

LA-UR- 11-04372

Approved for public release;  
distribution is unlimited.

*Title:*

Ultra-high resolution alpha particle spectrometry with  
transition-edge sensor microcalorimeters

*Author(s):*

M. Croce, M. Bacrania, E. Bond, D. Dry, W. A. Moody, M. Rabin (LANL)

J. Beall, D. Bennett, G. Hilton, R. Horansky, V. Kotsubo, D. Schmidt, J. Ullom (NIST, Boulder, Colorado)

R. Cantor (STAR Cryoelectronics, Santa Fe, New Mexico)

*Intended for:*

Presentation at conference



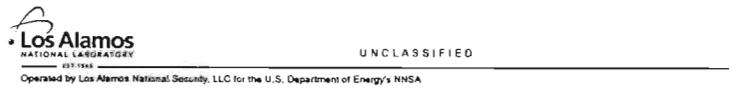
Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

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

M.P. Croce, M.K. Bacrania, E.M. Bond, D.E. Dry, W.A. Moody, M.W. Rabin  
(Los Alamos National Laboratory)

J.A. Beall, D.A. Bennett, G.C. Hilton, R.D. Horansky, V. Kotsubo, D. Schmidt, J.N. Ullom  
(National Institute of Standards and Technology, Boulder)

R. Cantor  
(Star Cryoelectronics)



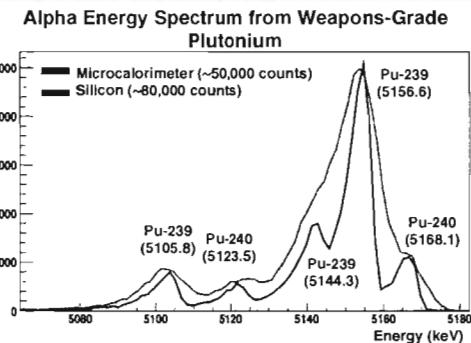
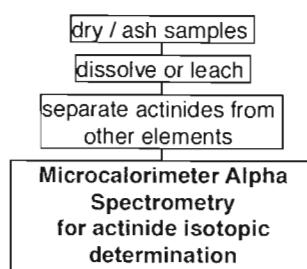
UNCLASSIFIED  
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Side 2

```

graph TD
    A[dry / ash samples] --> B[dissolve or leach]
    B --> C[separate actinides from other elements]
    C --> D[chemically separate U/Pu/Am/Cm from each other]
    D --> E[alpha spectrometry]
    E --> F[redissolve actinides]
    F --> G[more radiochemistry]
    G --> H[mass spectrometry]
  
```

## Microcalorimeter alpha spectrometry



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

UNCLASSIFIED  
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Side 3

## Conventional isotopic analysis of trace actinide samples

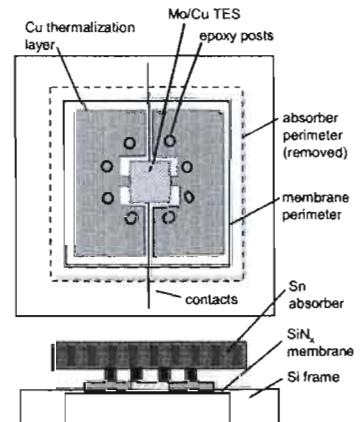
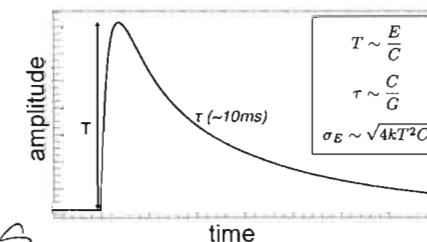
- Critical for nuclear forensics and environmental monitoring
- Requires Si alpha spectrometry and mass spectrometry
- Conventional Si alpha spectrometers: ~10 keV FWHM at 5 MeV
  - $^{238}\text{Pu}/^{241}\text{Am}$  : 13-20 keV alpha energy separation
  - $^{239}\text{Pu}/^{240}\text{Pu}$  : 12-15 keV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

UNCLASSIFIED  
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Side 2

## 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  $\Delta T \approx 3$  mK for 5 MeV alpha
- Mo/Cu bilayer TES on SiN membrane,  $T_c \approx 120$  mK,  $T_{bath} \approx 80$  mK, voltage biased to ~30% of  $R_{normal}$

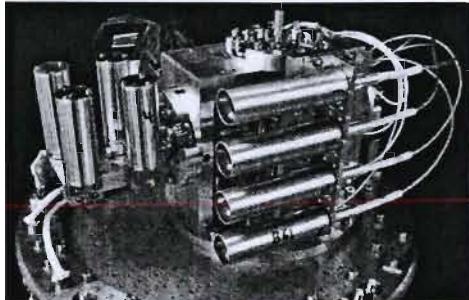


UNCLASSIFIED  
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Side 4

## 2008-2011: LANL four channel spectrometer system

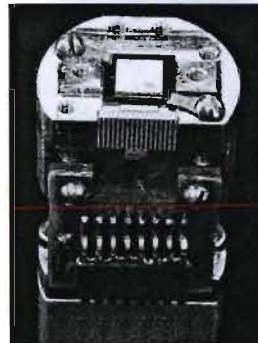
- Janis LHe/LN<sub>2</sub> cryostat with adiabatic demagnetization refrigerator
- 30 hours at 80 mK, limited by ADR
- Star Cryoelectronics two-stage SQUID readout
- TES chips from NIST and Star Cryoelectronics



• Los Alamos  
NATIONAL LABORATORY  
1945-1995

UNCLASSIFIED

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

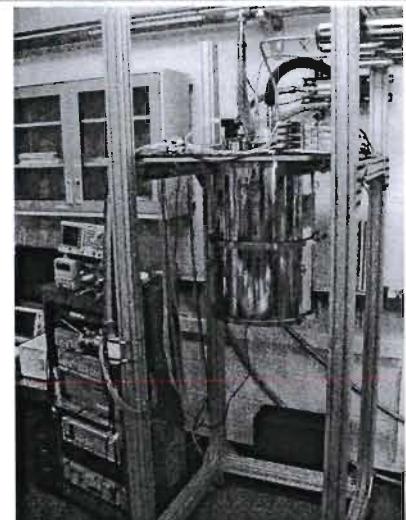


Side 5

NASA

## 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



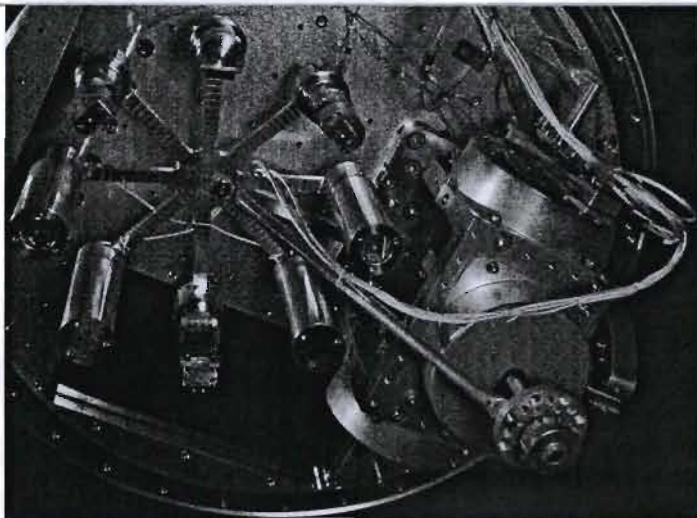
• Los Alamos  
NATIONAL LABORATORY  
1945-1995

UNCLASSIFIED  
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Side 6

NASA

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



• Los Alamos  
NATIONAL LABORATORY  
1945-1995

UNCLASSIFIED

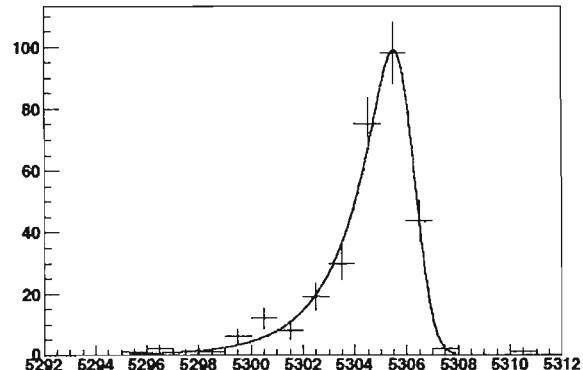
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Side 7

NASA

## Demonstrated resolution comparable to record

- 1.23 keV FWHM at 5.3 MeV from measurement of <sup>210</sup>Po



• Los Alamos  
NATIONAL LABORATORY  
1945-1995

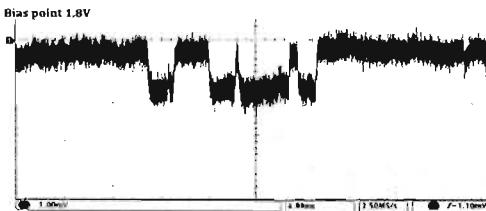
UNCLASSIFIED  
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Side 8

NASA

## 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



• Los Alamos  
NATIONAL LABORATORY

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

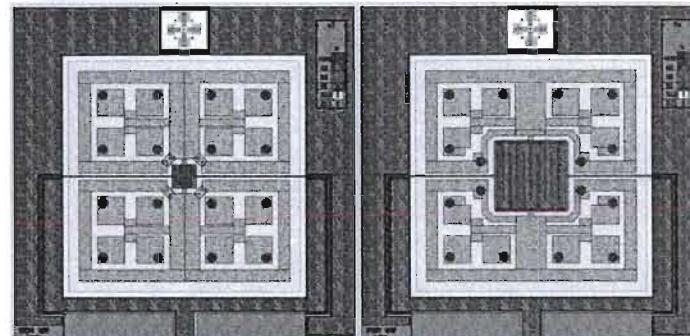
UNCLASSIFIED

Slide 9

NASA

## 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



• Los Alamos  
NATIONAL LABORATORY

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

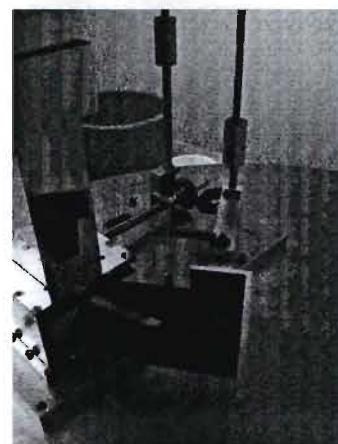
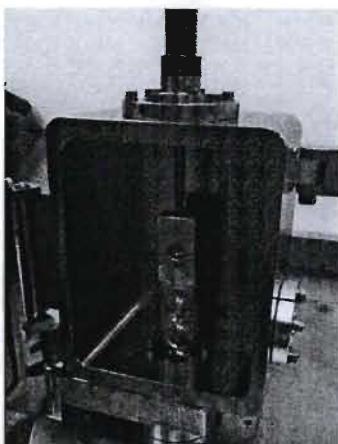
UNCLASSIFIED

Slide 10

NASA

## Cryogenic load-lock in development at NIST

- Rapid sample exchange is required for an analytical instrument



• Los Alamos  
NATIONAL LABORATORY

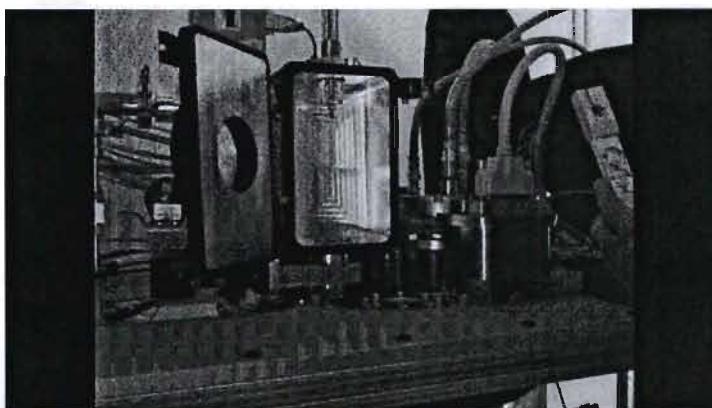
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

UNCLASSIFIED

Slide 11

NASA

## Cryogenic load-lock demonstration



• Los Alamos  
NATIONAL LABORATORY

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

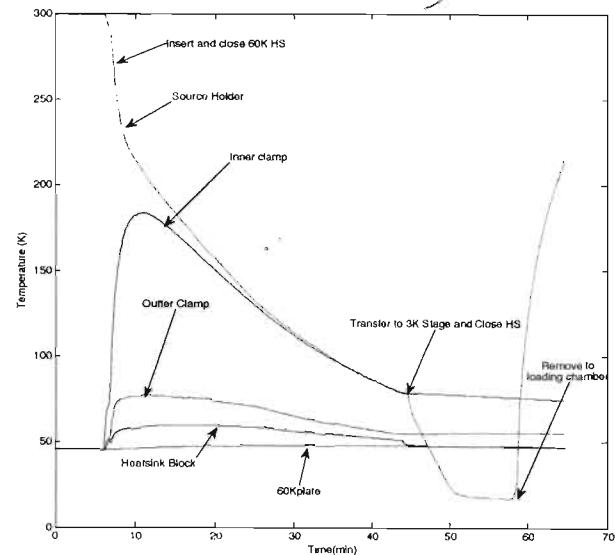
UNCLASSIFIED

Slide 12

NASA

## Cryogenic load-lock: 60 minutes to 5K

2 3 4



Slide 13  
VSS

## 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