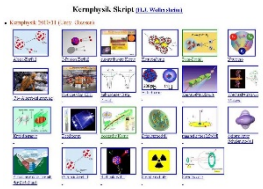
Outline: Bound β-decay

Lecturer: Hans-Jürgen Wollersheim

e-mail: h.j.wollersheim@gsi.de

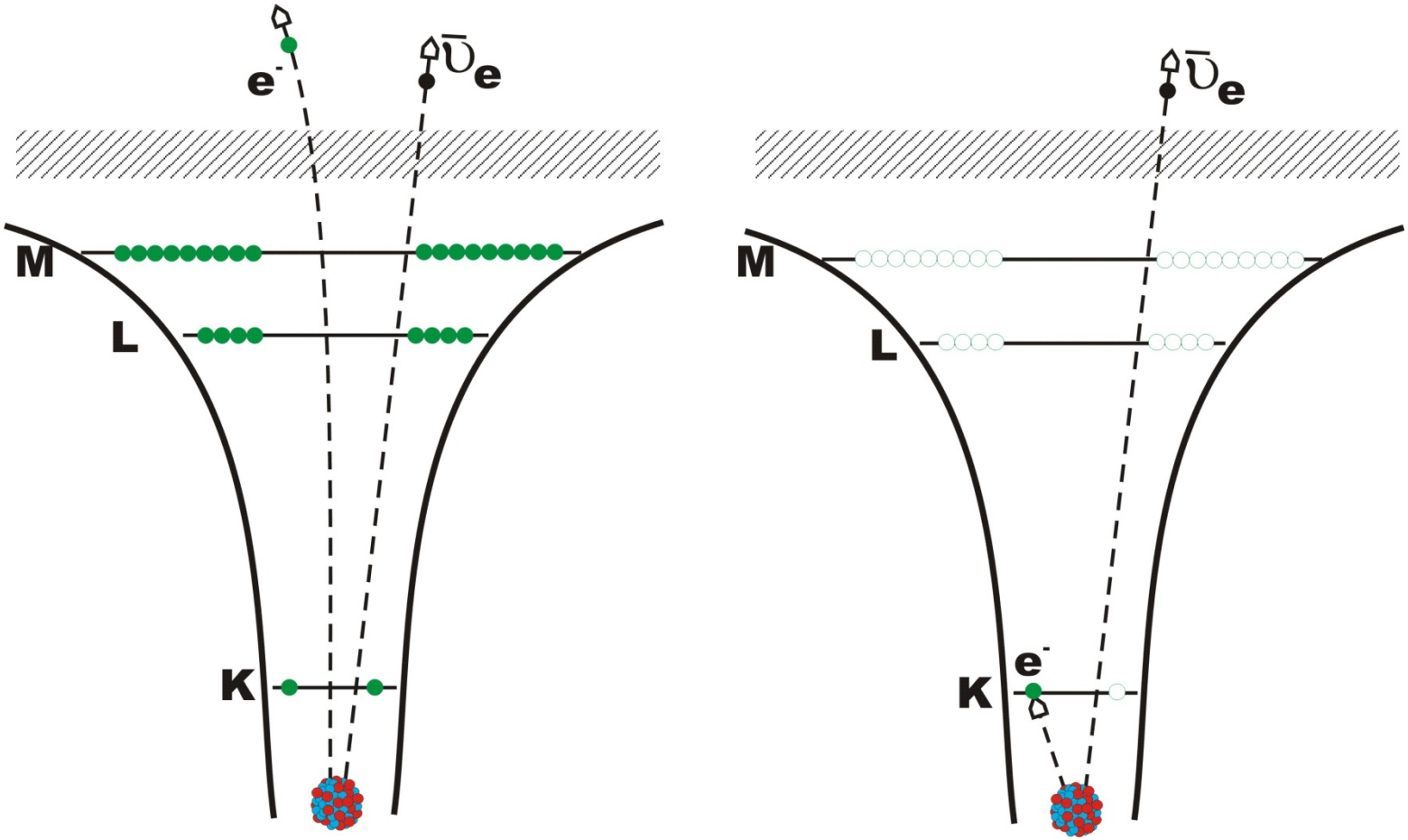
web-page: https://web-docs.gsi.de/~wolle/ and click on



1. β-decay to bound states in the atomic cloud
2. first observation in the experimental storage ring

Bound β-decay

First observation at ESR (^{163}Dy, ^{187}Re, ^{206,207}Tl)



Time-mirrored process of orbital electron-capture decay; predicted by Jean, Daudel and Lecoin in 1947 and observed at the ESR in 1992

β-decay to bound states in the atomic cloud

$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^{-} + \overline{\nu}_e $$

Q-value for electric neutral atoms:

from the mass difference of the atomic masses (mass of the nucleus + mass of the bound electrons)

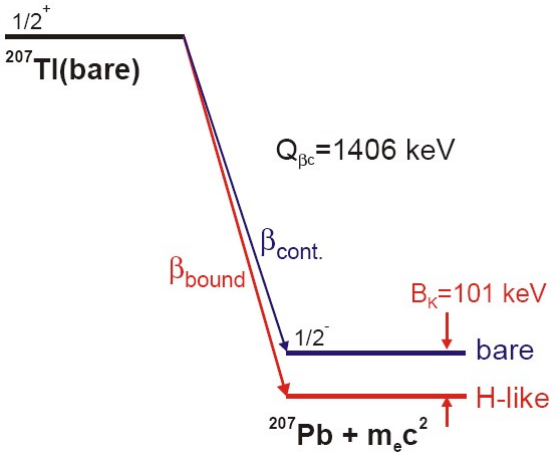
$$ Q_n = M(Z) - [M(Z+1) + BE_V + m_{\overline{\nu}_e}] $$

BE_V = binding energy of the outer most valence electrons (<25 eV), $m_{\overline{\nu}_e}$ = mass of the antineutrinos (<2 eV)

Q-value of the completely ionized atoms:

$$ Q_0 = [M(Z) + BE_n(Z)] - [M(Z+1) + BE_n(Z+1) + m_{\overline{\nu}_e}] $$
$$ = Q_n - [BE_n(Z+1) - BE_n(Z)] $$

BE_n = sum of the binding energies of all electrons



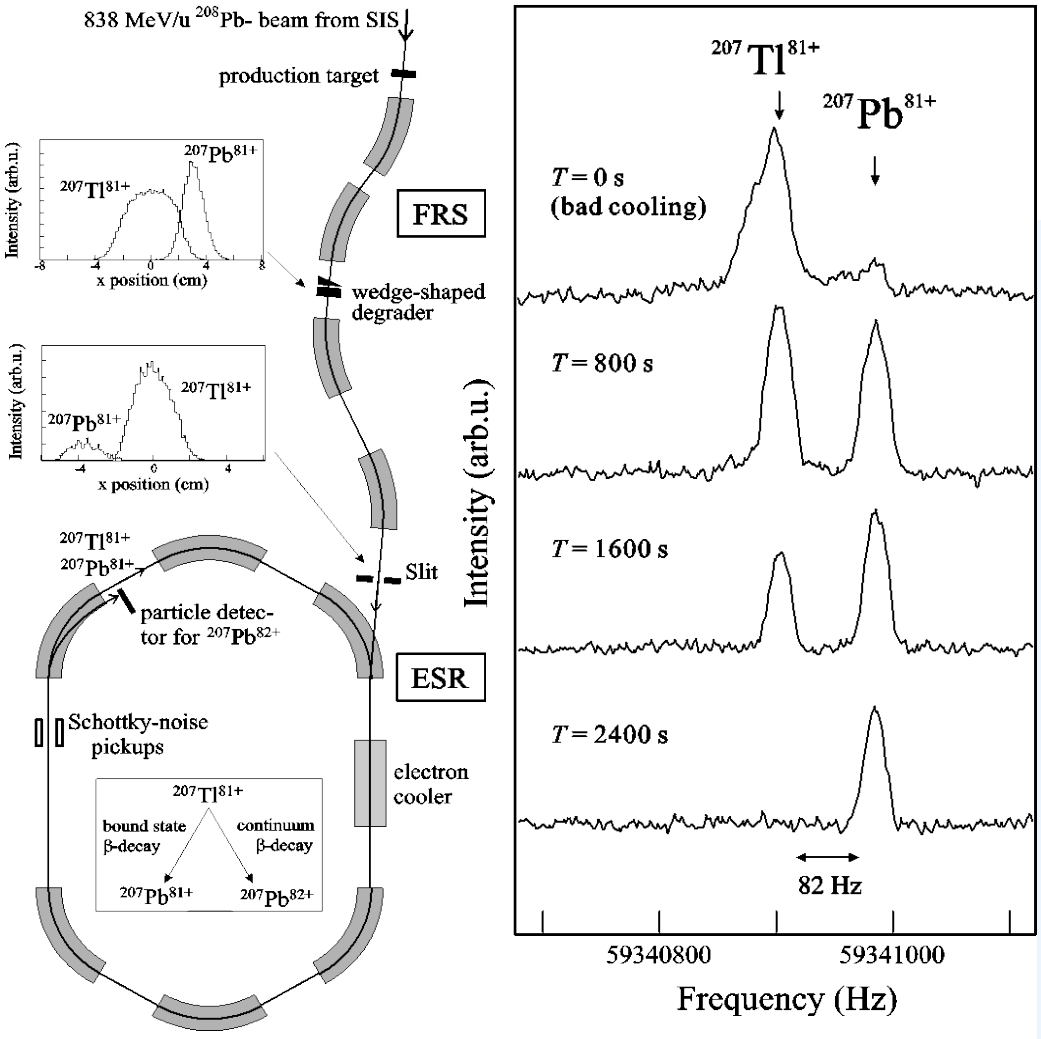
Q-value for the β-decay in a bound state of the K-shell:

$$ Q_K = Q_n - [BE_n(Z+1) - BE_n(Z)] + BE_K = Q_0 + BE_K $$

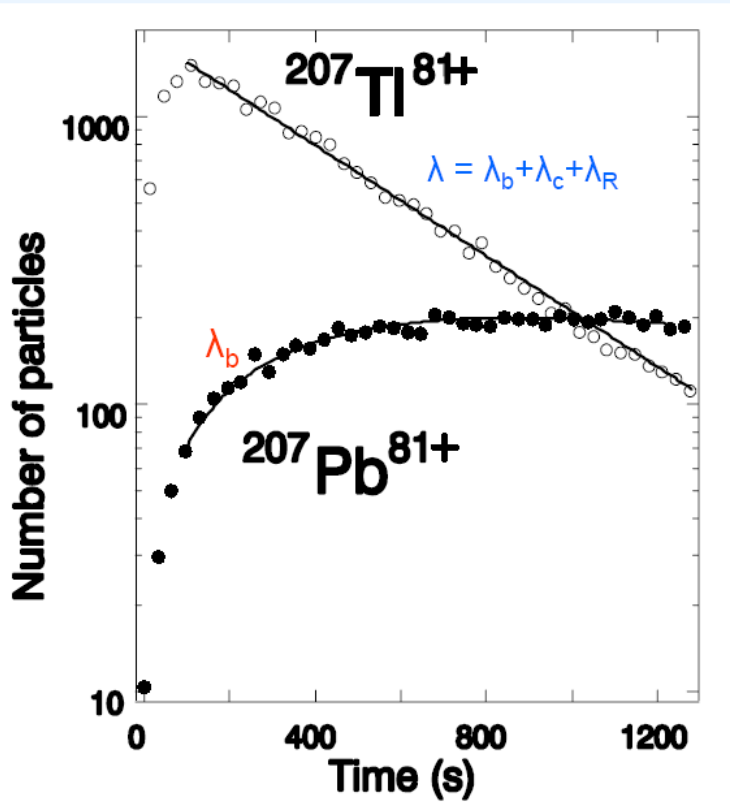
BE_K = binding energy of the K-shell

For ^{187}Re, ^{241}Pu: $Q_n < [BE_n(Z+1) - BE_n(Z)]$ is the β-decay into the continuum energetically not possible.

First direct observation of bound-state β-decay

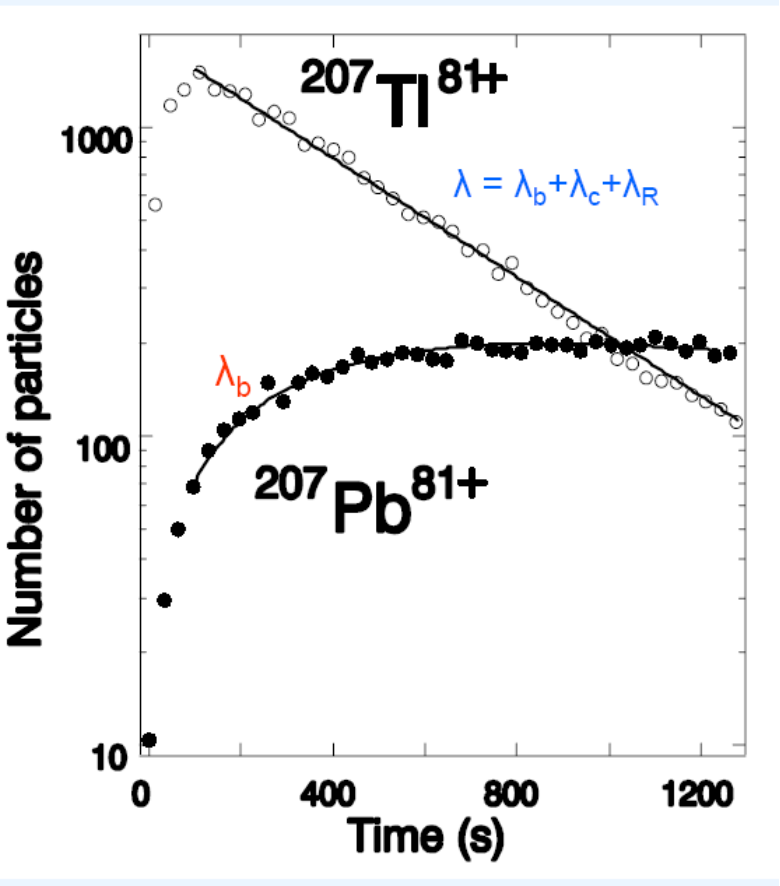


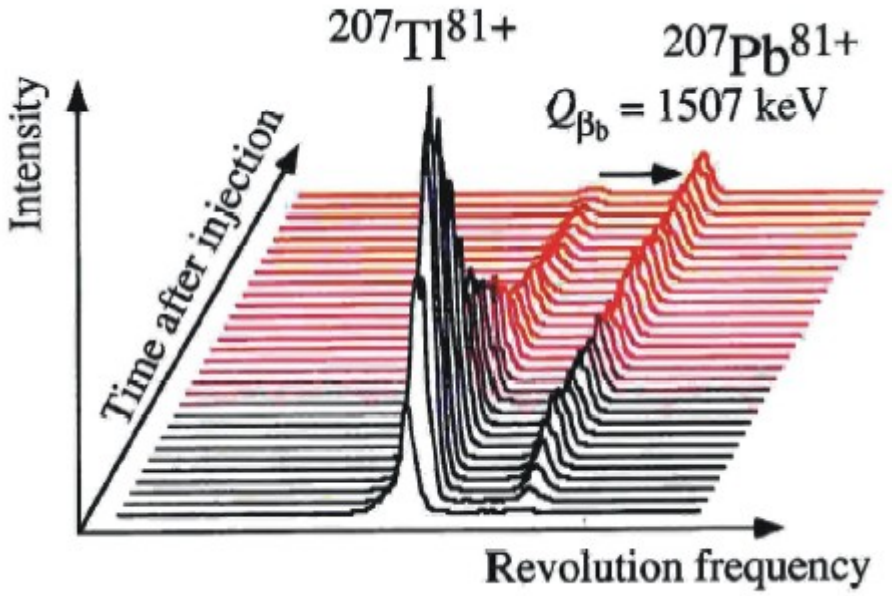
Parent and daughter ions are in the same spectrum



T. Ohtsubo et al., PRL **95** (2005) 052501

Bound β-decay: results

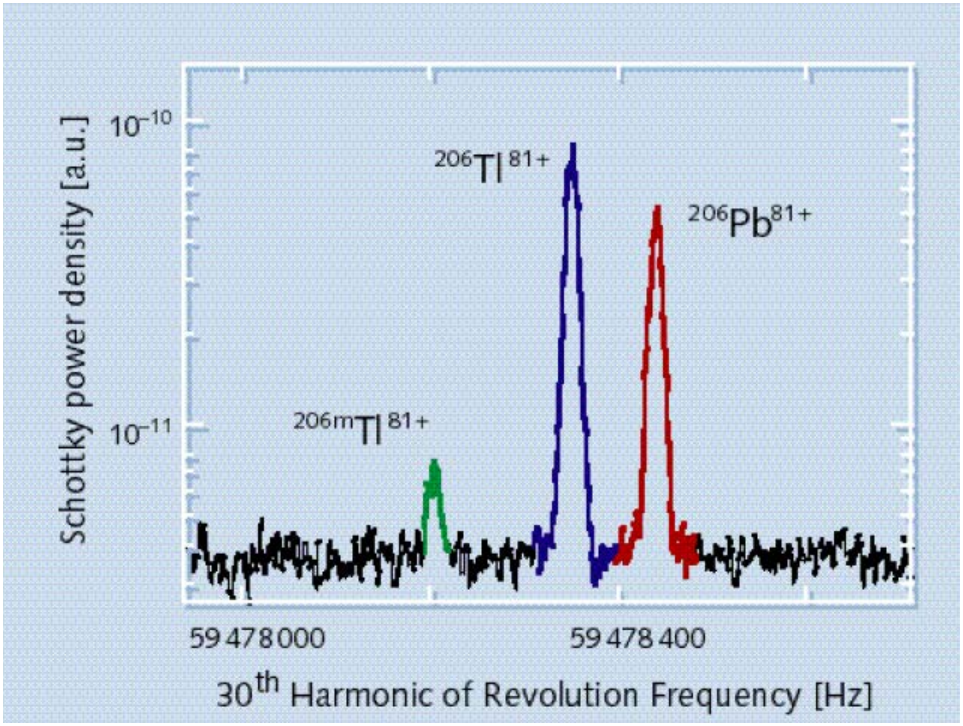


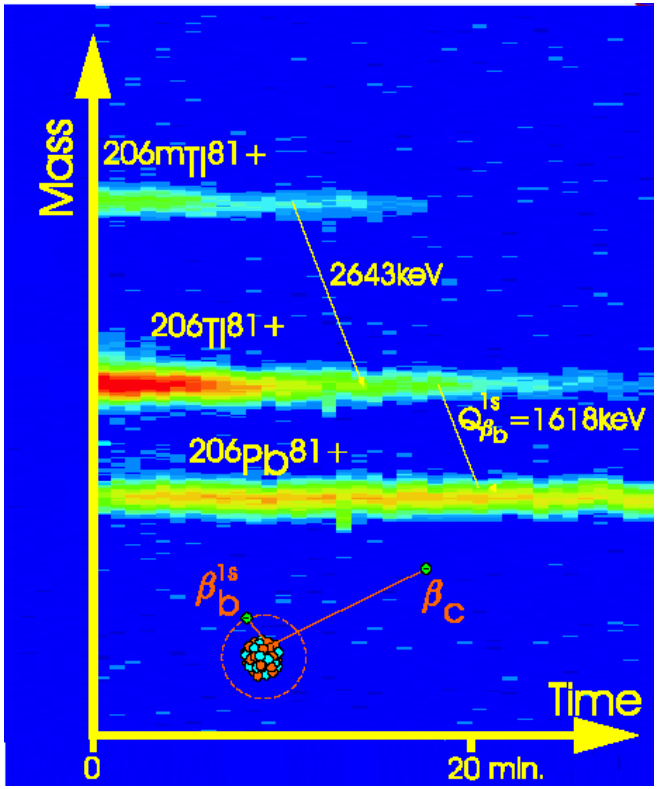


bound/continuum branching ratio
→ Fermi function f(Z) of the β^- decay

direct Q-value determination

Bound β-decay: results





bound/continuum branching ratio: 10-20%

direct Q-value determination