CAL Calibration Procedure

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CAL Crystal Energy Scale Calibration

- Calibrate Individual Crystals
  - Charge injection AND
  - Muons on the ground
  - Protons and GCR heavy ions in flight
- Heavy Ion Measurements
  - Beam tests (GSI)
    - Measure dL/dE (aka "quenching" or "antiquenching"
- "Collective" Calibration
  - Beam test (CERN)
    - Calibrates groups of xtals
    - Dependent on individual xtal calibrations
    - Dependent on predictions of shower shape
    - Dependent on lost energy reconstruction
    - More a test of simulation than a true calibration
    - Necessary due to reliance on simulation for determination of ionization energy deposit

- Crystal Energy Scale Calibration
  - Nonlinearity
    - Electronics calibration
    - Run: calibGen_flt
  - MevperDAC
    - Crystal light output, transmission and collection calibration
  - Asymmetry
    - Crystal emission nonuniformity calibration
    - Used for longitudinal position measurement
- Calibration "Tools"
  - Charge Injection
  - Protons
  - GCR Heavy Ions
  - Simulations
    - GLEAM
    - Other sims based on Elliott & Co. work
  - Beam Test Results
- Not Discussed Today
  - Threshold measurements
    - Sasha will discuss at Bari

- Available at Launch
  - Most recent ground calibrations: TVAC
    - Hot and Cold Thermal Balance: Complete
    - Use cold unless statistics are inadequate
    - Runs:
      - calibGen_flt
      - calibGen_gnd
        - » Superset of calibGen_flt including muon gain
      - LAT71x muons

- L&EO
  - Charge Injection
    - Day L+15
    - calibGen_flt
  - Protons
    - Best range only
    - MIP filter run
      - Days L+24 – L+26
      - Offaxis or allaxis?
    - DGN_GEM filter
      - Continuous from L+14 onward
  - GCR Heavy Ions
    - Continuous
    - 4-range
  - NOTE: Thresholds may vary early on
    - Until L+33 or so
    - 2^{nd} order effects

- Flight Ops
  - Charge Injection
    - 4/yr
    - calibGen_flt
  - Protons
    - Best range only
    - DGN_GEM filter
  - GCR Heavy Ions
    - Continuous
    - 4-range

- “MIP” spectra: How do we use them?
  - Not really MIPs
    - Most are highly relativistic
      - dE/dx increases logarithmically with incident energy
    - Splash and albedo protons can be lower energy and slow down as well
      - dE/dx increases rapidly with decreasing energy
    - Fe slows down in CAL
      - Only important at large incident angles
  - So how do we account for dE/dx variations?
    - dE/dx depends on incident energy
    - Hence, depends on incident spectrum
    - No incident energy measurement =>
    - We must integrate over incident spectra
    - => SIMULATIONS!
      - Energy deposit spectra
      - Systematic uncertainties
        - » Due to uncertainties in incident spectra, overall procedure
        - » Almost certainly small

– Procedure

- Simulate proton, GCR flight inputs
  - Must include dL/dE effects to produce “E/M shower equivalent” energy deposit
  - “Big Run” backgrounds lack this feature
  - GCRcalib outputs for heavy ions
  - Need code to filter MIP and DGN_GEM output for protons, He
  - MC truth or TKR to determine path length (?)
  - Analyze resulting dE/dx spectra (proton Landau and GCR sorta-Gaussian peaks) for most probable value of E/M equiv. deposited energy
    - » Fit simple model to peak region only
    - » Experience has shown this procedure to be relatively stable
- Critical to use similar sampling of incident spectra in sim. and data
- Result is an energy to associate with measured MPV for each species

Calibration Procedure

- Preflight
  - Produce dL/dE (E,Z) models for inclusion in sim
  - Simulate incident proton, He, GCR spectra to determine MPV energies
    - Including dL/dE
  - Investigate effects of systematic uncertainties in dL/dE on representative source spectra (pulsars may be easier to interpret)[David Smith]
    - Vela?
    - Crab?
    - Geminga?
- L&EO and Flight Ops Data Collection
  - Charge injection
    - calibGen_flt
    - L+15
    - ~4/yr during flight ops
  - Collect GCR heavy ions continuously
    - Starting ~L+15
    - 4-range
    - GCRcalib
  - Collect protons and He
    - MIP filter L+24 – L+26 only
    - DGN_GEM filter continuously
    - Best range only
    - Need mods to GCRcalib code or something else for analysis

- Energy Scale Calibration Sequence
  - Charge injection (calibGen_flt) analysis
    - Std calibGen analysis
    - Produce nonlinearity calibration products
  - Produce filtered proton, He and heavy ion datasets
    - GCRrecon and GCRselect
    - GCRselect.root outputs
  - Proton MevperDAC calibration
    - Calibrate LEX8 with protons
      - As with muons
    - Calibrate LEX1
      - Use known “8:1” ratio (actually ~9:1) measured by CI
      - Can’t use protons directly due to best range output
    - Use CNO heavy ions to intercalibrate LEX and HEX
      - 4-range makes this possible
      - dL/dE not an issue
      - HEX8 calibrated directly
      - HEX1 calibrated via known ratio

- GCR Heavy Ion MevperDAC calibration
  - Use He, heavy ions for direct calibration of LEX, HEX
    - Mean of MevperDACs from each species
    - Requires dL/dE
    - Consistency of parameters from each species is an early test of:
      - » dL/dE
      - » fitting techniques
      - » Differences in data cuts, orbital integration between sims and data
  - Allows fit of calibration to multiple points plus consistency tests
  - Rates about same as proton

- Compare Proton and HI Calibrations
  - Repeat of GSI analysis
  - Integrated over incident spectrum for "many" orbits
  - If dL/dE functions disagree with GSI, reconstruct to match flight results
- Check calibrations by examination pulsar spectra
  - Crab, Vela, Geminga?
  - Pulsars avoid bkgd issues
  - Confusion with Aeff systematics
  - At what level does this indicate a problem?
  - Indicator only – do not calibrate from celestial source spectra!

- Reserve decision on which method is primary until examination of results
- To maximize usable rates, use both methods for calibration monitoring

- Asymmetry Calibration Sequence
  - Similar to existing asymmetry calibration process
  - Use protons, HE, HI for LEX
  - At least initially, use same 10 slices as on the ground (ignore end slices)
  - Use HI for HEX
  - Use CNO for LEX/HEX
    - C deposits 400 MeV
    - O deposits 720 MeV
    - Both visible in LEX1 and HEX8
  - Use TKR tracks to define actual positions
  - Slight mods to calibGenCAL required
    - Some muon-related assumptions about expected channels must be made smarter

- Collection Time Requirements
  - Answer to this question really requires simulations
    - Big run should be usable for this since dL/dE is not important
    - Care needs to be taken to assure orbit integration
  - Current best estimates are from Fred's Aug 07 talk:

Ion	Incident (Hz)	Trig Eng 4 (Hz)	HIP (Hz)	GCRselect (Hz)	Time to 1000/xtal (Avg; days)
C	2	1	0.8	0.6	0.5
N	0.5	0.3	0.2	0.1	2.8
O	2	1	0.6	0.4	0.7
CNO					0.25
Ne	0.3	0.2	0.08	0.05	5.6
Mg	0.5	0.4	0.1	0.07	4.0
Si	0.4	0.3	0.08	0.05	5.6
NeMgSi					1.6
Fe	0.4	0.4	0.02	0.01	28
Total	6.2	3.6	1.9	1.3	0.2

- Proton Collection Times
  - MIP mode
    - ~100 Hz raw
    - ≥ 10 Hz after calibGenCAL cuts (rather strict)
    - ~200K sec during L&EO
    - ≥80K events/xtal during 3-day test
    - Depends on whether off-axis or all-axis mode chosen
    - More than adequate for MevperDAC and Asymmetry
  - DGN_GEM mode
    - ~1-3 Hz after cuts (very approximate)
    - ~3K – 9K events/xtal-day
    - Adequate for MevperDAC and Asymmetry in ~day