ACCURATE MODELLING OF TRACK LENGTH DISTRIBUTIONS WITH SRIM/TRIM

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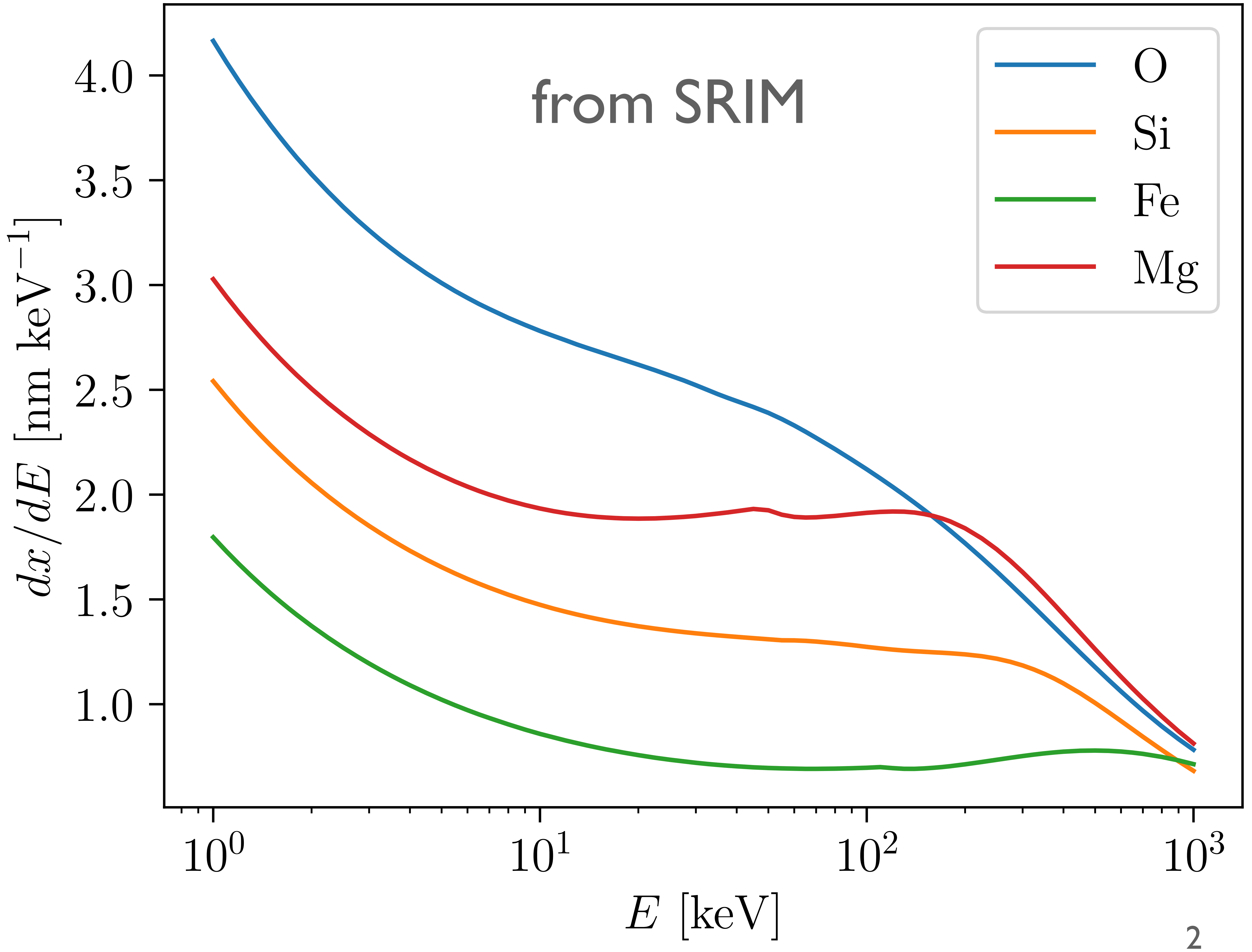
MOTIVATIONS

$$\frac{dR}{dx} = \frac{dR}{dE} \times \left|\frac{dx}{dE}\right|^{-1}$$

Energy spectrum of the incoming particle

stopping power of the target

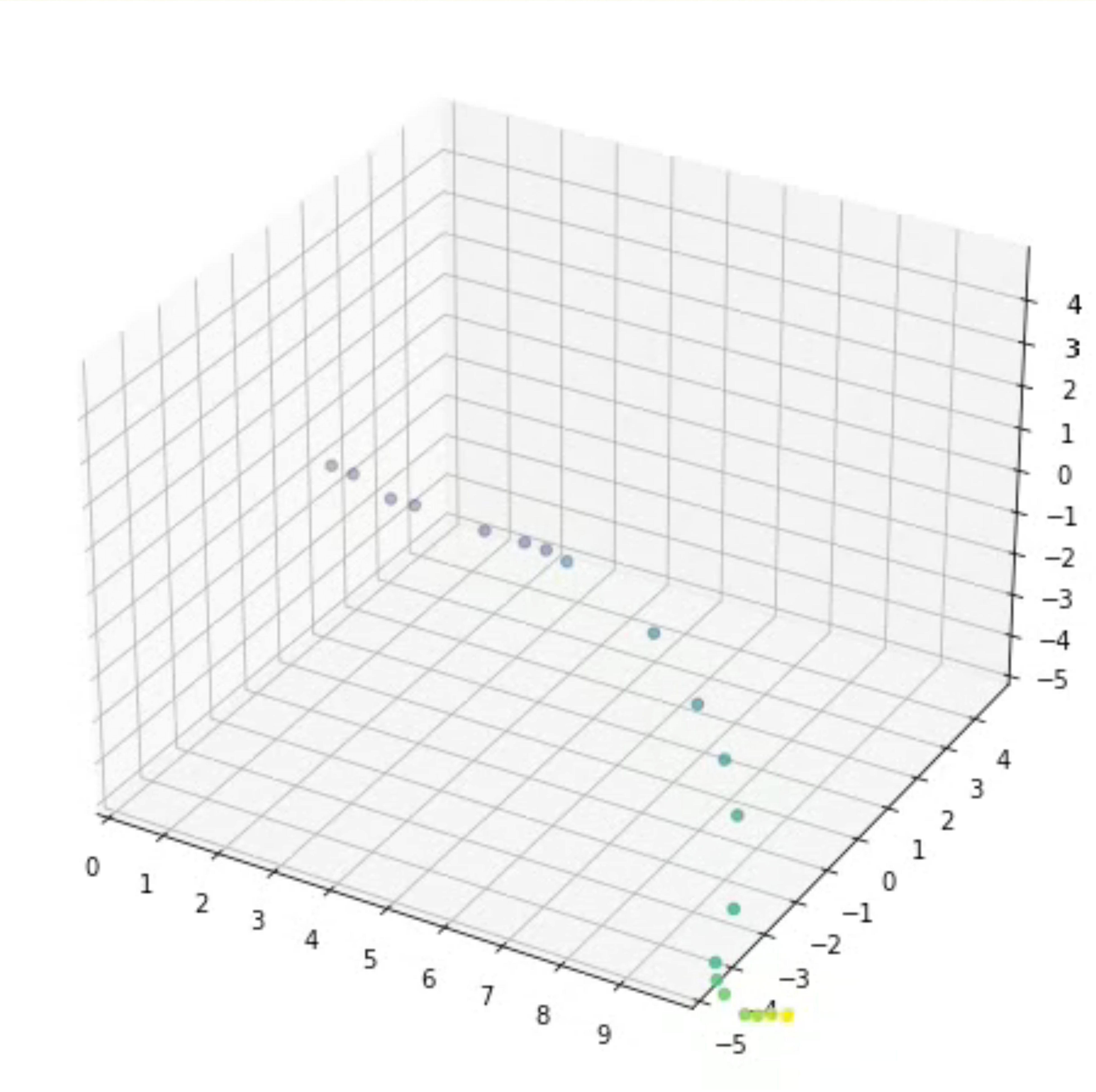
- Stopping power is a statistical average
- Ions of a given recoil energy could give rise to a distribution of track lengths



TRACK LENGTH DISTRIBUTION MODELLING WITH SRIM/TRIM

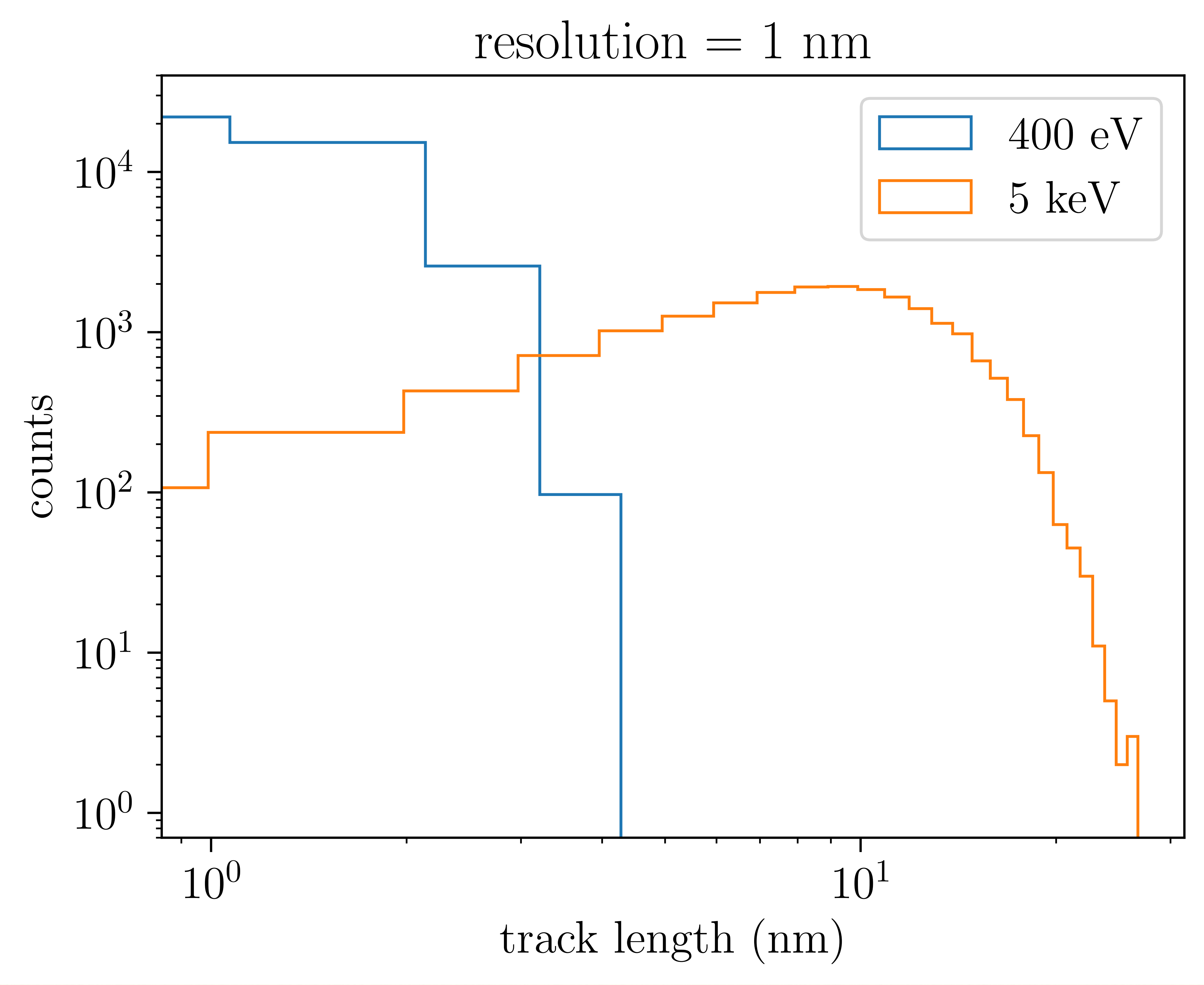
TRIM (TRANSPORT OF IONS IN MATTER)

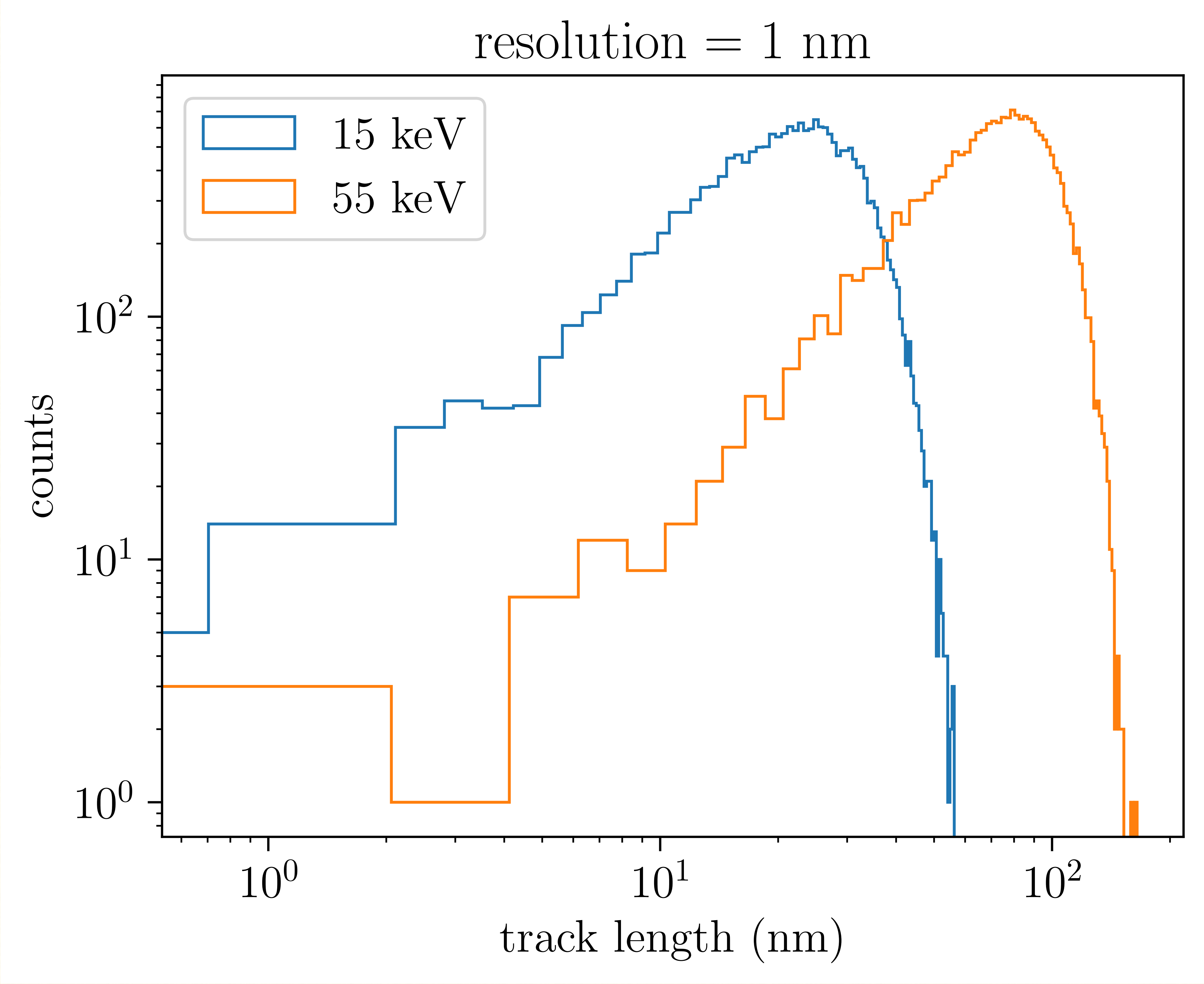
- a Monte Carlo program that calculates interatctions of ions with amorphous targets
  - simulates cascades of produced by irradiated ions
  - record the locations of all collisions between irradiated ions and target atoms
- e.g. irradiate a 5keV ion onto Olivine 200 times



- 5 keV proton
- with Si in Olivine

TRACK LENGTH DISTRIBUTION OF Si IN OLIVINE $(Mg, Fe)_2\ SiO_4$



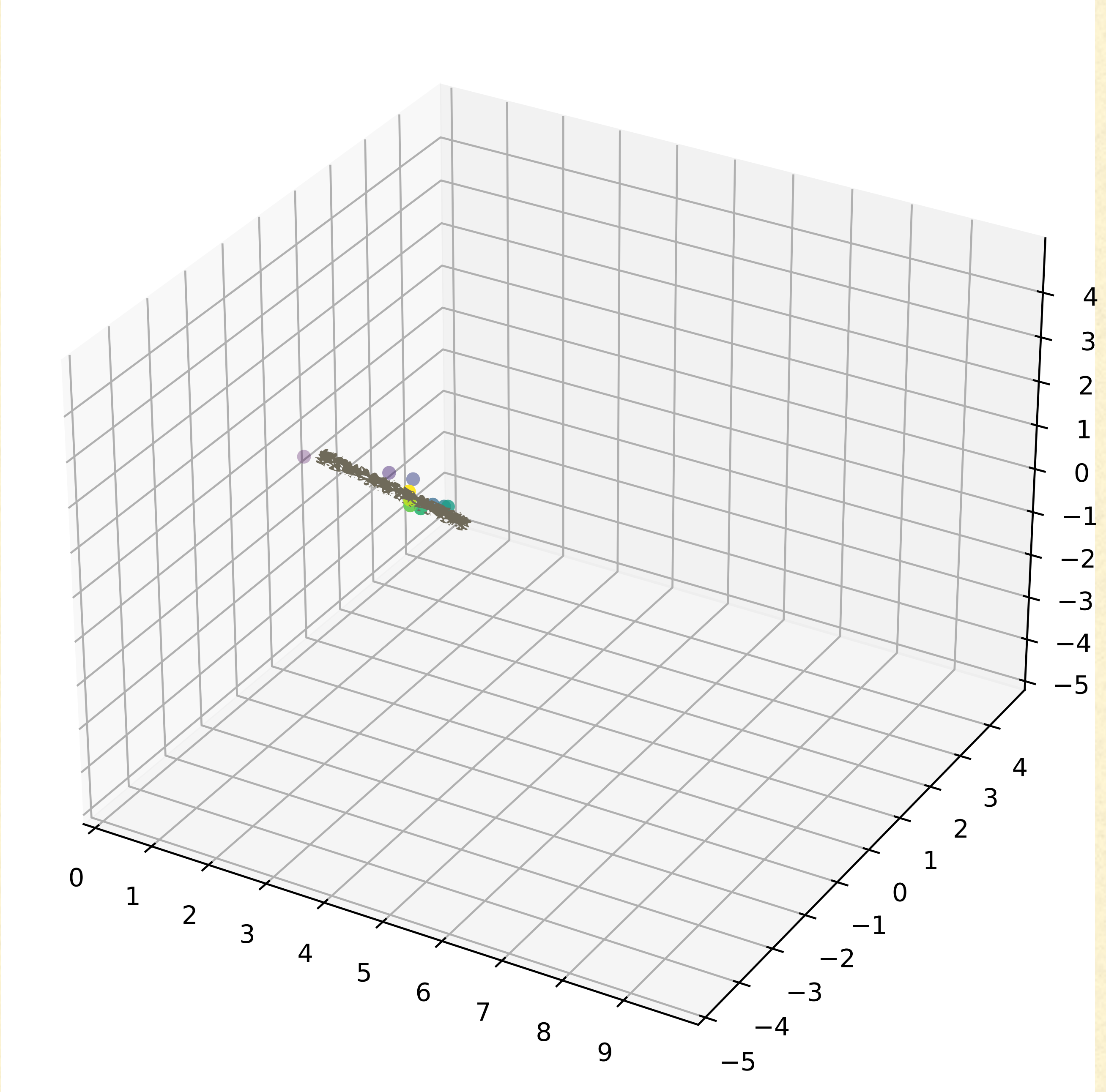


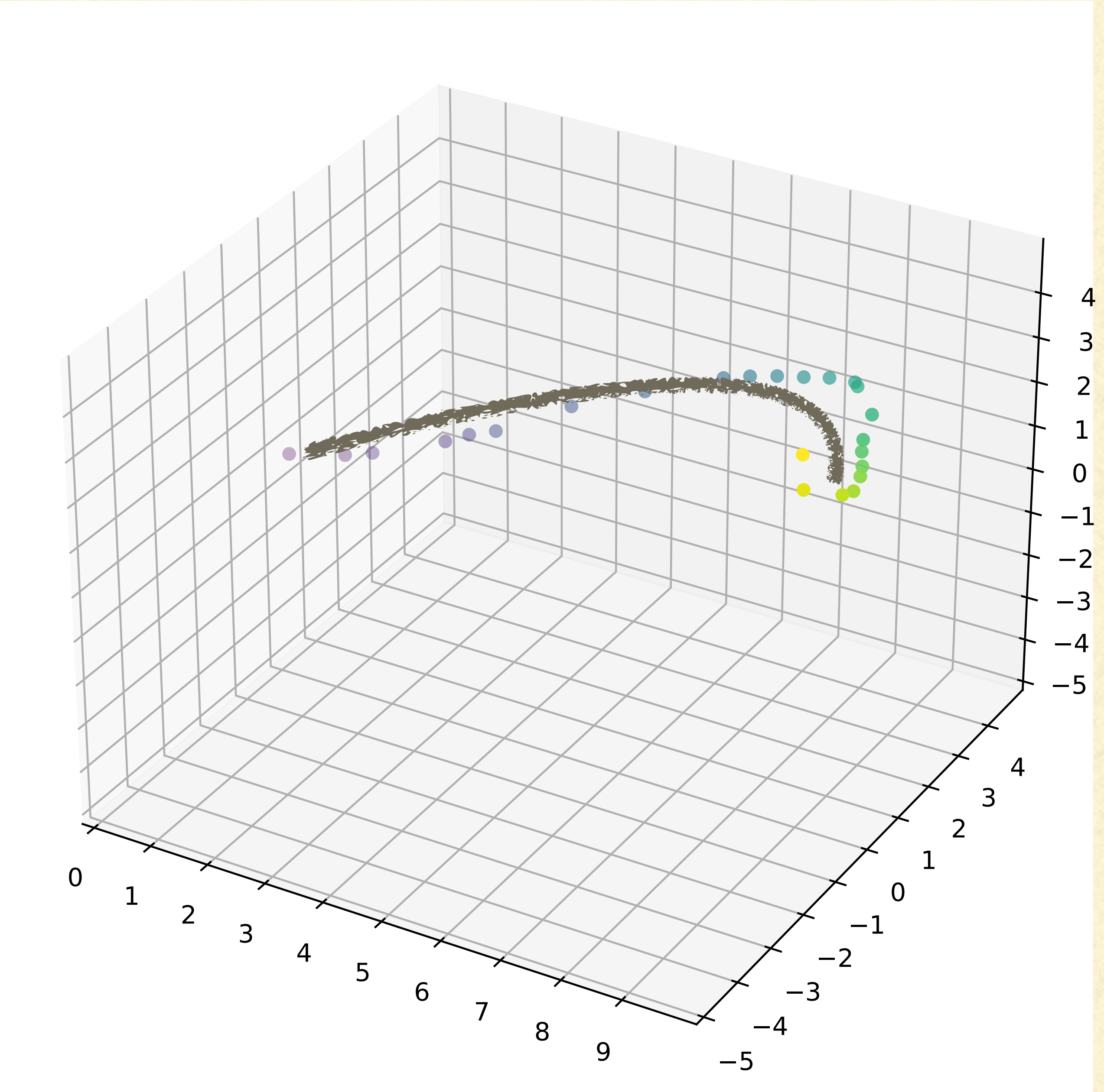
COMPUTING dR/dx

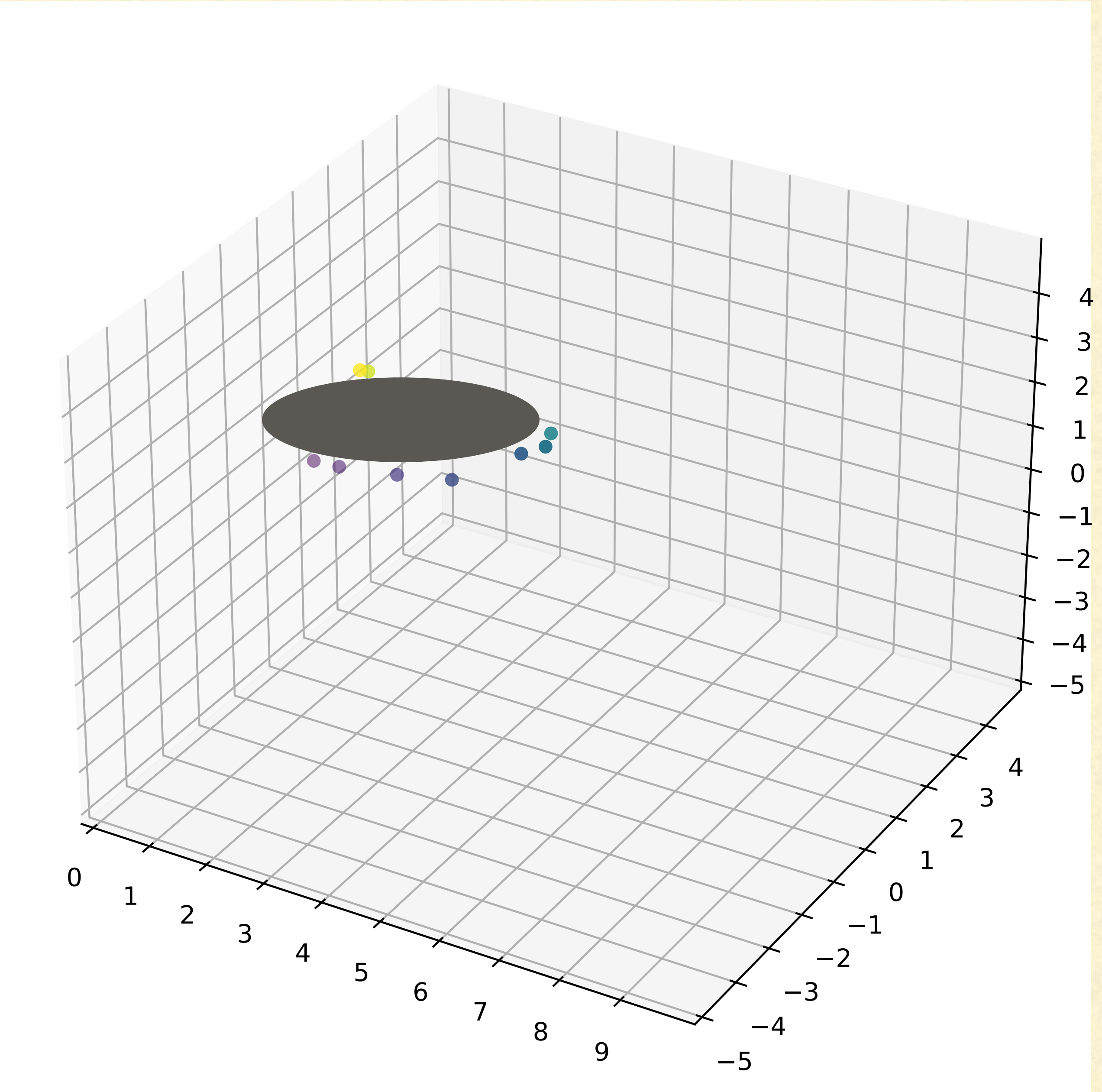
- $\frac{dR}{dx} = \frac{dR}{dE} \times |\frac{dx}{dE}|^{-1}$
- $\frac{dR}{dx}(x) = \int dE_R \frac{dR}{dE_R}(E_R)\mathscr{P}(E_R|x)$

- $\mathscr{P}(E_R|x)$: the probability that a track length x is induced by a recoil with energy E_R

DEFINING TRACK LENGTH



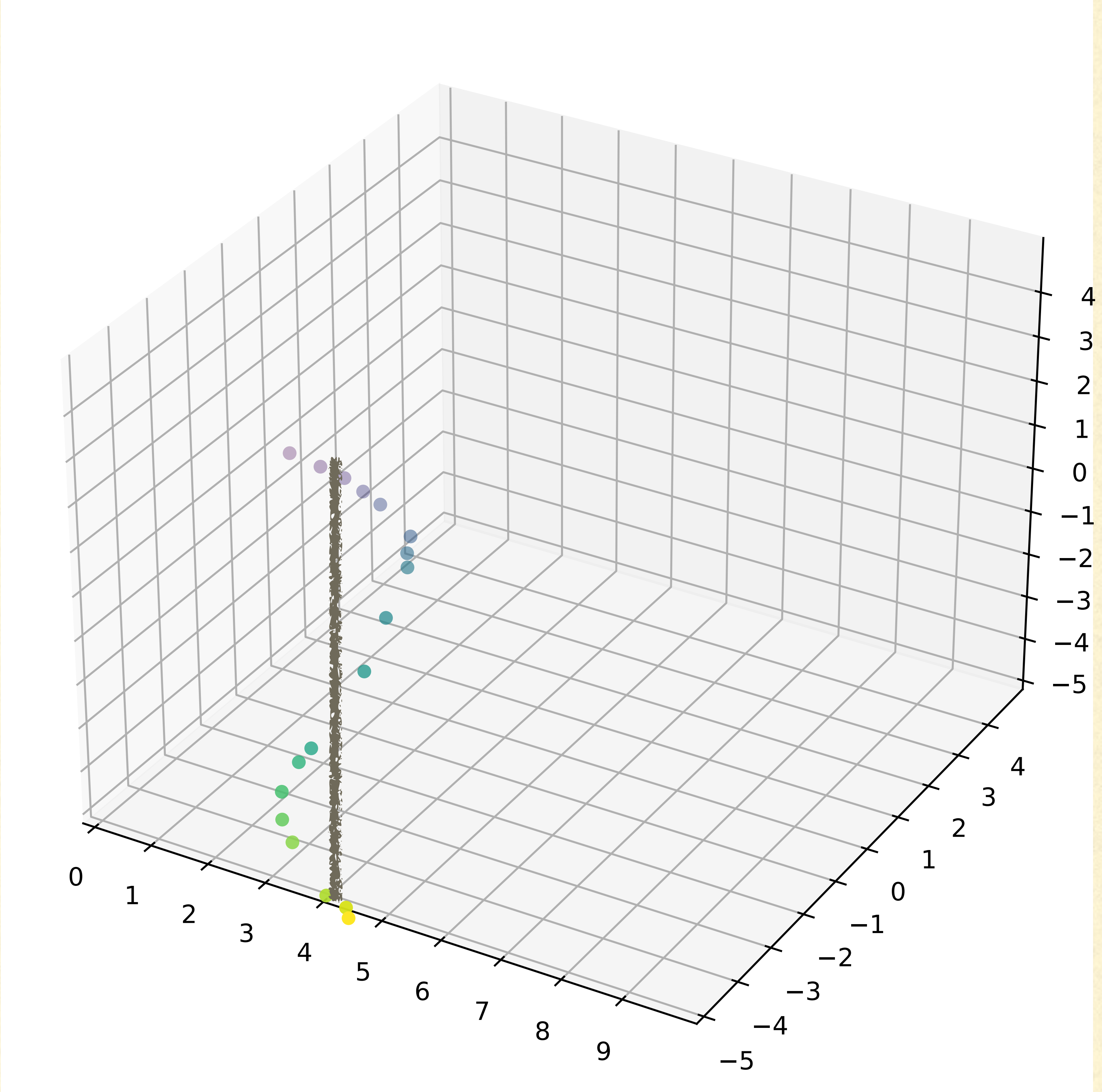


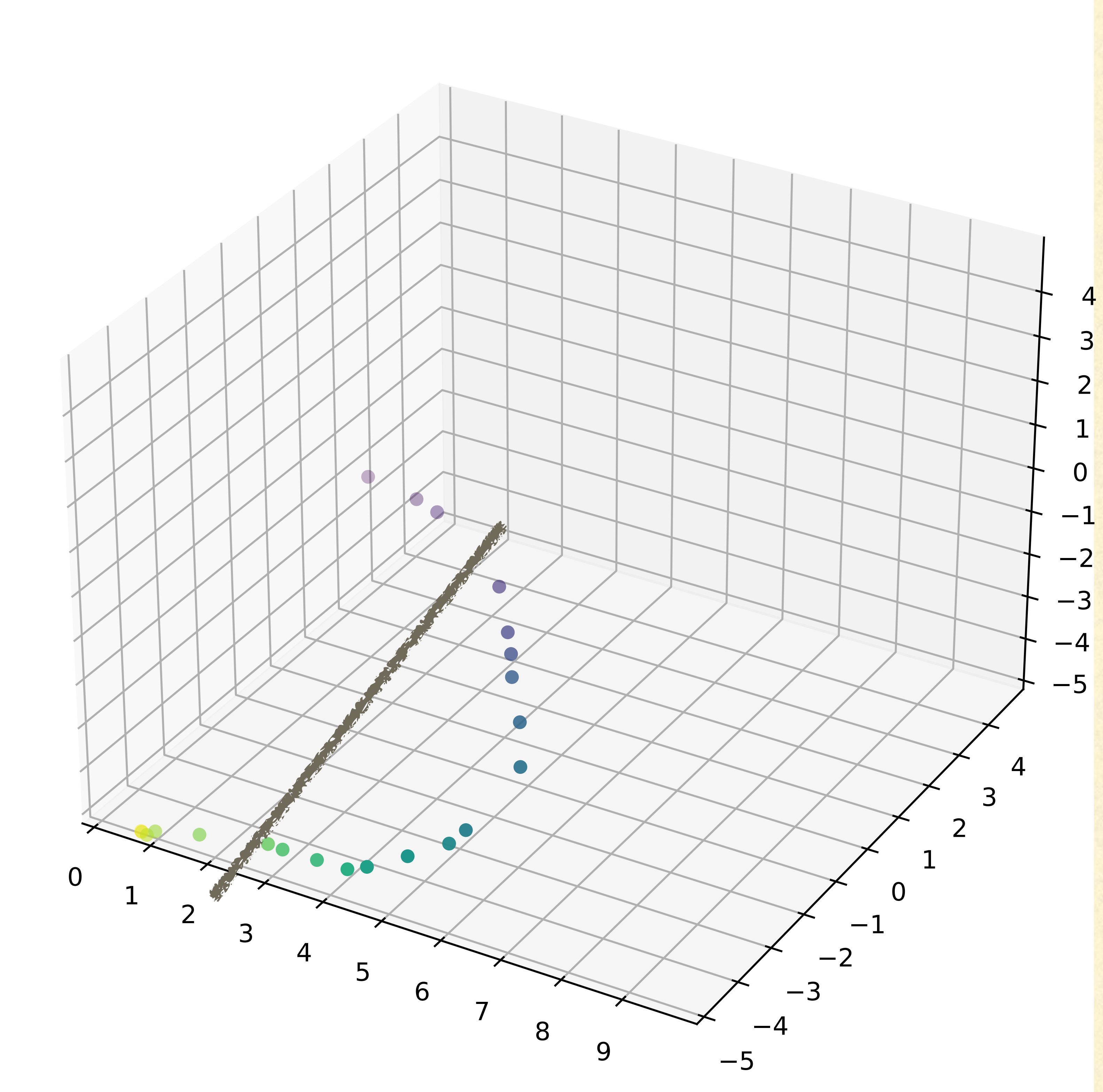


PRINCIPAL COMPONENT ANALYSIS (PCA)

- decomposing multivariate data (i.e. spatial coordinates) into principal components
- principal components: eigenvectors of the covariance matrix
- first component: eigenvector with maximum variance
- track length ≡ projected length along first component

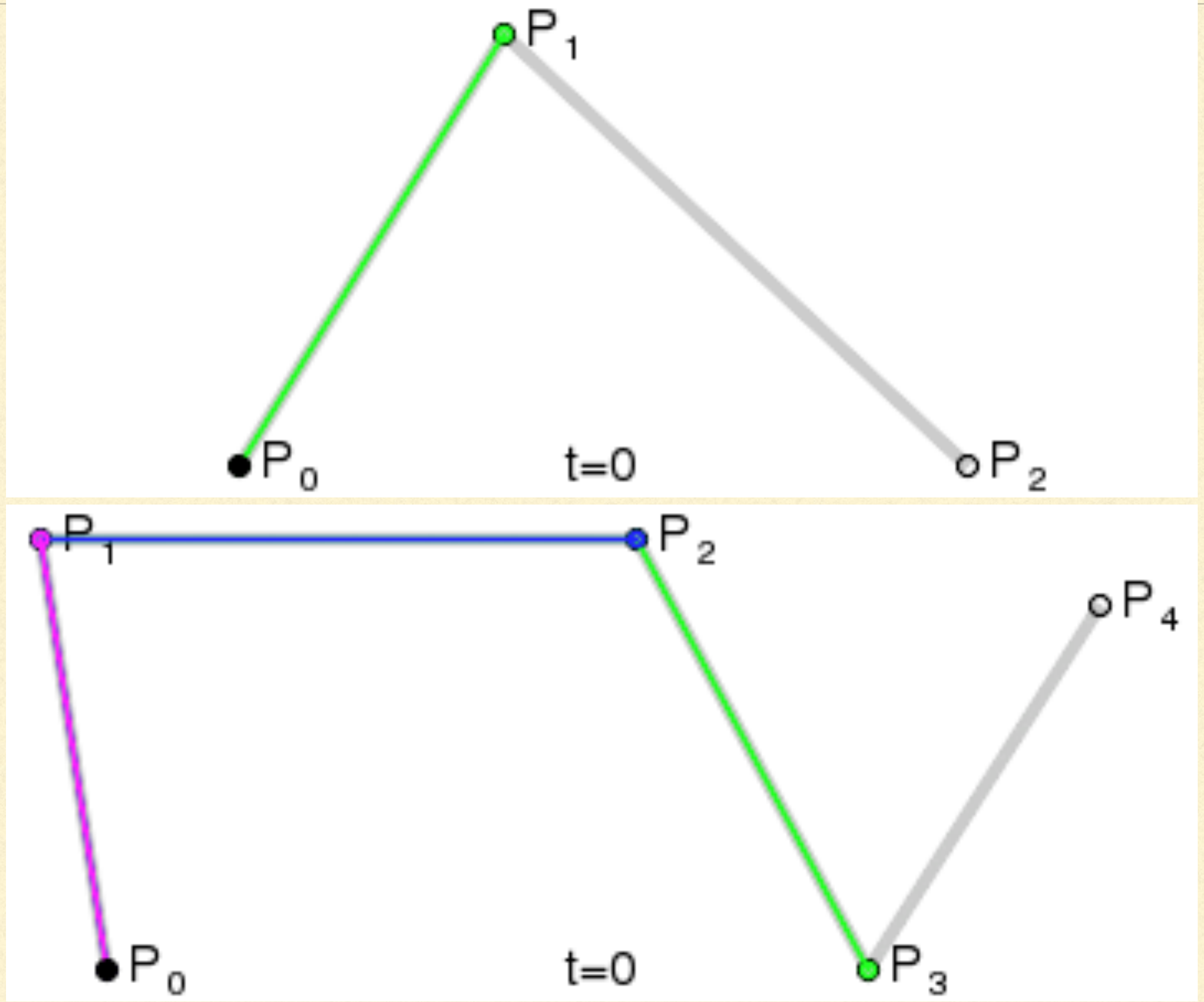
PRINCIPAL COMPONENT ANALYSIS



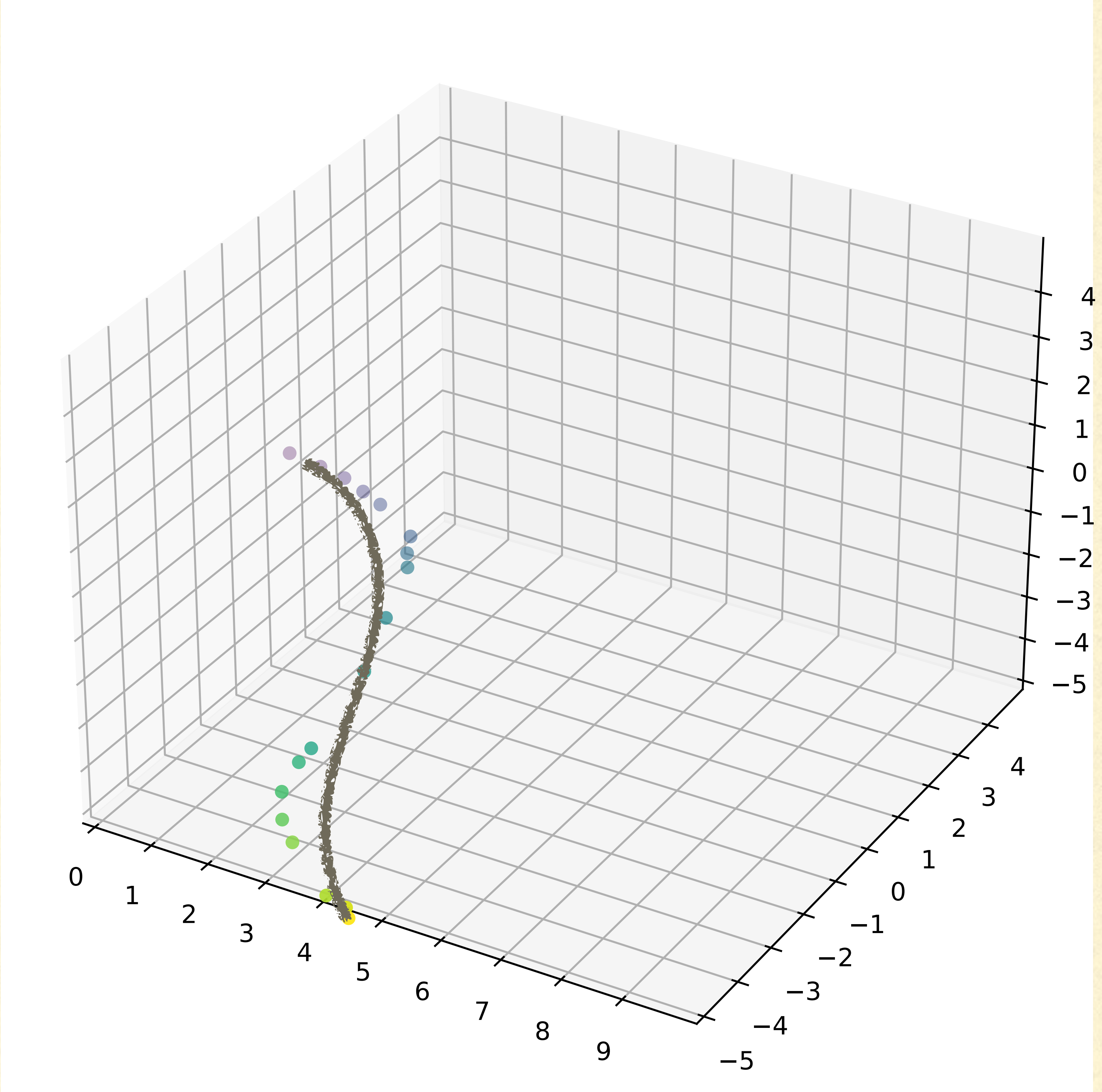


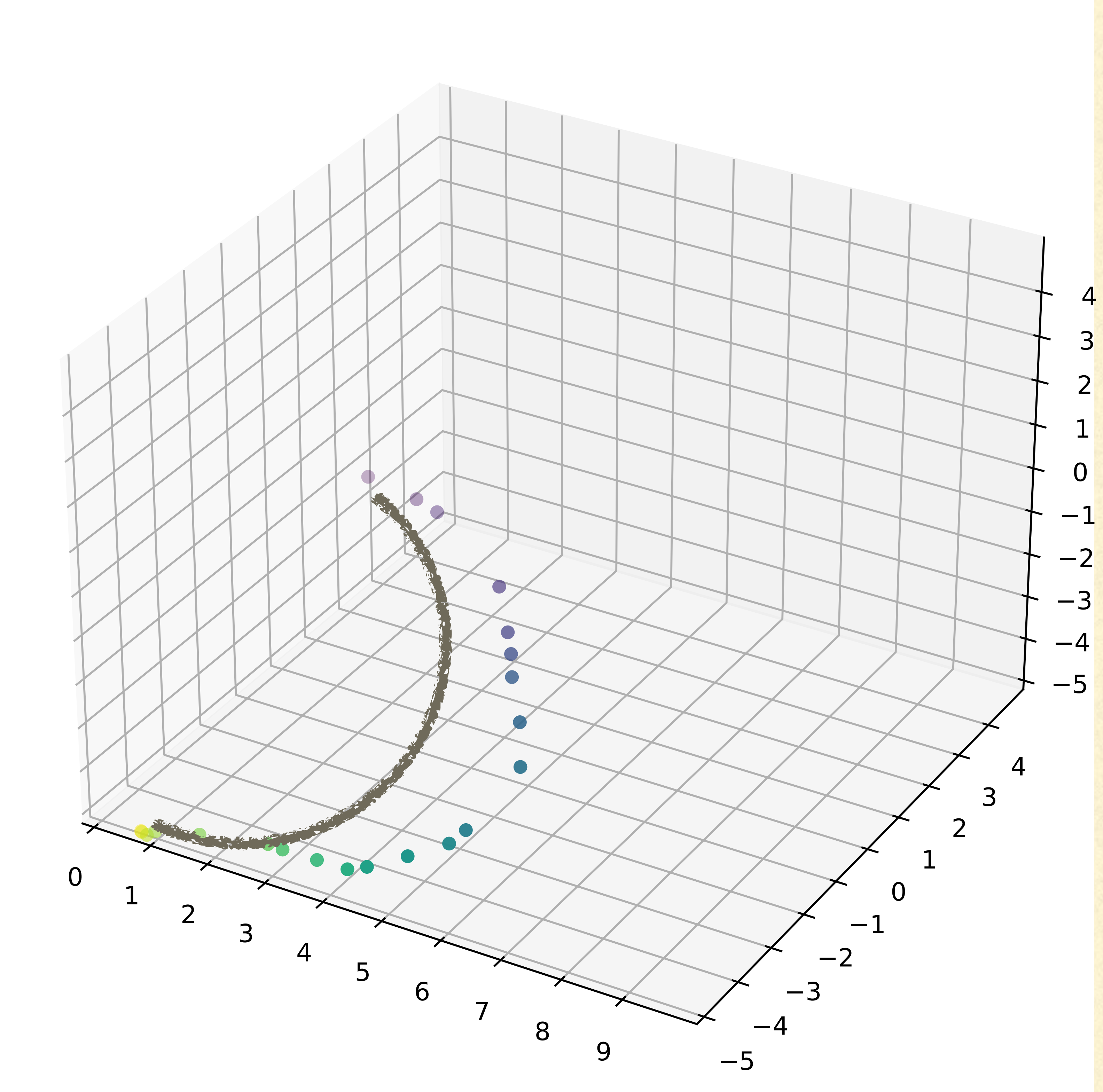
BEZIER CURVE FITTING

- defined by control points
- $\mathbf{B}(t) = \mathbf{P}_0 + t(\mathbf{P}_1 - \mathbf{P}_0),\ 0 \le t \le 1$
- better fits to arbtirary geometric features
- controllable resolution

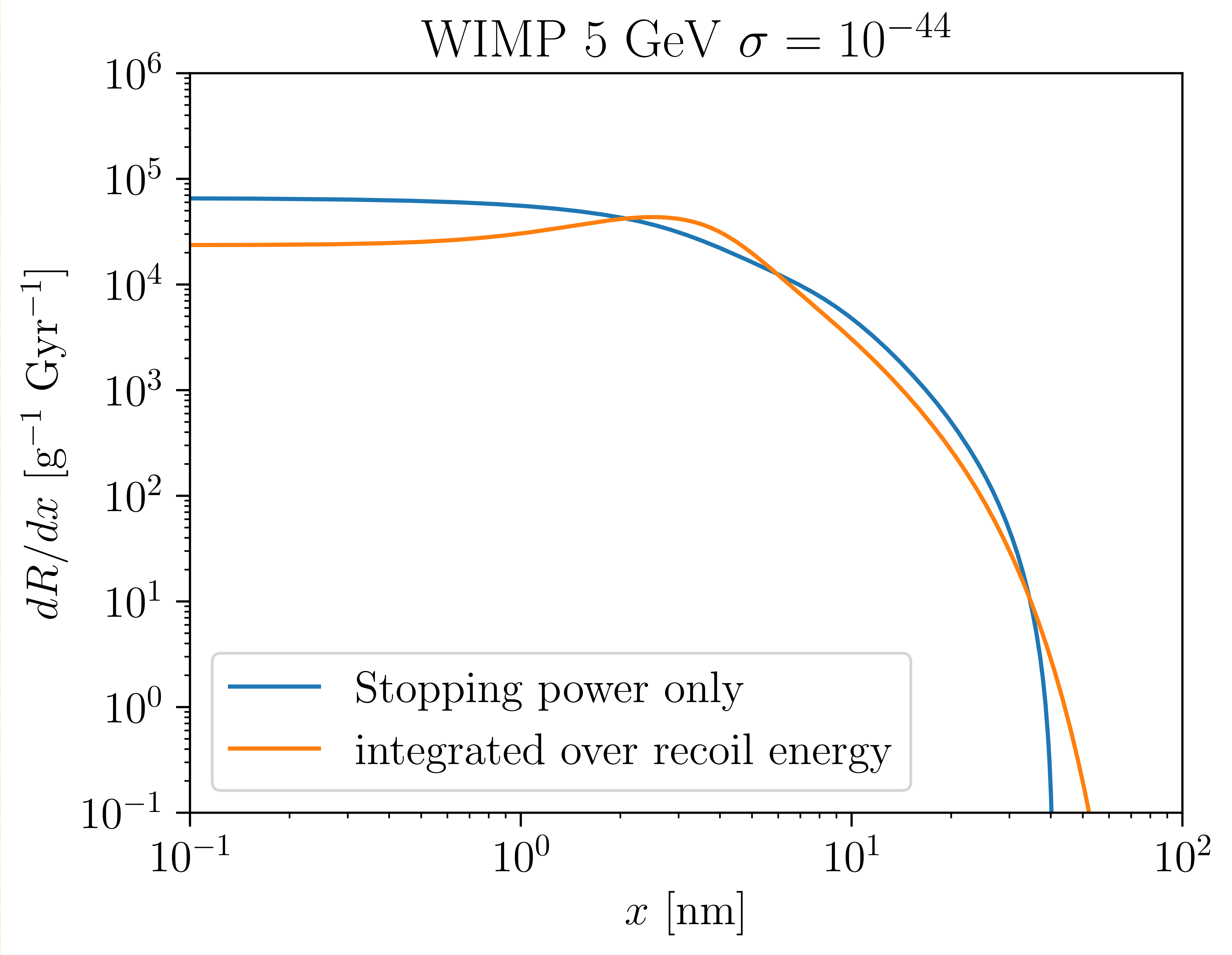


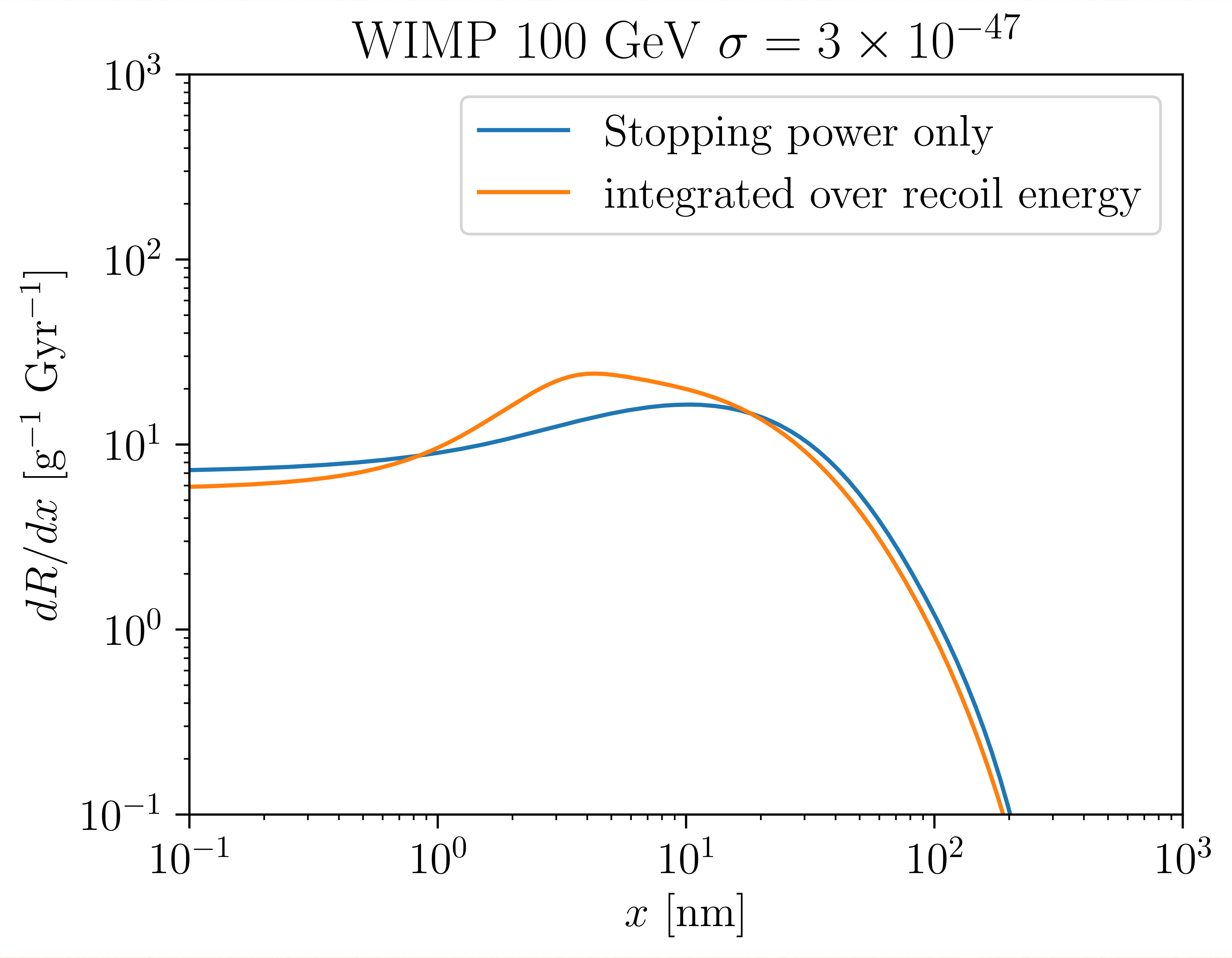
BEZIER CURVE FITTING





RECOIL SPECTRA COMPARISON



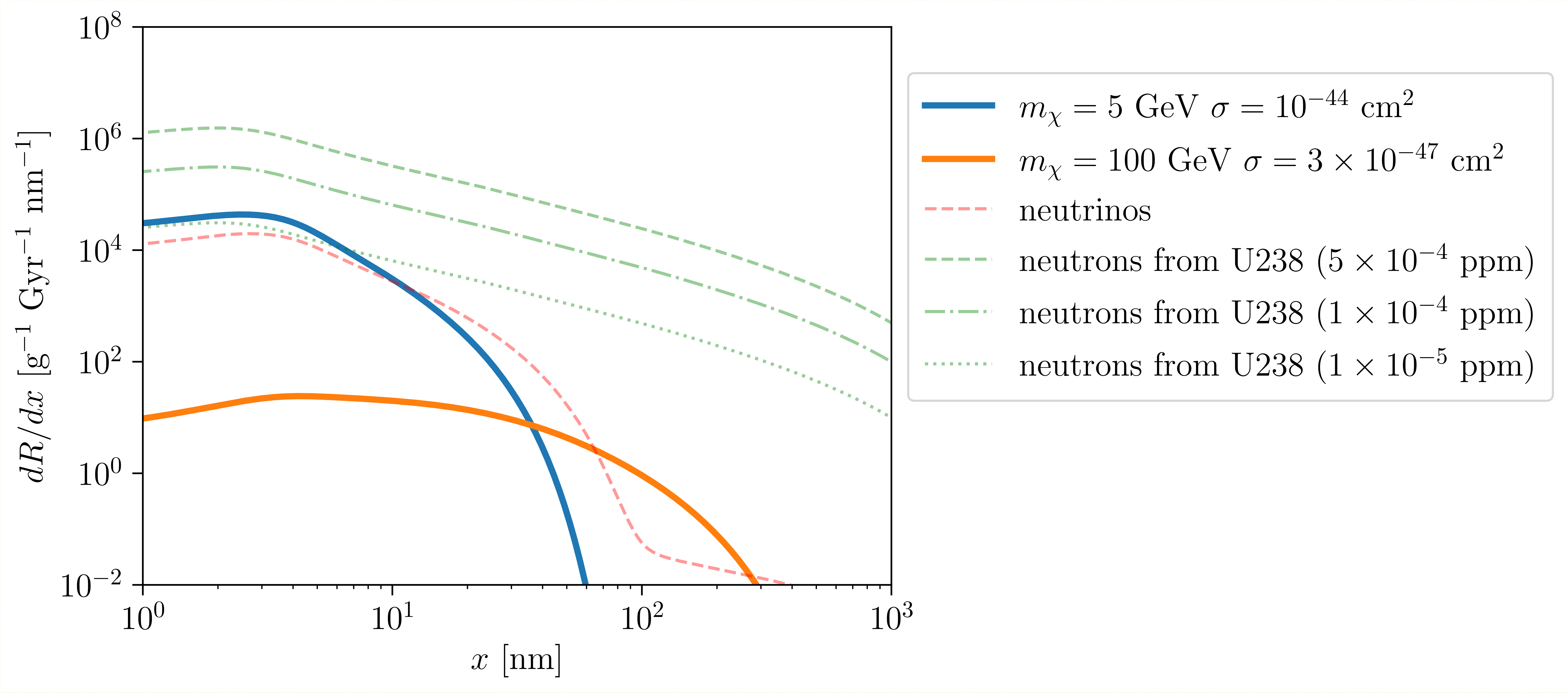


TESTING NEW PHYSICS WITH PALEO DETECTORS

BACKGROUNDS

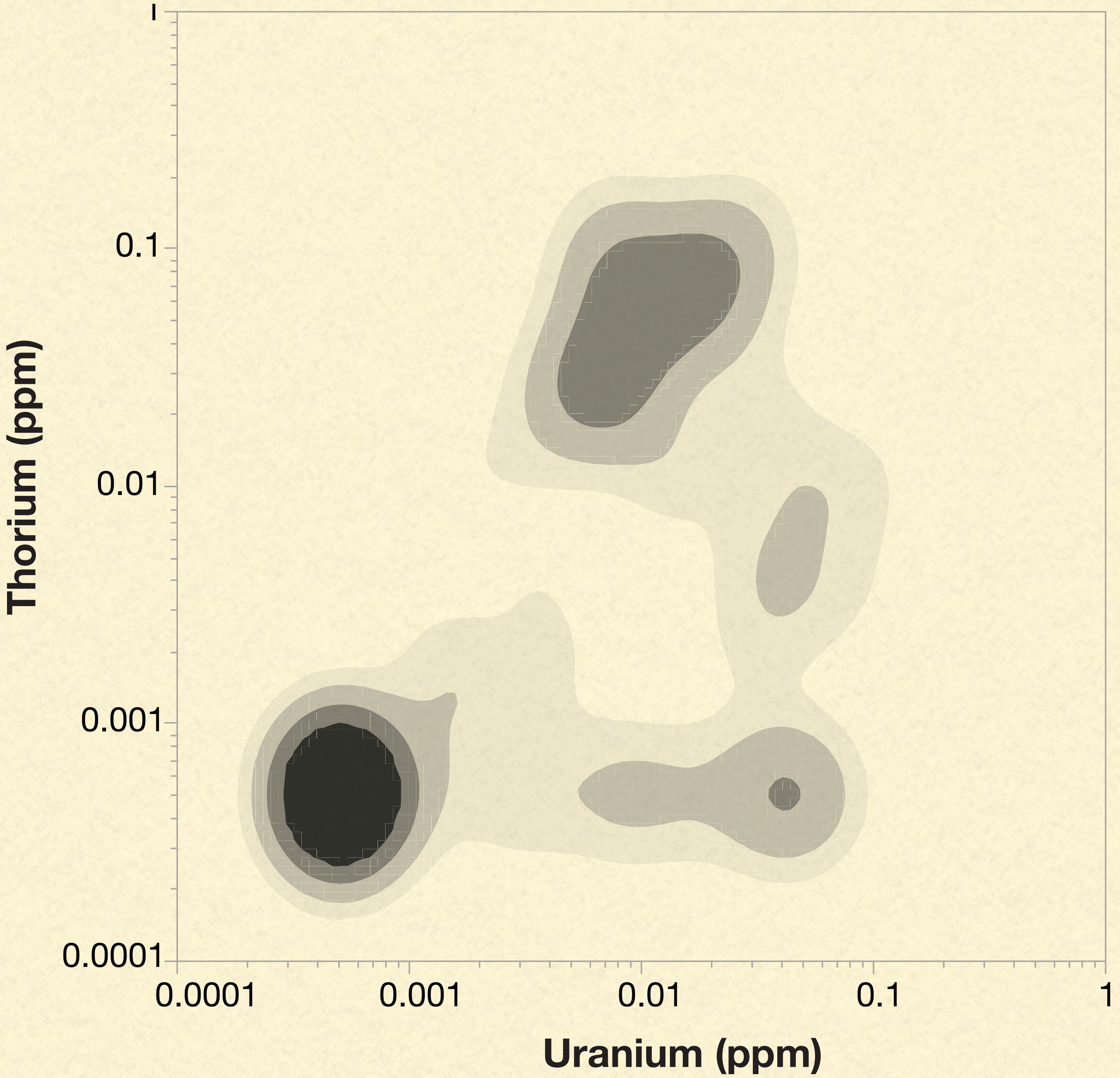
- solar neutrinos
- atmospheric neutrinos
- diffuse supernova neutrino background
- neutrons from ^{238}U

WIMPS

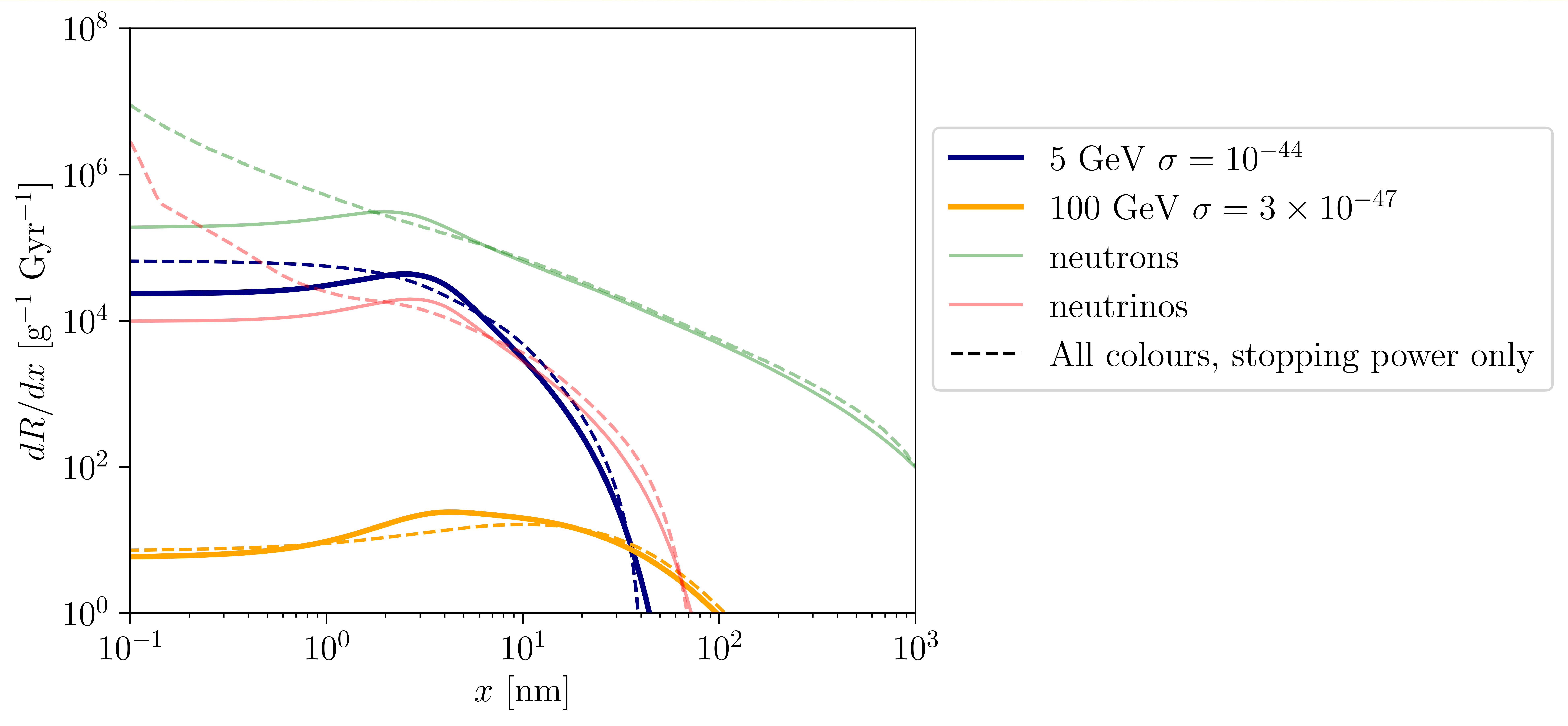

10^8
10^6
10^4
10^2
10^0
10^{-2}
dR/dx [g^{-1} Gyr^{-1} nm^{-1}]
10^0
10^1
10^2
10^3
x [nm]
$m_\chi = 5$ GeV $\sigma = 10^{-44}$ cm^2
$m_\chi = 100$ GeV $\sigma = 3 \times 10^{-47}$ cm^2
neutrinos
neutrons from U238 (5×10^{-4} ppm)
neutrons from U238 (1×10^{-4} ppm)
neutrons from U238 (1×10^{-5} ppm)

URANIUM CONCENTRATION IN OLIVINE

- detection threshold at 5×10^{-4} ppm

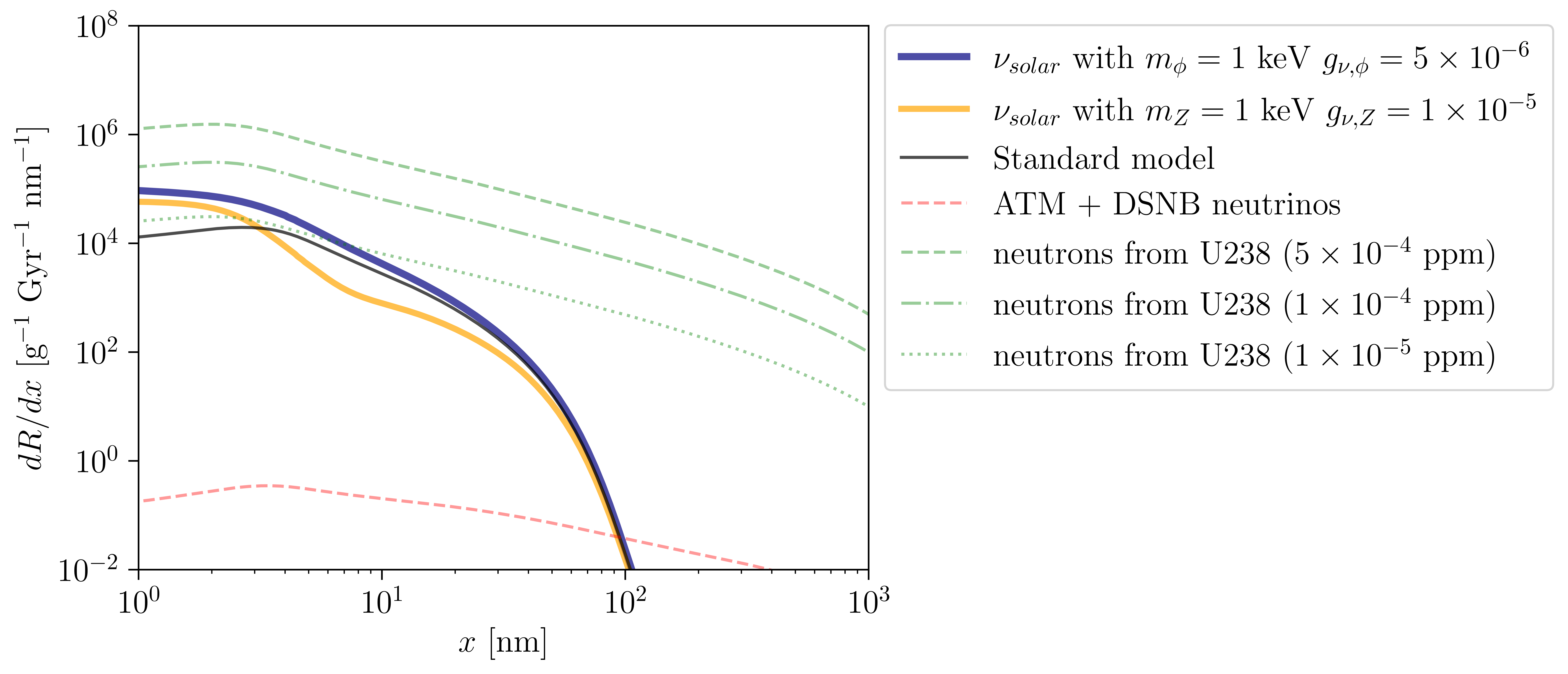


WIMPS

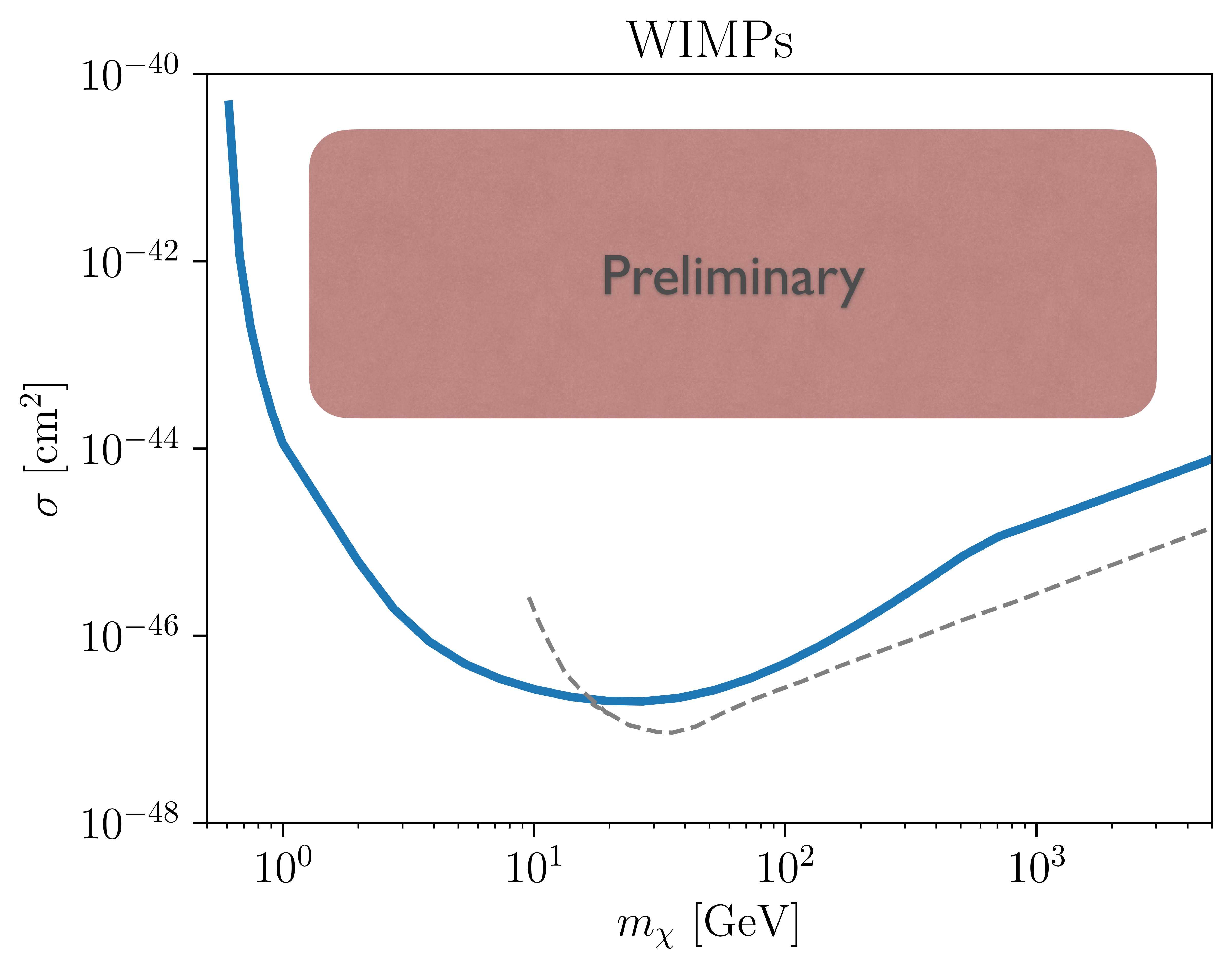


10^8
10^6
10^4
10^2
10^0
dR/dx [g^{-1} Gyr^{-1}]
10^{-1}
10^0
10^1
10^2
10^3
x [nm]
5 GeV $\sigma = 10^{-44}$
100 GeV $\sigma = 3 \times 10^{-47}$
neutrons
neutrinos
All colours, stopping power only

LIGHT MEDIATORS



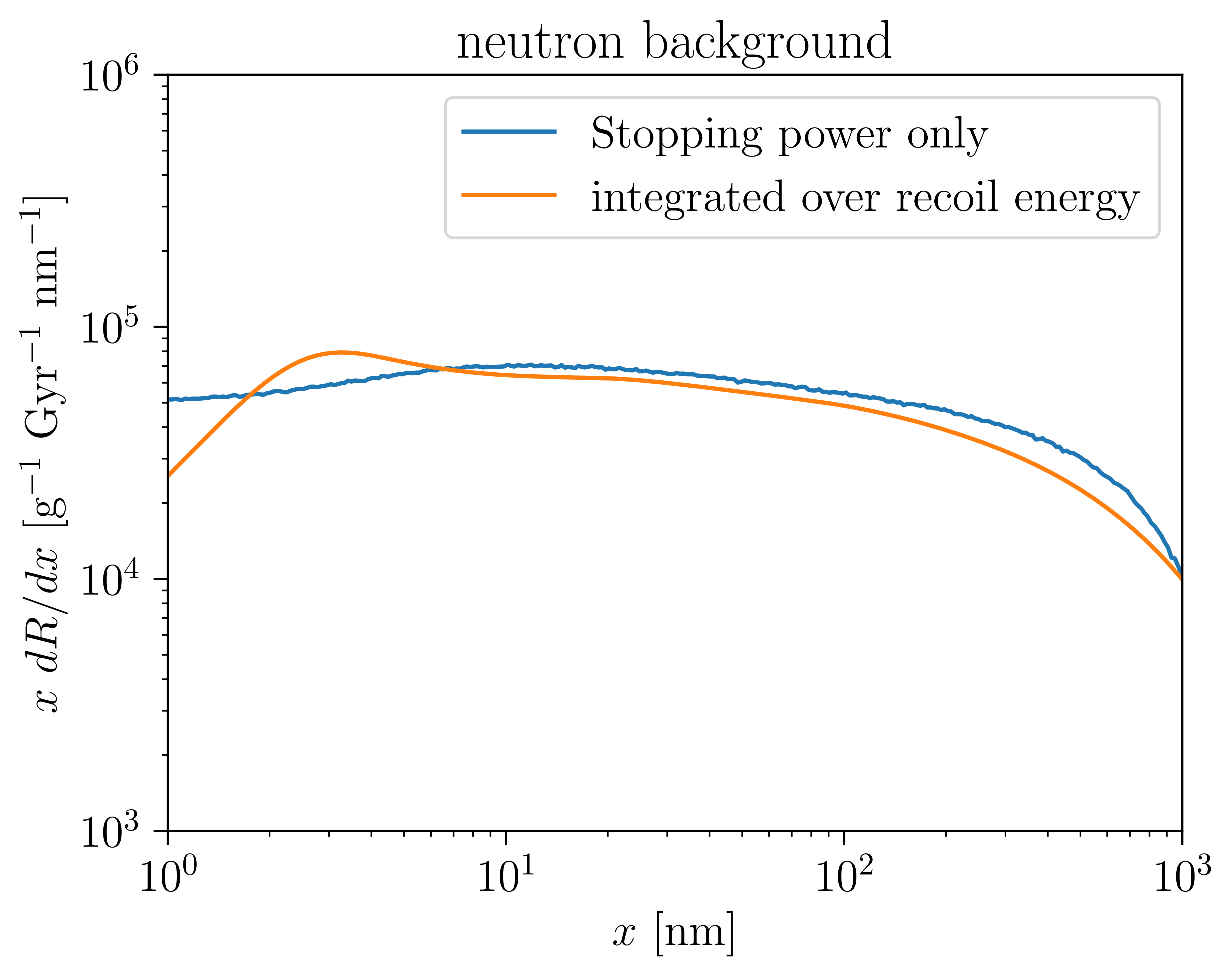
LIMITS


WIMPs
Preliminary
10^{-40}
10^{-42}
10^{-44}
10^{-46}
10^{-48}
σ [cm^2]
10^0
10^1
10^2
10^3
m_χ [GeV]

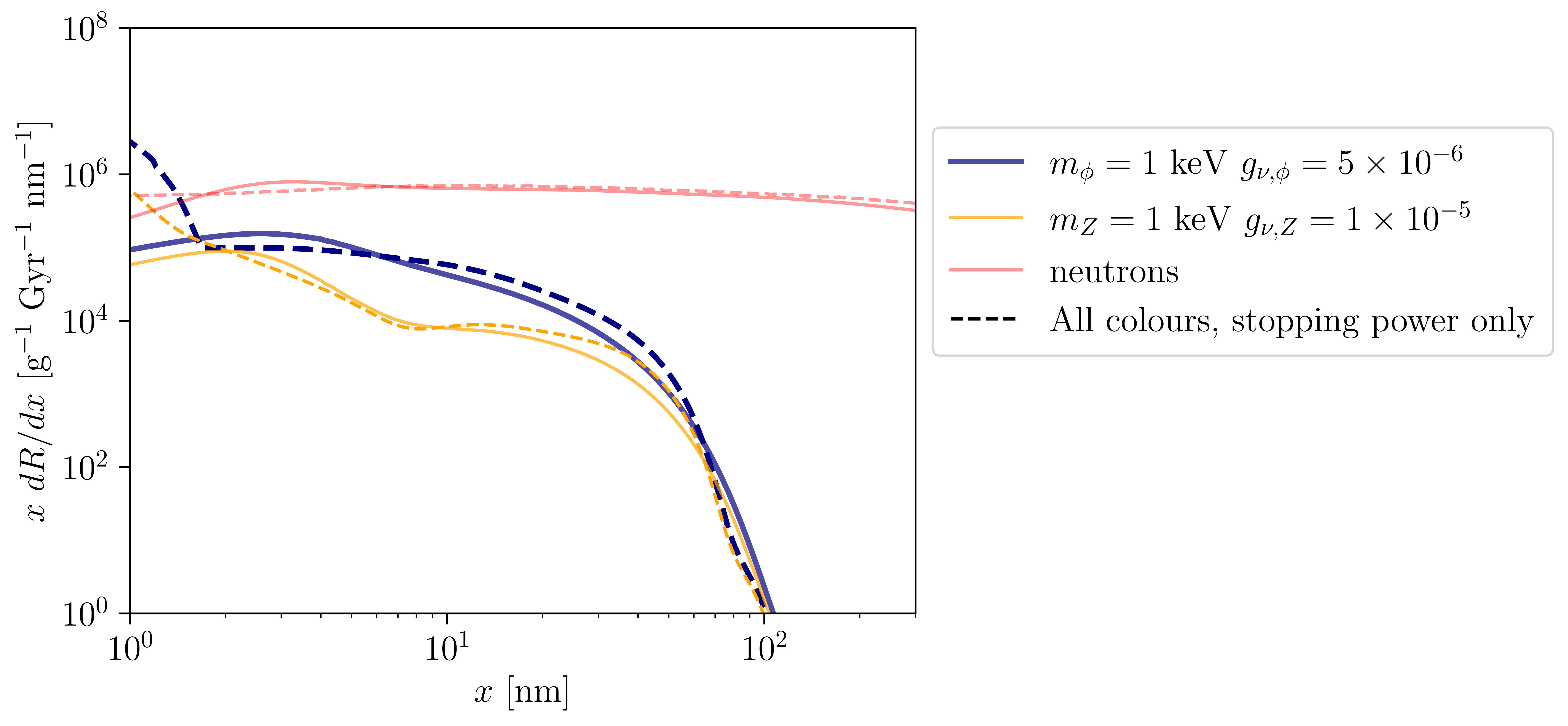
Thank you for listening, all questions and comments are welcome :)

Backup slides

NEUTRONS


neutron background
Stopping power only
integrated over recoil energy
$x \, dR/dx$ [g^{-1} Gyr^{-1} nm^{-1}]
10^6
10^5
10^4
10^3
10^0
10^1
10^2
10^3
x [nm]

LIGHT MEDIATORS



BACKGROUNDS

- solar neutrinos
  - B. Collaboration, Nature 512, 383 (2014).
- atmospheric neutrinos + diffuse supernova neutrino background
  - Phys. Rev. D 80 (2009) 012001
  - J. F. Beacom, Ann. Rev. Nucl. Part. Sci. 60, 439 (2010)
- neutrons from ^{238}U
  - S. Baum, A. K. Drukier, K. Freese, M. G´orski, and P. Stengel, (2018) (PaleoSpec)