



University of California  
San Francisco

Macroscopic calculation of Ionization Detail (ID) parameters  
and cluster dose with condensed history Monte Carlo

Association of ID parameters with cell survival in-vitro  
conditions following proton to Ar irradiation

Ramon Ortiz, PhD

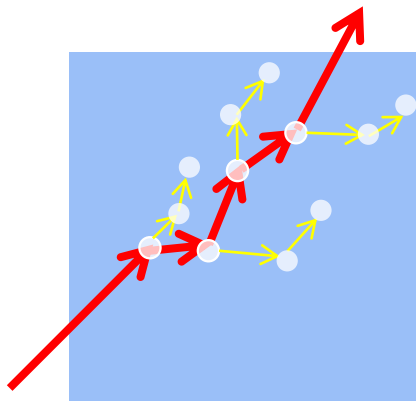
9/22/23

# ID quantities

- At nanoscale

ID quantities ( $I_p$ )	$N_k = \sum_{v=k}^{v_{max}} v f(v)$	number of ionizations in clusters of k or more ionizations	$N_2 \dots N_{10}$
	$F_k = \sum_{v=k}^{v_{max}} f(v)$	number of clusters of k or more ionizations	$F_1 \dots F_{10}$

- At macroscale



$$I_p^{\varphi_j} = \frac{\sum_{c \in \varphi_j} t_j^c I_p^c}{\sum_{c \in \varphi_j} t_j^c} = \frac{\sum_{c \in \varphi_j} \phi_j^c I_p^c}{\sum_{c \in \varphi_j} \phi_j^c}$$

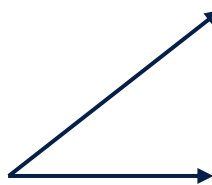
$$f^{\varphi_j}(v) = \frac{\sum_{c \in \varphi_j} t_j^c f^c(v)}{\sum_{c \in \varphi_j} t_j^c} = \frac{\sum_{c \in \varphi_j} \phi_j^c f^c(v)}{\sum_{c \in \varphi_j} \phi_j^c}$$

# ID quantities

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- At macroscale

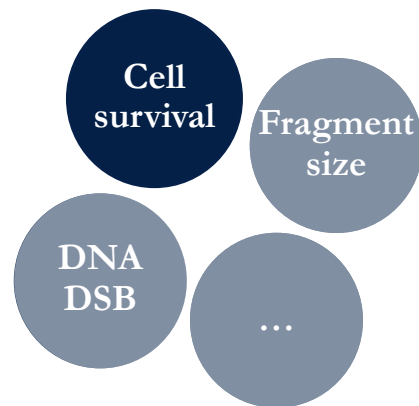
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# ID quantities

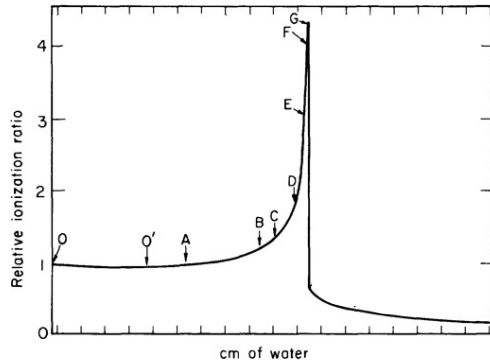
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Cluster dose:  $g_j^{(I_p)} = \phi_j I_p^{\phi_j} / \rho_o$

The same cluster dose is expected to lead to the same biological endpoint, independently of the particle type.

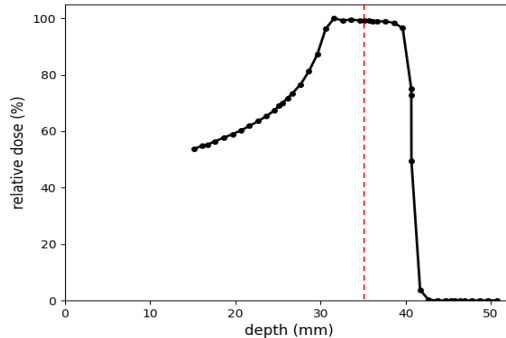


# Association with biological endpoints



Blakely, 1979

- Human kidney T-1 cells in aerobic and hypoxic conditions
- Monoenergetic beams:
  - Carbon - 400 MeV/u
  - Neon - 425 MeV/u
  - Argon - 570 MeV/u

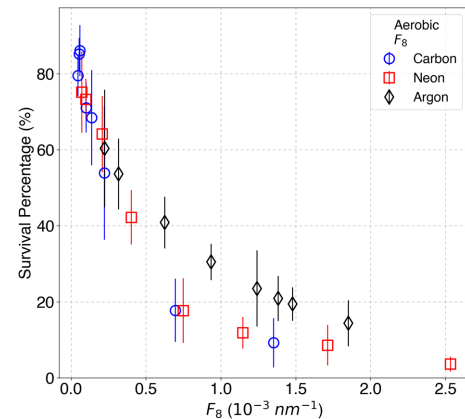
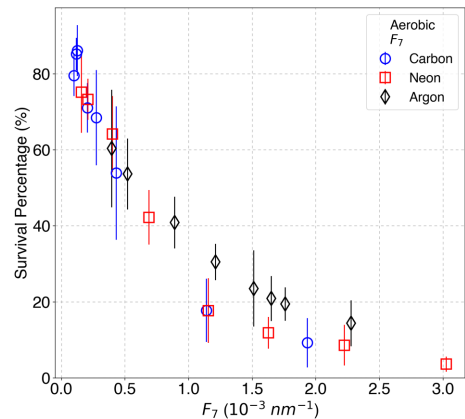
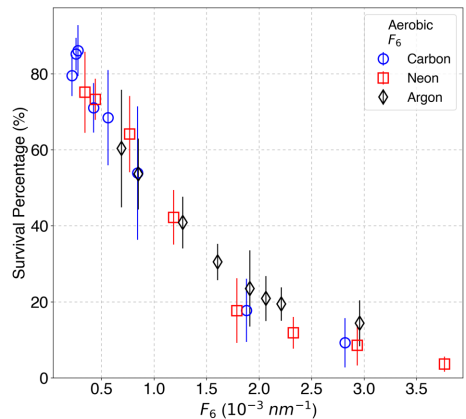
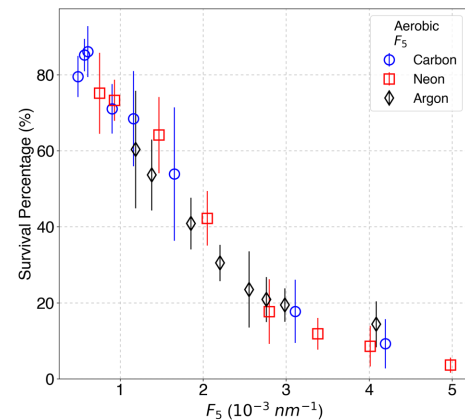
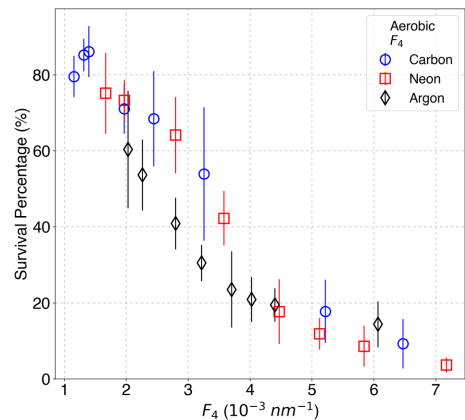
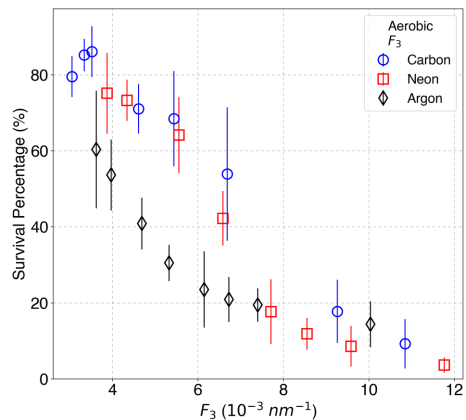


Dokic, 2016

- Human alveolar carcinoma cells in aerobic conditions
- 1 cm SOBP:
  - Proton - 70 MeV
  - Helium - 70 MeV/u
  - Carbon - 130 MeV/u
  - Oxygen - 150 MeV/u

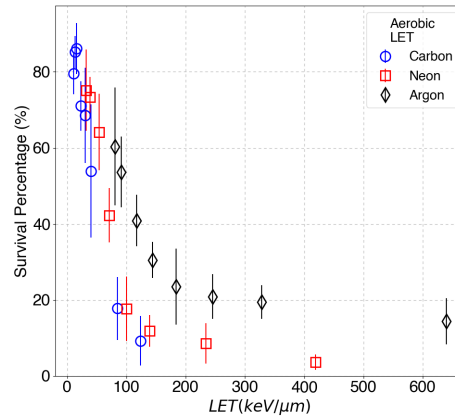
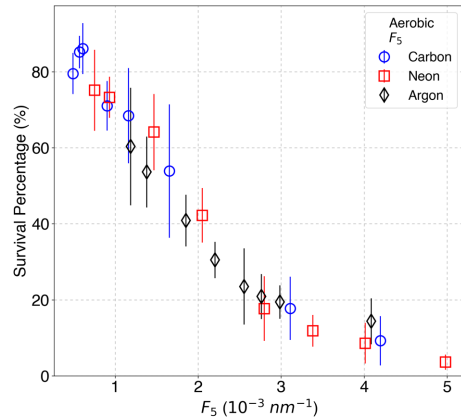
# Determination of preferred $I_p$

Constant fluence

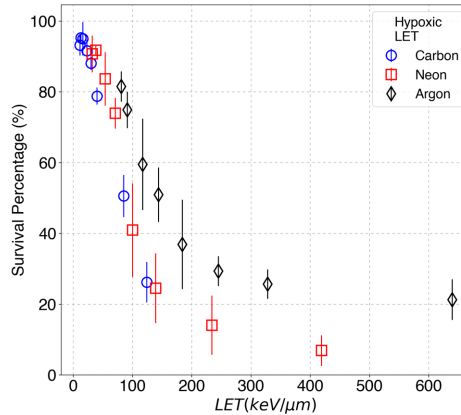
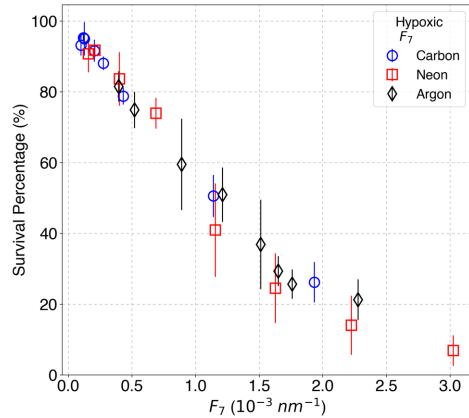


# Determination of preferred $I_p$

Aerobic



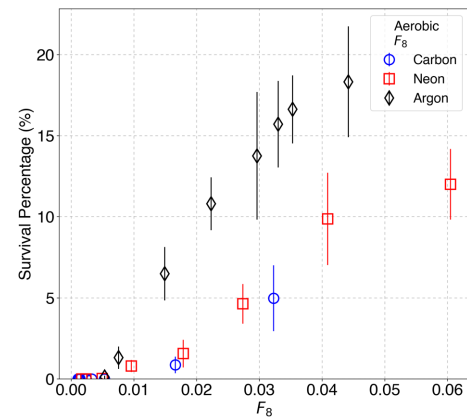
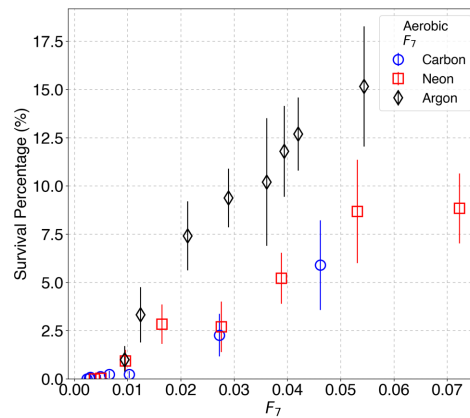
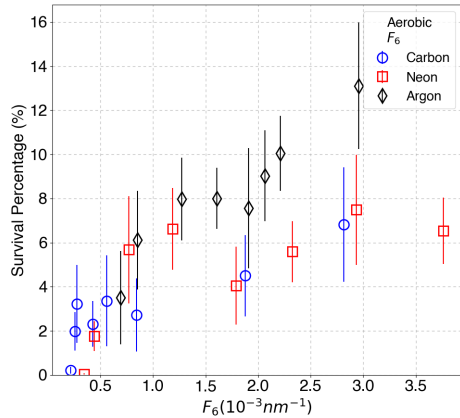
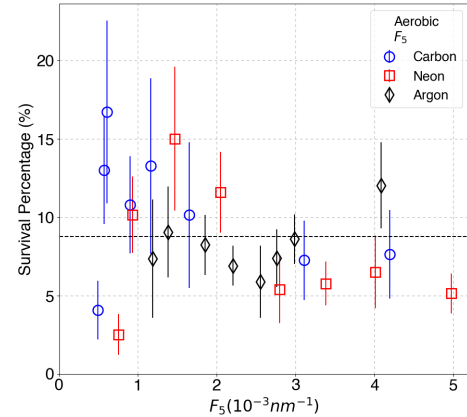
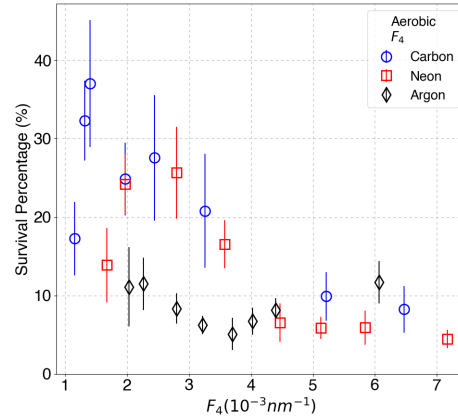
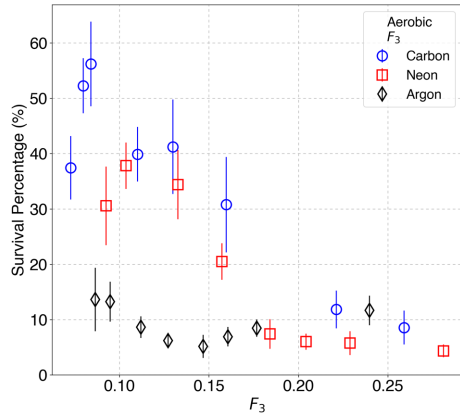
Hypoxic



- There exists an ID parameter that correlates to cell survival more strongly than LET.

# Association of cluster dose with cell survival

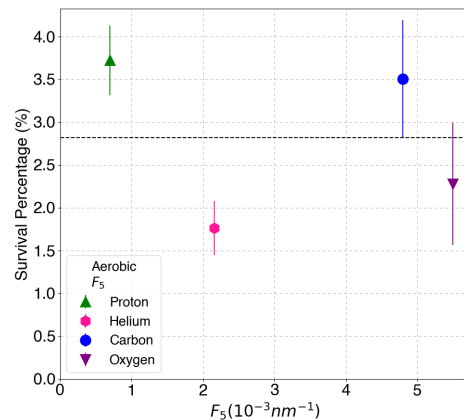
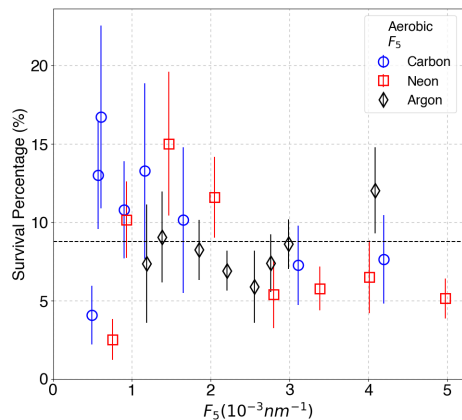
Constant cluster dose



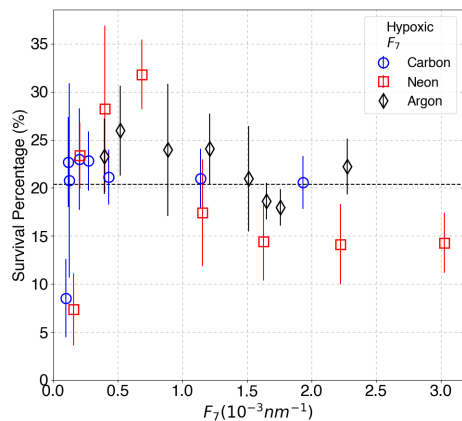


# Association of cluster dose with cell survival

Aerobic



Hypoxic



- Survival of cells irradiated with the same cluster dose agrees with the average within 2 SD for 79% of measured points.

# Conclusions and outlook

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- There exists a preferred  $I_p$  that more closely associated with biological effects than LET.

Identify other choices for  $I_p$  with a larger set of measurements and endpoints.

- There is a close relationship between aerobic and hypoxic cell survival and  $g^{F5}$  and  $g^{F7}$ , respectively.

Study the potential of this quantity for use in particle beam treatment planning.

## Results published at

BA Faddegon, EA Blakely, L Burigo, Y Censor, I Dokic, JN D-Kondo, R Ortiz, J Ramos-Mendez, A Rucinski, KE Schubert. Ionization detail parameters and cluster dose: a mathematical model for selection of nanodosimetric quantities for use in treatment planning in charged particle radiotherapy, *Phys Med Biol.* 2023.



### **ID NIH R01 Grant collaboration:**

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