APPLICATIONS OF NEUTRON ACTIVATION SPECTROSCOPY

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- Introduction
- Neutron radiography
- Cancer detector
- Homeland security
- Summary

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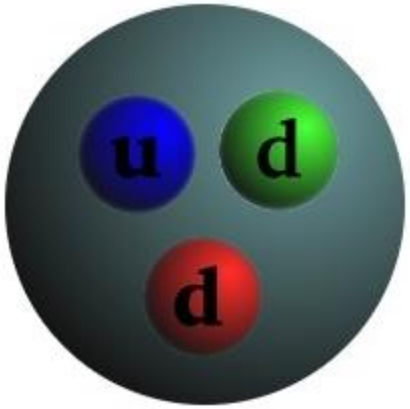
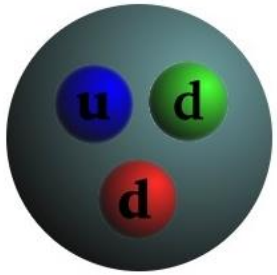
Neutrons: particles with great application potential

- **They are highly penetrating**
- **Can be used as nondestructive probes**
- **They are sensitive to light atoms**
- Neutrons have a magnetic moment: they can be used to study microscopic magnetic structure, to develope magnetic materials, …..



Neutron interactions with matter



- Elastic scattering: (n, n) reaction
  (moderation of neutrons)
- **Inelastic scattering: (n, n'γ) reaction**
  (stochiometry analysis)
- Neutron capture: (n,γ) reaction
  (neutron radiography)
- Charged particle emission: (n, p) and (n,α) reactions
  (neutron detection and shielding)
- Neutron producing reaction: (n, 2n) and (n, 3n) reactions
  (fast neutrons, neutron intensity increasing)
- Fission

Some practical applications

- Neutron radiography:
  - Validating the proper fill of explosives in actuators
  - Studying the flow of oil in automobile transmissions
  - Detect leaks in complex piping systems using Isotope tracers
  - Facilitate Fluid flow analysis
  - Determine pyrotechnic product quality
  - Study radioactive samples
  - … and much more!

photograph

neutron

X-ray

Some practical applications

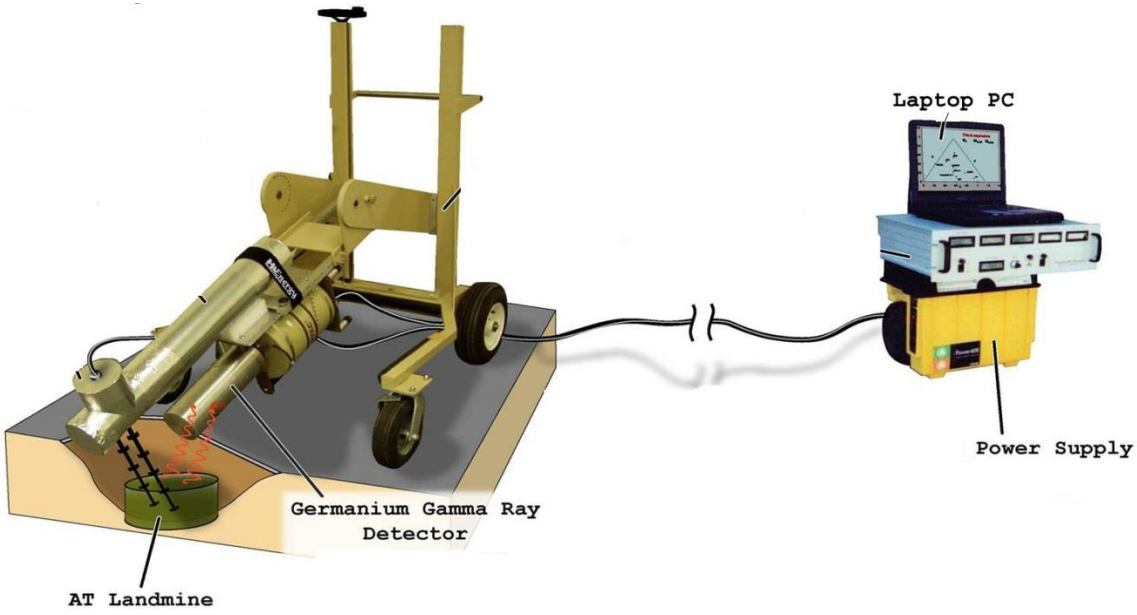
- Neutron breast cancer detector

- Cancerous tumors chemically differ from healthy tissue by the oxygen content
- Large tumors: 0_2 content < 0_2 Normal tissue (Defficient=”hypoxia”)
- Small tumors 0_2 content > 0_2 Normal tissue (Excess =”hyperoxia”)

- **Malignancy: $M = O_{tumor}/O_{tissue} - 1$**

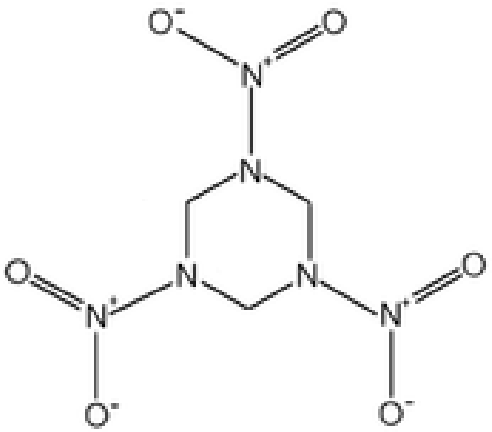
Some practical applications

- **Counter-terrorism/IED detection**



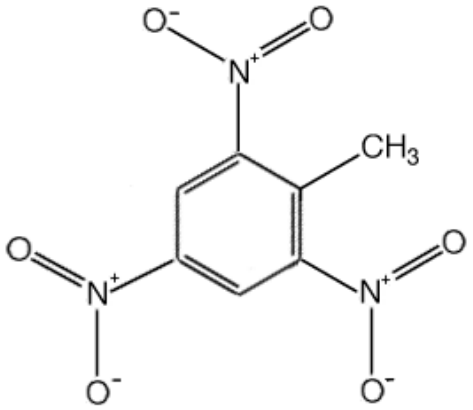
Stoichiometry of explosives and drugs

- Main elements: H, C, N, O
- **Stoichiometry ⇔ relative content of elements**
- **Explosives:** high content of nitrogen and oxygen
- **Drugs:** rich in hydrogen and carbon



RDX : $C_3N_6O_6H_6$

C : N : O : H = 0.5 : 1: 1 : 1



TNT : $C_7N_3O_6H_5$

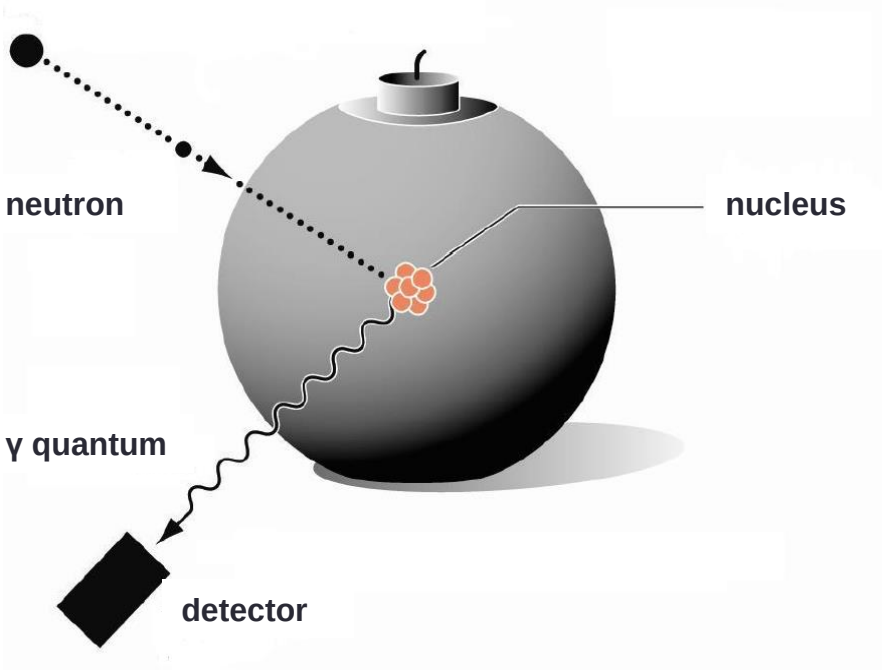
C : N : O : H = 1.1 : 0.5 : 1 : 0.9

Detection method

- Inelastic neutron scattering

D+T → α + n

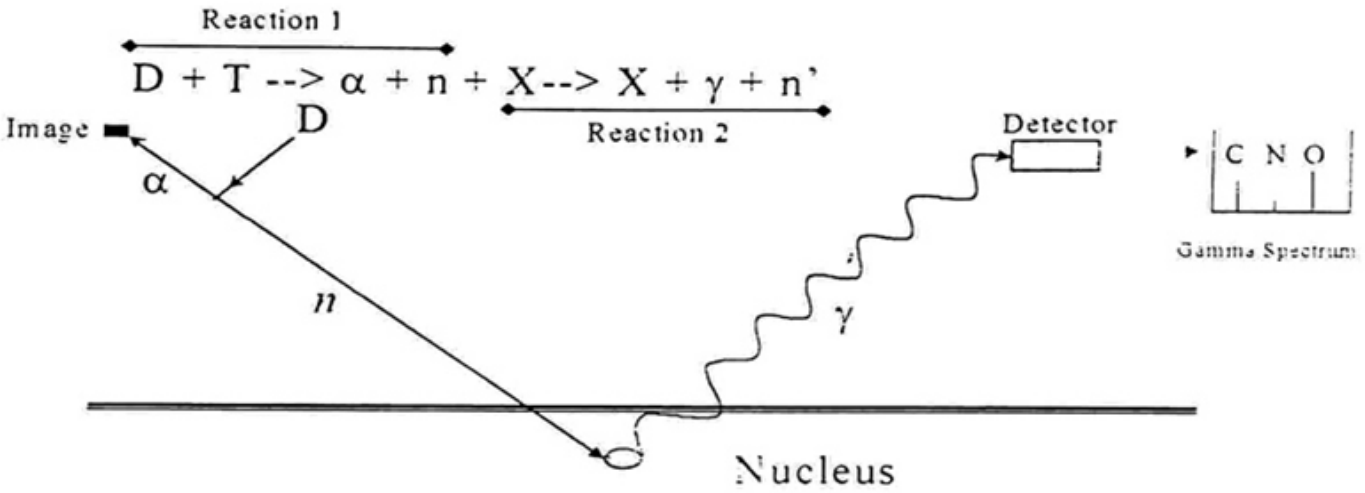
n + nucleus → nucleus + γ + n



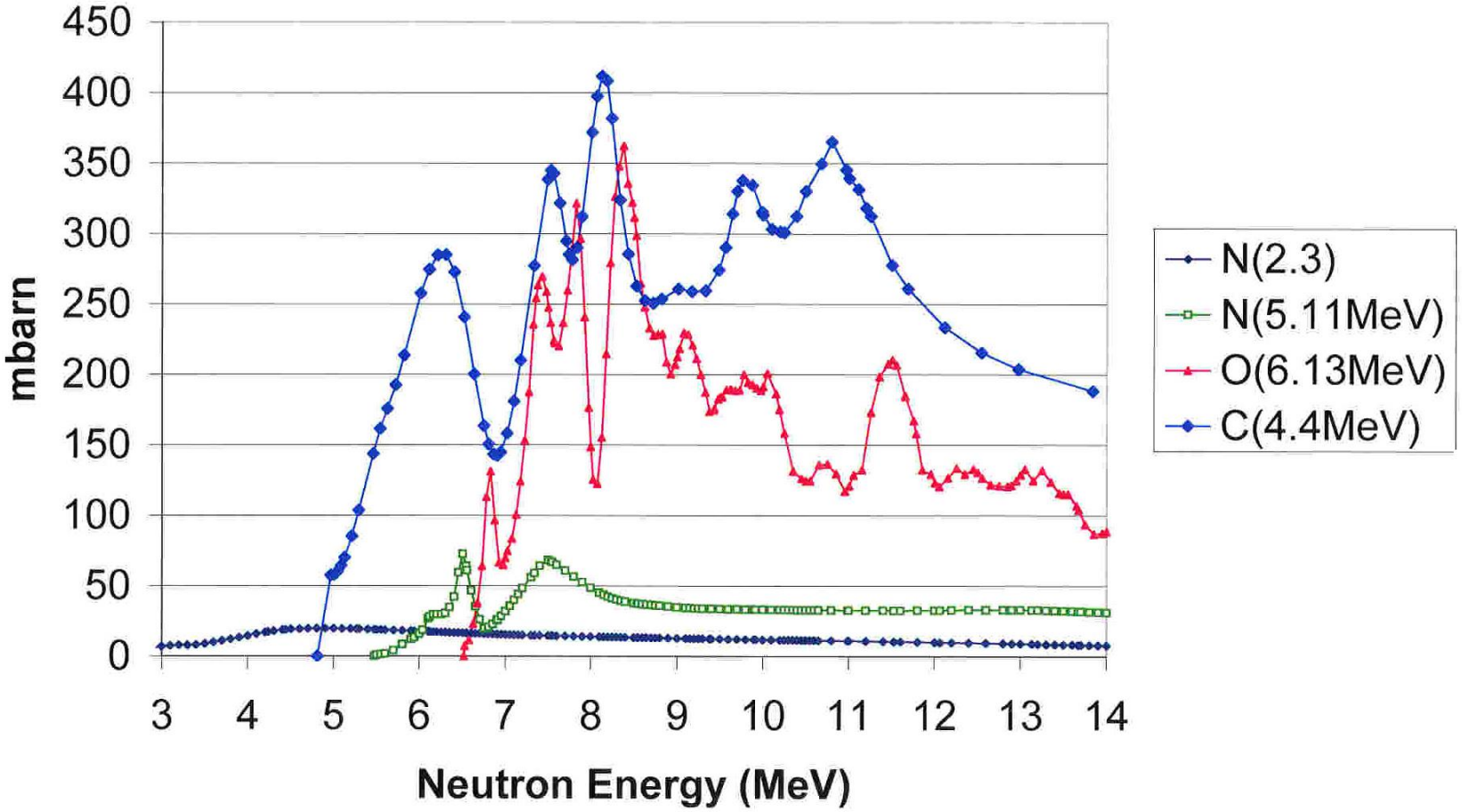
- Fast neutron beam bombards the test object
- Signature: gamma quanta from following nuclei**:**
  ^{12}C (4.43 MeV), **^{16}O** (6.13 MeV)
  ^{14}N (2.31 MeV, 5.11 MeV)
- The use of pulse generators and detection of α particles allows to mesure the neutron time of flight $\Leftrightarrow$ tomographical picture of the chemical composition of the substance

Detection methods based on neutrons

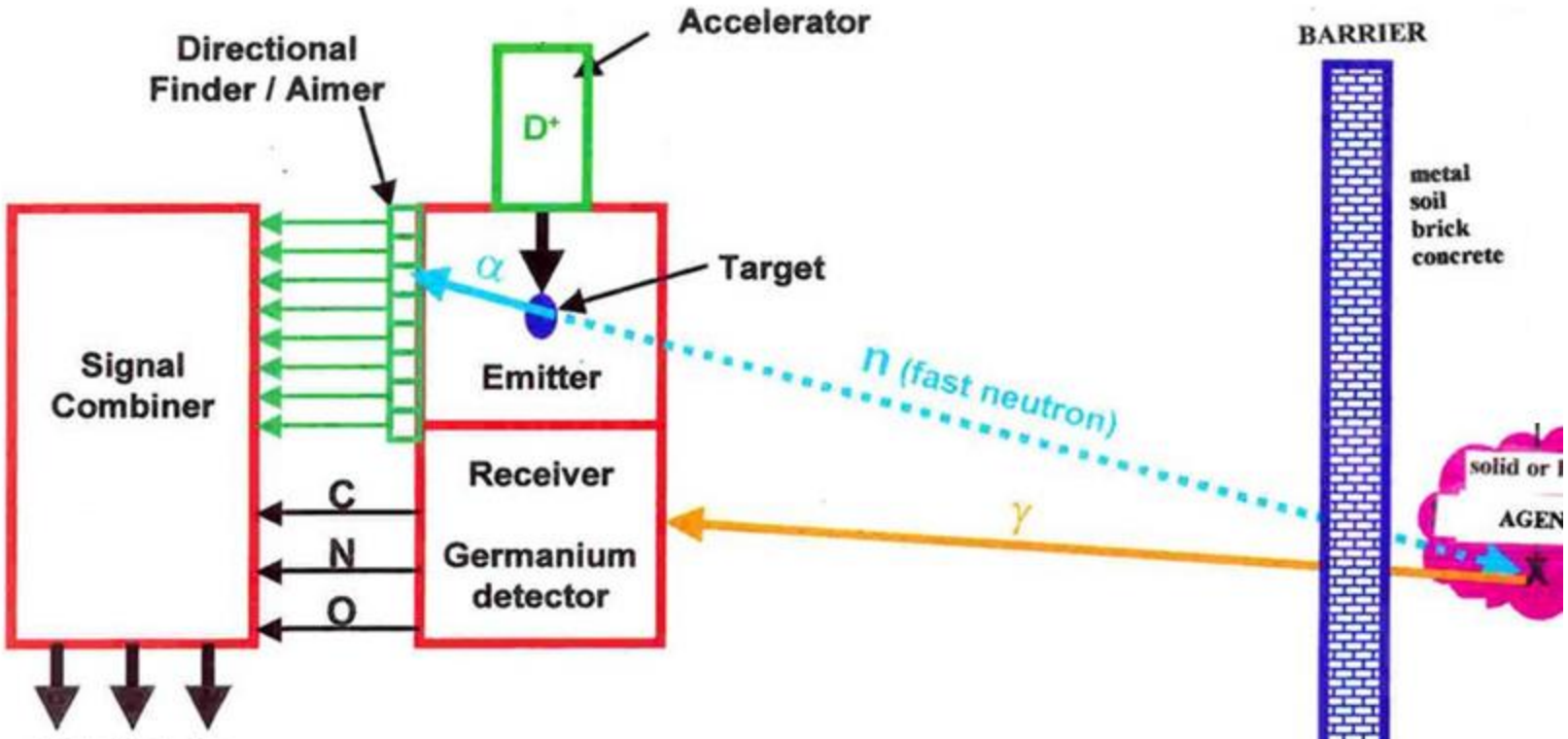
- High penetration allows detection of explosives which are hidden in vehicles, buried, etc.
- Interaction occurs only with the nuclei of atoms and depends on the energy and the type of element
- **The excited nuclei emit gamma quanta with characteristic energy dependent only on the type of nucleus**
- Detection of these quanta gives information on the substance stoichiometry



Cross Section as a function of incident neutron energy. Cross Sections are obtained from Brookhaven National Laboratory.



Scheme of the detection system



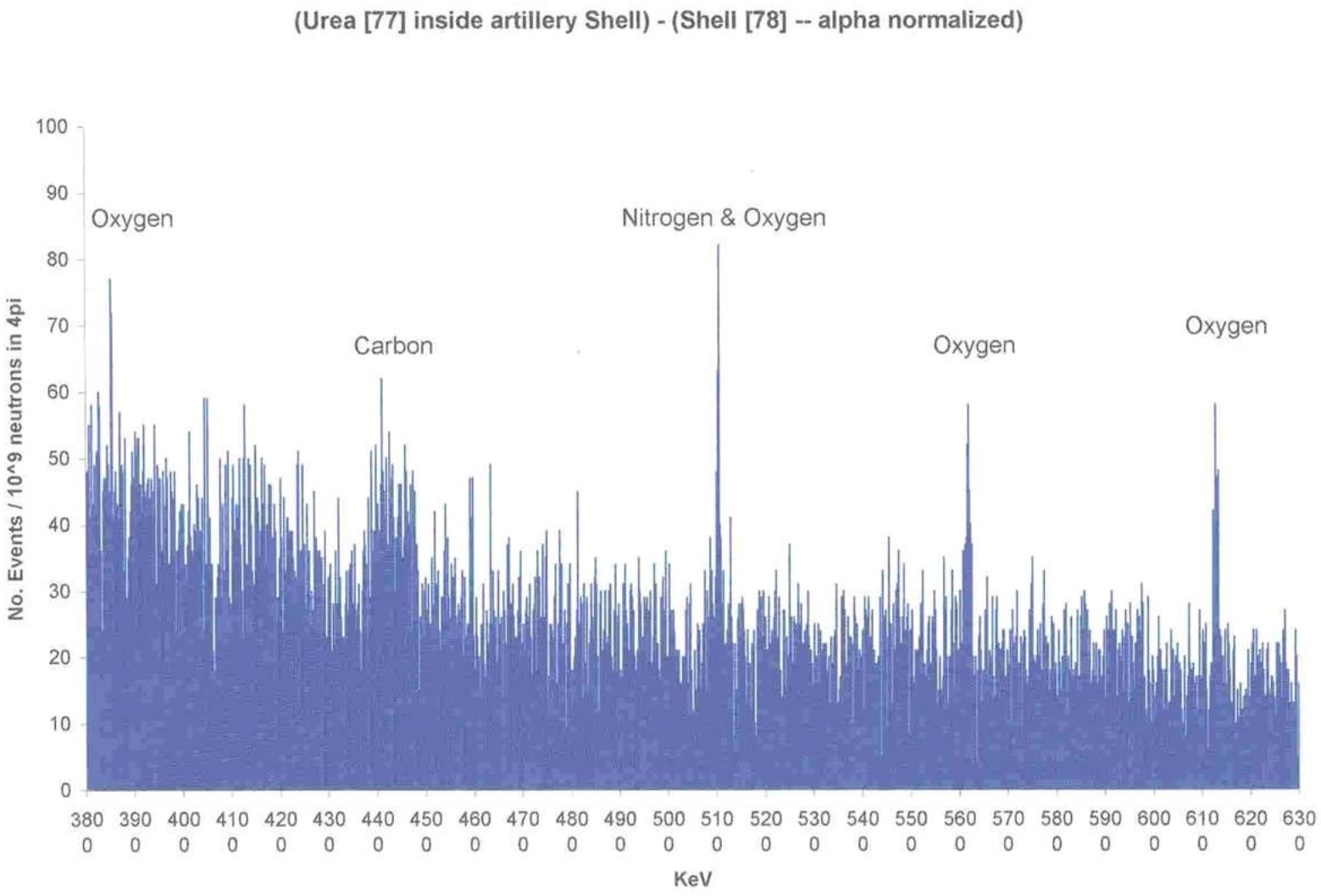
OUTPUTS:

1. Empirical Chemical Formula
2. 3D Imaging
3. Speed

$C_aN_bO_c$

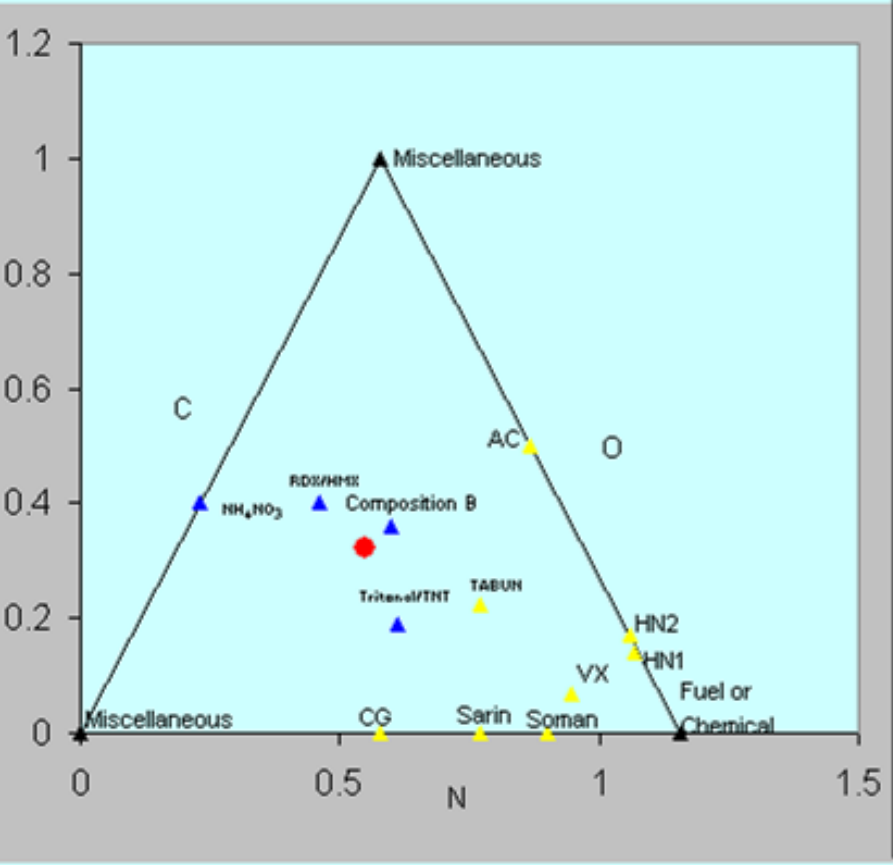
X, Y, Z

$MT / L^4 = 100\ kg\ s/m^4$ = Atometric Constant


(Urea [77] inside artillery Shell) - (Shell [78] -- alpha normalized)
No. Events / 10^9 neutrons in 4pi
100
90
80
70
60
50
40
30
20
10
0
Oxygen
Carbon
Nitrogen & Oxygen
Oxygen
Oxygen
380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600 610 620 630
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
KeV

$C_{1.0}$ $N_{1.0}$ $O_{1.2}$ $H_{0.1}$

This is explosive/Chemical



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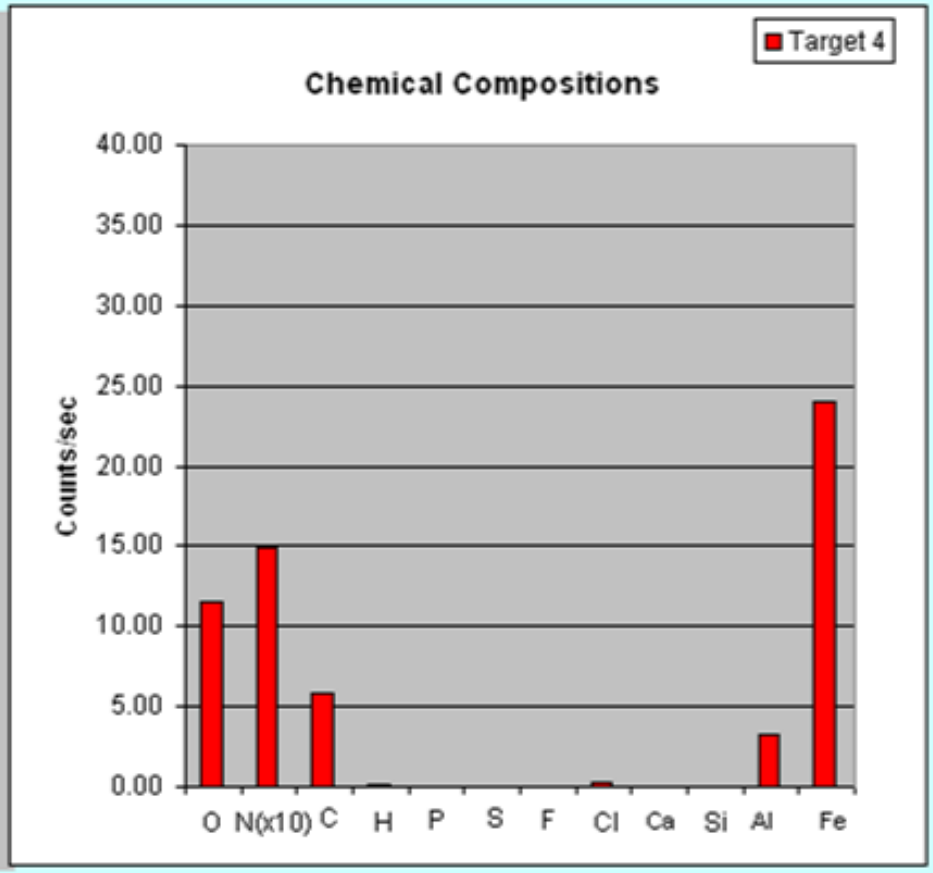
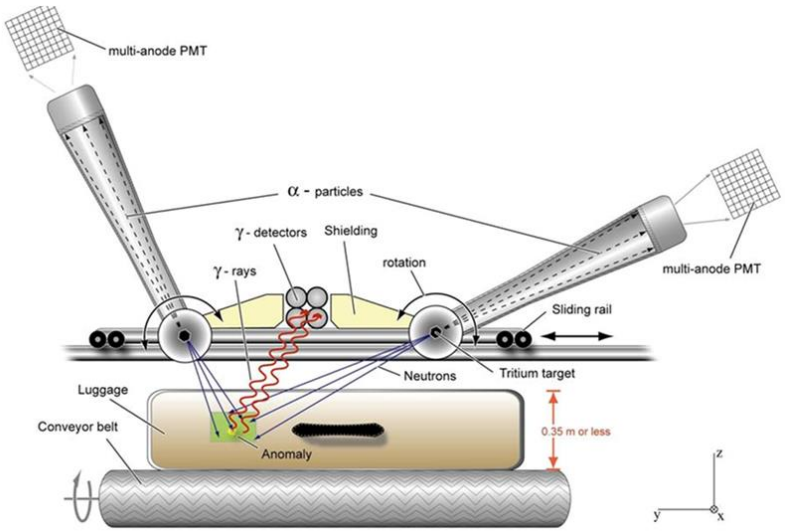
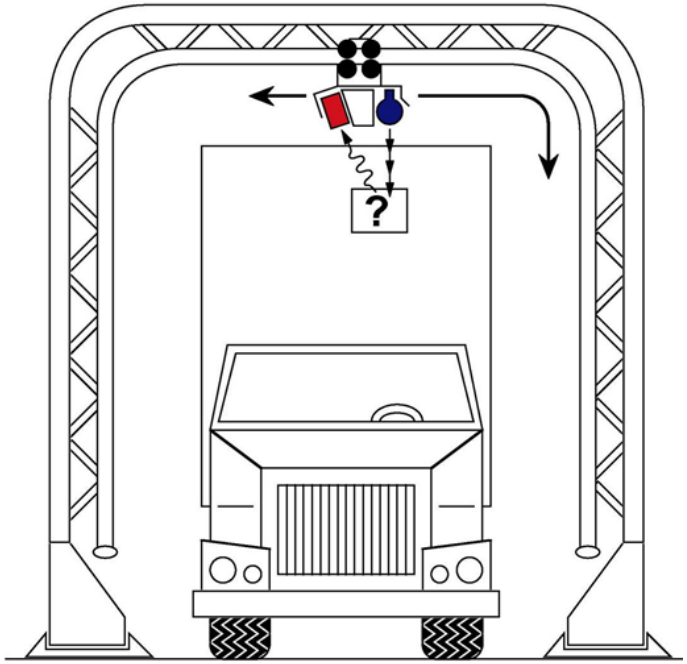


Realization ideas



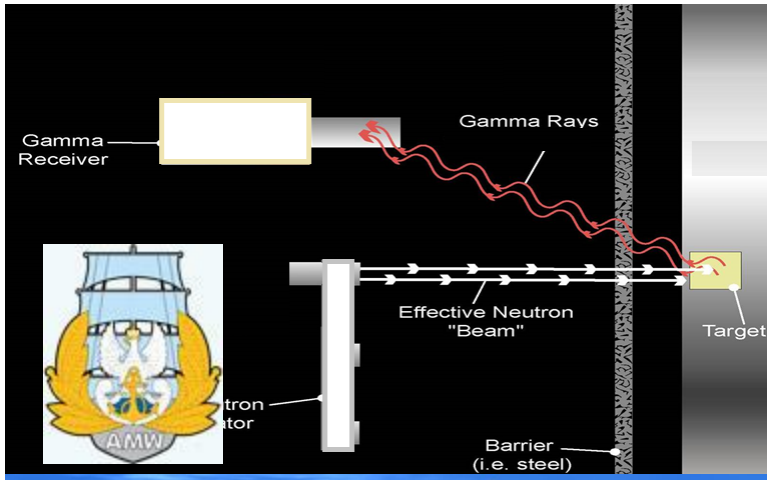


Realization ideas

SABAT

(Stochiometry Analysis By Activation Techniques)

- Replacment of the Germanium detector with scintillators (increase of the mobility)
- Detection of the dangereus war leftovers in the Baltic Sea (bombs, war gases, etc.)



Summary

- Methods based on neutron allow to determine the stoichiometry of suspicious items
- In the future they will provide a good alternative / supplement to existing methods for detection of explosives, drugs and radioactive and chemical weapons
- Also ideally suited for applications in industry, chemistry and geology
- Practical use of neutrons requires:
  - Design of appropriate equipment
  - Developing of methods for analysis of recorded signals and reducing background
  - Optimization of the prototype detector (simulations, testing)
  - **Tests with true hazardous materials**

Thank you for your attention

Goya, *Witches sabbath*

Oddziaływanie neutronów z materią