Determination of Environmental Dependence of the β^- Decay Half-life of ^{198}Au

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Content

- Background –
  - Previous Publications
  - The Debye plasma model
  - Our group publication (2007)
  - Comparison
  - Current experiment
- Set-up – Equipment
- Data Collection
- Data Analysis
- Conclusions
- Acknowledgements

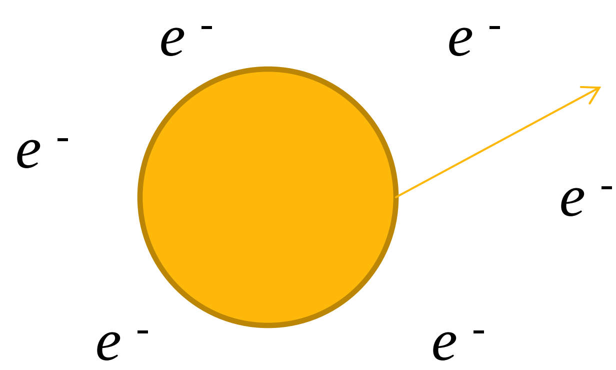
Background

- A series of articles by the C. Rolfs group* claimed changes in the half-lives of isotopes undergoing α, β^-, β^+, and electron-capture decays as the temperature was reduced to 12 K from room temperature
- Until then, radioactive half-lives were considered independent of environmental factors
- The isotopes they studied were contained in metallic, conductive environments

*T. Spillane *et al.,* Eur. Phys. J. A **31**, 203 (2007)

Background

- The Debye plasma model
  - Conductor electrons present in all metals
  - Forms a plasma that decreases the phase space



  - If there are negative decay particles (β^-, EC), the decay process takes longer and $t_{1/2}$ increases
  - If there are positive decay particles (β^+, α), the decay process speeds up and $t_{1/2}$ decreases

Background

- The Debye plasma model
  - By cooling to very low temperatures, the effect of from plasma is emphasized

β^- → Nuclide contained in a conductive metal → Increased $t_{1/2}$

β^- → Nuclide contained in a conductive metal $\xrightarrow{\text{COOL}}$ Larger Increase $t_{1/2}$

Background

- The original articles claimed to see a change in the β^+ decay half-life of ^{22}Na in Pd
- Other articles, changes were noted in:
  - electron-capture decay half-life of ^{7}Be in Pd and In
  - α decay half-life of ^{210}Po in Cu
  - β^- decay half-life of ^{198}Au in Au

Background

First hints on a change of the ^{22}Na β^+-decay half-life in the metal Pd

B. Limata *et al.*, Eur. Phys. J. A **28**, 251 (2006).

•Observed a decrease by 1.2±0.2% in Pd

Change of the ^{7}Be electron capture half-life in metallic environments

B. Wang *et al.*, Eur. Phys. J. A **28**, 375 (2006).

•Observed an increase by 0.9±0.2% in Pd and 0.7±0.2% in In but no change in Li_2O

First hint on a change of the ^{210}Po alpha-decay half-life in the metal Cu

F. Raiola *et al.*, Eur. Phys. J. A **32**, 51 (2007).

•Observed a decrease by 6.3±1.4% in Cu

The ^{198}Au β^--half-life in the metal Au*

T. Spillane *et al.*, Eur. Phys. J. A **31**, 203 (2007).

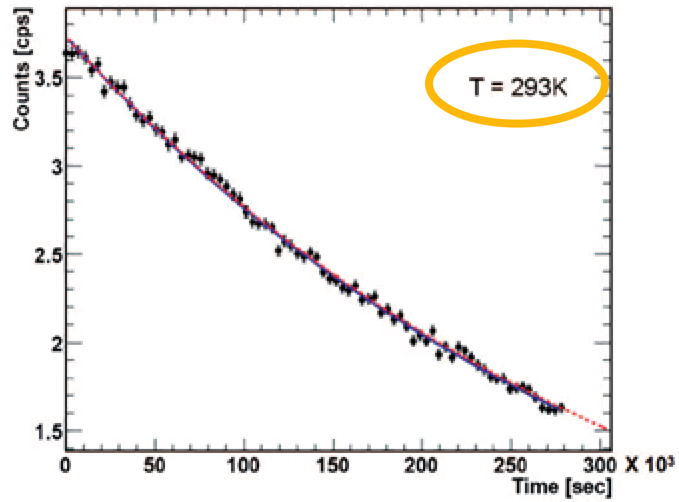
•Observed an increase by 0.4±0.7% at room temp and by 4.0±0.7% at 12 K in Au

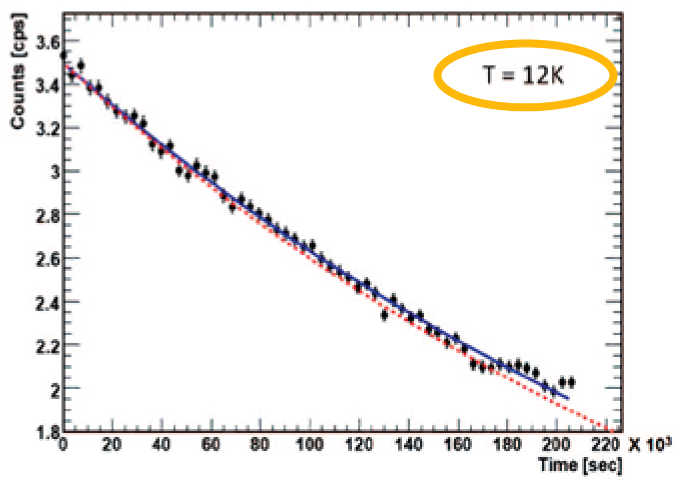
Our Findings

- Following the publication of these articles, our group began a series of experiments to test these claims
- In 2007, we conducted an experiment using ^{198}Au in a metallic gold environment
- Our findings showed no change in the half-life of ^{198}Au between 19 K and room temperature

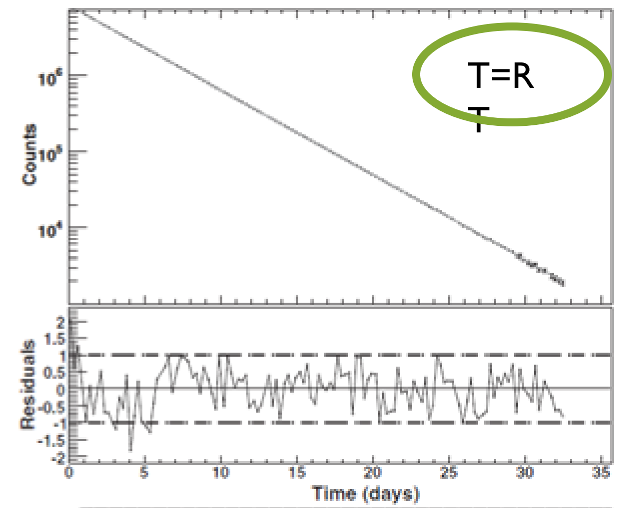
Comparison

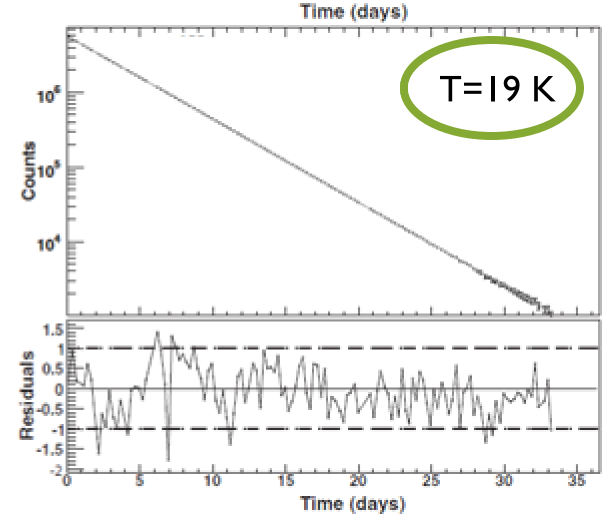
- Rolfs group results
  - Log plot
  - One half-life, less counts





- Hardy group results
  - Linear plot
  - 10+ half-lives, more counts



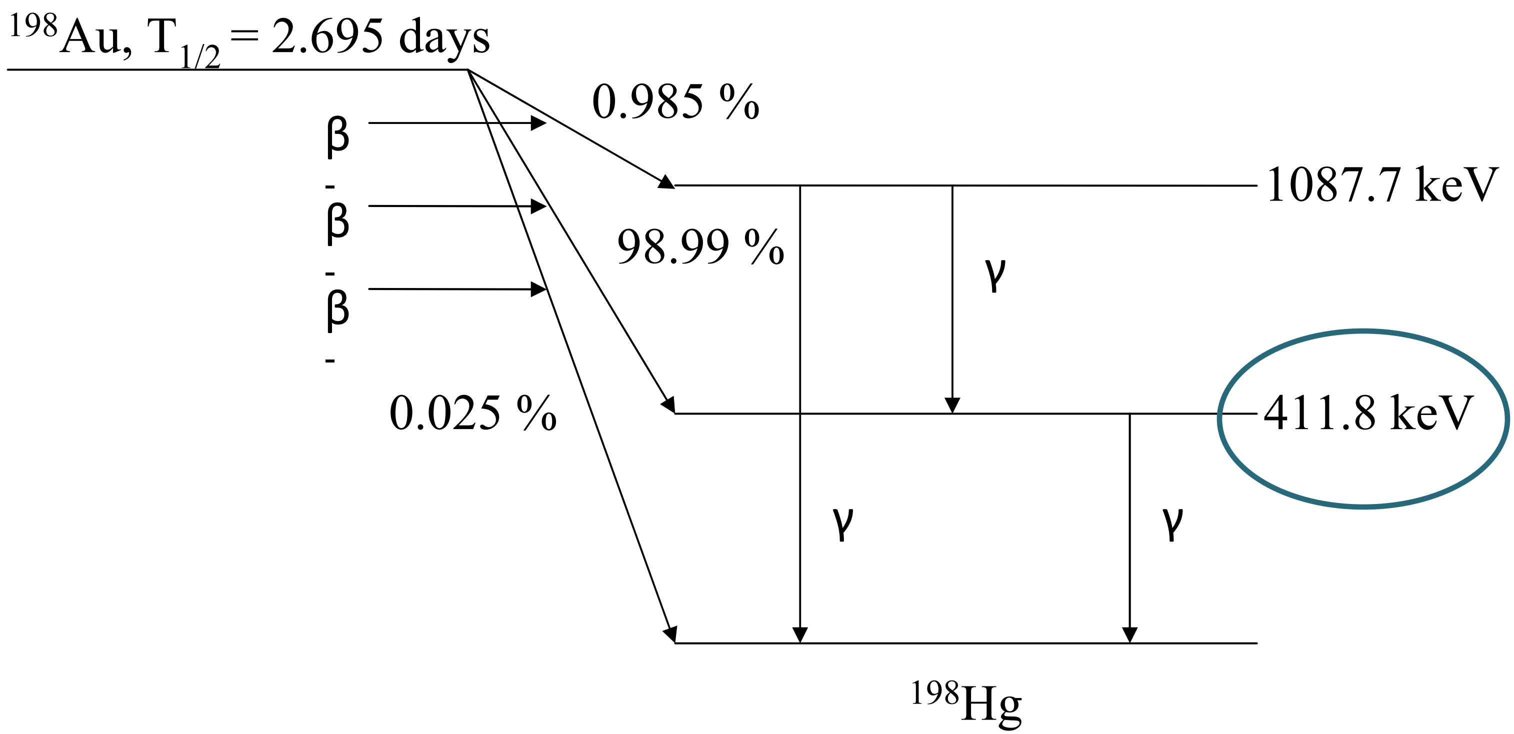


Current Experiment

- It was also suggested that the radioactive half-lives may change according to whether the source was in a conductive or insulated medium
- To test this suggestion, we compared the half-life of ^{198}Au in an insulated environment with our previous measurement in the conductive environment (gold metal)
- The insulator used is Au_2O_3 (gold (III) oxide)

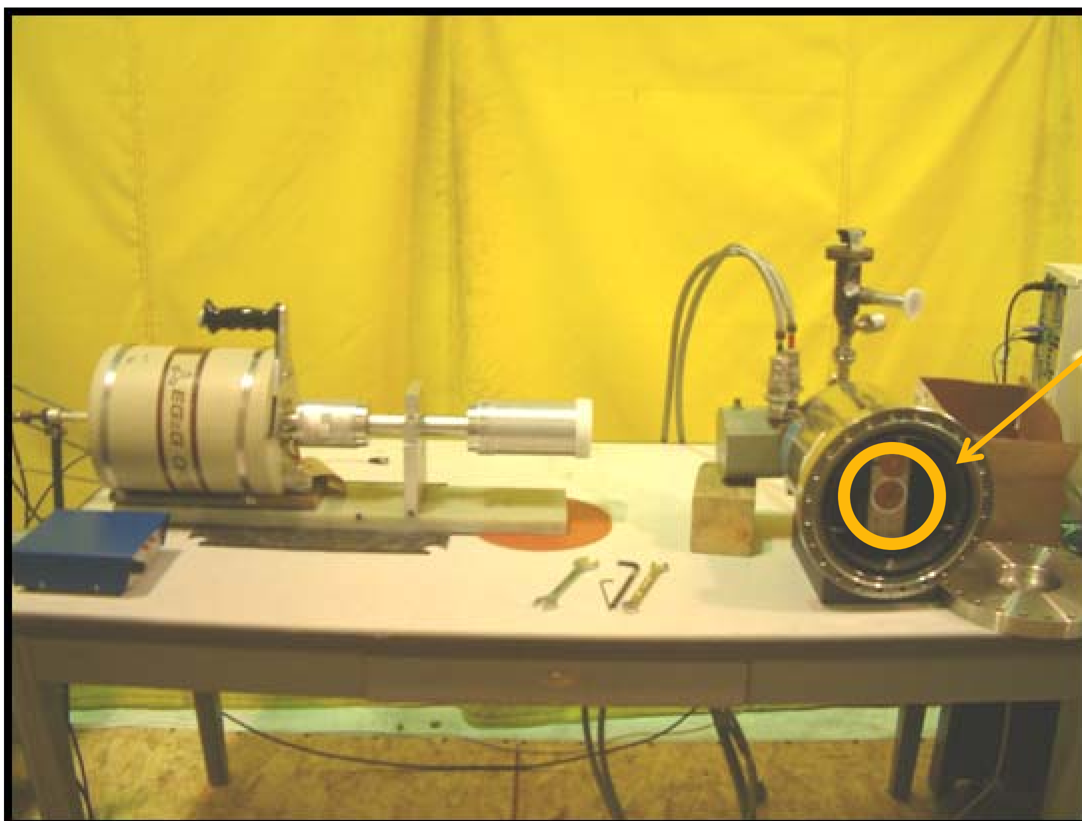
Equipment

- ^{198}Au
  - Accepted half-life: 2.695 days
  - Decay mode: β^- decay to ^{198}Hg
  - ^{197}Au irradiated at the TAMU Triga reactor via neutron capture



Equipment

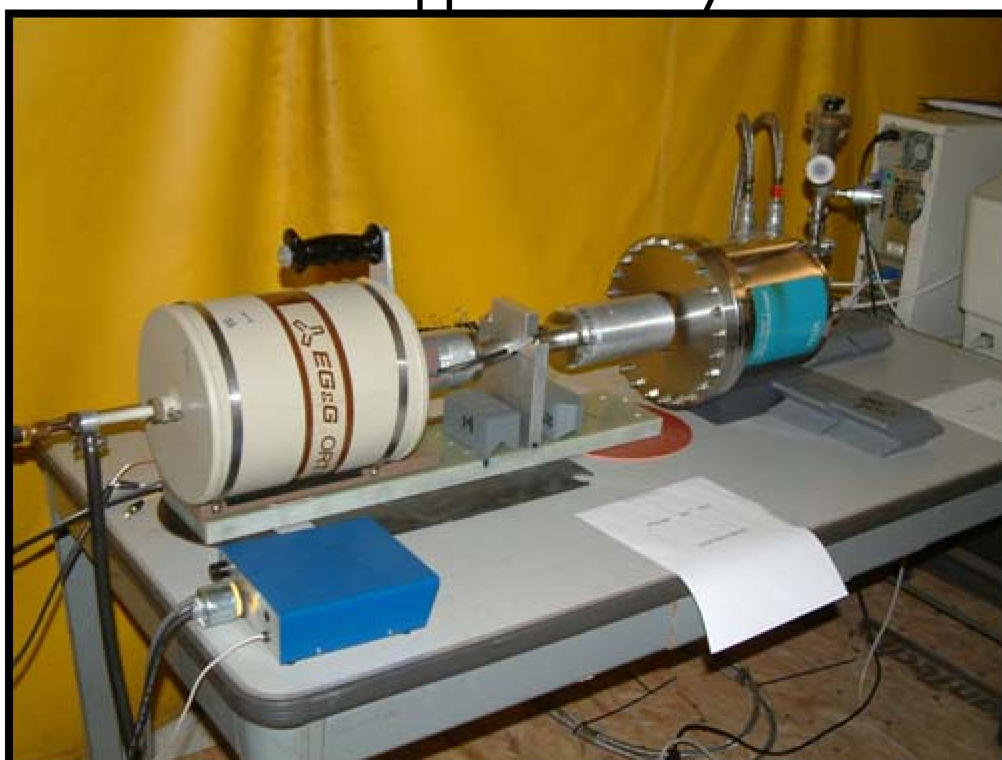
- Cryopump
  - The irradiated sample was placed on a planchet, then attached to the cold head
  - 3.5 mm thick stainless steel plate covers the cryopump in front of the sample.
- HPGe detector
  - Recorded the γ-ray spectra



Sample

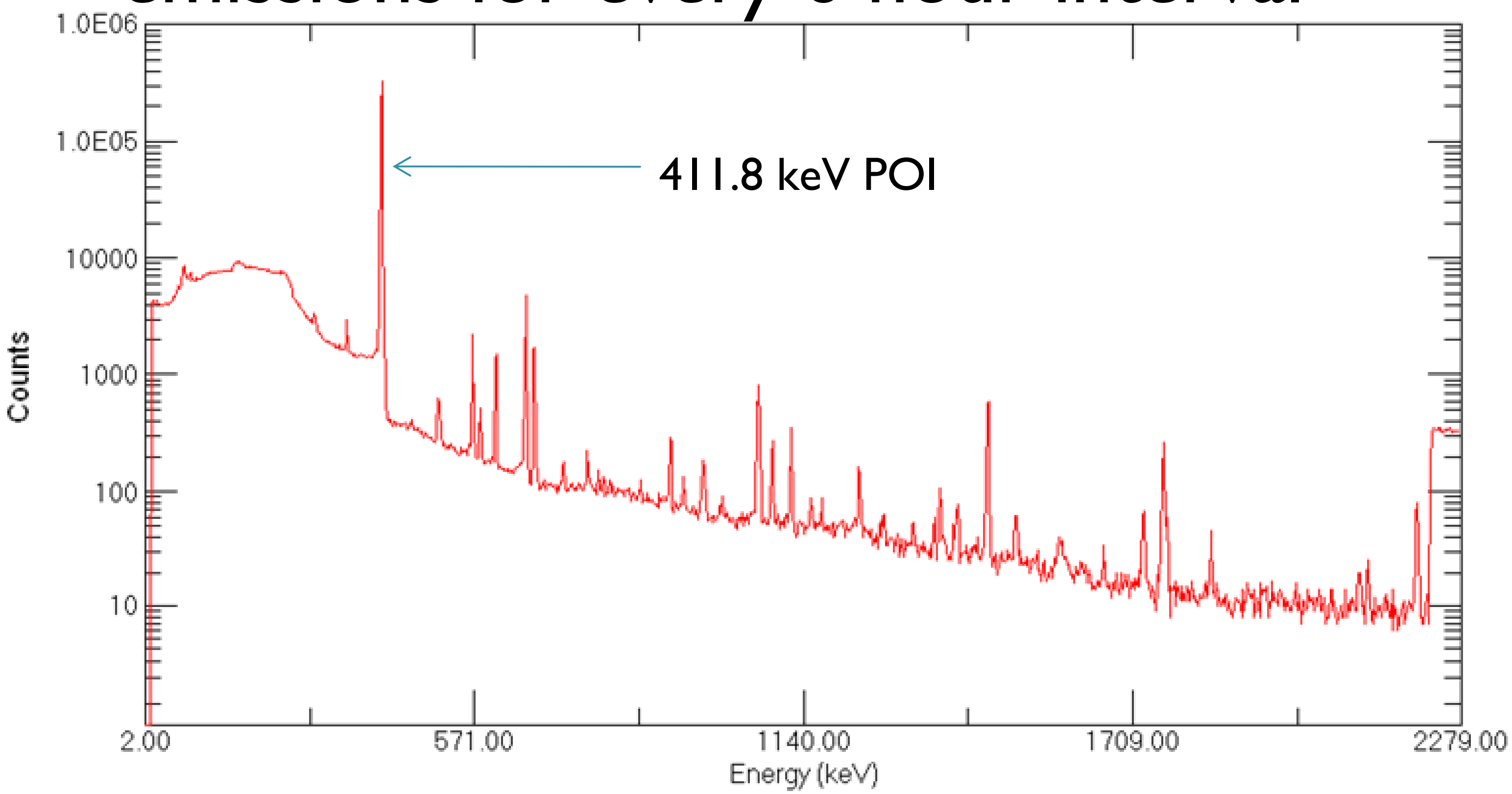
Data Collection

- The cryopump was placed directly in front of the HPGe detector – 42. 5 mm between the sample and the detector
- The detector signal was sent to an Ortec Trump™ card, which was controlled by the Maestro program
- Data were collected for approximately 10 half-lives (about 27 days)



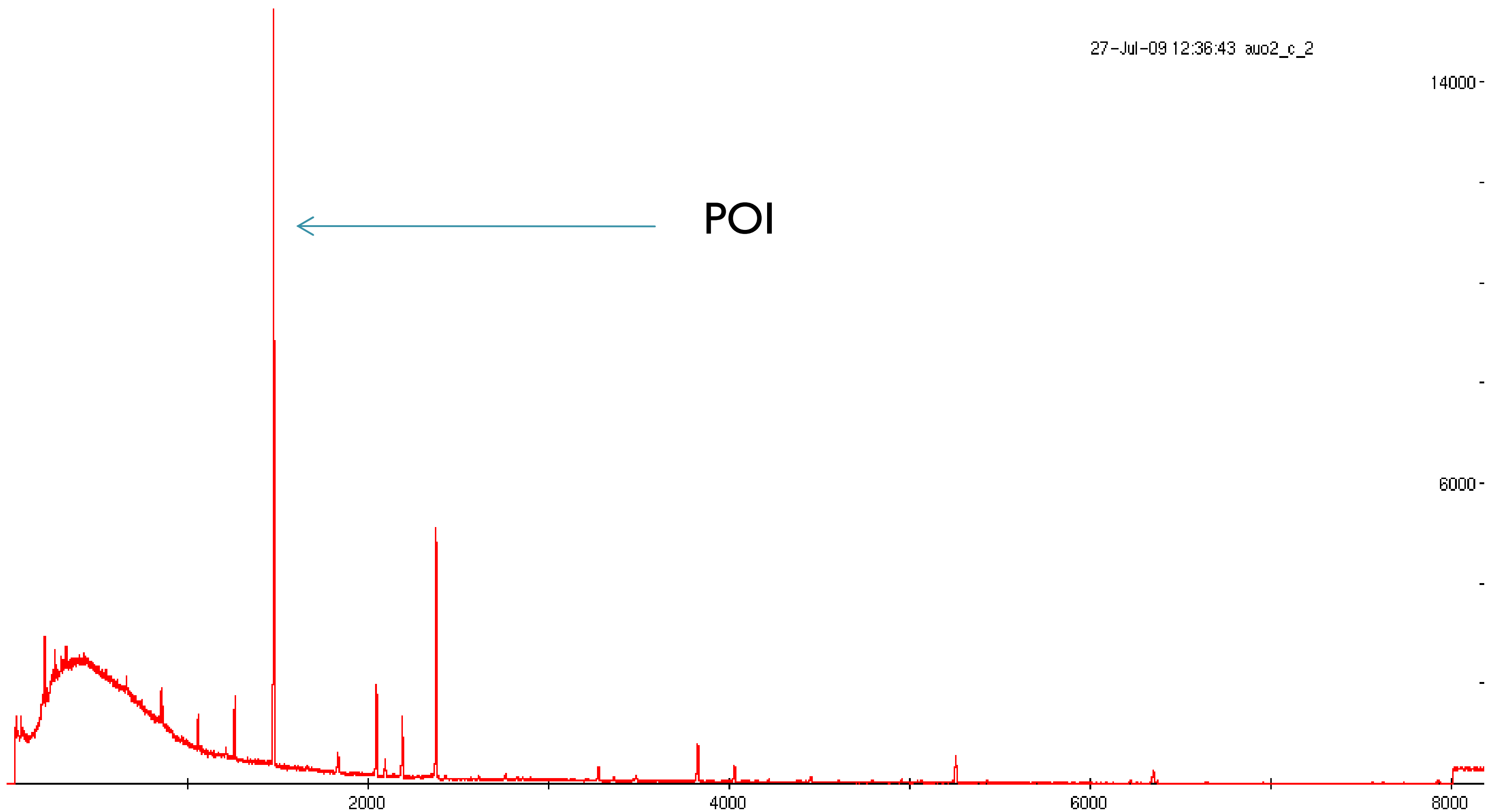
Data Analysis

- The Maestro program collected the data and created a spectrum of the γ-ray emissions for every 6 hour interval



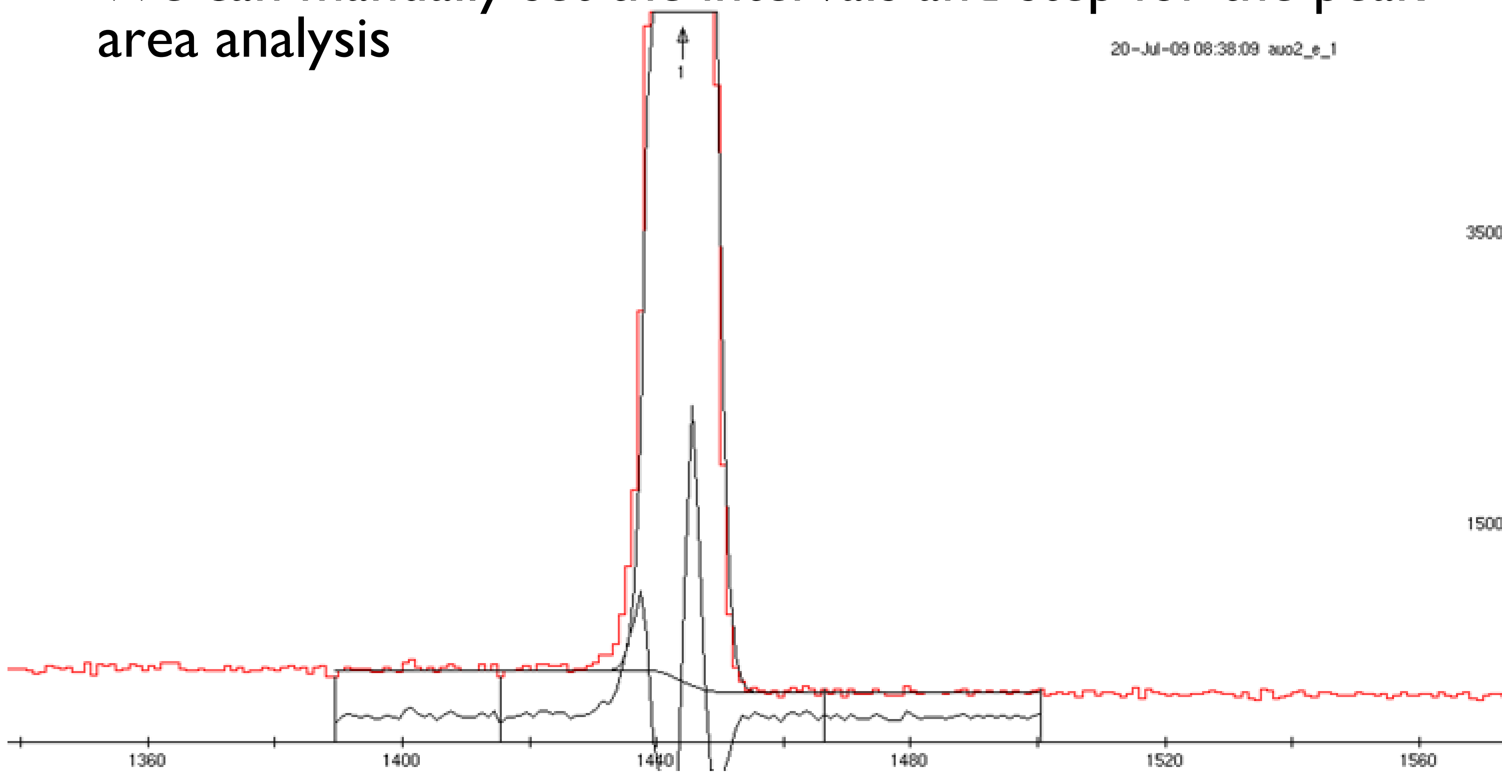
Data Analysis

- The spectrum is then converted over to Radware …



Data Analysis

- The peak of interest is analyzed using the gf3 fit program on Radware
  - The gf3 fit program allows us to make a very precise determination of the peak area and uncertainty in each 6-hour spectrum
  - We can manually set the intervals and step for the peak area analysis

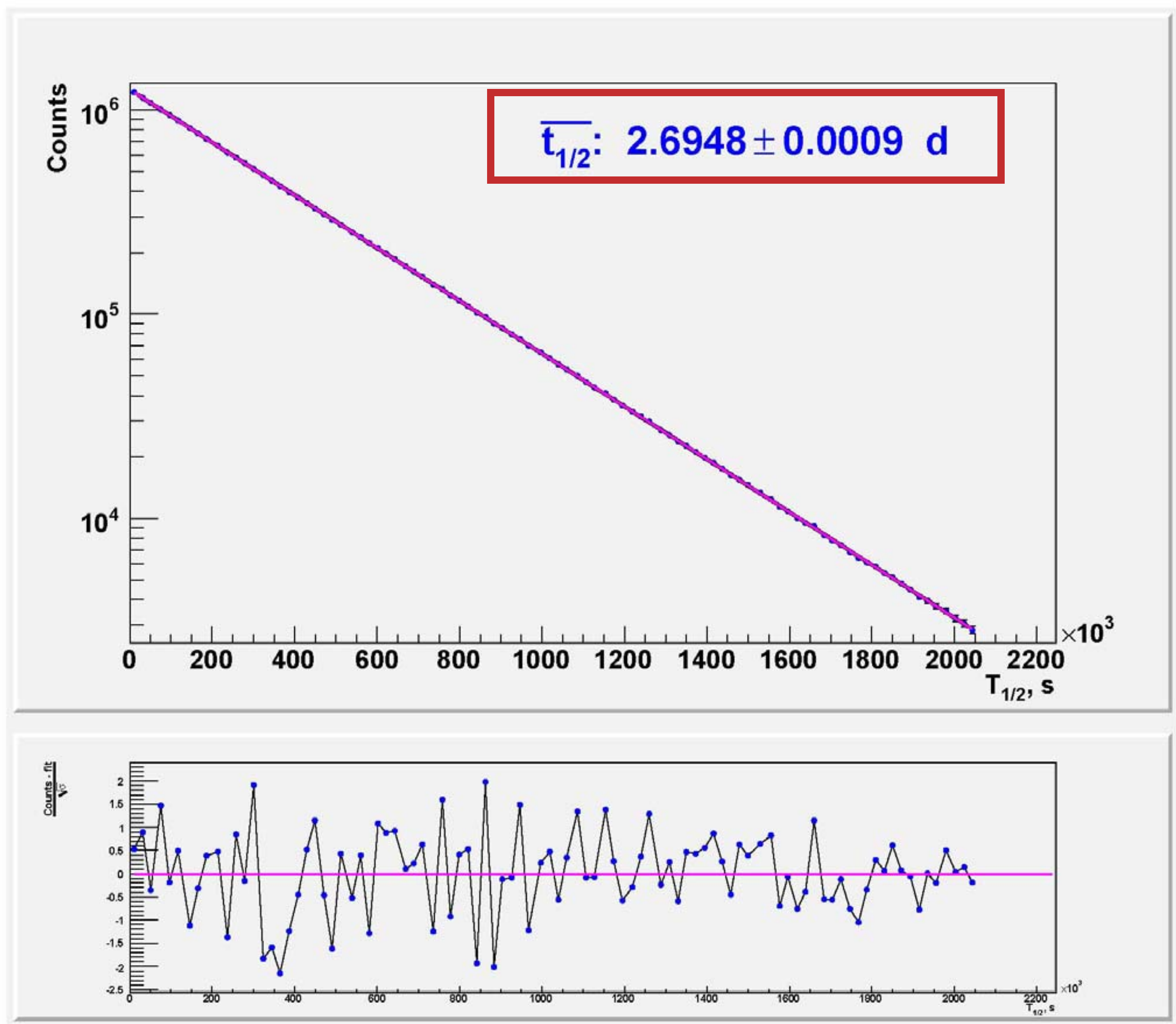


Data Analysis

- The results are then evaluated by a maximum likelihood single exponential fit, using the ROOT program
- ROOT gives a linear fit line of the number of counts vs the half-life in seconds
- The residuals, shown below the fit line, is calcuated by

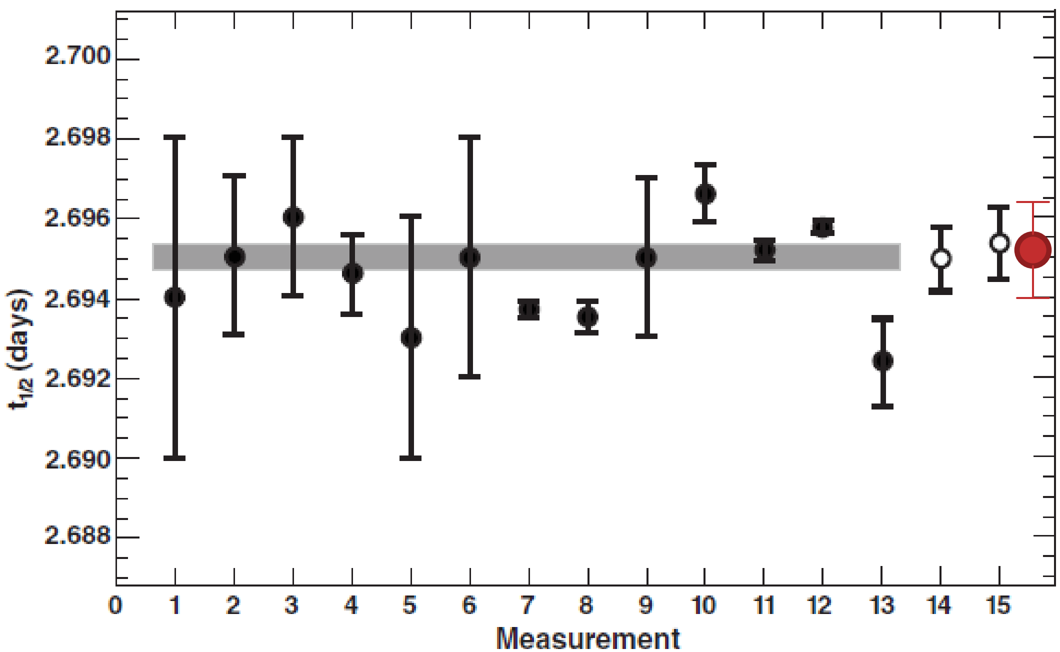
$$\frac{(\#counts)-(fit\ value)}{\sigma}$$

Data Analysis



Conclusions

- At this time, the experiment is still running and is expected to end around August 10, 2009
- Our latest ROOT fit shows the half-life to be the same (within error bars) as the half-life in metal.



The black points represent data collected since 1965; the gray bar represents their averages with uncertainty. The white points represent our measurements at RT and at 19 K in a conductive metal; the red point represents the current preliminary results in a metallic insulator

Acknowledgments

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