Beta Spectroscopy in Penning Traps

The backscatter problem and a potential solution

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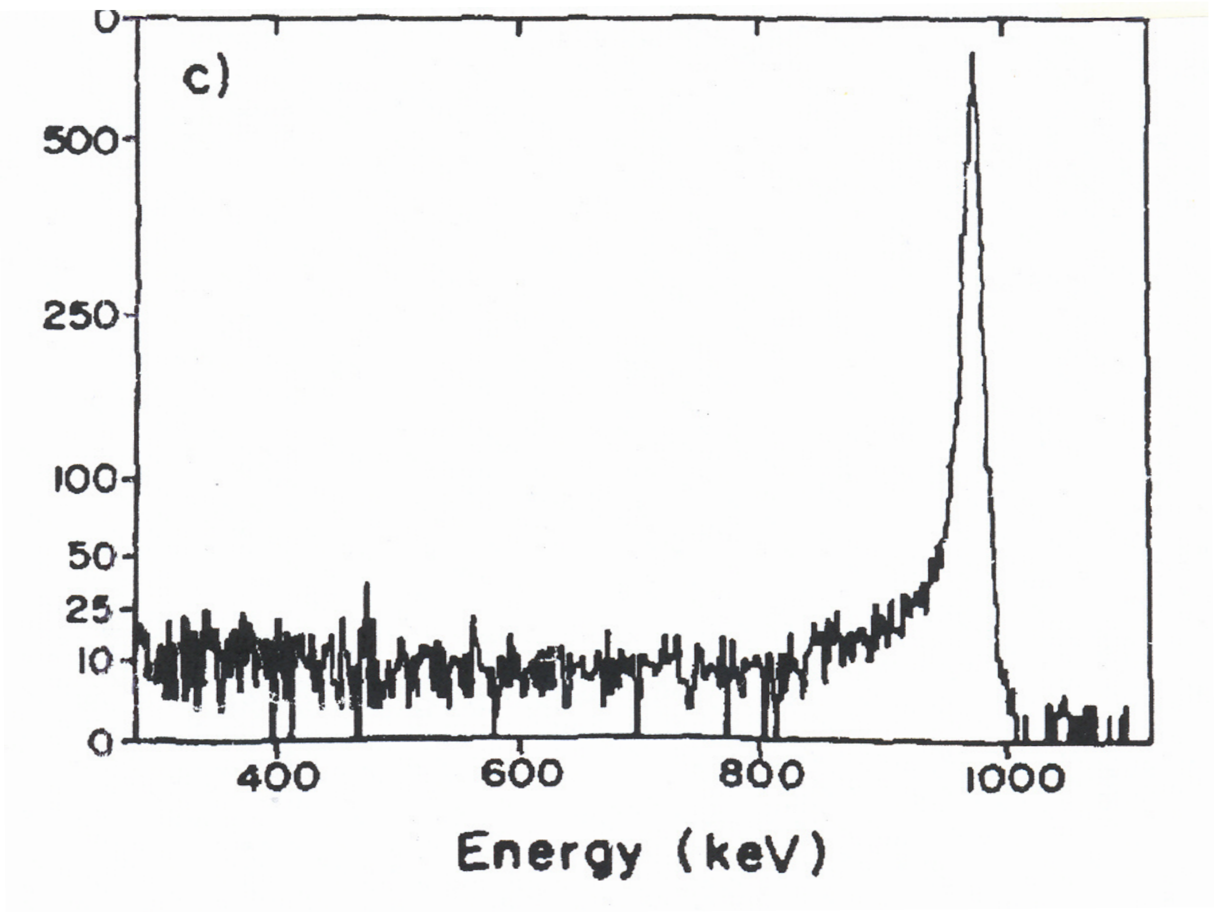
1. The Problem

The peak efficiency of the response function of the detector should be as high as possible



Response function of a Si(Li) detector for monoenergetic electrons, from R.D. von Dincklage and J.Gerl, NIM A 235 (1985) 198

Effects that lead to a decrease of the peak efficiency for electrons

- Scattering in the source

- Energy loss between the source and the detector

- Backscattering from the detector

- Bremsstrahlung that escapes from the detector

- X-rays that escape from the detector

- Incomplete collection of the e-h pairs in the detector

- Problems with the electronics

Backscattering

Total Backscatter probability

$$\eta = \eta_{1(E)}\eta_{2(\theta)}$$

For detectors from Silicon

$$\eta_{1(E)} = \frac{0.14}{1 + 0.25\left(\frac{E_{in}}{m_e c^2}\right)^{1.24}}$$

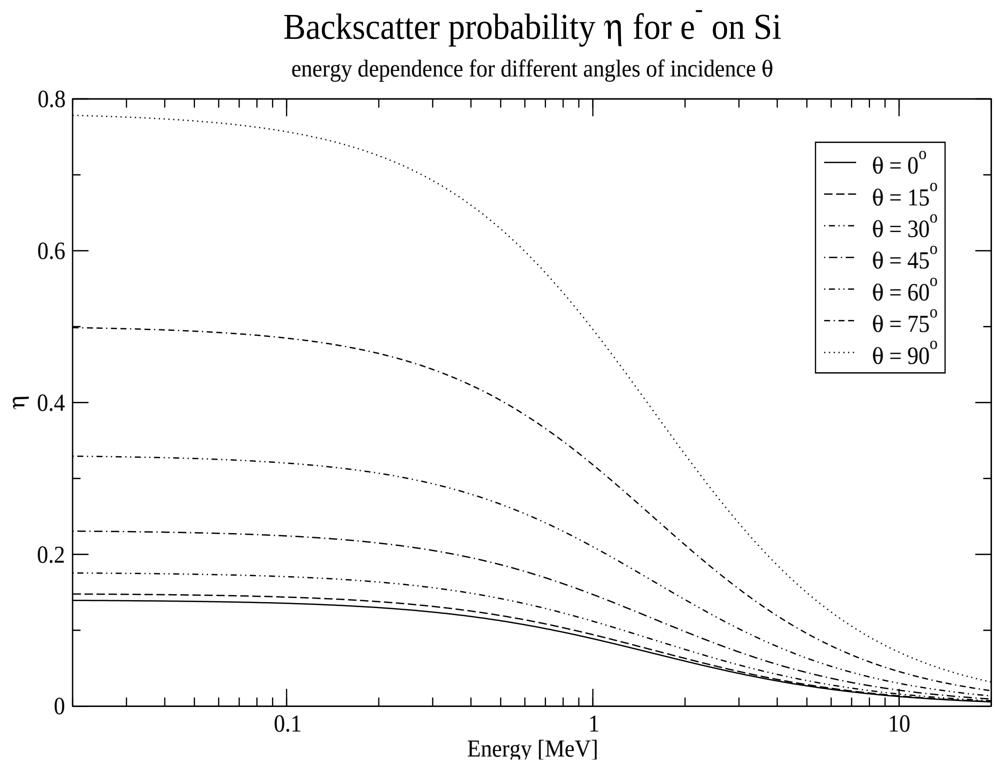
(T.Tabata, R.Ito and S.Okabe, NIM 94 (1971) 509 eq.1)

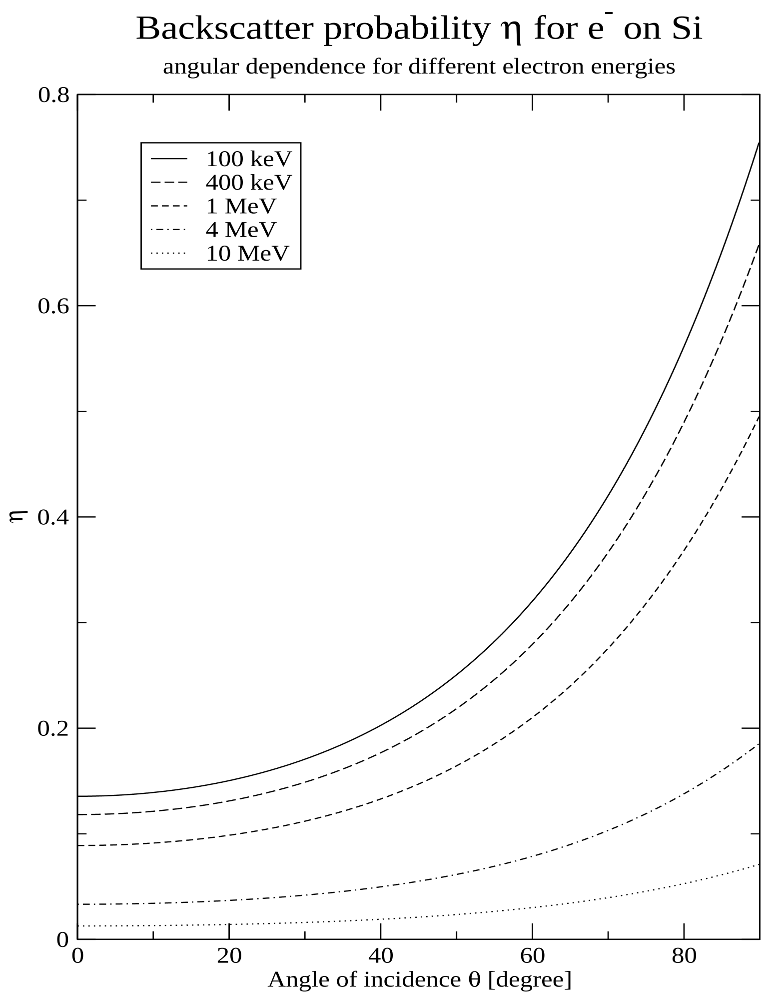
$$\eta_{2(\theta)} = e^{1.72(1-cos\theta)}$$

(K.Kanaya and S.Ono, J. Phys. D 11 (1978) 1495, eq.18 & fig.6)

resulting in

$$\eta = \frac{0.14}{1 + 0.25\left(\frac{E_{in}}{m_e c^2}\right)^{1.24}} \cdot e^{1.72(1-cos\theta)}$$


Backscatter probability η for e- on Si
energy dependence for different angles of incidence θ
0.8
0.6
0.4
0.2
0
η
0.1
1
10
Energy [MeV]
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
θ = 75°
θ = 90°


Backscatter probability η for e- on Si
angular dependence for different electron energies
0.8
0.6
0.4
0.2
0
η
0
20
40
60
80
Angle of incidence θ [degree]
100 keV
400 keV
1 MeV
4 MeV
10 MeV

Effects of a Penning trap

A Penning trap

- removes scattering in the source

- introduces scattering in the buffer gas

- increases (!) backscattering from the detector

- introduces energy loss due to synchrotron radiation

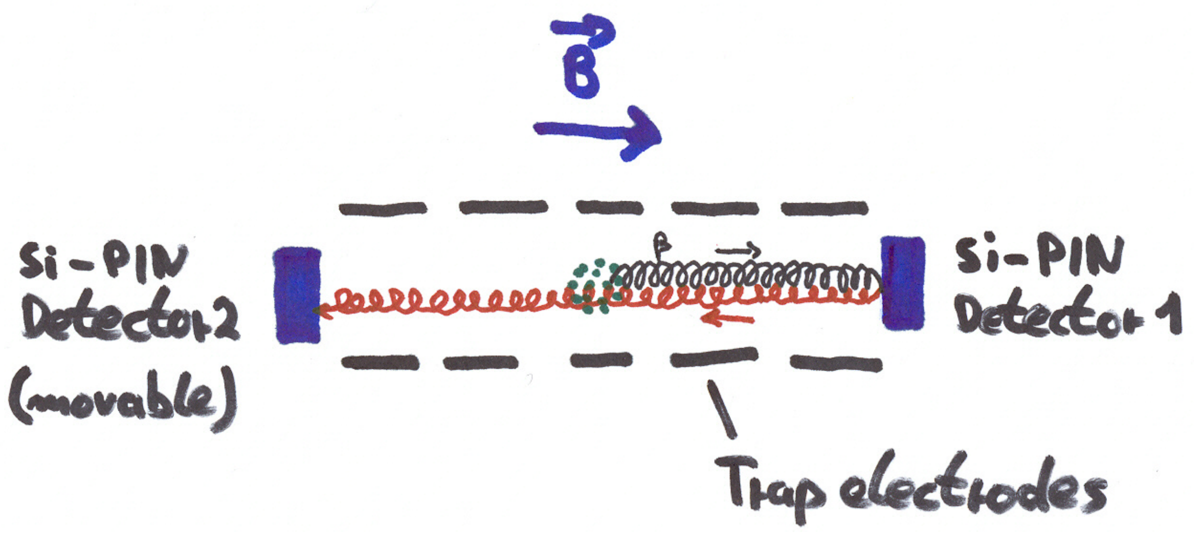
So why use a Penning trap for beta-spectroscopy?

Because we can get around the backscatter problem by measuring the backscattered beta-particle!

2. Penning trap with two detectors

The Penning trap collimates the beta-particles into two directions. It also collimates the backscattered beta-particles into the same directions.

Principle:



The backscattered beta-particle moves *through the ion cloud* to the opposite detector.

Two potential modes of operation:

I. Do not use events with a delayed coincidence in the second detector

Disadvantage: Change in spectral shape

II. Use the sum of the signals of the two detectors from (multiple) delayed coincidences

Disadvantage: For low countrates only

3. Summary

It may be possible to reduce the effect of backscattering on the response function by using a Penning trap.

- The outgoing distribution of E_{out} and θ_{out} are needed

- Simulations have to be done

- What is the effect of the other processes like Bremsstrahlung?

$\rightarrow$ Much work still has to be done