GLAST Large Area Telescope:

I&T Science Verification Analysis and Calibration (SVAC)

Instrument Data Analysis Smorgasbord

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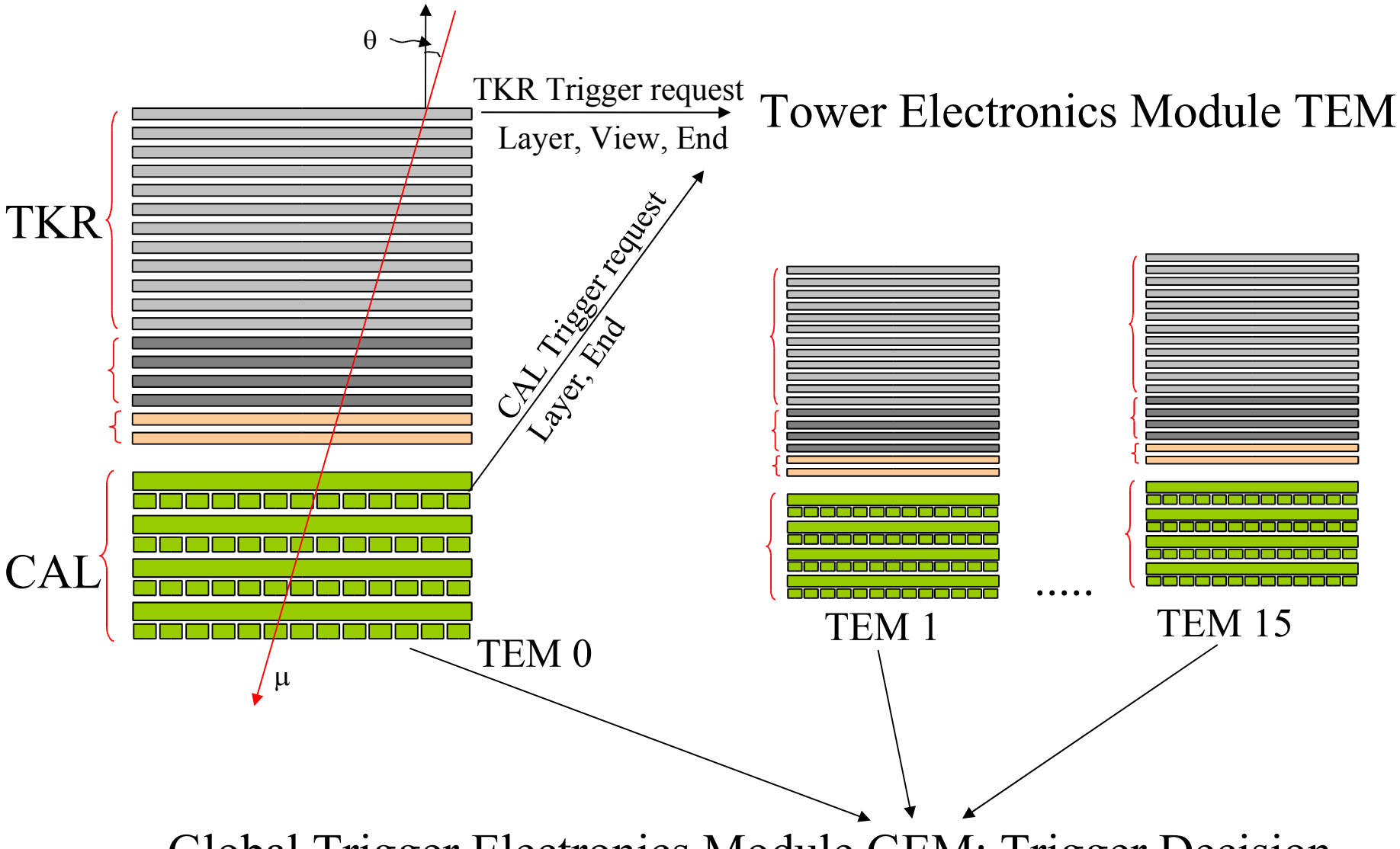
Instrument Data Analysis

- With hardware comes new things to look at!
  - What are they?
  - Do we want (all of) them?
  - Will they be available?
  - Where will they be available?
    - » Maybe here, maybe there, but certainly not everywhere!
- Hardware:
  - Tower Electronics Module (TEM)
  - Global Trigger Electronics Module (GEM)
  - Event size(s)
- Track reconstruction strategy for muons (during Integration):
  - Minimum track energy?
- Trigger information:
  - Current status

Trigger Requests and Trigger Decision



Tower Electronics Module TEM

- **Tower Electronics Module (TEM):**
  - **LAT-TD-00605**
  - **TEM processes data from and manages the Front-End electronics:**
    - **Will not talk about readout and error contributions here.**
  - **Will concentrate on:**
    - **TEM Diagnostic information = Trigger Primitives**
  - **Trigger primitives:**
    - **Information the TEM received from the TKR and CAL electronics.**
    - **Transmitted to the Global Trigger Electronics Module GEM.**
    - **Used by the GEM to make the trigger decision.**

TEM: Trigger requests ⟶ GEM: Trigger Decision

Trigger Primitives

- Trigger primitives:
  - Detailed status of trigger request information:
    - For each end (of each view) of each layer in each tower
      - » i.e. There is a TKR trigger request from the positive End of View X of Layer 5 in Tower 8.
      - » i.e. There is a CAL LE trigger request from the positive End of Layer 2 in Tower 8.
- Warning!
  - Information lives in electronics space.
  - Sometimes non-trivial decoding to physical space!
    - » 'X' may be what you think of as 'Y' ..... :-)

Trigger Primitives for the CAL

- CAL:
  - Two (nominal) trigger thresholds:
    - CAL Low Energy: 100 MeV
    - CAL High Energy: 1 GeV
  - Thresholds may change for Integration.
  - Trigger requests for
    - Each threshold and for
      - » Each layer
      - » Each end of layer
    - i.e. Don't know which crystal fired!
  - Know for each crystal whether it was above the zero suppression threshold.

Trigger Primitives for the TKR

- TKR:
  - Trigger request is '3-in-a-row' XY pairs of hits.
  - Trigger requests for:
    - Each layer: 0-15
    - Each view: X and Y
    - Each end of layer
      - i.e. Don't know which strip fired!
- For both CAL and TKR:
  - Don't have exact location of trigger request!

Trigger Primitives: Where Art Thou?

- Trigger primitives are in:
  - TDS
  - Digi root files
- Trigger primitives are also in the SVAC ntuple:
  - Electronics space (bitwise words):
    - TkrTp [Tower][0-7]
    - CalTp [Tower][0-7]
  - Decoded into physical space:
    - TkrReq [Tower][Layer][View][End]
    - CalReq [Tower][Layer][End]
      - » CAL LE and CAL HE are OR'ed together in CalReq.
- In addition, in the SVAC tuple:
  - Number of crystals per tower above the zero-suppression threshold:
    - CalNumHit [Tower]

The GASU

- We now have a GAS Unit.
- GASU is a container for the four modules:
  - ACD Electronics Module (AEM)
  - Global Trigger Electronics Module (GEM) ← GEM!
  - Command/Response Unit (CRU)
  - Event Builder Module (EBM)
- How do you make the acronym 'GAS' out of this?
- Will only talk about the GEM contribution here.

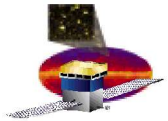
NEW!

Global Trigger Electronics Module GEM

- More details in LAT-TD-01545.
- GEM's principal function:
  - Process trigger inputs from the TEMs and ACD.
  - Make the decision whether to read out the event:
    - An otherwise triggerable event can be prescaled away or the instrument can be busy.
- Provides two types of information:
  - Trigger information at the tower level:
    - Which subsystem triggered and in which tower
      - » i.e. There is a TKR trigger in tower 8
  - Time and event counters.
- Provides the overall trigger word:
  - GEM Conditions Summary
    - 7 bits summarizing why the event triggered.
    - ACD ROI – TKR – CAL LE – CAL HE – ACD CNO – Periodic - Solicited

GEM Event Contribution: What Triggered Where?

- What triggered and in which tower:
  - 16-bits vectors with trigger signals:
    - TKR, CAL LE, CAL HE, ACD ROI, ACD SNO (12 bits)
      - » i.e. There is a TKR trigger in Tower 8.
- ACD tile list:
  - State of all the ACD tiles:
    - Hit/No Hit
- Event Summary:
  - CALSTROBE, Tag, TACK, 4-range readout, Zero-suppression, Marker, Event number



GEM Event Contribution: Time Counters

- GEM provides several time counters in ticks of 50 ns:
  - Live time:
    - 1/deadtime
    - 24 bits
  - Trigger time:
    - Free running counter incrementing at the system clock
    - Counts from when it was reset to the event was declared
    - 25 bits
  - 1-PPS time:
    - Seconds:
      - Number of seconds since the GEM was reset
      - 7 bits
    - 1-PPS time:
      - Time in 50 ns ticks of the last arrived 1-PPS signal
      - 25 bits
  - Delta event time: See later

What time is it? Time To Roll Over

- All of these counters roll over and at different times.
- Time counters can give absolute time for an event:
  - Only with Flight software .....?
  - Flight Software:
    - Keeps track of rollovers.
    - Anchors events within and keep track of 1-PPS signals.

Time Counters Usable?

- Not obvious what we can do:
  - Without Flight Software.
  - No 1-PPS signal.
- Online provides two event time stamps:
  - 60 Hz clock
  - 20 MHz system clock (50ns ticks):
    - This is when the event is shipped from the Event Builder.
    - Events queueing up may increase this time! (Buffered System)
- Not obvious how/if we can relate GEM time counters to Online time stamps.

Delta Event Time

- GEM Delta Event Counter:
  - Delta event time is usable!
    - Time between event (n-1) and event n.
  - 16 bits
  - It saturates at 3.2 ms
    - i.e. Only usable above 300 Hz!

GEM Event Contribution: Event Counters

- Event counters:
  - Prescaled count:
    - Number of triggered events not passing the prescalers
    - 24 bits
  - Discarded count:
    - Number of triggered events passing prescalers, but lost due to LAT being busy.
    - 24 bits
  - Sent count:
    - Number of triggered events read out.
    - Same as number of Trigger Accept Messages (TAMs) sent by the GEM.
    - 16 bits
  - Usable without Flight Software?

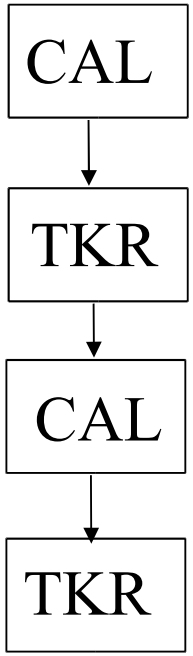
GEM Event Contribution: Where to find it?

- GEM Event Contribution:
  - TDS
  - Digi root files
- Merit tuple:
  - GEM Conditions Summary word is in Merit.
- SVAC tuple:
  - GEM Conditions Summary word
  - Event summary
  - All the time and event counters.
  - TKR, CAL LE, CAL HE, ACD ROI and ACD CNO vectors
    - Will be implemented as arrays.

Event Size(s)

- We can get the size of the following event contributions:
  - ODS (Online time stamps)
  - GEM: Fixed size
  - TEM 0: Variable size
  - .....
  - TEM 15: Variable size
  - ACD: Variable size
- Will be put into
  - TDS
  - Digi root files
  - SVAC tuple
- Do we want separate CAL and TKR event sizes?
  - Calculated offline from the hits?

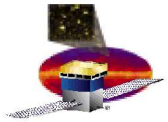
Track Reconstruction Strategy For Muons



- Current track reconstruction works in iterations:
  - CAL:
    - Get preliminary energy estimate.
  - TKR:
    - Track finding and preliminary track fit.
  - CAL:
    - Update energy estimate.
  - TKR:
    - Update track fit with improved energy estimate.
- Energy estimate is used to estimate multiple scattering:
  - Directly influences the errors.
  - Also determines track reconstruction strategy:
    - Low energy means lots of multiple scattering
      - » i.e. Only use the first few points to estimate the incident direction.

Got Energy?

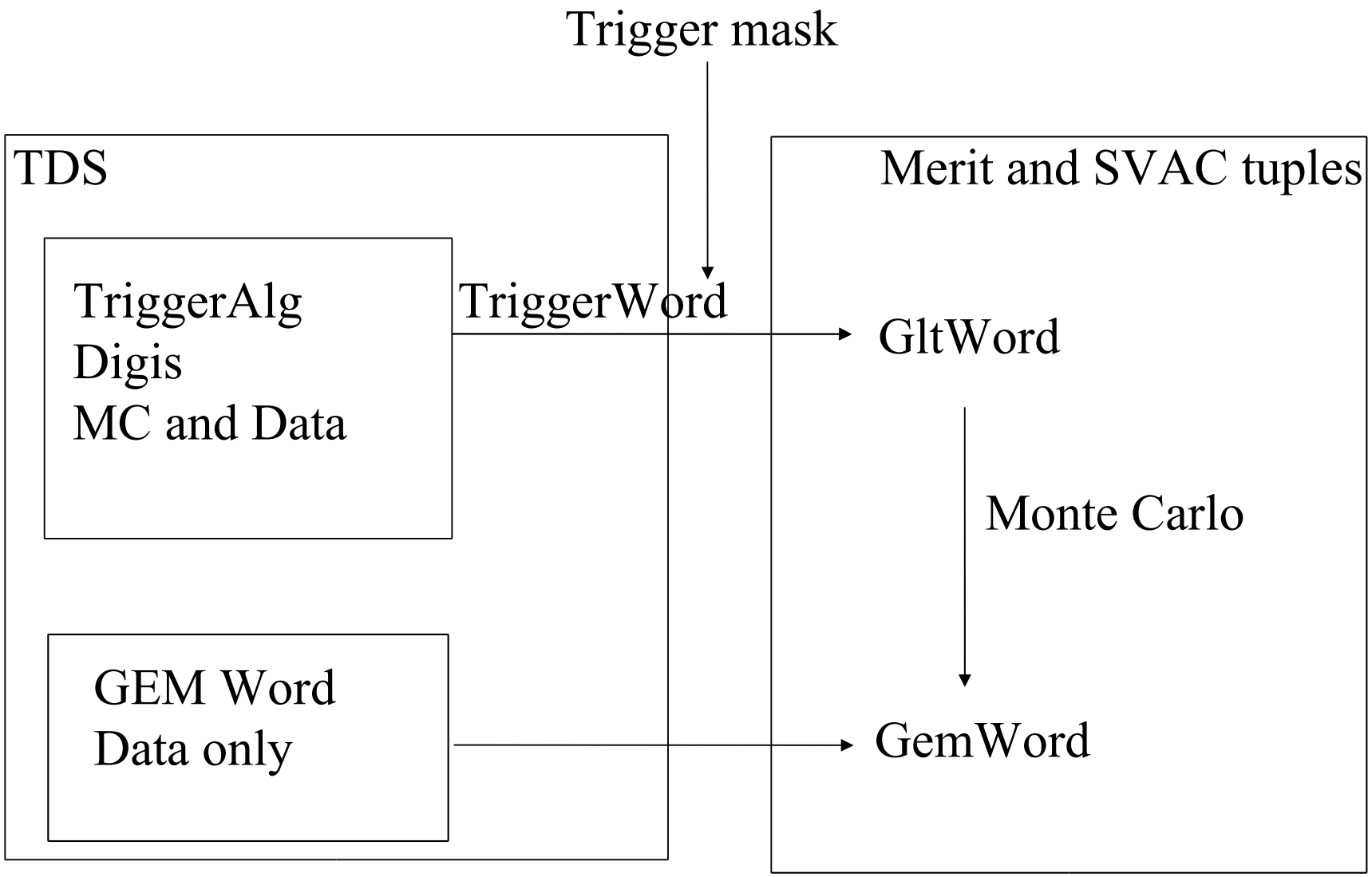
- Muons get assigned the wrong energy:
  - MIP leaves ~90 MeV in the CAL.
  - Track reconstruction assumes the muon is a 90 MeV track
    - i.e. Badly overestimates multiple scattering.
- Current track reconstruction also assumes the electron hypothesis:
    - Muon hypothesis available in latest version.
- Muon hypothesis sets a minimum track energy for reco to use.
- Non trivial problem:
  - Which energy to choose?
    - 1 GeV, 2 GeV, 3 GeV, ...?
  - How sensitive is it?
  - Is there a 'best' value?
  - Needs study!



Set a Minimum Energy?

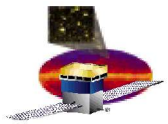
- Can also set a minimum energy in the current MC version:
  - TkrInitSvc.TkrMinEnergy = 2000.0;
  - TkrIter.Members={};
- Do we want to regenerate the Workshop MC with this?
  - Files exists for TkrMinEnergy = 2 GeV:
    - You can find it in the usual place for Workshop MC (directory 'cr_minTkrEnergy').
    - Also includes end-of-track parameters and both CAL end energies in the SVAC tuple.
- What do we want to do during Integration?

Trigger Information: Current Status



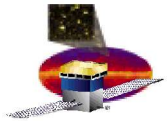
GEM Word and GltWord

- Trigger information from different and independent sources:
  - GEM Conditions summary word:
    - Trigger information from the hardware.
    - No GEM simulation
  - TriggerAlg, TriggerWord and the GltWord:
    - Made from the digis.
    - Exists for both MC and data.
    - GltWord is set from TriggerAlg/TriggerWord.
  - Content and order of bits are different between GemWord and GltWord!
    - GemWord:
      - ROI – TKR – CAL LE – CAL HE – CNO – Periodic - Solicited
    - GltWord:
      - ACD L – ACD H – TKR – CAL LE – CAL HE – Throttle – Livetime



Trigger Words In The Ntuples

- **Merit ntuple:**
  - **Glt variables are made as before i.e.**
    - **From the digis**
    - **GltWord is set by TriggerAlg/TriggerWord.**
  - **GEM conditions Summary word is a separate word.**
  - **MC:**
    - **Relevant bits from GltWord is copied to GemWord.**
      - » **i.e. Can always make a selection based on the GemWord, even for MC.**
- **SVAC ntuple:**
  - **Same as Merit for GltWord and GemWord.**
  - **SVAC tuple will contain Luis' '3-in-a-row' digi combinations.**



Trigger Words And Real Data: Who's The Boss?

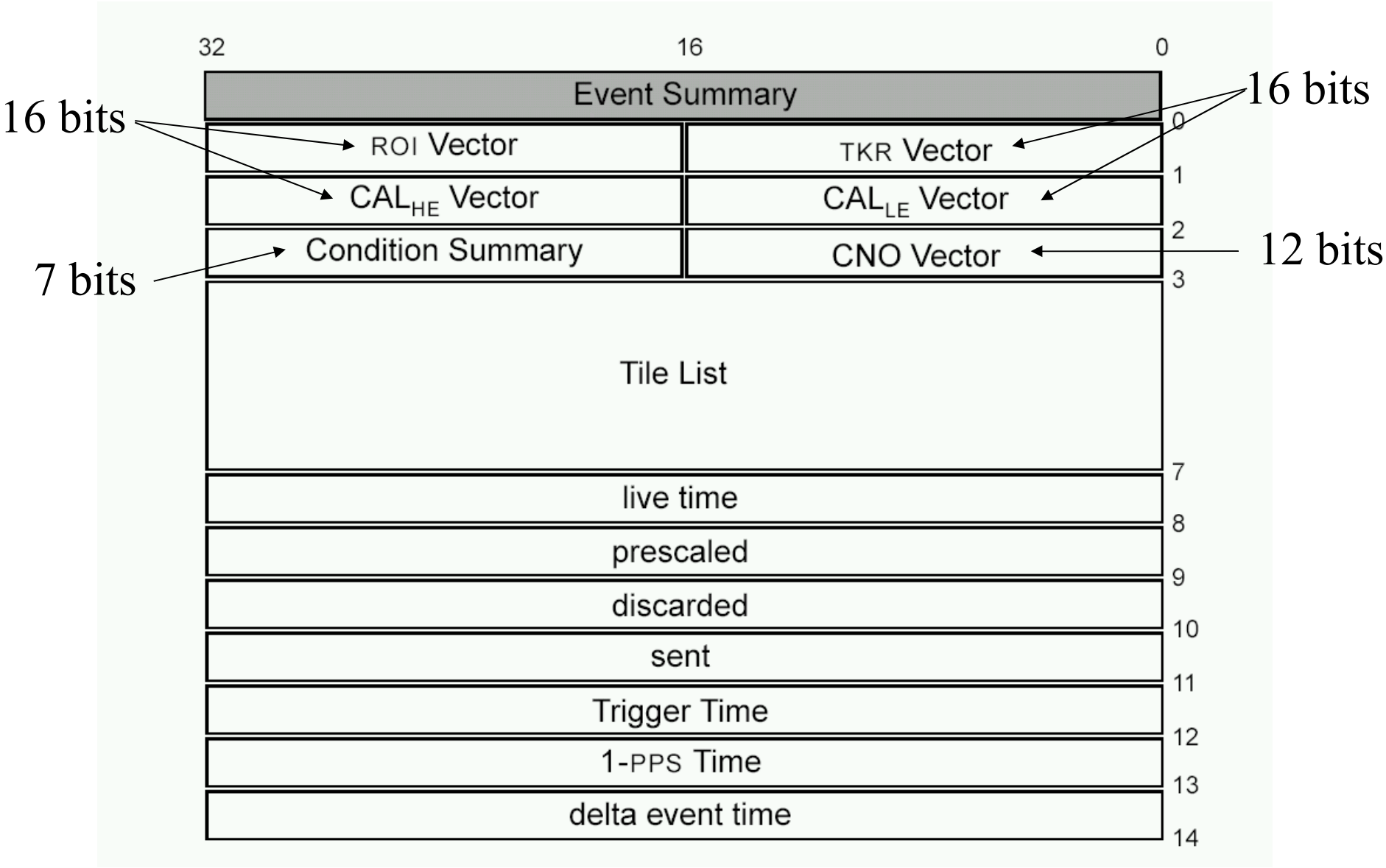
- **Real Data:**
  - GEM Conditions Summary word is the ultimate authority.
  - TriggerAlg runs and calculates the 'usual' digi based Trigger word in TDS.
  - GltWord is a 'copy' of the digi based Trigger word.
  - To write out all the already triggered events (digi.root), you must set:
    - TriggerAlg.mask = 0;
    - If not, the digi based Trigger word will remake a trigger decision i.e. You can drop an already triggered event!

Conclusion

- Will soon(er or later) get towers!
- Lots of things to look at.
  - TEM trigger primitives
  - GEM:
    - Trigger information
    - Time and event counters
  - Need to think about
    - What we want.
    - Where we want it.
    - Usable?
      - » Only with Flight Software?
  - See also Su Dong's email to the Trigger list Sept 26 2004:
    - Additional GEM DAQ data on trigger timing?
- Minimum track energy for muon tracks in track reconstruction?
- Make sure we don't get lost in trigger words ..... :-)

Backup Slides!

GEM Event Contribution: Fourteen 32 bit words



Merit Trigger Variables: Not Much Overlap With GEM

- Merit contains the following GLT variables calculated from digi:
  - GltWord
    - Bit encoded word saying what (TKR,CAL) triggered
    - Cf Condition summary in the GEM!
  - GltTower
    - ID of tower (with lowest recon layer) that triggered.
  - GltXTower, GltYTower
  - GltLayer
    - First layer of trigger in GltTower
  - GltTotal
    - Number of possible triggers
  - GltNumTowers
    - Number of towers which triggered
  - GltType
    - Number of exposed sides for the triggered tower
    - Cf ACD tiles

TEM Diagnostic Contribution

WARNING! In electronics land!

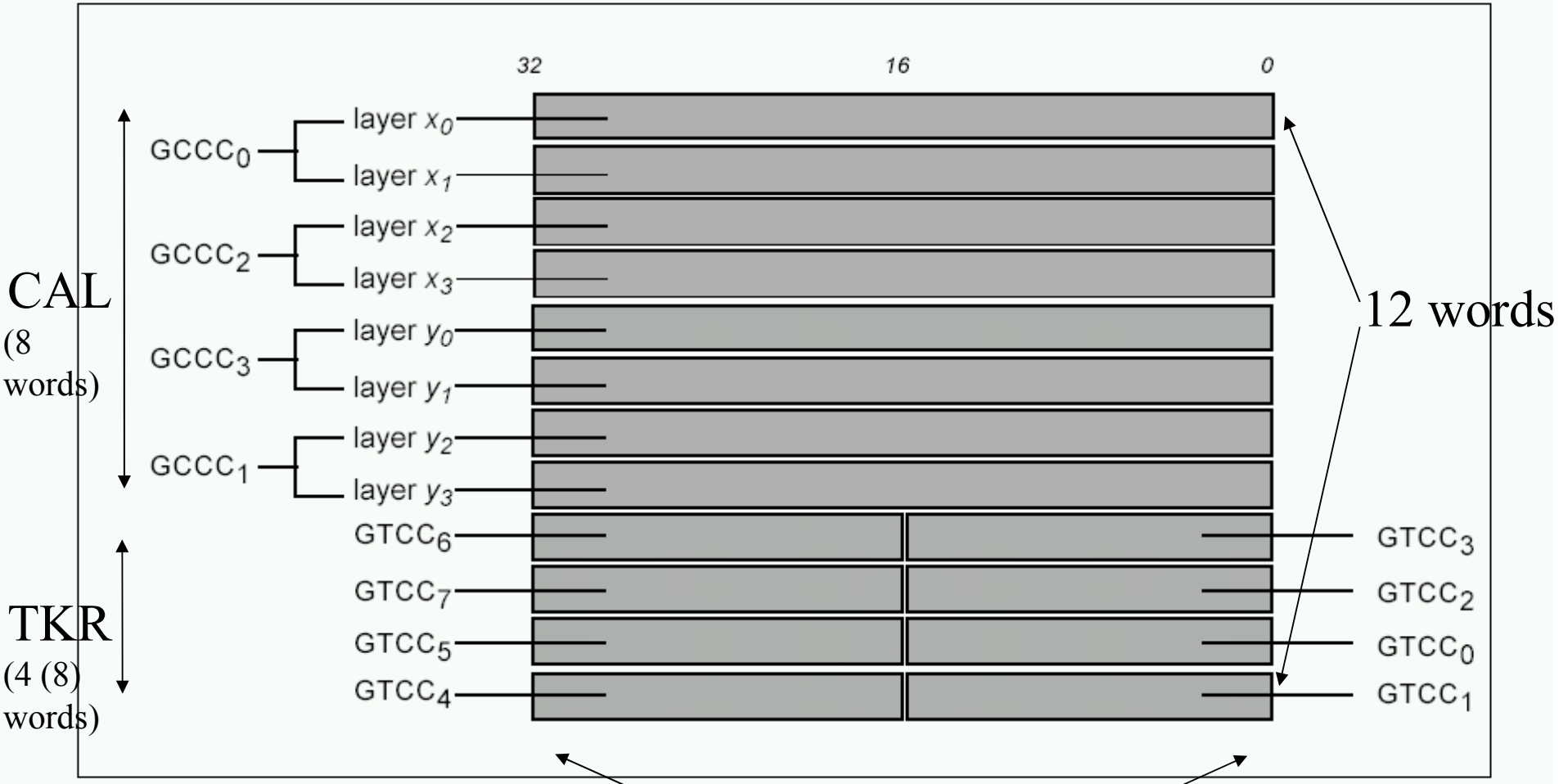


Figure 118 Overall structure of the TEM's diagnostic contribution

The Calorimeter: Layer and Ends

- For each tower (TEM)
  - we have CAL LE and HE trigger request information for:
    - Each layer
    - Each End (positive and negative)
  - We know if each log was above zero-suppression threshold

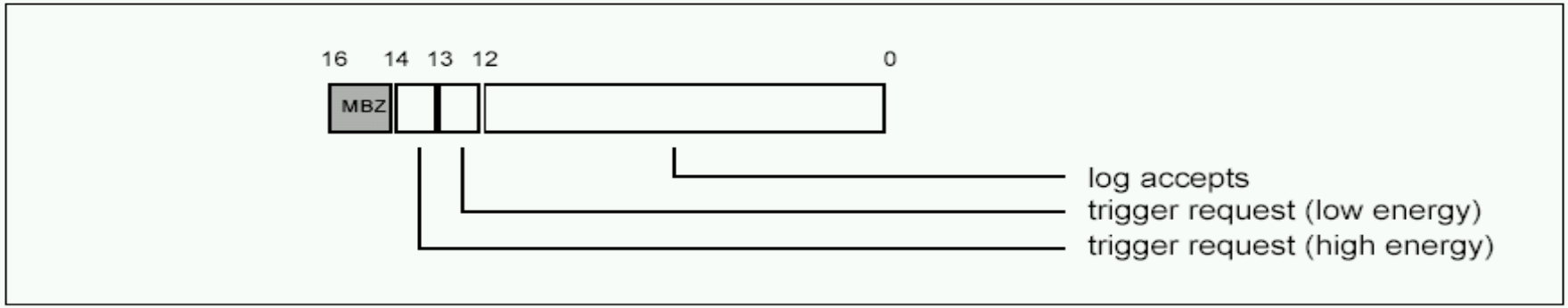


Figure 119 Calorimeter layer-end contribution to diagnostic data

Figure 120 Calorimeter layer contribution to diagnostic data

The Tracker

- For each tower (TEM)
  - we have '3-in-a-row' trigger request information for:
    - Each layer
    - Each view (X and Y)
    - Each End (positve and negative)

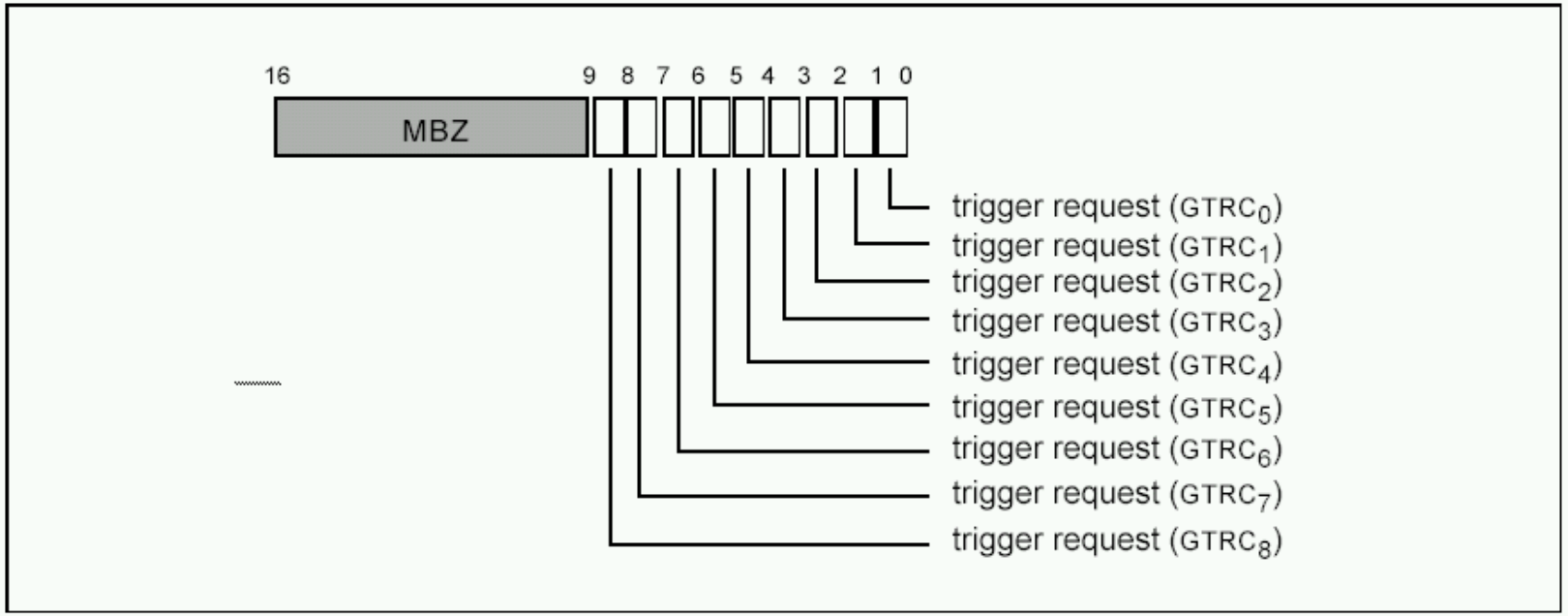


Figure 121 GTCC contribution to diagnostic data