Case Studies: Digital Gammasphere

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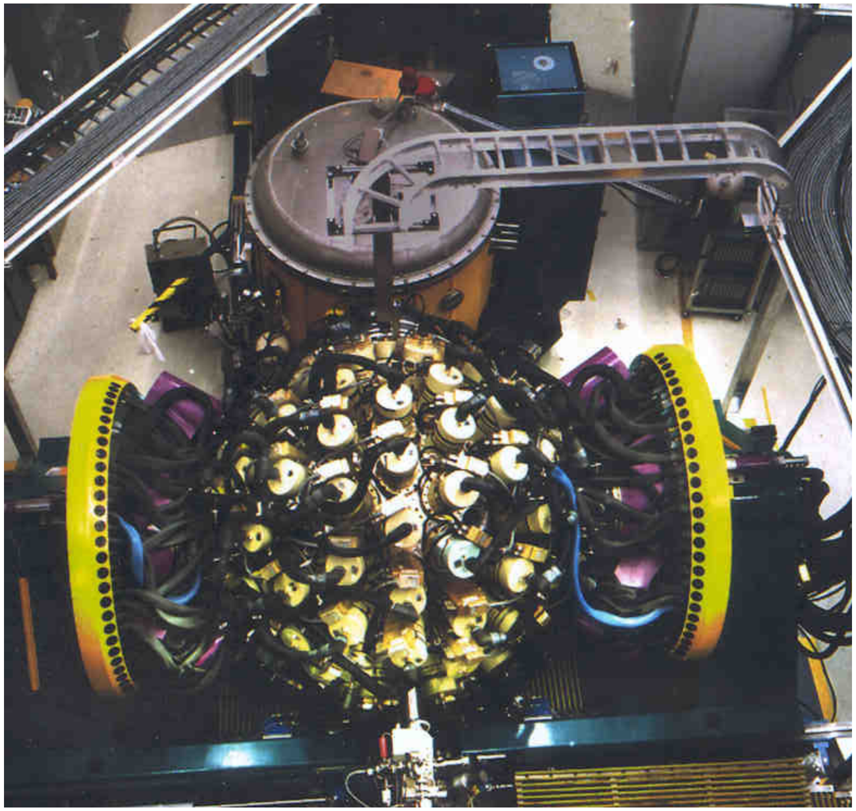
Gammasphere (Analog)

- Nominally 110 Compton Suppressed Ge detectors (HPGe + BGO).
- Custom VXI electronics
  - One card instruments two GS modules
  - Trigger modules provide multiplicity based on Compton-Suppressed Ge hits.
  - VXI to ECL interface allows ancillary detectors to be triggered and injected into Gammasphere event stream.
- The device has operated at the 88-inch Cyclotron at LBNL and at ATLAS at ANL.
- A number of different detector systems interfaced via ECL readout – standardized ancillary detector implementation.
- Default DAQ for both Gammasphere and FMA



Gammasphere Limitations and Liabilities

- **Count Rate Limitations**
  - Processing time for Ge shaper is ~10μsec which gives ~6% pileup at 10,000 cps, 20% pileup @ 30,000 cps and ~30% pileup @ 50,000 cps.
  - ***Solution*** – reduce Ge shaping time allows higher rates.

- **Trigger Limitations**
  - Gammasphere DAQ is dead for at least ~ 25μsec for triggered events (no pipelining).
  - Single and 2-fold Ge triggers saturate Gammasphere rate capability.
  - ***Solution*** – flexible trigger incorporating triggerless option.

- **Aging Electronics**
  - Gammasphere VXI electronics was developed and built nearly 20 years ago (GS commissioning in 1995).
  - Component failure without replacement is big concern.
  - ***Solution*** – replace VXI electronics before system is compromised.

Digital Gammasphere (DGS)

By replacing current analog electronics with a digital pulse processing data acquisition system , the major limitations and liabilities can be overcome.

- Decreasing processing time of Ge shaper from ~10 to ~2.5μsec should allow Ge to run at 40,000 cps with same pileup percentage with current analog system at 10,000 cps.

- Improved trigger model will improve throughput limits imposed by current trigger:
  - Singles throughput from 40,000 event/sec to 500,000 event/sec
  - High Spin throughput from ~15,000 event/sec to >50,000 event/sec

- Replacement of VXI electronics solves liability due to aging components.

Extended Physics Reach with DGS

Selective External Triggers (e.g. FMA) – ^{100}Sn region, Z>100
DGS will allow one to increase rate in Ge detectors from ~10/sec to ~50k/sec (factor 5 increase)

High Multiplicity trigger – Ultra-high spin, Hyperdeformation search
DGS will allow increases in high-fold readout rate by factor 3-5 allowing for multiplicity conditions on high-fold event to be set higher giving higher resolving power in searching for exotic modes at high-spin.

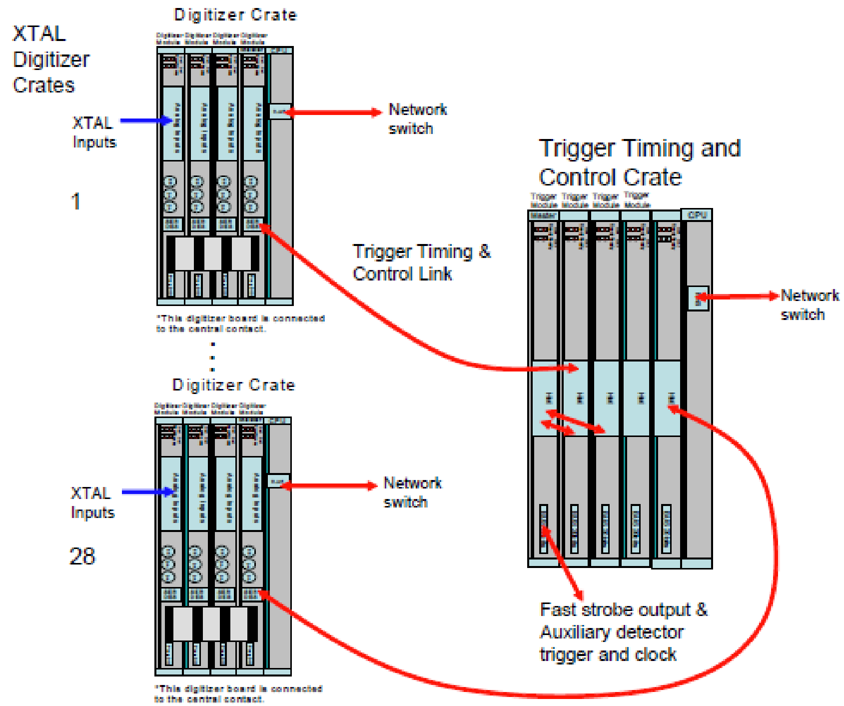
Low Multiplicity trigger (inbeam)–Deep inelastic, Coulomb Excitation
DGS will allow increases in readout rate 3-10 times depending on reaction and multiplicity setting.

Low Multiplicity trigger (decay)– Decay of stopped CARIBU beams.
DGS will allow lossless Ge clean singles rate at up to 10kcps/crystal. Current lossless rate is ~400cps/crystal.

Extended ATLAS reach – More approved experiments/year.
GS experiments can be performed >3 times faster.

Choice of Digitizers and Trigger

- Instrument current Gammasphere electronics with Gretina digitizers and trigger modules
- Local and community support
  - LBNL designed digitizers and data acquisition system
  - ANL designed trigger system.
- Leverages investment DOE and community have made in GRETINA electronics.
- Synergy between GRETINA and Gammasphere.



This choice saves us time, effort and ultimately cost in building up new data acquisition system.

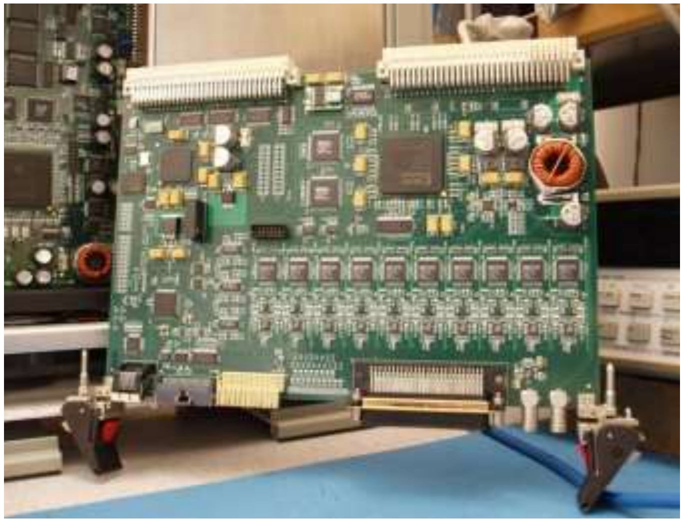
GRETINA Hardware Components

Digitizer Module (LBNL)

- 10 Channel
- 14 Bit, 100 MHz
- Energy
- Leading Edge Timing
- Constant Fraction Timing
- Pulse Shape

Trigger Timing and Control Module (ANL)

- 1 Master, 1 Router/8 Digitizers
- Sync All Clocks
- Fast Multiplicty Triggers < 300ns
- Slow triggers ~ 2msec
  - Multiplicty
  - Energy
  - Hit Pattern

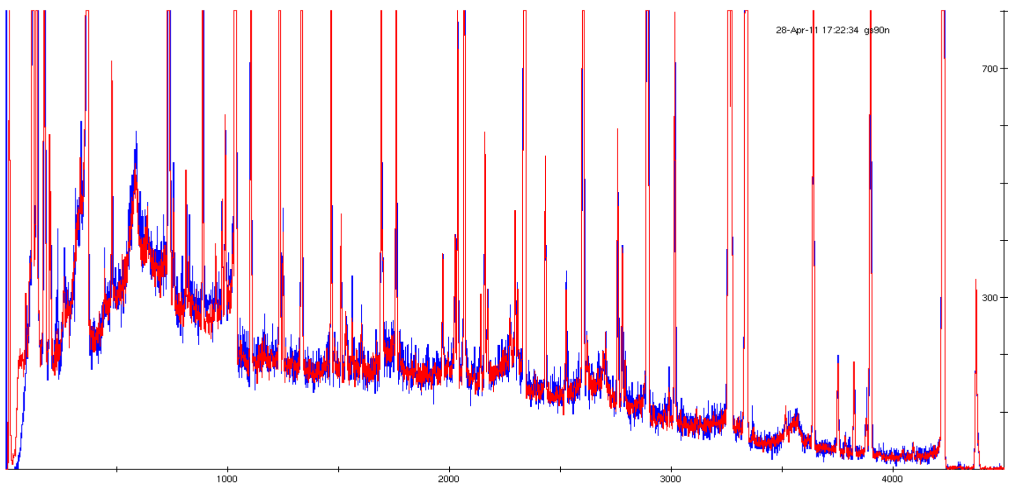


Initial Phase of Project

Phase I

- Digitize Ge central contact and BGO summed signal.
- Use current VXI electronics for slow control.
- Utilize GRETINA firmware and DAQ and assess what modifications would be required to optimized for Gammasphere.

Red is DGS and Blue is GS



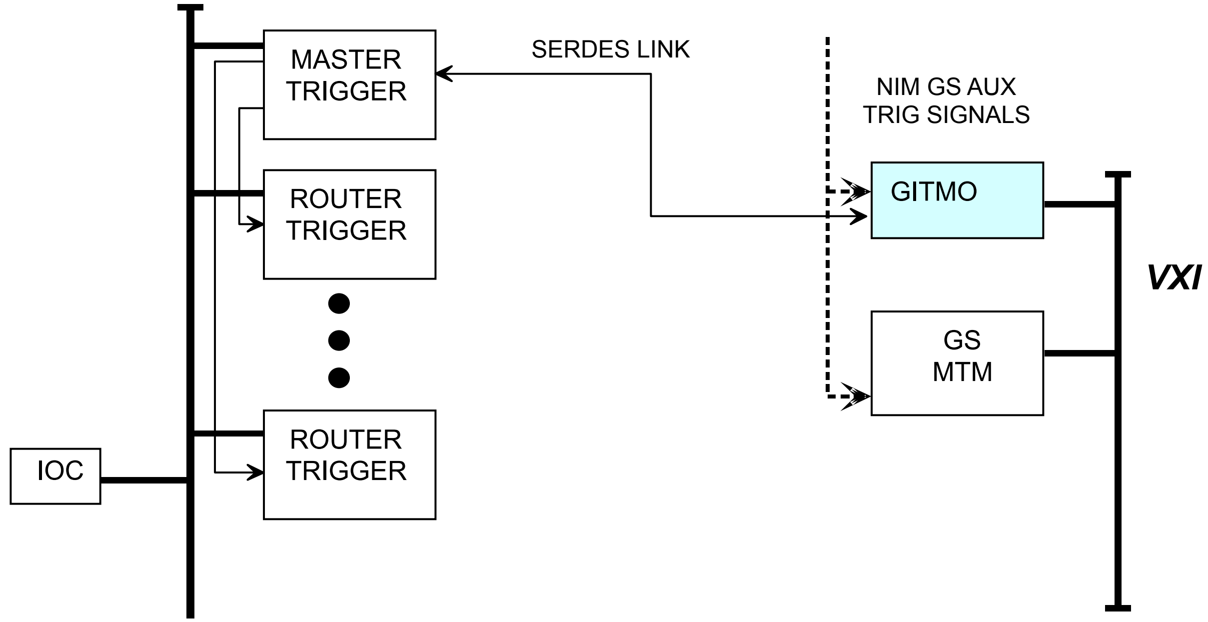
^{152}Eu

- **The Good** – Analog and digital Gammasphere provide similar quality spectra.
- **The Bad** – difficulties arose in implementation with actual experiments *e.g.* first experiments with GS and FMA resulted in 40 TB of data.

Solution and Final Implementation at ATLAS

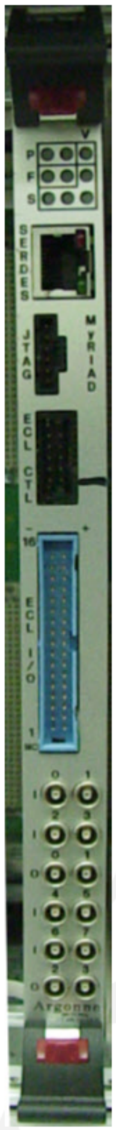
- Develop a general digital DAQ for ATLAS, utilizing hardware developed for the GRETINA project – digitizers (LBNL) and trigger modules (ANL)
- Develop new firmware for both digitizers and trigger modules using a generic design which can be easily modified to accommodate different requirements imposed by major detectors systems *e.g.* Gammasphere, FMA focal plane, Helios, X-Array and CAGRA (Compton-suppressed clover array) – *J. Anderson and M. Oberling*
- Modify existing EPICS control system to handle implementation of independent based channel operation – *T. Madden*
- DAQ can be implemented behind NAT box and highly portable
  - Interfaced with BGS focal plane (D. Seweryniak)
  - Operated with CAGRA array RCNP – Osaka University.
- For DGS, we meet initial benchmarks for energy resolution and throughput.
- **Major Limitation** – Digitizer is a one-time development – no upgrade path to faster ADCs – limits use with fast scintillators. However, firmware is portable.

Gammasphere Interface Trigger Module (John Anderson– HEP)



- Interface module resides in GS master VXI crate and picks off all relevant GS trigger signals and GS clock, transmitting copies to the DGS Master Trigger via SERDES link
  - *Same SERDES as used in GRETINA trigger system*
  - *GRETINA trigger modules already support external clock source via SERDES*
  - *GS clock is distributed to all digitizers in Digital GS by trigger*
  - *Can use to utilize VXI to ECL interface if needed.*
- We have also developed time synchronization and cross triggering between Digital DAQ based on the same Hardware *e.g.* Digital FMA and Digital Gammasphere (Darek and John's presentation).

MγRIAD (multipurpose gamma-ray interface to auxiliary detectors) - *jta*



- A generic interface between the SERDES link, VME and ECL/NIM
  - Large number of ECL I/O
  - Good number of NIM I/O with fast receivers
  - Works in any VME crate (standard or VME64)
  - Sufficient FPGA for general gating logic
  - Large FIFO allowing buffering of auxiliary detector data
  - Capable of acting as FERA data receiver if needed
- CHICO usage @ Gammasphere in 2013
  - Receive timestamp from Master Trigger via SERDES
  - Latch timestamps when CHICO triggers
  - Provide gating logic as necessary with other NIM or ECL signals (e.g. Gammasphere fast multiplicity)
  - Add MγRIAD to CHICO readout so that CHICO events have matching timestamps for offline event merging
  - Send CHICO trigger signals to Master Trigger of Digital Gammasphere for monitoring
- Generic interface to auxiliary detectors for both Gammasphere and GRETINA
  - Current Implementations - Chico 2, Phoswich wall, RCNP VME DAQ.
  - Future Implementations – Goddess, LaBr detector array, Microball Hybrid.

Summary

- Digital Gammasphere is a case study of leveraging developments from another detector system (GRETINA).
- Lots of teething problems.
  - DGS was not ready for consideration when GRETINA DAQ designed.
  - Current system meets benchmarks.
- Utilizing same hardware as GRETINA offers opportunities for standardization especially in context of interfacing with other DAQ's *e.g.* DFMA
- Implementing Digital DAQ with other major equipment at ATLAS saves time, money and resources.
  - Common firmware base which services a number of different detector systems..
  - Opportunity to perform large quantity purchasing to drive down prices.
- Major limitations:
  - Digitizer not readily/impossible to upgrade, *i.e* faster ADC, newer FPGA.
  - VME bus limitations.
- Myriad is essential for our implementation of Digital Gammasphere allowing timing synchronization between independent DAQ systems.
- Future - stay pat or hitch a ride with GRETA.