Spent fuel online monitoring: opportunities from new technologies

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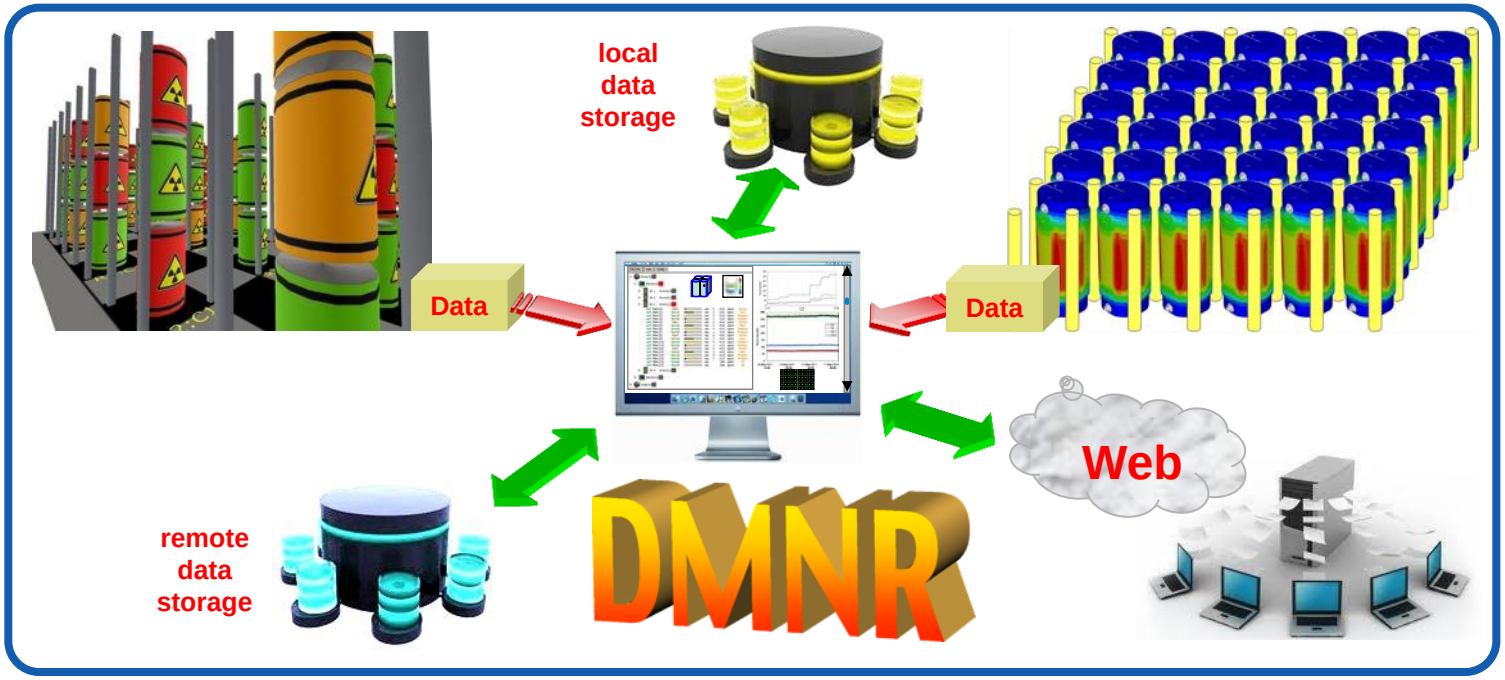


Detector Mesh for Nuclear Repositories

INFN

National Institute of Nuclear Physics

University

Theoretical / experimental
nuclear and subnuclear physics

≈ 30 Sections

+ 4 National Laboratories

INFN

Industry

Medicine

Cultural heritage

Computer science

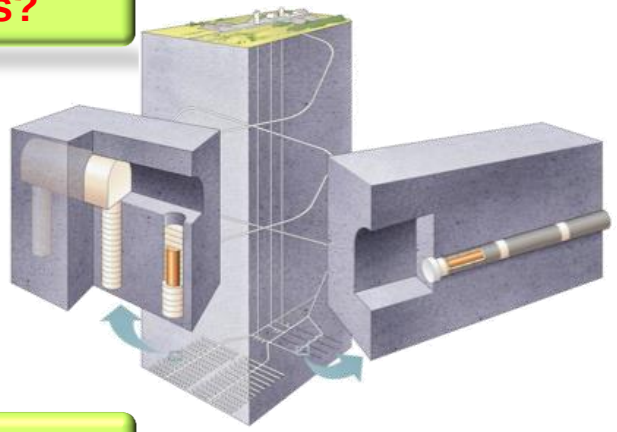
Electronics

ENERGY: strategic project

INFN-E

JOPRAD

why monitoring? why new tools?



radwaste lasting hundreds of thousands years
➔ geological repository

but... predisposal & preclosure?

handling, transportation, interim, ...
➔ monitoring?

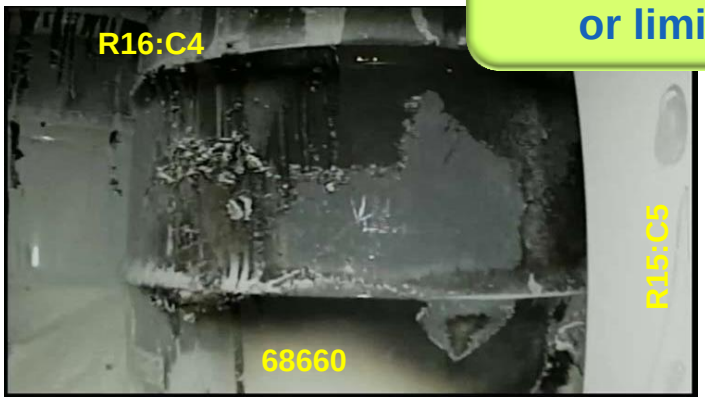
conventional methods

new technologies?

WIPP
Waste Isolation Pilot Plant
14-Feb-2014 New Mexico

OFFICE OF ENVIRONMENTAL MANAGEMENT

Drum 68660



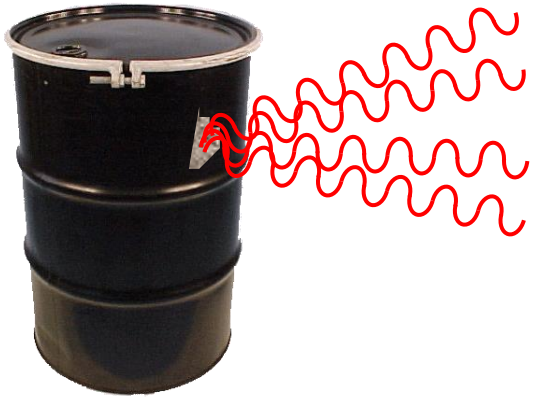
Could individual online monitoring have prevented or limited the accident?

Why monitoring?

To have a complete and detailed record of the history of each cask

Accidents may happen, for instance:

- *a cask might be damaged while being displaced (for inspection?)*
- *a cask might crack (and leak out) due to corrosion, accident, etc.*



What would be desirable?

individual and continuous online monitoring of casks, even during possible displacements

or better, never displace the casks, monitor them in place

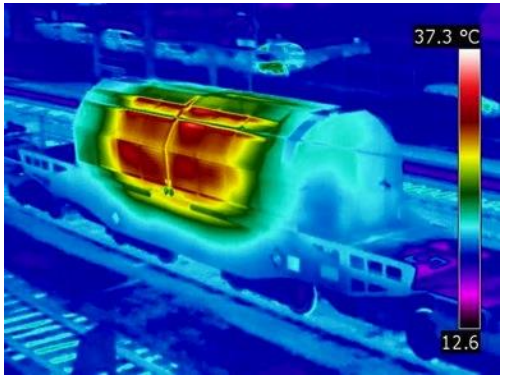
...and...

in order to improve the acceptability of waste repositories for populations

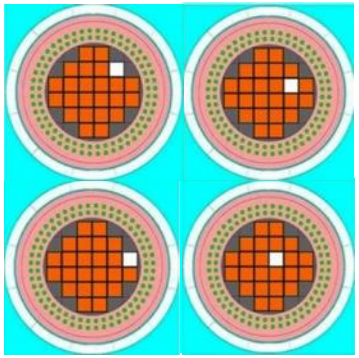
we need safety, security, transparency

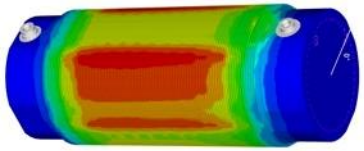
what for?

minimizing direct human intervention



monitoring in place and/or during transportation





detecting possible diversion from casks

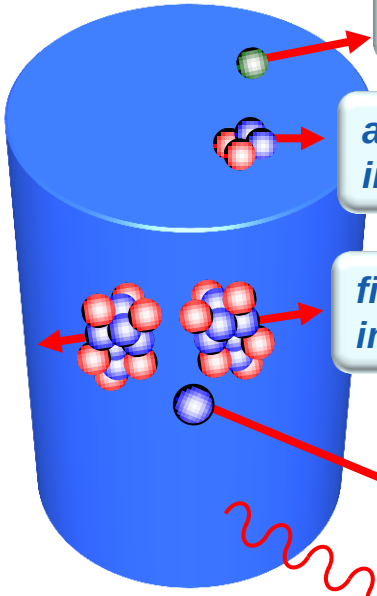
preventing illicit trafficking

role of new technologies: provide additional features

public | **single user** | **additional features**

we (scientists) trust the exponential decay law of radioactivity

what about laypersons?
environmentalists?
public acceptability?



beta particles are mostly stopped inside the material and in air

alpha particles are immediately stopped inside the material

fission fragments are immediately stopped inside the material

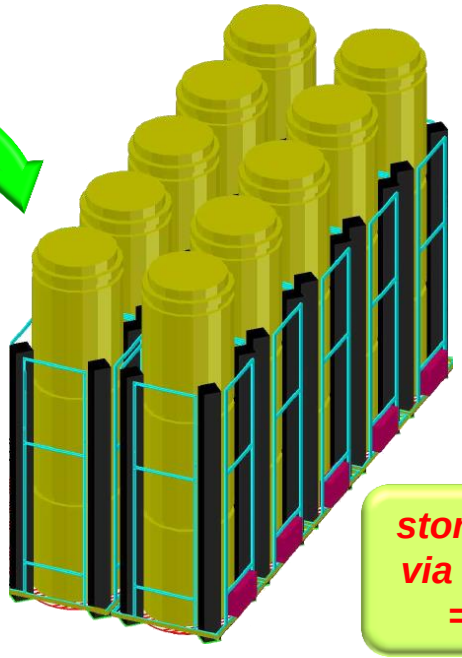
neutrons (from fission) are penetrating

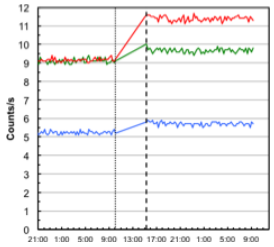
gamma rays are penetrating

electronic seal, similar to CRC for computer data

cask

characterization



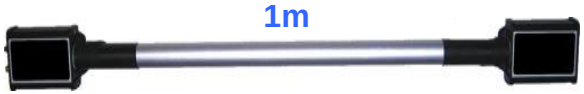


storage & monitoring via a sensor network = fingerprinting

neutrons and gamma rays convey information from the inside

an unexpected change in counting rate is a precursor of anomaly

low-cost linear gamma ray counter



miniature low-cost gamma ray spectrometer

1cm³

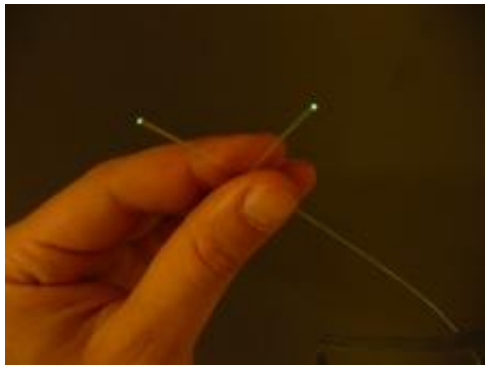
miniature low-cost neutron counter

3cm x 3cm

deployment of sensor arrays around casks

IT tools for data acquisition
and historical archive

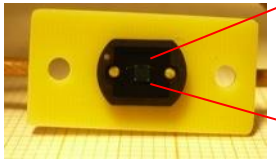
low-cost linear gamma ray counter

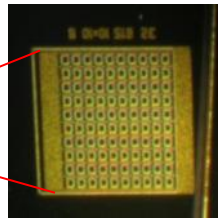


scintillating fiber + 2 SiPM

the SiPM detects the very short scintillation light pulse produced by gamma interaction

SiPM





low bias voltage (30V)
high gain

1 mm

radiation hardness ≈100-1000 years close to a drum with 10-100 mGy/h

robustness yes, plastic scintillators; SiPM not damaged by ambient light exposure

low efficiency ≈0.1-1%

high sensitivity: few photons

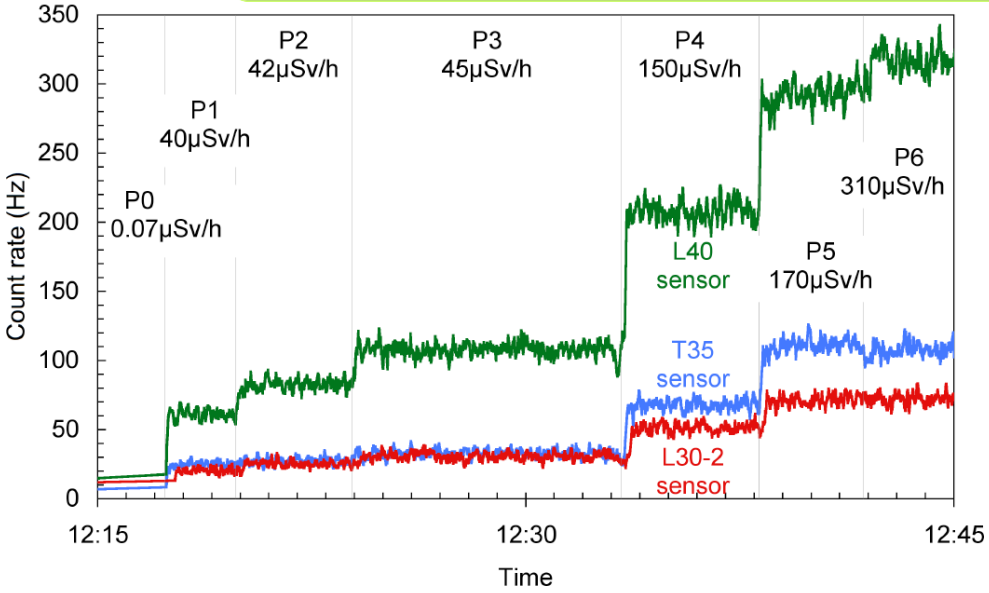
reliability yes

ease of handling yes

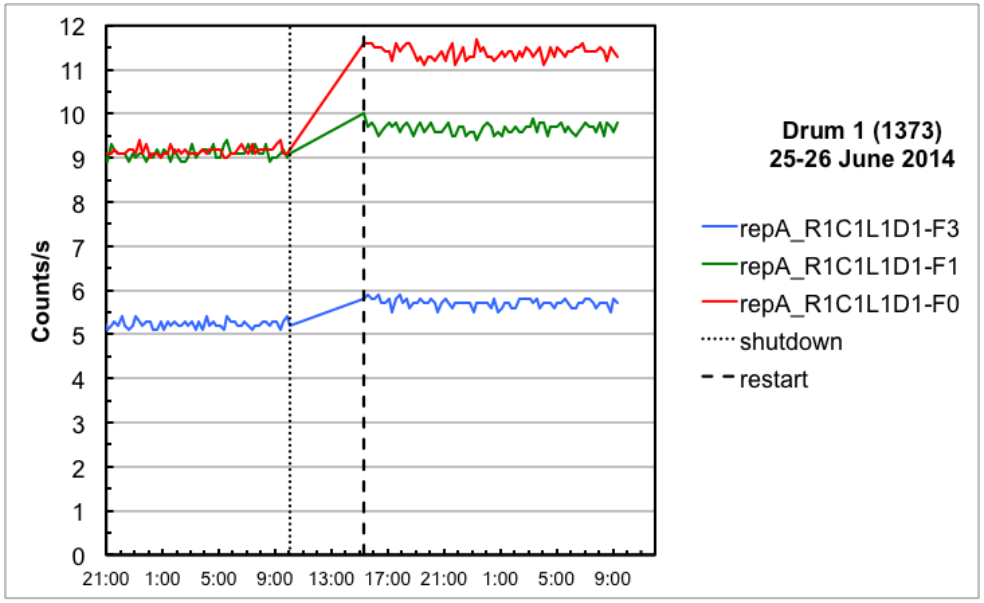
low cost yes

from 1cm to 2m long

low-cost linear gamma ray counter

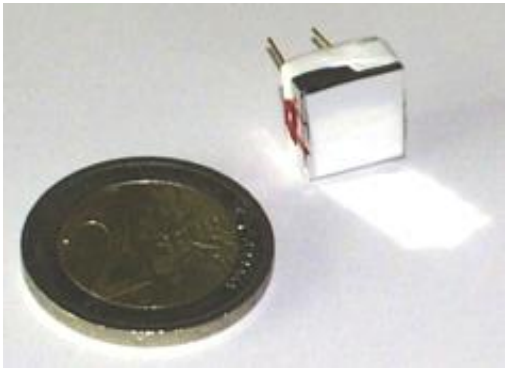


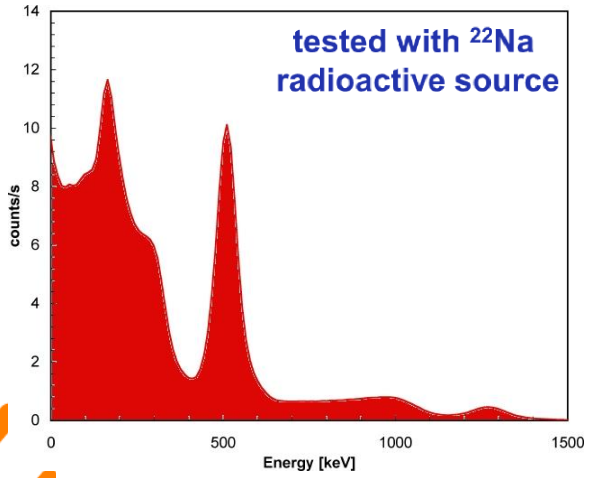
tested with ILW at decreasing distances



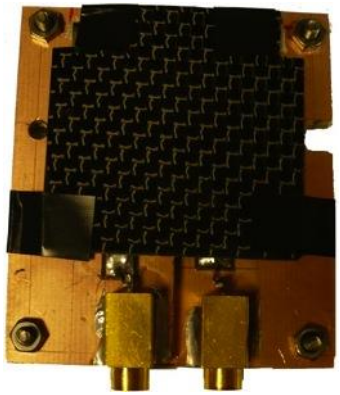
tested with LLW for three months

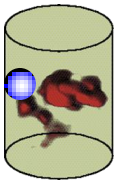
miniature low-cost gamma ray spectrometer



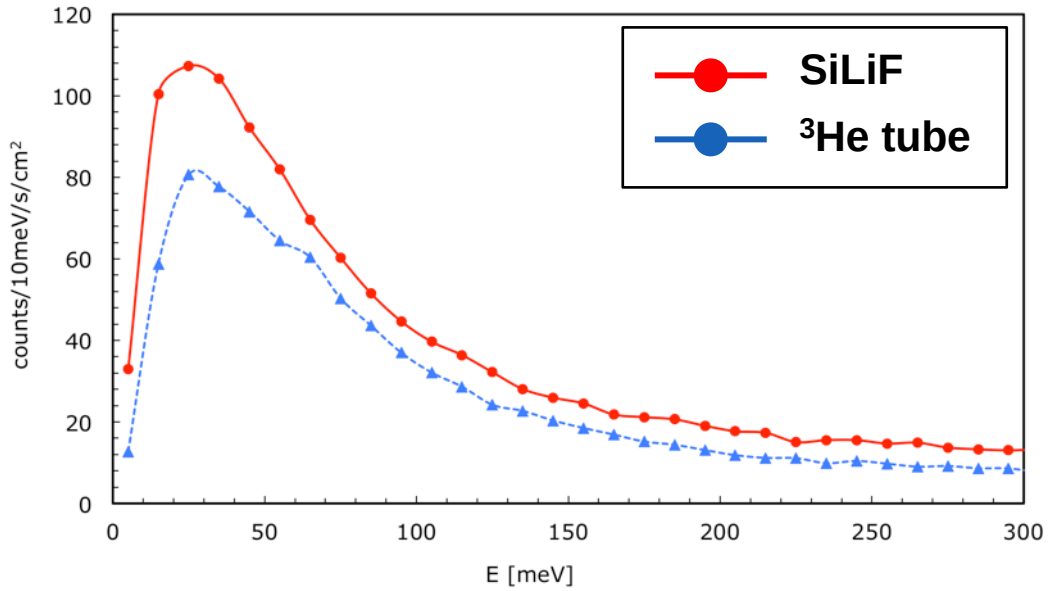


miniature low-cost neutron counter



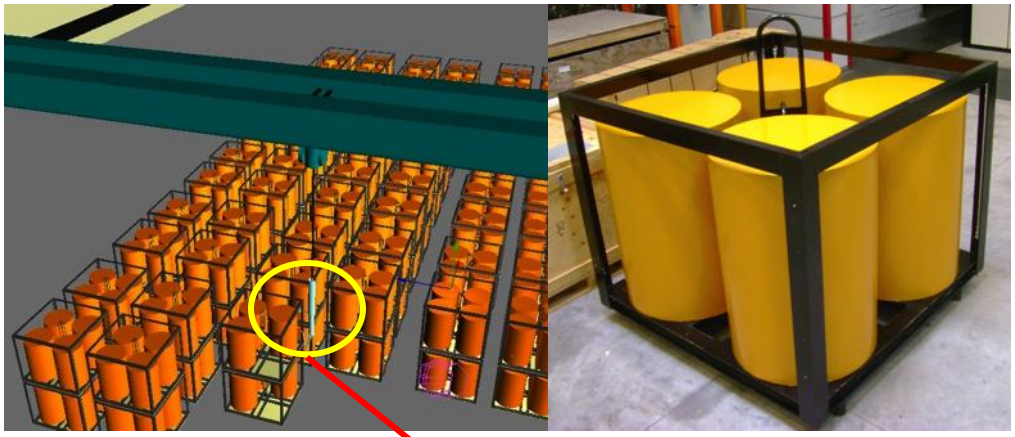


- solid state ^{6}LiF + Silicon
- low voltage (20V)
- intrinsic efficiency up to 15-20%
- robust and reliable
- monitor criticality issues?
- tested with AmBe sources
- tested against ^{3}He at RAL ISIS neutron beam facility
- in use at nTOF neutron beam facility at CERN

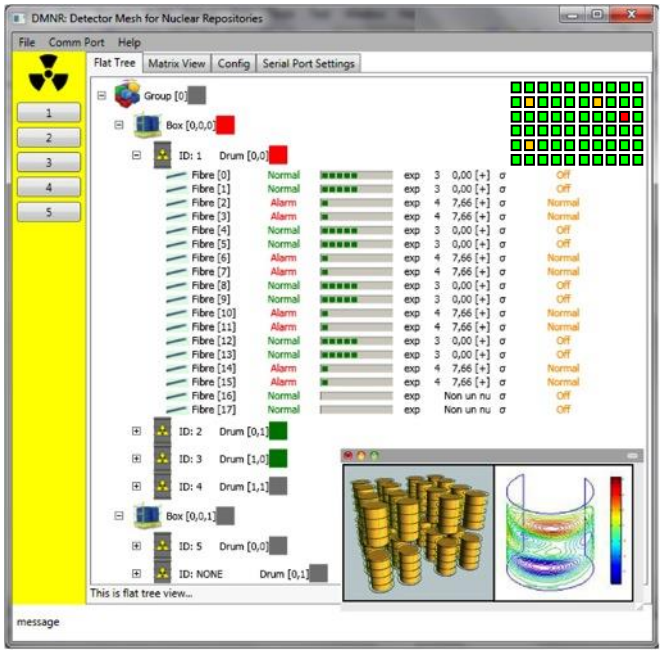


deployment of sensor arrays around casks

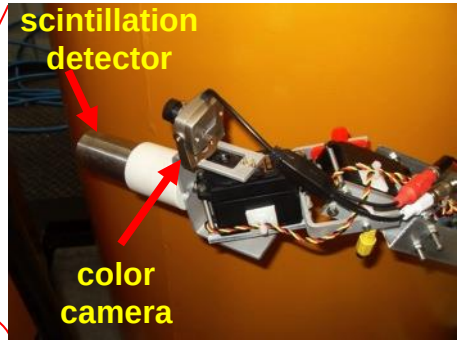
Full details about the single cask available in real time
Cask history and specifications available



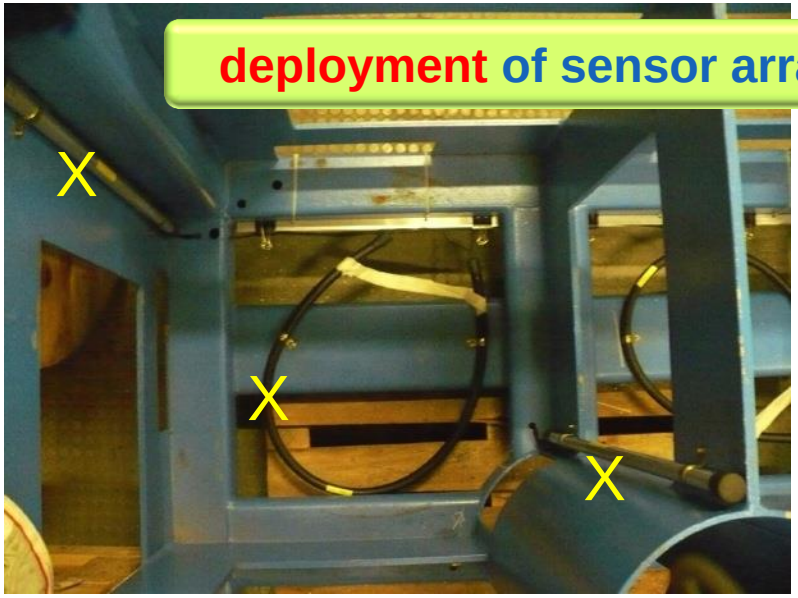
demo platform



robotic arm for
remote inspection



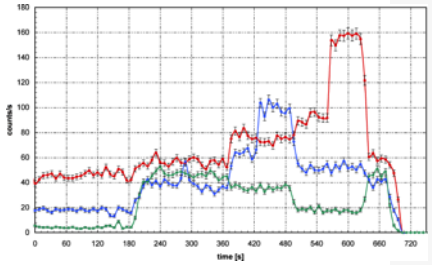
deployment of sensor arrays around casks



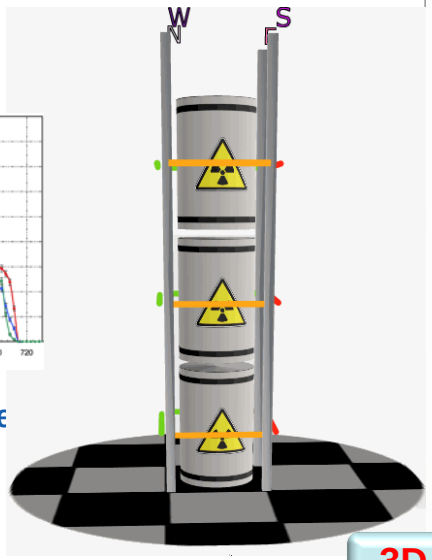
IT tools for data acquisition and historical archive

- online display and data check
- counting rate channel by channel
- programmable alarm levels

details available in real time down to the single cask and to the single detector

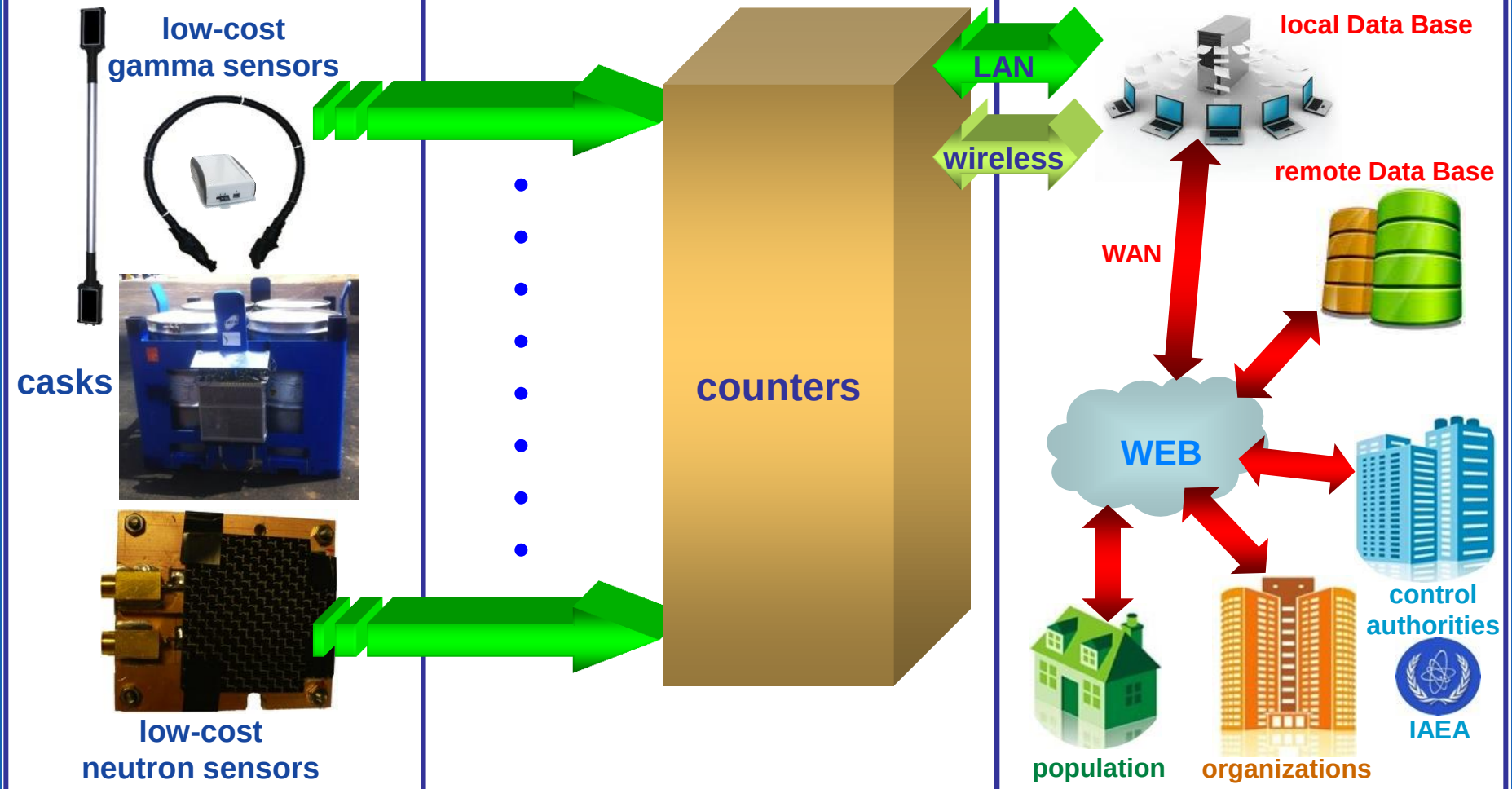


direct connection to the sensor database



3D virtual navigation tool

IT tools for data acquisition and historical archive



storage site

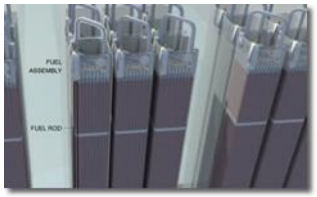
FPGA data acquisition and control

- local wireless and LAN
- global WAN

monitoring where?

Nuclear Power Plant → Temporary Storage → Interim Storage → Processing → Disposal

nuclear fuel

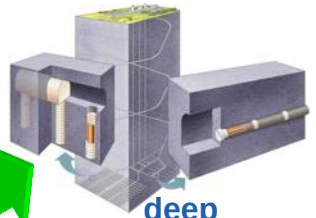


recycled nuclear fuel

wet storage

dry storage

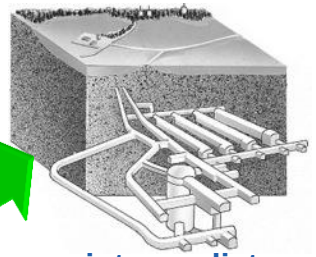
direct disposal



deep geological disposal

treatment

partitioning (& transmutation)



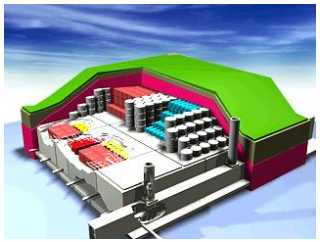
intermediate depth disposal

temporary storage

reactor

Spent Fuel Management Cycle

new technologies provide viable solutions for full transparency of radwaste handling



real-time online radiological monitoring could improve

- trust
- public acceptance
- reliability
- accident prevention
- safety
- security
- logged data quality

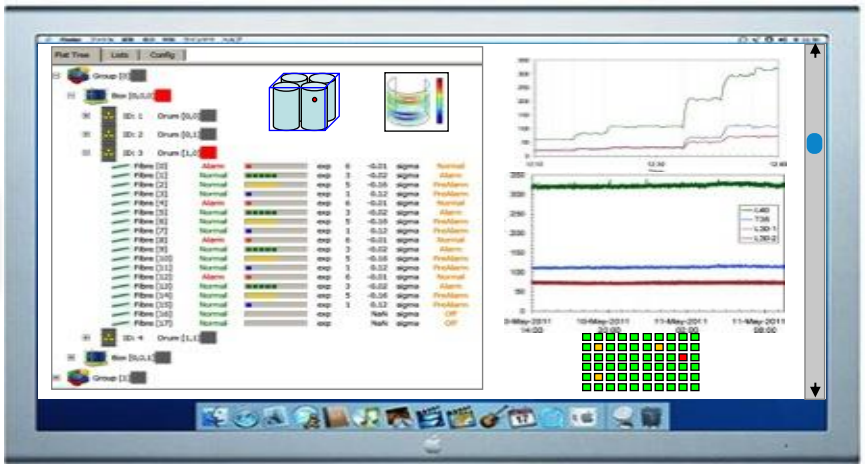
contributing to

Conclusion

we cannot only talk about canister thickness, bentonite, solubility, etc.

the bottom line is: people are worried about radiation

we have to show radiation data



to convince people (and ourselves) that we are able to handle the problem of radwaste repositories, in the short, medium, and long term.

to know or.... not to know?

I would like to pass to the future generations the maximum possible information about the legacy radwaste we are going to leave them