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The School of Physics
The University of Melbourne
PARKVILLE 3052
AUSTRALIA

Neutron Capture on Nitrogen as a means of detecting Explosives

M. N. Thompson and R. P. Rassool

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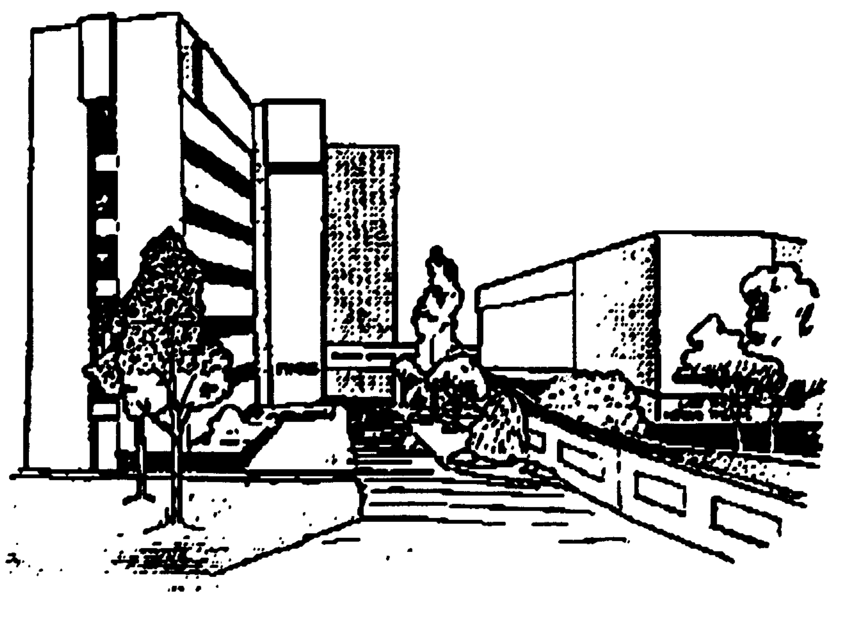
A talk presented at
The In-Service Training Seminar
of the
International Association of Bomb Technicians and Investigators

Held in Canberra ACT
October 13 1994



Neutron Capture on Nitrogen as a means of detecting Explosives

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Introduction

My colleague and I are somewhat interlopers in this conference. We do not come from a security environment, but from the University of Melbourne School of Physics. We intend to tell you of a development that we think is relevant to security, namely bomb detection; however we are here to learn about the areas of security that are important, and are very much the students in this field.

I list below the people who are associated with this program

Associations

Photonuclear Research Group
School of Physics
University of Melbourne

Roger Rassool	***Researcher and Executive Manager of School***
Max Thompson	***Group Leader and Deputy Head of School***
Craig Everton	***MSc Student***
Prof H. Hadizadeh	***Visiting Research Fellow***

With Acknowledgments to

Prof. K. G. McNeill Toronto University

Why we left the ivory tower

One might ask why we two academics have left the safety of our ivory tower to venture into the world of bomb detection.

Last March there was a bomb sent to the NCA which killed one person and did significant damage. This shocked me, as I saw this as completely alien to the Australian way of life. The newspaper report, perhaps wrongly that the bomb could not have been detected. This seemed at odds with my knowledge of science, and I wrote at once to the NCA saying that if they could not have detected the bomb my research group could have.

We had, a few years earlier developed a device, using nuclear principles, to measure the protein content of the human body. This unit is now in routine use in one of the large Melbourne hospitals. The NCA promptly called us in for an interview, and we have spent some six months researching a device, based on nuclear physics principles, that will detect parcel and letter bombs. The research goes on, but I wish to show you the status that our group has reached with, what for a better word, we call SNUPA.

The University of Melbourne
School of Physics

Slow
Neutron
Universal
Parcel
Analyser

Our aim in the first instance is to develop a unit that will examine parcels and mail articles, and indicate whether or not they contain explosive material as small as 100 gram. The intention in the first instance is that this unit will give an answer in a period of about 10 minutes.

We would plan that ultimately the device will be developed to provide mass screening of mail, and other articles as a routine security check.

In order to compare our device, I want to summarise what little I have gleaned about the current methods of explosive detection. Here I claim little expertise, and assume that in some period after the talk you will fill me in as to where my presumptions are in error.

Some available detection methods

x-rays

- Advantages
  - currently in operation
  - relatively cheap
- Dissadvantages
  - poor contrast for light materials
  - rely on shape recognition
  - subject to operator fatigue and boredom

Vapour detectors

- Advantages
  - very sensitive
- Dissadvantages
  - probably too sensitive...not discriminative
  - problems if explosive completely sealed

Dogs

- Advantages
  - fairly sensitive
  - 95% effective
- Dissadvantages
  - requires skilled trained personnel

By contrast, I want now to list the characteristics of the unit we are currently developing. I have listed the advantages as we perceive them in the following vugraph. We believe that this unit will answer a real need in explosive detection

Parcel Analyser

sensitive
currently 40 gram of explosive

completely objective
no operator subjectivity

Routine operation

insensitive to nature of container

does not rely on vapour emissions

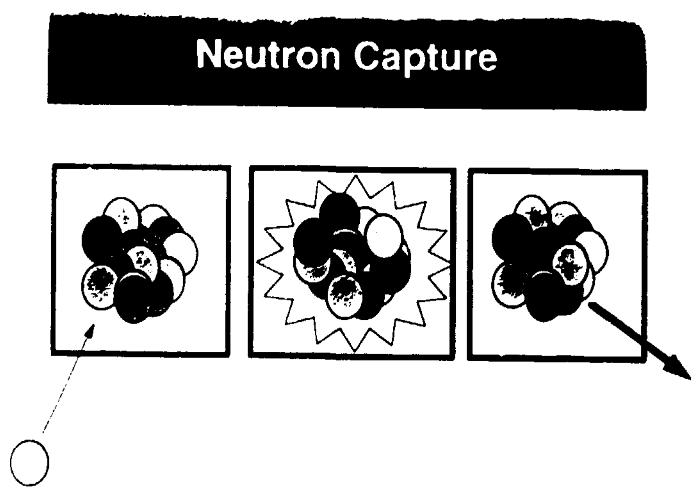
Principle of operation

Let me now tell you how the device operates. I will not give you a complete course in nuclear physics, with an emphasis on neutron capture, but I think that you might be interested to know how fundamental is the principle of operation, and how this might lead to its fundamental integrity and reliability.

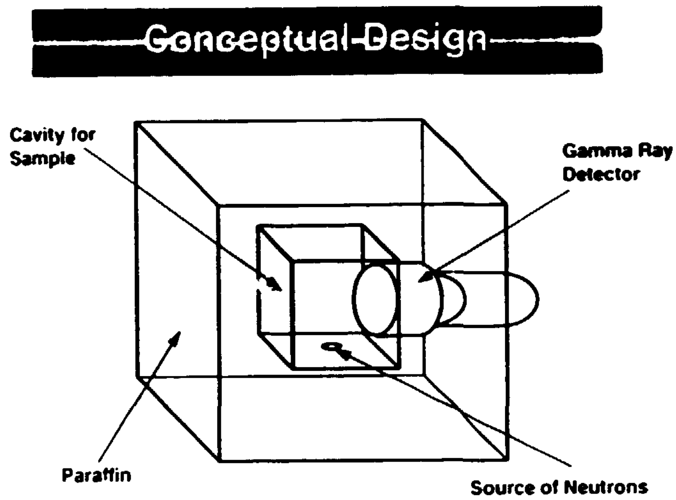
Principle of Operation

- # Stable explosives contain the element <u>nitrogen</u>
- # We can detect the presence of nitrogen using nuclear techniques
- # The nucleus of normal nitrogen contains 7 protons and 7 neutrons
- # We force the nitrogen nucleus to absorb another neutron
- # The nucleus is too heavy and emits a gamma ray
- # The size (energy) of this gamma ray is unique for nitrogen
- # We detect this 10.8 MeV gamma ray
- # The presence of these gamma rays indicates possible presence of explosive.

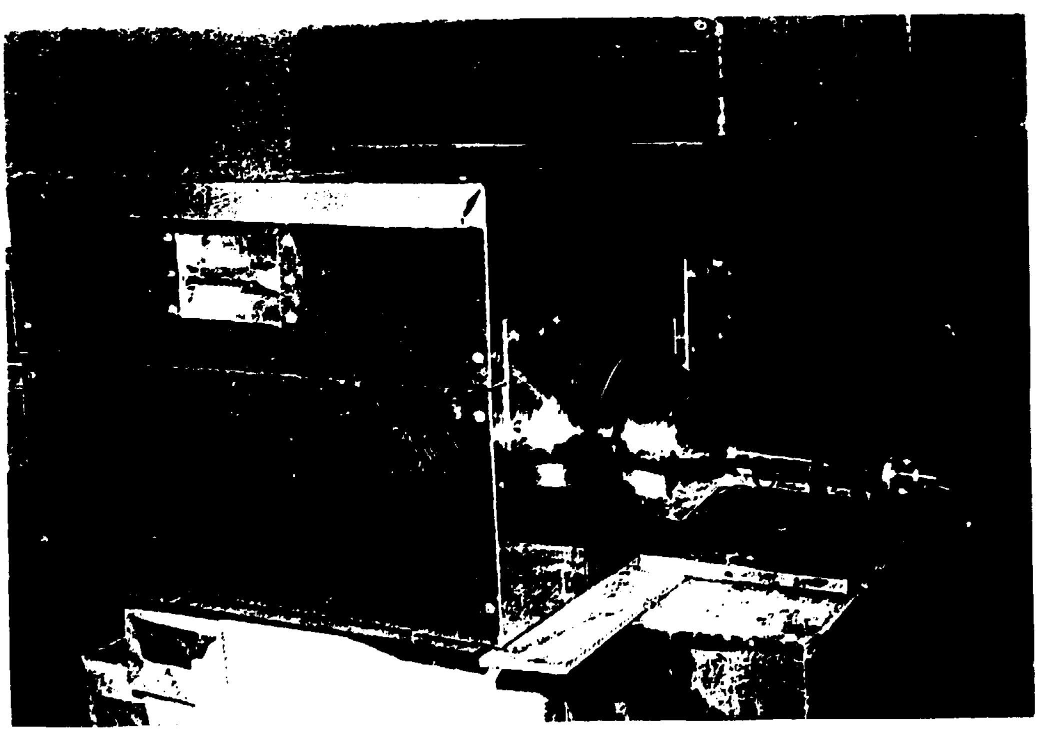
The nucleus of nitrogen has 7 protons and 7 neutrons, and as such is quite stable. If we can force it to absorb an extra neutron, it becomess essentially too heavy to be stable. It subsequently gets rid of this extra energy in the form of a gamma ray or high-energy x-ray. The energy of this gamma ray is 10.8 MeV, and is unique to the process of neutron capture by nitrogen. It is this gamma ray that is detected as an indication of the presence of nitrogen, and the probable presence of nitrogen-containing explosive. The nuclear process is illustrated below



Requirements
How do we put this principle of operation into practice. The reality is that the unit is basically very simple. It consists of a source of neutrons, which we want to have captured by the nitrogen nuclei, and a detector with which to observe the emitted gamma rays when the neutrons are captured. Since the nuclei are so small, we need all the help we can get to improve the chance that the nitrogen will accept a neutron. This is achieved by slowing down the neutrons, which leave the source with tremendous velocities, so that when they amble past the nitrogen they will be sucked in. The basic design is shown in the following viewgraph.

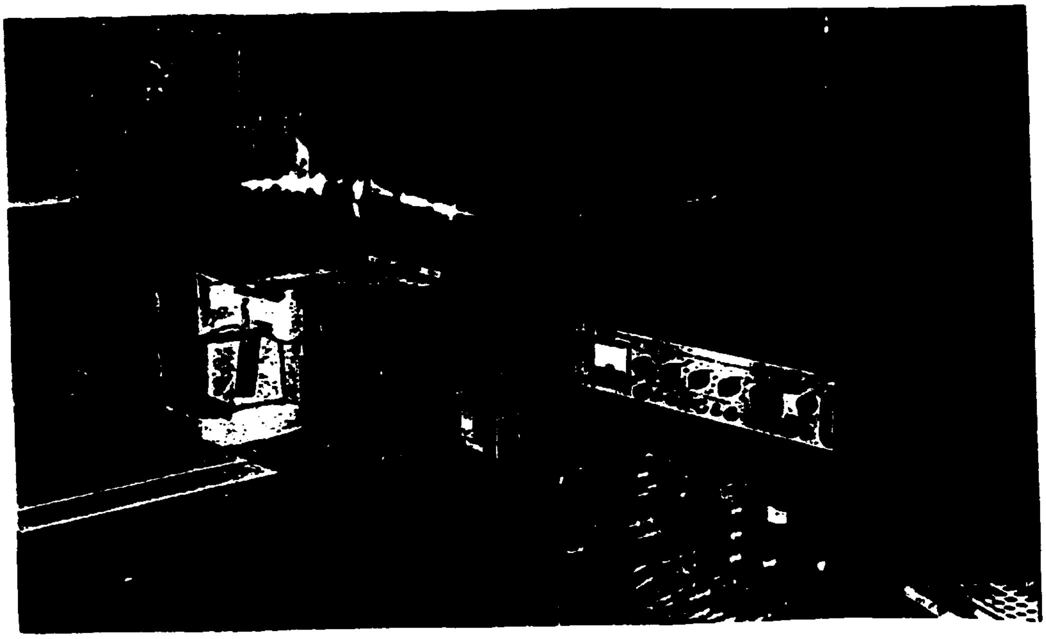


In reality the unit is quite small, and is shown in the following slide

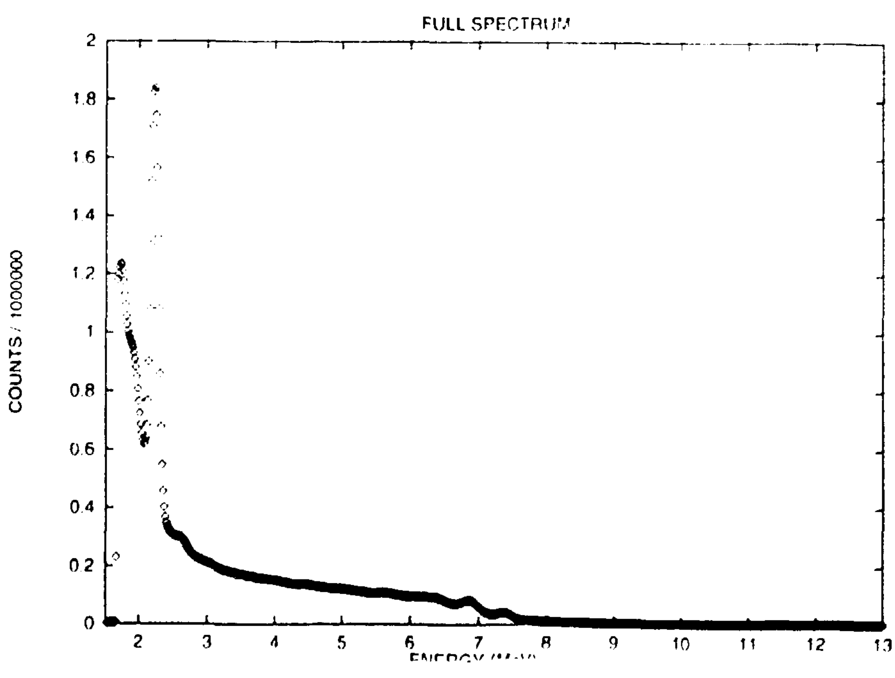


What do we see that is evidence of the presence of nitrogen in the sample inside the cavity?

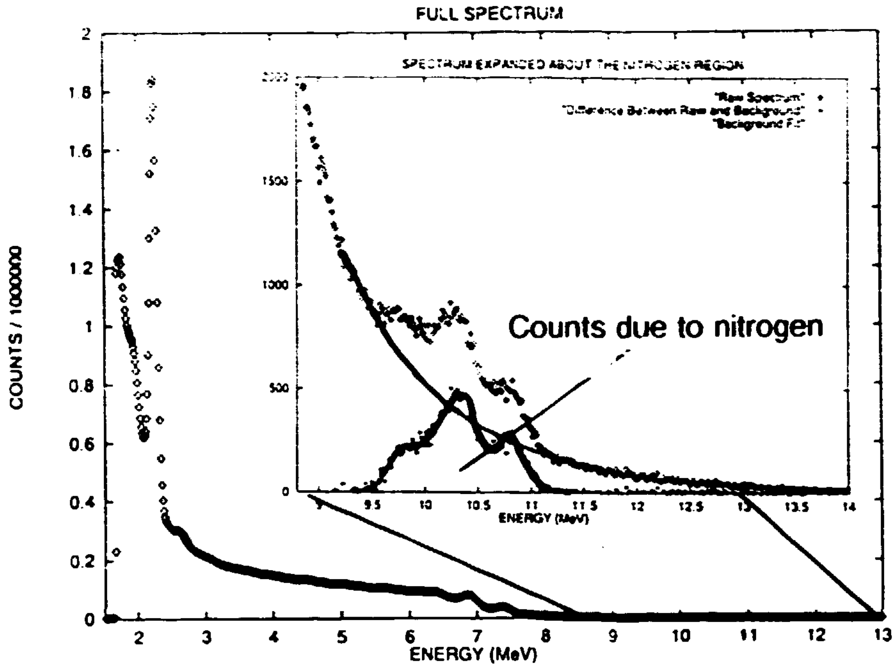
The signal from the large gamma-ray detector is analysed by a unit that sorts out the signals according to size. In practice this is a small computer interfaced to a Pulse-Height-Analyser. The test electronics is shown in the next slide



Let me show you what the plot of pulse-height looks like in practice what do we see? The figure below is a plot of the spectrum obtained with a sample containing some 70 gram of nitrogen (equivalent to about 200 gram of plastic explosive) . It is a quite complicated picture, with literally millions of recorded events, and when I remind you that we are looking for evidence of a gamma ray of energy 10.8 MeV, you might well throw up your hands and say there is none there.



Here we are very fortunate. The nuclear physics of Nitrogen ensures that the gamma ray from nitrogen is the most energetic of all common capture gamma rays. Let me focus in on the high-energy region of the spectrum, and magnify it.

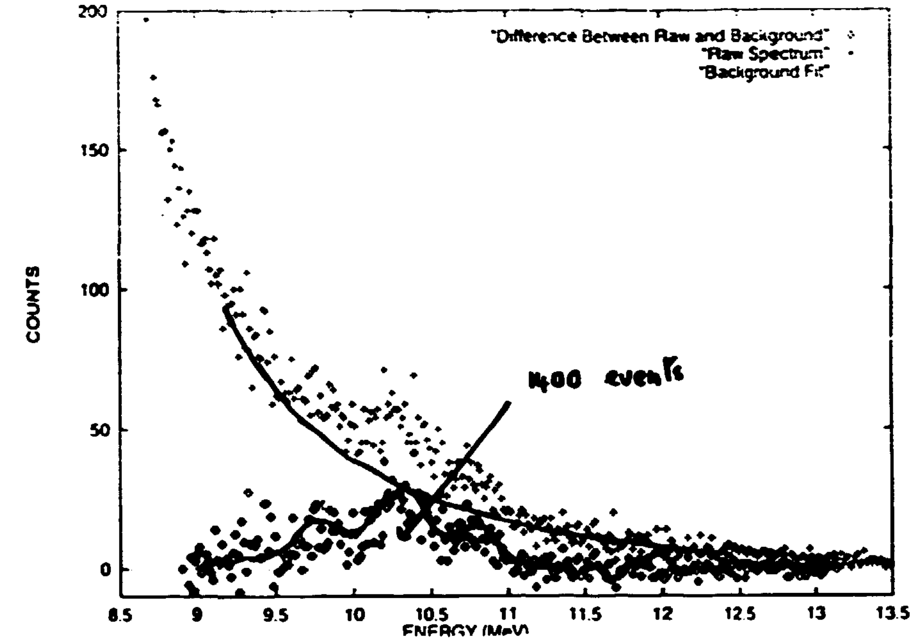


Here we can see the part of the spectrum that says there is nitrogen in the parcel. There are many hundreds of gamma rays in this energy region associated with the presence of nitrogen. They are made more evident if we subtract the smooth, underlying detector-response as shown.

Limited tests with explosives

We were fortunate to have been lent some samples of standard explosives. These included 700 gram of TNT and some 160 gram of PE4.

The TNT sample was easily detected in a run of 10 minutes. The presence of the nitrogen gamma-rays can be clearly seen in the spectrum below. The number in this region would in fact allow a quantitative measurement to be made.



With our developmental unit we were able in a similar period to identify the presence of the plastic explosive from the spectrum. Even the 35 gram detonator gave a response that would have indicated that, if it were in a parcel, the parcel was unsafe to open.

Developments

Future Research Developments

"User friendly" system

Current research prototype needs researchers to operate

Commercial unit will simply say "open" or "DON"T open"

Increased sensitivity

Research into neutron flux.

Use of multiple gamma-ray detectors

Inclusion of this unit as one of a series of tests

x-rays, vapour detectors

Neural networking

Teach the driving computer to interpret many clues as to the content of the package.

Our research prototype must be further developed. Its sensitivity needs to be improved, and importantly it needs to be made "user friendly". We envisage that it will form part of a routine scanning procedure in the future.

Cost of unit as currently developed

The cost of developing our research prototype is quite high. The infrastructure, and research time that has gone into it must sum to well over $150,000, not realistically including manpower costs. Indeed we find the program severely limited because of the lack of ready funding for development. However it seems to us that a unit capable of detecting 100 gram of explosive in a time frame of about 10 minutes will cost of order $100,000.

Naturally there are more serious limitations if even higher sensitivity is needed, and if time constraints are more stringent. The sensitivity requirements bear strongly on the unit cost.

Summary

We plan to continue our research and development, and I summarise the characteristics that make our venture likely to succeed.

What we offer

Experienced researchers

A proven and routinely operated total-body-protein unit operating in a Melbourne hospital.

A unique combination of expertise in

Nuclear Physics
Data acquisition
Computer innovation

A demonstrated research unit with sensitivity better than 100 gram.

The intellectual ability and research infrastructure to improve and adapt the technique.