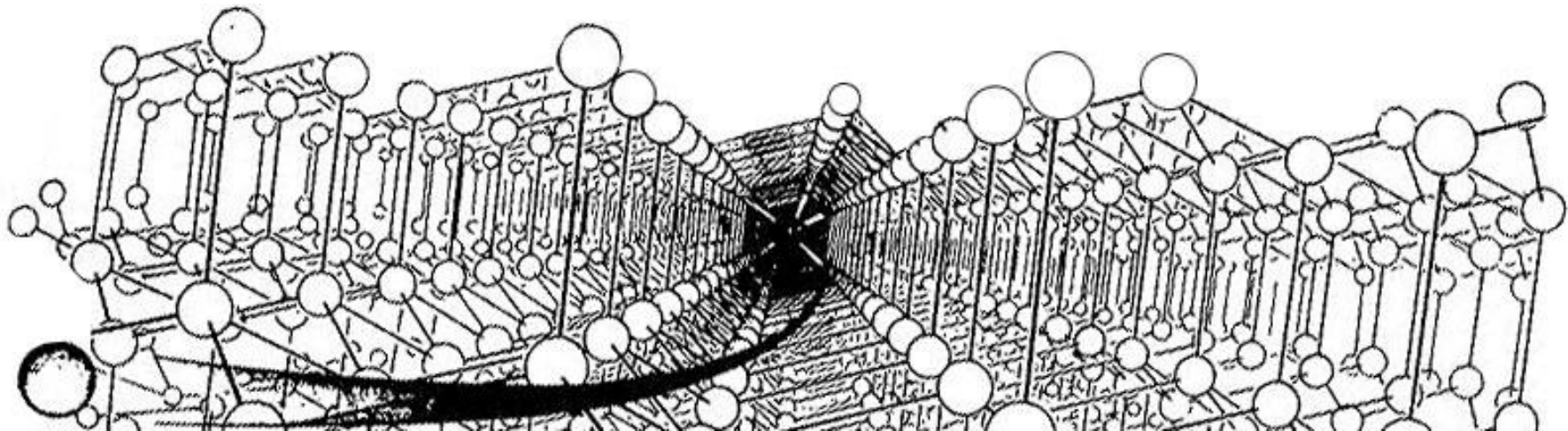


Samostalni seminar iz istraživanja u fizici

# Mjerenje defekata u kristalnim materijalima pomoću RBS metode u kanalirajućem modu

Ana Petrinec

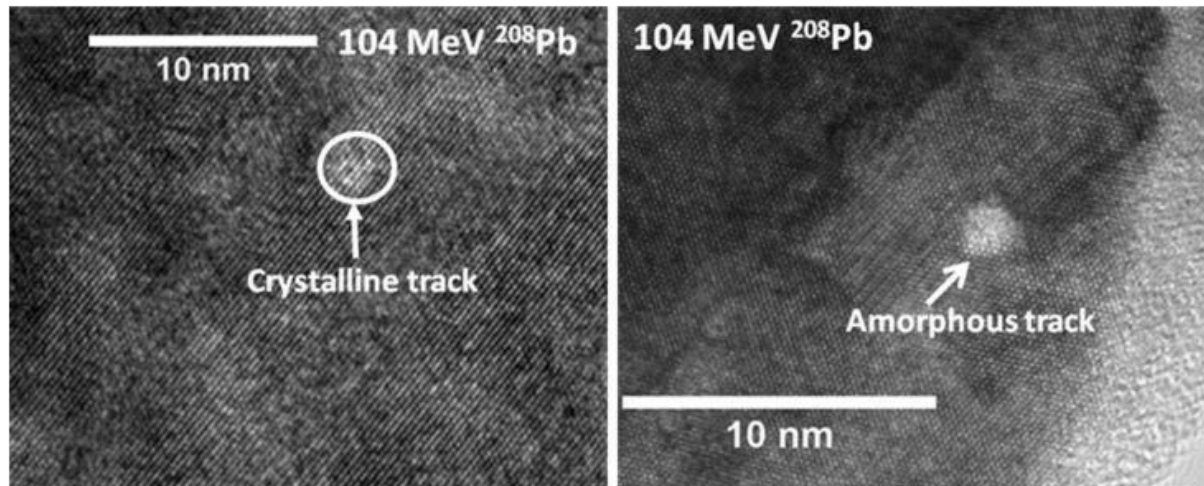
Mentor: Stjepko Fazinić



# Proučavanje defekata u materijalima

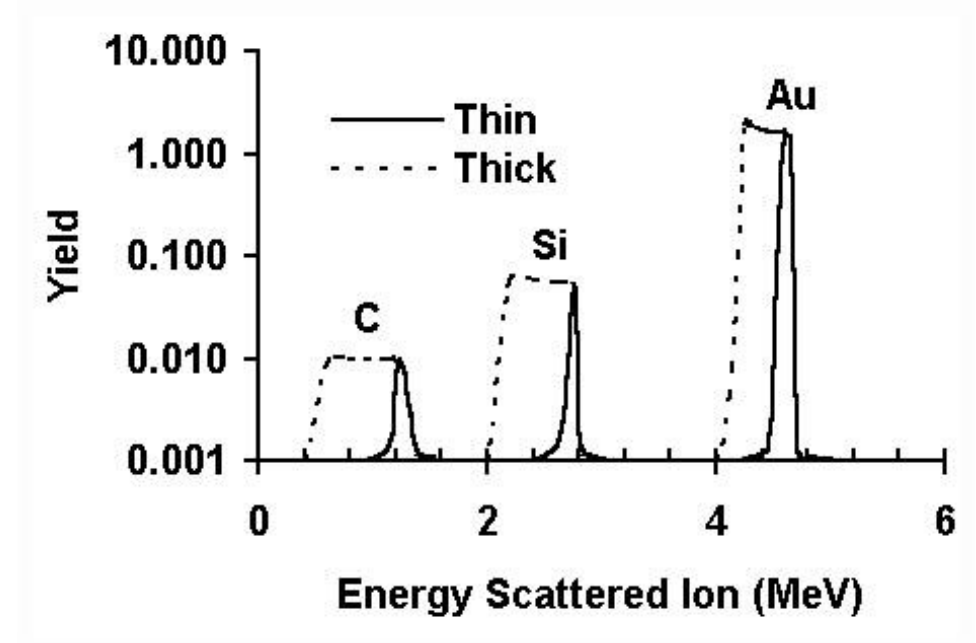
## DIREKTNE METODE

- AFM → „slika” površine
- TEM

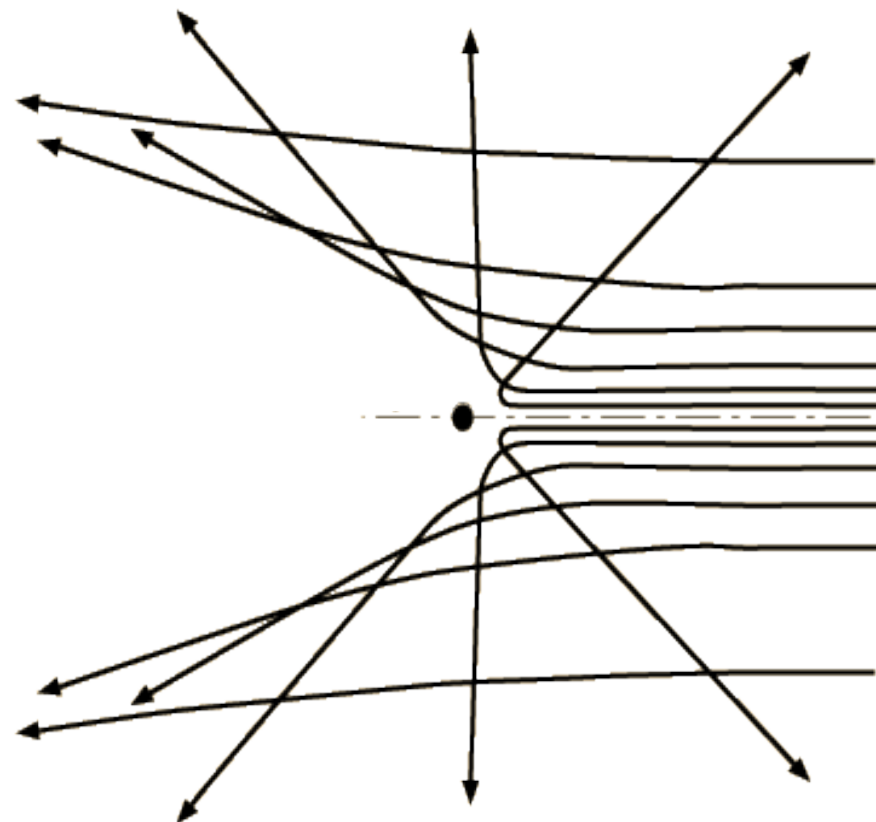
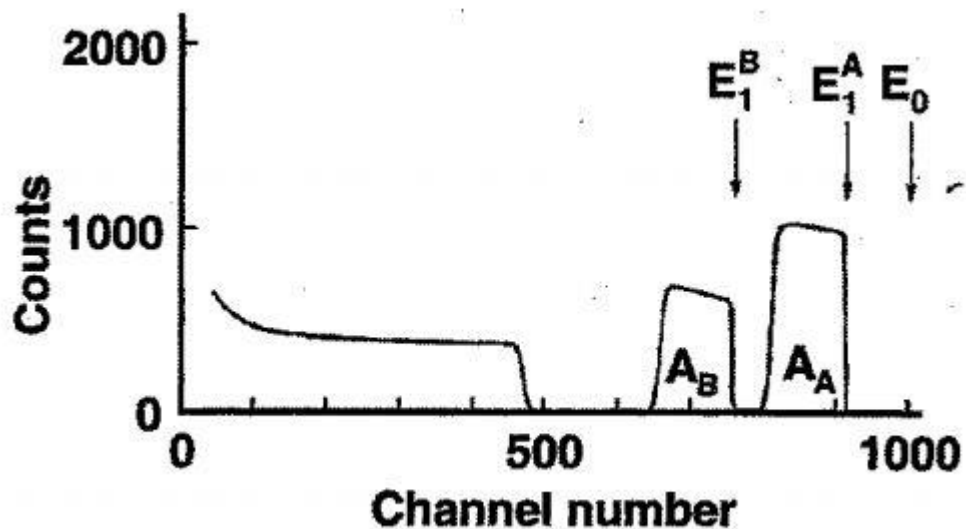
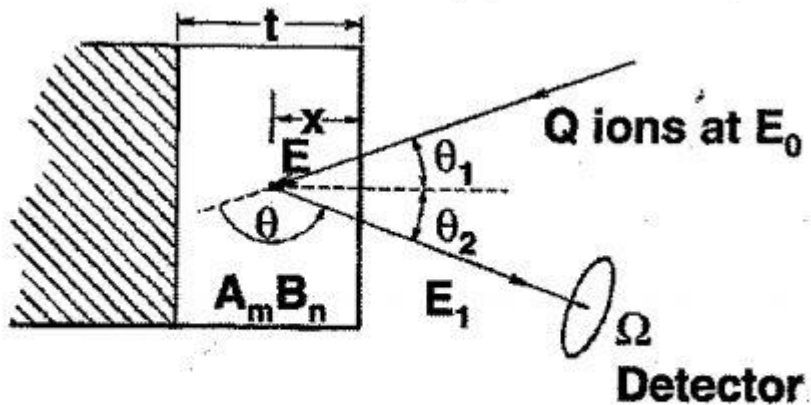


## INDIREKTNE METODE

- RBS i RBS/c → gubi se zor, ali podaci spremni za statističku obradu

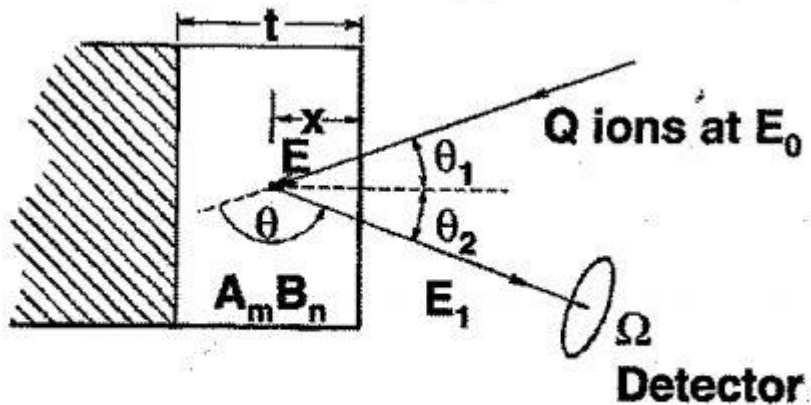


# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)

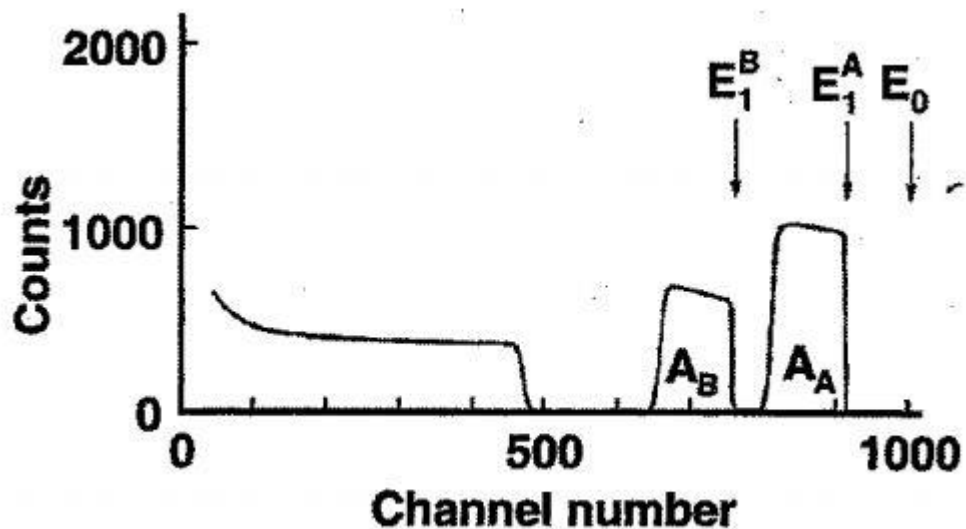


$$\text{Energija} = \alpha \cdot \text{kanal} + \beta$$

# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)

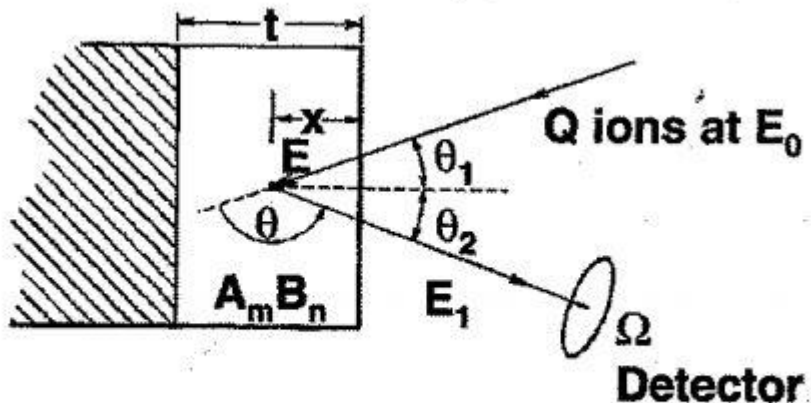


$$K \equiv \frac{E_1}{E_0} = \left( \frac{\sqrt{M_2^2 - M_1^2 \sin^2 \theta} + M_1 \cos \theta}{M_1 + M_2} \right)^2$$



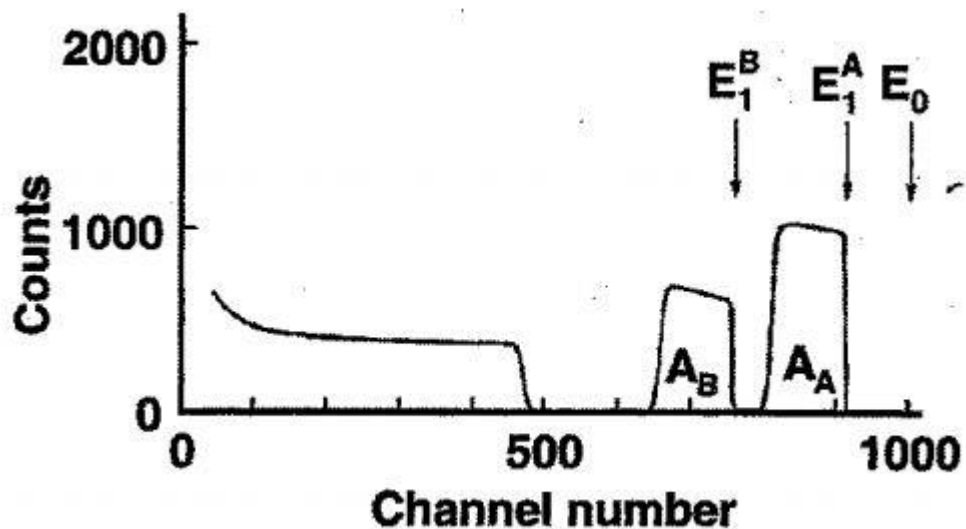
$$\text{Energija} = \alpha \cdot \text{kanal} + \beta$$

# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)



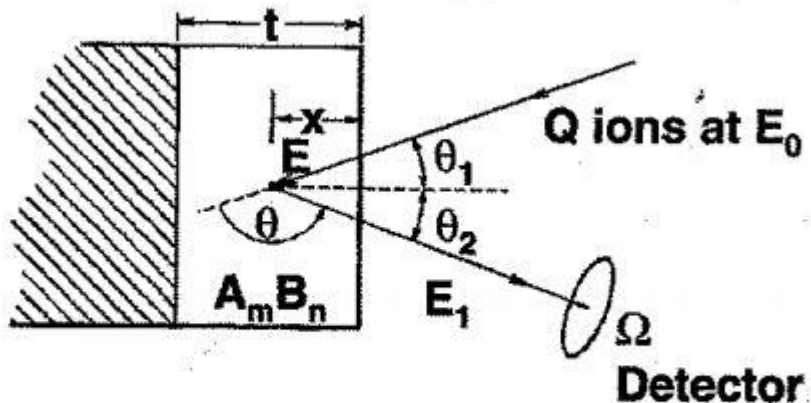
$$\theta = \pi - |\theta_1 \pm \theta_2|$$

$$K \equiv \frac{E_1}{E_0} = \left( \frac{\sqrt{M_2^2 - M_1^2 \sin^2 \theta} + M_1 \cos \theta}{M_1 + M_2} \right)^2$$



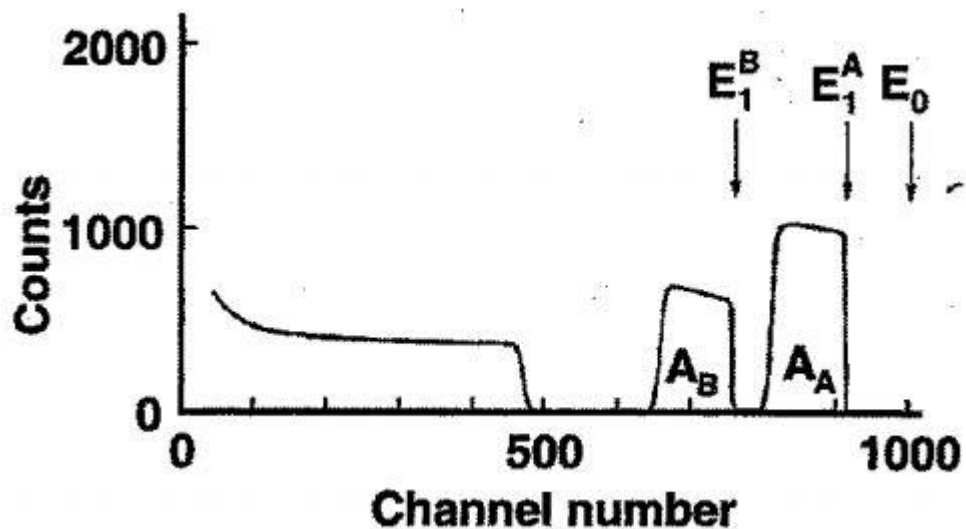
$$\text{Energija} = \alpha \cdot \text{kanal} + \beta$$

# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)



$$\theta = \pi - |\theta_1 \pm \theta_2|$$

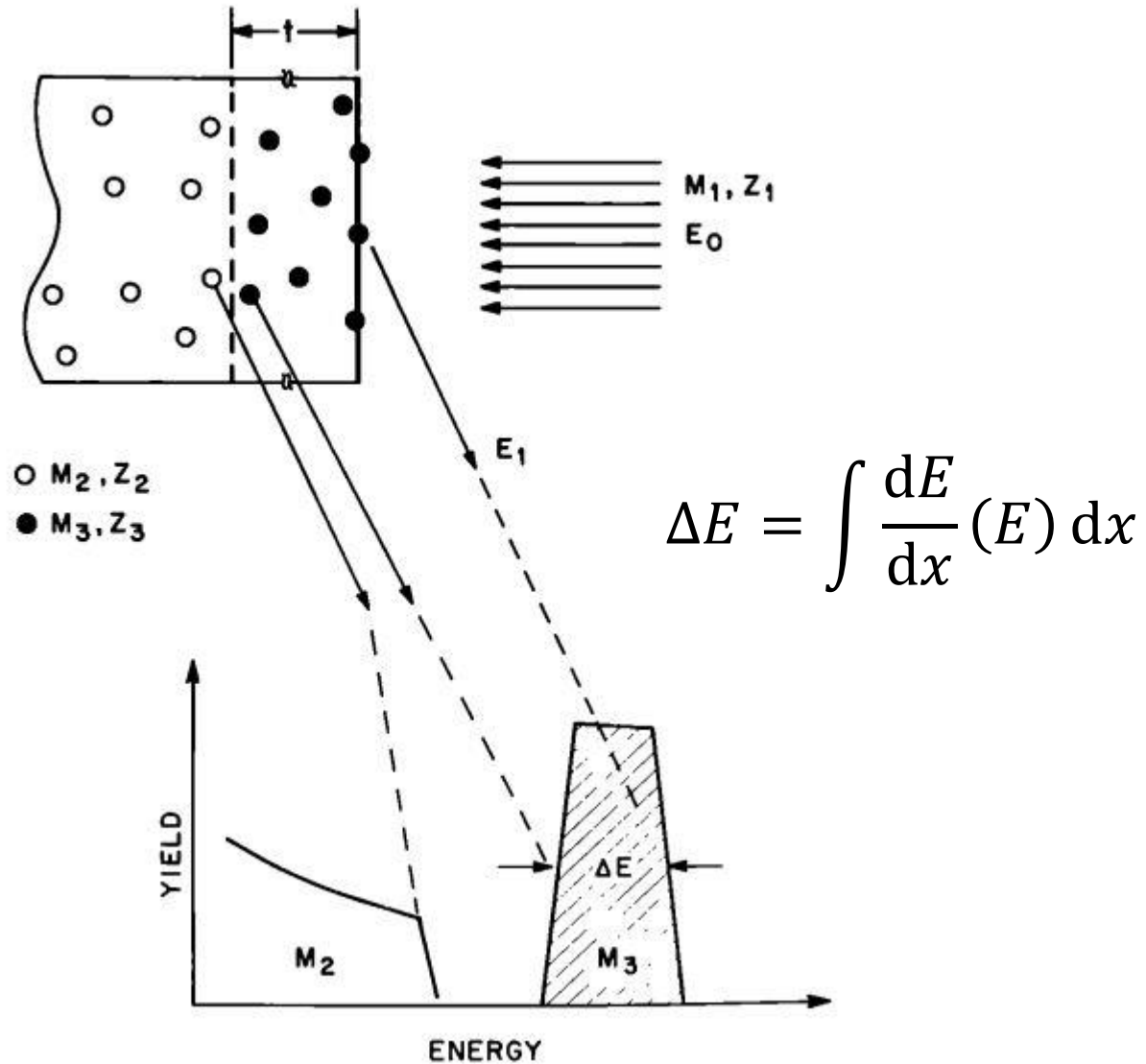
$$K \equiv \frac{E_1}{E_0} = \left( \frac{\sqrt{M_2^2 - M_1^2 \sin^2 \theta} + M_1 \cos \theta}{M_1 + M_2} \right)^2$$



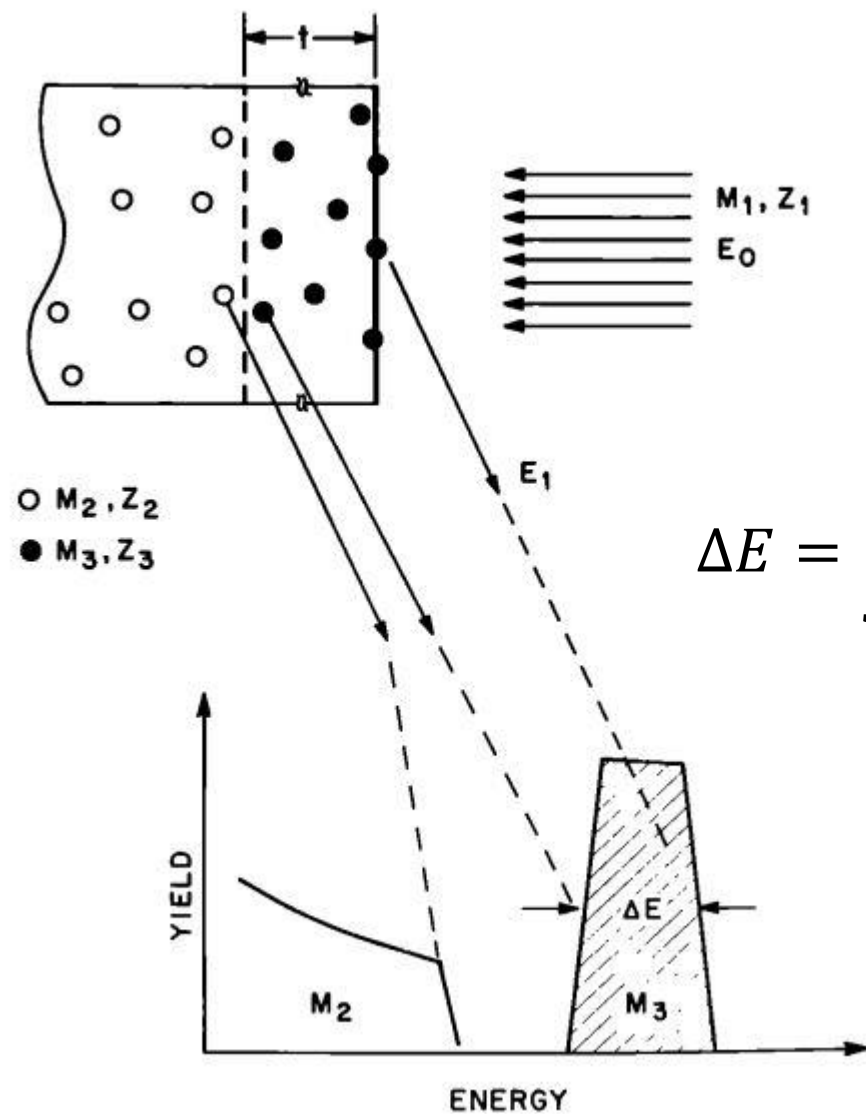
$E_0, M_1$  – energija i masa iona u snopu, zadano  
 $\theta$  – kut raspršenja, zadano geometrijom eksp. postava  
 $E_1$  – očita se iz spektra za signal od interesa  
 $M_2$  – masa jezgre mete – nepoznato!

$$\text{Energija} = \alpha \cdot \text{kanal} + \beta$$

# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)



# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)



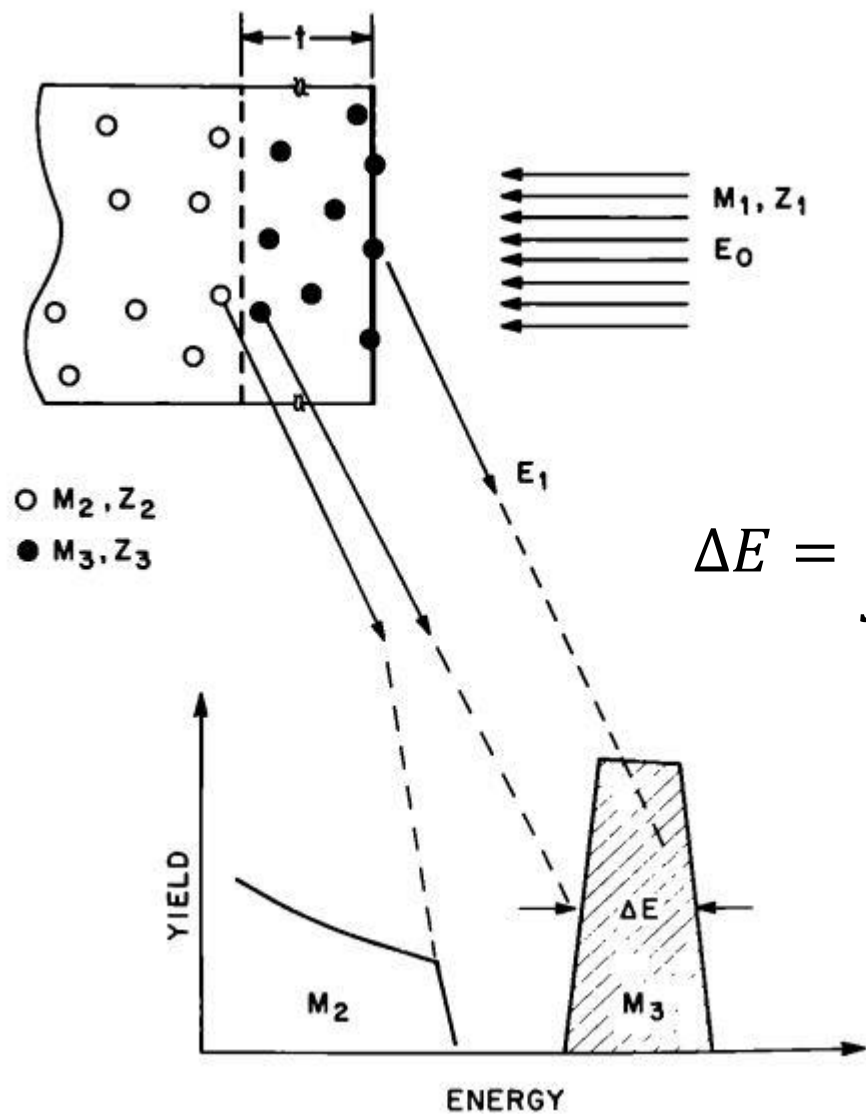
$$\Delta E = \int \frac{dE}{dx} (E) dx$$

$$S = - \frac{dE}{dx}$$

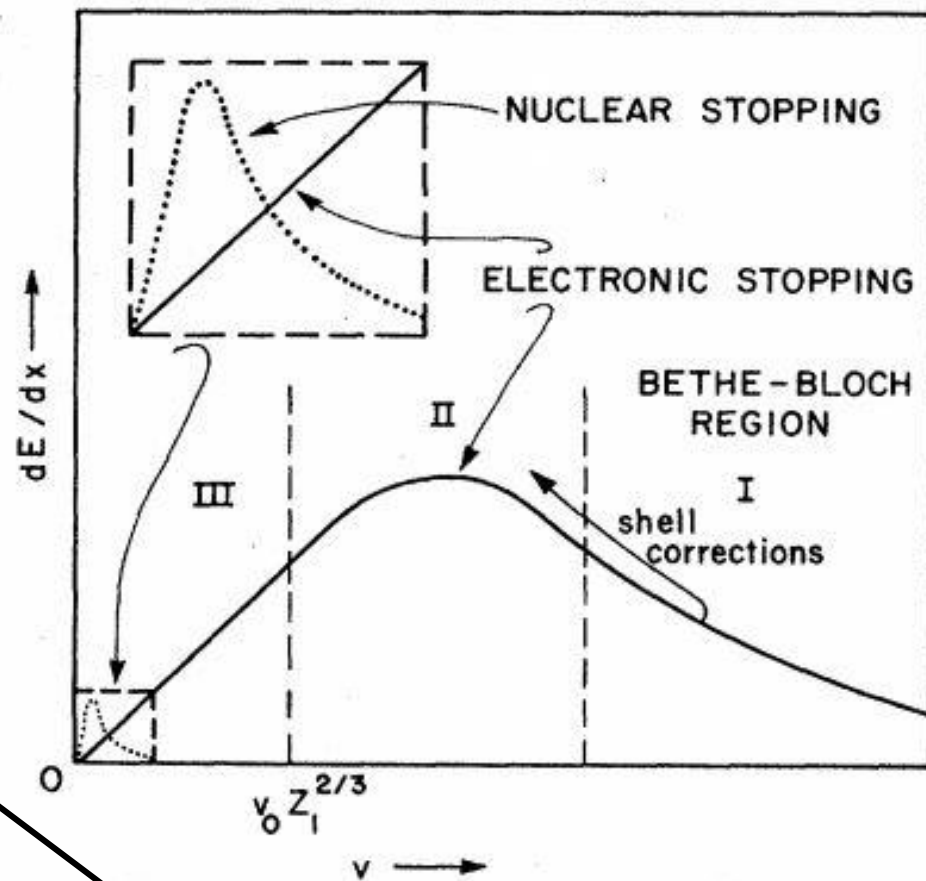
Zaustavna moć  
(stopping power)



# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)



$$\Delta E = \int \frac{dE}{dx} (E) dx$$



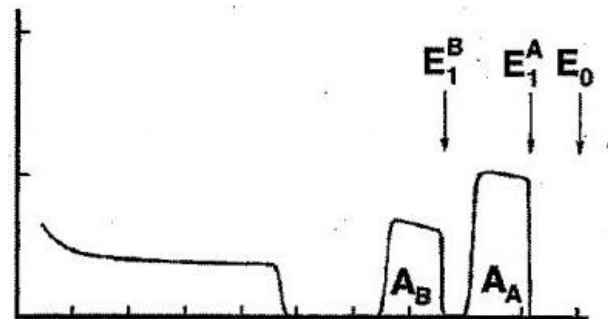
$$S = - \frac{dE}{dx}$$

Zaustavna moć  
(stopping power)

# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)

Određivanje  
stehiometrije  
uzorka:

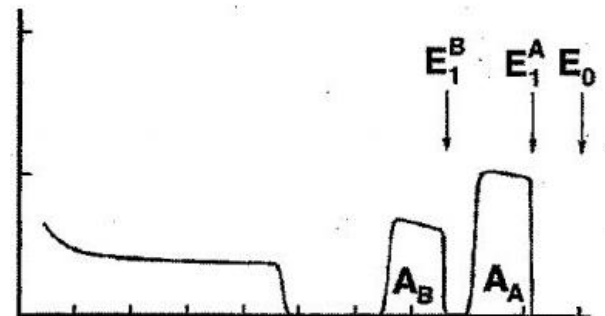
$$\frac{n}{m} = \frac{A_B}{A_A} \cdot \frac{\sigma_A(E, \theta)}{\sigma_B(E, \theta)}$$



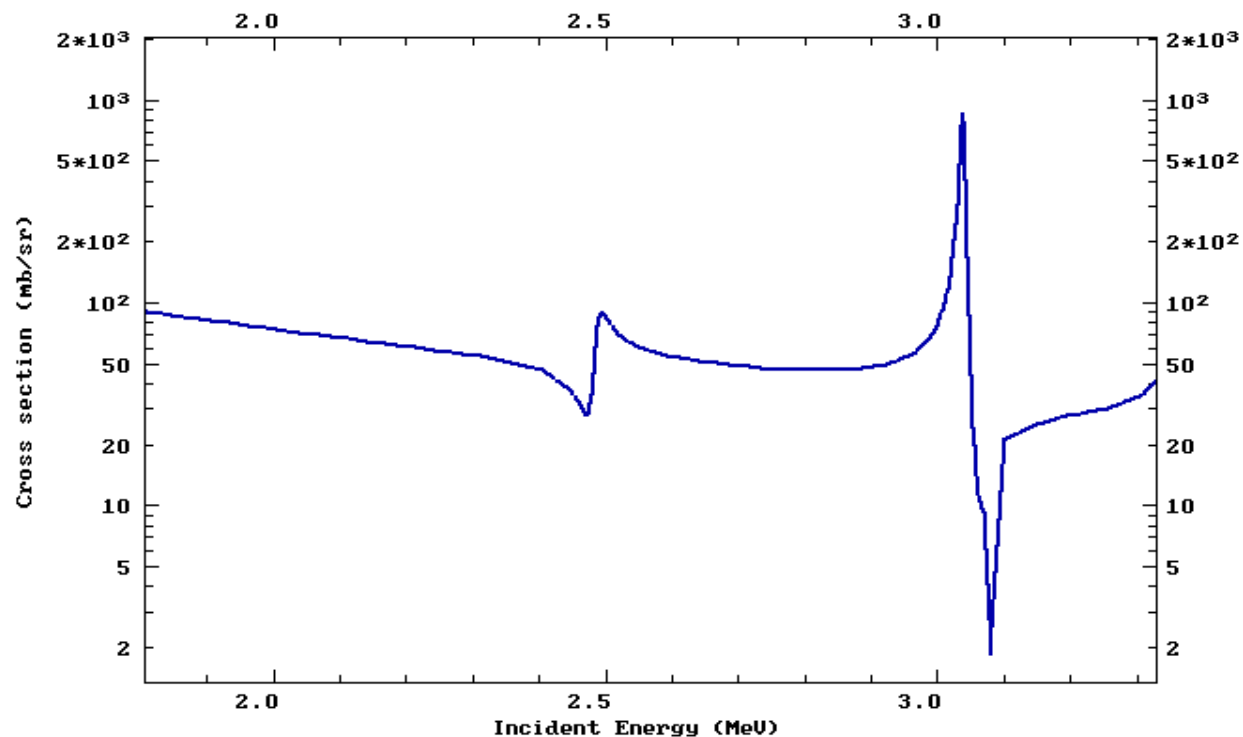
# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)

Određivanje  
stehiometrije  
uzorka:

$$\frac{n}{m} = \frac{A_B}{A_A} \cdot \frac{\sigma_A(E, \theta)}{\sigma_B(E, \theta)}$$



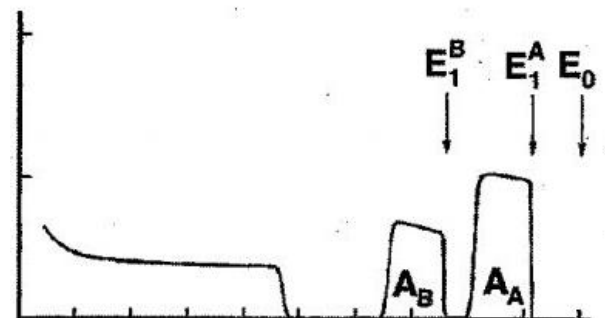
IBANDL, 2018/01/23, 18:22:13  
SigmaCalc, 160(a,a0)160 170.0deg.



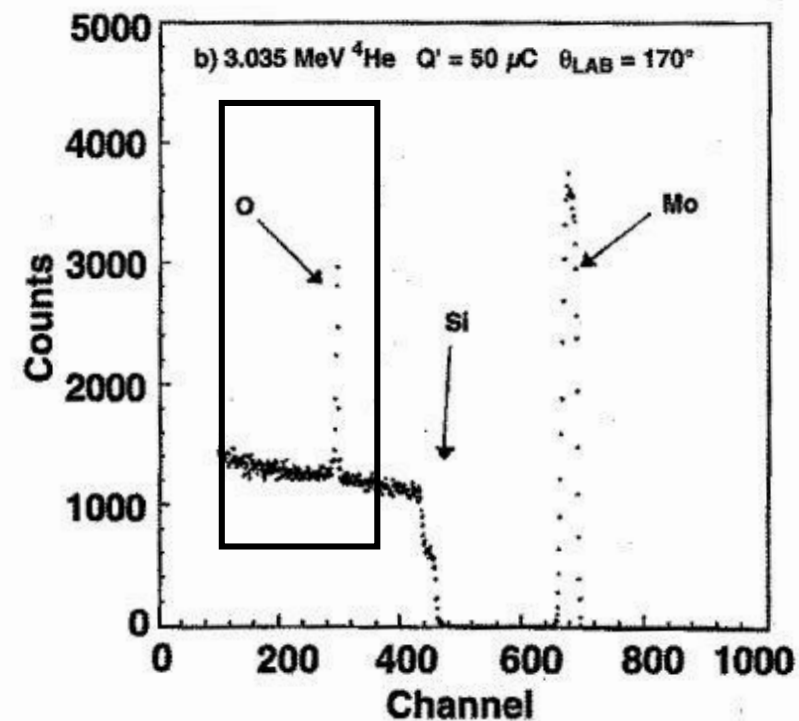
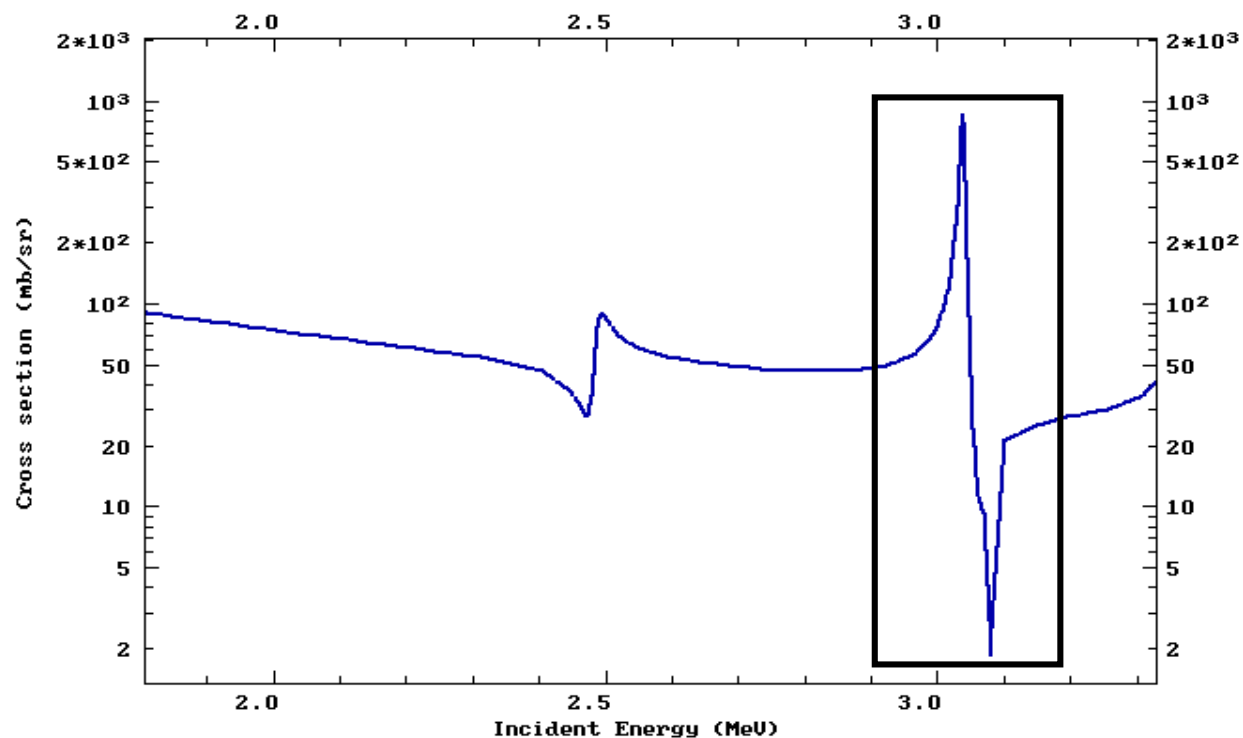
# Rutherfordova spektroskopija unatrag raspršenih iona (RBS)

Određivanje  
stehiometrije  
uzorka:

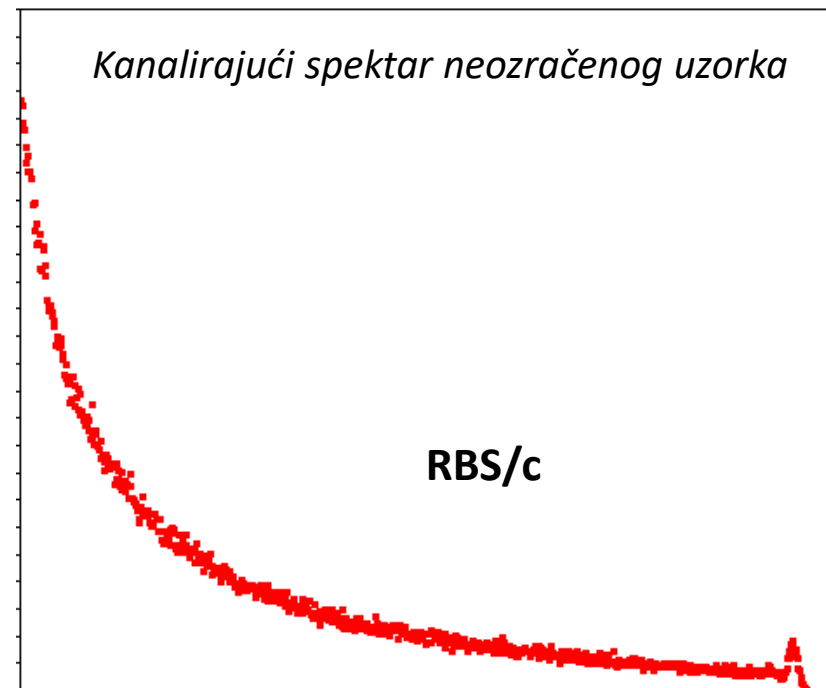
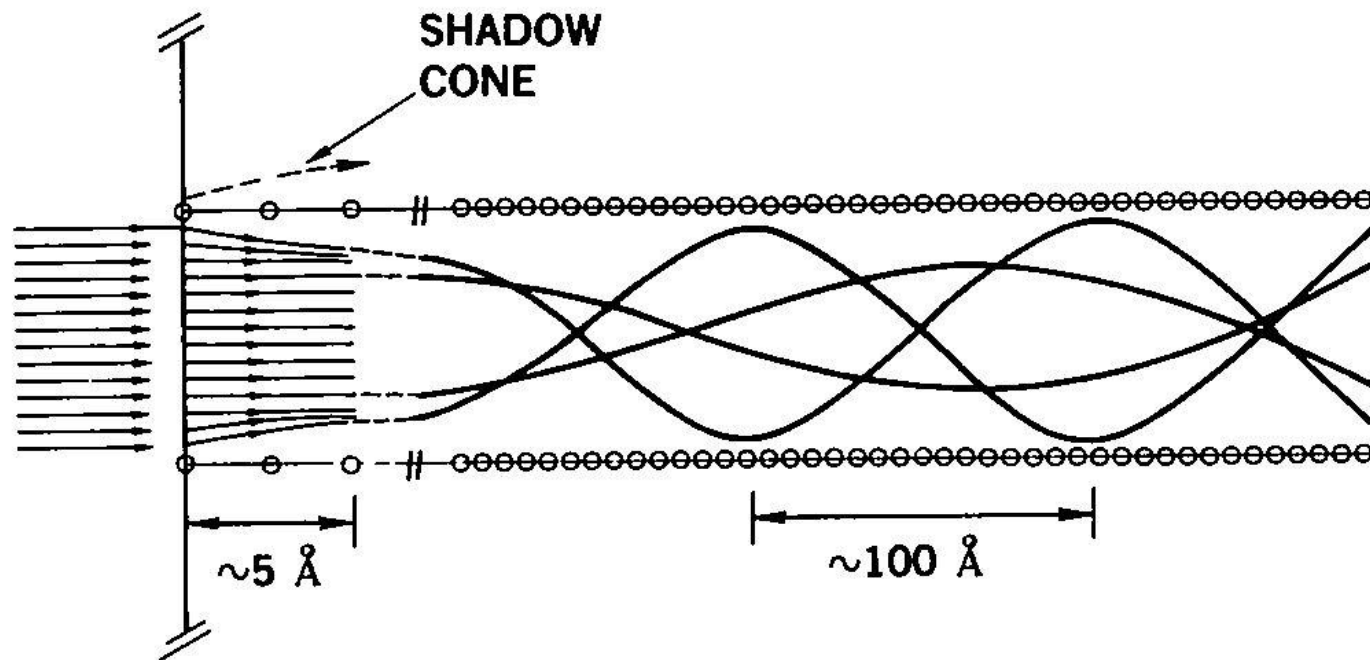
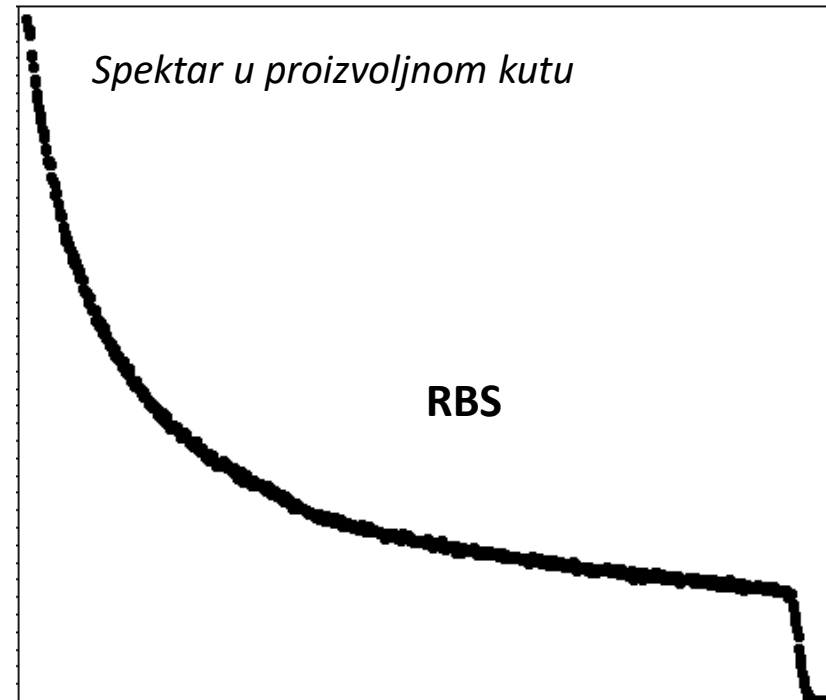
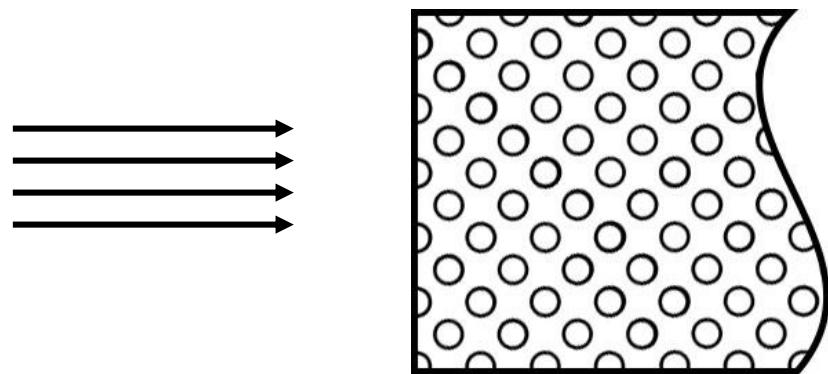
$$\frac{n}{m} = \frac{A_B}{A_A} \cdot \frac{\sigma_A(E, \theta)}{\sigma_B(E, \theta)}$$



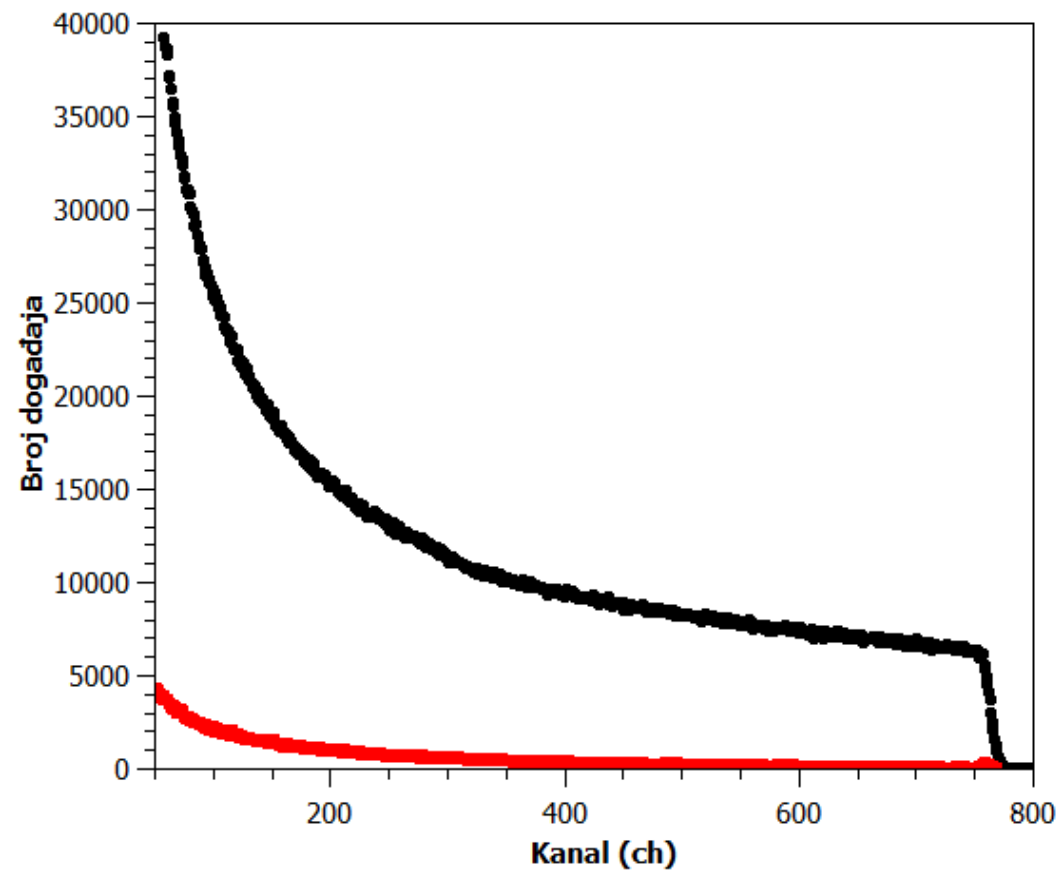
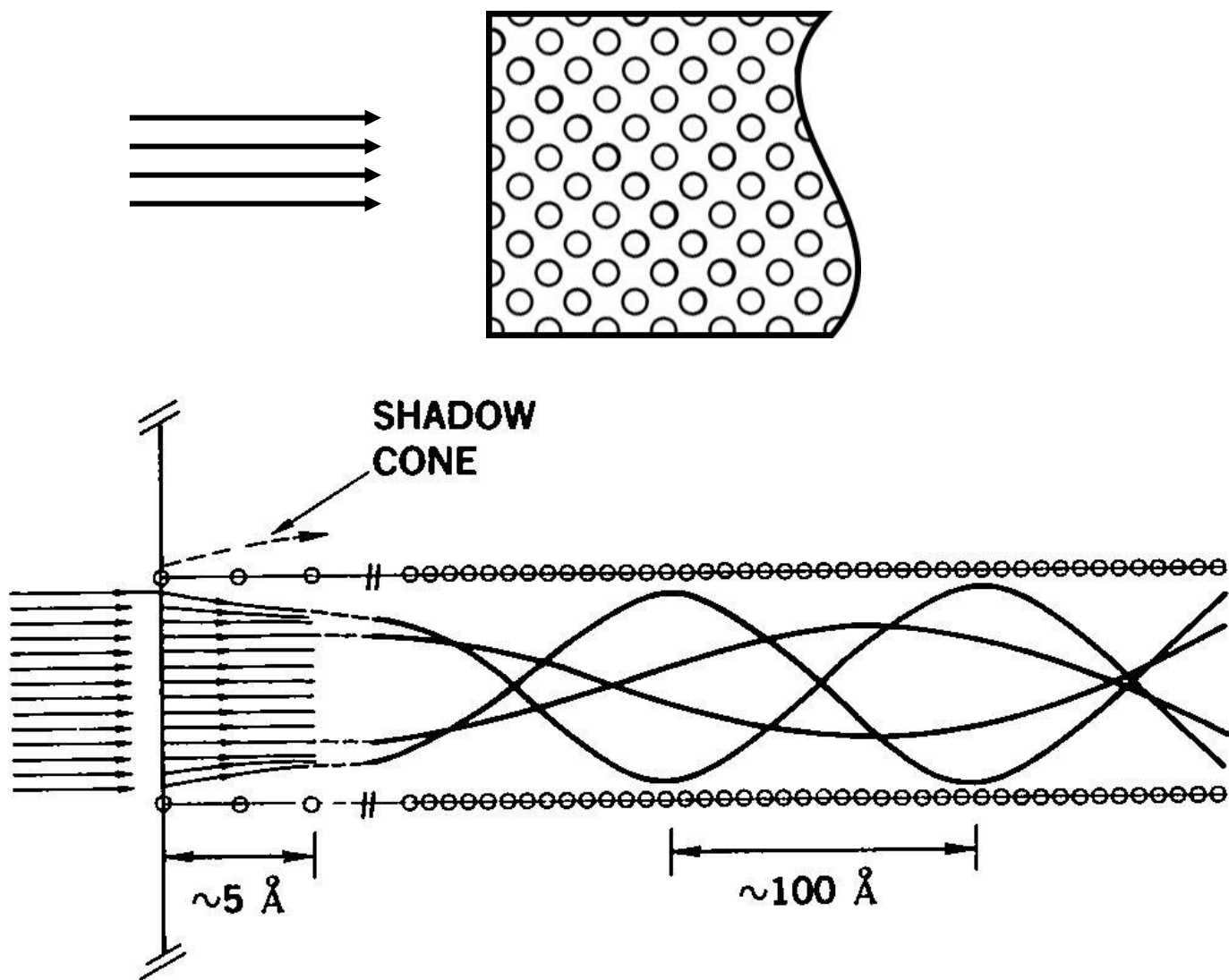
IBANDL, 2018/01/23, 18:22:13  
SigmaCalc, 160(a,a0)160 170.0deg.



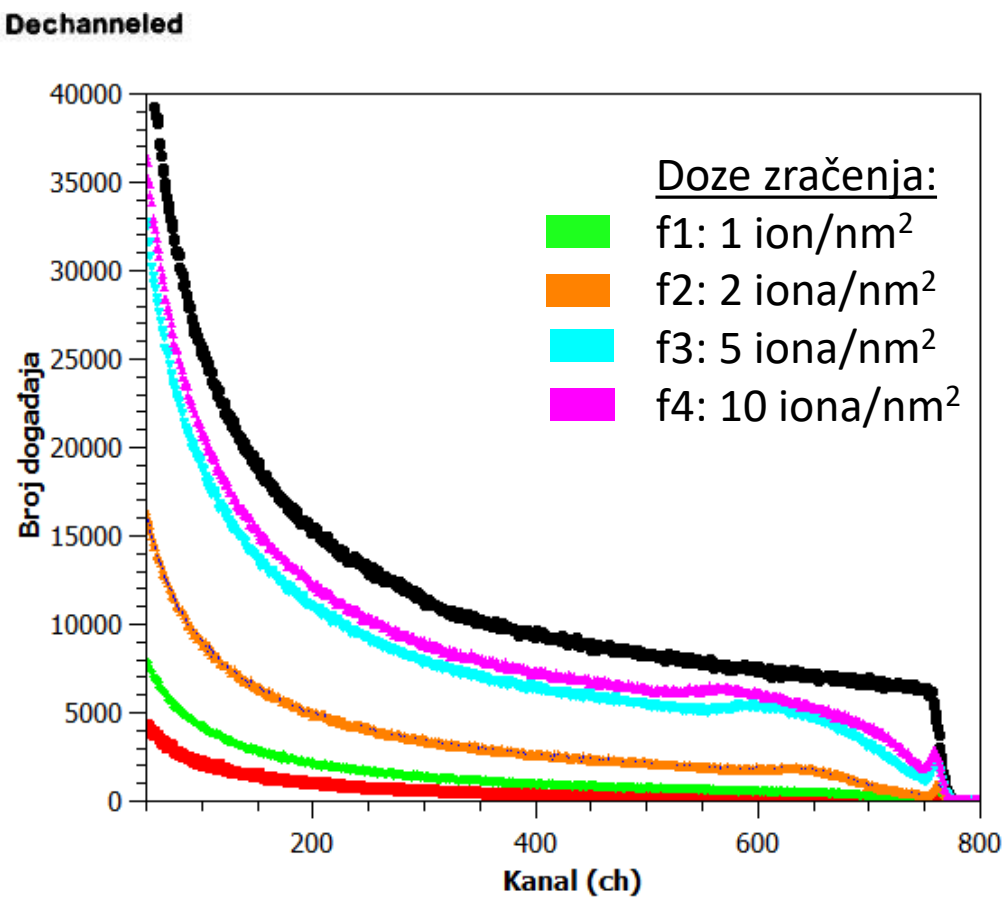
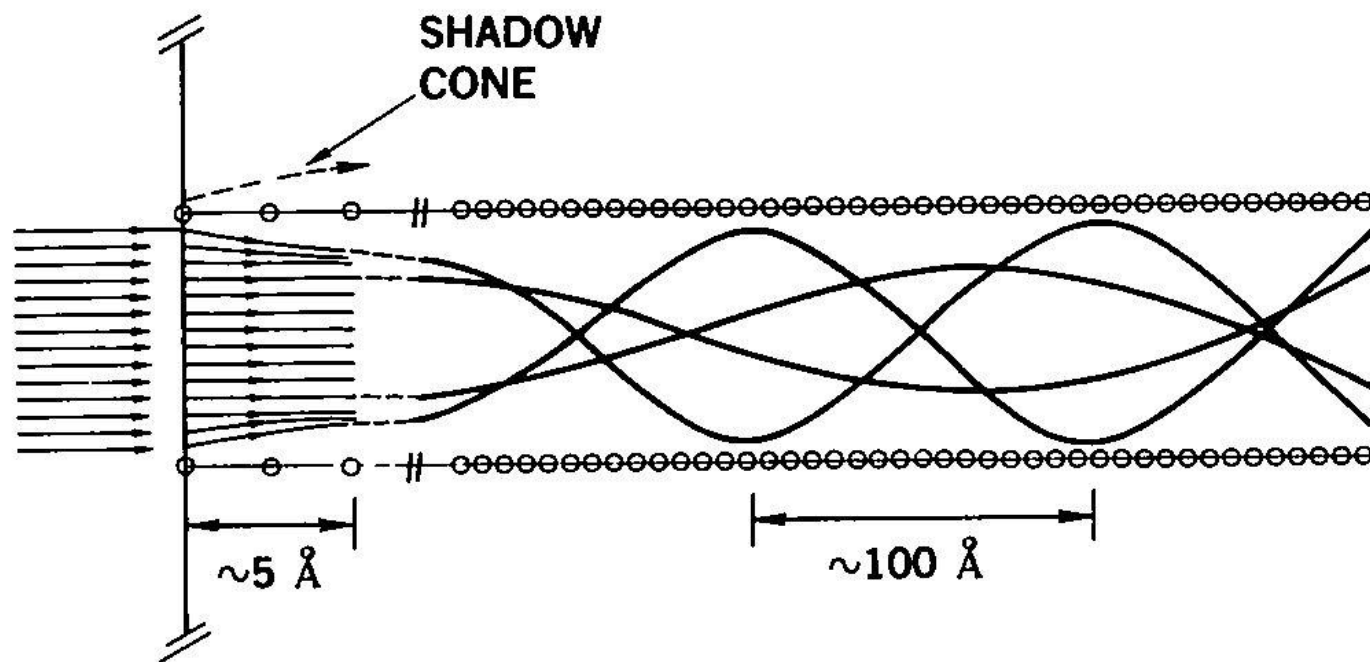
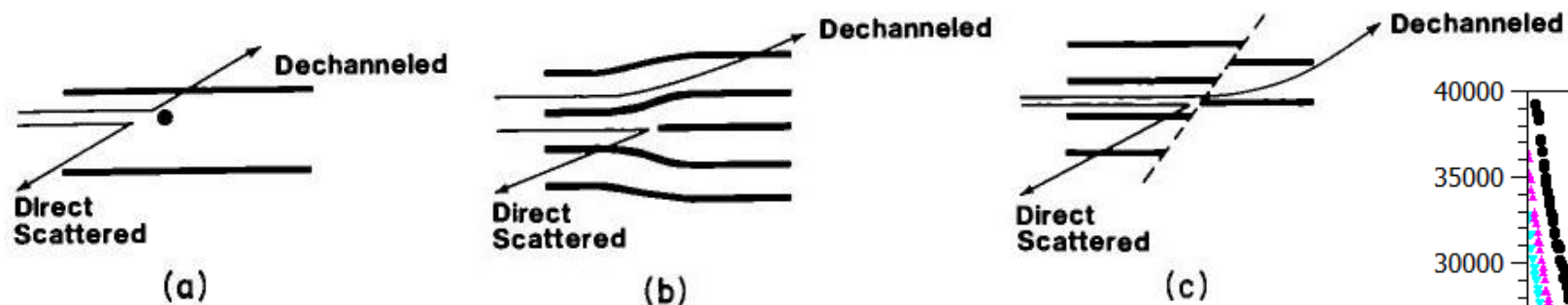
# Kanaliranje i RBS/c



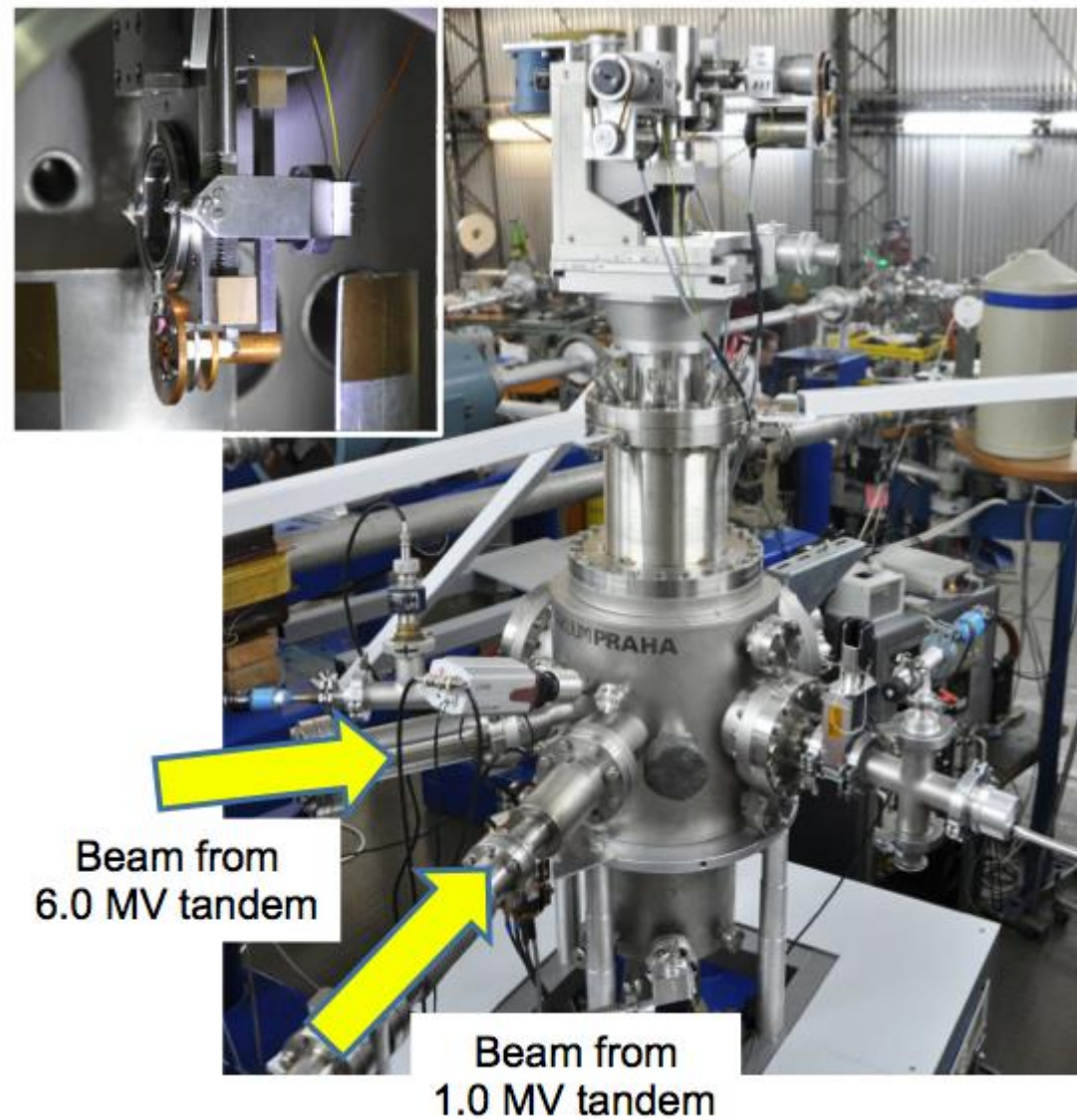
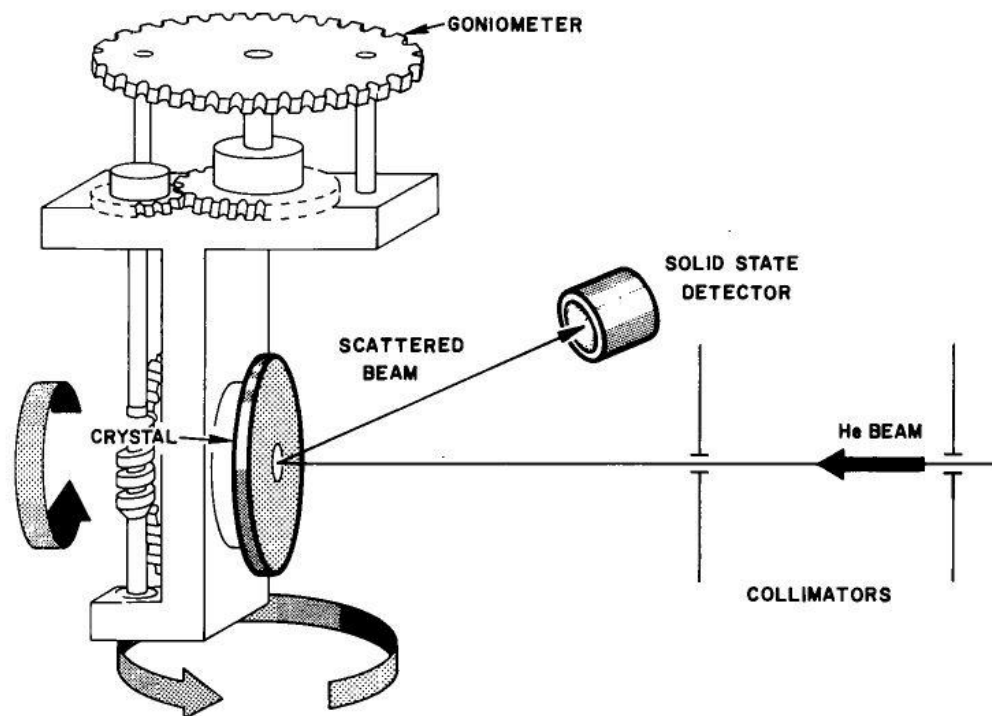
# Kanaliranje i RBS/c



# Kanaliranje i RBS/c

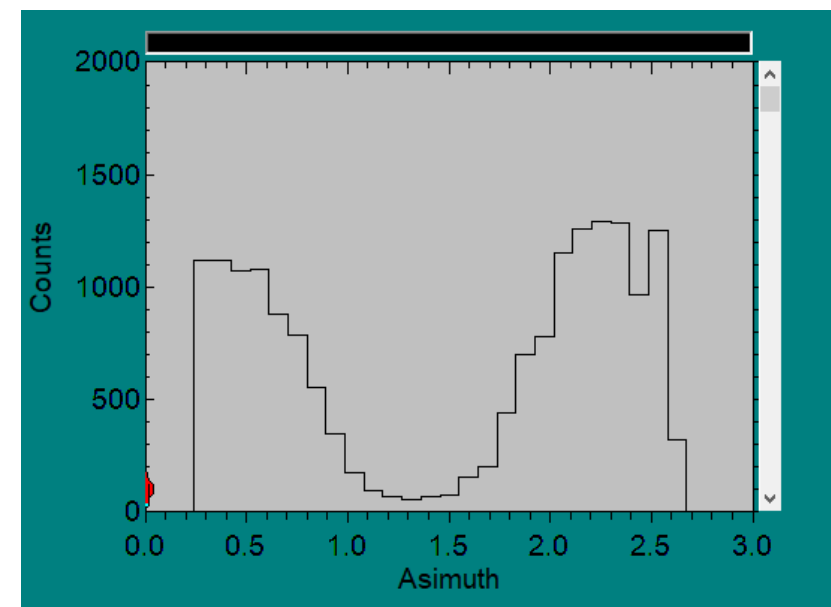
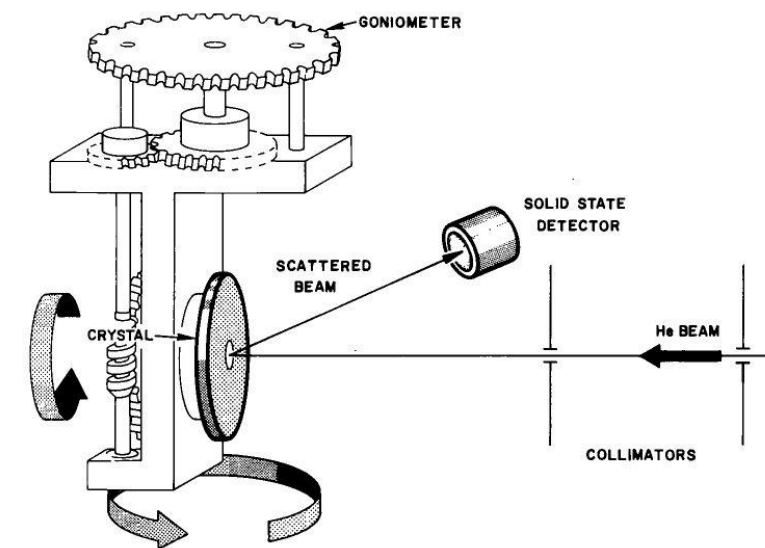
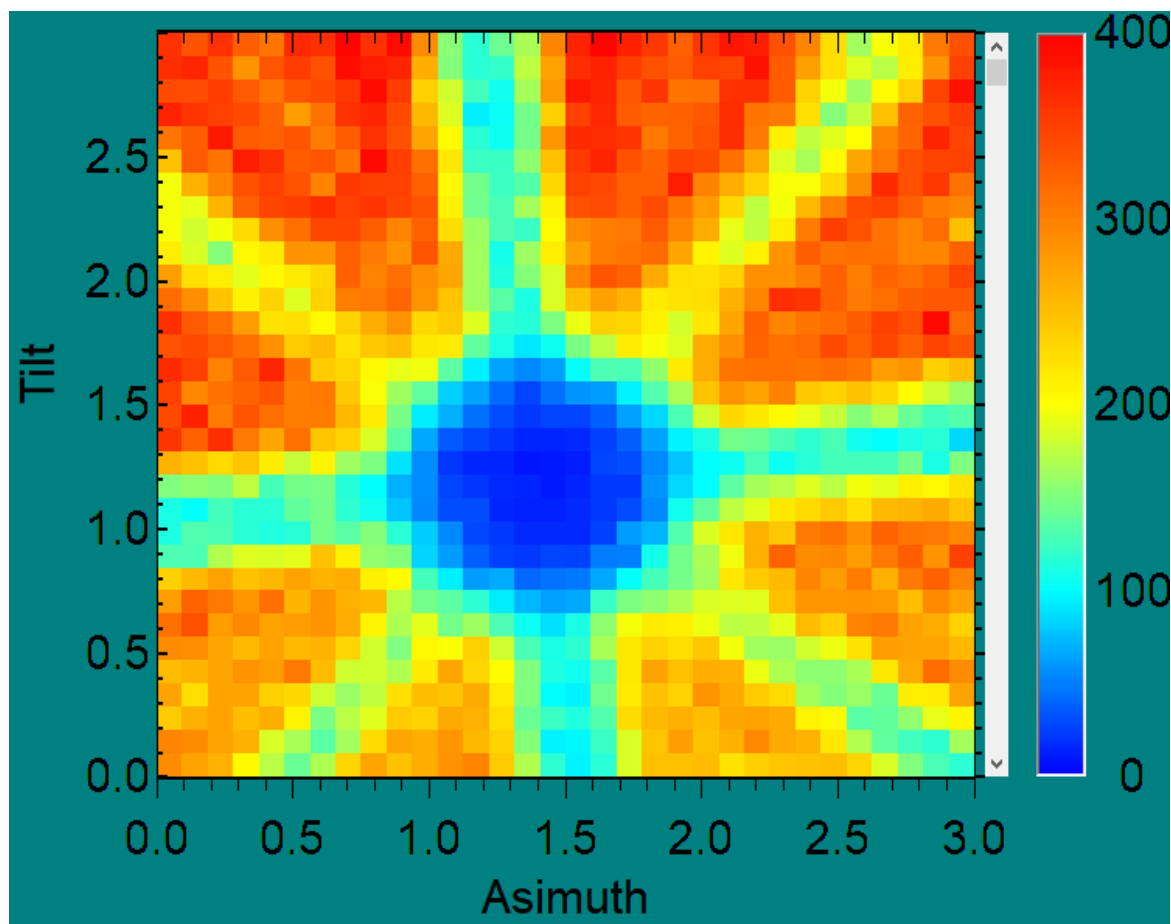


# Provedba RBS/c experimenta



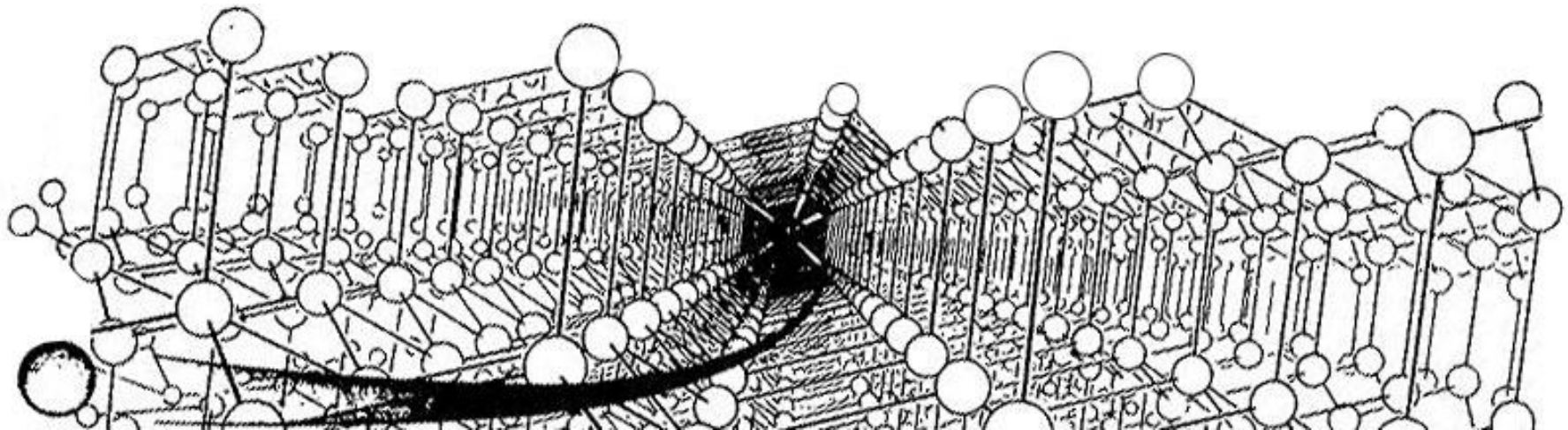


# Provedba RBS/c eksperimenta

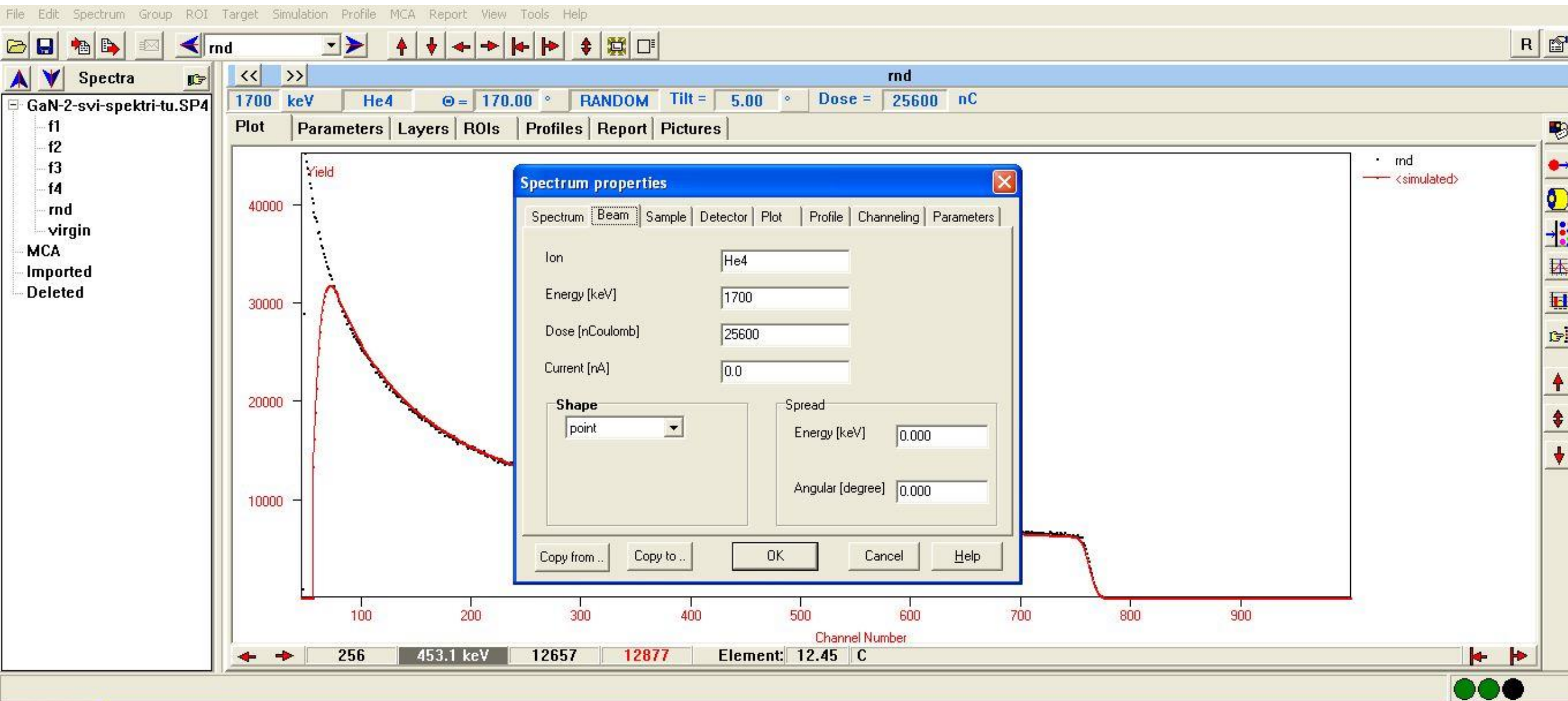


Slijed mjerenja: RBS, RBS/c na neozračenom uzorku, RBS, RBS/c na ozračenom uzorku, RBS

# Analiza spektara



# RBX – program za simulaciju i analizu spektara



# RBX – program za simulaciju i analizu spektara

The screenshot displays the RBX software interface. The main window is titled "f2" and shows simulation parameters: 1700 keV, He4,  $\theta = 170.00^\circ$ , C\_AXIS, Tilt =  $5.00^\circ$ , and Dose = 25600 nC. The "Parameters" tab is active, showing the layer structure for "layer-f2.LAY".

**Layer Structure:**

```
r=3.186
points, Ga69, 0.06
points, N14, 0.06

!sloj15
a=3000
Ga69,0.5
N14,0.5
c=ZnS
o=<001>
r=3.186
points, Ga69, 0.055
points, N14, 0.055

!supstrat
s=
Ga69,0.5
N14,0.5
c=ZnS
o=<001>
r=3.186
```

**Format of Layers:**

- START LAYER WITH IT'S THICKNESS
- d= 1e18 => thickness in at/cm2
- a= 1000 => thickness in A
- m= 1 => thickness in micrometer
- g= 2.33 => thickness in microg/cm2
- s= => substrate

**PARAMETERS OF LAYERS**

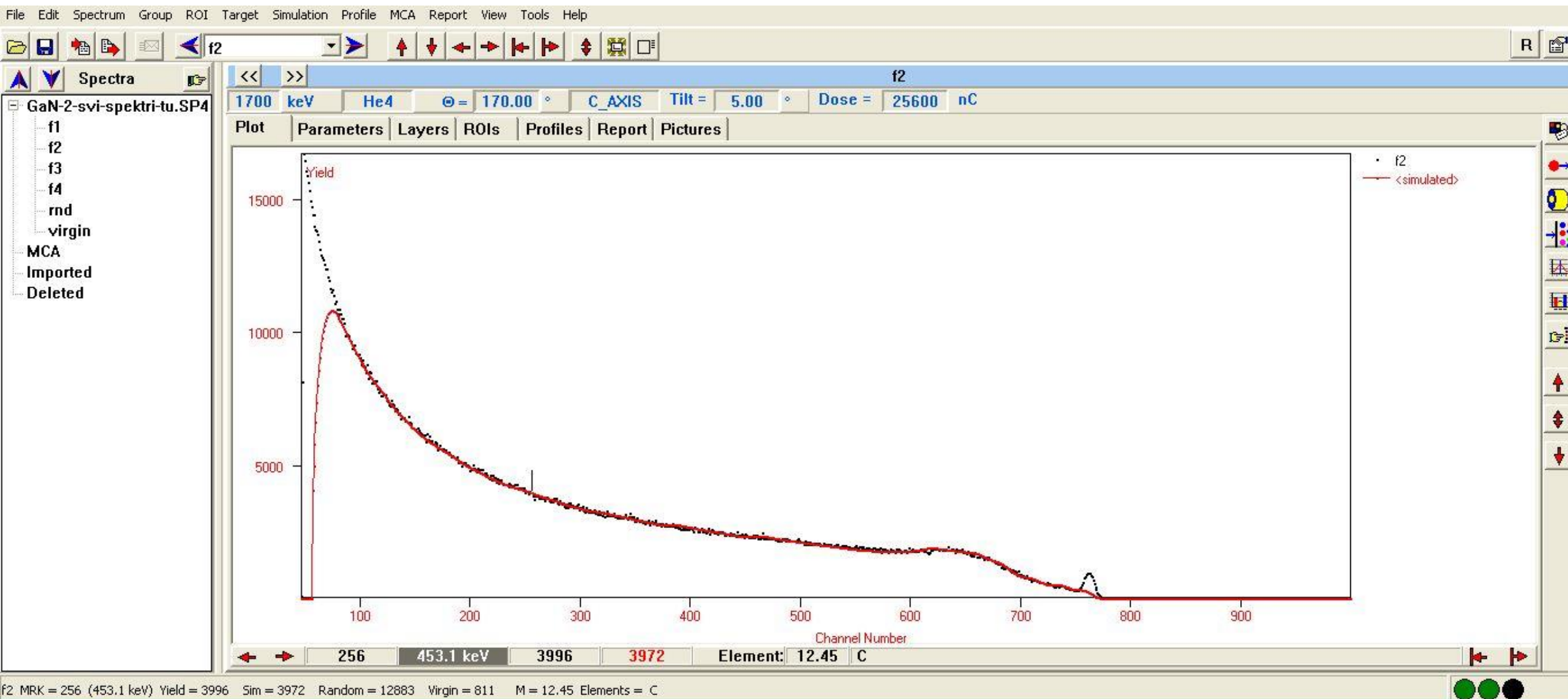
- n= 1e22 => density of layer in at/cm3
- n= 1.23 => density in g/cm3 [value < 100]
- t= 543 => Debye temperature in K
- c= fcc => Crystal type (fcc,bcc,diamond NaCl,ROCKSALT,CaF2,FLUORITE ZnS,ZINCBLLENDE,CsCl,2H,4H,6H)
- o=<100> => Orientation of the layer
- R= 5.43 => Crystal parameter in Angstroms

**COMPOSITION**

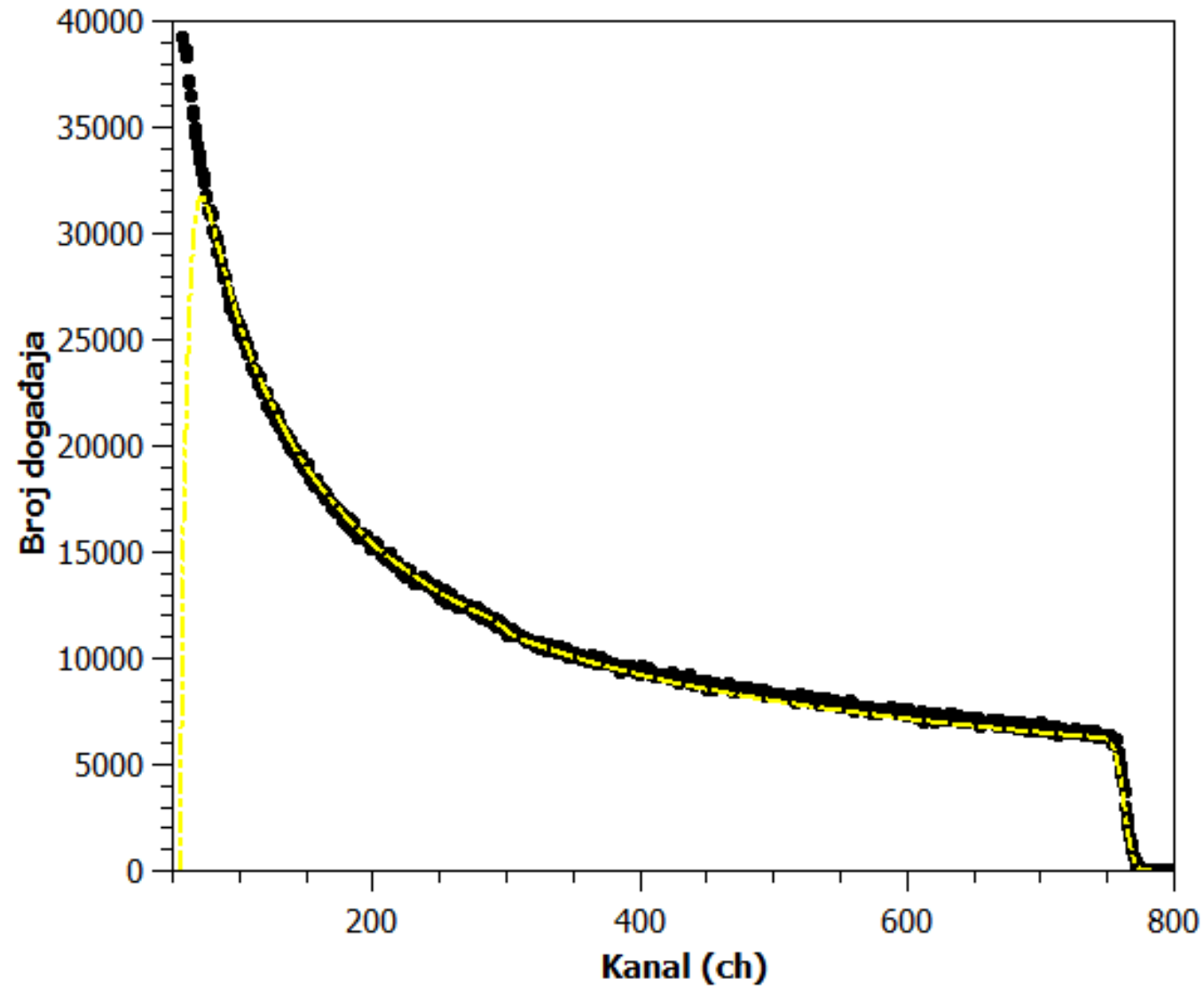
- Si,1 => Chemical symbol of element + relative concentration of atoms
- ..or..
- Si28,1 => 28 is the AMU of element

**Status:** No layer

# RBX – program za simulaciju i analizu spektara



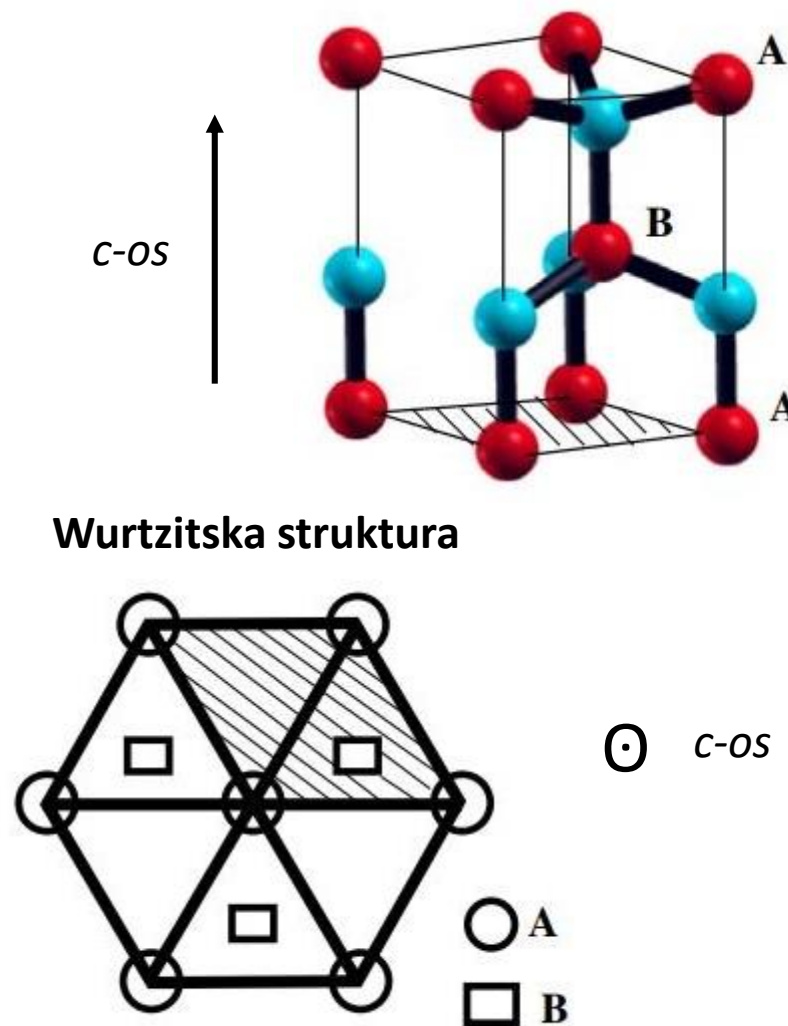
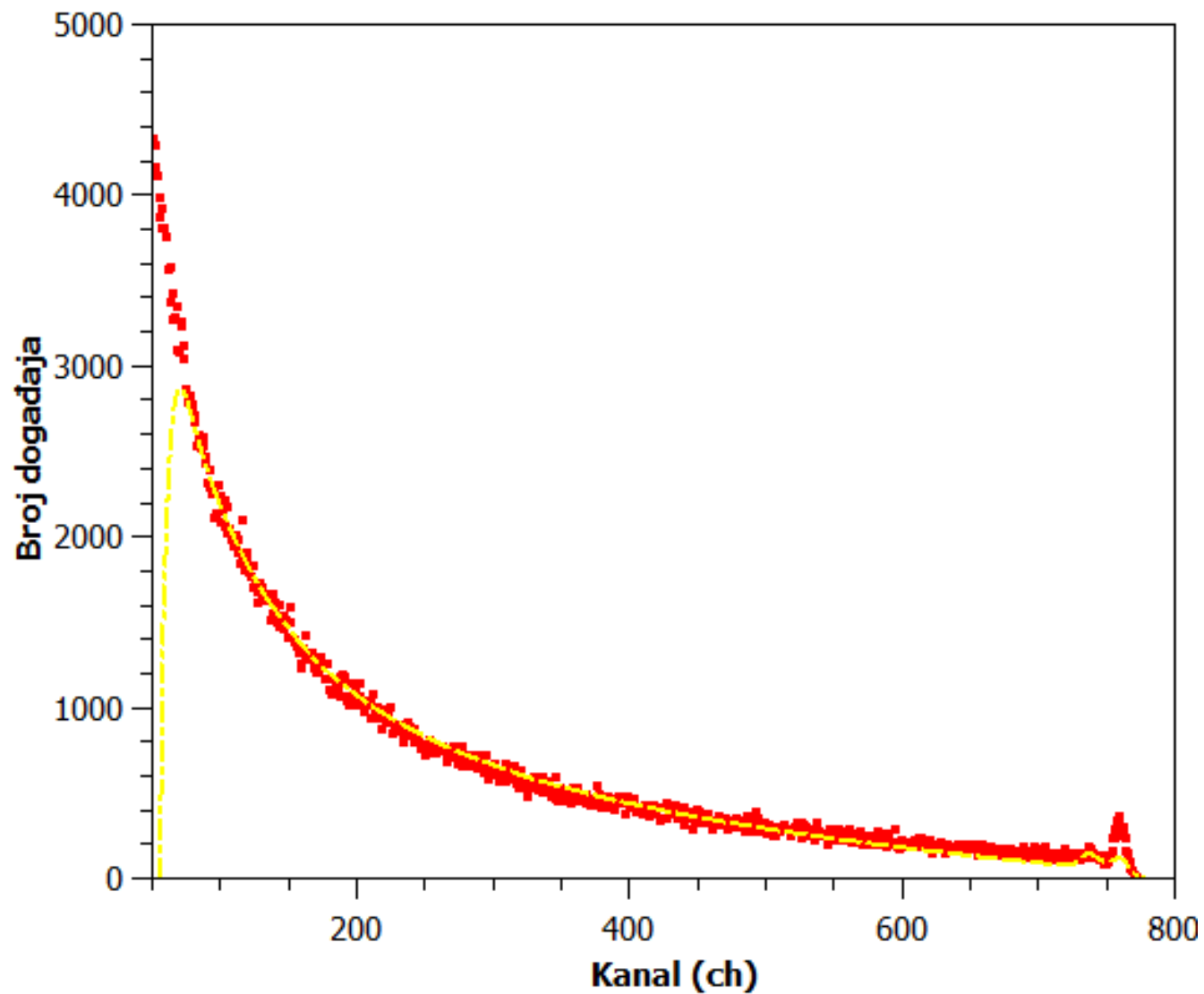
# GaN: spektar u proizvoljnom kutu



**Doza: 25600 nC**

**Energijska kalibracija:  
1.770 keV/kanal**

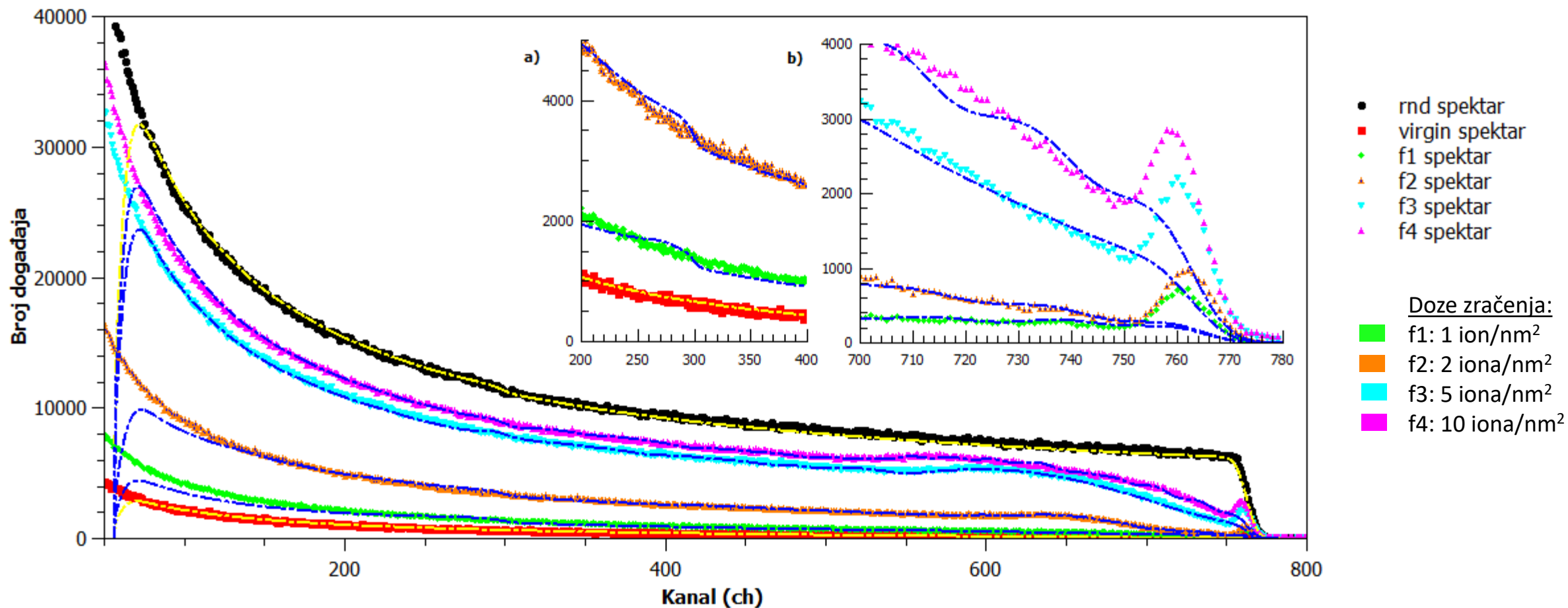
# GaN: RBS/c spektar neozračenog uzorka



# GaN: RBS/c spektri ozračenih uzoraka

Udio defekata N>>Ga

GaN: izmjereni spektri i pripadne simulacije za slučaj N>>Ga

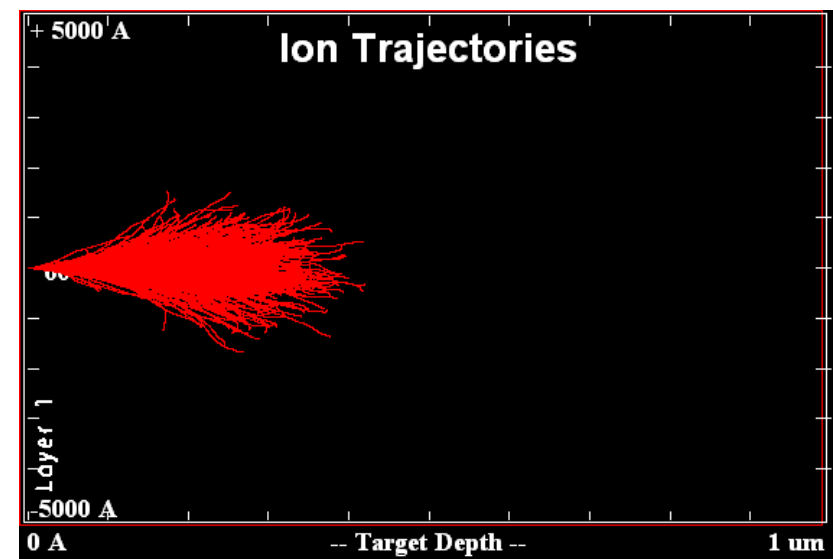
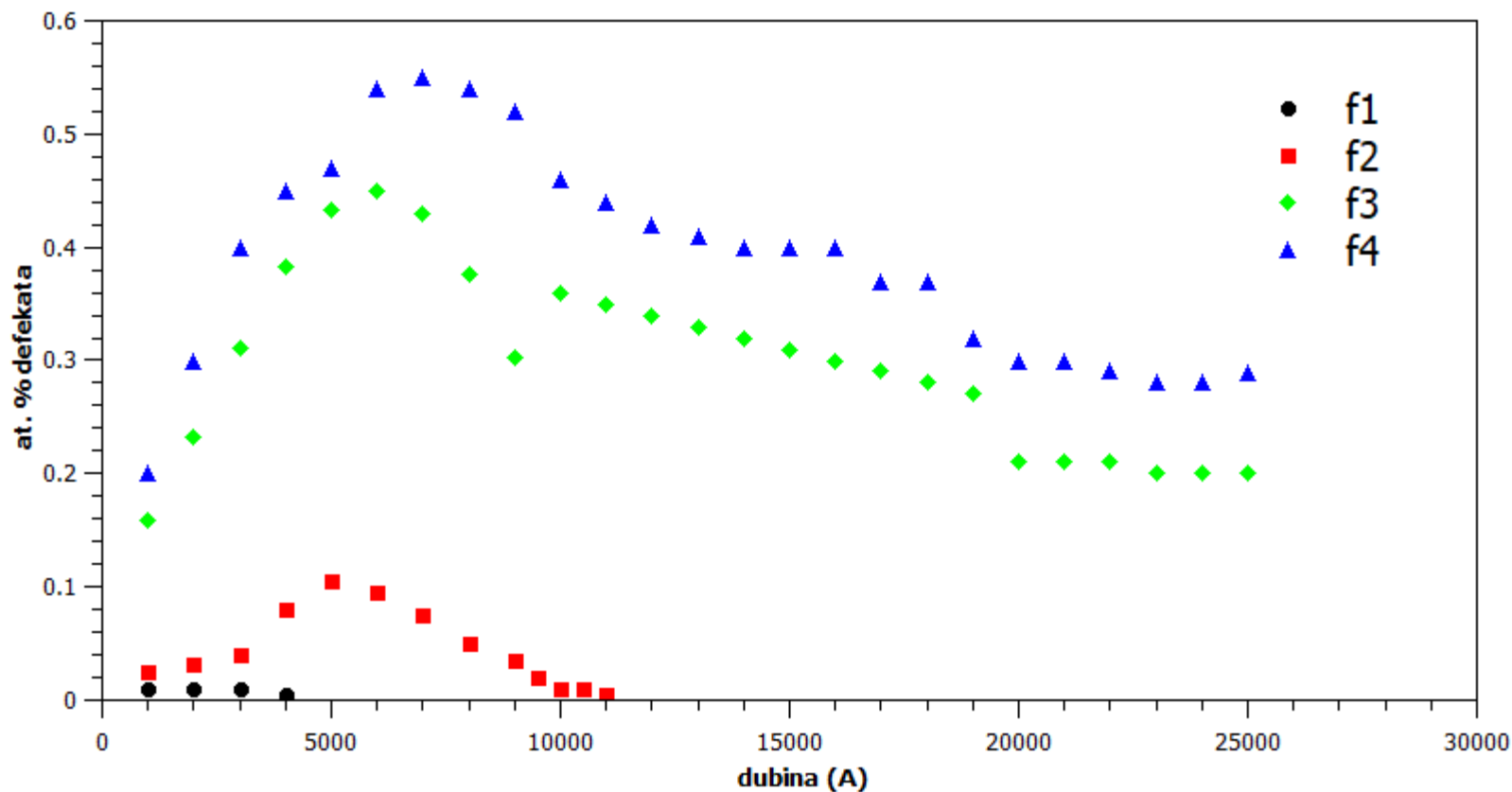




# GaN: RBS/c spektri ozračenih uzoraka

Udio defekata N>>Ga

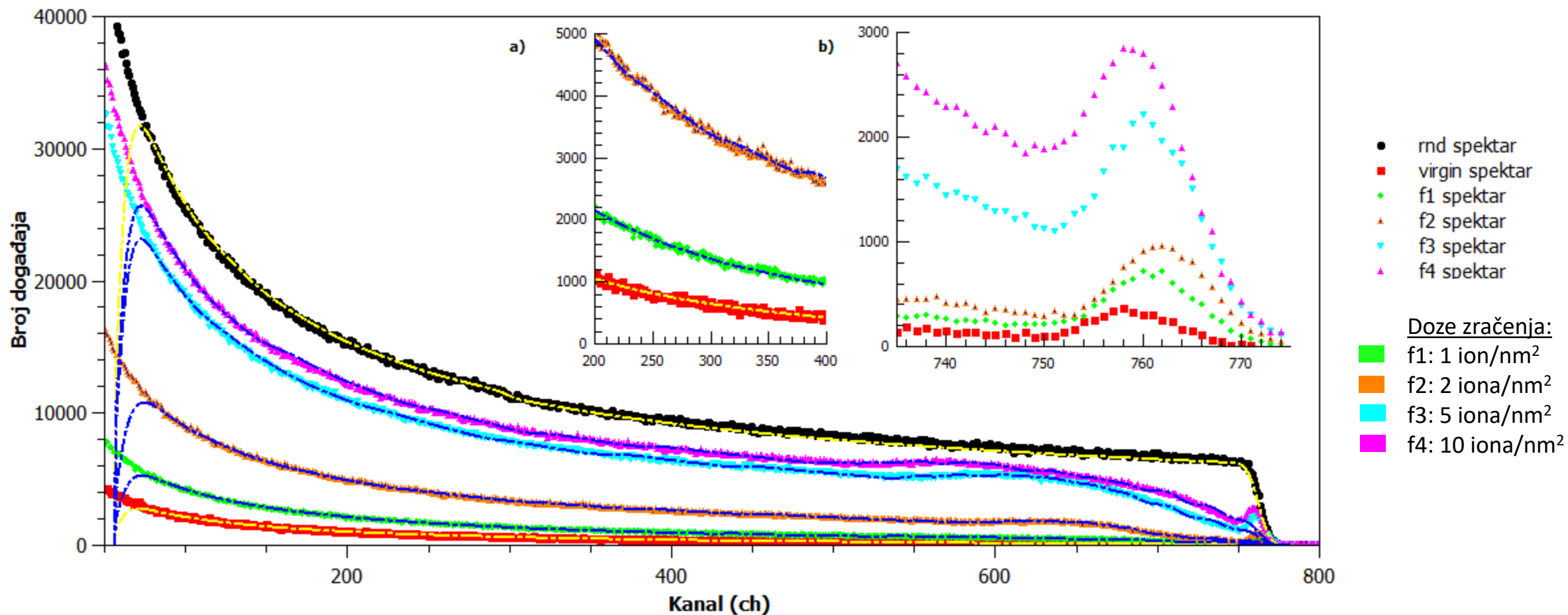
Ga - Dubinski profil točkastih defekata



# GaN: RBS/c spektri ozračenih uzoraka

Udio defekata N=Ga

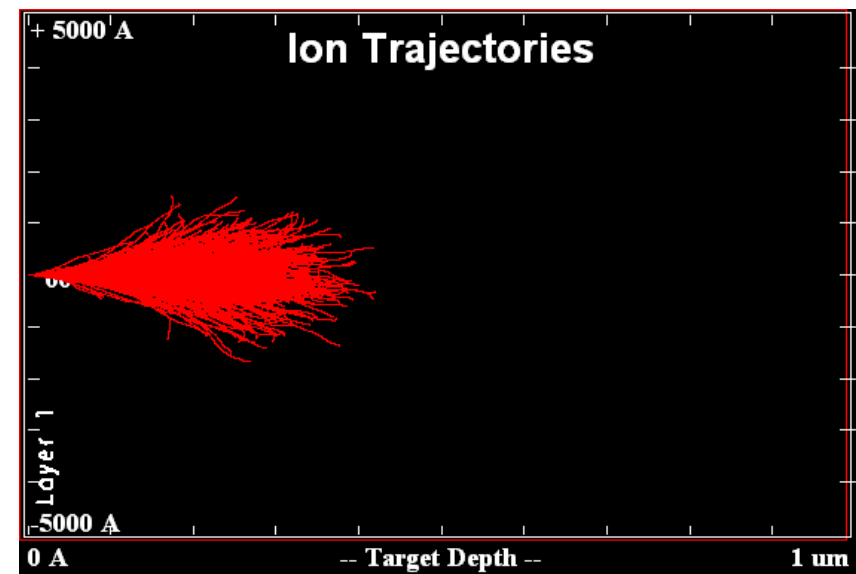
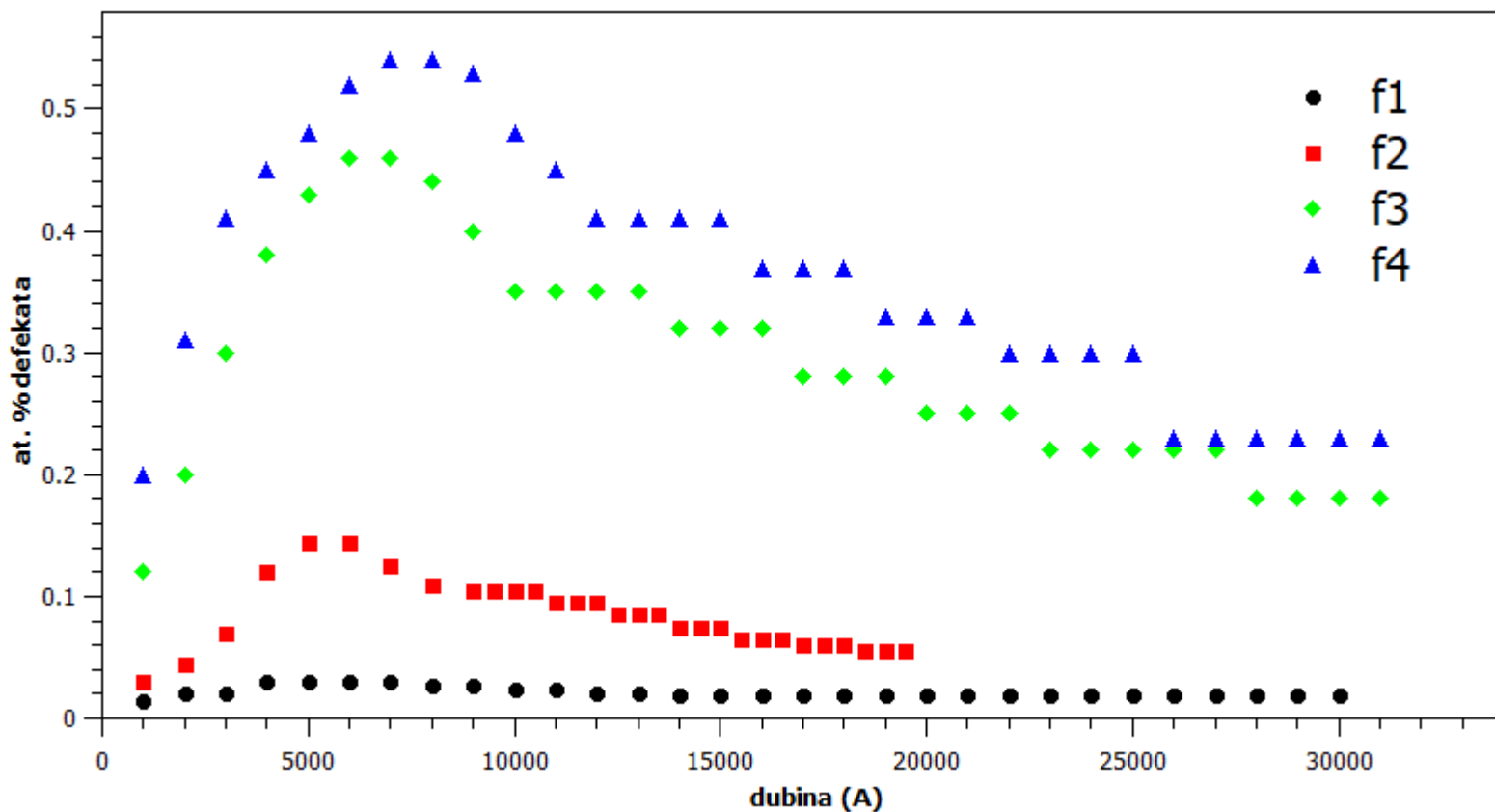
GaN: izmjereni spektri i pripadne simulacije za slučaj N=Ga



# GaN: RBS/c spektri ozračenih uzoraka

Udio defekata N=Ga

Ga=N - Dubinski profil točkastih defekata



Hvala na pozornosti!

Pitanja?

