Implantation Detector in the ^{100}Sn Experiment

clean fragment separation ← ← FRS

unique fragment identification → A, Z

fragment position → x, y, z

decay radiation → position correlation for
β, α, p, conv. electron
(not for isomeric γ)
precise energy
with highest efficiency

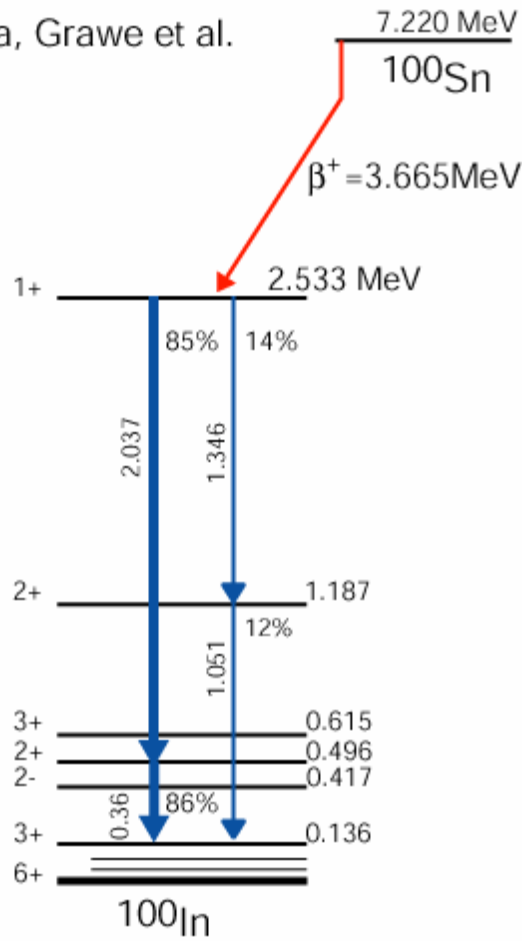
detectors

Robert Schneider, *Andreas Stolz*, *Elmar Wefers*, *T. F.*

Measurement of the Gamov-Teller-strength

^{100}Sn, calculated

Gorska, Grawe et al.



Pure GT-decay to only one final state of the daughter nucleus:

$$B_{GT} = \frac{6127\,\mathrm{s}}{(g_A/g_V)^2 \cdot f(E_0) \cdot T_{1/2}}$$

weak coupling constants $g_A/g_V = 1.26$

Fermi-integral $f(E_0) \propto (E_0)^5$

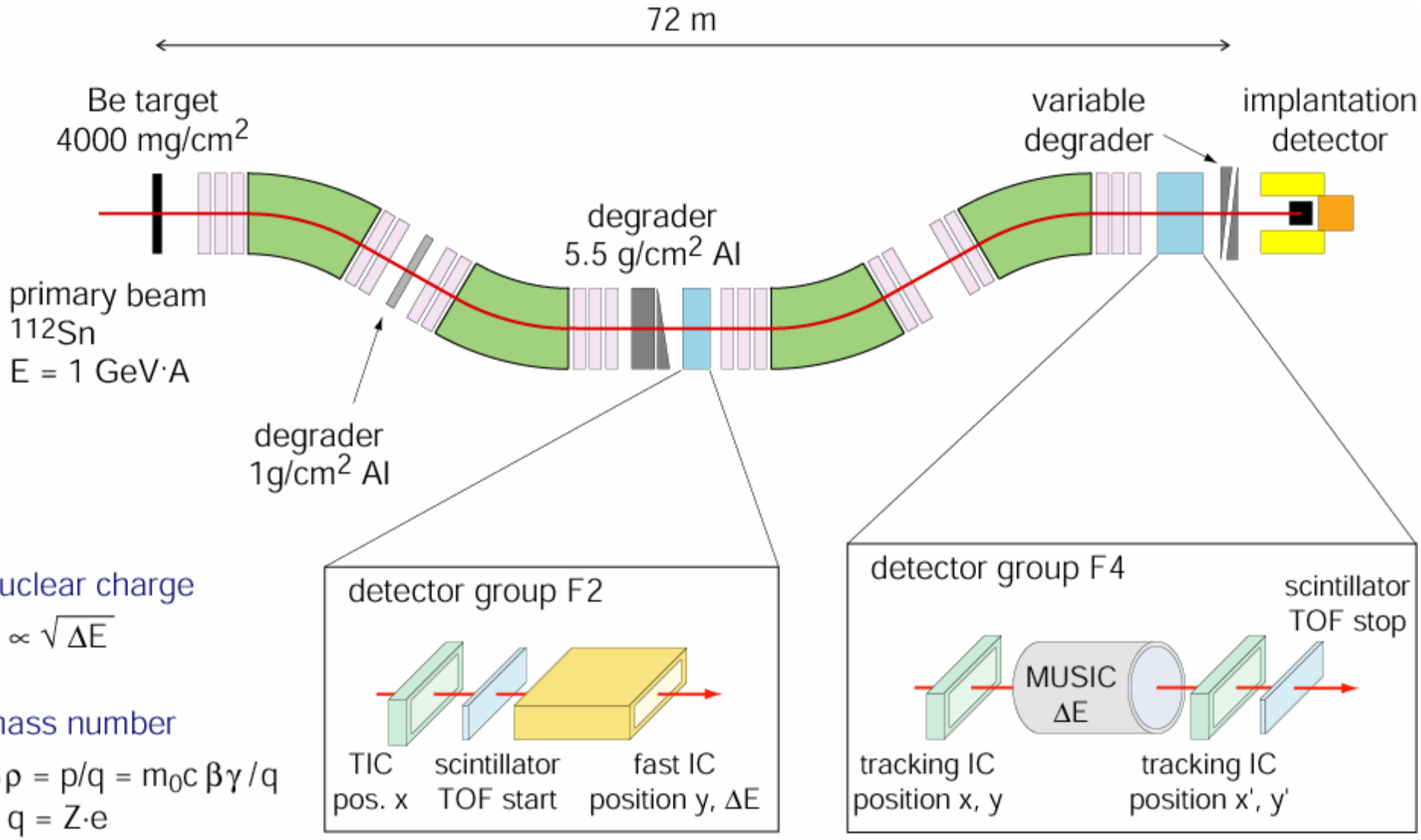
Beta-endpoint energy E_0

Half-life $T_{1/2}$

GT-decay into several final states:

$$B_{GT} = \sum_i B_{GT_i} = \sum_i \frac{3860\,\mathrm{s}}{f_i \cdot t_i}; \quad t_i = \frac{T_{1/2}}{I_{\beta_i}}$$

Fragment Separator at GSI



nuclear charge

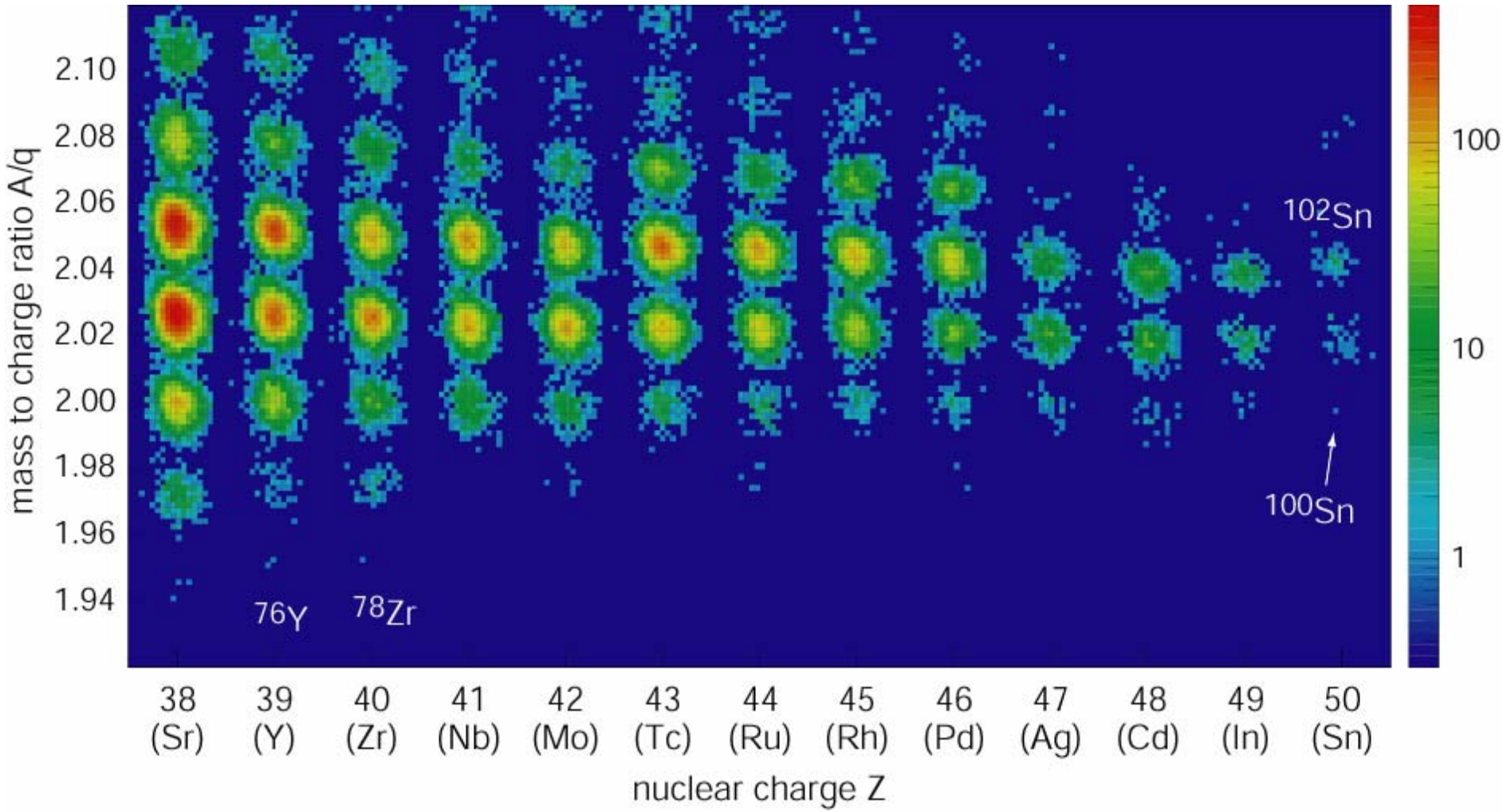
$Z \propto \sqrt{\Delta E}$

mass number

$B\rho = p/q = m_0 c\, \beta\gamma / q$

$q = Z \cdot e$

Fragment identification



nuclear charge resolution:

$\Delta Z = 0.23$ (FWHM)

mass resolution:

$\Delta A = 0.32$ (FWHM)

Implantation detector

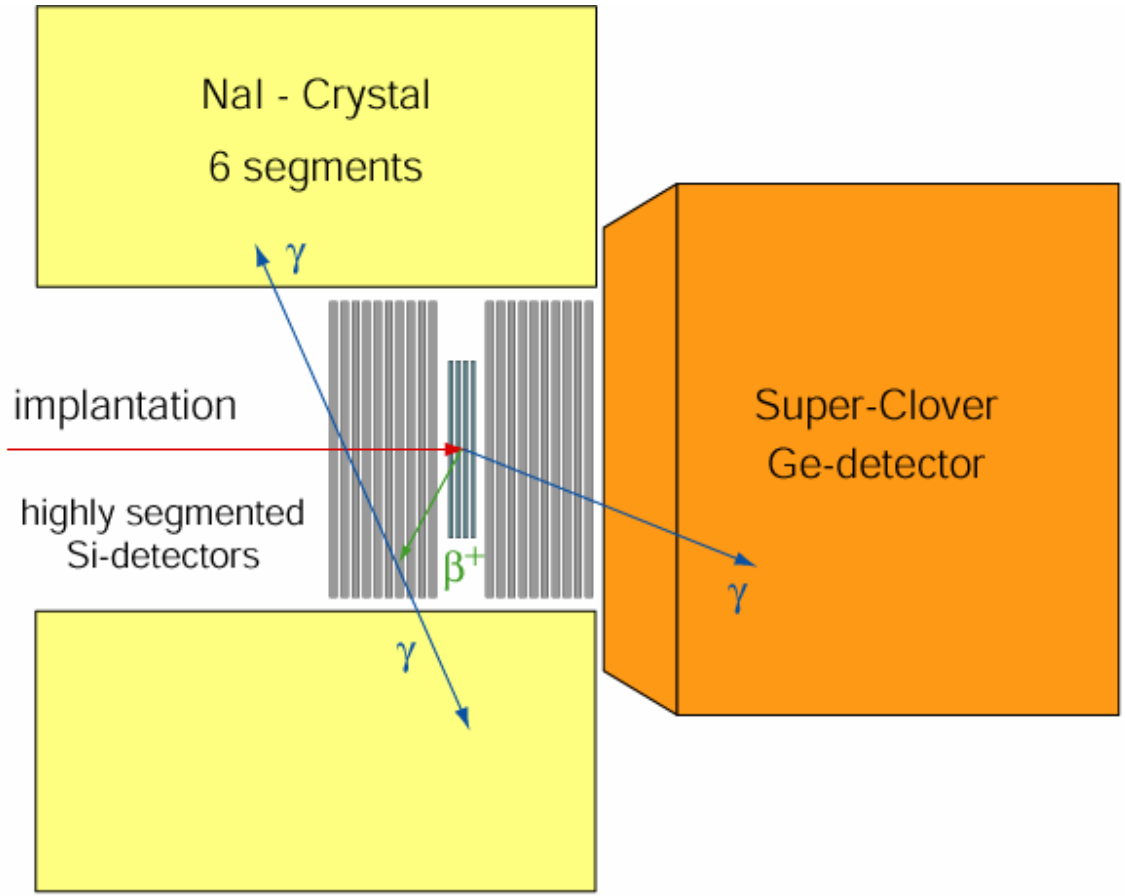
Silicon beta calorimeter

4π-detector for

- α-decay
- β-decay
- p emission

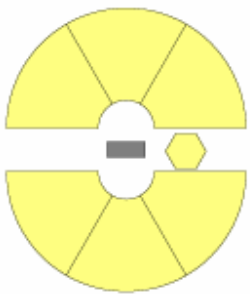
for half-life t > 5 ms

high detection efficiency for decays



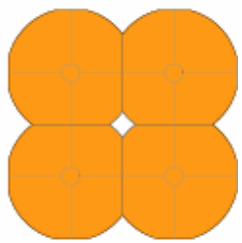
NaI-Crystal

- covers 50% of solid angle
- 6 segments in 2 semi-circles



Ge-detector

- covers 25% of solid angle
- 9-fold segmentation
- energy resolution
  ΔE = 2.5 keV (E_γ=1.3 MeV)



detector types

Beta absorber

2 x 10 silicon PIN diodes

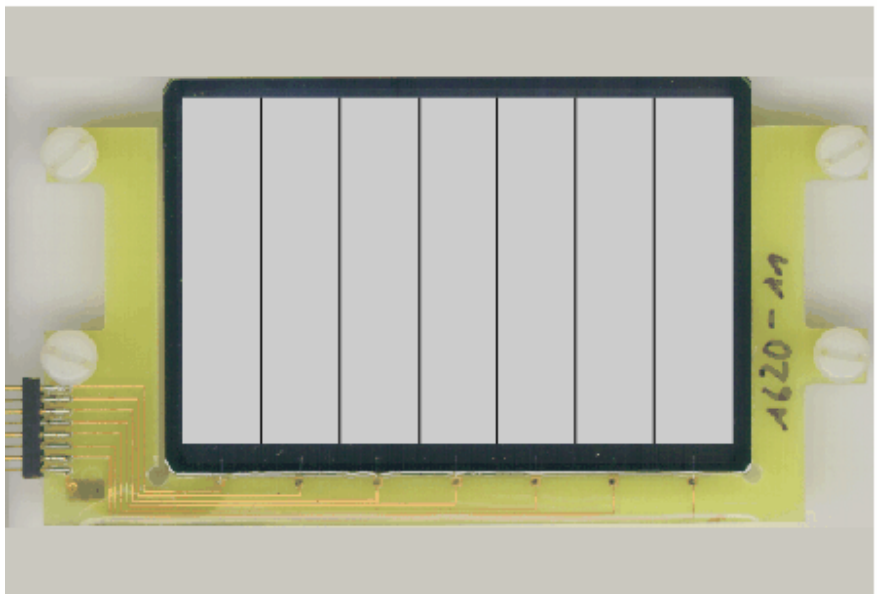
- active area 60 x 40 mm^2, thickness 1 mm
- 7-fold segmentation for suppression of compton electrons
- small photo absorption cross section for gammas
- read-out by discrete amplifiers

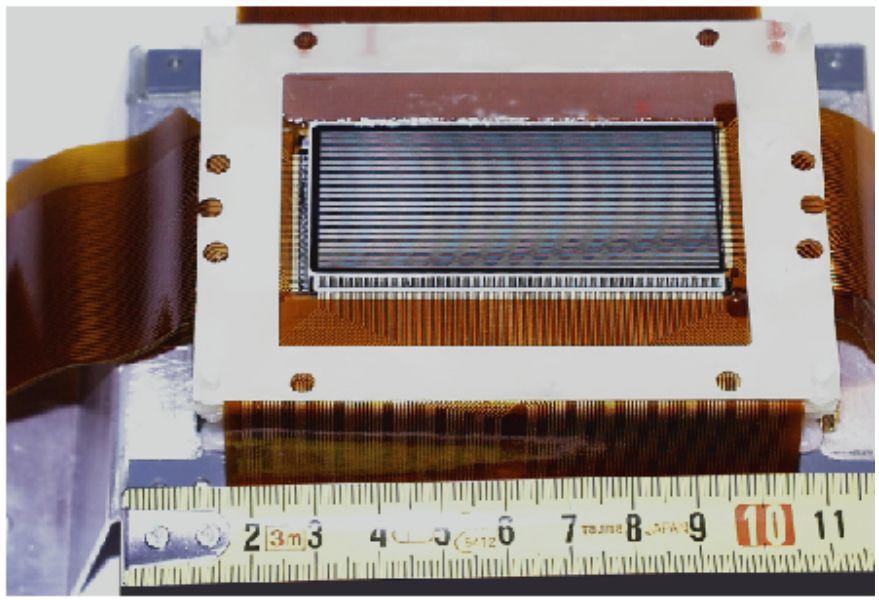
Implantation zone

4 double sided silicon strip detectors

- active area 64 x 25 mm^2, thickness 0.5 mm
- n-side: 50 horizontal strips, 0.5 mm pitch read-out by 16 discrete amplifiers
- p-side: 128 vertical strips, 0.5 mm pitch read-out by GASSIPLEX chip (CERN)
- granularity: 8192 pixel

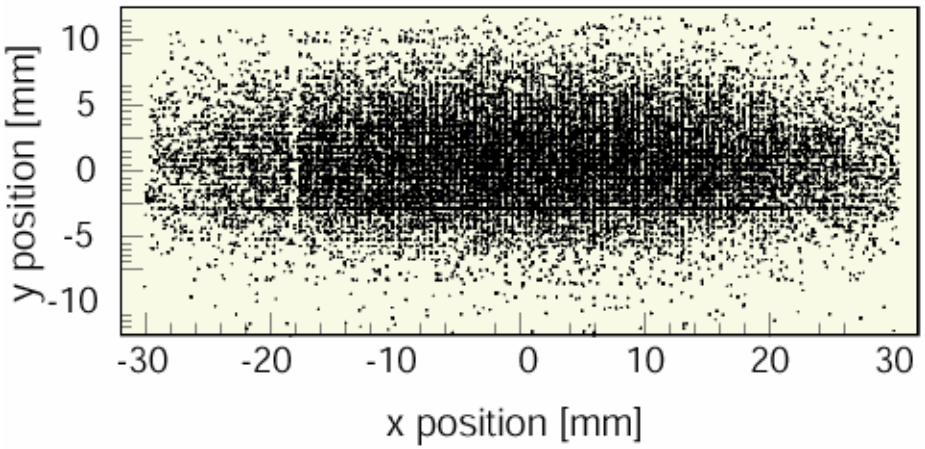
⇒ effective background suppression



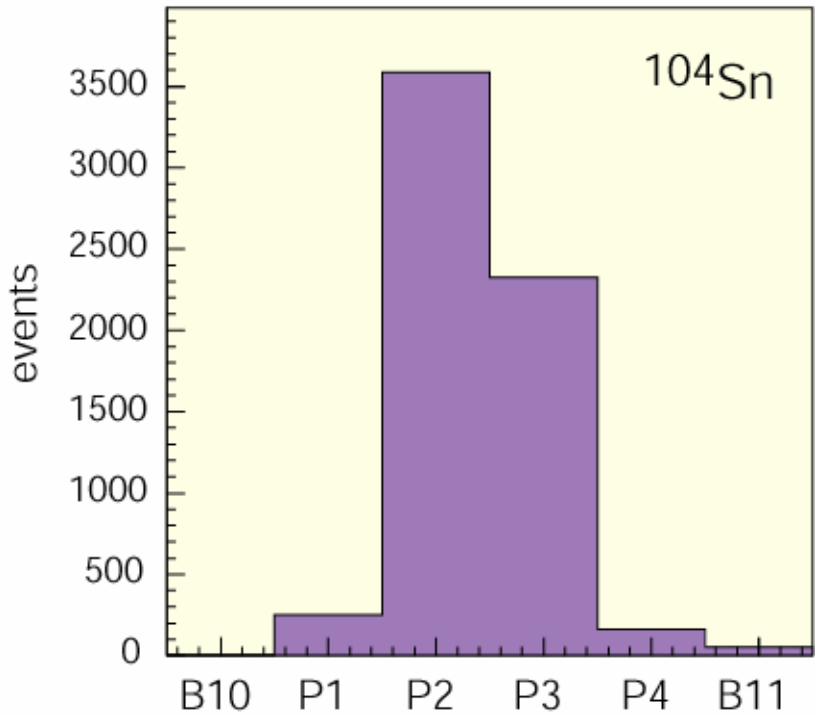


Implantation profile

Position distribution in implantation zone

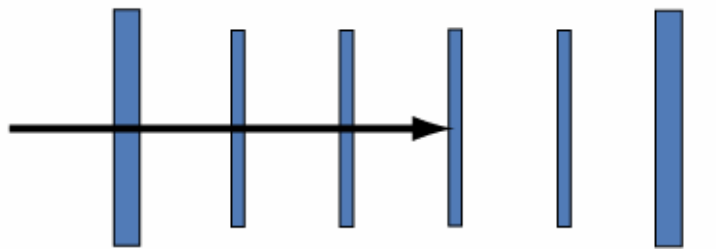


Implantation depth



distribution x position: Δx = 30 mm (FWHM)

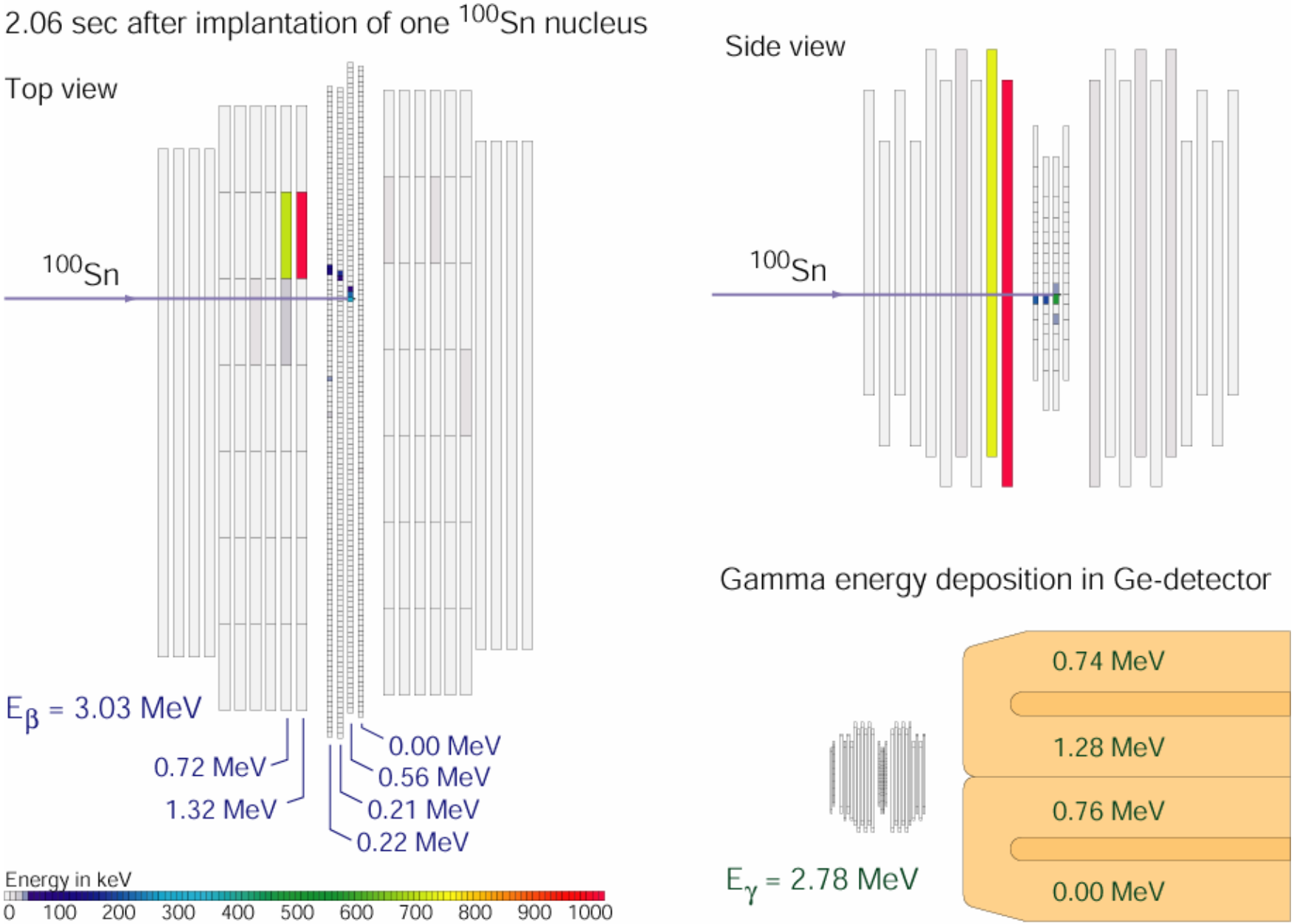
distribution y position: Δy = 7.5 mm (FWHM)



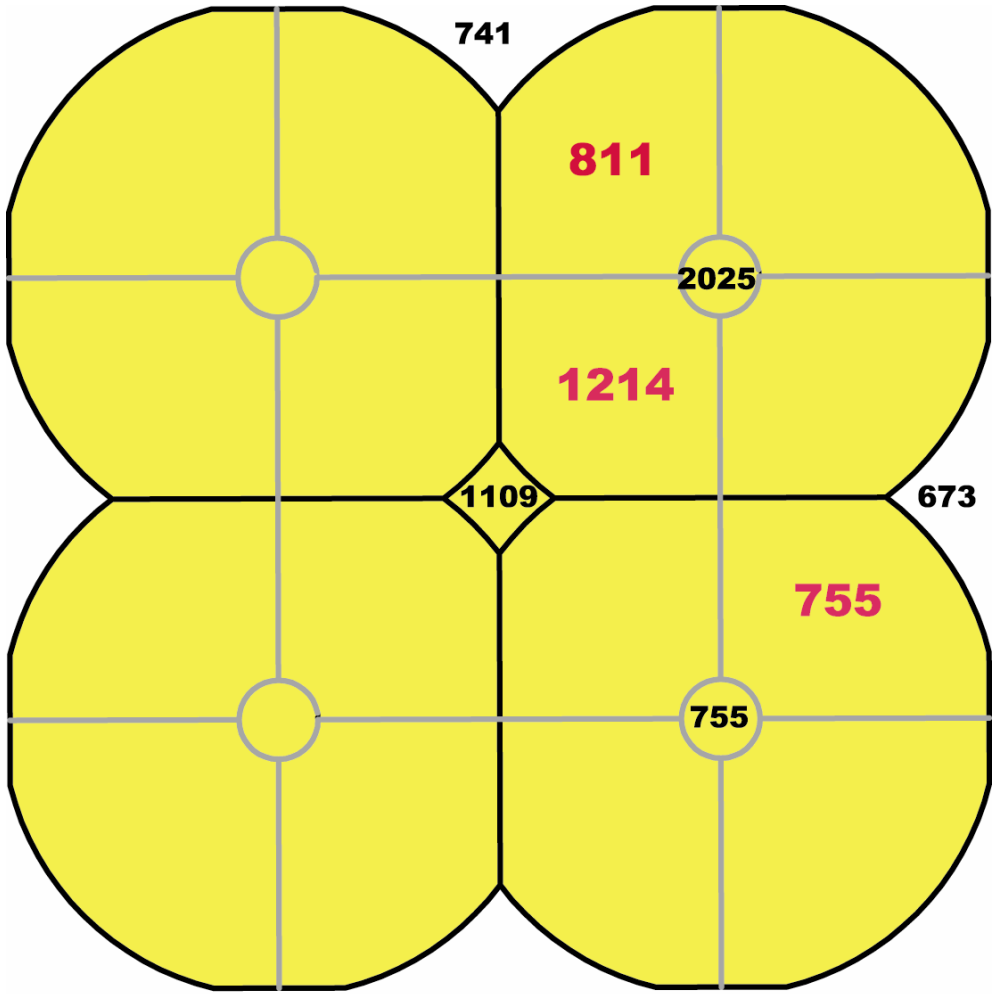
80% of identified nuclei survive implantation

20%: fragmentation in degrader
and detector matter

Implantation detector



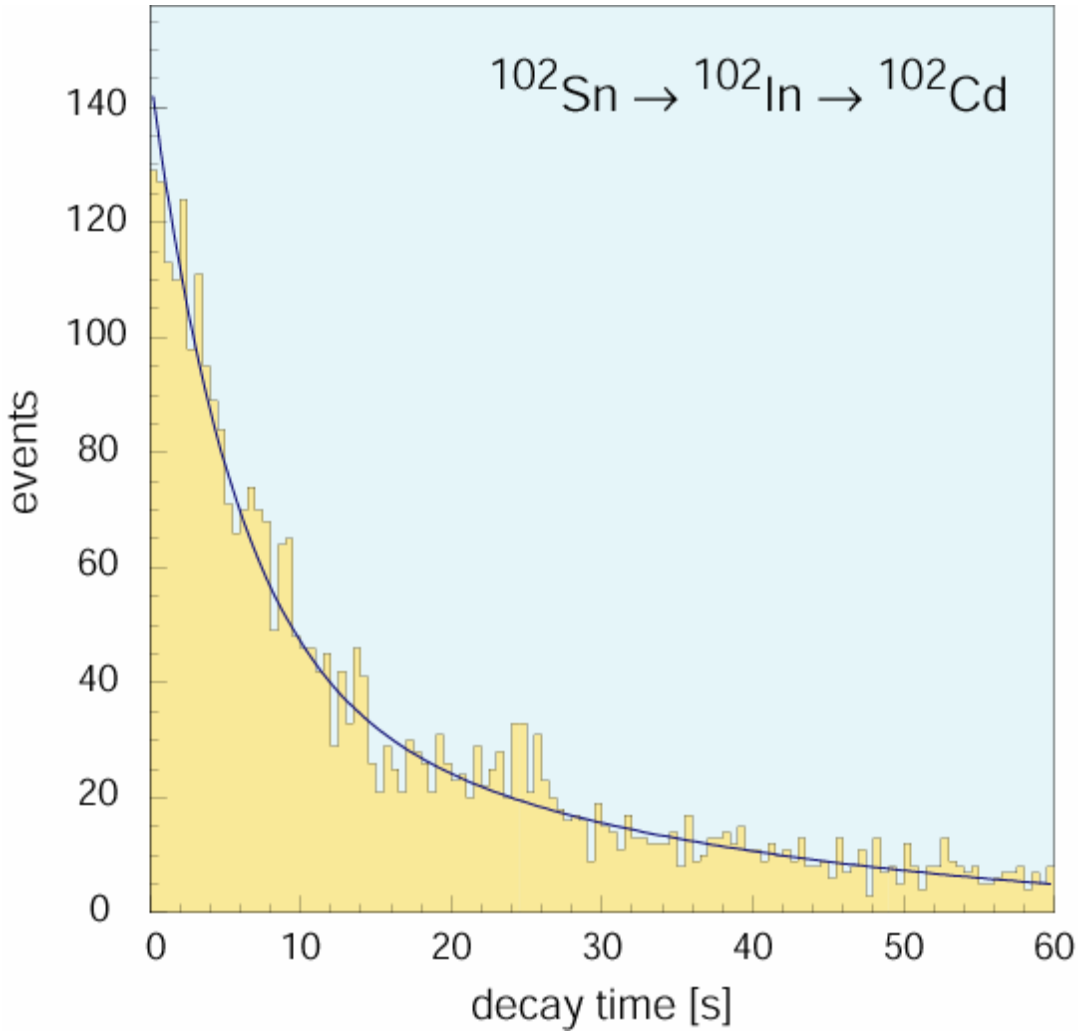
^{100}Sn event in Super-Clover



Total: 2780 keV

Segments increased by ~ 10%

Half-life of 102Sn



Implantation of 2800 ^{102}Sn

correlation time: t_{cor} = 60 s

analysis of 1620 decay chains

Half-life ^{102}Sn:

$T_{1/2}$ = 3.8 ± 0.2 s

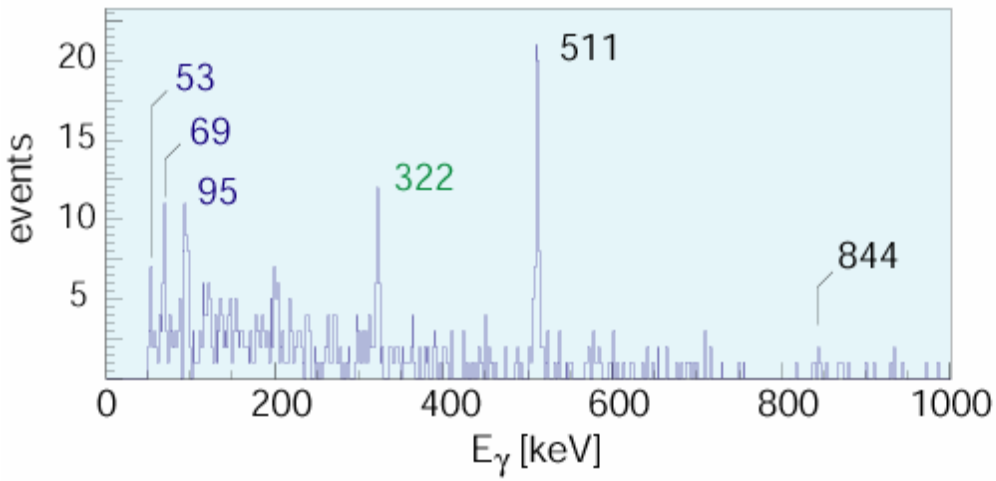
Calculation with maximum likelihood method (3 decay generations)

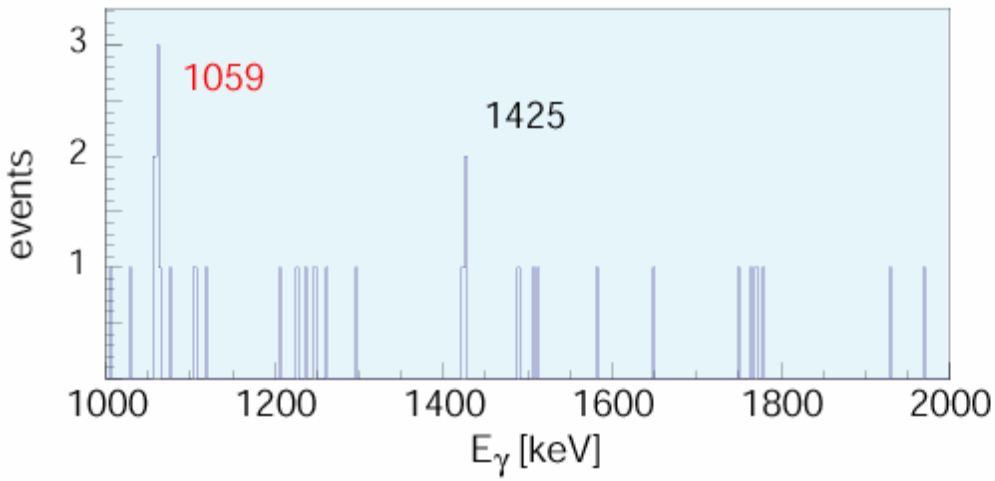
R. Schneider, 1996:

$T_{1/2}$ = 4.6 ± 1.4 s (42 events)

Decay scheme of 102Sn

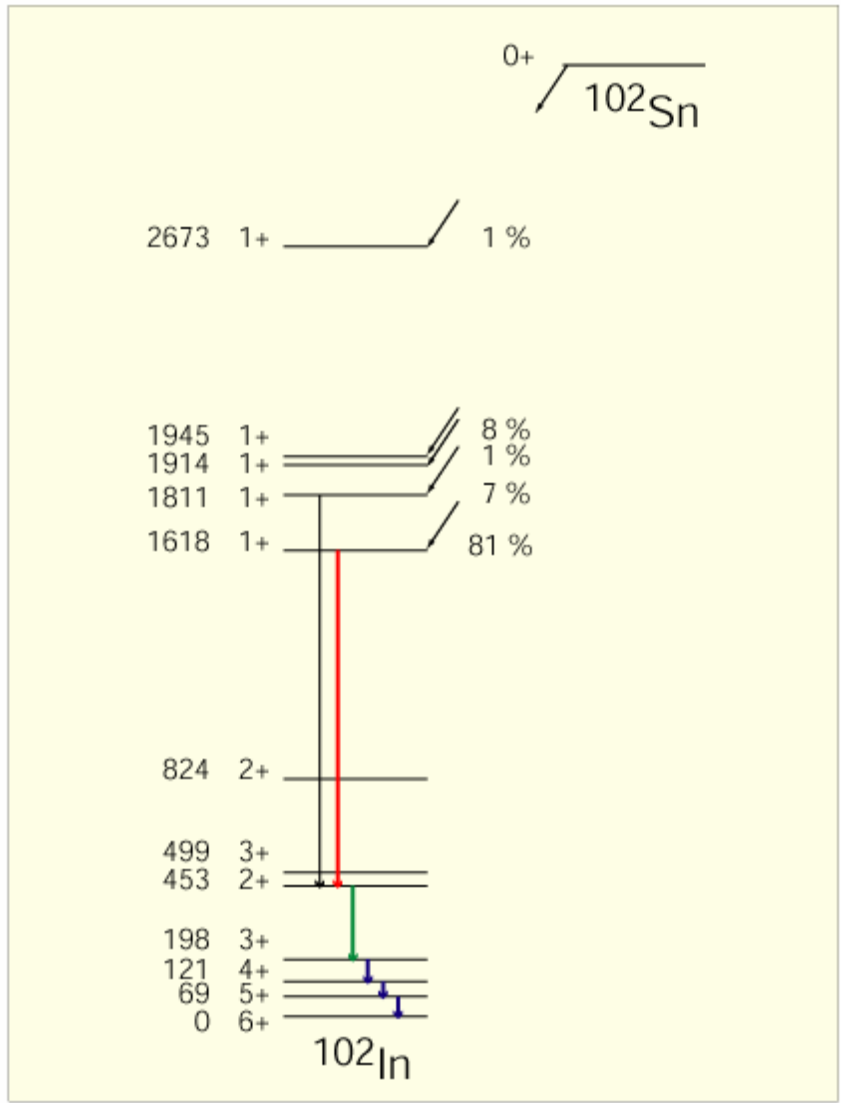
Gamma energy $^{102}Sn \rightarrow {}^{102}In$



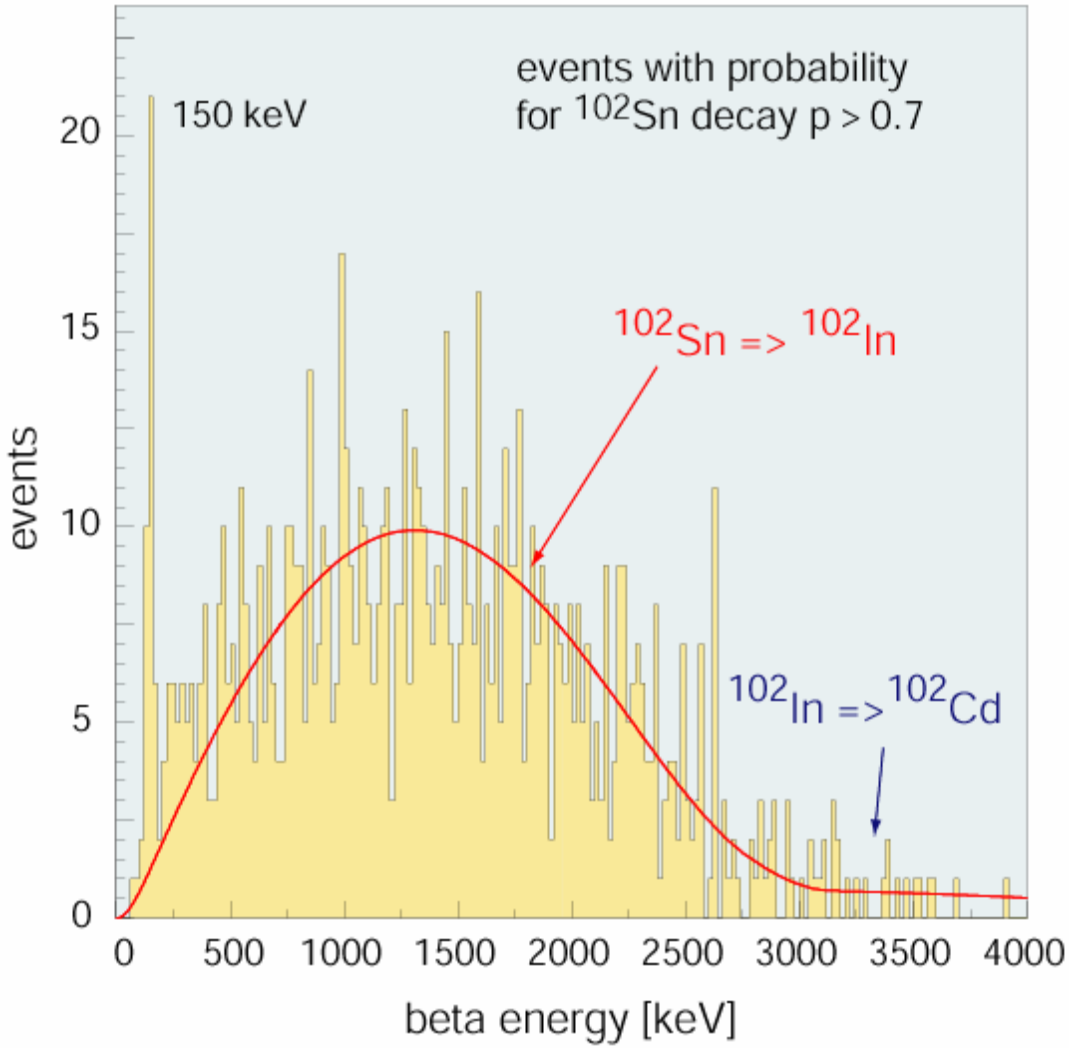


events with probability for ^{102}Sn decay p > 0.75

Shell model calculation A. Brown



Beta decay of 102Sn



Analysis of 900 decay events

correlation time: t_{cor} = 60 s

Beta endpoint energies:

E_{01} = 3140 ± 90 keV (70%)

E_{02} = 2775 ± 90 keV (30%)

analysis with MLH method
(7 % daughter decay events)

beta branching from γ data

E [keV]	Iβ⁺ [%]
1598	$70\ ^{+0.17}_{-0.10}$
1964	$30\ ^{+0.10}_{-0.17}$

Q-value ^{102}Sn => ^{102}In:

Q_{EC} = 5760 ± 90 ± 50 keV

Gamov-Teller strength of Sn isotopes

Experimental GT strength:

$B_{GT}^{exp} = 4.0 \pm 0.6$

sum over 2 observed beta branches

Single particle shell model as reference

$$B^{ref} = \frac{4\,I}{2\,I+1} \cdot N\pi_{g9/2} \cdot \left(1 - \frac{1}{8} N\nu_{g7/2}\right)$$

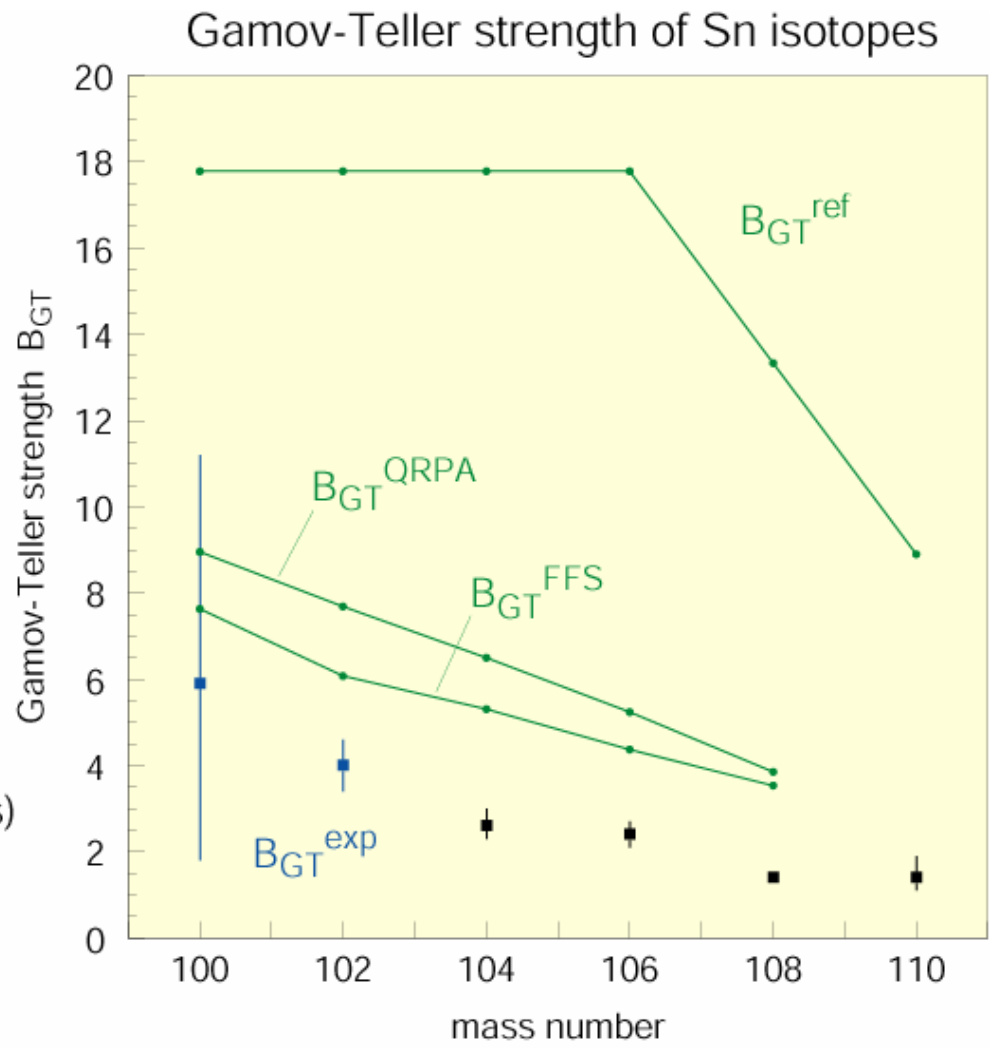
$$= \frac{16}{9} \cdot 10 \cdot \left(1 - \frac{1}{8} N\nu_{g7/2}\right) \quad \text{for } Z=50$$

hindrance factor $h = B_{GT}^{ref} / B_{GT}^{exp}$

pairing corrections (realist. occupation numbers)
$h_{pc} = 1.0 - 1.3$

core polarisation (2p2h-excitations)
$h_{cp} = 1.2 - 1.8$

higher order corrections (Δ-nucleon-hole states)
$h_{ho} = 1.6$



A. Bobyk & W. Kaminski, 2000

Conclusions

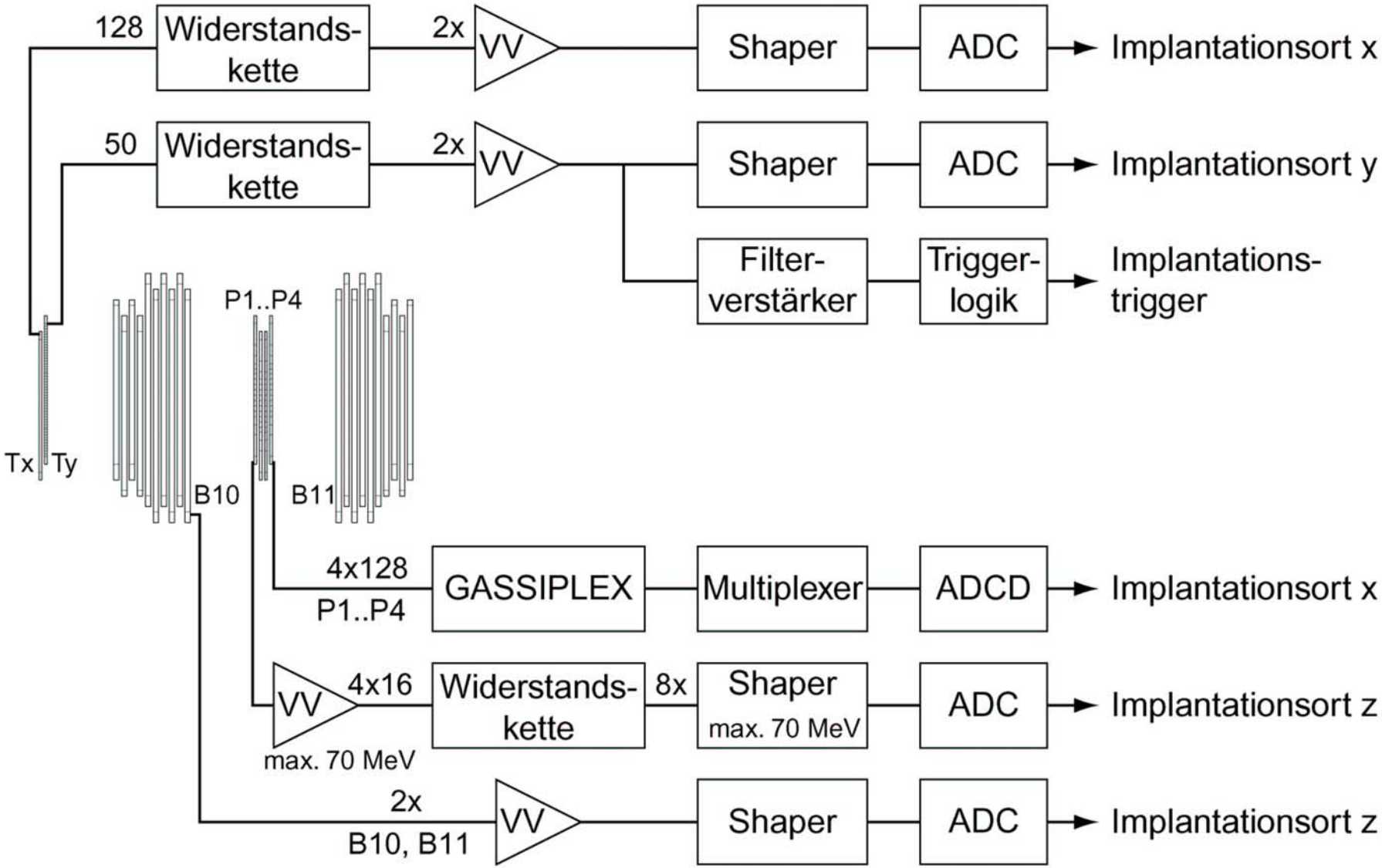
correlation of decay with implanted fragment gives clean spectra

this requires fine 3 dim. position of fragment and decay

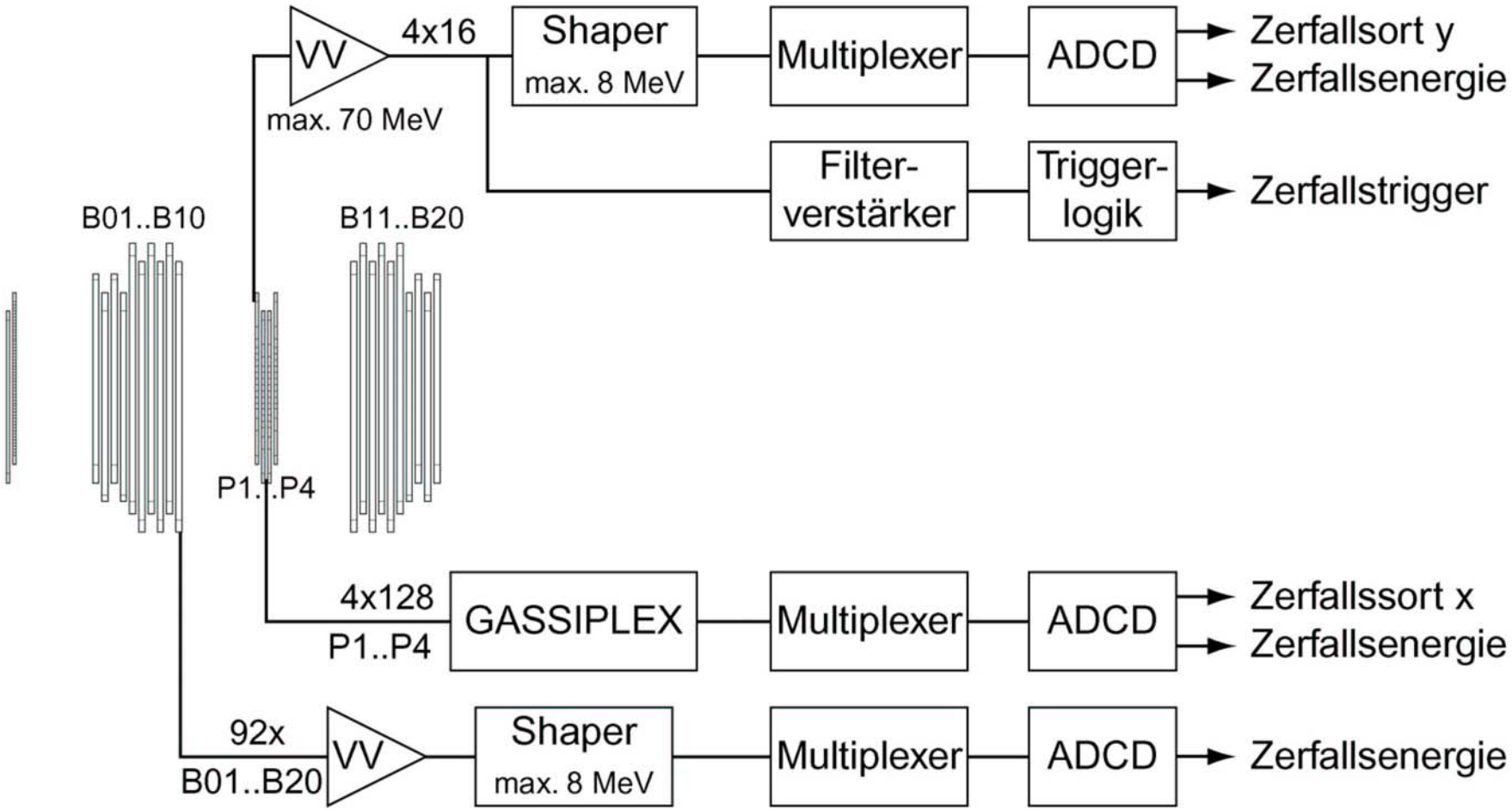
highest efficiency and energy resolution for all detectors

^{100}Sn is still a challenge

readout for implantation

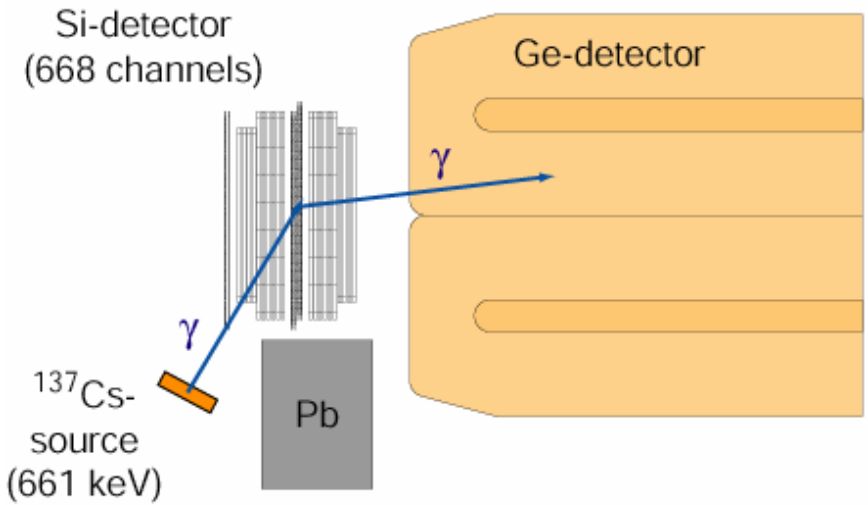


readout for decay

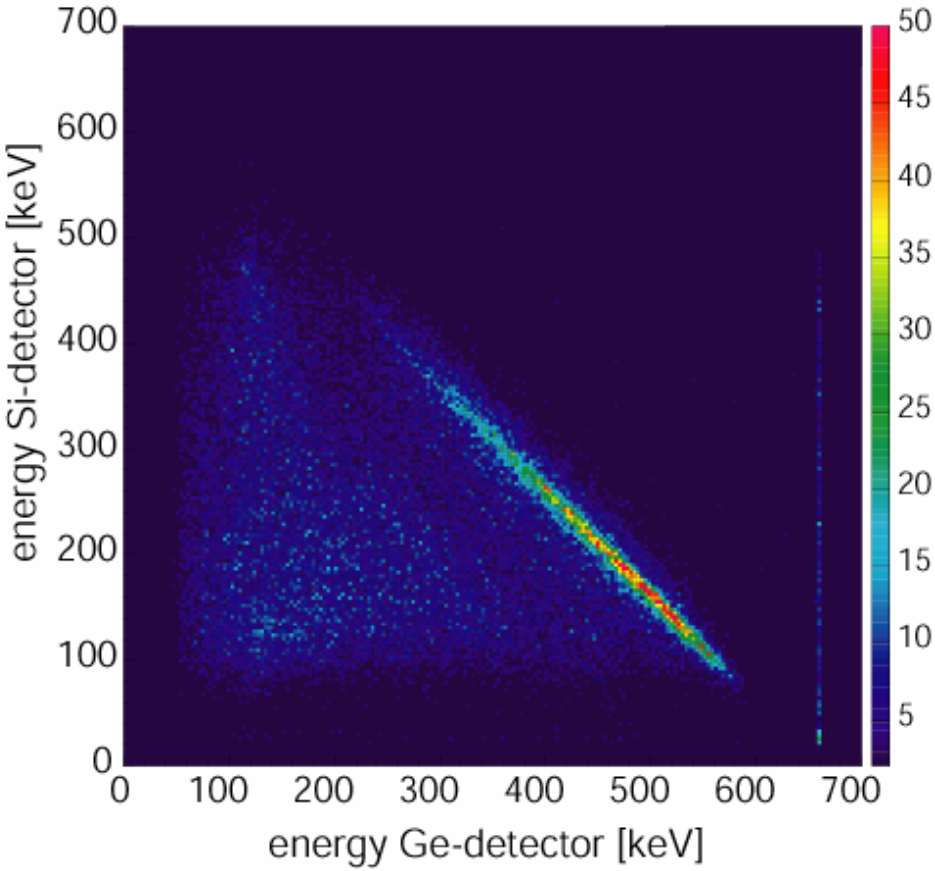


Energy calibration of the implantation detector

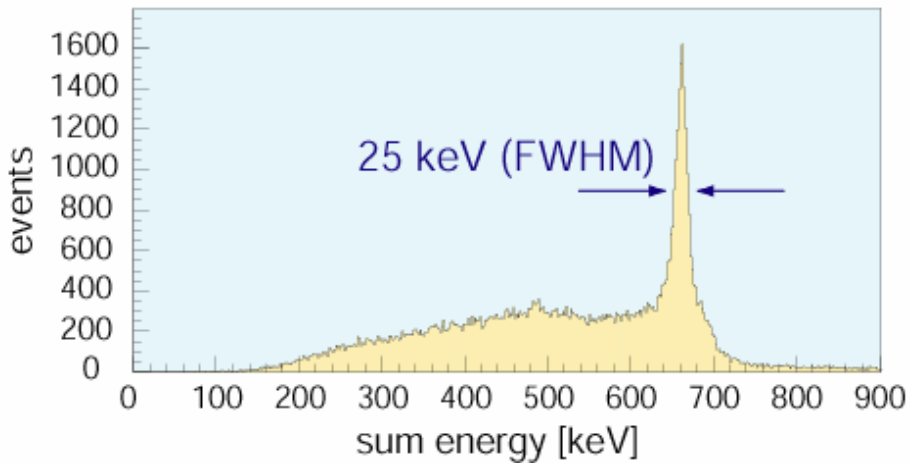
Energy calibration using Compton scattering



Energy correlation Si-detector – Ge-detector



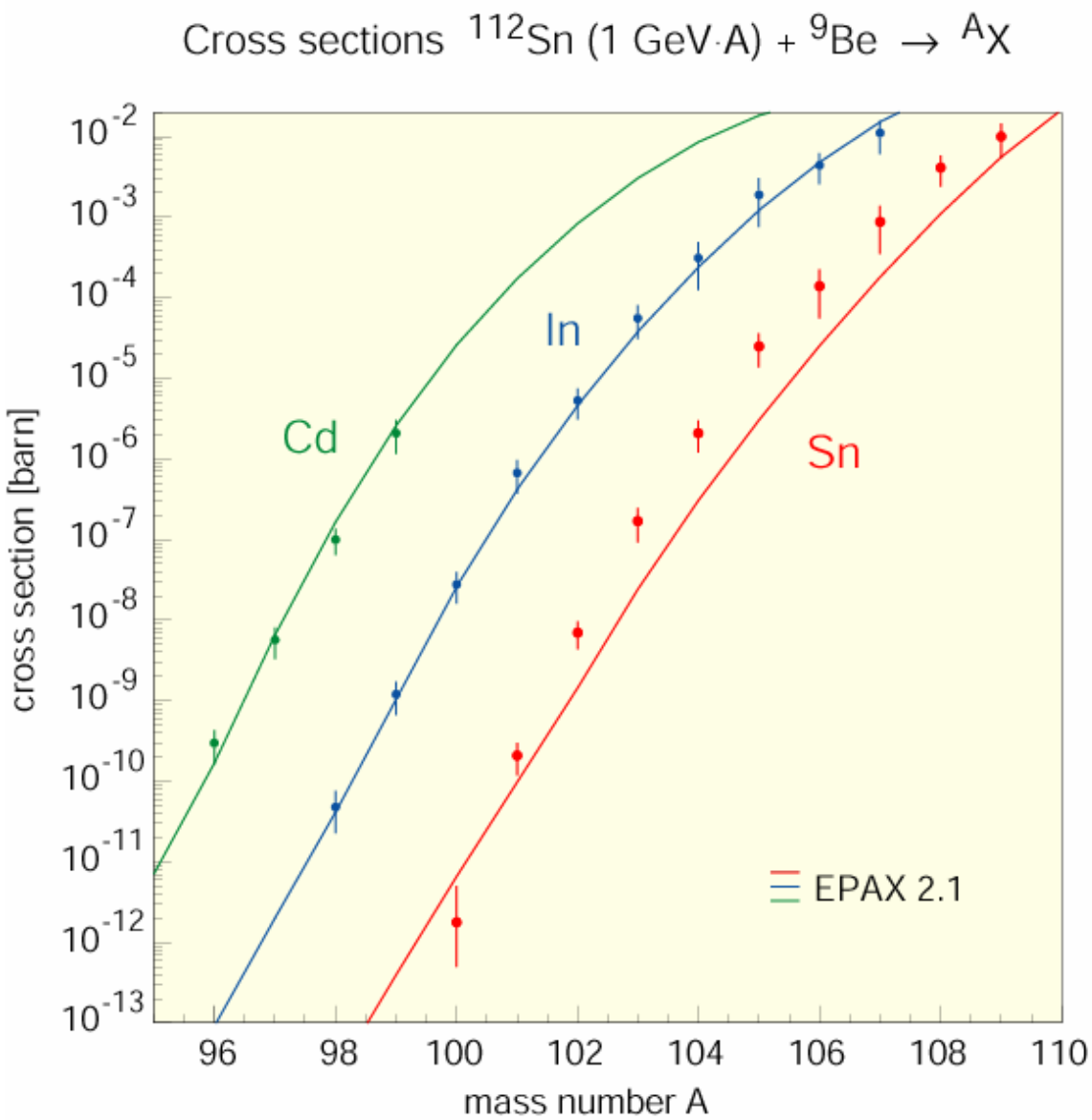
Sum energy Si strip detector + Ge-detector



Peak to total ratio: ε = 25 %

for gamma radiation from Si-detector (300-600 keV)

Production cross sections



Production cross section for ^{100}Sn

GSI 1998:
^{112}Sn (1 GeV·A) + ^{9}Be
$\sigma(^{100}\text{Sn}) = 1.8\ (+3.2\ -1.3)$ pb

GSI 1994:
^{124}Xe (1 GeV·A) + ^{9}Be
$\sigma(^{100}\text{Sn}) = 11\ (\pm 4.6)$ pb

GANIL1994:
^{112}Sn (63 MeV·A) + ^{nat}Ni
$\sigma(^{100}\text{Sn}) \approx 120$ pb