Radiological backgrounds simulations

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Introduction

- Generation of the decay particles has traditionally been done with the “RadioGen_module” in our simulations.
  - Relatively complex to add new beta decays (someone needs to calculate the spectrum)
  - Not really able to handle decays which happen one after another (^{214}Bismuth / ^{214}Polonium for example)
- Recently we decided to use another package to simulate the decays
  - Decay0 from F. Mauger, V. Tretiak et all.
    - https://github.com/BxCppDev/bxdecay0
  - Used by the SuperNEMO collaborators (part of their simulation chain Bayeux)
  - Integration Pull Request on https://github.com/LArSoft/larsim/pull/23

Decay0

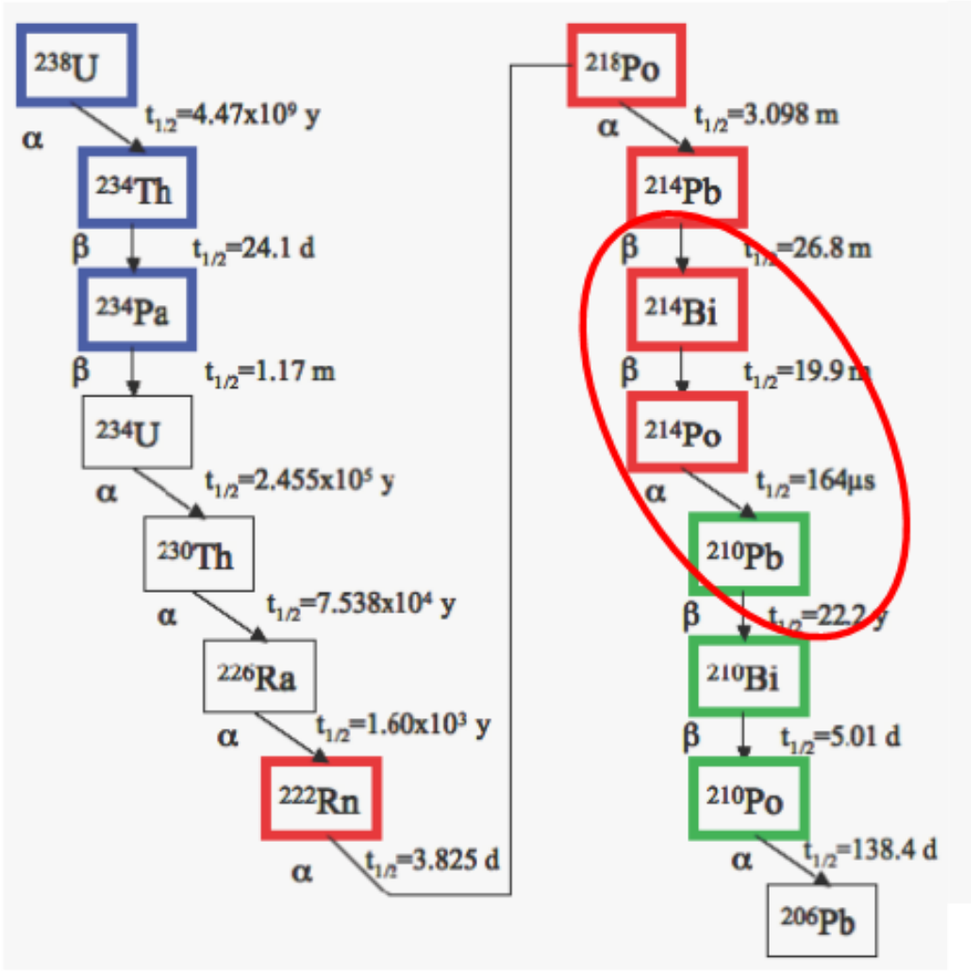
- Software handling the primary decays for neutrinoless double beta decay experiment
- Able to simulate:
  - Most of the beta decays (including ^{39}Ar, ^{42}Ar)
  - Alpha decays, all the ^{238}U chain is there
  - Also able to do the neutrinoless double beta decays (but not in the LArSoft version)
- Uses:
  - ENSDF (nuclear tables) for most of the half lives and de-excitation levels
  - Direction correlation for the emitted photons from theory paper
  - Spectrum from theory and experiments (forbidden decays)

Decay0 in LArSoft

- Integration Pull Request in https://github.com/LArSoft/larsim/pull/23
  - Decay0 should be made a UPS package soon (thanks Lynn, Tom!)
- People can then use the package Decay0_module in LArSim
  - Developing documentation: https://cdcvs.fnal.gov/redmine/projects/larsim/wiki/Running_Decay0_simulation_in_LArSim
- Explains how to choose volumes, decay rates, etc.

^{238}U chain

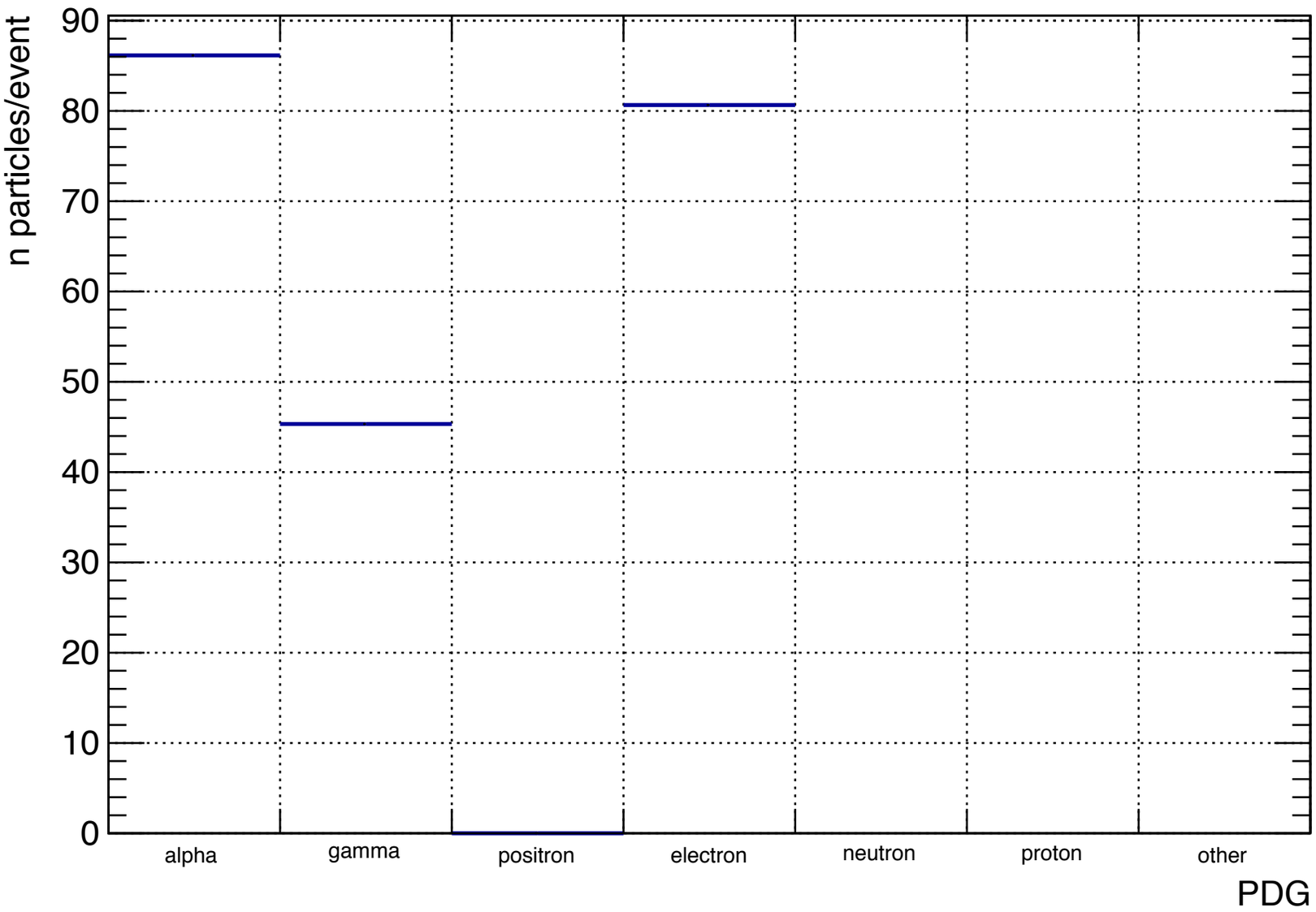
- As a proof of concept, I have generated decays using the full ^{238}U decay chain using Decay0, for about 2.5 seconds (10 kT equivalent).
- Assumes the Radon contamination requirement is met (1 mBq / kg of LAr) and generate at this rate for all the ^{238}U daughter isotopes.
- Includes the ^{214}Bismuth / ^{214}Polonium coincident decays
- The chain is assumed to be in equilibrium (which most probably won't be the case).
- Objective is to test the impact on SN triggers.



1 Bq ^{238}U/kg = 81 ppb U (81 10^{-9} gU/g)
1 Bq ^{232}Th/kg = 246 ppb Th (246 10^{-9} gTh/g)

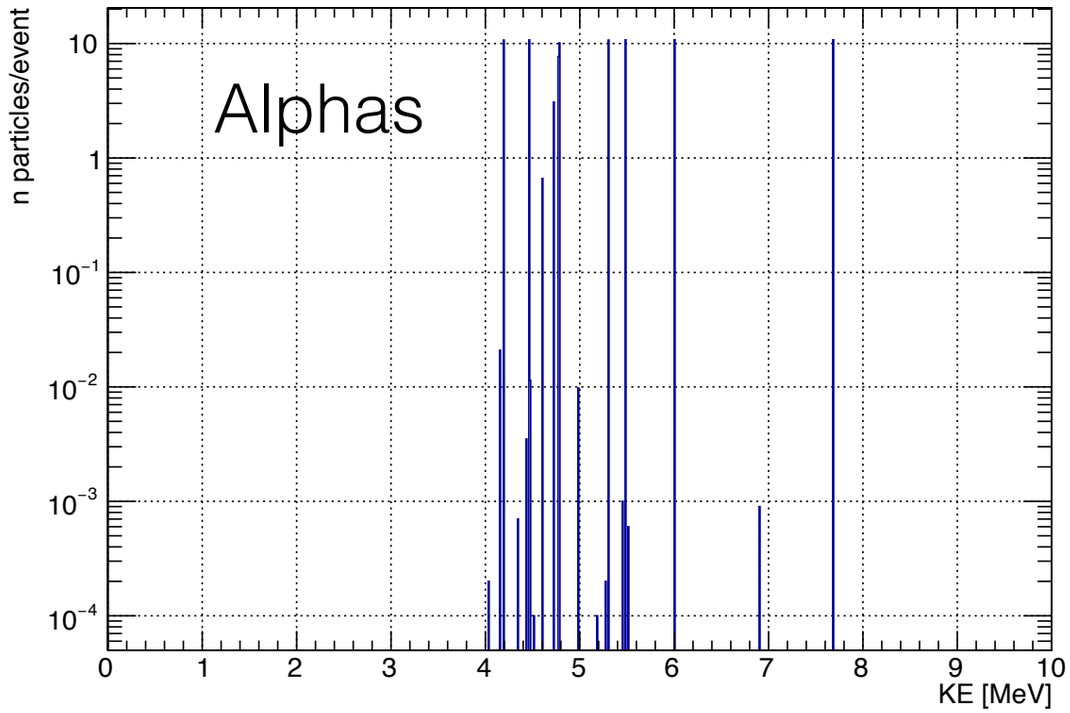
^{238}U chain

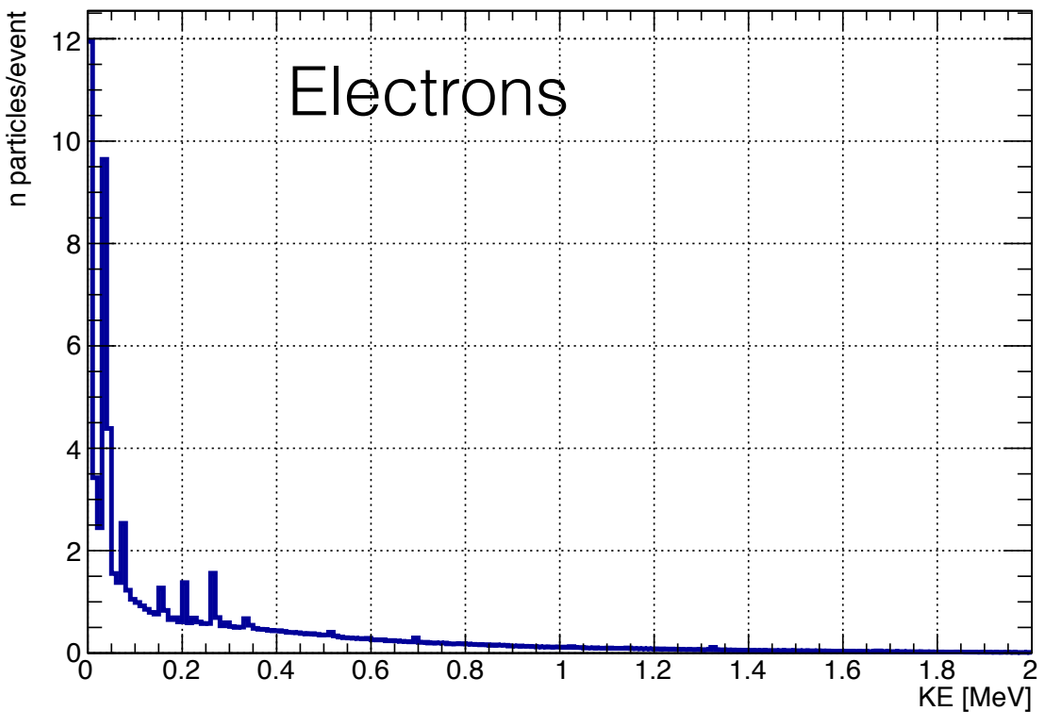
- Particle content (event = 1x2x6 LArSoft event)

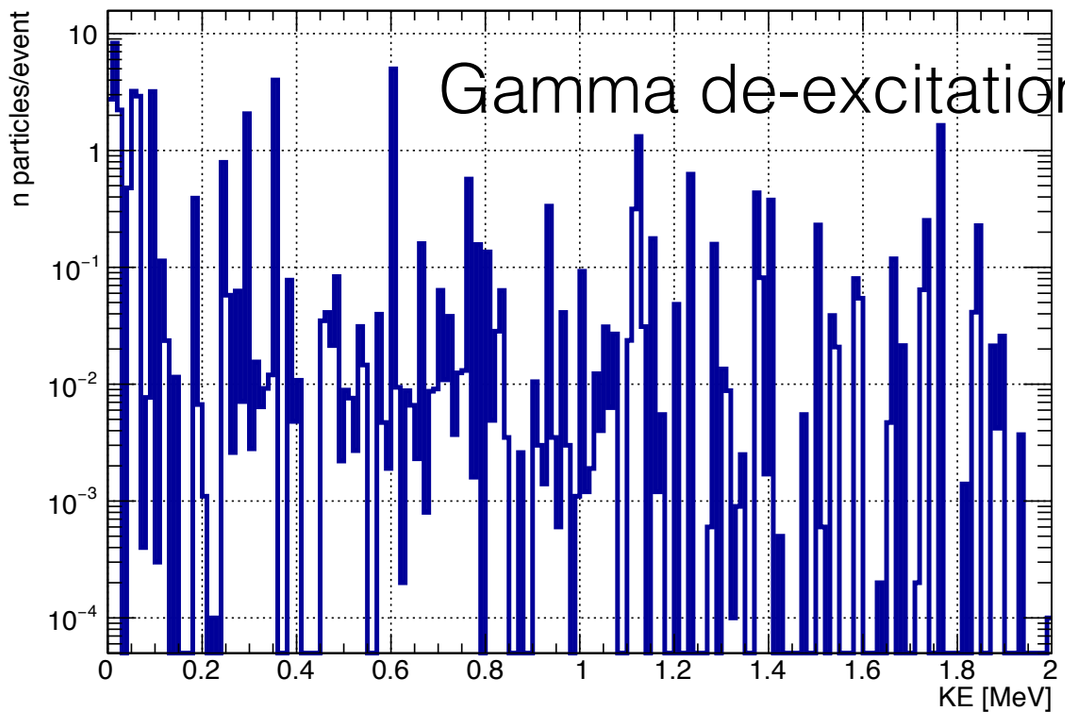


^{238}U chain

- Takes care of all the alphas decays, including the transition to excited daughter nuclei
- Includes beta spectrum (with forbidden decays)
- Emits gammas to return to non-excited state

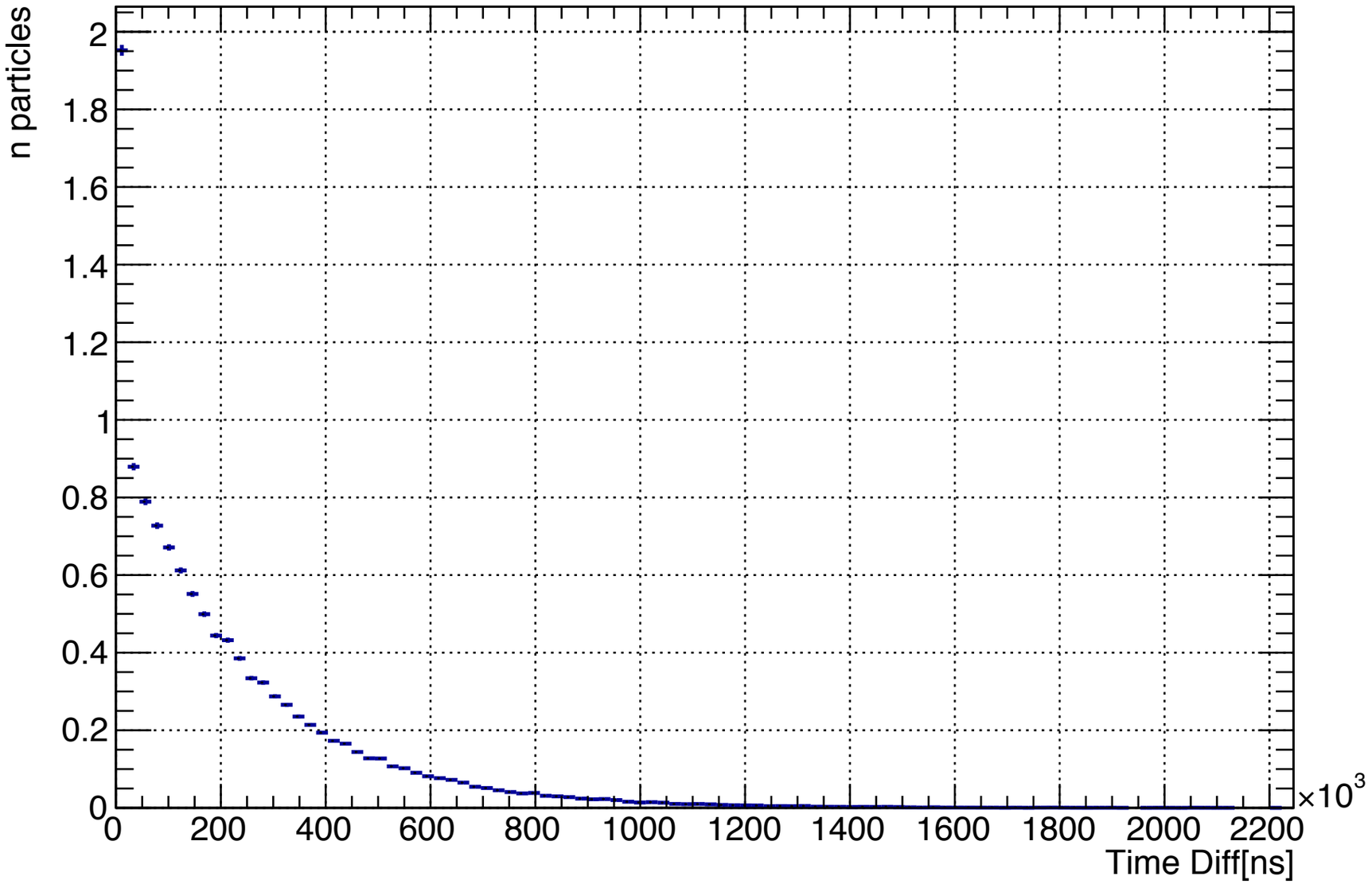






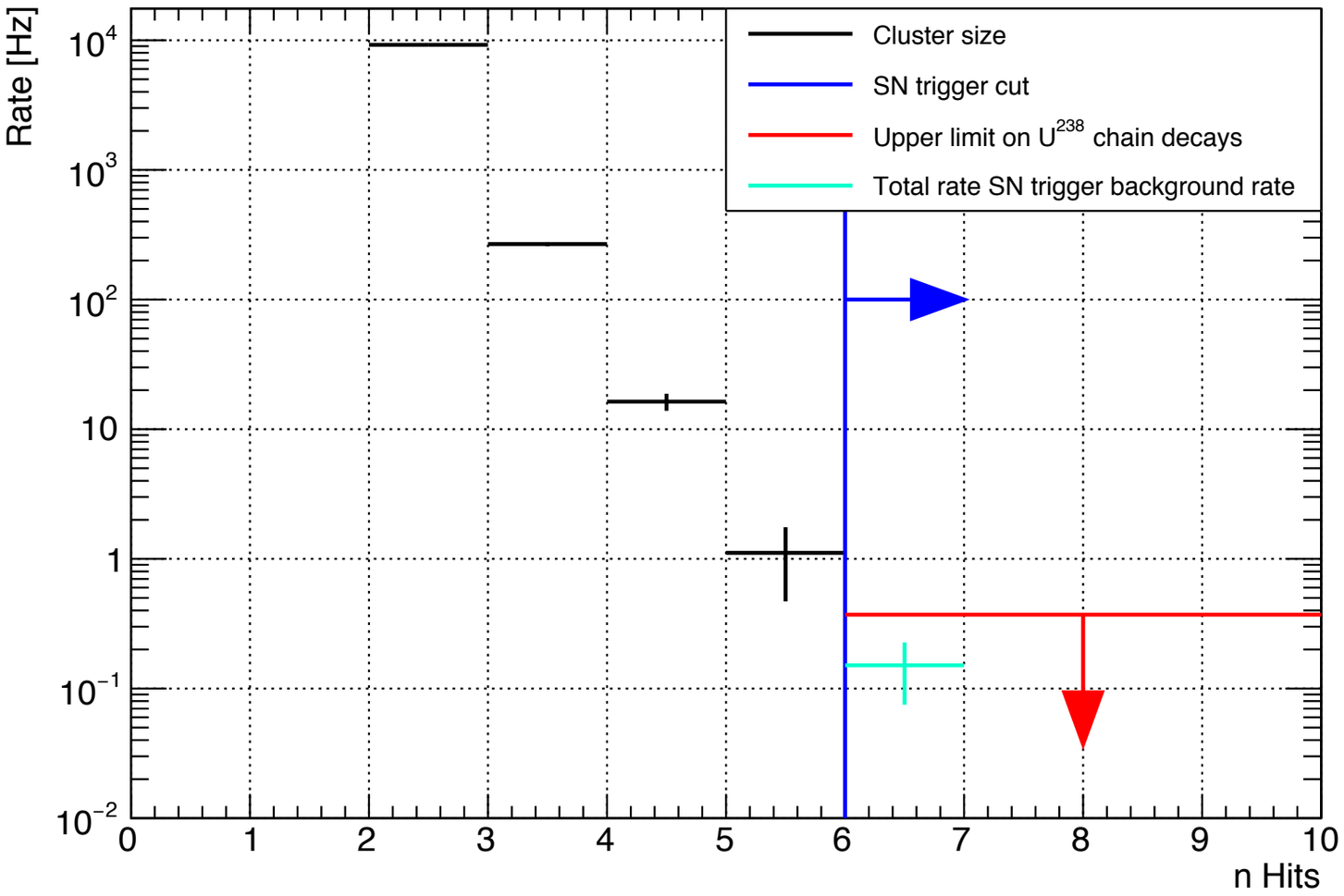
^{238}U chain

- Bismuth Polonium time correlation (t_alpha - t_beta)



Impact on the SN trigger

- As in Thiago's talk, run a "trigger primitive" algorithm (i.e. hit maker) very similar to what was run online in ProtoDUNE, and clustering to form "trigger candidates"
- Check for size of the cluster against rate
  - The bigger the cluster is, lower is the rate (as expected for low-E events)



- Not enough stats to unambiguously conclude that ^{214}Bi-^{214}Po decays are subdominant compared to neutron.
- Enough to say that these backgrounds won't break the SN triggers.

Conclusion

- Radiological studies can now use a more generic and precise radiological generator
  - Thanks to Lynn, Tom, F. Mauger for support
  - Able to generate anything in the ^{238}U decay chain, and many beta decays.
  - Fully ported inside LArSoft (but not on master yet)
- Checked the ^{214}Bi-^{214}Po impact on SN trigger
  - Not yet conclusive but strong evidence that the SN trigger won't be affected too much by