Target Characterization Using Rutherford Backscattering Spectroscopy

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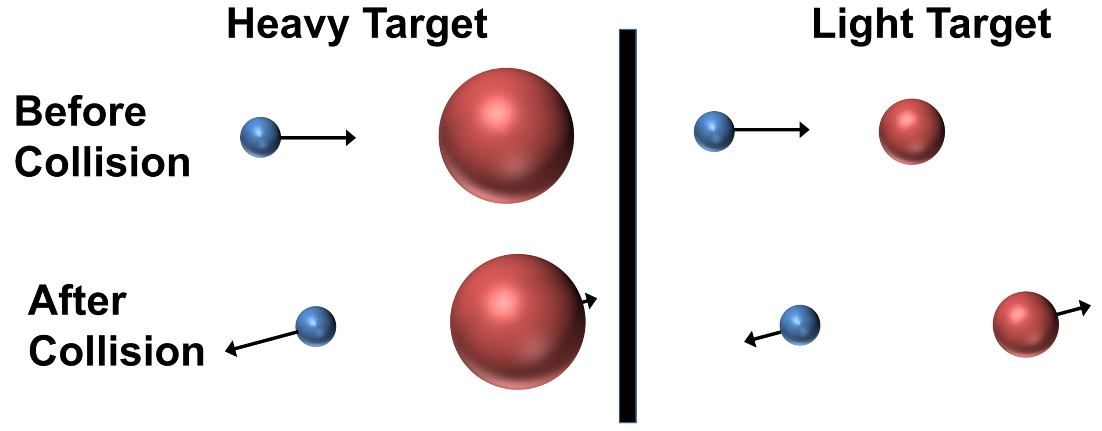
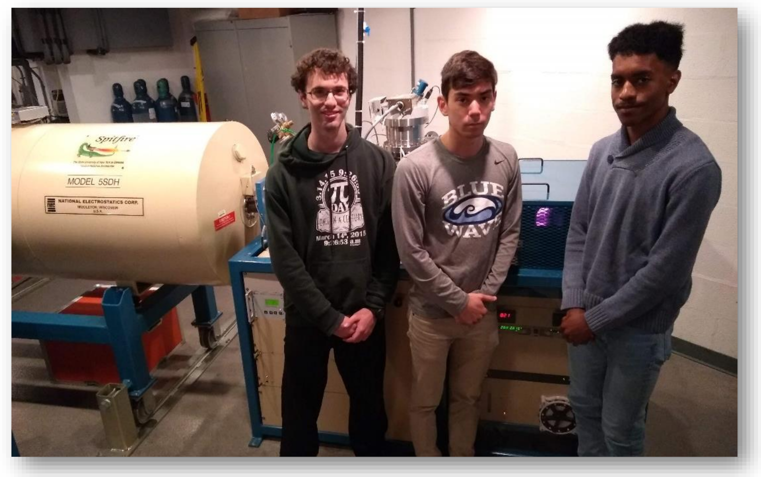
Rutherford Backscattering

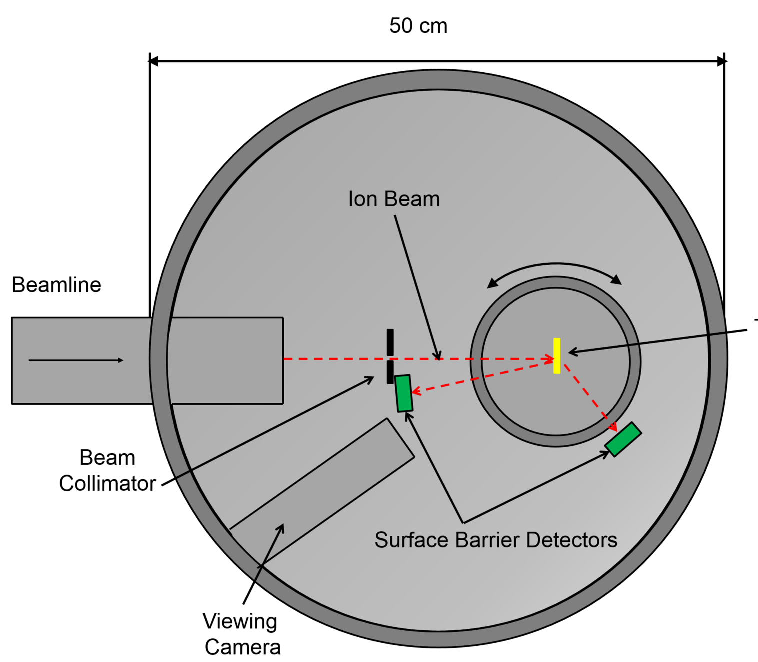
Rutherford backscattering spectroscopy (RBS) is a non-destructive ion-beam analytical technique that is used to determine properties of a target such as thickness, areal density, and elemental composition. This scattering is the result of Coulomb forces between the target atoms and the incident particle. The energy spectrum of the scattered ions depends on the atomic number of the target atoms as well as the target thickness.

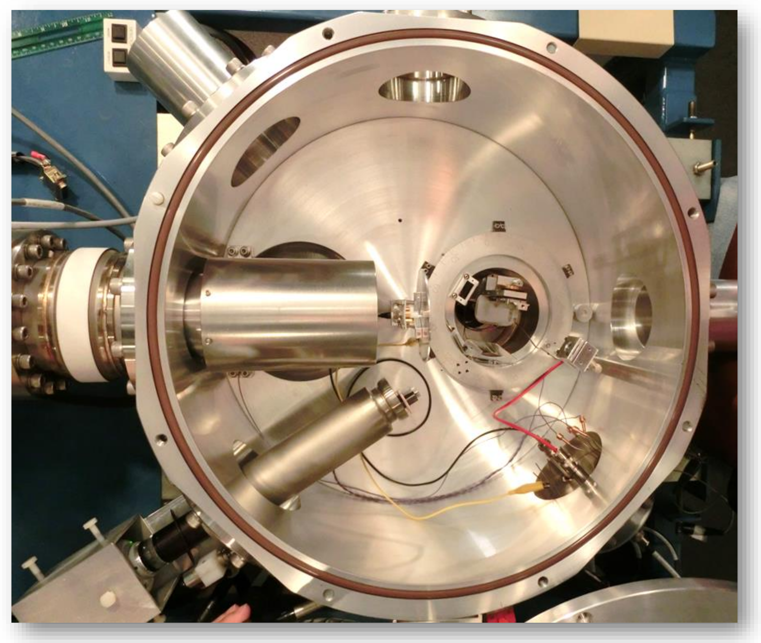


The Accelerator

The RBS experiments were carried out at the SUNY Geneseo Accelerator Laboratory. The accelerator is a 1.7 MV tandem Pelletron accelerator from the National Electrostatics Corporation (NEC). An alphatross RF alkali charge-exchange ion source produces hydrogen or helium with maximum energies of 3.4 MeV and 5.1 MeV respectively.







RBS Theory

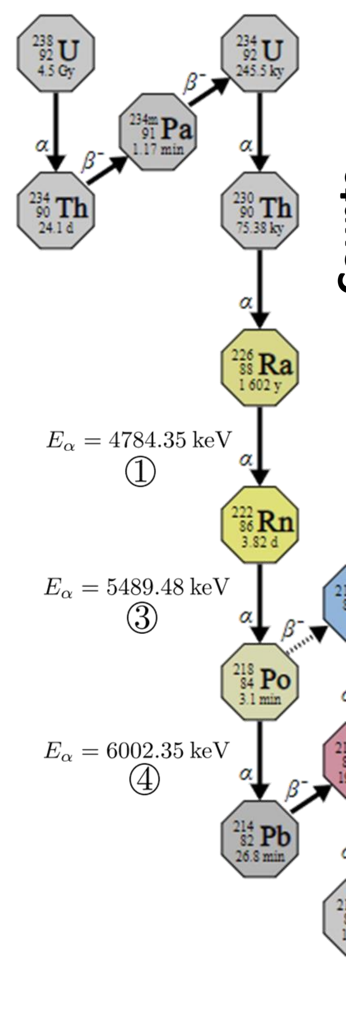
$$N(\theta) = \frac{N_i n L Z^2 k^2 e^4}{4r^2 K E^2 \sin^4\left(\frac{\theta}{2}\right)}$$

N_i = number of incident particles
n = atoms per unit volume in target
L = thickness of target
r = target-to-detector distance

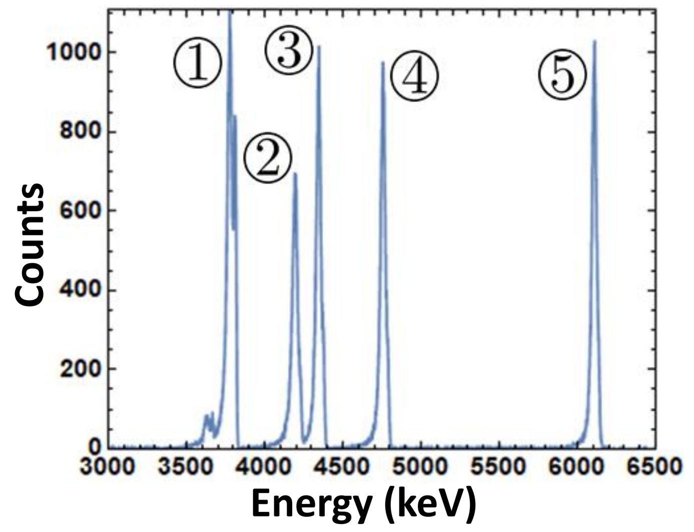
$$\frac{E_1}{E_0} = \frac{M_1^2}{(M_1+M_2)^2}\left\{\cos\theta + \left[\left(\frac{M_2}{M_1}\right)^2 - \sin^2\theta\right]^{1/2}\right\}^2$$

E_0 = incoming ion energy
E_1 = post-collision ion energy
M_1 = incoming ion mass
M_2 = target mass

Detector Calibration

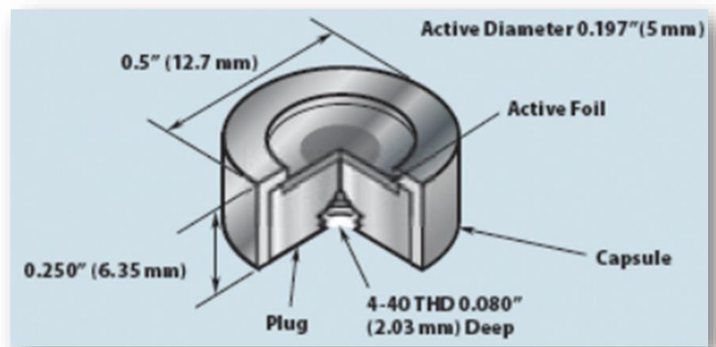


"Decay chain of ^{238}U, the primordial progenitor of ^{226}Ra" (https://en.wikipedia.org/wiki/Radium#/media/File:Decay_chain(4n+2,_Uranium_series).svg) by Tosaka is licensed under CC BY 3.0 (https://creativecommons.org/licenses/by/3.0/legalcode). Indexed energies added by C. G. Freeman.



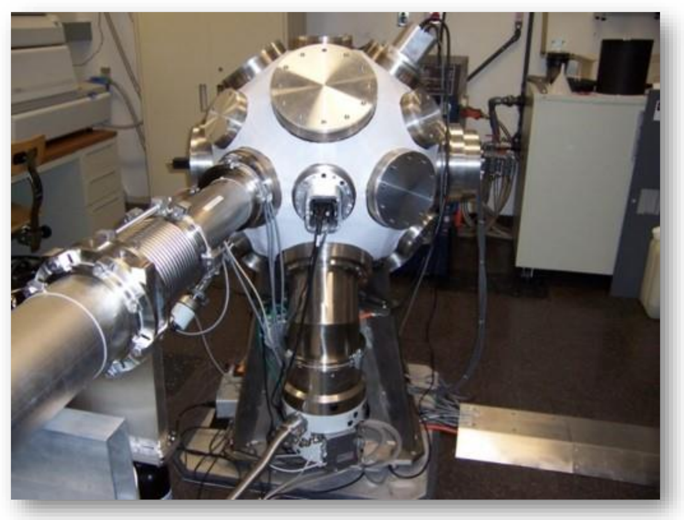
An ion-implanted silicon detector was used to detect the scattered ions. This detector was calibrated using alpha particles from a radium-226 source. This radioactive source emits alpha particles with several different energies, making a channel-to-energy calibration possible.

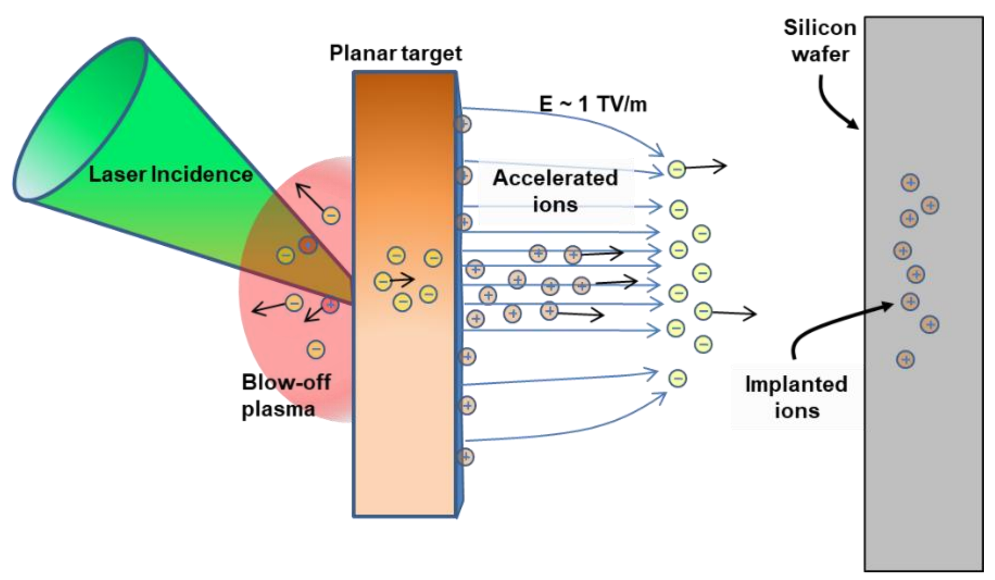
Radium-226 alpha source

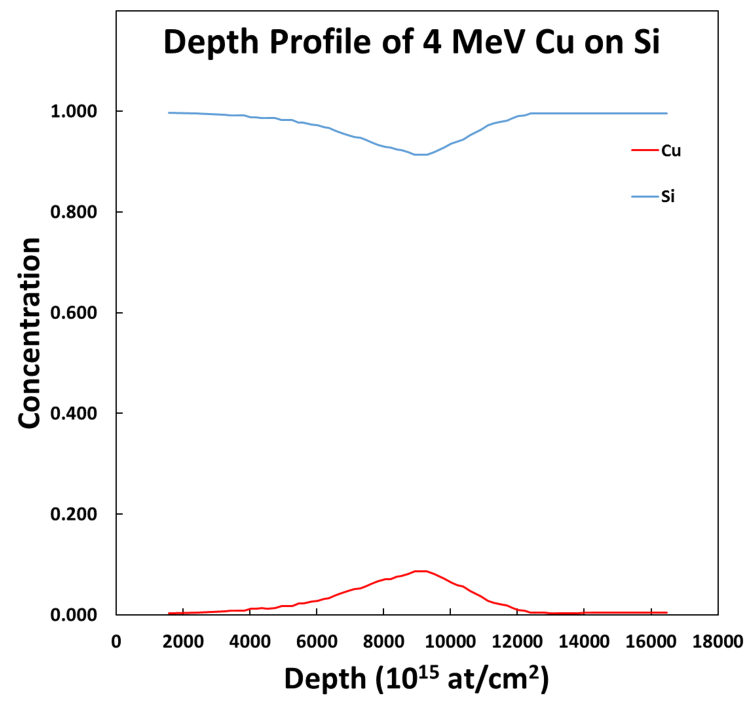


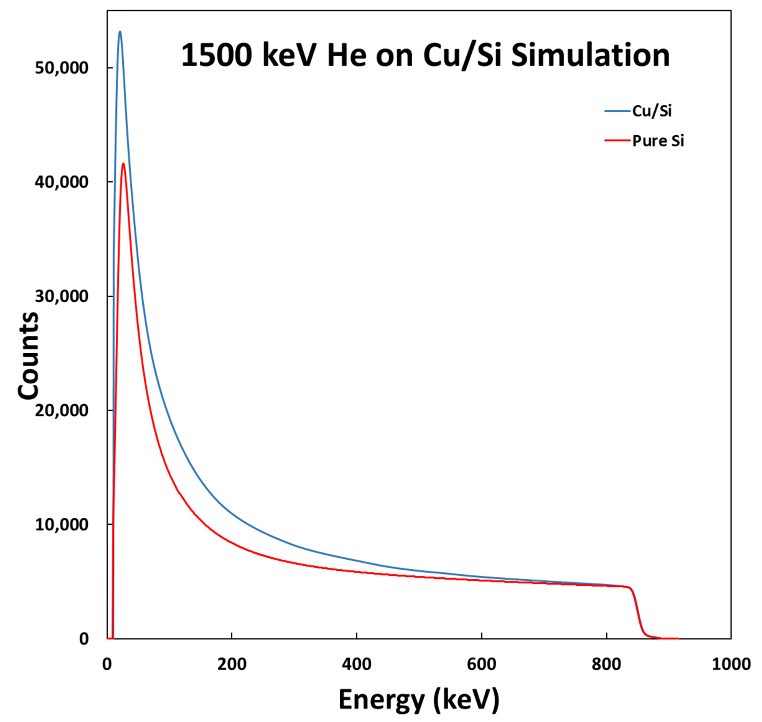
Laser-Accelerated Ions

At the Multiterawatt laser at LLE, ions are accelerated from the rear side of a target in a process called target-normal sheath acceleration (TNSA). We plan to place a silicon wafer behind the target to stop these ions. The energy spectrum of the accelerated ions can be measured by performing RBS depth profiling at the Geneseo accelerator laboratory.



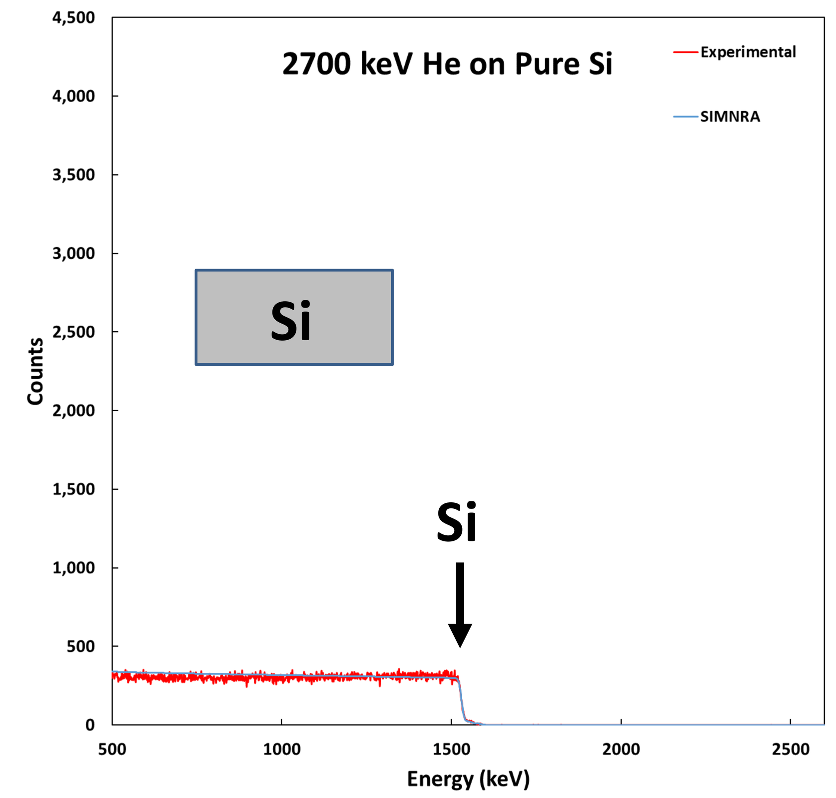


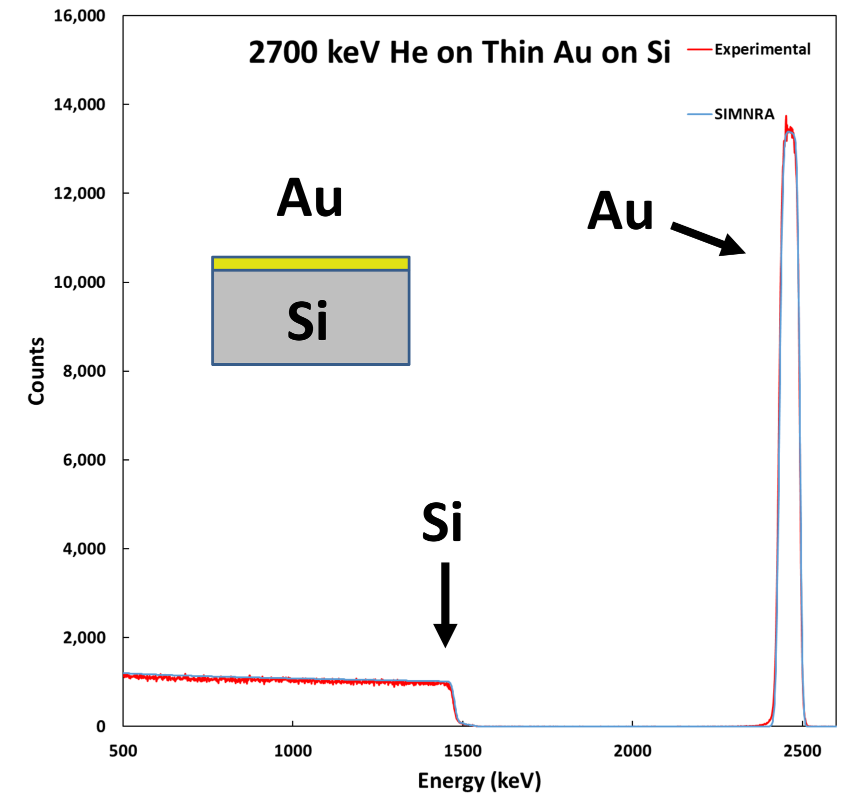


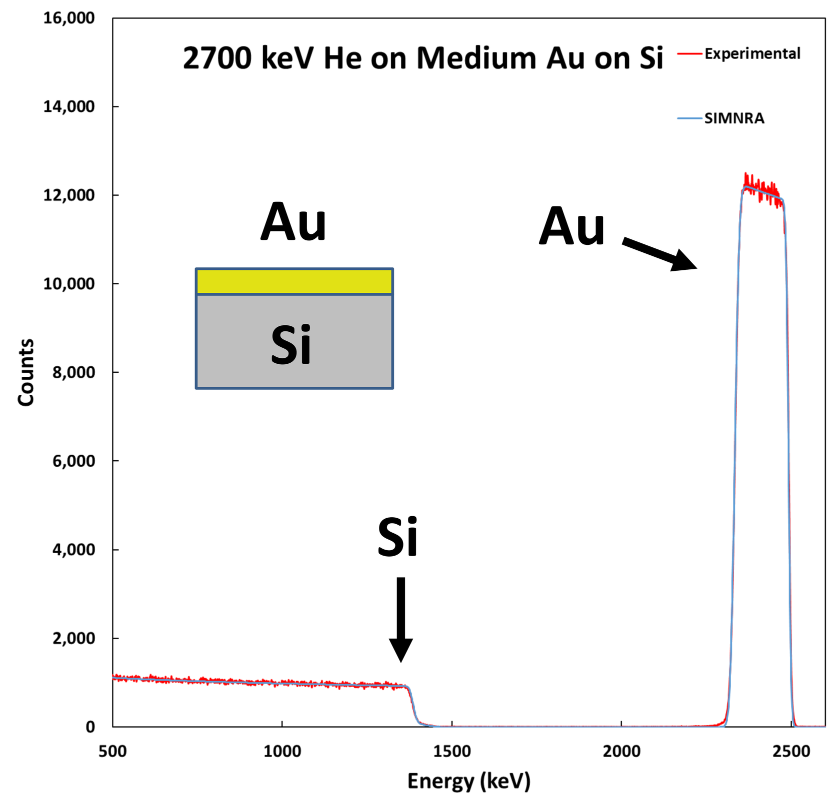


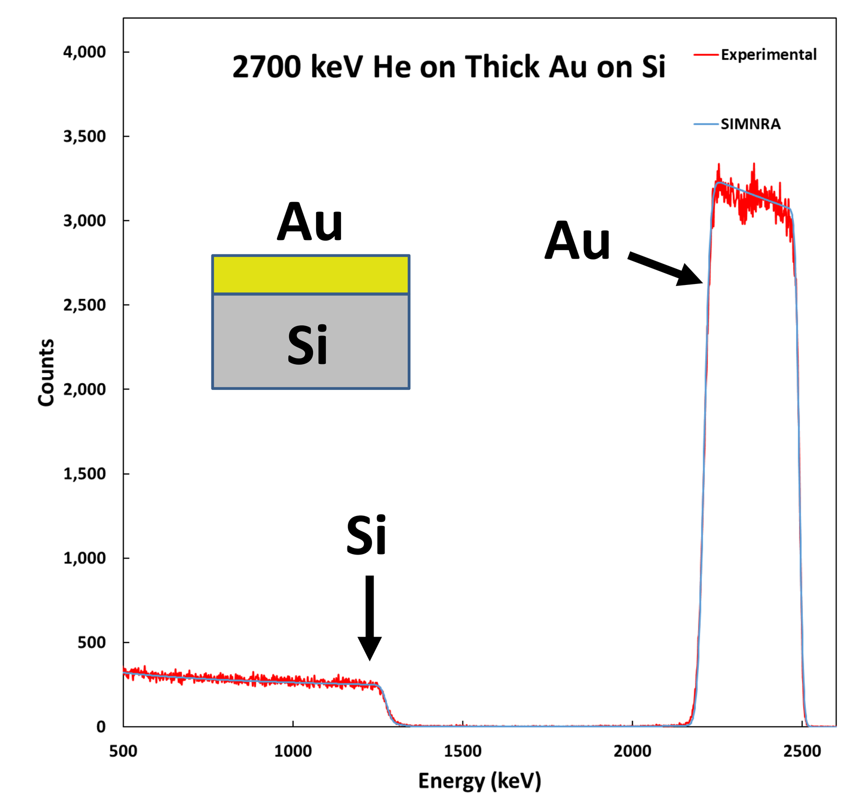
RBS with Gold-Plated Silicon

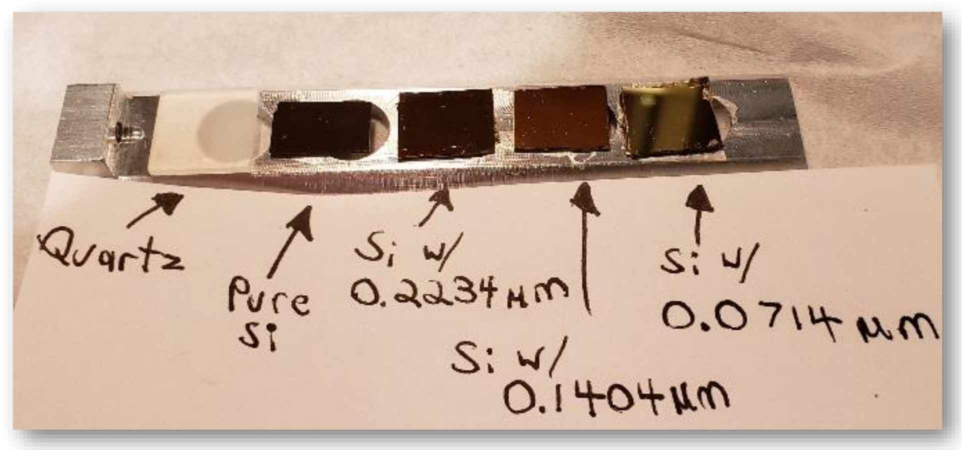
SUNY Geneseo's thin film evaporator was used to deposit different thicknesses of gold onto silicon wafers. The computer program SIMNRA was used to analyze the resulting spectra. The thickness of the gold as calculated from RBS was compared to the thickness as measured by the rate deposition monitor installed on the evaporator. These tests help to validate the RBS technique.











The three targets produced by the thin film evaporator, with pure silicon for comparison.