# Progress Report of Precision Electron Conversion Coefficient Measurements with transitions in:

# *$^{127m}$Te, $^{125m}$Te, $^{103m}$Rh*

*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**
- ***Is the series of measurements complete?***
- ***Are there other critical cases to measure?***

# 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***

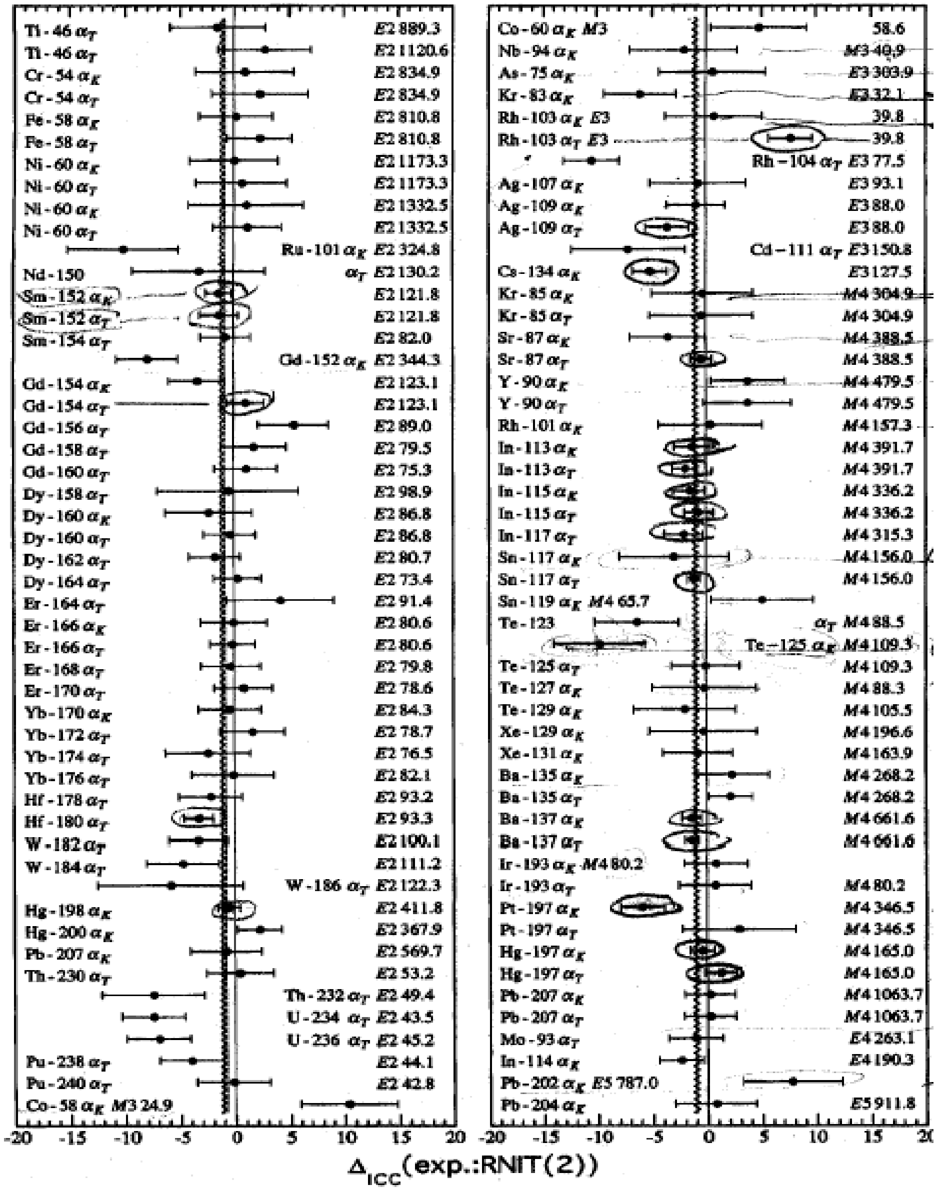
  ***(no relaxation of ion orbitals))***

***PHYSICAL ARGUMENT***

***K-shell filling time vs. time to leave atom***

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

# 2002Ra45: 100 $\alpha_K$(exp) cases compared with 'hole FO' calculations



# Texas A&M precision ICC measurements:

- **KX to γ rays ratio method**

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

  - $N_K$, $N_\gamma$ **measured from *only one K-shell converted transition***
  - $\omega_K$ **from 1999SCZX (**compilation and fit**)**

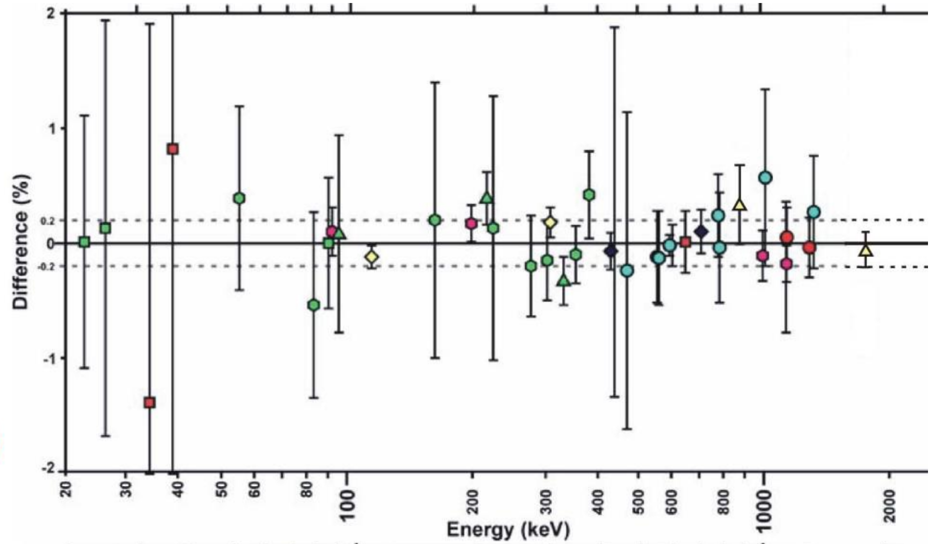
- **Very precise detection efficiency for ORTEC γ-X 280-cm$^3$ coaxial HPGe at standard distance of 151 mm:**
  - **0.2% , 50-1400 keV (2002HA61, 2003HE28)**
  - **0.4% , 1.4-3.5 MeV (2004HE34)**
  - **1% , 10-50 keV (KX rays domain)**

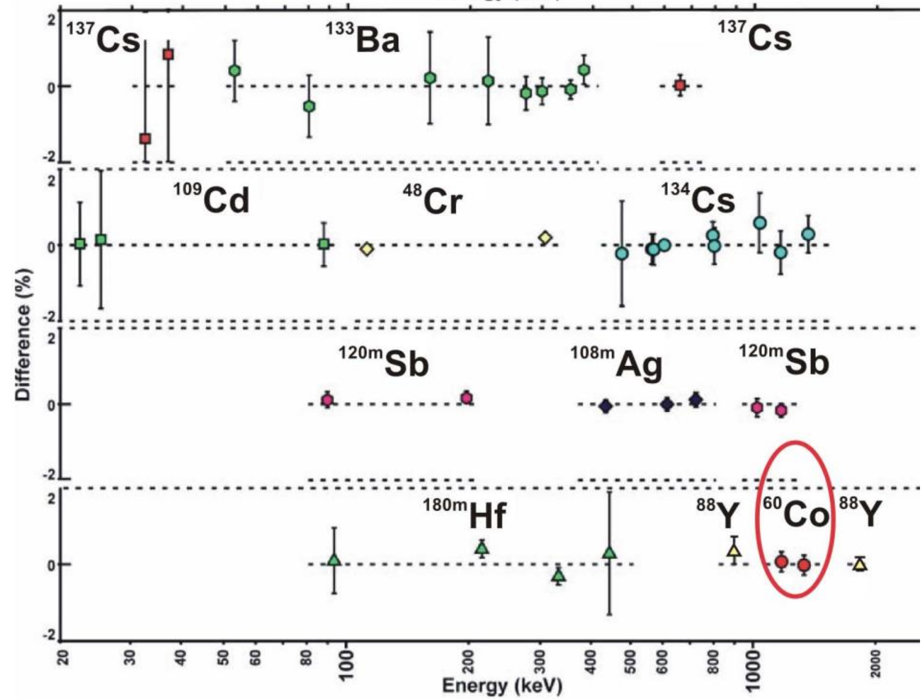
# DETECTOR EFFICIENCY
# 50 keV < $E_\gamma$ < 1.4 MeV

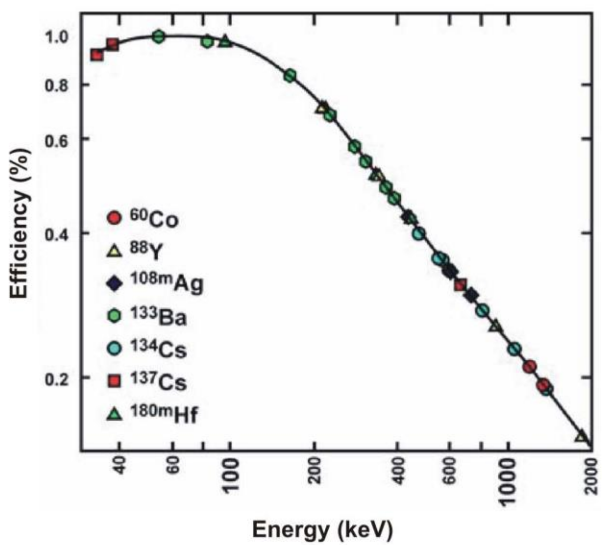
Coaxial 280-cc n-type Ge detector:

- 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-rays)**
  - **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**

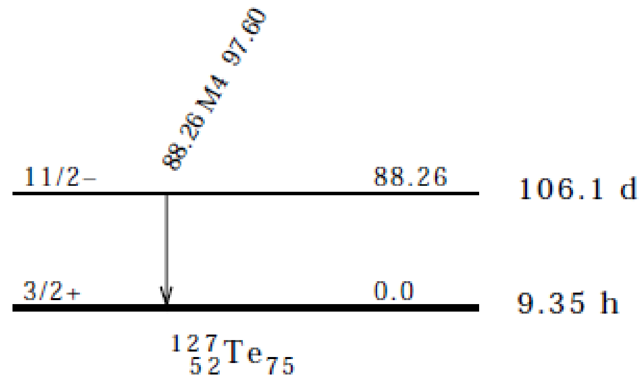
# I. $^{127m}$Te 88.2 keV, M4 transition

- **α(K)exp = 484 *23* (1977So06), %unc=4.8**
- **α(K)$_{hole\_FO}$ = 486.4 *17*, α(K)$_{no\_hole}$ = 468.6 *17***

$^{127}$Te IT Decay (106.1 d) 1970Ap02

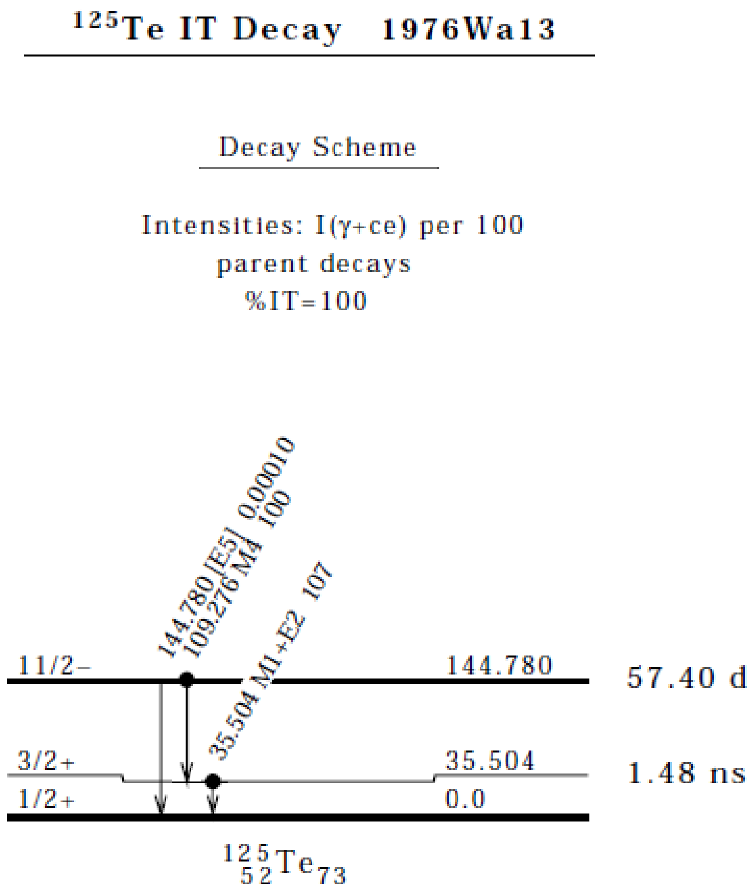
Decay Scheme

Intensity: I(γ+ce) per
100 parent decays
%IT=97.6 *2*



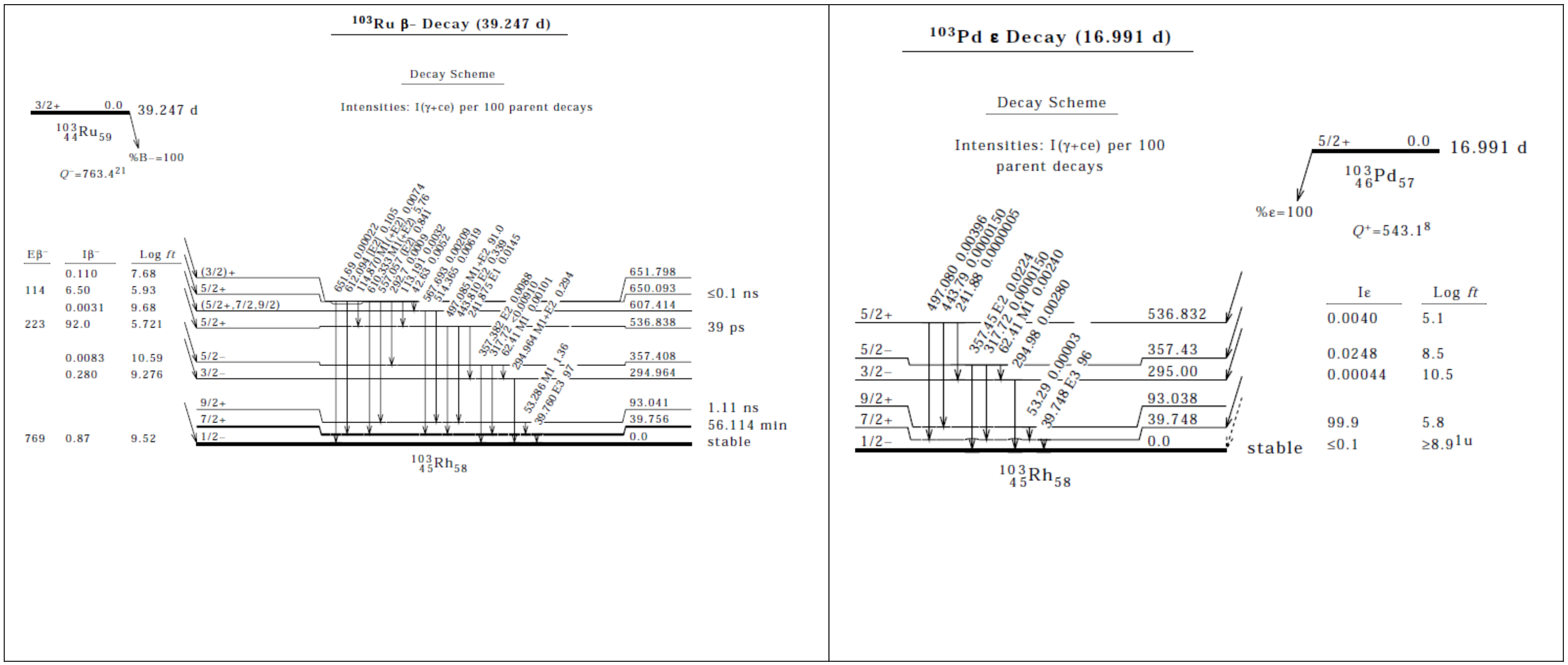
# II. $^{125m}$Te 109.3 keV, M4 transition

- α(K)exp = 166 *9* (1998Sa26), %unc=4.8
- $\alpha(K)_{hole\_FO}$ = 185.2(1), $\alpha(K)_{no\_hole}$ = 179.5(1)



# III. $^{103m}$Rh 39.748 keV, E3 transition

- α(K)exp = 138 *5* (1970NiZV), %unc=3.6
- α(K)exp = 127 *6* (1975Cz03), %unc=4.7
- $\alpha(K)_{hole\_FO}$ = 185.2(19), $\alpha(K)_{no\_hole}$ = 127.4(18)



# $^{127m}$Te 88.3 keV, M4 transition

- $^{126}$Te 98%+ enriched metal powder grinded at micron size
- Samples: 1.3 mg, disk of 1 cm diameter x 2.7-μm thick covered with 1 mil-thick mylar foils
- Neutron activation at Triga reactor @ TAMU,
  - $\Phi = 7.5 \times 10^{12}$ n/(cm$^2$s)
  - $\alpha_{th} = 0.135(23)$ b
  - Sample activated 24 h, then cooled down for 2 months
  - Measured for 3 weeks
- Measured with HPGe detector at 151 mm distance for three weeks

# $^{125m}Te$ 109.3 keV, M4 transition

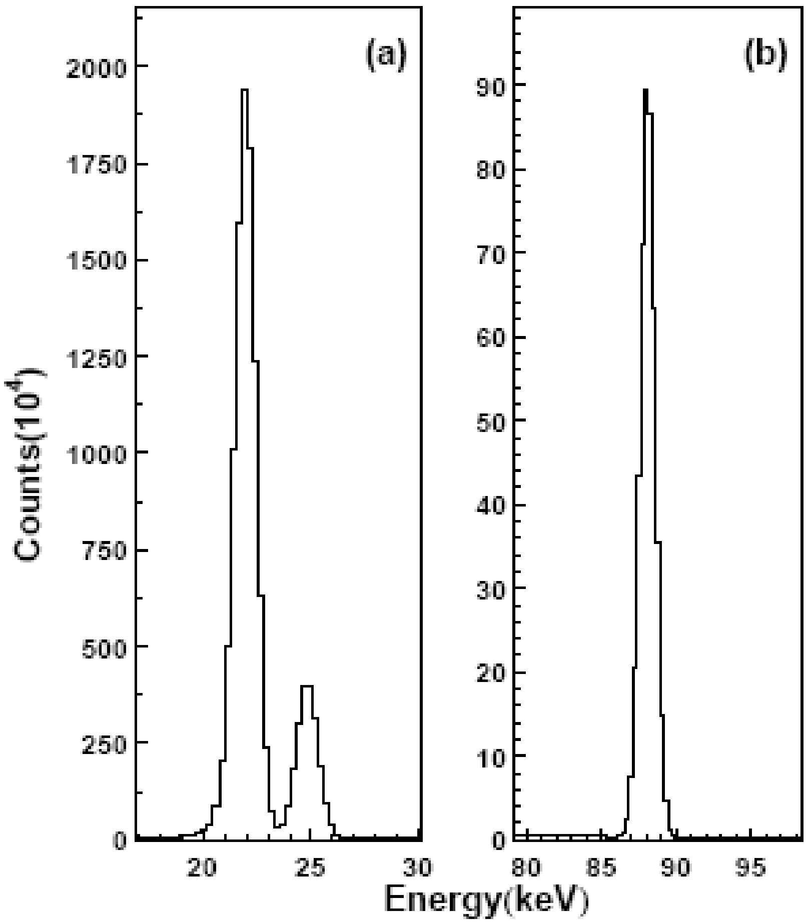
- $^{124}Te$ 99.32%+ enriched metal powder
- 0.49(2) μm thick, 17 mm diameter $TeO_3$ disk electroplated on 10 μm 99.999%-pure Al backing
- Activated
  - $\Phi = 7.5 \times 10^{12}$ n/(cm$^2$s)
  - $\alpha_{th} = 0.040(25)$ b
  - Sample activated 24 h, then cooled down for 3 weeks
  - Measured for 112 h

# $^{103m}$Rh 39.748 keV, E3 transition

- 25 mm × 25 mm × 4 μm $^{nat}$Pd foil
  - $\Phi = 7.5 \times 10^{12}$ n/(cm$^2$s)
  - $\alpha_{th} = 3.4(3)$ b
  - Sample activated 10 h, then cooled down for 15 days
  - Measured for several weeks

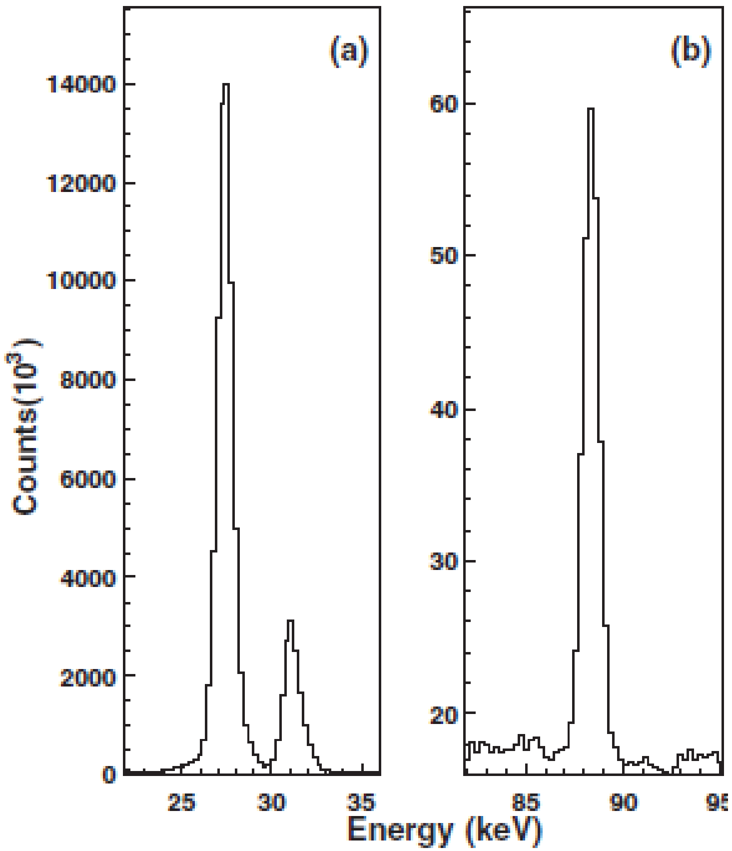
# $^{109}$Cd Efficiency Calibration

## 22.6-keV AgKx & 88.0-keV E3 γ regions

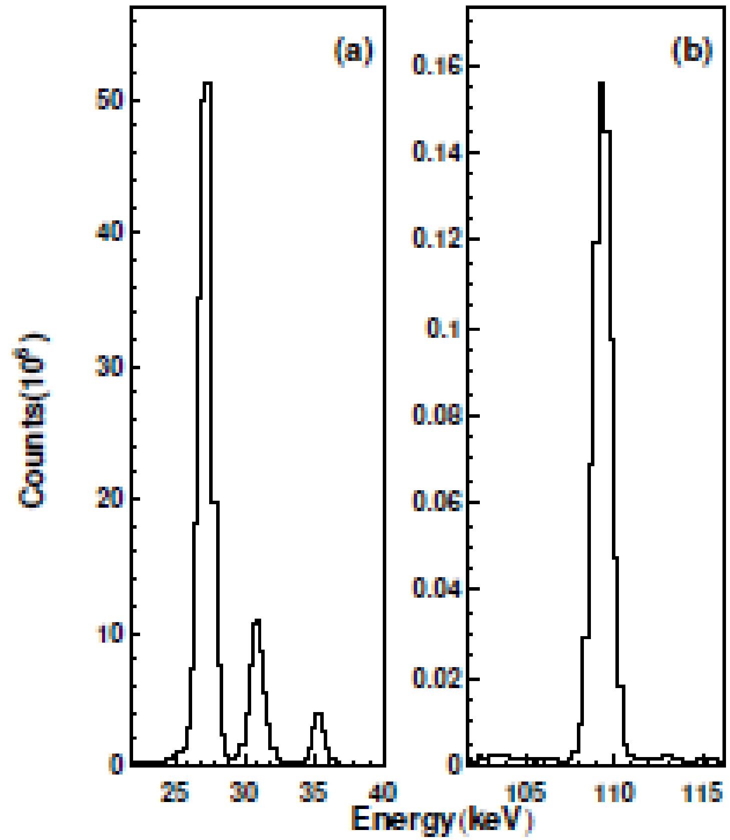


# Regions of interest

$^{127m}$Te




$^{125m}$Te



# *Results*

## $^{127m}$Te 88.2 keV, M4 transition (2017Ni03)

| Model | $\alpha_K$ | Δ (%) |
|---|---|---|
| Experiment | 484(6) | |
| Theory | | |
| No vacancy | 468.6(17) | +3.3(13) |
| Vacancy, frozen orbitals | 486.4(17) | −0.5(13) |
| Vacancy, SCF of ion | 483.1(17) | +0.2(13) |

## $^{125m}$Te 109.3 keV, M4 transition

| Model | $\alpha_K$ | Δ(%) | $\alpha_T$ | Δ(%) |
|---|---|---|---|---|
| Experiment | 185.0(40) | | 350.0(38) | |
| Theory: | | | | |
| No vacancy | 179.5(1) | +3.0(22) | 348.7(3) | +0.4(11) |
| Vacancy, FO | 185.2(1) | −0.1(22) | 355.6(3) | −1.6(11) |
| Vacancy, SCF | 184.2(1) | +0.4(22) | 354.2(3) | −1.2(11) |

# *Results (continued)*

**$^{103m}$Rh 39.748 keV, E3 transition, $^{103m}$Pd ε decay**

***Using $\alpha_K$=131.3(39) (average "hole" and "no hole" calculations) one gets***

***(a) Experimental:***

***$\alpha_T$ = 1438(44) (very preliminary)***

***(b) Theory***

***No Vacancy: $\alpha_T$= 1404(20)***

***Vacancy FO: $\alpha_T$= 1389(20)***

***To be done:*** **$^{103m}$Ru $\beta^-$ decay**