Radioprotection advanced example

Modifications for ease of use and microdosimetric application

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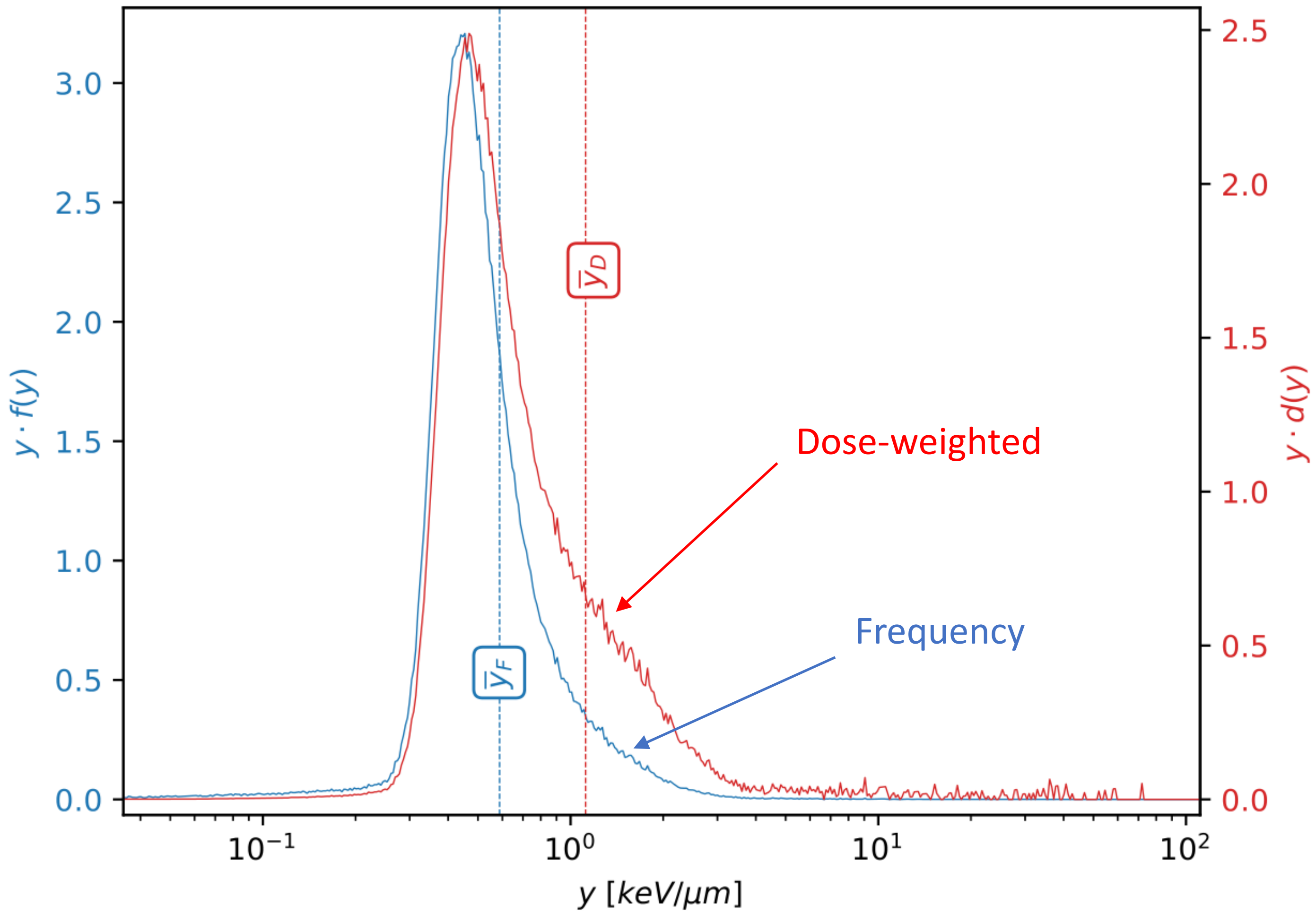
About microdosimetry

- stochastic approach
- lineal energy: $y = \frac{\varepsilon}{\bar{l}}$
  - ε → <u>single-interaction</u> 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

- already built around microdosimetric detector

  however

- focussed on space applications

  we need a clinical setup

- unwieldy to modify

  a user needs to be familiar with C++ and Geant4 just to change the position and size of the detector!

Initial changes already added to the official repo

- addition of two new detectors

  ease of use as a goal: only macro commands needed to switch detector

  no change to C++ code

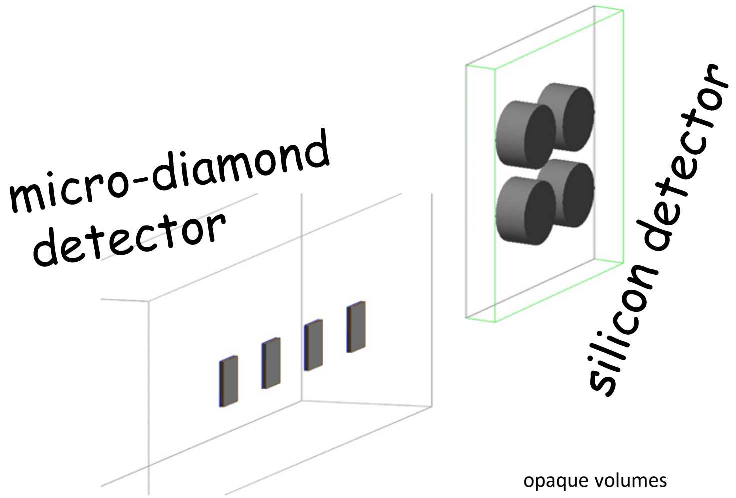
- scoring of microdosimetric quantities

  collection of ε and l for each event

- no data analysis in C++

  the Geant4 program merely collects stochastic quantities for each even

  to obtain the spectrum: separate Python program →



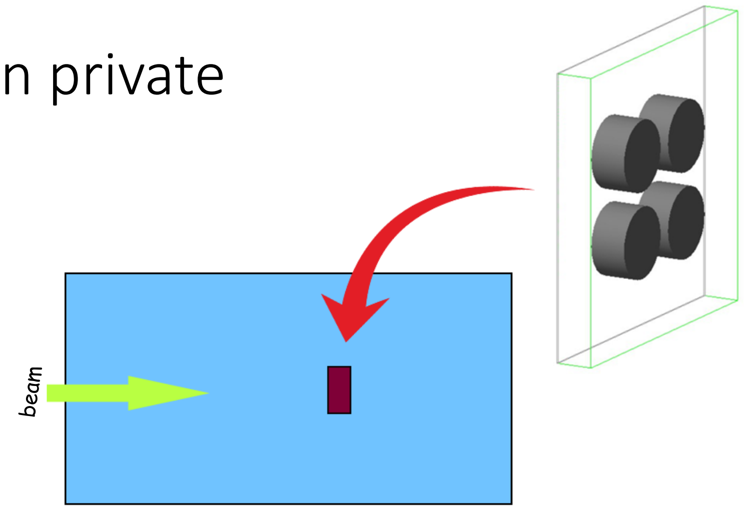
opaque volumes are sensitive

- easy to read and modify for third parties
- speed penalty not significant in this step
- pretty plots w/ Matplotlib

Further changes already implemented in private

- (optional) use of water phantom

  the detector can be simulated either in vacuum or in a water phantom



- macro controls

  relevant parts of the geometry (detector size, SV count, depth in water phantom) can be changed via macro

  - most use cases can simulated without touching the source code
  - allows running hundreds of jobs in parallel to test different parameters

- higher precision only in the inner area

  microdosimetry requires sub-µm cuts

  only applied in the vicinity of the detector, higher elsewhere

validated against similar published Geant4 simulations

Bolst et al. 2019

Further changes to be implemented / WIP

- implementation of two-stage telescope detector

  almost done in Geant4

  some work to be done for its data analysis

- tracking of parent particle

  most of the energy is deposited by secondary, tertiary, etc electrons

  can we trace them back to the last hadron that caused the ionisation?

- additional controls over region-based cuts

  most of this has already been implemented via macros on recent Geant4 releases

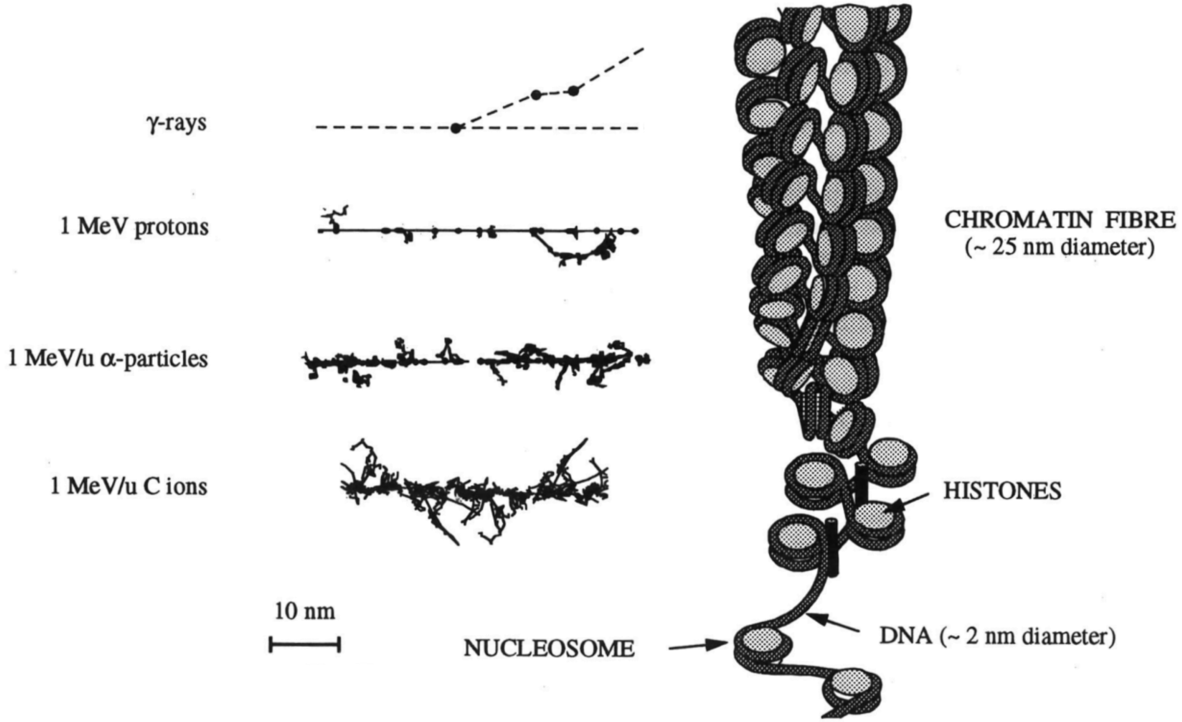
  there appears to be some issue when applying them to the inner region while changing geometry

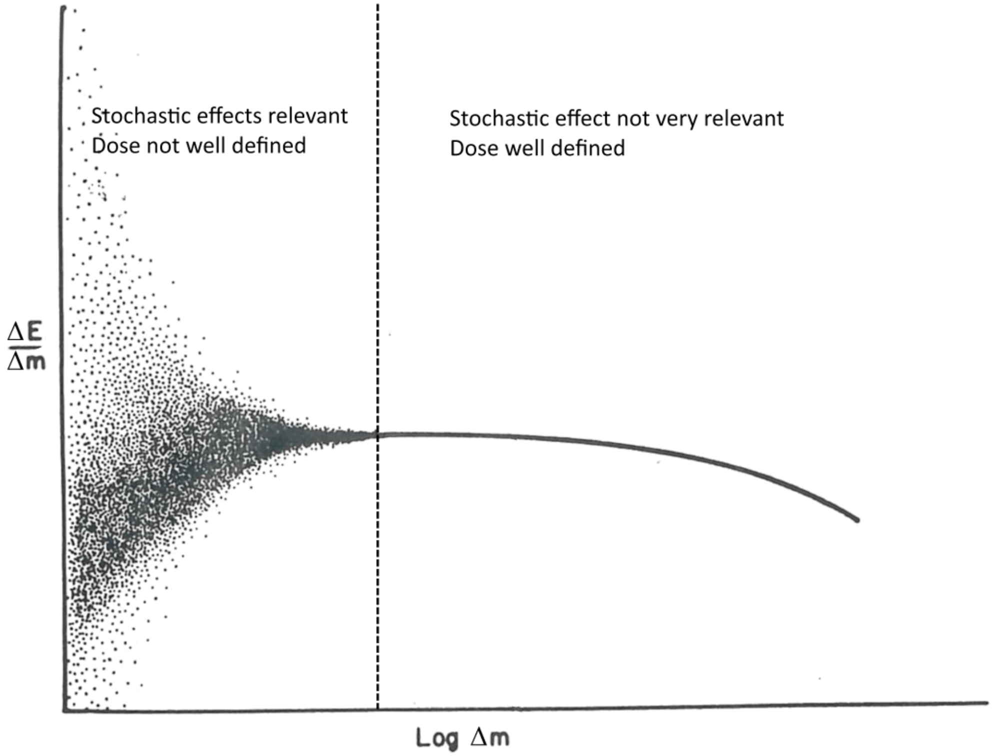
  more test needed

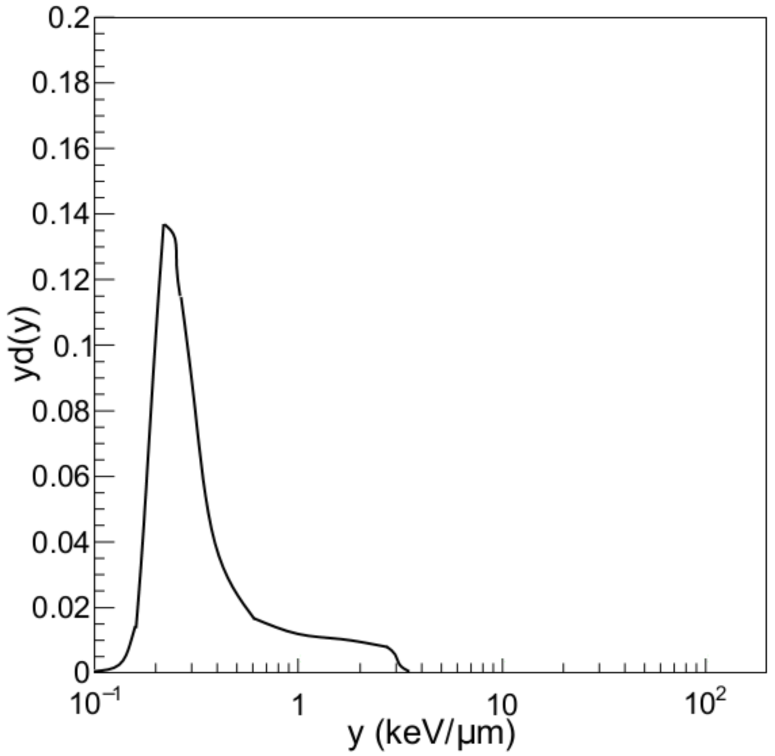
完

the end

Backup slides

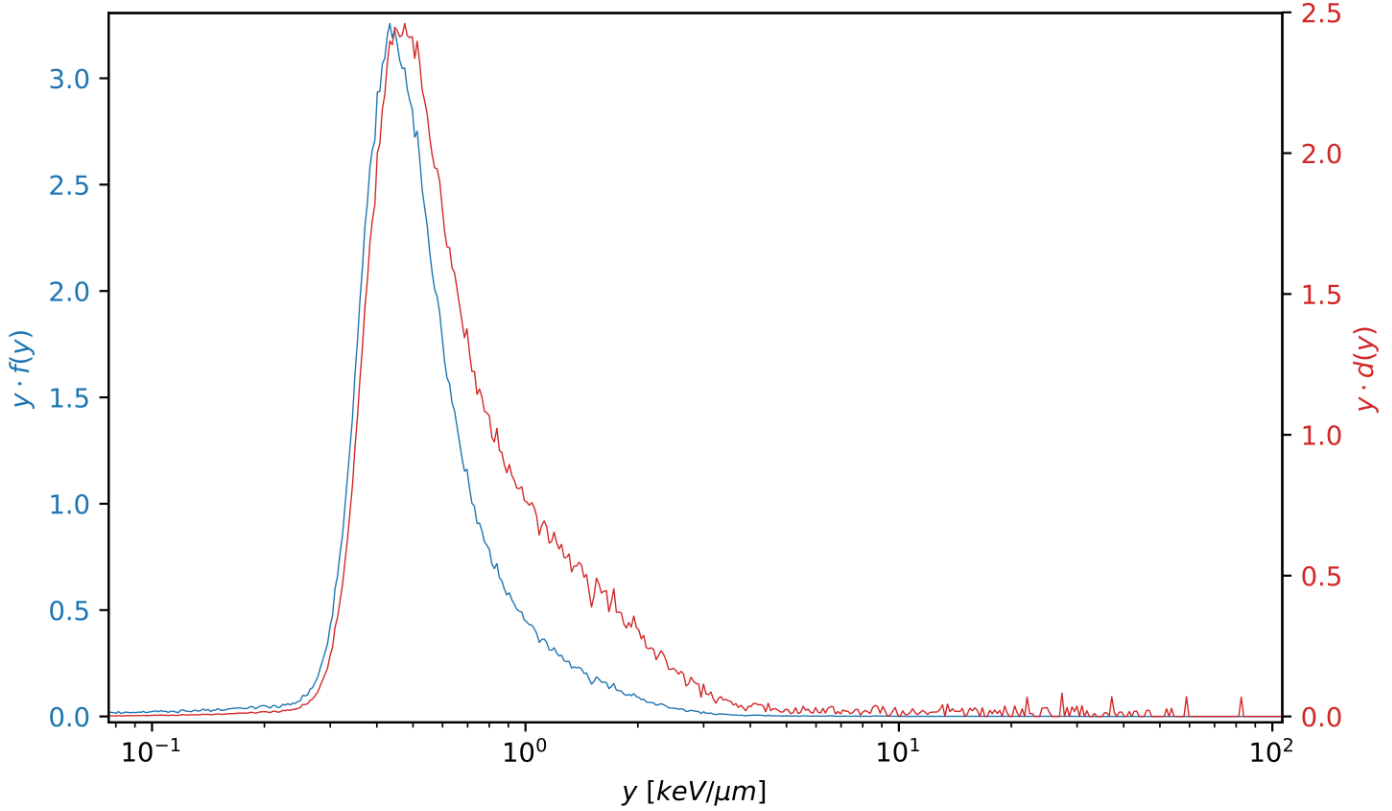

γ-rays
1 MeV protons
1 MeV/u α-particles
1 MeV/u C ions
10 nm
NUCLEOSOME
CHROMATIN FIBRE
(~ 25 nm diameter)
HISTONES
DNA (~ 2 nm diameter)


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

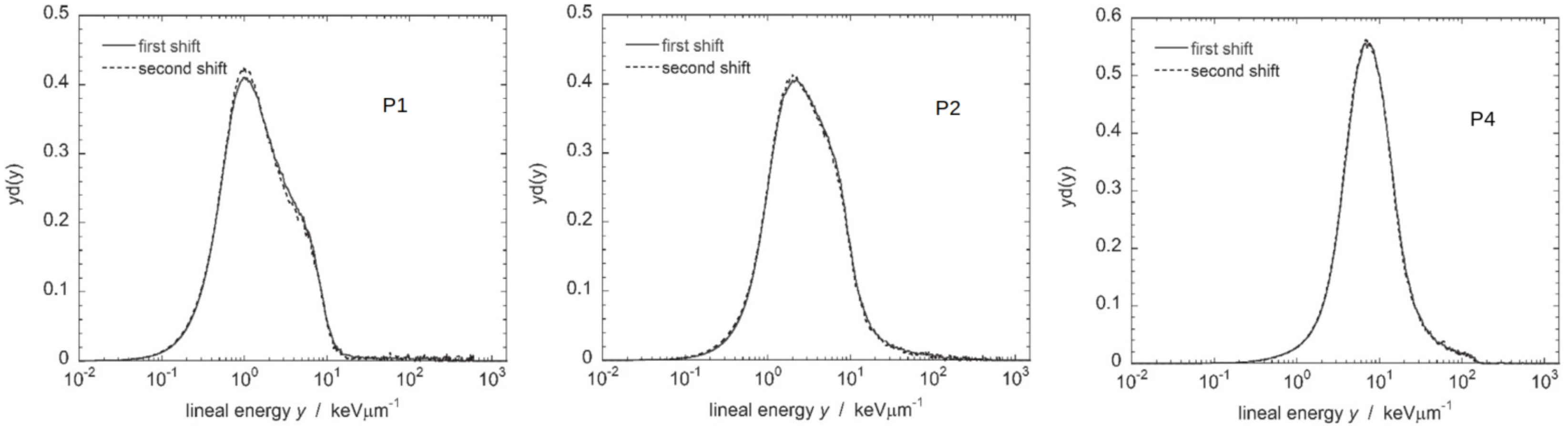


Bolst et al. 2019

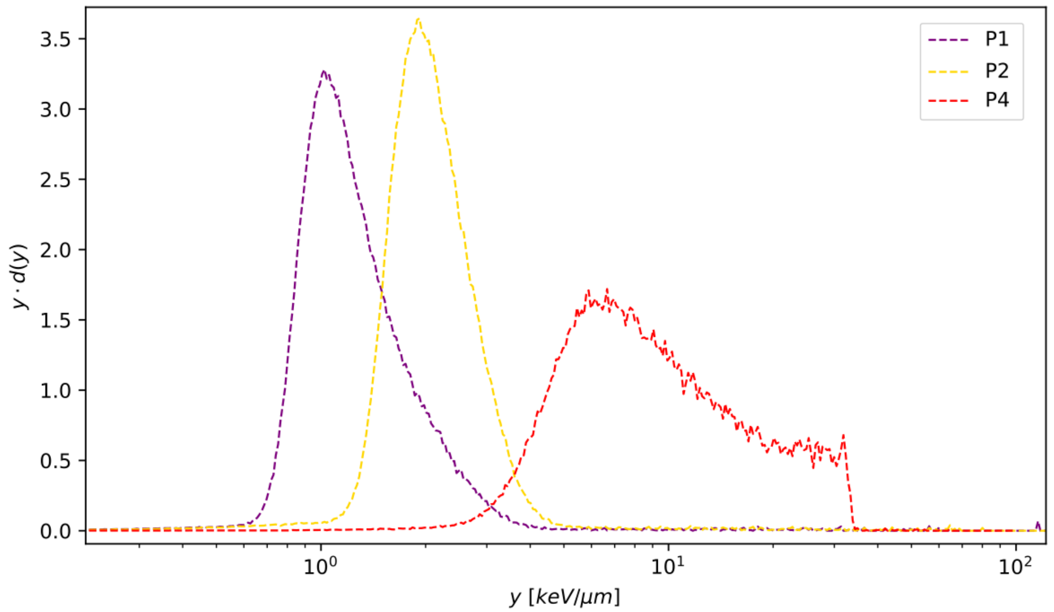
Simulated monoenergetic
proton beam



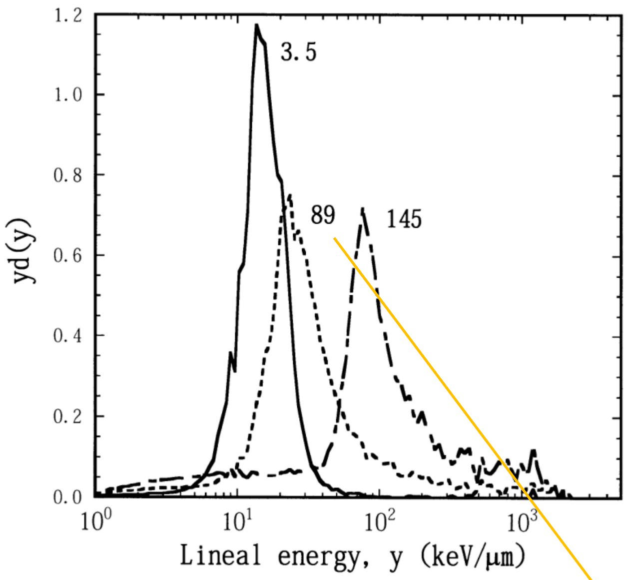
Measurements from paper with CATANA 62MeV proton SOBP



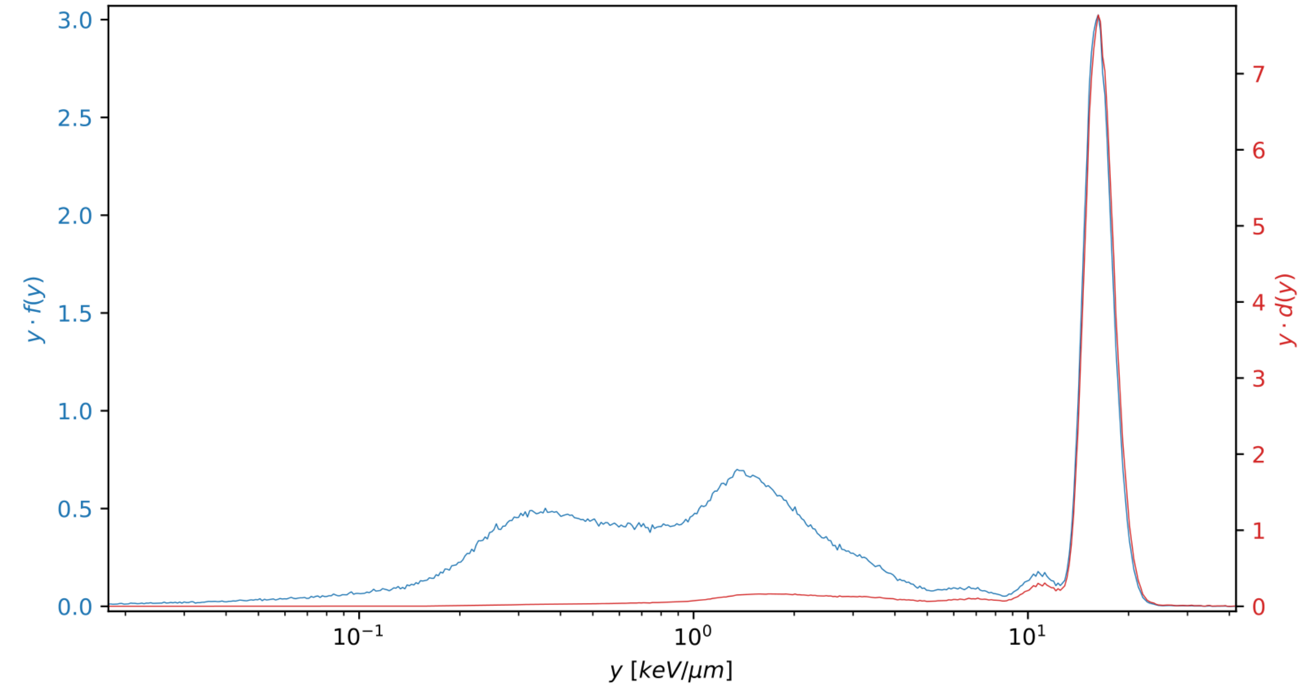
Conte et al. 2019

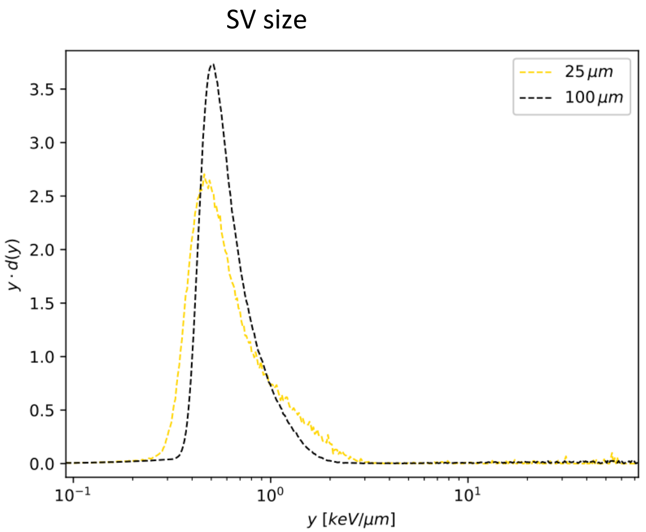


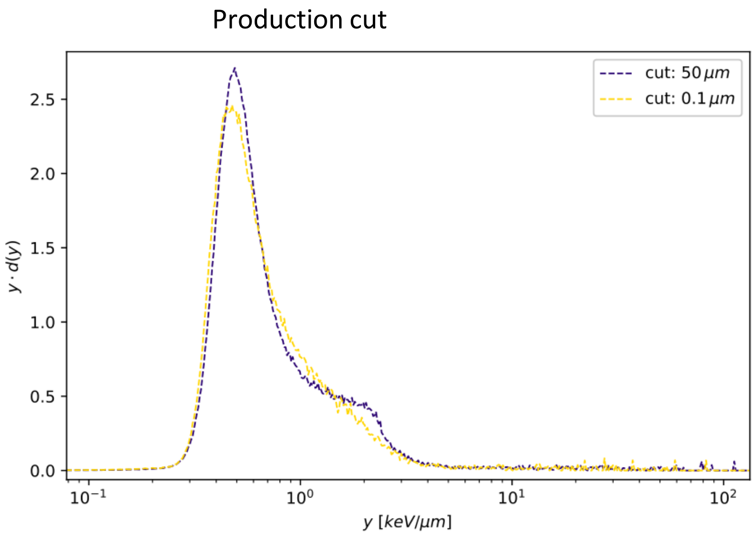
Simulated 290MeV/c carbon SOBP

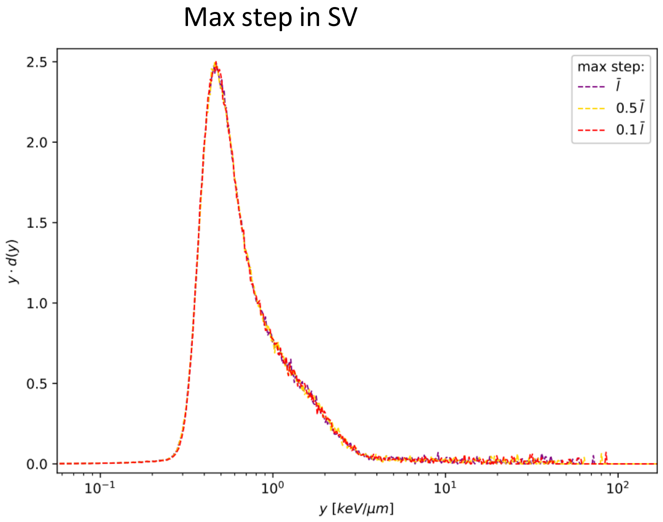


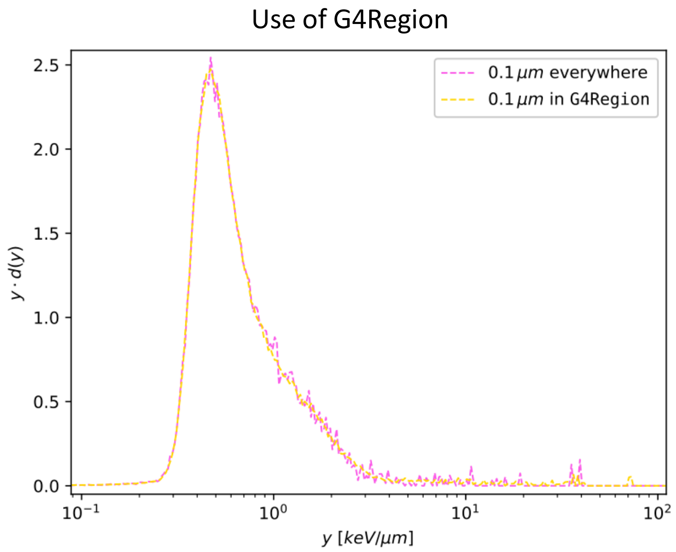
Kase et al. 2006

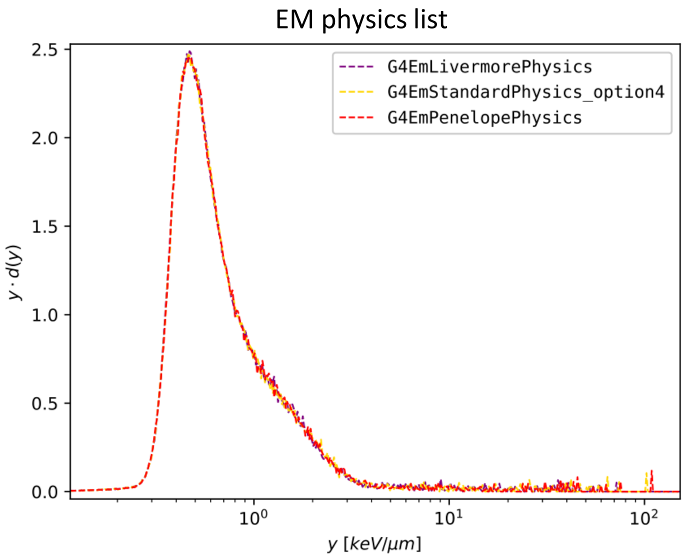



SV size
25 μm
100 μm
y · d(y)
y [keV/μm]


Production cut
cut: 50 μm
cut: 0.1 μm
y · d(y)
y [keV/μm]


Max step in SV
max step:
l̄
0.5 l̄
0.1 l̄
y · d(y)
y [keV/μm]


Use of G4Region
0.1 μm everywhere
0.1 μm in G4Region
y · d(y)
y [keV/μm]


EM physics list
G4EmLivermorePhysics
G4EmStandardPhysics_option4
G4EmPenelopePhysics
y · d(y)
y [keV/μm]