Predicting biological outcomes in cancer ion therapy by the BIANCA biophysical model

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1 Introduction: the BIANCA model

Particle therapy with heavy ions requires biophysical models to predict tumour cell-killing Relative Biological Effectiveness (RBE) and side effect probability.

$$RBE = \frac{D_\gamma}{D_{ion}}\Big|_{isoeffect}$$

Side effects
- Tissue reactions (e.g. skin reactions) → Cell-killing
- Stochastic effects (e.g. radiation-induced tumours) → Chromosomal damage

Aim

We developed **BIANCA**, a Monte-Carlo biophysical model, based on mechanistic assumptions and 2 adjustable parameters [1].

BIANCA can predict cell death and chromosomal damage, induced by ionizing radiation, across multiple ion species (p, He, C, O ions), energies and cell lines.

2 Methods: biological outcome predictions

BIANCA BIOPHYSICAL MODEL ↕ FLUKA, GEANT4 A SIMULATION TOOLKIT, PHITS Particle and Heavy Ion Transport code System

→ Particle therapy mixed radiation field → **Predictions**

IN VITRO
- Cell survival curves
- Chromosomal damage

IN VIVO
- Rat and patient RBE
- Rat NTCP

Radiobiological parameters derived by the BIANCA model - Underlying radiation physics reproduced through radiation transport codes. These parameters are then used to predict in vivo RBE and Normal Tissue Complication Probability (NTCP).

3 Results: IN VITRO and IN VIVO biological outcome validation

IN VITRO

Fig. 1: CHO cell surviving fraction vs depth in water for **He-ion** irradiation [2].

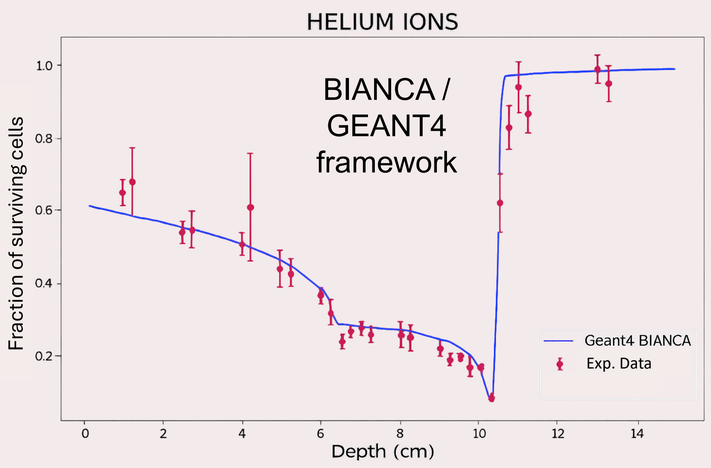
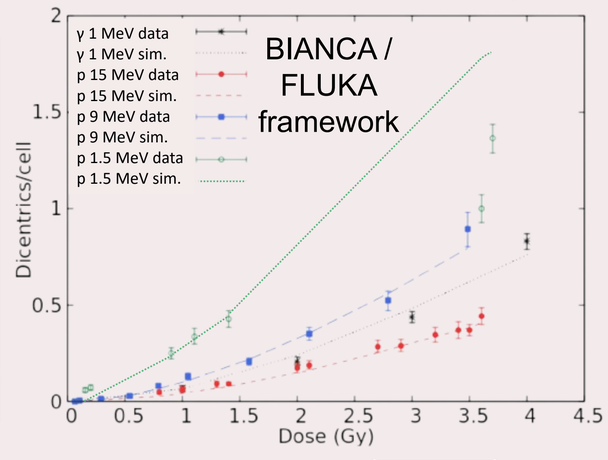


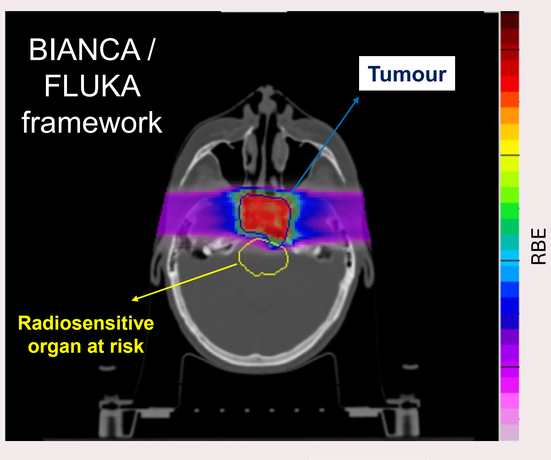
Fig. 2: BIANCA mean number of dicentrics (chromosomal damage) per lymphocyte vs dose, for photons and **proton** beams at different energies [3].



Other ions: SCAN ME

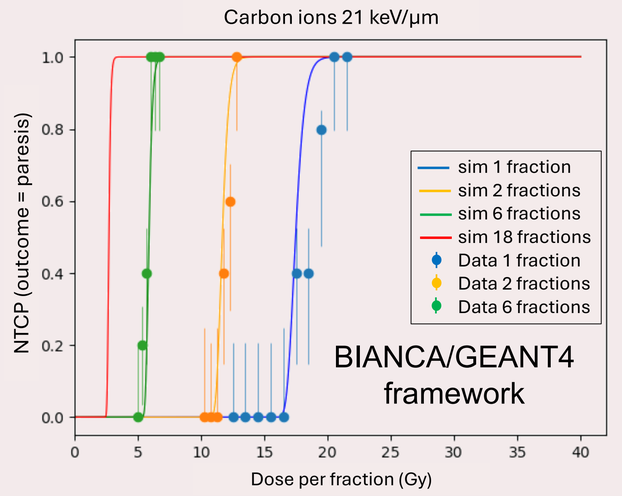
IN VIVO

Fig. 3: BIANCA cell-killing RBE for a chordoma patient case irradiated with **C-ions** [4].



Other patients: SCAN ME

Fig. 4: Rat NTCP vs dose per fraction following **C-ion** irradiation [5].



Results, validated by dedicated statistical analysis and data comparison, demonstrate the **strong predictive power** of BIANCA.

4 Conclusions & impact

- BIANCA enables reliable simulations for all ion species currently applied in particle therapy.
- BIANCA model allows assessment of both tumour control and healthy tissue side effects.
- BIANCA would **enhance treatment plan optimization** in real ion beam therapy scenarios.

References

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- Feedback welcome ☺