Radioprotection advanced example

Extension for clinical microdosimetric application

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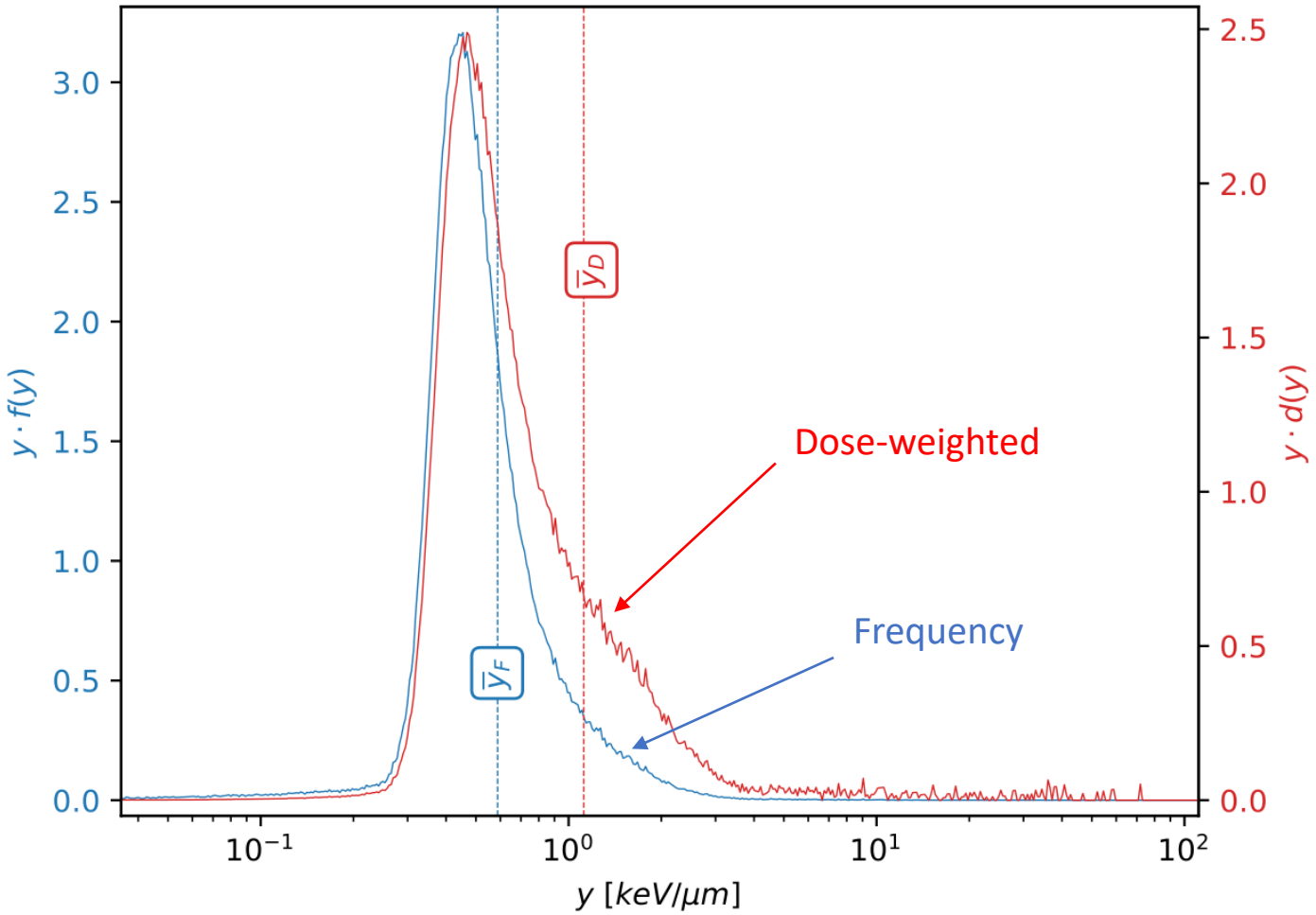
About microdosimetry

- stochastic approach
- lineal energy: $y = \frac{\varepsilon}{\bar{l}}$

  ε: single-interaction energy deposit

  $\bar{l}$: mean path-length inside detector
- studied via distributions $f(y)$, $d(y)$…
- … and respective means $\overline{y_F}, \overline{y_D}$

can be related to traditional dosimetric quantities (i.e. LET) with some caveats



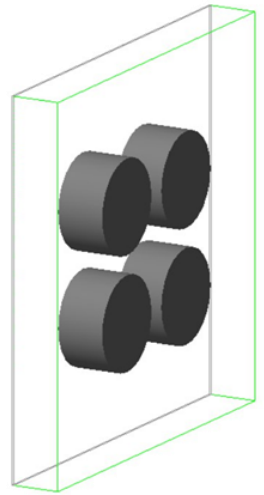
Radioprotection example

- simulates several microdosimetric detectors
- scores deposited energy ε and secondaries
- provides basic data analysis for microdosimetry
  spectra, means, and radiobiological effectiveness (requires ROOT or Python)

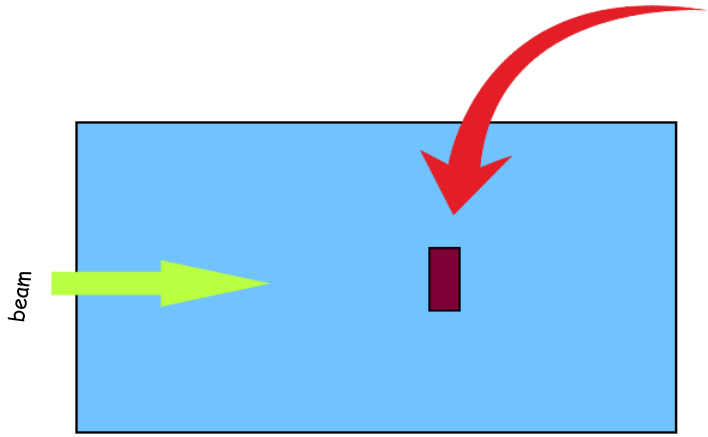
however

- traditionally focussed on space applications
  the detector is in vacuum, but clinical measurements happen in water phantoms
- unwieldy to customise
  the user needs to be familiar with C++ and Geant4 to change the properties of the detector

Pending changes final implementation may vary



- (optional) use of water phantom
  - the detector can be simulated either in vacuum or in a water phantom
  - lower cut only in the vicinity of the detector via G4Region

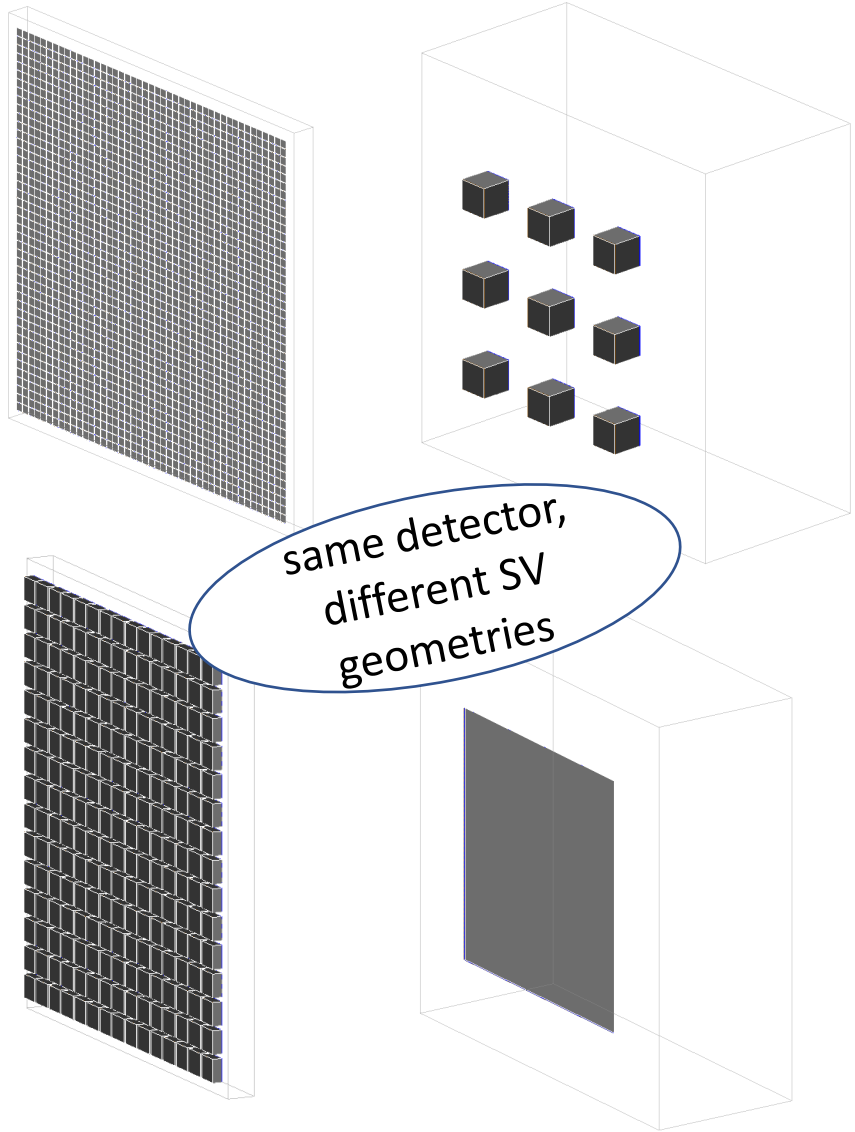


- scoring of hadron path length in SV
  - users can use this to calculate $\bar{l}$ from the MC
  - compare $\bar{l}$ across geometries + no need for hardcoded values from literature

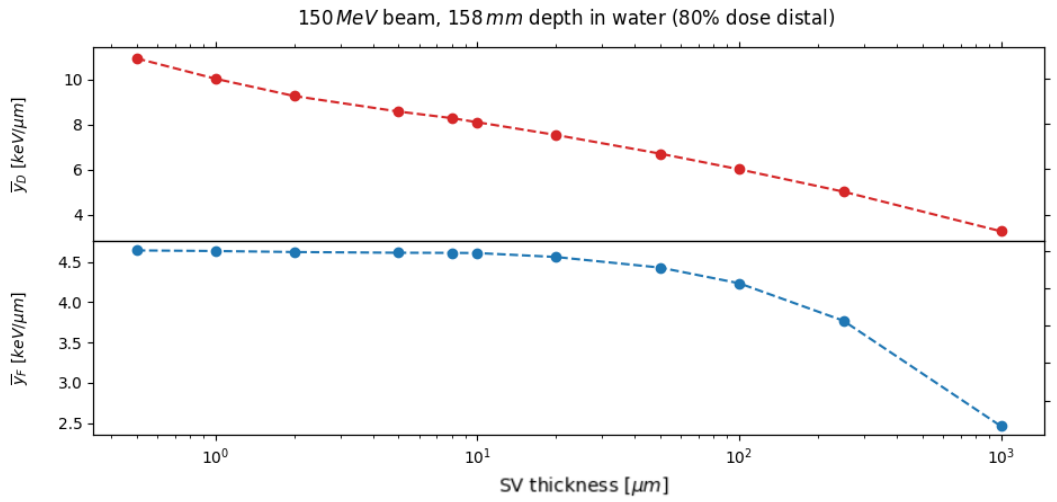
Pending changes final implementation may vary

- extended setup customisation via macro
  - users can test different detector types, geometries, and configurations without knowing C++
  - allows for testing several setups in parallel without recompiling

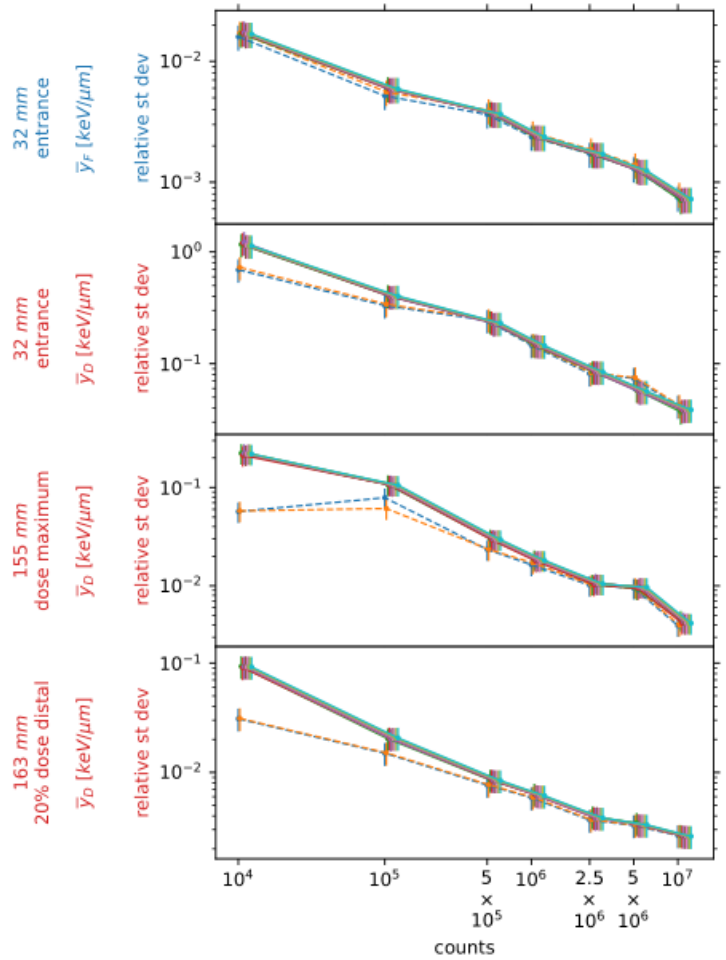
- set target based on collected statistics
  - the simulation only stops after the desired no. of events has been collected inside the SV
  - useful to get consistent statistics across different setups (especially different depths!)
  - set via macro



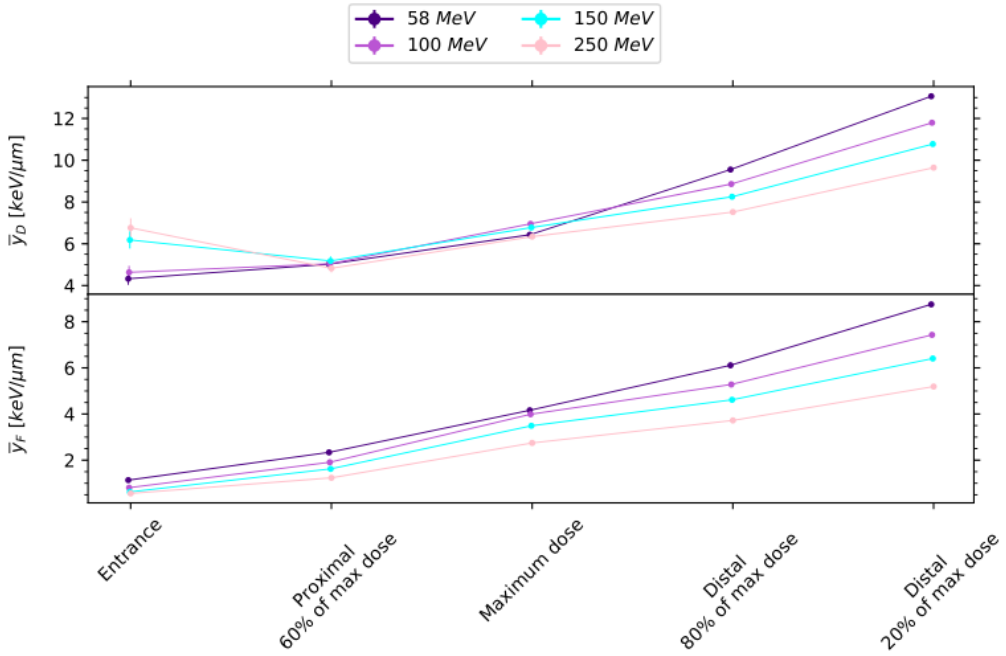
Here are some examples of what this allows you to test:



Effect of SV thickness at an arbitrary point of the Bragg curve



Influence of count statistics

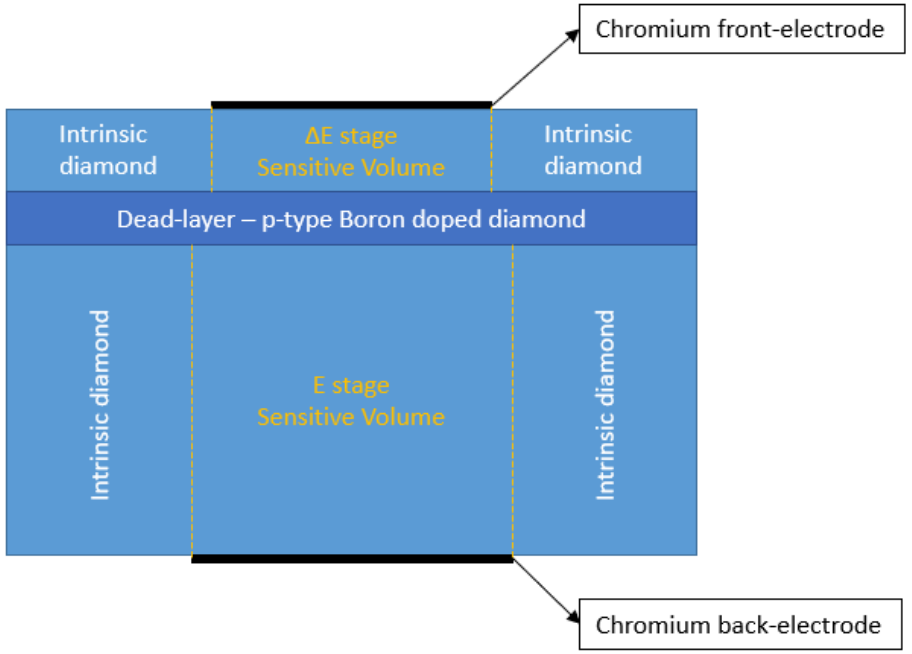


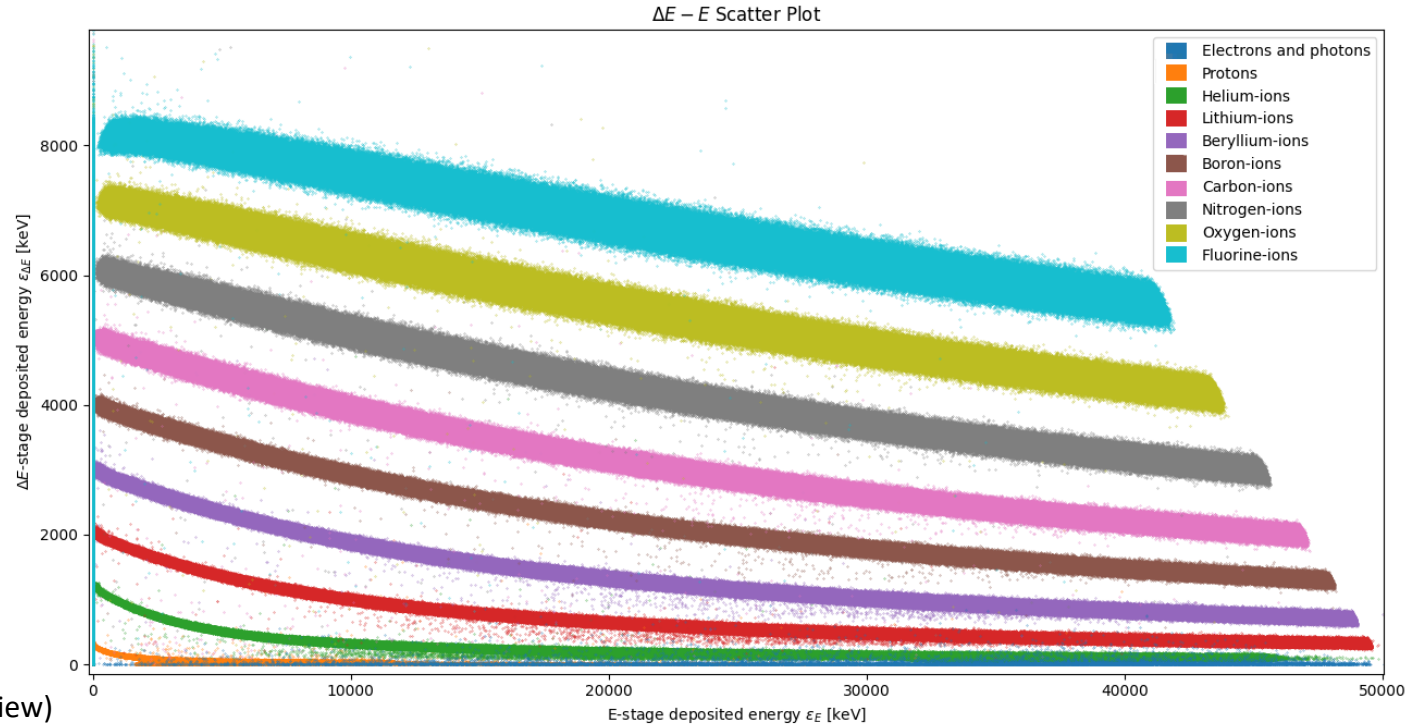
Comparison of different primary beams at the same relative position along the dose curve

Pictures from WIP paper

New detector: two-stage Diamond

- ΔE stage acts as a microdosimeter, E scores the total energy
  - allows to discriminate different hadrons in a $\Delta E - E$ plot
- Scoring modified accordingly
  - each event is labelled according to the stage in which it's scored





Pictures by Gabriele Parisi from http://dx.doi.org/10.2139/ssrn.4203262 (under review)

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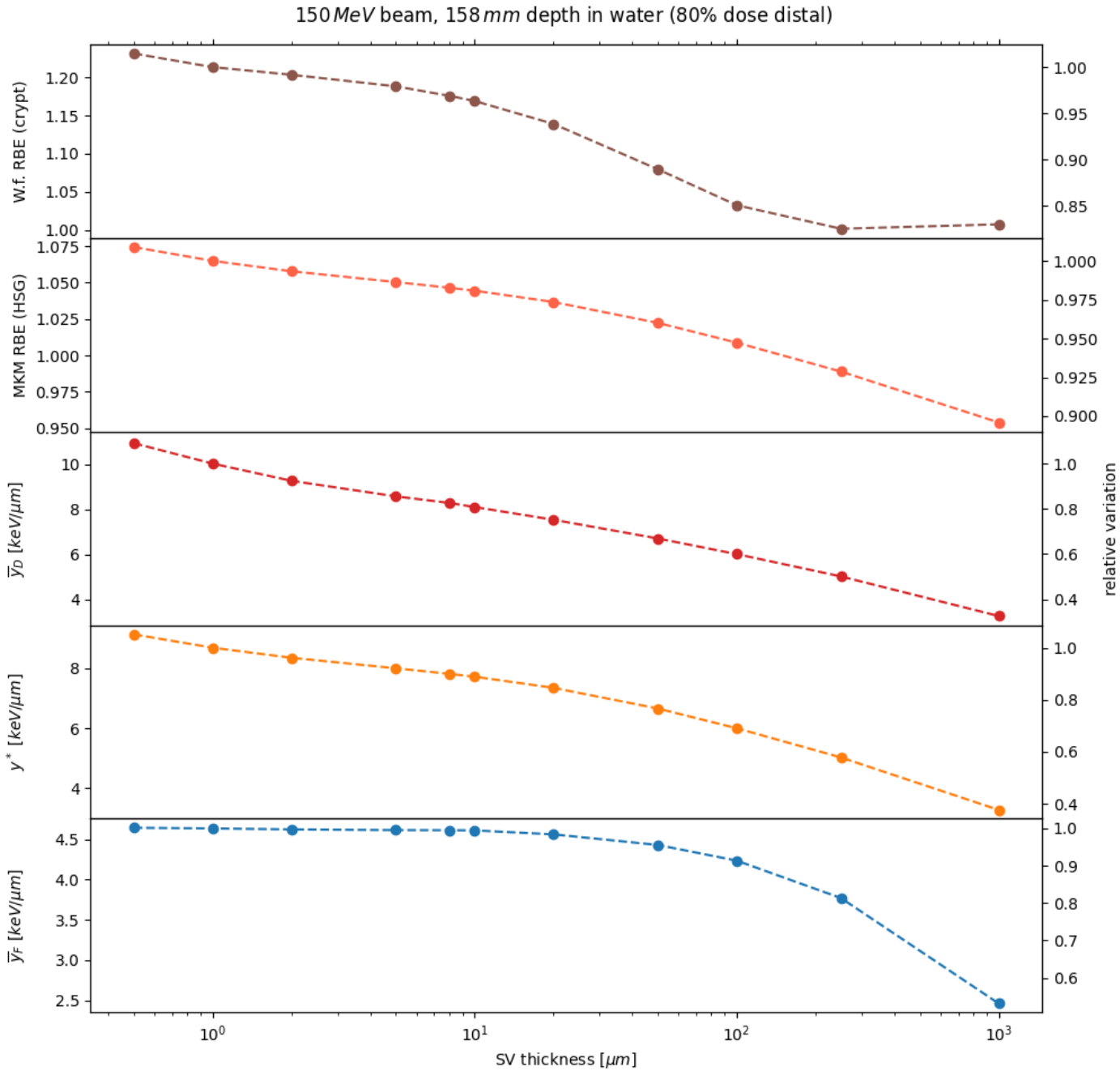
the end

Backup slides

Effect of SV thickness on means and biological effectiveness



Pictures from WIP paper

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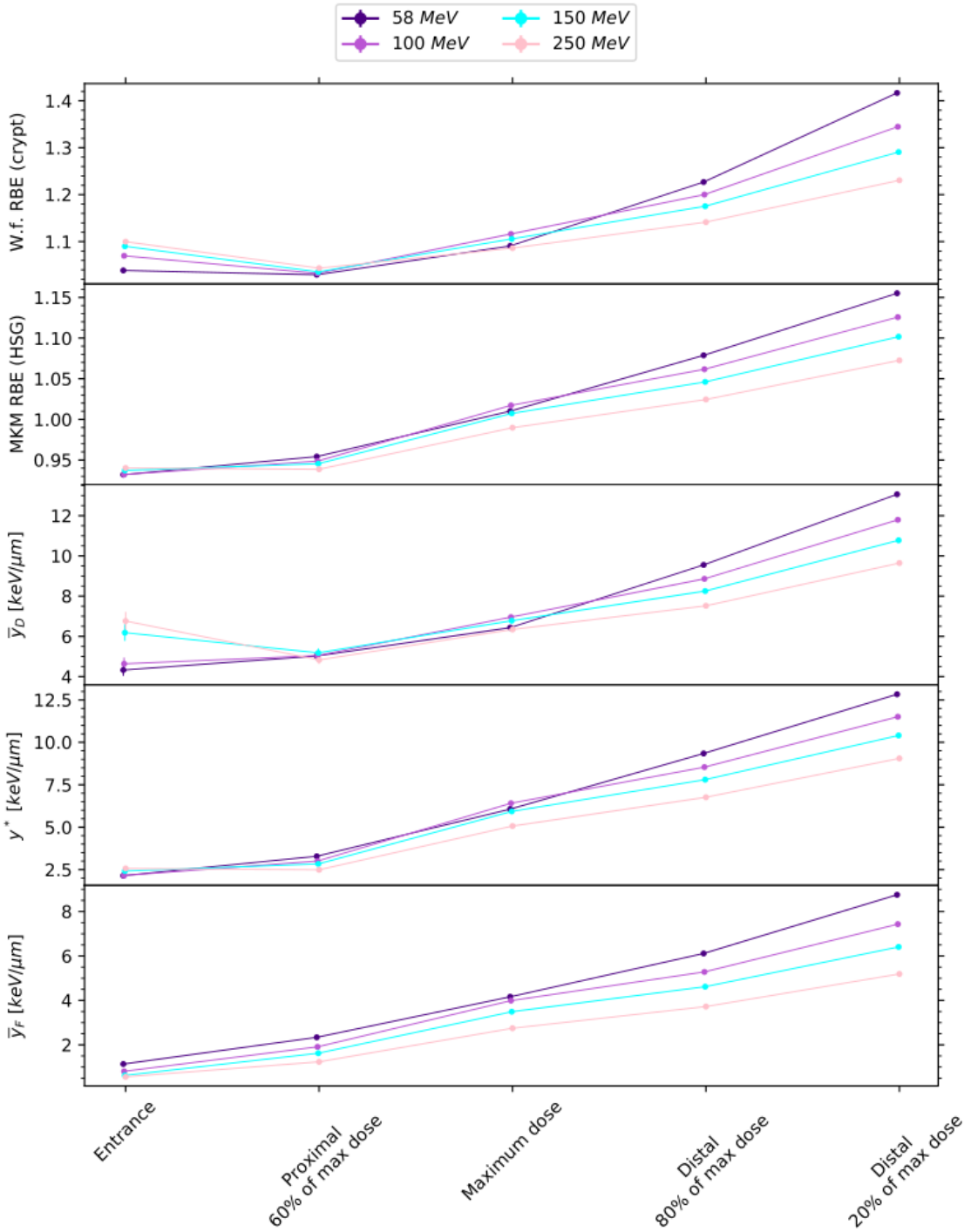
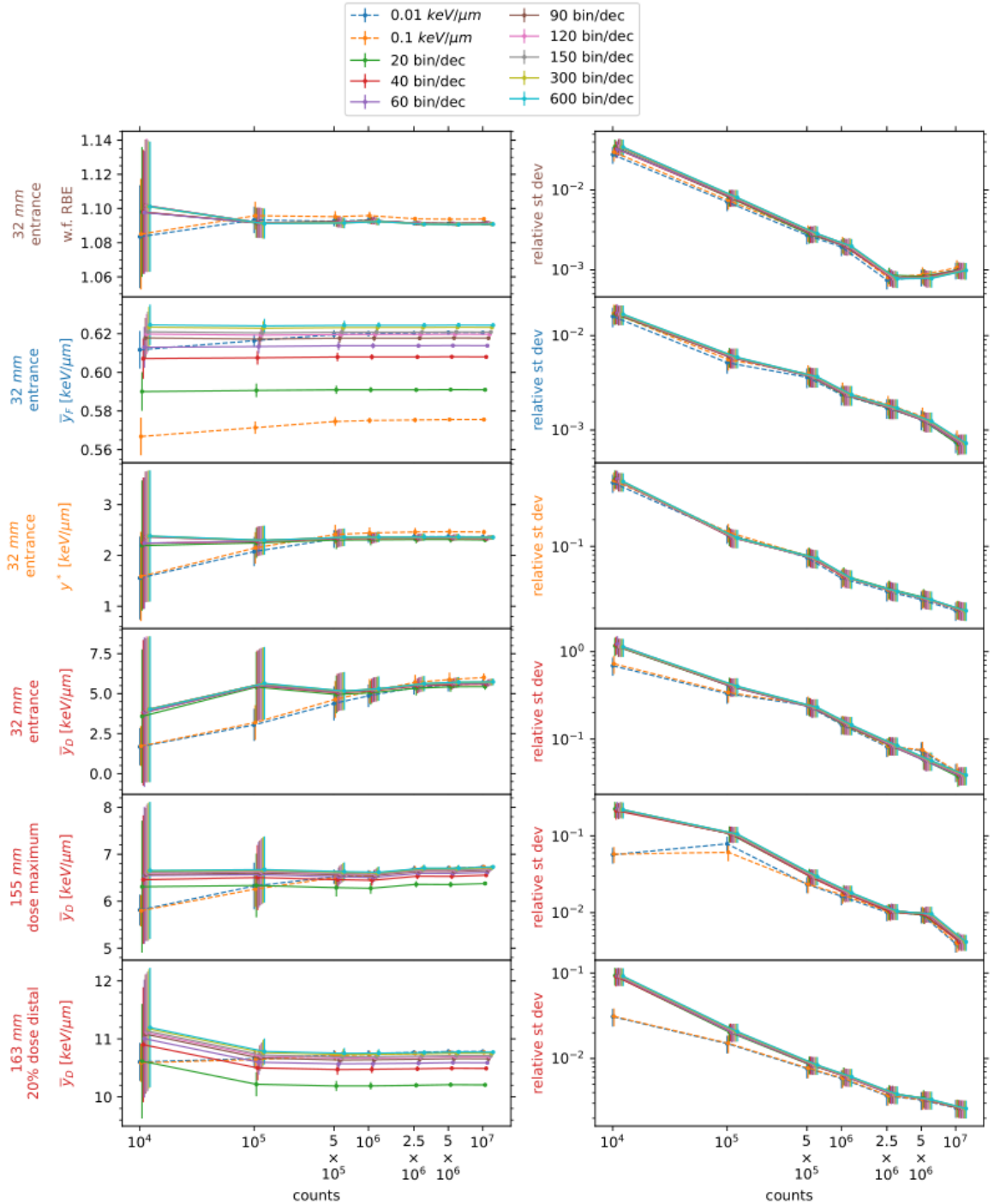


Pictures from WIP paper

Influence of count statistics
on the resulting means



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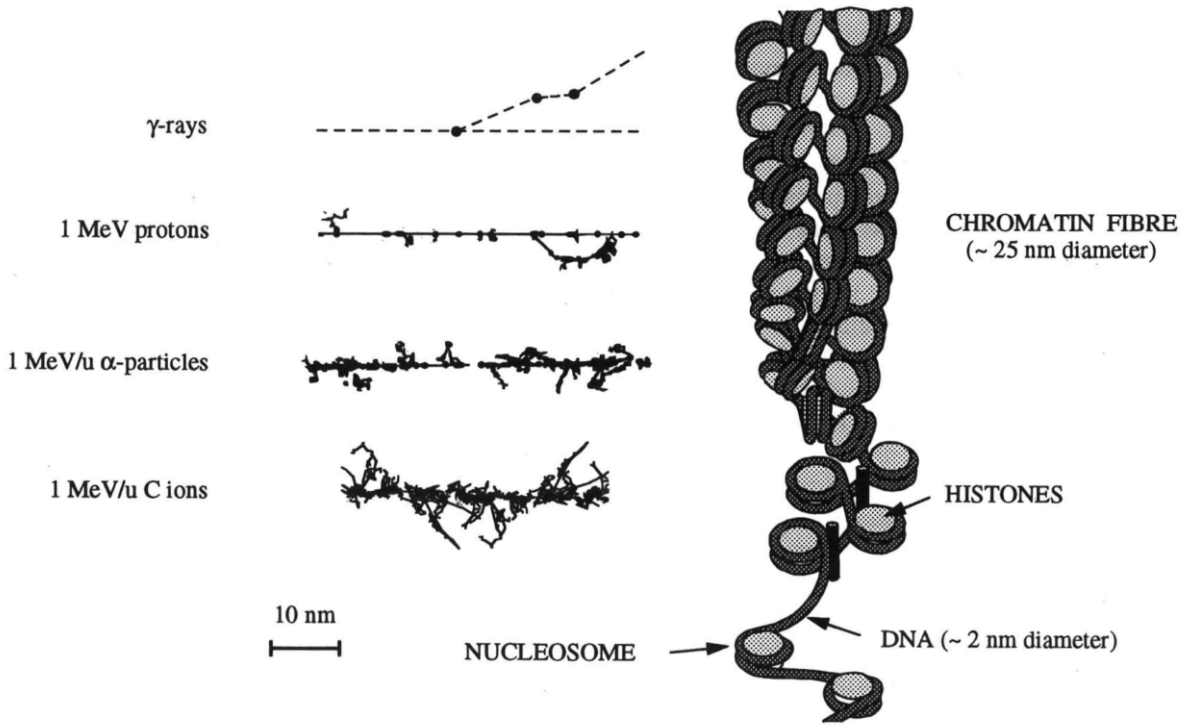
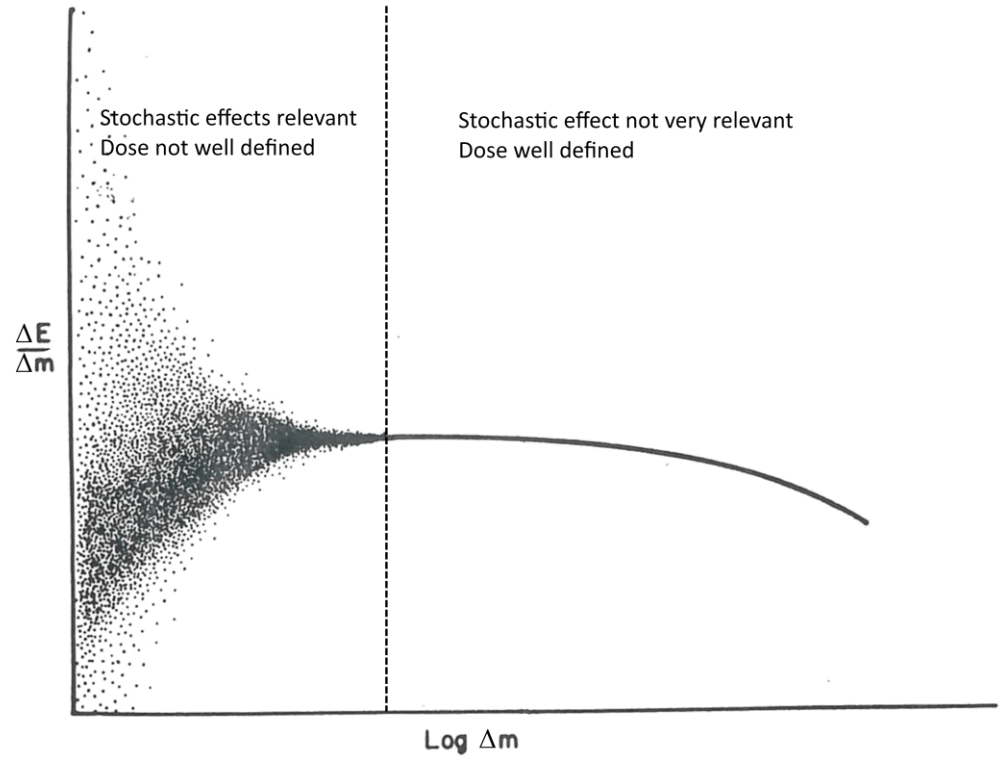

γ-rays
1 MeV protons
1 MeV/u α-particles
1 MeV/u C ions
10 nm
NUCLEOSOME
CHROMATIN FIBRE
(~ 25 nm diameter)
HISTONES
DNA (~ 2 nm diameter)


Stochastic effects relevant
Dose not well defined
Stochastic effect not very relevant
Dose well defined
ΔE/Δm
Log Δm