

IV Geant4 International User Conference at the physics-medicine-biology frontier

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ESTIMATION OF ENERGY IMPARTED

FROM IONIZATION-BASED MEASUREMENTS AT THE NANOMETRE SCALE





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MICRODOSIMETRY AT THE NANOMETRE LEVEL



Simulated volume: from 500 nm down to 25 nm



For small SV sizes (< 100 nm) proportionality between energy imparted and ionization yield may be lost! (Amols et al., 1990)

 $\varepsilon = \mathbf{X} \cdot \mathbf{v}$

Can we use a different conversion factor to calibrate these data to lineal energy?

THE SIMULATION SETUP

Geometry

- Liquid-water spheres immersed in water
- Sphere diameter I, 10, 100 nm

Physics

- Geant4-DNA EM processes
- Option 4, Option 2 physics lists
- No hadronic physics

Primary ions

- Protons and carbon ions
- Initial energy 1, 10, 100 MeV/u
- «Pencil-beam» and «extended-beam» geometry

Scoring

- Simultaneous scoring on energy imparted ε and ionization yield ν
- Calculation of mean values $\overline{\varepsilon}$ and $\overline{\nu}$

A NEW CONVERSION FACTOR: $\widetilde{\omega}$

$$\widetilde{\boldsymbol{\omega}} = \overline{\boldsymbol{\varepsilon}} / \overline{\boldsymbol{\nu}}$$

"Volumetric" analogue of the W-value

Analyse variations of $\widetilde{\omega}$ as a function of ion type, energy, SV size, beam geometry...



Ideally, the conversion factor should be independent of all these parameters

VARIATIONS OF $\widetilde{\omega}$ - PENCIL BEAM





- Independent on ion energy (< 1%)</p>
- Weakly dependent on ion type (± 5%)
- Dependent on SV size (~ 20%)

A. Selva et al., Radiat. Phys. Chem. 192, 109910 (2022)

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VARIATIONS OF $\widetilde{\omega}$ - EXTENDED BEAM



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VARIATIONS OF $\widetilde{\omega}$ - "OPTION 4" VS "OPTION 2"



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PROBABILITY DISTRIBUTIONS







P(v)

Probability density distribution of energy imparted

CONTINUOUS!

 $f(\varepsilon)$

for each $(\nu - 0.5)\widetilde{\omega} < \varepsilon < (\nu + 0.5)\widetilde{\omega}$ $\nu \in \mathbb{N}$

 $f^*(\varepsilon) = \frac{P(\nu)}{\widetilde{\omega}(D)}$

600

CONTINUOUS!

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Probability distribution of ionization yield

DISCRETE!

9

COMPARISON OF PROBABILITY DISTRIBUTIONS (I)



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Ionization-based measurements can still be interpreted in terms of energy imparted, also at the nanometre scale...



- **Accuracy within 10%**, due to particle-type dependence
- Dependence on site size within **20%**

CONCLUSIONS Ш 26/10/2022 IV GEANT4 INTERNATIONAL USER CONFERENCE



- Primary ion vs secondary electron contribution
- "Broad-beam" geometry: new relativistic electron models
- Alpha particles



Thanks to all members of Task 6.2 for the valuable input

THE ROAD GOES ON...







Laboratori Nazionali di Legnaro

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