OVERVIEW OF PRECISION INTERNAL CONVERSIO MEASUREMENTS AS TESTS OF INTERNAL CONVERSION THEORY

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ICC's:

- **Essential role in analysis of nuclear decay schemes, crucial in precision applications**
- ***1974RA14*: HS theoretical ICC's *systematically 2-3%* larger than 19 experimental E3 and M4 measured ICC's**
- ***2002RA45*: Survey of *theoretical calculations* and *experimental ICC's*:**
  - **Theory: detailed comparison of RHFS (HS, RFAP, BT) and RDF (BTNTR, RNIT1, RNIT2) calculations**
    - **Exchange interaction**
      - **The exact RDF better than the approximation of free electron gas used by RHF**

- **Hole treatment**
  - ***No hole*:**
    - **Bound and continuum states - SCF of neutral atom**
  - ***Hole-SCF*:**
    - **Bound state - SCF of neutral atom;**
    - **Continuum state - SCF of ion + hole (full relaxation of ion orbitals)**
  - ***Hole-FO*:**
    - **Bound state - SCF of neutral atom;**
    - **Continuum state – ion field constructed from bound wave functions of neutral atom**
      (insufficient time for relaxation of ion orbitals)
- **Finite size of nucleus**
  - **SC model (BT, BTNTR, RNIT1,2) better than NP (HS, RFAP)**

- **Experiment**:
  - ***Selected & evaluated* 100 measured ICC's**
  - **E2, M3, E3, M4, E5**
  - **0.5%-6% precision**
  - ***very few <1% precision***

- ***2002RA45 conclusions*, Δ(exp:theory)%**
  - **RHFS calculations: ~ -3% higher than measured ICC's**
  - **RDF calculations:**
    - **No hole (BTNTR): +0.19(26)% *BEST!***
    - **Hole-SCF (RNIT1): -0.94(24)%**
    - **Hole-FO (RNIT2): -1.18(24)%**

PHYSICAL ARGUMENT!

K-shell filling time vs. time to leave atom

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

- **Recommended measuring α_K of 80.2-keV, M4 transition in $^{193}Ir^m$ for which hole - no hole calculations are 11% apart**

TEXAS A&M PROGRAM TO MEASURE ICC's

- **Continues 2002RA45 by:**
  - α_K **measurements of** ***≤ 1% precision***
  - **in a number of cases relevant for theory *vs*. experiment comparison,**
  - **especially for establishing if the *physical argument for hole calculations is valid***
- ***METHOD***

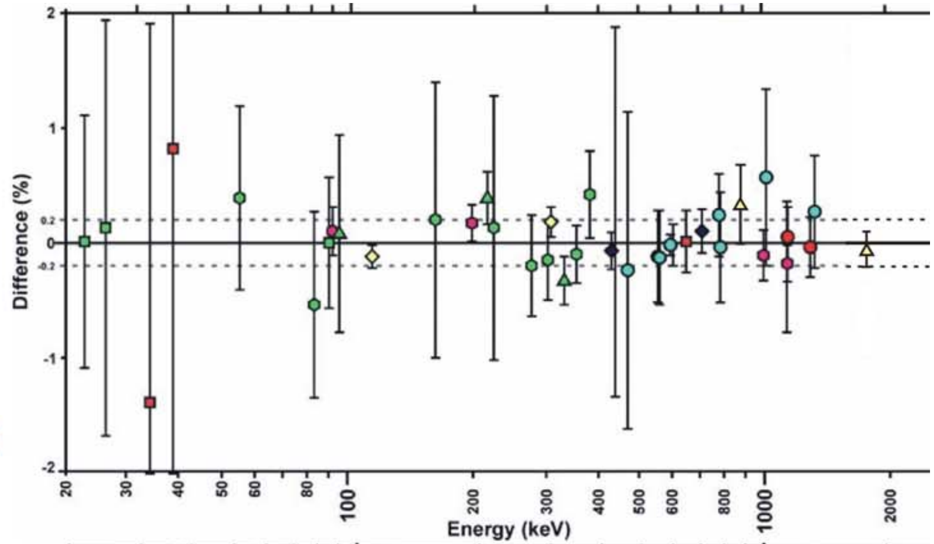
$$\alpha_K \omega_K = \frac{N_K}{N_\gamma} \cdot \frac{\varepsilon_\gamma}{\varepsilon_K}$$

  - N_K, N_γ ***measured*** **from** ***only one K-shell converted transition***
  - ω_K **from *1999SCZX*, or *measured***
  - ε **at 151 mm for *ORTEC γ-X 280-cm³ coaxial HPGe*:**
    - **0.2% , 50-1400 keV *(2002HA61, 2003HE28)***
    - **0.4% , 1.4-3.5 MeV *(2004HE34)***
    - ***Not know precisely for 10-50 keV (some K x-rays)***

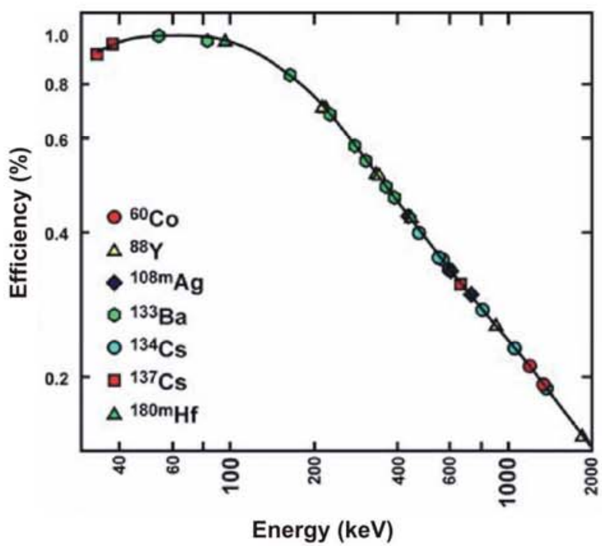
DETECTOR EFFICIENCY
50 keV < E_γ < 1.4 MeV

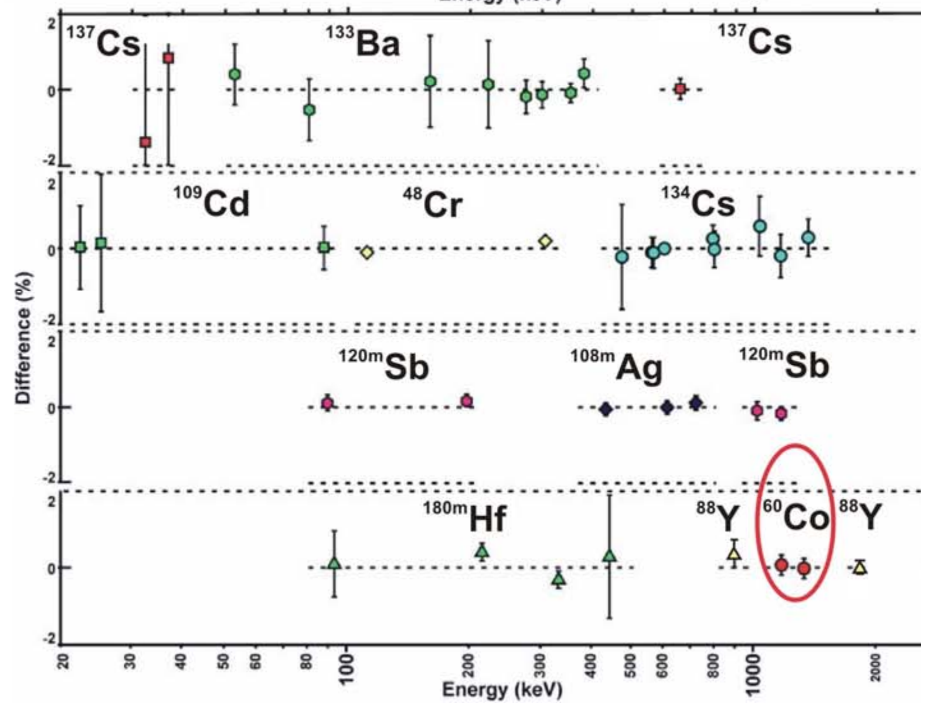
Coaxial 280-cc n-type Ge detector:

- 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)

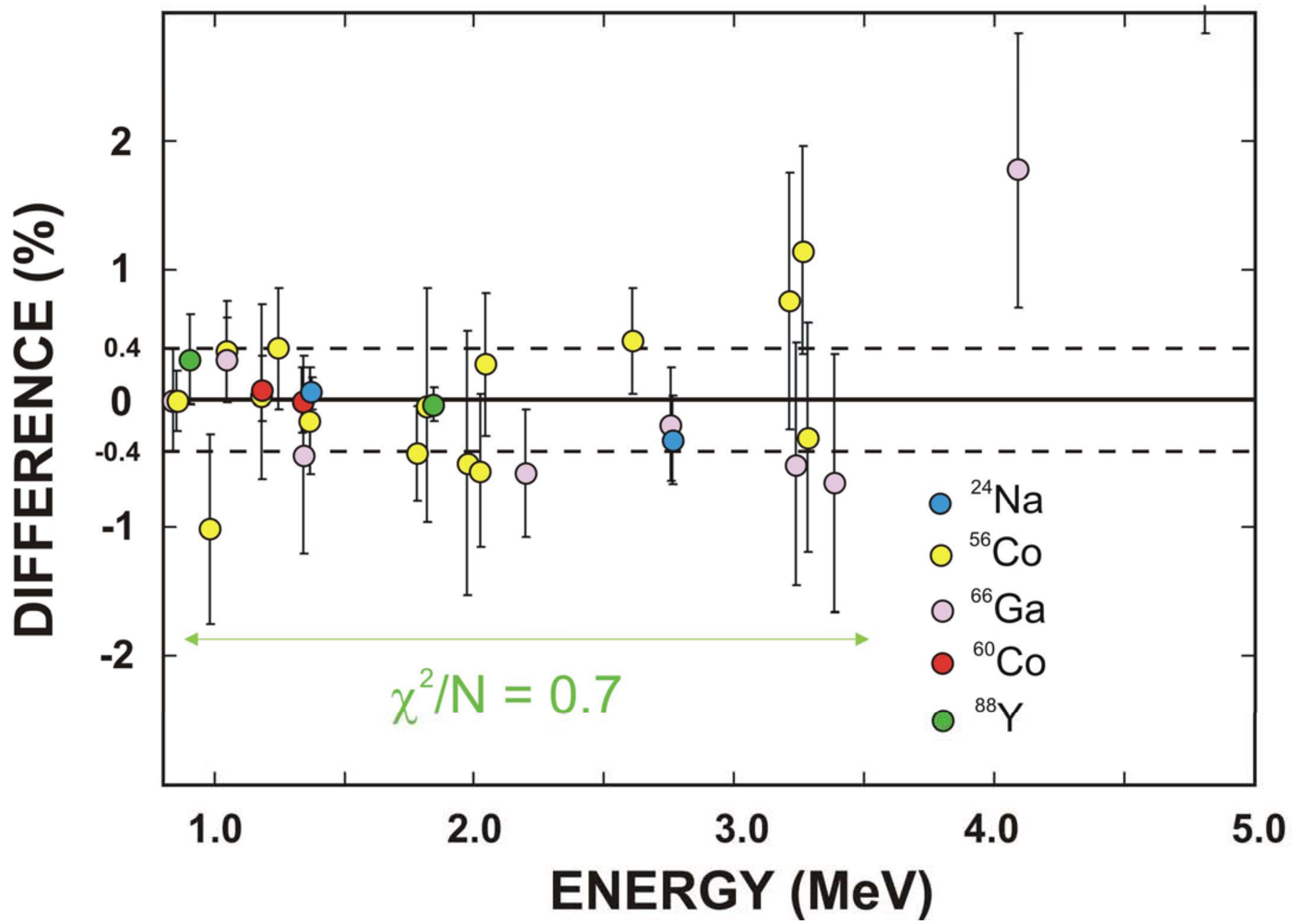


0.2% uncertainty for the interval 50-1400 keV



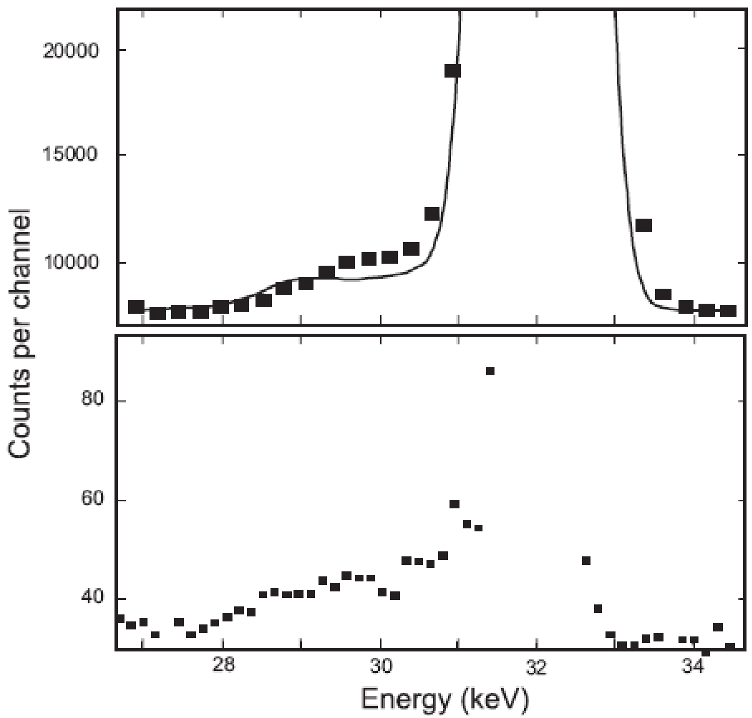


MEASUREMENT *vs* MONTE CARLO CALCULATIONS, E_γ > 800 ke



- ***METHOD***
  - **Design and produce sources for n_{th} activation**
    - **Small absorption (< 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-rays region**
  - **Voigt-shape (Lorentzian) correction for X-rays**
    - **Done by simulation spectra, analyzed as the real spectra**
  - **Coincidence summing correction**

- Scattering correction
  - **Monte-Carlo (Cyltran) simulation spectra and experiment**



The analysis is based on:

- ***skilled knowledge*** **of the HPGe detector response,**
- ***painstaking rigor*****,**
- ***realistic uncertainties*** **by varying the experimental conditions**

RESULTS

1. $^{193}Ir^{m}$, 80.236(7) keV, M4, α_K

- values know by *2002RA45*
  - 104(3) (*1987LI16*) - adopted by *2002RA45*,
  - 92.6(9) (*1988ZH11*)

	α_K	Δ(exp:th)(%)
Exp (*2004Ni14, 2006HA36*)	103.0(8)	
Theory, hole – FO	103.5	-0.5(8)
Theory, no hole	92.3	11.6(9)

2. ^{191}Ir, 129.415(13) keV, M1+E2, δ=-0.402(7), ω_K

- ω_K=0.954(9) (*2005NI12*)
- ω_K=0.958(4) (*1999SCZX*)

	$\alpha_K(^{193}Ir^{m})/ \alpha_K(^{191}Ir)$	Δ(exp:th)(%)
Exp (*2005NI12*)	48.3(4)	
Theory, hole – FO	48.1(2)	0.4(8)
Theory, no hole	43.0(2)	12.3(9)

3. $^{134}Cs^{m}$, 127.502(3) keV, E3, ^{137}Ba, 661.657(3) keV, M4, α_K ratio

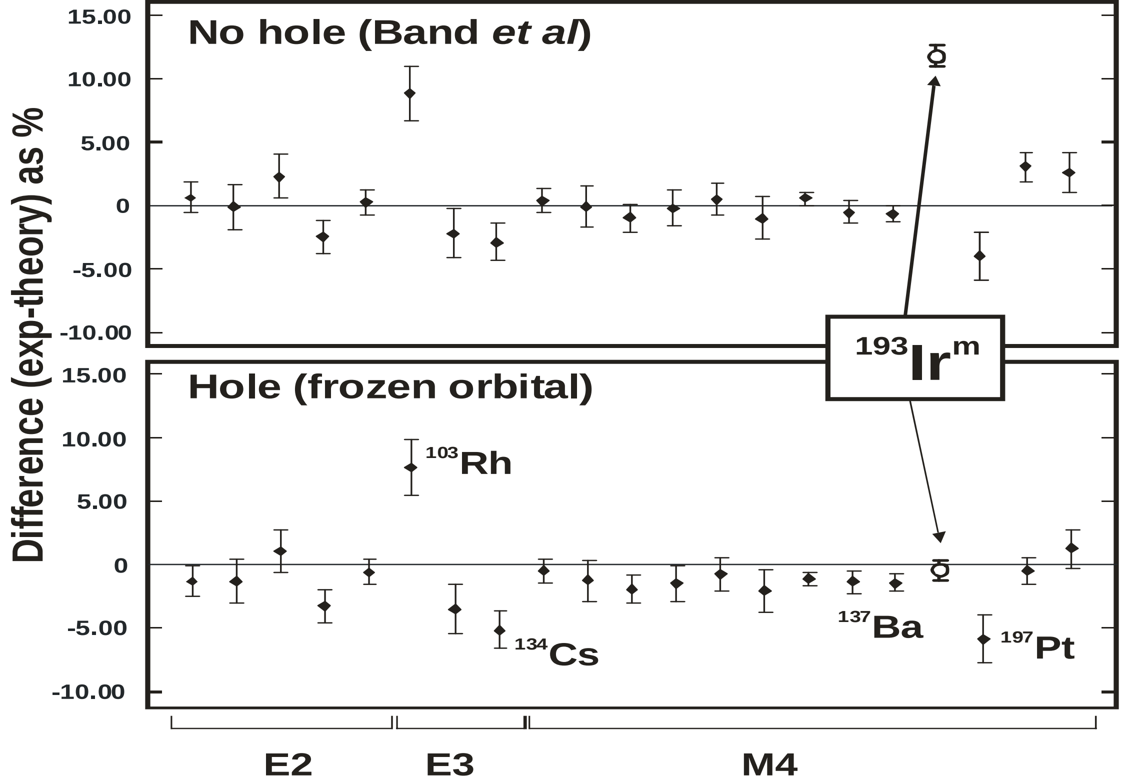
	$\alpha_K(^{134}Cs^m)/\alpha_K(^{137}Ba)$	Δ(exp:th)(%)
Exp (*2007NI04*)	30.01(15)	
Theory, hole – FO	29.96	0.2(5)
Theory, no hole	29.52	1.7(5)
Exp (*2002RA45*)	28.5(5)	

4. ^{139}La, 165.8575(11) keV, M1, ε(34.16 keV, LaKX)

preliminary

- ε(34.16 keV, LaKX)= 0.988(7)%,
- 1.4% less than before,
- 0.7% precison, compare to ~2% before

	$^{134}Cs^m$, α_K	Δ(exp:th)(%)	^{138}Ba, α_K	Δ(exp:th)(%)
Exp (*prelim.*)	2.745(16)		0.0915(6)	
Theory, hole – FO	2.741	0.2(5)	0.09148	<0.1(6)
Theory, no hole	2.677	1.7(5)	0.09068	0.9(6)
EXP (*2002RA45*)	2.60(4)		0.0902(8)	



RDF	Raman *et al.* (2002)		Best 20 cases		**Best 20 plus remeasured $^{193}Ir^m$, $^{134}Cs^m$, ^{137}Ba**	
	Δ_{avg} (%)	χ^2/N	Δ_{avg} (%)	χ^2/N	Δ_{avg} (%)	χ^2/N
No hole	+0.19(26)	1.7	+0.10(38)	2.4	**+1.33(84)**	**14.9**
Hole, FO	-1.18(24)	1.4	-1.25(36)	2.2	**-0.77(30)**	**2.0**