Joint Institute for Nuclear Research
Frank Laboratory of Neutron Physics

JINR Summer student practice

ION BEAM ANALYSIS

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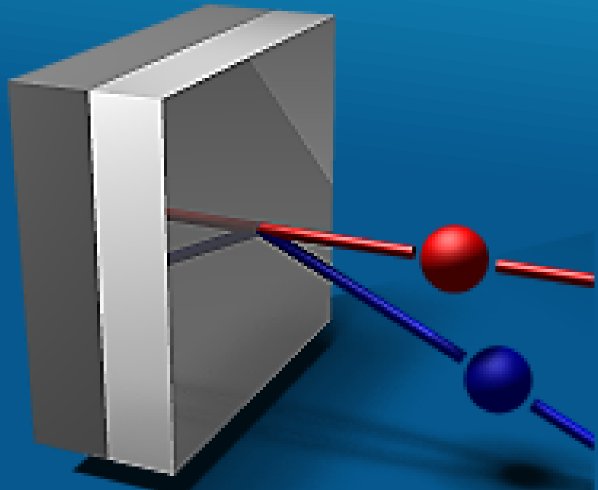

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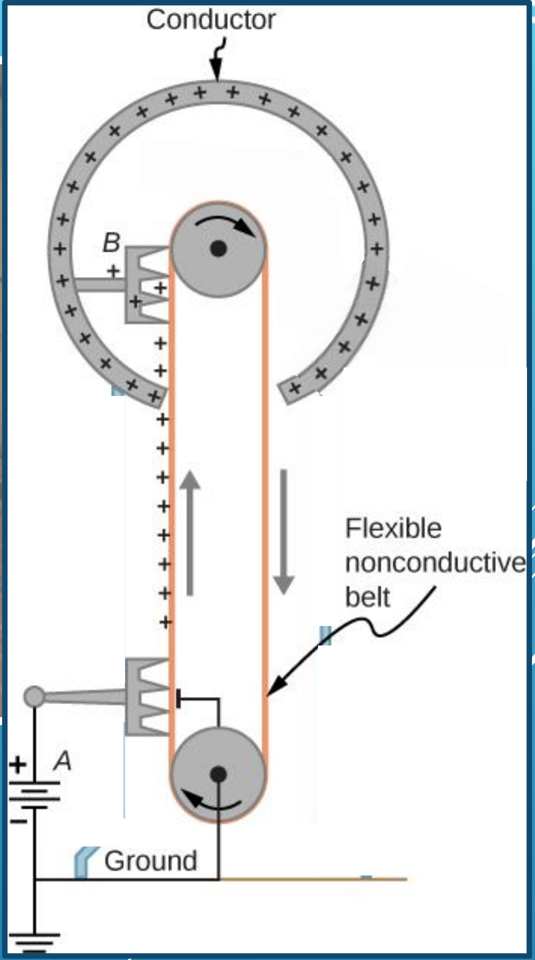
Contents

1. Van de Graaff accelerator
2. Rutherford backscattering spectrometry (RBS)
3. Experimental spectra of RBS and analysis
    - RBS sample – one layer systems
    - RBS samples - multilayer system
4. Nuclear reaction
5. Elastic recoil detection (ERD)
6. Concludion analysis of ERD spectra

Characteristics of Van de Graaff accelerator (EG-5)

- This Generator was built in 1965.
- Ion source placed at the top part the accelerated tube
- Van de Graaff accelerator placed in a tank under pressure of 9 atmospheres of dry nitrogen.
- Energy : 0.9 – 3.5 MeV
- Beam intesity for H^+ : 30μA
- Beam intesity for He^+ : 10μA
- Energy spread : < 500 eV
- Energy precision: 2 keV
- Number of beam lines: 6



A – electrical source
B – pointed conductor

Scheme of Van de Graaff generator

Rutherford backscattering spectrometry (RBS)

- For near-surface layer analysis of solid
- Elemental composition without any standard
- Elemental depth profiles, dopants
- Analysing depth for He^+ ions is 2 μm and for H^+ is 20 μm
- Sensitivity: for heavy elements – 0.01 at. %, and for light elements is less
- Typical depth resolution is 10-30 nm

Collision kinematics give information about the mass of the constituents.

- Interaction between charged particle and atom is described by one elastic collision
- Was used lows of kinetic energy and momentum conservation

$$\frac{1}{2}M_1v_0^2 = \frac{1}{2}M_1v_1^2+\frac{1}{2}M_2v_2^2$$

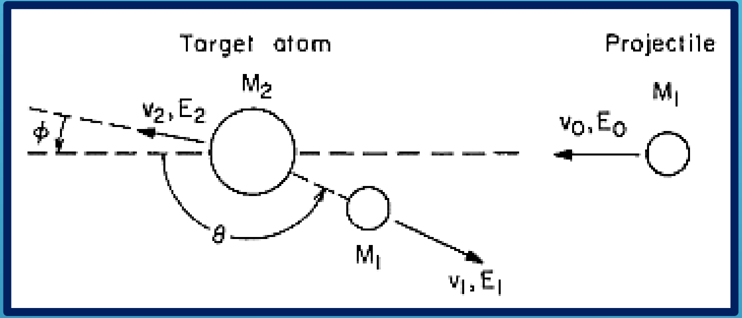
$$M_1v_0 = M_1v_1\cos\theta + M_2v_2\cos\emptyset$$

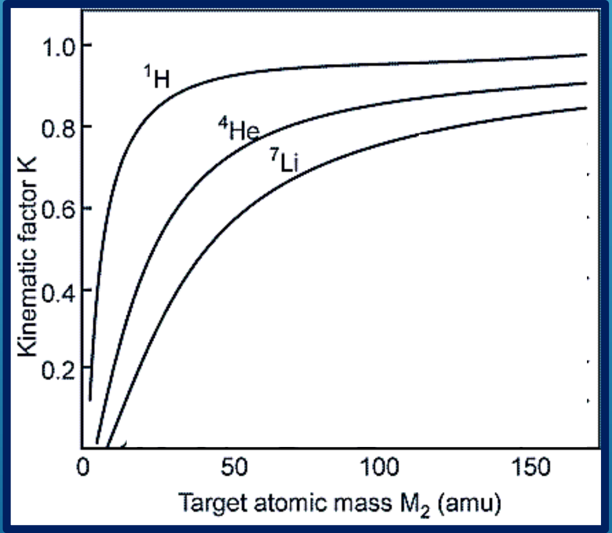
$$0 = M_1v_1\sin\theta - M_2v_2\sin\emptyset$$

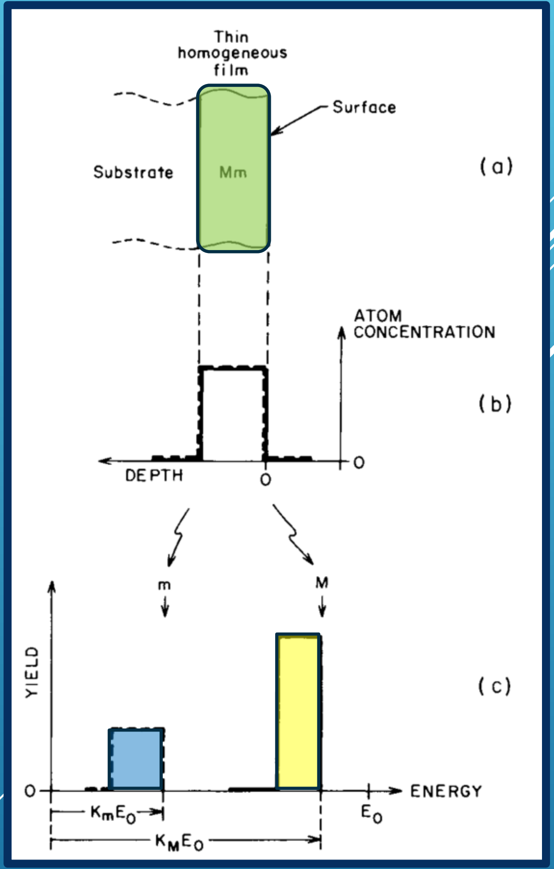
$$\frac{v_1}{v_0} = \frac{\left[\left(M_2^2-M_1^2\sin^2\theta\right)^{1/2}+M_1\cos\theta\right]}{M_1+M_2}$$

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

K – Kinematic factor





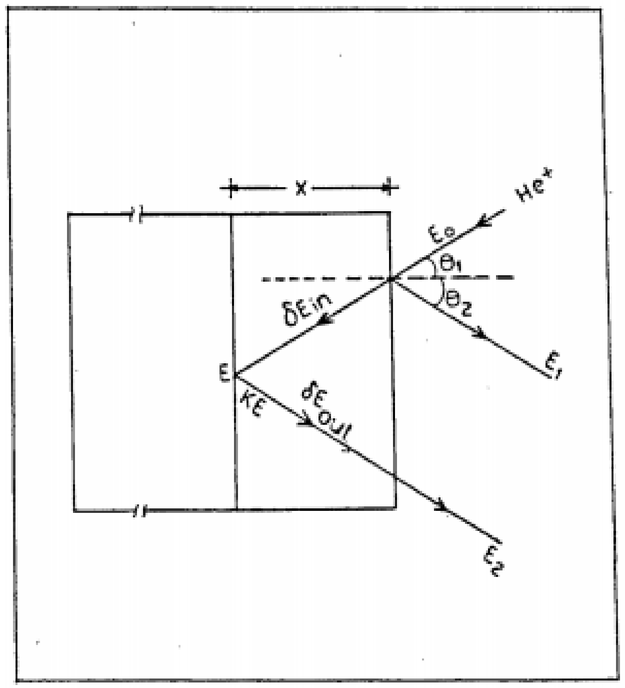


Rutherford cross section

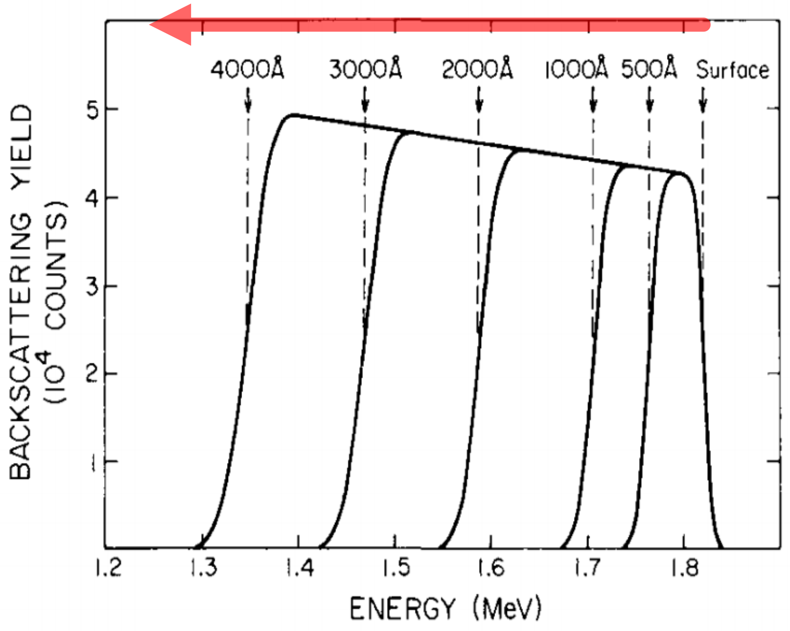
$$\frac{d\sigma}{d\Omega} = \left(\frac{Z_1 Z_2 e^2}{4E}\right)^2 \frac{4}{\sin^4\theta} \frac{\left\{\left[1 - \left((M_1/M_2)\sin^2\theta\right)\right]^{1/2} + \cos\theta\right\}^2}{\left[\left[1 - \left((M_1/M_2)\sin^2\theta\right)\right]^{1/2}\right]}$$

$$A = \sigma\Omega \cdot Q \cdot Nt.$$

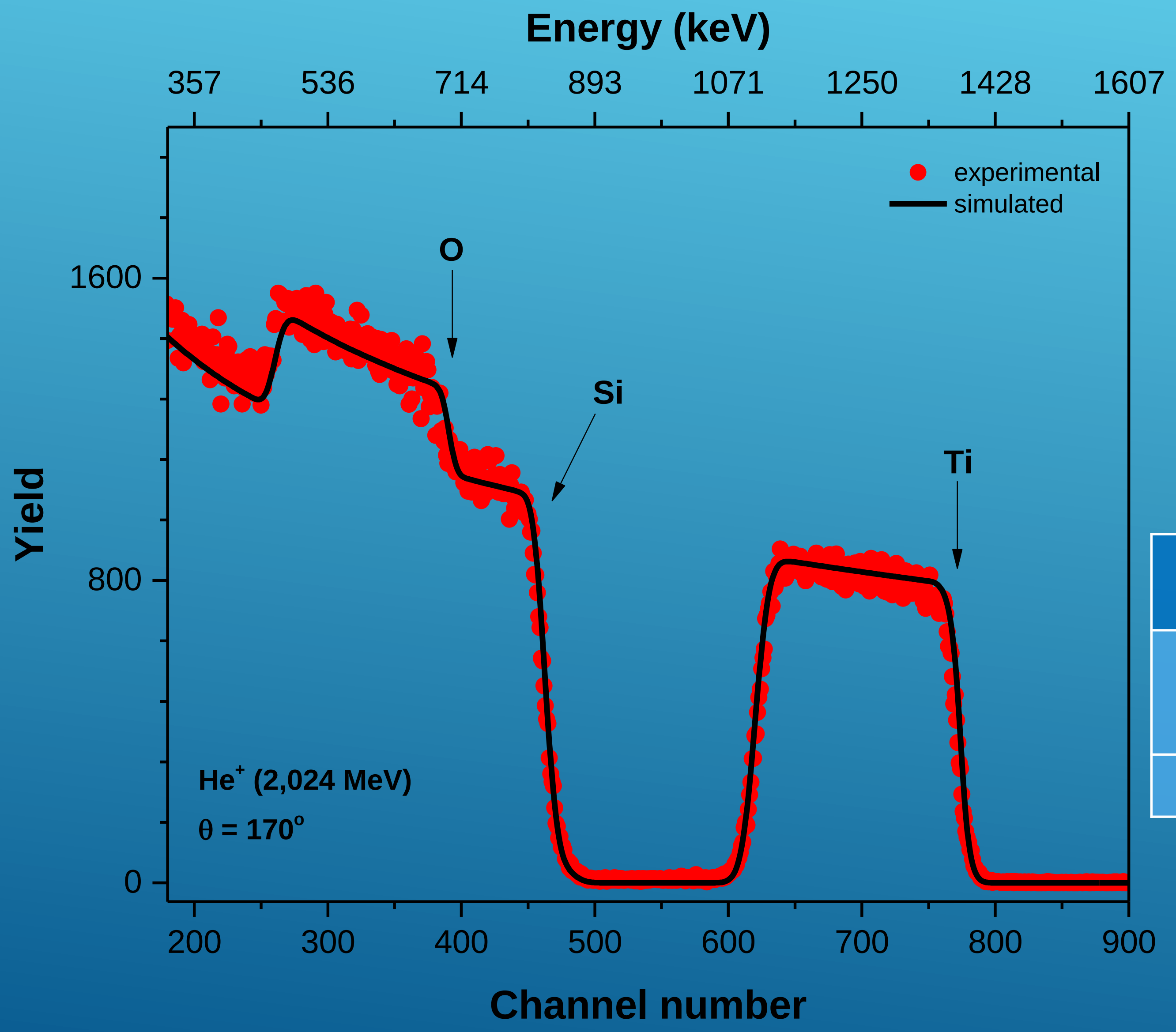
$$\begin{pmatrix}\text{number of}\\ \text{detected particles}\end{pmatrix} = \sigma\Omega \cdot \begin{pmatrix}\text{total number of}\\ \text{incident particles}\end{pmatrix} \cdot \begin{pmatrix}\text{number of target}\\ \text{atoms per unit area}\end{pmatrix}.$$

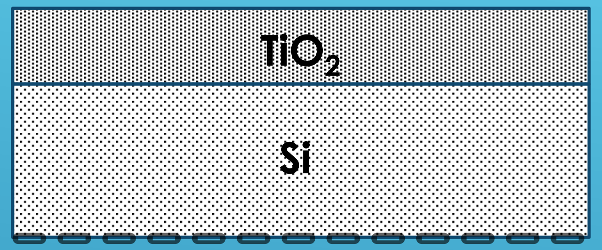


$E_1 = KE_0$
$E = E_0 - \delta E_{in}$
$E_2 = KE - \delta E_{out}$
x = Thickness



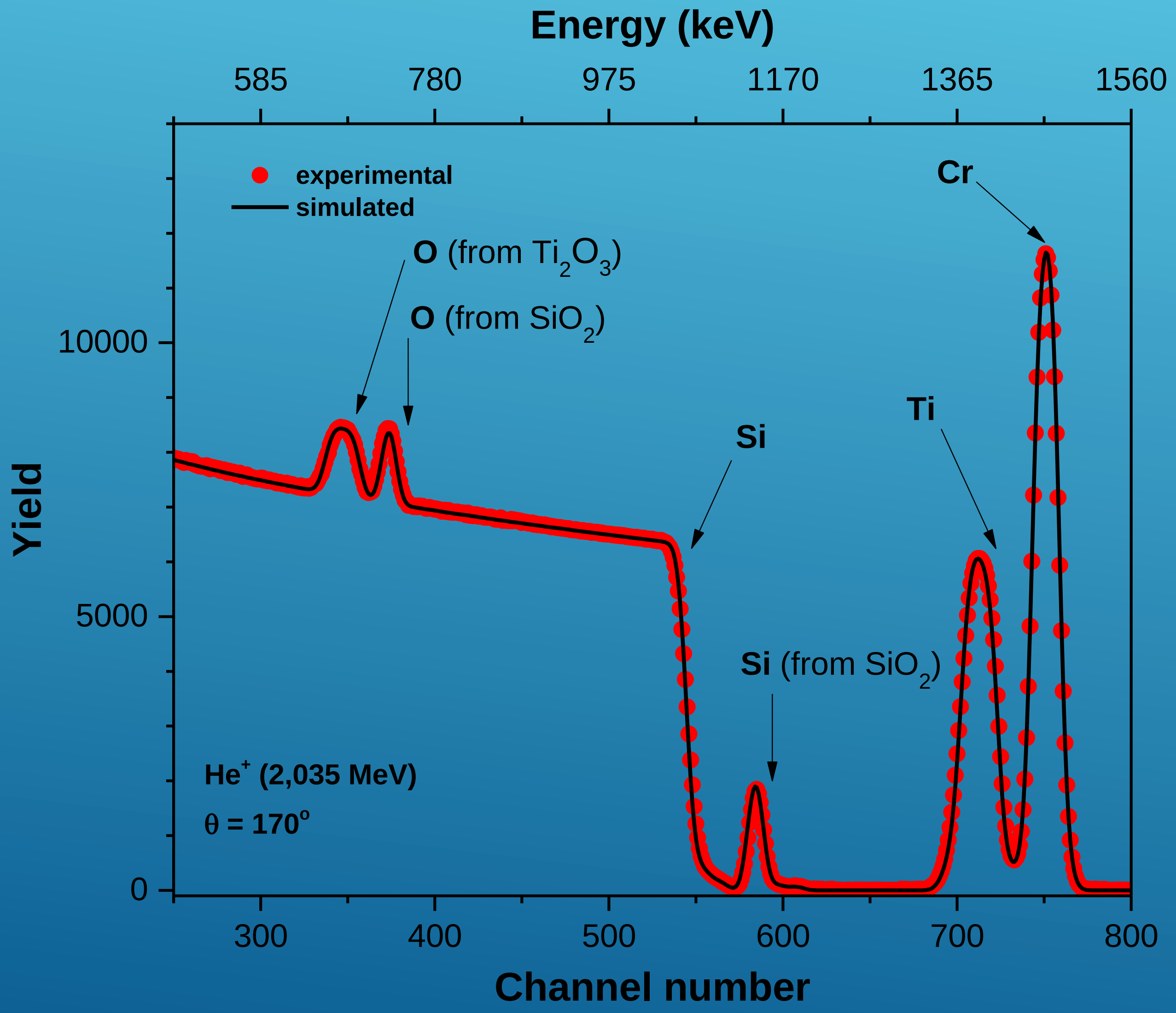
Example 1

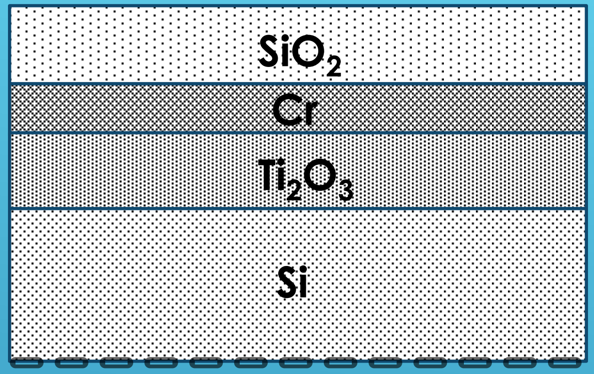




Number of layer	Element	Conc. (at. %)	Thickness (atom/ cm²)*10¹⁵	Thickness (nm)
1	Ti	32	2980	316
	O	68		
2	Si	100	/	/

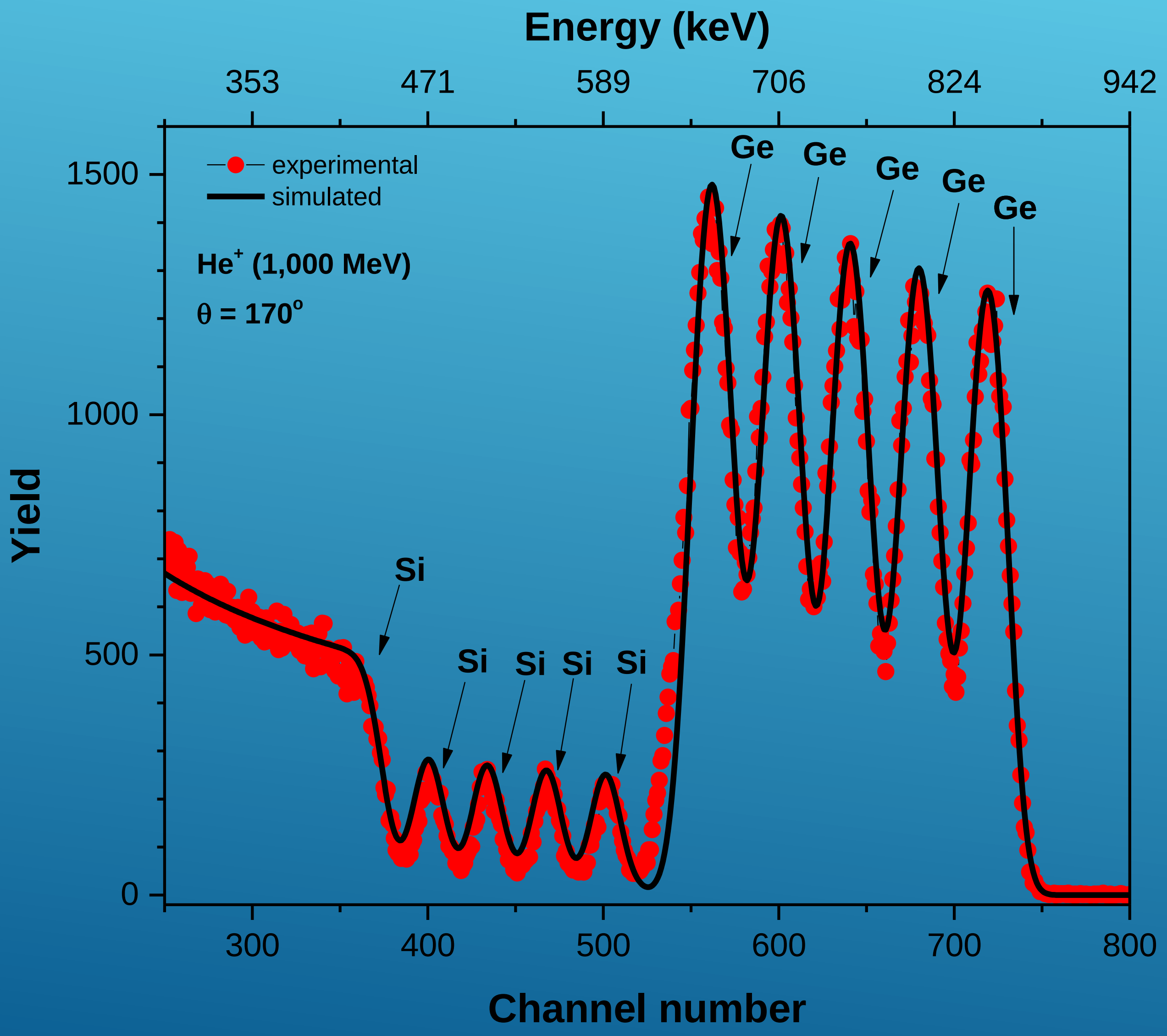
Example 2

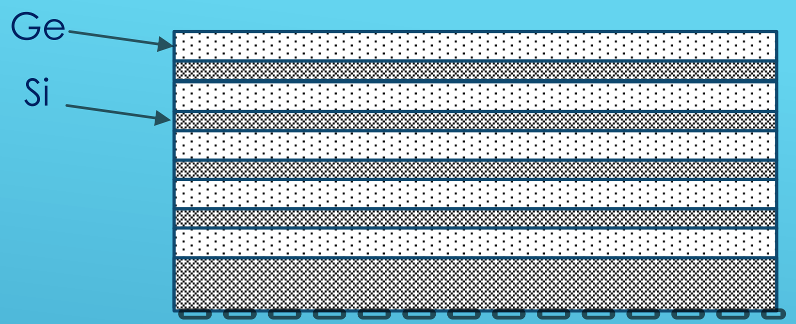




Number of layer	Element	Conc. (at. %)	Thickness (atom/ cm^2)*10^{15}	Thickness (nm)
1	Si	33	180	23
	O	67		
2	Cr	100	200	24
3	Ti	41	400	42
	O	59		
4	Si	100	/	/

Example 3



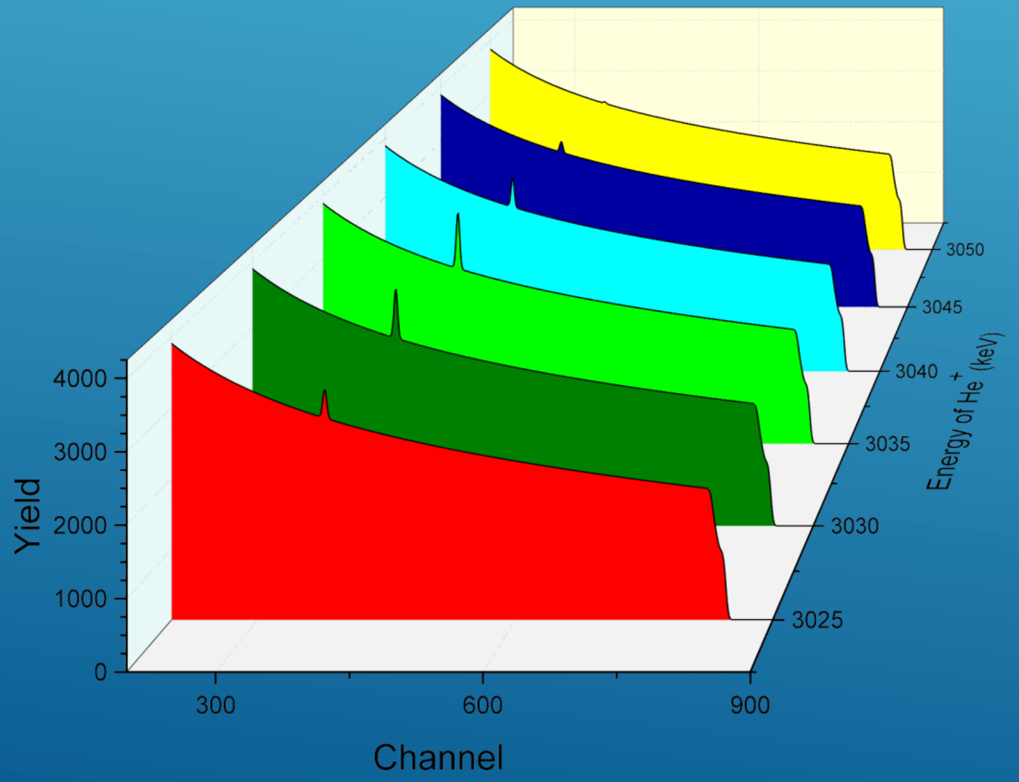


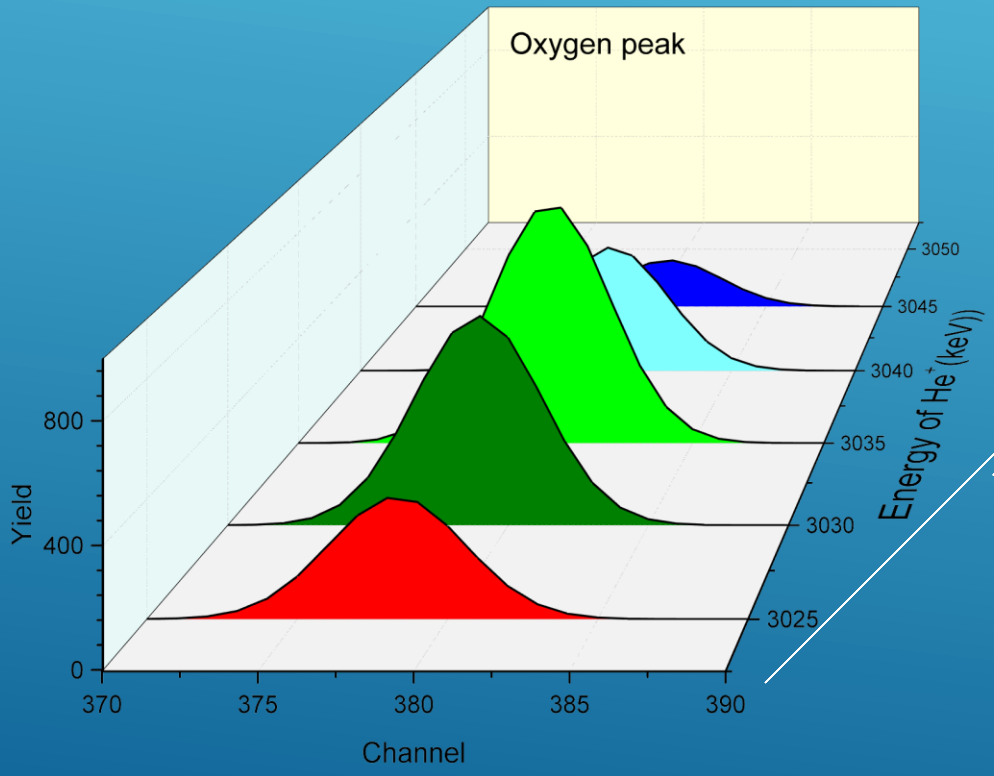
Number of layer	Element	Conc. (at. %)	Thickness (atom/ cm^2)*10^{15}	Thickness (nm)
1	Ge	100	170	38
2	Si	100	140	28
3	Ge	100	170	38
4	Si	100	140	28
5	Ge	100	170	38
6	Si	100	140	28
7	Ge	100	170	38
8	Si	100	140	28
9	Ge	100	170	38
10	Si	100	/	/

Nuclear reaction method

- Measurement of light element (oxygen) in thin layer on the surface GaAs will be improved using NR method

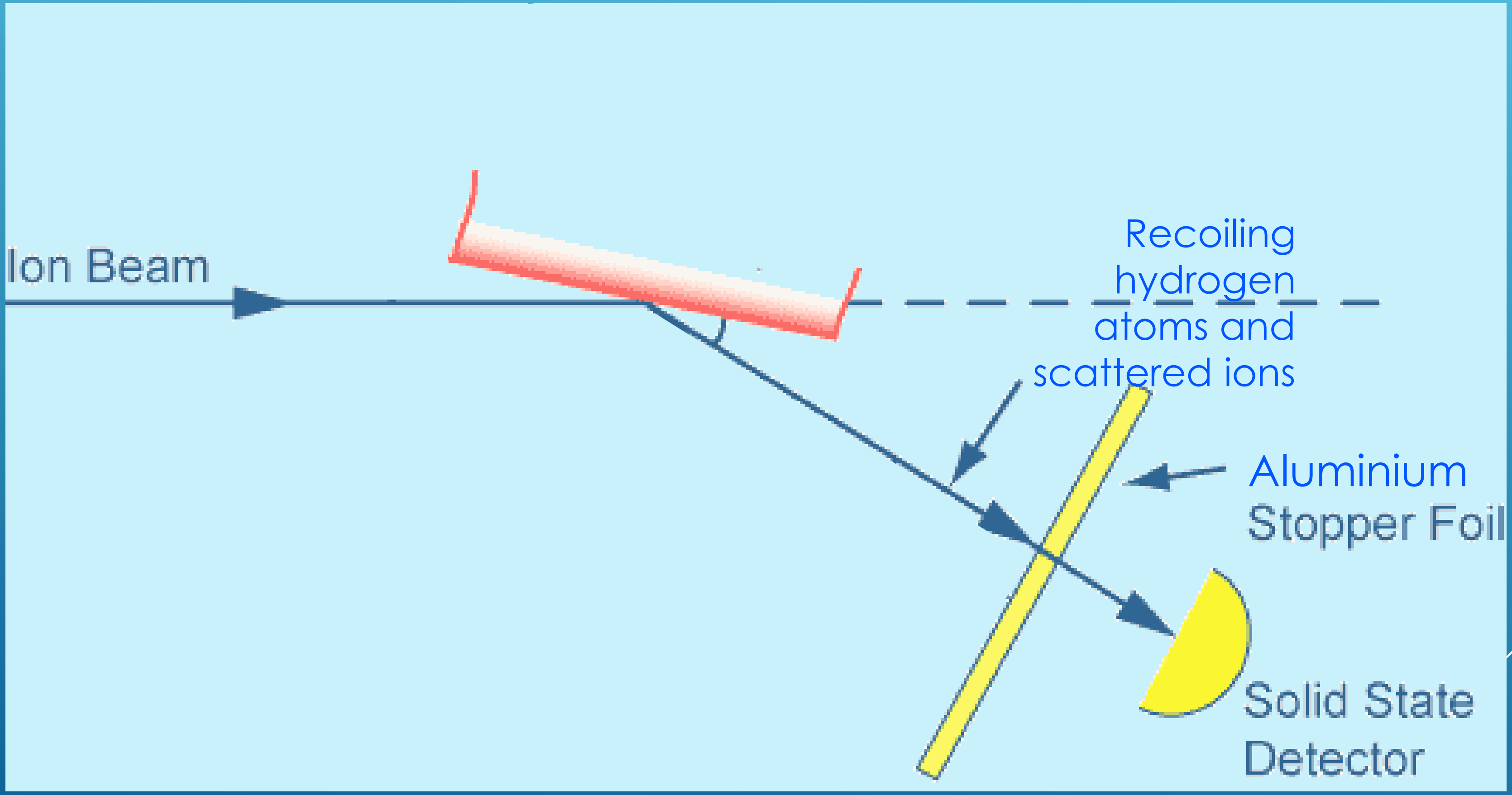
$$^{16}O\ (\alpha,\alpha)\ ^{16}O$$



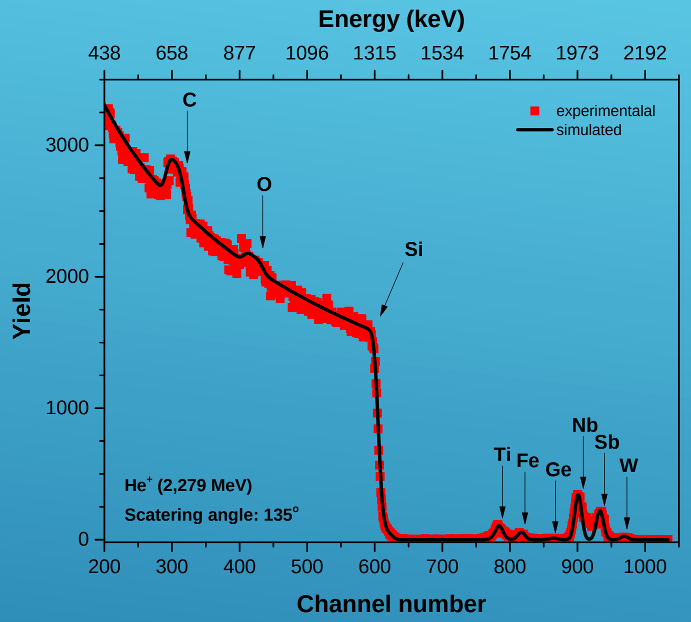


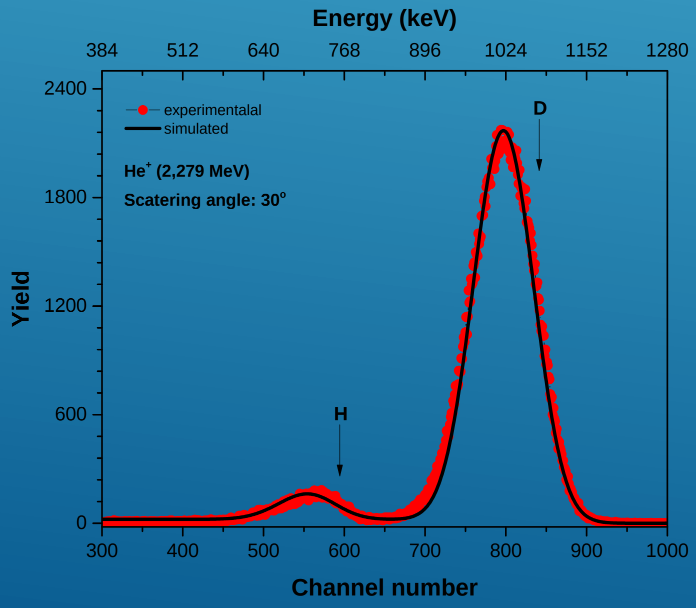
Elastic recoil detection (ERD)

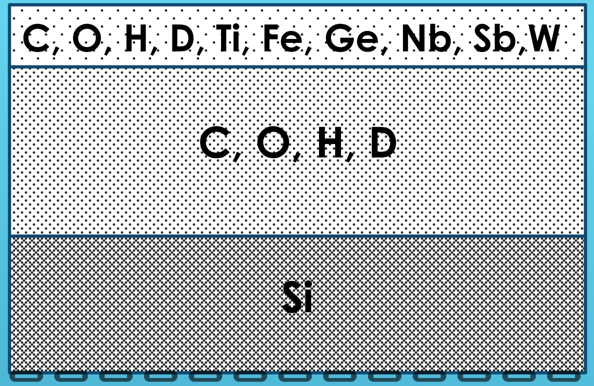
- technique for depth profiling of light elements (isotopes of hydrogen) in multilayer systems



Example







Number of layer	Element	Conc. (at. %)	Thickness (atom/ cm^2)*10^{15}	Thickness (nm)
1	C	36.00	100	13
	O	5.26		
	Ti	5.30		
	Fe	1.80		
	Ge	0.30		
	Nb	4.20		
	Sb	1.80		
	W	0.10		
	H	10.00		
	D	34.84		
2	C	34.00	1150	160
	O	5.50		
	H	20.00		
	D	40.50		
3	SI	100.00	/	/

Thank for your attention!