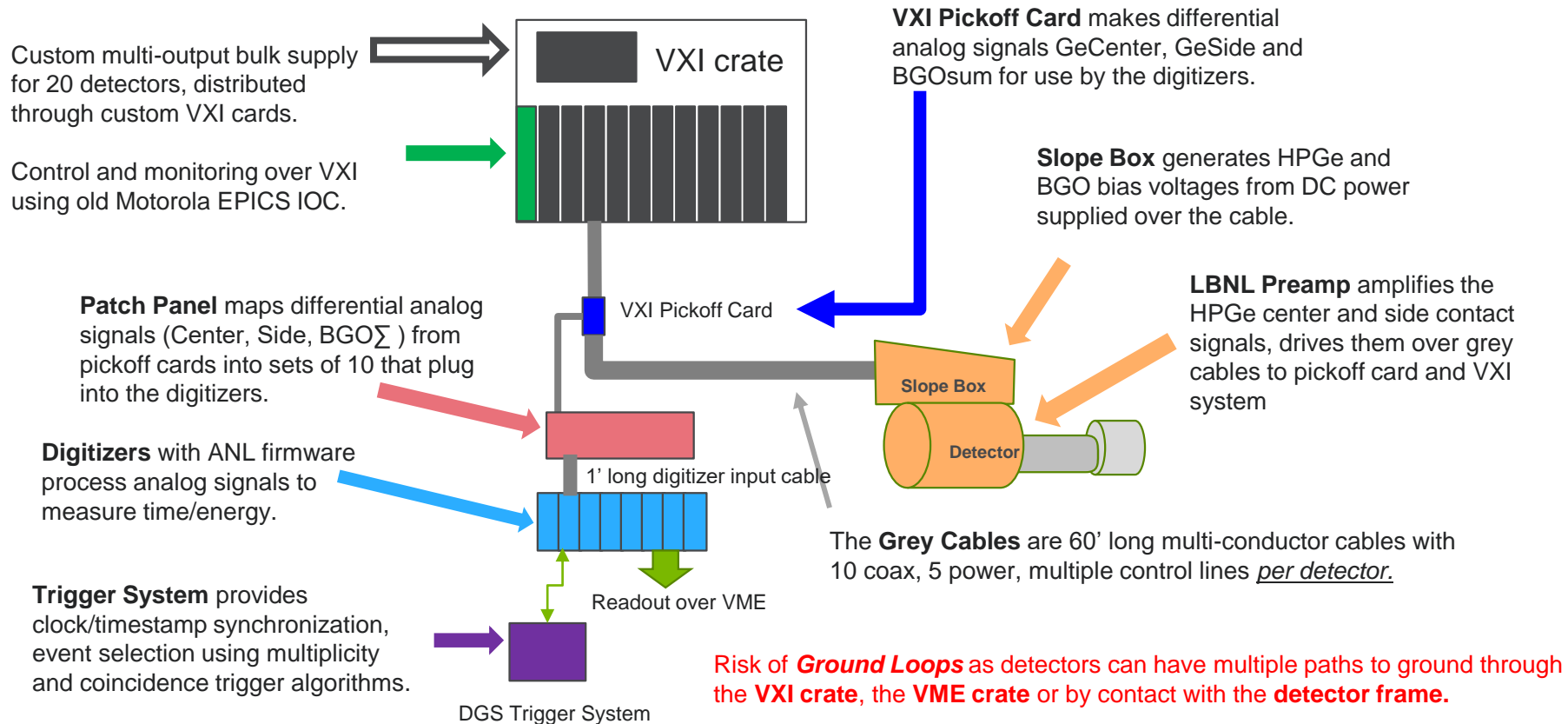# GAMMASPHERE UPGRADE PROJECT OVERVIEW

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December 2, 2022

GAMMASPHERE UPGRADE: PROJECT OVERVIEW

- Root Cause Analysis

- Upgrading Detector & Signal Processing Electronics

- Legacy Hardware Removal & New Possibilities

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GAMMASPHERE BEFORE THE UPGRADE
Block Diagram

Custom multi-output bulk supply for 20 detectors, distributed through custom VXI cards.

Control and monitoring over VXI using old Motorola EPICS IOC.

VXI crate

VXI Pickoff Card makes differential analog signals GeCenter, GeSide and BGOsum for use by the digitizers.

Slope Box generates HPGe and BGO bias voltages from DC power supplied over the cable.

VXI Pickoff Card

Patch Panel maps differential analog signals (Center, Side, BGO∑) from pickoff cards into sets of 10 that plug into the digitizers.

LBNL Preamp amplifies the HPGe center and side contact signals, drives them over grey cables to pickoff card and VXI system

Slope Box

Detector

Digitizers with ANL firmware process analog signals to measure time/energy.

1' long digitizer input cable

The **Grey Cables** are 60' long multi-conductor cables with 10 coax, 5 power, multiple control lines *per detector.*

Readout over VME

Trigger System provides clock/timestamp synchronization, event selection using multiplicity and coincidence trigger algorithms.

DGS Trigger System

Risk of *Ground Loops* as detectors can have multiple paths to ground through the **VXI crate**, the **VME crate** or by contact with the **detector frame.**

GAMMASPHERE UPGRADE: *PRIMARY DRIVERS*

- Replaced all BGO PMT bases in 2017, required full shutdown of Gammasphere
- After shut down for BGO refurbishment, many HPGe **not operating properly**
- User Feedback: Reports of data analysis excluding half of installed detectors

- Led to thorough **Root Cause Analysis** of Primary Drivers of observed issues:
  - Insufficient Number of HPGe in Operation
  - Many channels not working due to cable/connection issues
  - Poor HPGe Resolution
  - Readout Problems with varying event rate
  - BGO Pattern analog signal not available
  - Electric Honeycomb suppression not implemented in digital system

- Repair of HPGe detectors:
  - Since June 1st, 2019 hired electronics technician for diagnostics and repairs
  - Systematically replacing annealing stations

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GAMMASPHERE UPGRADE: *ROOT CAUSES*

- **Vacuum/crystal issues in some detectors**
- **Failing/intermittent connections in cables and boards**
- **System grounding had changed over 20 years of other Area IV changes**
- **LBNL preamp aging effects**
  - Noisy operation from leaky capacitors and marginally stable transistors
  - Insufficient gain margin in LBNL preamps for newer FETs
- **VXI crate aging effects**
  - Component failures in VXI cards
  - VXI crate power supplies overloaded/overheating
- **Some signals of 'analog' Gammasphere not duplicated in 'digital' Gammasphere**
  - Electric honeycomb requires system-wide collection of individual BGO hits not available to digitizers
  - VXI pickoffs did not implement BGO pattern circuitry
- **Channel matching issues**
  - Oscillatory response to preamp reset in some channels
  - DC offset/gain not well matched across all VXI pickoffs
- **Software problems**
  - Readout code had errors in buffer management
  - Readout code did not utilize firmware features for more efficient readout
  - Mismatches between firmware, EPICS driver, and user screens due to manual updating processes

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GAMMASPHERE UPGRADE: *DELIVERABLE SOLUTIONS*

- **Update and improve on-site detector repair processes**
  – Digital records of detector maintenance
  – Renewed repair contract with Ortec

- **Develop new electronics from preamp to digitizer**
  – Signal processing relocated to the detector
  – New cabling scheme across the system
  – Integration with EPICS for software control of every parameter

- **Rewrite data acquisition software**
  – Maximize data throughput efficiency
  – Streamline EPICS database formation

- **Redesign power supply subsystem**
  – Enhance ground isolation
  – Compact profile

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GAMMASPHERE UPGRADE: BEFORE AND AFTER
Block Diagram

The **48V Power supply** replaces the multi-output power supply of the **VXI Crate**

The **Collector Box** replaces the **Patch Panel** and the **VXI Crate**

New **digitizer firmware** provides better data for pole-zero and baseline corrections

Updated **trigger firmware** adds readout of triggering data over VME like the digitizers

Fiber Expander allows distribution of trigger modules across hemispheres

Commercial single output 48V supply

48VDC, isolated

Collector Box with Raspberry Pi IOC for control/monitoring

1' long digitizer input cable

VME Fiber Expander

DGS trigger system

20' long commercial DVI cable, *per detector*

New **ANL Preamp** replaces LBNL preamp adding improved FET monitoring, temperature/humidity monitors and a reliable *test pulser* for in-situ gain calibration

SBX   Slope Box

Detector

Dongle

Dongle identifies which detector position each DVI cable connects to

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UPGRADING DETECTOR & SIGNAL PROCESSING ELECTRONICS

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NEW GAMMASPHERE ELECTRONICS
HPGe Preamps, SBXs, Collector Boxes

Left:
- Collector Box
- 30 DVI Inputs (Top)
- 12 Digitizer Outputs (Bottom)
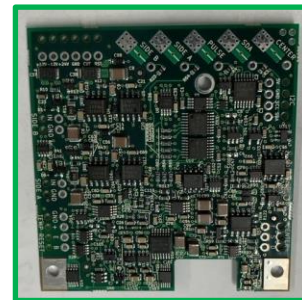
Top Right:
- ANL Preamp

Right:
- GS Module in Digital Standalone Mode
- Mechanical Chain: BGO, Ge, Slope Box, SBX, DVI-I Cable

Bottom Center:
- Raspberry Pi Onboard SBX
- Power Board
- ANL Pickoff Card
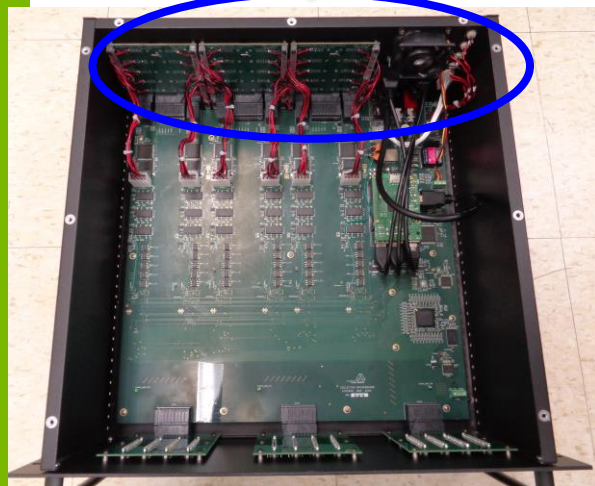
DETECTOR UPGRADE PIPELINE
All HPGe with ANL Preamps and SBXs

Phase 1

1) Remove Ge From Array

2) MCA Test w/ LBNL Preamp

4) Install ANL Preamp (Seg. Or Non-Seg.)

5) MCA Gain Test ANL Preamp (Tune Rise Time, Reset Slew Rate, Measure Gain and Resistance Required for Correction)

Phase 2

6) MCA Check Corrected Gain (Within 2%)

7) SBX Performance Test (matches MCA)

8) Update Recorded Performance Settings (Scripts and EEPROM, Assign GS #)

9) Return to Array (Enable LV, HV, and LN)

Picture of Analog MCA Test Stand used to check detector performance after upgrades

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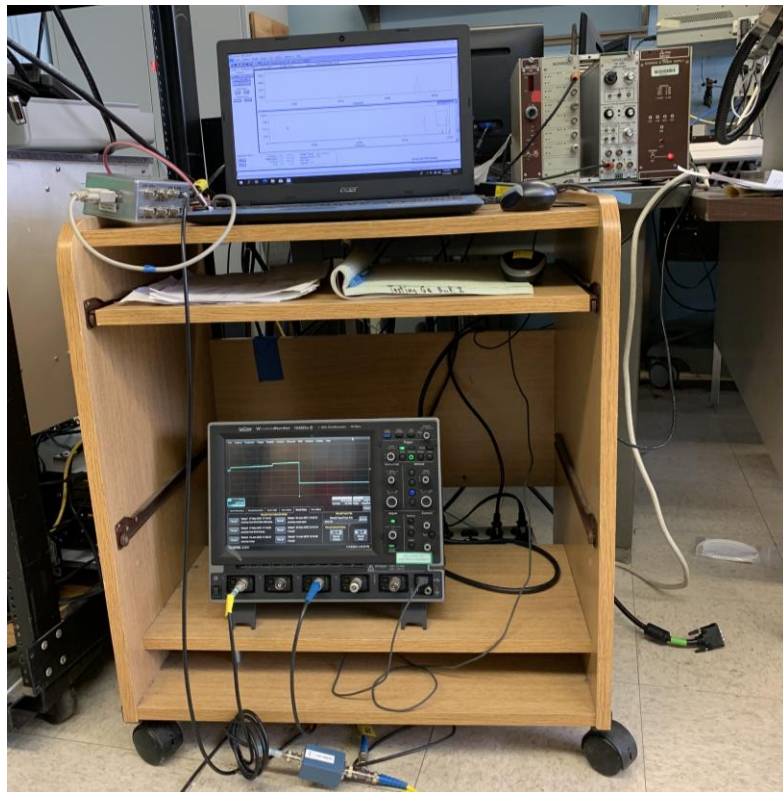
DETECTOR UPGRADE PIPELINE
All HPGe with ANL Preamps and SBXs

Picture of Digital Test Stand used to check detector performance after upgrades

Phase 1

1) Remove Ge From Array

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4) Install ANL Preamp (Seg. Or Non-Seg.)

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Phase 2

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DIGITAL GAMMASPHERE: UPDATED USER INTERFACE

EDM Screens:
- GS Module (Ge + BGO) Control
- SBX Pickoff Control
- Slope Box Control

New Screens Not Shown Here: Preamp, Power Board, RAM Buffer, Pickoff FPGA Control, Global Digitizer Fan-Outs, Collector Box Controls/Monitors
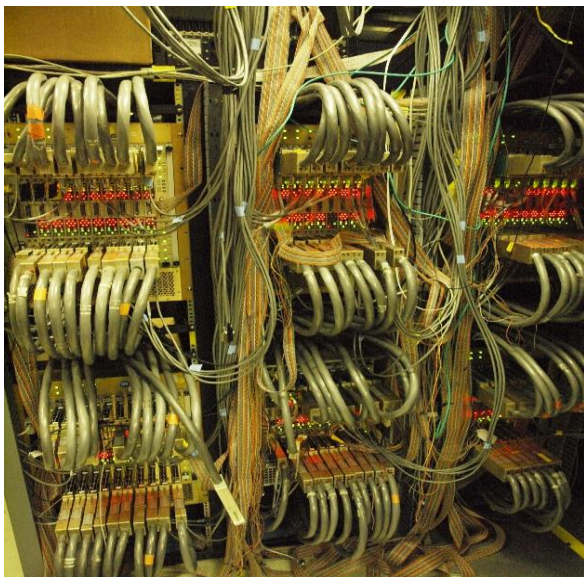
# LEGACY REMOVAL & NEW POSSIBILITIES

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LEGACY HARDWARE REMOVAL: VXI CRATES

Remaining VXI Functions Now Integrated in Collector Box and SBX:

- Low Voltage to Slope Box

- Communication Interface for Slow Control and Monitoring
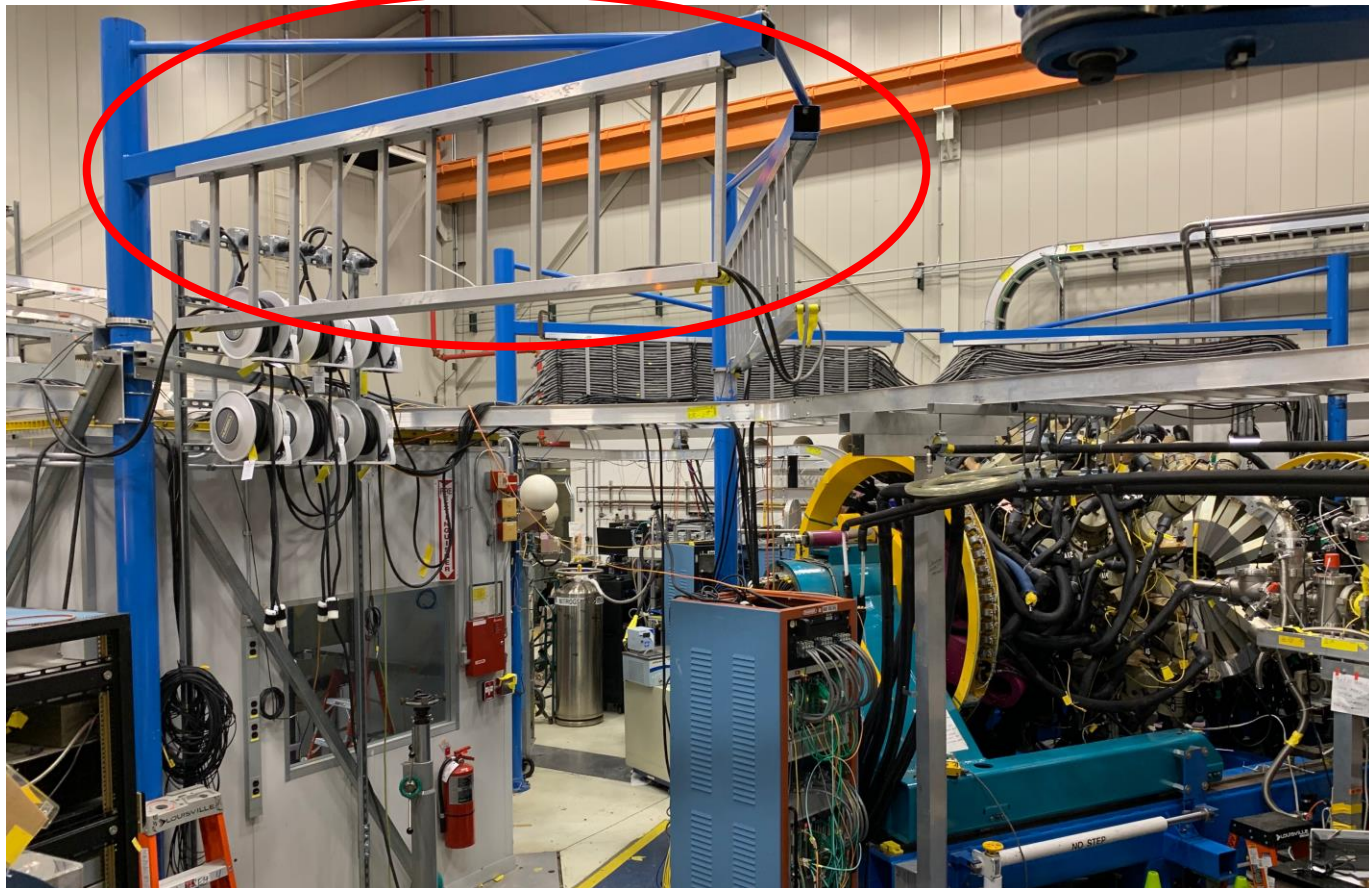
- Provide power to the VXI pickoff card

South Hemi, HPGe removed for upgrade and final VXI decommissioning

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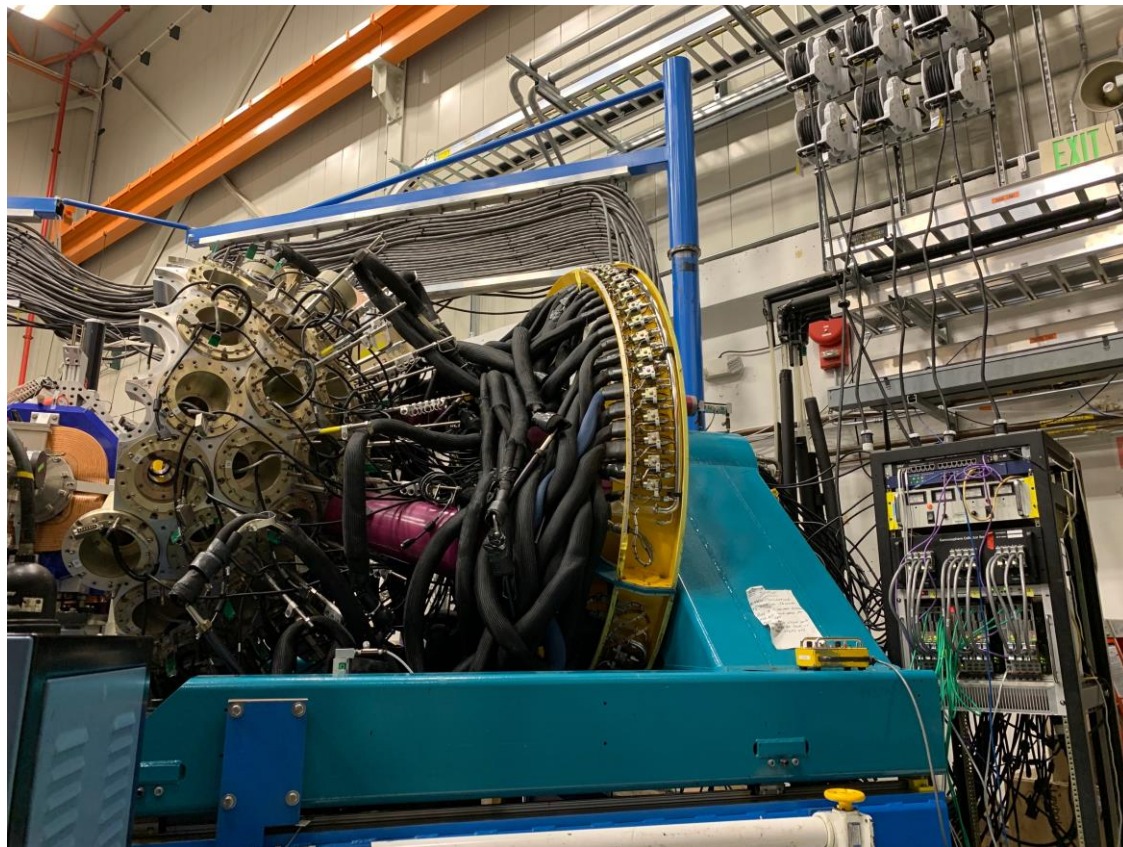
LEGACY HARDWARE REMOVAL: GREY CABLES

Free of Grey Cables:

- 60-ft 50-conductor grey cables ran from Hemis, to overhead trays, and into electronics shack

- 6600 ft of cables!

- The Hemispheres, the shack, and the North overhead trays are free of cables

- One 6.5 ft electronics rack supports one Hemi

- ***Gammasphere now independent of shack***

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GAMMASPHERE MOBILITY—NEW POSSIBILITIES

- Mount Rack Electronics directly to A-Frame
- Entire data acquisition system contained within footprint of GS
- Move to Area 1 for dedicated campaign of decay spectroscopy experiments
- Digital standalone module operation
- Unique opportunities for "table-top" experiments (N = 126 Factory, lifetime measurements)

GAMMASPHERE UPGRADED ELECTRONICS CONFIGURATION The SBX+Collector Signal Path

The **DVI-I cable** containing the detector signals, power, and communication interface connects the **SBX** to a **Collector Box**.

Collector boxes drive to **VME digitizers** and **Electric Honeycomb** to Trigger
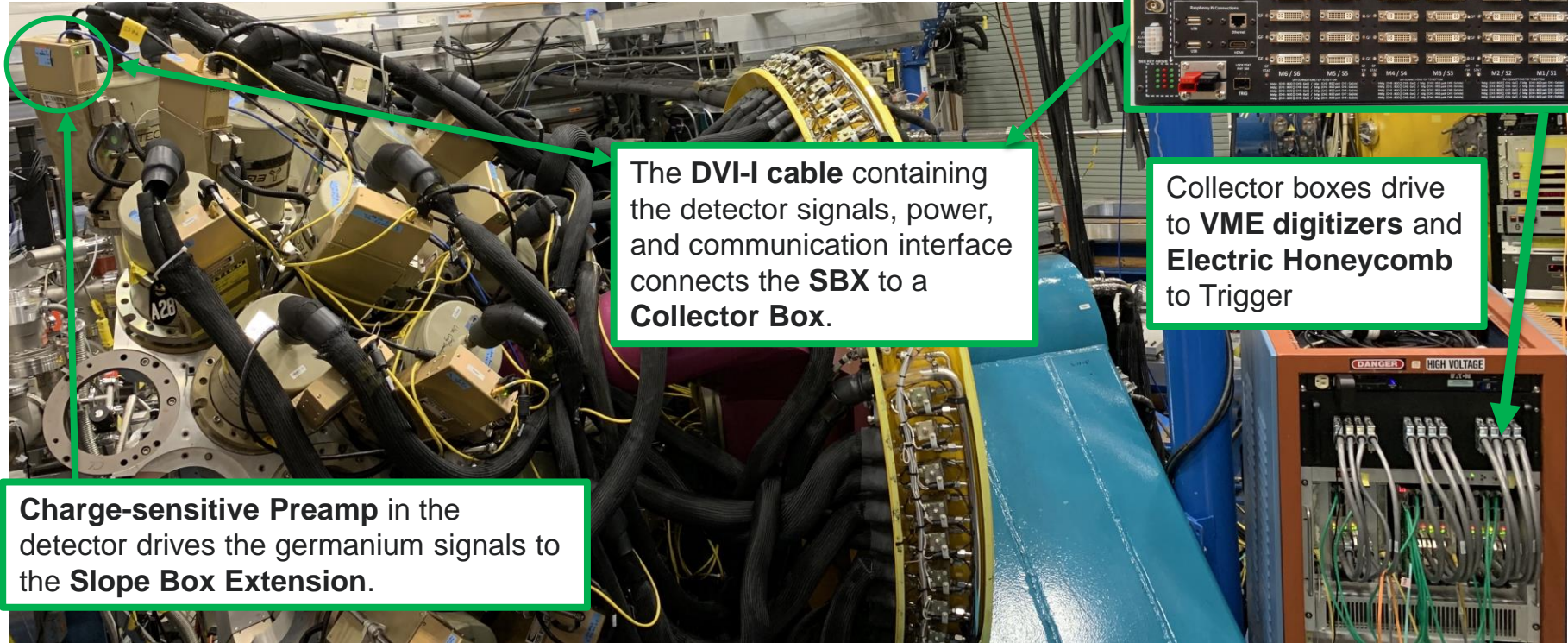
Charge-sensitive Preamp in the detector drives the germanium signals to the **Slope Box Extension**.

DGS PERFORMANCE: HPGE RESOLUTION

- Overall Improvement in Resolution

- Further Improvement from established turning procedures **FWHM < 3.5 keV** for all HPGe detectors

DGS FWHM vs GS ID

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CLOSING REMARKS

Gammasphere Upgrade Milestones for CY2022:

- All HPGe have ANL preamps and SBX units
- All VXI crates decommissioned, all grey cables removed from Gammasphere
- Digital DAQ will be mounted to GS frame December 2022
- Gammasphere no longer dependent on Area 4 infrastructure
- Convert North Hemi to Final Implementation (SBX+Dongle with Active Collector Boxes)
- Automate Performance Tuning Procedure (DC Offsets, PARST Clamp Voltage, etc.)

Next Steps in CY2023:

- Firmware/Software updates (PVs accessible in screens, BGO disc. bit readout, TAC-II)
- Electric Honeycomb for nearest neighbor Compton Suppression

Next Talks:

- John and Michael will go through all the new hardware, software, and mechanics in more detail

THANKS FOR YOUR ATTENTION!

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