Analysis of Alpha Particle Quenching in SNO+ Liquid Scintillator

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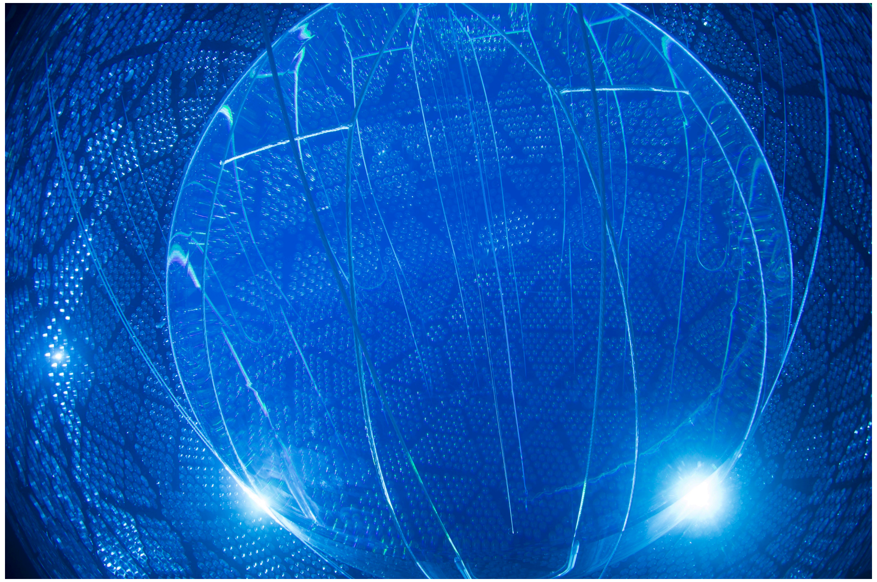
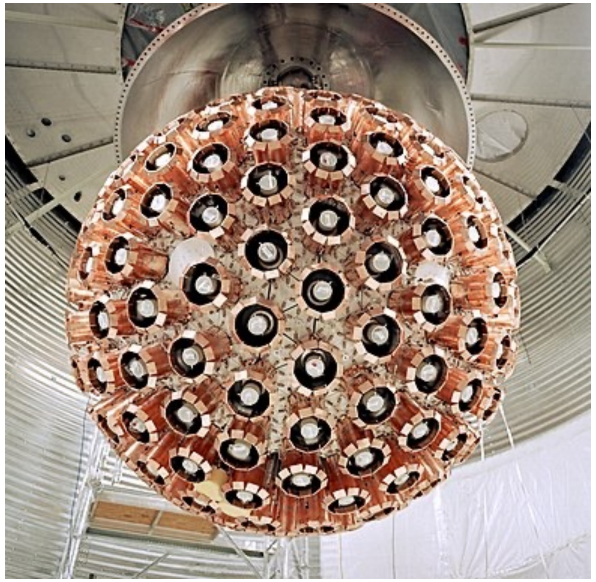
Session #5



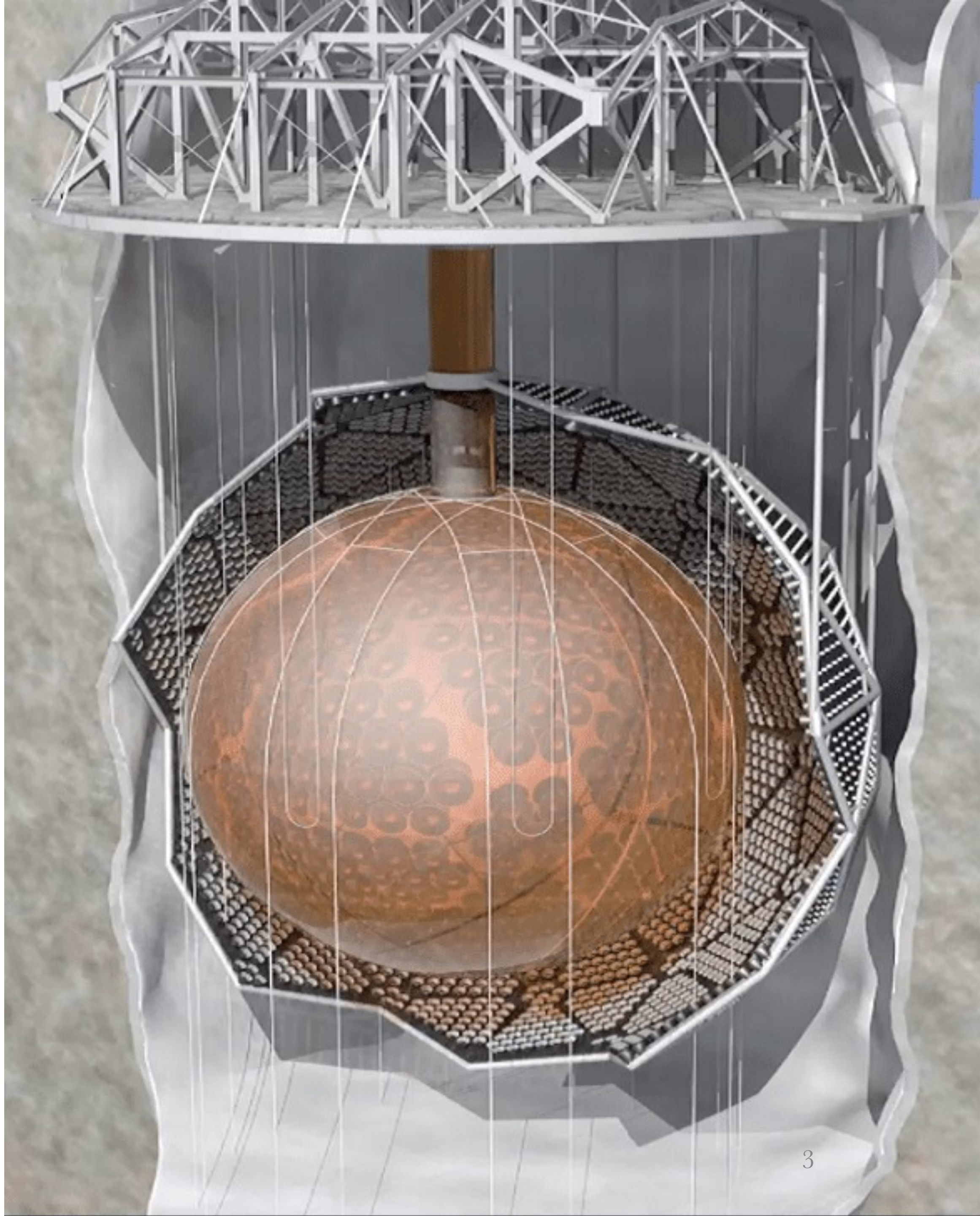


SNOLAB Site

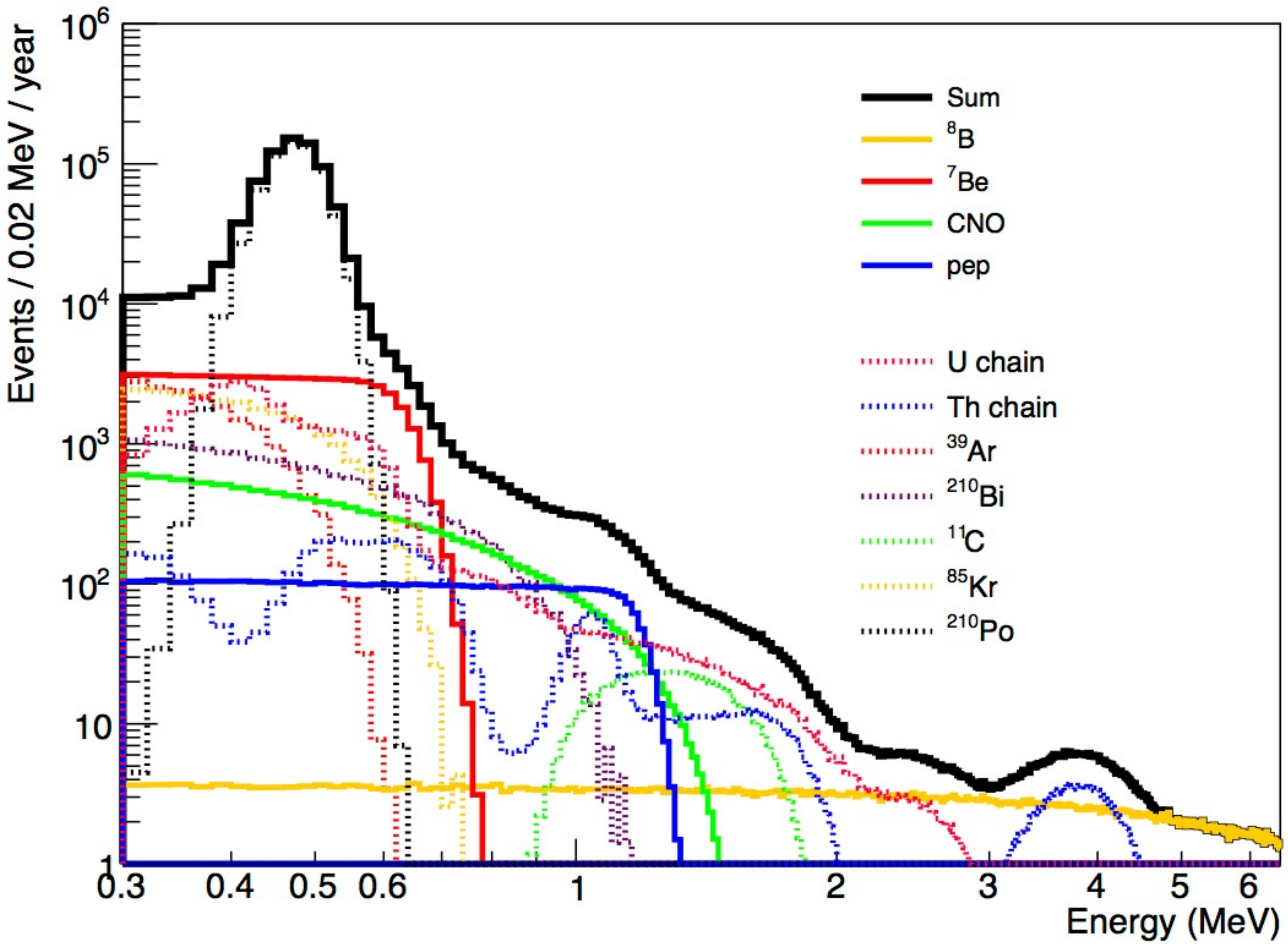
- Located 2 km underground in the Creighton mine near Sudbury, ON, Canada.
- Deep underground for reduction of background radiation.
- Focuses on research in neutrinos and dark matter.

SNO+ Experiment

- Probe the nature of neutrinos.
- 6m radius acrylic vessel (AV) containing LAB as scintillator.
- PMTs are mounted on an 8.5m radius geodesic sphere.
- Entire structure suspended in 30m tall cavity containing ultra-pure water.



Solar Neutrino Spectra + Backgrounds



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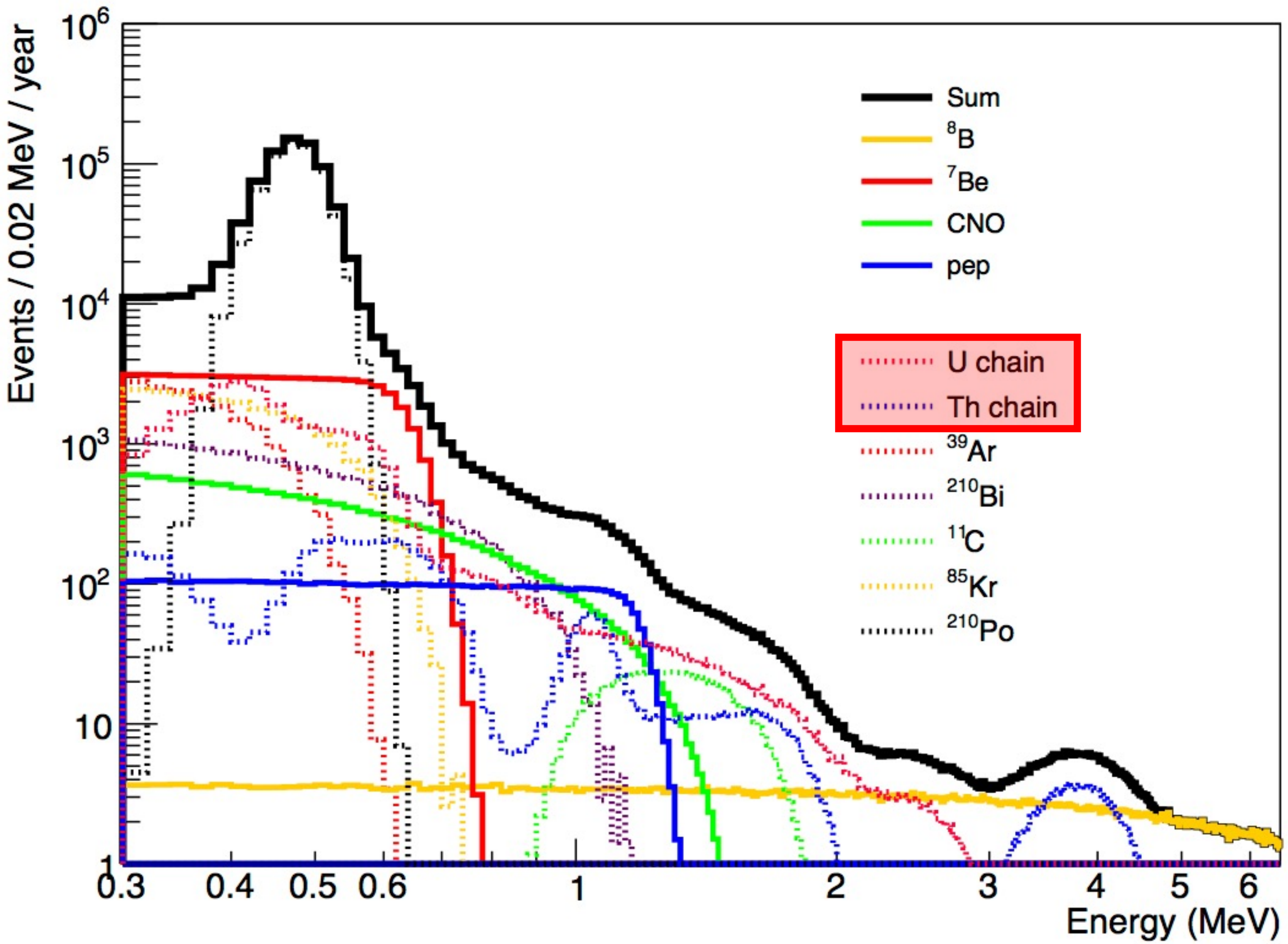
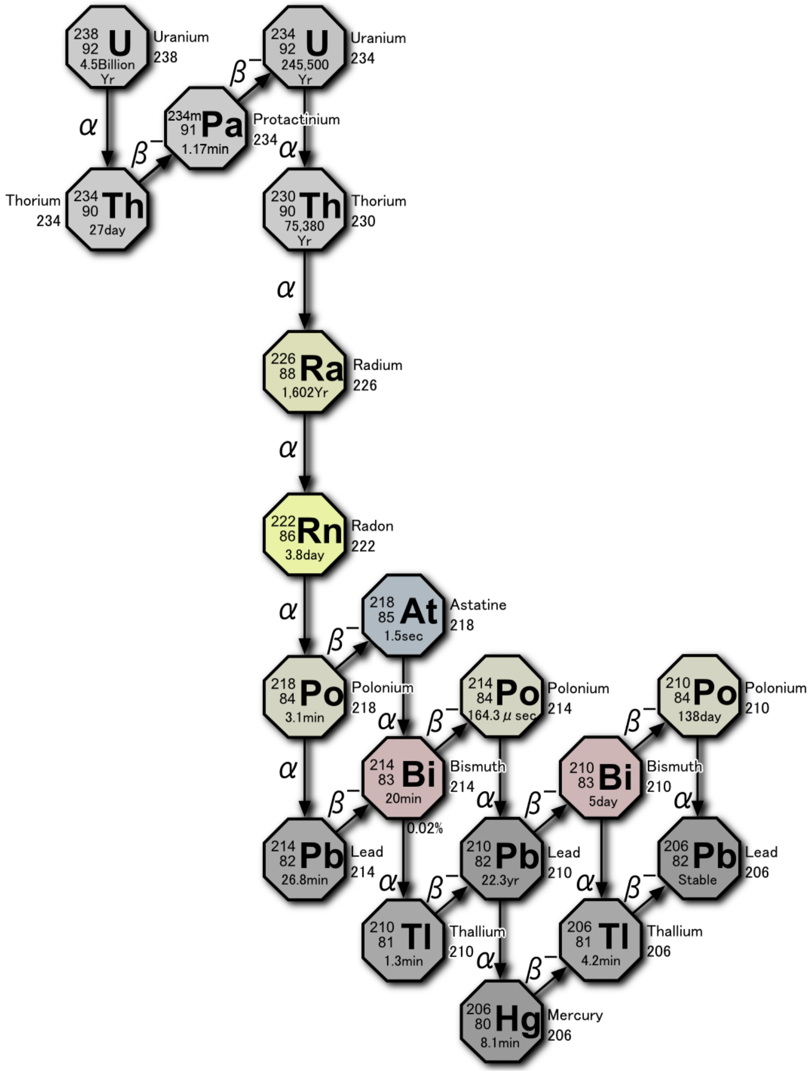
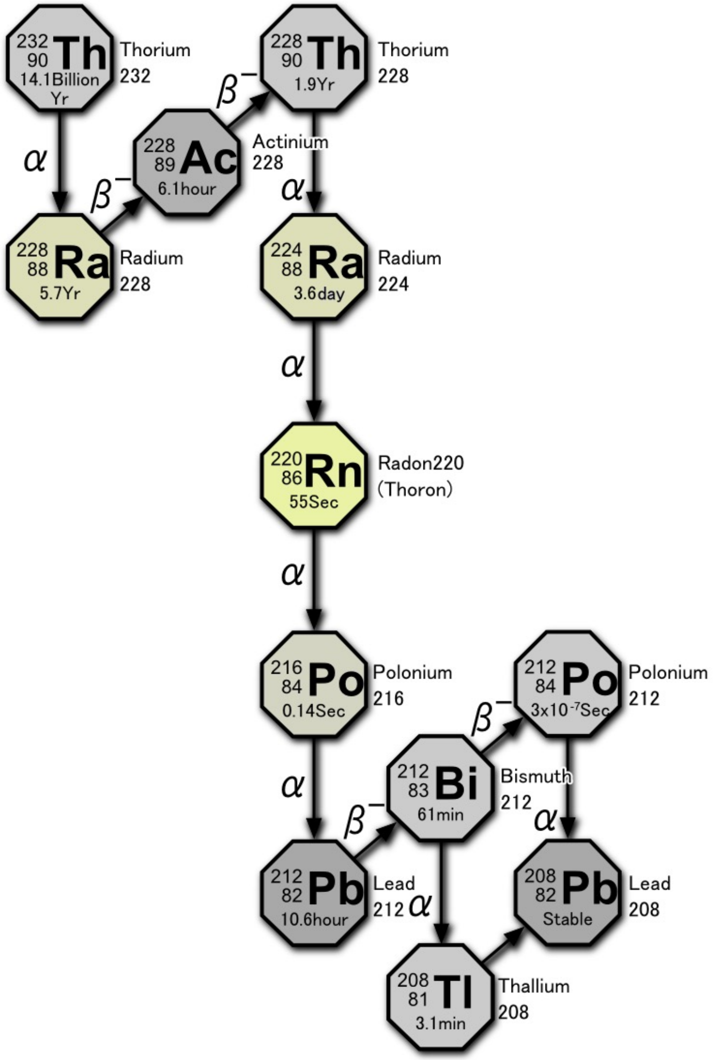
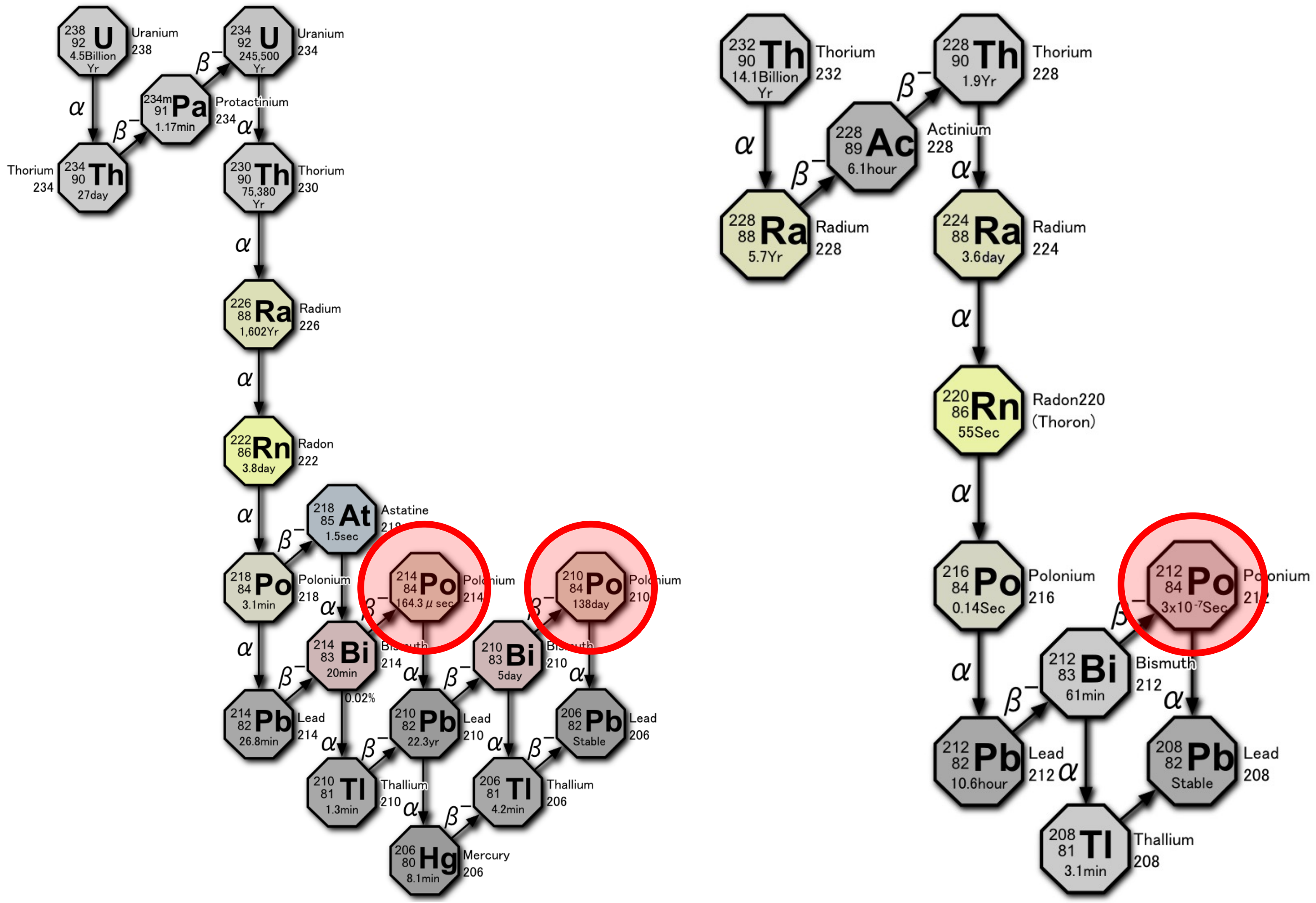


SNO+ Backgrounds





SNO+ Backgrounds



Organic Scintillation

Mechanism | Light Yield | Quenching

Organic Scintillation Process

π-electrons are excited upon interactions with ionizing radiation.

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Excitation releases light.

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Scintillation light is measured by the PMTs.

Spectral Modelling

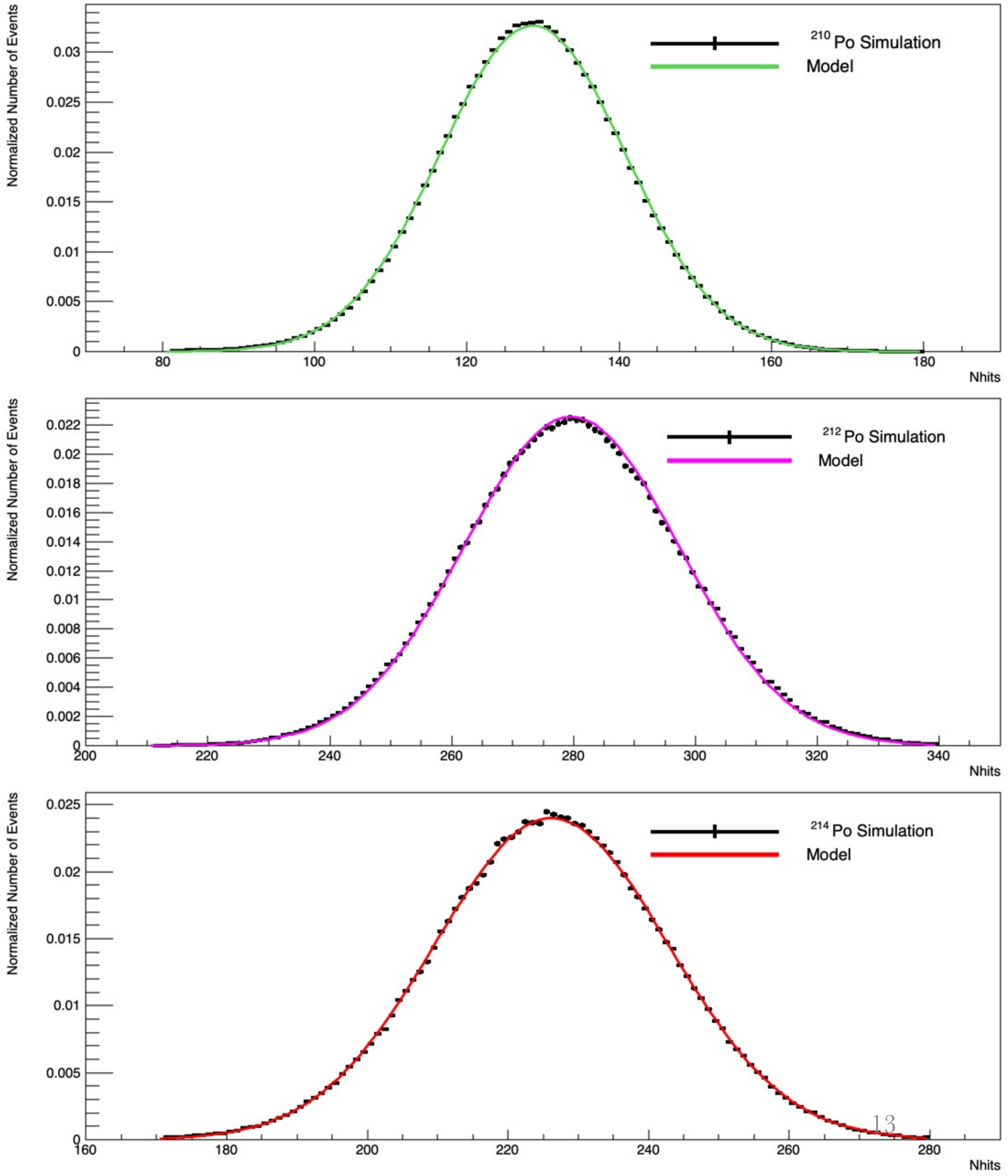
Monte Carlo | Data Selections | Modelling

Monte Carlo Simulation

- Decay is monoenergetic.
- Various effects cause smearing in the energy spectrum.
- Gaussian mean is taken to be the emitted decay energy.

$$f(x;\mu,\sigma,\lambda) = \int_0^\infty dx'\, A_0 \exp\left(-\frac{x-x'}{\lambda}\right) B_0 \exp\left(-\frac{(x'-\mu)^2}{2\sigma^2}\right)$$

$$= C_0 \exp\left(\frac{x-\mu+\sigma^2/\lambda}{\lambda}\right) \times \text{erfc}\left(\frac{x-\mu+\sigma^2/\lambda}{\sqrt{2}\sigma}\right)$$



^{210}Po Spectrum

$$f(x;\mu,\sigma,\lambda) = \int_0^\infty dx'\, A_0 \exp\left(-\frac{x-x'}{\lambda}\right) B_0 \exp\left(-\frac{(x'-\mu)^2}{2\sigma^2}\right)$$

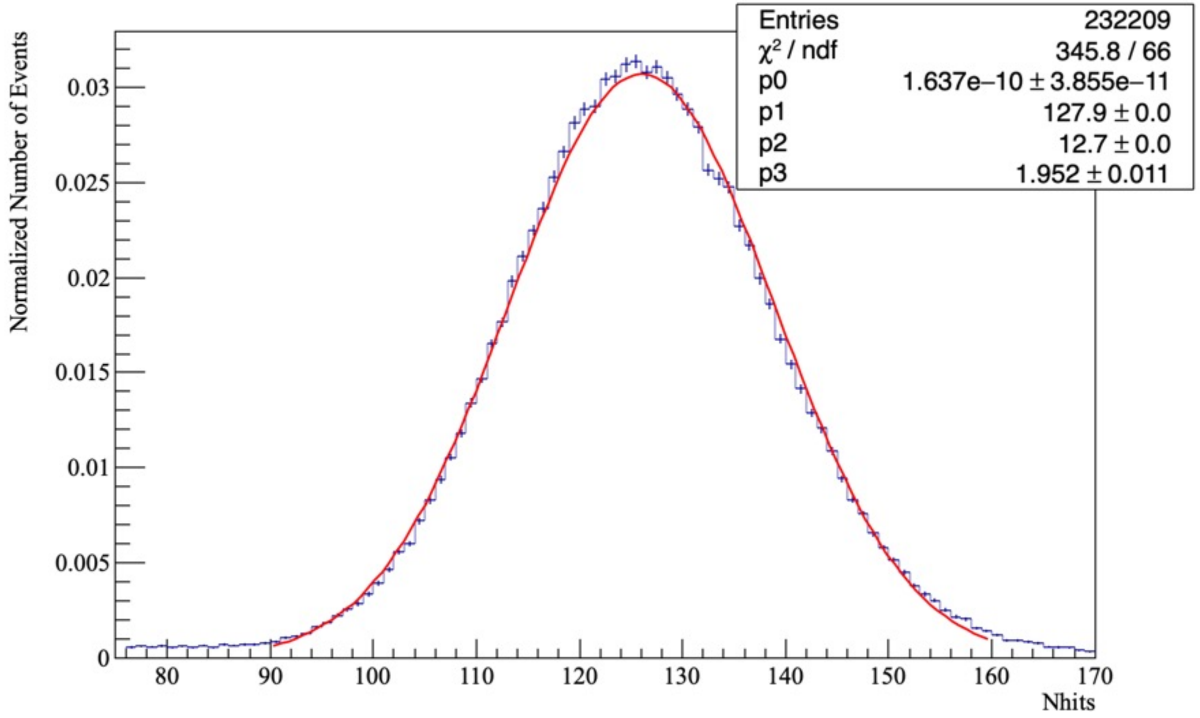
$$= C_0 \exp\left(\frac{x-\mu+\sigma^2/\lambda}{\lambda}\right) \times \mathrm{erfc}\left(\frac{x-\mu+\sigma^2/\lambda}{\sqrt{2}\sigma}\right)$$

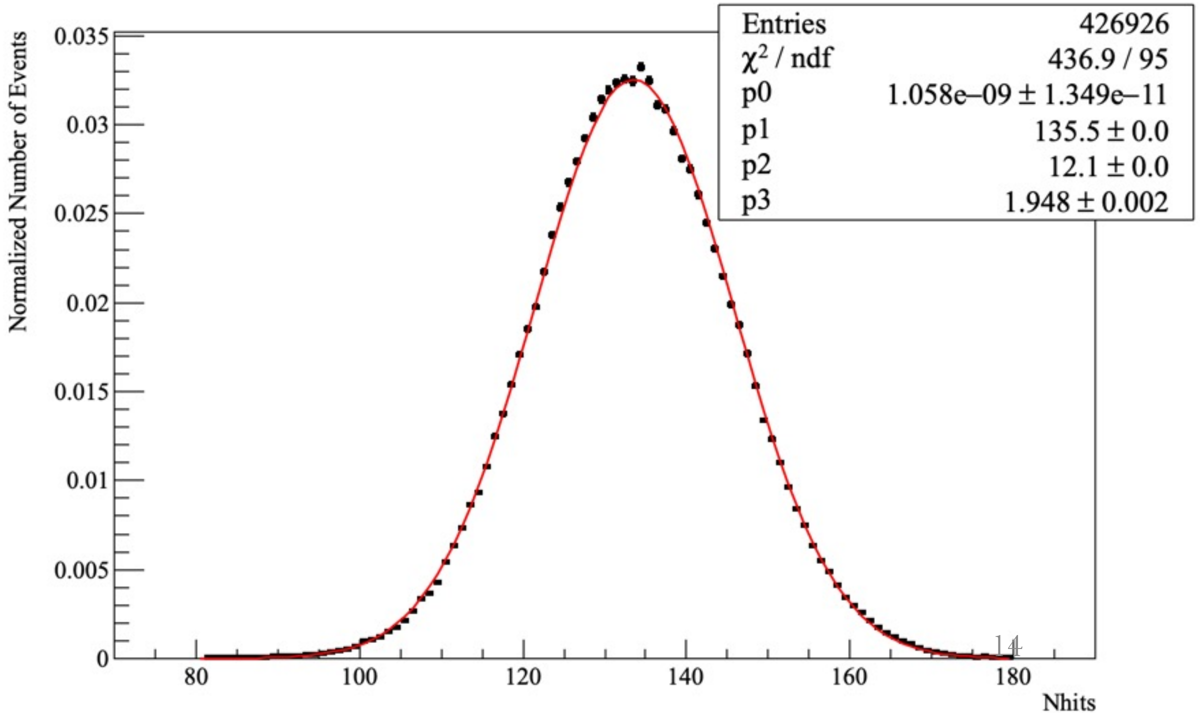
Parameter	Selection
Radial Position:	$R_{xyz} < 5200$ mm
Vertical Position:	$Z > 700$ mm (partial fill phase)
Nhits:	$80 <$ `Nhits` < 160
Event Fitter:	`partialFit == 1`

Mean Nhits [Data]: 127.9 ± 0.03

Mean Nhits [MC]: 135.5 ± 0.02

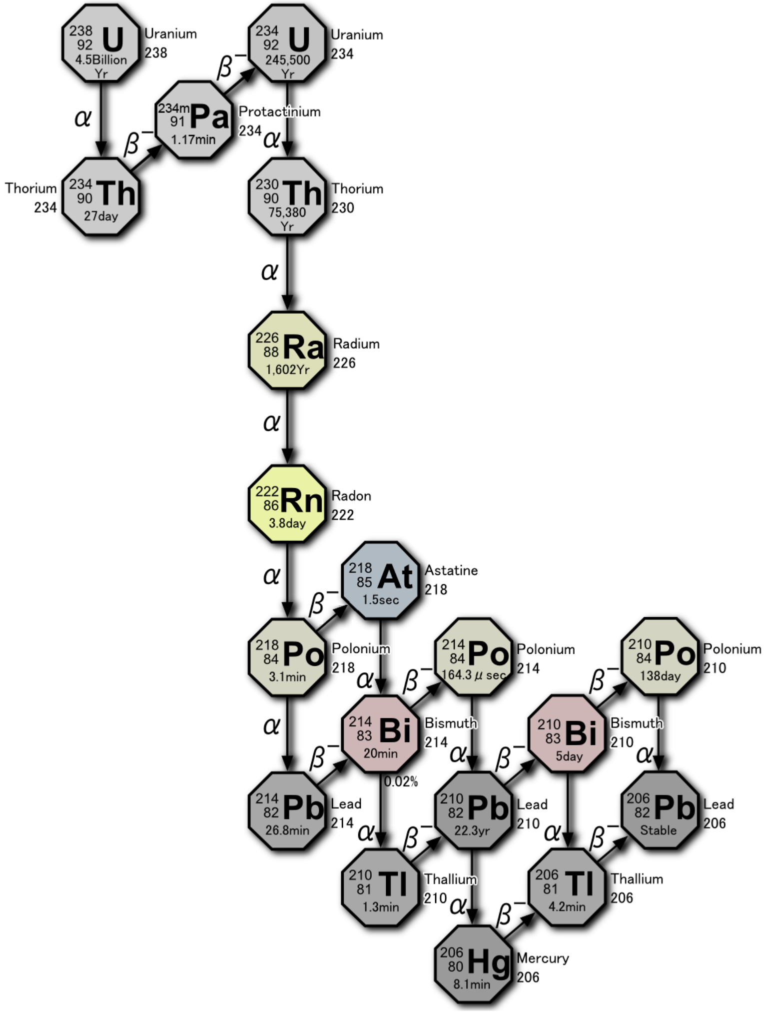
ΔNhits: 7.6 ± 0.04

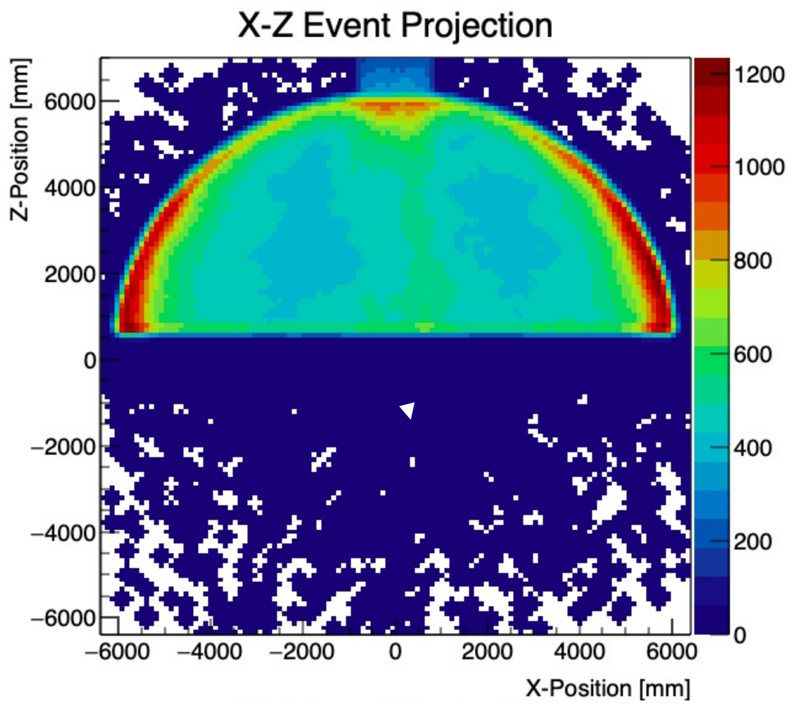


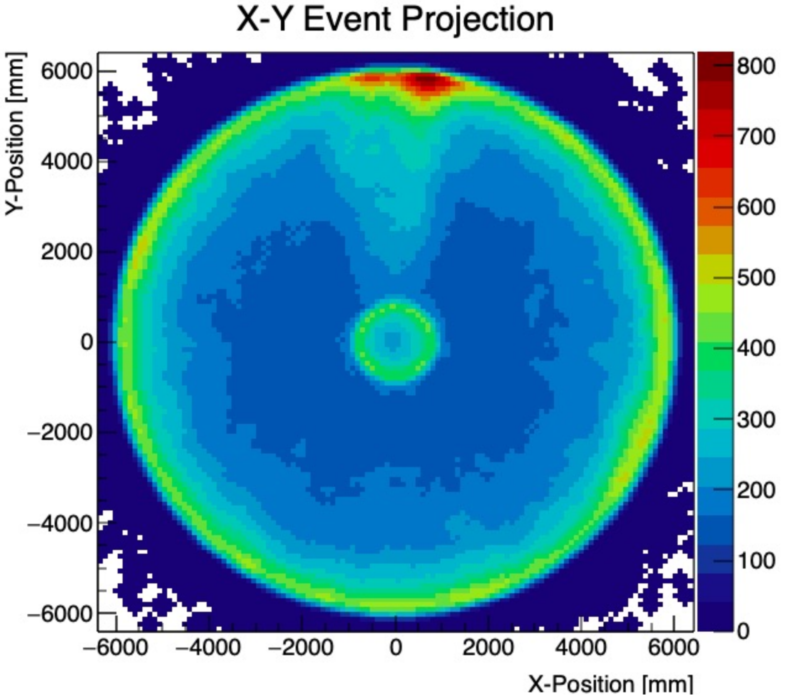


Motivating ^{214}BiPo Data Selections

- 4000 ns $< \Delta t <$ 1e6 ns
- $\Delta r < 1000$ mm
- `partialFit == 1`
- $R_{xyz} < 5600$ mm
- $Z > 700$ mm
- $150 <$ `Nhits` < 350







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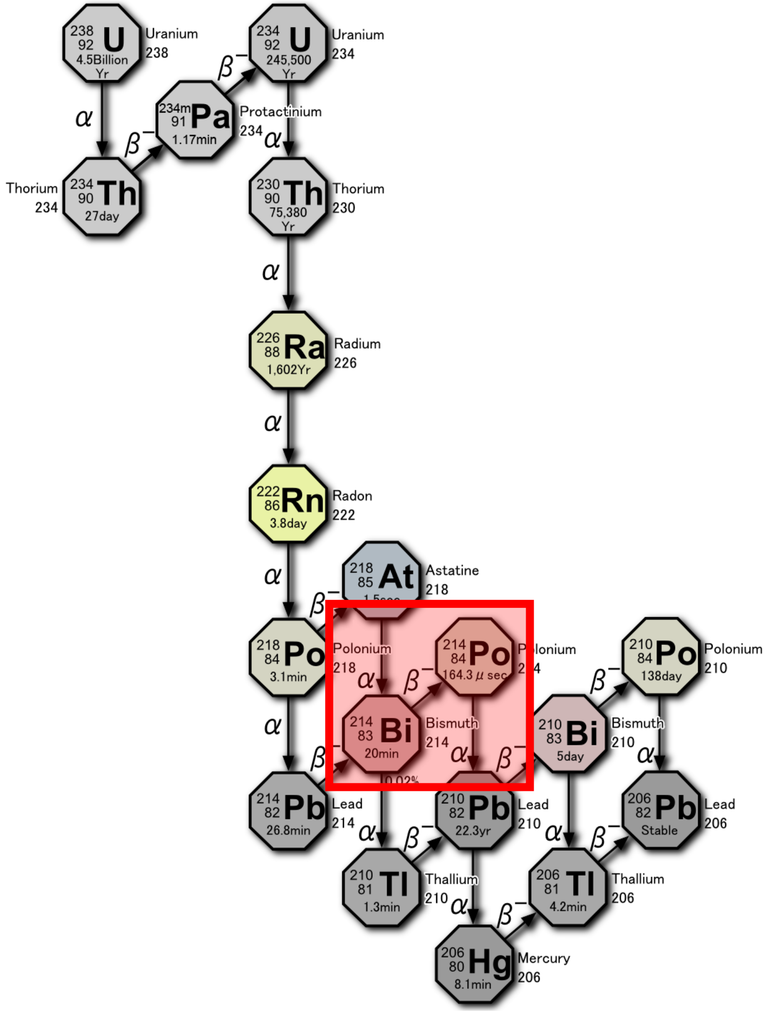
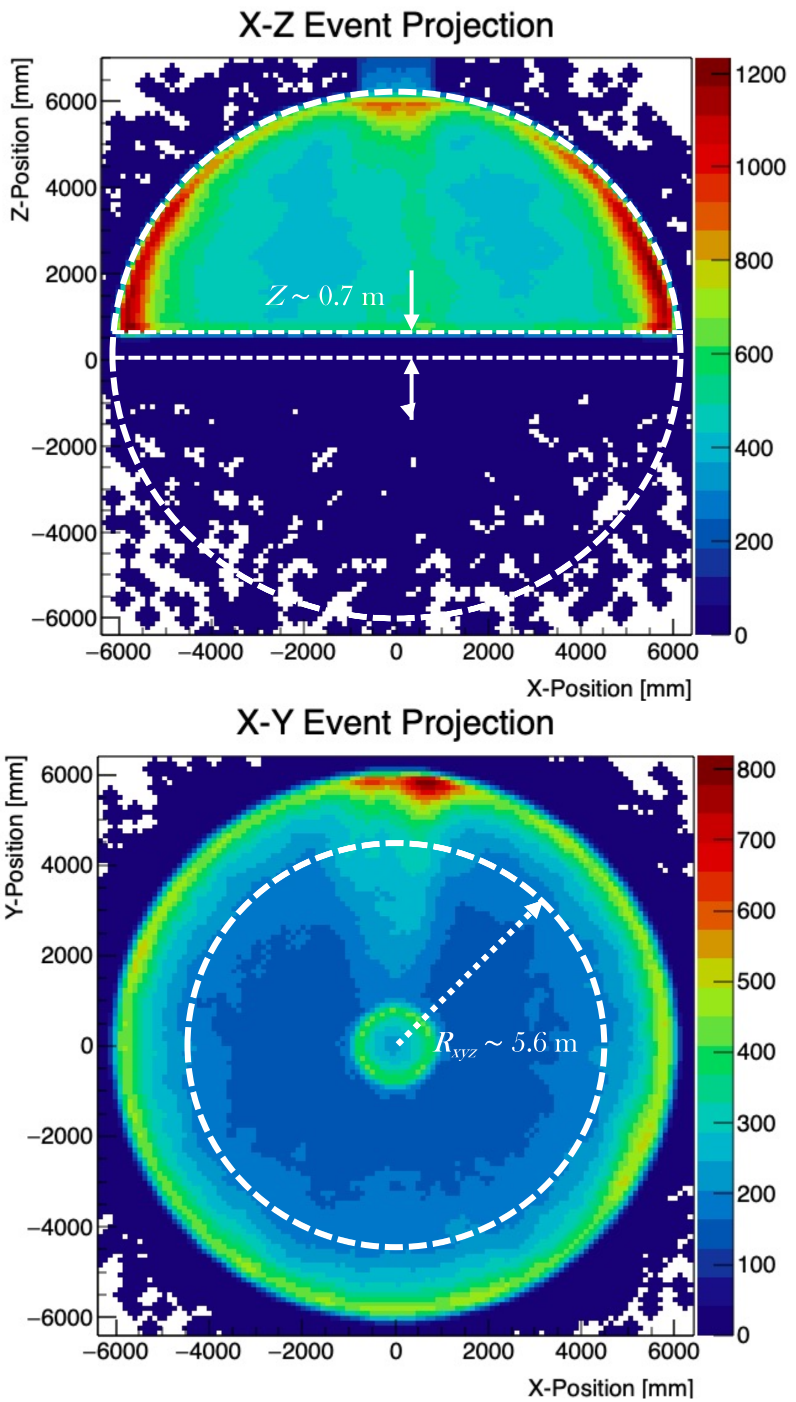




^{214}Po Spectrum (Aug – Oct 2020 Data)

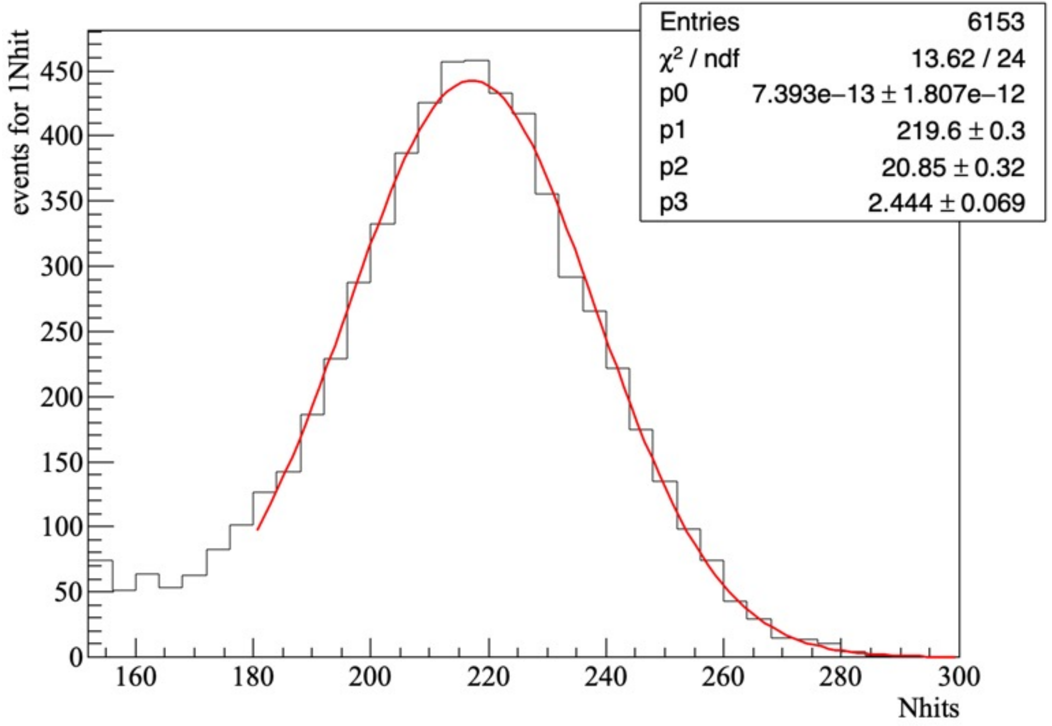
$$f(x;\mu,\sigma,\lambda) = \int_0^\infty dx'\, A_0 \exp\left(-\frac{x-x'}{\lambda}\right) B_0 \exp\left(-\frac{(x'-\mu)^2}{2\sigma^2}\right)$$

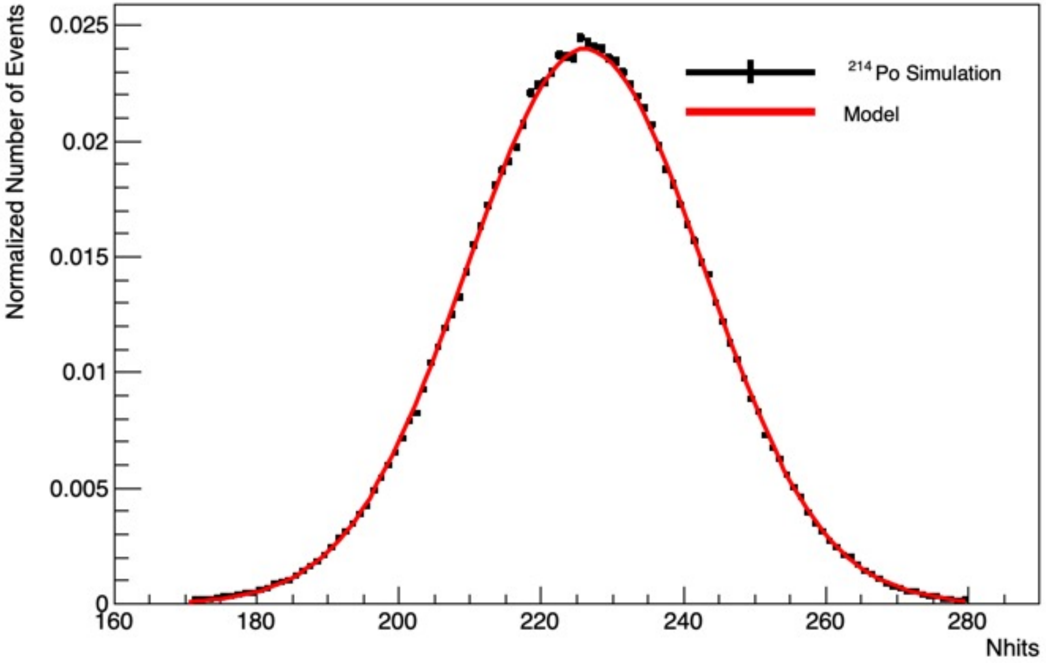
$$= C_0 \exp\left(\frac{x-\mu+\sigma^2/\lambda}{\lambda}\right) \times \mathrm{erfc}\left(\frac{x-\mu+\sigma^2/\lambda}{\sqrt{2}\sigma}\right)$$

Mean Nhits [Data]: 219.6 ± 0.3

Mean Nhits [MC]: 227.3 ± 0.03

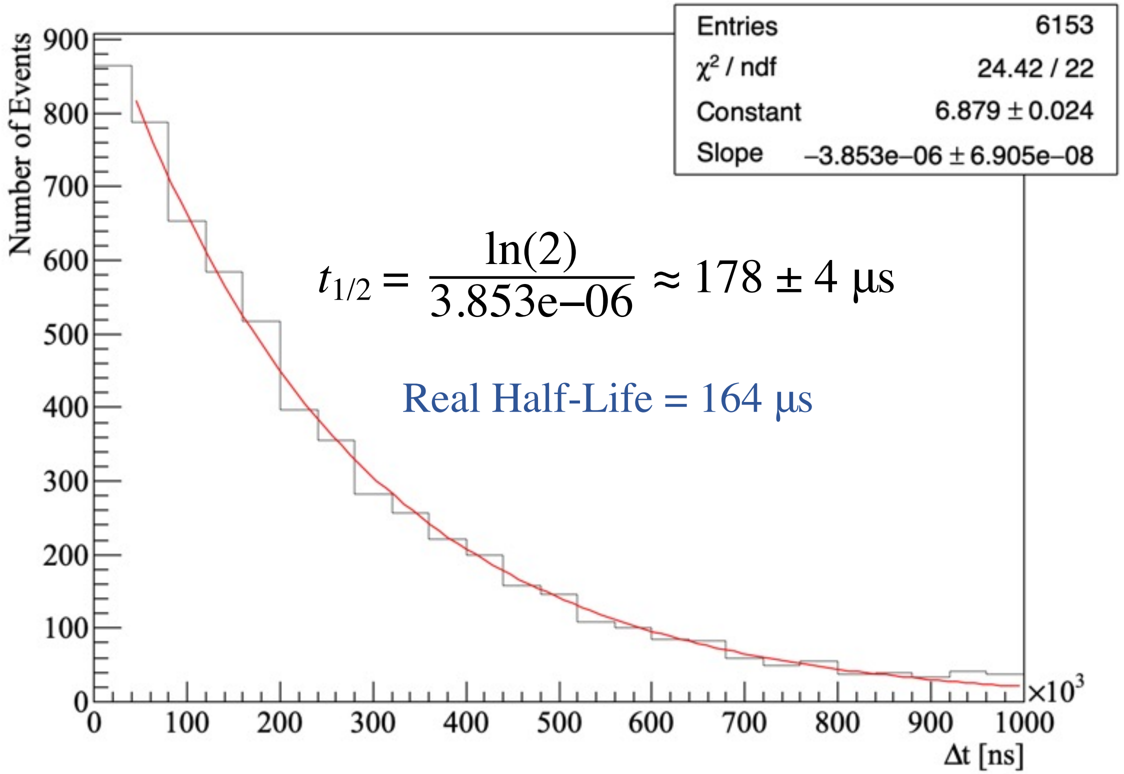
Δnhits: 7.7 ± 0.3



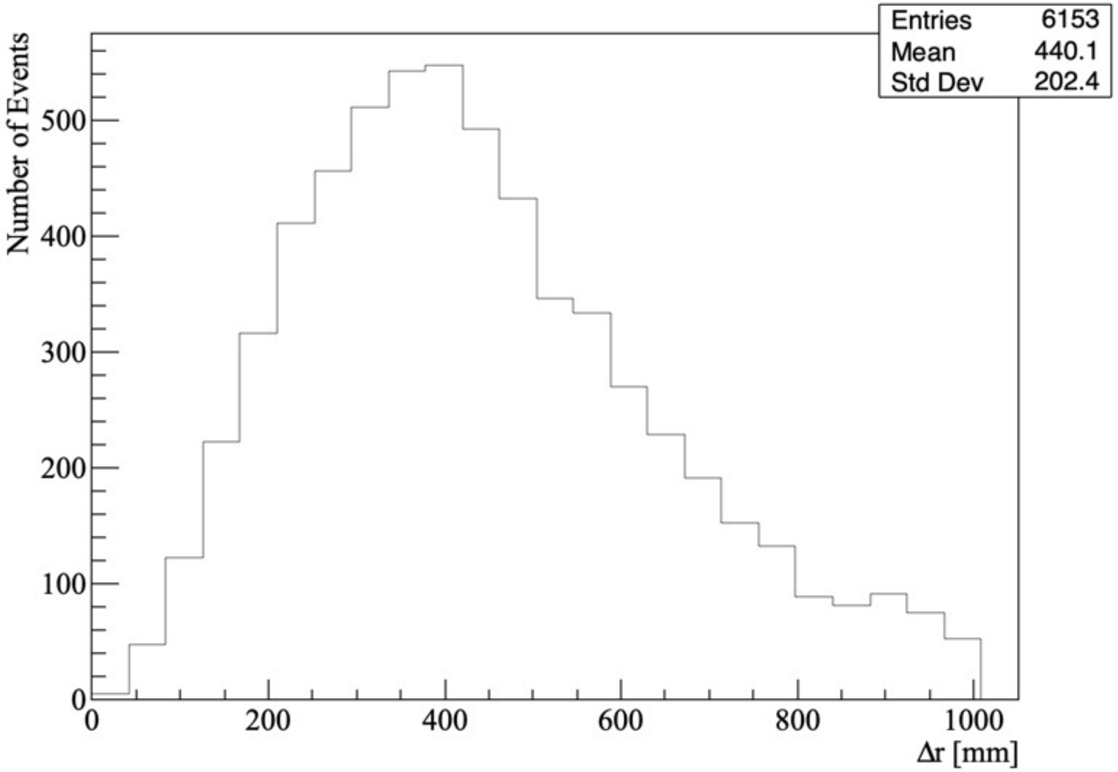


^{214}Po Background – Δt and Δr

Time Difference Between Prompt and Delayed Events. Cut: (4000, 1e6) ns

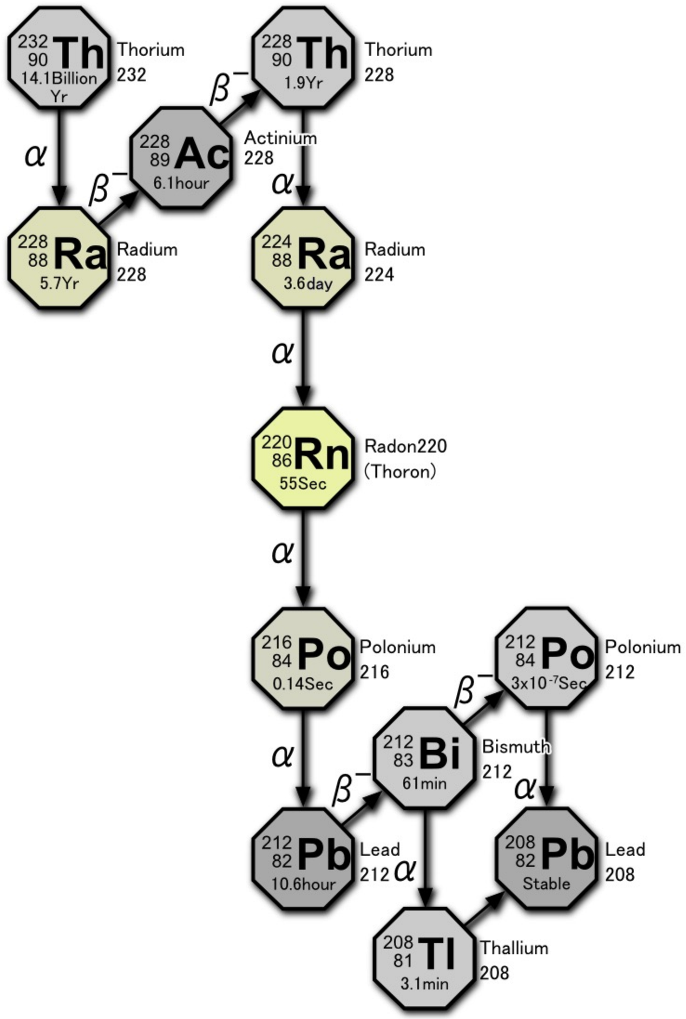


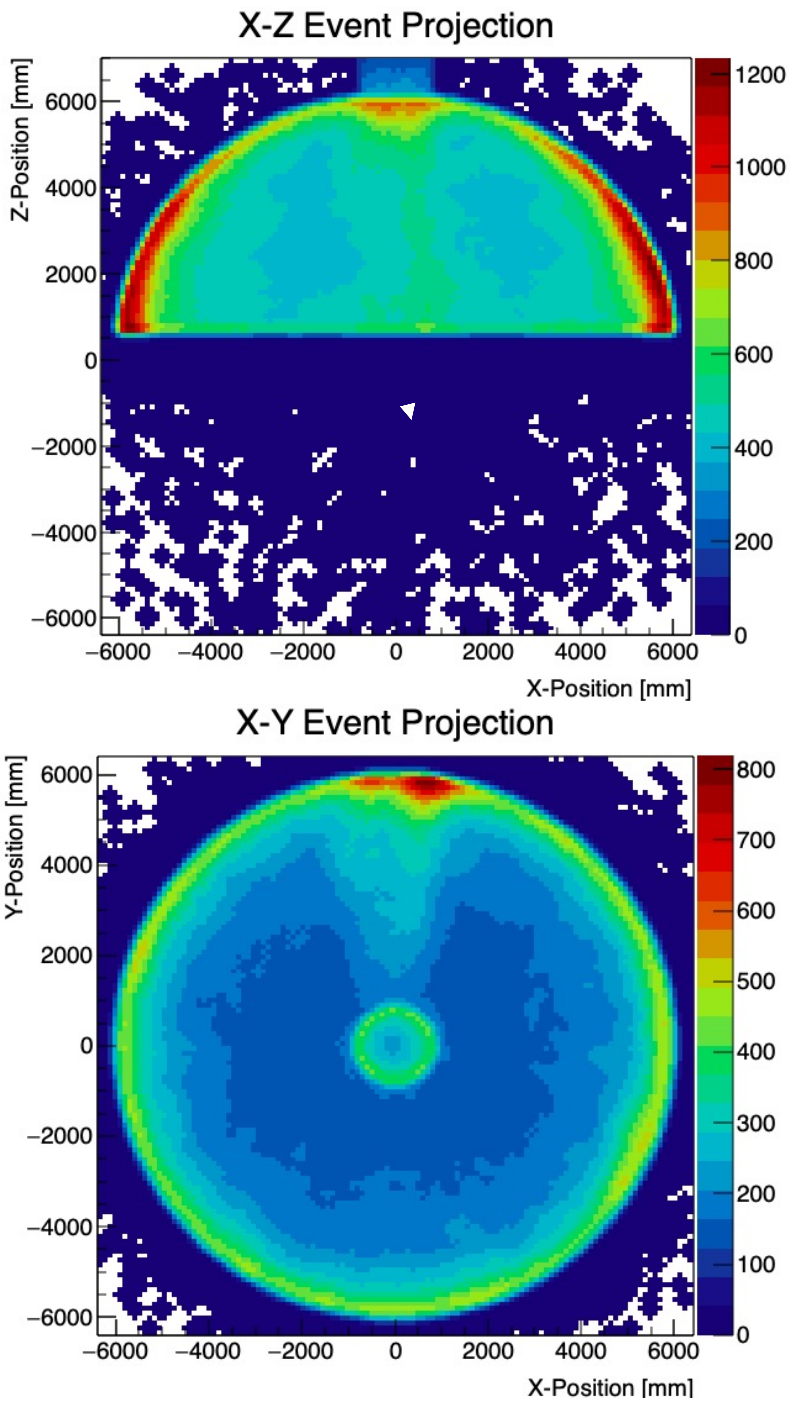
Position Difference Between Prompt and Delayed Events. Cut: < 1000 mm



Now for ^{212}BiPo Data Selections…

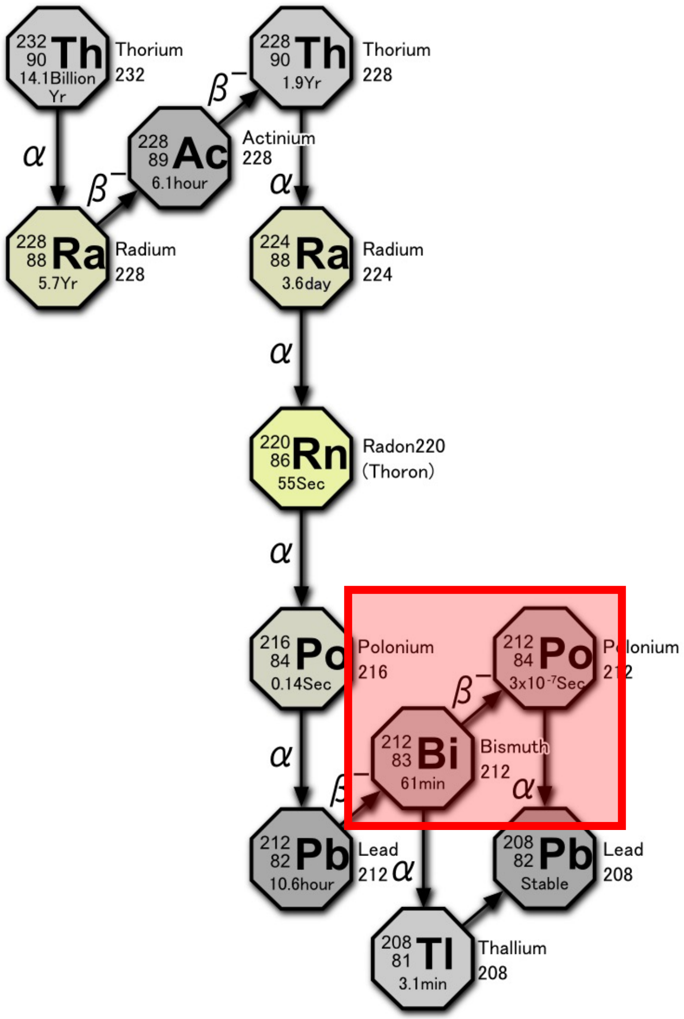
- 400 ns < Δt < 800 ns
- Δr < 1000 mm
- `partialFit == 1`
- R_{xyz} < 5600 mm
- Z > 700 mm
- 230 < `Nhits` < 430

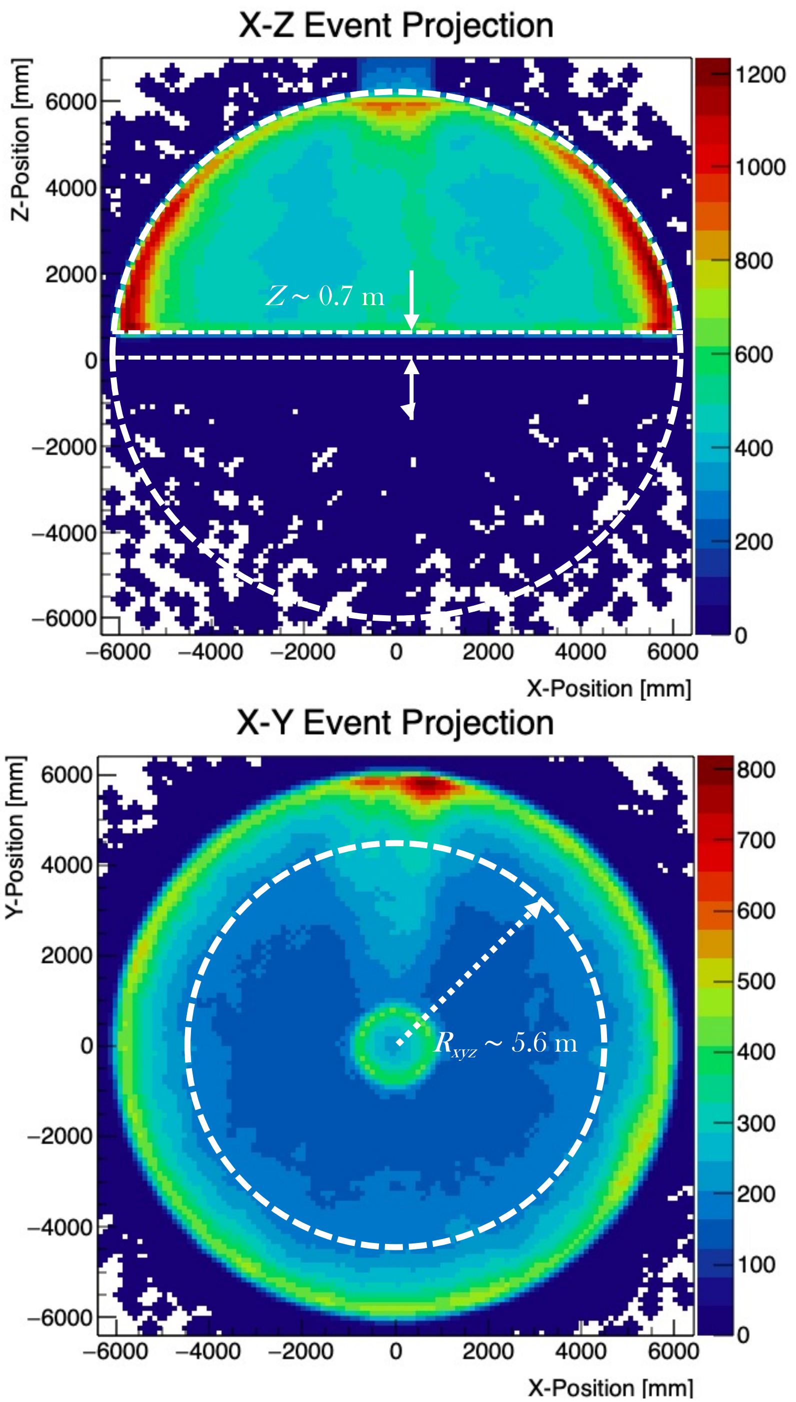




Now for ^{212}BiPo Data Selections…

- $400\ \mathrm{ns} < \Delta t < 800\ \mathrm{ns}$
- $\Delta r < 1000\ \mathrm{mm}$
- `partialFit == 1`
- $R_{xyz} < 5600\ \mathrm{mm}$
- $Z > 700\ \mathrm{mm}$
- $230 <$ `Nhits` < 430





^{212}Po Spectrum (Aug – Oct 2020 Data)

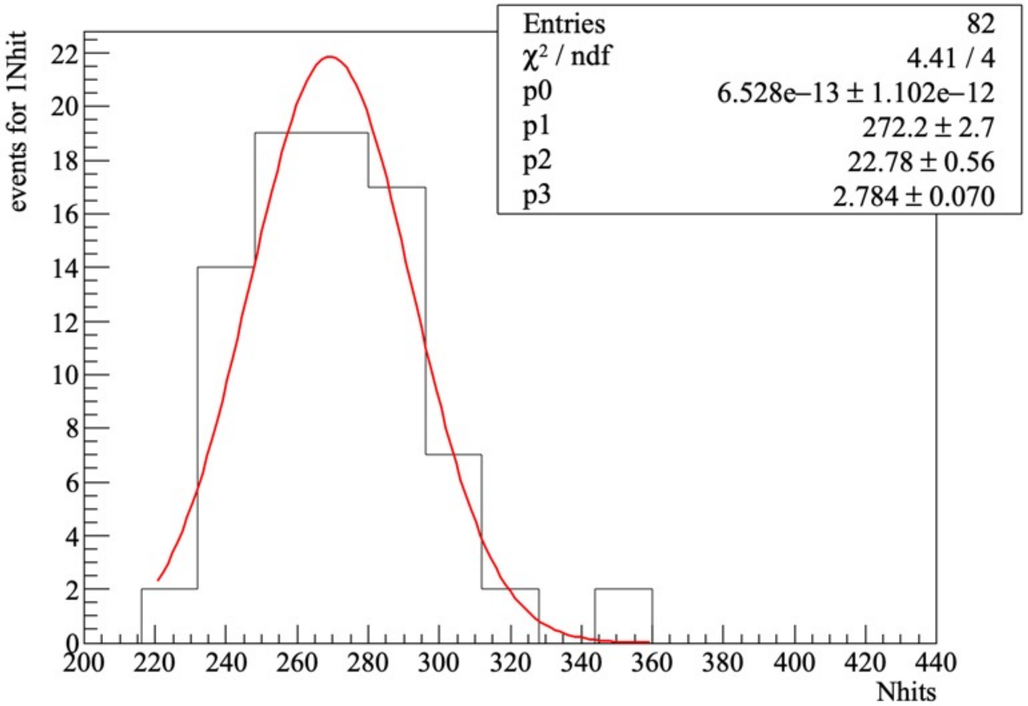
$$f(x;\mu,\sigma,\lambda) = \int_0^\infty dx'\, A_0 \exp\left(-\frac{x-x'}{\lambda}\right) B_0 \exp\left(-\frac{(x'-\mu)^2}{2\sigma^2}\right)$$

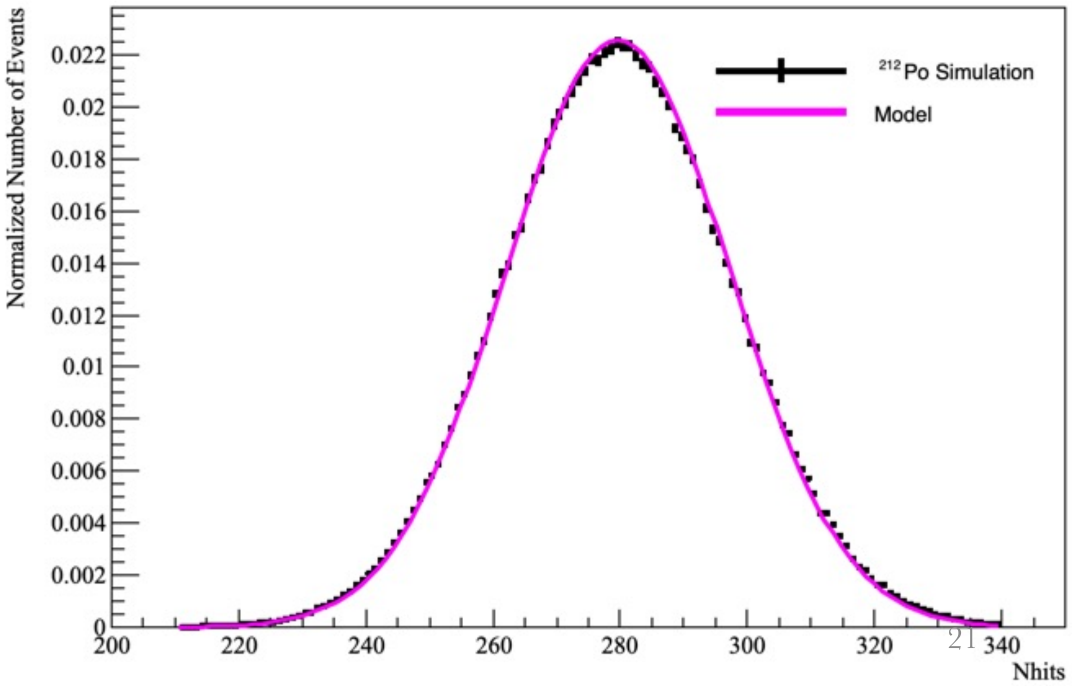
$$= C_0 \exp\left(\frac{x-\mu+\sigma^2/\lambda}{\lambda}\right) \times \mathrm{erfc}\left(\frac{x-\mu+\sigma^2/\lambda}{\sqrt{2}\sigma}\right)$$

Mean Nhits [Data]: 272.2 ± 3

Mean Nhits [MC]: 281.5 ± 0.03

Δnhits: 9.3 ± 3





Summary

- Exponentially modified Gaussian model agrees well to both data and simulation for the backgrounds studied, with the differences between data and simulation quantified.
- Able to see the ^{212}Po spectrum, even with low statistics!
- These results will be used as part of a global calibration for the SNO+ detector, which include externally deployed calibration sources and internal backgrounds.
- Results can also be used to fine-tune MC framework to data in scintillator.

Acknowledgements

Thank you to Dr. Christine Kraus, Dr. Ryan Bayes and the Laurentian & Queen's research groups for supervising me throughout this project and providing invaluable support.