PORTABLE THYROID MONITOR FOR EMERGENCY USE

THYMON

USE AND MAINTENANCE MANUAL

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Table of contents

Section 1
General information

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1.1 Purpose

This Manual provides detailed instructions on how to operate the THYMON portable thyroid monitor for emergency use.

1.2 Document Organization

The THYMON Manual includes the following sections:

Section 1: General Information

Provides legal details and information about security and manual organization.

Section 2: Product Description

Provides the description of the product and a schematic diagram.

Section 3: Handling and Starting

Provides instructions about the proper handling and starting of the instrument.

Section 4: Software

Provides complete software instruction to the User.

Section 5: Maintenance

Describes maintenance procedures and instruction about how to manage breakdown or malfunction.

Section 6: Technical Data

Technical features and specifications.

1.3 Notations

A «Note» is represented as follows:

NOTE: Important information.

The following picture indicates that attention should be paid:

ATTENTION: Important information concerning a safe and appropriate use of the product.

A reference within the document is marked as follows: Section X.

1.4 Copyright

The rights of the THYMON Manual wholly belong to ELSE NUCLEAR. ELSE NUCLEAR forbids its publication and allows its private use only for operation and maintenance of THYMON.

The document can be disclosed and/or delivered to third parties only upon a written authorization by ELSE NUCLEAR. Procedure descriptions and functioning schemes shall not be made available to third parties. The document can be copied only for internal use.

Information can be modified by ELSE NUCLEAR without notice. In this case, ELSE NUCLEAR shall not be responsible for notice failure.

All the information and data contained in this manual are STRICTLY CONFIDENTIAL. It is absolutely forbidden to reproduce or share this manual or part of it without the company's authorization.

1.5 Warranty

ELSE NUCLEAR guarantees that the new product is without manufacturing defects and can be repaired under warranty for a period of twelve months after its acceptance date (unless otherwise specified by the Sales department in commercial documents).

Warranty applies only in the case of a correct use of the instrument.

1.6 Security, Reliability and Performance

ELSE NUCLEAR shall not be responsible for any repercussion on security, reliability and performance of THYMON that is referrable to:

- Maintenance, transport, installation, use or repair operations carried out by the customer's personnel without following either the instructions written in this manual or the instructions given by the ELSE NUCLEAR's personnel
- Instrument alteration without ELSE NUCLEAR's authorization
- Use by non-qualified or untrained personnel
- Non-authorized removal of security equipment

1.7 Decline of Responsibility

ELSE NUCLEAR declines any responsibility for any damage to the personnel or the equipment that is attributable to an inappropriate use of THYMON.

1.8 Guidelines for Security

This instrument has been designed and manufactured to guarantee the highest level of security during ordinary operations. It should always be used in compliance with the following precautions and guidelines (as well as any other instruction illustrated in this manual) concerning safety:

- THYMON can be disassembled or repaired only by ELSE NUCLEAR's authorized personnel, or by other assistance staff upon written notice by ELSE NUCLEAR
- THYMON cannot be altered in any part without ELSE NUCLEAR's authorization
- Before allowing anyone to use THYMON, it is necessary to check whether the person has read and understood this User Manual. It would be appropriate to compile a list of authorized users
- Non-authorized personnel should be prevented from having access to THYMON

If the instrument is not working properly or is not responding to controls as expected, even though all instructions have been carefully followed, it is necessary to contact immediately the ELSE NUCLEAR Service Department to report the breakdown.

1.9 Owner's Liability

The instrument's owner shall make sure that anyone who uses THYMON has read and fully understood this Manual and any other relevant information concerning THYMON and its class of instruments in general. ELSE NUCLEAR does not guarantee that the mere reading of this Manual qualifies someone to operate THYMON.

Section 2
Product Description

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2.1 General description

The ELSE NUCLEAR THYMON is a portable instrument specifically conceived for screening I-131 accumulated in human thyroid in a radiological or nuclear emergency situation. The design of the instrument addresses the following key parameters:

1. Portability and light weight, to ensure a fast and easy deployment in emergency situations.
2. Ruggedness and high IP grade, which ensure the device usability by competent authorities and supporting actors in all relevant weather and environmental conditions.
3. Simple and intuitive user interface, to speed up screening procedures.
4. High counting efficiency, yet maintaining high measurement accuracy, to enhance throughput which allows reliably screening large amounts of people in short time.
5. Automatic and built-in measurement routines, which include pre-defined automatically-uploaded age-dependent efficiency curves, activity alarm thresholds, automatic activity calculation algorithms, automatic gain-temperature compensation routines, etc.
6. High adaptability, to ensure the correct measurement setup in a fast and reliable way.

The design of the instrument was conceived according to the previous 6 key features. Moreover, the instrument was specifically optimised to cover the entire range of iodine activity in thyroid as outlined in several national and international guidelines ([1],[2],[3]) in reasonable counting time (2 minutes as default), also including additional design features specifically conceived to lower measurement uncertainties, both in terms of counting statistics and detector-to-thyroid positioning.

THYMON compactness, ruggedness, light-weight, together with its simple and intuitive built-in software interface, make the device perfectly suited for emergency screening applications.

[1] *TMT handbook, Triage, Monitoring and Treatment of people exposed to ionising radiation following a malevolent act, SCK-CEN, NRPA, HPA, STUK, WHO 2009.*
[2] *Nordic Guidelines and Recommendations, Protective measures in Early and Intermediate Phases of a Nuclear or Radiological Emergency, Nordic Emergency Preparedness Group – NEP.*
[3] *Mats Isaksson, Lilian del Risco Norrlid, 2015:20 Guide for thyroid monitoring in the event of release of radioactive iodine in a nuclear emergency, SSM (2015).*

Figure 2.1: overall presentation of THYMON (open case)

The device is composed of three main parts, all housed in a **heavy-duty rugged technical case**:

- **Detector probe**, which can be used either handheld or mounted on its dedicated support. - "A" in figure 2.1, and figure 2.2
- **Robust, light-weight and easily-deployable support**, which ensures the correct, yet comfortable, person positioning (lowering the measurement uncertainty) during measurement. The support

therefore provides the possibility of hands-free operation. - “B” in figure 2.1, and figure 2.3

- **Rugged high-IP-grade tablet**, on which the proprietary ELSE NUCLEAR software allows detector control and data visualisation and analysis. The tablet is connected to the probe with a dedicated USB cable. The charger for the tablet is placed under the foam lodging. - “C” in figure 2.1 and figure 2.4

The THYMON is shipped with the battery disconnected from the tablet, and stored under the tablet lodging together with the charger.

- **KCl calibration source**, in the form of a self-contained assembly including about 350 g of KCl (15 Bq/g activity concentration), specifically designed to be coupled to the detector head. - “D” in figure 2.1 and figure 2.5
- **Tablet holder and detector USB cable** - “E” in figure 2.1

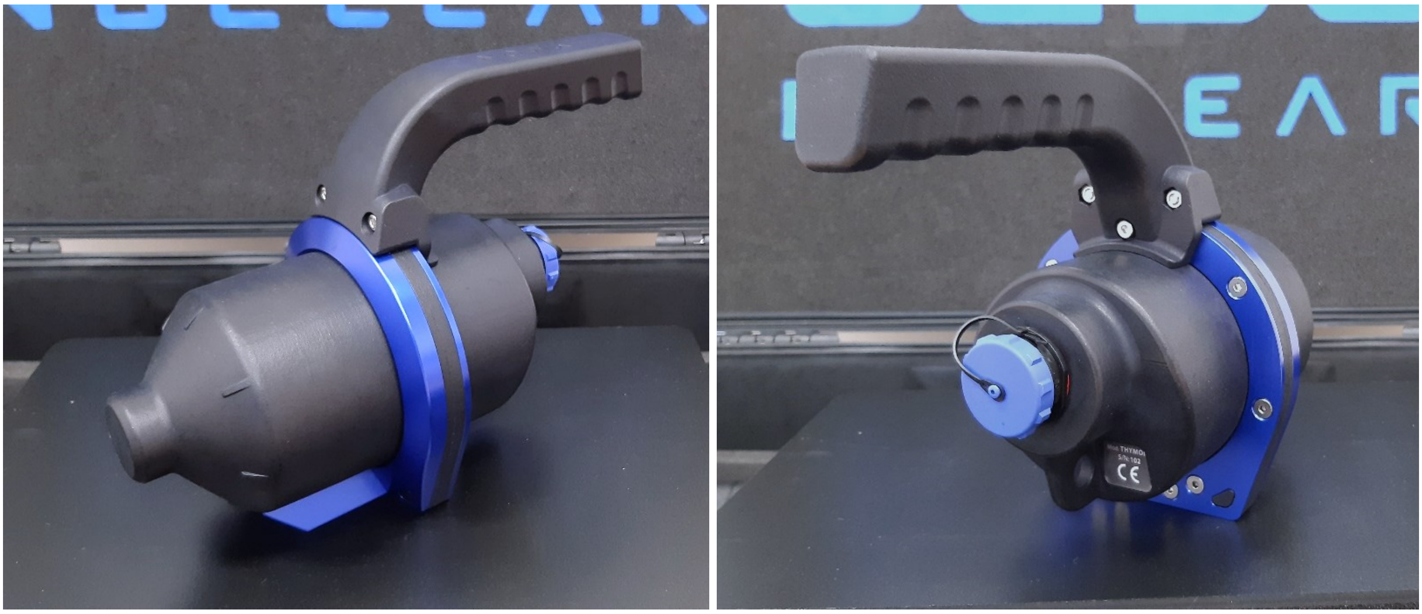

Figure 2.2: detector probe detail

Figure 2.3: THYMON mounted on the support tripod

Figure 2.4: control tablet

Figure 2.5: included KCl source

The simple and intuitive proprietary software allows performing an easy, yet complete and reliable, measurement of individuals. Data are stored locally on the tablet internal memory, and can be analysed and downloaded with dedicated software routines.

The instrument collects the gamma ray spectrum and directly calculates the thyroid activity concentration thanks to the built-in analysis software. The default conversion coefficients from counts per second (cps) under the I-131 photopeak to the activity in thyroid are calculated by means of dedicated Monte Carlo calculations based on mathematical age-dependent thyroid phantoms, i.e. 1 yo, 5 yo, 10 yo, 15 yo (also valid for Adult Female), and Adult Male. The model is derived from the pioneering mathematical description of Ulanovsky et al. ([4],[5]). The model was validated

[4] *ULANOVSKY, A. & ECKERMAN, K. 1998. Absorbed fractions for electron and photon emissions in the developing thyroid: foetus to five years old. Radiat Prot Dosimetry, 79, 419-23.*

[5] *ULANOVSKY, A., MINENKO, V. & KORNEEV, S. 1997. Influence of measurement geomery on the estimate of 131I activity in the thyroid Monte Carlo simulation of a detectof and a phantom. Health Physics, 72, 34-41.*

against experimental tests performed with physical, age-dependent, thyroid phantoms.

The accurate design of the instrument, including collimation, positioning supports, etc., allows performing accurate measurements of I-131 activity concentration in thyroid in an extremely short time. Namely, the Minimum Detectable Activity (MDA) for the Adult Male achievable in 2 minutes in condition of average indoor background (100 nSv/h) is as low as about 100 Bq. If enabled, the automatic background subtraction subroutine allows further lowering MDA and measurement uncertainty without increasing the counting time.

2.2 Components description

2.2.1 Transport and storage case

THYMON is housed in a medium-size, watertight technical case made of impact-resistant polypropylene, formulated from a proprietary copolymer that ensures superior mechanical strength combined with reduced weight. The enclosure is IP67 certified (with lid closed) and compliant with MIL-STD standards for drop, shock, and environmental resistance, making it suitable for intensive field use under harsh conditions.

Figure 2.6: technical case (closed lid)

Figure 2.7: technical case (transport handle)

The case provides protection against impacts, liquids, and dust, ensuring secure housing for all system components during transport and operation. It is suitable for rugged deployment scenarios where resistance to environmental stress and mechanical integrity are essential.

Key features of the case include:

- Reinforced padlock-compatible hasps for enhanced security
- High-sealing polyurethane gasket injected into the lid for watertight performance
- Ergonomic handles for firm and comfortable grip
- Integrated anti-tip stops for stable placement
- Wheels and a retractable telescopic handle for easy transport

Internally, the case is filled with foam inserts, shaped to properly hold each component of the device ensuring their stability and protection during transportation and storage.

2.2.2 Scintillator and acquisition chain

The sensitive component is based on a high-sensitivity 1.5” × 1.5” NaI(Tl) scintillator. The scintillator is read by a SiPM matrix. The compact front-end electronics is directly embedded in the crystal external housing.

The input of the SiPM is DC-coupled to the SiPM-anode. Input pulses are then processed via a track and hold amplifier and measured with a 12-bit ADC. A 20-point lookup table that describes the desired operating voltage vs temperature behaviour is used to counteract the SiPM gain drift. The lookup table is usually defined in the temperature range from -30 °C to 65 °C in steps of 5 °C. Dedicated factory characterisation tests guarantees the correct channel-to-energy conversion of the entire spectrum by simply measuring natural 40K, i.e. no radioactive test sources are required for energy calibration.

Digital data are directly analysed by the embedded 1024 channel MCA. Even if the software is specifically conceived for the 131I activity quantification, the device shows good spectrometric properties, which enable the user to observe the entire photon energy spectrum from 30 keV to about 2 MeV. The detector energy resolution is typically < 9% FWHM @662 keV.

2.2.3 Tablet

The information provided in this paragraph are related to the typical configuration of THYMON. They may be subject to changes according to improvement or availability, without them being necessarily reported in this Manual.

The THYMON system is equipped with a rugged industrial tablet PC, model Winmate M900EKN/EN, featuring an 8.4" TFT LCD display. This device is specifically designed for demanding environments, offering:

- High ingress protection (IP65), also effective without additional casing
- MIL-STD-810G compliance for shock, vibration and temperature resistance
- A wide operating temperature range
- Durable capacitive multi-touch screen usable with gloves or in humid conditions

The tablet is equipped with multiple hardware resources, including:

- Wi-Fi and Bluetooth connectivity

- USB interfaces
- High-performance CPU and expandable memory

Although these features exceed the minimum requirements for the THYMON application, only the USB interface is used in the current configuration.

The USB connection ensures direct power supply and data communication with the THYMON device, and does not require any additional sealing or accessories thanks to the tablet's native environmental protection.

The following are the general specifications of the tablet PC:

- Display: 8.0" IPS TFT LCD, 1280×800 resolution, capacitive multi-touch
- Touchscreen: Projected capacitive (PCAP), glove/rain mode, optical bonding for sunlight view
- Processor (CPU): Intel® Celeron® N6211, 1.2 GHz (Turbo up to 2.6 GHz)
- Memory (RAM): 4 GB LPDDR4 (8 GB optional)
- Storage: 128 GB SSD (256 / 512 GB optional), expandable via microSDXC
- Operating System: Windows 11 IoT Enterprise LTSC (Windows 10 IoT optional)
- Connectivity: Wi-Fi, Bluetooth 5.0, 4G LTE (optional), GNSS (GPS, GLONASS)
- Ports: 1× USB 3.0 Type-A, 1× USB 3.0 Type-C, 1× RJ45 GigaLAN, micro SDXC, audio jack
- Docking Connector1× 19-pin docking connector
- Camera: 2 MP front, 8 MP rear with autofocus and LED flash
- Battery: 7.6 V, 4200 mAh Li-Polymer (2S2P), ~6 h operating time
- Buttons: Power, Menu, 3× Programmable Function Keys
- Environmental Protection: IP65 rated, fanless design
- Certifications: CE, FCC, MIL-STD-810H (shock, vibration, drop from 5 ft)
- Operating Temperature: –20 °C to +60 °C
- Storage Temperature: –30 °C to +70 °C
- Dimensions: 225 × 148 × 20.5 mm

- Weight: 0.9 kg (with battery)

Standard Accessories Supplied with the Tablet PC

The tablet PC is supplied with the following accessories as standard items, ensuring full operational readiness and user convenience in field applications:

- Capacitive stylus pen

The stylus pen is designed to work seamlessly with the projected capacitive (PCAP) touchscreen of the tablet.

It enables accurate user interaction even when fine data input or calibration points are required, especially in contexts where fingers may be gloved or the interface needs to be used with greater precision than a fingertip allows.

Its lightweight and rugged construction ensures durability in harsh environments, fully matching the robustness of the tablet.

Figure 2.8: stylus pen

The tablet PC is supplied with an AC adapter and power cord. It converts 100–240 VAC (50/60 Hz) to 19 V DC at 3.42 A, suitable for global use with country-specific Schuko (Type F) plug included.

Use only the original adapter and its accompanying Schuko AC cable. Substitution with unapproved power supplies components (i.e. not provided/authorised by ELSE NUCLEAR) is not recommended, as it may compromise device safety certifications and field reliability.

The adapter is engineered for reliable operation in rugged field environments, with integrated protection against overcurrent, short circuit, and over-temperature. The Schuko cable terminates in a Type F (CEE 7/7) plug (German standard).

Figure 2.9: tablet charging module/cable

2.2.4 Support tripod

The support tripod is designed to hold the detector probe in a suitable position for the intended use (i.e. it allows an easy alignment of the detector "nose" to the thyroid).

Moreover, the tripod can be used for both standing measurements and sitting measurements, thanks to its modular and adaptable concept.

Please refer to Section 3 for in-depth instructions on how to setup the support tripod in both the above-mentioned measurement setups.

2.2.5 Battery

The tablet is powered by a removable lithium-polymer battery, rated at:

- 7.6 V,
- 4200 mAh,
- 31.92 Wh total energy capacity.

This battery is designed for use in mobile field environments and can be easily replaced by the operator to extend autonomy or perform maintenance without special tools.

Operating Autonomy

The system has been tested and optimized to achieve a battery life of approximately 5 hours under standard operating conditions.

This result was obtained through an efficient configuration of the tablet's hardware and software resources, ensuring adequate performance while maximizing power efficiency.

Note: actual autonomy may vary depending on:

- ambient lighting (affecting display brightness),
- data acquisition frequency,
- screen interaction time and operating mode,
- use of communication interfaces (e.g., USB or wireless).

This autonomy makes the system suitable for typical on-site inspection and measurement sessions without the need for intermediate recharging.

Charging Time

Full charging of the battery via the supplied AC power adapter typically requires about 3 to 3.5 hours with the tablet powered off.

Charging time may be slightly longer if the device is in use during the process or operating in elevated ambient temperatures.

Additional batteries are available as spares to ensure uninterrupted use in extended field operations.

2.2.6 Calibration source

A dedicated calibration source is supplied with the THYMON system to enable periodic performance checks and calibration procedures.

The source has a cylindrical shape with a recessed profile specifically designed to match the front geometry of the THYMON probe, allowing the probe to be firmly positioned vertically on the source for stable and repeatable measurements.

The source housing is made of 3D-printed Nylon, ensuring mechanical strength and chemical resistance.

The enclosure is sealed with a dedicated screw-locked cap (fixed with five screws) and an O-ring, which guarantees containment of the internal material.

The radioactive content consists of approximately 350 grams of potassium chloride (KCl), a naturally occurring material containing the isotope ^{40}K, which emits low-level gamma radiation. This source provides a stable and safe reference level for calibration activities.

Section 3
Handling and Starting

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3.1 How to handle

THYMON is a high-level technological instrument, composed of elements which may be damaged by an unproper handling. Therefore, the User must consider and follow the instructions here reported. Any damage or malfunction, as well as any harm to the User, due to unproper handling will be entirely considered under the User responsibility.

- Do not intentionally tamper any of the device parts such as cables and connectors, to avoid damaging the instrument or harming oneself. Please follow the starting procedure when setting up the device.
- When plugging/unplugging the cables, do not damage the pins pulling or pushing them with too much strength. In general, do not try to force the connectors to plug: if they do not fit it means they are mis-aligned with the plug.
- THYMON is designed for on-field use, and as such it is composed of rugged and sturdy components, designed to be resistant. Nevertheless, do not use any of THYMON parts outside its scope of application and intended use.

3.1.1 Operating conditions

THYMON is designed for outdoor use in harsh environments, ensuring reliable performance even under adverse weather conditions typically encountered during field campaigns, including emergency scenarios.

Both the detector probe and the control tablet are rated IP65, providing full protection against dust ingress and protection from low-pressure water jets from any direction.

This ensures proper functioning in conditions such as:

- Rain, humidity, and water splashes
- Dusty, sandy, or dry environments
- High and low temperatures (from –20 °C to +50 °C)
- Non-ideal terrains such as post-accident sites or rugged outdoor areas

To support transport and storage, the system is supplied with a dedicated rugged transport case, compliant with IP67 protection grade, ensuring:

- Total dust tightness
- Temporary immersion resistance (up to 1 m depth for 30 minutes)

This guarantees safe handling and protection of the equipment during shipping, vehicle transport, and temporary storage in severe environmental conditions.

The system can be deployed and operated by a single user, even when wearing gloves or protective equipment (PPE).

3.2 Starting procedure

THYMON power supply is entirely provided by the control tablet.

To properly setup and power the system, follow the sequence here described:

1. Open the THYMON case to access its components
2. Setup the support tripod (see paragraph 3.2.1 and paragraph 3.2.2 for further details)
3. Mount the detector probe on the support tripod (see paragraph 3.2.3)
4. Install the tablet battery (if previously disconnected or during first unboxing) and mount the control tablet on the dedicated support on the tripod (see paragraph 3.2.4)
5. Power on the control tablet through the built-in power button (hold for 3 seconds) and wait for the ELSE NUCLEAR software to initialise

The software must be initialised before connecting the detector probe.

6. Connect the detector probe to the control tablet through the dedicated included cable (see paragraph 3.2.5)

Now the device is completely operative.

To shut down THYMON, first close the software application and confirm the shutdown of the entire system by following the on-screen instructions.

Now, if necessary, the device can be separated in its main parts to be put back in the technical case.

3.2.1 Support tripod setup procedure – standing position

This paragraph provides graphic indications to set up the support tripod in its standing position.

STEP 1

Hold the tripod by the foam grip and open the 3 legs moving them outwards until you hear the third “click” (i.e. “high angle” position, see detail below).

STEP 2

Release the first two legs’ locks in order to extend them at their maximum.

After steps 1 and 2, the tripod will look like this:

STEP 3

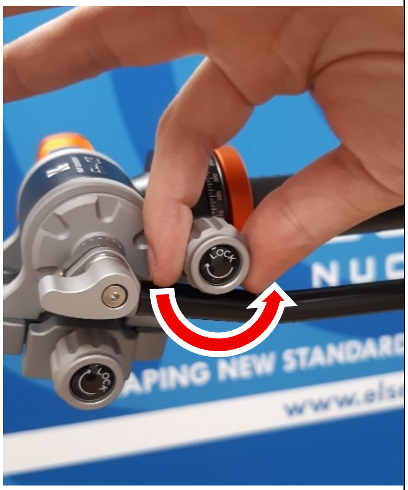
Unlock the centre column locking knob and extend the column to its maximum.

STEP 4

Loosen the centre column horizontal locking knob and align the column horizontally, then firmly tighten the horizontal locking knob.

STEP 5

Push back the column to reach the “CAUTION” sign on the column itself, then firmly tighten the centre column locking knob.

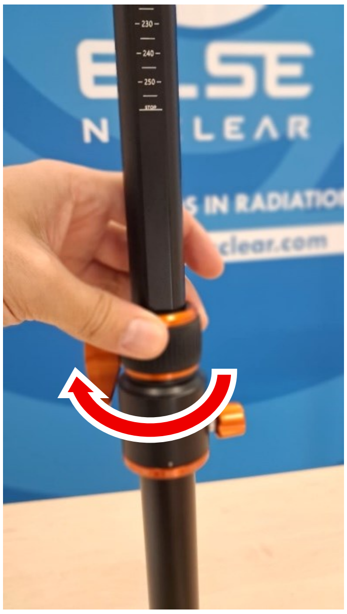
STEP 6 Loosen the head plate knob and rotate the plate upwards. 	

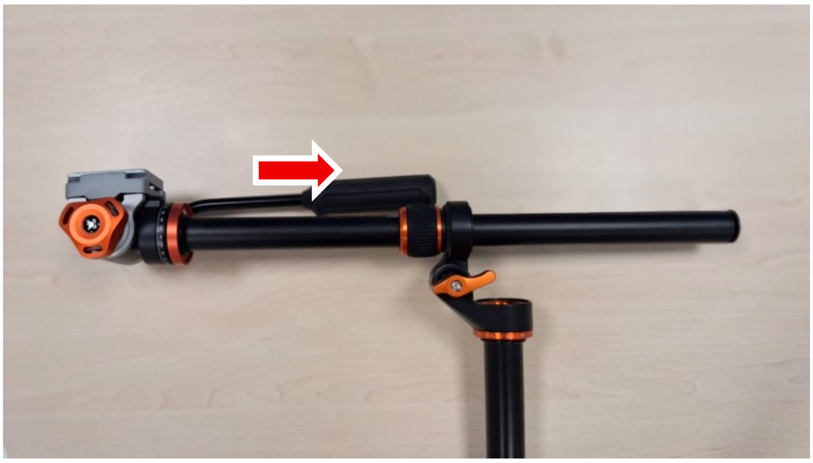
Ensure to tighten all the knobs and locks before mounting the detector probe.

3.2.2 Support tripod setup procedure - table top position

This paragraph provides graphic indications to set up the support tripod in its table-top position.

STEP 1 Open the 3 legs moving them outwards until you hear the second "click".	
STEP 2 Unscrew the stability hook at the end of the centre column and remove it completely.	

STEP 3 Loosen the dedicated knob for height adjustment and extract the column.	
STEP 4 Loosen the centre column locking knob and extend the column to its maximum. Loosen the centre column horizontal locking knob and align the column horizontally, then firmly tighten the horizontal locking knob.	 

STEP 5 Push back the column to reach the "CAUTION" sign on the column itself, then firmly tighten both the locking knobs.	 
STEP 6 Insert the column back into the tripod main support from the bottom to the top (reverse position).	

STEP 7 Loosen the head adjustment knob and rotate the head to reach the horizontal position shown in the picture. Tighten the knob.	 
STEP 8 Loosen the handle knob and rotate it in order to reach a suitable and handy position. Tighten the knob.	 

3.2.3 Mounting the detector probe on the support tripod

STEP 1 Detach the mounting plate from the tripod head and firmly screw it under the detector head, using the central threaded hole.	 
STEP 2 Position the detector probe on the head mount and firmly tighten the plate screwing the fixing knob. Align the detector probe with one of the tripod's legs (standing position) or the short leg (table-top position). The image here shown visualises an example of alignment (standing position)	 

STEP 3

Adjust as needed the height of the detector probe by loosening the dedicated knob and sliding the column in or out. Firmly tighten the column once reached the desired height.

This adjustment is applicable also to the table-top configuration.

Ensure that the detector probe is aligned with one of the tripod legs, in order to obtain the most stable condition.

To increase the level of stability during operations, as well as to minimise random movements that would affect the measurement, the person to be monitored shall put his/her hands on the tripod as shown in the pictures below.

Figure 3.1: Examples of measurement position for standing and table-top configurations

The nose of the probe should rest on the top of the manubrium of the sternum (green in Figure 3.2). This ensures the best alignment between the probe and the thyroid. In particular, given the size of the crystal and the average size of the human thyroid, this simple positioning guarantees excellent crystal-to-thyroid alignment, and completely counteracts the distance shift, limiting it to fractions of, or a few, millimetres, i.e. the same order of magnitude as the physiological variability of the position of the thyroid in the neck. Finally, for optimal operation, it is recommended that the individual be asked to partially tilt his or her head backwards.

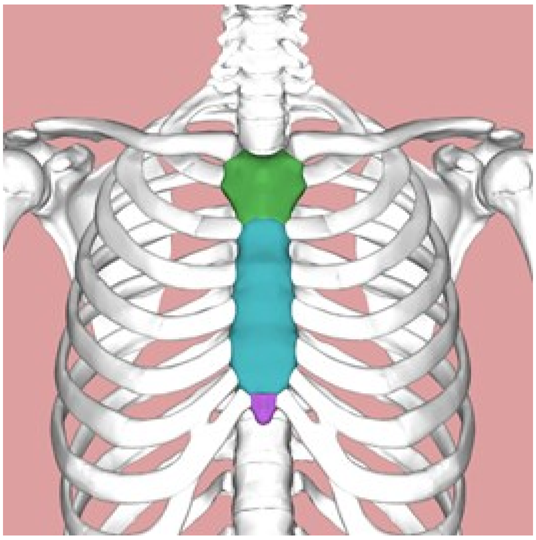


Figure 3.2: Human sternum

3.2.4 Mounting the control tablet on the dedicated support

To ensure stable field use of the control tablet, the system includes a custom mounting solution composed of:

- A metal articulated arm with adjustable joints and 1/4” standard thread, secured to one leg of the tripod using a removable crab-style clamp. This element provides high flexibility in positioning and orientation.
- A custom mechanical adapter, machined to connect the 1/4” screw to the tablet cradle plate, allowing secure and repeatable snap-in docking of the tablet.

The cradle itself is mounted with multiple screws and offers full mechanical stability during operation.

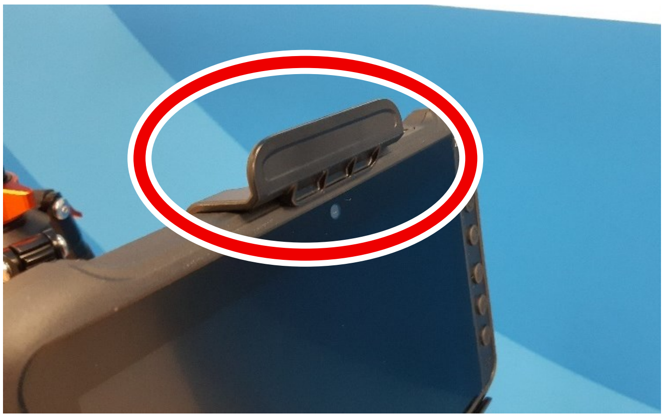
This setup enables:

- Quick installation of the tablet on site
- Adjustable tilt and rotation for optimal screen visibility
- Fast release for packing or reconfiguration

Figure 3.3: Tablet cradle (front and rear)

Figure 3.4: Cradle holding pegs and tablet mounting holes

STEP 1 Loosen the articulated arm locking knob, extend the arm as desired, then tighten the locking knob. Loosen also the clamp to mount the cradle on the tripod.	 
STEP 2 Mount the cradle on one of the tripod's legs and firmly tighten the clamp.	

STEP 3 Mount the tablet into the cradle fitting the holding pegs in the holes (see figure 3.4). Then push the tablet into position, ensuring that the upper holding part is properly clamping the tablet.	 

3.2.5 Connecting the control tablet to the detector probe

To connect the control tablet to the detector probe, use the included dedicated cable.

1. Connect the cable to the detector (circular connector)
2. Connect the cable to the upper IP65 USB port of the control tablet (see figure 3.5)

The software must be initialised before connecting the detector probe.

Figure 3.5: upper USB port

3.3 Handling, storage and transportation

3.3.1 Introduction

Handling issues while operating with measuring instruments may derive from intrinsic dangers (sharp corners, weight, moving parts, dangerous substances, etc.) or from activities related to the use of the instrument itself (positioning of the object, distraction, dangerous emissions, etc.). This is valid for both human and environmental damages.

A proper use of the instrument and the respect of the common basic safety precautions for radiation detectors, are enough to exclude any possibility of damage to people or the environment. The operator must behave as instructed during the training course (if provided) while handling the instruments. Any type of tampering or unauthorized maintenance is strictly forbidden.

3.3.2 Specific danger analysis

Handling

The instrument weight implies a related risk while handling it, thus proper and related safety measures have to be applied to prevent any harm to people or objects due to accidental dropping. The danger's nature in this case would be purely mechanical.

While handling the THYMON components, the User must follow the instructions given during the training course and/or in this manual; in general, normal caution measures must be applied. It is also important to avoid any type of unnecessary shock or hit to the instrument.

Electric shocks

The User cannot reach any dangerous point that could generate electric shocks, if not by intentionally tampering the cables or the electronics components, so no particular caution measures have to be taken. A proper use of the instrument is simply recommended, which means neither tampering nor unauthorized maintenance activities. In particular, if maintenance is needed, or if the unit's electronics or cable are damaged and exposed, the User must not touch anything while the detectors are connected to the power, and he/she must immediately turn off the power supply before carrying out any activity.

Working conditions

THYMON can withstand normal outdoor conditions; however, the User shall not intentionally immerge the control tablet in water or any other liquid.

Storage and transportation

The THYMON system is designed to be easily transported and stored, in accordance with its intended field use under emergency or mobile conditions.

For this purpose, all components are supplied inside a PELI™ 1650-021-110E rugged technical case, which offers:

- IP67 protection rating: dust-tight and waterproof (1 m immersion for up to 30 minutes)
- Automatic pressure equalization valve
- Reinforced double-step latches
- Integrated wheels and retractable handle for easy transport
- Stackable design and padlock-ready holes
- External dimensions: 78.6 × 52.0 × 29.0 cm
- Weight: ~11.8 kg (empty) - ~18.5 kg (full)

The interior of the case is completely filled with custom-cut closed-cell foam, based on Plastazote® LD33 and/or Ecozote® LDR27. These materials are selected for their excellent:

- Shock-absorbing properties
- Lightweight and mechanical strength
- Resistance to water absorption and chemical agents
- Dimensional stability in variable temperature conditions

All system components (probe, tablet, accessories, source, cables) are housed in dedicated compartments to prevent damage from vibrations, shocks, or rubbing during handling and transport.

Before any storage or transport operation, ensure that:

- **the system is clean and dry,**
- **cables and connectors are properly placed,**
- **the foam inserts are undamaged and correctly aligned,**
- **the lid is fully closed and latched.**

Monitoring of environmental conditions (especially temperature and humidity) is recommended for long-term storage.

Section 4
Software

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4.1 Introduction

This section describes the proprietary control and analysis software provided with the THYMON system.

The software is pre-installed on the supplied control tablet and has been designed to be both intuitive and feature-rich, enabling users to carry out measurements and data analysis in a straightforward yet powerful way.

Through a user-friendly interface, operators can easily perform measurements, view spectra, analyse and save data, and interact with key functions without requiring prior training.

Upon measurement start, the system automatically enables built-in algorithms for I-131 activity estimation, streamlining the monitoring workflow.

In addition to basic measurement functionalities, the software includes several configurable parameters to adapt the system to different monitoring scenarios.

Users can define alarm thresholds and select stopping conditions for the measurement process. The interface also allows setting key acquisition parameters, such as the duration of the measurement and data saving options.

These features ensure flexible and controlled operation while maintaining ease of use through a self-explanatory layout.

4.2 Software start

The software automatically starts as the control tablet is switched on. The first action of the software is to search for connection with the detector.

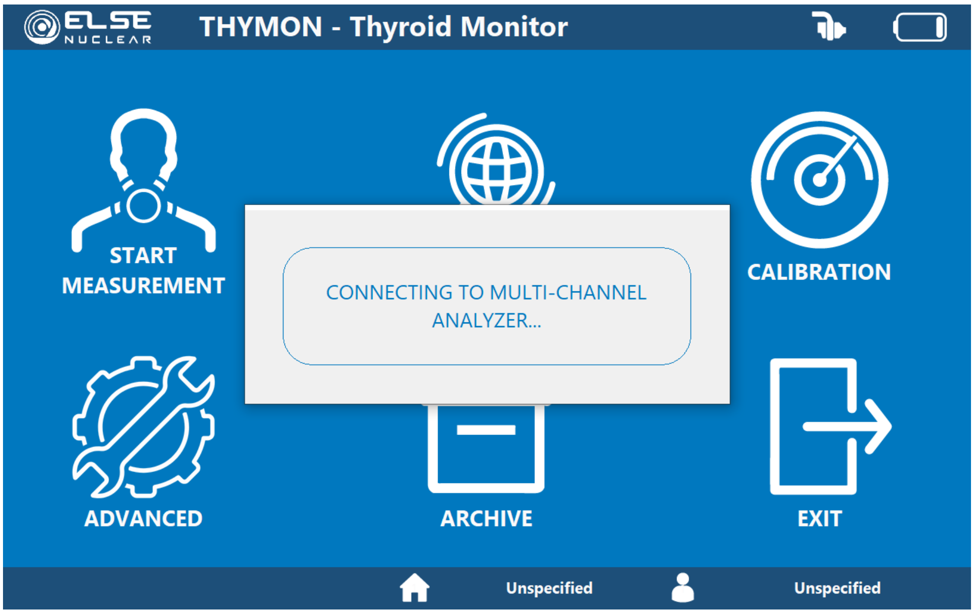


Figure 4.1: THYMON software main panel when powered on

If connection is established, all software functions are available. If connection is not established, all functions related to the usage of the detector are not accessible.

By default, the software attempts to establish communication with the detector up to three times, using progressively longer waiting intervals. If all three attempts fail and the connection cannot be established, all functions related to detector operation will become unavailable.

4.3 System status information

All main windows display indicators about the system status:

1. Software version (accessible by tapping the logo button)
2. Name of the window
3. Detector connection status
4. Tablet battery status
5. Operator name
6. Institution name

7. Current date time

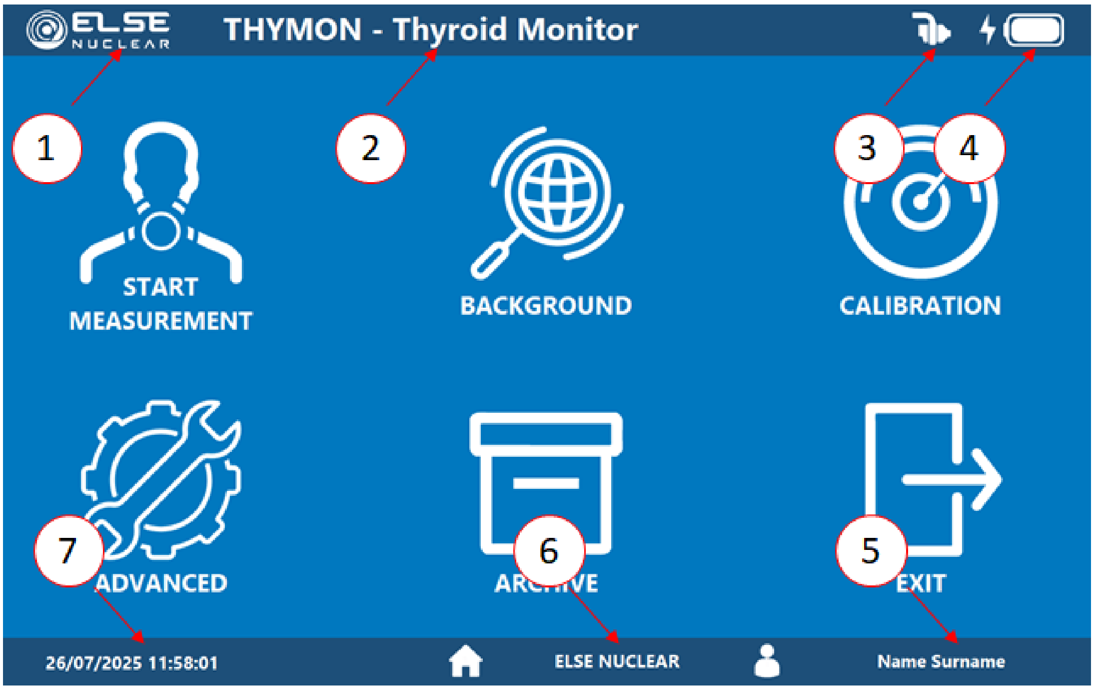


Figure 4.2: main panel status information

4.3.1 Software version window

The software version window is opened as the icon on the top-left of the screen is tapped.

Figure 4.3: software information window

4.3.2 Detector connection icon

The detector connection icon can assume one of the following two forms:

 meaning: **Detector probe connected**

 meaning: **Detector probe not connected**

4.3.3 Battery status icon

The battery status icon can assume one of the following forms according to the **residual charge level** (left to right: full → intermediate → low):

During the **charging of the battery**, the icon will change as shown below (left to right: charging, full → charging, intermediate → charging, low):

4.4 Main panel

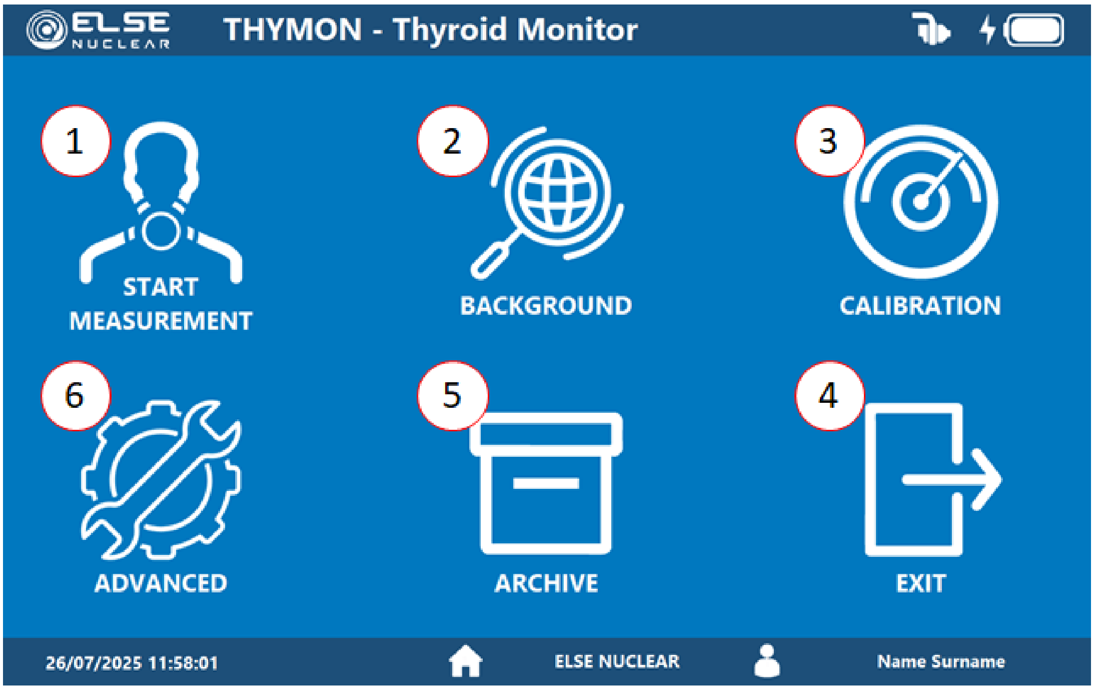


Figure 4.4: THYMON software main panel

The Main window allows the user to access all software main function via an intuitive touch-screen graphical interface. The main functions/sub-windows which can be accessed from the Main window are, clockwise from top-left:

1. **Start Measurement**: starts the thyroid screening routine (chapter 4.5)
2. **Background**: starts the background acquisition (chapter 4.6)
3. **Calibration**: starts the energy calibration routine (chapter 4.7)
4. **Exit**: closes the program
5. **Archive**: opens the Archive window and allows accessing the data export routines (chapter 4.8)
6. **Advanced**: opens the Advanced Functions window (chapter 4.9)

4.5 Thyroid measurement

The suggested measurement procedure consists of:

a) Perform the energy calibration of the system;

b) Acquire a background spectrum;

c) Launch the thyroid screening routine.

Steps (a) and (b) are not mandatory, but it is suggested to perform both steps at least at the beginning of a measurement session, and repeat them if the environmental conditions change abruptly (e.g. the system is relocated in a different room).

The thyroid measurement process in THYMON is designed to be semi-automatic, requiring minimal user interaction.

At the beginning of each session, the user is prompted to specify (or confirm) the **Measurement ID** and to select the **Age Group** of the subject.

Once these parameters are confirmed, the software automatically retrieves all necessary system configurations, including:

- The most recent background spectrum (if background subtraction is enabled).
- The latest energy calibration.
- All measurement settings associated with the selected age group, which include:
  - Age group name
  - Conversion coefficient (cps/Bq)
  - Default acquisition time
  - Pre-alarm threshold (in Bq)
  - Alarm threshold (in Bq)

Based on these configurations, the system automatically starts the acquisition and processes the data. The software extracts the net counts corresponding to Iodine-131 from the multichannel spectrum and applies all enabled algorithms to determine both the thyroidal iodine activity (using a conversion coefficient specific to the chosen age group) and the Minimum Detectable Activity (MDA).

The results are automatically compared with the pre-alarm and alarm thresholds configured by the user. If visual and/or audible alarms are enabled, the measurement outcome is highlighted at the end of the procedure via display messages and/or sound alerts.

The alarms can be disabled, and in this case the status is not displayed in real time but is still recorded and stored in the system's archive.

The steps here described will be detailed in the next paragraphs.

4.5.1 Start the measurement routine (ID and age group)

After pressing the measurement icon on the main window, the following window is prompted:

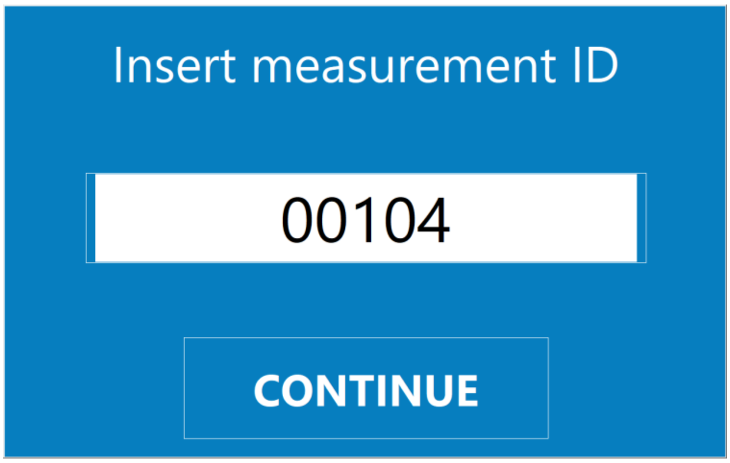


Figure 4.5: ID definition window

This window allows the user to introduce the measurement ID. An incremental ID (00001, 00002, etc.) is introduced as default. A user-defined ID can be introduced from a popup virtual keyboard after tapping on the ID field.

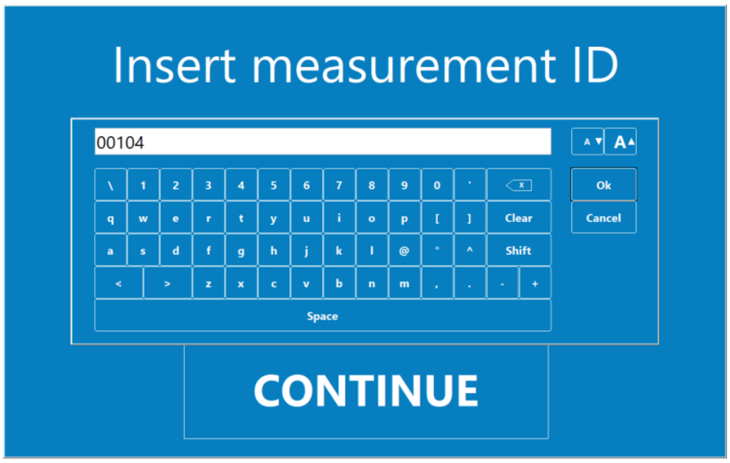


Figure 4.6: Example of pop-up virtual keyboard

After pressing the CONTINUE button, the user is prompted to select the age group. The pre-defined age groups are: 1 yo, 5 yo, 10 yo, 15 yo (Adult

Female), and Adult Male. Other age groups can be introduced with the dedicated advanced option. Each Age Group enables the automatic upload of the specific age-dependent calibration coefficients and alarm threshold values.

Age Groups as defined by ICRP Pub. 71 are the following:

- **1 year old: More than 1 year to 2 years**
- **5 years old: More than 2 years to 7 years**
- **10 years old: More than 7 years to 12 years**
- **15 years old: More than 12 years to 17 years. Adult female**
- **Adult Male: More than 17 years**

Figure 4.7: Age Group Selection window

After pressing the CONTINUE button, the following summary window is displayed. From this window, the user can rapidly check if the provided information is correct before starting the measurement.

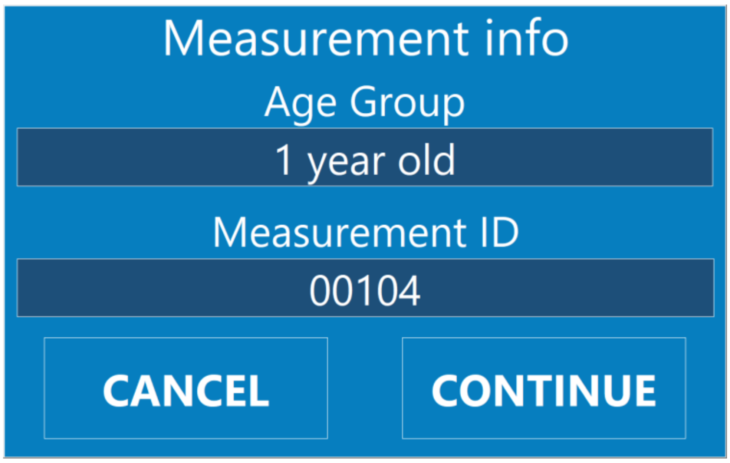


Figure 4.8: Measurement Summary window

Pressing the CANCEL button would erase the preliminary information just inserted, whereas after pressing the CONTINUE button, the measurement starts, and the main Thyroid Measurement window is displayed.

4.5.2 Thyroid Measurement window

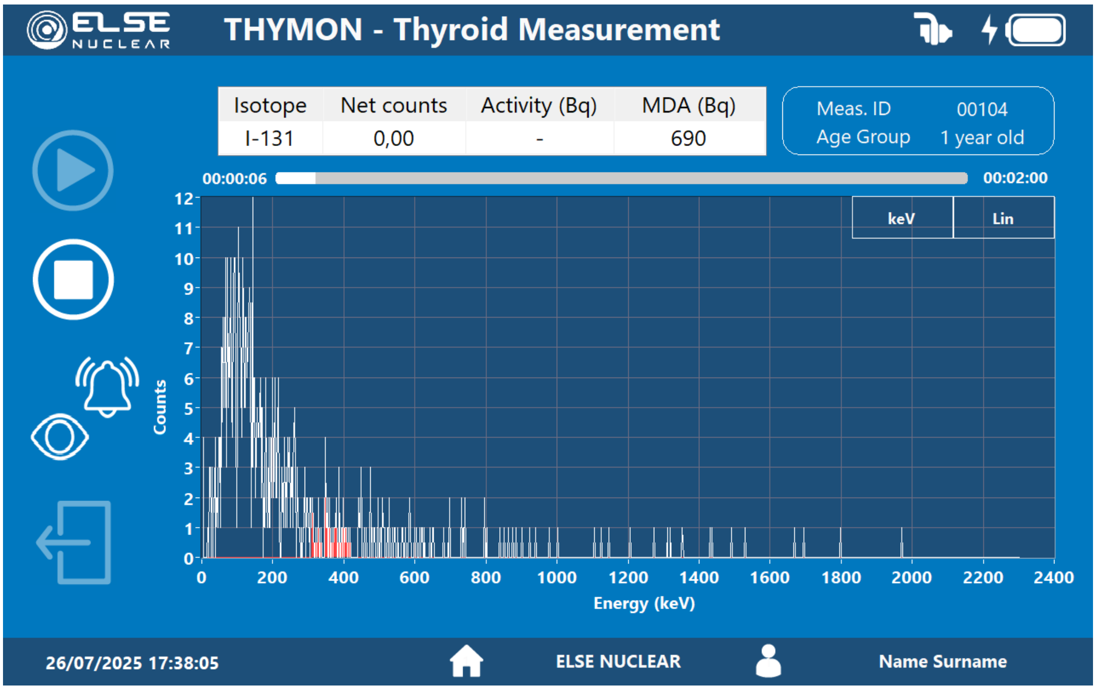


Figure 4.9: Measurement window

This window shows and updates real time all relevant information of the current measurement, including counts, activity, and MDA. The live spectrum and ancillary information (e.g. elapsed time, ID, etc.) are displayed as well.

At the end of the measurement, if enabled, the alarm status is clearly indicated using the standard green-yellow-red color logic (not contaminated, low alarm, high alarm levels). If enabled, an acoustic signal is triggered in the case of alarm.

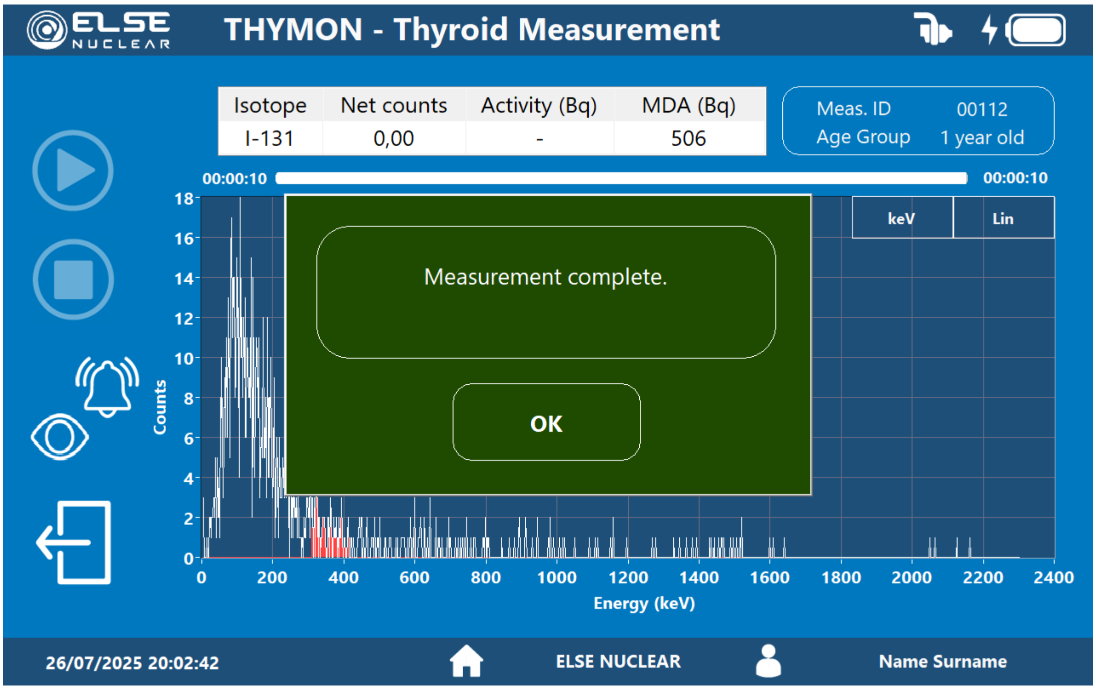


Figure 4.10: Thyroid Measurement window at the end of the acquisition (neither alarms, nor anomalies)

The summary contains all relevant information about the last measurement, as well as a clear indication of the alarm status.

4.5.3 Measurement window commands and indicators

The Thyroid Measurement window includes the following commands and indicators (see figure 4.11):

1. **Control icons**. The user can perform actions as the measurement runs (see below).
2. **Live spectrum plot**. This plot updates real time as the measurement runs. The I-131 relevant ROI is shaded in red. The user can select real time the x-axis scale (keV/channels) and the y-scale (lin/log) by tapping on the corresponding buttons on the top-right of the plot.

3. **Progress bar**. It includes the elapsed real time (on the left) and the pre-set real time (on the right).
4. **Measurement results table**. The Measurement Results Table updates automatically during the acquisition, displaying the net counts, calculated activity, and MDA values.
5. **Current measurement** information table.

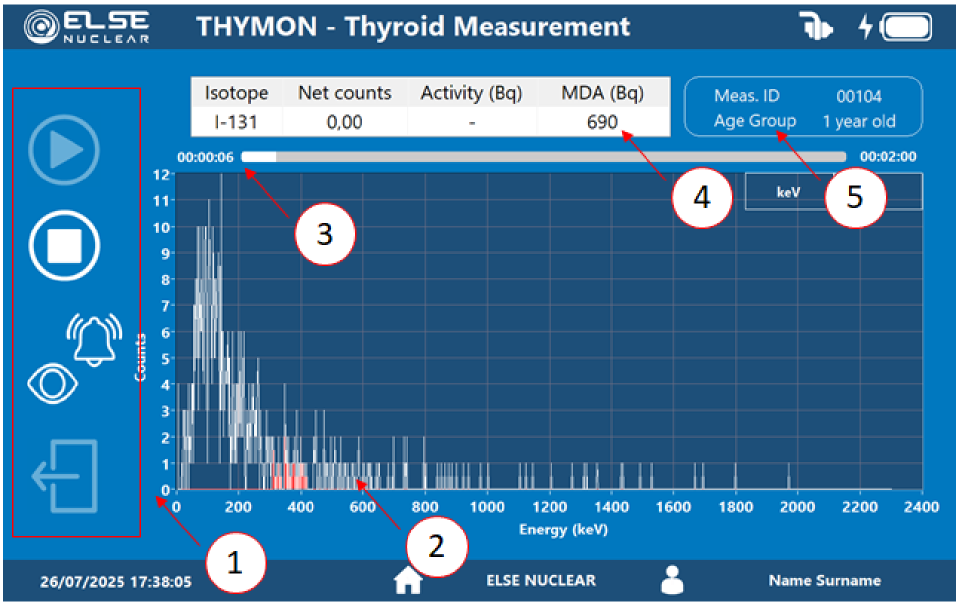
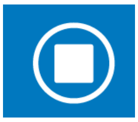
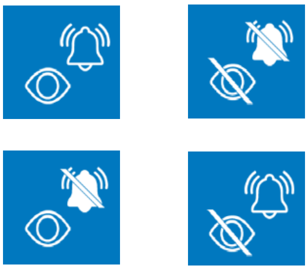


Figure 4.11: Thyroid Measurement window (details)

The following table describes the control icons.

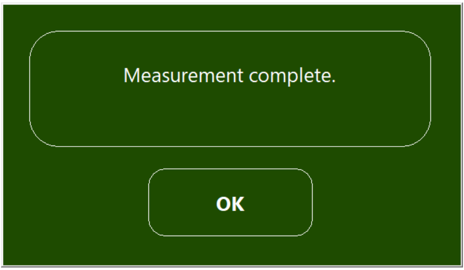
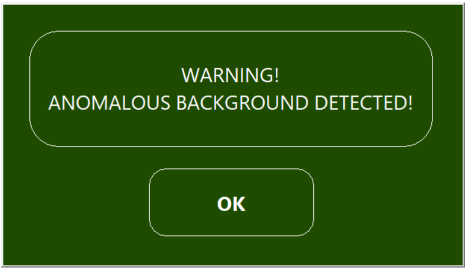
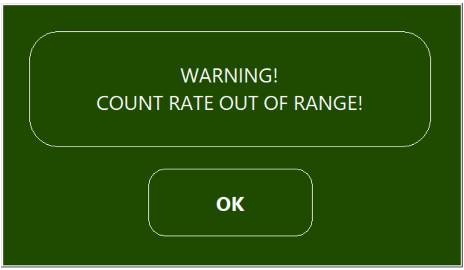
	**Start acquisition**. Always disabled (measurement starts automatically)
 	**Stop acquisition**. Enabled as the measurement runs. This button allows the user to stop the measurement in advance with respect to the pre-set measurement time.

	**Alarm controls**. Visual and acoustic alarms can be enabled or disabled as the measurement runs by tapping on the corresponding icons. The default alarm value is loaded from the system settings. Clockwise, from top left: • Visual and acoustic alarms enabled. Tap to disable. • Visual and acoustic alarms disabled. Tap to enable. • Visual alarm disabled; tap to enable. Acoustic alarm enabled; tap to disable. • Visual alarm enabled; tap to disable. Acoustic alarm disabled; tap to enable.
	**Back to Main window**. Disabled as the measurement runs. Enabled as the measurement stops.

4.5.4 Thyroid measurement results

The analysis is performed in real time. Thus, net counts, activity and MDA are shown in real time. The comparison with alarm thresholds is performed at the end of the acquisition. If visual and/or audible alarms are enabled, the measurement outcome is highlighted at the end of the procedure via display messages and/or sound alerts. When alarms are disabled, the status is not displayed in real time but is still recorded and stored in the system's archive.

The following table collects all the possible popup windows that can be displayed by the software at the end of each measurement and their meaning.

Visual popup	Visual alarm enabled	Visual alarm disabled
	The measurement was completed successfully. No warnings and alarms were triggered.	The measurement was completed successfully.
	The measurement was completed successfully. An anomalous value of the background was detected, but the measured activity was below the pre-alarm and alarm thresholds. Note: only available if the background subtraction algorithm is enabled.	The measurement was completed successfully. An anomalous value of the background was detected. Note: only available if the background subtraction algorithm is enabled.
	The measurement was completed successfully. The count rate was higher than the declared range, so pile-up effects might have lowered the reliability of the results. The measured activity was below the pre-alarm and alarm thresholds.	The measurement was completed successfully. The count rate was higher than the declared range, so pile-up effects might have lowered the reliability of the results.

Visual popup	Visual alarm enabled	Visual alarm disabled
PREALARM DETECTED! OK	The measurement was completed successfully. The detected activity plus one standard deviation is higher than the pre-alarm threshold, but lower than the alarm threshold.	Not displayed
ALARM DETECTED! OK	The measurement was completed successfully. The detected activity plus one standard deviation is higher than the alarm threshold.	Not displayed
Measurement interrupted due to malfunctioning. BACK	The measurement was not completed successfully due to malfunctioning. This measurement is not saved in the archive.	The measurement was not completed successfully due to malfunctioning. This measurement is not saved in the archive.
Measurement interrupted by user. Save or discard? Discard Save	The user tapped on the stop icon. The analysis is performed only if the Save button is selected.	The user tapped on the stop icon. The analysis is performed only if the Save button is selected.

4.6 Background measurement

The suggested measurement procedure consists of:

a) **Perform the energy calibration of the system;**

b) **Acquire a background spectrum;**

c) **Launch the thyroid screening routine.**

Steps (a) and (b) are not mandatory, but it is suggested to perform both steps at least at the beginning of a measurement session, and repeat them if the environmental conditions change abruptly (e.g. the system is relocated in a different room).

The duration of the background acquisition can be set with a dedicated function in the System settings window. Typically, background acquisition should last 5 times longer than the actual measurement time. The default duration of the background acquisition is equal to 10 minutes, which gives an estimation of the background with a relative uncertainty equal to about 5% due to counting statistics, in the case of a standard NORM environment.

The background acquisition should be performed in conditions which have to be representative of the subsequent measurements' session. It is suggested to perform the background acquisition (1) at the beginning of each measurements' session, and (2) if the measurement conditions considerably change during a single measurements' session.

The Background Measurement window is accessed after pressing the background icon on the Main window.

4.6.1 Background window commands and indicators

The Background Measurement window includes the following commands and indicators (see figure 4.12):

1. **Control icons**. The user can perform actions as the measurement runs (see below).

2. **Live spectrum plot**. This plot updates real time as the measurement runs. The I-131 relevant ROI is shaded in red. The user can select real time the x-axis scale (keV/channels) and the y-scale (lin/log) by tapping on the corresponding buttons on the top-right of the plot.

3. **Progress bar**. It includes the elapsed real time (on the left) and the pre-set real time (on the right).
4. **Measurement results table**. The measurement results table updates automatically during the acquisition, displaying:
   a. Isotope of interest (I-131)
   b. Cps in the I 131 ROI
   c. Total counts in the I 131 ROI
   d. Relative standard deviation of the counts in the I 131 ROI
   e. Cps in the spectrum
   f. Total counts in the spectrum

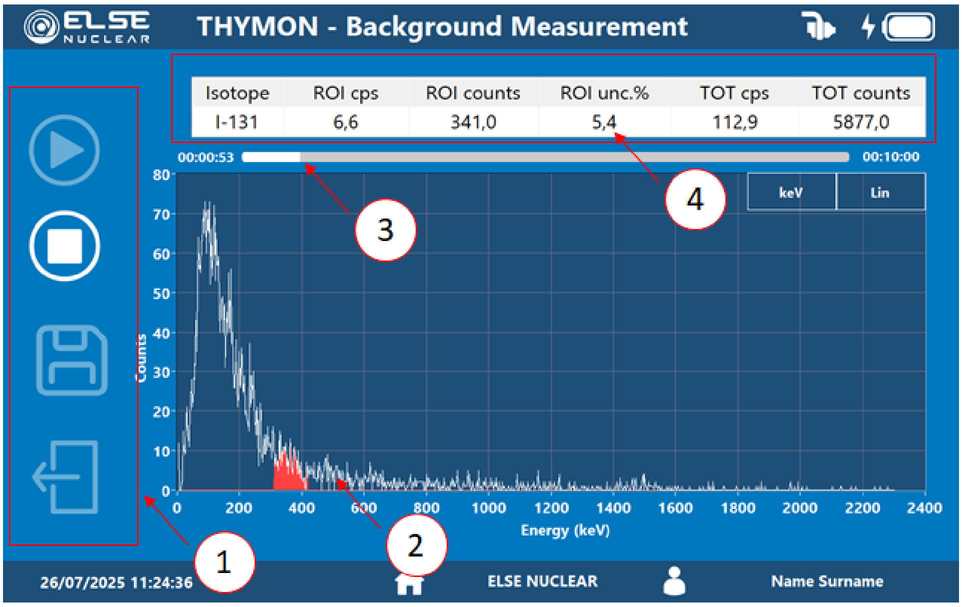


Figure 4.12: Background Measurement window (details)

The following table describes the control icons.

	**Start acquisition**. Starting the acquisition after having stopped the measurement will erase the current spectrum.
	**Stop acquisition**. Enabled as the measurement runs. This button allows the user to stop the measurement.

	**Save background**. Enabled after pressing the stop icon or at the end of the pre-set measurement routine.
	**Back to Main window**.

If the user presses the save icon, the background spectrum is saved in N42 format in `C:\THYMON\Config\BG`. The last saved background spectrum will be automatically uploaded by the software for the calculations if the background subtraction algorithm is enabled.

The spectrum obtained during the background acquisition is employed by the background subtraction algorithm. The last saved background spectrum is automatically uploaded for the calculations. Therefore, the user is encouraged to verify that the last saved background spectrum is representative of the actual background expected during the measurement session. If not, the most reliable options are (1) repeat a representative background acquisition, or (2) disable the background subtraction algorithm during the measurements' session.

4.7 Calibration

The suggested measurement procedure consists of:

- **a) Perform the energy calibration of the system;**
- **b) Acquire a background spectrum;**
- **c) Launch the thyroid screening routine.**

Steps (a) and (b) are not mandatory, but it is suggested to perform both steps at least at the beginning of a measurement session, and repeat them if the environmental conditions change abruptly (e.g. the system is relocated in a different room).

The calibration routine is semi-automatic, meaning that the algorithm automatically corrects for NaI(Tl) non-proportionality, while the user is only asked to highlight the ^{40}K peak by moving the cursors on the screen and press the SET button when the (displayed) fit is satisfactory. The always-active temperature-gain compensation algorithm compensates for the thermal drift of the SiPM gain, therefore the ^{40}K peak centroid falls usually in the same few-channel interval.

The system automatically recalls the last saved calibration; thus, the cursors are automatically positioned in the proper region of the spectrum.

Calibration relies on natural ^{40}K only, so measuring background suffices to perform the energy calibration. However, the system is delivered with a dedicated KCl calibration source to be placed on the top of the probe's top; this allows speeding up the calibration procedure (down to 2 minutes, on average).

The picture below shows the probe inserted in the calibration source. Please note that the picture does not include the detector's cable, being a representative example of how to position the detector.

Figure 4.13: Calibration setup example

4.7.1 Calibration window commands and indicators

The Calibration window is accessed after pressing the calibration icon on the Main window.

The Calibration window includes the following commands and indicators (see figure 4.14):

1. **Control icons**, see below.
2. **Live spectrum plot**. This plot updates real time as the measurement runs. The user can select real time the y-scale

(lin/log) by tapping on the corresponding buttons on the top-right of the plot.

3. **Live plot cursors**. The user can drag the cursors to highlight the K-40 peak on the live plot. The software will automatically fit the peak in the region included within the two cursors (shown as red shaded area), and automatically calculates the centroid of the peak.
4. **Peak channel indicators and controls**. The first indicator *"New peak channel"* is updated real time: it corresponds to the channel of the centroid of the peak identified between the cursors as the measurement is running. After tapping the SET button, the current *"New peak channel"* value updated the *"Current peak channel"* value. The *"Current peak channel"* value is actually stored and used for the calibration (if the calibration is saved).

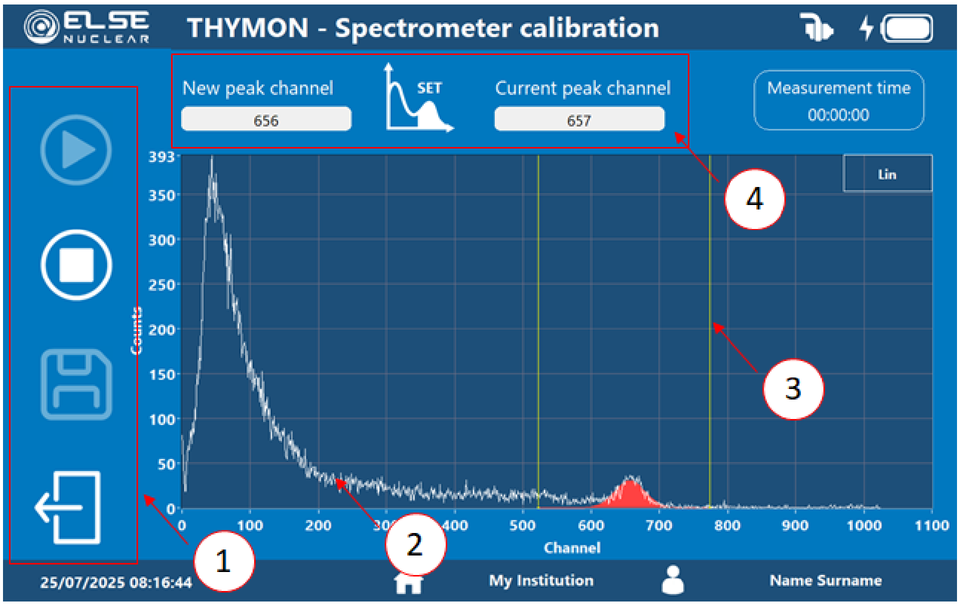


Figure 4.14: Calibration window (details)

It is recommended to (a) wait until the fit is satisfactory—meaning the shaded area closely matches the peak—and (b) ensure that the *"New peak channel"* value remains stable for a few seconds. Only then should you set the new *"Current peak channel"* value, as this will ensure a more reliable calibration.

The following table describes the control icons.

	**Start acquisition**. Starting the acquisition after having stopped the measurement will erase the current spectrum.
	**Stop acquisition**. Enabled as the measurement runs. This button allows the user to stop the measurement.
	**Save calibration**. Enabled after pressing the SET button.
	**Back to Main window**.

If the user presses the save icon, the calibration spectrum is saved in N42 format in `C:\THYMON\Config\Calib`. The last saved calibration spectrum will be automatically uploaded by the software for the MCA calibration.

The spectrum obtained during the calibration function is employed by the MCA algorithms. The last saved calibration spectrum is automatically uploaded for the calculations. Therefore, the user is encouraged to verify that the last saved calibration spectrum is representative of the actual condition expected during the measurement session.

4.8 Archive

All files in the archive can be consulted and sorted/selected based on the alarm status and/or datetime and/or age group. The selected data can be consulted directly on the archive window, or downloaded for post-processing analysis.

The Archive window includes the following commands and indicators (see figure 4.15):

1. **Control icons**. They allow the user to filter and export data, or go back to the main window. See below.
2. **Applied filters' summary**.
3. **Filtered data**.

4. **Measurement information**. Relevant information about the currently highlighted measurement in the filter data is displayed here. Information includes:
    a. Age Group
    b. Measurement date
    c. Measurement ID
    d. Acquisition time
    e. Warning (if present)
    f. Alarm status
    g. Measurement output
    h. Measured spectrum

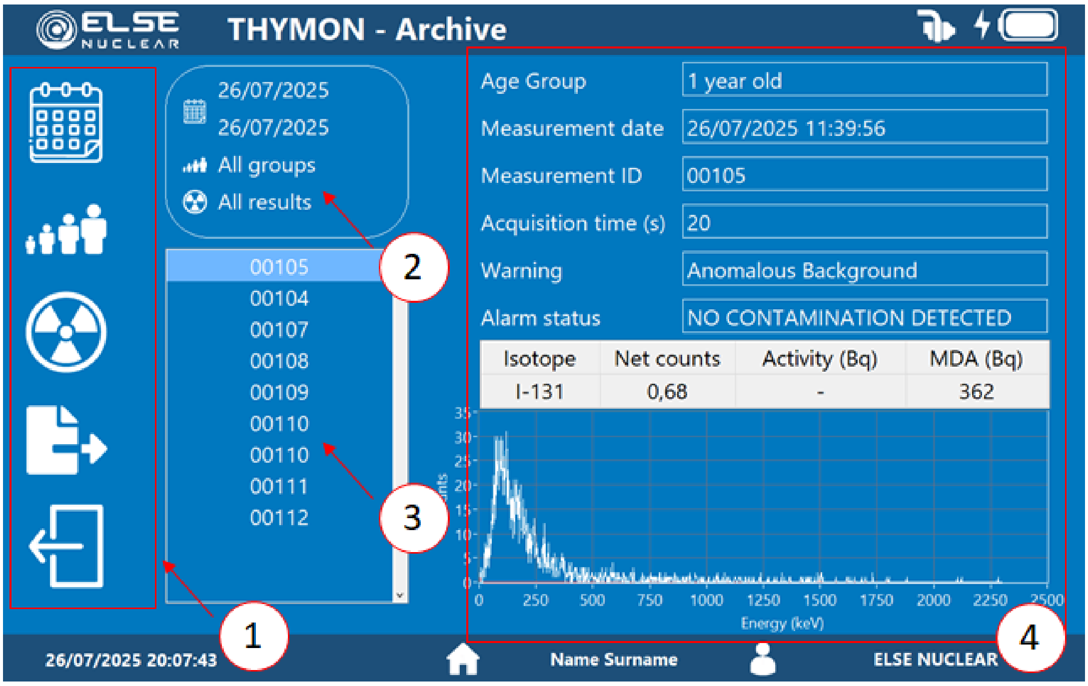


Figure 4.15: Archive window (details)

The following table describes the control icons.

	**Date/Time Filter**: opens two pop-ups in sequence to set the start and end date/time.

	**Age Group Filter**: filters measurements by selected age group.
	**Result Filter**: filters by measurement outcome (All, Contaminated, Not Contaminated).
	**Export**: Exports the currently displayed (filtered) data. See next paragraph for details about the export function.
	**Back to main window**

4.8.1 Archive structure

The structure of the archive is the following:

- `C:\THYMON\Archive\` folder
  This is the main archive folder, which contains all saved data. This main folder contains subfolders, named:
  - `C:\THYMON\Archive\yyyy\` folder
    "yyyy" corresponds to the year in which measurements were performed. Each yyyy subfolder contains a series of files and folders.
    - `C:\THYMON\Archive\yyyy\PDFReport\` folder
      This folder contains the measurement reports saved in pdf format. Each report contains all relevant measurement data (measurement ID, Age Group, alarm status, etc.) and the plot of the acquired spectrum.

Pdf reports are printed and stored only if the corresponding option is enabled in the System Settings window.

    - `C:\THYMON\Archive\yyyy\SpectraN42\` folder

This folder contains the measured spectra in standard ANSI N42 format.

- `C:\THYMON\Archive\yyyy\ SpectraTxt\ folder`

  This folder contains the measured spectra (counts vs energy) as plain text.

- `yyyy-mm-dd.txt files`

  These files contain compact information of the measurement performed each day. They include:

  - Identifiers (e.g., measurement ID, operator name, etc.)
  - System settings data (e.g. alarm threshold values, background acquisition time, etc.)
  - Measurement settings data (e.g. age group, measurement time, etc.)
  - Measurement outcomes (e.g. measured activity, MDA, etc.)

4.8.2 Archive's file structure

Pdf reports' structure

The pdf reports include a series of measurement information:

- Measurement ID
- Operator name
- Institution name
- Measurement date and time
- Age Group
- Acquisition time (real time)
- Warning messages (if any)
- Measurement result (contaminated/not contaminated)
- Measurement results' table (net counts, activity, MDA)
- Spectrum plot

Spectra in N42 format structure

These spectra are structure following the standard ANSI N42 xml format. The user is referred to the ANSI documentation for the detailed description of the file structure. The spectra files include the following information:

- Manufacturer name
- Instrument model name

- Instrument class code
- Instrument version
    - Component name
    - Component version
- Detector information
    - Detector category code
    - Detector kind code
- Energy calibration information
    - Channel list
    - Energy list
- Rebin factor
- Measurement ID
    - Spectrum ID
    - Class code
    - Start date and time
    - Real time
    - Live time
    - Channel data (spectrum)

Spectra in plain text format

These files include the following information as plain text:

- Measurement date and time
- Channel corresponding to the 40-K peak centroid
- Live time
- Real time
- Spectrum
- Energies

yyyy-mm-dd.txt files

These files contain information about the measurement session of the day. These files are written as tab-separated tables (plain text): the first row is a header, and each of the following rows contain information about each single measurement of the session. Each column corresponds to a specific information, indicated in the header. The information included in the `yyyy-mm-dd.txt` file is:

- Measurement ID
- Date and time
- Operator name

- Institution name
- Measurement time (real time)
- Background acquisition time (real time)
- Pre-alarm threshold value (in Bq)
- Alarm threshold value (in Bq)
- Age Group
- Name and path of the corresponding spectrum in N42 format
- Warning (if any)
- Pre-alarm status (true or false)
- Alarm status (true or false)
- Isotope name (I-131)
- Net counts under the isotope main peak
- Measured activity (in Bq), if the activity is > MDA
- MDA (in Bq)

4.8.3 Archive Export function

The export function allows the user to select a folder to export all selected data (the function then produces an `Export\` subfolder, containing all exported data).

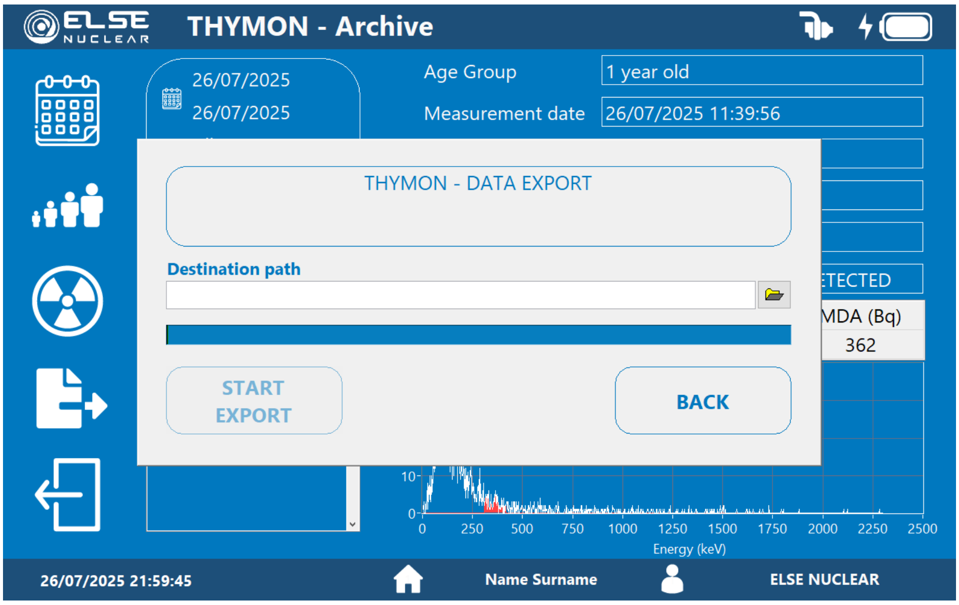


Figure 4.16: Data Export popup

The export function creates:

- `Summary.txt` file

This file contains compact information about all selected measurements. The structure of the Summary.txt file is analogous to the yyyy-mm-dd.txt file.

- …`\yyyy-mm-dd\` folders

Exported data are organised on a day-by-day basis. Each of these folders contains:

  - `yyyy mm dd.txt` file
  - …`\yyyy-mm-dd\xxxxx_yyyy mm dd_hh.mm.ss\` folders

These are the subfolders related to each single measurement. "`xxxxx`" corresponds to the measurement ID, "`yyyy mm dd`" corresponds to the measurement day, "`hh.mm.ss`" corresponds to the measurement time. Each of these folders include the pdf reports (if the corresponding option was enabled during measurement) and the spectrum files in N42 format and as plain text.

4.9 Advanced functions

Advanced functions allow the user to set system and measurement parameters, as well as performing a free (not quantitative) spectrum analysis, and perform data backup.

The Advanced window is accessed after pressing the Advanced icon on the main window.

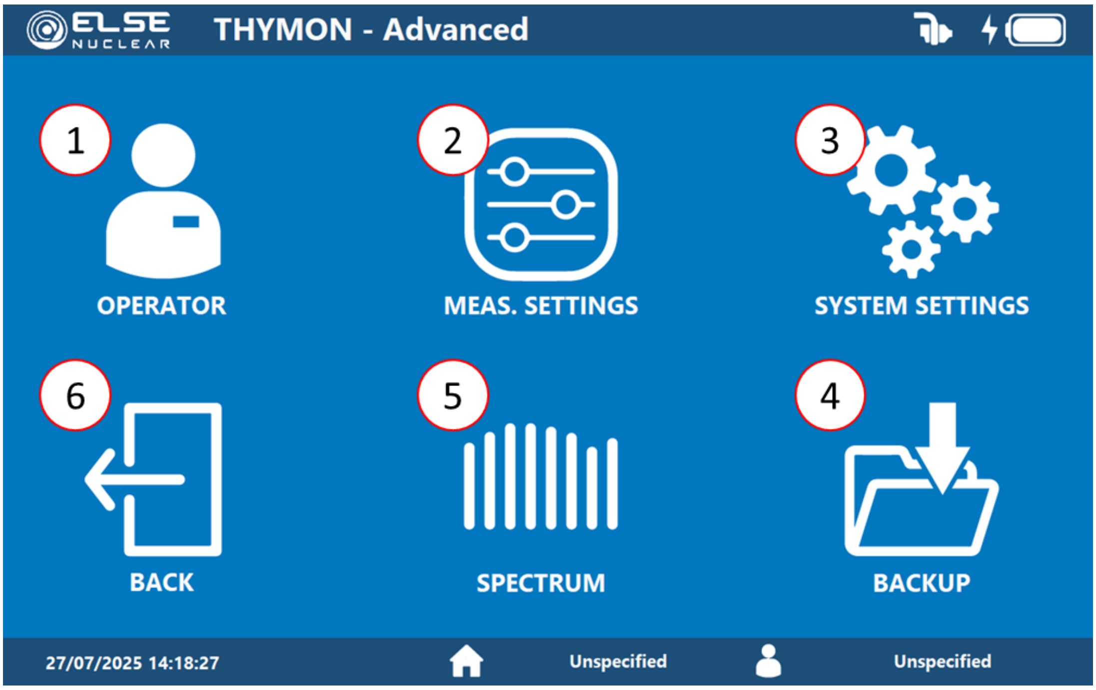


Figure 4.17: Advanced window (details)

The Advanced window allows the user to access all software advanced functions via an intuitive touch-screen graphical interface. The advanced functions/sub-windows which can be accessed from the Advanced window are, clockwise from top-left:

1. **Operator**: This function allows the user to enter its name and institution. As the instrument is started these fields are filled with the "Unspecified" string. Empty fields do not modify other measurement functions.
2. **Measurement settings**: This function allows the user to set and modify measurement options related to specific Age Group.
3. **System settings**: This function allows the user to modify option related to the system.
4. **Backup**: The backup function allows creating a copy of the main software folder (C:\THYMON) and of all its contents in a dedicated backup folder.
5. **Spectrum**: This function allows the user to perform a free, not quantitative, spectrometric measurement.
6. **Back**: Go back to the Main window.

4.9.1 Operator window

By tapping on the operator icon, the user is prompted to the following window.

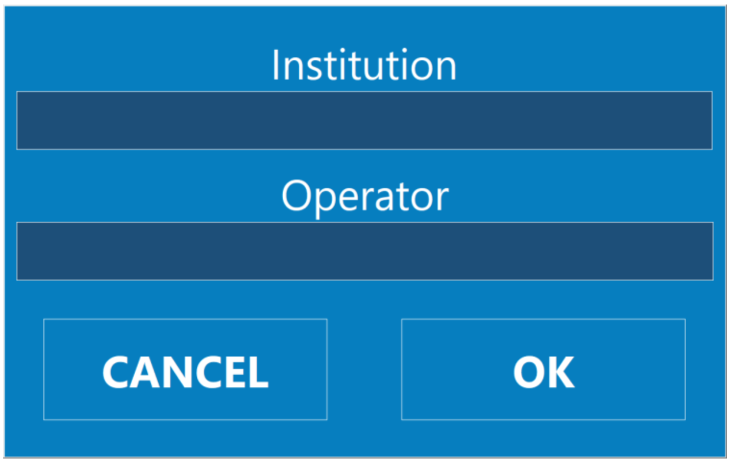


Figure 4.18: Operator information window

By tapping on the two fields, the user can insert the institution and operator name.

This information will be displayed in all main windows together with other system status information, and will be saved in the archive.

> **Filling these two empty fields is not mandatory to perform any other action on the software. The "*Unspecified*" string will be automatically entered in place of both institution and operator names.**

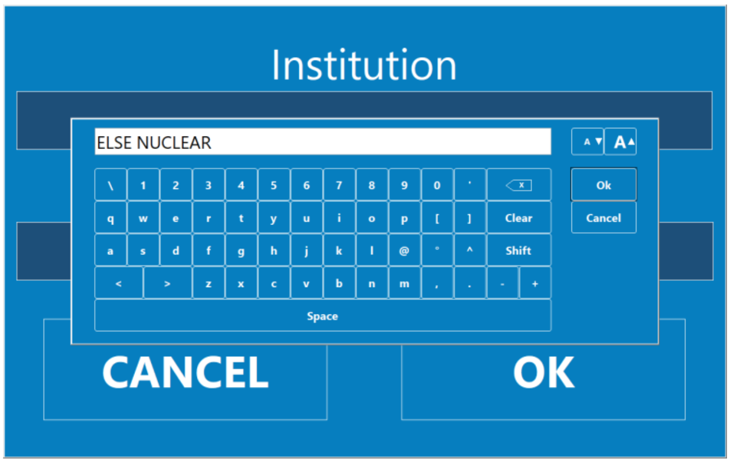


Figure 4.19: Example of pop-up virtual keyboard

4.9.2 Measurement settings window

By tapping on the measurement settings icon, the user is prompted to the following window.

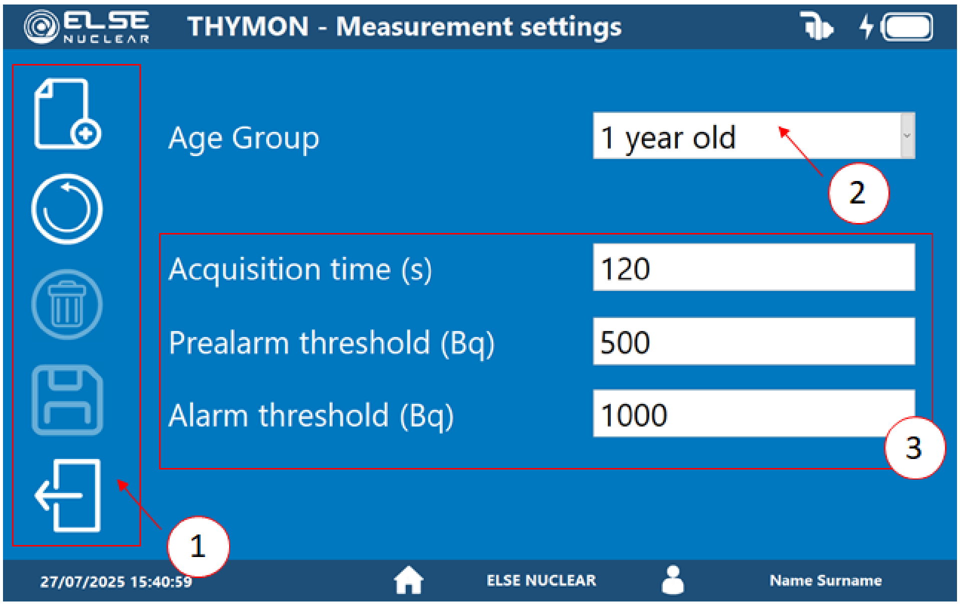


Figure 4.20: Measurement settings window (details)

This window allows the user to set and modify measurement options related to specific Age Groups. This window includes the following commands and indicators:

1. **Control icons**. The user can perform different actions (see below).
2. **Age Group selection**. The user can select different age groups from the drop-down list. Each Age Group selection will load Age-Group-specific options (point 3 below).
3. **Age Group options**. They include the pre-set acquisition time (in second) and pre-alarm/alarm values (in Bq). The user can freely edit these parameters for all Age Groups by tapping on the related numerical field.

The following table describes the control icons.

	**Add new Age Group**. By tapping this button, the user can define a new Age Group. To define a new Age Group, the user has to: 1. Tap on the Add new Age Group icon

	2. Insert the new Age Group name 3. Set default acquisition time, pre-alarm threshold, and alarm threshold 4. Set the detection efficiency, expressed in [cps/emitted gamma-ray per second]
	**Set all Age Group options to default**. Default values are: • Acquisition time: 120 s • Pre-alarm threshold: 500 Bq • Alarm threshold: 1000 Bq
 	**Delete Age Group**. This command is enabled only for Age Groups defined by the user, i.e. other than the default ones, which cannot be deleted.
 	**Save changes**.
	**Back to Advanced window**.

Adding a new age group

The following figure shows an example of definition of a new Age Group.

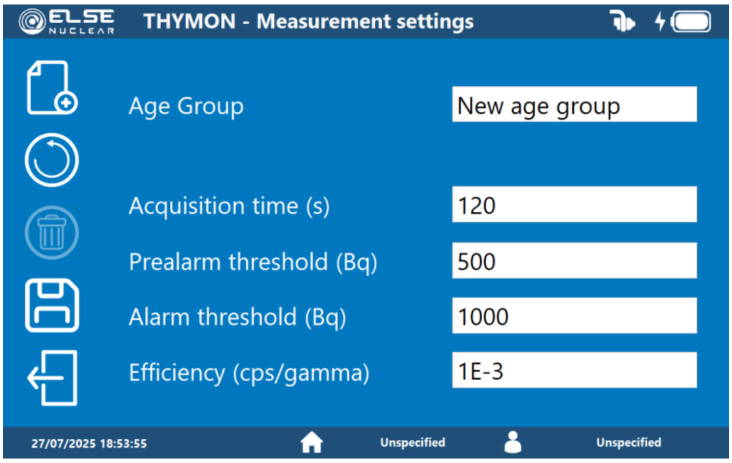


Figure 4.21: Definition of a new Age Group

> **The predefined age groups are: 1 year old, 5 years old, 10 years old, 15 years old, and Adult. The user is not allowed to modify the pre-set age groups. Age Groups other than the predefined ones can be either modified or removed.**

4.9.3 System settings window

By tapping on the system settings icon, the user is prompted to the following window.

This window allows the user to set and modify measurement options related to the system. This window includes the following commands and indicators:

1. **Control icons**. The user can perform different actions (see below).
2. **Alarm settings**. Use these buttons to enable or disable the acoustic and visual alarms that are triggered when measurement results exceed the defined pre-alarm or alarm thresholds. Even if alarms are disabled and no warning is displayed or sounded at the end of the measurement, the alarm status is still recorded in the archive.
3. **Pdf report print**. This button sets the automatic print of the pdf report in the archive at the end of a successful measurement.
4. **Background algorithm options**. Entries are the following:

a. Bkg subtraction algorithm: by tapping on this button, the user can either enable or disable the automatic background subtraction algorithm.

b. Bkg time (s): by tapping on the related field, the user can set the pre-set measurement time, in seconds, for the background acquisition. Default value: 600 s.

c. Bkg tolerance (Sigma): the user can set the total cps (integral over the total spectrum) threshold above which the warning of anomalous background is signalled by the software. This value is given in multiples of the background standard deviations – the background standard deviation is calculated as the square root of the total counts integrated during the background acquisition divided by the corresponding live time. Default value: 5 sigmas.

d. Bkg tolerance – ROI (Sigma): the user can set the ROI cps (integral over the ROI related to the I-131 main peak) threshold above which the warning of anomalous background is signalled by the software. This value is given in multiples of the background standard deviations – the background standard deviation is calculated as the square root of the total counts in the ROI integrated during the background acquisition divided by the related live time. Default value: 5 sigmas.

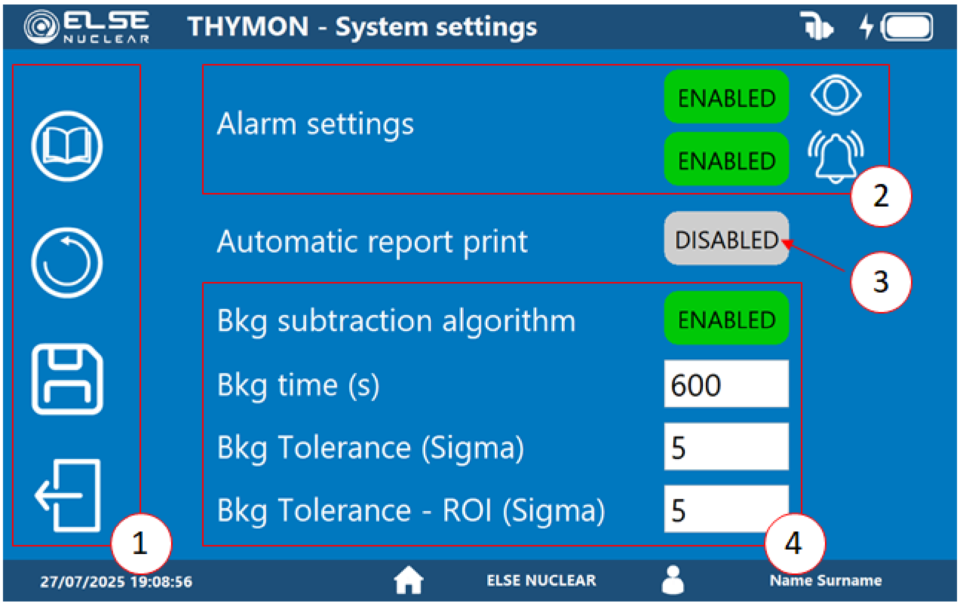


Figure 4.22: System settings window (details)

The following table describes the control icons.

	**Open the Library management window**.
	**Set all options to default**. Default values are: • Visual alarm enabled • Acoustic alarm enabled • Automatic report print disabled • Background subtraction algorithm enabled • Background time: 600 s • Background tolerance: 5 sigmas • Background tolerance (in ROI): 5 sigmas
 	**Save changes**.
	**Back to Advanced window**.

4.9.4 Library management window

THYMON relies on a built-in isotope library, Library.lib, located in the `C:\THYMON\Config\` folder. The library includes a series of pre-defined isotopes and peaks, which are automatically loaded in each of the functions involving the usage of the MCA and related calculations algorithms. The library can be freely edited by the user, who can add, remove or edit isotopes and peaks.

The pre-set library includes the main peaks of the following isotopes:

- Am-241
- Ba-133
- Ce-139
- Co-57
- Co-60
- Cs-137

- Eu-152
- I-131
- K-40
- Mn-54
- Na-22
- Cs-134
- Pu-239
- Ra-226
- Sm-153
- Tc-99m
- Y-88
- Zn-65

Library management window description

By tapping on the corresponding icon in the System settings window, the user can access the main Library management window.

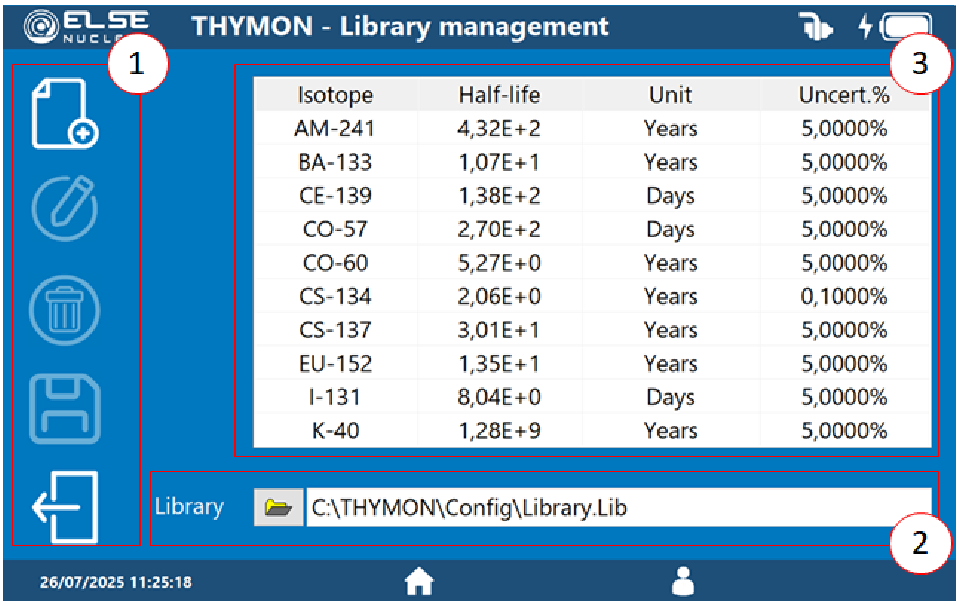


Figure 4.23: Library management window (details)

This window allows the user to add, delete or select isotopes from the isotope library. This window includes the following commands and indicators:

1. **Control icons**. The user can perform different actions (see below)
2. **Library selection**. The default isotope library file is Library.lib, located in the `C:\THYMON\Config\` folder.
3. **Isotopes' table**. The table shows the isotopes included in the selected library. After selecting an isotope from the table, the user can edit or remove it from the list using the dedicated control icons (see below).

The following table describes the control icons.

	**Add a new isotope**
	**Edit the selected isotope**. This icon is enabled as soon as one isotope in the table is selected.
	**Remove the selected isotope**. This icon is enabled as soon as one isotope in the table is selected.
	**Save changes**.
	**Back to Advanced window**.

After pressing the add or edit icons, the Isotope management window appears:

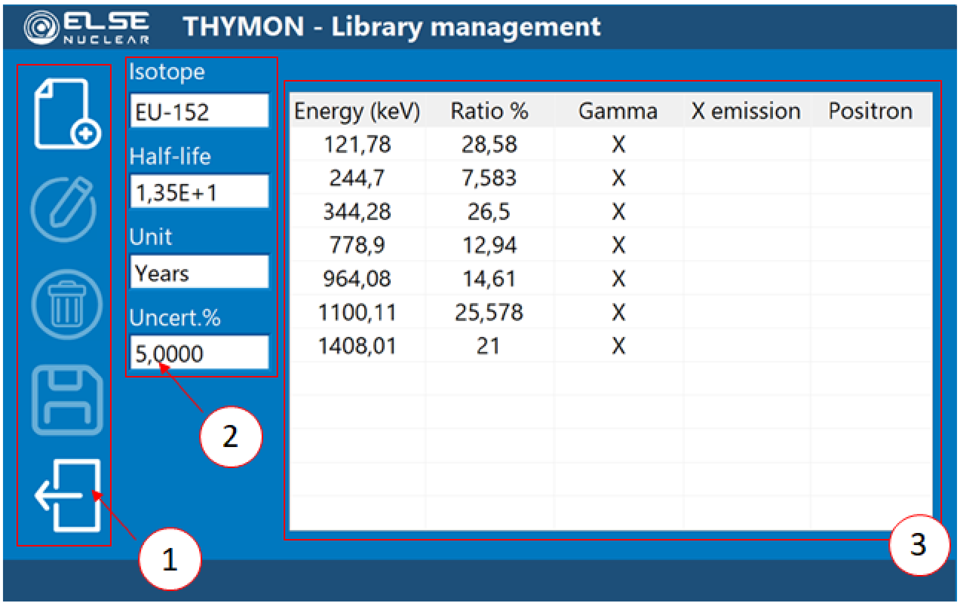


Figure 4.24: Isotope management window (details)

This window allows the user to set and modify the peaks' properties of the isotope library. This window includes the following commands and indicators:

1. **Control icons**. The user can perform different actions (see below)
2. **Isotope properties**. The user can modify (or add) isotope properties:
    a. First field: isotope name
    b. Second field: half life
    c. Third field: half life unit (seconds, minutes, hours, days or years)
    d. Fourth field: half life uncertainty
3. **Peaks' table**. The table shows the peaks related to the selected (or newly defined) peak included in the selected library. After selecting a peak from the table, the user can edit or remove it from the list using the dedicated control icons (see below).

The following table describes the control icons.

	**Add a new peak**
 	**Edit the selected peak**. This icon is enabled as soon as one peak in the table is selected.
 	**Remove the selected peak**. This icon is enabled as soon as one peak in the table is selected.
 	**Save changes**.
	**Back to the Library management window**.

When editing (or adding) a peak, the following popup appears:

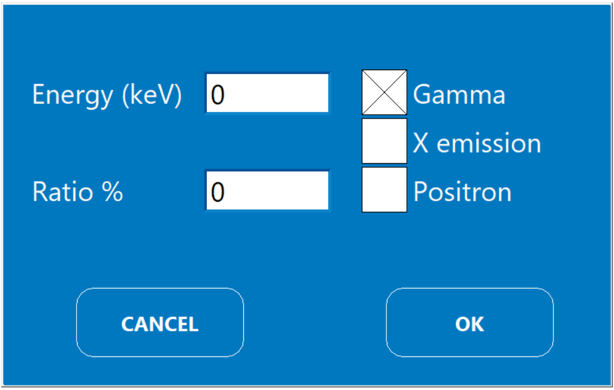
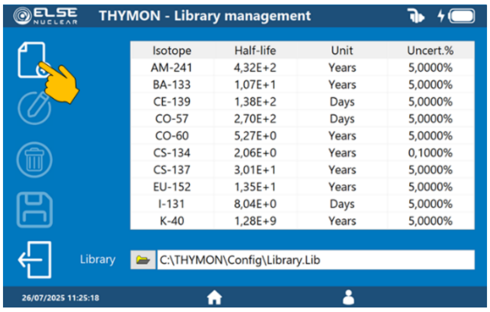


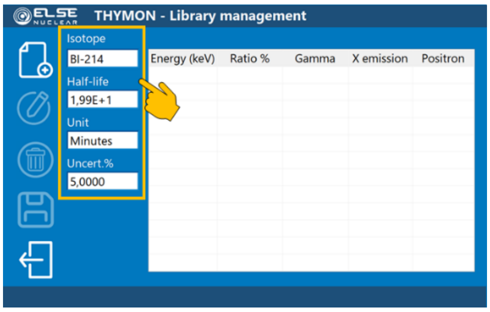
Figure 4.25: Peak Editor popup

The user is asked to add the energy and branching ratio of the peak, as well as its category (gamma ray, x ray, positron).

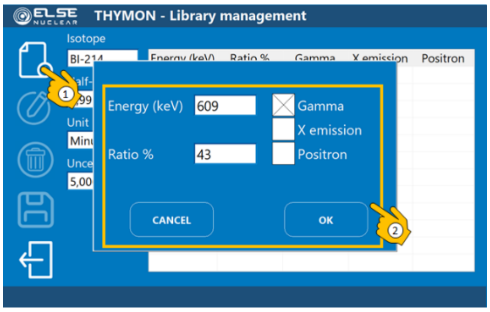
An example of the addition of a new isotope with one gamma ray peak is shown below.



Tap on the *"Add isotope"* icon.



Edit the isotope properties by tapping on the isotope properties' fields. Virtual keyboards will pop up as soon as the properties' fields are selected.



Tap on the *"Add peak"* icon. Edit the peak properties by tapping on the peak properties' fields. Virtual keyboards will pop up as soon as the properties' fields are selected.

The library is accessed by the software to retrieve all information about isotope properties, emission lines, etc. It is strongly discouraged to edit the I 131 and K-40 properties, since they are retrieved from the same file to calculate the thyroid activity and for calibration purposes.

4.9.5 Data Backup

By tapping on the backup icon, the user is prompted to the following popup window.

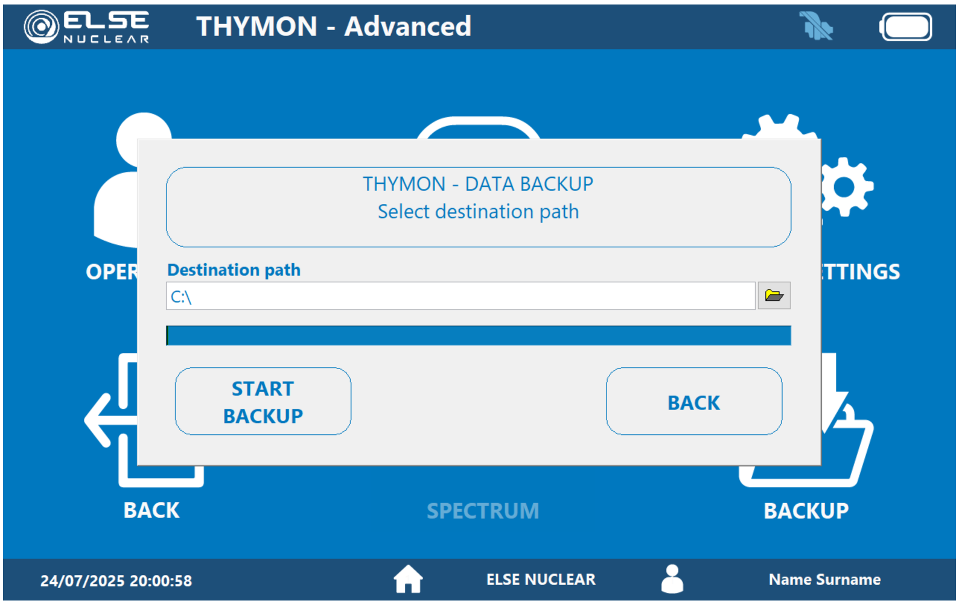


Figure 4.26: Data Backup popup

By pressing on the folder icon, the user can browse the path where the backup folder will be created. Backup starts after tapping on the START BACKUP button. The backup function copies the entire `C:\THYMON` folder in the desired location.

4.9.6 Spectrum acquisiton

By tapping on the spectrum icon in the Advanced window, the user is prompted to the following window.

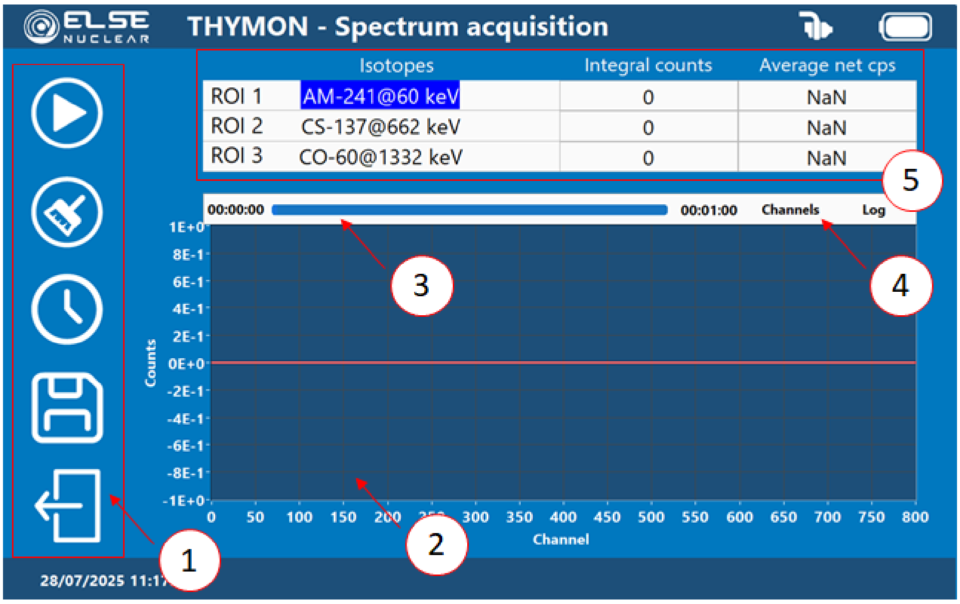


Figure 4.27: Advanced Spectrum window (details)

The advanced Spectrum acquisition window includes the following commands and indicators:

1. **Control icons**. The user can perform actions as the measurement runs (see below)
2. **Live spectrum plot**. This plot updates real time as the measurement runs. Up to three ROIs set by the user are shaded in red.
3. **Progress bar**. It includes the elapsed real time (on the left) and the pre-set real time (on the right).
4. The user can select real time the x-axis scale (keV/channels) and the y-scale (lin/log) by tapping on the corresponding buttons on the top-right of the plot.
5. The ROI selection table allows the user to select up to three peaks from the library. The table includes the following entries (updated real-time):
    a. ROIs' number
    b. ROI's isotope and peak energy
    c. Integral counts in the ROIs
    d. Average net cps in the ROIs

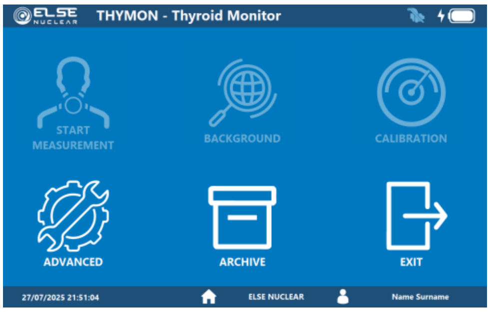
The following table describes the control icons.

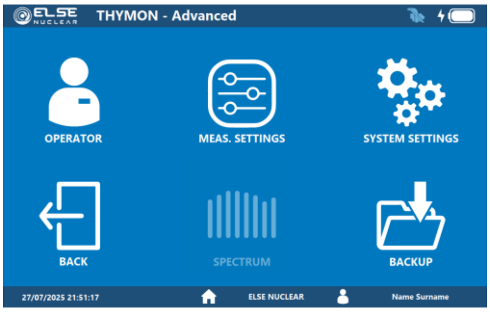
	**Start/stop acquisition**. If a measurement is re-stated after pressing stop, the spectrum is not automatically cleared.
	**Clear spectrum**. Enabled only if the measurement is stopped.
	**Set time**. By tapping this icon, the user can set a defined acquisition time for the measurement.
	**Save spectrum**. After pressing this icon, the user is asked to select the destination folder and the name of the spectrum. Spectrum is saved in ANSI N42 format (see chapter 4.8 for format details).
	Back to Main window.

4.10 Disconnection and underflow error

If a connection error occurs, the detector connection icon turns in its deactivated state.

While disconnected, all functions related to the usage of the MCA are disabled.





If the error occurs during an acquisition, the measurement is interrupted, an error message is displayed, and data is not saved.

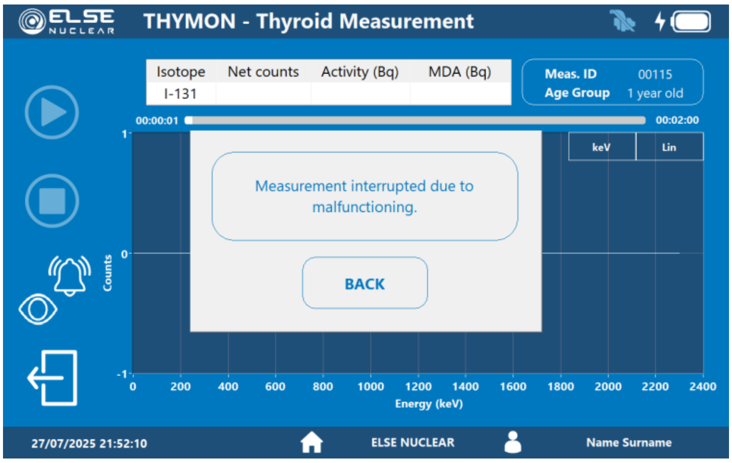


Figure 4.28: Error message (details)

The user is not allowed to run a measurement if a connection error occurs.

Periodic reconnection attempts will be made automatically until the detector becomes available.

4.11 System shutdown

To shut down the system, press the exit icon in the Main window, and follow the instructions provided by the pop-up message.

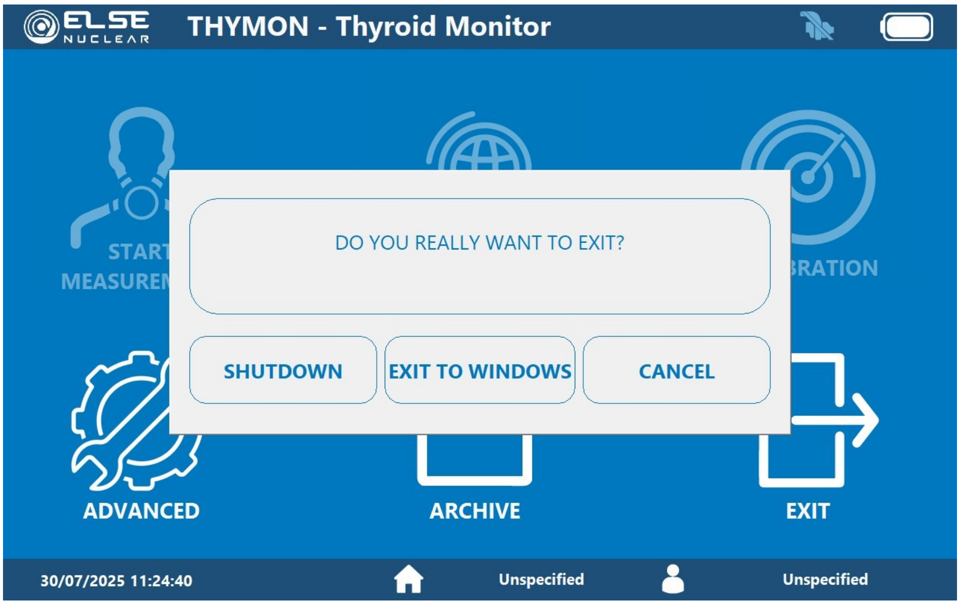


Figure 4.29: Shutdown window

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Section 5
Maintenance

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5.1 Ordinary maintenance

The system needs limited ordinary maintenance to be performed by the customer. The following operations can be put in place by the User regularly in order to ensure the highest level of efficiency of the system:

- Clean the external surfaces and check that the hardware parts are all firmly fixed and solid
- Check the integrity of the connection cable.

Inform immediately ELSE NUCLEAR in case any of the cable parts show any external deterioration. This may seriously affect the system operation.

Battery check – every 1 month

If stored longer than 1 month, the battery pack should be charged every 2 months and maintained between 30–70% state of charge.

Operational check – every 6 months

If stored longer than 6 months, each system shall be checked to verify its full operational functionality, performing the following actions: power-up, self-check, calibration and background acquisition.

5.1.1 Storage and transportation requirements

Storage and transportation conditions shall preserve the system's mechanical integrity, measurement stability, and environmental robustness as specified below.

Storage Conditions

The system must be stored in its dedicated protective transport case. Storage conditions shall not exceed the environmental conditions 1K20/1Z1/1B1/1C2/1S10/1M11 defined in standard IEC 60721-3-1. This implies controlled indoor environments with moderate temperature fluctuations, low mechanical stress, and limited exposure to humidity, dust solar radiation, and corrosive contaminants.

Class	Category	Description
1K20	Climatic	Indoor controlled climate (5–40°C, 5–85% RH)
1Z1	Radiation - Heat	No significant solar radiation or heat sources
1B1	Biological	No biological activity (mold, pests, etc.)
1C2	Chemical	Urban air pollution (SO_2, NO_x), no aggressive chemicals
1S10	Dust - Particles	Virtually dust-free environment
1M11	Mechanical	Very low vibrations (e.g. HVAC, light traffic)

Transportation Conditions

Transportation shall be carried out using the system's dedicated protective case. Transport conditions shall not exceed the environmental conditions 2K13/2B1/2C2/2S5/2M5 defined in standard IEC 60721-3-2. Transport conditions shall not exceed the vibration, shock, humidity, and chemical exposure limits specified therein. No disassembly is required. All components remain immobilized within the case to prevent damage.

Class	Category	Description
2K13	Climatic	Severe outdoor transport (−45°C to +45°C, high humidity)
2B1	Biological	Negligible biological risk during transport
2C2	Chemical	Urban/light industrial pollution during transit
2S5	Dust/Particles	Moderate airborne dust/sand during transport
2M5	Mechanical	Moderate to strong vibration and shocks (e.g. drops, handling)

Post-Transport Functional Check

After prolonged transport or intense mechanical stress, a functional verification shall be performed. This includes power-up, self-check, and background acquisition.

5.2 Service

Before cleaning the instrument, make sure that it is disconnected from any external power supply (following the proper procedure described in Section 3).

5.2.1 General safety notes

Keep the unit clean and free from dirt and contamination.

Do not use chemical detergents.

Use a soft and clean cloth.

Do not use powdered or abrasive solvents on any part of the instrument.

5.2.2 Repairs

Do not try to repair this instrument by yourself. Contact ELSE NUCLEAR for any repair related for example to the following events:

- Damaged cables

- Device does not operate properly although instructions of this manual have been followed
- Damaged device

5.2.3 Long-term maintenance contract

The Company provides upon request a specialised technical assistance and maintenance service on all the ELSE NUCLEAR radiation monitoring instrumentation installed and/or supplied to the Customers, in the form of a maintenance contract defined in a dedicated technical-economical offer.

The contract terms shall be agreed upon between the Company and the Customer, according to the requirements and the relevant applicable constraints. Typically contract terms are 3 or 5 years, effective from the maintenance order date. Once expired, the contract can be renewed upon a renewal proposal, defined by the involved parties.

During the contract term, it is typically performed n.1 (one) preventive ordinary maintenance intervention every year on the instrumentation, to verify the proper operation of the systems and to ensure their continuous and reliable performance.

The typical foreseen activities include:

- Hardware components integrity check
- Cables and connectors integrity check
- Detector functionality check (and adjustment, if needed):
- Acquisition electronics functionality check (and adjustment, if needed):
- Overall system check
- System communication

If extraordinary repair maintenance interventions are needed, they will be evaluated and performed upon request in case of system malfunctioning, and they will be aimed to restore the optimal functioning conditions of the systems. Such interventions will be computed and evaluated at the end of the activities according to the fees described in the maintenance contract offer.

5.3 Connection Error and Underflow Management

A connection error or underflow may occur during operation if the communication between the tablet and the detector is interrupted. This condition can typically be traced back to one of the following causes:

- Loose or disconnected communication cable – The USB (or other) cable connecting the tablet to the detector may not be firmly plugged in or may have been accidentally disconnected.
- Unproper starting procedure – the starting procedure has not been performed as outlined in chapter 3.2.
- Hardware fault – The detector itself may be malfunctioning or damaged.

5.3.1 Troubleshooting Procedure

- Step 1 – Check the cable connection.

Ensure that the communication cable is securely attached at both ends (tablet and detector). Gently disconnect and reconnect the cable to make sure the connector is properly seated.

- Step 2 – Inspect the cable and ports.

Check for visible damage to the cable, bent pins, or dust/debris in the connectors. Replace the cable if necessary.

- Step 3 – Restart the system.

Close the software and switch off the control tablet. Start again the control tablet making sure that the detector is connected to the USB port after the software initialisation.

- Step 4 – Communication check.

Wait 30 seconds and verify that the connection error is not issued anymore.

- Step 5 – Connect the detector probe cable to the side USB port

In case the connection error persists, connect the detector probe cable to the side USB port (open the lid as in figure 5.1)

The side USB port of the control tablet is not IP65 rated.

Figure 5.1: Side USB port of the control tablet

- Step 6 – Contact Customer Support.

If the problem continues after following the above steps, the detector may be damaged. In this case, do not attempt to open or repair the instrument. Contact Customer Support for further diagnostics and assistance.

> **Do not send a contaminated instrument for repair or calibration under any circumstance.**

If the instrument requires servicing, please contact ELSE NUCLEAR Service Department at the following address:

Company	ELSE NUCLEAR s.r.l.
Address	Via Sacro Monte 3/12 21052, Busto Arsizio (VA) ITALY
Telephone	+39-0331 620533
E-Mail	info@elsenuclear.com

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Section 6
Technical data

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The content of this section shall be considered related to the typical standard configuration of THYMON.

Alternative configurations and expansions are available upon request. ELSE NUCLEAR provides custom solutions to meet specific operational requirements.

6.1 System Overview

- System name: THYMON – Portable Thyroid Monitor for Emergency Use
- Use case: Emergency response, iodine-131 activity screening
- Software version: THYMON v1.00 (pre-installed)

6.2 Mechanical Specifications

- Detector probe dimensions (L × W × H): 260 × 123 × 180 mm
- Detector probe weight: ~2.7 kg
- Transport case external dimensions: 62.8 × 49.2 × 22.3 cm
- Overall system weight: ~19 kg (including probe, tablet, tripod, charger, calibration source, foam inserts)
- Main materials: Nylon (3D-printed parts), lead (shielding), aluminum (probe and tripod parts)

6.3 Environmental and Protection Ratings

- Operating temperature range: –20 °C to +50 °C
- Storage temperature range: –30 °C to +70 °C
- Tablet and detector: IP65
- Transport case: IP67 (lid closed)
- Drop and shock resistance: MIL-STD-810 compliant (tablet and case)

6.4 Power Requirements

- Power supply source: via tablet USB interface
- Tablet battery: 7.6 V, 4200 mAh Li-ion (removable)
- Battery life: ~5 hours (optimized THYMON configuration)
- AC charger: 100–240 VAC input, 19 VDC output (3.42 A), Schuko plug (CEE 7/7)

6.5 Detector Probe and MCA Specifications

- Scintillator type: NaI(Tl), 1.5" × 1.5" cylindrical crystal
- Photodetector: SiPM array with temperature compensation
- Energy range: from about 30 keV to about 2.5 MeV (optimised for target isotope's emission)
- Linearity: ± 30%
- Effective range of activity measurement in thyroid: < 100 Bq to > 3 MBq
- Energy resolution: <9% FWHM at 662 keV
- Maximum count rate: > 10^5 s^{-1}
- MCA: Embedded 1024-channel, 12-bit ADC
- Temperature compensation: dynamic SiPM gain correction via lookup table covering -30 °C to +65 °C
- Data output: digital spectrum with real-time cps and ROI-based analysis
- Embedded 10 mm lead ring for background suppression and collimation of the field of view

6.6 Calibration Source

- Isotope: Natural 40K in KCl salt (~350 g)
- Estimated activity: ~15 Bq/g
- Enclosure: Cylindrical 3D-printed Nylon body, recessed to match probe face
- Sealing: 5-screw lid with sealing O-ring

6.7 Control Tablet

- Model: Winmate M900EK/EN
- Display: 8.0" IPS LCD, 1280 × 800 px, capacitive touch (glove/rain compatible)
- CPU: Intel Celeron N6211 (dual-core, 1.2–2.6 GHz)
- Memory: 4 GB RAM, 128 GB SSD, microSDXC slot
- Interfaces: USB 3.0, Bluetooth 5.0, Wi-Fi, optional 4G LTE
- Battery autonomy: ~6 hours (nominal), ~5 hours (with THYMON)
- Ruggedness: IP65, MIL-STD-810G (shock, vibration)
- Operating temperature: –20 °C to +50 °C
- Weight: ~0.9 kg

6.8 Software and Functional Specs

- User interface: Self-explanatory, icon-based
- Functions: Real-time measurement, data logging, spectrum display, I-131 estimation
- Configurable parameters: Alarm thresholds, acquisition time
- Export formats: CSV, XML, proprietary

6.9 Compliance and Certification

- EMC standards: EN 61000-6-1 / 6-3, EN 61000-4-2/3/6
- CE marking: Declared

6.10 Accessories and Kit Contents

- Transport case: PELI 1650-021-110E, IP67 certified, anti-shock foam layout
- Tablet mounting system: Cradle with clamp and 1/4" tripod adapter
- Tripod: Foldable, modular, for tabletop or ground use
- Other accessories: Charger, calibration source, stylus pen, documentation

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Appendix 1
Algorithms

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Algorithms and Data Processing

The THYMON system integrates a suite of algorithms designed to ensure reliable, accurate, and user-independent assessment of thyroid I-131 activity in emergency contexts. The implemented routines cover the full analysis pipeline, from spectral processing to activity estimation and sensitivity evaluation. The software workflow has been optimized for ease of use in the field, minimizing the need for user intervention while ensuring scientific robustness and traceability.

The core components of the processing pipeline are summarized below.

Peak Identification for I-131

The detection of I-131 relies on the identification of its characteristic gamma emission at 364.5 keV. A dedicated algorithm automatically locates the peak within the calibrated energy spectrum, defining a Region of Interest (ROI) centered on the nominal energy and adjusting for possible shifts in energy calibration. The algorithm includes signal smoothing and local maxima detection, with built-in thresholds to discriminate against statistical noise. Peak integration is performed using a trapezoidal method, and the gross area is used as the input for background subtraction.

Background Subtraction and Anomaly Detection Algorithm

When background subtraction is enabled, the user is asked to perform an additional acquisition to measure environmental background prior to the actual thyroid activity measurement. This background spectrum is filtered and smoothed using a proprietary algorithm to minimize statistical fluctuations.

During the thyroid measurement, a synthetic background estimate is generated in real time based on the acquired spectrum. This estimated background is then statistically compared to the previously acquired reference background spectrum. The comparison is performed independently over two domains:

- Global count rate analysis (total cps across the full spectrum)
- ROI-based analysis (cps within the Region of Interest around the 364.5 keV I-131 peak)

For both domains, the algorithm evaluates the deviation of the measured spectrum from the expected background by applying a user-defined threshold based on multiples of the standard deviation (σ) of the reference background. If the deviation exceeds the selected threshold, the user is notified via a warning message.

This dual-domain anomaly detection approach provides enhanced reliability and robustness by:

- Improving detection performance without increasing acquisition time, due to more precise net peak area estimation.
- Detecting inconsistencies such as non-representative background conditions (e.g., local environmental changes, not significant blank sample).
- Identifying possible contamination from isotopes other than I-131.

The ROI-specific analysis is particularly useful for detecting anomalies in the high-energy portion of the spectrum that could interfere with I-131 quantification. The total cps analysis, on the other hand, provides a global check across the entire spectrum, improving sensitivity to unexpected isotopes emitting at both low and high energies, which might have contaminated people or the environment.

This comprehensive background management system enhances both the analytical accuracy and situational awareness, especially in field scenarios where measurement conditions may rapidly change.

Energy Calibration

The THYMON system adopts an optimized calibration strategy specifically designed for rapid deployment and ease of use in emergency scenarios. Unlike traditional spectrometric systems that require sealed radioactive sources for calibration, THYMON is pre-configured to perform its energy calibration using a naturally radioactive potassium chloride (KCl) sample, supplied with the system. This reference material, weighing approximately 400 g and emitting ~15 Bq/g of K-40, allows the user to complete the calibration process without handling any regulated radioactive sources. This feature proves particularly advantageous in emergency contexts, where logistical, safety, or regulatory constraints might limit access to standard check sources.

The calibration routine is based solely on the detection of the K-40 peak at 1460.8 keV, significantly simplifying the procedure and reducing the risk of operator error. Even personnel with limited spectrometric experience can perform a reliable calibration, as the system automatically executes fits and calculates relevant quantities.

To maintain measurement stability over time and under varying environmental conditions, THYMON implements an advanced gain stabilization algorithm. This correction procedure is based on a Look-Up Table (LUT) derived during factory characterization and compensates for non-linearities and temperature-induced SiPM gain shifts. The LUT is built from experimental data collected across the full energy range, ensuring accurate peak alignment over the entire spectrum.

In addition, temperature-dependent gain drift is actively monitored and corrected in real time. This correction is based on a model derived from a dedicated thermal characterization campaign conducted in a certified climatic chamber (range -20 °C ÷ +50 °C). The system tracks temperature variations affecting the detector and associated electronics and applies dynamic adjustments to maintain spectral fidelity. Thanks to this real-time stabilization, recalibration during a measurement session is typically unnecessary, provided environmental conditions remain stable.

This combination of (1) calibration without sealed sources, (2) a simple, single-peak alignment routine, and (3) a robust software-based compensation mechanisms, ensures that the THYMON unit maintains high measurement reliability and stability with minimal user intervention.

Efficiency Calibration and Activity Determination

Activity calculation is based on detection efficiency functions obtained through detailed MCNP ([6],[7]) Monte Carlo simulations. The efficiency curves are specific to each of the five supported age groups (1, 5, 10, 15 years – adult female, and adult male), and account for detector geometry, collimation, source-detector positioning, and thyroid anatomy. Each efficiency function is embedded in the software and automatically selected based on the age category of the subject. The net peak count rate, together with the appropriate gamma emission yield and efficiency value, is used to compute the measured activity in the thyroid gland.

Thyroid phantom

To simulate thyroid contamination, a dedicated Monte Carlo model was developed. The model was derived from the pioneering mathematical description of Ulanovsky et al. ([8],[9]). This mathematical model is realistic, age-dependent – 1 yo, 5 yo, 10 yo, 15 yo (Adult Female), Adult Male – and has previously been adopted by the Medical Internal Radiation Dosimetry (MIRD) committee of the Society of Nuclear Medicine. The model was recently compared and validated in international inter-comparison studies of age-dependent thyroid phantoms for thyroid monitoring in radiological

[6] *Online: https://mcnp.lanl.gov (accessed on March 10, 2023).*
[7] *Online: http://www.mcnpvised.com/visualeditor/visualeditor.html (accessed on March 10, 2023).*
[8] *ULANOVSKY, A. & ECKERMAN, K. 1998. Absorbed fractions for electron and photon emissions in the developing thyroid: foetus to five years old. Radiat Prot Dosimetry, 79, 419-23.*
[9] *ULANOVSKY, A., MINENKO, V. & KORNEEV, S. 1997. Influence of measurement geometry on the estimate of ^{131}I activity in the thyroid Monte Carlo simulation of a detector and a phantom. Health Physics, 72, 34-41.*

emergencies ([10]) and by comparison with dedicated experimental measurement and physical thyroid phantoms.

The source term was modelled as volumetric and isotropic, uniformly dispersed in thyroid. The hypothesis of homogeneous dispersion is adopted following the IDEAS guidelines ([11],[12]) (the IDEAS guidelines have been widely adopted internationally as the basis for internal dose assessment). The volume of the thyroid model was derived following the guidelines from ICRP Publication 71 ([13]).

The model was validated against age-dependent physical neck and thyroid phantoms ([14]) filled with a mixture of Ba-133 (~90%) and Cs-137 (~10%), mimicking the presence of I-131 in thyroid. The following figure shows the comparison between the reference and measured activity. Results show good agreement for all age groups.

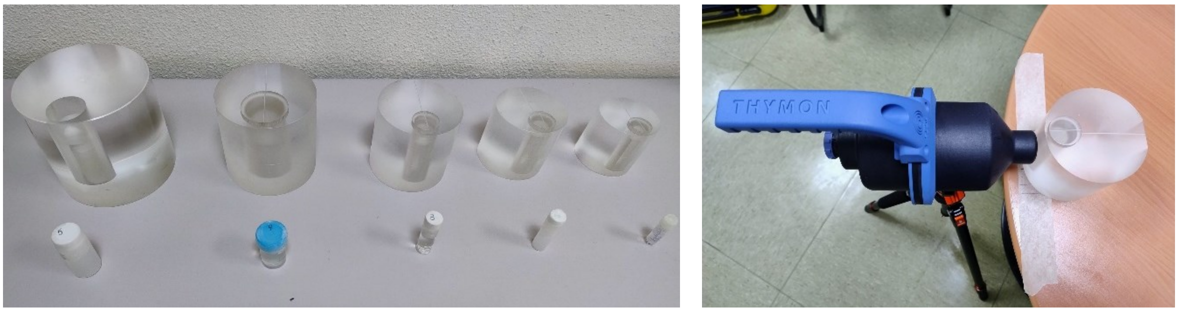

Figure A.1: Experimental setup of the validation experiment

[10] ULANOVSKY, A., MINENKO, V. & KORNEEV, S. 1997. Influence of measurement geometry on the estimate of ^{131}I activity in the thyroid Monte Carlo simulation of a detector and a phantom. Health Physics, 72, 34-41.

[11] Doerfel, H. et al. General Guidelines for the Estimation of Committed Effective Dose from Incorporation Monitoring Data. Report FZKA 7243, Forschungszentrum Karlsruhe, GmbH (2006).

[12] Castellani, C. M., Marsh, J. W., Hurtgen, C., Blanchardon, E., Berard, P., Giusani, A. and Lopez, M. A. IDEAS Guidelines (Version 2) for the Estimation of Committed Doses from Incorporation Monitoring Data. EURADOS Report 2013-01 (2013).

[13] ICRP, 1995. Age-dependent Doses to Members of the Public from Intake of Radionuclides - Part 4 Inhalation Dose Coefficients. ICRP Publication 71. Ann. ICRP 25 (3-4).

[14] B Pérez López, J F Navarro, M A López, METHODOLOGY AT CIEMAT WHOLE BODY COUNTER FOR IN VIVO MONITORING OF RADIOIODINE IN THE THYROID OF EXPOSED POPULATION IN CASE OF NUCLEAR EMERGENCY, Radiation Protection Dosimetry, Volume 182, Issue 2, December 2018, Pages 171–176, https://doi.org/10.1093/rpd/ncy045.

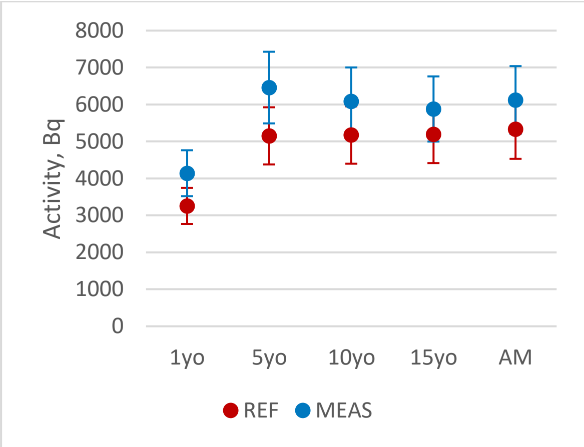

Figure A.2: Results of the experiment

Calculation of Minimum Detectable Activity (MDA)

The determination of the MDA is a fundamental aspect of the system's performance characterization and quality assurance, particularly in emergency monitoring scenarios where accurate low-level measurements are essential. The MDA defines the lowest level of thyroidal I-131 activity that the system can reliably distinguish from background, under predefined confidence levels and measurement conditions.

THYMON calculates the MDA based on the recommendations of IEC 61582 and by referencing the ISO 11929-1 framework for decision thresholds and detection limits. The MDA is computed starting from the Low Limit of Decision Threshold (LLD) and is determined from the relationship:

$$MDA = \frac{LLD}{\epsilon}$$

Where ϵ is the efficiency of detection for the measurement of I-131 in thyroid, expressed in count-rate per unit of activity (Bq). The detection efficiency is derived from age-specific Monte Carlo models.

LLD is determined by the relation stated in ISO 11929-1:

$$LLD = \frac{1}{2 \cdot t_0} \cdot k_{1-\alpha}^2 [1 + \sqrt{1 + \frac{4 \cdot R_b t_0}{k_{1-\alpha}^2} \cdot (1 + \frac{t_0}{t_b})}]$$

where

- R_b is the background count rate;
- t_0 is the measuring time;
- t_b is the background measuring time;
- $k_{1-\alpha}$ are the quantiles of the standard normal distribution.

For the purposes of meeting the requirements of IEC 61582, $k_{1-\alpha}$ is taken such as there is a 1% risk of activity indicated when in fact there is no activity present (false positive probability equal to 1%).

The implementation ensures that the MDA is continuously updated and displayed to the operator for every measurement, reflecting actual acquisition parameters and background levels. If background subtraction is enabled, the algorithm further reduces the MDA by enhancing the signal-to-noise ratio through optimized spectral filtering and anomaly detection routines.

Moreover, the MDA estimation process in THYMON is compliant with IEC 61582, which requires the characterization of the MDA for each target radionuclide under realistic background and measurement time conditions. In practical terms, the system reaches an MDA as low as 100 Bq of I-131 in less than 2 minutes under background levels of approximately 100 nSv/h, ensuring timely and sensitive screening in field conditions.

The calculated MDA values are also valuable for emergency decision-making, as they help determine whether a measurement is actionable or falls below the system's threshold of detection. This functionality directly supports triage operations and early protective action decisions in the event of radiological exposure.

DOCUMENT REVISION TABLE		
REV. #	**DATE**	**REVISION OBJECT**
00	29/07/2025	First emission
01	30/09/2025	Paragraph 3.2.2 revision
02	11/11/2025	General revision (technical data)

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