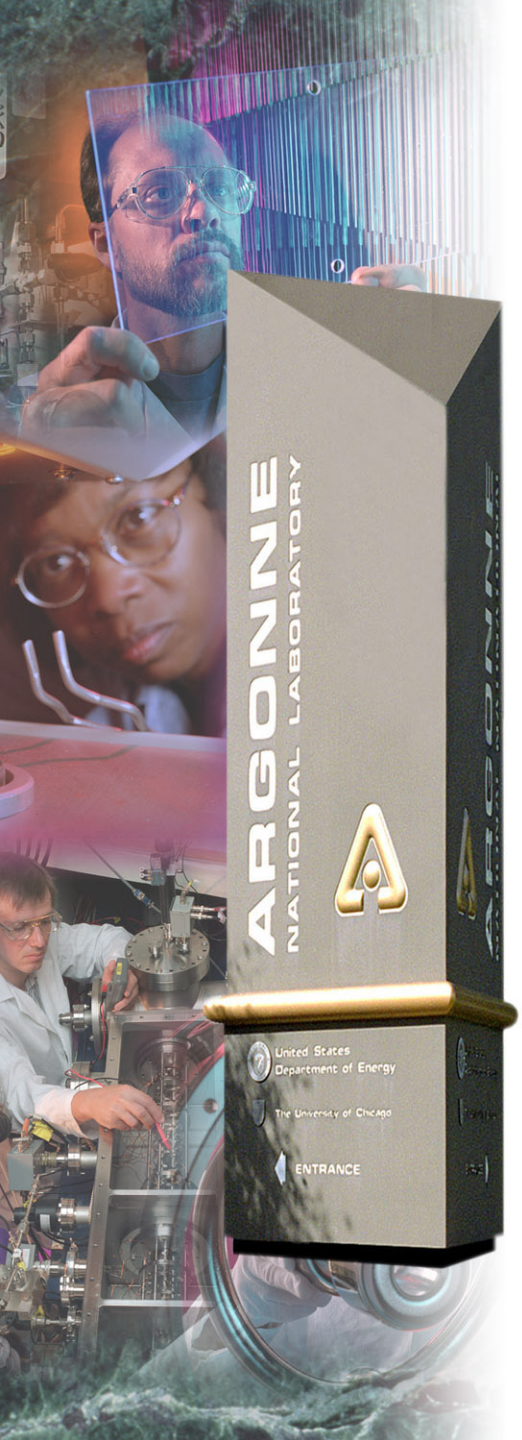


# *Experimental Activities Report ANL Nuclear Data Program*

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*Nuclear Engineering Division*

*2003 CSEWG Meeting*
*Brookhaven National Laboratory, November 4-6, 2003*

**Argonne National Laboratory**

Office of Science
U.S. Department of Energy

*A U.S. Department of Energy*
*Office of Science Laboratory*
*Operated by The University of Chicago*

# *Program Overview*

- *Compilation and evaluation of nuclear structure & decay data (ENSDF). Responsibility for A=199-209 mass chains.*
- *Compilation and evaluation of decay data for nuclei that are of interest to various applications (DDEP) and for nuclear isomers.*
- *Experimental activities intended to fill gaps in the existing data bases focused on properties of heavy- and super-heavy nuclei, nuclei far from the line of stability and nuclear isomers*
- *Experimental validation and parameter sensitivity studies for various nuclear models used in fast neutron induced reactions*
- *Compilation of charged-particle reaction cross section data for nuclei in the mass range A=30-50 that are of interest for astrophysical applications.*
- *Development of improved methods for representing and propagating errors in both experimental and derived nuclear quantities*

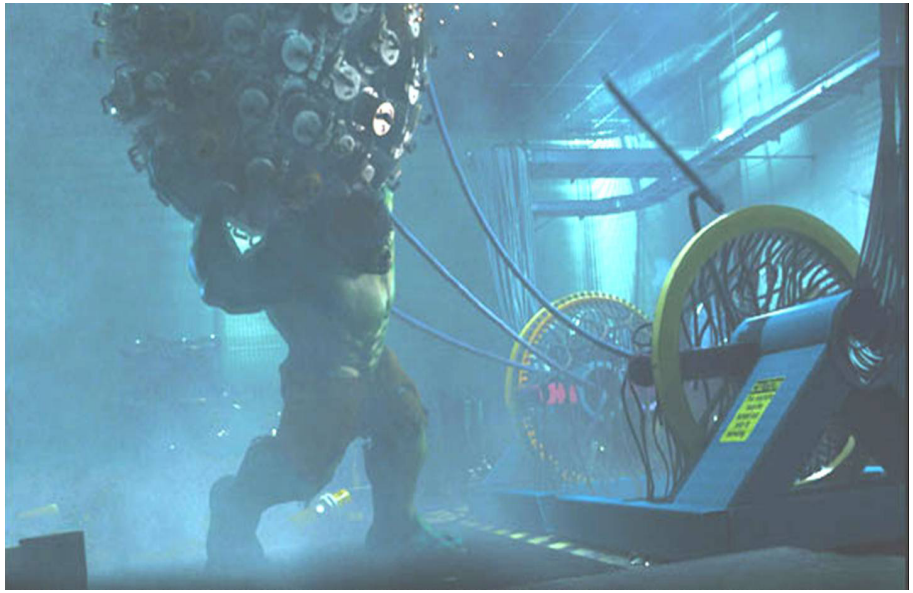
# Recent Experimental Activities

➢ ***Motivation:*** *To fill gaps and improve quality of existing databases & to find new applications of nuclear data in the areas of basic physics, astrophysics, nuclear energy and national security research*

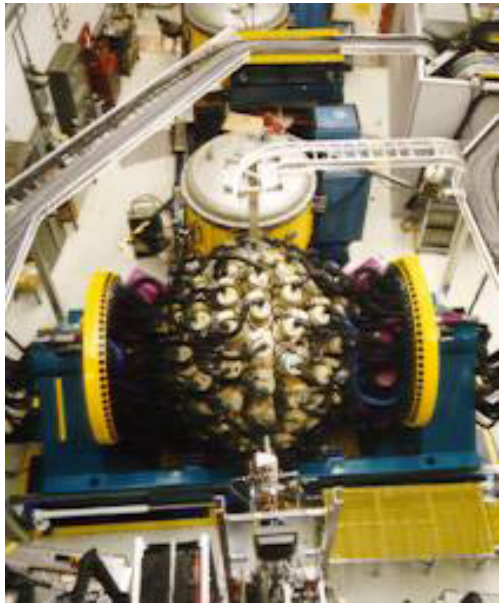
- *Properties of Nuclear K-Isomers in the A~180 mass region (GS)*
- *Properties of nuclei at the proton drip line (GS&FMA)*
  - *Data on $^{181}$Pb, $^{181}$Tl and their daughters*
  - *Data on odd-odd Au isotopes*
  - *Radiative capture in HI fusion (e.g. $^{90}$Zr+$^{92}$Mo, $^{90}$Zr+$^{89}$Y)*
- *Spectroscopy of heavy nuclei*
  - *Decay data on $^{251}$Cf (ANL)*
  - *Decay data on $^{253}$Es (GS&ANL)*
  - *Lifetimes of very long-lived $^{245,246}$Cm & $^{239}$Pu nuclei (ANL)*
- *Neutron cross section measurements in the 13-20 MeV region (IRMM)*

# *"Gammasphere in Action … "*

*Universal Studio Picture*

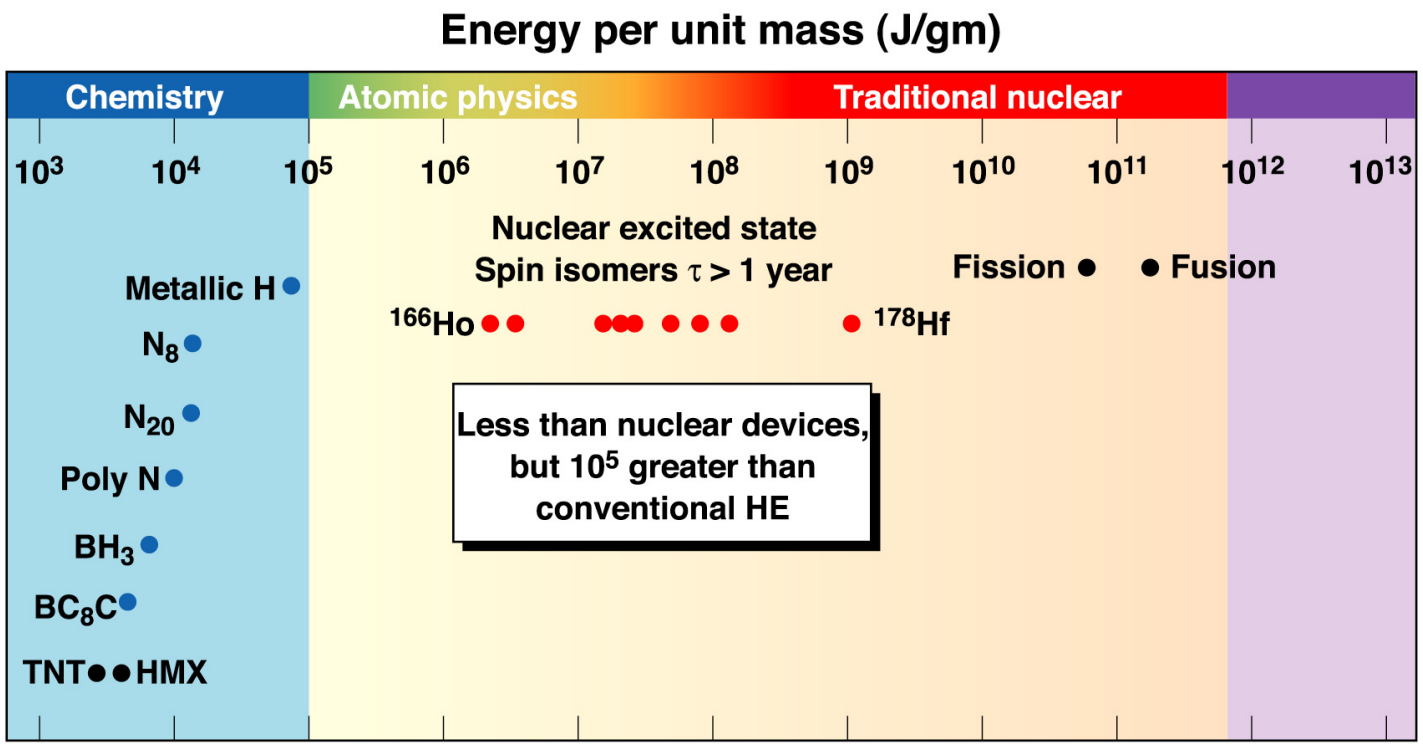



*Gammasphere at ANL*



*How we do research with Gammasphere*

# Why should DOE-NE care?
# — Unprecedented energy storage opportunities




**Isomers may be a controllable energy source**

- **With energy density intermediate between fission/fusion and chemical**
- **With long shelf life (> 1 year)**

P02555-jab-u-004

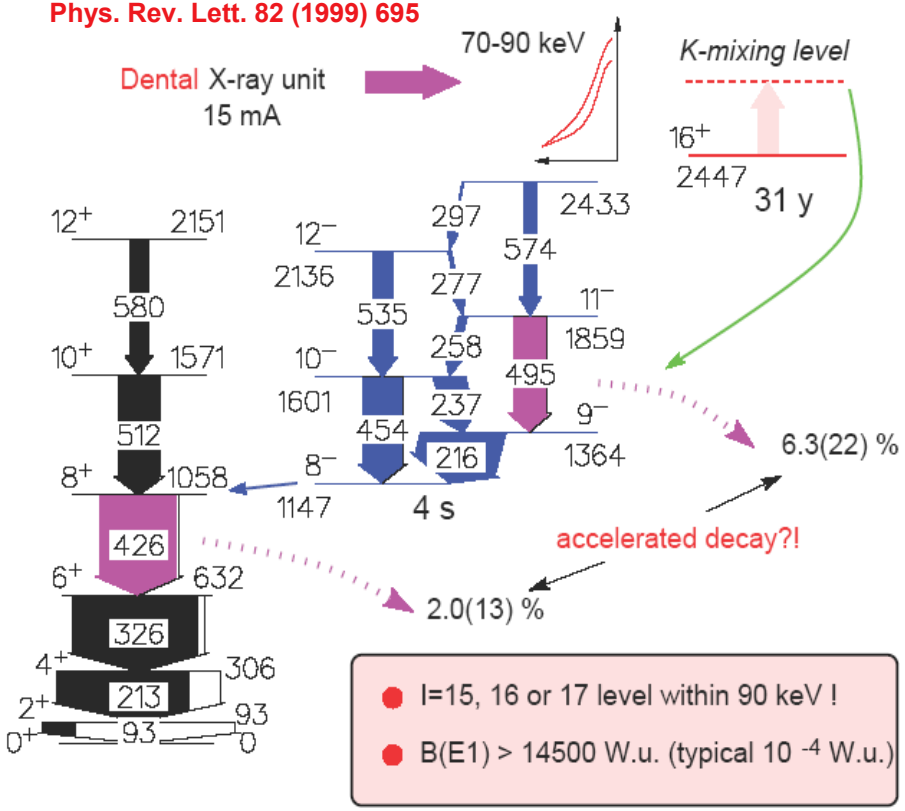
*Courtesy to John Becker, LLNL*

Physics & Advanced Technologies

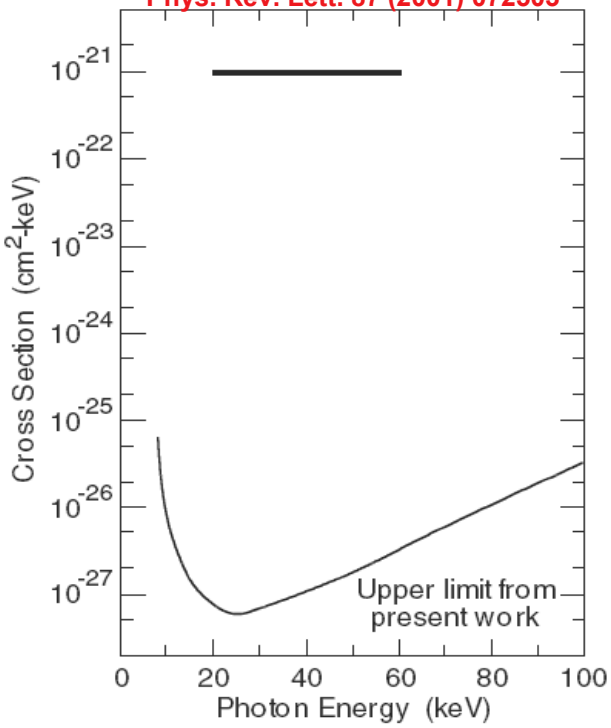
# Nuclear Isomers

***Energy in 1 g of the "charged up" $^{178m}$Hf equivalent to 500 lbs of TNT!***

**Texas/AFRL/SNL Collaboration**
**Phys. Rev. Lett. 82 (1999) 695**



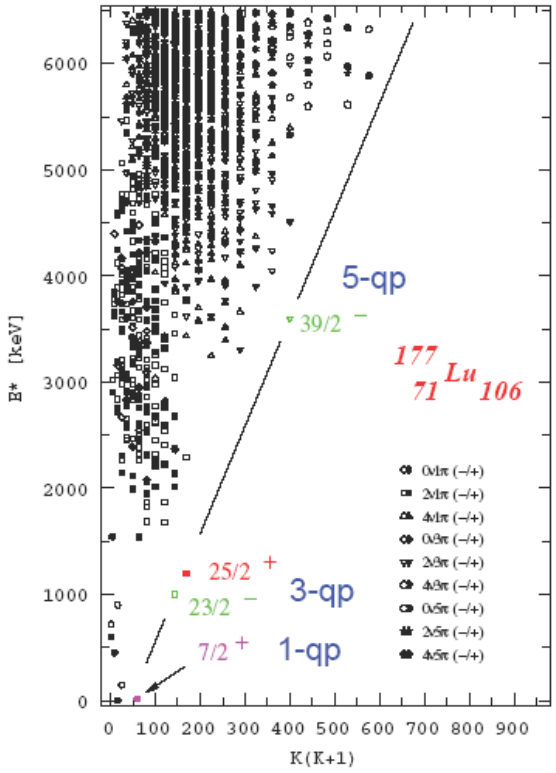

**ANL/LANL/LLNL Collaboration**
**Phys. Rev. Lett. 87 (2001) 072503**

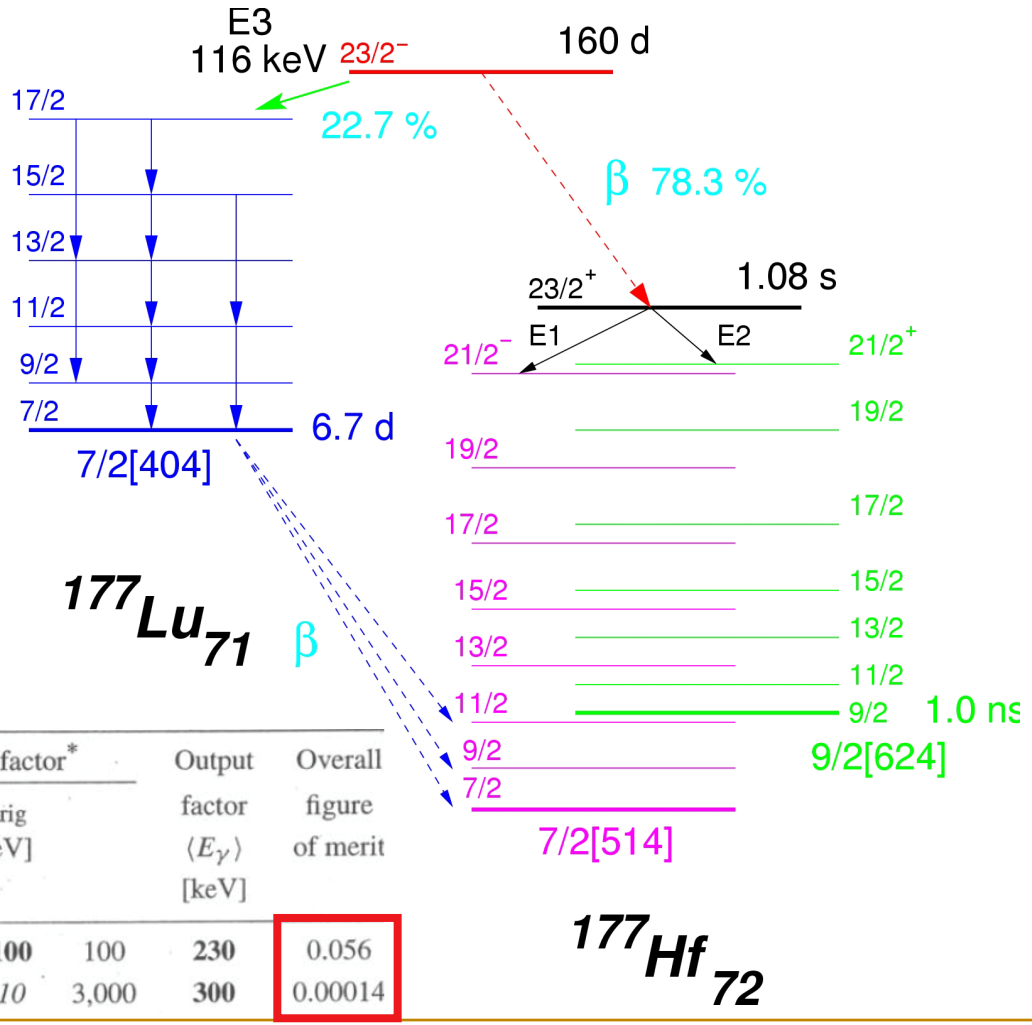



***Results are very controversial, but the stakes are enormous!***

***The Nuclear Data input – vital!***

# *Nuclear Isomers – cont.*




J.J. Carroll *et al.*, *Hyp. Int.* 135 (2001) 3

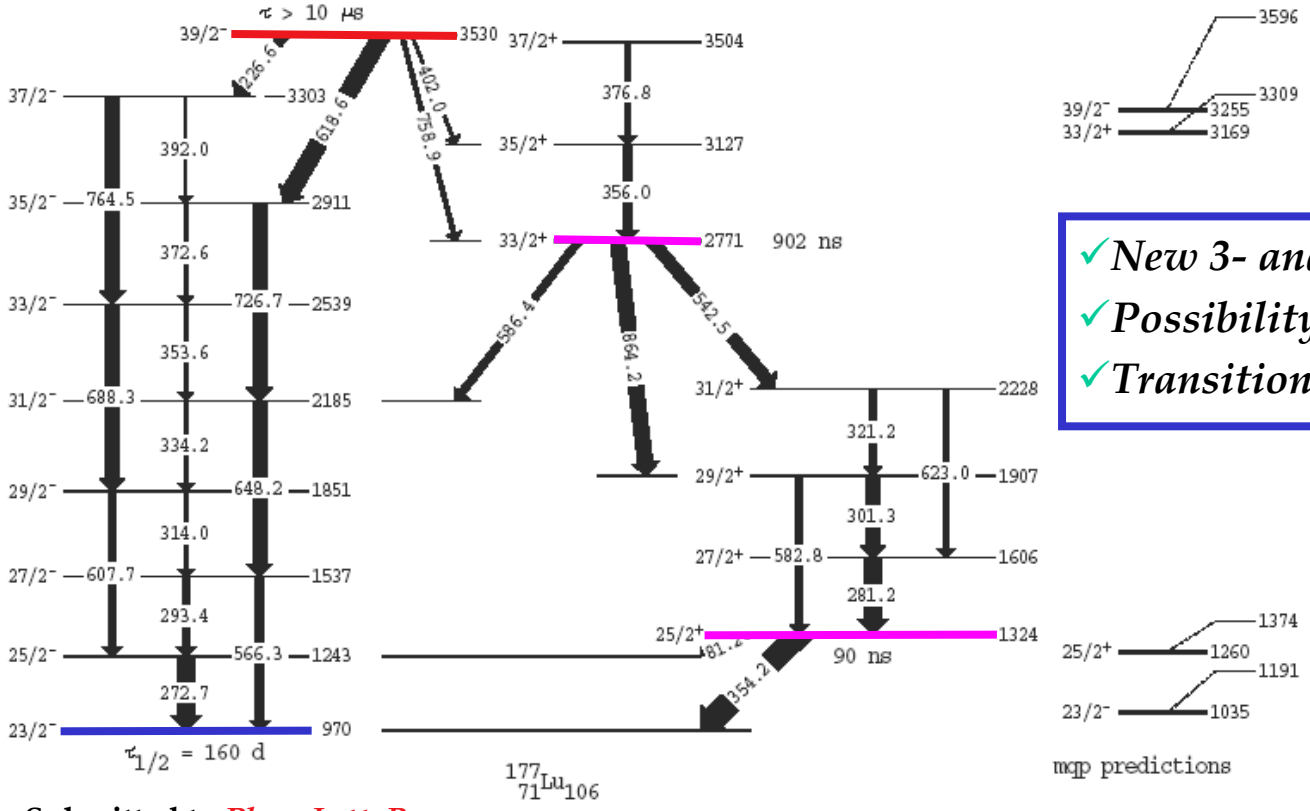
| Isomer | Prod. factor $\sigma_{(n,\gamma)}$ [b] | Storage factor $E_s$ [keV] | Storage factor $T_{1/2}$ [y] | Triggering factor* ICS$_{trig}$ [eV b] | Triggering factor* $E_{trig}$ [keV] | | Output factor $\langle E_\gamma \rangle$ [keV] | Overall figure of merit |
|---|---|---|---|---|---|---|---|---|
| $^{177}Lu^{m}$ | 2.8 | 970 | 0.44 | 427 | $\sim 10^4$ | <100 | 100 | **230** | 0.056 |
| $^{178}Hf^{m2}$ | $\sim 10^{-6}$ | 2,446 | 31 | 75,826 | $\leqslant 3 \times 10^4$ | $\sim 10$ | 3,000 | **300** | 0.00014 |

# Nuclear Isomers – cont.

*$^{176,177}$Lu: no stable beam/target combination to produce them in HI,xn*

*Tool: deep inelastic and multi nucleon transfer reactions*

*Experiment: $^{136}$Xe beam on enriched $^{176}$Lu target @ 6 MeV/A (~20% above the Coulomb barrier)/Pulsed beam & Gammasphere*










- ✓*New 3- and 5-qp Isomers*
- ✓*Possibility of β– branch*
- ✓*Transition strength – K robustness*

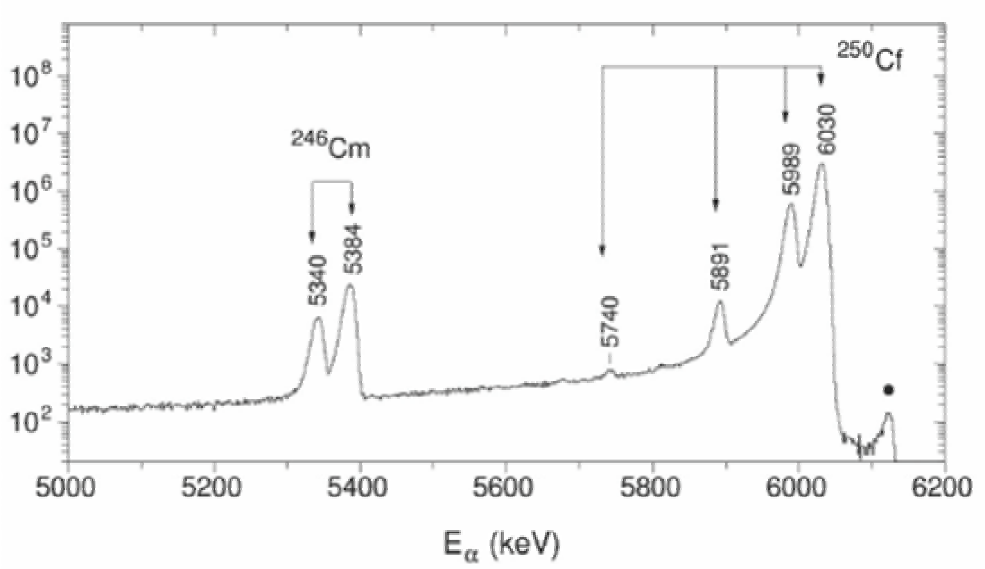
**Submitted to *Phys. Lett. B***

# *Lifetimes of very long lived actinide isotopes*

- *Conventional techniques are compromised when the lifetimes are long, e.g. hundreds and thousands of years*
- *Mass spectrometry approach - systematic uncertainties are unknown or potentially large*

**Our Approach**

- *Mass separated samples (1975!)*
- *Parent/daughter activity*
- *Alpha counting technique*
- *Applied to $^{245,246}Cm$ and $^{239}Pu$*




$^{250}Cf \xrightarrow[13\ y]{\alpha} {}^{246}Cm \xrightarrow[4747\ y]{\alpha} {}^{242}Pu \xrightarrow[510^5\ y]{\alpha}$

*$T_{1/2}$=4747 (46) years / Compared to values ranging from $T_{1/2}$=2300 up to 6620 years*

# *Nuclear Model Development*

- *Argonne is participating in an international effort under the auspices of WPEC (Subgroup 19) to improve the reliability of model calculations for neutron activation cross sections.*

- *Argonne is contributing in the following areas:*
  - *Methodology development*
  - *Participation in neutron activation cross-section measurements at IRMM, Geel, Belgium.*
  - *Compilation of measured results in EXFOR format for submission to data centers.*
  - *Estimate uncertainties in evaluated results by performing parameter sensitivity analysis*

# *Nuclear Model Development – cont.*

- *Energy range is mainly from 13-20 MeV but also some work done at lower and higher energies*
- *Elemental and enriched samples of F, Na, Mg, Al, Si, P, Cl, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zr, Nb, Mo, Tc, Sn, Ba, and Pb were used*