On-line remote monitoring of radioactive waste repositories

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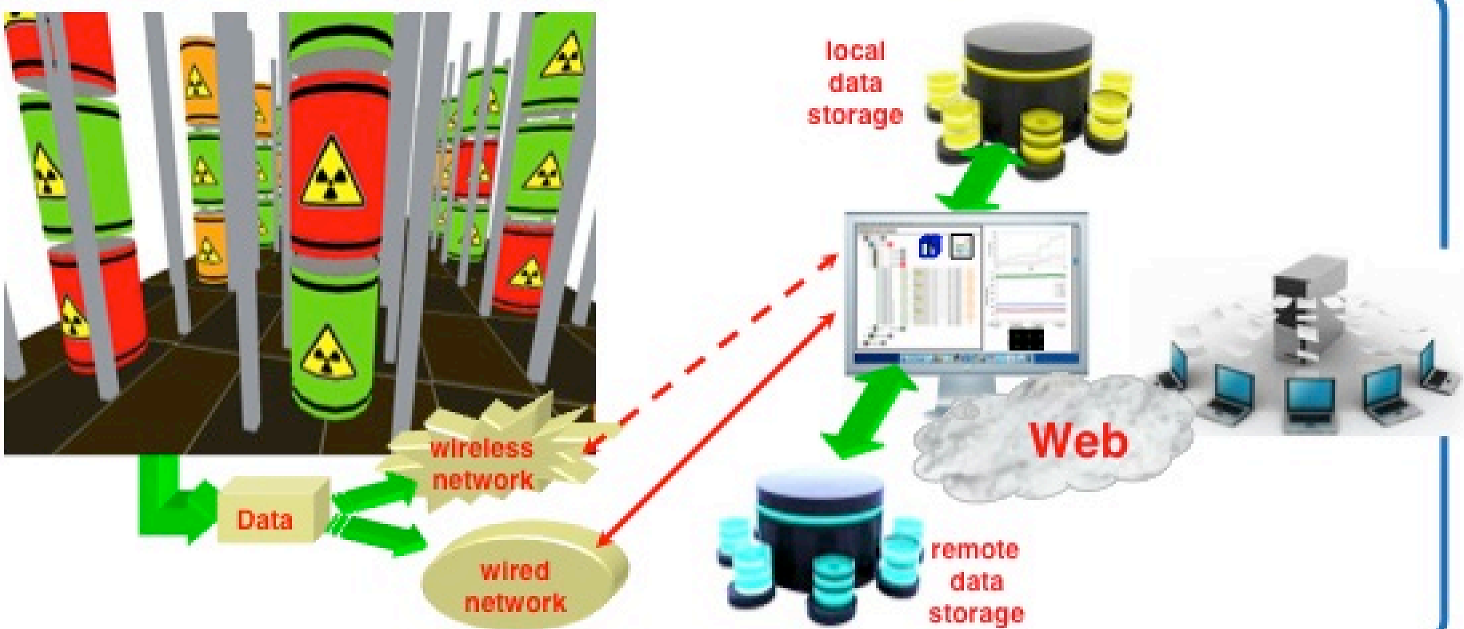


DMNR Detector Mesh for Nuclear Repositories

Radioactive waste confined into long-lasting drums

DMNR project: topics

- On-line monitoring of short/medium term radioactive waste storage
- Application of non-conventional detectors for decommissioning

DMNR project: goals

- real-time monitoring: activity, mechanical stability, etc.
- real-time availability of data to control authorities, fire departments, local and national governments, etc.
- radwaste handling by means of advanced tools and procedures suitable for **reducing the risks** to the **local workers** and to the **population**

Why do we want to monitor?

We want to have a complete and detailed record of the history of each drum.

Accidents may happen, most likely:

- ✓ *drums might be damaged while being displaced (mainly for inspection!)*

- ✓ *the concrete matrix containing the waste might crack (and leak out)*
- ✓ *liquid waste?????*

What would be desirable?

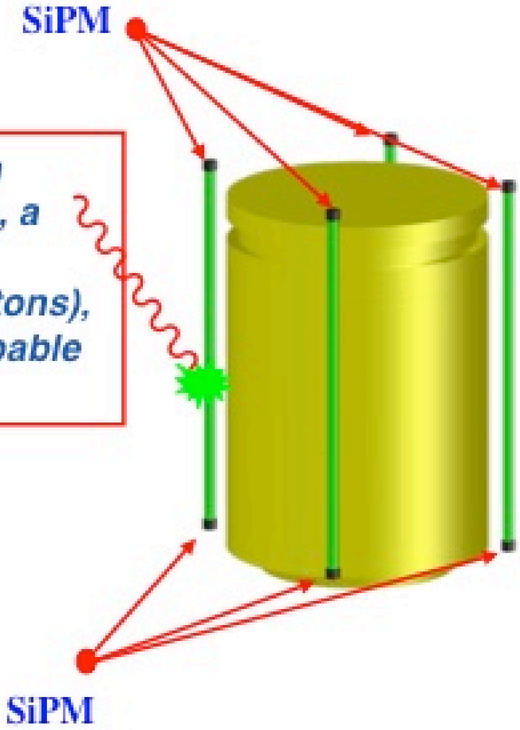
individual and continuous online monitoring of drums, even during possible displacements
or better, never displace the drums, monitor them in place

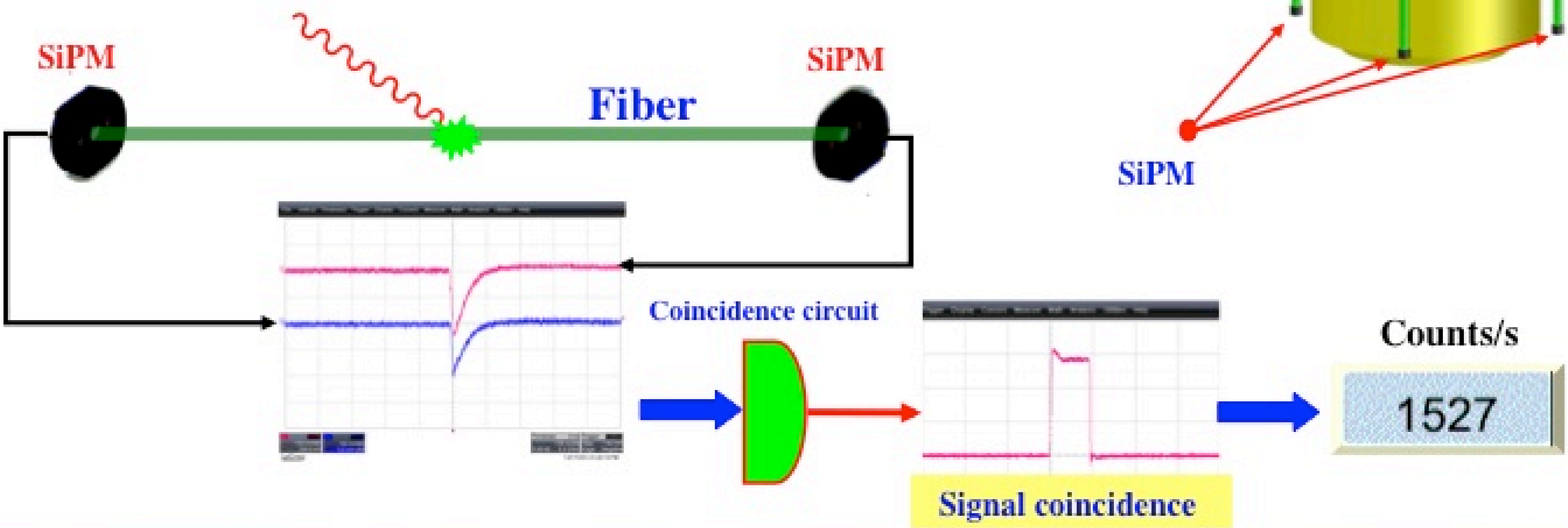
How do we want to monitor? → Basic sensor unit

Sensor requirements and goal:

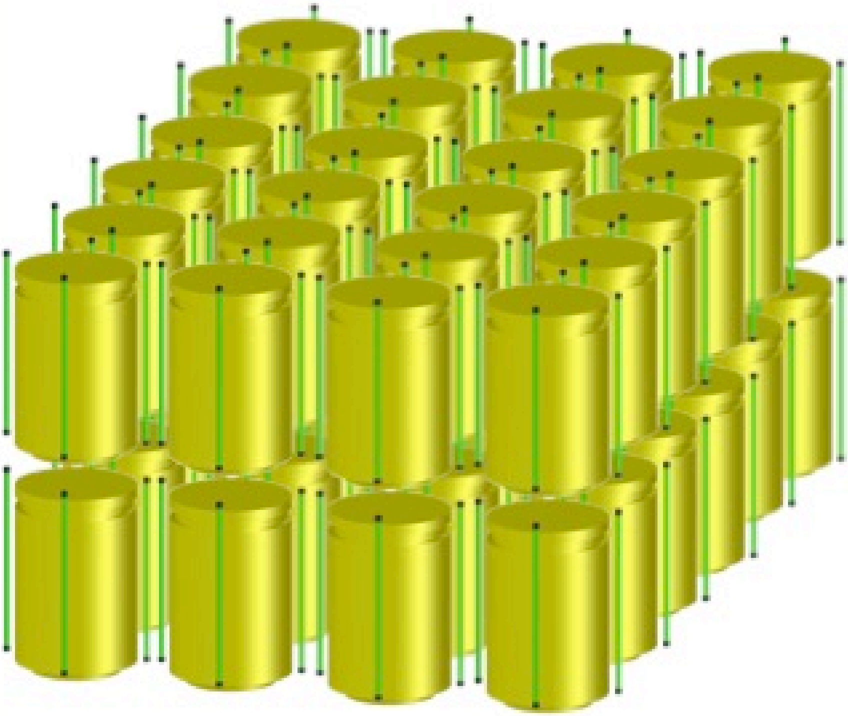
- radiation hardness yes several years close to a drum with 10-100 mGy/h
- robustness yes, plastic scintillators; SiPM not damaged by ambient light exposure
- low efficiency, high sensitivity yes
- reliability yes
- low cost yes

Whenever radiation stimulates the fibre, a tiny light pulse is produced (few photons), and the SiPM is capable of detecting it

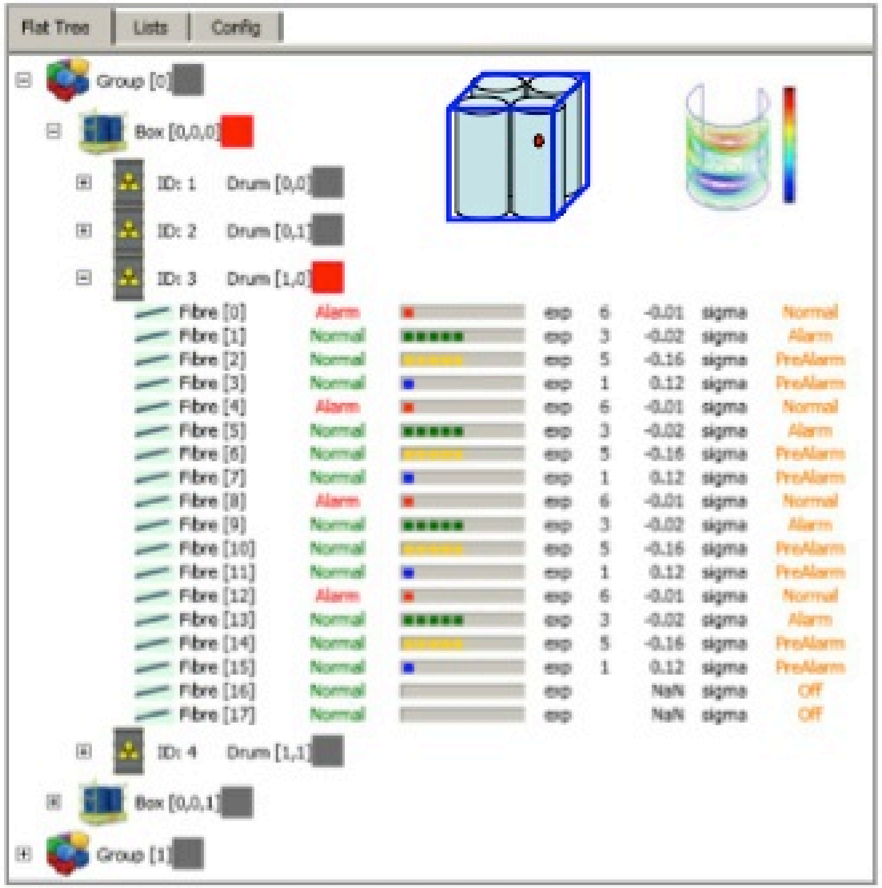




Repository: 3-D map sketch

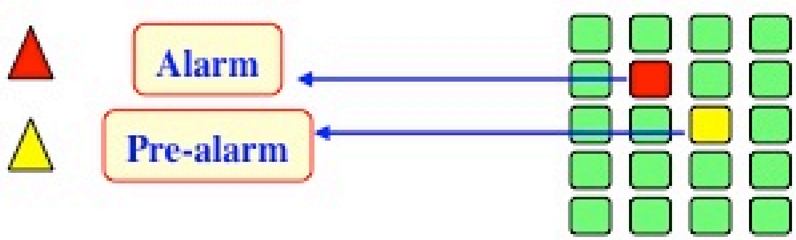


Counts channel by channel

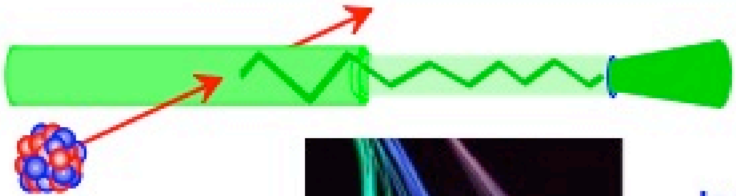


Fibre [0]	Alarm	exp	6	-0.01	sigma	Normal
Fibre [1]	Normal	exp	3	-0.02	sigma	Alarm
Fibre [2]	Normal	exp	5	-0.16	sigma	PreAlarm
Fibre [3]	Normal	exp	1	0.12	sigma	PreAlarm
Fibre [4]	Alarm	exp	6	-0.01	sigma	Normal
Fibre [5]	Normal	exp	3	-0.02	sigma	Alarm
Fibre [6]	Normal	exp	5	-0.16	sigma	PreAlarm
Fibre [7]	Normal	exp	1	0.12	sigma	PreAlarm
Fibre [8]	Alarm	exp	6	-0.01	sigma	Normal
Fibre [9]	Normal	exp	3	-0.02	sigma	Alarm
Fibre [10]	Normal	exp	5	-0.16	sigma	PreAlarm
Fibre [11]	Normal	exp	1	0.12	sigma	PreAlarm
Fibre [12]	Alarm	exp	6	-0.01	sigma	Normal
Fibre [13]	Normal	exp	3	-0.02	sigma	Alarm
Fibre [14]	Normal	exp	5	-0.16	sigma	PreAlarm
Fibre [15]	Normal	exp	1	0.12	sigma	PreAlarm
Fibre [16]	Normal	exp		NaN	sigma	Off
Fibre [17]	Normal	exp		NaN	sigma	Off

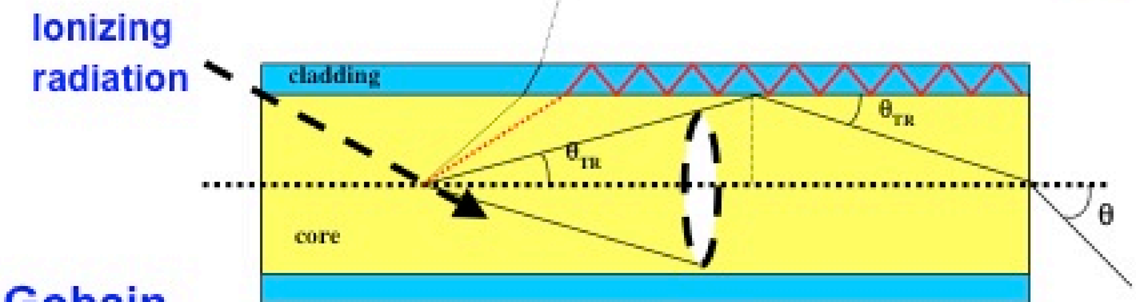
Available details on every single drum



Used scintillating fiber: BCF- 20



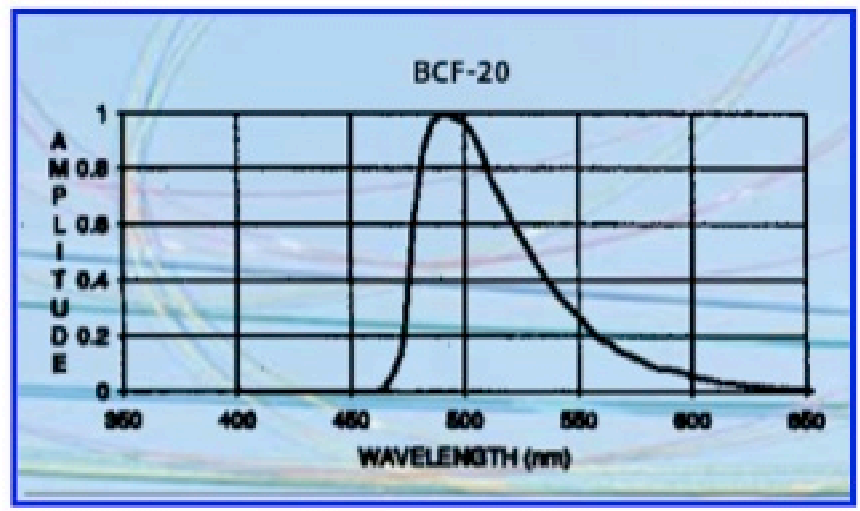
Collecting light efficiency at one end of the fiber ≈ 3.5%



Scintillating fiber → Saint-Gobain

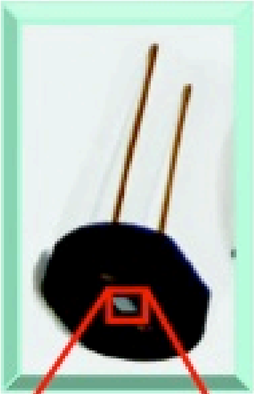
- ✓ Core → Polystyrene
- ✓ Decay time: ~3ns
- ✓ Diameter → 1 mm
- ✓ L_{att} → > 3.5m
- ✓ λ_{emis} → 480nm
- ✓ Entrapment efficiency → 3.5%
- ✓ Light yield ~ 10^4 photons/MeV (gamma rays and electrons)

Emission spectrum BCF – 20



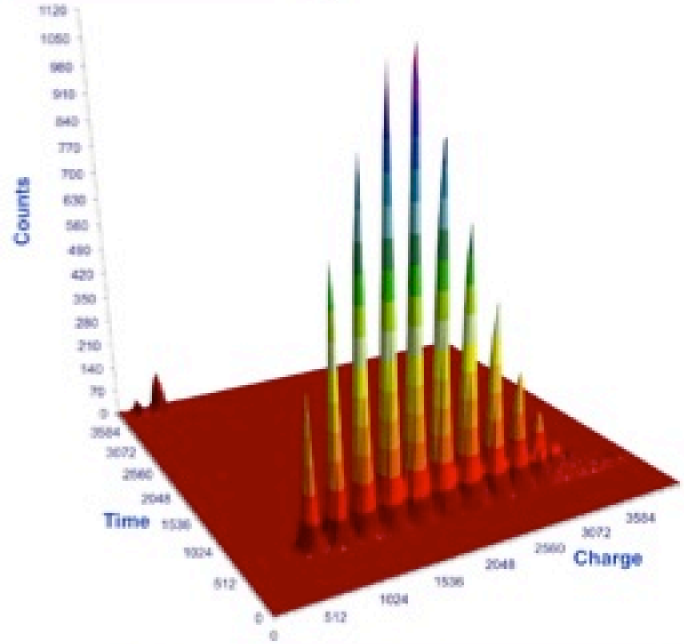
SiPM: response to light

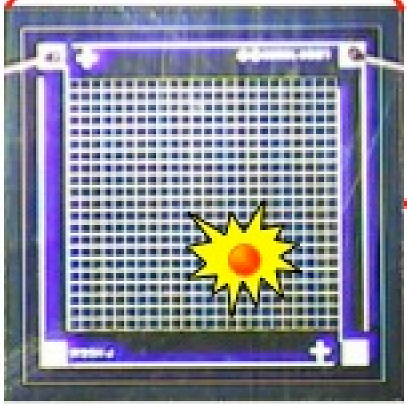
1mm x 1mm
576 cells
SensL



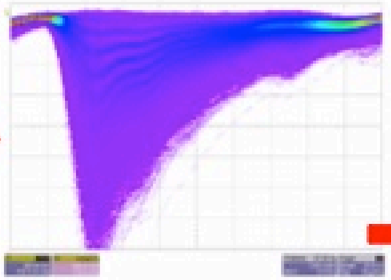
SiPM → SiliconPhotoMultiplier

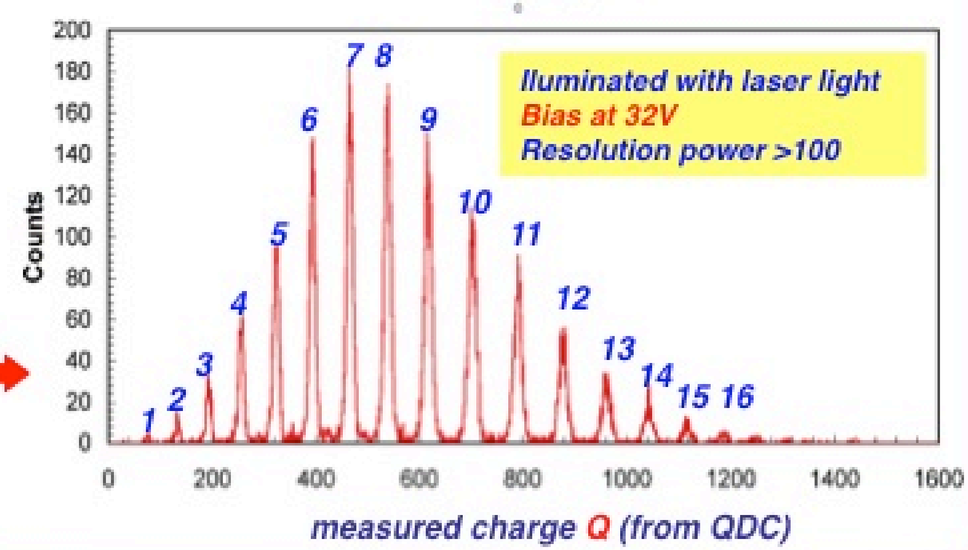
1. array of a Single Photon Avalanche Diode (SPAD) biased beyond breakdown (Geiger mode)
2. the avalanche is quenched by means of integrated resistors
3. <u>Sensitive to single photon</u>





SiPM in use



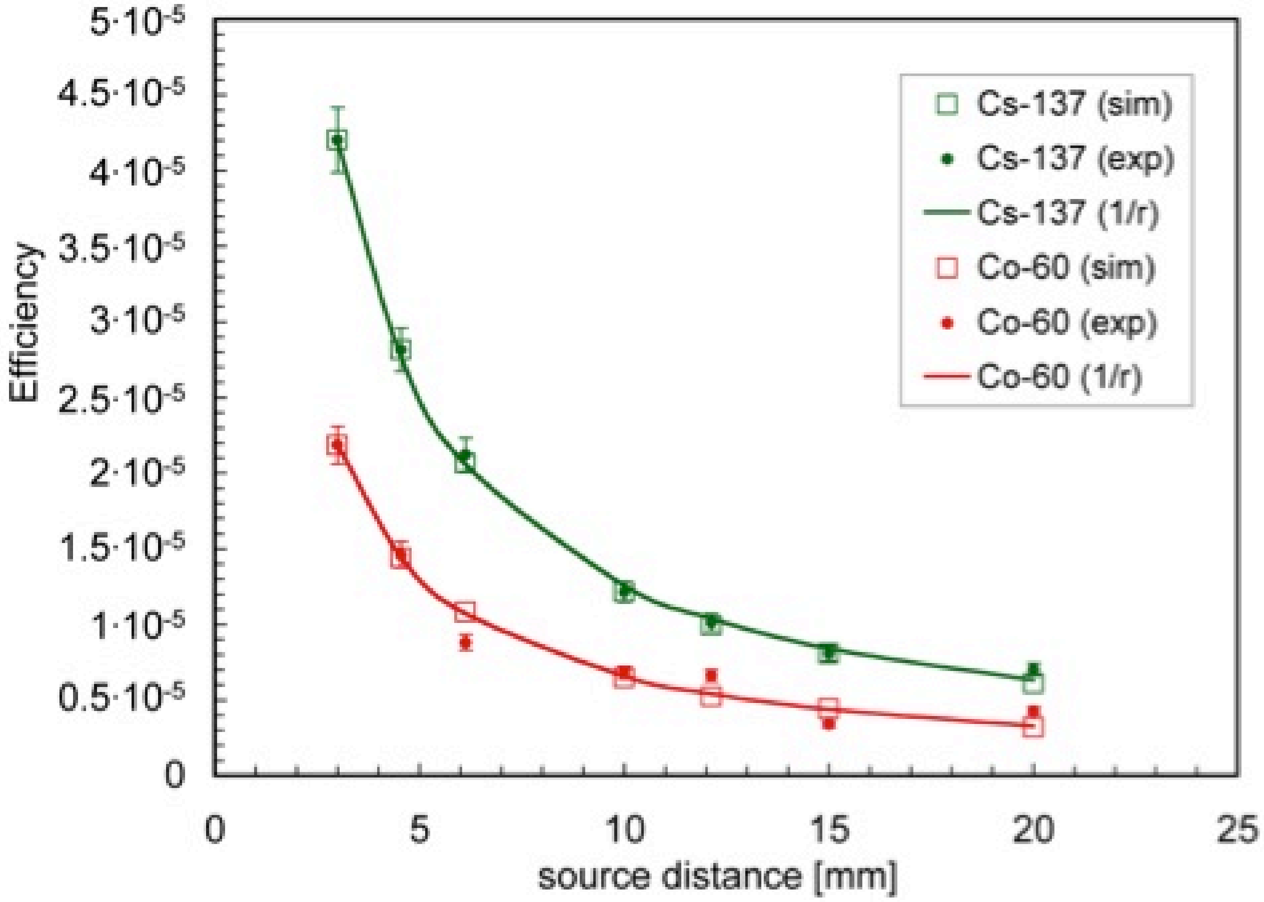


Gamma detection efficiency (pointlike source)

— calculated

□ simulated

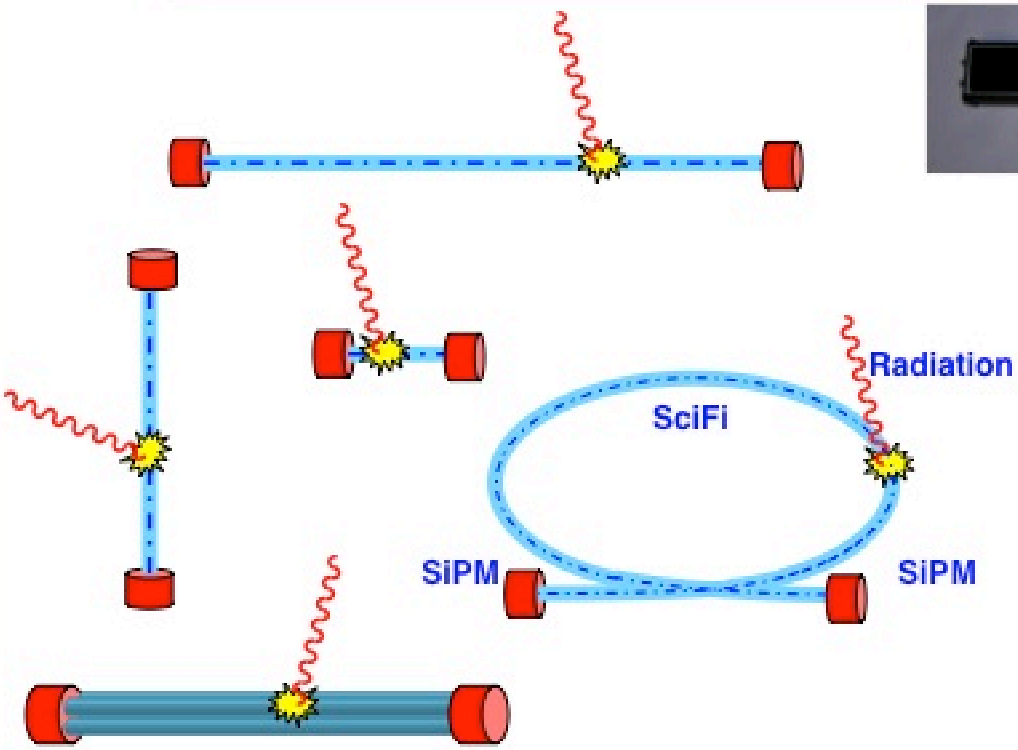
● measured



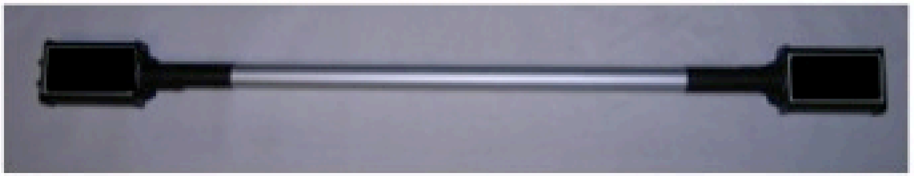
→ systematic normalization due to optical coupling and PDE

→ after normalization to the first point the data are self-consistent

Geometrical efficiency: can be varied by changing fiber length and/or thickness

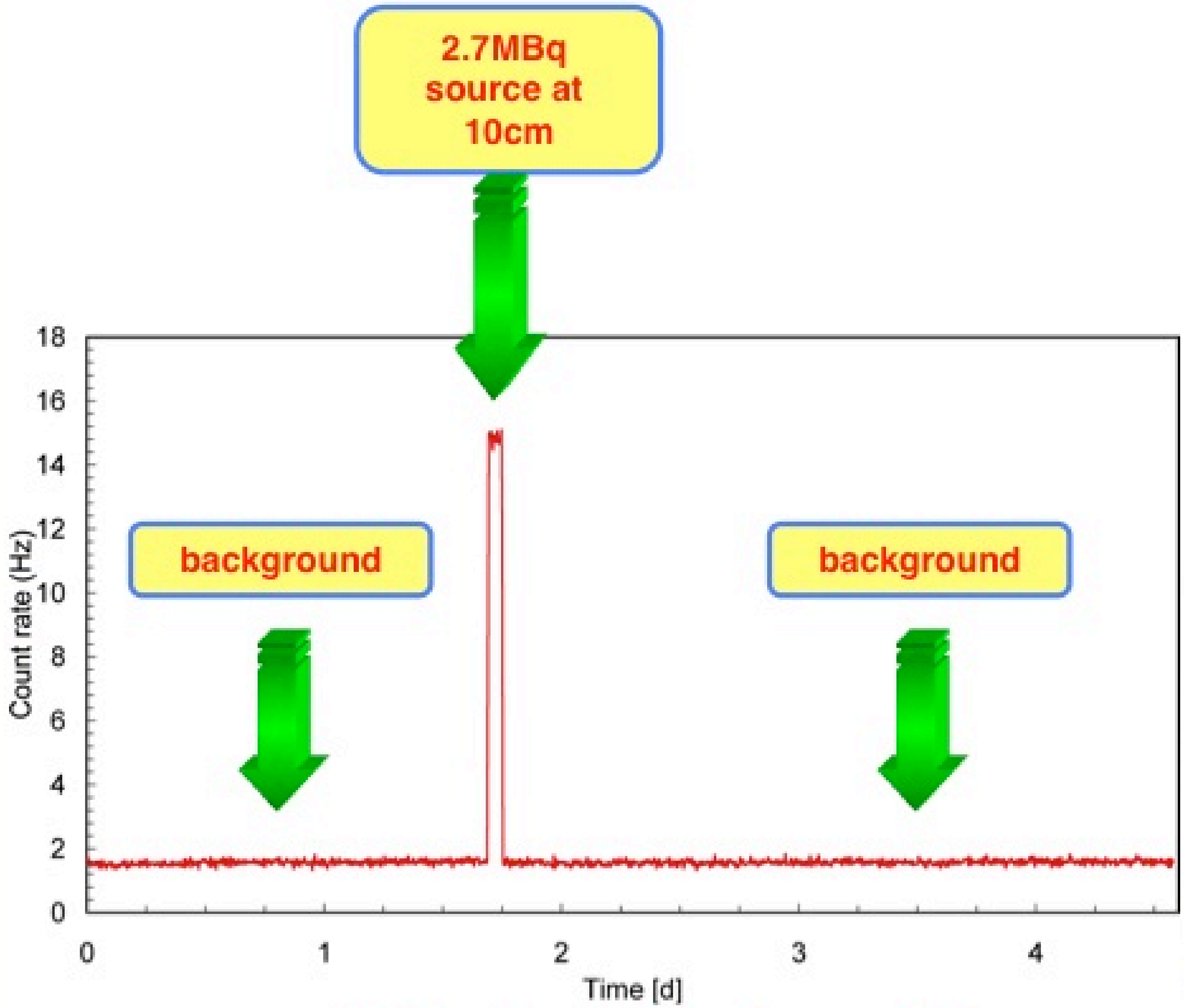


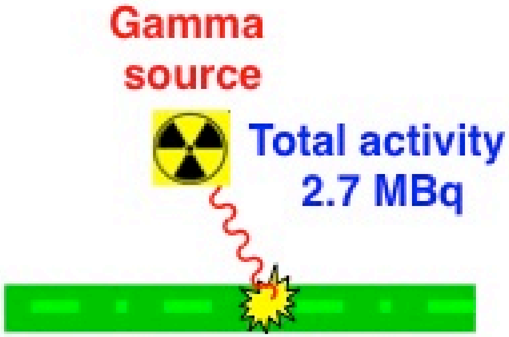
several fibers coupled to larger area SiPM's



**flexible sensors,
both mechanically and conceptually**

Detector test

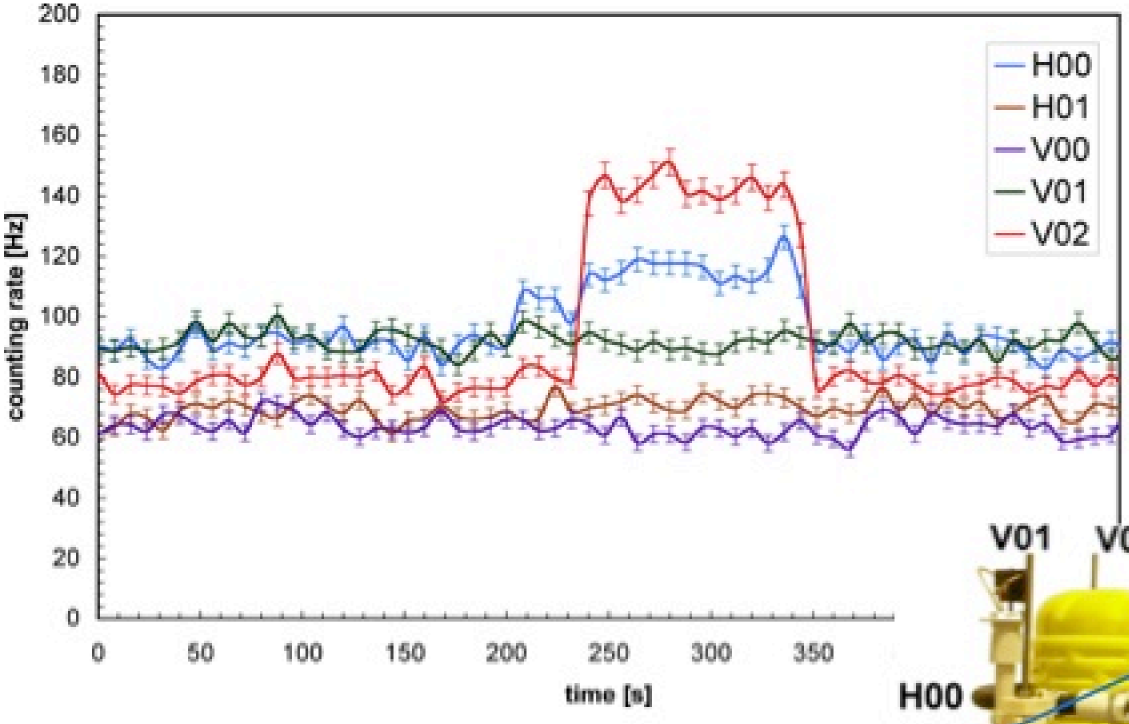




4.5 days test

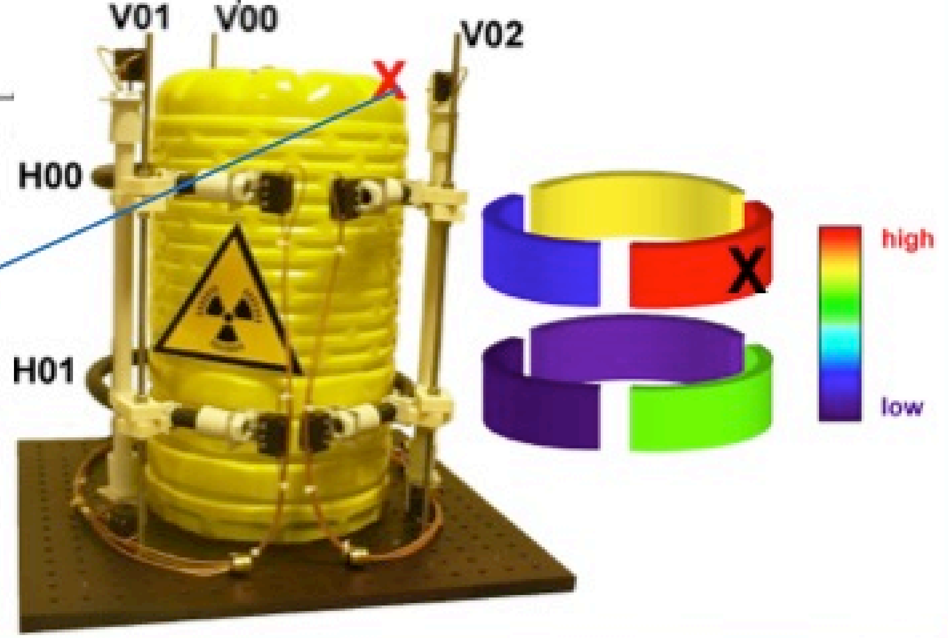
the instant S/B ratio was ≈9

First prototype test



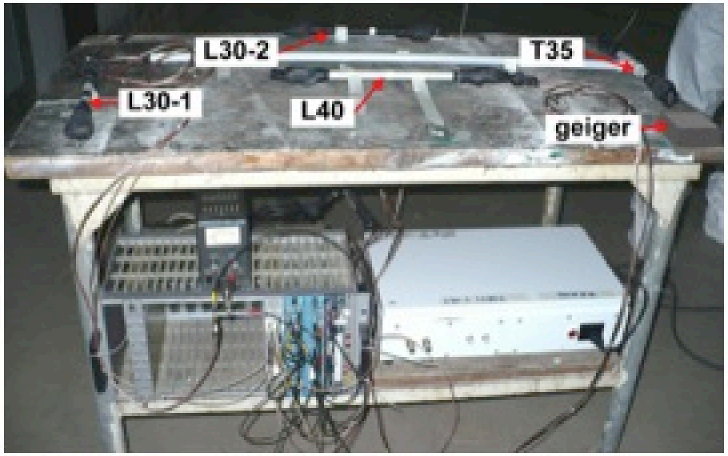
3D reconstruction by crossing fibers

Test with minidrum: 5 fibers and mixed gamma sources, total 2.7MBq



Test with real radwaste drums

preliminary test with real radwaste drums in a storage site inside the former nuclear power plant of Garigliano (SOGIN S.p.a.)

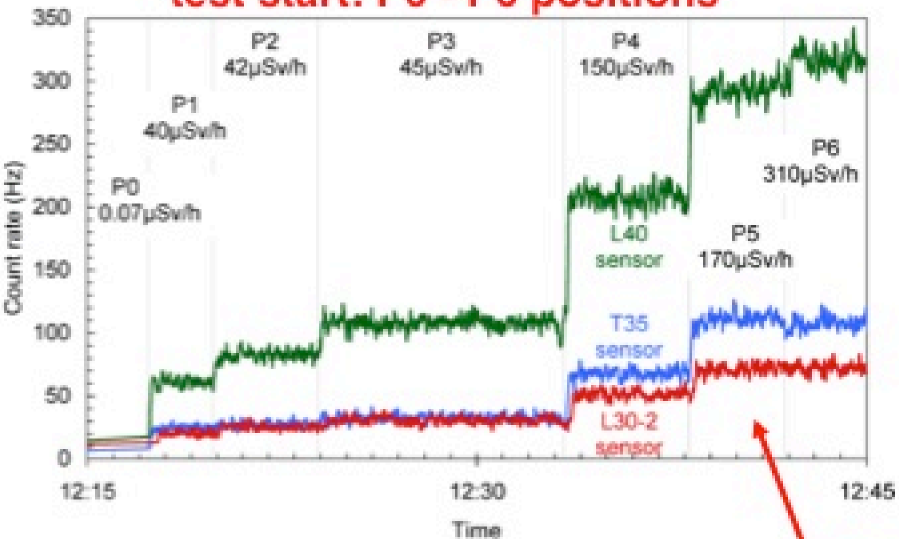


We thank A.Lucciola, C.Nasti, G.Pipola, A.Gargiulo, F.Pisciotta, U.Doti, A.M.Esposito, M.Iorio, A.Mariani, S.Alfieri of Sogin S.p.a. for providing access to the storage site and for the invaluable help and support during the test.

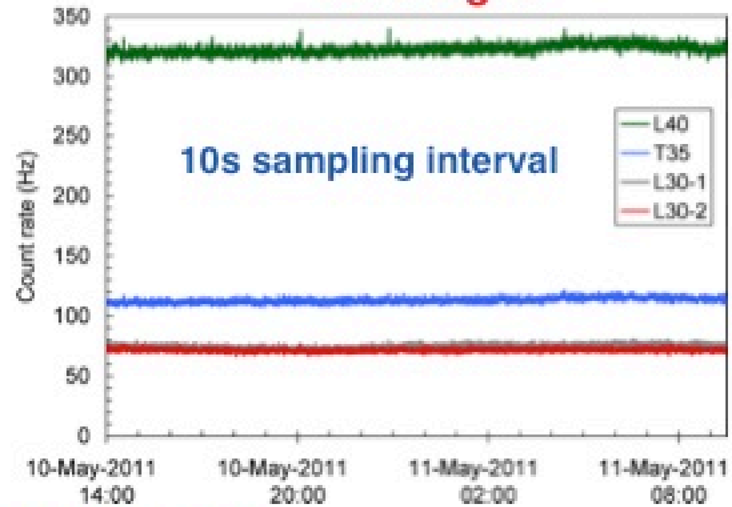
- **4 detectors (+geiger) on a pushcart moved at 7 positions (P0-P6) with increasing dose rates**
- **left in position P6 overnight**
- **then quickly removed**

Results

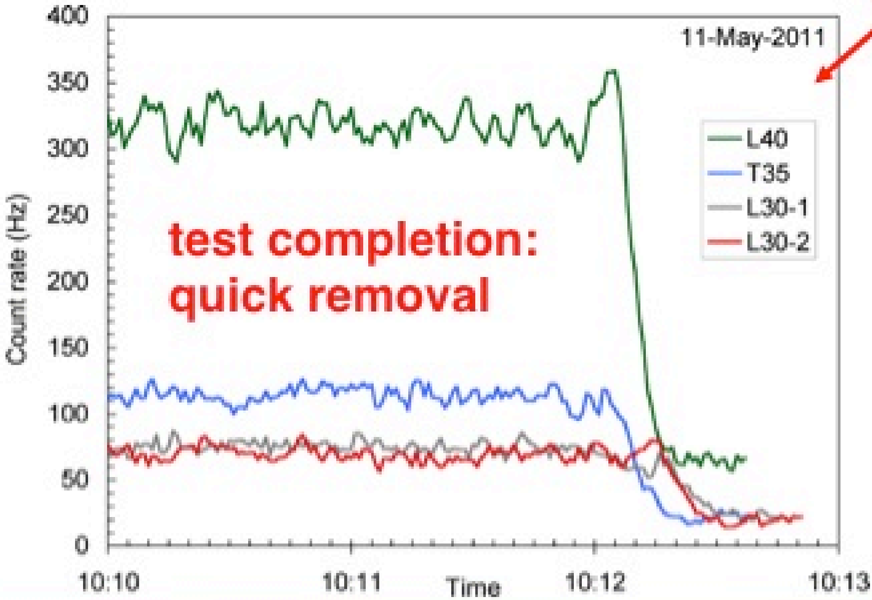
test start: P0 - P6 positions

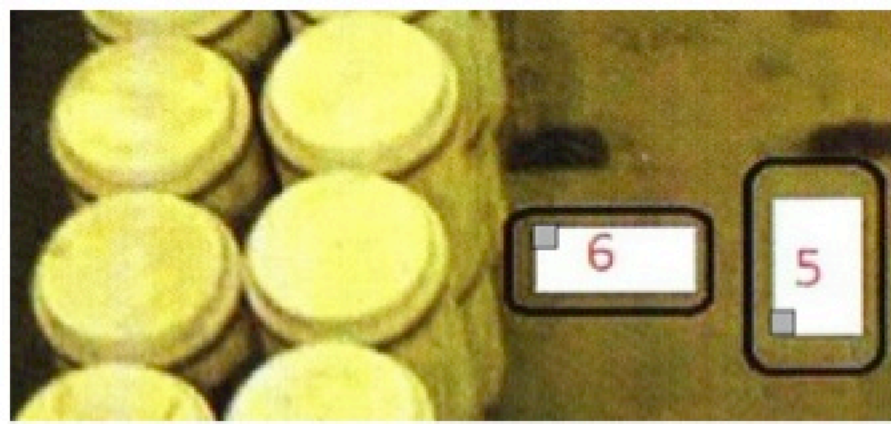


overnight



1s sampling interval





Agreement: INFN - SOGIN

DMNR → DETECTOR MESH FOR NUCLEAR REPOSITORIES

8 November 2012: signed agreement between → INFN – SOGIN S.p.A

DMNR demonstrator at the Garigliano repository.

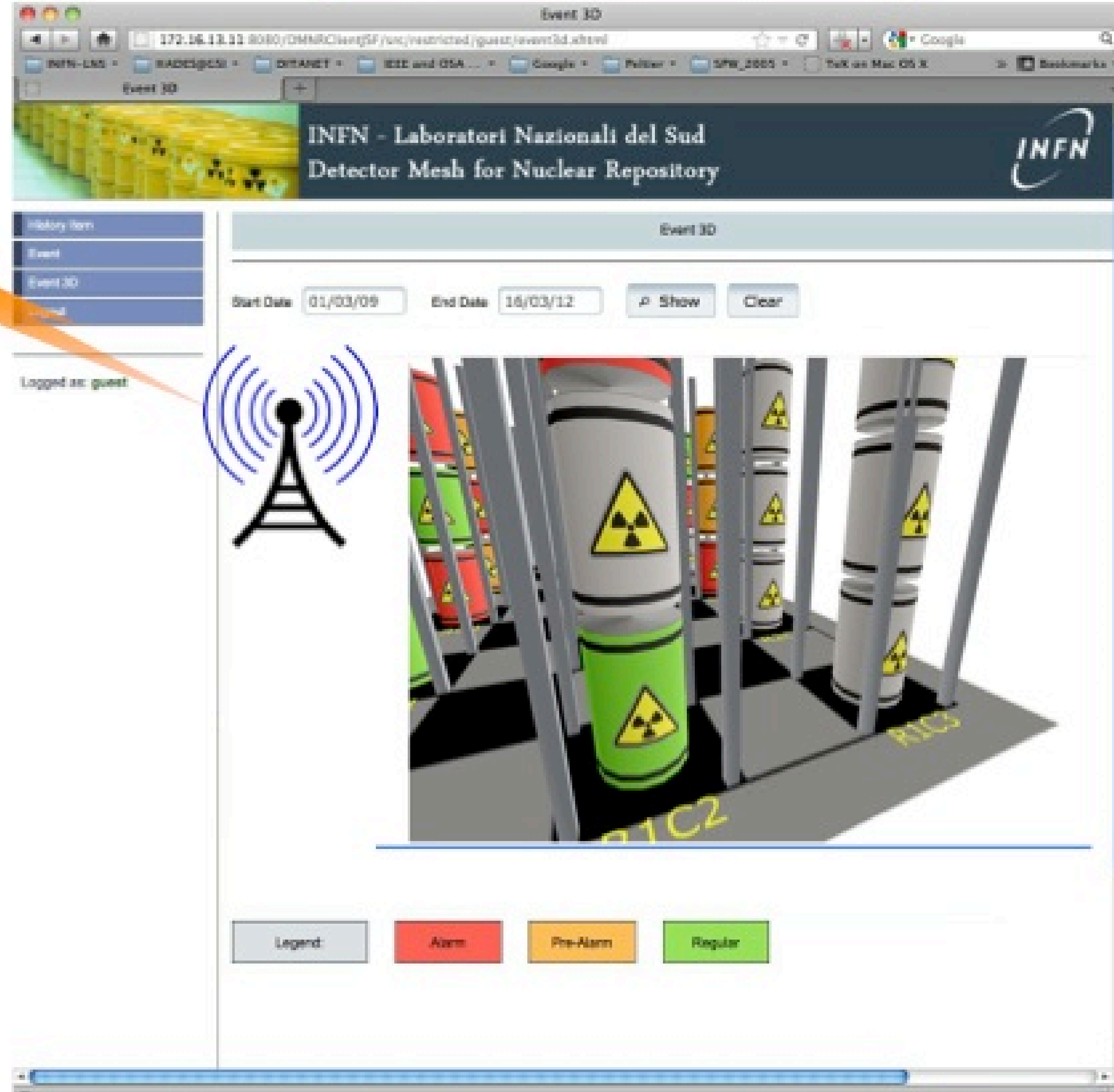
A fraction of the drums will be equipped with the proposed solution

Project duration: 2 years

Real-time castor storage monitoring?

Wireless transmission

JRC & Euratom collaboration

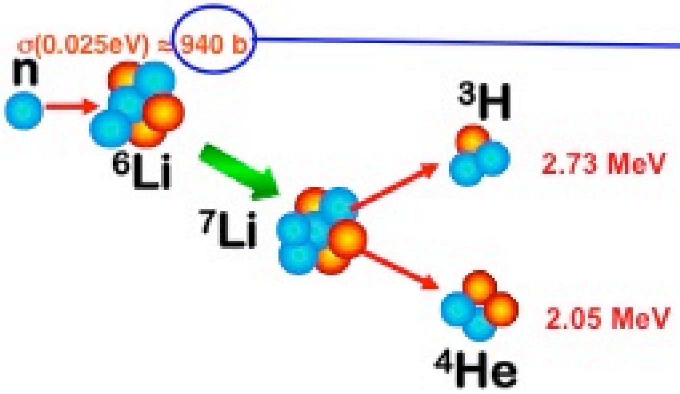


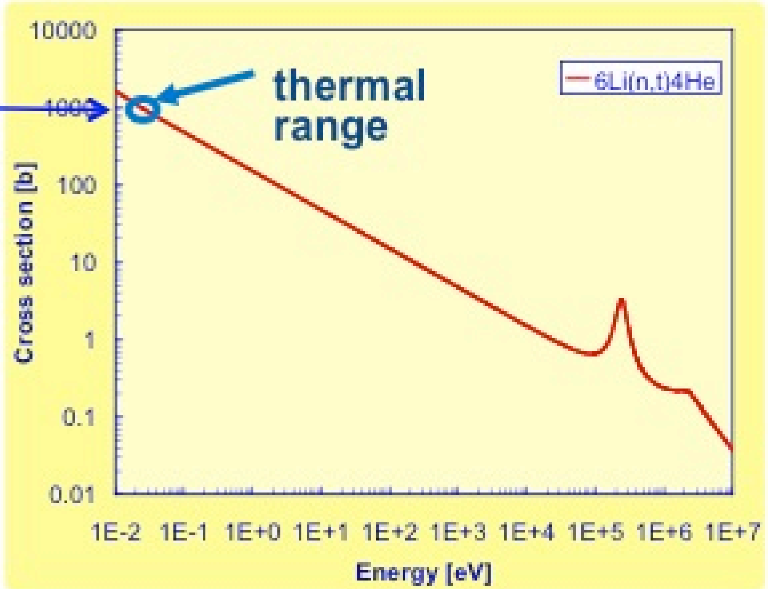
Easy to implement the neutron detection in the DMNR design:

- electronic set-up
- data acquisition
- Graphical User Interface
- data logging

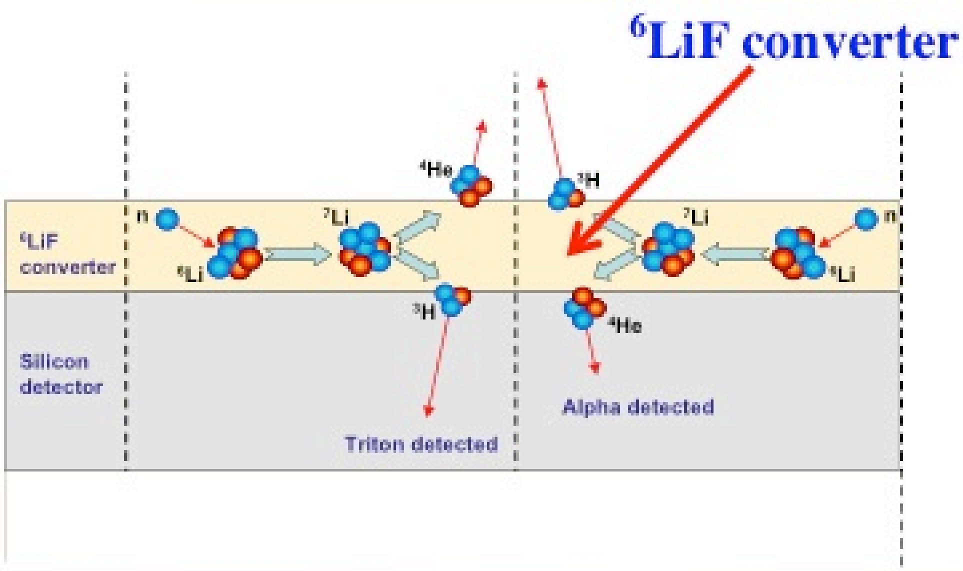
Is it possible to detect thermal neutrons too?

YES

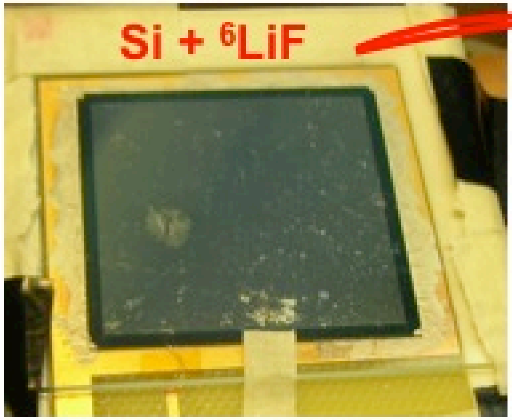


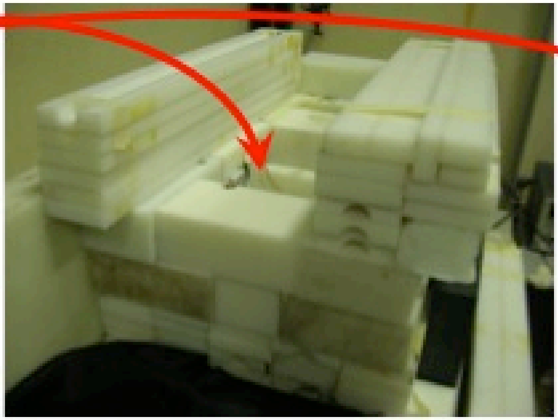


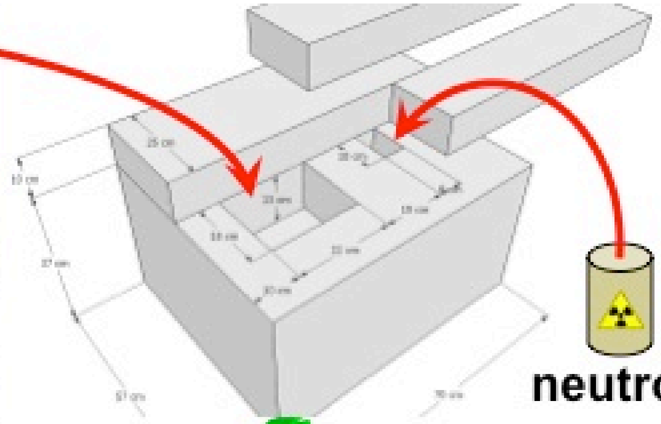
Silicon detector 3cm x 3cm x 300 μm
^{6}LiF converter on suitable substrate



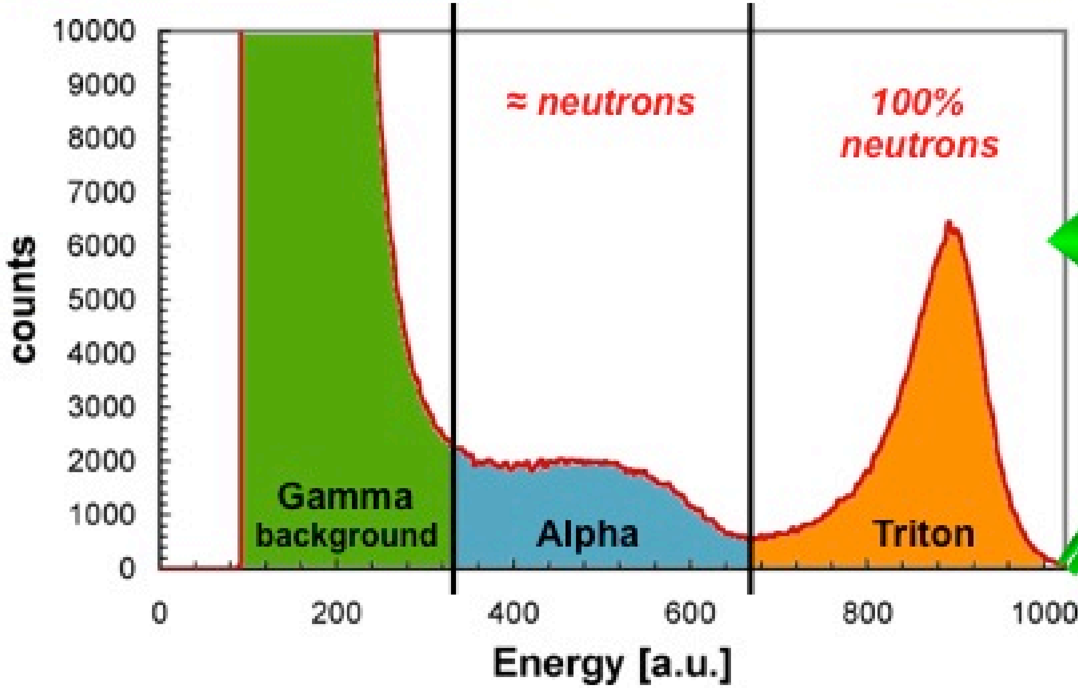
Test at JRC Ispra: AmBe source (1.6 x 10^6 n/s)



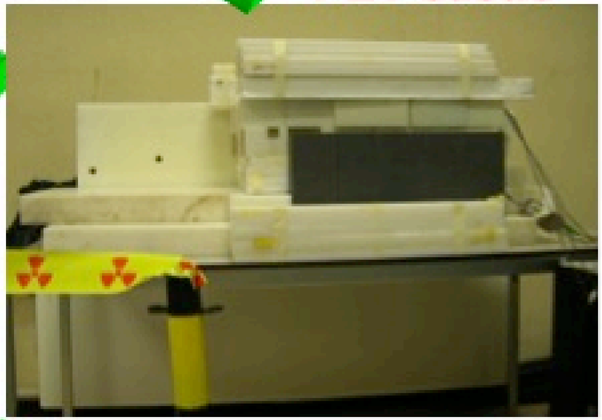




neutron source

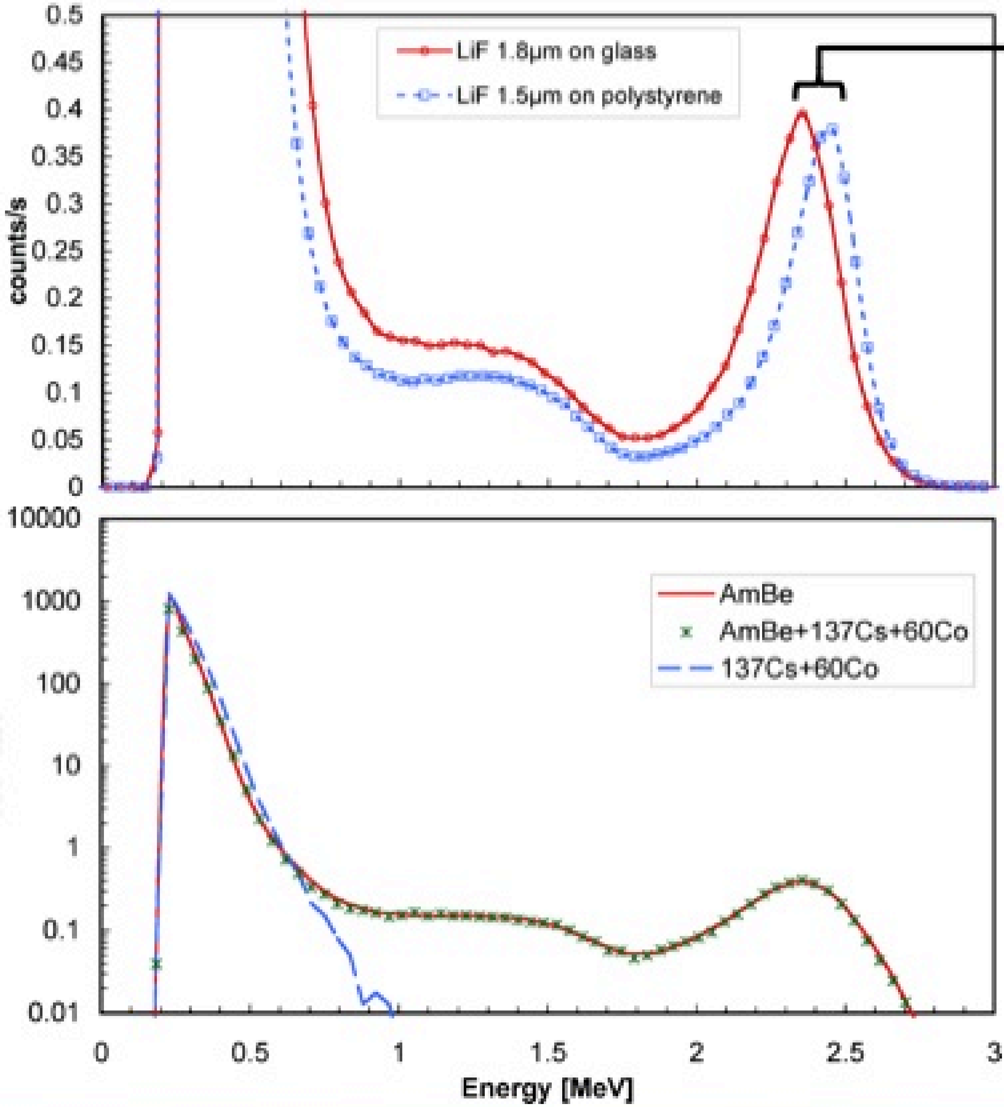


PET castle



Rough simulation: 130n/s/cm^2
Measured: 150 n/s/cm2

Test at JRC Ispra: AmBe source (1.6 x 10^6 n/s)

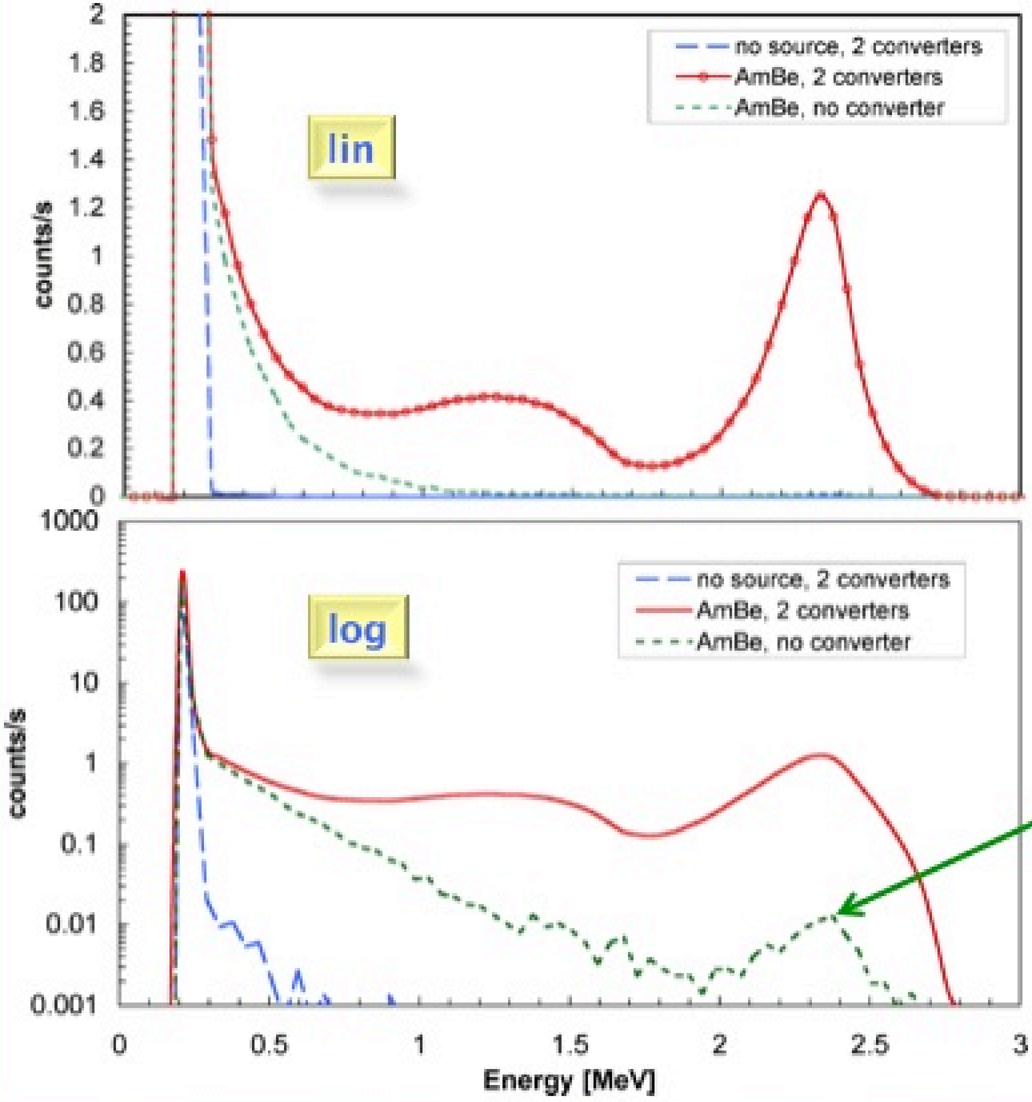


ΔE calculated: 195 keV
ΔE measured: 200 keV

1.8µm vs 1.5µm (thickness)
Efficiency: 20% more

Two gamma sources added for rejection test (740 MBq)

Test at JRC Ispra: AmBe source (1.6 x 10^6 n/s)

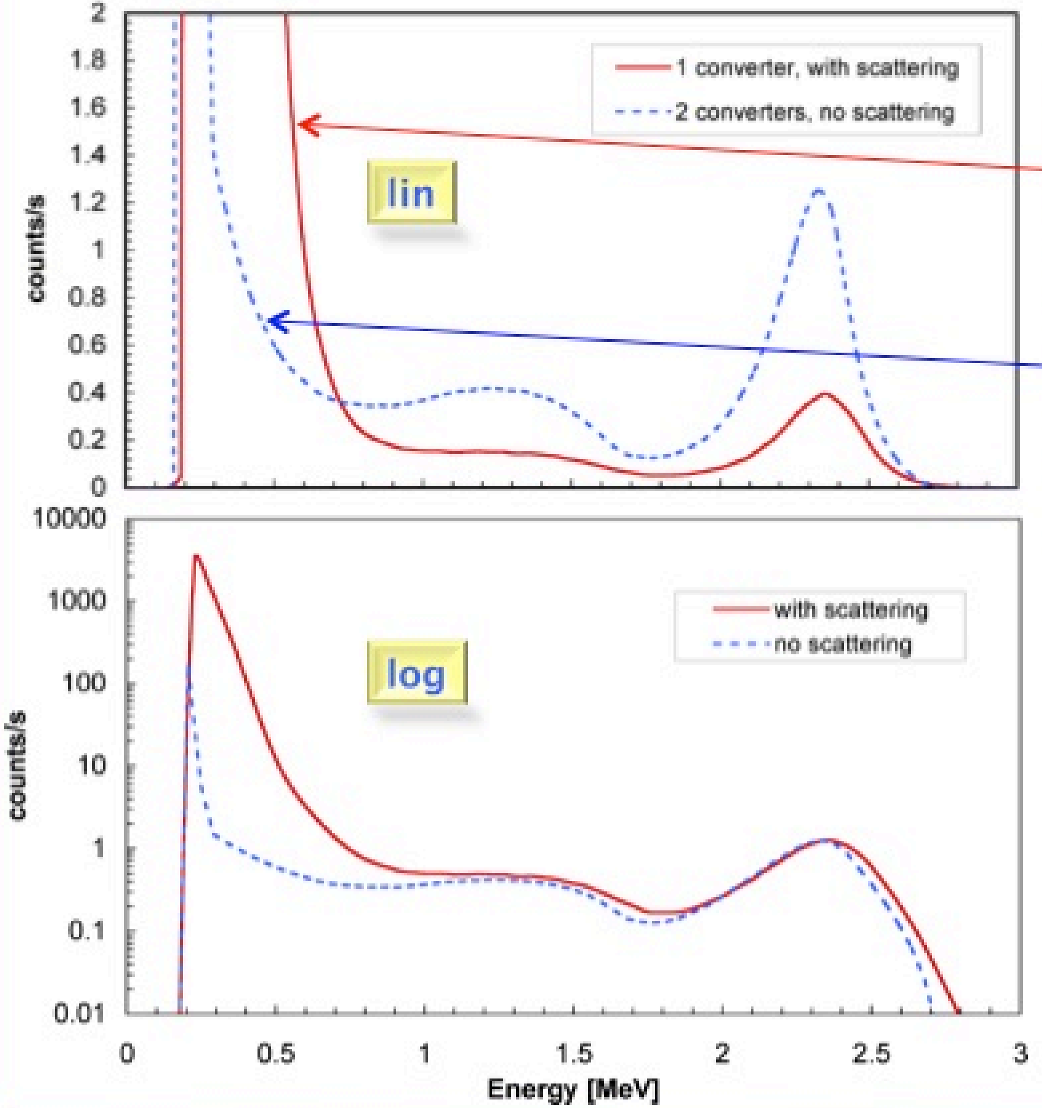


No source: background
2 converters: double efficiency
No converter: gamma contribution only

But in logarithmic scale we can see….

Unexpected neutrons?
Fraction of ^{6}LiF migrates from substrate to silicon

Test at JRC Ispra: AmBe source (1.6 x 10^6 n/s)



Heavy material near the detector. High energy gamma background (scattering)

Heavy material removed: The gamma background is suppressed

As above but in logarithmic scale

Neutron detector based on scintillators

Patent pending

Conclusion

- efficient real-time monitoring of radioactive waste
- low cost for detectors and data transmission
- fast identification of leak position
- reduce potential radiation doses to workers
- possibility to detect neutrons

THANKS FOR THE ATTENTION