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AMETEK


# HPGe Detectors at ORTEC/AMETEK

5 December 2018

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Director of Detector Technology

# ORTEC/AMETEK Ge Detectors

ORTEC®

- ORTEC Overview
- New Developments
  - *Expansion of GEM-C profile detector product line*
  - *Resolution - Profile SP series with LNBC*
  - *Large diameter GEM-S and GEM-SP detector products*
  - *Application benefits*
  - *Mechanical cooling for Customized Solutions*
- ORTEC's special detectors
  - *Standard and Segmented Clovers*
  - *Double Sided Ge Strip detectors*
  - *Special Point Contact*
- Low Background
- Summary

# ORTEC Overview

ORTEC®

ORTEC is an industry leader in the design and manufacture of ionizing radiation detectors, nuclear instrumentation, analysis software, and integrated systems. Our technologies, products, and services are instrumental in materials analysis for radioisotopic content. Key industry segments include nuclear power, nuclear security and materials safeguard, academia and research, environmental management, and health physics.

- **Headquarters:** Oak Ridge, TN with global sales and service offices
- **Employees:** 300+ worldwide
- **Core focus:** Ionizing radiation detection, identification and analysis systems
- **Ownership:** AMETEK, Inc., a leading global manufacturer of electronic instruments and electromechanical devices with 2017 sales of $4.5 billion

*ORTEC was founded in 1960 by researchers from Oak Ridge National Labs to commercialize charged particle detectors*

# ORTEC Global Footprint


**With distribution coverage across all non-direct countries…**

# ORTEC Core Competencies

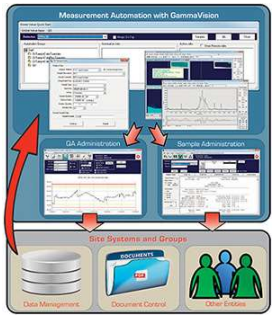
ORTEC®

- **High Purity Germanium Crystal Mfg.**
  - *Purest industrial substance in the world*
  - *~ 1x10$^{10}$ atoms/cc of impurity or better (out of about 1.2x10$^{23}$ atoms/cc total)*
  - *Additional silicon and Li6 detectors*

- **Cryocooling Technologies**
  - *Vertically intergraded design and manufacturing of Stirling coolers*

- **Data Acquisition Electronics**
  - *Highly specialized for nuclear, corrosion and materials analysis*

- **Analysis Software**
  - *Comprehensive offerings for integrated hardware control, data analysis, visual display, and reporting*

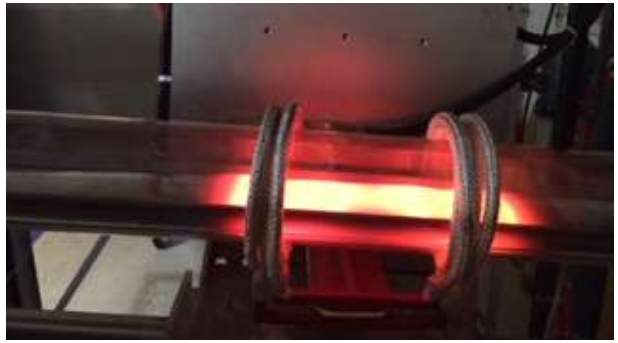
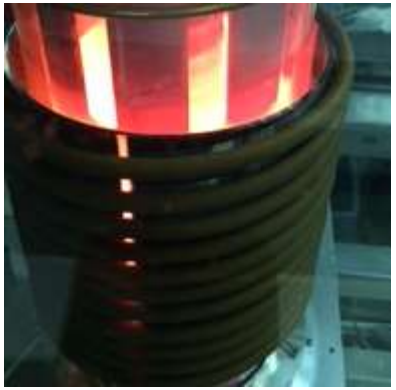


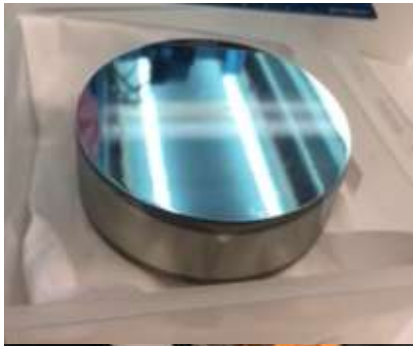

- **Integrated System Applications**
  - *Focused expertise to assess and configure or customize targeted customer solutions*

# ORTEC HPGe Detector Manufacturing

ORTEC®

- Vertically integrated
  - *High purity germanium crystal growth*
  - *HPGe shaping*
  - *HPGe fabrication*
  - *Detector assembly and testing*
- Special and advanced detector systems – design and fabrication
- Technology advancement – detector development with 70 + years of experience with radiation detection and cryostat design and cooling



# HP Germanium detector production

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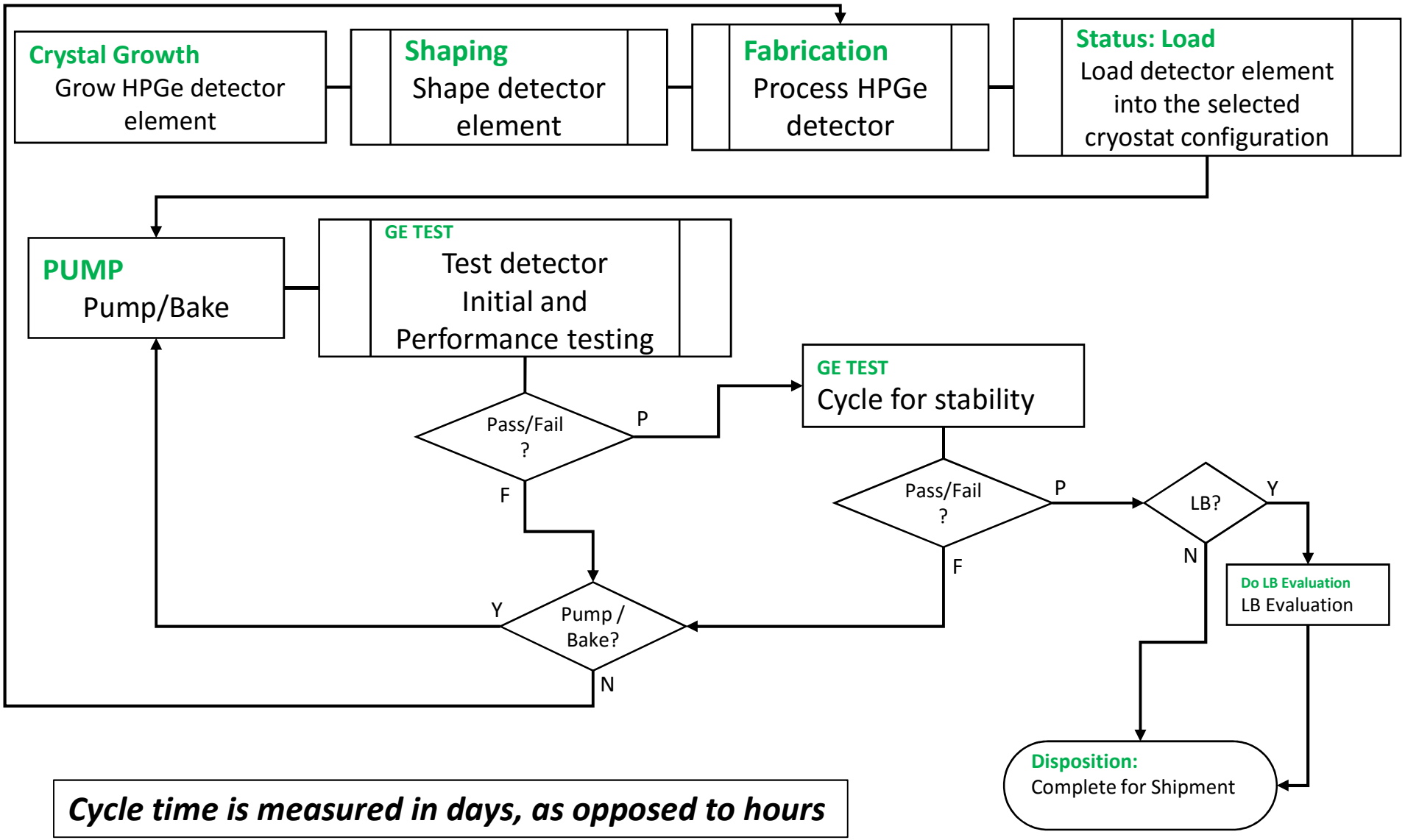


***Cycle time is measured in days, as opposed to hours***

# ORTEC/AMETEK Ge Detectors

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- New Developments
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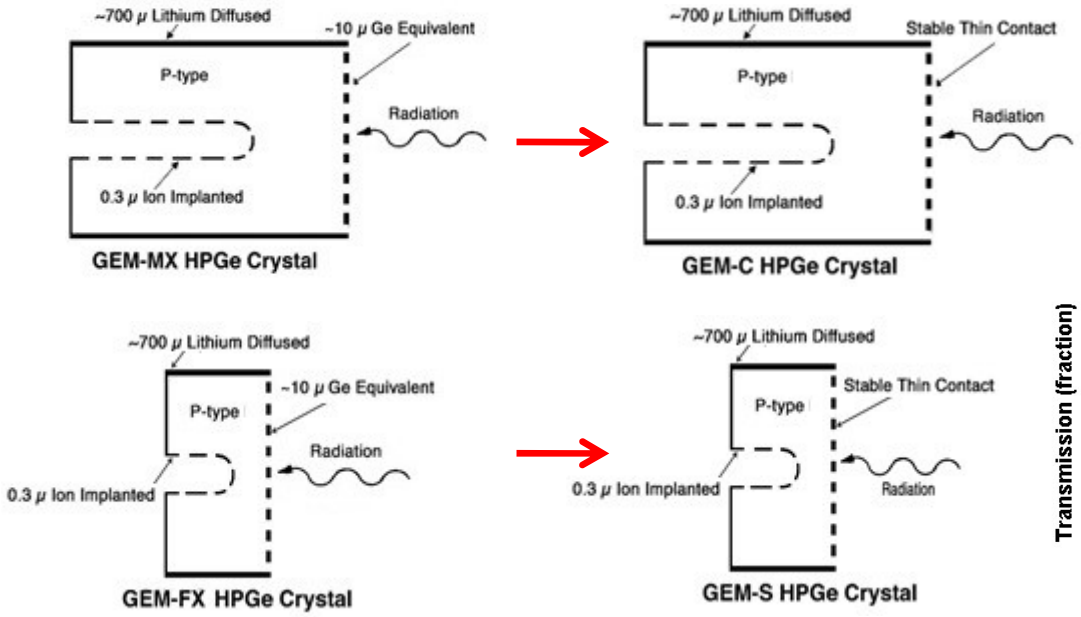
  - *Large diameter GEM-S and GEM-SP detector products*
  - *Application benefits*
  - *Mechanical cooling for Customized Solutions*
- ORTEC's special detectors
  - *Standard and Segmented Clovers*
  - *Double Sided Ge Strip detectors*
  - *Special Point Contact*
- Low Background
- Summary

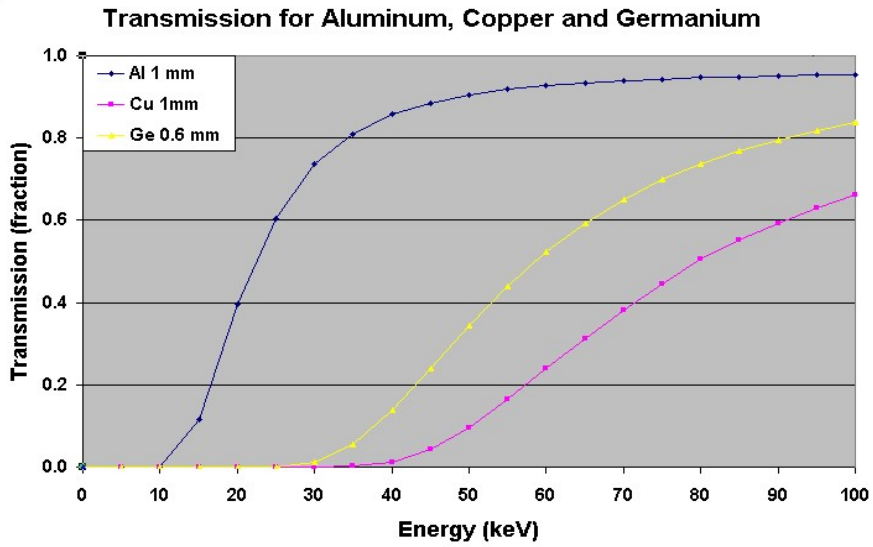
# Expansion of Profile S and C ORTEC Product Lines

- Stable Thin Front Contact (STFC) Released in July 2014

- STFC contact for the premium P-type detectors improves low energy (< 100keV) efficiency performance.

- STFC is a stable contact, allowing warm storage of the HPGe detector for prolonged time (months/years) without losing efficiency performance



# Efficiencies in 3 Geometries

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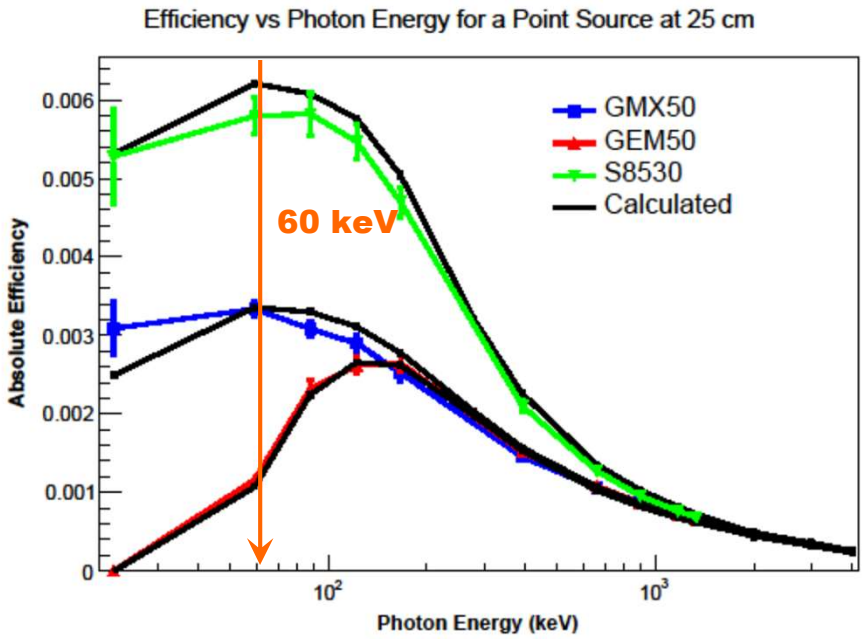


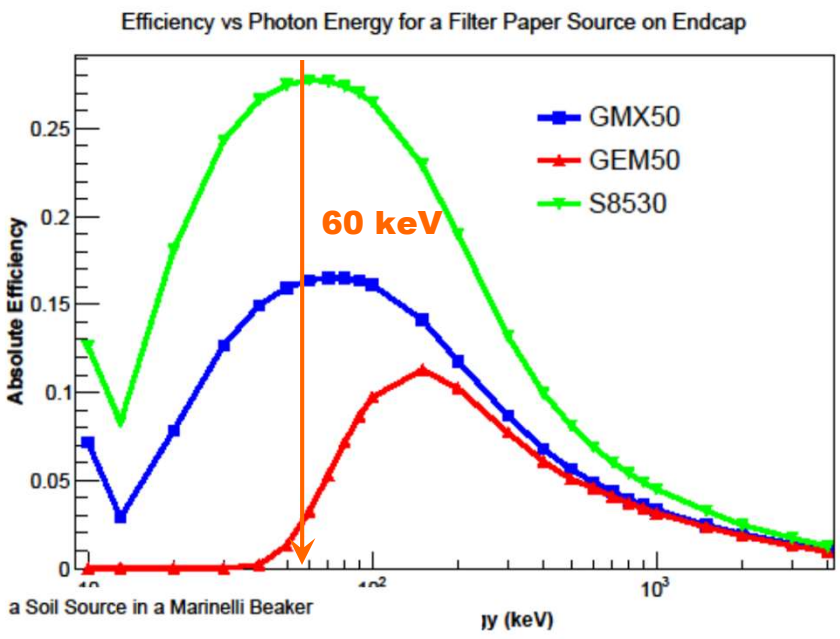


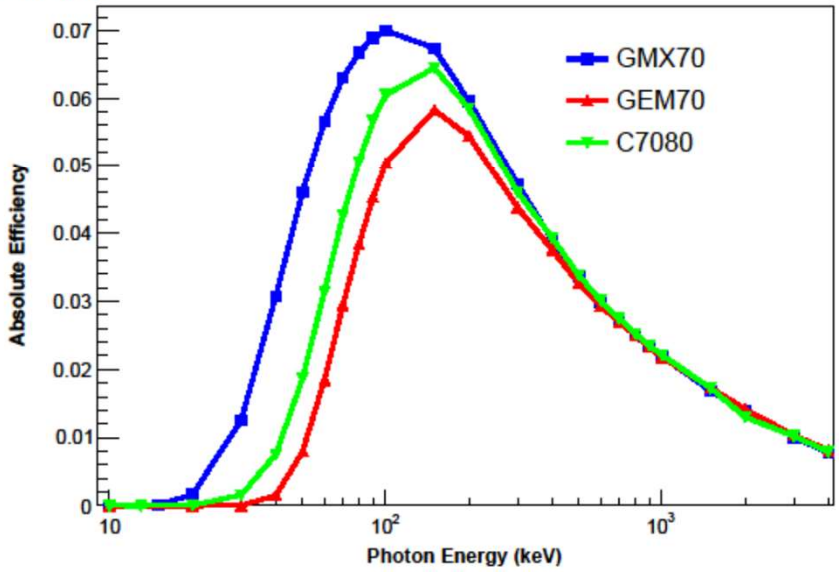


- *Stable Thin Front Contact (STFC) presented at the IEEE NSS/MIC, November 2014 in Seattle, Washington – Kyle T. Schmitt, Gregor G. Geurkov, Elaine. G. Roth, Timothy R. Twomey, and Teresa Underwood "Improved Efficiency at Low Energies with P-Type High Purity Germanium Detectors".*

# Profile C Models and Specs

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| Profile Model | | Crystal Dimension | | Energy Resolution (FWHM) | | | Peak Shape | | P:C Warr. | Nominal Relative Efficiency% | Endcap Dia. (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual Diameter (+0/–2 mm) | Actual Length Minimum | 5.9 keV Warr. (eV) | 122 keV Warr. (eV) | 1.33 MeV Warr. (keV) | FW.1M/ FWHM Typical | FW.02M/ FWHM Typical | | | |
| C-series | GEM-C5060P4 | 50 | 60 | 725 | 850 | 1.8 | 1.9 | 2.55 | 60 | 20 | 70 |
| | GEM-C5970P4 | 59 | 70 | 750 | 900 | 1.8 | 1.9 | 2.65 | 62 | 38 | 70 |
| | GEM-C7080P4 | 70 | 80 | 830 | 950 | 1.9 | 2.0 | 3.1 | 75 | 66 | 83 |
| | GEM-C8295P4 | 82 | 95 | 1215 | 1250 | 2.1 | 2.0 | 3.1 | 85 | 115 | 95 |
| | GEM-C94100P4 | 94 | 100 | 1230 | 1300 | 2.3 | 2.0 | 3.1 | 90 | 175 | 108 |

● - performance advantage ● - performance matches competition ● - performance disadvantage over competition

- *Expanding from 5 models to 23 models*
- Match every efficiency offered in the standard GEM detector product line
- Efficiencies offered: 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 90, 100, 110, 120, 130, 140, 150, and 175%

**Advantages in:**

- **Resolution**
- **Peak to Compton**
- **Peak Shape**
- **Endcap Diameter**

**Features included:**

- **Premium resolution performance offered down to 3 keV**
- **HPGe detector fills the endcap**
- **Not limited by efficiency**

# Expanded Profile C Models and Specs

ORTEC®

- *Released in October 2017*
- *23 models*

| Model No. | Crystal Dimension | | FWHM/Energy Resolution (warranted) | | | Peak Shape | | P:C Warr. | Nominal Relative Efficiency % | Endcap Dia. (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual Diameter (+2/–2 mm) | Actual Length Minimum | 5.9 keV (eV) | 122 keV (eV) | 1.33 MeV (keV) | FW.1M/ FWHM Typical | FW.02M/ FWHM Typical | | | |
| GEM-C10 | 50 | 25 | 600 | 800 | 1.8 | 1.9 | 2.55 | 41 | 10 | 70 |
| GEM-C15 | 50 | 44 | 635 | 820 | 1.8 | 1.9 | 2.55 | 46 | 15 | 70 |
| GEM-C20 | 50 | 60 | 650 | 820 | 1.8 | 1.9 | 2.55 | 60 | 20 | 70 |
| GEM-C25 | 57 | 50 | 690 | 850 | 1.8 | 1.9 | 2.60 | 56 | 25 | 70 |
| GEM-C30 | 57 | 62 | 715 | 850 | 1.8 | 1.9 | 2.60 | 60 | 30 | 70 |
| GEM-C35 | 57 | 75 | 730 | 850 | 1.8 | 1.9 | 2.60 | 62 | 35 | 70 |
| GEM-C40 | 64* | 58 | 760 | 870 | 1.8 | 1.9 | 2.60 | 64 | 40 | 76 |
| GEM-C45 | 64* | 68 | 800 | 900 | 1.8 | 1.9 | 2.60 | 64 | 45 | 76 |
| GEM-C50 | 68 | 62 | 800 | 900 | 1.9 | 1.9 | 2.60 | 66 | 50 | 83 |
| GEM-C55 | 68 | 70 | 830 | 1000 | 1.9 | 1.9 | 2.60 | 67 | 55 | 83 |
| GEM-C60 | 68 | 77 | 830 | 1000 | 1.9 | 1.9 | 2.80 | 70 | 60 | 83 |
| GEM-C65 | 68 | 86 | 830 | 1000 | 1.9 | 1.9 | 3.00 | 73 | 65 | 83 |

● - performance advantage ● - performance matches competition ● - performance disadvantage over competition

# Expanded Profile C (cont.)

ORTEC®

| Model No. | Crystal Dimension | | FWHM/Energy Resolution (warranted) | | | Peak Shape | | P:C Warr. | Nominal Relative Efficiency % | Endcap Dia. (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual Diameter (+2/–2 mm) | Actual Length Minimum | 5.9 keV (eV) | 122 keV (eV) | 1.33 MeV (keV) | FW.1M/ FWHM Typical | FW.02M/ FWHM Typical | | | |
| GEM-C70 | 70* | 85 | 900 | 1000 | 2.0 | 1.9 | 3.00 | 75 | 70 | 83 |
| GEM-C75 | 80 | 56 | 900 | 1000 | 2.0 | 1.9 | 3.00 | 73 | 75 | 95 |
| GEM-C80 | 80 | 61 | 950 | 1000 | 2.0 | 1.9 | 3.00 | 73 | 80 | 95 |
| GEM-C90 | 80 | 70 | 950 | 1100 | 2.0 | 1.9 | 3.00 | 80 | 90 | 95 |
| GEM-C100 | 80 | 82 | 1000 | 1100 | 2.1 | 1.9 | 3.00 | 83 | 100 | 95 |
| GEM-C110 | 80 | 91 | 1050 | 1100 | 2.1 | 1.9 | 3.00 | 85 | 110 | 95 |
| GEM-C120 | 82* | 98 | 1050 | 1100 | 2.1 | 1.9 | 3.00 | 86 | 120 | 95 |
| GEM-C130 | 92 | 67 | 1100 | 1200 | 2.1 | 2.0 | 3.10 | 83 | 130 | 108 |
| GEM-C140 | 92 | 74 | 1100 | 1200 | 2.2 | 2.0 | 3.10 | 83 | 140 | 108 |
| GEM-C150 | 92 | 81 | 1100 | 1300 | 2.3 | 2.0 | 3.10 | 90 | 150 | 108 |
| GEM-C175 | 94* | 100 | 1100 | 1300 | 2.3 | 2.0 | 3.10 | 90 | 175 | 108 |

● - performance advantage ● - performance matches competition ● - performance disadvantage over competition

# Minimum Detectable Activity

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$$MDA\ (E) \sim \frac{\sqrt{B(E)}}{t \times \varepsilon(E)}$$

- *E = gamma energy of interest*
- *t = counting time*
- *B(E) = background rate*
- *ε (E) = absolute efficiency*

*Note: B(E) is indirectly proportional to detector resolution*

New detectors enable researchers to achieve lower MDA:

- ❑ Superior energy resolution reduces the background contribution (improves peak-to-noise)
- ❑ Increased detector efficiency reduces count times

# Profile SP with LNBC

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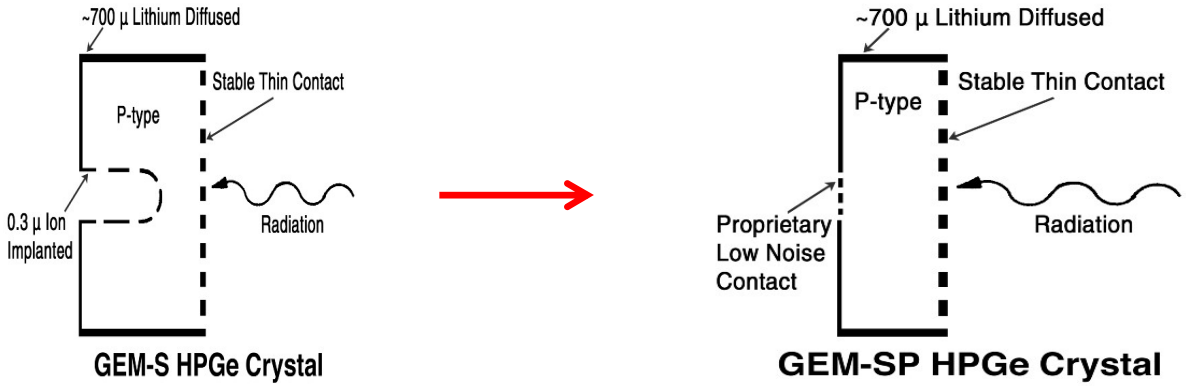
- System resolution $\sqrt{R(d)^2 + R(E)^2}$
- R(d) is the detector resolution and R(E) is the electronic resolution
- To a very good approximation R(d) (in keV) = $1.35\sqrt{E(in\ MeV)}$
- R(E) depends on the capacitance of the detector and the capacitance depends on the surface area of the contact




- Low Noise Back Contact (LNBC) Released in July 2015
  - *Low Noise Back Contact (LNBC) presented at the IEEE NSS/MIC, November 2016 in Strasbourg, France – Gregor G. Geurkov, Elaine. G. Roth, Kyle T. Schmitt, and Teresa Underwood "Profile SP (P-type) HPGe detectors – premium resolution at low to medium energies".*
- LNBC is a new proprietary contact for P-type detectors that improves low to medium energy (<700 keV) resolution performance

# Largest Diameter with Premium FWHM

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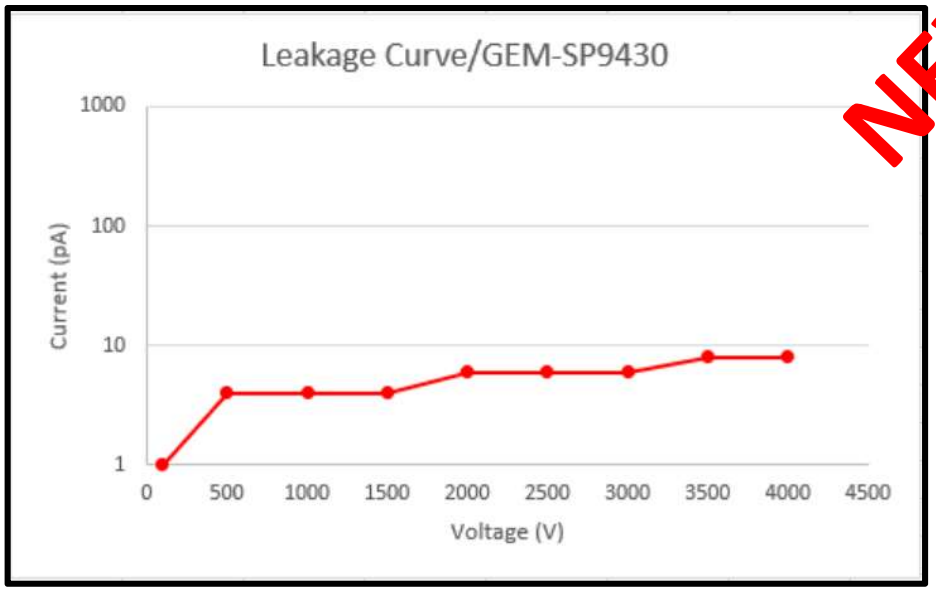
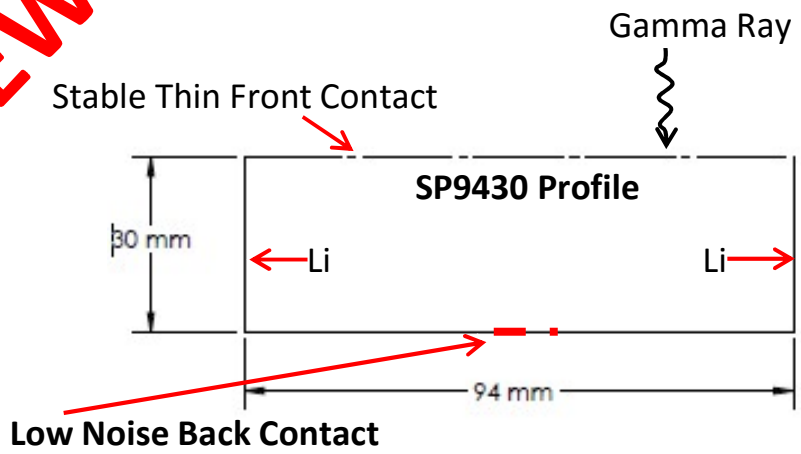



NEW




**To be released 2018**

| FWHM @ different energies/cooling mechanisms | | | | | | | Measured with GEM-SP9430 |
|---|---|---|---|---|---|---|---|
| FWHM in keV @ 1332 keV energy | FWHM in eV @ 122 keV energy | FWHM in eV @ 5.9 keV energy | Peak-to-Compton | FW.1M / FWHM | FW.02M / FWHM | Shaping Time | Cooling |
| 1.71 | 564 | 344 | 71.1 | 1.87 | 2.51 | 6 | Liquid Nitrogen |
| 1.77 | 593 | 348 | 68.0 | 1.93 | 2.91 | 6 | Mobius On |
| - | 557 | 322 | - | - | - | 6 | Mobius Off |
| 1.66 | 577 | 364 | 72.7 | 1.85 | 2.49 | 10 | Liquid Nitrogen |

# Profile SP9430 Competition

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## Competitive Comparison

| Base Detector Model | Crystal Dimension | | Warranted Full Width Half Max resolution (in eV) at | | | Peak Shape | | Peak to Compton warranted | Nominal Relative Efficiency (%) | Endcap Diameter (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter (+0/-2 mm) | Minimum Thickness (mm) | 5.9 keV | 122 keV | 1332 keV | FW.1M/ FWHM | FW.02M/ FWHM | | | |
| GEM-SP9430 | 94 | 30 | 425 | 630 | 1900 | 2.00 | 2.90 | 65 | 65 | 108 |
| GEM-S9430 | 94 | 30 | 500 | 700 | 1900 | 2.00 | 2.90 | 65 | 65 | 108 |
| Model "B" | 90 | 30 | 500 | 750 | 2000 | N/A | N/A | N/A | 60 | 114 |

**Profile S favorable…**

- Greater efficiency, higher throughput
- Better resolution at higher energies
- Smaller endcap

**Profile SP ideal…**

- Premium resolution and efficiency
- Better resolution at lower energies
- Smaller endcap

## Sample Result from an order

| Base Detector Model | Crystal Dimension | | Warranted Full Width Half Max resolution (in eV) at | | | Peak Shape | | Peak to Compton warranted | Nominal Relative Efficiency (%) | Endcap Diameter (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter (+0/-2 mm) | Minimum Thickness (mm) | 5.9 keV | 122 keV | 1332 keV | FW.1M/ FWHM | FW.02M/ FWHM | | | |
| Smp/GEM-SP | 94 | 30 | 346 | 579 | 1740 | 1.90 | 2.71 | 70 | 67.3 | 108 |
| GEM-SP9430 | 94 | 30 | 425 | 630 | 1900 | 2.00 | 2.90 | 65 | 65 | 108 |
| Smp/GEM-S | 94 | 30 | 418 | 614 | 1740 | 1.88 | 2.64 | 71 | 72.3 | 108 |
| GEM-S9430 | 94 | 30 | 500 | 700 | 1900 | 2.00 | 2.90 | 65 | 65 | 108 |

# Profile SP Detector Models and Specs

ORTEC®

| Profile Model | | Crystal Dimension | | Energy Resolution (FWHM) | | | Peak Shape | | P:C Warr. | Nominal Relative Efficiency % | Endcap Dia. (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual Diameter (+0/–2 mm) | Actual Length Minimum | 5.9 keV Warr. (eV) | @122 keV Warr. (eV) | @1.33 MeV Warr. (keV) | FW.1M/ FWHM Typical | FW.02M / FWHM Typical | | | |
| SP-series | GEM-SP5020P4 | 50 | 20 | 300 | 585 | 1.8 | 1.90 | 2.55 | 35 | 7 | 70 |
| | GEM-SP5825P4 | 58 | 25 | 340 | 585 | 1.8 | 1.90 | 2.65 | 35 | 15 | 70 |
| | GEM-SP7025P4 | 70 | 25 | 380 | 585 | 1.8 | 1.95 | 2.75 | 40 | 20 | 83 |
| | GEM-SP8530P4 | 85 | 30 | 400 | 630 | 1.9 | 2.00 | 2.90 | 55 | 50 | 108 |
| | GEM-SP9430P4 | 94 | 30 | 425 | 630 | 1.9 | 2.00 | 2.90 | 65 | 65 | 108 |
| | GEM-SP10530P4 | 105 | 30 | 450 | 630 | 2.0 | 2.00 | 2.90 | 65 | 80 | 121 |

● - performance advantage ● - performance matches competition ● - performance disadvantage over competition

## Advantages in:

- Resolution
- Peak to Compton
- Peak Shape
- Endcap Diameter

## Observations:

- Better resolution and Peak-to-Compton is important in improving MDA performance

**Premium resolution specs!**

- 15% lower guaranteed resolution at 5.9 keV as compared to Profile S
- 10% lower guaranteed resolution at 122 keV as compared to Profile S
- 13-19% lower guaranteed resolution at 122 keV as compared to competition

# Largest Diameter Semi-Planar HPGe

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**Key Drivers**

- Maximized counting efficiency
- Nuclide identification over as wide an energy range as possible
- Simple handling and lower storage cost with no loss of detector efficiency

**Technology / Product Implementation and Solution**

- Semi-planar P-type HPGe detectors
- Crystal diameter maximization within the endcap
- Maximum efficiency and resolution targeting research / health physics / waste assay / LB labs

# Detector Efficiency

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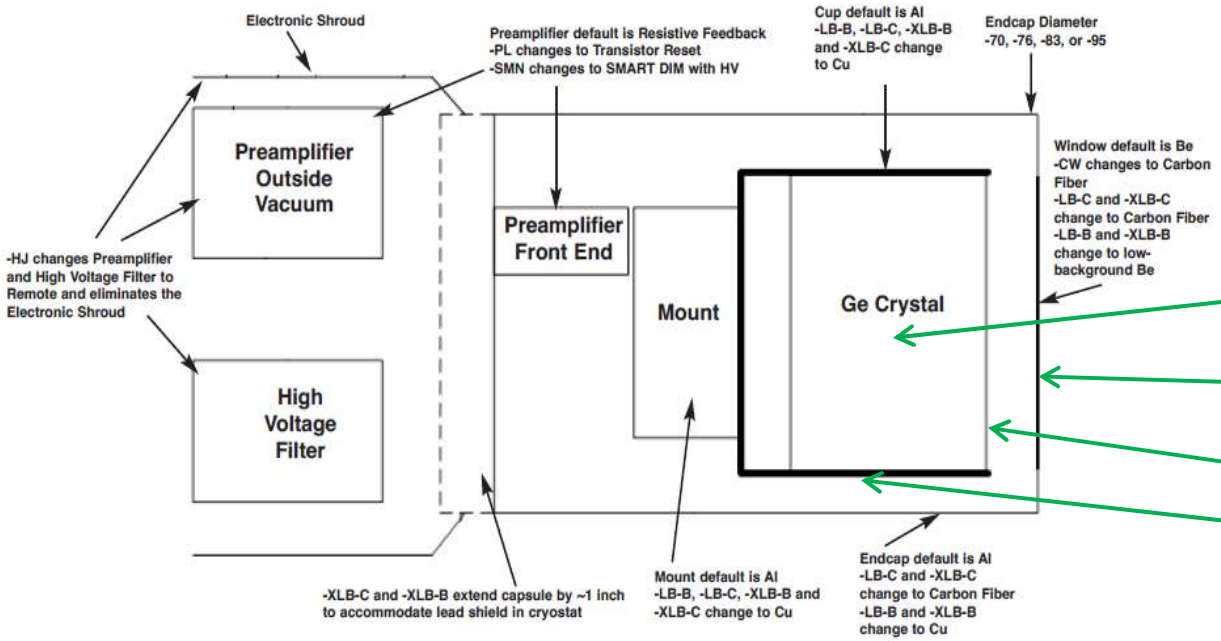


Components affecting efficiency:

- Crystal dimensions
- Front and sides of the endcap
- *Crystal contact
- Crystal holder

- *Stable Thin Front Contact (STFC) Released in July 2014

*Technical paper presented at the IEEE NSS/MIC, November 2016 in Seattle, USA –*
*Gregor G. Geurkov, Elaine. G. Roth, Kyle T. Schmitt, Timothy R. Twomey and Teresa Underwood*
*"*Improved Efficiency at Low Energies with P-Type High Purity Germanium Detectors*".*

- *STFC is a new thin contact for P-type detectors that improves low energy (<40keV) efficiency performance.

- *STFC is a stable contact, allowing warm storage of the HPGe detector for prolonged time (months/years) without losing efficiency performance from the front contact

# Largest Diameter Semi-Planar HPGe Detector

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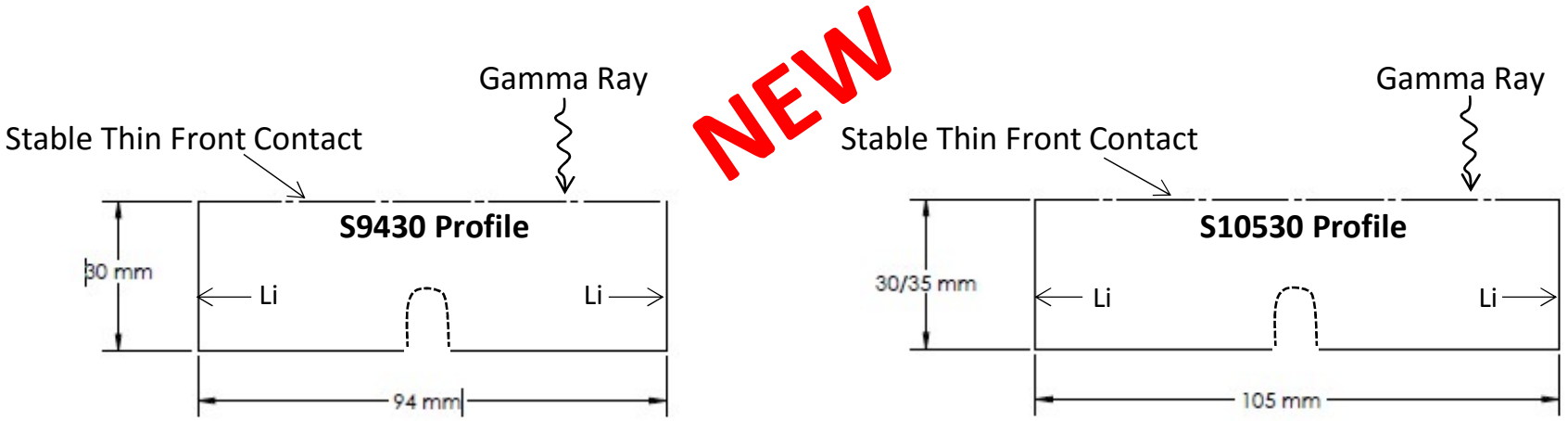
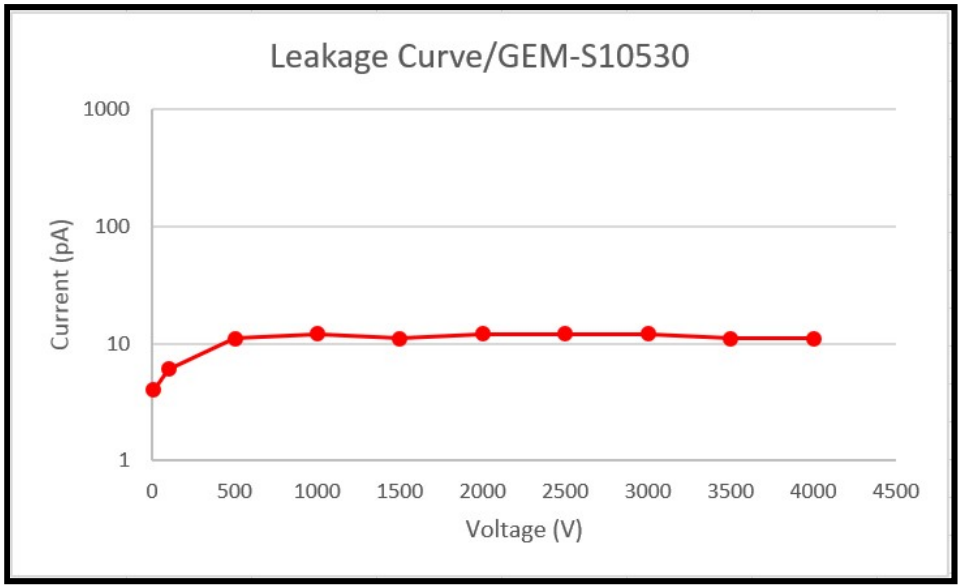


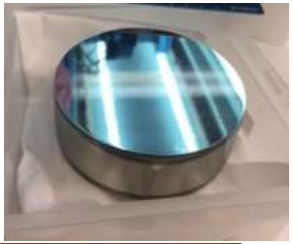

**Released in 2016*

**To be released 2018**




## Measured Performance/GEM-S10530

- FWHM at 1.33 MeV - 1.91 keV
- Pulser - 400
- P:C - 66.9
- FW.1M/ FWHM - 1.96
- FW.02M/ FWHM - 2.86
- Rel. Eff - 82.6%



# Measure GEM-S10530 Performance/Cooling Methods




| FWHM @ different energies/cooling mechanisms | | | | | | Measured with GEM-S10530 | |
|---|---|---|---|---|---|---|---|
| FWHM in keV @ 1332 keV energy | FWHM in eV @ 122 keV energy | FWHM in eV @ 5.9 keV energy | Peak-to-Compton | FW.1M / FWHM | FW.02M / FWHM | Shaping time / Peaking equivalent | Cooling |
| 1.85 | 597 | 403 | 67.5 | 1.95 | 2.85 | 6 | Liquid Nitrogen |
| 1.96 | 620 | 433 | 64.3 | 1.95 | 2.94 | 6 | X-Cooler |
| 1.87 | 631 | 456 | 66.6 | 1.96 | 2.82 | 6 | ICS-P4 |
| 1.70 | 616 | 442 | 76.7 | 1.88 | 2.55 | 10 | Liquid Nitrogen |
| 1.78 | 648 | 469 | 75.1 | 1.82 | 2.45 | 10 | X-Cooler |
| 1.71 | 656 | 491 | 75.4 | 1.87 | 2.48 | 10 | ICS-P4 |
| 1.65 | 598 | 400 | 76.9 | 1.91 | 2.92 | 12 | Liquid Nitrogen |
| 1.72 | 592 | 410 | 74.6 | 1.87 | 2.80 | 20 | Liquid Nitrogen |
| 1.68 | 603 | 421 | 75.9 | 1.90 | 2.89 | 20 | Mobius On |
| 1.68 | 598 | 410 | 75.5 | 1.92 | 2.91 | 20 | Mobius Off |

- *Performance of GEM-S10530 detector in an ORTEC PopTop capsule configuration with a CFG-PV4 cryostat*

# Efficiencies - Point Source 25cm away

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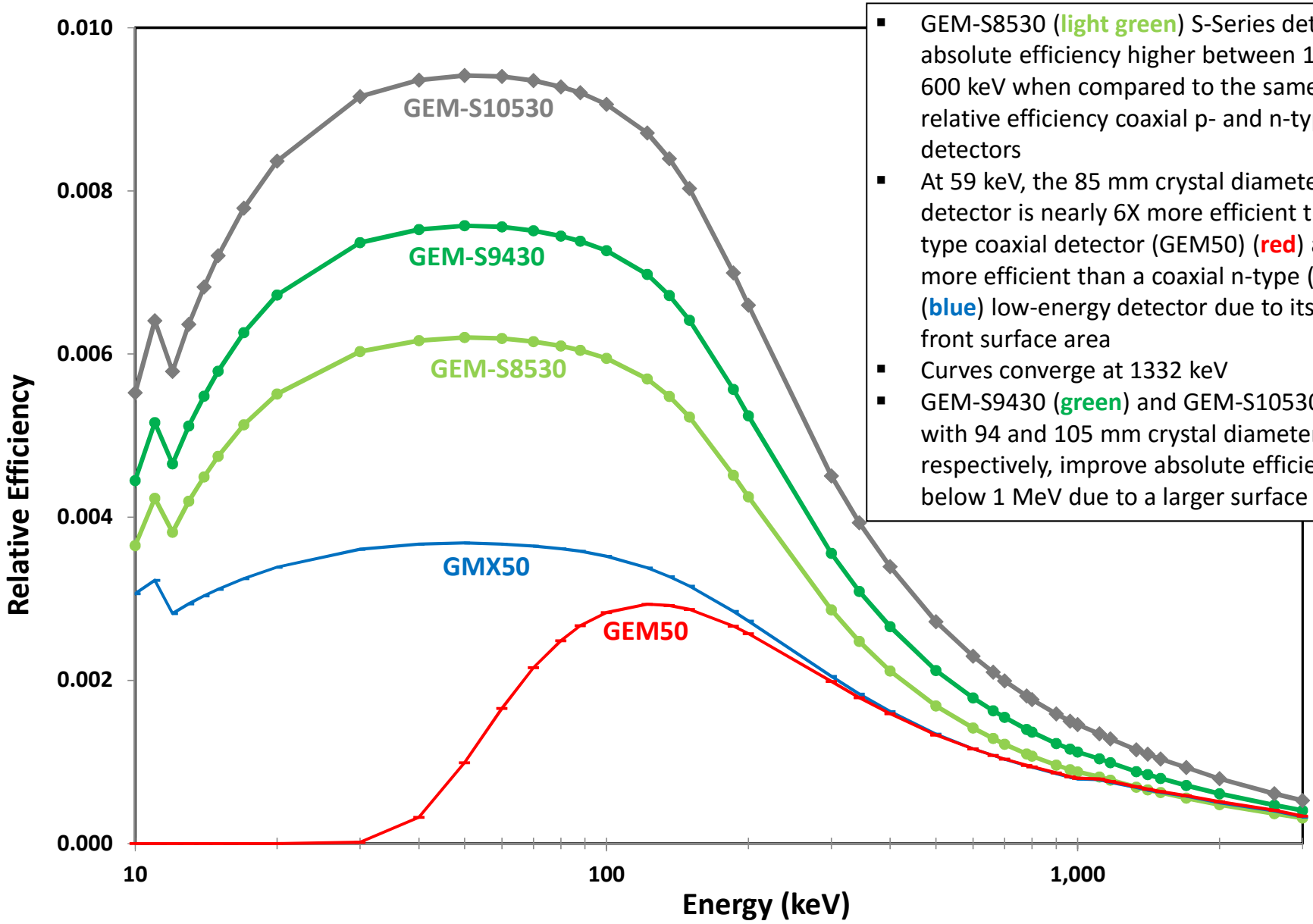


- GEM-S8530 (**light green**) S-Series detector's absolute efficiency higher between 10 keV and 600 keV when compared to the same 50% relative efficiency coaxial p- and n-type detectors
- At 59 keV, the 85 mm crystal diameter S-Series detector is nearly 6X more efficient than a p-type coaxial detector (GEM50) (**red**) and 2X more efficient than a coaxial n-type (GMX50) (**blue**) low-energy detector due to its greater front surface area
- Curves converge at 1332 keV
- GEM-S9430 (**green**) and GEM-S10530 (**gray**) with 94 and 105 mm crystal diameter, respectively, improve absolute efficiencies below 1 MeV due to a larger surface area

# Efficiencies – 10cm diameter Filter paper

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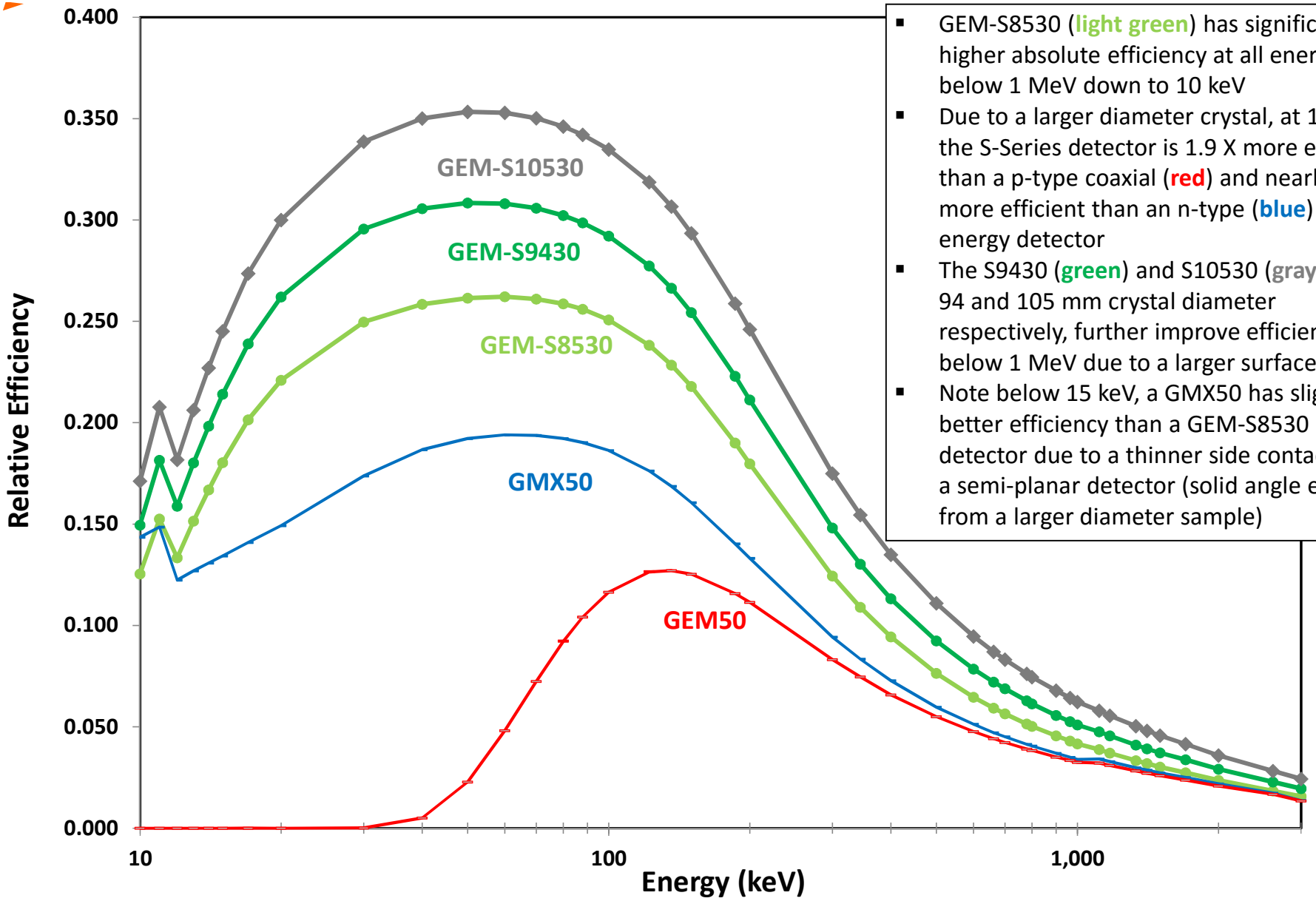



- GEM-S8530 (light green) has significantly higher absolute efficiency at all energies below 1 MeV down to 10 keV
- Due to a larger diameter crystal, at 122 keV, the S-Series detector is 1.9 X more efficient than a p-type coaxial (red) and nearly 1.4 X more efficient than an n-type (blue) low-energy detector
- The S9430 (green) and S10530 (gray) with 94 and 105 mm crystal diameter respectively, further improve efficiencies below 1 MeV due to a larger surface area
- Note below 15 keV, a GMX50 has slightly better efficiency than a GEM-S8530 detector due to a thinner side contact than a semi-planar detector (solid angle effect from a larger diameter sample)

# Profile S Detector Models and Specs

ORTEC®

| Profile Model | | Crystal Dimension | | Energy Resolution (FWHM) | | | Peak Shape | | P:C Warr. | Nominal Relative Efficiency % | Endcap Dia. (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual Diameter (+0/–2 mm) | Actual Length Minimum | 5.9 keV Warr. (eV) | @122 keV Warr. (eV) | @1.33 MeV Warr. (keV) | FW.1M/ FWHM Typical | FW.02M / FWHM Typical | | | |
| S-series | GEM-S5020P4 | 50 | 20 | 350 | 650 | 1.8 | 1.90 | 2.55 | 35 | 7 | 70 |
| | GEM-S5825P4 | 58 | 25 | 400 | 650 | 1.8 | 1.90 | 2.65 | 35 | 15 | 70 |
| | GEM-S7025P4 | 70 | 25 | 450 | 650 | 1.9 | 1.95 | 2.75 | 40 | 20 | 83 |
| | GEM-S7030P4 | 70 | 30 | 450 | 700 | 1.9 | 2.00 | 2.90 | 40 | 28 | 83 |
| | GEM-S8530P4 | 85 | 30 | 500 | 700 | 1.9 | 2.00 | 2.90 | 55 | 50 | 108 |
| | GEM-S9430P4 | 94 | 30 | 500 | 700 | 1.9 | 2.00 | 2.90 | 65 | 65 | 108 |
| | GEM-S10530P4 | 105 | 30 | 550 | 700 | 2.0 | 2.00 | 2.90 | 65 | 80 | 121 |
| | GEM-S10535P4 | 105 | 35 | 550 | 700 | 2.0 | 2.00 | 2.90 | 65 | 90 | 121 |

● - performance advantage ● - performance matches competition ● - performance disadvantage over competition

**Advantages in:**

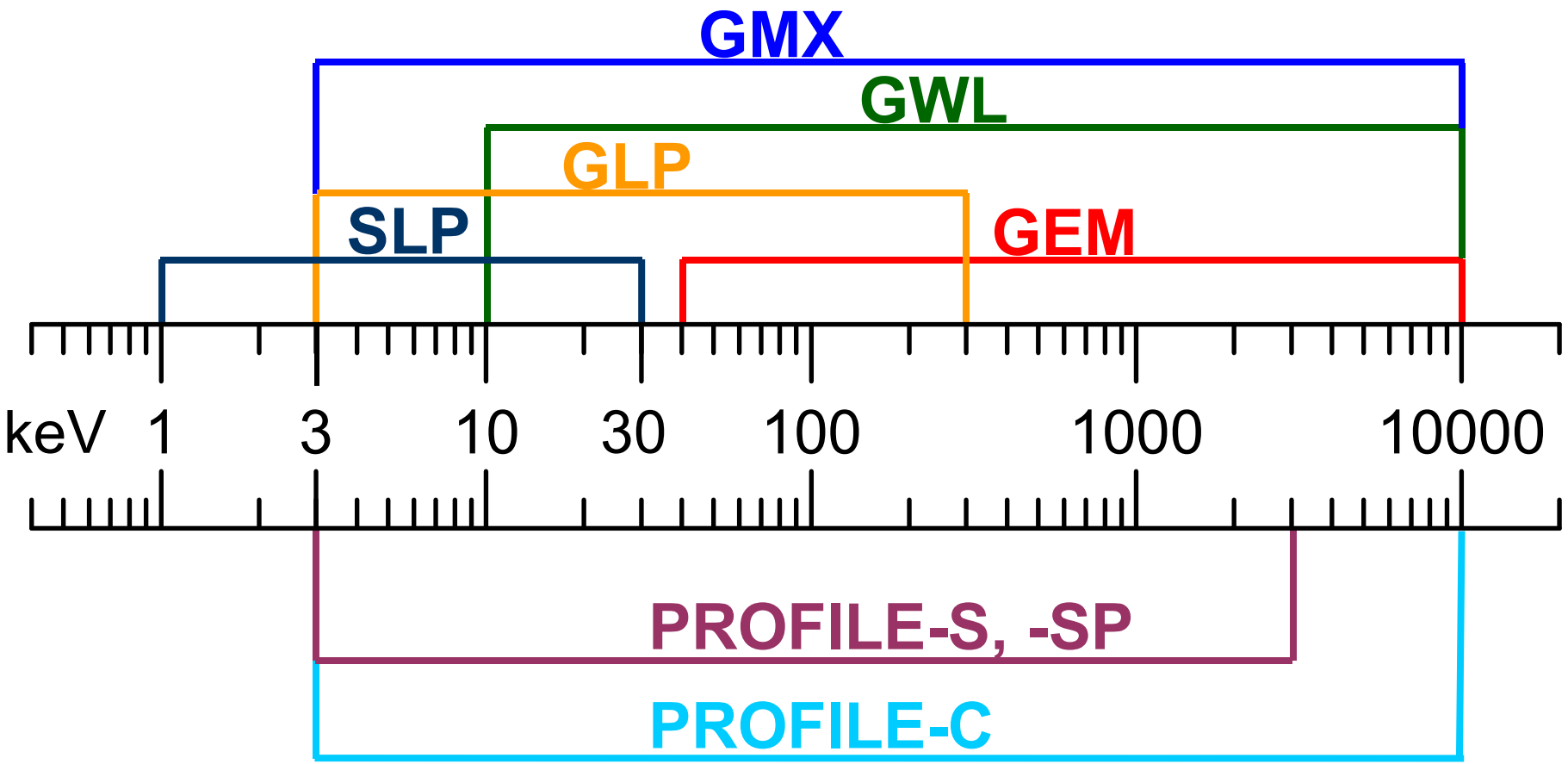
- Resolution
- Peak to Compton
- Peak Shape
- Endcap Diameter

**Observations:**

- Better resolution and Peak-to-Compton is important in improving MDA performance

# HPGe Types and Energy Ranges

ORTEC®



# Conclusions

ORTEC®

- Premium performance of new detectors confirmed at various shaping/peaking times, both analog and digital
- Large diameter profile detectors produce the best absolute and relative efficiencies from the front of the detector endcap
- Improved detector characteristics result in reduced count time and lower Minimum Detectable Activity
- Superior resolution minimizes peak misidentification and reduces false IDs

# Introduction – Cooling HPGe Detectors

ORTEC®

Using Liquid Nitrogen as cooling method has significant challenges:

- It is a hazardous material
- It is costly both in terms of man-hours used in filling operations and the actual cost of the $LN_2$
- Detector performance may be degraded during filling
- It is not always available, thus limiting the applications for HPGe detectors

# Introduction (continued)

ORTEC®

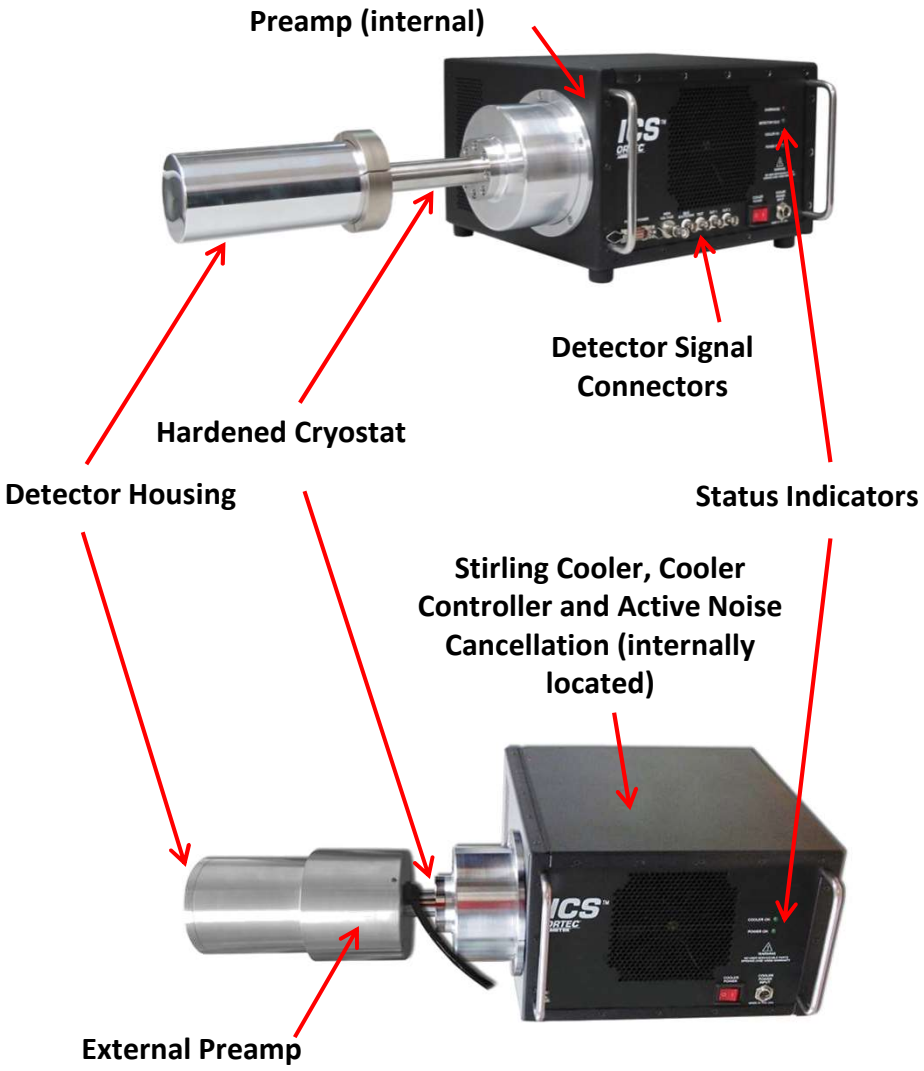
- ORTEC has been manufacturing mechanical coolers since mid ‘70s
  - *Old generations coolers*
    - Solvay (mid 70s) and Joule Thompson (early 90s) technologies
    - Klemenko cycle (X-cooler I,II,III since 2004).
  - *New generation coolers*
    - Stirling (Detective family since 2004).
    - Stirling (LDM/Mobius/ICS since 2010/2013/2014 correspondingly)

- ORTEC is the only detector manufacturer that is vertically integrated in non-$LN_2$ cooling
  - *ORTEC purchased Sunpower in 2013*
  - *Stirling coolers are:*
    - More efficient than other technologies
    - More reliable (longer MTTF) than other technologies
    - Smaller foot-print (one box design)
    - Same microphonic noise performance as Pulse-Tube
  - *Control over quality and cooler developments*

# ICS® Integrated Cryocooling System

ORTEC®

## *Superior electro-mechanical cooling system for HPGe detectors*




### Key Drivers

- Premium, $LN_2$ like resolution performance without using $LN_2$, with improved operational ease-of-use, application flexibility, and superior system uptime

### Technology / Product Implementation and Solution

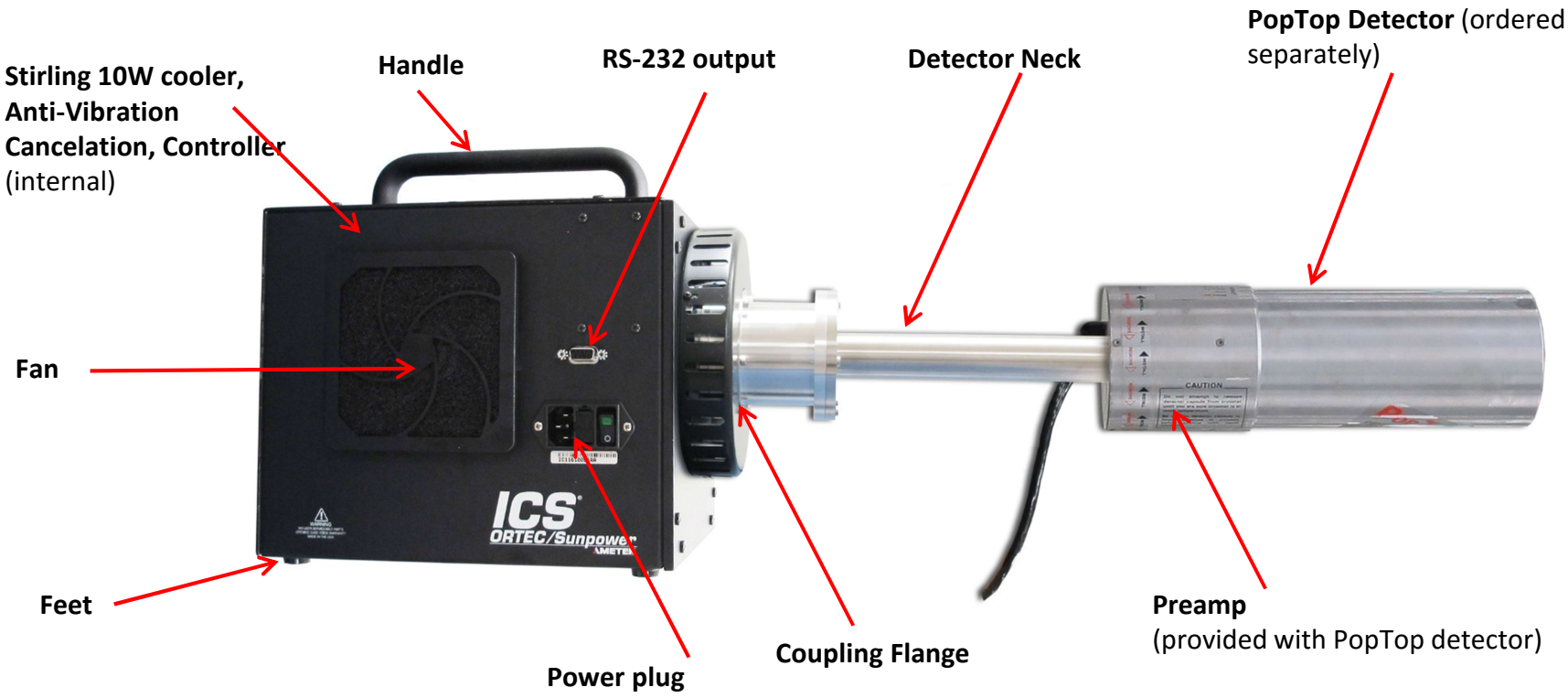
- Delivers $LN_2$ like resolution for a variety of HPGe detector models
- Fully integrated Sunpower Stirling cryocooler incorporates Active Vibration Cancellation technology and provides excellent cooler MTTF
- Vacuum hardened cryostat for superior vacuum integrity and no thermal cycling
- Ultra-quite design in a small, compact, single unit footprint provides installation flexibility

# PopTop® -ICS® (ICS-P4)

ORTEC®

## Key Differences From Vacuum Hardened version

- Conventional cryostat
- Field Upgradable
- Higher power consumption
- Lower weight

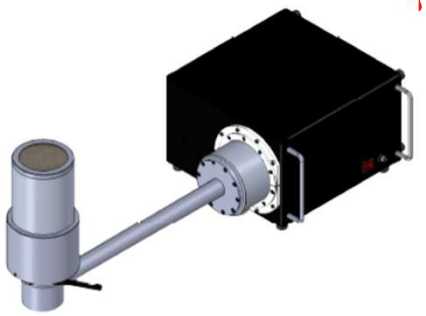


# Mechanical cooling for Customized Solutions

ORTEC®

**90-degree angle ICS configuration with any size/type detector**

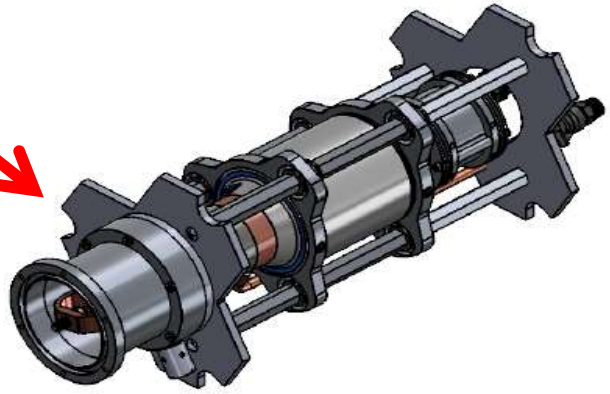
**Complete system designs with MCA and software**



**Multi-Detector "Hydra" designs**

**Special Detectors**

?



ORTEC offers unique cooling solutions to meet and design requirements

# ORTEC/AMETEK Ge Detectors

ORTEC®

- ORTEC Overview
- New Developments
  - *Expansion of GEM-C profile detector product line*
  - *Resolution - Profile SP series with LNBC*
  - *Large diameter GEM-S and GEM-SP detector products*
  - *Application benefits*
  - *Mechanical cooling for Customized Solutions*
- ORTEC's special detectors
  - *Standard and Segmented Clovers*
  - *Double Sided Ge Strip detectors*
  - *Special Point Contact*
- Low Background
- Summary

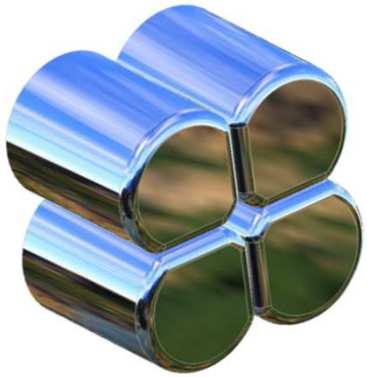
# Advance Special Detector History

ORTEC®

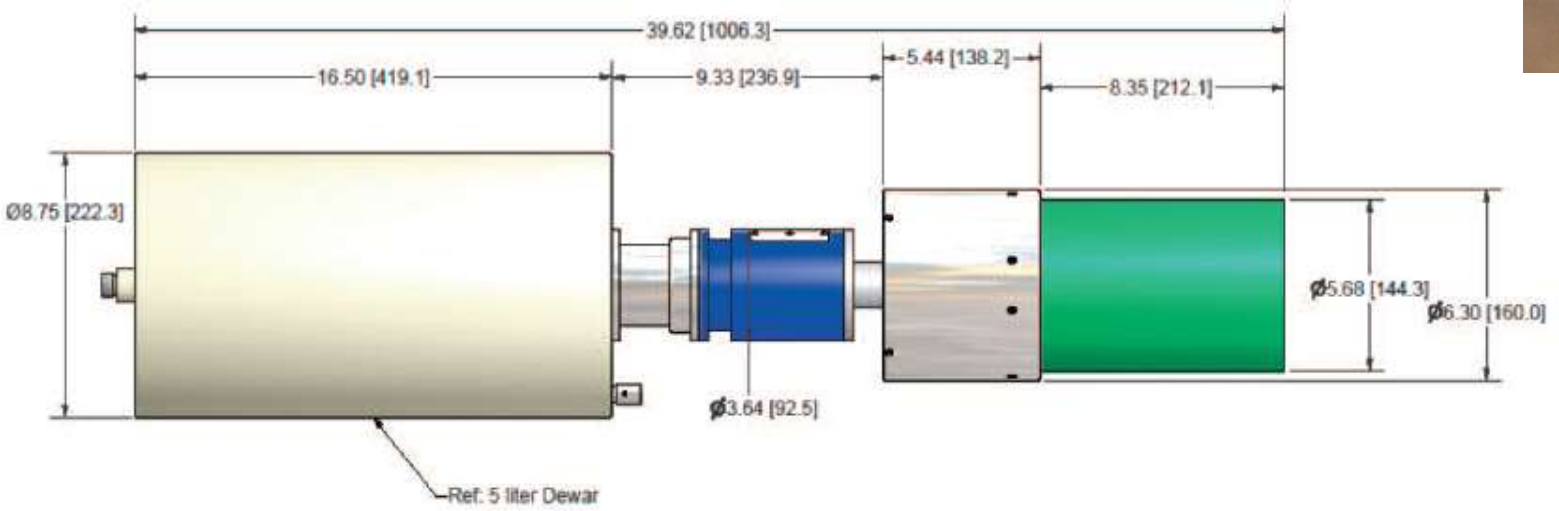
| Advance Detector | First Unit built | Number of Units built | Application Examples |
|---|---|---|---|
| Gamma Sphere<br>GaSp | Early 1990s<br>1990s | 110+<br>40 | Nuclear Physics, beamlines |
| Clover Detectors | Mid 1990s | 20+ | Nuclear Physics, Health Physics |
| Point Contact (coaxial, semi-planar) | 2009 | 50+ | Neutrino and Dark Matter, High Resolution Spectrometry, Safeguards |
| PopTop/Encapsulated | Mid 1980s | Hundreds | Multi-detector (limited space) or multi-orientation, electro-mechanical coolers |
| Double Sided Strip Detectors | Early 2000 | Several | Nuclear physics, Beamlines, Imaging, Medical |
| Shields, Low Background Hardware | 1970s | Hundreds | Low count rate, Underground low background studies |
| Segmented | 2000 | Several | Spin Spectroscopy, Tracking, Doppler Shift |
| Arrays | Early 1990s | Several | Synchrotrons and beamlines, EXAFs |

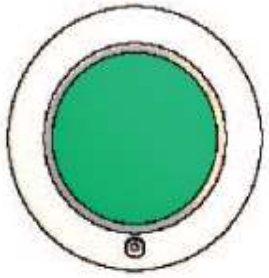
# Clover Detector Systems

ORTEC®





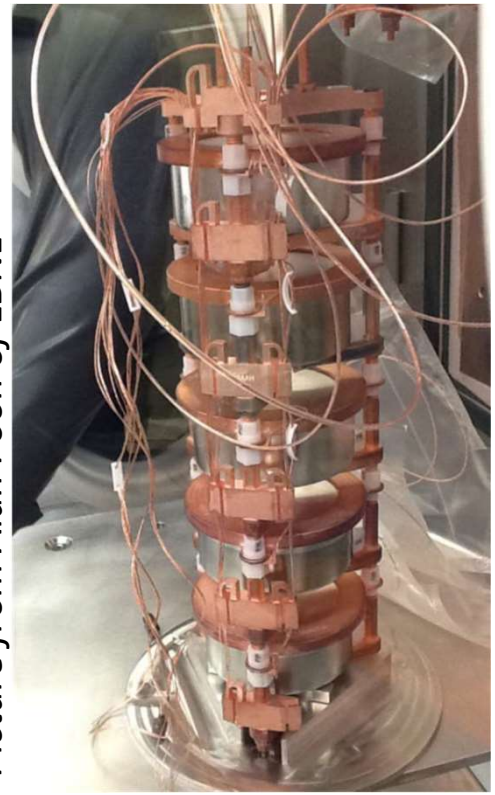


# Point Contact Detector (Majorana Demonstrator)

ORTEC®

- 30+ Ge-76 detectors built
  - Manufacturing scheduled
  - Advantageous crystal growth and fabrication yield
- Pulser < 400 eV on average
- FWHM @ 1.33 MeV nominally 1.90 keV on average
- Exposure rate far below calculated acceptance value



*Picture from Alan Poon of LBNL

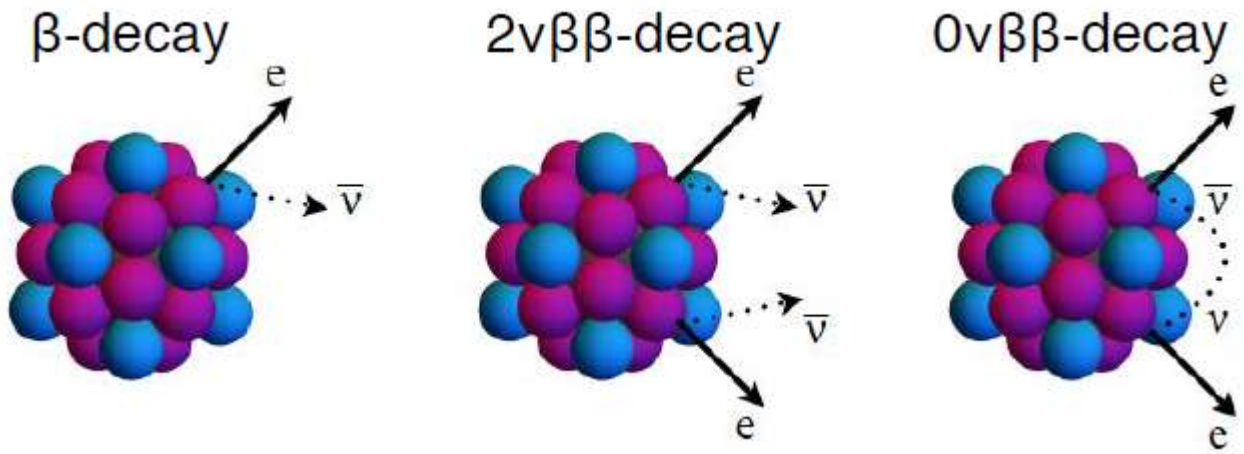
Considerations:

- Background exposure
- High yield of high-cost Ge-76 material

| ORTEC Factory Advantages |
| --- |
| Vertical manufacturing facility – maintain control in the exposure of material through growth and manufacturing process |
| Superior resolution and detector yield |
| Control of cosmic exposure |

# Coaxial Point Contact (Dark Matter)

ORTEC®




- Dark Matter experiments require coaxial (larger) crystal geometry and have
  - lower energy (<5keV detection) requirements than Majorana Demonstrator (few MeV)
  - Lower FWHM (pulse) requirement <300eV (Majorana's requirement was FWHM ~400eV for pulser), tested in a standard cryostat
- ORTEC completed a project for low-energy point-contact detectors that resulted in measured performance:
  - FWHM at 1.33 MeV - 1.7 keV
  - **Pulser – 237**
  - P:C - 75
  - FW.1M/ FWHM - 1.88
  - FW.02M/ FWHM - 2.56
  - Rel. Eff - 56%
  - FWHM at 122 keV - 513 eV
  - FWHM at 5.9 keV - 273 eV

- Requirement: pulser of 300
- Performance was achieved
- Continued improvements in low energy performance will be realized following the conclusion of ongoing development activities at Oak Ridge

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  - *Special Point Contact*
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- Summary

# ORTEC Low Background History

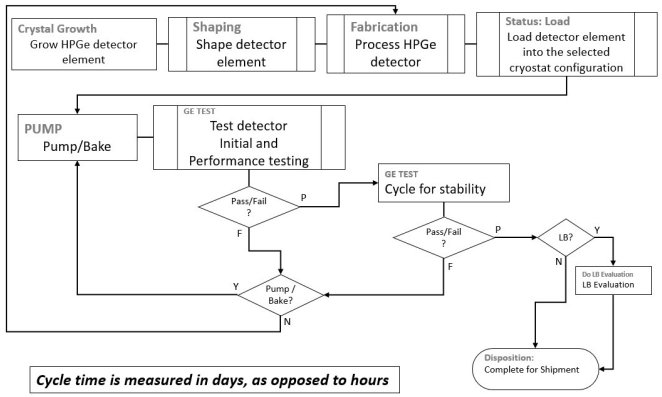
| Key Feature | Application Benefit |
|---|---|
| Largest P- (up to 200% rel. eff.) or N-type (120+ rel. eff.) HPGe sizes | Decreases count times and increases MDA due to higher efficiency |
| Low background shielding with low Pb210 content | Minimizes cosmogenic and ambient background |
| Low background detector hardware (OFHC copper, High Purity Aluminum, CF endcap) | Minimizes MDA emanating from detector subcomponents |
| Remote preamplifier | Minimizes background from electronics components |

- Low background hardware has been available since 1970
- In 2015 ORTEC started a campaign to assay low background components and enhance low background performance capabilities
- Partnerships with low background or underground labs are desired to continue to built premium performance database

# Material assay of LB materials

ORTEC®

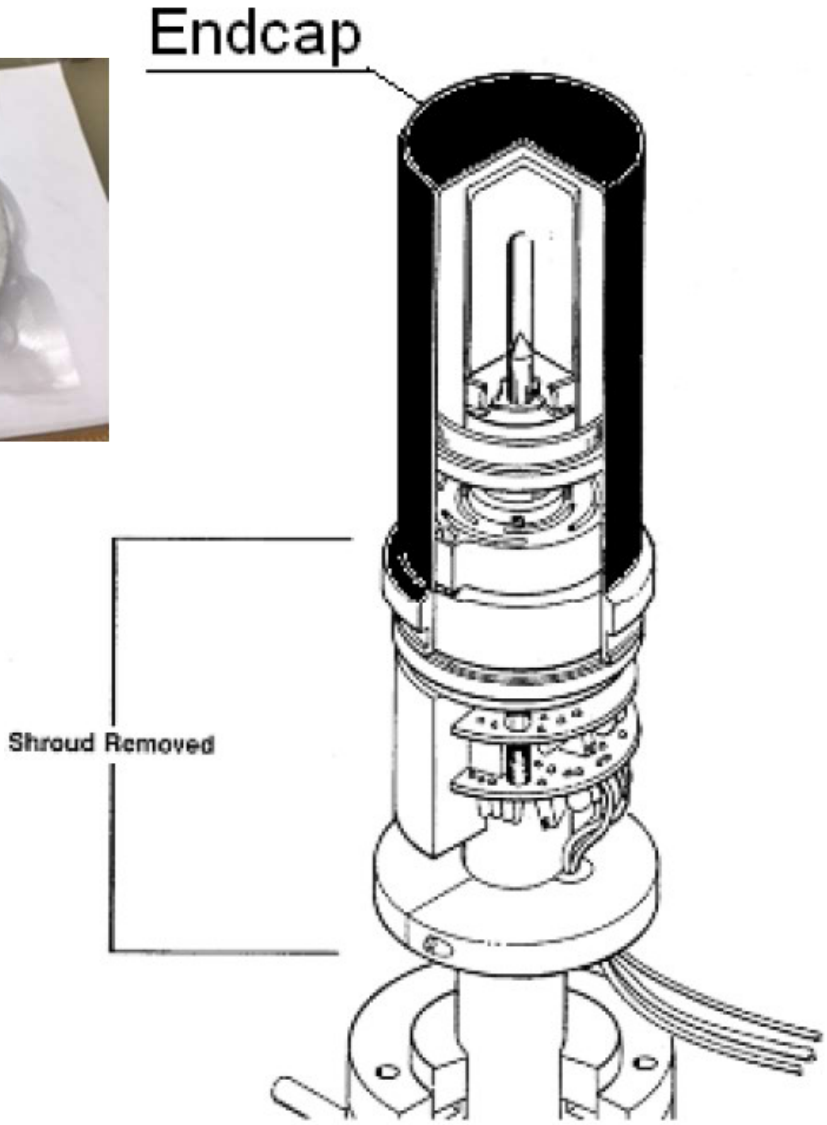
- Receipt of material samples – Al, SS





- Background evaluation performed on samples in dedicated material cave
  - *Material cave is > 35 years old*
  - *Includes a GMX25 LB detector*

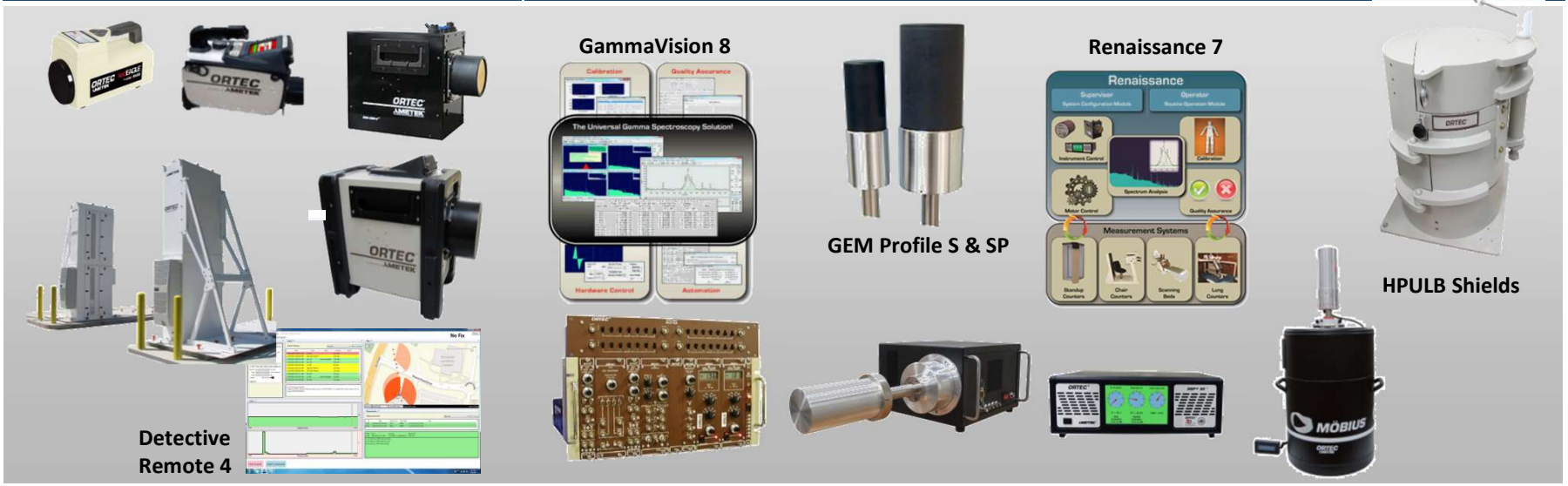
- Material is approved/rejected
  - *Approved:*
    - Material is isolated
    - Components made only from approved material
  - *Rejected:*
    - Supplier provide new material sample



# ORTEC Served Markets

ORTEC®

| Nuclear Security & Safeguards | Radiochemistry, Health Physics, Nuclear Power, Research and Education |
|---|---|




| | | |
|---|---|---|
| • Scintillation based detection and ID<br>• Enhanced mobile search software | • Integrated gamma spec. software<br>• High resolution, wide energy HPGe | • Advanced whole body cntg. software<br>• Ultra-low background lead shielding |

# Summary

ORTEC®

- ORTEC re-ignites focus on special and custom detector market to service Research and Education Community with customized solutions

- Recent developments
  - *Segmentation*
  - *Electro-Mechanical cooling for custom and special systems*
  - *Largest diameter detectors*

- Experts in ionizing radiation detection, identification and analysis instruments and systems

- Broad product portfolio with key focus on detectors, cryocoolers, data acquisition electronics, analysis software and systems integration

- Diverse market applications and balanced sales across all major global geographies

- World-class engineering and manufacturing in the US, with exceptional field sales, support and service facilities worldwide

THANK YOU!

***Contact*** –
- *Local sales agent / distributor*
- *Product Manager – Gregor Geurkov (Gregor.Geurkov@ametek.com)*
- *Director of Detector Technology – Elaine Roth (Elaine.Roth@ametek.com)*