Introduction

Goal: Can we reconstruct the energy depositions of the proton in the brain if we are able to reconstruct the photons produced during this process ? [This document.]

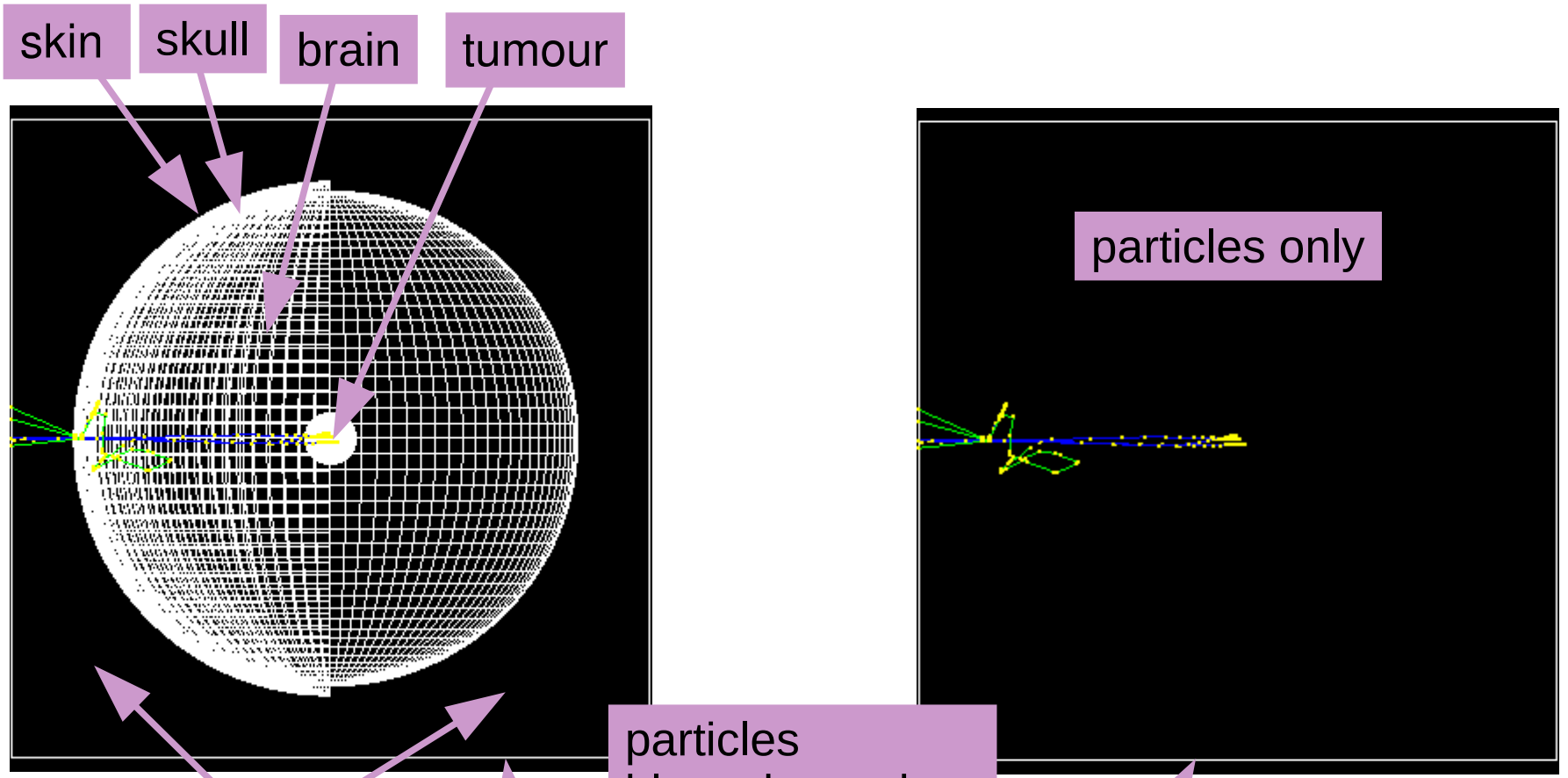
Simulating particle interactions with Geant4

- Geant4[*] simulation used to produce a simple model of a brain tumour:
  - 4 components ('volumes'): air, skull, brain, tumour
  - made from simple geometric shapes
- Protons generated at 180 MeV (configurable).
- Particles are tracked until they leave a defined volume around the head →this is were a detector would be located
- Output data stored in “root”[**] compatible format for analysis:
  - Hits (marks a Geant step): position, energy, 'volume'
  - Tracks: hits, particle id, generation process

[*] http://geant4.cern.ch/
[**] https://root.cern.ch/drupal/content/about

Imperial College London

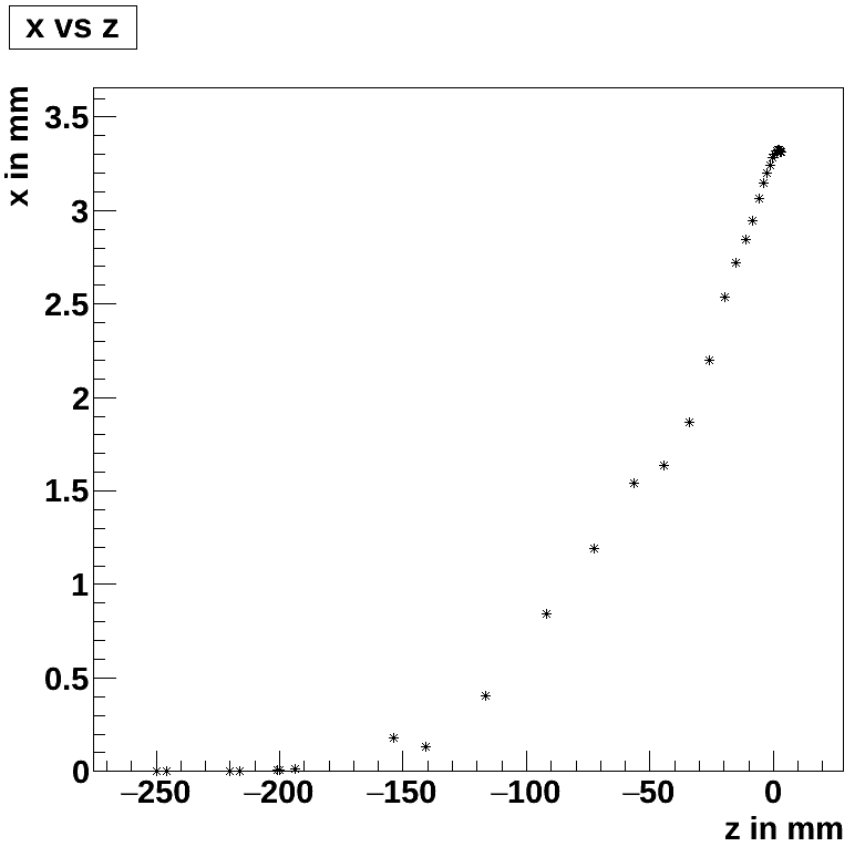
Geant Simulation



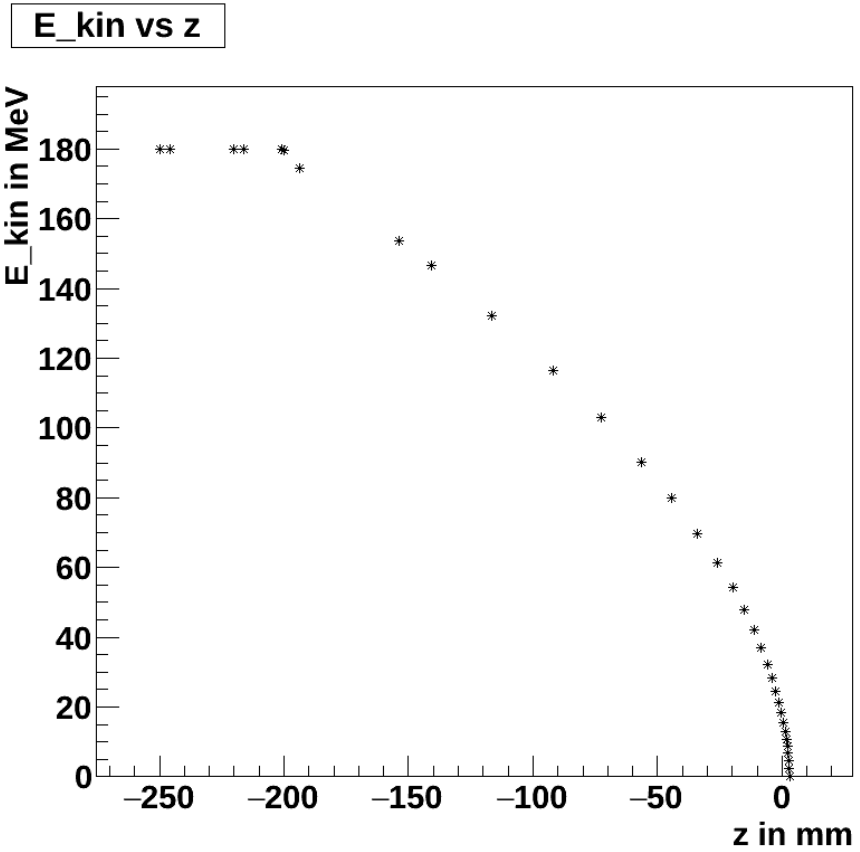
Imperial College London

Protons in the simulation

x and z position of each hit (note scale)

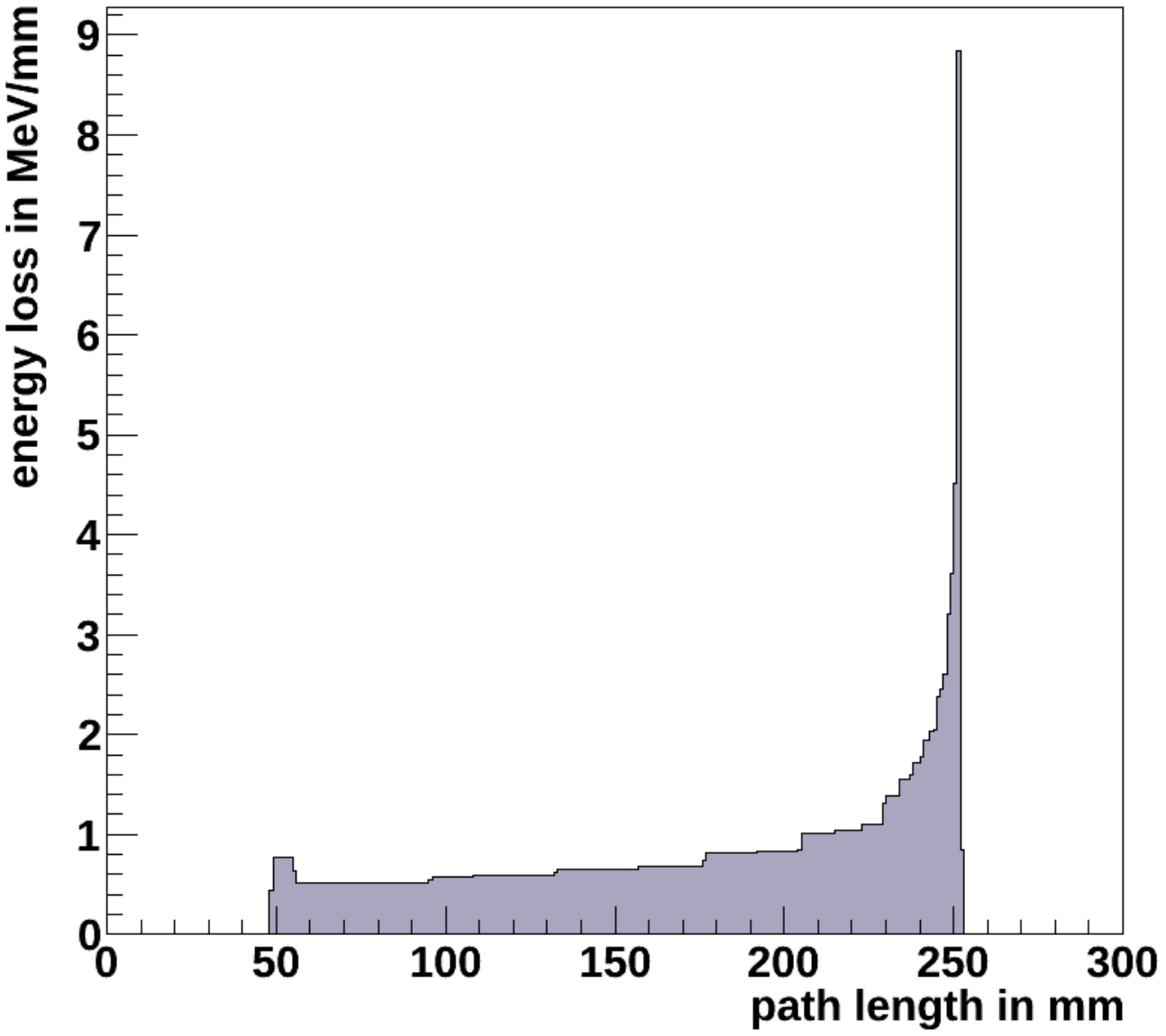


E_kin at each point in the simulation



This information can be combined and converted to show the Bragg peak

Bragg peak

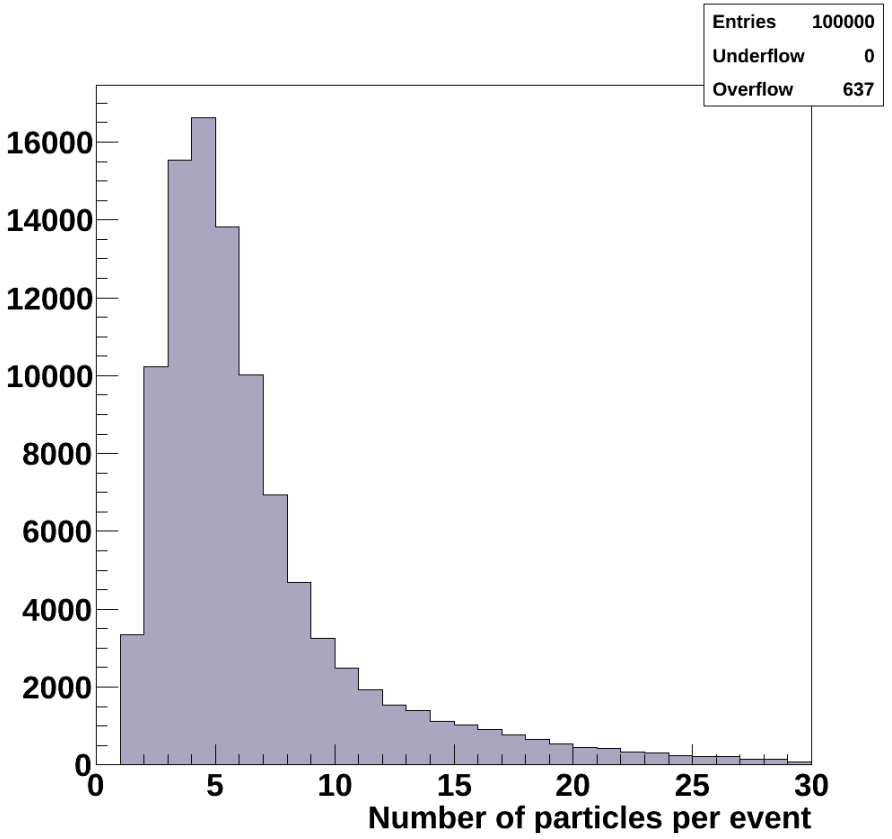

energy loss in MeV/mm
0
1
2
3
4
5
6
7
8
9
0
50
100
150
200
250
300
path length in mm

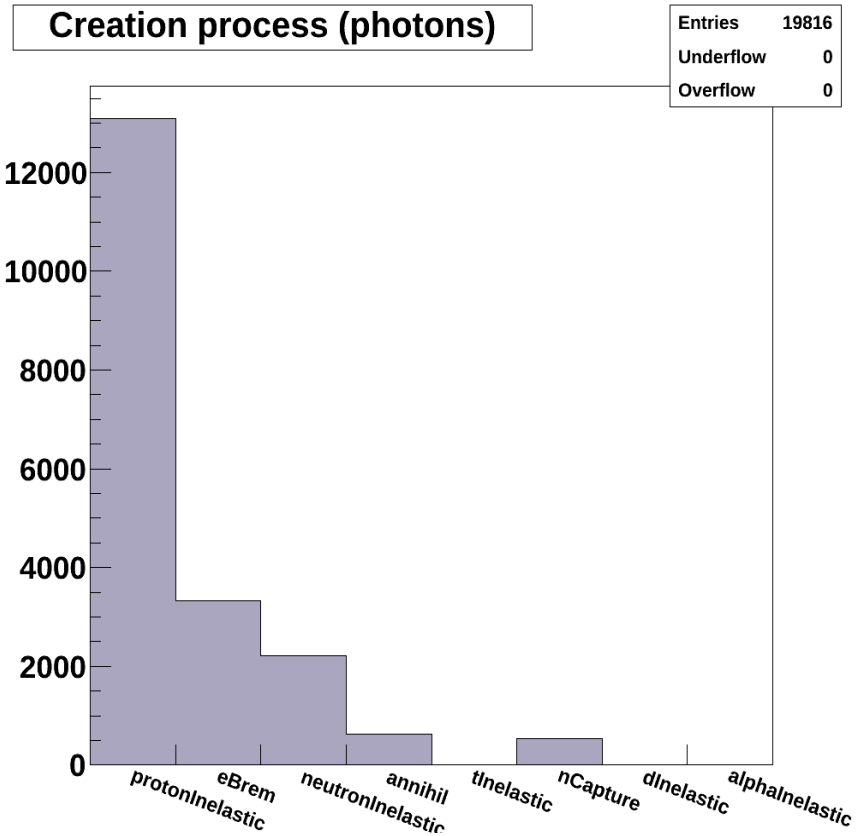
Imperial College London

The (raw) data sample

100000 protons generated,
~20000 photons produced, ~15000 photons leave the head

(only these photons are being considered)



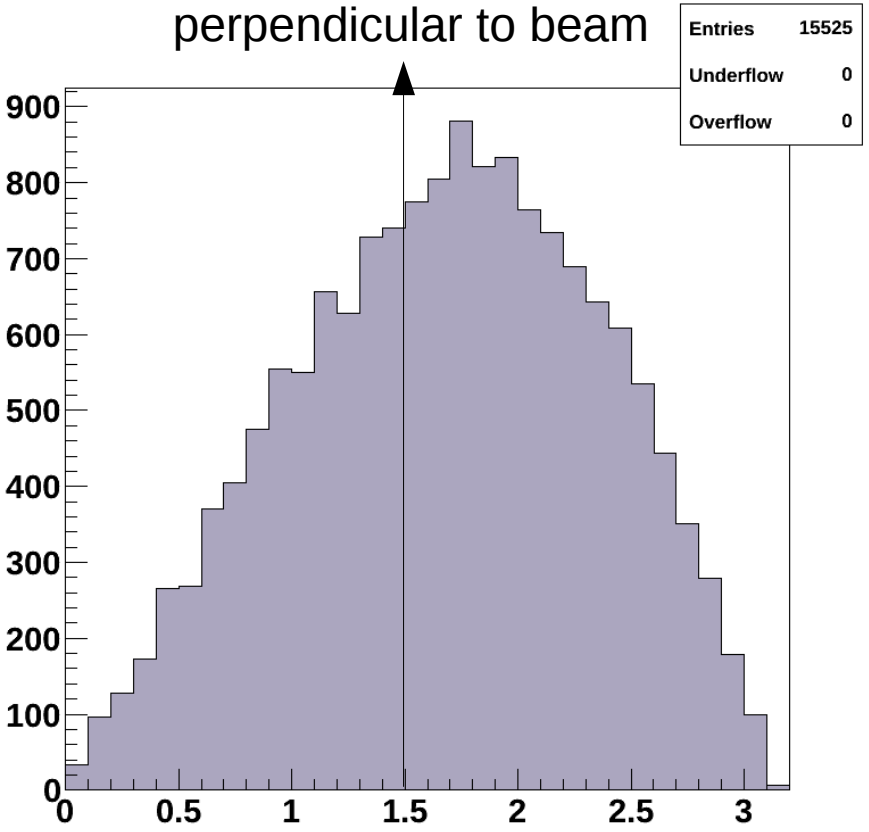


Photon properties

aligned with beam direction

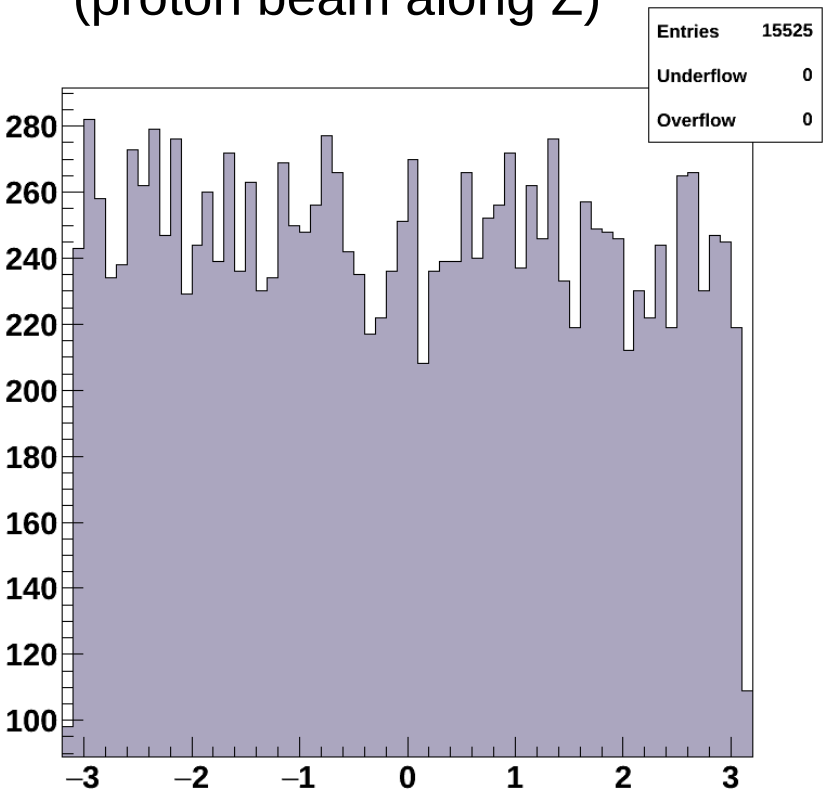
against beam direction

perpendicular to beam



Theta

symmetric in (X,Y) plane (proton beam along Z)

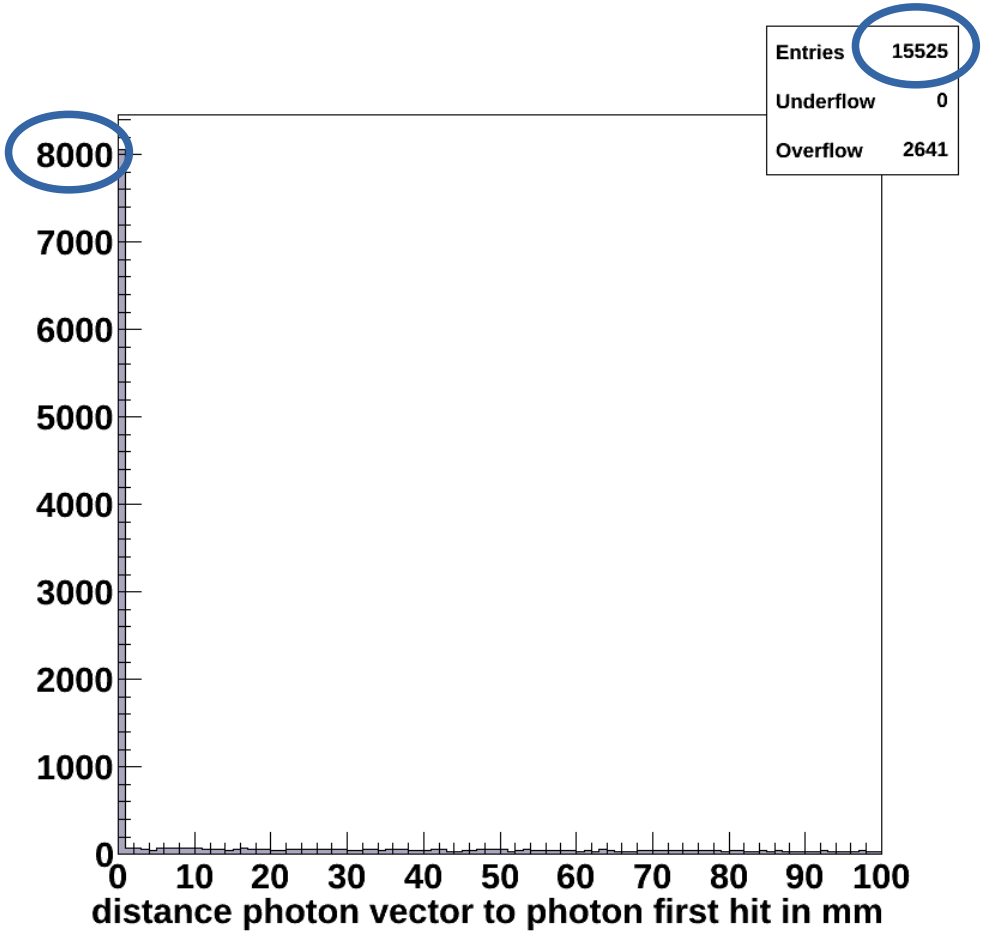


Phi

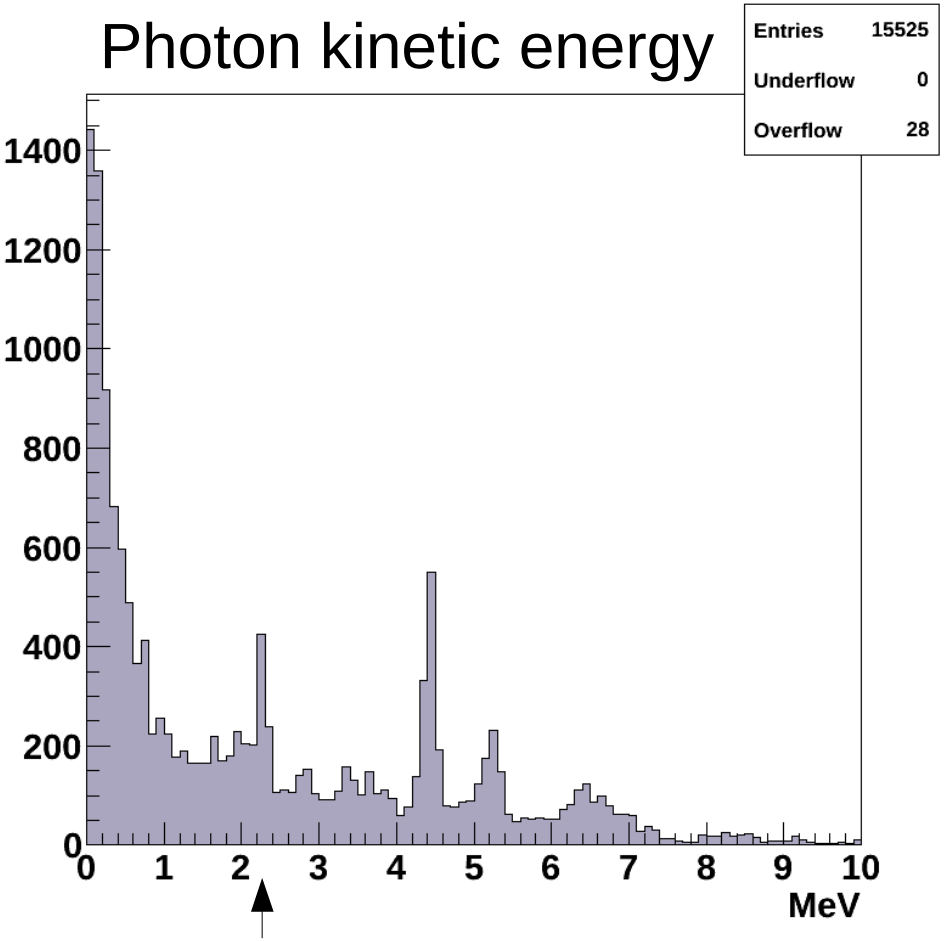
Imperial College London

Photon properties

Photon scattering:
~ 50% of all photon point back to their origin



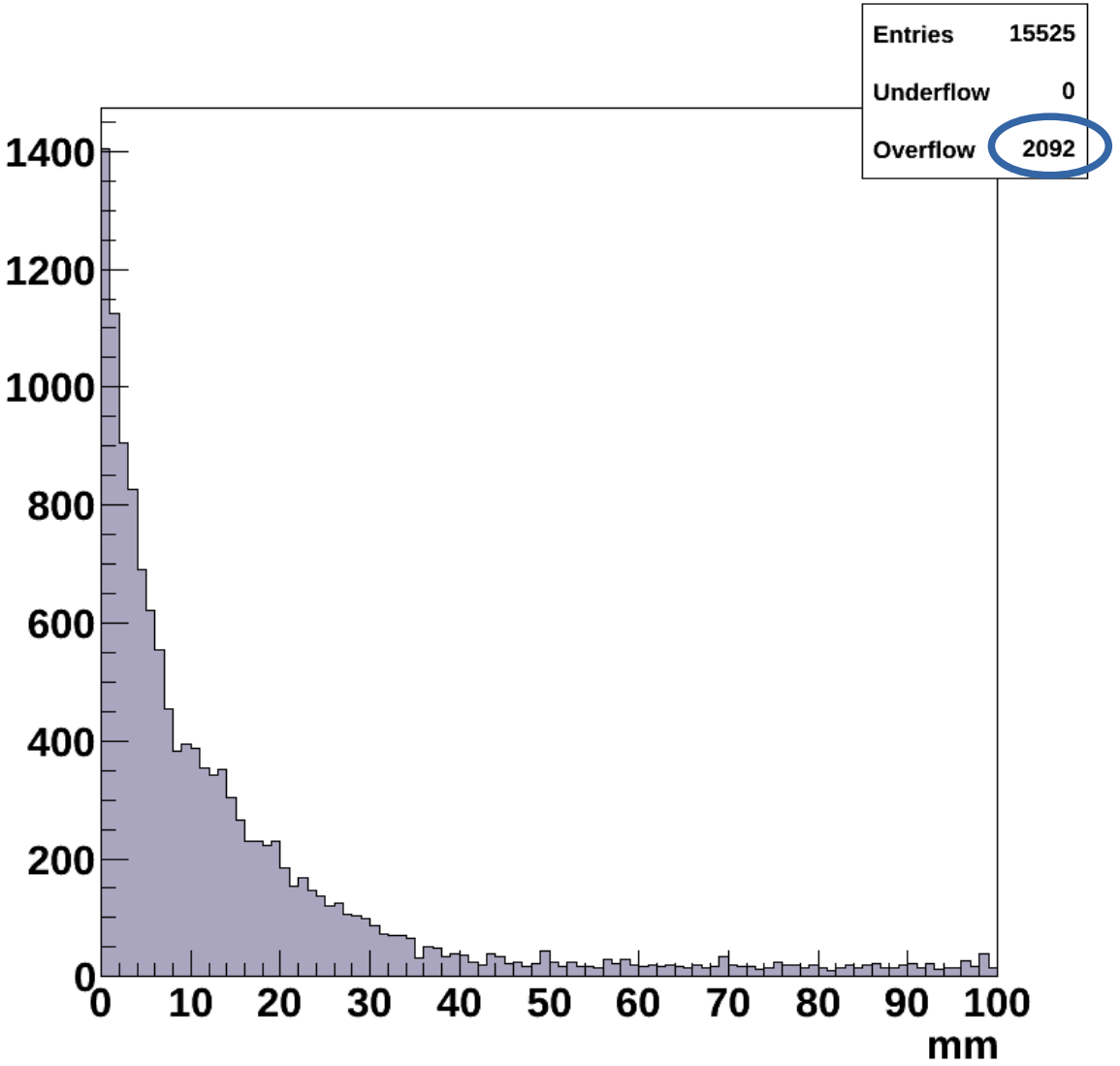
Photon kinetic energy



e.g. neutron capture in water

Photon properties

Distance last simulated proton his to first simulated photon hit in mm

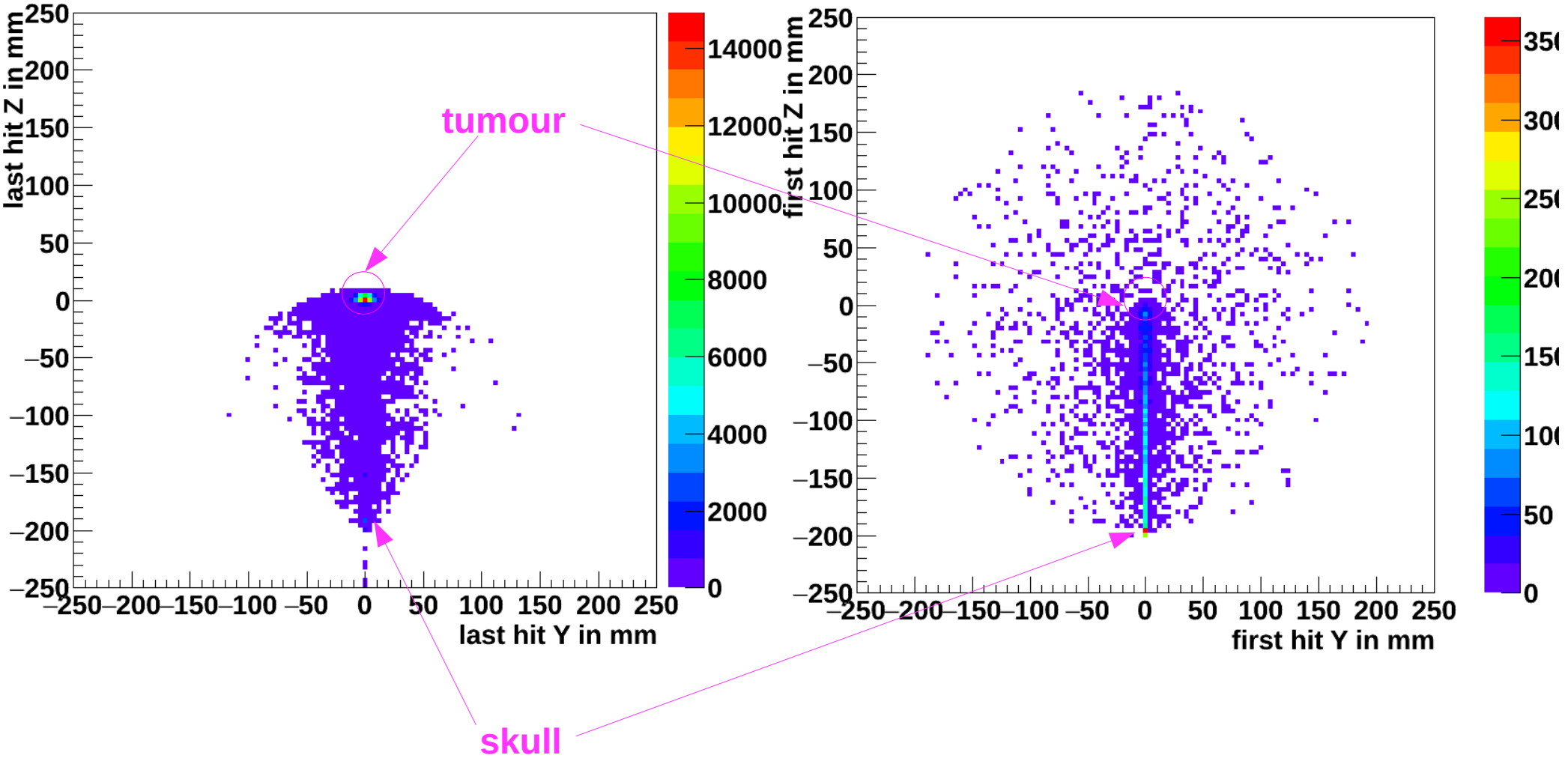


This is dominated by distance in z (along the proton beam)

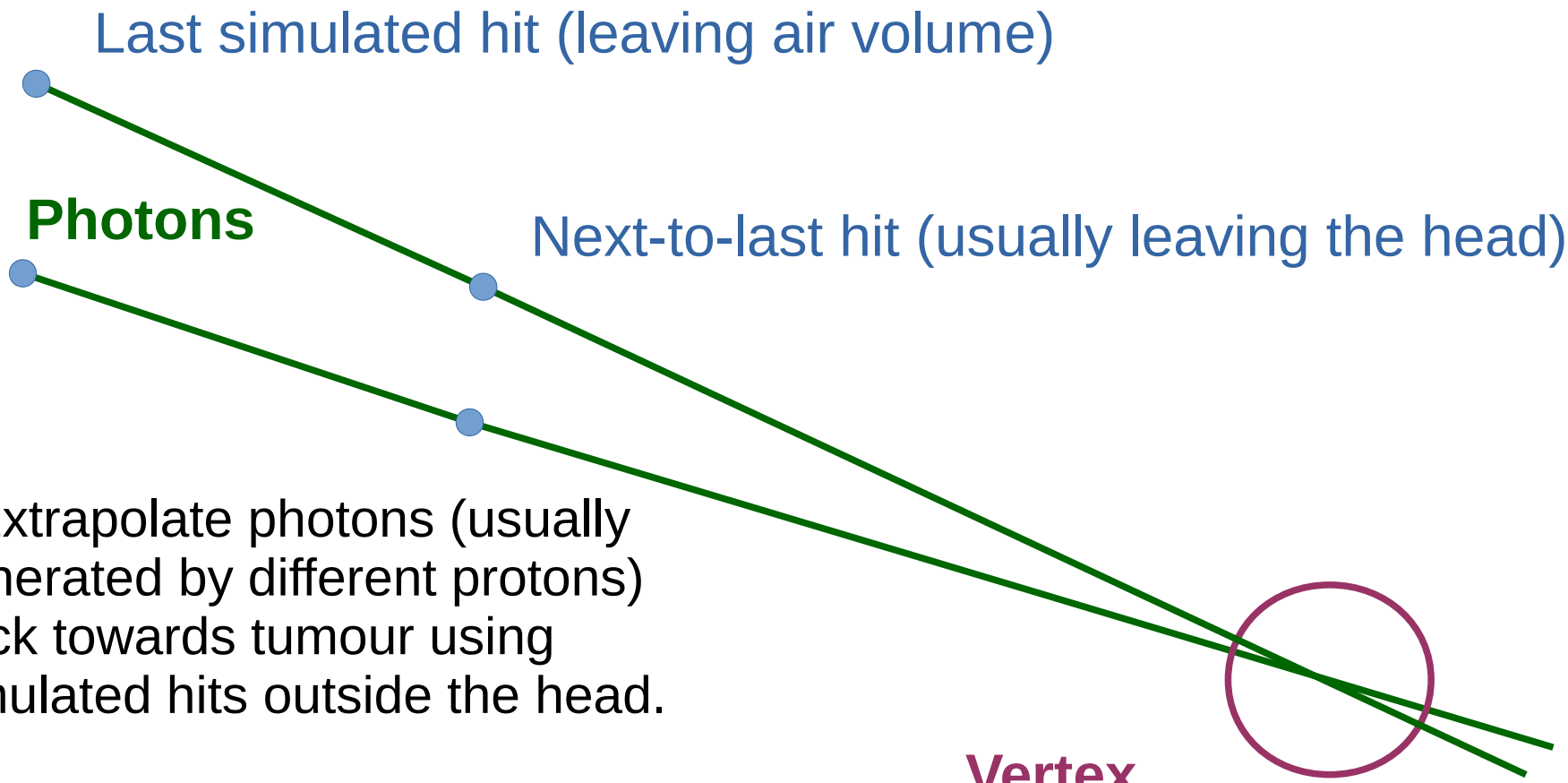
Proton → Photon

Proton: Last Hit

Photon: First Hit

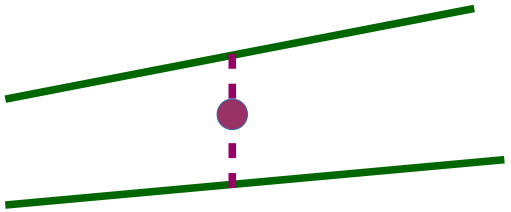


Vertexing



- Extrapolate photons (usually generated by different protons) back towards tumour using simulated hits outside the head.

- Use midpoint of the point of closest approach as vertex.



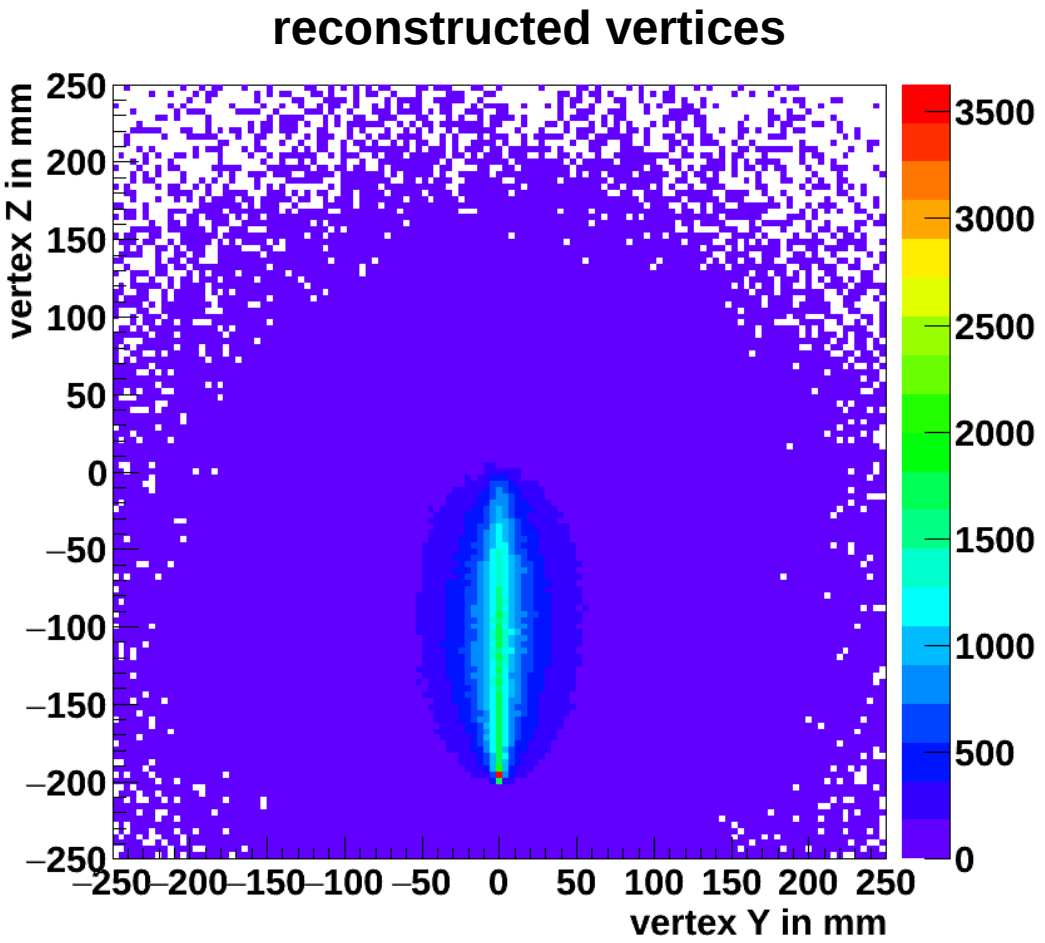
Vertex

Note: In 3d space these lines usually do not intersect

Vertexing

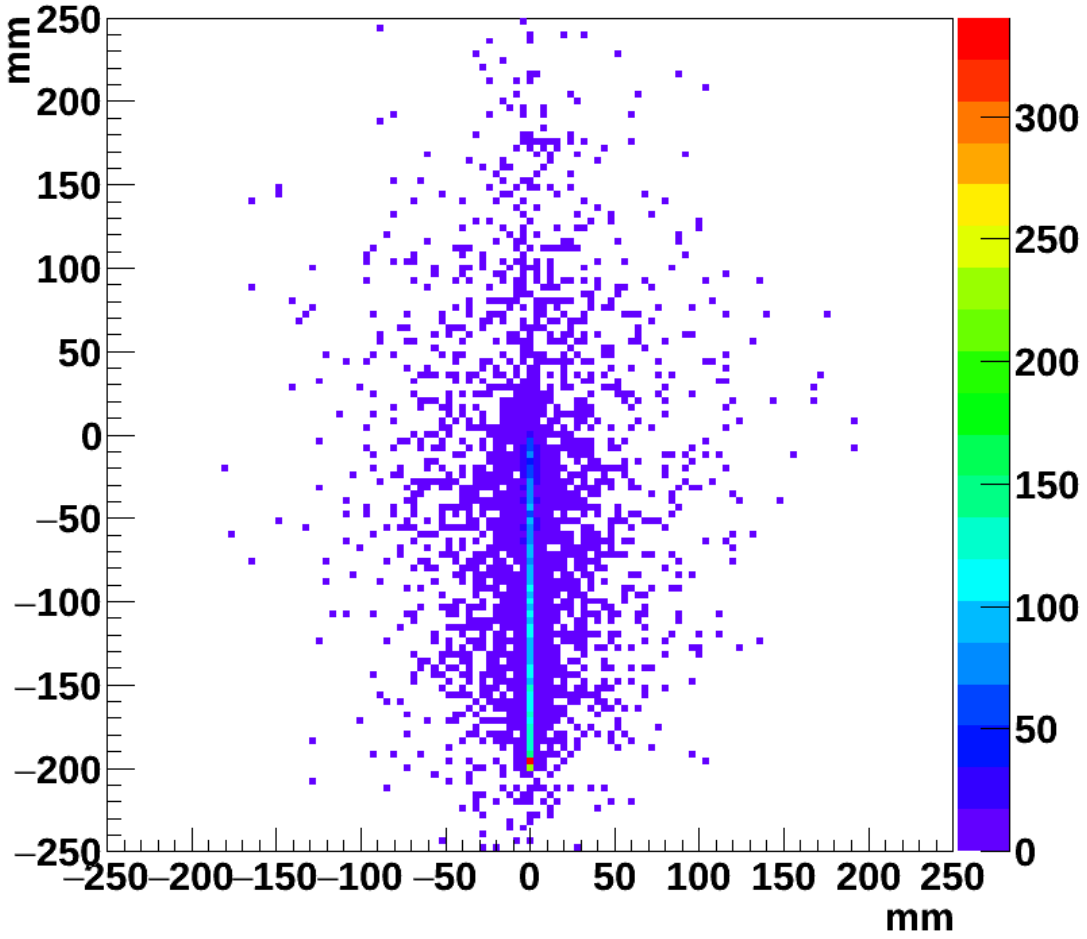
Algorithm:

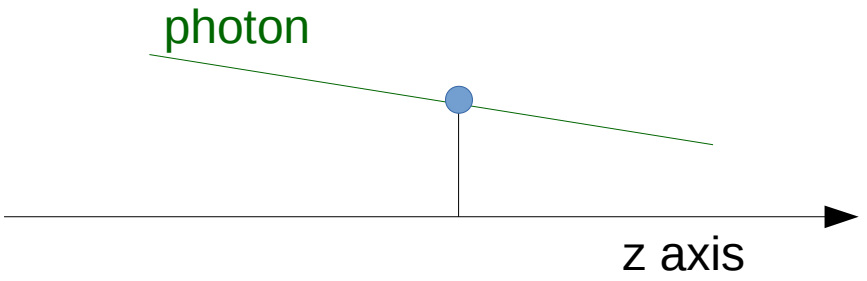
- Every ~200 photons calculate the vertex for each pair of photons and enter into a 2d histogram.
- True areas of increased photon generation should show up with increased frequency.
- These plots are for photons with E_kin > 1.0 MeV.



z-axis constraint

- As the deviation from the beam in the x,y plane is small, use point of closest approach to z (=proton beam) axis of photons to reconstruct proton interactions.





On this and the previous plots, the interactions at the entry point to the skull (z= -200, y = 0) are clearly visible.