α_k

Precise Measurements of α_k for the 346.5 keV M4 Transition in $^{197}Pt^m$

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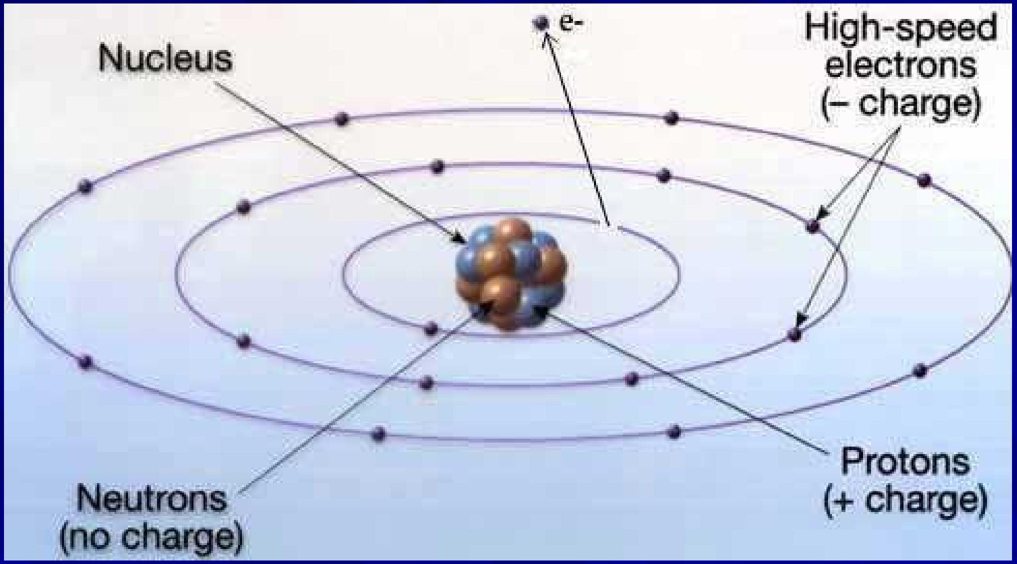
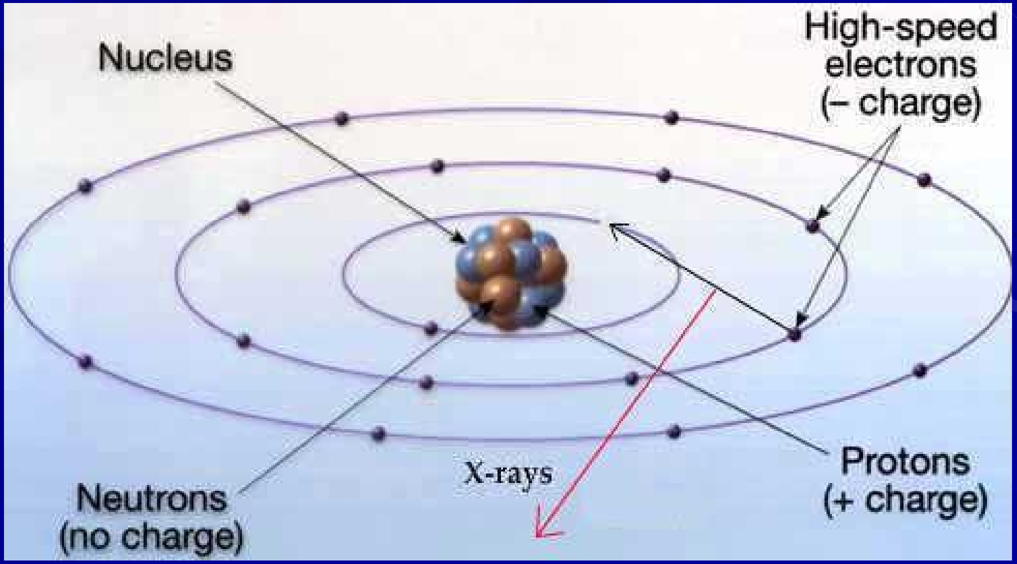
Internal Conversion

- Nuclear de-excitation energy transferred to electron.
- Electron emission from atomic orbital.
- Typically observed in inner shell electrons (K, L, and M).
- Higher-shell electron moves down to fill atomic vacancy; characteristic x-ray emission results.
- Competes with gamma-ray emission.



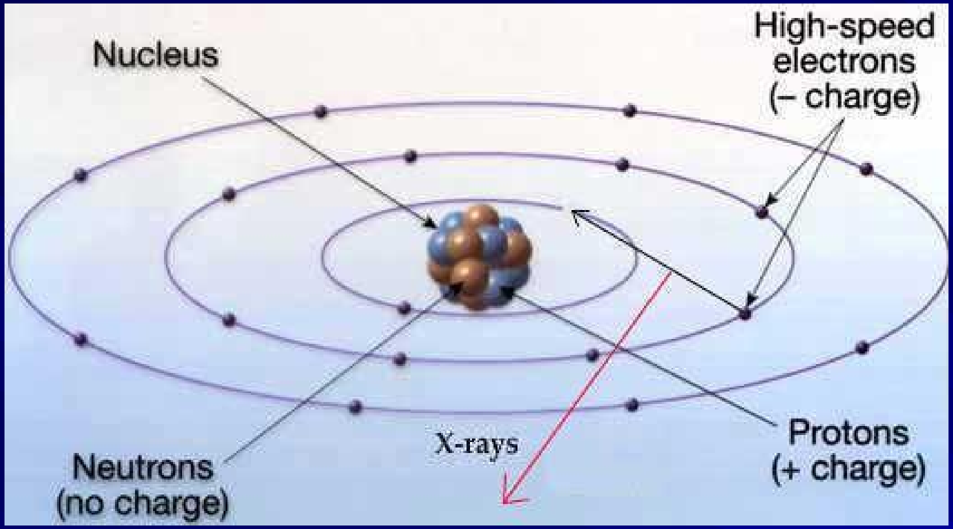


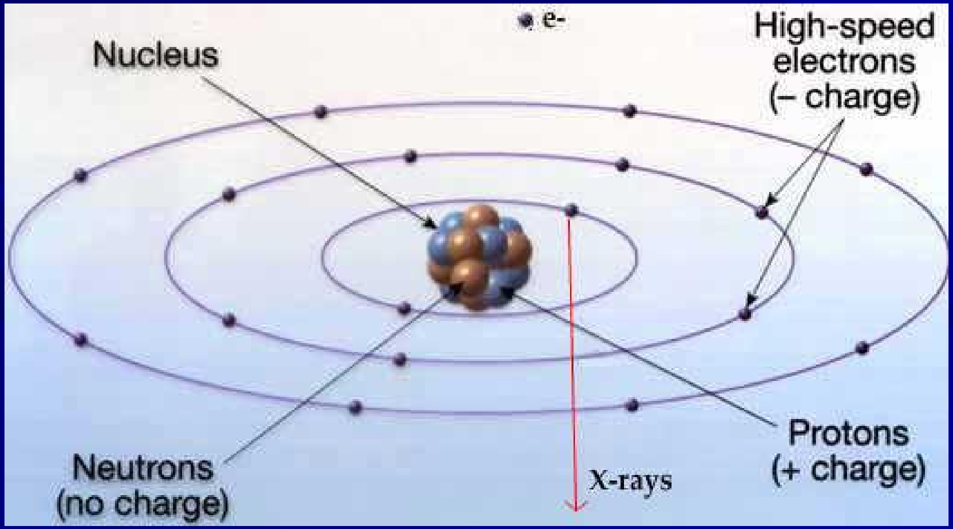
Internal Conversion Coefficient (ICC)

$$\alpha = \frac{\text{number of de-excitations via electron emission}}{\text{number of de-excitations via gamma-ray emission}}$$

- The ICC is the ratio of the total number of decays for a particular transition that proceed by internal conversion to those that proceed by gamma emission.
- ICC measurements are important in the study of nuclear decay schemes: branching ratios, spin and parity assignments, and transition rates.
- Precise ICC measurements are useful for detector efficiency calibration.

Theoretical ICC Calculations

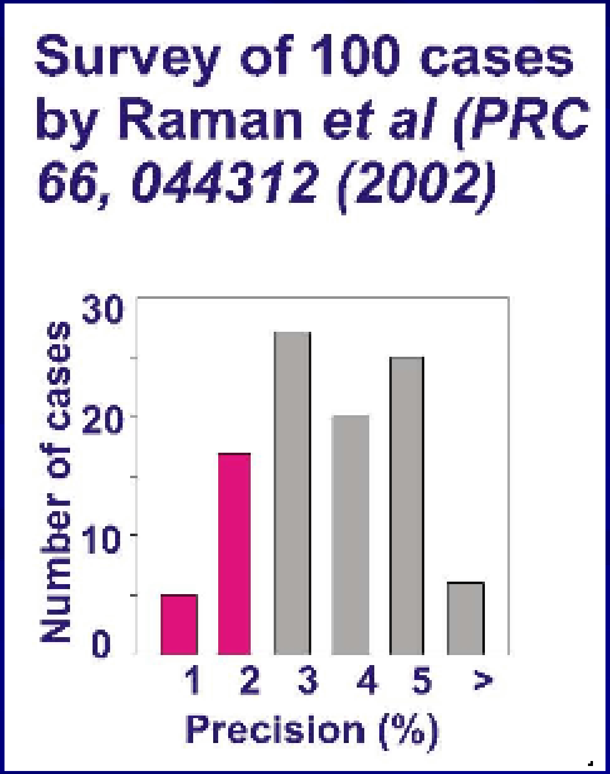


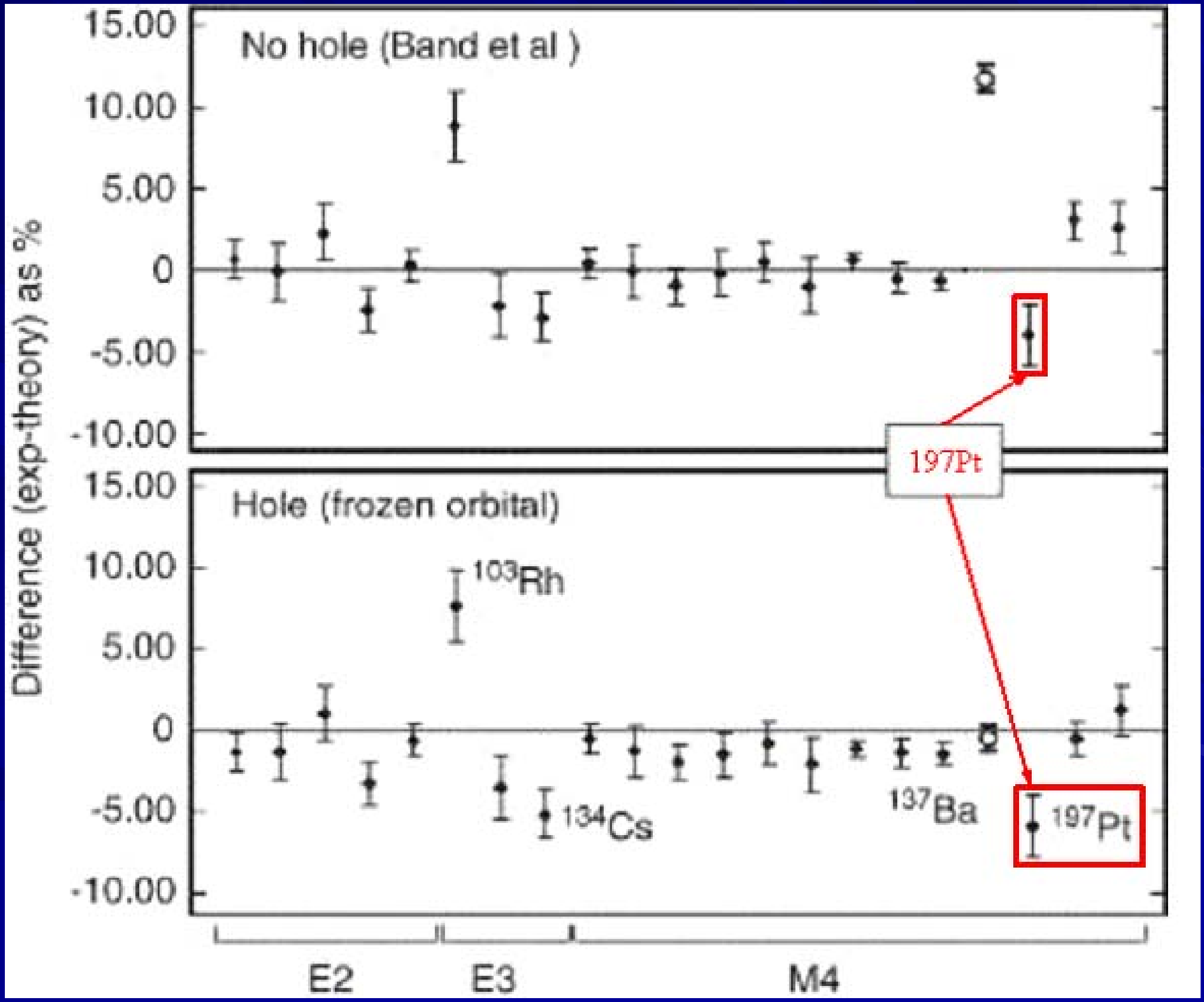


- Methods:
  - Hager and Seltzer
  - Rosel et al.
  - Band and Trzhaskovskaya
- Primary difference:
  - Hole ("Frozen Orbital")
  - No hole

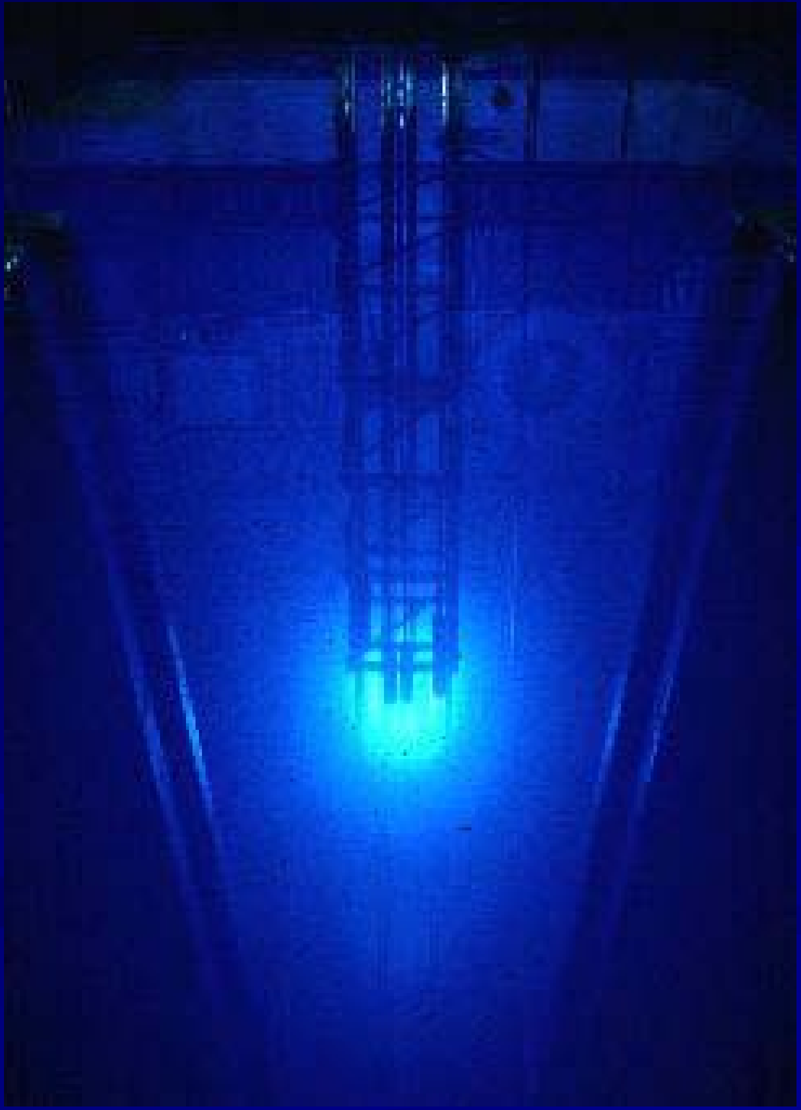
Theoretical and Experimental Discrepancies

A 2002 survey by Raman, et al. called into question the precision of existing ICC measurements; it also highlighted the discrepancies between existing theories.





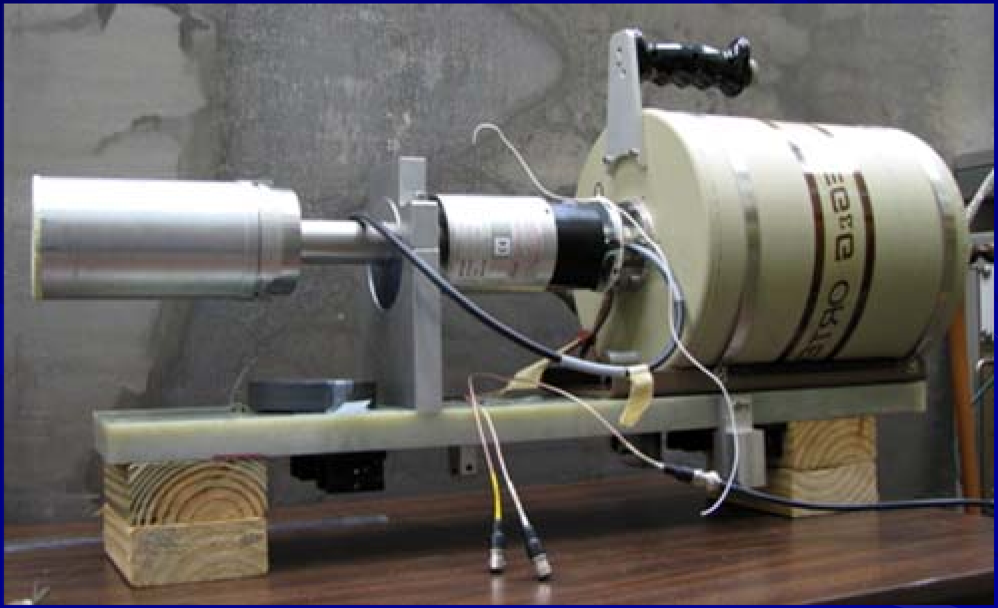
Precision Experiments



- Precise ICCs measured for:
  - ^{193}Ir
  - ^{134}Cs
  - ^{137}Ba
- These ICC measurements all suggested the "frozen orbital" (hole) approximation was a better theory.

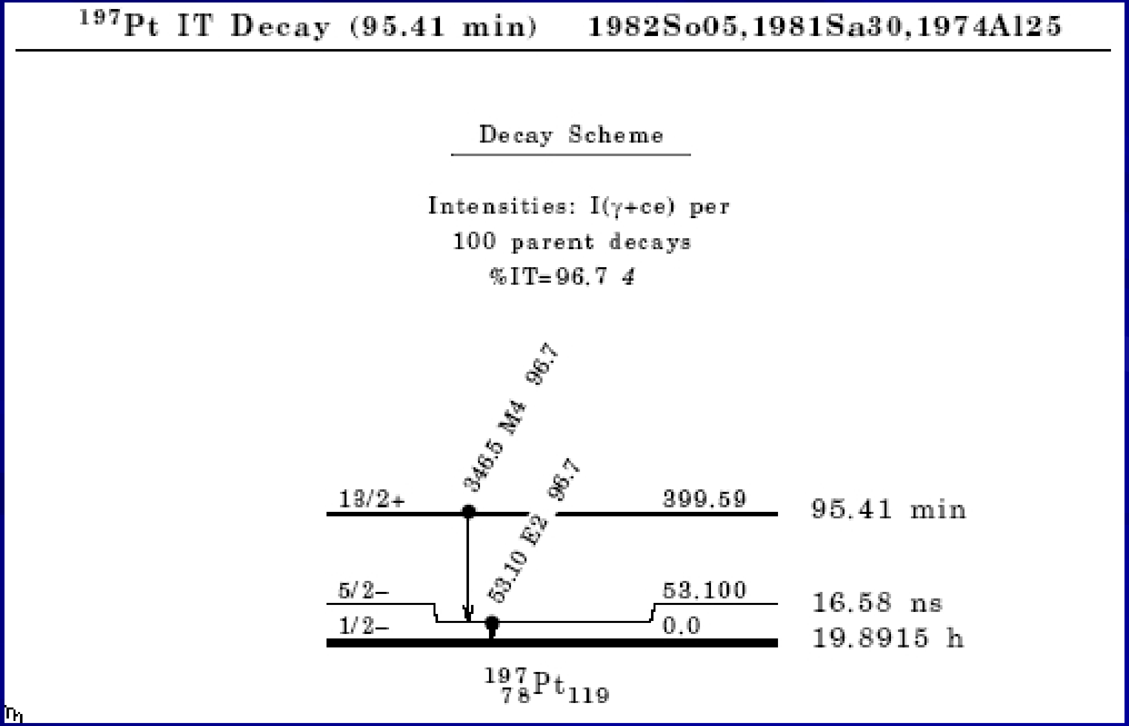
HPGe Detector

- High Purity Germanium crystal detector
- Detects x-rays and gamma-rays
- +/- .15% relative efficiency uncertainty
- +/- .20% absolute efficiency uncertainty



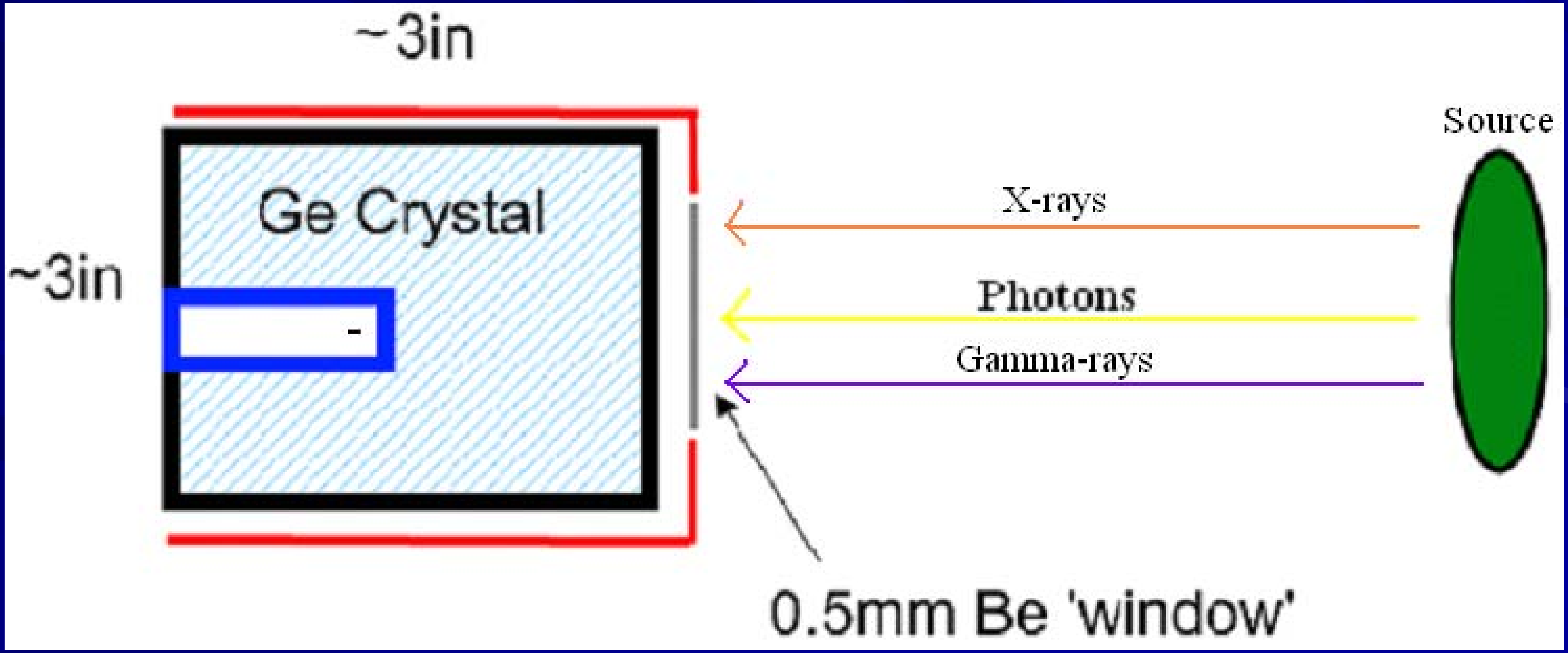
346.5 keV M4 Transition in $^{197}Pt^{m}$

- A 1987 paper by I.N. Vishnevsky, et al. gave the ICC of the 346.5 keV M4 Transition in $^{197}Pt^{m}$ as: $\alpha = 4.02 +/- 0.08$
- The measurement's disagreement with both theories makes this transition a good test case.

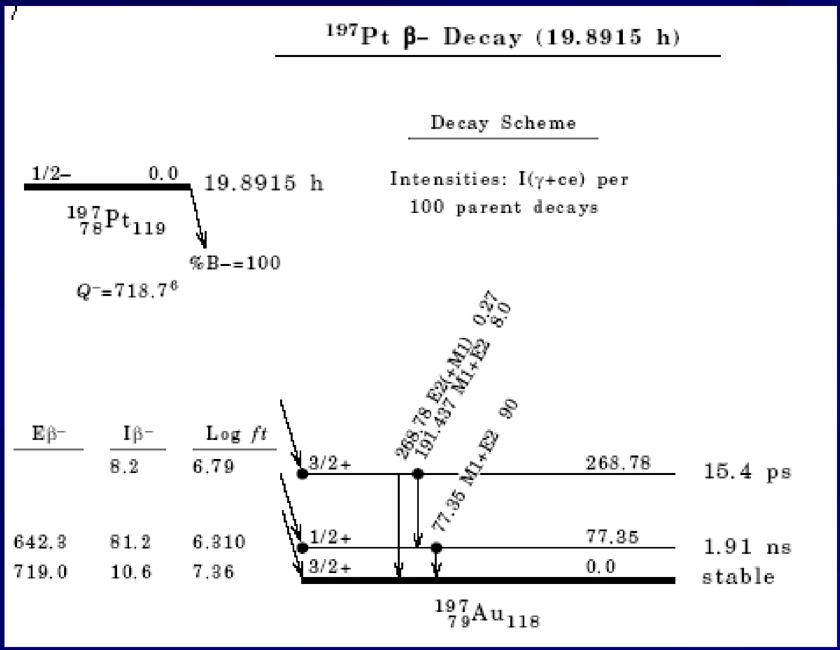


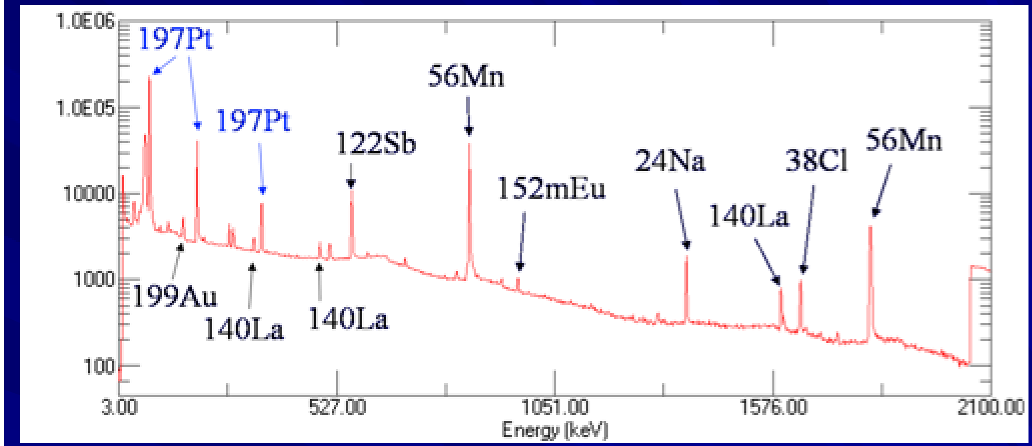
$^{197}Pt^{m}$ Experiment

- ^{196}Pt (97.43% pure) on Mylar backing; source covered by thin Mylar
- $^{196}Pt \rightarrow ^{197}Pt^{m}$ by thermal neutron activation
- $^{196}Pt \rightarrow ^{197}Pt^{gs}$ also occurs
- S1: Longer activation time resulted in more impurities
- S2: Shorter activation time resulted in less impurities
- X-ray and gamma-ray emissions from both sources recorded by HPGe detector.



Impurities



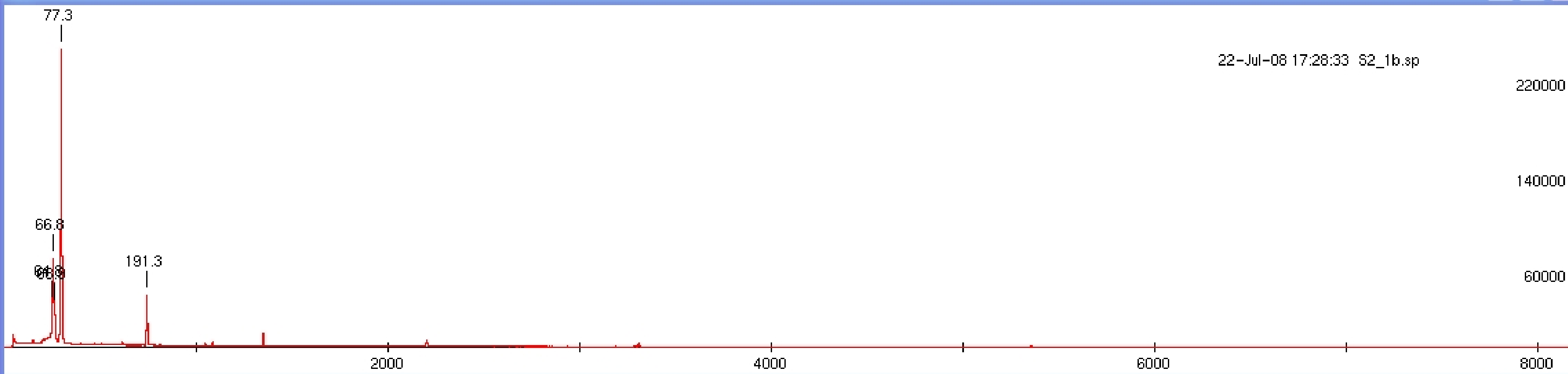


- ^{197}Pt^{m} IT decays to ^{197}Pt^{g}, which beta decays to ^{197}Au.
- In addition, the original samples of ^{196}Pt contained traces of ^{190}Pt, ^{192}Pt, ^{194}Pt, ^{195}Pt, and ^{198}Pt.
- The presence of these nuclides and others creates a number of small impurities which must be considered in a high precision measurement.

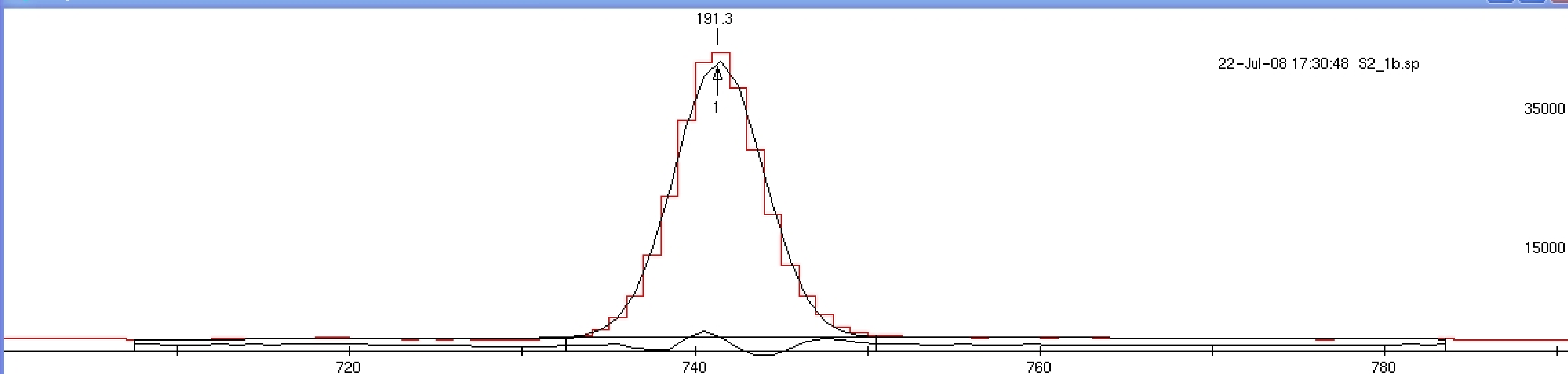
Radware: GF3

- Powerful, commonly used program
- Used to fit Gaussian curves to peaks on spectra
- Customized JCH version allows integration of peaks with tails and background subtraction
- Parameters adjusted manually to enhance precision of fit

Graphics Window



Graphics Window



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```
Spectrum file or ID = ?S2_1b
 Sp. S2_1b.sp   8192 chs read.
?ds
?ec
Do you want an energy calibration? (Y/N)y
 The energy calibration (in keV) is  E = A + B*X +C*X*X  etc. (X = ch
. no.)
   Current values are : 2.381 0.25602
 New values = ? (rtn for old values, filename for ENCAL file)197Pt2
*Energy Calibration [first degree polinomial using 2 (E_gamma,Channel
) points]*
?ds
?
```

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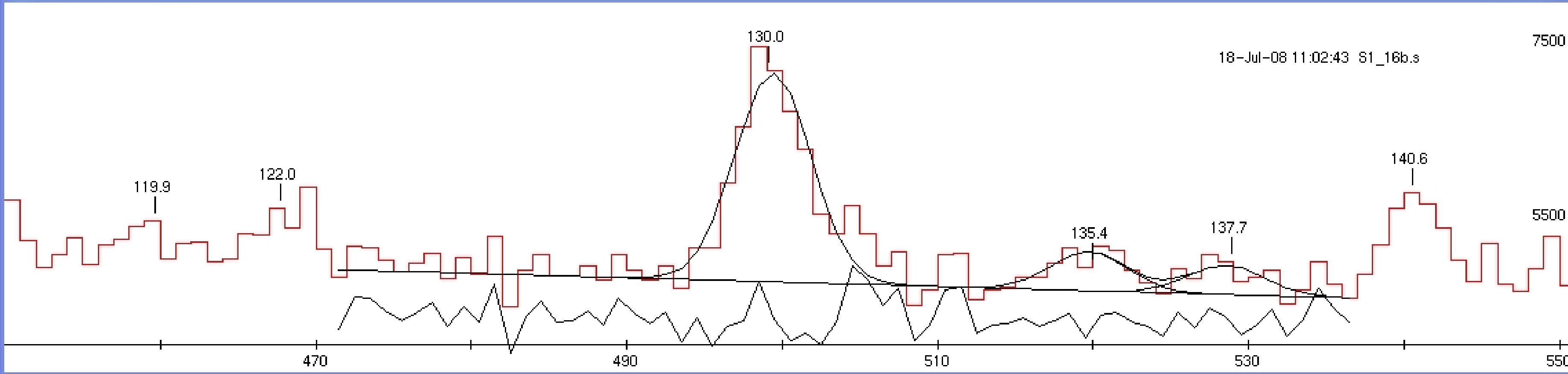
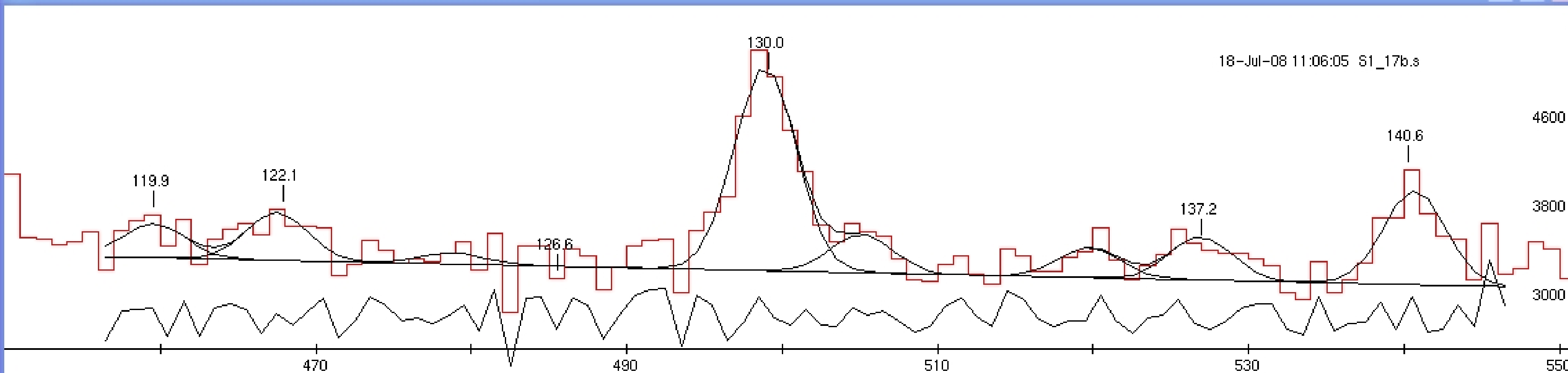
```
 Background: A = 1975(10),  B = 1.26(22),  C = -0.208(13)
      Shape: R = 0.0(0),  Beta = 1.7294(0),  Step = 0.0(0)
   position      width       height       area         centroid
  energy
 1 740.895(6)    6.019(8)     39954(104)    255967(545)    740.895(6)
  191.3621(15)
?jh
Use mouse buttons or any character to enter limits...
                           ...T to type limits, X to exit.
  Chs 732 to 750;  peak number 1
Chs 732 to 750,  Area (Int, Tails, Total): 257131 47 257179(543)
   Cent: 740.940(7)   Energy: 191.3735(17)
?
```

Graphics Window



Graphics Window



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Relative widths fixed.
 9 iterations,  Chisq/d.o.f.= 9.399
 Background: A = 4700.0(0),  B = -5.0(0),  C = 0.0(0)
      Shape: R = 0.0(0),  Beta = 1.6630(0),  Step = 0.0(0)
   position      width      height      area       centroid
  energy
 1 498.91(5)     5.73(8)    2399(48)    14639(244)  498.91(5)
  130.110(14)
 2 519.2(3)      5.75(8)    452(35)     2762(209)   519.2(3)
  135.32(7)
 3 528.1(4)      5.75(8)    333(34)     2040(206)   528.1(4)
  137.57(9)
?
```

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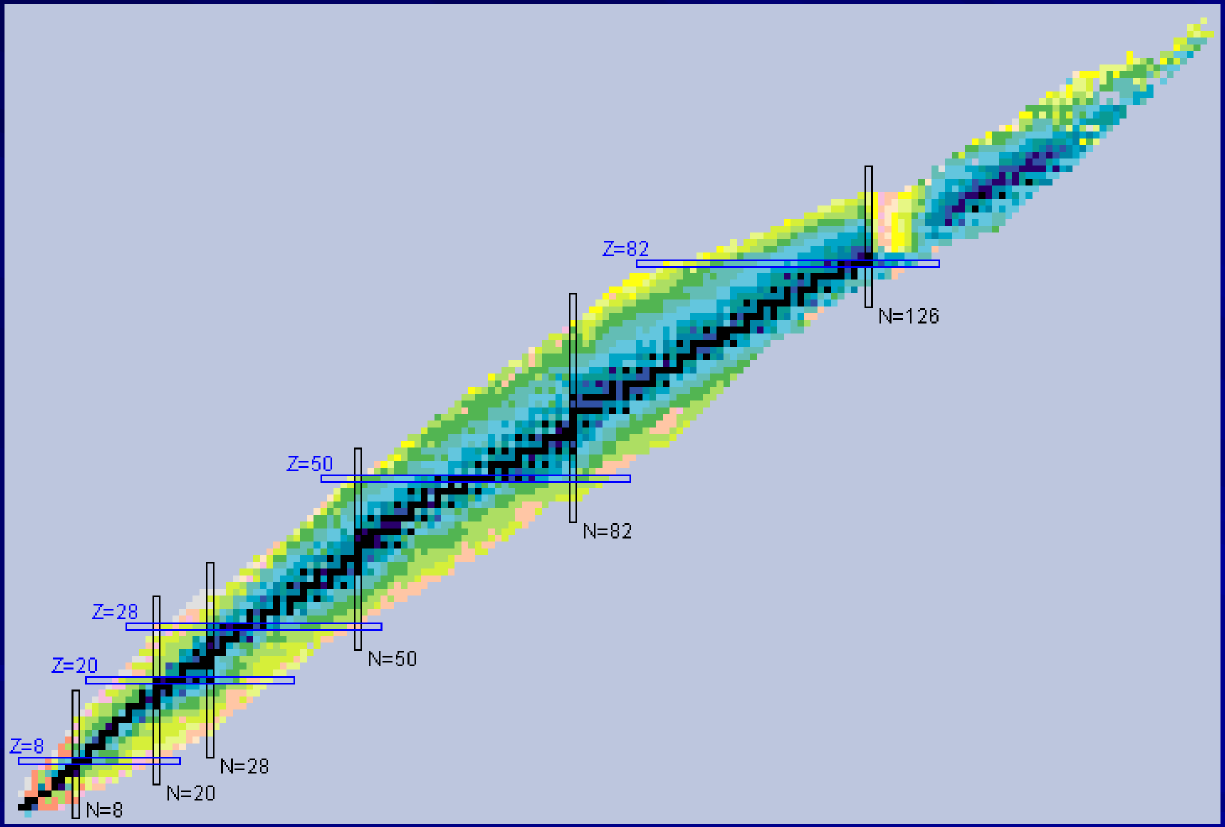
```
 3 478.3(8)      4.64(7)    103(31)     511(153)    478.3(8)
  124.83(21)
 4 498.40(6)     4.65(7)    1849(43)    9158(190)   498.40(6)
  129.981(15)
 5 504.7(3)      4.66(7)    345(35)     1708(166)   504.7(3)
  131.58(8)
 6 519.3(3)      4.67(7)    273(31)     1354(155)   519.3(3)
  135.33(8)
 7 526.43(23)    4.67(7)    391(32)     1943(157)   526.43(23)
  137.16(6)
 8 540.19(10)    4.68(7)    850(34)     4234(164)   540.19(10)
  140.68(3)
?
```

Impurity Identification and Analysis

- S1: 1-17 spectra
- S2: 1-27 spectra
- RADWARE: GF3_JCH
- NuDat
- Peak Fits
- Half-lives
- ENSDF Tables

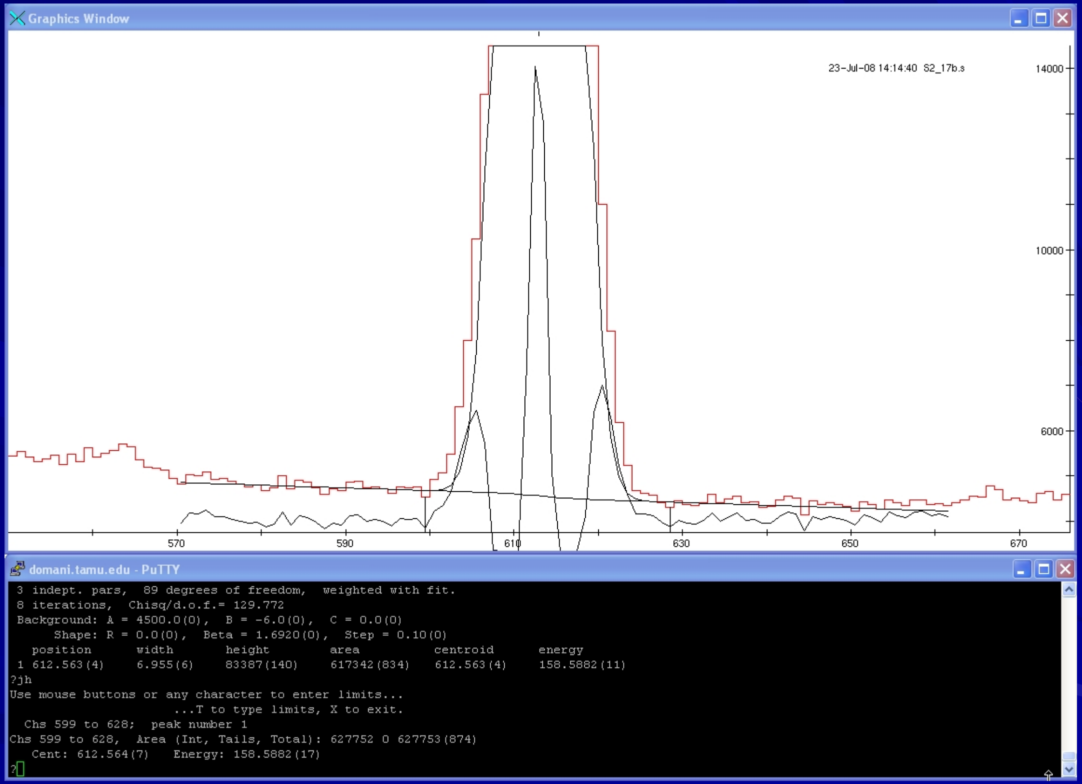
NuDat



- All known nuclides
- Activation creates unstable nuclides
- Unstable nuclides undergo beta decay
- Chart enables identification of theoretical impurities
- Contains half-life and gamma peak data for identifying actual impurities

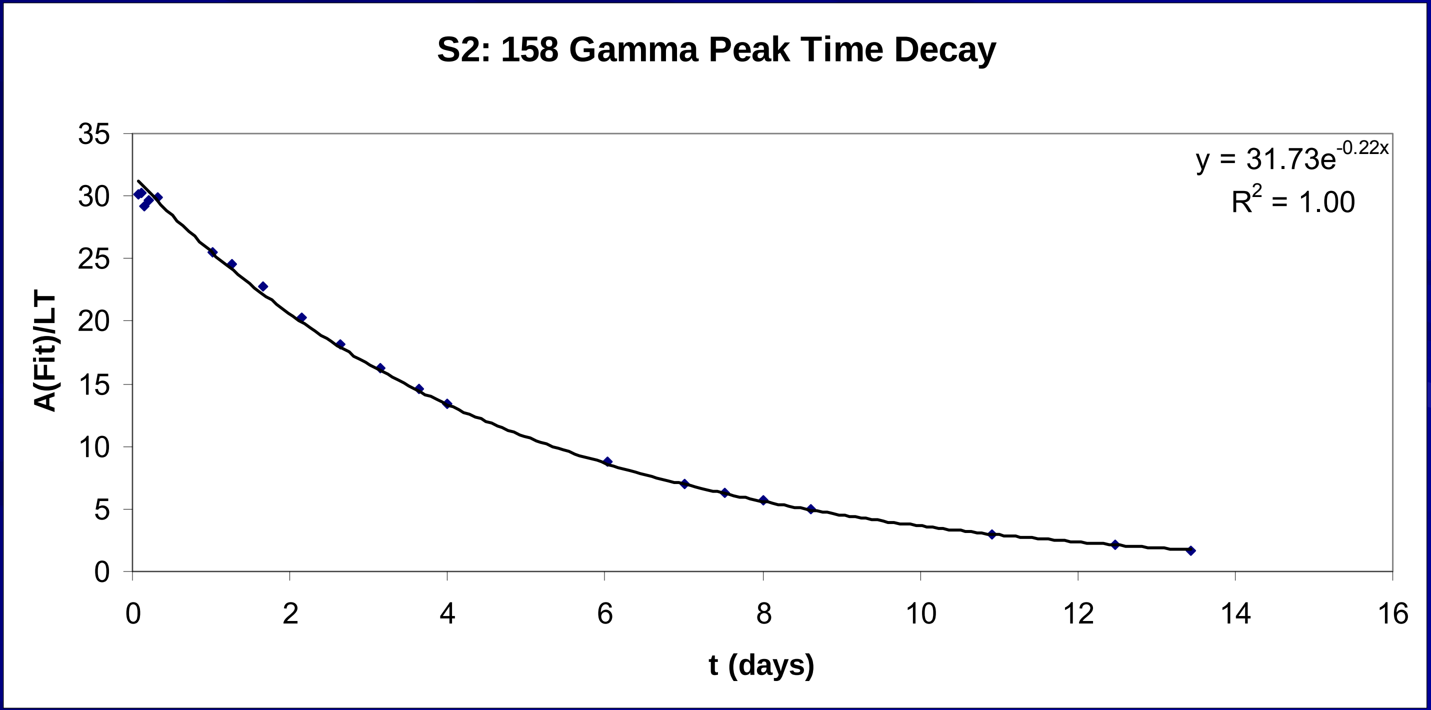
Peak Fits

- Gamma-ray peaks
- Fits and JCH integration give area
- Areas give relative contribution of impurities
- Areas can be used sequentially to obtain a half-life

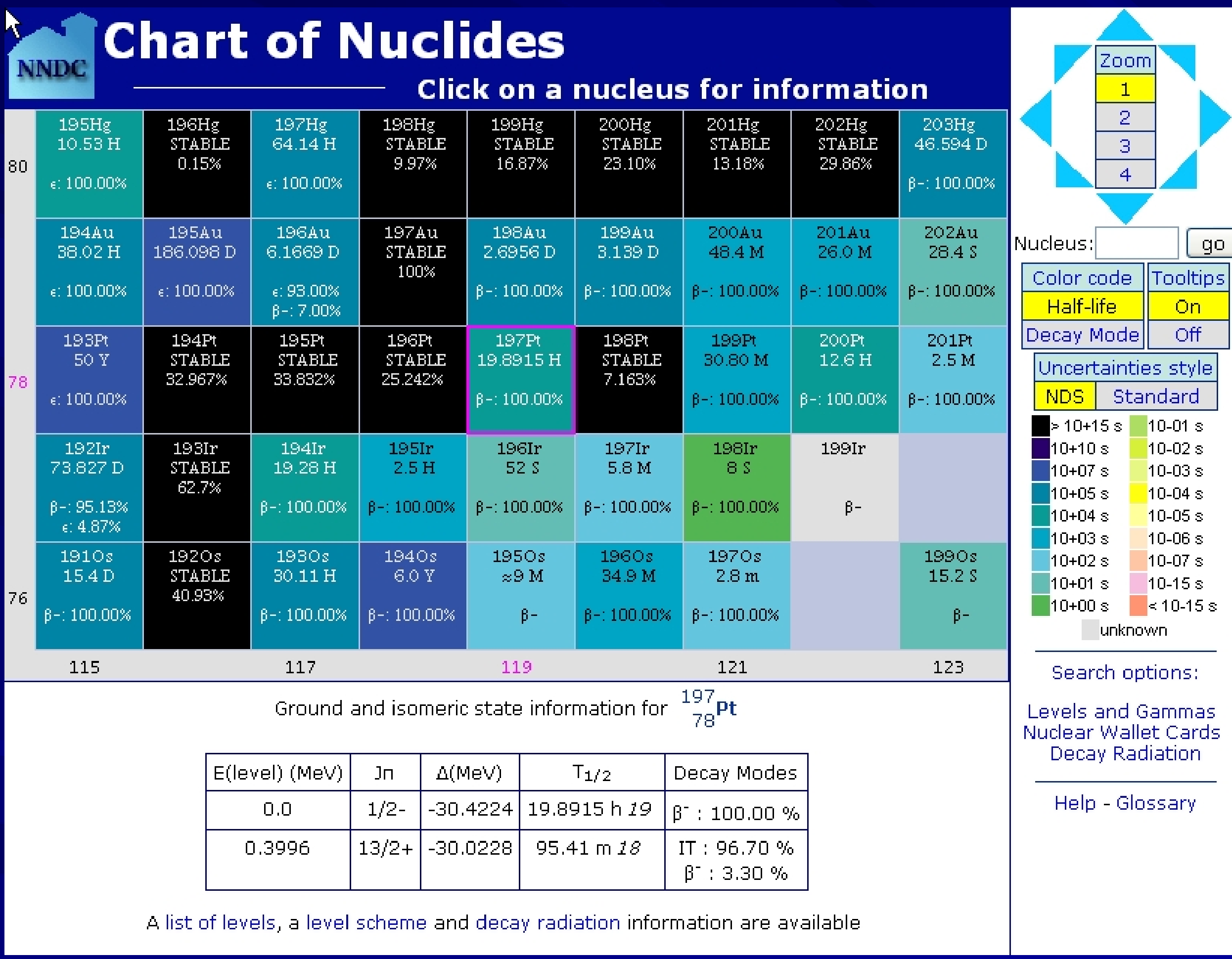


Half-life: $T_{1/2}$

- Plot changes in area of a gamma peak with time
  - Fit to exponential trend-line
    - Equation form: $Ae^{-\lambda x}$
      - $T_{1/2} = \ln(2)/\lambda$
    - $^{197}Pt^{m}$ $T_{1/2} = 19.9$ h
- $T_{1/2} \neq 19.9$ h indicates the presence of an impurity.



Data Comparison



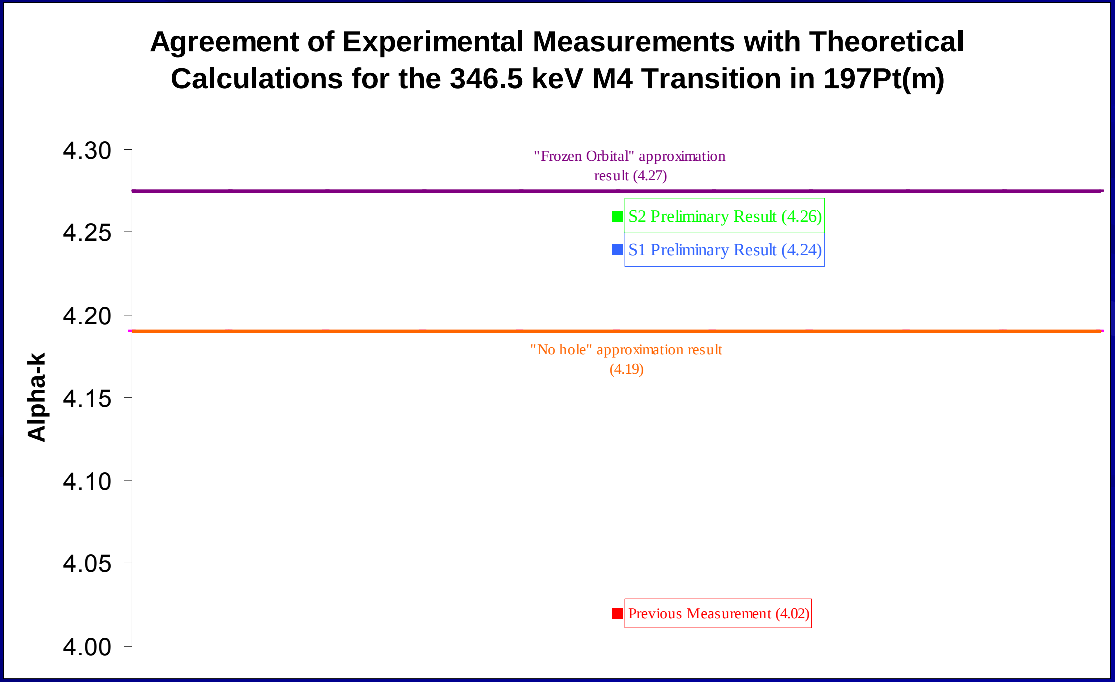
- Databases provide nuclide information
- Gamma-ray energy, intensity, and $T_{1/2}$ all help identify impurities

Attenuation Correction

- Presence of other media en route to the detector, including the source itself, cause attenuation
- S1: .7 mg of 10 mm diameter Pt in .5 mil thick Mylar; average thickness 4.5 μm
- S2: 1.53 mg of 10 mm diameter Pt in .5 mil thick Mylar; average thickness 2.1 μm
- $I_\gamma = I_{\gamma 0} e^{-\mu x}$, where μ is the attenuation coefficient.
- X-rays, gamma-rays, and the Mylar cover are considered to calculate the attenuation correction
- S1: 0.6% attenuation
- S2: 1.4% attenuation

Preliminary Results

- Theoretical:
  - With hole:
    - α_k = 4.275 +/- 0.0010
  - No hole:
    - α_k = 4.190 +/- 0.0010
- Experimental:
  - S1:
    - α_k = 4.24 (13)
  - S2:
    - α_k = 4.26 (8)



Conclusions

- The agreement of our preliminary result with the value obtained from the “frozen orbital” (hole included) theoretical method, combined with the agreement from prior precision ICC measurements of ^{193}Ir, ^{134}Cs, and ^{137}Ba, continues to support the “frozen orbital” method’s agreement with experimental measurements.
- The uncertainty in the results for the α_k value means that this agreement is still tentative; the final result will hopefully demonstrate closer agreement with the “frozen orbital” theory.

Future Work

- Complete identification of impurities
- Subtract remaining impurity contributions from spectra
- Obtain final precision values of α_k for both S1 and S2.
- Compare final results with no-hole and "frozen orbital" (hole) theoretical values for α_k .
- Publish results.

Acknowledgments

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