Fabrication and Characterization of thin ΔE-Detector for Spectroscopic Application

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Outline

- –Introduction
- –Detector fabrication
- –Processing Remarks
- –Characterisation
- –Conclusion

Introduction

Single track irradiations

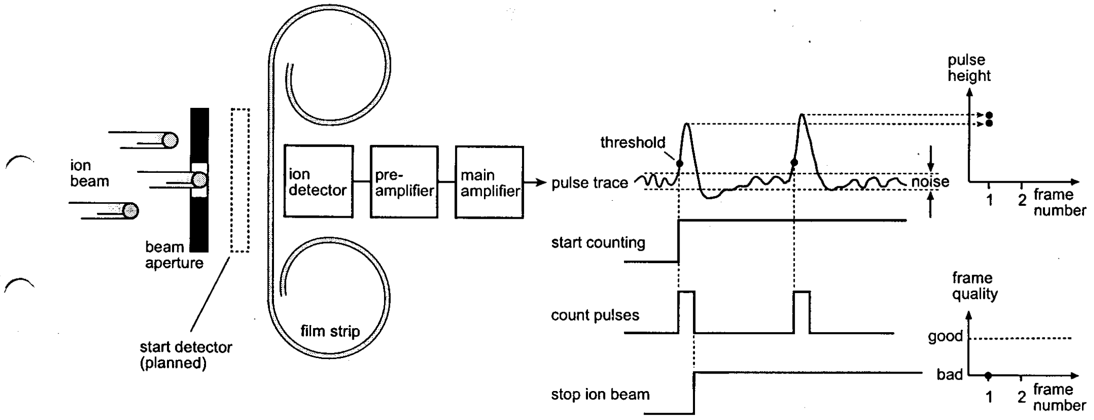
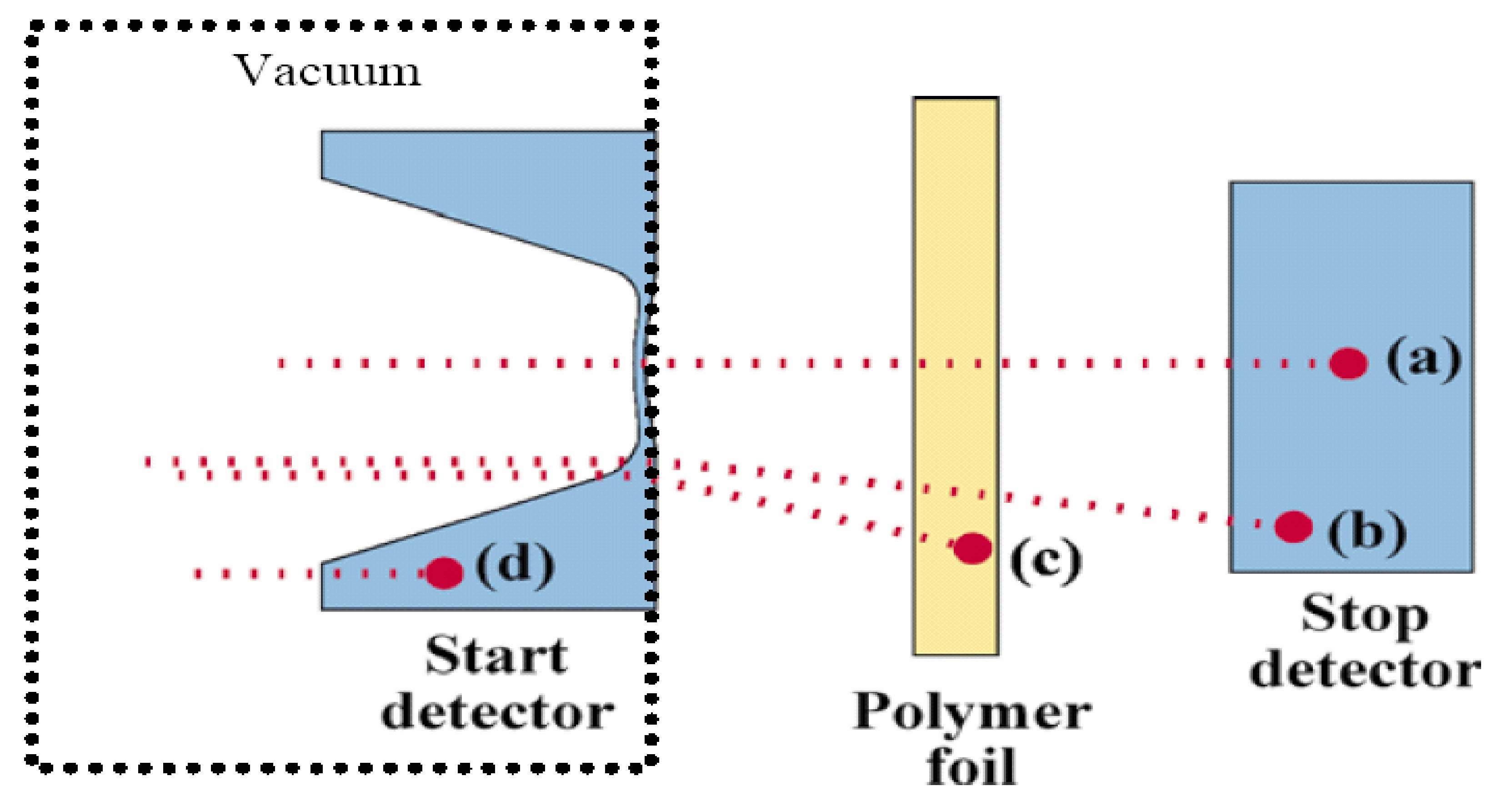
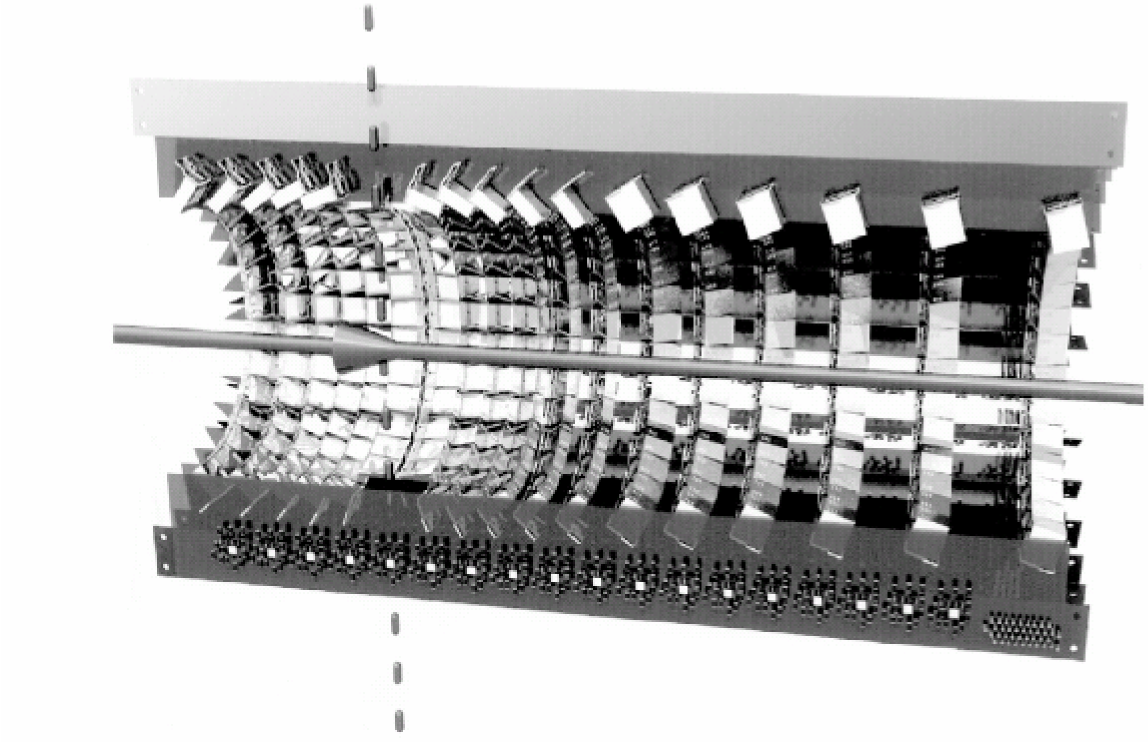


Fig. 1 Principle of irradiation system

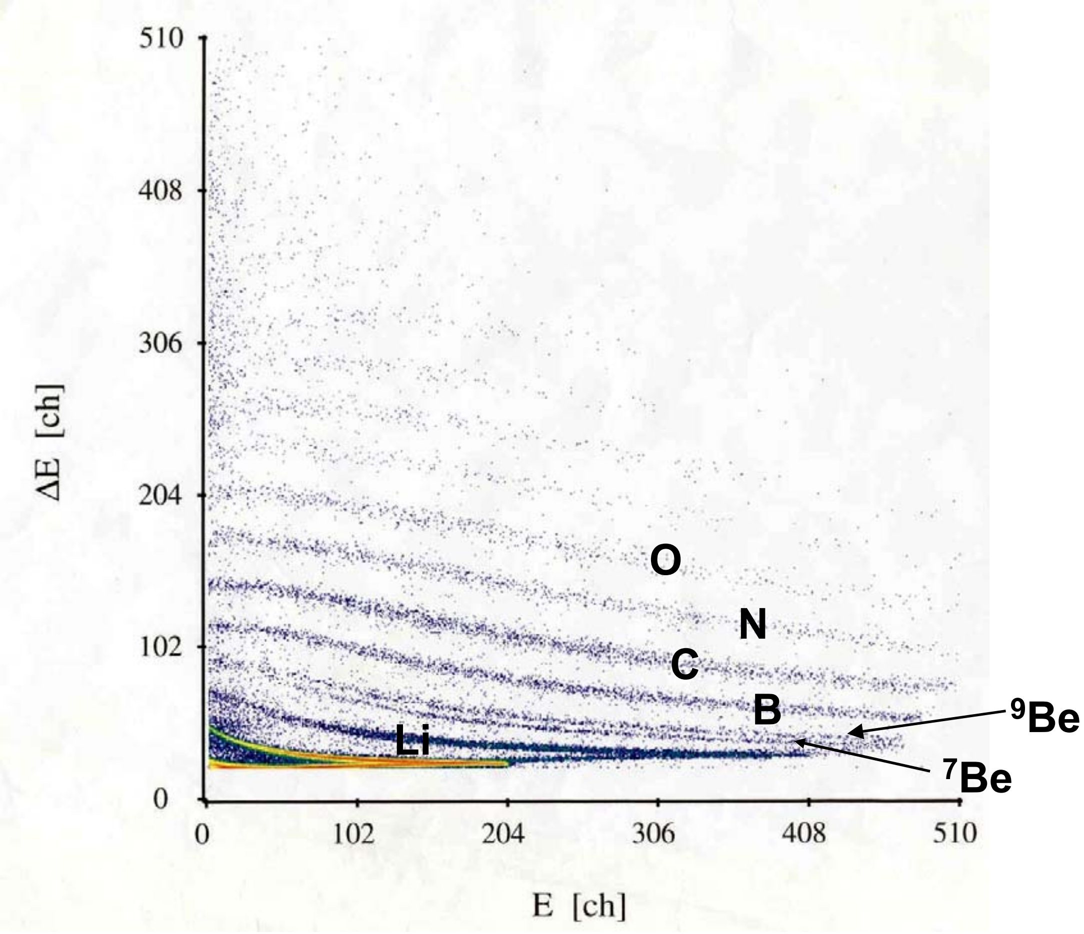

Vacuum
(a)
(b)
(c)
(d)
Start detector
Polymer foil
Stop detector

CHICSi

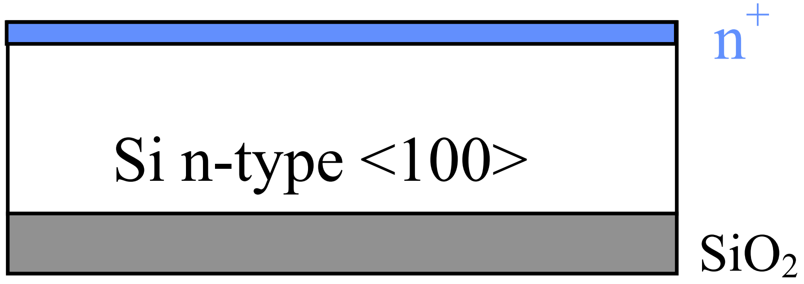
”CELSIUS Heavy-Ion Collision Silicon Detector System”



CHICSi—a compact ultra-high vacuum compatible detectorsystem for nuclear reaction experiments at storage rings. I. General structure, mechanics and UHV compatibility, **L. Westerberg et.al., Nuclear Instruments and Methods in Physics Research A 500 (2003) 84–95**

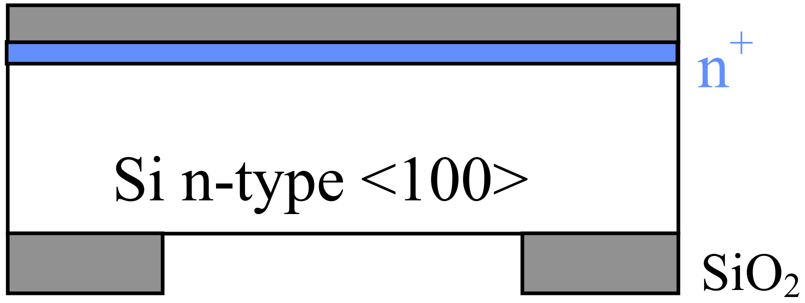

510
408
306
204
102
0
ΔE [ch]
0
102
204
306
408
510
E [ch]
O
N
C
B
^{9}Be
^{7}Be
Li

Detector fabrication

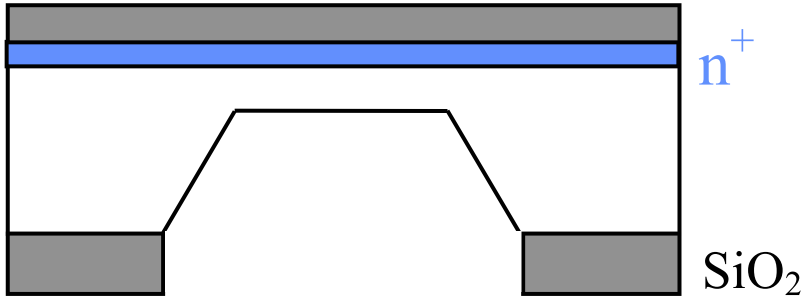


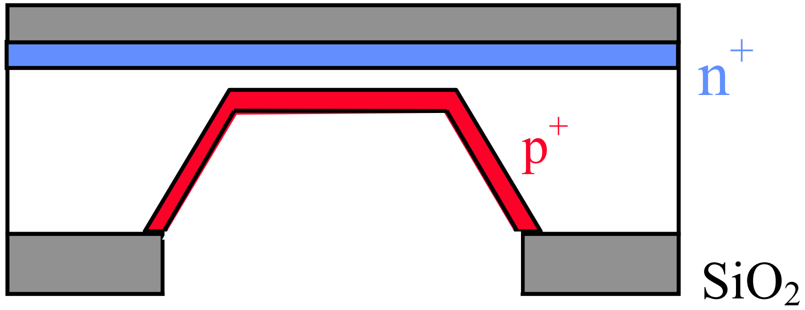
- **Silicon Wafer**
  - **FZ**
  - **<100>**
  - **1000 to 5000 Ωcm**
  - **380 μm, diameter 100 mm**
  - **N-type**
  - **Double side polished**
- **Processing**
  - **Growth of 0.5 μm SiO_2**
  - **Doping at 900 °C for 30 min using solid phosphorus-oxide source in N_2 ambient**

- **Processing**
  - **Re-growth of SiO_2**
  - **Opening of detector window 2x2 mm^2**

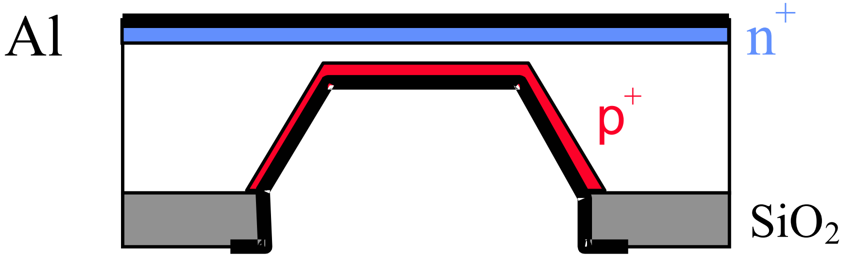


- **Processing**
  - **Etching in 25 w% TMAH at 80 °C for 14 h.**



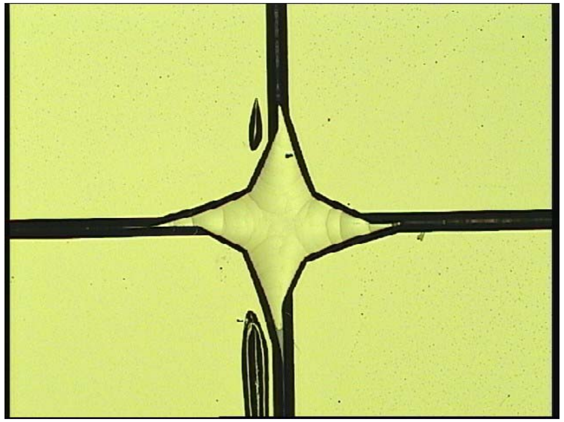


- **Processing**
  - **Doping of detector window by using a solid boron-oxide source at 950 °C for 30 min in N_2 followed by annealing 30 min in O_2**
  - **Oxide in the detector window is removed by 5% hydro-fluoric-acid**

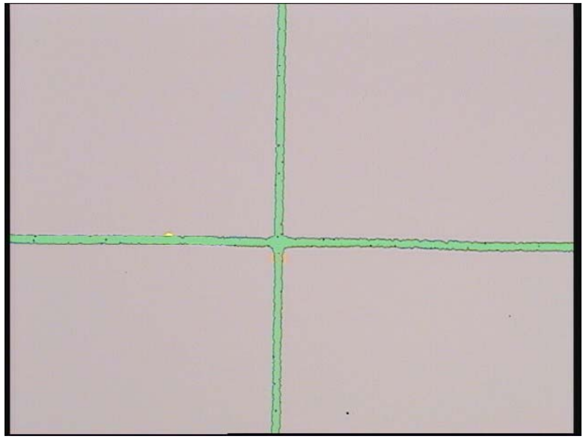


- **Processing**
  - **Electron beam evaporation of Aluminium.**
  - **0.1 µm**
  - **Detector window metallization is patterned**
  - **Forming Gas Annealing 400 °C in 5% H_2 and 95% N_2 for 30 min.**

Processing remarks

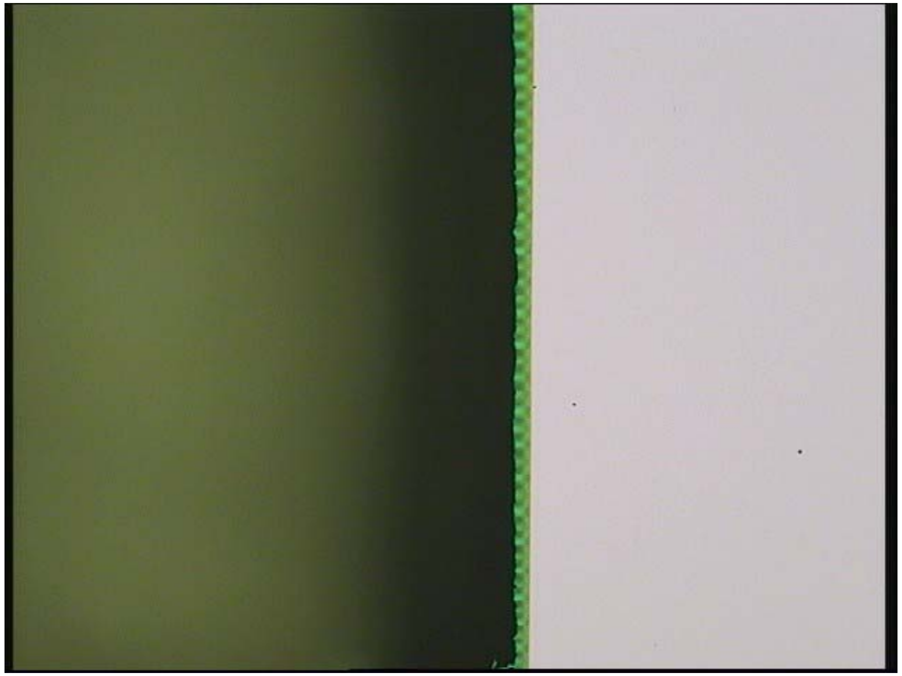


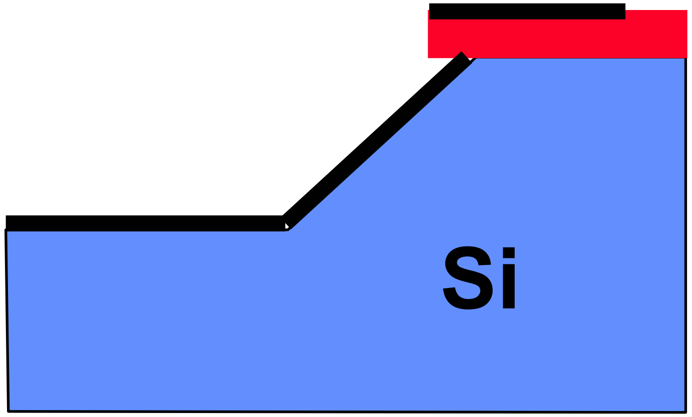
- **Aligning marks**
  - **Wet etching undercut**

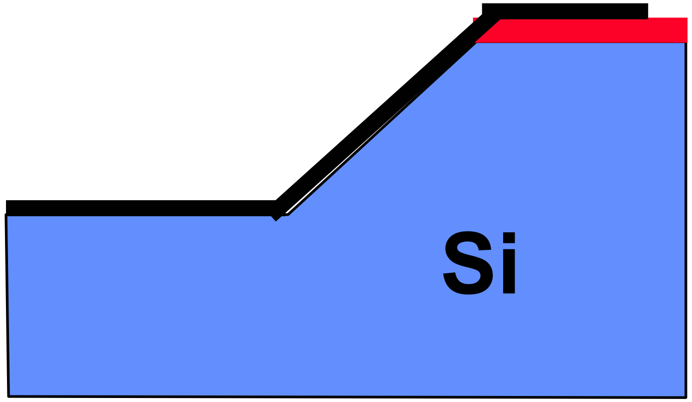


Solution !
Etch the oxide until 1/3 of the oxide thickness remain. Cover the aligning marks with resist. After baking, continue to etch the detector windows.

Processing remarks

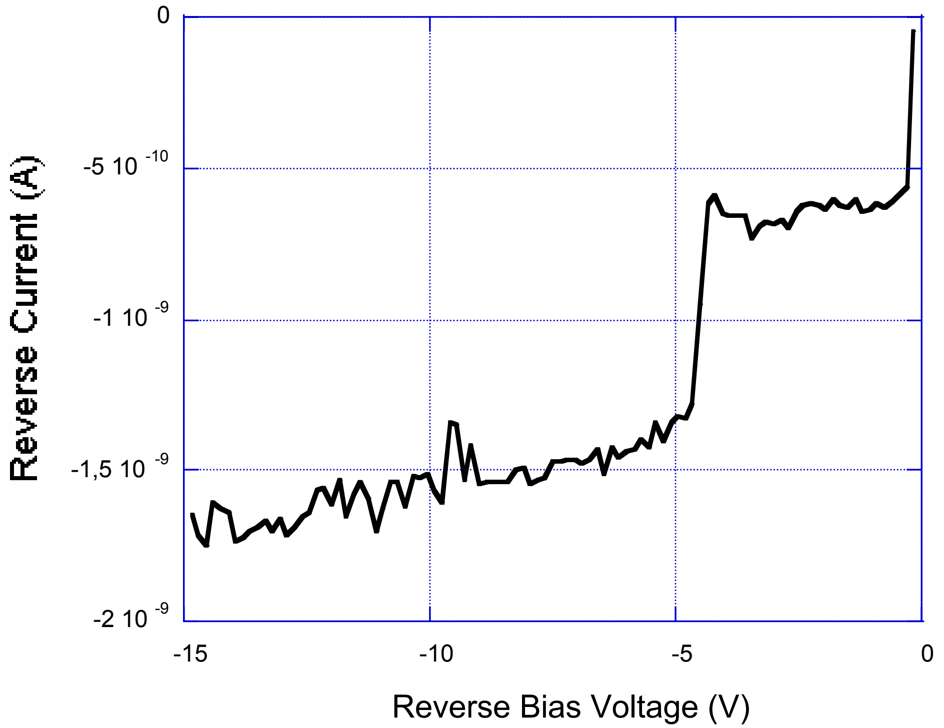




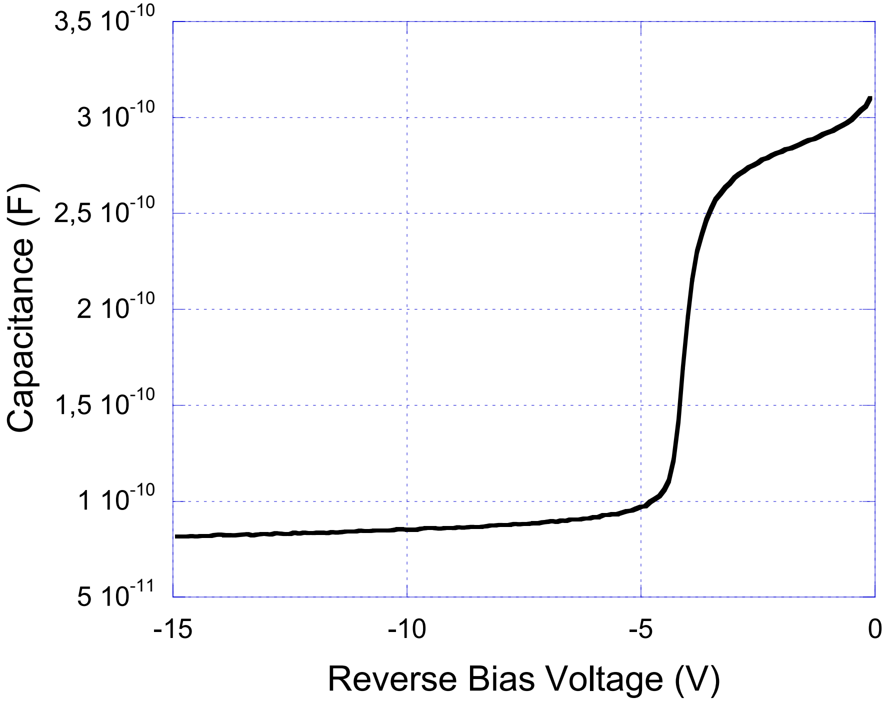


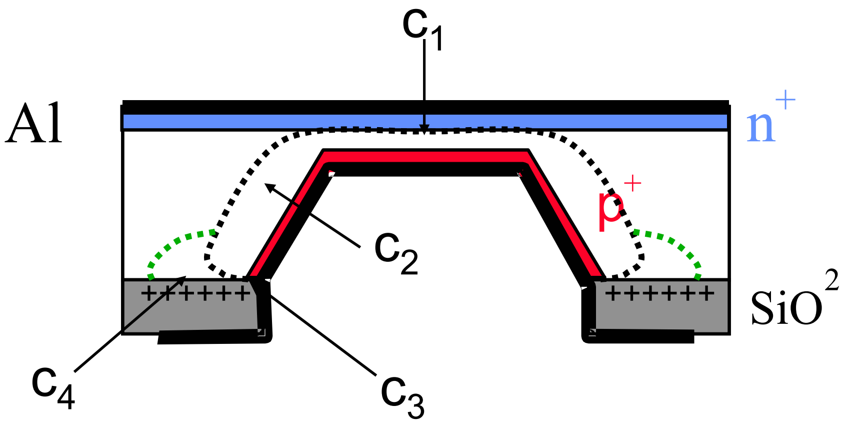
Characterization

- **IV characterization**
  - **8.8µm ΔE-detector**



• CV-characterization

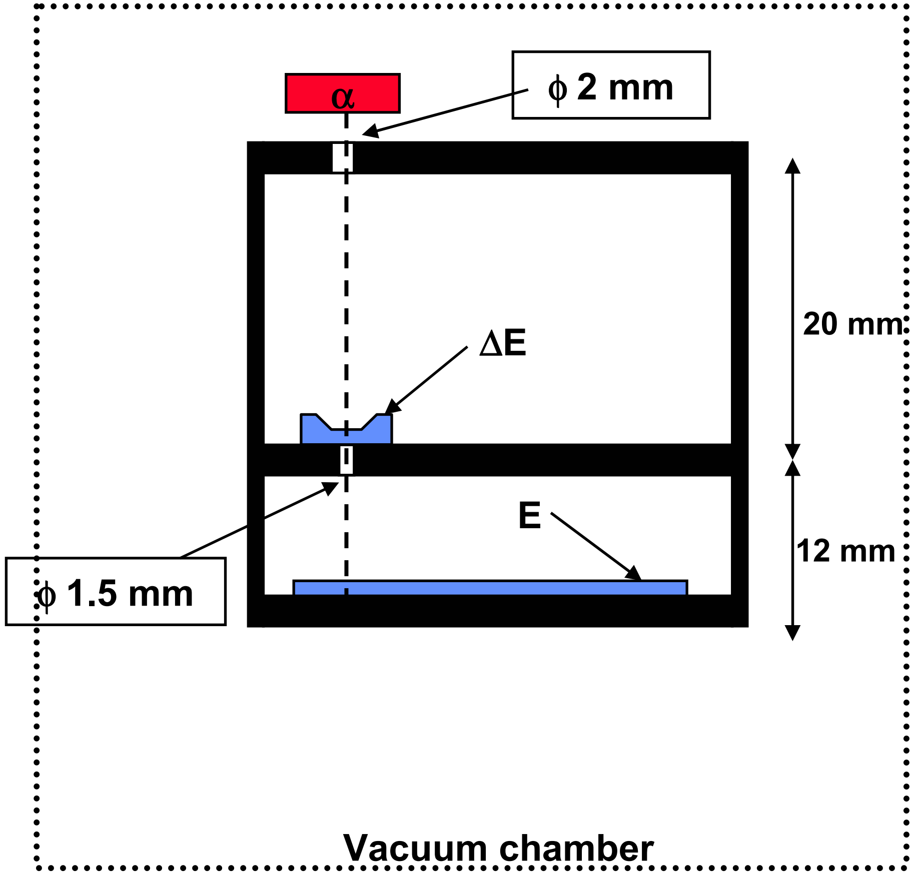




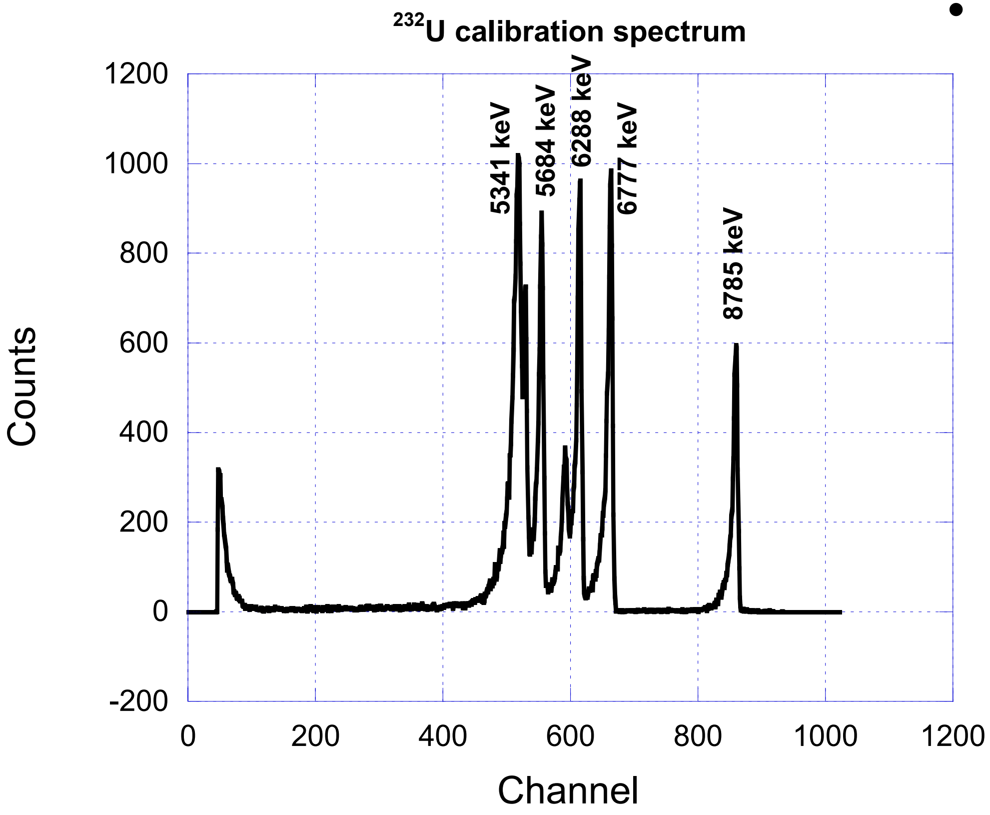
$$C_{total}=c_1+c_2+c_3+c_4$$

$$C_4(0V) \approx \frac{\varepsilon_{ox}}{d_{ox}} \cdot A = 310\text{pF (oxide cap.)}$$

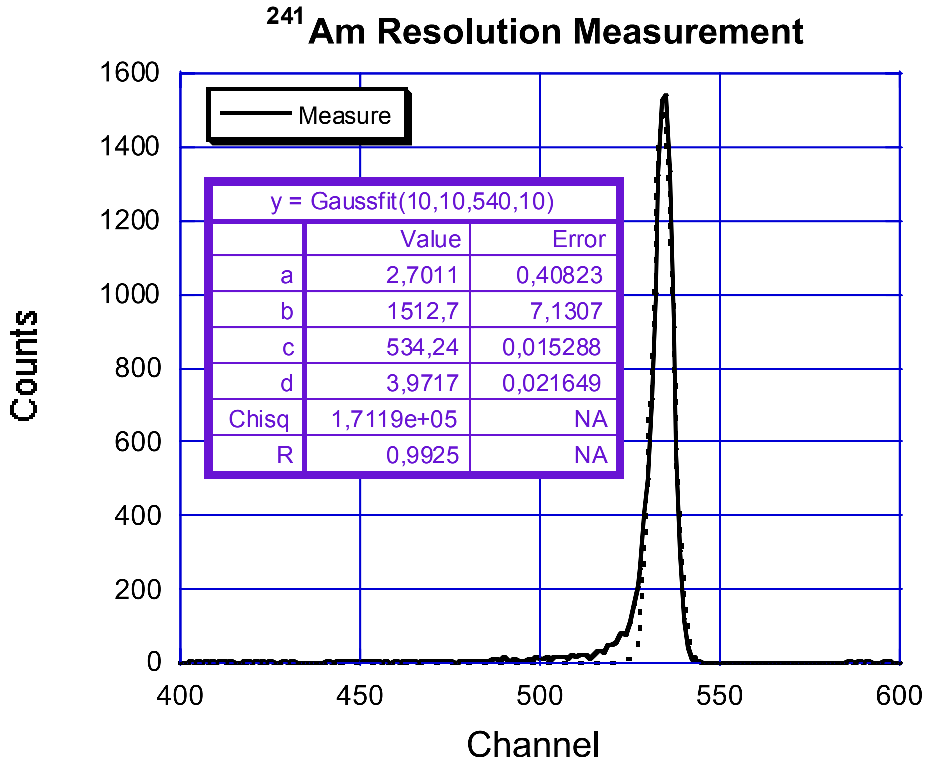
$$C_4(>3V) \approx \frac{\varepsilon_{ox}}{d_{ox}} \cdot A \text{ “decrease rapidly”}$$



- **Experimental setup**
  - **ΔE Bias: 7V**
  - **E detector 300 μm thickness, 200 mm^2, 19000 Ωcm, Bias: 40V, I_{leak}=8 nA**
  - **Pressure: 2*10^{-2} torr**
  - **Preamplifiers: Ortec 142 A,B**
  - **Shaping Amp.: Ortec 570, 1 μs**
  - **Two parameter MCA**



- Irradiation with alfa source
  - Calibration of the E-detector
    - Energy/channel=10 keV
    - E=10*ch+134 (keV)

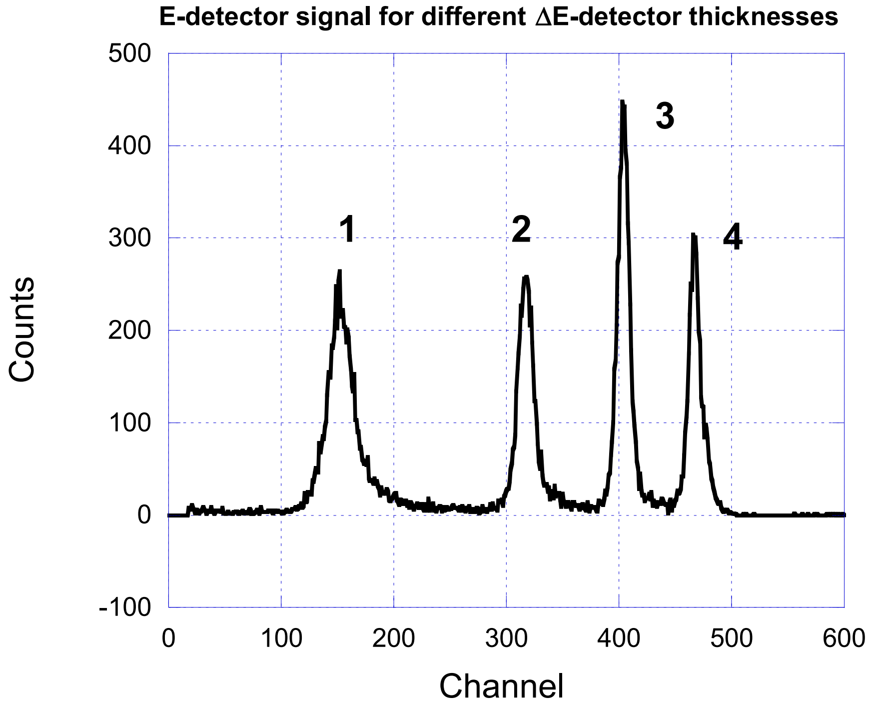


^{241}Am Resolution Measurement

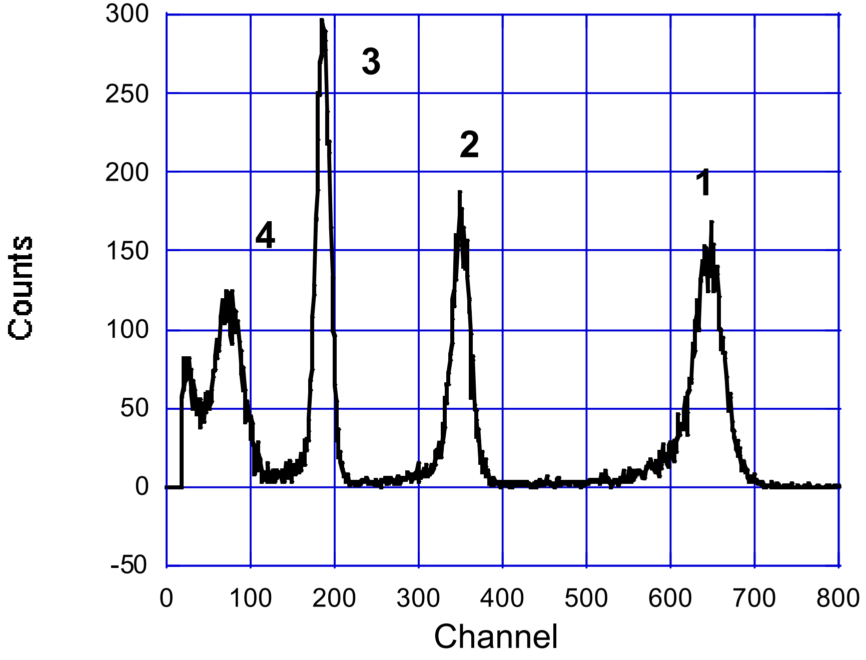
y = Gaussfit(10,10,540,10)

	Value	Error
a	2,7011	0,40823
b	1512,7	7,1307
c	534,24	0,015288
d	3,9717	0,021649
Chisq	1,7119e+05	NA
R	0,9925	NA

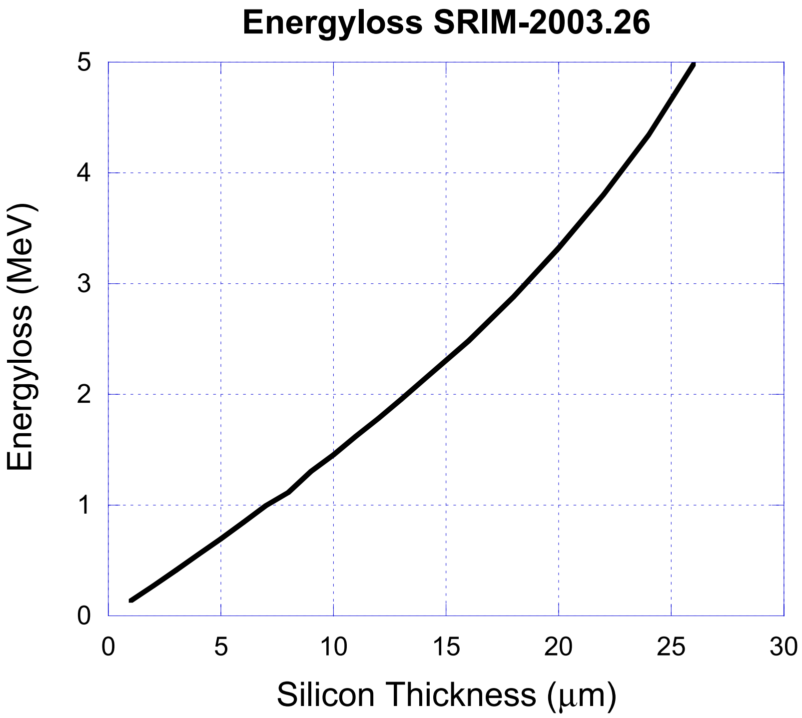
- **Resolution of the E detector**
  - $2*\sigma^2=d^2$ (ch^2)
  - $R_{fwhm}=2.355*\sigma$ (ch)
  - $E_{fwhm}=66$ keV



- **Measurement of the ΔE-E detector telescope, E-detector**
  - **1) ch: 153 result in an E=1664 keV**
  - **2) ch: 317 result in an E=3304 keV**
  - **3) ch: 404 result in an E=4174 keV**
  - **4) ch: 468 result in an E=4814 keV**



- **Calibration of ΔE-Detectors**
  - **ΔE-detectors with different thickness, irradiated with ^{241}Am**
  - **1) ch: 645 and ΔE= 3817keV**
  - **2) ch: 350 and ΔE= 2176 keV**
  - **3) ch: 186 and ΔE=1263 keV**
  - **4) ch: 71 and ΔE=625 keV**
  - **Result in a cal. Eq.**
  - **ΔE=5.57*ch+227 (keV)**



- **Estimation of ΔE-detector thickness**
  - **$\Delta X = -0.0347 + 7.558 * E - 0.441 * E^2 - 0.00565 * E^3$**

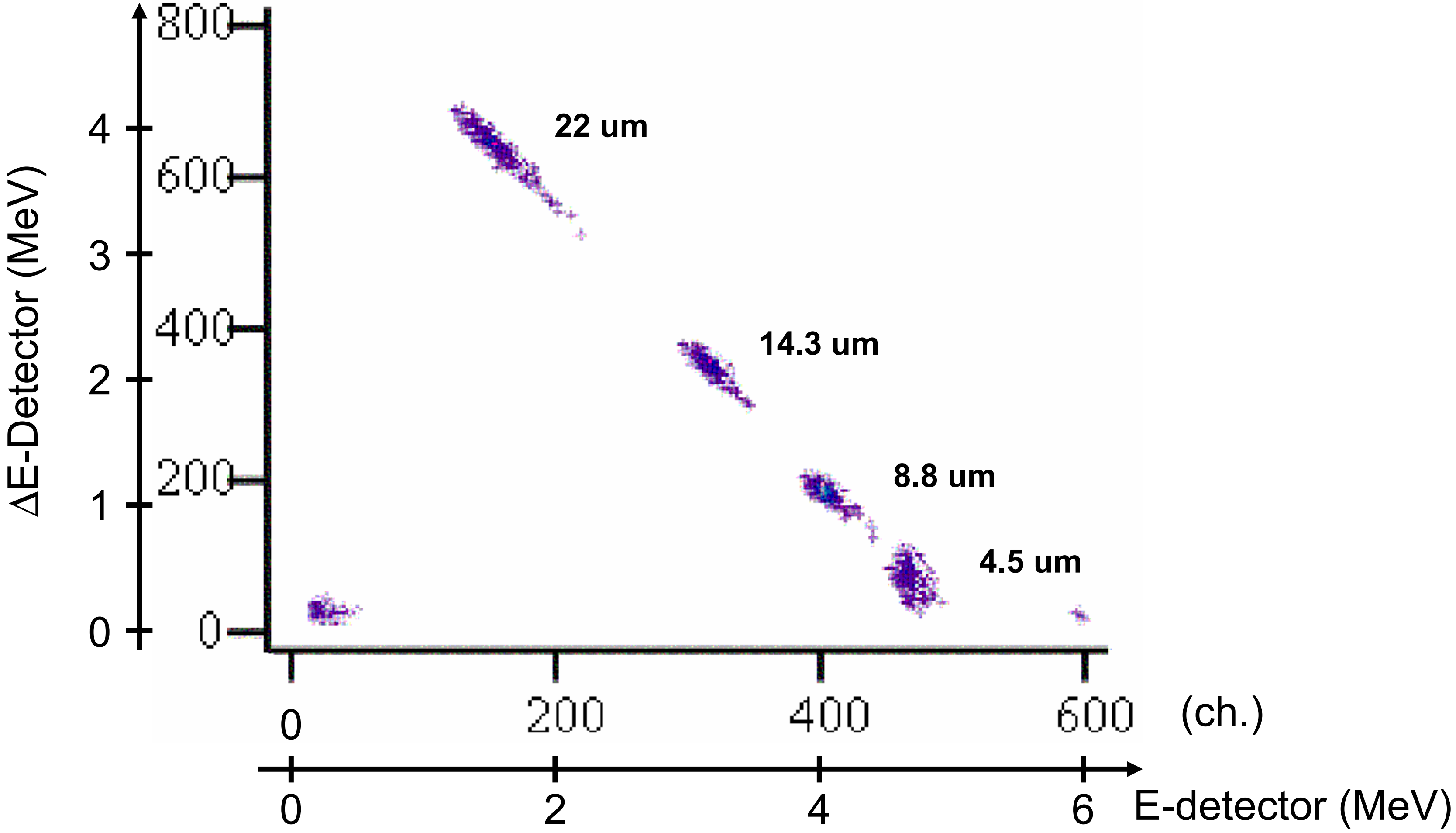
1) ΔE=3817 result in ΔX=22 um

2) ΔE=2176 result in ΔX=14.3 um

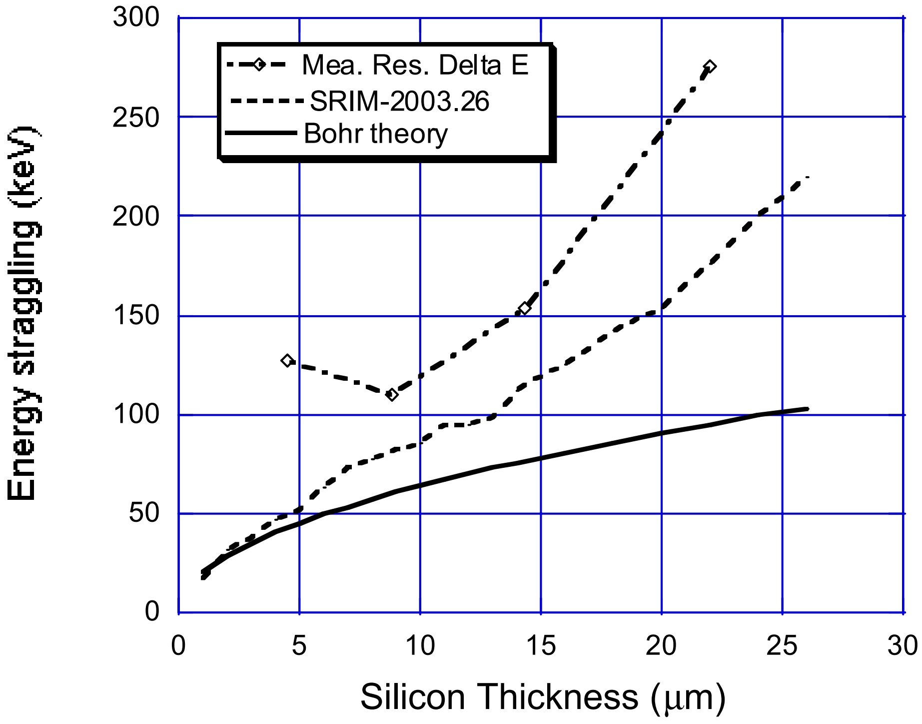
3) ΔE=1263 result in ΔX=8.8 um

4) ΔE=625 result in ΔX=4.5 um

Measured ΔE-E plot of a ^{241}Am source, for different ΔE thicknesses

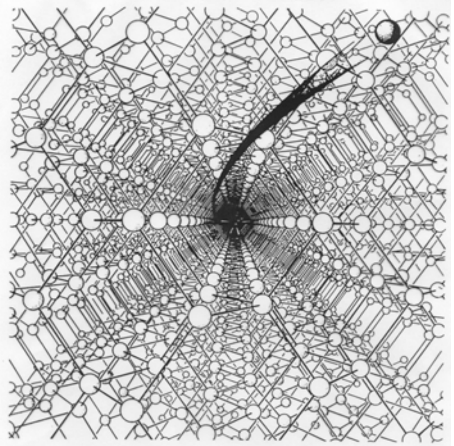


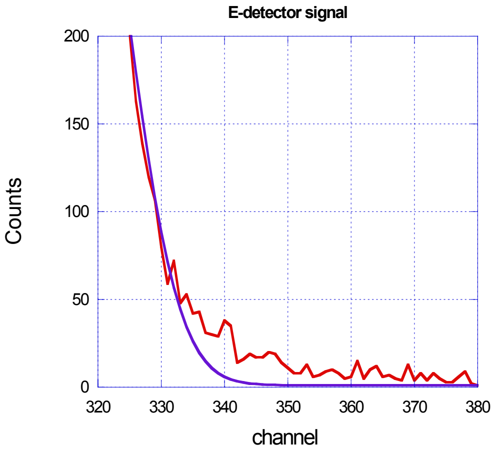
Energy Straggling

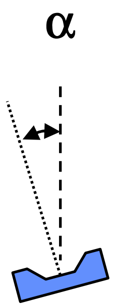


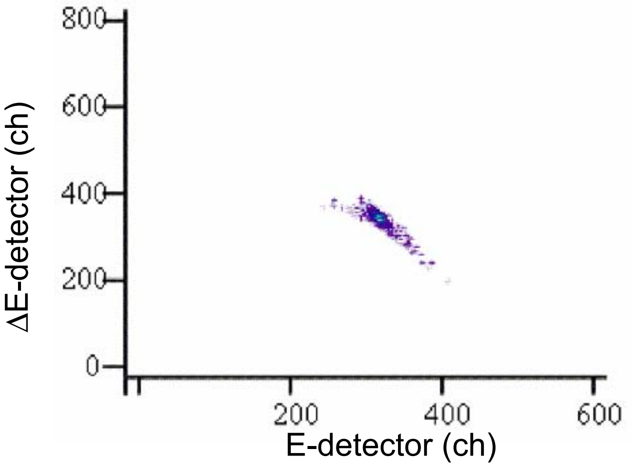
- $\Omega^2 = \Omega_d^2 + \Omega_{res}^2 + \Omega_{strag}^2$
- Ω_{res}=66 keV
- Ω_{strag}="SRIM-2003.26"
- Ω_d= "thickness variation"
  - Ω_{d1}= 204 keV (22 um)
  - Ω_{d2}=102 keV (14.3 um)
  - Ω_{d3}=70 keV (8.8 um)
  - Ω_{d4}=117 keV (4.5 um)
  - $\Delta X_{\Delta E1}$=0.62 um
  - $\Delta X_{\Delta E2}$=0.31 um
  - $\Delta X_{\Delta E3}$=0.22 um
  - $\Delta X_{\Delta E4}$=0.36 um

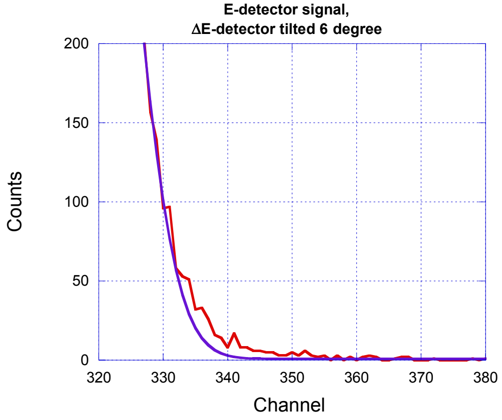
Channeling











ΔX (um)	0°	6°
8.8	7%	-
14.3	7%	1%
22	11%	3%

Conclusion

- Ultra thin ΔE-detectors for spectroscopic applications has been fabricated and characterized down to a thickness of 4.5 um.
- The fabrication was in use of a common one side mask aligner.
- The detector display low leakage current and the resulting capacitance is close to the detector window capacitance below a threshold voltage
- The detector telescope should be slightly tilted to reduce the probability for channeling
- However, even better thickness uniformity is needed to improve the resolution in the ΔE-E detector telescope