SNIPER-GN
Innovative Special Nuclear Material Identifier

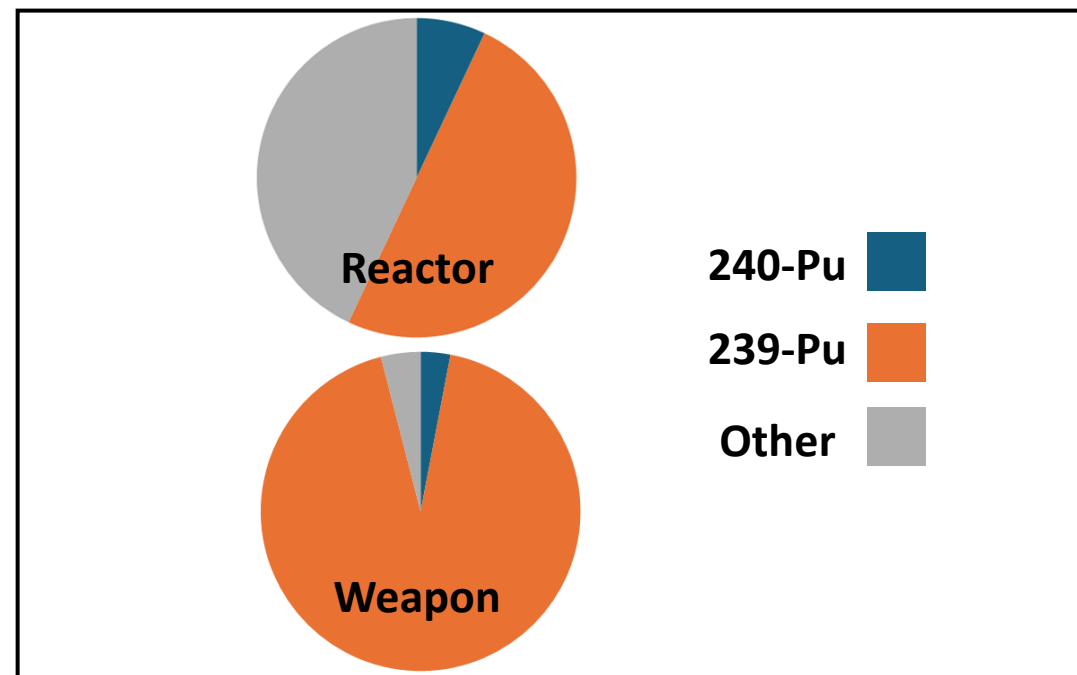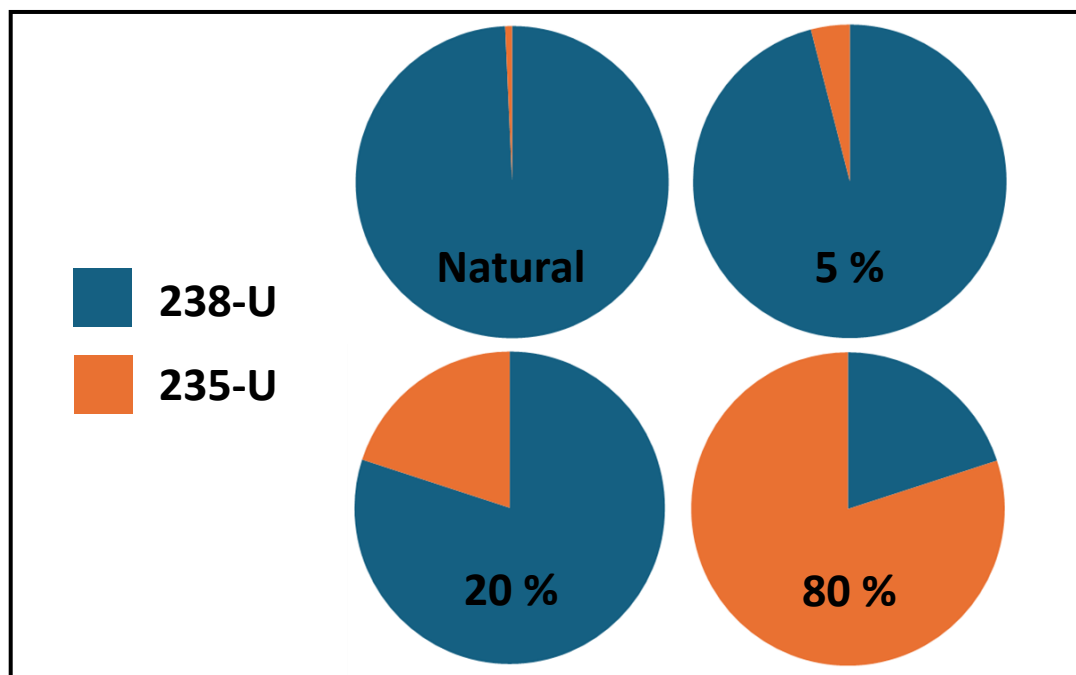M. Venaruzzo, M. Morichi, F. Davolio and C. Del Bene

What is Special Nuclear Material?

Special Nuclear Material is defined by Title I of the Atomic Energy Act of 1954 as **plutonium**, **uranium-233**, or uranium enriched in the isotopes uranium-233 or **uranium-235**

SNM is only mildly radioactive, but it includes fissile isotopes that, in concentrated form, could be used as the primary ingredients of nuclear explosives

Why detect Special Nuclear Material?

Detecting SNM is critical because **incidents involving unauthorized possession, loss, or trafficking of nuclear material are reported every year**

The **IAEA has highlighted the persistent global threat** and the urgent need for effective detection capabilities

Incidents and Trafficking DataBase divides incidents in:
- **Group I:** incidents that are, or are likely to be, connected with trafficking or malicious use
- **Group II:** incidents of undetermined intent
- **Group III:** incidents that are not, or are unlikely to be, connected with trafficking or malicious use

4390 confirmed incidents	**353** Group I	**1065** Group II	**2972** Group III

Transport-related

Overall, about 53% of all thefts reported to the ITDB since 1993 have occurred during the authorized transport of such materials. This figure stands at almost 65% in the last decade, which highlights the ongoing importance of strengthening transport security measures.

53% occurred during authorized transport
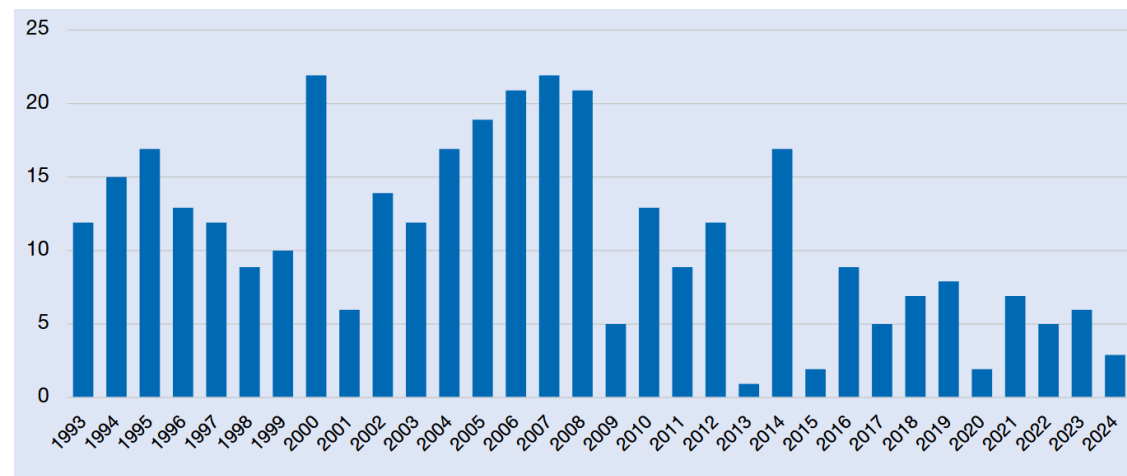
Incidents reported in the ITDB in Group I

Figure 2. Incidents reported to the ITDB that are confirmed, or likely, to be connected with trafficking or malicious use, 1993–2024.
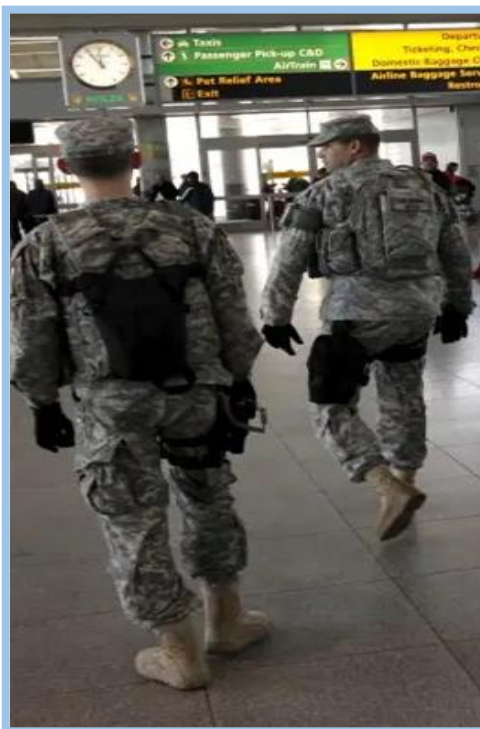
Detection of Special Nuclear Material

Detection of Special Nuclear Material is crucial in different contexts

CBRN

Dirty bombs and smuggled material

Security control in airports

First responder prompt intervention

Custom border inspection

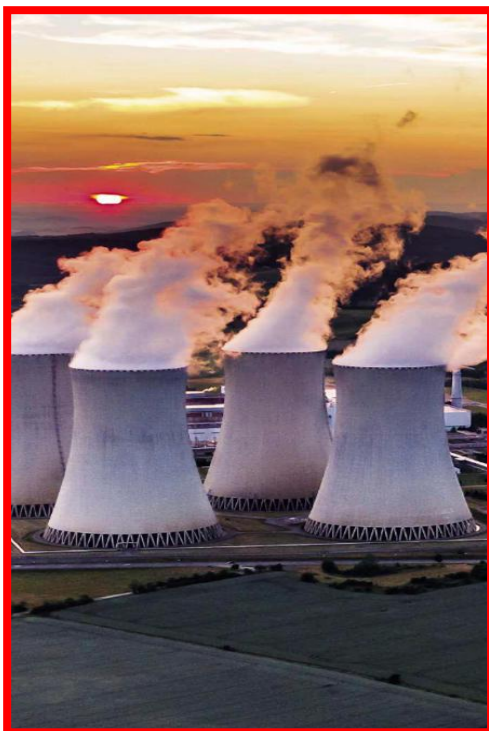**Radiological Dispersal Device detection and identification**

Detection of Special Nuclear Material

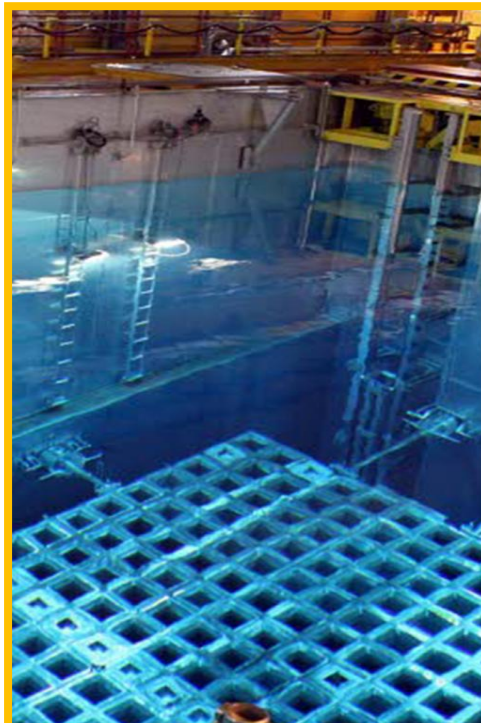**Detection of Special Nuclear Material is crucial in different contexts**

INDUSTRIAL

Critical infrastructure's perimeter monitoring

Enrichment plant survey and verification

Spent fuel safeguards

UF6 cylinder characterization

Fast waste screening

Detection of Special Nuclear Material

Detection of Special Nuclear Material is crucial in different contexts

CIVIL

Public events fast deployment

Parcel scanning

Harbor's container or airport's cargo areas

Preventive radiation survey in crowded areas

Neutron detection, why?

Gamma detection and identification

- Many technologies available
  (e.g. NaI, HPGe, CeBr$_3$)
- Wide energy range
- ID of different sources
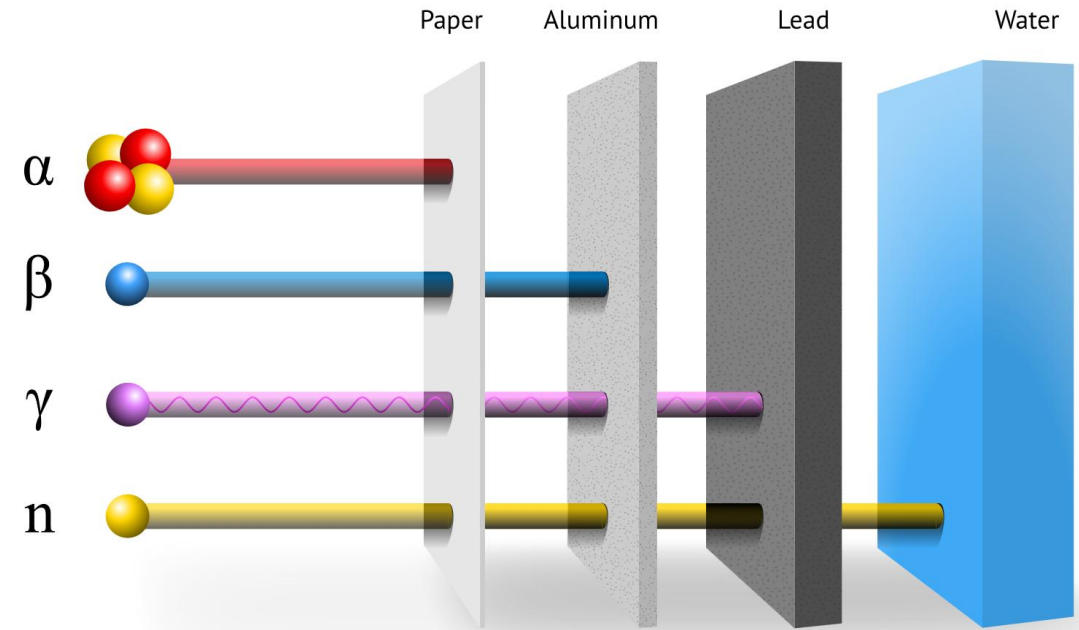 (e.g. Medical, Industrial, NORM)

BUT Nuclear fuels and weapon grade materials emit **low energy gamma rays**, which can be **easily shielded by lead**

Neutrons are also emitted by nuclear fuels and weapon grade materials

Neutrons:

- Increase the chance of detecting radioactive material with lower energy gamma rays
- Harder to shield
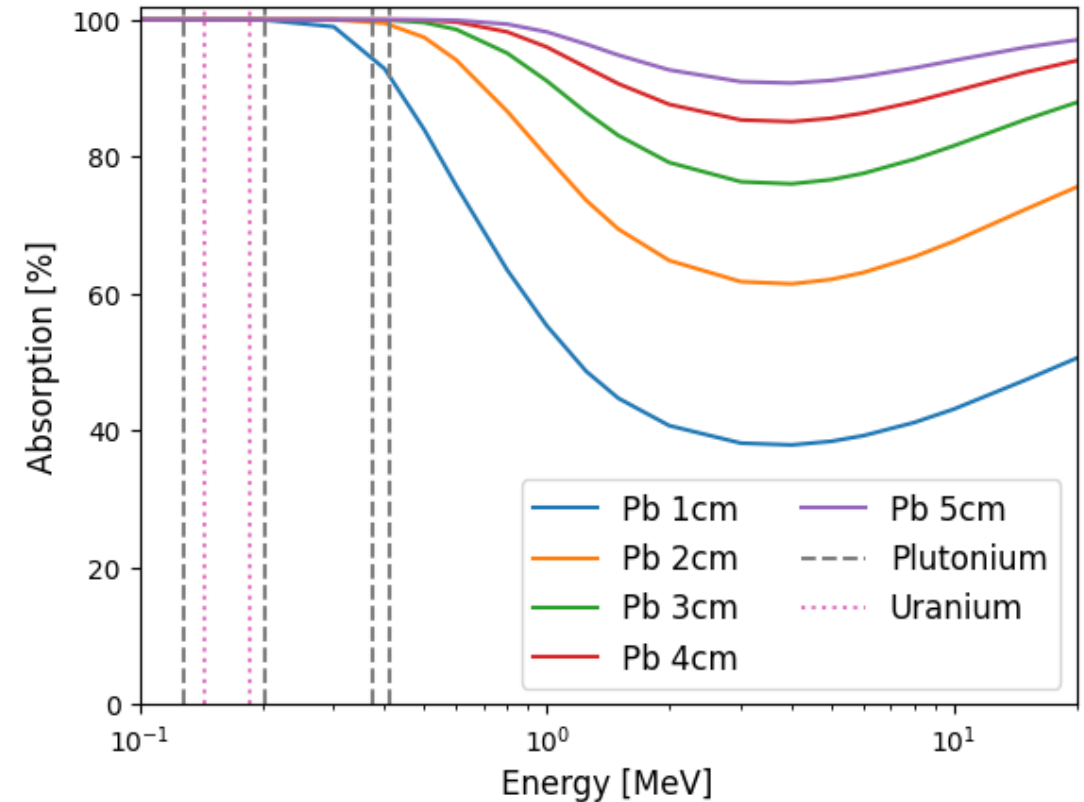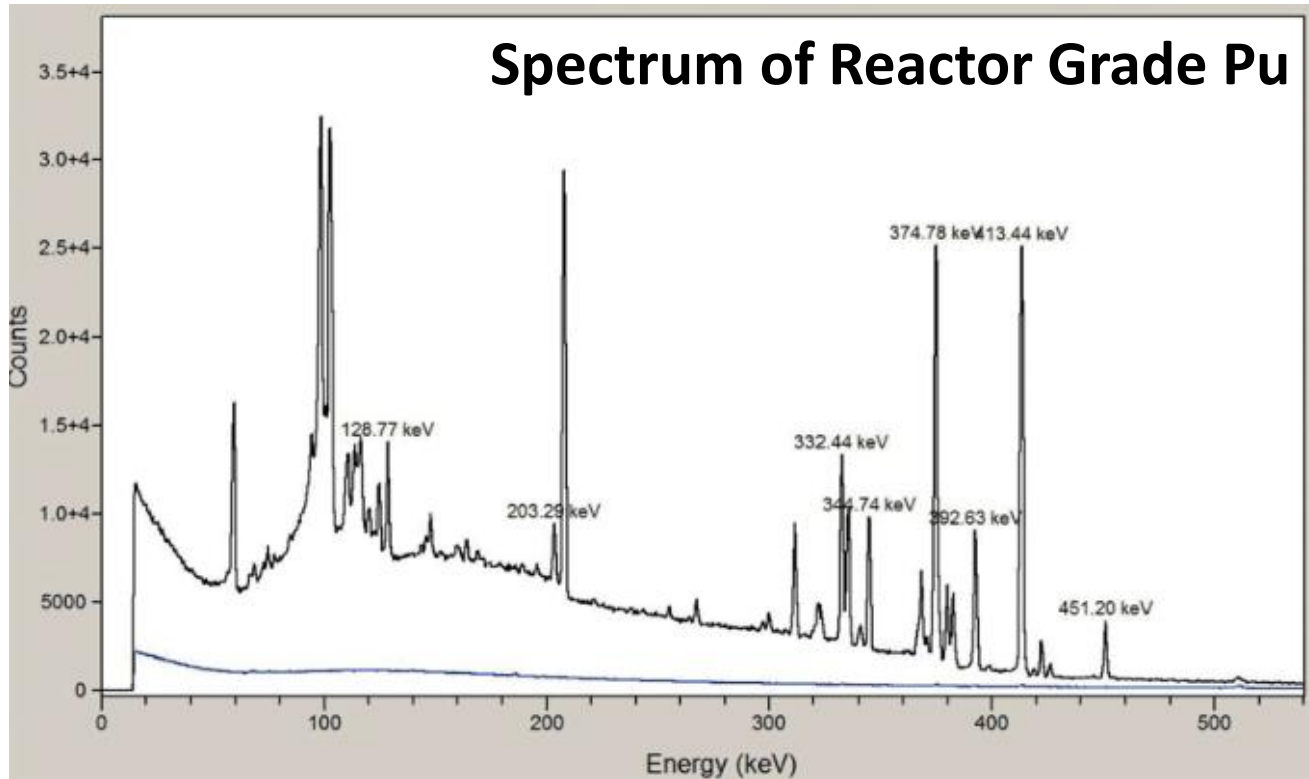
Neutron detection, why?

Just 3 cm of Lead can stop all Pu-239 and U-235 gamma rays

Spectrum of Reactor Grade Pu

Absorption probability of thermal neutrons in 3 cm of Lead < 2% → **Neutrons can be detected behind shielding**

Detection of Special Nuclear Material: Today

From

"*Fission Meter Information Barrier Attribute Measurement System: FY2018 Office of Nuclear Verification FNI/UKC Task 2 Documentation Package*"

12 hrs + 1 Nuclear Measurement Expert + 3 measuring systems to clear the scenario with a perfect understanding of the SNM

P. Kerr, D. Decman, M. Prasad - February 23, 2018

NEUTRON

- 100.3 x 67.3 x 7.9 cm
- 26.8 kg
- 0 – 40 °C
- Id in 15-20 min
- "designed to identify slightly elevated count rates"
- "several hours to obtain an accurate partitioning"

GAMMA

- 39.4 x 16.3 x 34.9 cm
- 11.1 kg
- <12 hours for cooling
- 2-10 min for identification

- "the intent is that the data will be provided to experts for later analysis"
- "Threshold mass detection for WGPu is 25 g"

Detection of Special Nuclear Material: SNIPER-GN

SNIPER-GN is a portable radiation detection system for homeland security

Weighs less than 8 Kg
38 x 30 x 14 cm^3
8-hour battery (hot-swap)
Wireless/USB Connectivity
Autonomous offline identification

SNIPER-GN is the most performant GAMMA and NEUTRON isotope identifier for Special Nuclear Material
"5 g. Pu Identified in less than 1 min"
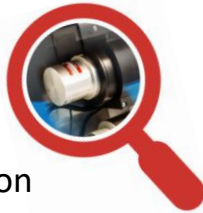
SNIPER-GN: Detectors

The SNIPER-GN has **2 detectors**, one selected for its gamma resolution efficiency and one capable to discriminate neutrons

CeBr$_3$ Gamma Detector

- Superior resolution <3.5% @662 keV
- Enables gamma peak search identification
- Allows SNM enrichment level estimation
- Enhanced signal-to-noise ratio

EJ309 Neutron Detector

- High-efficiency liquid scintillator
- Gamma/neutron discrimination via PSD
- Onboard pulse shape analysis
- Maximizes detection distance

The system includes an **extended gamma library** covering NORM, industrial, medical, and SNM sources, making it versatile for multiple applications.

The **dual-detector approach** provides comprehensive radiation monitoring with **excellent** discrimination **capabilities**
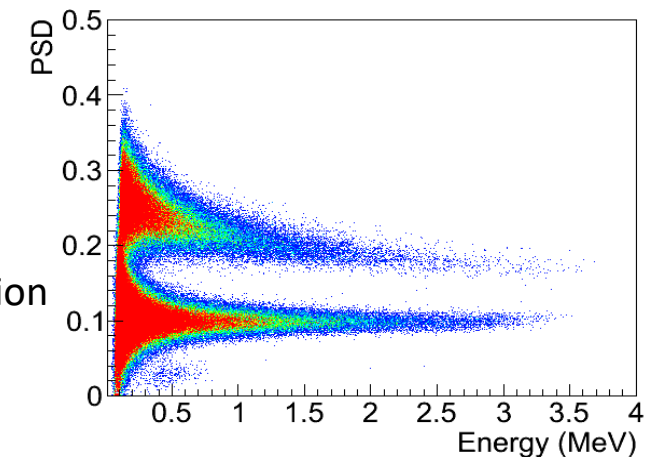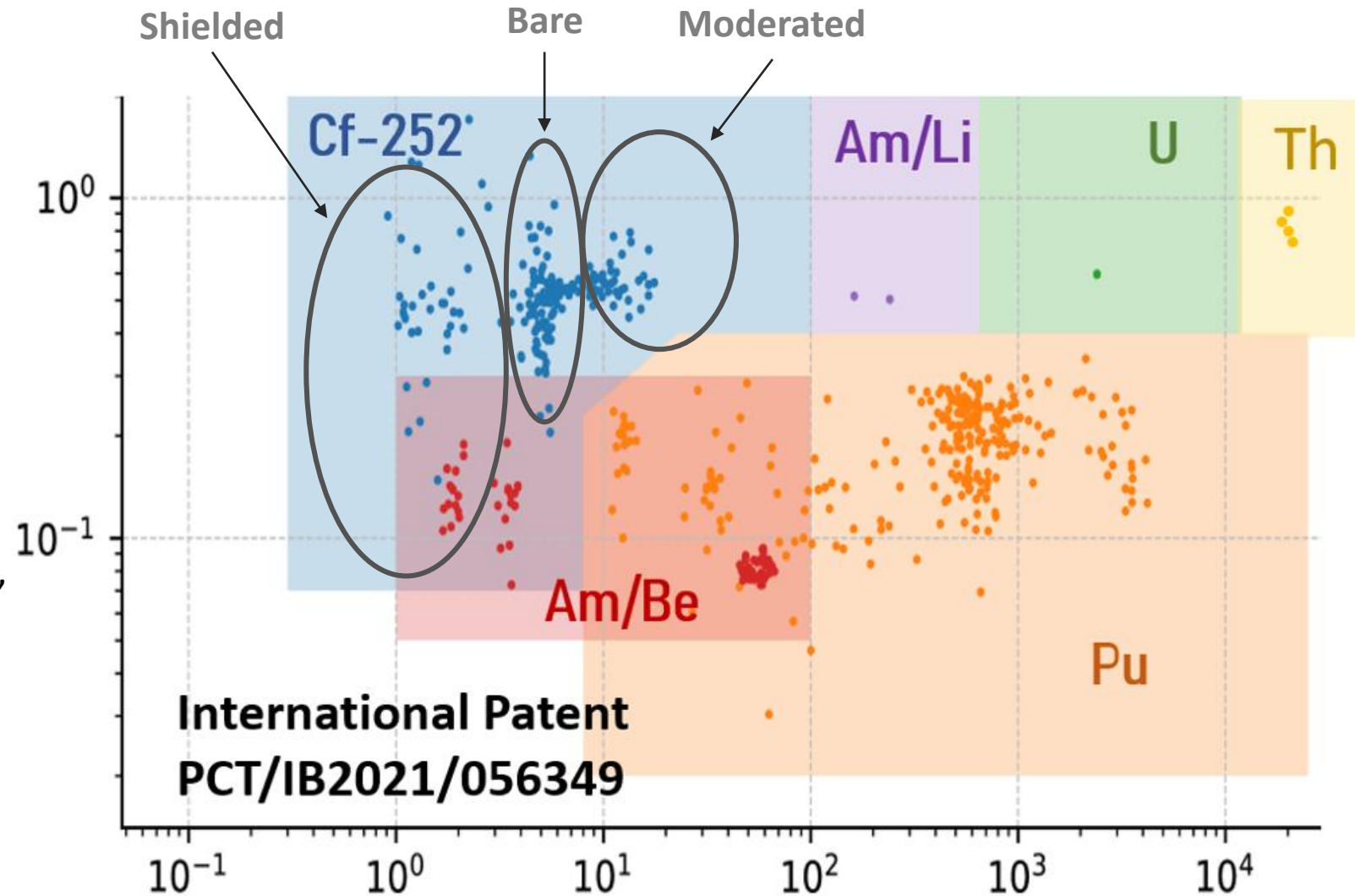
SNIPER-GN: Neutron Identification

NEUTRON source identification

Each point is an ID measurement in a different condition:

- Bare sources

- Moderated sources

- Shielded sources

Overlapping areas, as Am/Be (red area), are discriminated through a 3rd parameter!

PATENTED ALGORITHM

SNIPER-GN: Exceeding Standards

IEC 62327 – 2017 (EU)

Hand Held Instruments for the Detection and Identification of Radionuclides

- 1 s for gamma alarm (500 nSv/h above bkg, moving at 0,5 m/s @ 1m)
- 2 s for neutron alarm (^{252}Cf 20.000 n/s @25 cm)
- 1 min or less for identification of isotope

Minimum detectable activity to trigger a gamma alarm

International Reference (IEC62327)		500 nSv/h
SNIPER-GN	1/10 Standard ➠	50 nSv/h

Minimum distance to detect the neutron source

International Reference (IEC62327)	☢ ➠ ▢ =	25 cm
SNIPER-GN	☢ ➠ ▢▢▢▢▢ =	125 cm (Standard X5)

Minimum shielding to detect the neutron source

International Reference (IEC62327)	☢ ➠ =	5 cm polyethylene
SNIPER-GN	☢ ➠ =	Standard + 5 cm polyethylene + 5 cm Lead

SNIPER-GN: Functionalities

CONNECTIVITY
Wi-Fi, USB and autonomous offline mode available

Weighs less than 8 Kg
38 x 30 x 14 cm^3
8-hour battery (hot-swap)
Wireless/USB Connectivity
Autonomous offline identification

FOOD/ENV. SAMPLES
Quantitative analysis
Bq/g or Bq/l
in fixed geometries

COUNTING
Real-time gamma and neutron rates and thresholds update

SNIPER-GN software runs via **web-interface**

No installation required on tablet or mobile device

The web-interface allows to detect, identify and localize radioactive materials such as SNM and RDD

AIR FILTERS Measurements
Quantitative measurements on filter paper and iodine cartridges

SEARCHING
Gamma and neutron counting and Gamma Spectrometry

MAPPING
Real-time position visualized on the map with customized colored legend

REPORT
Alarm report with list of identified isotopes, spectra, coordinates and extra info

SNIPER-GN: Connectivity

Wi-Fi connection to its designated tablet (or any other mobile device) for undercover data visualization

Wi-Fi allows for higher distance than Bluetooth thus reducing user exposure

USB connection is also available

USB is preferable in the presence of an emergency Wi-Fi jammer

Autonomous Offline Identification

No worries if you forget your tablet — the system keeps working, and reports can be downloaded later from the office!

SNIPER-GN can autonomously perform isotope identification without needing a connected device

When gamma or neutron counts **exceed** the **threshold**, an **automatic ID** is triggered and logged in a dedicated **report**

SNIPER-GN: Connectivity Overview

SNIPER-GN: Counting

REAL-TIME COUNTING

Separated real-time gamma and neutron rates
(separation based on PSD discrimination)

BACKGROUND AND ALARM THRESHOLDS

Automatic separated gamma and neutron alarm threshold
calculation based on the surrounding background
Proximity of the rate to the alarm threshold is displayed

ALARMING

When the threshold is exceeded an alarm pop-up is
visualized and the identification starts autonomously
(Pop-up alerts can be turned off)
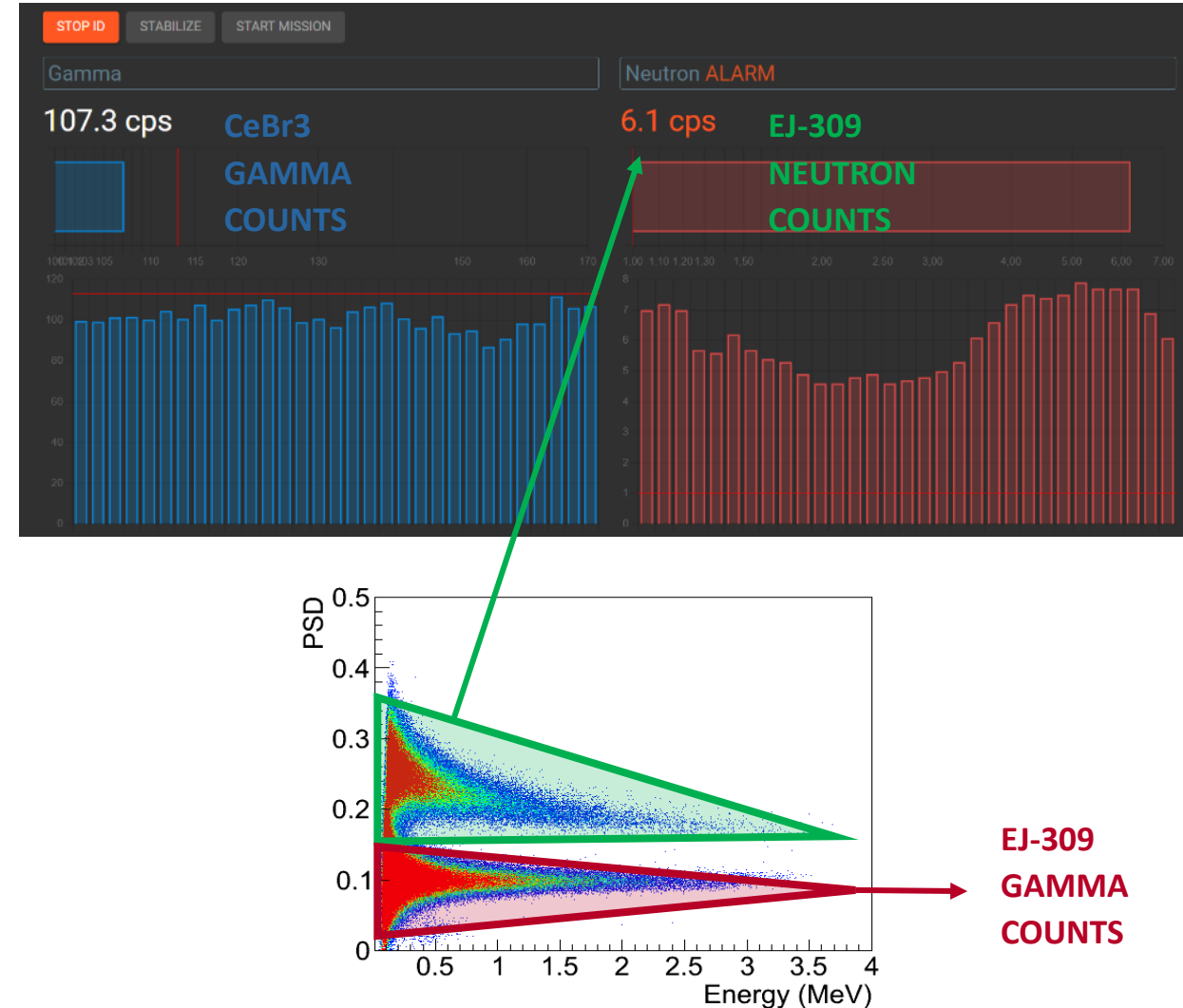
SNIPER-GN: Searching

TREND VISUALIZATION

Rates over last few seconds with the respective alarm thresholds visualized to enable hot-spot searching

WARM-UP PROCEDURE

3 minutes for the **default** gamma and neutron background acquisition and alarm threshold calculation

+2 minutes for **default** temperature stabilization of the gamma spectrum

DEFAULT TOTAL: 5 min to be FULLY OPERATIVE

Default settings are user-configurable!
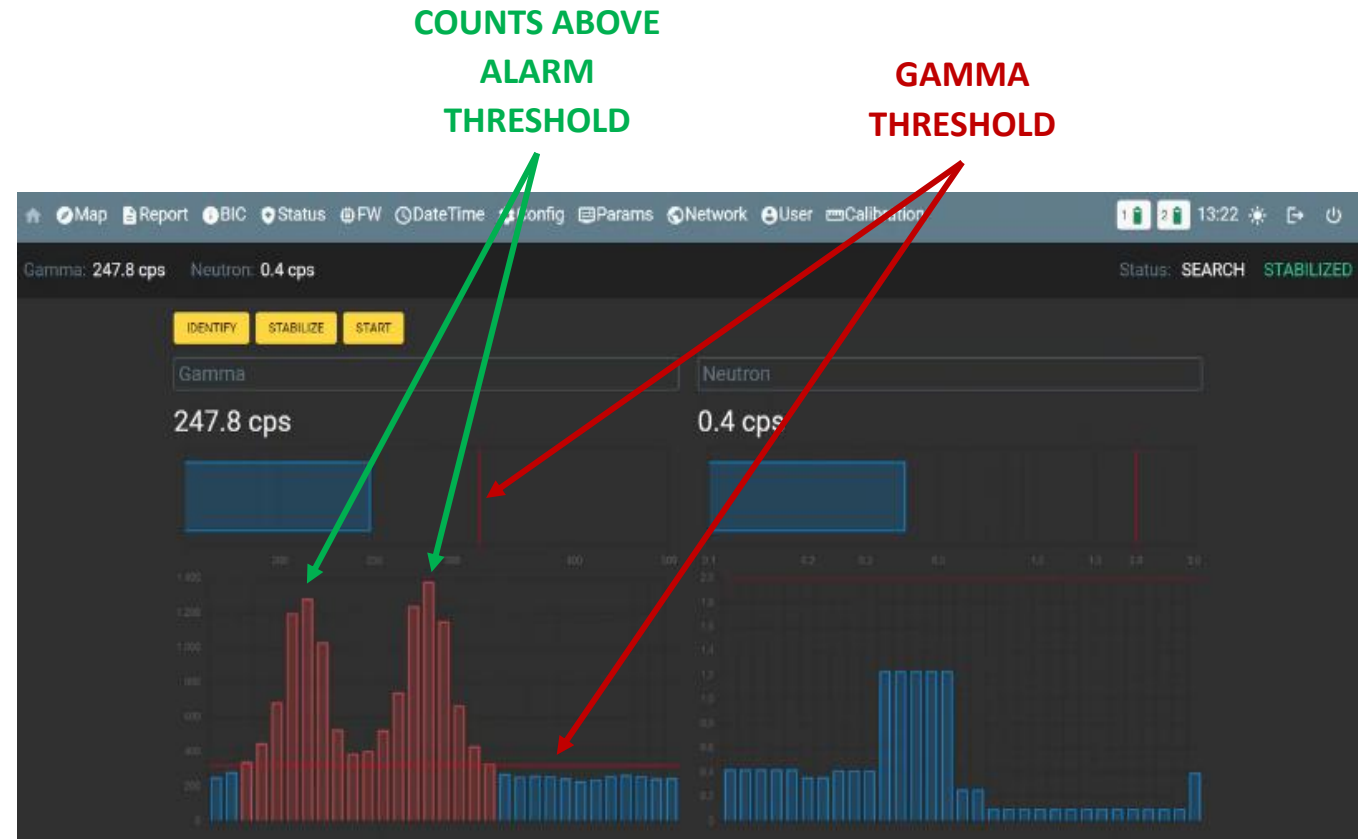
BACKGROUND UPDATE

The background updates dynamically during movement (every 30s by default, configurable). If counts remain below threshold, a **moving average** is applied. Thresholds adjust continuously while moving.

COUNTS ABOVE ALARM THRESHOLD

GAMMA THRESHOLD

SNIPER-GN: Mapping

REAL-TIME POSITION

The included GPS allows to monitor the real time position on the map

Live Gamma & Neutron Map

Legend is totally user-configurable!

HOT-SPOT VISUALIZATION

ID measurements, alarmed or forced, are shown on the report map with ID results and CPSs

Customized colored map for tailored mission

TRACK STORAGE

The track of the user is recorded and saved in a dedicated "MISSION" files

Both lat-long and MGRS coordinates are available

Report Map & ID's pop-up

REPORT

After each identification, a result **pop-up** appears automatically. In addition, data is saved both on the connected device and locally on the Sniper-GN
Local saving can be disabled if needed!

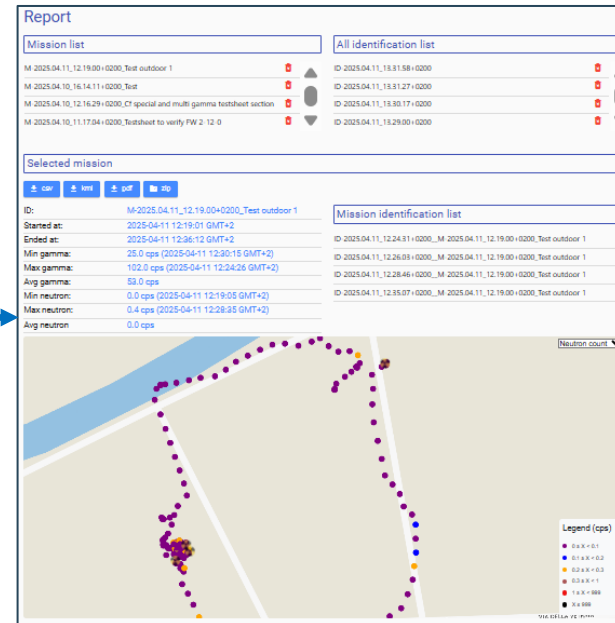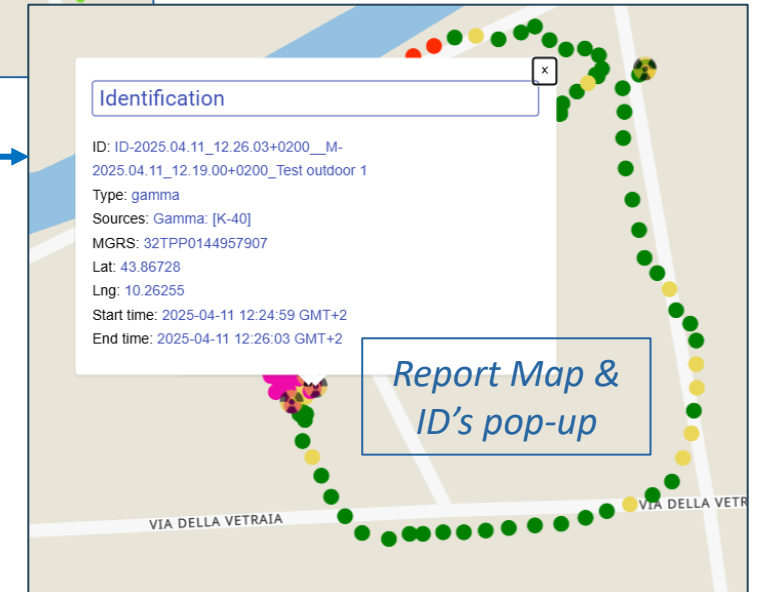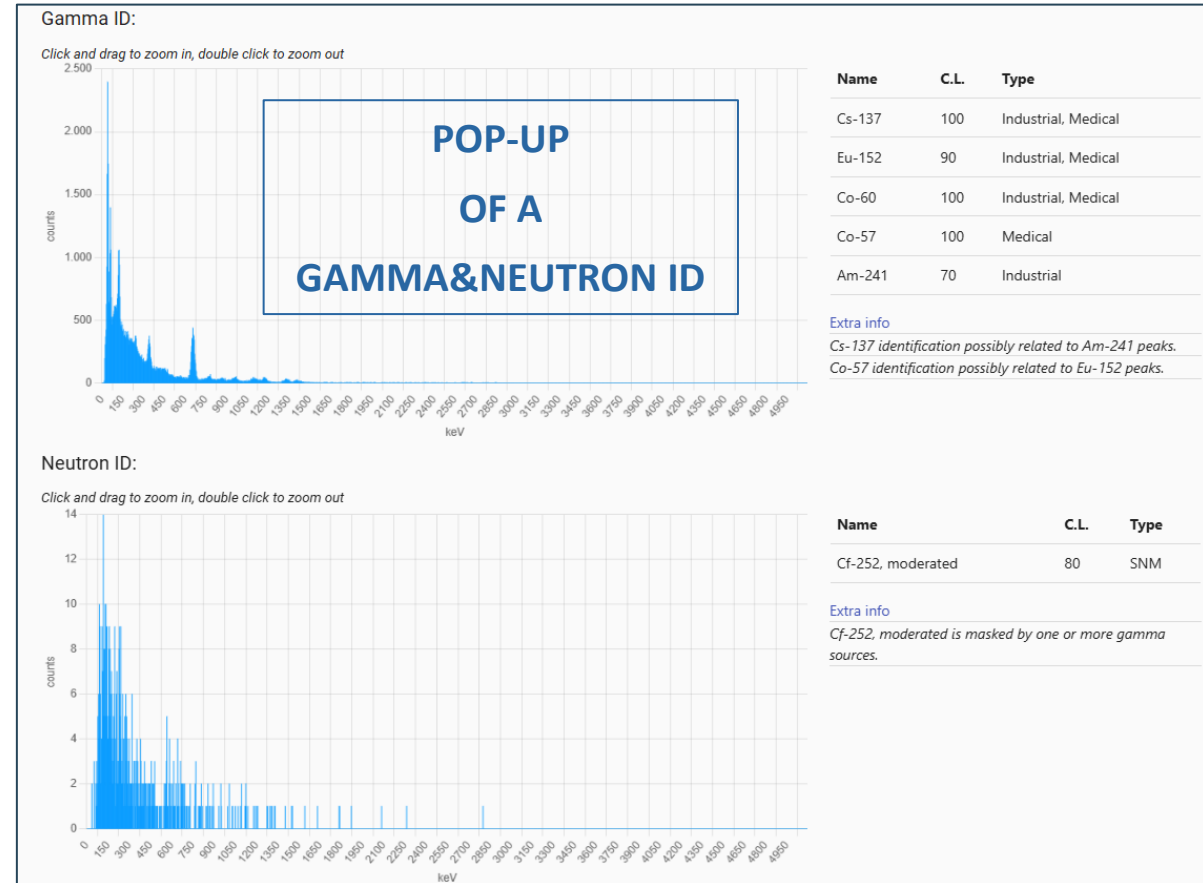**Multiple formats** are available, including SPE, CSV, PDF, and KML

PDF MISSION REPORT

MISSION REPORT
M-2025.04.10_11.17.04+0200_Testsheet to verify FW 2-12-0

SUMMARY
Type:	MISSION
Acquisition Start Time:	2025-04-10 11:17:04 GMT+2
Acquisition Stop Time:	2025-04-10 12:15:05 GMT+2

DEVICE INFO
Model:	Sniper-GN Plus
PID:	53171
Software version:	3.0.6
Manufacturer:	CAEN SyS by CAEN SpA

NEUTRON COUNT RATE
Status	ALARMED
Average:	0.6 cps
Minimum:	cps 2025-04-10 11:17:08 GMT+2
Maximum:	8.4 cps 2025-04-10 11:53:30 GMT+2

GAMMA COUNT RATE
Status	ALARMED
Average:	140.0 cps
Minimum:	64.6 cps 2025-04-10 12:13:35 GMT+2
Maximum:	448.0 cps 2025-04-10 11:34:10 GMT+2

Gamma ID:
Click and drag to zoom in, double click to zoom out

POP-UP OF A GAMMA&NEUTRON ID

Name	C.L.	Type
Cs-137	100	Industrial, Medical
Eu-152	90	Industrial, Medical
Co-60	100	Industrial, Medical
Co-57	100	Medical
Am-241	70	Industrial

Extra info
Cs-137 identification possibly related to Am-241 peaks.
Co-57 identification possibly related to Eu-152 peaks.

Neutron ID:
Click and drag to zoom in, double click to zoom out

Name	C.L.	Type
Cf-252, moderated	80	SNM

Extra info
Cf-252, moderated is masked by one or more gamma sources.

A ZIP file is also available for downloading all mission and identification report files at once!

AIR SAMPLING MODE

Filter papers: used to measure the radioactivity of airborne particulate matter, including ^{137}Cs

Iodine cartridges: designed to capture ^{131}I, which is present both in particulate and gaseous forms

^{137}Cs AND ^{131}I MONITORING

^{137}**Cs** contributes to **long-term environmental contamination**

^{131}**I** presents **short-term health risks**, especially to thyroid

DIRECT ACTIVITY MEASUREMENT

Following a nuclear fallout, **quantitative measurement of airborne radionuclides is vital**

The fixed and well-defined measurement geometry ensures accurate results

FOOD & ENVIRONMENTAL MONITOR

Assessment of radiological activity in **soil, water, and food** following suspected contamination in an **emergency scenario**

Filter paper

Iodine cartridge

SNIPER-GN: Performance Testing

Goal

Present laboratory test campaign of SNIPER-GN device with reference to ANSI standards

Scope

Evaluate gamma and neutron identification capabilities under challenging conditions

Method

Static and dynamic test scenarios with reference sources

Performance Testing: Extensive Lab Activities

Extensive test campaign in several laboratories with different gamma and neutron sources

Neutron sources:
- Cf-252
- AmBe
- AmLi
- Th-232
- U (different enrichments)
- Pu (different enrichments)

Shielded and moderated conditions

Performance Testing: ANSI Standards

Reference Standard

ANSI N42.34

(Cf-252 alarm-neutron test)

Adaptation for Pu

Rescaled source-detector distances to match ANSI neutron flux

Objective

Validate SNIPER-GN alarm and identification capabilities under equivalent conditions

Sources	Total Neutron Emission Rate [n/s]	Standard Distance [cm]	Neutron Flux [n/ (s*cm^2)]
ANSI Standard	20000	25	2.546
CBNM61	4174	**11.4**	2.546
CBNM84	1409	**6.6**	2.546

"Expose the instrument to a ^{252}Cf neutron field that is equivalent to the flux emitted from an unmoderated ^{252}Cf source with a fluence rate of 2×10^4 n/S $\mp$ 20% placed approximately 25 cm from the instrument. The neutron alarm shall activate within 2 s".

CBNM61 Pu Source

Mixture of plutonium isotopes (238 to 242) with a total neutron emission rate of **4174 n/s**

CBNM84 Pu Source

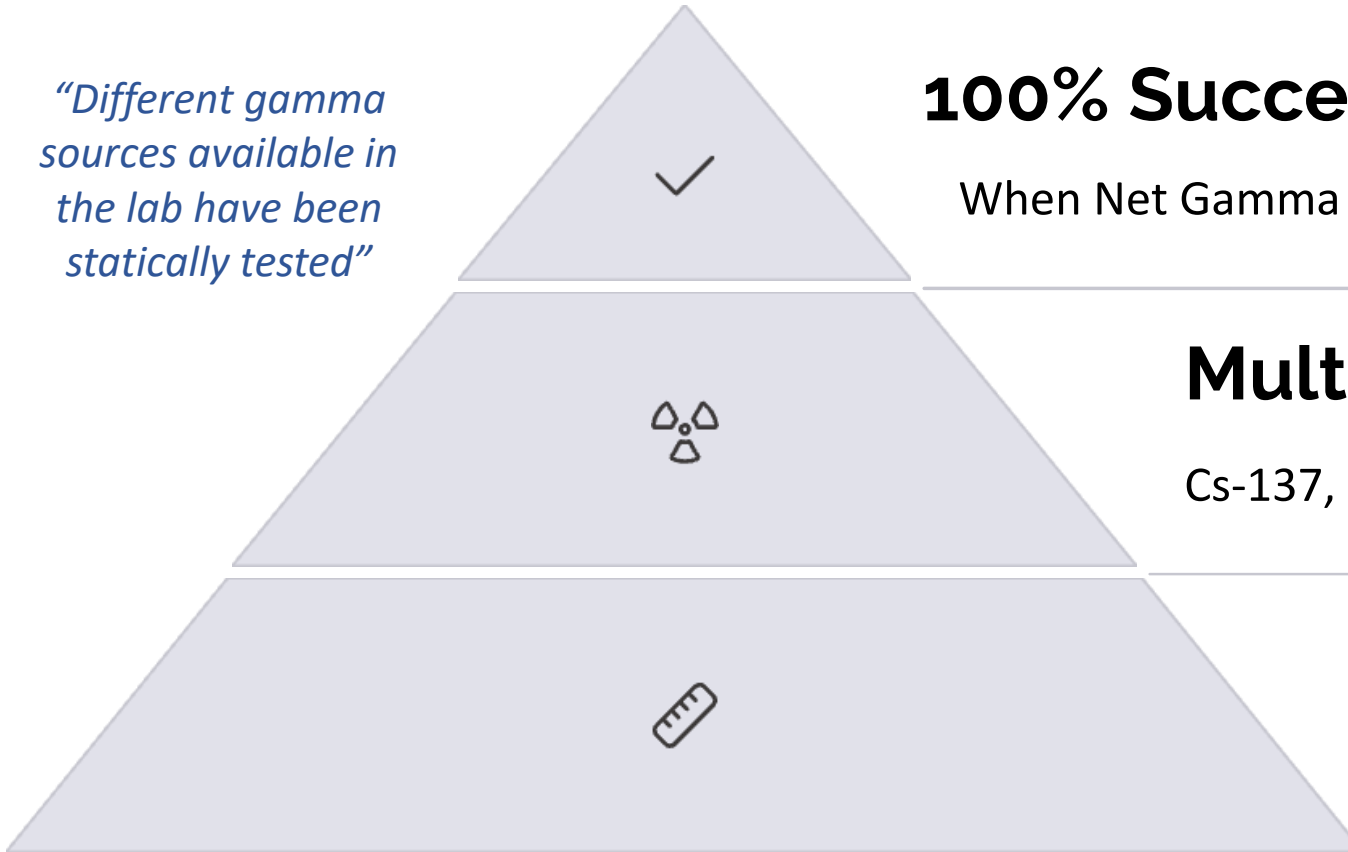Mixture of plutonium isotopes (238 to 242) with a total neutron emission rate of **1409 n/s**

But...

Rescaled distances are too short! Sniper is intended to be used at 20-30 cm from the source. Greater distances, **"better than ANSI"**, have been selected!

Performance Testing: Gamma Identification

"Different gamma sources available in the lab have been statically tested"

100% Success Rate

When Net Gamma CPS > 60

Multiple Sources

Cs-137, Co-60, Am-241

Various Distances

20–400 cm static measurements

Average background of 250 CPS with detection limit of 9.5 CPS

Decreased performances with strong **high-energy masking sources** placed very close

Performance Testing: Neutron Identification

Tests with mixtures of Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241

CBNM61 Results

1 — **100% ID up to 70 cm – 0.8 CPS**
Corresponds to X37 ANSI standard

2 — **66% ID at 1 meter**
Equivalent to X77 ANSI standard

3 — **80% ID Pu@50cm + 2E6 Bq 137Cs@20cm**
Gamma source equivalent to a 13E6 Bq 137Cs @50 cm!

4 — **Degraded with strong masking**
High-energy gamma masking reduce performance

CBNM84 Results

100% ID up to 35 cm
Corresponds to X28 ANSI standard

> 80–100**% identification** even with shielding, up to 20 cm source/detector distance: corresponds to **X9 ANSI standard bare!**

Shielding

- Lead - 3 mm
- Polyethylene - 5 cm

Setup

CBNM84 carried past stationary SNIPER-GN on a chair

Standard

ANSI N42.53 (Backpack detection systems)

Findings

Gamma alarms reliably triggered during passage

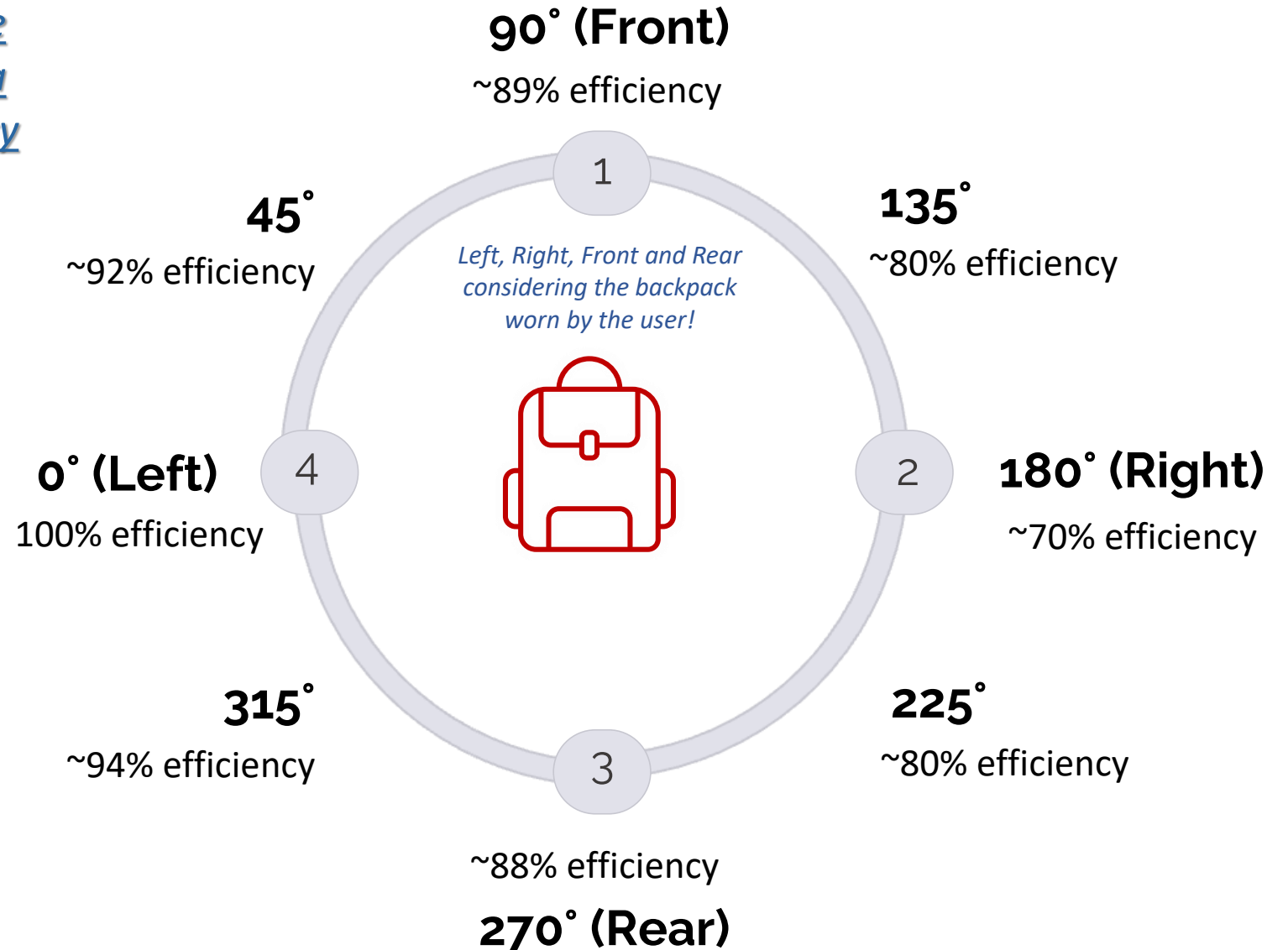Neutron detection less evident due to longer **integration time** (10s)… but now it is an **editable parameter**!

Dynamic detection effective but requires static confirmation

Performance Testing: Angular Response

Relative Gamma Efficiency

90° (Front)
~89% efficiency

45°
~92% efficiency

135°
~80% efficiency

Left, Right, Front and Rear considering the backpack worn by the user!

0° (Left)
100% efficiency

180° (Right)
~70% efficiency

315°
~94% efficiency

225°
~80% efficiency

~88% efficiency

270° (Rear)

1

2

3

4

Detector shows expected anisotropy

Maximum efficiency on the **left of the user** during **backpack** field use!

MEASUREMENT OF MINIMUM DETECTABLE ACTIVITY (MDA) WITH IODINE CARTRIDGES

Conducted one air sampling measurements with an air sampling time of 5 minutes, along with a blank control measurement using a cartridge not exposed to air sampling.

SNIPER-GN measurement time set to 5 minutes.

Sampling Time (minutes)	MDA (Bq)	Air Volume (L)	MDA Concentration (Bq/L)
0 (Blank)	26 ± 3	//	//
5	24 ± 3	360 ± 4	0,067 ± 0,007

Absolute MDA consistent between the blank and sampled cartridge, confirming no detectable activity in the sampled air.

MDA Concentration represents the detection limit under the given sampling and measurement conditions

Performance Testing: Filter Papers MDA

MEASUREMENT OF MINIMUM DETECTABLE ACTIVITY (MDA) WITH FILTER PAPERS

Conducted three air sampling measurements with varying air sampling volumes, along with a blank control measurement using a filter not exposed to air sampling.

SNIPER-GN measurement time set to 5 minutes.

Sampling Time (minutes)	MDA (Bq)	Air Volume (L)	MDA Concentration (Bq/L)
0 (Blank)	7,9 ± 0,8	//	//
3	7,6 ± 0,8	240 ± 2	0,032 ± 0,003
5	8,1 ± 0,8	420 ± 4	0,019 ± 0,002
10	7,5 ± 0,8	870 ± 9	0,009 ± 0,001

Absolute MDA remains constant regardless of air sampling time

MDA Concentration and its uncertainty significantly decrease as sampling time increases
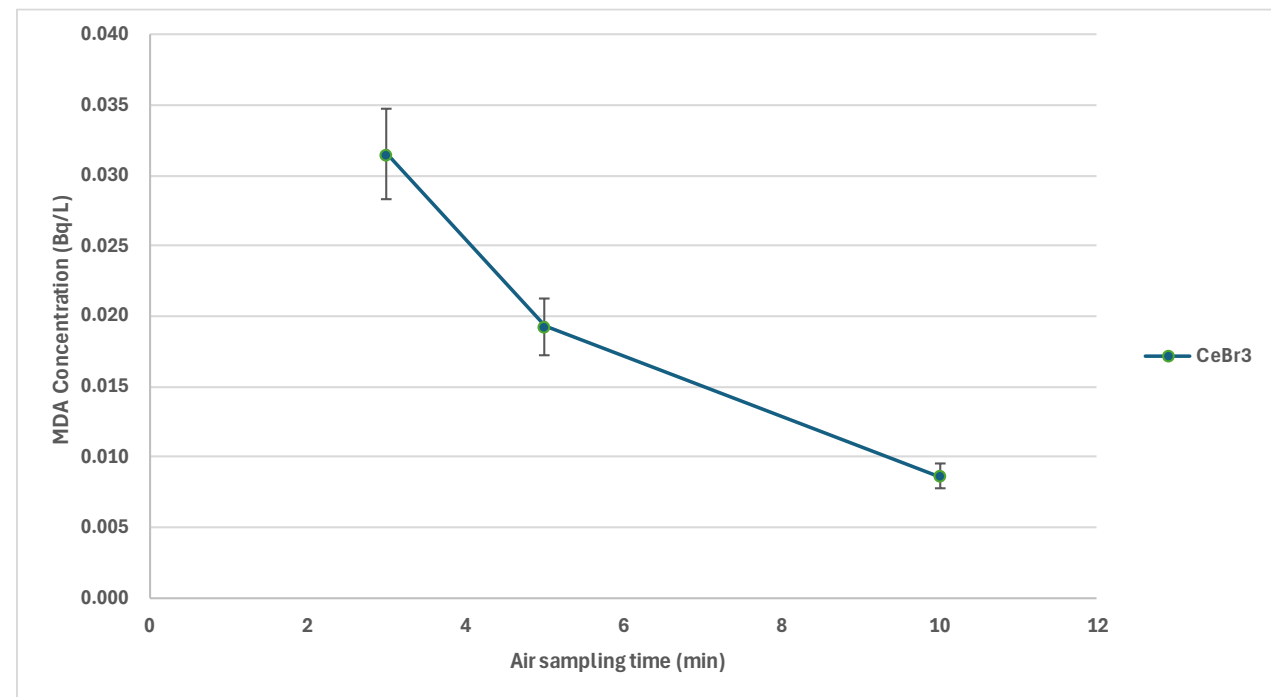
SNIPER-GN: Perfect for Fast and Accurate Measurements

- **Real-time gamma and neutron detection and identification**

- **Automatic thresholds setting and alarming**

- **Quantitative analysis in fixed geometries**
  Filter papers
  Iodine cartridges
  Food and environmental samples

SECURITY

On-site Special Nuclear Material detection

Identification of Gamma and Neutron emitter in one minute

EMERGENCIES

Environmental samples measurements

Fuel process & nuclear backend measurements

Fast & Reliable laboratory measurements in emergencies

Weighs less than 8 Kg
38 x 30 x 14 cm^3
8-hour battery (hot-swap)
Wireless/USB Connectivity
Autonomous offline identification