

PTCOG 47

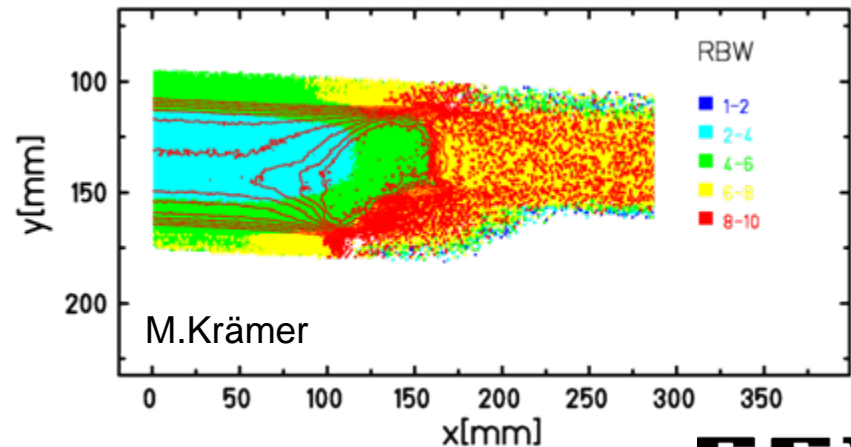
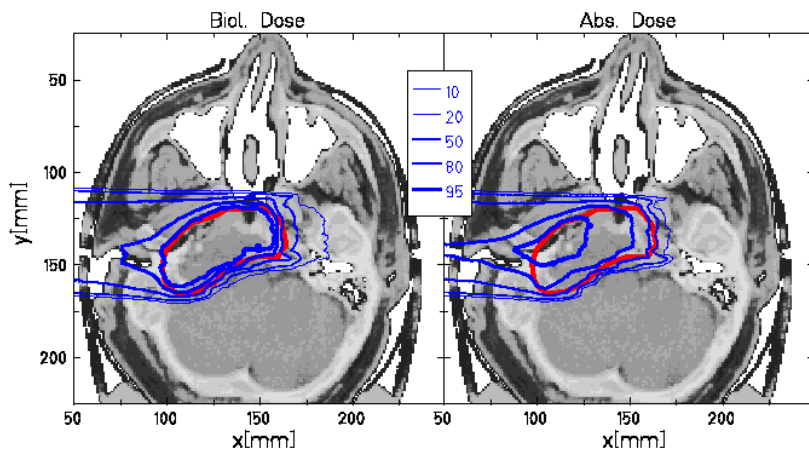
Investigation of the Therapeutic Ratio for Cancer Treatment with Carbon Ions

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GSI Biophysics

Motivation

- Complex dependence of RBE on energy, ion species, cell type and dose
- Biophysical RBE modelling is required for Heavy Ion Therapy
- Validation of models with experimental data
- Implications for Treatment planning

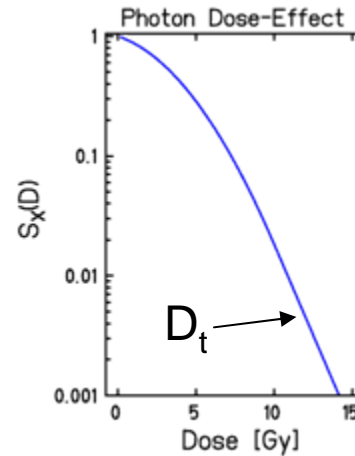
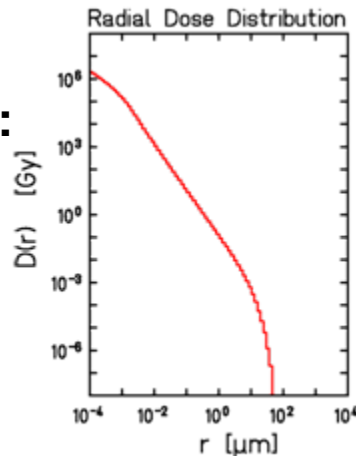


Local Effect Model (LEM)

Physics

Radial Dose Distribution:
Monte-Carlo (Krämer),
Experimental Data

$$D(r) \propto \frac{1}{r^2}$$



Biology

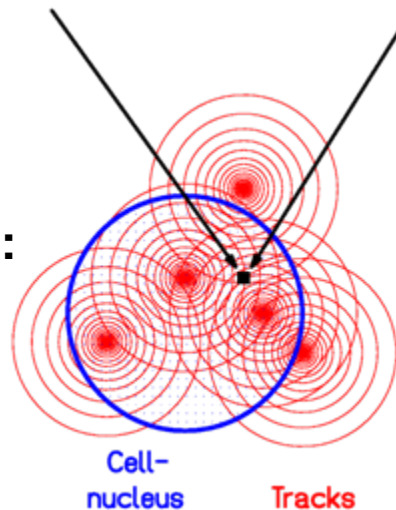
Photon Survival Curve:
additional assumptions
for large doses

$$S = e^{-(\alpha D + \beta D^2)}, \quad D < D_t$$

$$S = e^{-s_{\max} \eta (D - D_t)}, \quad D \geq D_t$$

Geometry

Target (cell nucleus):
Experimental Data

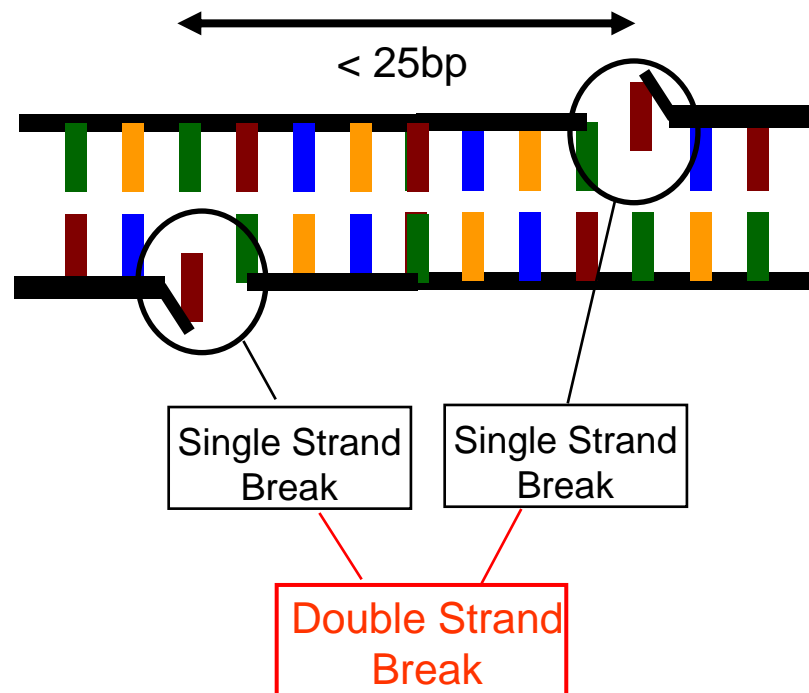


**Local Effect (Ions) =
Local Effect (Photons)**

High Dose Cluster Effects

Experiments with plasmid DNA

- Non-linear yield of DSB
- Clustered SSBs reason for non-linearity
- Stagger size between 5 bp and 60 bp



larger damage at high local dose

Energy dependent track center (LEM III)

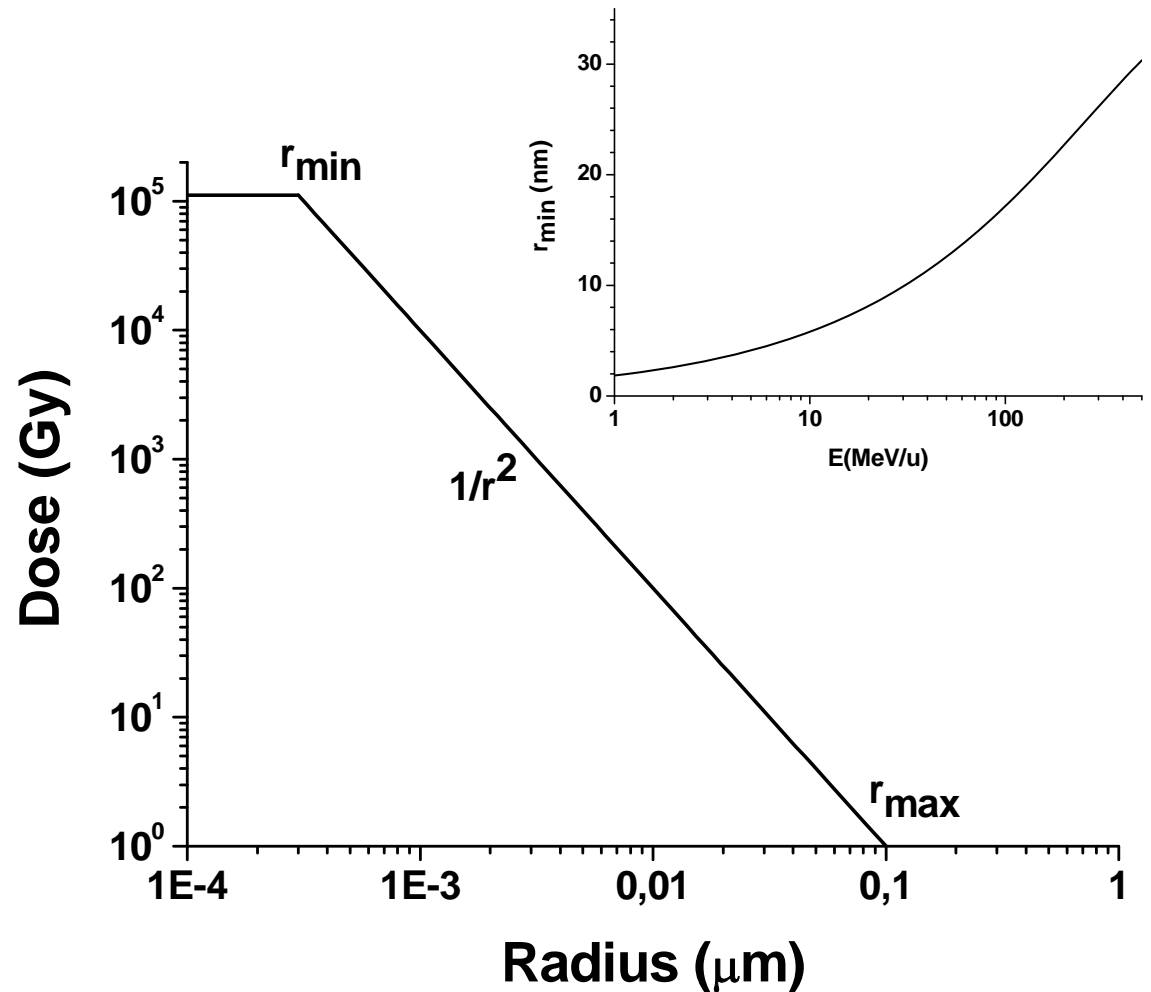
In condensed media
(liquid water):

track center depends on
particle energy

=>

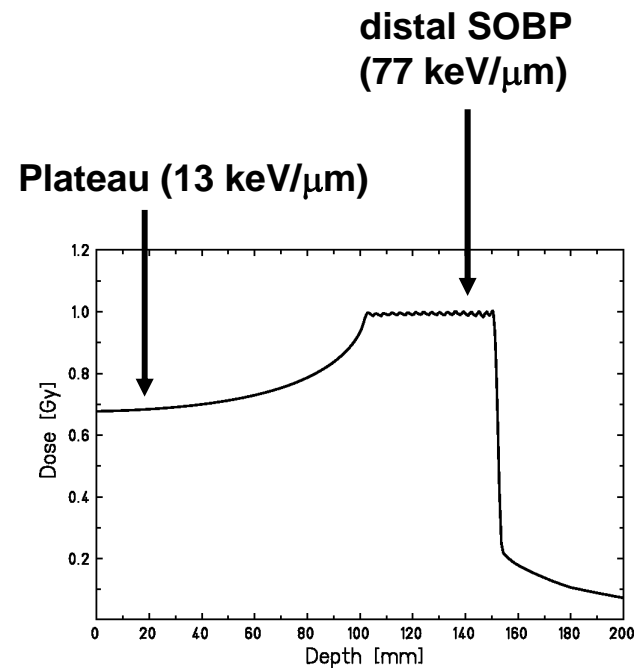
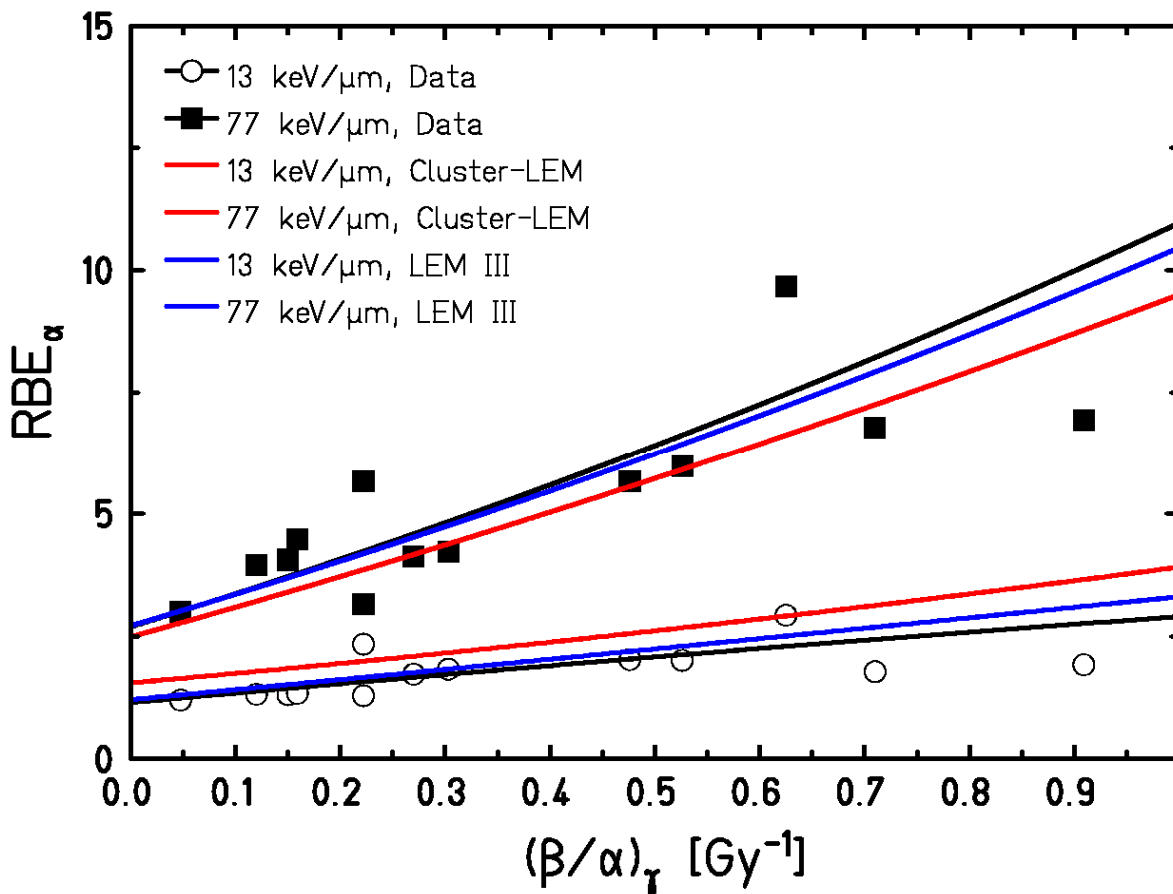
$$r_{\min} = 40\text{nm} \cdot \beta \quad \beta = v/c$$

40nm - empirically adjusted
for best
agreement with ion data



Accuracy of LEM

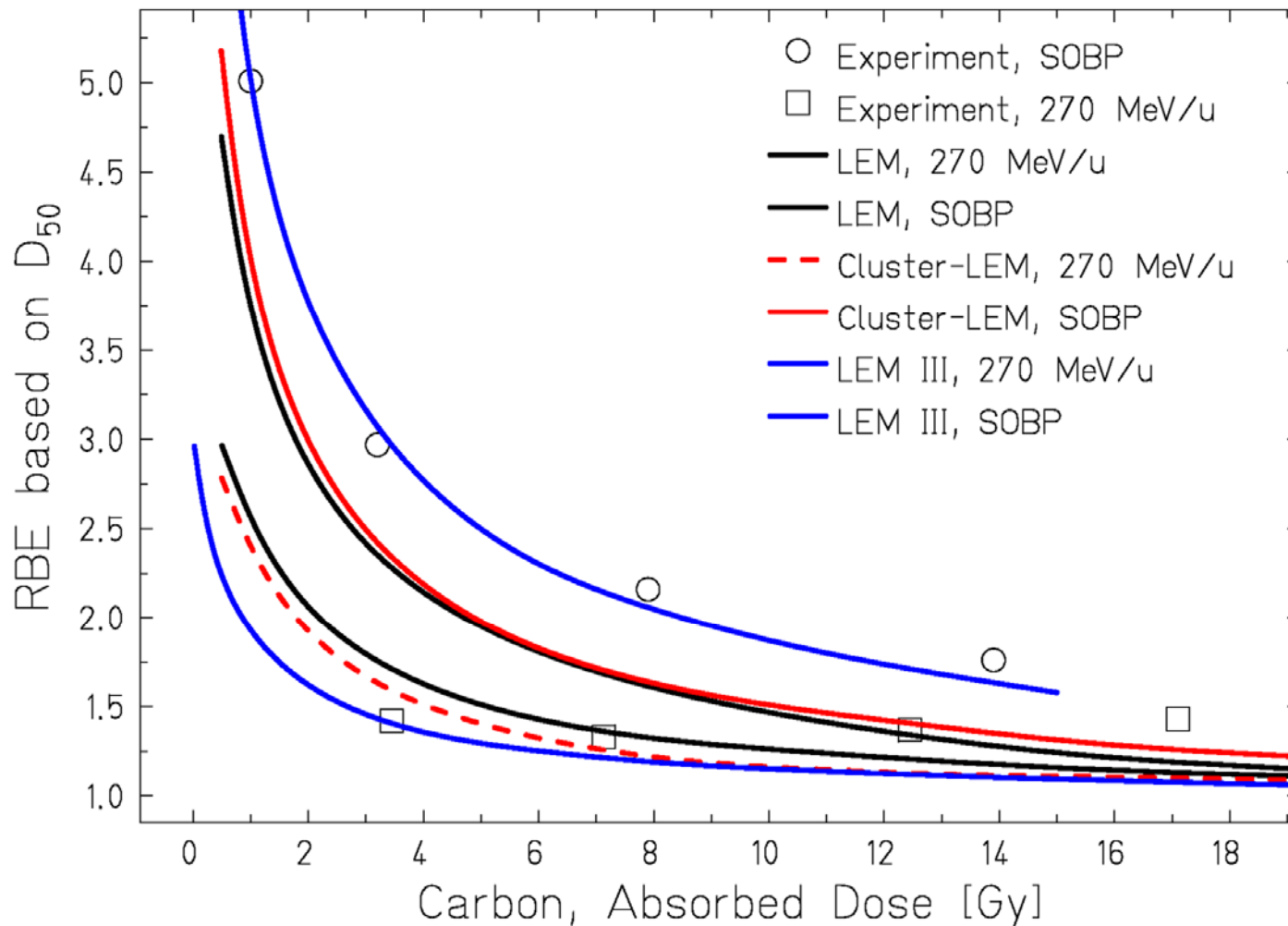
Different human cell lines of tumor and normal tissue



$RBE(\alpha/\beta \text{ low}) > RBE(\alpha/\beta \text{ high})$

Exp. Data: Suzuki et al., *IJROBP* 2000

Radiation tolerance – rat spinal cord



Experimental data
Karger et al. 2006

Conclusions for Model Versions

Generally, good agreement of key features

Improvement due to cluster extension

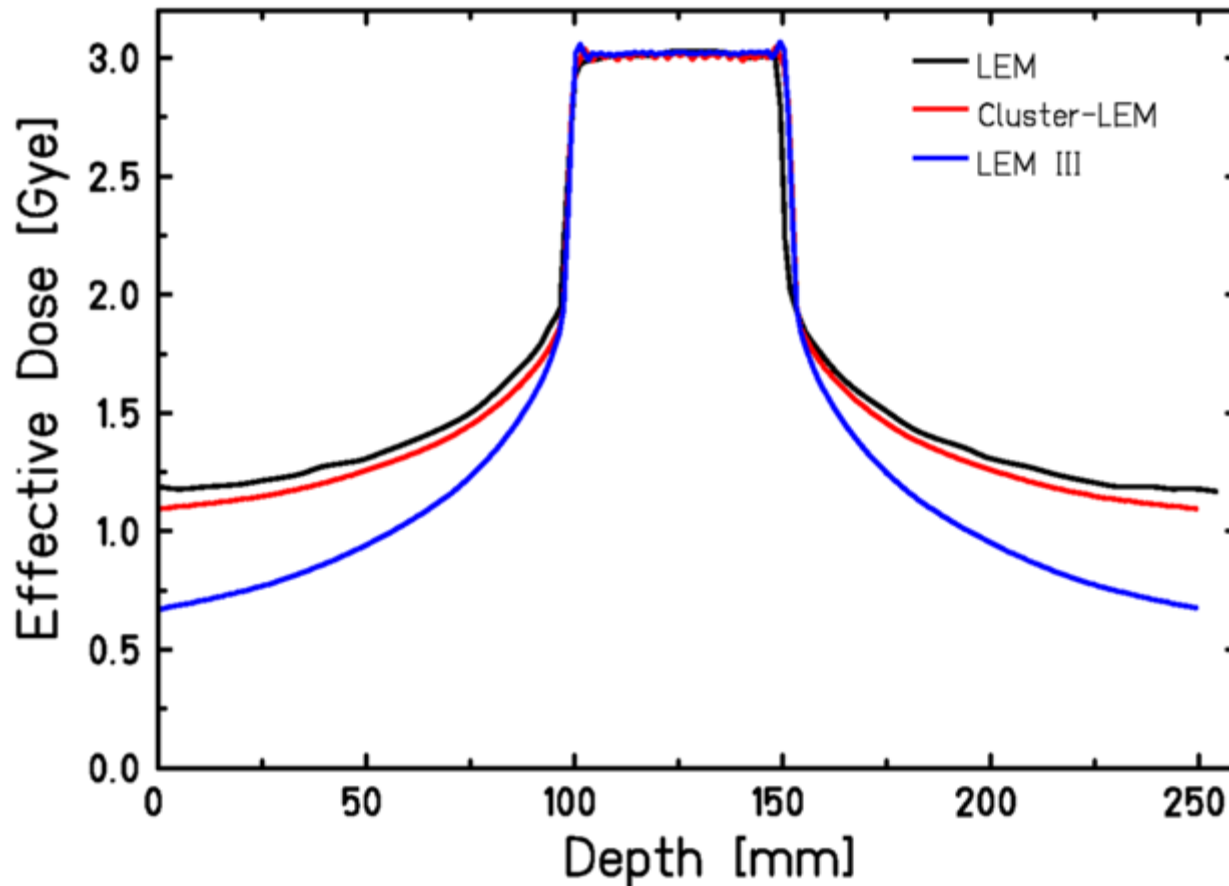
Intriguing agreement with exp. data for LEM III

Benchmark: radiation tolerance of rat spinal cord

comprehensive study of survival

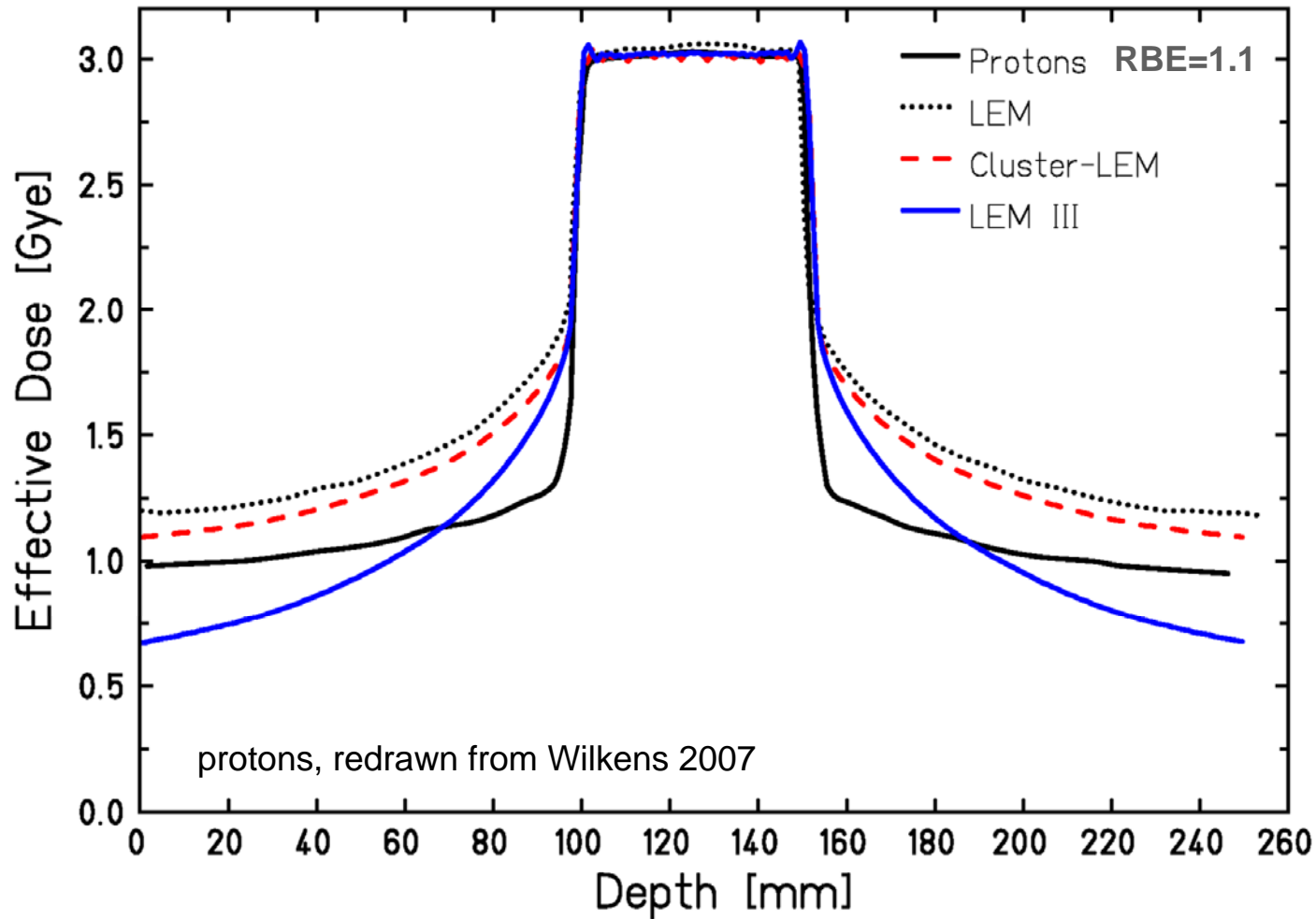
Model improvements give more realistic therapeutic ratio

Typical treatment scenario

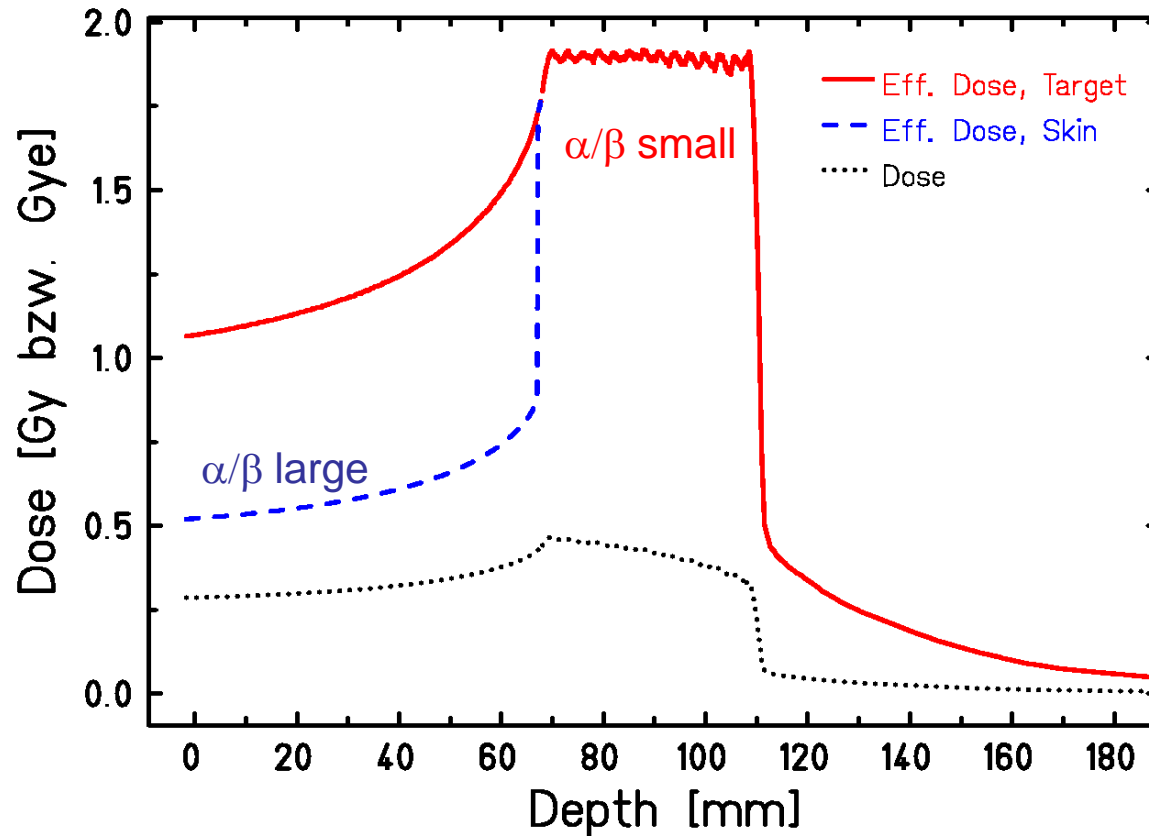


Chordoma $\alpha/\beta=2$, two-field irradiation, 5cm SOBP in 10cm depth

Comparison Proton vs. Carbon

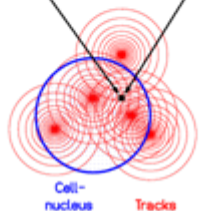
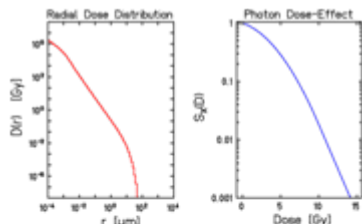


Influence of Tissue Composition

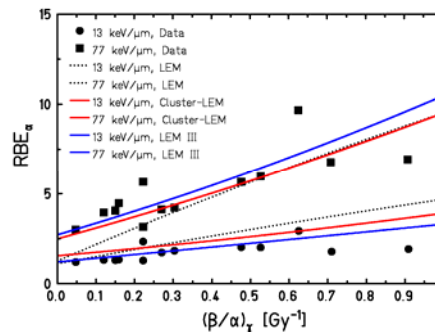


Krämer and Scholz, *Phys. Med. Biol.* 2000

Summary - Conclusions

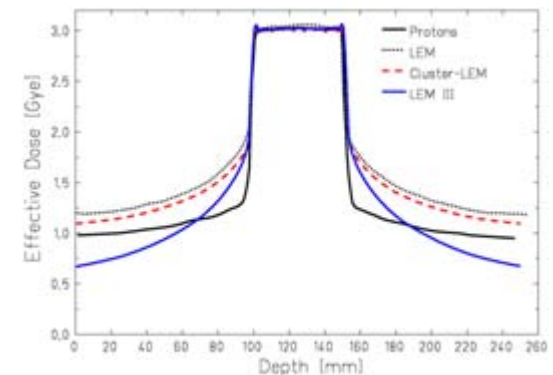


- Local Effect Model
- Cluster extension, Track structure (r_{\min})



- Clinically relevant scenario
- Comparison of protons and carbon ions

Good agreement with a large set of *in vitro* and *in vivo* data



- Deviations for low Z -> Further model improvement necessary
- Consideration of different tissues in treatment planning

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