

AHCAL Time Walk Dependencies and Corrections



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Hit time dependences on:

- hit energy
- occupancy/cell#
- beam crossing
- low/high gain

Timing and resolution

This work was supported by
NSERC and DAAD
and hosted by MPP



AHCAL

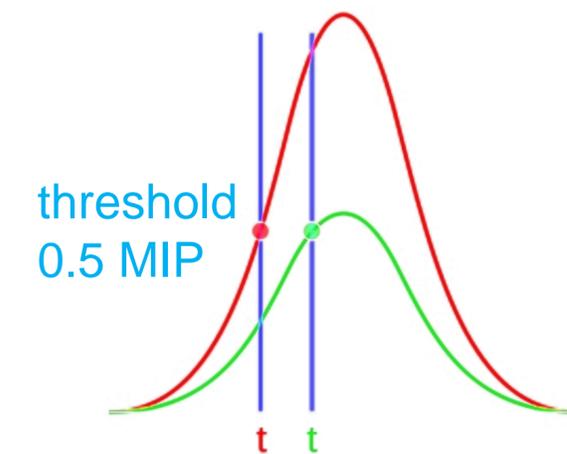
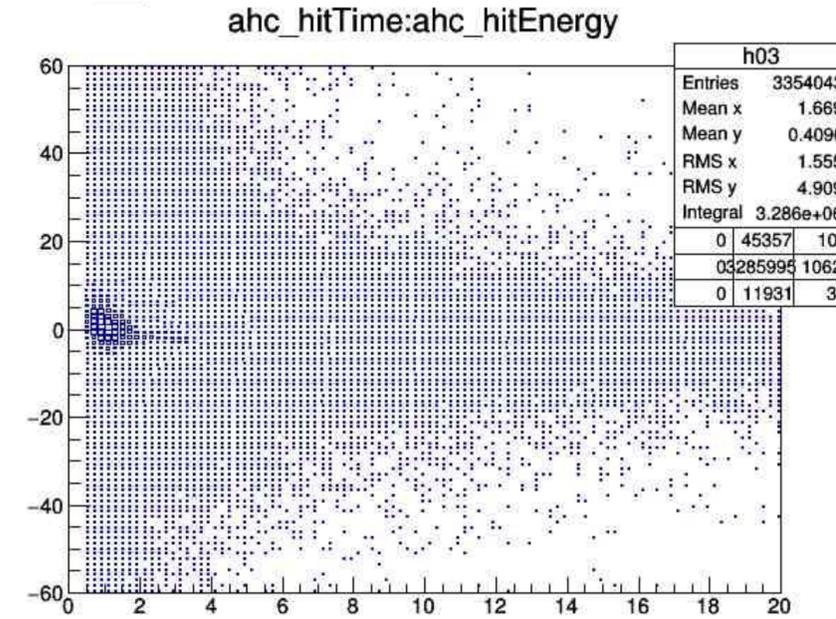
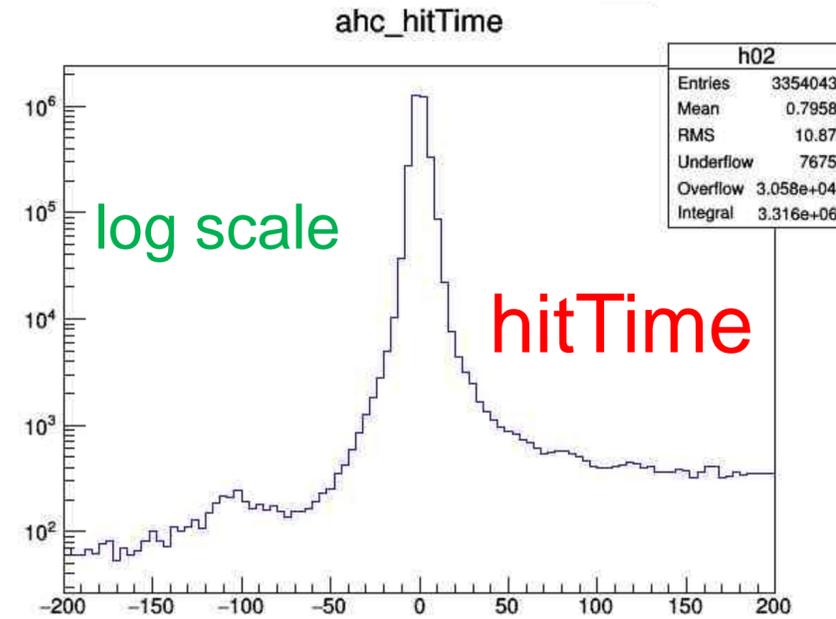
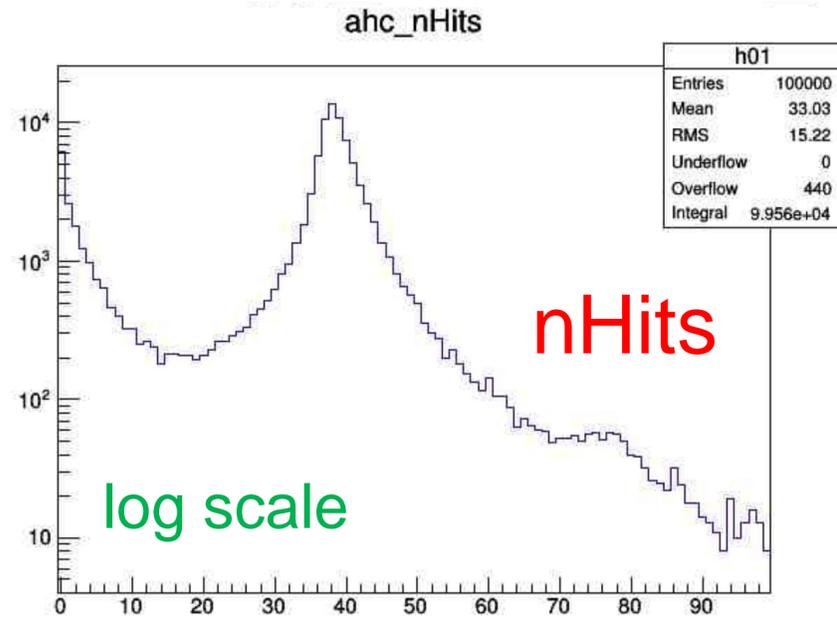
Each AHCAL cell hit by particles provides energy deposition and time information.

Main datasets available by Lorenz for this study (May-July 2019):

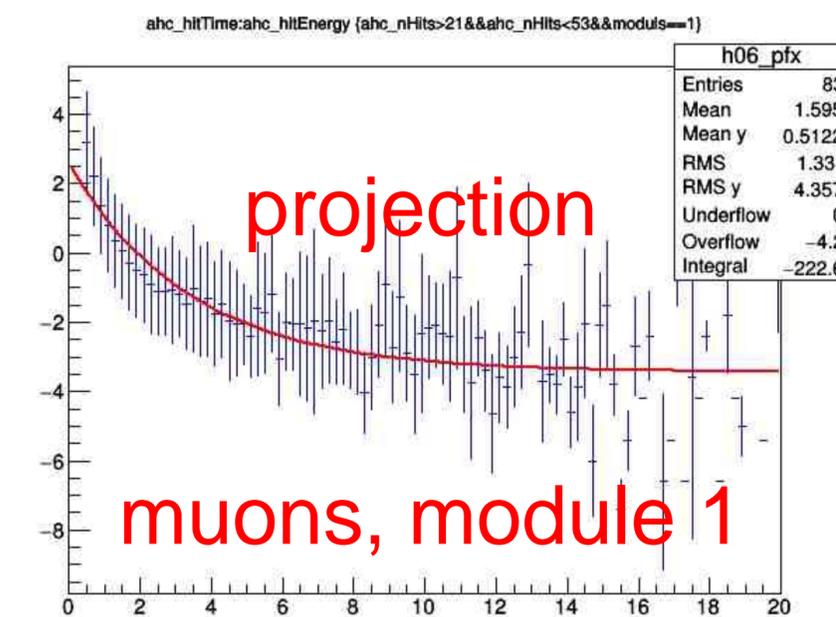
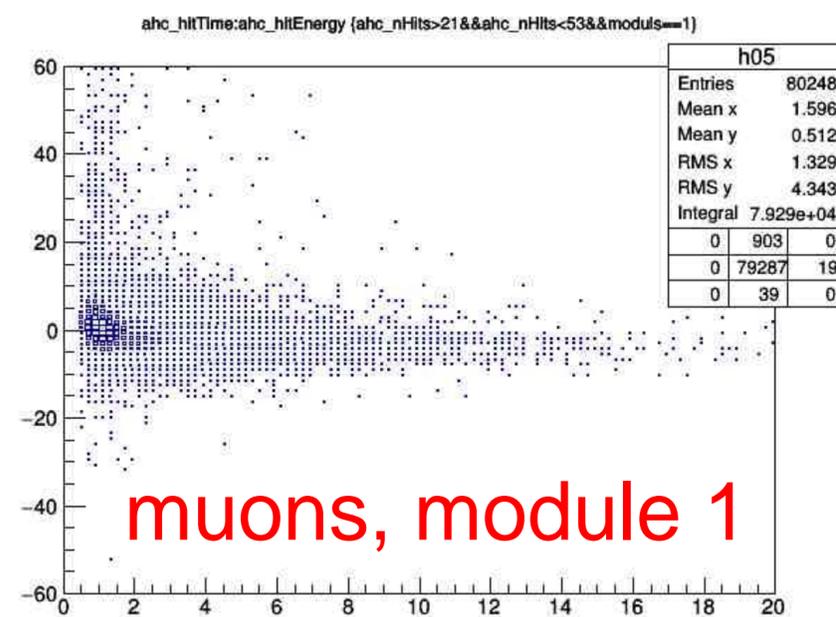
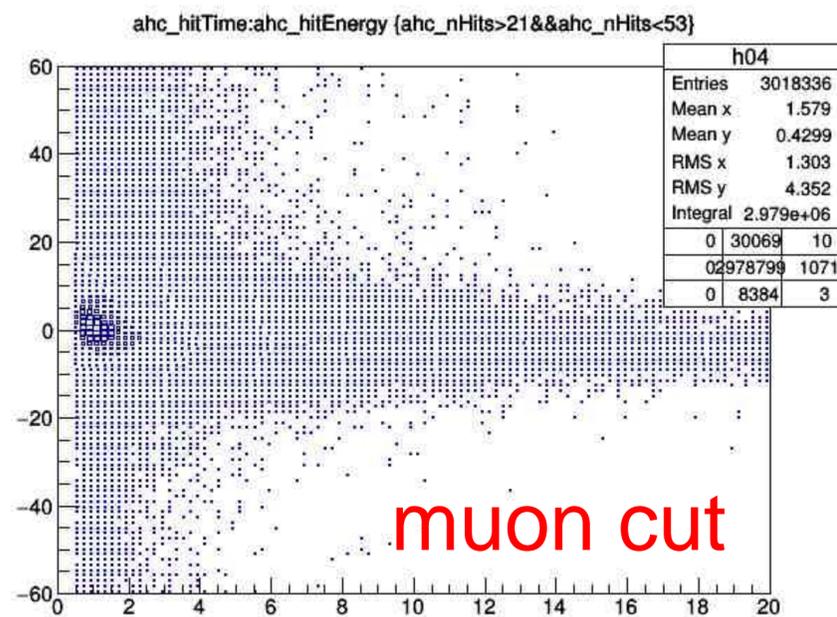
pions	reco_pion_n40GeV.root reco_MC_40GeV-Pions_scan_0ns.root	uncorrected time old format
muons	reco_run60382.root reco_run60382_testNewConstants.root	uncorrected time corrected time
electrons	reco_run60512_testNewConstants.root	corrected time

“End User” type of analysis: investigate the data contents.

Muons available with corrected times



hit Time vs hit Energy
[-30,30]ns [0,20]MIP

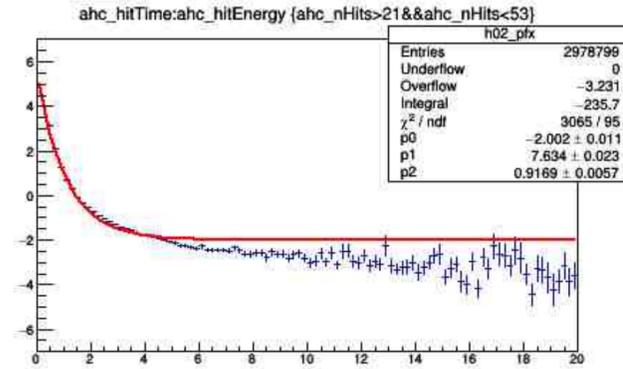
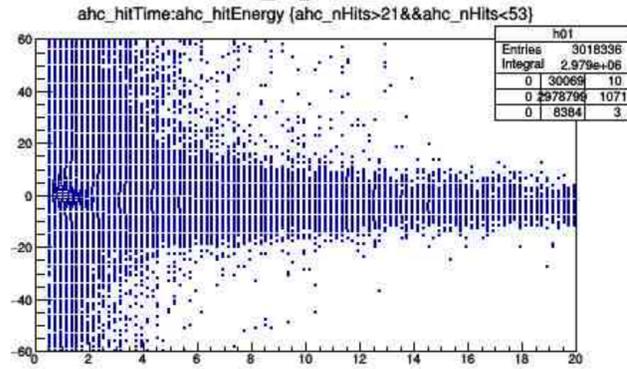


$$f_{01}(x) = a + be^{-cx}$$

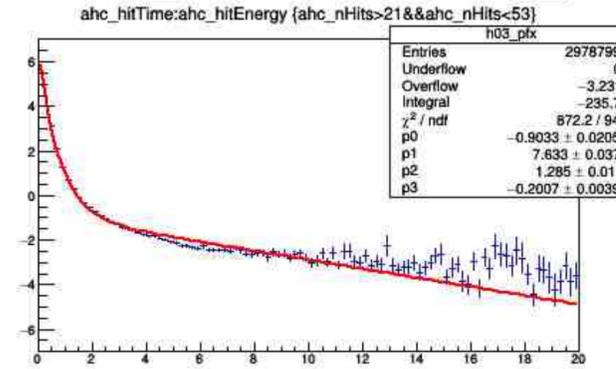
clear time walk observed
as function of hit energy
(error bars on plot not ok).

Functional Forms

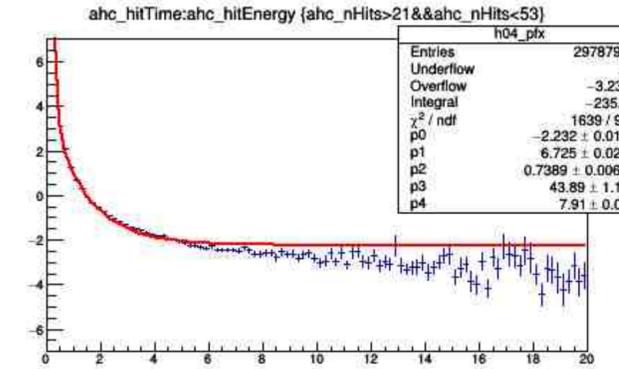
Muons: Time walk vs hit Energy [0-20 MIP]



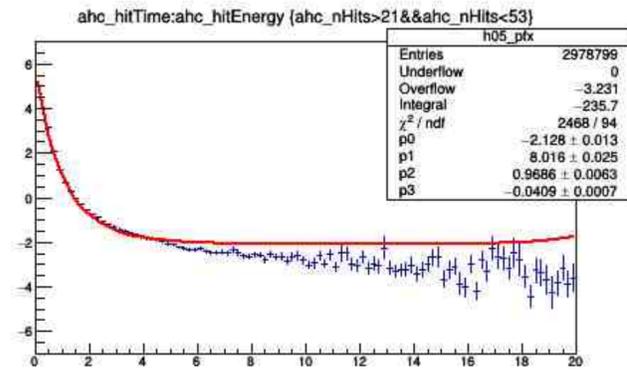
$$f_{01}(x) = a + be^{-cx}$$



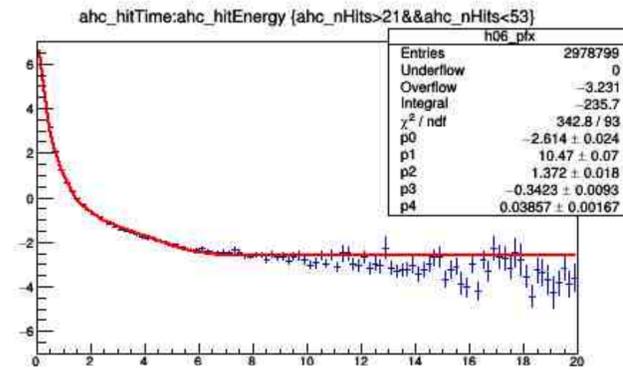
$$f_{02}(x) = a + be^{-cx} + dx$$



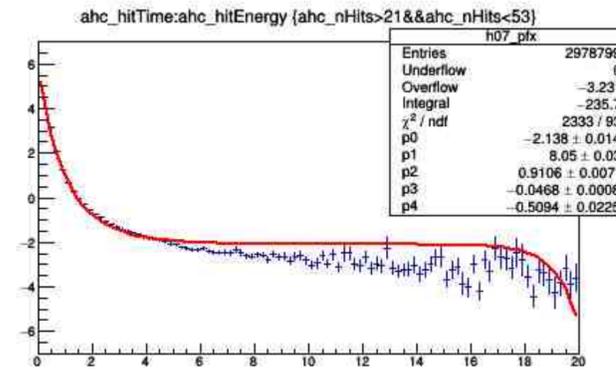
$$f_{03}(x) = a + be^{-cx} + de^{-ex}$$



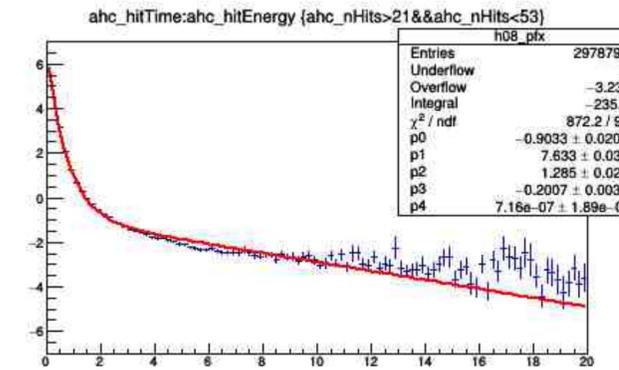
$$f_{04}(x) = a + be^{-cx-dx^2}$$



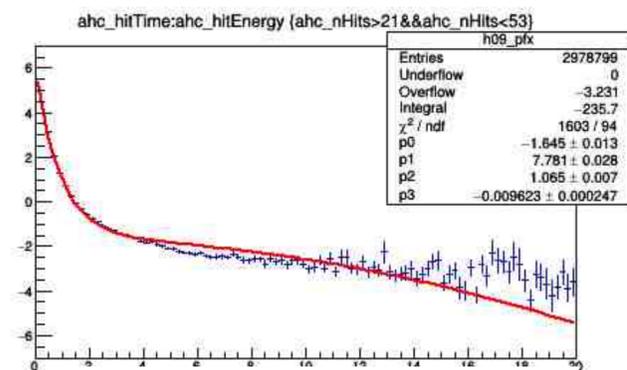
$$f_{05}(x) = a + be^{-cx-dx^2-ex^3}$$



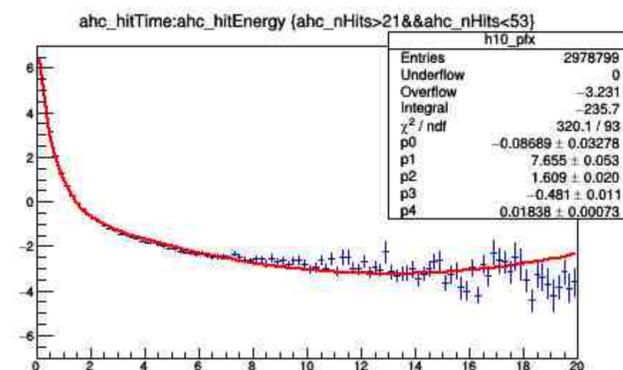
$$f_{06}(x) = a + (b + dx)e^{-cx-ex^2}$$



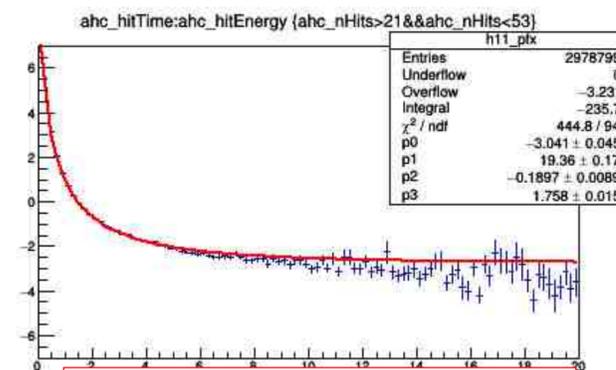
$$f_{07}(x) = a + (b + dx)e^{-cx} + ex$$



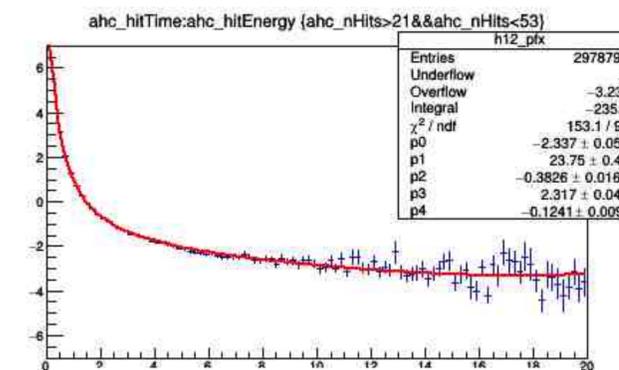
$$f_{08}(x) = a + be^{-cx} + dx^2$$



$$f_{09}(x) = a + be^{-cx} + dx^2 + ex^3$$



$$f_{10}(x) = a + be^{-cx-d\sqrt{x}}$$

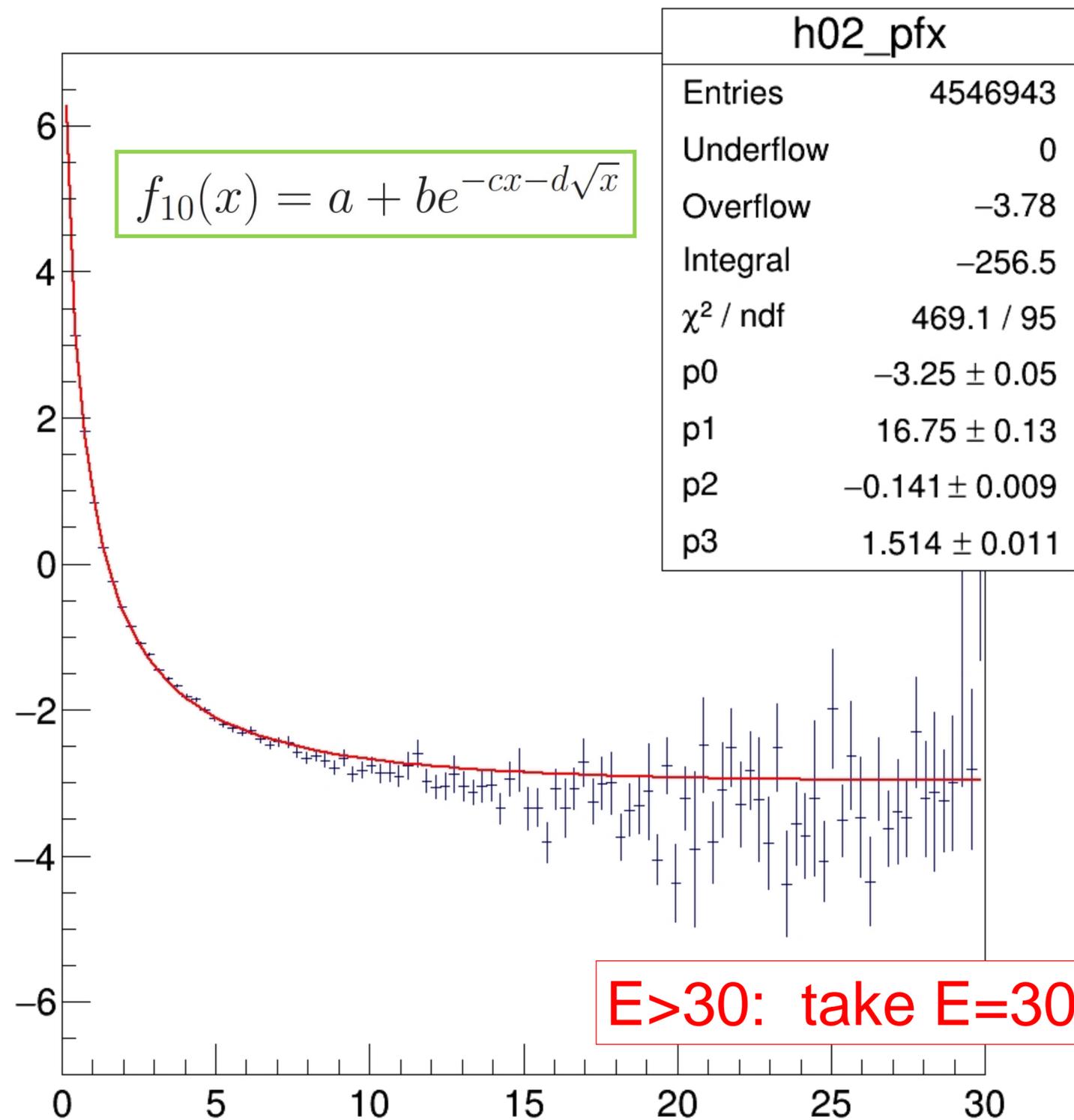
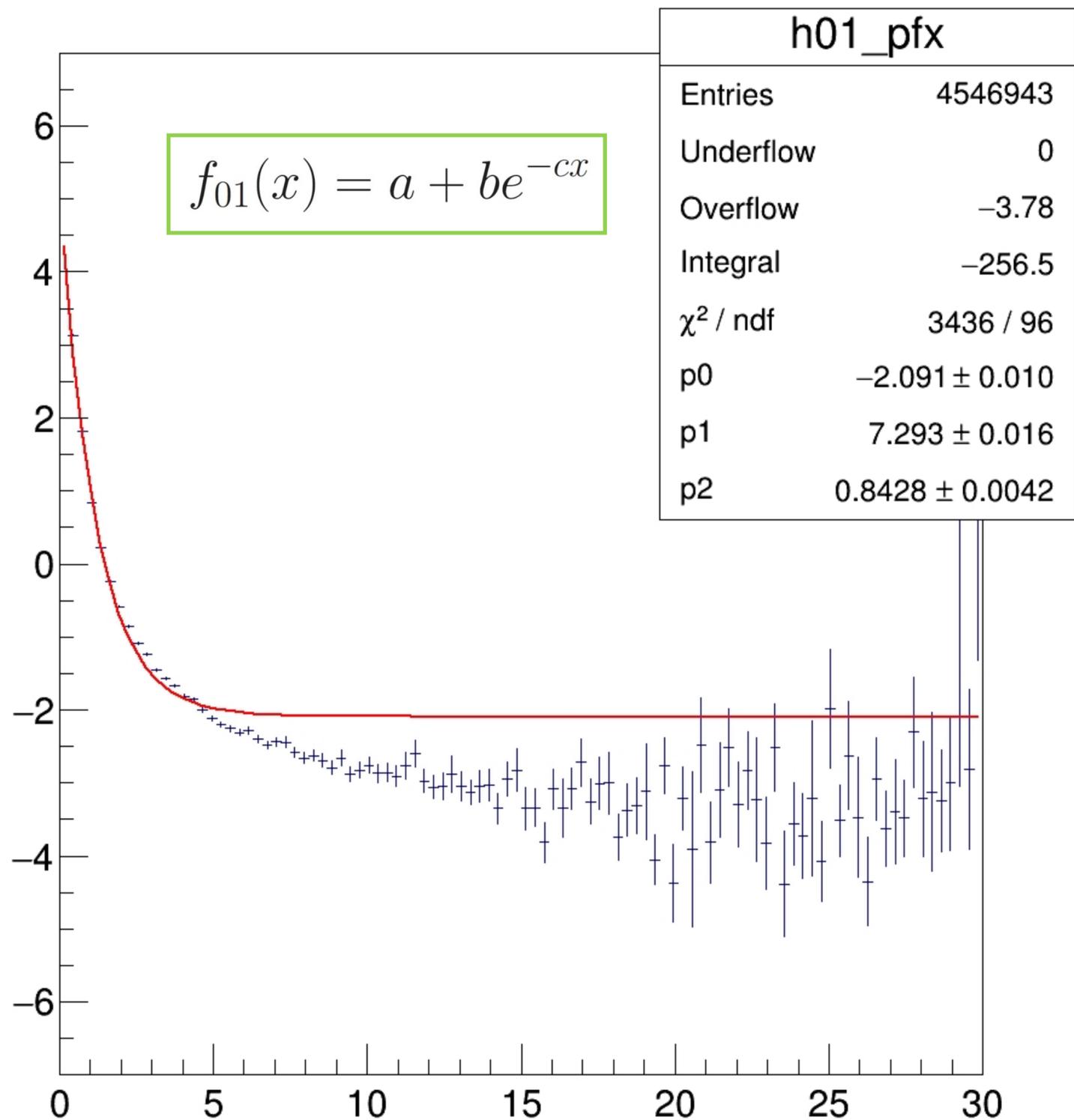


$$f_{11}(x) = a + be^{-cx-d\sqrt{x}} + ex$$

Form 1 ~ok until 8 MIPS.

Form 10 better behaved and robust.

Functions



E>30: take E=30 value

Muon Hits – Time vs Energy per channel

(integrated over modules and chips)

38 modules
 16 chips/module
 36 channels/chip
 16 cells/channel

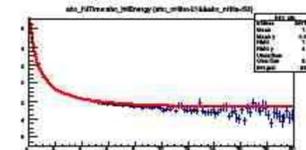
$$f_{10}(x) = a + be^{-cx-d\sqrt{x}}$$

Integ'd per module or
 per chip also done:
all plots very similar.

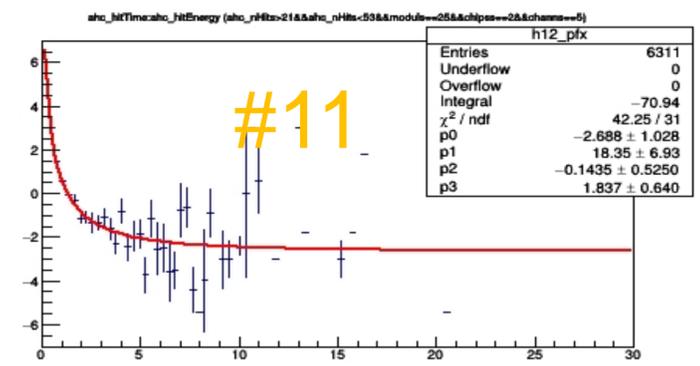
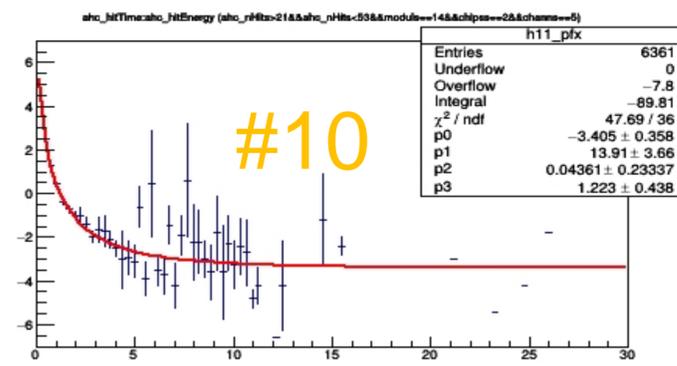
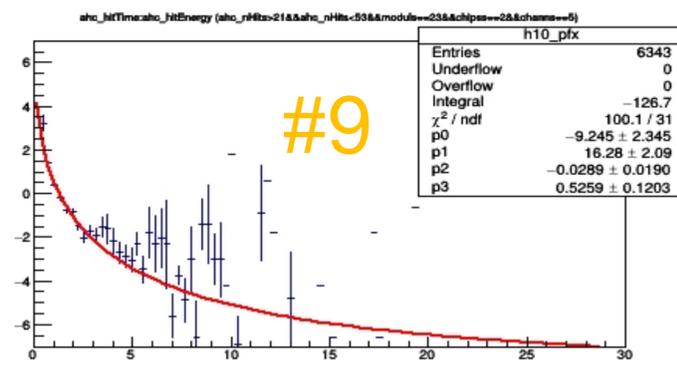
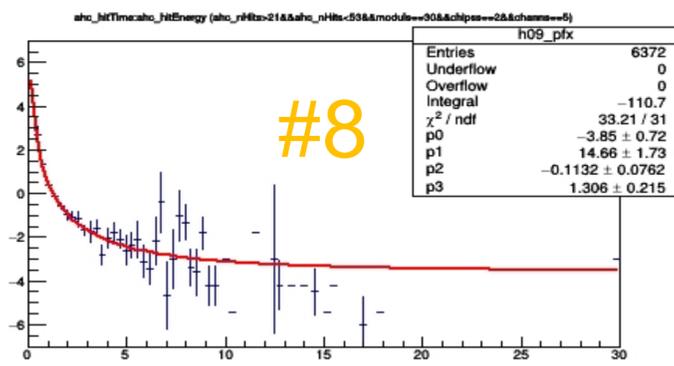
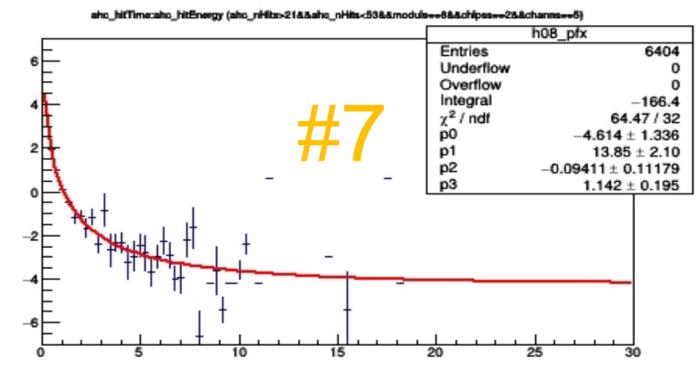
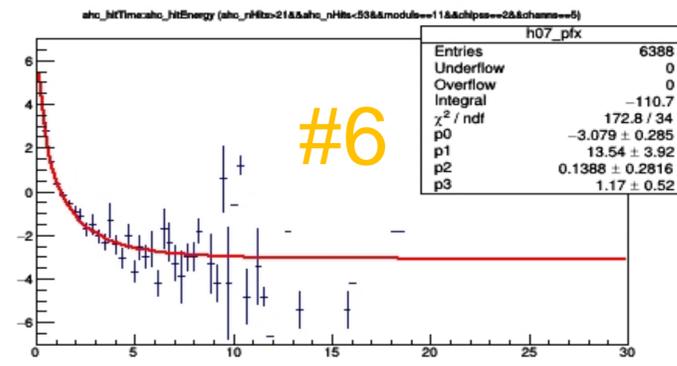
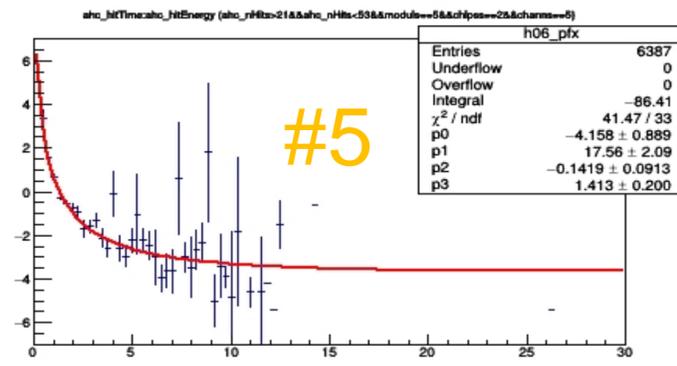
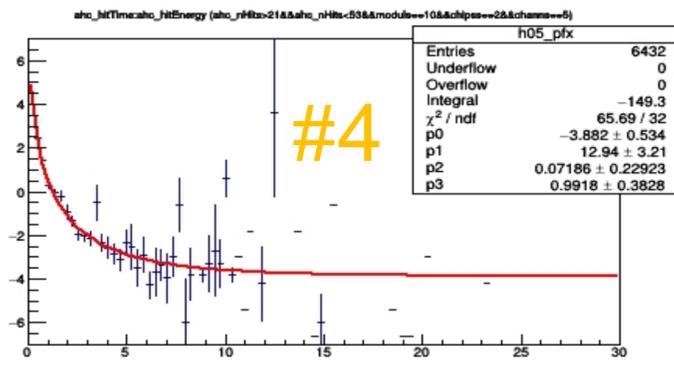
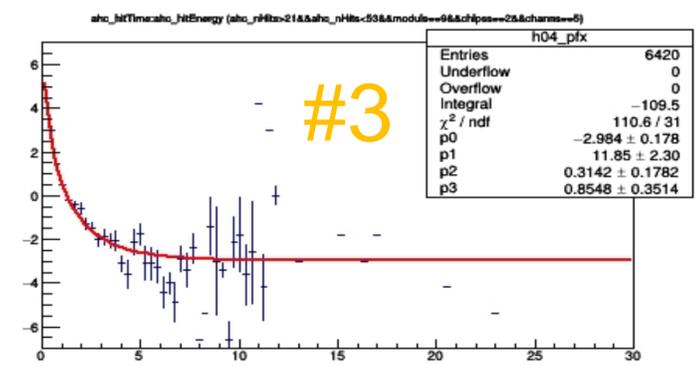
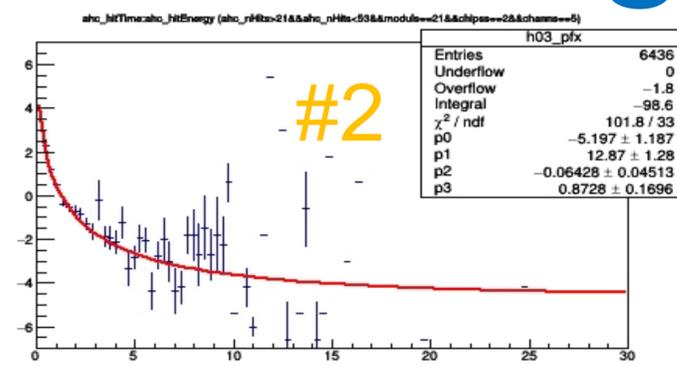
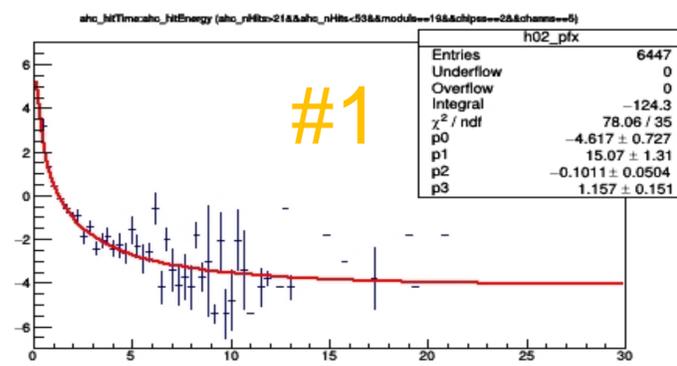
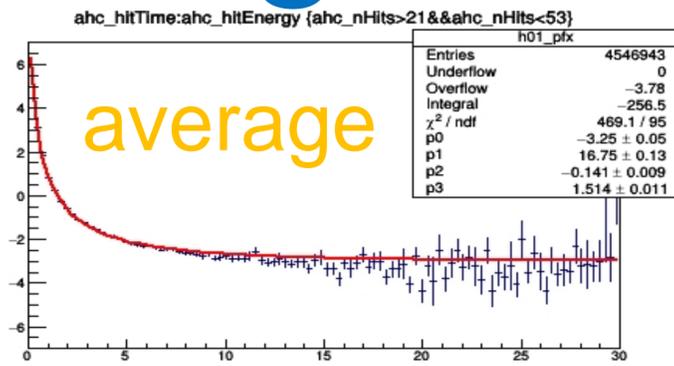
For single channels:
 (38x16x36=21888), done
 but not enough statistics.

[0-20 MIP]

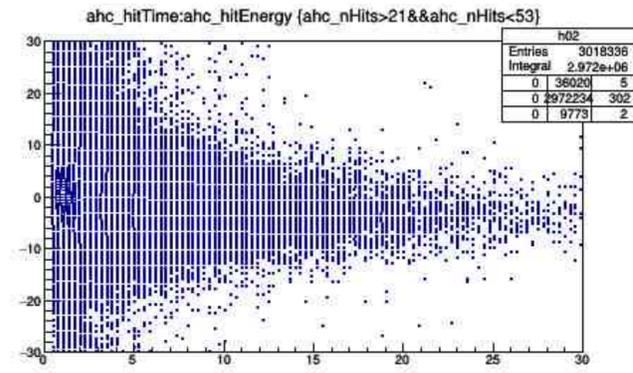
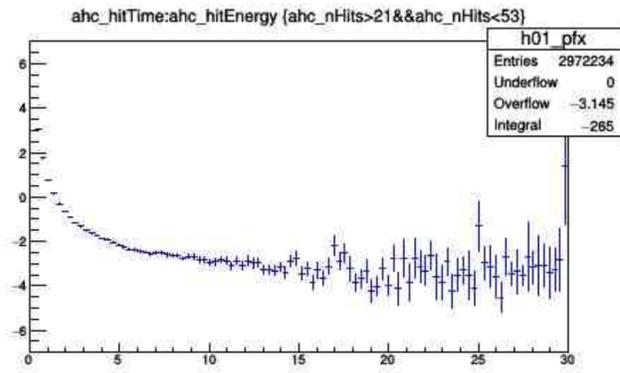
sum over all
 channels:



Single Channel Fits with Largest Statistics

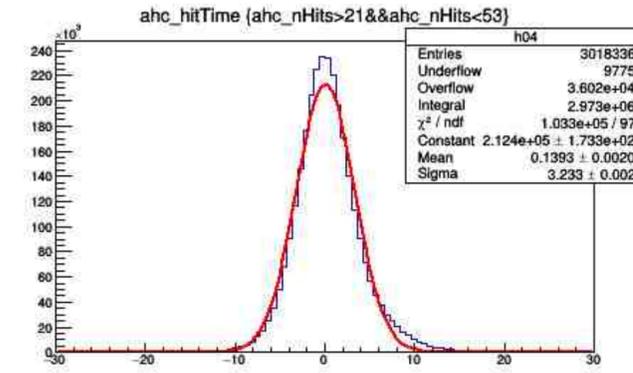


Muons – Time Correction

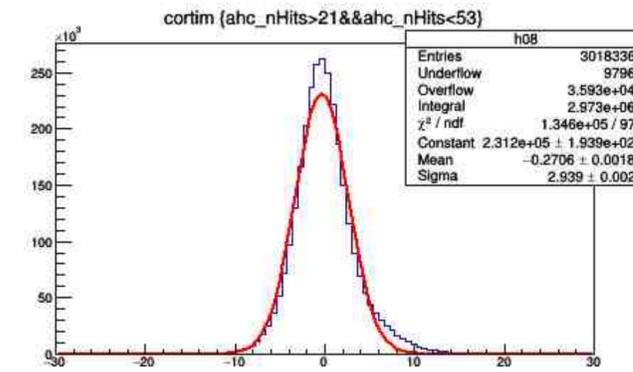
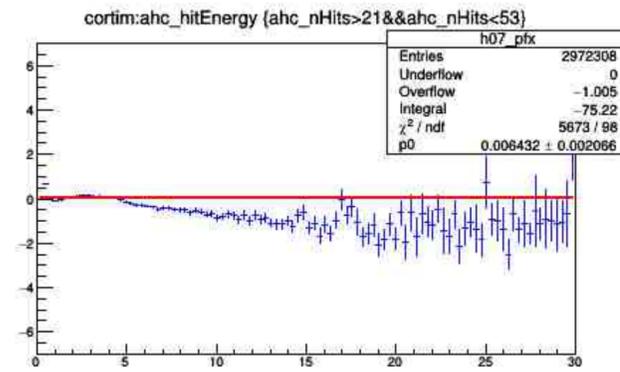
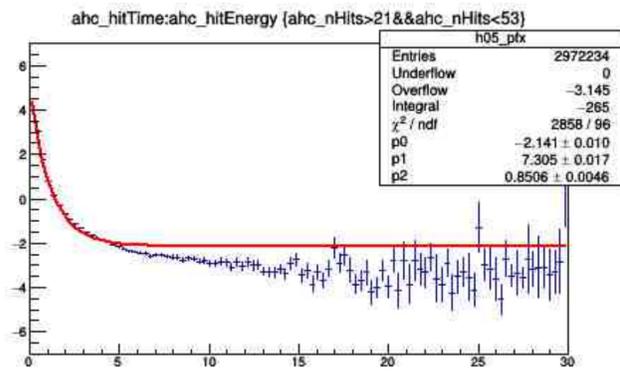


hit time vs energy

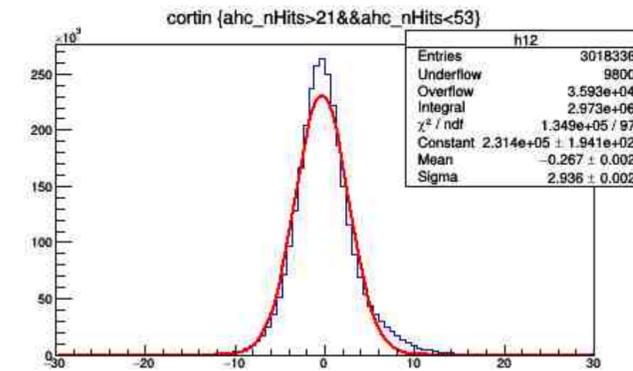
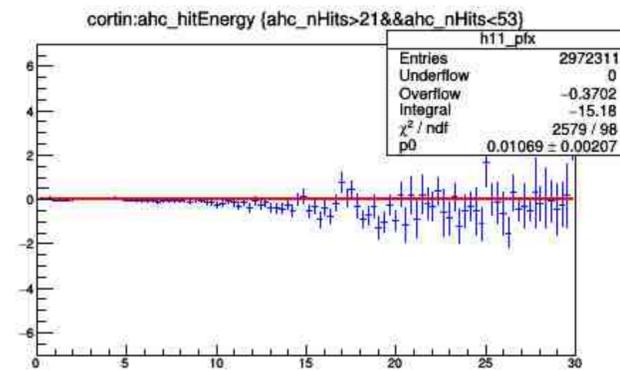
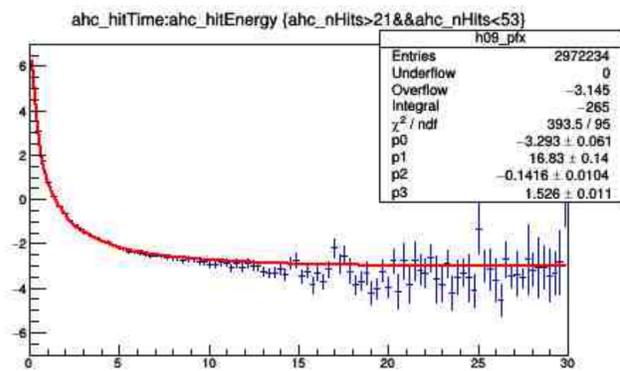
[0-30 MIP]



raw data



$$f_{01}(x) = a + be^{-cx}$$



$$f_{10}(x) = a + be^{-cx-d\sqrt{x}}$$

energy dependence

.. after correction

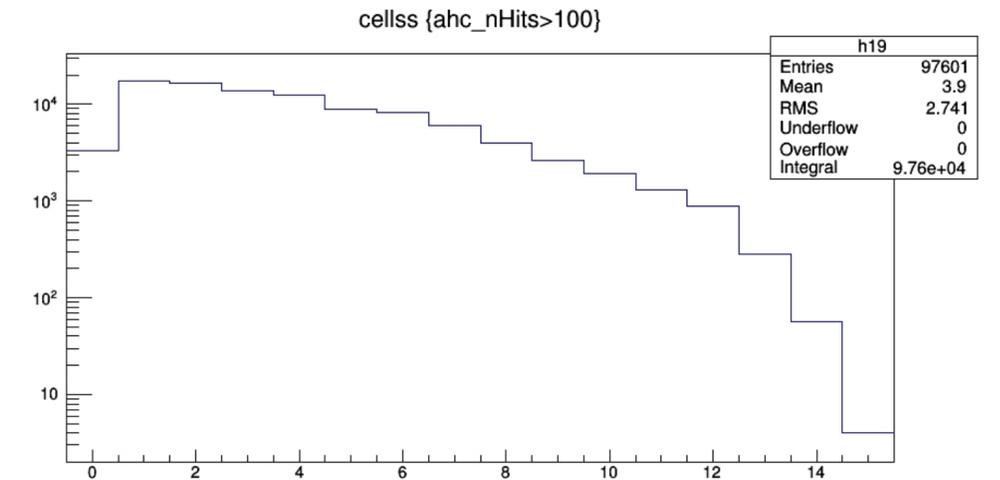
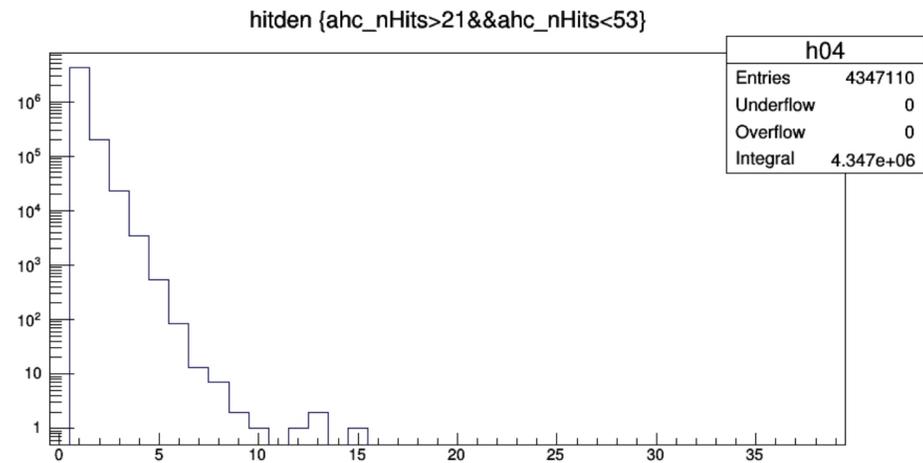
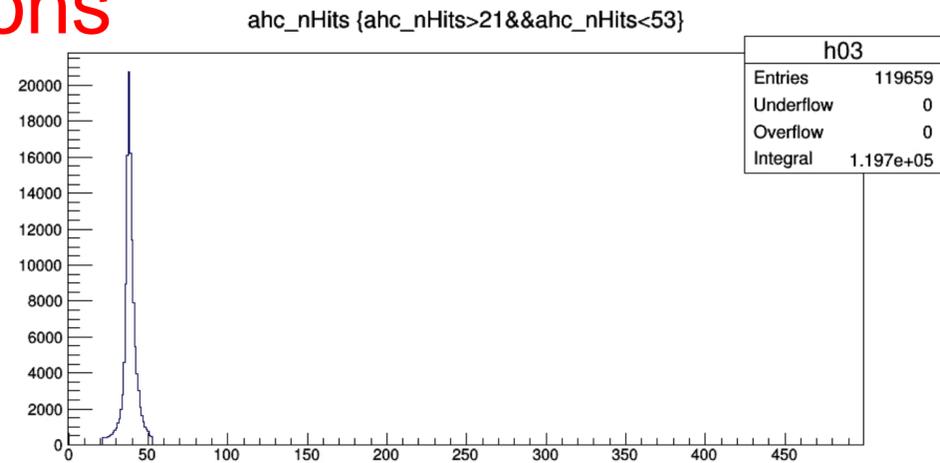
resolution ~10% better to ~2.9 ns

Occupancy and Cell Number

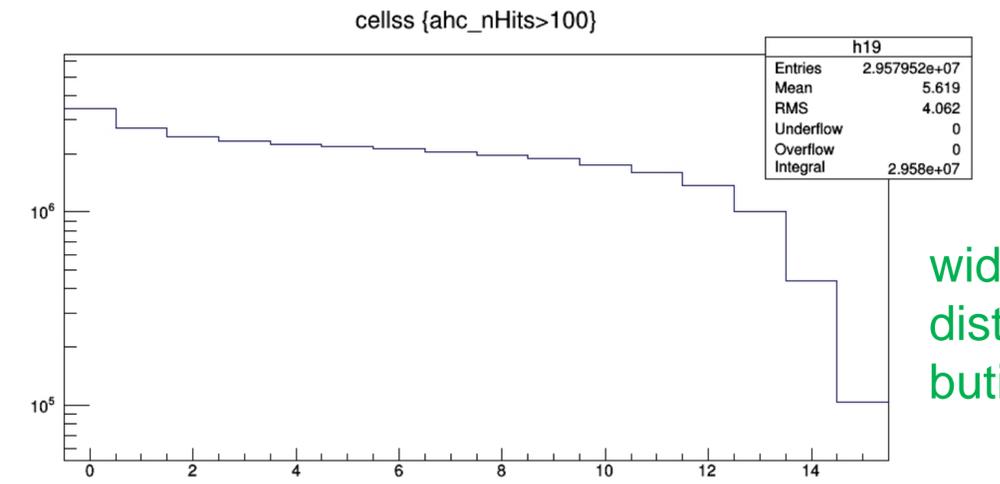
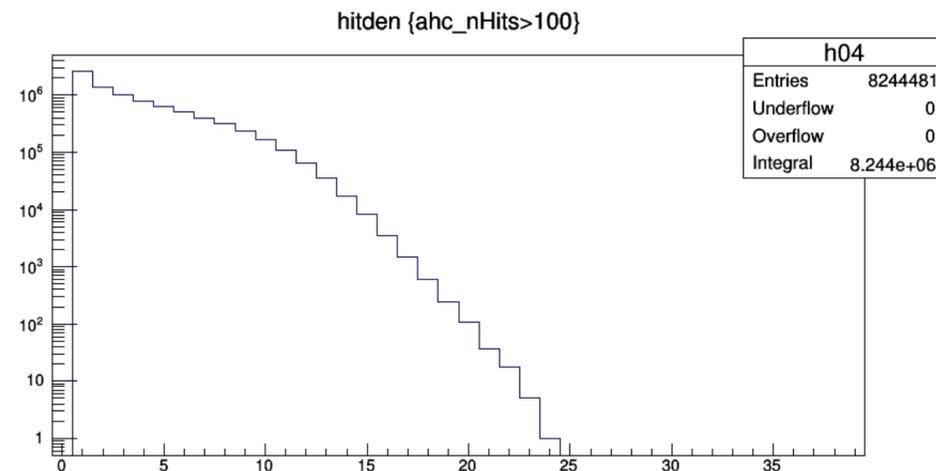
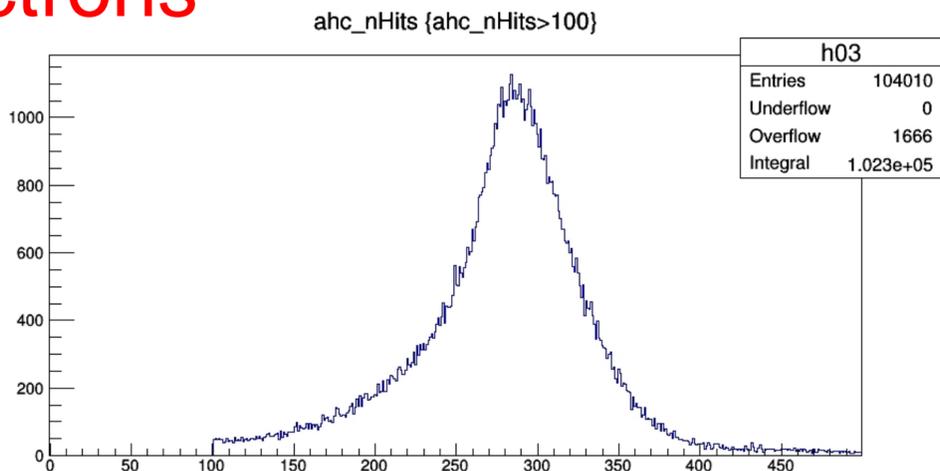
occupancy = hit density per single chip

cell number = position in channel at readout time (i.e. how full was the channel)

muons



electrons



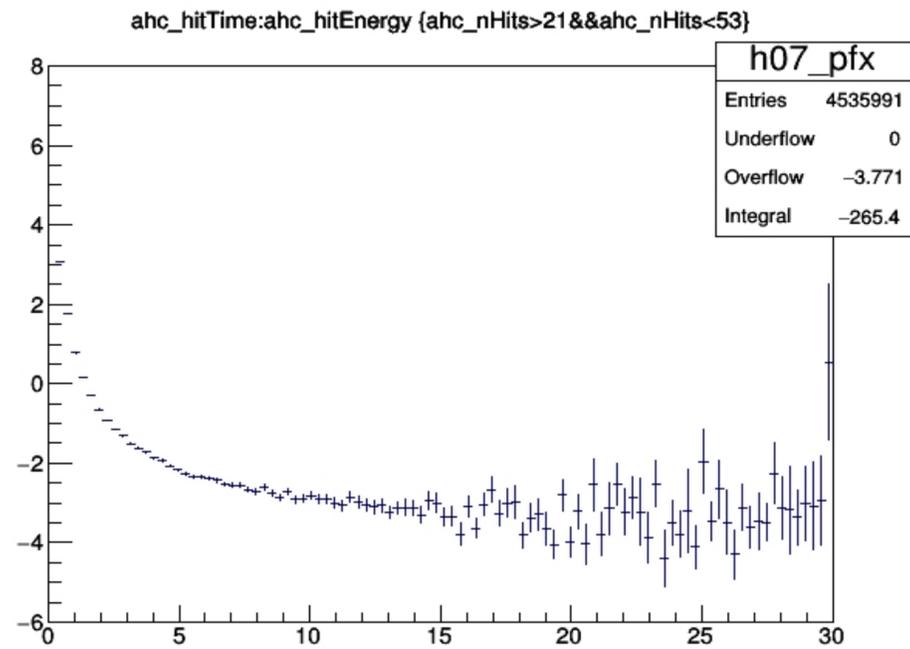
wider distributions

#hits

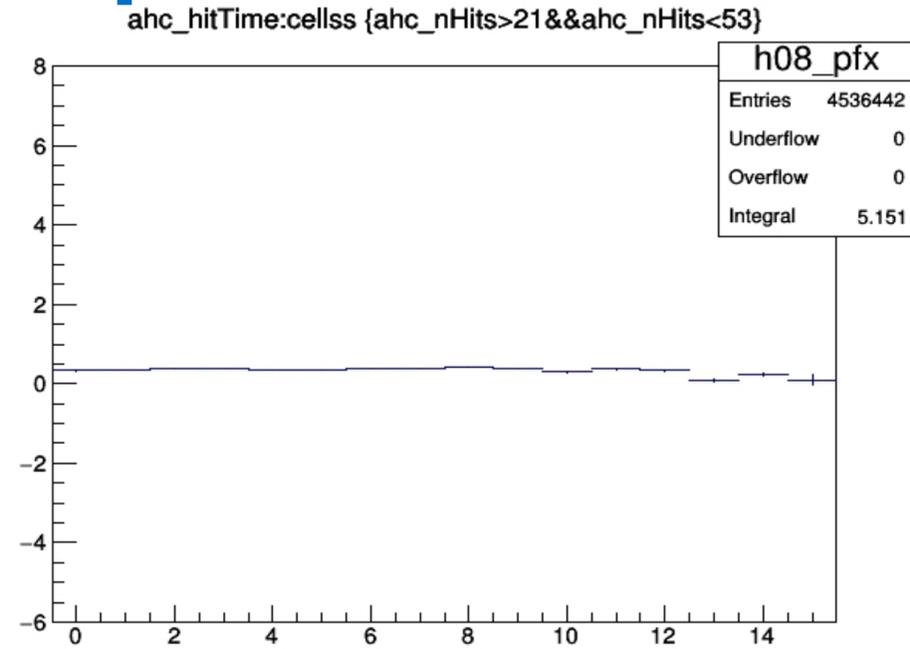
occupancy

cell#

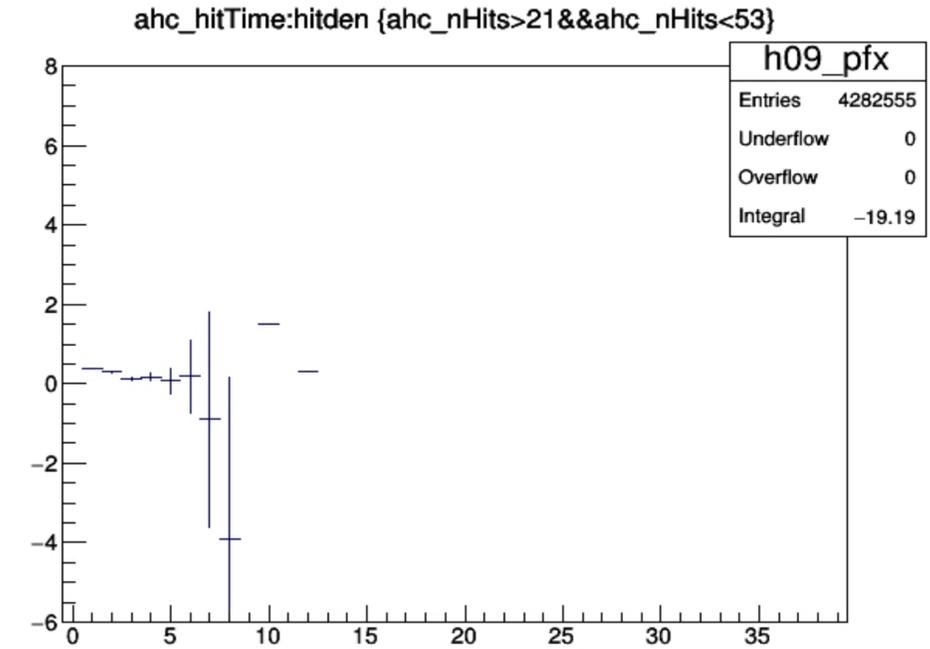
Time Dependencies - Muons



vs Energy

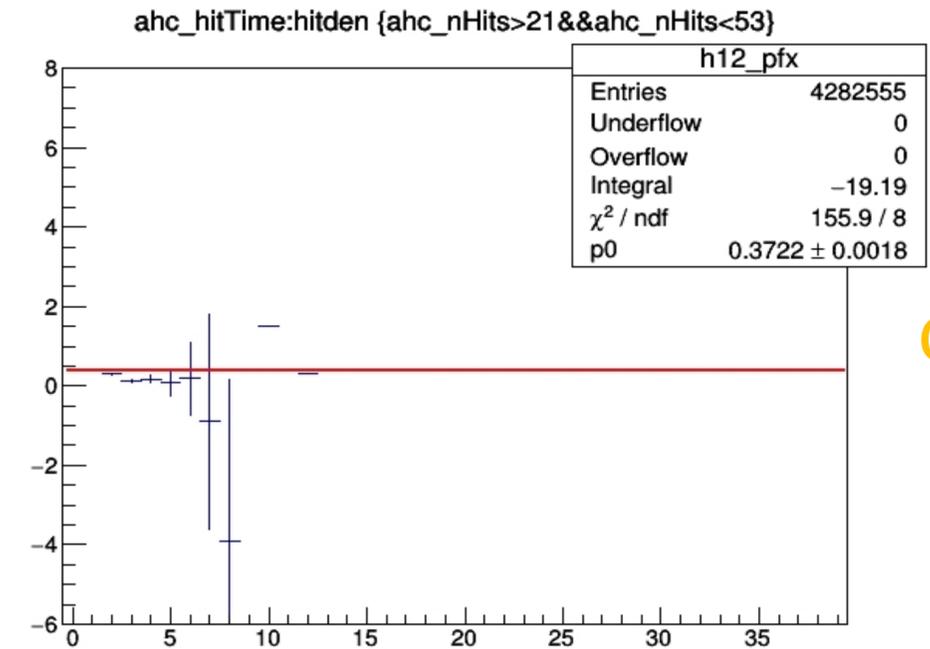
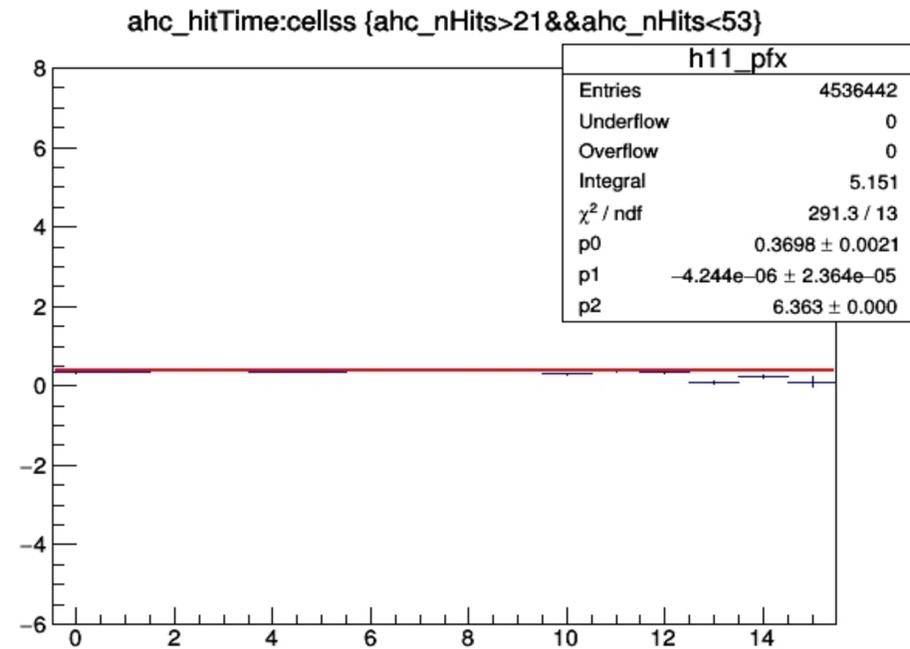
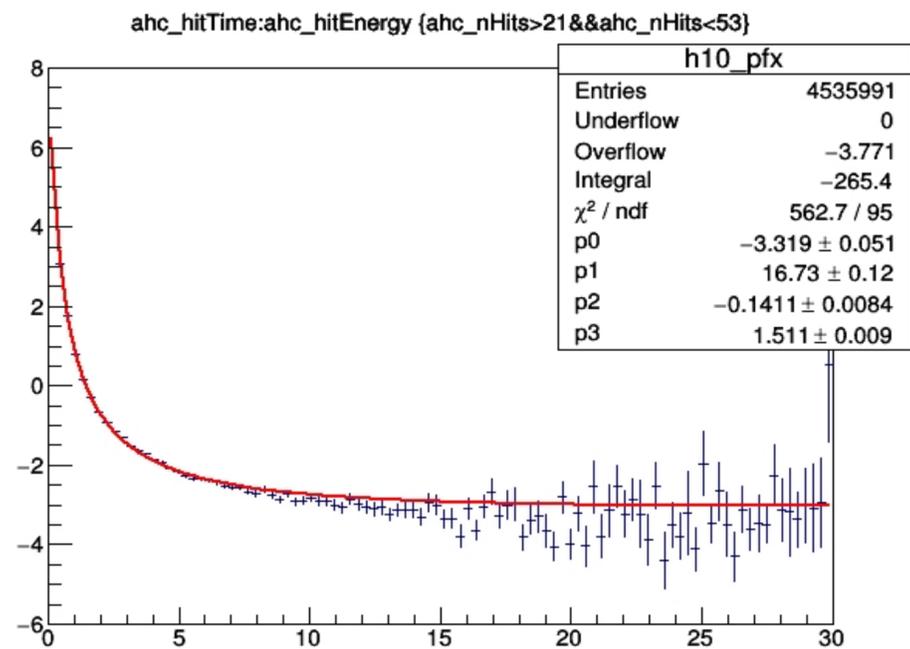


vs Cell#



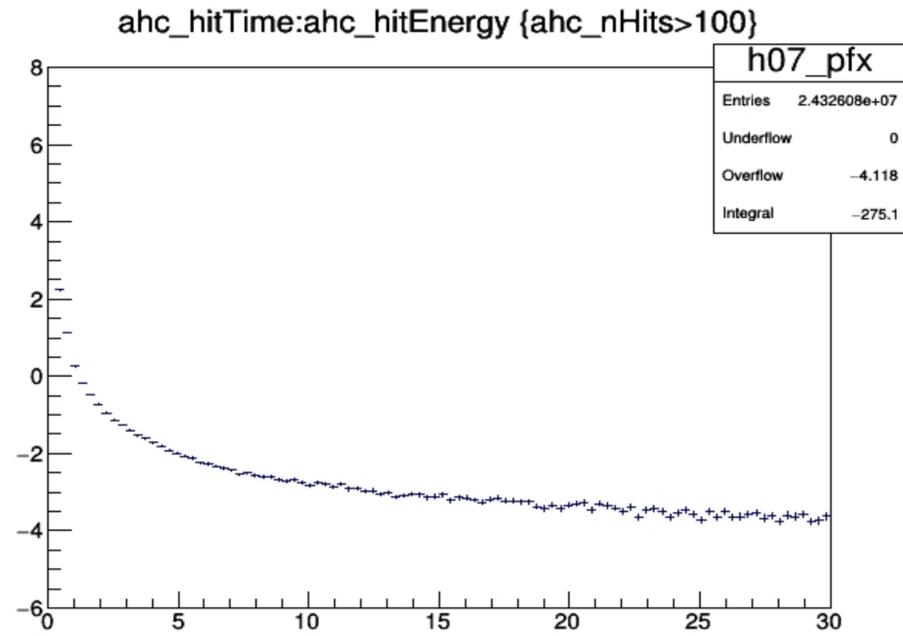
vs Occupancy

data

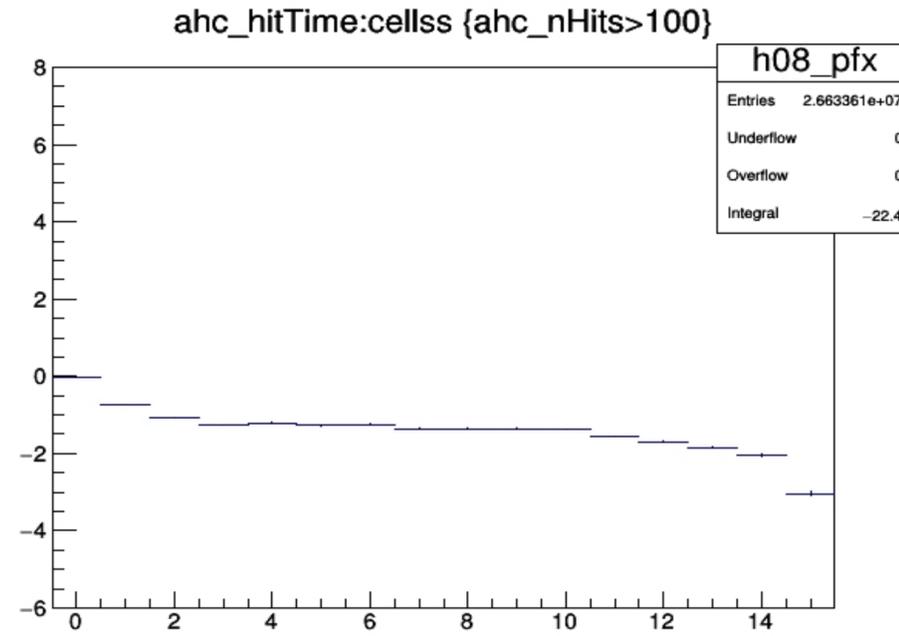


data+fit

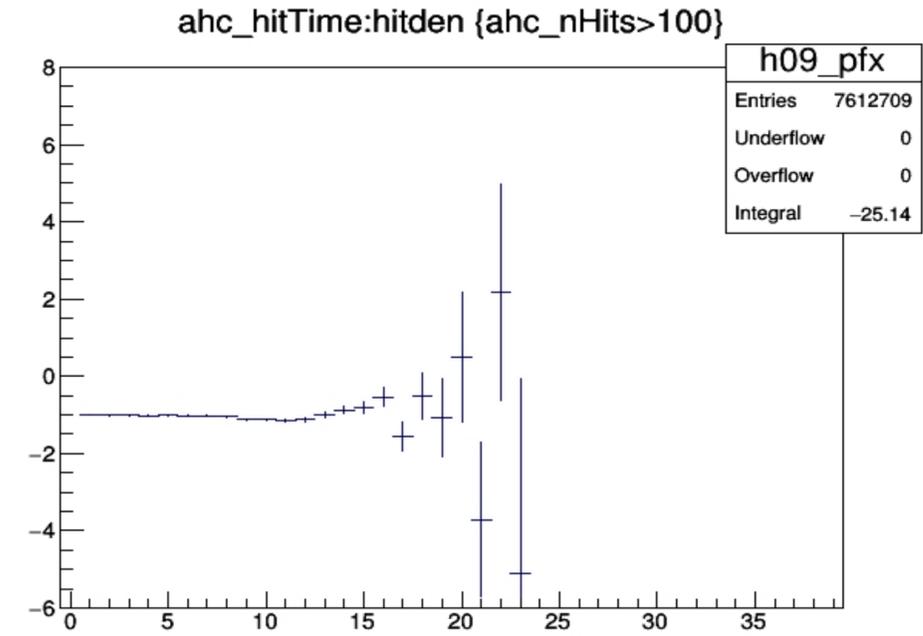
Time Dependencies - Electrons



vs Energy

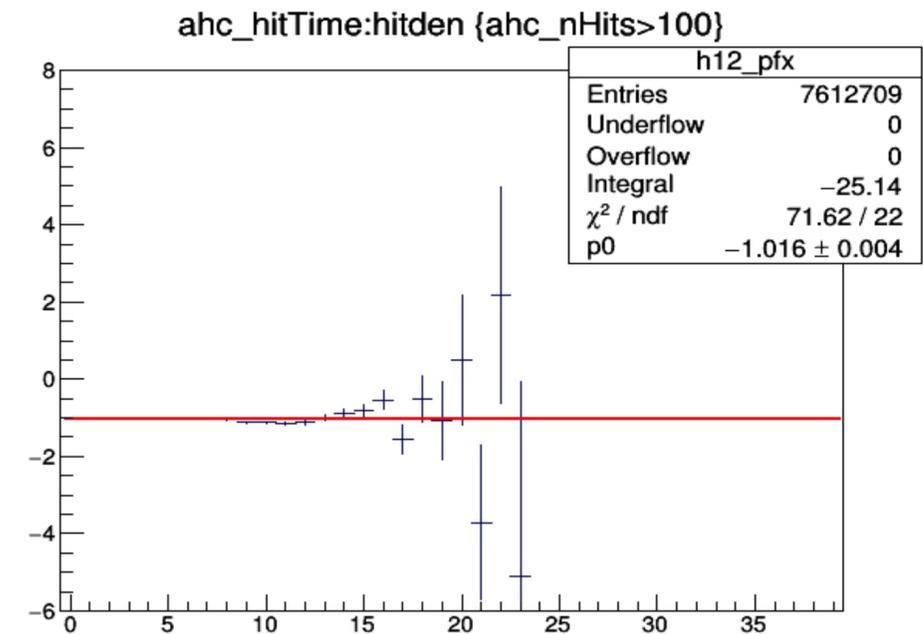
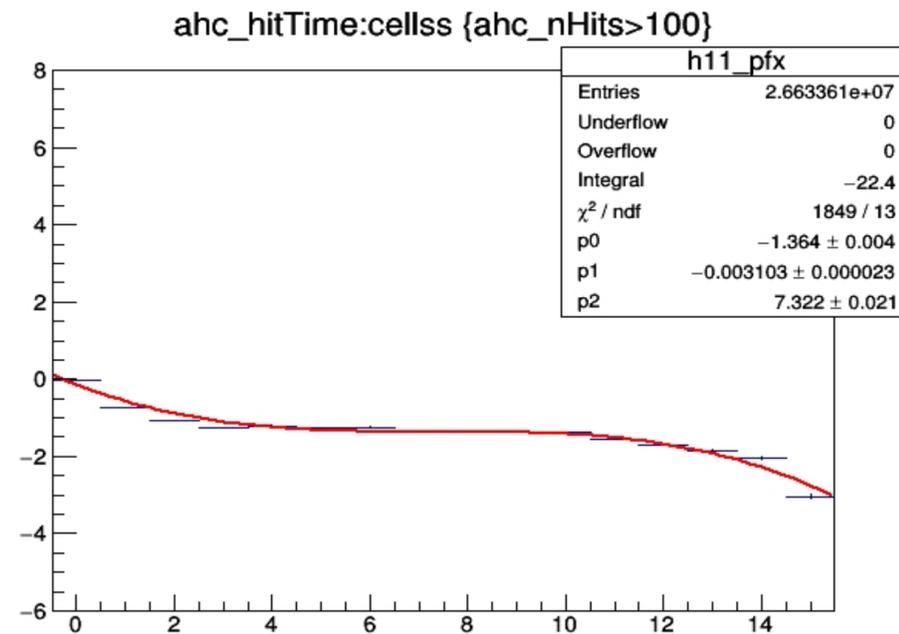
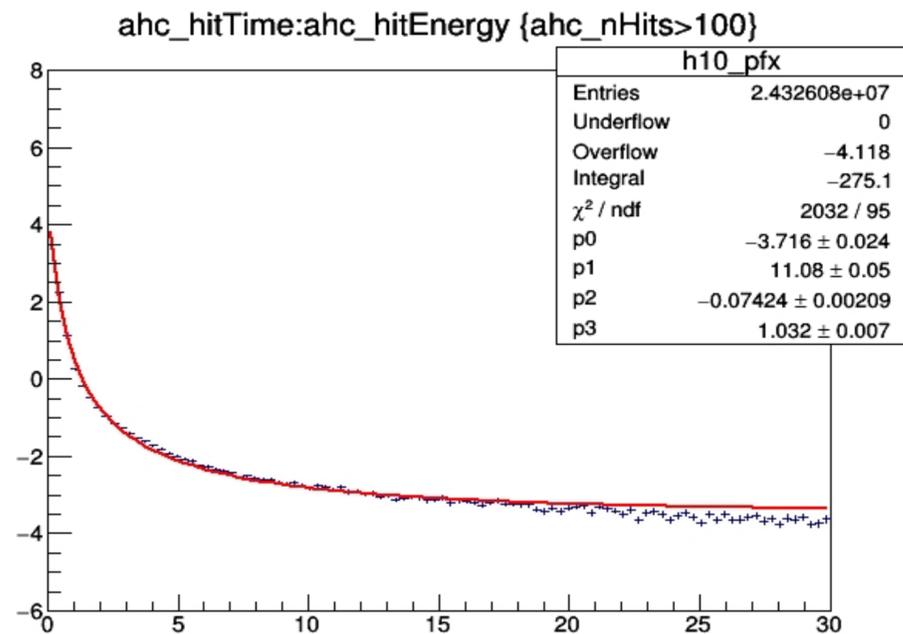


vs Cell#



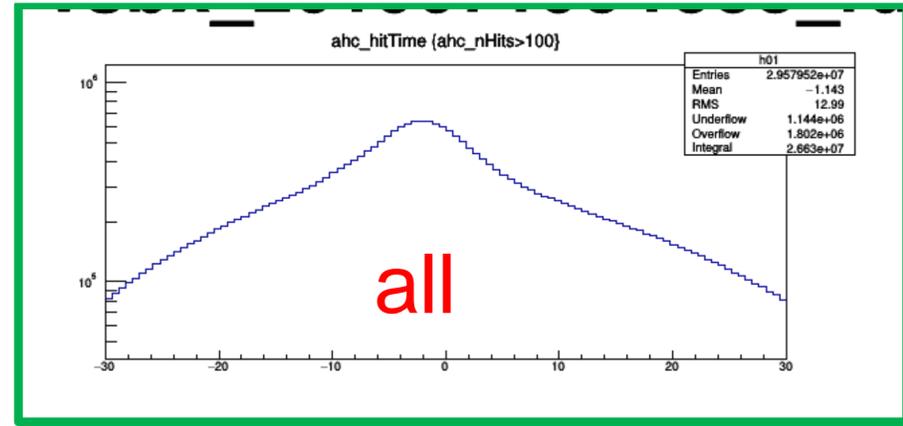
vs Occupancy

data



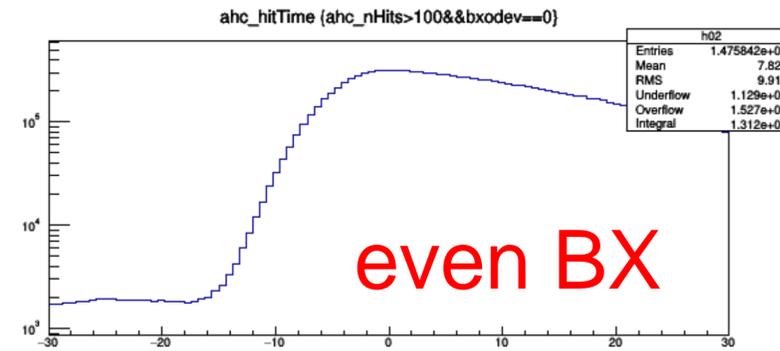
data+fit

Electrons: hitTime vs Gain/BeamCrossing

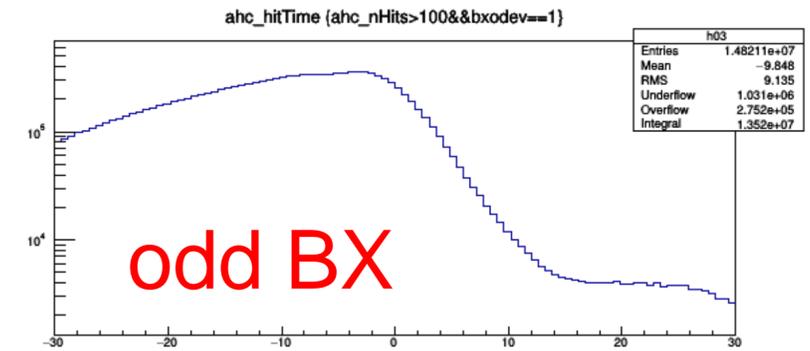


all

[-30,+30] ns

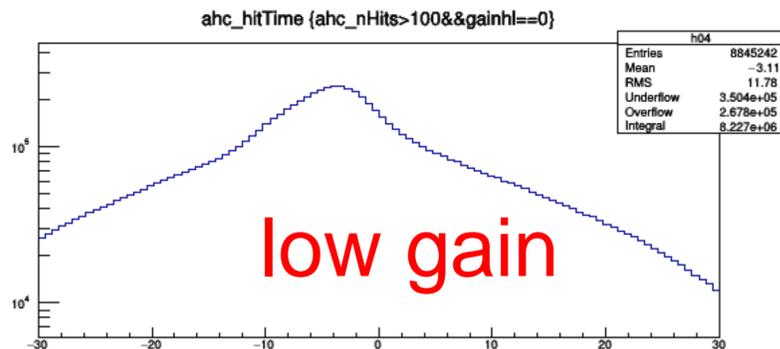


even BX

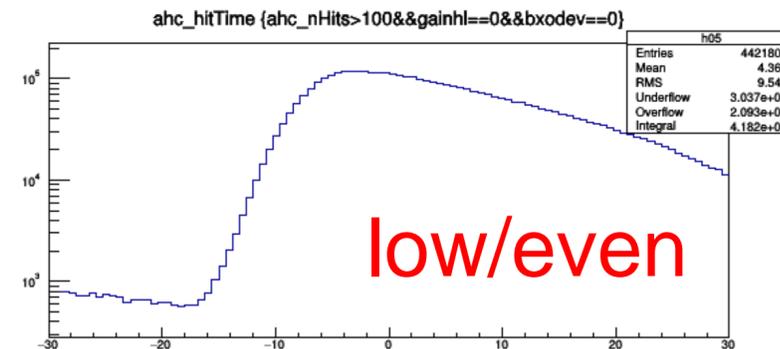


odd BX

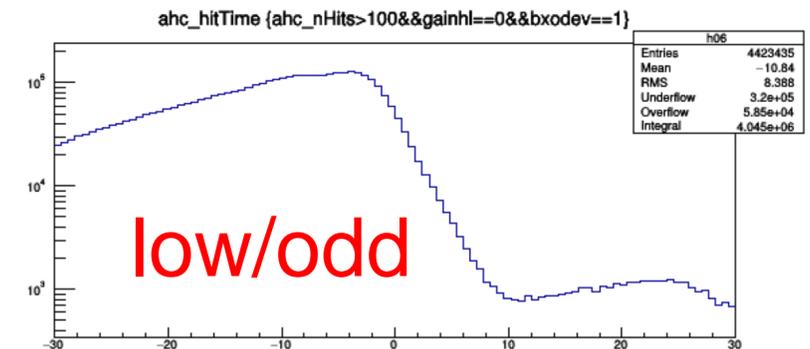
asymmetric
behaviour:
even vs odd



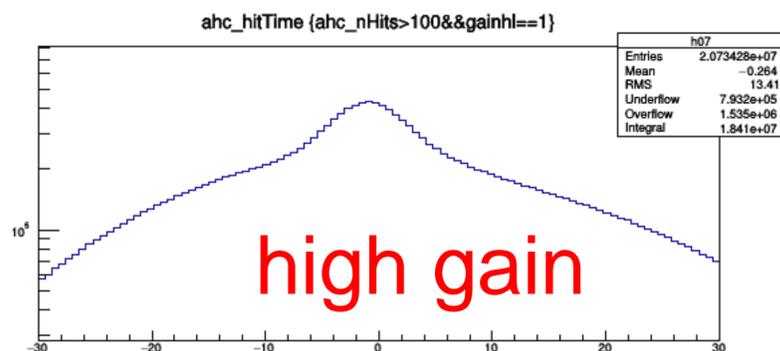
low gain



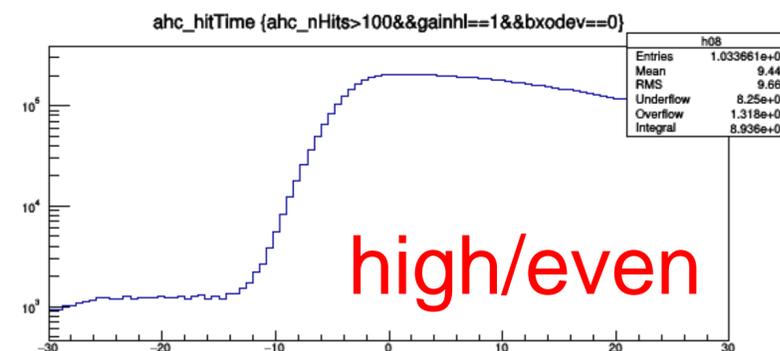
low/even



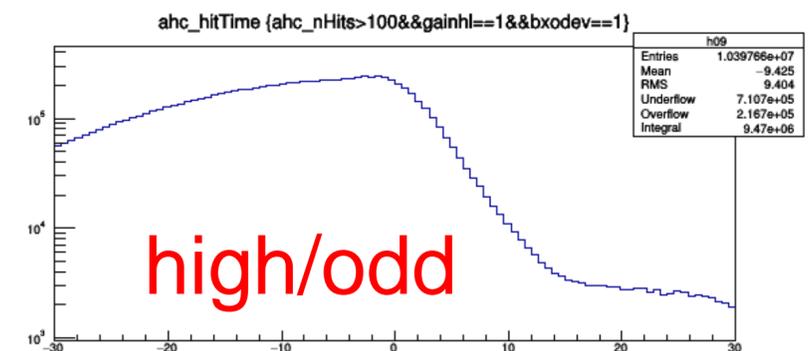
low/odd



high gain



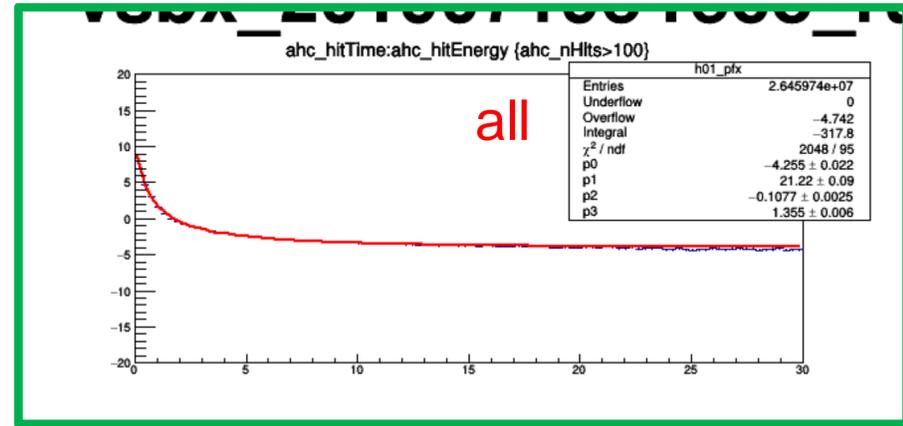
high/even



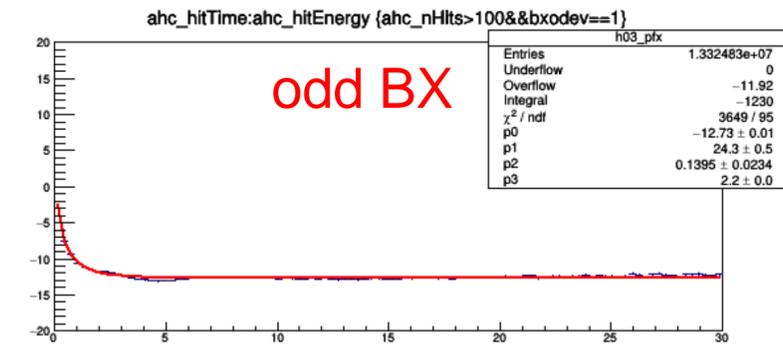
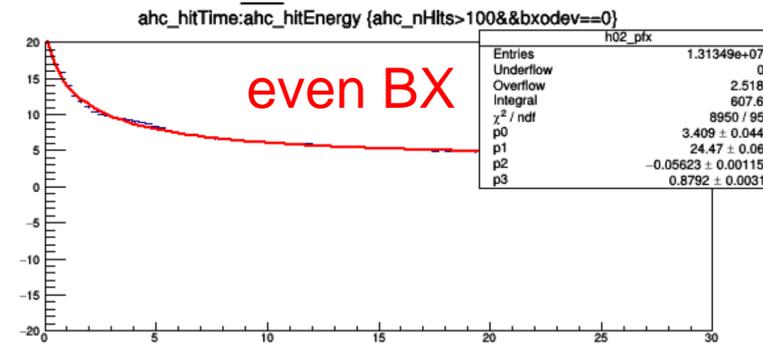
high/odd

Electrons: Hit Time vs Hit Energy

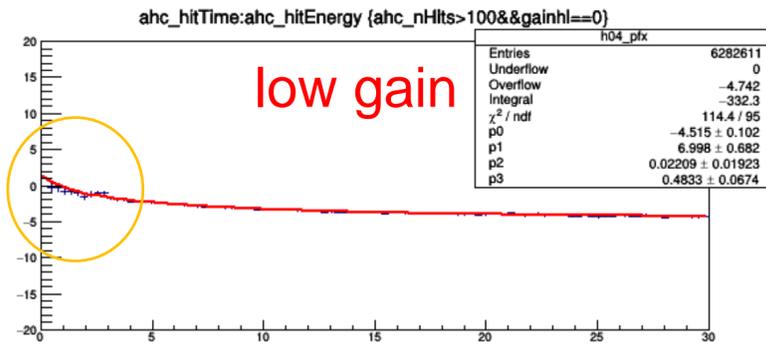
[-20,+20]ns



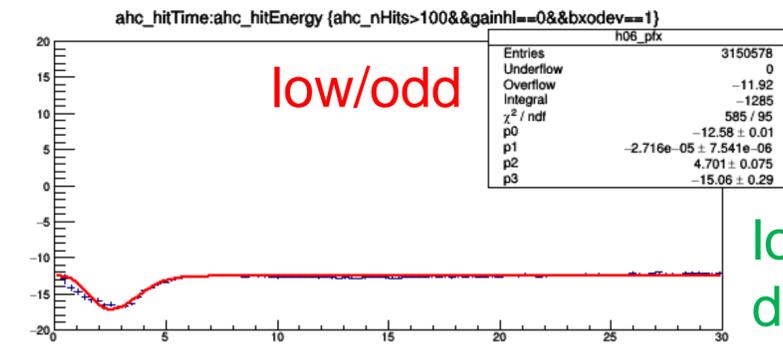
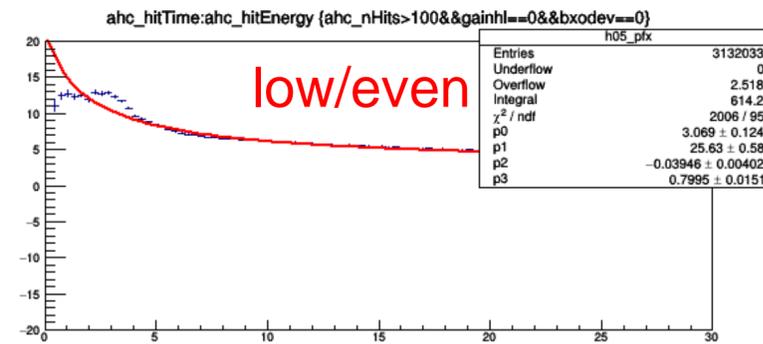
[0,+30] MIP



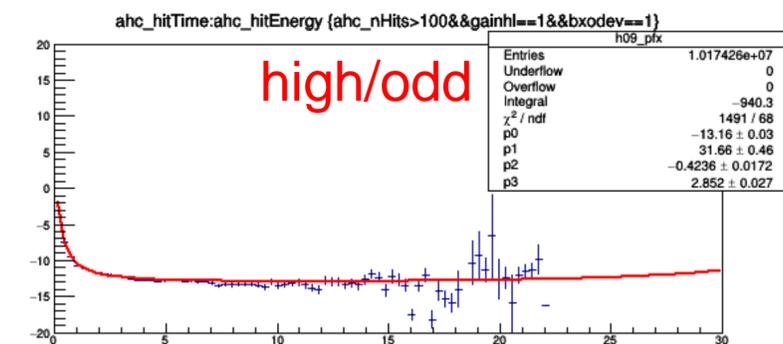
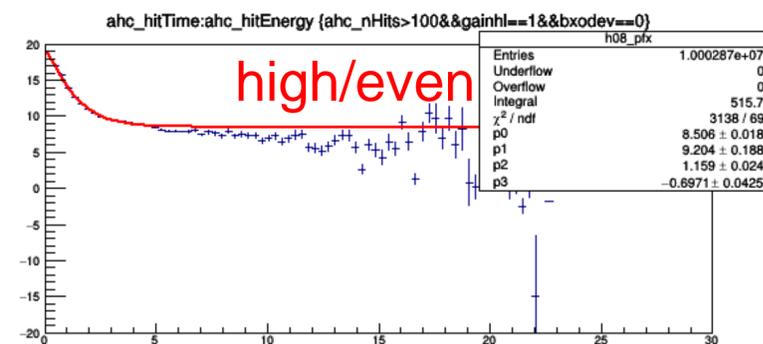
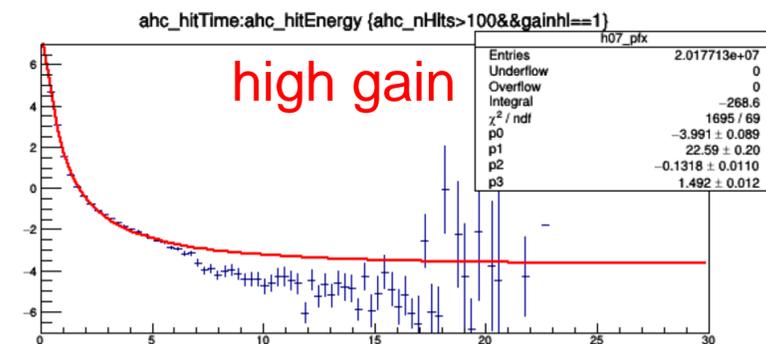
again large time shift: even vs odd



low gain shows several hits below threshold (more in backup)

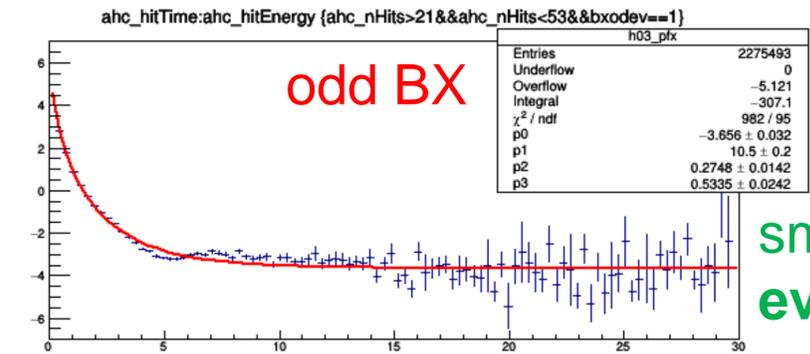
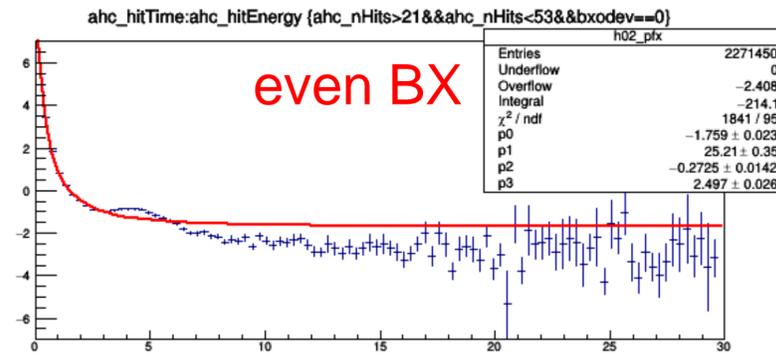
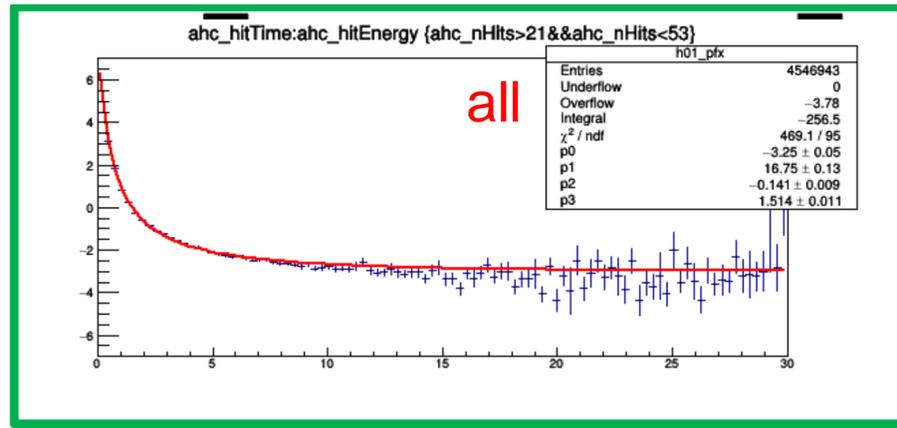


low gain shapes different even vs odd



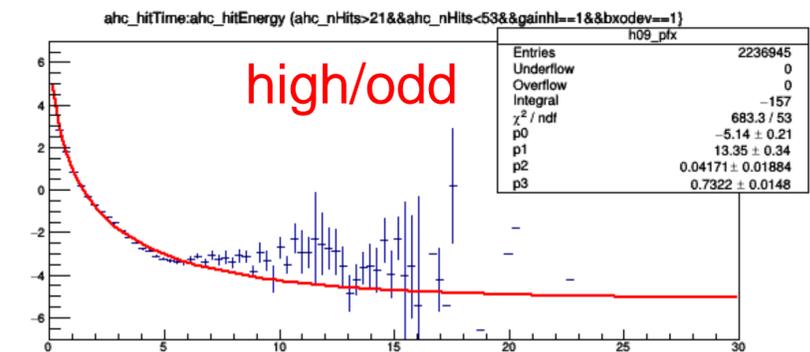
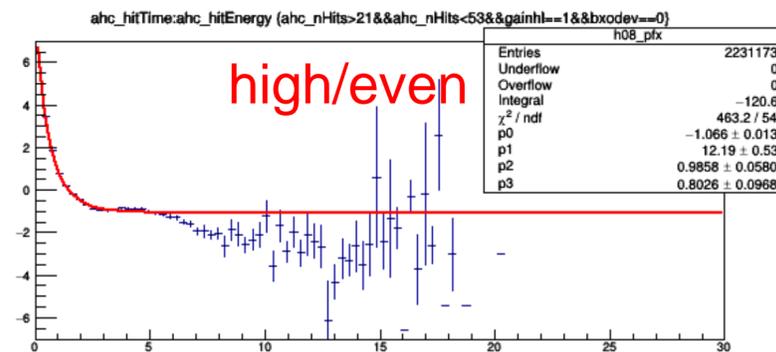
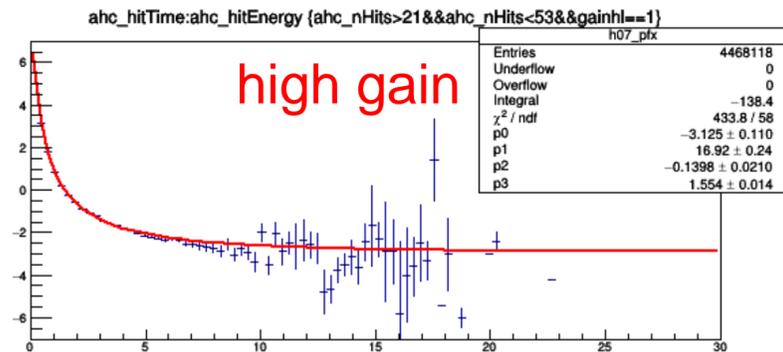
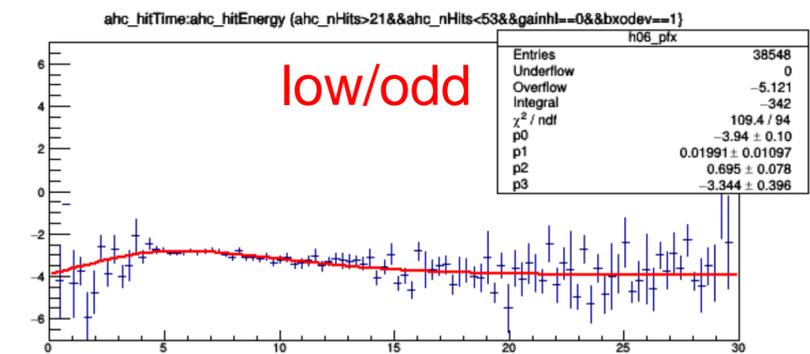
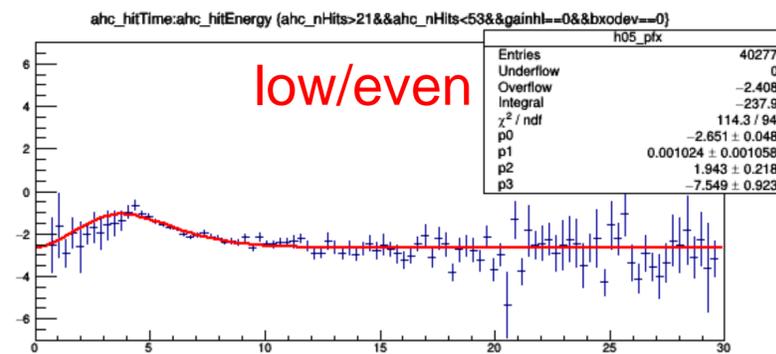
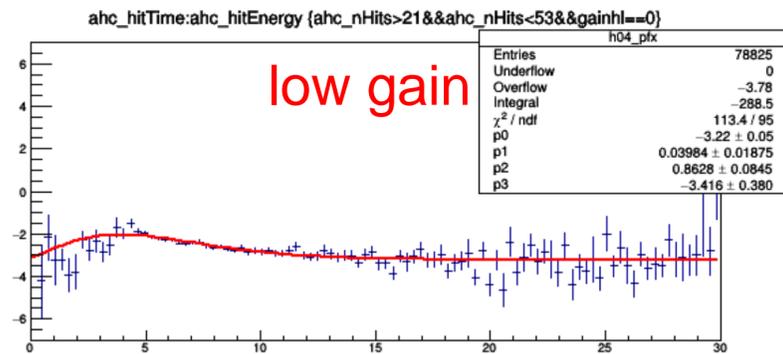
Muons: Hit Time vs Hit Energy

[-7,+7]ns

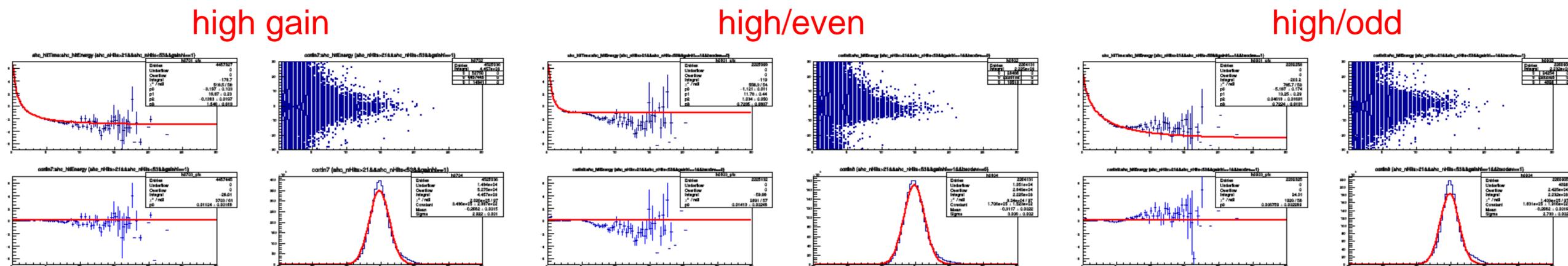
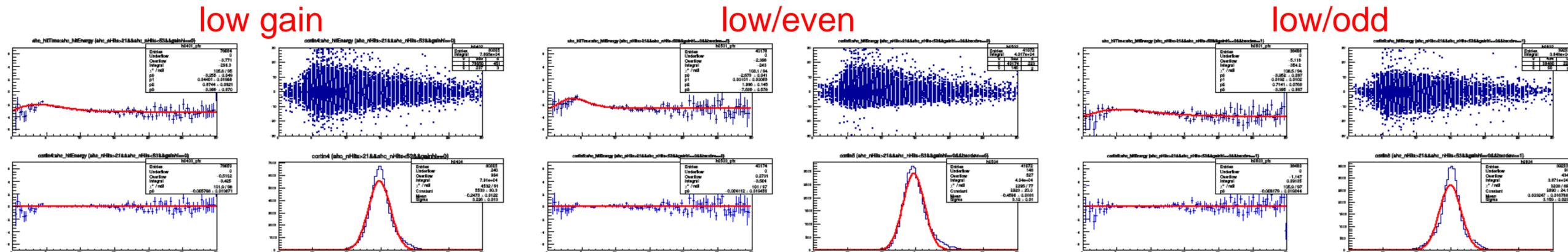
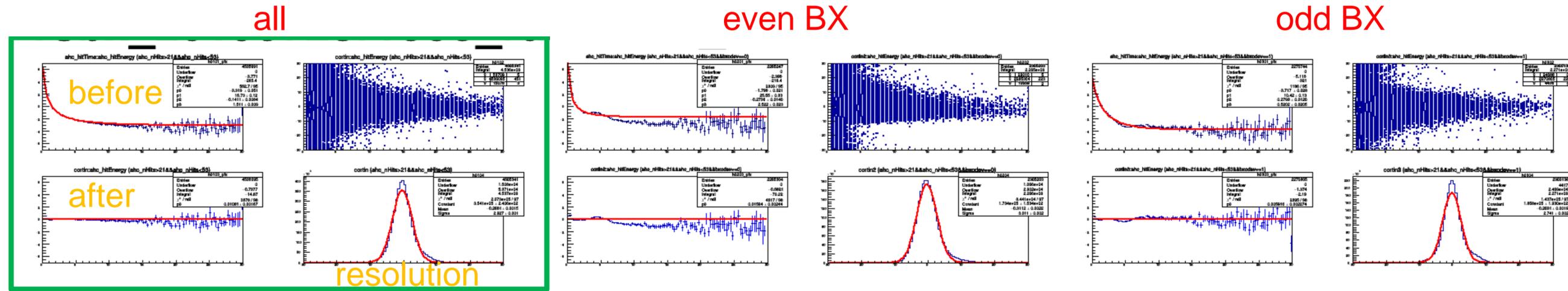


smaller shift:
even vs odd

[0,+30] MIP



Muons: Time Walk Correction + Resolution



whichever way,
again only 10%
improvement

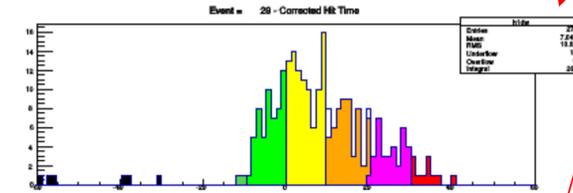
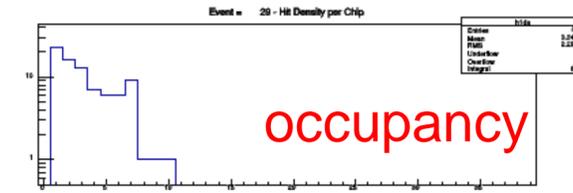
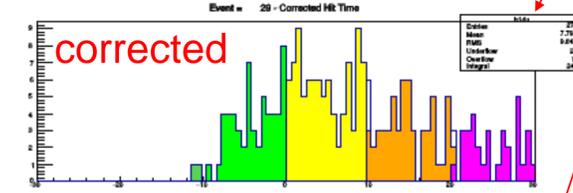
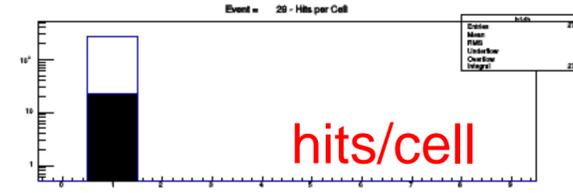
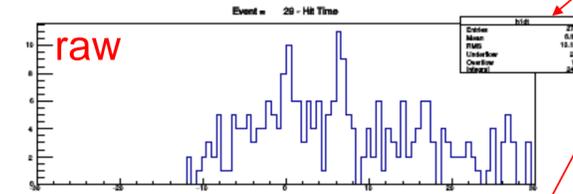
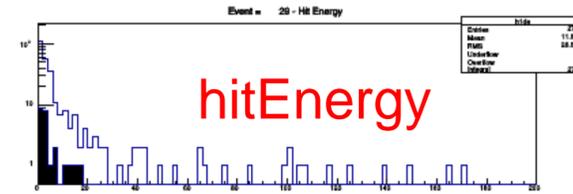
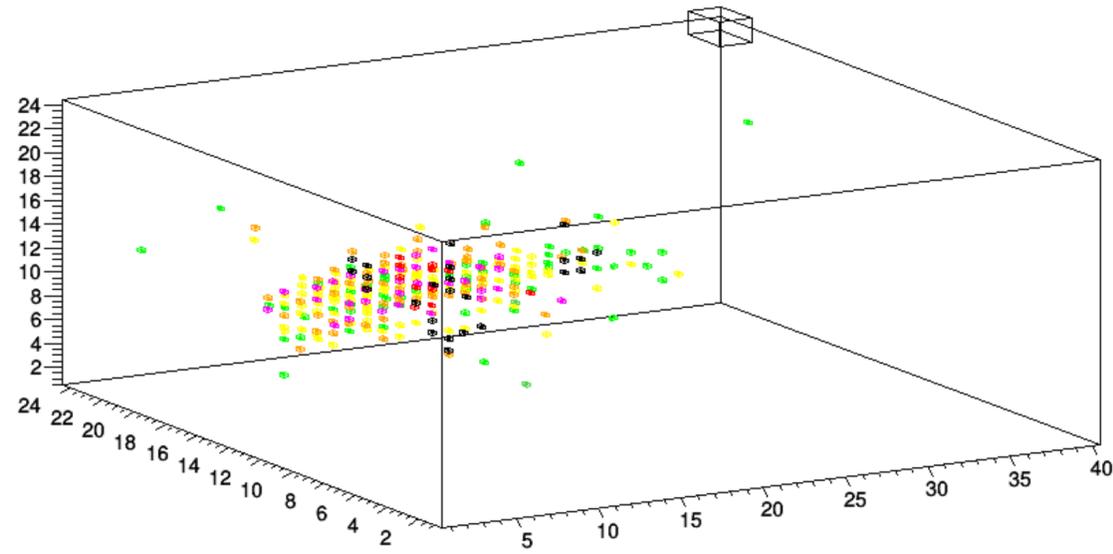
down to 2.9 ns
in resolution for
muons, ~10 ns
for electrons.

Event Display: Electron

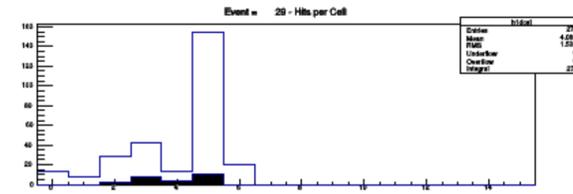
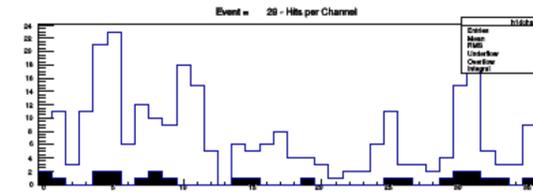
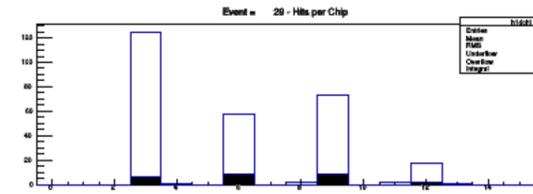
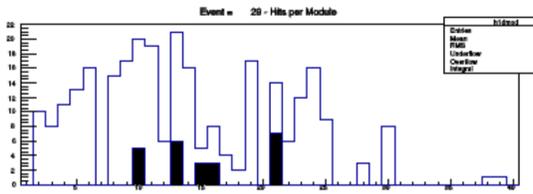
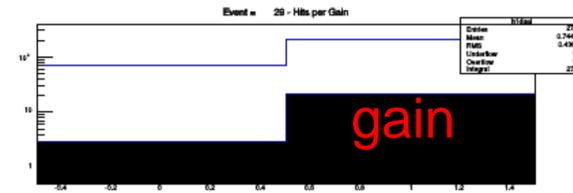
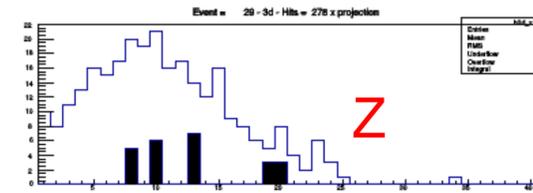
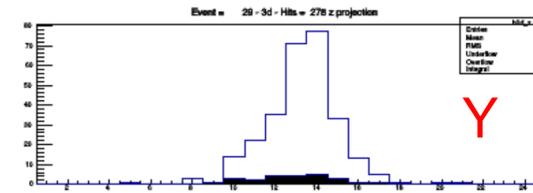
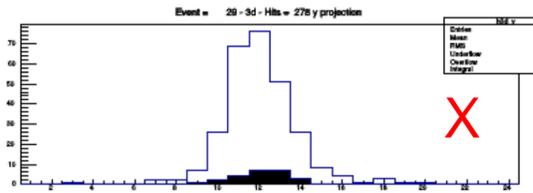
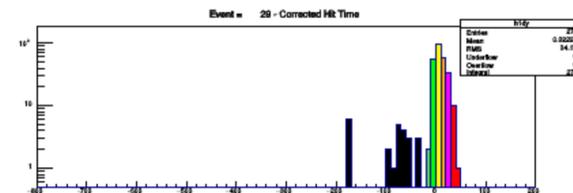
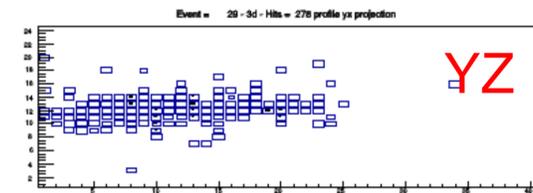
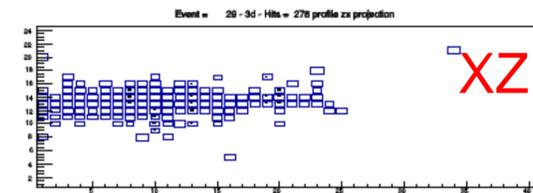
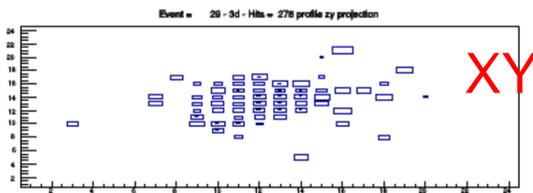
hitTime

e

Event = 29 - 3d - Hits = 278



black: $t < -30$ nsec



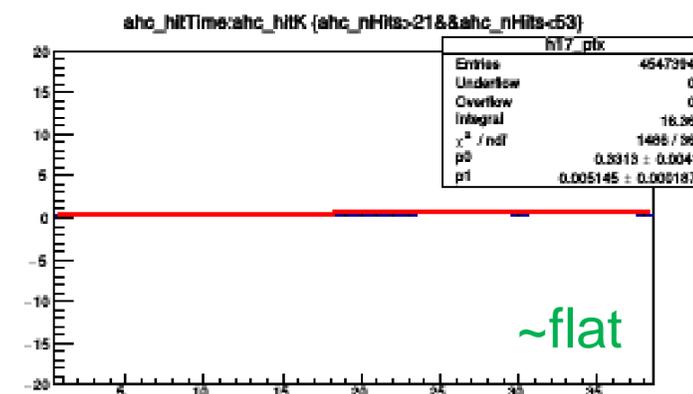
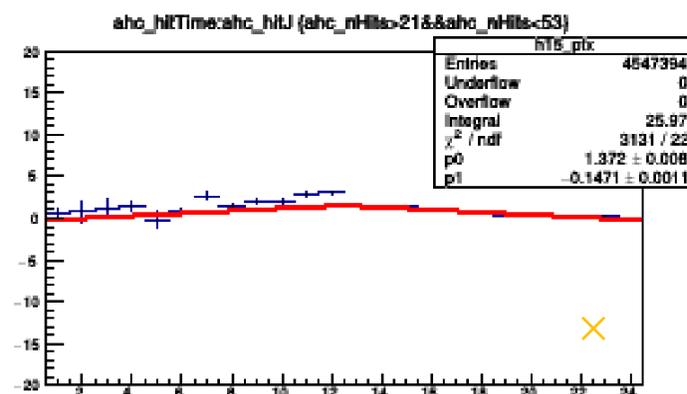
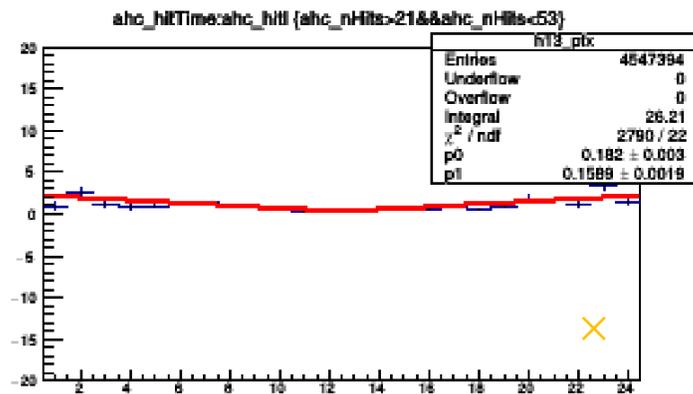
Muon Data: hit time vs position

vs X

vs Y

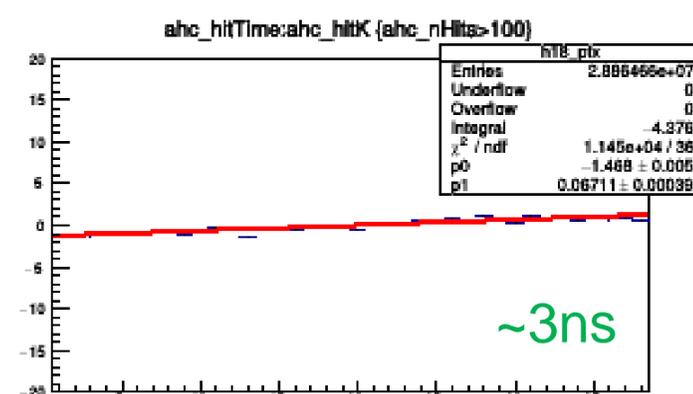
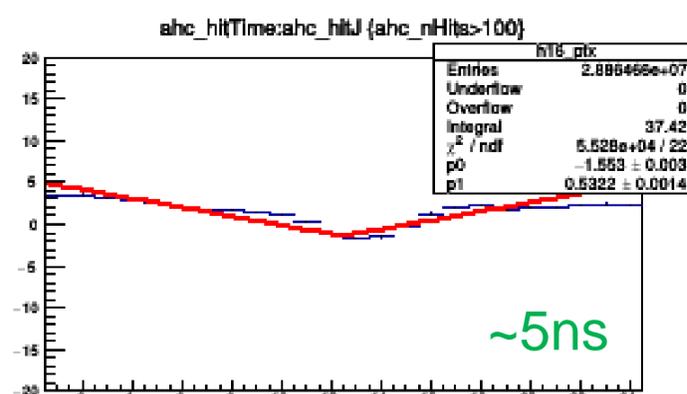
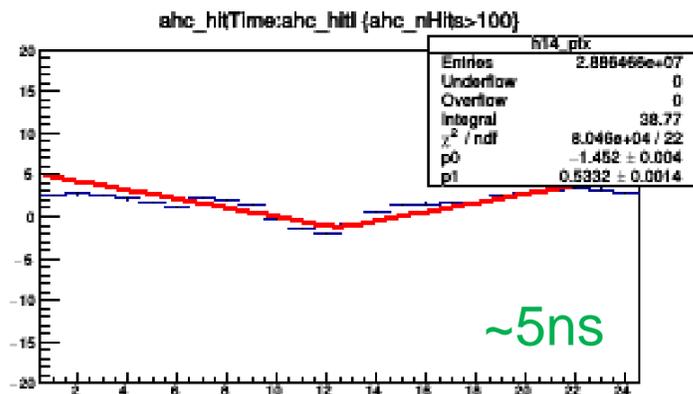
vs Z

muons



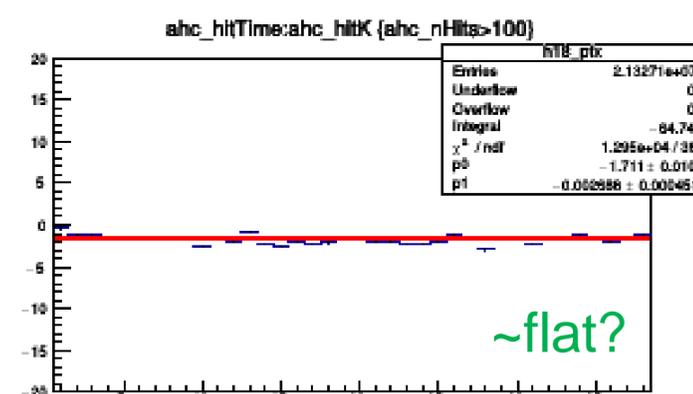
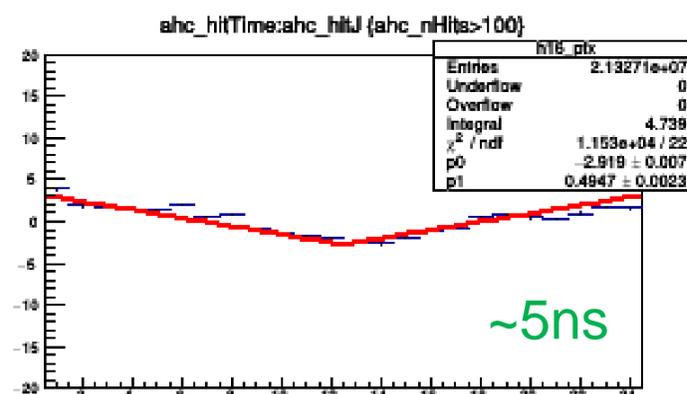
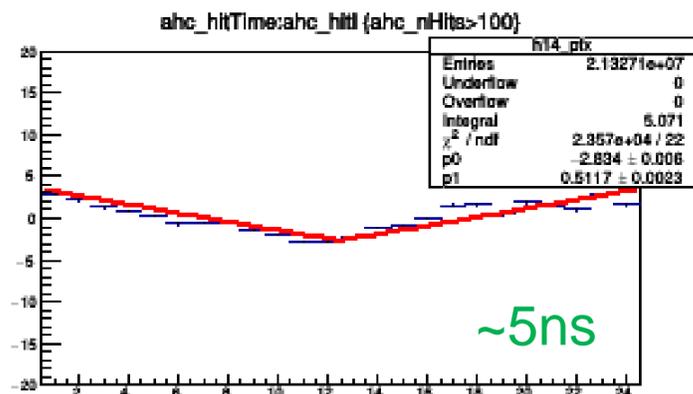
as expected

electrons



sides later slope in Z

pions



sides later no Z slope? (old calibration)

Summary

AHCAL hit time response is:

- very **strongly dependent** on hit energy (due to time walk / threshold), but similar for all types of particles, modules, chips, channels.
- somewhat **dependent** on memory cell number within channel at readout, especially for busy events such as in electron showers.
- almost **independent** on occupancy/hit density within a single channel ?
- very **dependent** on beam crossing (odd or even), especially for electrons, which leads to low time resolution. Is it an electronic effect ?

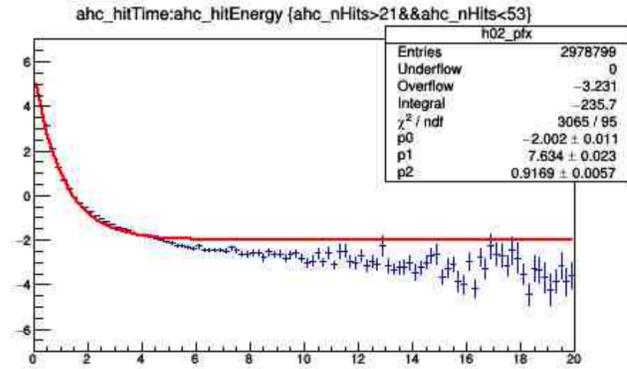
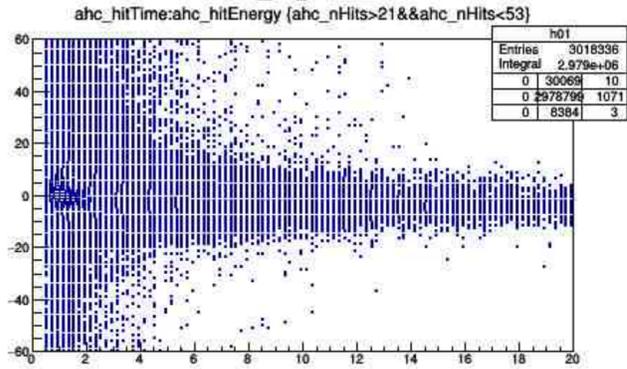
Correlations with other event infos were investigated: no clear pattern emerges.

Time walk corrections improve resolution by 10% (for muons).

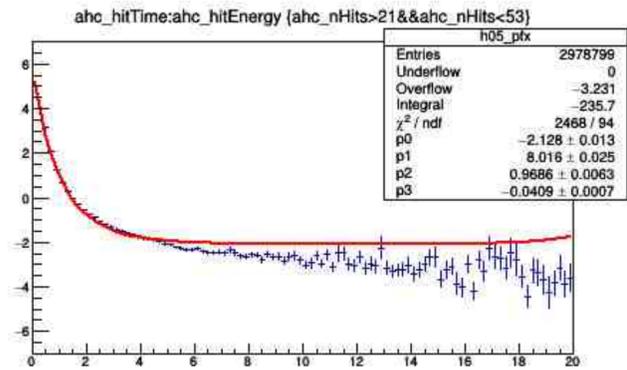
This study shows limited usability of current time information/resolution.

Backup

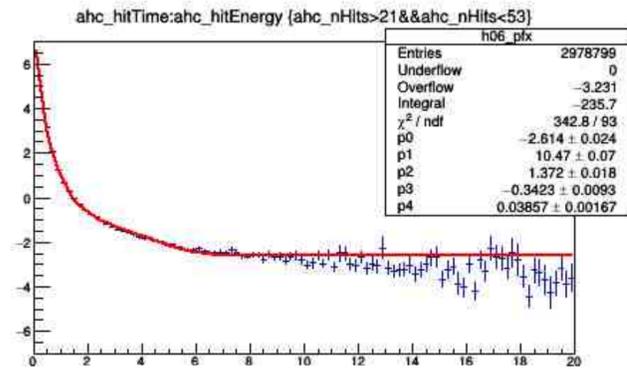
Functional Forms



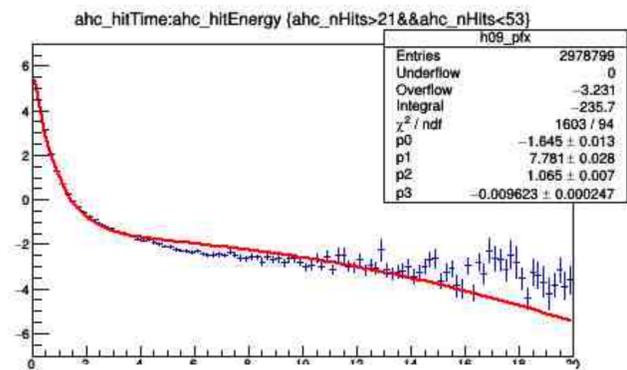
$$f_{01}(x) = a + be^{-cx}$$



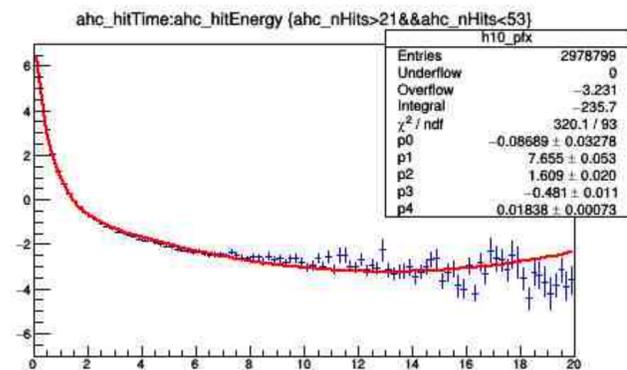
$$f_{04}(x) = a + be^{-cx-dx^2}$$



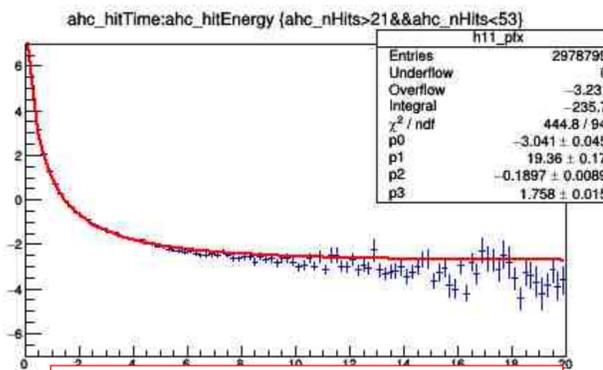
$$f_{05}(x) = a + be^{-cx-dx^2-ex^3}$$



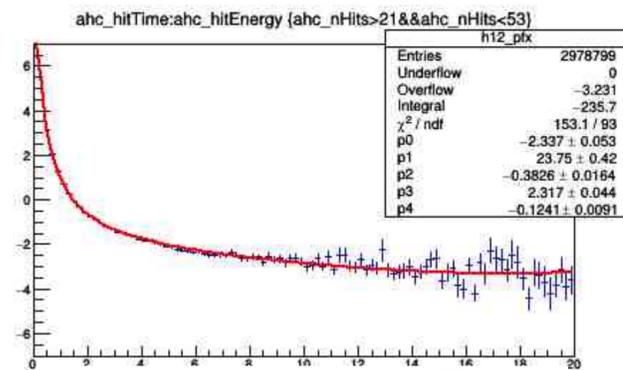
$$f_{08}(x) = a + be^{-cx} + dx^2$$



$$f_{09}(x) = a + be^{-cx} + dx^2 + ex^3$$

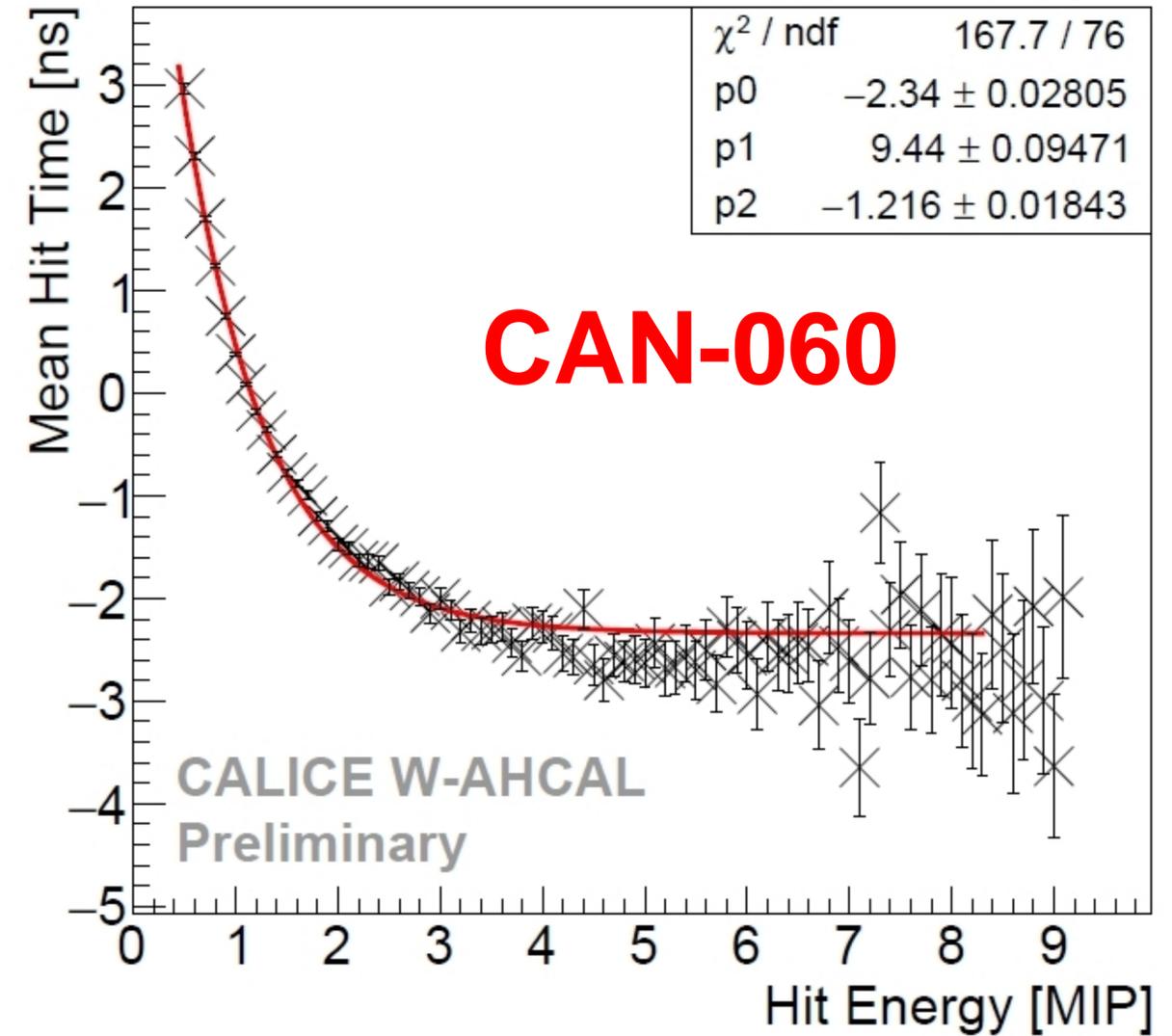


$$f_{10}(x) = a + be^{-cx-d\sqrt{x}}$$



$$f_{11}(x) = a + be^{-cx-d\sqrt{x}} + ex$$

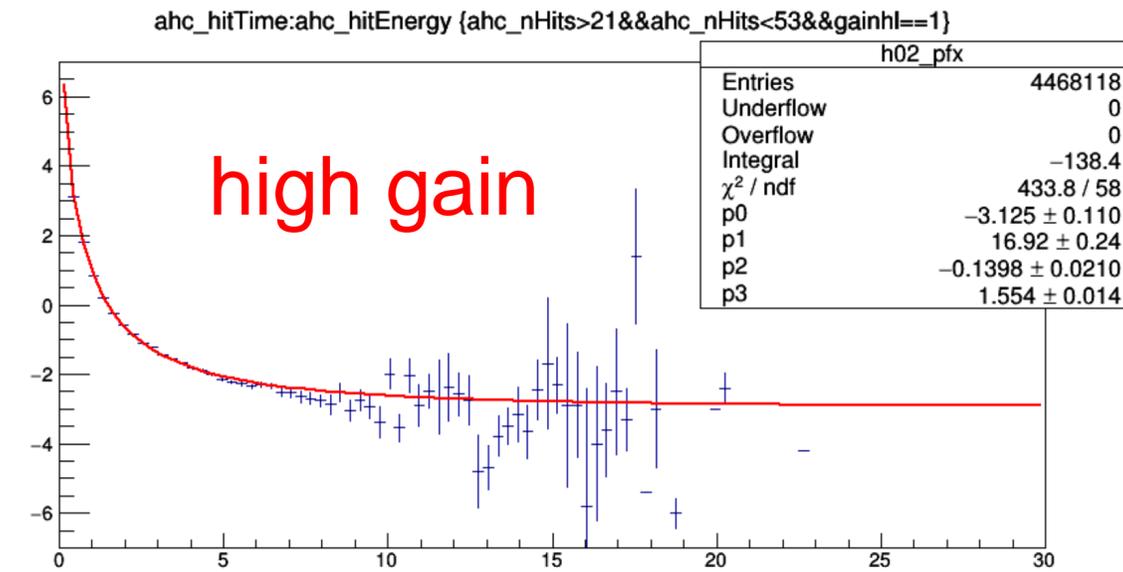
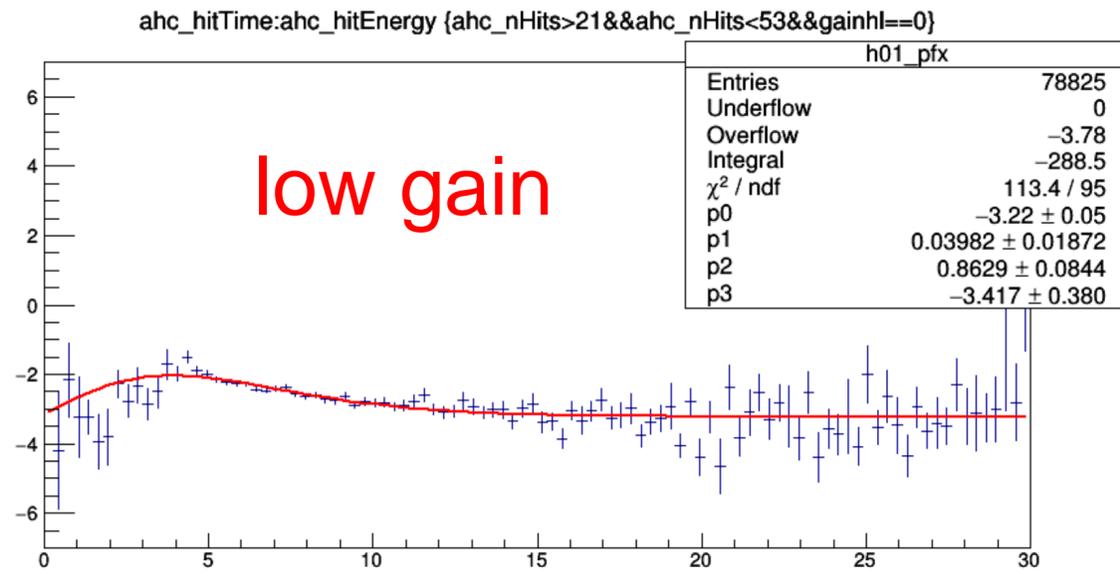
Time Walk Correction



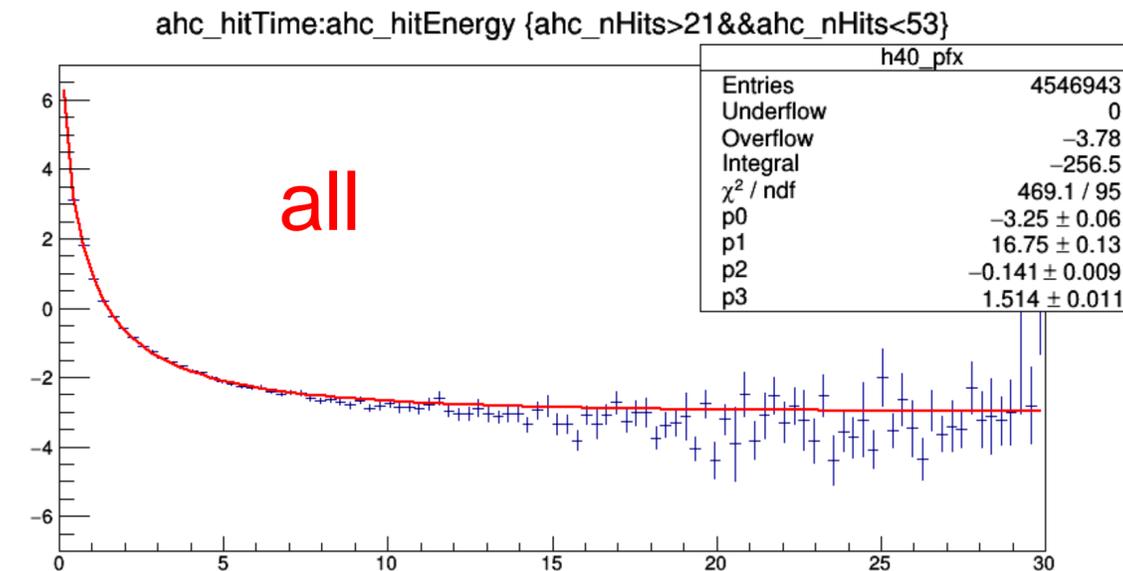
Form 1 ~ok until 8 MIPS.

Form 10 better behaved and robust.

Time Walk for muons: low/high gain

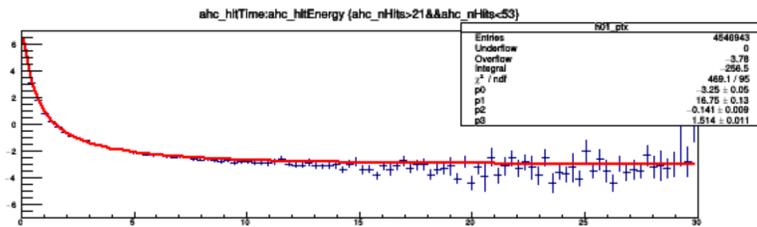


very different responses

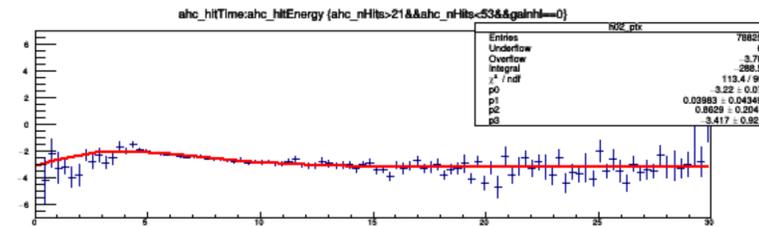


Muons: Low vs High Gain

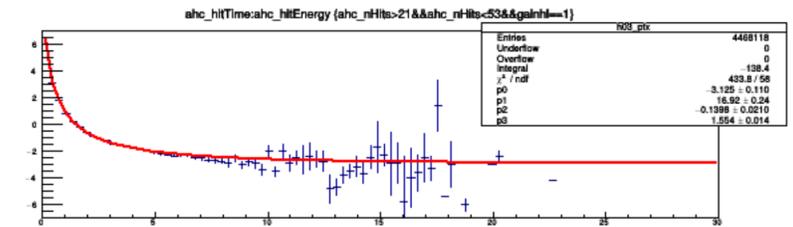
time vs energy



all

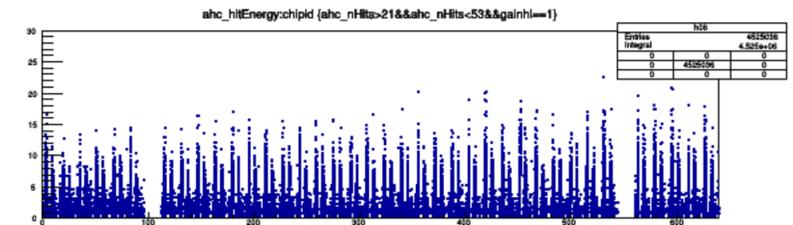
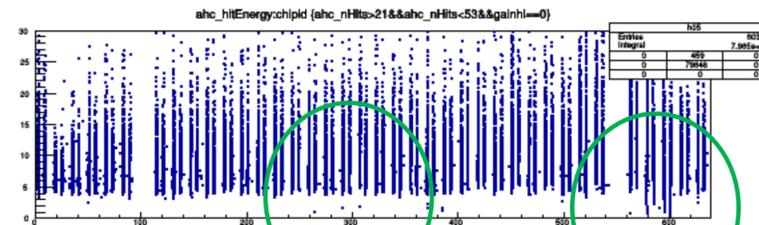
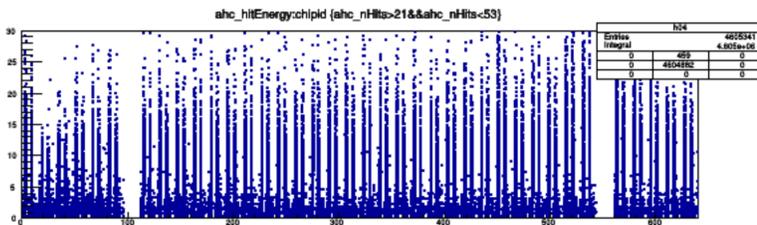


low gain



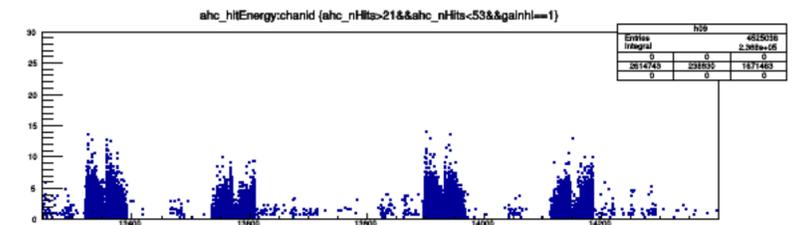
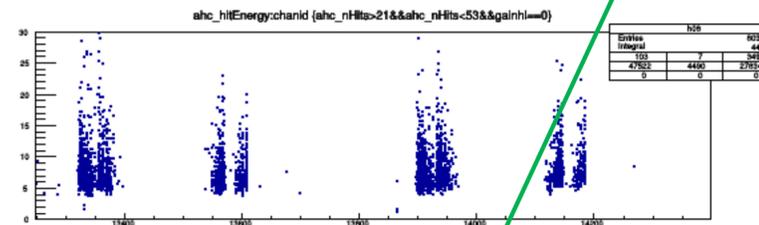
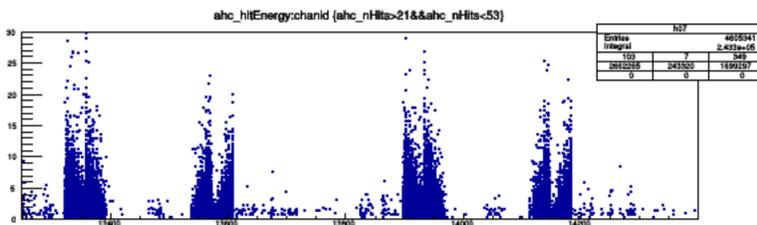
high gain

time vs chipID

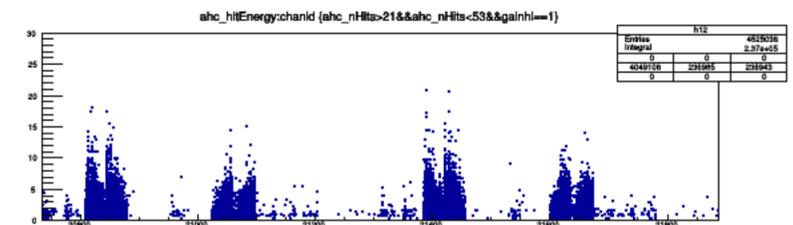
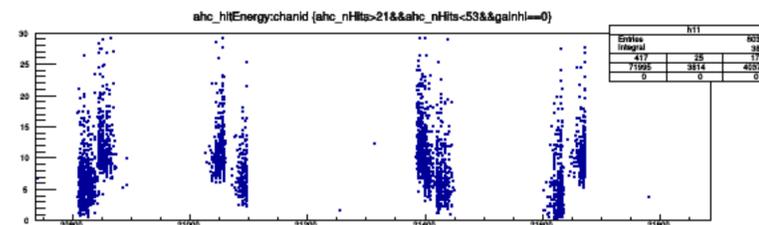
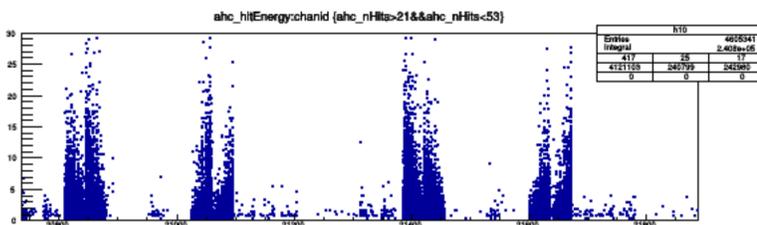


problem chips?

time vs channelID

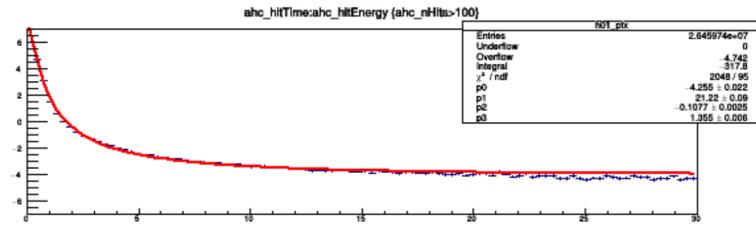


time vs channelID

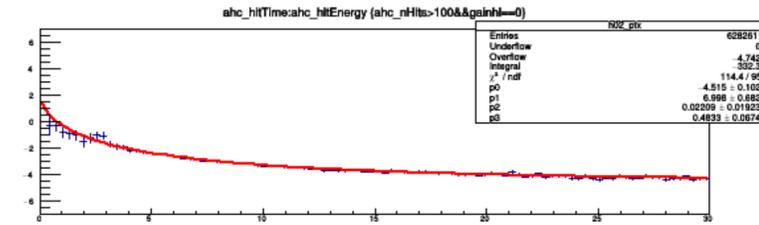


Electrons: Low vs High Gain

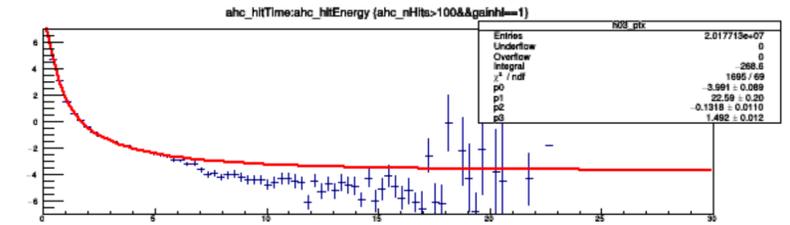
time vs energy



all

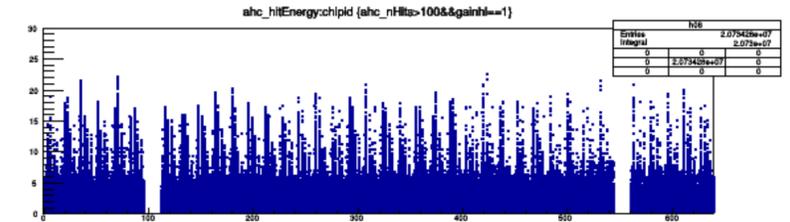
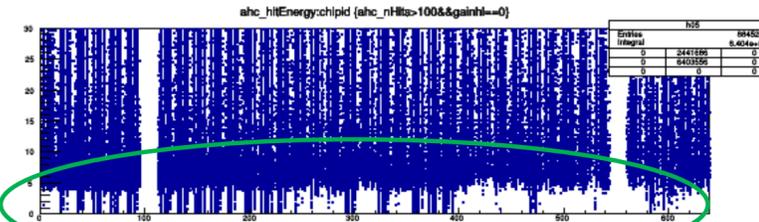
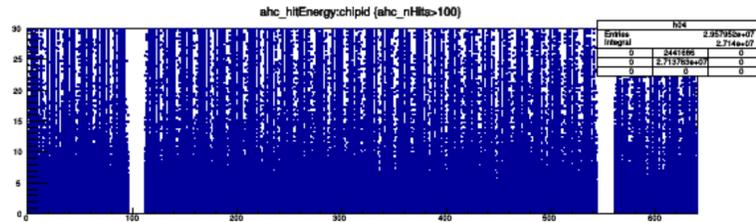


low gain



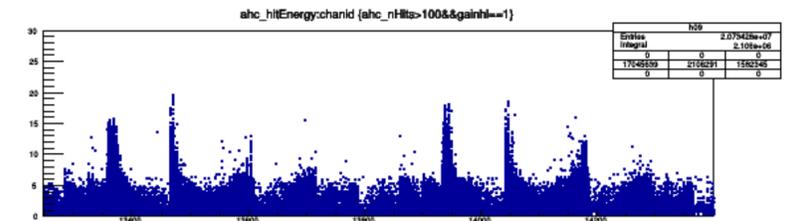
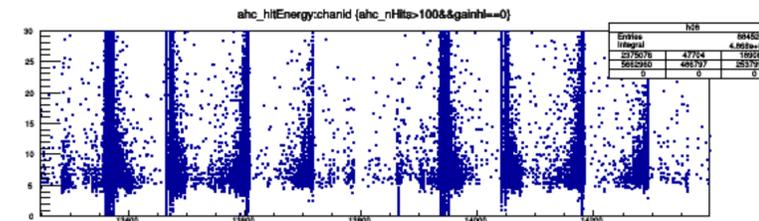
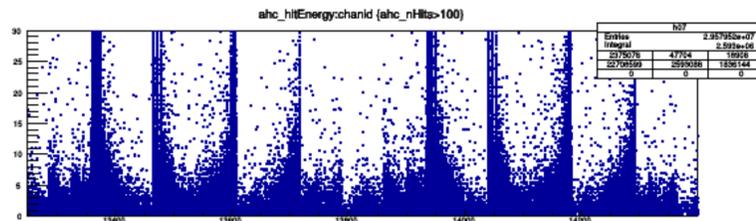
high gain

time vs chipID



much more often the case

time vs channelID



time vs channelID

