NEW PRECISION INTERNAL CONVERSION MEASUREMENTS AS TESTS OF INTERNAL CONVERSION THEORY
^{197m}Pt CASE

TEXAS A&M PROGRAM TO MEASURE ICC

N. NICA

Electron Internal Conversion Coefficients (ICC)

- **Central for nuclear data programs**
- **Big impact on quality of data**
- **Overall big impact on quality of nuclear science**
- ***Until recently still a disputed issue!***

2002RA45 survey ICCs' 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**

Hole treatment and 2002RA45 conclusions, Δ(exp:theory)%

- ***No hole*****:** +0.19(26)% ***BEST!***
  - Bound and continuum states - SCF of neutral atom
- ***Hole-SCF*****:** -0.94(24)%
  - Bound state - SCF of neutral atom;
  - Continuum state - SCF of ion + hole (full relaxation of ion orbitals)
- ***Hole-FO*****:** -1.18(24)%
  - 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)

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)

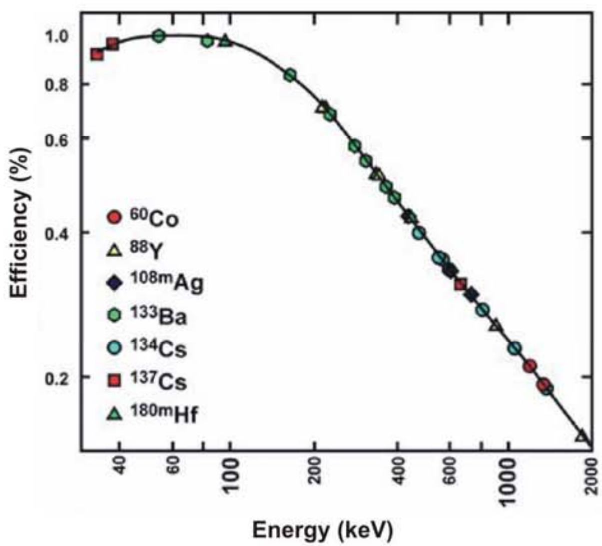
- **Very precise detection efficiency for ORTEC γ-X 280-cm^3 coaxial HPGe at standard distance of 151 mm:**
  - **0.2% , 50-1400 keV (2002HA61, 2003HE28)**
  - **0.4% , 1.4-3.5 MeV (2004HE34)**
  - **0.7% , 10-50 keV (KX rays domain)**

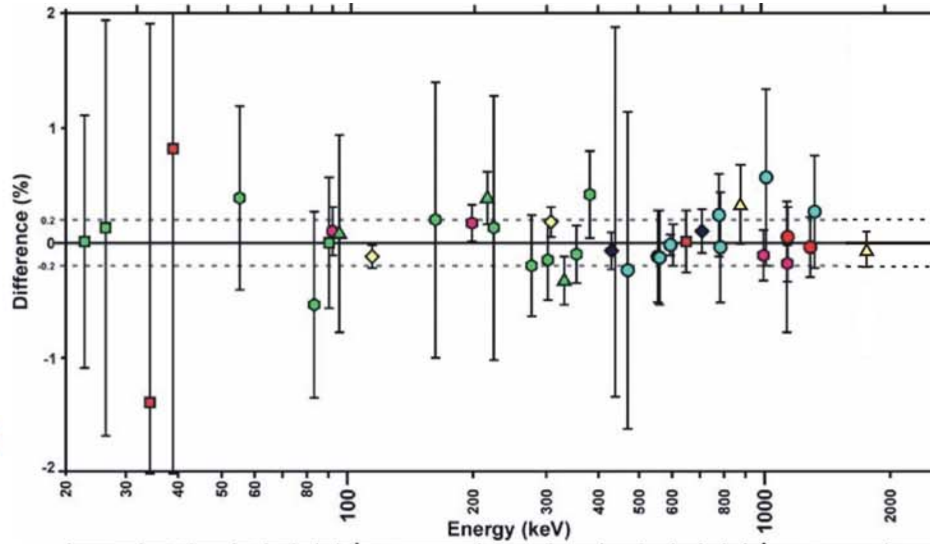
DETECTOR EFFICIENCY
50 keV < Eγ < 1.4 MeV

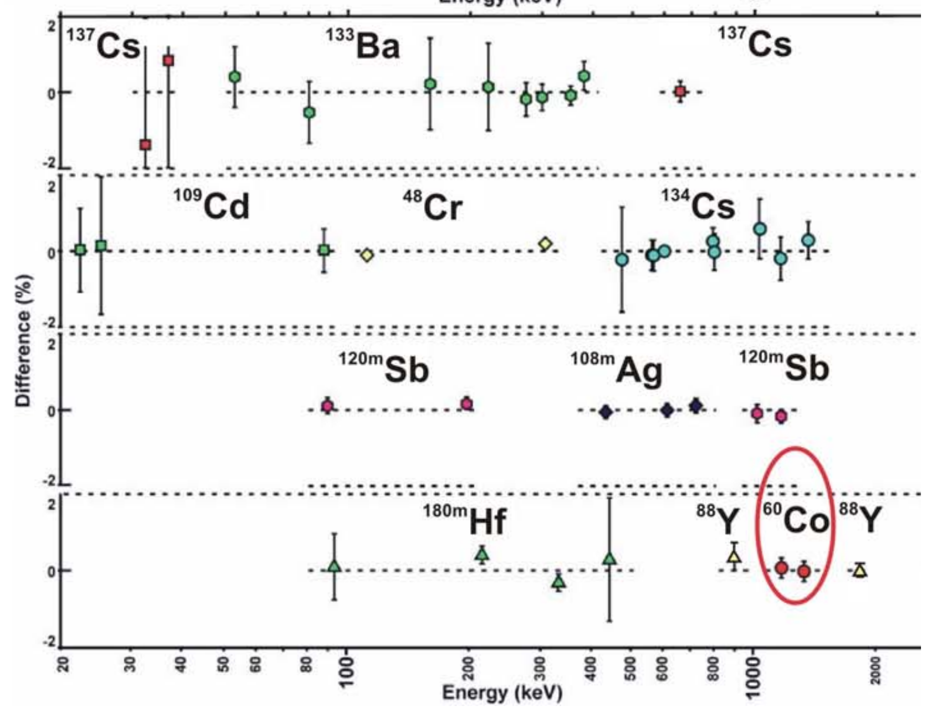
Coaxial 280-cc n-type Ge detector:

- 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)

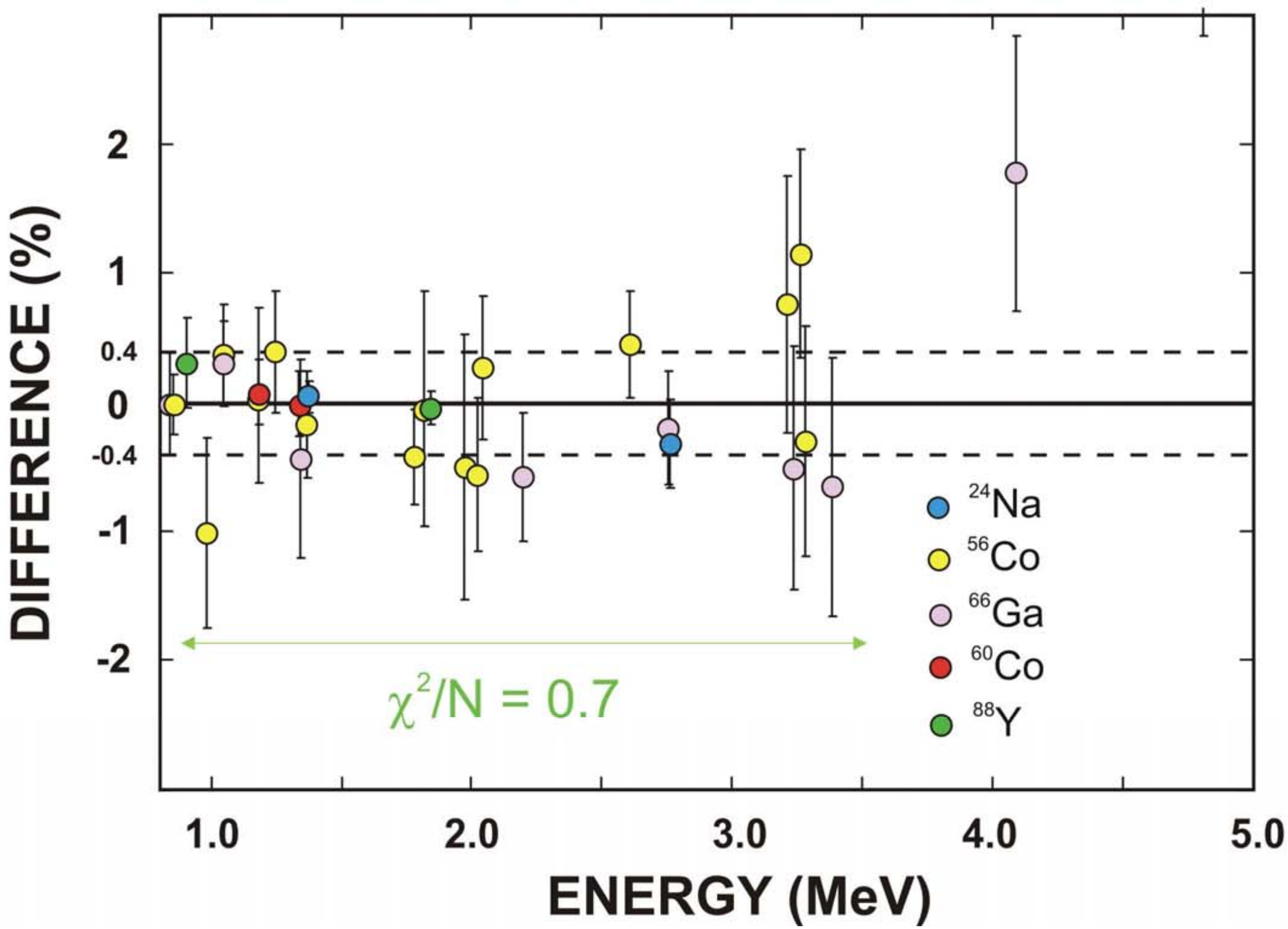
0.2% uncertainty for the interval 50-1400 keV







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



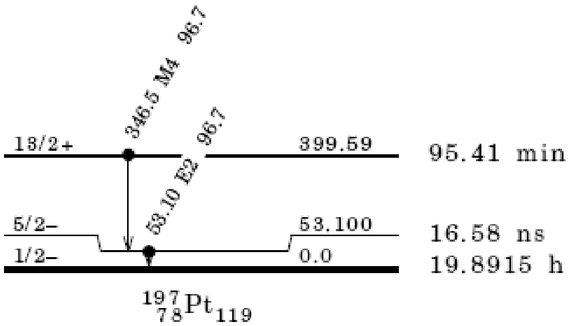
KX to γ rays ratio method

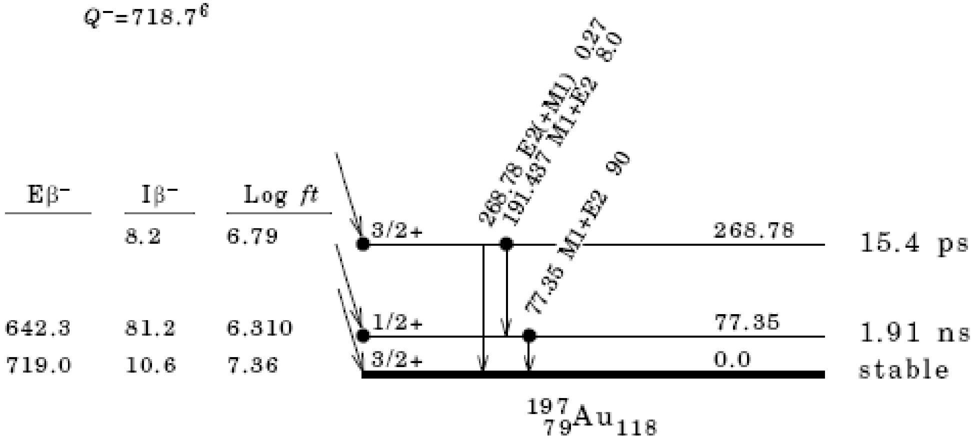
- Sources for n_{th} activation
  - Small absorption (< 0.1%)
  - Dead time (< 5%)
  - Statistics (> 10^6 for γ or x-rays)
  - High spectrum purity
  - Minimize activation time (0.5 h)
- Impurity analysis - *essentially based on ENSDF*
  - Trace and correct impurity to 0.01% level
  - Use decay-curve 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

^{197m}Pt 346.5 MeV, M4 transition α(K) measurement

- α(K)exp = 4.02 *8* (1987Vi08), α(K)$_{no\_hole}$ = 4.190, α(K)$_{hole\_FO}$ = 4.273
- α(K)exp *discrepant* relative to "no hole" and "hole-FO" theories

%IT = 96.7 *4*; %β$^-$ = 3.3 *4*





^{197m}Pt 346.5 MeV, M4 transition α(K) measurement – cont.

- **Activation cross section small; cross-section ratio unfavorable…**

  $\sigma_{th}(^{197}Pt^{m}) = 0.044$ b $\sigma_{th}(^{197}Pt^{gs}) = 0.72$ b

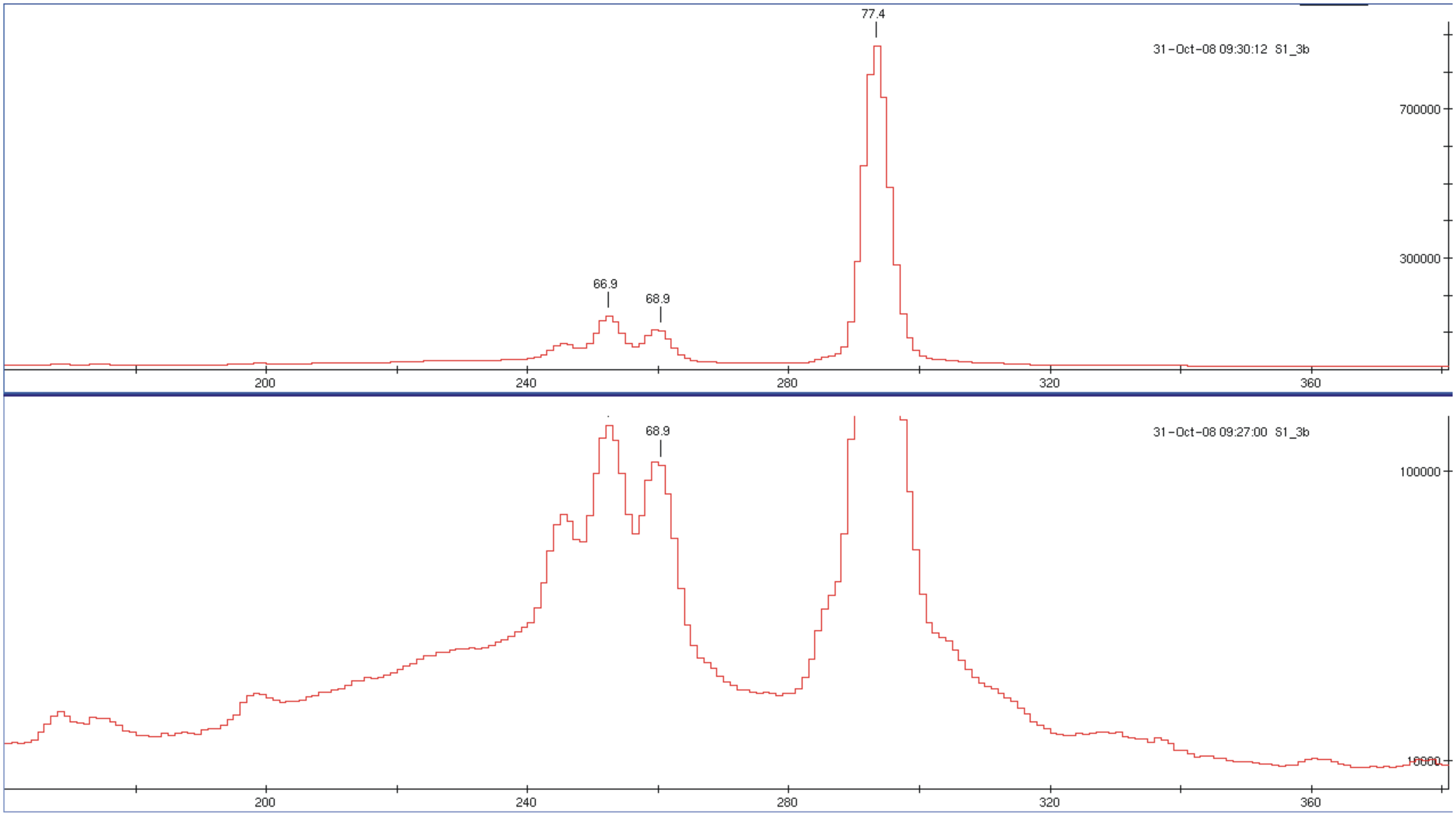
- **Relatively high mass of ^{196}Pt(97.5%) = 1.5 g …**
- **Relatively high attenuation correction, 1.4(5) % …**
- **Unfavorable decay-rate ratio**

  $$D.R.(^{197}Pt^{m}) / D.R.(^{197}Pt^{gs})|_{ini} = 0.07 \ldots$$

- **High acquisition dead time, 28% - 14% …**
- **For $t_{activation}$ = 60 min**

- **77γ from $^{197}Pt^{gs}$ decay …**
  - **Fully obturates the 75 - 78 keV Kβ X rays of Pt …**
  - **Gives a huge back-scattering bump beneath the 65-67 keV Kα X rays of Pt**

KX-rays region for ^{197}Pt decay



Channel

Impurities affecting the PtKX and 346.5γ regions

PtKX region: % impurity and % uncertainty relative to pure PtKX from the internal conversion of 346.5γ

^{197}Hg(AuKX)	1.62%	0.20%
^{199}Au(HgKX)	1.30%	0.13%
^{195}Ptm (PtKX)	1.06%	0.12%
^{199}Pt(AuKX)	0.117%	0.012%
^{192}Ir (OsKx, PtKX), ^{194}Ir (PtKX), ^{198}Au(HgKX)	0.0394%	0.0013%
Total KX impurities	4.1%	0.3%

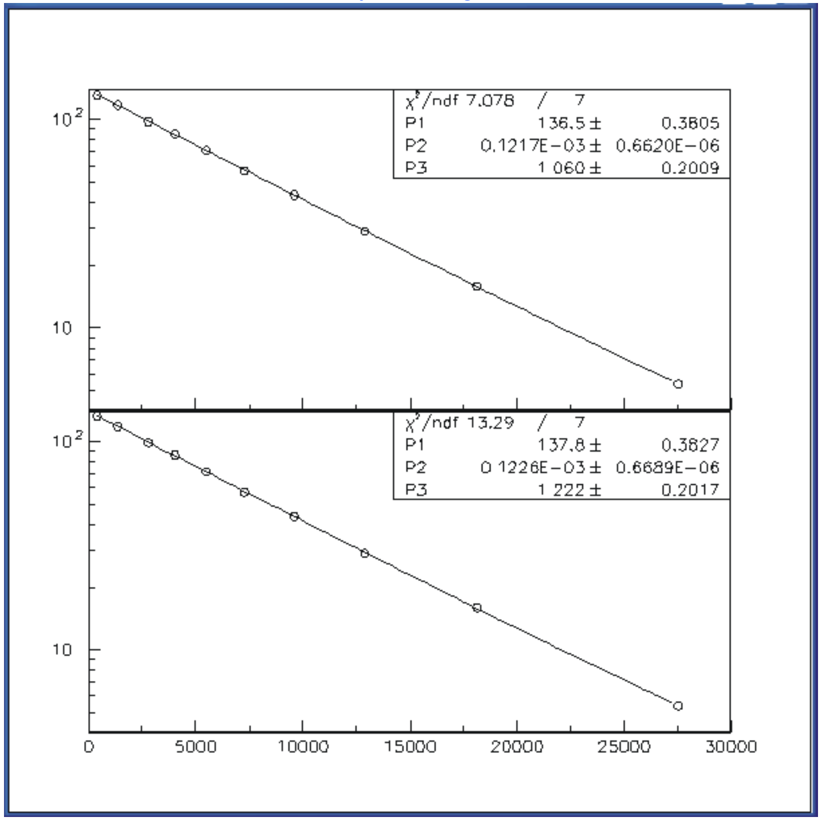
346.5γ region: % impurity and % uncertainty relative to pure 346.5γ

344γ (^{152}Eu^{m})	0.65%	0.10%

Fit of $^{197}Pt^{m}$ decay curves

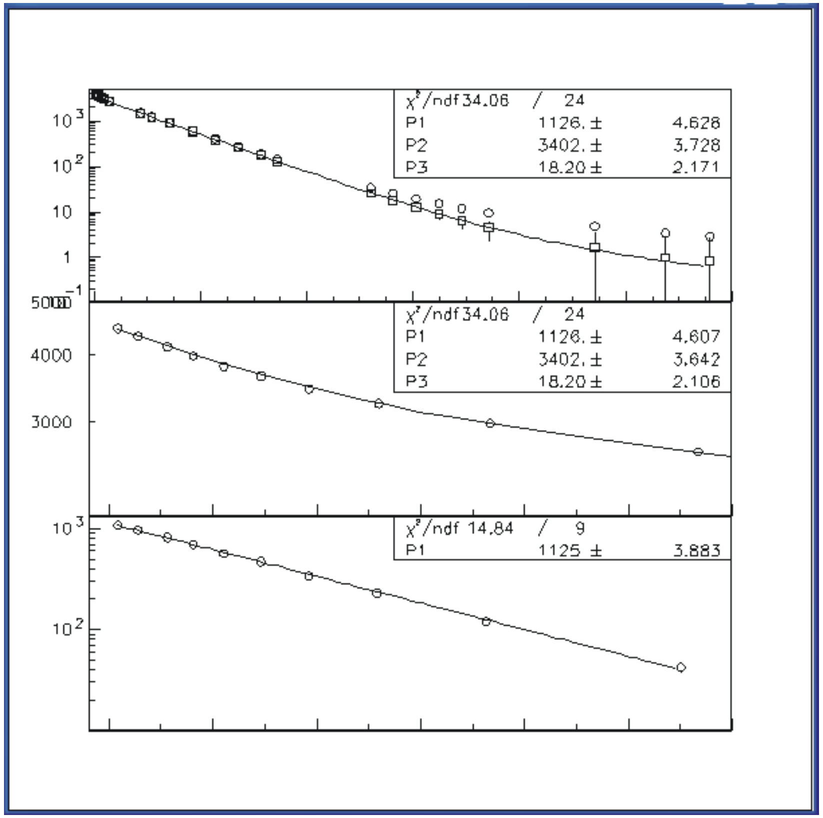
a) 346.5γ

Up: smaller γ-ray region
Down: larger γ-ray region



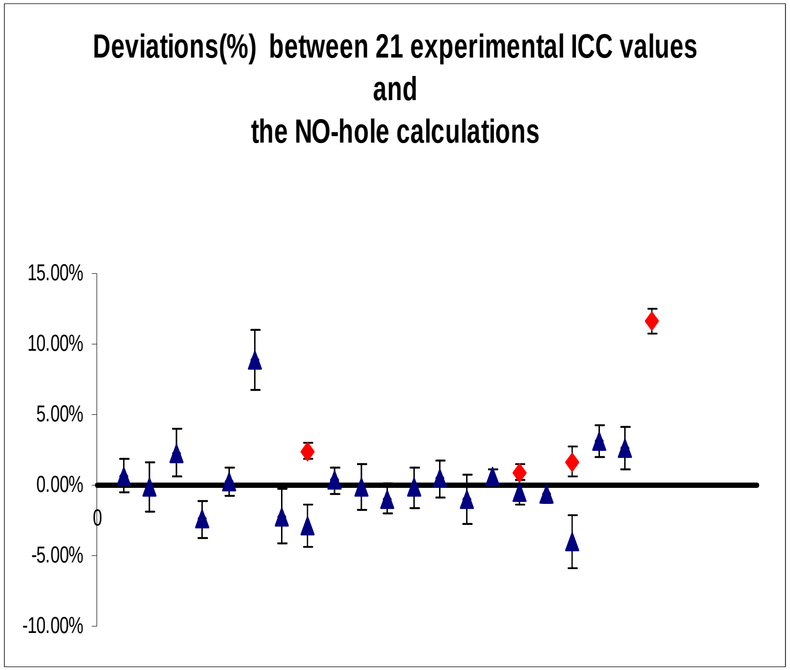
b) KX rays

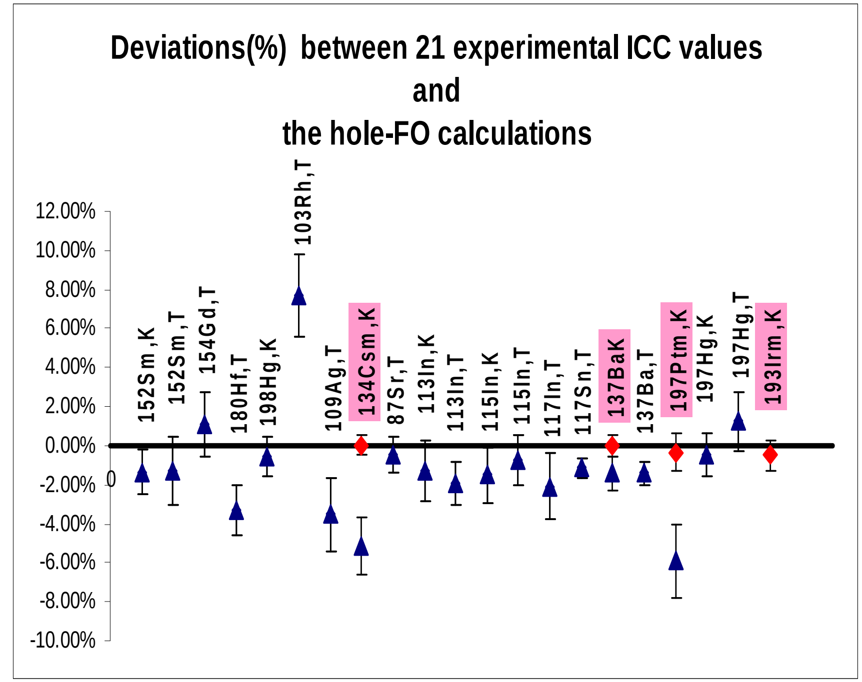
Up: $^{197}Pt^{m}$, $^{197}Pt^{gs}$, ^{197}Hg, all 27 points
Middle: same, first 10 points
Down: pure $^{197}Pt^{m}$ (first 10 points)



Results

	Value	Unc	%Unc
PtKX, D.R.(0), (s^{-1})	1126	7	0.7%
346.5g, D.R.(0), (s^{-1})	136.4	0.3	0.3%
ω_K(Pt)	0.959	0.004	0.4%
ε(KX=69.34keV), (%)	1.019	0.002	0.2%
ε (346.5γ), (%)	0.518	0.001	0.2%
Raw α_K(exp,346.5γ)	4.37	0.04	0.8%
CoinSum(346.5g-53γPtLX)	2.3%	0.3%	11.1%
^{197}Pt β^-(AuKX)/IT(PtKX)	1.8%	0.1	2.6%
Atten corr factor	1.014	0.005	0.5%
α_K(exp,346.5γ)	**4.26**	**0.04**	**1.0%**
α_K(no-hole, 346.5γ)	4.190		
α_K(hole-FO, 346.5γ)	4.273		





	Raman *et al.* (2002)		Best 20 cases		Best 20 plus remeasured $^{193}Ir^m$, $^{134}Cs^m$, ^{137}Ba	
No hole	+0.19(26)	1.7	+0.10(38)	2.4	**+1.4(8)**	**14.7**
Hole, FO	-1.18(24)	1.4	-1.25(36)	2.2	**-0.66(25)**	**2.0**