



Geneseo's

Ion Speedometer!

Dr. Kurt Fletcher
SUNY Geneseo
Physics & Astronomy
May 02, 2019

Image: <https://www.yourmechanic.com/article/how-to-replace-a-speedometer-cable-and-housing-on-most-cars-by-ty-thompson>

Acknowledgements

Many undergraduate researchers...

Most recently, Ethan Nagasing,
Ethan Smith, Kallah Eddy

This work has been supported by U.S. Department of Energy through the Laboratory for Laser Energetics (SJP), Indirect Cost Recovery Funds, and the SUNY Geneseo Department of Physics and Astronomy

Sabbatical

[*suh*-bat-i-kuh |] [SHOW IPA](#) 

[EXAMPLES](#) | [WORD ORIGIN](#)

[SEE MORE SYNONYMS FOR *Sabbatical* ON THESAURUS.COM](#)

adjective

- 1 of or pertaining or appropriate to the Sabbath.
- 2 (*lowercase*) of or relating to a [sabbatical year](#).
- 3 (*lowercase*) bringing a period of rest.

noun

- 4 (*lowercase*) [sabbatical year](#).
- 5 (*lowercase*) any extended period of leave from one's customary work, especially for rest, to acquire new skills or training, etc.

Outline

- The Low Energy Ion Facility
- Rutherford Backscattering
- The Time-of-Flight Spectrometer
- Time Trials
- Thin Film Analysis

The Low Energy Ion Facility

Duoplasmatron Ion Source
(in Faraday cage)

Einzel
Lens 1

Einzel
Lens 2

TOF Spectrometer

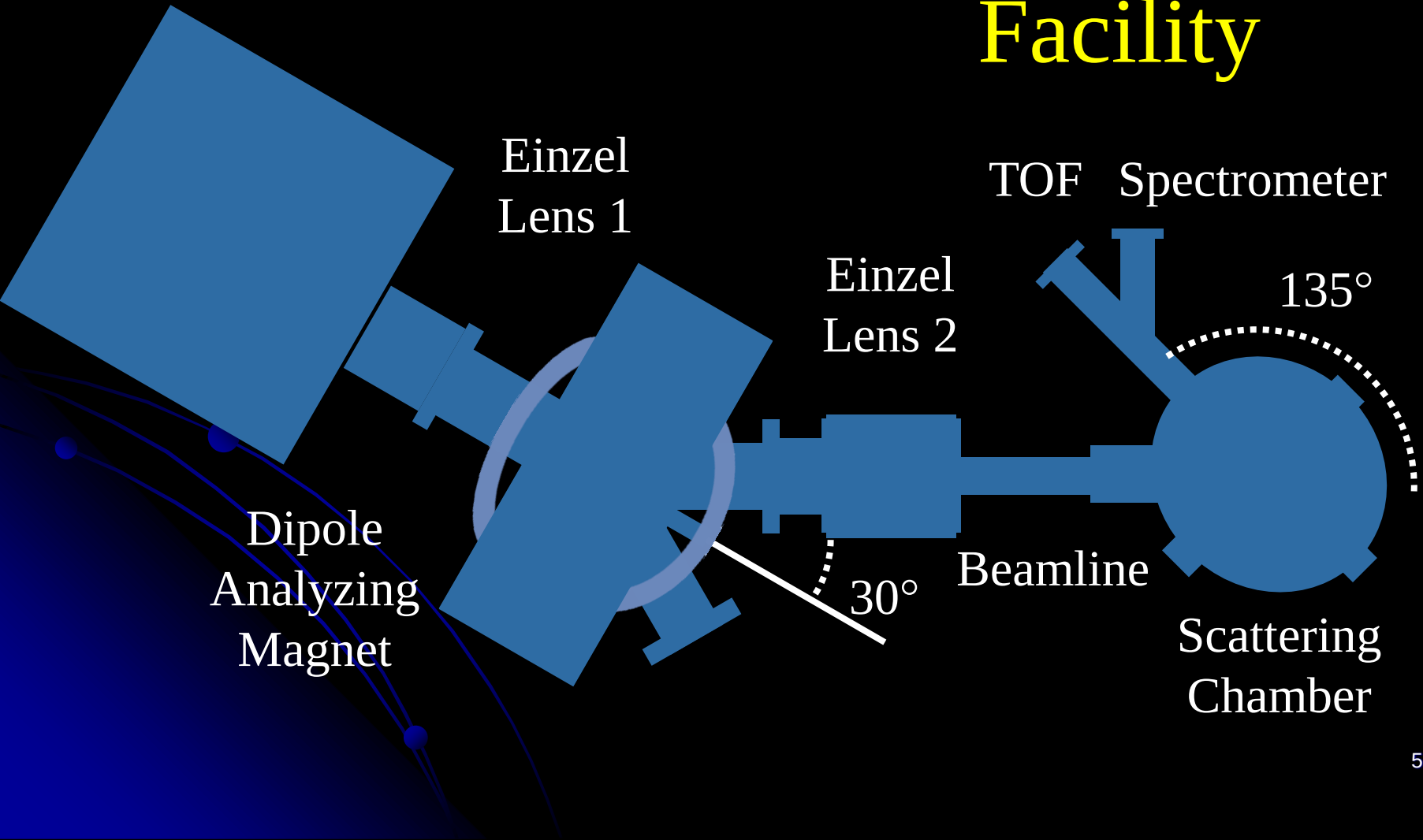
Dipole
Analyzing
Magnet

Beamline

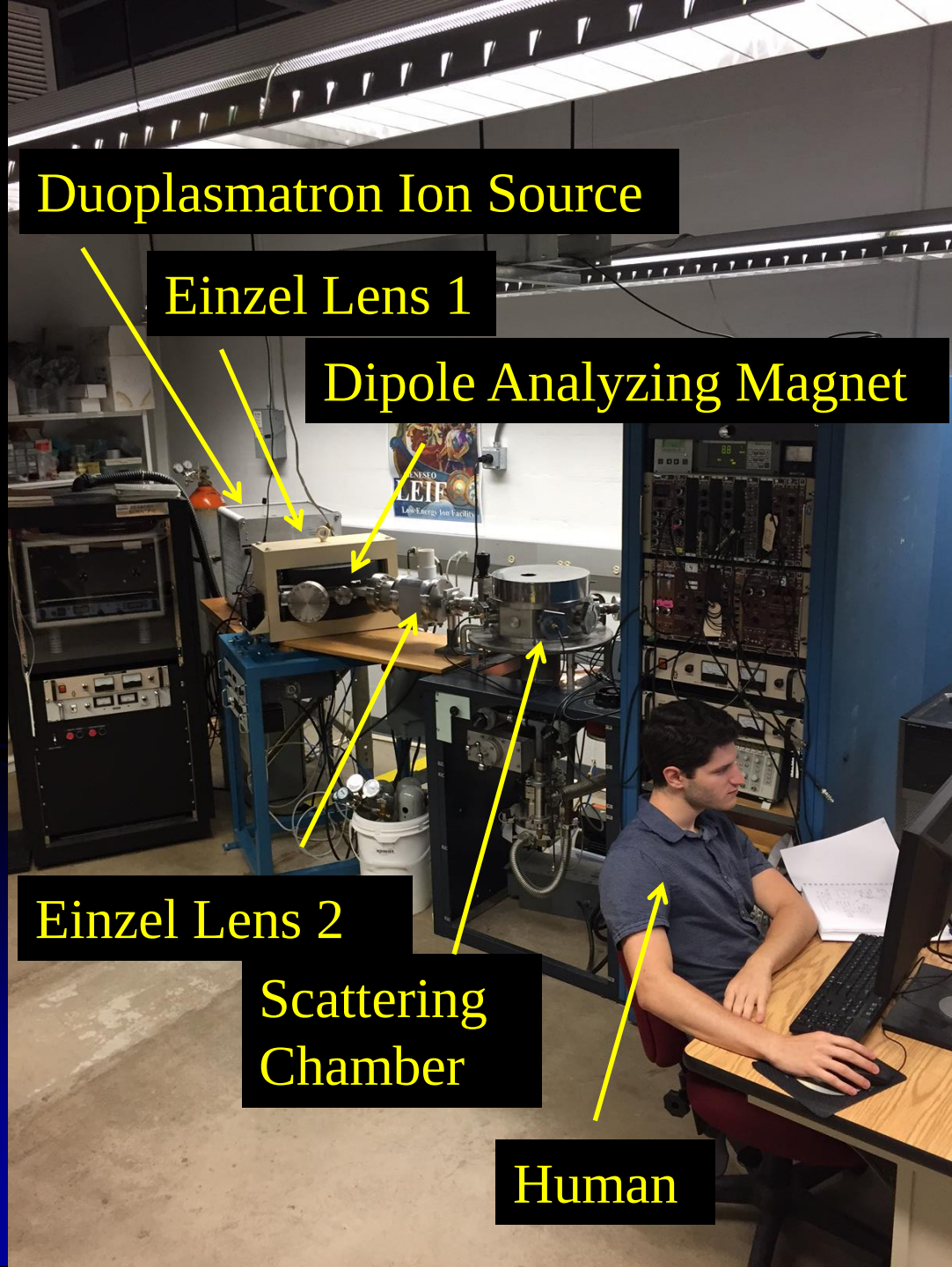
Scattering
Chamber

135°

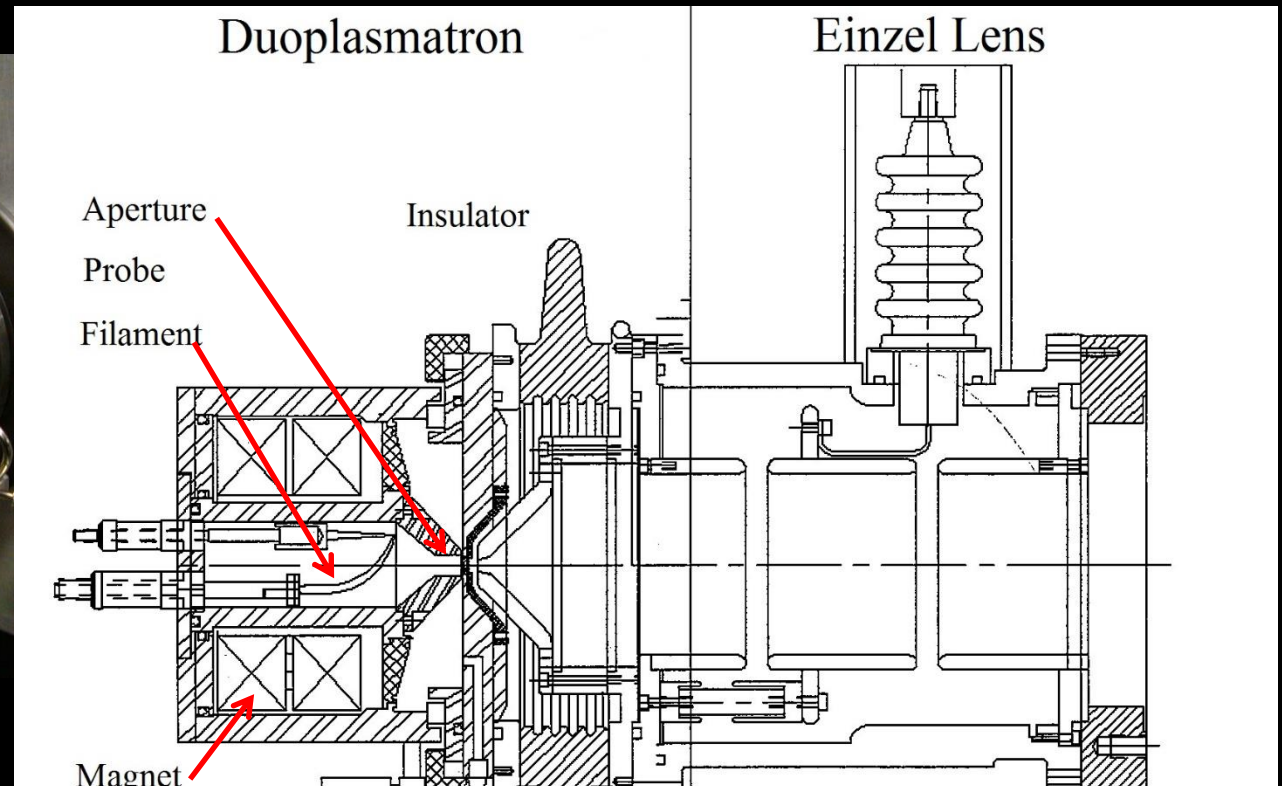
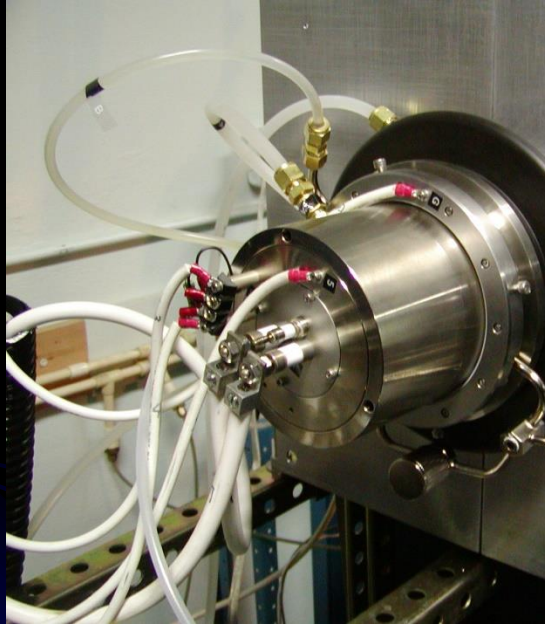
30°



The Low Energy Ion Facility (LEIF)

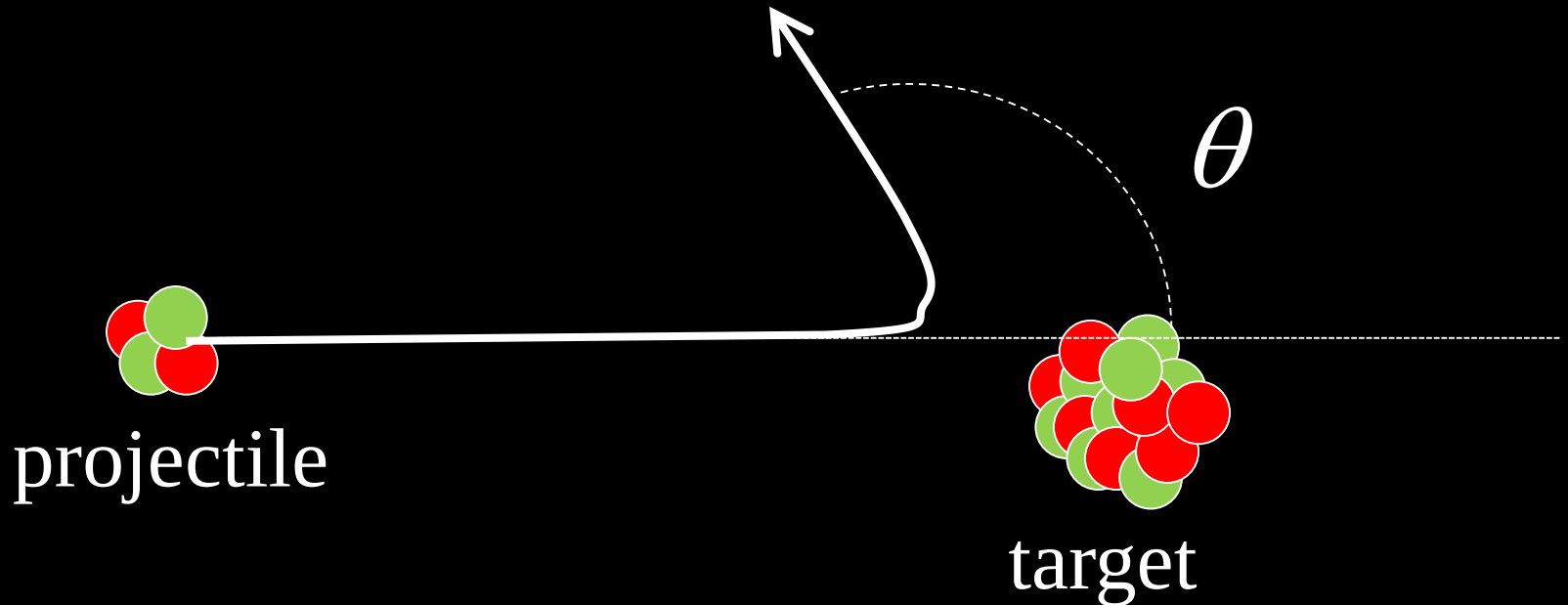


The Peabody Scientific Duoplasmatron Ion Source



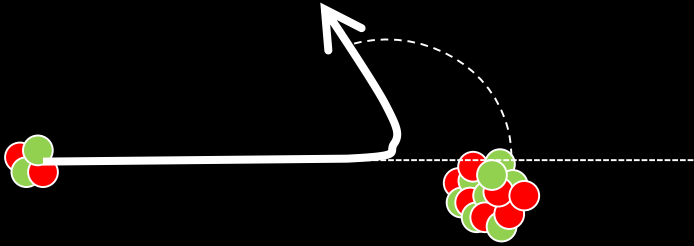
$$0 \text{ kV} < V_{\text{source}} < 30 \text{ keV}$$

Rutherford Backscattering (RBS)



$$N(\theta) = \frac{N_i n t}{16} \left(\frac{e^2}{4\pi\epsilon_0} \right)^2 \frac{Z_1^2 Z_2^2}{r^2 (K)^2 \sin^4 \left(\frac{\theta}{2} \right)}$$

Rutherford Backscattering (RBS)



Elastic Collision

$$P_i = P_f$$

$$KE_i = KE_f$$

- $KE_{\text{recoil ion}} < KE_{\text{projectile}}$

For large M_{target} , $KE_{\text{recoil ion}} \approx KE_{\text{projectile}}$

“The fastest recoil ions bounced off the heaviest target nuclei”

Rutherford Backscattering (RBS)



Rutherford Backscattering (RBS)

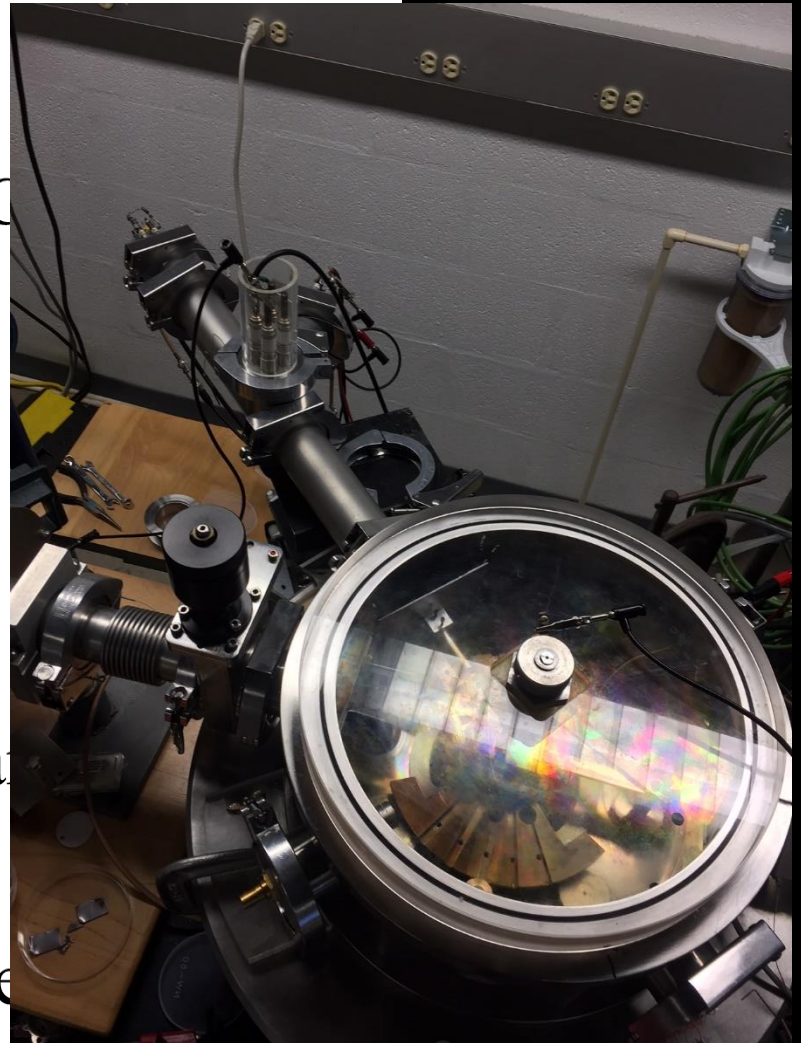
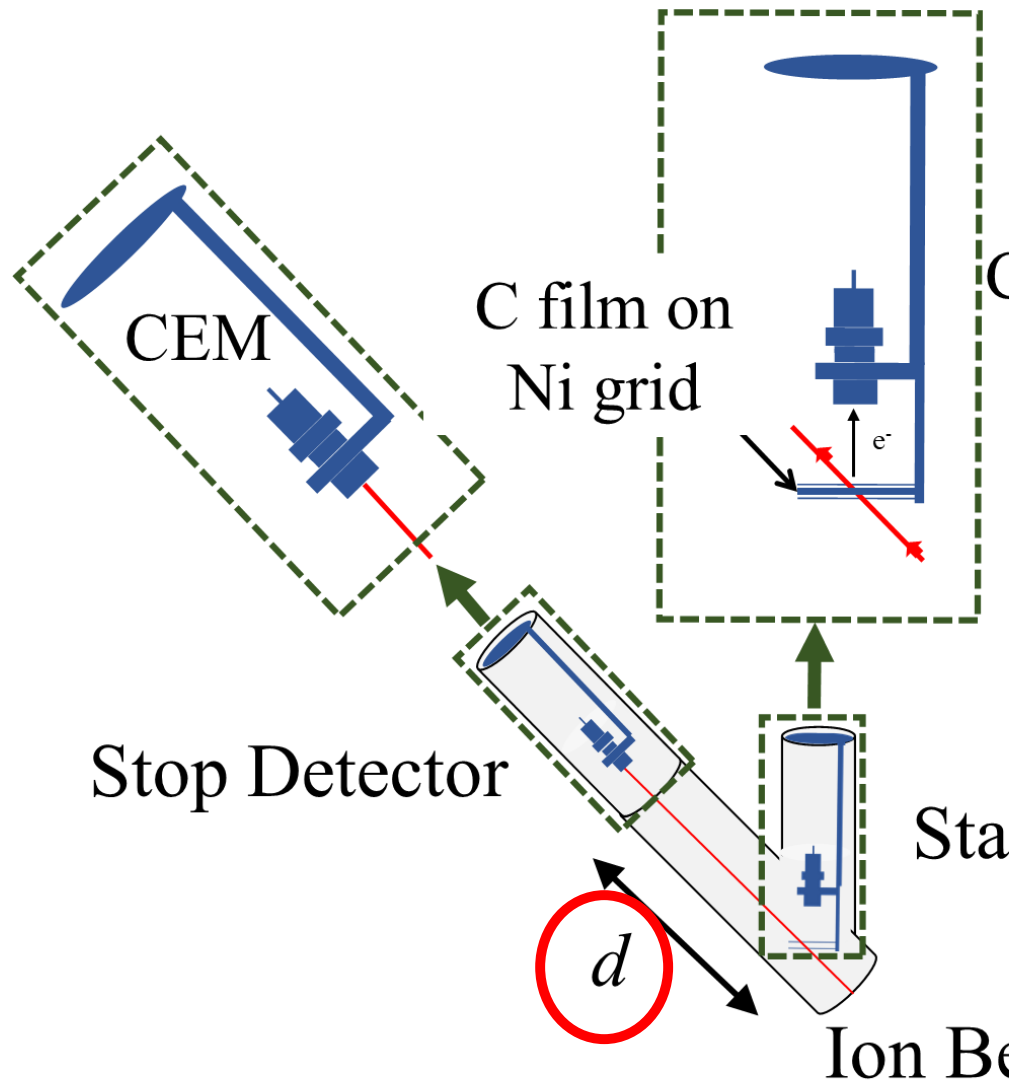
The Big Idea: Use low energy ions for RBS.

The Advantages

The Problem:
Determining the energy
of the low energy ions

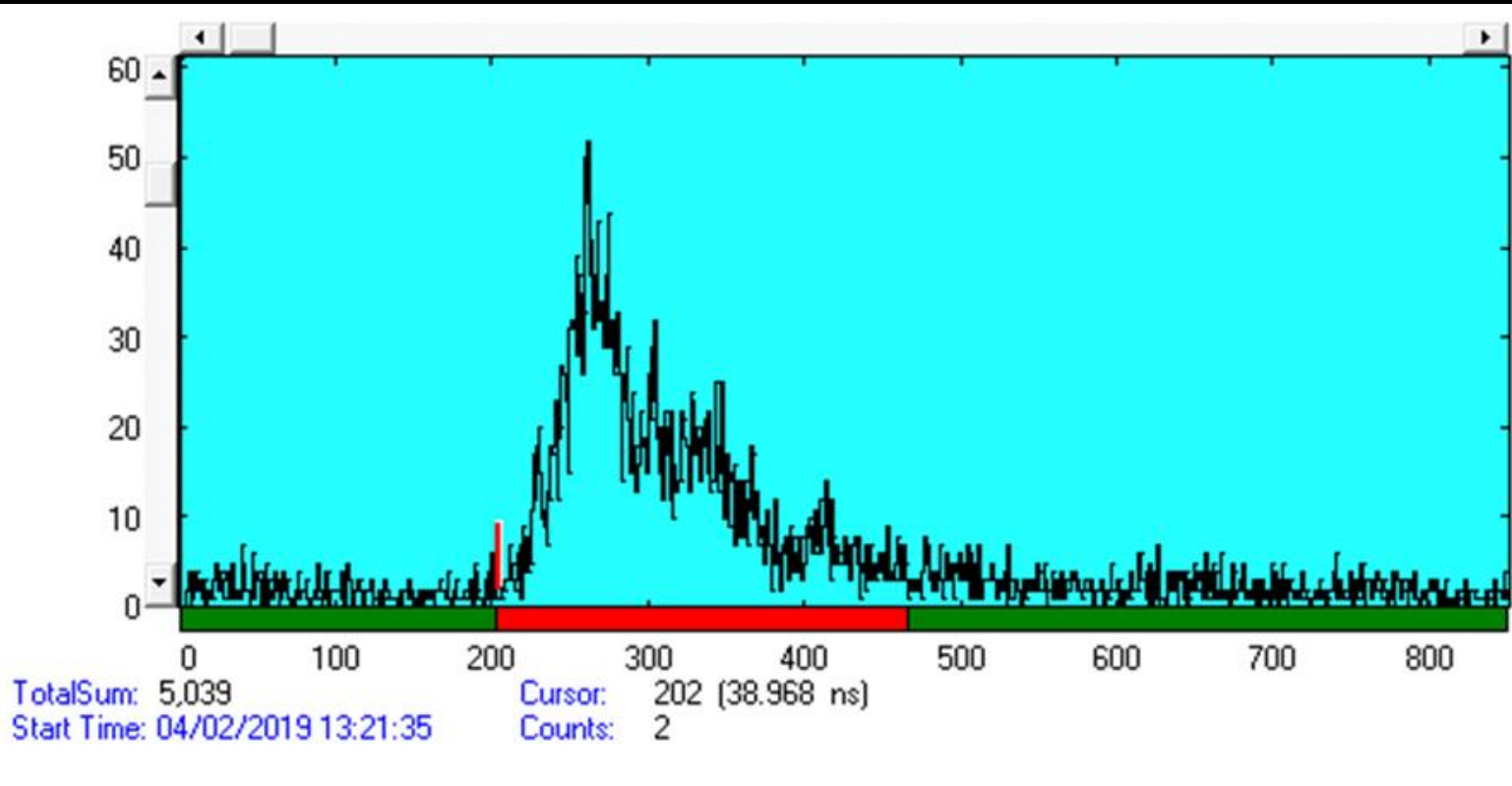
The Solution....

The Time of Flight Spectrometer



The Time of Flight Spectrometer

Signal Processing



Time to
Amplitude
Converter
(TAC)

To MPA/Computer

The Drama

POSSIBLE TO

02/08/19 -
RECO
500 by me

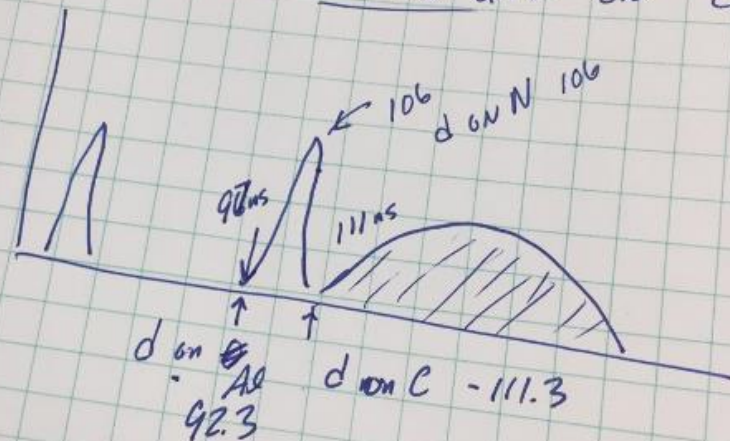
LOOKED A.D. NOT RUN w/
ON THE FROM
THE CEM
IF THIS

DO NOT RUN w/
2.3 MA BEAMS!

d on O - 70.1
α on T Al - 73.3
d on C - 75.9

d on Al - 92.9
α on N - 96.2

REDUCED TO "25 keV α+" ON CEM



TRIED TO RUN 25 keV α+ w/ MAG. AT
G6T 2.3 MA BEAM - ON TA TARGET.
MIGHT HAVE DAMAGED START CEM.
SLOW COUNTING ON TA w/

stood by me,

Date

Invented by

Time Trials -

Alphas transmitted through a $5 \mu\text{g}/\text{cm}^2$ carbon foil: 41.7 keV

50 keV alpha

The screenshot shows the TRIM Setup Window with the following settings:

- TRIM (Setup Window)**: Read Me, TRIM Demo, Restore Last TRIM Data.
- Type of TRIM Calculation**: DAMAGE (Ion Distribution and Quick Calculation of Damage), Basic Plots (Ion Distribution with Recoils projected on Y-Plane).
- ION DATA**: Symbol (PT), Name of Element (Helium), Atomic Number (2), Mass (amu) (4.003), Energy (keV) (46.385), Angle of Incidence (? 0).
- TARGET DATA**: Add New Layer.
- Input Elements to Layer**: Add New Element to Layer, Compound Dictionary.
- Target Layers**: Layer Name (Layer 1), Width (222 Ang), Density (g/cm3) (2.253), Corr (1), Gas (?).
- Input Elements to Layer**: Symbol (PT), Name (Carbon), Atomic Number (6), Weight (amu) (12.01), Atom Stoich or % (1), Damage (eV) (100.1, 28, 3, 7.4).

Elastic scattering off Ta at 135°
 $KE = 46.385 \text{ keV}$

Two-Body Kinematics Calculator and Plotter

This script generates plots and tables representing products of nuclear reactions, along with elastic and inelastic nuclei involved, the kinetic energy of the projectile, any excitation energy of the products and select the desired page.

Enter Isotopes (^AEl) or Masses (AMU or MeV). Isotopes should be of form 1H , 4He , ^{16}O ... etc, case insensitive. neutron, proton, deuteron, triton, ^3He , alpha, gamma, electron and positron. Shorthand is also available for p , n , d , t , ^3He , α , γ , e^- and e^+ . More could be added by request. Isotope masses are taken from the table of atomic masses, [NIST](#).

Please note: the notation has been changed so that m_1 has the kinetic energy. For an explanation of the calculation, see the [FAQ](#).

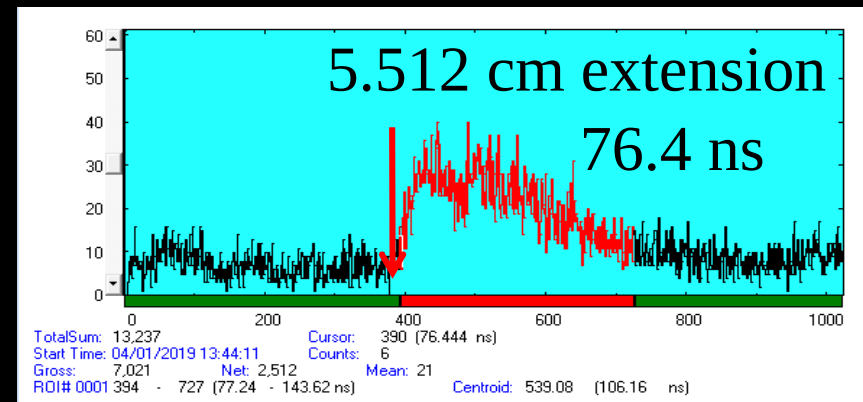
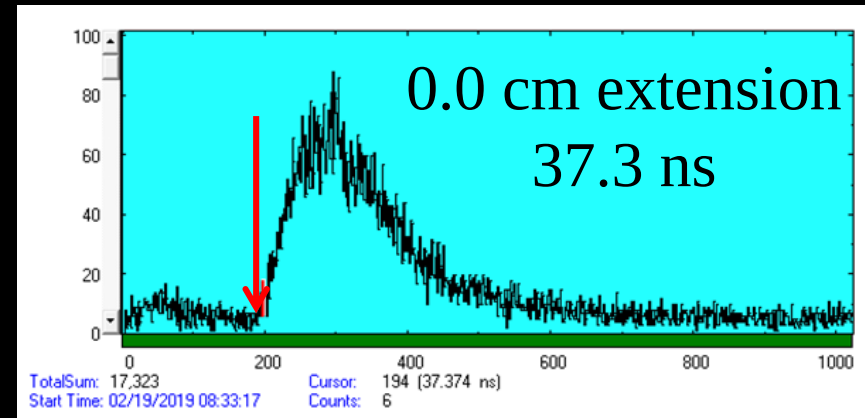
Projectile (m_1): ☒ ^AEl ☐ AMU ☐ MeV
 Target (m_2): ☒ ^AEl ☐ AMU ☐ MeV
 Ejectile (m_3): ☒ ^AEl ☐ AMU ☐ MeV
 Recoil (m_4): ☒ ^AEl ☐ AMU ☐ MeV

Projectile Energy: MeV ☒ kinetic ☐ total

Excitation Energy: MeV

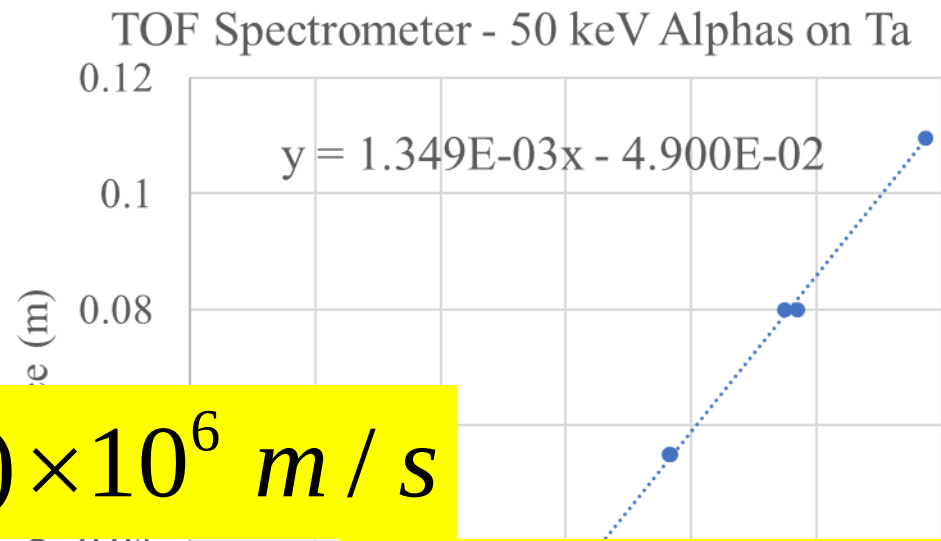
Time Trials - Experiment

Vary d and measure t , compare to calculations



Time Trials – Results with Alphas

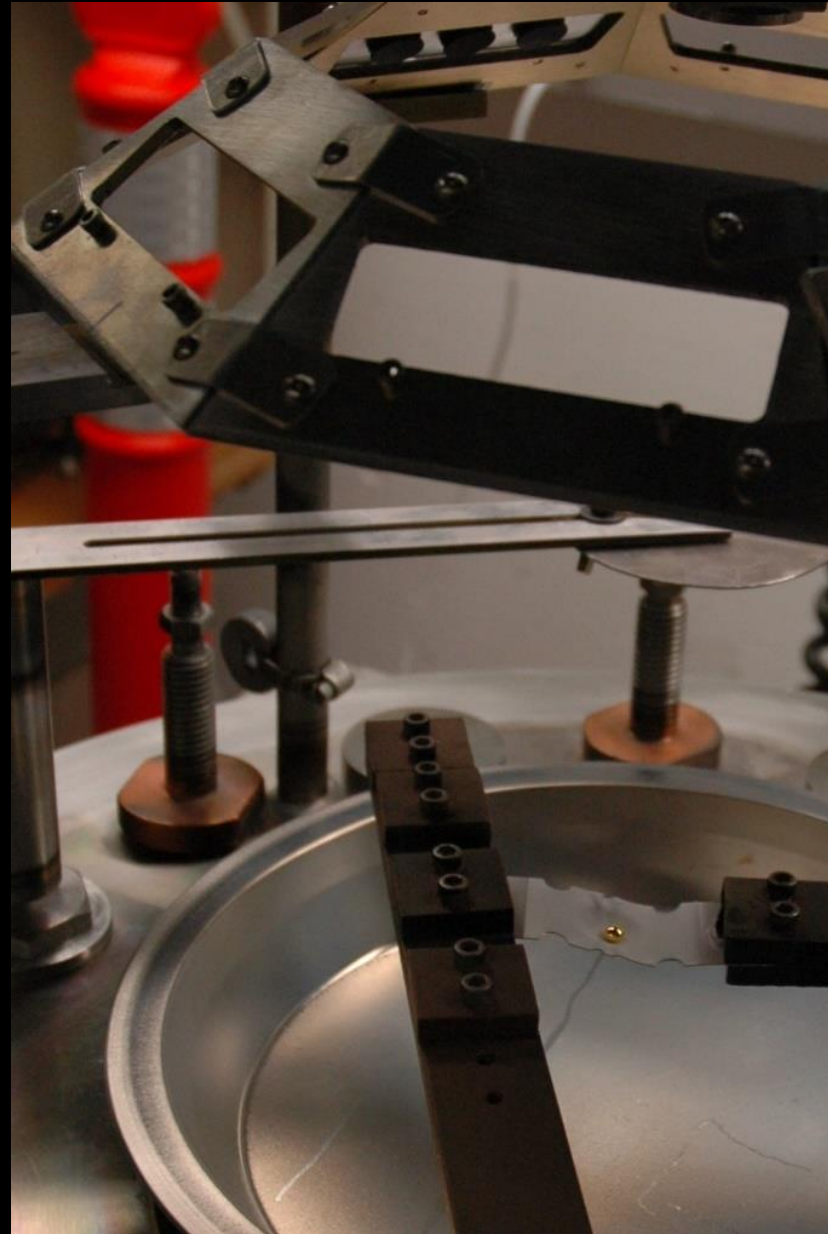
$$v = (1.349 \pm 0.030) \times 10^6 \text{ m / s}$$



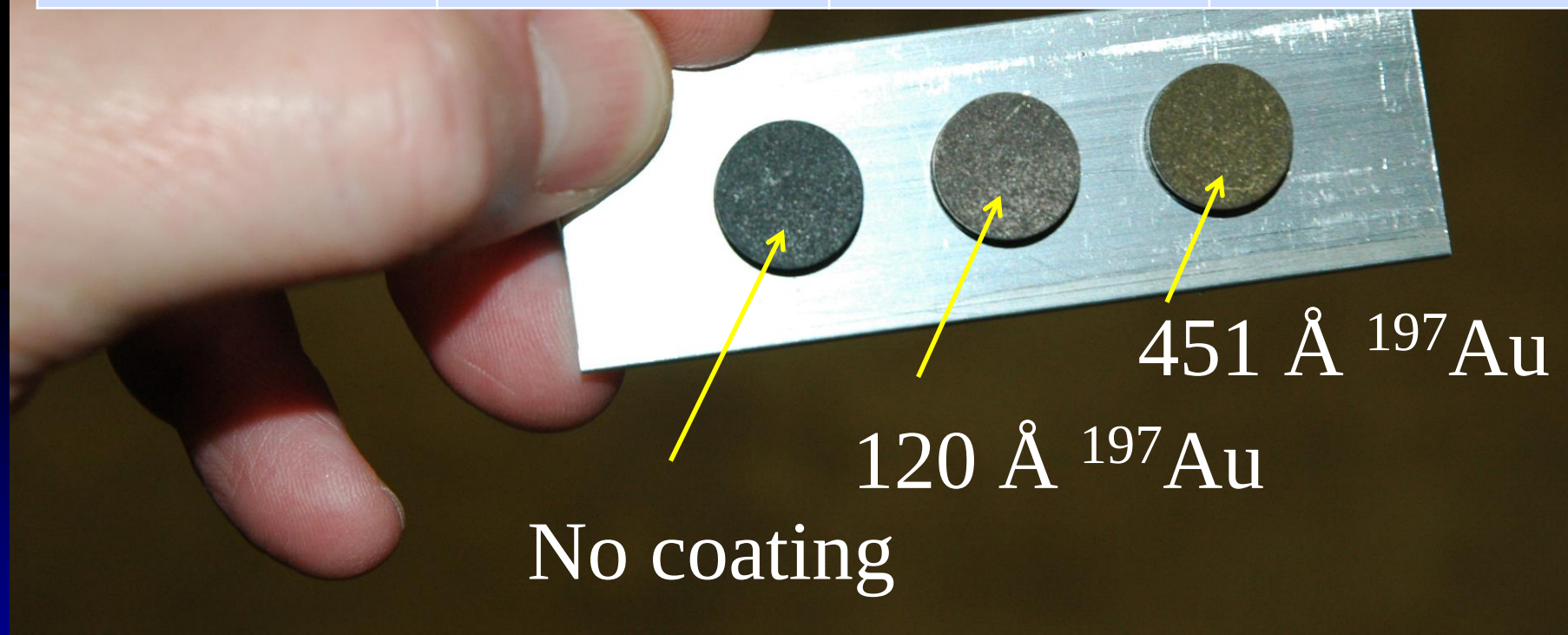
$$KE = \frac{1}{2} (mc^2) \left(\frac{v}{c} \right)^2$$

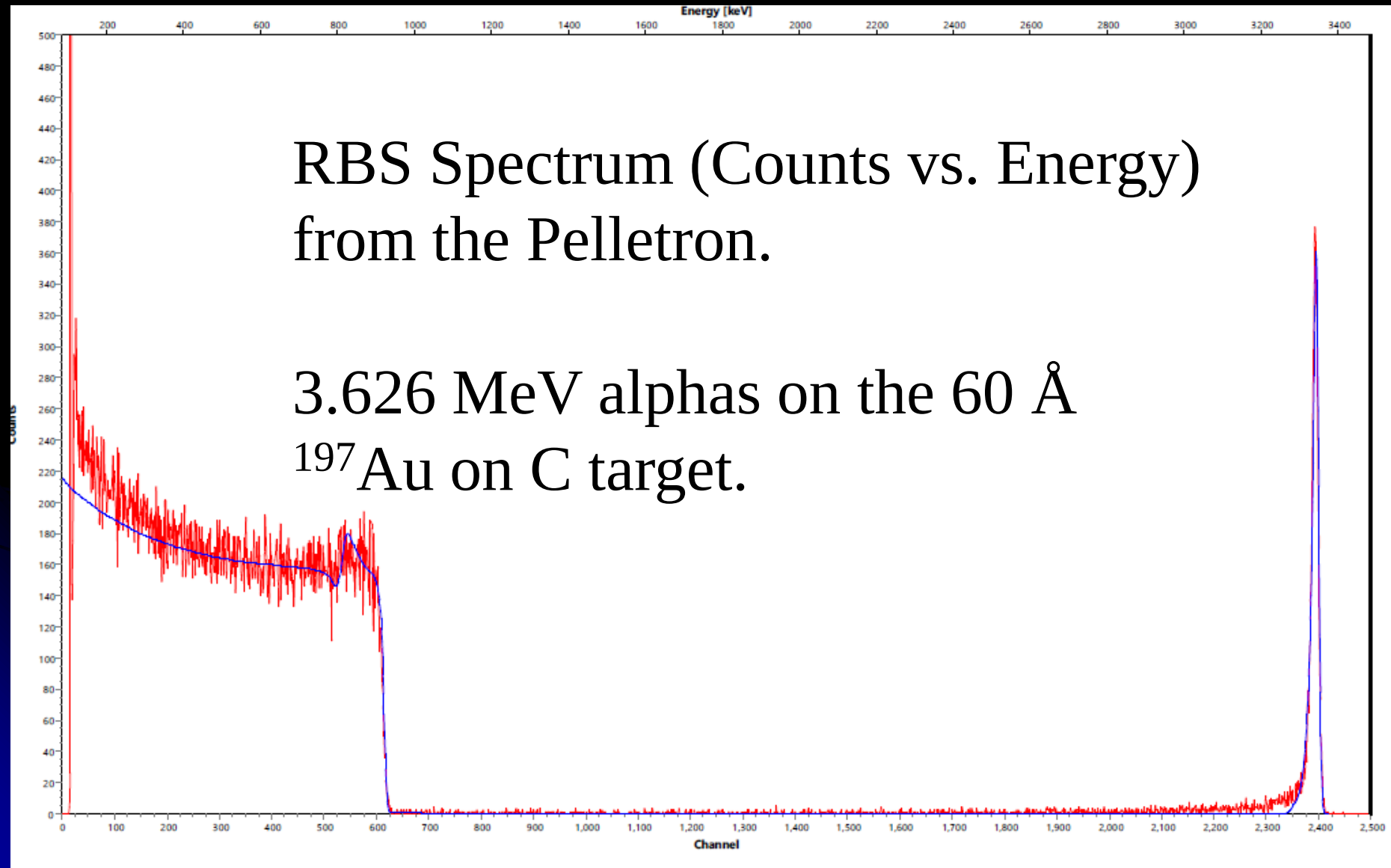
Beam Energy (keV)	Target	Measured KE (keV)	KE (KeV)
50	Tantalum	37.67 ± 1.69	41.7
50	Aluminum	26.3 ± 2.9	26.1
25	Tantalum	19.9 ± 1.6	19.7

Thin Film Analysis Test



Date	2019-04-23	2019-04-29	2019-04-30
Thickness (RDM)	521 Å	138 Å	70 Å
RDM $\times$ Cos(30°)	451 Å	120 Å	60 Å
Thickness (Pelletron RBS)	(444.8 ± 2.2) Å	(101.77 ± 0.71) Å	(56.41 ± 0.60) Å





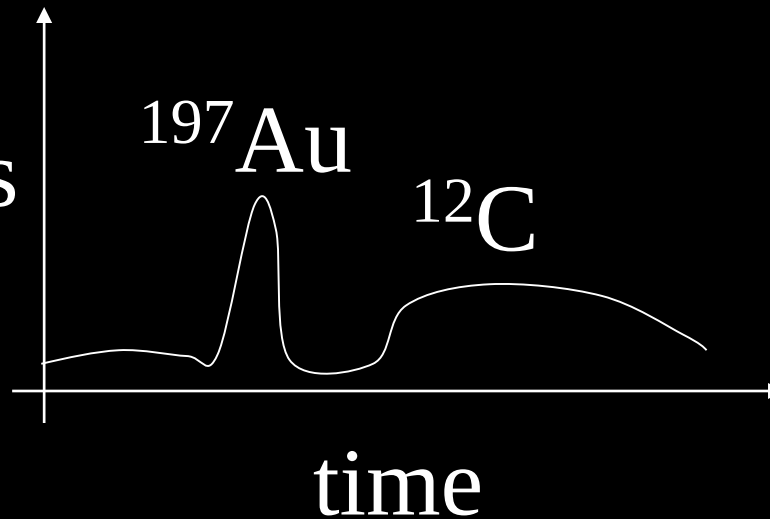
Thin Film Analysis Test Expectations

Thin ^{197}Au
Film



Thick ^{12}C
substrate

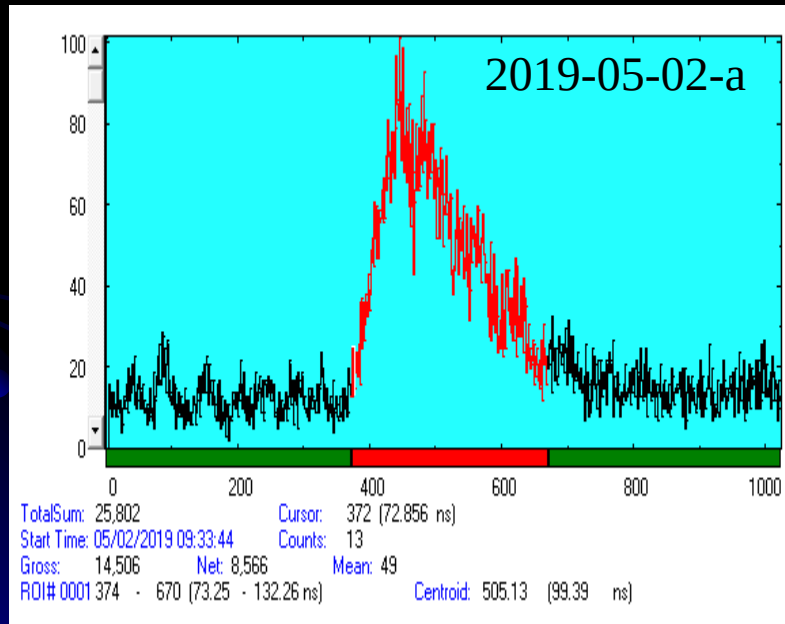
counts



Thin Film Analysis Test

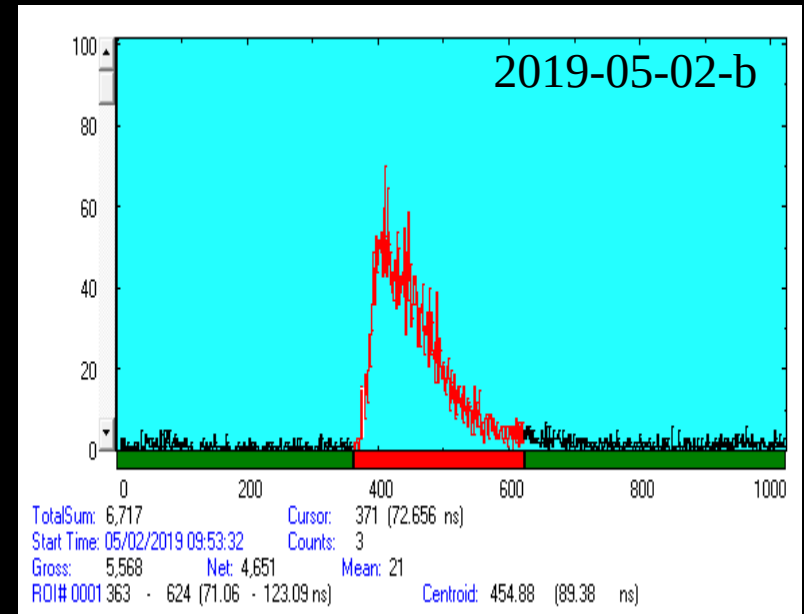
Results (with 5.51 cm extension)

445 Å layer
 ^{197}Au on ^{12}C



Leading edge
predicted at 75.7 ns

56 Å layer
 ^{197}Au on ^{12}C



Same integrated beam current.
“**Similar**” detector conditions.²²

Future Work

- CEM Bias / Count rate
- Other ions (protons, deuterons)
- Improve time resolution
- Explore applications – surface science
- Everything's better when you add accordion bellows



Future Work

- Publish?
- Other ions (protons, deuterons)
- Improve time resolution
- Explore applications
- Everything's better when you add accordion bellows

Summary

A Time-of-Flight Spectrometer has been designed, built, and tested to measure the kinetic energy of low energy ions produced by the duoplasmatron ion source and elastically scattered from targets.

The TOF spectra can be used to analyze the surfaces of such targets.

Thank you!