HPGe Detector updates
The iPA II preamplifier
The CP5-Plus cryocooler

Dieter Pauwels

Product Line Manager Standard HPGe Detectors

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Agenda

- HPGe detector basics
- Introduction of the iPA II preamplifier
  - What is new?
  - How will it make your life easier?
- The CP5-Plus electrically refrigerated cryostat
  - Some basics
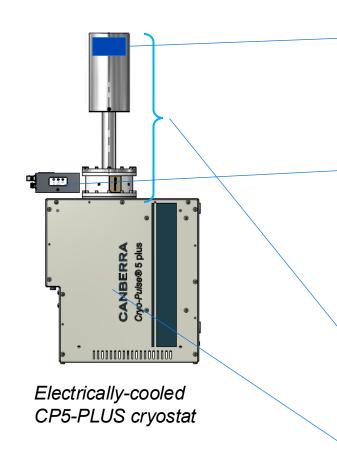 - How does it make your life easier?

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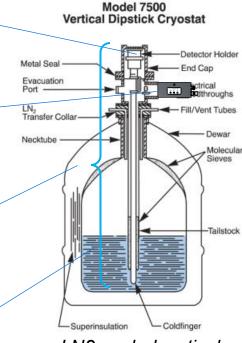# Basics of HPGe detectors

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Introduction: the four HPGe detector building blocks

Electrically-cooled CP5-PLUS cryostat
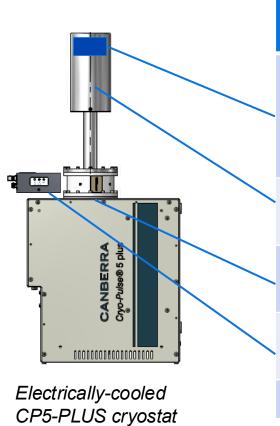
- Germanium detector
  - Absorb and convert gamma-ray energy into proportional amount of electron-hole pairs
  - Collect electrons and holes at detector contacts

- Detector preamplifier
  - Convert number of holes and electrons to a proportional voltage pulse
  - Access to **detector/cryostat/preamp** State-of-Health (SoH) information

- Detector cryostat
  - Vacuum chamber for thermal and electrical isolation
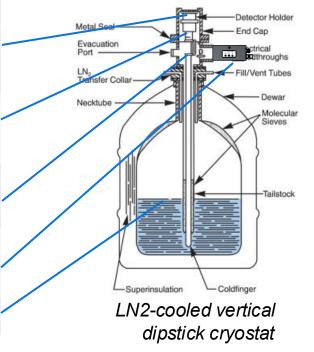
- Cooler
  - Cooling source for the germanium detector

Model 7500
Vertical Dipstick Cryostat

Metal Seal
Evacuation Port
LN₂ Transfer Collar
Necktube
Detector Holder
End Cap
Electrical Feedthroughs
Fill/Vent Tubes
Dewar
Molecular Sieves
Tailstock
Superinsulation
Coldfinger

LN2-cooled vertical dipstick cryostat

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Preamp provides critical SoH info

Electrically-cooled CP5-PLUS cryostat
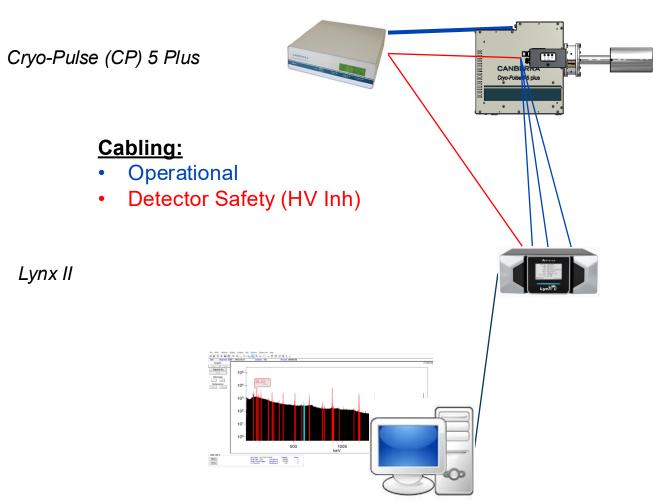
SoH parameter	Short description	Importance / Indicative for
Detector leakage current	Leakage current	Diode issue? Vacuum issue? Preamp/cabling issue? FET broken?
PRTD1	HPGe temperature	HV ready? Vacuum issue?
PRTD2	Cold-tip temperature	HV safety? Cooler issue?
Ambient Temperature	Electronics temperature	Ambient temperature issue?
LN2 level	LN2 level	Vacuum issue?

LN2-cooled vertical dipstick cryostat

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The HPGe Signal Chain

Cryo-Pulse (CP) 5 Plus

Cabling:
- Operational
- Detector Safety (HV Inh)

Lynx II
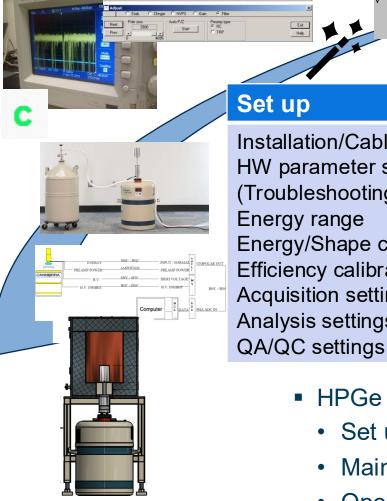
- Preamplifier
  - Detector Pulse processing
  - (HPGe/Cryostat SoH)
- Cooler controller

- Multi-Channel Analyzer (MCA)
  - Detector signal analysis
  - Spectral information storage

- User Interface
  - Genie / Apex

HPGe detector operation: what does it take?

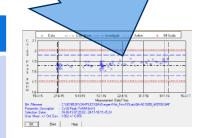| Set up	Maintenance	Operation
Installation/Cabling/cooling down HW parameter settings (Troubleshooting) Energy range Energy/Shape calibration Efficiency calibrations Acquisition settings Analysis settings QA/QC settings	(LN$_2$ refilling) QA/QC measurements QA/QC reviews (Troubleshooting)	Sample measurement Data Review/Interpretation (Troubleshooting)

- HPGe detectors require a lot of human expertise to
  - Set up
  - Maintain
  - Operate
- **How can Mirion make the user's life easier?**

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How can Mirion make HPGe life easier?

How?	What is needed?
100% electric cooling solution (w/o impact on detector performance)	Reliable / Low-vibration electric cryocooler
Automate QA/QC program	Digital access to SoH data Digital access to detector-specific settings/performance data
Ensuring the detector is healthy (State-of-Health monitoring)	
Ensuring the detector will be healthy (Predictive Maintenance)	Smart algorithms
Automate set up procedure	Digital access to detector-specific settings/performance data Basic use-case input Smart algorithms
Get rid of cabling	Integrated system

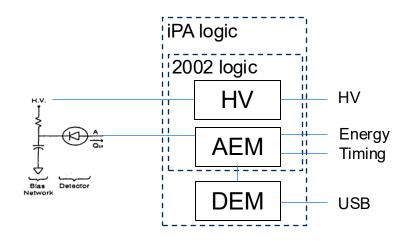# Introducing the iPA II preamplifier

What is iPA II?

- **RC-feedback preamplifier solution for Mirion HPGe detectors:**
  - Analog pulse processing on Analog Electronics Module (AEM) board:
    - Kept pulse processing logic that was optimized on the 2002C preamplifier
  - Standard solution for ~95% of all standard Mirion HPGe detectors

- **Digital backend (as introduced with iPA):**
  - Connecting AEM to Digital Electronics Module (DEM) Board
  - Interface through USB
  - Enabling continuous and remote SoH monitoring, not requiring:
    - Multimeter;
    - LN2 NIM electronics
  - Easy access to recommended detector setup parameters

- **New with iPA II:**
  - New feature: Local storage of detector-specific data
  - Quality and serviceability improvements

All in same footprint as the old analog 2002C preamplifier

Enable data-driven/remote troubleshooting

Enable predictive maintenance

Improve ease of use

iPA II stores Detector-Specific Data

- **Users can access user-accessible PDF files with Lynx II(*):**

  - Detector outline drawing

  - Detector spec sheet

  - HPGe Manuals and Application Note

  - ISOCS characterization reports

- **Files only accessible by Service:**

  - Factory iPA II config file

  - ISOCS characterization data

  - Data for adequate detector QA/QC and troubleshooting: e.g., reference CNF files

(*) FW V1.2 is required to view and download all iPA II PDF files. Service has access to all files stored on the iPA II.
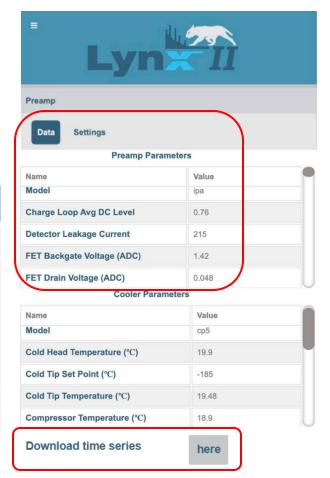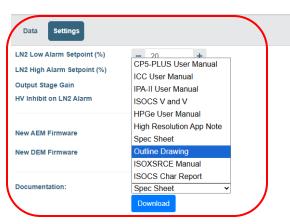
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iPA (II) Monitoring and Control with the Lynx II MCA

- USB connection to Lynx II
- Access via the Lynx II web client UI
  - Common platform for:
    - MCA
    - iPA or iPA II
    - CP5-Plus or iCC

iPA II Feature	V1.0	V1.1	V1.2
Continuous Data Monitoring	🚫	✔️	✔️
Settings control			
FW management			
Real-Time SoH log file			
Access to iPA II PDF files	🚫	🚫	✔️

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How can Mirion make HPGe life easier?

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Get rid of cabling	Integrated system

iPA II preamplifier   *Lynx II MCA*

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- **Files only accessible by Service:**

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  - Data for adequate detector QA/QC and troubleshooting: e.g., reference CNF files

> The iPA II preamplifier has a local storage of all relevant HPGe-specific data and documentation.
>
> The iPA II preamp and Lynx II MCA are the backbone of the future-proof HPGe detection system.

(*) FW V1.2 is required to view and download all iPA II PDF files. Service has access to all files stored on the iPA II.

Other iPA II Improvements (vs iPA)

Feature	Benefit	iPA	iPA II
Integrated USB isolator Note: with USB-C connector	Easier installation, cleaner setup	 Mini-B connector:	 C connector:
Longer Slimline pig tails Slimline units delivered with firmly fixed USB cable	Easy access to connectors: also in lead shields and for Slimline MAC/CP5-PLUS	10-inch pigtail cables 	20-inch pigtail cables

Other iPA II Improvements (vs iPA)

Feature	Benefit	iPA	iPA II
HV network on potted PCB	More rugged against arcing and ESD		
Enhanced AEM board protections			
Flexible power-up logic	MCA-USB power-up sequence independent of order	1st: preamp power 2nd: USB power	Redesigned power management board logic
Firmware AEM communication bug fix	Continuous visibility to all SoH parameters	Bug: possible communication loss with AEM board Recovery: reboot preamp Fix: Install iPA II AEM/DEM FW	FW fix in AEM (V4160) and DEM (V2.0) FW versions Backward compatible with iPA

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iPA II Summary

- iPA II:
  - Maintaining excellent 2002C low-noise detector pulse processing performance
  - Maintaining iPA digital backend enabling continuous and remote SoH monitoring
  - Adding the capability to store detector-specific files
  - Improving quality and serviceability
- Basic detector operation is compatible with standard HPGe MCA models
- Detector-specific data are only accessible by the Lynx II MCA:
  - Lynx II FW V1.1 (and later): hardware parameter monitoring of detector, preamplifier and cryocooler
  - Lynx II FW V1.2 (and later): view and download all iPA II PDF files (spec sheet, manuals, reports)
  - Future Lynx II releases can leverage iPA II stored detector information for automated algorithms
- Combination of iPA II preamplifier and Lynx II MCA is Mirion's **future-ready** hardware platform

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The CP5-Plus electrically refrigerated cryostat

The difference between Stirling and Pulse Tube

Compressor: cycles of compression (gas warming up) and decompression (gas cooling down)

	Stirling cold finger	**Pulse tube cold finger**
What?	Mechanical gas displacement with mass-spring system	Gas displacement results from flow resistance in inertance tube and buffer tank

The difference between Stirling and Pulse Tube

Compressor: cycles of compression (gas warming up) and decompression (gas cooling down)

	Stirling cold finger	Pulse tube cold finger
What?	Mechanical gas displacement with mass-spring system	Gas displacement results from flow resistance in inertance tube and buffer tank
Advantages	Efficient (direct gas displacement)	No vibrations (no moving parts in cold tip) No mechanical wear
Disadvantages	Vibrations => microphonics noise Mechanical wear	Less efficient => larger/heavier system

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Mirion Standard Detector Cooling Solutions

- Cryo-Cycle cooler
  - LN2-redundant cryocooler system
  - Stirling technology
    - Very reliable (based on >500 units since 2021)
      - CP5-PLUS compressor
      - Expected cooler MTTF: >200K hours
      - Expected cooler lifetime: >7 years

- CP5-Plus cooler
  - Completely LN2 free
  - Nominal power consumption: ~100 W
  - Pulse-Tube technology
    - Extremely reliable (based on >3,300 units since 2006)
      - Cooler MTTF > 6M hours, System MTTF > 1M hours (repairable items)
      - Cooler Lifetime >>15 years, only 5% system failure probability within 1st 7 years
  - Lowest vibration levels => no microphonics impact

Hybrid cooling:
Intelligent Cryo-Cycle cryostat

LN2 cooling

Electric cooling:
CP5-PLUS cryostat

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CP5-Plus vs LN$_2$-based system: cost comparison

	CP5-PLUS	LN$_2$ based
Investment cost	**Large (+ ~$45k)**	**Small**
Operational cost	**Small** Electricity : ~100 W => ~875 kWh/y	**Large (+ ~$9k/y)** LN2 consumption and rental costs Labor (preparations, filling, handling) Down time during filling (Cost of safety)

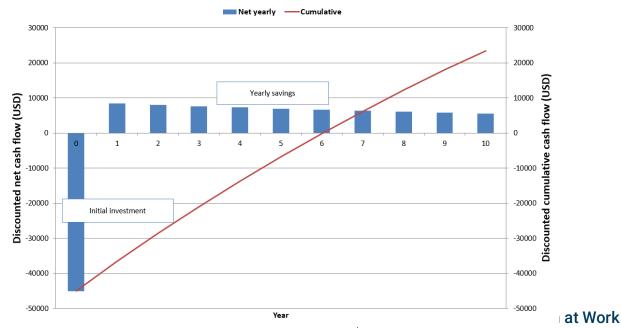- Interest rate: 8%
- Inflation rate: 3%
- CP5-PLUS life time: 15 years

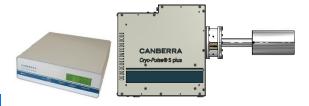- Payback period: 6.0 years
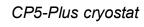- Net Present Value: 47,200 USD

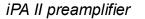ROI analysis CP5-plus vs LN$_2$

How can Mirion make HPGe life easier?

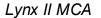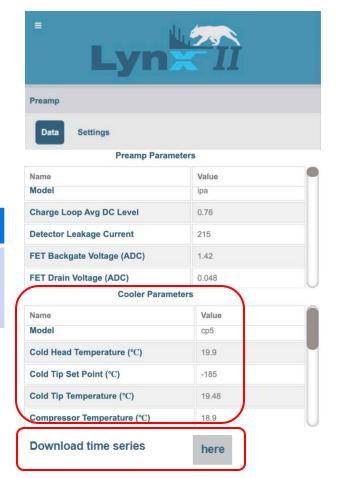| How?	What is needed?
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Get rid of cabling	Integrated system

CP5-Plus cryostat   *iPA II preamplifier*   *Lynx II MCA*

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CP5-Plus Monitoring with the Lynx II MCA

- USB connection to Lynx II
- Access via the Lynx II web client UI
    - Common platform for:
        - MCA
        - iPA or iPA II
        - CP5-PLUS or iCC

CP5-PLUS Feature	V1.0	V1.1	V1.2
Continuous Data Monitoring	🚫	✔	✔
Real-Time SoH log file			

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CP5-Plus: Summary and Outlook

- Exceptionally reliable Pulse-Tube cryocooler:
  - Almost no maintenance required:
    - Estimated lifetime fans = 5 years
  - Lifetime at the level of the HPGe detector: unique in the market

- Exceptionally performant cryocooler:

  - Detector specifications same as LN_2-cooled system (even at lowest gamma energies)
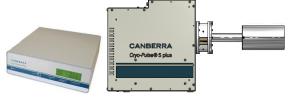
- Outlook:

  - Integrate iPA II and cooler controller into the coldhead enclosure

    - ~26% Volume reduction / Reduced cabling / easier setup

  - Lynx II is the envisioned central hub of the detector system

    - Leveraging the readily available detector-specific input

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Get rid of cabling	Integrated system (Future)

CP5-Plus cryostat   *iPA II preamplifier*   *Lynx II MCA*

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Thank you