TECHNISCHE UNIVERSITÄT WIEN
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MEDIZINISCHE UNIVERSITÄT WIEN

Diplomarbeit

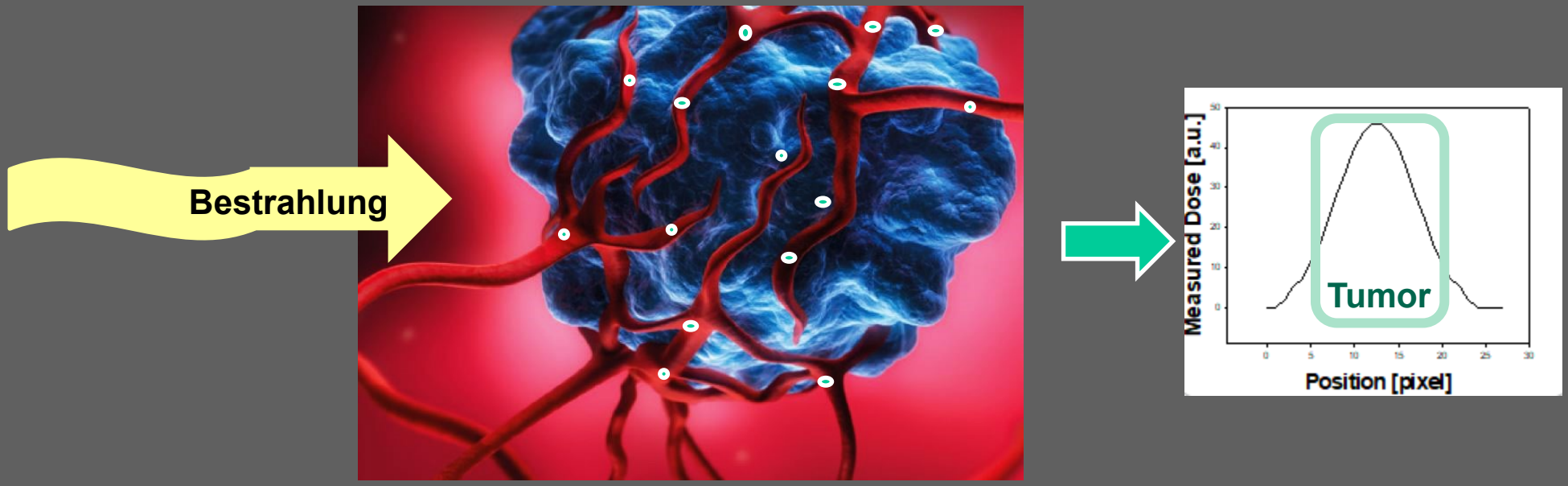
Magnetic resonance based polymergel dosimetry: The impact of add-ons to standard gel dosimeters for increasing local dose in radiation therapy

Katharina Buchner

1 Ziel

- Begrenzung der maximalen Dosis auf die pathologischen Bereiche
- Gleichzeitige Schonung des umliegenden Gewebes

- Injizierung von Zusätzen mit Atomen hoher Ordnungszahl



https://www.krebshilfe.de/blog/wp-content/uploads/190521_Tumore-hemmen3.jpg 07.12.2020

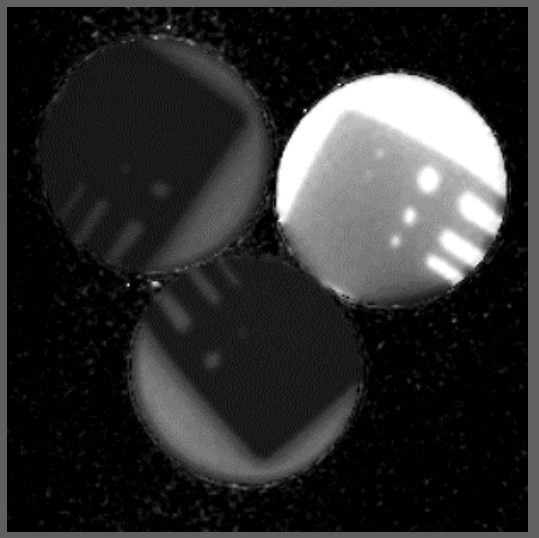
2 Methoden

Unbestrahlte Polymer-Gele

Bestrahlte Polymer-Gele

Durch Bestrahlung injizierter Polarisationsprozess

Auswertung mithilfe des 7T MRT



Erhöhung der transversalen Relaxationsrate R2

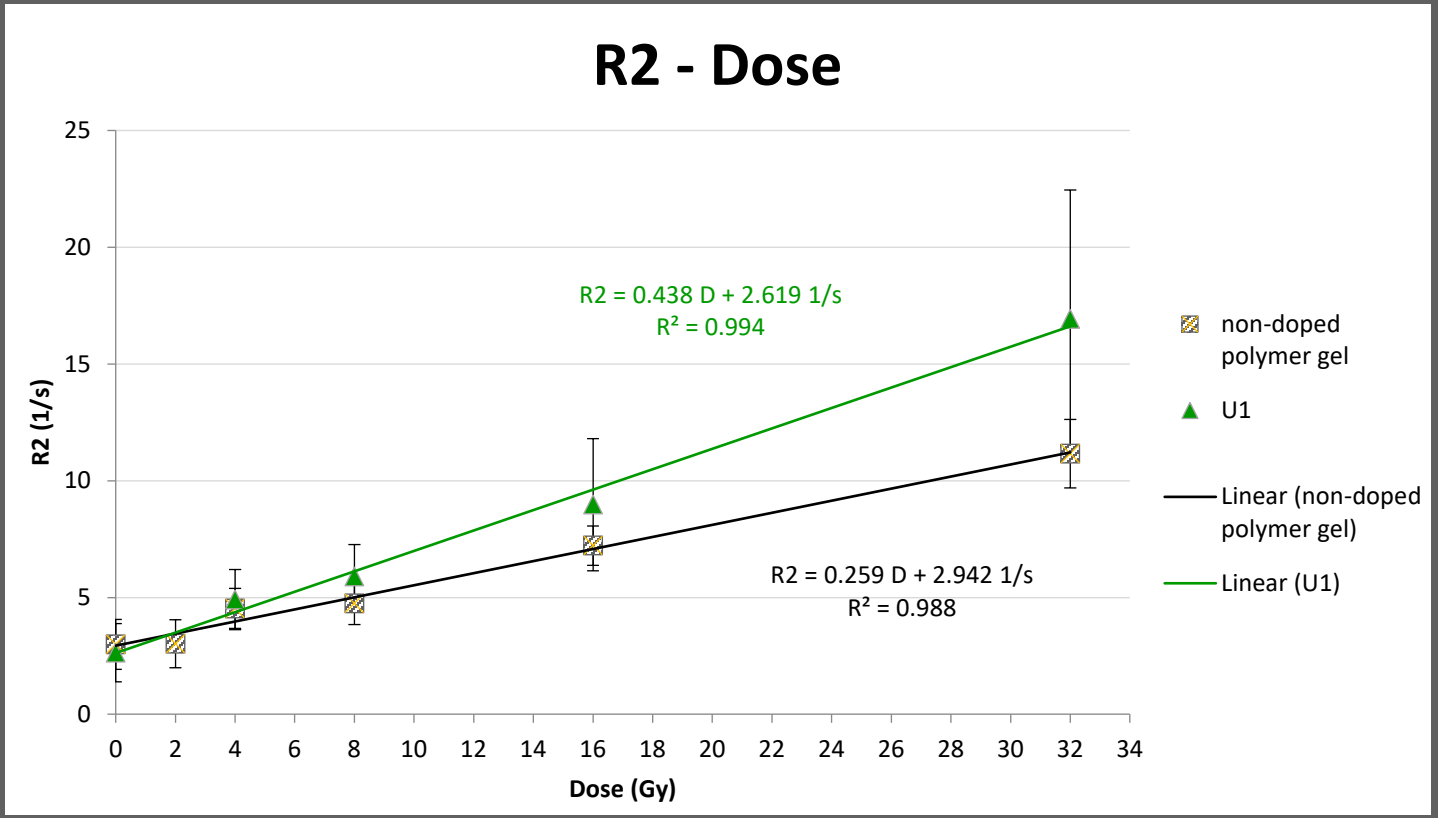
Messungen am Hochfeld-MR-Center/MedUniWien/AKH

Vorteile:

- 3D-Dosimeter mit hoher räumlicher Auflösung
- Gewebeäquivalenz

3 Ergebnisse: ULTRAVIST (I) - Iopromide

Zusatz: Iod



Konzentration w_{Z_lopr}/w_{doped_Gel} = 0.006 → dose increase of 70 % (rDE ~1.7)

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2 Methods: MRI - Based Polymer Gel Dosimetry

„In-house“ manufacturing of polymer gel dosimeter in simply equipped laboratory at the Medical University of Viennna: fume hood; no clean room technology

1. Preparation

2. Mixing

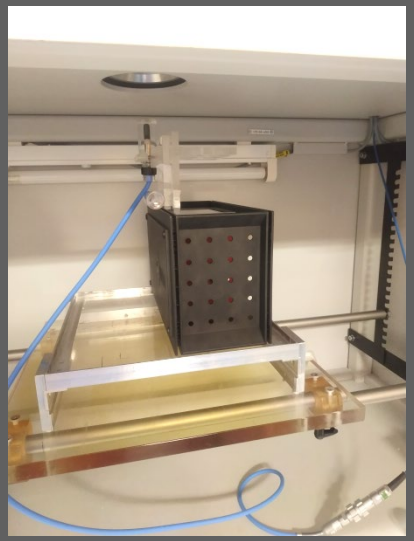
3. Temperature control after foam

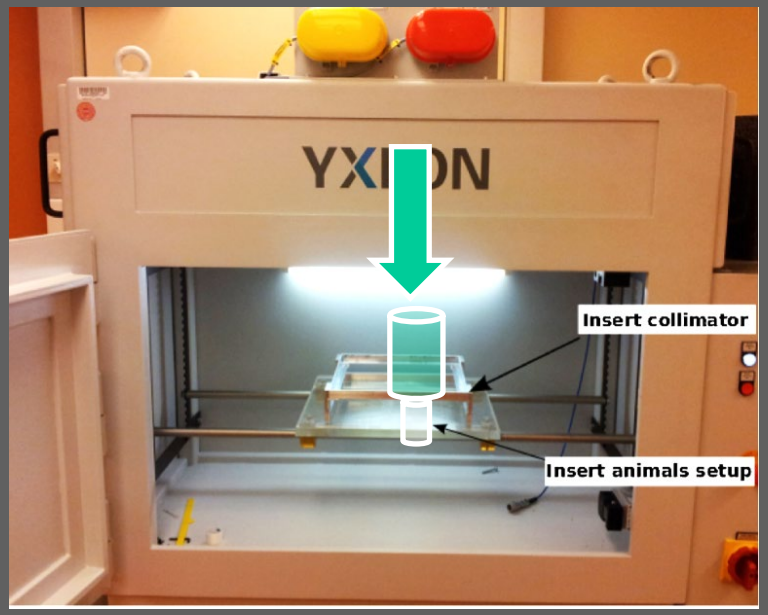
4. Irradiated polymer gels at different dose levels

2 Methods: Irradiation with YXLON

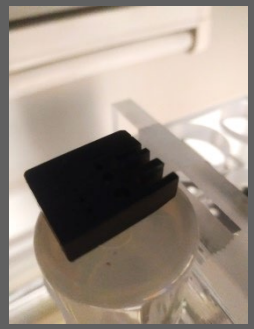
YXLON Maxishot:

- Commercially available oil cooled X-ray unit
- Target material is tungsten
- Accelerating voltage 10 kV – 320 kV, max voltage: 200 kV
- Max current: 21 mA
- Focus: 5.5-3.0 mm
- External control unit



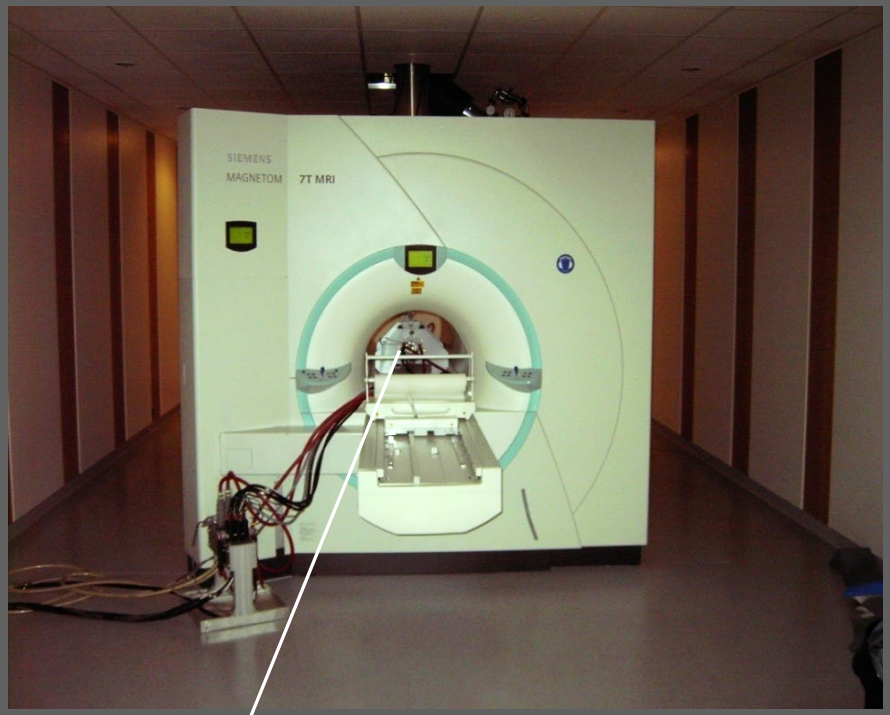


Source: Peter Kuess: Dosimetric challenges of small animal irradiation with a commercial X-ray unit



2 Methods: Magnetic Resonance Scanning

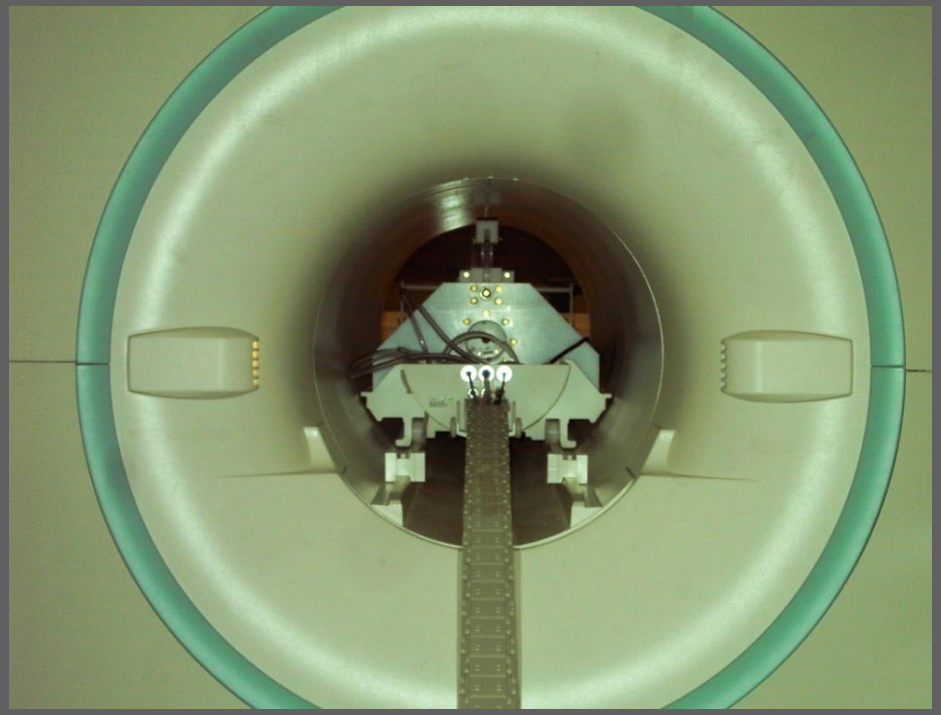
Berg et al: ISMRM 2010



Gradient system inserted in 7T human scanner:

- power cables
- sensors
- water cooling tubes

are supplied via intermediate supporting stand

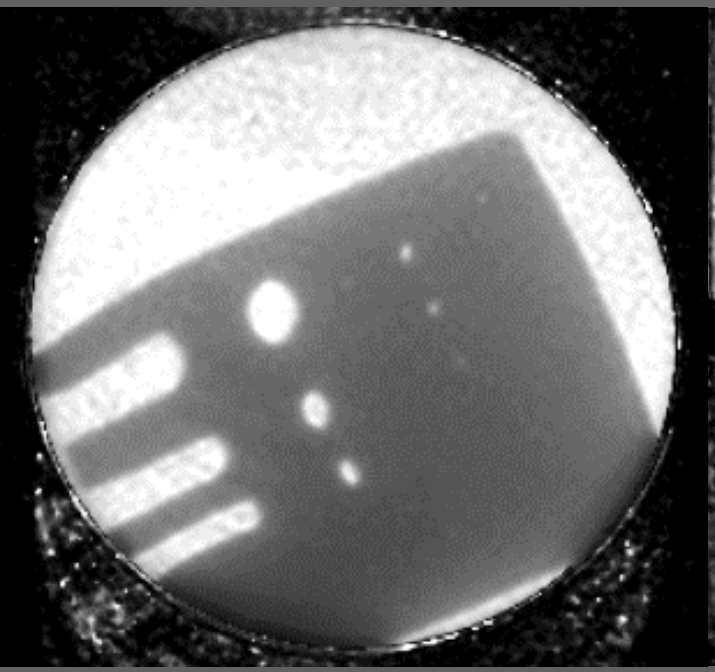


Prototype within research cooperation (not commerciallly available)

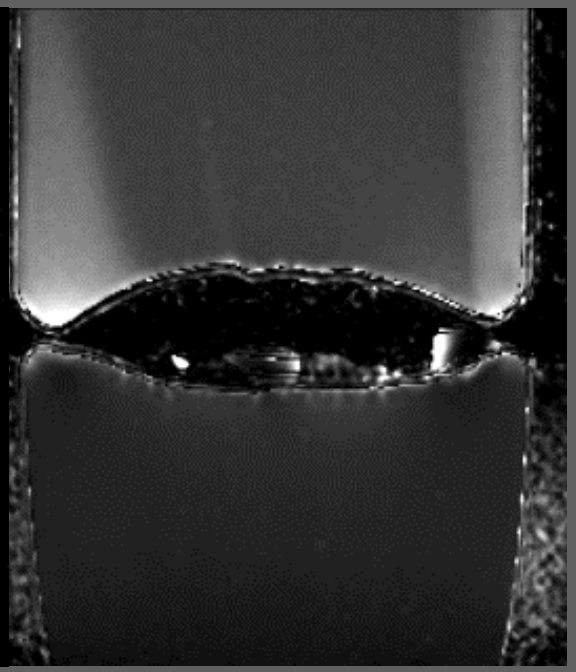
Gradient system inserted in 7T scanner (Back view)

2 Methods: R2 (=1/T2) Images

Micro Imaging-System

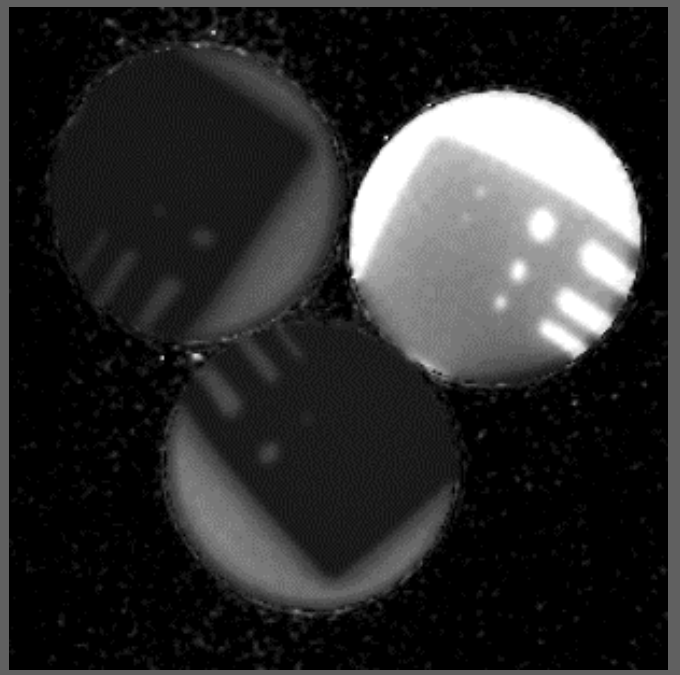


coronal



sagittal

Whole Body-System



2 Methods: The New Add-Ons

Iopromide

$C_{18}H_{24}I_3N_3O_8$

I: Z = 53
N: Z = 7

Contrast agent – Ultravist™ 300

Silver Iodide

AgI

I: Z = 53
Ag: Z = 47

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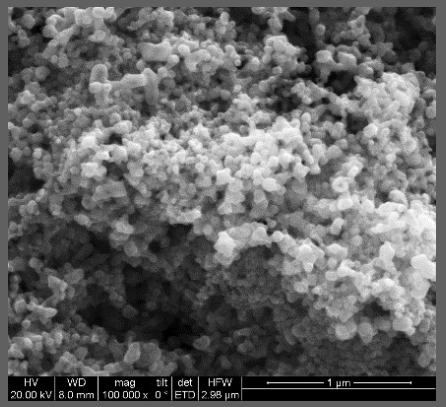
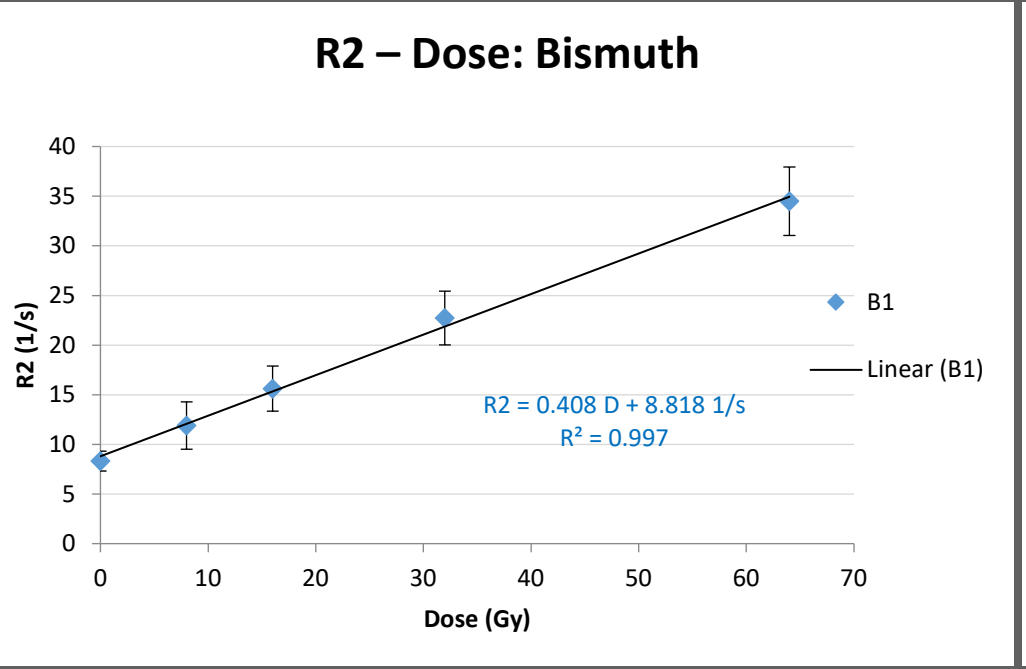
Bismuth

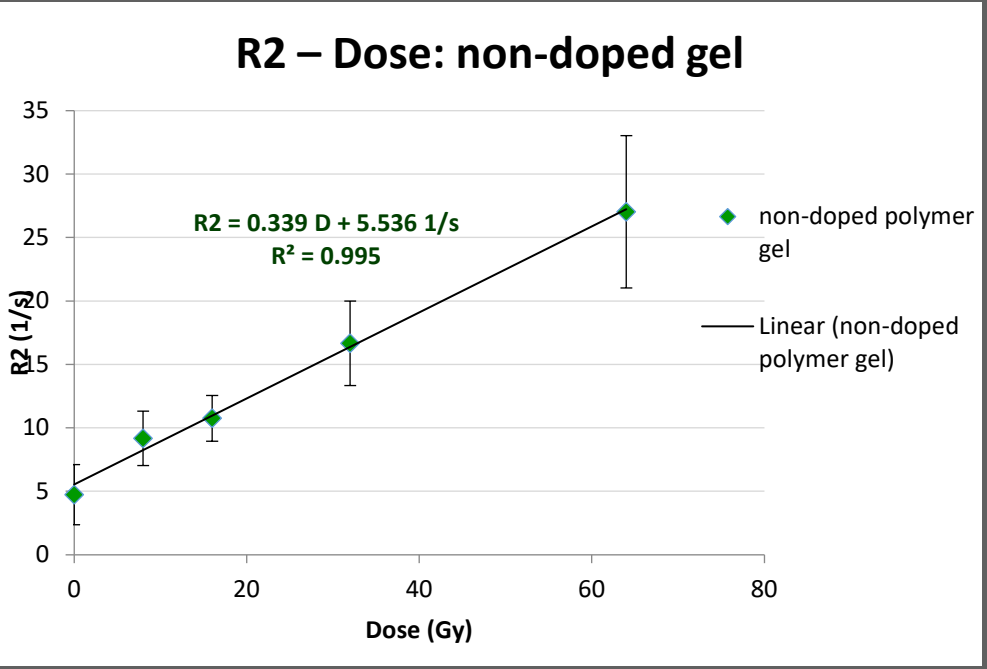
Bi: Z = 83



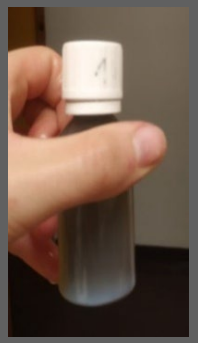
https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.ssnano.com%2Finc%2Fsdetail%2Fbismuth_nanopowder__nanoparticles__bi__99_9___100nm_%2F5120&psig=AOvVaw0dkDjm97sXLawowCWZDUZz&ust=1600849569920008&source=images&cd=vfe&ved=0CAIQjRxqFwoTCNiiucTr9sCFQAAAAAdAAAAABAE 16.11.2020

3 Results: Bismuth (Bi)

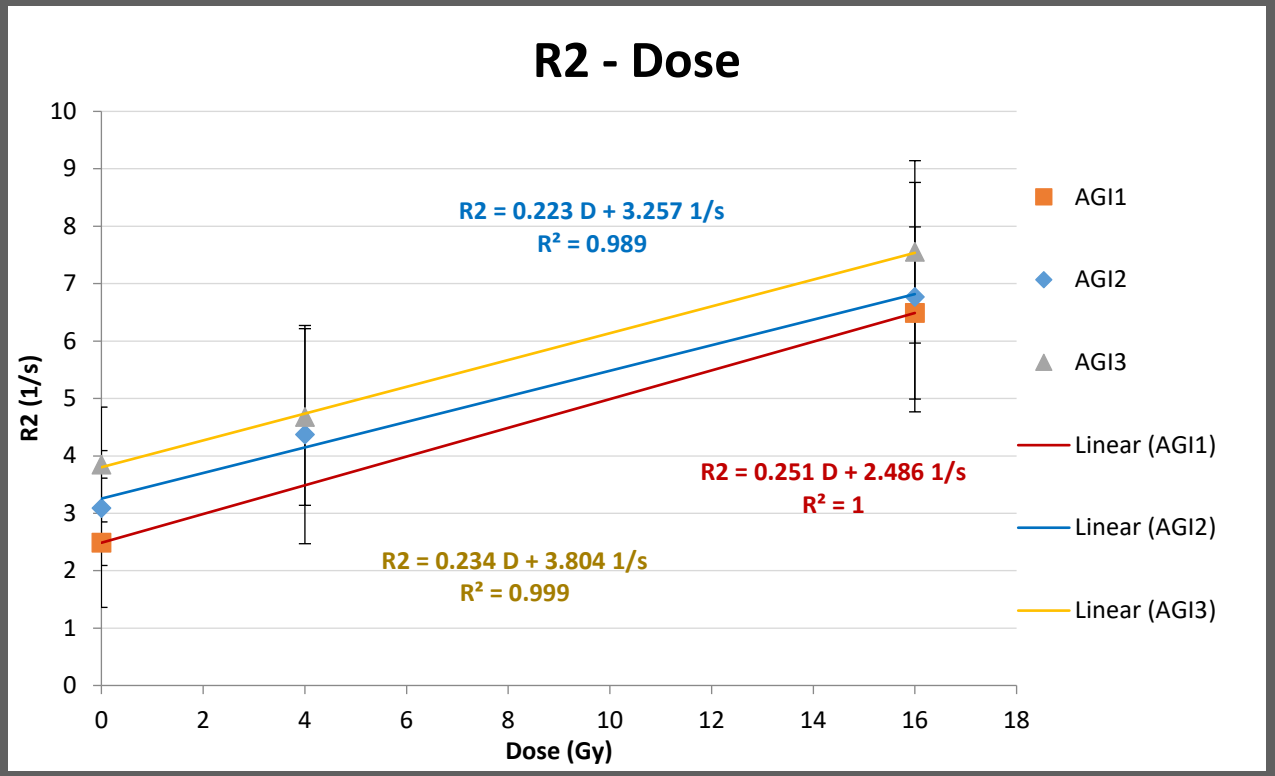


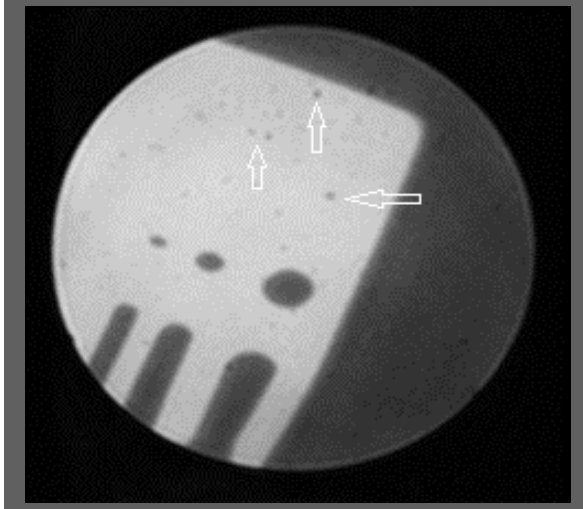


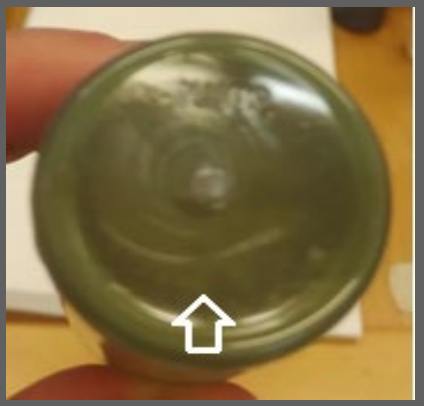
- Concentration w_{Z_Bi}/w_{doped_Gel} = 0.003 → dose increase of 20 % (rDE ~1.2)
- Higher concentration are problematic → agglomeration, segregation



3 Results: Silver iodide (AgI)







- no dose enhancement
- hypotheses for interpretation: agglomeration
- local dose increase around grains, not homogeneous

4 Conclusion and Future Projects

- local dose-enhancement by elements with high-Z
- Dose enhancements estimated based on mass energy absorption coefficients
- Firstly proposed in this master thesis: Ultravist 300, AgI, Bi

- Results:
  - Ultravist 300 with $w_{Z\_Iopr}/w_{doped\_Gel} = 0.006$ → rDE 1.7
  - Bismuth with $w_{Z\_Bi}/w_{doped\_Gel} = 0.003$ → rDE 1.2
  - AgI → rDE effect cannot be proven (agglomeration?)

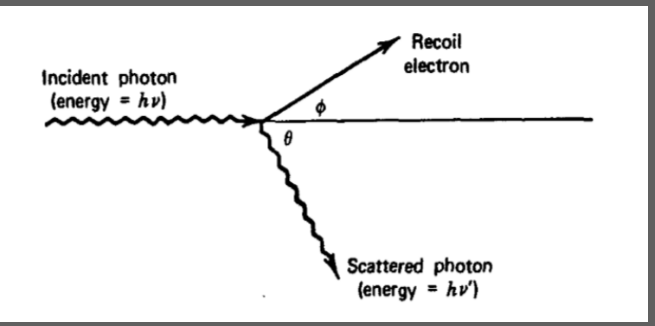
- Future:
  - Different concentrations, gel -preparations and energies for the add-ons

1 Introduction: Aspects of optimization of HIGH-Z-Therapy

- Optimum high Z material for relative Dose Enhancement (rDE)
- Hazard impact of high Z add-ons during preparation for manufacturing staff
- Problem of chemical interaction between high Z material and polymer gel
- Possible impact of in-accurate T2-mapping for quantification of dose
- Costs

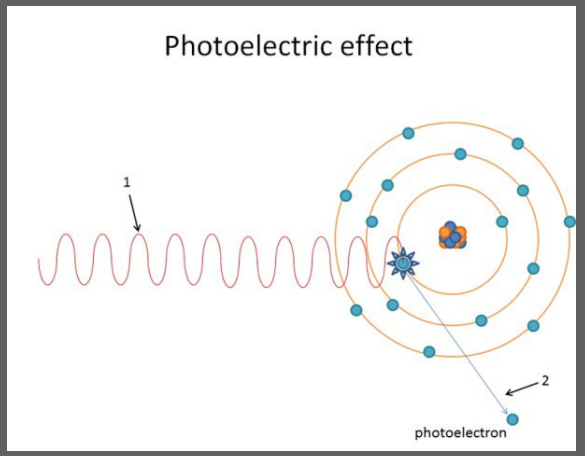
1 Introduction: Why High Z?

Compton Scattering:



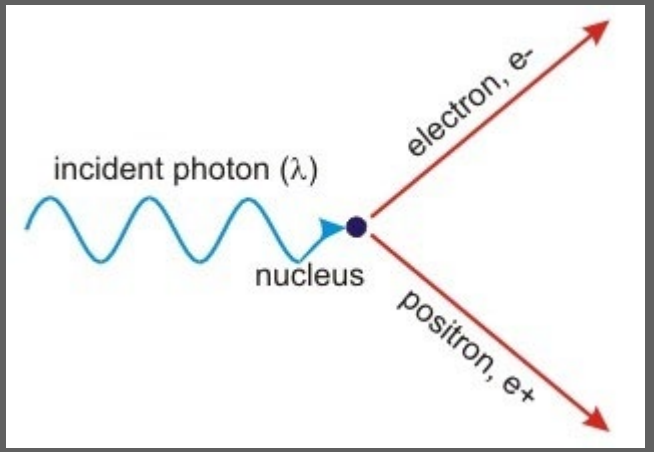
Compton Scattering (Knoll,2000)

Photoelectric effect:



https://oralradiology.files.wordpress.com/2012/10/photoelectric-effect-1.jpg 18.11.2020

Pair production:



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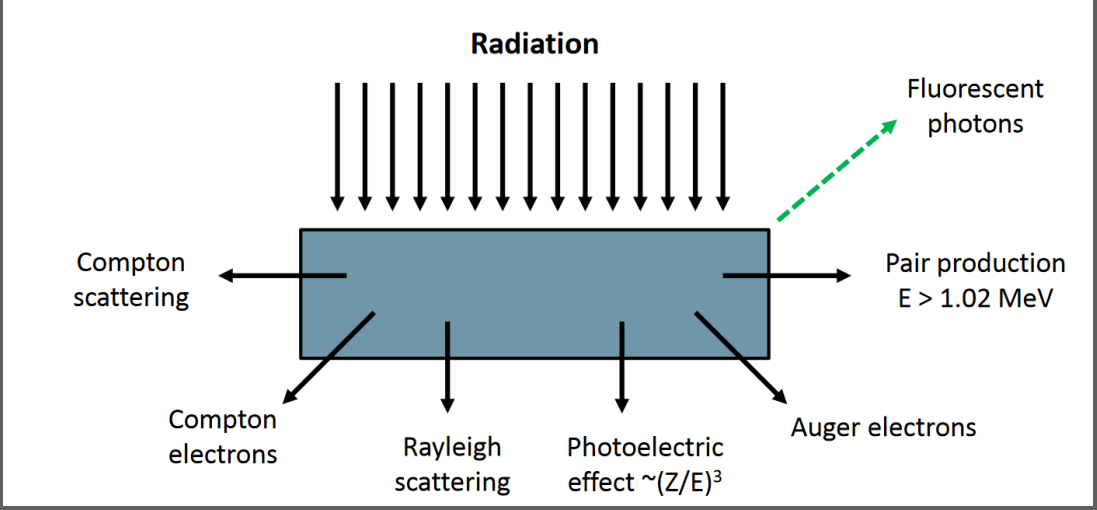
1 Introduction: Why High Z?

- For low photon-energies: Compton and photoelectric effect dominant
- Photoelectric interactions increase with concentration of doping agent high Z (in tumor)
- Resulting Auger electrons and photo-electrons produce a localised relative Dose Enhancement (rDE).



https://www.inc.uam.es/wp-content/uploads/radiation_effects.pdf 18.11.2020

2. Methods: MRI-based Polymer gel dosimetry (MRPD) principle

Composition for 1000 g polymer gel	MAGADIT-type Gel
Distilled water	≅ 82%(w/w)
Gelatin	12% (w/w)
Methacrylic acid	6-8% (w/w)
Dithiothreitol	2 mmol/kg
New add-ons with different concentrations	high Z material

Source: Khan et al: Polymers_2019

2. Methods: Theory of dose enhancement:

What enhancement ratio DER (rDE) for dose are expected?

$$DER = \frac{\left(\frac{\mu_{en}}{\rho}\right)_E^{Z\ doped\ gel}}{\left(\frac{\mu_{en}}{\rho}\right)_E^{Z\ gel}} = \frac{w_Z \left(\frac{\mu_{en}}{\rho}\right)_E^{Z} + (1 - w_Z)\left(\frac{\mu_{en}}{\rho}\right)_E^{gel}}{\left(\frac{\mu_{en}}{\rho}\right)_E^{gel}}$$

- Dose enhancement ratio **DER** = relative Dose Enhancement **rDE**
- is calculated from the variation of the increase of the mass energy-absorption coefficient of the target to the high Z atom

with $(\mu_{en}/\rho)_E$ the mass energy absorption coefficent irradiated with energy *E* and w_z the fraction by weight of the compound *Z* in the gel

Source: Corde et al: Radiation Protection Dosimetry 2005