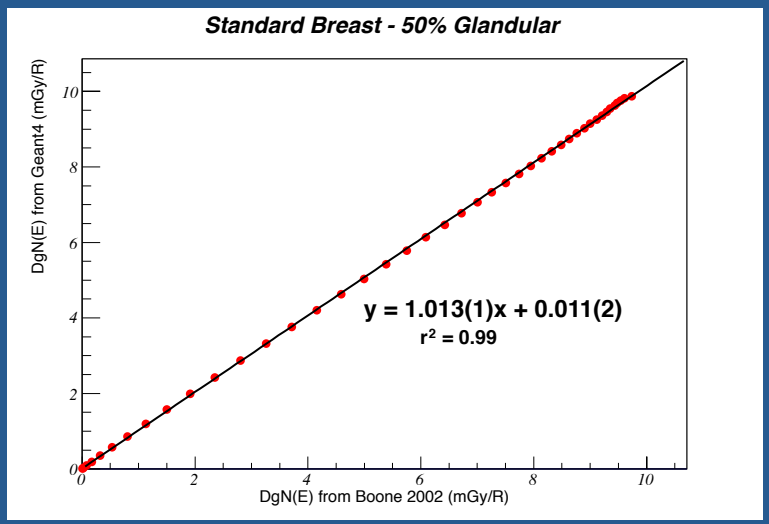
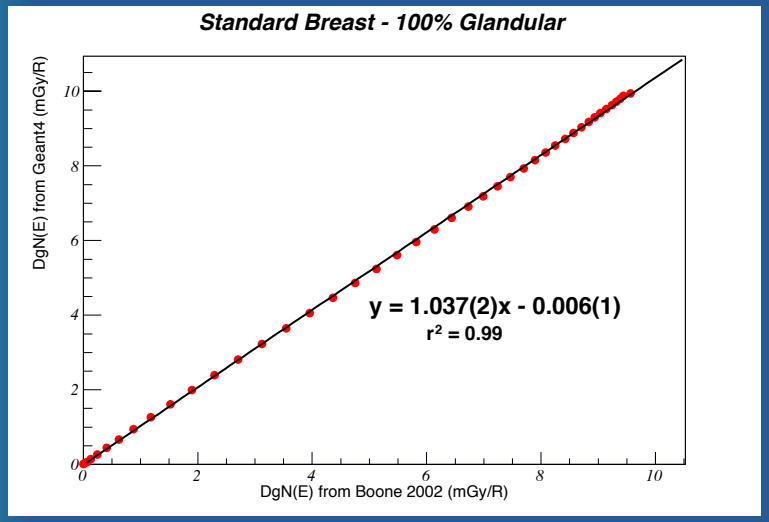
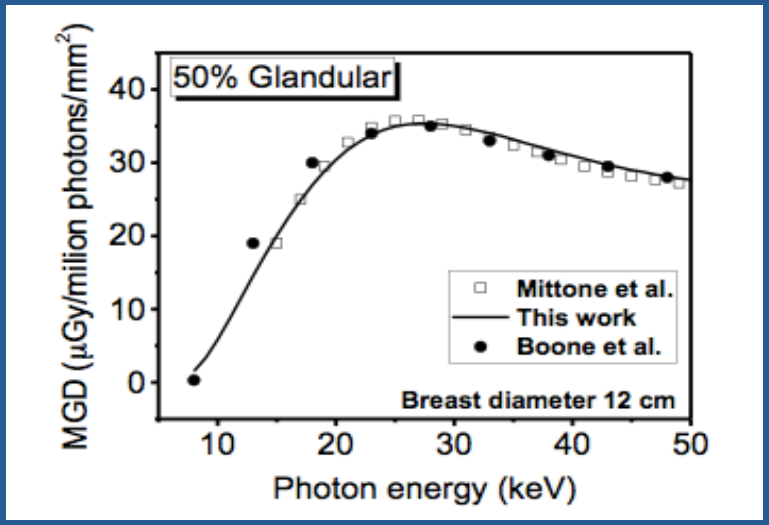
Energy range → 8-50 keV







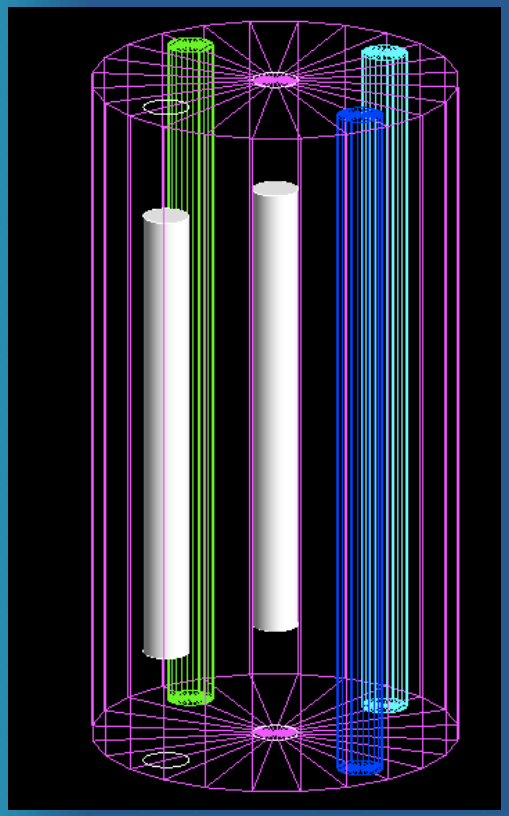


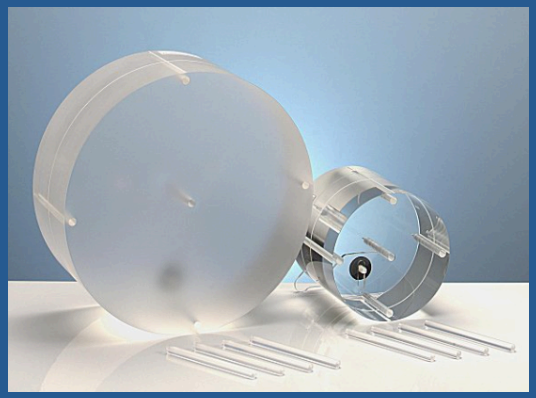
Excellent agreement with previous literature

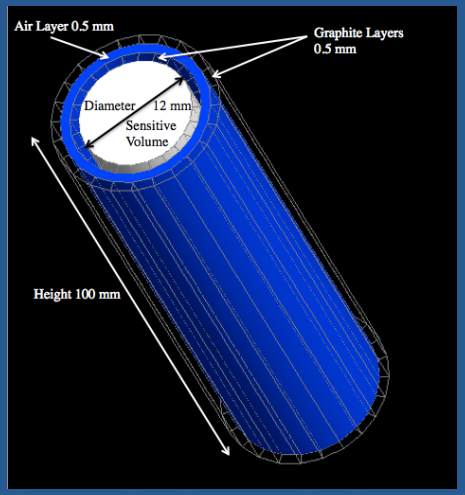
Experimental Validation

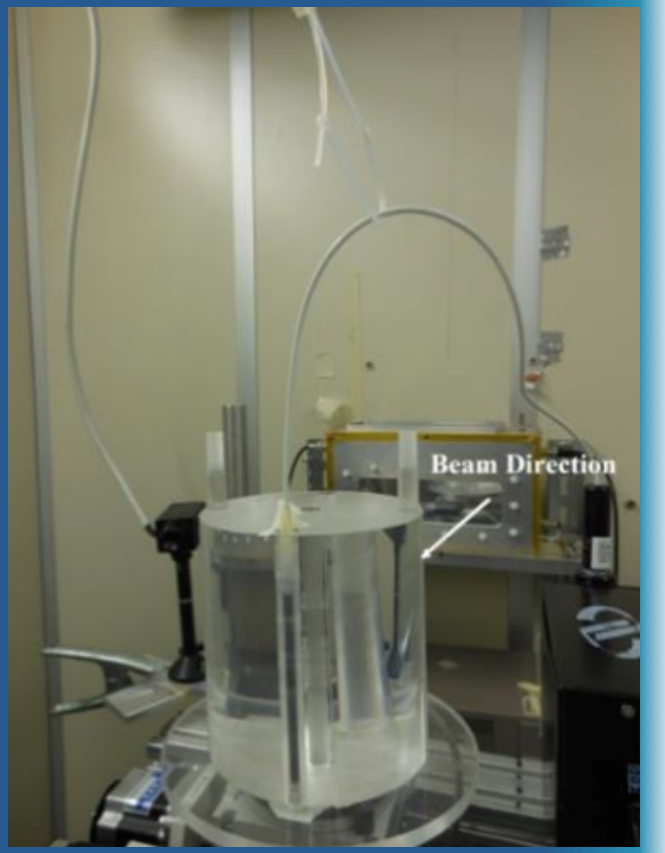
$CTDI_w$ was used for experimental validation

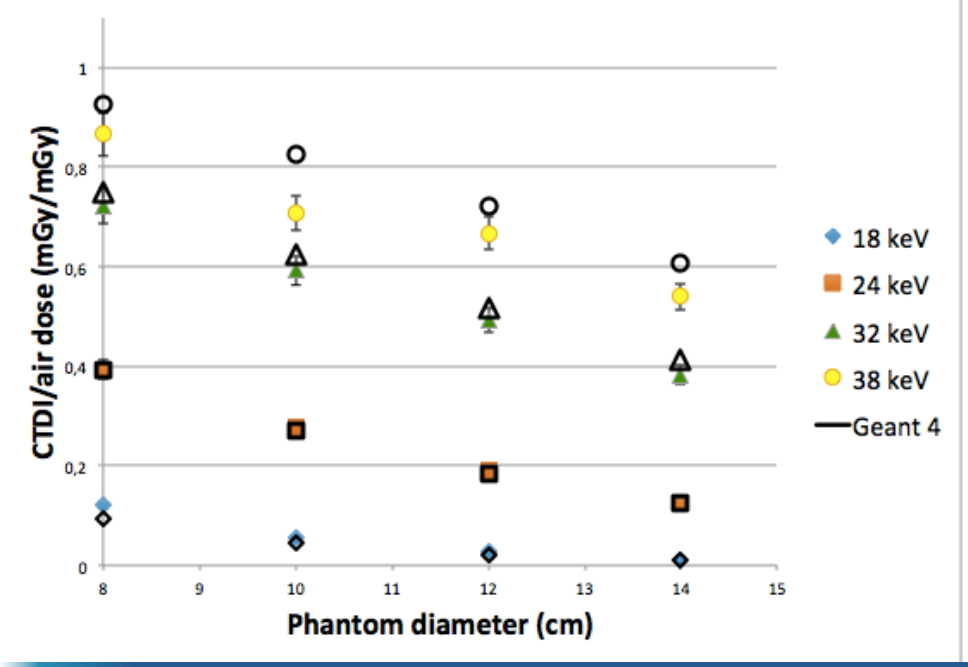
$$CTDI_w = \frac{1}{3} CTDI_{100,center} + \frac{2}{3} CTDI_{100,peripheral}$$

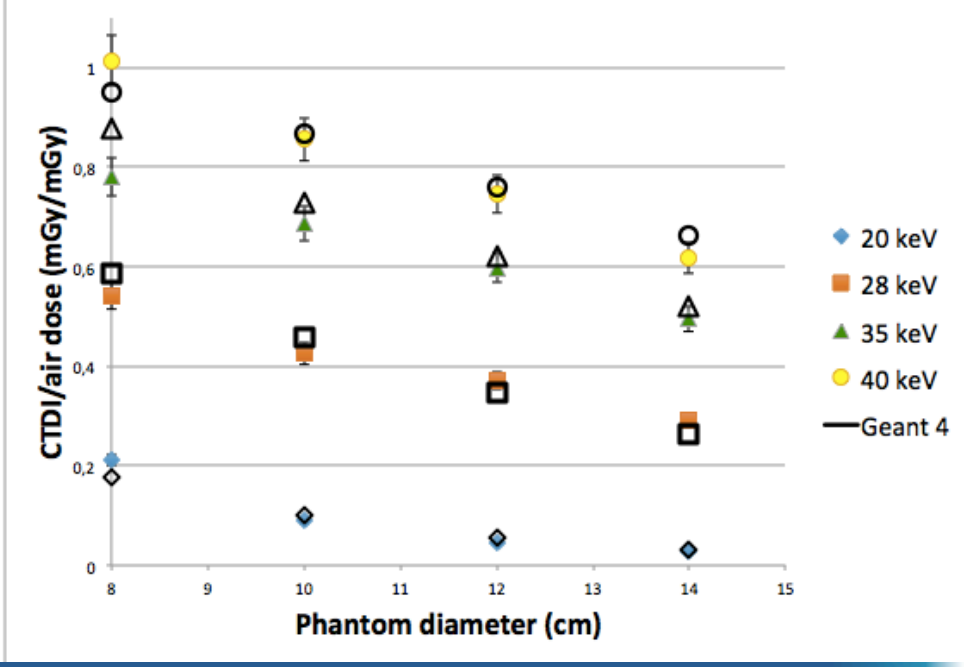










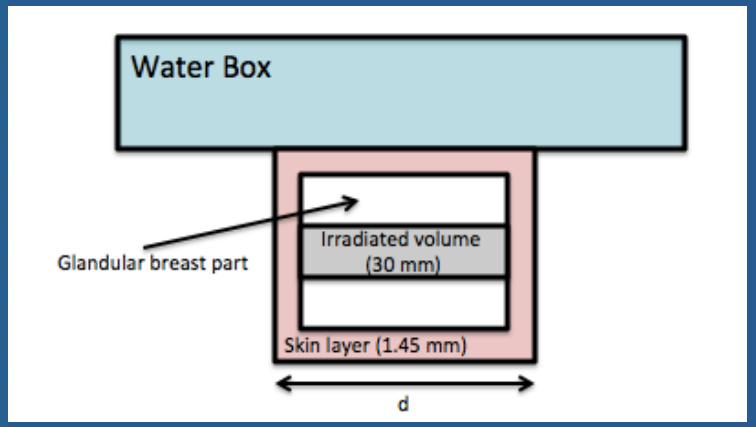


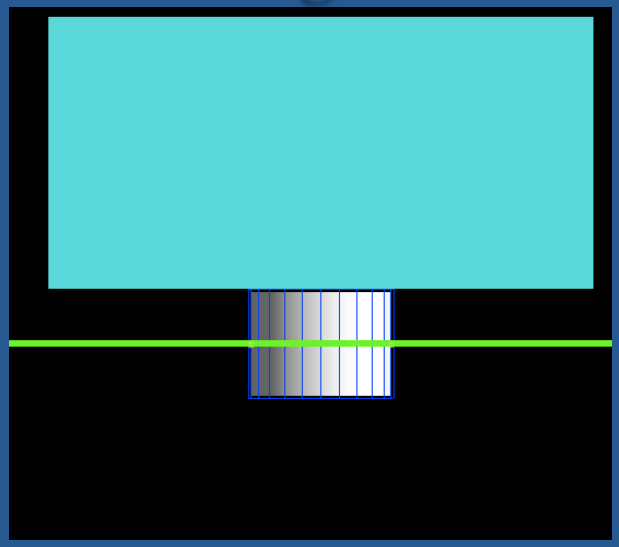
Closed symbols for **EXPERIMENTAL DATA** (σ=5%)
Open symbols for **SIMULATED DATA** (COV<1%)

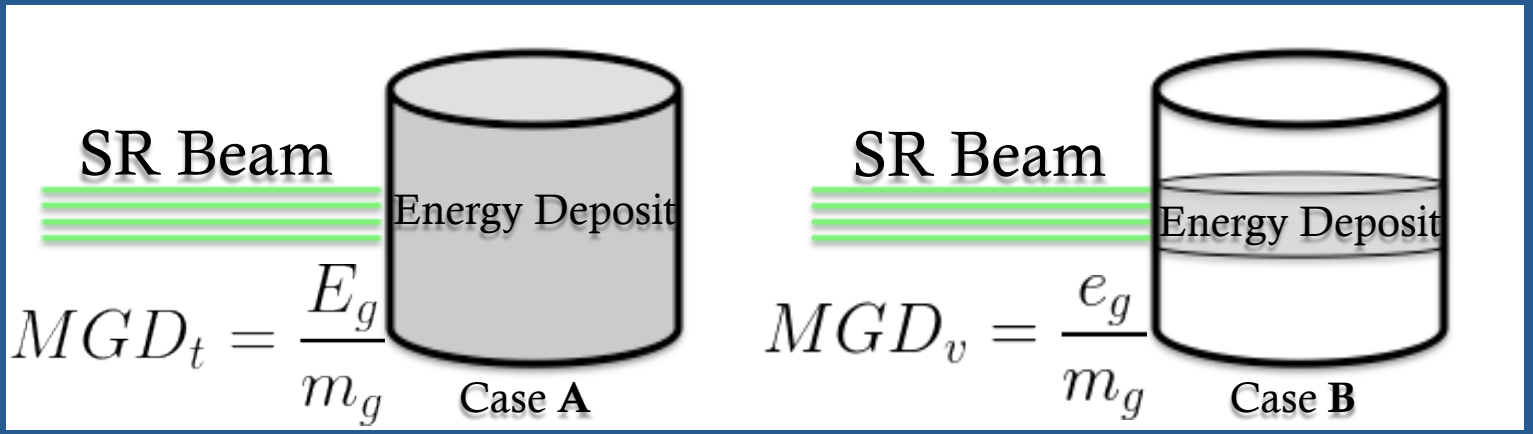
Good agreement with experimental measurements

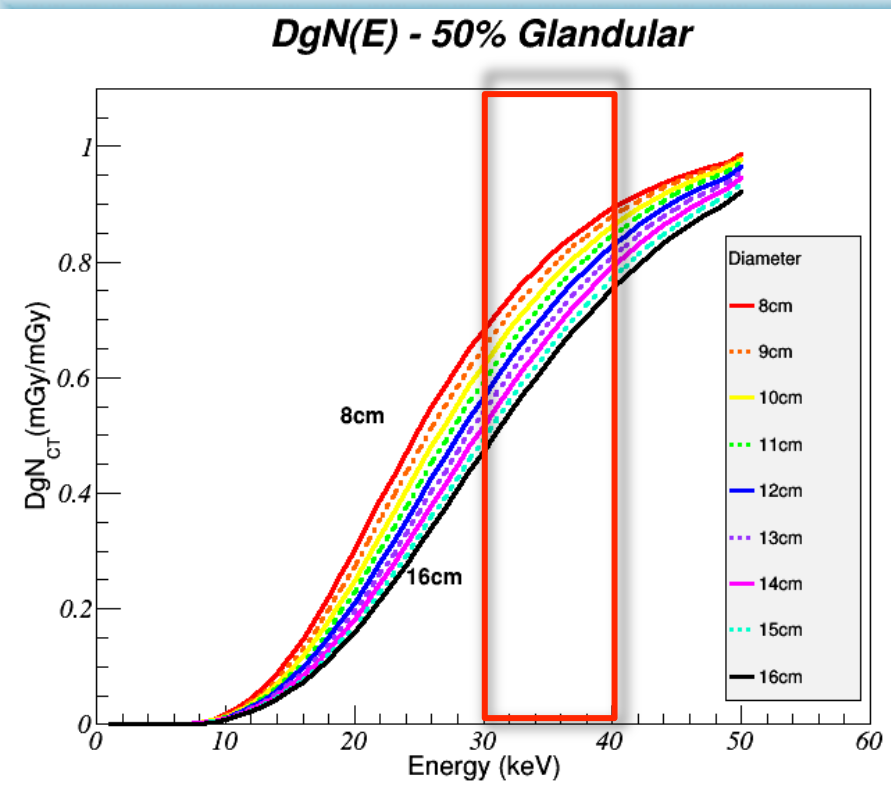
SYRMA-CT Dosimetry

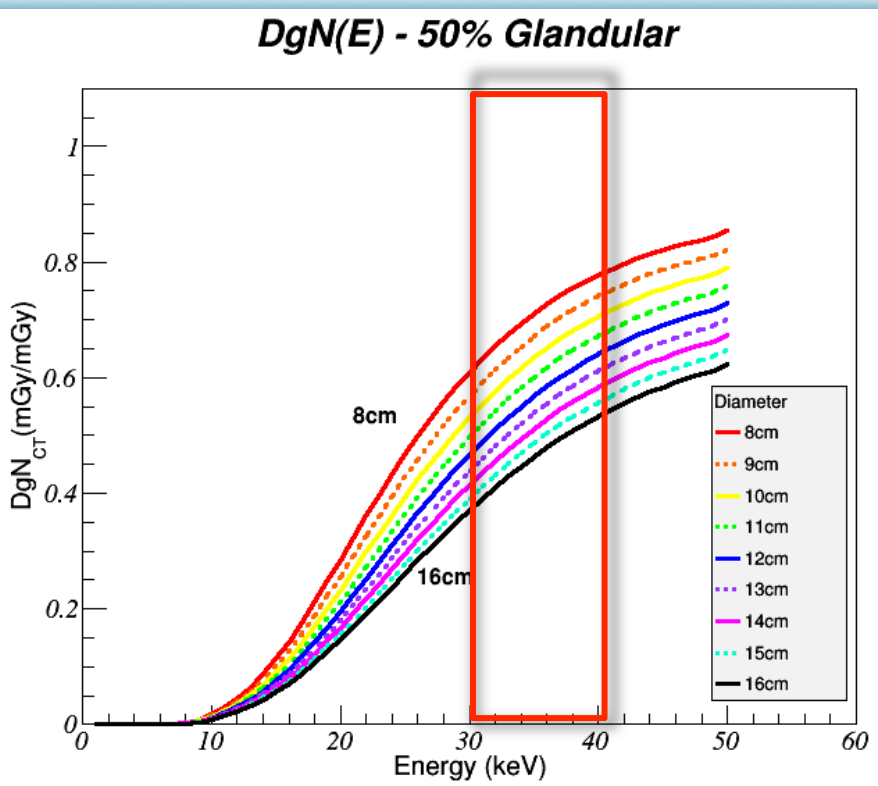
The breast will be partially irradiated: a height of 30 mm is taken into account











Case A

- Energy in the whole glandular part
- Mass irradiated volume

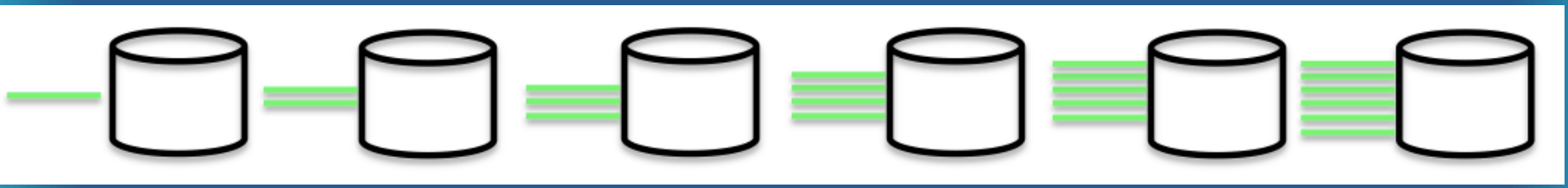
$$MGD_t = \frac{E_g}{m_g}$$

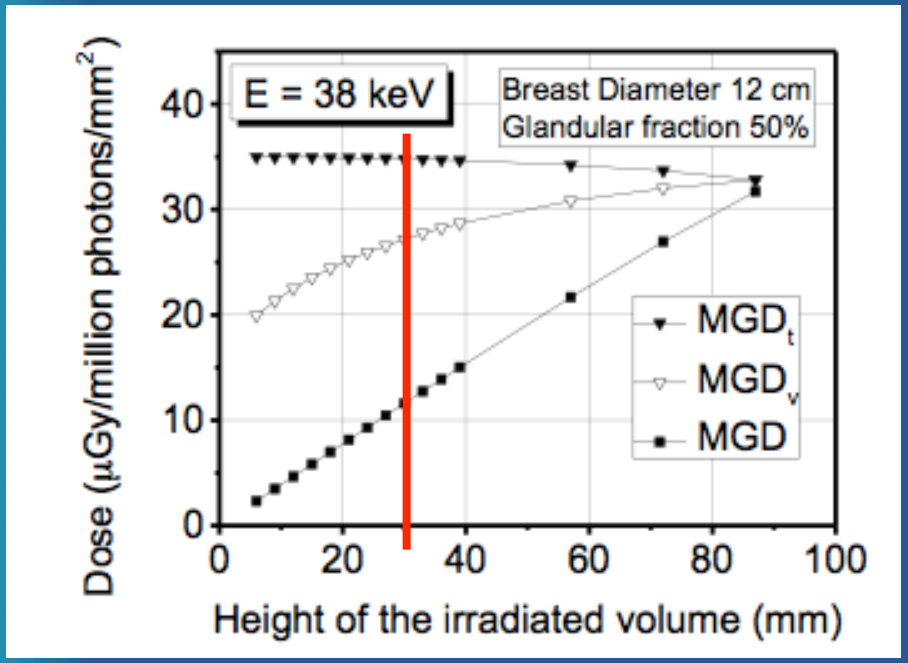
Case B

- Energy in the irradiated volume
- Mass irradiated volume

$$MGD_v = \frac{e_g}{m_g}$$

To evaluate the energy deposit in the region next to the irradiated slice, the beam height was increased





$$MGD_t = \frac{E_g}{m_g}$$

$$MGD_v = \frac{e_g}{m_g}$$

$$MGD = \frac{E_g}{M_g}$$

Irradiating 30 mm there is a mean difference of 28%

Conclusions

The study analyzed the peculiar irradiation mode of breast-CT with synchrotron radiation

Two parameters are found to be the optimal dosimetric quantities for the breast-CT exam

The study will be the basis for the dosimetry protocol of the clinical study