GammaX Study

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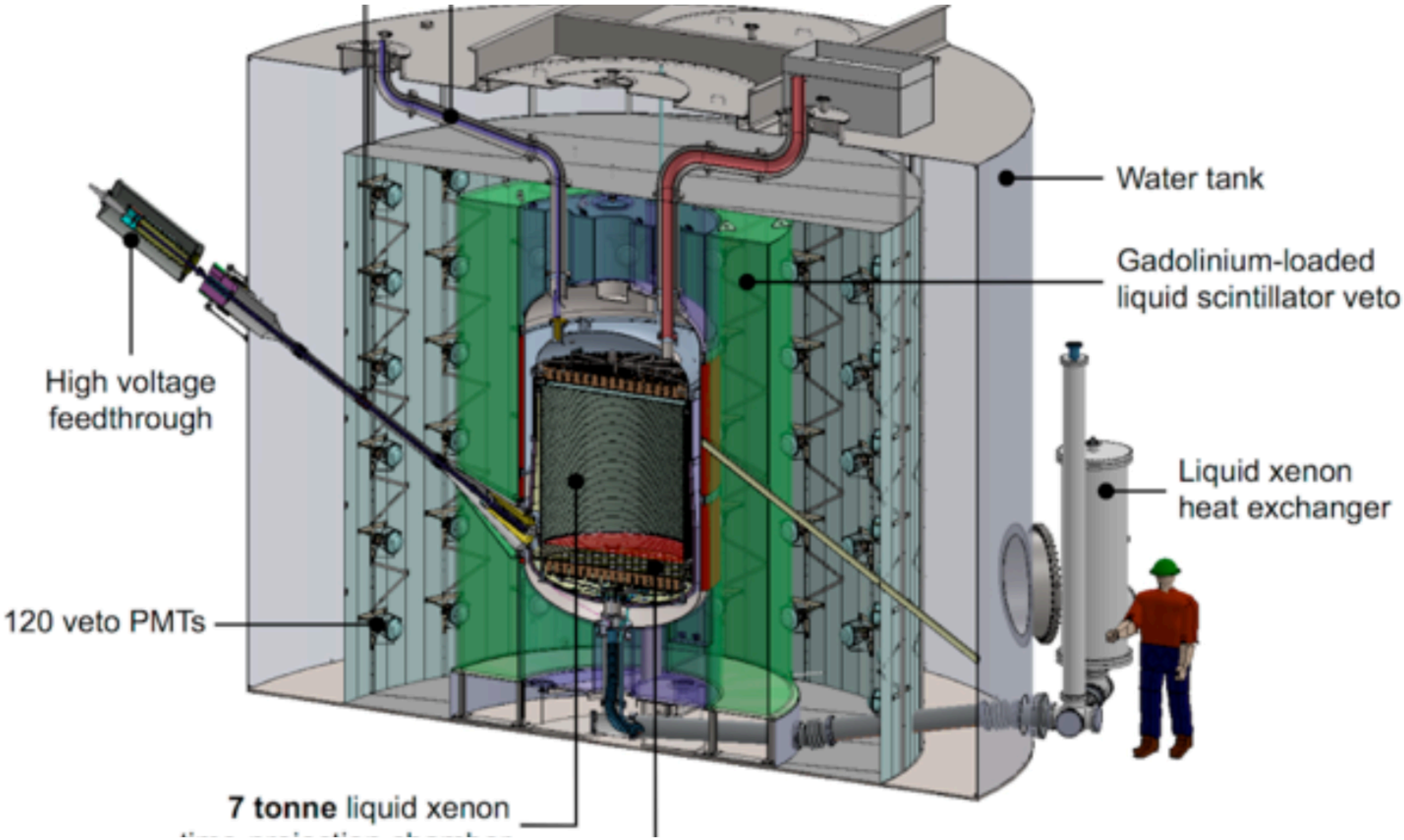
+ Introduction



Introduction

- Active Region = Liquid Xe contained between the bottom PMTs and the liquid surface.
- Drift Region = Liquid Xe contained between the cathode grid and the liquid surface, within the active region. Any event with more than 1 vertex in this region can be rejected as a multiple-scatter event.
- Reverse Field Region = Liquid Xe contained between the bottom grid and the cathode grid within the active region.
- Under-cathode region = Liquid Xe contained between the bottom PMT's and the cathode grid.

+ Gamma-X Event

- GammaX Event : It is a multiple-scatter gamma event within the active region, with only one vertex in the drift region.
- Resulting signal has a composite S1 from all vertices, but S2 signal only from the drift region vertex.

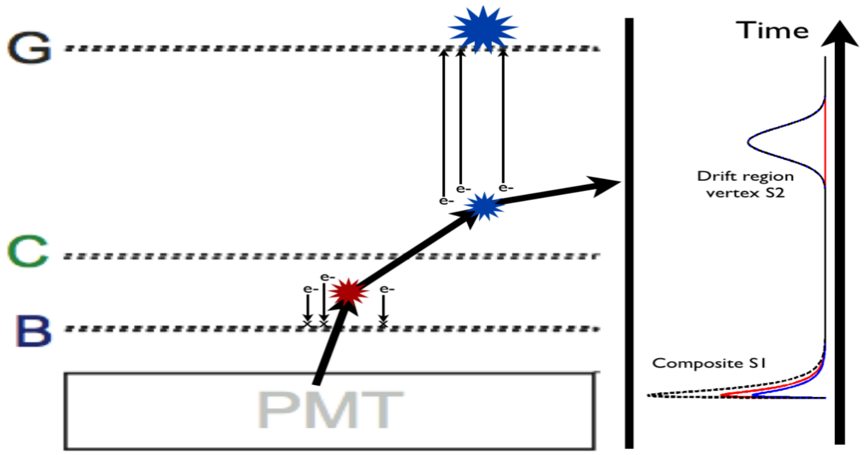


Figure 5.15: Qualitative representation of a gamma-X event. (Left) A γ scatters multiple times in the active region, with a single vertex in the drift region (small blue) and one or more vertices under the cathode (red). The resulting signal is shown at right as a function of time. The measured S1 signal is a composite signal from all vertices. Ionization is not collected from the vertices under the cathode. The resulting event has a single S2 which has a contribution only from the drift region vertex (large blue). (Right) The resulting waveform with detected S1 and S2 signals (black dashed). Shown are the contributions from the drift region vertex (blue) and RFR vertex (red). The reduced S2/S1 ratio for the event greatly lowers discrimination efficiency.

How Gamma-X will be generated?

- Most likely scenario for the generation of a gamma-X event is a gamma emitted from underneath the cathode grid, scattering once in the drift region and one or more times in the below-cathode region (reverse field region – between the cathode grid and the bottom grid, where the electric field is in the upward direction).
- The reverse field orientation underneath the cathode grid will push the electrons away from the drift region, resulting in only the drift region ionization signal being detected.
- Source of gamma-ray scattering in the reverse field region is the bottom PMT arrays, provided that gamma emission in the detector is dominated by the PMT's.

Gamma-X Event

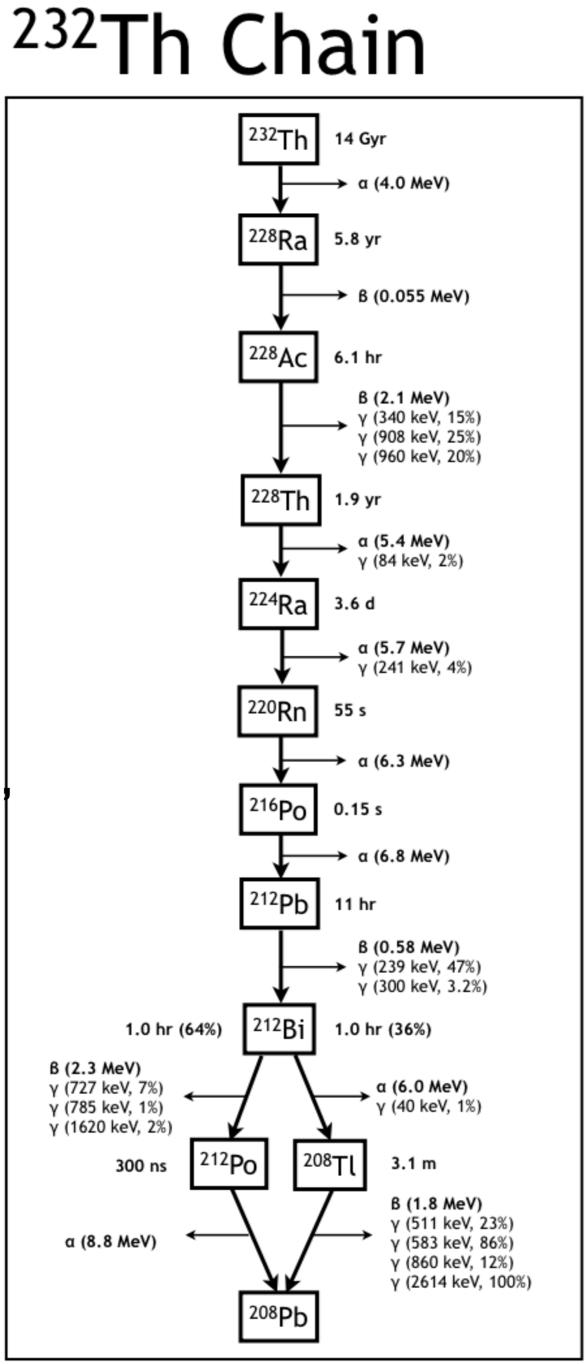
- A Gamma-X event is considered to be an event in which
  - Energy deposition in the drift region is non-zero and
  - Energy deposition in the reverse field region OR under-cathode region is non-zero
- Simulations – a radioactive source in the bottom PMT array, mainly considered four different radioactive isotopes U-238, Th-232, K-40, Co-60.

+ Th-232 chain

How radioactive decays are simulated In LZ ?

Found an interesting paper by Kareem on the same, couldn't read it yet.

" Nuclear Instruments and Methods in Physics Research A 654 (2011) 170–175"

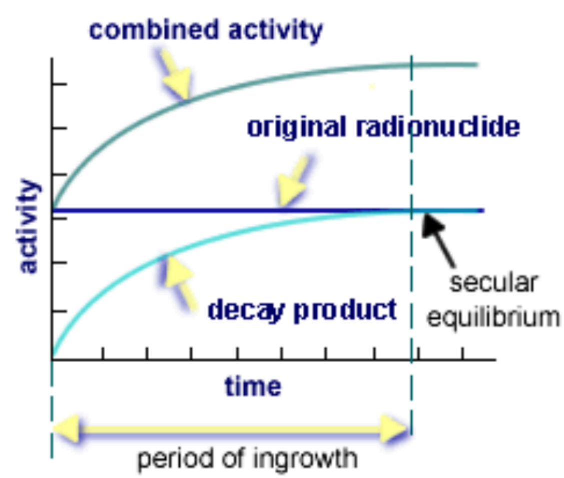


Simulated Th-232 events

- Looked at the tracking information, by doing simulation myself for 2 events by setting Th-232 source in bottom and top PMT
  - /LUXSim/source/set Top_PMT_Vacuum DecayChain_Th232 1 mBq 100 yr
  - /LUXSim/source/set Bottom_PMT_Vacuum DecayChain_Th232 1 mBq 100 yr
  - 100 yr corresponds to secular equillibrium
  - Outfile file is attached as a pdf "Th232_simulation_output.pdf"

Radioactive Equillibrium

- When the production and decay rates of each radionuclide in the decay chain are equal, the chain has reached **radioactive equilibrium**
- When half-life of a original radionuclide is much longer or than the half-life of the decay product then decay product generates radiation more quickly. Within about 7 half lives of the decay product, their activties are equal, and the amount of radiation (activity is doubled). Beyond this, the decay product decays at the same rate it is produced, a state **called secular equillibrium**



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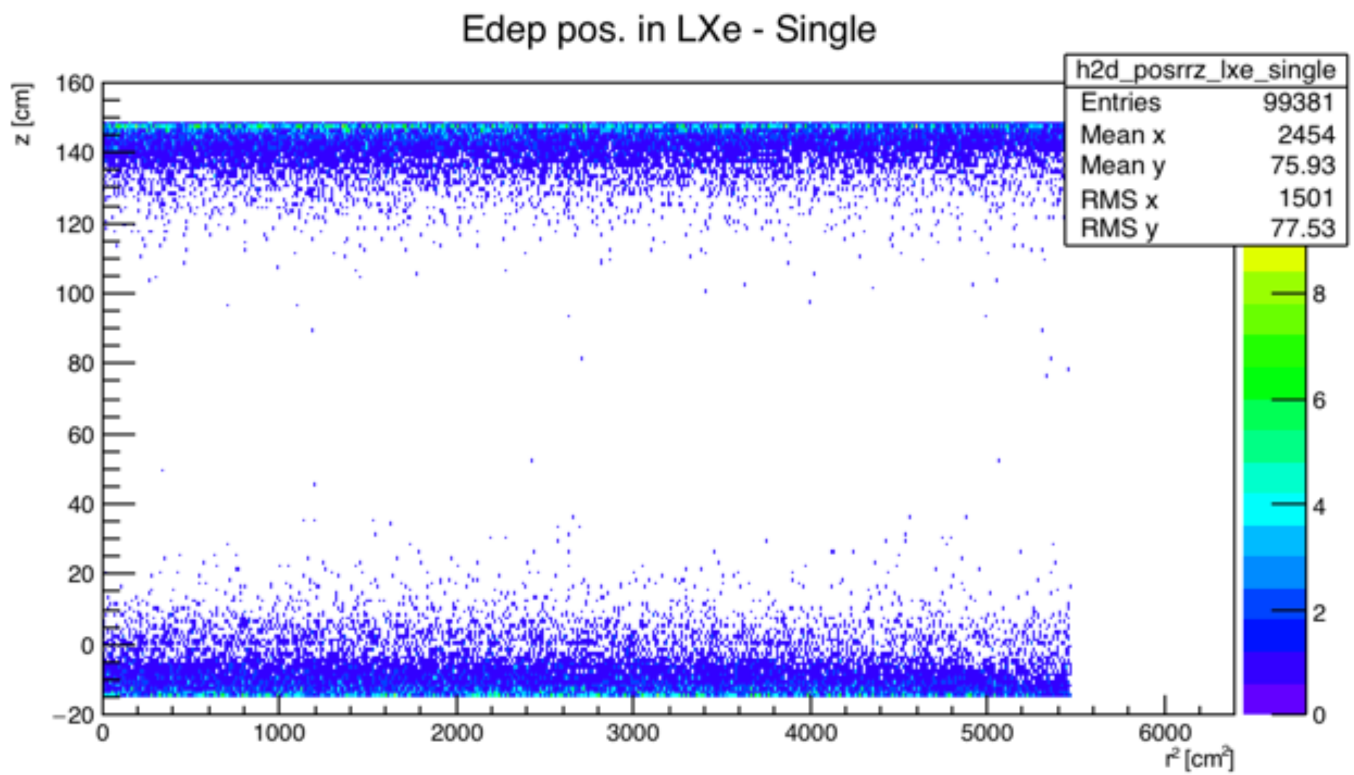
Analyzing Gamma-X events

- Information stored in root files :
  - Detector is volume oriented (look into volumes)
  - Nentries (whatever is happening in the detector)
  - Particle ID (id of the particle stored, eg : 22 for photon, 11 for e-)
  - IRecordsize (No of steps a particle has taken to deposit its energy)
  - And For every step – x, y, z position and deposited energy
- Let's consider a event, where energy is deposited in 3 different volumes LiquidXenonSkin, InnerLiquidXenon, Scintillator Veto
  - Nentries = 3
  - iRecordSize will be different for these 3 volumes. Let's say particle deposited all its energy in 2 steps for LiquidXenonSkin and InnerLiquidXenon, whereas only 1 step for Scintillator Veto
  - So iRecordSize = 2 (LiquidXenonSkin & InnerLiquidXenon)
  - iRecordSize = 1 (Scintillator Veto)

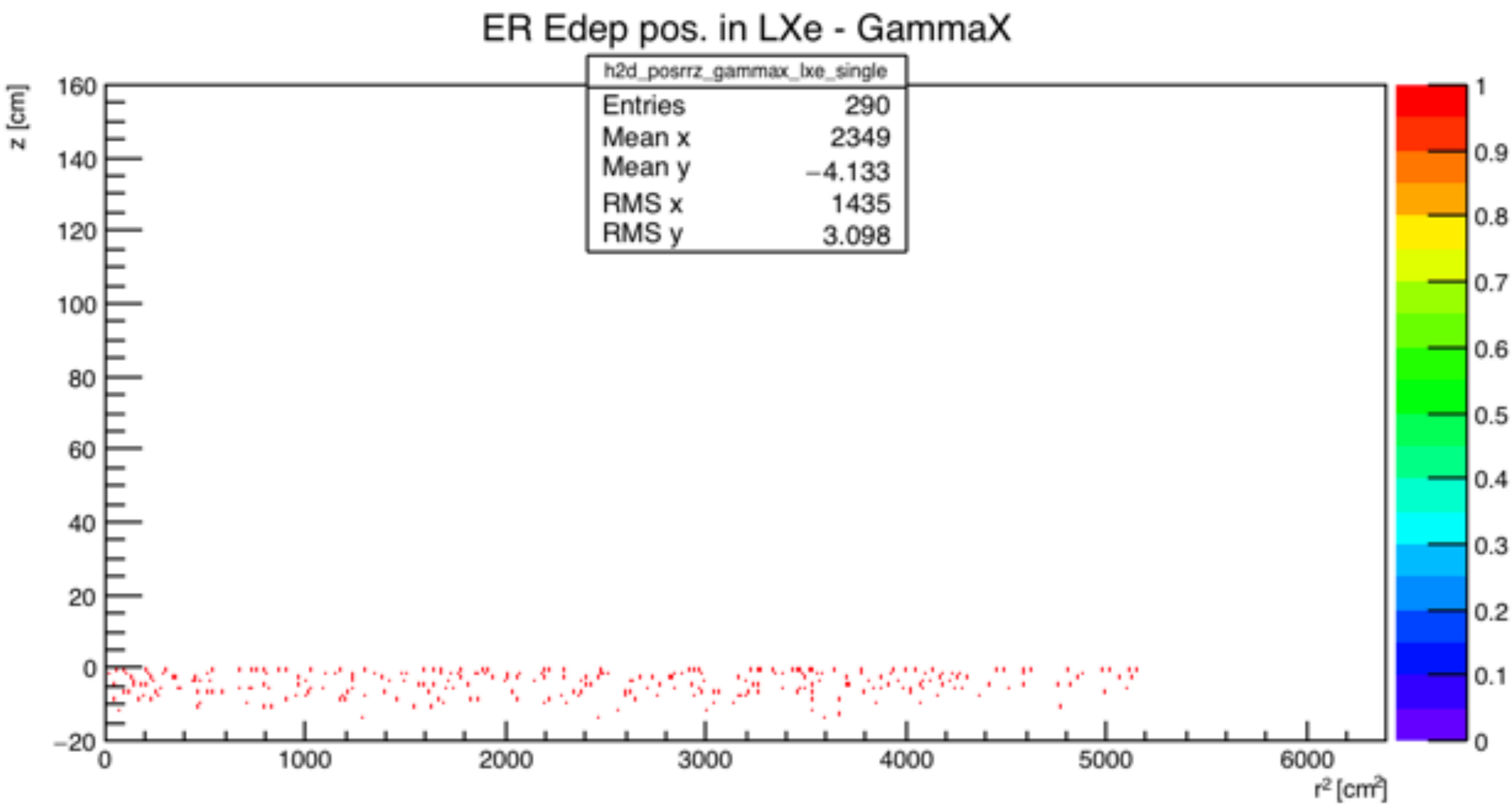
Electron Recoil Events

- Working on simulation files - U-238 source in bottom and top PMT from Paolo
- Consider a volume = InnerLiquidXenon || LiquidXenonTarget
- Select a Electron Recoil event(particle id == 22)



Gamma-X Event

- Along with cuts mentioned in slide 10, require event to be below cathode (position_Z[iirec] < -0.4 cm) and in the drift region (position_Z [iirec]> -0.4cm && position_Z [iirec] < 145.7 cm)



Z position of gamma-x events

- iientr: 673548 iEvtN: 375069
- pos_total_er_drift_z: -0.335743 pos_total_er_below_cathode_z: -10.5969
- iientr: 680500 iEvtN: 378857
- pos_total_er_drift_z: -0.268951 pos_total_er_below_cathode_z: -2.12775
- Can z position in the drift region be so close to cathode for real gamma-x events?. I don't think so..
- Did few more checks – > https://www.hep.wisc.edu/~gomber/out1.txt
- Selected 1 event which passes gamma_X selection cuts, on slide 10+11.
  - Print all the information – ivolume, particle ID, position_Z
  - Looks like, one should consider the drift position from the volume 2563 (LiquidXenonTarget) instead of 2561(InnerLiquidXenon)
  - Need to confirm with Paolo/Matthew

Backup

+ Photon_Attenuation length vs energy

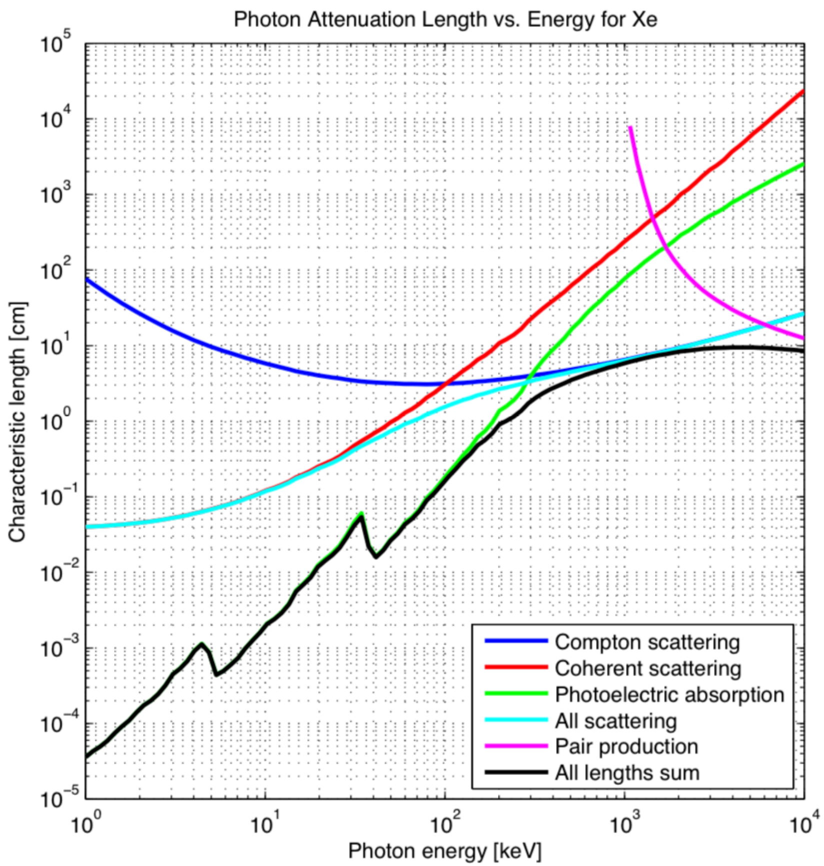


Figure 2.1: Photon attenuation length (mean free path) for γ rays in liquid Xe, as a function of energy. The mean free path is broken down into various energy deposition processes. Data is taken from [87]. (LUX Matlab function gamma_length.m.)

^{238}U Chain

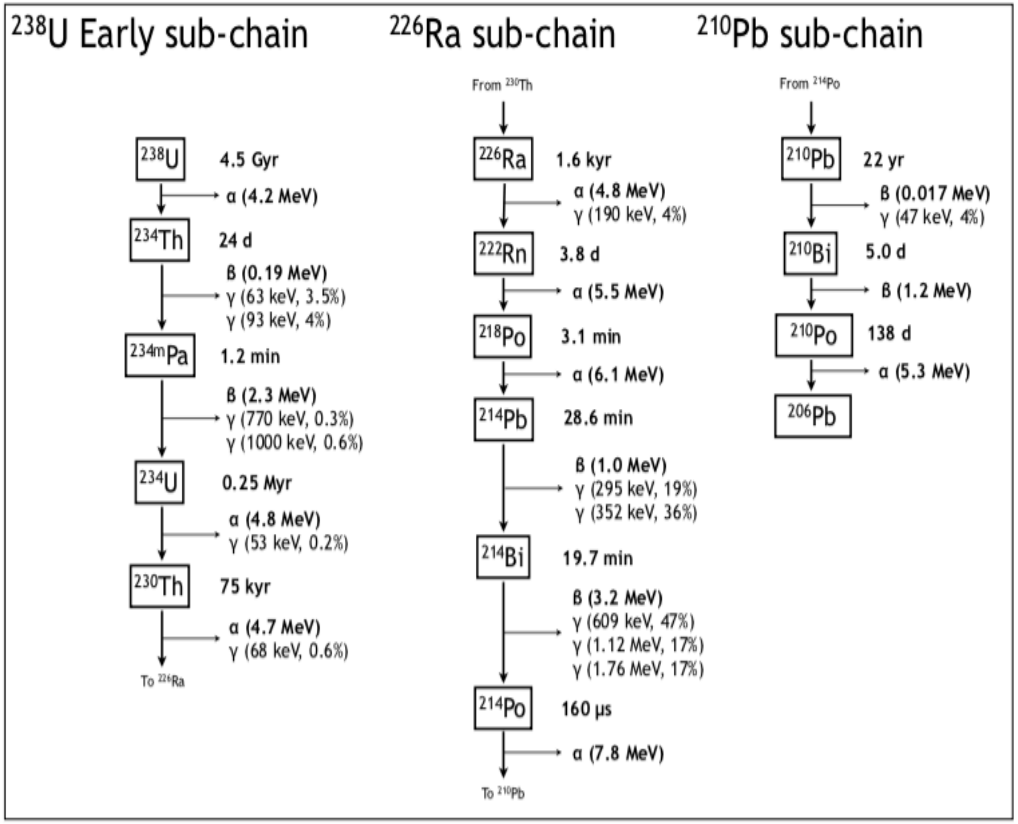


Figure 6.1: The decay chain for ^{238}U. The decay chain is broken into three sub-chains: the ^{238}U early sub-chain, the ^{226}Ra sub-chain, and the ^{210}Pb sub-chain. Isotopes are shown with their half-lives and probability for α or β emission, if not 100%. Decays with probability $<1\%$ are not shown. Alpha or β emission is listed under each isotope, with the mean α energy or β decay endpoint given. Energies and intensities are listed for γ emission with intensity $>1\%$, with the exception of the ^{238}U early chain which lists γ rays with intensity $>0.1\%$. Data from [135].

Glossary

- Half Life = It is the time required for the disintegration of one half of the radioactive atom that are present when measurement starts.

- Disintegration = Each occurence of a nucleus emitting particles or energy is referred to as a disintegration. The number of disintegrations per unit time is referred to as activity(rate of emission) of a sample.