IL PROGETTO INFN "ENERGIA"

1st INFN Innovation Meeting:

TOWARDS A MORE EFFECTIVE COLLABORATION BETWEEN RESEARCH AND INDUSTRY

DOVE E QUANDO?

MILANO, 20 NOVEMBRE 2014
UNIVERSITÀ DEGLI STUDI DI MILANO-BICOCCA
PIAZZA DELLA SCIENZA 4 - EDIFICIO U4 - AULA 08

M. Ripani

INFN Sezione di Genova

MOTIVATIONS

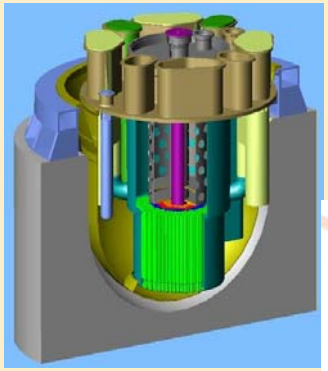
Nuclear power currently not adopted in Italy, but:

- **Research** on future generation fission and fusion reactors and related technologies continues
- **INFN involved in fusion research** through RFX Consortium (CNR, ENEA, Padova University, INFN joined in 2005) and IFMIF project within Broader Approach
- **Nuclear waste management and nuclear safety/security** are important beyond power plants (e.g. disposal of medical and industrial sources)
- **Knowledge preservation** in nuclear science and technology is a critical issue in the EU
- **INFN can give a contribution** to the above topics based on its historical research fields (fundamental nuclear physics, detectors, accelerators)
- Based on the above considerations, in 2008 a dedicated applied nuclear physics program was started

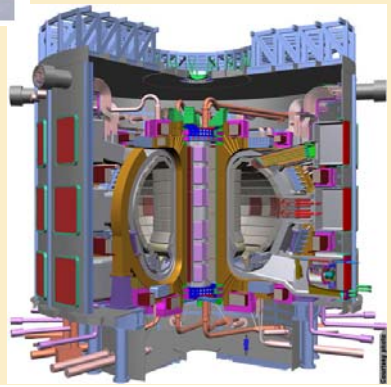
TOPICS

- Nuclear safety and security: innovative systems and instrumentation for radiation monitoring with applications to
  - ✓ Waste storage sites
  - ✓ Port security
  - ✓ Inspections

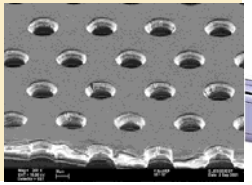
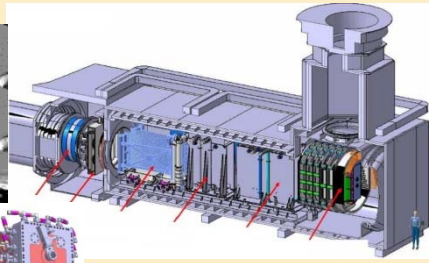
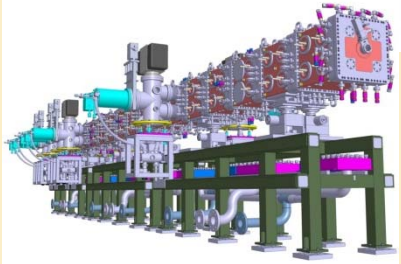





- Fusion:
  - ✓ Neutral Beam Injection
  - ✓ Material irradiation
  - ✓ Diagnostics



- Fission
  - ✓ Neutron physics aspects in fast reactors
  - ✓ Accelerator Driven Systems
  - ✓ Transmutation
  - ✓ Diagnostics

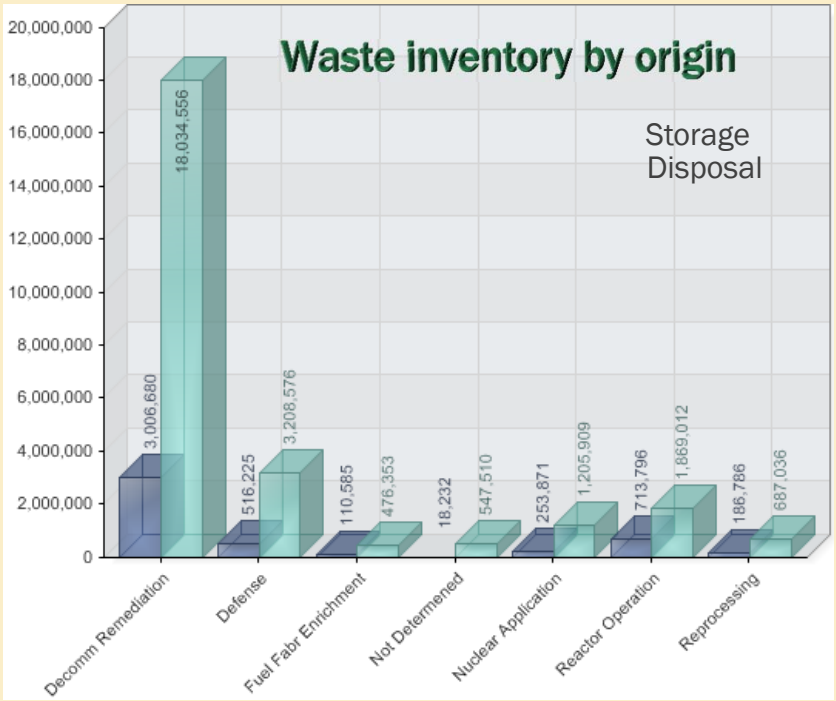




A TOOL FOR REAL-TIME RADIOACTIVE WASTE MONITORING

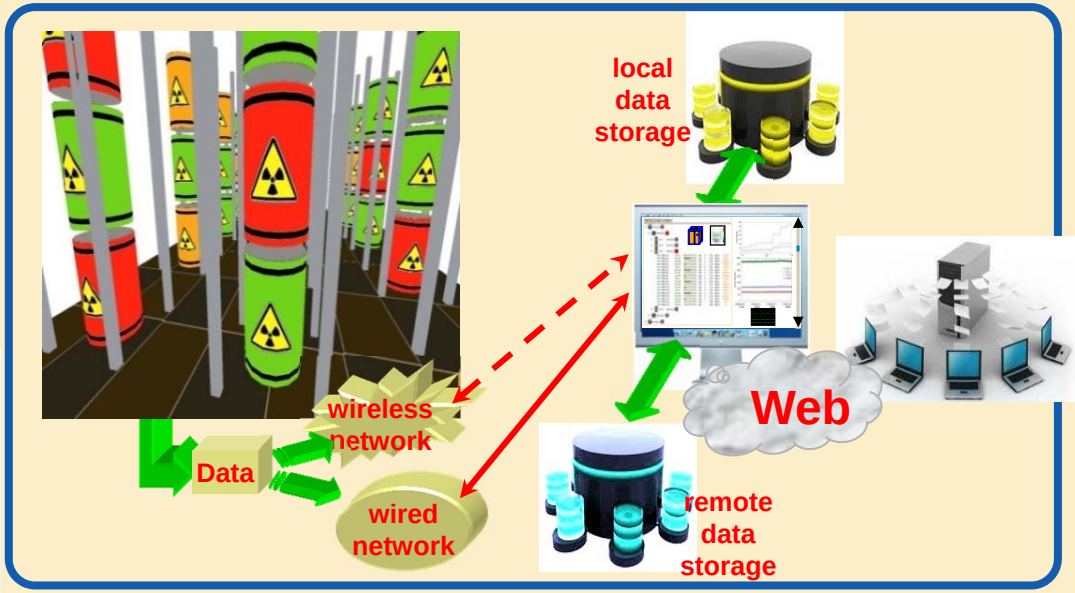
IAEA 2012

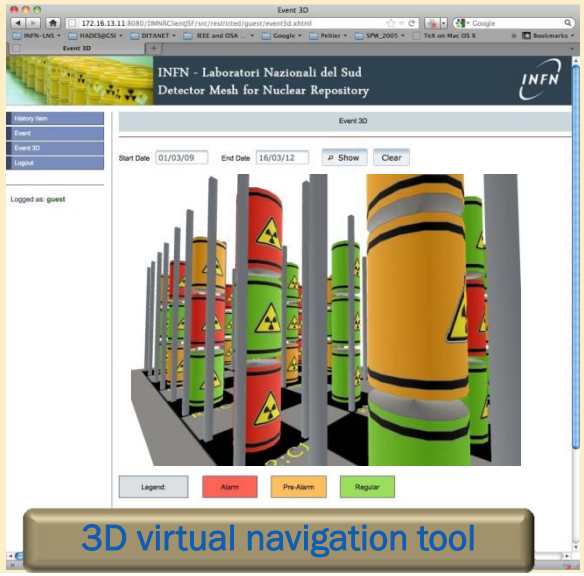
(Net-Enabled radioactive Waste Management DataBase, NEWMDB)

total of > 30 million m^3



INFN-LNS, Catania in collaboration with Ansaldo Nucleare and Sogin





Further developments reported in a patent application

NEW CONCEPTS IN WASTE MANAGEMENT

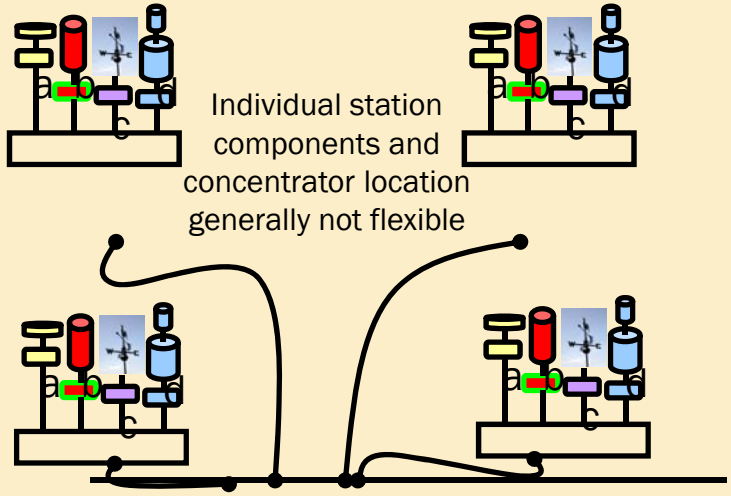
Sorting table for hot spot detection in decommissioning

patent in preparation

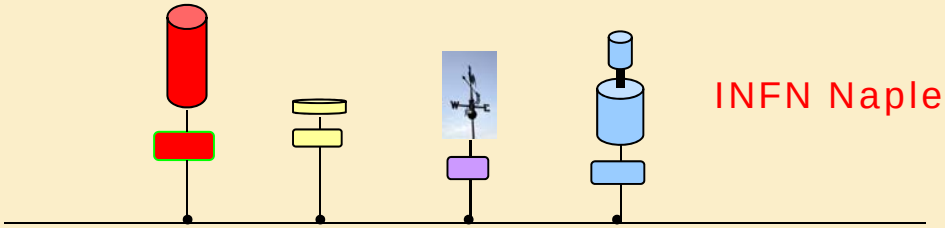
INFN-LNS + Joint Research Center EURATOM, Ispra (Italy)

CONFIDENTIAL

Monitor network: old concept

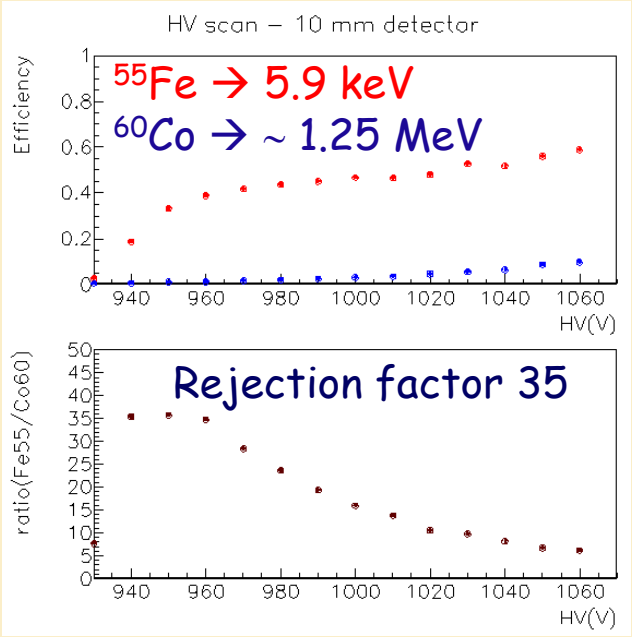


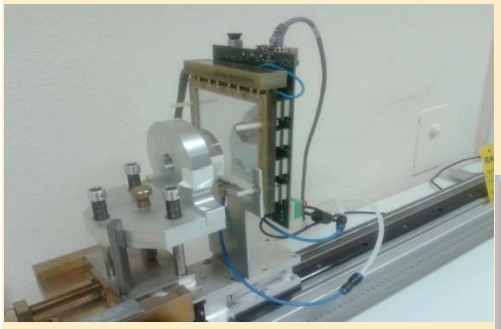
New concept:
«Smart» detectors on a network (wired or wireless), operated as virtual clusters according to requirements



INFN Naples

X RADIOACTIVITY WITH GAS ELECTRON MULTIPLIERS AND SILICON DRIFT DETECTORS

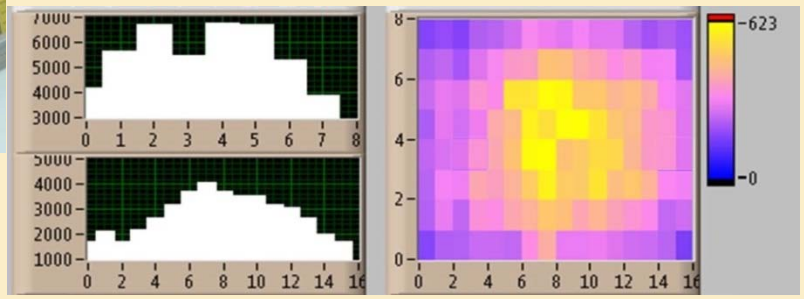


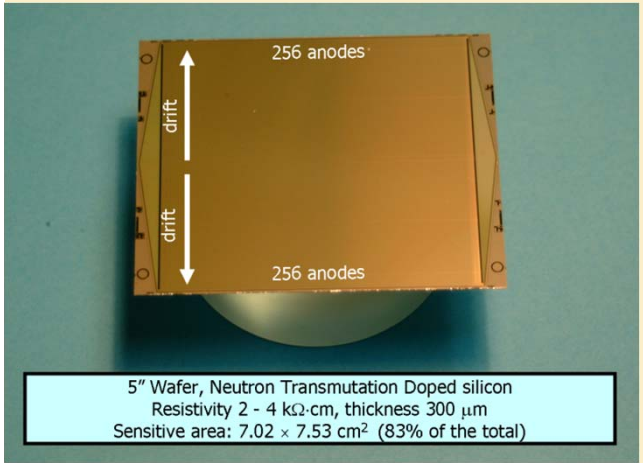


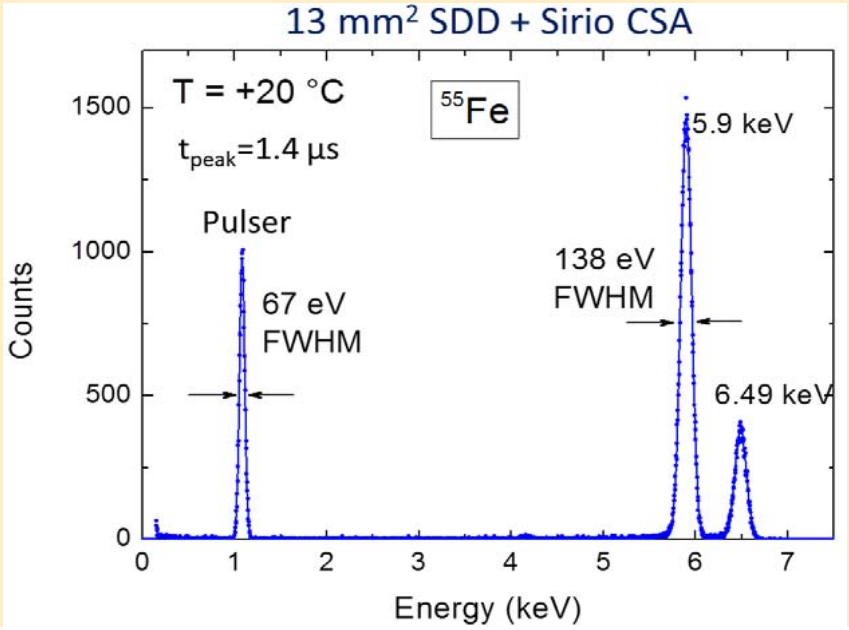
INFN-LNF
in collaboration with CERN

At CERN → cavities and beam pipes from LEP to release from radiation control ?
Stringent limit on ^{55}Fe, chemical analysis lengthy → GEMs could be a good monitor

Possibility to find a hot spot



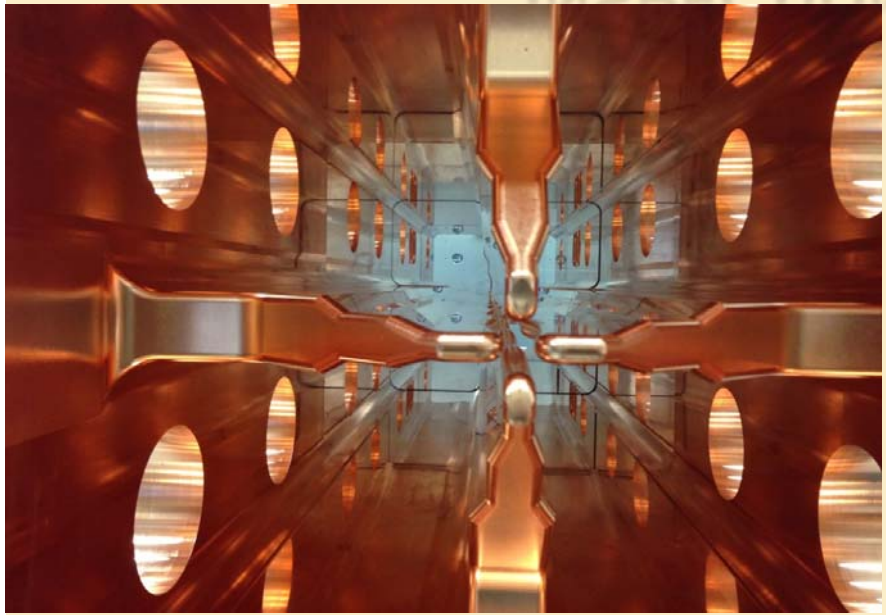


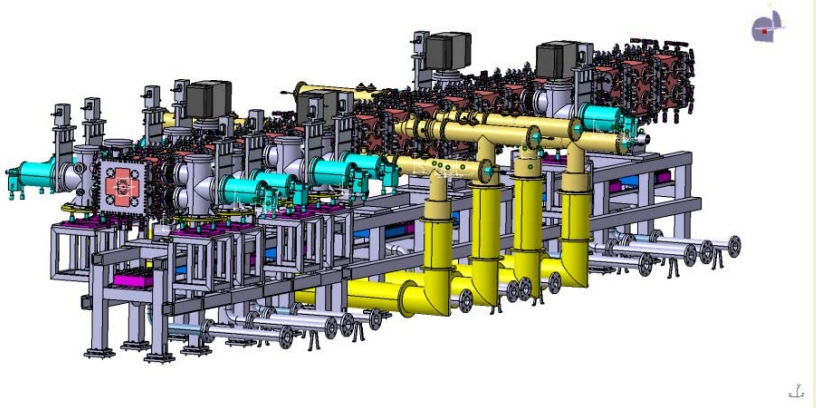


Possibility to identify X-lines at room temperature with excellent resolution

INFN Trieste

A HIGH-POWER NEUTRON SOURCE FOR ACTIVE INSPECTION OF THE WASTE





IFMIF-EVEDA , prototype accelerator for the IFMIF system devoted to material tests for the fusion program, uses as first stage an RFQ under construction by INFN:
it will be the most powerful RFQ in the world, with a length of 9.8 m, it will provide 130 mA of deuterons at 5 MeV kinetic energy

- Main applications:
  - Injectors of multi MW linacs (protons E>1GeV) for multi MW spallation neutron sources (e.g. **ADS** for nuclear waste transmutation, **radioactive nuclear beams**) or neutrino production
  - Injector for deuteron linac (about 40 MeV) for **Fusion Material Irradiation** tests under large neutron fluxes.
- Lower beam power (e.g. 5 MeV 30 mA)
  - Stand alone application as neutron source for **Boron Neutron Capture cancer Therapy**
  - Intense pulsed neutron source for nuclear waste characterization
  - (Part of special grant from Ministry of Education, University and Research, 2012)

With such a high-power source the sensitivity to Pu contamination could be dramatically improved

INFN-LNL

WASTE MANAGEMENT IN HORIZON 2020

INFN participates as third party to a Consortium formed to respond to the call EURATOM Fission NFRP-04-2014-2015
Topic: EU concerted development of Member State research on radioactive waste management

Also, INFN was accepted as a member of the Technology Platform "Implementing Geological Disposal of radioactive waste" (IGD-TP)
P. Finocchiaro (LNS) is INFN contact person

"SCINTILLA" EU PROJECT

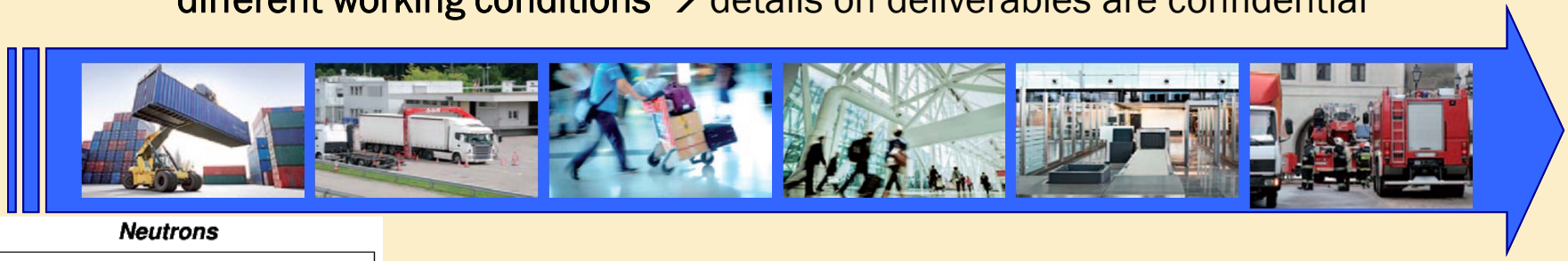
SCINTILLA is an European project within the 7th Framework Program (2007/2014)

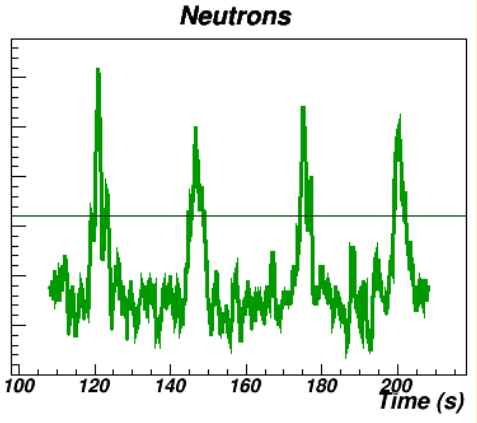
International consortium of **9 groups**:

- 5 research groups: *CEA, EK, Fraunhofer INT, INFN and JRC*
- 4 companies: *Ansaldo Nucleare (ANN), Arttic, Saphymo and Symetrica*

Seventh Framework Programme (FP7/2007-2013). Grant Agreement n.285204

The aim of the project is to develop of a **toolbox of devices for nuclear safety to monitor and detect nuclear materials, masked and shielded radioactive sources in different working conditions** → details on deliverables are confidential





Ex. Of 4 cart transits of a ^{252}Cf neutron source shielded from gammas @1.5 m distance and 1.2 m height from single pillar detector

INFN & ANN developed a Radiation Portal Monitor (RPM) device for the inspection of containers and vehicles

Neutron and gamma radiation detector based on the Gd-lined plastic scintillator technology

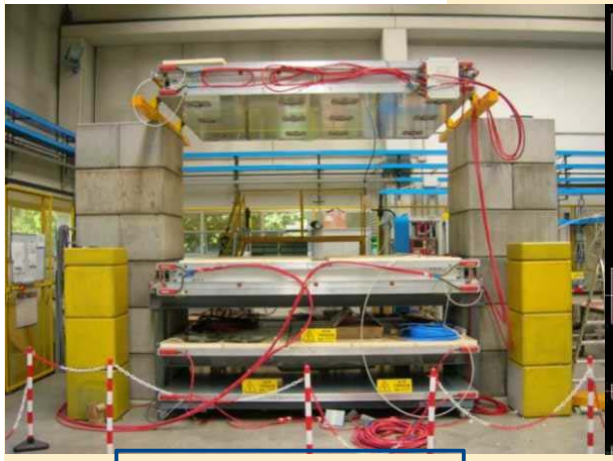
The performances of our detector comply or exceed the RPM international standards for both gamma and neutron detection

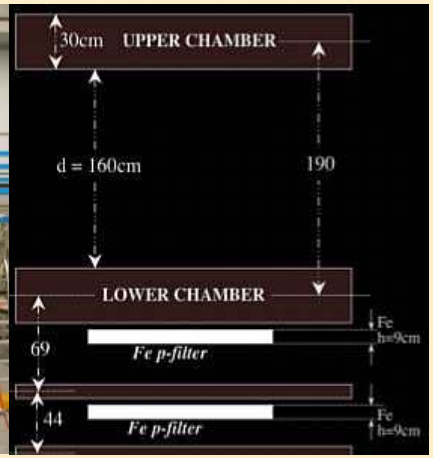
MUON TOMOGRAPHY

Research Fund for Coal & Steel

PROJECT TITLE: "MUONS SCANNER TO DETECT RADIOACTIVE SOURCES HIDDEN IN SCRAP METAL CONTAINERS"

Grant Agreement Number: RFSR-CT-2010-00033





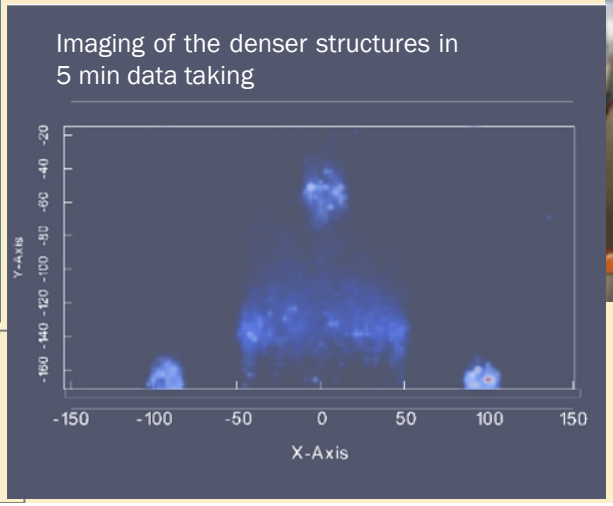
At INFN National Laboratories in Legnaro, a demonstrator based on the technology developed for the CERN experiments has been realized

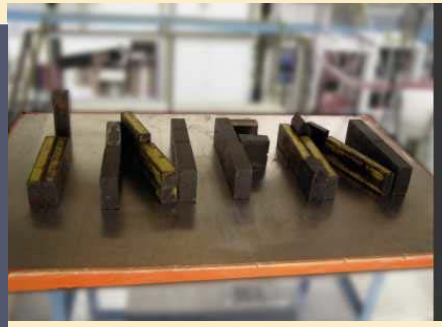
A system of hardware and software components were developed by the group to test and refine the technique

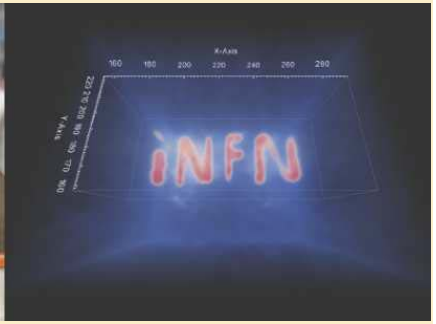
INFN Padova, University of Brescia, University of Padova, INFN Genova

12 liters **lead** test

100x100x65 cm
fine scraps metal container

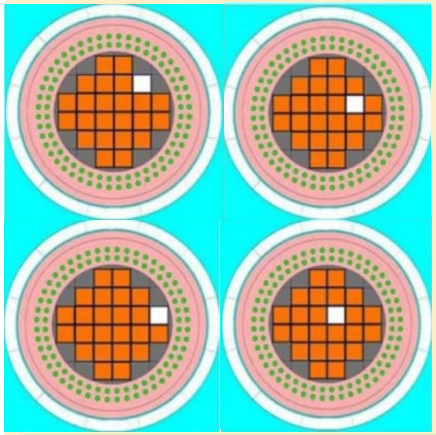






- INFN participates to Consortium for call in **Border Security and External Security, H2020-BES-2014**
- **Further technology transfer → Mu-Blast:** characterization of furnaces, Approved EU project

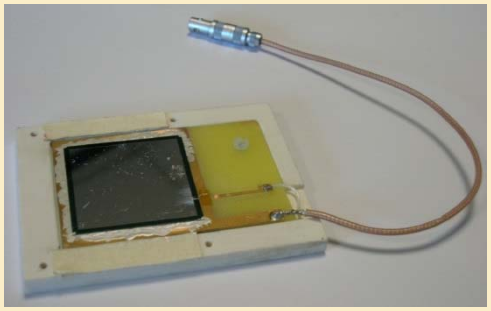
POWER PLANTS, SPENT FUEL AND CASTOR® INSPECTIONS



(INFN patent pending RM2013A000254)

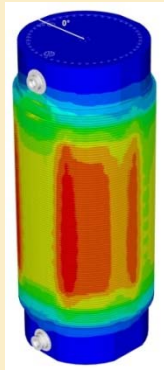
spent fuel monitoring
in place and/or during transportation

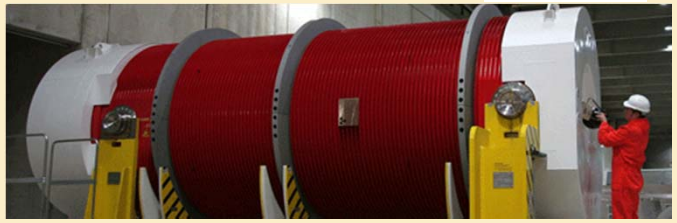
^{3}He-free Lithium-based neutron monitors



detection of possible diversion of fuel elements from Castor containers

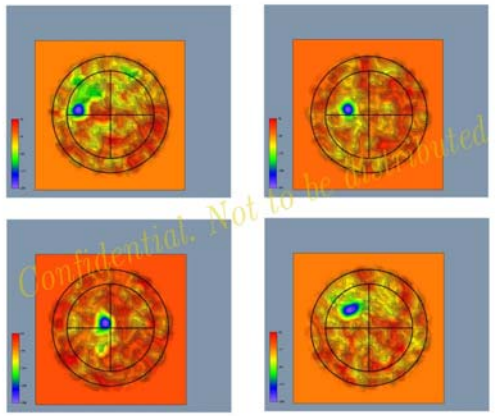
preventing the smuggling of nuclear fuel





INFN-LNS +Joint Research Center EURATOM, Ispra (Italy)

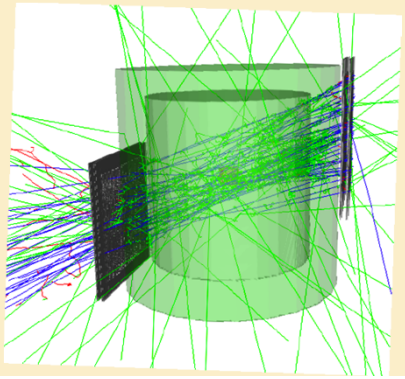
Castor muon tomography
INFN Padova



Simulation of 1 hr exposure

Small and large silo muon radiography
INFN Naples

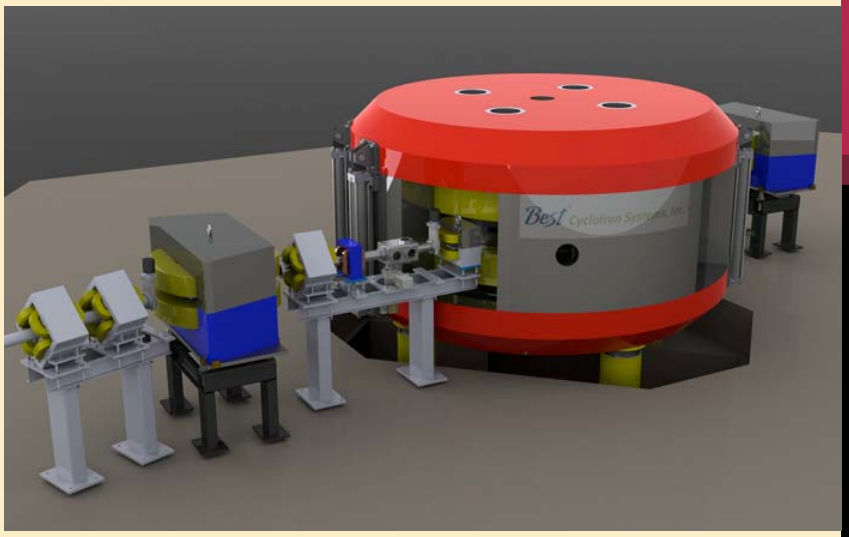
Possible applications at waste storage sites:
Sellafield UK Legacy Nuclear Waste
Collaboration with University of Glasgow and NNL/Sellafield



THE PROPOSAL FOR A LOW POWER ACCELERATOR DRIVEN SYSTEM

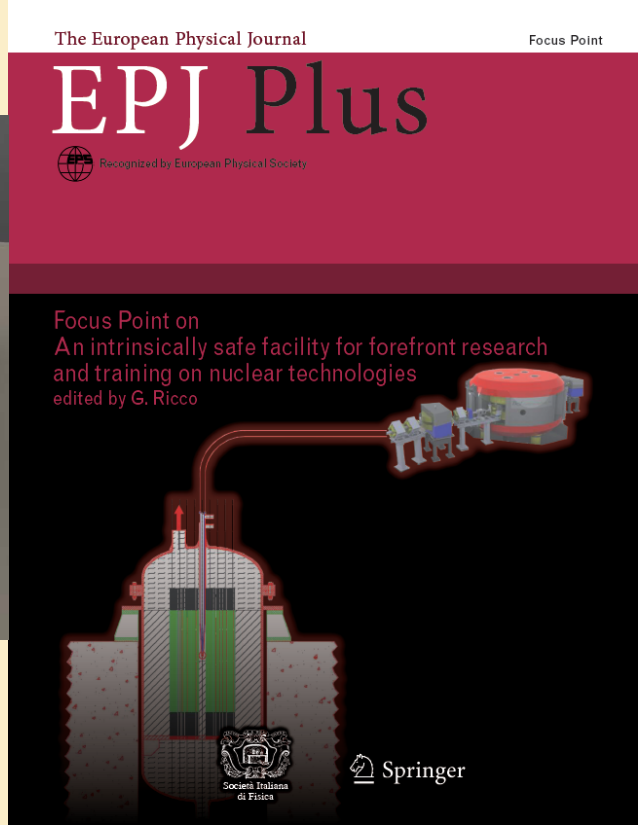
Motivation

- Reference to **70 MeV, 0.5 mA proton** cyclotron purchased by INFN for Legnaro Laboratory as a possible driver
- Collaboration with Ansaldo Nucleare, leader in technology for fast reactors based on **Lead coolant** (also, one of the proposed technologies in the EU)
- Choice of **Pu-free fuel** to minimize security issues → UO_2 w/ 20 % ^{235}U
- **Low thermal power 150-200 kW** to limit safety issues but sufficient to study some aspects of dynamics
- **Temperature < 300 C°** → solid Lead matrix
- **Neutron multiplication k_{eff} ~ 0.95** (limit for storage facilities)
- Relatively low beam energy → Target: Beryllium (weakly bound n)



Broad collaboration between

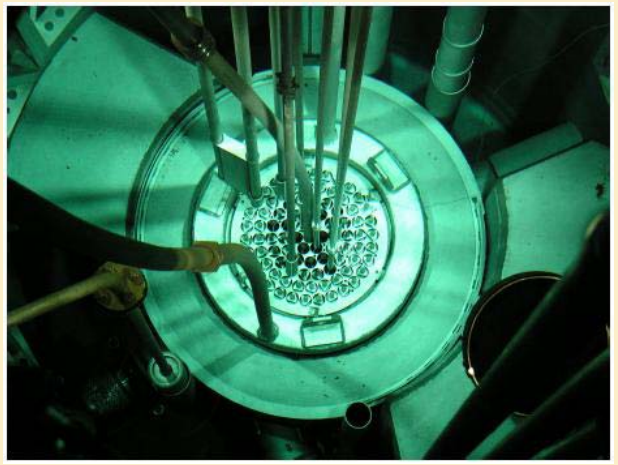
- INFN
- Ansaldo Nucleare
- ENEA
- Milan Polytechnic University
- Turin Polytechnic University,
- LENA-University of Pavia
- University of Genoa



Proposal inside EU roadmap towards fast systems, Myrrha, Alfred...

KNOWING FISSION REACTORS BETTER

- Systematic study of TRIGA research reactor fast neutron components in various locations
- Identifying fast irradiation channels in the TRIGA
- Study of transmutation of Uranium and Transuranics
- Study of materials for fast reactors



- Complete development of thermohydraulic model
- Implementation of “parametric“ multiphysics model
- System for direct measurement of fuel rod poisoning
- Analysis and validation of computing techniques for multiplying assemblies
- Study and design of a fast neutron facility

Based on the **analysis of 48 yrs of reactory history**, core has been **reconfigured**

→ Reactivity increased by 0.5 $ without adding fuel

→ Core Excess values simulated: 2.63±0.05 $, measured: 2.49±0.03 $

INFN application to become a member of EERA-SET (JP Nuclear Materials)

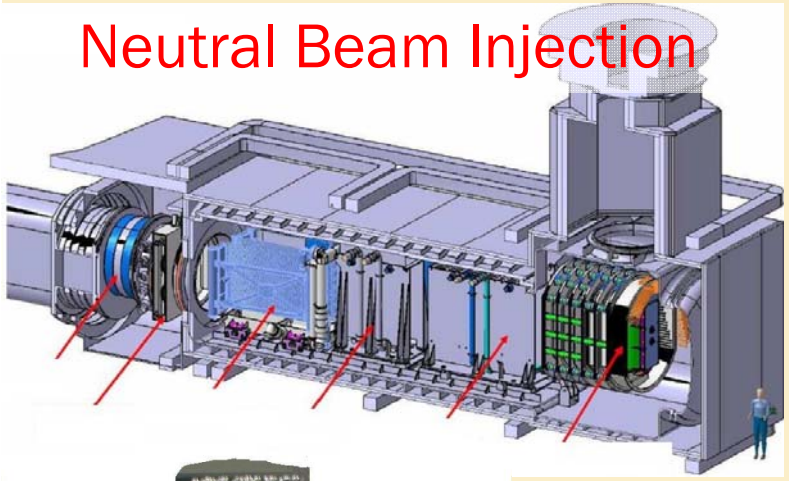
EERA
European Energy Research Alliance

Coordinating energy research for a low carbon Europe

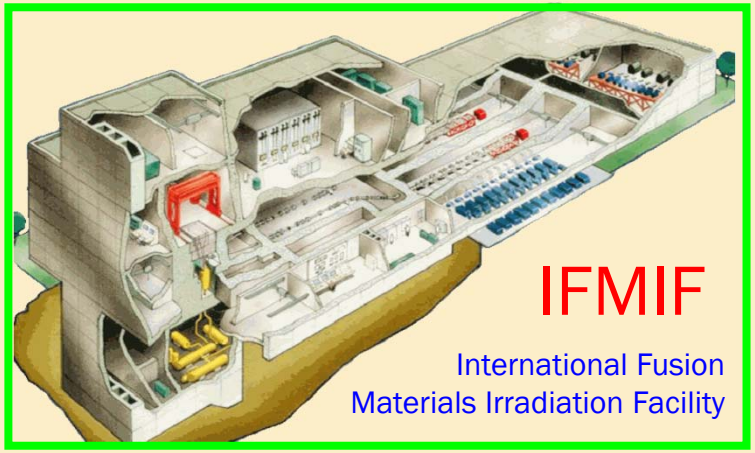
INFN Milano Bicocca
University of Pavia – Laboratory for Applied Nuclear Energy (LENA)

FUSION RESEARCH

Neutral Beam Injection



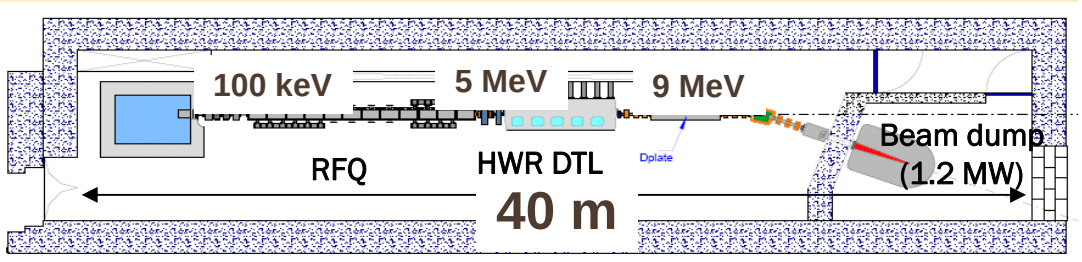
Test D2- source:
INFN Legnaro National Laboratory



IFMIF

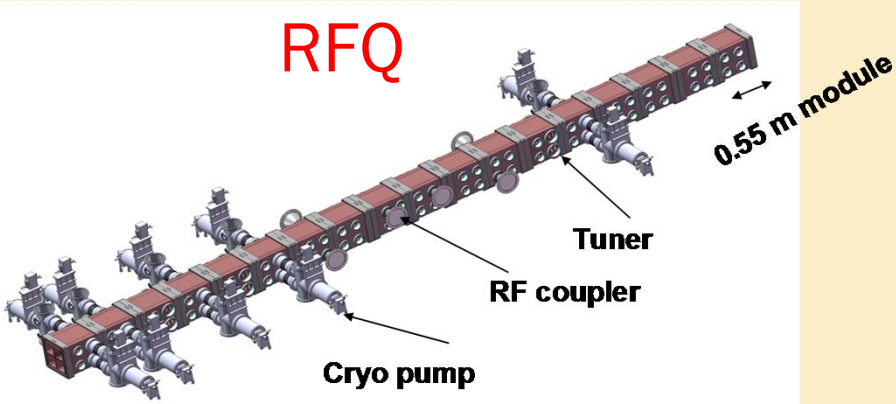
International Fusion Materials Irradiation Facility

Prototype IFMIF-EVEDA



INFN Legnaro National Laboratory, Padova, Turin, Bologna

RFQ



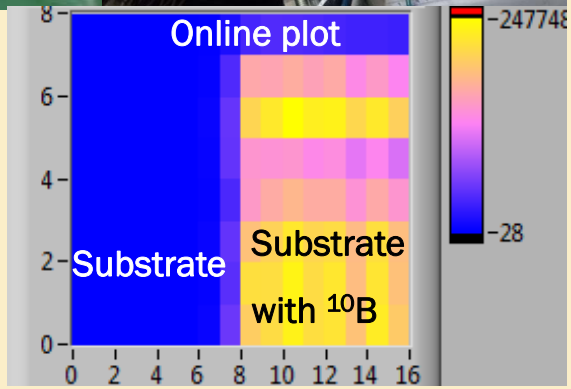
X-RAY AND NEUTRON DIAGNOSTICS

GEMs with ^{10}B coating

at Triga (ENEA)

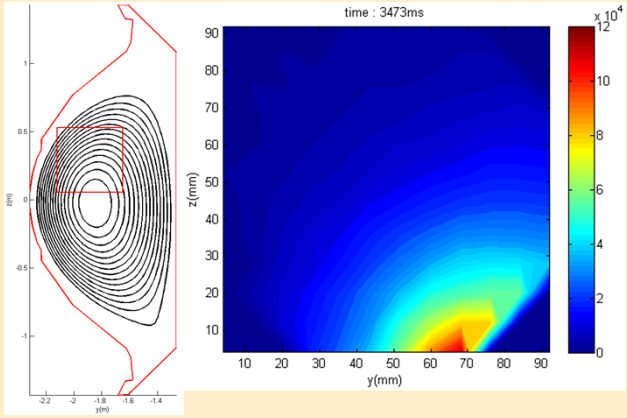
Gamma background free
Without electronic noise

INFN-LNF+ENEA

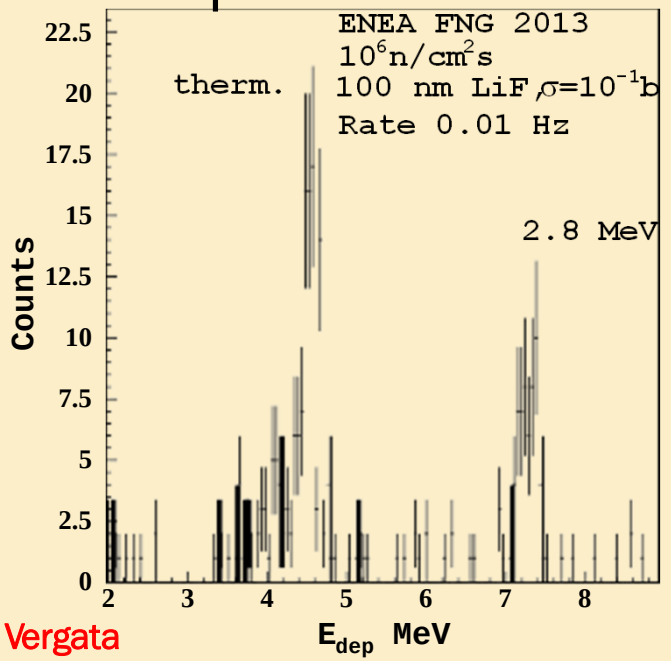


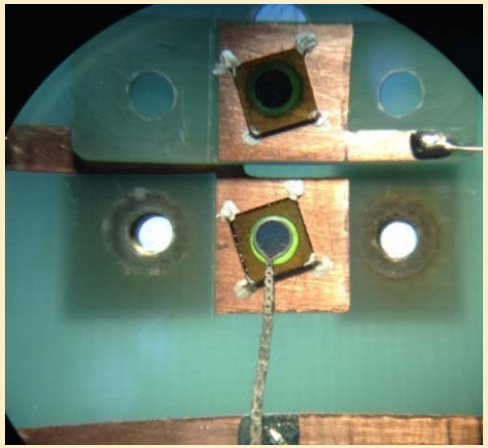
X-ray imaging at Korean Tokamak KSTAR

INFN-LNF
+ENEA



n Spectrum

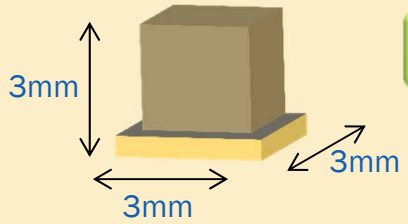




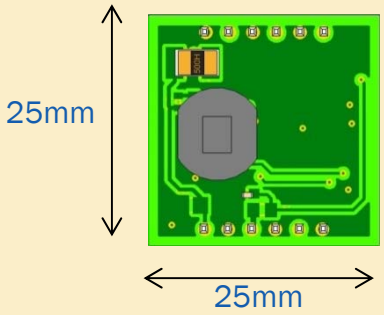
Diamond devices for neutron spectroscopy
Resolution > ~200 keV FWHM but can do better at low rates

INFN Genova, INFN Rome 2, INFN Turin, CNR, ENEA Frascati, University of Tor Vergata

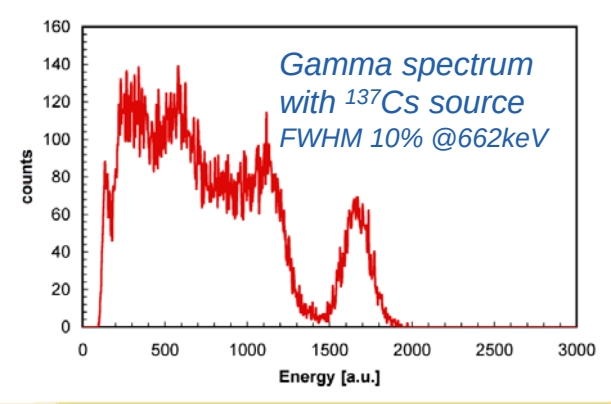
MINIRADMETER: A CHEAP AND PERFORMING PERSONAL DETECTOR



scintillator



sensor electronics



spectrum obtained in ≈5min with a source 20kBq @1cm and 2x2 mm scintillator (30K events)

minimum overall sensitive volume 3mm x 3mm x 3mm could be integrated inside a mobile phone or tablet: there are educational and dissemination aspects → show to the public that radioactivity is a natural phenomenon

20kBq (tiny lab) source @10cm doubles the natural background: gives rise to additional 1cps

Dose at 10sigma in 2min (30s with a 3x3x3 mm scint.)

INFN National Southern Laboratory and Milano

CONCLUSIONS

- INFN's technical developments for experiments in fundamental science can find applications in the field of

✓ Decommissioning and radioactive waste management
✓ Industrial and public safety, port security
✓ Reactor monitoring
✓ New generation fission systems (ADS and fast reactors)
✓ Nuclear fusion program

- Several successful examples

- Opportunities for partnerships
  - ✓ To develop specific products
  - ✓ To devise specific applications
  - ✓ To participate to Horizon 2020 programs