Using Neutrons to Screen for Explosives

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Summary

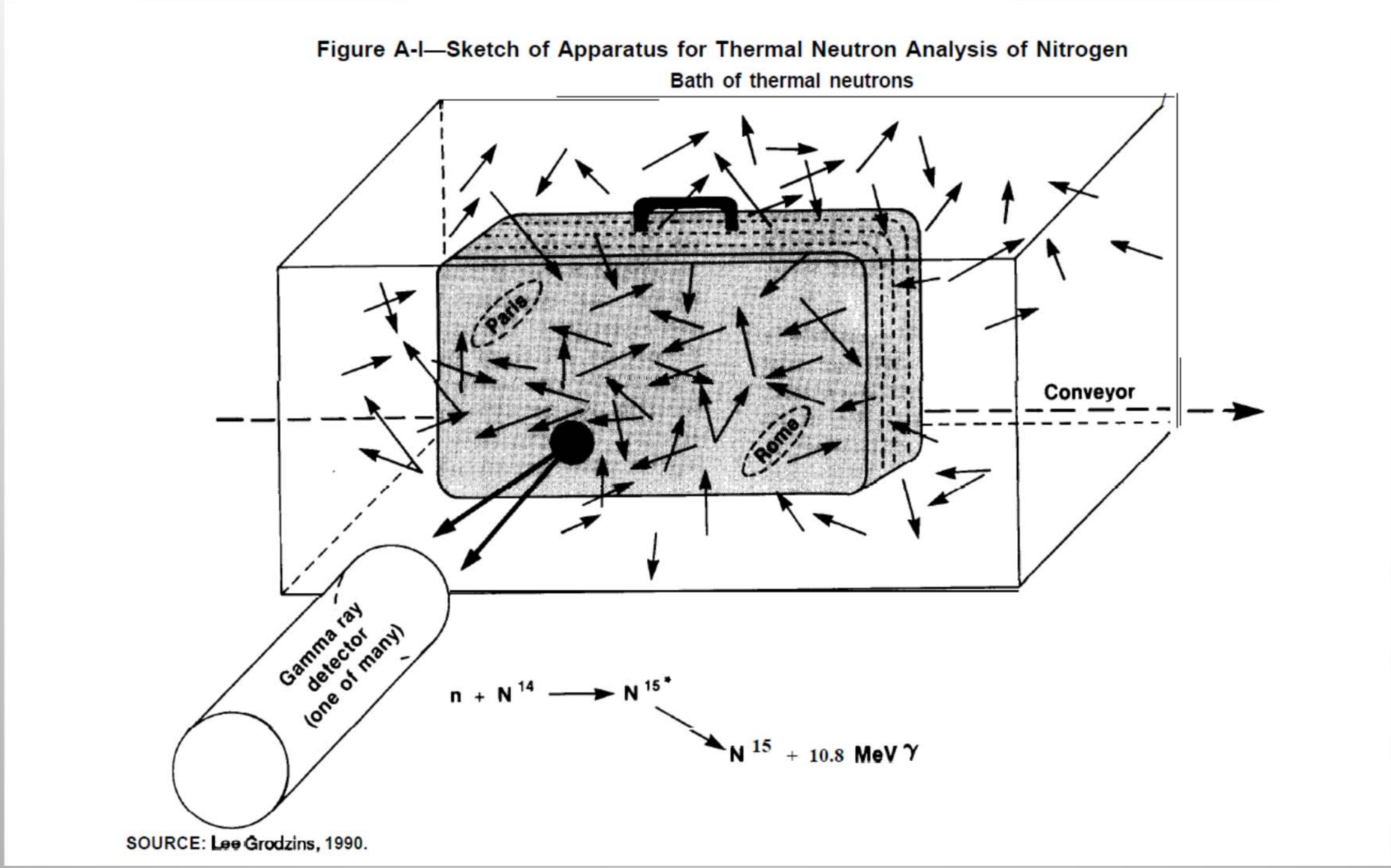
- Several neutron-based explosives screening systems (many of which I do not have time to discuss) have been investigated
- They have major technical limitations in either
  - Depth of penetration in large cargo and/or
  - Ability to detect a particular explosive class
- Furthermore most have practical limitations including
  - Large size and weight for accelerator/large radiation shielding
  - Regulatory and safety issues associated with neutron-based technologies
- Given this they have not been able to compete with X-ray-based technologies

P. Griffin, et al., Assessment of the Practicality of Pulsed Fast Neutron Analysis for Aviation Security, NAP, 2002.

Agenda

- Summary
- Neutron physics and operation of
  - TNA
  - FNA
  - PFNA
- Summary

Thermal Neutron Analysis—TNA Physics



TNA measures nitrogen via thermal neutron capture gamma rays

Summary of SAIC TNA machine airport deployments

- Under a contract awarded to SAIC in 1985, the FAA purchased six TNA machines to detect plastic explosives
- The six TNA machines needed to be combined with X-ray unit and were called XENIS—X-ray Enhanced Neutron Interrogation System
- Four were installed at
  - JFK
  - Dulles
  - Miami
  - Gatwick

Report to the President by the President's Commission on Aviation Security and Terrorism May 15, 1990*

- Commission began November 1989
- Charges
  - Evaluate existing aviation security systems
  - Options for handling terrorists threats
  - Treatment of families of victims of terrorists acts
  - Pan Am 103 tragedy (Dec 1988) was a point of reference
  - Findings with respect to the deployment of Thermal Neutron Analysis (TNA)
- Report completed May 1990

* http://books.google.com/books?id=PU2gl3TwFQ4C&pg=PA65&lpg=PA65&dq=Why+did+TNA+failed+to+detect+explosives+at+JFK&source=bl&ots=-3SBh9eqMi&sig=Yg13YThvRbXAZL9wud_XE4xwb5o&hl=en&sa=X&ei=cfdSUq-nI8mCygH4gYHgCw&ved=0CCsQ6AEwAA#v=onepage&q=Why%20did%20TNA%20failed%20to%20detect%20explosives%20at%20JFK&f=false

Commission's TNA machine findings and recommendations

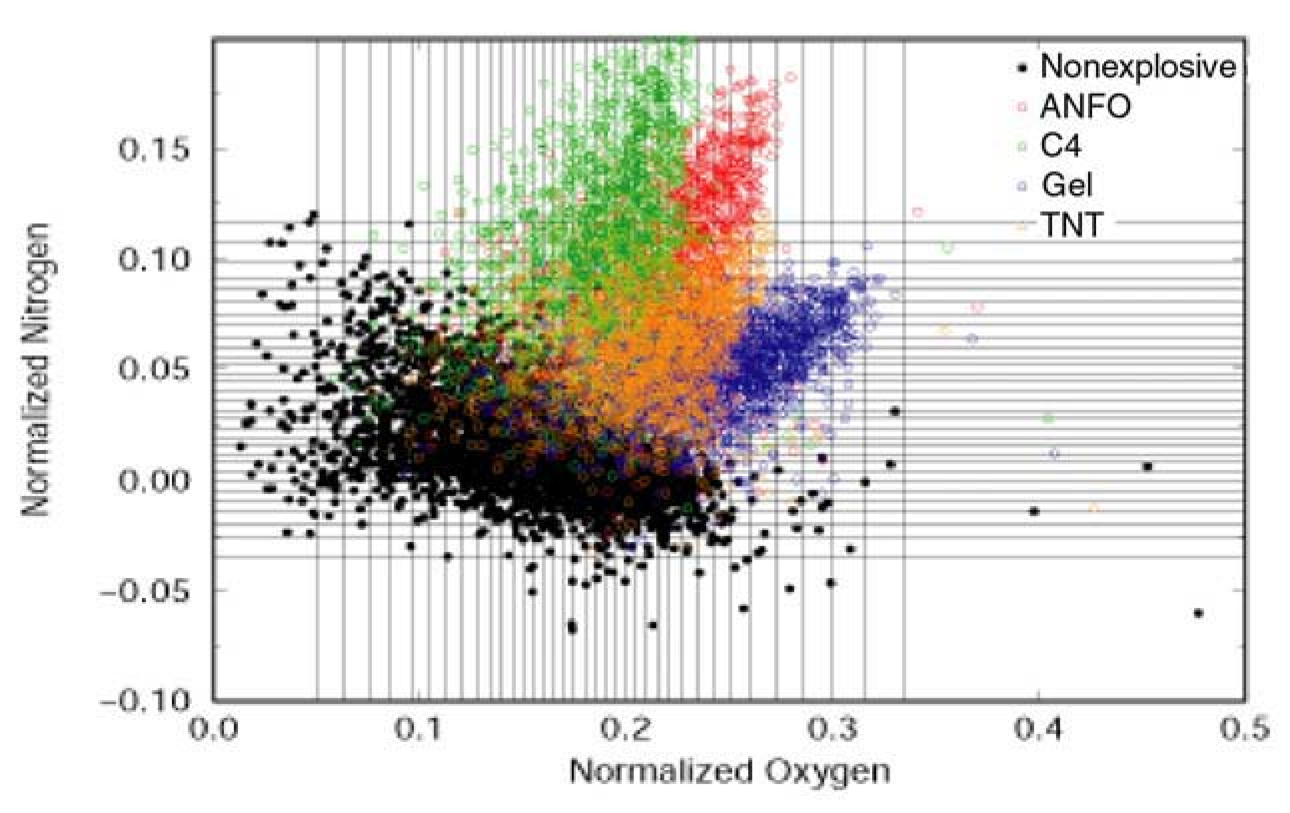
- Findings
  - Under a contract awarded to SAIC in 1985, the FAA purchased six TNA machines to detect plastic explosives
  - These machines by design and performance detected only amounts far greater than the weight used by terrorists
    - For example the bomb that destroyed Pan Am 103 is believed to have weighed half or less than the amount than the TNA machine would reliably detect
  - They were not fully automated
  - The TNA/XENIS machine is massive, weighing close to 14 tons and a footprint for the TNA alone is about 12 m^2, and an additional equivalent area would be needed to add an x-ray system and baggage diverter* NAP: TNA weighted 28,000 lbs., required 41-m^2 and cost $1.4M & $0.7M operational cost/yr.
  - For threat masses of concern the false alarm rates are too high
- Recommendation
  - The program to require US airlines to purchase and deploy ~150 existing TNA machines should be deferred.
  - The FAA should create an R&D program to detect small amounts of plastic explosives.

Given the large false alarms for TNA machines other neutron based methods were explored

* http://www.skyjack.co.il/pdf/Thermal-Neutron-Analysis.pdf

Oxygen vs. Nitrogen signatures

38,000 Pulsed Fast Neutron Transmission Spectroscopy (PFNTS) measurements from actual airline suitcases, with and without explosives



From Chmelik, et al., Analysis of Blind Tests for Explosives in Luggage Through Fast-Neutron Transmission Spectroscopy, 1997.

Hydrogen vs. Carbon signatures

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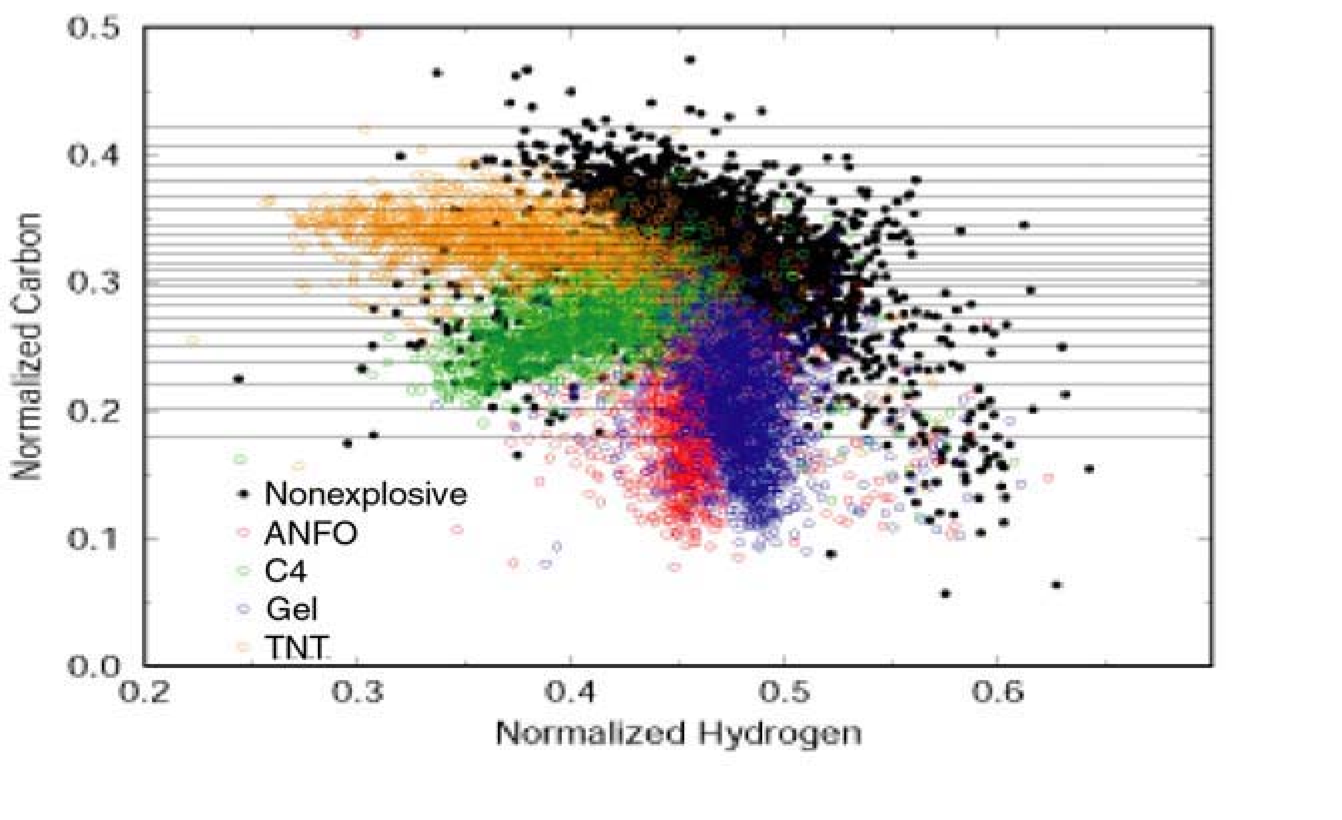

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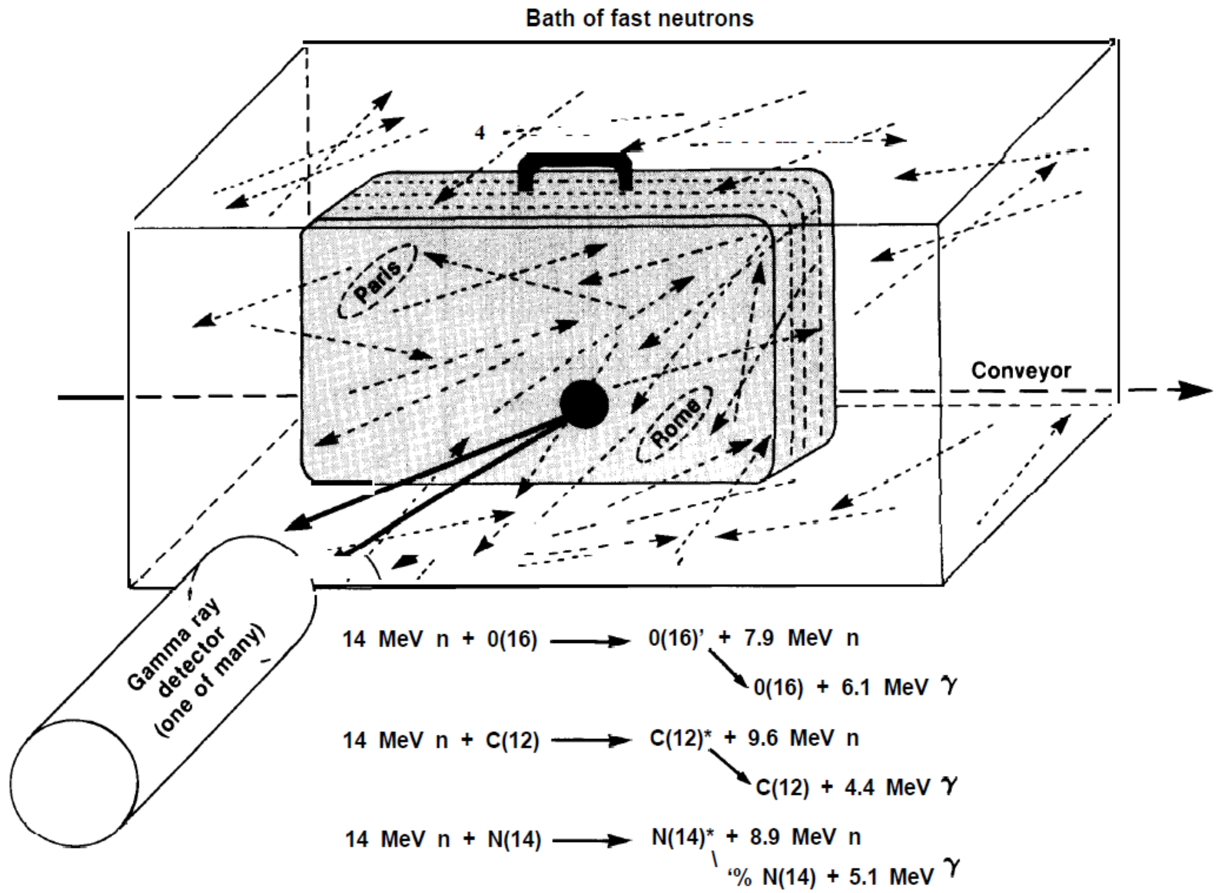
Fast Neutron Analysis–FNA Physics



SOURCE: Lee Grodzins, 1990.

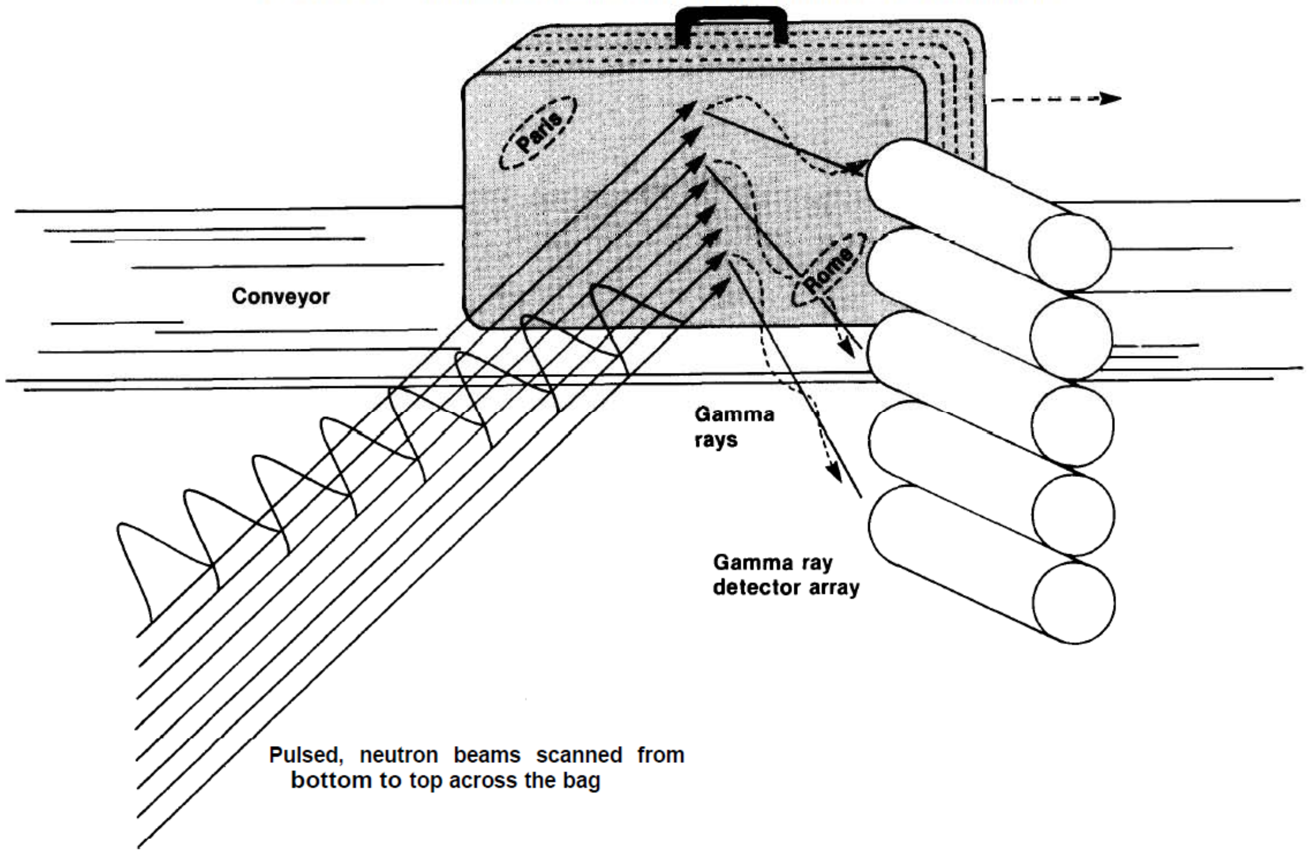
FNA measures gamma rays via fast neutrons inelastically scattered off of C, O and N

Summary of Fast Neutron Analysis—FNA

- FNA can measure more than just N so it should improve detection while reducing false alarms
- FNA is physically similar to TNA but there are significant differences in the neutron source, shielding requirements and gamma-ray detector resulting in an increase in cost size and weight
  - A fast neutron source requires an accelerator, e.g., $^{2}H(d,n)^{4}He$
  - Requires more shielding
- The fast neutrons create a lot of background in the gamma detectors
- 2D images were generated by collimation of the neutron beam
- 2D image is not good enough to sort threats from non-threats just using the atomic ratio features

Pulsed Fast Neutron Analysis—PFNA

Figure A-3-Sketch of Apparatus for Pulsed Neutron Beam Analysis



SOURCE: Lee Grodzins, 1990.

Summary of Pulsed Fast Neutron Analysis—PFNA

- PFNA concept is similar to the FNA concept except that a focused collimated, pulsed beam of neutrons is used
- A lower energy neutron beam accelerator, $^2H(d,n)3H,e$ is used since it generates less background in gamma detectors
- The collimated neutron beam provides two-dimensional position
- Timing and image reconstruction provides the third dimension
- The 3D image provides an improvement over the FNA data but with large isotropic voxels 5 cm x 5 cm x 5 cm
- A prototype system to look at LD-3 containers was not very promising it had PD and PFA issues*:
  - Can't see zone
  - Cannot detect a particular class of explosives
- An SAIC system built to screen cargos for large threat masses in cargo
- The system is much larger than a TNA system

* C. Bell and D. Green, Pulsed Fast Neutron Analysis (PFNA) October 2000 Test Overview, viewgraphs presented to NAS PFNA study Panel, Jan, 2001.

Schematic of PFNA for cargo inspection

D.R. Brown, T. Gozani / Nucl. Instr. and Meth. in Phys. Res. B 99 (1995) 753–756

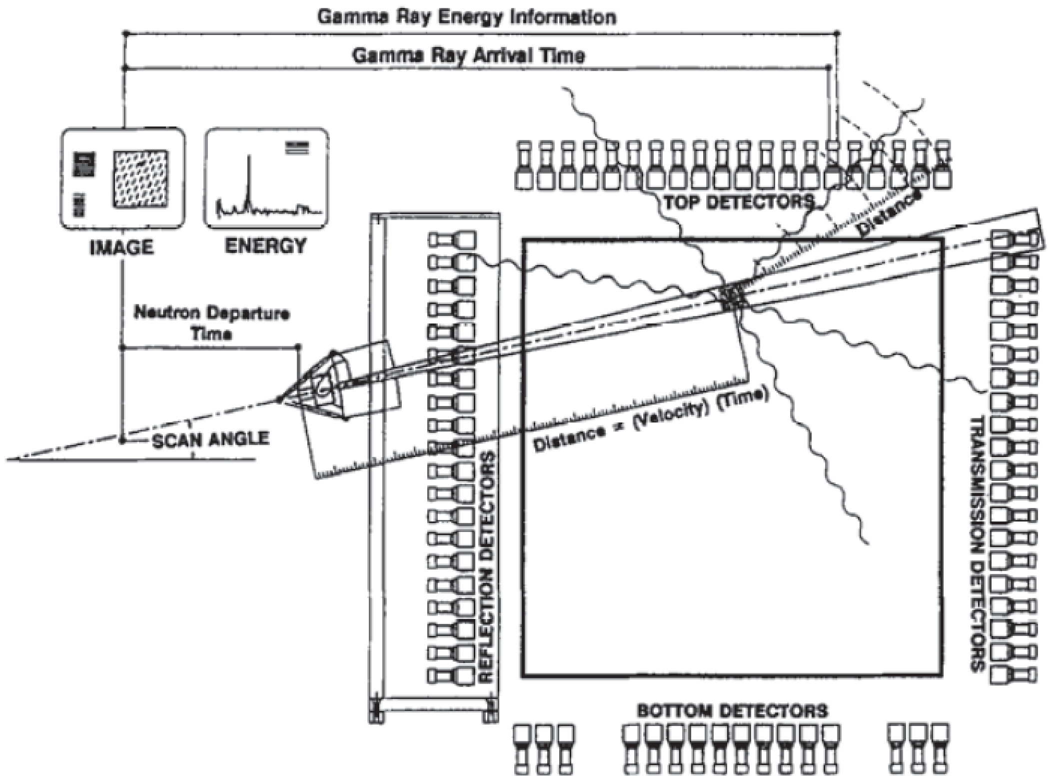


Fig. 1. Schematic view of the cargo inspection system based on PFNA.

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