Reducing medical isotope nuisance alarms in radiation portal monitors

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Motivation

- ❑ Smuggling of special nuclear material (SNM) → deployment of thousands of radiation portal monitors (RPMs) at borders, shipping ports, airports
- ❑ RPMs alarm on presence of elevated radiation above background (gammas, neutrons)
- ❑ Types of alarms
  - ○ Threat alarms (SNM, dirty bomb material): rare [1]
  - ○ False alarms (natural background fluctuation): can be avoided
  - ○ Nuisance alarms (nuclear medicine patients, cargo containing naturally occurring radioactive material (NORM)): PROBLEMATIC!
    - 100,000s of nuisance alarms in United States annually [2]
    - Largest culprits are ^{99m}Tc (medical) and kitty litter (NORM) [3]
    - Nuisance alarms processed with handheld spectroscopic radiation detectors → time, money
- ❑ Objective: RPM on-the-fly radionuclide identification → distinguish threat/nuisance

Fig. 1. RPMs at Baltimore port. http://www.kentimmerman.com/hkdox/portal-monitors.JPG

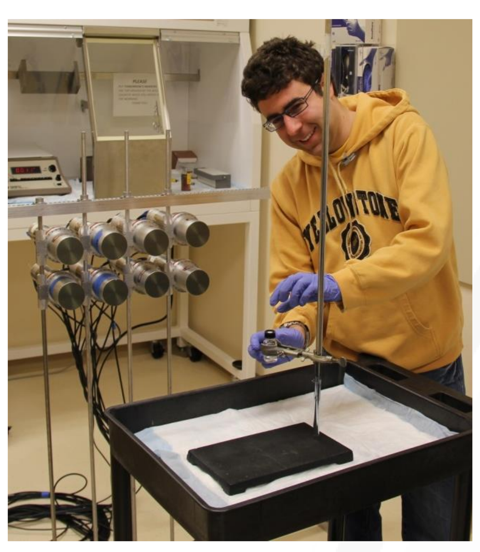

Fig. 2. Medical isotopes + pedestrian RPM at C.S. Mott Children's Hospital

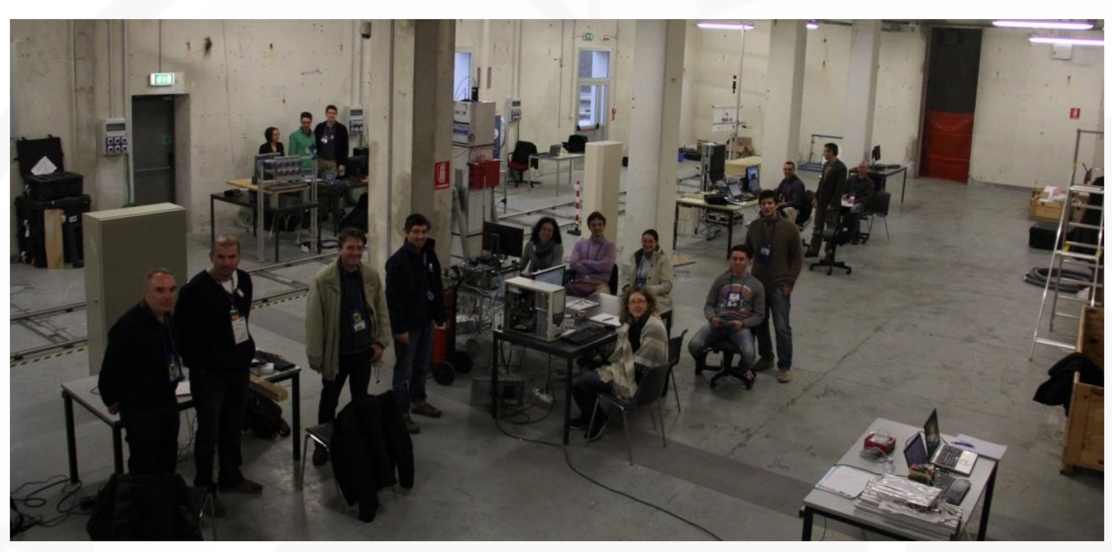

Fig. 3. Testing our pedestrian RPM at European Commission Joint Research Centre, Ispra, Italy.

Previous Work

- ❑ Pedestrian and vehicle RPM prototypes using organic liquid scintillation detectors [4-5]
- ❑ Tested on SNM and other sources at European Commission Joint Research Centre in Ispra, Italy, and at Los Alamos National Laboratory
- ❑ Strengths: zero false alarm rate; reliable alarming on shielded neutron and gamma sources
- ❑ Weakness: radionuclide identification algorithm worked well for many sources, but struggled with low energy sources (^{57}Co, ^{241}Am)

A New On-The-Fly Radionuclide Identification Algorithm Using Spectral Angular Mapping

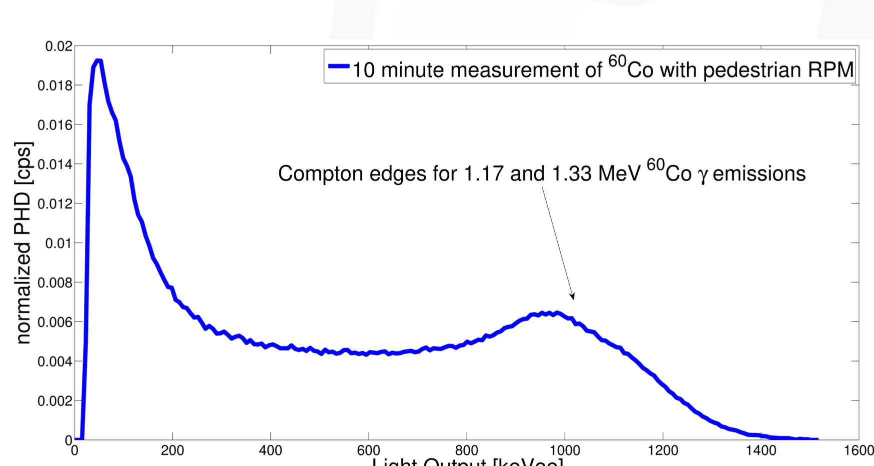

Fig. 4. Pulse height distribution (PHD) for long measurement time with pedestrian RPM.

- ❑ Radionuclide ID easy with good statistics (long measurement time)
- ❑ In reality, we get this →

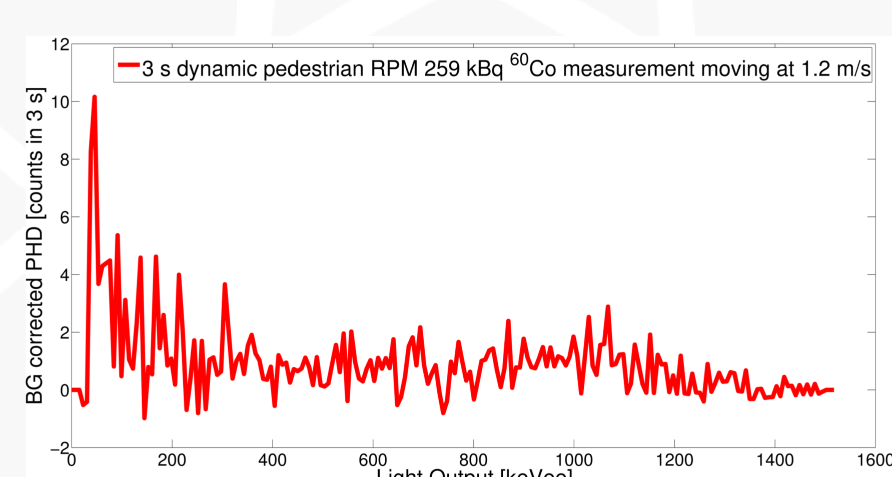

Fig. 5. PHD for moving ^{60}Co with pedestrian RPM at JRC Ispra in February 2014.

- ❑ Use CDFs to smoothen PHDs
- ❑ SNM, industrial, NORM, and medical sources

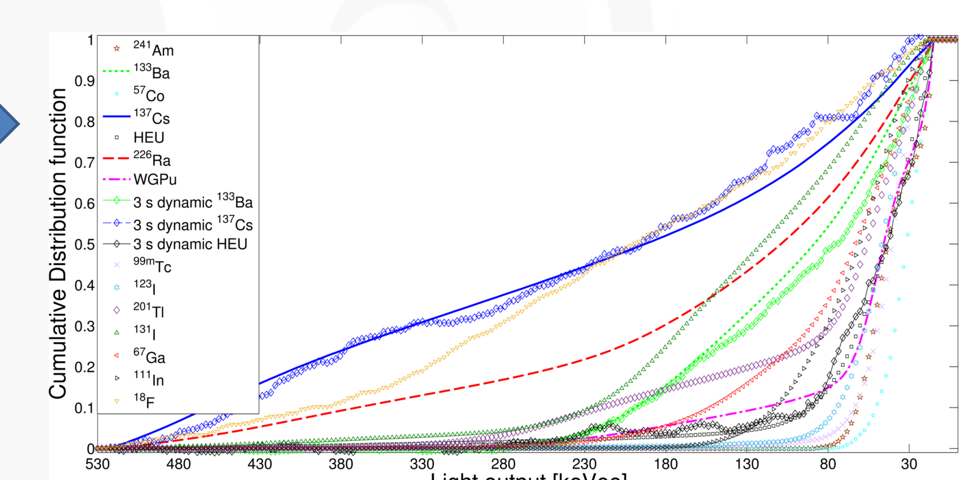

Fig. 6. Cumulative distribution functions (CDFs) for library spectra of low energy gamma sources and three dynamic measurements for pedestrian RPM at JRC Ispra in February 2014.

- ❑ FFT converts CDF into frequency domain → how rapidly does CDF change over its domain?

$$FFT(k) = \sum_{n=1}^{N} x(n) \exp\left(-j * 2 * pi * (k-1) * \frac{n-1}{N}\right), 1 <= k <= N,$$

where *FFT(k)* is amount of frequency in signal, *x(n)* is the CDF, *n* is the sample, *N* is the number of samples, *k* is the frequency

- ❑ For a continuous signal, the power spectral density (PSD) computes how "power" is distributed over frequency of the CDF by computing the square of the FFT.

$$PSD(k) = |FFT(k)|^2$$

- ❑ Spectral angular mapping (SAM) computes the spectral angle (in radians) between the PSD vector and a matrix of library PSD spectra for the library of radionuclides; the smaller the SAM value the better the agreement:

$$\alpha_i = \cos^{-1}\left[\frac{(PSD(k) \cdot PSD_{matrix}(:,i))}{\|PSD(k)\| \|PSD_{matrix}(:,i)\|}\right],$$

where we compute the spectral angle α between the PSD of one measurement and the library PSD spectra for any isotope i.

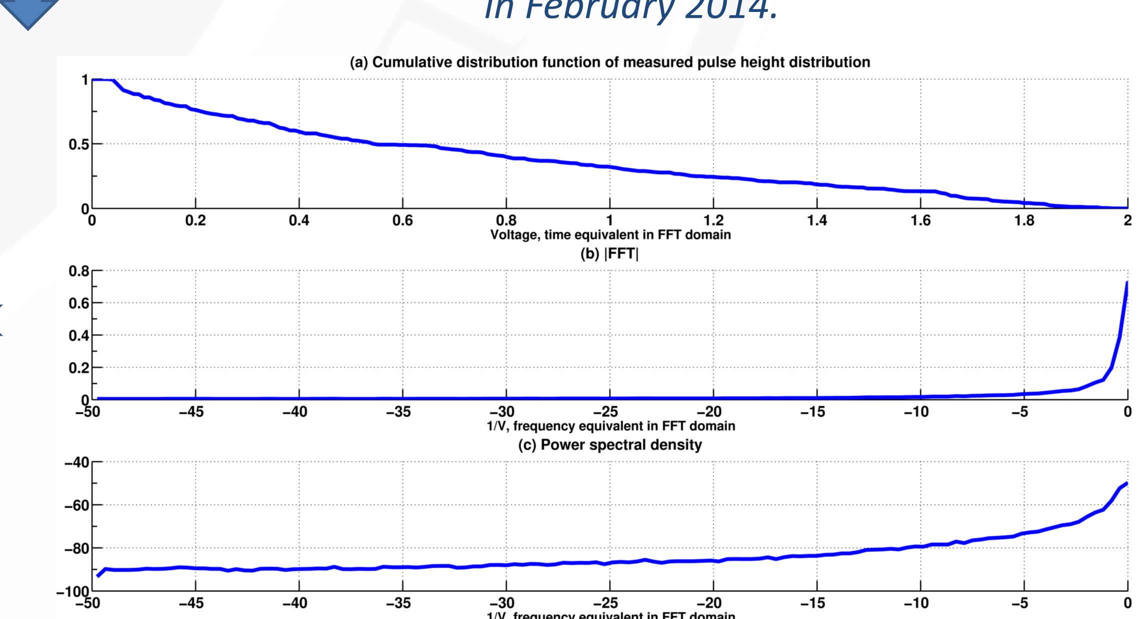

Fig. 7. (a) CDF of dynamic ^{137}Cs measurement with pedestrian RPM; (b) Fast Fourier transform (FFT) of CDF; (c) Power spectral density of FFT.

Results and Conclusions

- ❑ 100% correct identification with < ~5000 pulses (corresponding to 3 s dynamic measurement of source moving at 1.2 m/s past pedestrian RPM at 70 cm) on 30 trials per radionuclide for SNM (51 g HEU, 6.6 g WGPu), and a variety of medical and industrial isotopes (see Figure 6)
- ❑ Vast improvement over least squares CDF analysis [4]

Acknowledgments

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References

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