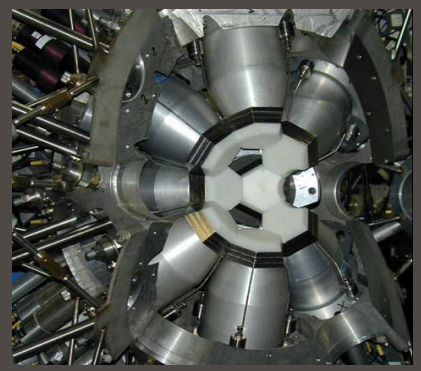
TRIUMF

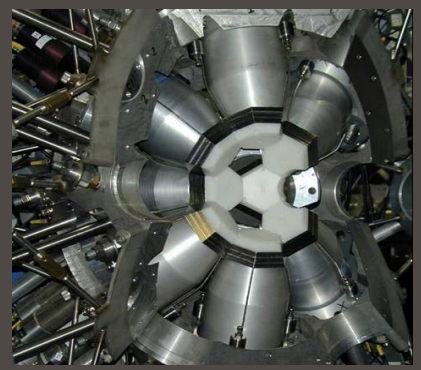
Canada's National Laboratory for Particle and Nuclear Physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules

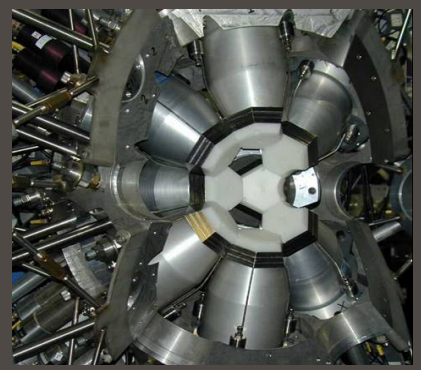
Improved Measurement of the Half-Life of ^{121}Xe

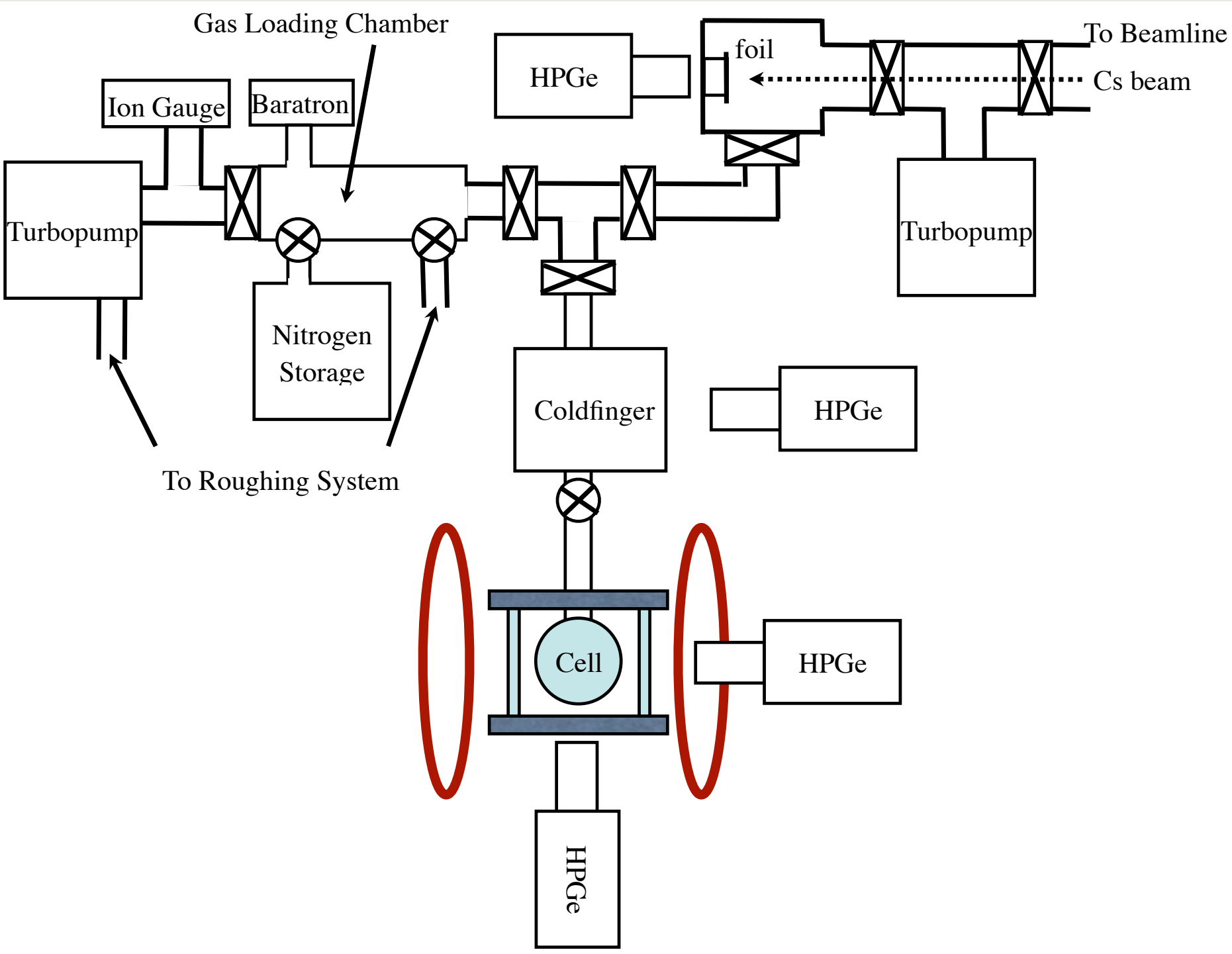
Eric Tardiff | Radon EDM | ISAC Science Forum

March 14, 2012



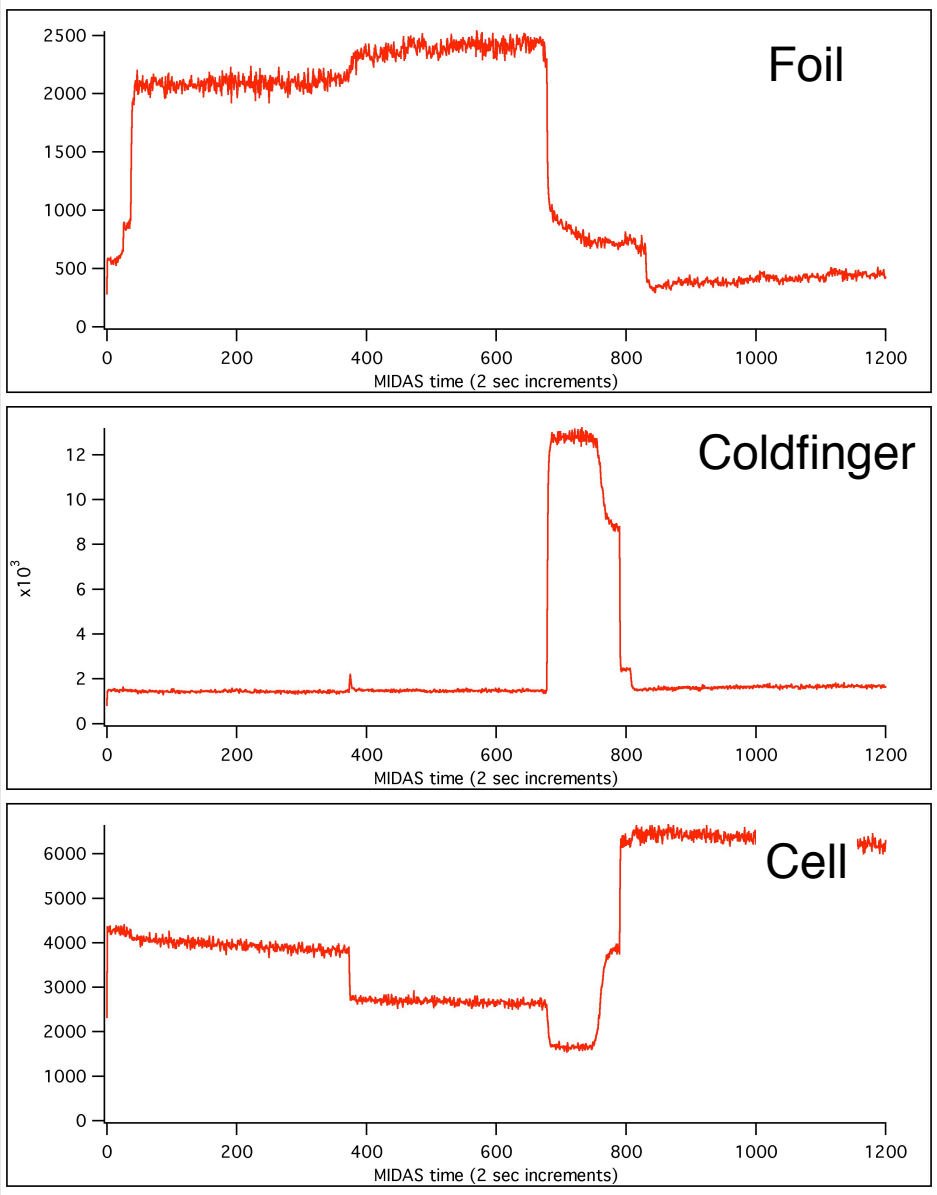




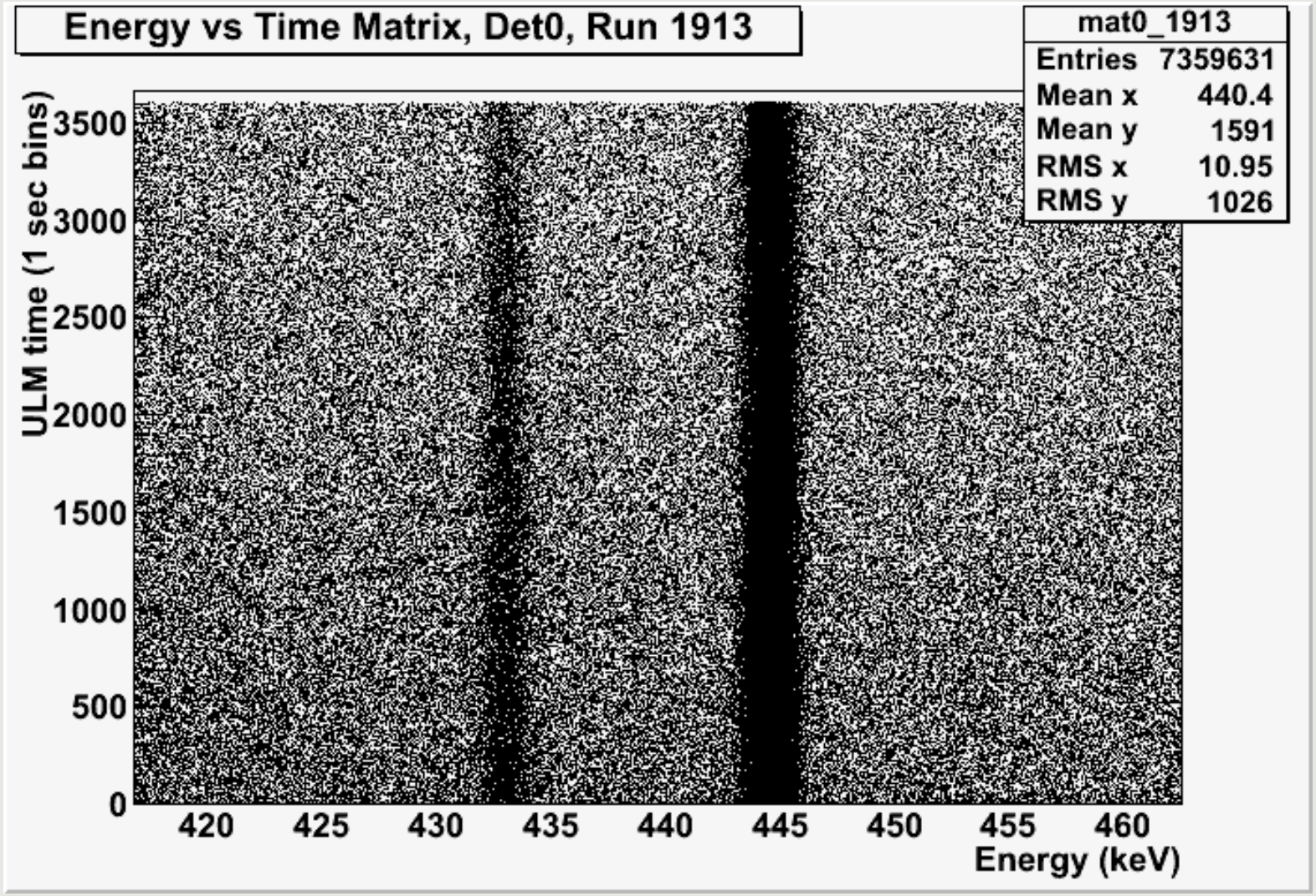

Gas Loading Chamber
HPGe
foil
To Beamline
Cs beam
Ion Gauge
Baratron
Turbopump
Turbopump
Nitrogen
Storage
Coldfinger
HPGe
To Roughing System
Cell
HPGe
HPGe

Monitoring Gas Tansfer

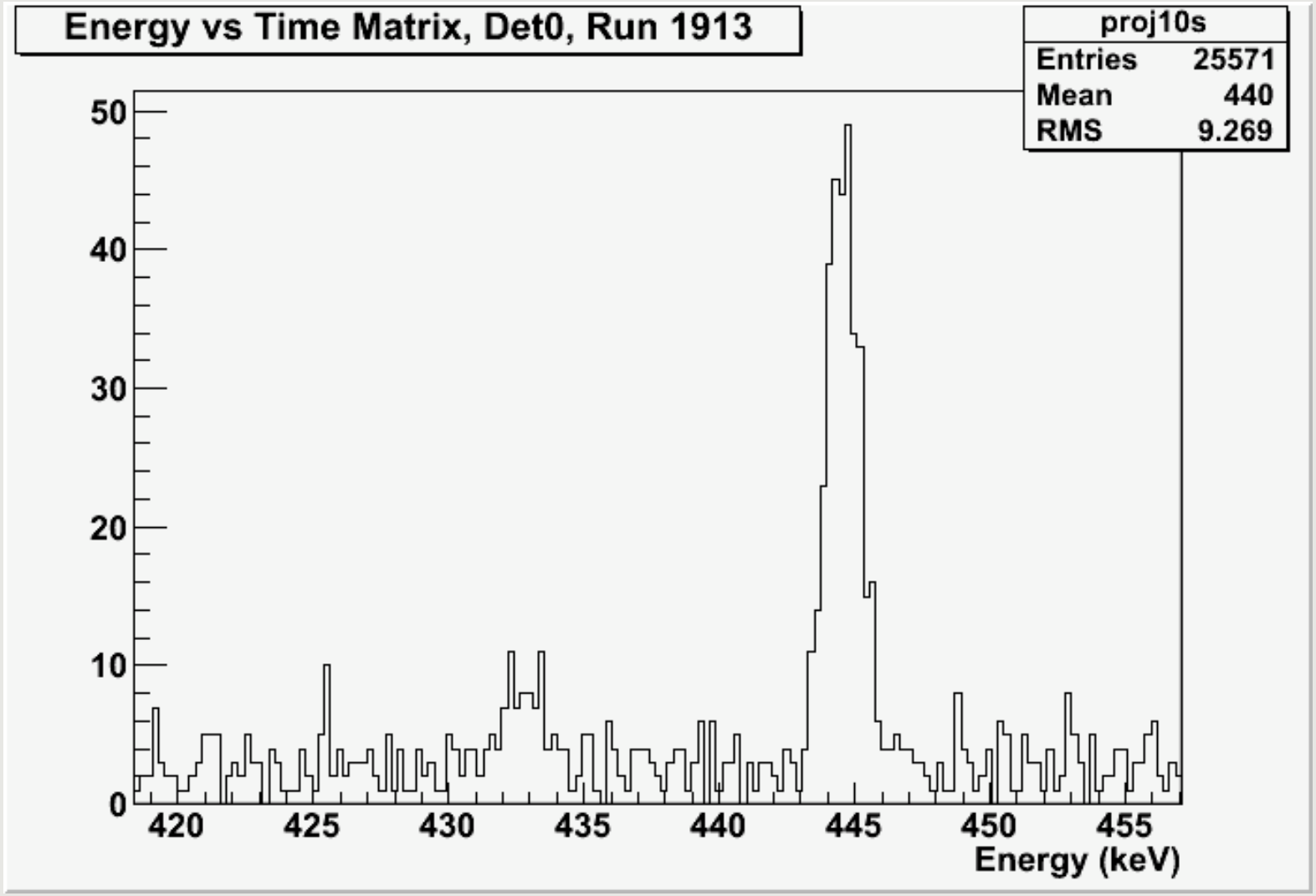
- Moved lead shield away from foil detector, waited for cell to cool.
- Pumped out cell, cooled coldfinger.
- Heated foil to transfer xenon to coldfinger.
- Warmed coldfinger to release xenon into cell and coldfinger volume.
- Pushed xenon into cell with nitrogen.
- Moved lead back in front of foil detector.
- Overall transfer efficiency was $\sim$ 80%.



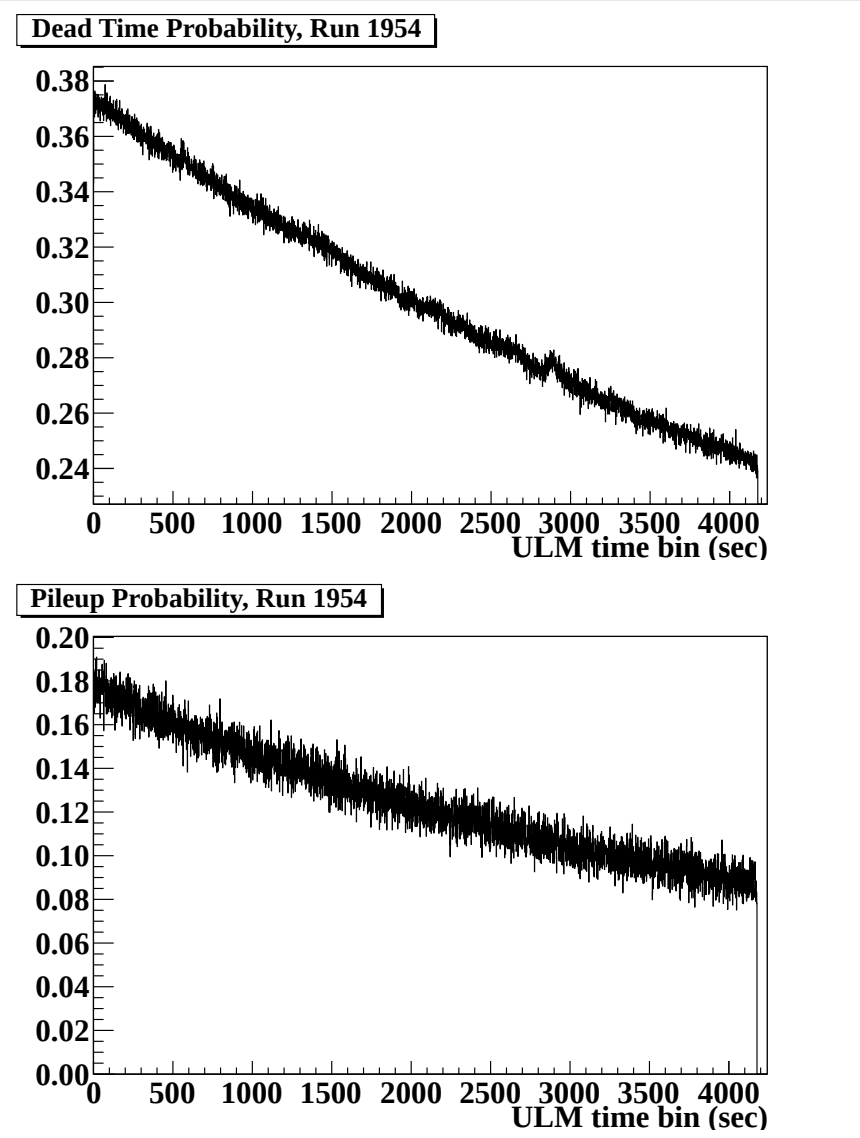
γ Energy vs Time matrix



time projections



Deadtime and Pileup Corrections



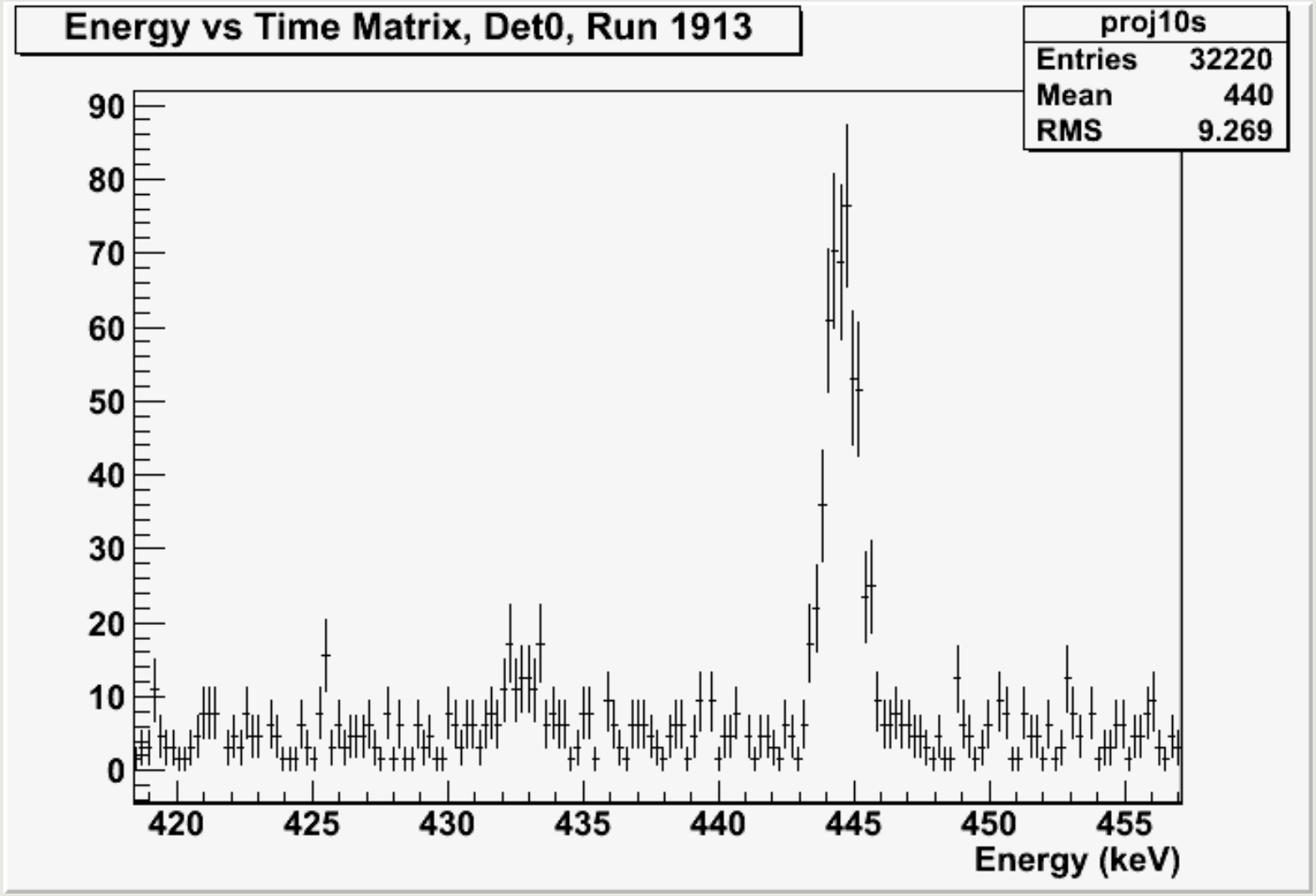
- 8π DAQ has both free-running and deadtime-vetoed ULM clocks.
- Calculate probability of being dead for time bin i, D_i.
- DAQ marks events as pileup or not-pileup

$$P_i = \frac{p_i}{p_i + np_i}$$

- With N observed events, the corrected number of events is

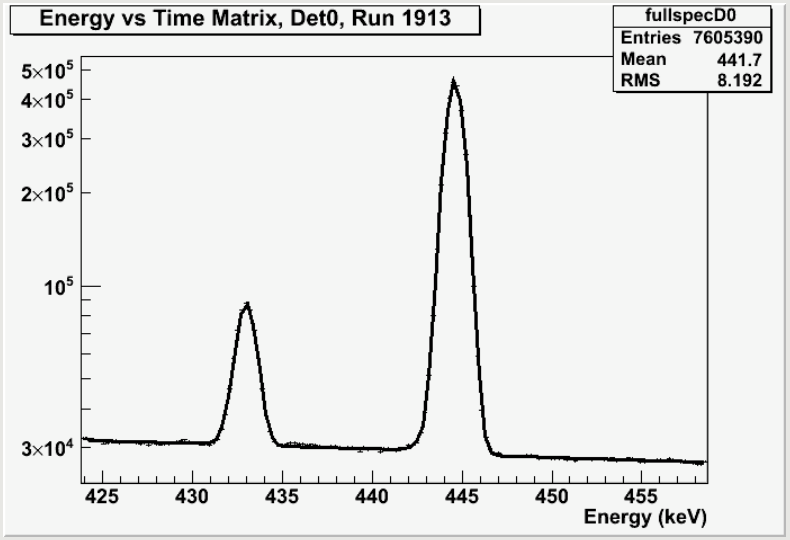
$$N' = \frac{N}{1 - (P_i + D_i - P_i \cdot D_i)}$$

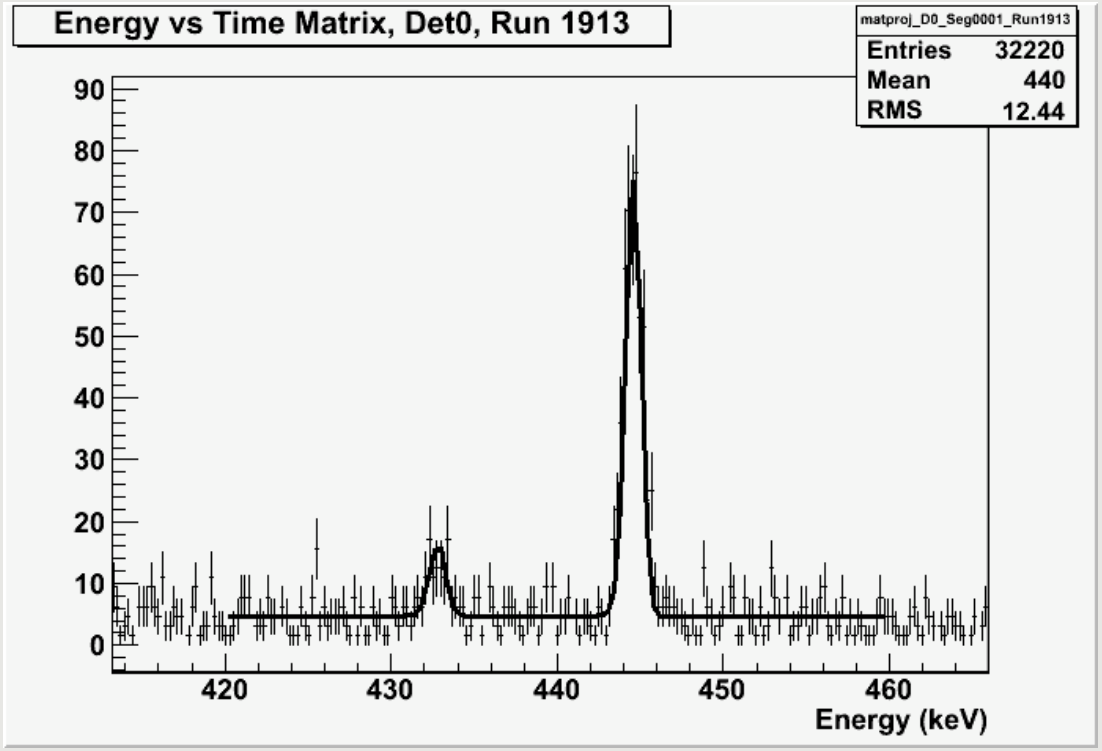
Apply Corrections



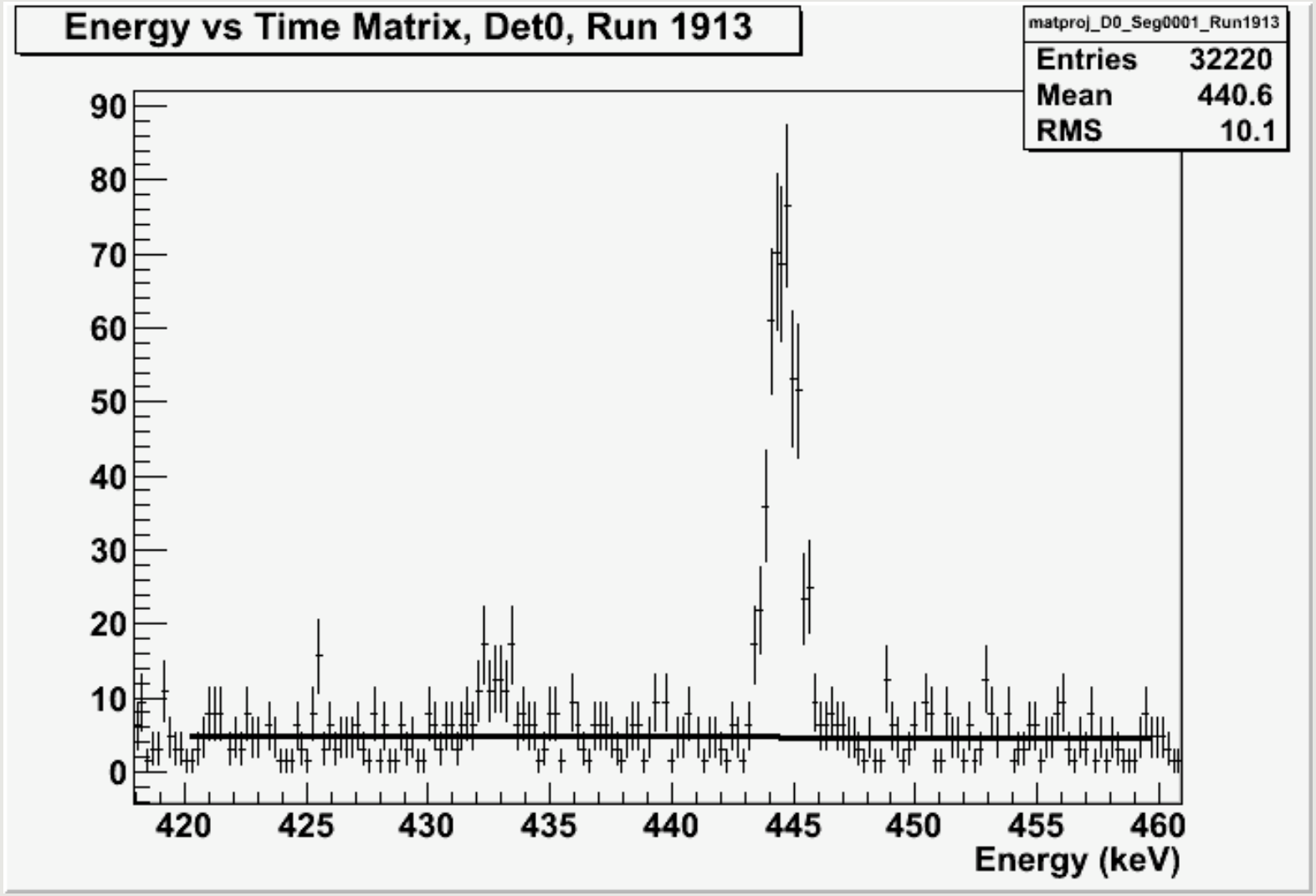
Fit to γ lineshape

- γ lineshapes include gaussian, skew-gaussian, step-function, and linear background components.
- the “skewness” parameter and the relative height parameters for the skew-gaussian and step function are fixed based on fits to the full data set.



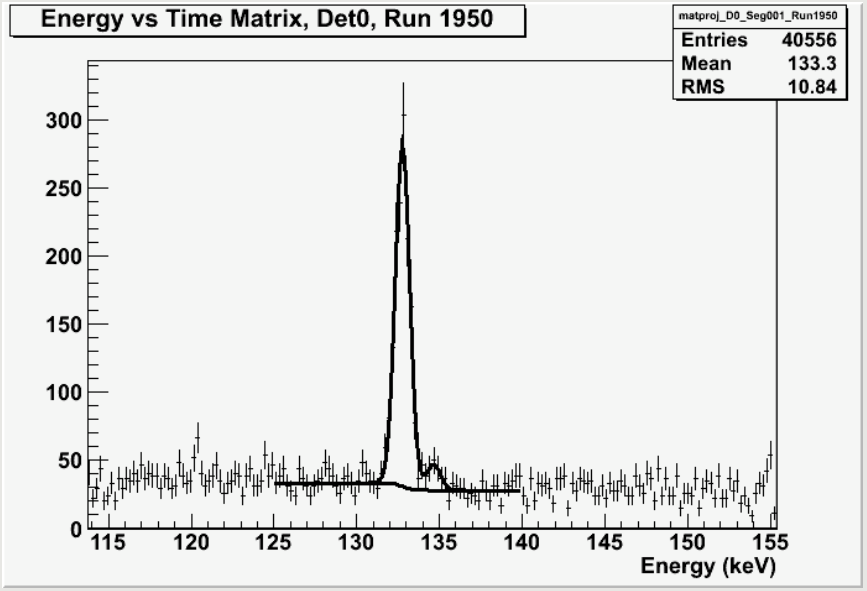


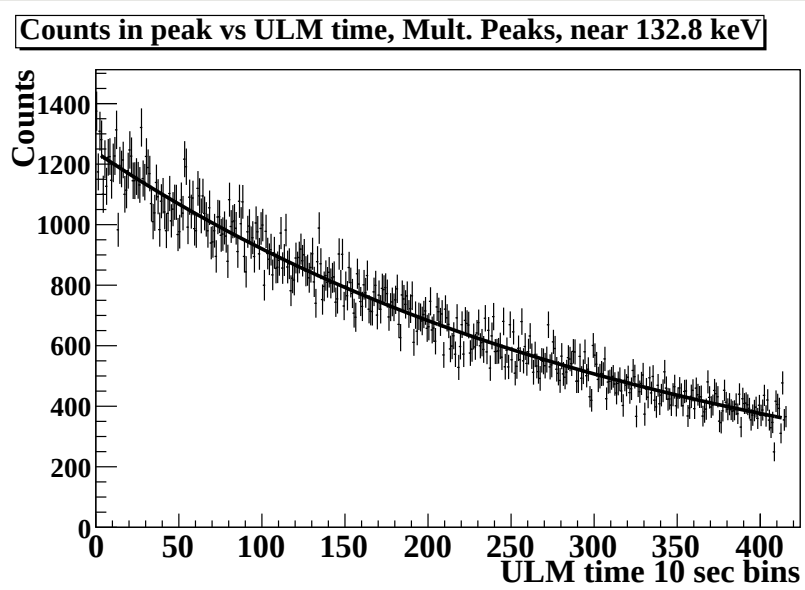
Counts Above Background

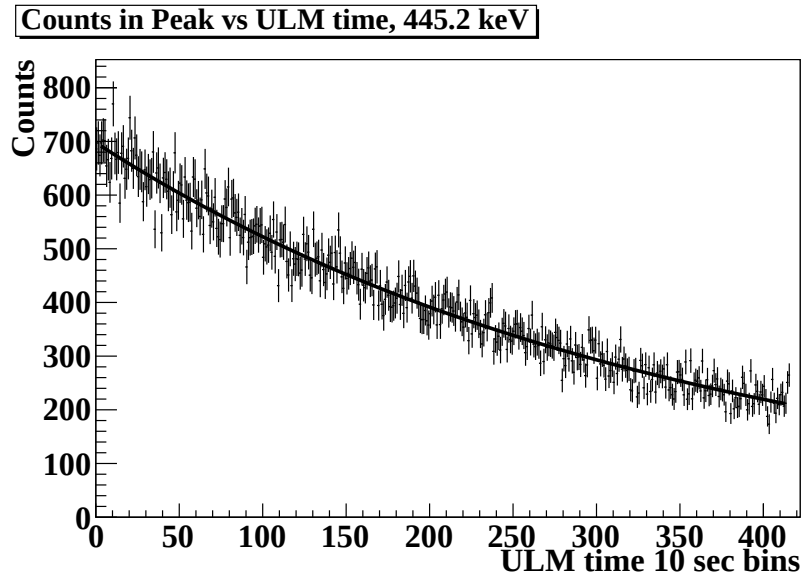


Decay Histogram

- Counts above background from each 10-sec projection entered into a decay histogram
- fit to a bare exponential, $\exp(p_0 + p_1 \cdot x)$, using log-likelihood minimization







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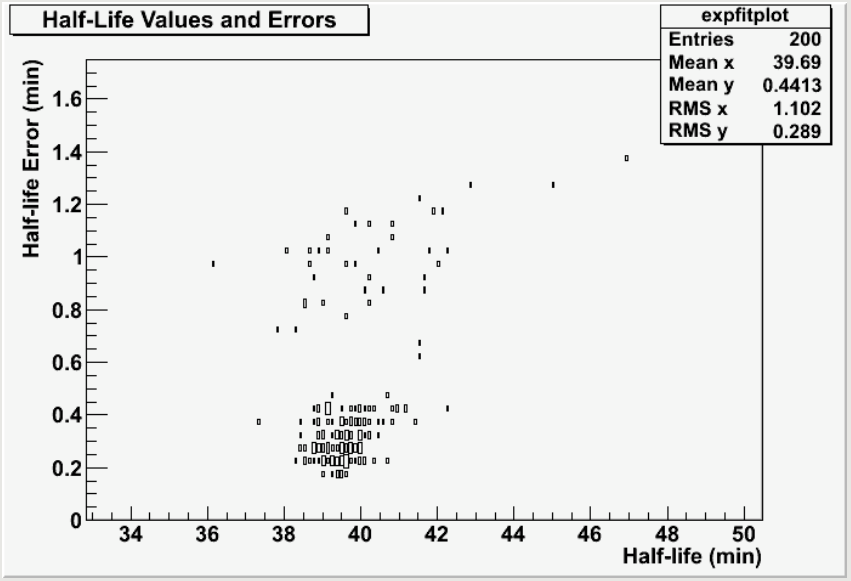
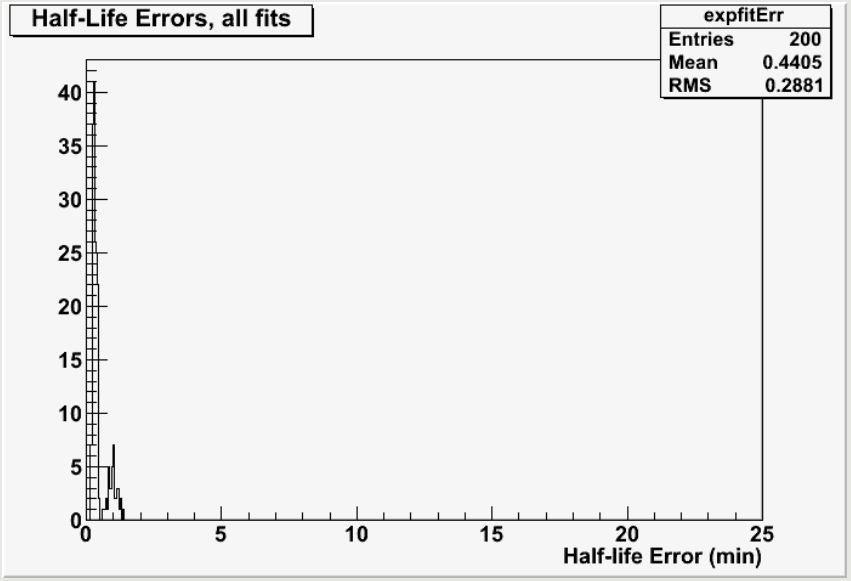
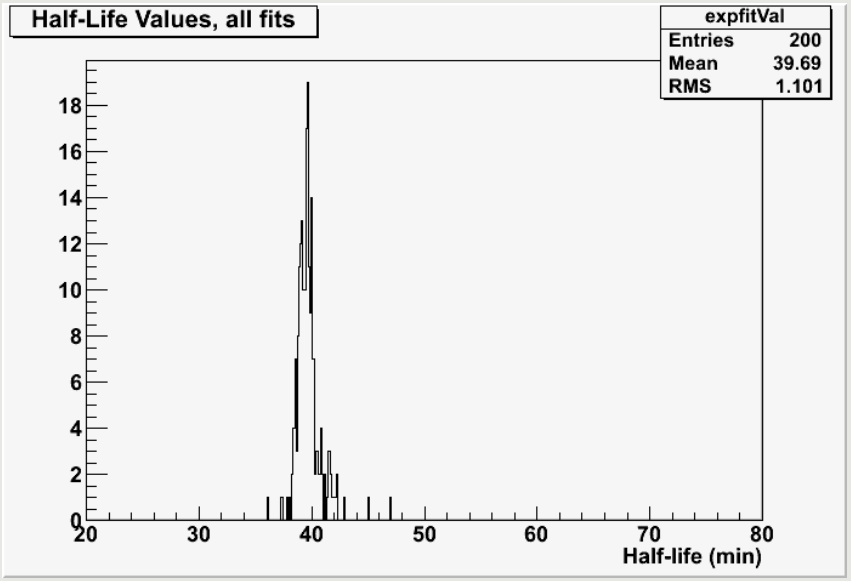
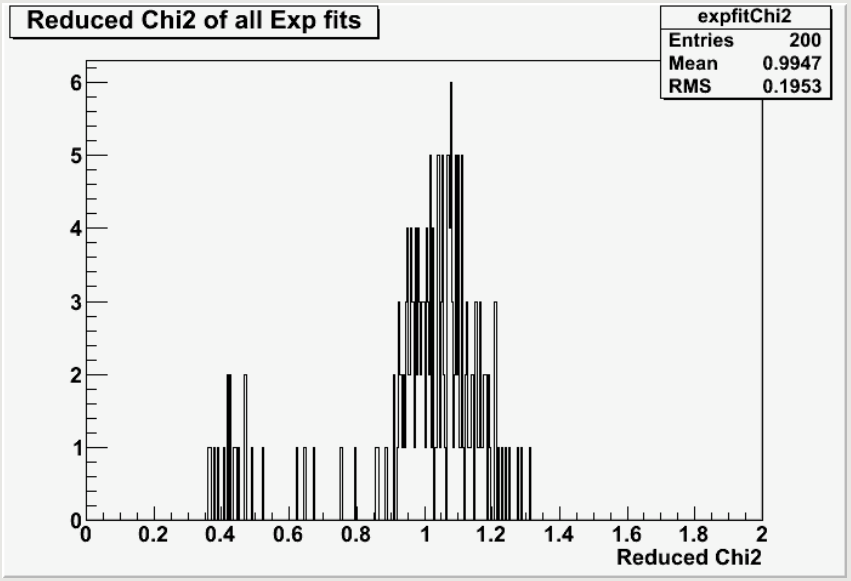
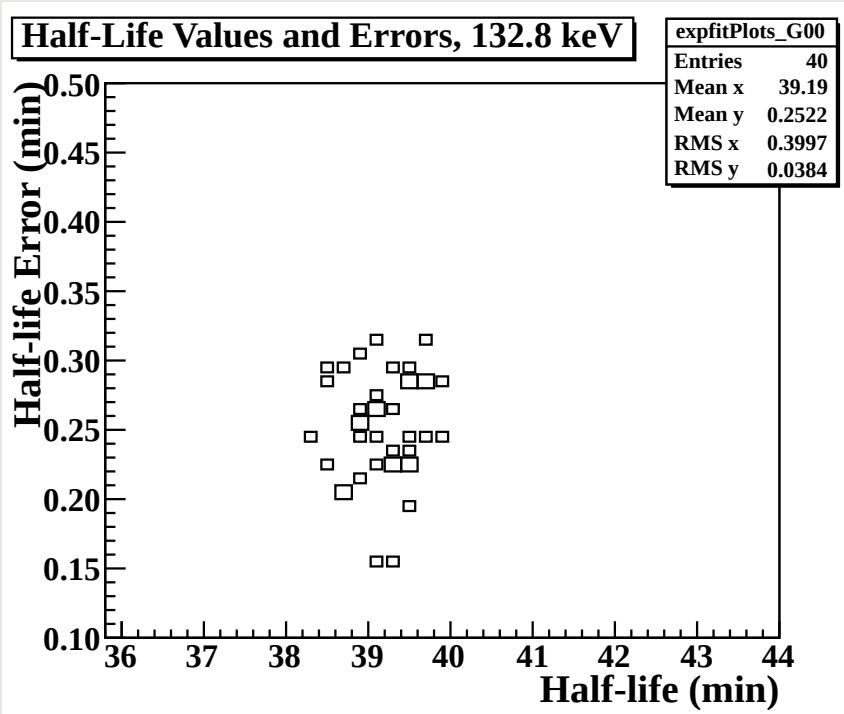
Half-Life Results: 39.46(2) min

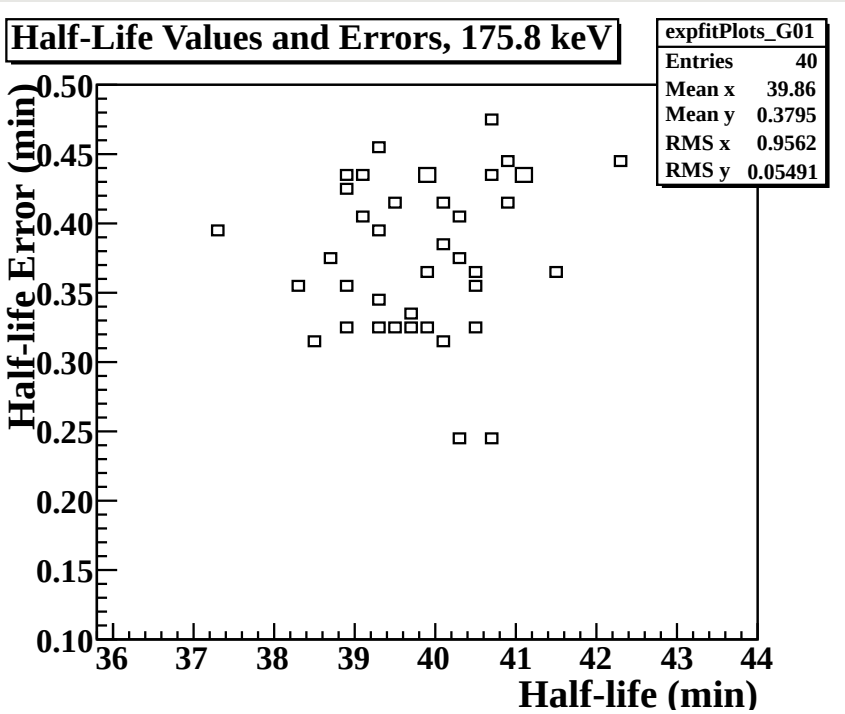


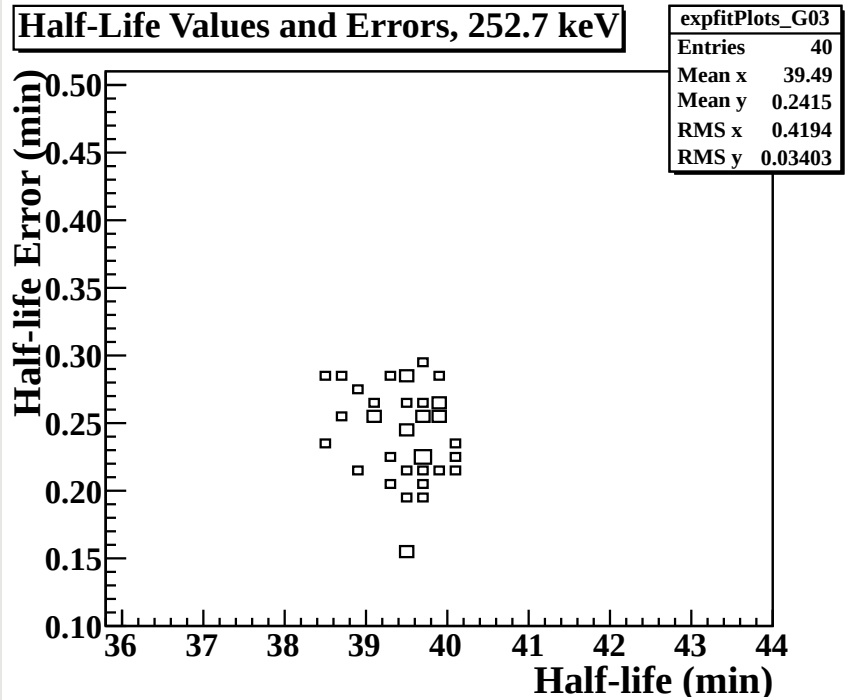


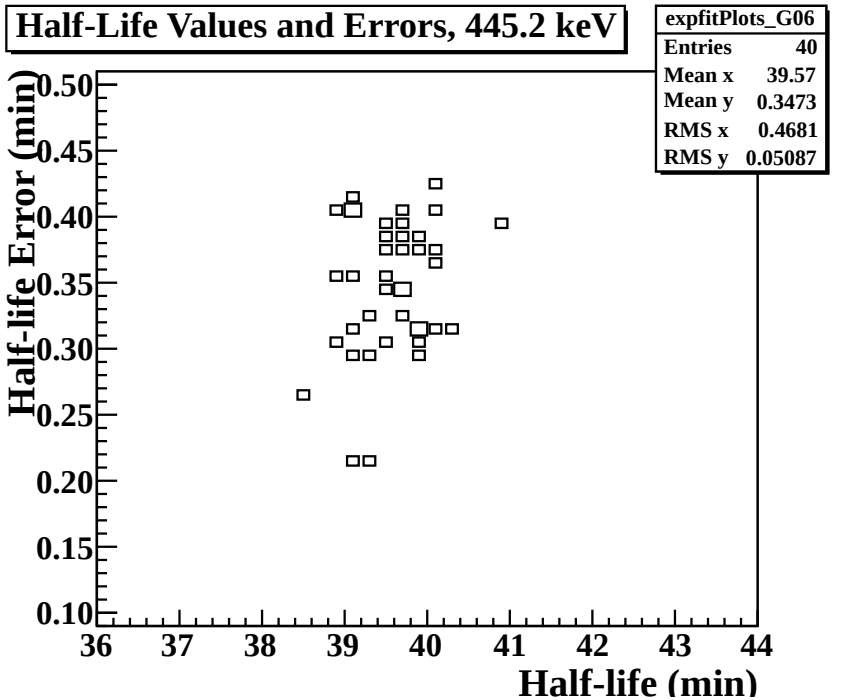




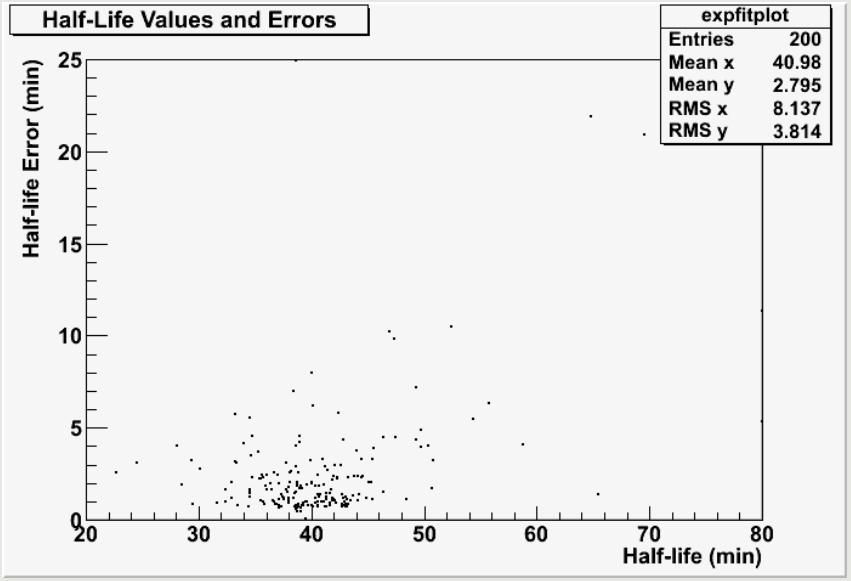

Half-Life Values and Errors, 132.8 keV
expfitPlots_G00
Entries 40
Mean x 39.19
Mean y 0.2522
RMS x 0.3997
RMS y 0.0384
Half-life Error (min)
Half-life (min)

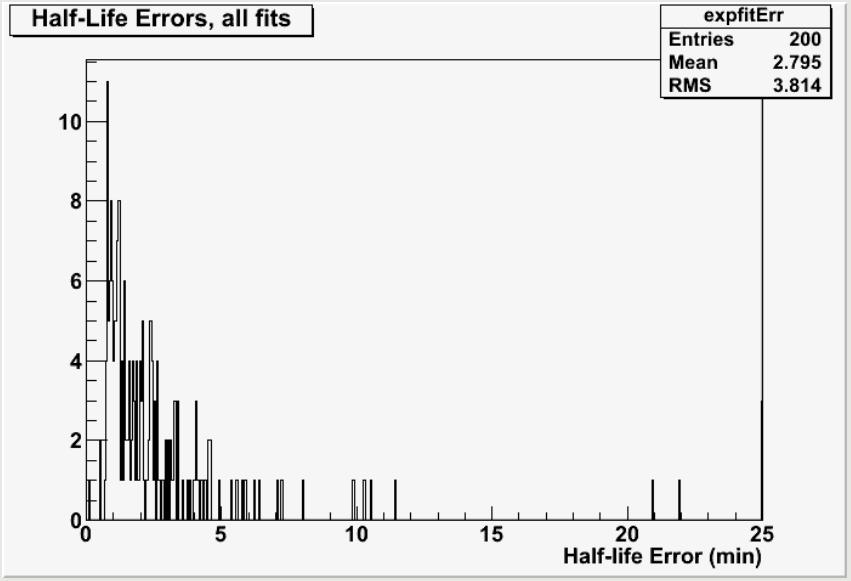

Half-Life Values and Errors, 175.8 keV
expfitPlots_G01
Entries 40
Mean x 39.86
Mean y 0.3795
RMS x 0.9562
RMS y 0.05491
Half-life Error (min)
Half-life (min)

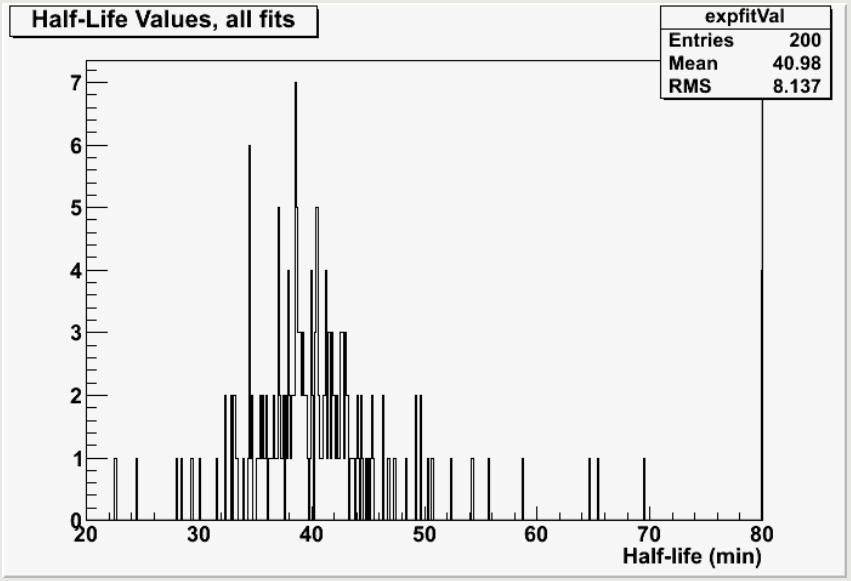

Half-Life Values and Errors, 252.7 keV
expfitPlots_G03
Entries 40
Mean x 39.49
Mean y 0.2415
RMS x 0.4194
RMS y 0.03403
Half-life Error (min)
Half-life (min)

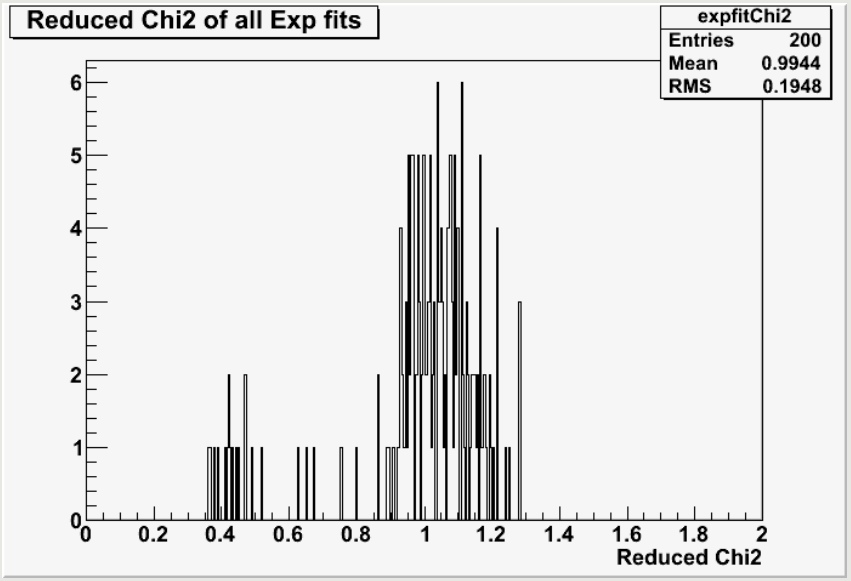

Half-Life Values and Errors, 445.2 keV
expfitPlots_G06
Entries 40
Mean x 39.57
Mean y 0.3473
RMS x 0.4681
RMS y 0.05087
Half-life Error (min)
Half-life (min)

Effect of Including a Constant: 39.38(8) min

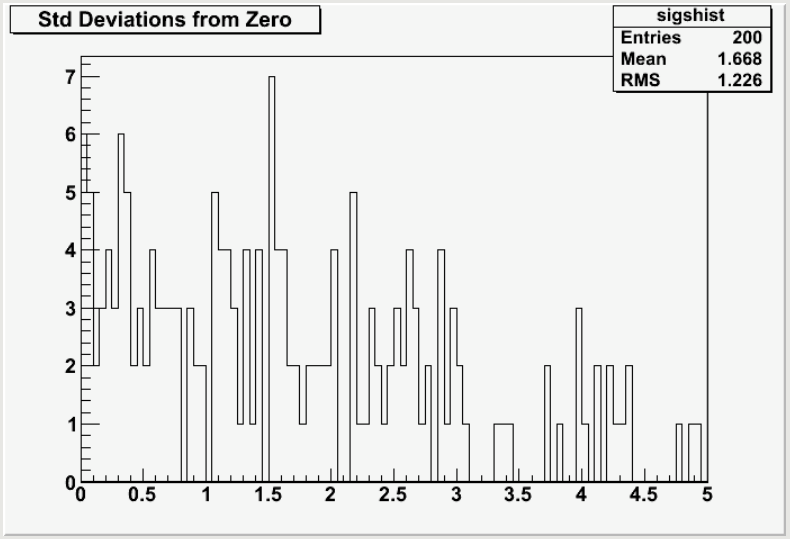


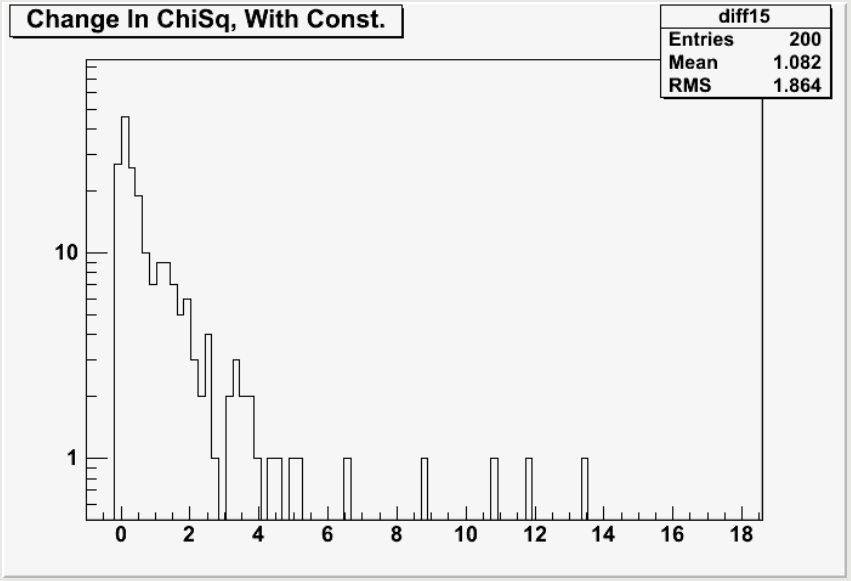






Statistical Checks of Inclusion of a Constant

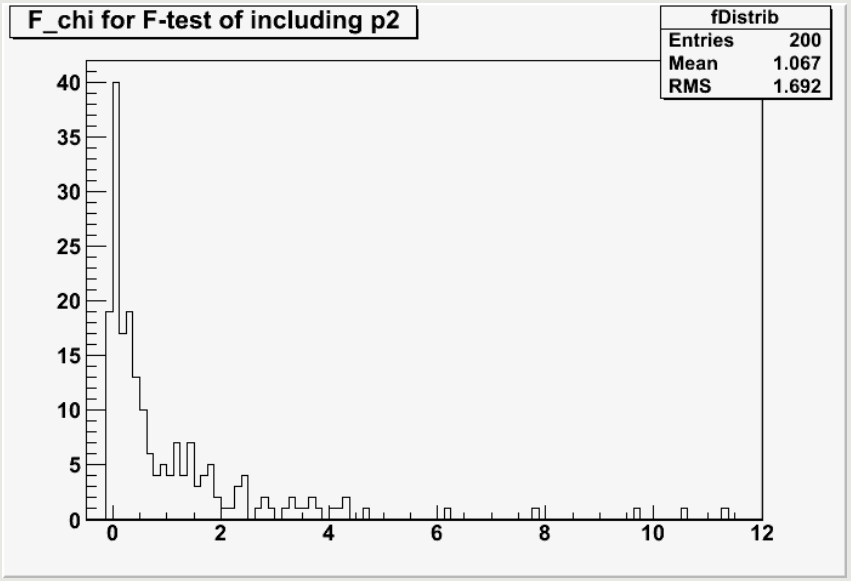




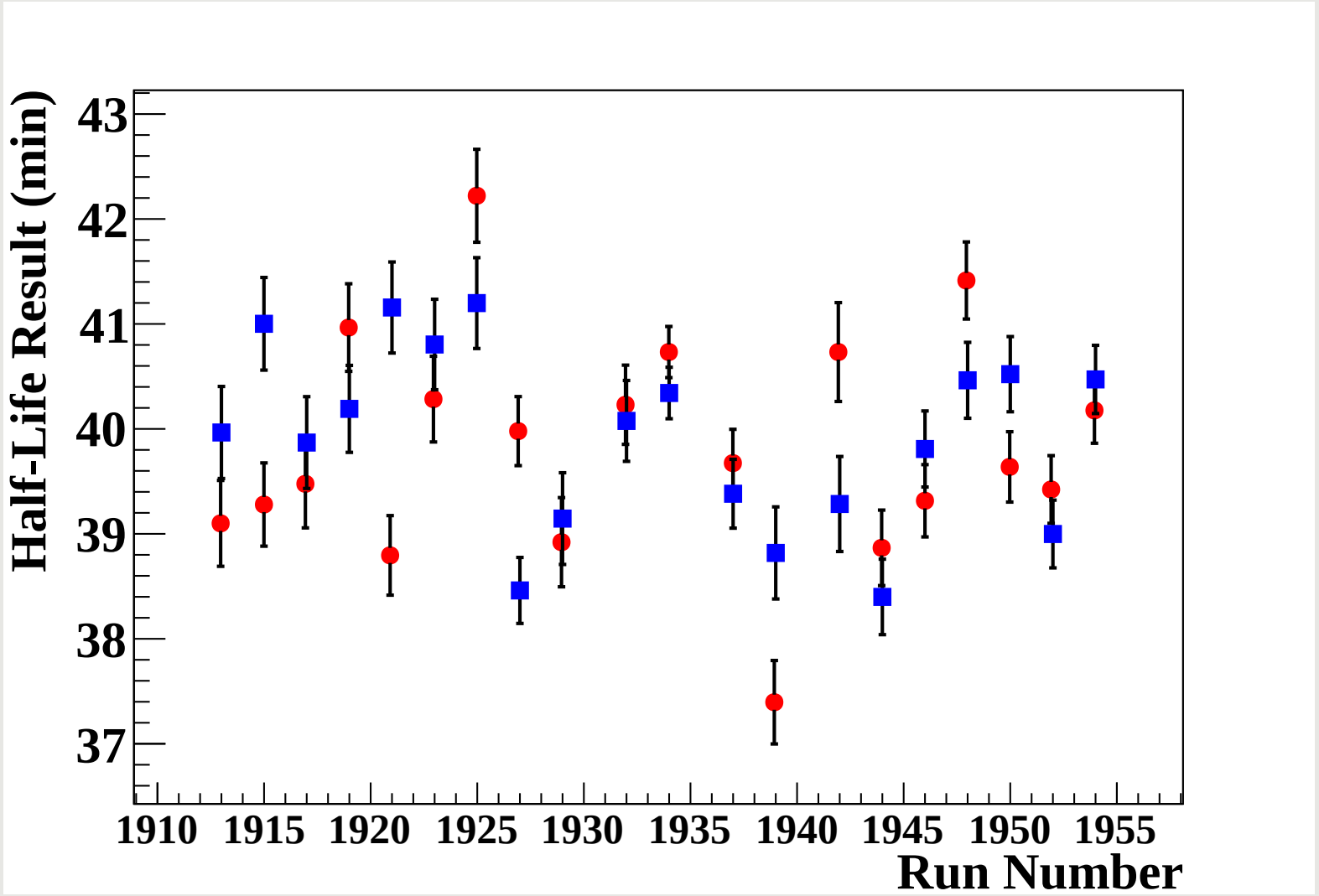
- On average, including a parameter for a constant in the exponential fit decreases χ^2 by just over 1.

$$F_\chi = \frac{\chi^2(m) - \chi^2(m+1)}{\chi^2(m+1)/(N-m-1)}$$

- In the F_χ test statistic for the addition of this parameter, 95% of the fits have $F_\chi < 4$, which is a p-value of 5% for fits with 360 d.o.f.

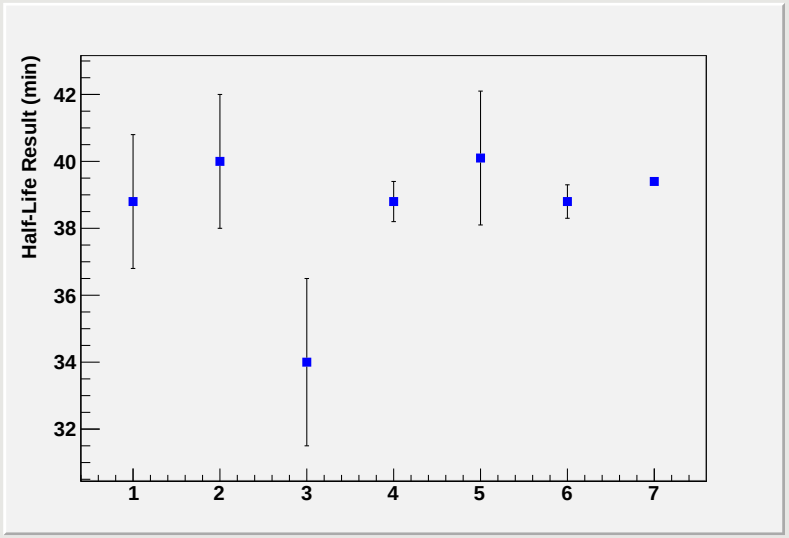


Apparent Underestimation of Error Bars

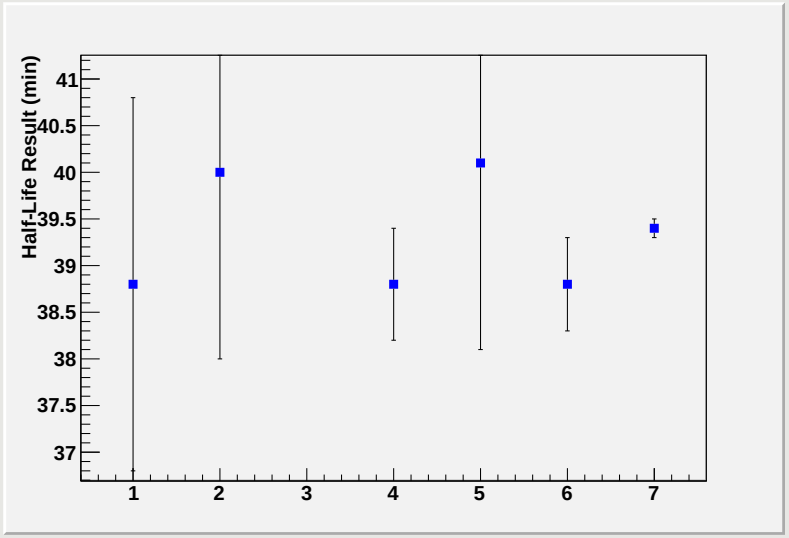


Rescaled Half-Life Results

γ's in Decay Hist.	Half-Life Result (min)
132.8 + 134.6 keV	39.18 ± 0.06
175.8 + 177.7 keV	39.86 ± 0.14
252.7 keV	39.49 ± 0.06
433.4 keV	40.10 ± 0.28
445.2 keV	39.51 ± 0.08



- total weighted average: 39.43 ± 0.04 min.
- the χ^2 of these 5 results is 8.18. This appears to be a systematic effect. If rescaling the results by $\sqrt{\chi^2_\nu}$ provides an estimate of the size of this systematic effect, we get a result of 39.4 ± 0.1 min.
- The weighted average of all measurements cited in ENSDF is 38.8 ± 0.5 min.
- ENSDF and ToI use the Nucl. Phys. A '72 result, 40.1 ± 2.0 min, as the quoted half-life.



Systematic Checks

- Reverse the order of operations between the counts-above-background determination of the photopeak area and the application of the deadtime+pileup corrections
- Change the size of the fit region for the background determination
- A volume reduction test over a weekend indicated a 700 torr sample could leak 3 torr into the vacuum system over that time, for a fractional loss rate of $\sim 1 \times 10^{-6}$/min. This would change the half life result by 0.002 min.
- Investigate whether the data can support including a second exponential in the decay fit

Thank You

The Radon EDM Collaboration includes members from TRIUMF, the University of Guelph, The University of Michigan, and Simon Fraser University.

Thanks go out to the GRSI group, ISAC operations, ISAC ion source and target development, and the Nuclear Physics Group at Guelph.