DESIGNING A TEMPLATE INFORMATION BARRIER BASED ON LOW-RESOLUTION GAMMA SPECTROSCOPY

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Deutsche Physikalische Gesellschaft, Regensburg, 2016

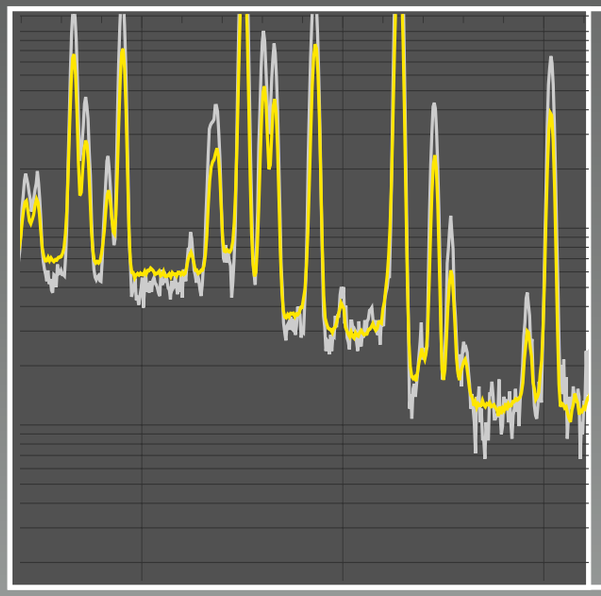
Revision 2

BACKGROUND

PASSIVE GAMMA SPECTROMETRY FOR WARHEAD VERIFICATION

Successfully demonstrated as a verification technology “to confirm the identities of treaty accountable items” — both with attribute and template approaches (e.g. TRIS and TRADS developed at Sandia)

However, gamma spectrometry (alone) is not suited to determine fissile material mass due to self shielding effects; strictly speaking, also not suited to confirm identity of any two items



THIS TALK …

Characterize the potential (capabilities and limits) of gamma spectrometry for verification applications (using the template-matching approach)

Use simulated spectra for a basic test item with simple “diversion” scenarios

Identify possible areas of future research

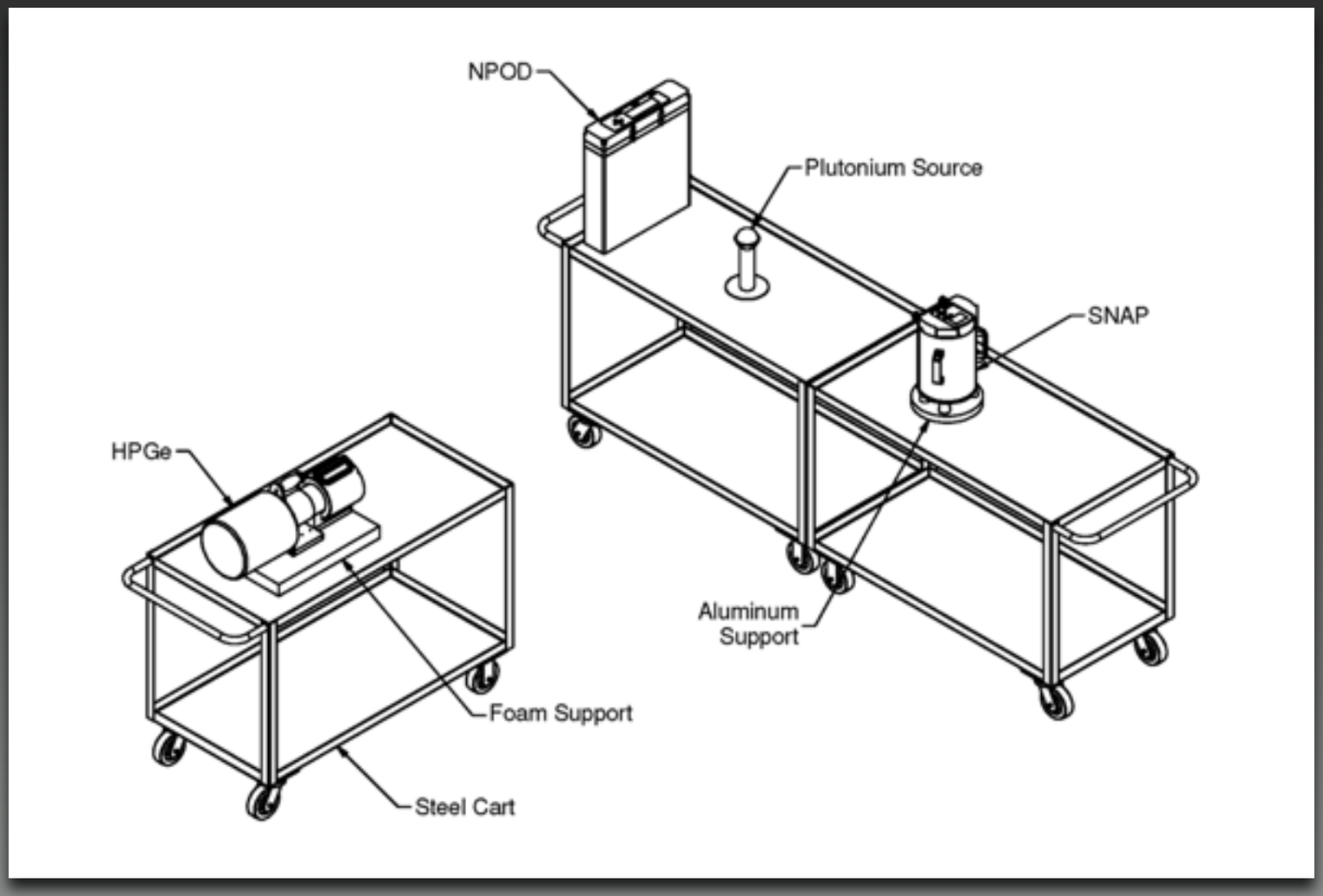
Source: U.S. Department of Energy (photo); K. Seager et al., “Trusted Radiation Identification System,” 42nd INMM Meeting, 2001 (quote)

COMPUTER MODEL

AND BENCHMARK WITH EXPERIMENTAL DATA

MODEL EXPERIMENTAL SETUP

OF PLUTONIUM SOURCE (BeRP BALL) AND HIGH-PURITY GERMANIUM DETECTOR

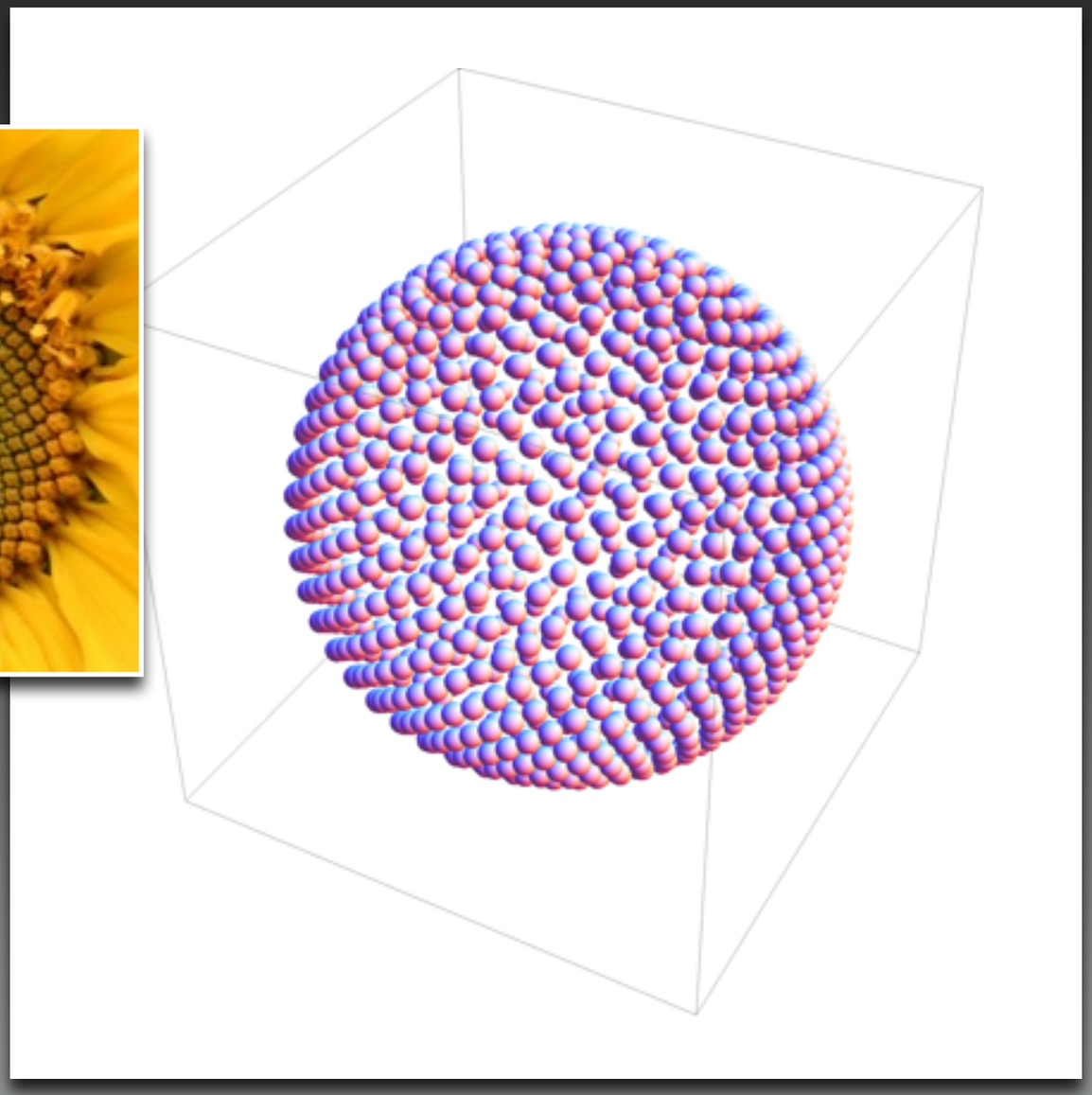


John Mattingly, *Polyethylene-Reflected Plutonium Metal Sphere: Subcritical Neutron and Gamma Measurements* SAND2009-5804 Revision 1 (Unclassified Unlimited Release), November 2009

See also J. Mattingly and D. J. Mitchell, *Applied Radiation and Isotopes,* 70 (2012), 1136–1140

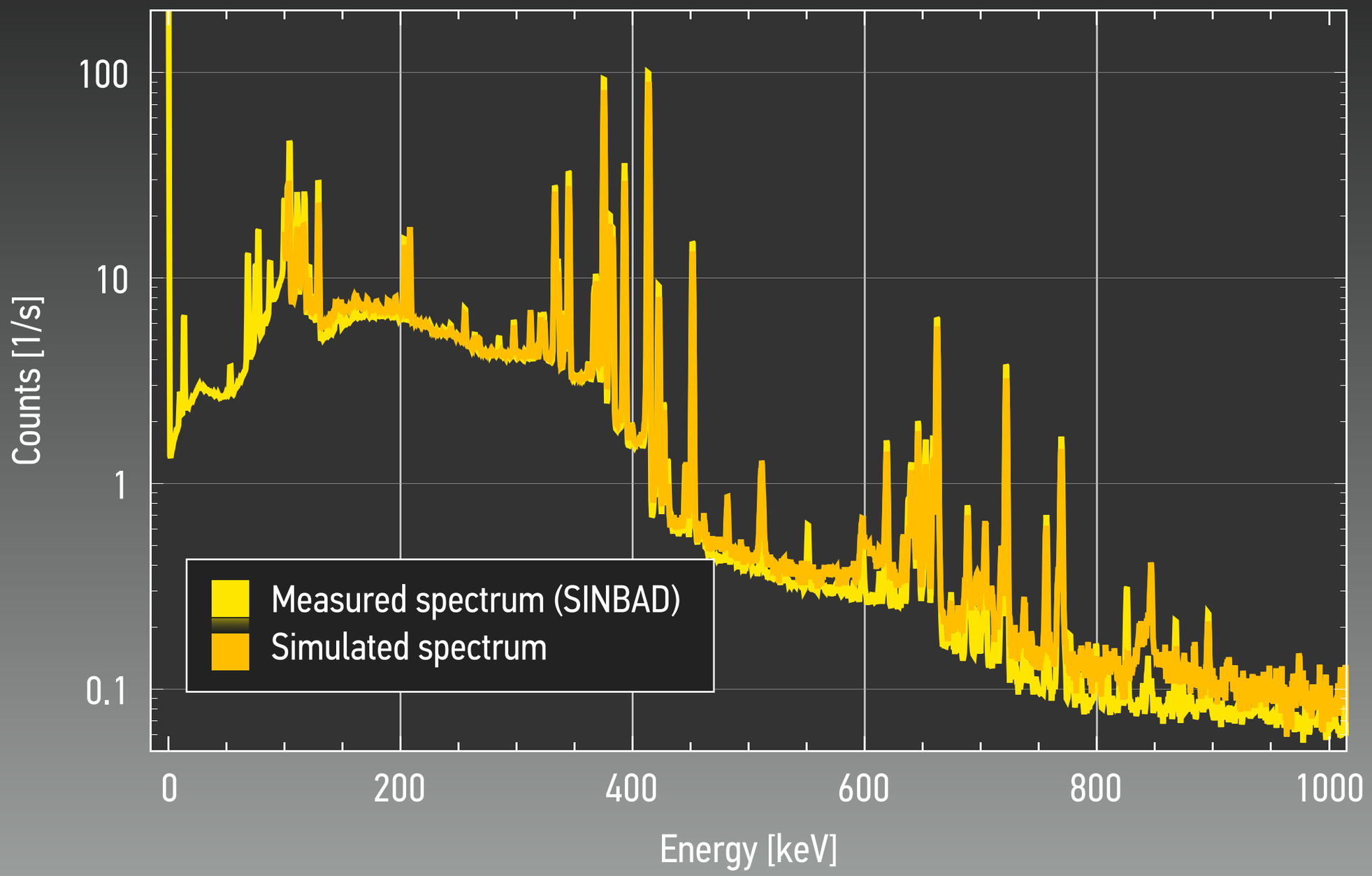
DISTRIBUTING N POINTS ON A SPHERE

(1000 IDENTICAL DETECTORS TO INCREASE EFFICIENCY OF MCNP CALCULATIONS)



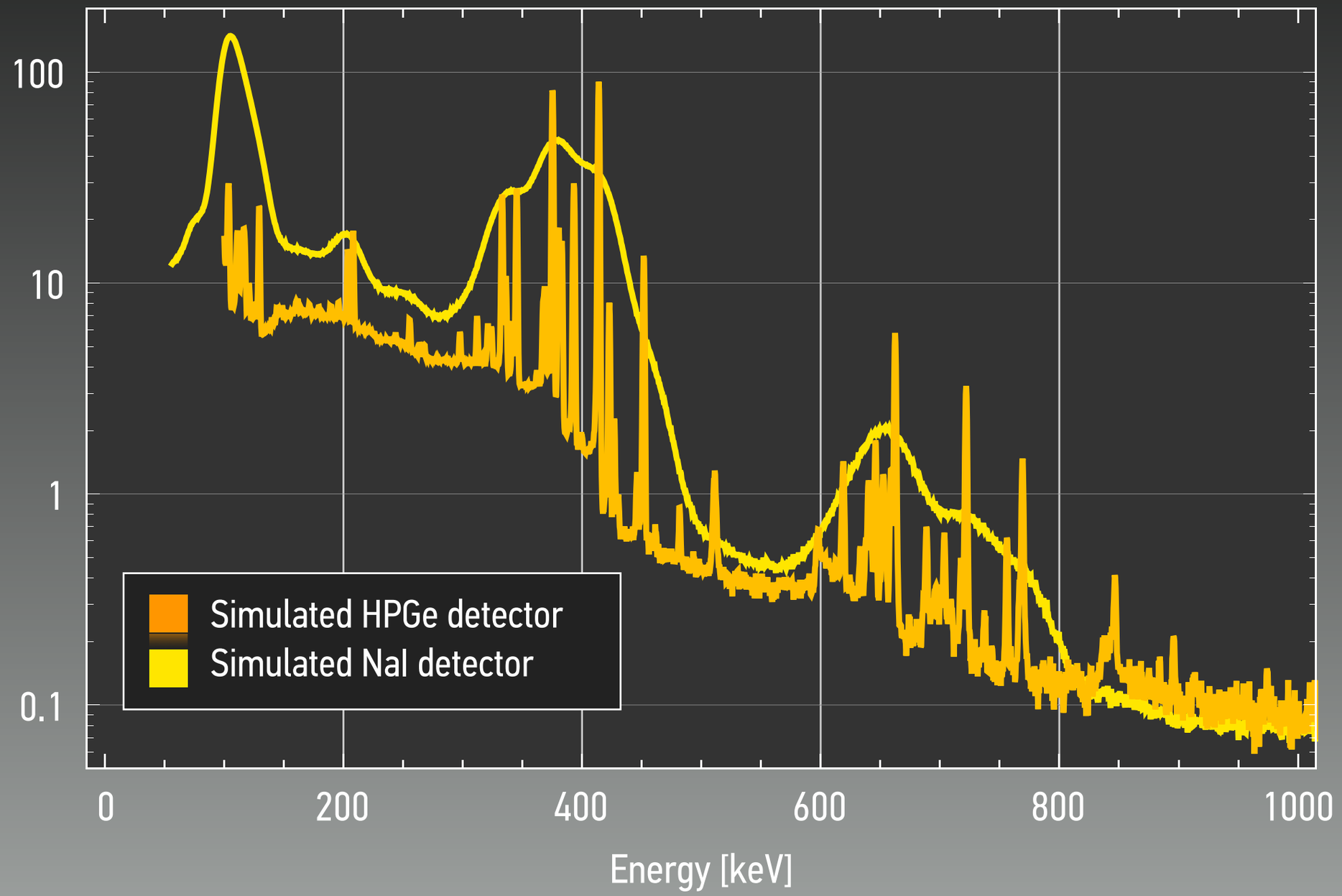
Helmut Vogel, “A Better Way to Construct the Sunflower Head,” *Mathematical Biosciences,* 44 (3–4), June 1979, pp. 179–189
See blog.marmakoide.org/?p=1 for Python implementations in 2D and 3D

MEASURED AND SIMULATED HIGH-RESOLUTION SPECTRA OF THE BeRP BAL



SIMULATED SPECTRA

BeRP BALL, NaI vs HPGe DETECTOR

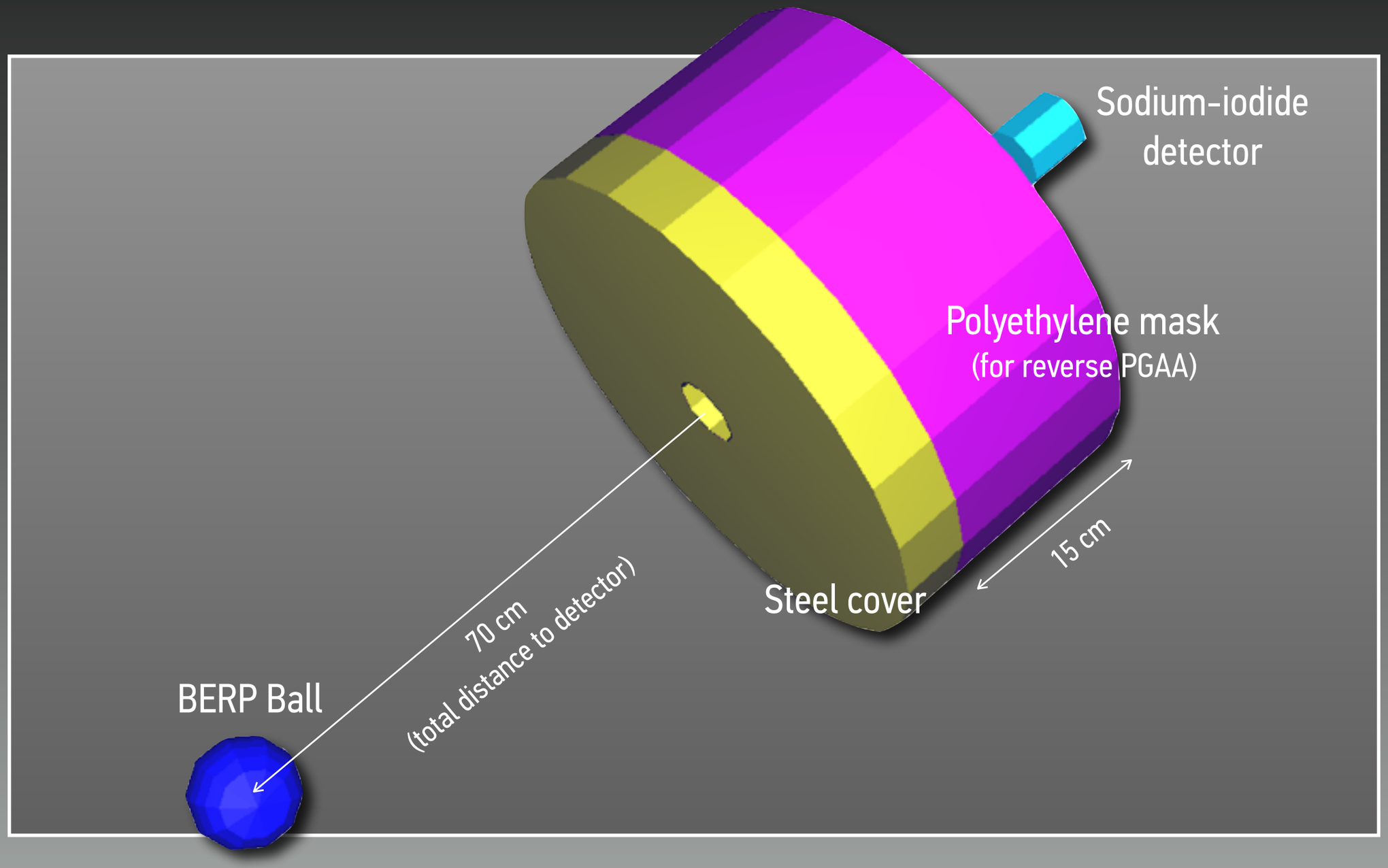


PROPOSED APPROACH

"MULTIMATCH TEMPLATE" WITH SODIUM-IODIDE DETECTOR

MODEL EXPERIMENTAL SETUP

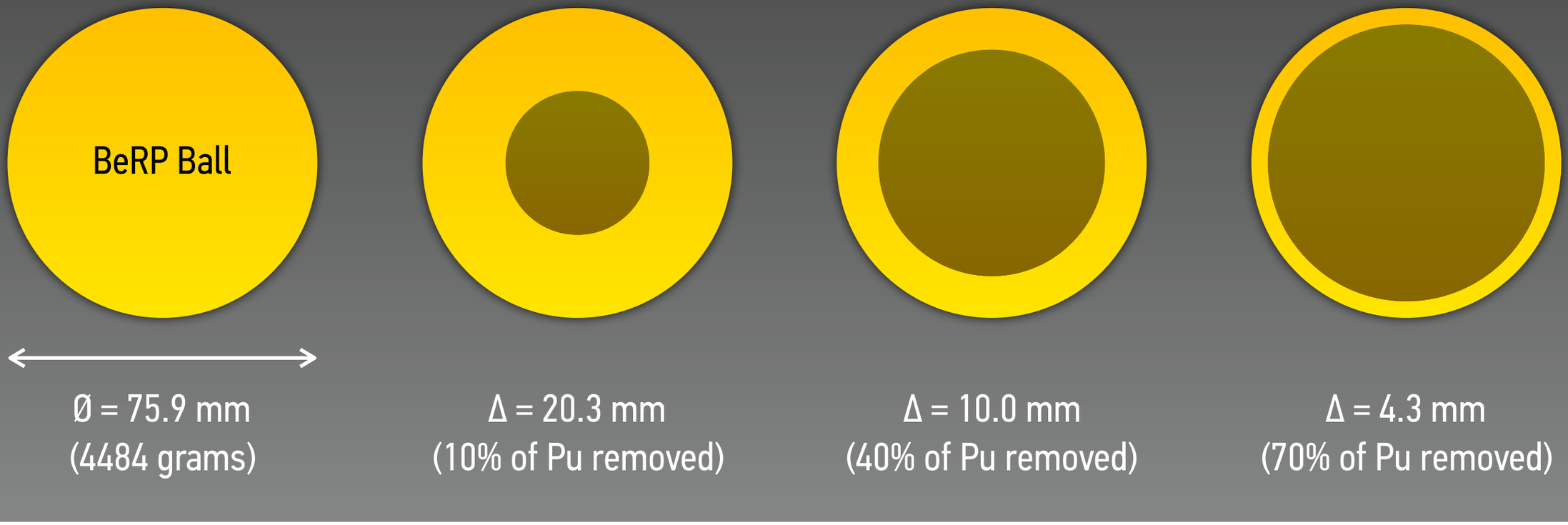
AS PROPOSED FOR MEASUREMENTS AT THE DEVICE ASSEMBLY FACILITY, JULY 2016



NOTIONAL DIVERSION SCENARIOS

FOR THE BERP BALL

MAIN DIVERSION SCENARIO: OUTER DIAMETER UNCHANGED; REMOVING MATERIAL FROM THE INSIDE



“MULTIMATCH TEMPLATE”

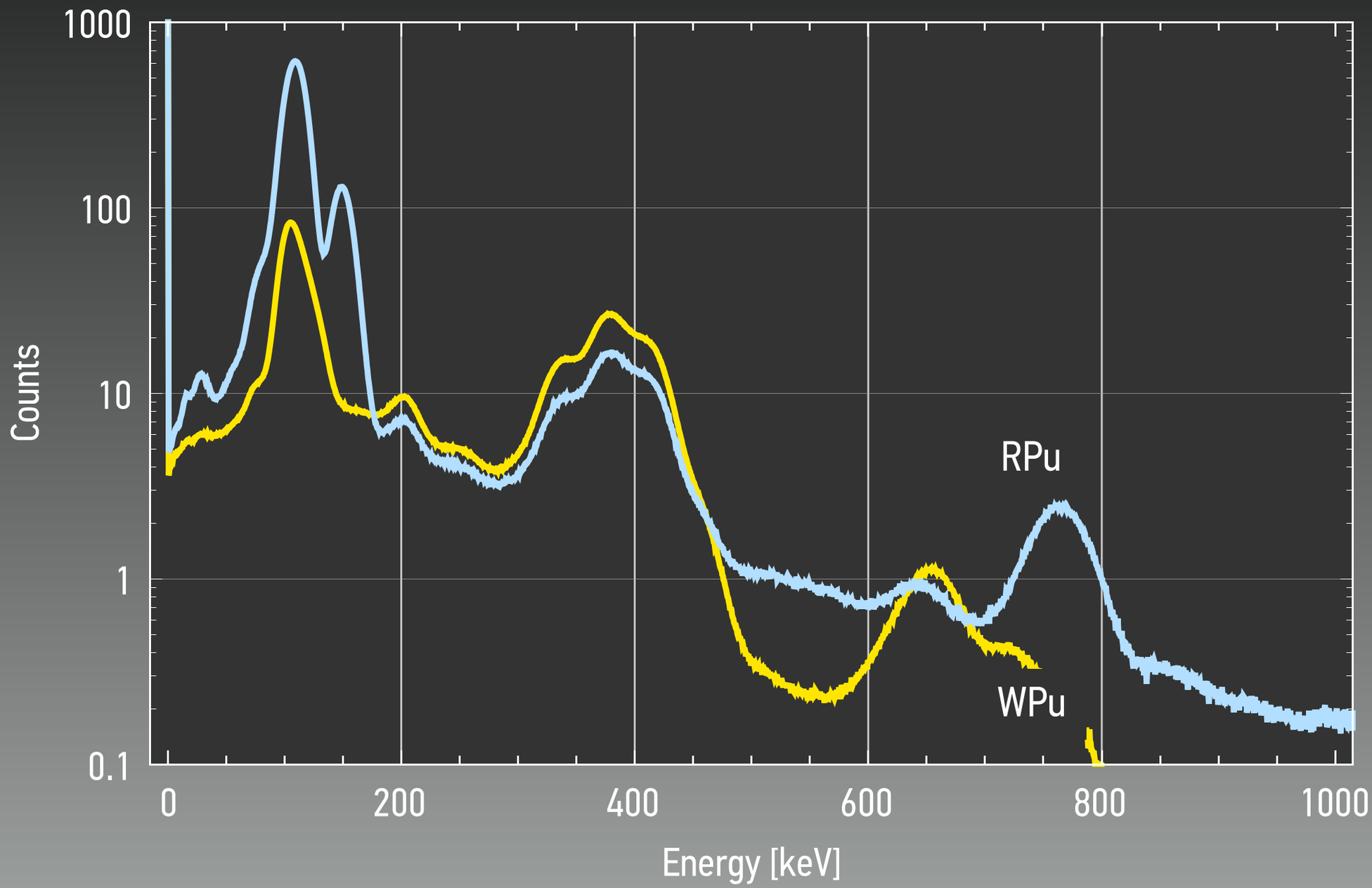
USING (THREE) INDEPENDENT TESTS FOR MAXIMUM SENSITIVITY TO DIFFERENT TYPES OF DIVERSION

	MODIFIED KS TEST	TOTAL GAMMA	TOTAL NEUTRONS
ISOTOPICS	expect good sensitivity	TBD	TBD
SIZE (PROJECTED SURFACE)	TBD	expect good sensitivity	TBD
MASS	TBD	TBD	expect good sensitivity

Template measurement accepted if (and only if) item passes all three tests simultaneously

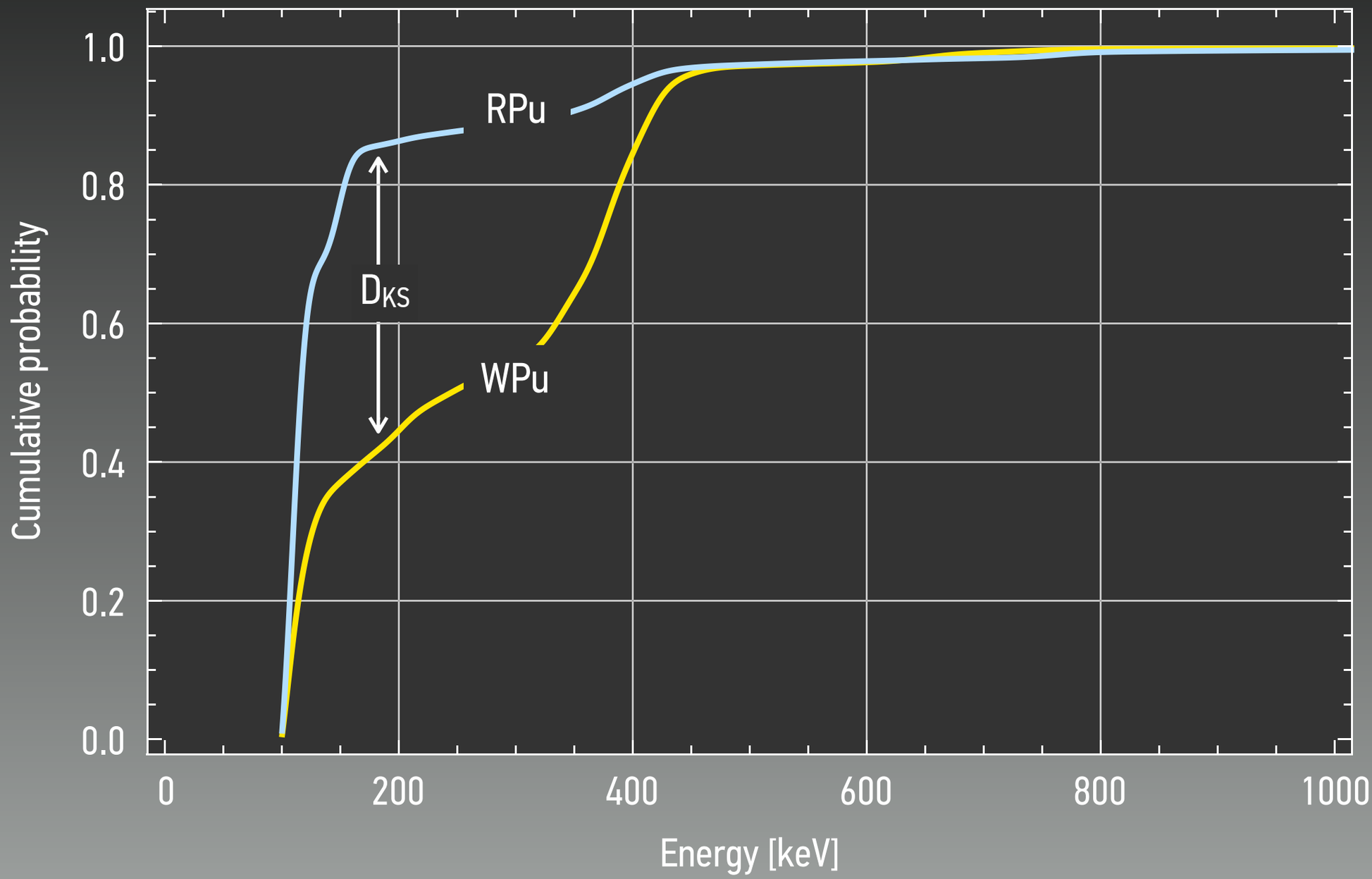
MODIFIED KS TEST

INTERPRETING GAMMA SPECTRA AS PROBABILITY DENSITY FUNCTIONS



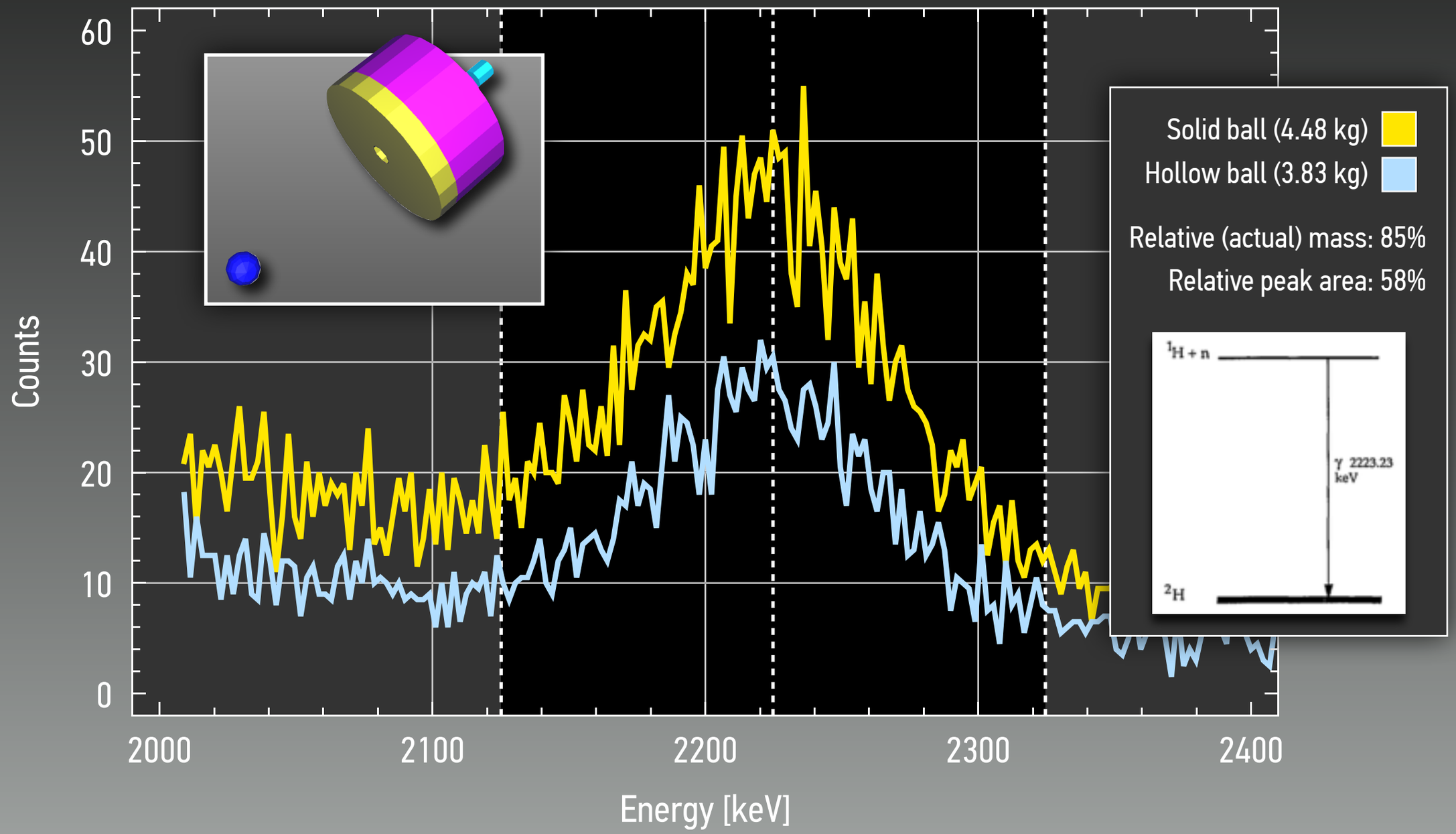
CUMULATIVE DISTRIBUTION FUNCTION

REACTOR-GRADE VS WEAPON-GRADE PLUTONIUM



TURNING NEUTRONS INTO GAMMAS

"REVERSE" PROMPT GAMMA ACTIVATION ANALYSIS (PGAA) CAN PROVIDE A ROBUST SIGNATURE FOR THE MASS OF PLUTONIUM

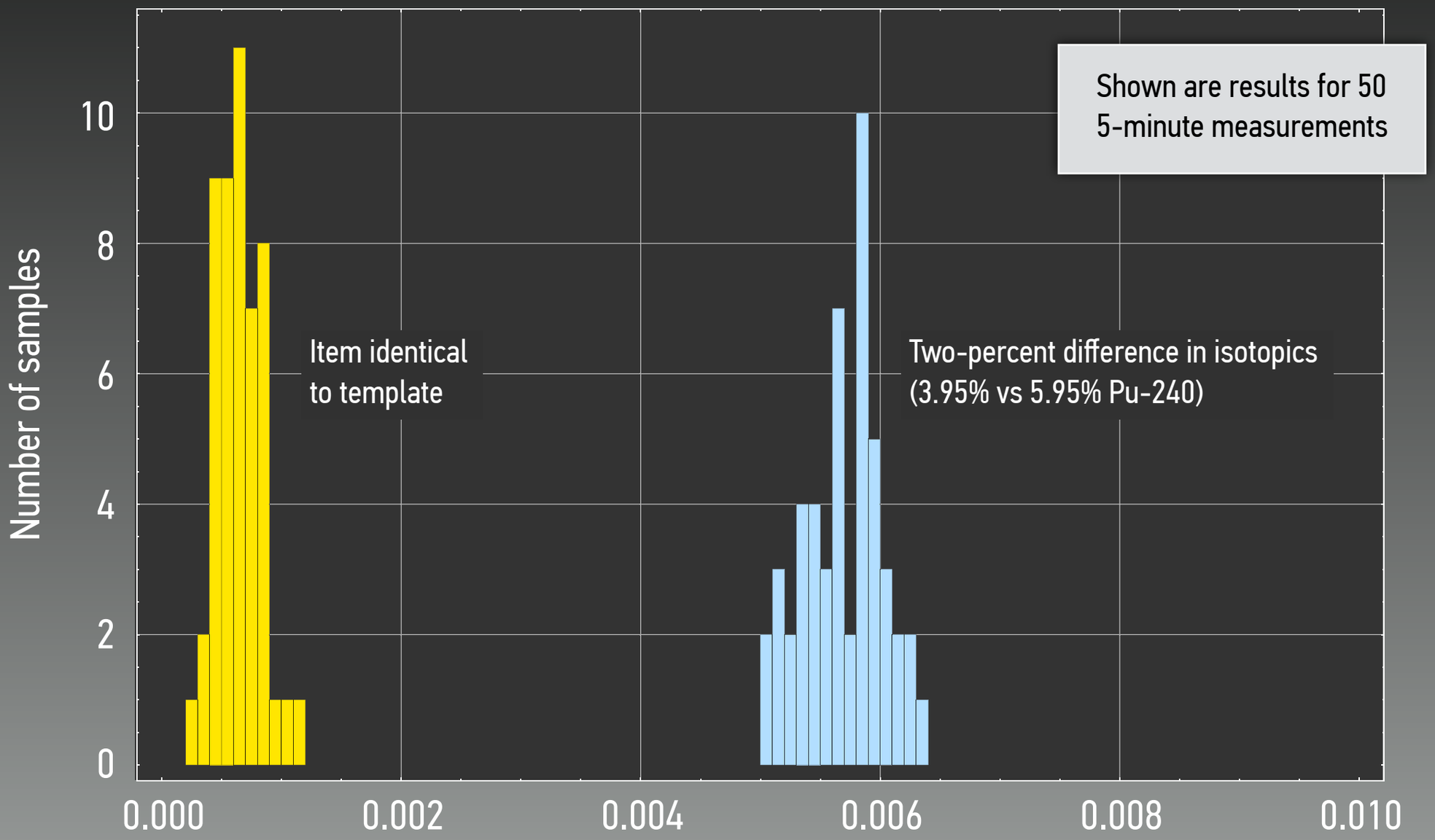


RESULTS

(PRELIMINARY)

"MODIFIED KS TEST"

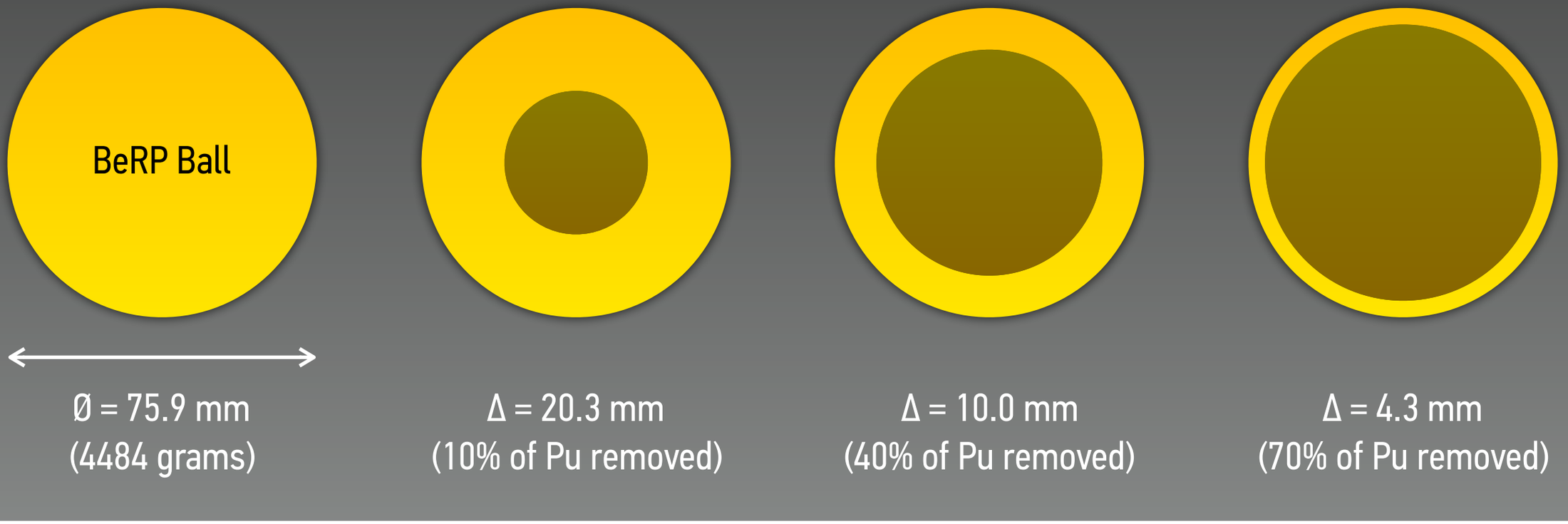
(VERY SENSITIVE TO ISOTOPICS OF INSPECTED ITEMS)



NOTIONAL DIVERSION SCENARIOS

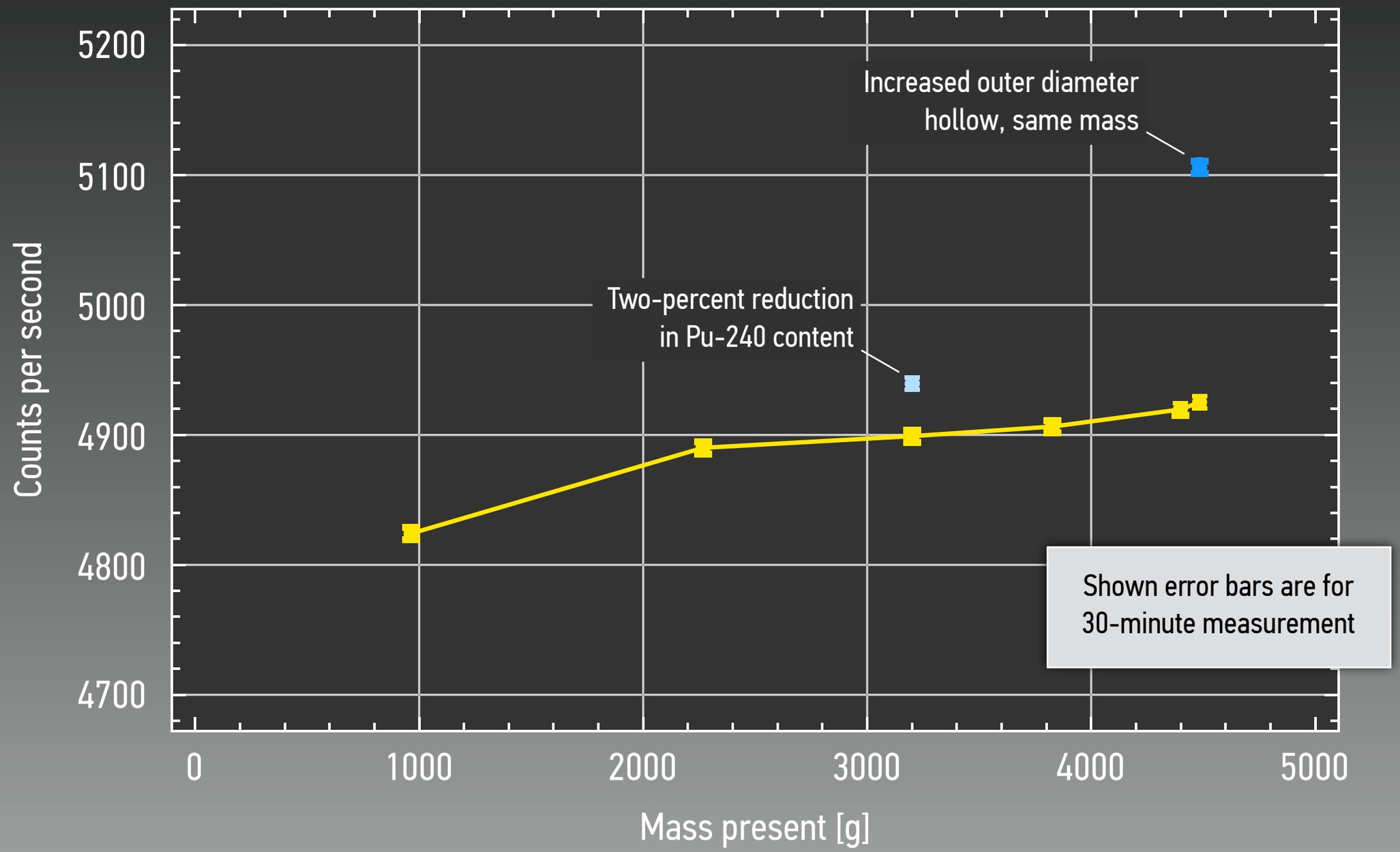
FOR THE WEAPON-GRADE PLUTONIUM BERP BALL

DIVERSION SCENARIO: OUTER DIAMETER UNCHANGED; REMOVING MATERIAL FROM THE INSIDE



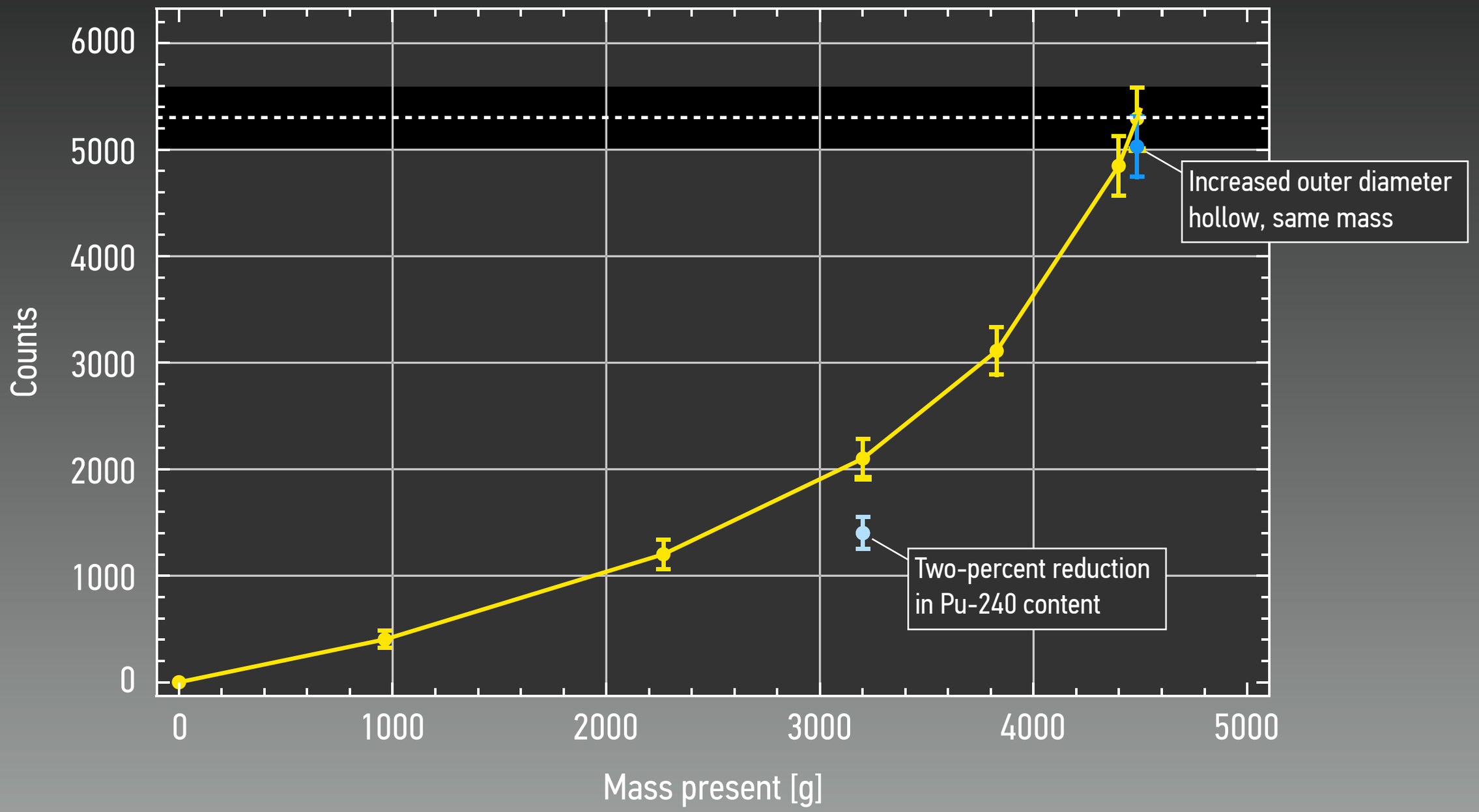
TOTAL GAMMA COUNT

(VERY SENSITIVE TO PROJECTED SURFACE AREA OF ITEM – BUT NOT TO HIDDEN CHANGES)



NEUTRON MEASUREMENT

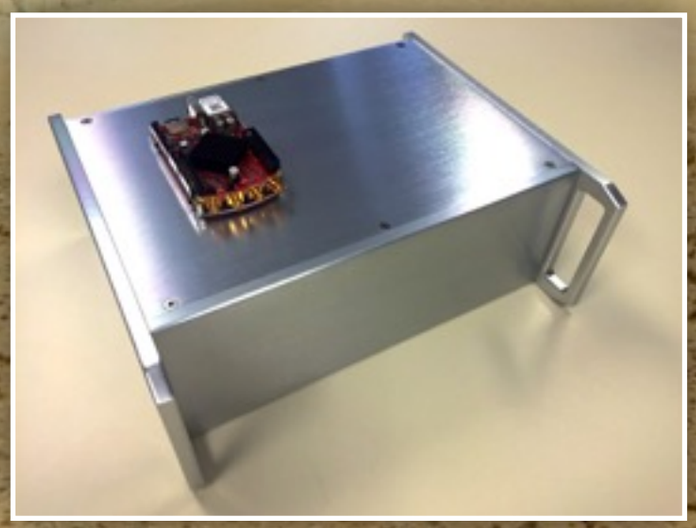
30-MIN MEASUREMENT REVEALS 5%-MASS DIVERSION



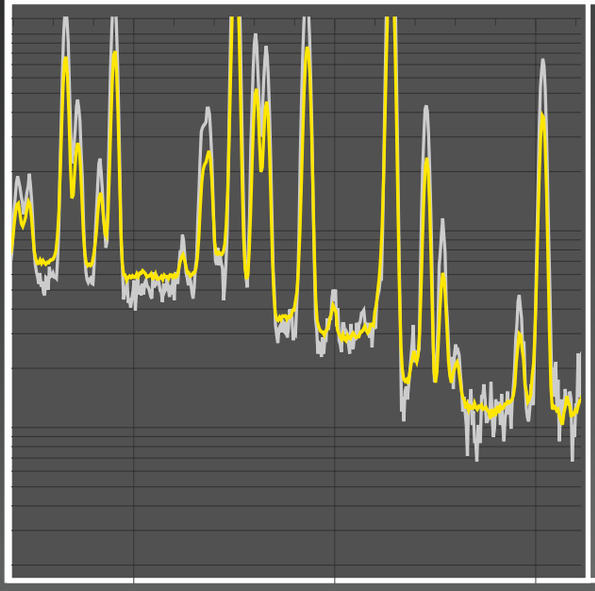
“MULTIMATCH TEMPLATE”

SUMMARY OF RESULTS

	MODIFIED KS TEST	TOTAL GAMMA	TOTAL NEUTRONS
ISOTOPICS	**Excellent indicator**	**Good indicator** (in combination with others)	**Good indicator** (in combination with others)
SIZE (PROJECTED SURFACE)	**Good indicator** (in combination with others)	**Excellent indicator** (in combination with others)	Inadequate
MASS	Weak indicator	Weak indicator	**Excellent indicator** (in combination with others)

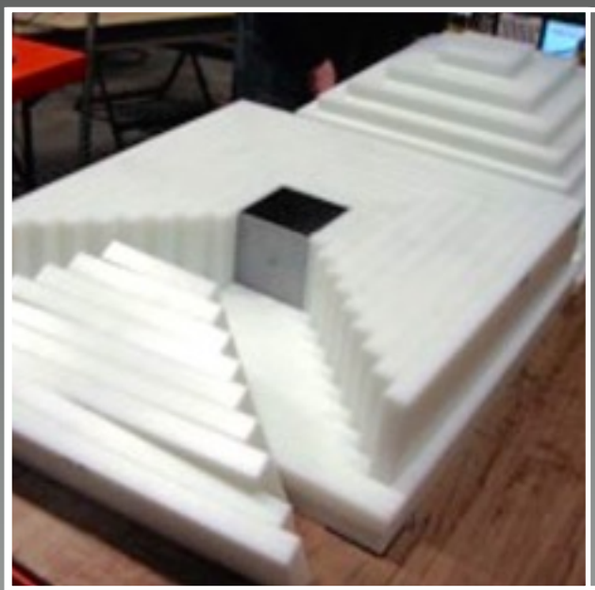


CONCLUSION



SUMMARY AND FINDINGS

- Notional diversion scenarios using template-matching approach
- Items with different surface areas: straightforward
- Items with same outside dimensions: more challenging
- Indirect neutron measurements offer strategy to confirm mass
- Sensitivity of NaI and HPGe not too different for template matching



AREAS OF POSSIBLE FUTURE WORK

Propose and agree on “universal test objects” (and their respective gamma spectra) for computational and experimental benchmarks

Propose and agree on reference match/diversion scenarios
to further develop and validate algorithms
(for example: Item should pass if age within ±10 years of template age)

Photo: Joint U.S.-U.K. Report on Technical Cooperation for Arms Control, U.S. Department of Energy, Washington, DC, 2015