ScintiClear™ based radiation detectors for high-precision gamma spectroscopy

Ivan Khodyuk, Maria Hackett,
Amlan Datta, Shariar Motakef

CapeSym, Inc., MA, USA

khodyuk@capesym.com

ISMART 2018

October 10, 2018

CapeSym company overview

- Founded 1992, spinoff of thermal modeling R&D at MIT
- Employees: 12 (3/4 are PhD's)
- Science + Manufacturing: Thermal modeling, GEANT4, wet chemistry, crystal growth, fabrication, characterization
- Newly launched ScintiClear™ high-performance SrI_2
  - SPRD cores, RIID cores, custom detectors
- Pre-production with PVT/scintillator composites
- In the pipeline: CHC, new elpasolite scintillators, TlBr

CapeSym, Inc.

PRESS RELEASE - MAY 25, 2018 4:41PM EST

CapeSym Announces New ScintiClear (TM) Gamma Sensor

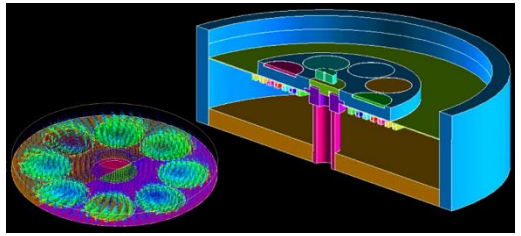
CapeSym introduces new SrI2-based scintillator for unambiguous detection of hazardous nuclear materials. Sizes up to 2"-diameter are available now.

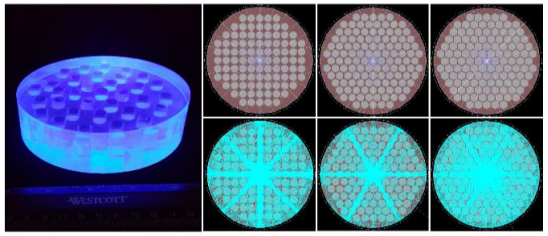
NATICK, Mass., May 25, 2018 (PressRelease.com) - CapeSym, Inc today announced the introduction of their ScintiClear(TM) nuclear ID crystals. ScintiClear addresses the need for lower-cost, rugged sensors that deliver more capability to identify hazardous nuclear materials than has previously been available at this price. It is based on strontium iodide technology originally developed by Government laboratories. CapeSym has productized this crystal using co-doping and other industrial processes that drive cost down, and performance up. Barriers to consistent performance that were problematical in laboratory testing have been identified and eliminated. Energy resolution of ≤ 3.3% is warrantied, even in 2-inch diameters. High sensitivity is provided in a compact package, ready for integration. ScintiClear makes large, actinide free, low-cost high-resolution sensors a reality.

IEEE NSS MIC 2017 Atlanta

CapeSym R&D Capabilities

Thermal and GEANT4 modelling

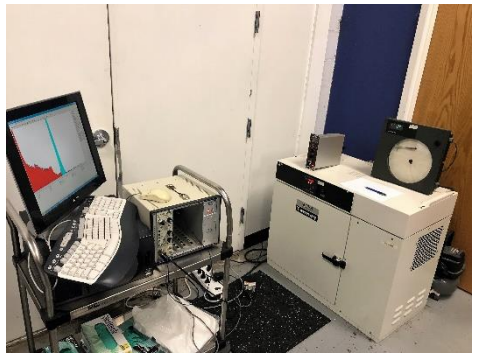




Crystal growth process development

Wet chemistry and materials purification

Characterization



CapeSym Manufacturing Capabilities

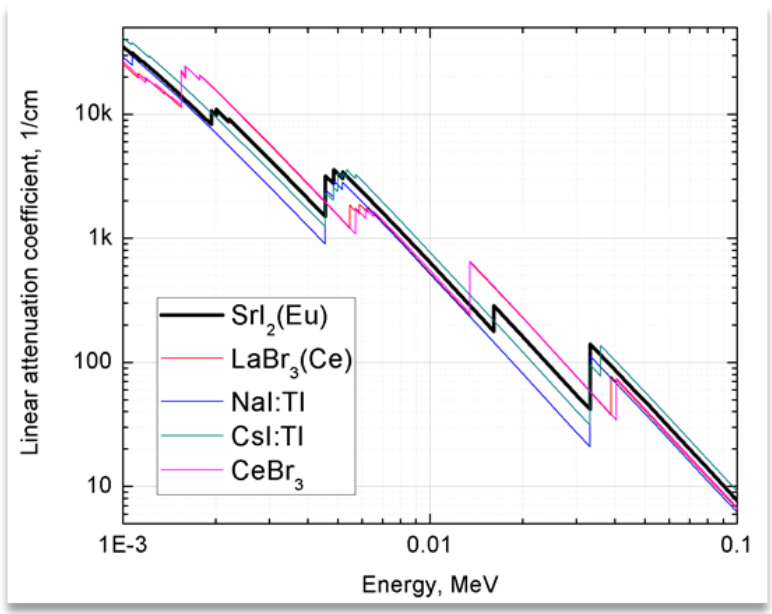
- Today: 500 detectors/year
- All process stations + furnaces designed and built at CapeSym
  - Low cost
  - Can scale rapidly – 3 months
- Automated crystal growth, cutting and polishing
- Low moisture glove boxes, multiple gamma sources, DD neutron generator, environmental chamber, oxygen tester
- High-throughput encapsulation process
- Rugged encapsulation with PMTs and SiPM arrays
  - Meets ANSI environmental standards

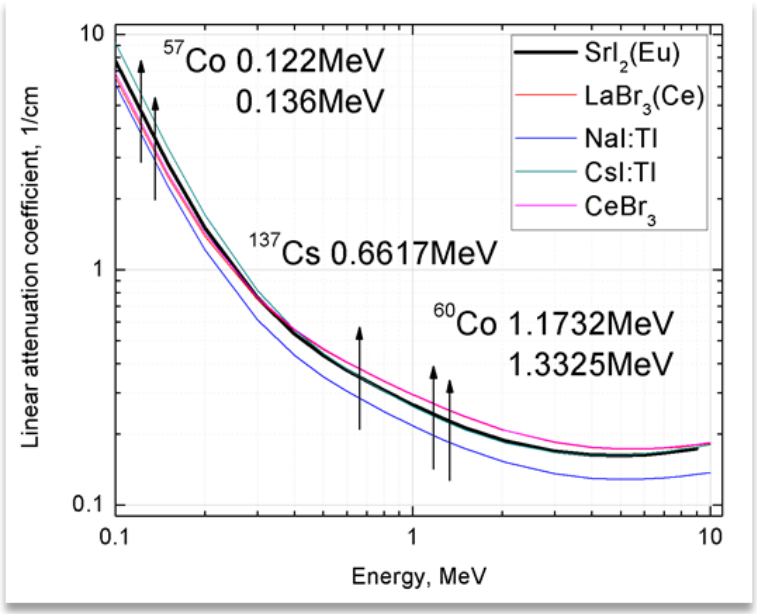
ScintiClear™ - high performance $SrI_2(Eu)$

Light Yield	80,000 ph/MeV
Energy Resolution @ 662keV	3%
Decay Time	1-3 μs
Emission Range	400-480 nm
Max Emission	430 nm

Density	4.6 g/cm^3
$Z_{effective}$	50
Intrinsic activity	<0.05 Bq/cm^3
Moisture Sensitivity	Hygroscopic (similar to NaI(Tl))
Refractive Index	1.85
Thermal shock	up to 10 °C/min

Linear attenuation coefficient, 1/cm



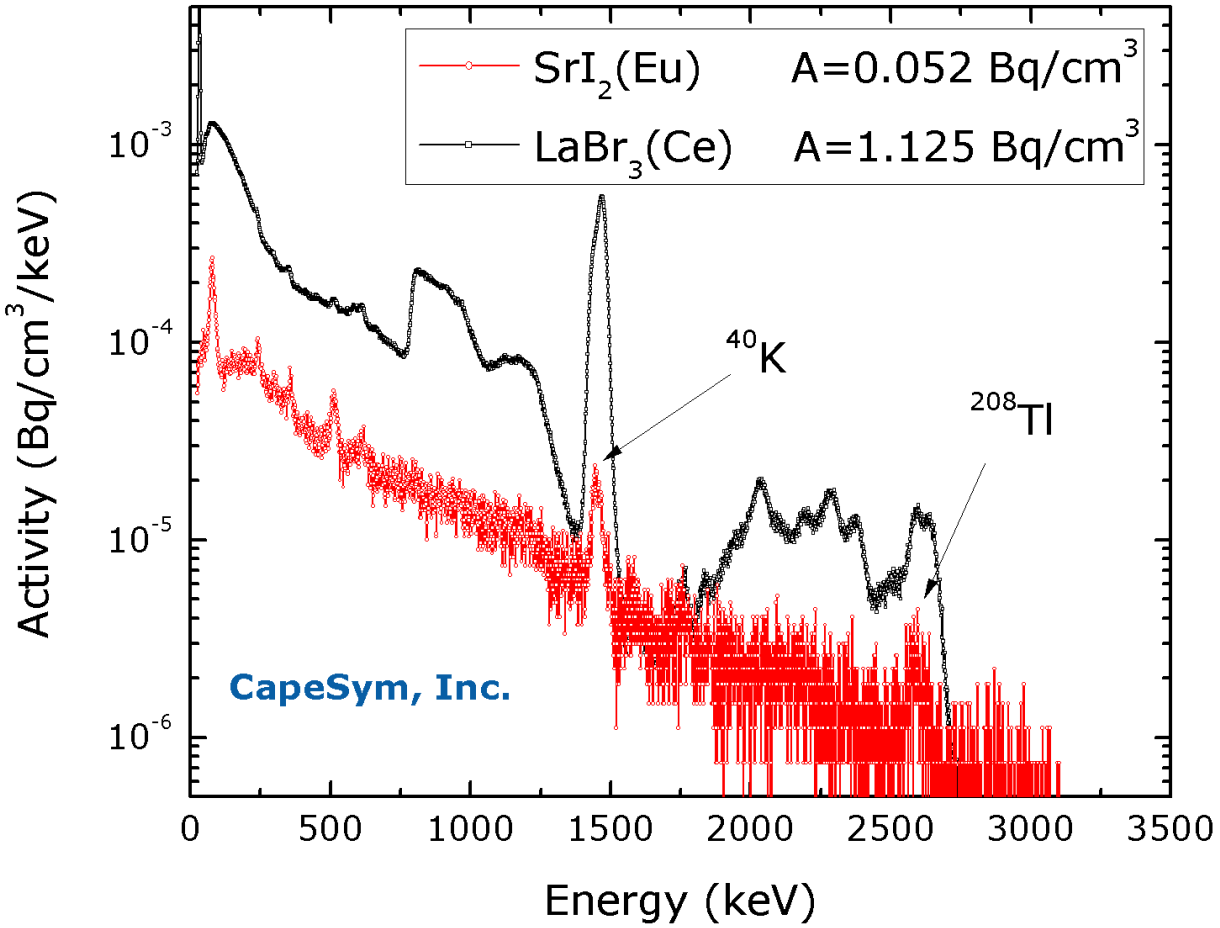


$SrI_2(Eu)$ was originally proposed as a radiation detector by R. Hofstadter in 1968.

In 2008 scientists from Lawrence Livermore National Laboratory (USA) spearheaded the development of $SrI_2(Eu)$ into a leading edge radiation detector.

In 2017 commercial version of $SrI_2(Eu)$ has been lunched by CapeSym under ScintiClear tade marked name

ScintiClear™ has low to no internal activity

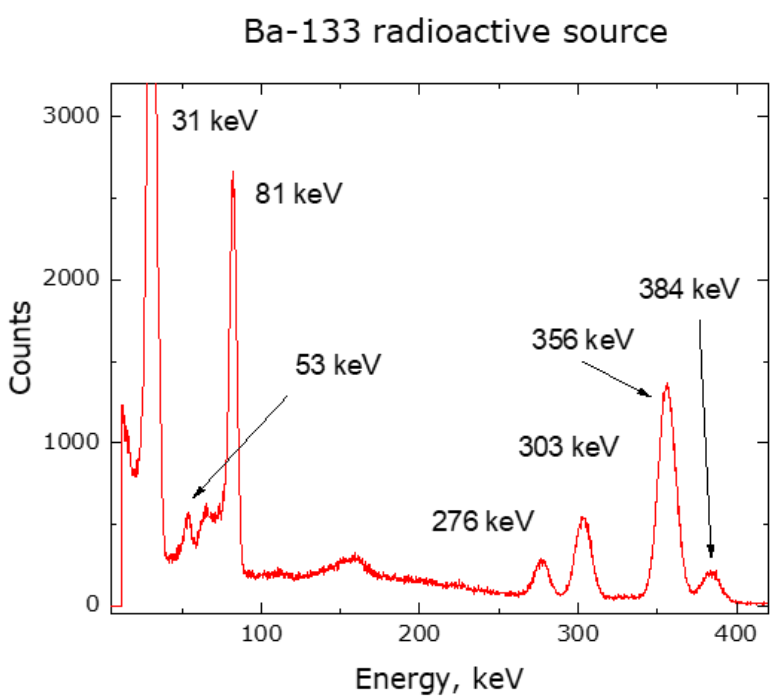


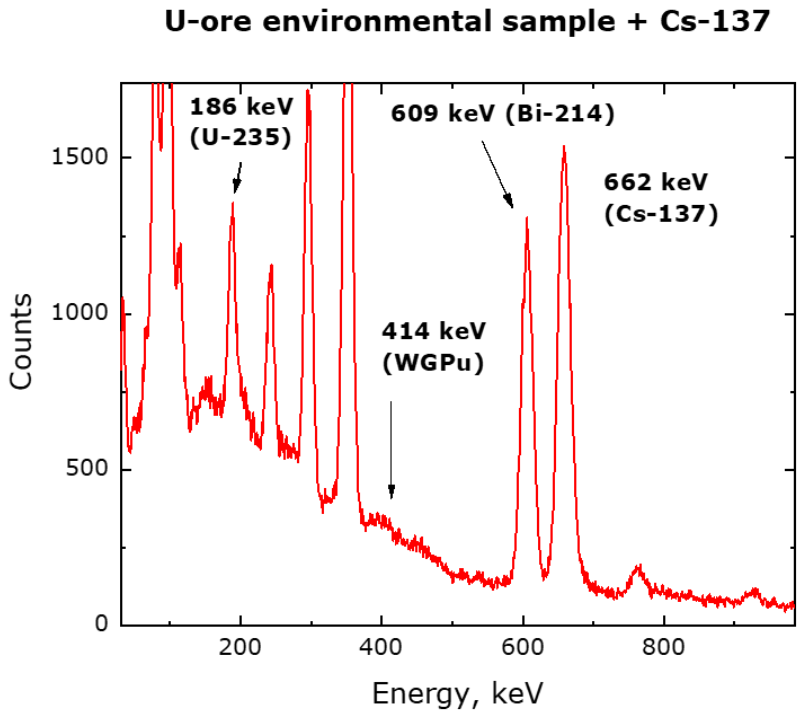
- SrI_2 has naturally stable isotopic composition.
- Intrinsic activity of $SrI_2(Eu)$ is up to forty times smaller compare to $LaBr_3(Ce)$.
- Sr is the 15th most abundant element on Earth.
- Although Strontium Iodide salt becomes corrosive when exposed to air, Strontium is fundamentally non toxic.

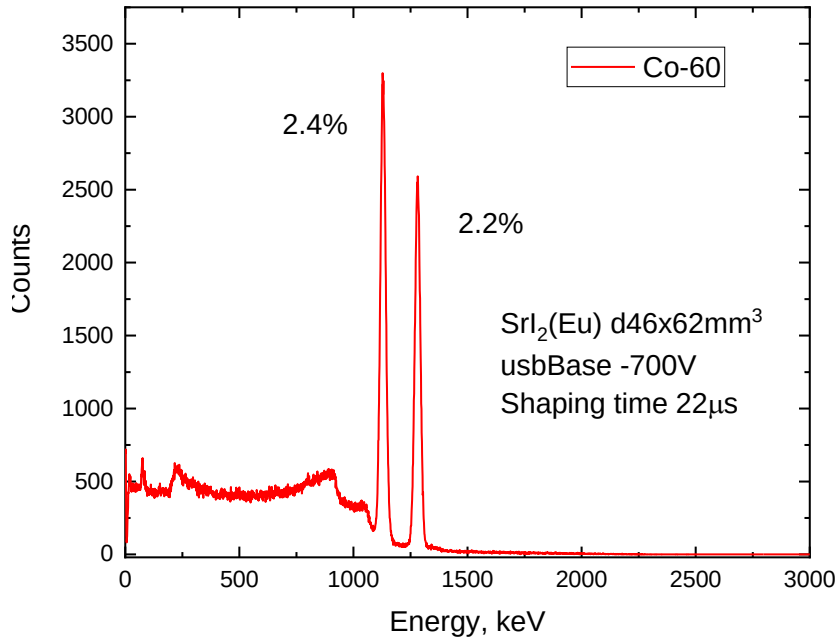
Internal activity spectrum of a standard 1.5" $SrI_2(Eu)$ in comparison with $LaBr_3(Ce)$, as measured inside a Pb castle with 2 inch thick walls.

High energy resolution in the entire energy range

Energy resolution can be as good as **12%** at 32.4keV, **2.8%** at 662keV and **2.1%** at 1332keV.







Critical situations demand immediate and accurate identification of the radiological material present. ScintiClear easily separates the ^{137}Cs and ^{134}Cs lines (662 keV and 605 keV respectively) and eases the task of identifying the 186 keV line (HEU) and 414 keV line (WGPu) even in the presence of interfering radionuclides.

ScintiClear™ SPRD detector cores

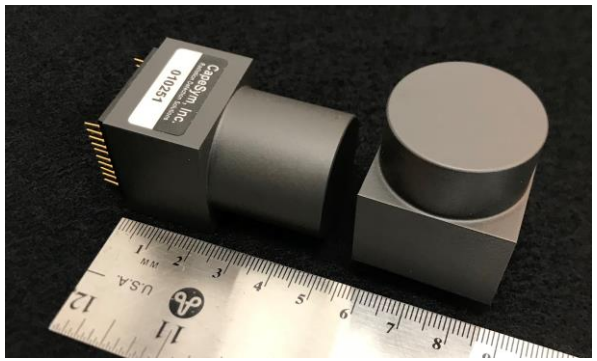
We have developed a sensor technology that drives superior radionuclide identification for an SPRD device. Our ScintiClear technology enables an instrument that achieves (a) very good nuclide ID capability (superior energy resolution); (b) fast time to detect and identify (good sensitivity); (c) cost reasonableness and (d) rugged design.

Key benefits:

- **Superior energy resolution from 10 to 3000 keV (≤3.3% at 662 keV)**
- **High sensitivity and SIGMA FOM**
- **No internal activity**
- **Compact, rugged, and ready for integration design**
- **Spectroscopic information up to 50mR/h (^{137}Cs)**
- **Higher dose rates are measured via the PMT current**

ScintiClear sensors on R11265U PMTs before and after encapsulation.

ScintiClear™ is a $SrI_2(Eu)$ based scintillation technology manufactured using CapeSym's proprietary crystal growth process. The crystals maintain excellent energy resolution by minimizing the negative effects of Eu self-absorption.



Comparison of ScintiClear detector cores with a commercial CZT SPRD

	SC-SPRD-S	CZT SPRD
Crystal(s) size, mm^3	Ø25.4 x 12.7 (6.5 cc)	3 ea. 15 x 13 x 5 (2.925 cc)
Package dimensions, mm	Ø30.0x30.0 L=40.0	55.0 x 18.0 x 15.0
ER % at 662keV	≤3.3 (Gaussian)	≤3.5
Gamma sensitivity, cps/uR/h at 662keV	1.8	0.82 (detection) 0.47 (identification)
Internal activity, cps	<0.1	NA
Temperature range, °C	-25° to +55°	-25° to +55°
Thermal shock	ANSI N42.48-2008	ANSI N42.48-2008
SIGMA FOM $A\epsilon_p/R$ at 1.17 MeV, $cm^2/\%$	0.056	0.003

Energy resolution & experimental set-up

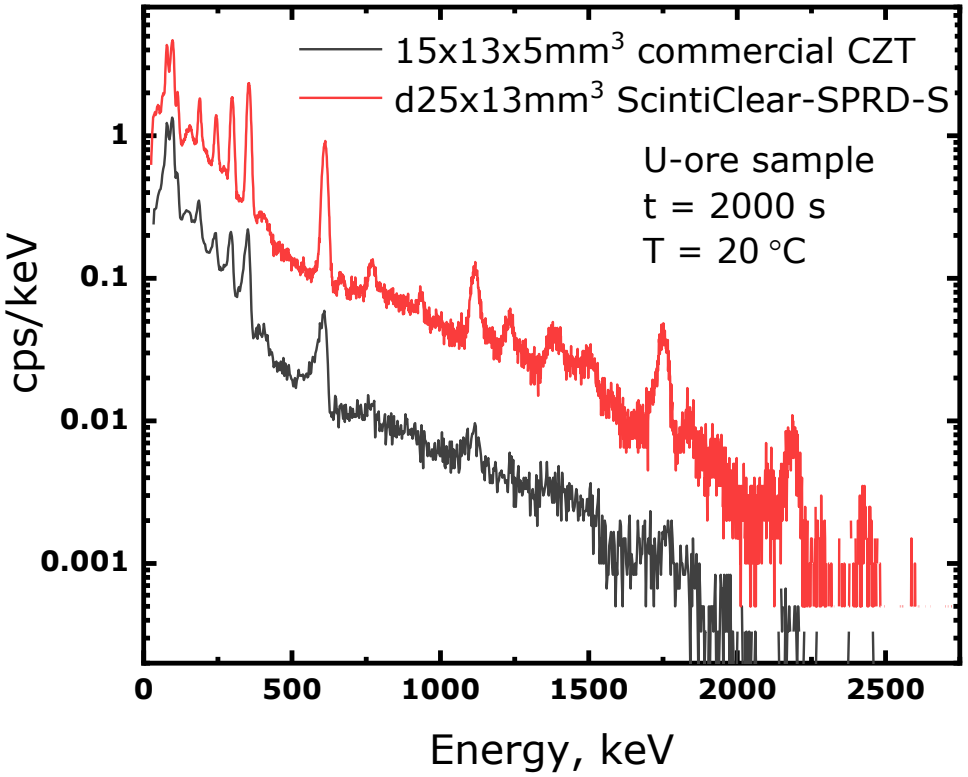
Energy, keV	ER,% SC-SPRD-S	ER, % CZT-SPRD
32.4	12.5	22
59.5	9.3	15
186	4.7	7.7
295	4.0	6.8
352	3.3	6.2
609	3.2	3.8
662	3.1	3.5
1173	2.4	2.6
1333	2.2	2.5
2448	1.8	no peak

Experimantal set-up:
R11265U PMT @ -550V
Canberra 2005 Preamp
Canberra 2025 Amplifier
12 μs shaping time
Amptek 8000D pocket MCA

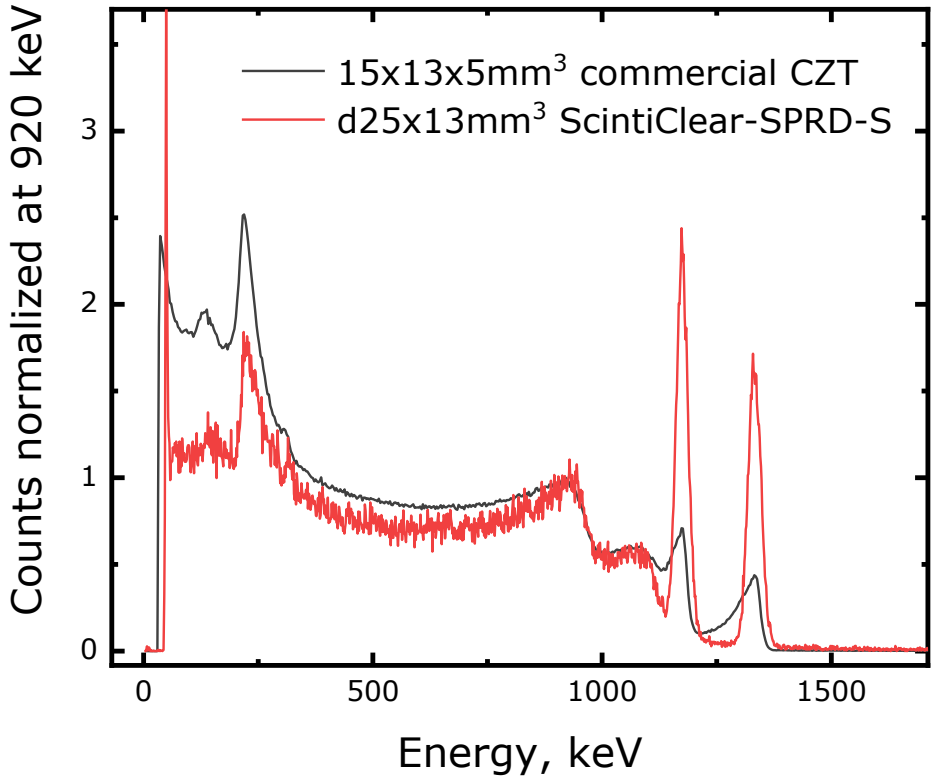
No digital signal correction or post-processing

2x higher detection sensitivity and 3x higher ID sensitivity compare to commercial CZT SPRD.

Energy resolution & sensitivity

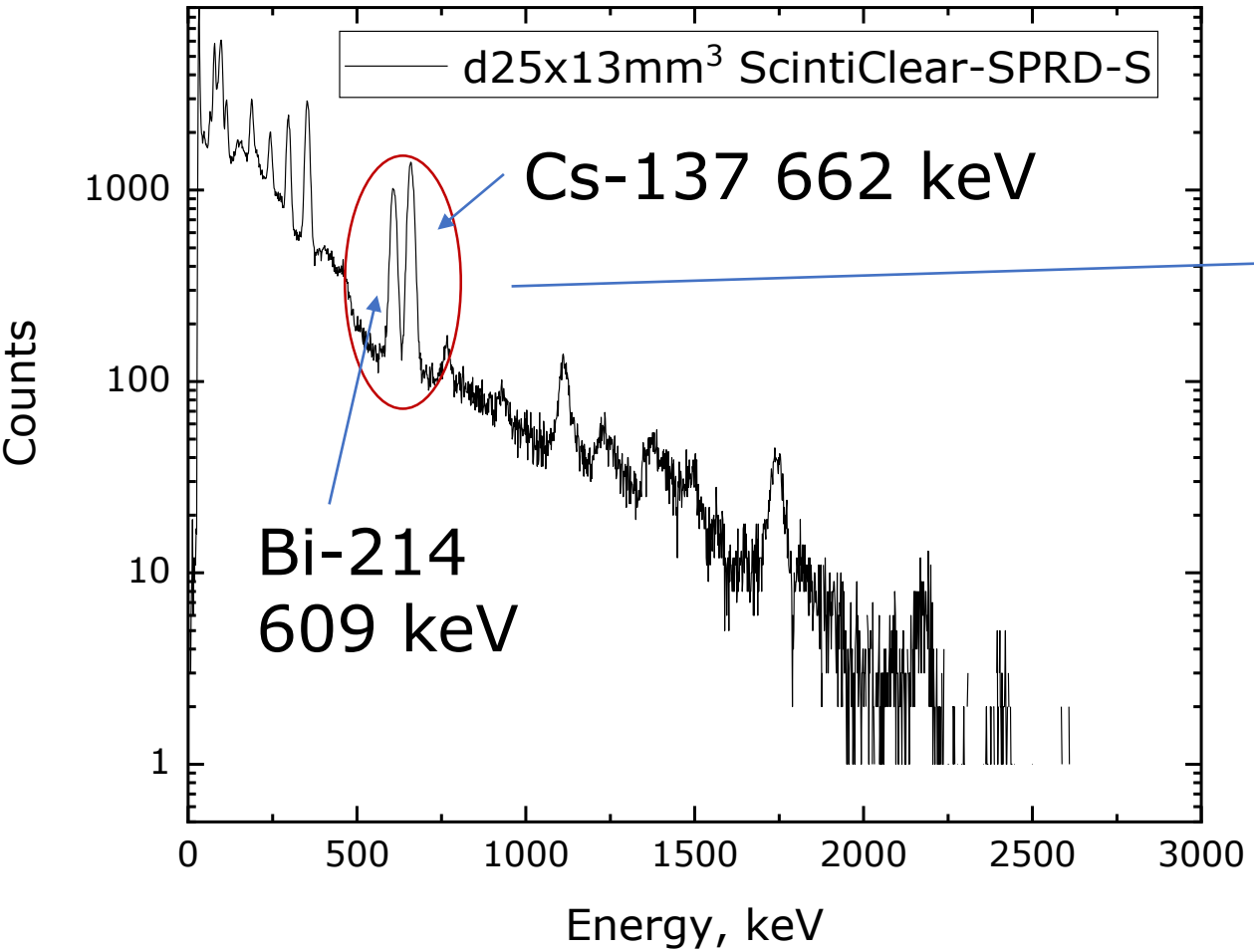


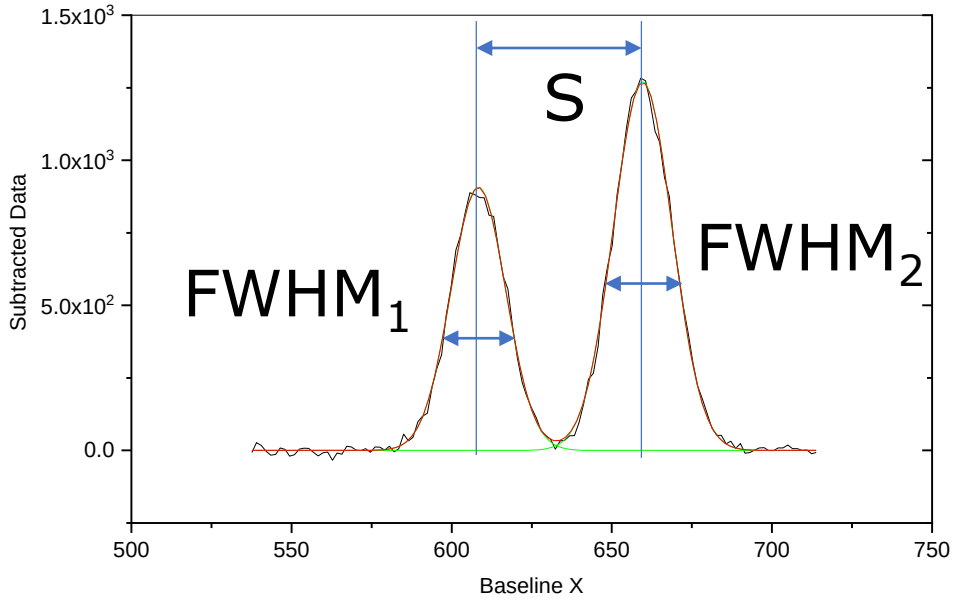
Pulse-height spectra of U-ore measured with ScintiClear-SPRD-S and with a commercial CZT SPRD, under the same experimental conditions.



Pulse-height spectra of Co-60 measured with ScintiClear and with a commercial CZT SPRD normalized at 920keV (Compton edge).

SC-SPRD-S performance

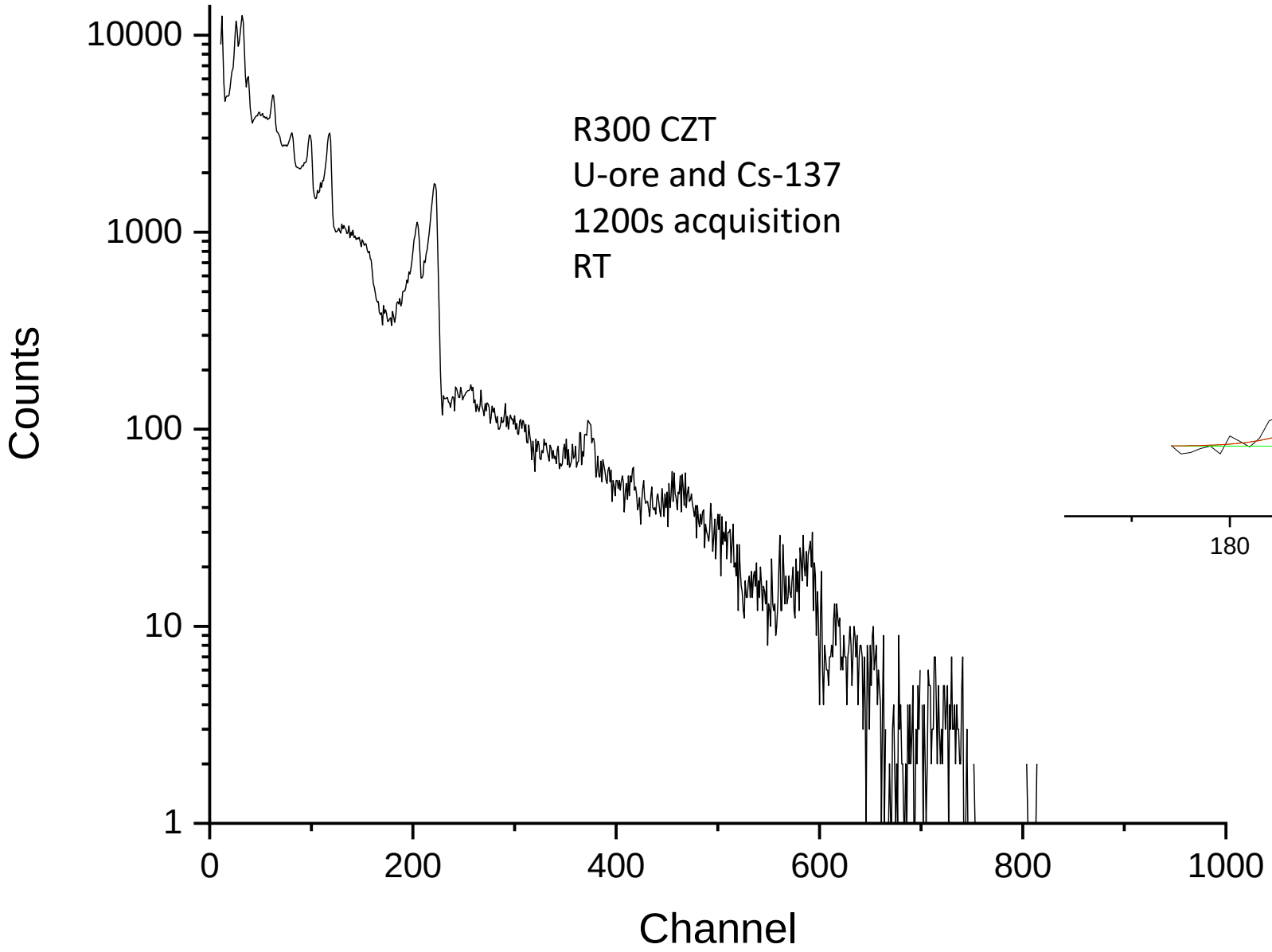


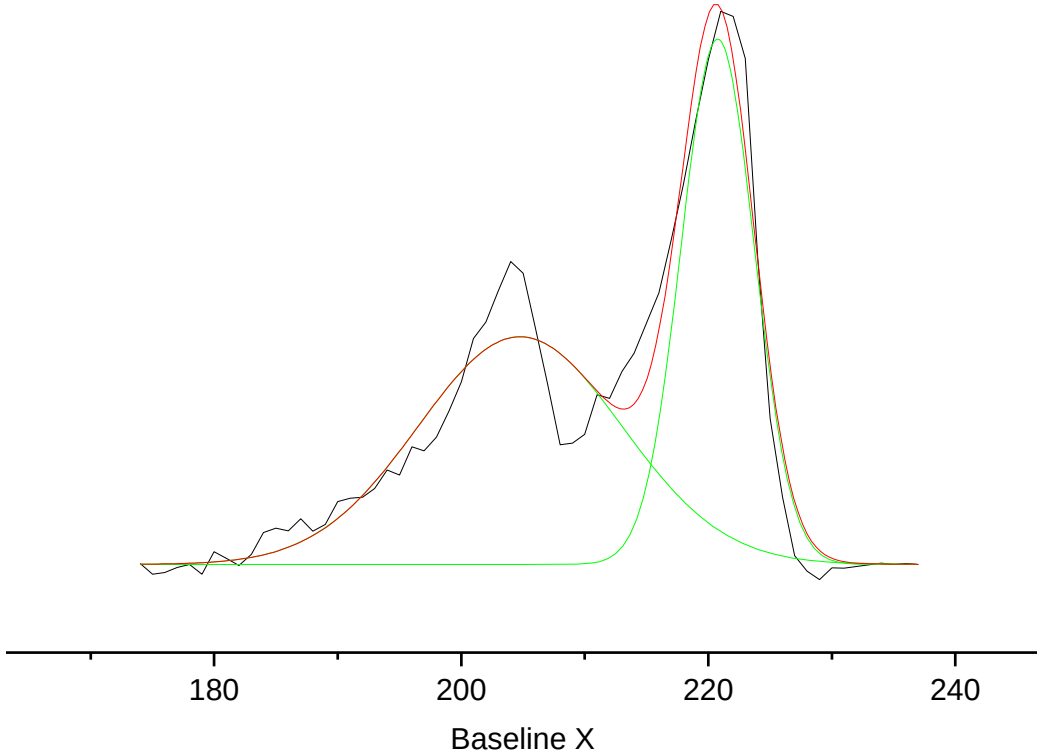


$$FOM = S/(FWHM_1 + FWHM_2)$$

Pulse-height spectra of U-ore and Cs-137 shows separation for Cs-134 and Cs-137 lines (605 keV and 662 keV, respectively).

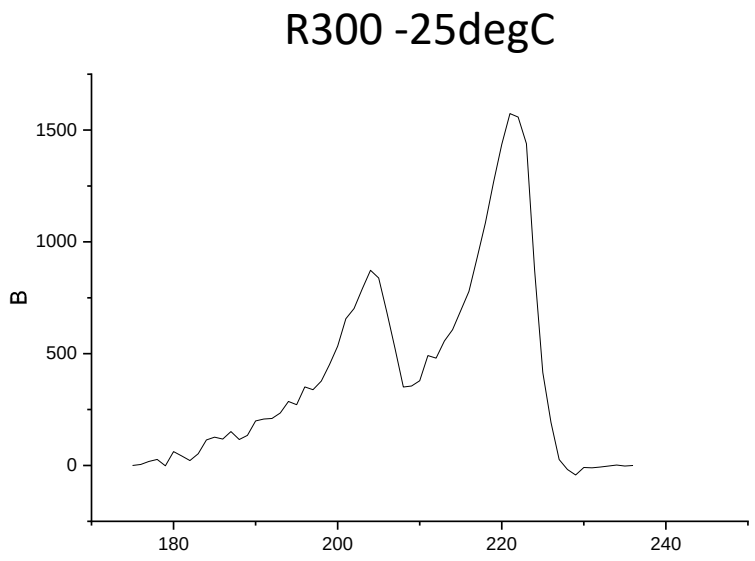
CZT-based commercial SPRD performance

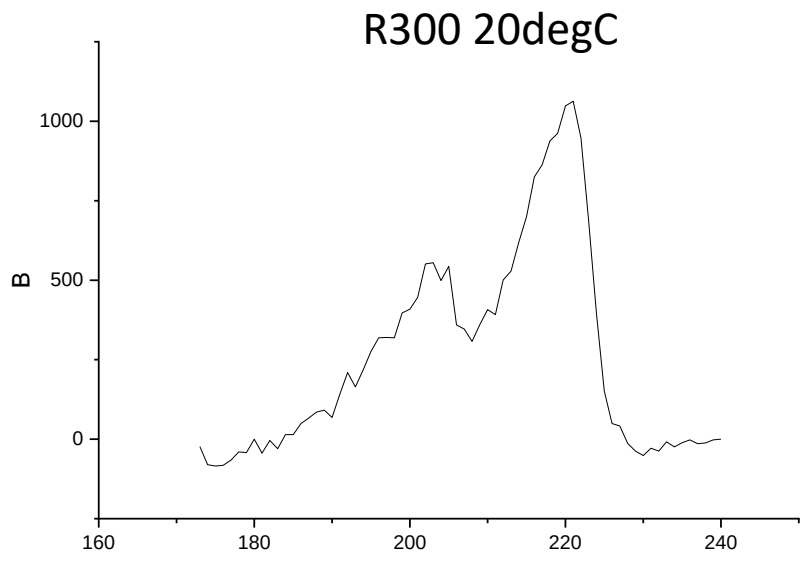


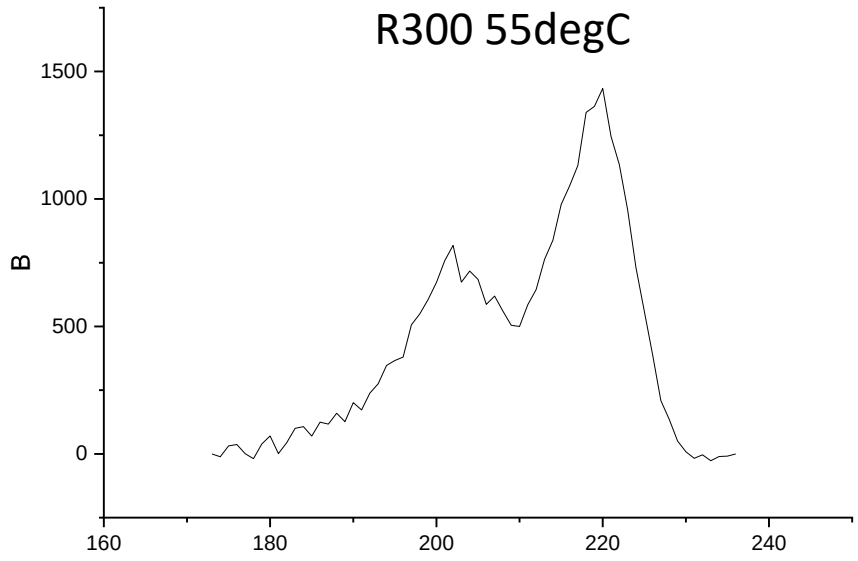


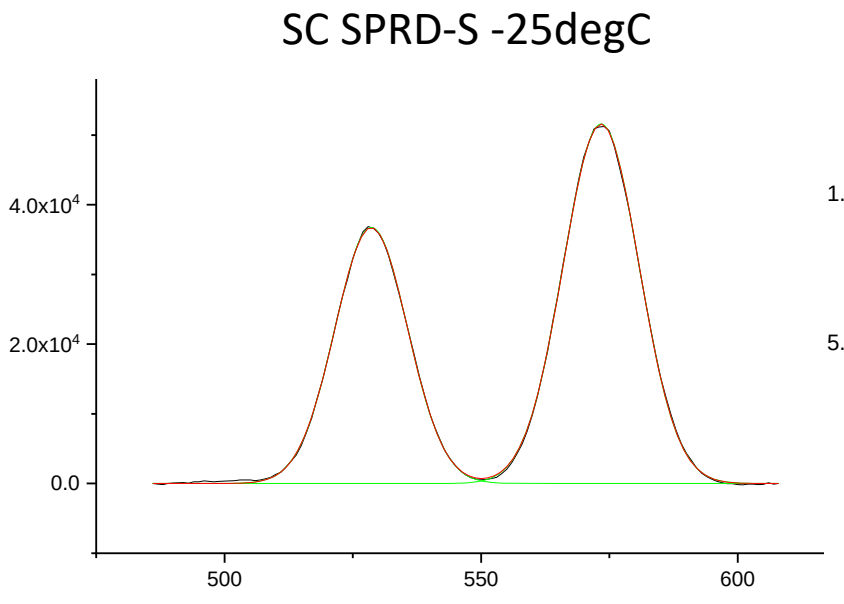
Double Gaussian fit doesn't converge in OriginPro because of the asymmetric peaks

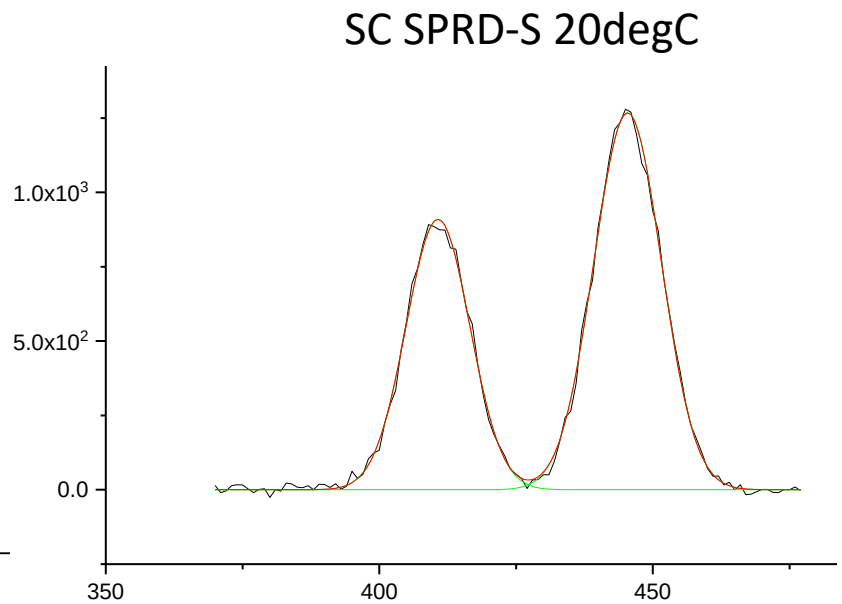
Performance vs temperature

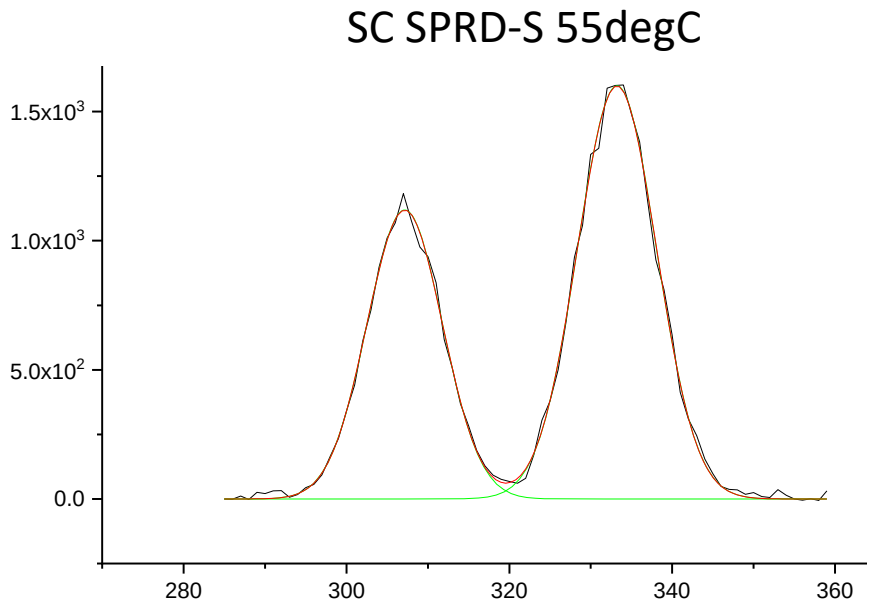




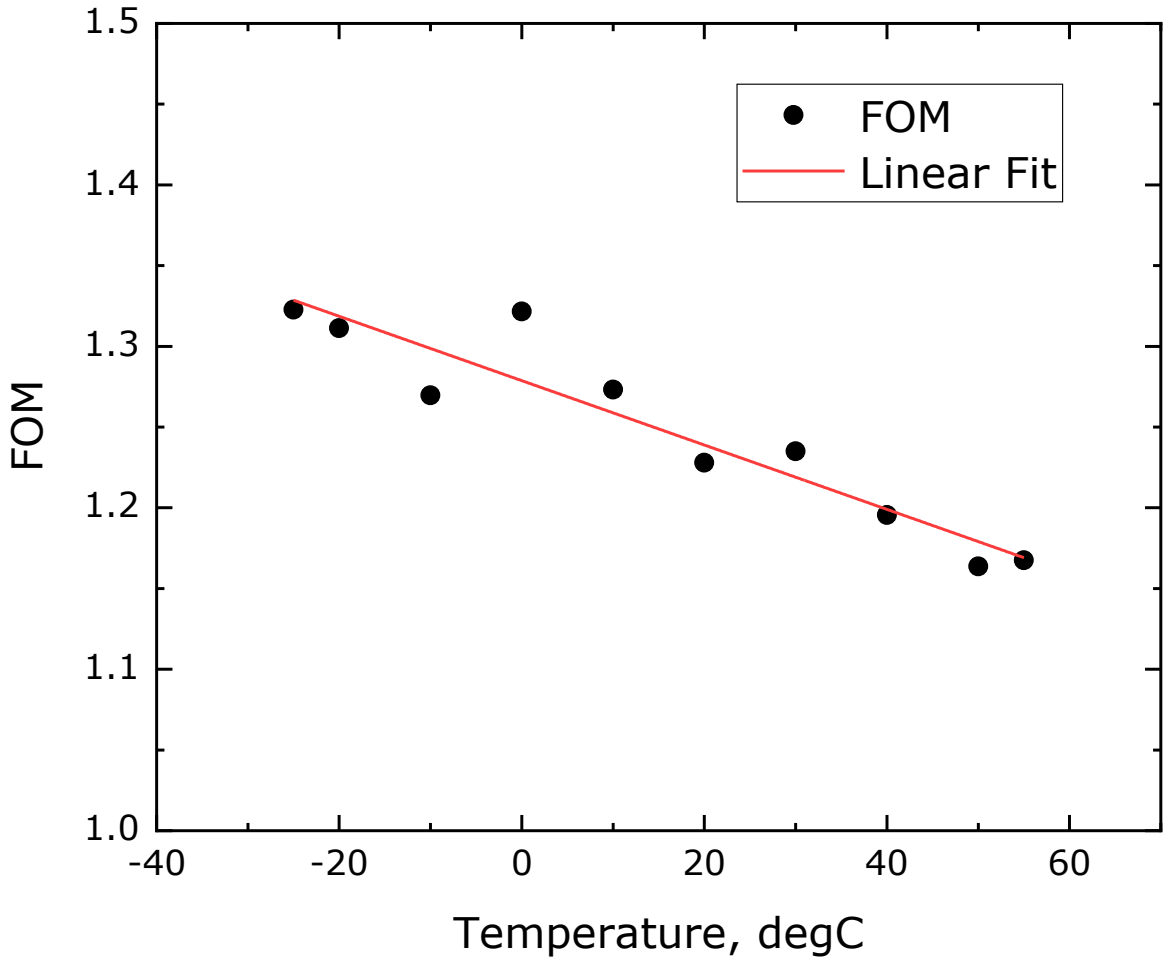


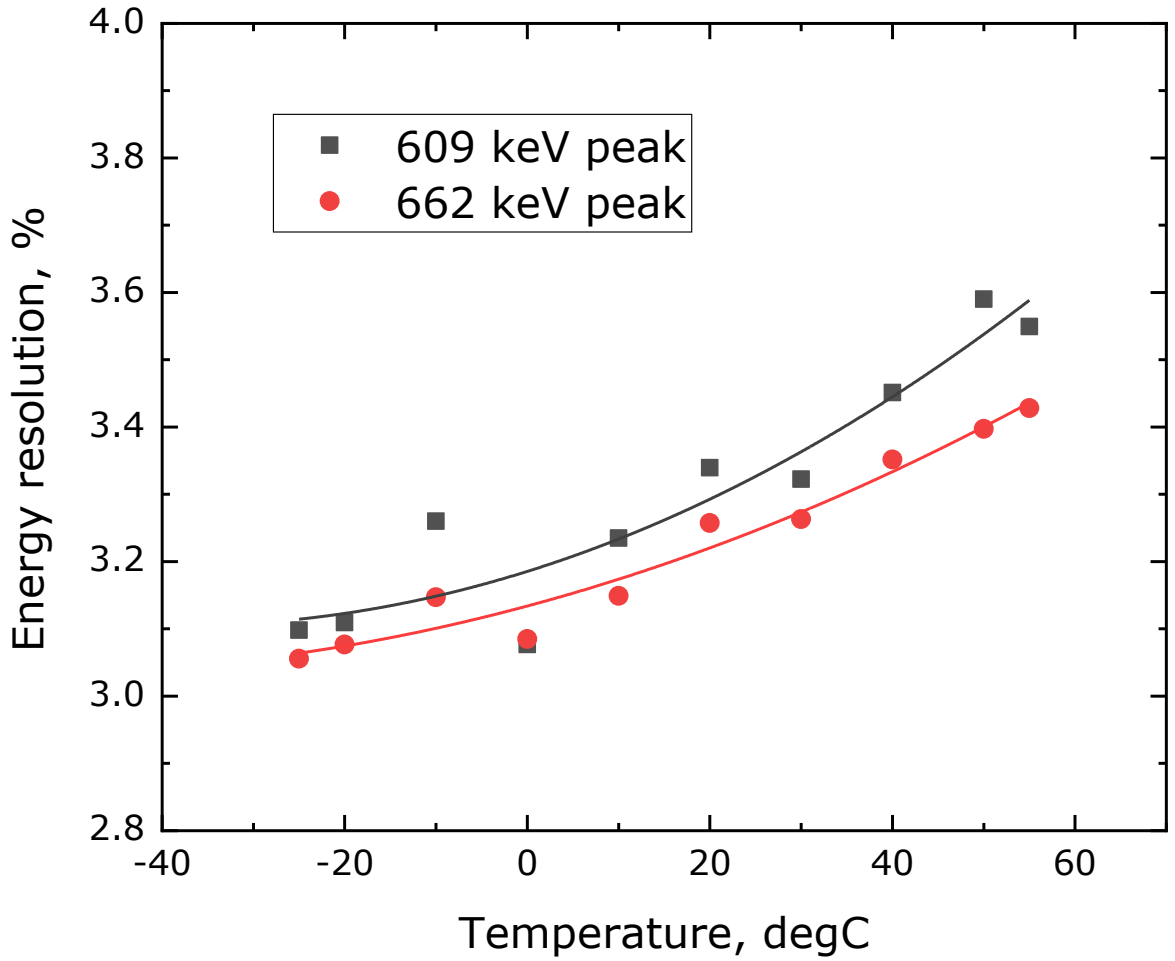






Performance vs temperature FOM





Temperature dependence of FOM (left) and energy resolution measured with ScintiClear-SPRD-S detector core following ANSI N42.48-2008 procedure.

Summary

- **ScintiClear™ is a high-performance $SrI_2(Eu)$-based scintillator.**
- **Typical energy resolution of large crystals is ≤ 3.3%.**
- **ScintiClear-SPRD-S detector core (6.1cc scintillator + PMT assembly) has 1.8 cps/μR/h at 662 keV spectroscopic sensitivity.**
- **Based on peak-specific sensitivity, identification time can be reduced up to 10 times with appropriate software (compare with commercial CZT-based SPRD).**
- **Signal integration time does not exceed 10 μs, allowing spectroscopic information up to 100kcps (50 mR/hr dose rate).**
- **Our encapsulation exceeds ANSI N42.48-2008 environmental performance requirements.**

Thank you for your attention.