An ID Metric to Quantify Gamma-ray Energy Resolution

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Radiological and Nuclear Detection Symposium

25-26 March, 2014

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Gamma Detection Basics

Sensitivity - ability to detect a weak source of radiation

Devices Are Weak Sources

>Well understood metrics

Selectivity - ID Unique Signatures:

Applies for both Passive & Active/Stimulated Applications

Actionable information

>for gamma ray this means energy resolution

>mission parameters critical (isotopes to ID, background, shielding)

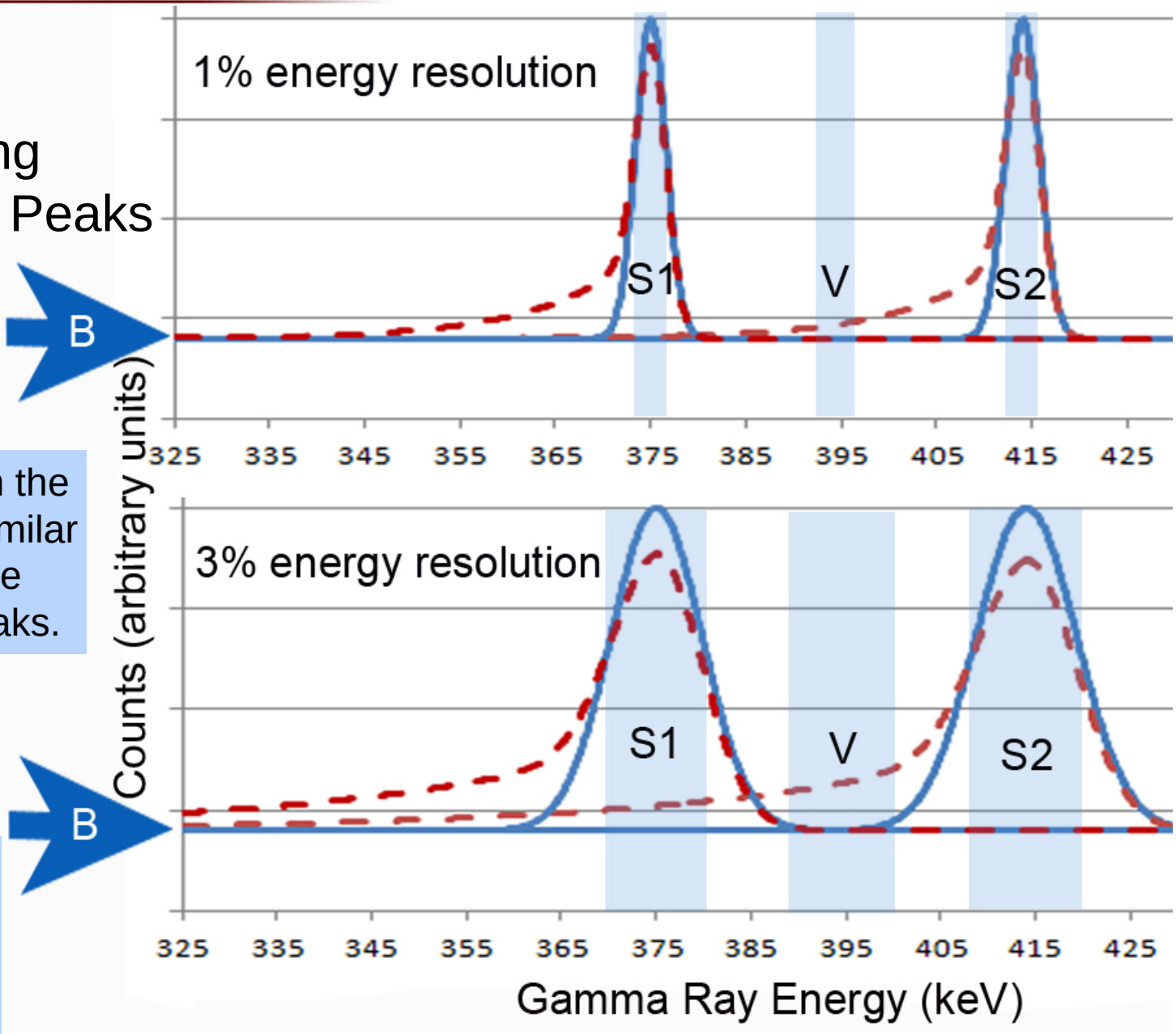
>poor selectivity leads to false and nuisance alarm nightmares

General ID Metric doesn't exist!

GOAL: Develop General ID metric

- Quantify gamma ray energy resolution impact
  - Closed mathematical form
  - Require no templates or Monte Carlo modeling
  - Requires minimal inputs beyond detector energy resolution
- Tool for program managers and system developers
  - Applicable generally to wide range of systems & missions
  - Conservative: inclined to under-predict energy resolution impact rather than over-predict
  - Simple enough for easy use in programmable calculators or smart phone APPs

Approach
ID by Resolving Characteristic Peaks



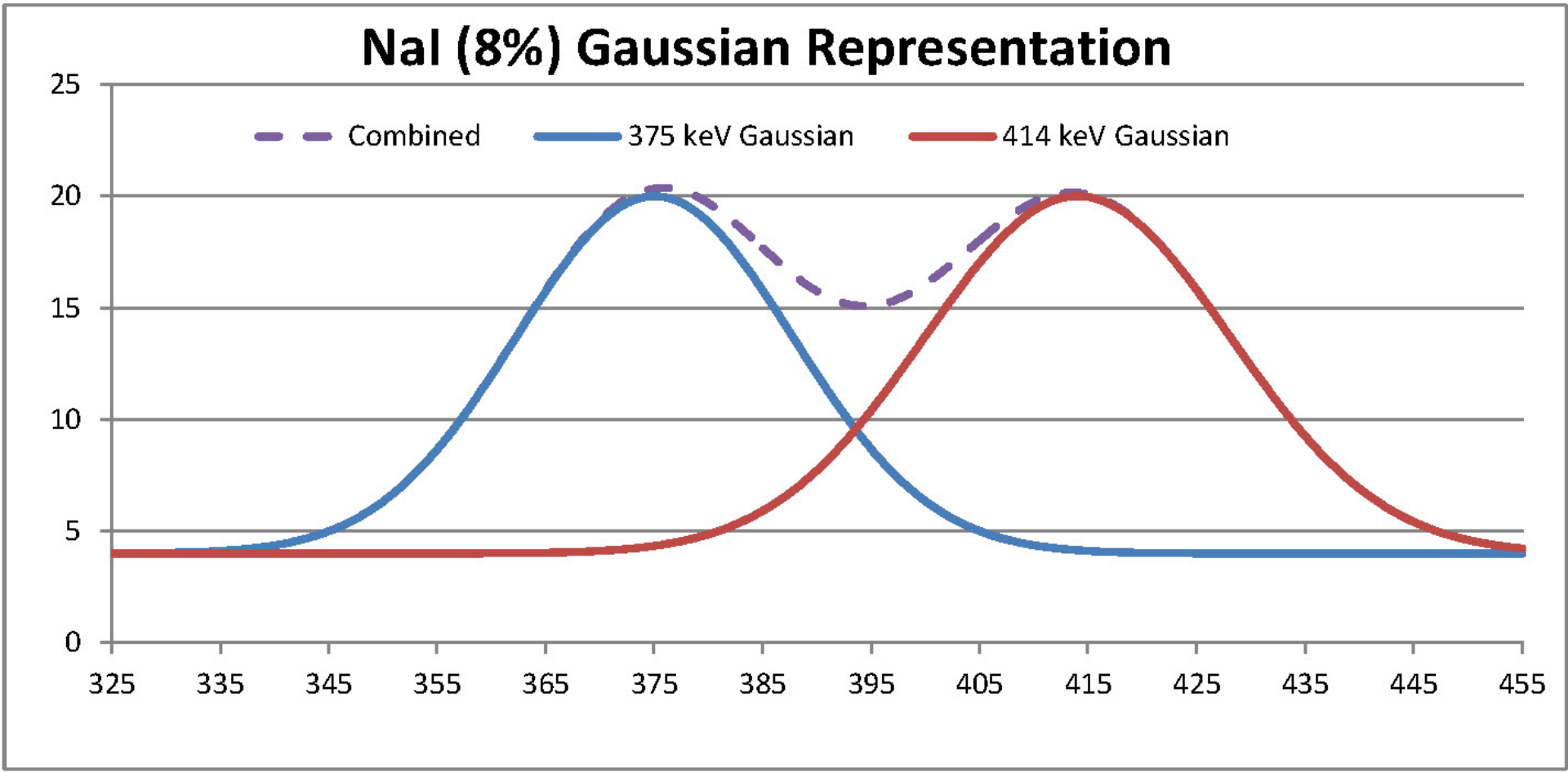
Compare counts in the peaks (fwhm) to similar region (fwhm) in the valley between peaks.

Gaussian will under-predict impact of energy-resolution

Simplifying Assumptions

- For equality of comparison, baseline detectors for different energy resolutions are all assumed equal.
  - Sized such that they have equal counts in equal times for isolated peaks collected in the absence of background.
- Gaussian peak shape.
  - Under-predicts the impact of better energy resolution.
- Equal isotopic peak intensities for different energy lines.
  - This is just for simplicity and not mathematically necessary; a form without this limitation is being developed.
- Only two peaks considered, others ignored.
  - Multiple peak version being developed.
- Background flux assumed as a constant ratio of source flux
  - Model for more complex backgrounds being developed.

^{239}Pu Primary Peaks Blur at NaI Resolution



Note: energy resolutions are quoted at 137Cs reference standard. Actual are worse at these energies.

Energy Resolution Metric

Two different detectors A and B with different energy resolutions, but detection efficiencies matched to have the same counting times to detect isolated peak in the absence of background.

$$TR(i)AB = \frac{\left(0.808 + 0.532 \cdot Z(A) \cdot \frac{E(1)+E(2)}{E(i)} + 2 \cdot BR\right) \cdot \left(0.808 - 0.532 \cdot Z(B) \cdot \frac{E(1)+E(2)}{E(i)}\right)^2}{\left(0.808 + 0.532 \cdot Z(B) \cdot \frac{E(1)+E(2)}{E(i)} + 2 \cdot BR\right) \cdot \left(0.808 - 0.532 \cdot Z(A) \cdot \frac{E(1)+E(2)}{E(i)}\right)^2}$$

where:

$$Z(x) = ERF\left(\frac{1.66 \cdot (E(2) - E(1))}{eR(x) \cdot (E(1) + E(2))} + 0.832\right) - ERF\left(\frac{1.66 \cdot (E(2) - E(1))}{eR(x) \cdot (E(1) + E(2))} - 0.832\right)$$

TR(i)AB:	ratio of counting time to resolve peak i (i=1,2) with different energy resolution detectors A, B
eR(x):	energy resolution of detector x (x=A,B)
E(i):	energy of peak i (i=1,2)
BR:	ratio of background flux to source flux at peak energies

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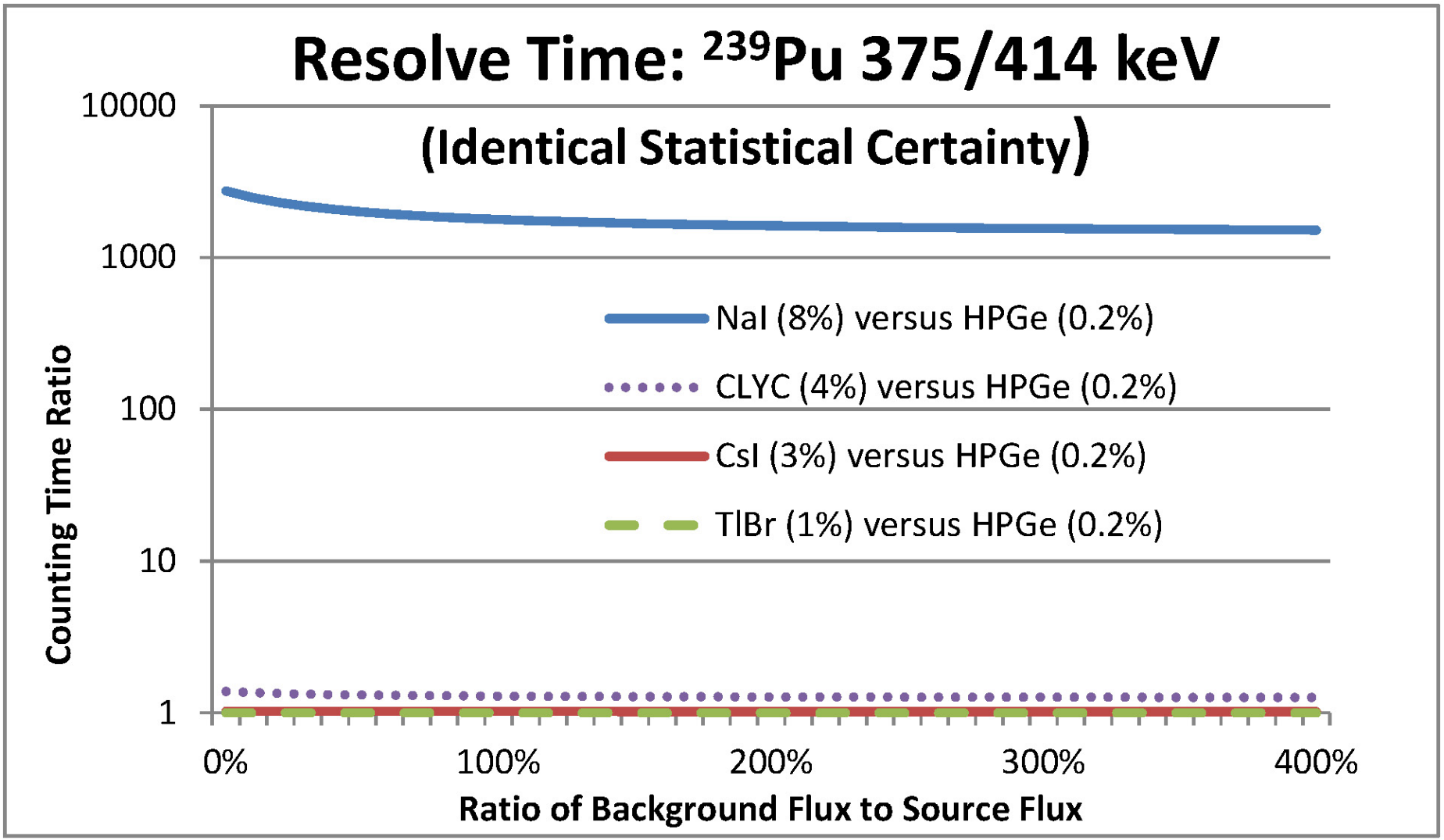

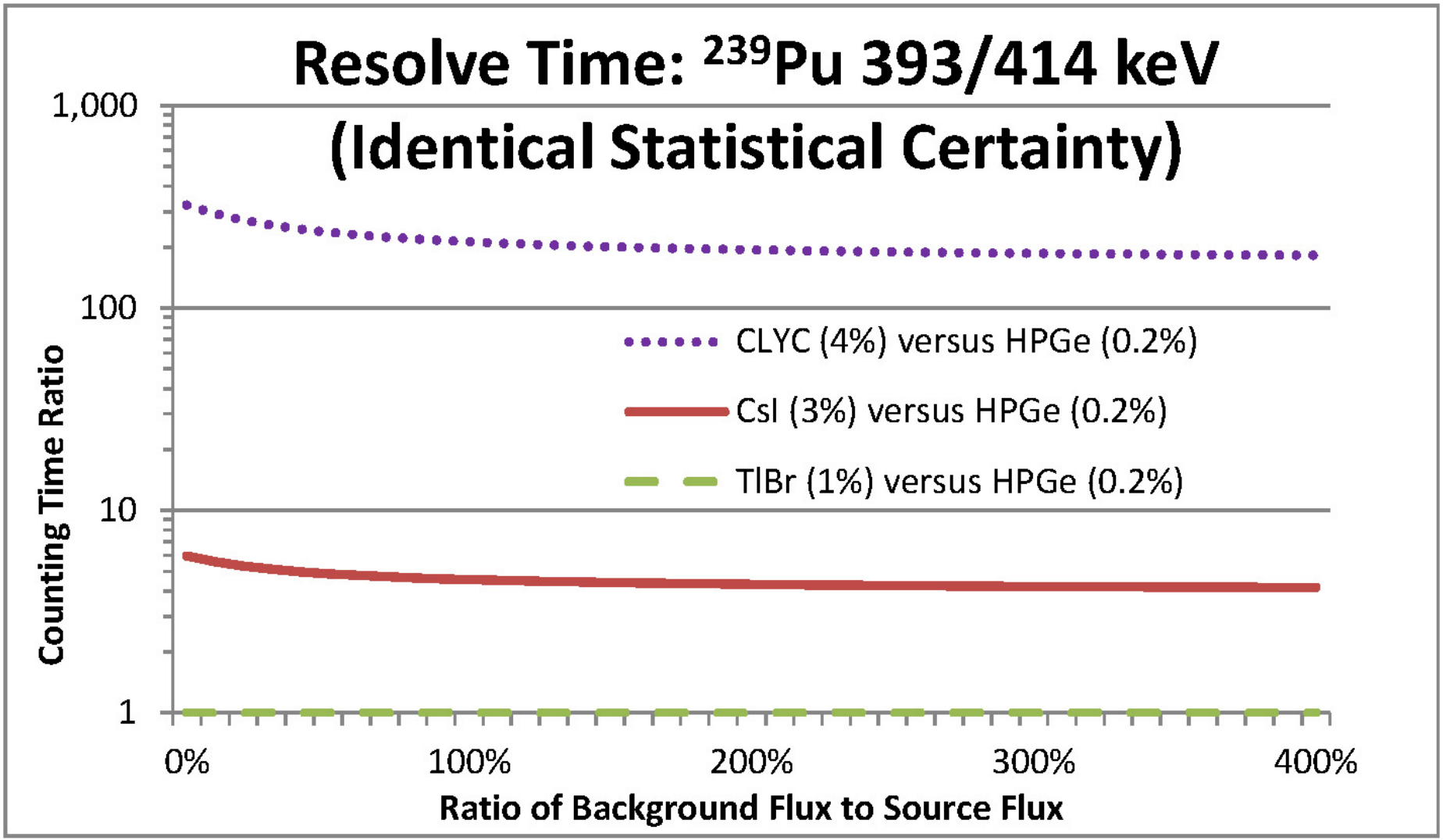

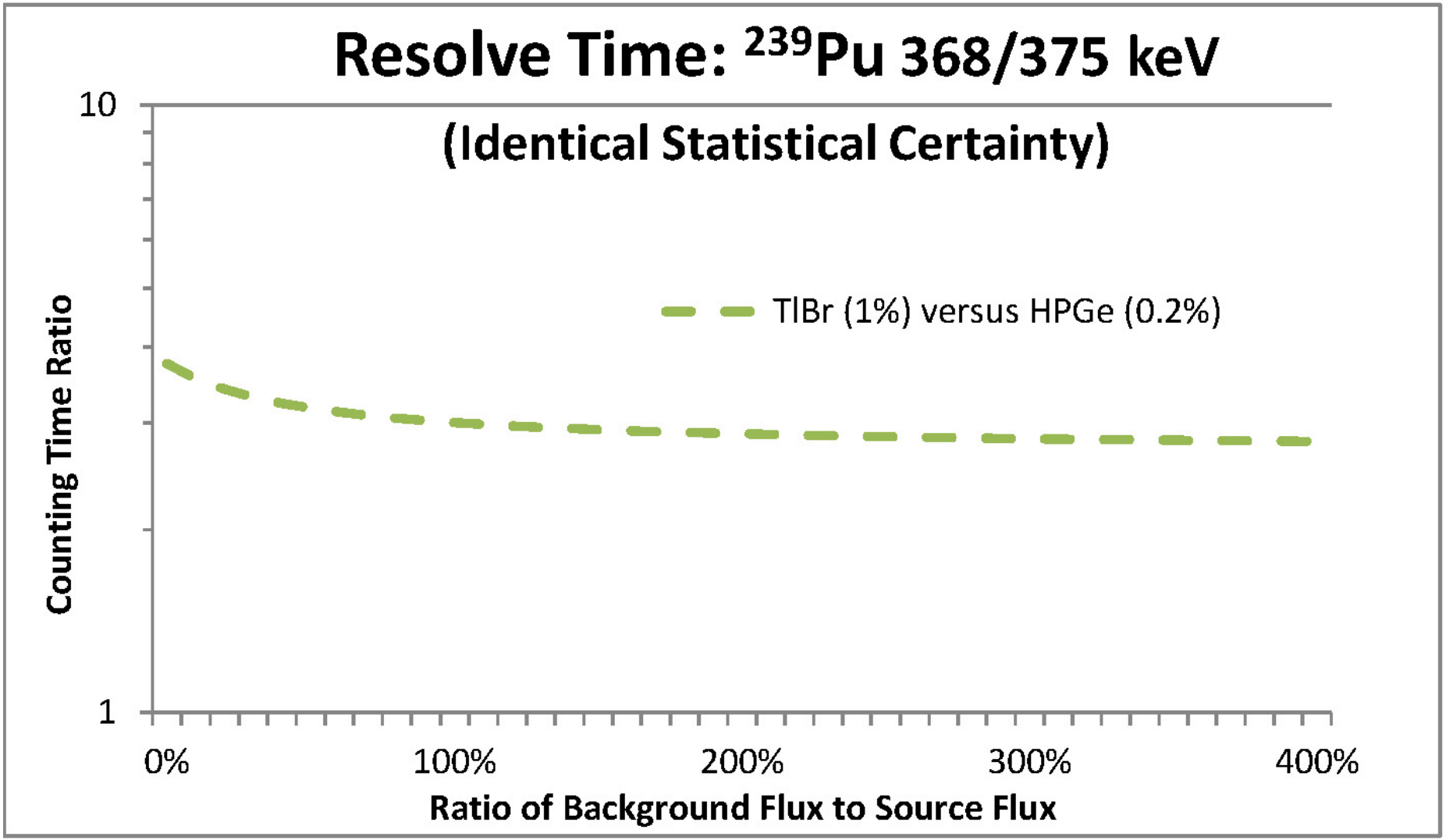

Conclusions

- Metric can help select necessary energy resolution where the mission is clearly outlined in terms of isotopes of interest, masking isotopes and backgrounds (natural and shielding induced).
- NaI energy resolution does not reasonably resolve even basic primary peaks for ^{239}Pu.
  - Should only be used in CONOPS where other methods of inspection are available to complement ID
- This simple metric is sufficient to guide many detector selections.
  - Eventual more complex metric will fine-tune but not overturn utility.