Time Encoded Fast Neutron Imager for Large Standoff SNM Detection

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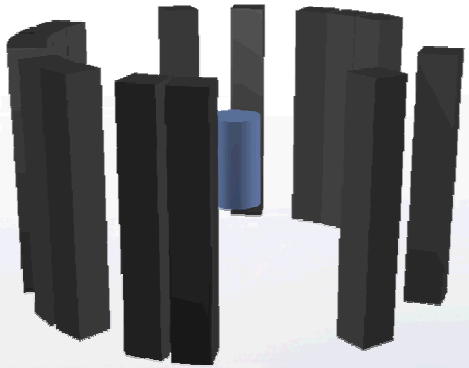

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SNM detection/imaging

Standoff detection

Cargo screening

Arms control treaty verification

Emergency response

SNM detection applications

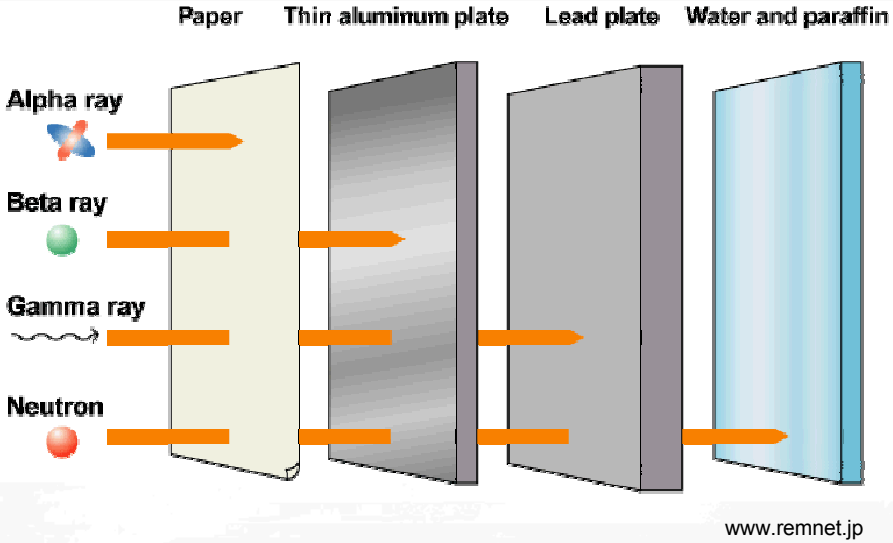
- **Low signal rate**
  - Need large area detectors!
- **Low signal to background**
  - Need background discrimination!

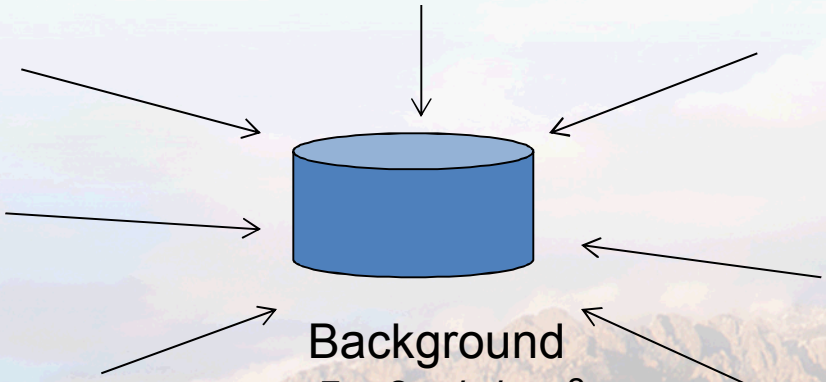
SNM imaging applications

- **High resolution required**
  - Fine detector segmentation
- **Multiple or extended sources**

Why fast neutrons?

- **Special nuclear material emits ionizing radiation.**
  - Sensitive and specific signature
- **Only neutral particles penetrate shielding.**
- **Low and fairly well understood background.**





Background
~5e-3 n/s/cm^2

~5.5e4 n/s/kg
IAEA sig = 8 kg

~1.5 n/s/kg
IAEA sig = 20 kg

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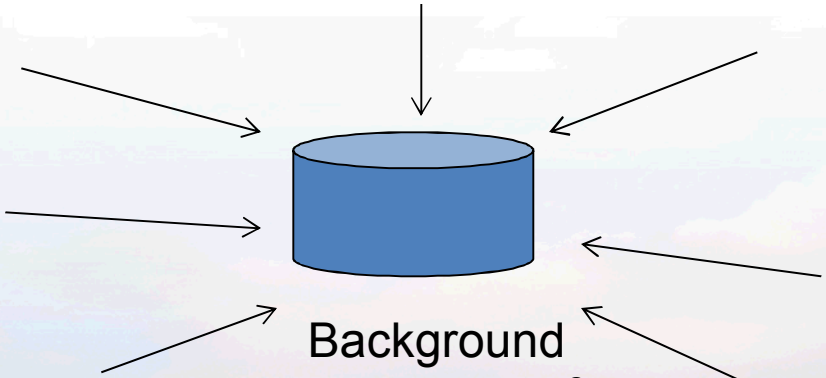
Why image fast neutrons?

- **Large stand-off application (100 meters)**
  - 8 kg WGPu = ~4.4e5 n/s → 4.4e5 *exp(-R/100)/$4\pi R^2$ **~1.3 n/s/m^2**
  - Background = **~50 n/s/m^2** (at sea level)
  - 100% efficient, 1 m^2 detector → 5σ det in ~13 minutes
  - 10% efficient, 1 m^2 detector → 5σ det in ~2 hours



Background
~5e-3 n/s/cm^2

~5.5e4 n/s/kg
IAEA sig = 8 kg

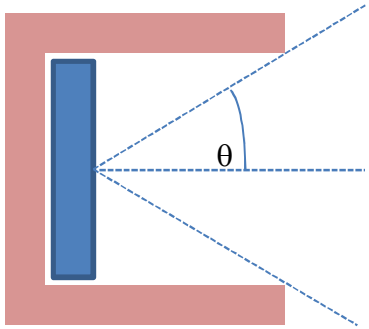
Signal to Noise Considerations

4π counter

S/N ~ S/√(B)

Colimated counter

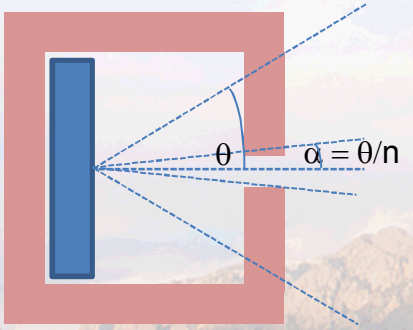
~ **Counter** / √ (1-cos(θ))/2)



Pinhole

~ **Counter** / √ (n/2 (1-cos(θ/n)))

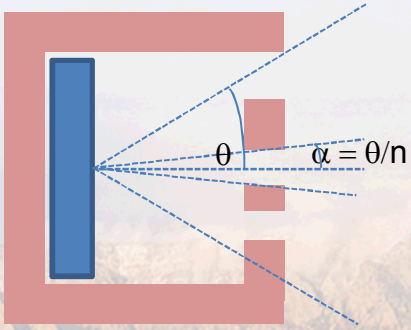
< Counter



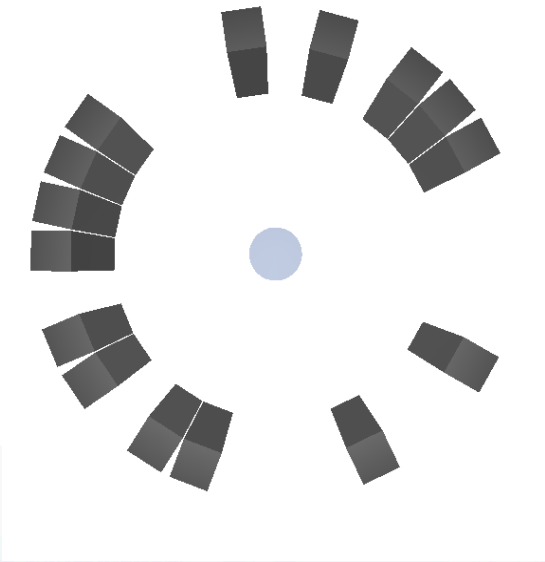
Coded Aperture

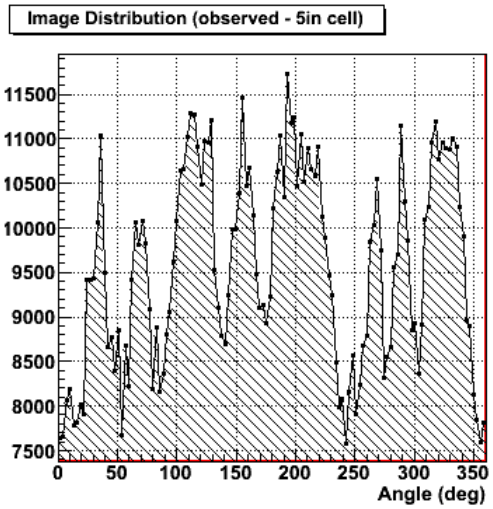
~ **Counter** / √ (1-cos(θ/2))

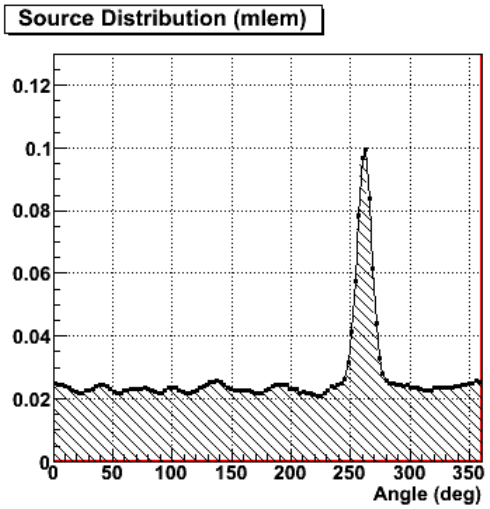
< Counter but > Pinhole



Time Encoded Concept

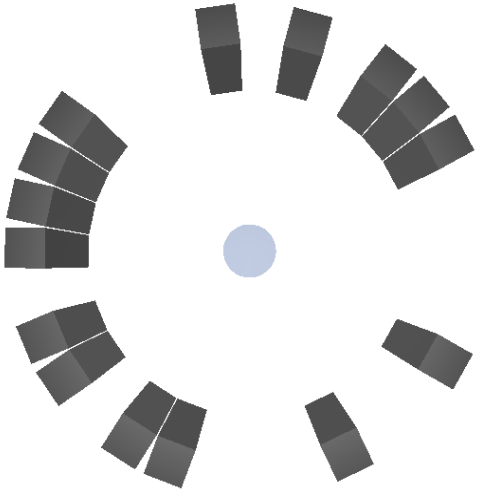


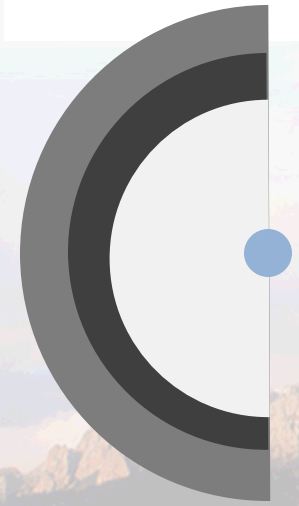


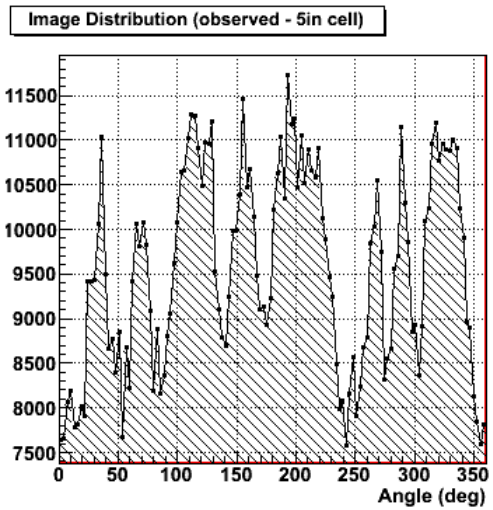


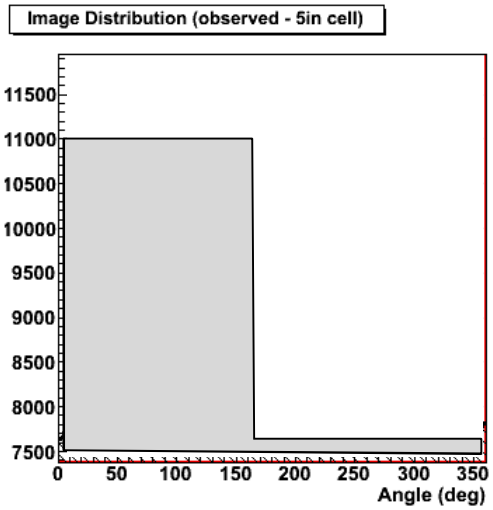
- Switch spatial modulation for time modulation.
- Simple and robust, low-channel-count detectors.
- Can scale to large effective area.

S/N vs. Angular Resolution

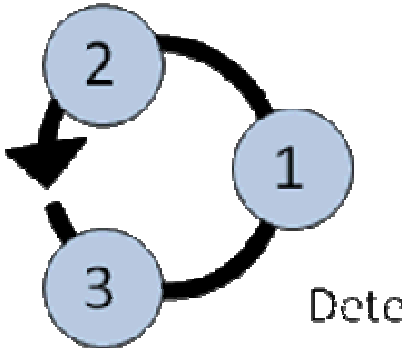


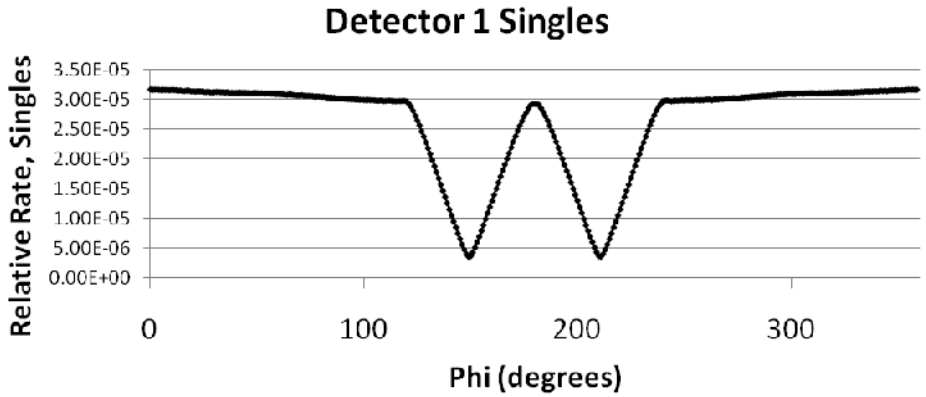






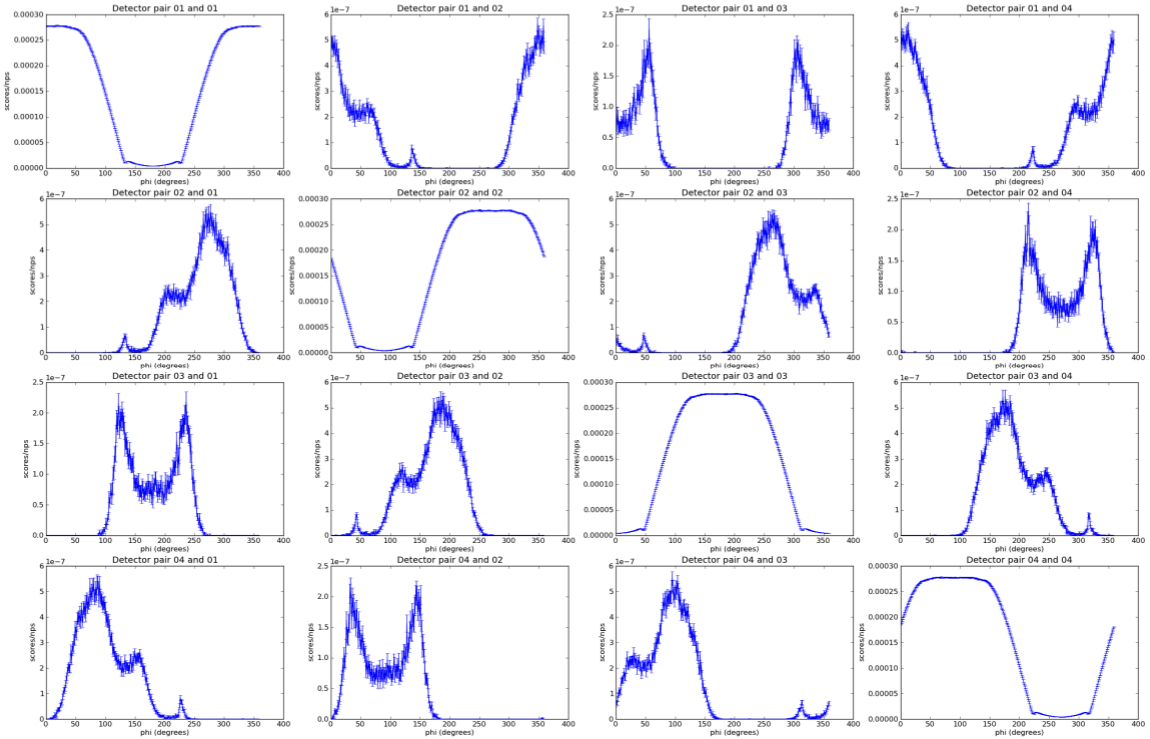
Rotational Self Modulation Concept





- Portable Rotating Imager using Self Modulation (PRISM).
- Rotating Collimator minus passive shielding material.
- More compact and easily scalable at the cost of intrinsic angular resolution.

PRISM imager – Monte Carlo Study



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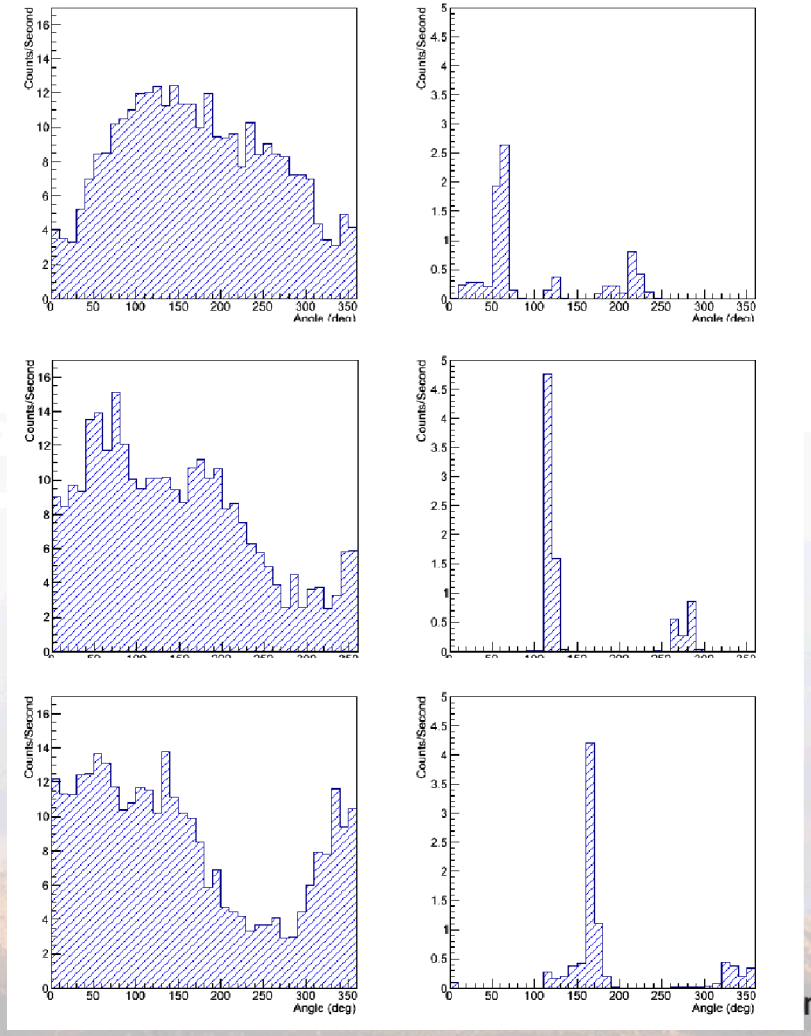
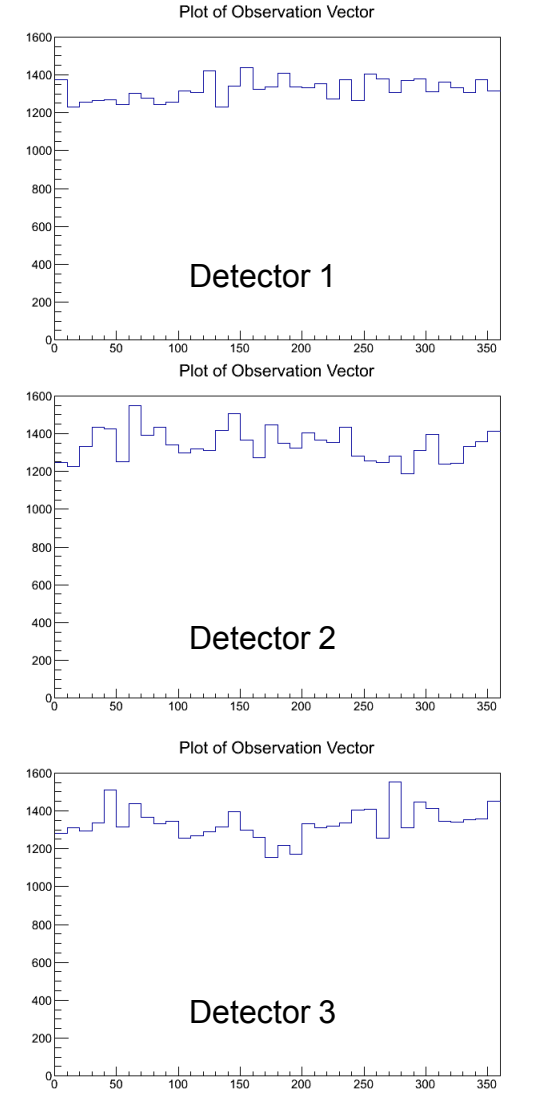
Stand-off tests (10 meters)

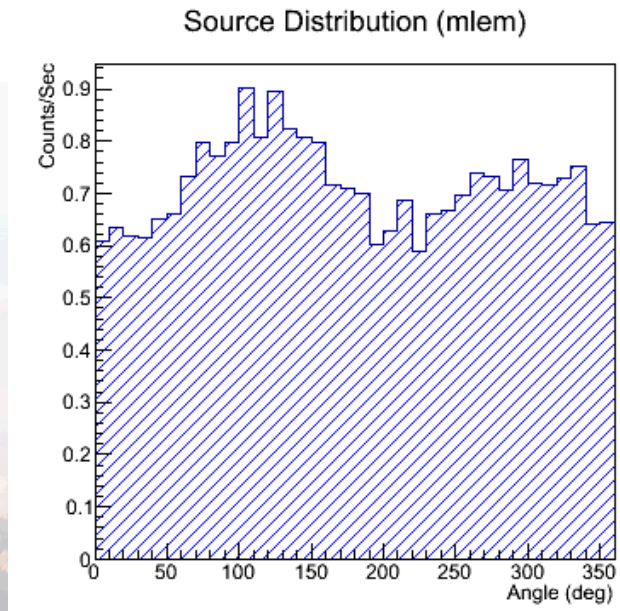
- Imager installed in 20 foot trailer for stand-off tests at Sandia.



Stand-off tests (60 meters)



- Source imaged and detected at 60 meters.
- 10 sigma detection above background in 1.3 hours.
- Systematics are still being worked out.



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Conclusions

- Extension of coded aperture imaging into the time domain successfully demonstrated.
- New rotational self collimating detector concept developed.
- Demonstration imager built and tested.
- Successfully detected and imaged fission sources at large stand-off.
- Future work includes two dimensional imaging using time encoding concept.