MIRION Connect AMERICAS 26

Annual Users' Conference

ADVANCING RADIATION SAFETY. EMPOWERING PROGRESS.

M Resort, Henderson, NV | June 15 – June 18

MIRION TECHNOLOGIES

Advancing Radiation Safety.
Empowering Progress.

Advanced RMS Applications

Spectroscopy, MCNP Modeling and Mechanical Design

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Mirion Connect | Annual Users' Conference 2026

Henderson, NV

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Daily Check-In:

Tuesday

Please take a moment to check in for today's session.

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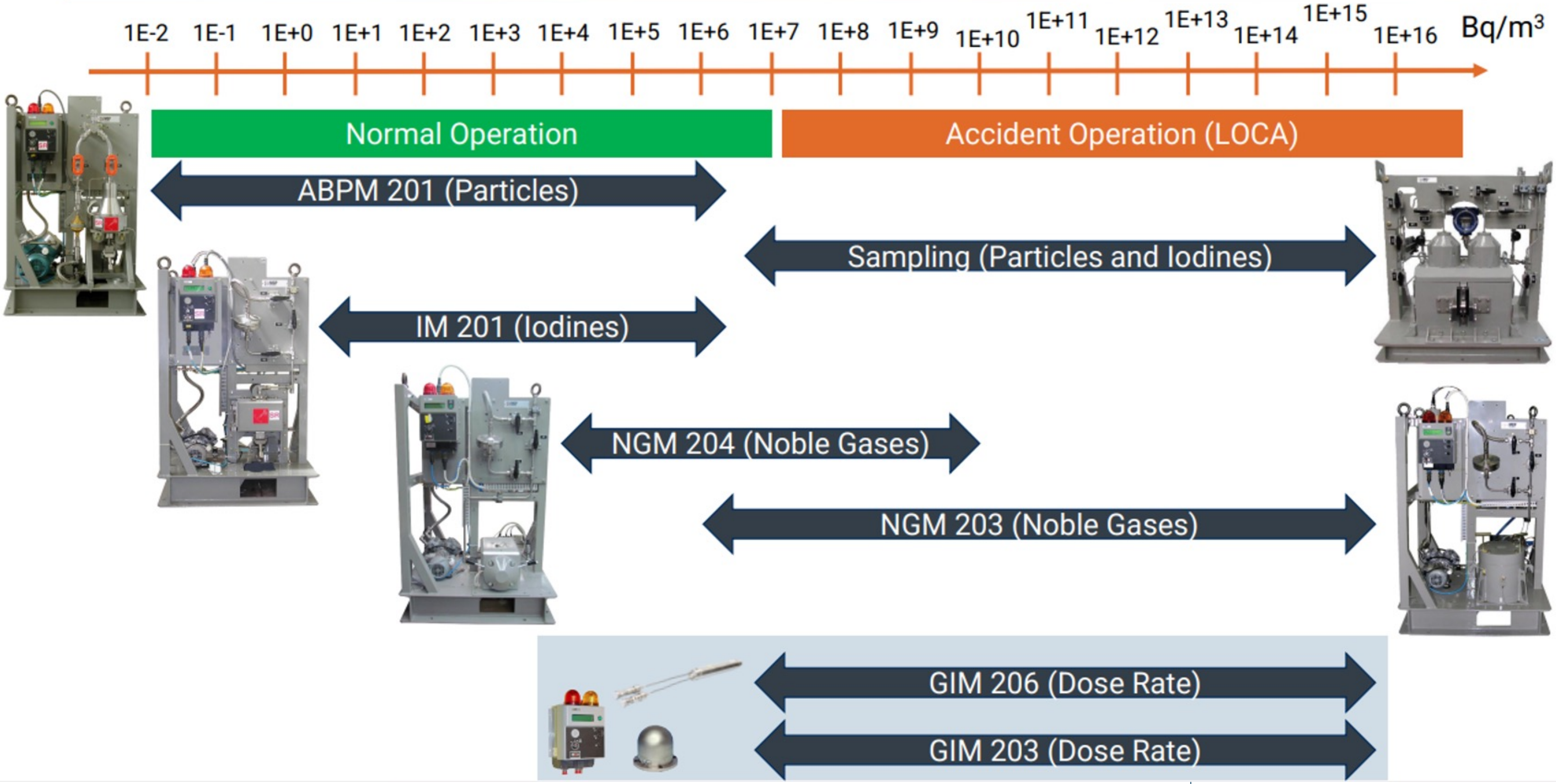
Overview

- *Advanced Topics*
  - *Spectroscopy in RAMSYS Applications*
  - *MCNP Modeling and Design*
  - *Mechanical Design Topics*

RMS Effluent Release – Measurement Range



Spectroscopy in RMS Applications

Spectrum Analysis in RMS Applications

Basic Concept:

- The output of any radiation detector is proportional to the *intensity* of the incident radiation being measured (otherwise it's not a very good detector!)

  → "Intensity" = cps, CPM, amps, etc…

- In the case of *some* detectors, the output is also proportional to the *energy* of the incident radiation.

  → "Energy" = eV, keV, MeV, etc…

Spectrum Analysis in RMS Applications

Detectors with Energy-Proportional Output:

Type of Detector	Use in RMS Applications
Scintillation • Inorganic: NaI(Tl), CsI(Tl), BGO, Etc. • Organic (Plastic)	Ubiquitous
Large Area Silicon: SSB, PIPS	Alpha & Beta monitoring (typically particulate & noble gas)
Proportional Counter	Neutron area monitoring (but spectroscopy capability not commonly used)
Ionization Chamber (IC)	Area & Process monitoring (but use of ICs configured for spectroscopy is rare)
Semiconductor detectors • High Purity Germanium (HPGE) • Cadmium Zinc Telluride (CZT)	Use in industrial/RMS environment is rare but growing. Limitations on qualification, software QA Electric coolers for HPGE eliminate need for LN2; not req'd for CZT

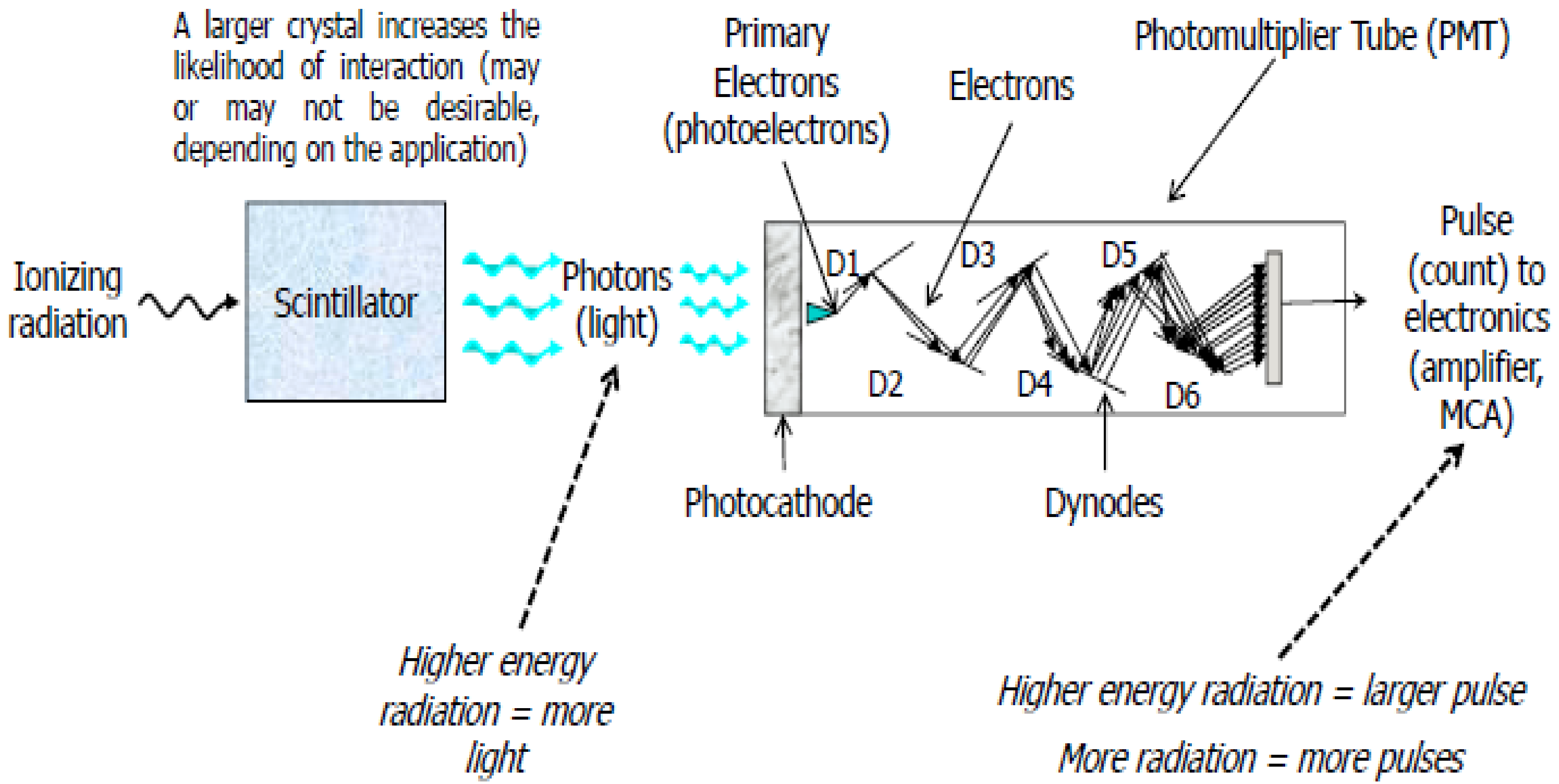
Spectrum Analysis in RMS Applications

Choosing a Detector:

- What is being measured?
  - Gamma only?
    - Need to differentiate between isotopes?
  - Alpha and/or beta?
    - Need to differentiate between [alpha] isotopes?
  - Beta only, no gamma (ideally)?
  - Beta and gamma?
- Other considerations
  - What are the range requirements?
  - What are the temperature requirements or other environmental requirements (TID)?
  - Etc.

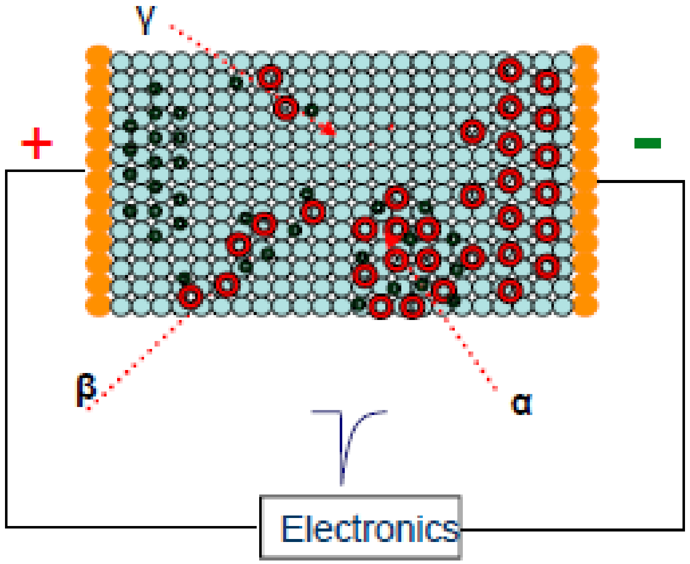
Spectrum Analysis in RMS Applications

Scintillation Detectors:



Spectrum Analysis in RMS Applications

Passivated Implanted Planar Silicon (PIPS) Detectors):



Higher energy radiation = larger pulses

More radiation = more pulses

Ionizing radiation entering the PIPS diode creates free electrons and corresponding "holes" in the diode. A bias voltage (~80 V) is applied to the diode to collect the electrons and holes, generating a pulse (count). Because the active layer of the diode is thin and not very dense, the diode is more sensitive to charged particles (alpha & beta) than to photons (gamma).

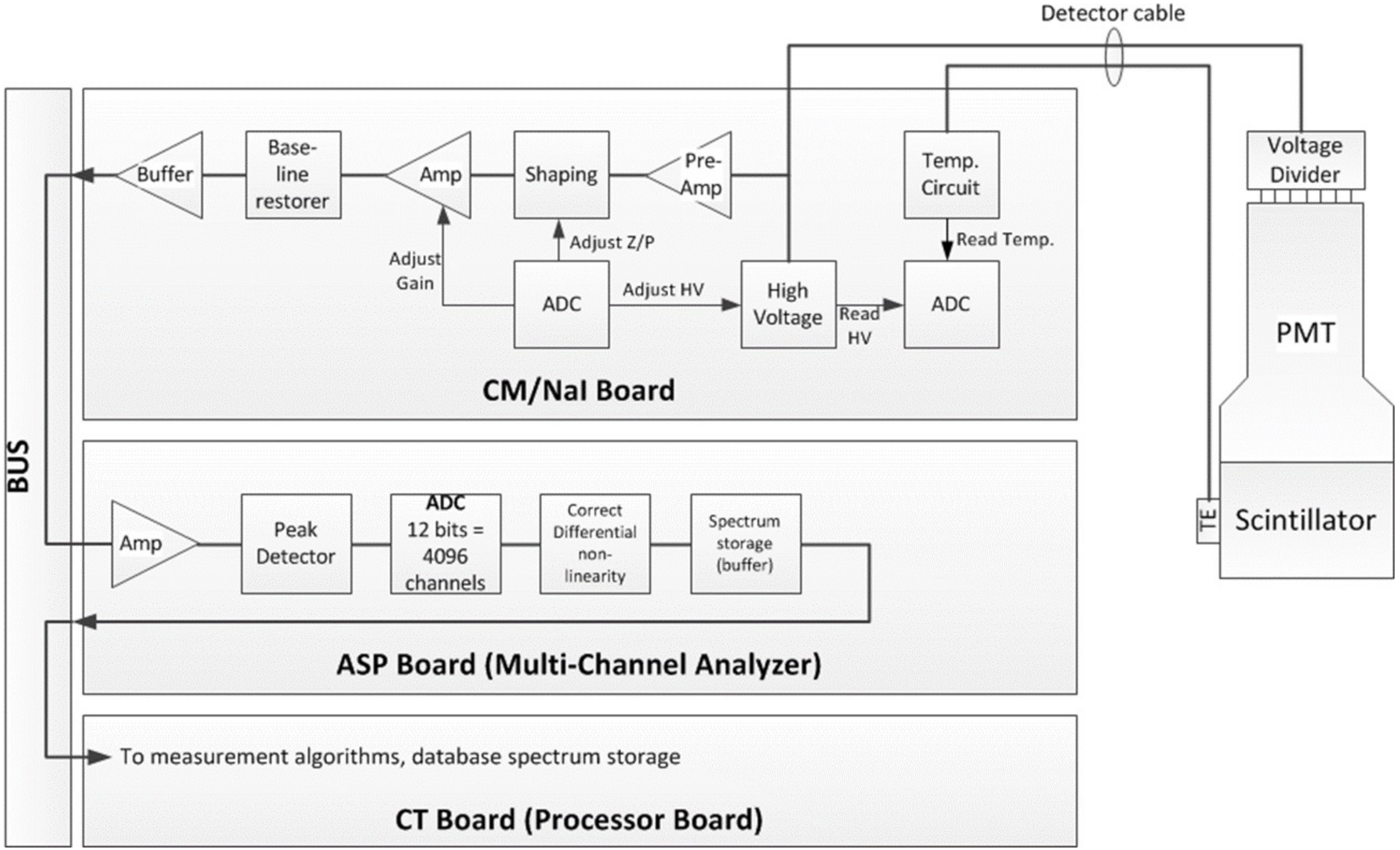
Spectrum Analysis in RMS Applications

Processing the Detector Output:

- *The pulse output of the detector (any type) is amplified, shaped and digitized.*
- *From there, it is fed into a multi-channel analyzer (MCA) which classifies the pulses into channels according to their amplitude*
- *The MCA allows measurements to be made in multiple windows covering different bands of radiation energy*
- *Energy calibration is the process of calibrating the MCA*

Spectrum Analysis in RMS Applications

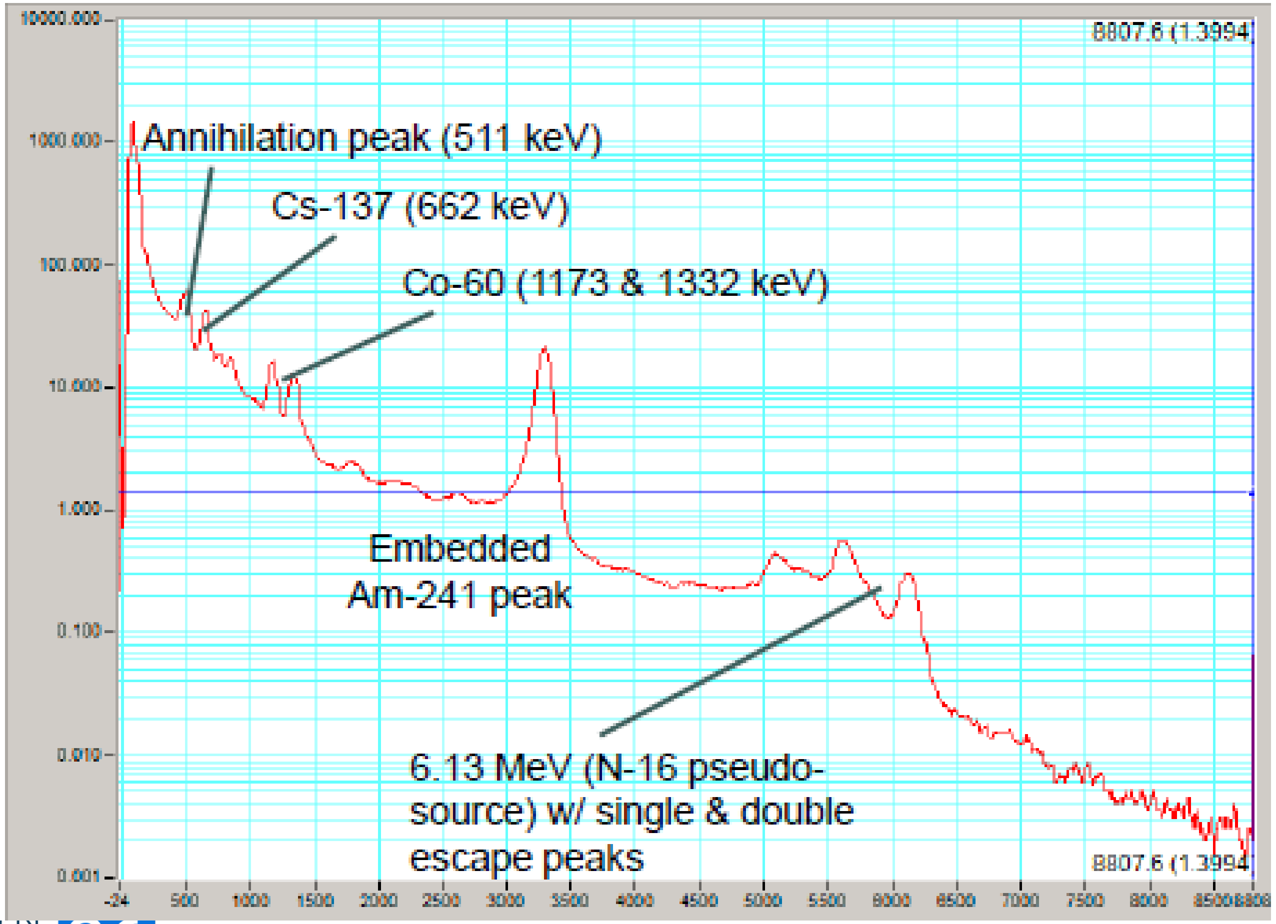
Processing the Detector Output (example for Scintillation Detector):

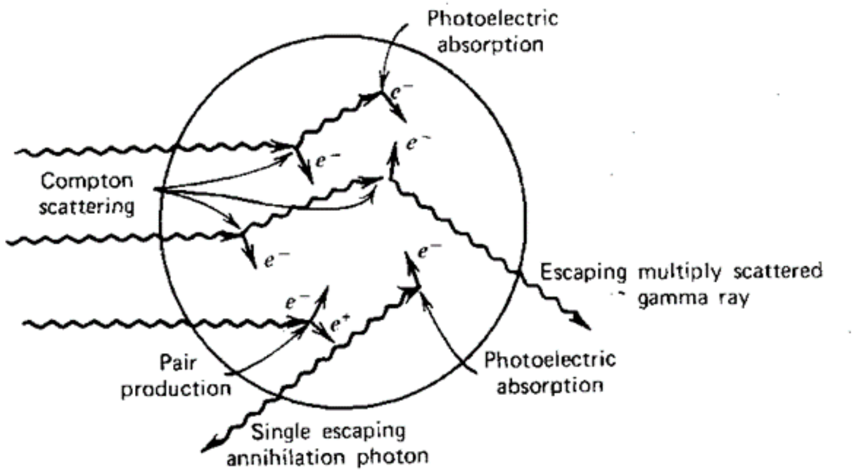


Spectrum Analysis in RMS Applications

Gamma Spectroscopy with NaI(Tl):

Example with multiple sources (log scale):





Spectrum Analysis in RMS Applications

Physics constraints: Gamma Scintillation detectors

Resolution of "RMS-grade" detectors (e.g. NaI, CsI) doesn't really permit isotope identification, specifically in the presence of multiple isotopes

Resolution can be improved substantially with specialized scintillators (LaBr, CeBr)

Or significantly with HPGE or CZT

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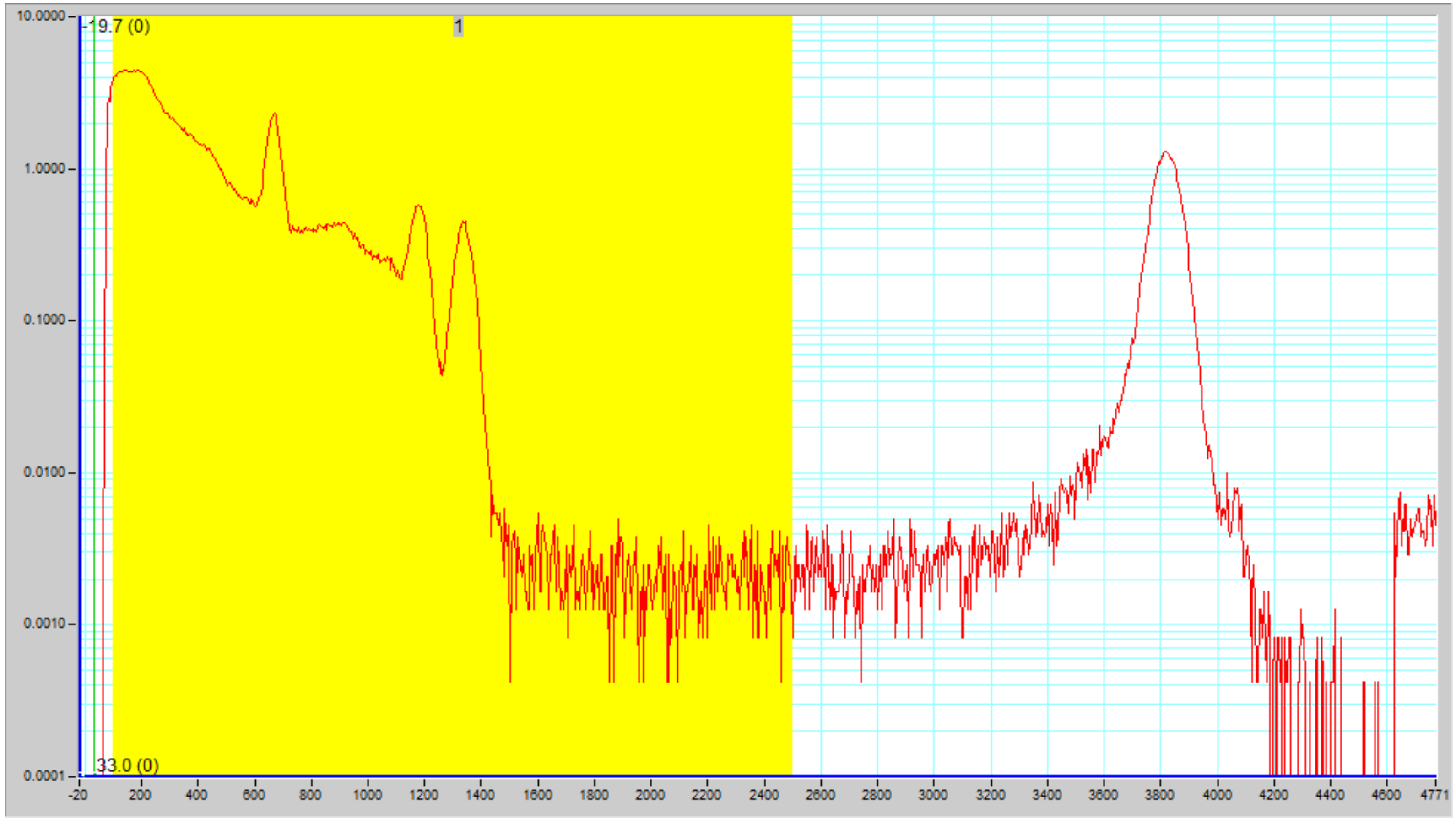
Spectrum Analysis in RMS Applications

Gamma Monitoring with NaI(Tl)

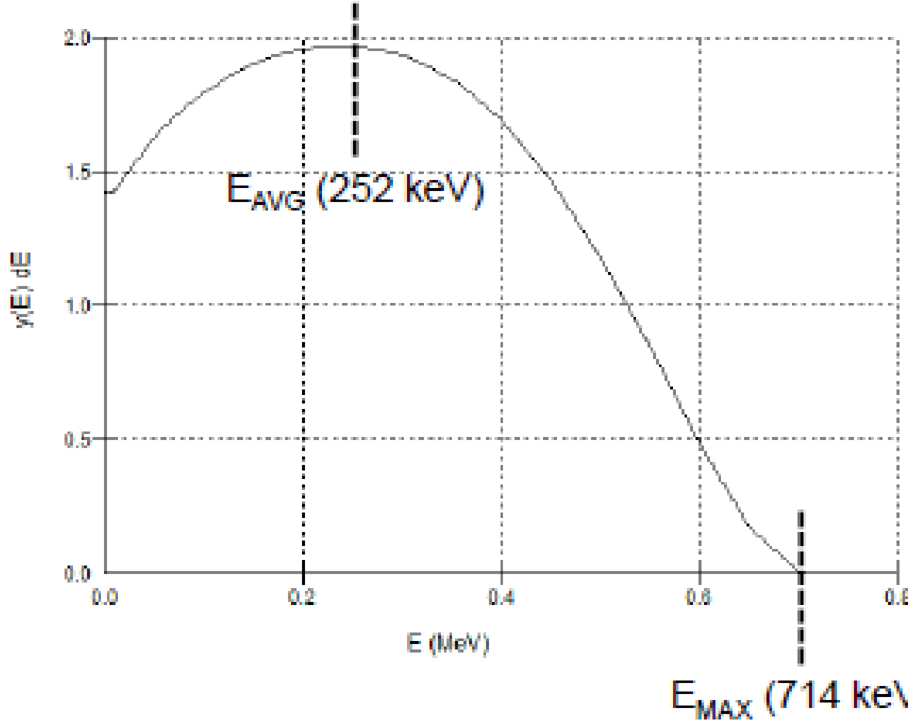
Example: Liquid monitor with a large window (ROI from 150 to 2000 keV)



Spectrum Analysis in RMS Applications

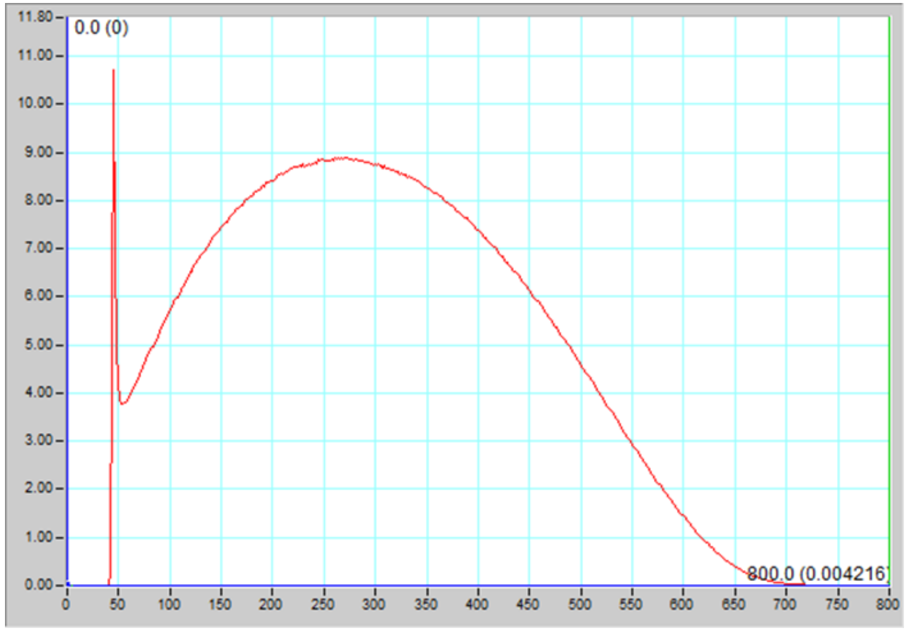
Beta Spectroscopy with Plastic Scintillator

Beta emission spectrum of Cl-36:



Beta spectrum is continuous, characterized by an average energy and a maximum energy, rather than discrete energy peaks . Because of this, RMS applications are typically limited to gross beta monitoring.

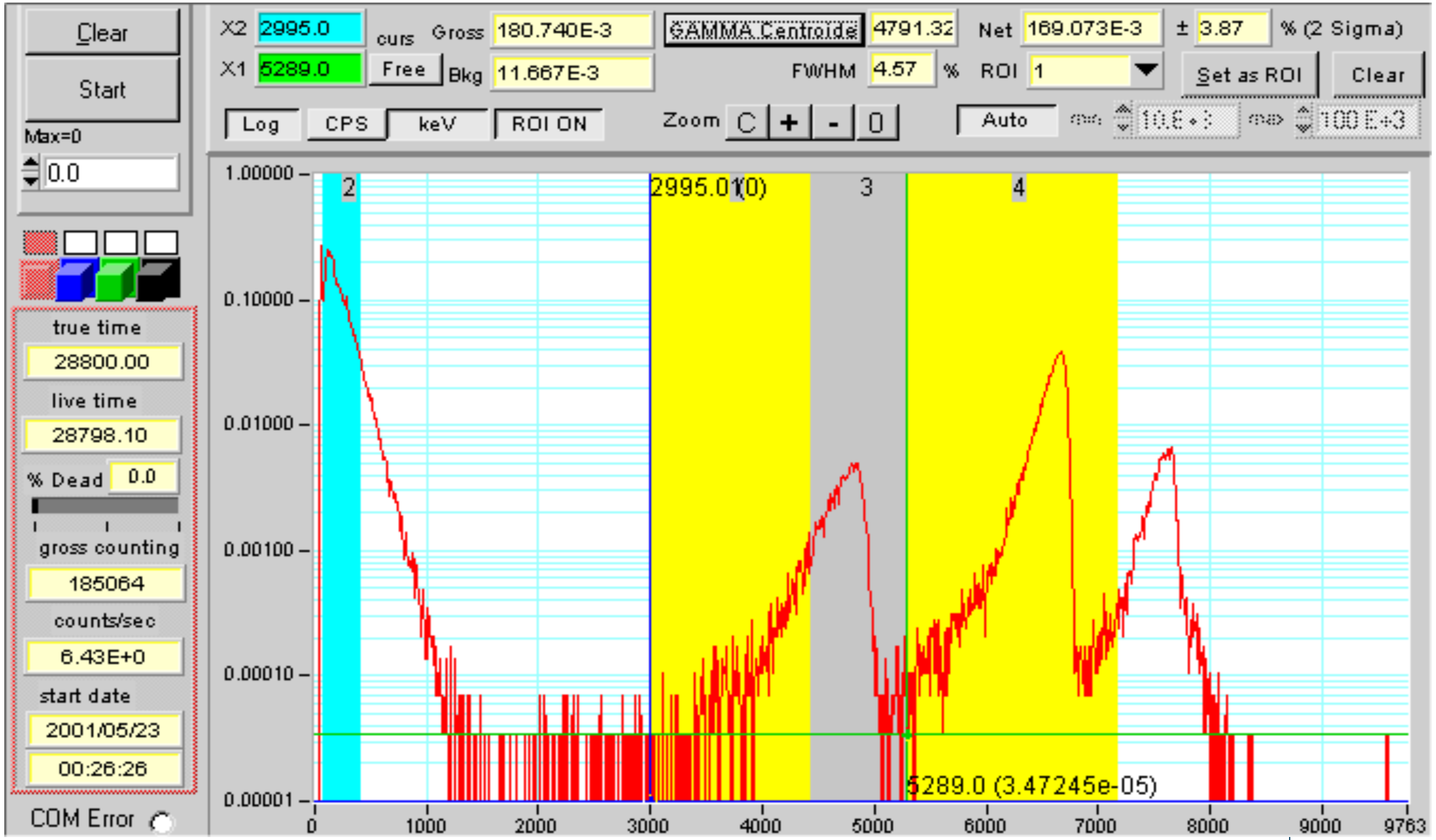
Beta spectrum of Cl-36 captured with 10mm x 50mm PVT detector:



Spectrum Analysis in RMS Applications

Charged Particle Spectroscopy with PIPS Diodes

Naturally occurring Radon daughter background



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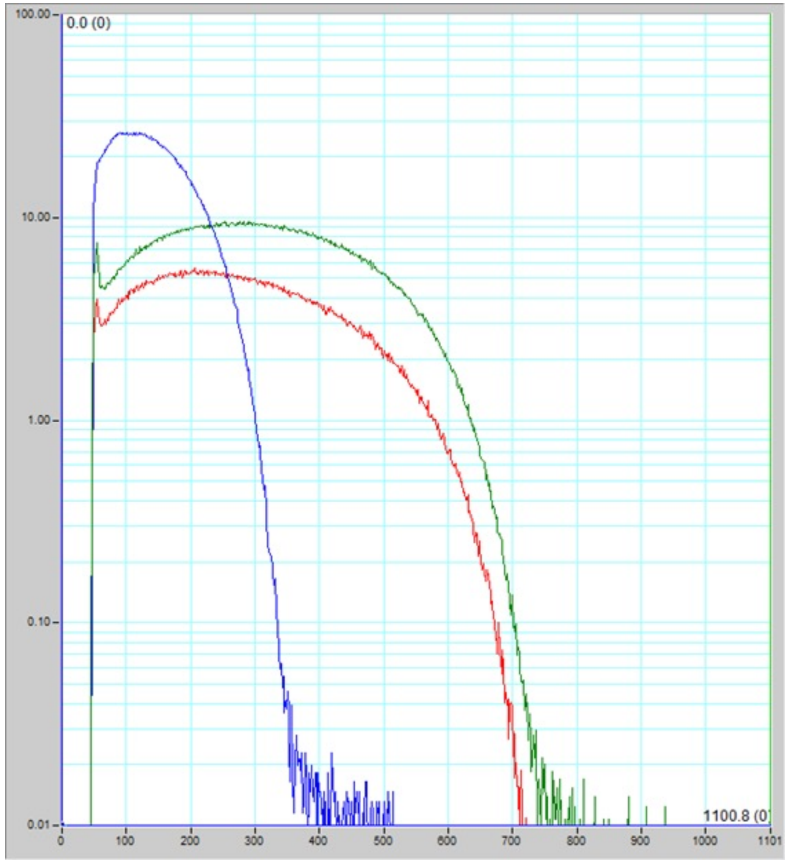
Spectrum Analysis in RMS Applications

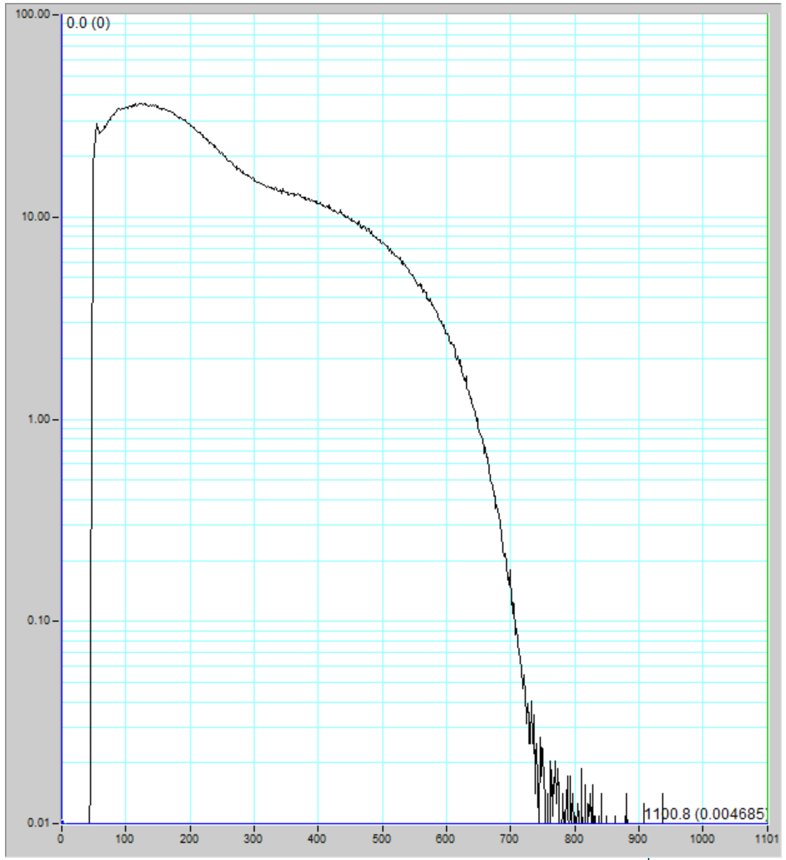
Physics constraints: Beta detectors (PIPS or Scintillation)

Continuous energy spectrum of beta particles does not permit isotope ID

Individual isotopes:



Mixture of isotopes:



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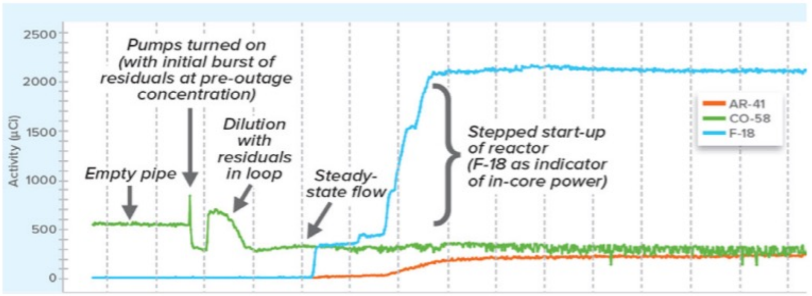
Mirion Spectroscopy Applications

NGM-id: Noble Gas Monitor with isotope identification for stacks

- *Designed for air sampling in ventilation ducts, gaseous treatment systems and stacks of nuclearfacilities*
- *Equipped with a High Purity Germanium (HPGe) detector*
- *Marinelli-type sampling chamber (2 volumes: 18.5 liters for BAN, 3 liters for TEG)*
- *High accuracy and reliable gamma spectrometric measurements*
- *Isotope identification and quantification of volumetric activities*
- *Available with electrical cooling or Intelligent Cryo-Cycle™ Hybrid Cryostat*

Real-time monitoring of isotopic activity with similar Mirion Product CSM + Data Analyst w/ CZT detector & simulated HPGe spectrum



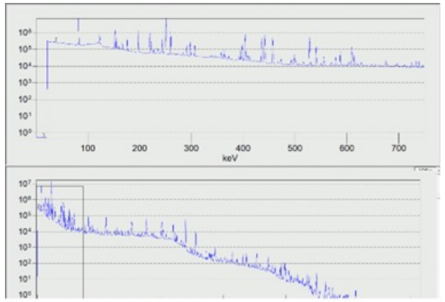
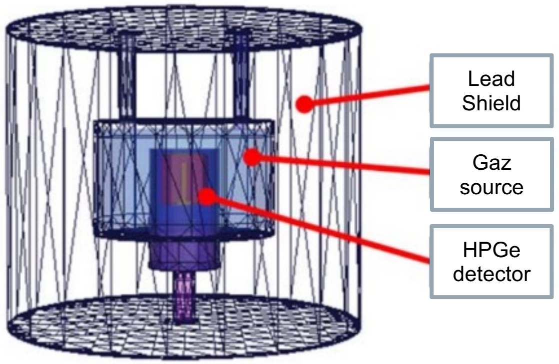


Figure 3 Simulated HPGe spectrum



NGM-id

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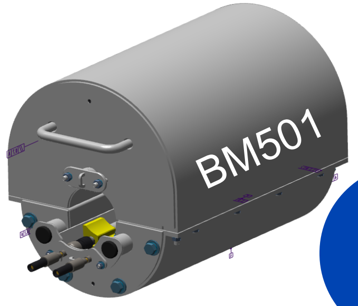
Boron-meter

Boron-meter Solutions – Development and Innovation capabilities

Installed and calibrated on 25 NPPs

Further >30 NPPs confirmed for the future (including EPRs)

New customer needs: prevention of dilution incidents during Unit Planned Outage



2014 Development → 2016 Qualification → 2017 Fabrication → 2018 Commissioning → 2023

- **Development:**
  - *New design*
  - *New fully qualified product*
  - *New skills acquired*
- **Innovation:**
  - *State of the Art uncertainties estimation*
  - *Calibration model*
  - *Fluid temperature compensation*
- **Feedback:**
  - *At first, half of the France NPPs equipped with BM501*
  - *Thanks to the positive feedback → the other half will be equipped (ongoing) / EPR (ongoing)*

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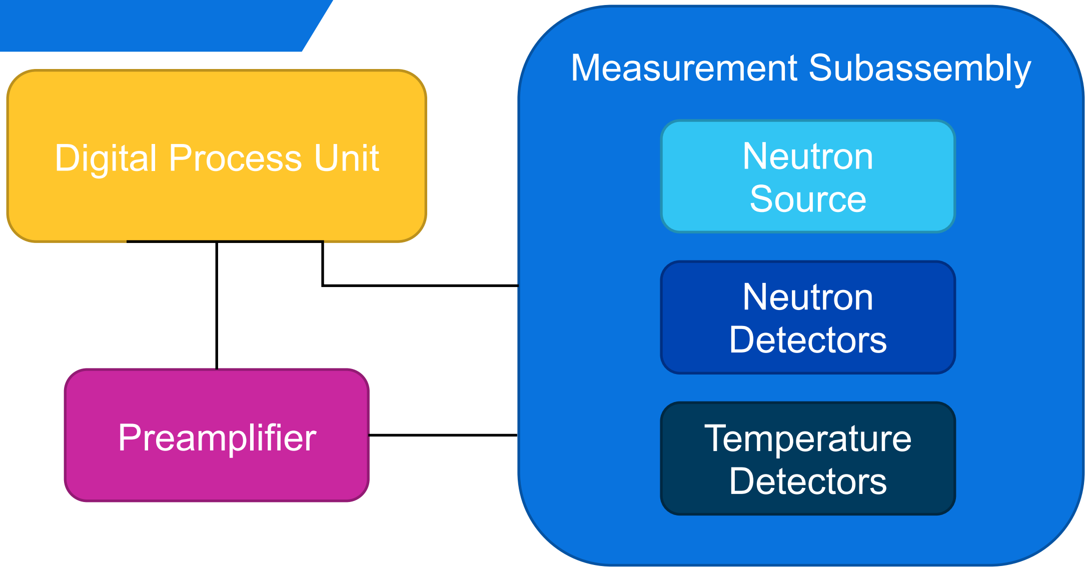
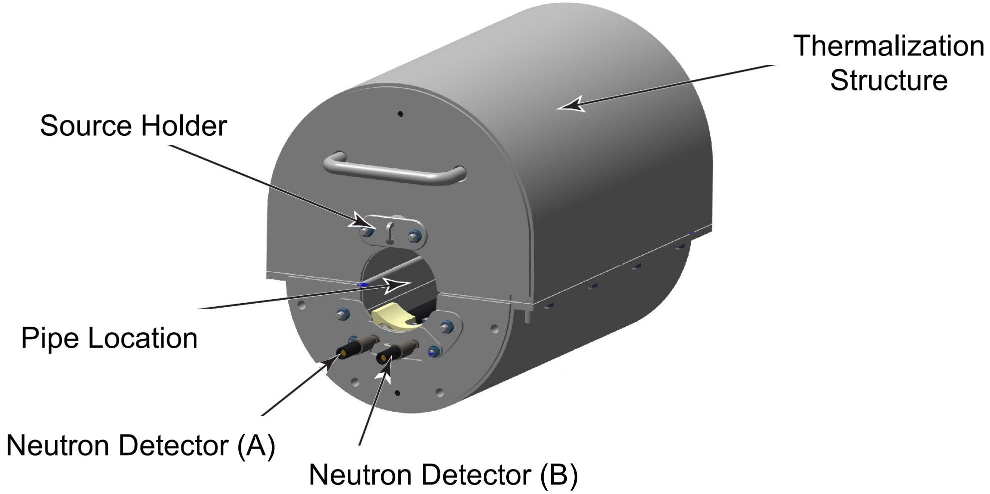
Boron-meter Solutions – Development and Innovation capabilities

- **Continuous and non-intrusive measurements of boron concentration in nuclear reactor**
- **Adaptable solutions**
- **Normal and incidental conditions**
- **Adapted safety classifications**
- **Flexible range of application:**
  - *Prevention of dilution accidents*
  - *Continuous monitoring of boron concentration for safety-related applications.*
  - *Integration into automated systems (such as the automatic lithium injection system).*
  - *etc.*





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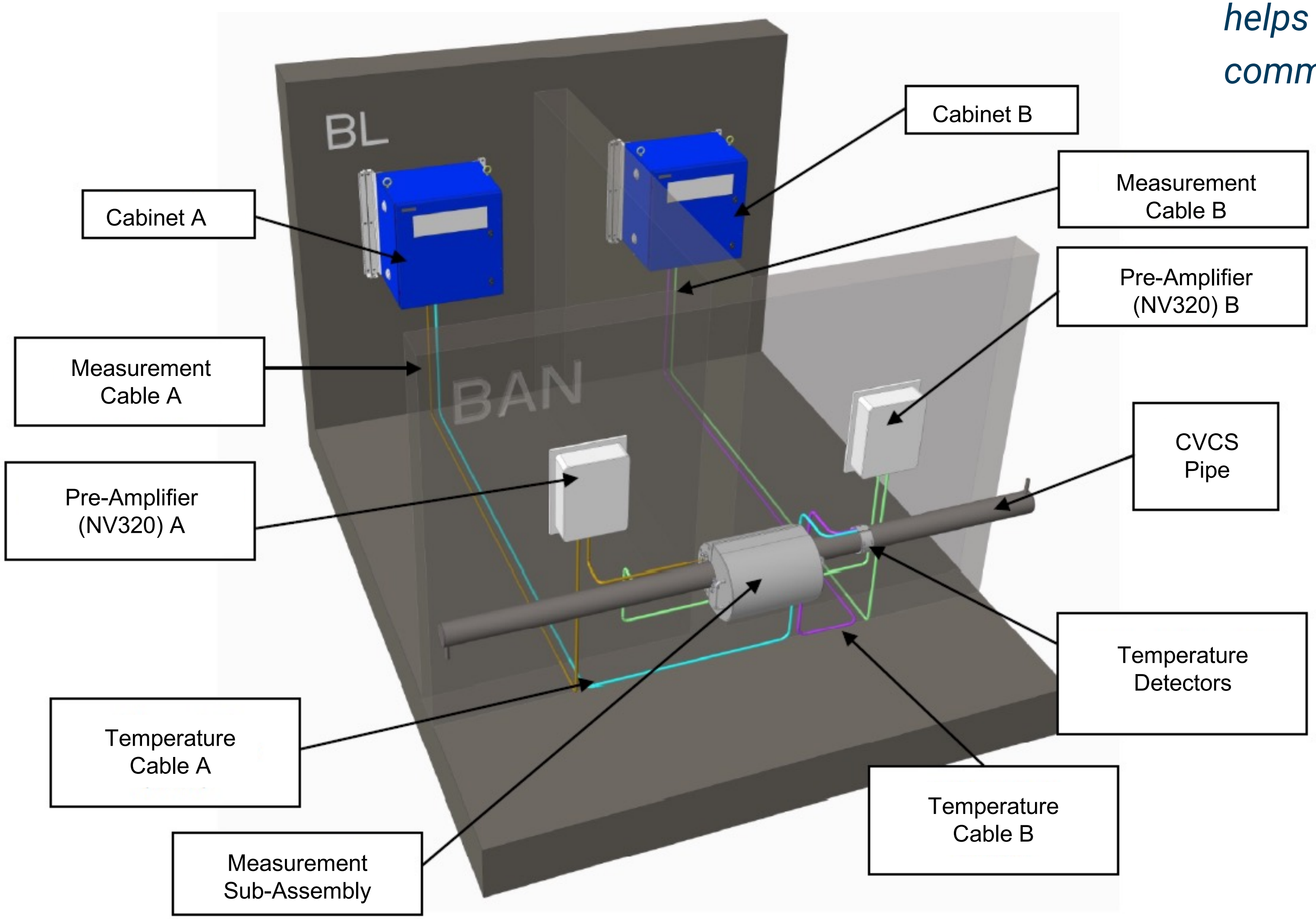
Boron-meter Solutions – site configuration (@ CVCS)

MIRION offers support in defining BM solutions tailored to the customer context. This support helps the customer through all commissioning activities.



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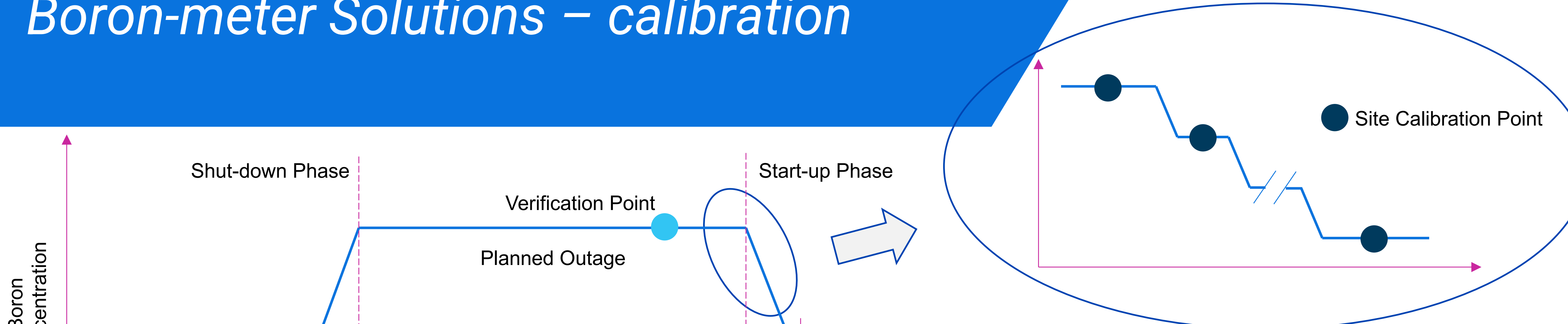
Boron-meter Solutions – calibration



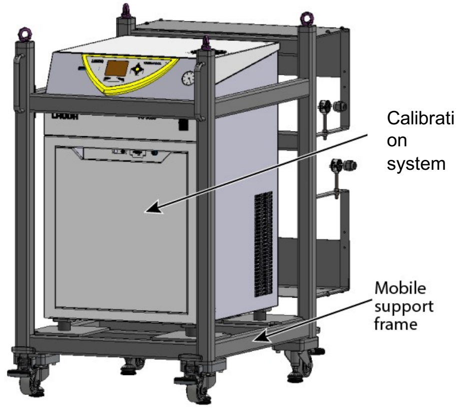
Chemical Analysis

System calibration is adaptable to site constraints.

Boron-meter site calibration at commissioning: several calibration points:

- *@CVCS: joint effort between the operator, on-site chemical laboratory and Mirion technicians*
- *@PSS: a portable calibration bench may be used (joint effort between on-site chemical laboratory and Mirion technicians)*

Boron-meter Verification at each cycle (maintenance phase): one verification point



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MCNP Modeling and Design

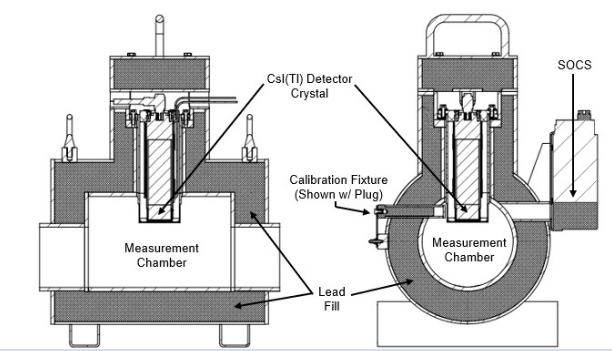
Radiation Monitoring Configurations

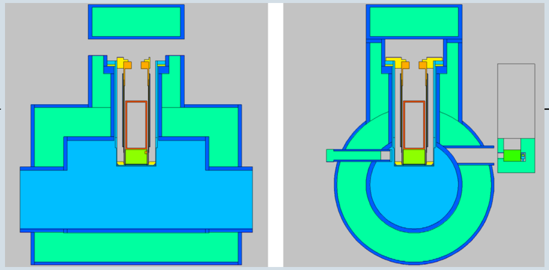
- *Area Monitoring*
- *Process and Effluent Monitoring*
  - *In-Line Configuration*
  - *Off-Line Configuration*
  - *Adjacent-to-Line Configuration*

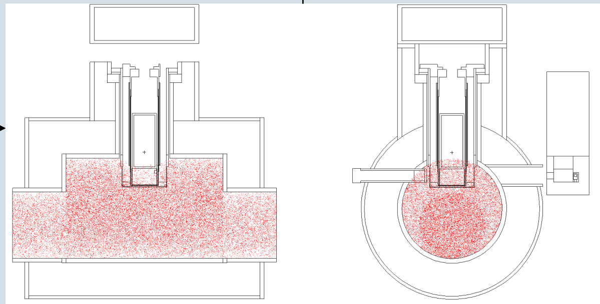
Example In-Line Monitor Analysis

Input:
Detector and Shield Design (Mirion)
Source Term (Customer)
Background Rad Field (Customer)

Output:
Background Rad Field Response
Minimum Detectable Concentration
Measurement Range

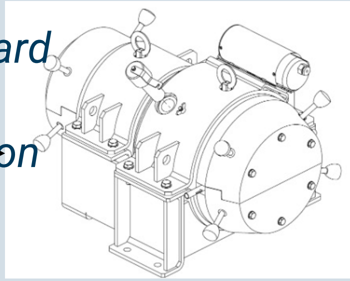


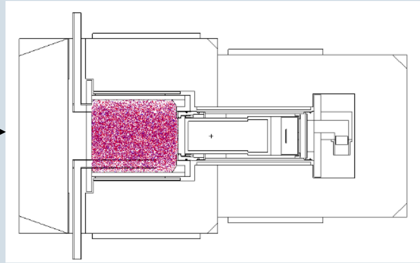




Off-Line Monitors Use Type Test for Standard Reference Isotopes (Typically)

Input:
Isotopes of Interest – Standard or Customer-Specific
Atypical Background Radiation Fields
(Typical: Cs-137 or Co-60)





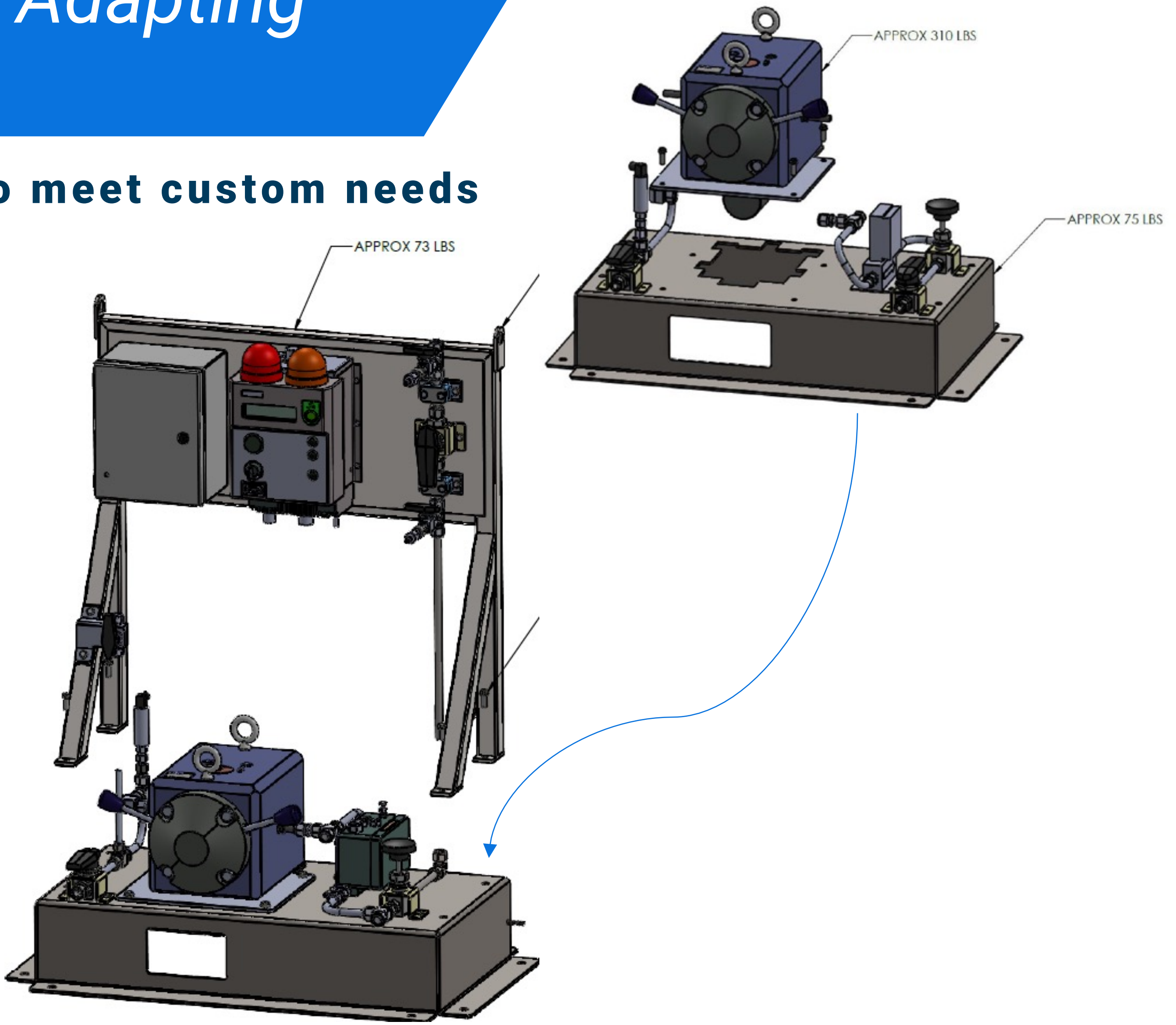
Output:
Reference Isotope Benchmarks
Customer-Specific Isotope Responses
Adjusted Measurement Ranges to Customer Applications/Specs

Mechanical Design Topics

Mechanical Design Topics – Adapting to Customer Specifications

Full suite of standard skids, but able to meet custom needs

- *Recent customized solution examples*
  - *Fully custom Severe Accident Sampling & Monitoring System at Canadian site*
  - *Specialized stack & containment monitoring in South America*
- *TVA Watts Bar – modular skids adapt to walk path constraints*
  - *Status = Equipment delivered, installation progress*
- *Modifications to existing skid designs to accommodate connections for redundant pumps, connection of high purity germanium detector (HPGe)*

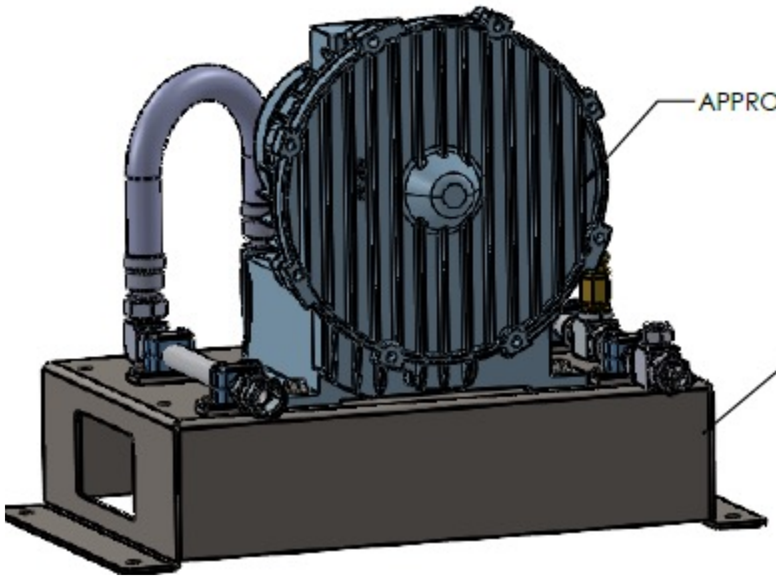


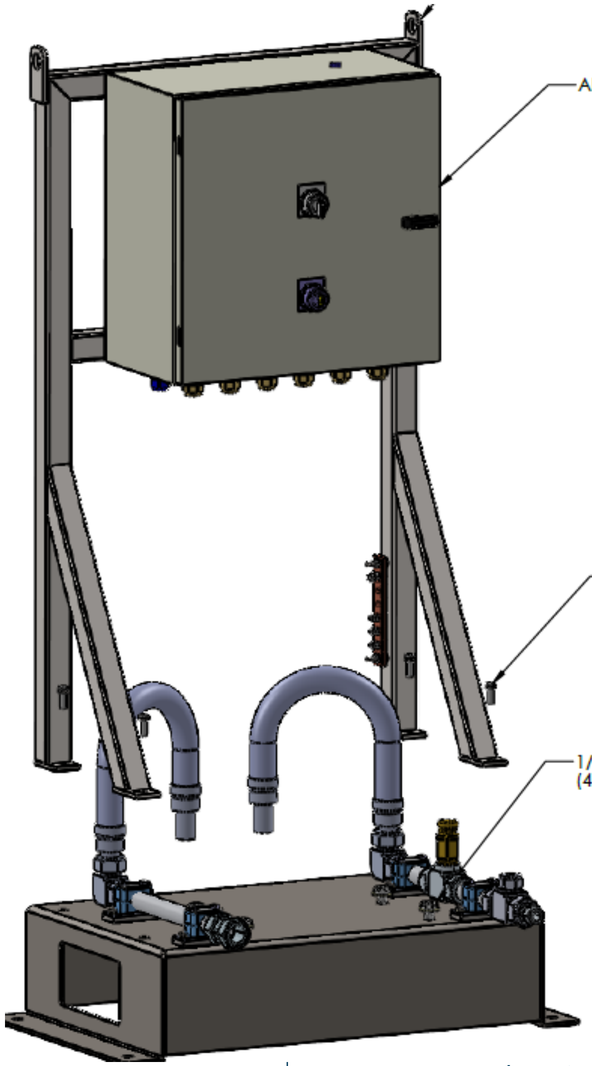
NGM 204SK

Mechanical Design Topics – Adapting to Customer Specifications

Full suite of standard skids, but able to meet custom needs

- TVA Watts Bar – modular skids adapt to walk path constraints
    - Status = Equipment delivered but not yet installed



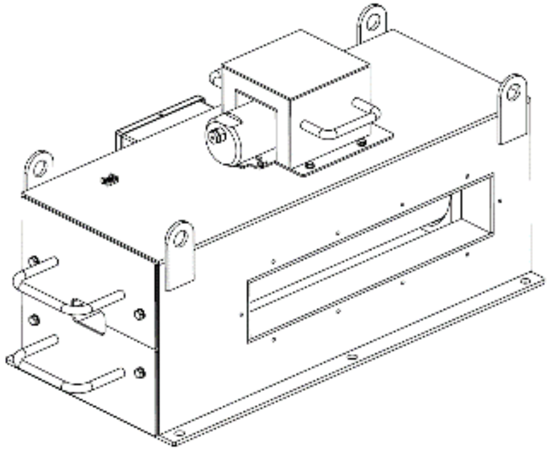


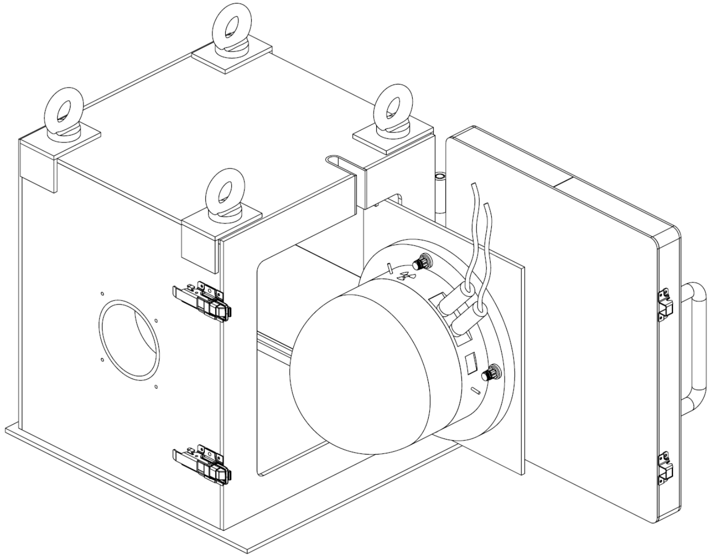
Pump Skid w/ Pump Skid w/ PDCU Box

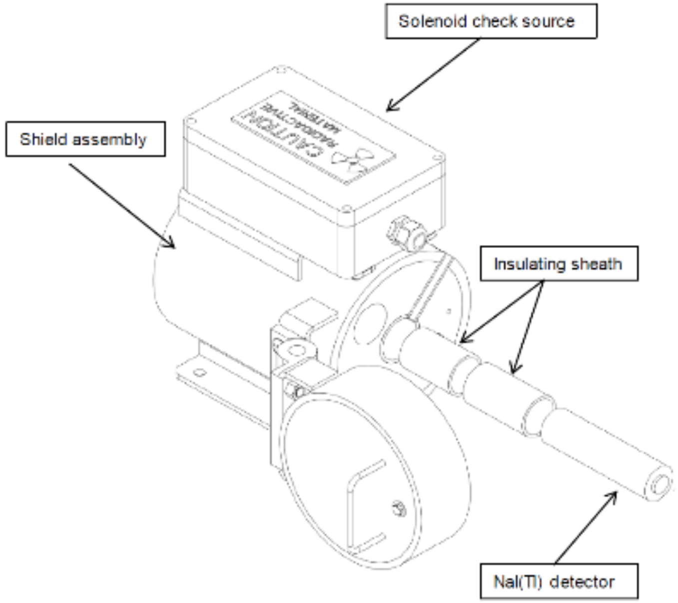
Mechanical Design Topics – Adapting to Customer Specifications

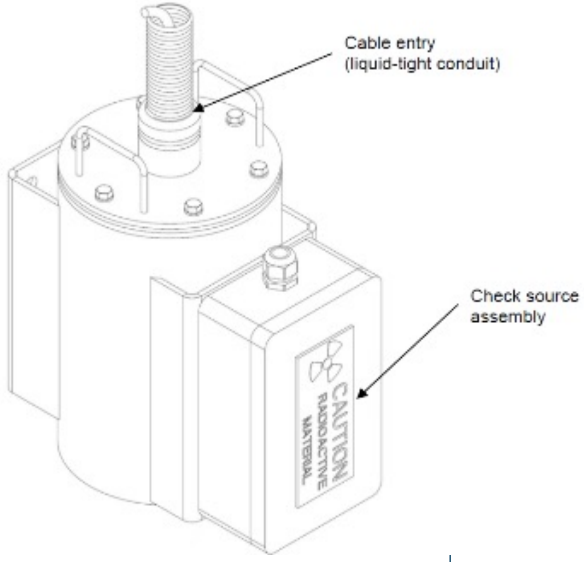
Custom Main Steam Line Monitors

- **4 different designs adhering to unique customer requirements**









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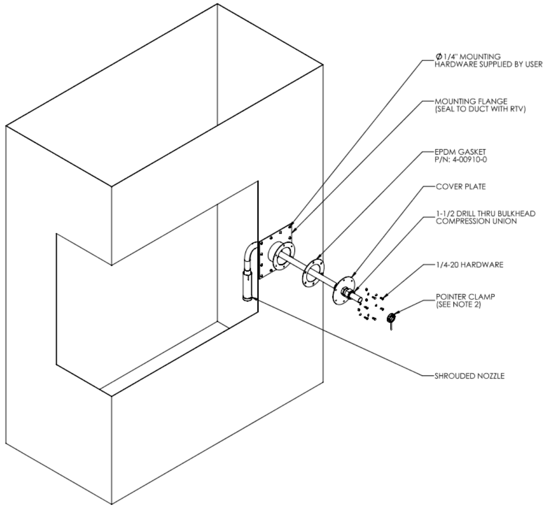
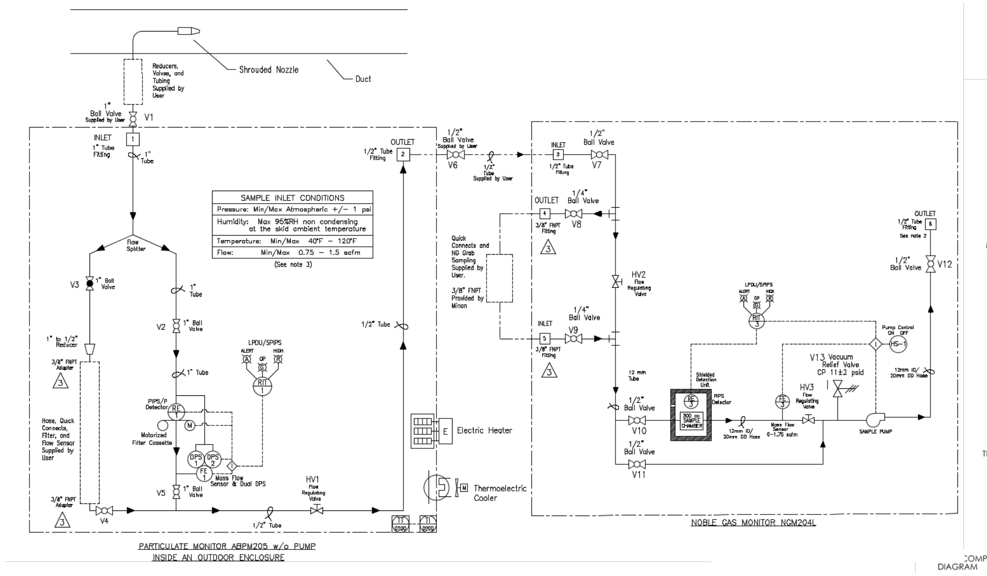
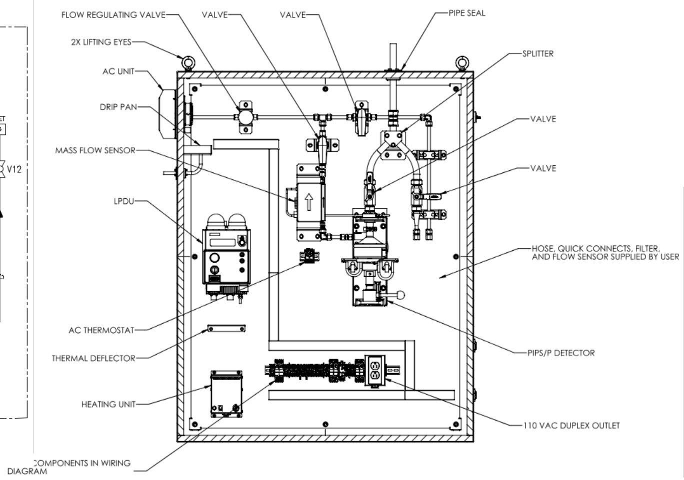
Mechanical Design Topics – Adapting to Customer Specifications



Custom Main Particulate and Noble Gas Monitoring System

- Due to particulate sample transport requirements, particulate monitor needed to be installed on rooftop, then routed to noble gas monitor within the customer facility.





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Survey and Q&A

Survey for:

Instrumentation and Control (I&C) Forum

Please take a moment to fill out a short survey on this session.

Thank you