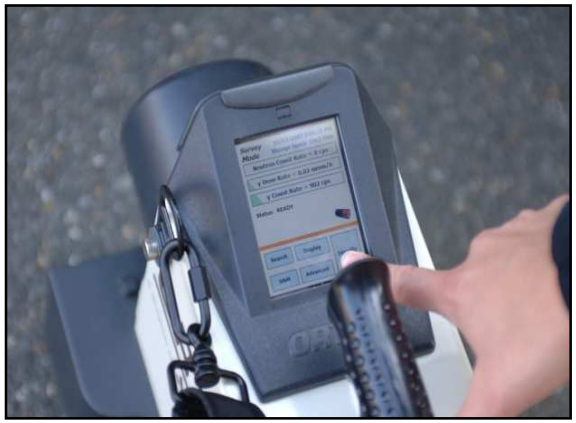
Radioactive Material Identification



Objective

Provide emergency responders advanced training on the ORTEC Detective to acquire high quality spectral data for radioactive material identification

Note: DOE will provide 2-3 Detectives for the course. Each Detective control display will be projected on a large screen to ensure maximum observation and participation by all students. If the host Competent Authority has access to additional Detectives, it would benefit having them in class enabling more hands-on training opportunities for the students.

Reason for Identification

Why conduct radionuclide identification?

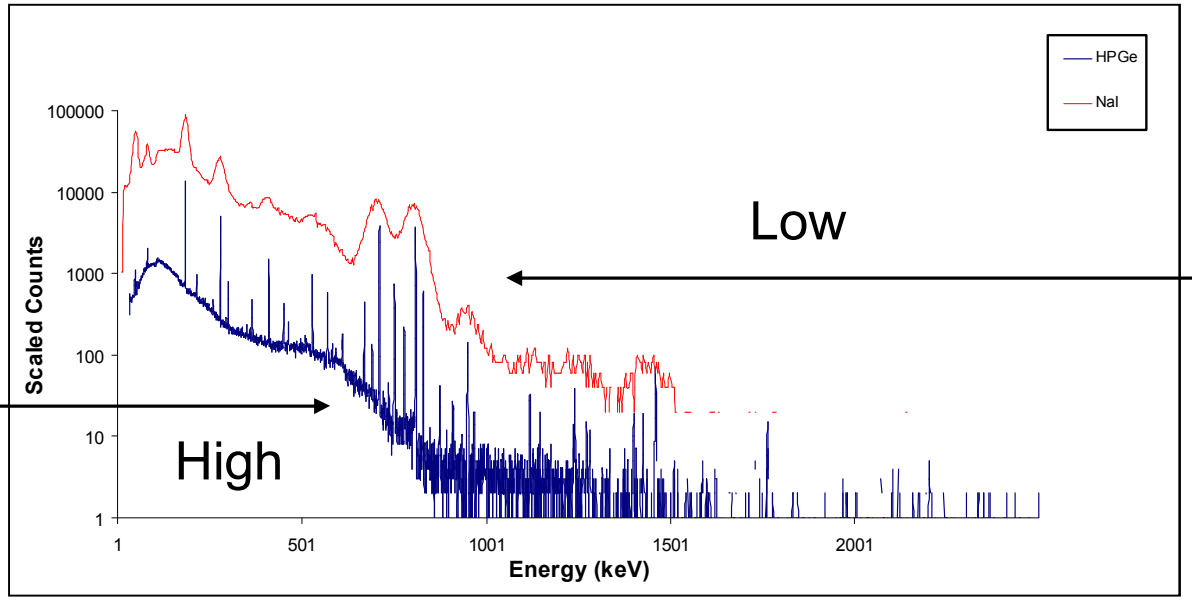
- To identify the radioisotope(s) causing the alarm
- To aid in law enforcement investigation and alarm adjudication
- To determine if cargo is consistent with the manifest
- To provide responders better understanding of potential hazard
- To allow responders to take appropriate protective actions
- To aid in law enforcement forensics investigations
- To aid in planning source recovery operations

Radioisotope Identification

High Resolution vs Low Resolution Gamma Spectroscopy

Resolution - "ability to resolve adjacent gamma peaks"

HPGe



NaI

High Purity Germanium (HPGe) is the *Gold Standard* for radioisotope identification

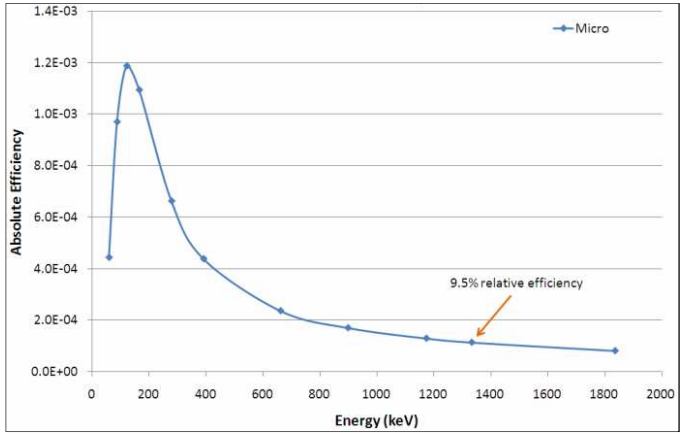
Detective-EX

ORTEC™ Detective-EX Specifications

Gamma – HPGe crystal (15% efficiency)[1]
- 5 cm diameter x 3 cm high

Gamma - Geiger-Mueller tube
Neutron - four ^{3}He tubes
- 10 cm x 1.2 cm diameter; 20 atm pressure
- Embedded in high density polyethylene

Multi-Channel Analyzer (MCA) – 8k channels
Cooler - low power Stirling type
Temperature - less than -245 F (-154 C)
Cool down time - 12 hrs
Internal 12 volt battery - 3 hrs duration

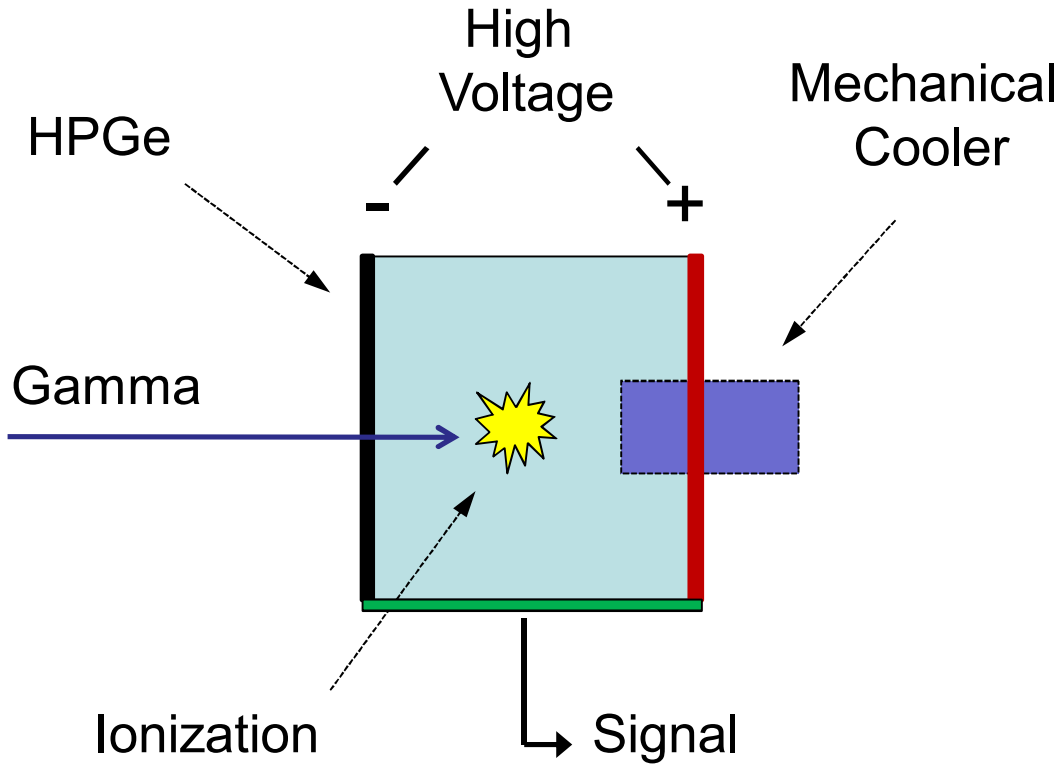


Size - 37 cm x 18 cm x 34 cm
Weight - 11.75 kg

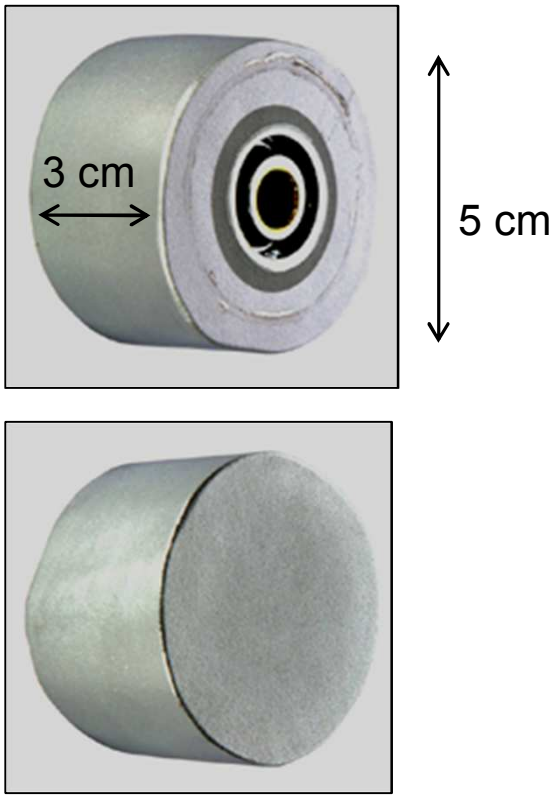
[1] *Industry standard is to report the HPGe detection efficiency as compared to a 7.6 cm x 7.6 cm sodium iodide detector for the ^{60}Co 1332 keV gamma at 25 cm.*

High Purity Germanium (HPGe)

Schematic of a typical detector

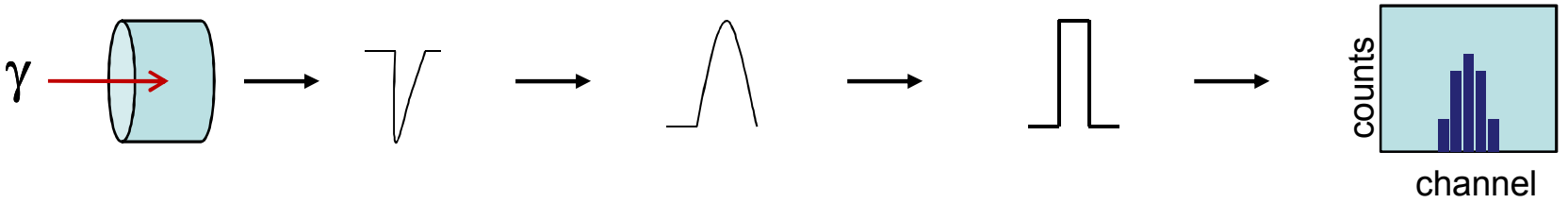


HPGe crystal

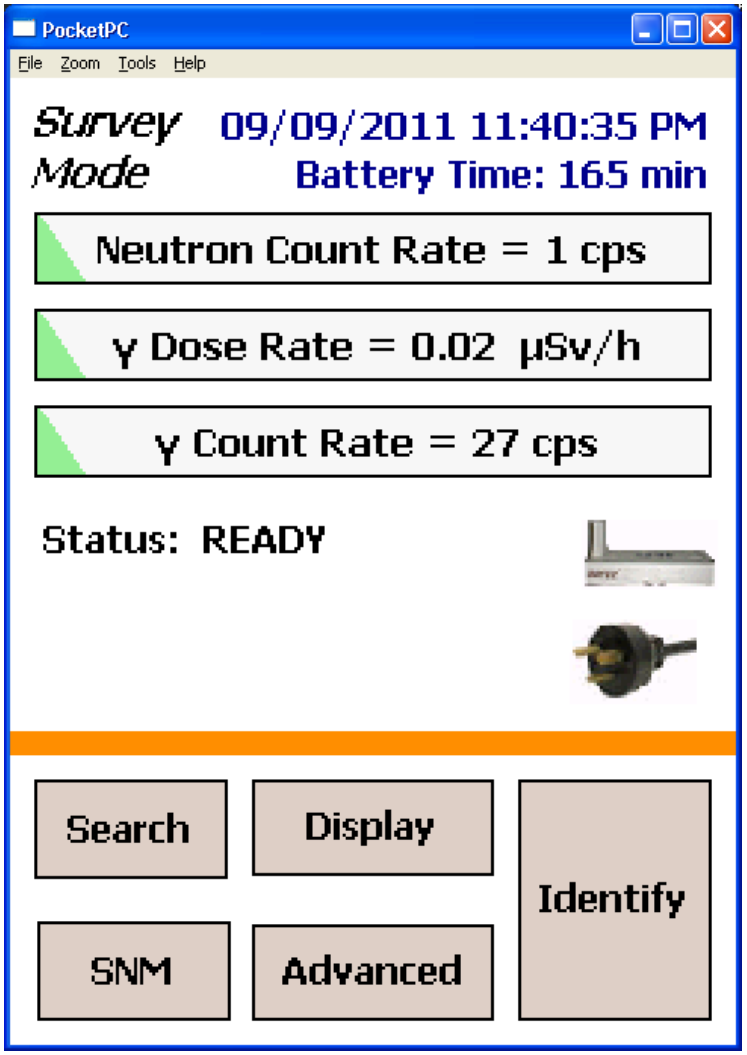


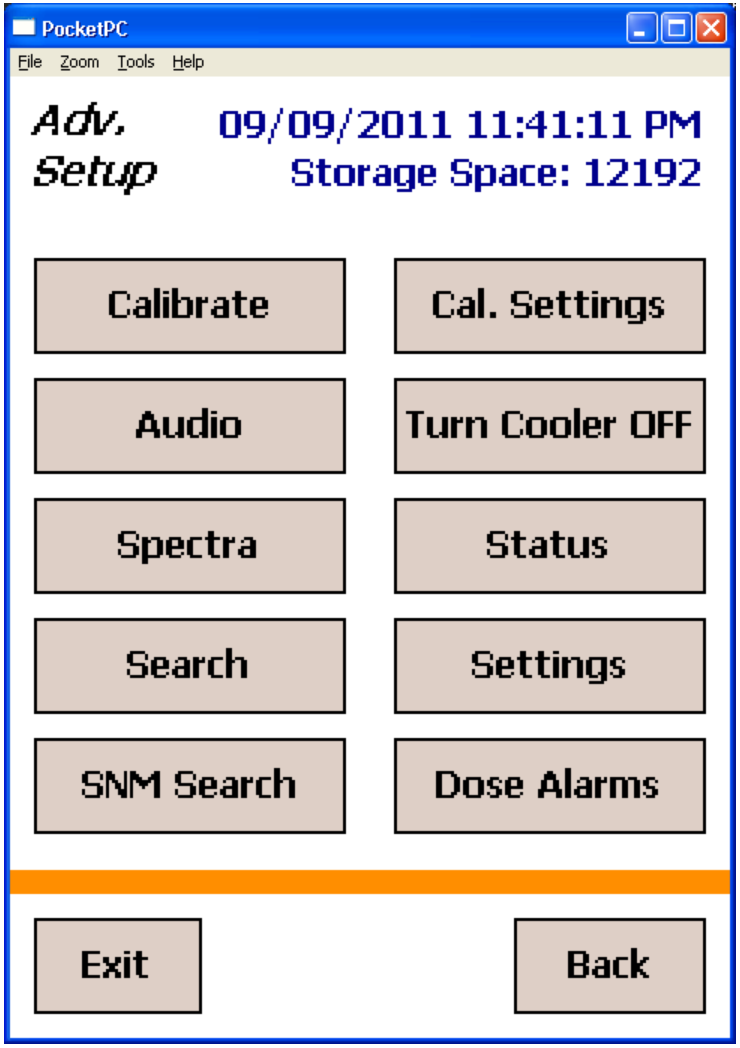
Electronics

Signal processing steps

HPGe Detector	Pre-Amplifier	Amplifier	Analog-to-Digital Converter (ADC)	Multi-Channel Analyzer (MCA)
				
Gamma interacts in detector producing ionizing charge	Charge is collected and converted to a fast negative millivolt analog signal	Analog signal is amplified to 0-8 volts and given positive unipolar shape and 2-6 microsecond width	Amplified analog signal is converted to digital signal	Digital signal is sorted into “bins” or channels based on pulse height (i.e. voltage) and displayed as a gamma spectrum

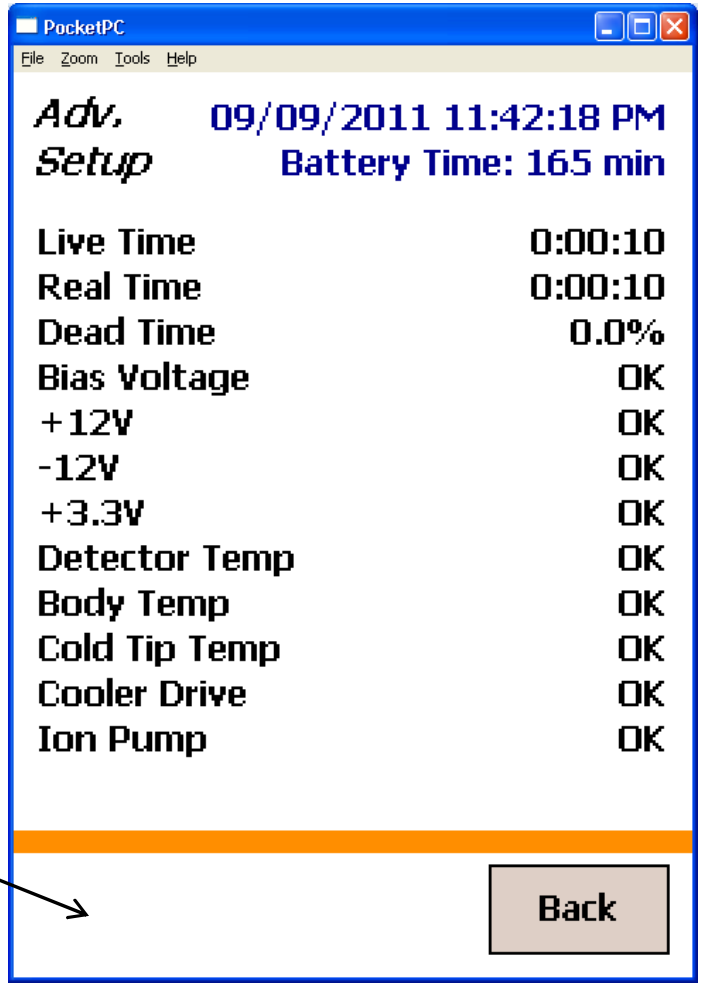
Main Window/Advanced Setup



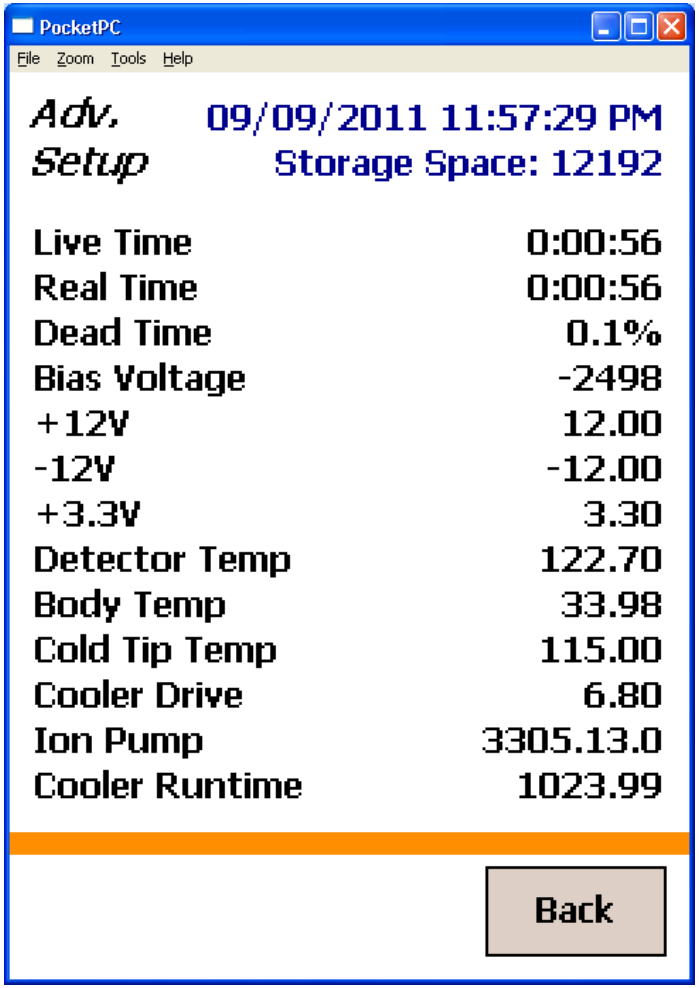


Operating Status Windows

Double click bottom left corner for system parameters



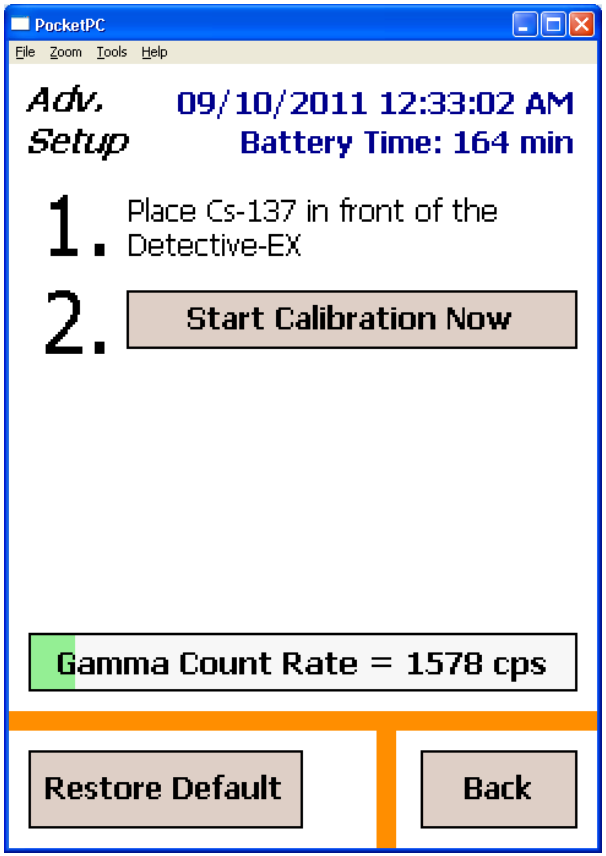
System Status



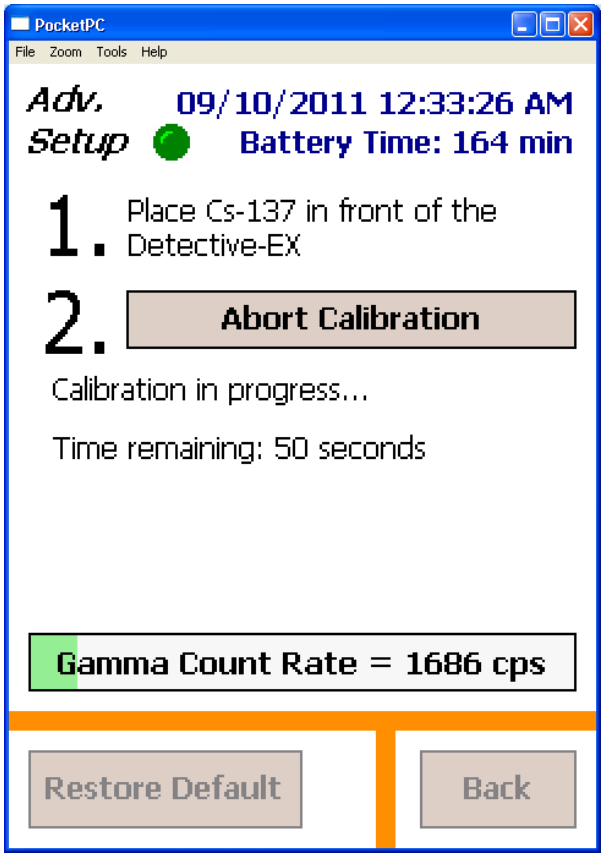
System Parameters

Calibration

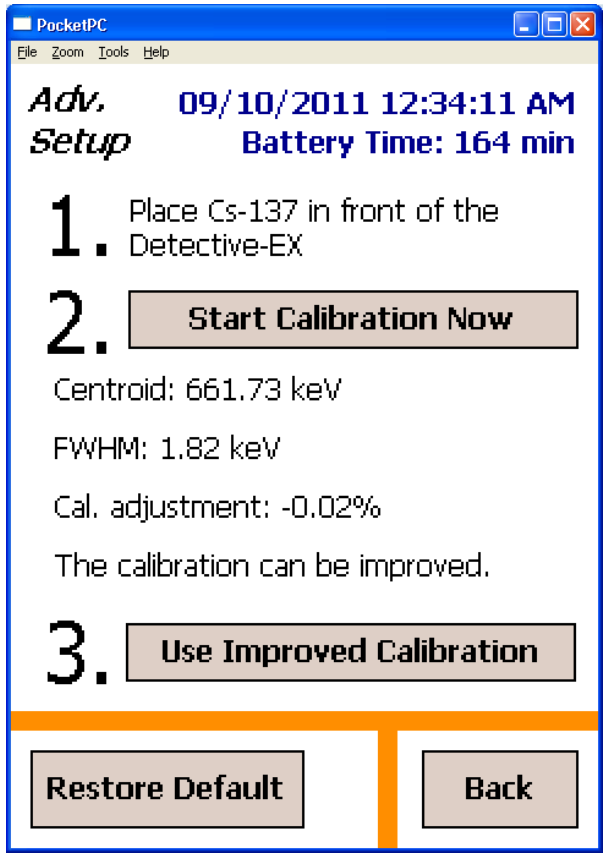
Three Step Process



Step 1



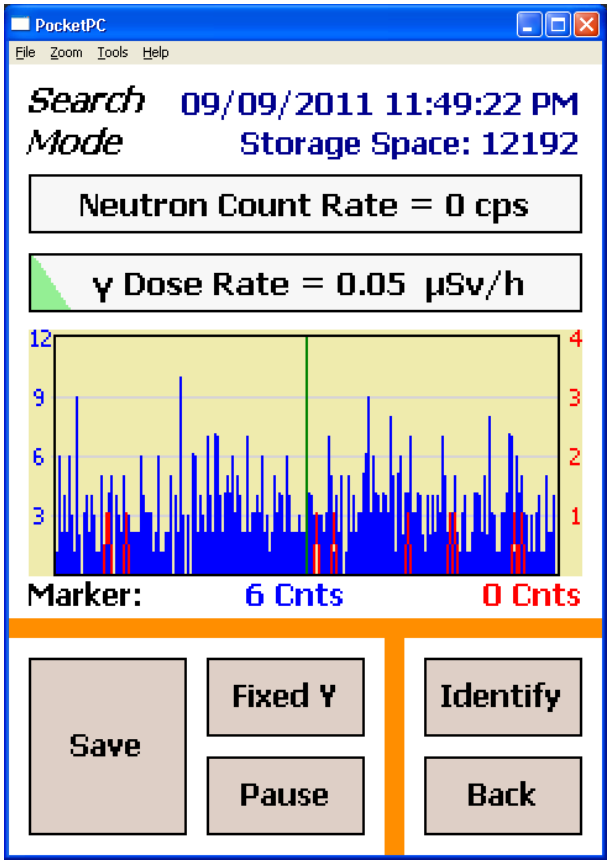
Step 2



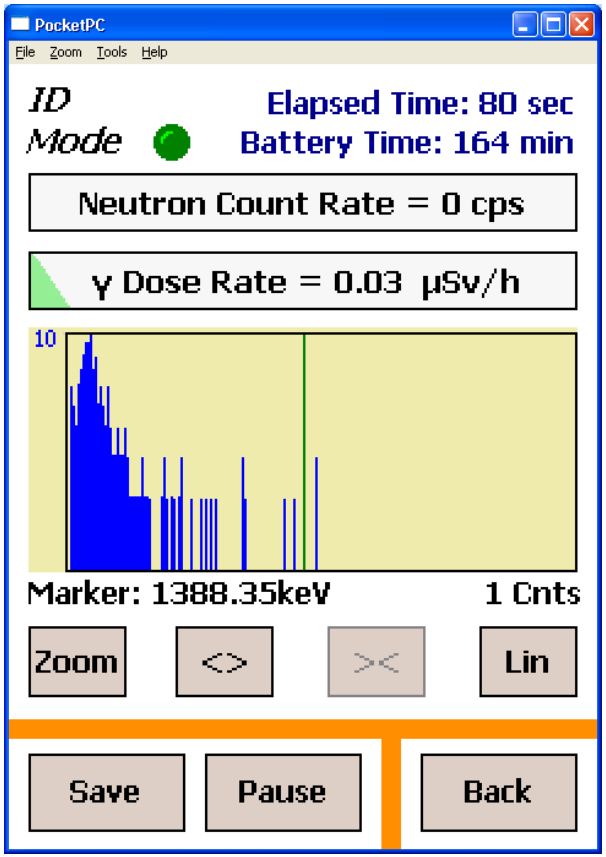
Step 3

Modes

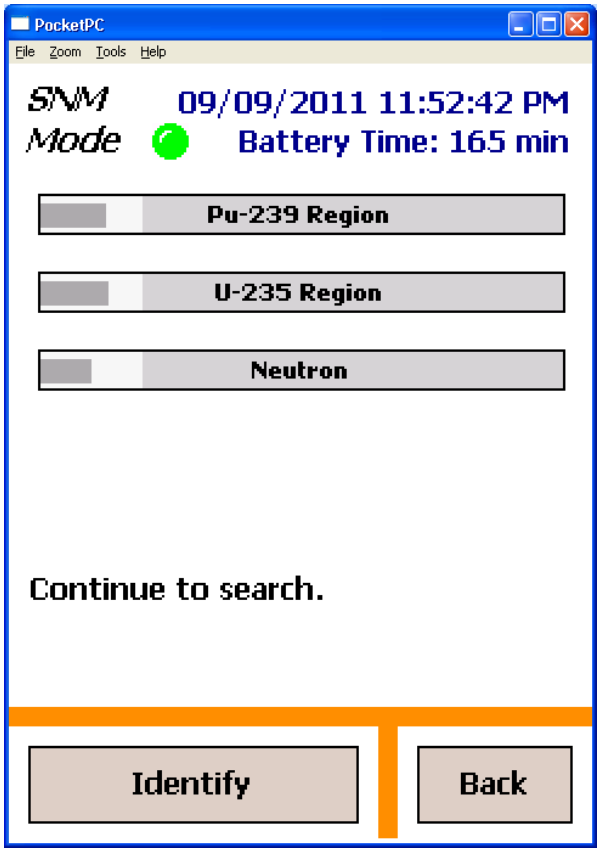
Search, ID and SNM Modes



Search

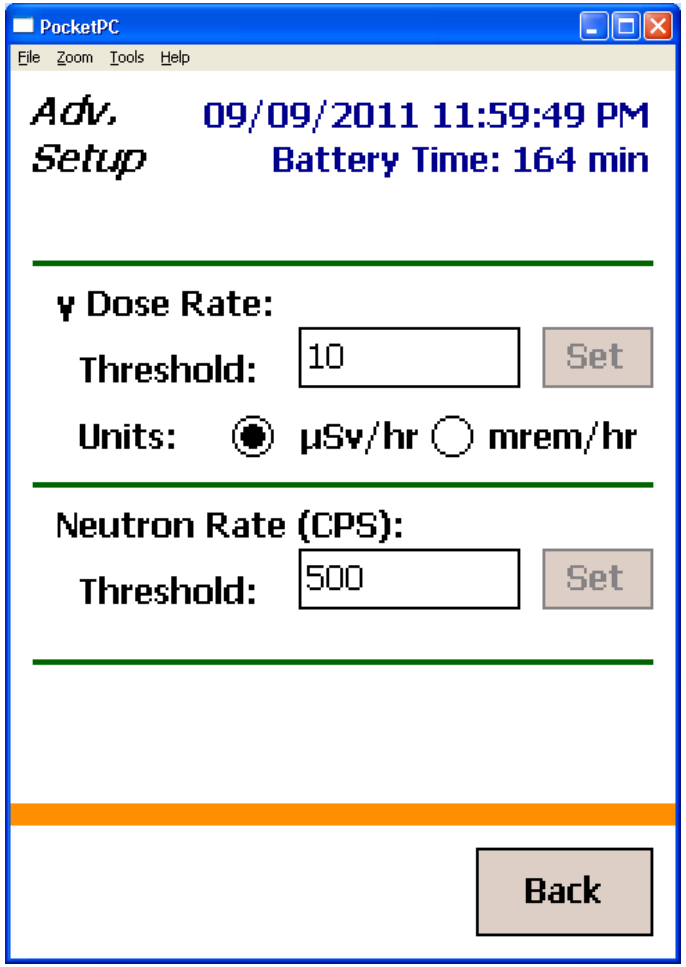


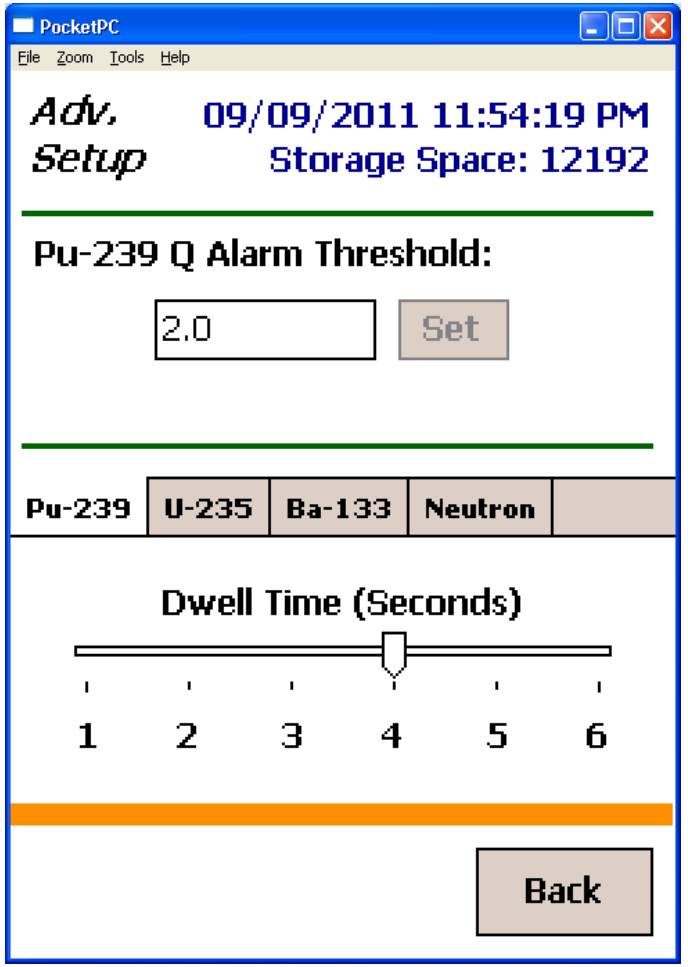
ID
"Identification"



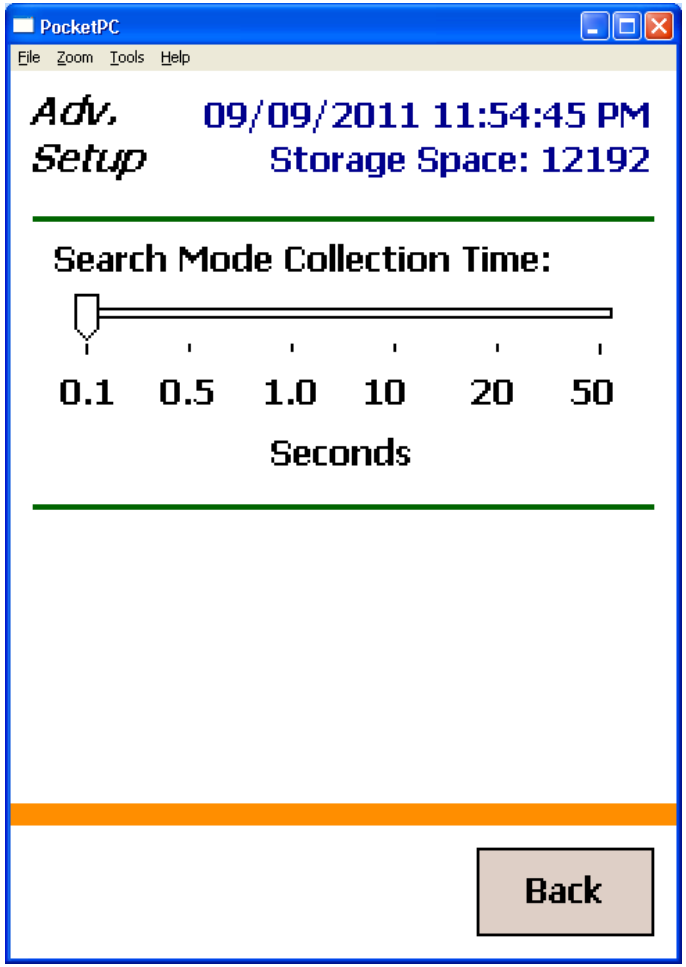
SNM
"Special Nuclear Materials"

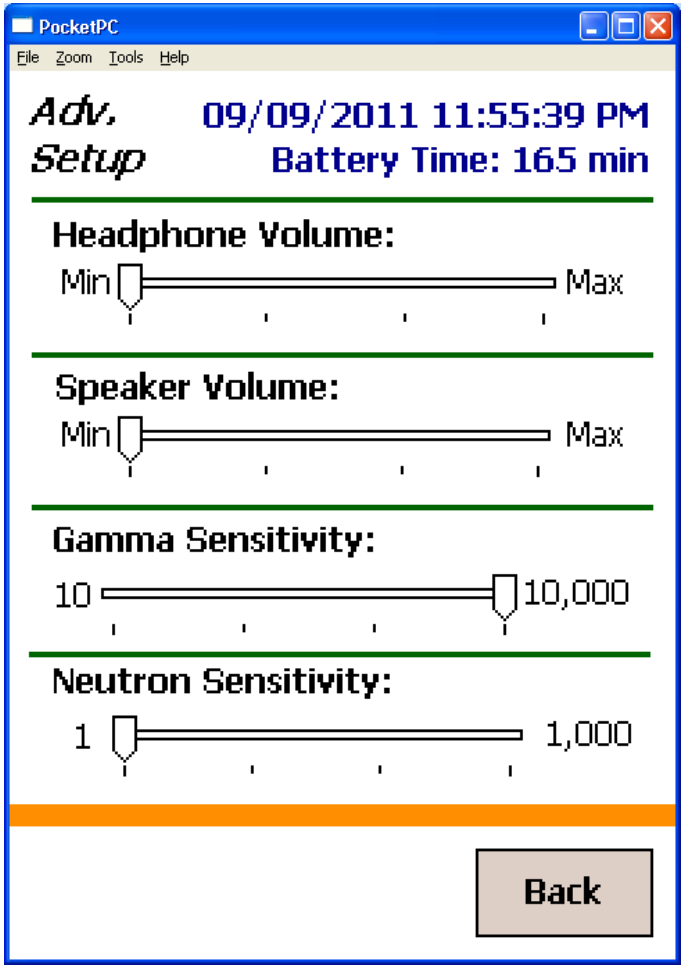
Advanced Setup Screens



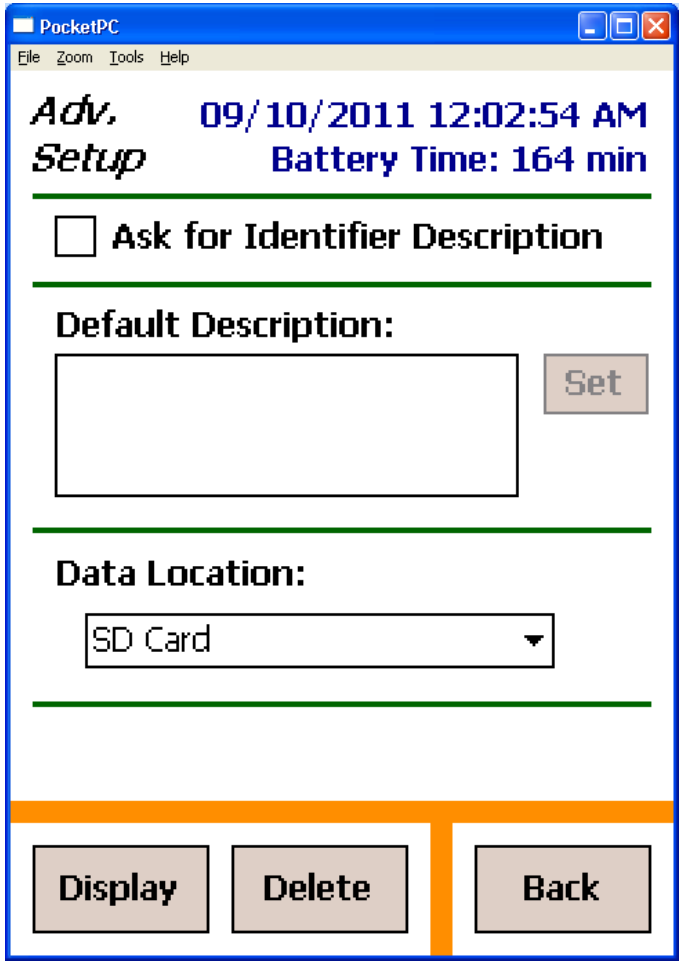


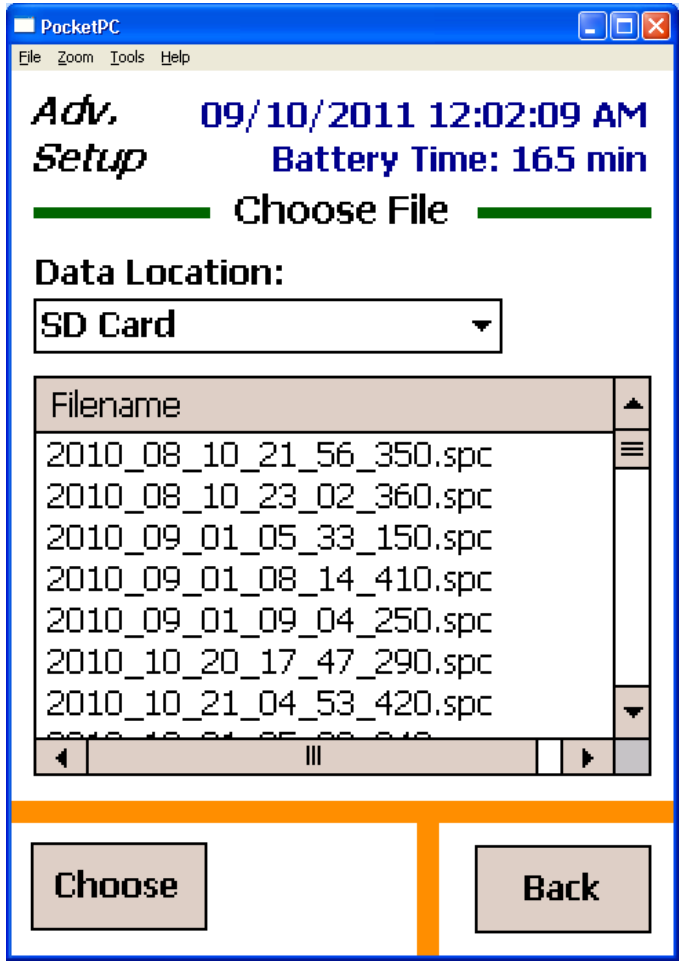
Advanced Setup Screens



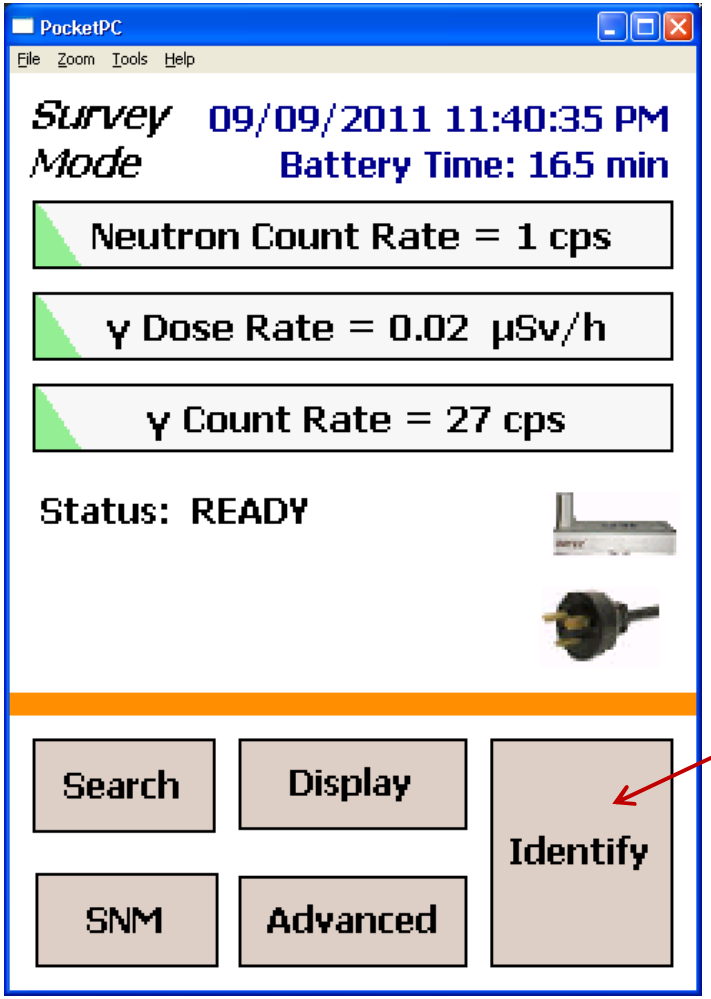


Advanced Setup Screens





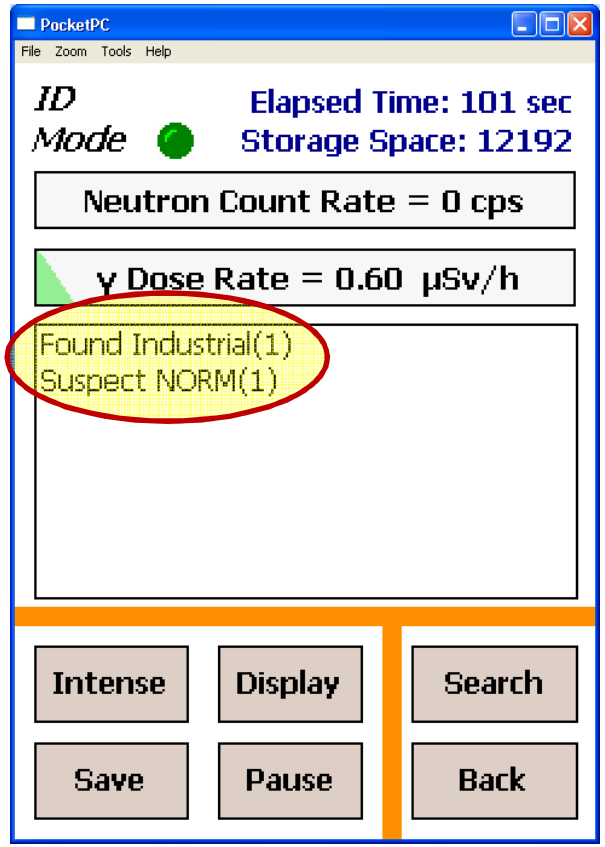
Collecting a Spectrum



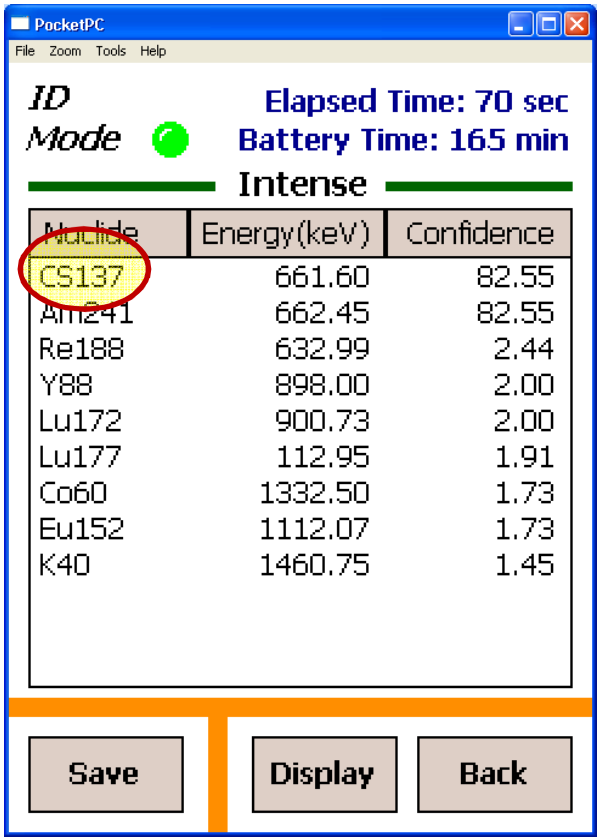
To collect a gamma spectrum, click on **Identify**

Cesium-137 (^{137}Cs)

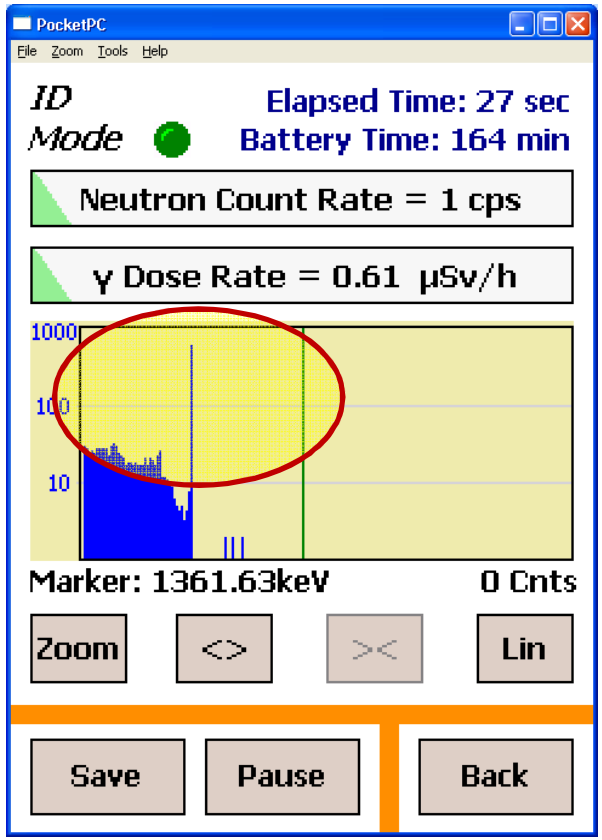
Three screens are available to monitor the data



Primary screen



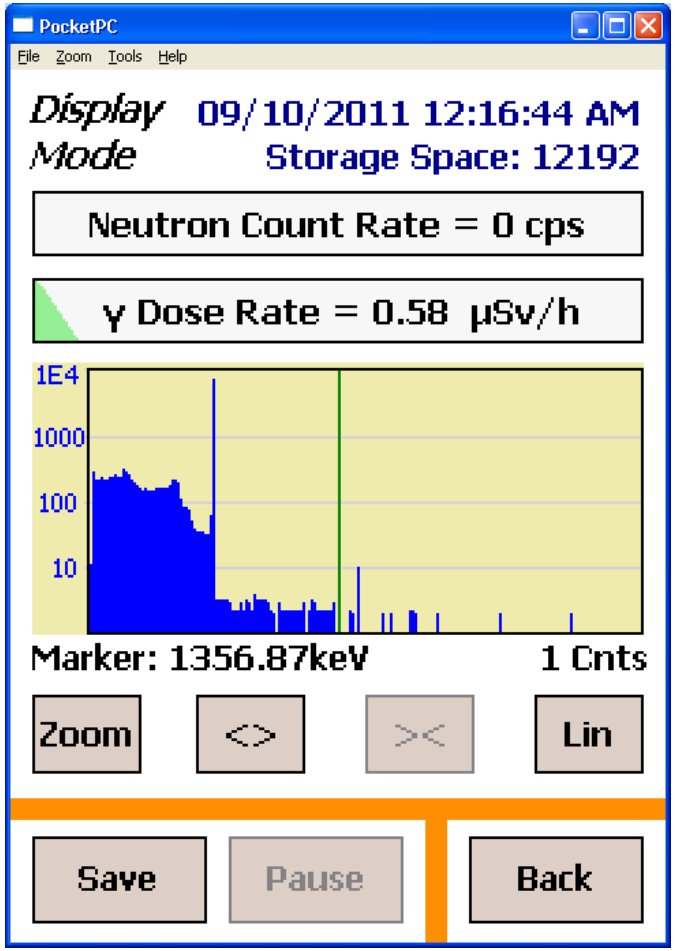
Intense screen



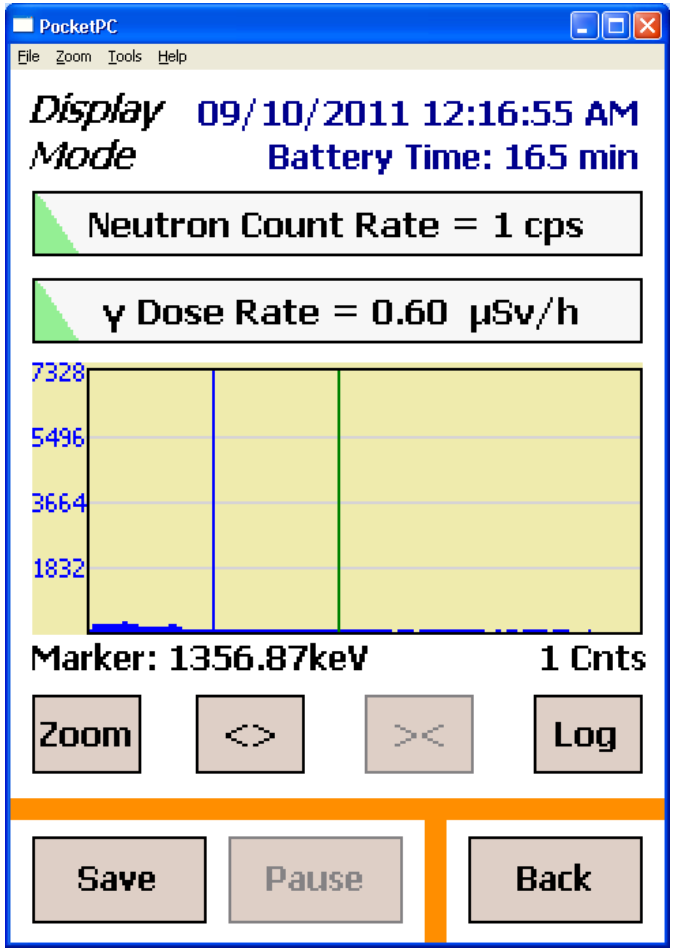
Display screen

Logarithm vs Linear Y-Axis

Log →



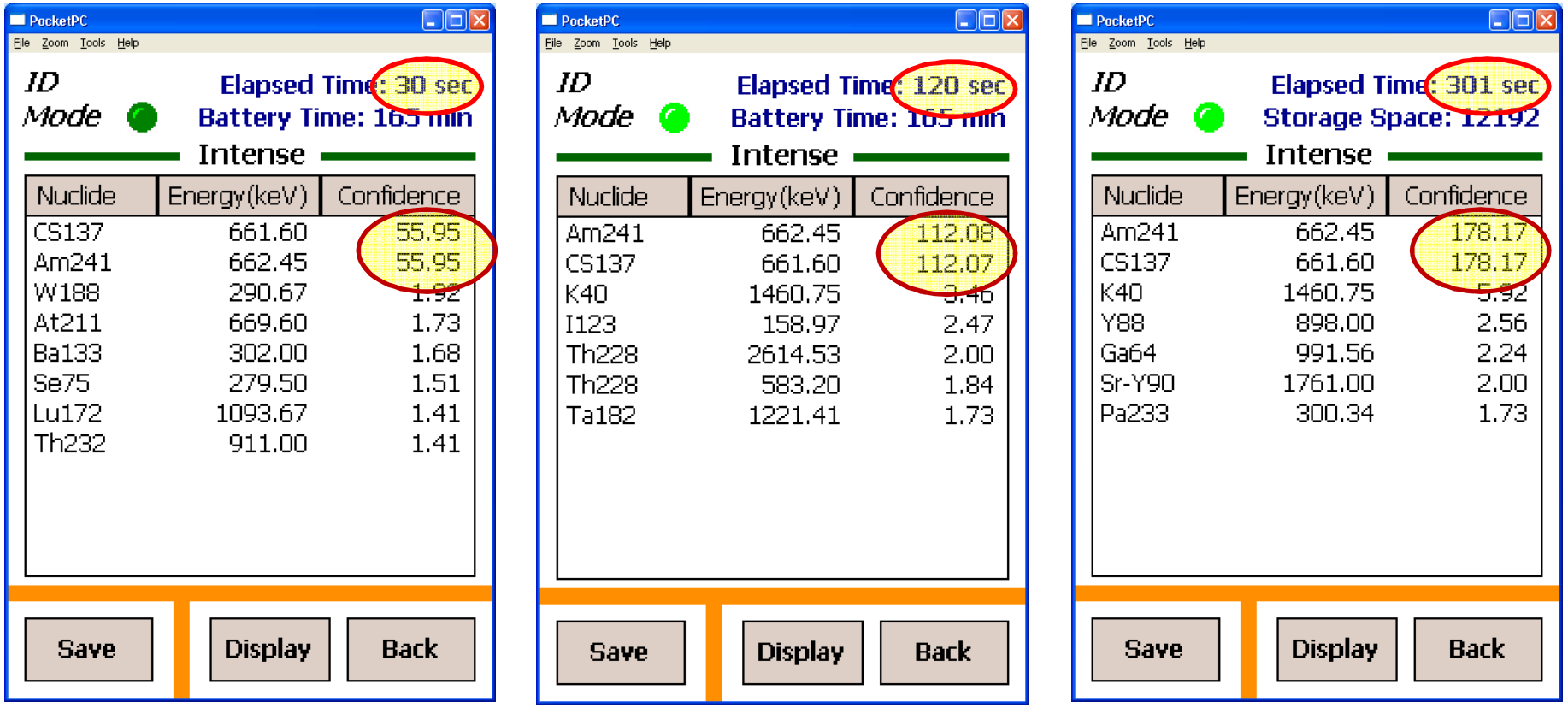
← Lin



Log scale provides "best" overall view of spectrum

Confidence Levels

Longer Collection Times = Higher Confidence



Recommend collecting data for 300 seconds (5 minutes)

Radioisotope Library

Detective has a library *"look-up"* table with up to 80 radioisotopes and hundreds of gamma-rays

Am241	Cf252-249	Sn113	Ga64*
Cs137	Ba133	Sr-Y90	Gd153*
Co60	Shielded	Tc99M	Gd159*
Co57	Ba133	Ga67	Pa233*
Mn54	Bi207	Cu64	Tl208*
Th228	Ta182	I123	Ho166m*
Th232	Ho166	I131	Pd103*
Eu152	Ir194	Xe131M	Au198*
K40 >NORM	Ir192	Xe133	Sm153*
K40	Po210	Xe135	Lu177*
Np237	Positron	Ra226	Shielded
Y88	emitter	I125	Lu177*
TL201	In111	At211	Lu172*
TL200	La140(FP)	Br76	W188*
TL202	Mo99	Cr51*	Re188*
TL204	Mo + Tc99M	Eu155*	Se75*
Co56	Na22	Eu156*	U233*
SrRb82	Pu239	Fe59*	U235
U238			

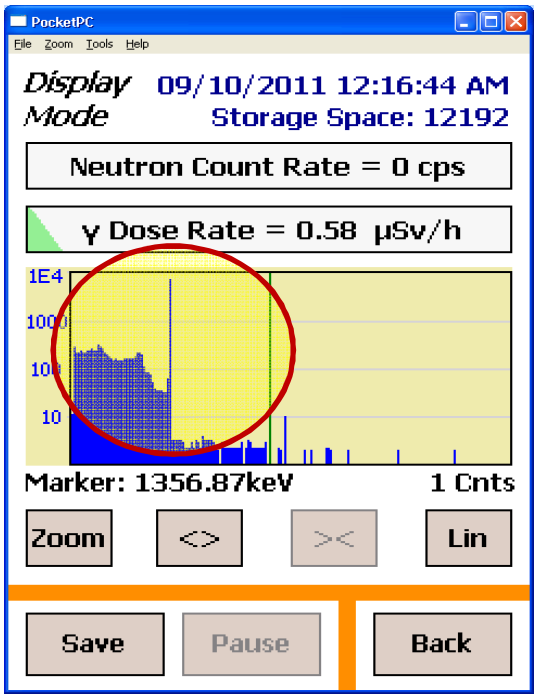
Radioisotopes in library

524.40	Pu-233	1.300000e-003
529.87	I-133	8.630000e-001
534.80	Pu-233	9.000000e-003
535.20	N-18	2.850000e-002
536.09	I-130	9.900000e-001
537.32	Ba-140	2.500000e-001
549.70	Rn-220	1.000000e-003
558.80	Pu-233	2.700000e-003
560.13	Pu-245	5.440000e-004
569.31	Cs-134	1.543000e-001
572.90	U-242	3.600000e-001
583.10	Tl-208	8.420000e-001
583.14	Th-232	3.083000e-001
583.30	Pu-233	8.600000e-004
585.00	U-242	3.700000e-001
600.56	Sb-125	1.780000e-001
602.71	Sb-124	9.787000e-001

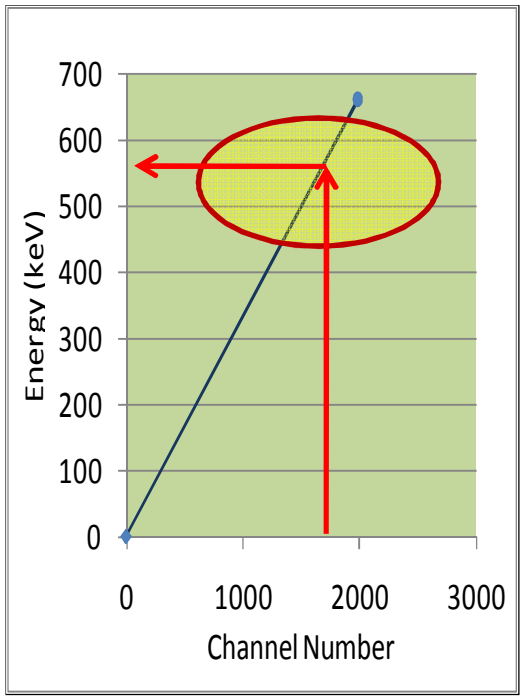
Look-up table is a spreadsheet with radioisotope data

Radioisotope ID

How does a Detective identify a radioisotope?



Algorithm finds strongest peak(s) in spectrum



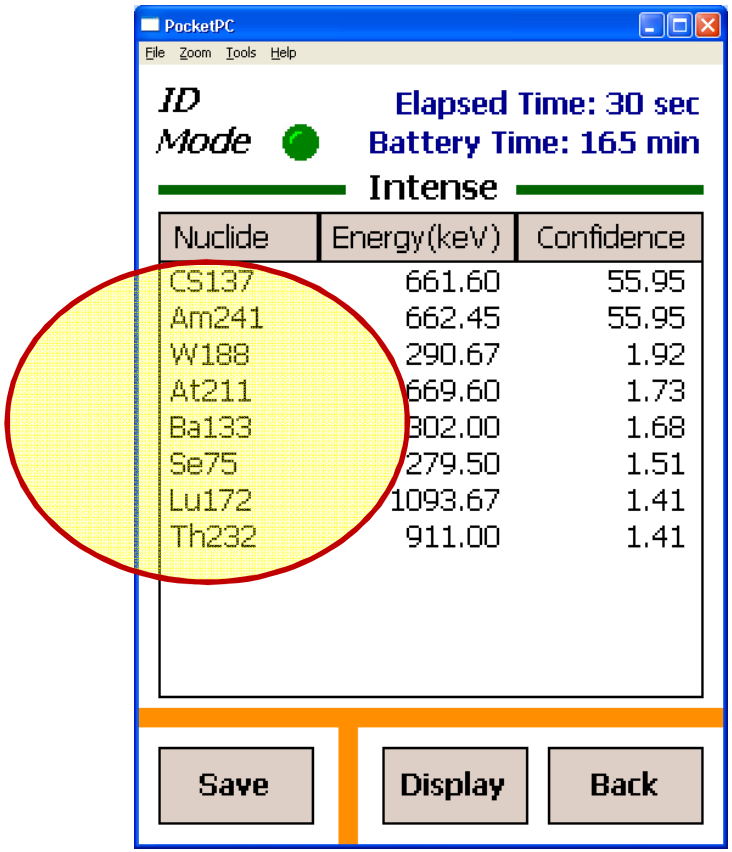
Energy is determined from calibration

524.40	Pu-233	1.300000e-003
529.87	I-133	8.630000e-001
534.80	Pu-233	9.000000e-003
535.20	N-18	2.850000e-002
536.09	I-130	9.900000e-001
537.32	Ba-140	2.500000e-001
549.70	Rn-220	1.000000e-003
558.80	Pu-233	2.700000e-003
560.13	Pu-245	5.440000e-004
569.31	Cs-134	1.543000e-001
572.90	U-242	3.600000e-001
583.10	Tl-208	8.420000e-001
583.14	Th-232	3.083000e-001
583.30	Pu-233	8.600000e-004
585.00	U-242	3.700000e-001
600.56	Sb-125	1.780000e-001
602.71	Sb-124	9.787000e-001

Energy is "looked-up" in library to find radioisotope

Radioisotope ID

Why does it identify so many radioisotopes?

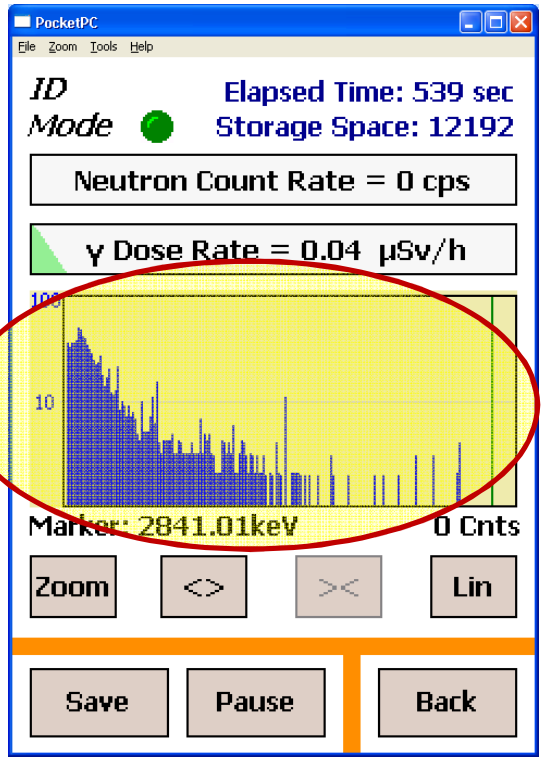


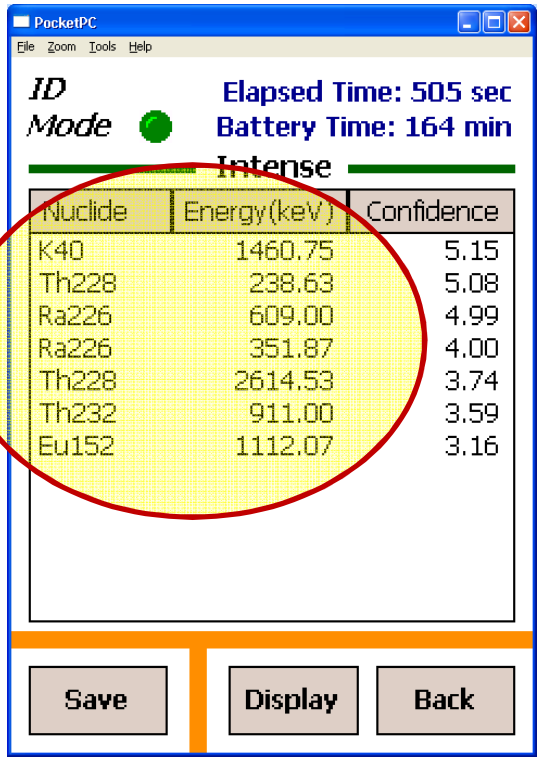
The look-up table has a large number of radioisotopes which have similar gamma energies

524.40	Pu-233	1.300000e-003
529.87	I-133	8.630000e-001
534.80	Pu-233	9.000000e-003
535.20	N-18	2.850000e-002
536.09	I-130	9.900000e-001
537.32	Ba-140	2.500000e-001
549.70	Rn-220	1.000000e-003
558.80	Pu-233	2.700000e-003
560.13	Pu-245	5.440000e-004
569.31	Cs-134	1.543000e-001
572.90	U-242	3.600000e-001
583.10	Tl-208	8.420000e-001
583.14	Th-232	3.083000e-001
583.30	Pu-233	8.600000e-004
585.00	U-242	3.700000e-001
600.56	Sb-125	1.780000e-001
602.71	Sb-124	9.787000e-001

Radiation Background

What does the radiation background look like?

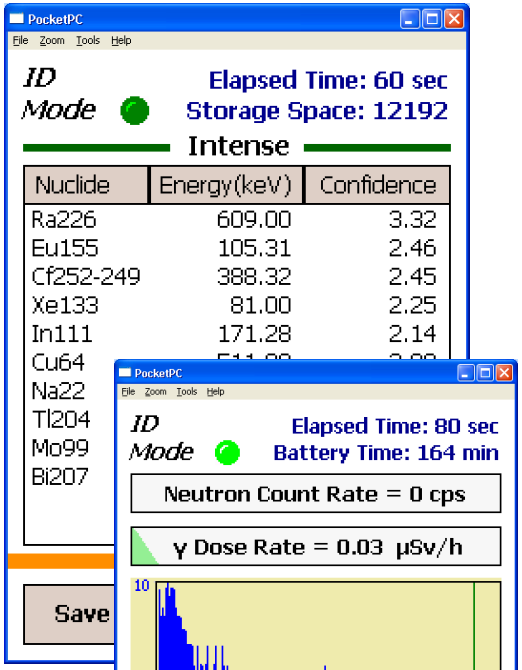


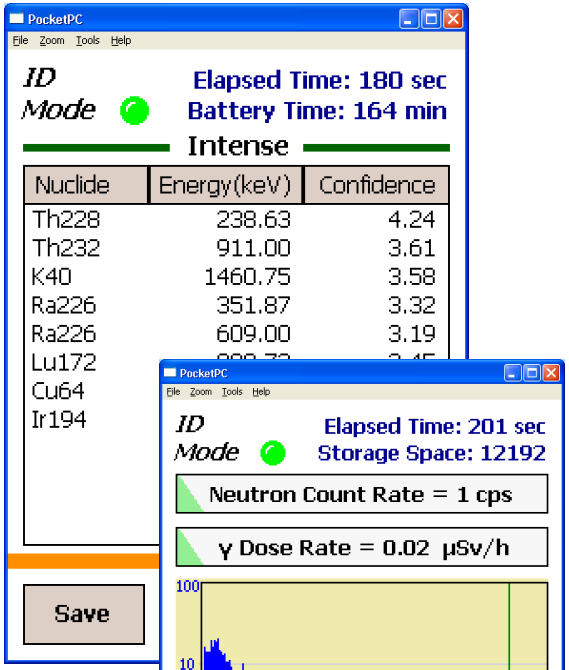


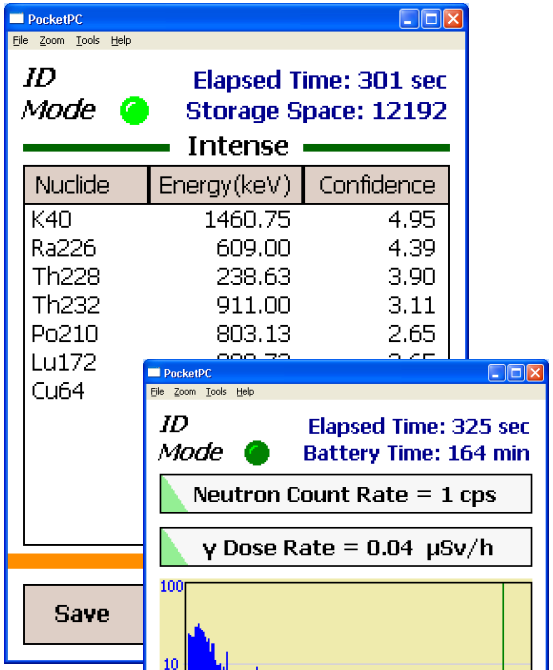
The natural radiation background is complex containing minute quantities of radioactive isotopes of ^{40}K, ^{238}U and ^{232}Th and their decay products

Radiation Background

It can take 300 seconds or more to identify the background





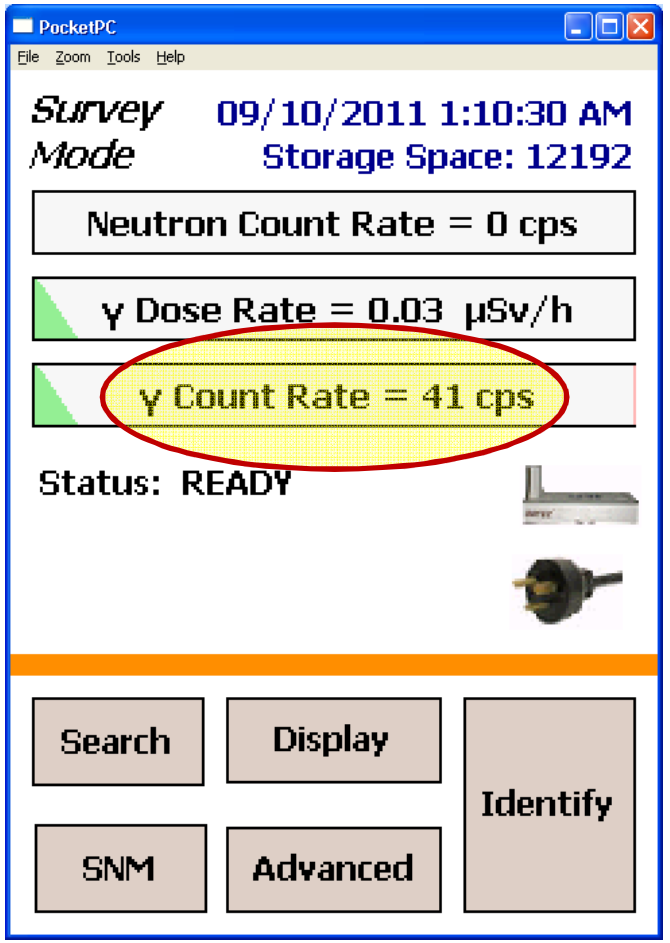


Radiation Background

Quality Control

A good quality control check of the Detective is to know the *gamma count rate per second (cps) at 1 meter* with no source present at your equipment staging location.

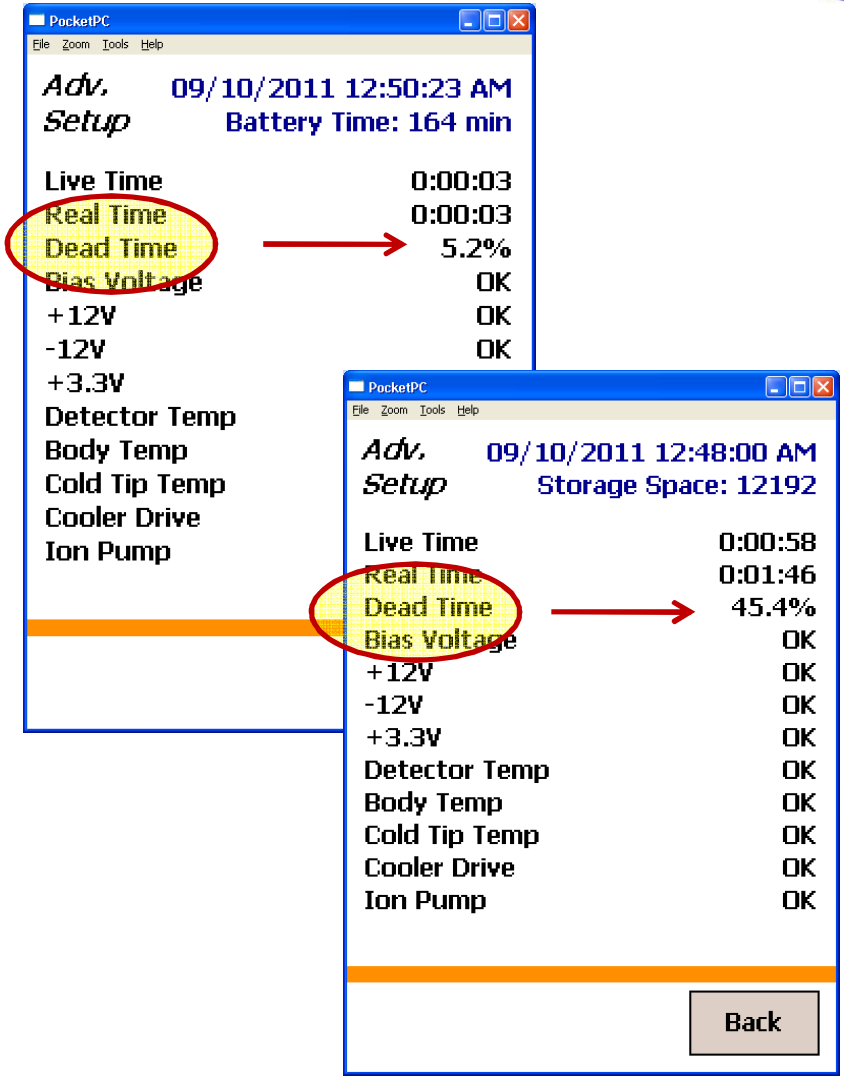
Before taking the Detective out for a measurement, verify the background gamma count rate.



What is Dead Time?

Dead time is the time in which the detector electronics cannot process the incoming data correctly (i.e. too much data coming in too fast). This results in a distorted spectrum with broadened peaks and electronic pile-up producing artificial summed peaks. If dead time is high, then you are too close to the source.

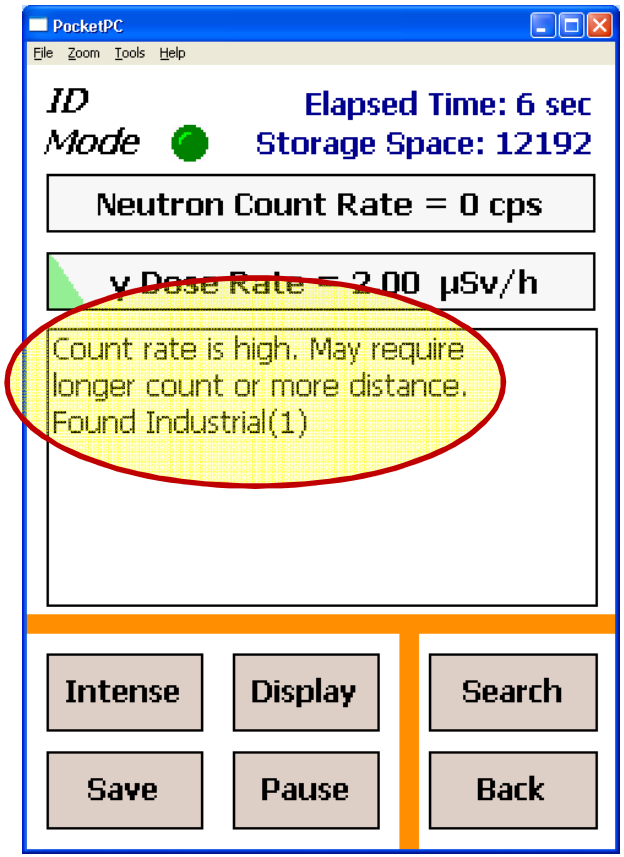
Keep dead time less than 5% by moving away from source



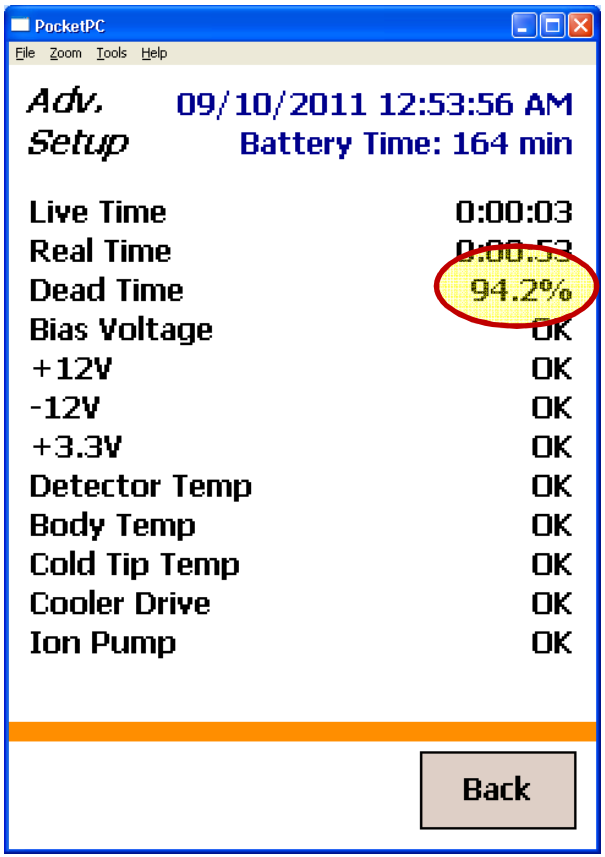
High Count Rate Warnings

Three ways to tell if count rate is too high

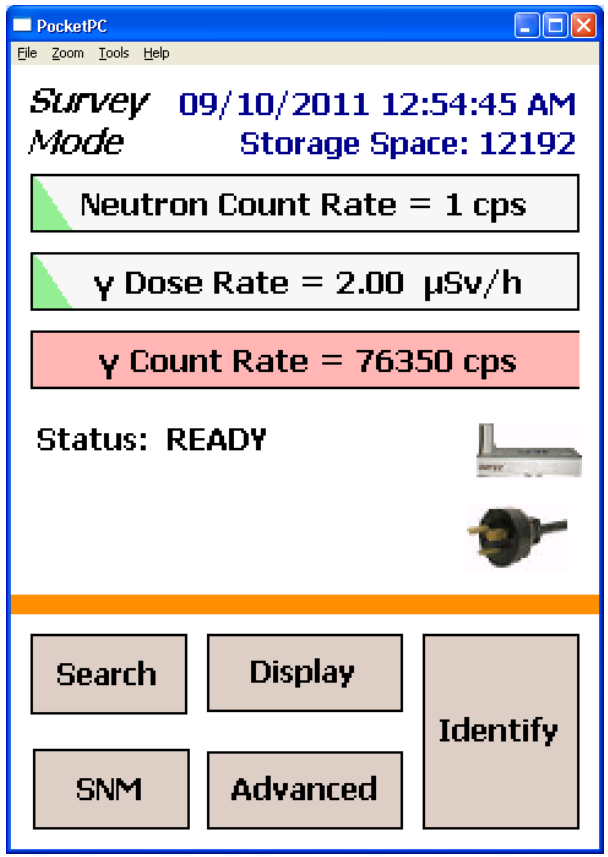
Text Warning



High Dead Time



Flashing Red Banner

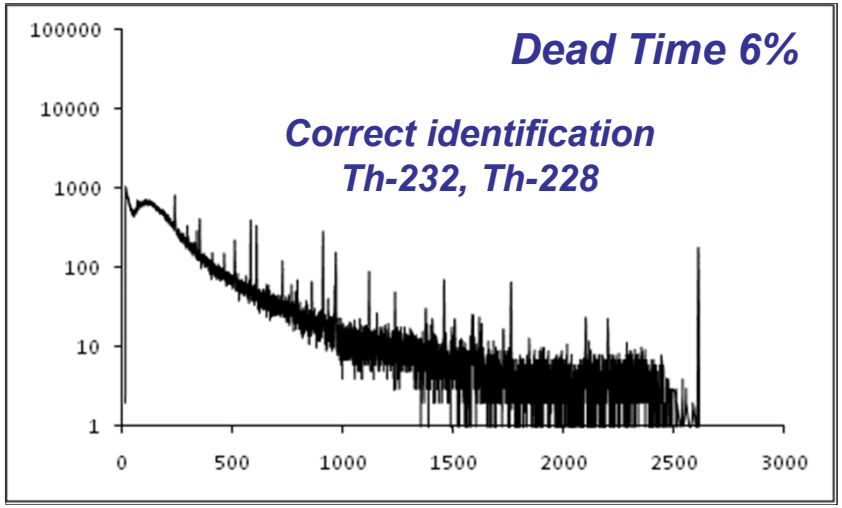


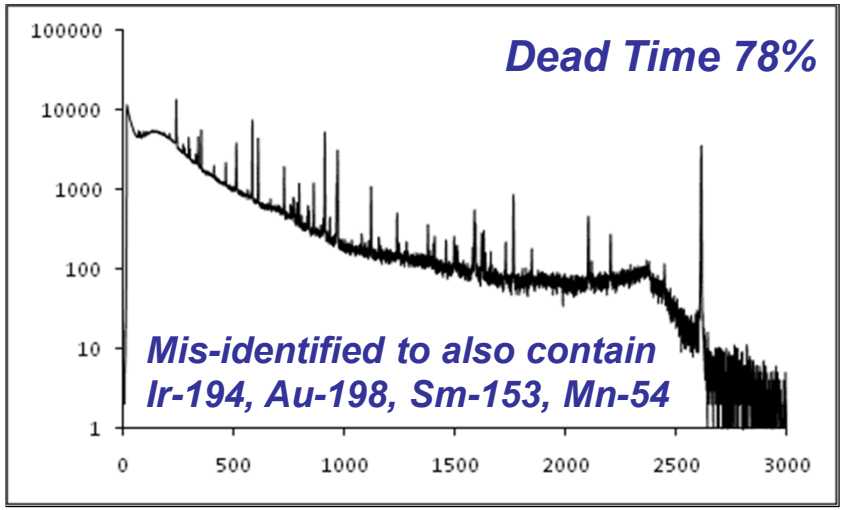
Dead Time Example

A cargo container filled with NORM can produce a ***radiation field*** significantly above background but still safe to ship

These radiation fields can cause the ***dead time*** of the detector to be quite high requiring measurements to be taken from over 10 m away

High ***dead time*** can produce artificial peaks in the gamma spectrum resulting in mis-identification

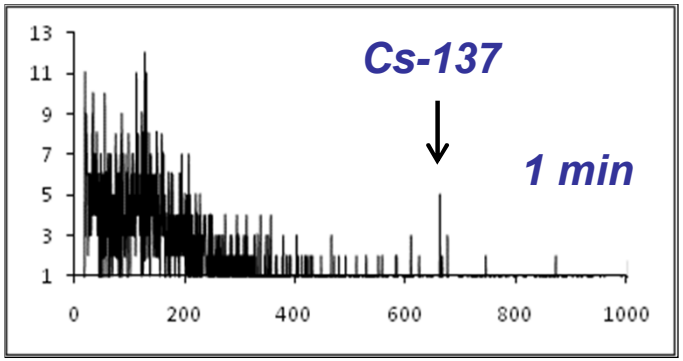




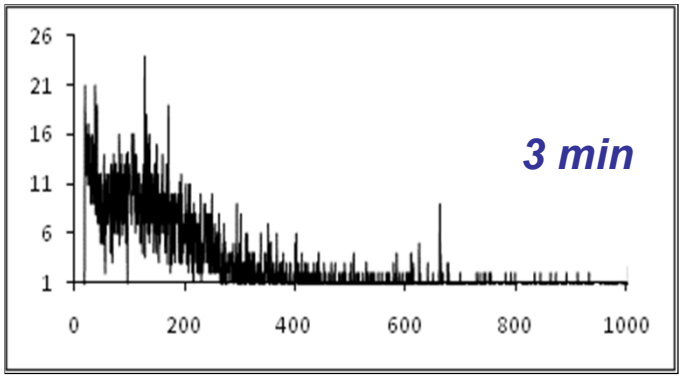
Lesson Learned - Embedded Source

If a RIID is too close to the Detective during a measurement, then the ^{137}Cs calibration source in the RIID can be detected

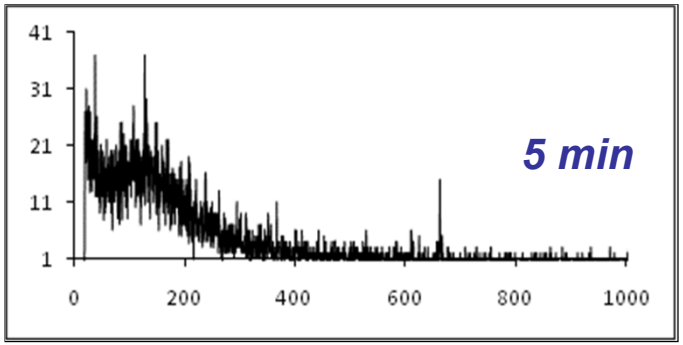
Keep RIID at least 5 meters away from Detectives



Background



Suspect: Cs-137



Found: Cs-137

Radioisotope Examples

The following section includes examples of Detective screen displays for some of the most common industrial radioisotopes:

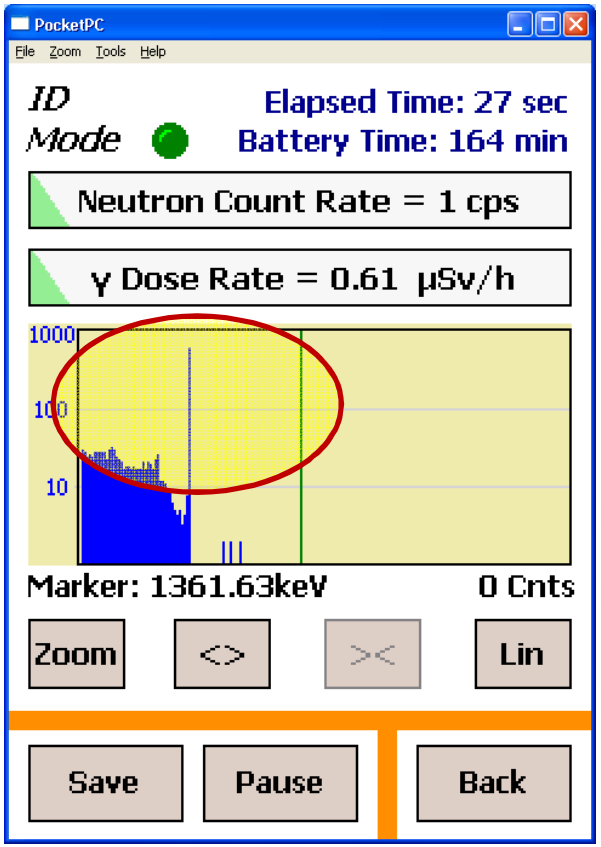
Cesium-137	(^{137}Cs)
Cobalt-60	(^{60}Co)
Bismuth-207	(^{207}Bi)
Sodium-22	(^{22}Na)
Americium-241	(^{241}Am)
Europium-152	(^{152}Eu)
Barium-133	(^{133}Ba)

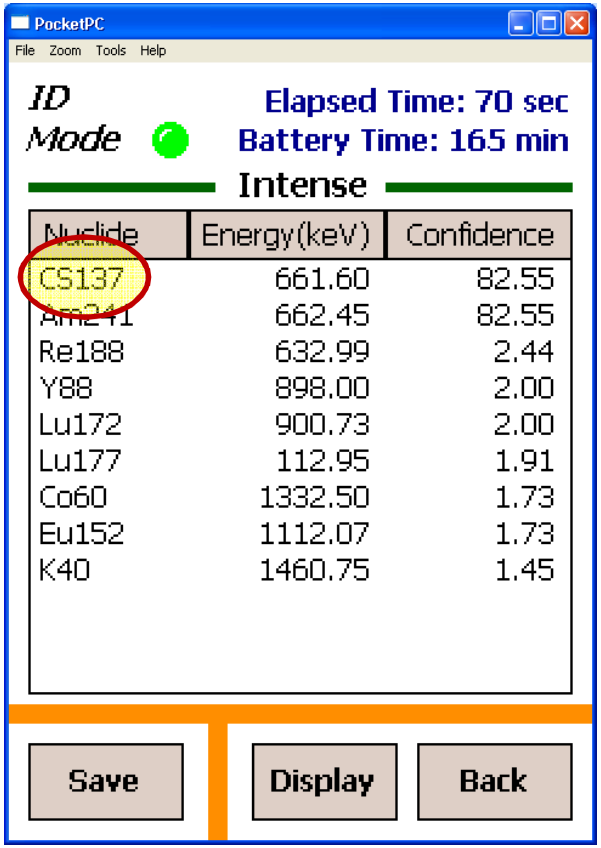
Quick Reference (most common in red)

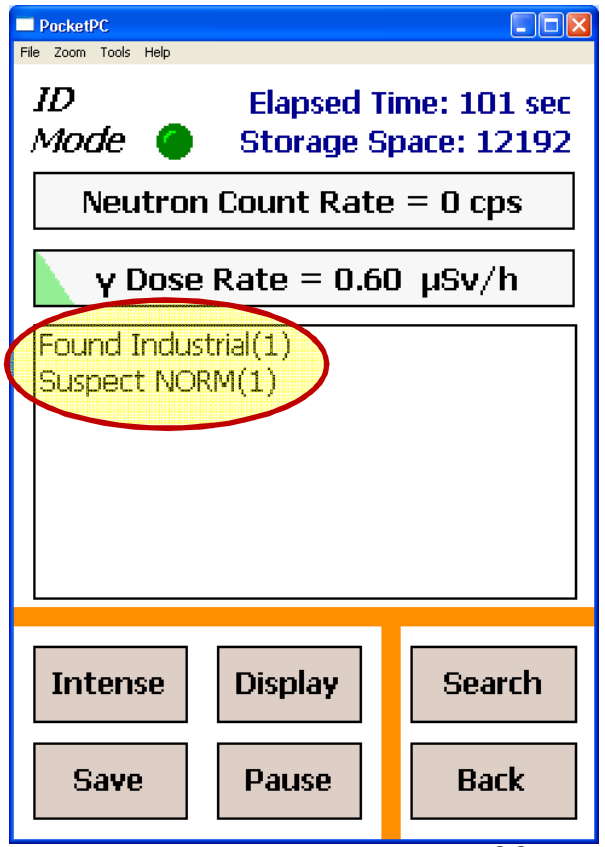
Industrial	**^{137}Cs, ^{60}Co, ^{192}Ir**, ^{241}Am, ^{57}Co, ^{133}Ba, ^{78}Se
Medical	**^{99m}Tc, ^{201}Tl, ^{131}I**, ^{19}F, ^{67}Ga, ^{111}In, ^{123}I, ^{133}Xe
Natural (NORM)	**^{40}K, ^{232}Th, ^{238}U**
Nuclear	**^{235}U, ^{239}Pu**, ^{237}Np, ^{233}U

Cesium-137 (^{137}Cs)

^{137}Cs has a gamma-ray at 661.6 keV and is an industrial source

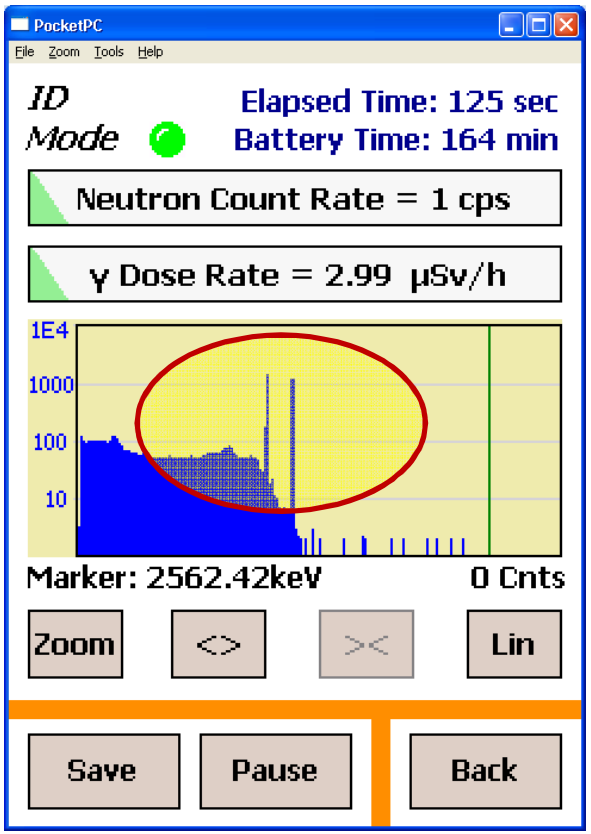


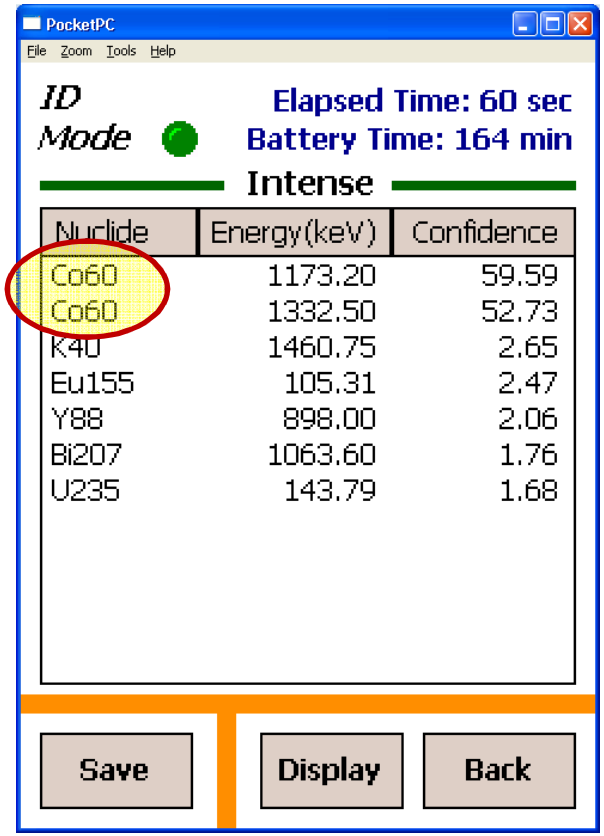


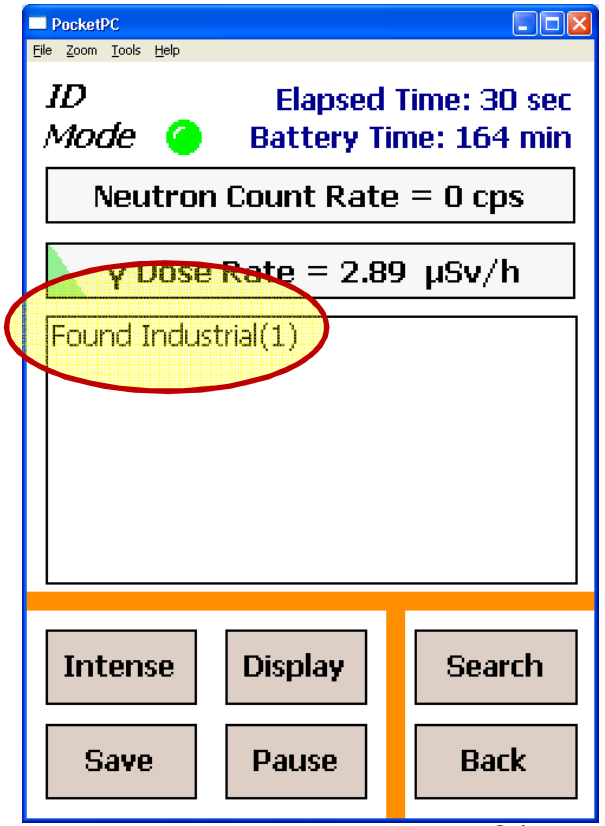


Cobalt-60 (^{60}Co)

^{60}Co has gamma-rays at 1173.2 and 1332.5 keV and is an industrial source

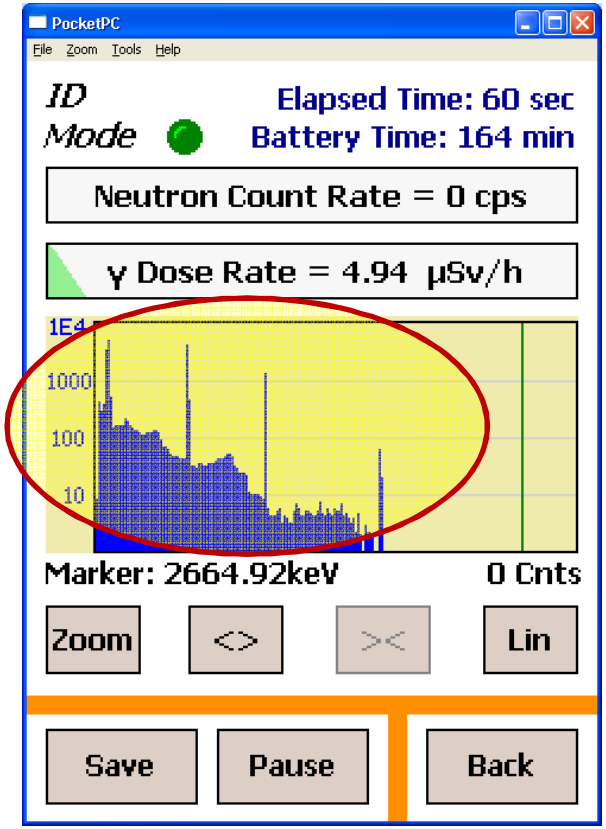


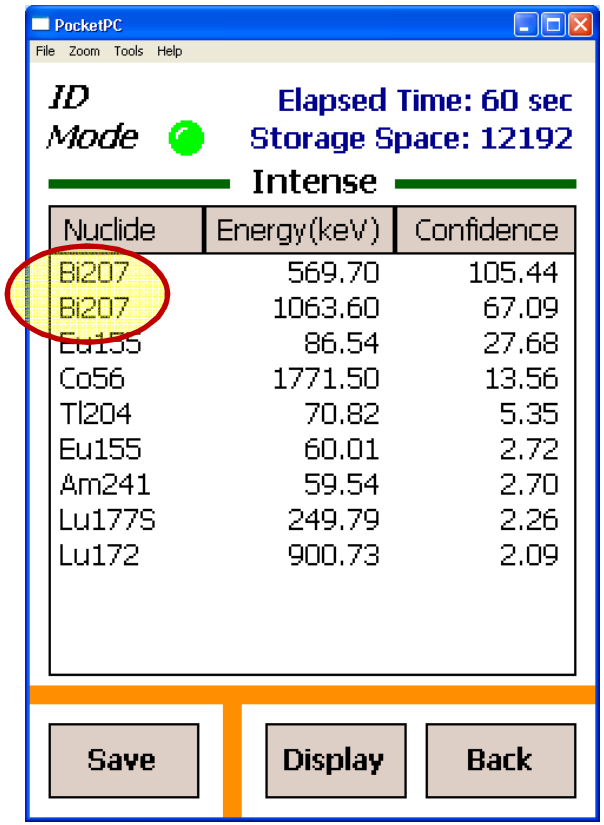


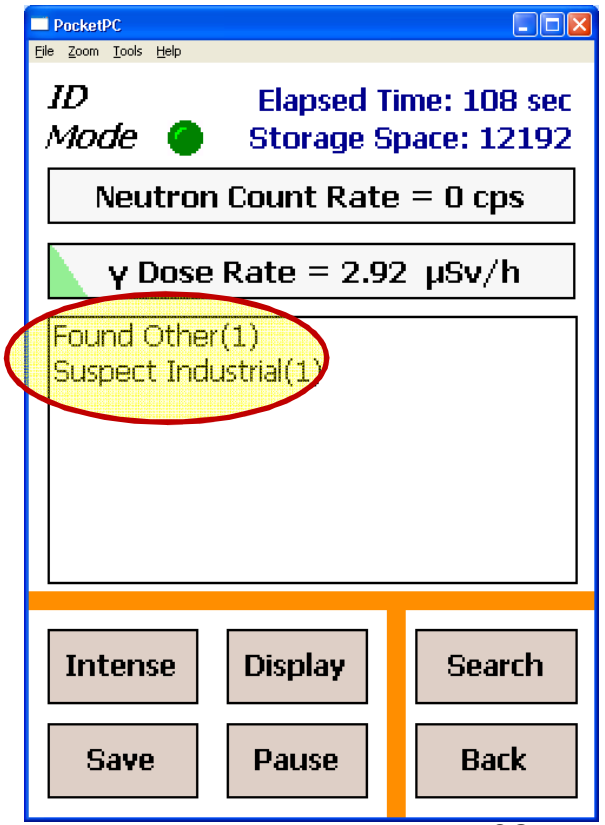


Bismuth-207 (^{207}Bi)

^{207}Bi has multiple gamma-rays and is an industrial source

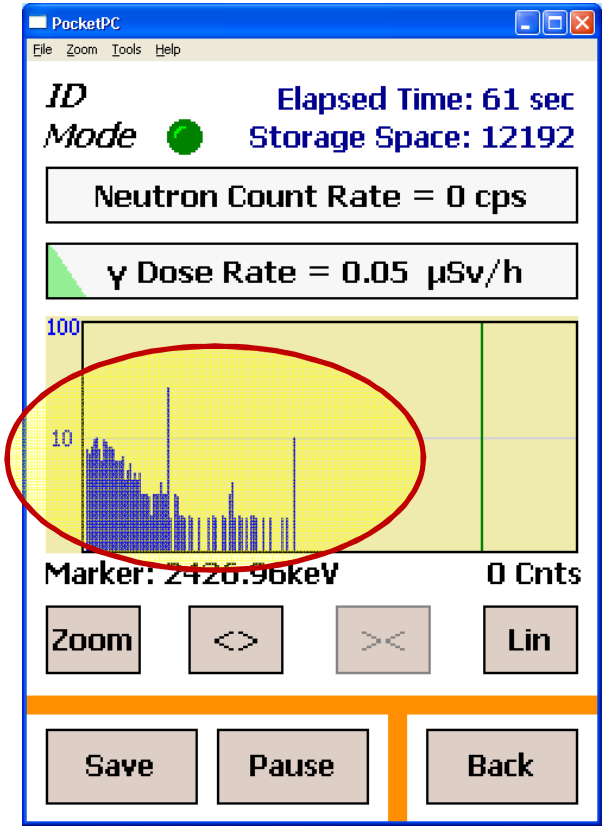


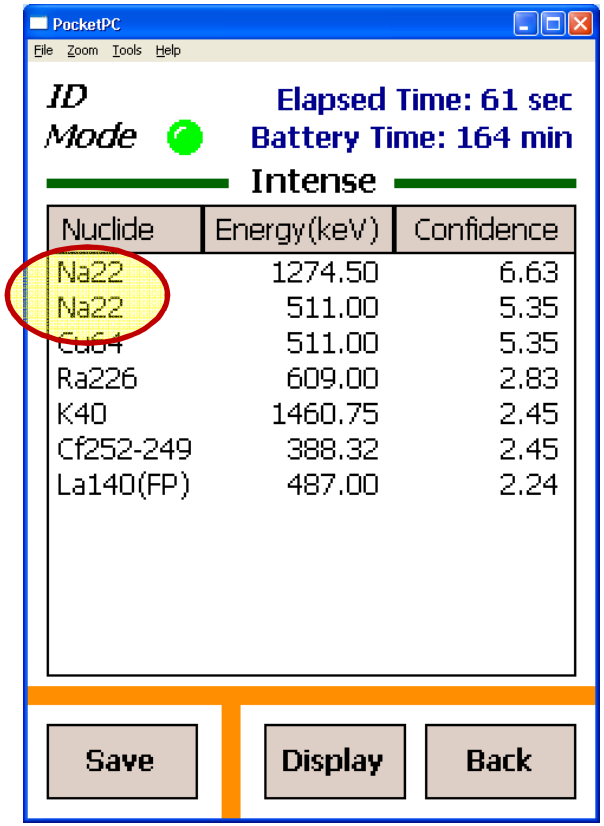


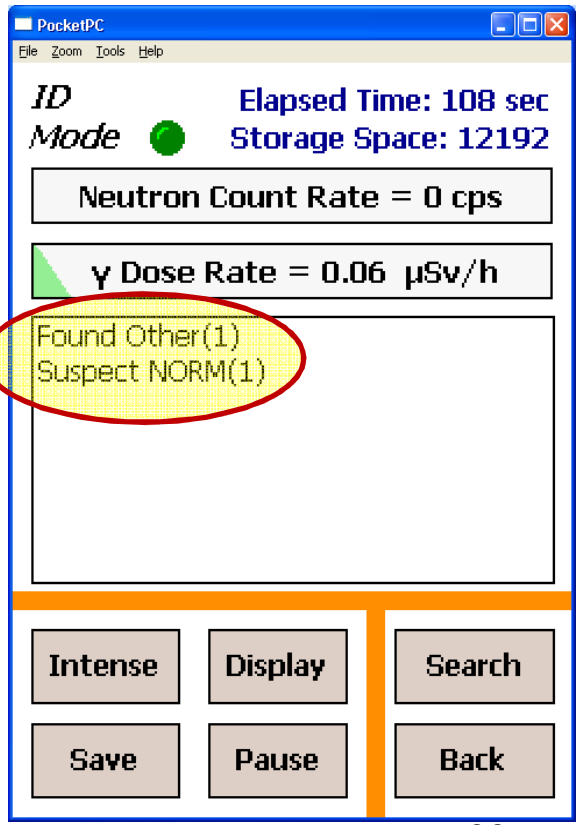


Sodium-22 (^{22}Na)

^{22}Na has gamma-rays at 511 and 1274.5 keV and is an industrial source

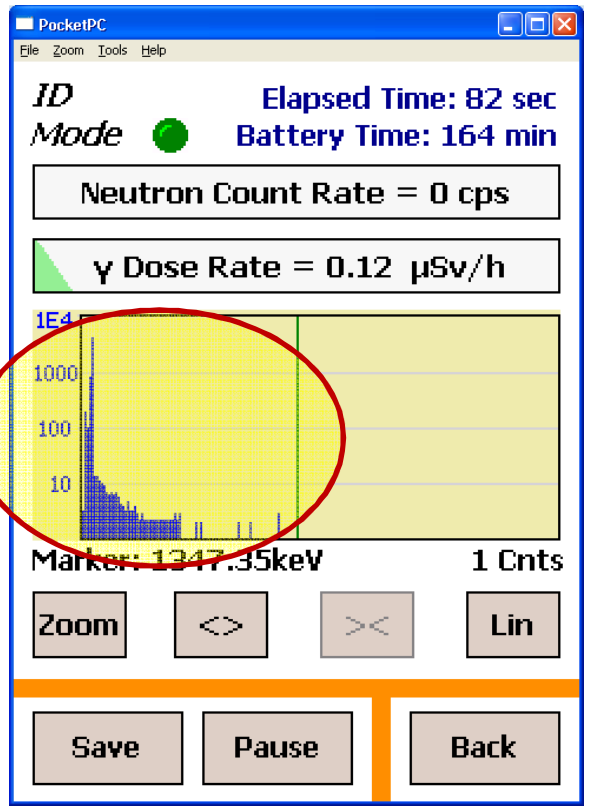


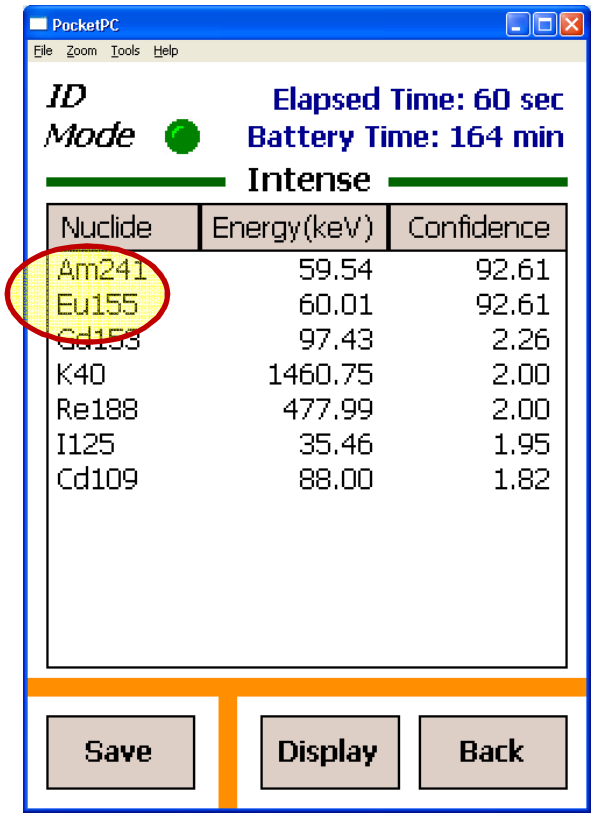


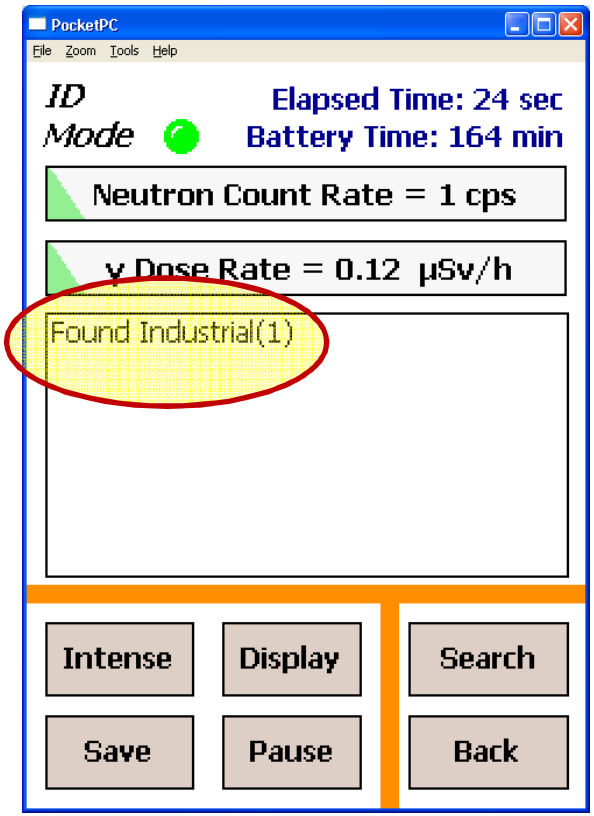


Americium-241 (^{241}Am)

^{241}Am has multiple gamma-rays and is an industrial source

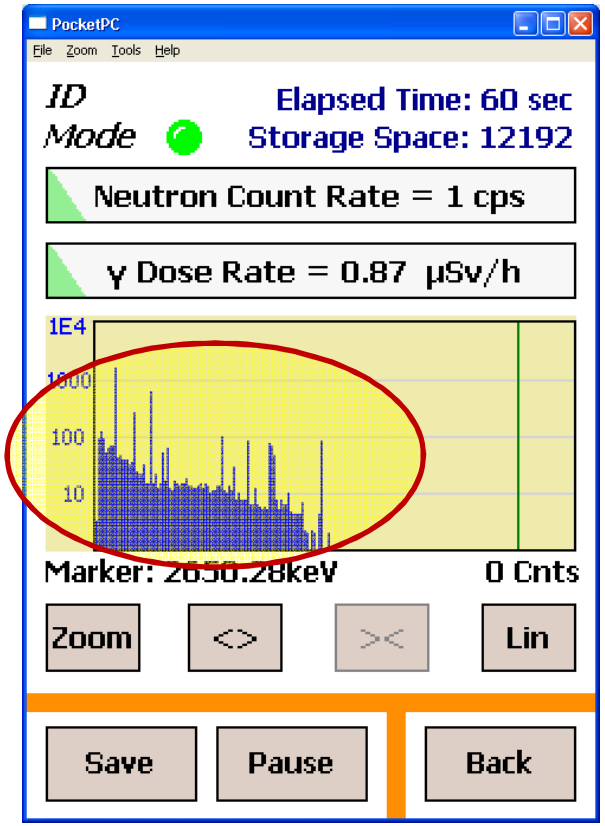


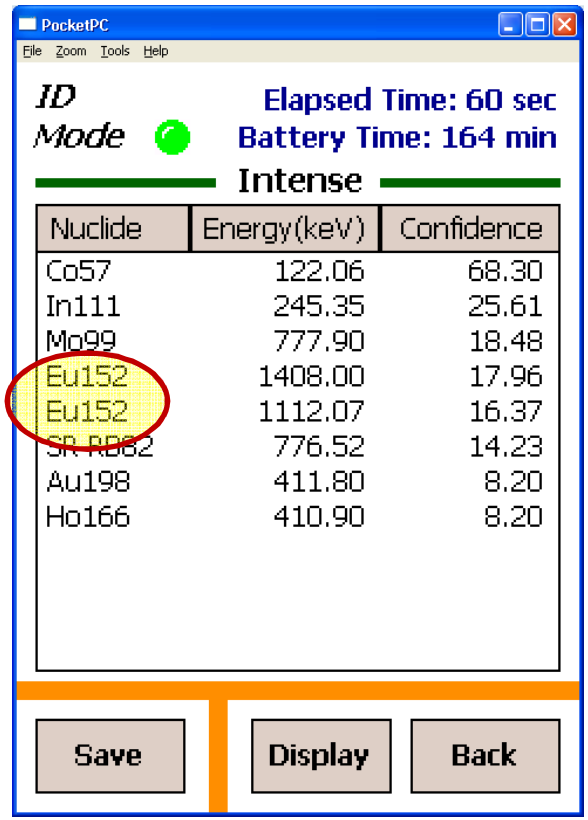


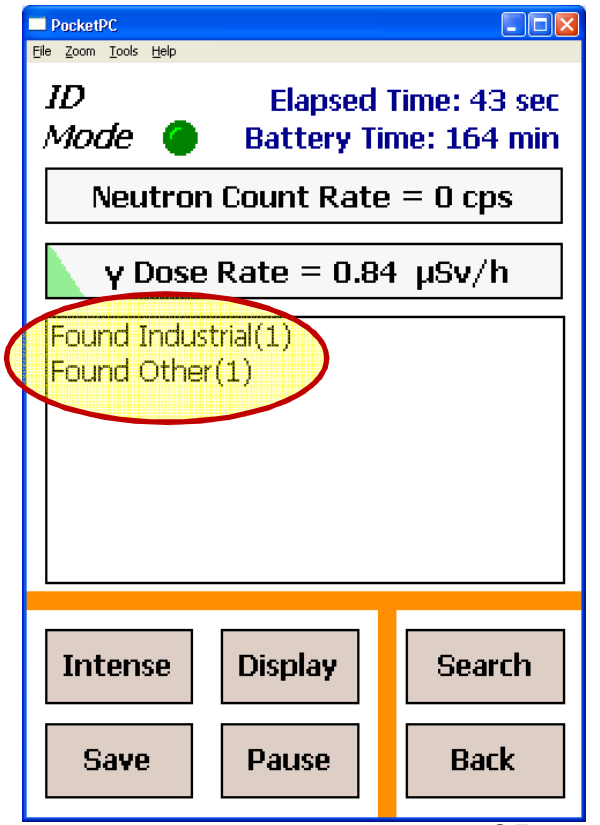


Europium-152 (^{152}Eu)

^{152}Eu has multiple gamma-rays and is an industrial source

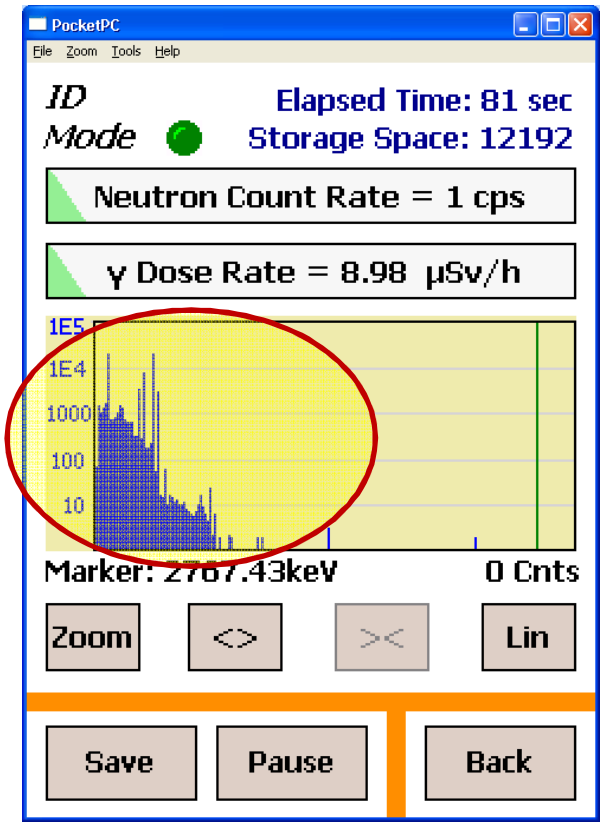


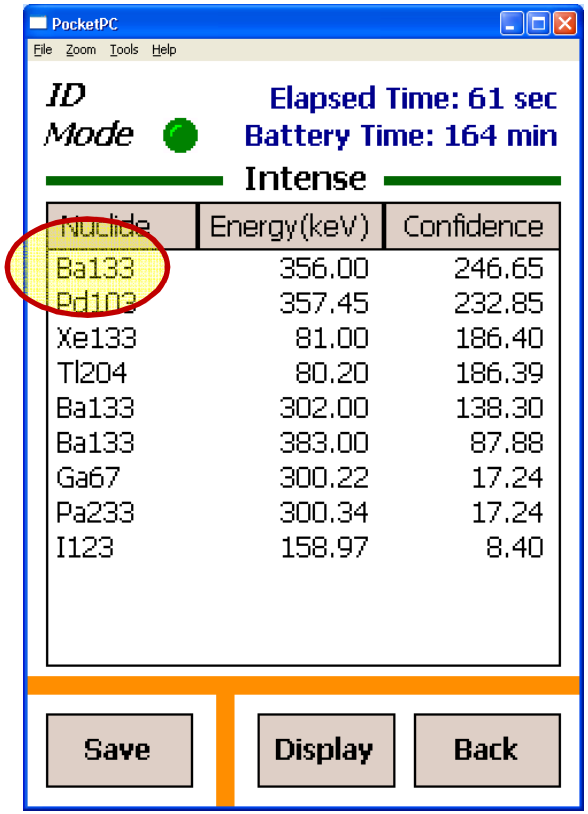


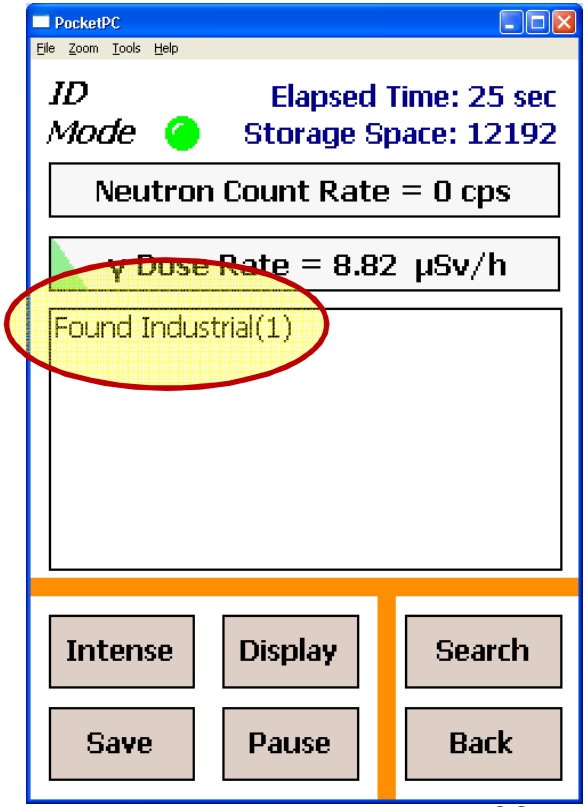


Barium-133 (^{133}Ba)

^{133}Ba has multiple gamma-rays and is an industrial source







Training and Exercise

Three HPGe Detectives will be setup with laptops, projectors and screens so that each group can view their PDA display

The instructor will divide the class into 3 groups and assign each group an expert to assist and answer questions

Each group will measure a series of radiation sources

For the Training Session, the radiation sources will be known

For the Exercise Session, the radiation sources will be unknown

All measurements will be saved and documented with a checklist

Spectroscopy Checklist

First Responder Gamma Spectroscopy Checklist - Group # _____							
Initial Setup Date/Time	Detective Serial Number	Detective Operating Status (ok)	Gamma Background Count Rate	Gamma Background Dose Rate	Background Measurement (300 seconds) Filename	Calibration Measurement (300 seconds) Filename	Calibration Source Activity/Date/Serial Number (kBq)
Source Measurements	Measurement (300 seconds) Filename	Detective Operating Status (ok)	Gamma Background Count Rate	Gamma Background Dose Rate	Measurement Dead Time (%)	Detection Distance (cm)	Radioisotopes Identified and Confidence Levels
Source 1							
Source 2							
Source 3							
Source 4							
Source 5							
Source 6							
Source 7							
Source 8							
Source 9							
Source 10							

Training

Review advanced setup screen and check operating status

Determine background count and dose rate as quality control check

Calibrate using ^{137}Cs and automated calibration feature

Collect and save 5 minute spectra for background and calibration

Check dead time for all measurements and adjust distance to source as necessary to obtain 5% or less

Collect and save 5 minute spectra for a series of known radiation sources

Complete a checklist for each radiation source

The training will be followed by questions and discussion

Exercise

Scenario

Intelligence sources intercept documents which indicate that an abandoned warehouse near the border will be used as a trans-shipment point for a smuggled weapons cache. The date is close to an upcoming national event with international participants.

A law enforcement team supported by an Explosive Ordnance Disposal (EOD) unit raids the warehouse and using their radiation pagers, locate several containers of radioactive material. The radiation pagers provide readings ranging from 3 to 7 on contact.

The EOD unit requests an expert radiological team collect data on the containers to identify the radioactive material and provide an assessment of their results.

Exercise

Determine background count and dose rate as quality control check

Calibrate using ^{137}Cs and automated calibration feature

Collect and save 5 minute spectra for background and calibration

Check dead time for all measurements and adjust distance to source as necessary to obtain 5% or less

Collect and save 5 minute spectra for a series of unknown radiation sources

Complete a checklist for each radiation source

Each group will provide a summary of their results and initial assessment

The exercise will be followed by questions and discussion

Questions?