ACD High Range – operation and flight calibration

Outline

1. ***Introduction to ACD High Range***
2. ***High Range Tasks***
3. ***High Range Calibration – how to perform it: template for 1 ACD channel***
4. ***Illustration of flight data***

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Introduction

What is the ACD High Range?

☐ Each of 194 ACD channels (PMT) has two ranges – Low and High.

☐ Low Range is the ACD main operation mode, which covers the signals from ~0.05 mip to 4-8 mip (varies from channel to channel). This is the range where the single *mip* signal is, the main ACD objective

☐ High range covers the range from 4-8 mip (starting from the point where the low range ends) up to several thousand.

☐ Switching from Low range to High Range occurs automatically when the signal exceeds the upper end of Low Range; bit in AcdRange[ ] variable changes from 0 to 1

☐ Both ranges are 4096 ADC bins

☐ Important – Low Range is very linear, and has been calibrated many times; High Range is very nonlinear, and has never been directly calibrated. The electronics calibration for High Range was performed with light pulser (simulating input light signal to PMT)

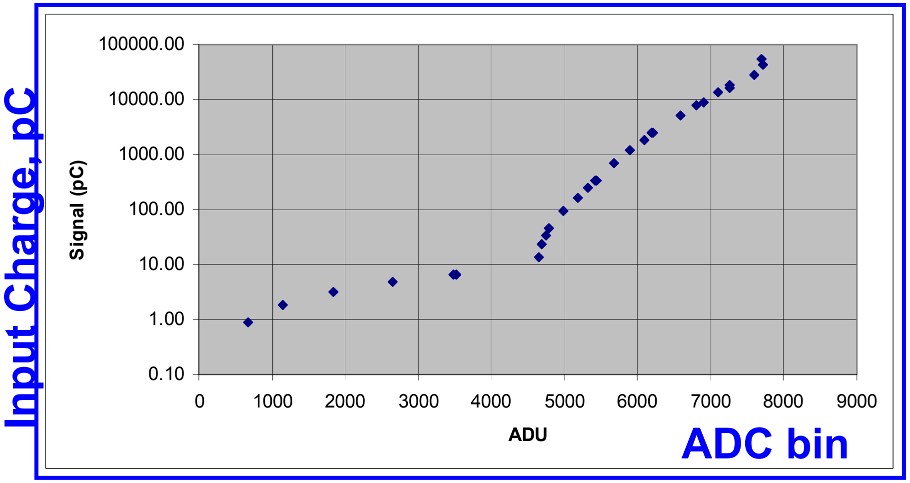
Introduction (cont.)

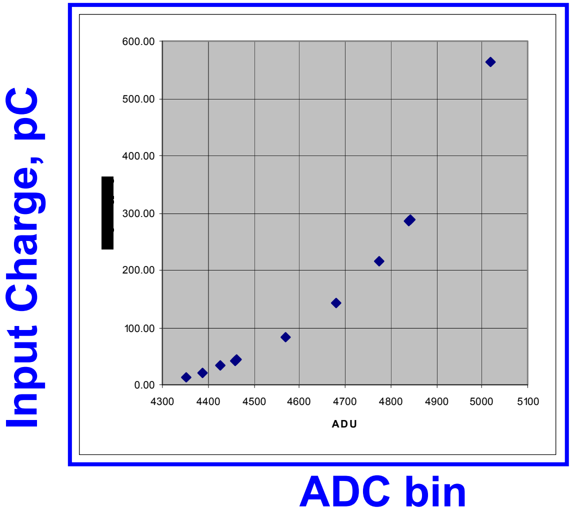
Why there is a problem with High Range calibration?

☐ this range has always been of the low priority for ACD group; its role in LAT is to signalize the arrival of the CR nucleus when the energy deposition in ACD tile is more than 15-20 *mip*. Pulse height analysis (PHA) for these signals is supplementary

☐ Scintillator response to the high-Z nuclei suffers from quenching effect, which is not well measured for large range of Z for plastic scintillators

☐ Electronics for High Range is nonlinear, and gain differs from channel to channel





Examples of High range electronics response

1 *mip* corresponds to ~1 pC

What needs to be done with ACD High Range?

1. **Main task (Task 1)** – provision of the "CNO" threshold values for the LAT onboard setting. Since the response of HighRange is nonlinear to the energy deposited in the tile, we have to use the units of A, or Z (atomic number of the element), rather than *mip*
2. **Supplemental task (Task 2)** – determination the Z of the particle passed through the ACD, and consequently what was the element (nucleus)

Note: when we say PHA, we mean the most probable value for given injected charge

To fulfill these tasks we need to know the dependence PHA_{high} vs. Z for each of ACD channels (top and two upper row tiles only)

HighRange PHA pedestal values – updated values will be available from in-flight run of ACD Pedestals script

In this presentation we will use channel 0-002 as an example and build a template how to do the calibration. ***The same procedure will have to be repeated for each of ACD channels***

Step 1. Low Range

Use:

a) single *mip* position in Low Range PHA_{mip}, known from particle calibration (corresponds to Z=1),

b) PHA vs. injected charge (C), known from light pulser bench calibration

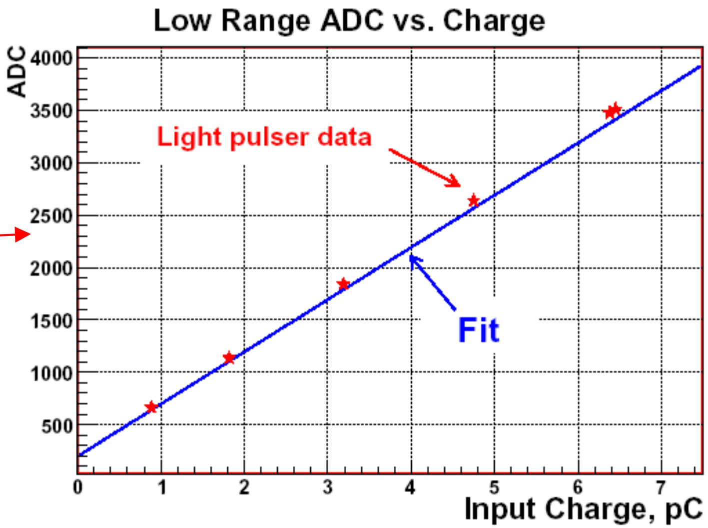
c) Highly linear response for Low Range

d) Voltz formula for C(Z)

Find: PHA vs. Z dependence for Low range

Pedestal P_{low} = 195

$PHA_{Z=1}$ = 425 (after pedestal subtraction)



- **From light pulser calibration:**

$PHA_{low}(C) = 498.7 \times C + P_{low}$

- **From this find:**

$C_{Z=1} = PHA_{Z=1} / 498.7 = 0.852\ \mathrm{pC}$ **! This is a key step – single mip calibration**

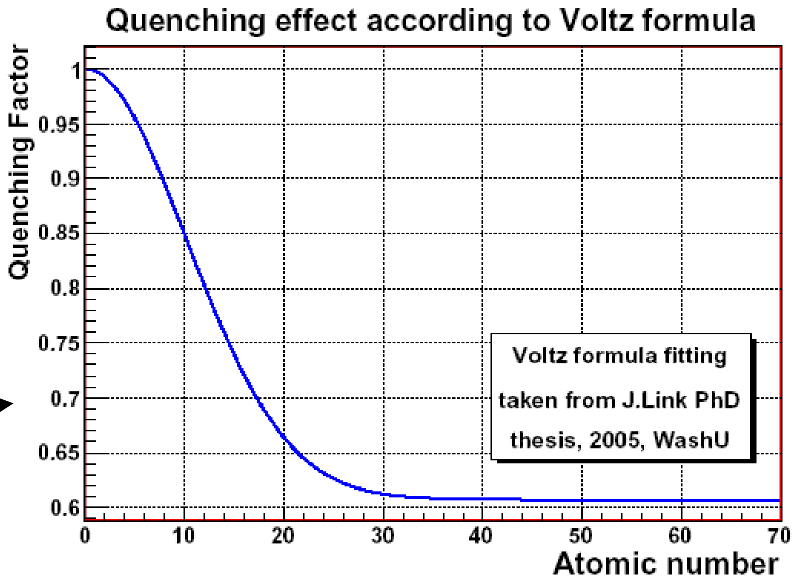
- **Voltz (fitted by J. Link) formula:**

$C_V(Z) = 0.608Z^2 + 0.393Z^2 \exp(-0.00483Z^2)$,

- **and now we can obtain the searched expression:**

$$PHA_{low}(Z) = 498.7 \times 0.852 \times C_V(Z) + P_{low}$$

Plot of quenching factor for plastic scintillator, obtained by Voltz fitted formula (J.Link)



Step 2. High Range

Use:

a) PHA_{high} vs. injected Charge (C), known from light pulser calibration

b) Voltz formula for C(Z)

Find: PHA vs. Z dependence for High range

From light pulser calibration:

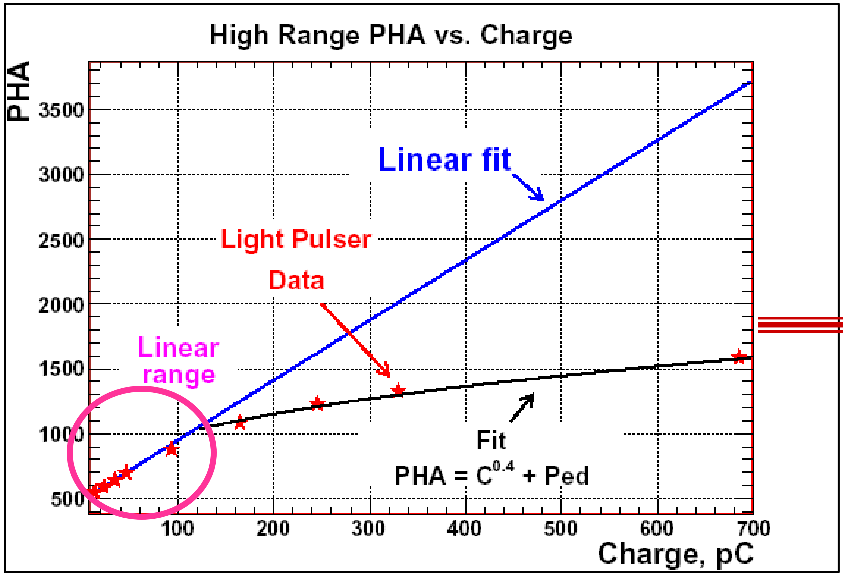
$$PHA_{high}(C) = 4.63\times C + 485 \qquad (1)$$

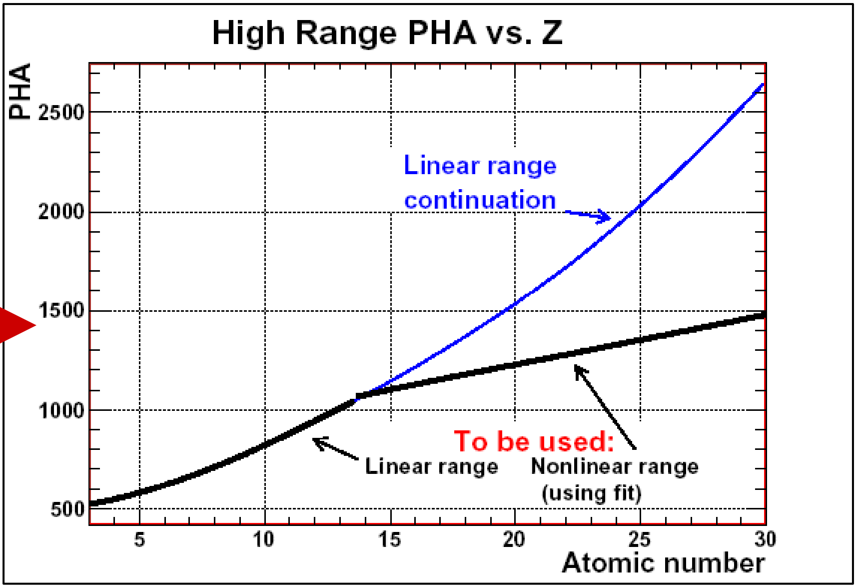
and

$$PHA_{high}(Z) = 4.63\times 0.852\times C_V(Z) + 485$$

This expression is valid only in the linear range of High Range response, where (1) is valid

Now let's check what is happening in the reality:





From this figure we see that PHA is linear to the C up to ~ 100 pC

For higher C the fit PHA≈ 80× $C^{0.4}$ + Ped can be used

Applying Voltz fitted formula, we see that linear range extends to Z ≈13

Black line shows the searched dependence

Conclusion:

For channel 0-002 we found:

$$PHA_{high}(Z) = 3.945\times [0.608Z^2 + 0.393Z^2 \exp(-0.00483Z^2)] + Ped \quad \text{for } Z < 13$$

and

$$PHA_{high}(Z) = 80 \times [0.608Z^2 + 0.393Z^2 \exp(-0.00483Z^2)]^{0.4} + Ped \quad \text{for } Z > 13$$

Example of solving Task 1: **If we want to set a CNO threshold at Z=4, we have to set it at PHA = 61 + Ped, or 546 for channel 0-002. The calibration of DAC setting vs. PHA is a separate issue (Eric Charles)**

✓ We should be able to provide the values for CNO threshold setting (according to desired Z threshold value) without flight calibration with CR. Note that the accuracy of CNO threshold is not high (I think ±0.5 of Z)

Illustration to the Task 2

We can expect the elements to peak in the following PHA bins:

Element (Z)	**C (6)**	**N (7)**	**O (8)**	**Ne (10)**	**Mg (12)**	**Si (14)**	**S (16)**	**Ca (20)**	**Fe (26)**
Cosmic Ray relative abundance (Protons = 1000)	**3.8**	**1.0**	**3.5**	**0.6**	**0.73**	**0.54**	**0.12**	**0.085**	**0.42**
Number of events for single top tile, ~normal incidence, for 1 year	**4×10^5**	**1×10^5**	**3.6×10^5**	**6.3×10^4**	**7.6×10^4**	**5.5×10^4**	**1.2×10^4**	**8.8×10^3**	**4.3×10^4**
PHA peak (ped. subtr)	**133**	**177**	**226**	**336**	**457**	**592**	**645**	**746**	**897**
Peak width, σ, bins	21	26	34	47	60	70	73	75	80

- **Peak width is estimated from GSI-2006 beam test, where we determined $\sigma=0.16$ for Carbon, and $\sigma=0.026$ for Xe. Assuming that width is linear depend on the PHA peak,**

$$\sigma=0.16-9.18\times10^{-5} \times (PHA-133)$$

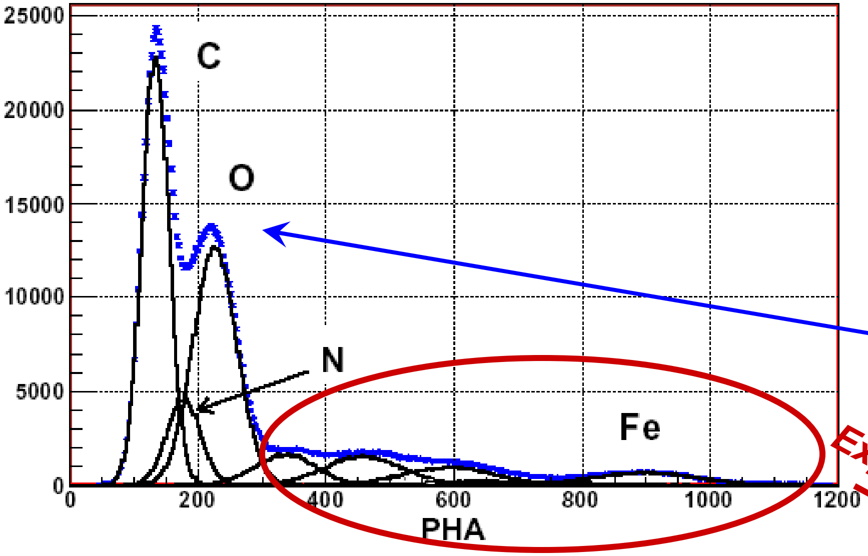
- **Number of events is estimated assuming:**

– **$G=6.7\times 10^{-3}$ m^2sr for single tile and quasi-normal incidence events**

— **proton integral flux above 5 GeV is 500 m^{-2} s^{-1} sr^{-1}**

– **cosmic ray abundance data**

Cosmic Ray abundance spectrum for single tile, 1 year



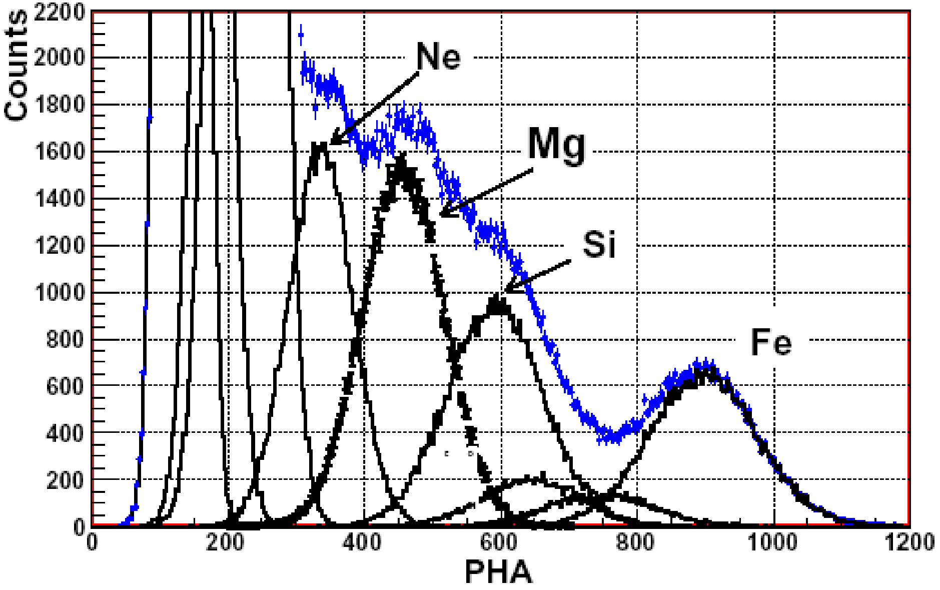
1 year of observation

Single tile

Quasi-normal incidence

Blue line is the total signal

Exploded Fe range



- This is what we expect relying on light pulser calibration data. It has to be calibrated with cosmic rays
- The C, O, Mg, and Fe will be the main calibration points
- Ne and Si can also be useful