^{119m}Sn

A Difficult Experimental Case to Test Internal-Conversion Theory

TEXAS A&M PROGRAM TO MEASURE ICC

N. NICA

Internal Conversion Coefficients (ICC):

- **Big impact on quality of nuclear science**
- **Central for USNDP and other nuclear data programs**
- **Intensely studied by theory and experiment**
- **Important result: hole calculation now standard**
- ***Still to measure critical cases!!!***

2002RA45 survey ICC's theories and measurements

- **Theory: RHFS and RDF comparison**

  Exchange interaction, Finite size of nucleus, ***Hole treatment***

- **Experiment:**

  100 *E2*, *M3*, *E3*, *M4*, *E5* ICC values, 0.5%-6% precision,

  very few <1% precision!

- **Conclusions, Δ(exp:theory)%:**

  No hole*: +0.19(26)% *BEST!

  (bound and continuum states - SCF of neutral atom)

  ***Hole-SCF*: -0.94(24)%**

  (continuum - SCF of ion + hole (full relaxation of ion orbitals))

  ***Hole-FO*: -1.18(24)%**

  (continuum - ion field from bound wave functions of neutral atom

  (no relaxation of ion orbitals))

PHYSICAL ARGUMENT

K-shell filling time vs. time to leave atom

$\sim 10^{-15} - 10^{-17}$ s » $\sim 10^{-18}$ s

Texas A&M precision ICC measurements:

- **KX to γ rays ratio method**

$$\alpha_K \omega_K = \frac{N_K}{N_\gamma} \cdot \frac{\varepsilon_\gamma}{\varepsilon_K}$$

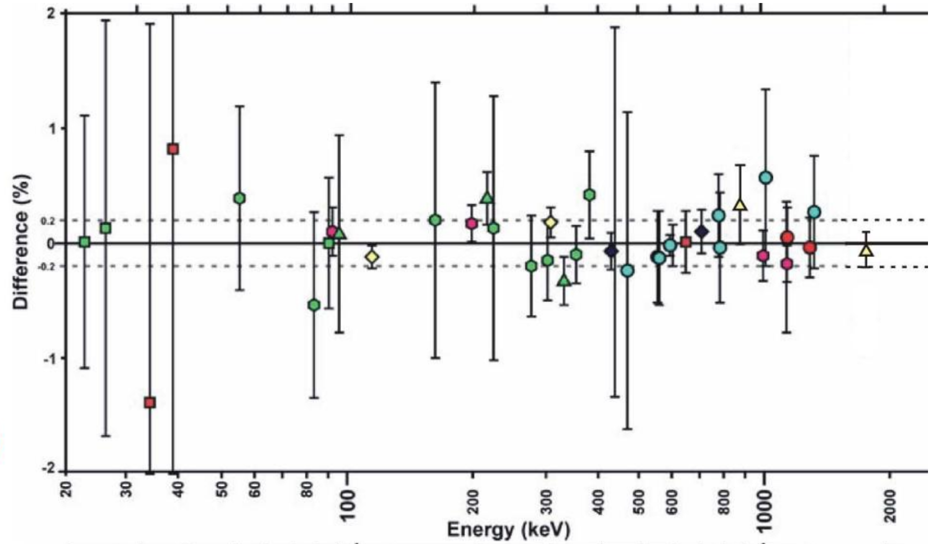
  - N_K, N_γ **measured from *only one K-shell converted transition***
  - ω_K **from 1999SCZX (**compilation and fit**)**

- **Very precise detection efficiency for ORTEC γ-X 280-cm^3 coaxial HPGe at standard distance of 151 mm:**
  - **0.2% , 50-1400 keV (2002HA61, 2003HE28)**
  - **0.4% , 1.4-3.5 MeV (2004HE34)**
  - **1% , 10-50 keV (KX rays domain)**

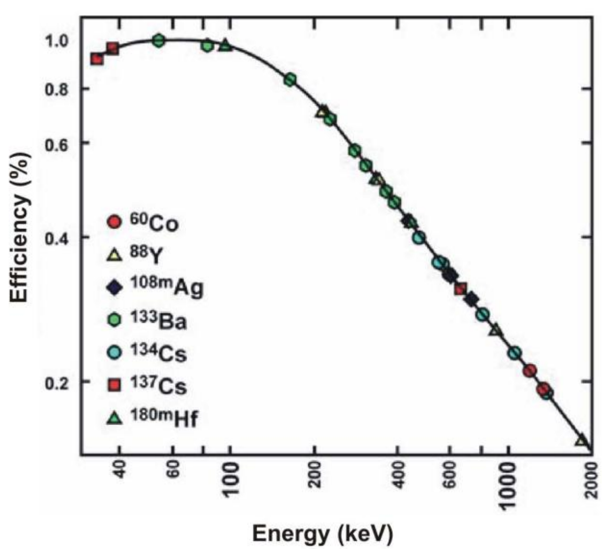
DETECTOR EFFICIENCY
50 keV < E_γ < 1.4 MeV

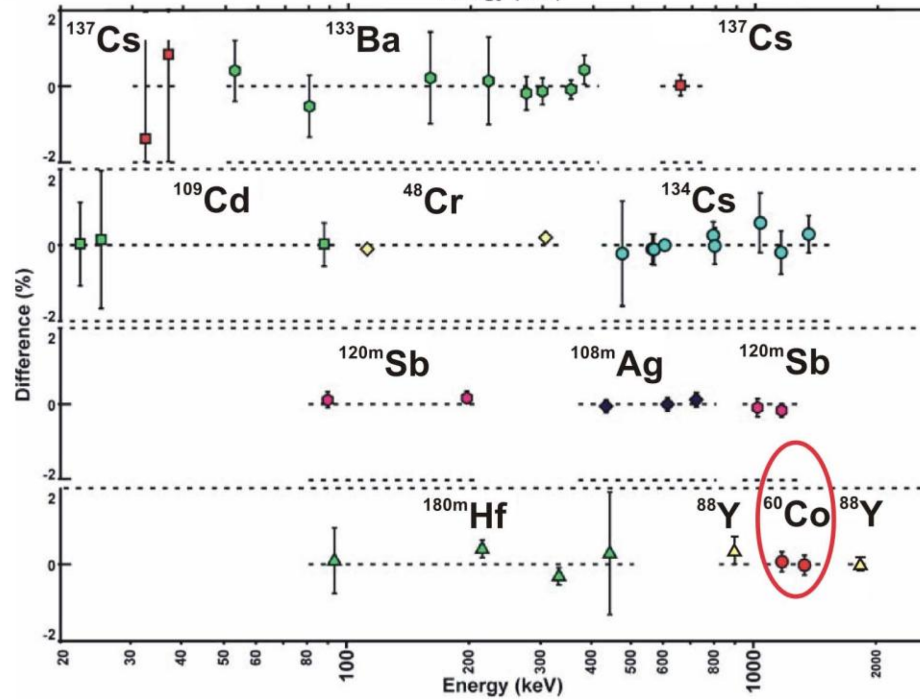
Coaxial 280-cc n-type Ge detector:

- Measured absolute efficiency (^{60}Co source from PTB with activity known to + 0.1%)
- Measured relative efficiency (9 sources)
- Calculated efficiencies with Monte Carlo (Integrated Tiger Series - CYLTRAN code)



0.2% uncertainty for the interval 50-1400 keV



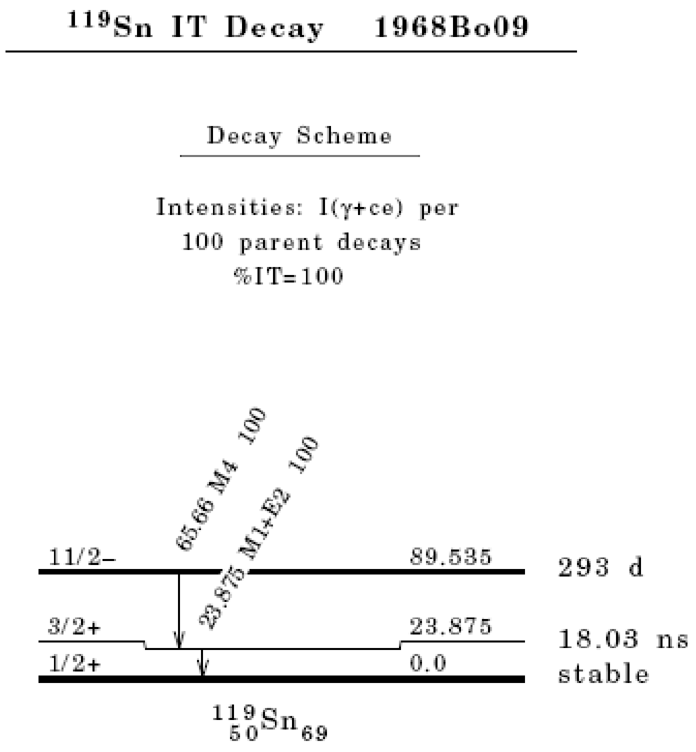


KX to γ rays ratio method

- **Sources for n_{th} activation**
  - **Small selfabsorption (< 0.1%)**
  - **Dead time (< 5%)**
  - **Statistics (> 10^6 for γ or x**
  - **High spectrum purity**
  - **Minimize activation time (0.5 h)**
- **Impurity analysis** - ***essentially based on ENSDF***
  - **Trace and correct impurity to 0.01% level**
  - **Use decay-curve analysis**
  - **Especially important for the K X-ray region**
- **Voigt-shape (Lorentzian) correction for X-rays**
  - **Done by simulation spectra, analyzed as the real spectra**
- **Coincidence summing correction**

^{119m}Sn 65.7 keV, M4 transition

- α(K)exp = 1610 82 (1975AB03)
- $\alpha(K)_{no\_hole}$ = 1544, $\alpha(K)_{hole\_FO}$ = 1618



^{119m}Sn 65.7 keV, M4 transition - α_K measurement

- ^{118}Sn 98.8% enriched (from 24% natural abundance)
- Difficult to roll to get small thickeness
- Samples: 1 cm^2 x 6.8 μm
- Neutron activation at Triga reactor @ TAMU,
  - $\Phi = 7.5 \times 10^{12}$ n/(cm^2s)
  - σ_{th} = 10 mb => very long activation times
  - Sample 1: 16 h (used to tune the real run)
  - Sample 2: 120 h (sample got corroded and stuck)
- First major difficulty: very low intensity of 65.7γ
  - very low counting rate 0.06 s^{-1}
  - Pb shielding of HPGe detector & low bgd room
  - Found 33.6% (!) impurities (^{75}Se, ^{182}Ta)

^{119m}Sn 65.7 keV, M4 transition - α_K measurement

- **Second major difficulty:**

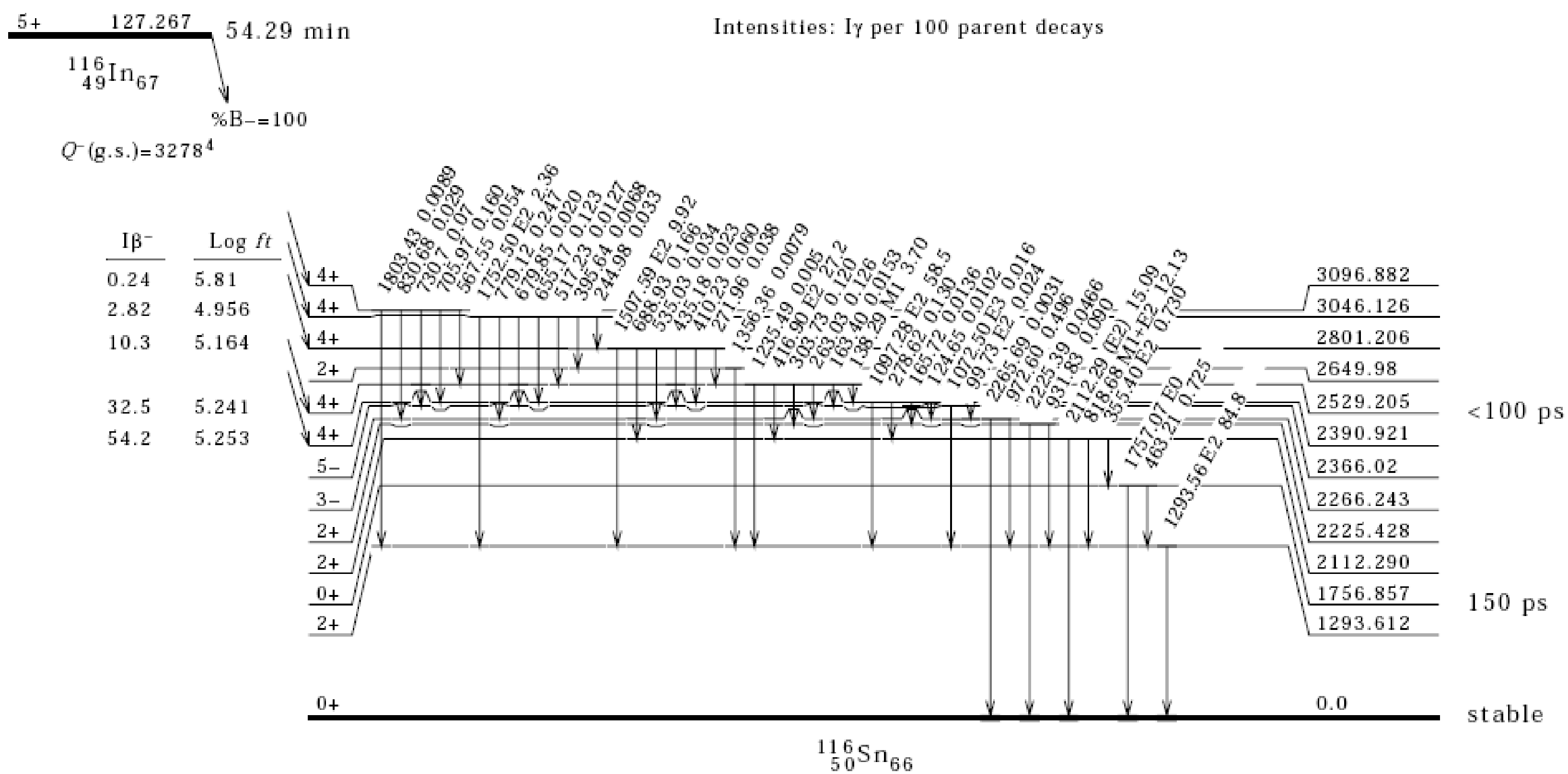
  65.7 γ … ^{75}Se, ^{182}Ta)

  - **^{75}Se: 23.0% straightforward correction**
  - **^{182}Ta: 44.6% corrected from:**
    1. **67.7-keV coplex peak (γ+3×K_β)**
    2. **WK_γ**
    3. **An auxilliary ^{182}Ta source was activated and measured to get its 65.7γ (2.9%) impurity**

  - **Should find a more reliable way of dealing with such big amount of impurity!**

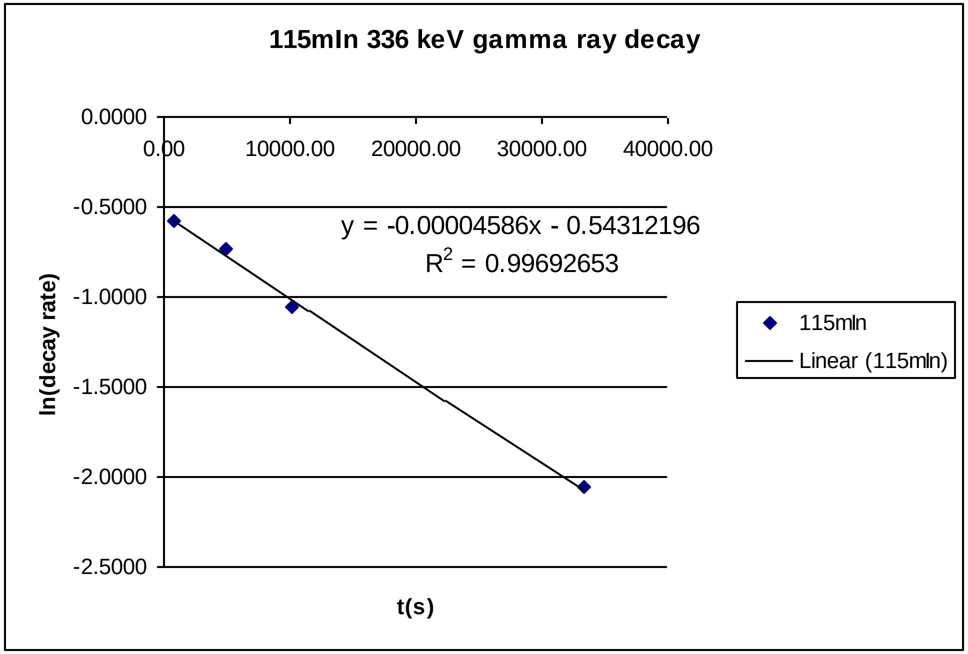
^{119m}Sn 65.7 keV, M4 transition - α_K measurement

- **Third major difficulty: ε known poorly below 50 keV**
  - **From ^{139}La case: ε(34.17 keV) = 98.8% of calculation**
  - **Need special determination of ε for 20-30 keV**
  - **Measurement of ^{116}In β^- decay for ε(SnKX)**



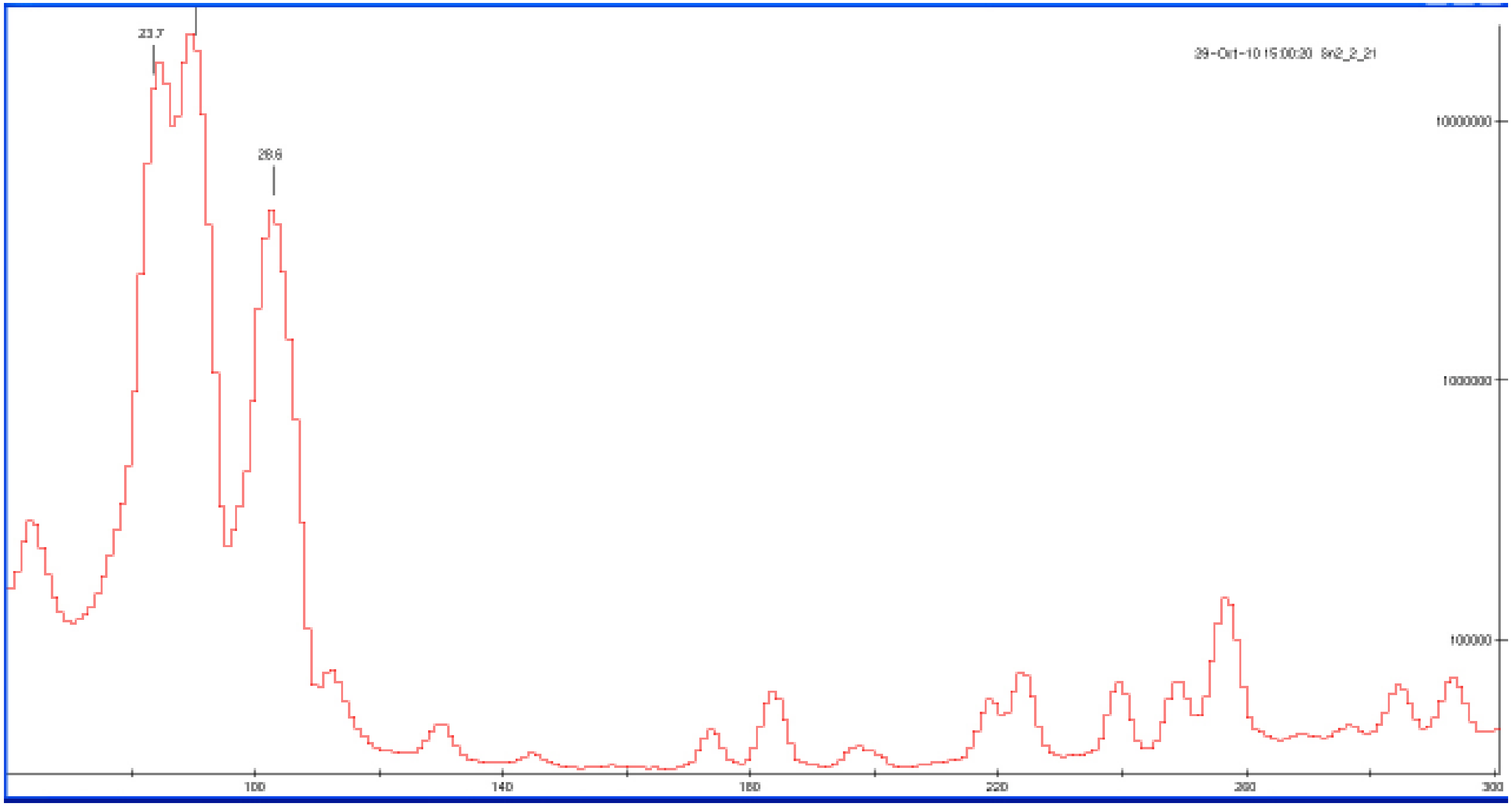
^{116}In β^- decay measurement

- 1 mg of 99.98%-enriched ^{115}In (In_2O_3)
- Found small impurity 339γ
- Identified from ^{115m}In $T_{1/2}$=4.486(4) h
- Populated by (n,n') on ^{115}In
- 3-50% impurity on SnKX rays
- Deduced ε(SnKX) significantly higher than calculated value
- Redo the measurement with precise ^{115}In subtraction
- ***Scattering!***



^{119m}Sn 65.7 keV, M4 transition - α_K measurement

- Third major difficulty: scattering affecting SnKx region
  - Rough estimate 4-5% effect
  - Correction: by simulation (Cyltran) and measurement (^{109}Cd)



^{119m}Sn 65.7 keV, M4 transition - α_K measurement

Addressing the difficulties:

- ^{119m}Sn source was remeasured 20 monts later when all major impurities, including ^{181}Ta and ^{75}Se were almost decayed. They total contribution reduced from 67.6% to 7.0%
- Scattering in the SnKx rays region was addressed by running Cyltran simulations to include scattering. The calculated scattering was normalized to the measured one by comparing the left-hand shelves of the peak
- ^{109}Cd was measured to get an efficiency calibration point at AgKx rays energy (22.6 keV)

^{119m}Sn 65.7 keV, M4 transition - α_K measurement

Result (still preliminary) !

- **Impurities:**
  - SnK_α + SnK_β: negligible (from 1.3% of In and Sn KX)
  - 65.7γ: 7.0% (from 67.6% of ^{75}Se and ^{182}Ta)

- **Result (still preliminary!):**
  - α_K(exp) = **1604** ***30*** **(1.8%)**
  - α_K(hole,FO)= 1618; α_K(no-hole)= 1544
  - …but still to do
    i. efficiency at AgKx (22.6 keV)