Detection of hidden explosives in different scenarios with the use of nuclear probes

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INPC2004

The problem of the detection of hidden explosives: the "toolbox approach"

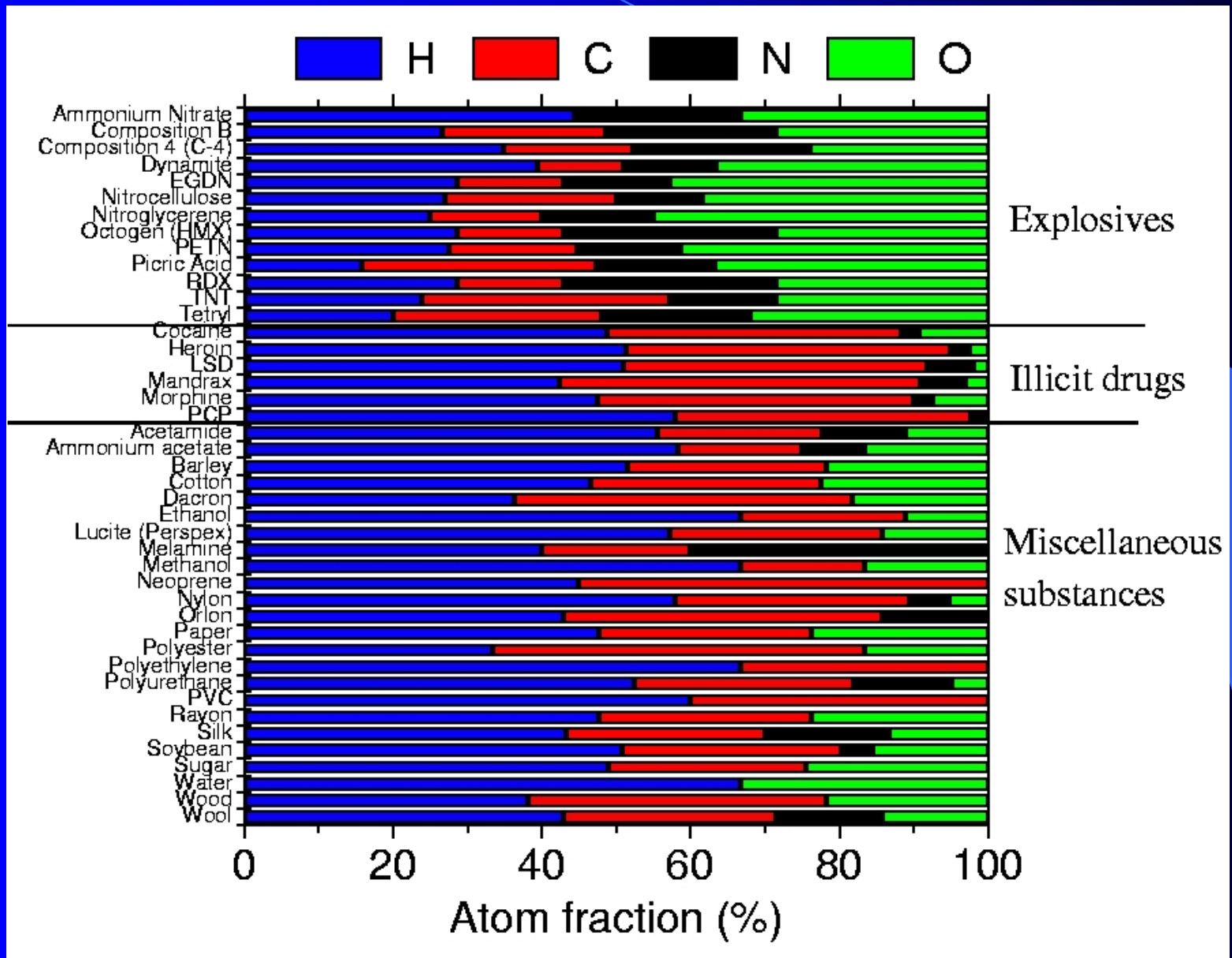
a) Detection of landmines buried by armies and/or irregular groups during recent conflicts (different landscapes of de-mining operations)

b) Detection of unexploded ordnance from recent as well as old conflicts (i.e. World War II)

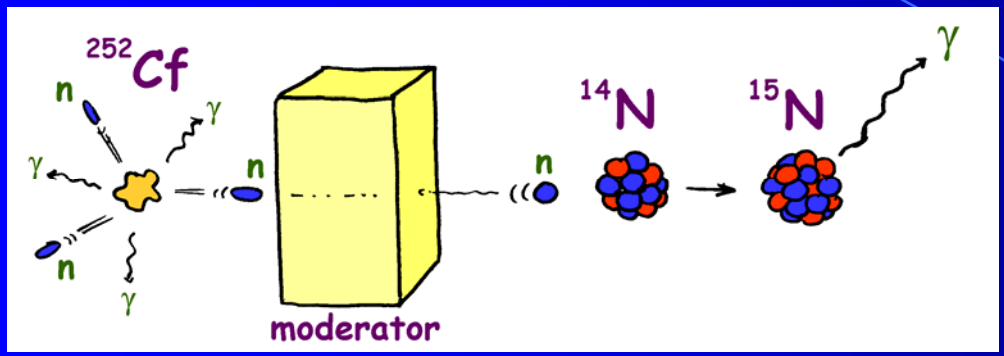
c) Detection of explosive devices in the counter-terrorism activity (protection of sensible sites)

d) Detection of illicit trafficking of explosives and other threat materials (freight transportation system)

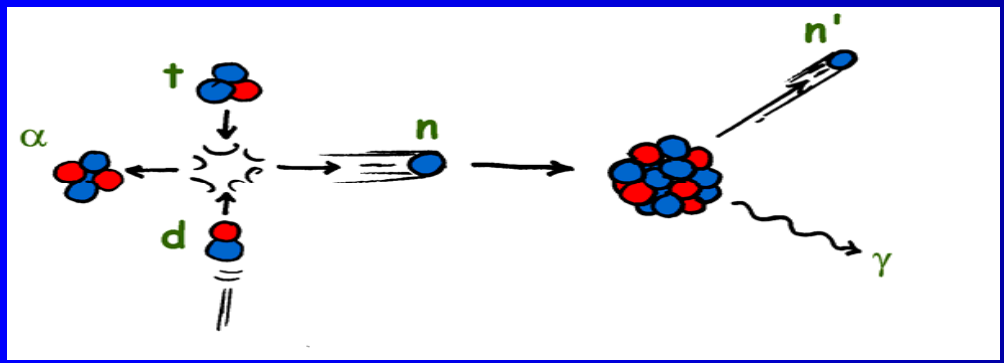
Chemical composition of different materials



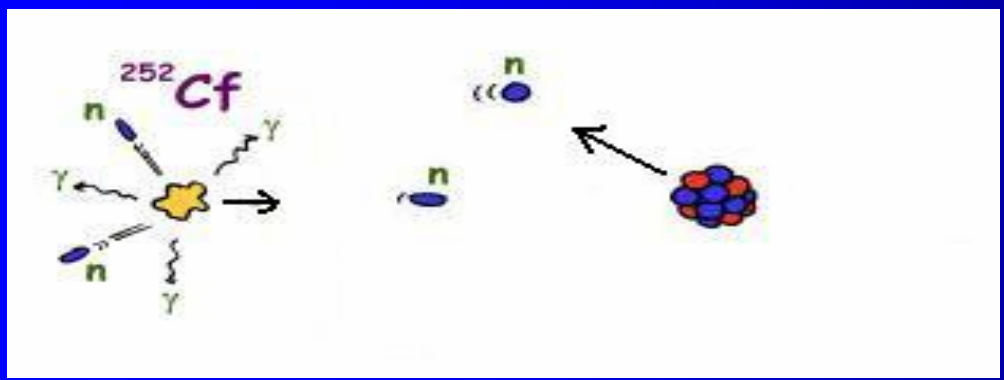
Neutron induced reactions



Thermal neutron capture



Inelastic scattering



Backscattering

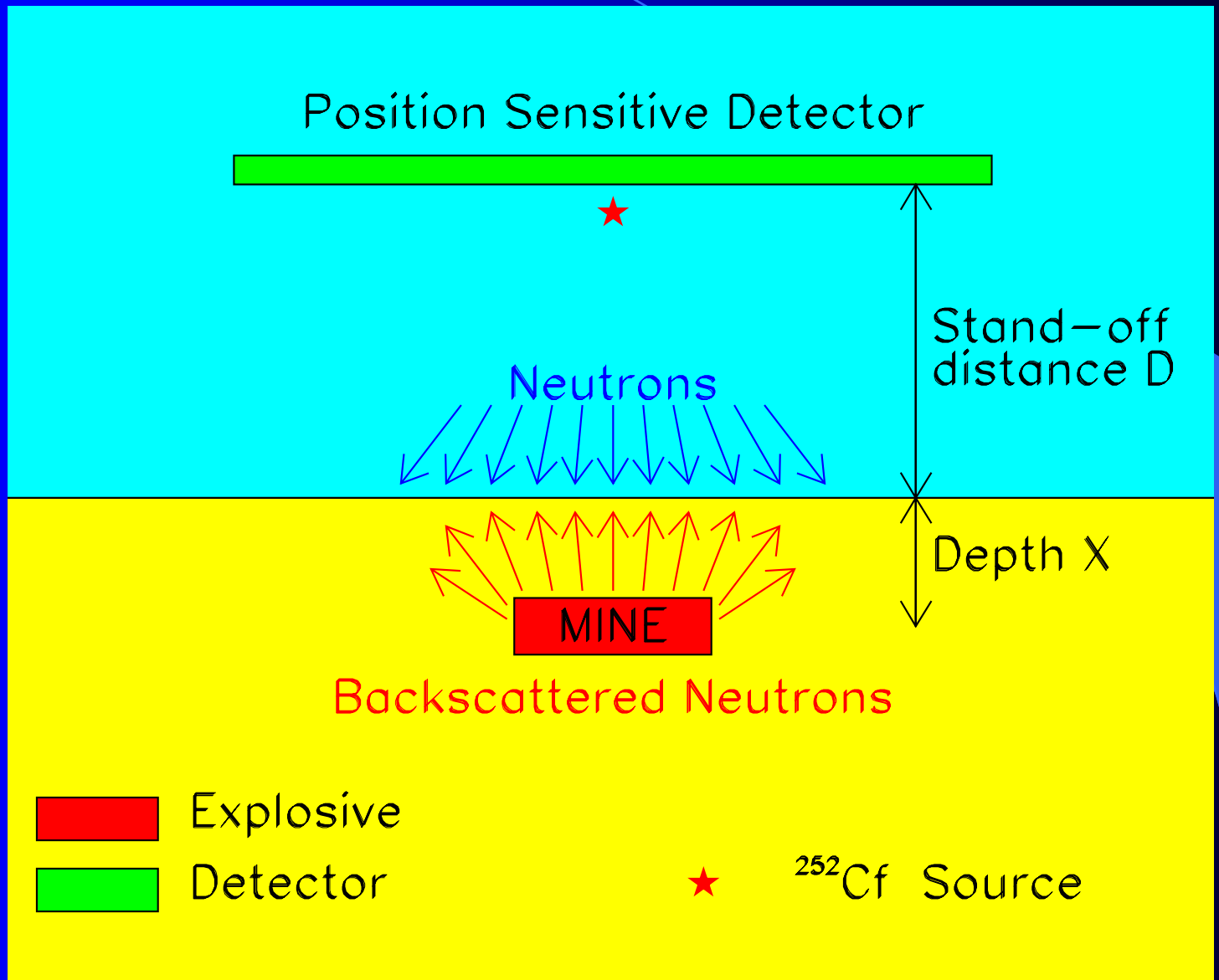
γ-ray transitions of relevant elements (MeV)

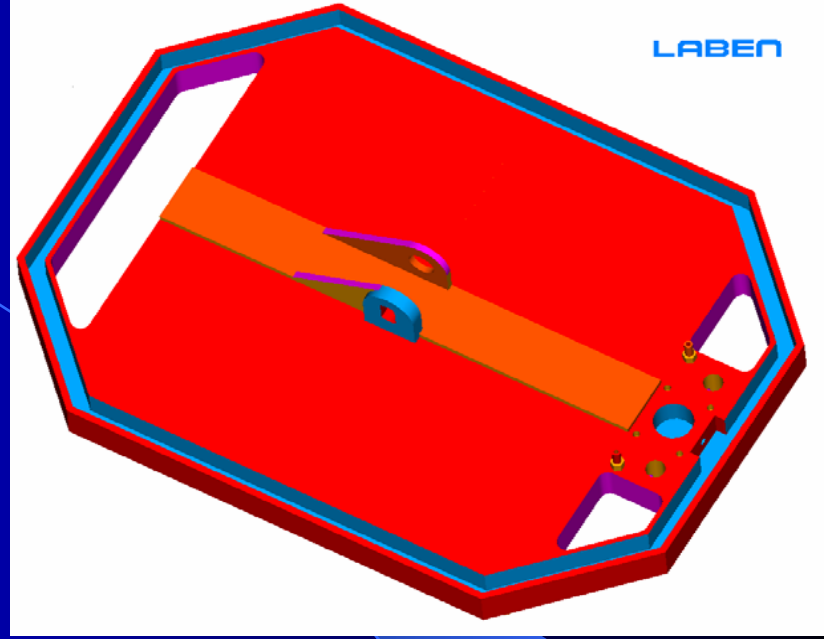
Element	capture	inelastic
H	2.2	
C		4.42
N	10.82	1.6 - 2.3 - 5.1
O		3.8 – 6.1

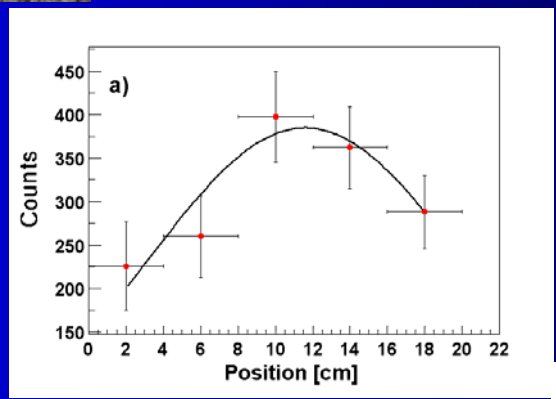
Different tools for different needs

For manual humanitarian demining one needs low-cost, handheld, operator-friendly equipment to substitute/compliment the use of metal detectors

“DIAMINE” a EU financed neutron backscattering detector for Humanitarian Demining (2000-2002)

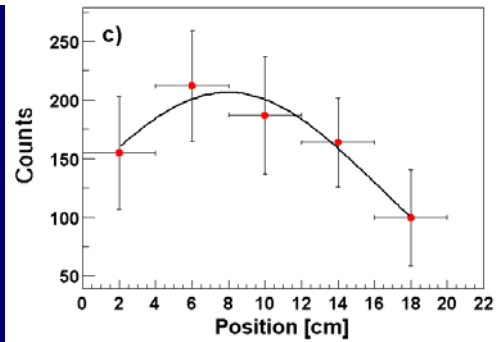






Hit distribution
at depth = 2 cm

Hit distribution
At depth = 10 cm



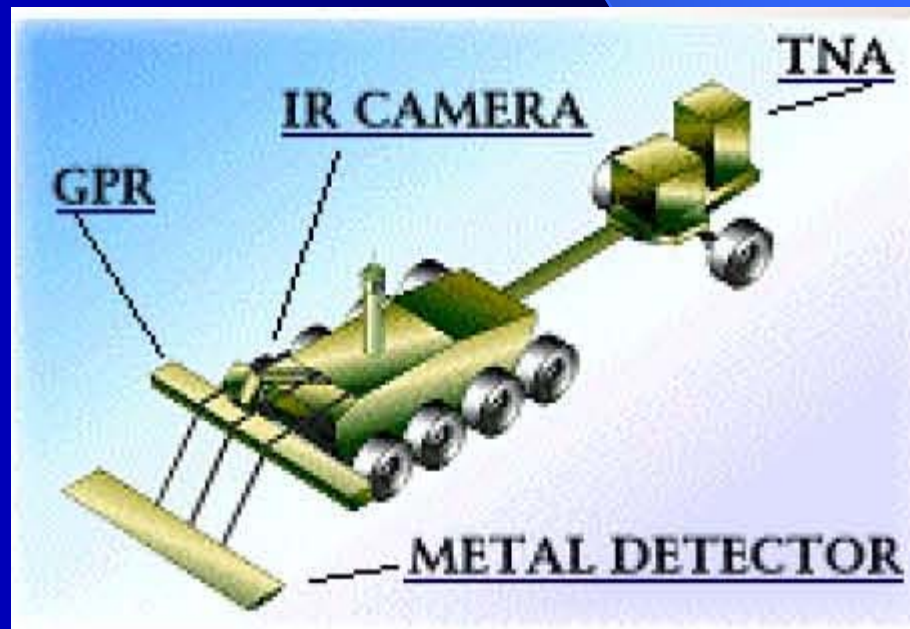
One prototype of handheld Neutron Backscattering Detector

Courtesy of Prof. Carel W.E. Van Eijk, Delft University of Technology, IRI, Delft, The Netherlands

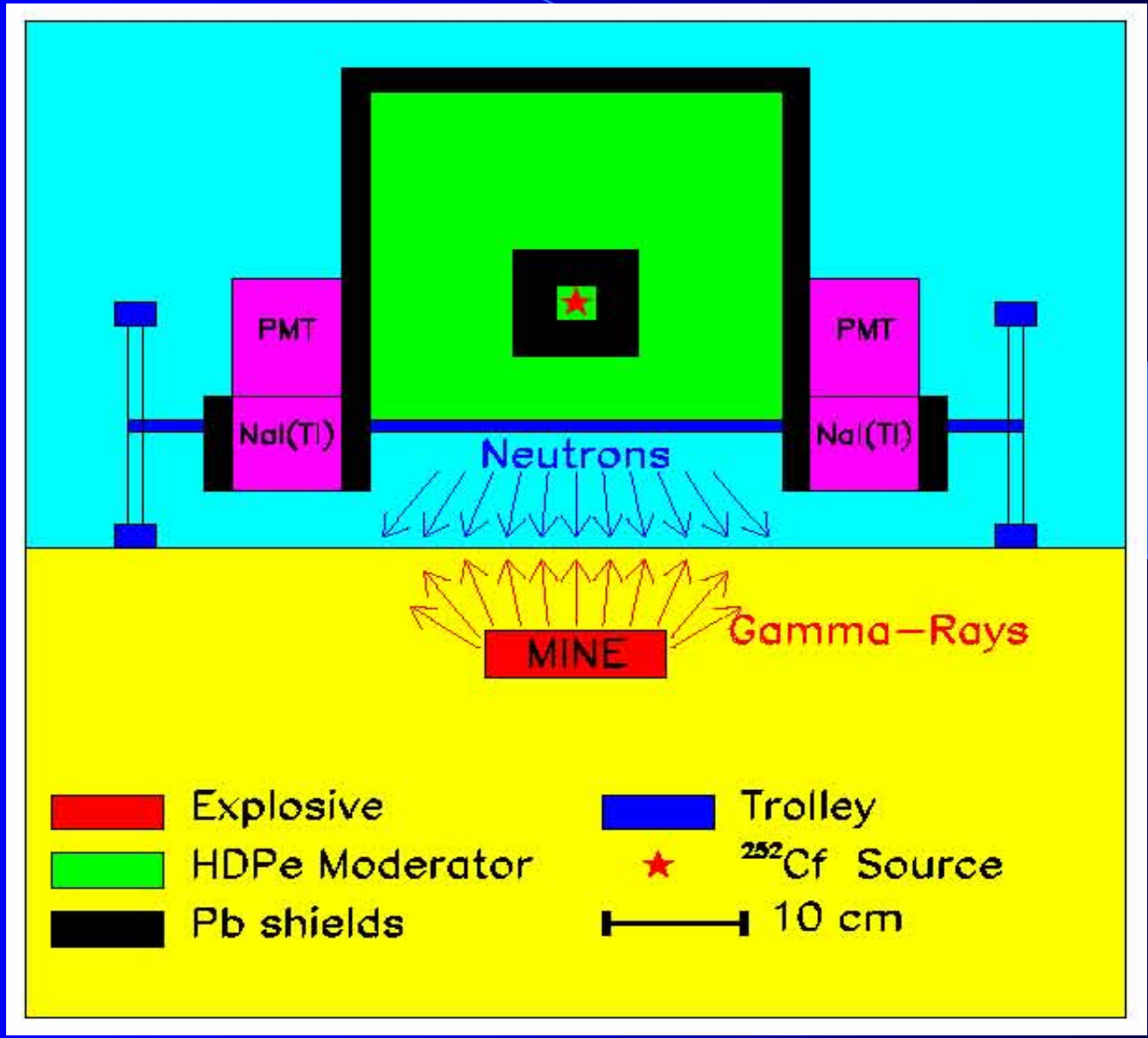
Infrastructural demining and vehicle mounted devices

In operations of “infrastructure demining” i.e. industrial sites, pipelines, houses etc. the portability of the device is not a strict requirement. The irradiation time is also a more flexible parameter

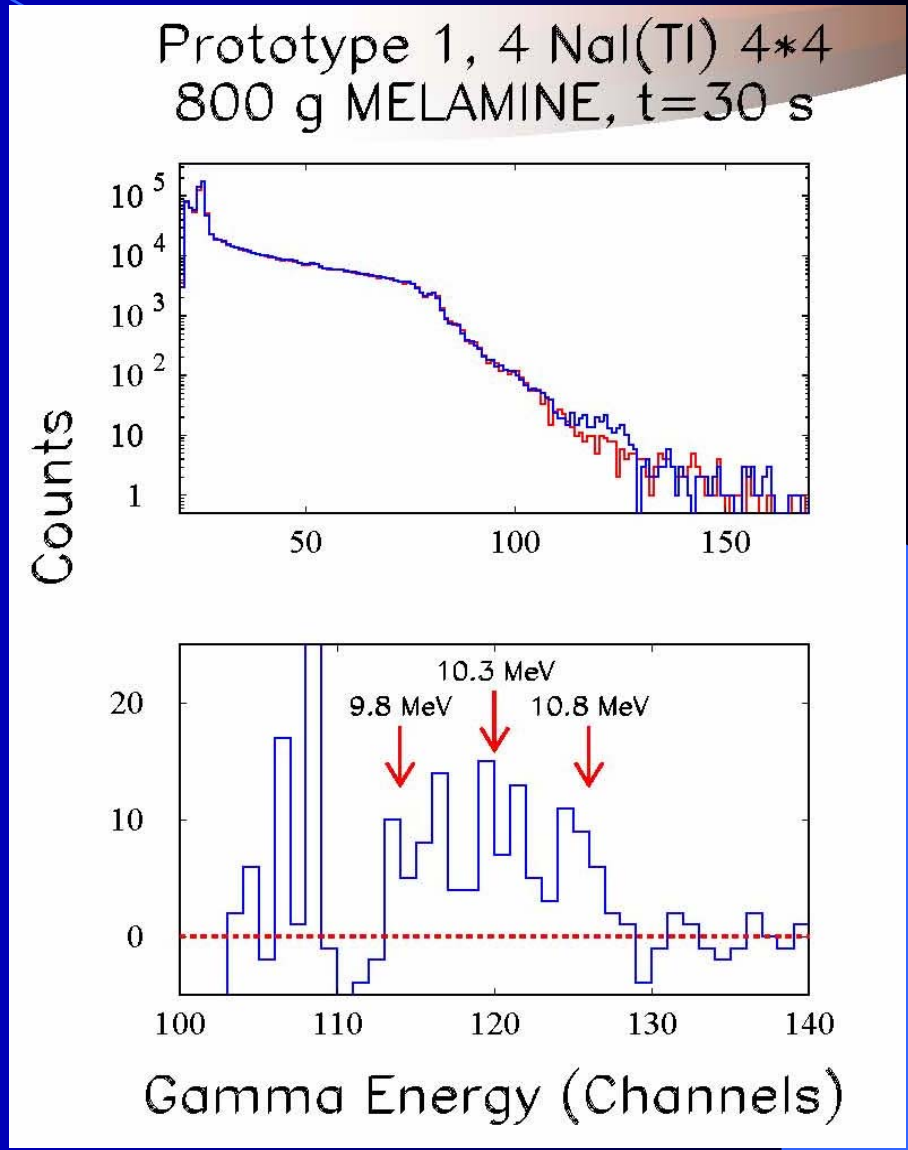
Vehicle mounted systems are made of different sensors like e.g. metal detectors, ground penetrating radars and infrared probes to which should be added a “confirmation sensor”.

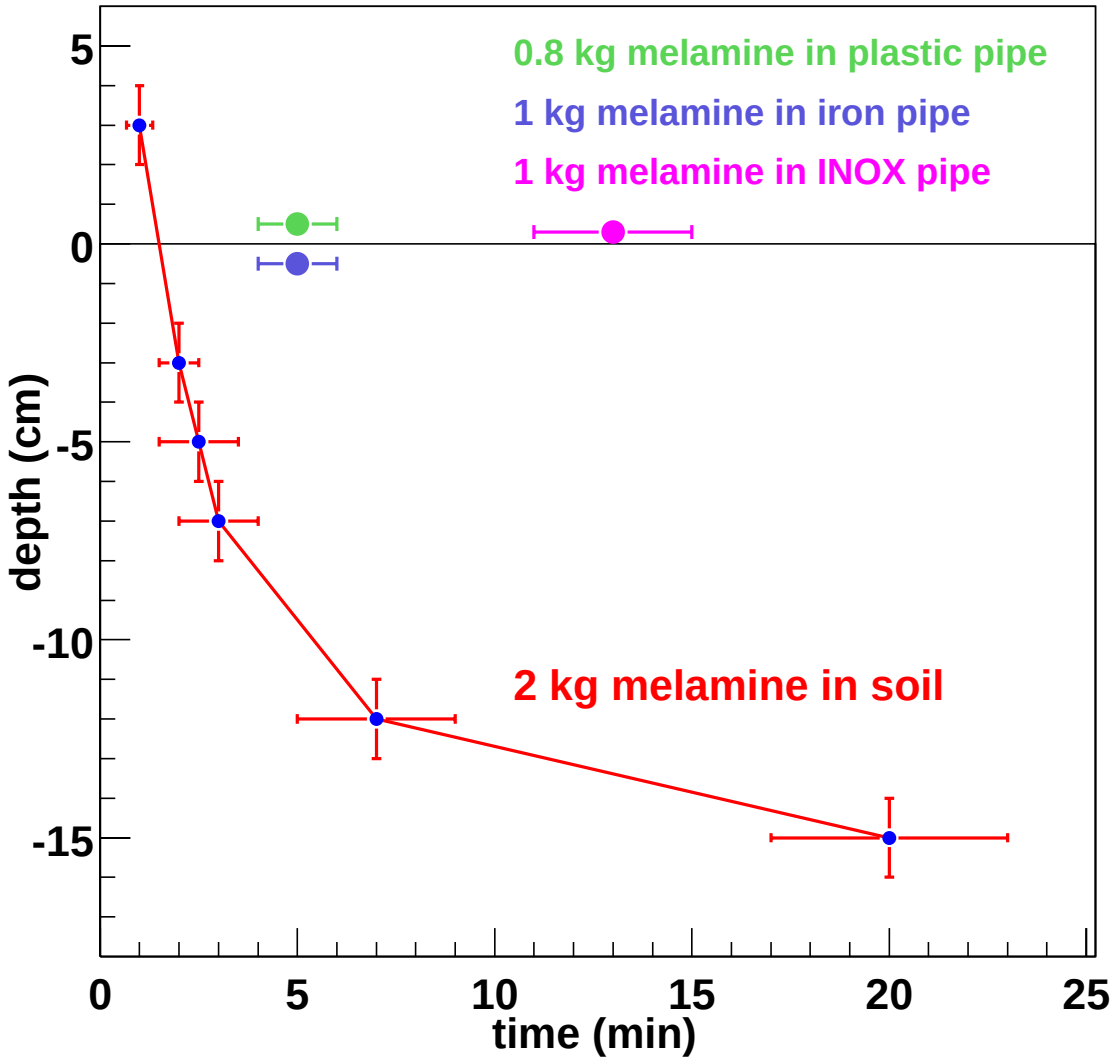


A Thermal Neutron Analysis sensor



The TNA sensor developed by INFN within the "EXPLODET" project (1998-2002)





Results of the TNA sensor installed at the Lab. Naz. di Legnaro (Italy) for irradiation of a sample of explosive simulant under different conditions.
The source is a Cf sealed neutron source delivering about 10exp7 n/sec.
The moderator is a cylinder of HDPE with a front thickness of 6 cm.

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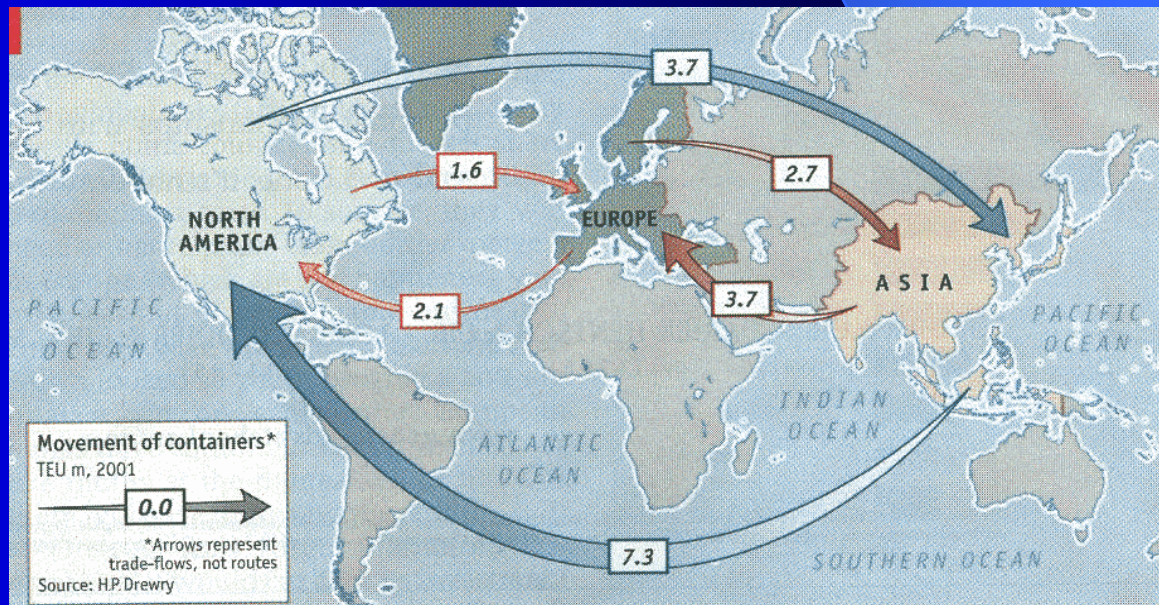
Detection of explosives in the trade system : countermeasures against illicit trafficking

The size of the container industry is enormous : in FY 2002 the world's total movement in containers amounted to about 72 M TEU ("Twenty-foot Equivalent Unit) that are transported by ships and deposited inside the harbours Customs areas.

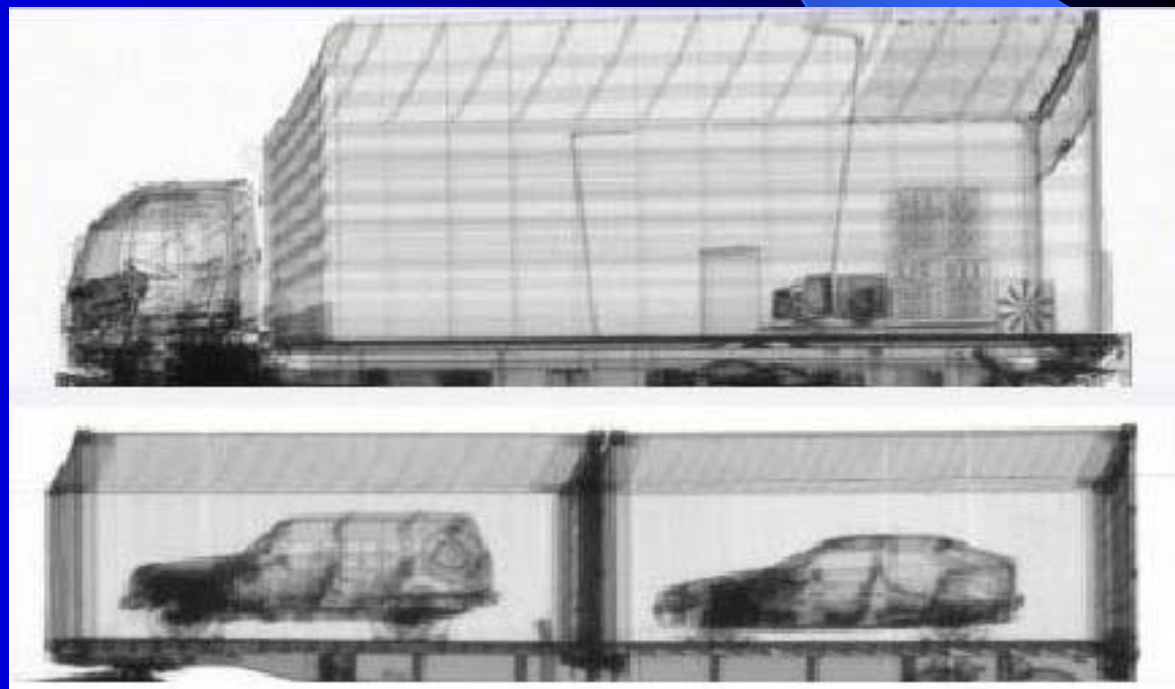
There is an increasing risk that sizeable amounts of "threat materials", including explosives, be hidden in cargo and transported by means of the standard commercial network.



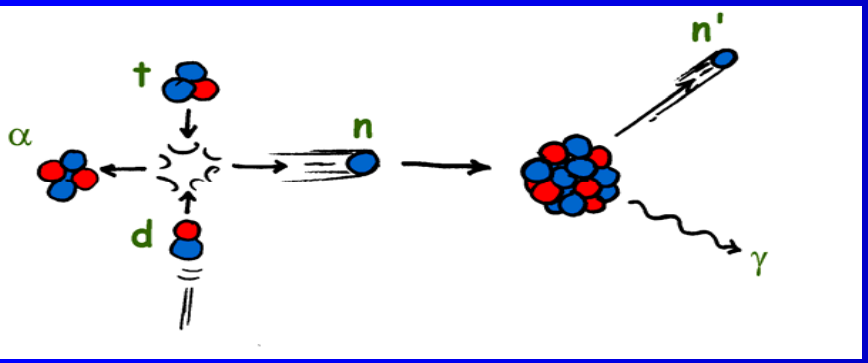
Present inspection systems at ports are based on x-ray or γ-ray radiography.

Courtesy of SAIC, San Diego, CA, USA

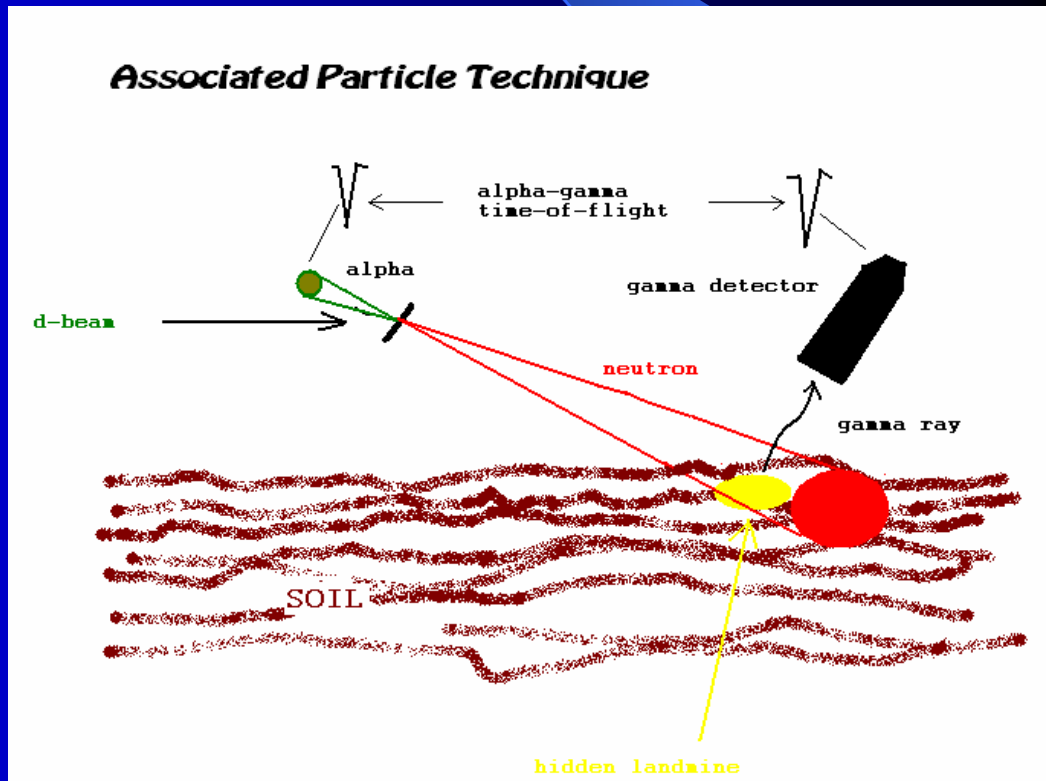
Although the pictures are rather detailed and 3D imaging is possible, the number of suspect unidentified areas is still high.



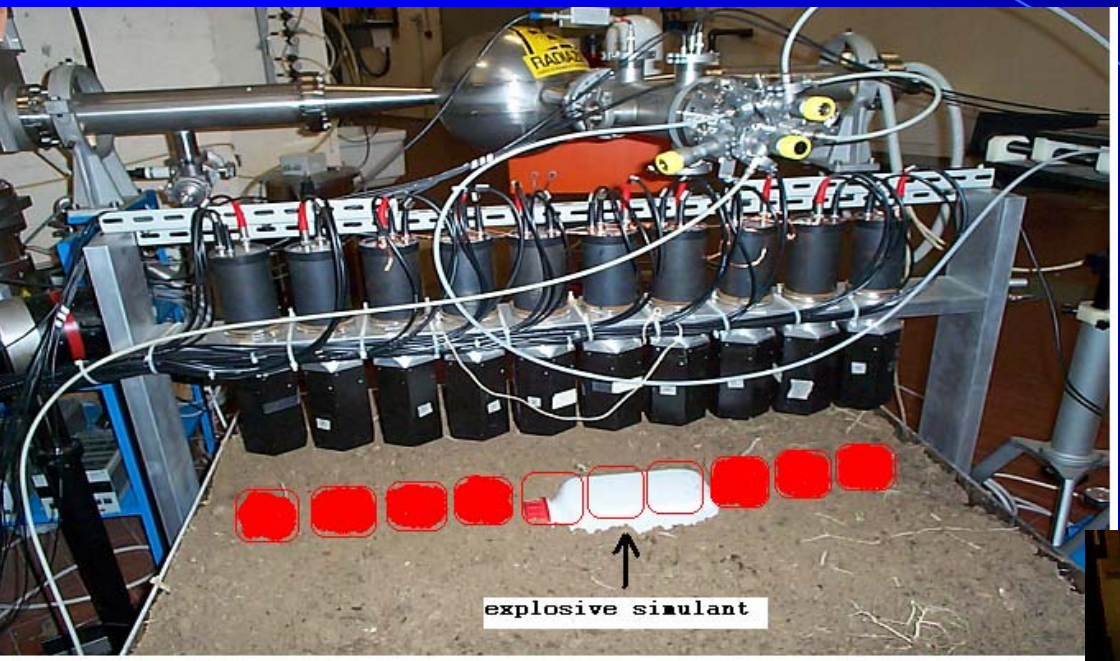
TNIS : Tagged Neutrons Inspection System based on the “Associated Particle Technique”



In the d + t reaction a neutron with energy of 14 MeV and an alpha particle with energy of 3.5 MeV are emitted “back-to-back” in the COM.



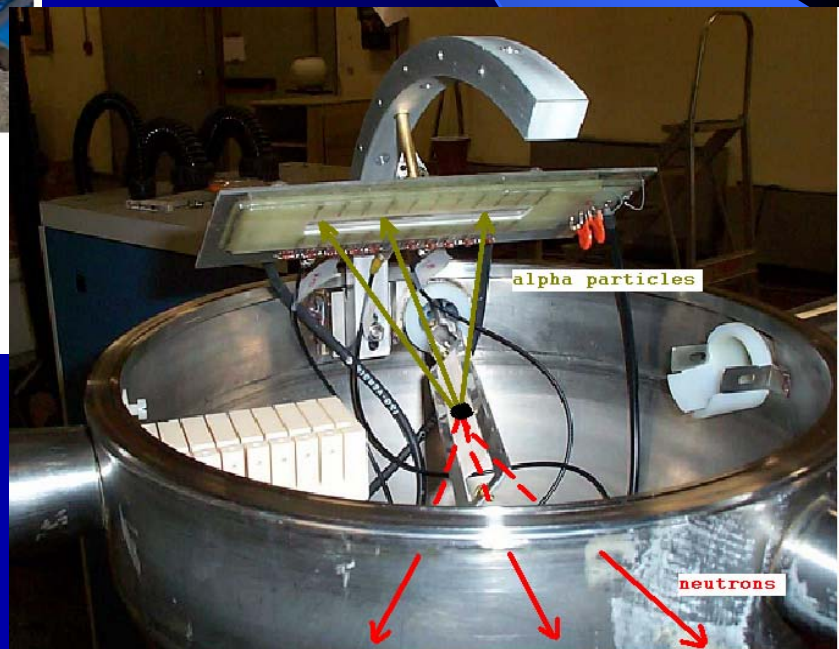
The “Associated Particle Technique” project financed by INFN, the Italian Ministry of University and Research and partly supported by the NATO-SfP programme



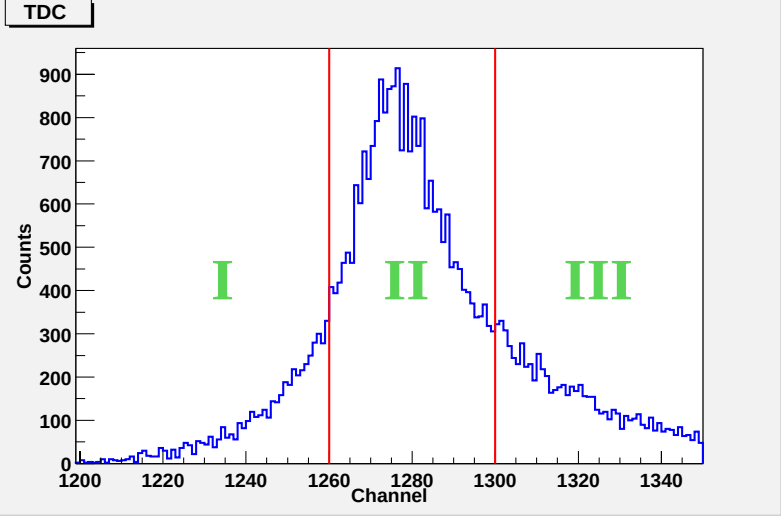
Accelerator setup with soil box

10 different neutron beams hitting the inspected area

The “COFIN99” setup installed at the CN 7 MV VdG accelerator at the Laboratori Nazionali di Legnaro (Italy)

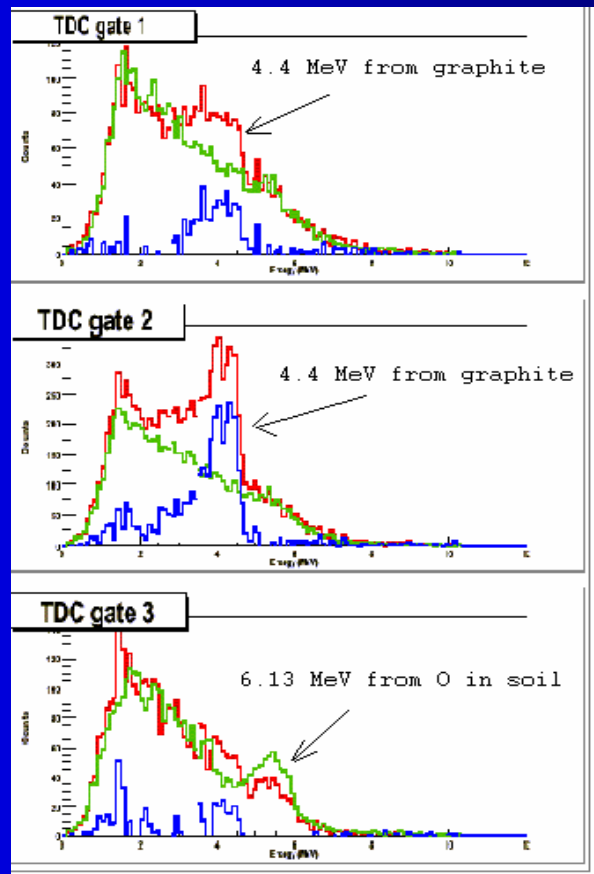


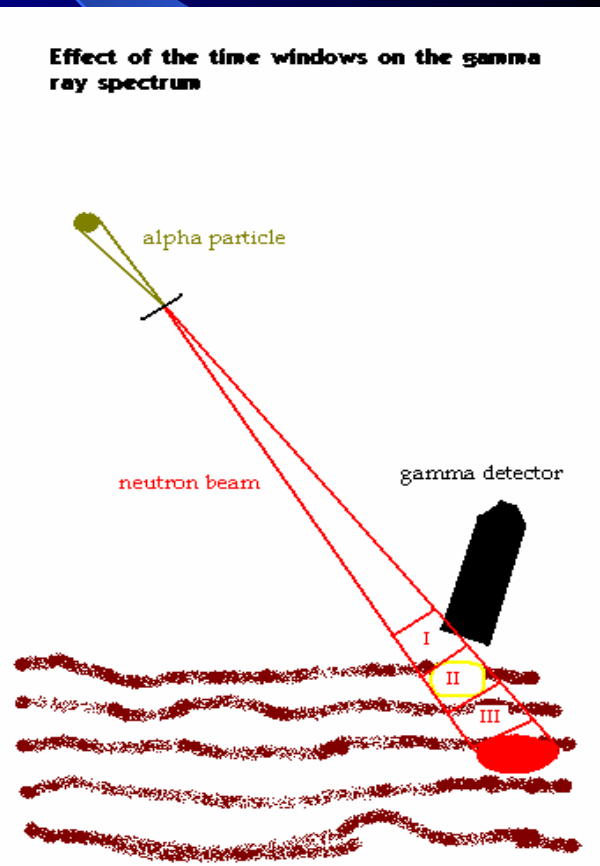
One Parallel Plate Avalanche Counter divided in 10 sectors allows tthe tagging of 10 different neutron beams.

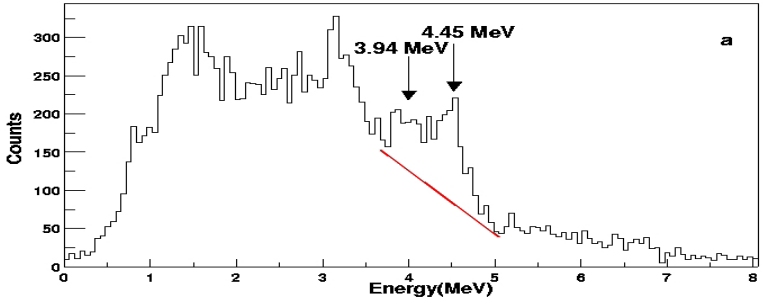


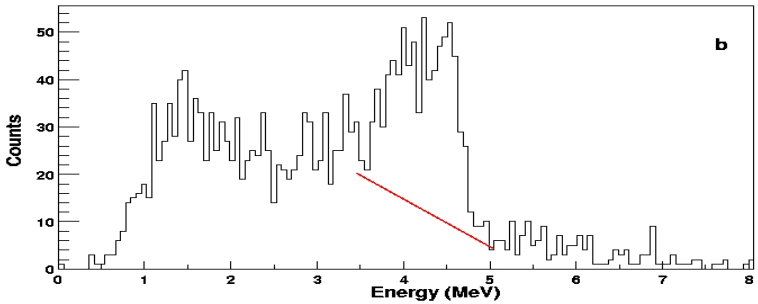
Alpha-Gamma time-of-flight and gamma energy signals are recorded and used to recognize the elemental composition of a well defined irradiated area.

Different elements are detected in different volume cells (“voxels”) using the tagged neutron beams.



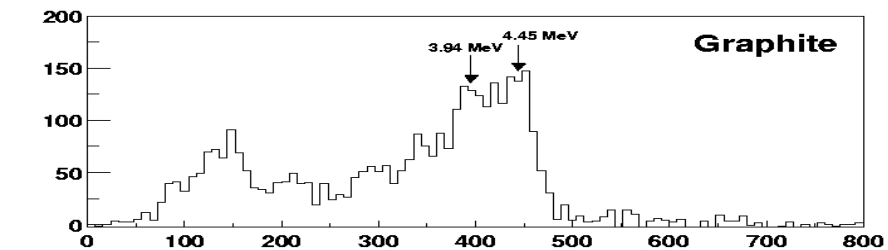


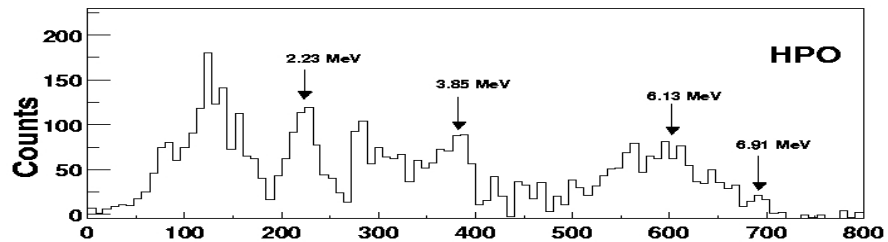


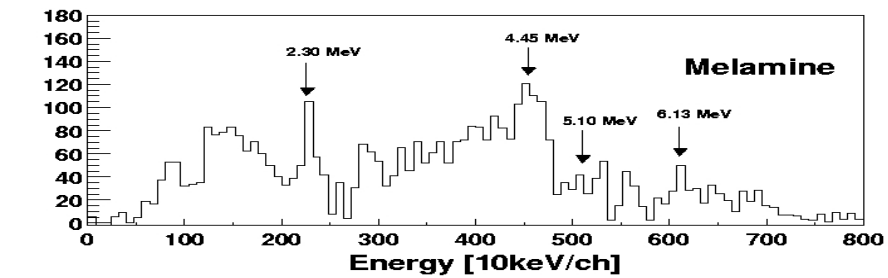


The use of the associated particle technique greatly reduces the background from the gamma-ray spectra allowing to increase the signal/noise ratio by a significant factor.

Irradiation of different test samples, in a “clean” spectrum it’s easy to recognize different elemental contributions through the characteristic gamma-ray transitions.



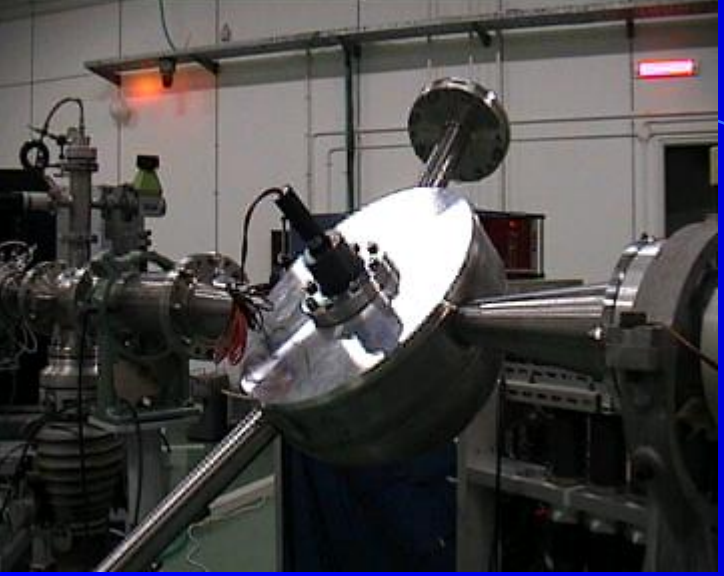




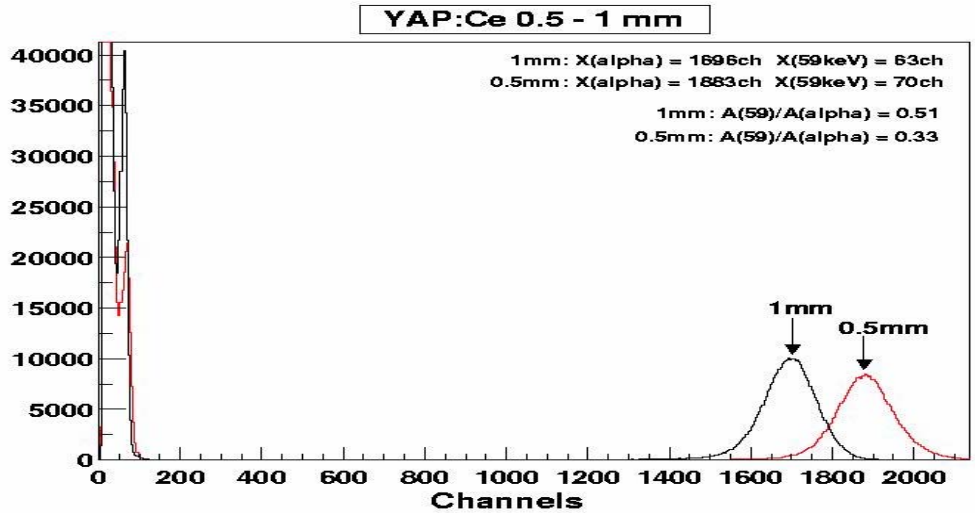
The experimental setup at the Institute Ruder Boskovic in Zagreb (Croatia)

The beamline dedicated to inspection of suitcases for airport security.

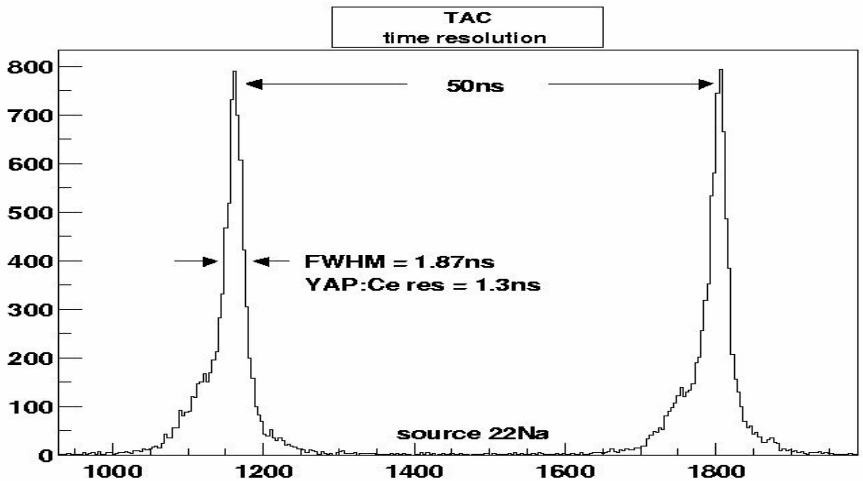
The beamline dedicated to inspection of containers for harbor security.



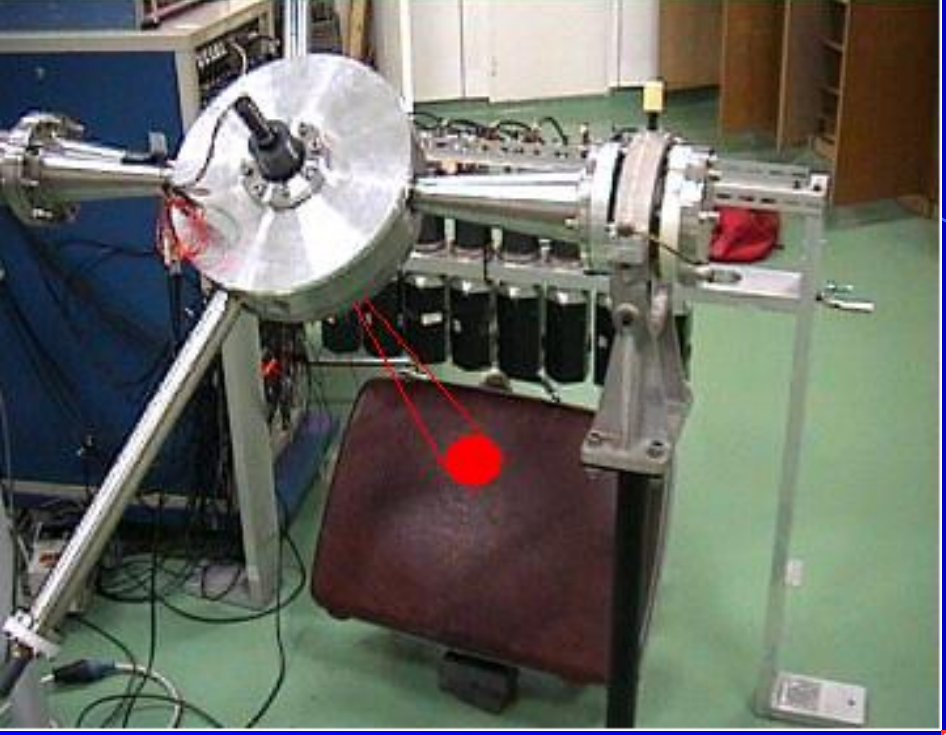
The alpha particle detector is a YAP(Ce) crystal of 40 mm diameter and 0.5 mm thick read out by a Hamamatsu R1450 PMT.



Energy resolution of YAP(Ce) for $E\alpha$ = 5.4 MeV and $E\gamma$ = 59 KeV



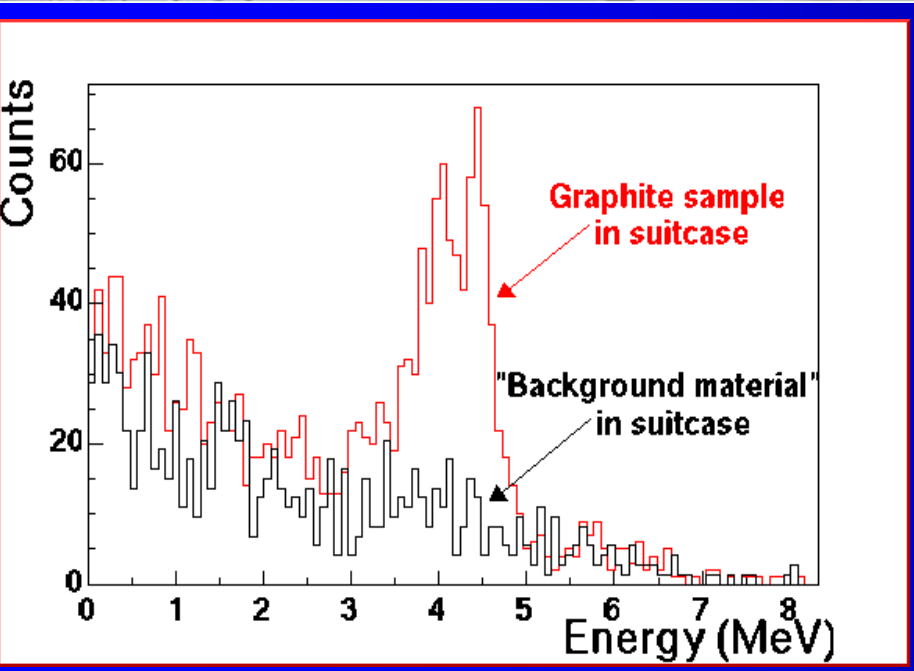
Timing resolution of two YAP(Ce) detectors for two coincident 511 KeV γ - rays

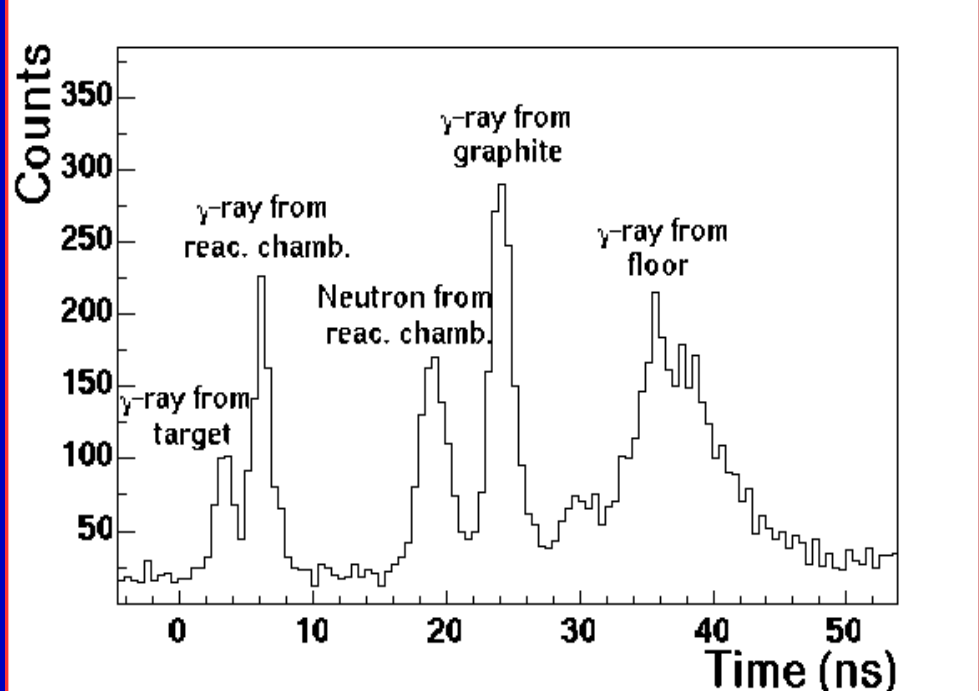


Irradiation of a 10x10x10 cm. graphite sample hidden inside the suitcase

Right : alpha-gamma timing spectrum

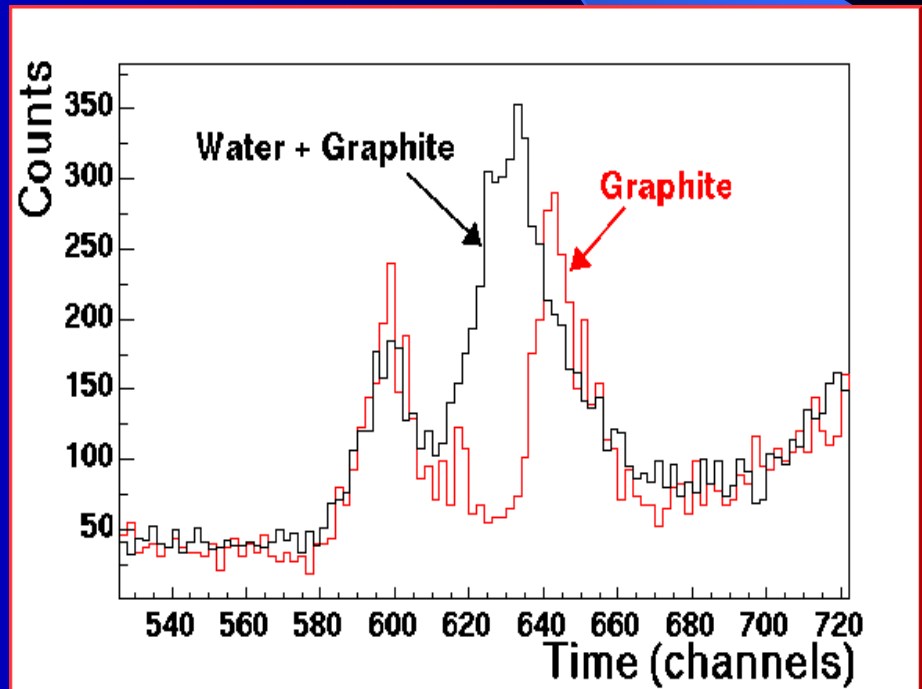
Left : gamma energy gated on the “graphite” in the timing spectrum



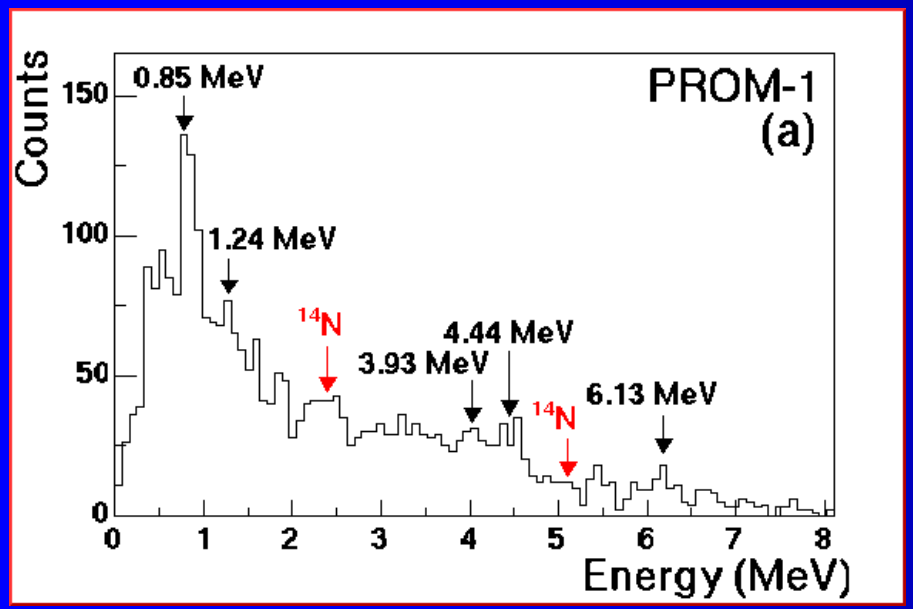


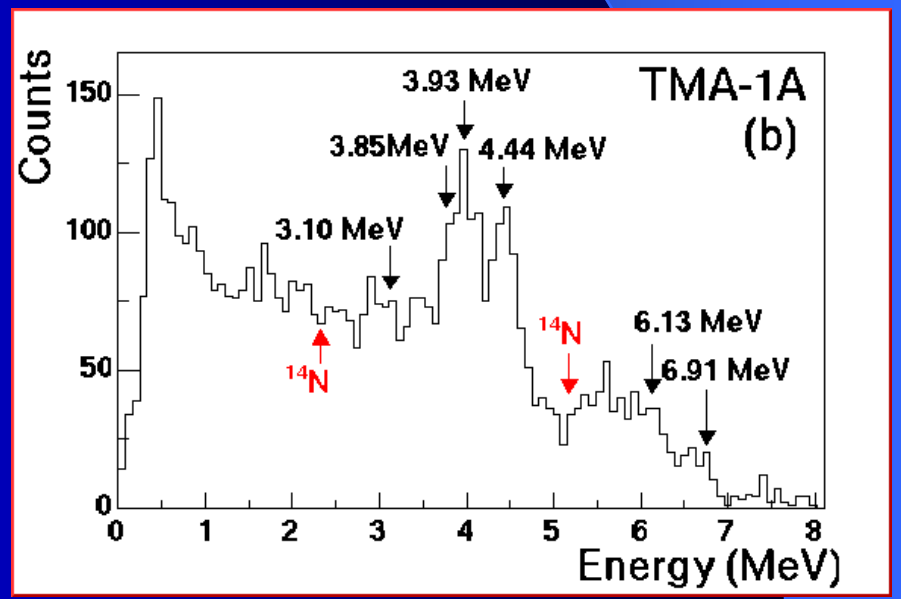
Inserting a bottle of water inside the suitcase in front of the graphite sample.

Effect of the bottle of water on the alpha-gamma timing spectrum, one can clearly see the component added at shorter time.

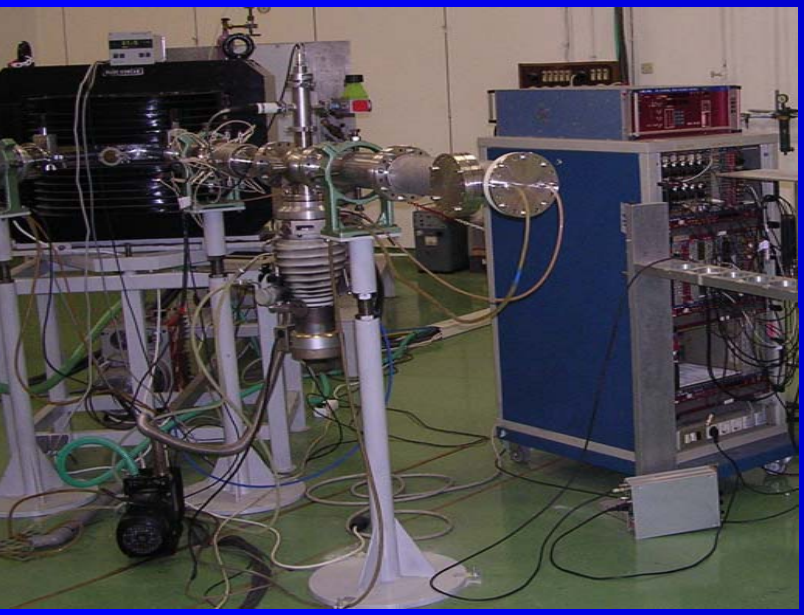


Inserting two different landmines (PROM-1 = 400 gr. of TNT and TMA-1A = 5 Kg. of TNT).
Effect of the explosive on the gamma energy spectrum (gated on the alpha-gamma timing).





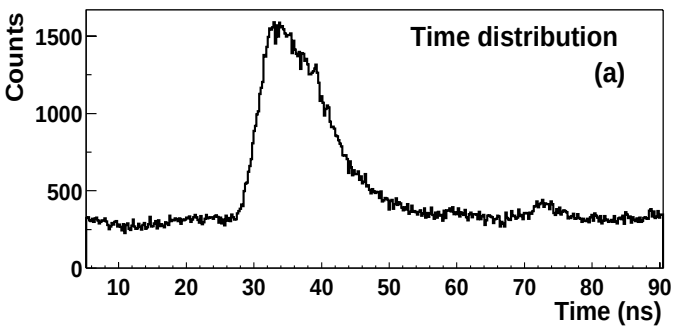
Present development : a portable sealed neutron generator with the associated particle detector (TPA)

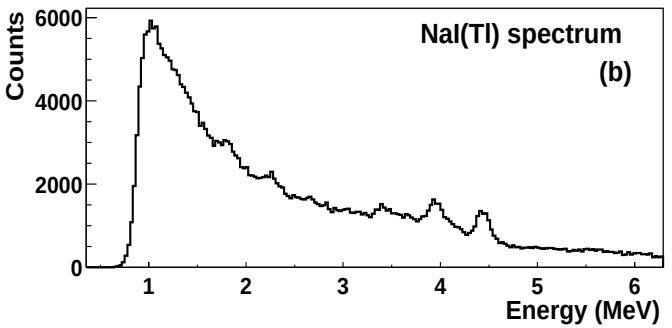


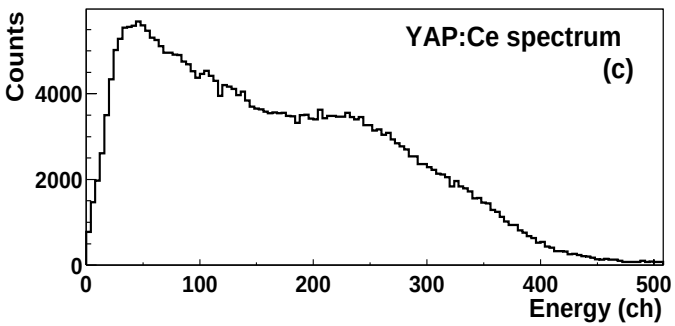
A portable sealed neutron generator capable of delivering 10exp8 neutrons/second.
Mounting the alpha particle detector inside the neutron generator.

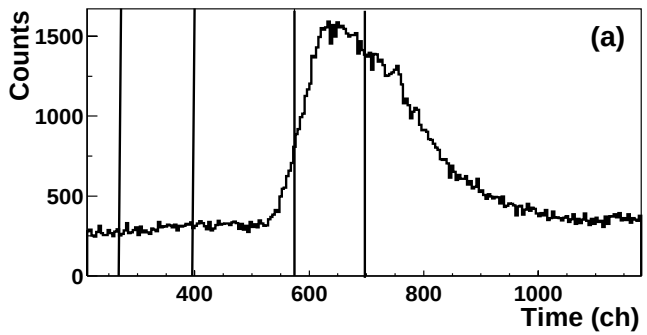
Courtesy of EADS-Sodern

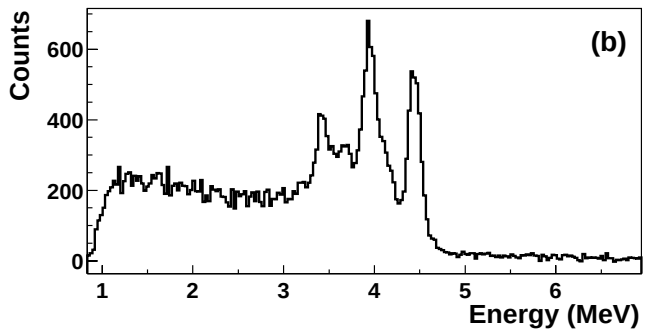
First results with the TPA

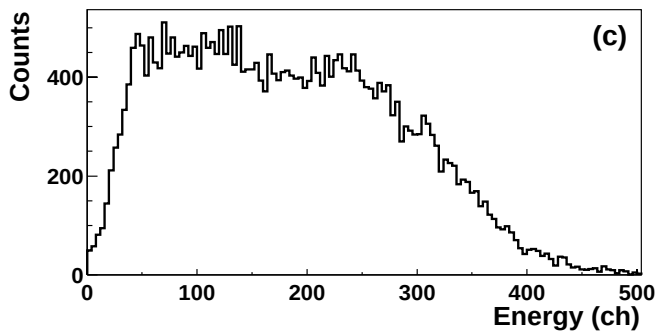












The future

Two new initiatives are ready to start the activity on the application of portable TPA neutron generators to the monitoring of cargo at Customs inspection stations in ports and airports.

EURopean Illicit Trafficking Countermeasures Kit (EURITRACK)

A consortium composed by a number of research institutes and SME's from Croatia, France, Italy, Poland, Sweden, has recently proposed a STREP initiative to EU. The proposal have been approved and the negotiation stage is concluded. The project should start on Oct. 1, 2004.

SfP – 980526

A collaboration between the INFN and IRB has proposed an R&D project to the programme "Science for Peace" of NATO.
The project has been scientifically approved and is now in the process of being financed . The project shuld start within the summer 2004.