High-precision measurements of half-lives for ^{85}Sr, ^{77}Kr, ^{79}Kr, ^{99}Mo, ^{196}Au, and ^{89}Zr radioactive nuclei via photoactivation at the Madison Accelerator Laboratory

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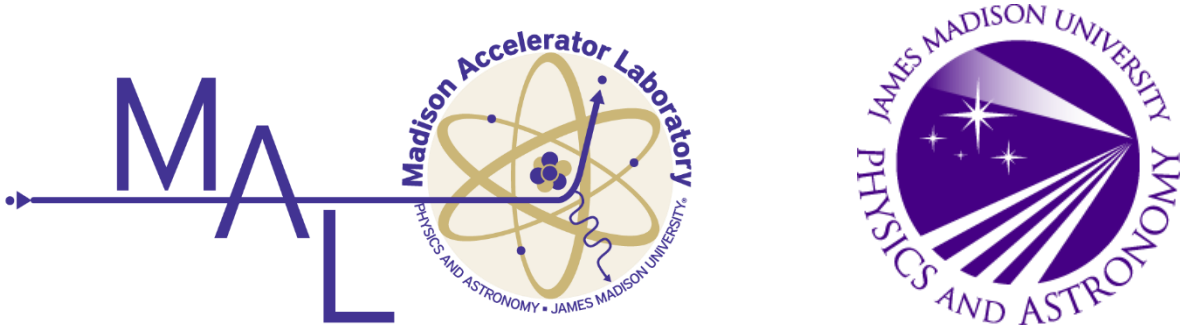


Undergraduate Physics Research Symposium

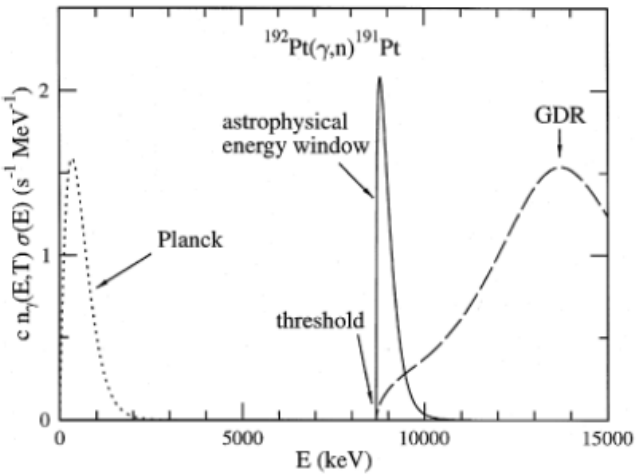
April 2, 2022

Astrophysically Relevant Photoneutron Reaction Rates

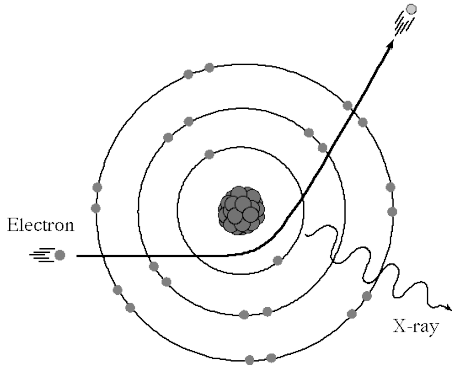
The reaction rate for a photodisintegration reaction

$$\lambda(T) = \int_0^\infty c n_\lambda^{Planck}(E,T)\sigma(E)dE$$

$$n_\gamma^{Planck}(E,T) = \left(\frac{1}{\pi}\right)^2\left(\frac{1}{\hbar c}\right)^3 \frac{E^2}{\exp(E/kT)-1}$$

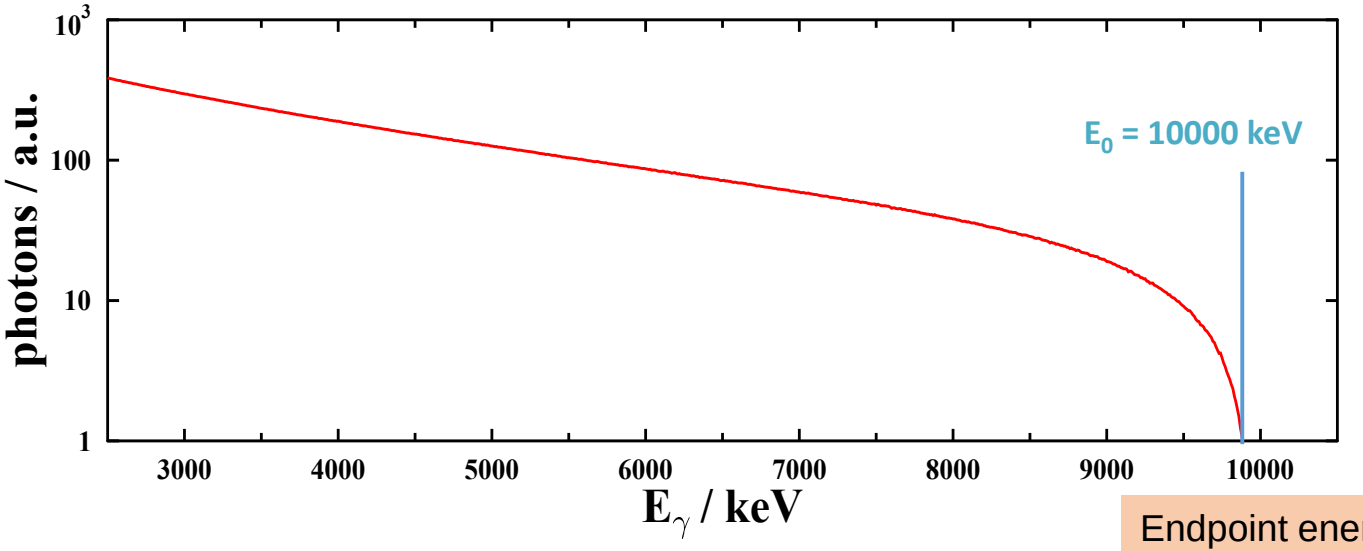


P. Mohr et al. (Phys. Lett. B 488, (2000))



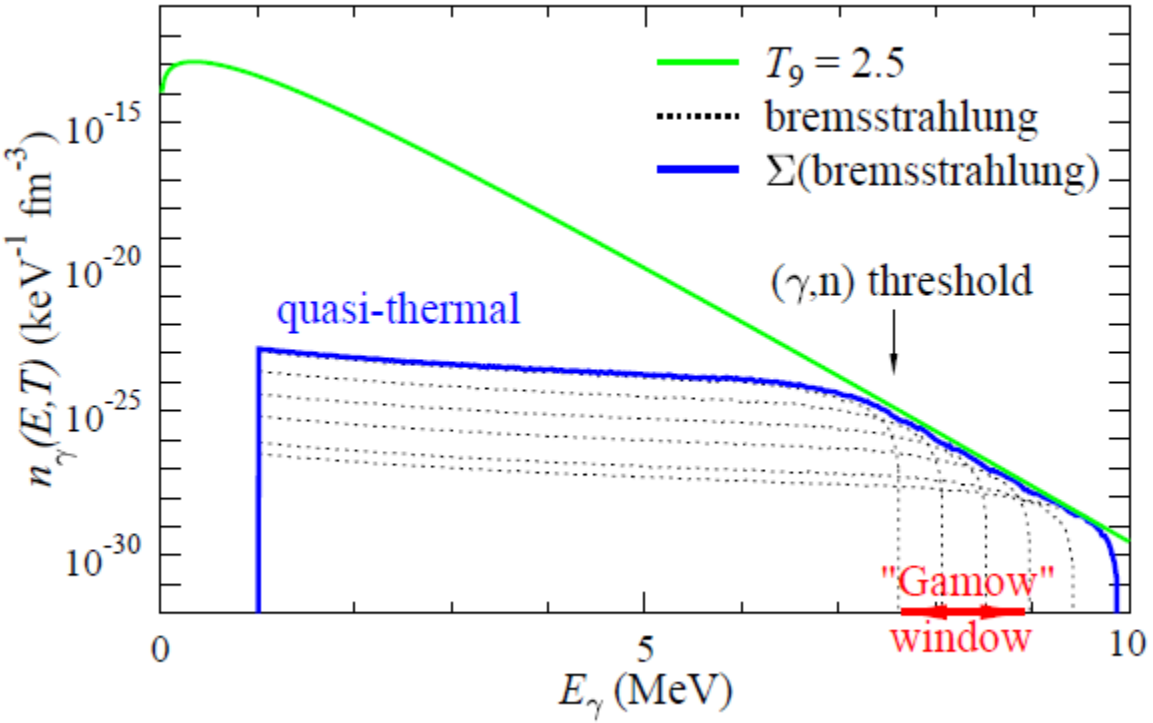
Bremsstrahlung

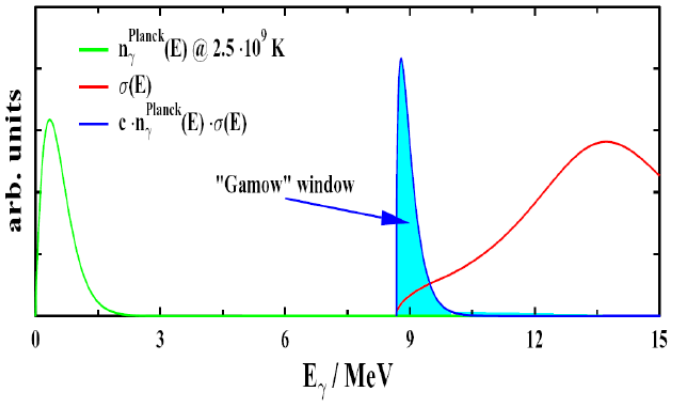
- Production by stopping of electron beam with energy E_0
- Continuous-energy photon spectrum with max. energy E_0



Endpoint energy

‘The superposition method’





D. Galaviz et al. (Nucl. Phys. A 758, 521c (2005))

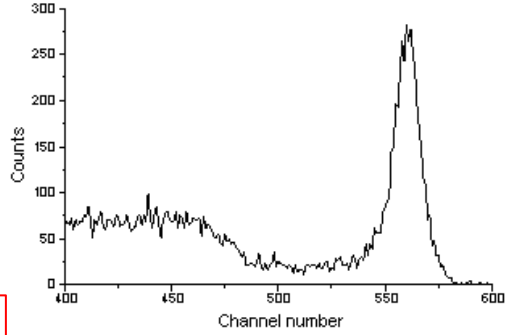
$$cn_\gamma^{Planck}(E,T) \approx \sum_i a_i(T)\Phi_\gamma^{brems}(E,E_{\max,i})$$

$$cn_{\gamma}^{Planck}(E,T) \approx \sum_{i} a_i(T)\Phi_{\gamma}^{brems}(E,E_{\max,i})$$

$$\lambda_{(\gamma,n)}^{gs}(T) \approx \sum_{i} a_i(T) \int_{E_{thr}}^{E_{\max,i}} \Phi_{\gamma}^{brems}(E,E_{\max,i})\sigma_{(\gamma,n)}(E)dE$$

$$\lambda_{(\gamma,n)}^{gs}(T) \approx \sum_{i} a_i(T) I_{\sigma_{(\gamma,n)},i}$$

$$\gamma + {}^{A}X \rightarrow {}^{A-1}X^{*} + n$$



$$A_\gamma = N_T \varepsilon_\gamma I_\gamma p \frac{t_{life}}{t_{real}} \frac{\left(1 - e^{-\lambda t_{irr}}\right)}{\lambda t_{irr}} e^{-\lambda t_{cool}} \left(1 - e^{-\lambda t_{meas}}\right) I_{\sigma(\lambda,n)}$$

$$\lambda = \frac{\ln 2}{T_{1/2}}$$

$A_\gamma \Rightarrow$ Number of counts in the decay lines of ${}^{A-1}X$

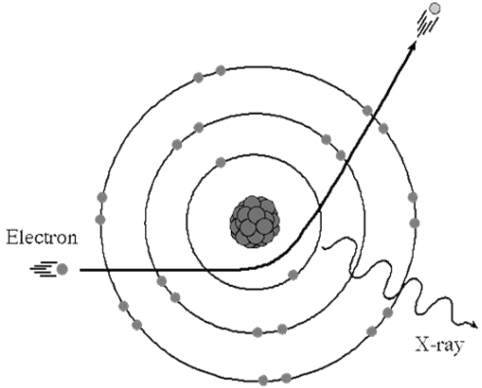
$\varepsilon_\gamma \Rightarrow$ Absolute detector efficiency

$t_{irr} \Rightarrow$ Duration of the irradiation

$t_{cool} \Rightarrow$ Time between the end of the irradiation and the beginning of the measurement

$t_{meas} \Rightarrow$ Duration of the measurement

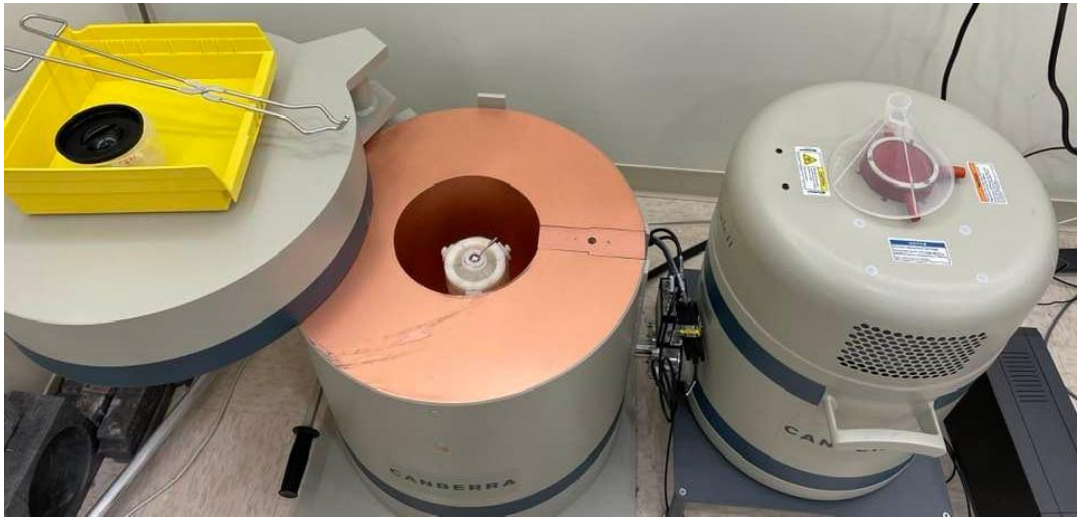
Experimental Setup



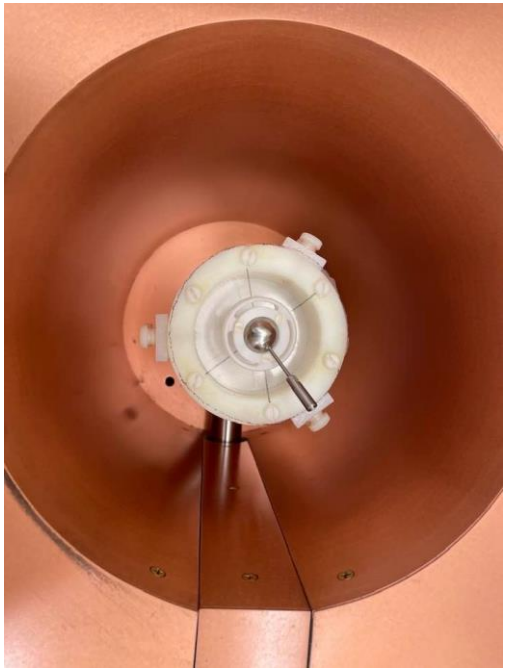
MAL's electron linear accelerator (linac)

Experimental Setup

Ultra Low Background Germanium Detector

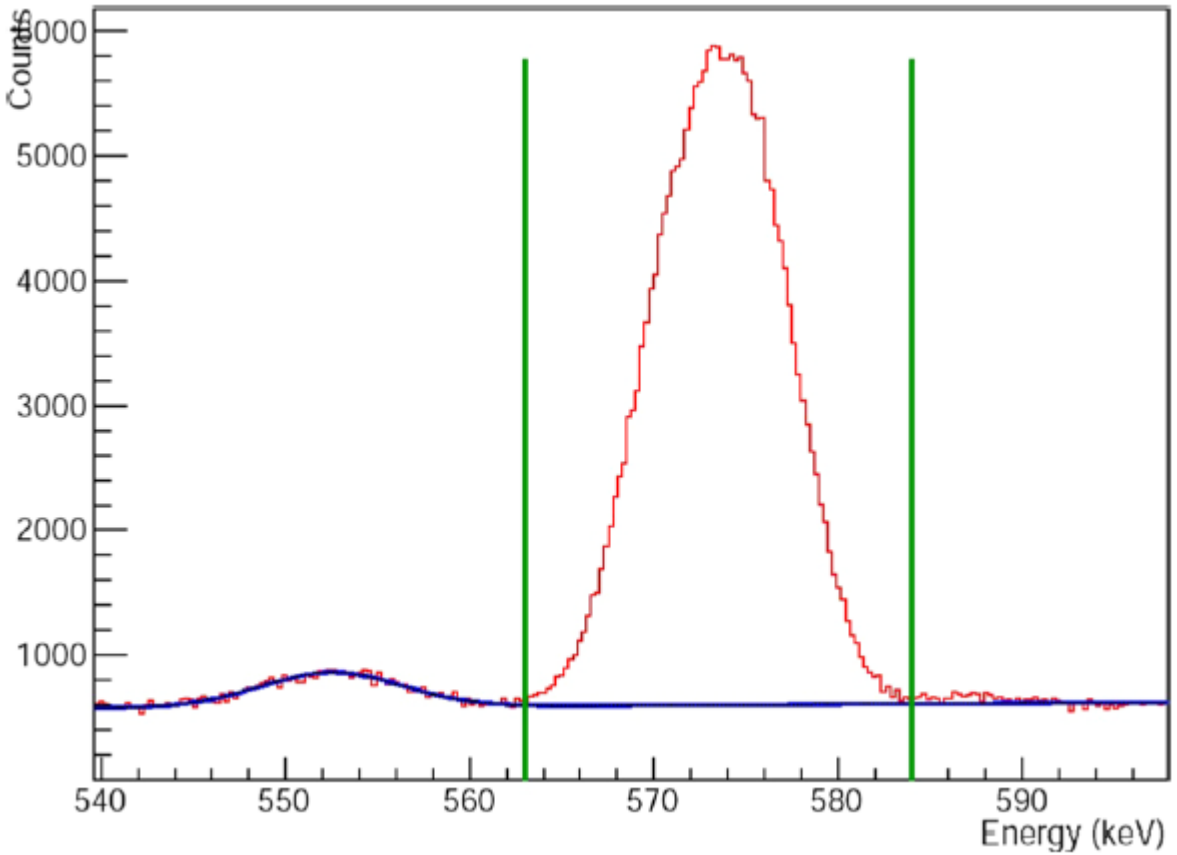


ULB Detector



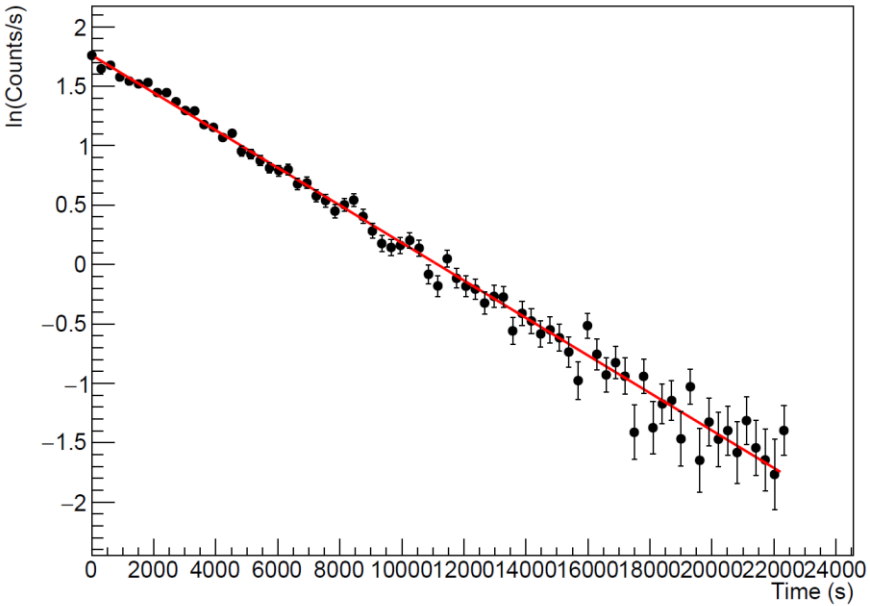
Inside ULB Detector

Data Analysis

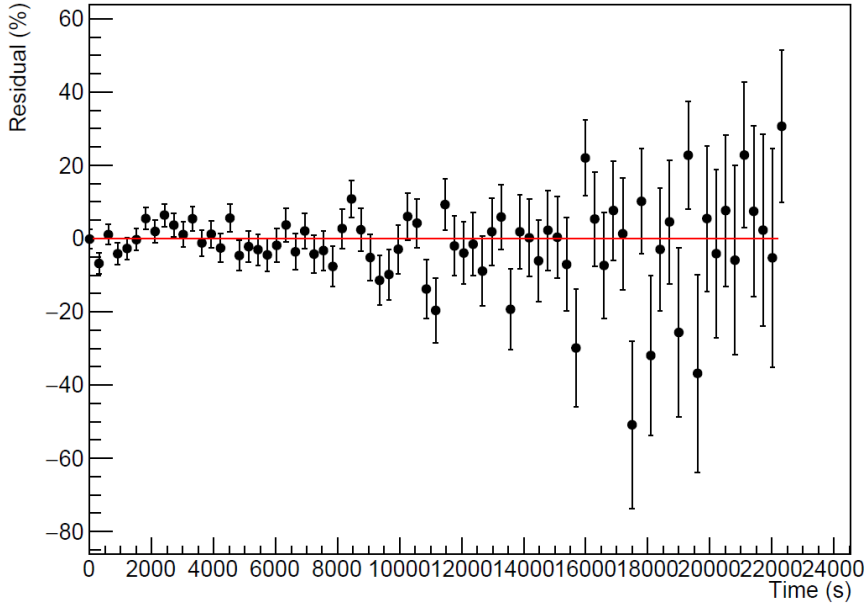


Data Analysis

^{79}Kr Half life Fit

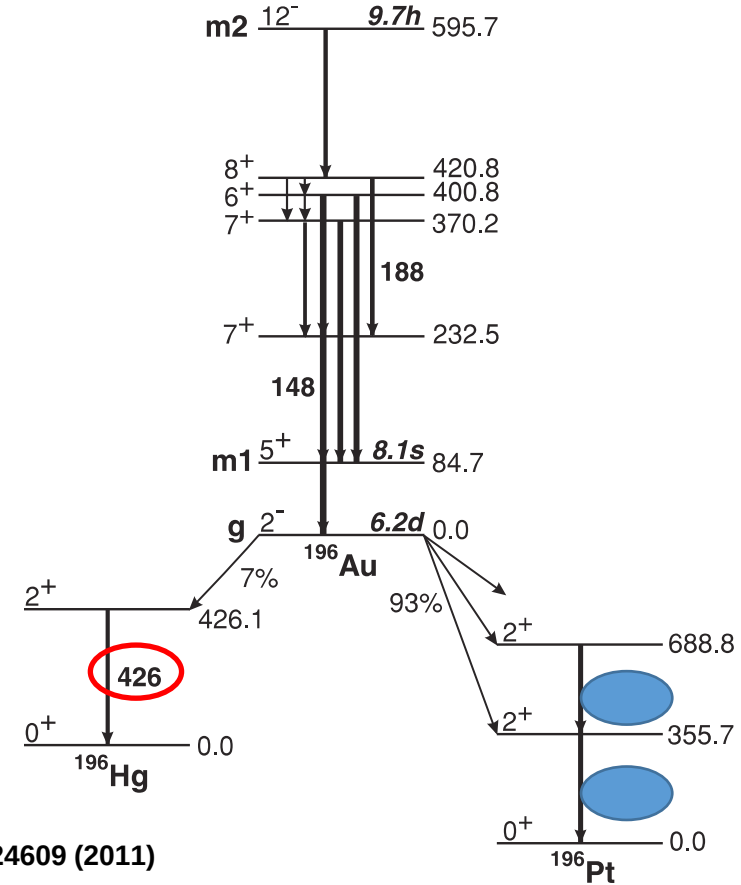


^{79}Kr Residual Fit



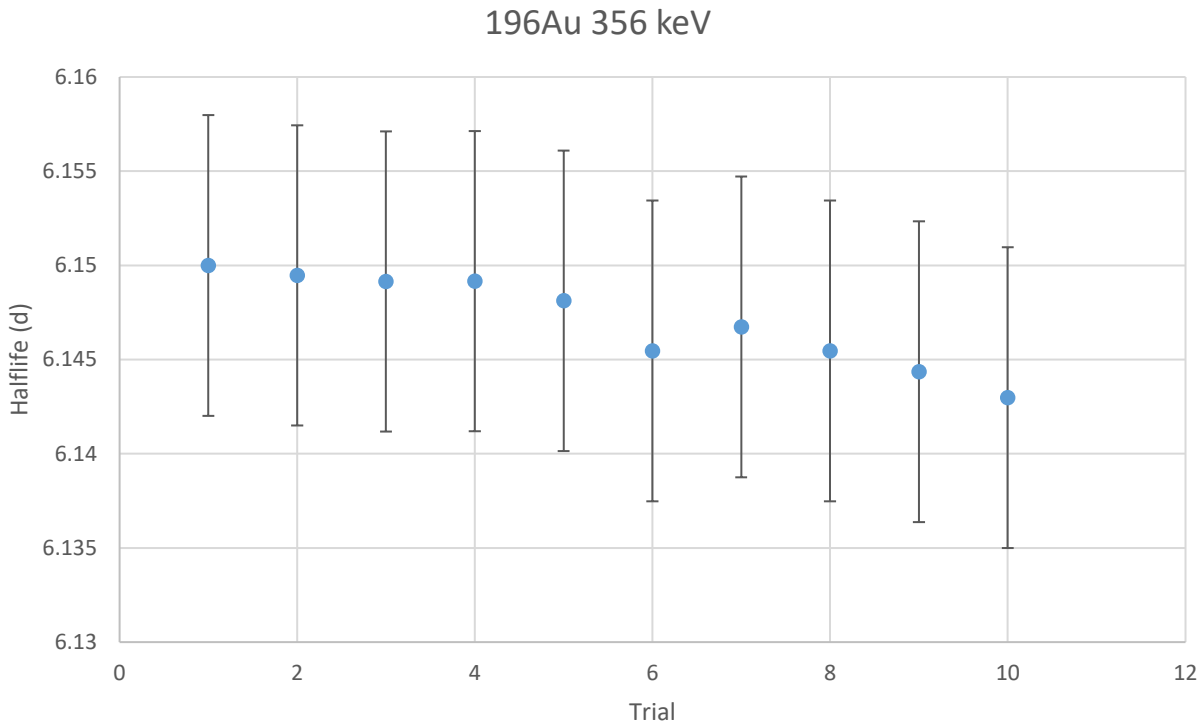
Simplified decay scheme of the residual nucleus ^{196}Au

$$\gamma + {}^{A}X \rightarrow {}^{A-1}X^{*} + n$$



A. Tsinganis et al, Phys. Rev. C 83, 024609 (2011)

Data Analysis – systematic error analysis investigation



Preliminary Results

^{85}Sr

Eγ (keV)	$T_{1/2}$
514	65.42 ± 0.34 (stat) or 0.52% (stat) d
Literature	64.849 ± 0.007 (stat) or 0.011% (stat) d

^{77}Kr

Eγ (keV)	$T_{1/2}$
129	75.16 ± 0.38 (stat) min
147	73.23 ± 0.67 (stat) min
Weighted Average	75.09 ± 0.11 (stat) or 0.15% (stat) min
Literature	74.40 ± 0.42 (stat) or 0.56% (stat) min

^{79}Kr

Eγ (keV)	$T_{1/2}$
261	34.87 ± 0.08 (stat) h
396	34.88 ± 0.12 (stat) h
606	35.52 ± 0.14 (stat) h
Weighted Average	34.99 ± 0.13 (stat) or 0.37% (stat) h
Literature	35.04 ± 0.10 (stat) or 0.29% (stat) h

^{196}Au

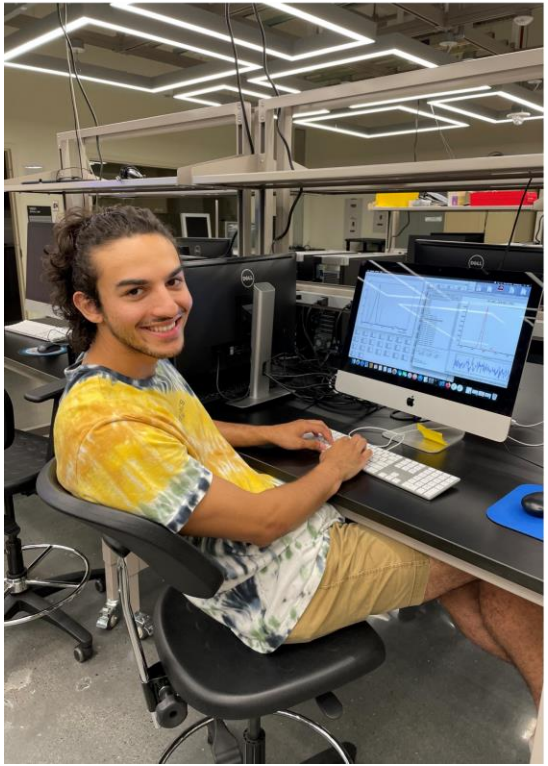
Eγ (keV)	$T_{1/2}$
333	6.140 ± 0.016 (stat) d
356	6.149 ± 0.008 (stat) d
426	6.162 ± 0.033 (stat) d
Weighted Average	6.148 ± 0.004 (stat) or 0.065% (stat) d
Literature	6.1689 ± 0.0006 (stat) or 0.0097% (stat) d

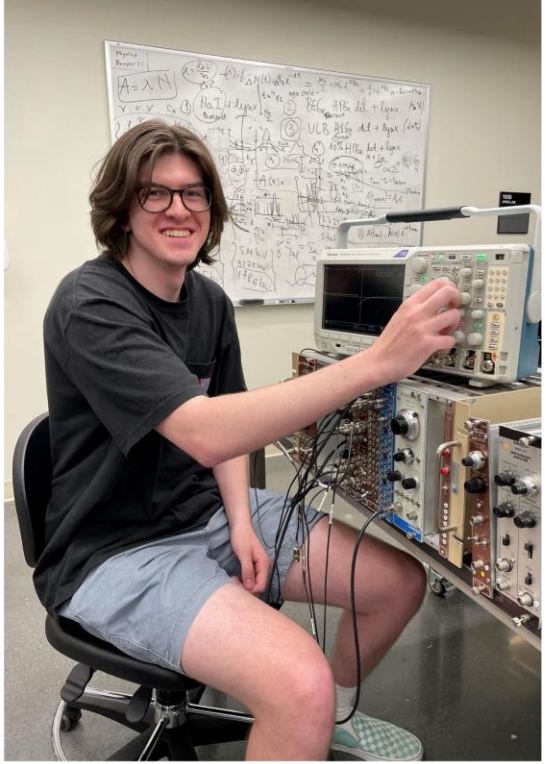
^{99}Mo

Eγ (keV)	$T_{1/2}$
182	66.45 ± 0.10 (stat) h
740	65.78 ± 0.10 (stat) h
778	65.85 ± 0.17 (stat) h
Weighted Average	66.07 ± 0.12 (stat) or 0.18% (stat) h
Literature	65.976 ± 0.024 (stat) or 0.036% (stat) h

^{79}Zr

Eγ (keV)	$T_{1/2}$
909	84.26 ± 0.89 (stat) or 1.05% (stat) h
Literature	78.41 ± 0.12 (stat) or 0.15% (stat) h





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David Purdham

Acknowledgements

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Thank You!