

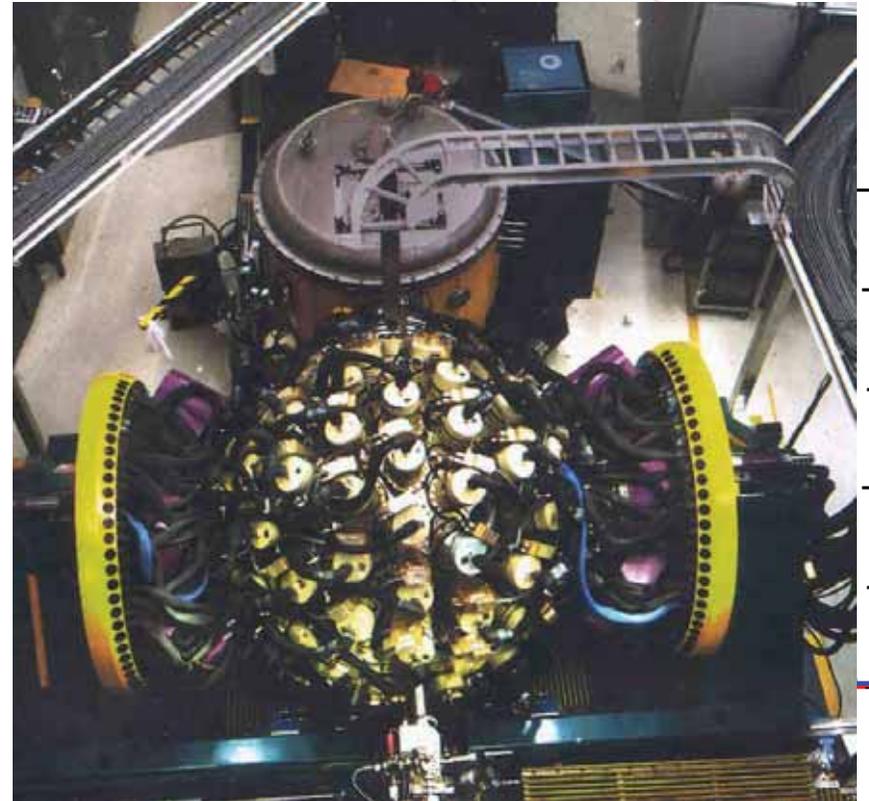
Digital Gammasphere

- 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 $\sim 10\mu\text{sec}$ which gives $\sim 6\%$ pileup at 10,000 cps, 20% pileup @ 30,000 cps and $\sim 30\%$ pileup @ 50,000 cps.
- **Solution** - reduce Ge shaping time allows higher rates.

- **Trigger Limitations**

- GammaSphere DAQ is dead for at least $\sim 25\mu\text{sec}$ for triggered events.
- Single and 2-fold Ge triggers saturate GammaSphere rate capability.
- Readout can only be aborted at main (300-1500ns) and late ($6\mu\text{sec}$)
- **Solution** - flexible trigger incorporating triggerless option.

- **Digital Gamma Sphere Rate Goals**

- 50,000 gamma/sec in each detector
- 500,000 gammas/sec to disk.

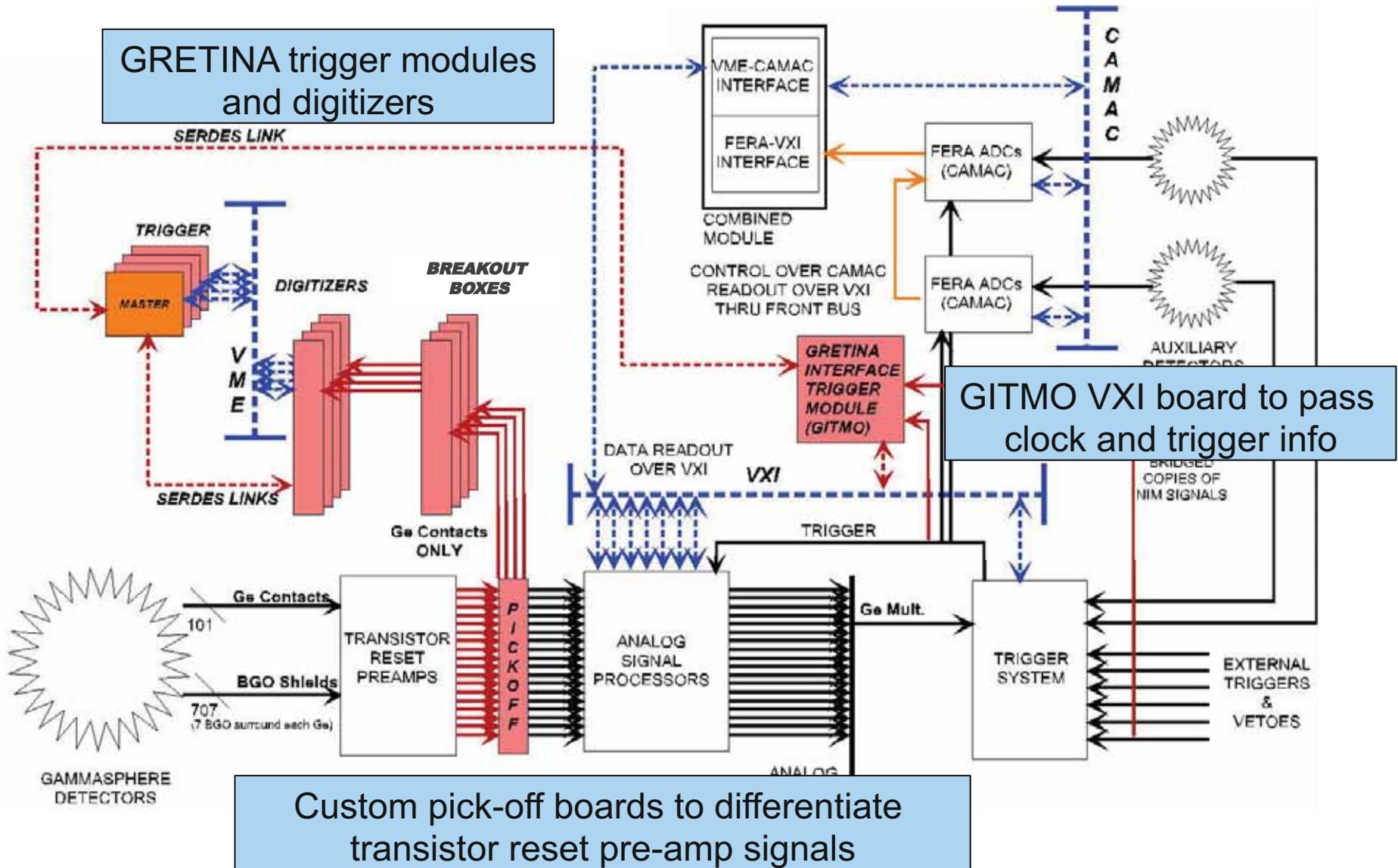


Digital Gammasphere - Replace current analog electronics with a digital pulse processing system based on the 10 channel Gretina Digitizer module.

- Decreasing processing time of Ge shaper from ~ 10 to $\sim 2\mu\text{sec}$ 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

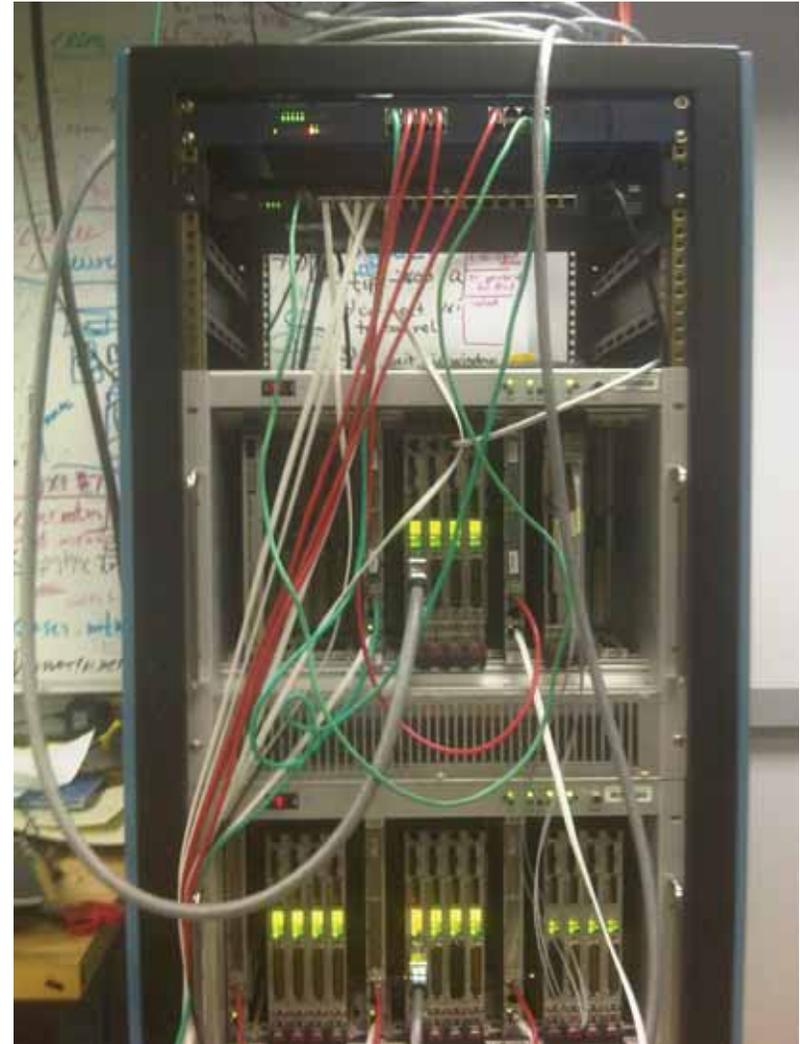


Digital Gammisphere as it now LOOKs

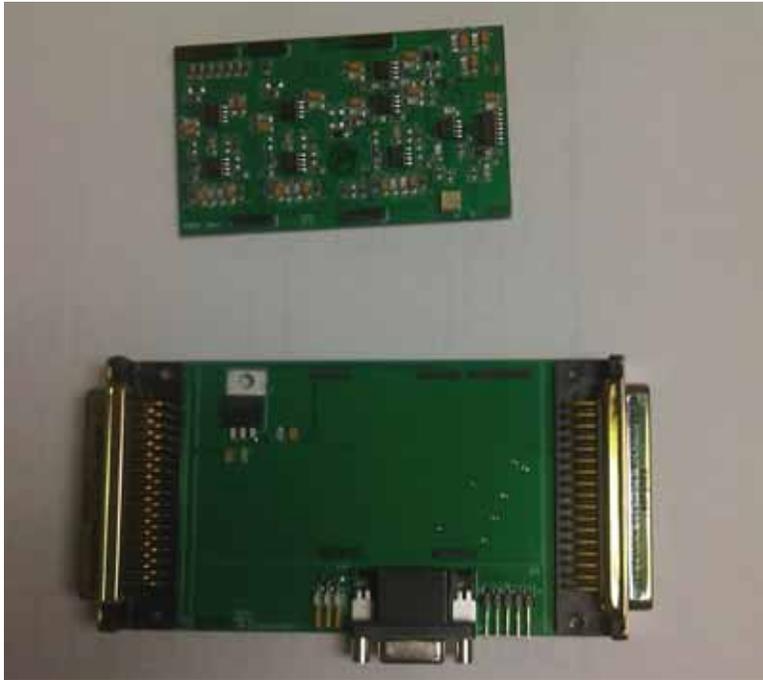
- 2 VME crates
- terminal server
- switch
- 5 MVME5500 (IOC)
- 2 trigger modules
- 16 Digitizers



VME Crate with 3-fold segmentation of back plane

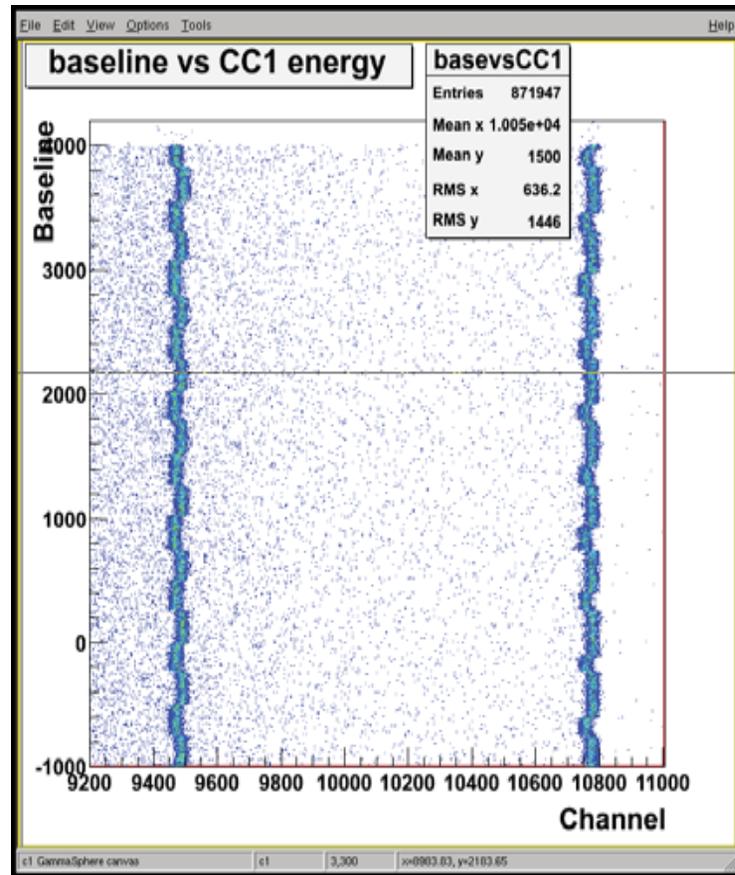
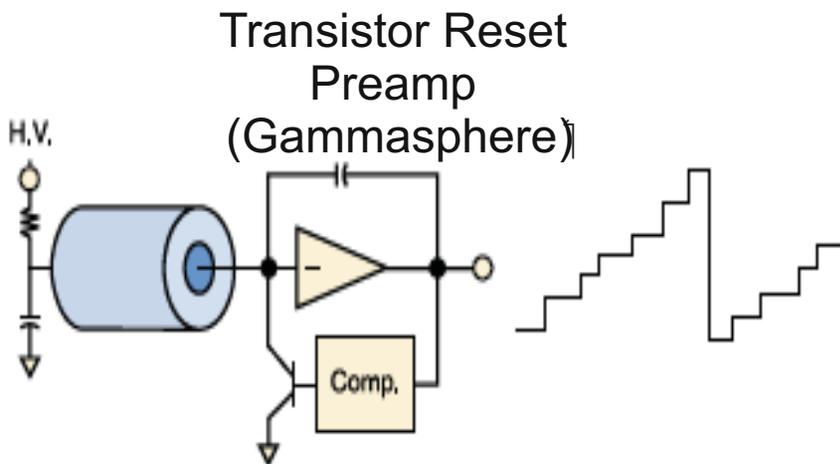
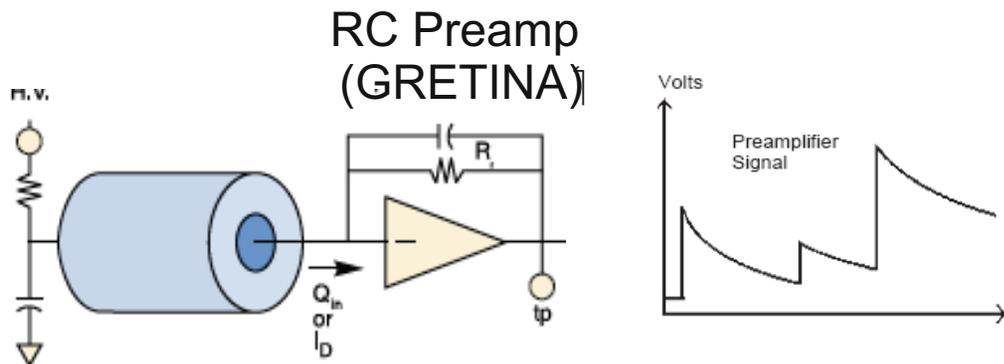


Pickoff Boards (Phil Wilt)



- 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.

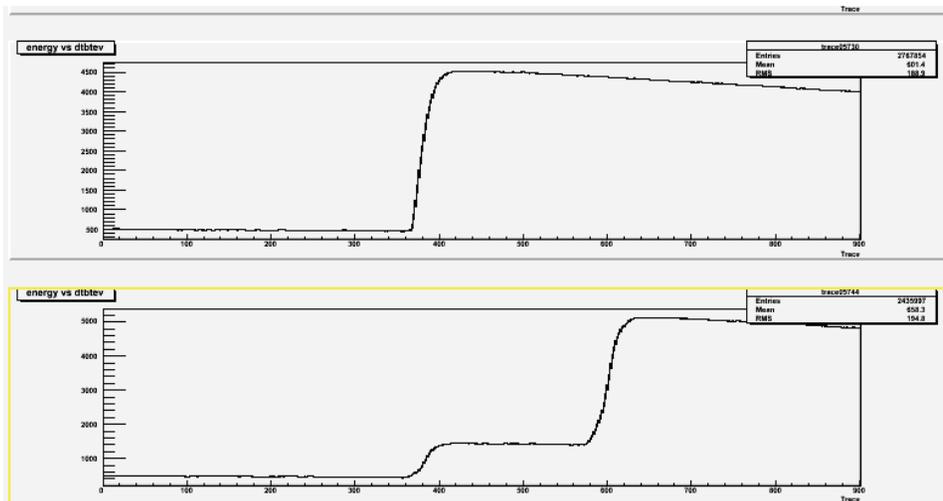
Preamplifiers for Ge detectors



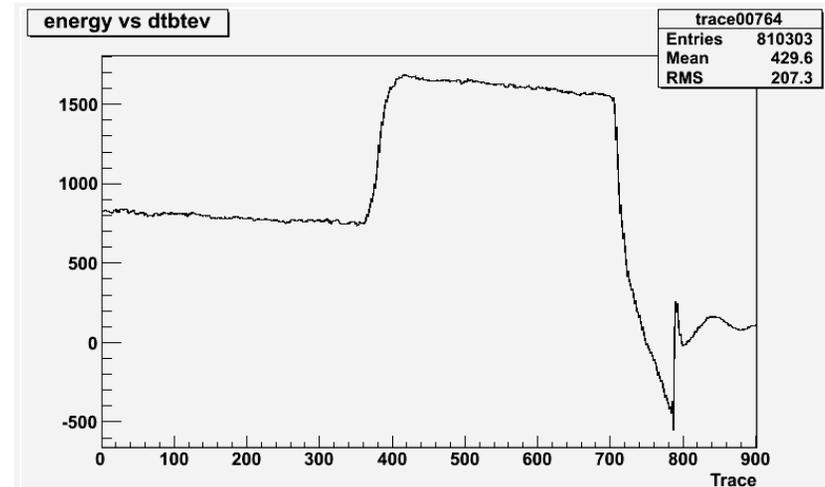
Sending GS pre-amp directly into digitizer

Digitizer Traces from Pickoff Board

Standard and Pile-up Event

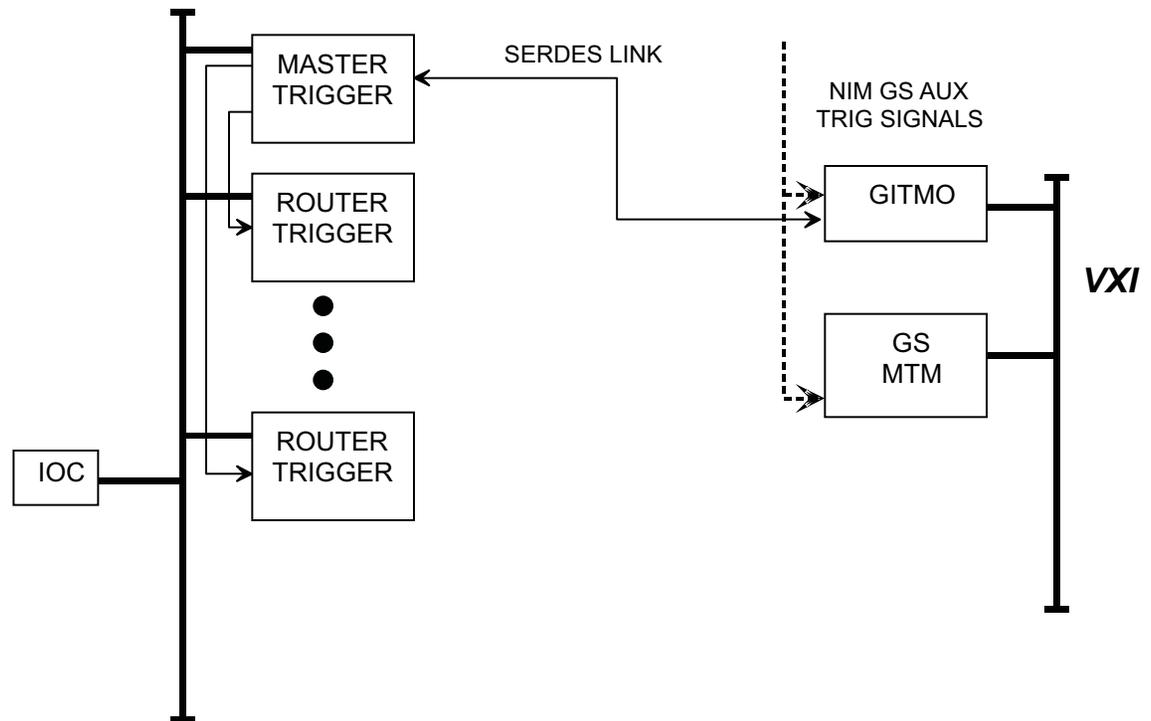


Trace with reset pulse



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

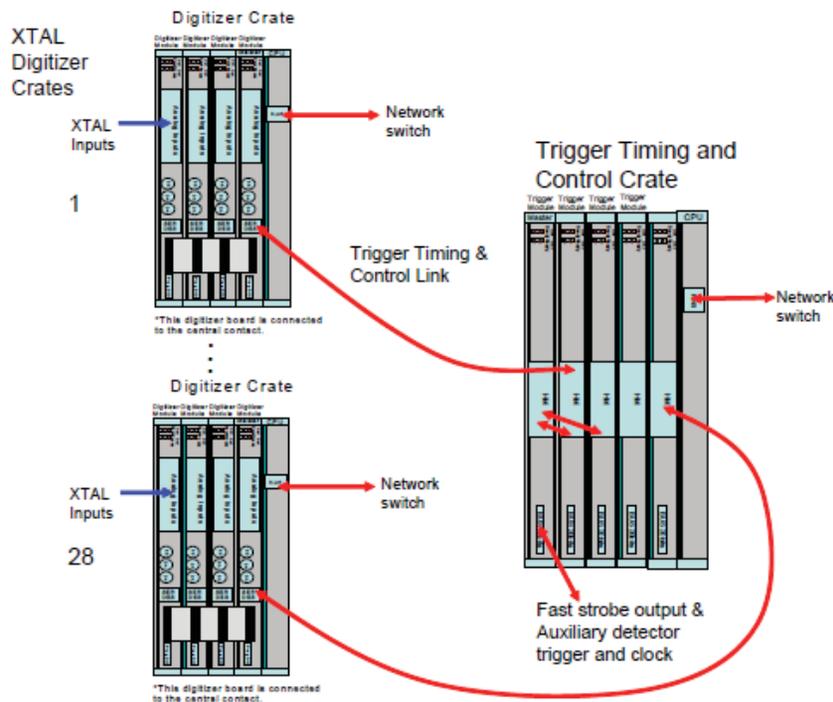
During initial roll-out of Digital Gammasphere, digitizer-based system will be run as slave to analog Gammasphere



- 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 Motorola MVME5500 running the vxWorks Real Time operating system.
- Control of digitizer and trigger modules performed 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

The screenshot displays the DGS Main Controller GUI with several active windows:

- DGS Main Controller:** Shows 'Run Control' (Running), 'Digitizer and Trigger Control' (Trigger, Global Control, Cluster), and 'VME 3' status (Enabled).
- DGS VME 3:** Lists VME 3 Boards (9 Segs, 10 Segs, 11 Segs, 12 Segs) and VME 3 IOC.
- VME 3 Event Rates:** A table showing event counts for 10 channels across 4 segments.
- Global Controls:** Configures parameters like Polarity (Positive), Pileup Mode (notify), and various delays.
- VME 3 Diagnostic Trace:** A graph showing a signal step from 0 to approximately 1000.
- AcqStatus:** A table of acquisition status for various channels.

	1	2	3	4
0	3589	0	0	0
1	14	0	0	0
2	2646	0	0	0
3	0	0	0	0
4	4	0	0	0
5	3	0	0	0
6	3	0	0	0
7	0	0	0	0
8	0	0	0	0
9	3	0	0	0

Polarity	Positive
Pileup Mode	notify
Debug Mode	normal
Trig Mode	Internal
Pole Zero Ena	disabled
Pole Zero Trace	Raw Data
PZ Mult	1750
LED Thresh	300
Raw Delay	0.00 us
Raw Len	1023 us
CFD Delay	50 ns
CFD Thresh	160 keV
CFD Fraction	1/2
Segment Enable	Enabled
Down Sample	1 point
Exit Win Len	0x7
Noise Win	0.64 us
Pileup Win	10.00 us
Exit Trig Delay	5.10 us
Collection T	1.00 us
Integration T	4.00 us
Aux I/O Mux	None
DCM Reset	None
File Send	Set
Set All	Set

Channel	Status	Channel	Status	Channel	Status
VME 3 ACQ Run	Running	DAQB10_CS_Ena	Running	DAQB11_CS_Ena	Running
VME 3 SenderWrite	Running	DAQB10_CV_Run	Running	DAQB11_CV_Run	Running
VME 3 Trighn	Running	DAQB10_CV_Run	Running	DAQB11_CV_Run	Running

GTSort and Run Control

The screenshot displays a Linux desktop with several windows open:

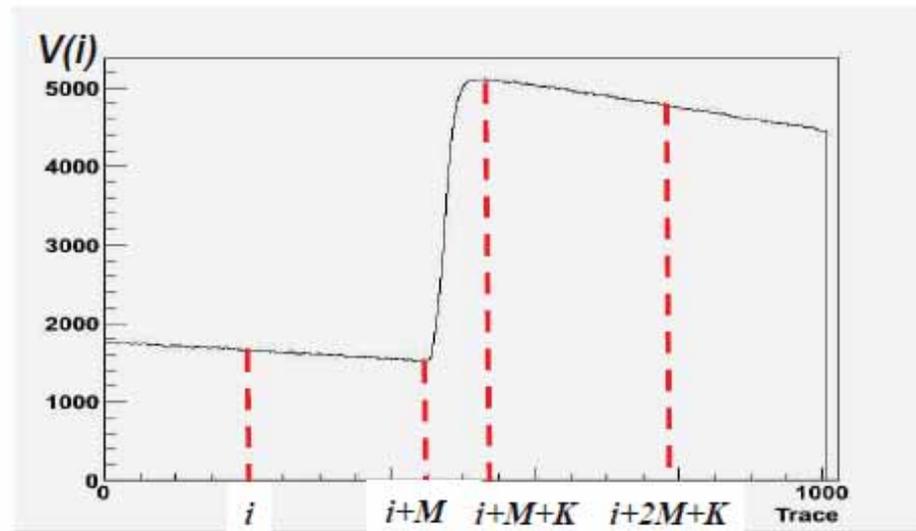
- DSSD bar:** A control panel with buttons for STOP, Load map file, Update spectra, Zap all spectra, display eh000, display eh011, and a Plot canvas (160x13700).
- online.log:** A log window showing system events and receiver sequence mismatches. It includes a table of receiver data:

Receiver	Sequence mismatch	29052570	29055024
Receiver	Sequence mismatch	29180290	29180233
Receiver	Sequence mismatch	29180274	29180233
Receiver	Sequence mismatch	29180878	29180830
Receiver	Sequence mismatch	29180674	29180676
Receiver	Sequence mismatch	29180799	29180713
Receiver	Sequence mismatch	29180809	29180994
- Terminal:** Shows terminal output for the GTSort command, including file names like 'ehi000' and statistics such as 'Total sum= 126001' and 'Entries= 14878'.
- GammaSphere canvas:** A plot window showing a histogram of 'Counts' vs 'Channel'. The plot is titled 'det 080 hi res'. A data table is overlaid on the plot:

ehi000	
Entries	3.756485e+07
Mean	1509
RMS	1228
- DGS Run Control:** A GUI window for configuring receivers. It includes fields for Base Name, Run #, File Size, and three Receiver configurations, each with Host, Server, and Data Directory options.

- 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

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

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

$$\Sigma_1 = \sum_i^M [V(i+K+M) - V(i)]$$

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

Modified Trapezoid with baseline correction

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

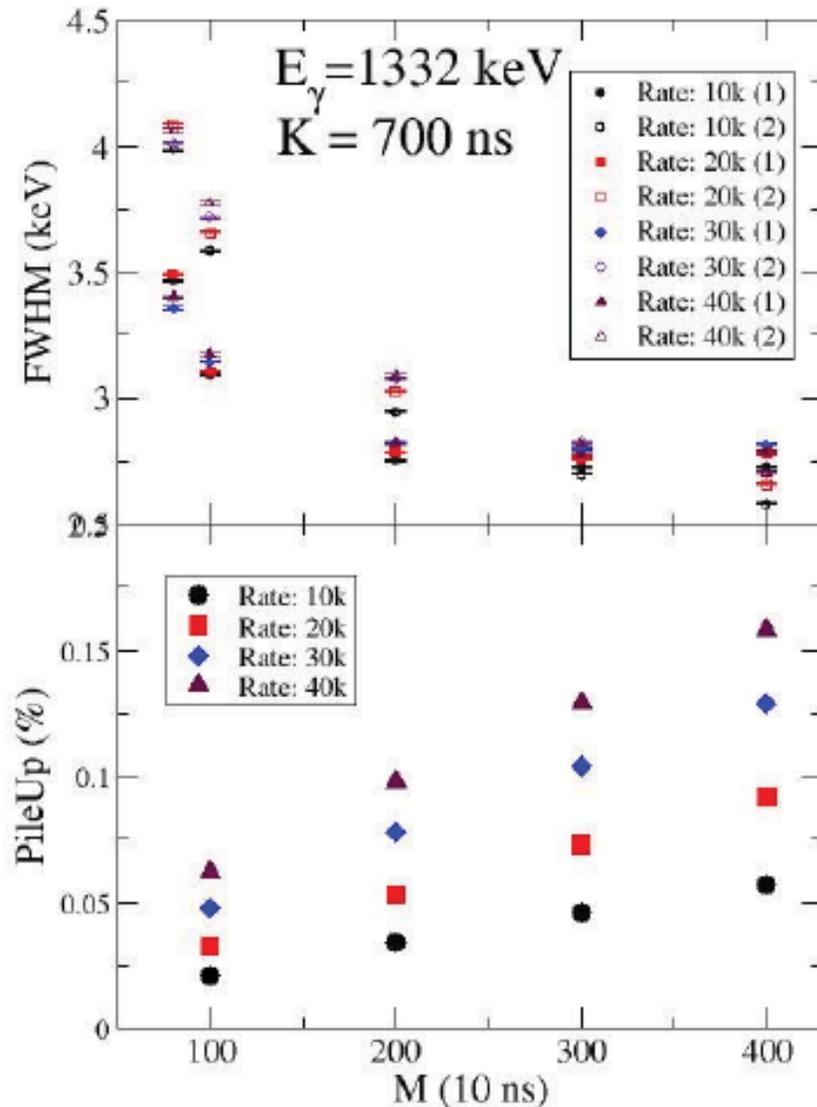
$$\kappa = e^{-\lambda(M+K)}$$

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

$$\Sigma_1 = \sum_i^M [V(i+K+M) - V(i)]$$

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

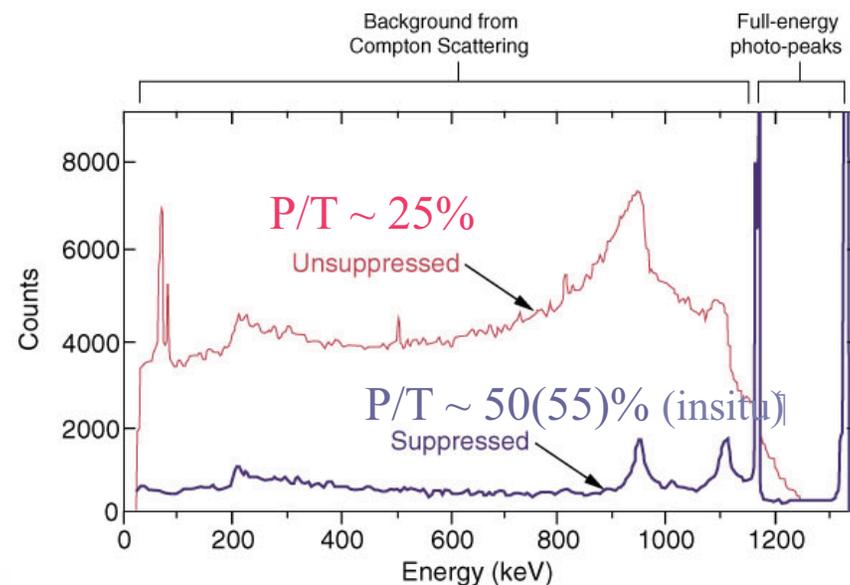
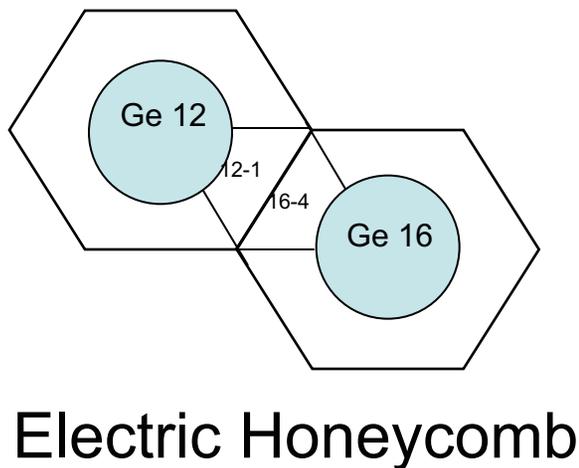
Comparison of two methods



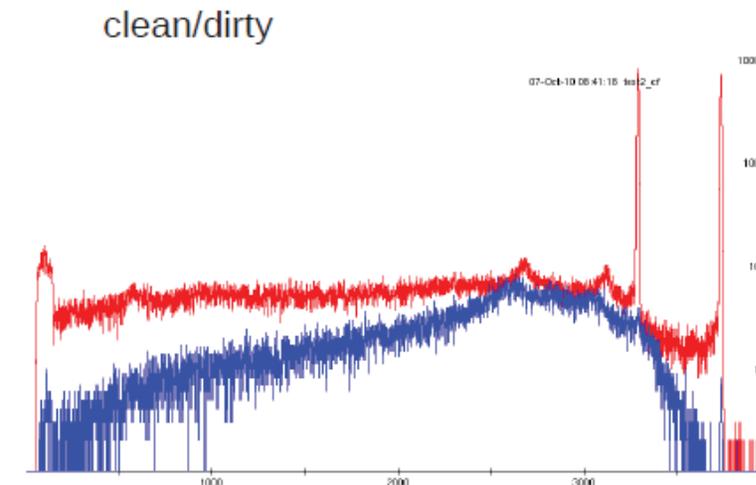
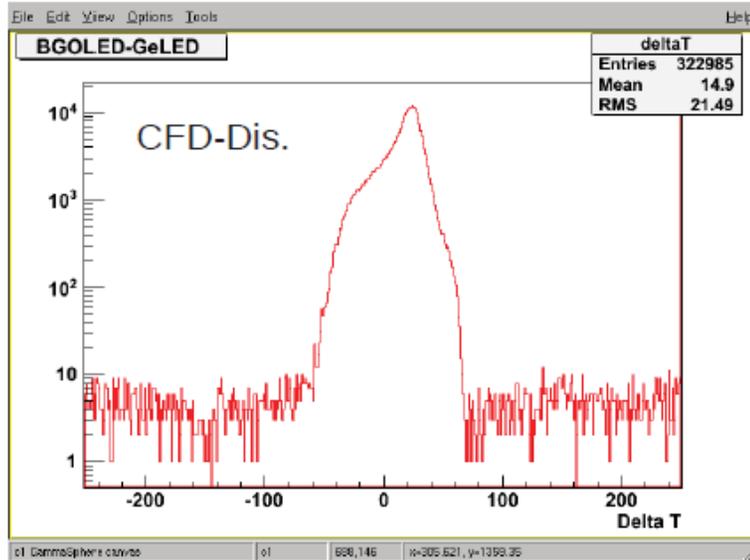
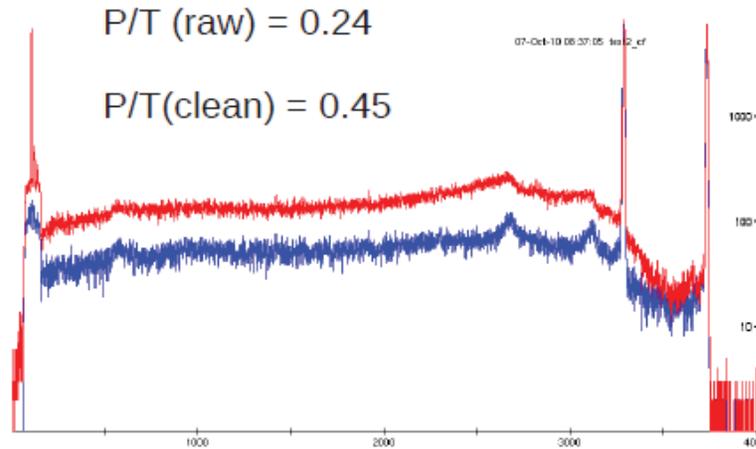
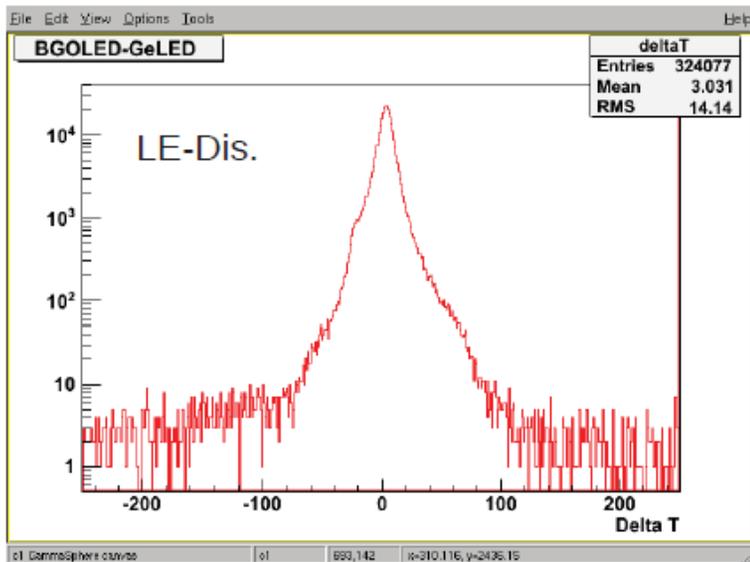
- For longer shaping times, full trapezoid gives slightly better energy resolution
- At shorter shaping times, modified trapezoid gives superior energy resolution.
- Related to uncertainty induced by integrating during detector rise time.
- For a processing time = $2.7 \mu\text{sec}$ ($m=1, k=0.7$), FWHM $\sim 3.10 \text{ keV}$.
- 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).



Initial Compton Suppression Tests

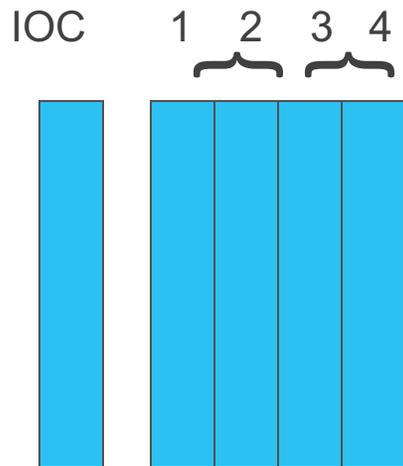


Phase III and beyond - Full Digital Gammasphere

- 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.