



UNICAMP



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Techniques for Medical Applications (MCMA2017)

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# Skin Model and its impact on Digital Mammography



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# Outline

## Motivation

- Mammography
- Dosimetry - Mean Glandular Dose

## Methodology

- Implemented Models
- How?

## Results

- MGD vs Skin Model
- Differences

## Conclusions

- Summary

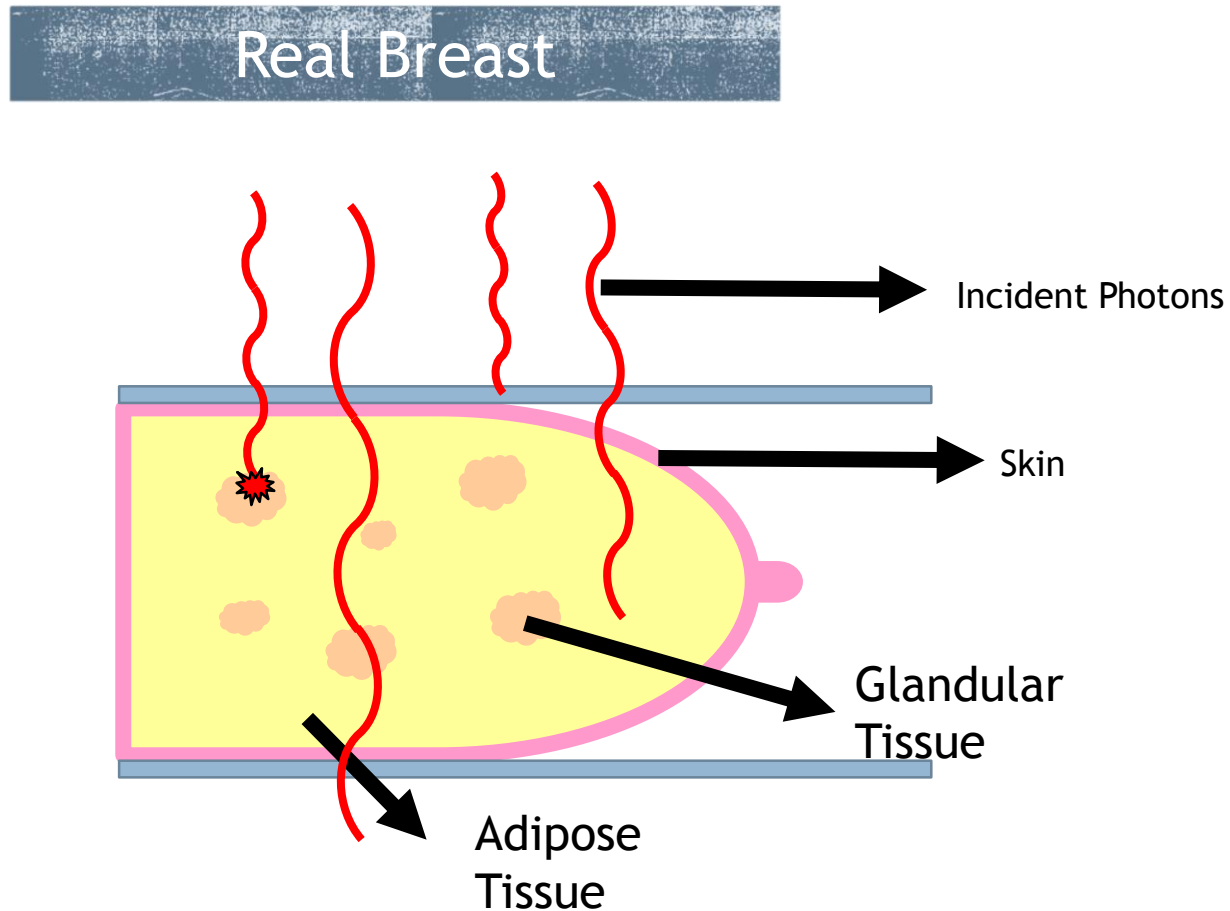
# Introduction

Why is dosimetry important in mammography?

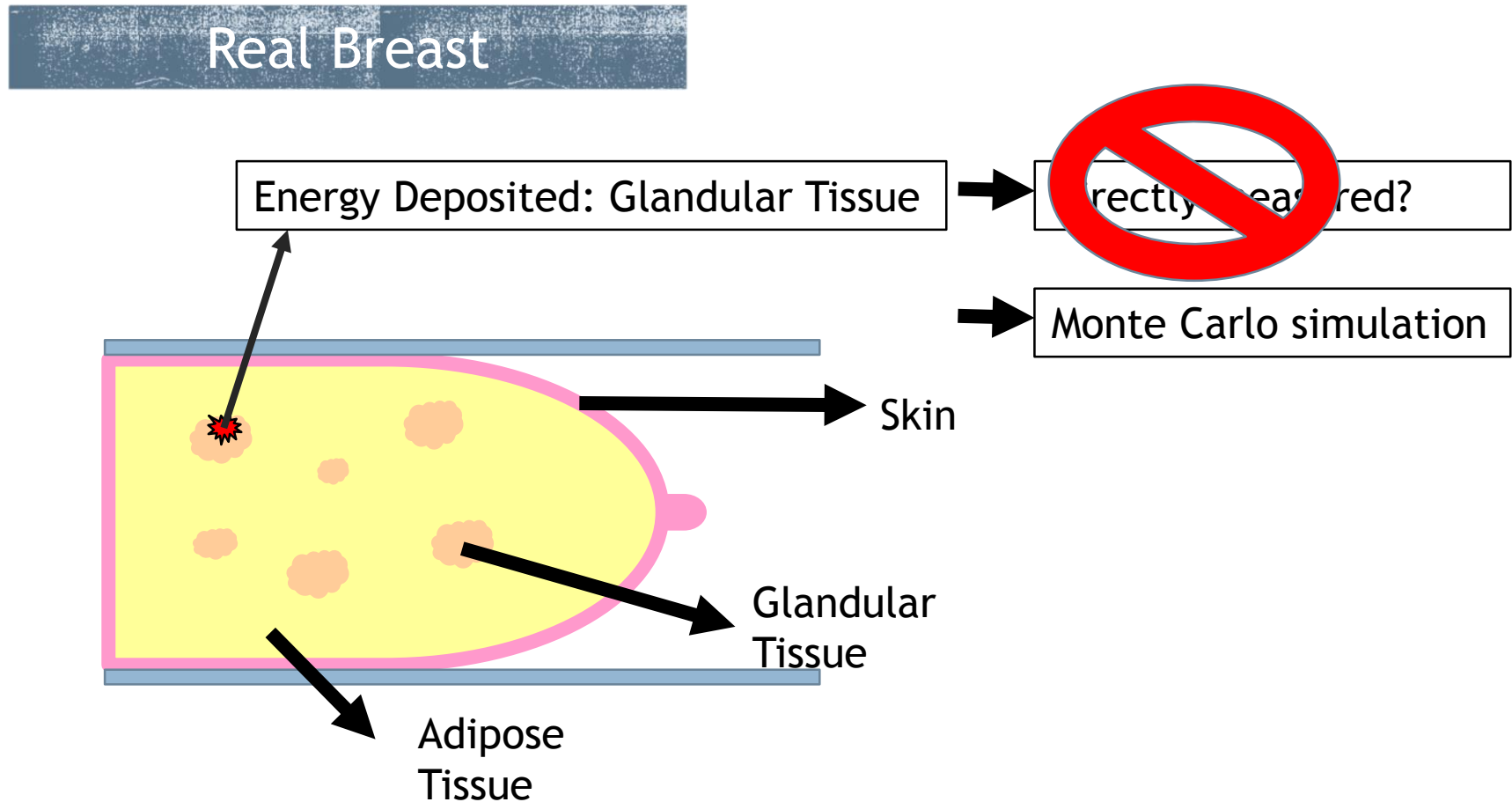
- Population-based screening programs
- Use Ionizing Radiation
- Quality Control and Optimization



# Mean Glandular Dose (MGD)

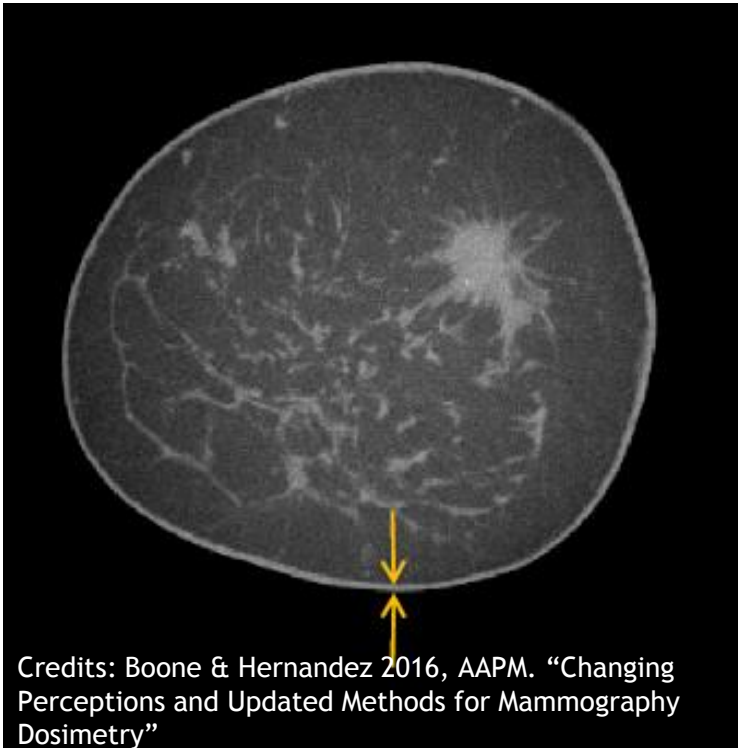


# Mean Glandular Dose (MGD)



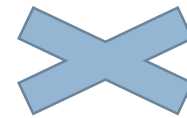
# Mean Glandular Dose (MGD)

Parameters to consider...



Previous Estimations:

- 5 mm Adipose Tissue ( Dance 1990)
- 4 mm Skin Tissue (Wu 1991/Boone 1999)



**64% thinner**

Current Measures:

Using breast-CT:  $\approx 1.44$  mm (Vedantham et al 2012)  
 $\approx 1.45$  mm (Huang et al 2008);  
+ adipose layer

# Objectives

Study the impact of skin models on Mean Glandular Dose in Digital Mammography

Adapt MC Code

- Geometry
- MGD calculus

Analysis

- MGD X Skin Models

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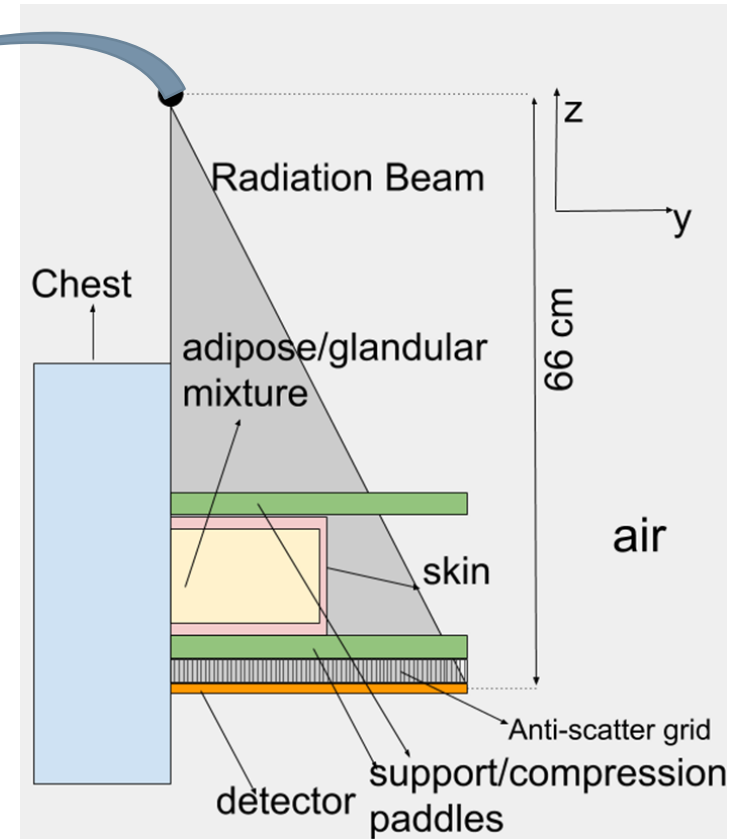
# Methodology

Monte Carlo code:

- PENELOPE (2014) + penEasy (2015)

Beam Parameters:

- Monoenergetic (8 - 60 keV)
- Polyenergetic (22 - 35 kV):
  - Mo (Mo-Rh)
  - Rh (Rh)
  - W (Rh-Al-Ag)

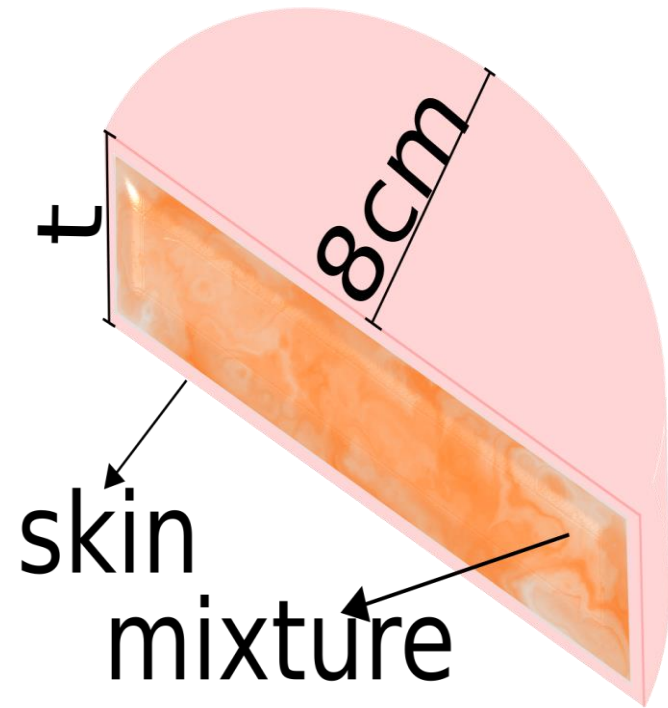


\*X-ray spectra from Hernandez et al (2014)

# Methodology

## Breast Model\*

- $t = 2 \text{ cm} - 8 \text{ cm}$
- Glandularity ( $f_g$ ) = 1%-100%



\*Compositions from Hammerstein et al 1979

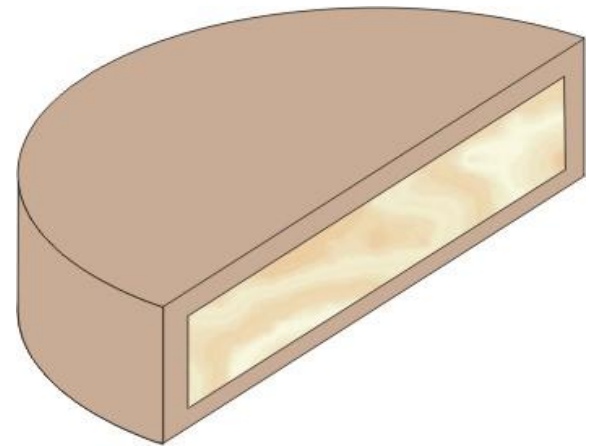
# Methodology

## Breast Model\*

- $t = 2 \text{ cm} - 8 \text{ cm}$
- Glandularity ( $f_g$ ) = 1%-100%

## Skin shielding Models

- I. 5 mm adipose;
- II. 4 mm skin;
- III. 1,45 mm skin;
- IV. 1,45 mm skin + 2 mm adipose;
- V. 1,45 mm skin + 3,55 mm adipose;

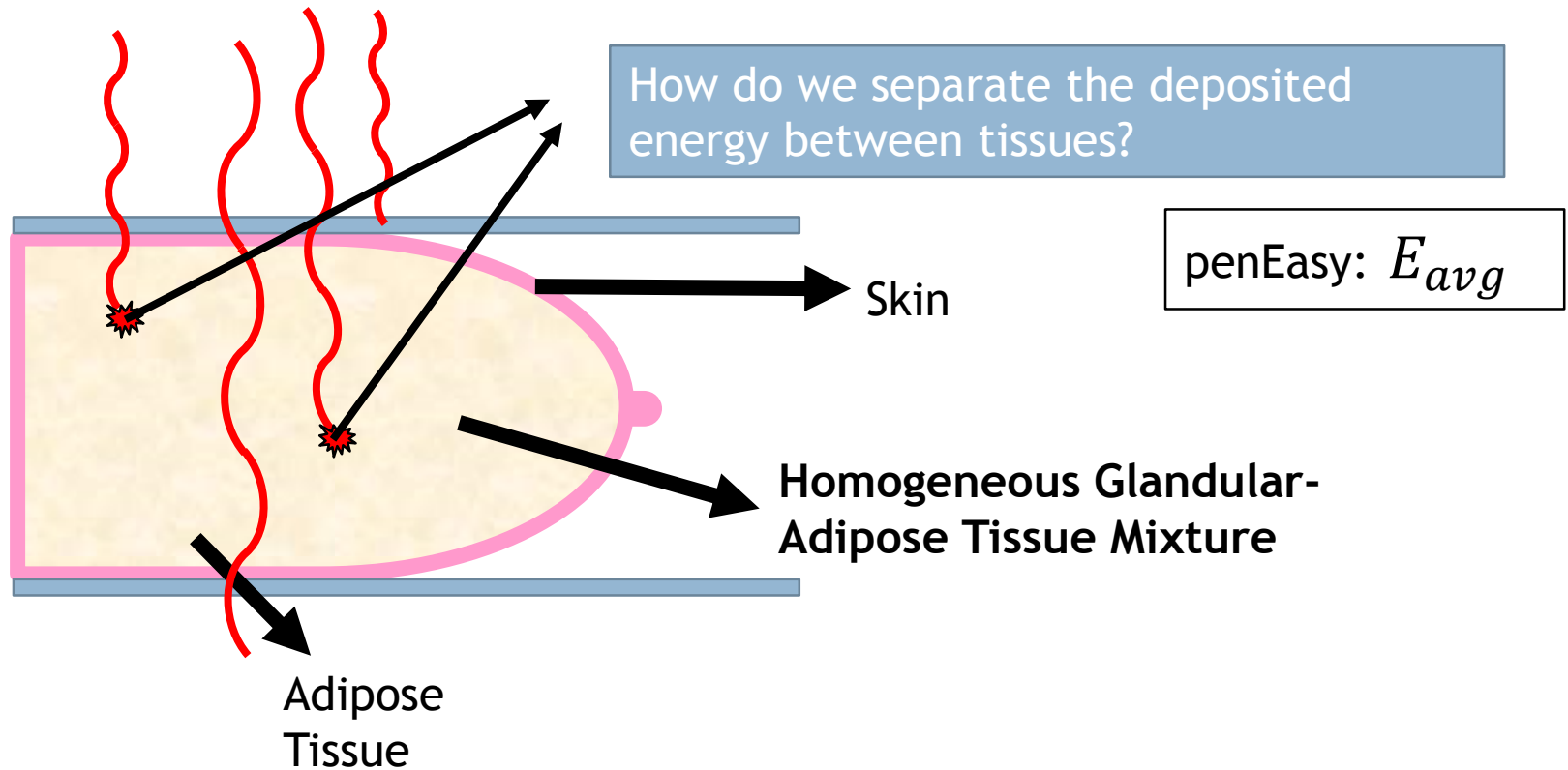


\*Compositions from Hammerstein et al 1979



# Mean Glandular Dose (MGD)

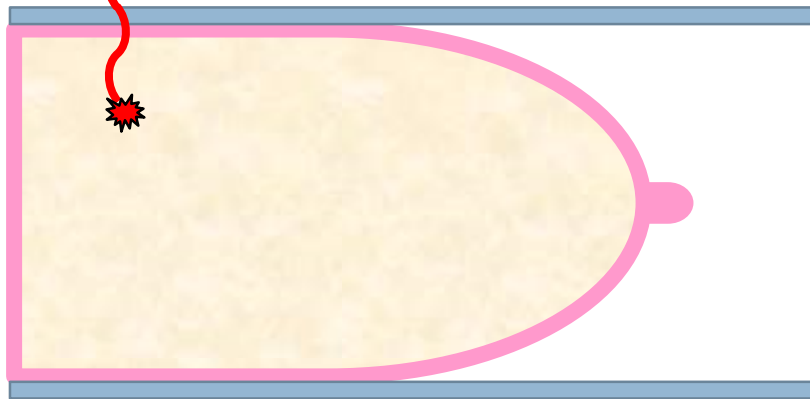
## Monte Carlo Simulations



# Mean Glandular Dose (MGD)

## MGD Weighing method (Dance 1990)

Simulation starts: (I)  
 $E_{gland} = 0$  (III)



(II)

Simulation Ends:  
 Return  $E_{gland}$

Random sampling  $\xi \in [0,1]$

$$MGD = \frac{E_{gland}}{Mass \times f_g}$$

$$E_{gland} = E_{gland} + dE$$

$$nMGD = \frac{MGD}{K_{air}}$$

)  
 a

# Code modifications...

Dosimetry

$$nMGD = \frac{MGD}{K_{air}}$$

```
[SECTION TALLY ENERGY GLAND DEPOSITION v.2016-09-27]  
OFF STATUS (ON or OFF)  
1 DETECTION MATERIAL  
0.50 GLANDULAR TISSUE PROPORTION (MUST BE FROM 0 TO 1)  
0.5 RELATIVE UNCERTAINTY (%) REQUESTED  
[END OF EDP SECTION]
```

```
[SECTION ION CHAMBER ENERGY DEPOSITION v.2016-11-21]  
OFF STATUS (ON or OFF)  
3 DETECTION MATERIAL  
0.0 RELATIVE UNCERTAINTY (%) REQUESTED  
[END OF EDP SECTION]
```

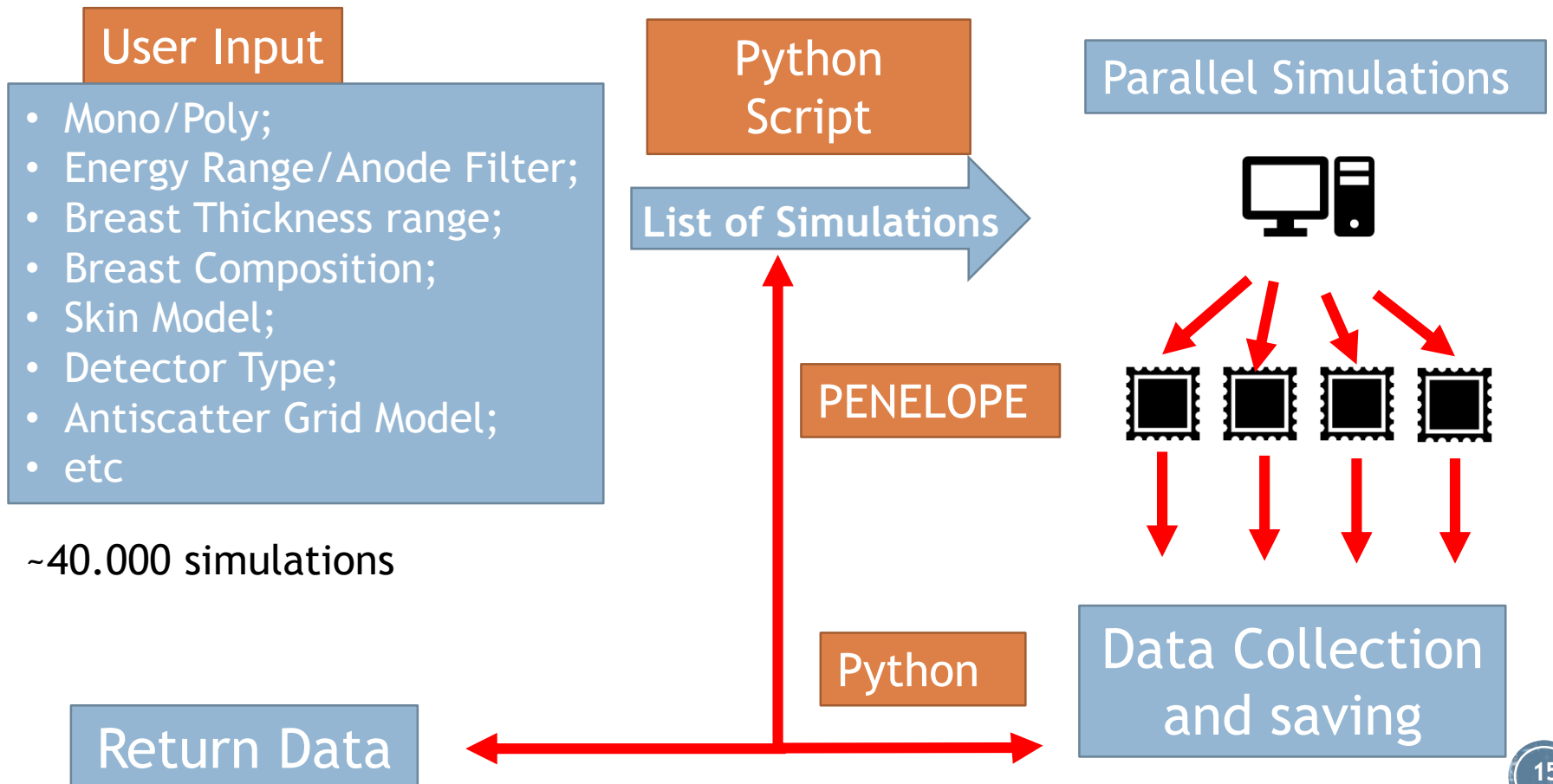
MGD

Air Kerma from Primary  
Photons

~40.000 simulations

# Automatization with Python™

Windows/Linux full compatibility



# Automatization with Python™

**penEasyMam V. 0.0.1**

Mono Poly

Beam Energy (keV)  
Min Max Steps  
8 60 1

Grid Type  
 Ideal  
 Linear  
 Cellular  
 None

Breast Thickness (cm)  
 2  
 4  
 6  
 8

Detector Type  
 Ideal  
 CR  
 DR

Skin Model  
 4 mm Skin  
 5 mm Adipose  
 1.45mm S 2mm A  
 1.45 mm Skin

Simulation Parameters  
Number of Histories  
Simulation Time  
Number of Processors  
Desired Uncertainty (%)

Glandularity List  
0.01

Generate List

**penEasyMam V. 0.0.1**

Mono Poly

Tube Potential (kV)  
Min Max Steps  
22 22 1

Anode/Filter  
 Mo/Mo  Mo/Rh  
 Rh/Rh  
 W/Rh  W/Al  W/Ag

Grid Type  
 Ideal  
 Linear  
 Cellular  
 None

Breast Thickness (cm)  
 2  
 4  
 6  
 8

Detector Type  
 Ideal  
 CR  
 DR

Skin Model  
 4 mm Skin  
 5 mm Adipose  
 1.45mm S 2mm A  
 1.45 mm Skin

Simulation Parameters  
Number of Histories  
Simulation Time  
Number of Processors  
Desired Uncertainty (%)

Glandularity List  
0.01

Generate List

3-10 min/simulation - Uncertainty ( $1\sigma$  - 0.25%)  
Processor i7 7700 3.6 Ghz



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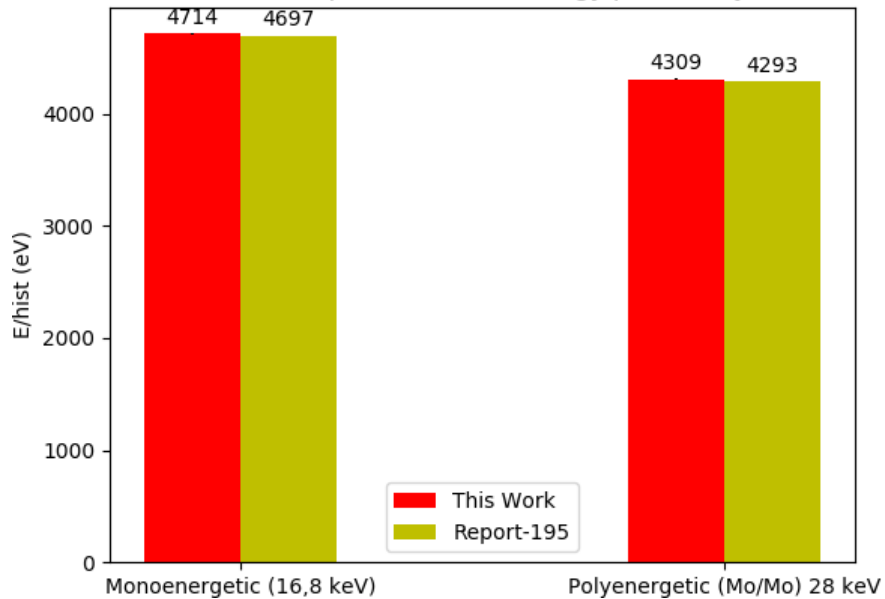
- Summary

# Results - Code Validation

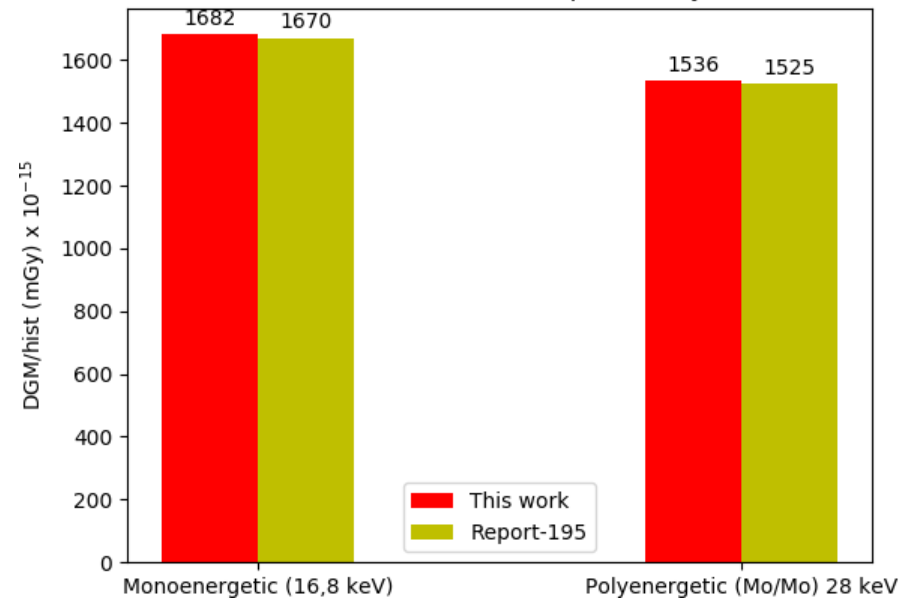
AAPM - Report 195 (2015)

<1%

Mean Deposited Breast Energy per history



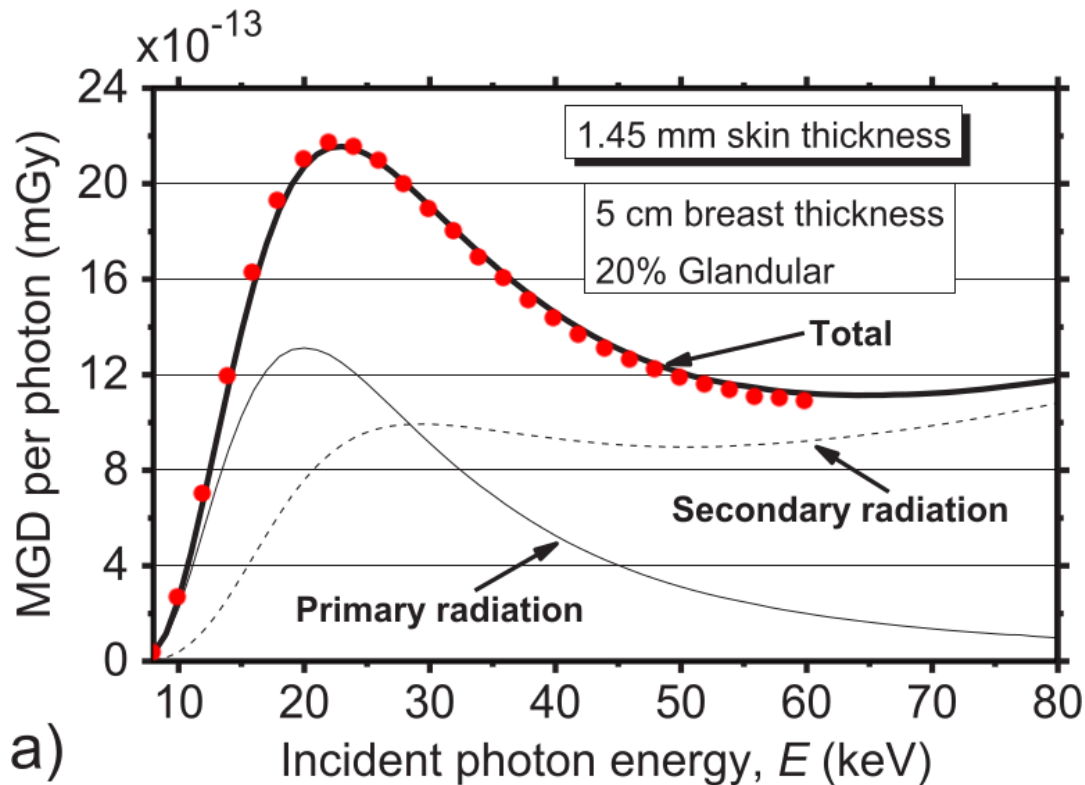
Mean Glandular Dose per history



# Results - Code Validation

Sarno et al 2016 - PMB

<4%

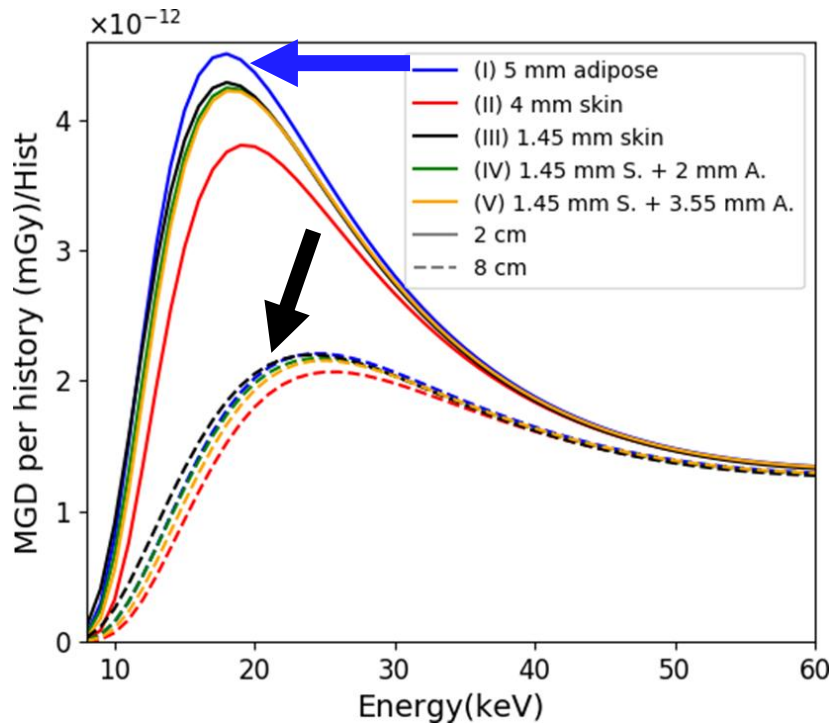


- 5 cm thick;
- 20%  $f_g$ ;
- 1.45 mm skin;

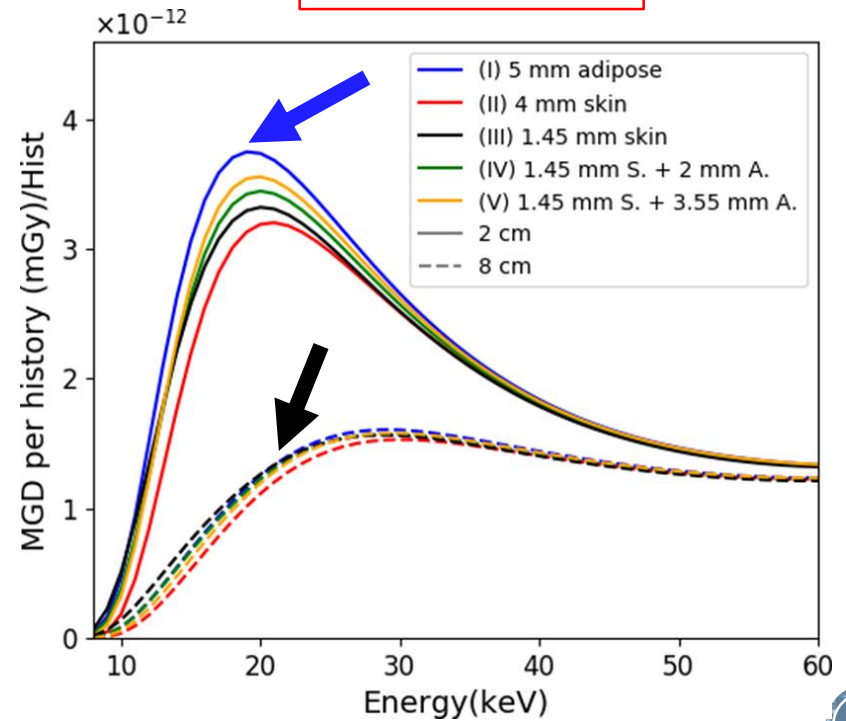
# Results: Skin shielding models

## Monoenergetic Beam

1%  $f_g$



100%  $f_g$

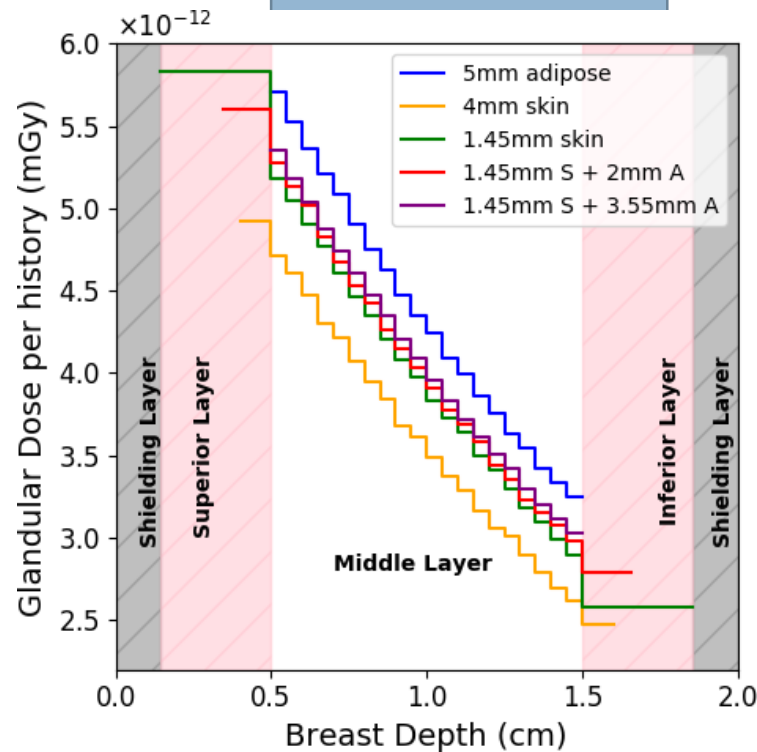


# Results: Skin shielding models

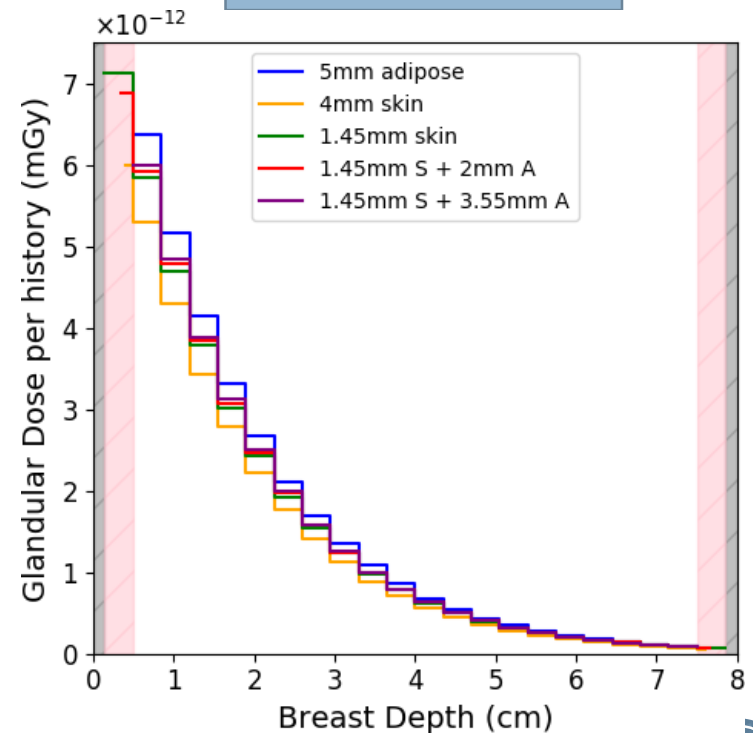
Monoenergetic Beam - Depth Dose 18 keV

20%  $f_g$

2 cm breast



8 cm breast



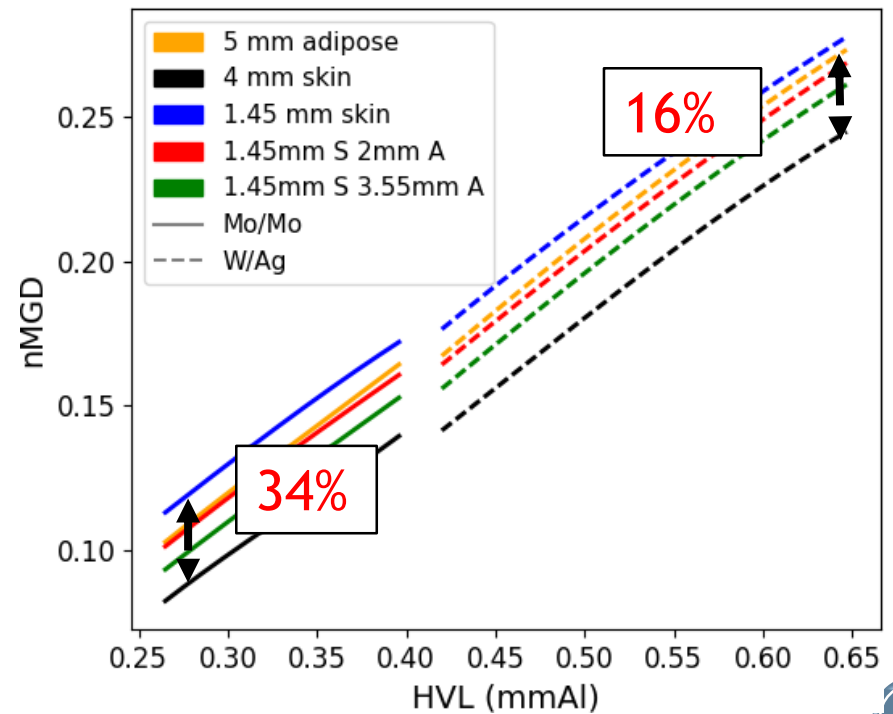
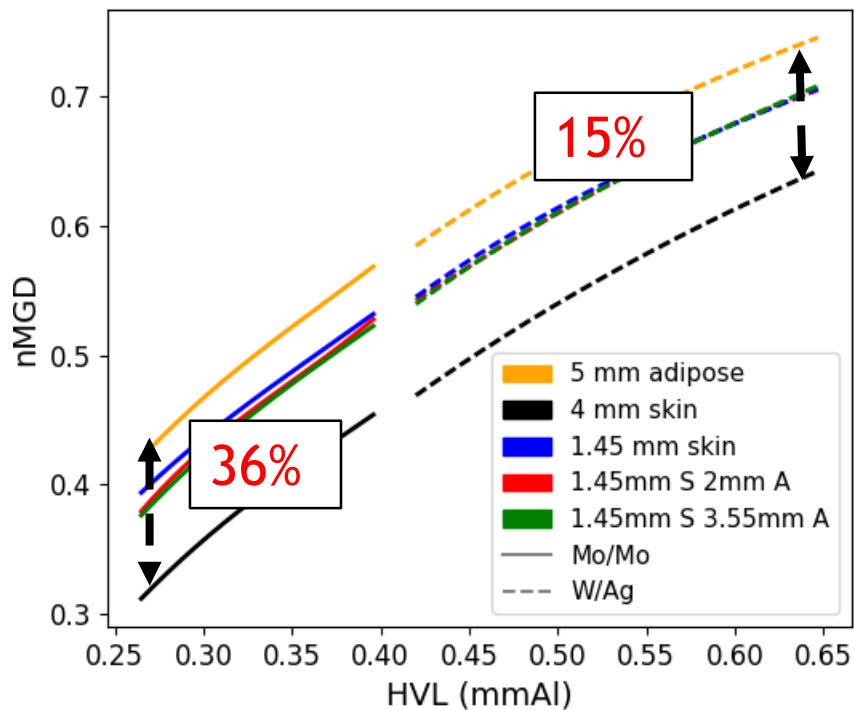
# Results: Skin shielding models

Polyenergetic Beam

20%  $f_g$

2 cm

8 cm

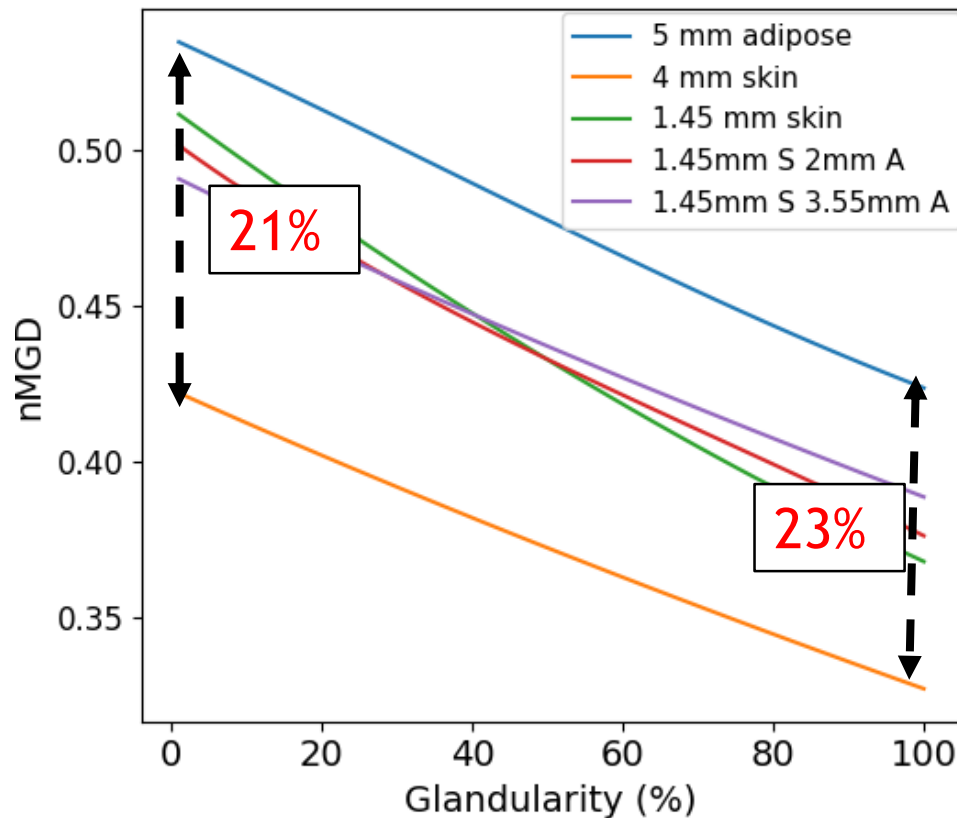


# Results: Skin shielding models

Polyenergetic Beam

Mo/Mo 28 kV

2 cm breast

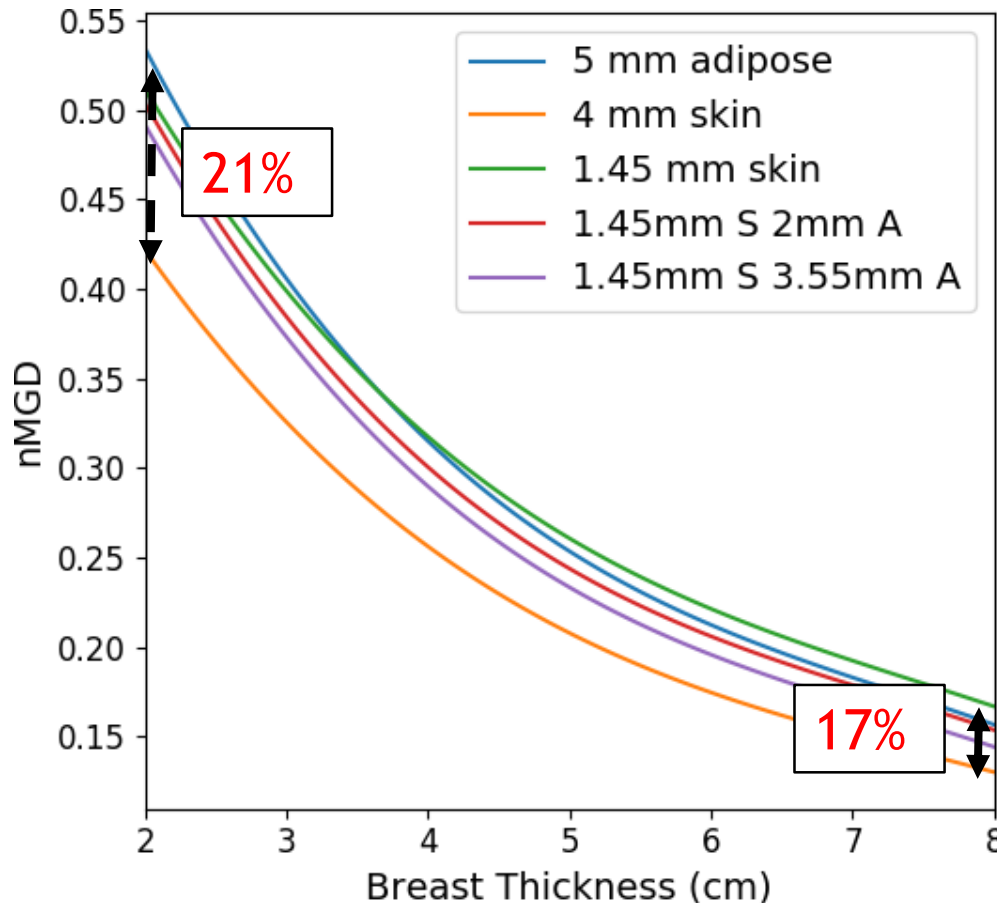


# Results: Skin shielding models

Polyenergetic Beam

Mo/Mo 28 kV

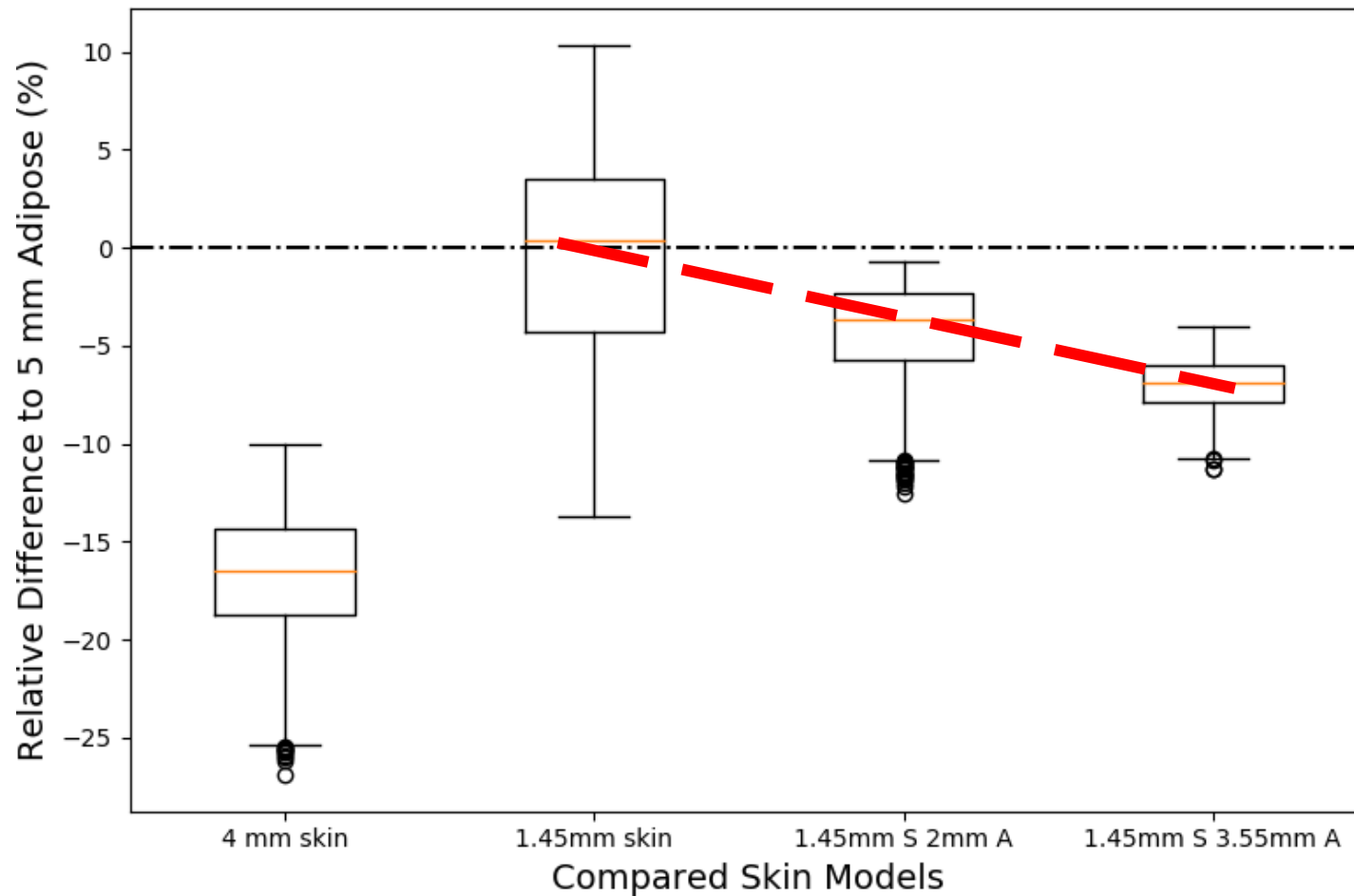
1%  $f_g$





# Results: Summary

## Polyenergetic Beam - Skin Models



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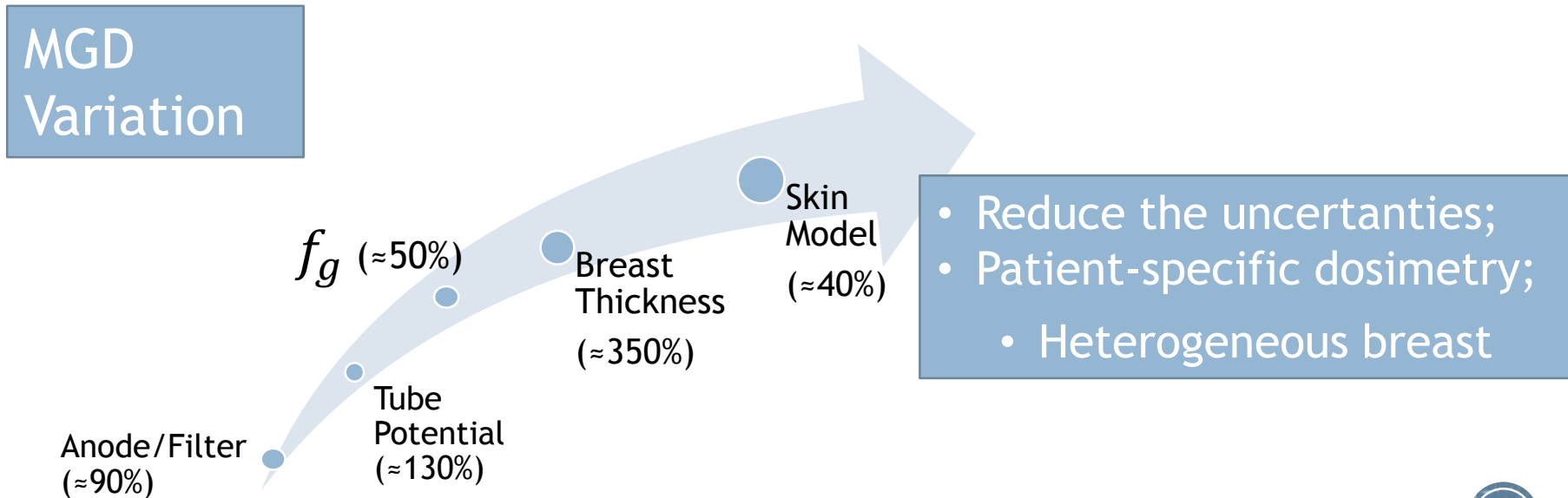
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# Conclusions

- The Skin Model has a significant impact on MGD estimates;
- Skin model affects the MGD up to 37%;
- Larger variations: low energies; high glandularity, thin breasts

Depth Dose : skin attenuation and Homogeneous Mixture Volume



# Acknowledgement



- Process 2016/15366-9
- Process 2015/21873-8



- Process 483170/2015-3



Fundo de Apoio ao Ensino, à Pesquisa e à Extensão



## *Lab Members and Alumni*



Rodrigo T. Massera



Bruno L. Rodrigues

## Collaborators



José Maria  
Fernandez-Varea



# Our Institution



Funded in 1966



Credits: Lucas Rodolfo de Castro Moura -  
<http://www.lrdronecampinas.com.br/>

University of Campinas (UNICAMP): 1st in Latin America





Thank You!



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