Effective Container Inspection at BORDer Control Points

C-BORD Final Public Workshop

9th October 2018

Rotterdam NL

TECHNOLOGY SUB-SYSTEM TNIS

WP 4

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WP4

TECHNOLOGY SUB-SYSTEM TNIS

RAPIDLY RELOCATABLE TAGGED NEUTRON INSPECTION SYSTEM

Partners: ***Fraunhofer***, ***DCA***

UNIPD: WP Leader, DAQ, Gamma Detectors tests

CEA DEN: RRTNIS Design, Laboratory and field tests, expert data processing

CEA LIST: Integration test, Decision Making

CAEN: Electronics

NCBJ: Mechanics

SYMETRICA: Unfolding Algorithm

JRC: Laboratory tests

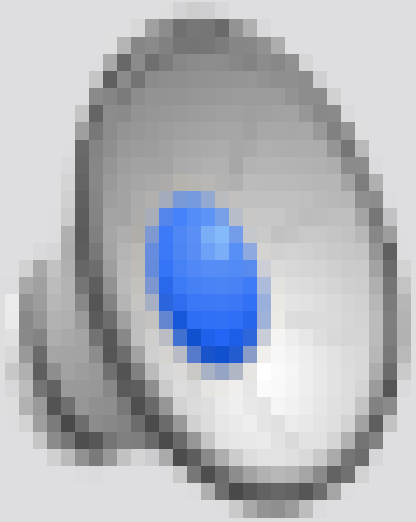
WHAT IS THE TECHNOLOGICAL METHOD BEHIND RRTNIS?

- The Tagged Neutron Inspection System combines the technology of inelastic neutron scattering with the associated particle time-of-flight spectroscopy to obtain an effective and accurate system for detection and identification of explosives and contraband drugs.

- In the TNIS, high energy neutrons are produced in a sealed tube neutron generator with an energy of 14 MeV and emitted isotropically from the source.

- Approximately 50 million neutrons are produced each second, and the units have demonstrated an average lifetime of about 2,000 hours of operation.

RRTNIS AT DEMONSTRATION SITE



RRTNIS AT DEMONSTRATION SITE

- RRTNIS is a second line inspection system
- Voxel position from X-ray scan
- Inspection time: 20 minutes
  - 10 minutes irradiation
  - Alignment and software analysis

RRTNIS TECHNOLOGY COMPARISON

The technology is compared to other technologies in the chart. The comparison is based on two criteria: (i) what the device can detect, (ii) its 3-dimensional scanning ability.

System	Element Detected	Scanning Ability
RRTNIS	N,C,O	3-Dimensional
Conventional X-ray radiography	Density	No depth information
Dual energy X-ray systems	Average Z of materials	2-Dimentional projection of hydrogenous materials
Thermal Neutron Analysis	N	Poor localization of threat
Vapor Detector	Vapor Pressure of explosives	None

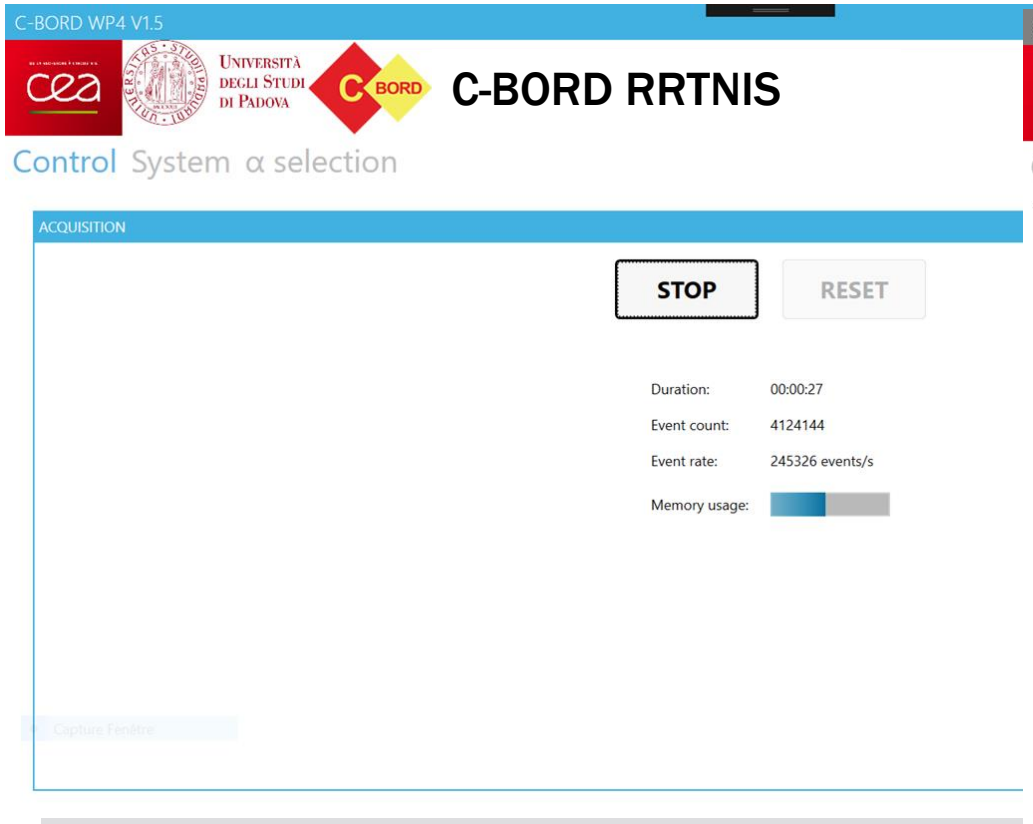
RRTNIS Machine Learning Software

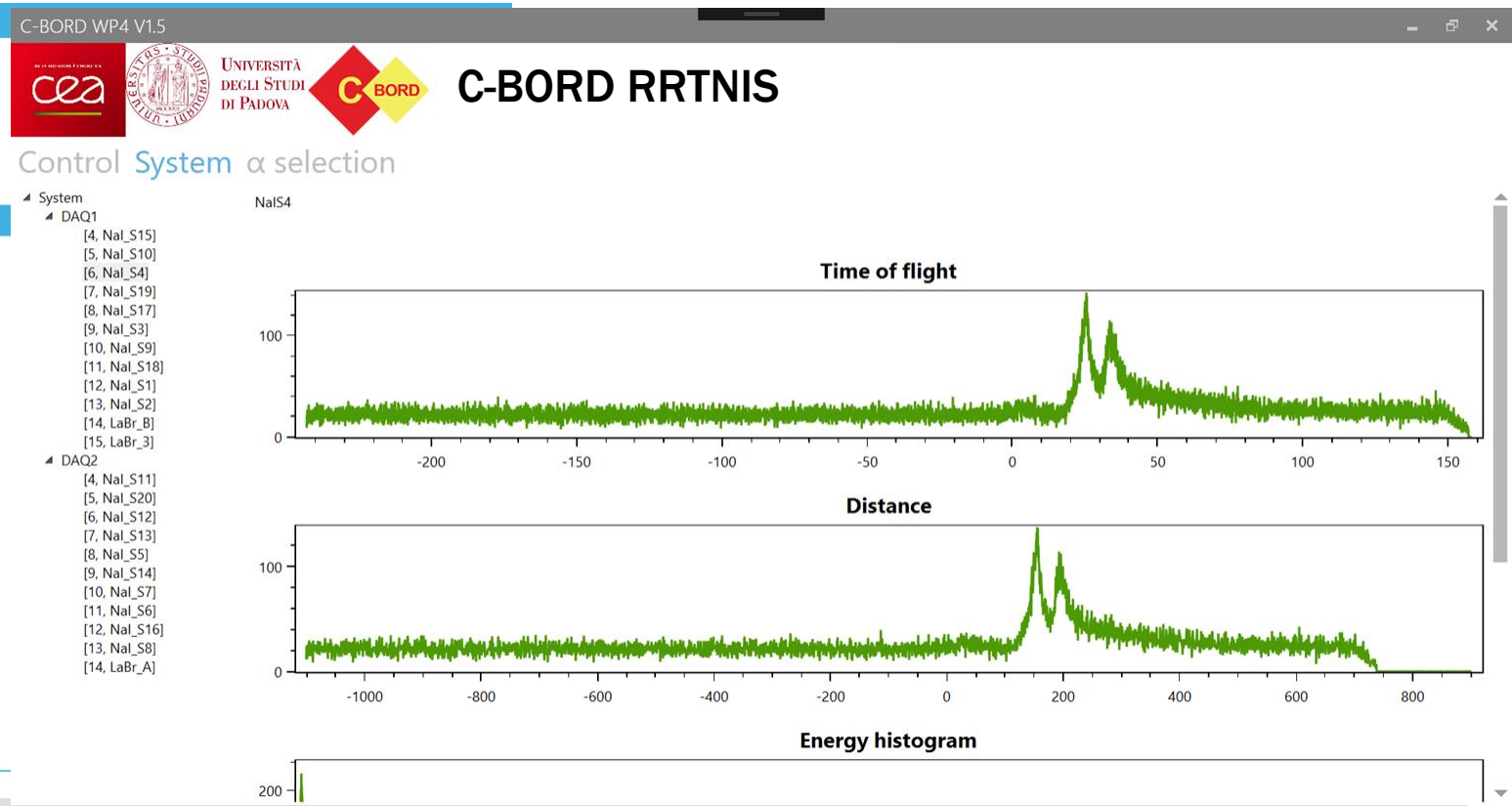
First machine-learning solution for Material Classification with TNIS: FUZZY Decision Tree

- **Two classification problems are addressed :**
  - ✓ four-class problem – organic, metallic, ceramic and chemical weapons
  - ✓ among the organic products, three-class problem – drug, explosive and benign

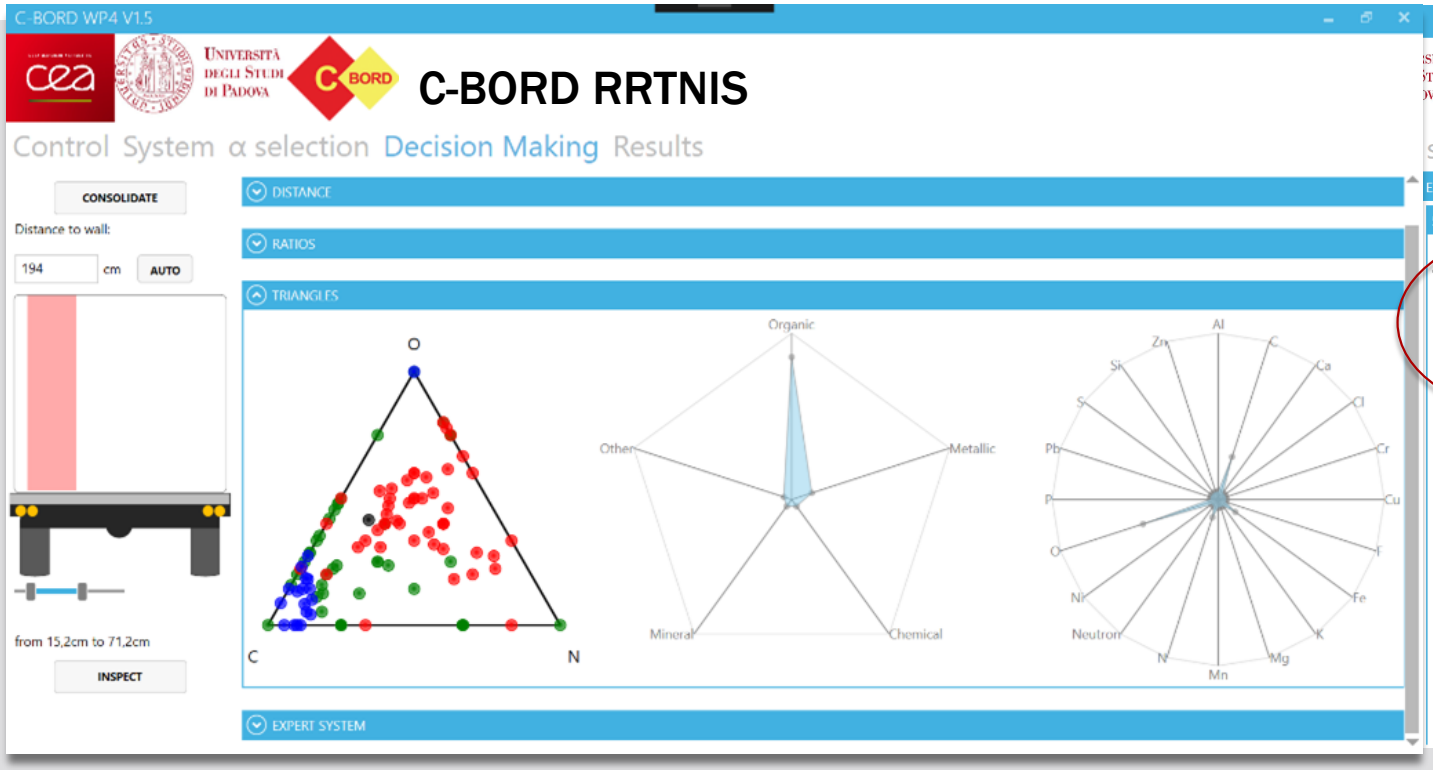
- **RRTNIS software :**
  - ✓ visual tools
  - ✓ numerical results from the classification (scores for each class)

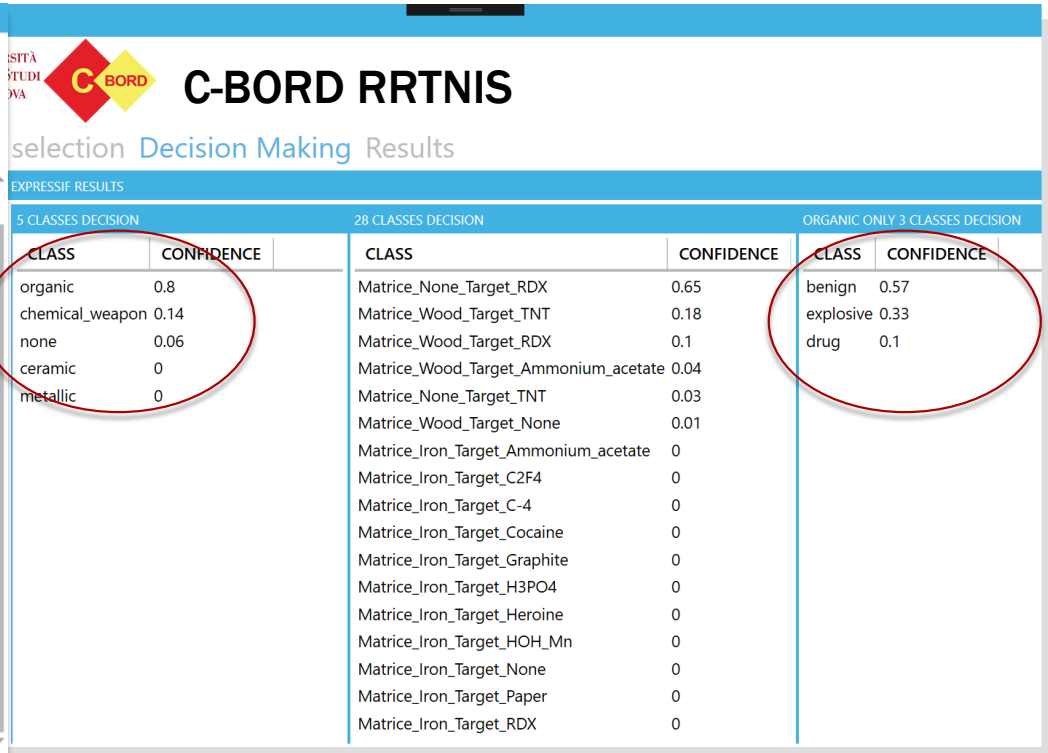
RRTNIS GUI


C-BORD WP4 V1.5
C-BORD RRTNIS
Control System α selection
ACQUISITION
STOP
RESET
Duration: 00:00:27
Event count: 4124144
Event rate: 245326 events/s
Memory usage:


C-BORD WP4 V1.5
C-BORD RRTNIS
Control System α selection
System
DAQ1
[4, NaI_S15]
[5, NaI_S10]
[6, NaI_S4]
[7, NaI_S19]
[8, NaI_S17]
[9, NaI_S3]
[10, NaI_S9]
[11, NaI_S18]
[12, NaI_S1]
[13, NaI_S2]
[14, LaBr_B]
[15, LaBr_3]
DAQ2
[4, NaI_S11]
[5, NaI_S20]
[6, NaI_S12]
[7, NaI_S13]
[8, NaI_S5]
[9, NaI_S14]
[10, NaI_S7]
[11, NaI_S6]
[12, NaI_S16]
[13, NaI_S8]
[14, LaBr_A]
NaIS4
Time of flight
Distance
Energy histogram

RRTNIS GUI


C-BORD WP4 V1.5
C-BORD RRTNIS
Control System α selection Decision Making Results
CONSOLIDATE
Distance to wall:
194
cm
AUTO
from 15,2cm to 71,2cm
INSPECT
DISTANCE
RATIOS
TRIANGLES
O
C
N
Organic
Other
Metallic
Mineral
Chemical
EXPERT SYSTEM

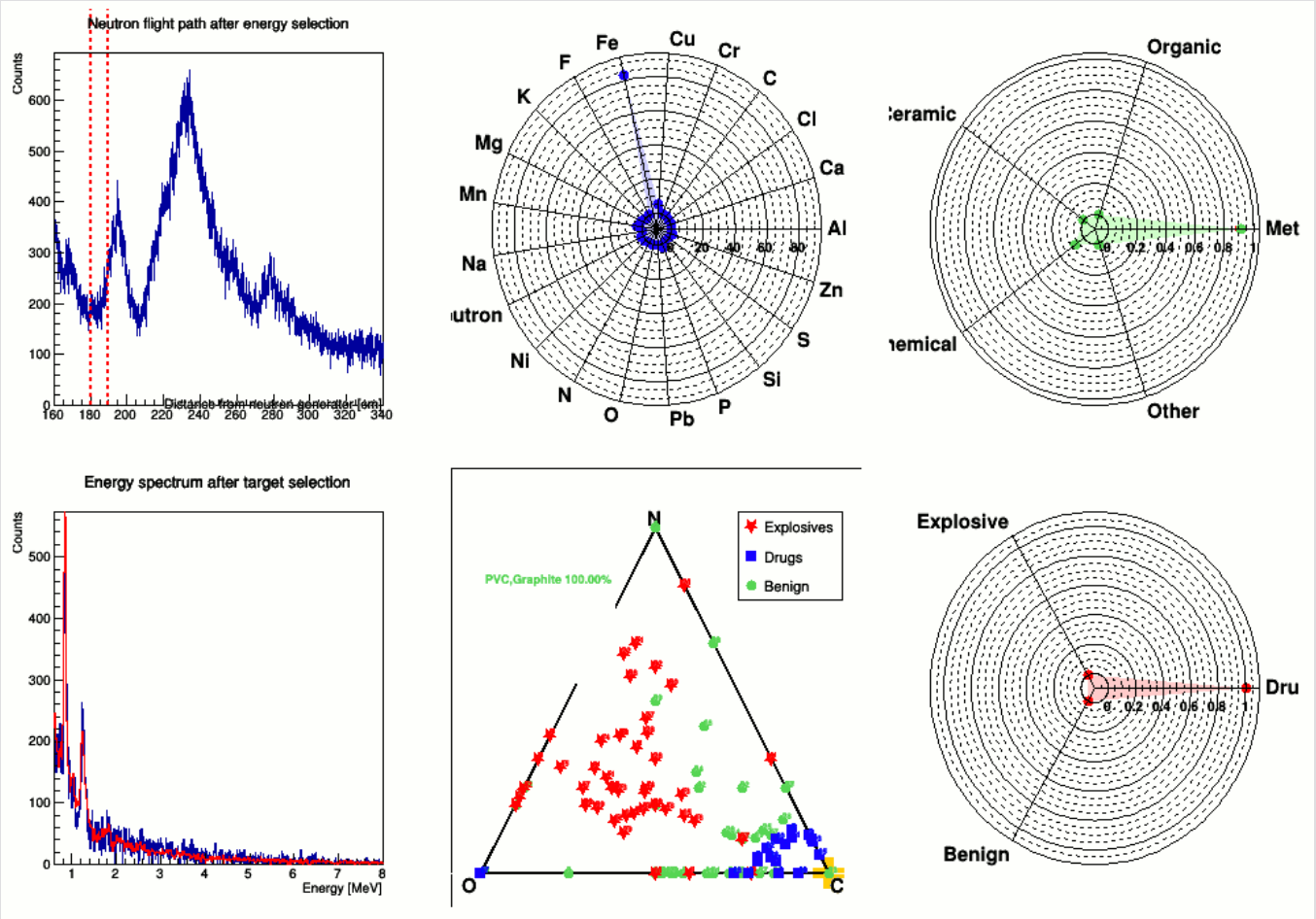

C-BORD RRTNIS
selection Decision Making Results
EXPRESSIF RESULTS
5 CLASSES DECISION
CLASS CONFIDENCE
organic 0.8
chemical_weapon 0.14
none 0.06
ceramic 0
metallic 0
28 CLASSES DECISION
CLASS CONFIDENCE
Matrice_None_Target_RDX 0.65
Matrice_Wood_Target_TNT 0.18
Matrice_Wood_Target_RDX 0.1
Matrice_Wood_Target_Ammonium_acetate 0.04
Matrice_None_Target_TNT 0.03
Matrice_Wood_Target_None 0.01
Matrice_Iron_Target_Ammonium_acetate 0
Matrice_Iron_Target_C2F4 0
Matrice_Iron_Target_C-4 0
Matrice_Iron_Target_Cocaine 0
Matrice_Iron_Target_Graphite 0
Matrice_Iron_Target_H3PO4 0
Matrice_Iron_Target_Heroine 0
Matrice_Iron_Target_HOH_Mn 0
Matrice_Iron_Target_None 0
Matrice_Iron_Target_Paper 0
Matrice_Iron_Target_RDX 0
ORGANIC ONLY 3 CLASSES DECISION
CLASS CONFIDENCE
benign 0.57
explosive 0.33
drug 0.1

FIELD TEST RESULTS

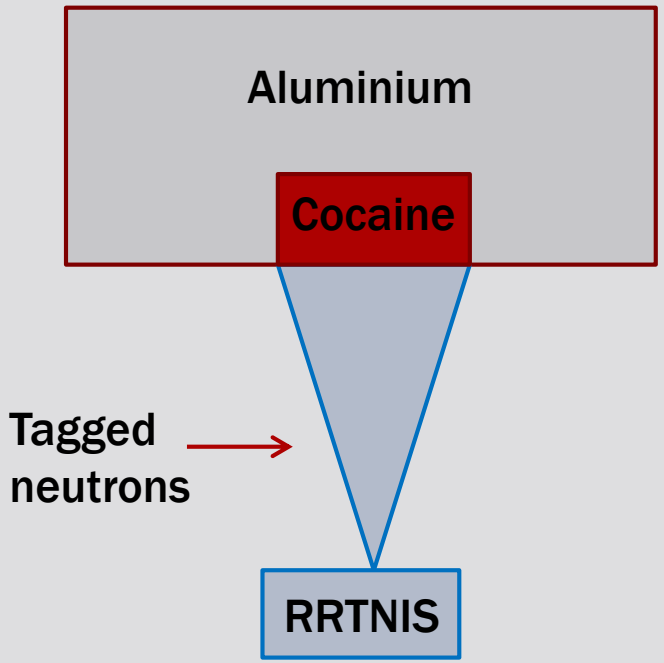
A. Sardet
CEA DEN

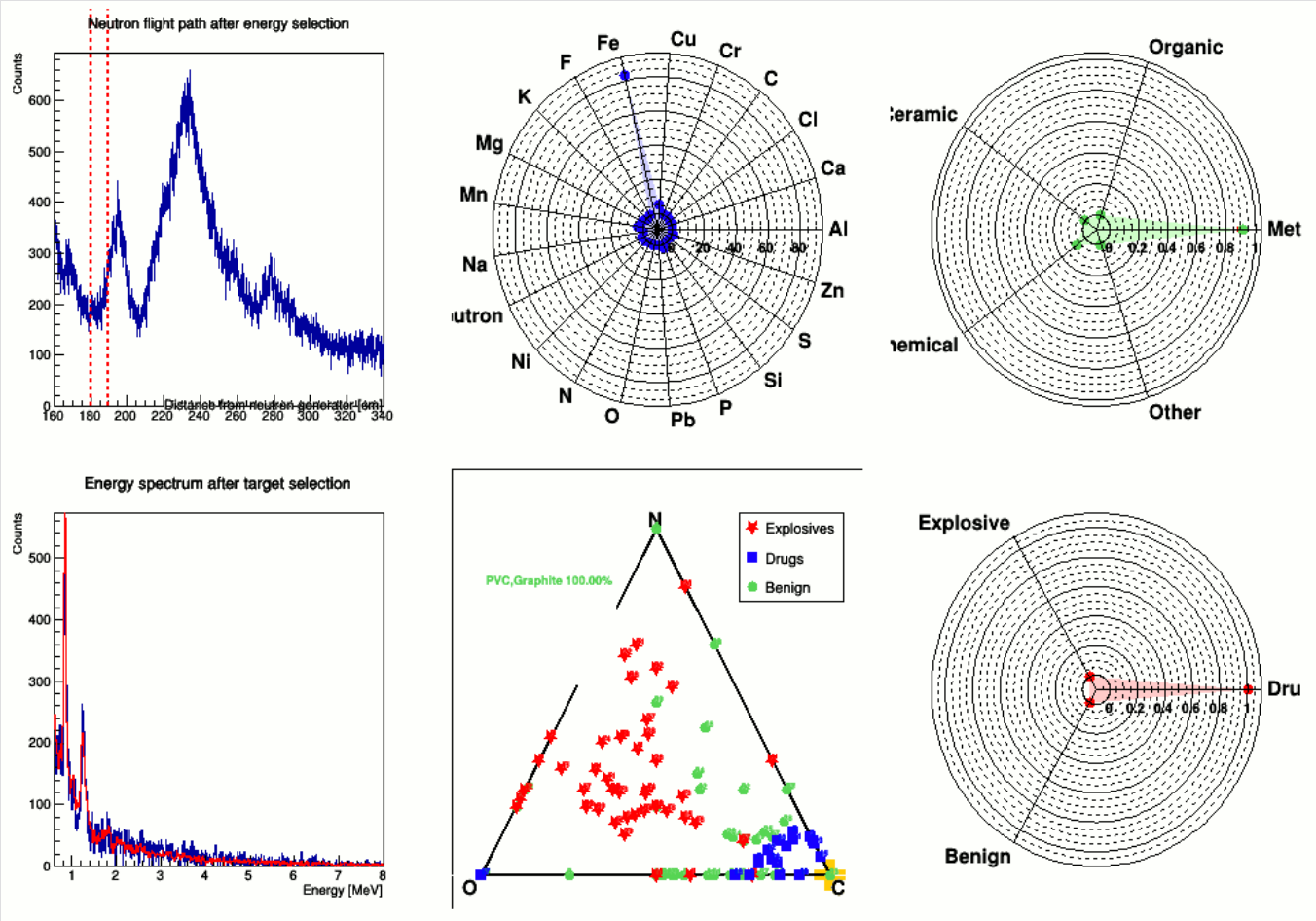
EXPERT MODE DISPLAY

- Peaks on the neutron flight path reflect changes in material/density
- The energy distribution changes as a function of depth
- Identification of the elements present
- Classification according to material type (metallic, organic, etc.)
- Differentiation between benign organic materials (wood, cotton, etc.) and explosives or drugs

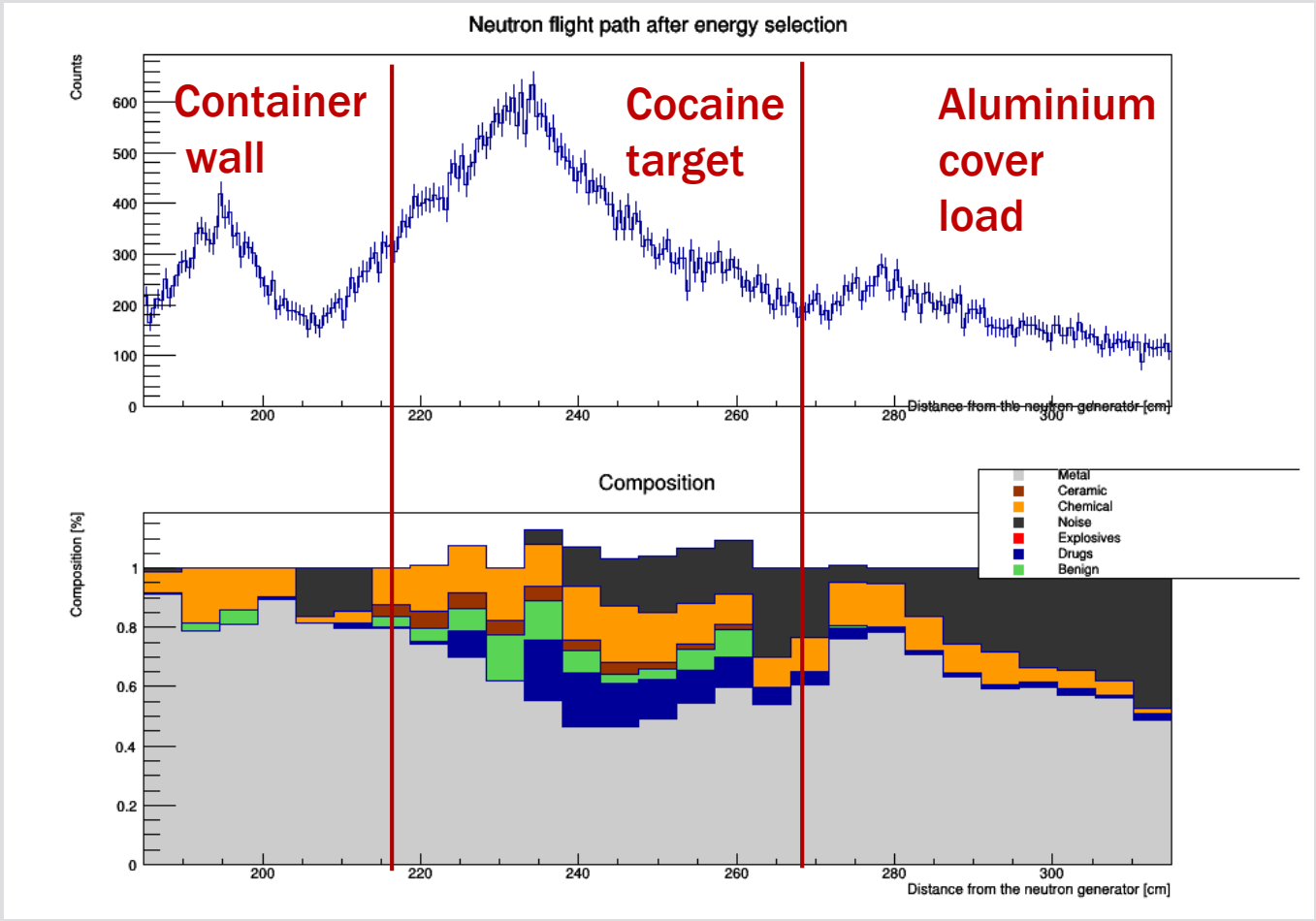


20 KG COCAINE TARGET HIDDEN IN AN ALUMINIUM COVER LOAD (1/2)

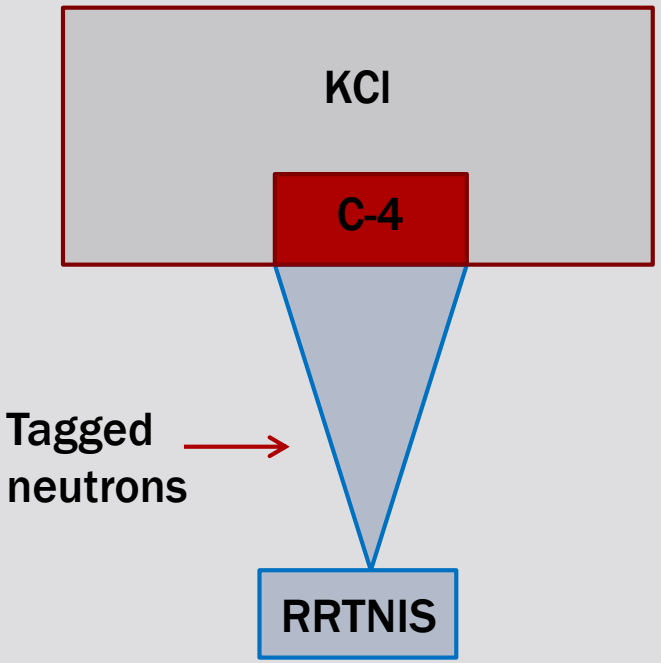


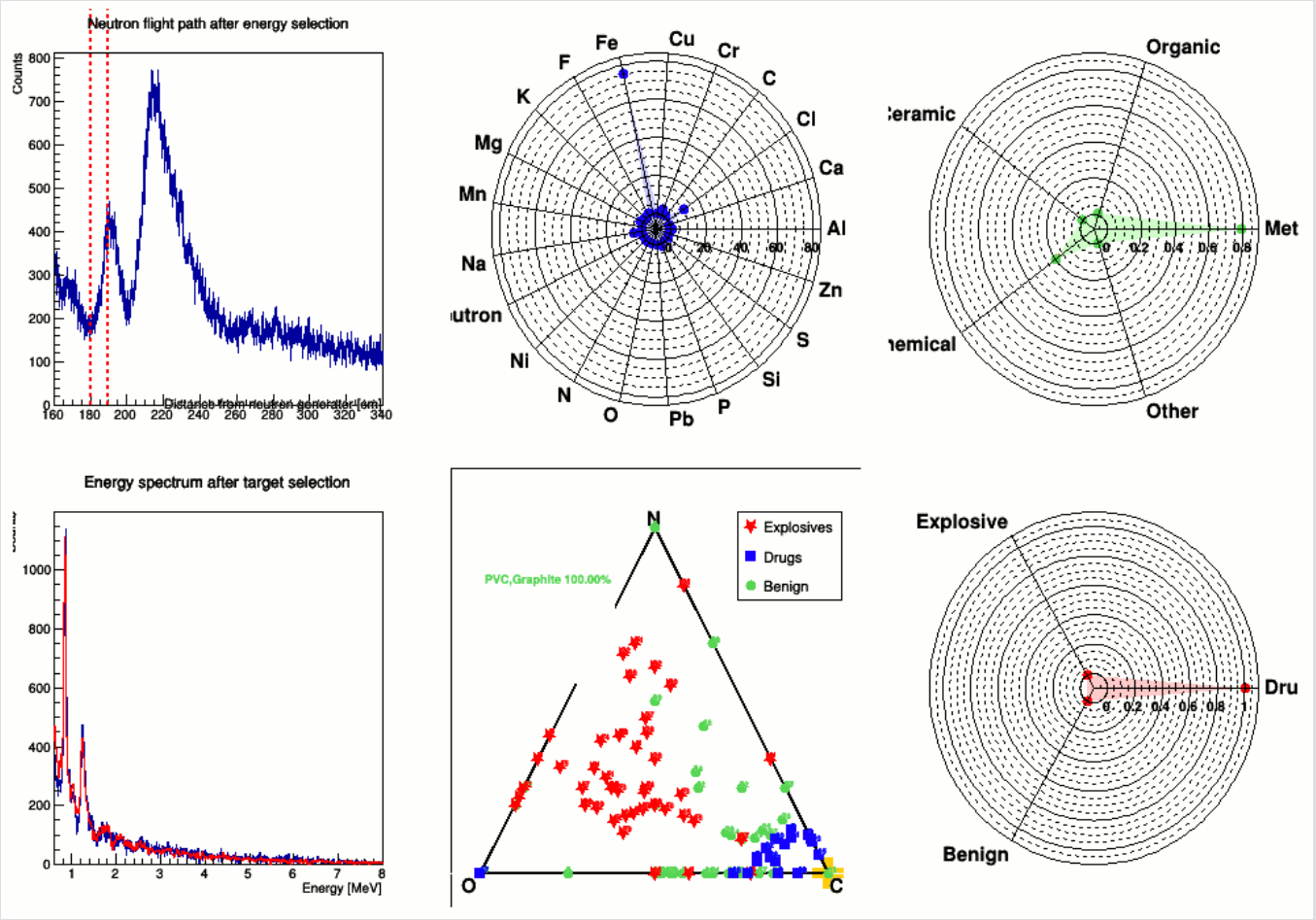


20 KG COCAINE TARGET HIDDEN IN AN ALUMINIUM COVER LOAD (2/2)

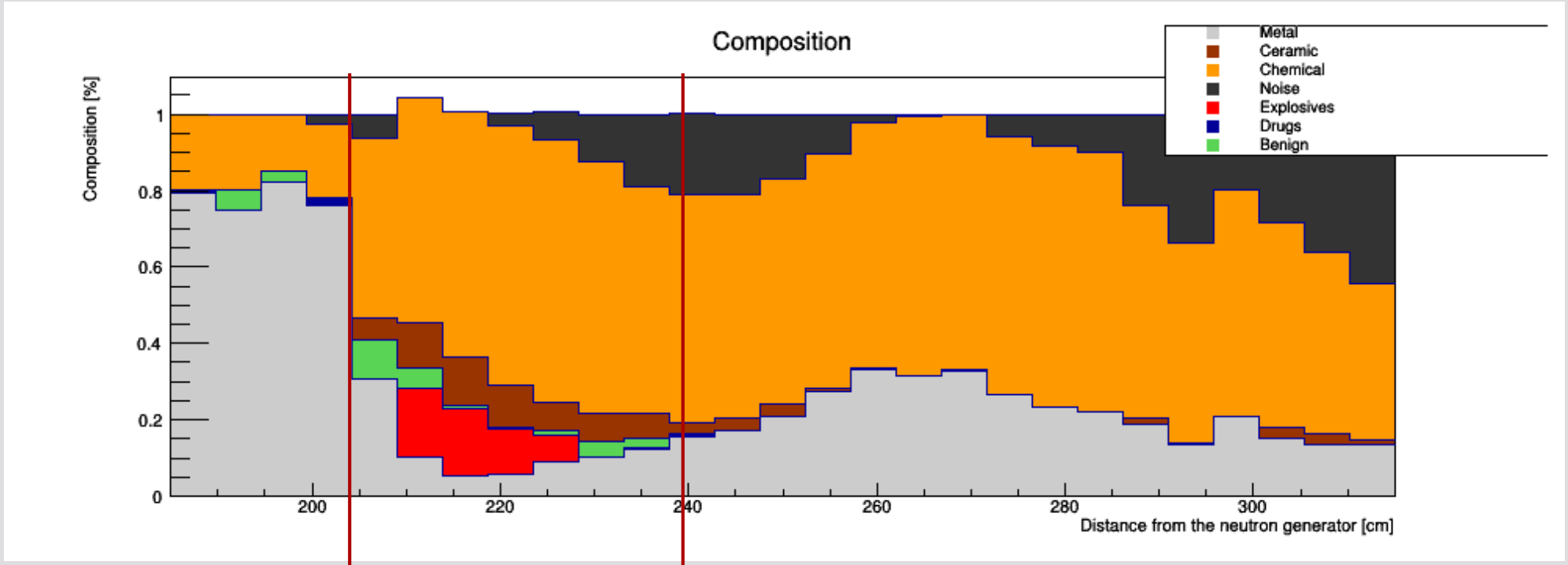


20 KG C-4 TARGET HIDDEN IN A KCL COVER LOAD (1/2)



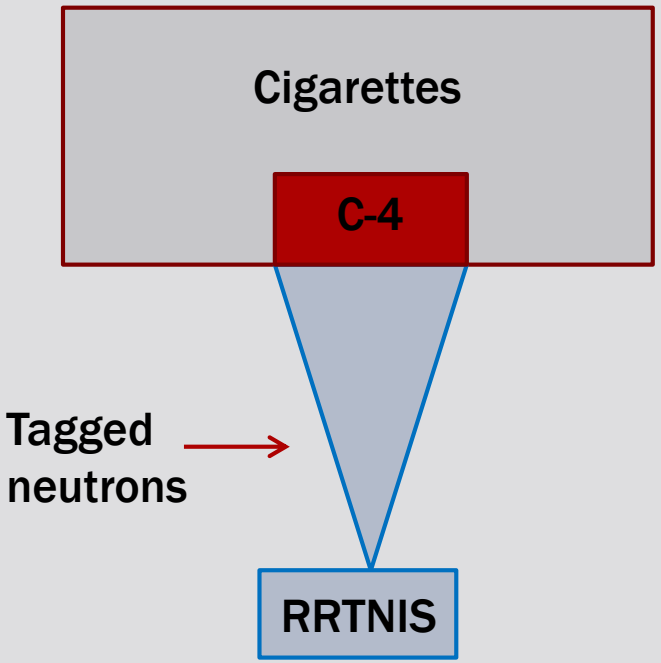


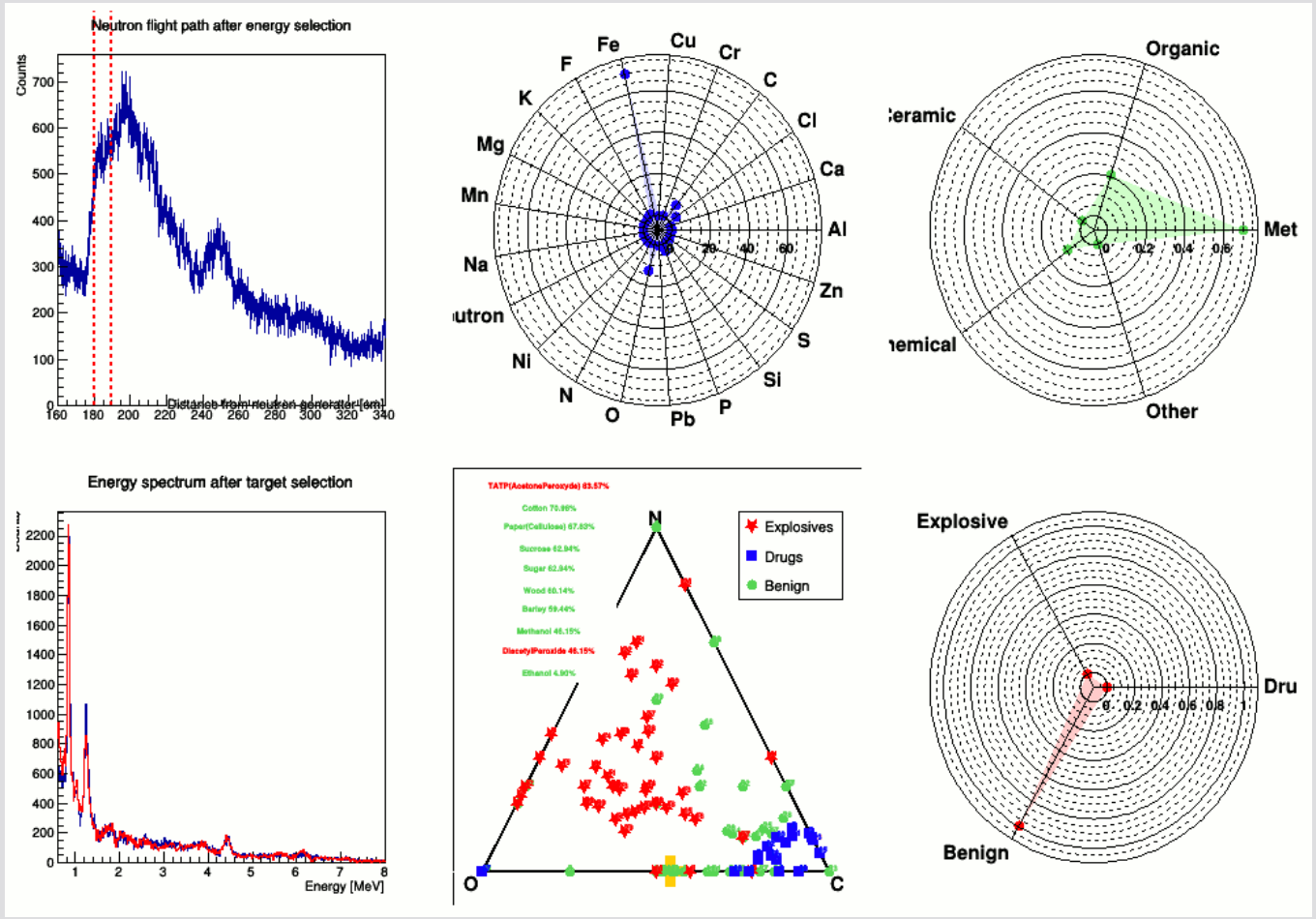
20 KG C-4 TARGET HIDDEN IN A KCL COVER LOAD (2/2)



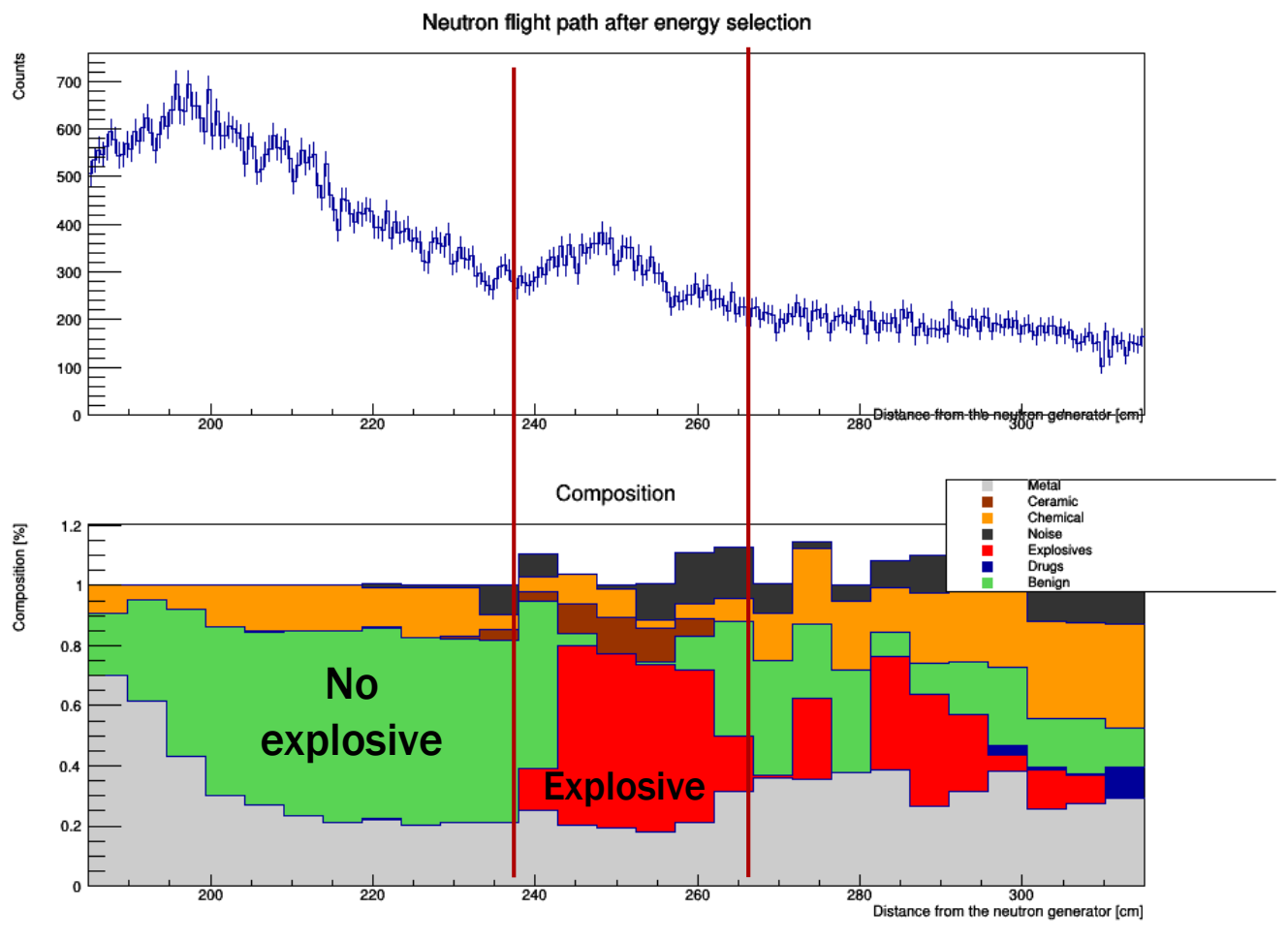
Identification of an area containing explosives

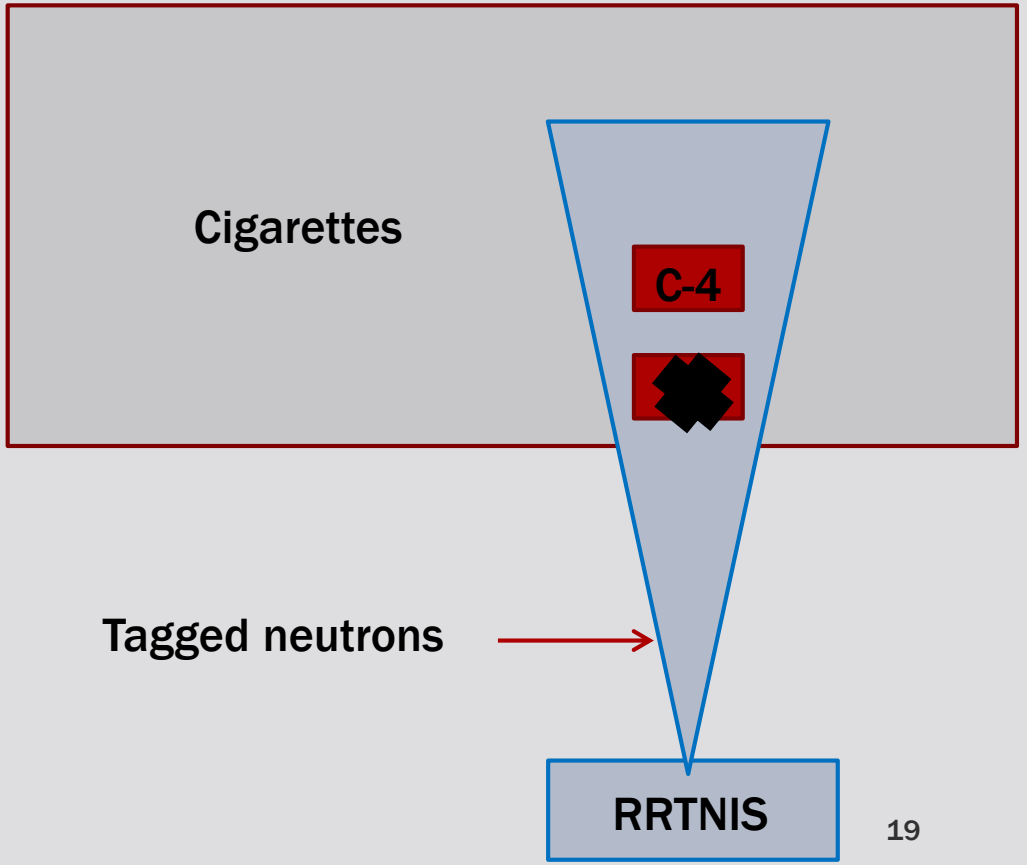
20 KG C-4 TARGET HIDDEN IN A CIGARETTES COVER LOAD (1/2)





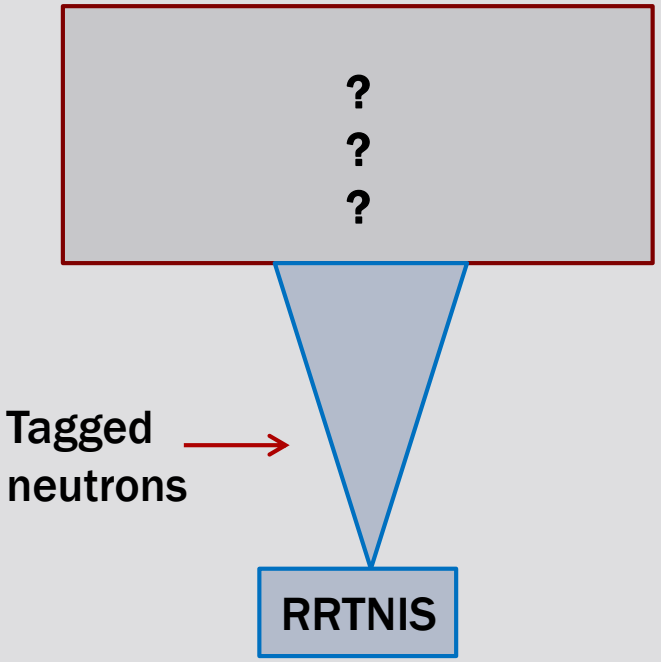
20 KG C-4 TARGET HIDDEN IN A CIGARETTES COVER LOAD (2/2)

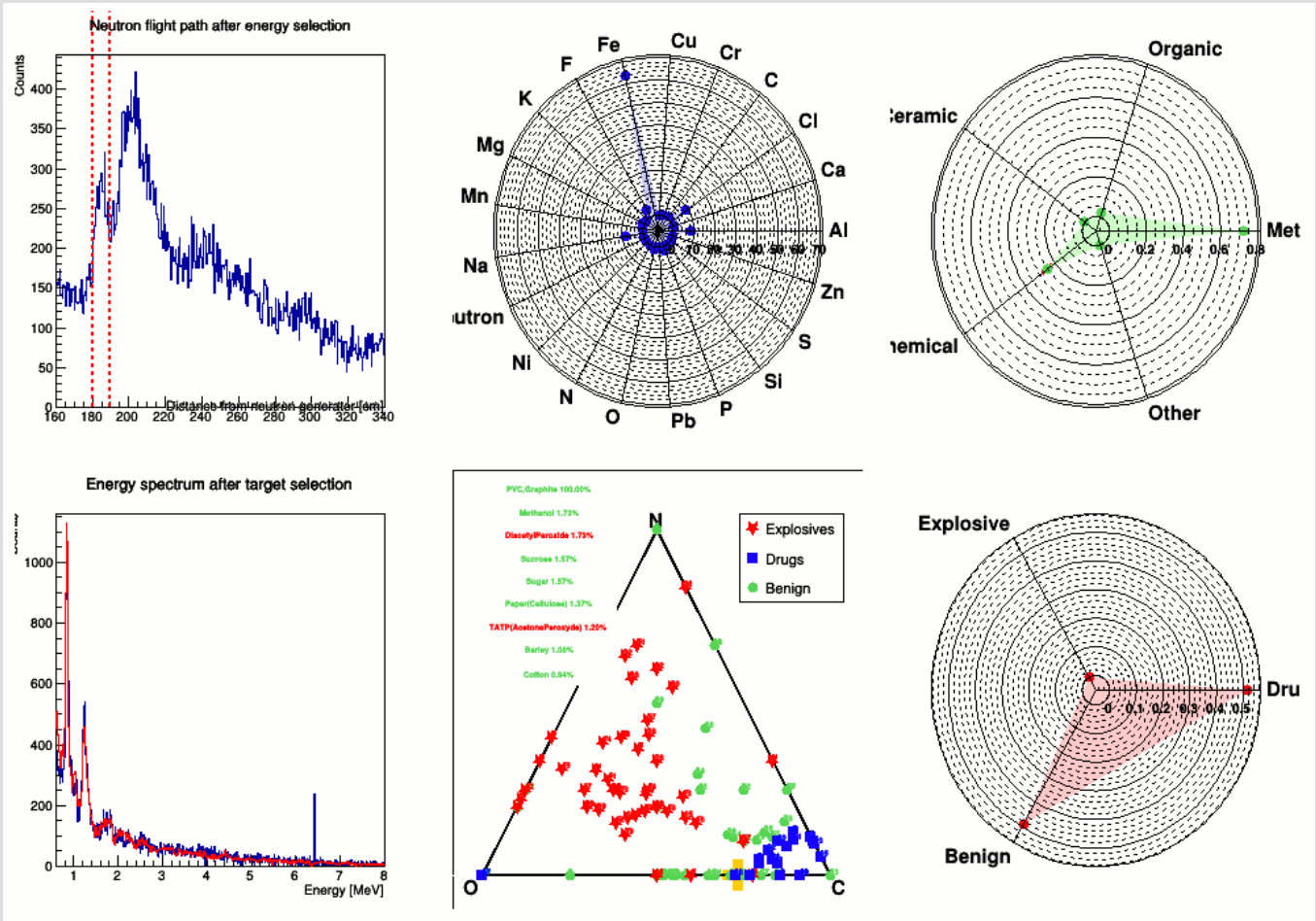




BLIND EXPERIMENT (1/2)

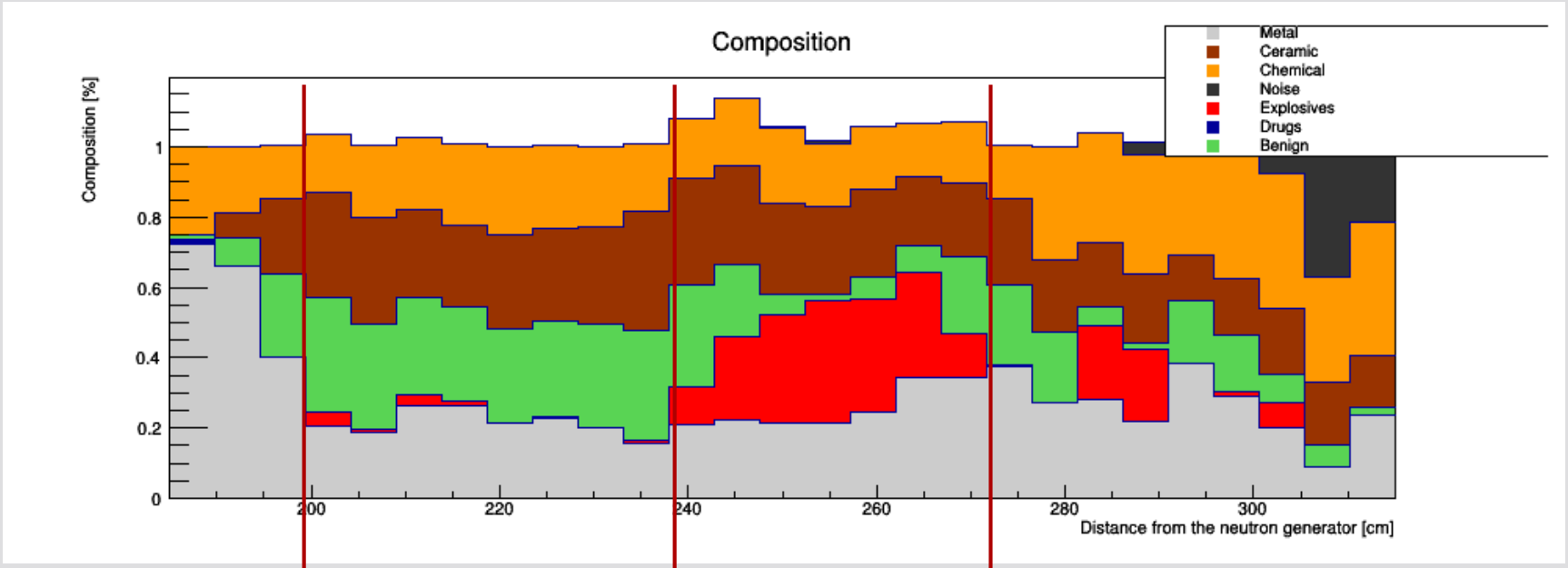
- No information on depth from X-ray





BLIND EXPERIMENT (2/2)

- Identification of a silicon dioxyde load with hidden explosive
- Reality : toilet bowls with few kg of C-4 simulant at 60 cm from container wall



Silicon + oxygen | Explosive | Silicon + oxygen

FREQUENTLY ASKED QUESTIONS

- **IS RRTNIS TECHNOLOGY SAFE FOR ALL TYPES OF MERCHANDISE– ELECTRONICS,ETC?**
  - Yes. No measurable radioactivity is induced in the tested samples.

- **HAS THE RRTNIS BEEN TESTED ON FOOD PRODUCTS AND OTHER ORGANIC MATERIALS?**
  - RRTNIS has tested numerous explosives and inert substances including bananas, wood, fertilizer, metallic materials, etc. In all cases the scanning equipment identified the Carbon, Nitrogen, Oxygen and Chlorine content of the sample.

- **IS THERE A FULL-SCALE OPERATIONAL PROTOTYPE OF THE RRTNIS system?**
  - A full scale prototype of the RRTNIS system is available for demonstration.

FREQUENTLY ASKED QUESTIONS ON THE SAFETY FOR RRTNIS

- **WHAT SAFETY MEASURES ARE TAKEN TO ENSURE THE SAFETY OF THE OPERATORS AND THE TRUCK DRIVERS?**

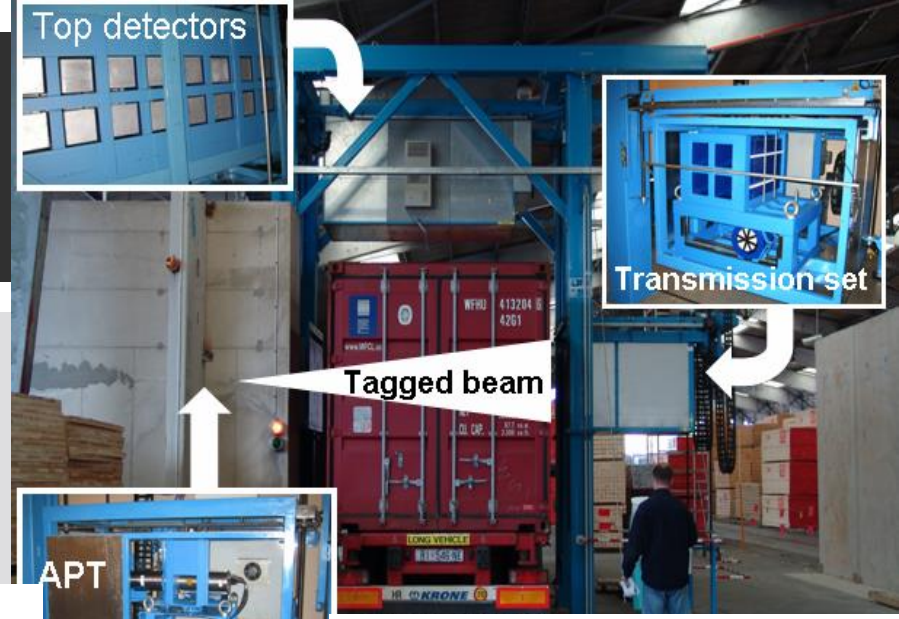
- Personnel operating the RRTNIS system are restricted in approach to the RRTNIS scanner by a safety area of 60m x 40m. Outside this safety area, radiation levels are below those approved by the EU legislation for public exposure to radiation producing equipment.

CONCLUSION OF FIELD TESTS

- The TNIS system can detect explosive materials in both a liquid or solid state, illegal drugs, chemicals, and items of interest to Customs even when they are in a camouflaged environment.
- TNIS technology is complementary to other explosive and contraband detection on the market today.
- Explosive materials that will be detected by the TNIS cargo scanner include: C4 and TNT. Virtually any other explosive or harmful compound can be detected

MAIN ACHIEVEMENTS

- Rapidly relocatable (no large fixed portal)
- Compact shielding (no fixed concrete walls)
- Limited restricted area
- 20 times better sensitivity than the previous EU project EURITRACK
  - From 100 kg TNT to few kg C4 in 10 min
  - in metallic or organic cargo



EURITRACK

C-BORD-RRTNIS

THANK YOU

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THANK YOU

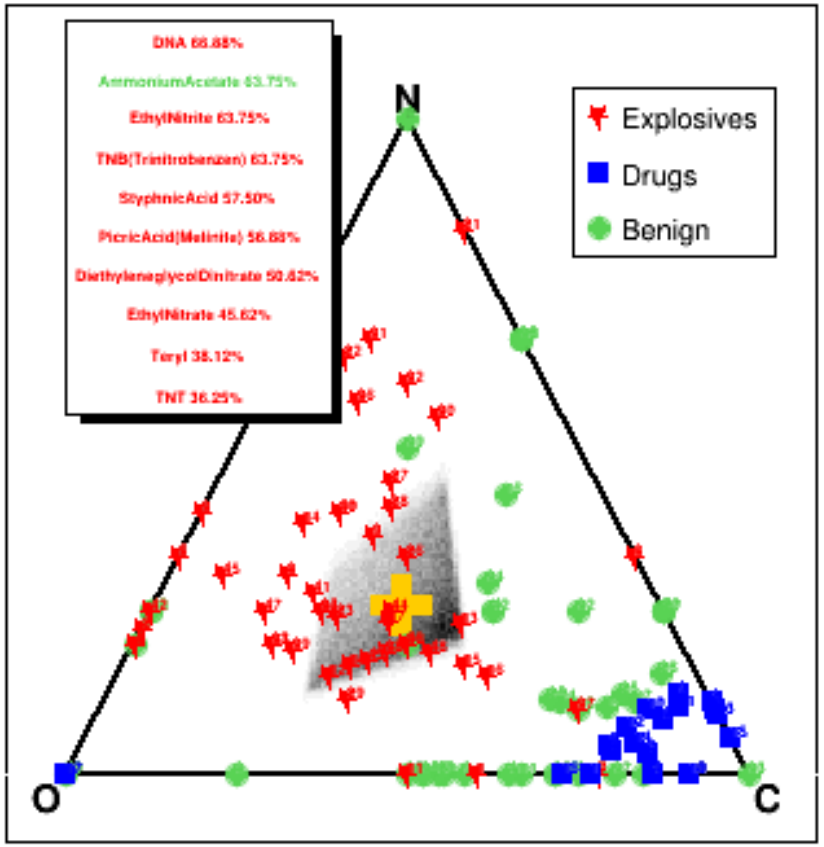
CONCLUSION AND PROSPECT

- TRL 6 – technology demonstrated in relevant environment: The prototype is capable of performing all the functions that will be required of the operational system.

- From TRL 6 forward:
  - ✓the full-scale testing, detection limits, false alarm, no detection..
  - ✓AI algortithm and machine learning with all data acquired and more..
  - ✓Final design for the system: improve mechanics, reduce noise, improve target focusing,..

DETECTION CAPABILITY

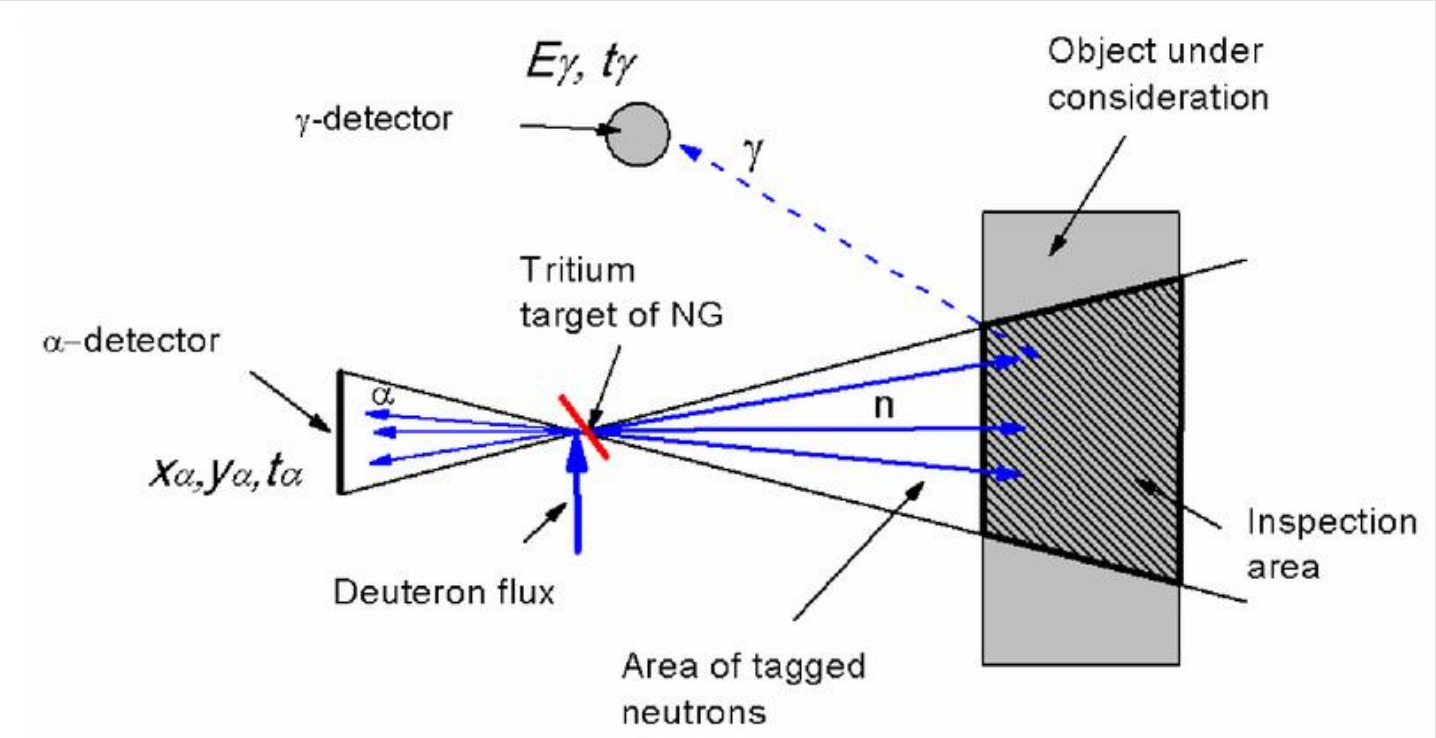
The lack of a single, unique property to characterize explosives and drugs and the availability of several, unusual properties lead to a conclusion that the more of these unusual properties a detection system measures the higher its probability of success.



- The RRTNIS system contains the inherent capability of being able to directly measure the amount of Carbon, Nitrogen and Oxygen present and identify conclusively the type of explosive or contraband drug. It makes it possible to scan a container on a volume element by volume element basis to uncover explosives, which are surrounded by inert substances.

WHAT IS THE TECHNOLOGICAL METHOD BEHIND RRTNIS?

- These high energy neutrons react with atomic nuclei of elements in the container to be assayed to produce gamma rays. Several nuclear reactions are possible, one of which is inelastic scattering with subsequent loss of neutron energy and production of gamma rays ranging in energy up to about 7 MeV.



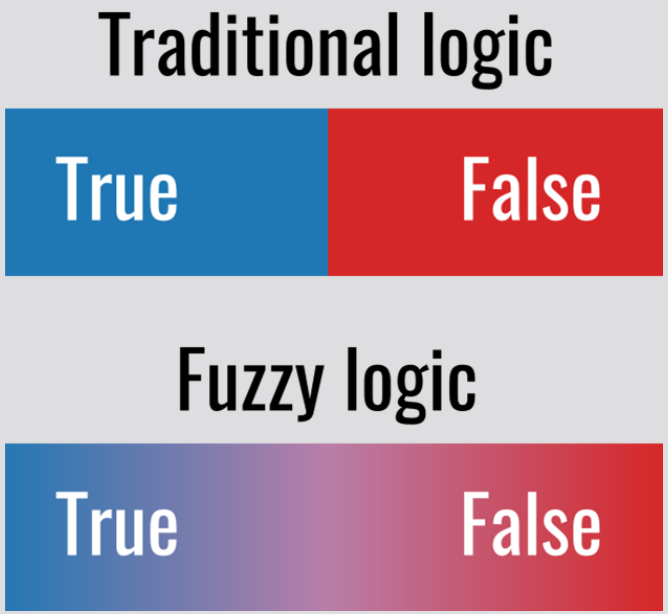
- The energy and number of the gamma rays identifies the element from which it is emitted and essentially forms a "fingerprint" from which the element can always be identified.

MATERIAL CLASSIFICATION BY MACHINE LEARNING

First machine-learning solution for Material Classification with TNIS:

FUZZY DECISION TREE

It combines all information and suggests a list of object types with *confidence levels*



MATERIAL RECOGNITION AS A FUNCTION OF CONTAINER DEPTH