

AHCAL Time Response Analysis



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IPP / McGill University
Supported by DAAD and MPP

DAAD

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Start from scratch

Learn the bash-shell



Learn ROOT .. many thanks to Christian G.! ..



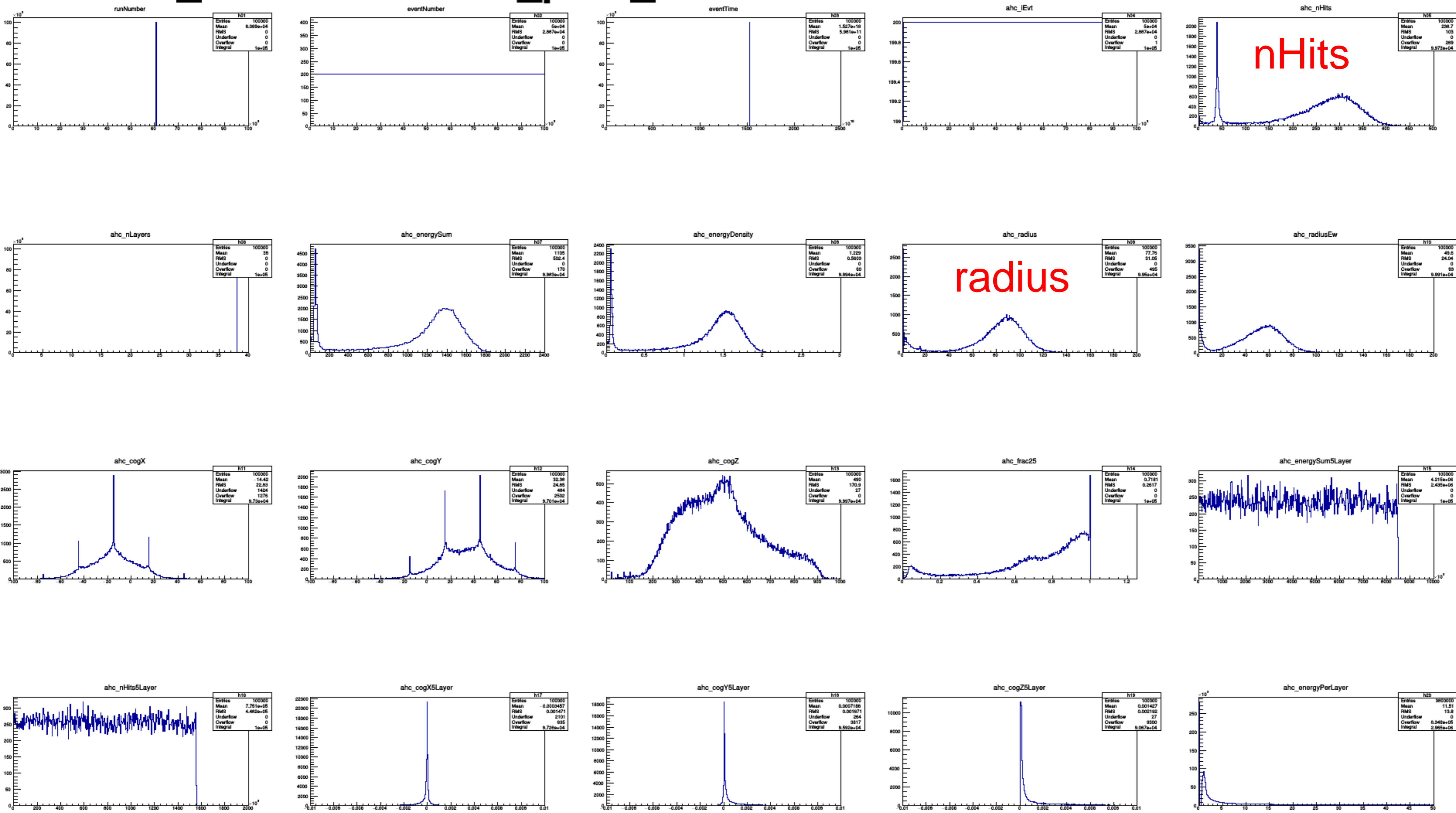
still puzzling & learning.

Datasets available:

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
electrons	reco_run60512_testNewConstants.root	

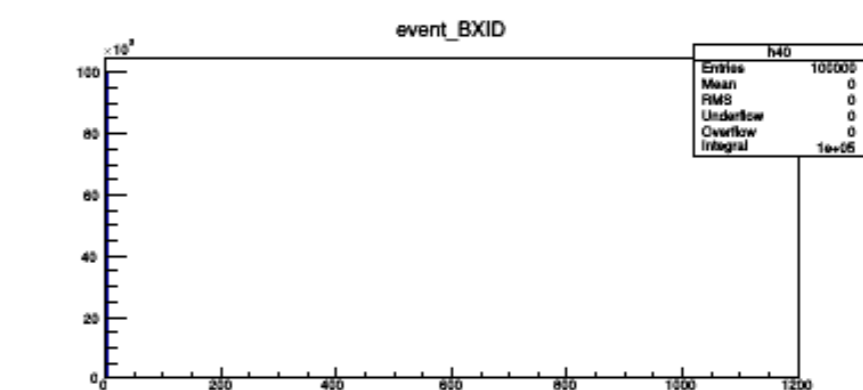
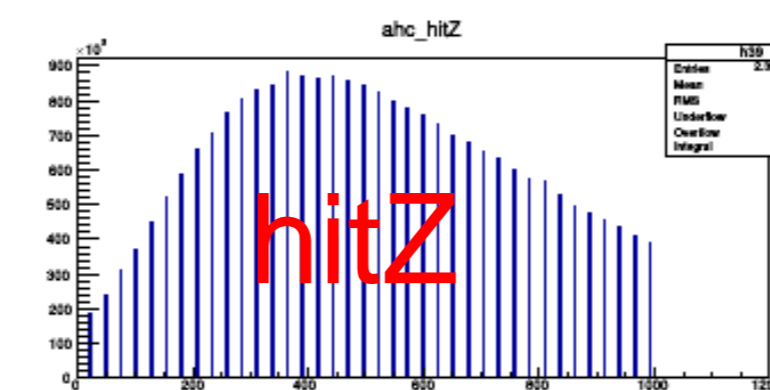
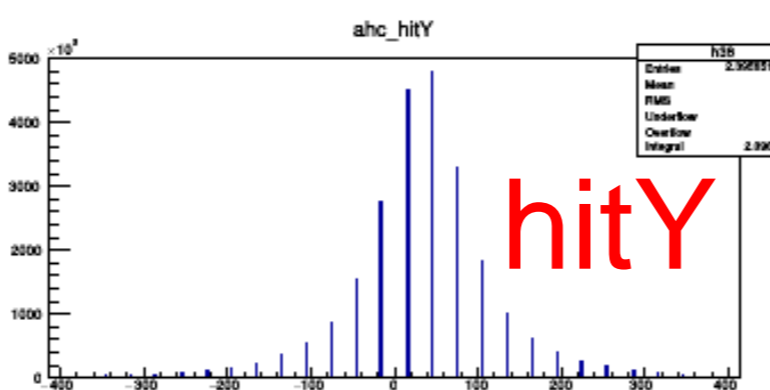
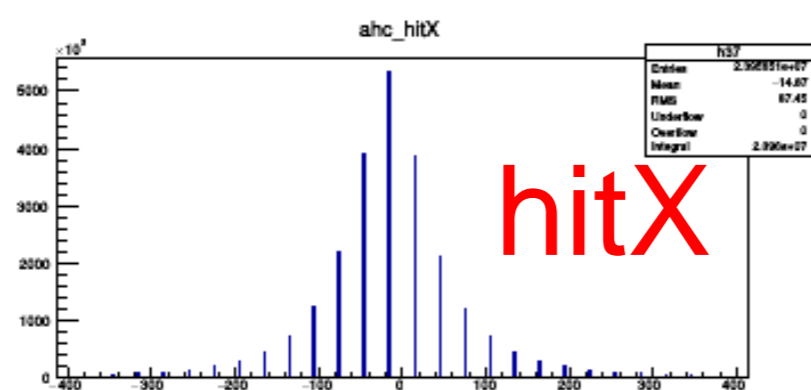
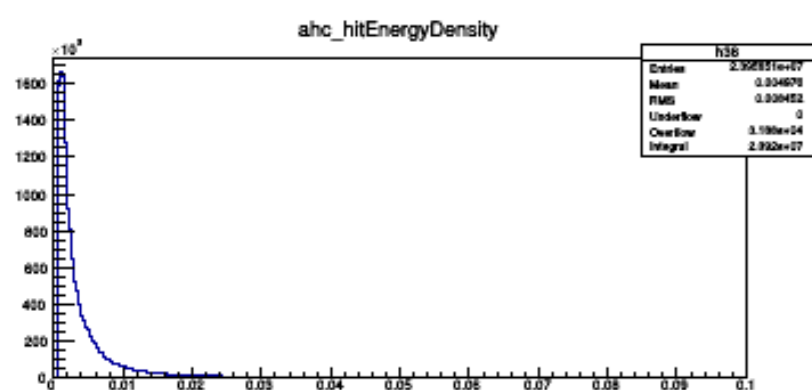
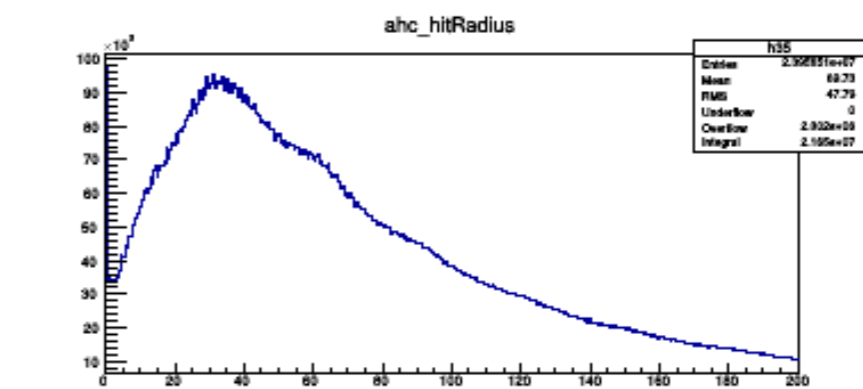
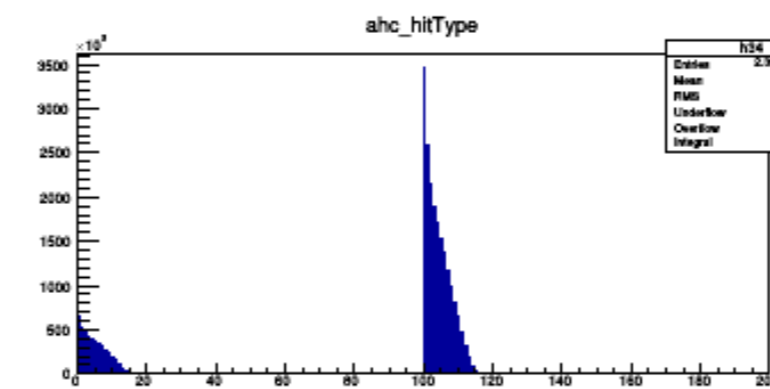
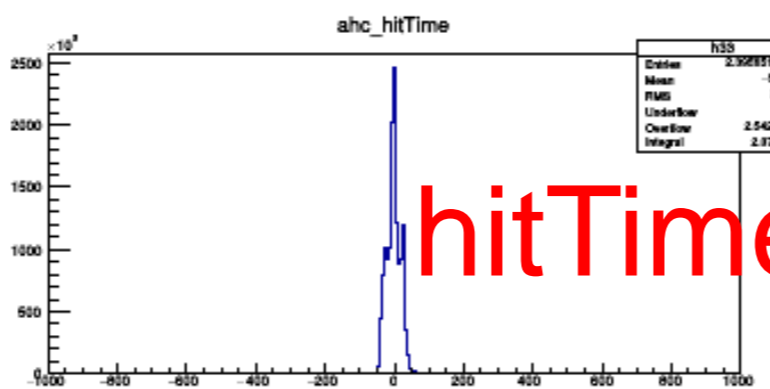
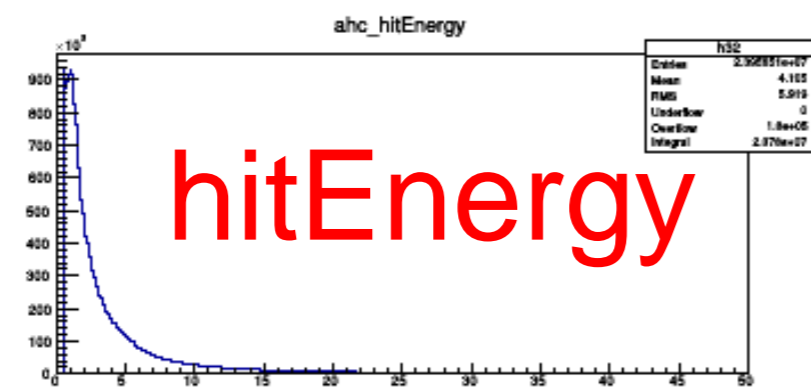
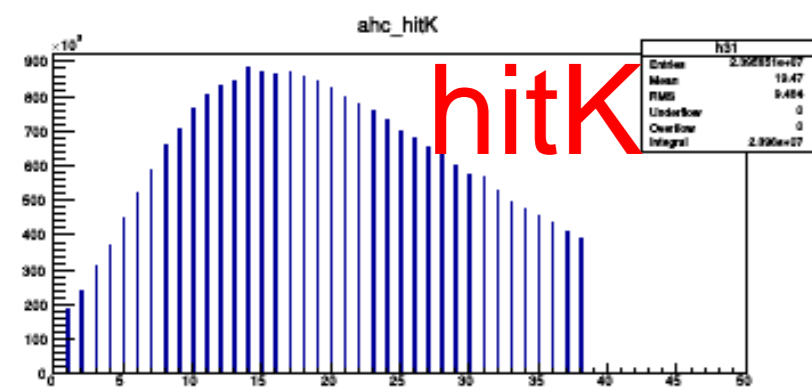
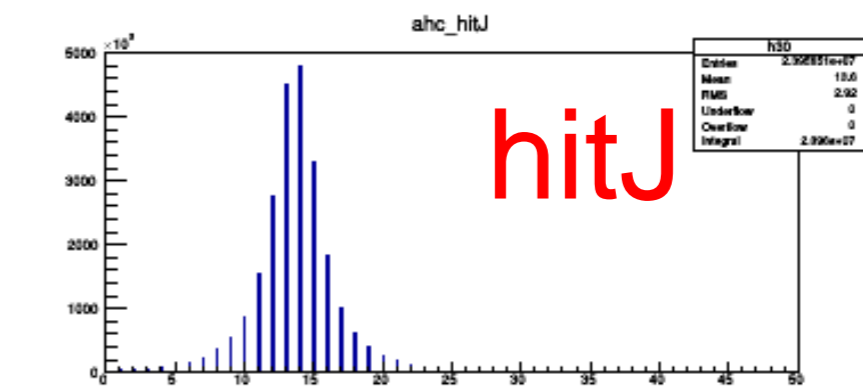
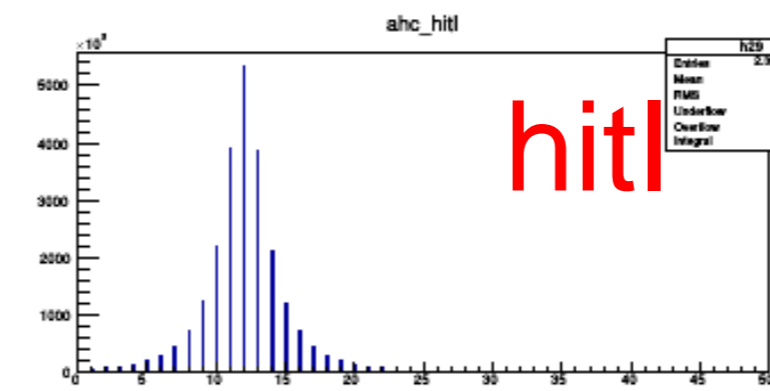
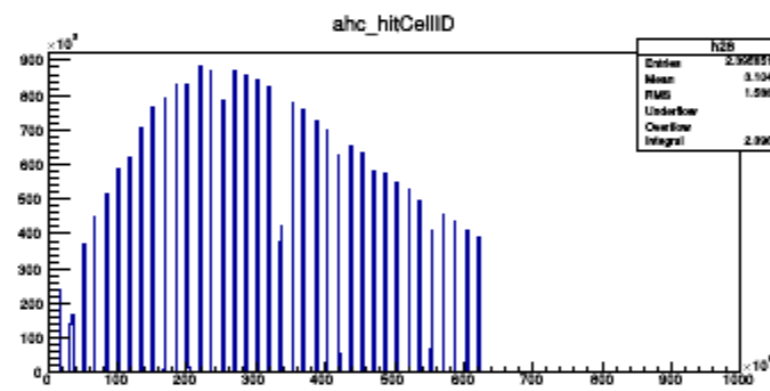
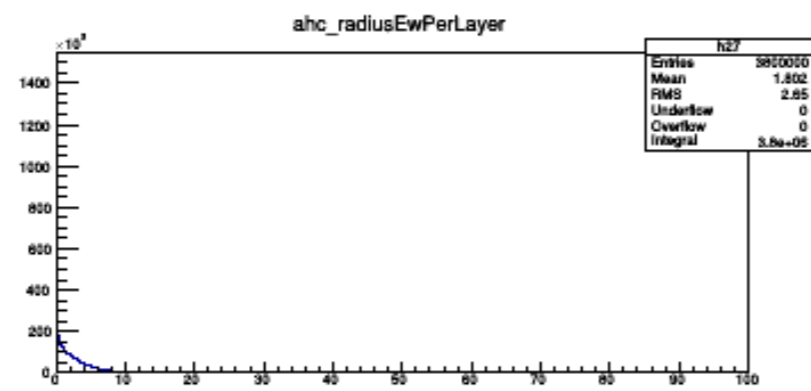
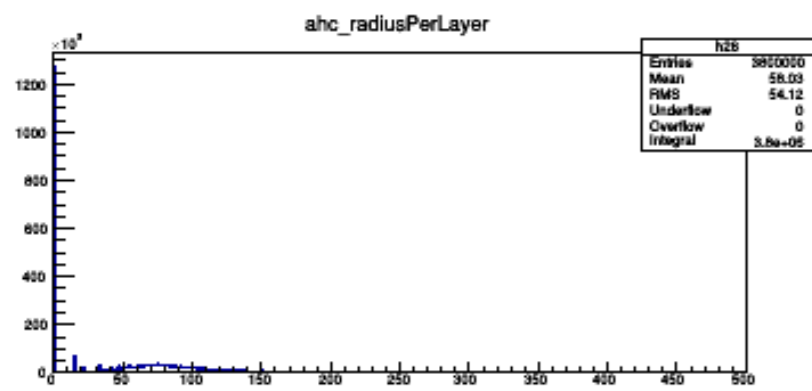
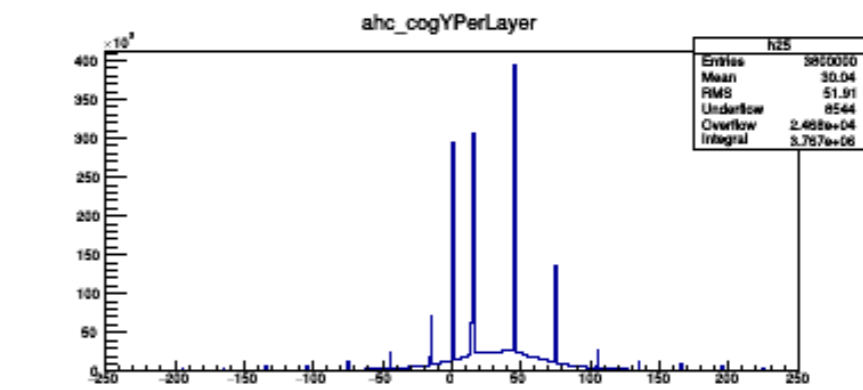
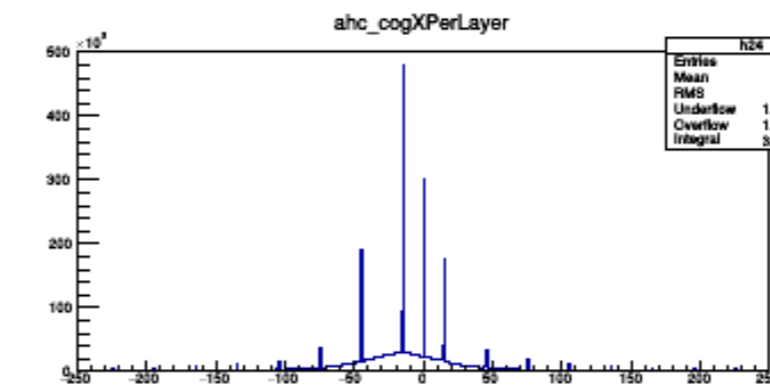
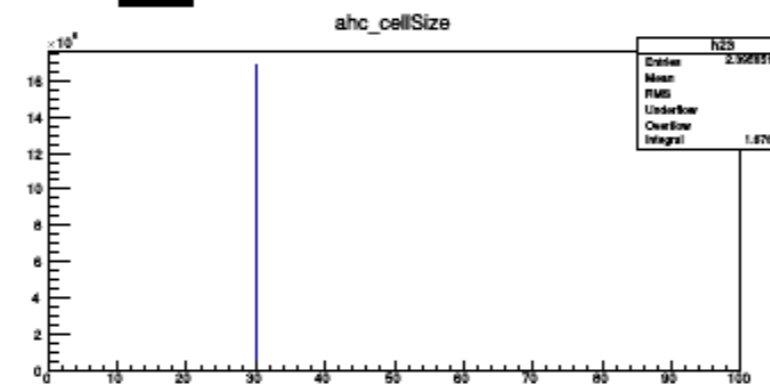
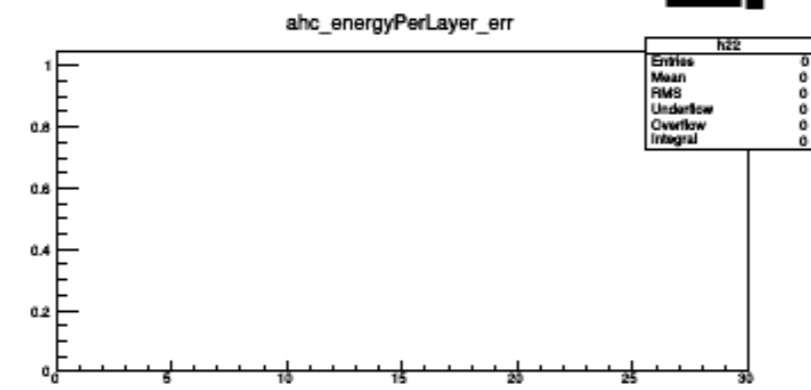
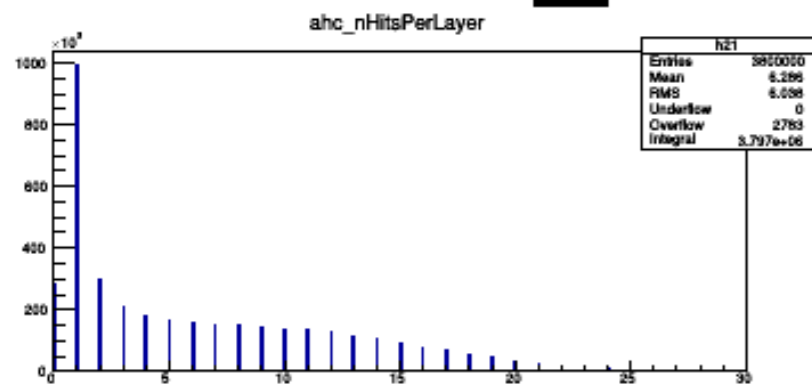
Standard Plots 1

standard_20190612b reco_pion_n40GeV.root



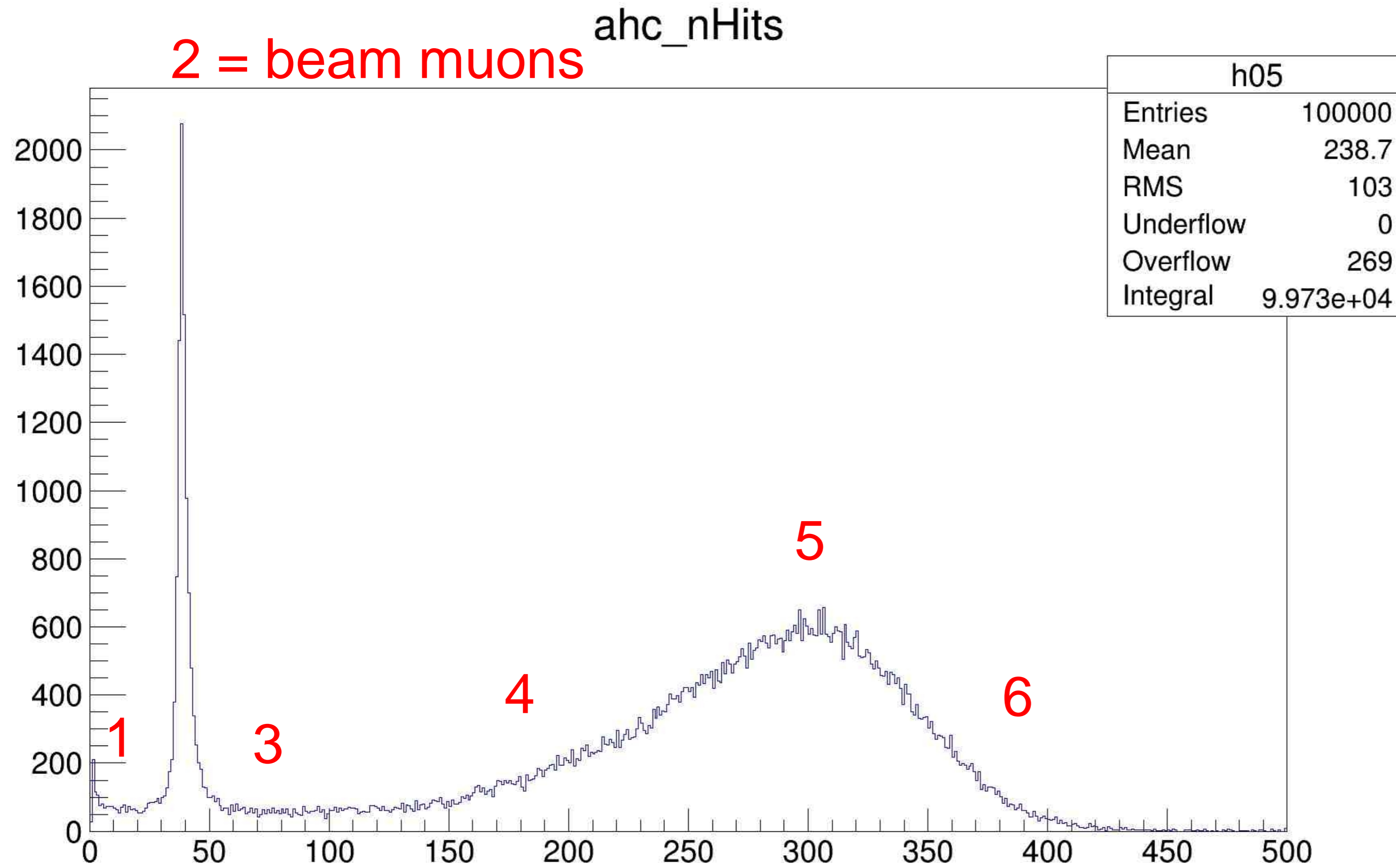
Standard Plots 2

standard_20190612b reco_pion_n40GeV.root



Useful reference for each data set

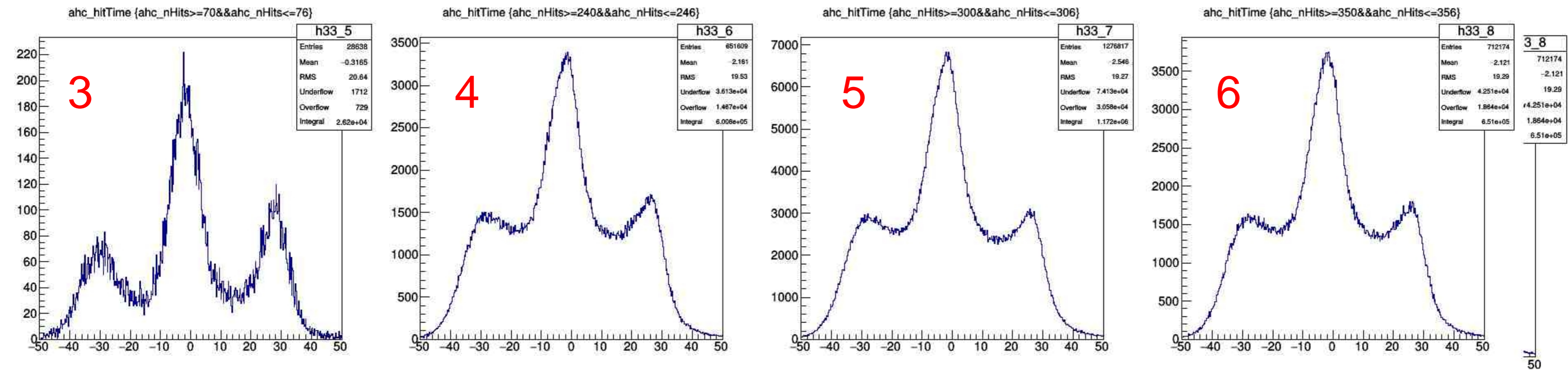
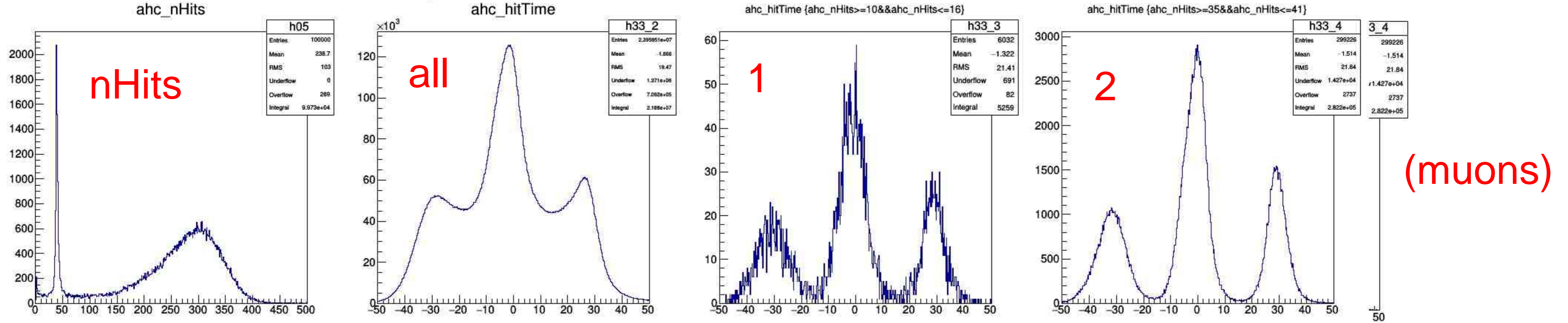
Pions - Hits per event



Select different regions

Pions – Hit Times

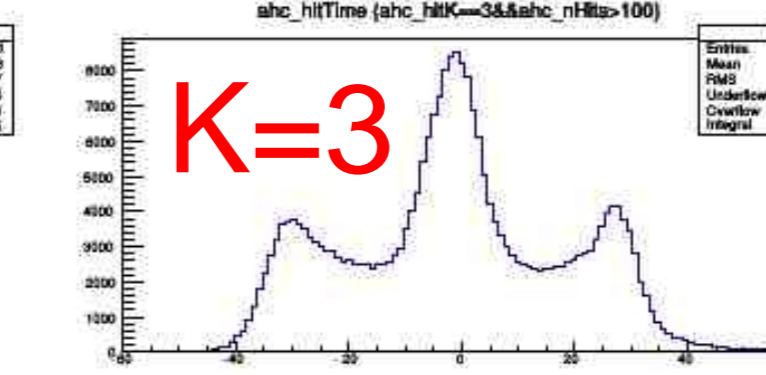
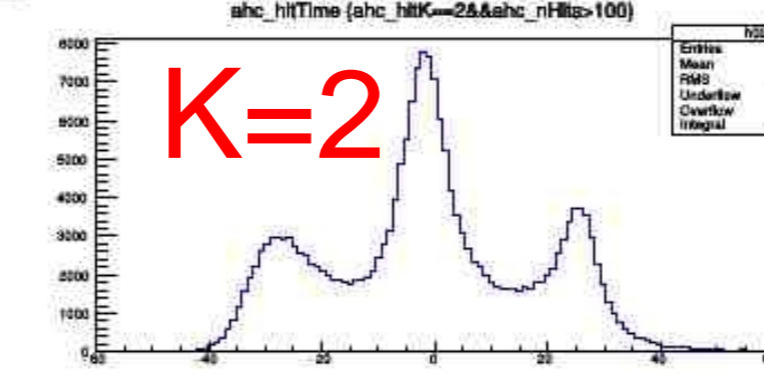
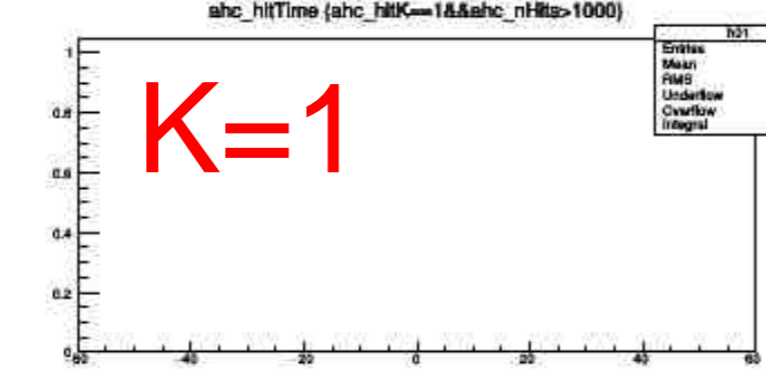
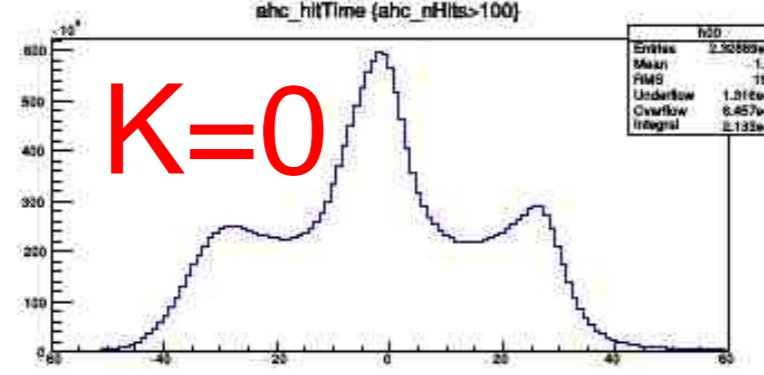
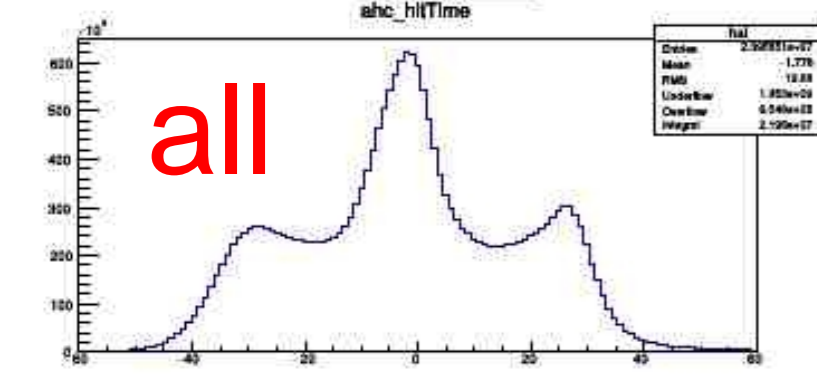
test_20190527a reco_pion_n40GeV.root



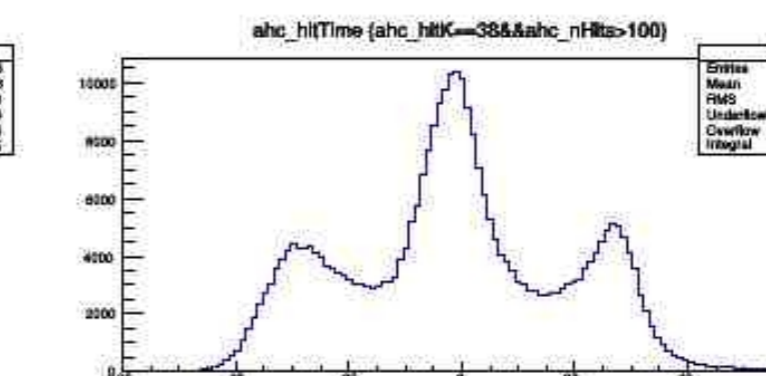
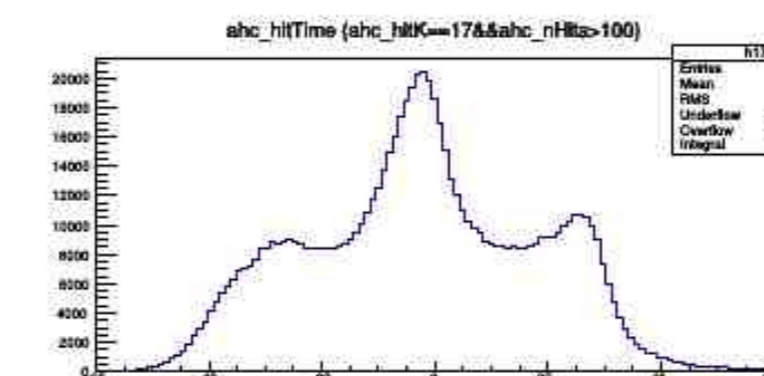
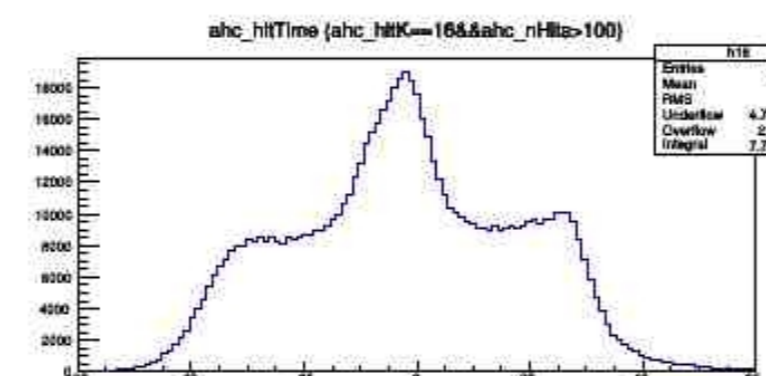
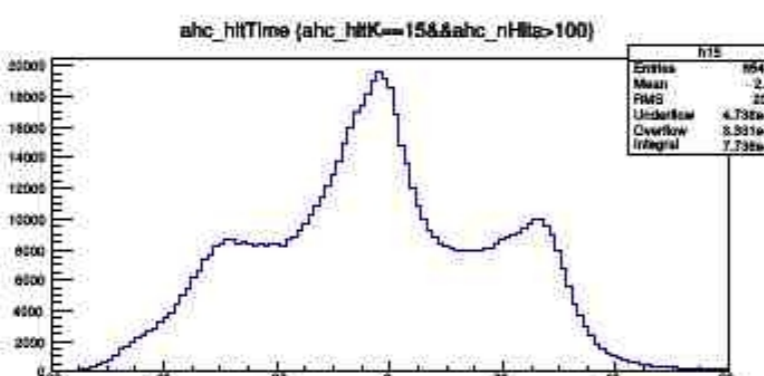
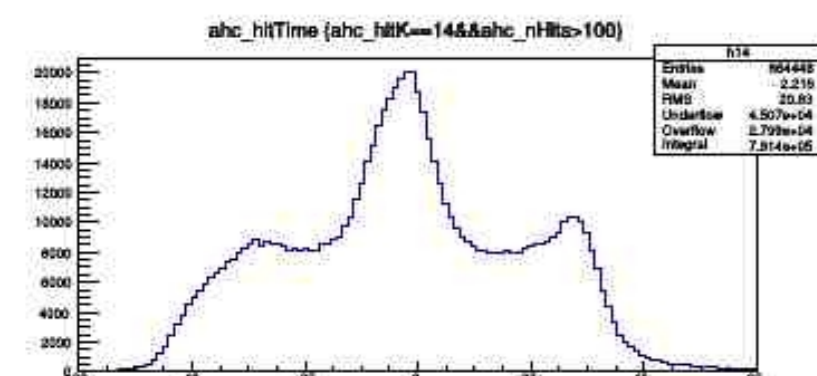
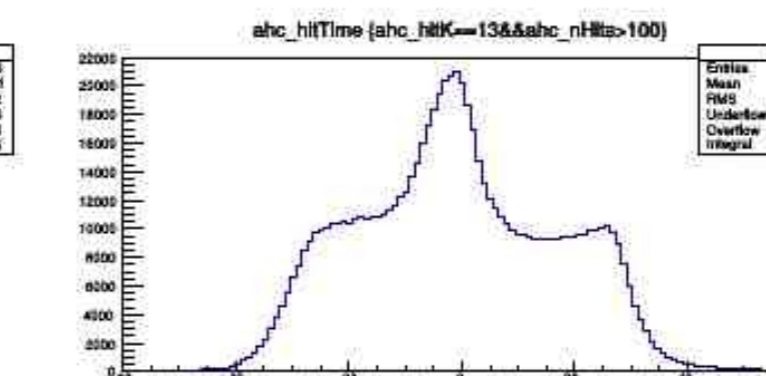
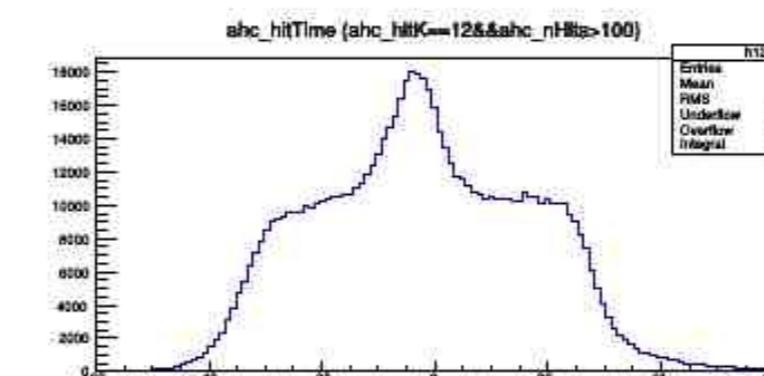
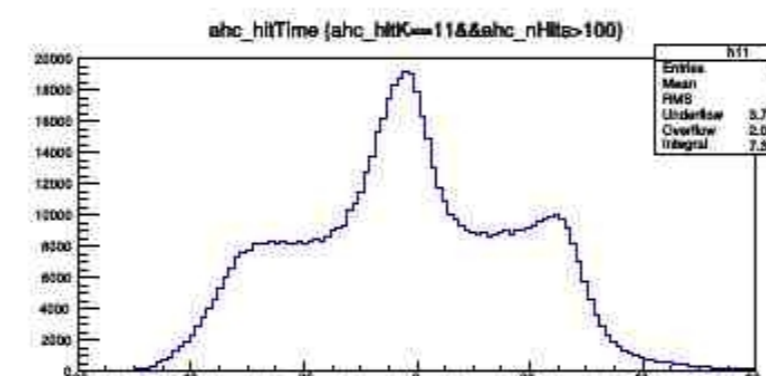
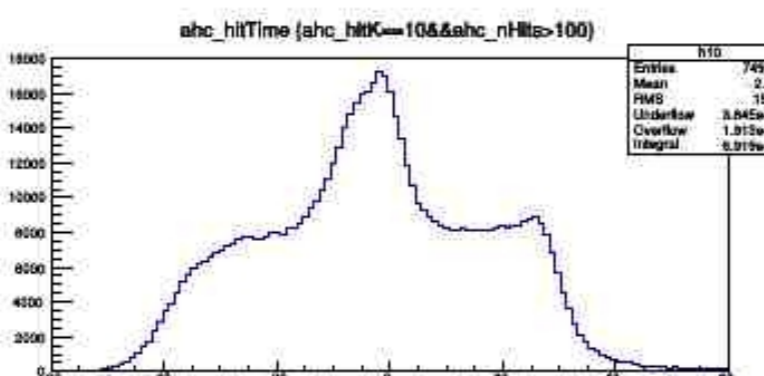
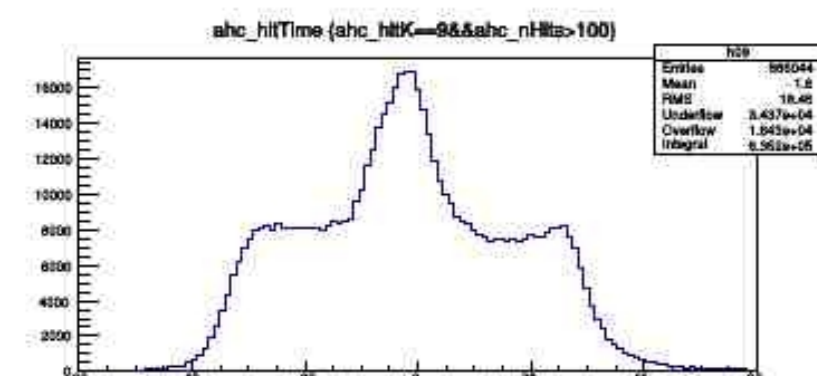
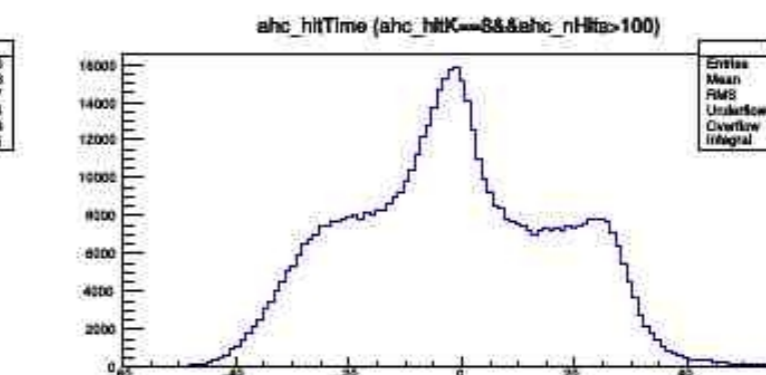
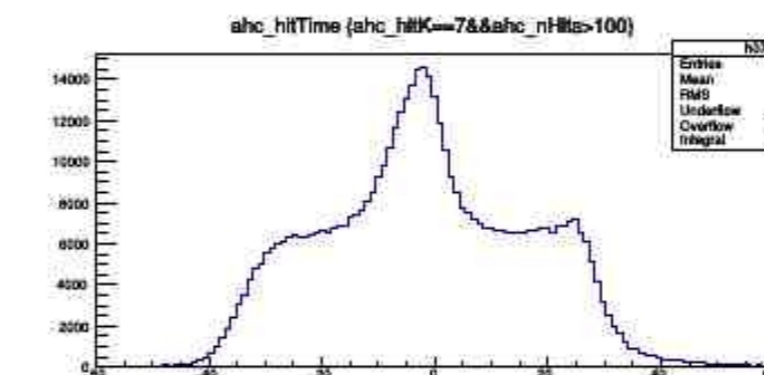
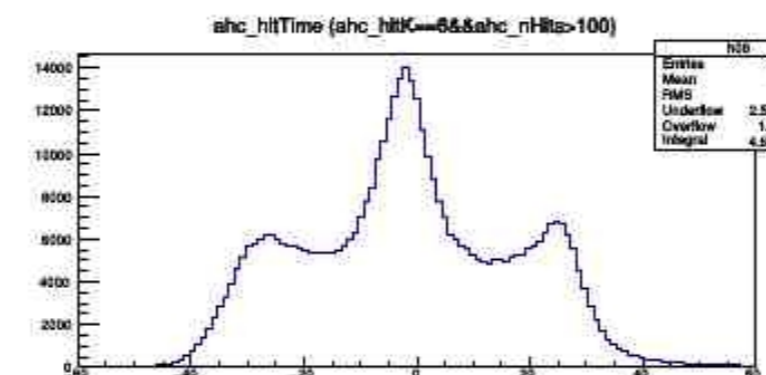
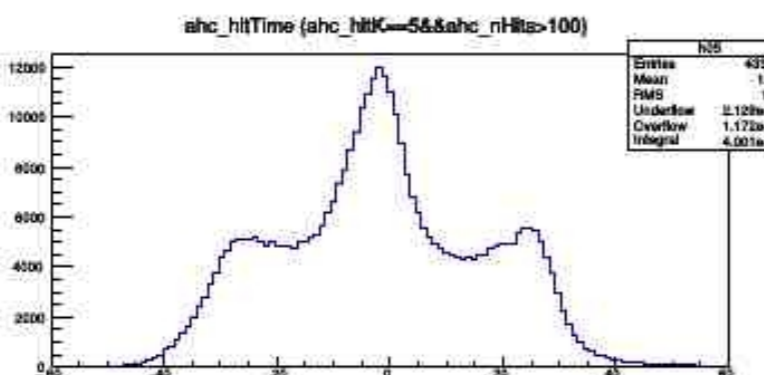
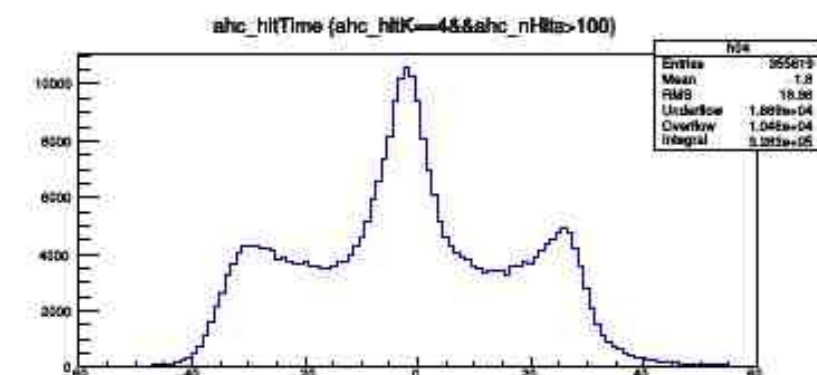
This was before
time response
was corrected

Pions – Time vs Layer

versust_20190527a_hitTimevsk reco_pion_n40GeV.root



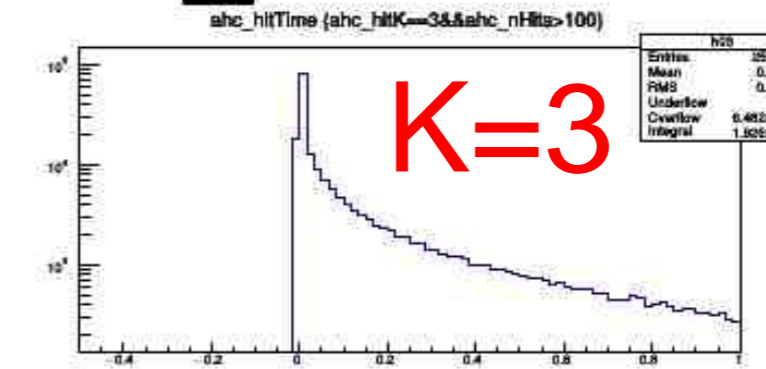
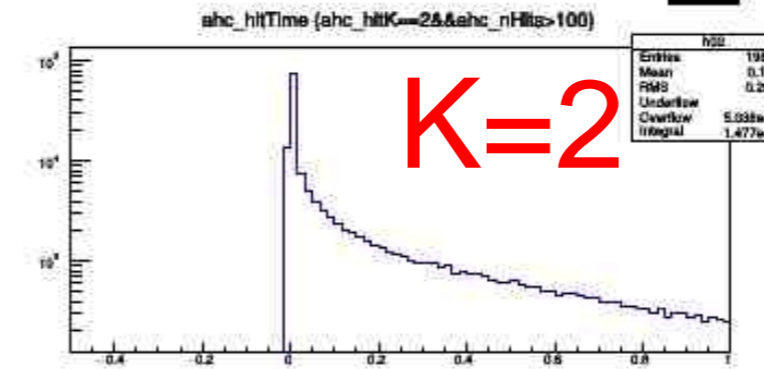
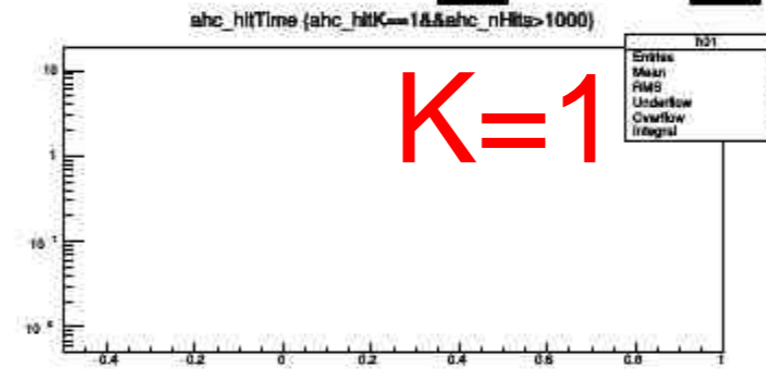
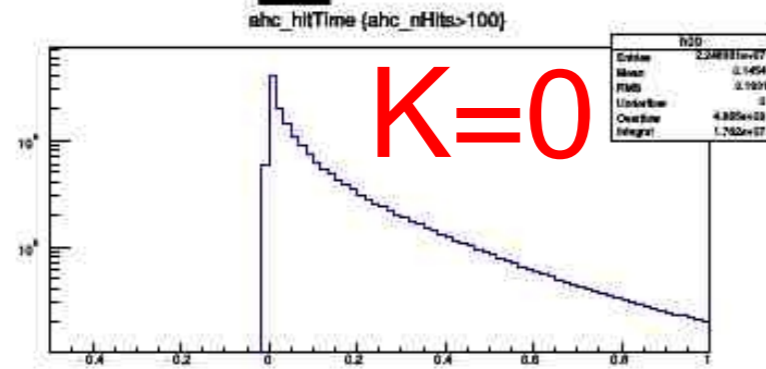
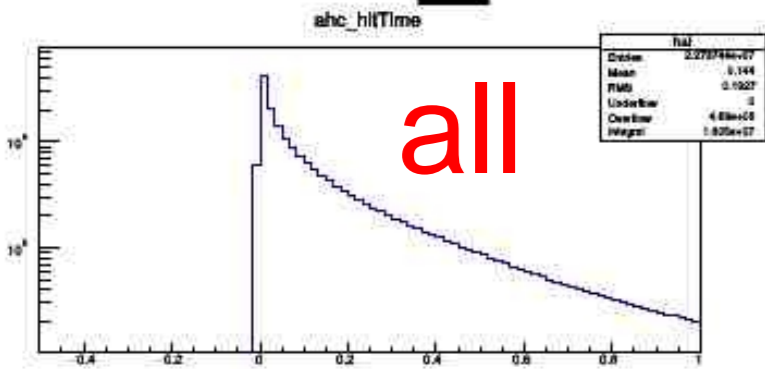
etc..



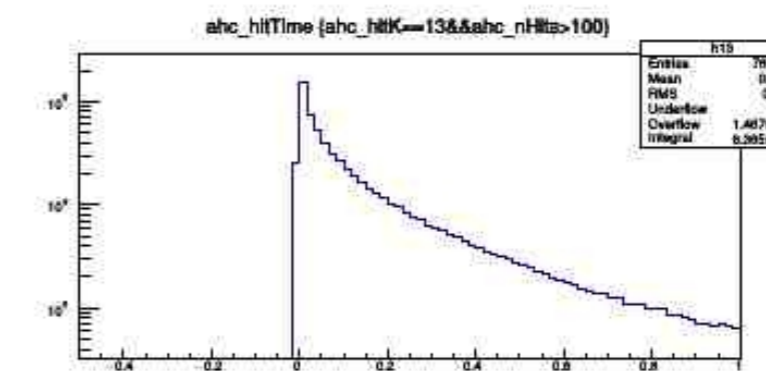
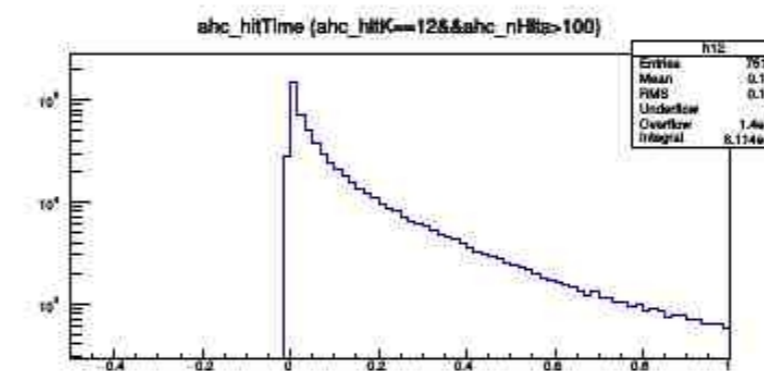
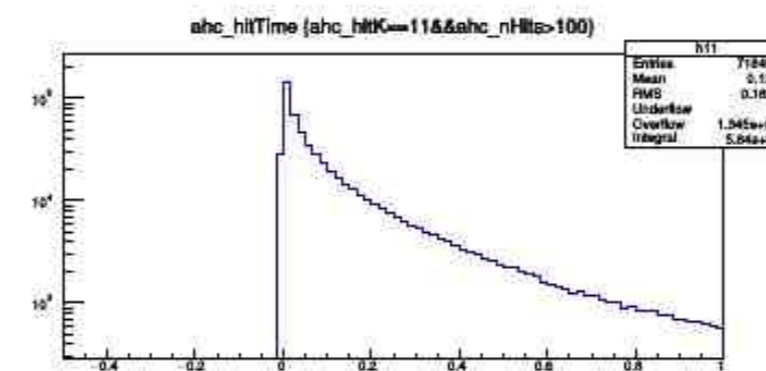
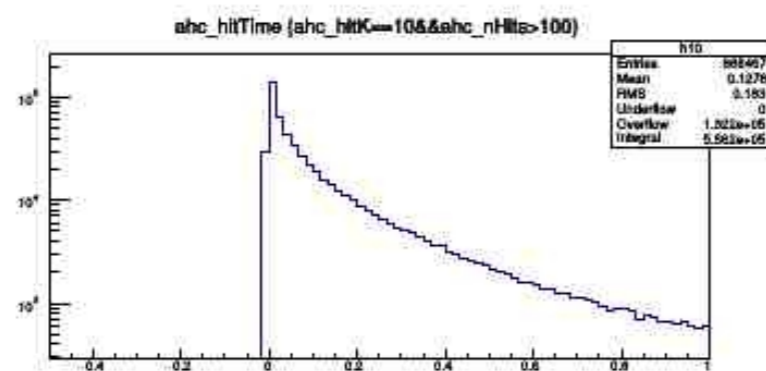
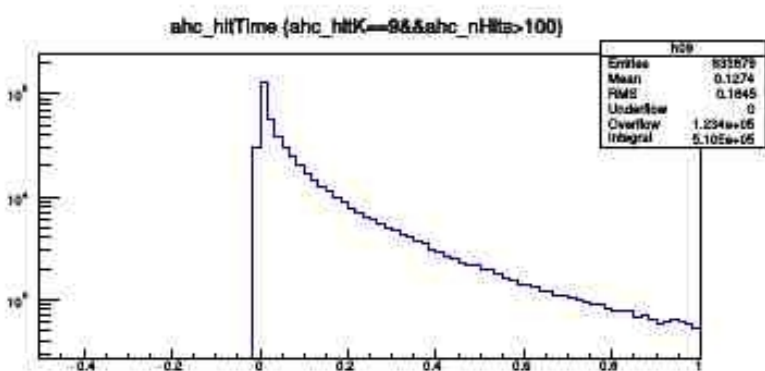
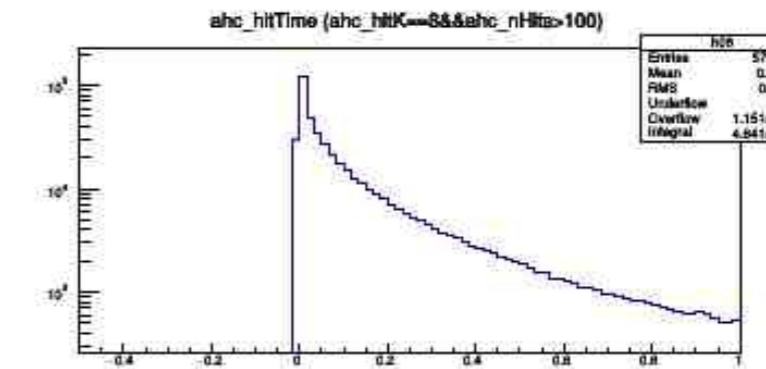
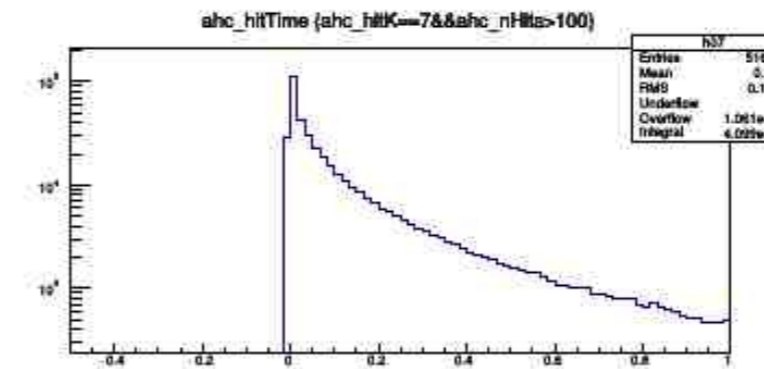
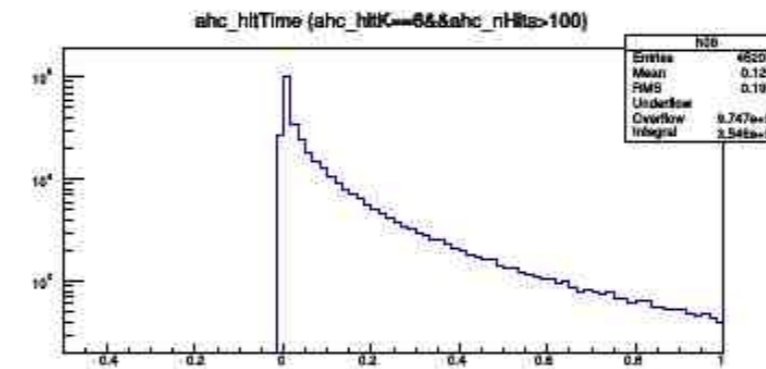
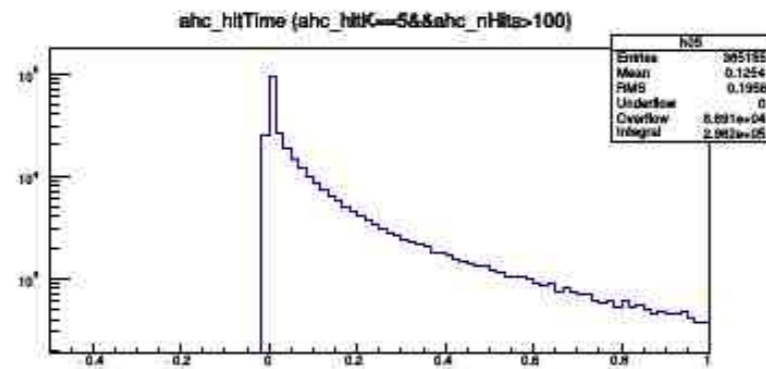
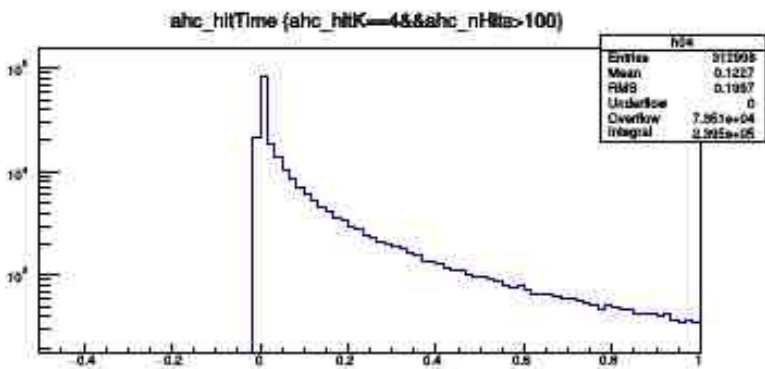
Similar for all layers

MC Pions – Time vs Layer

versust_20190528c_hitTimevsk reco_MC_40GeV-Pions_scan_0ns.root

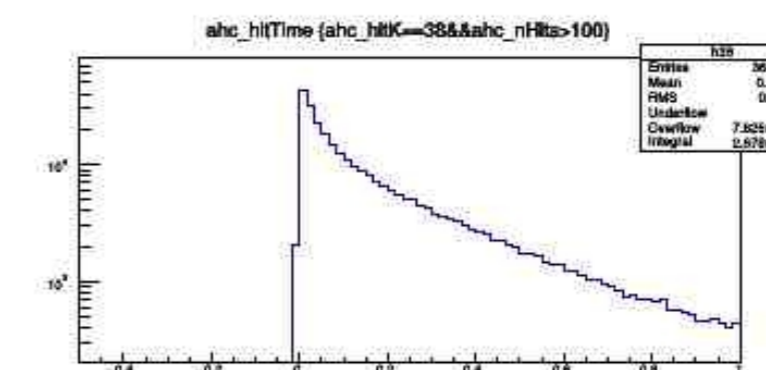
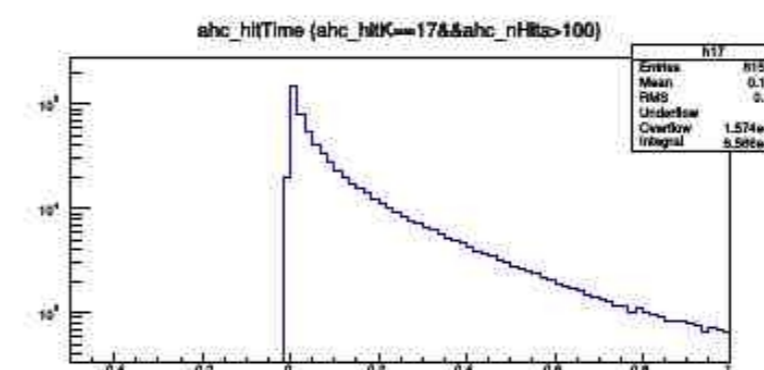
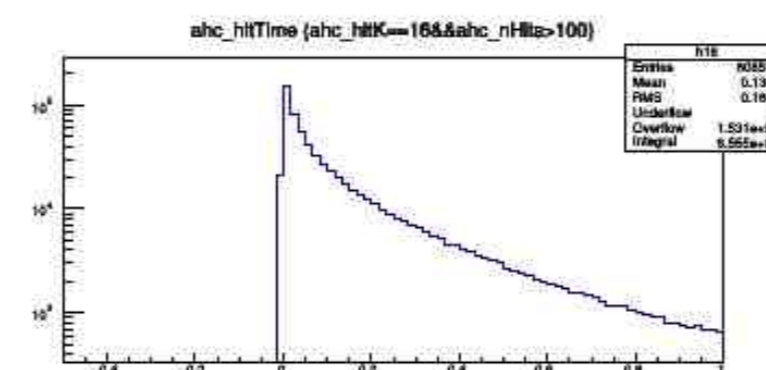
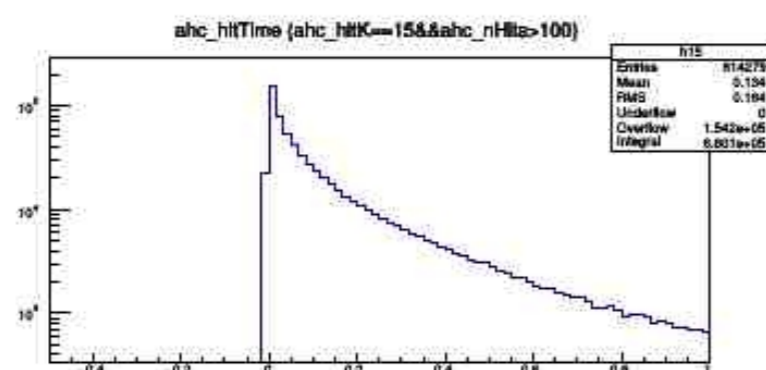
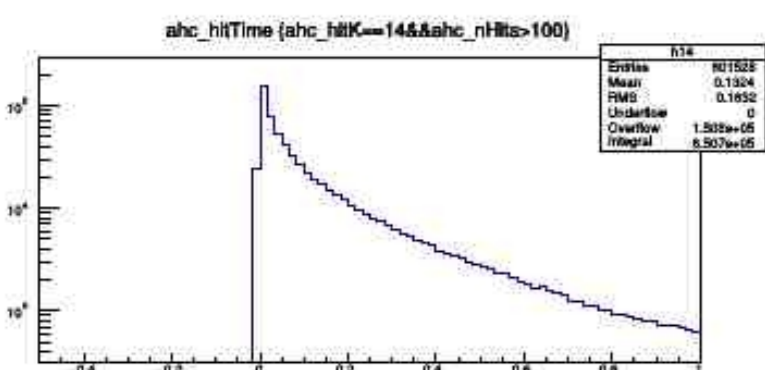


etc..



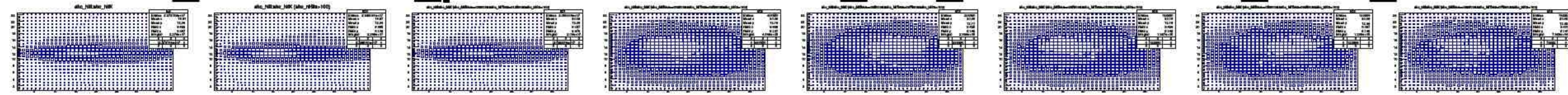
Only positive times in MC...

Time spreading observed deeper in calorimeter



MC Pions – XZ vs Time

versust_20190529f_posvshitTime reco_MC_40GeV-Pions_scan_0ns.root



all

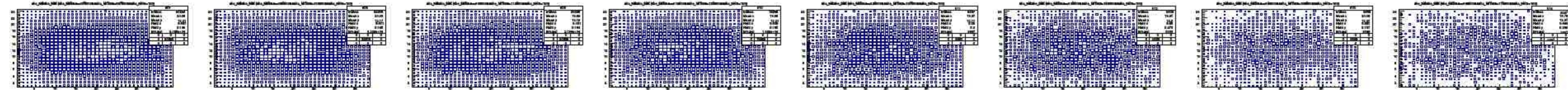
t0

t1

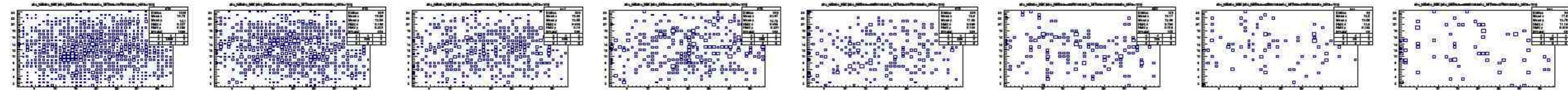
t2

t3

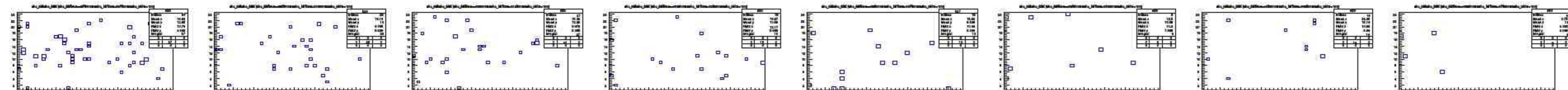
etc..



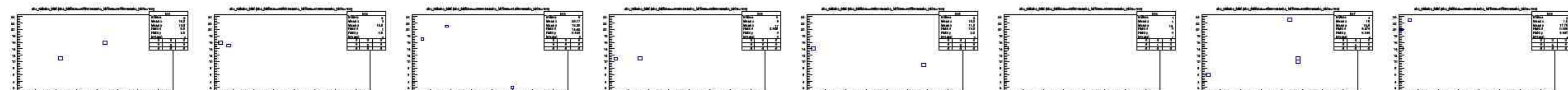
.. in steps of 12500 units



(only t>0)

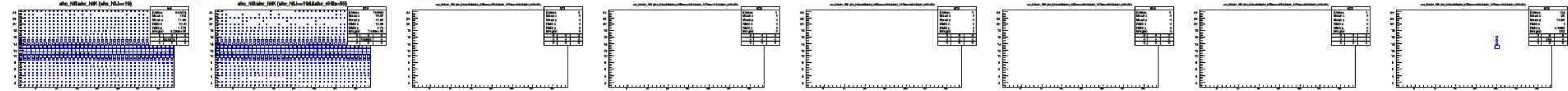


long-lived signals from neutrons



Muons – XZ vs Time

versust_20190529i_posvshitTime reco_run60382.root



all

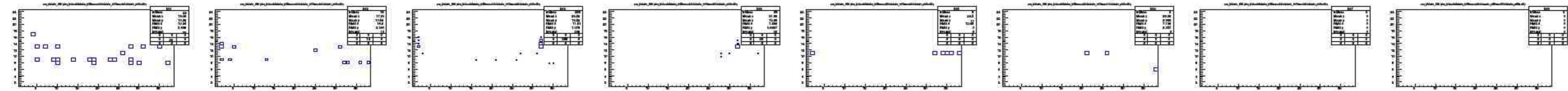
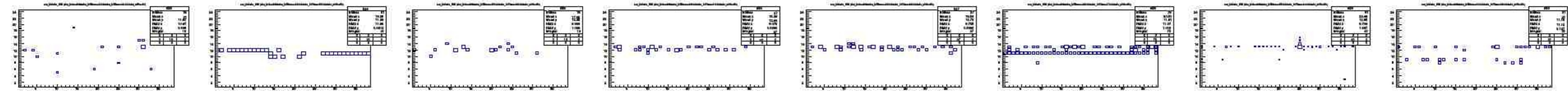
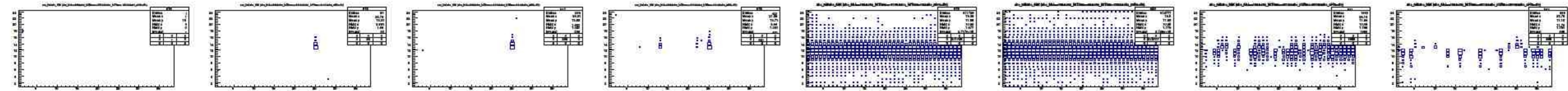
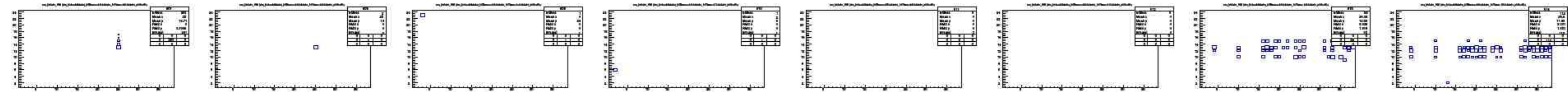
t0

t1

t2

t3

etc..



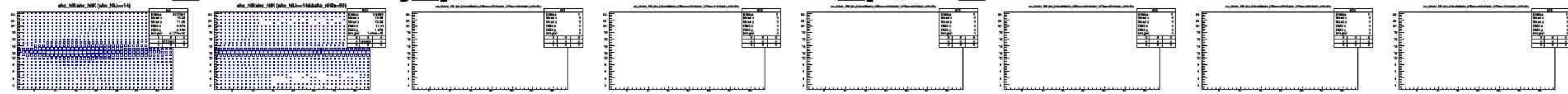
.. in steps of 300 units

(-5700 < t < 5700)

very few long-lived signals

Muons in Pion Data – XZ vs Time

versust_20190529j_posvshitTime reco_pion_n40GeV.root



all

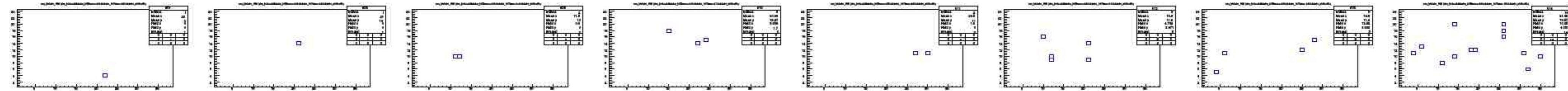
t0

t1

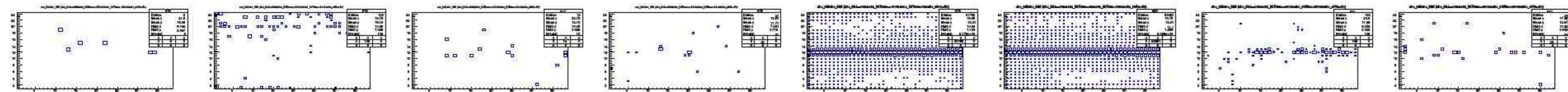
t2

t3

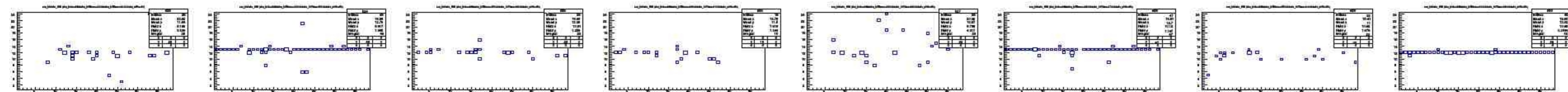
etc..



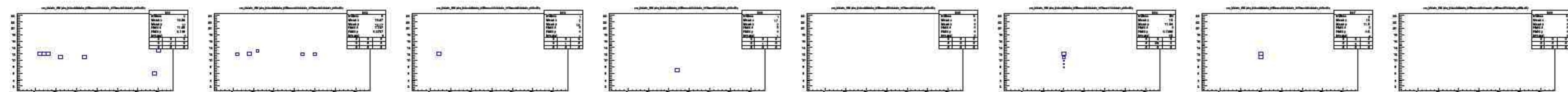
.. in steps of 300 units



(-5700 < t < 5700)

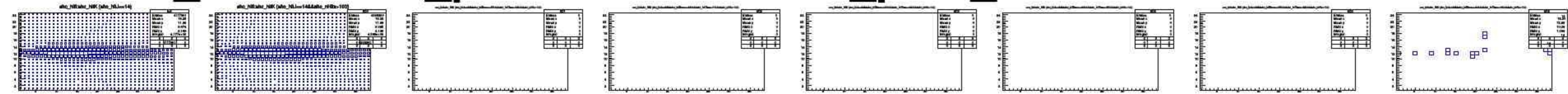


agrees with muon-only data



Pions – XZ vs Time

versust_20190529k_posvshitTime reco_pion_n40GeV.root



all

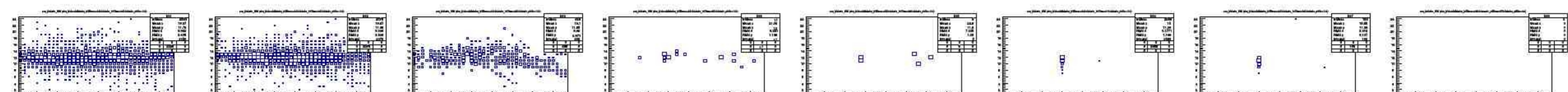
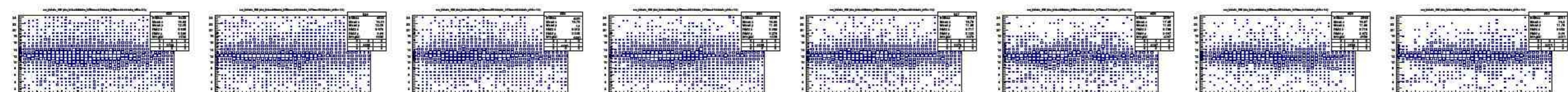
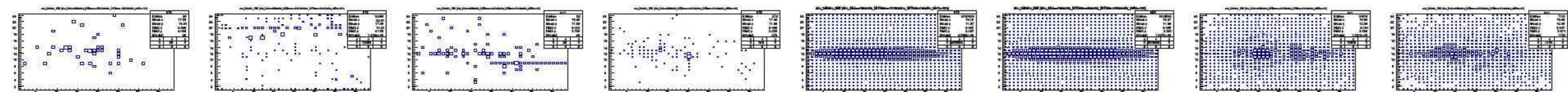
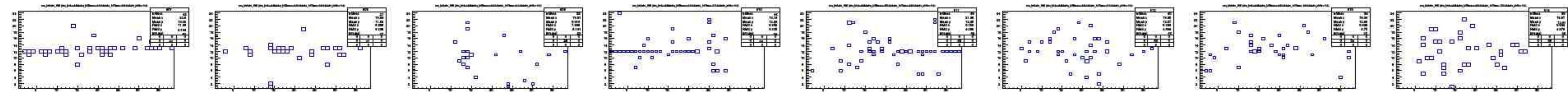
t0

t1

t2

t3

etc..



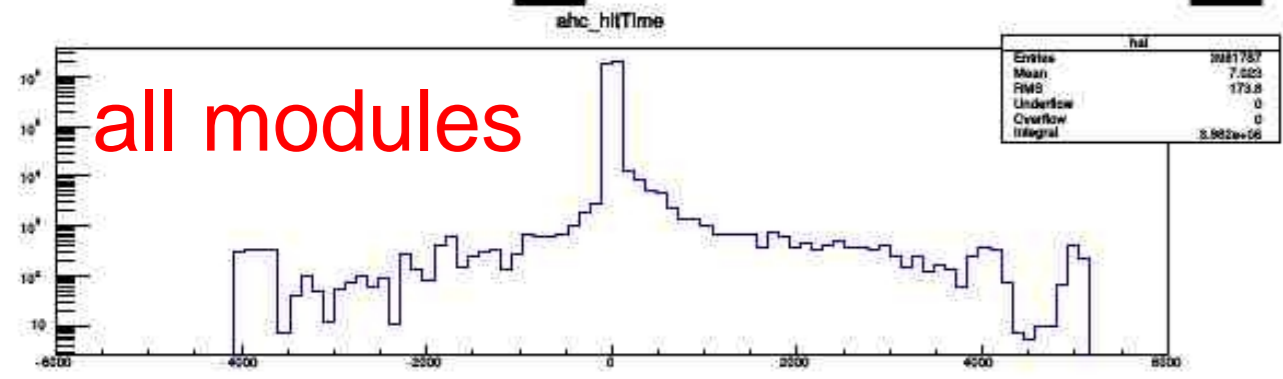
.. in steps of 300 units

(-5700 < t < 5700)

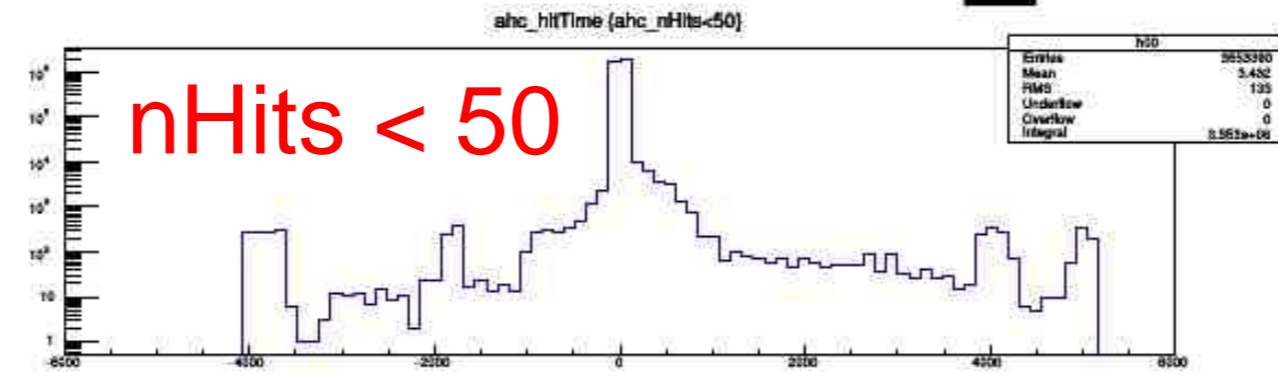
long-lived signals from neutrons

Muons – Time Response (modules, chips, channels)

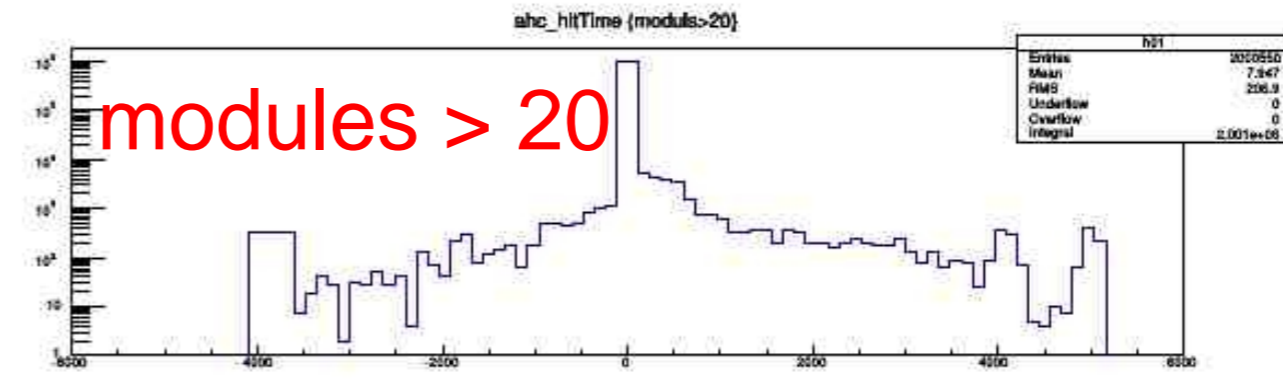
vsmodule_20190605h_hitTimevsMod reco_run60382.root



all modules

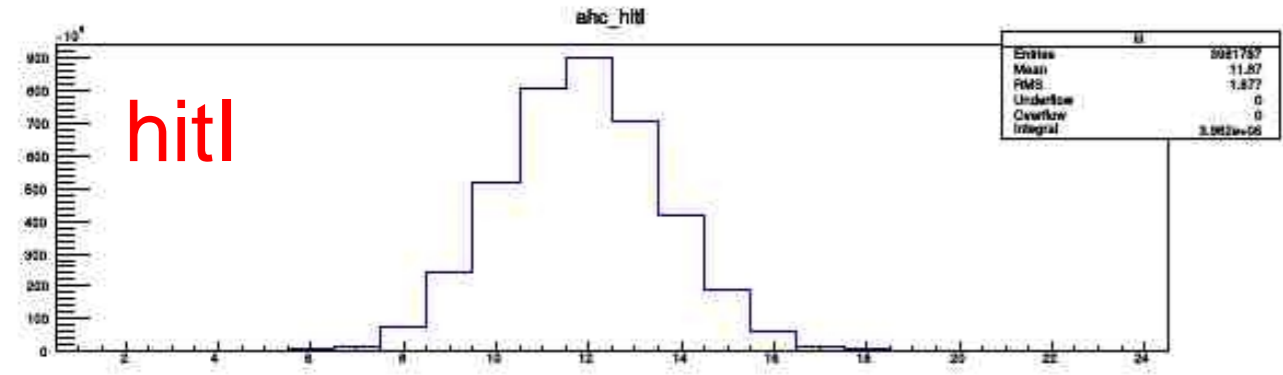


nHits < 50

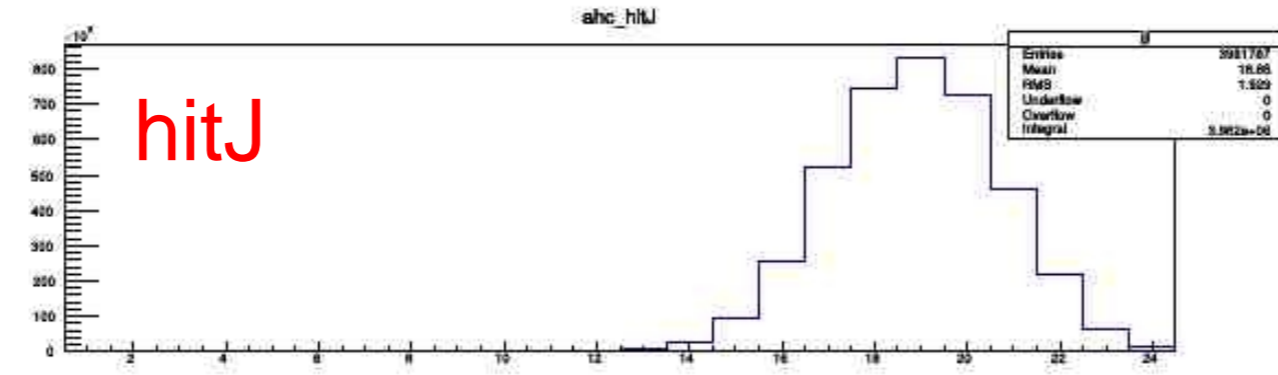


modules > 20

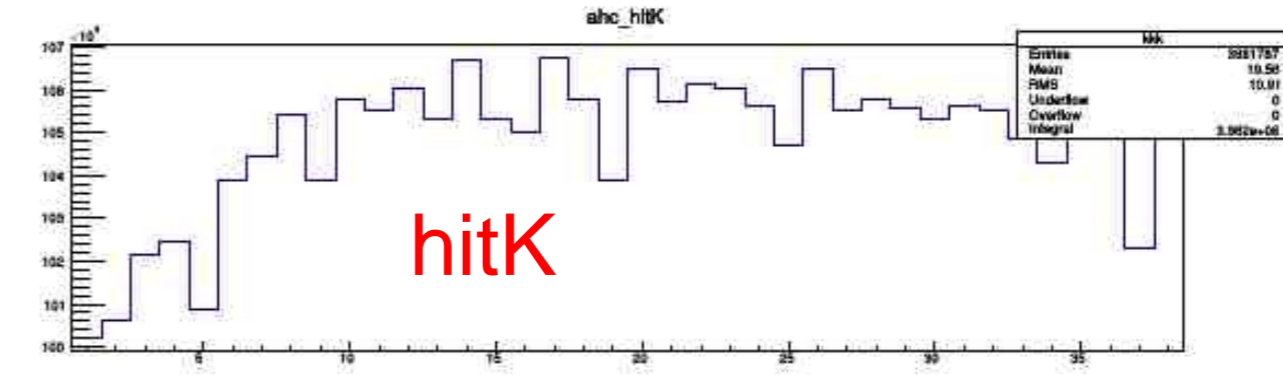
hitTime



hitI



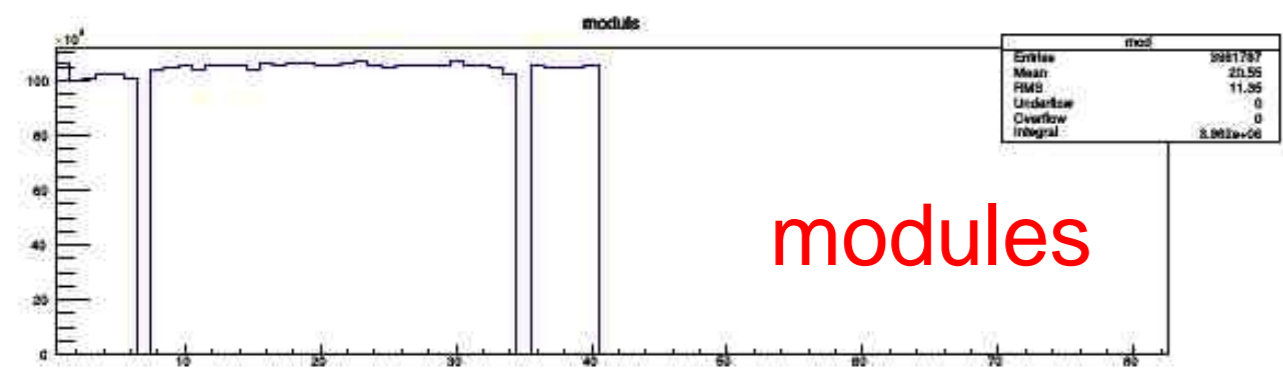
hitJ



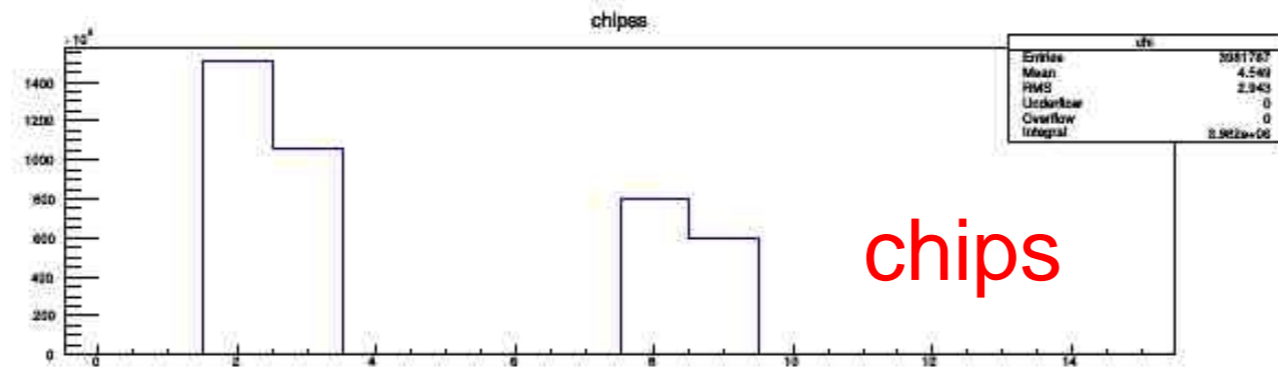
hitK

hitPosition

mapping done

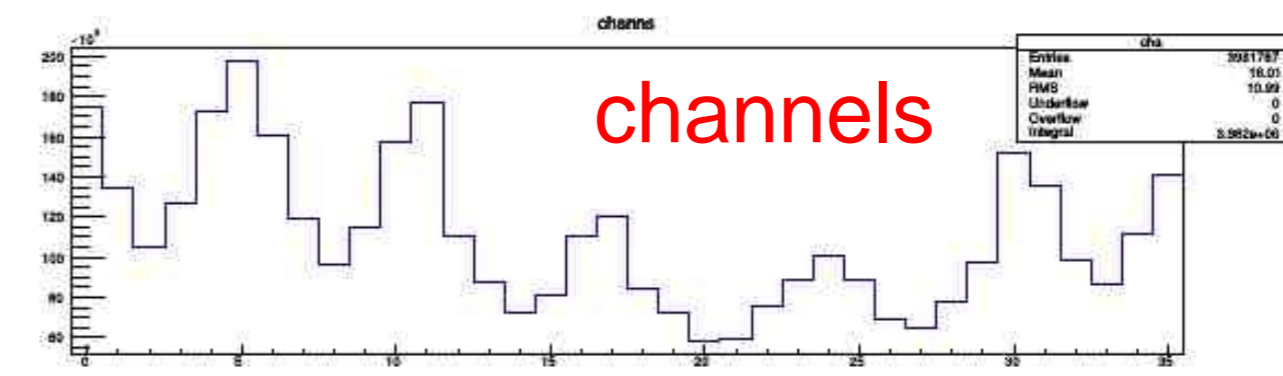


modules



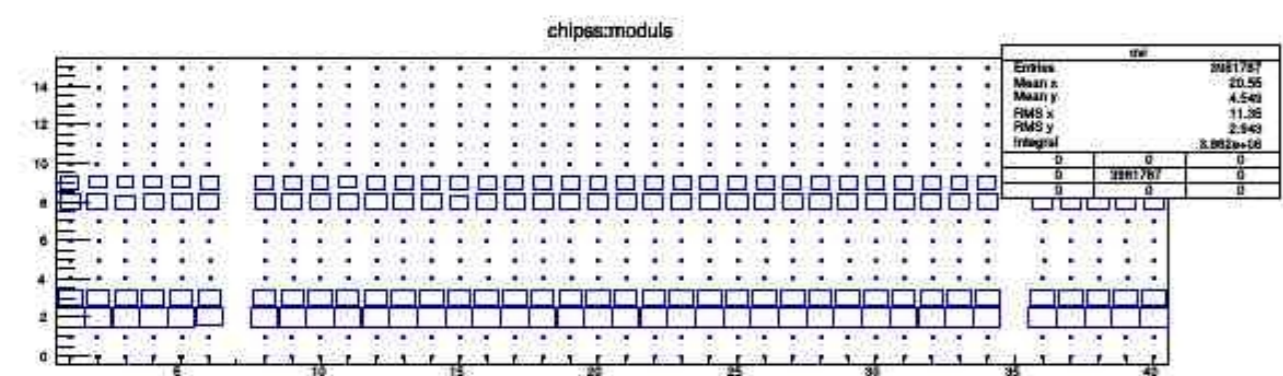
chips

only 4 really used

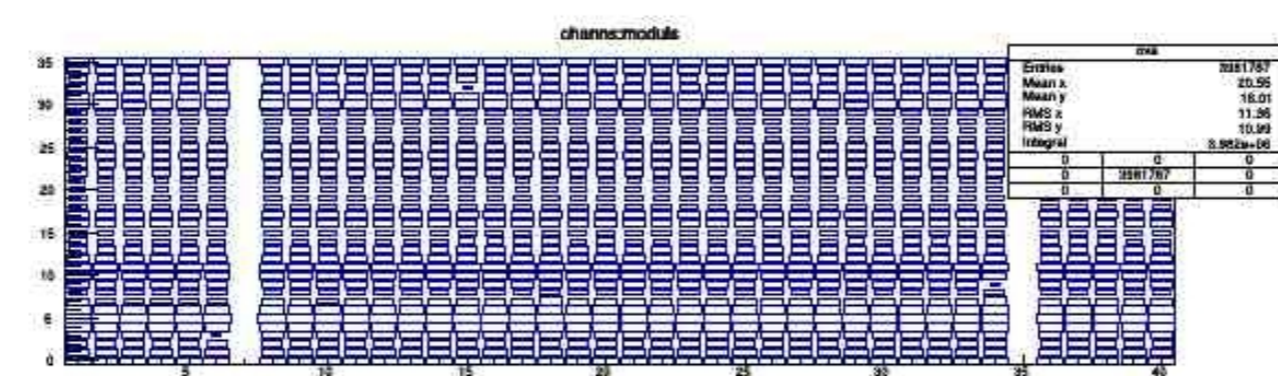


channels

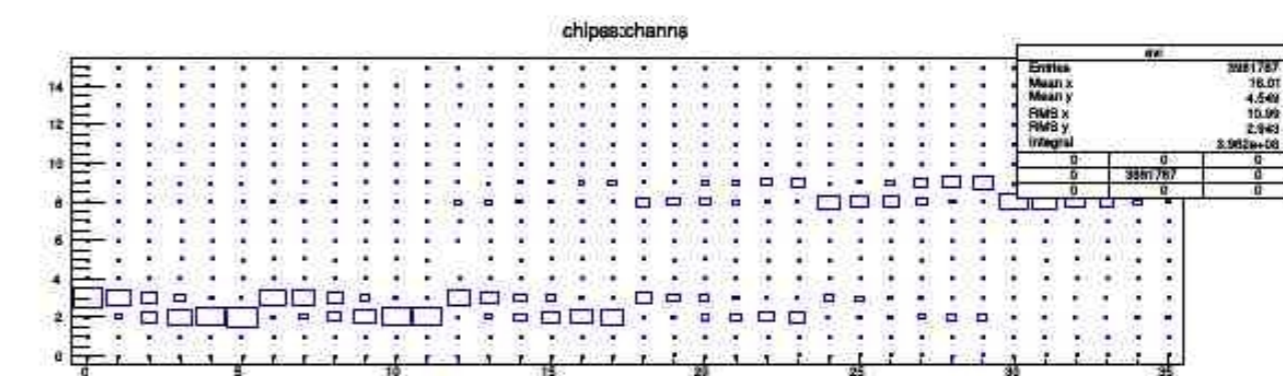
ASICs



chip vs module



channel vs module

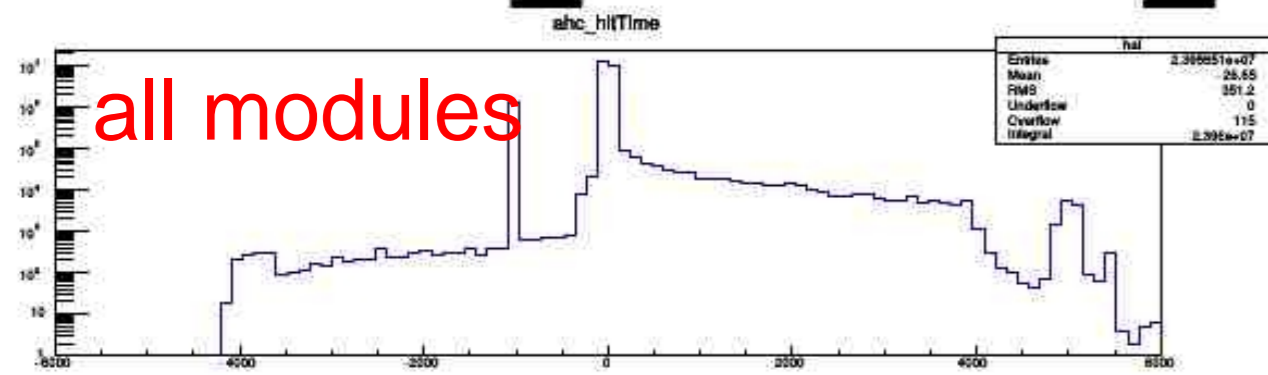


chip vs channel

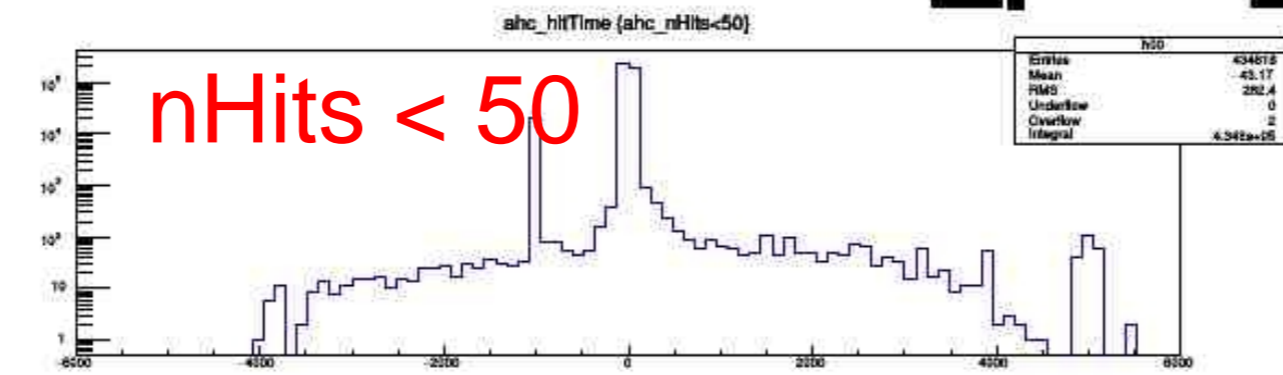
38 modules x
16 chips x
36 channels =
21888 units
to calibrate

Pions – Time Response (modules, chips, channels)

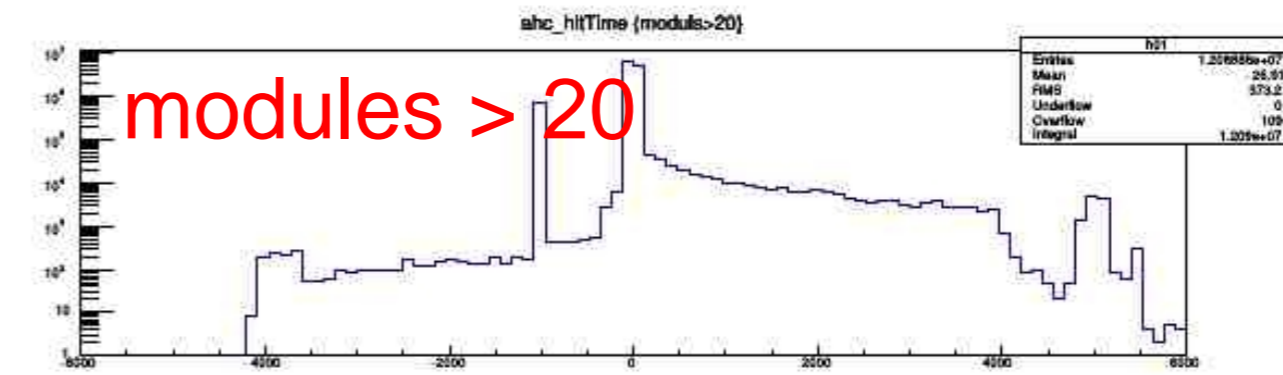
vsmodule_20190605i_hitTimevsMod reco_pion_n40GeV.root



all modules

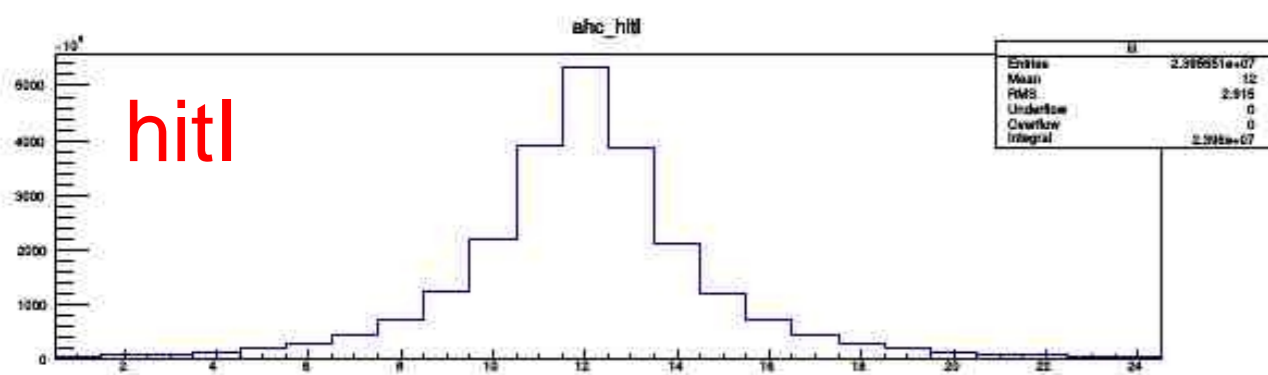


nHits < 50

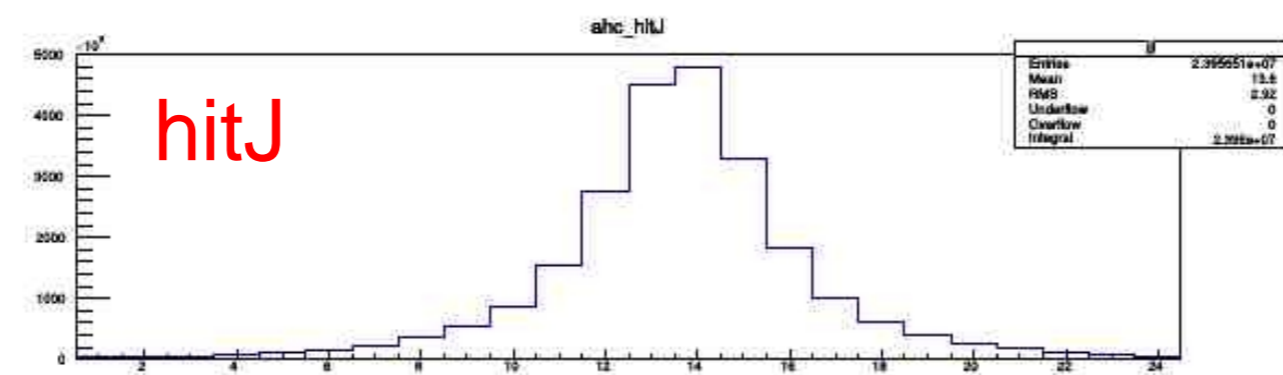


modules > 20

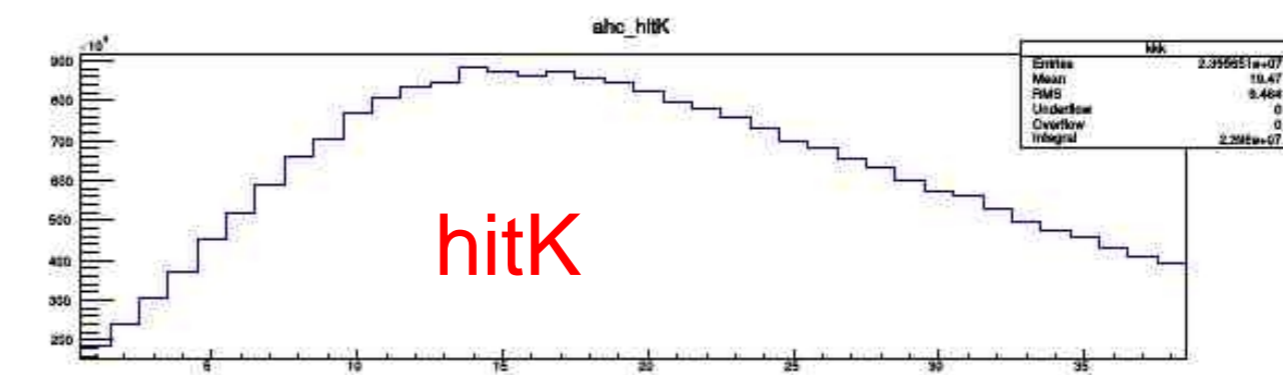
hitTime



hitI

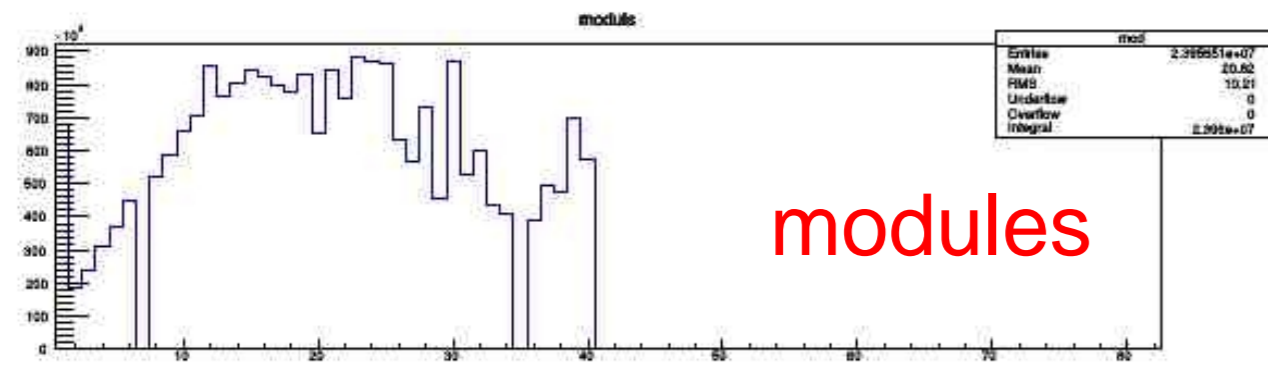


hitJ



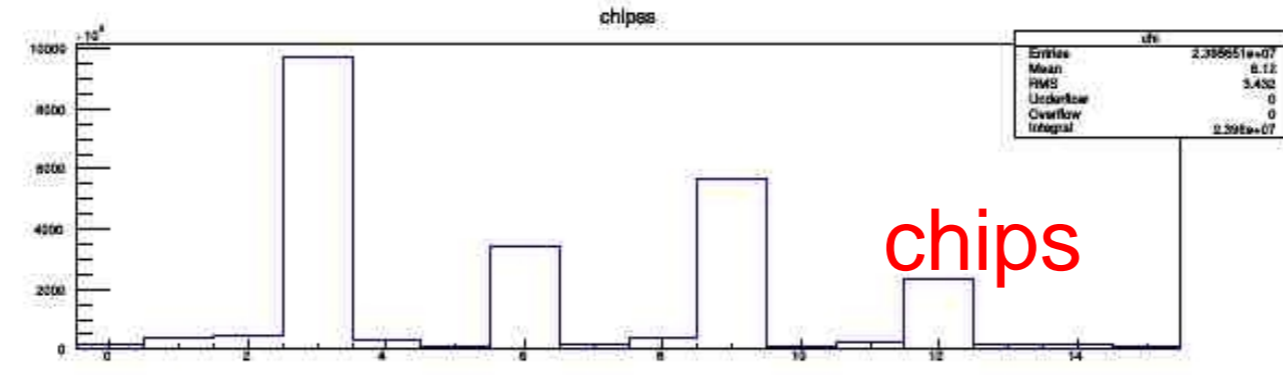
hitK

hitPosition



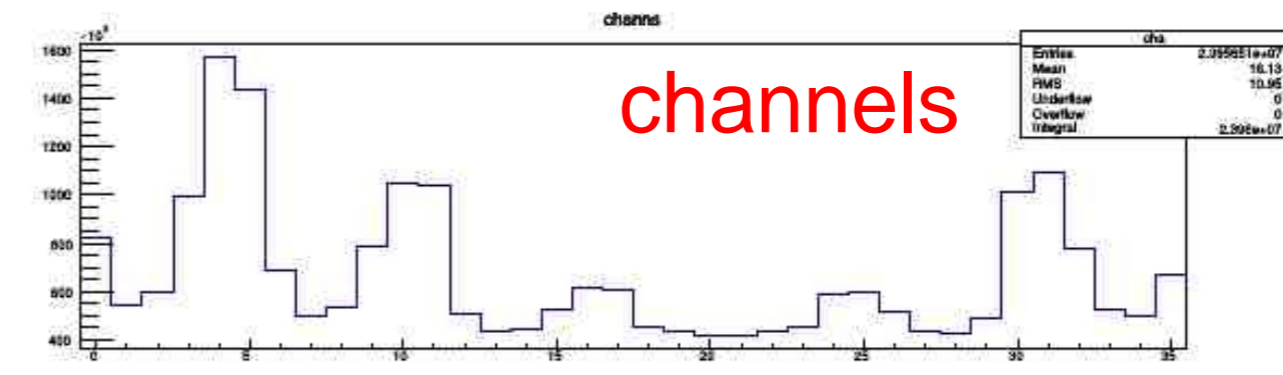
modules

not quite by layer



chips

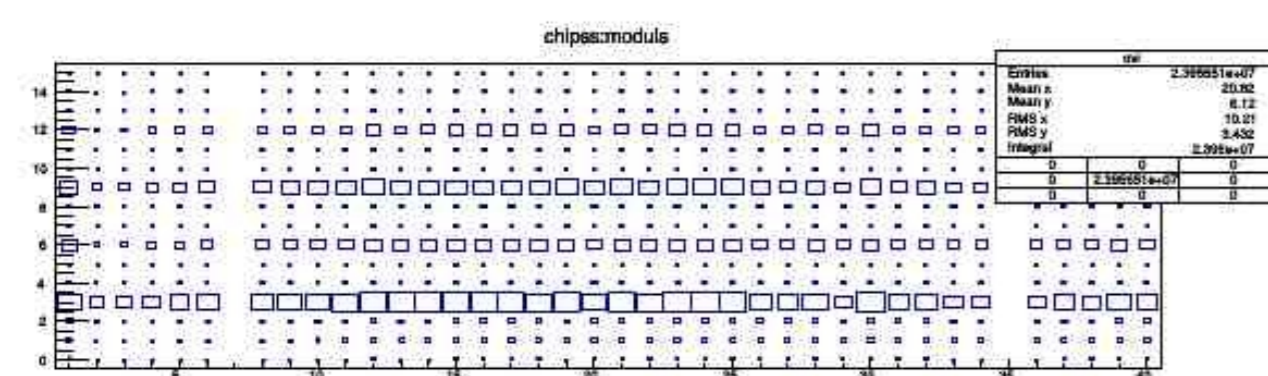
only 4 really used



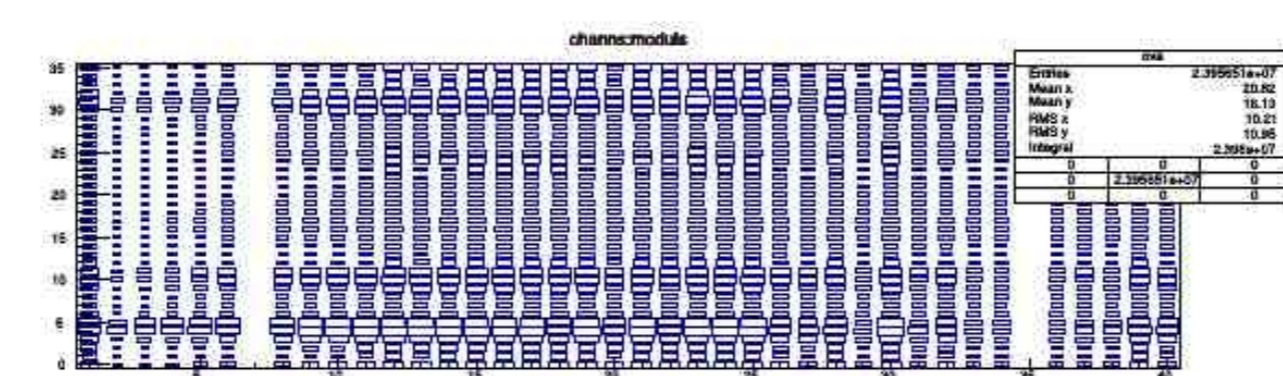
channels

ASICs

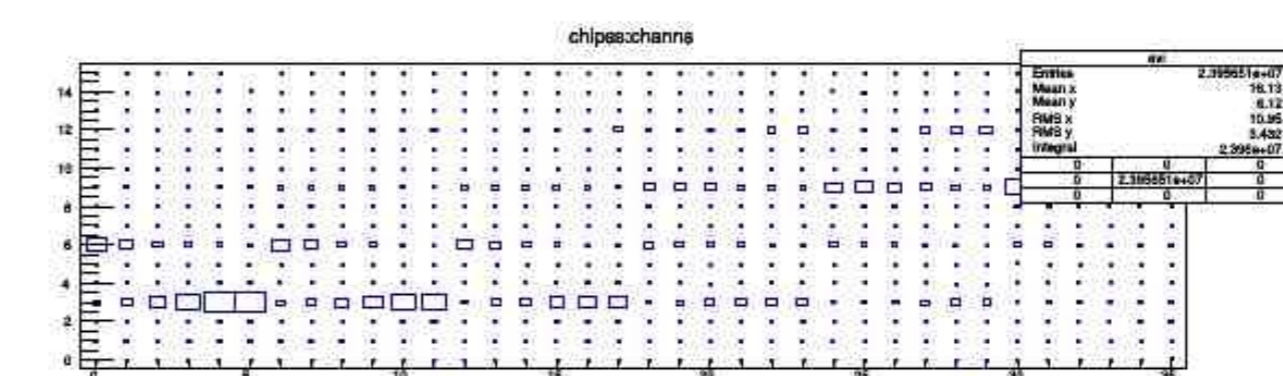
no obvious discrepancy yet observed



chip vs module



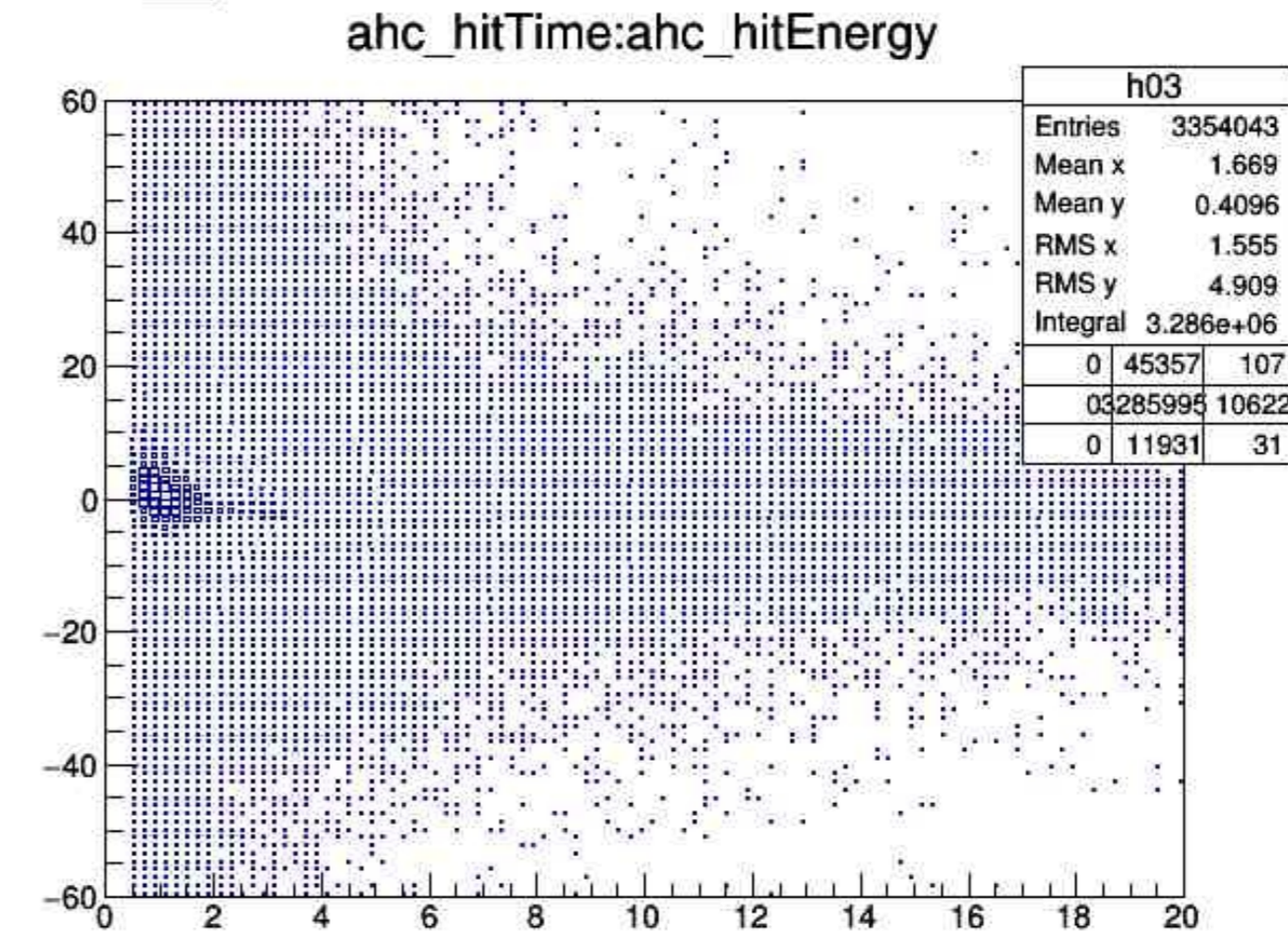
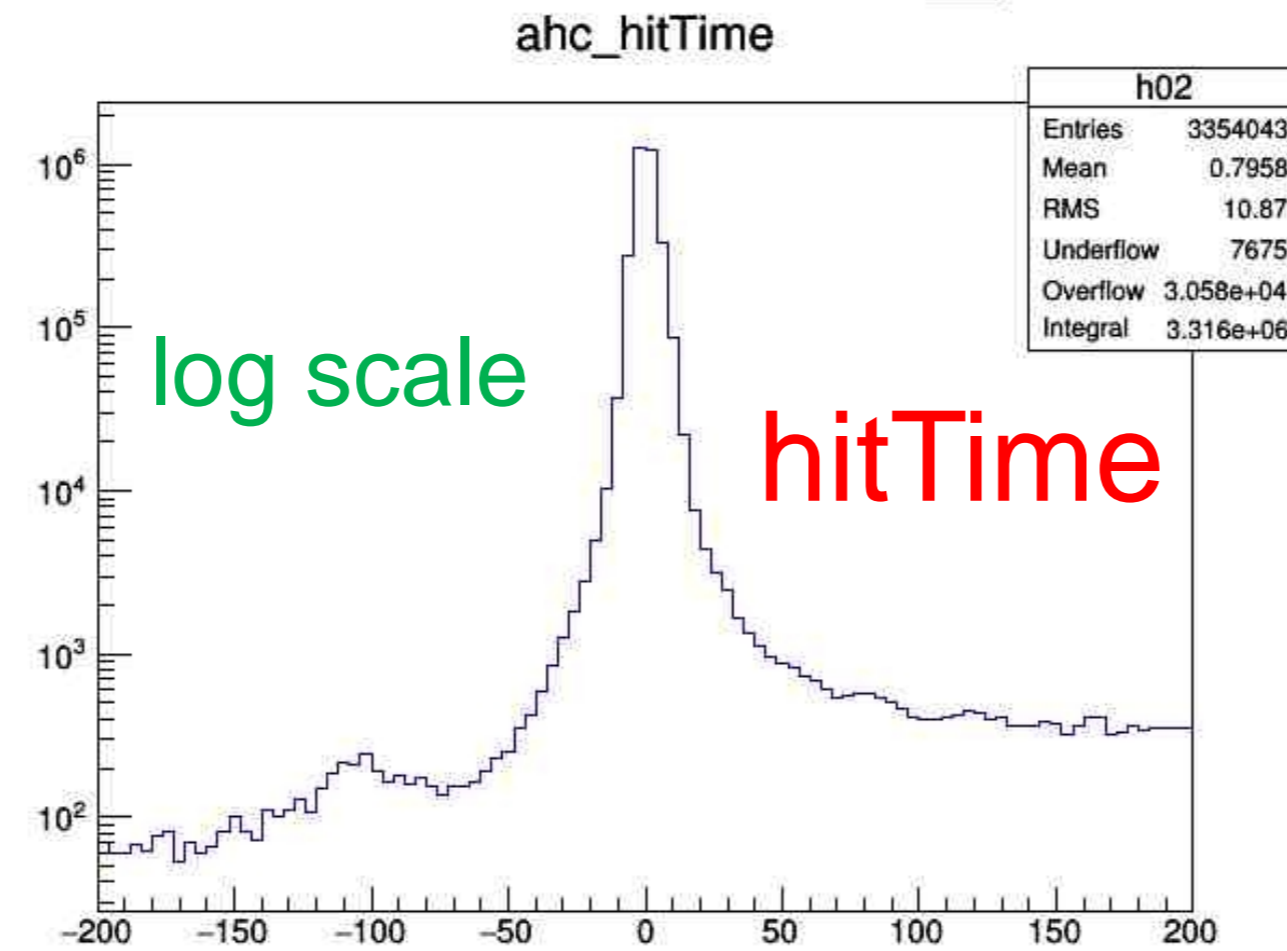
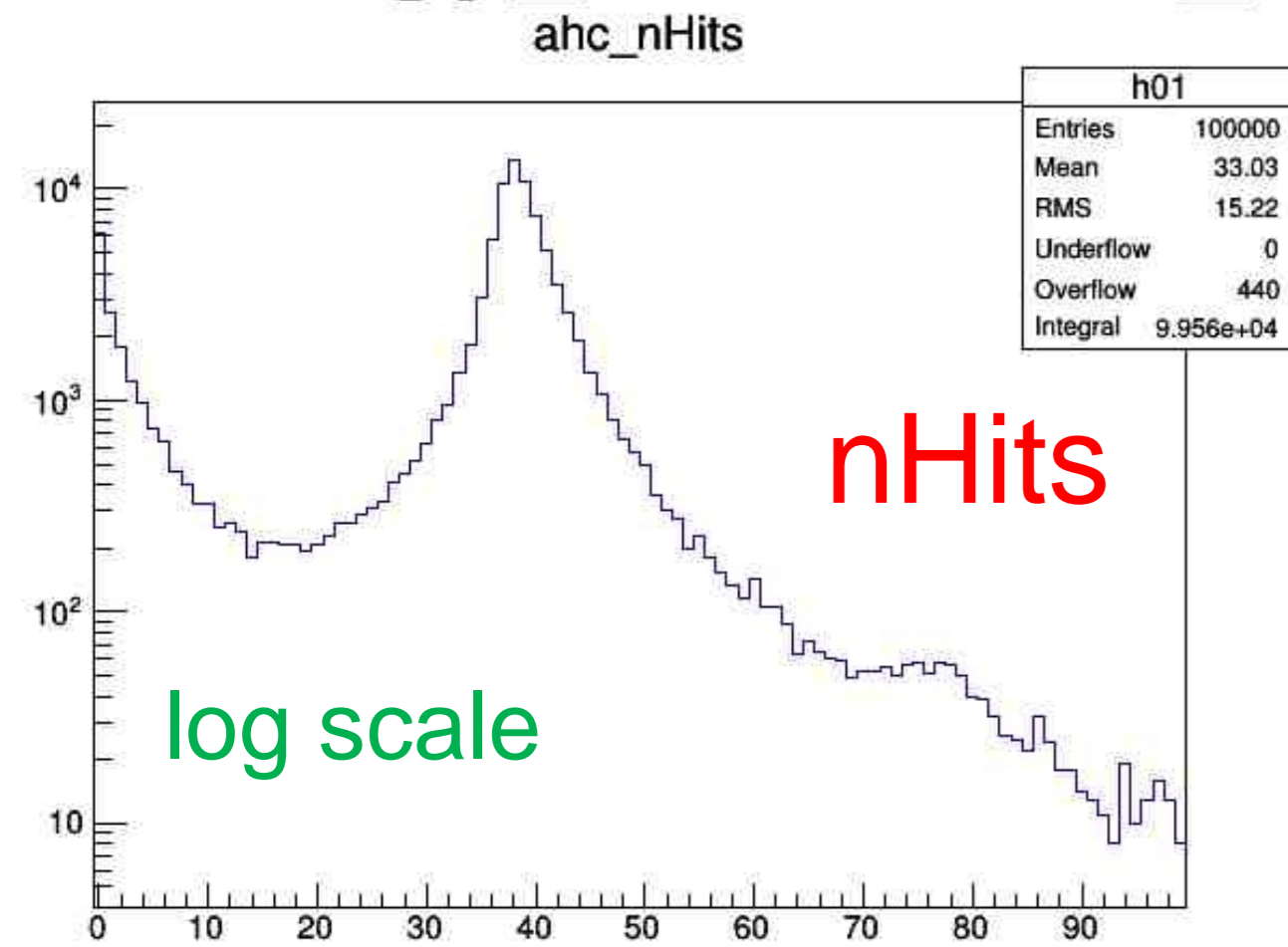
channel vs module



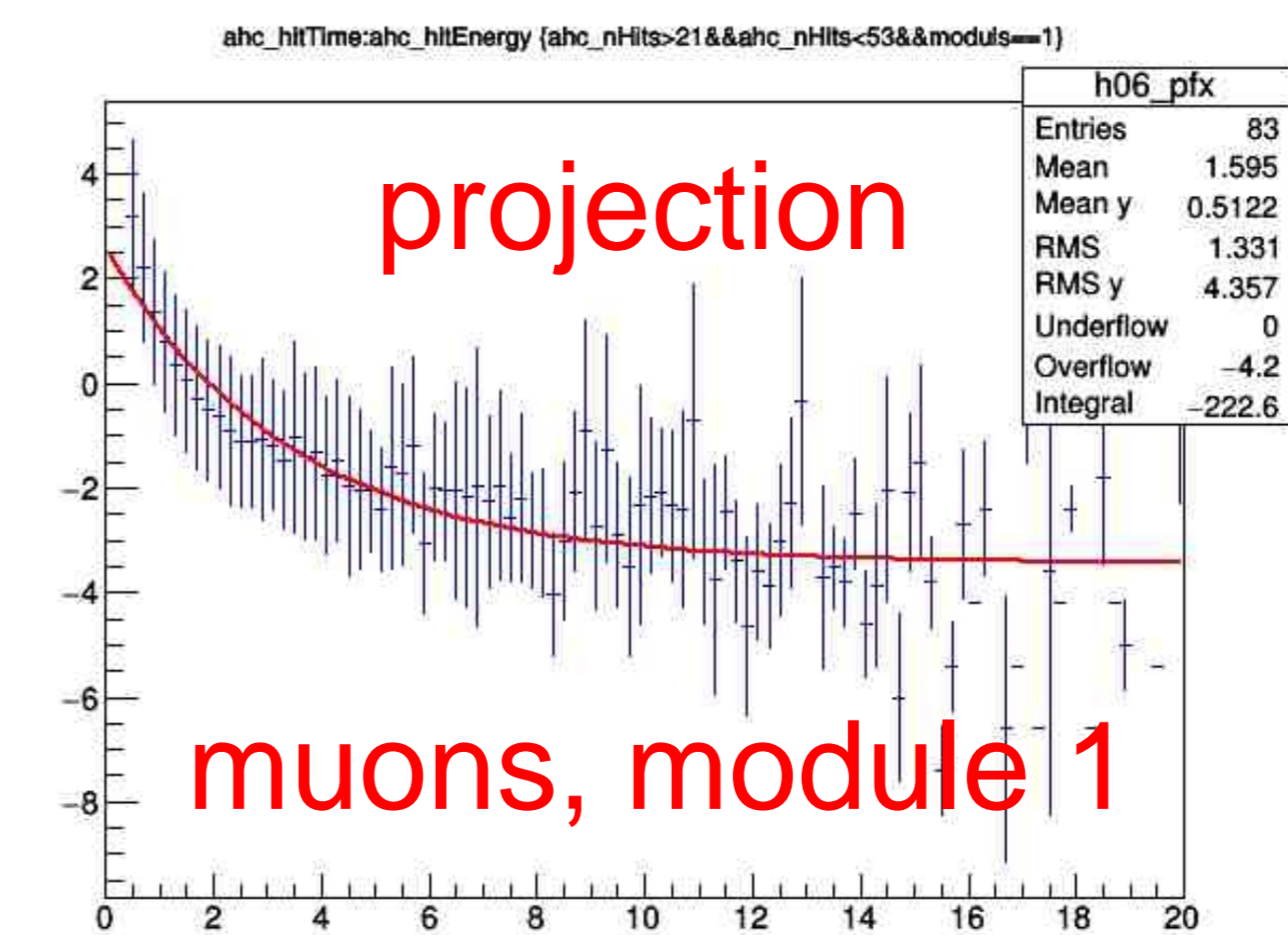
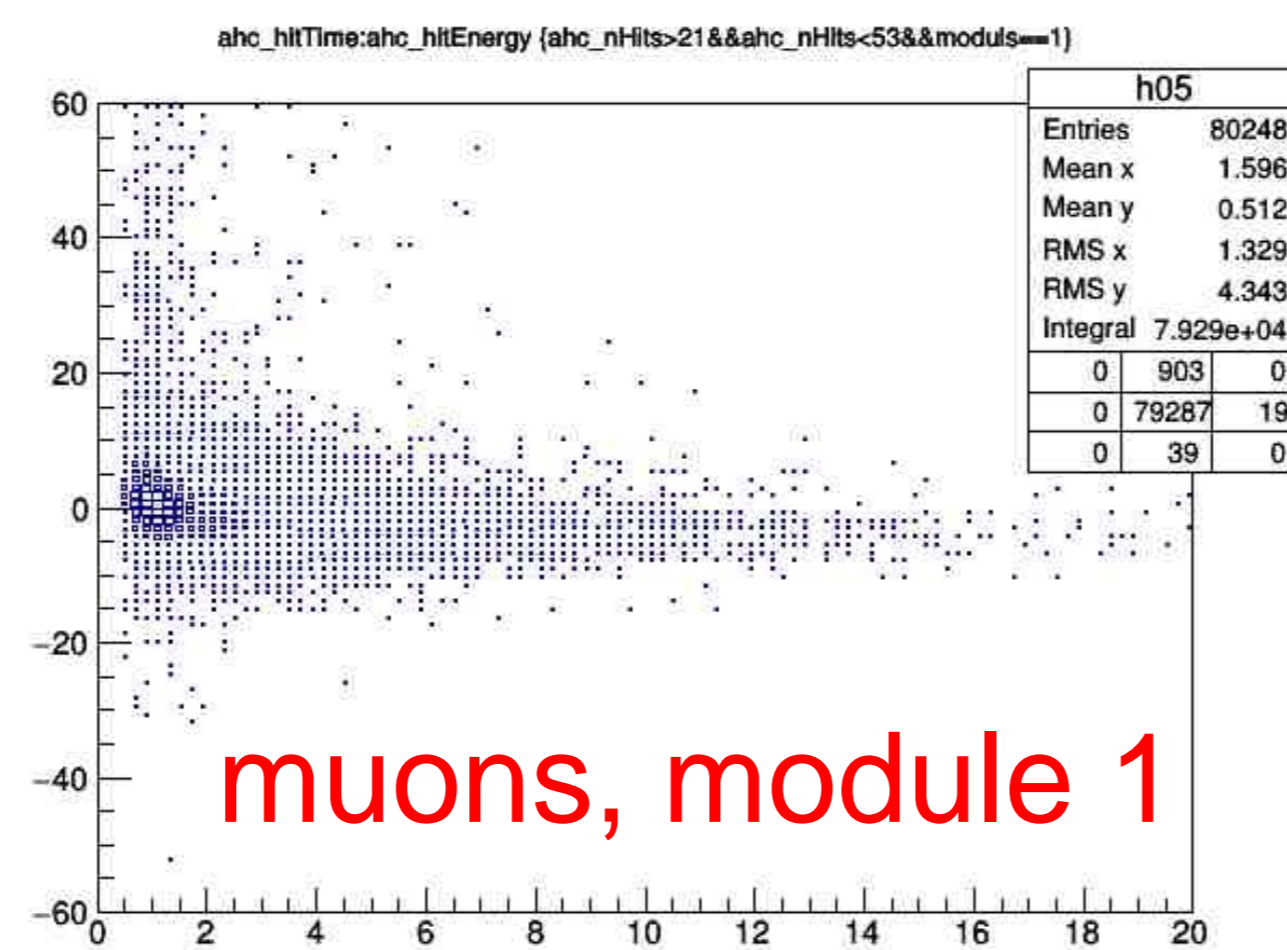
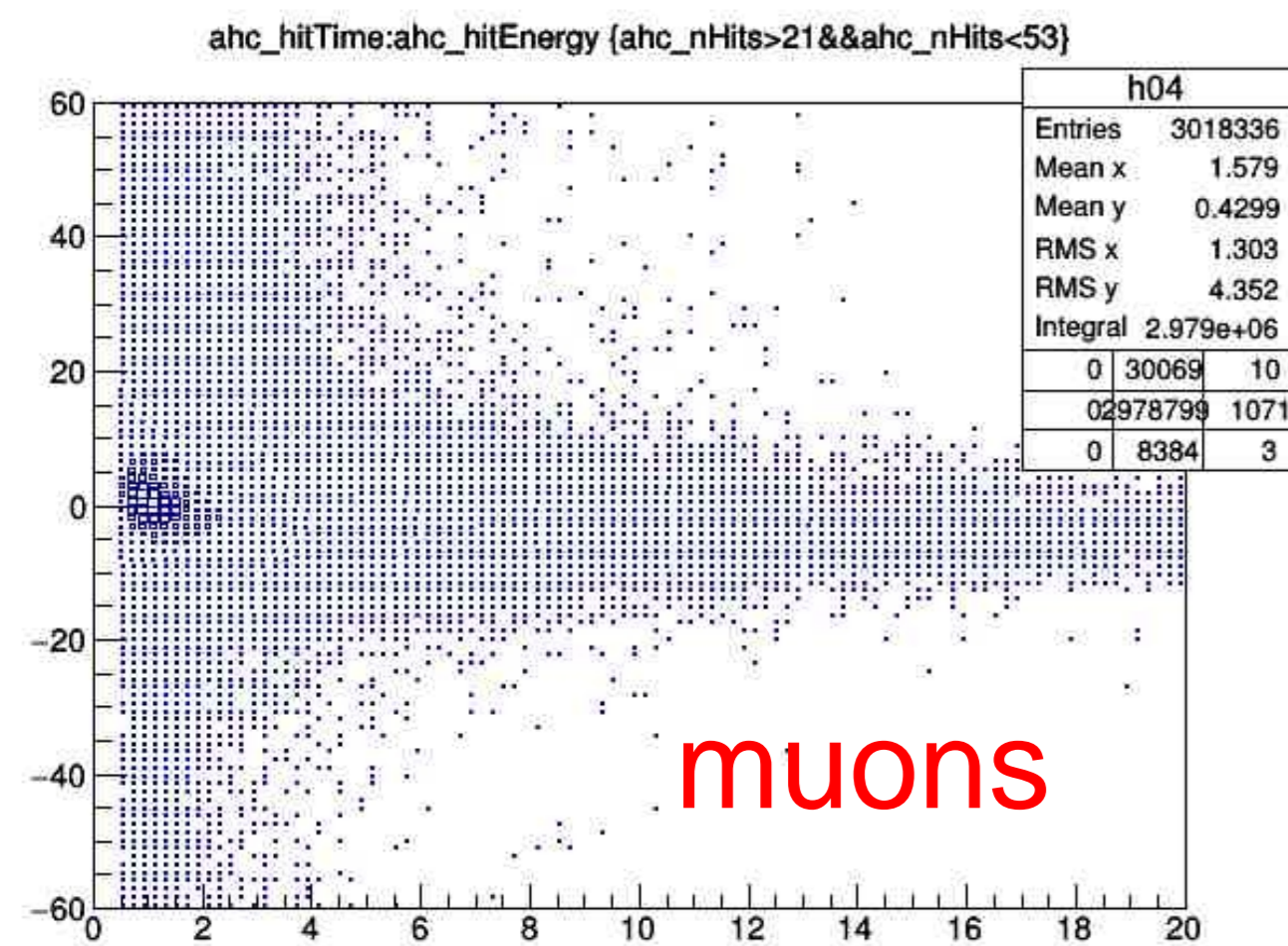
chip vs channel

Muons available with corrected times

vsenergy_20190606d_hitTimevsEne reco_run60382_testNewConstants.r



hitTime vs hitEnergy
[-30,30]ns [0,20]MIP



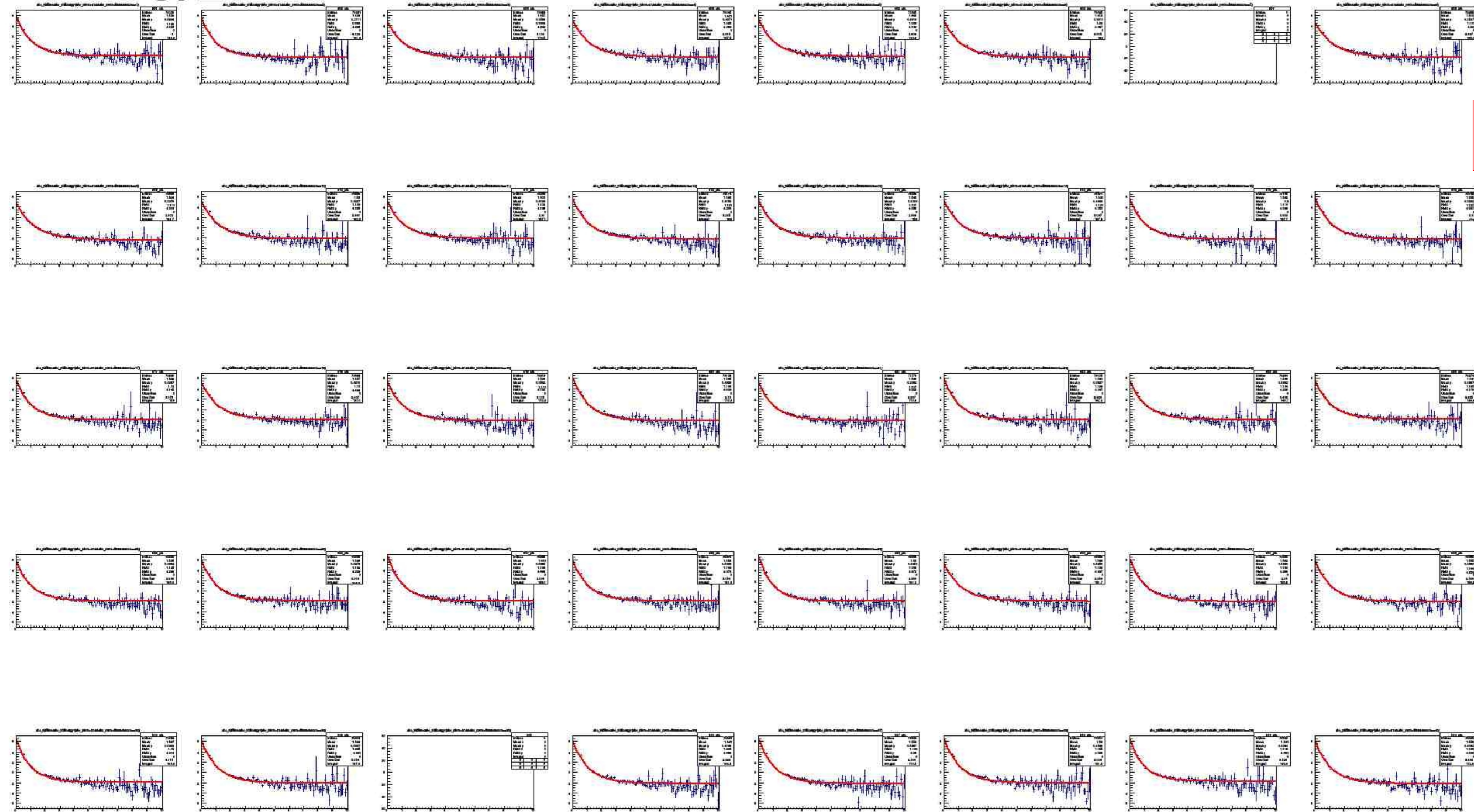
$$f_{01}(x) = a + be^{-cx}$$

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

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

Muon Hits – Time vs Energy per module

vsenergy_20190611n_hitTimevsEne reco_run60382_testNewConstants.r

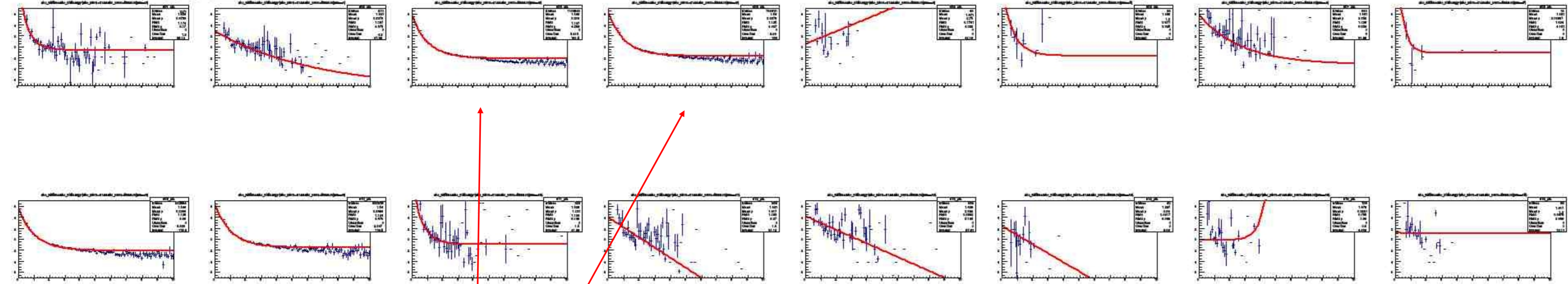


$$f_{01}(x) = a + be^{-cx}$$

Error bars now ok.
All look very similar,

Muon Hits – Time vs Energy per chip

vsenergy_20190611o_hitTimevsEne reco_run60382_testNewConstants.r



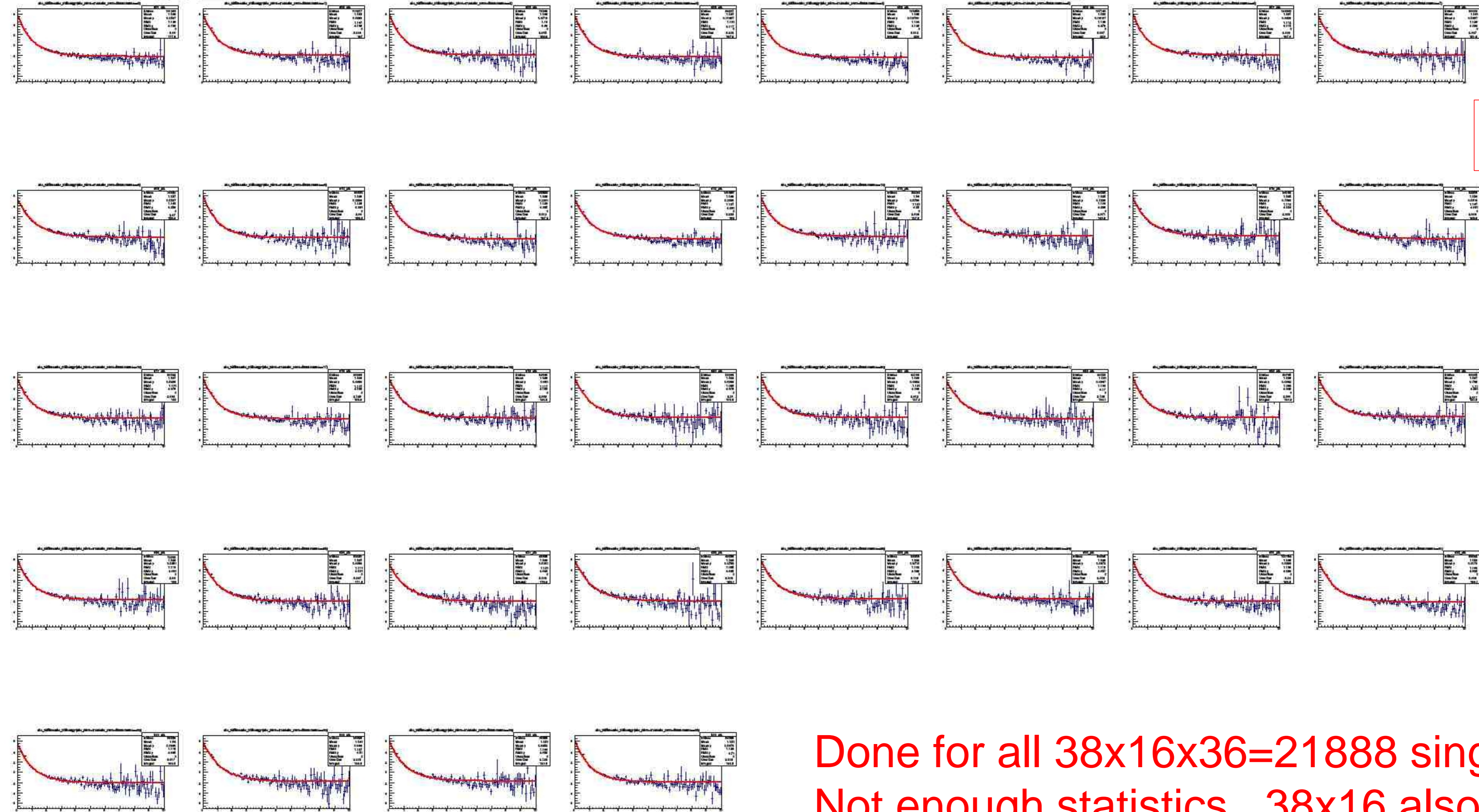
$$f_{01}(x) = a + be^{-cx}$$

only 4 really tested

Error bars now ok.
All look very similar,

Muon Hits – Time vs Energy per channel

vsenergy_20190611p_hitTimevsEne reco_run60382_testNewConstants.r



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

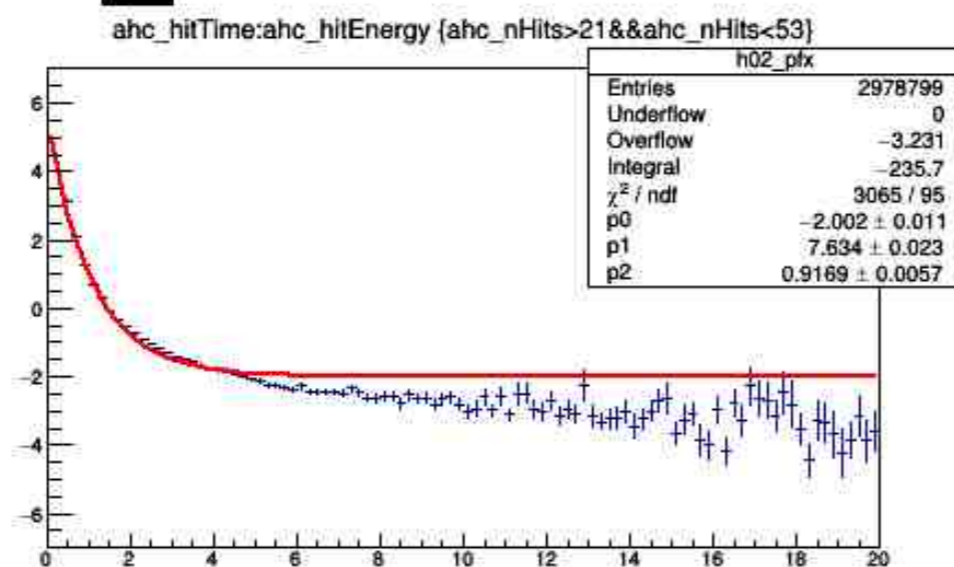
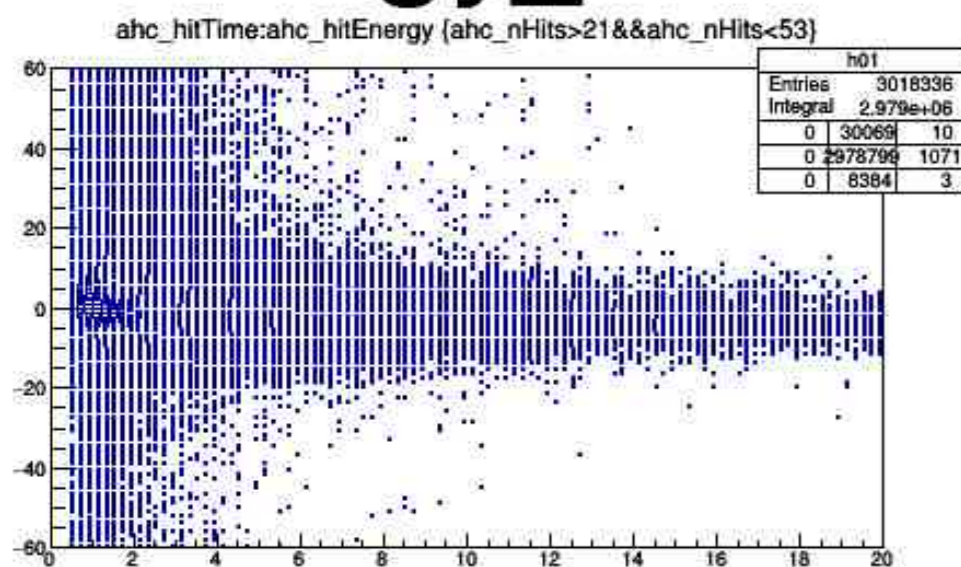
Error bars now ok.
All look very similar,

Done for all $38 \times 16 \times 36 = 21888$ single units.
Not enough statistics. 38×16 also done.

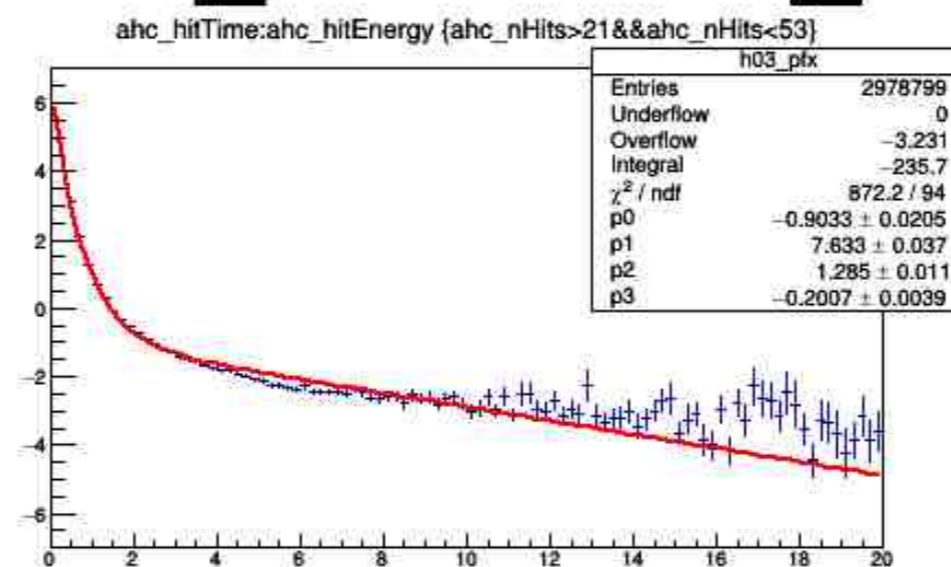
Time walk vs hitEnergy [0-20 MIP]

Functional Forms

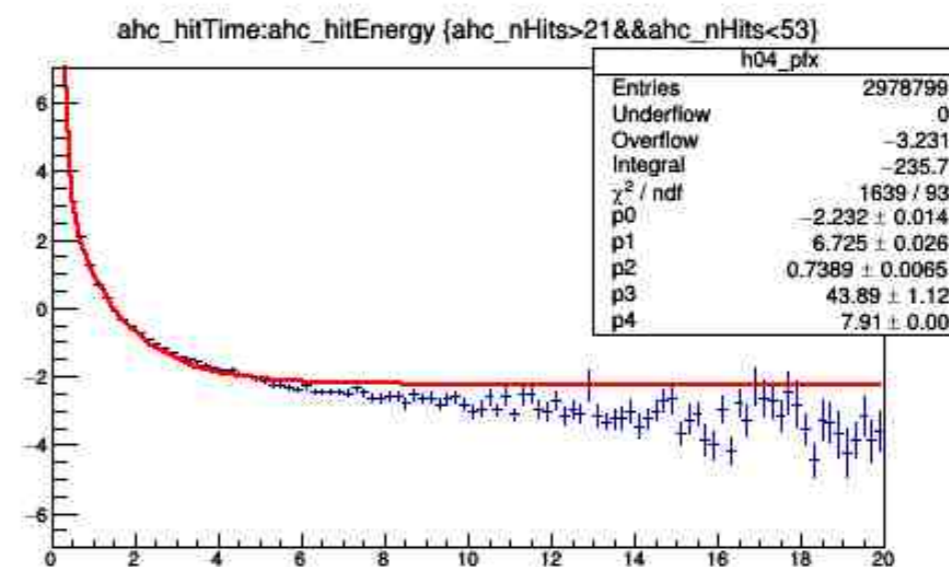
vsenergy_20190617f_hitTimevsEne reco_run60382_testNewConstants.rc



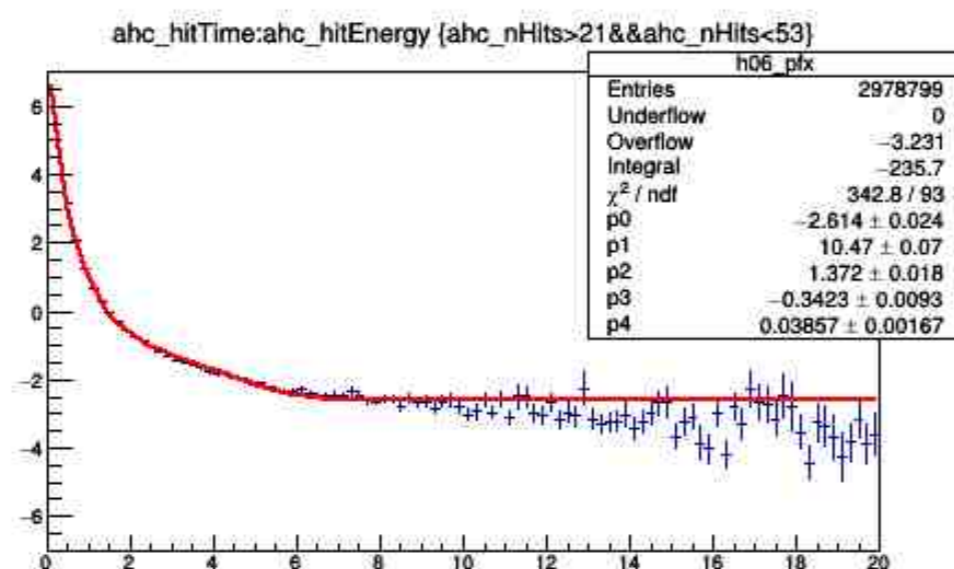
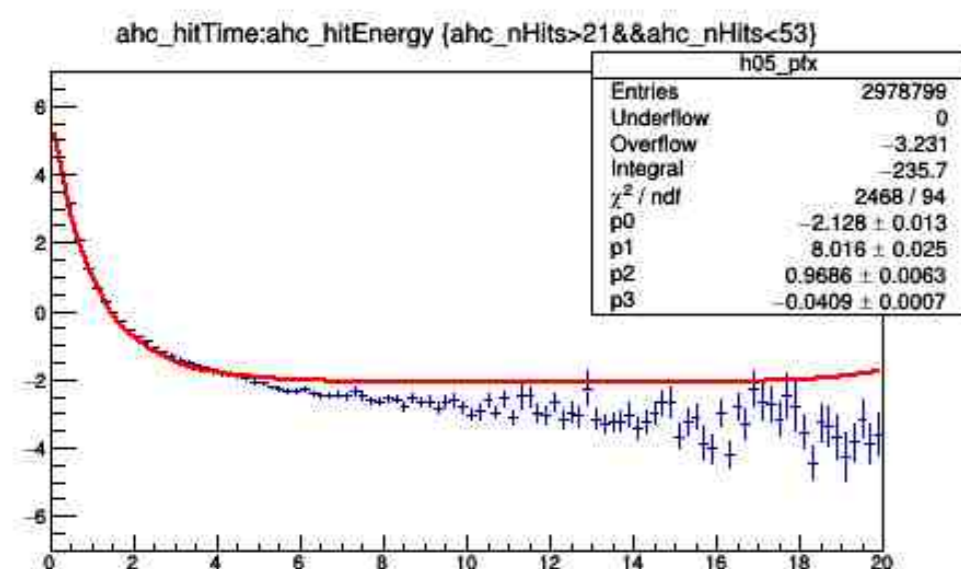
$$f_{01}(x) = a + be^{-cx}$$



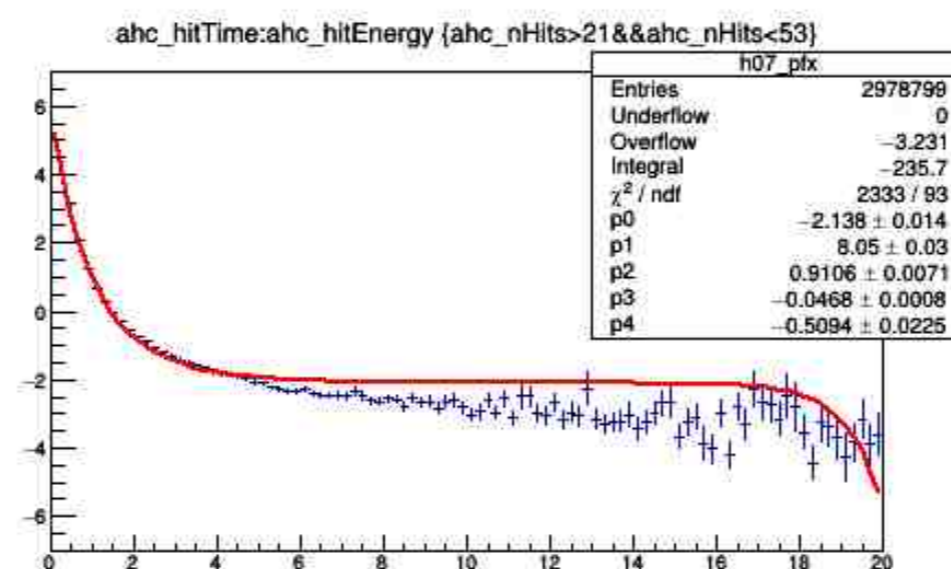
$$f_{02}(x) = a + be^{-cx} + dx$$



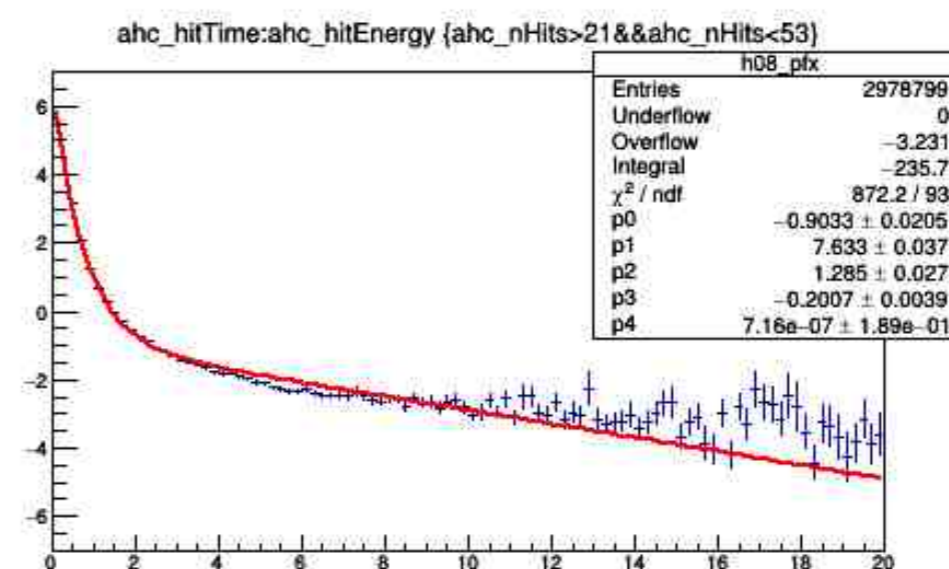
$$f_{03}(x) = a + be^{-cx} + de^{-ex}$$



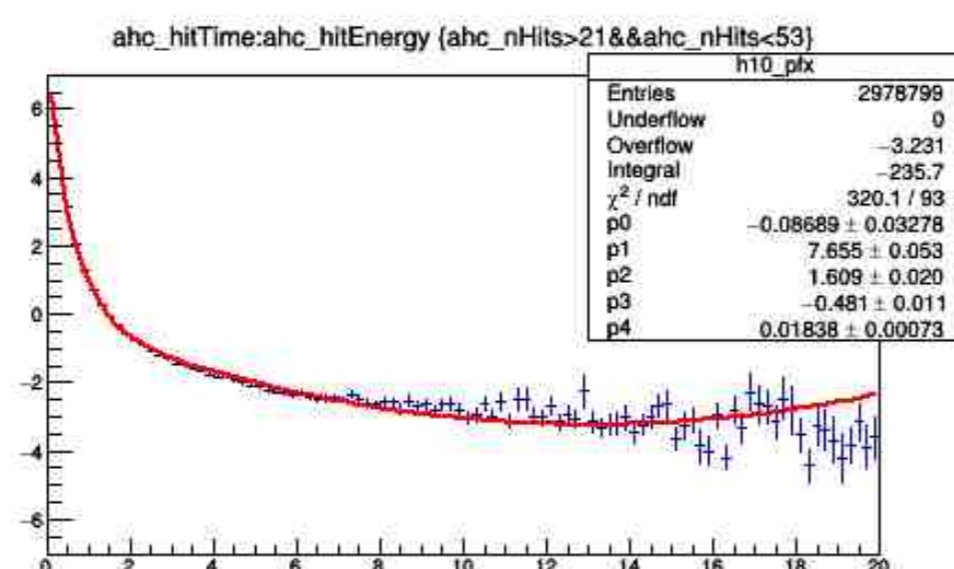
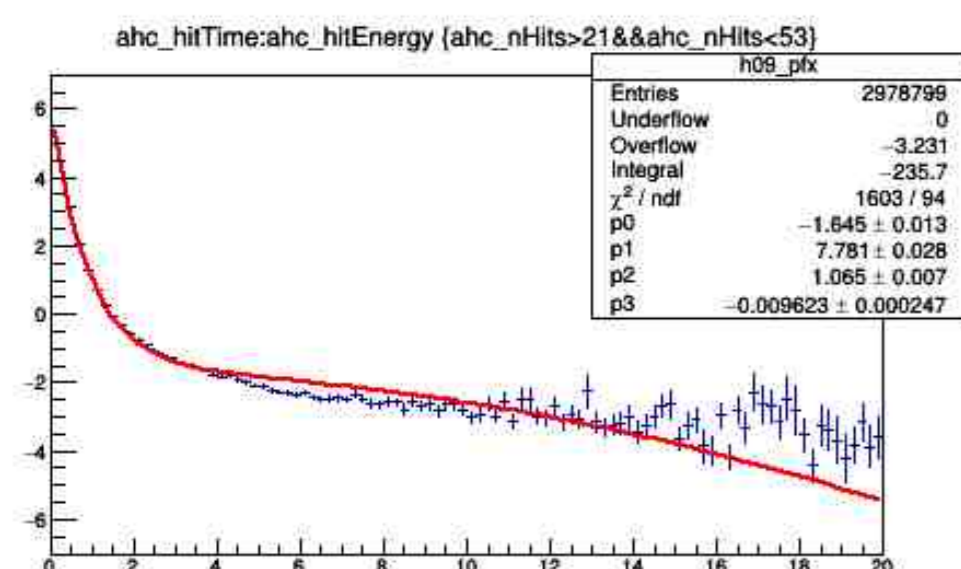
$$f_{05}(x) = a + be^{-cx-dx^2-ex^3}$$



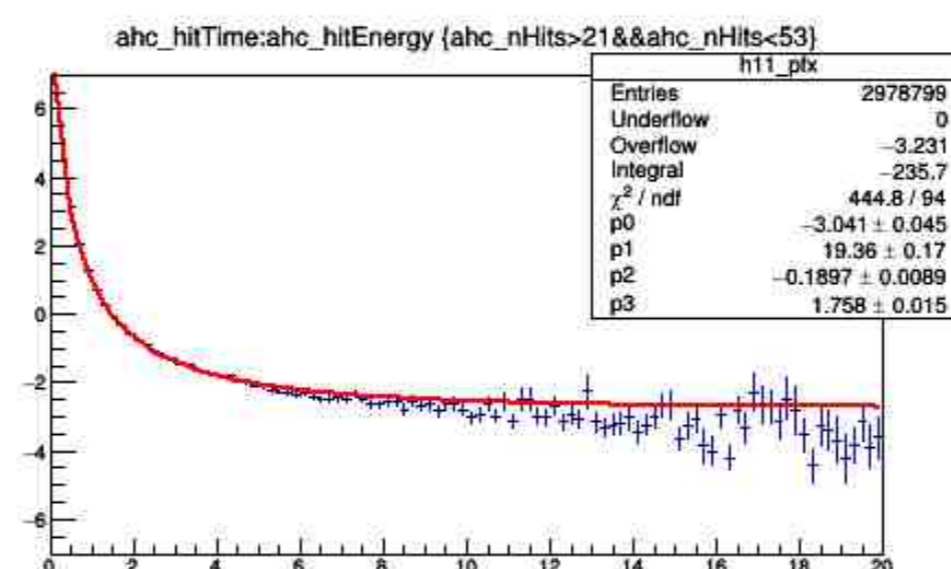
$$f_{06}(x) = a + (b + dx)e^{-cx-ex^2}$$



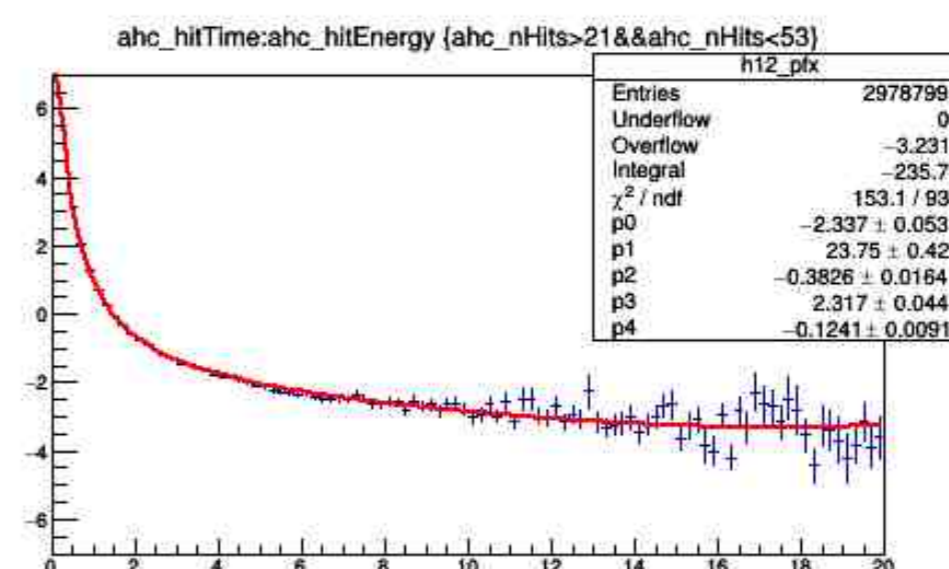
$$f_{07}(x) = a + (b + dx)e^{-cx} + ex$$



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



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

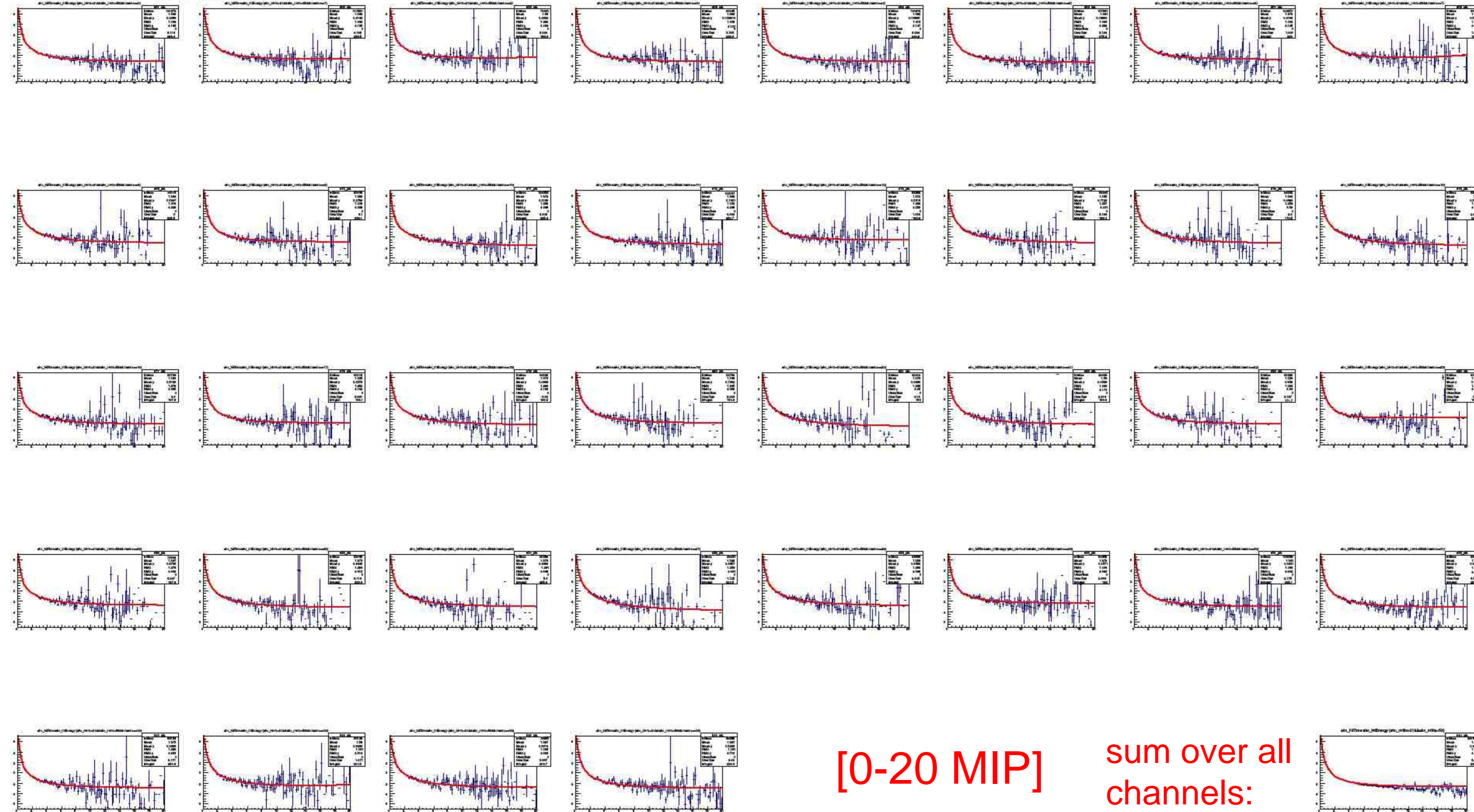


$$f_{11}(x) = a + be^{-cx-d\sqrt{x}} + ex$$

Form 1 ~ok until 8 MIPS.
Form 10 better behaved.

Muon Hits – Time vs Energy per channel

vsenergy_20190614c_hitTimevsEne reco_run60382_testNewConstants.ro



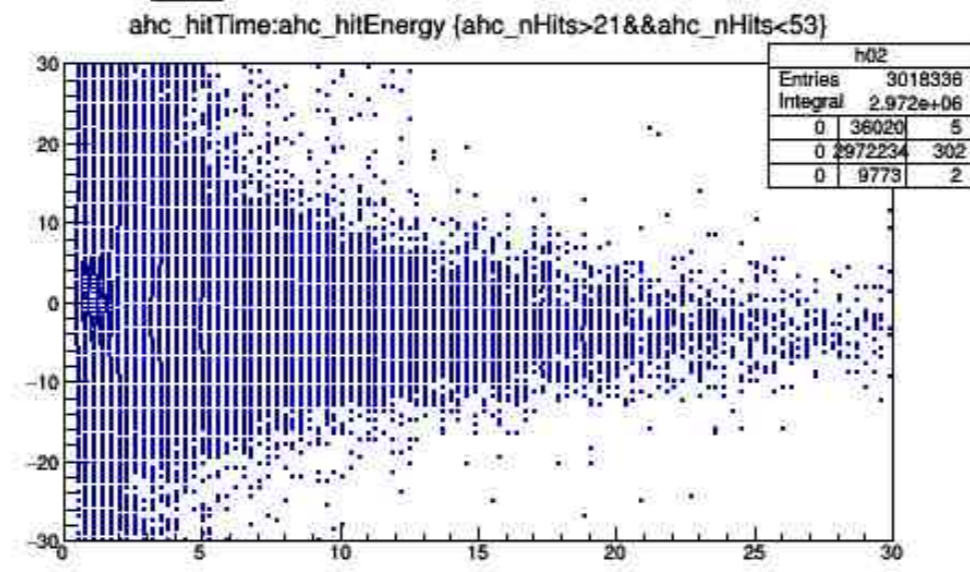
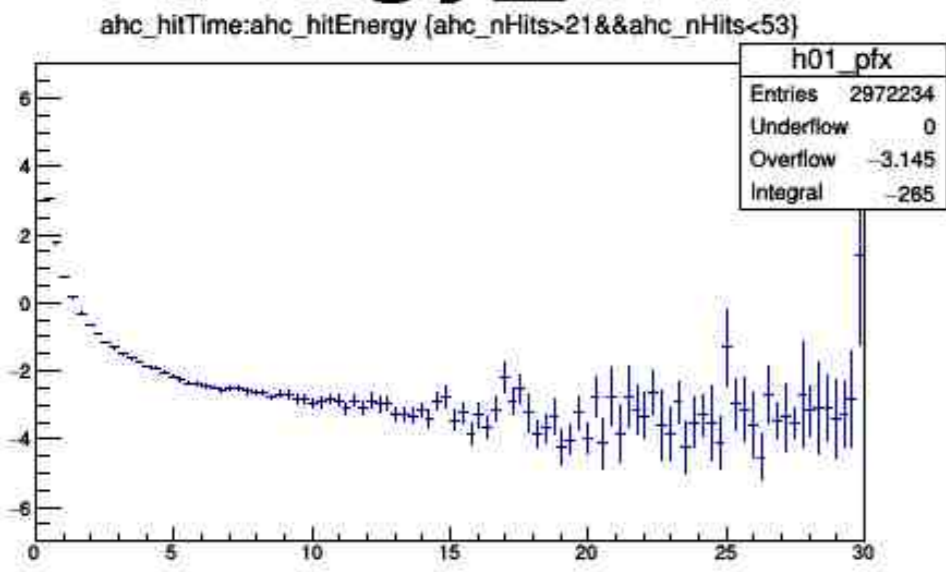
$$f_{10}(x) = a + be^{-cx-d\sqrt{x}}$$

Need much more data to calibrate time walk for each channel or decision to do it per chip only.

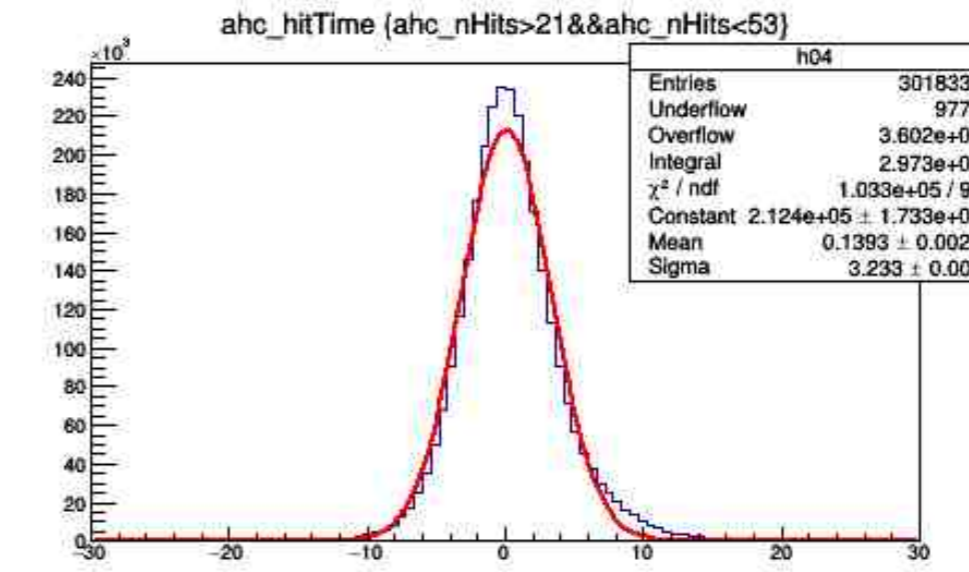
[0-20 MIP] sum over all channels:

Muons – Time Correction

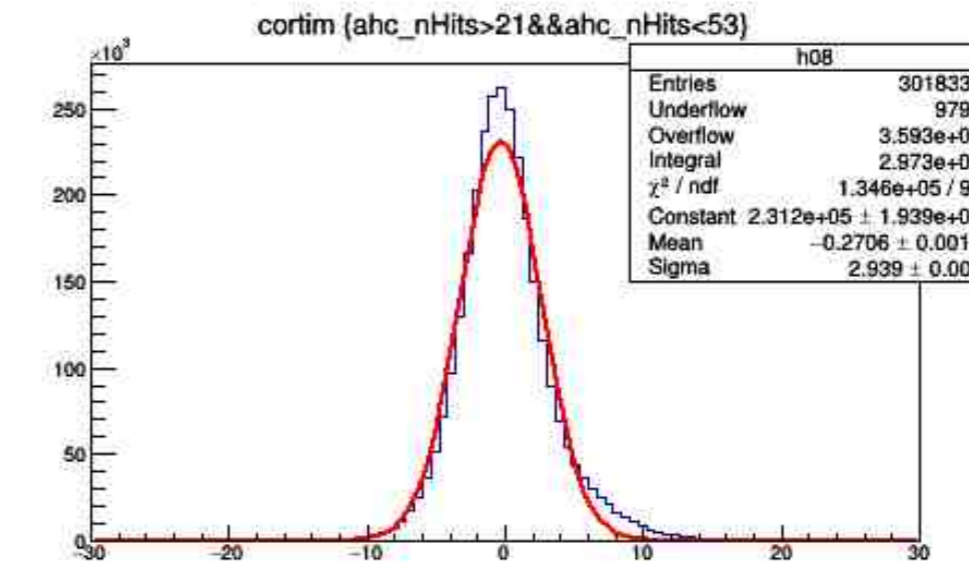
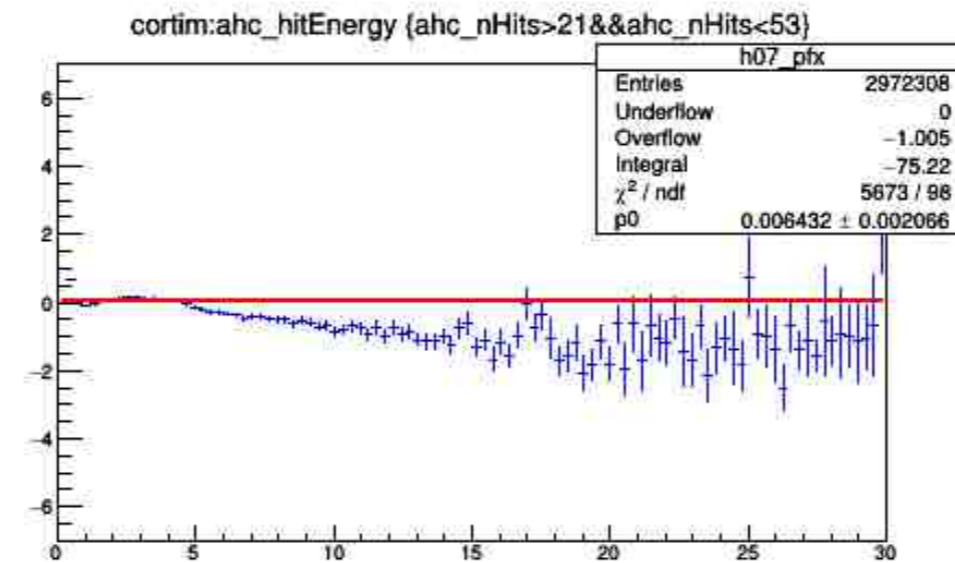
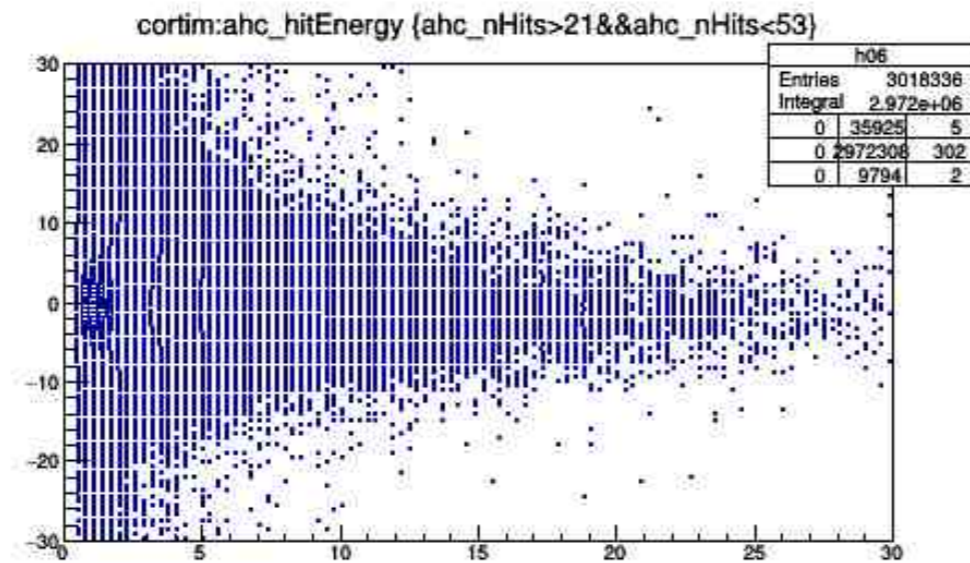
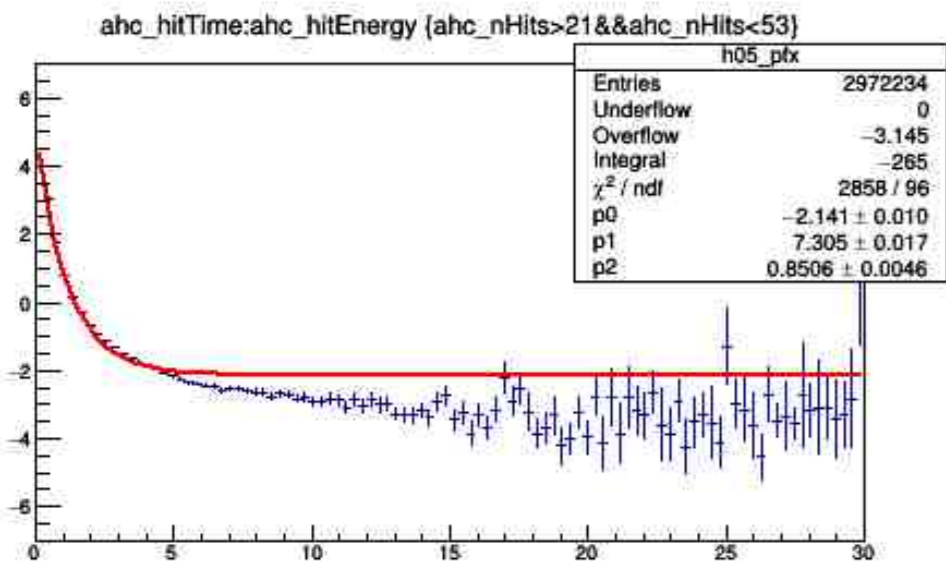
vsenergy_20190617h_hitTimevsEne reco_run60382_testNewConstants.r



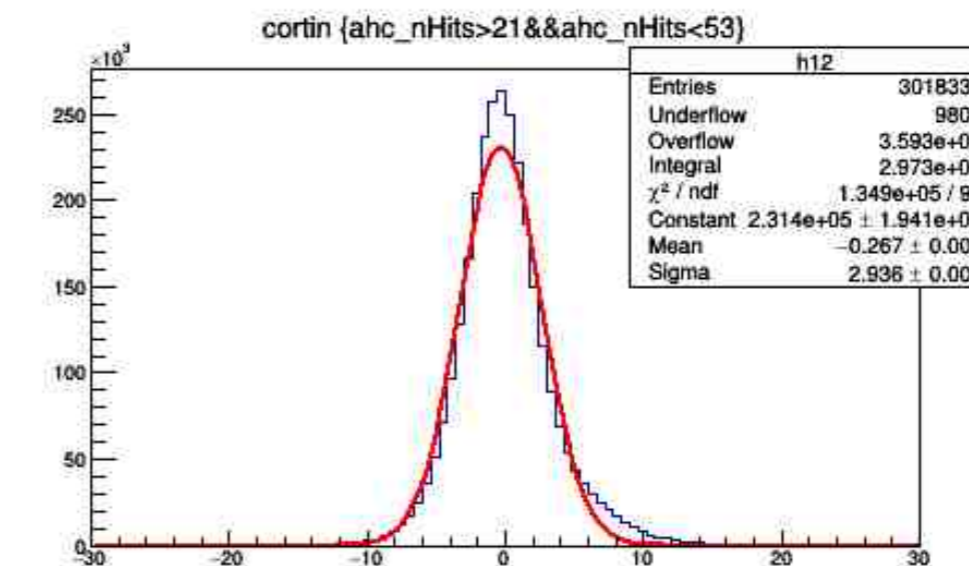
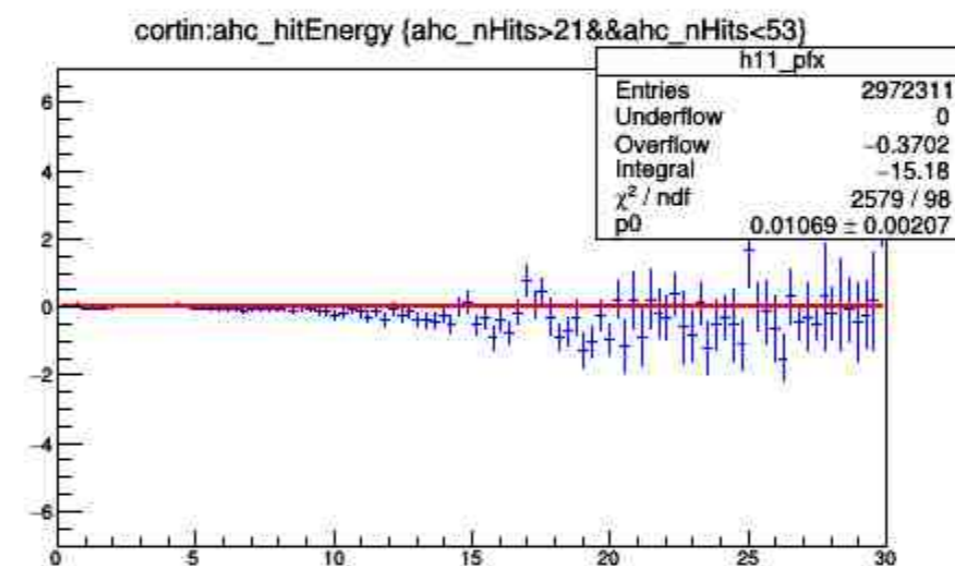
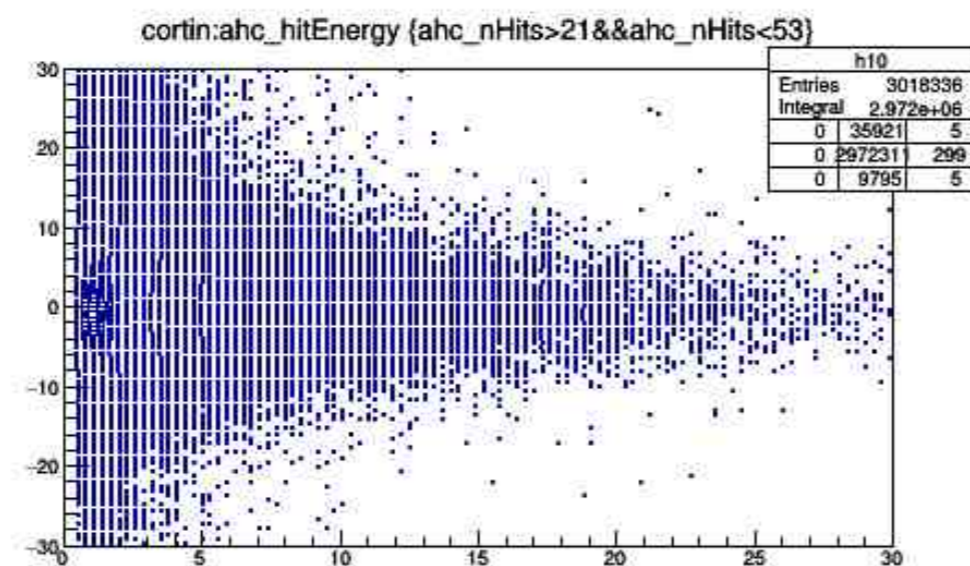
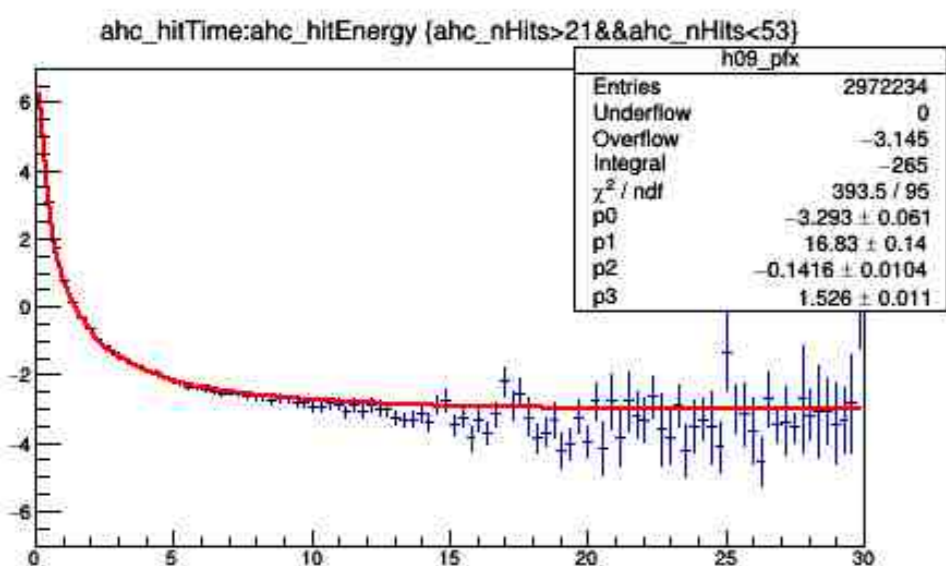
[0-30 MIP]



raw data



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



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

energy dependence

hit time vs energy

.. after correction

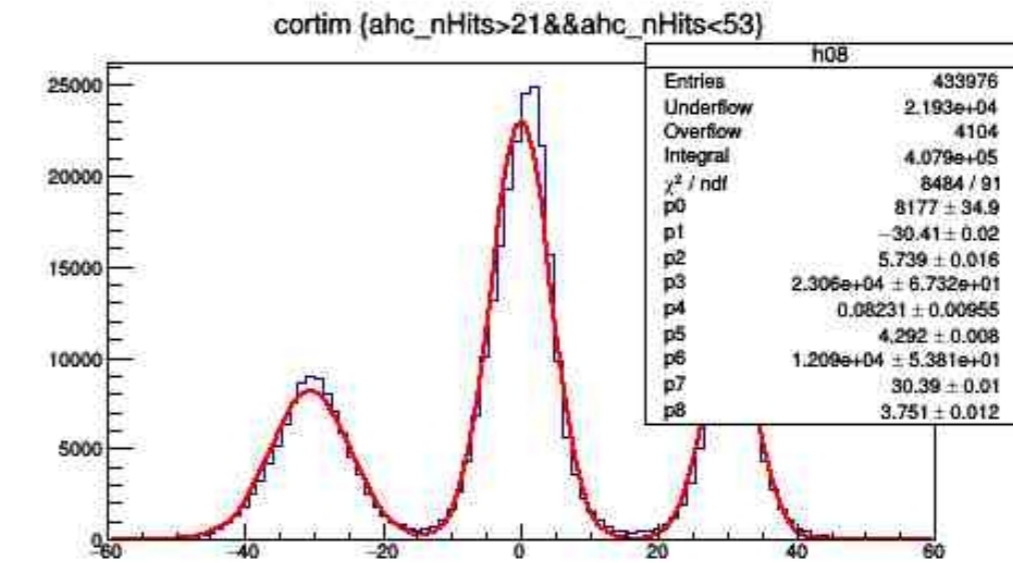
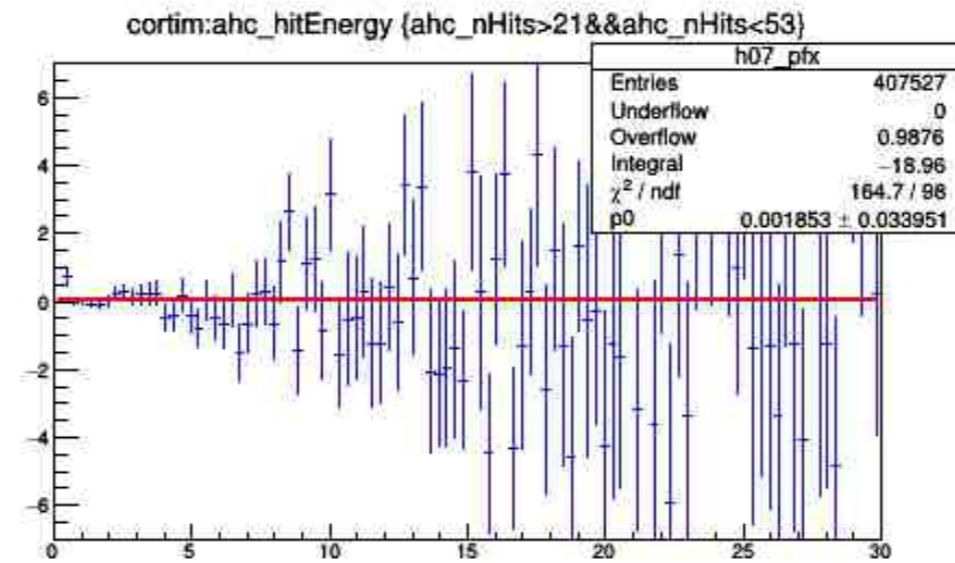
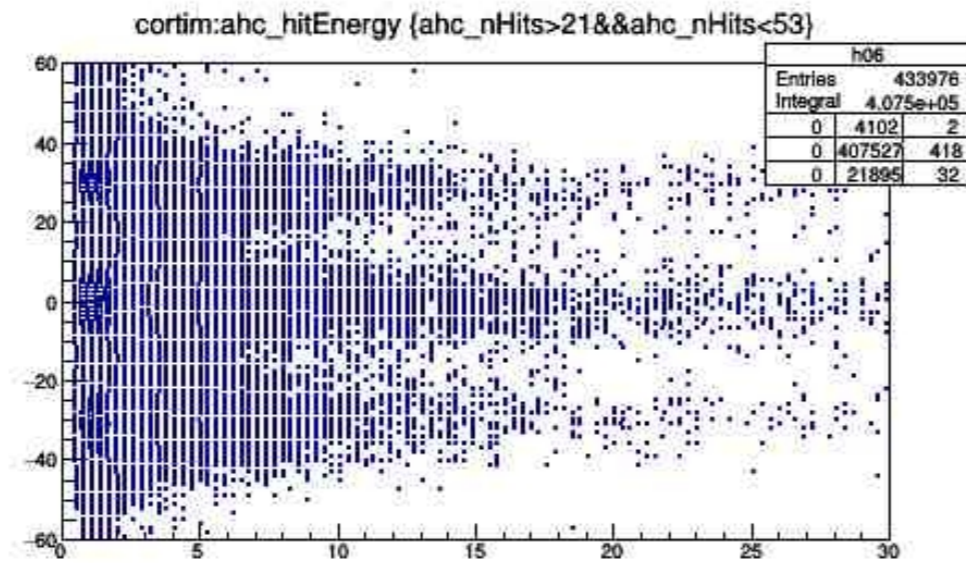
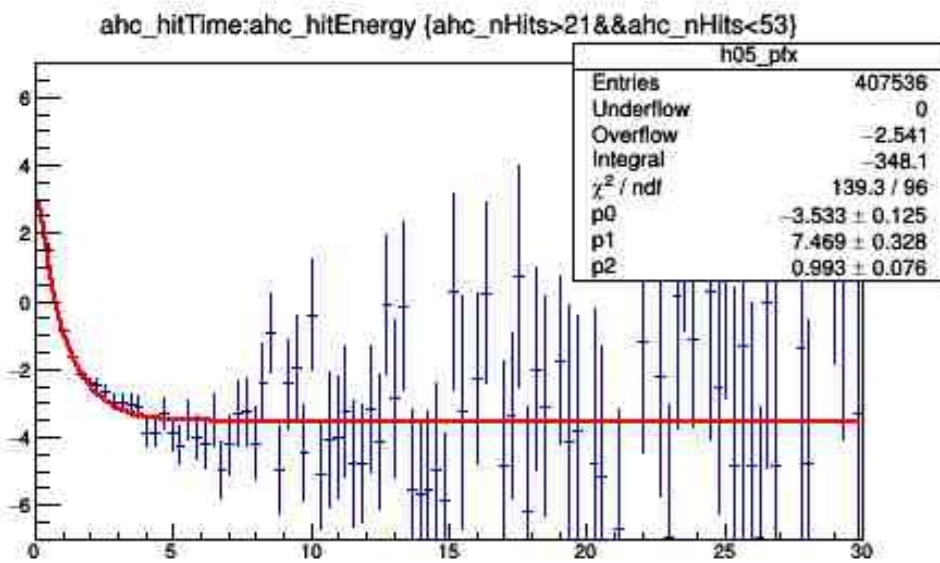
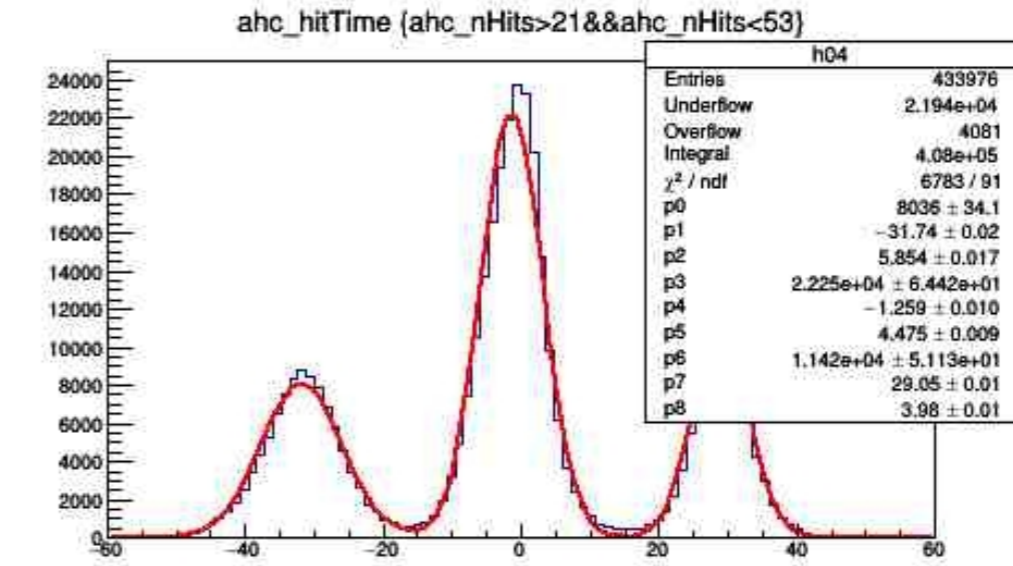
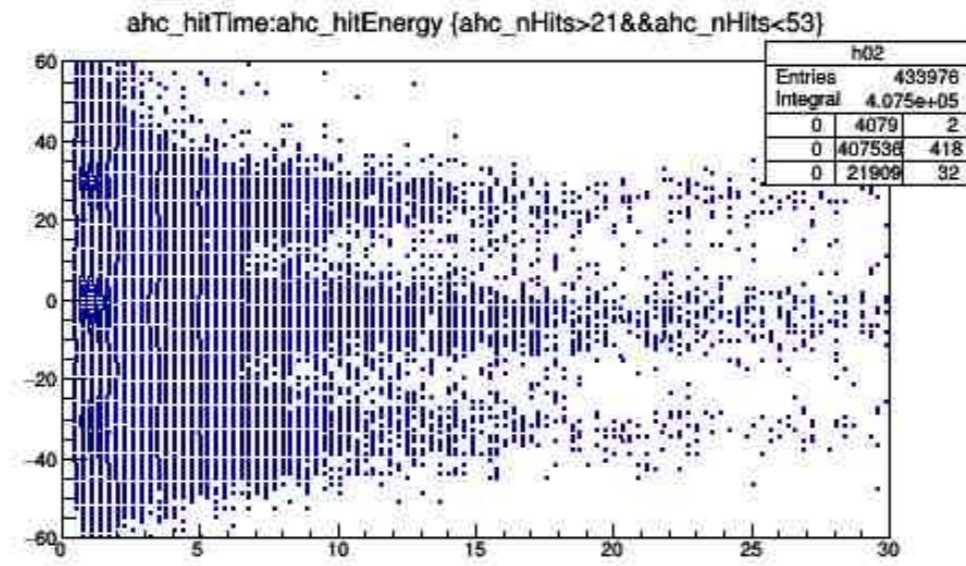
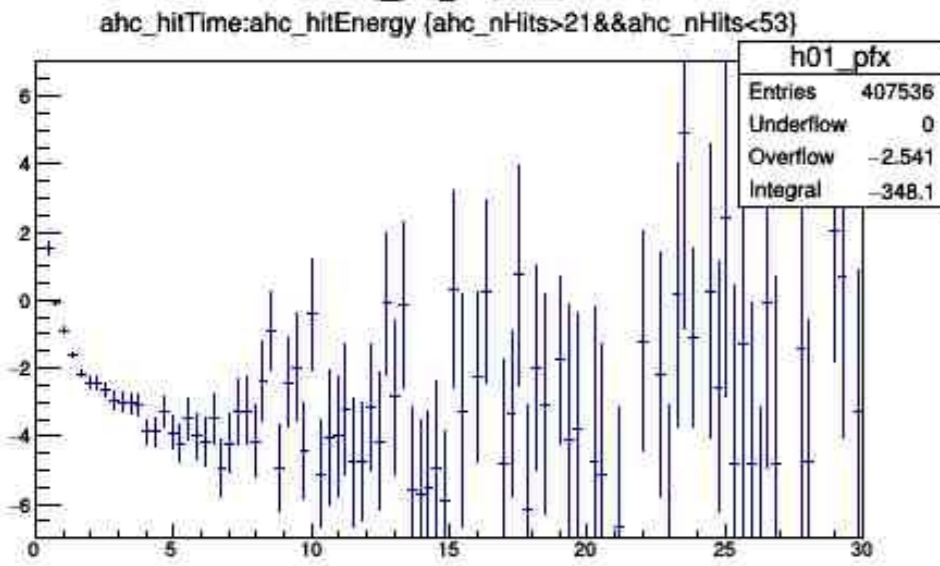
resolution ~10% better

Pions (old) – Time Correction

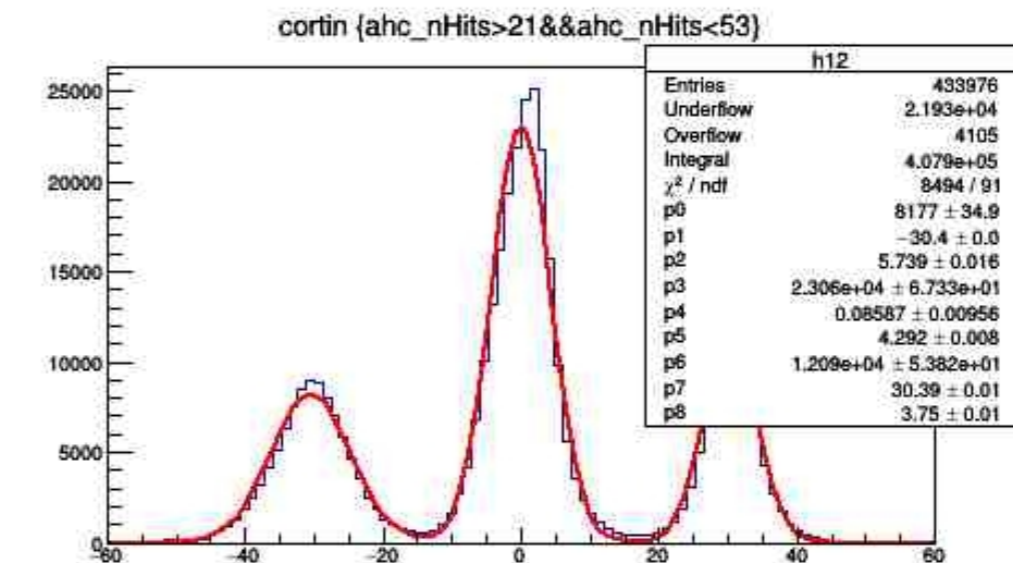
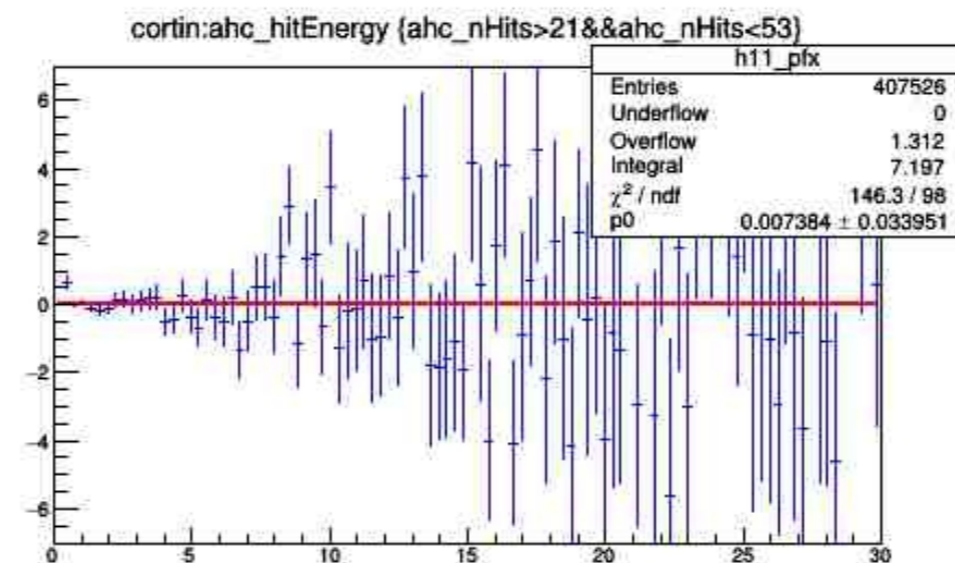
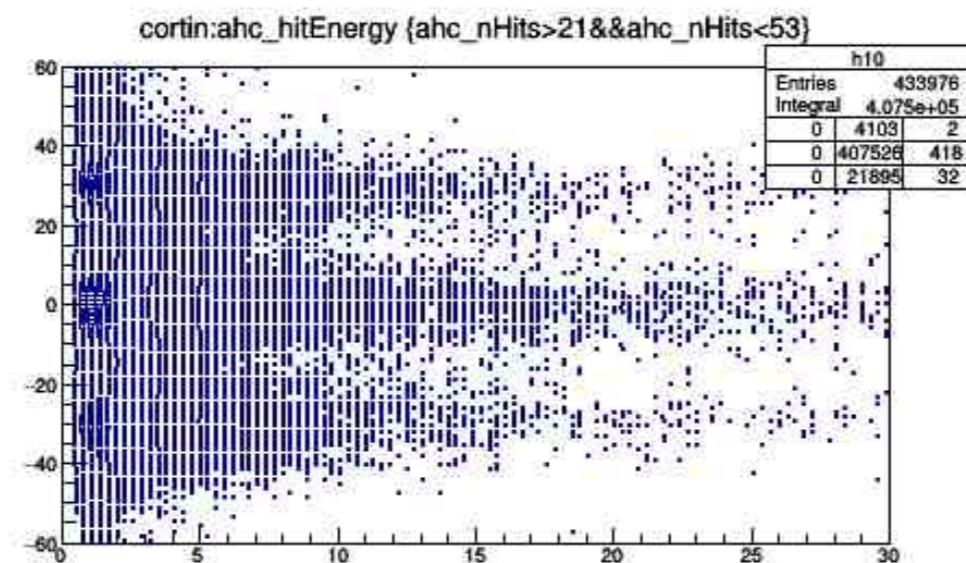
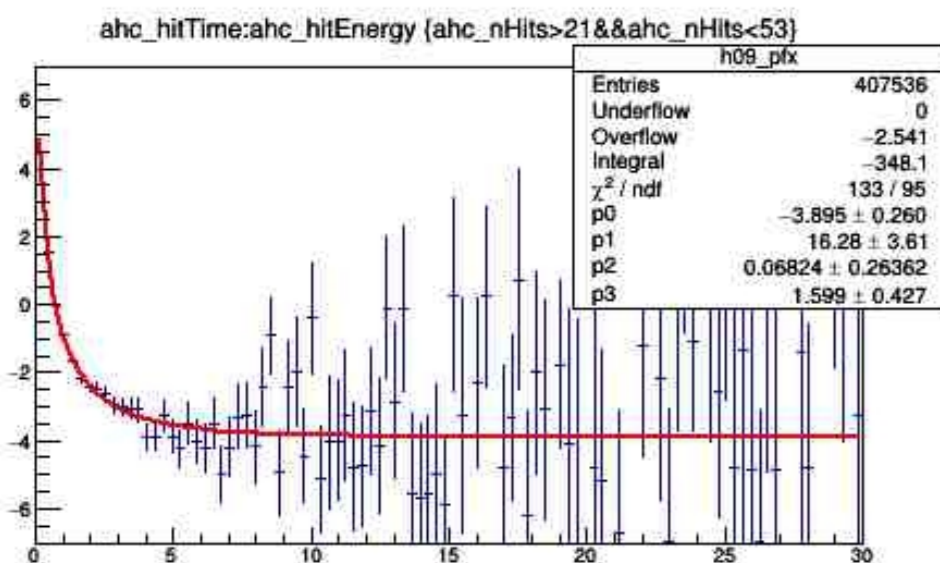
vsenergy_20190617h_hitTimevsEne reco_pion_n40GeV.root

[0-30 MIP]

raw data



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



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

energy dependence

hit time vs energy

.. after correction

resolution ~6% better

Summary

Learned to analyze AHCAL time data and look for response patterns.

There are indications that the time response with respect to the hit energy is strong but quite uniform.

A functional form should be usable to correct the time:

for all?

per module?

(maybe)

per module/chip?

(under study)

per module/chip/channel?

(unlikely due to statistics)

More muon data needed to cover all chips.

See whether there are particle-dependent effects, e.g. shower maximum.