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Proof of concept demonstration of CONFIDANTE

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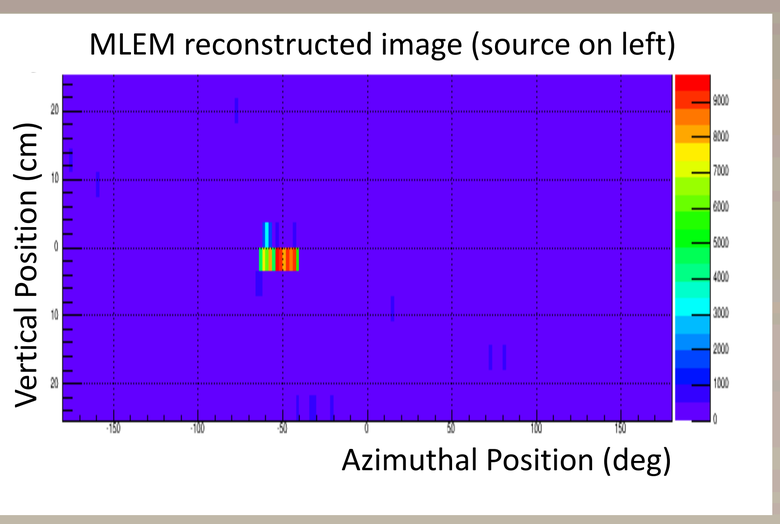
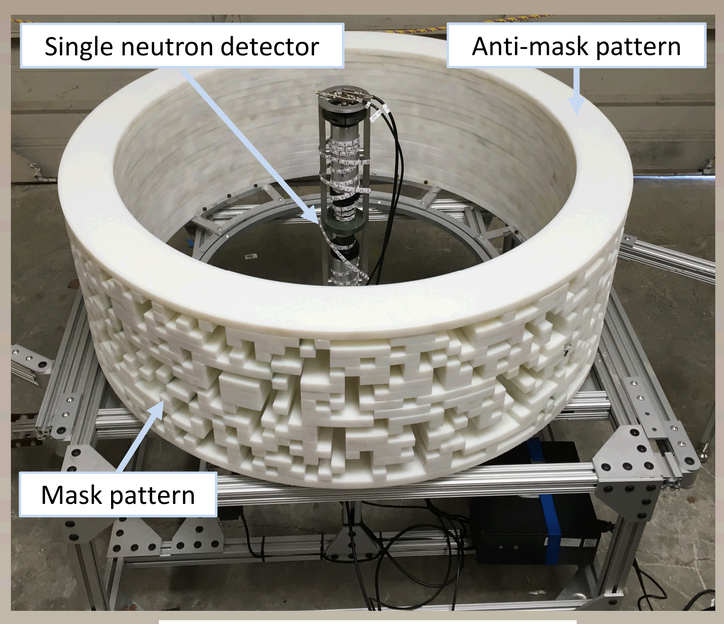
Motivation

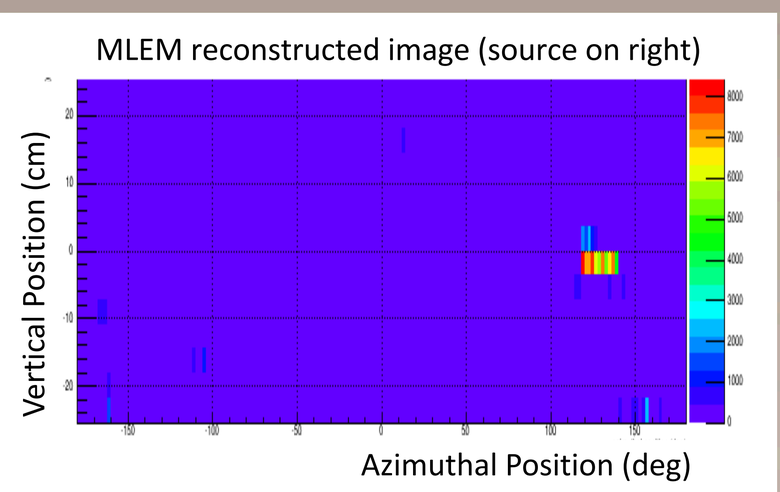
Future nuclear arms reduction treaties are likely to require technical means to verify declarations that items being dismantled and/or removed from a regime are in fact nuclear warheads. Because the radiation signatures of nuclear warheads carry information sensitive to key attributes unique to their nature, radiation detection measurements are often looked to as a means of providing confidence in confirming these declarations. However, for the same reason, the act of confirming certain attributes might reveal critical design information that treaty parties will likely wish to protect. Overcoming the hurdle of verifiably using unique radiation signatures to provide confidence while simultaneously protecting sensitive design data is the primary goal of this work.

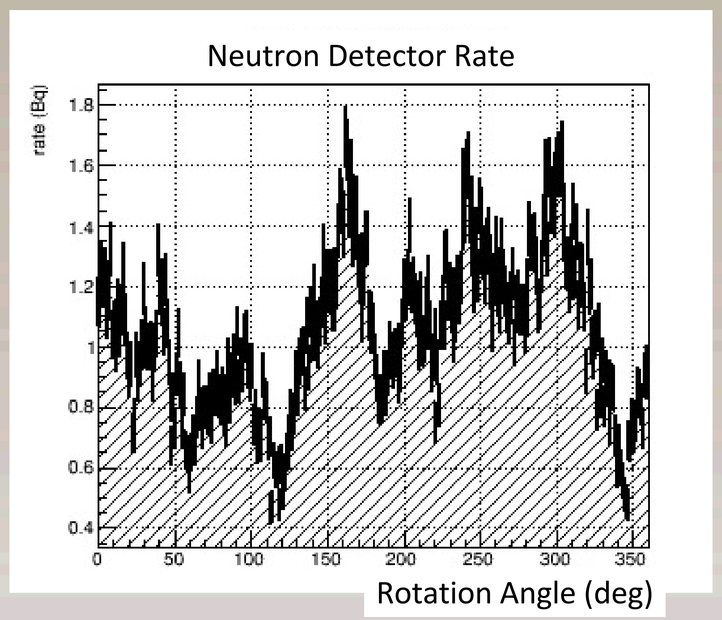
CONFIDANTE

CONfirmation using a Fast-neutron Imaging Detector with Anti-image Null-positive Time Encoding (CONFIDANTE) is a physical implementation of a Zero Knowledge Protocol[12] (ZKP) that uses time encoded imaging (TEI) to provide confidence that the nuclear material in two objects is identical in geometry and activity. TEI is a method which consists of a single fast neutron detector pixel surrounded by a rotating cylindrical coded mask[3]. A TEI with a mask designed such that the pattern on one half of the cylinder is accompanied by its anti-pattern on the opposite side exhibits an unmodulated detection rate if and only if two objects placed on opposite sides of the system are identical in geometry and activity. A positive confirmation is indicated by a constant rate at all times, revealing no additional information.

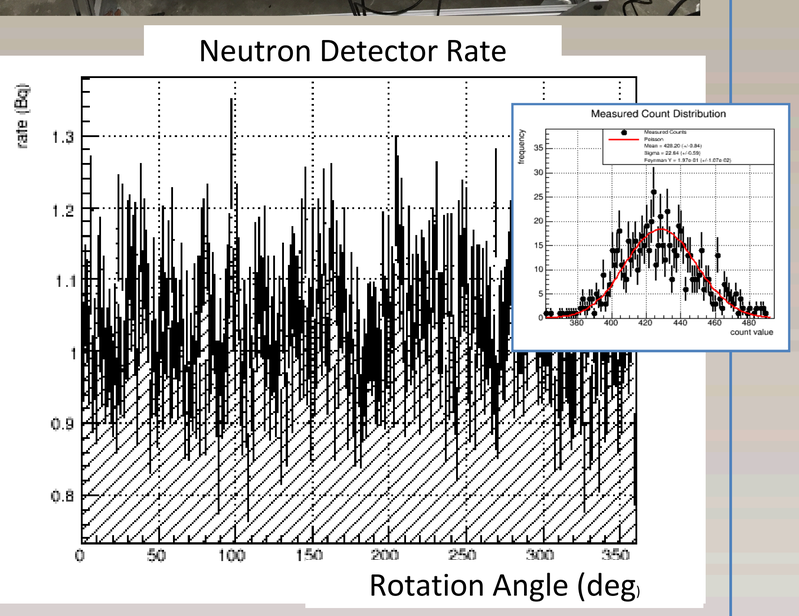




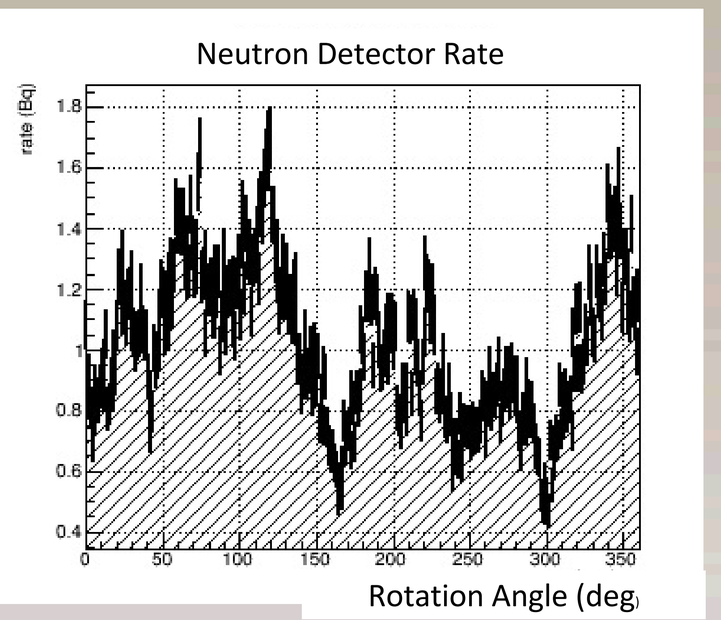




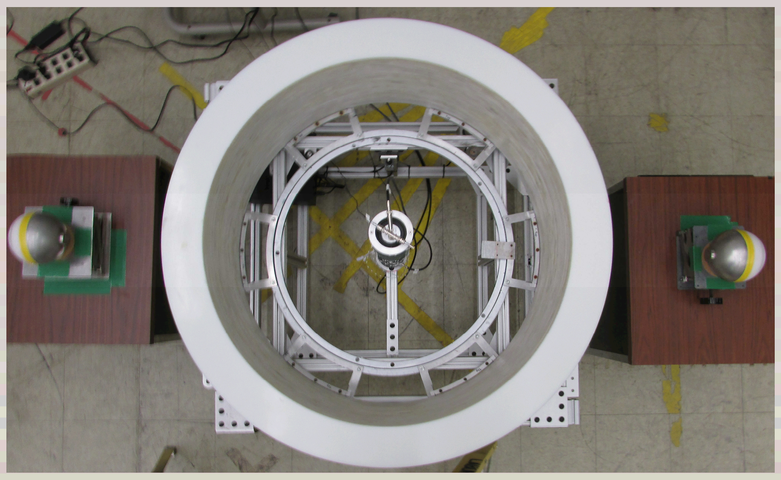
A pair of ^{252}Cf sources on the left side



Two identical pairs of ^{252}Cf sources on opposite sides



A pair of ^{252}Cf sources on the right side



Measurement of two identical Plutonium Oxide Hemispheres on opposite sides of CONFIDANTE

Object 1	Object 2	mean counts /deg	σ^2/deg	χ2/NDF	P(χ^2,NDF)
	Two ^{252}Cf at 130°	202.61	872.25	4.39	9E-152
Two ^{252}Cf at -50°		228.17	1219.55	5.43	2E-216
Two ^{252}Cf at -50°	Two ^{252}Cf at 130°	377.92	391.31	1.05	0.25
	PuO_2 hemi at 130°	9.97	12.45	1.28	3E-4
PuO_2 hemi at -50°		24.73	47.77	1.98	2E-25
PuO_2 hemi at -50°	PuO_2 hemi at 130°	19.16	19.56	1.04	0.27
PuO_2 hemi at -50°	PuO_2 hemi rotated by 90° at 130°	30.00	39.73	1.36	7E-6

Proof of concept measurements

The table (left) reports the results of two sets of proof of concept measurements: a pair of matched ^{252}Cf sources separated by 20 cm and a pair of matched PuO_2 hemispheres. Neutron counts as a function of rotation angle and reconstructed images of the ^{252}Cf pairs are shown above. It can be seen that when identical sources are exactly opposite, the rate is consistent with Poisson noise as indicated by the near equivalence of the count mean and variance and a χ^2/NDF of close to 1 against the null hypothesis of a constant rate. When one of the PuO_2 hemis is rotated by 90°, the null hypothesis is no longer consistent with the data.

[1] A. Glaser, B. Barak, R. J. Goldston, *Nature.* 13457, June 26, 2014, Vol. 510, pp. 497-502.
[2] P. Marleau, R. Krentz-Wee, Sandia Technical Report SAND2017-1649
[3] J. Brennan, E. Brubaker, M. Gerling, P. Marleau, et al, *Nuclear Instruments and Methods A.,* Vol. 802, pgs. 76-81, 2015.