Digital Gammasphere

- What is the evidence of new shell gaps at N=32 and 34 for Z<28.
- How robust is the N=40 gap for Z<28?
- Status of GRETINA for study of exotic beams.

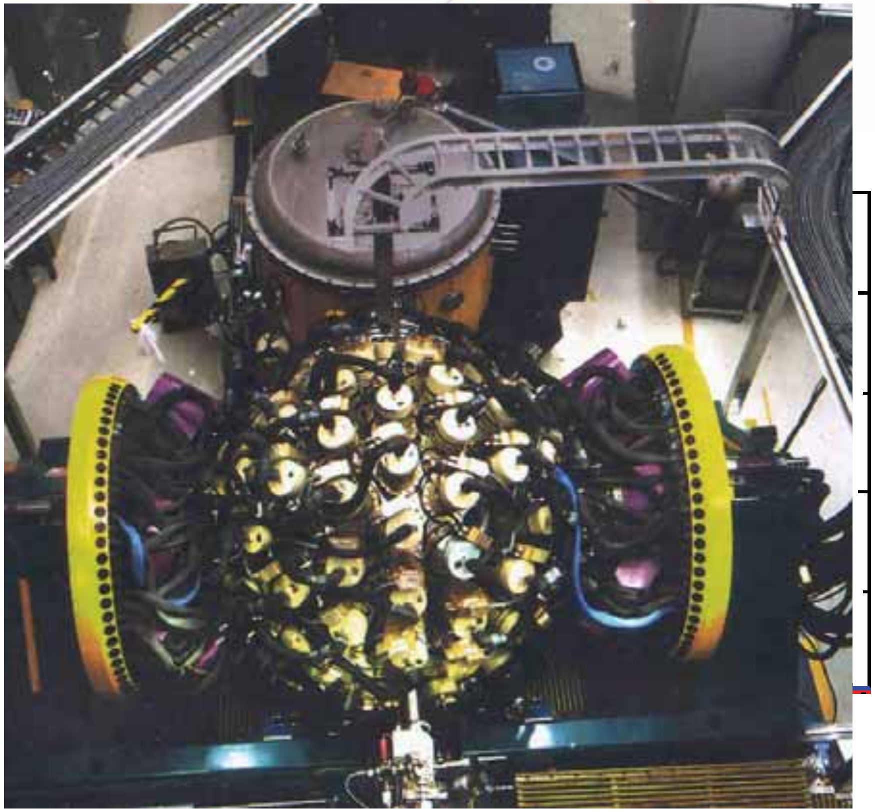
Workshop on "Decay Spectroscopy at CARIBU: Advanced Fuel Cycle Applications, Nuclear Structure and Astrophysics"

April 14-16, 2011

Michael P. Carpenter

Gammasphere

- Gammasphere can accommodate up to 110 Compton Suppressed Ge detectors.
- The relative efficiency of each Ge detector is 70-75%.
- The device began operations in the spring of 1993 with ~30 detectors (Early Implementation Phase).
- The device has operated at the 88-inch Cyclotron at LBNL and at ATLAS at ANL.
- Over 500 journal papers have been published reporting results from Gammasphere.



Gammasphere, CARIBU and Decay Spectroscopy

- **Most measurements with Gammasphere use in-Beam Reactions**
  - Fusion Evaporation
  - Inelastic Excitations
  - Coloumb Excitation

- **Used in a number of studies involving ^{252}Cf and ^{248}Cm fission sources**
  - Gamma-ray coincidences are used for selectivity
  - Spins, parities and mixing ratios can be determined from angular correlations.

- **Decay studies with CARIBU**
  - Device provides near 4π angular coverage (total gamma-ray energy)
  - Precise measurements of angular correlations (spin/parity of levels)
  - High coincidence efficiency (nuclear level structure)

Gammasphere Limitations

- **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.

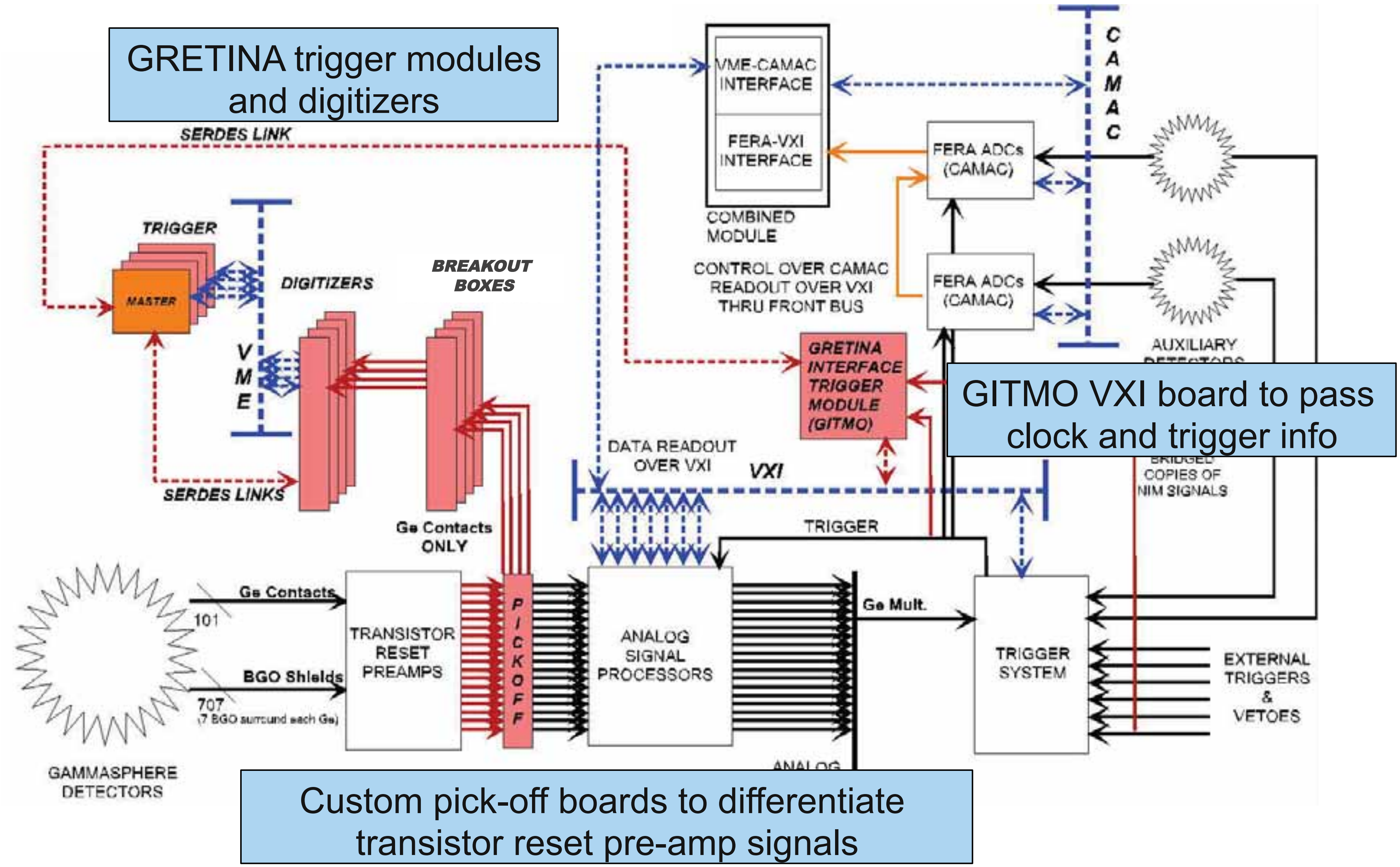
- **Trigger Limitations**
  - Gammasphere DAQ is dead for at least ~ 25μsec for triggered events.
  - Single and 2-fold Ge triggers saturate Gammasphere rate capability.
  - Readout can only be aborted at main (300-1500ns) and late (6μsec)
  - ***Solution*** – flexible trigger incorporating triggerless option.

  - Digital Gamma Sphere Rate Goals
    - 50,000 gamma/sec in each detector
    - 500,000 gammas/sec to disk.

Digital Gammasphere *- Replace current analog electronics with a digital pulse processing system based on the 10 channel Gretina Digitizer module.*

- Decreasing processing time of Ge shaper from ~10 to ~2μsec should allow Ge to run at 50,000 cps with same throughput.
- Gretina trigger model will improve throughput limits imposed by current trigger – triggerless is an option.
- DGS implementation would allow Gammasphere to take data in excess of 5 times current limited rates.
- Extended Gammasphere reach in these areas of interest.
  - ^{100}Sn region
  - $Z > 100$
  - Exotic modes (Hyperdeformation)
- Competitors are implementing or retrofitting arrays with digitizers *e.g.* Juroball, Clarion, SeGA, Tigress, *Gretina*, Agata.

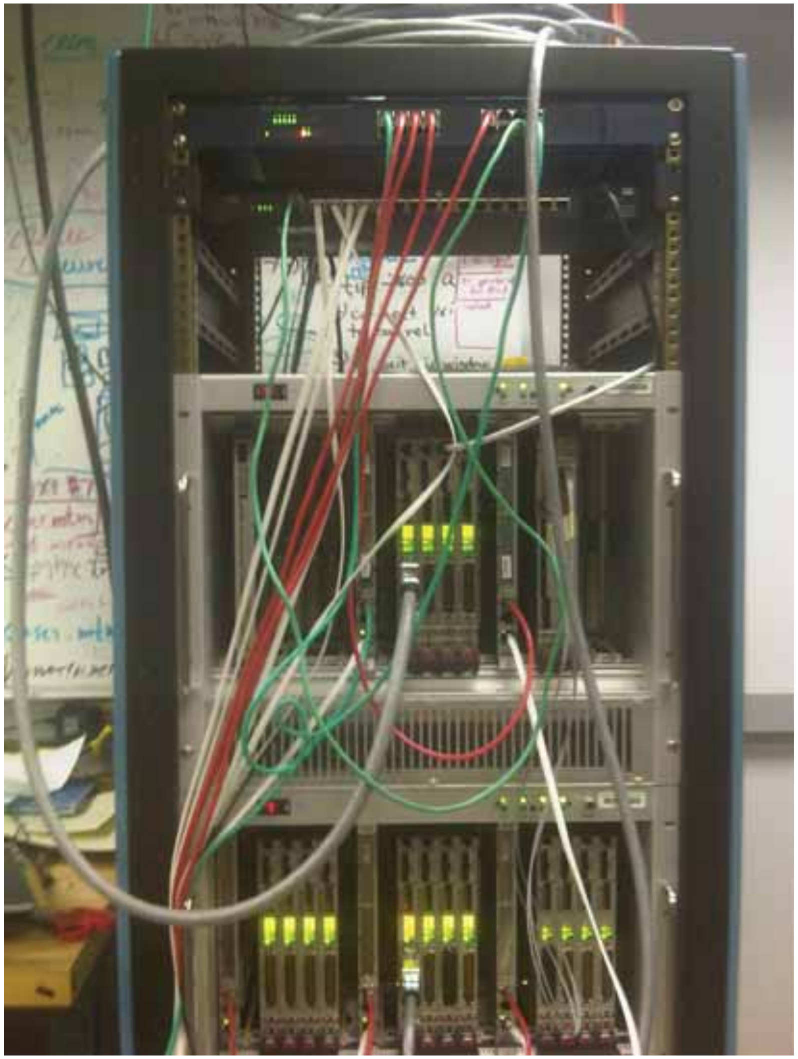
Digital Gammasphere Phase I



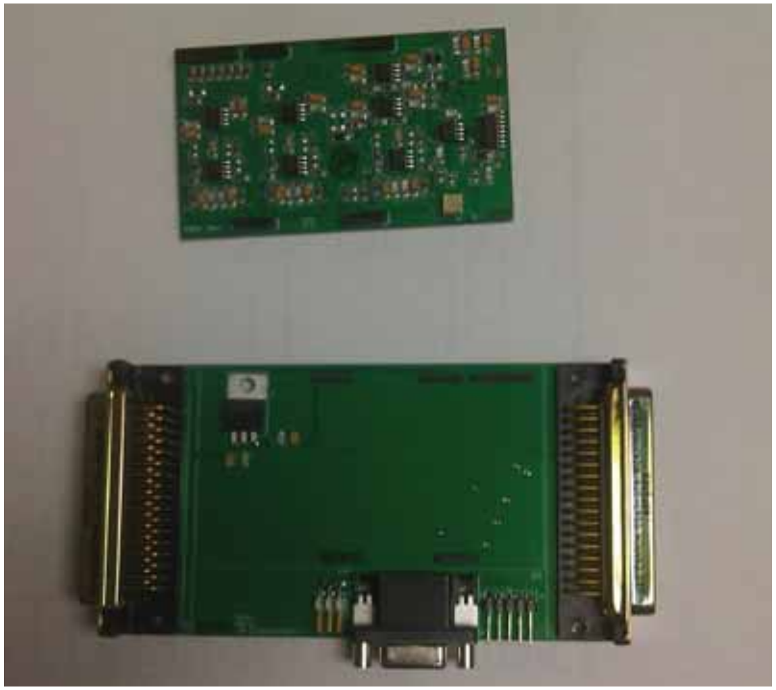
Digital Gammasphere as it now LOOKs

- 2 VME crates
- terminal server
- switch
- 5 MVME5500 (IOC)
- 2 trigger modules
- 16 Digitizers

VME Crate with 3-fold segmentation of back plane



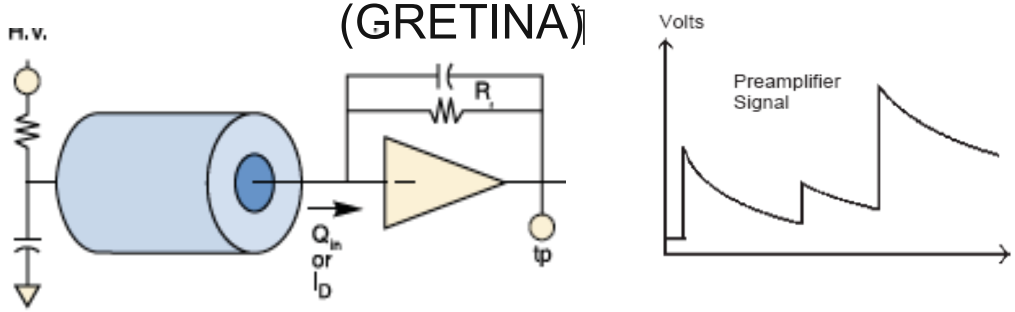
Pickoff Boards (Phil Wilt)



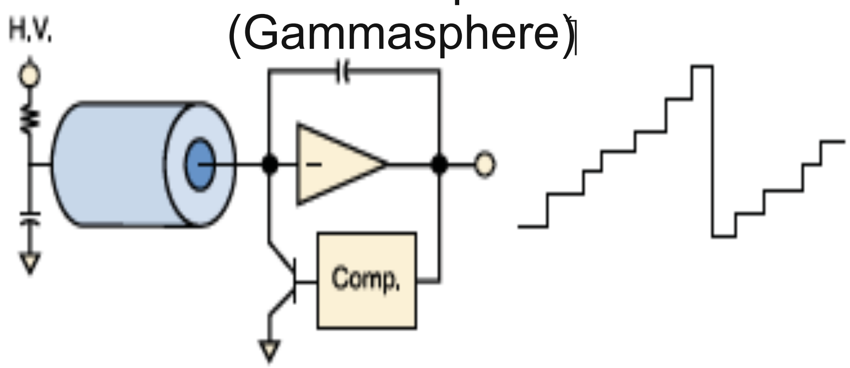
- Differentiates transistor reset preamp signal from Gammasphere preamp – output looks like resistive preamp signal.
- Differentiation turned off during pulse reset.
- Differentiated Ge signal, BGO Sum signal and Ge Side Channel are outputted via the 15 pin connector.

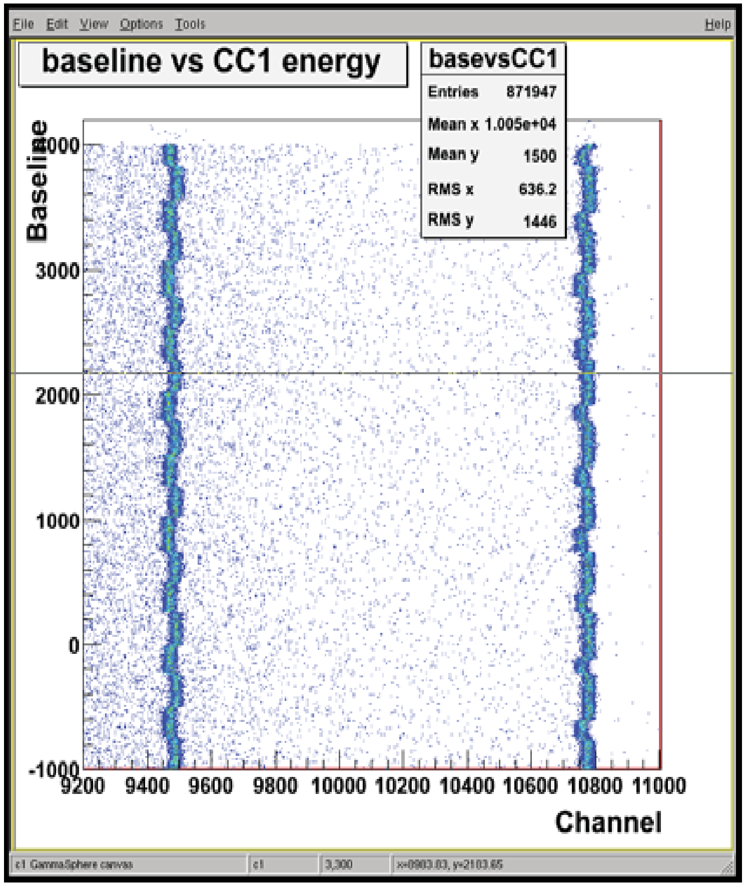
Preamplifiers for Ge detectors

RC Preamp
(GRETINA)



Transistor Reset
Preamp
(Gammasphere)

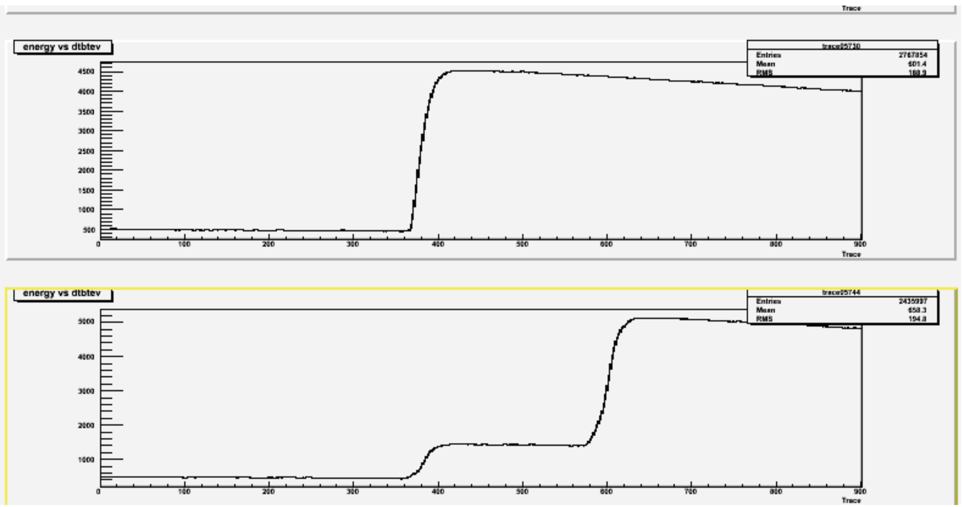




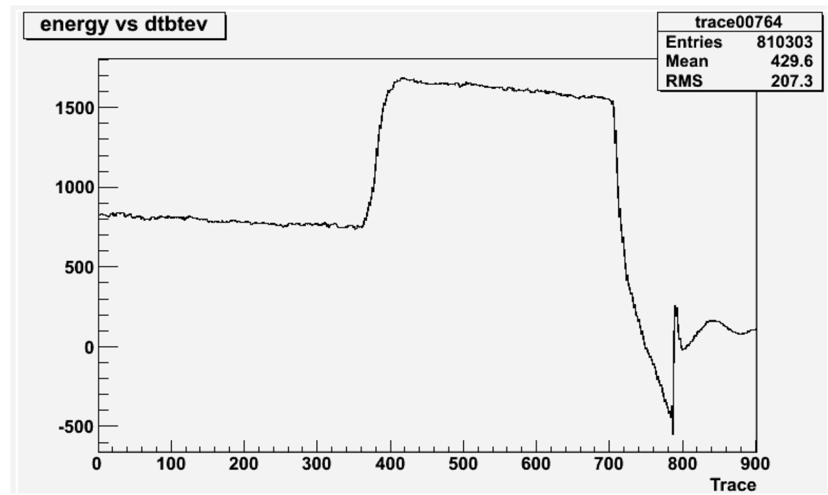
Sending GS pre-amp directly into digitizer

Digitzer Traces from Pickoff Board

Standard and Pile-up Event

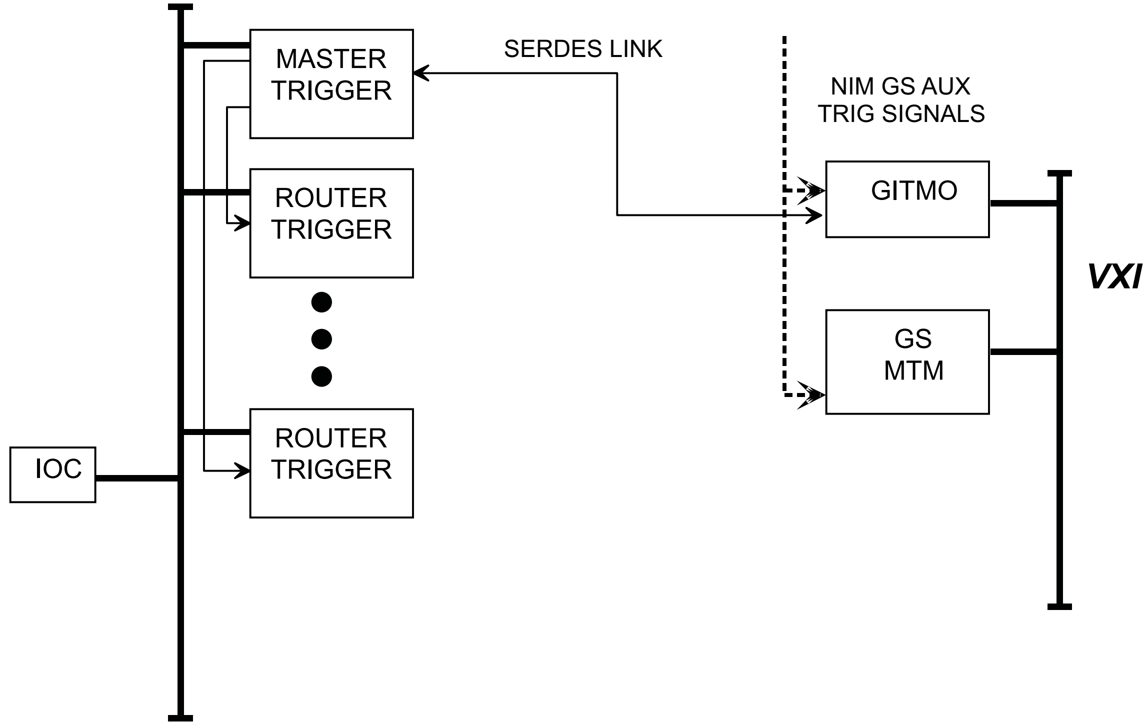


Trace with reset pulse



The "GITMO" – Gammasphere Interface to Trigger Module (John Anderson – HEP)

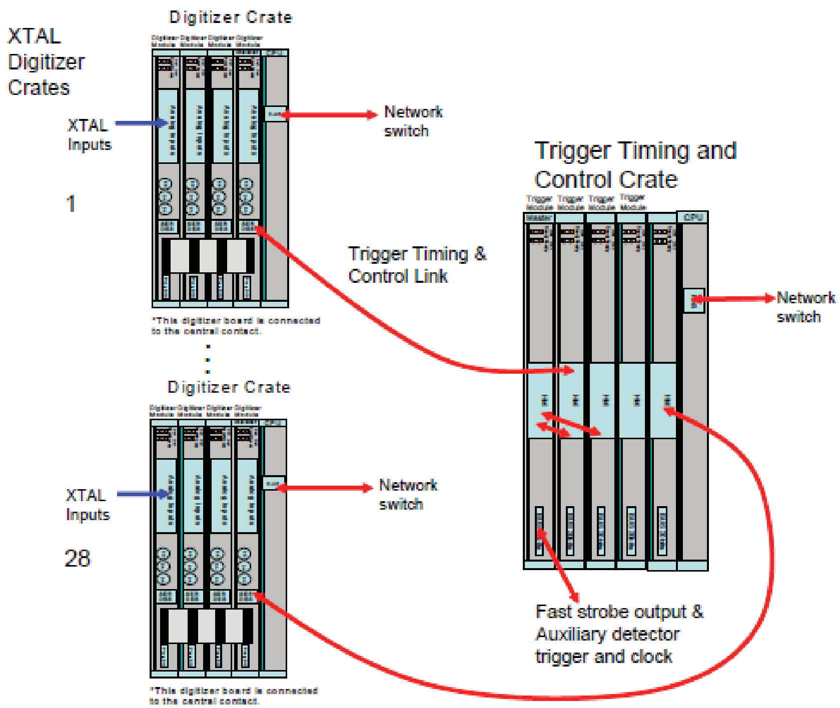
During initial roll-out of Digital Gammasphere, digitizer-based system will be run as slave to analog Gammasphere



- GITMO picks off all relevant Gammasphere trigger signals and GS clock, transmitting copies to Digital Gammasphere 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*
- DGS Master Trigger may use GS triggers as enables or vetoes of internal triggers

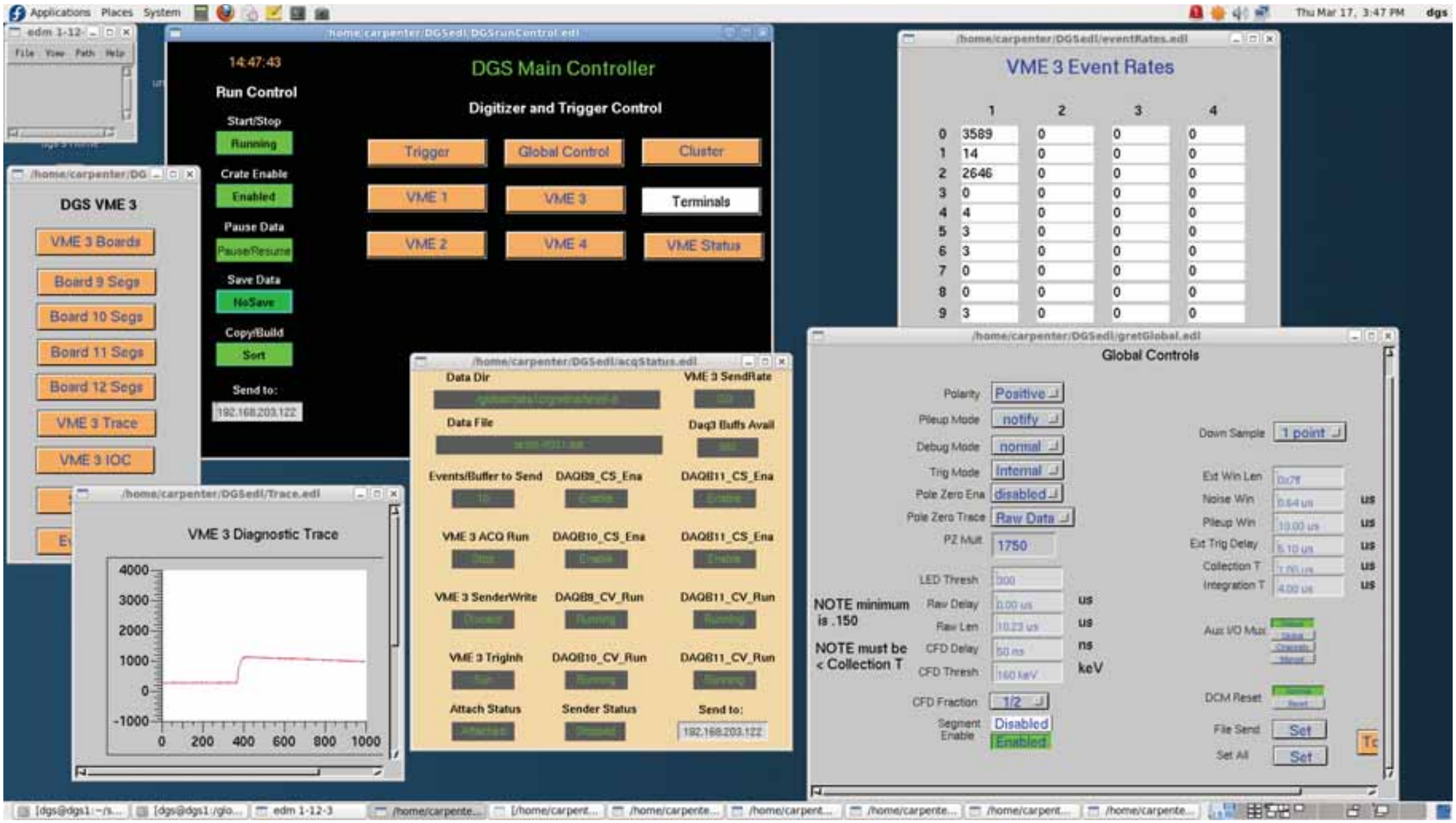
Data Acquisition (Lauritsen, Zhu, Carpenter)

- DGS DAQ is modification of the GRETINA DAQ which was designed by Carl Lionberger of LBNL.
- IOC's are Motrolola MVME5500 running the vxWorks Real Time operating system.
- Control of digitizer and trigger modules peformed using EPICS channel access protocol.

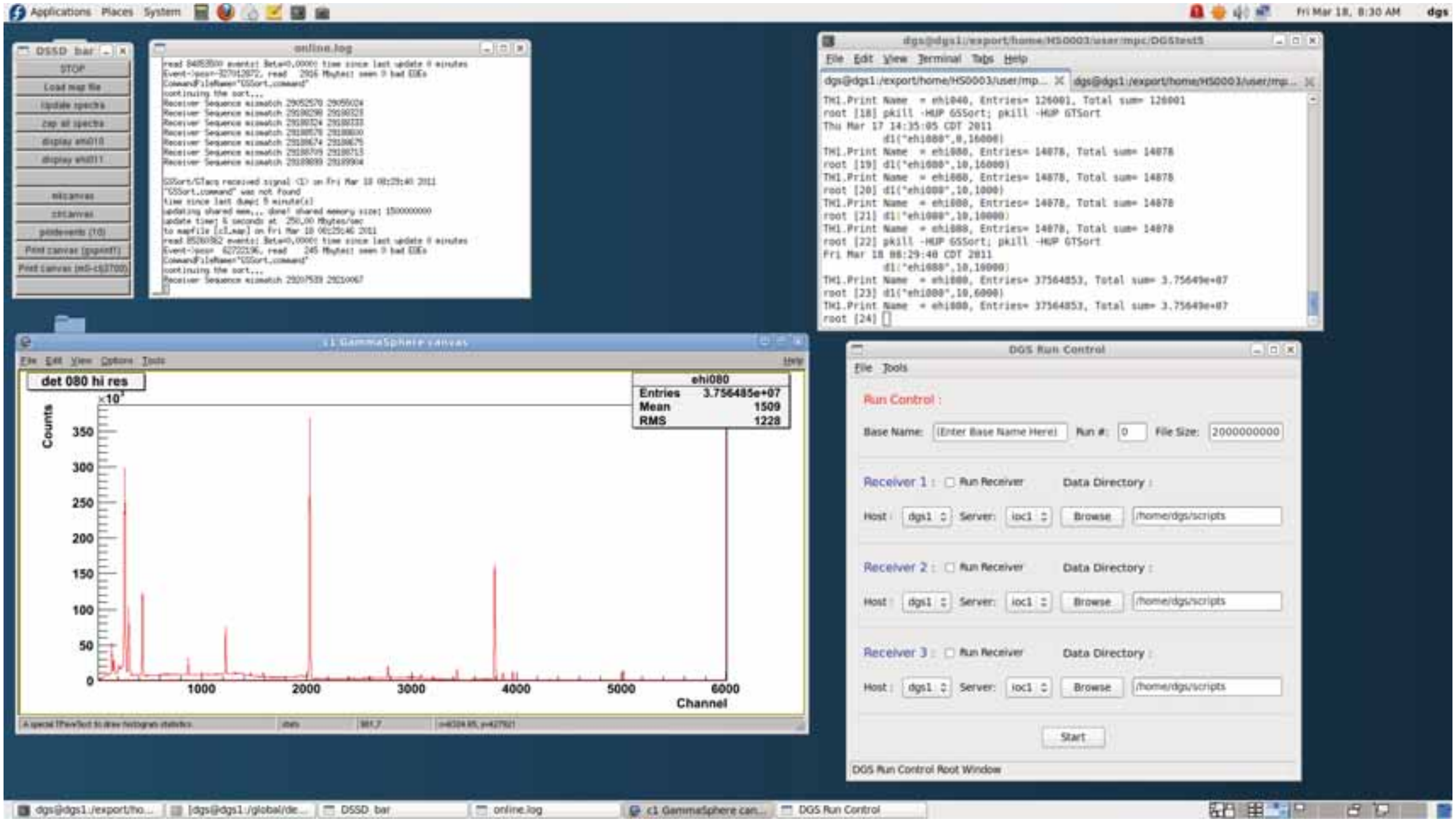


- Each IOC presents data to network either via UDP (online) or TCP/IP (disk storage) protocols.
- Online sorting is available using root based GTSort (Lauritsen)
- Data saved to disk using gtReceiver with a maximum rate of 12 Mbyte/sec (Lauritsen).
- Data files from individual IOC's merged using gtMerge (Lauritsen).

GUI for DGS Data Acquisition System

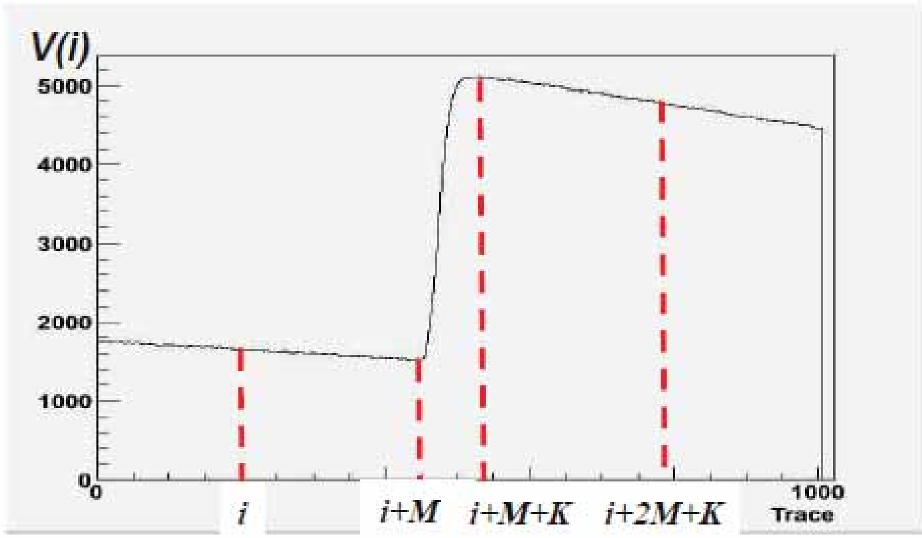


GTSort and Run Control



- GTSort is root based analysis package by T. Lauritsen
- Run control allows for the assignment of gtReceiver objects to individual IOC's and automatic update of run numbers (written in wxPython).

Offline Processing of Traces (Zhu and Seweryniak)



Trapezoid with full P/Z correction

$$E_1 = \sum_{i}^{i+M}\left\{(\lambda \sum_{i}^{i+M+K-1} V(i) + V(i+M+K) - V(i)\right\}$$

$$\frac{\delta E_1}{E_1} = \frac{\sqrt{2M}\delta}{\Sigma_1}\left(\frac{\sqrt{1+(M+K)\lambda}}{1+\frac{\Sigma_2}{\Sigma_1}}\right)$$

$$\Sigma_1 = \sum_{i}^{M}\left[V(i+K+M) - V(i)\right]$$

$$\Sigma_2 = \lambda \sum_{i}^{i+M} \sum_{i}^{i+M+K-1} V(i)$$

Modified Trapezoid with baseline correction

$$E_2 = \sum_{i}^{i+M}\left\{V(i+M+K) - \kappa V(i)\right\}$$

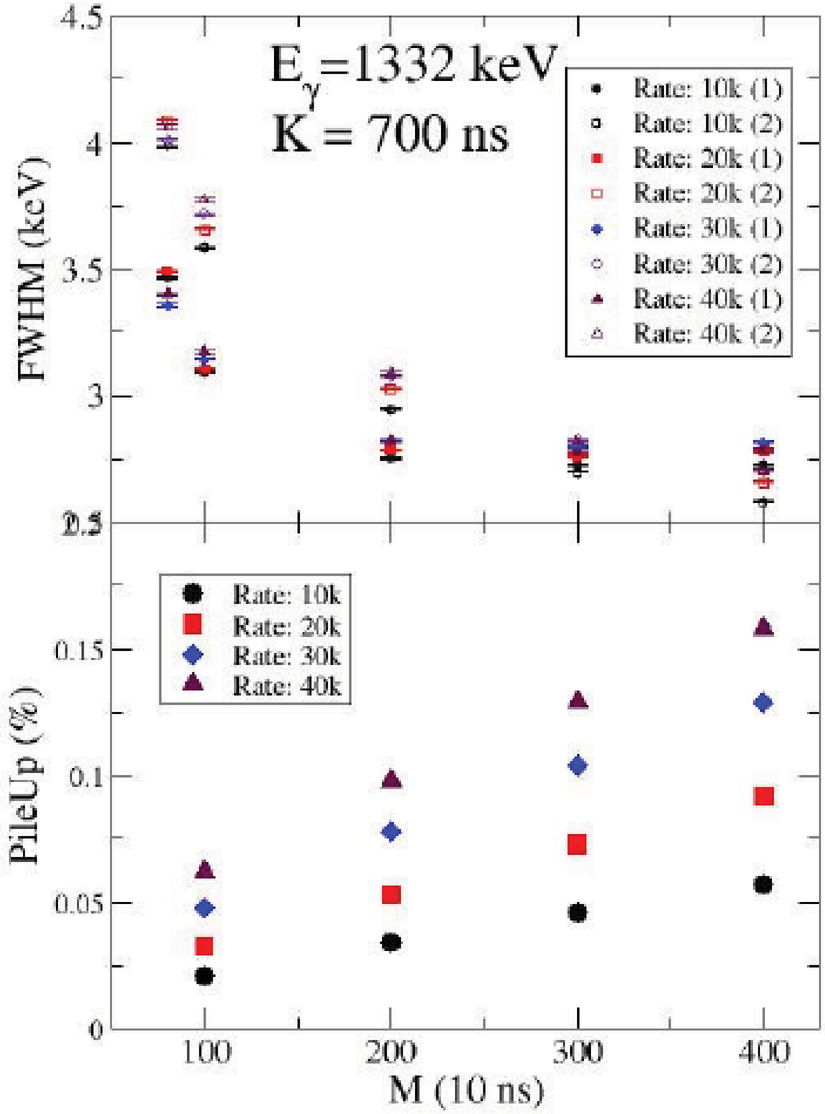
$$\kappa = e^{-\lambda(M+K)}$$

$$\frac{\delta E_2}{E_2} = \frac{\sqrt{2M}\delta}{\Sigma_1}\left(\frac{1-\lambda(M+K)}{1+\frac{\Sigma_2}{\Sigma_1}}\right) + \frac{\delta Q}{E_2}$$

$$\Sigma_1 = \sum_{i}^{M}\left[V(i+K+M) - V(i)\right]$$

$$\Sigma_2 = 1 + \sum_{i}^{i+M} \kappa V(i)$$

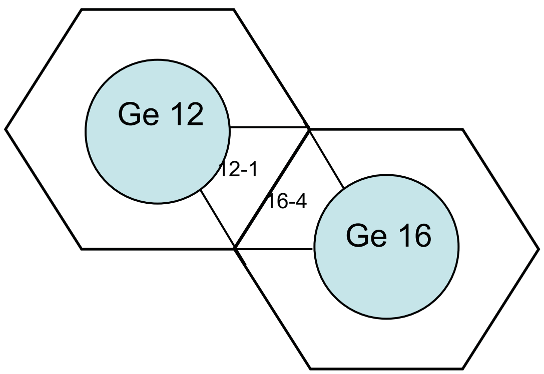
Comparison of two methods



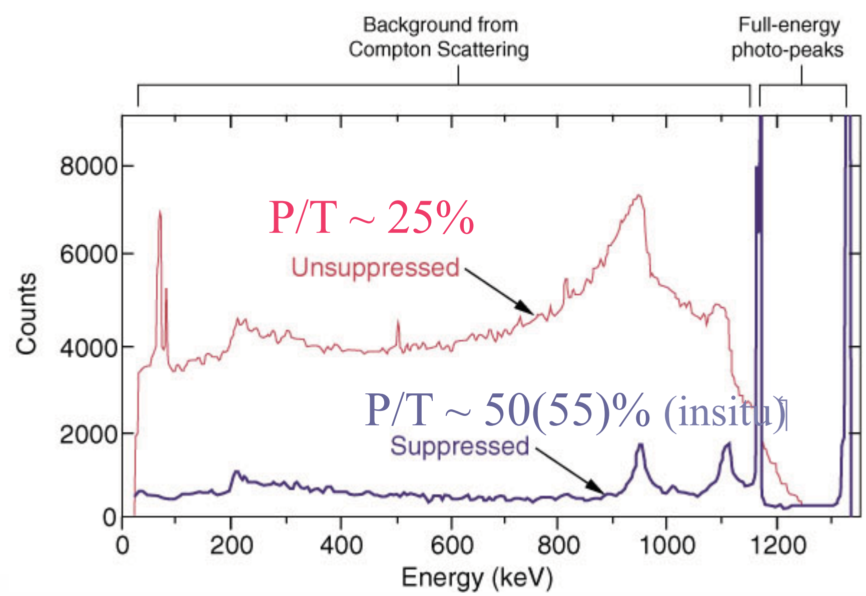
- For longer shaping times, full trapezoid gives slightly better energy resolution
- At shorter shaping times, modified trapezoid gives superior energy resolution.
- Related to uncertainty induced by integrating during detector rise time.
- For a processing time = 2.7μsec (m=1,k=0.7), FWHM ~ 3.10 keV.
- Using this shaping time, pileup at 40k is equivalent to pileup for current GS @ 10k.

Phase I and II (near term)

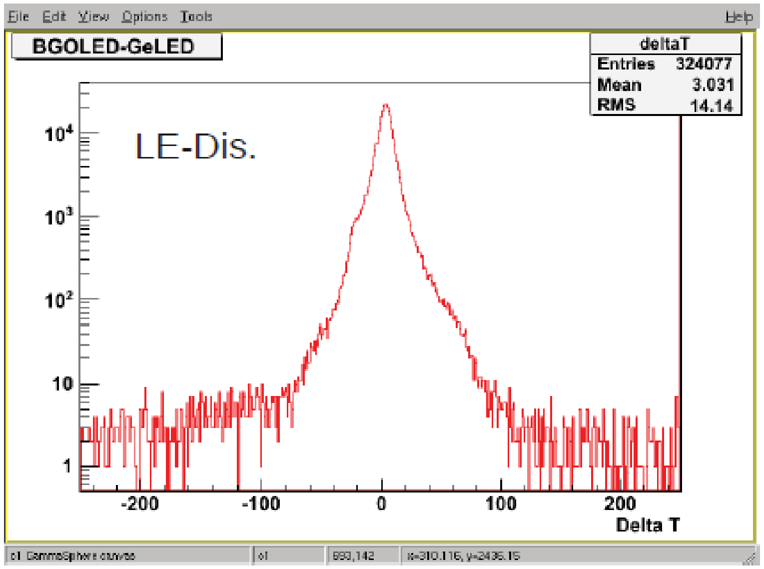
- Phase I with only Ge central contacts are recorded by DGS is on track for initial tests in June, 2011 (*breakout box, cables*).
- These measurements will be limited by current GS DAQ.
- Pickoff cards will also output BGO sum signal and side channels.
- With addition of 4 more digitizers, 100 Ge and BGO Sum signals can be processed digitally (200 channels, 20 digitizers).
- By using GS as trigger and abort at late time, we can run stand alone digital GS (no side channels and no electric honeycomb suppression).



Electric Honeycomb

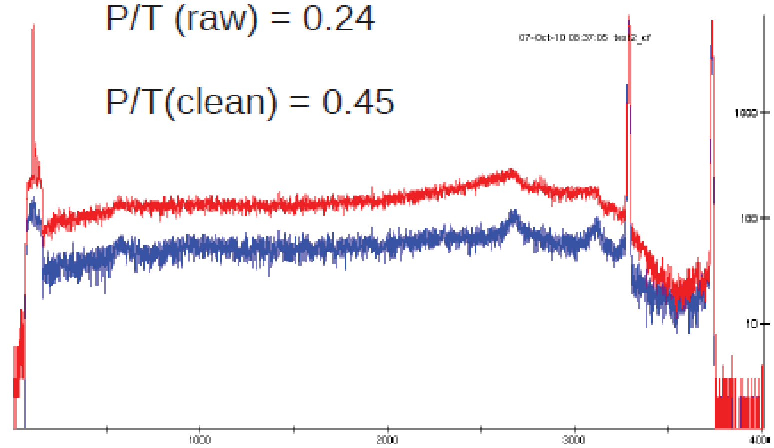


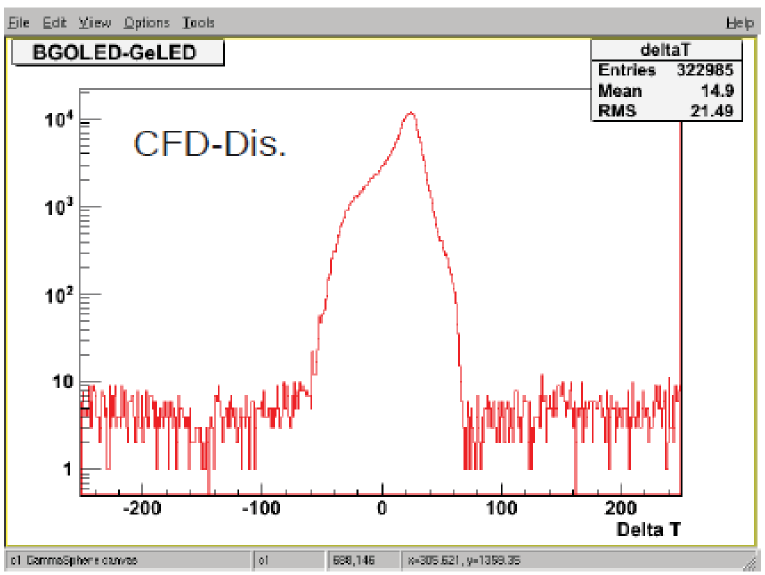
Initial Compton Suppression Tests



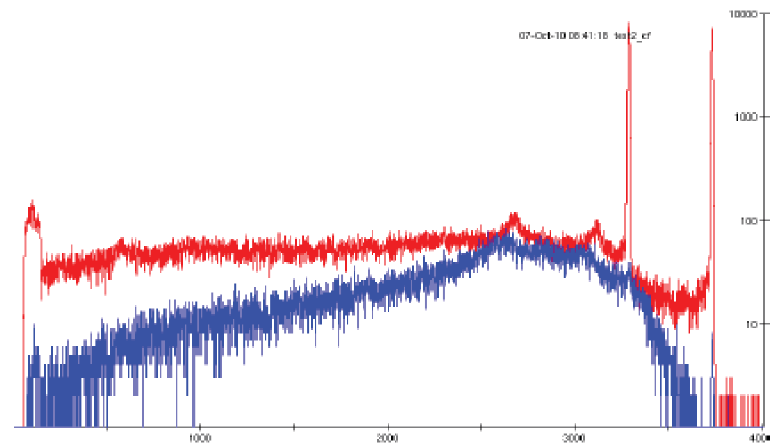
P/T (raw) = 0.24

P/T(clean) = 0.45





clean/dirty



Phase III and beyond – Full Digital Gammasphere

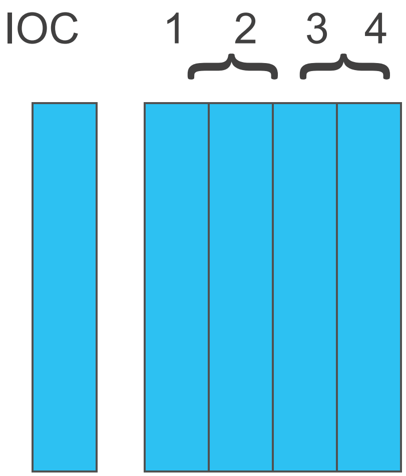
- A Gammasphere module provides up to 10 signals for processing
  - 1 Ge central contact (CC), 2 Ge outer contacts (SC), 7 BGO signals

- One Gretina digitizer card could instrument one Gammasphere Module.
  - Most expensive option ~ $720k for crates, digitizers, IOC and trigger mod.
  - Is full digitization of individual BGO energies necessary?

- Four Gretina digitizer cards instrument 10 Gammasphere Modules
  - Digitize 4 signals, Ge CC, Ge SC, BGO Sum, BGO Hit/Multiplex
  - Individual BGO energies not available – identical to analog Gammasphere
  - $300k for crates, digitizers, IOC's and trigger modules

- One Gretina digitizer card could instrument 2 Gammasphere Modules
  - Digitize 5 signals - Ge central contact, 1 side channel, 3 multiplexed BGO signals (2,2,3) – individual BGO energies available.
  - $360k for crates, digitizers, IOC's and trigger modules

Proposed configuration for final DGS



This configuration instruments 10 GS modules

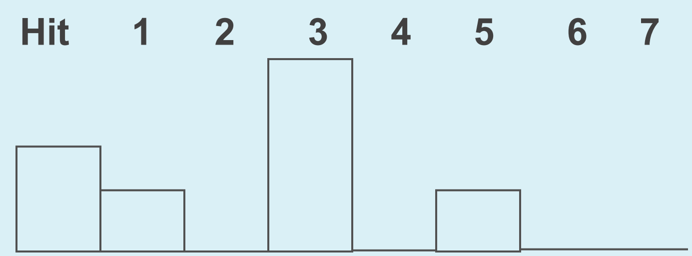
Digitizers 1,3: Ch 0-4, Ge central contact
Ch 5-9, BGO sum signals
Digitizers 2,4: Ch 0-4, Ge Side Channel
: Ch 5-9, BGO Hit/Multiplex

Fast Trigger will provides following possibilities:

1. Clean Ge Multiplicity *or*
2. Modular Multiplicity *or*
3. Ge Multiplicity

VXI boards will be replaced by custom boards which provide:

- Differentiated Ge signal
- BGO Sum energy
- BGO Side Channel
- Digital Hit Pattern (BGO seg. energies)
- Slow control of slope box (Ge and BGO HV).



Design Goal: >50,000 events/sec for high multiplicity measurements.

Other Initiatives:

- Full instrumentation of the FMA focal plane (D. Sweryniak)
  - 160x160 DSS
  - Clover array
  - PPAC
- Clover array for RIKEN (M.P. Carpenter)

Cast of Characters:

M. Alcorta, J. Anderson, P. Camboulives, M.P. Carpenter, G. Henning,
C. Hoffman, A. Kreps, T.L. Khoo, T. Lauritsen, C.J. Lister, D. Seweryniak,
P. Wilt, S. Zhu.