Two-particle correlations in low efficiency detector systems

ADSA10-Explosives Detection in Air Cargo

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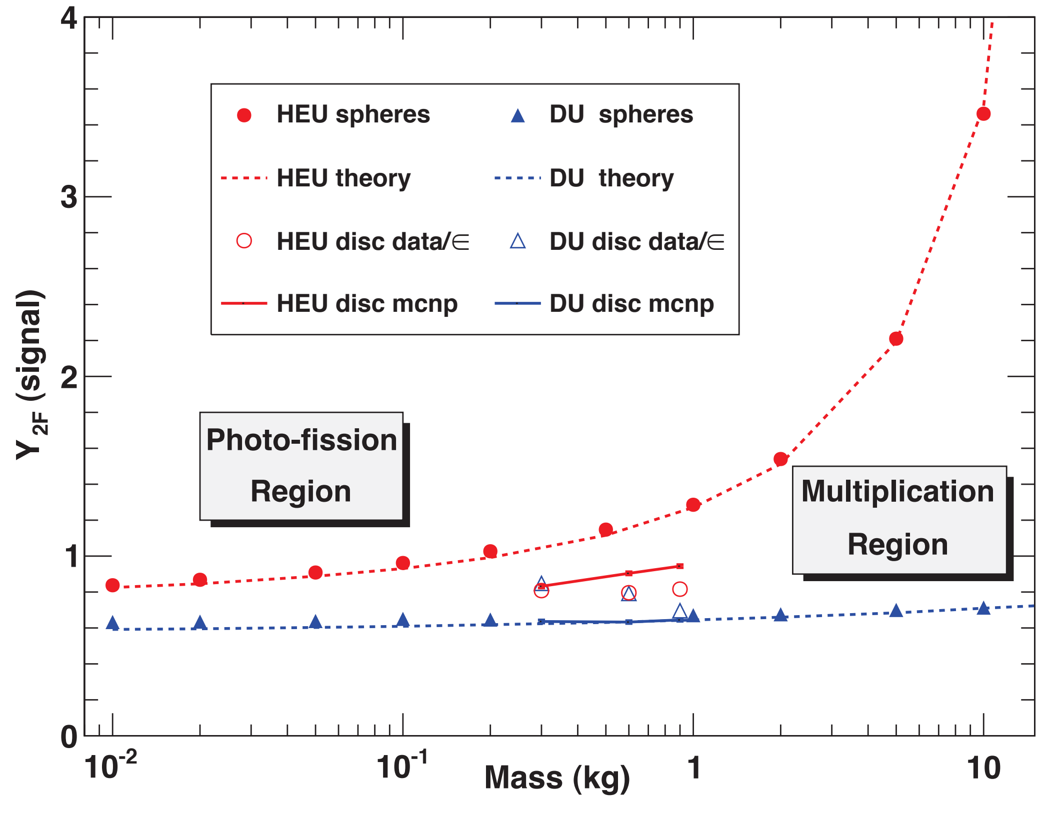
Why TSA should care.

- Surprising detection signature technologies can be generalized to other domains.
- These technologies may not require major changes to existing detector schemes.
- These signatures might be included in a suite of signatures in a complimentary manner to increase the confidence of detection.

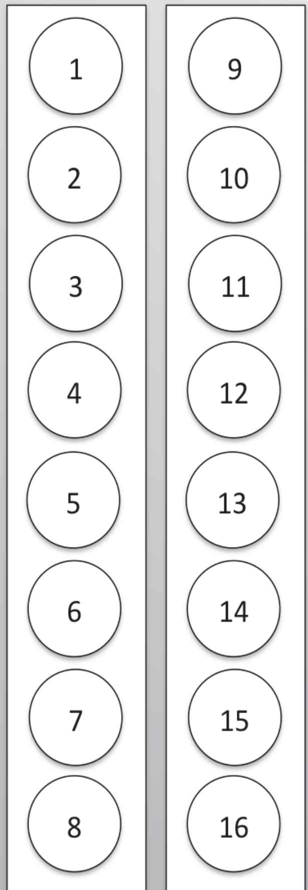


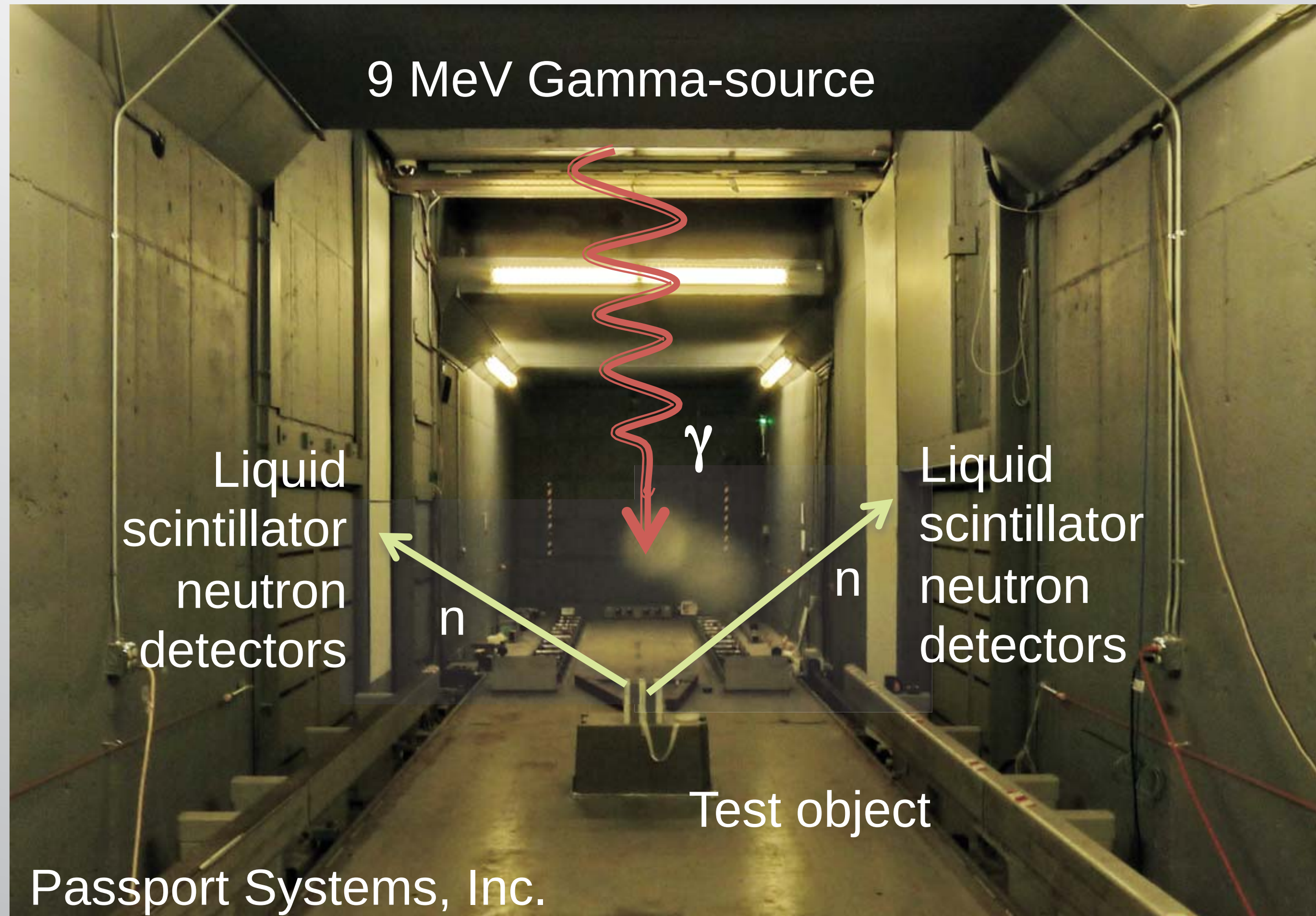
$$1+Y\equiv\frac{\langle n^2\rangle-\langle n\rangle^2}{\langle n\rangle}$$

For random emissions: $\langle n^2\rangle-\langle n\rangle^2=\langle n\rangle$

R. P. Feynman, F. De Hoffmann, R. Serber, *J. Nucl. Energy*, **3**, 64 (1956)

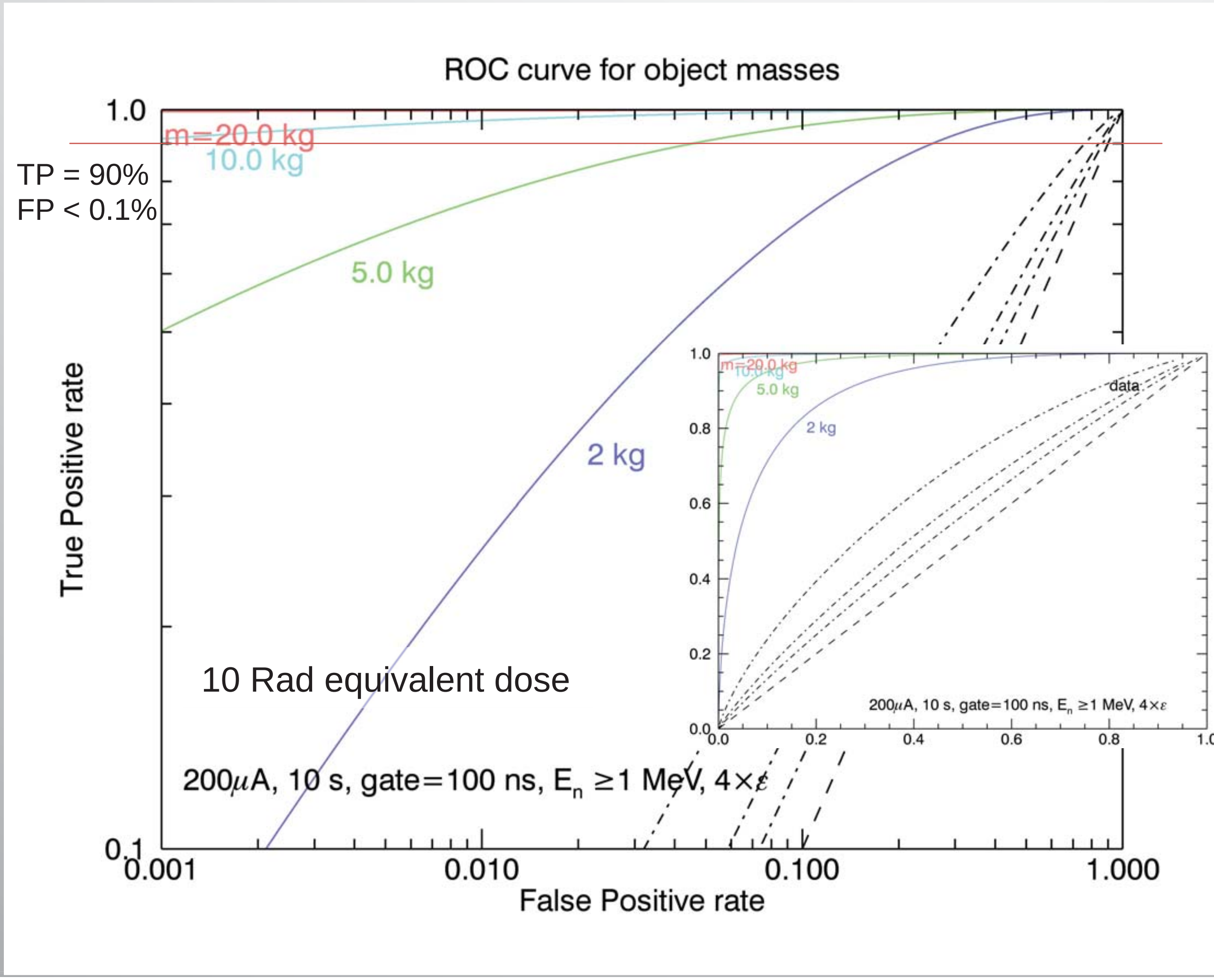
What we did: detection of fissile material using active interrogation.





Single particle efficiency $\varepsilon \approx 0.1\%$, two particle efficiency $\varepsilon^2 \approx 0.0001\%$
Only modification was a common time stamp for all detector channels.

How well does it work?



"True positives" are HEU objects.

The "false positives" are equivalent mass DU objects.

These curves are created from a combination of data, monte carlo calculation and scaling.

First fission puzzle

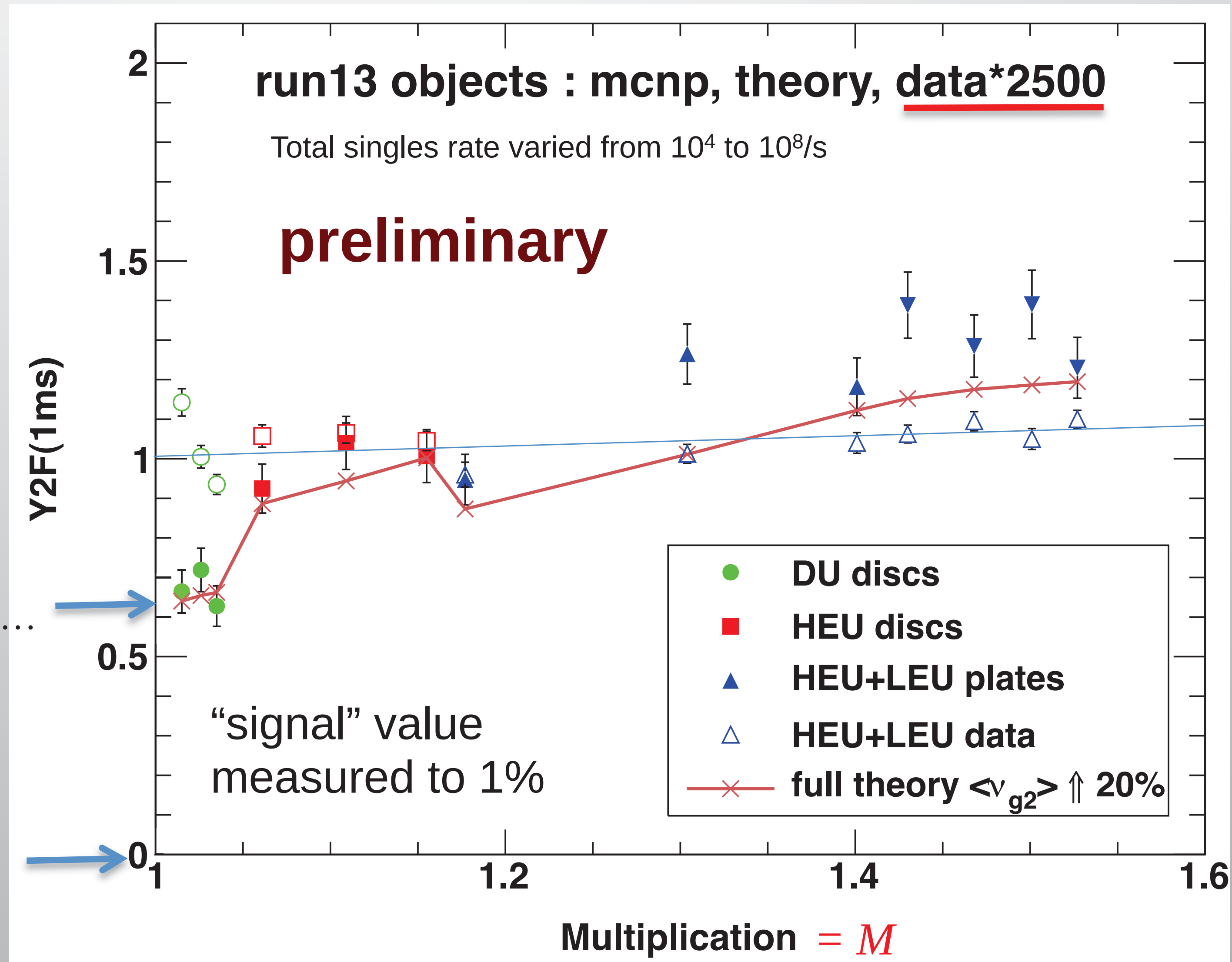
Unexpected:
For very small masses we have non-zero signal.

$$Y_{2F} \approx \varepsilon\left[\frac{\nu_{\gamma 2}}{\nu_{\gamma}} + \left(\frac{\nu_{\gamma 2}}{\nu_{\gamma}}\frac{\nu-1}{\nu} + \frac{\nu_{2}}{\nu}\right)(M-1)\right]\cdots$$

$M=1$

This is due to the first fission.

expected



S. Walston LLNL-TR-414245

Single fission signal

- Details of photofission are not known well enough to explain these data;
- The average neutron multiplicity is known to a few percent;
- The width of the neutron multiplicity might be the same for all fission;
- A few percent difference in the ratio $\nu_{\gamma 2}/\nu_{\gamma}$ between ^{235}U and ^{238}U would be distinguishable.
- 2-neutron correlation from the first fission only.

For neutron induced fission

DISTRIBUTIONS OF FISSION NEUTRON NUMBERS 787

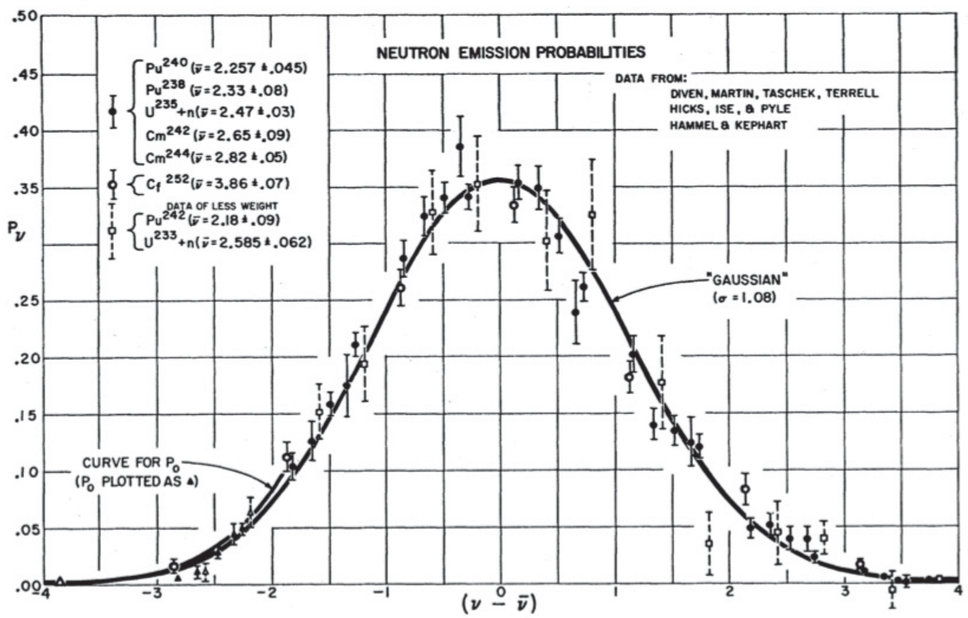


FIG. 4. Experimental noncumulative neutron emission probabilities. The continuous curves are for a "Gaussian" distribution. Experimental data are from references 14–16; standard deviations are shown.

J. Terrel, *Phys. Rev.* **108**, 783 (1957)

Conclusions and possibilities

- We have demonstrated fissile material detection in a realistic setting using 2-neutron time correlations from fissions induced by 9 MeV X-rays.
- The results indicate the possibility of very low mass detection of fissile material using the “first fission” difference of the isotopes of interest.
- Correlated 2-particle signals can be detected in active interrogation at the one part per million level in the presence of large single particle rates.

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