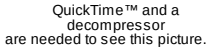
Field Application of CZT Detector for Evaluation of Radiation Source Term



Dr. David W. Miller, AEP D.C. Cook

Dr. Zhong He, PhD, Nuclear Engineering Department, University of Michigan**

2012 Asian ISOE ALARA Symposium, Tokyo, JAPAN

September 24 -25, 2012

Presentation Outline

- **Introduction**
  - EdF
  - INPO Event Notice
- **Why CZT and Canberra Instrument?**
- **Radiation Measurement and Performance Metrics**
  - Source Term Tracking
- **CZT Benchmark Results**
  - First Field Trial Turkey Point 3R22
  - DC Cook-1,2
- **3D CZT**

INPO Event Notice, July 5th 2011
Inadequate CRE Improvements

- **"During the past five years, the trend for reducing collective radiation exposure (CRE) has not been acceptable.**
  - Several units remain well over the current industry CRE goal and have not made significant progress toward reducing collective dose.
  - The boiling water reactors as a group did not meet the 2010 CRE annualized cycle dose goal of less than120 person-rem"

- **"Two major causes of high collective dose were**
  - elevated radioactive source terms and
  - shortfalls in outage dose reduction planning and work execution."
- **2010 AFIs Revealing Weaknesses**
  - Source Term Management
  - Outage Dose Reduction Planning

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Électricité de France (EDF) Leadership

- **Equipment and MethodDeveloped by Commissariat à l'énergie atomique (CEA)**
  - Licensed to Canberra
- **EdF Plant Aging Program**
  - Deployed to all 58 EdF Nuclear Plants
  - Standard Protocols Measurements ALL RFOs
- **Purpose:**
  - Source Term Changes
  - EPD's and Instrument Cal
  - ALARA
  - Effective Dose Equivalent
  - Component Degradation
  - Dose Reduction Actions

QuickTime™ and a decompressor are needed to see this picture.

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What is CZT?

Cadmium Zinc Telluride (CZT) Gamma Spectroscopy

- **New Gamma Spectroscopy Technology**
  - Identifies Isotopes in Energies between 100 keV to 1800 keV
  - Isotopes ID for NPP:
    - **Co-58, Co-60, Ag-110m, Cs-137, Sb-124 &122, Cr-51, Fe-59, Mn-54, Zn-65**
- **Small and Lightweight**
- **Portable**
- **Cost Effective**
- **No Cooling Required**
- **Refueling Outages**
  - 2 day Measurement
  - 2 day Analysis

Operating Characteristics

- **No Cooling Required**
  - Therefore no risk of having the detector compromised because of a lack of adequate cooling
  - The resolution is sufficient for determination of key power plant radioisotopes,
    - **cobalts and cesiums, as well as Fe-59, Zn-65 and radioiodines**
- **For power plant operations, the ability to have a hand held, easily positioned detector is a premium**
  - spaces are tight, or
  - positioning is difficult due to pipe placement, shielding, or
  - other equipment is challenging the operator's ability to perform quality measurements.

CZT Device and Analysis
Energy Fluence vs. Deposited Activity

- **CZT Output:**
  - Gamma Energy Emission
  - Isotopic Identification
- **Needs**
  - Pipewall thickness and diameter
  - Insulation material, if any
  - Station ion chamber results
- **Energy Fluence Rate**
  - MeV/photon
  - Worker Energy Field
- **Results from MicroShield output,**
  - Deposited activity in mCi/cm2
  - Dose contributions from each radioisotope
- **Energy Fluence Rate ≠ Deposited Activity**
  - Co-58 Attenuation ~ 20% to 25% by Pipewall

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Benefits: Strength Added to RP and Chemistry Programs

- **Source Term Reduction**
  - Tracking Performance RFO to RFO
  - Sister Plant Comparison
  - Including 58 EdF Units
- **Dosimetry**
  - Electronic Dosimetry
- **ALARA**
  - Shielding
  - Areas Identified for Dose Reduction
- **Instrument Calibration**
- **Component Aging**
  - Isotope Signature

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Canberra CZT Gamma Spectroscopy Field Trials

- **Origins at CEA and EdF in France**
  - All EdF sites Have CZT Instrument, 58 units
- **Needed to Trend and Track Source Term Reduction**
- **NPE/Bartlett Nuclear - Field Trials and Measurements**
  - **2005 Turkey Point-3R18- Was First**
  - 2010/2011/2012
    - **DC Cook U1C23**
    - **Braidwood A1R15**
    - **Beaver Valley 1R20**
    - **Surry-1**
    - **Nine Mile Point-1**
    - **DC Cook U2C19**
    - **Braidwood A2R15**
    - **Beaver Valley-2R15**
    - **VC Summer R19**
    - **Turkey Point 4R26**
    - **Kewaunee**
    - **North Anna**
    - **Turkey Pt 3R27**
- **Utility Initiated Field Trials**
  - **Byron-1R17** - **Dresden** - **Peach Bottom**
  - **Quad-Cities** - **DC Cook 2C20** - **Duke (McGuire/Catawba?)**

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How CZT Field Results Are Used to Benchmark Performance

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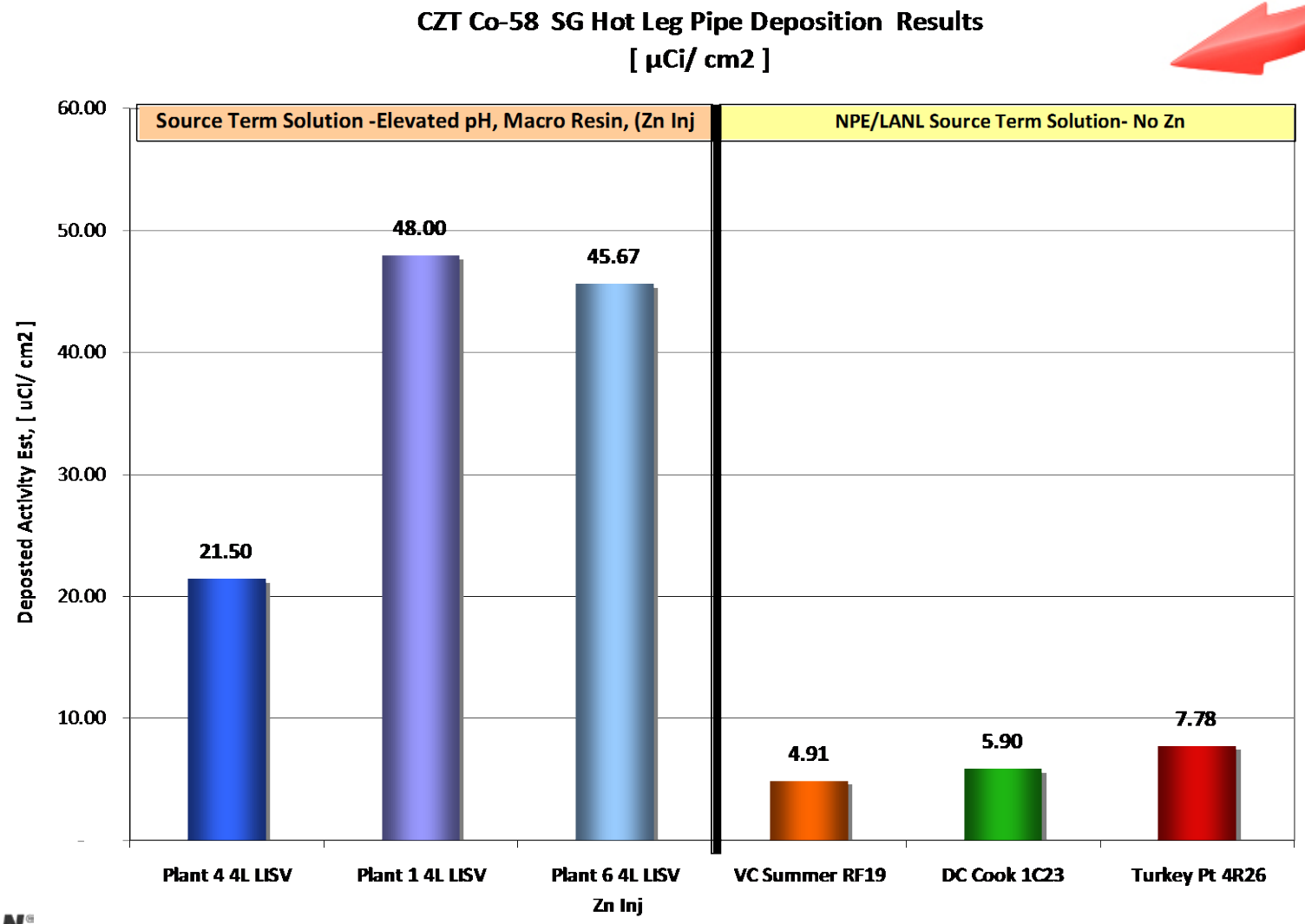
CZT Results - Benchmarks

Co-58 SG Hot Leg Piping Deposited Activity



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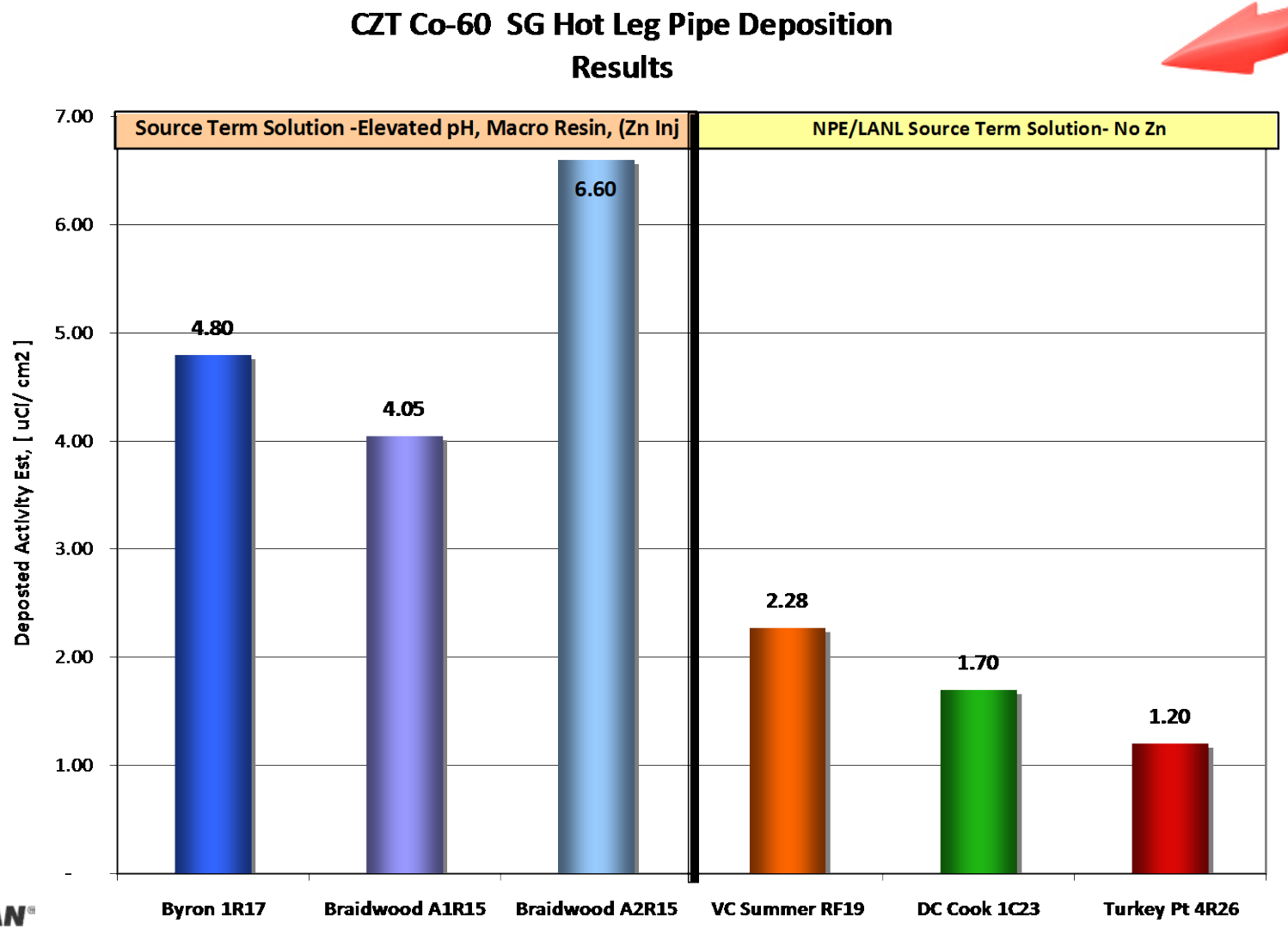
CZT Results - Benchmarks

Co-60 SG Hot Leg Piping Deposited Activity



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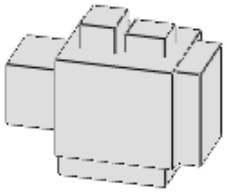
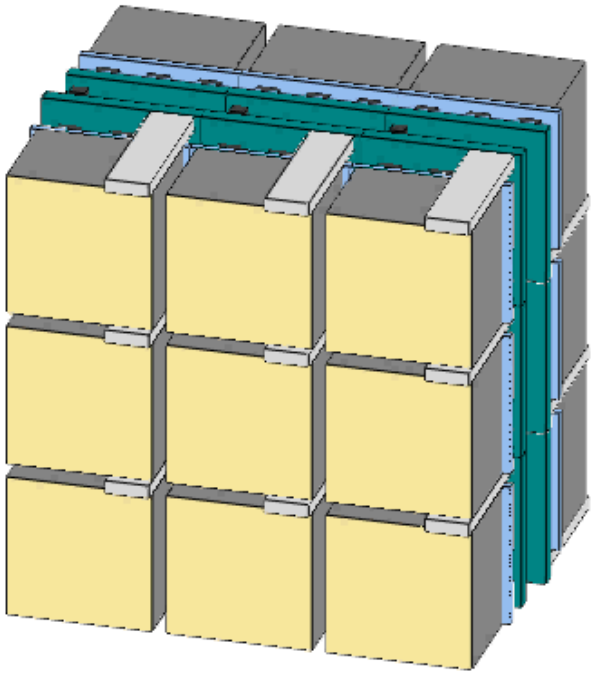
Data Sharing Through ISOE North Amercian Technical Center

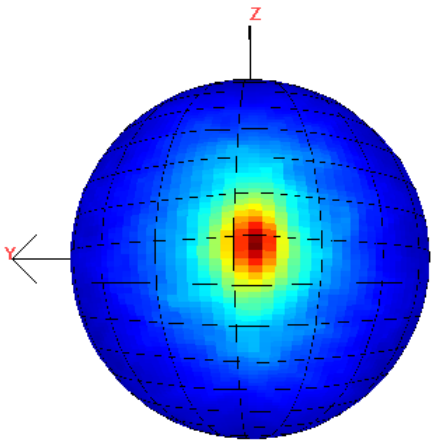
- **Standardized EDF Protocol**
  - Being Implemented in US NPP
  - AEP and Exelon Taking US Leadership.
    - **Exelon committed to the process over the next 4 years as an assessment tool for determination of source term reduction success. Others above following suit.**

- **IAEA/ISOE Data Base**
  - Director, Dr. David Miller
  - NATC MOU for Data Upload - EdF and US NPP
  - Permits Comparison of Plant Performance
    - **Different Source Term reduction strategies and their impacts are measured promptly!**

New Development on Polaris 3D Gamma-Ray Imaging Spectrometer







Number of photons: 2033

Performance Goals:
ΔE/E ≤ 1% FWHM
(at 662 keV)
Real-time γ Imaging
+ isotope I.D.

Eighteen 2×2×1.5 cm^3 CdZnTe detectors
(108 cm^3, 648 grams = 1.43 lb)

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Polaris # I

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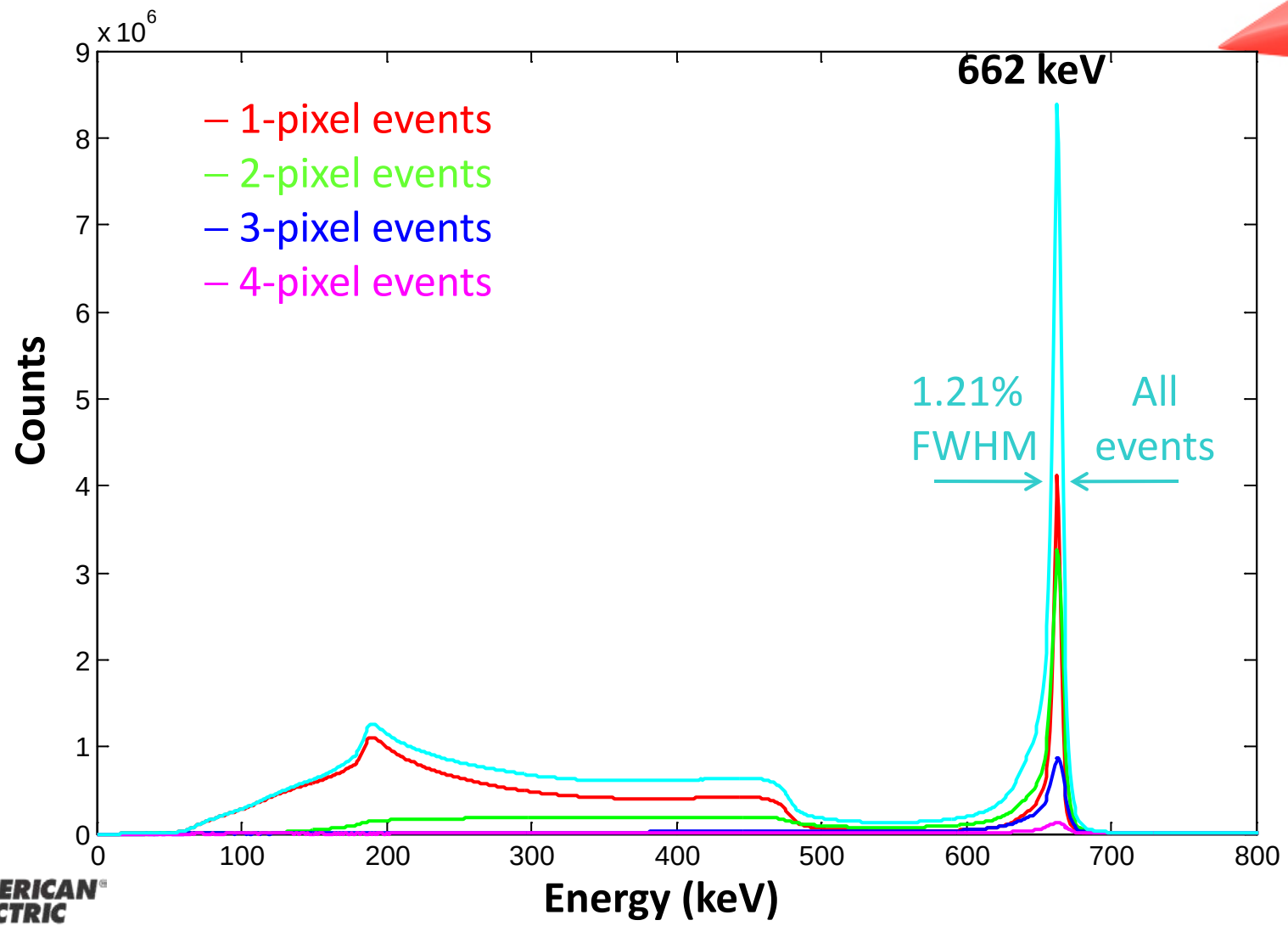
^{137}Cs Energy Spectra of the 2nd Polaris system

(From all 18 detectors of Polaris, 24°C, uncollimated ^{137}Cs)



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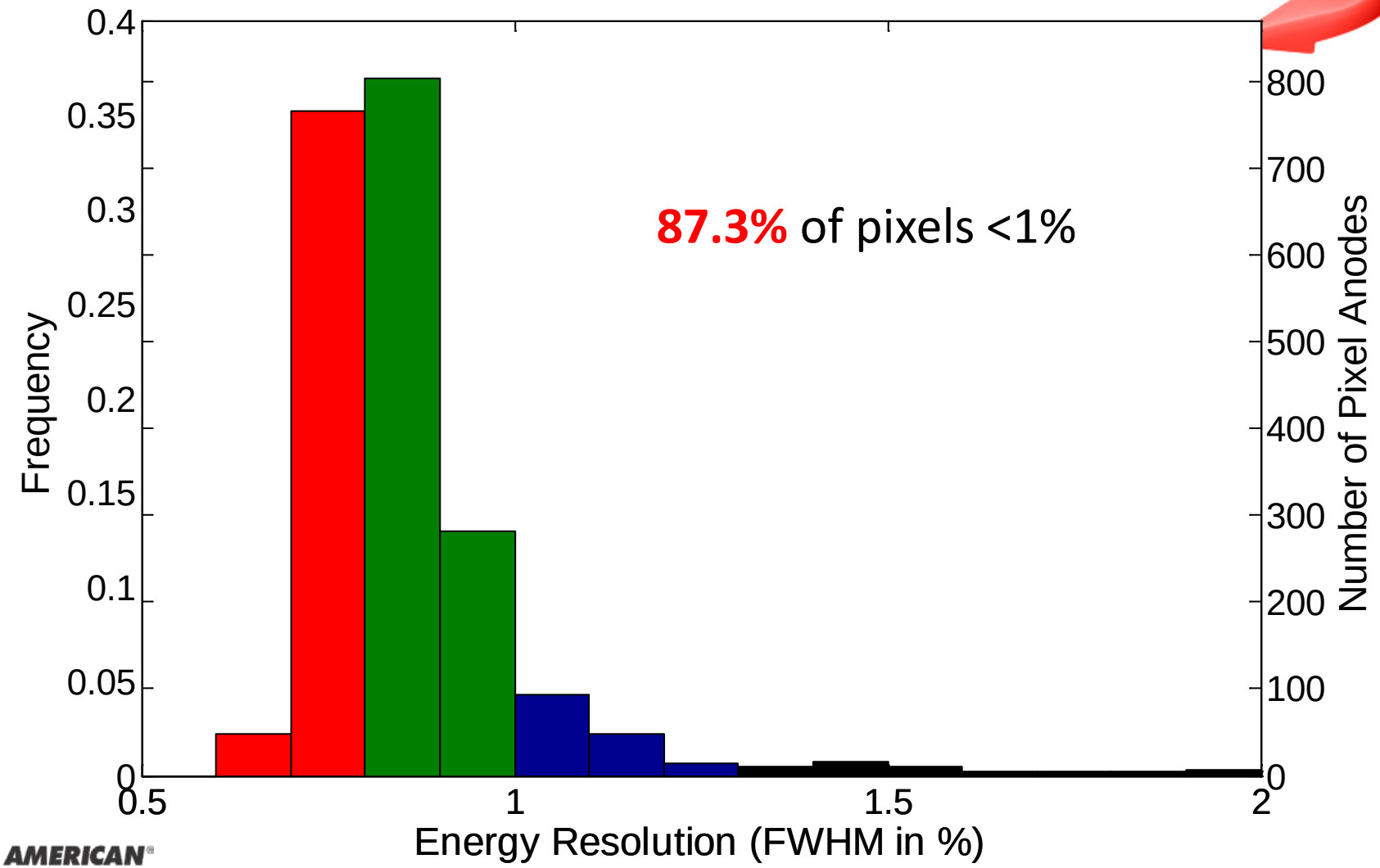
Distribution of Single-Pixel Energy Res. of Polaris #2

(Each Polaris has 2178 pixel anodes, 24°C, uncollimated ^{137}Cs source)



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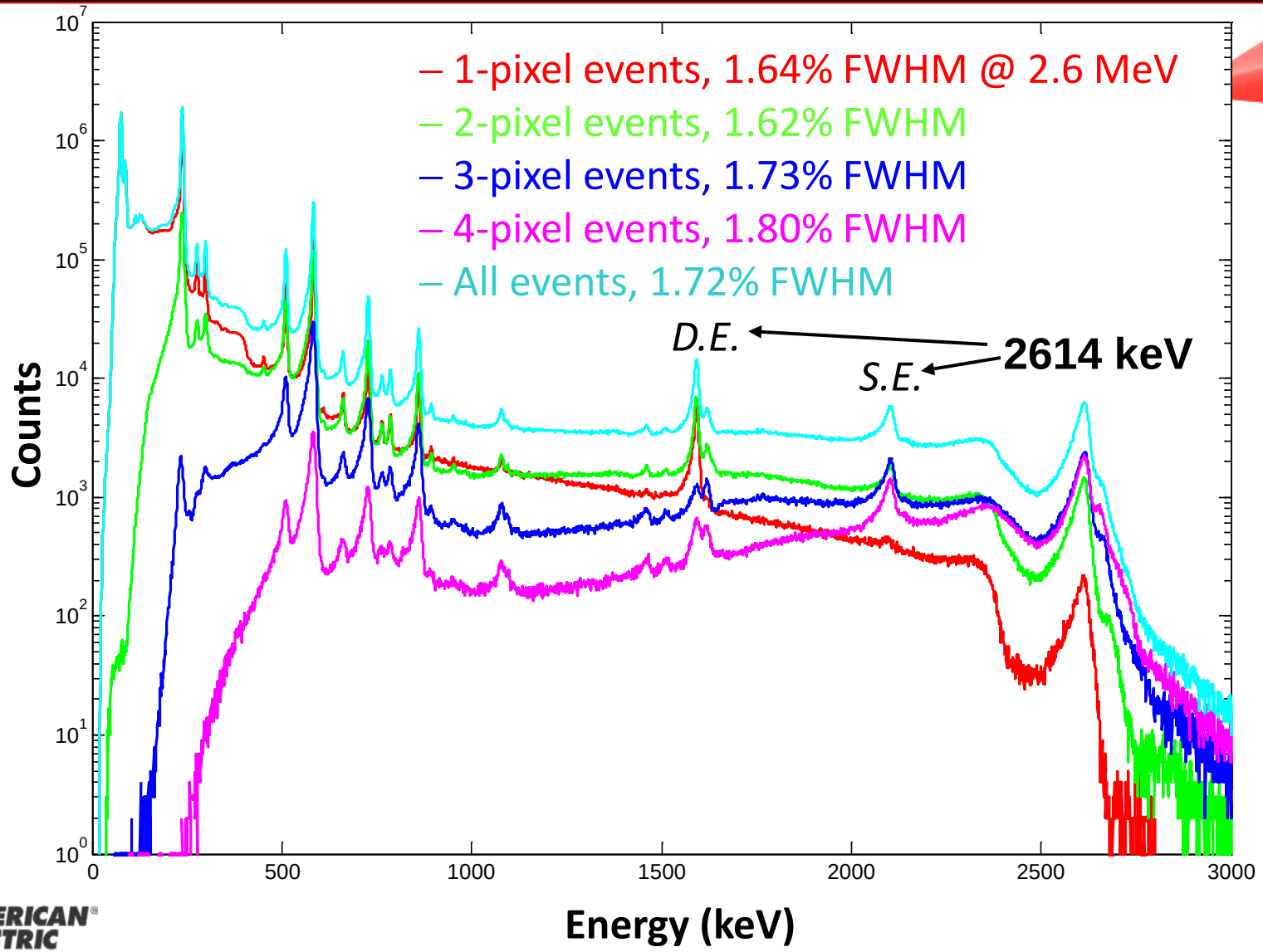
^{228}Th Energy Spectra Polaris-2



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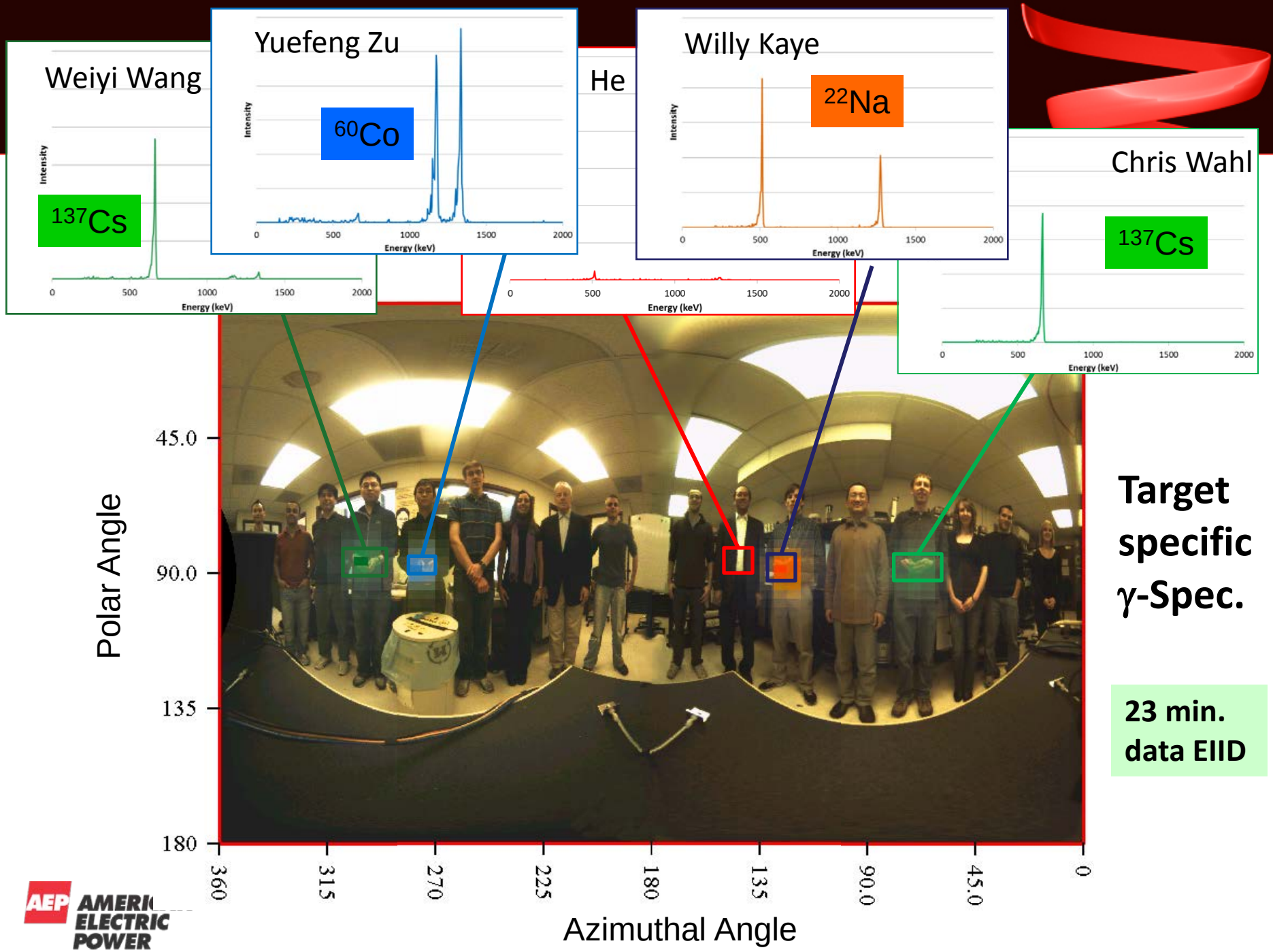

Target specific γ-Spec.

23 min. data EIID

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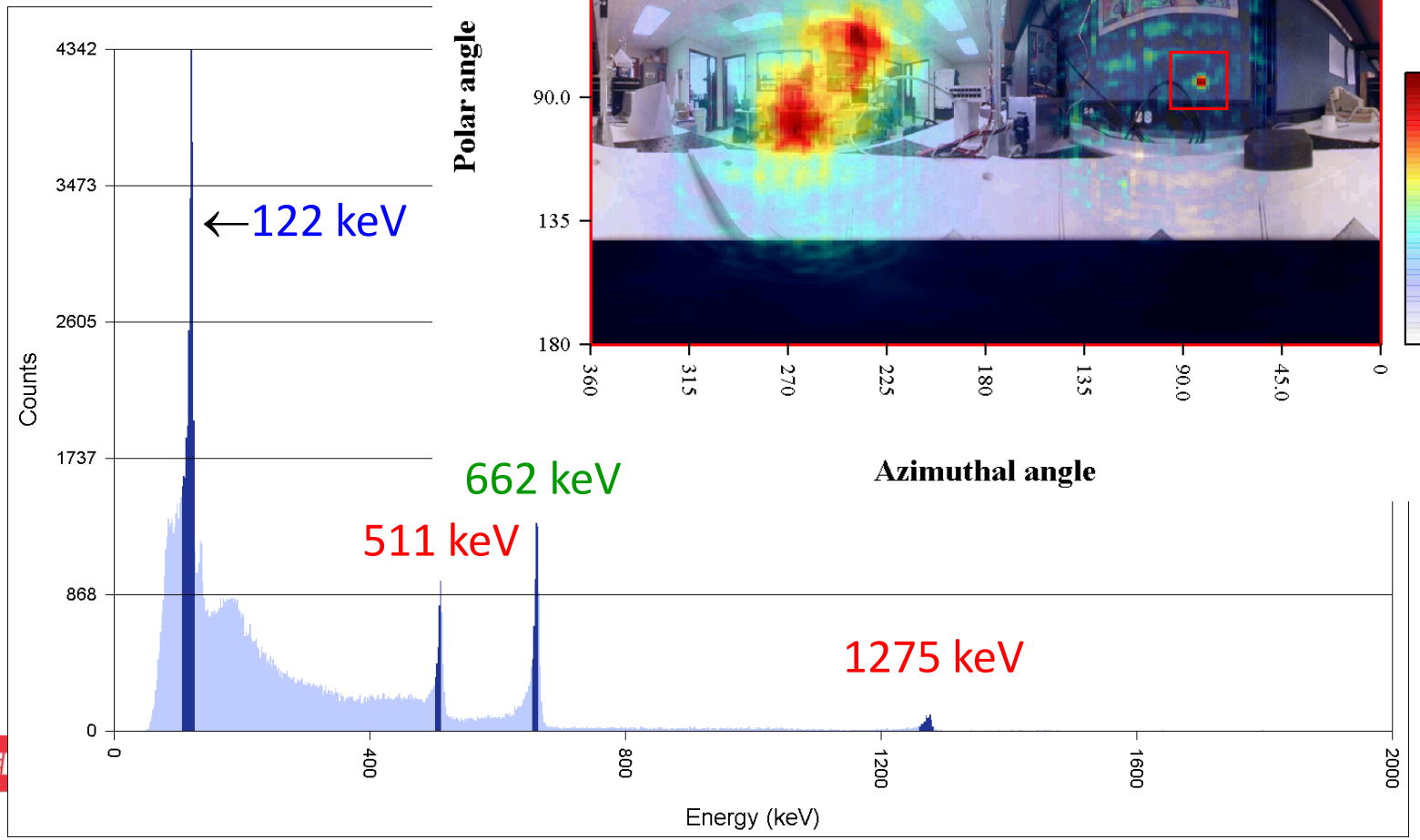
Real-Time Combined Coded Aperture and Compton Imaging for Locating Sources

From all 18 detectors

Isotope selected:

^{57}Co, ^{22}Na, ^{137}Cs



Expected improvements/challenges

(1) Further improve energy resolution from current ~1.3% FWHM at 662 keV for all events $\rightarrow \leq 1\%$

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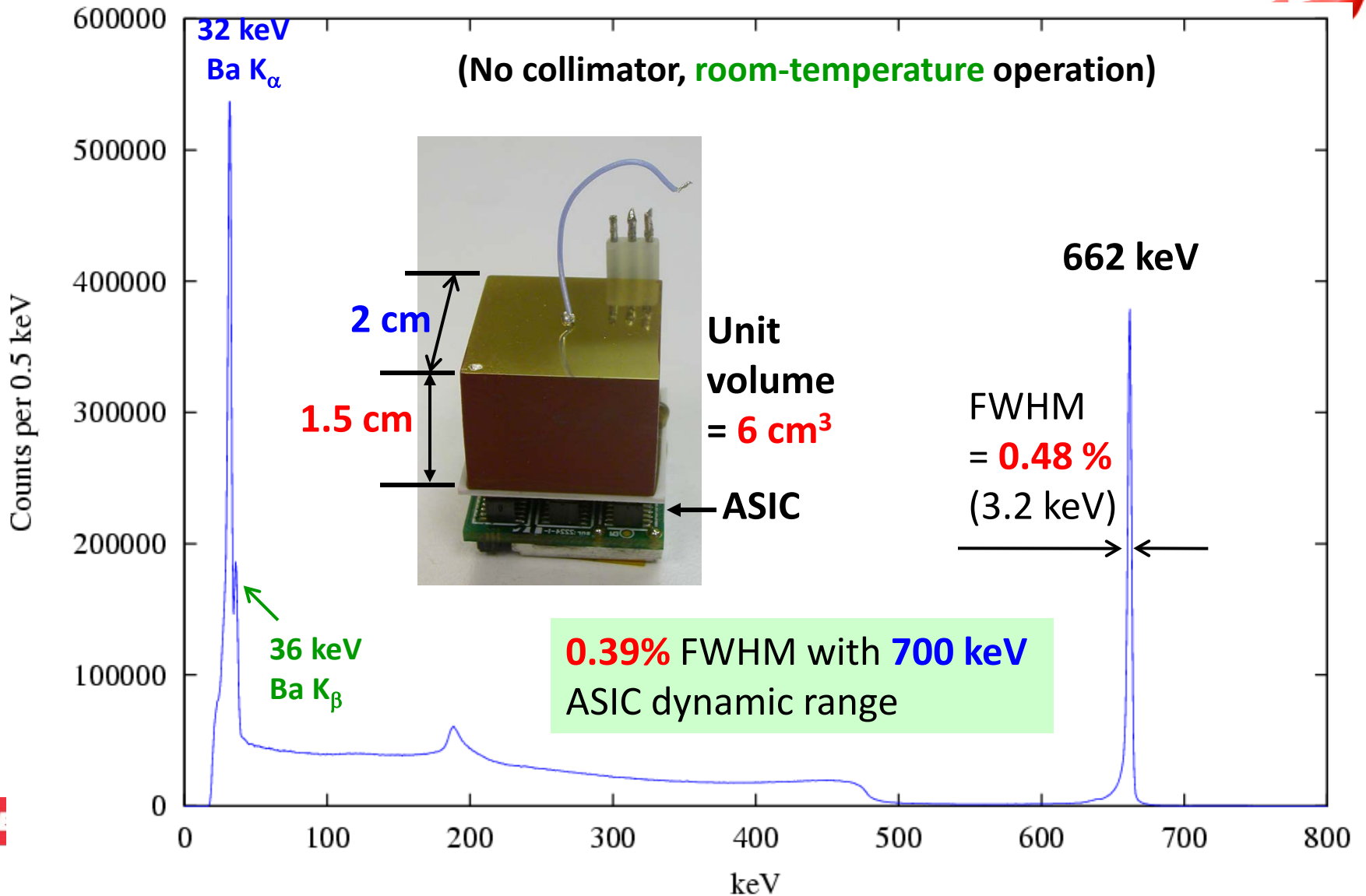
Single-Pixel ^{137}Cs Spectrum of CdZnTe #4E-1 (121 Pixels)

Seven best Redlen, Inc. detectors: **Single**-pixel $\Delta E/E \leq$ **0.6%**



Conclusions

- Conclusions:

(1) High resolution (<1% FWHM for single pixel events, ~1.3% FWHM for all events) and high relative efficiency (>30%) 3-D CdZnTe γ-ray imaging systems have been developed and operated by independent operators ~2 months in Nevada & ~2 months in Oak Ridge National Laboratory.

(2) The Polaris project funded by DTRA has enabled Redlen to produce $2\times2\times1.5$ cm^3 CZT detectors commercially.

(3) Further performance improvements, such as $\rightarrow$ 0.5% FWHM energy resolution, are achievable.

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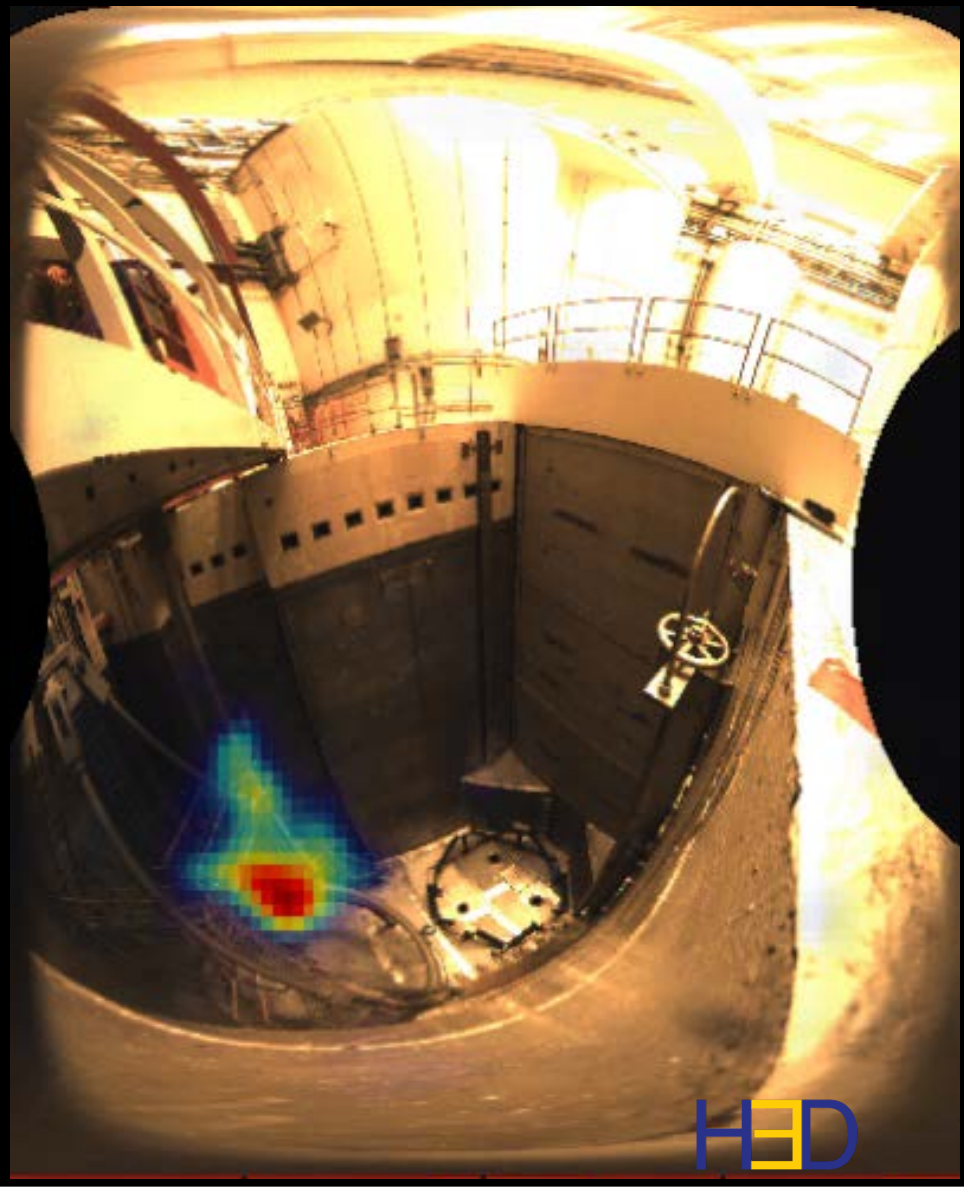
Initial Measurement of Reactor Cavity

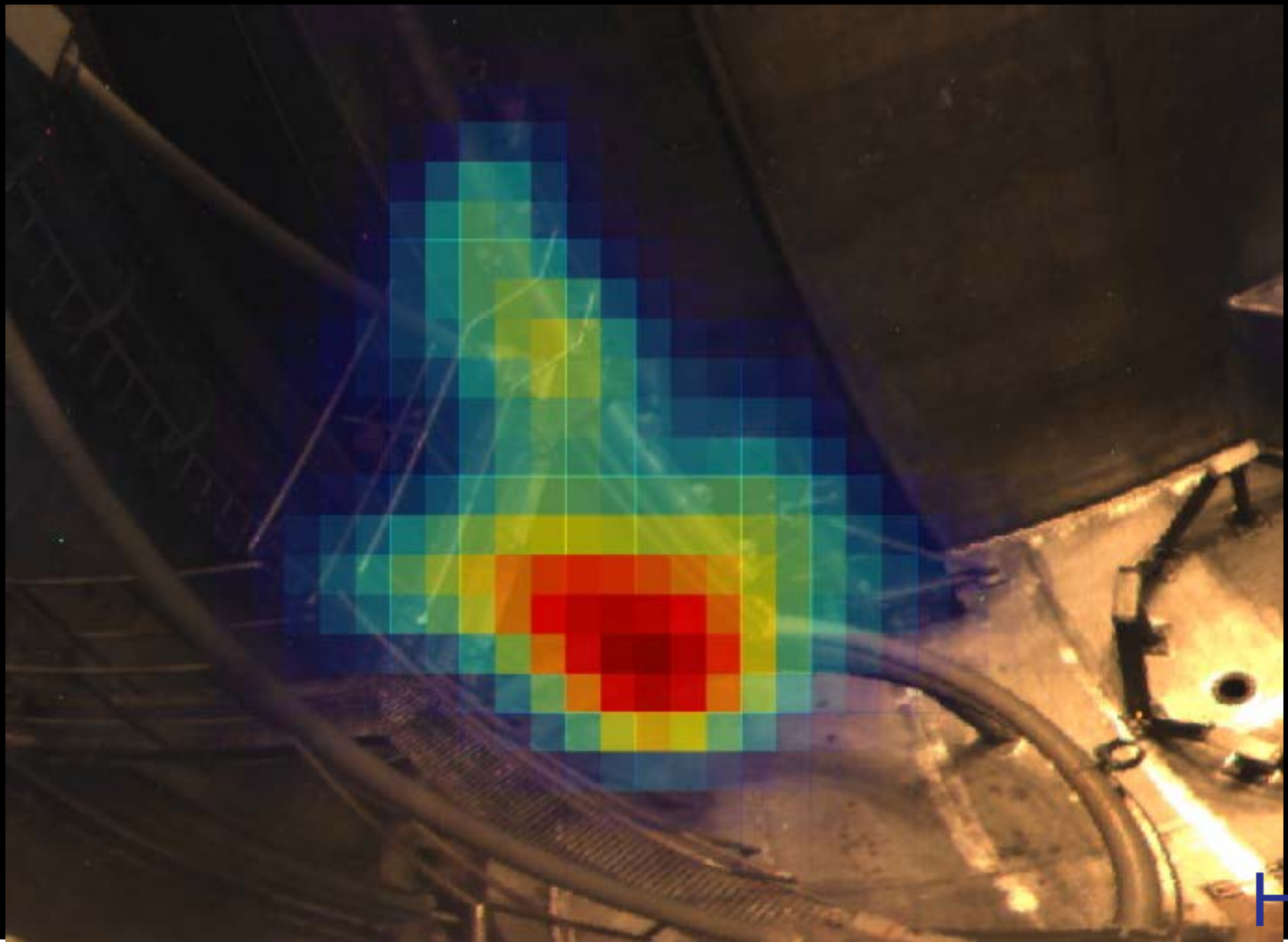
Optical Image

Gamma-Ray Image

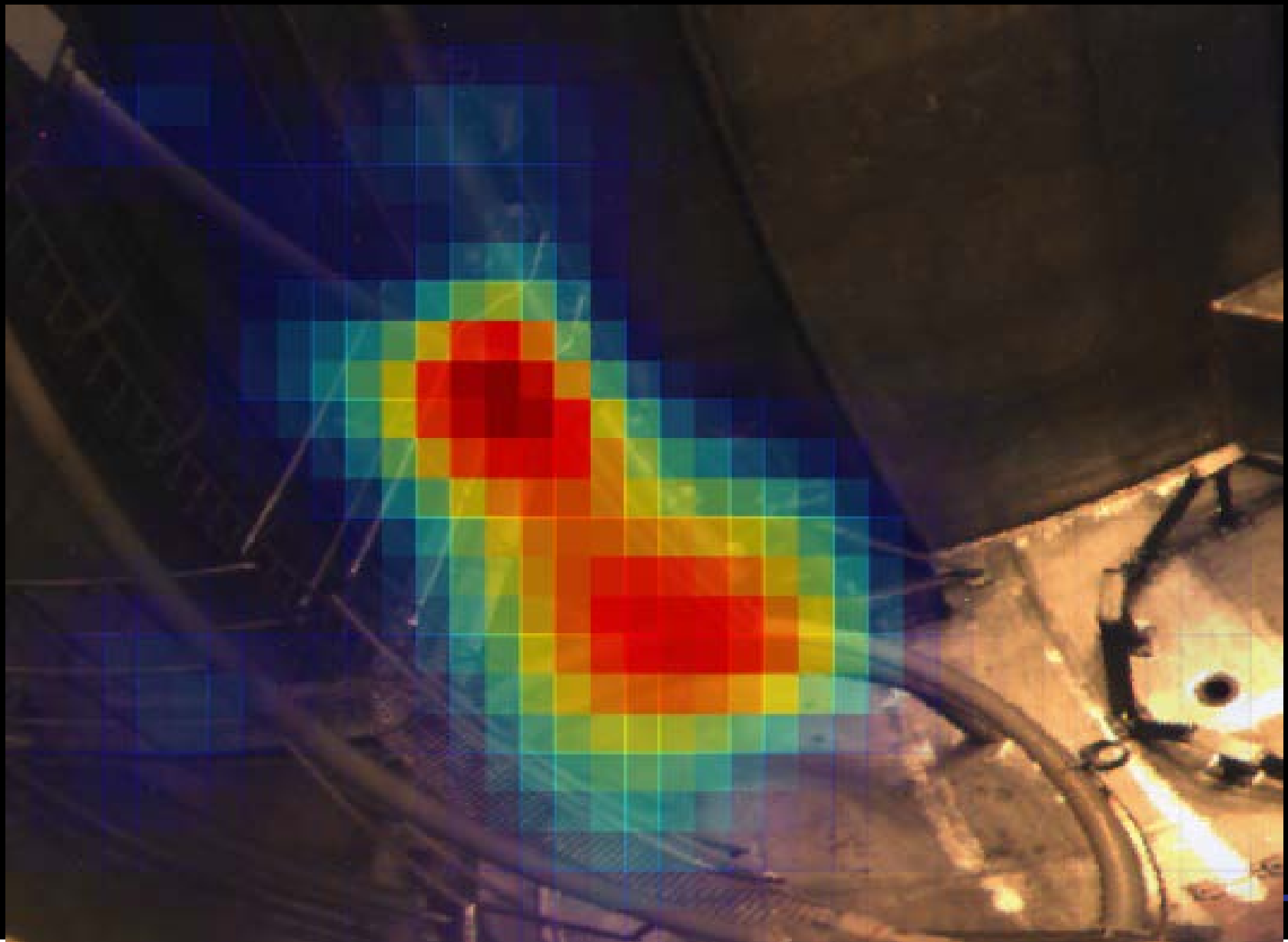


Zoom-View: Optical Image

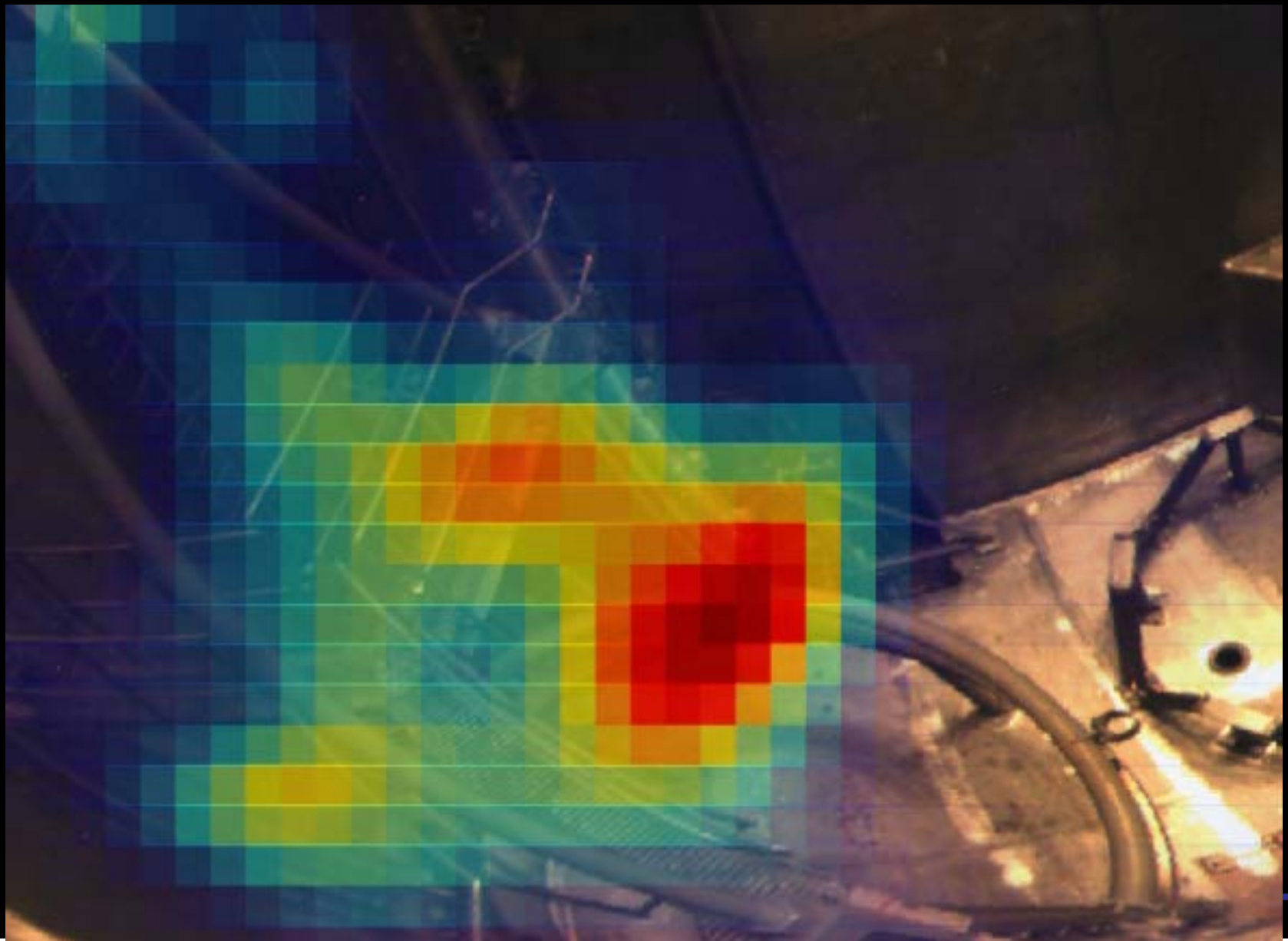
Co-60 (1333 keV) Image Overlay



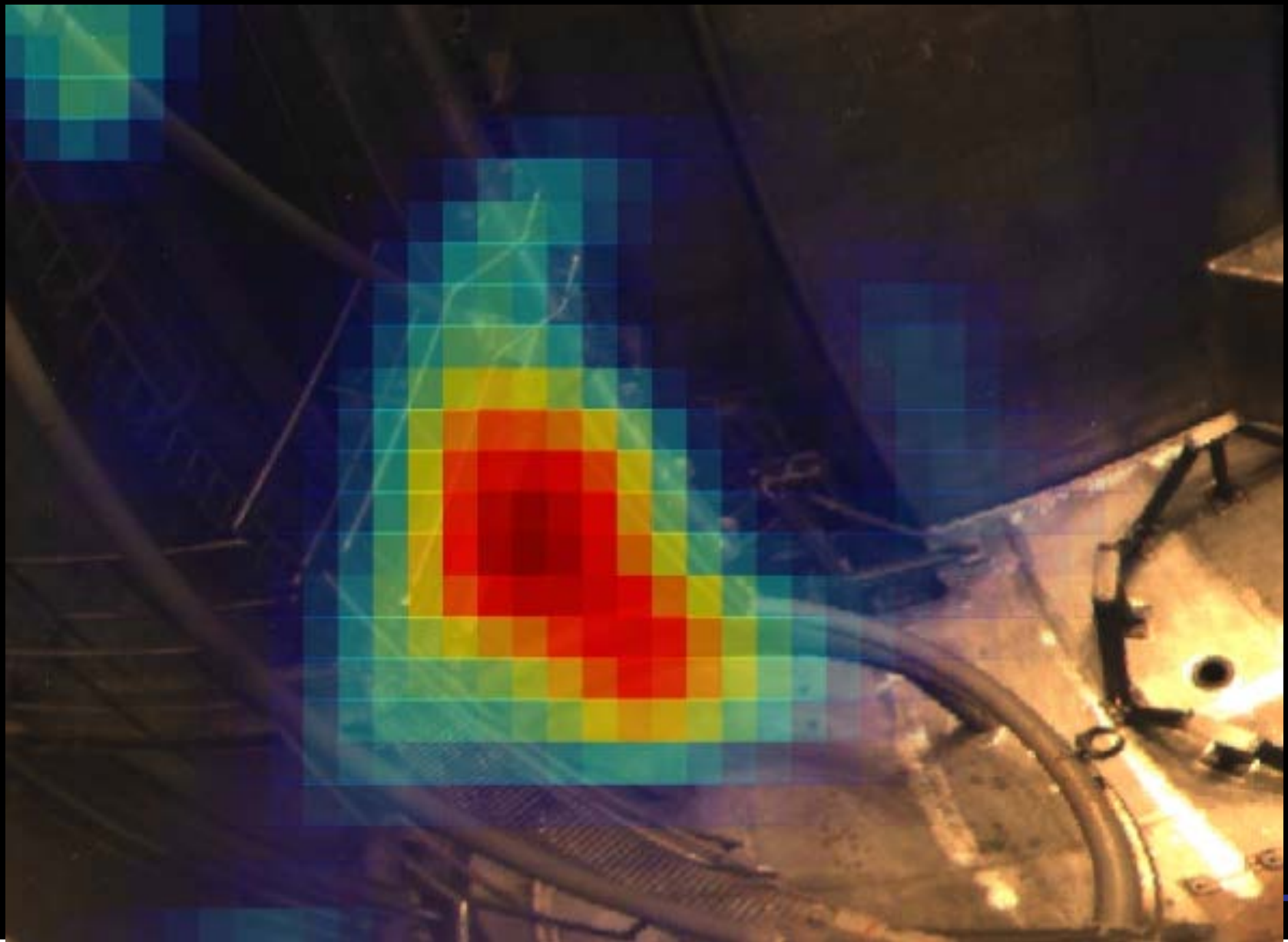
Nb-95? (766 keV) Image Overlay



Co-58 (811 keV) Image Overlay

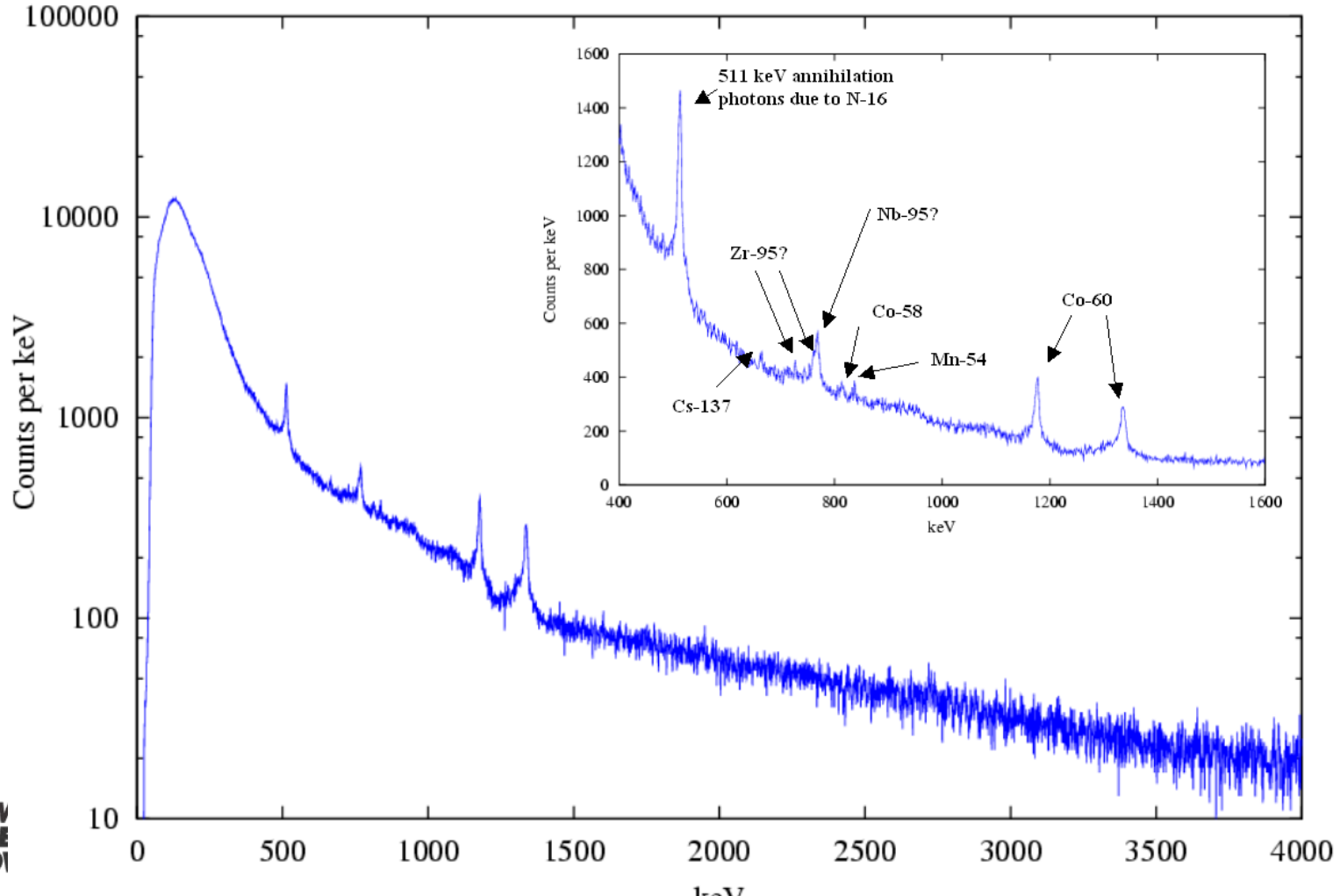


Mn-54 (834 keV) Image Overlay



H3D Detector: Second Cavity Measurement

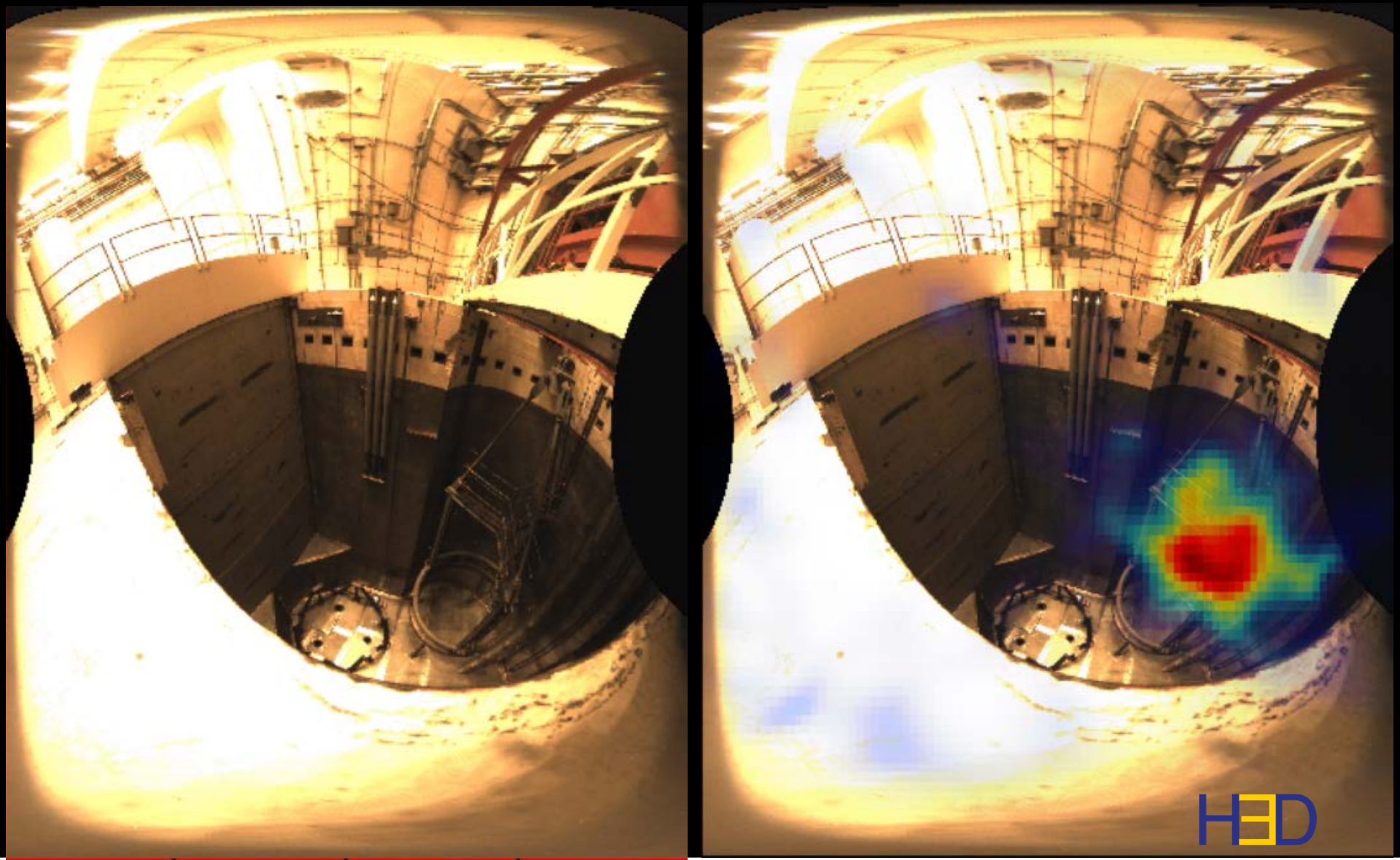
- Energy spectrum after a 35 minute measurement on the opposite edge of the cavity
- At the new angle the intensity of all isotopes has decreased relative to N-16



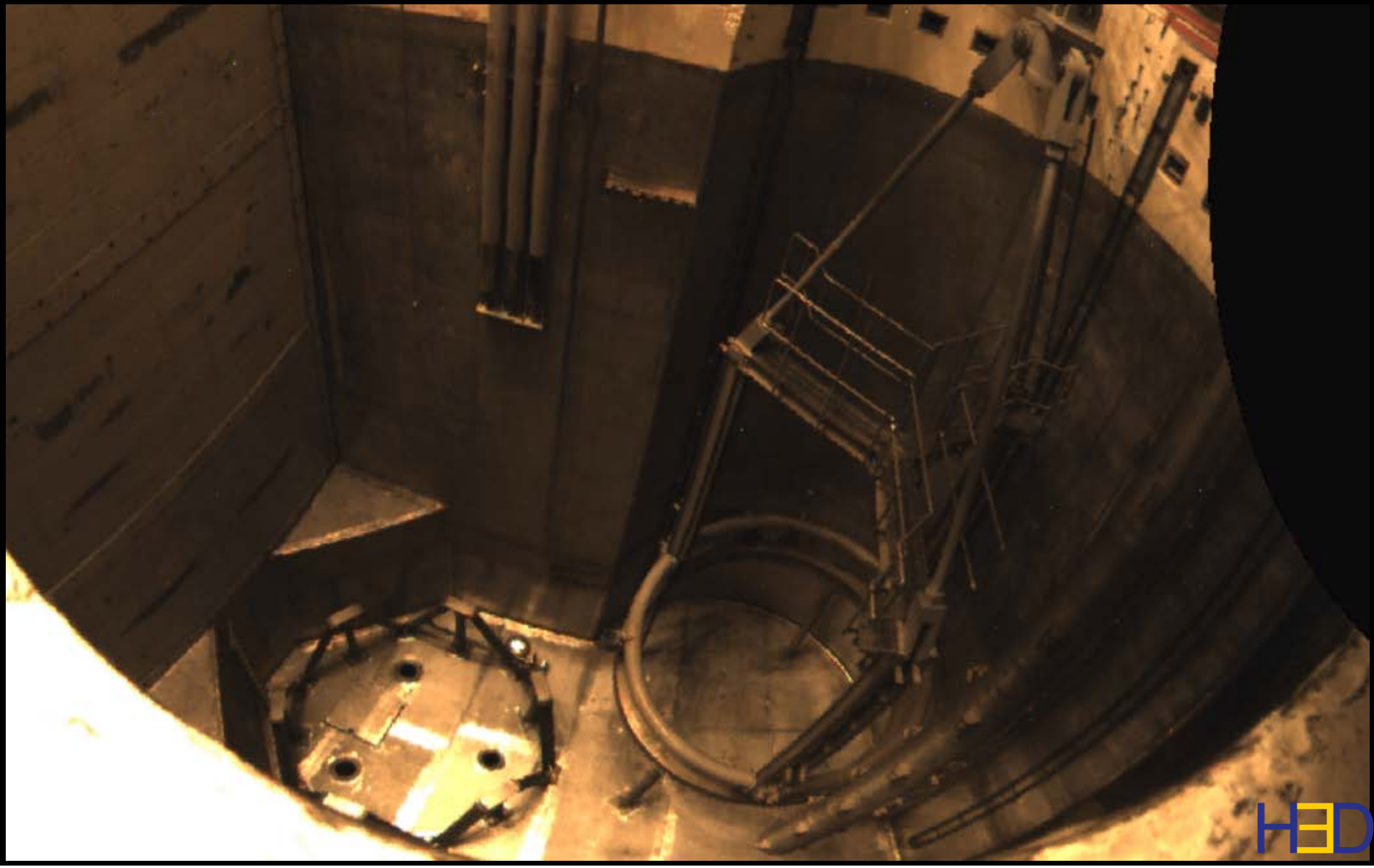
Second Exposure of Reactor Cavity

Optical Image

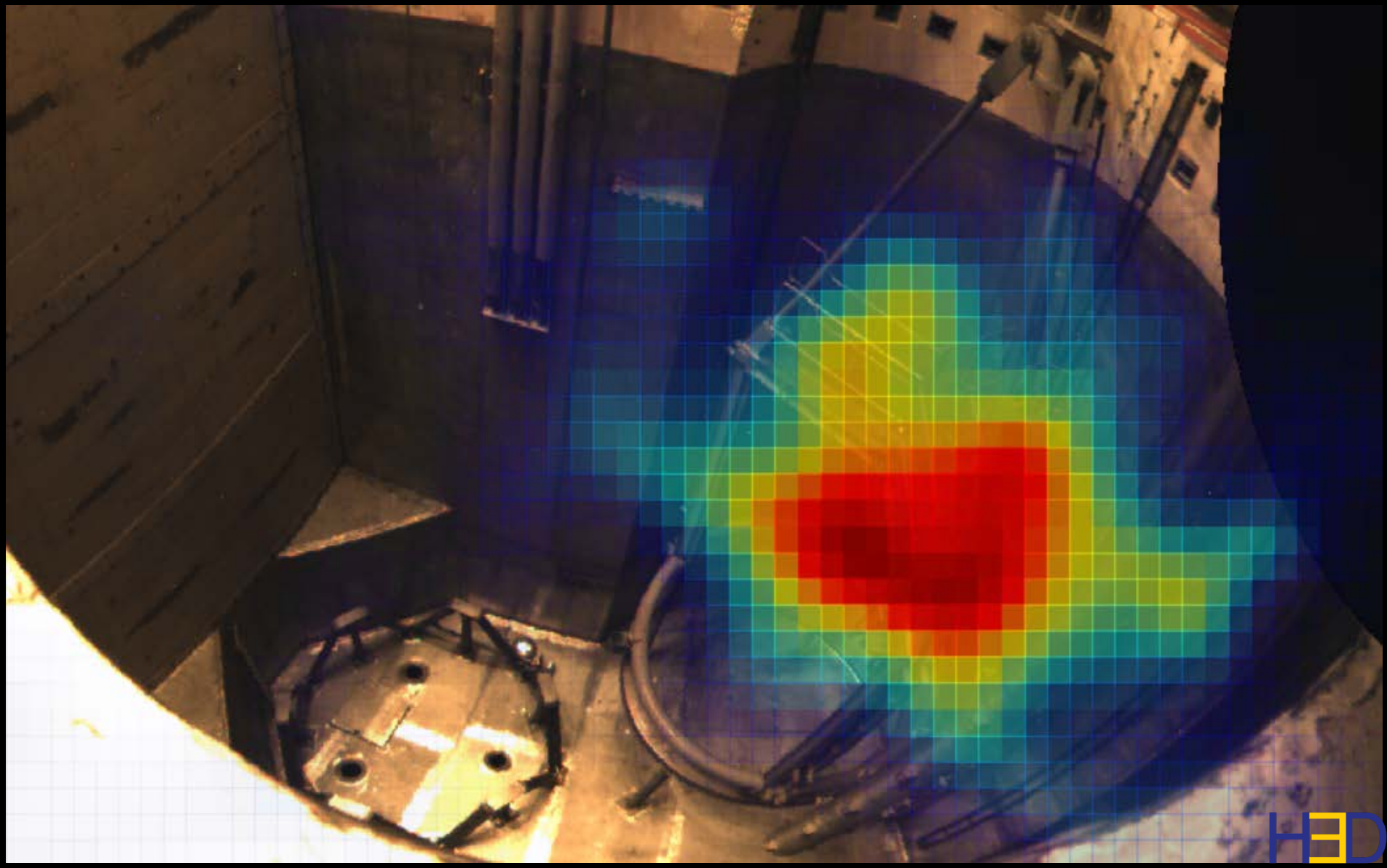
Gamma-Ray Image



Zoom-View: Optical Image from New Angle



Co-60 (1333 keV) Image Overlay



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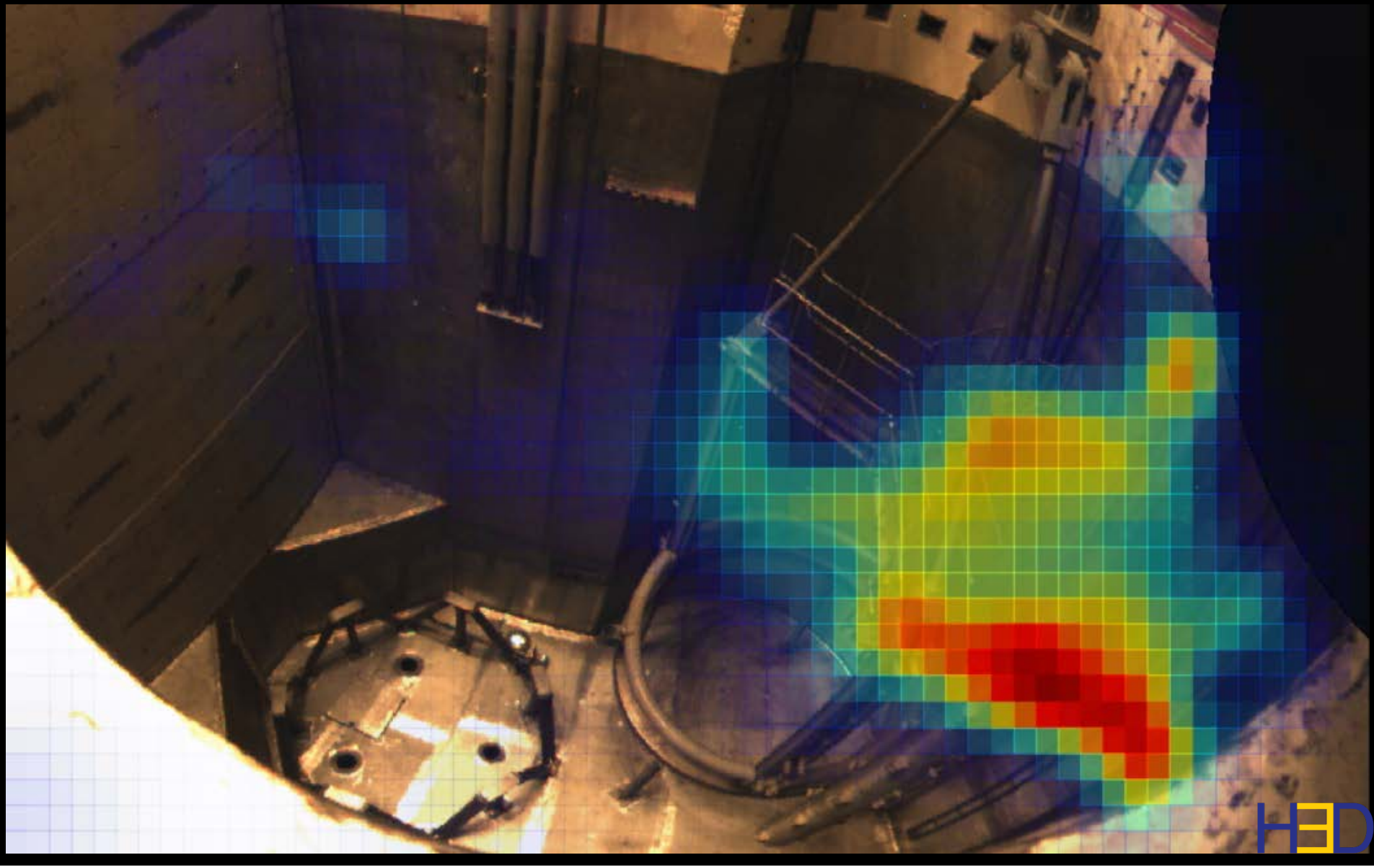
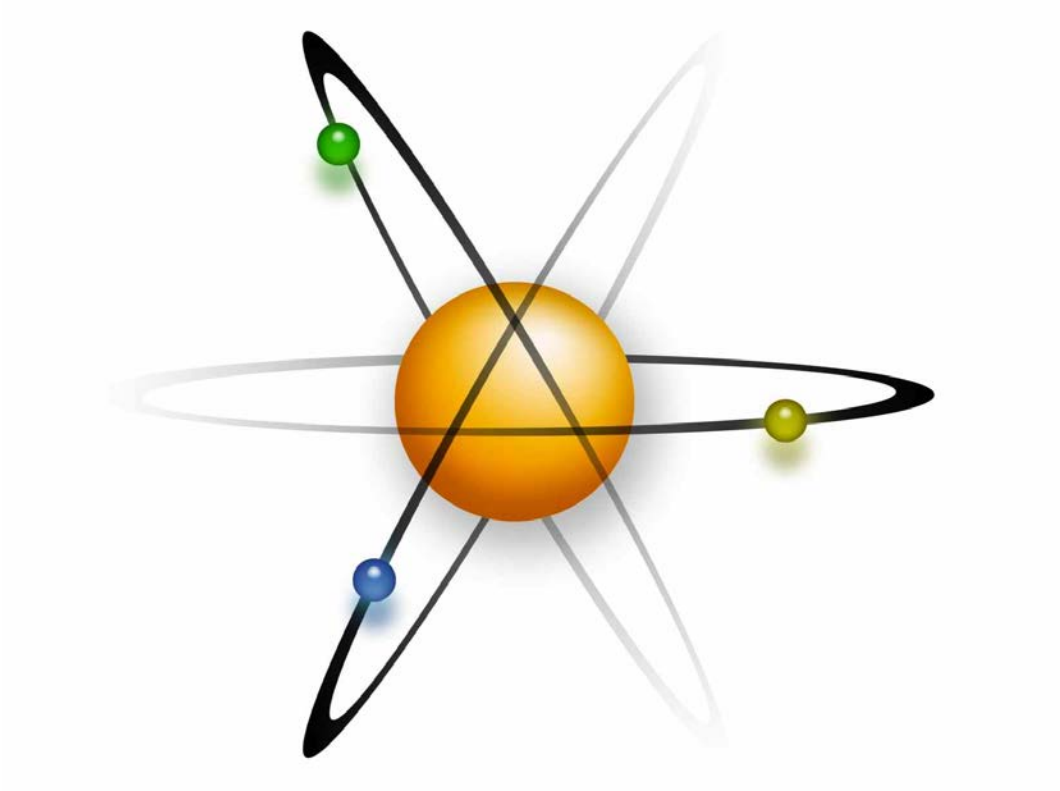


Questions?



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