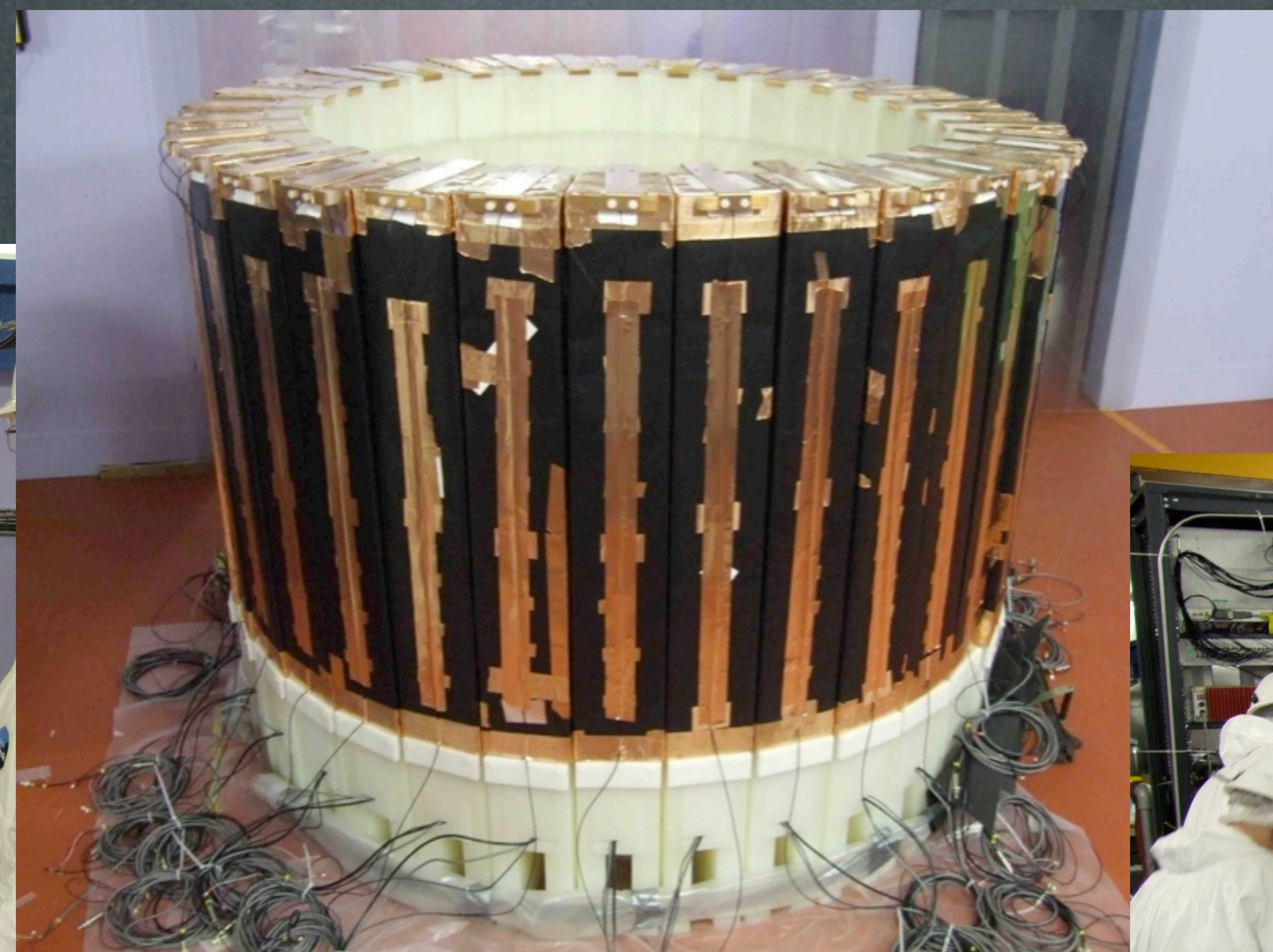
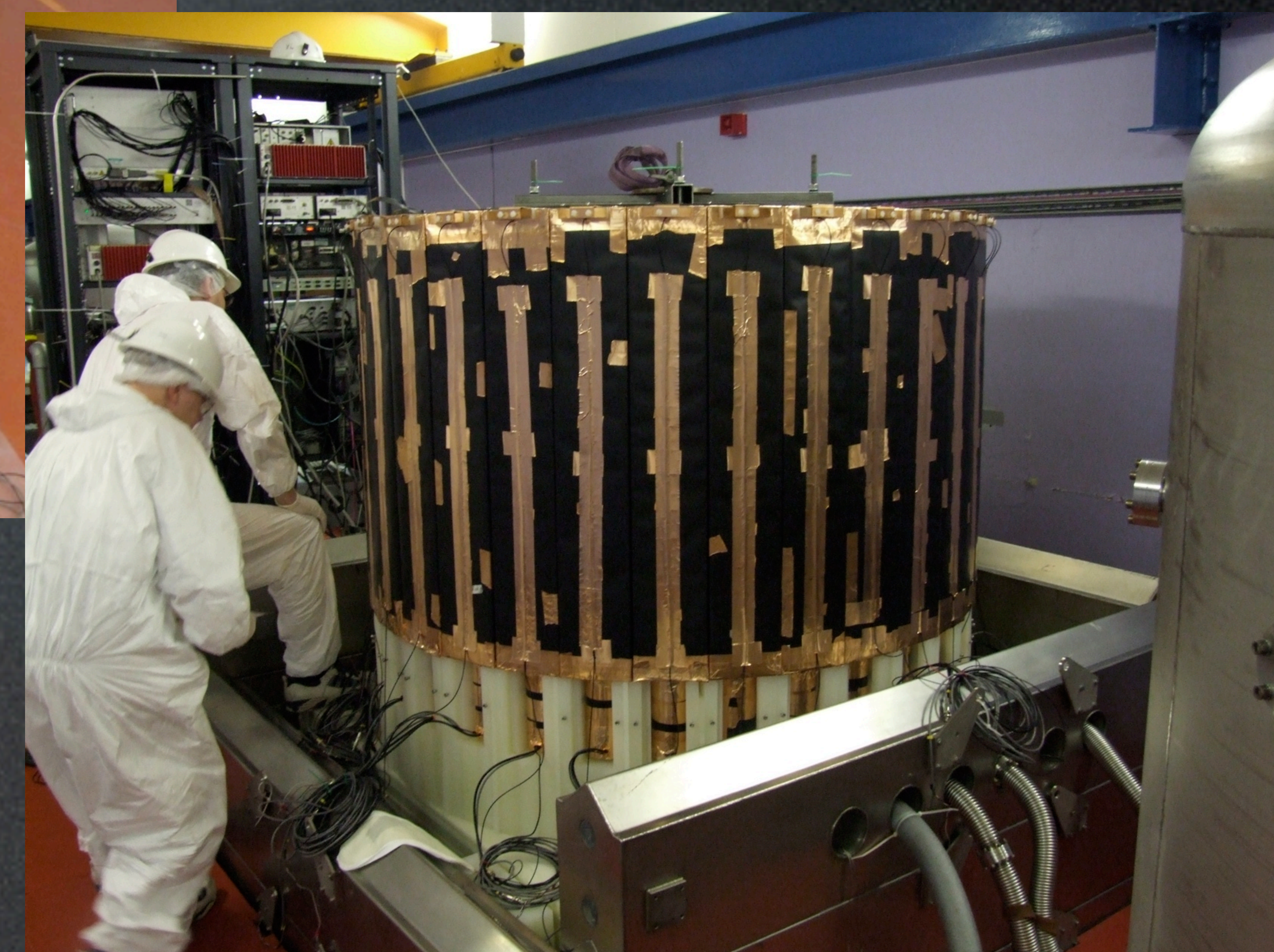
Using the ZEPLIN-III veto detector as a diagnostic tool





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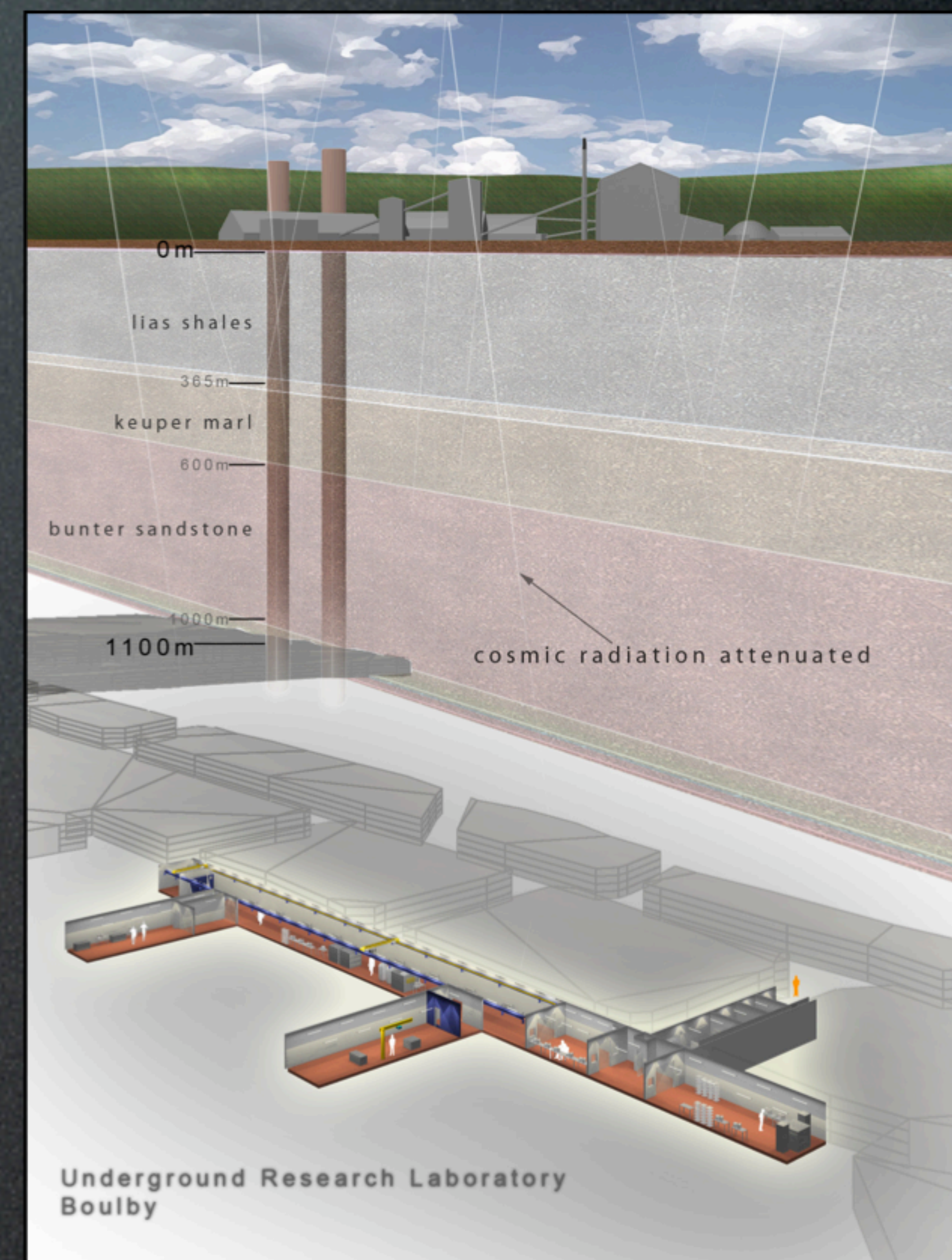
On behalf of the ZEPLIN-III collaboration

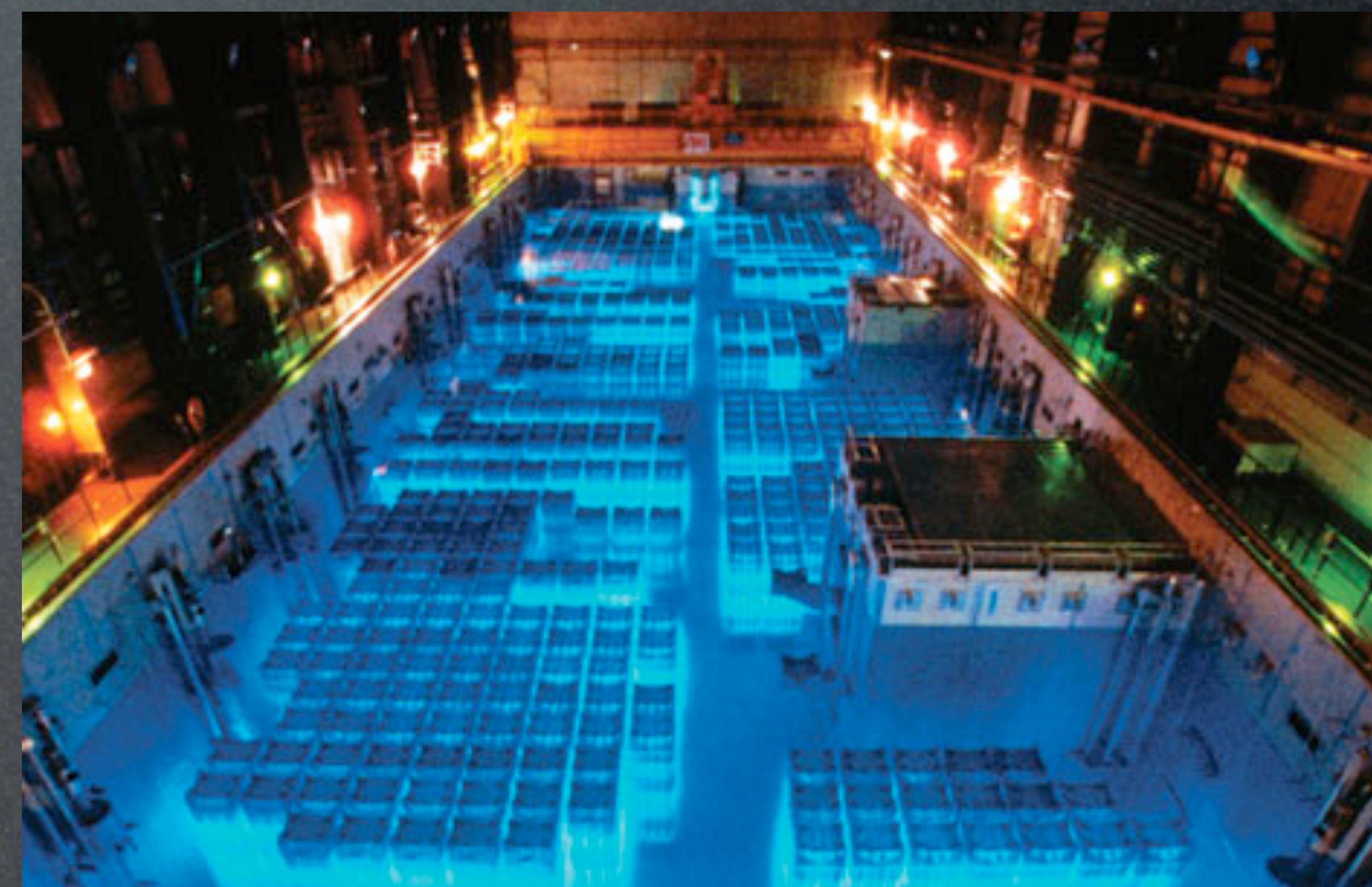
ZEPLIN-III

The ZEPLIN-III instrument is a two phase dark matter detector. The target medium is xenon. In order to observe rare events a low background is essential.



Kr contamination

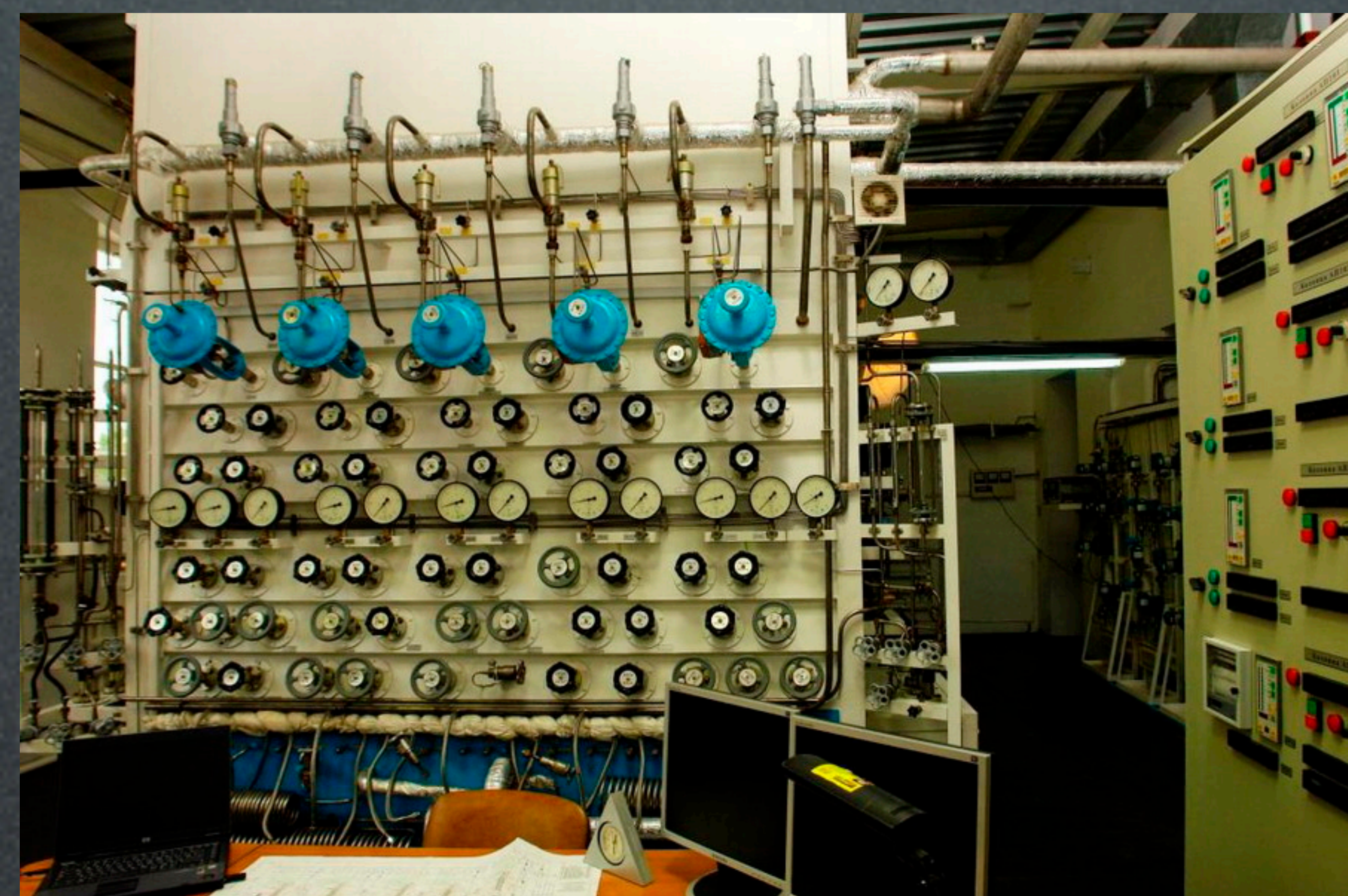
A significant threat to all WIMP searches using xenon is posed by ^{85}Kr ($t_{1/2}$=10.76 years, β_{max}=687 keV).



^{85}Kr present due to fuel reprocessing and nuclear testing

Kr contamination

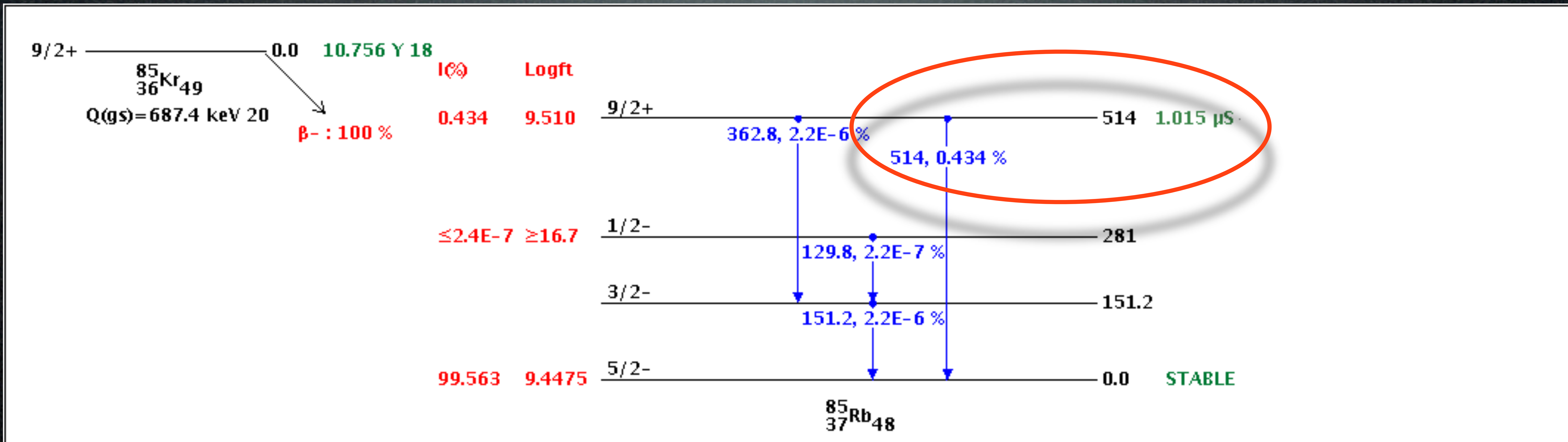
The ZEPLIN-III xenon was sourced from an underground air supply in Russia in the late 1970s.



The ratio of $^{85}Kr/Kr$ was determined to be 1.5×10^{-12}.

Kr contamination

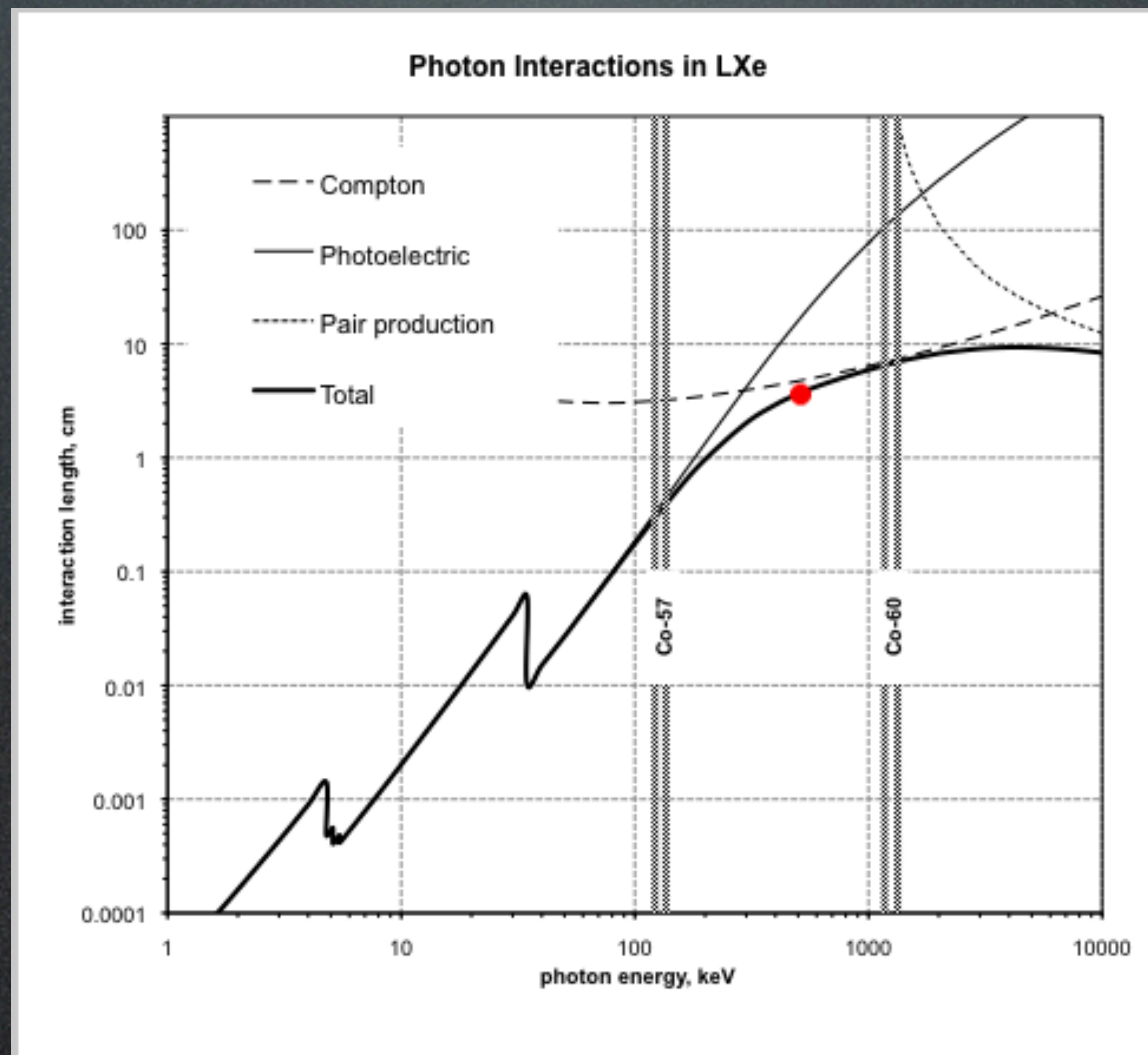
^{85}Kr has 3 decay channels, one of these with a branching ratio of 0.434% is to a short lived excited state of ^{85}Rb.



This state has a lifetime of 1.464 μs and decays with the emission of a 514 keV gamma-ray.

Kr contamination

The photon interaction length is about the column height for 514 keV gamma-rays, so about e^{-1} would escape.



Kr contamination

These escaping gamma-rays may then leave a delayed signal in the veto detector.

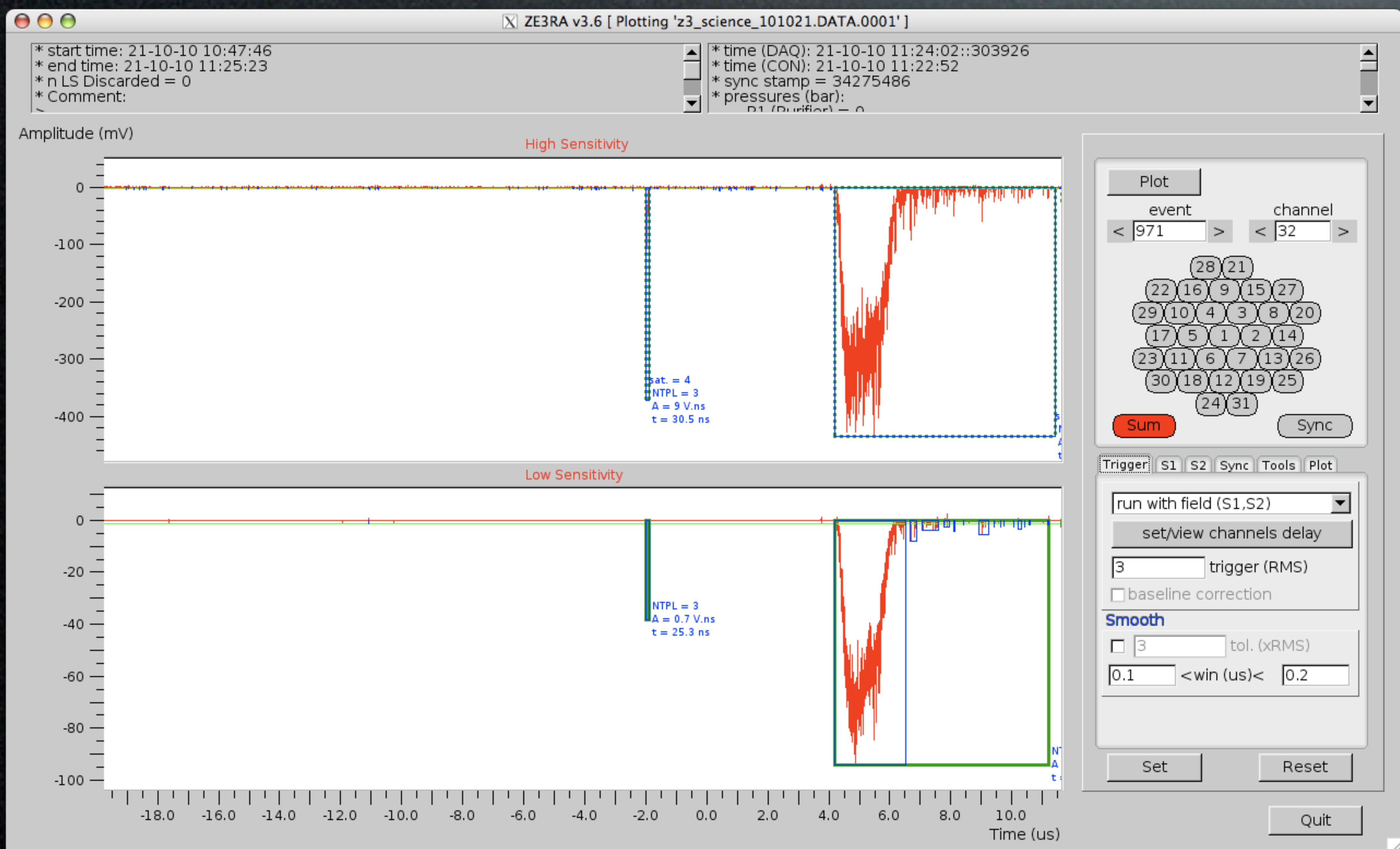
gamma-ray hits veto ~microseconds later

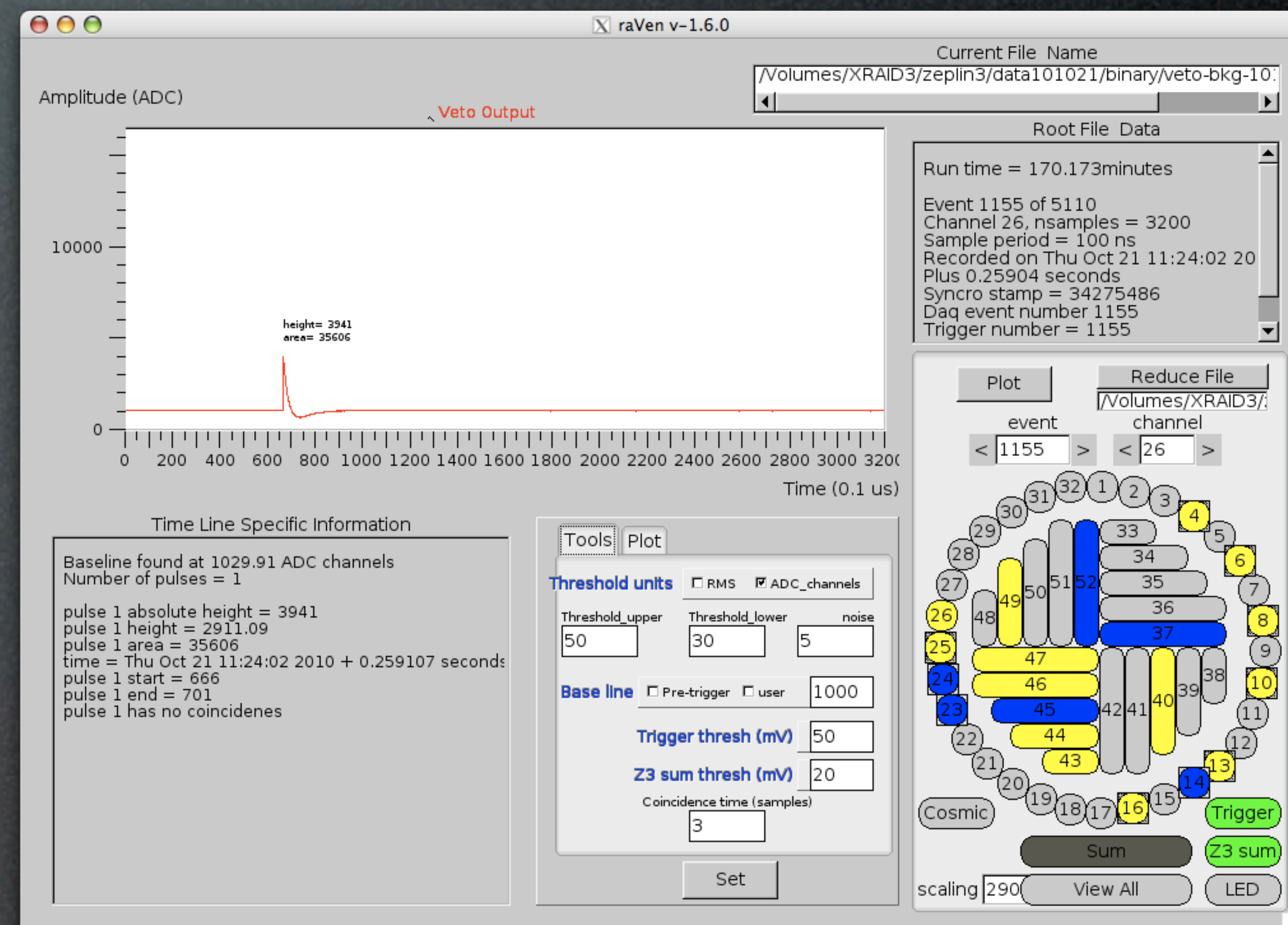
beta decay creates ZEPLIN-III event

^{85}kr nucleus beta decays, the decay via this channel has β_{max} = 173.4 keV

Kr contamination

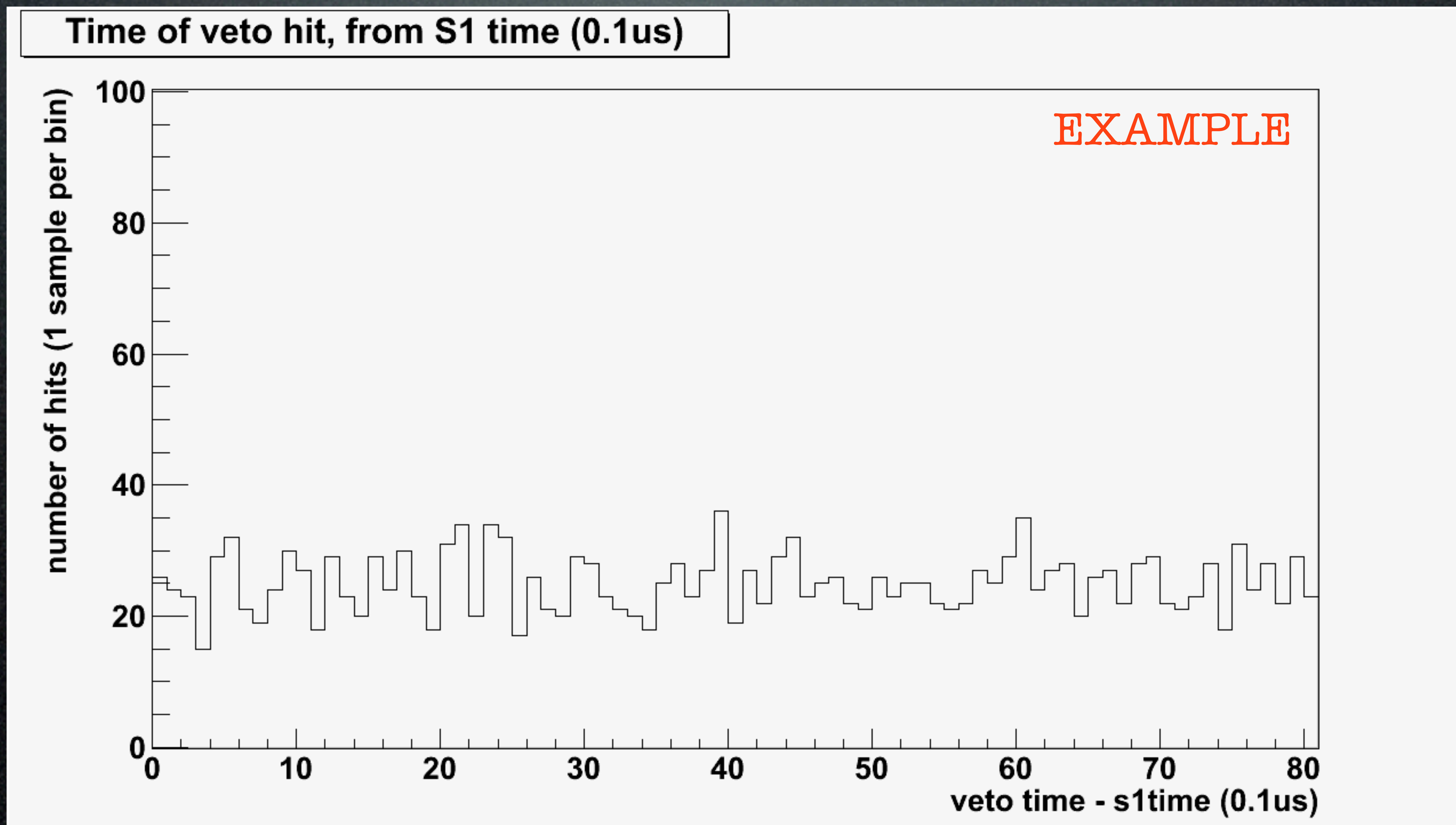
This shows an example of a delayed energy deposit in the veto for a ZEPLIN-III event





Kr contamination

If present this signal could be found by plotting the difference between ZEPLIN-III event time and the time of veto pulses.



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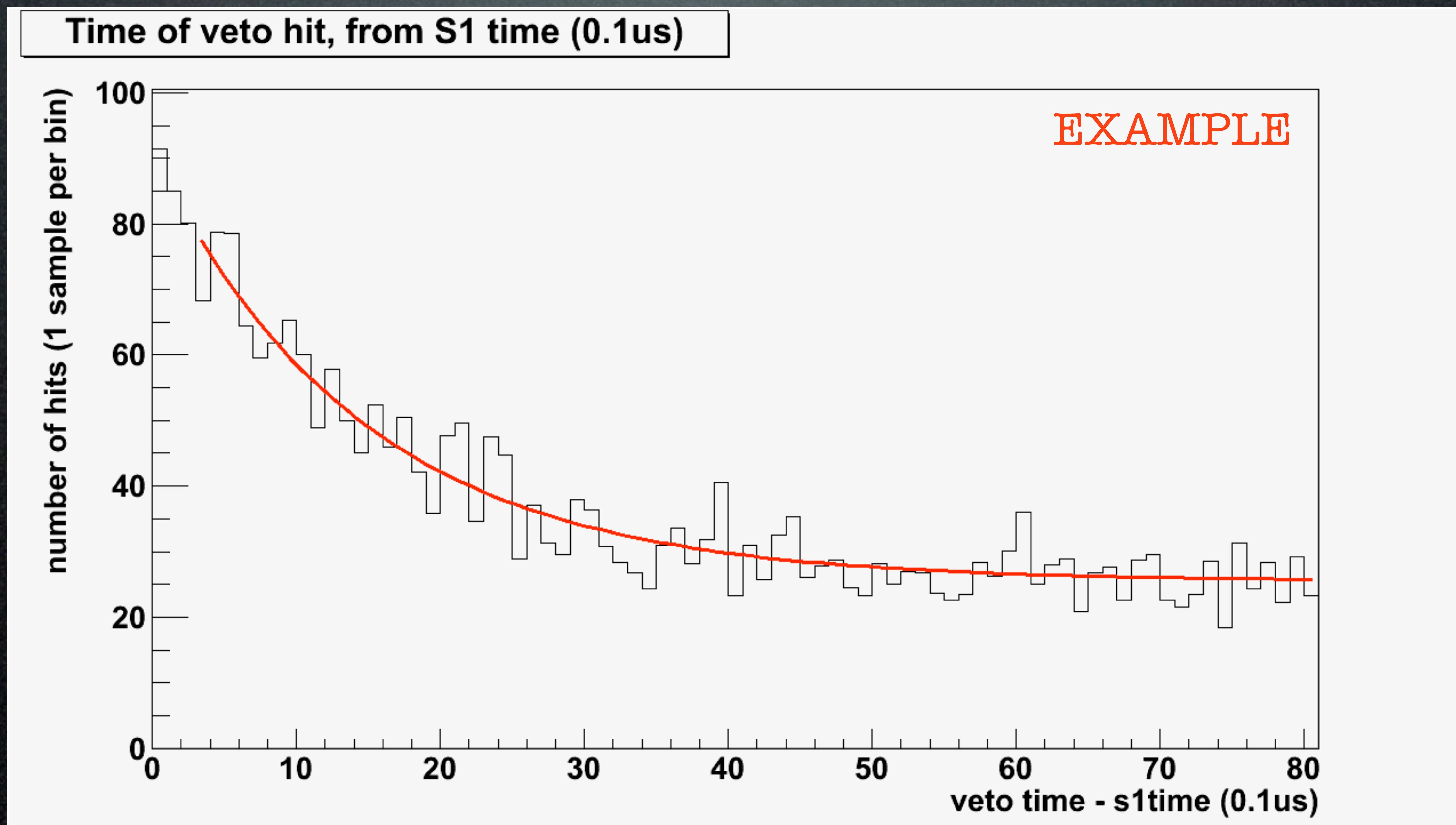
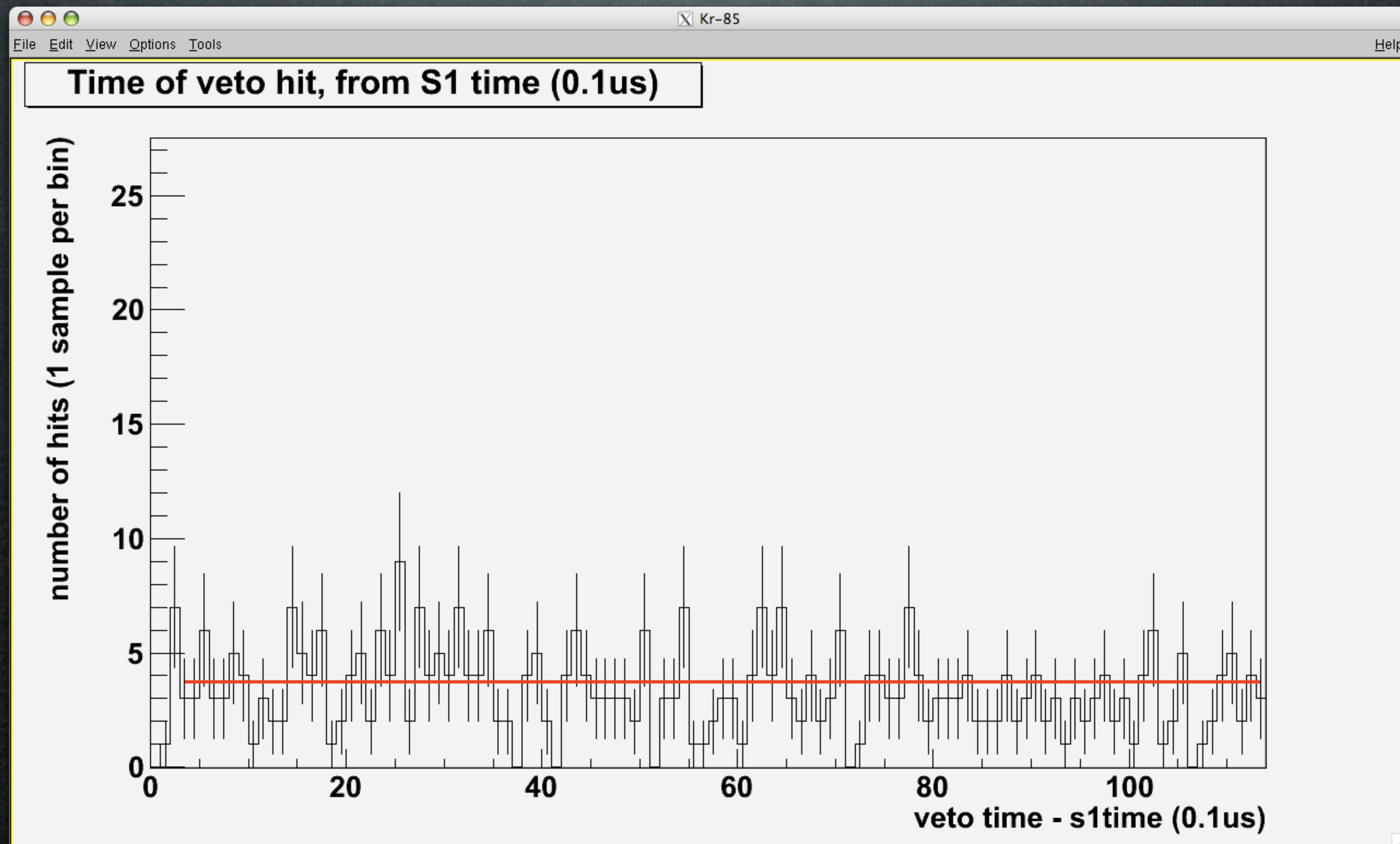


Kr contamination

The results show a flat background, this can be used to set a limit on the amount of ^{85}Kr in the detector.

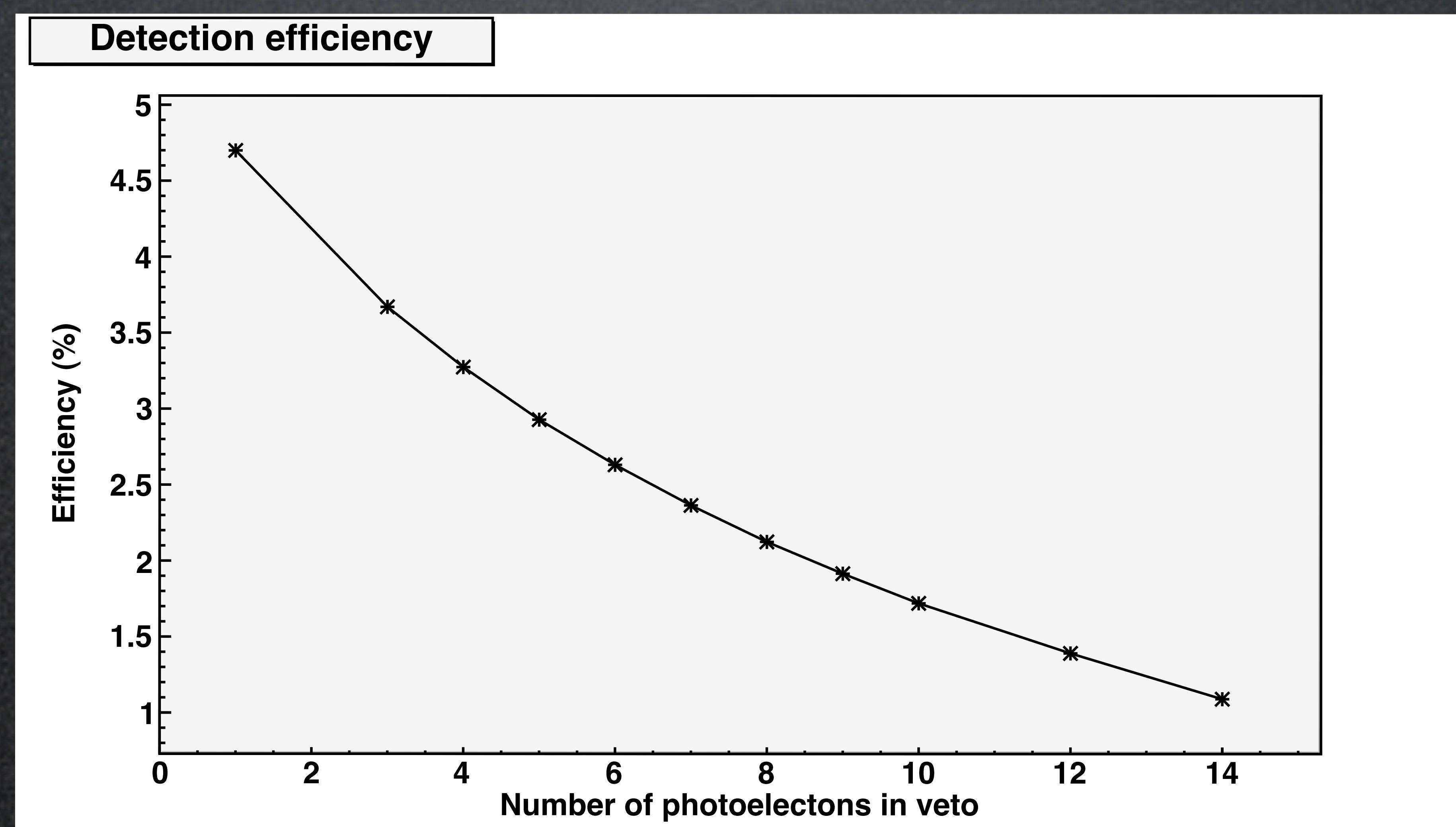


A likelihood fit of the form $(A/\tau)e^{-t/\tau} + B$ is show in red

Kr contamination

A geant4 simulation was performed using accurate geometry of both instruments and the shielding.

Deposit energy in Z3	Escape Z3	Hit veto	Deposit more than 80 keV in veto
68%	32%	5.28%	3.27%



Kr contamination

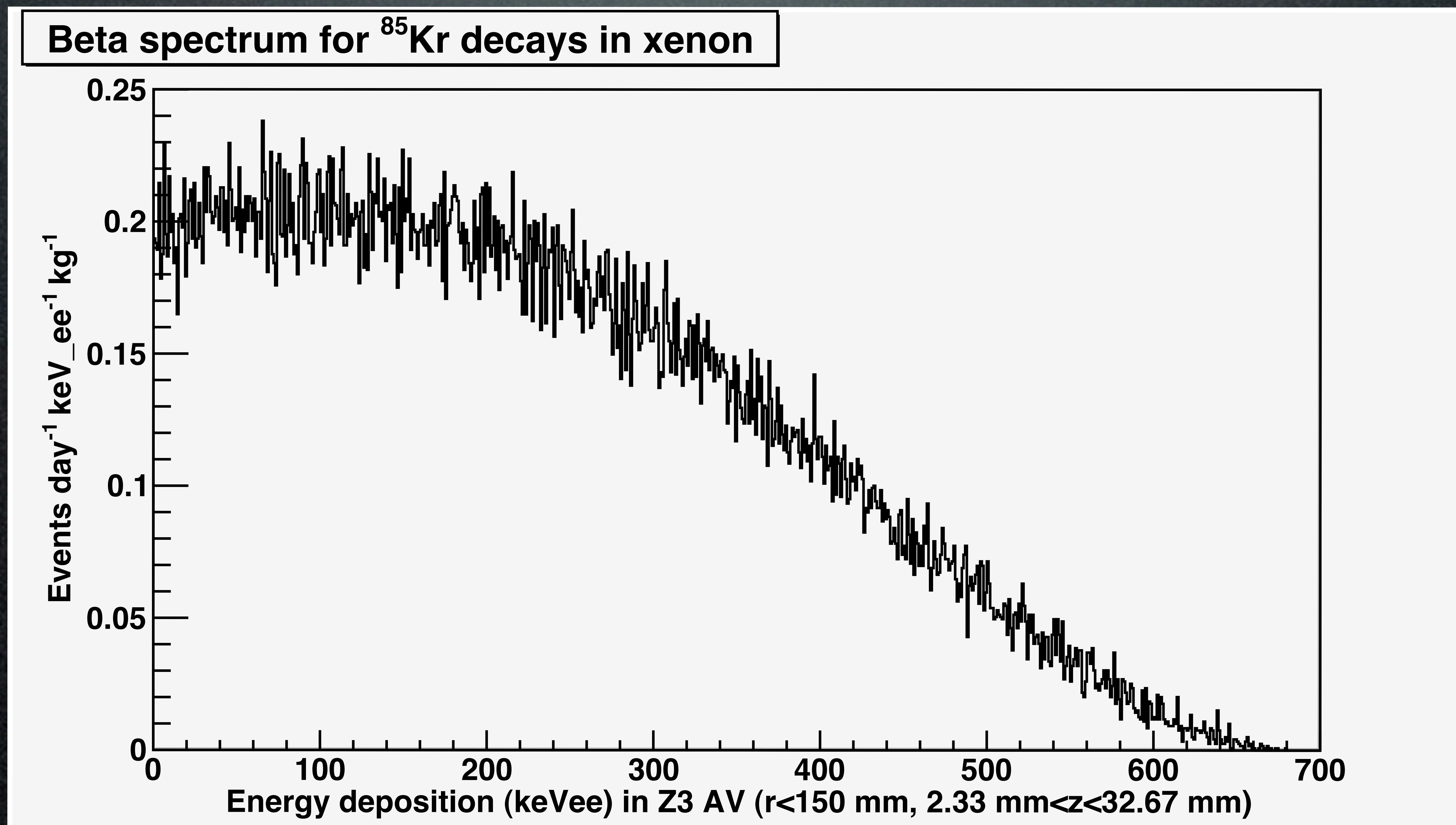
A 90% upper limit of the number of events observed is <13 gamma-rays

Accounting for the detection and selection efficiencies this represents <583 beta decays

With a branching ratio of 0.434% this would represent a total of <134,370 ^{85}Kr decays

Kr contamination

A geant4 simulation of decaying ^{85}Kr nuclei was used to scale the number of events observed to the number of events per kg per day per keV (DRU)



Kr contamination

Using these results an upper limit of <0.3 DRU at 10 keV was set for ^{85}Kr contamination in the ZEPLIN-III xenon.

This is an upper limit of <63 ppb of Kr.

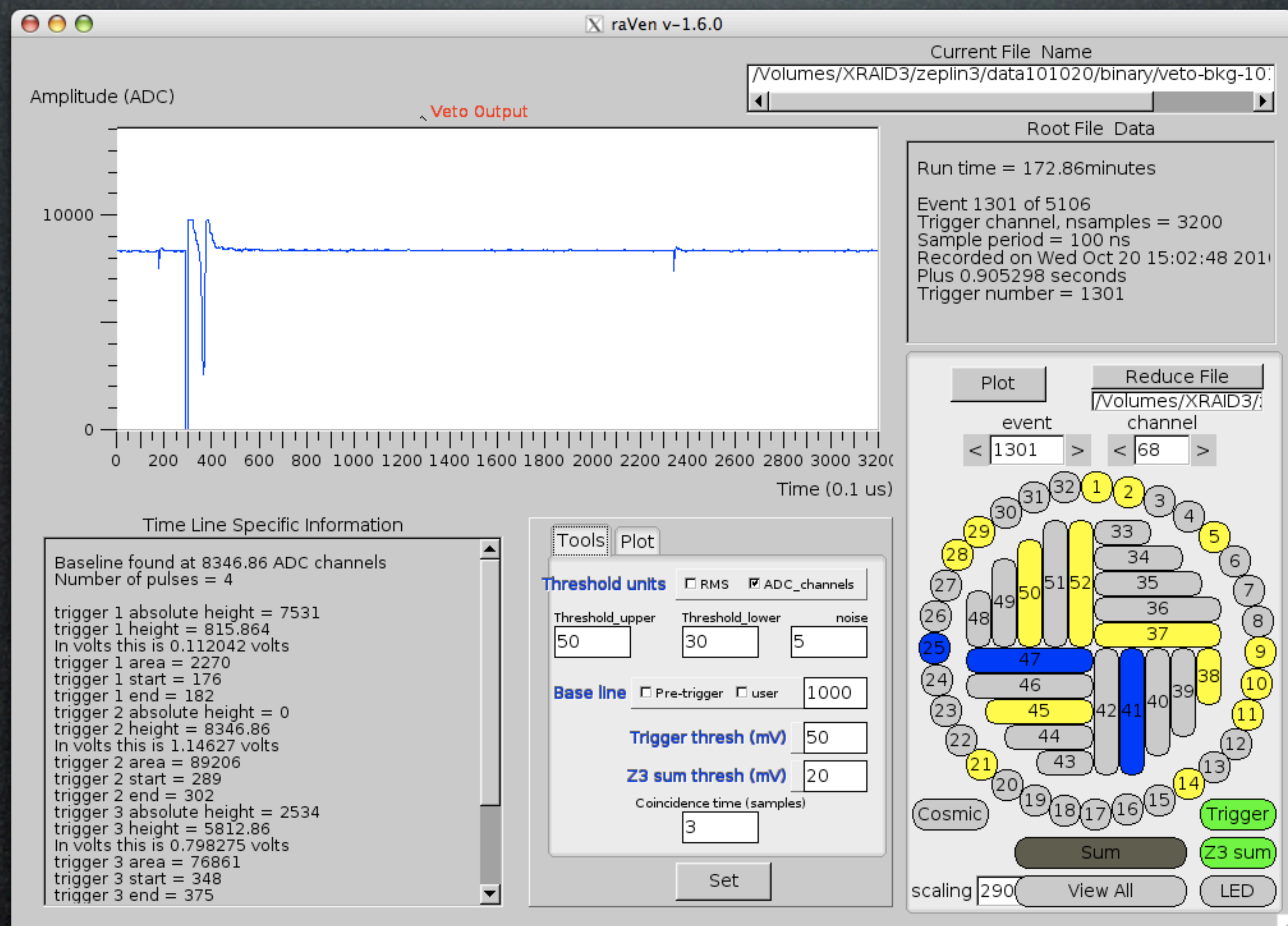
Kr contamination

These results show that ^{85}Kr does not pose a significant threat to ZEPLIN-IIIs ability to detect dark matter given its discrimination power. Using both instruments to detect these events provides a robust method of detection.

Analysis of the background energy spectrum seen by ZEPLIN-III indicates ^{85}Kr contamination of <0.1 DRU. Early indications from looking for ^{85}Kr decays where both signals are seen in ZEPLIN-III agree that the contamination is much less than 0.1 DRU, this analysis is ongoing

Veto diagnostics

The veto detector has several other uses. Firstly the sum channel from the ZEPLIN-III detector was plugged into the veto daq. The veto is used to record each ZEPLIN-III event with a lower resolution 320 μs timeline.



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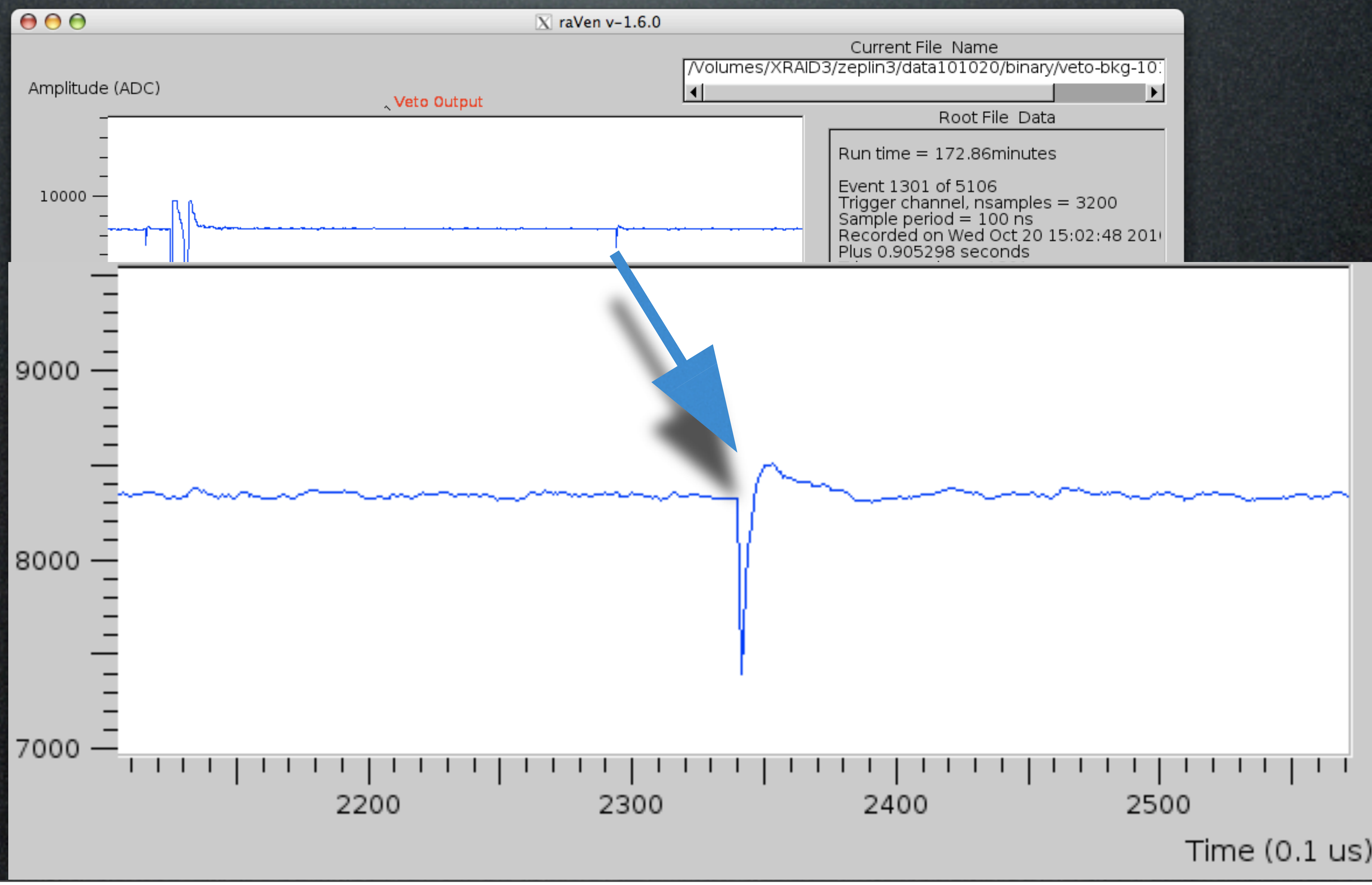
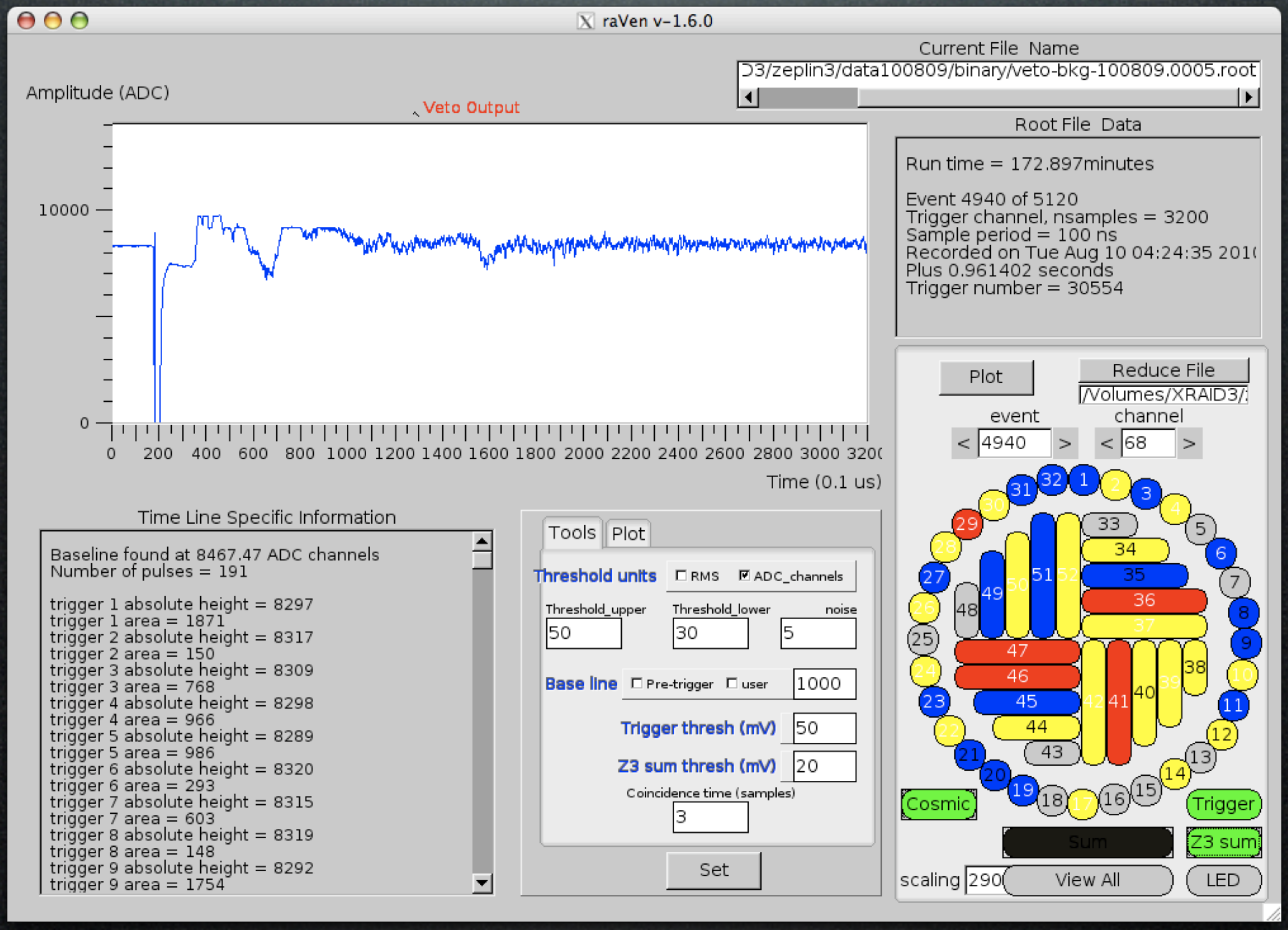


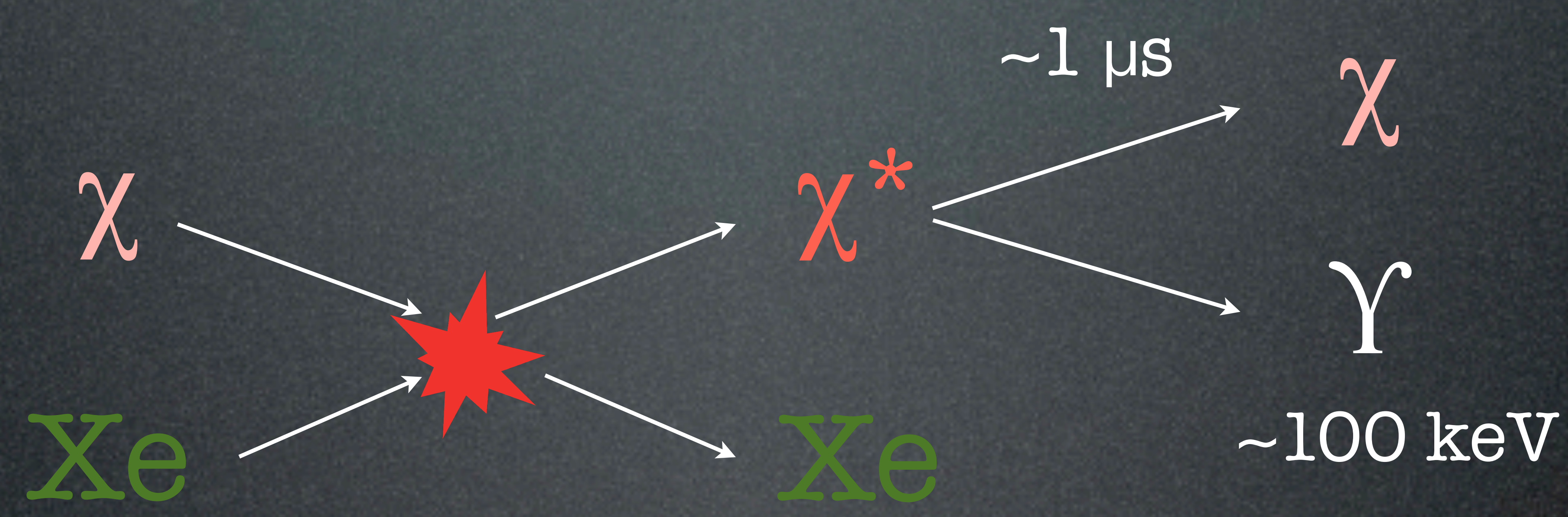
Veto diagnostics

The veto has a second trigger mechanism. The 20 roof modules are connected to a muon trigger. This can be used to search for muon induced neutrons



Exotic dark matter

The veto may also be useful to search for exotic dark matter candidates such as magnetic inelastic dark matter.



With $\langle V_{DM} \rangle \sim 220\ kms^{-1}$ the sparticles would travel ~ 22cm within the lifetime of the excited state so monte carlo simulations will be needed to calculate efficiencies.