Instituut voor Kern- en Stralingsfysica

KATHOLIEKE UNIVERSITEIT LEUVEN

WITCH

first measurement and recent developments

Michaël Tandecki[a]

S. Coeck[a], V. Yu. Kozlov[a], N. Severijns[a], S. Van Gorp[a], F. Wauters[a], M. Beck[b], P. Friedag[b], Ch. Weinheimer[b], D. Zakoucky[c]
P. Delahaye[d], A. Herlert[d], F. Wenander[d]

[a] IKS - Katholieke Universiteit Leuven, Belgium
[b] IKP - Westfälische Wilhelms-Universität Münster, Germany
[c] NPI Rez, Prague, Czech
[d] CERN

ISOLDE workshop, 17th-19th of December, 2007

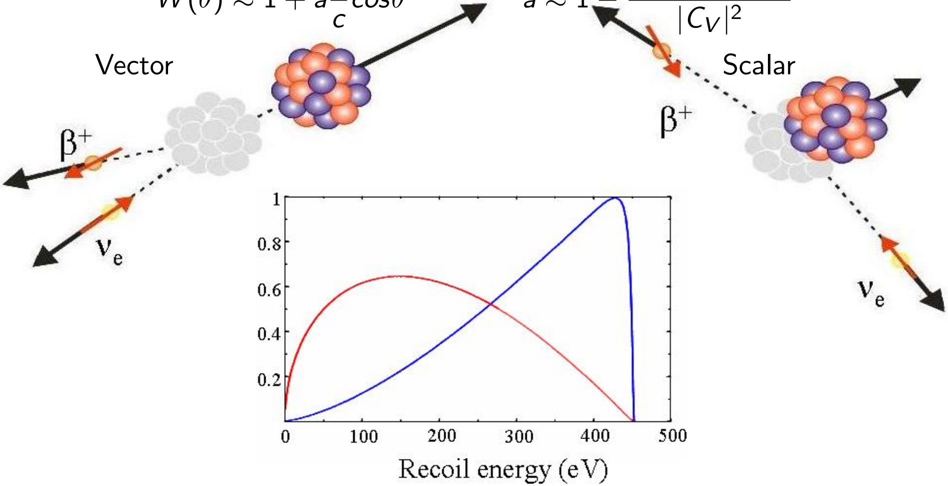
Outline

1. Motivation and set-up
   - Measurement principle
   - WITCH set-up
2. Nov 2006 Run: ^{124}In
   - Choice of isotope
   - Results
   - Analysis
3. 2007 Improvements
4. Oct 2007 Run: ^{35}Ar
5. Outlook & Conclusion

β-ν angular correlation

e.g: Fermi β decay ($0^+ \rightarrow 0^+$)

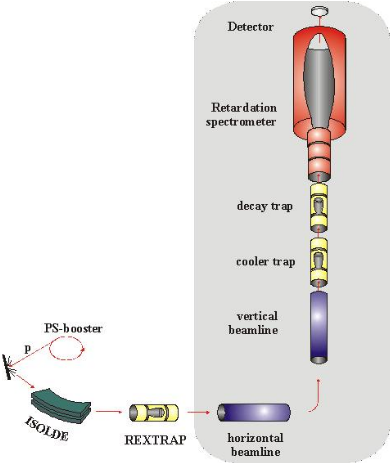
$$W(\theta) \approx 1 + a\frac{v}{c}cos\theta \qquad a \approx 1 - \frac{|C_S|^2 + |C_S'|^2}{|C_V|^2}$$



WITCH: **W**eak **I**nteraction **T**rap for **Ch**arged Particles[1]

- Double Penning trap system to prepare the ions and to act as a scattering-free source

- Retardation spectrometer to probe the energy of the recoiling ions



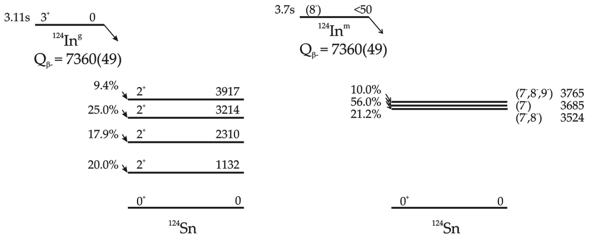
[1] V. Yu. Kozlov, *et al.*, Int. J. Mass. Spectrom. **251** (2006) 159

Choice of isotope

- Production yield at ISOLDE: 10^6-$10^7/\mu C$
- Half-life: $\sim$ 1 second (long enough for trapping, short enough for statistics)
- Low ionization potential
- Decay mode: β^- ($\pm$10 times more ions than β^+)
- Stable daughter isotope
- Minimal isobaric/isomeric contamination
- Simple decay scheme

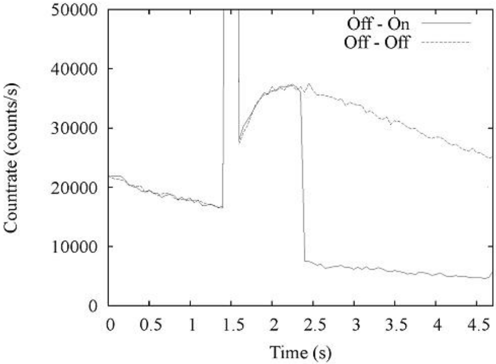
$\Rightarrow$ ^{122g}In (Our prime physics candidate is ^{35}Ar)
The ground state of ^{122}In is not produced, only $^{122}\text{In}^{m1,2}$

^{124}**In** was chosen; complex decay schema, and isomeric contamination.
$T_{1/2}(^{124g}\text{In}) = 3.11(10)$ s, $T_{1/2}(^{124m}\text{In}) = 3.7(2)$



On-Off measurement

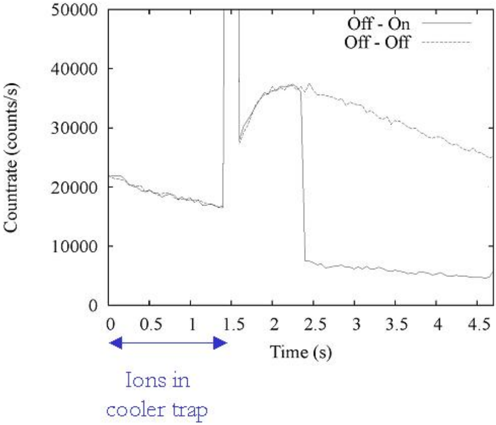
On: Retardation = 200V
Off: Retardation = 0V



On-Off measurement

On: Retardation = 200V

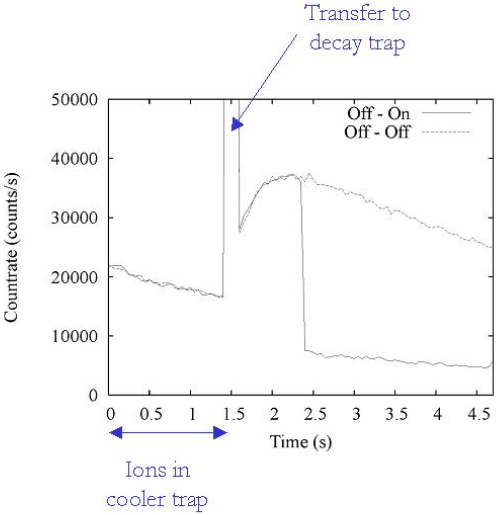
Off: Retardation = 0V



On-Off measurement

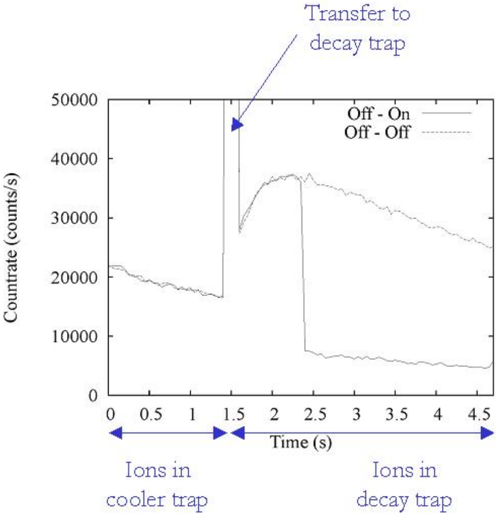
On: Retardation = 200V

Off: Retardation = 0V



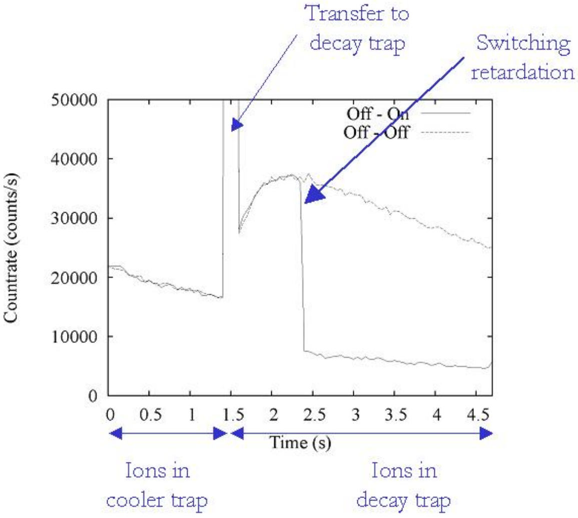
On-Off measurement

On: Retardation = 200V
Off: Retardation = 0V



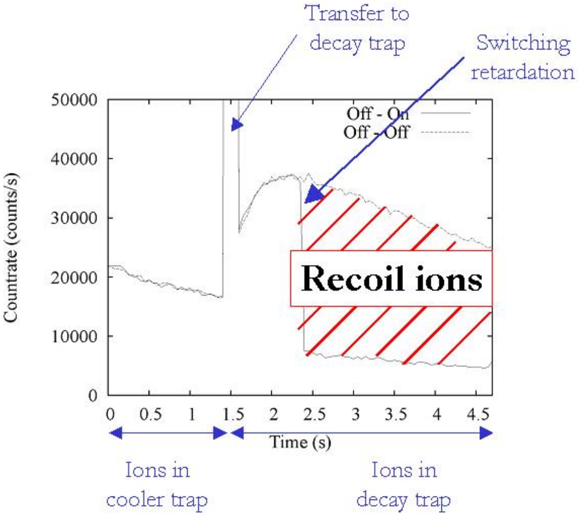
On-Off measurement

On: Retardation = 200V
Off: Retardation = 0V



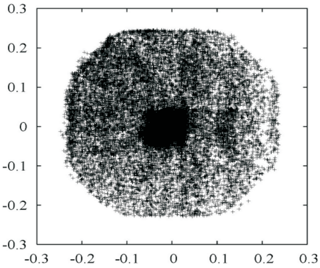
On-Off measurement

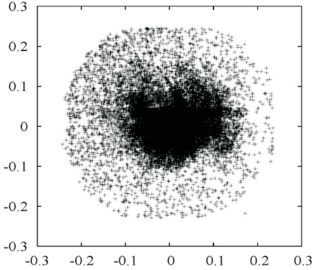
On: Retardation = 200V
Off: Retardation = 0V



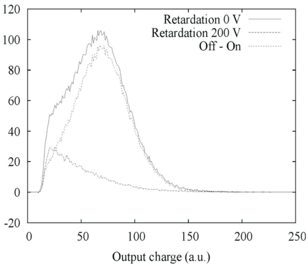
Systematic checks

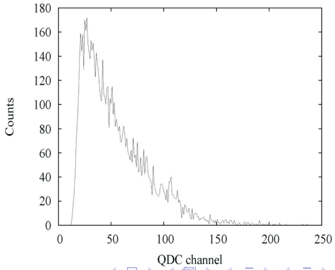
Position



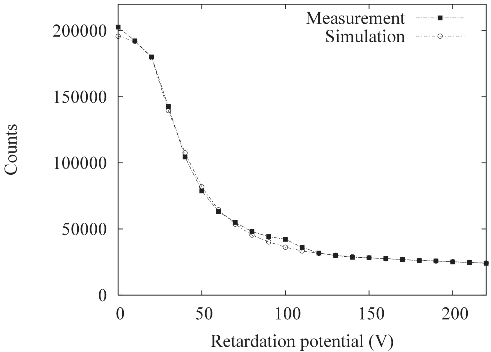


Pulse height distribution





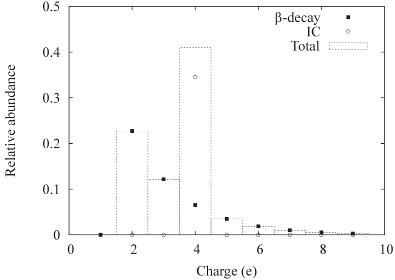
^{124}In integral spectrum, November 2006



Fit Parameters

- Offset of applied potentials
- Fraction of isomeric contamination
- Overall scaling
- Background scaling
- Charge state distribution

Shake-off



^{124}Sn electron structure: [Kr] $5s^2 4d^{10} 5p^2$

- Position Auger charge distribution
- Width Auger charge distribution
- Slope β-decay charge distribution

Physics behind this:

- IT + Auger (e.g. ^{133}Xe [2])
- β Shake-off (e.g. ^{41}Ar [3])

[2] A.H. Snell, *et al.*, Phys. Rev. **111** (1958) 1338
[3] T.A. Carlson, Phys. Rev. **131** (1963) 676

Mass resolving power of our new traps

Mass purification is done by a combination of RF excitations in the trap and buffer gas cooling[4]

$$\text{Mass resolution:} \quad \frac{m}{\Delta m} = \frac{f}{\Delta f} \tag{1}$$

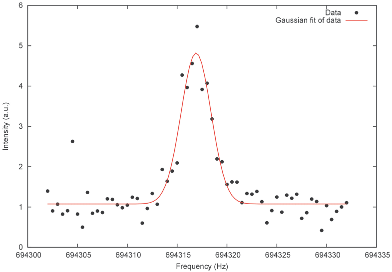


Figure: ω_c quadrupole excitation on ^{133}Cs, FWHM = 3.54 Hz, in 6T

Applications: Spectroscopy measurements with a very pure sample ⇒ Tapestation

[4] S. Coeck, *et al.*, Nucl. Instrum. and Meth. A **574** (2007) 370

^{35}Ar, Oct 2007 run

The run did not go as hoped..

- ^{35}Cl (stable) contamination
  At first: The Cl:Ar was 400:1
  Optimized: 25:1 ratio, but greatly reduced yield
  This issue in *under investigation* by the target group
- Charge exchange
  REXTRAP: half-life of 63 ms
  WITCH: Even worse half-life; this prevented us from preparing the ion cloud
  ⇒ No useful recoil spectrum was obtained
  ⇒ Probably cause; bad vacuum
  ⇒ We will *improve our vacuum* to ensure a *pure buffer gas*

Outlook for the not too distant future

- Detailed simulations to characterize the secundary ionization in the spectrometer
- A scintillation detector between our traps to have a proper normalization
- A tapestation to do (γ-)spectroscopy measurements
- β-spectrosocpy with Si-detectors. Penning trap as a scattering-free ion source. Development of a **M**ulti**w**ire **D**rift **C**hamber to have a scattering-free detector (E. Traykov)

Conclusion

- Our primary goal is to measure the β-ν angular correlation coefficient, but other physics cases are possible as well
- Our first recoil spectrum was obtained in Nov. 2006 and has been analyzed in the meantime
- We have measured the first charge state distribution on an element that is not an alkali or noble gas, and on top of that it was an ion (has never been done)
- Traps were improved $\Rightarrow$ Mass resolution of 300000 in 9T on ^{133}Cs
- Plans for 2008: First technical developments...