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MIRION Connect 24

Annual Users' Conference

July 29 - August 2 | Omni Dallas Hotel, Dallas, TX

MIRION TECHNOLOGIES

The iPA™ II Preamplifier

More Than Just a Preamplifier

Dieter Pauwels

Product Line Manager Standard HPGe Detectors

Mirion Connect | Annual Users’ Conference 2024

Dallas, Texas

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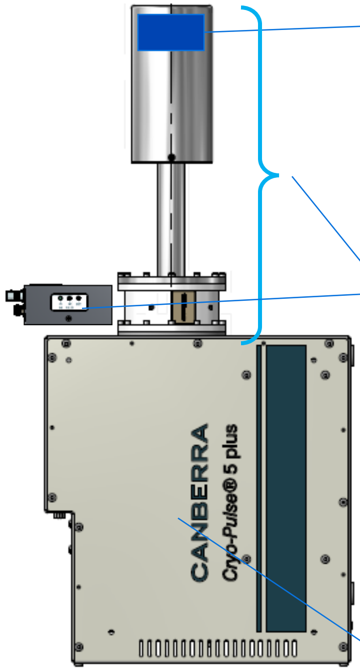
Agenda

- Introduction
  - HPGe detector building blocks
  - Preamplifier models and history
  - How can a preamplifier facilitate troubleshooting and "Ease of Use"?
- The iPA preamplifier
  - What is it and connection to Lynx II
  - Troubleshooting and predictive maintenance
- The iPA II preamplifier
  - Enabling local data storage
  - Impact on troubleshooting and "Ease of Use"
- Broader preamp outlook and Q&A

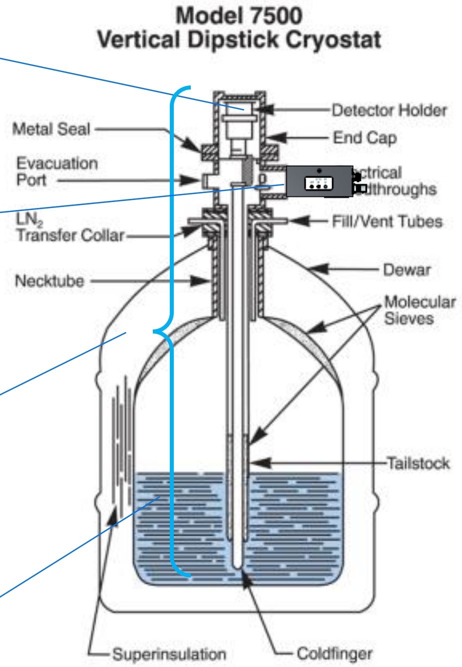
Introduction

The four building blocks of the HPGe detector



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



LN2-cooled vertical dipstick cryostat

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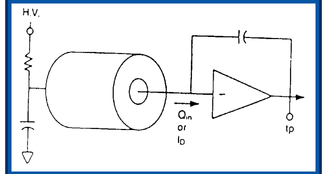
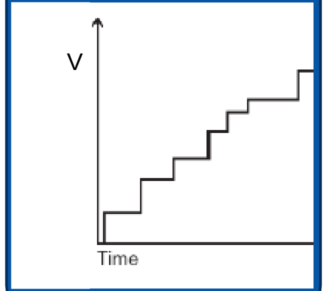
The three HPGe preamplifier models explained

Always one principle

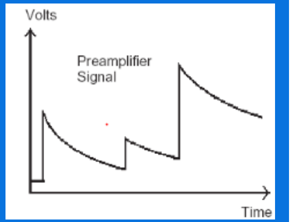


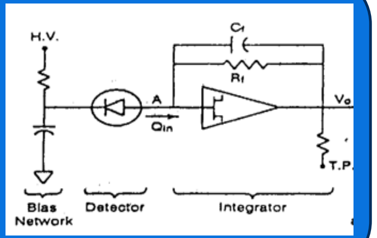
Charge-sensitive integrator: $Q \rightarrow V$



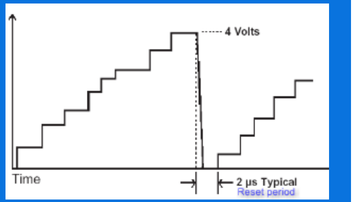
Two ways to restore

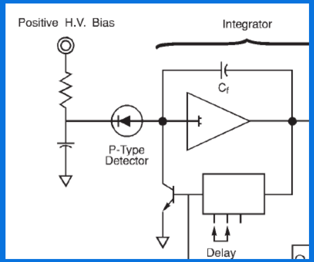
Dynamic charge restoration (RC feedback)





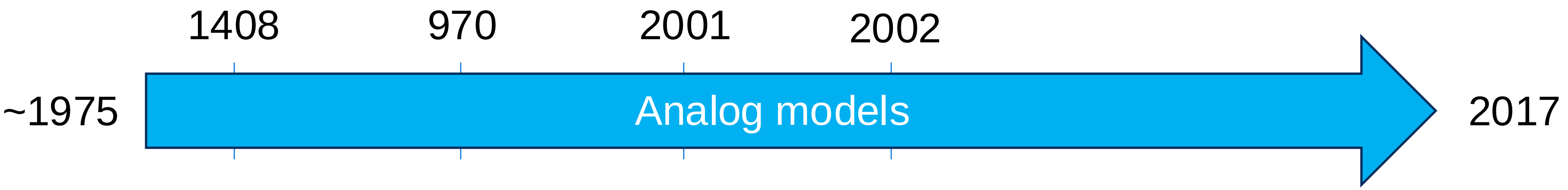
Reset charge restoration (Reset transistor)





Three models	Advantages	Drawbacks
iPA	Cost; Max throughput	Energy-rate limited (<=200 GeV/s); P/Z regulation
2101N/P (transistor switch)	No energy rate limit; OK for high energies	Cost; Throughput; Noise impact (LEGe, BEGe)
ITRP (integrated switch in FET)	No energy rate limit; Best noise performance	Cost; Only useable for low energies

Mirion history of the RC-feedback HPGe preamplifier

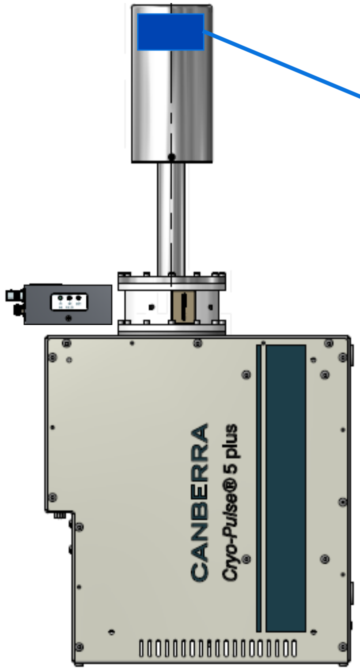


- Continuous performance improvements for >45 years:
  - Noise reduction for optimal energy-resolution performance
- Troubleshooting:
  - Get access to preamplifier (not always obvious with lead shields!)
  - Measure resistances/voltages (multimeter)

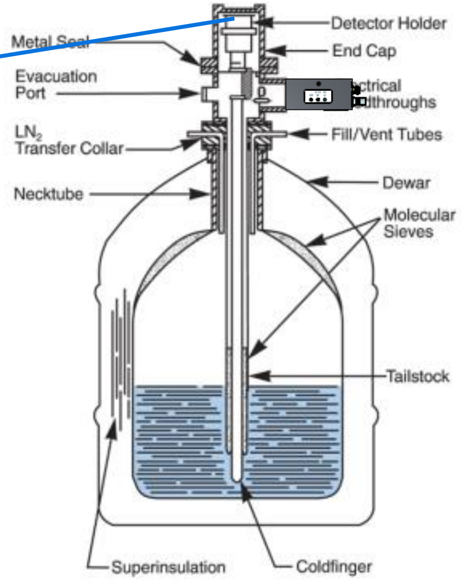
- Maintain excellent 2002 noise performance
- Enable predictive maintenance
- Facilitate data-driven/remote troubleshooting
- Improve ease of use

Predictive maintenance & Troubleshooting:
Which are critical preamp-provided SoH parameters?

SoH parameter	Short description	Importance / Indicative for
Detector leakage current	Leakage current	Diode issue? Vacuum issue? Preamp/cabling issue? FET broken?



Electrically-cooled CP5-PLUS cryostat



LN2-cooled vertical dipstick cryostat

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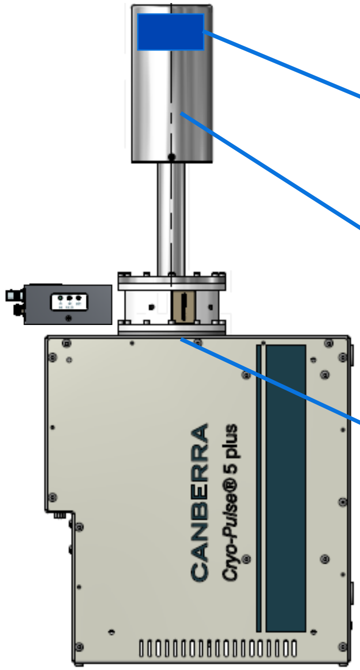
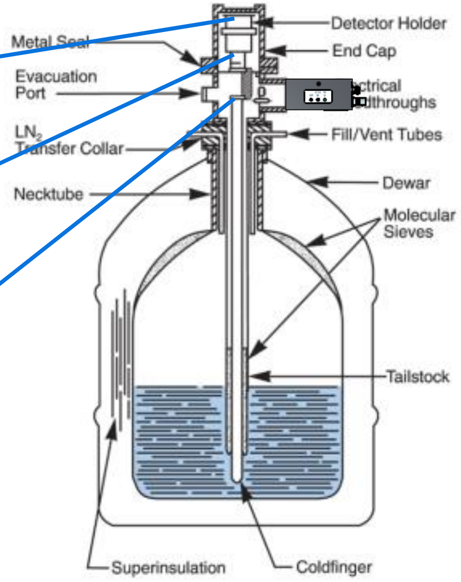


Electrically-cooled CP5-PLUS cryostat

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?



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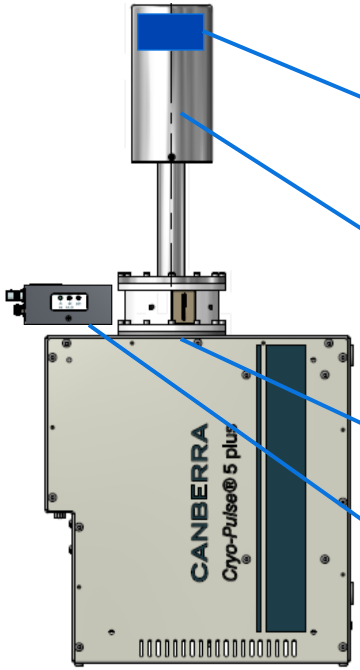
Predictive maintenance & Troubleshooting: Which are critical preamp-provided SoH parameters?



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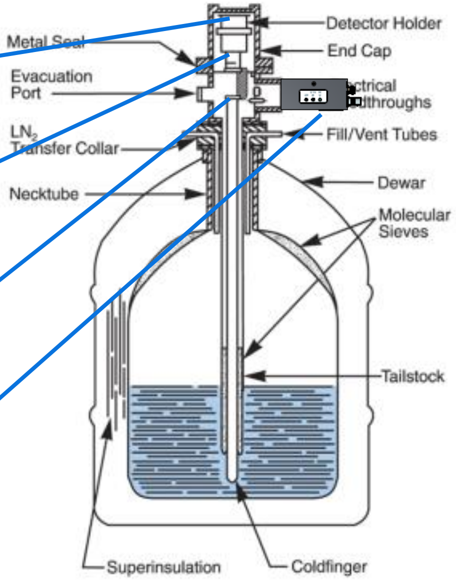
Ambient Temperature	Electronics temperature	Ambient temperature issue?



LN2-cooled vertical dipstick cryostat

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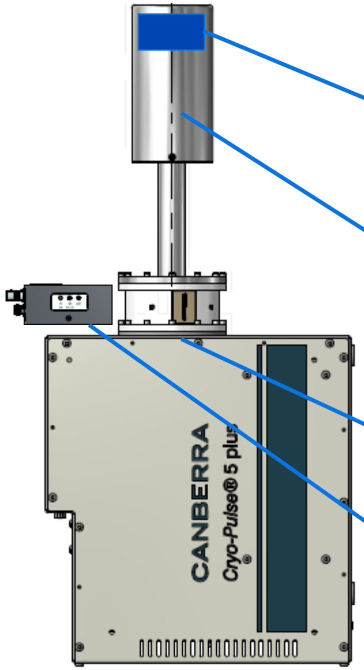

Electrically-cooled CP5-PLUS cryostat

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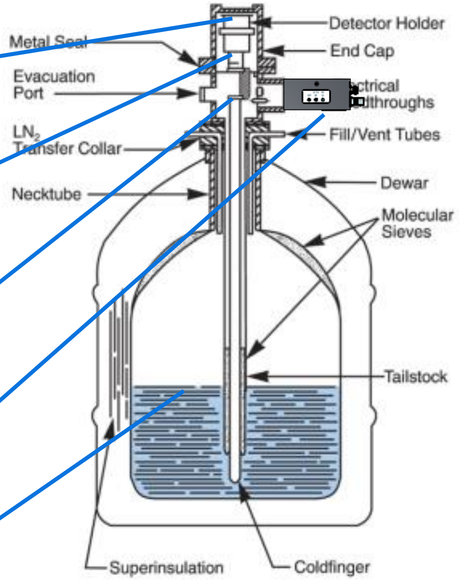
PRTD1	HPGe temperature	HV ready? Vacuum issue?
PRTD2	Cold-tip temperature	HV safety? Cooler issue?
Ambient Temperature	Electronics temperature	Ambient temperature issue?
LN2 level	LN2 level	Vacuum issue?



LN2-cooled vertical dipstick cryostat

“Ease of use”: what is the challenge?

Steps	Activities
Set up	HW parameter settings
	Energy calibration(s)
	Efficiency calibrations
	Establish QA/QC Baseline&Window
	Measurement settings
	Analysis settings
Measure	QA/QC
	Samples
Interpret	Interpret/Review results

“Ease of use”: what is the challenge?

Steps	Activities	Complexity
Set up	HW parameter settings	HPGe uniqueness Use-case dependent
	Energy calibration(s)	Source measurement
	Efficiency calibrations	Geometry dependent
	Establish QA/QC Baseline&Window	Determine good Baseline&Window
	Measurement settings	Use-case dependent
	Analysis settings	
Measure	QA/QC	Just measure
	Samples	Just measure
Interpret	Interpret/Review results	Understand unexpected results

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“Ease of use”: what is the challenge?

Steps	Activities	Complexity	Classical approach
Set up	HW parameter settings	HPGe uniqueness Use-case dependent	Use HPGe data sheet Use sources Use certificates Use ISOCS files Understand expected & required HPGe performance Understand use case & objectives → **<u>Human expertise</u>**
	Energy calibration(s)	Source measurement	
	Efficiency calibrations	Geometry dependent	
	Establish QA/QC Baseline&Window	Determine good Baseline&Window	
	Measurement settings	Use-case dependent	
	Analysis settings		
Measure	QA/QC	Just measure	Just do it
	Samples	Just measure	
Interpret	Interpret/Review results	Understand unexpected results	**<u>Human expertise</u>**

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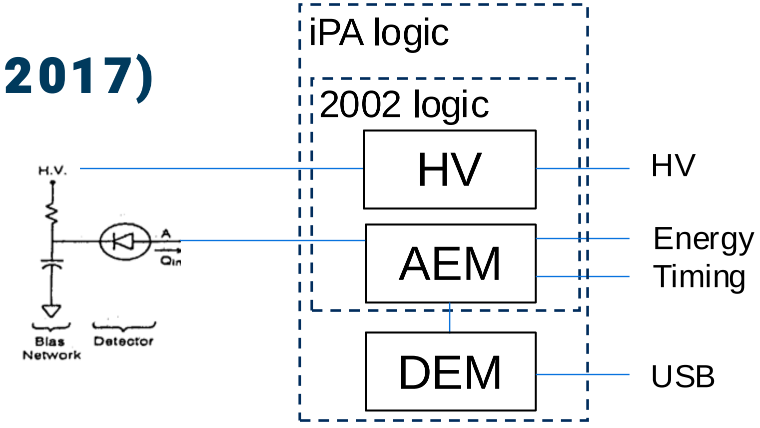
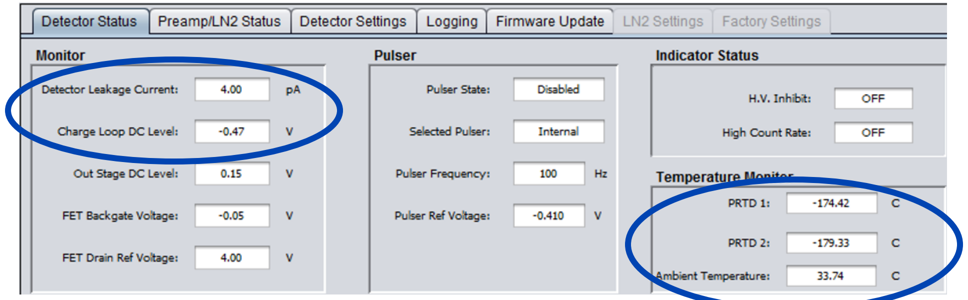
The iPA preamplifier: Mirion going digital

The iPA preamplifier: What is it?

Pioneering digital HPGe preamp introduced by Mirion (since 2017)

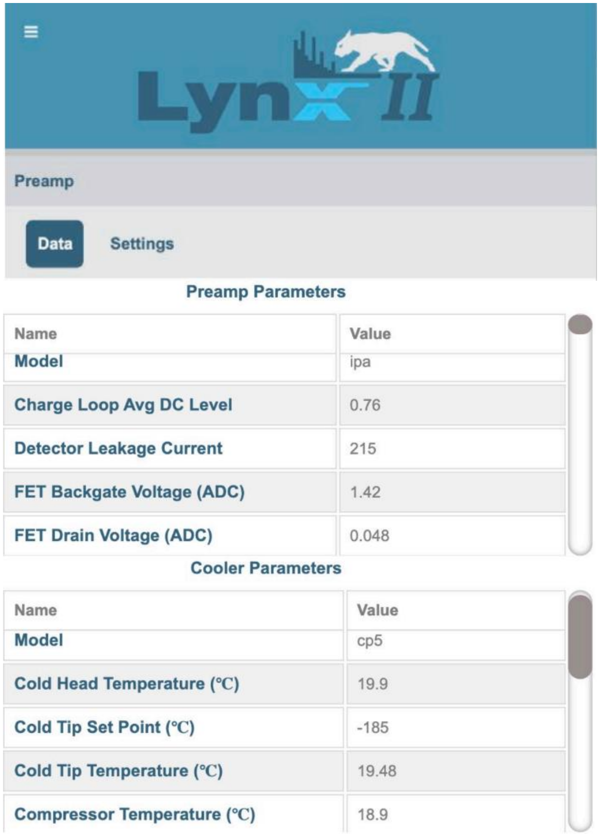
- Maintain excellent 2002C noise performance and footprint
  - Kept analog pulse processing logic (AEM board)
- Digitalization
  - Connecting AEM to digital DEM board
  - Interface through USB
    - Remark: external USB isolator recommended
  - Continuous and remote SoH monitoring, not requiring:
    - Multimeter;
    - LN_2 NIM electronics (requires DEM FW V1.2 or beyond)
  - Easy access to recommended detector setup parameters
    - Bias voltage
    - Polarities
    - RT/FT

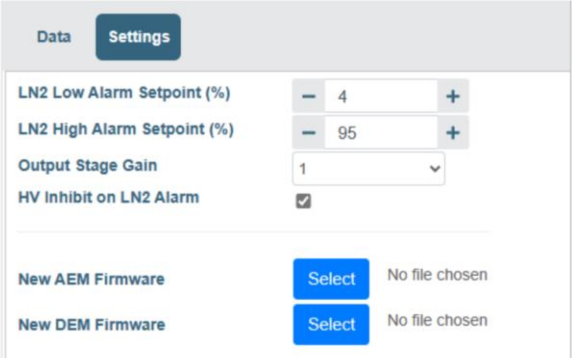




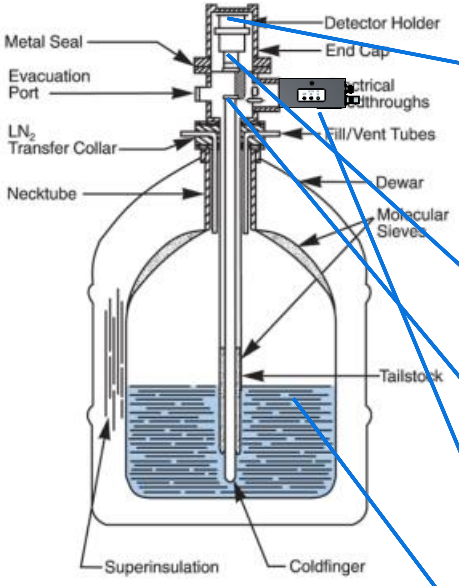
iPA monitoring and control with the Lynx II MCA

- Available with most recent Lynx II FW update: FW V1.1
- USB connection to Lynx II
- Access via the Lynx II web client UI
  - Continuous data monitoring
  - Settings control
  - FW management
  - Common platform for:
    - MCA
    - iPA
    - CP5-PLUS & iCC
  - Common real-time SoH log file





Predictive maintenance & Troubleshooting with iPA



LN2-cooled vertical dipstick cryostat

SoH parameter	Short description	Importance / Indicative for	2002	iPA (with Lynx II)
Detector leakage current	Leakage current	Diode issue? Vacuum issue? Preamp/cabling issue? FET broken?	Preamp access; Multimeter measurements	Enabling **continuous** readout for **remote** monitoring Note: interpretation still requires **human expert**
PRTD1	HPGe temperature	HV ready? Vacuum issue?		
PRTD2	Cold-tip temperature	HV safety? Cooler issue?	N/A	
Ambient Temperature	Electronics temperature	Ambient temperature issue?		
LN2 level	LN2 level	Vacuum issue?	External read-out needed	

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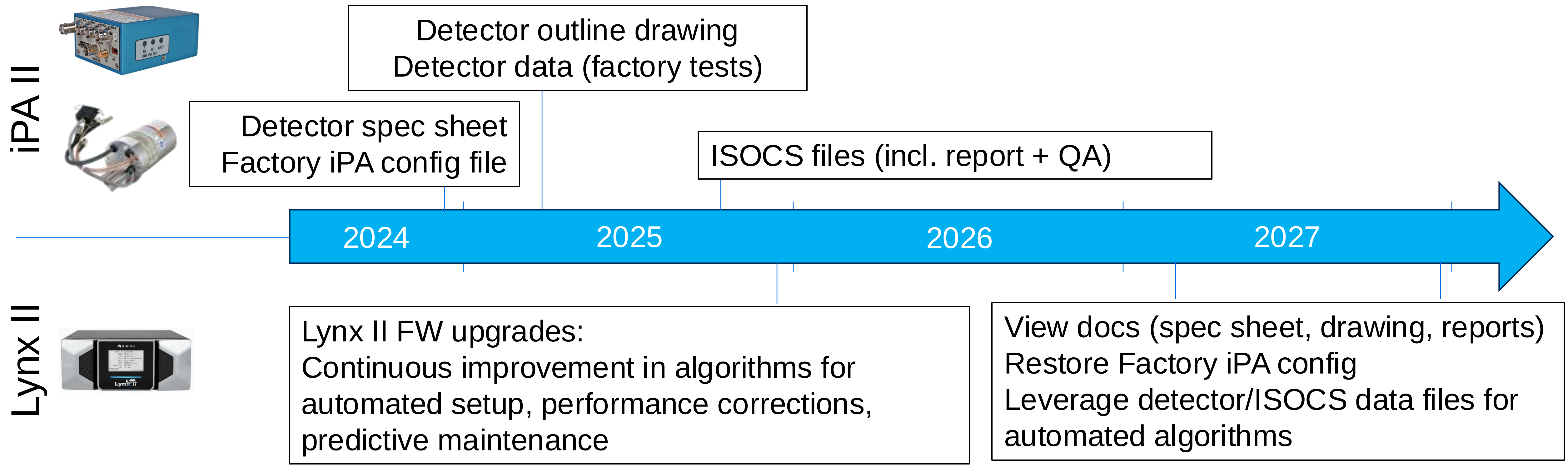
The iPA II preamplifier: preparing for Mirion's digital future

The key iPA II improvement (vs iPA): local data storage

- The iPA II will have a local storage of detector-specific data
- Lynx II FW updates will be required to access/leverage detector data on iPA II
- Overview of iPA II data storage and Lynx II monitoring features: (*)



(*) Timeline subject to change

“Ease of use” coming with local detector information

Steps	Activities	Analog preamp	iPA preamp	iPA II – Lynx II vision
Set up	HW parameter settings	Use HPGe data sheet Use sources Use certificates Use ISOCS files Understand expected & required HPGe performance Understand use case & objectives → **Human expertise**		User selects Use Case
	Energy calibration(s)			
	Efficiency calibrations			Select geometry
	Establish QA/QC Baseline&Window			Automated
	Measurement settings			Based on Use Case selection
	Analysis settings			
Measure	QA/QC	Just do it		Just do it
	Samples			
Interpret	Interpret/Review results	**Human expertise**		Human expertise

“Ease of use” and “SoH monitoring”: for who?

- Focus more on your core job;
- Spend/waste less time for:
  - Setup-related activities, also when use case/detector performance may change
  - Worrying about possible detector health issues
  - Determining actions in case of (upcoming) issues

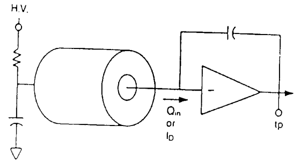
Complete iPA II improvement overview (vs iPA)

Improvement for	Feature	Benefit
Serviceability & User Experience	Integrated USB isolator (note: with USB-C connector)	Easier installation, cleaner setup
	Storage of detector-specific data (staggered approach)	Local availability of detector reference data for efficient setup and troubleshooting; Ready for future Lynx II FW with automated algorithm features
Serviceability	Longer Slimline pig tails (incl. USB!)	Easy access to connectors (also in lead shields and for Slimline MAC/CP5-PLUS)
	Easier to tune and setup	Enabling replacements/upgrades in the field
Quality	Improved HV filtering	More rugged against arcing and ESD
	Enhanced AEM board protections	
	Flexible power-up logic	MCA-USB power-up sequence independent of order

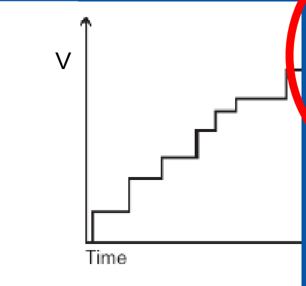
Next step on Mirion preamp roadmap?

The three HPGe preamplifier models

Always one principle

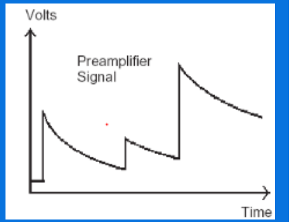


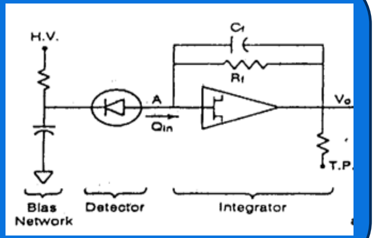
Charge-sensitive integrator: Q → V



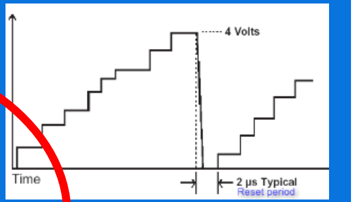
Two ways to restore

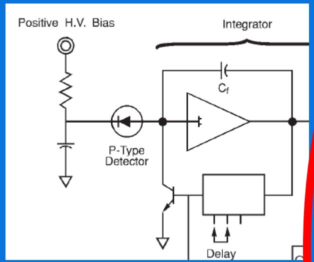
Dynamic charge restoration (RC feedback)





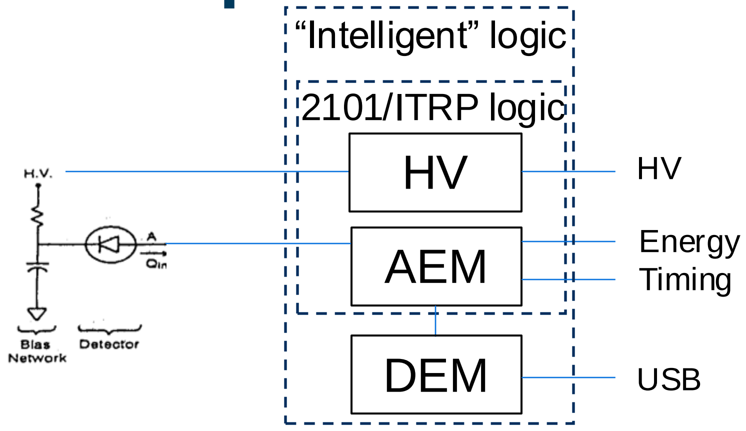
Reset charge restoration (Reset transistor)





Three models	Advantages	Drawbacks
iPA II	Cost; Max throughput	Energy-rate limited (<=200 GeV/s); P/Z regulation
2101N/P (transistor switch)	No energy rate limit; OK for high energies	Cost; Throughput; Noise impact (LEGe, BEGe)
ITRP (integrated switch in FET)	No energy rate limit; Best noise performance	Cost; Only useable for low energies

Development of Intelligent transistor-reset preamps?



- Technical opportunity exists:
  - Leverage the existing iPA/iPA II DEM board
  - Designed to become a common add-on for other preamp types
- But… Does the market opportunity exist?
  - ITRP:
    - Used for X-ray applications with Ultra-LEGe (or smallest LEGe) detectors
    - Very small market…
  - 2101N/P:
    - Used for high-energy rate applications (typically for high 60Co rates)
    - Usually, iPA is good enough (up to 200 GeV/s)
    - Rather small market… (but may change?)

Thank you