# Scintillator Coupled with Photographic Film for Application to Zero-knowledge Verification

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## Introduction and Motivation

- Verifying the authenticity of nuclear warheads requires gaining confidence on whether or not an object is a nuclear weapon *without* revealing any sensitive information.
- A zero-knowledge protocol using *pre-loadable* superheated-emulsion (bubble) detectors has previously been proposed for this purpose.
- As a possible alternative to these low-efficiency and spatial resolution bubble detectors, we propose a detection system of a ZnS(Ag) scintillator coupled with photographic film.

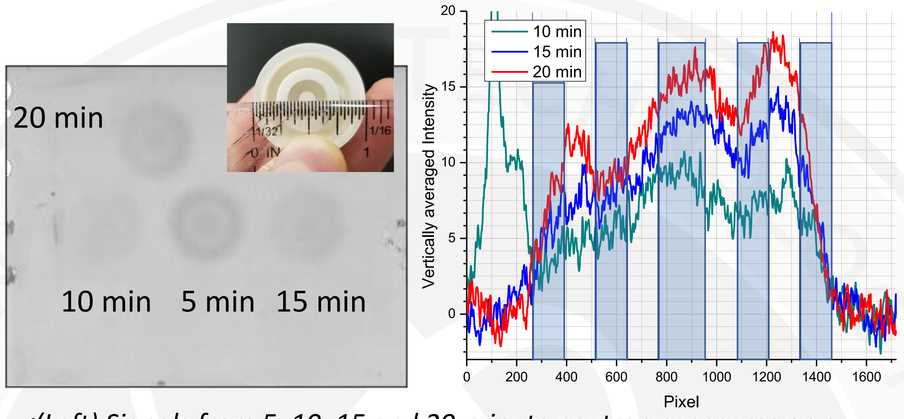
## Mission Relevance

- This study could present another pathway toward a practical and robust system for the development and implementation of arms control treaties.

## Technical Approach

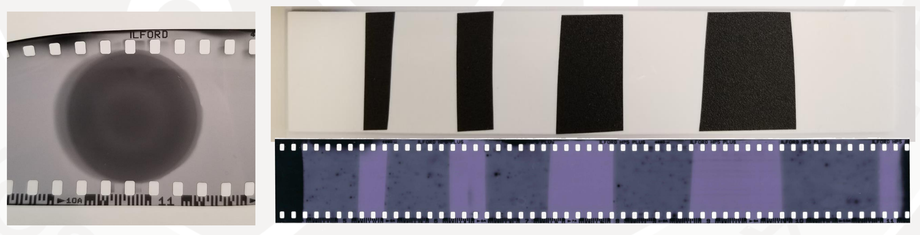
- At PPPL, we exposed 14 MeV neutrons on a 1” diameter EJ-410 ZnS(Ag) fast neutron scintillator half covered by a block of borated polyethylene, which was coupled with a 4”X5” Ilford HP5 400 photographic film.

## Results




*<(Left) Signals from 5, 10, 15 and 20-minute neutron exposures on a photographic film attached to a 1” EJ-410 ZnS(Ag) scintillator and (right) the film intensity for each signal. In the plot, the shaded regions correspond to the scintillator and the unshaded to the light guide.>*

- The side covered by poly had approximately 30% lower intensity as compared to the uncovered side.
- Image intensity vs. exposure time shows good agreement with the characteristic curve of the film.




*<(Left) A signal by a EJ-410 with 1-minute placement after 1-minute exposure to sunlight and (right) signals by a partially covered ZnS(Ag) screen (25 cm X 5 cm size) with one-hour placement after 1-minute exposure to sunlight.>*

- We noted the phosphorescence, or afterglow, effect of the scintillator when exposed to the sunlight.
- This effect was also observed with the ZnS(Ag) screen without a light guide, which showed non-uniform phosphorescence centers.

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## Expected Impact

- This study will provide a solid scientific basis for negotiation and a viable option for implementing a zero-knowledge protocol between two parties.

## MTV Impact

- Neutron exposure using a D-T generator (the Excalibur) was available at the TFTR site at PPPL.
- More neutron sources are to be tested at PNNL via 2021 summer internship.

## Conclusion

- A neutron scintillator coupled with photographic film might be able to be used as a good pre-loadable detector for zero-knowledge protocol.
- ZnS(Ag) should be out of light for anytime to avoid undesired afterglow effect or phosphorescence.

## Next Steps

- Neutron exposures are scheduled at PPPL and PNNL in March and summer 2021.
- We will study more on the property of ZnS detector and photographic film.

National Nuclear Security Administration