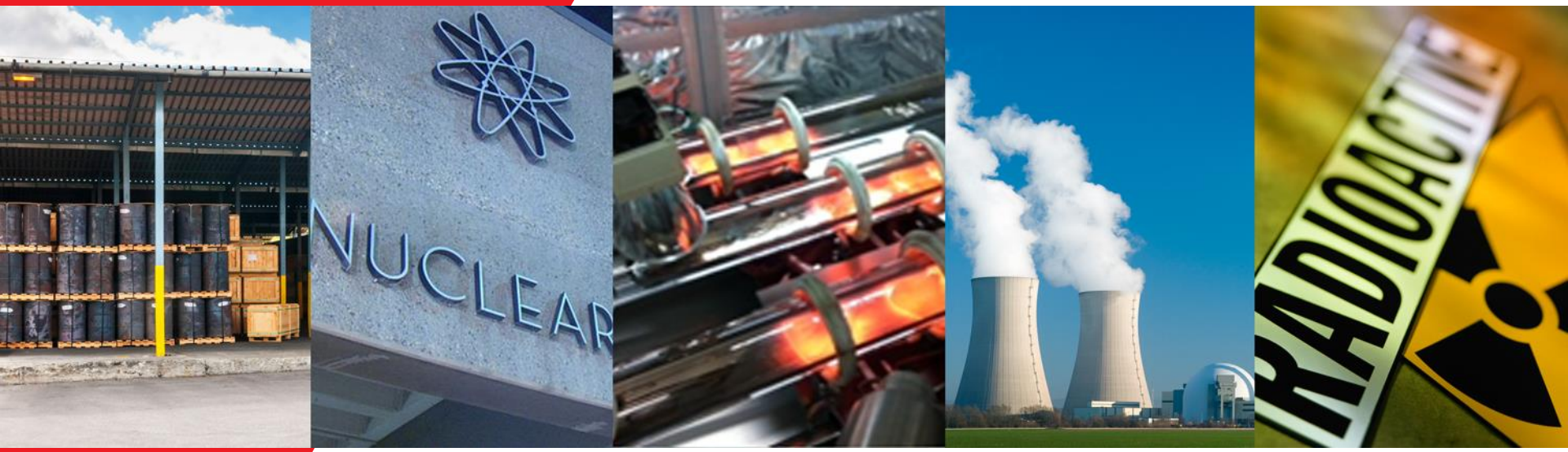
ORTEC®

AMETEK®




10 September 2018

# New Developments of HPGe Detectors at ORTEC

# Overview

ORTEC®

- ORTEC's special detectors reminder
  - *Standard and Segmented Clovers*
  - *Double Sided Ge Strip detectors*
  - *Special Point Contact*
- New Developments
  - *Large Diameter P-type semi-planar*
  - *Mechanical cooling for Customized Solutions*
- Summary

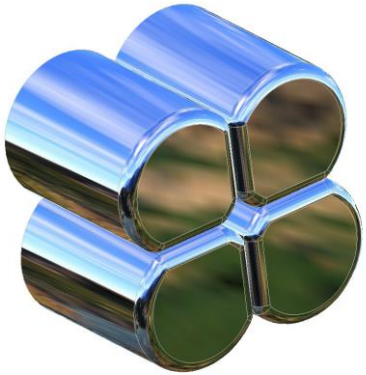
# Advance Special Detector History

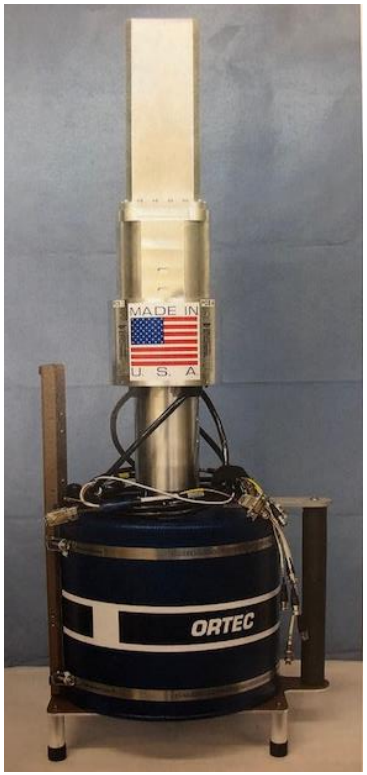
ORTEC®

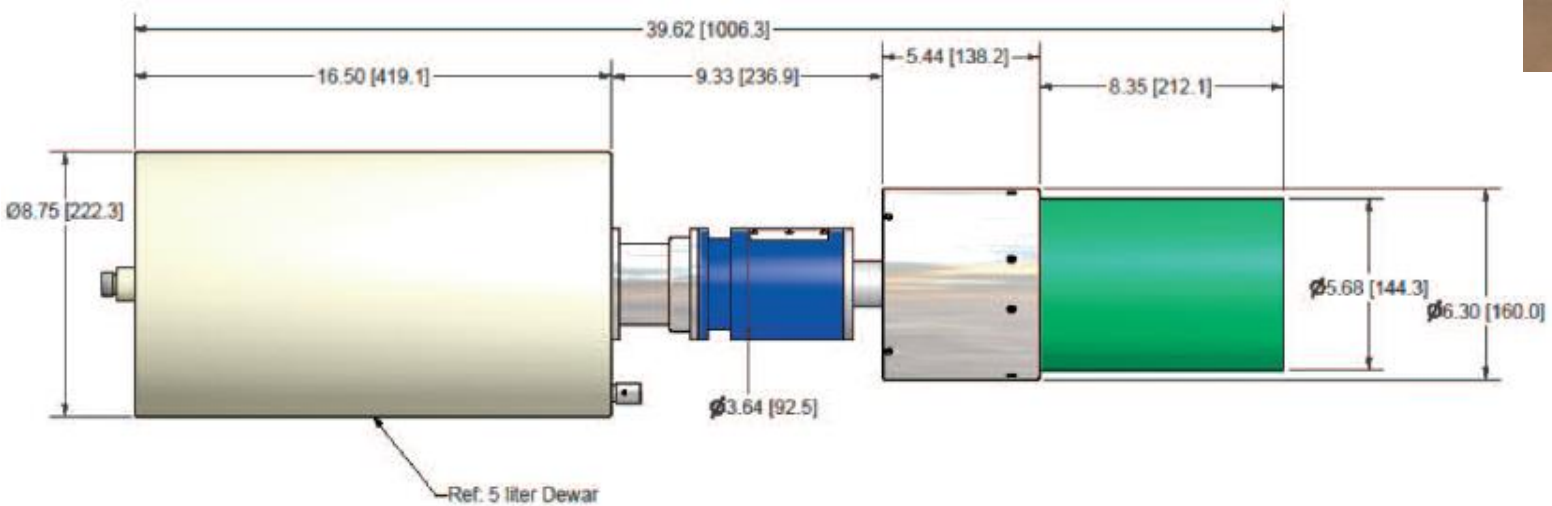
| Advance Detector | First Unit built | Number of Units built | Application Examples |
|---|---|---|---|
| Gamma Sphere<br>GaSp | Early 1990s<br>1990s | 110+<br>40 | Nuclear Physics, beamlines |
| Clover Detectors | Mid 1990s | 20+ | Nuclear Physics, Health Physics |
| Point Contact (coaxial, semi-planar) | 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 |

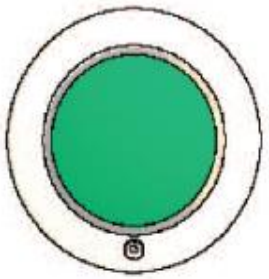
# Clover Detector Systems

ORTEC®

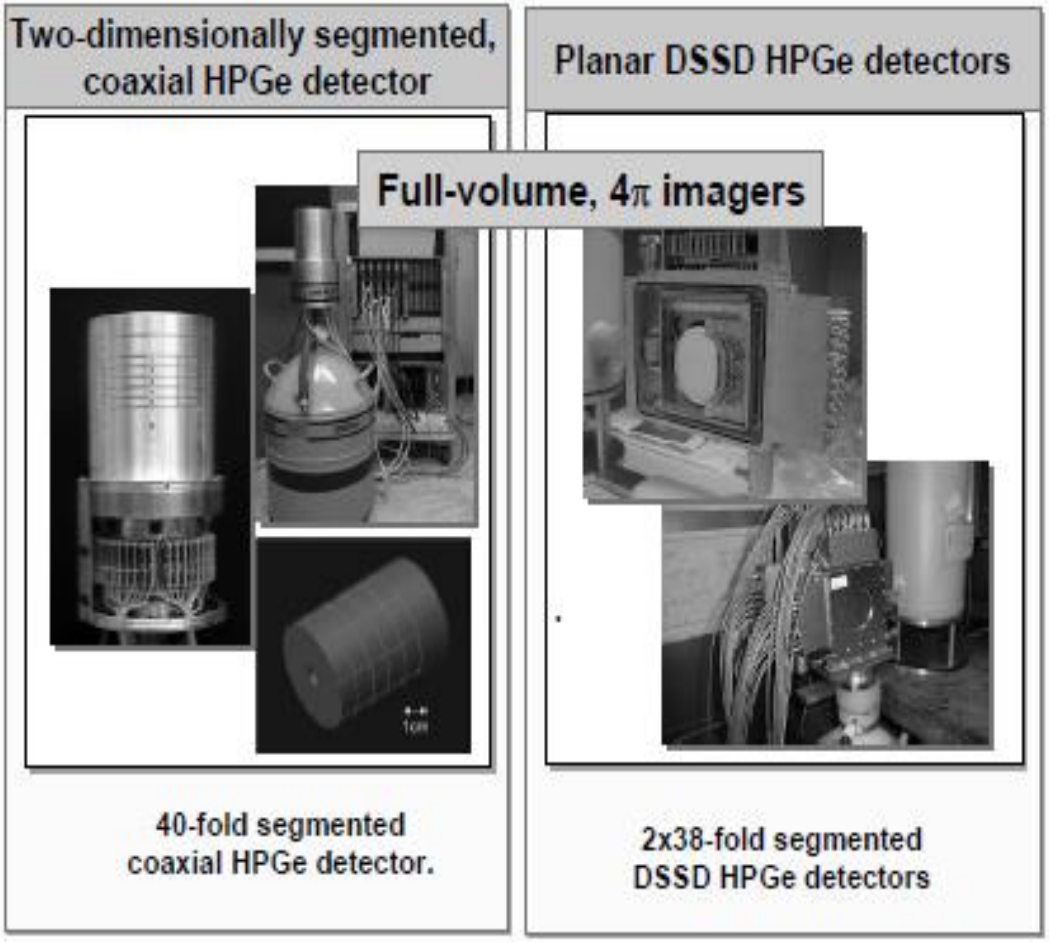


# Segmented Clovers




**IGRD Lawrence Livermore National Lab (LLNL)**

- 41 side channel segments and 1 central channel
- 50 X 70 mm N-type detector with an extra 15mm at the back of crystal grounded to hold and cool the crystal
- Goal was minimization of the stray capacitance to each channel
- Cryostat space requirement generous

# Additional Segmented Clovers

ORTEC®

**GREAT CLOVER University of Manchester**

- System modeled after EXOGAM
- 70 X 108 mm, included larger crystals

**PT-6x2 to Liverpool**

- 6 side channels and 2 center channels
- Retrofit “HEKO” preamplifiers onto the side channels as a solution to a problem the customer had where the outputs became noisy when all were connected simultaneously to the customer’s 50ohm instrument
- Preamplifier retrofit

**SEGA = PT-6x2**

- 6 side channels and 2 center channels
- 65 X 80 mm, 76-Ge enriched detector
- The crystal was processed as the one above but with enriched Ge and loaded into a temporary cryostat as the customer intended to operate by dunking for the benefits of low mass mounting

**Tracking 6x4 (TIGRE) to Liverpool**

- 24 side channel and 1 center channel
- 65 X 82 mm with an extra 10mm (unadvertised) length at the back to be grounded to hold and cool the detector

# Double Sided Ge Strip Detector

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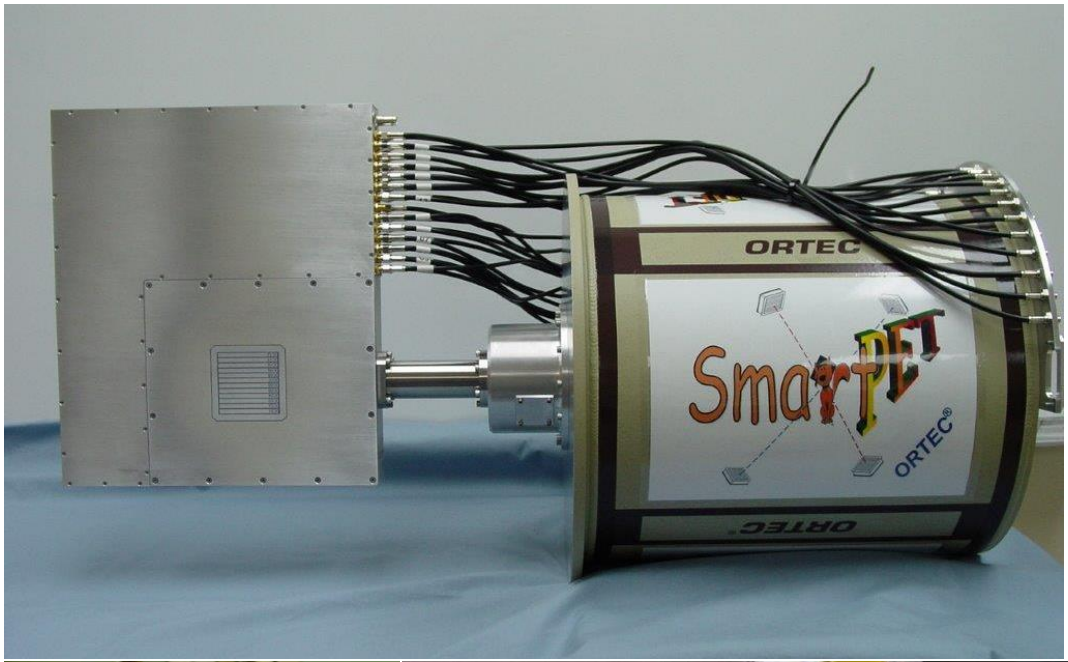


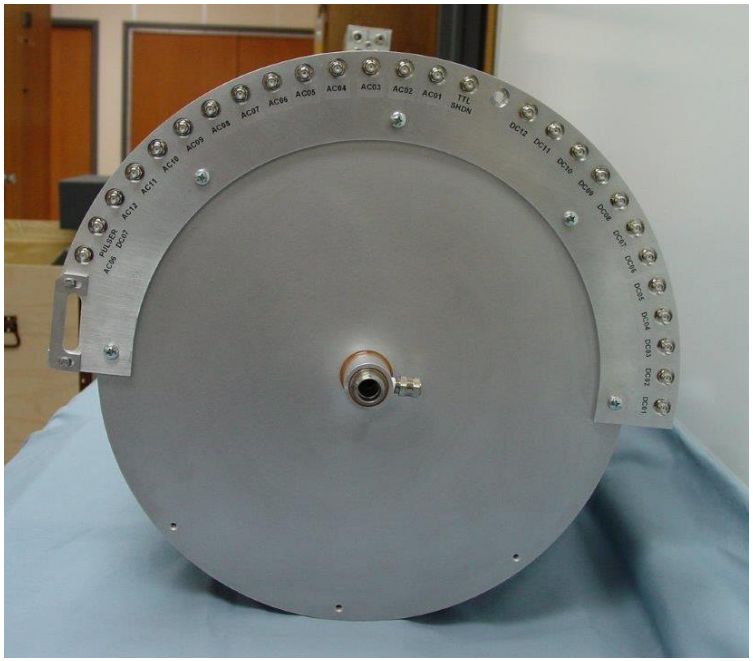

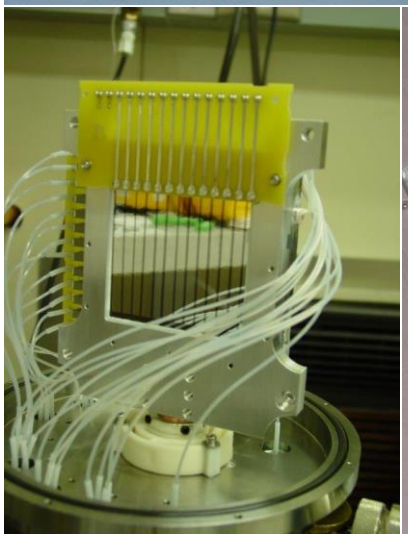

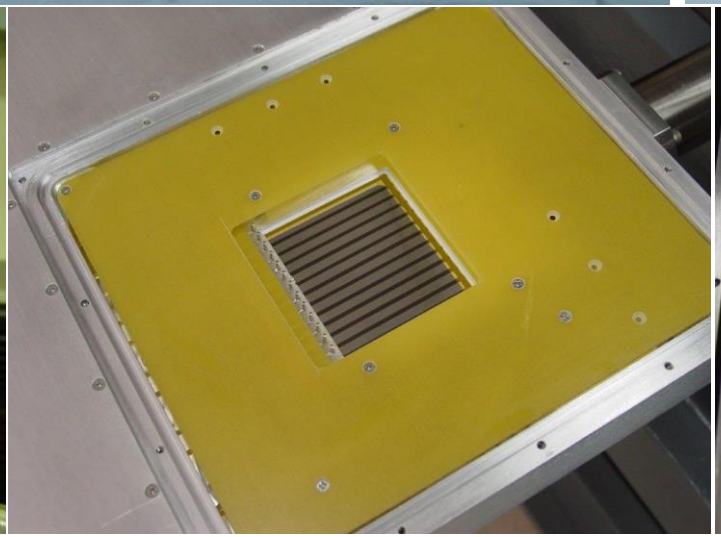

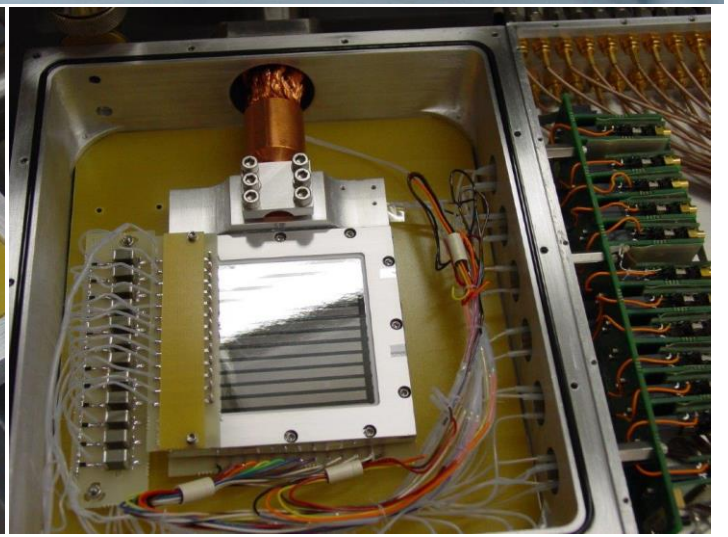

# Examples of Double Sided Ge Strip Detectors

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**ANL MK1 through MK4 Argonne National Lab**

- First crystal was square 87 X 87 X 20 mm, but with no guard ring. Later this crystal was upgraded and reduced to 14 X 14 channels to allow addition of the guard ring structure
- Second crystal was square 87 X 87 X 20 mm thick, with 16 X 16 channels plus guard ring
- MK2 and MK4 were upgrades to the original
- Sawed lithium

**SMARTPETs for Liverpool**

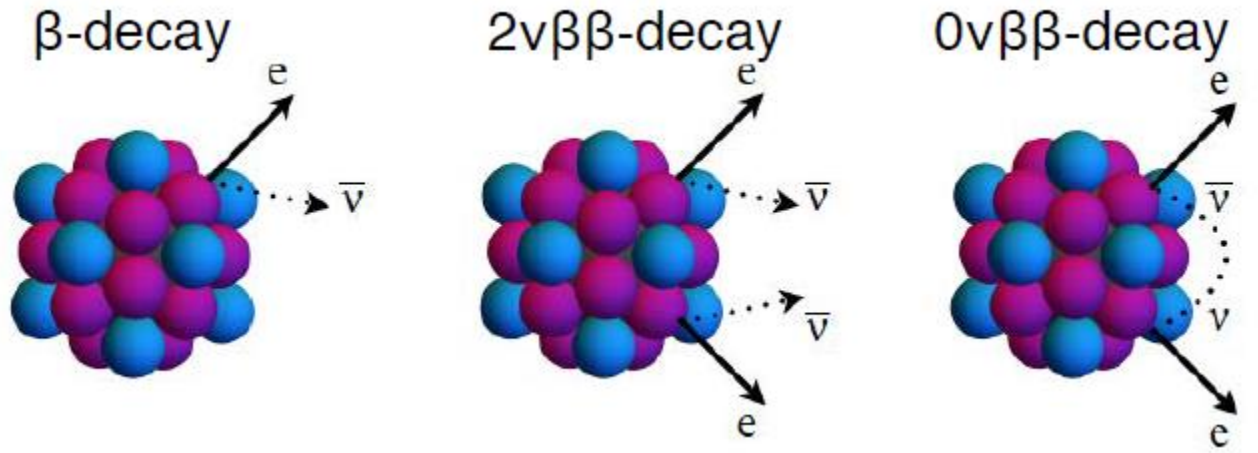
- Each with 12 X 12 channels plus guard ring on both sides
- 21 mm thick, required 99.2 mm starting diameter slice
- Guard ring fitted with preamp in at least one of the two systems
- Preamp and motherboard design in-house
- GG cryostats

**PROSPECTUS Liverpool**

- Delivered in 2010
- DSSD work for Liverpool - 2 each new SMARTPET crystals
- Collaborate with customer for a new mount design to integrate with customer-designed cryostat for medical imaging

# 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 <100eV (Majorana's requirement was FWHM ~400eV for pulser)
- ORTEC completed a project for low-energy point-contact detectors with measured performance
  - FWHM at 1.33 MeV - 1.7 keV
  - **Pulser – 237 (requirement <=300eV)**
  - 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

Continued improvements in low energy performance will be realized following the conclusion of ongoing development activities at Oak Ridge

# Overview

ORTEC®

- ORTEC's special detectors reminder
  - *Standard and Segmented Clovers*
  - *Double Sided Ge Strip detectors*
  - *Special Point Contact*
- New Developments
  - *Large Diameter P-type semi-planar*
  - *Mechanical cooling for PopTop and Encapsulated*
- Summary

ORTEC®

# Curie's MDA formula:

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

t = time (s)
B(E) = background rate (cts/s)
ε (E) = efficiency
E is energy in (keV)

# Detector Efficiency

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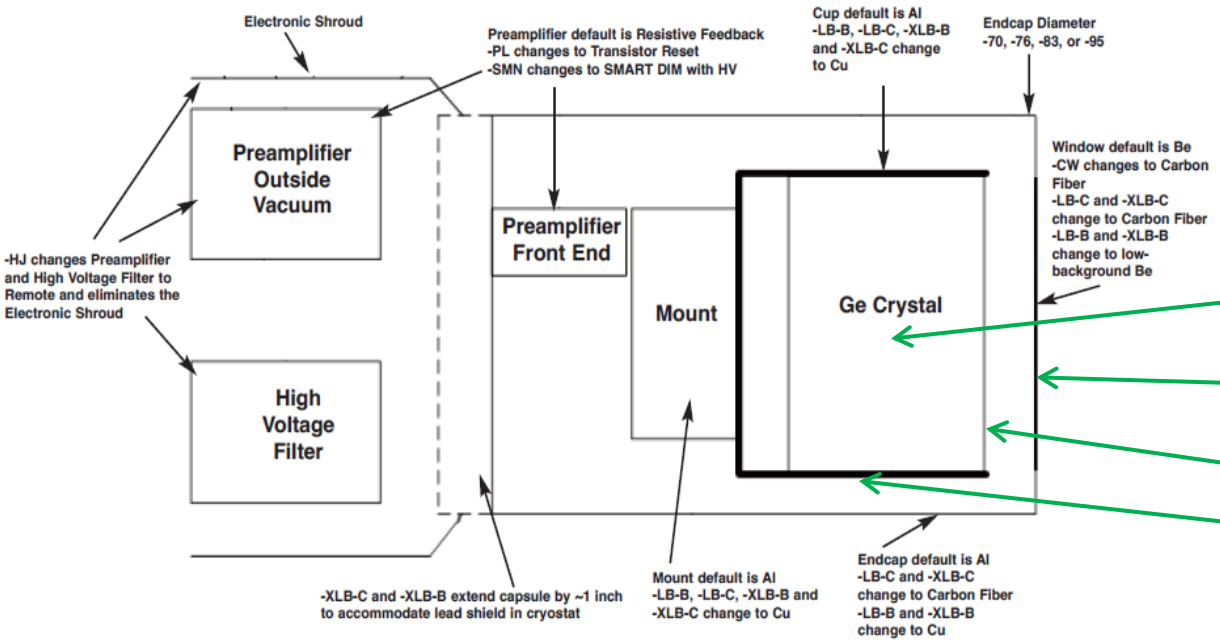


Components affecting efficiency:

- 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

# *Larger* Largest Diameter Semi-Planar HPGe

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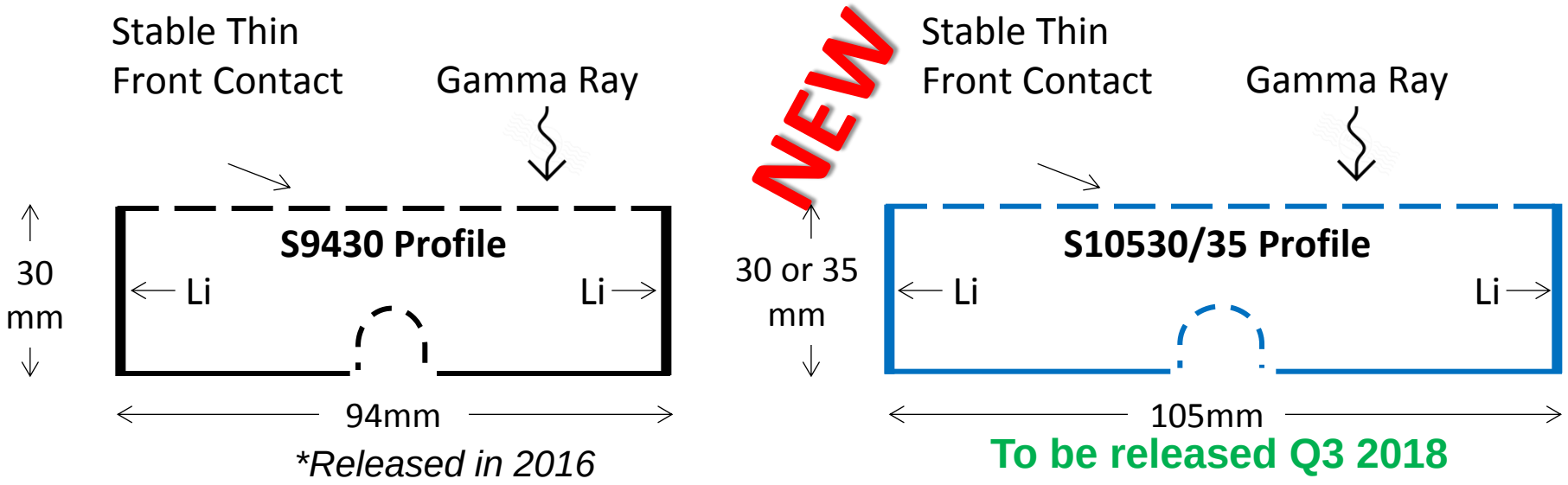
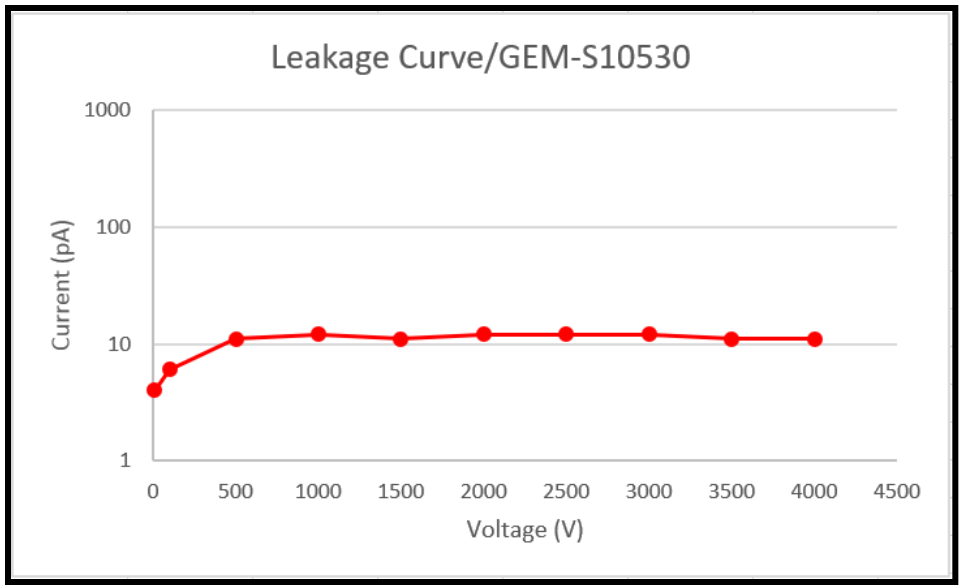



*Released in 2016

**To be released Q3 2018**




**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%

# Efficiencies - Point Source 25cm away

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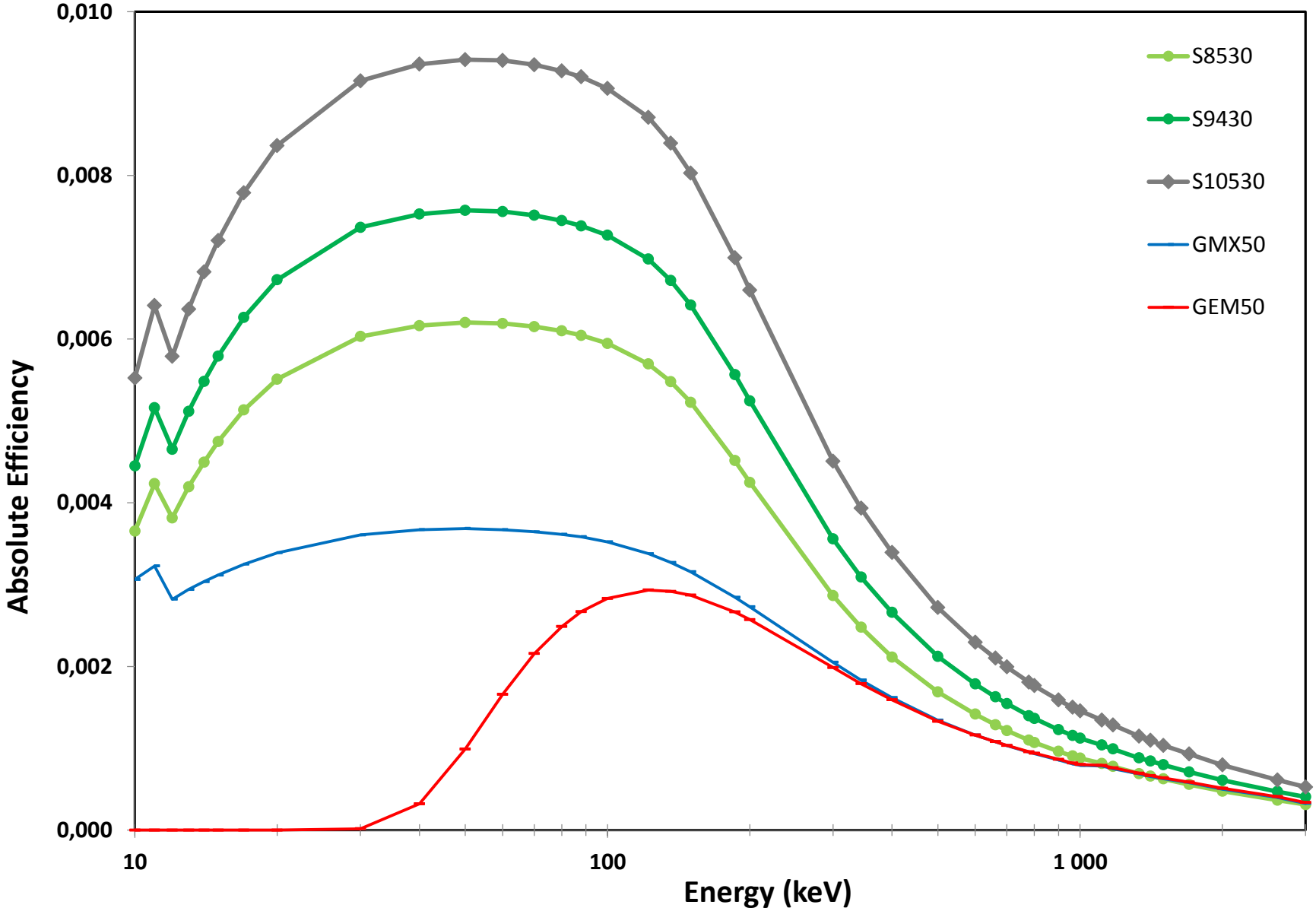
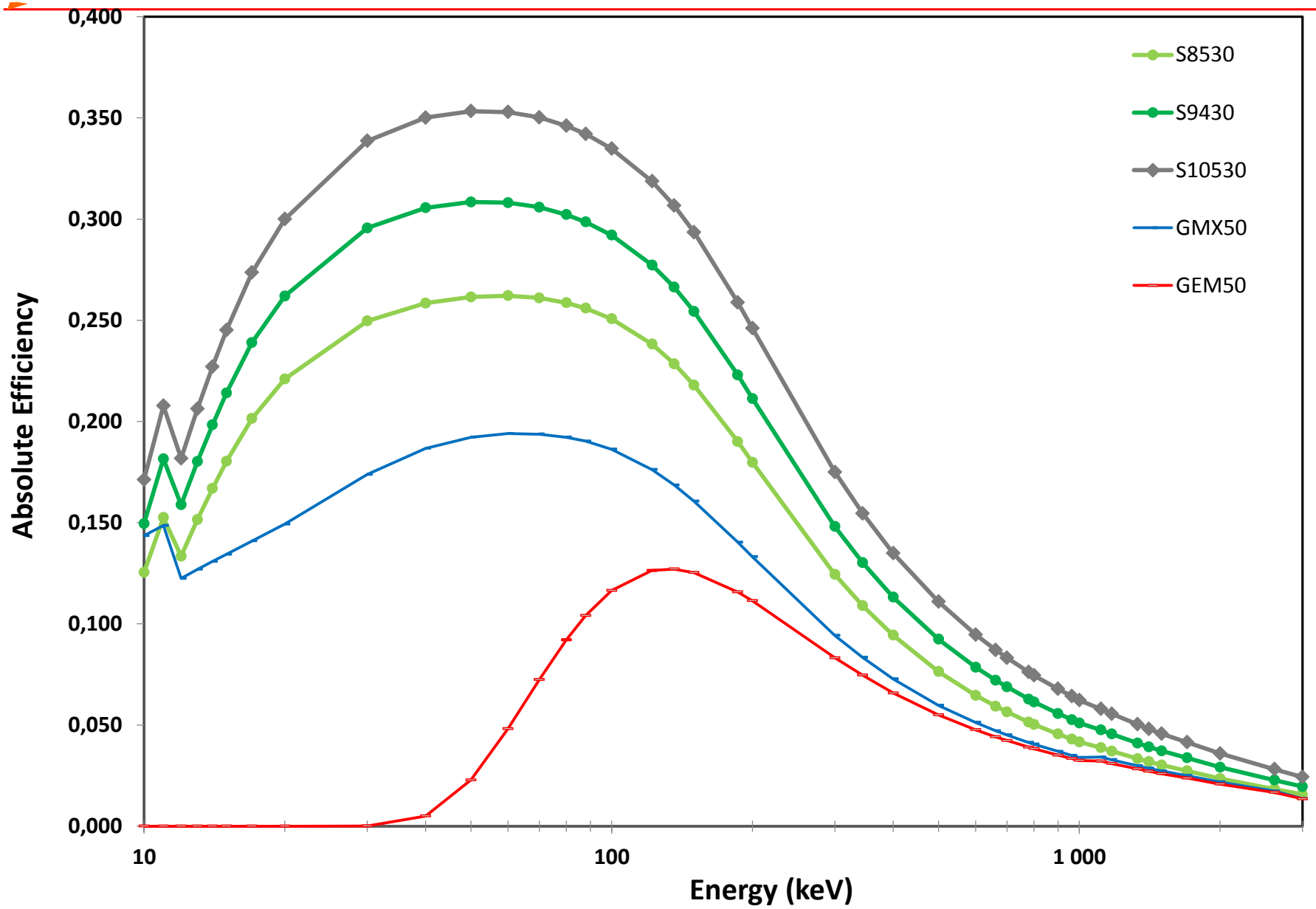


# Efficiencies – 10cm diameter Filter paper



# Measured Performance of GEM-S10530

ORTEC®

- Performance of GEM-S10530 detector in an ORTEC PopTop cryostat
- FWHM at 1.33 MeV, 122 keV, and 5.9 keV
- Measurements made at different shaping times with analog and digital electronics
- Premium resolution achieved at various shaping times and energies

| FWHM in eV @ | | | With a Liquid Nitrogen Cryostat | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1332 keV | 122 keV | 5.9 keV | Peak-to-Compton | FW.1M/FWHM | FW.02M/FWHM | Relative Eff. | Shaping Time | Peaking Time |
| 1850 | 597 | 403 | 67.5 | 1.95 | 2.85 | 86.2 | 6 | |
| 1700 | 616 | 442 | 76.7 | 1.88 | 2.55 | 86.3 | 10 | |
| 1650 | 598 | 400 | 76.9 | 1.91 | 2.92 | 88.4 | | 12 |
| 1720 | 592 | 410 | 74.6 | 1.87 | 2.80 | 88.1 | | 20 |
| 2000 | 700 | 550 | 65 | 2.00 | 2.90 | 80 | Published specs | |

# Measure GEM-S10530 Performance/Cooling Methods

ORTEC®




**FWHM @ different energies and cooling methods**

| FWHM in keV @ 1332 MeV energy | FWHM in eV @ 122 keV energy | FWHM in eV @ 5.9 keV energy | Peak-to-Compton | FW.1M / FWHM | FW.02M / FWHM | Relative Eff. | Shaping Time | Peaking Time | Cooling |
|---|---|---|---|---|---|---|---|---|---|
| 1.85 | 597 | 403 | 67.5 | 1.95 | 2.85 | 86.2 | 6 | | Liquid Nitrogen |
| 1.96 | 620 | 433 | 64.3 | 1.95 | 2.94 | 85.6 | 6 | | X-Cooler |
| 1.87 | 631 | 456 | 66.6 | 1.96 | 2.82 | 85.5 | 6 | | ICS-P4 |
| 1.70 | 616 | 442 | 76.7 | 1.88 | 2.55 | 86.3 | 10 | | Liquid Nitrogen |
| 1.78 | 648 | 469 | 75.1 | 1.82 | 2.45 | 85.9 | 10 | | X-Cooler |
| 1.71 | 656 | 491 | 75.4 | 1.87 | 2.48 | 85.4 | 10 | | ICS-P4 |
| 1.65 | 598 | 400 | 76.9 | 1.91 | 2.92 | 88.4 | | 12 | Liquid Nitrogen |
| 1.72 | 592 | 410 | 74.6 | 1.87 | 2.80 | 88.1 | | 20 | Liquid Nitrogen |
| 1.68 | 603 | 421 | 75.9 | 1.90 | 2.89 | 88.2 | | 20 | Mobius On |
| 1.68 | 598 | 410 | 75.5 | 1.92 | 2.91 | 88.0 | | 20 | Mobius Off |

# Profile S 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.

# Curie's MDA formula:

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

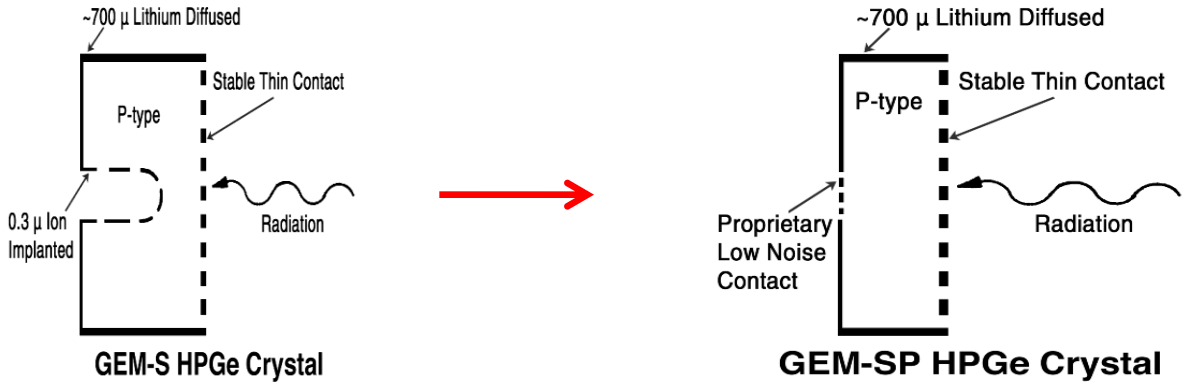
t = time (s)
B(E) = background rate (cts/s)
ε (E) = efficiency
E is energy in (keV)

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

# Profile SP with LNBC

ORTEC®

- System resolution = $\sqrt{R(d)^2 + R(E)^2}$
- Where 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 on the capacitance of the detector
  - Capacitance depends on the surface area of the contact

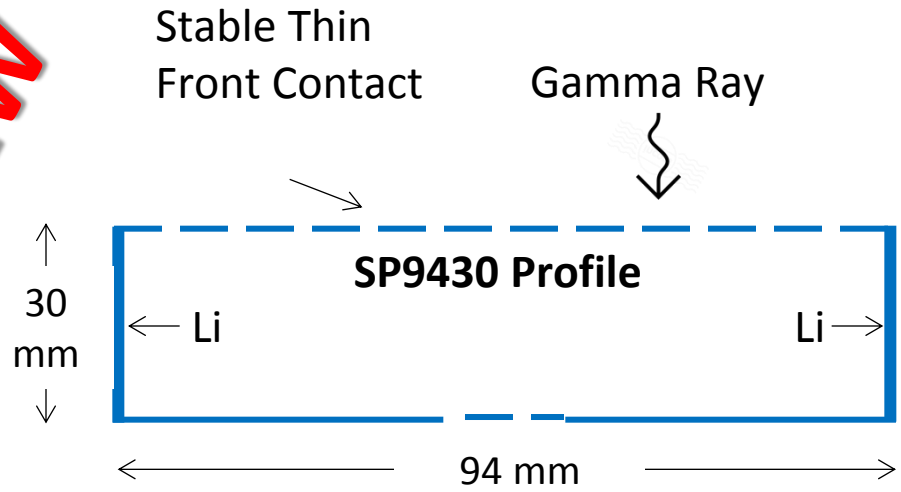



- Low Noise Back Contact (LNBC) Released in July 2015
  - *Low Noise Back Contact (LNBC) presented at the IEEE NSS/MIC, November 2016 in Strasbourg, France – Gregor G. Geurkov, Elaine. G. Roth, Kyle T. Schmitt, and Teresa Underwood "Profile SP (P-type) HPGe detectors – premium resolution at low to medium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

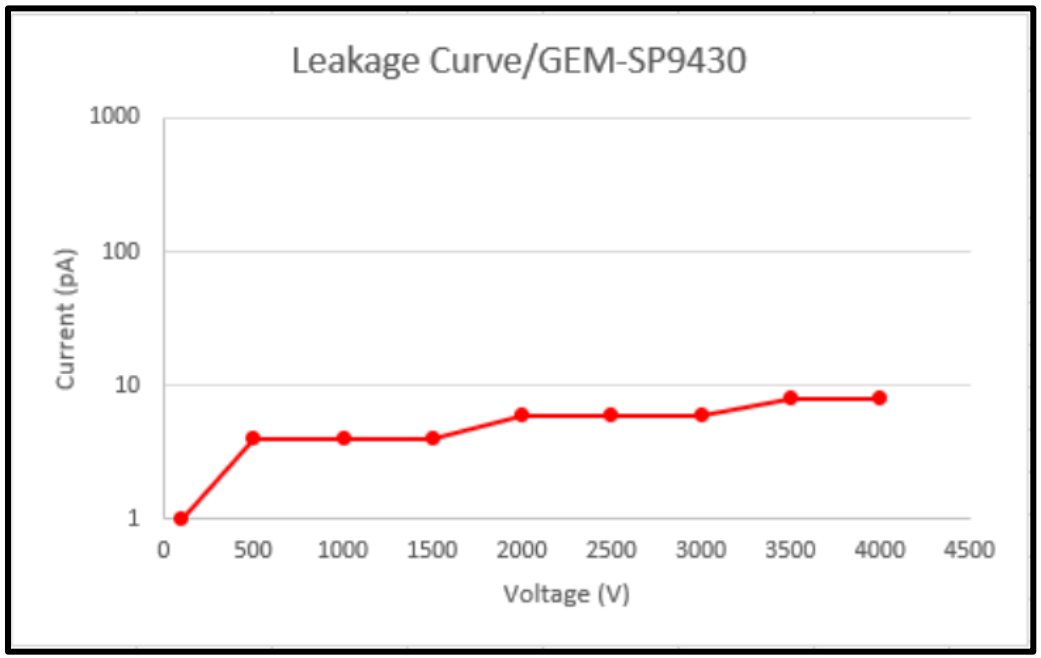
# Largest Diameter with Premium FWHM

ORTEC®

NEW




**To be released Q3 2018**




## Performance/GEM-SP9430

- FWHM at 1.33 MeV – 1.7 keV
- Pulser - 326
- P:C - 71
- FW.1M/ FWHM – 1.87
- FW.02M/ FWHM – 2.51
- Rel. Eff - 65

# Measure GEM-SP9430 Performance/Cooling Methods

ORTEC®



**FWHM @ different energies with LN2 and Mobius**

| 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 | Relative Eff. | Shaping Time | Cooling |
|---|---|---|---|---|---|---|---|---|
| 1.71 | 564 | 344 | 71.1 | 1.87 | 2.51 | 65.2 | 6 | Liquid Nitrogen |
| 1.77 | 593 | 348 | 68.0 | 1.93 | 2.91 | 69.4 | 6 | Mobius On |
| | 557 | 322 | | | | | 6 | Mobius Off |
| 1.66 | 577 | 364 | 72.7 | 1.85 | 2.49 | 63.6 | 10 | Liquid Nitrogen |
| 1.90 | 630 | 425 | 65 | 2.00 | 2.90 | 65 | Published Specs | |

# Profile SP 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 |

● - 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.**

# ORTEC's Mechanical Cooling History

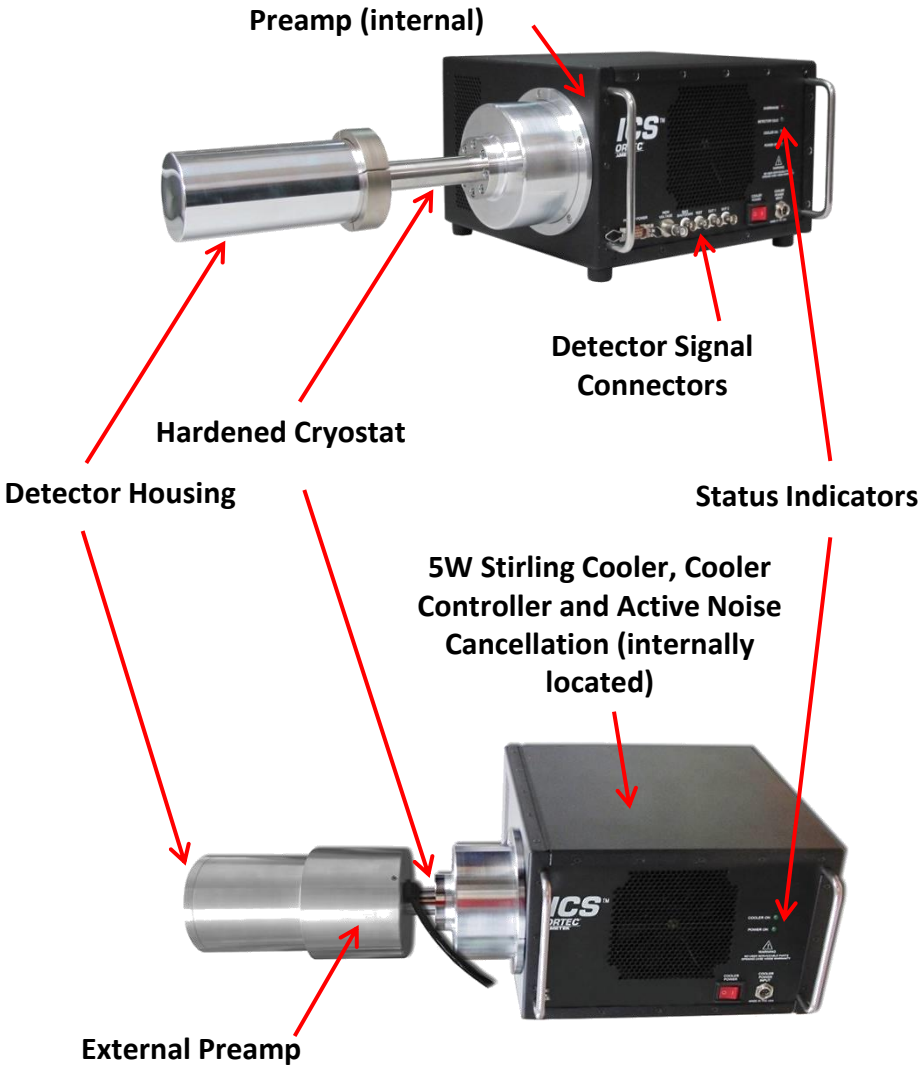
ORTEC®

- 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

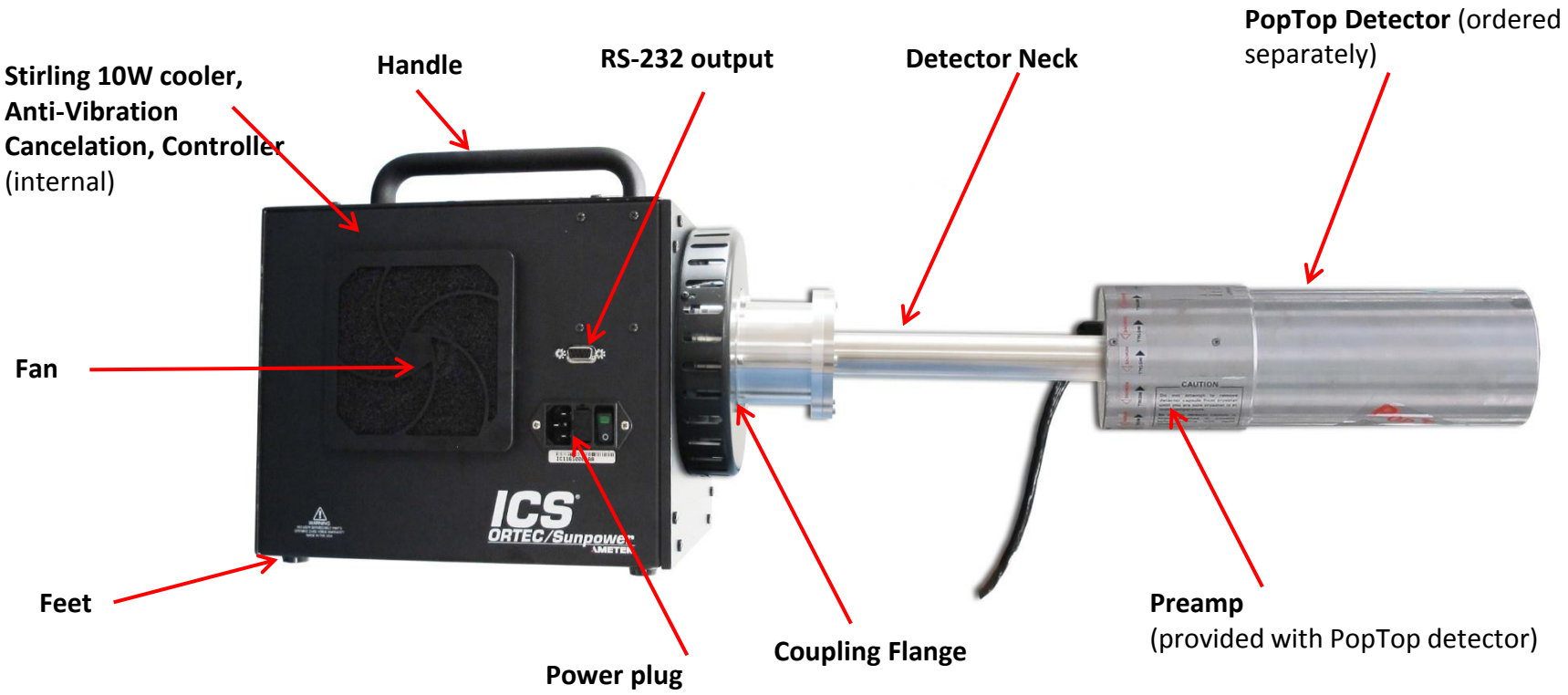
- Premium, $LN_2$ like resolution performance without using $LN_2$, with improved operational ease-of-use, application flexibility, and superior system uptime

### 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

## Key Differences From Vacuum Hardened version

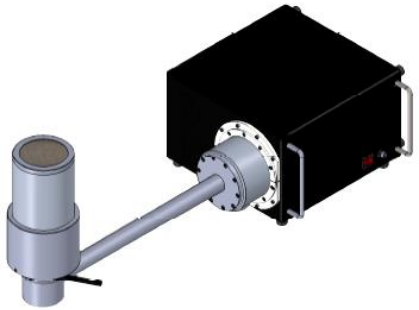
- Conventional cryostat
- Field Upgradable
- Higher power consumption
- Lower weight



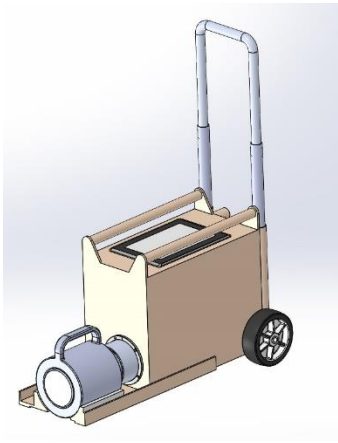
# Mechanical cooling for Customized Solutions

ORTEC®

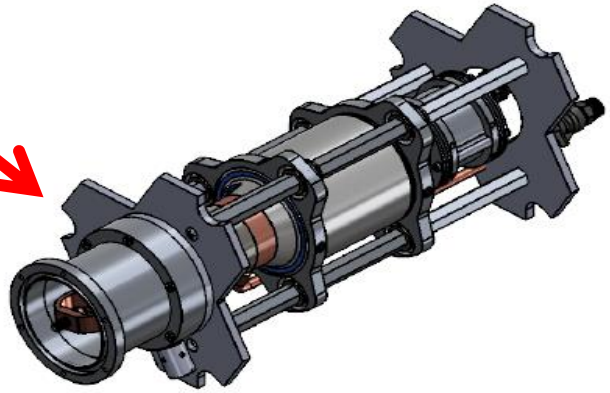
**90-degree angle ICS configuration with any size/type detector**



**Complete system designs with MCA and software**



**Multi-Detector "Hydra" designs**



**Special Detectors**

?

ORTEC offers unique cooling solutions to meet and design requirements

# Summary

ORTEC®

- ORTEC re-ignited and continues to 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 (paper will be published at IEEE 2019)*

- Any questions?

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

THANK YOU!