Coding a Real-Time Radioisotope Production From $^{209}Bi(\alpha,2n)^{211}At$ Binary Nuclear Reaction

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Introduction

- Radioisotope production from charged-particle fixed target activation technique is hard to precisely measure in experimental runs from changing beam current.
- Short-lived nuclei pose a challenging aspect to production yields as the first-order decay rate is proportional to amount produced.
- The incident particle beam will not always be hitting the fixed target.
- Unknown activity levels before HPGe detection give chemist uncertainty about experimental run timetables.
- Having a program that takes in a value for current throughout a bombarded target and displaying the activity of the desired radioisotope lets researchers use past performance to predict future activity at end of bombardment (EoB) and future run time.

- **Integrated Radionuclide Production Rate:**
  - $A = R\left(1-e^{-\lambda t}\right);\ R = \sigma\varphi x N_T'$
  - $R = \frac{\sigma I x \rho N_A}{(\pm e) Z m_a};\ \frac{R}{I} = D$
  - $A = DI\left(1-e^{-\lambda t}\right)$
- **Iterative Counter:**
  - $A_1 = D_1 I_1\left(1-e^{-\lambda t_1}\right) + A_0 e^{-\lambda t_1}$
  - $A_2 = D_2 I_2\left(1-e^{-\lambda t_2}\right) + A_1 e^{-\lambda t_2}$
  - $\vdots \qquad\qquad \vdots$
  - $A_{n-1} = D_{n-1} I_{n-1}\left(1-e^{-\lambda t_{n-1}}\right) + A_{n-2} e^{-\lambda t_{n-1}}$
  - $A_n = D_n I_n\left(1-e^{-\lambda t_n}\right) + A_{n-1} e^{-\lambda t_n}$

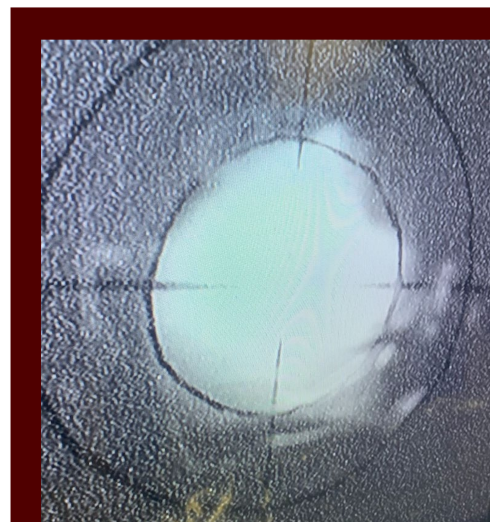
Methods

- From previously gathered current data read from a Keithley 6485 Picoammeter on the non-electrically isolated stacked bismuth target circuit an iterative calculation script was created to return activity levels of Astatine-211 at each measurement interval of ~5 seconds.
- $^{209}Bi(\alpha,2n)^{211}At$ nuclear reaction Padé-fit cross-sectional data was used with bismuth material data and SRIM calculated beam depth to calculate the dimensionless unit D throughout the run.
- Plotting the activity throughout the run and comparing it to results from detected At-211 activity from the X-ray fingerprint from the target showed the difference in actual verses calculated results.
- Faraday Cup 02 (FC02) in TAMU Cyclotron Institute had measurement taken throughout runs and compared to values given by the picoammeter to calibrate to true beam intensity.
- User friendly Python script was created to display the live plot of gathered activity data.

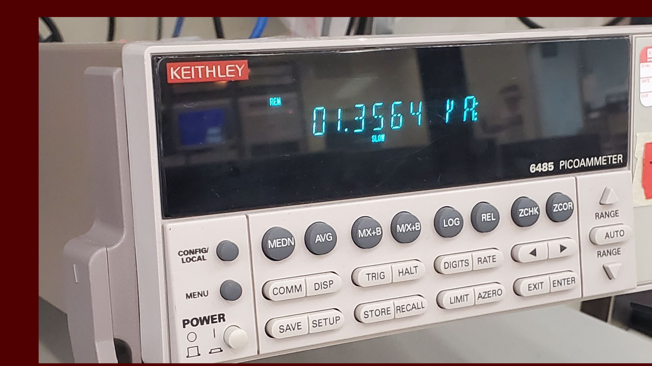
Assumptions

- SRIM 0.5 MeV depth changes yields a negligible error for final calculations.
- Other nuclear reactions happening with the target nuclei are smaller than desired reaction.
- If summed production rate is small compared to target areal density measurements, then D is unchanging throughout run.
- Between current measurements the beam intensity does not rapidly change.
- Target nuclei are either stable or near stable.
- The particle beam is only hitting the area of target nuclei on the target.
- The fixed target material is thicker than the usable depth for the production as determined by the cross section for desired reaction.

Results

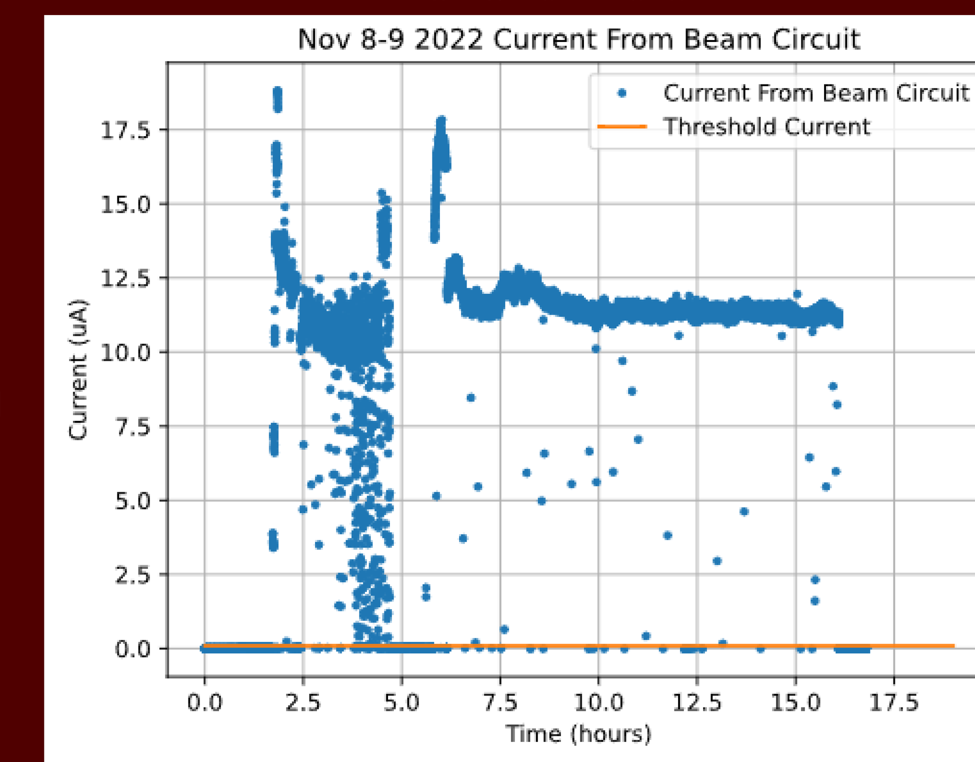


Beam centered on bismuth target

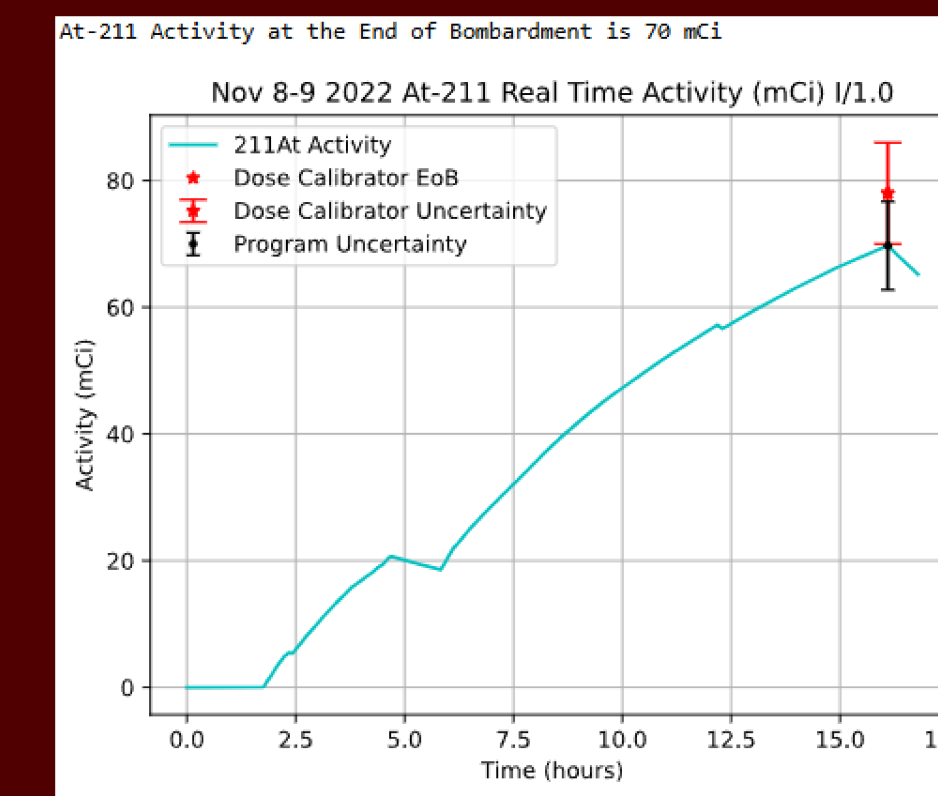


Keithley picoammeter feeding current data to script

Inserted bismuth target in irradiation chamber



Current from picoammeter over At-211 production run of Nov 8-9 2022



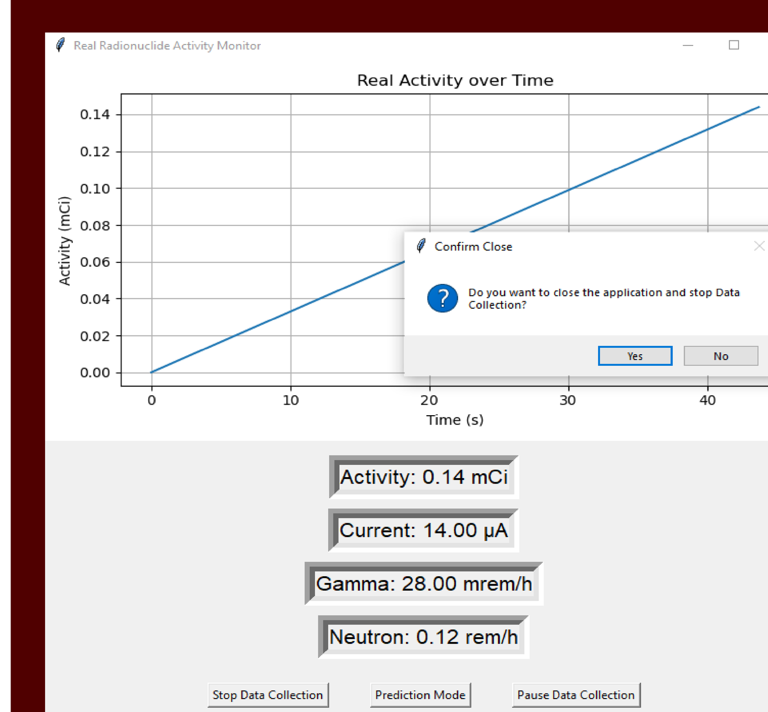
Iterative calculated Activity of At-211 during production run of Nov 8-9 2022

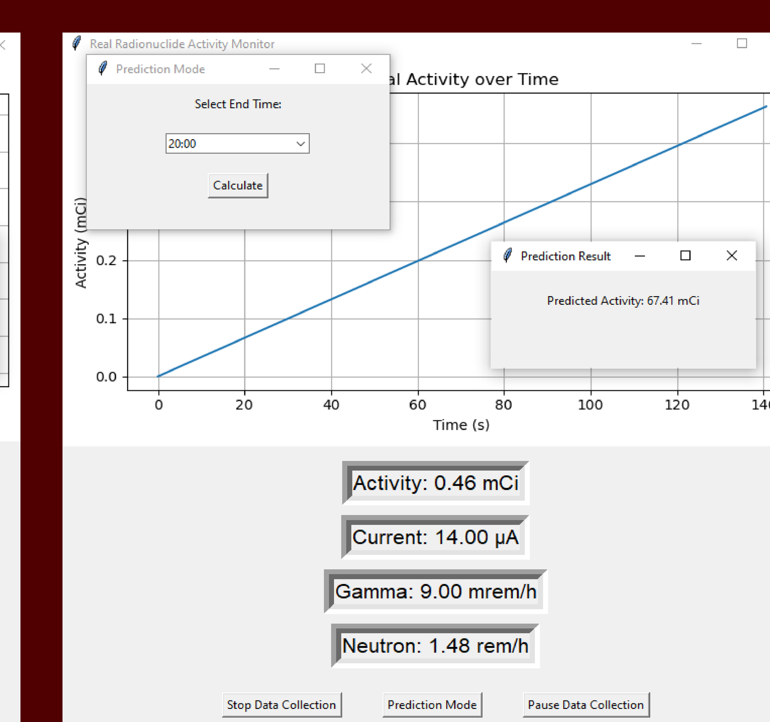
Run Date	EOB Time	Dose Calibrator Determined Activity	Dose Calibrator Uncertainty	Program Calculated Activity (I/1.0)	Program Uncertainty	Within Dose Calibrator Error
4/26/2022	7:30:39	121	±12	126	±13	TRUE
6/7/2022	6:38:38	159	±16	123	±12	FALSE
8/2/2022	7:27:59	84	±8	62	±6	FALSE
9/3/2022	6:52:24	57	±6	57	±6	TRUE
10/11/2022	6:30:52	74	±8	75	±7	TRUE
11/5/2022	6:29:41	78	±8	70	±7	TRUE
3/28/2023	6:29:30	88	±9	82	±8	TRUE
4/19/2023	5:32:03	81	±9	74	±7	TRUE
5/16/2023	6:31:24	89	±11	84	±8	TRUE
7/31/2023	6:32:39	72	±8	64	±6	TRUE

Table of previous ^{211}At production runs EoB activity for dose calibrator and python script program

CONCLUSION

Iterative Counter gives a small enough error for ~5 second current measurements. User-Interface features protects data sufficiently against accidental closures. COM-port competition leads to consolidation of programs. FC02 calibration is not yet reliable for verified use. Fit data preforms well in script.





User-Interface Tkinter GUIs for data-collection tests

Future Work

Better calibration to the actual beam current from the picoammeter to FC02 current readings. More HPGe verification measurements to test the program. Switching to non-destructive beam current measurements from DC current transformers.

References

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