# Discussion of ADC board requirements

Not a set of prescriptions!

A starting point for discussion of physics NEEDS

relating to the ADC and trigger.

# Outline

- CDR: ELECTRONICS SYSTEM REQUIREMENTS
  - Define what these numbers mean for spectroscopy
- ADC issues
  - Observed issues
  - Link between ADC linearity and ADC range
  - ADC overflow causes
  - Mitigation strategies depend on cause and need
- Trigger
  - Fast trigger with defined terms
- Discussion of key questions

### Electronics System Requirements

- Deliver digital signal processing electronics to instrument 30 Quad Detector Modules, capable of digitizing detector preamplifier signals at 100 MHz sampling frequency, over a dynamic range up to 25 MeV, maintaining the intrinsic detector energy resolution of $\leq$2.5 keV (FWHM) at 1.33 MeV.
- Ensure integral (differential) non-linearity $\leq \pm$ 0.01% (1%) as measured in the final energy spectrum with a nominal gain of 0.3 keV/channel over 10 MeV.
- Ensure synchronous ADC sampling across the array.
- Provide a global timestamping mechanism to allow event reconstruction including external detector systems.
- Provide real-time energy and timing filters and waveform windowing.
- Provide a trigger system capable producing a fast trigger output ($<$ 500 ns) to auxiliary detectors, identifying physics events for readout and incorporating trigger inputs from external detector systems.

# CDR numbers meaning for spectroscopy

- Dynamic range “up to 25MeV”
  - Preamplifier voltage output range in which signals could be measured
- Final energy spectrum: 0.3 keV/channel, 0-10 MeV
- Integral non-linearity [INL](<= 0.01%) >>> 10000keV*0.01% = 1keV
  - Up to +/-1 keV deviation anywhere in 0-10MeV spectrum
- Differential non-linearity [DNL](<= 1%) >>> 0.3 keV/ch *1%=0.003keV/ch
  - Channel width may vary up to 1% >>> counts vary <= 1% systematic
- Relation INL<->DNL >>> 1keV/(0.003keV/ch) = 333ch
  - 1keV max calibration deviation (INL) must occur slowly due to DNL
  - 1keV variation takes at least 333 channels >>> 333ch * 0.3keV/ch = 100keV
- INL and DNL set limits, not average behavior. Multiple deviations could occur in spectrum with or without a pattern
- Effective requirement, <=2.8keV FWHM @1.33MeV (at rate)
  - Also constrains INL condition

# GRETINA lessons: ADC linearity (and fidelity)

- Linearity effects
  - Shifts peak positions relative to linear (typically asymmetric sawtooth residuals)
  - Can produce peak shoulder or doublet (for some, not all peaks)
  - At higher rates, peaks shift with baseline (becomes complicated)
    - Broadens peaks, can cause doublets or tails to high or low energy
  - ADC STEP scale problem >>> Smaller spectrum effects from smaller kev/ch
- Fidelity
  - Issues beyond static ADC channel width variation
  - Observed time-structure to some problems
  - Energy resolution at rate depends on Pole-Zero math accurately describing the waveform
    - Signal = sum of exponentials
- Must TEST ADC thoroughly!
  - signal=expectation, exhaustive pulser tests, and real preamp signals at varying rates

# GRETA needs

- Select best ADC for GRETA use case
  - Requires testing (my problem) and knowledge of REQUIREMENTS (your input)
- In the absence of a perfect, economical, low-power ADC,
  - Choices, tradeoffs, mitigation of problems, maximize physics reach
  - All ADCs will have some nonlinearity
  - The effect on the spectrum will scale with gain/range, i.e. keV/ch or total MeV
- Spectrum nonlinearity ~ (ADC step nonlinearity) * (energy range)
- The #1 question I have for testing ADC & building Digitizers:
  - <u>What energy range(s) are actually needed and why?</u>

# How to chose ADC range and preamp reset ?

- Biggest gamma-ray to observe  <= your physics
- Energy deposition distribution and rate <= your physics + background
  - Need gamma spectrum emitted or energy spectrum measured
  - Need rates
  - Energy deposited + Rates + Statistical simulation >>>     predicted baseline distribution
- Protons (light charged particles)
  - Observed at S800
  - Bigger issue at HRS – forward angles populated
  - 10’s MeV deposited in core and one-few segments
- Which mitigation strategies will work for various cases
- Do all energies need “best” obtainable resolution?
  - If someone studies a 12MeV gamma, do they care if the resolution degraded?
  - How much degradation is acceptable?

# Related: ADC Overflow

- Overflow depends on both past gamma tails and current gamma amplitude
- Sources
  - Many gammas (e.g. 1 MeV) stack-up in a short time period ($\tau_{preamp}$ = 50 $\mu$s)
  - One high energy gamma, >10MeV
  - One high energy particle
- Mitigation Strategies
  - Wait => dead time    Overflow time + Filter restart/recovery
  - Segment sums
  - Time-over-threshold
  - Resistive preamp + pulsed reset

# ADC Non-Linearity Mitigation Strategies

- Channel-scale issue => maximize channels per keV, Minimize Range
- Tailor to signal polarity
  - Gretina has +/- 10MeV segment ADCs
  - One might change that to -2MeV to 10MeV, reducing non-linearity by 40% in energy
- Have multiple ADC ranges for same signal
  - Buffer Amp copies signal faithfully
  - Telescoping Ranges as in Gretina: 2.5, 5, 10, 30 MeV
  - Stacking Ranges
    - Shifted ranges with small overlap
    - Each ADC covers same energy delta
    - E.g. 0-10, 9-19, 18-28 MeV

# ADC Non-Linearity Mitigation Strategies

- Calibration of ADC step heights
  - Depends on static vs. dynamic effects
  - Depends on stability of non-linearity as a function of conditions and reset
  - Perhaps correct some subset of similar, large-problem channels
  - Must be done at 100MHz, or in parallel to energy filter, on FPGA
- Imposed signal
  - Think Dither or Gatti slider
  - Adding a known, varying signal in analog and subtracting it in digital
  - Depends on distribution of non-linearities and added signal quality
- Offset signal
  - Conditionally subtract an offset in analog to allow expanded effective range for ADC

# Triggering

- Fast output
  - Current goal: < 500 ns
    - For energies above 500keV.  Lower E: walk dominates
    - Simple crystal multiplicity only
    - MEANS: pulse from trigger system relative to gamma ray waveform on oscilloscope
  - Needs?
- Slow filters
  - Energy sum on ~1$\mu$s integration
  - CFD
  - Hit pattern / estimated multiplicity
- Interaction with Aux. devices
  - Send and accept clock and triggers
  - Form of communication TBD

# Discussion (focus areas)

- People to get us started
  - Fast beam + spectrometer: Dirk Weisshaar
  - Slow beam + spectrometer: Darek Seweryniak
  - GRETA standalone: Mike Carpenter
  - Slow beam + Aux: Walter Reviol
- GRETA electronics requirements to consider:
  - Triggers required for physics [event readout trigger]
    - Functionality and inputs needed
    - Acceptable trigger latency
    - Rates
  - Specs desired/needed for “fast” trigger
  - ADC ranges? For CC & segments
    - Energy deposition during experiment, rate and distribution