SAND2015-6095C

Treaty Verification without an Information Barrier

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U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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The problem

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- Current treaty verification tests for delivery systems
- What if in the future, countries want to test if a warhead has been disarmed?
- Monitor wants to verify, host wants to preserve sensitive information on construction of objects.
- Many current proposed methods utilize an information barrier (IB)
  - IB: hardware or software

“Traditional” template matching

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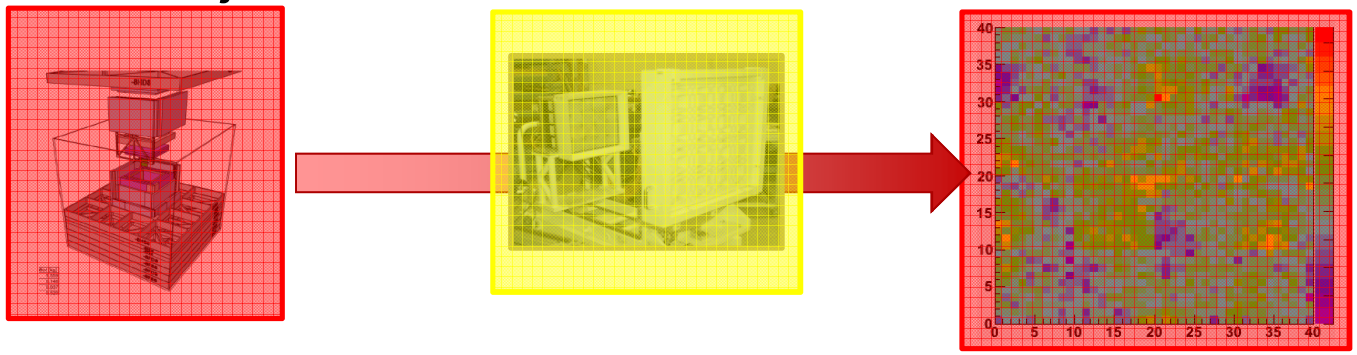
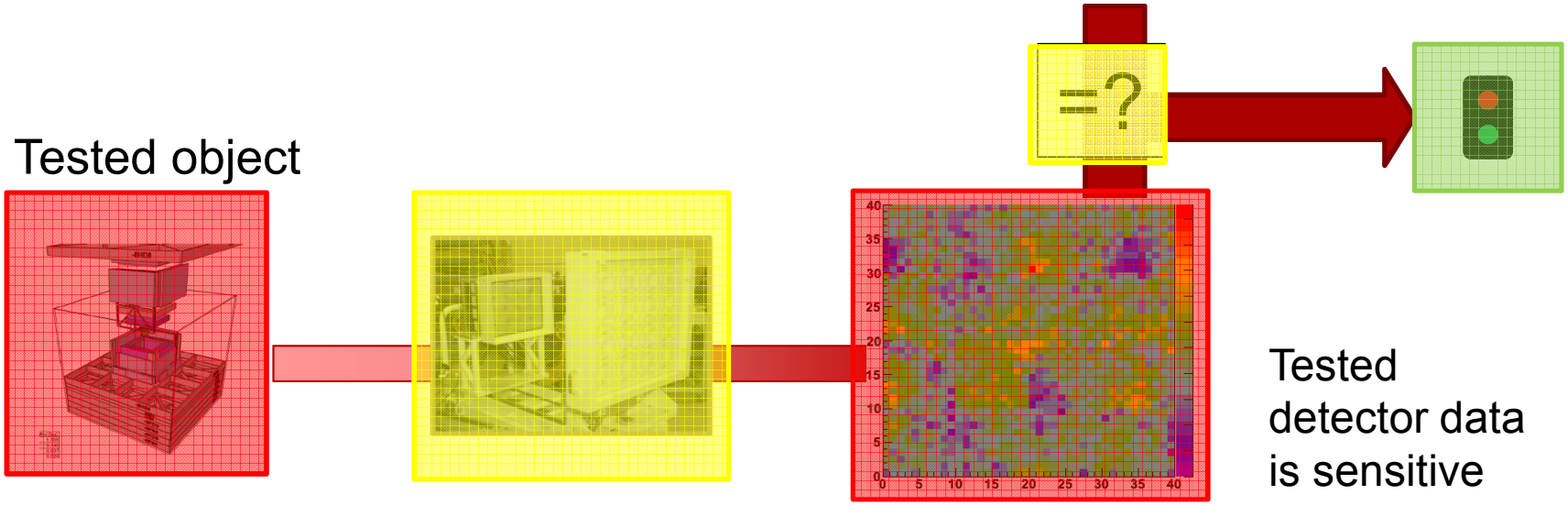
Trusted object



Calibration data is sensitive
IB required

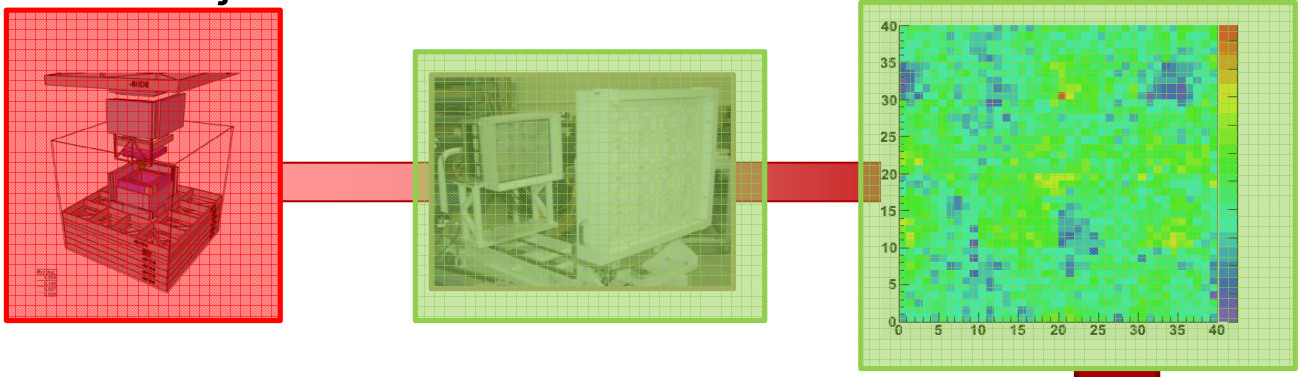
Tested object



Tested detector data is sensitive
IB required

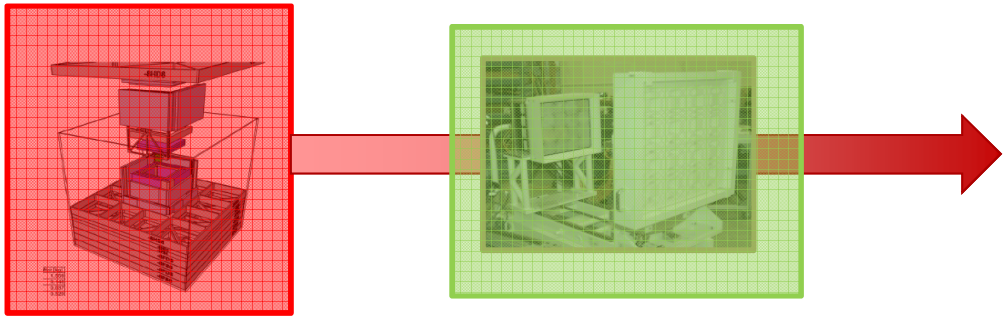
Our proposal

Trusted object



Hypothetical observer stores info sufficient for confirmation but not sensitive

Tested object



Testing data is processed event by event, only updating test statistic.

Data not aggregated

Linear template observers

- Testing and training event data $\{A_n\}$ binned into data vector *g* (P x 1).

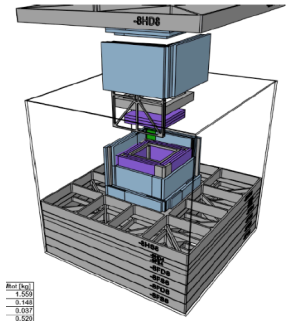
$$g_p = \sum_{n=1}^{N} f_p(A_n)$$

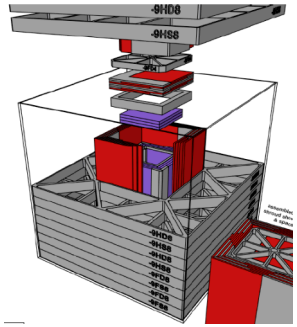
- Linear template W (P x 1) acts on g_{test} , result is thresholded to make a decision

$$t_{test} = W^{\dagger} g_{test}, \; t_{test} \lessgtr t_{thresh}$$

Experiment (simulation)

- Binary discrimination experiment using gamma spectra.
  - Distinguish objects 8 (Pu surrounded by DU) and 9 (Pu surrounded by HEU) developed by Idaho National Lab.
  - Fast-neutron coded-aperture detector with liquid scintillator.

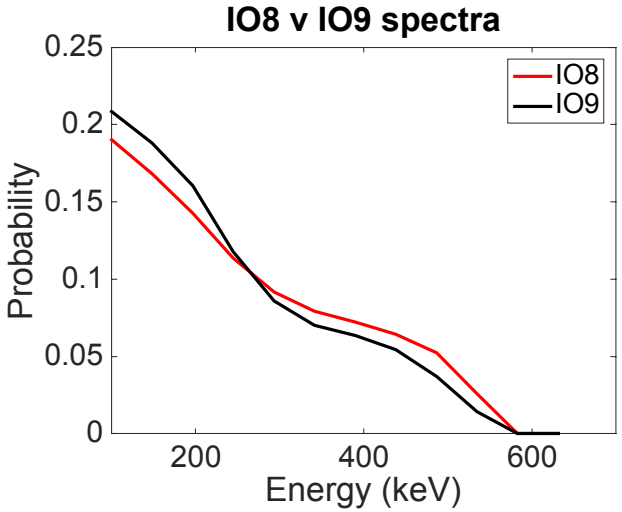




- Models created in GEANT4 toolkit to acquire testing and training data.

Hotelling observer

- Data on the inspection objects differ in their spectra and count rate.

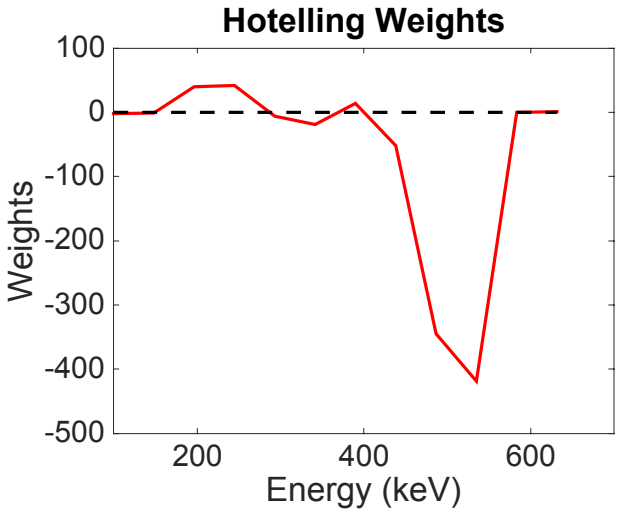


- Hotelling observer is template *W* defined as:

$$W = K_g^{-1}\overline{\Delta g}$$

$$K_g^{-1} = \frac{K_1 + K_2}{2}$$

$$\overline{\Delta g} = \overline{g_2} - \overline{g_1}$$



Channelized Hotelling

- Channelize vector *g*(Px1) with operator *T*(QxP) into much smaller vector *v*(Qx1)

$$v = Tg$$

$$W_v = K_v^{-1}\overline{\Delta v}$$

$$W_v^{\dagger} v_{test} \lessgtr t_{thresh}$$

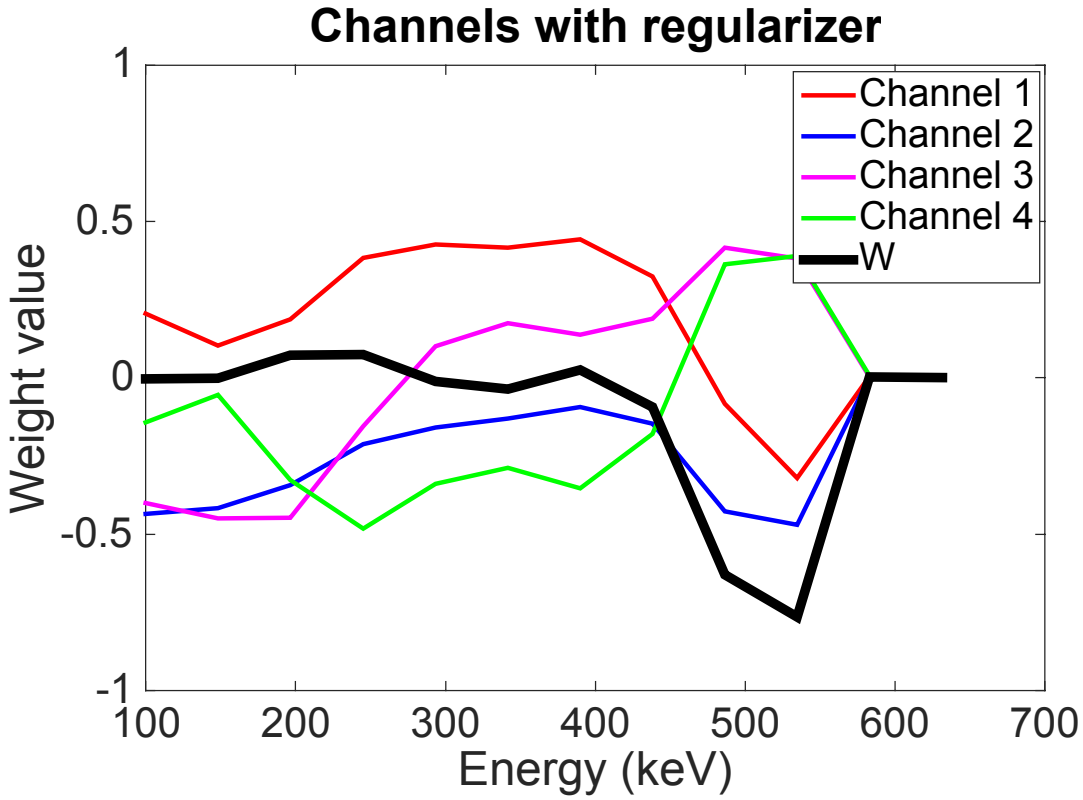
- Regularizer used in optimization to limit channel performance

- Taken sensitive Hotelling template *W* to *T* and W_v, neither are sensitive without other.

$$W = W_v T$$

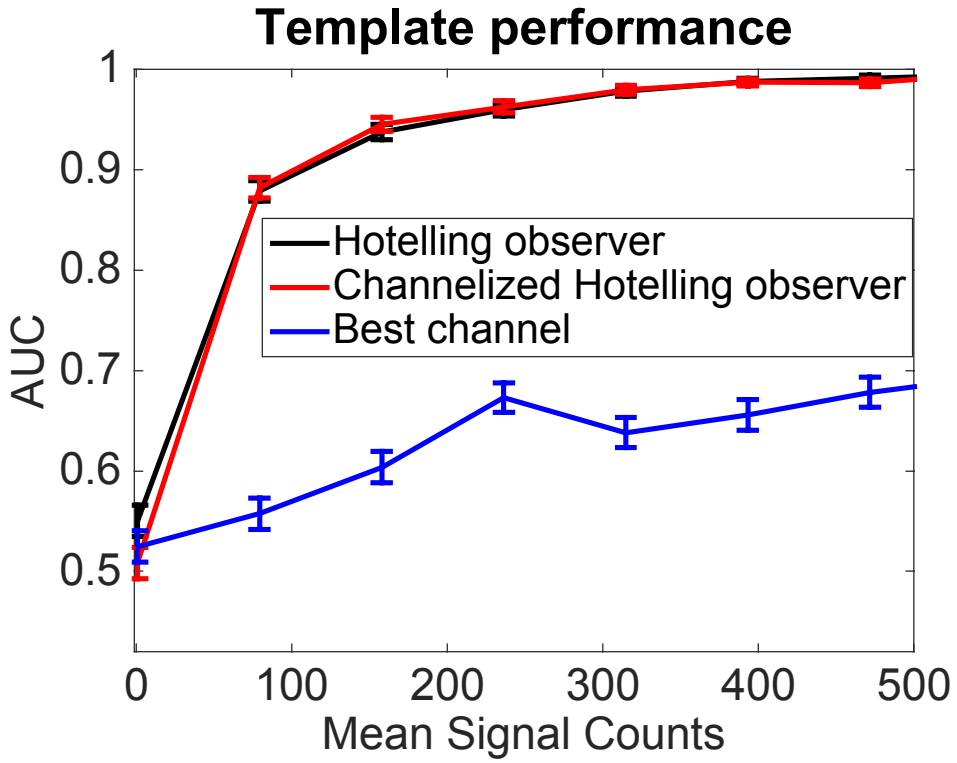
Channelized Hotelling in practice

- With regularizer, channels are different from the true Hotelling weights.



Channelized Hotelling in practice

- Hotelling and channelized Hotelling's ability to differentiate tested sources are equivalent.
- Each channel performs poorly.



Future work

- Development of a null hypothesis test (is this source A or not source A?)
  - Null hypothesis tests often based on distance metrics that can't be used with list-mode data
  - Is there an analogue to the Hotelling observer that we can use?

- Can a regularizing term prevent discrimination based on sensitive information?