Ion Beam Analysis

Frank Laboratory of Neutron Physics

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OUTLINE

- Van de Graaff accelerator
- Rutherford Backscattering Spectrometry (RBS)
- Elastic Recoil Detection (ERD)
- Conclusions

Van de Graaff

Robert J. Van de Graaff

December 20, 1901- January 16, 1967 (aged 65)

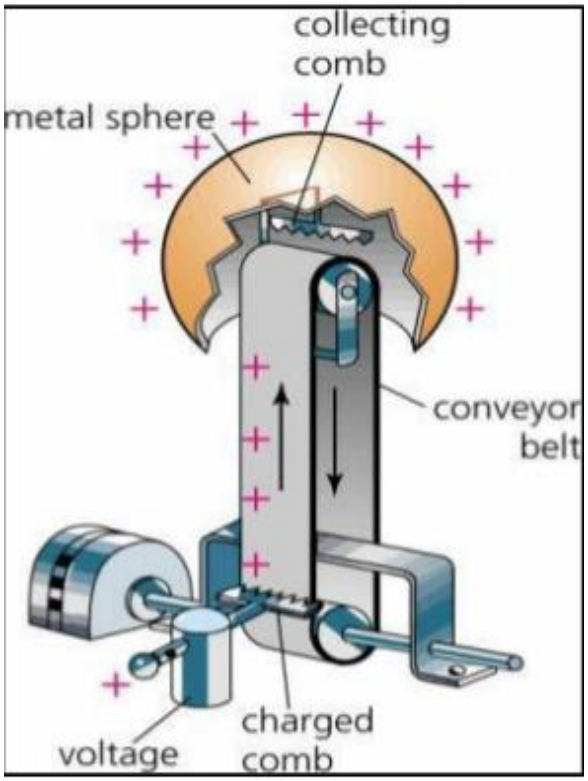
Patents

- Electrostatic Generator
- High Voltage Electromagnetic Apparatus Having An Insulating Magnetic Core

Van de Graaff Accelerator

Properties (EG5)

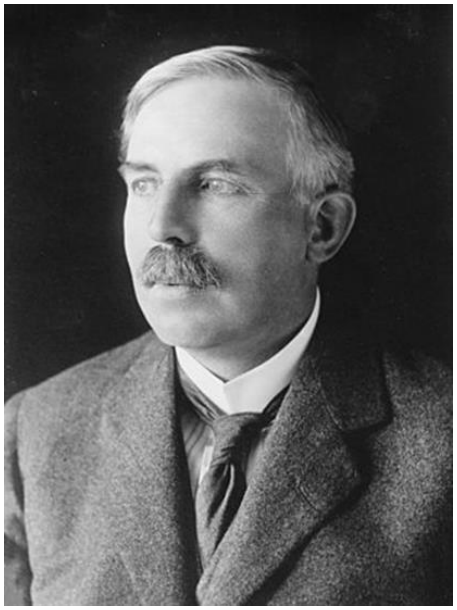
- Energy Region : 0.9-3.5 MeV
- Energy Spread <500 eV
- Beam Intensity: 30 μA (H^+)& 10 μA (He)
- Six beam lines



Operation

- Voltage supply of 30 KeV
- Rotation speed of conveyer belt :20 m/s
- Charges collected at metal sphere

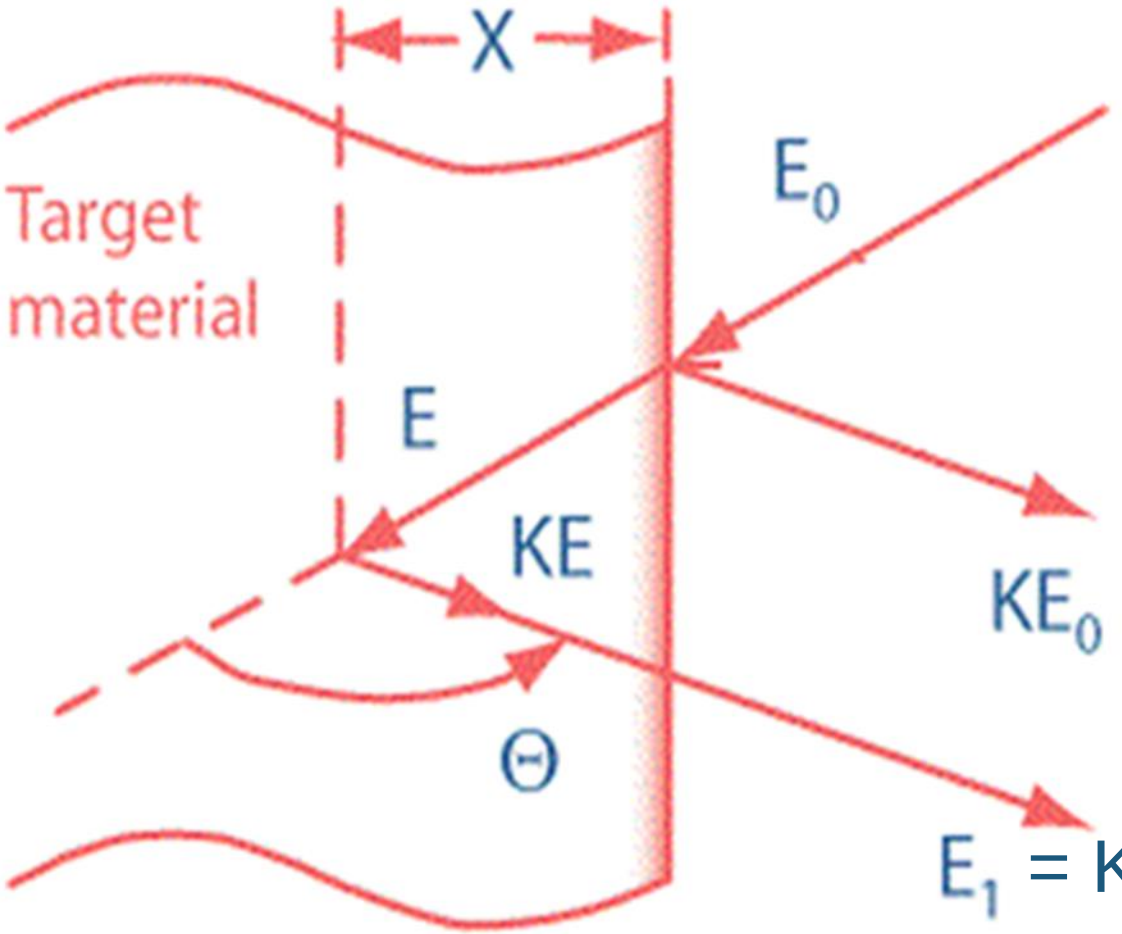
Ernest Rutherford



- 30 August 1871 – 19 October 1937
- New Zealand-born British physicist
- President of the Royal Society (1925–1930)

- Father of nuclear physics
- The element rutherfordium, Rf, Z=104
- Rutherford Medal-Royal Society of New Zealand

RBS Principle



$E_1 = K(E_0-\Delta E_{in})-\Delta E_{out}$

X is the thickness of the layer

http://neutron.ujf.cas.cz/vdg/methods_rbs.html

Rutherford Backscattering Spectrometry (RBS)

- Number of the backscattered alpha particles

$$H(E_1) = Q\sigma(E_0,\theta)\frac{\Delta\Omega\delta E}{([s]\cos\Theta)}$$

- Kinematic Factor

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

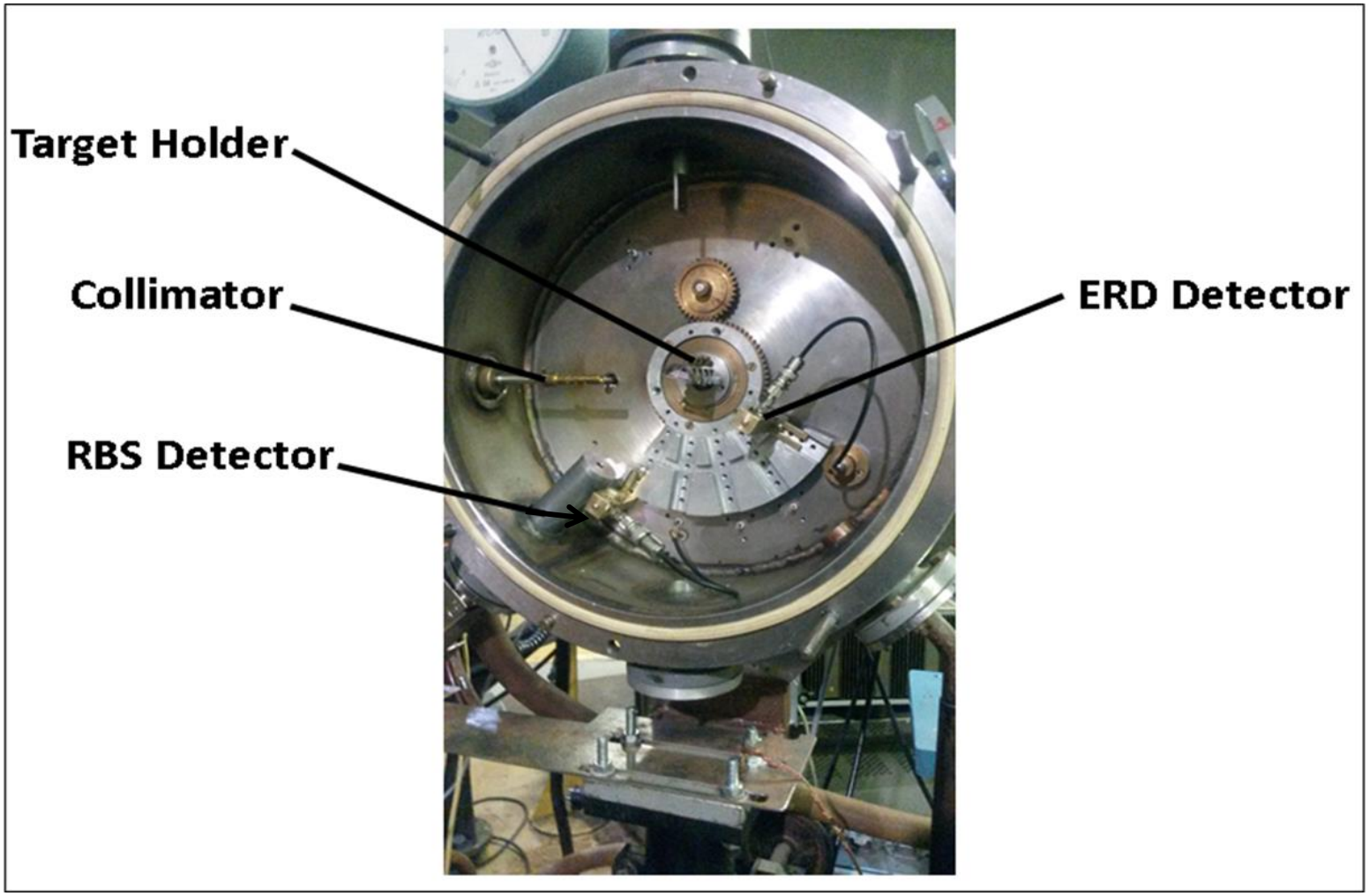
- Rutherford Cross-section

$$\frac{d\sigma}{d\Omega} = (\frac{Z_1 Z_2 e^2}{4E})^2 \frac{4}{\sin^4\theta} \frac{\{[1-((M_1/M_2)\sin\theta)^2]^{1/2} + \cos\theta\}^2}{[1-((M_1 - M_2)\sin\theta)^2]^{1/2}}$$

- Stopping cross section

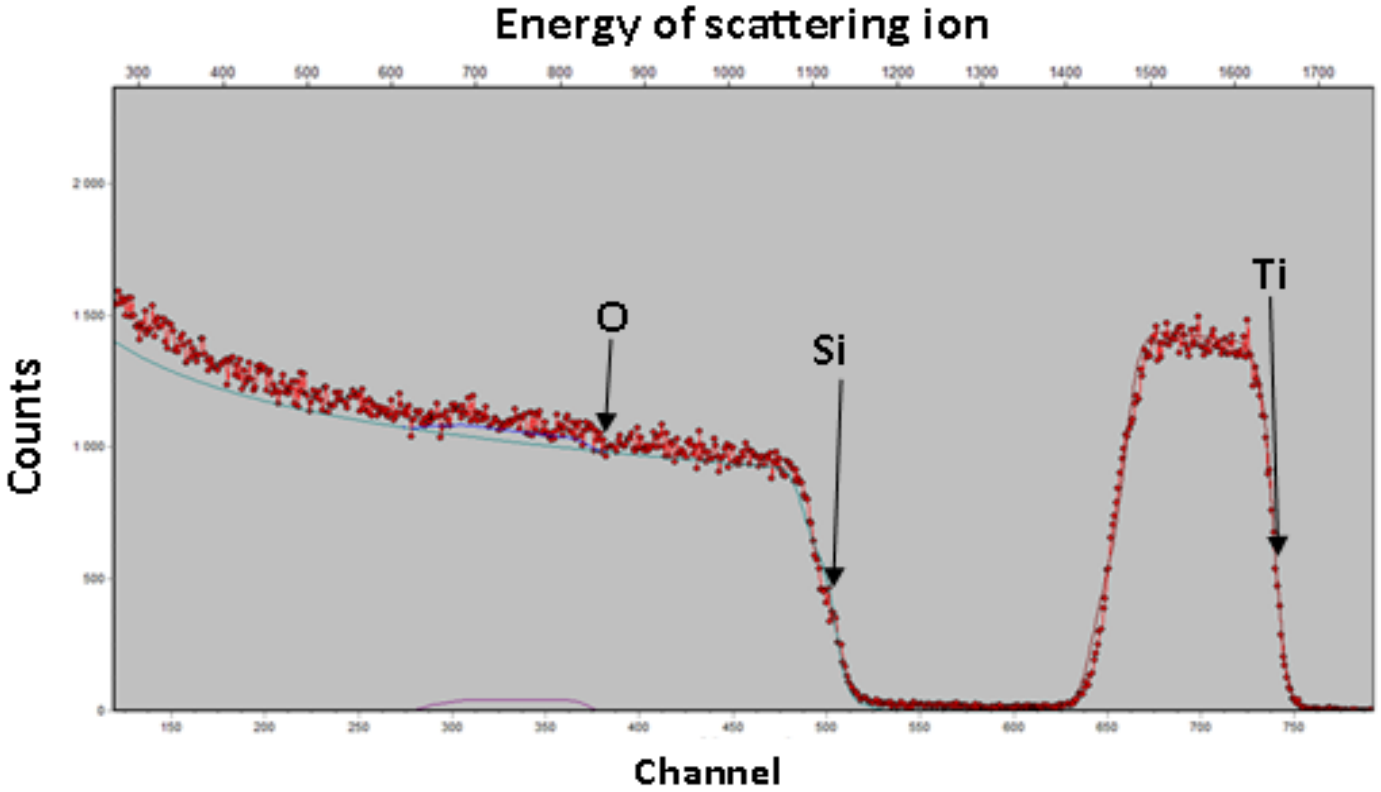
$$\epsilon = \frac{1}{N}\frac{dE}{dx}$$

RBS and ERD Set-up



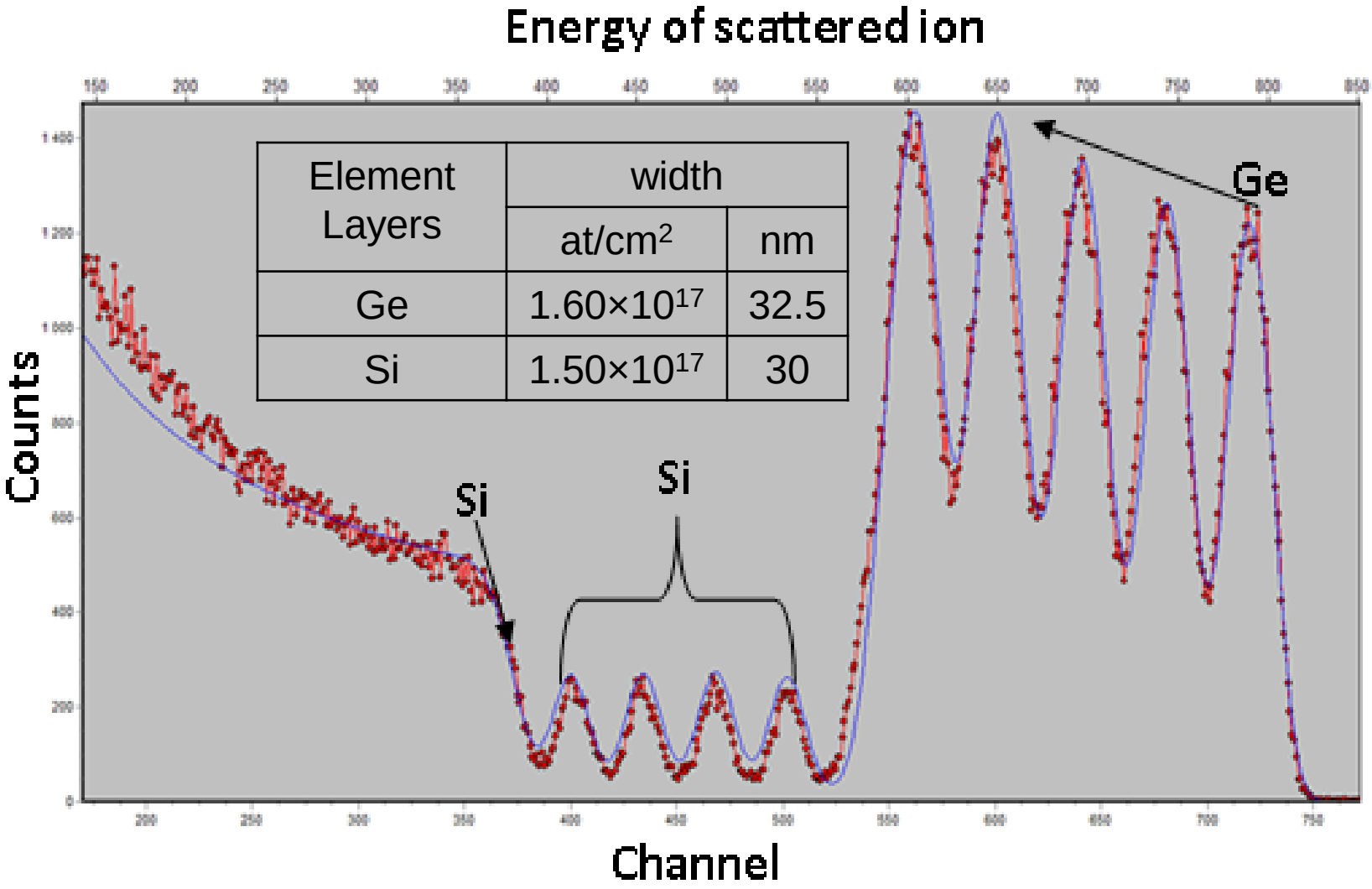
RBS Spectrum

ELEMENTS	THICKNESS		CONCENTRATION (at.%)
	$1x10^{15}$ at/cm^2	(nm)	
Ti & O	1155	204	Ti-82; O-18
Si, Ti & O	300	57	Ti-24; O-10; Si-66
Silicon	8500	Bulk	100



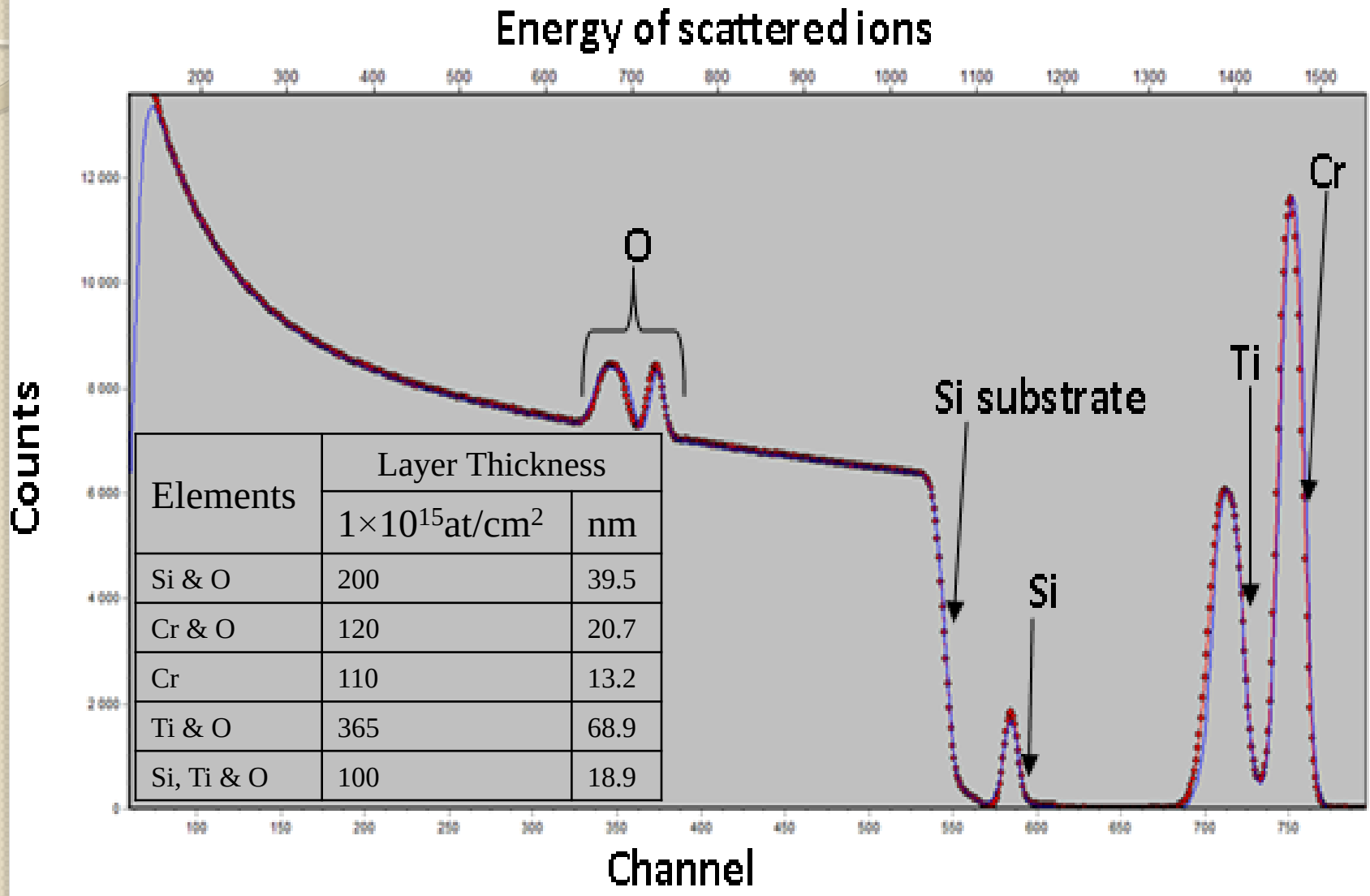
RBS Spectrum Cont.

Multi-layer structure



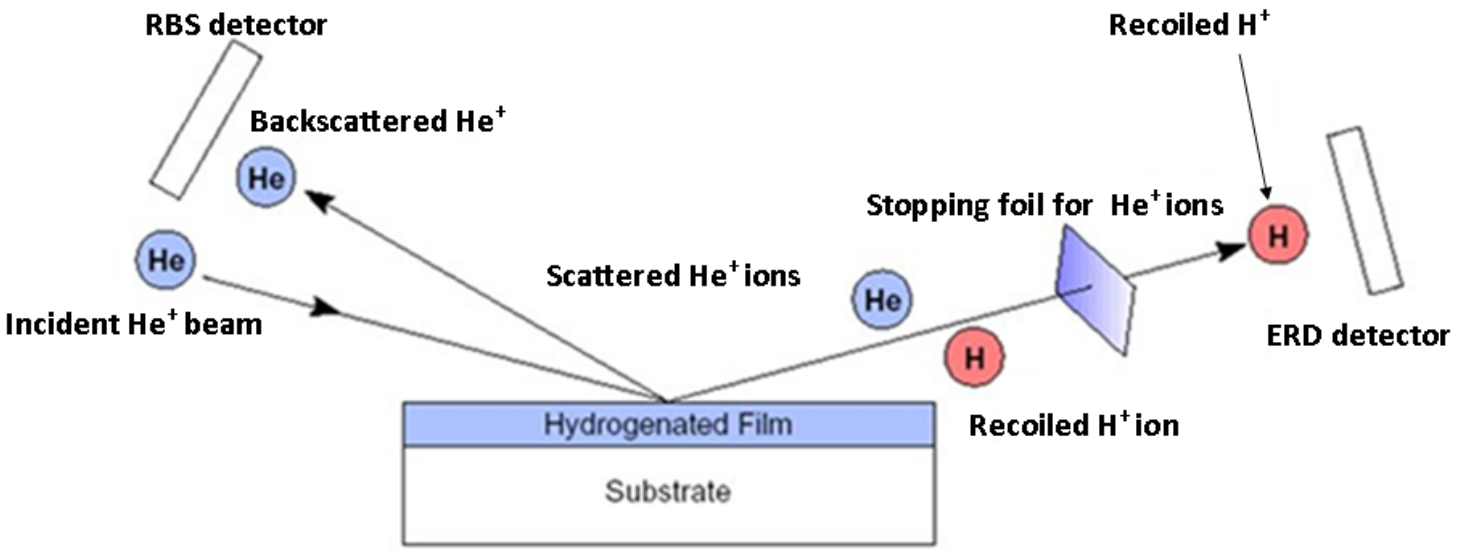
Element Layers	width	
	at/cm^2	nm
Ge	1.60×10^{17}	32.5
Si	1.50×10^{17}	30

RBS Spectrum Cont.



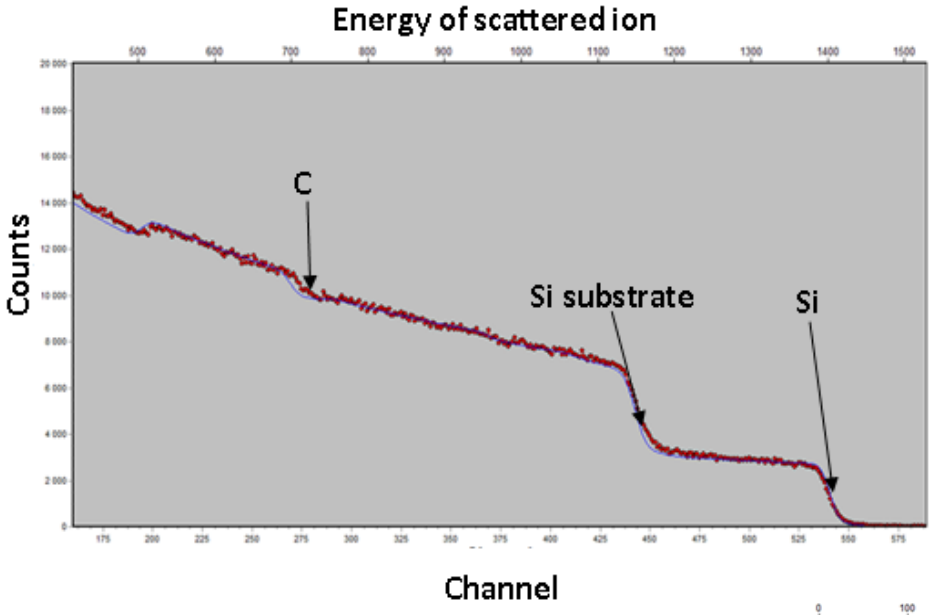
Elements	Layer Thickness	
	1×10^{15}at/cm^2	nm
Si & O	200	39.5
Cr & O	120	20.7
Cr	110	13.2
Ti & O	365	68.9
Si, Ti & O	100	18.9

Elastic Recoil Detection (ERD)



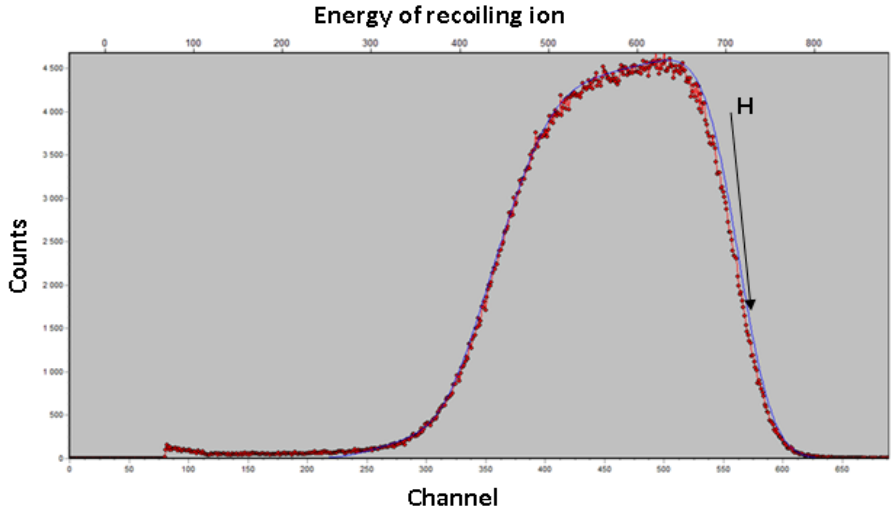
- Quantitative H^+ and D^+ profiling
- ERD can be used simultaneously with RBS
- Used to detect elements of lighter nuclei

RBS and ERD Spectra For The Same Target Cont.

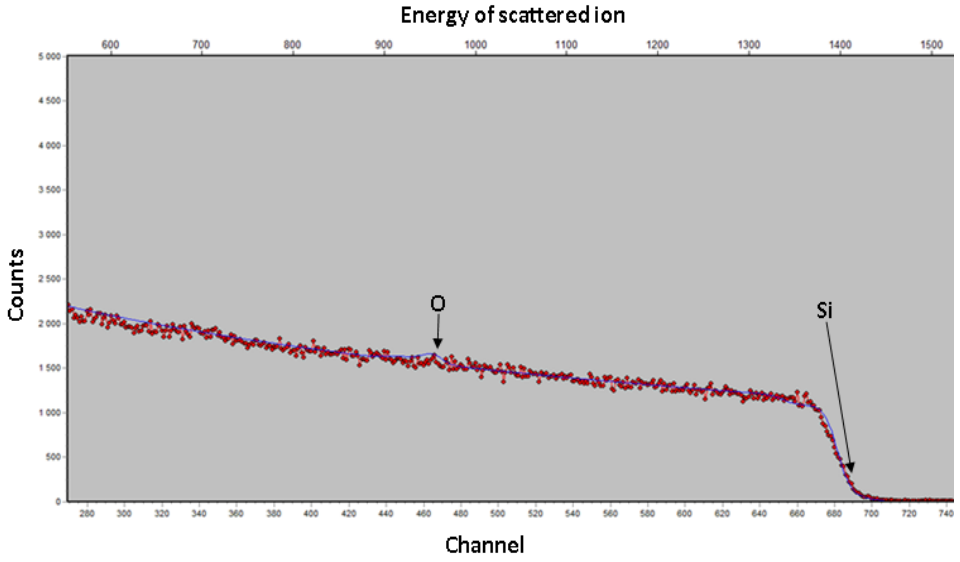


RBS spectrum showing yield of He ions scattered on heavy elements

ERD spectrum showing yield of recoiled H^+ ions

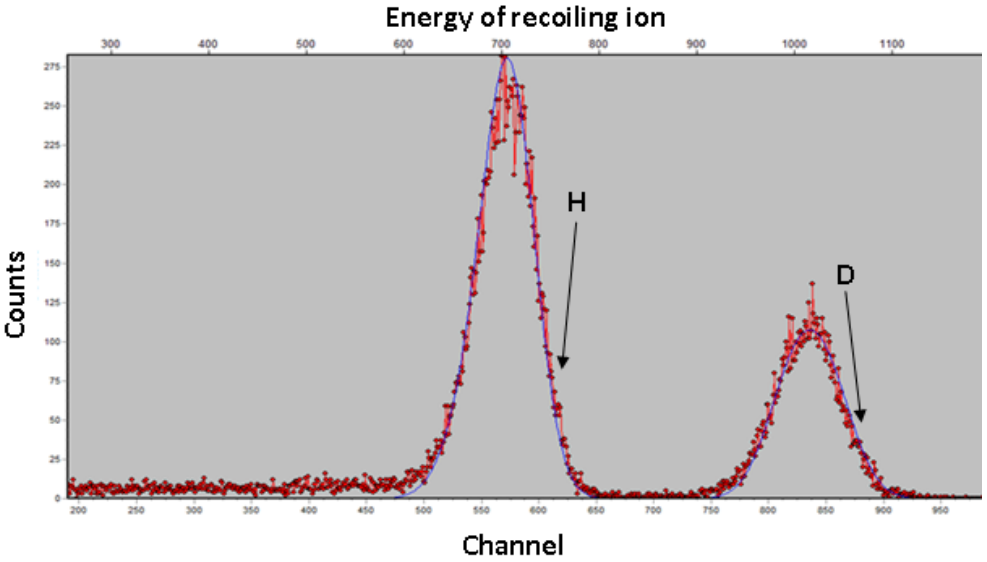


RBS and ERD Spectra For The Same Target



Experimental Set-up	
Ion beam Energy (keV)	2297
Incident angle (α^0)	75
Exit angle (β^0)	75
Scattering angle (θ^0)	30

Experimental Set-up	
Ion beam Energy (keV)	2297
Incident angle (α^0)	75
Exit angle (β^0)	30
Scattering angle (θ^0)	135



Conclusion

- RBS and ERD can be used all elements from light to heavy elements
- Minimal Thickness layer about 10 nm
- Concentration of elements on each layer (1-100 %)
- Nuclear analytical methods: Intensity of beam <1 μA

Acknowledgements

- Special thanks to Dr A.P Kobzev
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Thank you for not asking any!!!