Monte Carlo estimation of dose difference in lung from Ir-192 Brachytherapy due to tissue inhomogeneity

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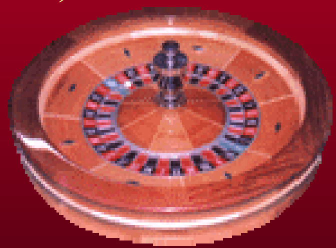
Purpose

•Lung Brachytherapy with Iridium 192 radionuclide (Ir-192) is a well established technique of radiation therapy for palliative intent in inoperable patients and as a currative intent in early stage lung cancers [1].

•However the majority of treatment planning treatments which are performing brachytherapy technique of level II and III do not have the ability to consider the inhomogeneity of lung in relation to normal tissue.

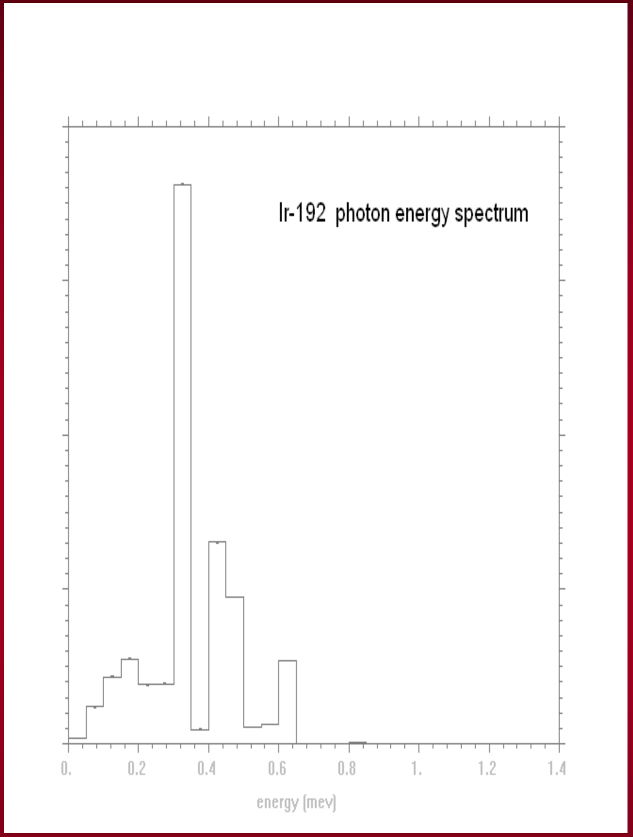
•Purpose of study was to estimate the dose difference due to the tissue inhomogeneity (density $\rho=0.296 gr/cm^3$) relative to water ($\rho=1 gr/cm^3$) with the Monte Carlo simulation method by MCNP.



[1] J.M. Vegnon et al. Place of cryotherapy, brachytherapy and photodynamic therapy in therapeytic bronchoscopy of lung cancers. Eur. Respir. J. 28: 200-218, 2006 .

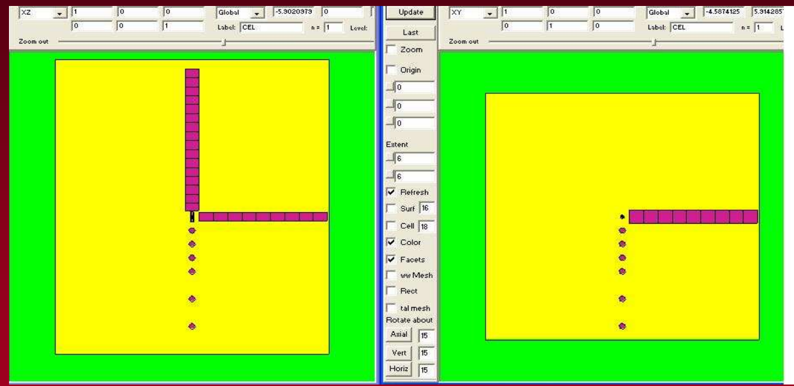
Material and Methods

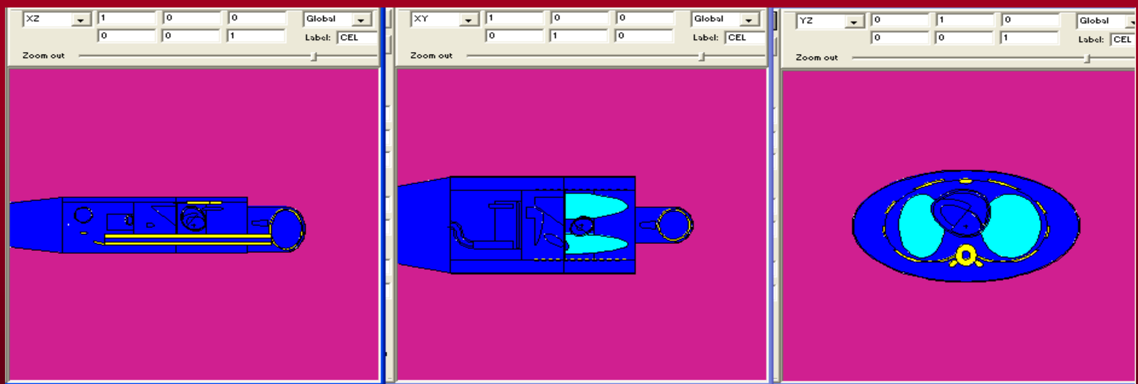
- ●Monte Carlo N-Particle code (MCNP-5) [2] was used in order to simulate the interaction of photons with matter and estimate the energy deposition, by using F6 (KERMA estimator) and F8 (dose estimator) tallies.
- ●Visual Editor (VisEd) was used for the visualization of the study.
- ●Appropriate energy spectrum of Ir-192 was used according to http://members.aol.com/rprice1495/data/Ir192.pdf.

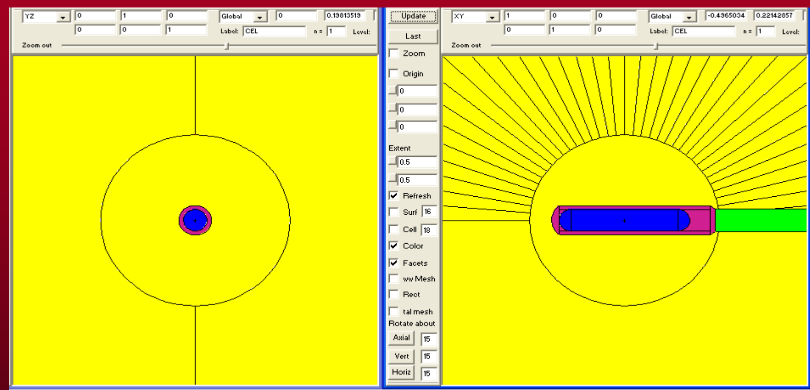


[2] X-5 Monte Carlo Team. MCNP – a general Monte Carlo N-particle Transport Code, v.5. rev. 10/3/2005.

- Two studies were performed, the first study was on cubic voxel phantom and the second study was on a adult ORNL (MIT) [3] mathematical phantom.
- Additional test was performed with the geometry of the cylindrical source Ir-192 of EURADOS's problem #1 [3].



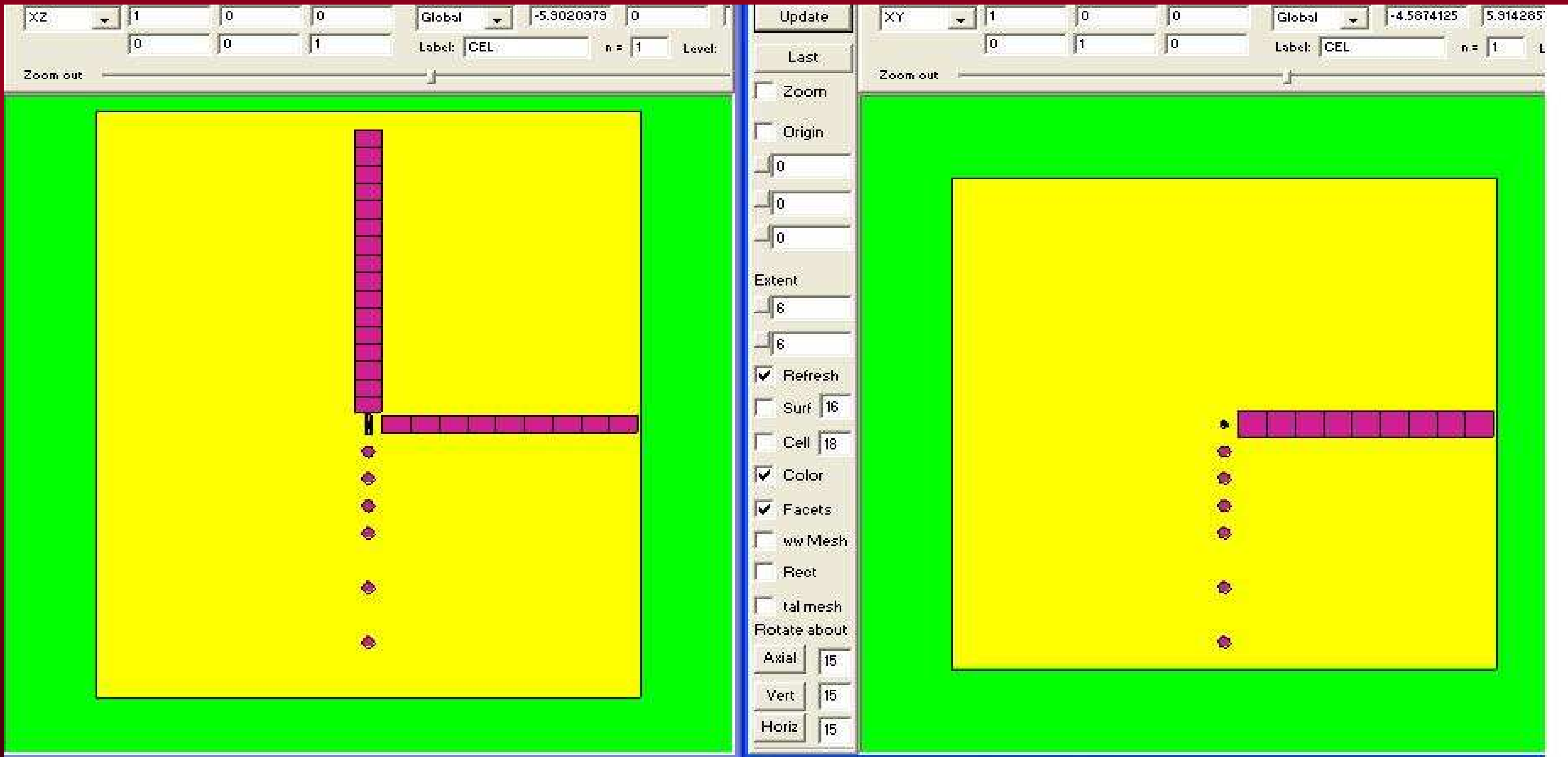




[3] Medical Physics Geometry Database LA-UR-08-2113B.

In the first study, voxel geometry, two simulations were run. In the first simulation the material around the source had chemical composition and density of water (ρ=1gr/cm^3).

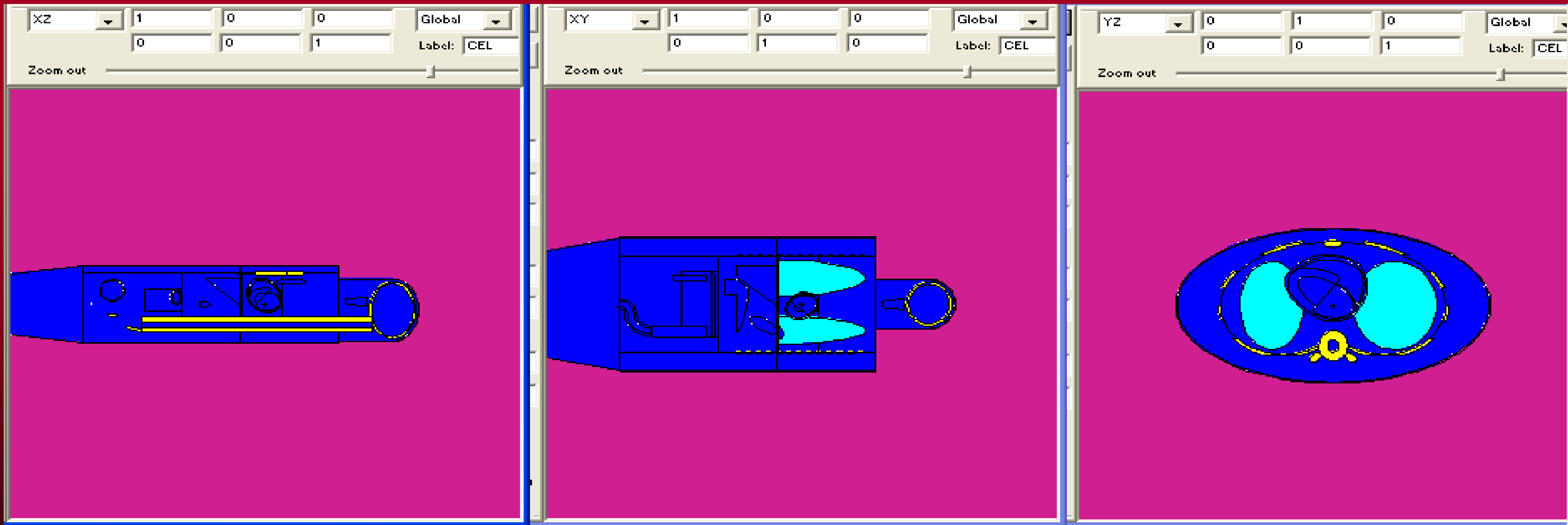
On the other simulation the material was similar to lung tissue (ρ=0.296gr/cm^3).



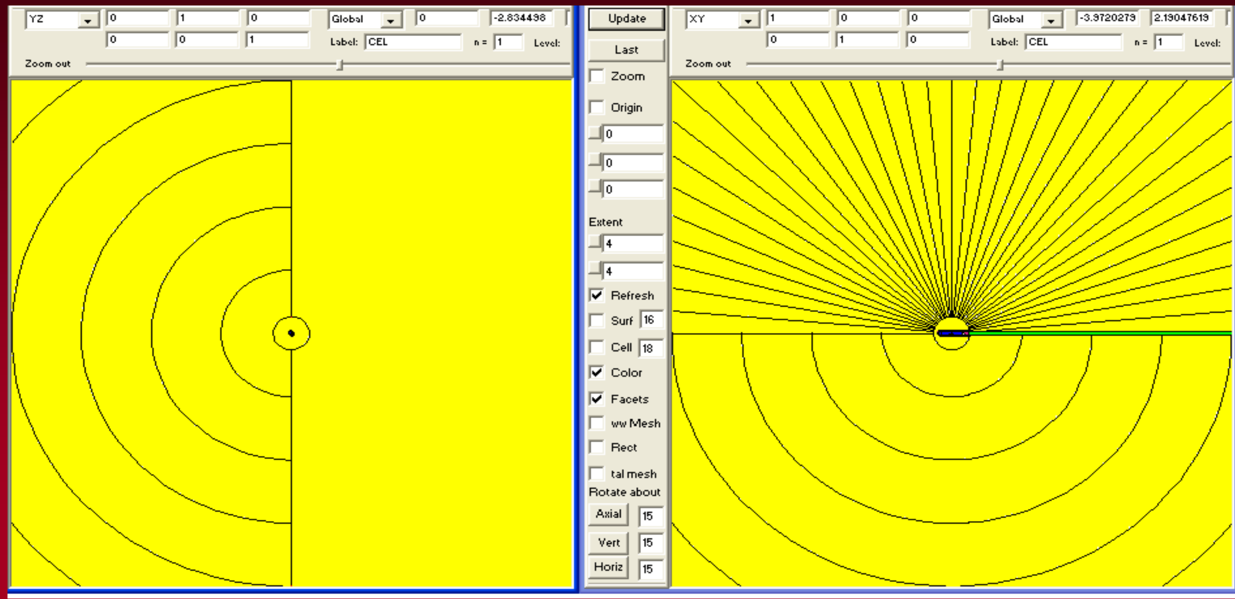
In the second study, phantom geometry, two simulations were run and the source of Ir-192 was placed in the centre of right lung.

In the first simulation all organs of the body, even body structures, had chemical composition and density of water.

On the second simulation, each organ's default chemical composition and density was used in the phantom.



Similar different simulations were run with the geometry of EURADOS's problem-1. The surrounding space or the source was filled by water (ρ=1gr/cm^3) or lung tissue (ρ=0.296gr/cm^3) respectively.



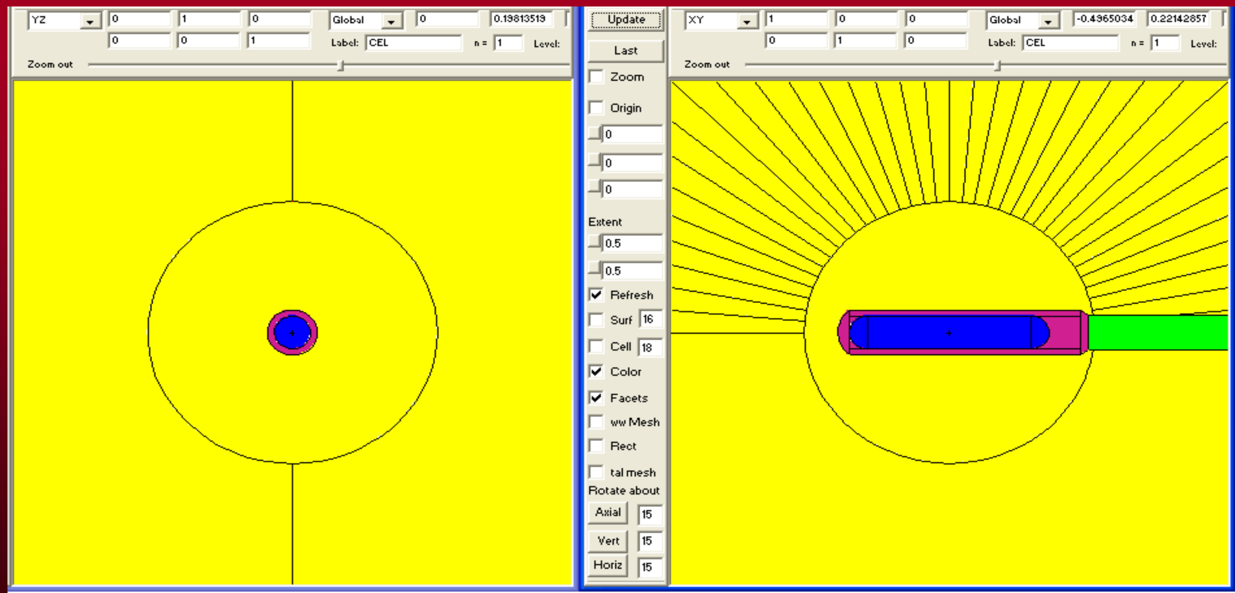


Image of the Ir-192 source magnified × 8

Results

- Results derived from F6 and F8 tallies showed that there was a sub dosage in neighborhood tissues due the inhomogeneity ignorance.
- The first study revealed that presence of lung instead of normal tissue was increasing monotonically the dose from the source to a distance which approached 8% at 4cm, in accordance with Das et al 2006 [4].

Distance in cm	Difference % Dose at ρ=1 to Dose at ρ=0,296 gr/cm^3
0.5	-5.9%
1.5	-6.4%
3.5	-7.2%
4.5	-8.0%

[4] I. Das et al. SU-FF-T-286: Inhomogeneity correction in Brachytherapy. Med. Phys. Vol. 33, 6, 2006.

●Second study, at the mathematical phantom, showed that the increase was relative low 2.1% for the lung, while was larger, for organ at risk as heart 6.8% and bone marrow 7.6%, and in any case the estimated dose was larger by taking account of the inhomogeneity.

●Organs' doses for the nearby organs are reported relative to lung's dose.

organ	Difference % Dose at ρ=1 to Dose at ρ=0,296 gr/cm^3	Relative organ dose to lung in MIRD phantom
Lung (both parts)	2.1%	100%
Heart	6.8%	5%
Stomach	17.1%	6%
Bone marrow	7.6%	9%
Thymus	5.2%	55%

Conclusions

- Without taking into account tissue inhomogeneity, dose calculations for near to target tissues and organ at risk were inaccurate.

- However it should be considered that due to the photon spectrum of Ir-192, the majority of dose absorption occurred mainly in the very first centimeters, so dose inaccuracy at greater distances (in other organs) has small clinical importance, as has been reported by other investigators [5].

- Additional, in the clinical practice, the gross tumor in the lung has density between 0.296 and 1 gr/cm^3 so dosimetric differences are even smaller.

[5] G. Anagnostopoylos et al. The effect of patient inhomogeneity in esophageal Ir-192 brachytherapy: a Monte Carlo and analytical dosimetry study. Phys. Med. Biol. 49, 2004.