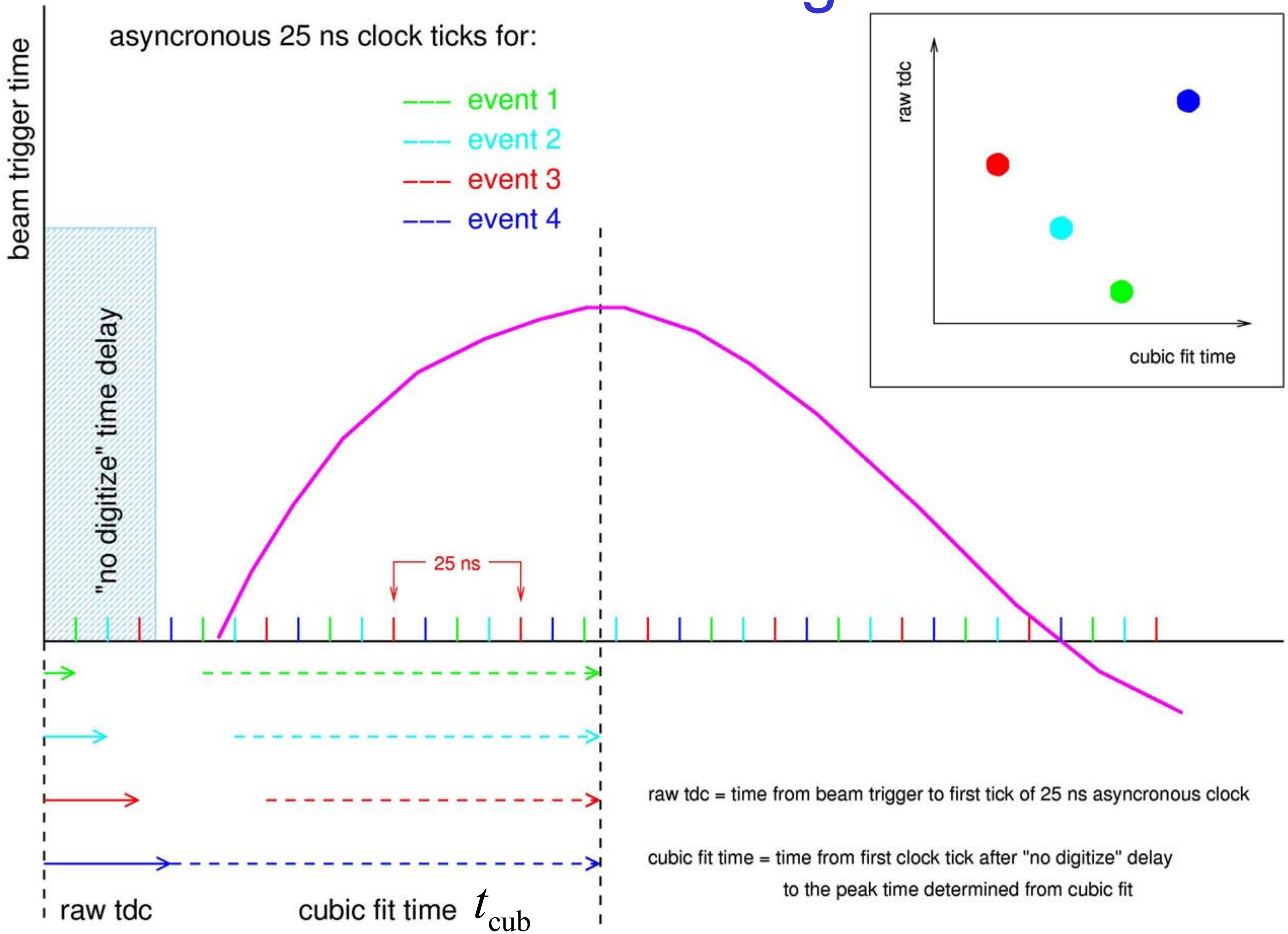
HEC-EMEC beam test data analysis Filtering weight synchronization and timing issues

ATLAS LAr week
19 November 2002

- TDC timing
- Cubic timing
- Digital filtering
  - TDC synchronization
  - cubic synchronization
  - LArDigitalFiltering

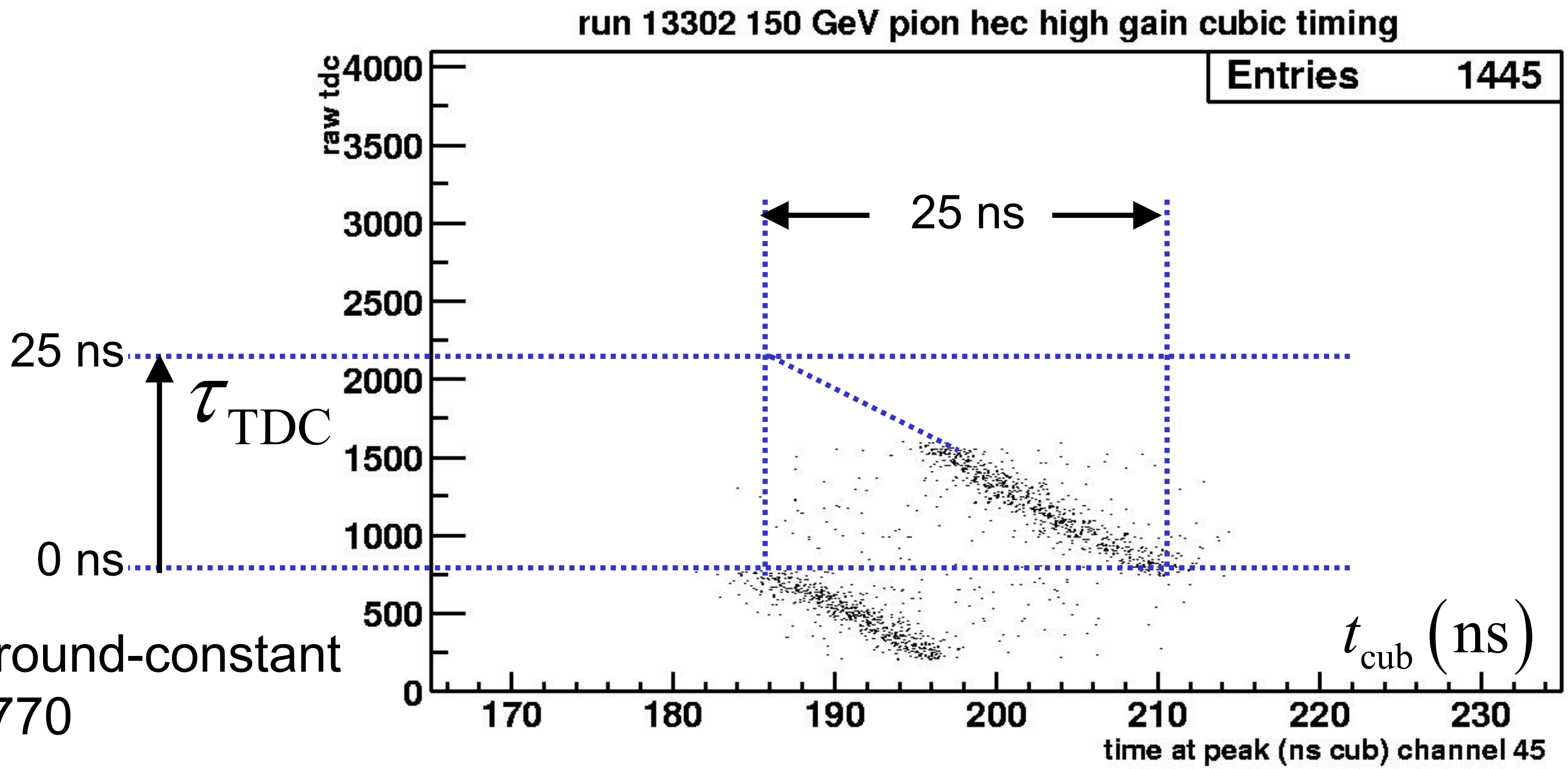
Michel Lefebvre
University of Victoria
Physics and Astronomy

TDC timing



beam trigger time
asyncronous 25 ns clock ticks for:
event 1
event 2
event 3
event 4
"no digitize" time delay
25 ns
raw tdc
cubic fit time
raw tdc = time from beam trigger to first tick of 25 ns asyncronous clock
cubic fit time = time from first clock tick after "no digitize" delay
to the peak time determined from cubic fit
raw tdc
cubic fit time t_{cub}

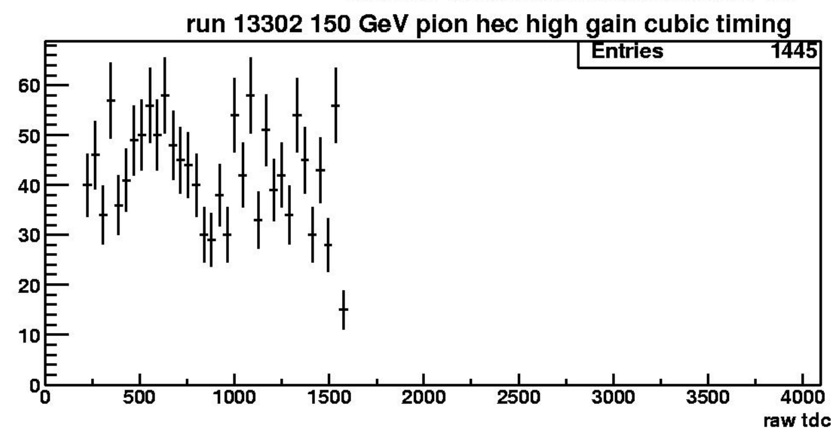
TDC timing



wrap-around-constant
wac = 770

for run 13302, wac_epi triggers

should be about flat →



TDC timing

There are three possible wac trigger types

trig_wac_c	(trig_daq_e	and not a bad trigger)
trig_wac_epi	(trig_daq_epi	and not a bad trigger)
trig_wac_mu	(trig_daq_mu	and not a bad trigger)

Each event is associated with only one wac trigger.

In principle, a different wac value is associated with each wac trigger.

Also, wac values change during a run period.

The wac values can be obtained from the data, and must be tabulated.

The tdc phase should be obtained this way:

$$\tau_{\mathrm{tdc}} = \begin{cases} \alpha\left(\mathrm{tdc} - \mathrm{wac}\right) & \mathrm{tdc} \geq \mathrm{wac} \\ \alpha\left(\mathrm{tdc} - \mathrm{wac}\right) + \delta & \mathrm{tdc} < \mathrm{wac} \end{cases} \qquad \begin{aligned} \alpha &\equiv 0.01816\ \mathrm{ns/tdc} \\ \delta &\equiv 25\ \mathrm{ns} \end{aligned}$$

which yields $\tau_{\mathrm{tdc}} \in \left[0, \delta\right)$

TDC timing

The following is what is currently implemented in the code:

$$\tau_{\mathrm{tdc}} = \begin{cases} \alpha\left(\mathrm{tdc} - \mathrm{wac}'\right) & \mathrm{tdc} \geq \mathrm{wac} \\ \alpha\left(\mathrm{tdc} - \mathrm{wac}'\right) + \delta & \mathrm{tdc} < \mathrm{wac} \end{cases}$$

where $\mathrm{wac}' \equiv 2\mathrm{wac} - \mathrm{wac}_{\mathrm{ref}}$

which yields $\tau_{\mathrm{tdc}} + \left(\mathrm{wac} - \mathrm{wac}_{\mathrm{ref}}\right) \in \left[0, \delta\right)$

where $\mathrm{wac}_{\mathrm{ref}}$ is one of the wac

This was found to work in the past for some runs where wac_epi and wac_c where present at the same time.

I suspect this was to correct for different T_0 (see later) for different trigger types

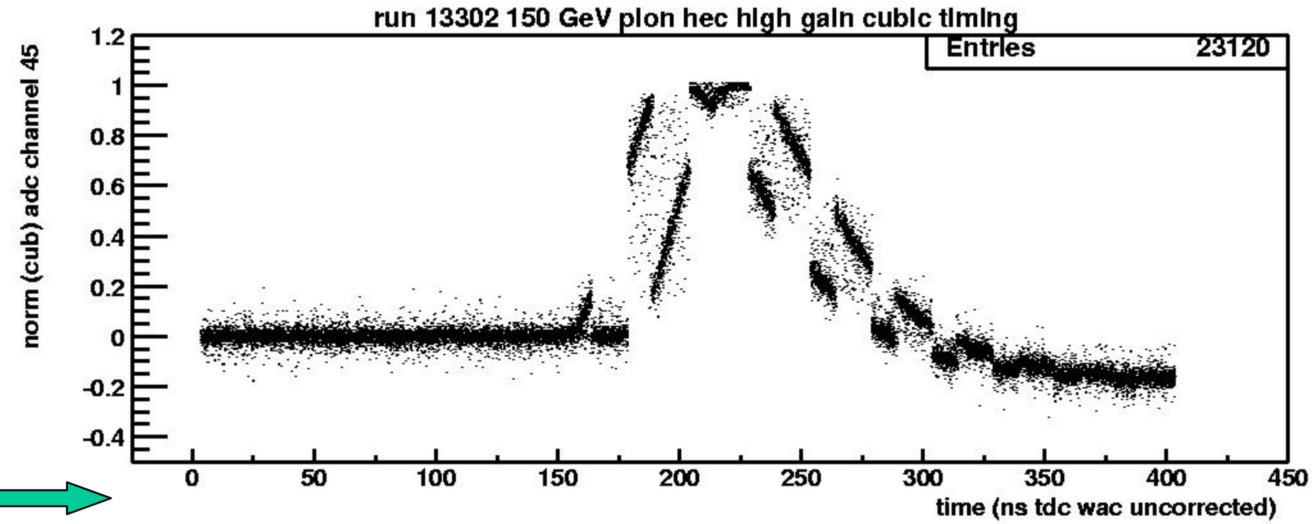
It is not clear whether this is still relevant or not.

? This should be checked by comparing the tdc phase corrected pulse shape for wac_c and wac_epi triggers taken close in time.

TDC timing and pulse shape

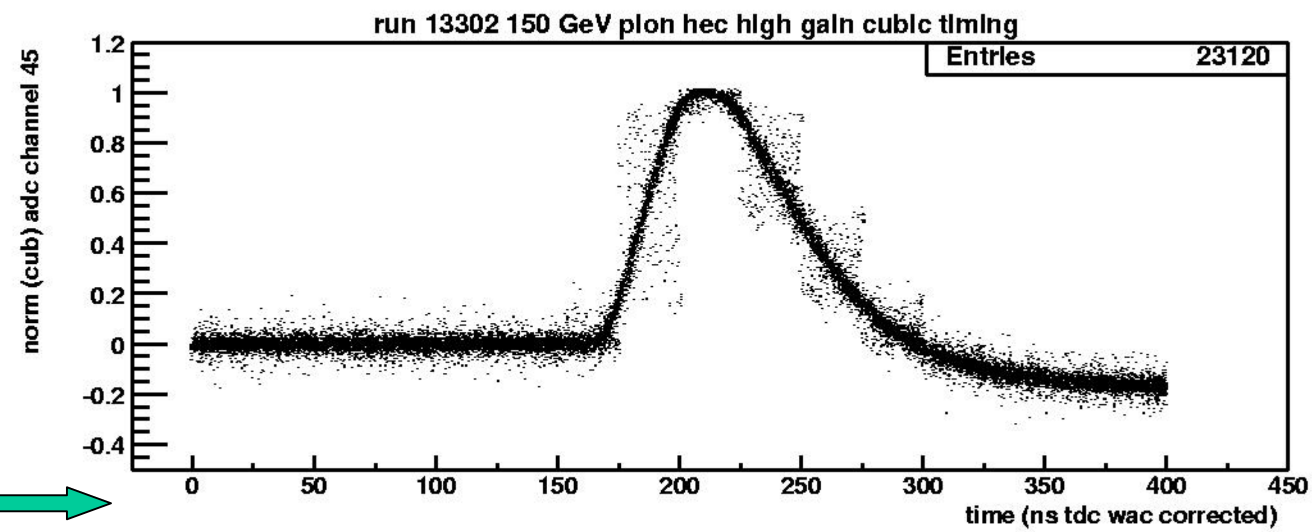
$$\frac{\text{adc} - \text{ped}}{\text{peak}_{\text{cub}}} \text{ vs } t$$

for time slice i,
position at time
$t = i\delta + \alpha\,\text{tdc}$

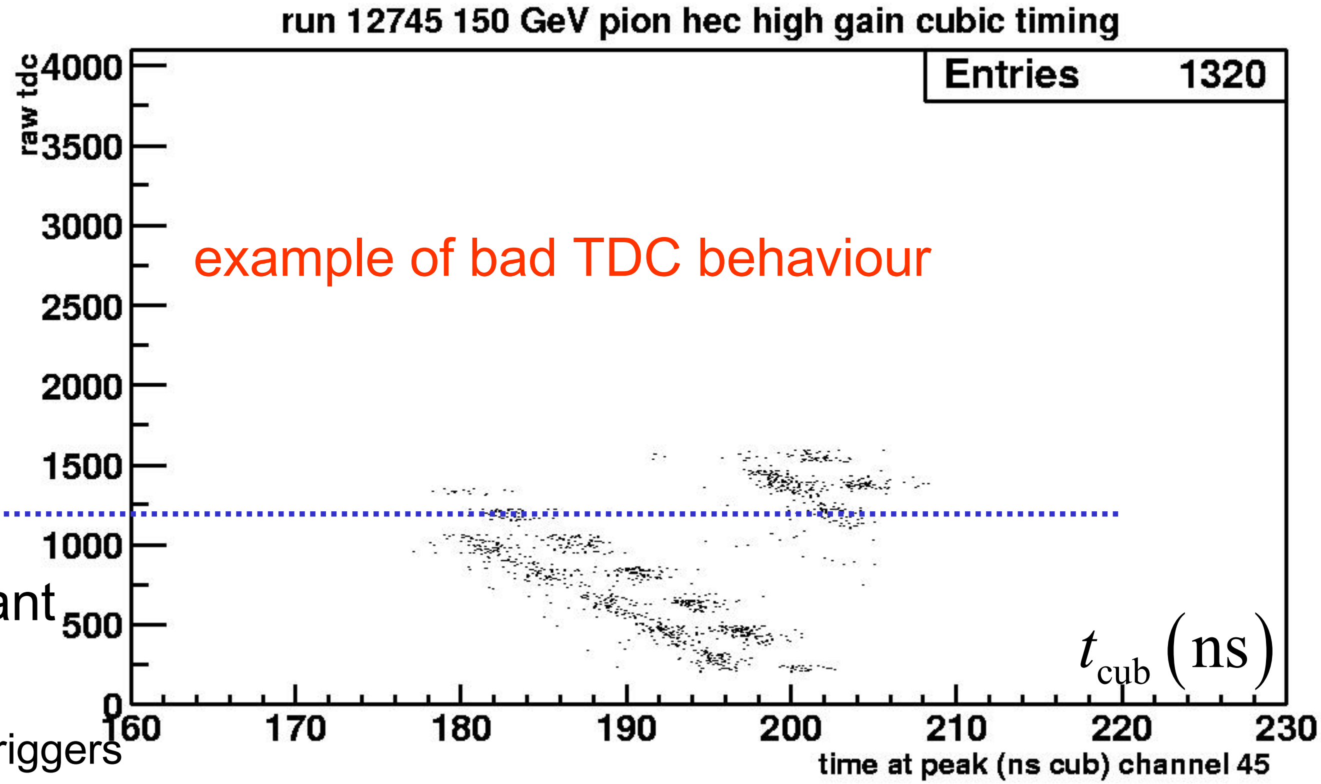


if cubic fit finds peak correctly, then this curves is maximum at a height of 1.

for time slice i,
position at time
$t = i\delta + \tau_{\text{tdc}}$



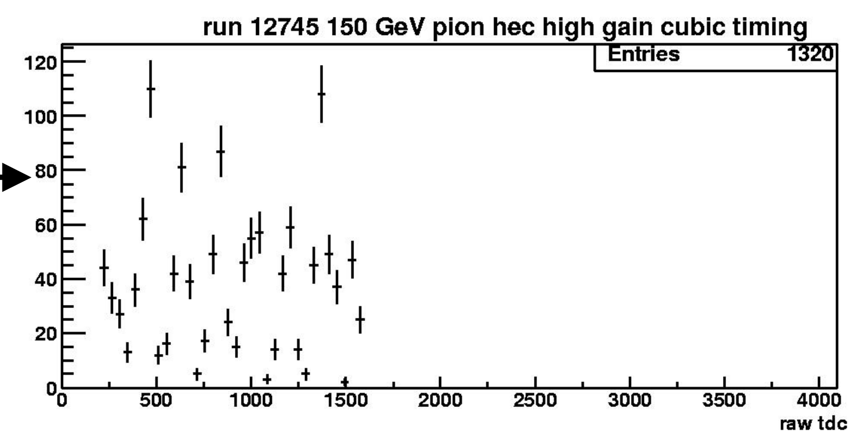
TDC timing



wrap-around-constant
wac_epi ≈ 1200

for run 12645, wac_epi triggers

not flat

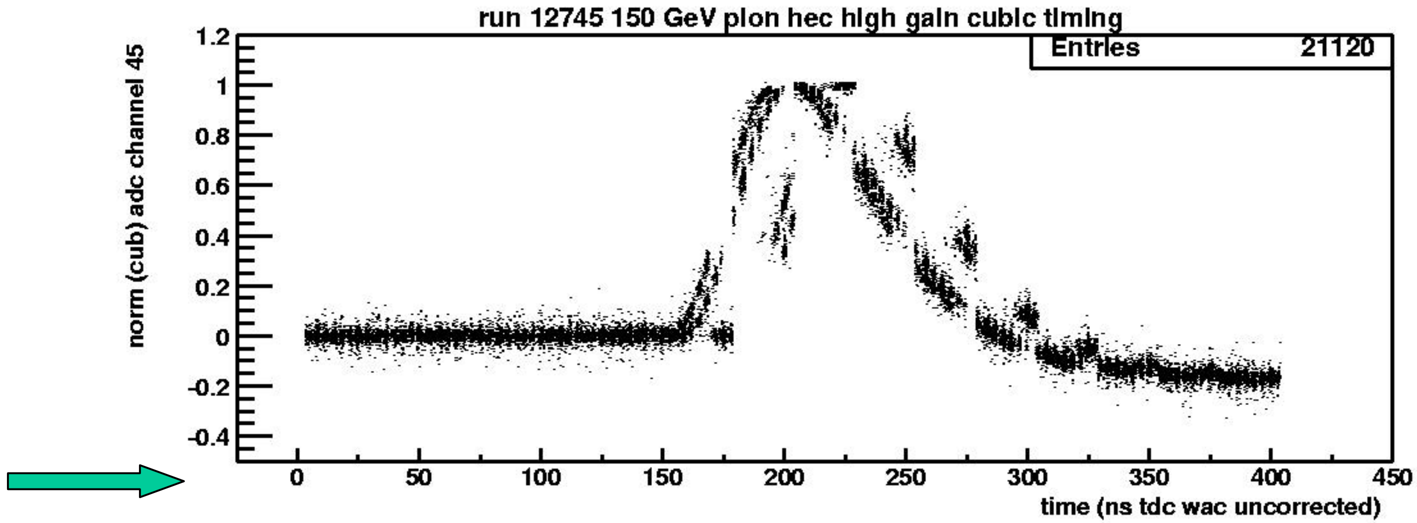


TDC timing and pulse shape

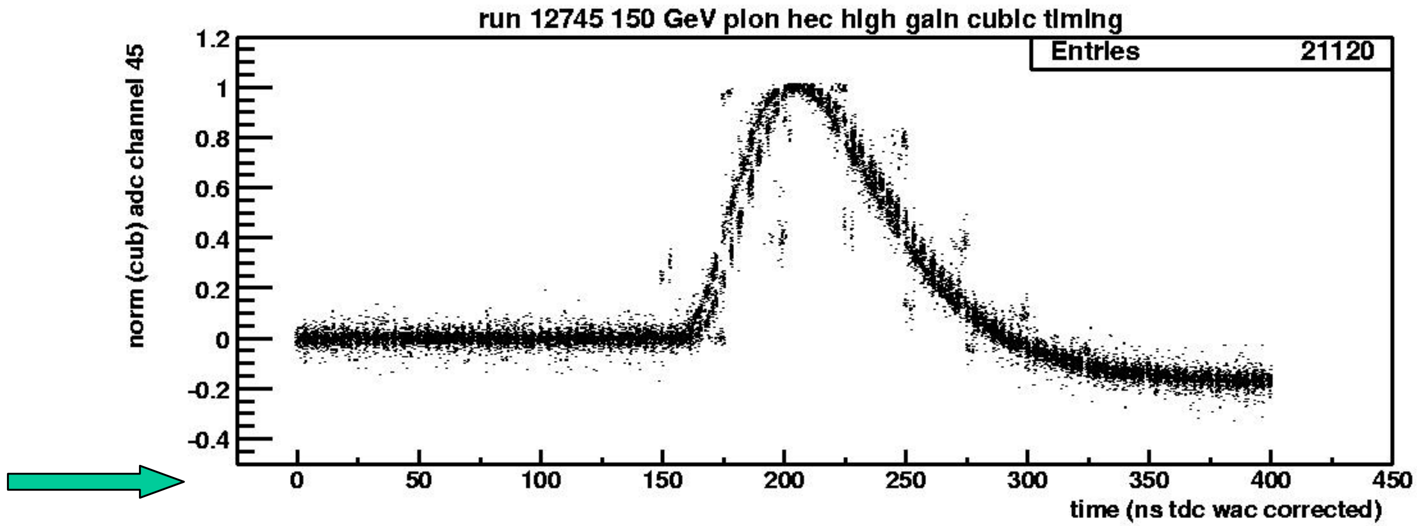
example of bad TDC behaviour

$$\frac{\text{adc} - \text{ped}}{\text{peak}_{\text{cub}}} \text{ vs } t$$

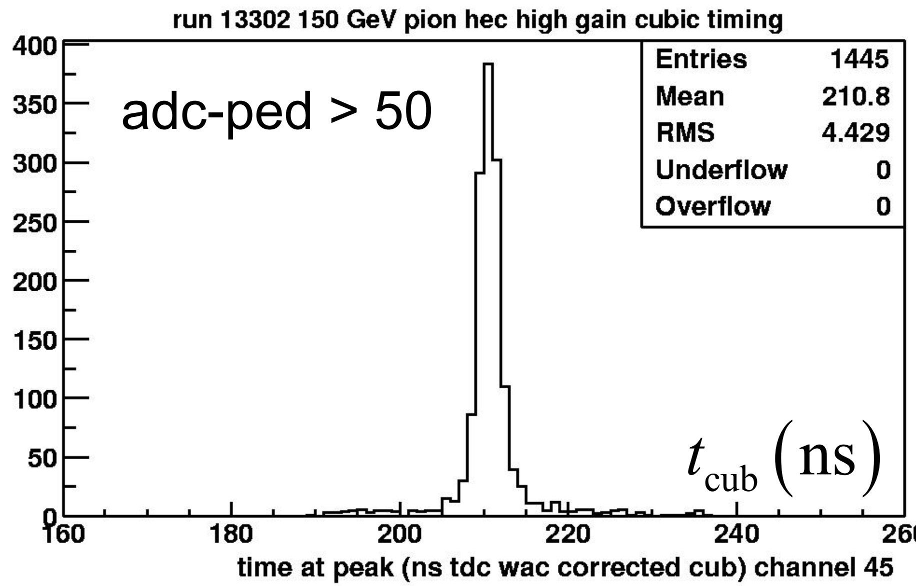
for time slice i, position at time $t = i\delta + \alpha\,\text{tdc}$



for time slice i, position at time $t = i\delta + \tau_{\text{tdc}}$



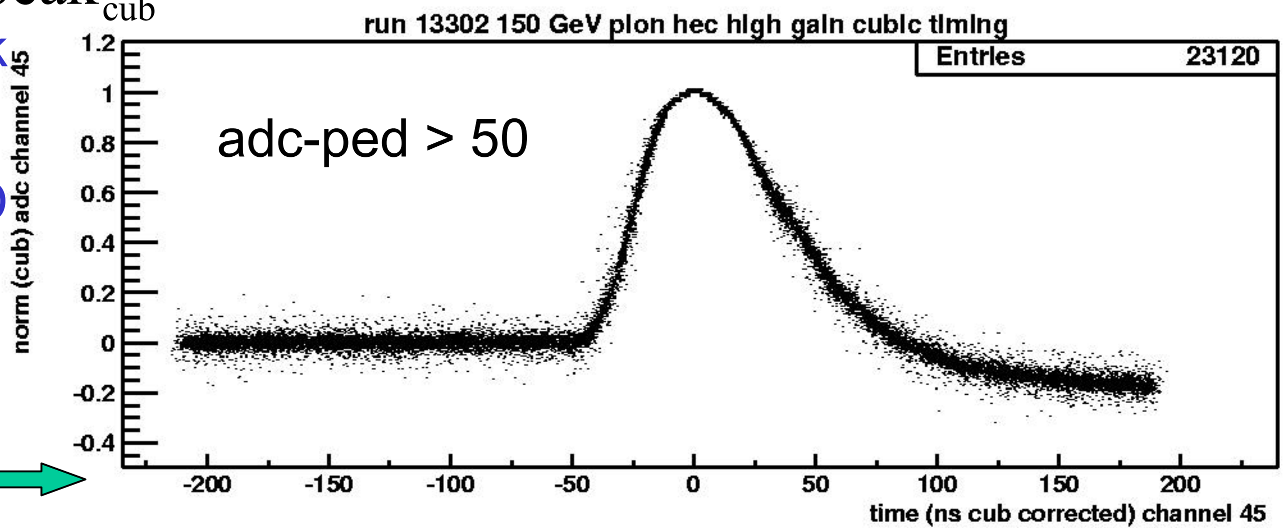
Cubic timing



$$\frac{\text{adc}-\text{ped}}{\text{peak}_{\text{cub}}} \text{ vs } t$$

if cubic fit finds peak correctly, then this curves is maximum at a height of 1 AND t=0

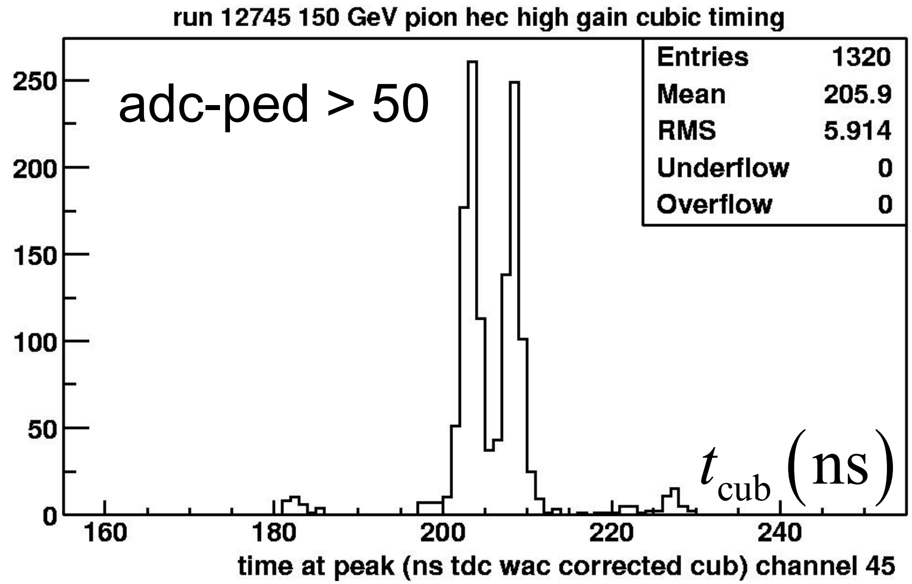
for time slice i, position at time $t = i\delta - t_{\text{cub}}$



Cubic timing

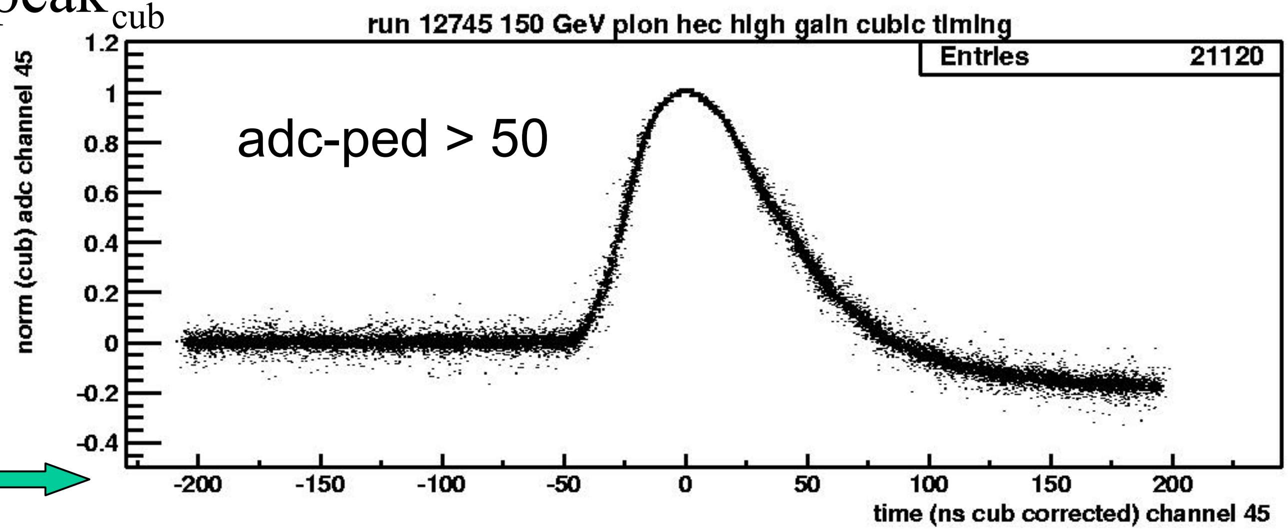
example of bad TDC behaviour

in this case there are two different timings…



$$\frac{\text{adc} - \text{ped}}{\text{peak}_{\text{cub}}} \text{ vs } t$$

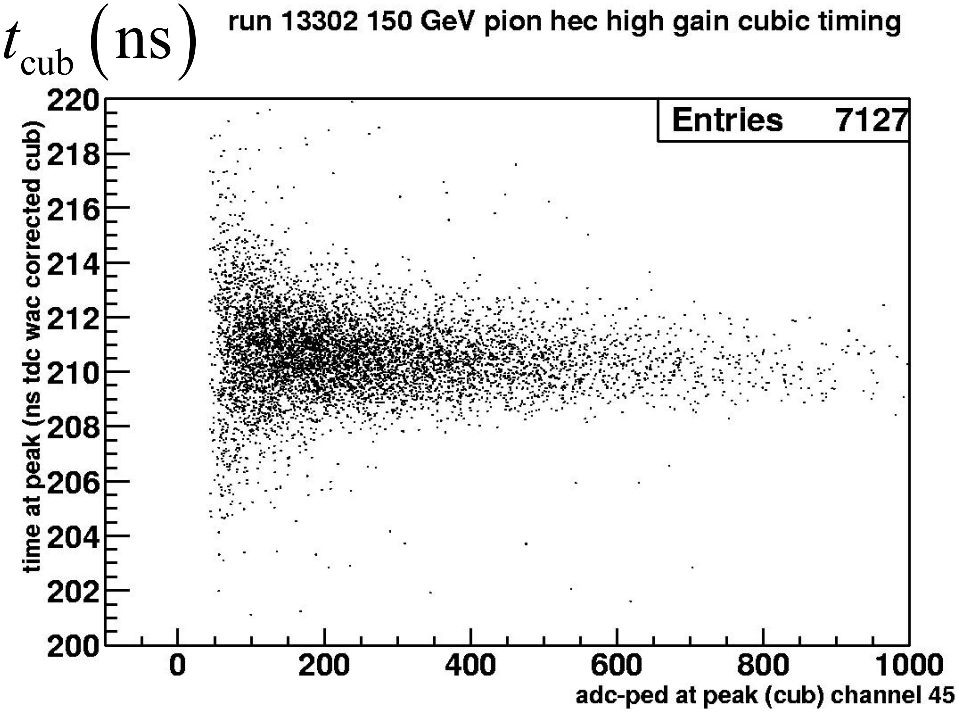
…but the cubic timing is of good quality

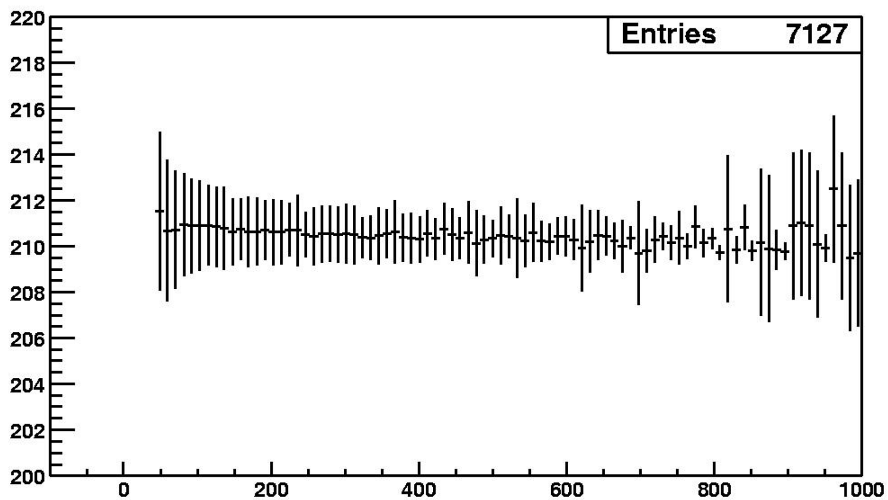


for time slice i, position at time $t = i\delta - t_{\text{cub}}$

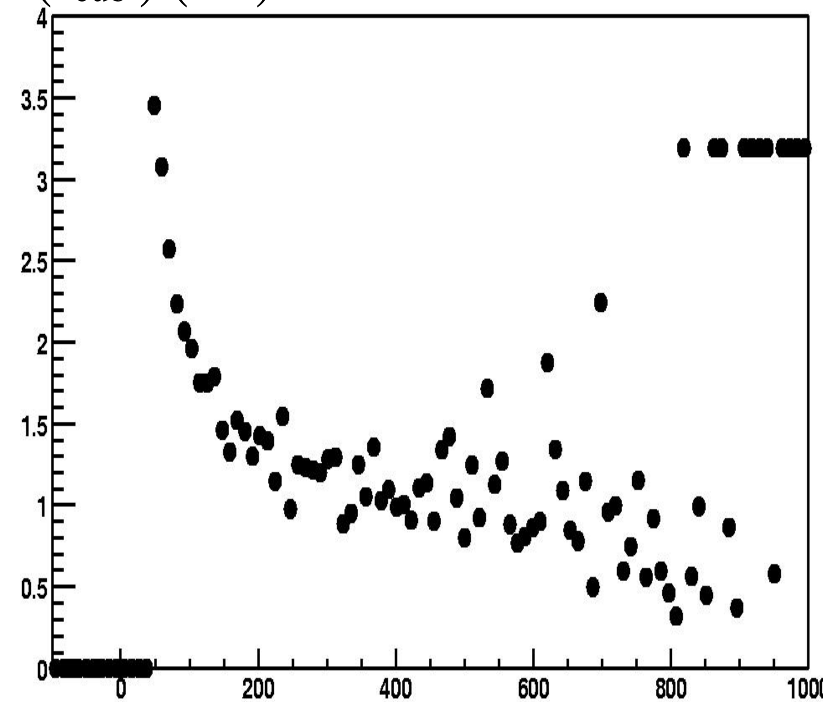
Cubic timing quality

$t_{\mathrm{cub}}\,(\mathrm{ns})$





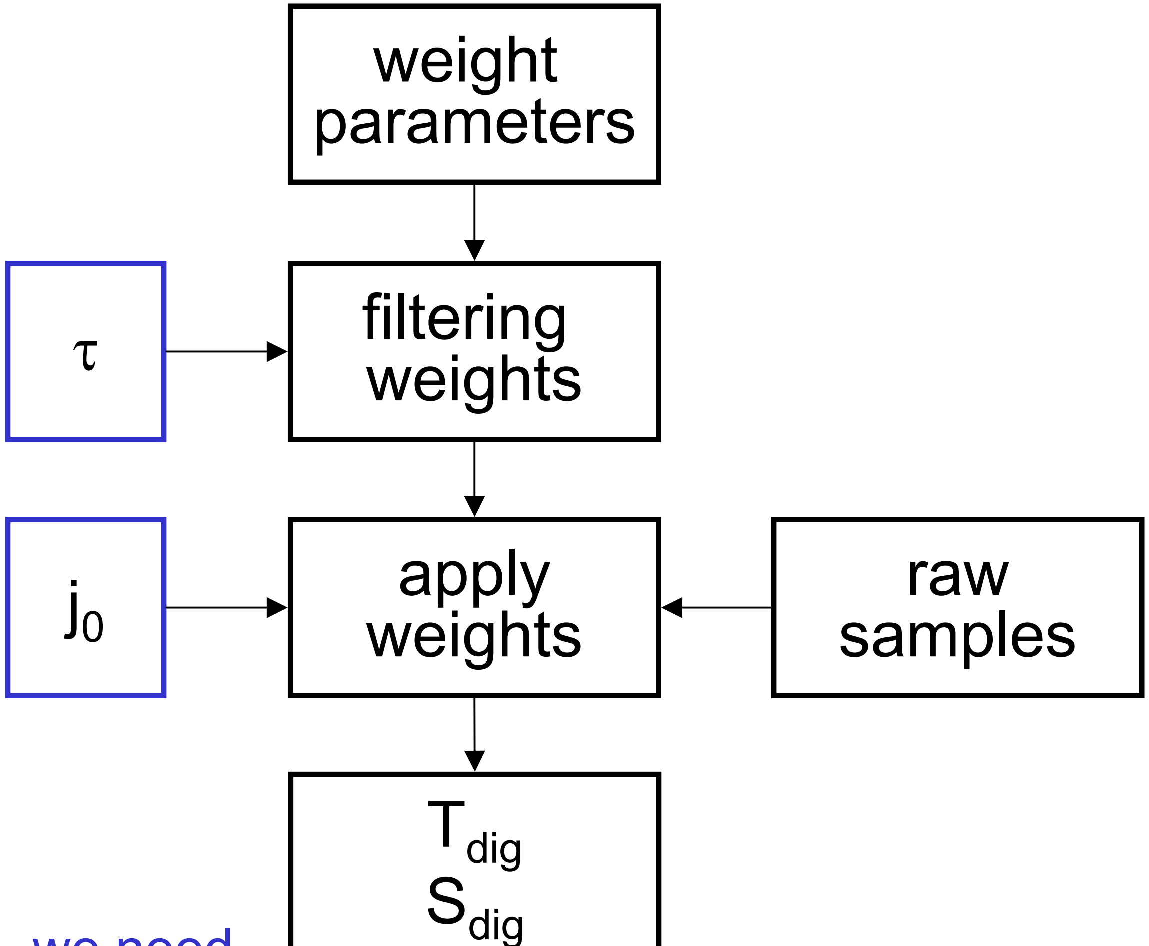
$\sigma(t_{\mathrm{cub}})(\mathrm{ns})$



adc-ped at peak(cub) channel 45

$\sigma(t_{\mathrm{cub}}) > 3.5$ ns for adc-ped < 50

Digital filtering

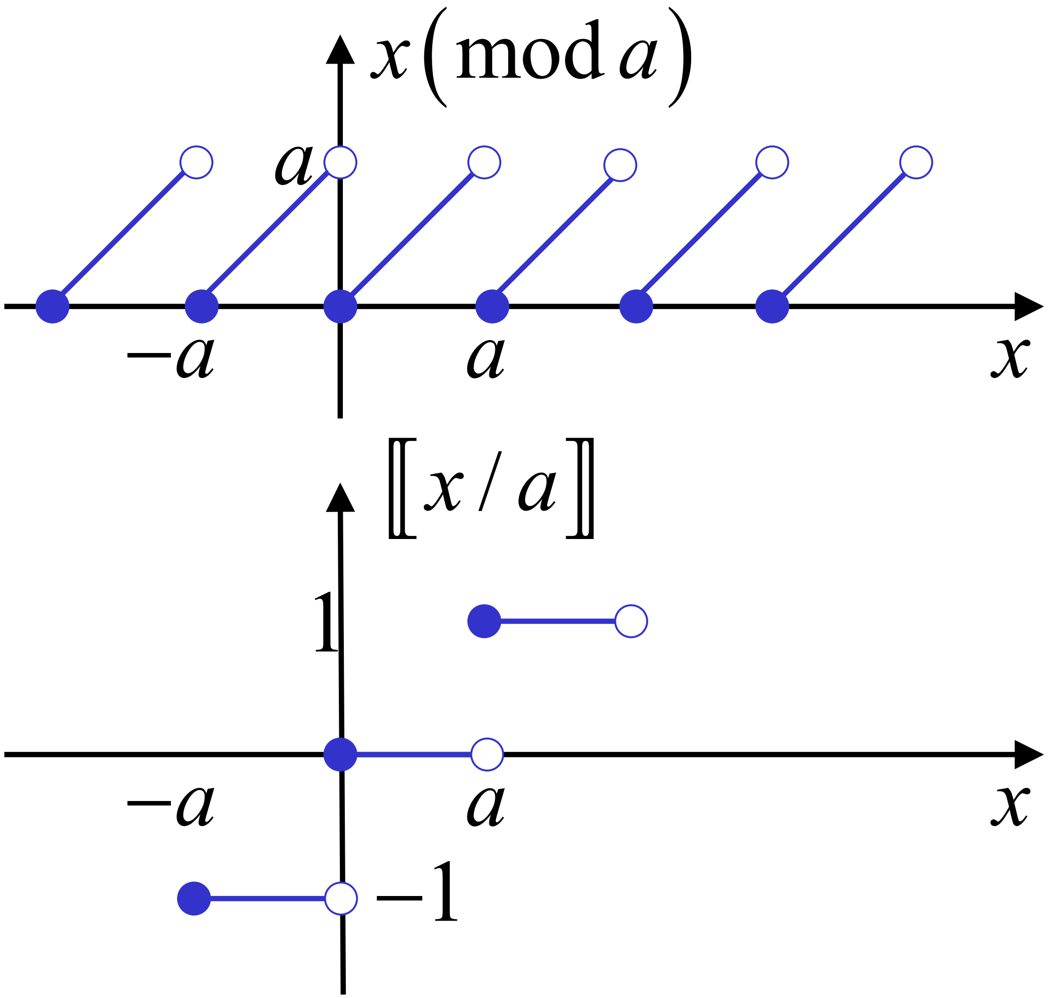


for each channel, we need

τ the digital filtering phase, $\in[0,\delta)$

j_0 weights to be applied to samples j_0 to j_0+4

int and mod



$[\![x/a]\!] \Rightarrow$ int intxa $=$ (x/a<0) ? int(x/a)-1 : int(x/a) or floor(x/a)

$x(\mathrm{mod}\, a) \Rightarrow$ float xmoda = x - intxa * a

Digital filtering: TDC synchronization

Let

$$T(k) = T_0^{\mathrm{tdc}}(k) + \tau_{\mathrm{tdc}}$$

then set

$$\tau(k) = T(k)(\mathrm{mod}\,\delta)$$

$$j_0(k) = i_0 - \left[\!\left[\frac{T(k)}{\delta} \right]\!\right]$$

where i_0 is a fixed sample number

then

$$\left\langle T_{\mathrm{dig}}(k) \right\rangle = 0 \quad \Rightarrow \quad T_0^{\mathrm{tdc}}(k)$$

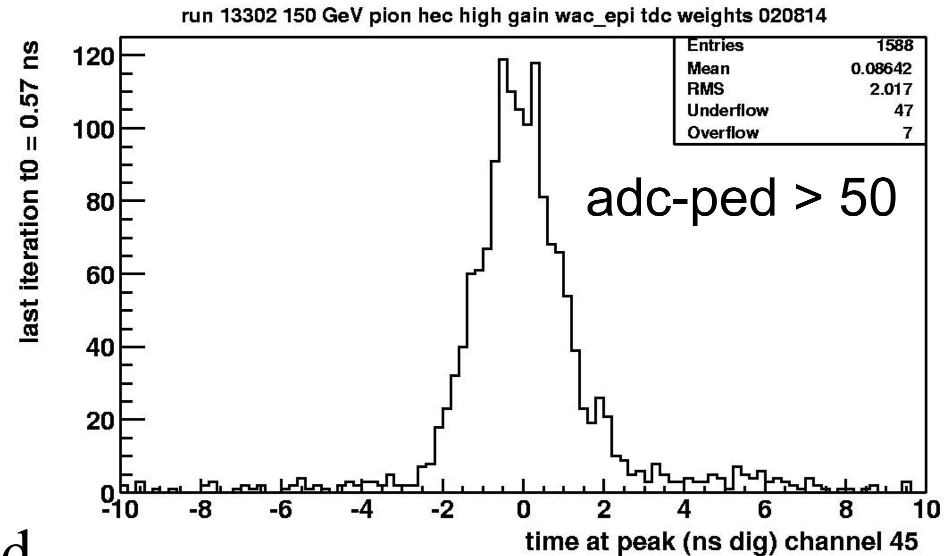
This procedure, in principle, yields $T_0^{\mathrm{tdc}}(k)$ for all channels with sufficient data in them

With the current TDC correction implementation, $T_0^{\mathrm{tdc}}(k)$ should be independent of trigger type. With recent TDC problems, this is not clear anymore.

Digital filtering: TDC synchronization

run 13302, k=45, weights 020814

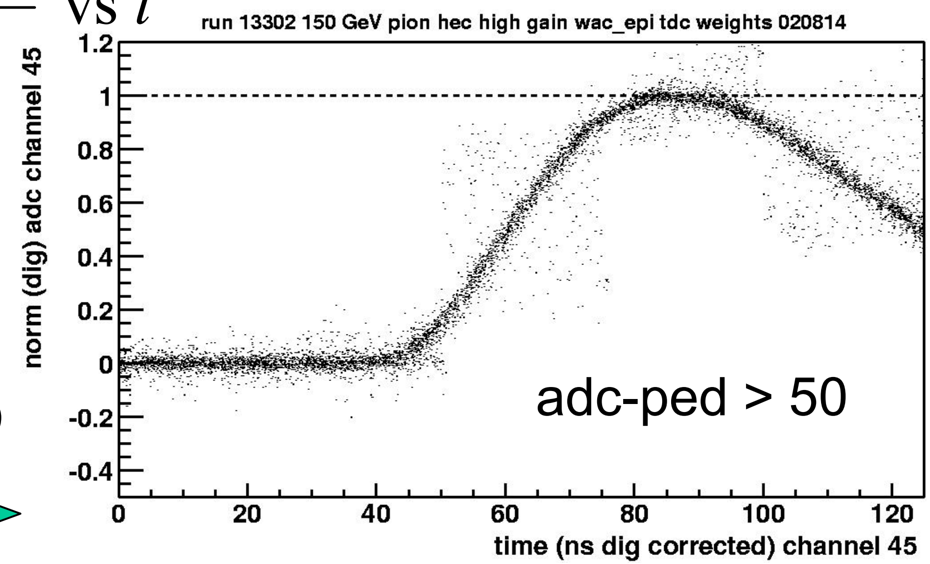
$$T_0^{\mathrm{tdc}}(k) = 0.6\ \mathrm{ns} \quad \Rightarrow \quad \left|\left\langle T_{\mathrm{dig}}(k)\right\rangle\right| < 0.1\ \mathrm{ns}$$



if digital filtering finds peak correctly, then this curves is maximum at a height of 1

$$\frac{\mathrm{adc} - \mathrm{ped}}{\mathrm{peak}_{\mathrm{dig}}} \text{ vs } t$$

this curves also shows the part of the signal used to make the weights…



for time slice $i = j_0 + n \quad (n = 0,1,2,3,4)$ position at time

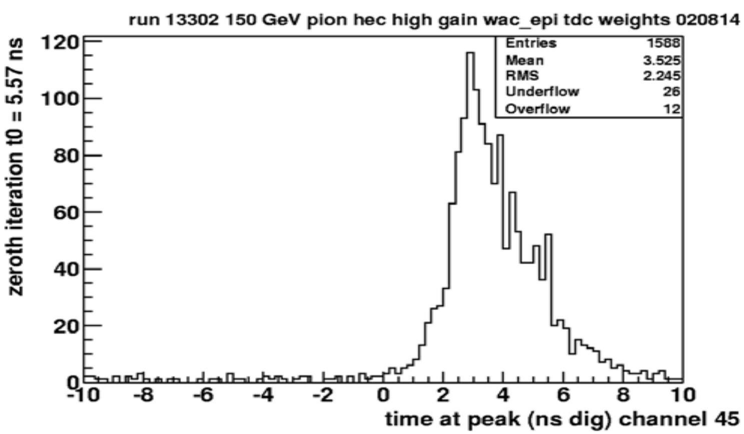
$$t = n\delta + \tau$$

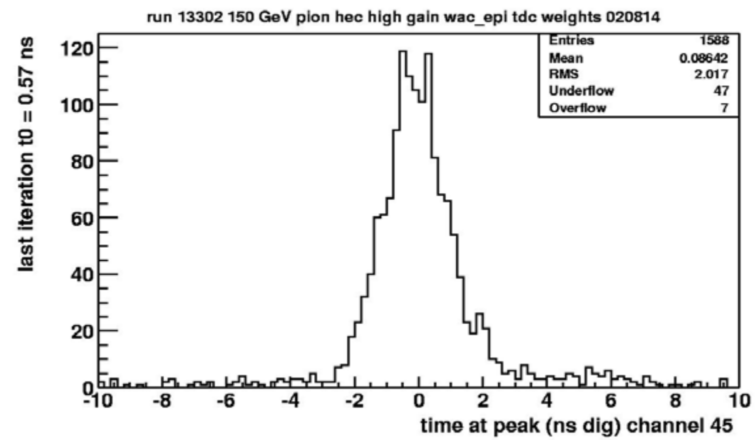
Digital filtering: TDC synchronization

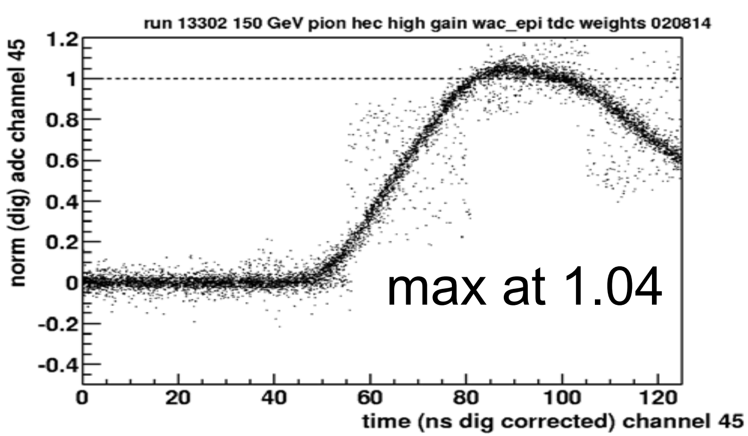
run 13302, k=45, weights 020814

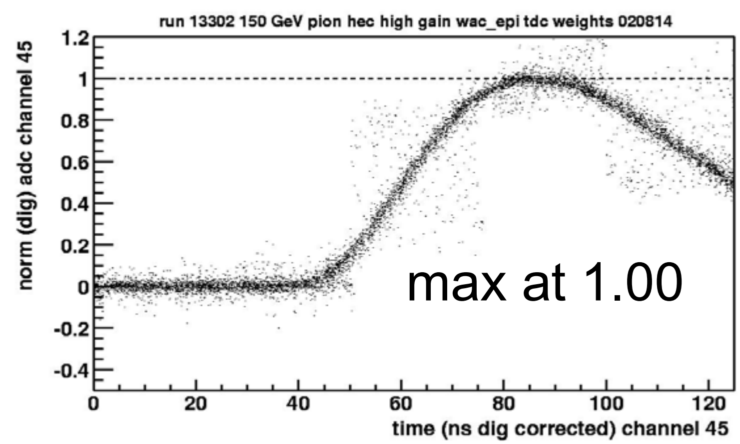
$$T_0^{\mathrm{tdc}}(k) = 5.6\ \mathrm{ns} \quad \Rightarrow \quad \langle T_{\mathrm{dig}}(k) \rangle = 3.5\ \mathrm{ns}$$

$$T_0^{\mathrm{tdc}}(k) = 0.6\ \mathrm{ns} \quad \Rightarrow \quad \left| \langle T_{\mathrm{dig}}(k) \rangle \right| < 0.1\ \mathrm{ns}$$

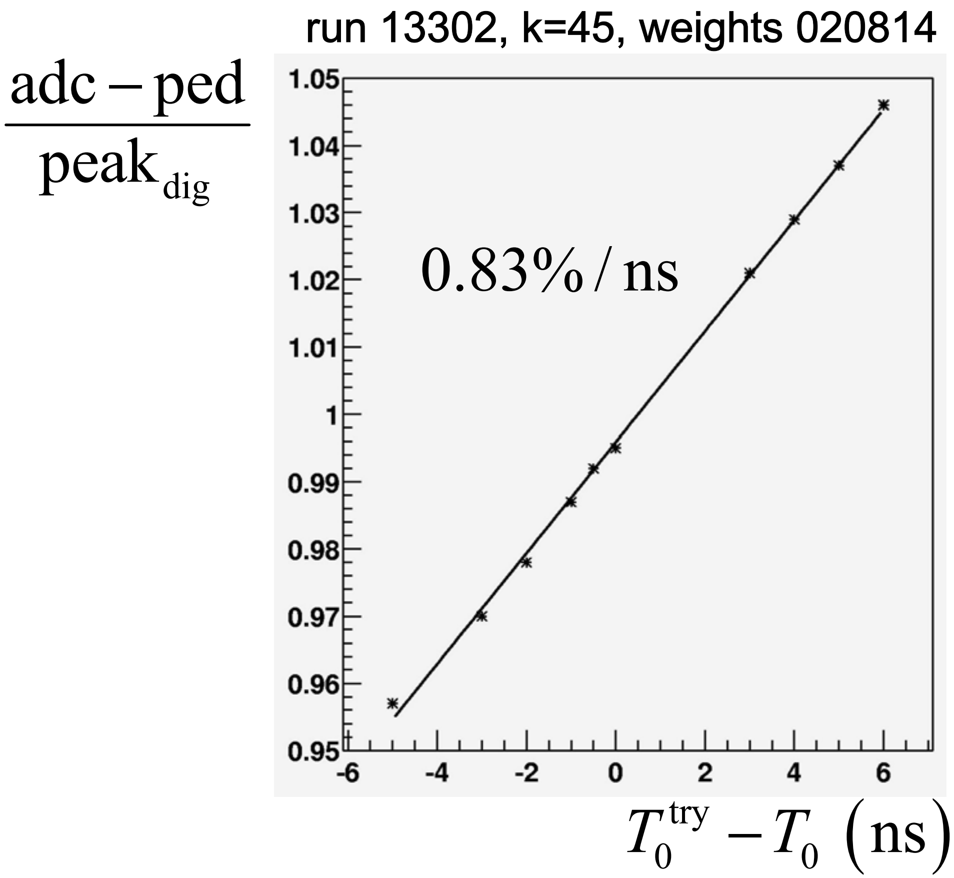




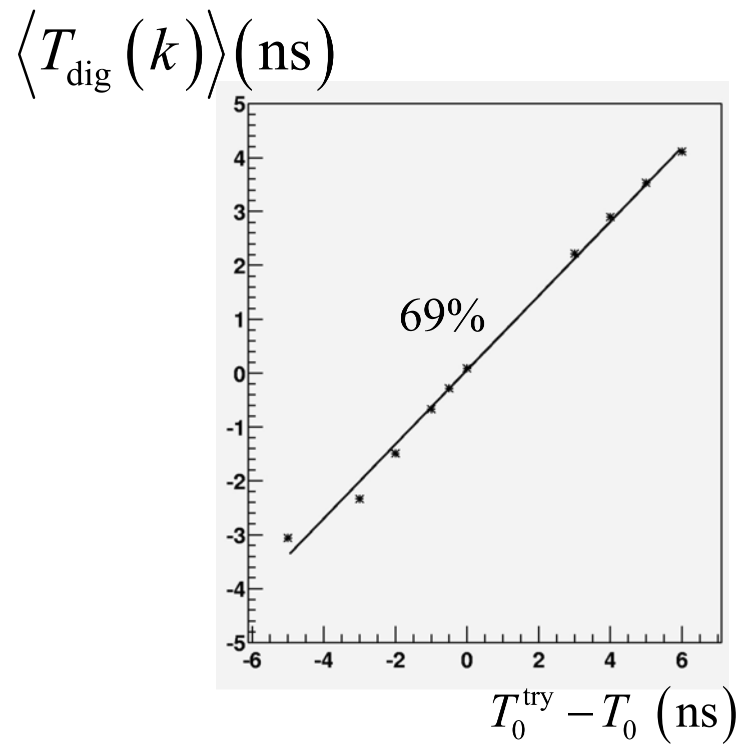




Digital filtering: TDC synchronization



if T_0 is off by 5 ns, then the reconstructed signal height is off by about 4%



Digital filtering: TDC synchronization

$T_0^{\text{tdc}}(k)$ depends on k and on the weights parameter file used

example: run 13302, trigger wac_epi, $\left|\left\langle T_{\text{dig}}(k)\right\rangle\right| < 0.1$ ns

weights 020814

k	$T_0^{\text{tdc}}(k)(\text{ns})$
45	0.6
46	−0.8
59	−5.3
62	0.2
139	−4.5

weights 020901

k	$T_0^{\text{tdc}}(k)(\text{ns})$
45	−2.3
46	−1.3
59	−6.4
62	−1.0
139	−5.7

weights 020902

k	$T_0^{\text{tdc}}(k)(\text{ns})$
45	0.3
46	−0.8
59	−5.3
62	−0.2
139	−4.5

weights 020911

k	$T_0^{\text{tdc}}(k)(\text{ns})$
45	−2.1
46	−1.1
59	−6.2
62	−0.7
139	−5.7

weights 020912

k	$T_0^{\text{tdc}}(k)(\text{ns})$
45	0.8
46	−0.7
59	−5.3
62	−0.3
139	−5.0

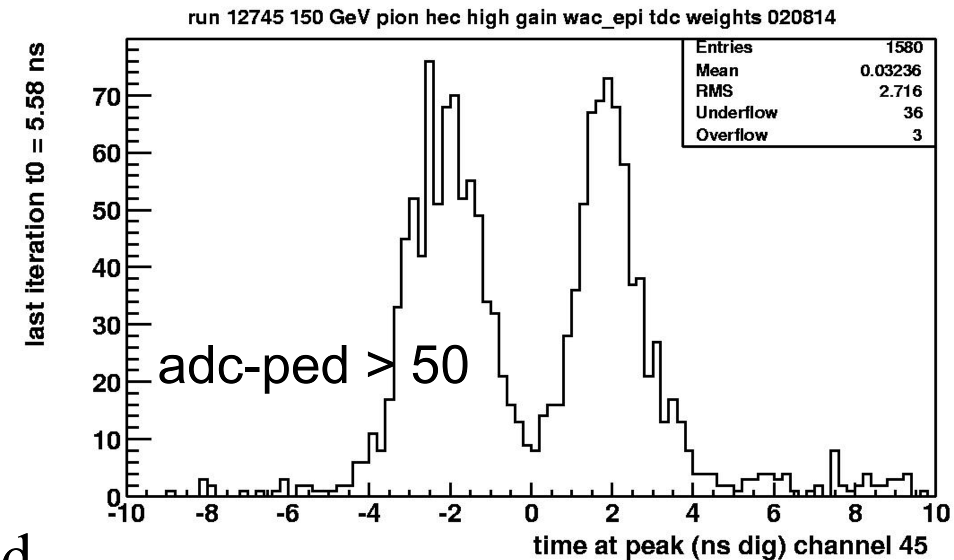
these weights parameters file are currently synchronized for k=45 and i_0=5 for run 13302

Digital filtering: TDC synchronization

example of bad TDC behaviour

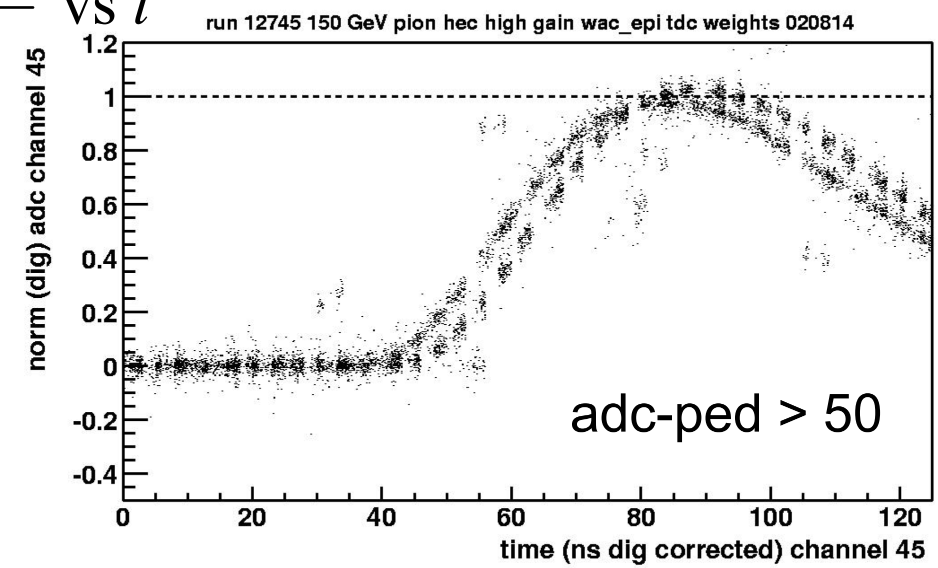
run 12745, k=45, weights 020814

$$T_0^{\text{tdc}}(k) = 5.6 \text{ ns} \quad \Rightarrow \quad \left| \langle T_{\text{dig}}(k) \rangle \right| < 0.1 \text{ ns}$$



$$\frac{\text{adc} - \text{ped}}{\text{peak}_{\text{dig}}} \text{ vs } t$$

to do a good job one would need to analyze the two types of timings separately…



for time slice $i=j_0+n \quad (n = 0,1,2,3,4)$
position at time

$$t = n\delta + \tau$$

Digital filtering: cubic synchronization

Let

$$T(k) = T_0^{\text{cub}}(k, k_0) - T_P(k_0)$$

where

$$T_P(k_0) = T_P(k') + \Delta T_P(k_0, k') \qquad \Delta T_P(k_1, k_2) \equiv T_P(k_1) - T_P(k_2)$$

where k_0 is a fixed reference channel
k' is the channel used for cubic synchronization of an event

in principle, $\Delta T_P(k_1, k_2)$ can be obtained from the data by analyzing cubit fit signal timing. It is sensitive to the signal peaking time and rise time differences between channels

then set

$$\tau(k) = T(k)(\operatorname{mod} \delta) \qquad j_0(k) = i_0 - \left[\!\left[\frac{T(k)}{\delta} \right]\!\right]$$

where i_0 is a fixed sample number

then

$$\langle T_{\text{dig}}(k) \rangle = 0 \;\Rightarrow\; T_0^{\text{cub}}(k, k_0)$$

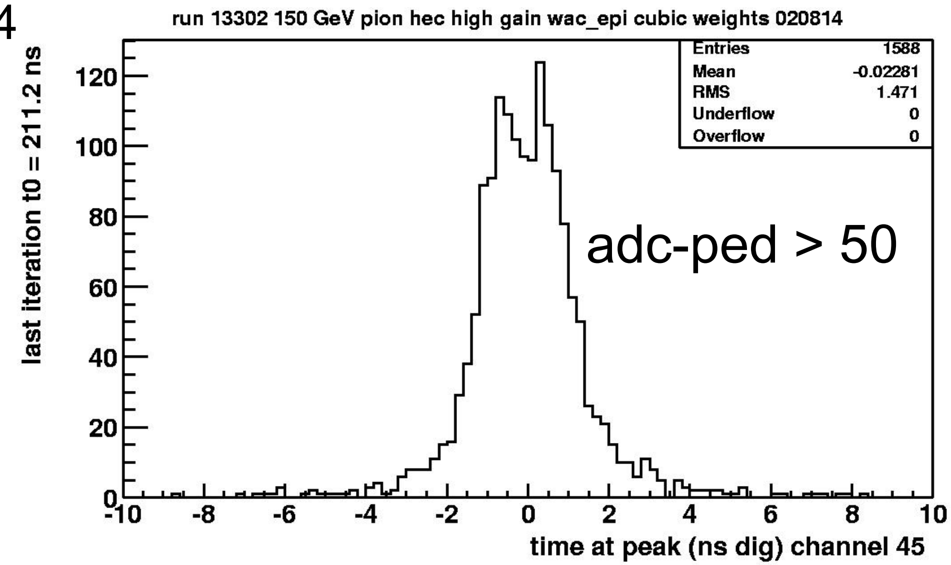
This procedure, in principle, yields $T_0^{\text{cub}}(k, k_0)$ for all channels with sufficient data in them

? It should not depend on trigger type.

Digital filtering: cubic synchronization

run 13302, k=k'=k_0=45, weights 020814

$$T_0^{\text{cub}}(k,k) = 211.2 \text{ ns} \;\Rightarrow\; \left|\left\langle T_{\text{dig}}(k)\right\rangle\right| < 0.1 \text{ ns}$$



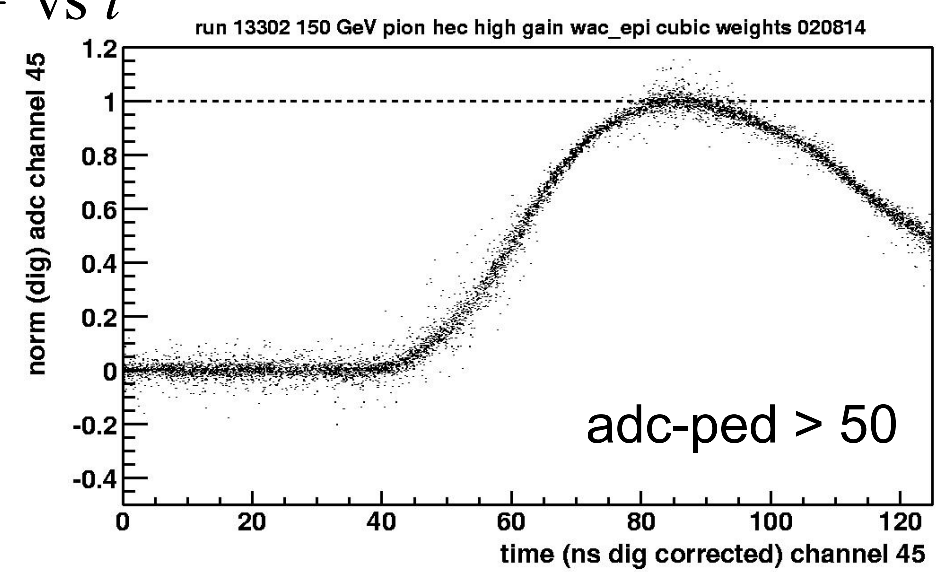
if digital filtering finds peak correctly, then this curves is maximum at a height of 1

$$\frac{\text{adc} - \text{ped}}{\text{peak}_{\text{dig}}} \text{ vs } t$$

this curves also shows the part of the signal used to make the weights…

for time slice $i = j_0 + n \quad (n = 0,1,2,3,4)$
position at time

$$t = n\delta + \tau$$



Digital filtering: cubic synchronization

$T_0^{\mathrm{tdc}}(k,k_0)$ depends on k, k_0 and on the weights parameter file used

example: run 13302, trigger wac_epi, $\left|\left\langle T_{\mathrm{dig}}(k)\right\rangle\right| < 0.1\ \mathrm{ns}$

weights 020814

k	$T_0^{\mathrm{cub}}(k,k)(\mathrm{ns})$
45	211.2
46	208.1
59	206.8
62	211.8
139	207.0

weights 020901

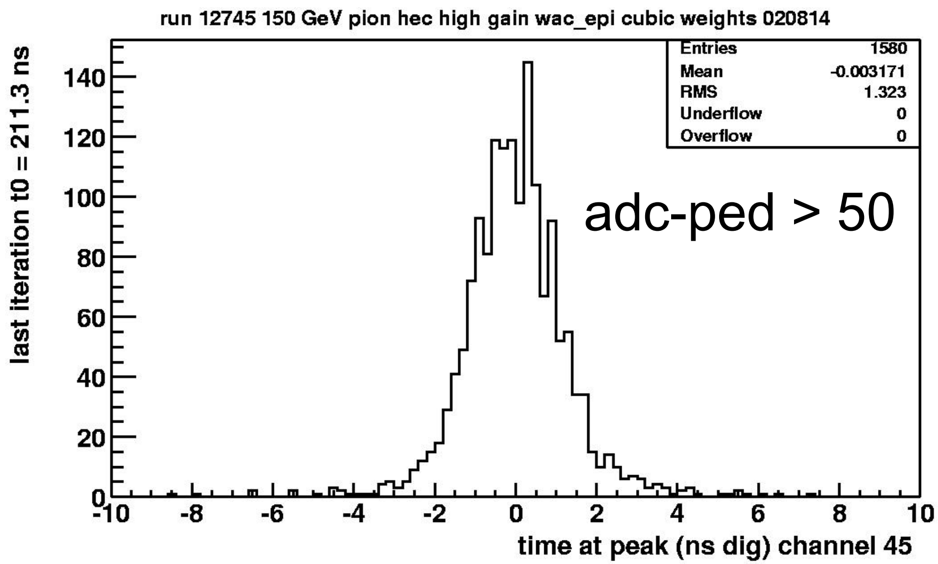
k	$T_0^{\mathrm{cub}}(k,k)(\mathrm{ns})$
45	208.5
46	207.7
59	205.9
62	211.1
139	205.9

Digital filtering: cubic synchronization

example of bad TDC behaviour

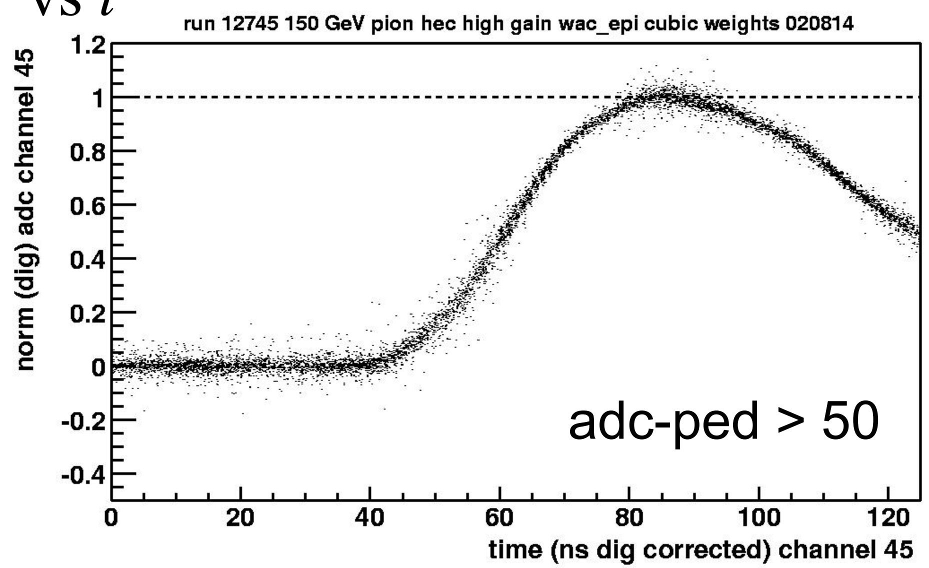
run 12745, k=k'=k_0=45, weights 020814

$$T_0^{\text{cub}}(k,k) = 211.3\ \text{ns} \quad \Rightarrow \quad \left|\left\langle T_{\text{dig}}(k)\right\rangle\right| < 0.1\ \text{ns}$$



$$\frac{\text{adc} - \text{ped}}{\text{peak}_{\text{dig}}} \text{ vs } t$$

here no need to worry about the two types of timings…



for time slice $i=j_0+n \quad (n = 0,1,2,3,4)$
position at time

$$t = n\delta + \tau$$

Digital filtering: synchronization

Note that the cell-to-cell differences of $T_0^{\text{tdc}}(k)$ and $T_0^{\text{cub}}(k,k_0)$ should be the same because the cubic timing is done with respect to a fixed channel k_0

- $$\Delta T_0(k_1,k_2) \equiv T_0^{\text{tdc}}(k_1) - T_0^{\text{tdc}}(k_2) = T_0^{\text{cub}}(k_1,k_0) - T_0^{\text{cub}}(k_2,k_0)$$
- It should be independent of trigger type.

Note that $\Delta T_P(k_1,k_2)$ is sensitive to physics signal rise and peaking times, while $\Delta T_0(k_1,k_2)$ is sensitive to the calibration signal start times.

Summarizing, we could consider

$$T(k) = \Delta T_0(k,k_0) + \begin{cases} T_0^{\text{tdc}}(k_0) + \tau_{\text{tdc}} \\ T_0^{\text{cub}}(k_0,k_0) - T_P(k') - \Delta T_P(k_0,k') \end{cases}$$

where k_0 is a fixed reference channel
k' is the channel used for cubic synchronization of an event

- With the current TDC correction implementation, $T_0^{\text{tdc}}(k)$ should be independent of trigger type. With recent TDC problems, this is not clear anymore.
- $T_0^{\text{cub}}(k,k_0)$ should not depend on trigger type.

Digital filtering: LArDigitalFiltering

Currently, LArDigitalFiltering has an implementation assuming

$$\Delta T_0\left(k_1,k_2\right)=\Delta T_P\left(k_1,k_2\right)=0$$

k' is the channel with highest cubic signal in the event

In the job options file, one can set

$$i_0, T_0^{\text{tdc}}\left(k_0\right), T_0^{\text{cub}}\left(k_0,k_0\right)$$

Currently, in the amplitude weights parameter file, there is provision for

$$i_0, T_0^{\text{tdc}}\left(k_0\right), k_0$$

- ? How many run ranges do we need to consider?

Finding $T_P\left(k'\right)+\Delta T_P\left(k_0,k'\right)$ averaged over many channels looks promising

- ? Need to obtain $\Delta T_0\left(k,k_0\right)$