LA-UR- 11-04372

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Title:	Ultra-high resolution alpha particle spectrometry with transition-edge sensor microcalorimeters
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Intended for:	Presentation at conference

Los Alamos
NATIONAL LABORATORY
EST. 1943

Form 836 (7/06)

Ultra-High Resolution Alpha Particle Spectrometry with Superconducting Transition-Edge Sensor Microcalorimeters

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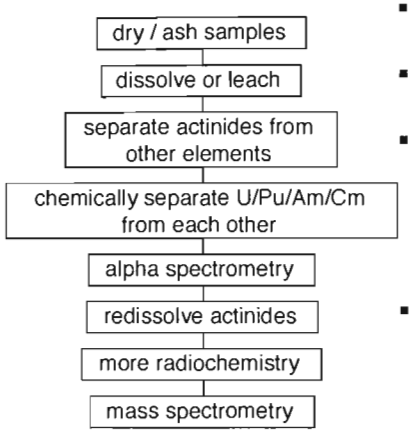
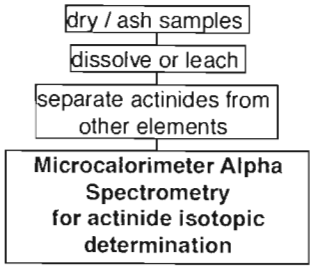
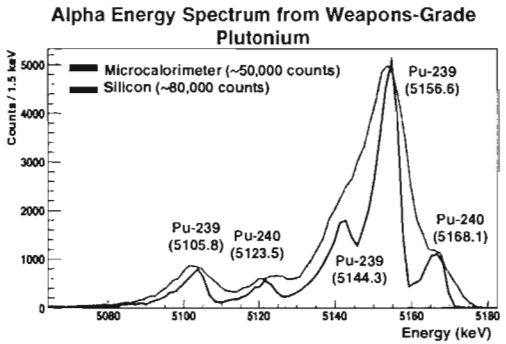
Conventional isotopic analysis of trace actinide samples



- **Critical for nuclear forensics and environmental monitoring**
- **Requires Si alpha spectrometry and mass spectrometry**
- **Conventional Si alpha spectrometers: ~10 keV FWHM at 5 MeV**
  - $^{238}Pu/^{241}Am$: 13-20 keV alpha energy separation
  - $^{239}Pu/^{240}Pu$: 12-15 keV alpha energy separation
- **Difficult and time-consuming actinide separation required**

Microcalorimeter alpha spectrometry

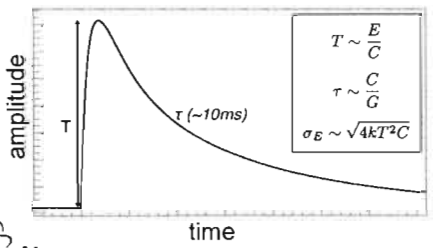


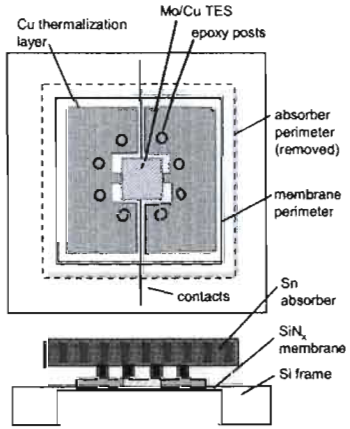


- **Microcalorimeter alpha particle energy resolution: up to 1.06 keV FWHM at 5.3 MeV (^{210}Po)**
- **Simplified sample preparation: cleanup, not separation chemistry**
- **One measurement for rapid isotopic analysis**

Microcalorimeter alpha detector basics

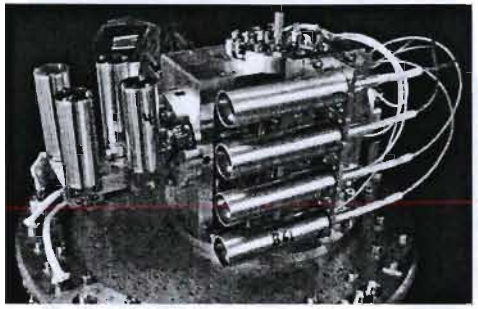
- **Alpha particles of interest: 4-6 MeV**
- **4mm x 4mm x 0.25mm Sn absorber coupled to TES by SU-8 epoxy posts**
- **Absorber ΔT≈3 mK for 5 MeV alpha**
- **Mo/Cu bilayer TES on SiN membrane, T_c≈120 mK, T_{bath}≈80 mK, voltage biased to ~30% of R_{normal}**

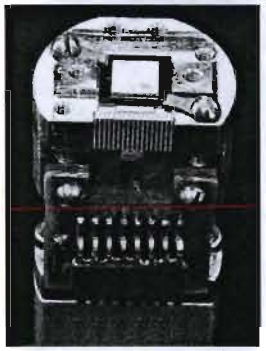




2008-2011: LANL four channel spectrometer system

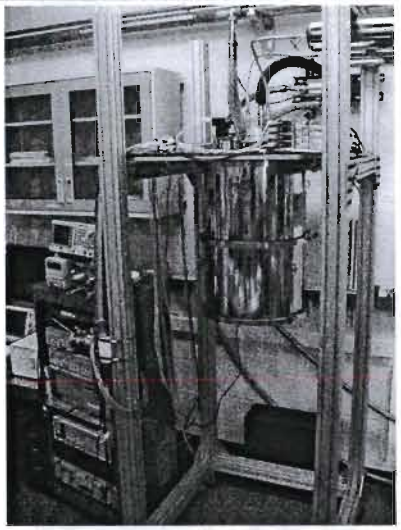
- Janis LHe/LN_2 cryostat with adiabatic demagnetization refrigerator
- 30 hours at 80 mK, limited by ADR
- Star Cryoelectronics two-stage SQUID readout
- TES chips from NIST and Star Cryoelectronics



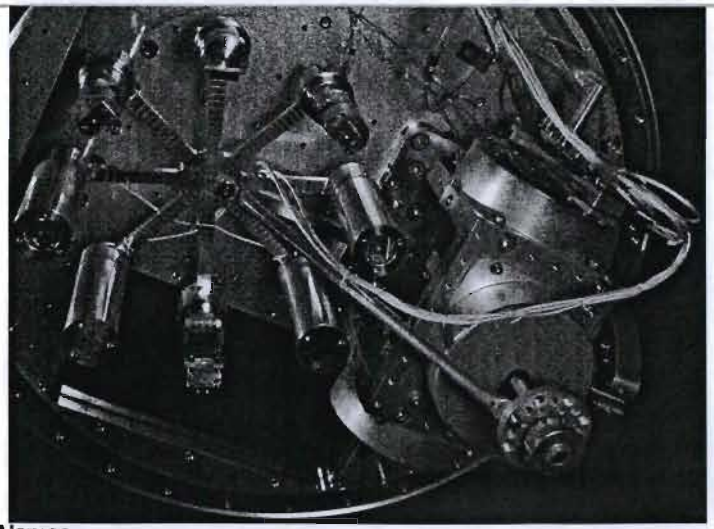


New LANL system: eight channels in dry cryostat

- HPD model 106 helium pulse-tube cryostat with adiabatic demagnetization refrigerator
- >50 hours at 80 mK, limited by ADR
- Eight independent detectors, sources, and readout channels
- Optimized for detector and source development with flexible configuration
- National Instruments PXI system: instrument control, TES voltage bias, 24-bit ADC

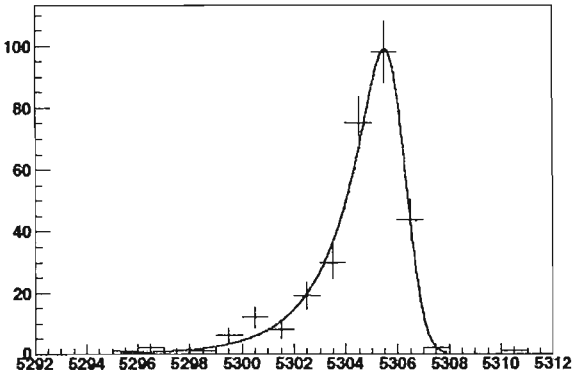


3K experimental space: Ø 34 cm X 21 cm tall



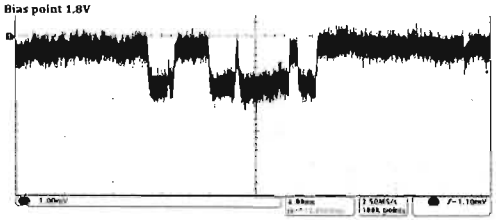
Demonstrated resolution comparable to record

- 1.23 keV FWHM at 5.3 MeV from measurement of ^{210}Po



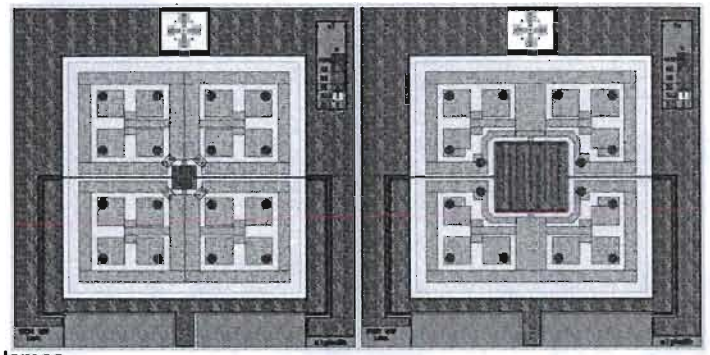
Instabilities in TES transition

- Used 1.5 micron thick SiN membrane on new fab for strength, instead of 0.5 micron
- Bistable switching appears at points throughout TES transition, primarily at high bias current
- Instabilities present at bias points up to 87%Rn
- Suspect that bias current density is too high with increased membrane thermal conductance, switching is between multiple current paths



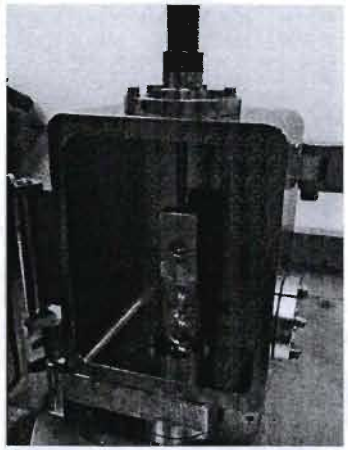
Modified TES for lower current density

- Increased TES side length by 3X
- Preliminary results indicate no instabilities at bias above 20% Rn
- Testing ongoing to determine alpha spectrometry performance

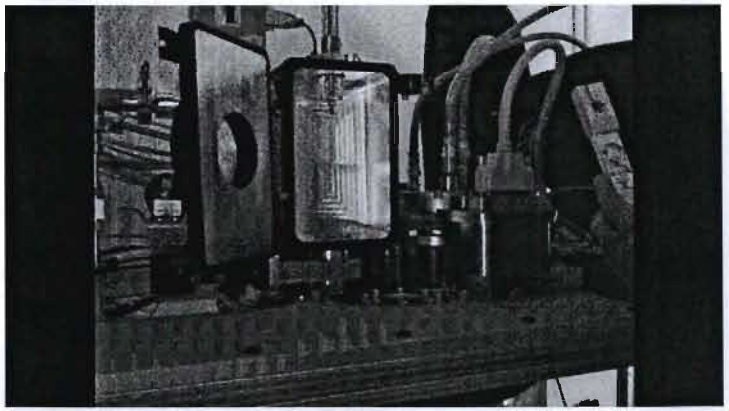


Cryogenic load-lock in development at NIST

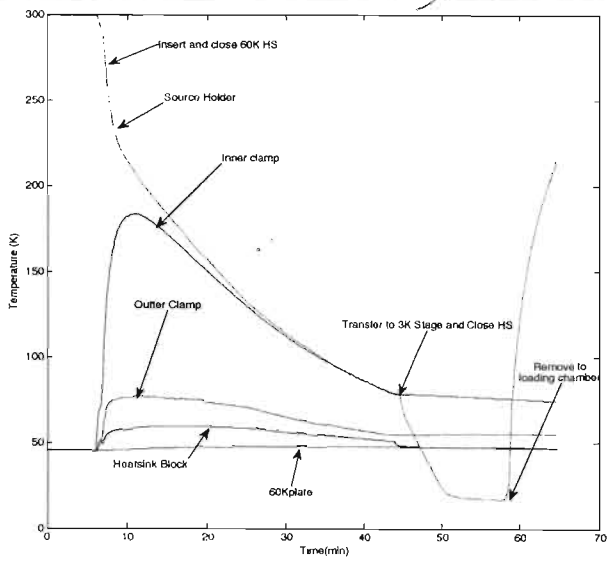
- Rapid sample exchange is required for an analytical instrument



Cryogenic load-lock demonstration



Cryogenic load-lock: 60 minutes to 5K



Future Work

- Characterize alpha spectrometry performance of new detector design
- Eight high-resolution detectors operating simultaneously in LANL 8-channel system
- Installation and testing of detectors in NIST load-lock system
- Measurements for improved understanding of alpha energy spectrum peak shapes and isotopic analysis with microcalorimeters