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Variance-Based Sensitivity Analysis of Biological Uncertainties in Carbon Ion Therapy

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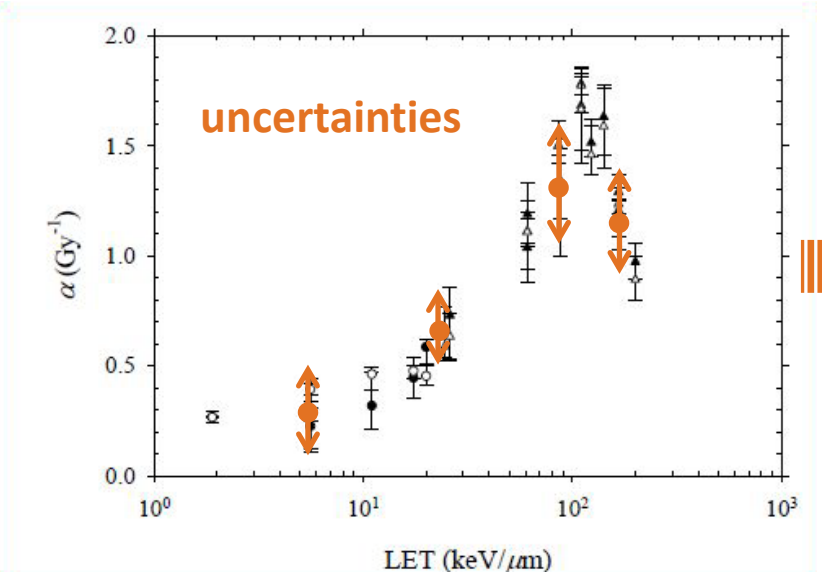
Biological Uncertainties in Carbon Ion Therapy

- RBE needed for carbon ion therapy

$$RBE(\alpha_X, \beta_X, \alpha_P, \beta_P, \mathrm{d_P})$$

Uncertainties in input effect RBE



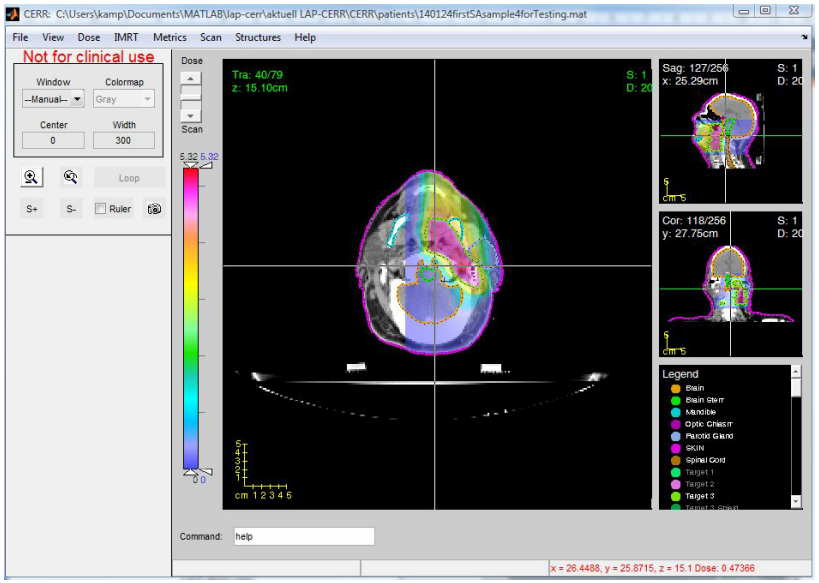
PhD Thesis David Carlson, 2006

Effect on

RBE ?

RBE · d ?

TPS: LAP-CERR



S. Schell and J. J. Wilkens, Med. Phys. 37, 5330-5340 (2010)
and www.cerr.info

Variance-Based Sensitivity Analysis

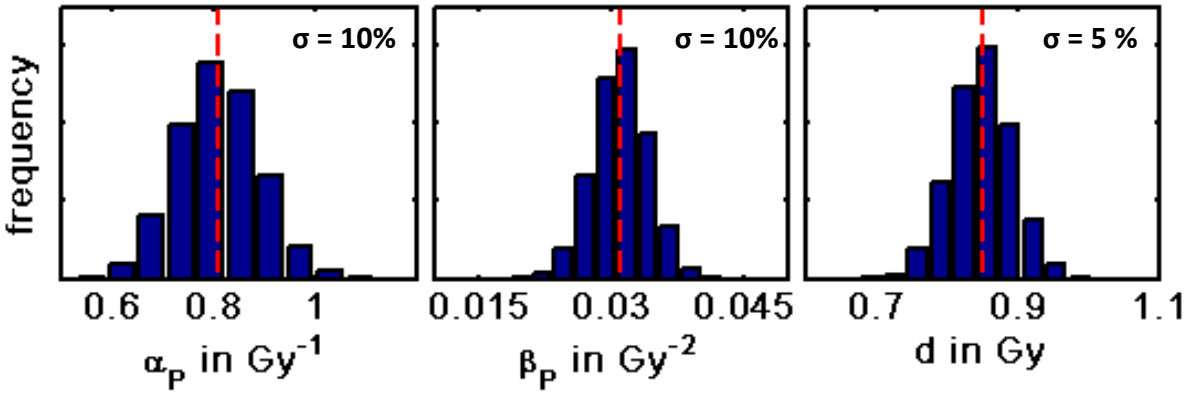
Simplified approach:

Assume: $RBE(\alpha_X, \beta_X, \alpha_P, \beta_P, \mathrm{d_P})$

constant

Uncertainties simulated with random distributions

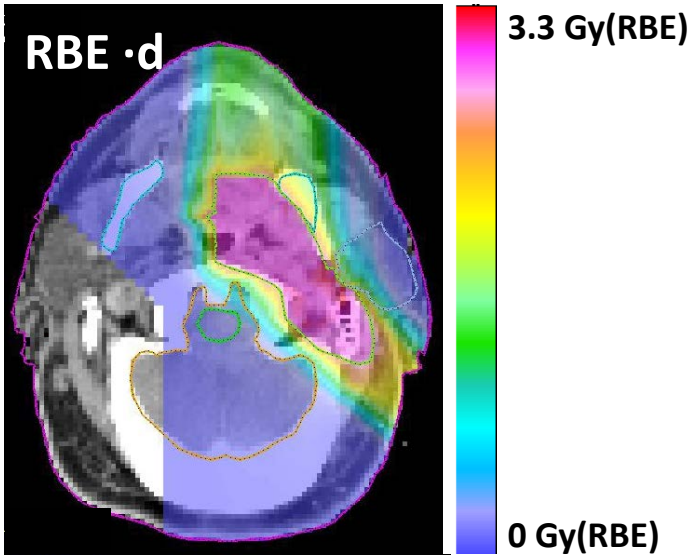
Used biological model:
LEM 1 implementation
http://totlxl.to.infn.it/lem/
α_X = 0.1Gy^{-1} and β_X= 0.05 Gy^{-2}

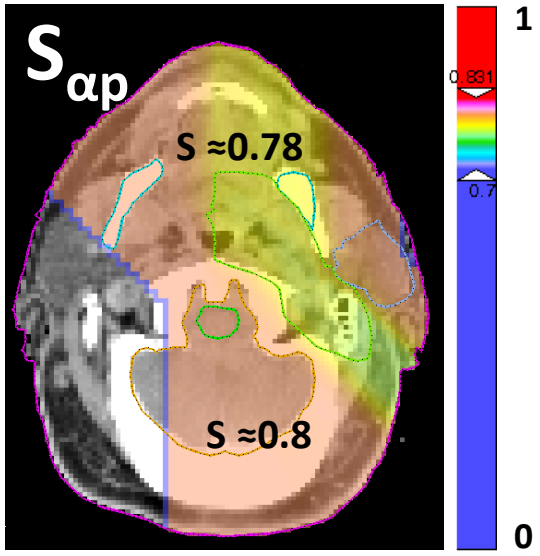


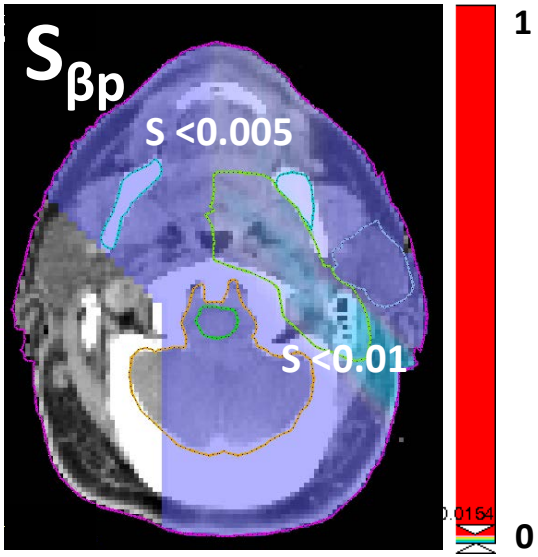
*A. Saltelli et al., Global Sensitivity Analysis The Primer, Wiley 2008.

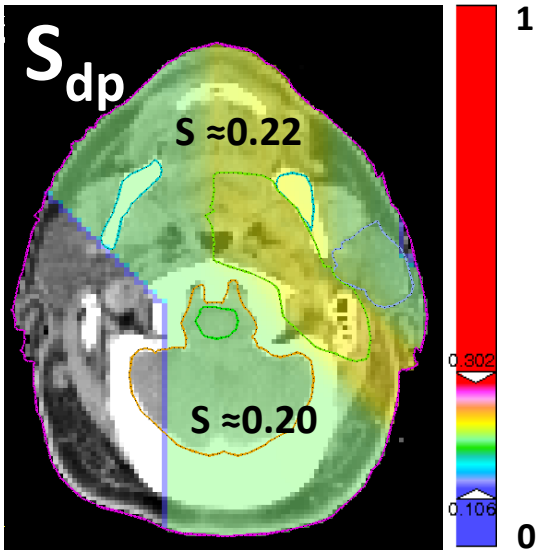
Voxel based 3D Sensitivity Maps

- $5 \cdot 10^5$ runs
- ~ $2 \cdot 10^5$ voxels
- ~ 3h
- 8 x 2.66 GHz, 32 GB RAM

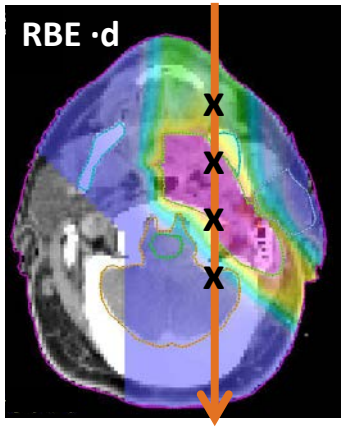




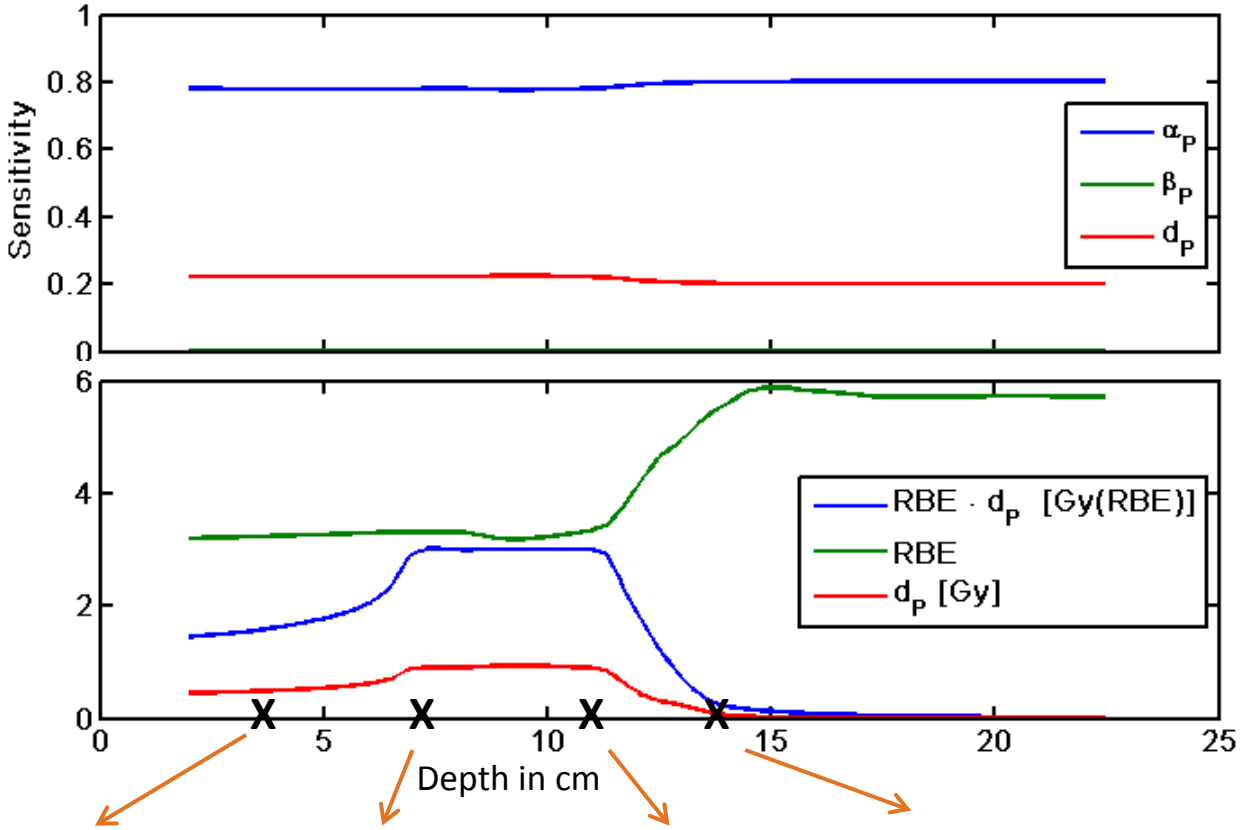


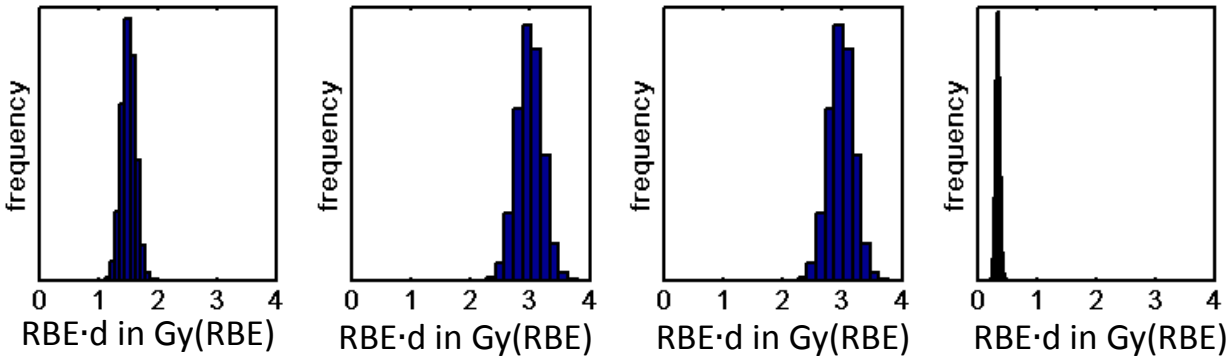


1D Sensitivity Profiles



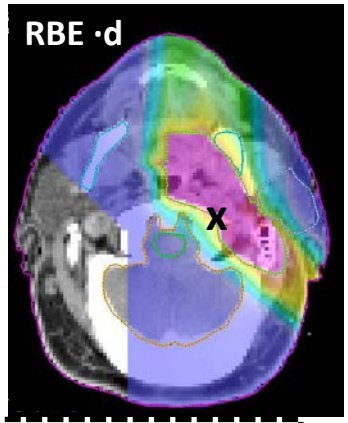
Additional variable
-> additional line





Depth dependent
RBE·d distribution

Voxel-based Sensitivity Result



Summary and Conclusion

- Sensitivity Analysis is a useful tool for carbon ion biology

- Variance-based sensitivity approach
  - Model independent
  - Variation of all input parameters at once
  - Ranking of the influence of input variables
  - Possible on 3D patient geometries (voxel for voxel)

- Uncertainties in ion α_P most influential (α_X and β_X not yet included!)

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- Thanks to K. Parodi, G. Cabal and A. Mairani for providing carbon ion fragmentation data
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