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Sterility Assurance

Low Energy Electron Beam

Goal of This Presentation

- Review a R&D case study of low energy electrons
- Dosimetry issues associated with low energy electrons
- Evaluation of dose measurements

Scenario

The Ask:

Dosimetry for absorbed dose measurements for a low energy electron beam irradiation of a thin product

Dose map to evaluate single and double sided processing

Process Optimization: Energy, Air Gap

Preliminary Evaluation

Preliminary evaluation consisted of Monte Carlo modeling:

a. Air gap
b. Energy
c. Dose depth profile for dosimetry assessments
d. Dose delivery as a double sided process simulated as the summation of two single sided irradiations

Air Gap Models

In low energy electron beam applications energy losses are heavily influenced by the air gap; energy losses in air

Two energy models were constructed to evaluate the energy losses at several air gaps

Initial Energy	Air Gap			
240 keV	10mm	15mm	20mm	25mm
300 keV	10mm	15mm	20mm	25mm

Air Gap Models

Initial Energy	Air Gap			
240 keV	10mm	15mm	20mm	25mm
	220.4 keV	219.2 keV	217.8 keV	215.8 kEv
300 keV	10mm	15mm	20mm	25mm
	290.2 keV	289.1 keV	287.4 keV	286.3 keV

Air Gap Models

Conclusions:

a. As the air gap is increased a corresponding increase in the energy loss over the air gap occurs

b. Energy losses were larger for lower initial energy primarily due to energy loss in window

c. Air gap variation due to product conveyance was known to be ±5mm ; a 15mm air gap was selected

Energy

Dose depth profiles were modeled to provide insight:

a. Expected penetration of the thin product

b. Estimate dose gradients for dosimetry assessment

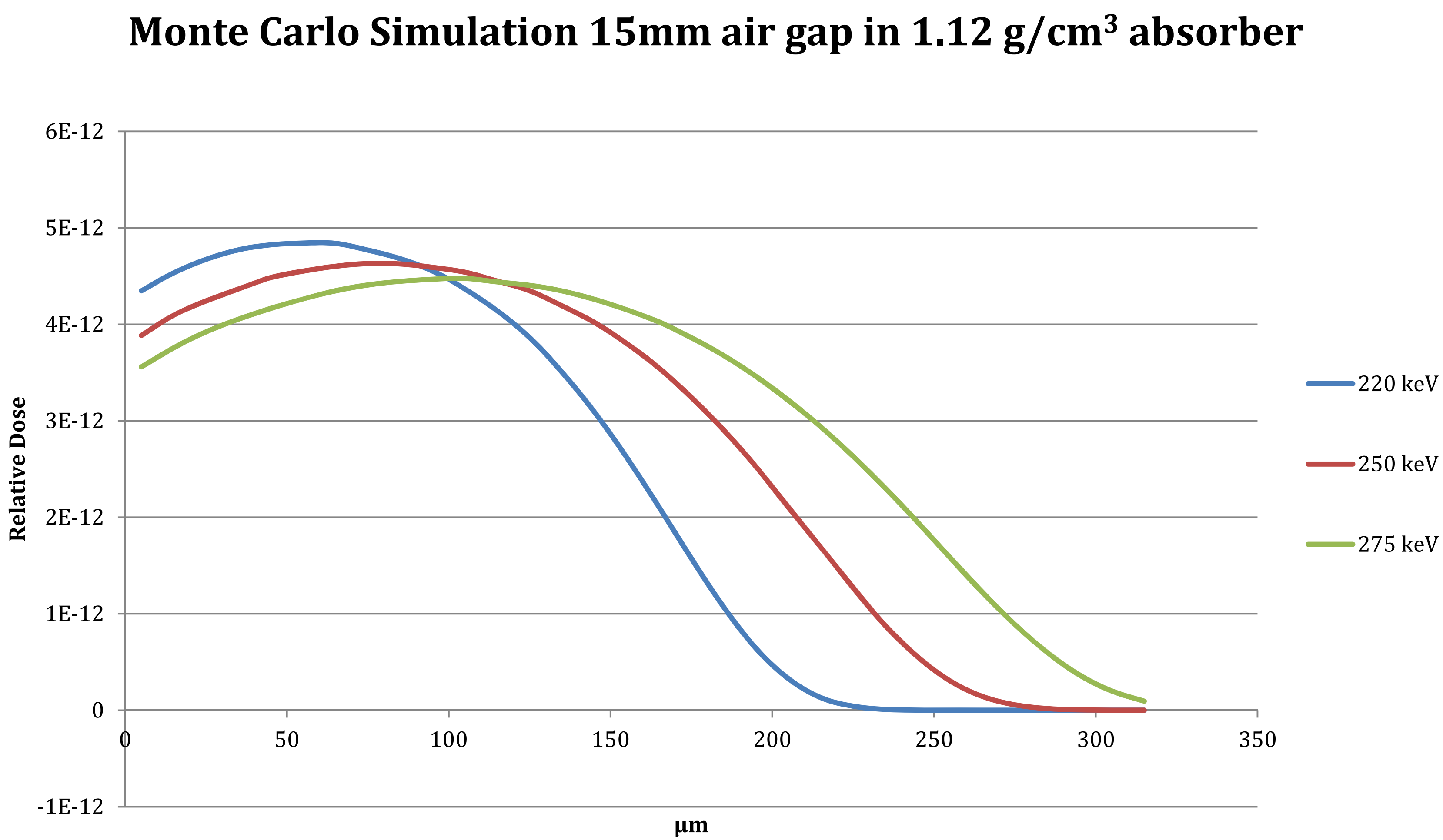
c. Three energies were initially evaluated

    220 keV

    250 keV

    275 keV

Dose Depth Profiles



Dose Depth Profiles

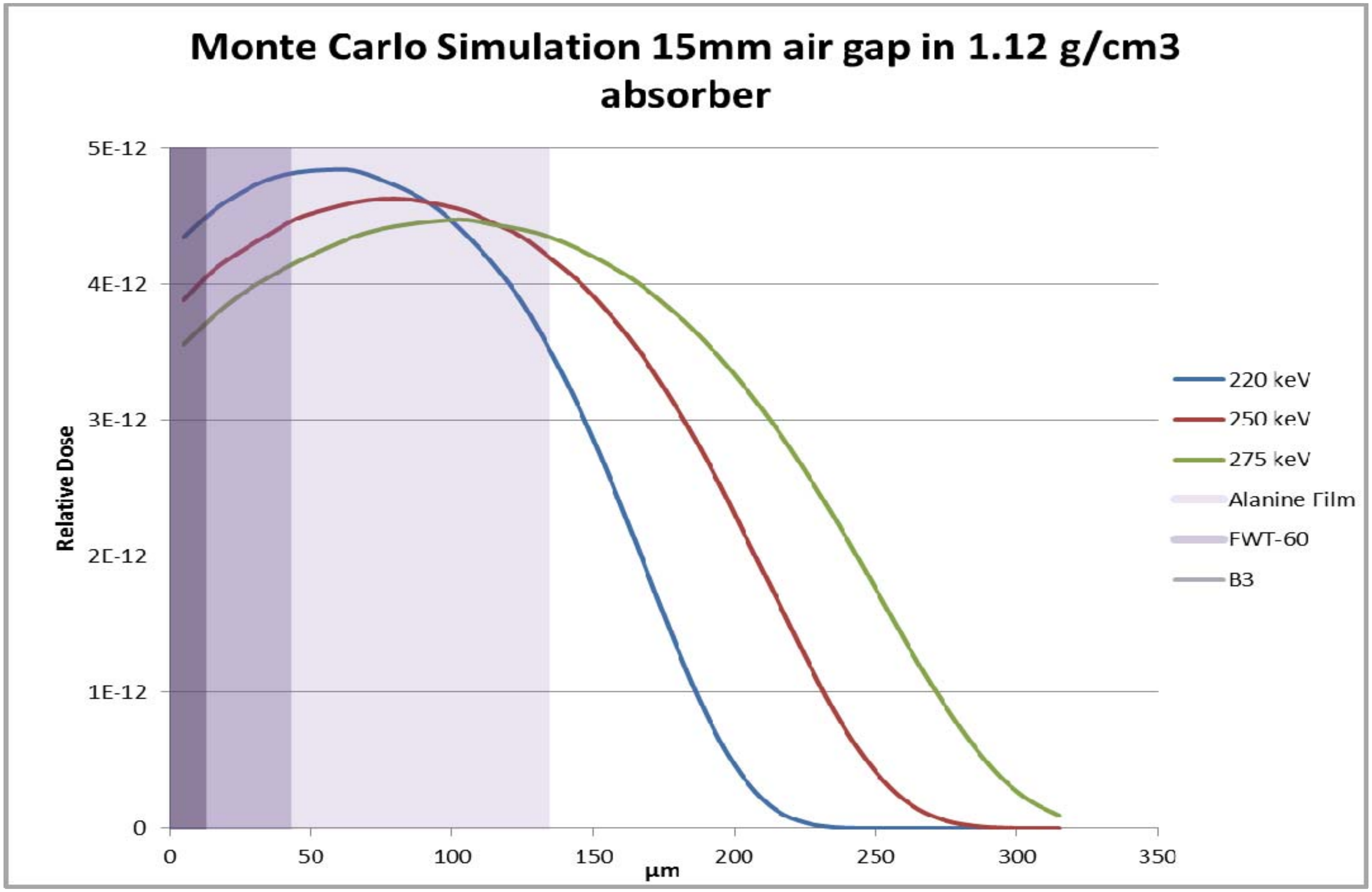
Conclusions:

a. Higher energies provided larger penetration

b. Higher energies provided smaller dose gradients*

*smaller dose gradients were a consideration for dosimetry

Dose Depth Profiles



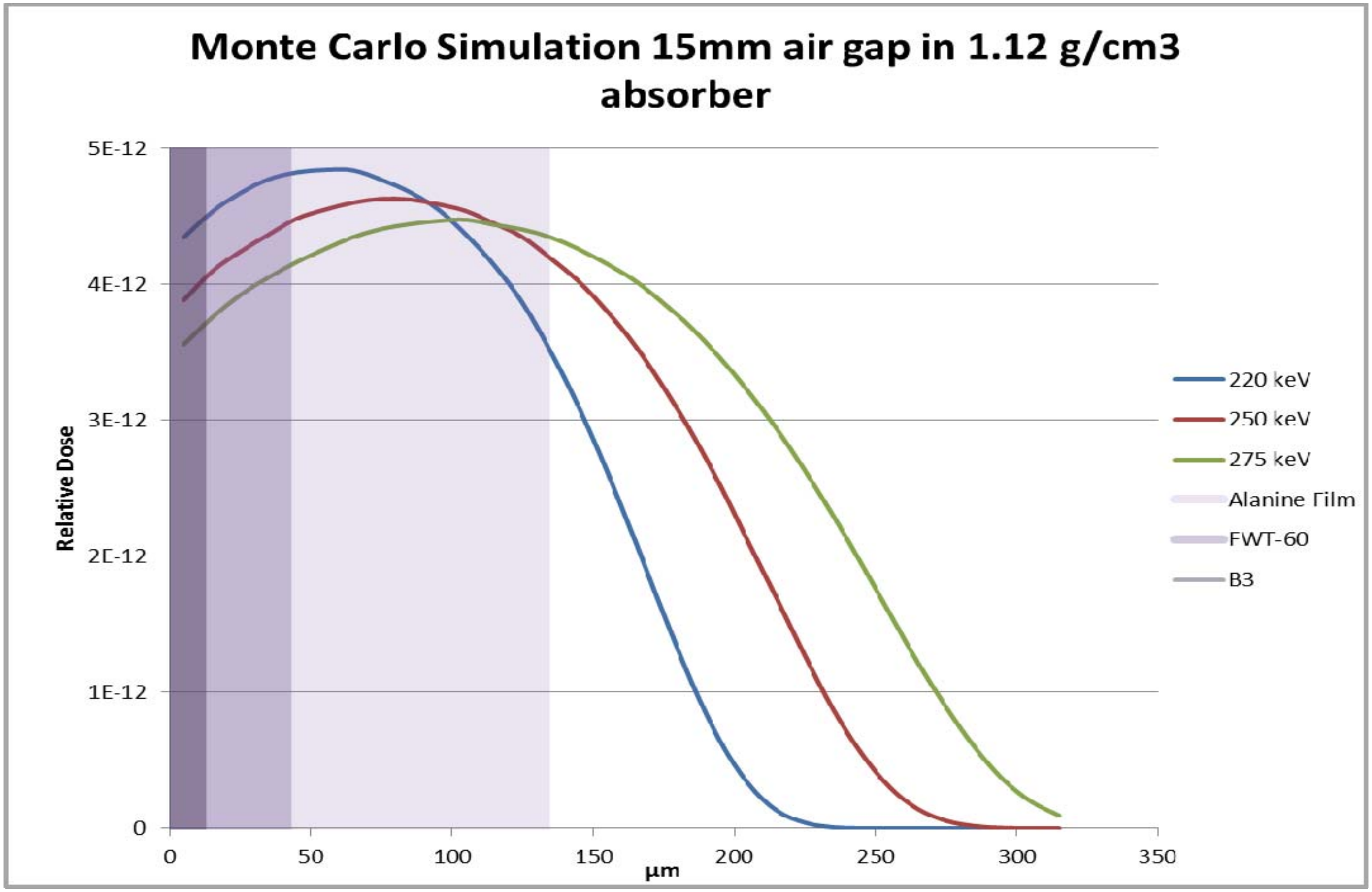
Dosimetry

The thinner the dosimeter the smaller the dose gradient

Significant when determining the absorbed dose measurement with dosimetry, i.e. average dose vs. apparent dose

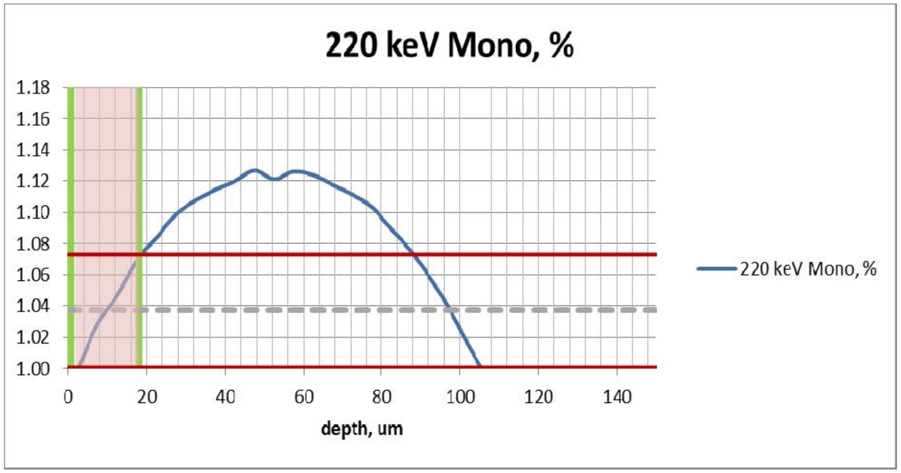
Large dose gradients over the thickness of the dosimeter would cause differences between average dose and apparent dose

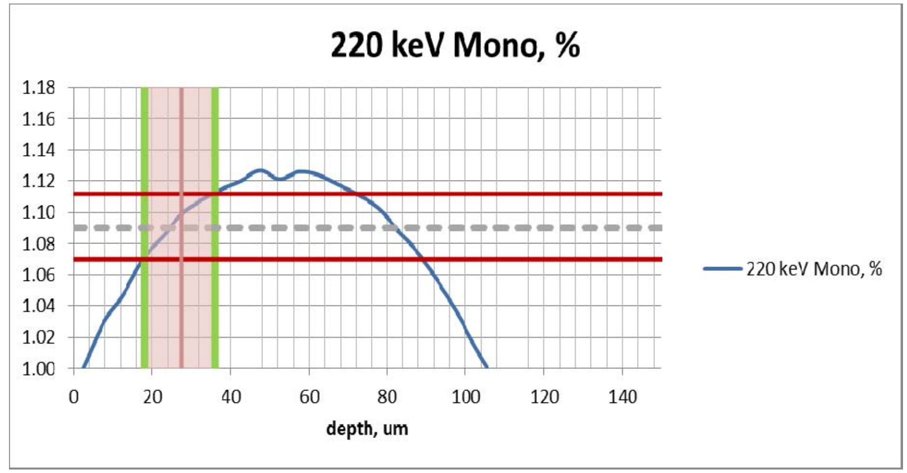
Dose Depth Profiles

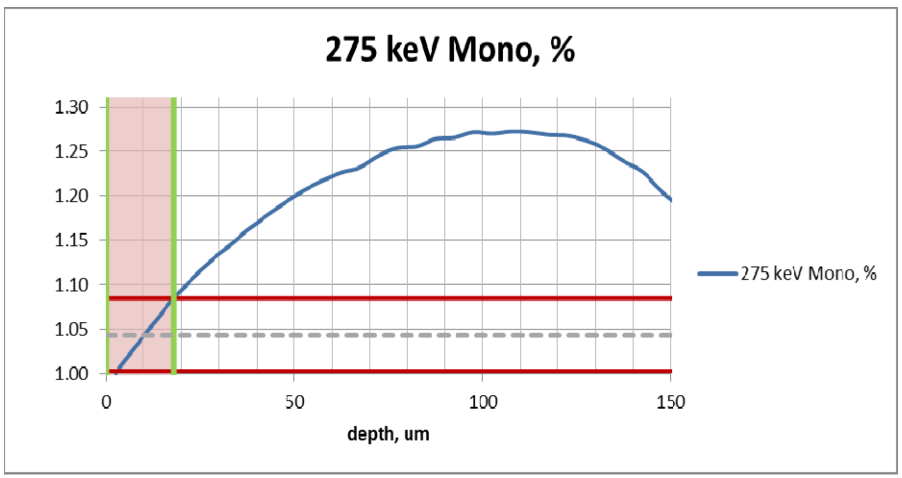


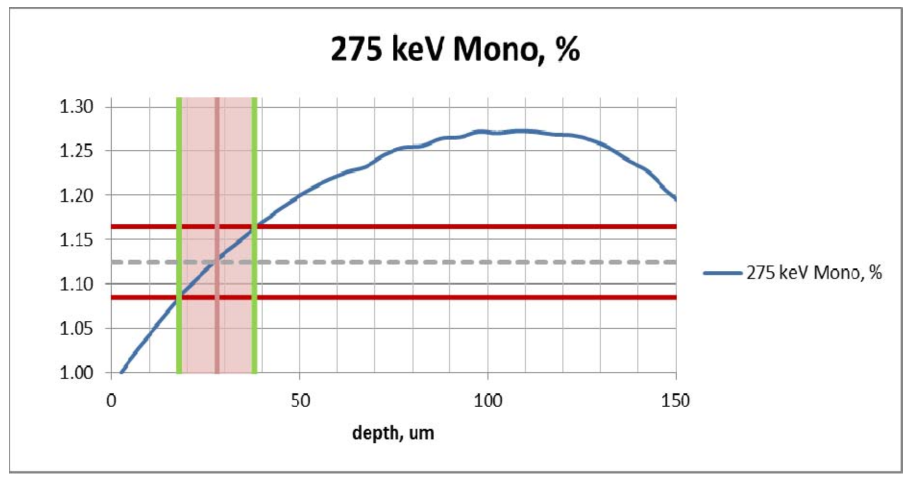
Dosimetry

Dose gradients over 18 um increments were evaluated using dose depth profiles







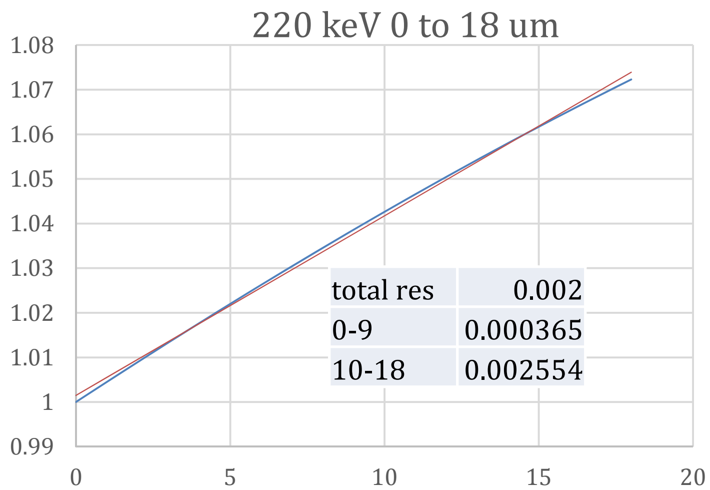


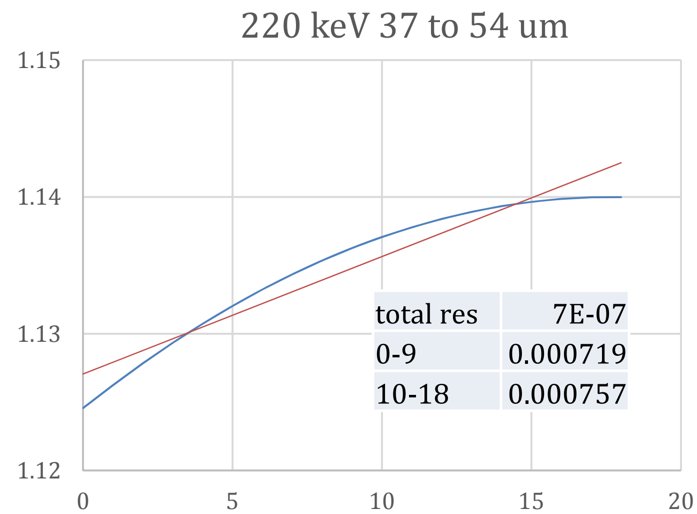
A low energy provided the most significant challenge with respect to dose gradients

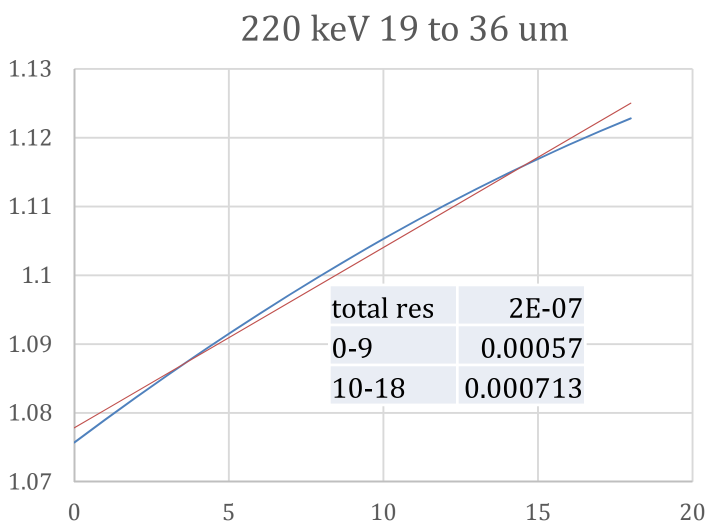
Dosimetry

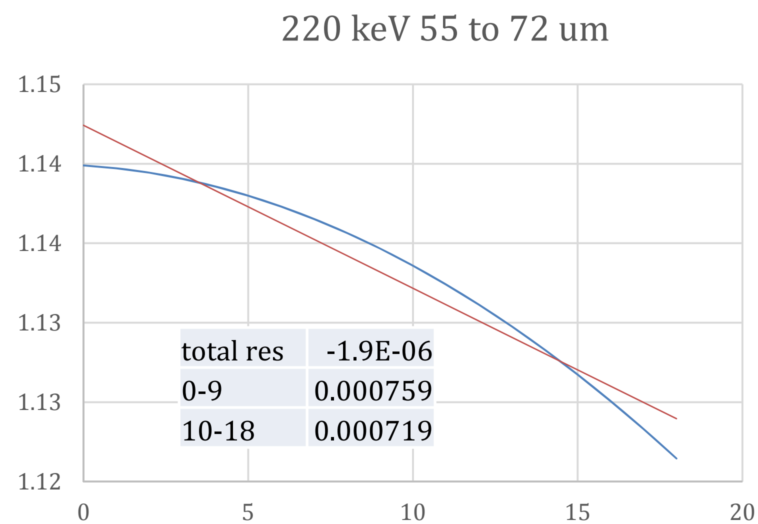
The 220 keV dose depth profile data was used to estimate the residuals of the actual dose depth profile and the estimate assuming constant gradient slope through the 18 um thickness of the B3 dosimeter

Dosimetry

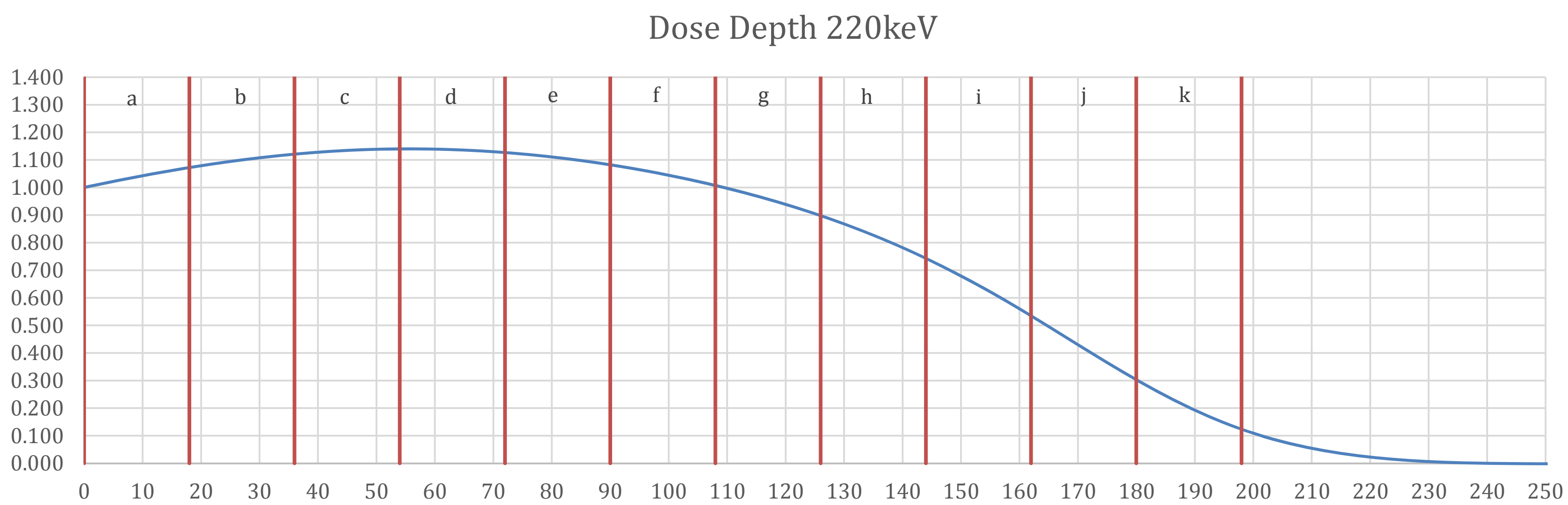

220 keV 0 to 18 um
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1
0.99
0
5
10
15
20
total res 0.002
0-9 0.000365
10-18 0.002554


220 keV 37 to 54 um
1.15
1.14
1.13
1.12
0
5
10
15
20
total res 7E-07
0-9 0.000719
10-18 0.000757


220 keV 19 to 36 um
1.13
1.12
1.11
1.1
1.09
1.08
1.07
0
5
10
15
20
total res 2E-07
0-9 0.00057
10-18 0.000713


220 keV 55 to 72 um
1.15
1.14
1.14
1.13
1.13
1.12
0
5
10
15
20
total res -1.9E-06
0-9 0.000759
10-18 0.000719

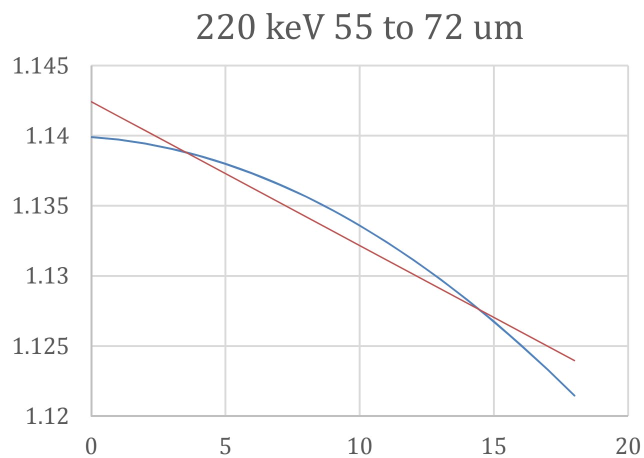
Dosimetry



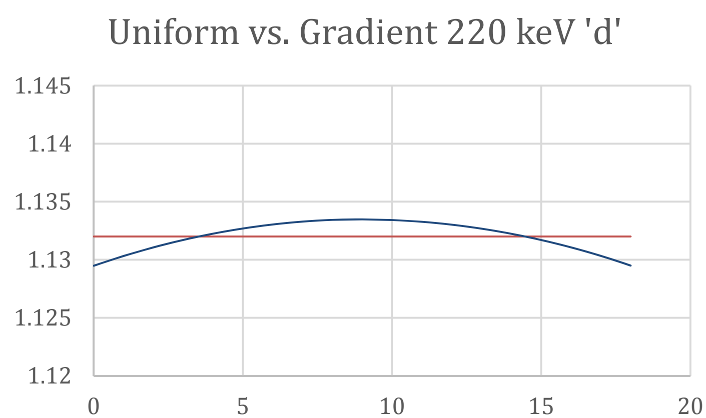
segment	sum res.	1-9	10-18
a	2.000E-03	0.000365	0.002554
b	2.000E-07	0.000570	0.000713
c	7.000E-07	0.000719	0.000757
d	-1.900E-06	0.000759	0.000719
e	5.000E-07	0.000720	-0.000719
f	8.000E-07	0.000681	-0.000680
g	0.000E+00	0.000833	-0.000833
h	1.600E-06	0.001256	-0.001255
i	-1.000E-07	0.001388	-0.001388
j	7.000E-07	-0.000375	0.000375
k	2.000E-07	-0.002309	0.002309

Dosimetry

No significant difference: apparent dose vs. average dose



total res	-1.9E-06



$$\frac{-0.000002}{1.132} = 0.00017\%$$

Dosimetry

Calibration irradiation of the B3 can be done either with low energy or high energy (in-situ)

If low, Alanine film would need to be corrected (apparent dose ≠ average dose)

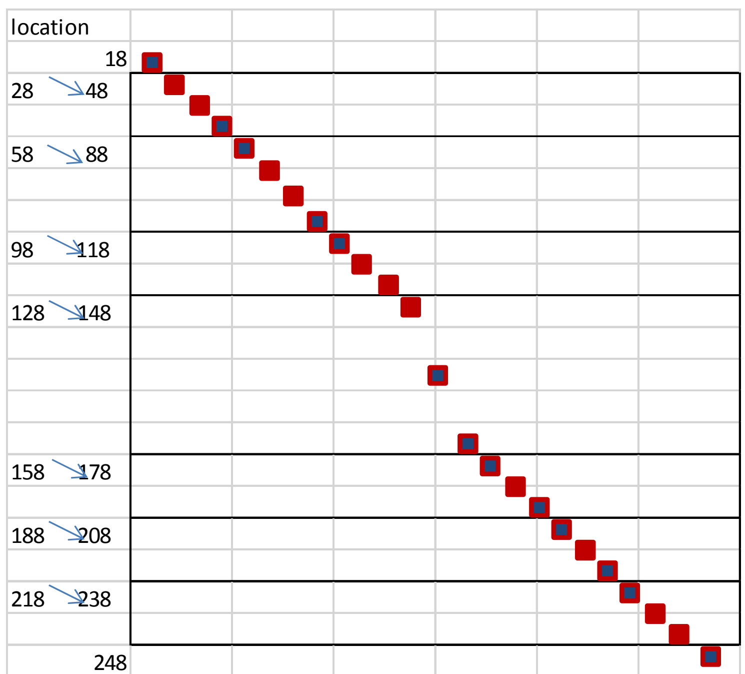
If high, Alanine film apparent dose = average dose

B3 in either low or high, apparent dose = average dose

Dose Mapping Simulations

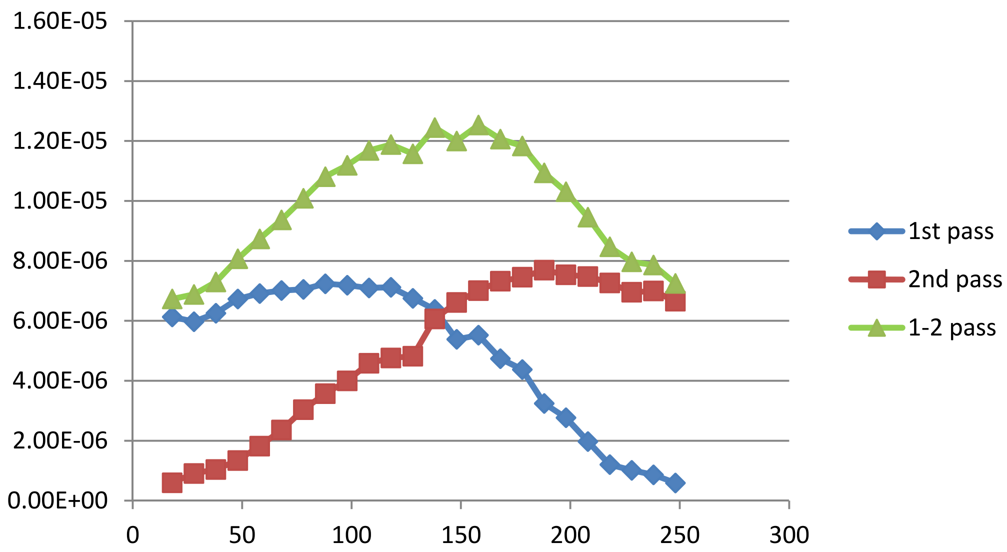
Dose mapping simulations using Monte Carlo

Simulate 2-sided irradiation with sum of 2 single-sided models



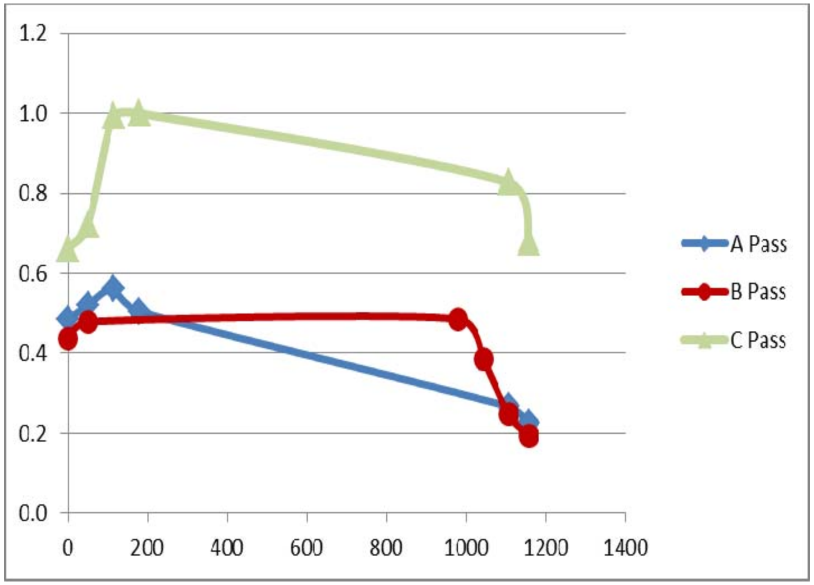
Dose Mapping Simulations

Dose mapping simulations using Monte Carlo

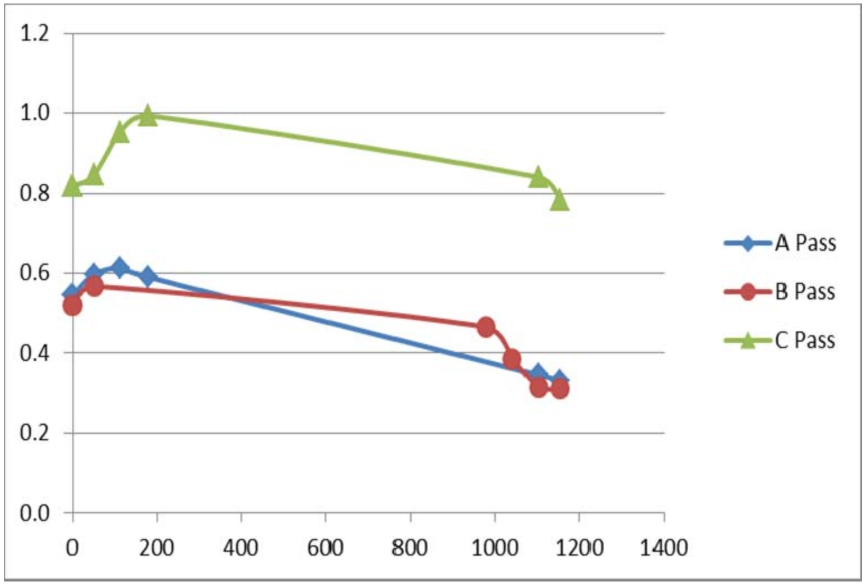


Dose Mapping Simulations

Dose Map vs. Monte Carlo 240 keV



Model Prediction



Dose Map Data

Low Energy Electron Beam

Conclusions:

a. Low energy electron beam was viable for thin product processing
b. At energies of 220 keV the difference of average dose and apparent dose are negligible in an 18 um thick dosimeter that is optically assayed
c. Execution of dose mapping proves a challenge as physical placement of a dosimeter influences the absorbed dose measurement