# Rutherford Backscattering Spectrometry: experimental aspects

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## Outline

1. Introduction:

Rutherford Backscattering Spectrometry

2. Experimental setup,

detectors, electronics, dose measurement

3. Data evaluation, use of simulation software

4. Examples

1. Introduction: Rutherford Backscattering Spectrometry

# Rutherford Backscattering Spectroscopy (RBS)
# Elastic Recoil Detection Analysis (ERDA)

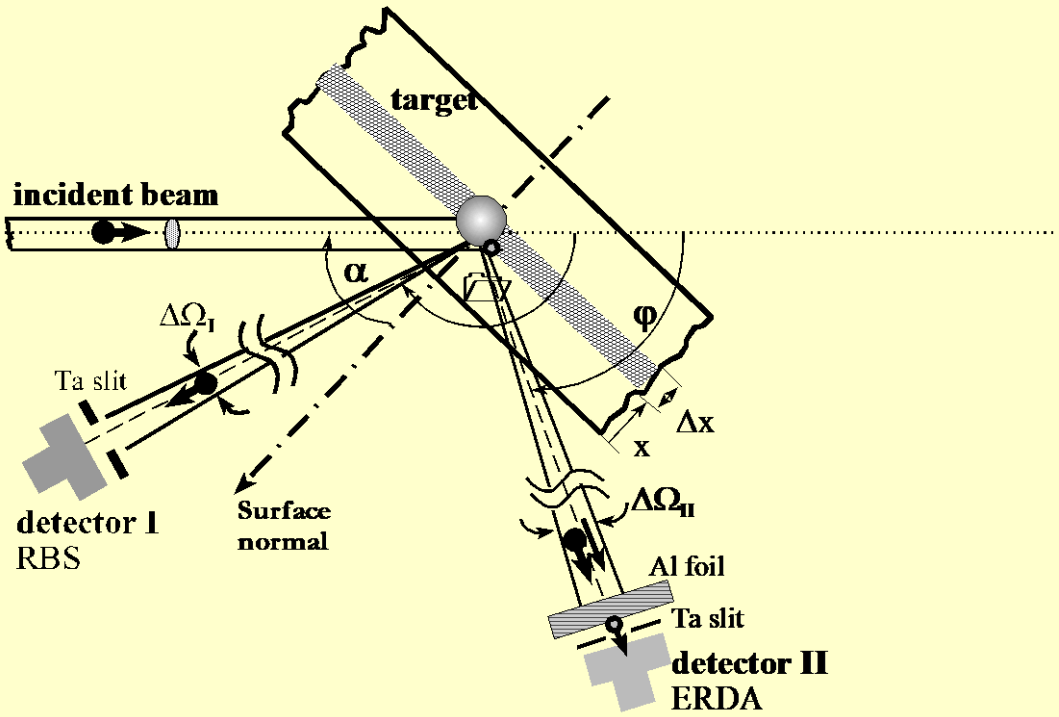
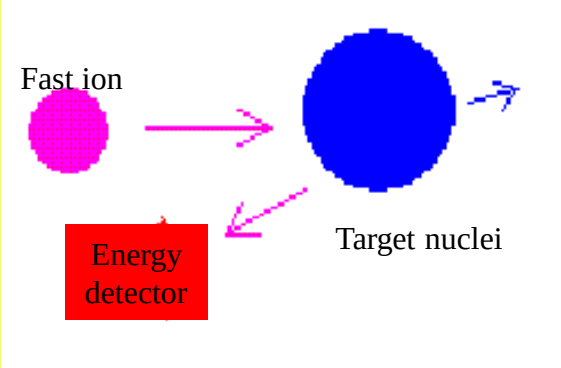
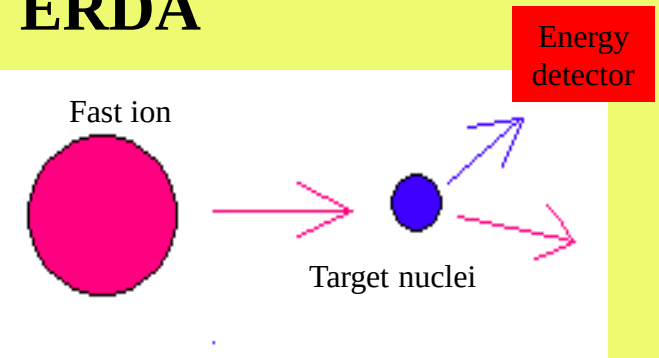



Fig.3. Schematic view of the RBS/ERDA experimet

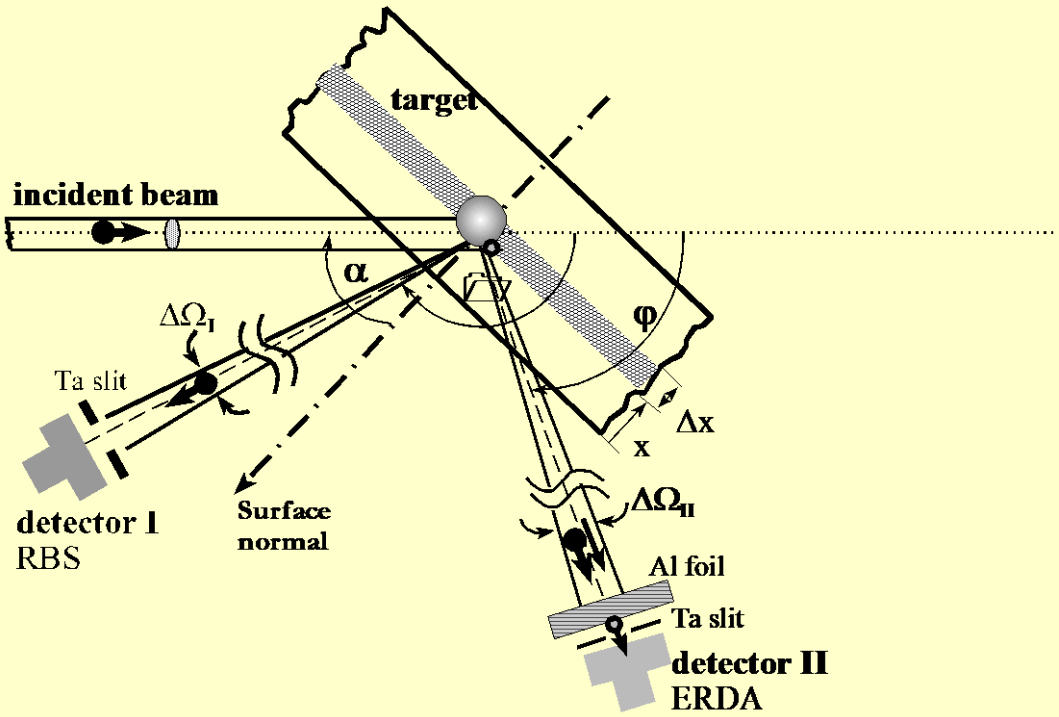
## RBS




## ERDA



# Rutherford Backscattering Spectroscopy (RBS)
# Elastic Recoil Detection Analysis (ERDA)

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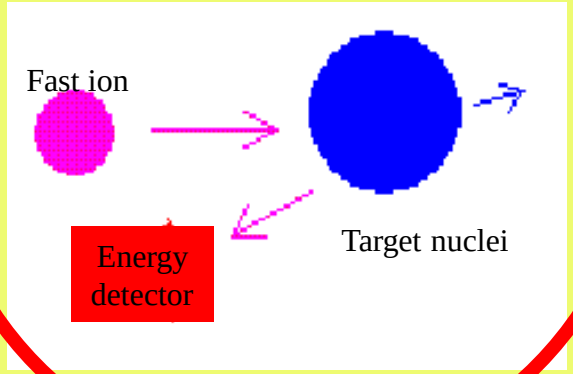
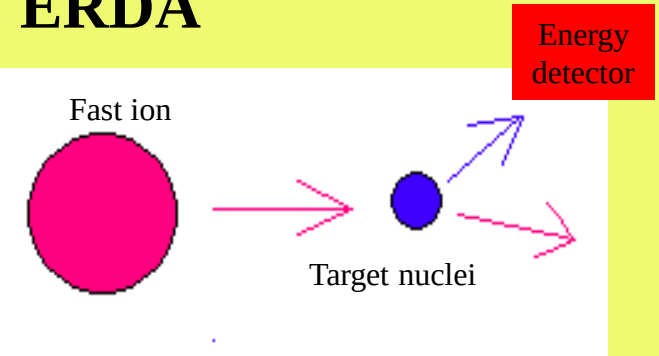
## RBS




## ERDA



## 2. Experimental setup: detectors, electronics, dose measurement

Standard RBS: Scattered ions are detected by silicon detectors

Old concept: surface barrier detectors

Modern concept: Ion implanted detectors

Characteristics:

Energy resolution:
FWHM of the $^{241}$Am alpha particle peak at 5.486 MeV

**SBD: Scratch sensitive !**

**Implanted: Could be washed by isopropyl-alcohol**

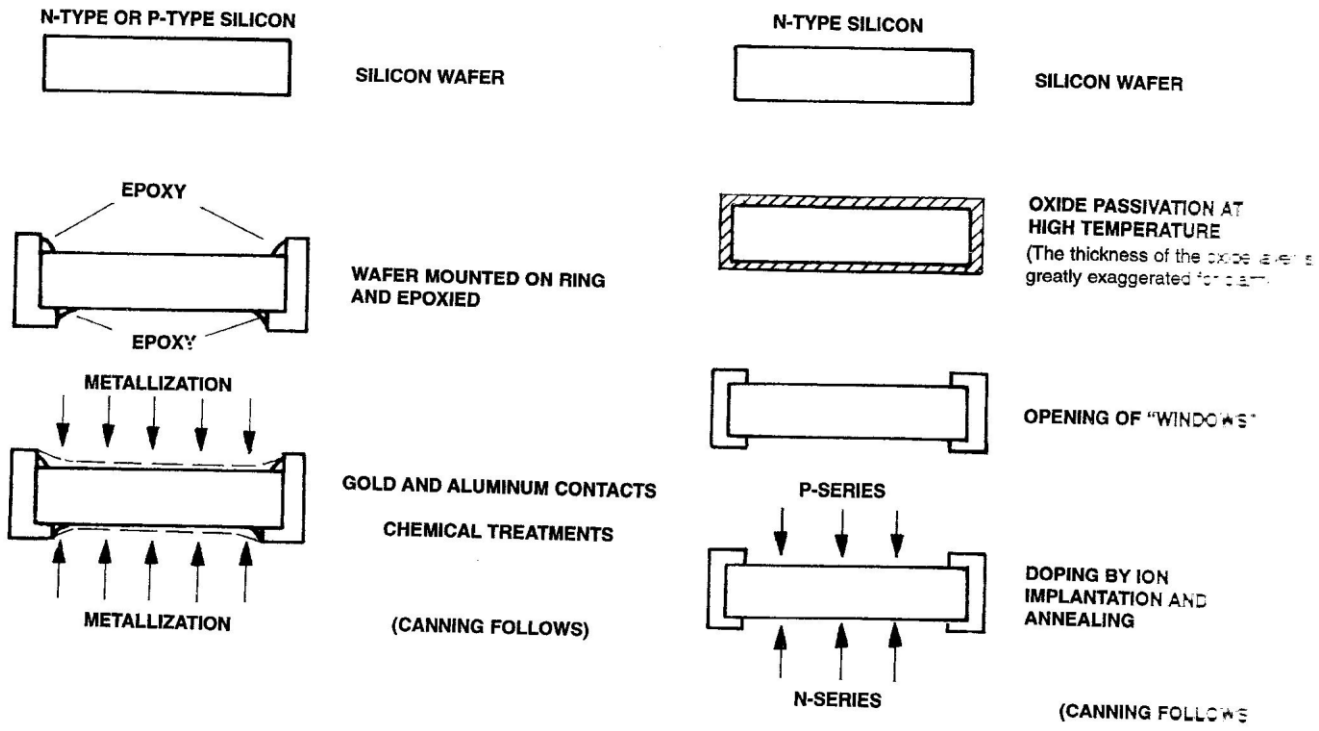



Fig. 1. (A). Simplified Diagram of Surface Barrier Si Detector Manufacturing.

Fig. 1. (B). Simplified Diagram of Ion-Implanted S Detector Manufacturing.

Manufacturing process: Surface Barrier Detector, Ion-Implanted Si Detector (Source: EG&G Ortec Catalogue, 95)

**Fig. 10.11.** Formation of a Schottky barrier junction

**Fig. 10.12.** Schematic diagram of a surface barrier detector (from *Ortec* [10.28])

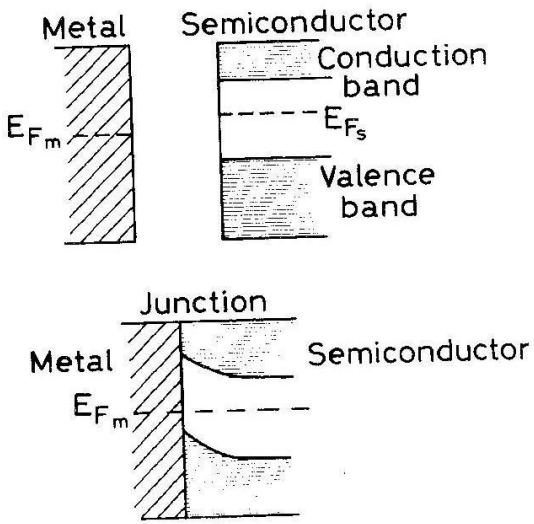



**Fig. 10.11**

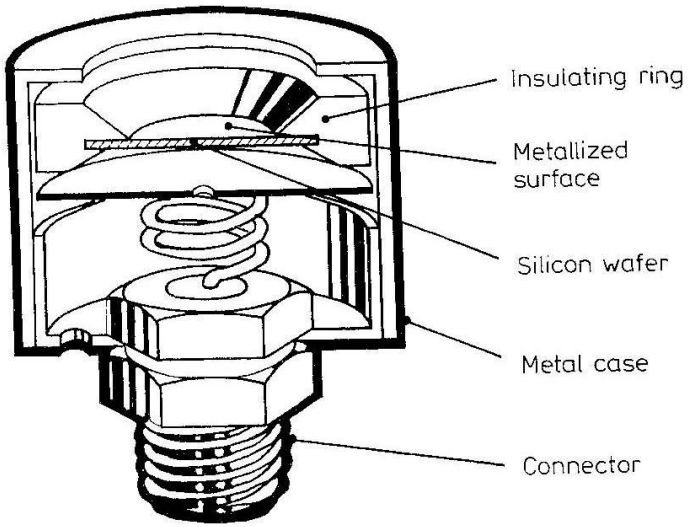



**Fig. 10.12**

Depletion layer formation in Surface-Barrier Detector, Packaging of the Si wafer into detector housing (Source: W.R. Leo, Techniques for Nuclear and Particle Physics Experiments, Springer)

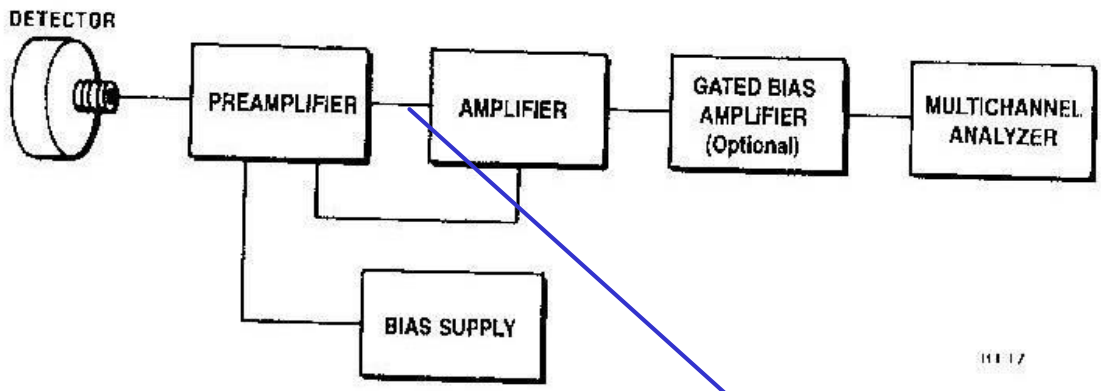



Fig. 6. Typical System for Charged-Particle Spectroscopy.

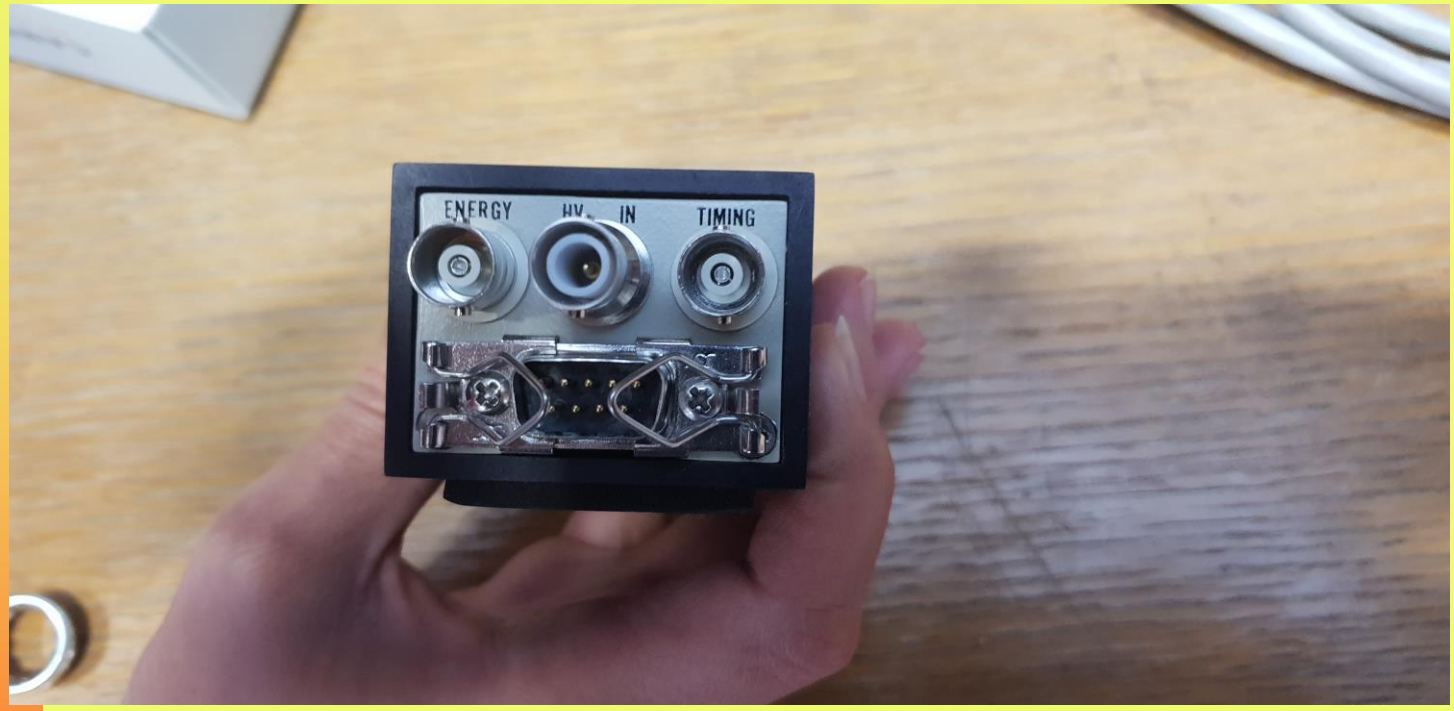
Source: EG&G Ortec Catalogue, 95

Digital Pulse Processor

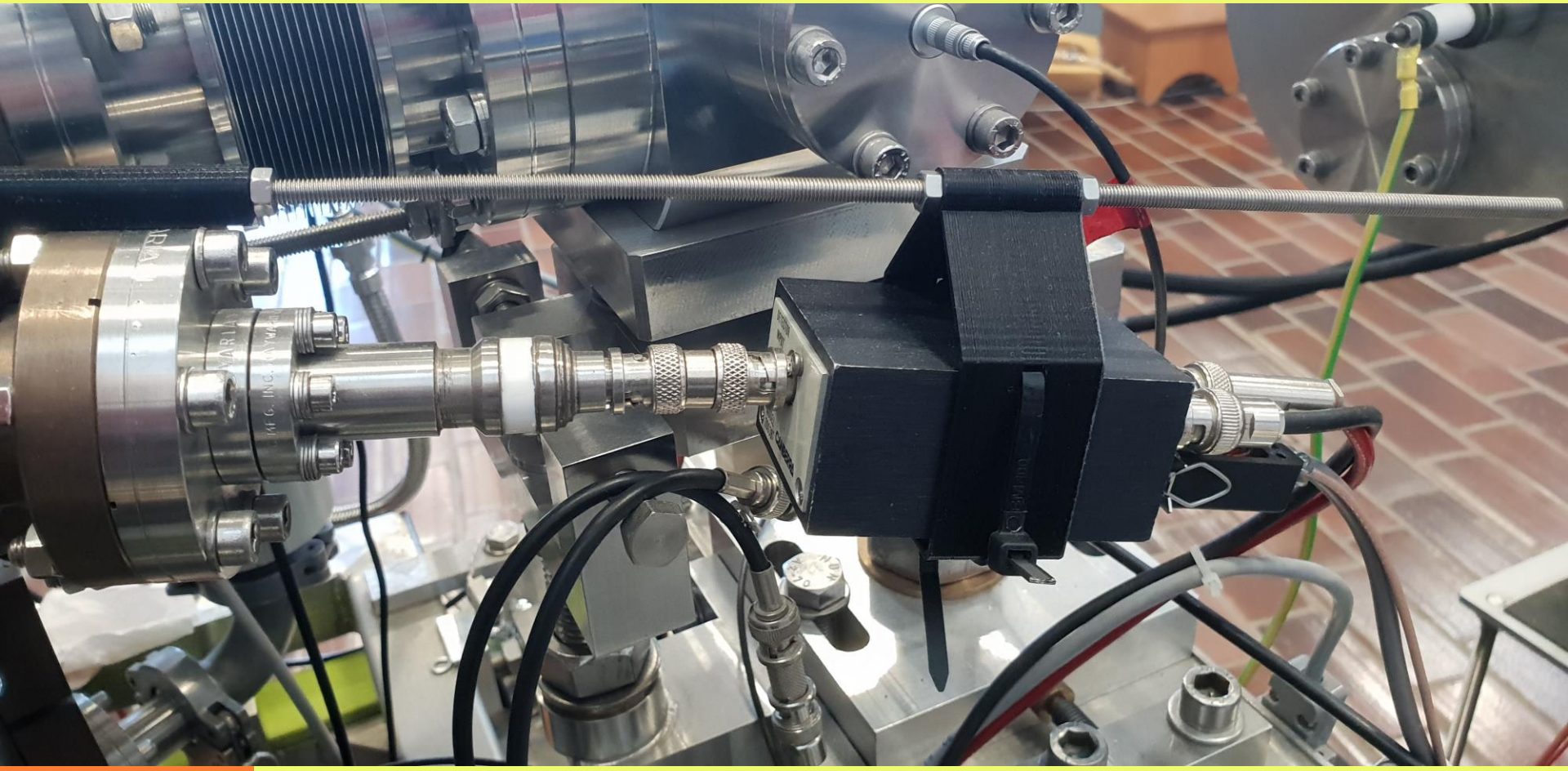
## Good practice rules

**Goal: to obtain declared energy resolution of the detector, or better! (i.e. 11 keV)**

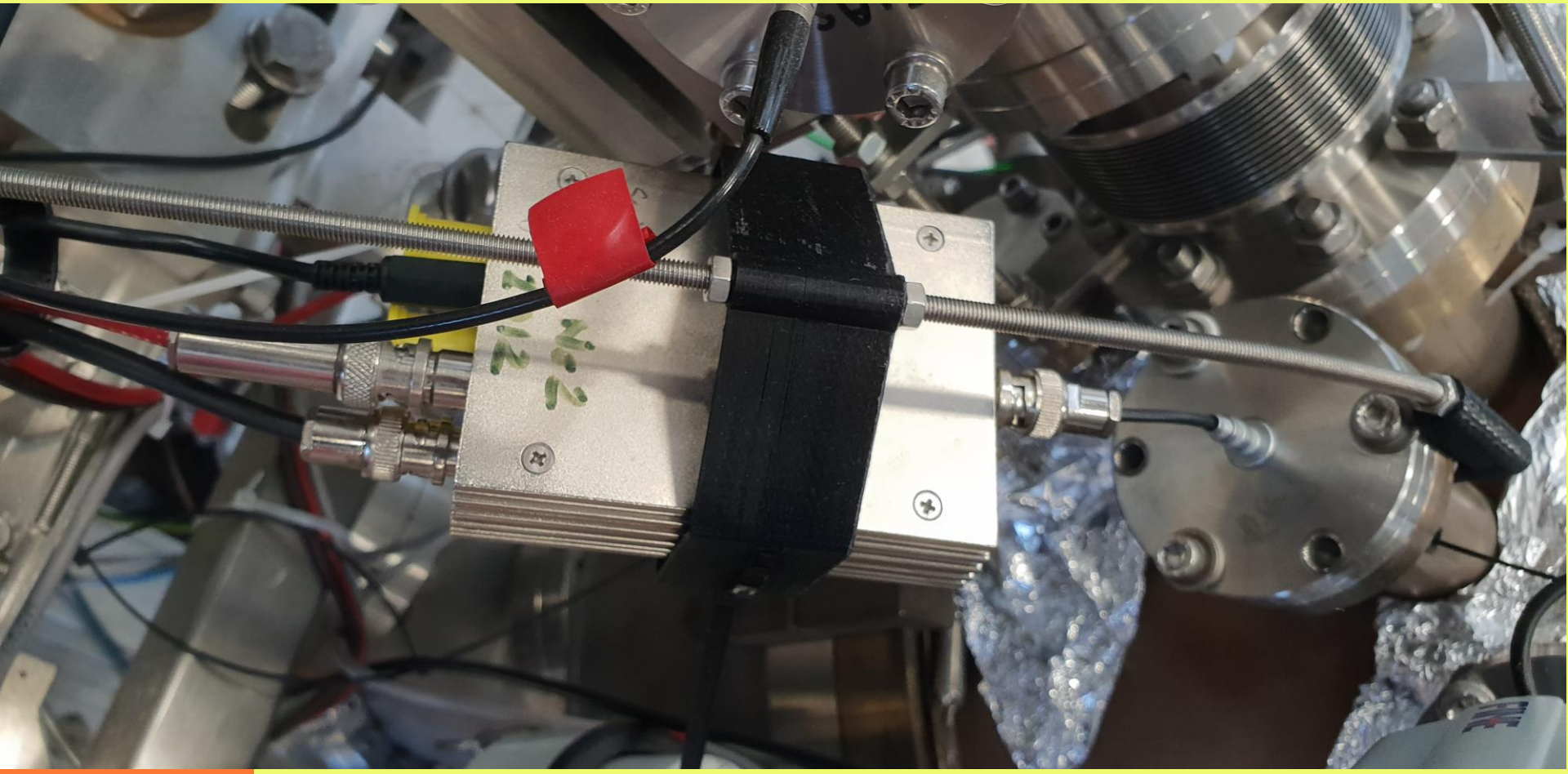
1. Connection Detector-Preamp as short as possible
2. Impendance of the coaxial cable (i.e. 50 Ohm) not interrupted from detector up to preamp. Keep the coaxial geometry, do not interrupt the outer shield of the coaxial cable
3. Detector, preamp and outer shield of the coaxial cable insulated from the vacuum chamber and/or beamline
4. If the cables from the preamp to the Spectroscopy amplifier or DPP long (more than i.e. 2 meters), use preamp with higher gain ( if available)



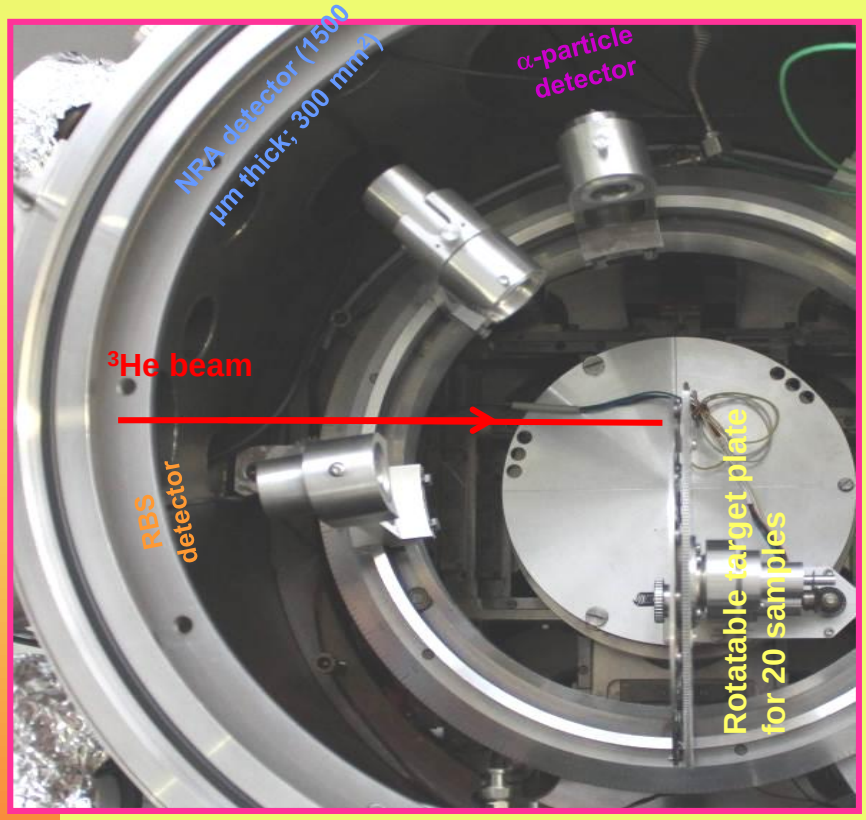

Preamplifier: input and output connections



UHV electrical feedthrough: Both Air and Vacuum-side with BNC connector, ceramic separator of the cable outer shield



Preamplifier with a Peltier-cooled FET: Amptek CoolFET

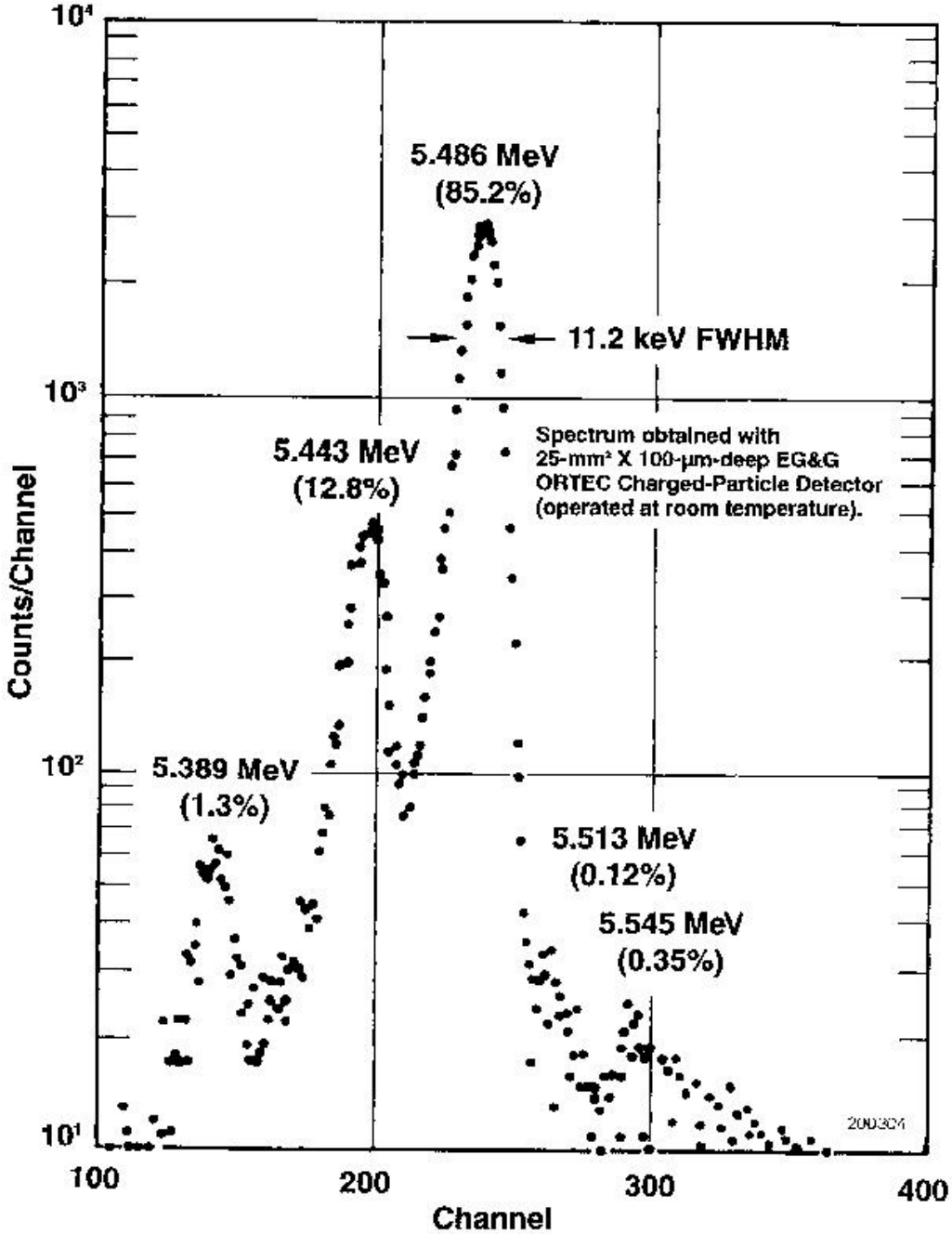



Mass resolution increases with scattering angle: Position the RBS detector as close as possible to 180°, i. e. at the scattering angle of 170°

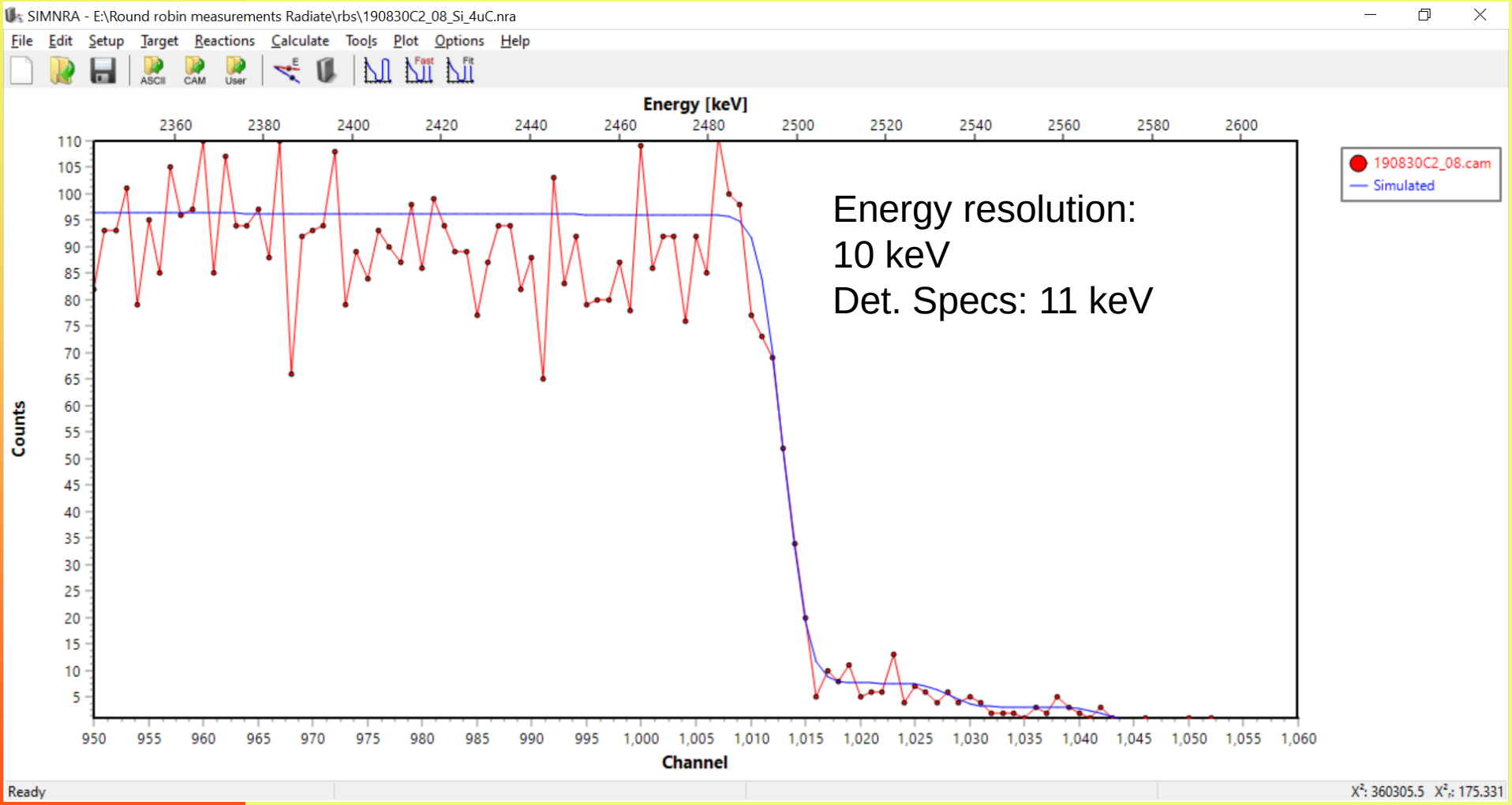
$^{241}$Am thin radioactive source:
Calibration standard for Alpha spectrometry, RBS

FWHM of the line at 5.486 MeV:
Criterion for energy resolution

(Source: EG&G Ortec Catalogue, 95)



If the guidelines are met, and with some experimental persistence to optimize the setup, we may reach(beat ?) the Specs of the detector



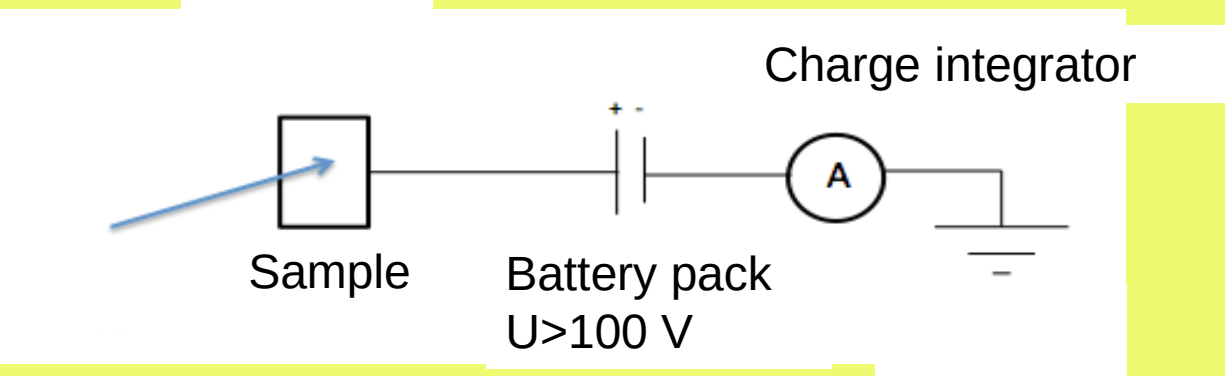

RBS on Si wafer: Beam $^3$He, E= 3.8 MeV,
Source: Dr. Sabina Markelj

# Measurement of incoming ion dose

1. **Charge integration on the sample:** secondary electrons (negative) escape from the sample, readout too high.

Mitigation strategies:

A: positively biased target:




B: Entire chamber insulated, earthed via charge integrator. Problems: system very susceptible to EM noise, big piece of metal-chamber is effective antenna, stray currents detected

## 2. In-beam devices

Deliver signal proportional to the incoming ion dose

Insensitive to the secondary electron escape from the sample, type of the sample

Need to be calibrated by well characterized samples

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Nuclear Instruments and Methods in Physics Research B 243 (2006) 392–396
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Beam Interactions with Materials & Atoms
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# Simple and accurate spectra normalization in ion beam analysis using a transmission mesh-based charge integration

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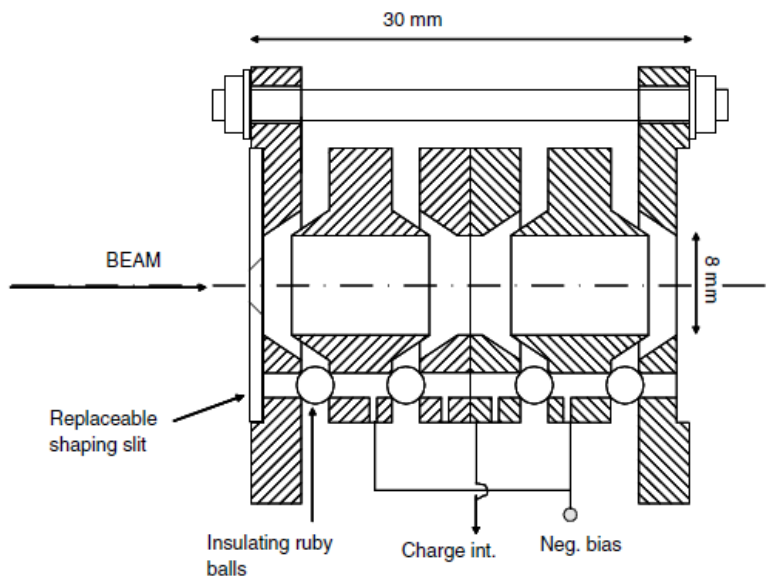
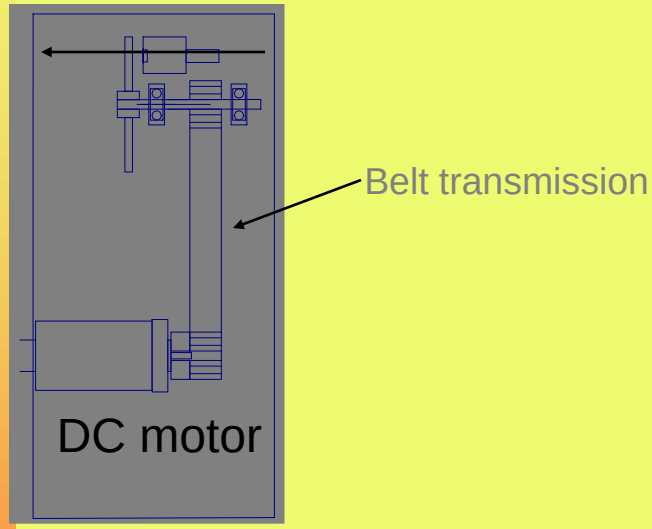
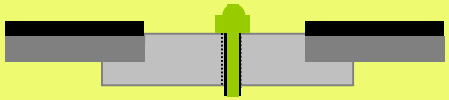


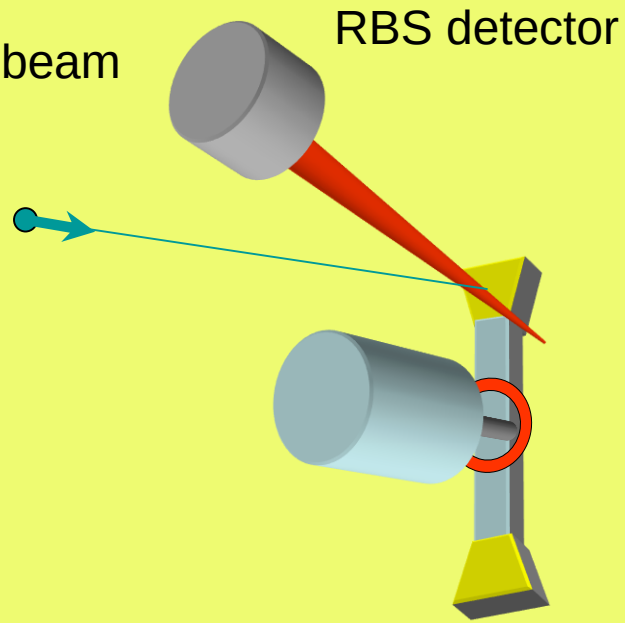

Fig. 1. Construction of the in-beam mesh charge collector. The tungsten mesh is inserted between the two central electrodes.

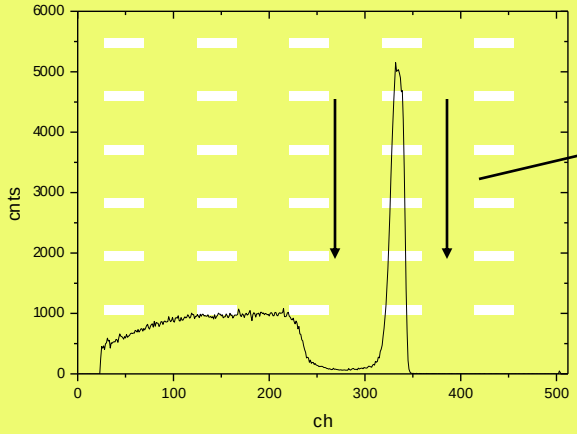
Dose normalisation by chopper:
RBS from rotating chopper positioned in the beam after the collimation slits



3x1 μm thick gold foil on graphite, mounted on aluminum support




Integrated Au signal proportional to the proton dose

# 4. Data evaluation: simulation software

## Energy calibration of the RBS detector:

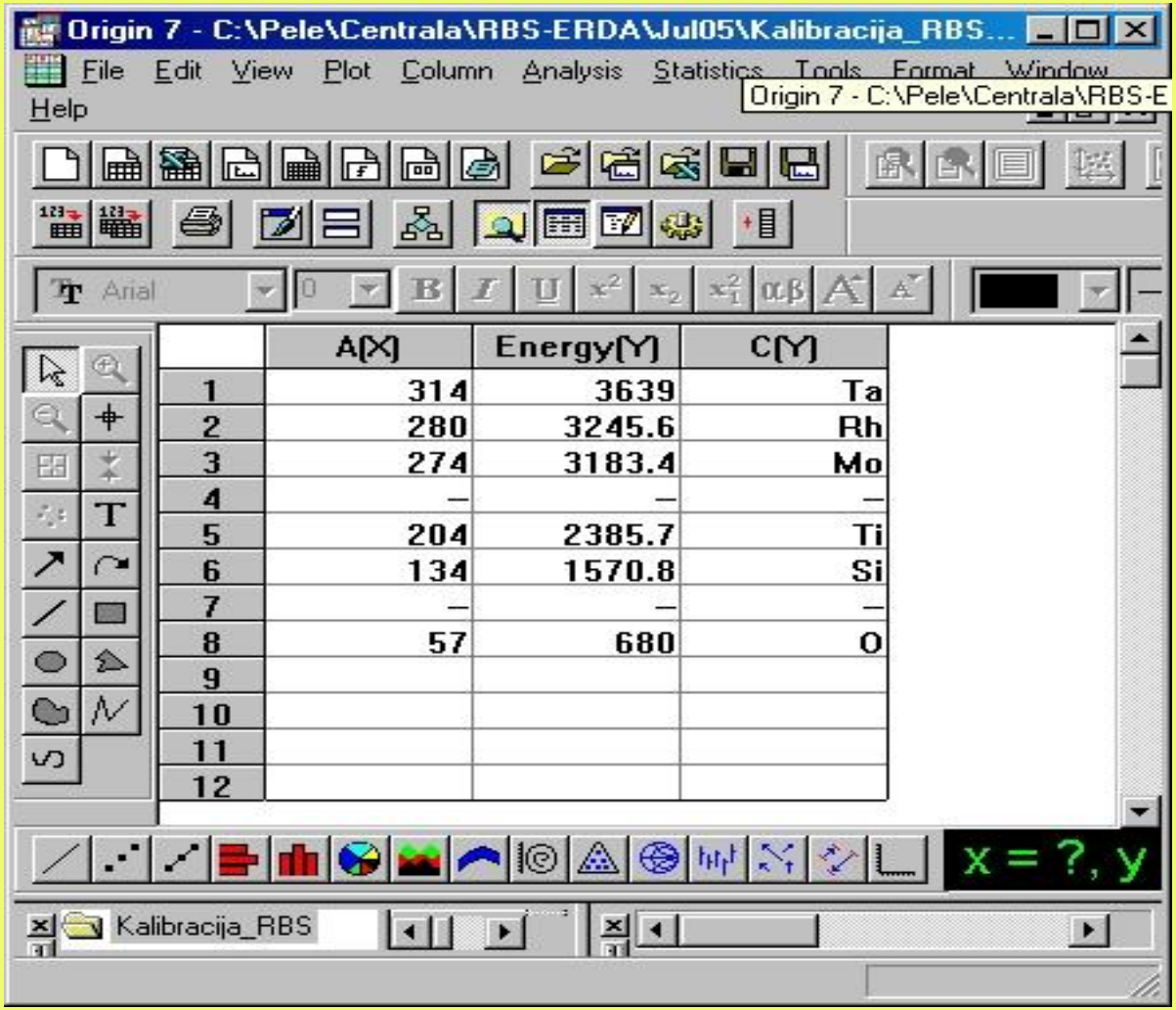
Assumptions:

1. Energy of incoming ions well known
(accelerator is energy-calibrated via nuclear reactions)

2. Any eventual foil in front of detector known for its thickness and composition

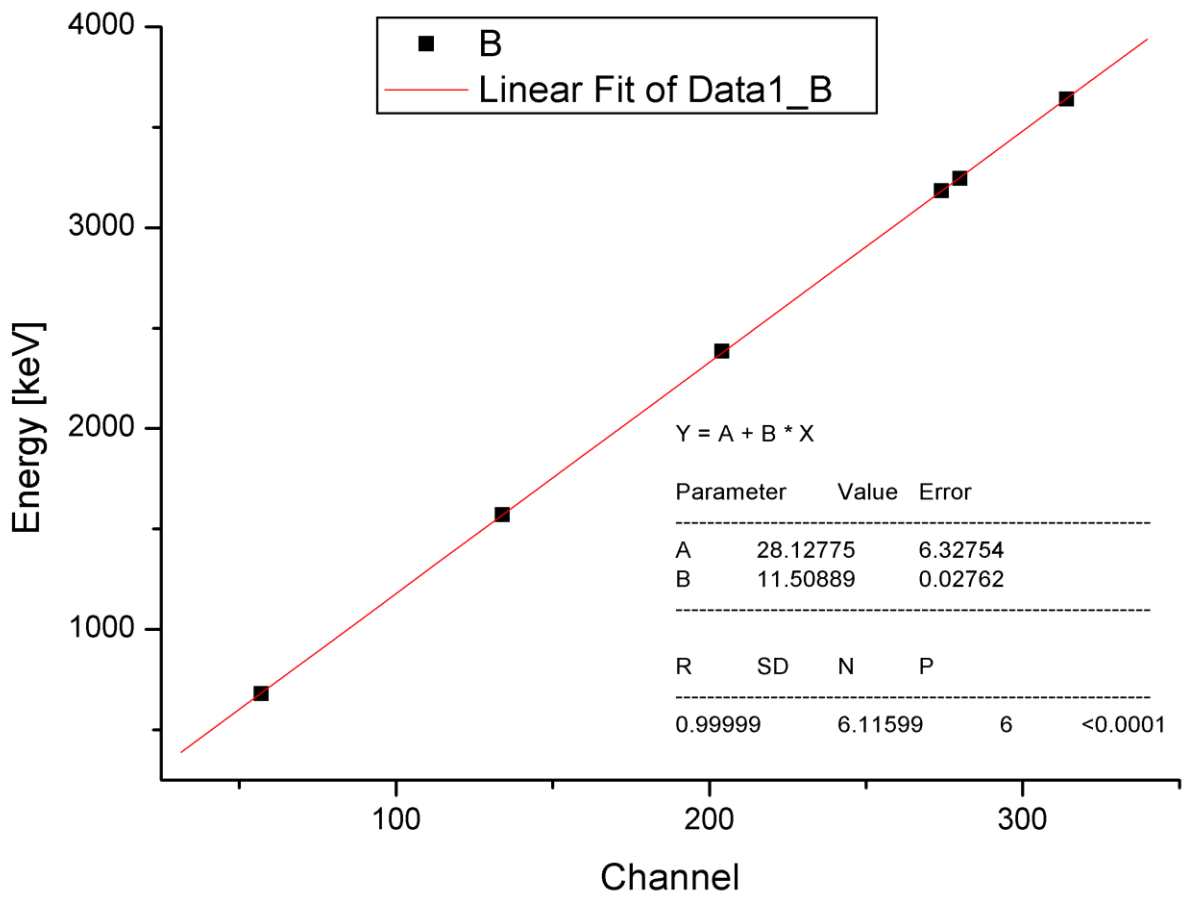
Set of monoelemental samples with smooth surfaces used

$$E_{scatt}\,(\text{surface}) = K\,(M_1, M_2, \theta)\ \ X\ E_{Initial}$$



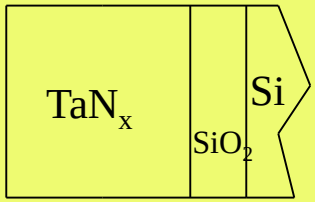

| | A(X) | Energy(Y) | C(Y) |
|---|---|---|---|
| 1 | 314 | 3639 | Ta |
| 2 | 280 | 3245.6 | Rh |
| 3 | 274 | 3183.4 | Mo |
| 4 | – | – | – |
| 5 | 204 | 2385.7 | Ti |
| 6 | 134 | 1570.8 | Si |
| 7 | – | – | – |
| 8 | 57 | 680 | O |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |

$$E_{scatt}\,(\text{surface}) = K\,(M_1, M_2, \theta)\ \ X\ E_{Initial}$$

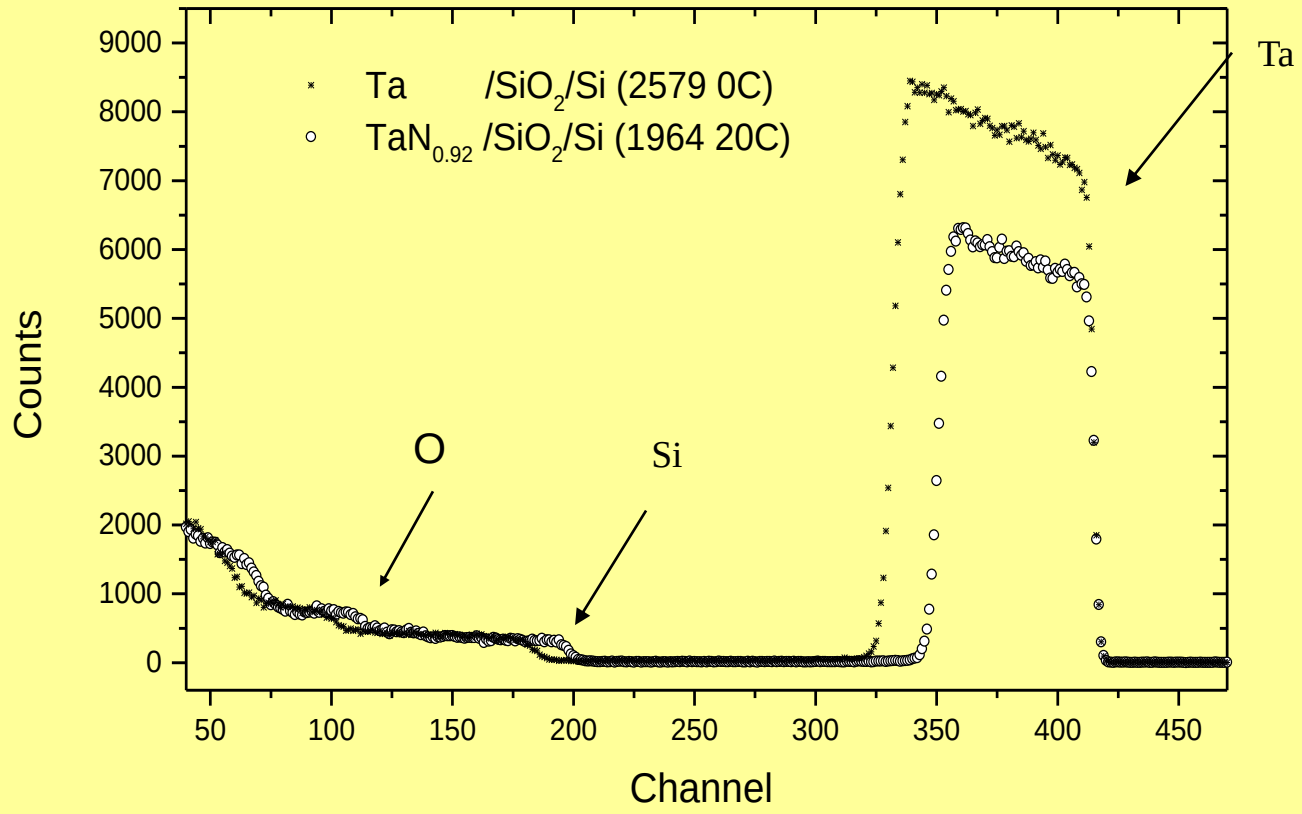



E = 11.509 keV/channel x NoOfChannel + 28.1 keV

5. Examples




Thickness $TaN_x$
200nm- 400nm



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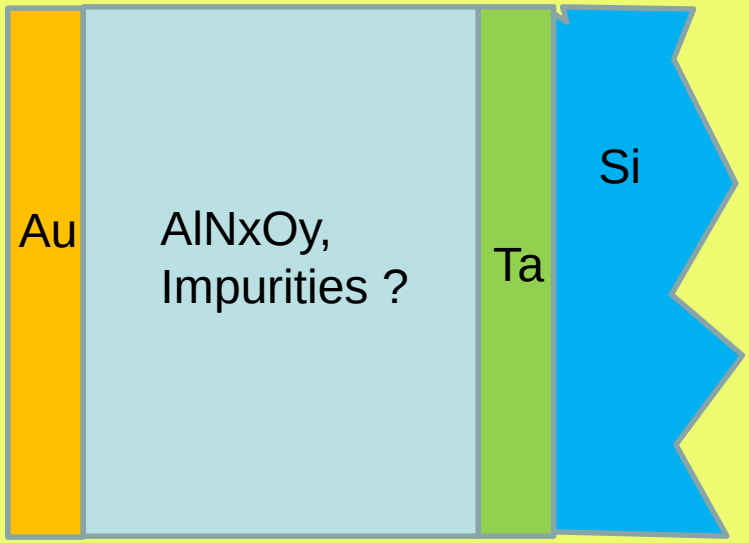
# A round robin characterisation of the thickness and composition of thin to ultra-thin AlNO films

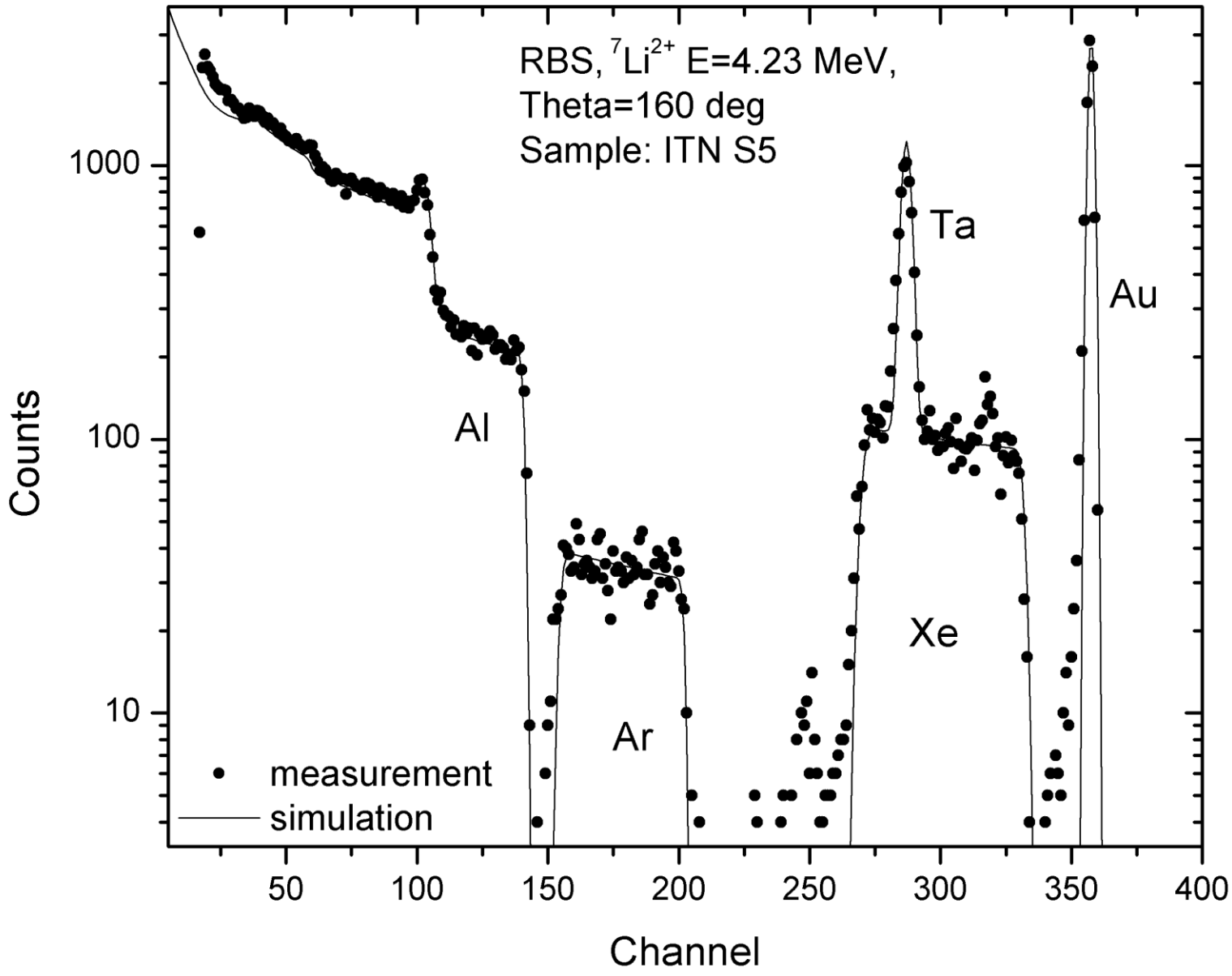
N.P. Barradas [a,b,*], N. Added [c], W.M. Arnoldbik [d], I. Bogdanović-Radović [e], W. Bohne [f], S. Cardoso [g], C. Danner [h], N. Dytlewski [i], P.P. Freitas [g], M. Jakšić [e], C. Jeynes [j], C. Krug [k], W.N. Lennard [l], S. Lindner [f], Ch. Linsmeier [h], Z. Medunić [e], P. Pelicon [m], R.P. Pezzi [k], C. Radtke [k], J. Röhrich [f], T. Sajavaara [n], T.D.M. Salgado [o], F.C. Stedile [o], M.H. Tabacniks [c], I. Vickridge [p]

Wafer S5: etch/ Ta 2nm/ AlNxOy  nm/ Au 2nm



Simulation:

SIMNRA software, author Matej Mayer, IPP Garching


RBS, $^{7}Li^{2+}$ E=4.23 MeV,
Theta=160 deg
Sample: ITN S5
Counts
Channel
1000
100
10
50
100
150
200
250
300
350
400
Al
Ar
Xe
Ta
Au
measurement
simulation

Thank you for your attention.