ν_τ analysis

Introduction

MC data for IC86 made by Claudio. Total size of the set is 100,000 ν_τ events.

Signal filter cuts: ν_τ charge current event

τ must decay to e or hadrons
both cascades should be inside IceCube

BG filter cuts: ν_τ neutral current events

ν_τ charge current events with small track length

Use data to check offline fitter (log likelihood)
• Test double seed (two cascades) selection
• Test the fitter itself compare reconstructed results with MC truth

Seed selection

ν_τ event have two cascades, so we need 2 I3Particles as a seed for the fitter. The seeds are made by TauDPSeedMaker module. It has several modes and can make a proper 2 particle seed from any inputs.

Seed selection: MC seed – uses MC truth positions of the cascades; for NC events TauDPSeedMaker creates two overlapping cascades, one of them has energy 0

clast seed – uses clast result to find position and direction of the first cascade; TauDPSeedMaker estimates how energy is split between τ and ν interaction cascade; then τ track length is estimated and the second cascade position is found using track length and the first cascade direction

split seed – split pulse map in two, finding pulses from the first and the second cascades; use clast for each map separately to find two cascades (energies and positions); the cascade directions are set as direction of the line connecting the first cascade with the second

Map splitting

DOM

track line

projection
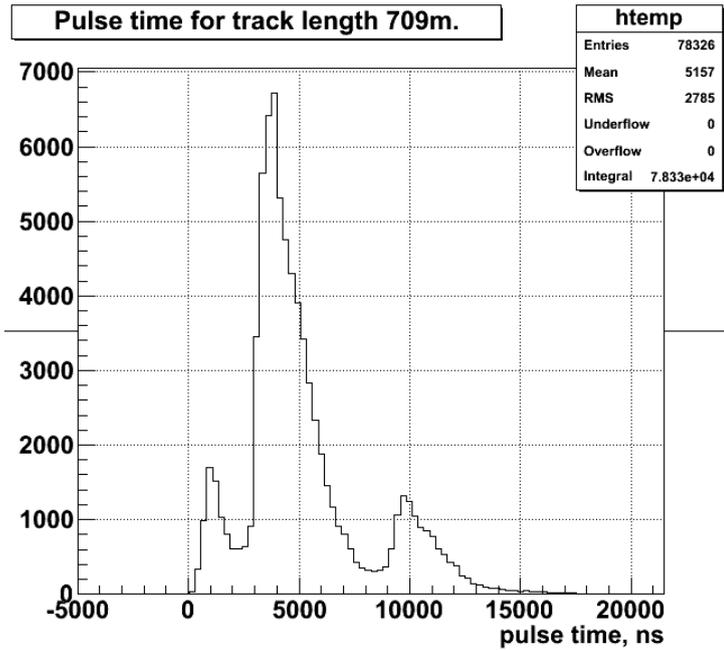
Pulse time splitting:

➢ *find start and end time of the event*

➢ *calculate split time of the event as a mean time of the event time interval*

➢ *all pulses before the split time belongs to the first cascade, all pulses after it belong to the second one*

➢ *all pulse times are shifted in such a way that the start time is 0*
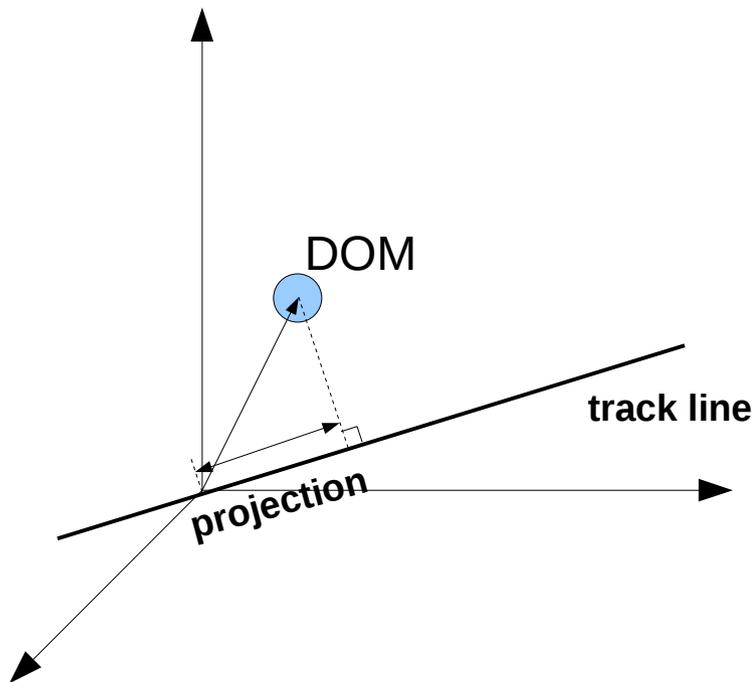
**Pulse position projection on the tau track line:**

➢ *find track line using line fit*

➢ *create projection distribution*

➢ *find the first and the last pulse projection*

➢ *calculate the middle of the projection segment*

➢ *all pulses that are projected to the first half of the segment belong to the first cascade, all pulses that are projected on the second half belong to the second cascade*

➢ *all distribution plots will be shifted that middle of the projection segment is at 0*
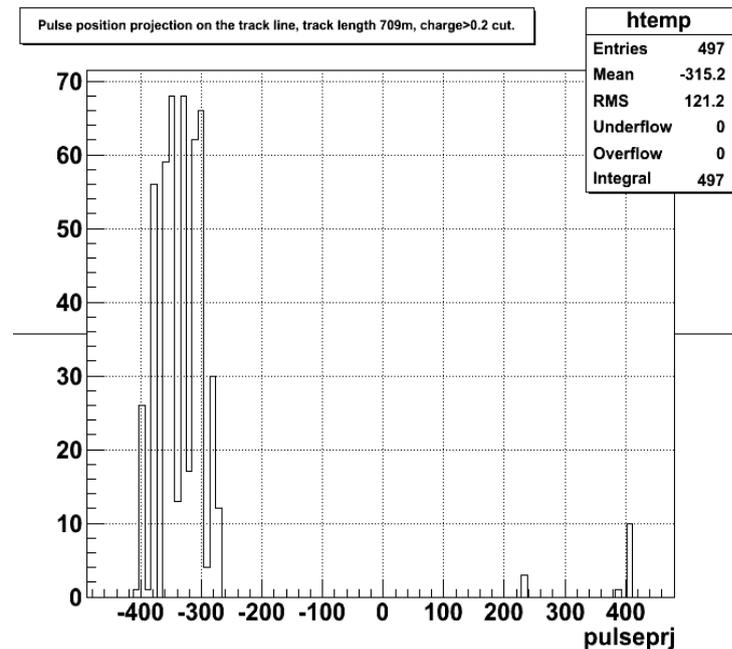
Map splitting example ($l_{\tau\,track}$=709m)
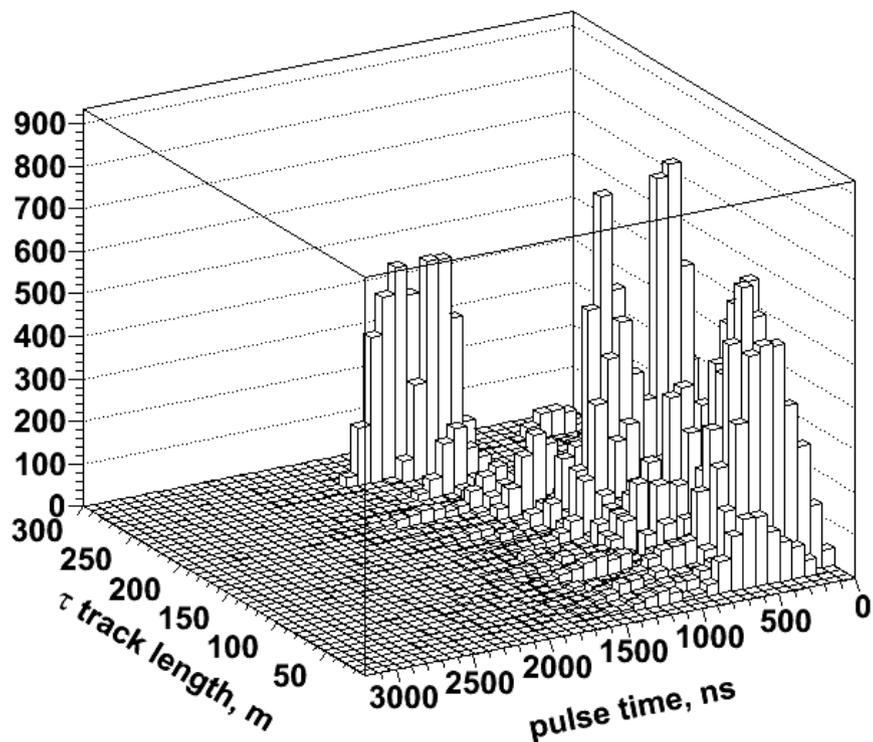

time splitting

$dt_{estim.}$=2000ns
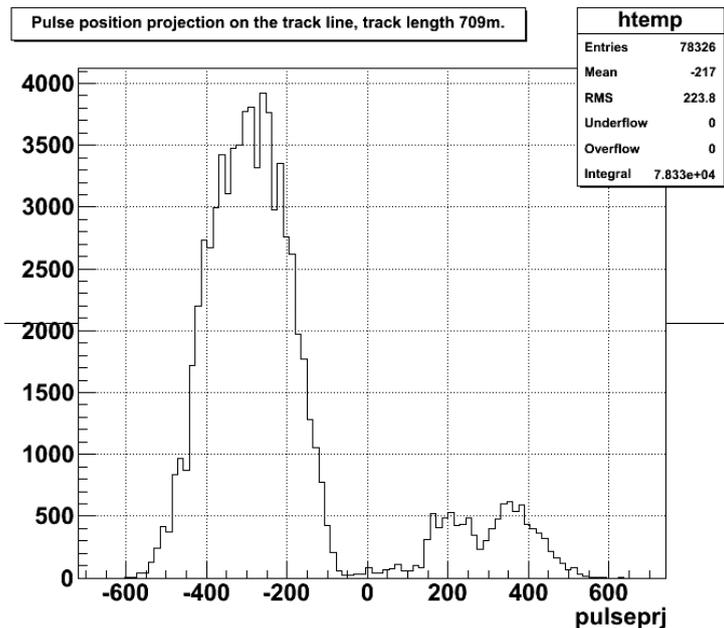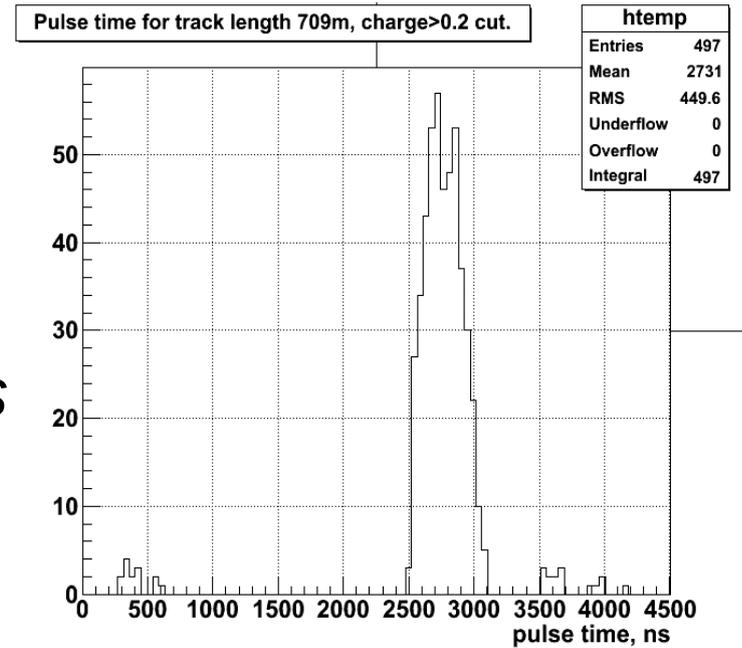
track projection splitting

Pulse time versus track length

Pulse time and MC τ track length, 30m<track<100m.

Pulse time and τ track length, track>100m.
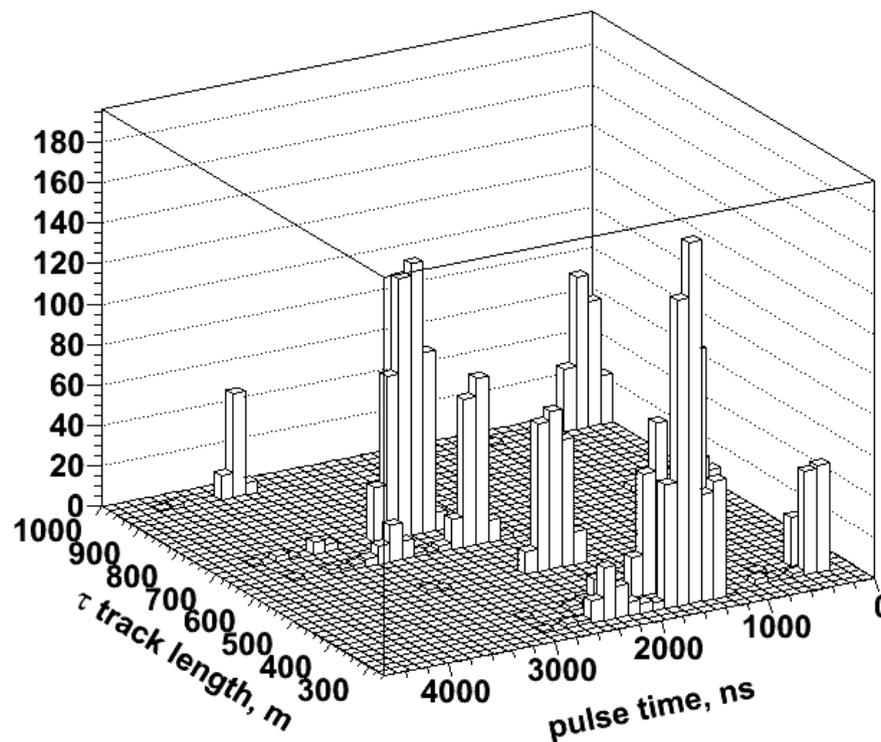
all pulses passed cut charge$_{pulse}$>0.2*charge$_{max}$.

Track projection versus track length

Pulse position projection on the track line, track lenghth<300m.

Projection of the pulse position on the track line, track length>300m.

all pulses passed cut charge$_{pulse}$>0.1*charge$_{max}$.

Map splitting conditions

Time splitting:

Make a 100 bins function ftime, each bin 100ns. Fill it with charge weighted pulse time.
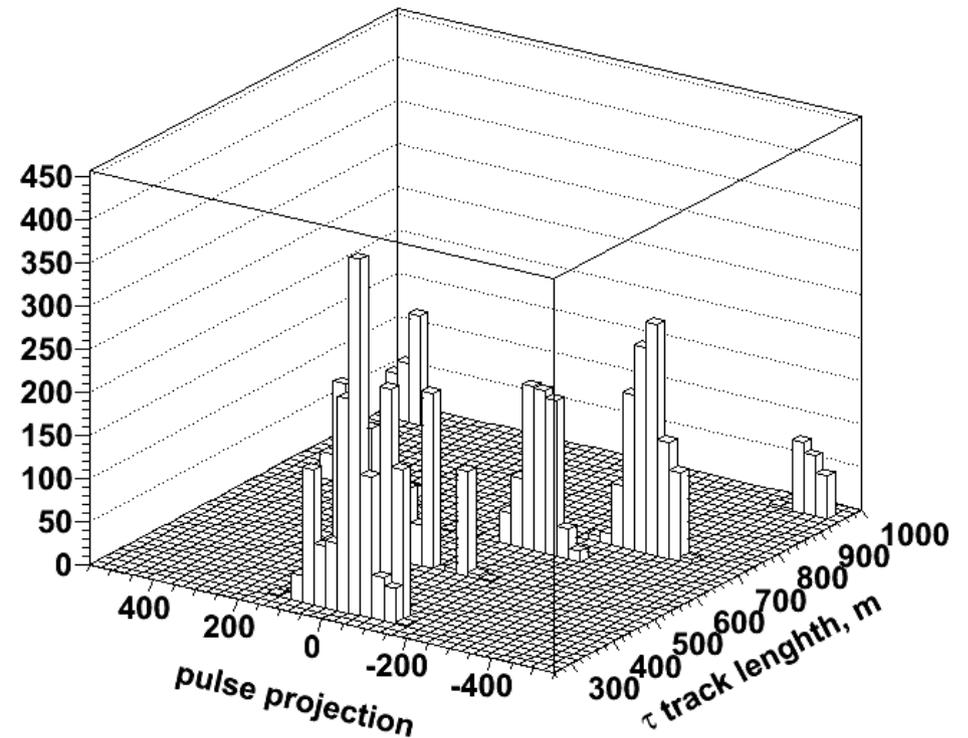

Pulse time / ftime
Entries 18356
Mean 3773
RMS 2420

unweighted pulse time, ns

Pulse time weighted by the charge / ftimew
Entries 18356
Mean 2650
RMS 1553

weighted pulse time, ns

Use ftime find event time range:

➢ ftime>5 for the first time marks start event time.

➢ ftime<1 after the start time marks end event time. If there are more peaks that are higher then 5, end time is shifted to the end of the last high enough peaks.

This example corresponds to event with L_{track}=510m, estimated time delay dt=1700ns

Track projection splitting:

Fit introduction
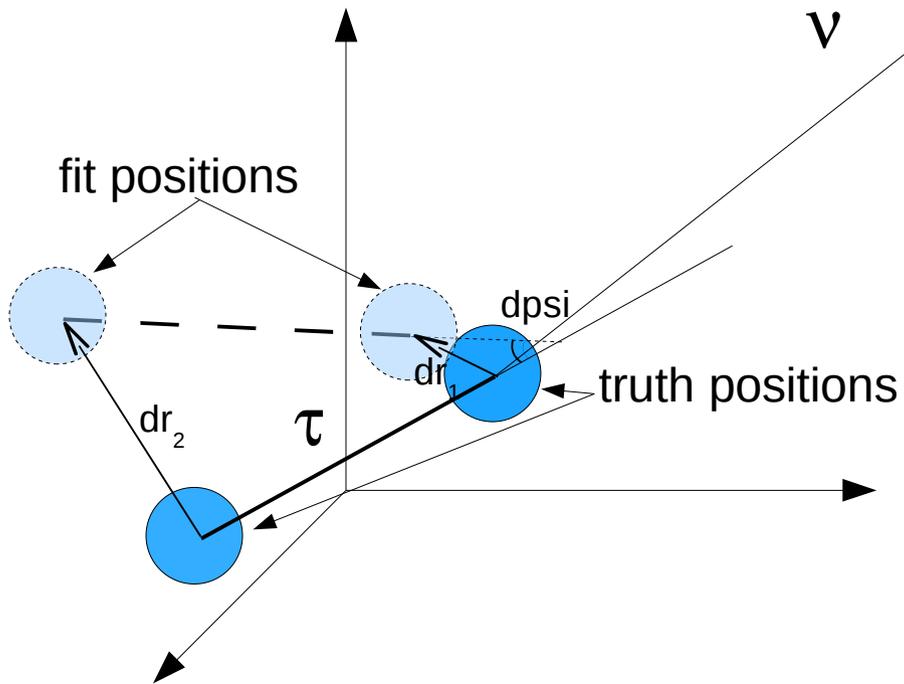
Seed and result of the double pulse fit are two particles. Transition between 2 I3Particles and fit variables is done by I3TauDPParametrization module.

Normal fit uses 7 variables:

event time, 3 coordinates, 2 direction angles and energy.

Double pulse fit needs 9 variables:

the first cascade time and its 3 coordinates, 2 direction angles (the same for both cascades), $\log_{10}$ of total energy, $\log_{10}(E1/E2)$ and distance between cascades (track length).

Time difference

Event time difference-track length, mc seed

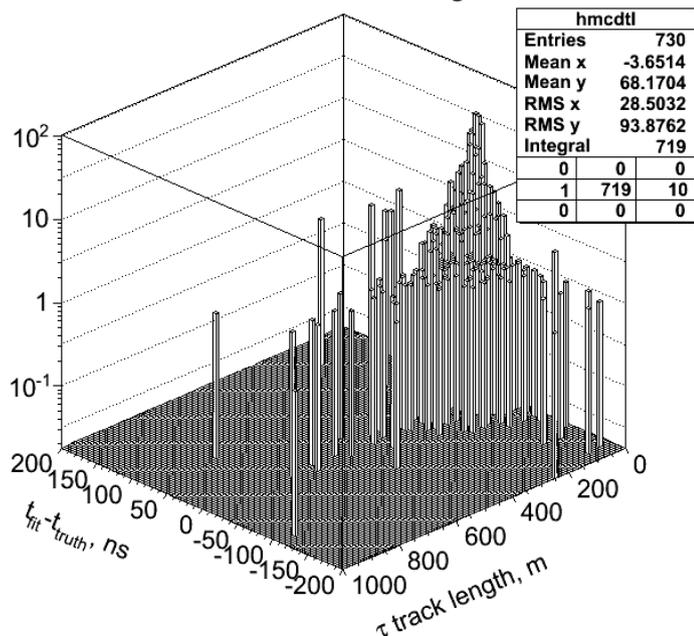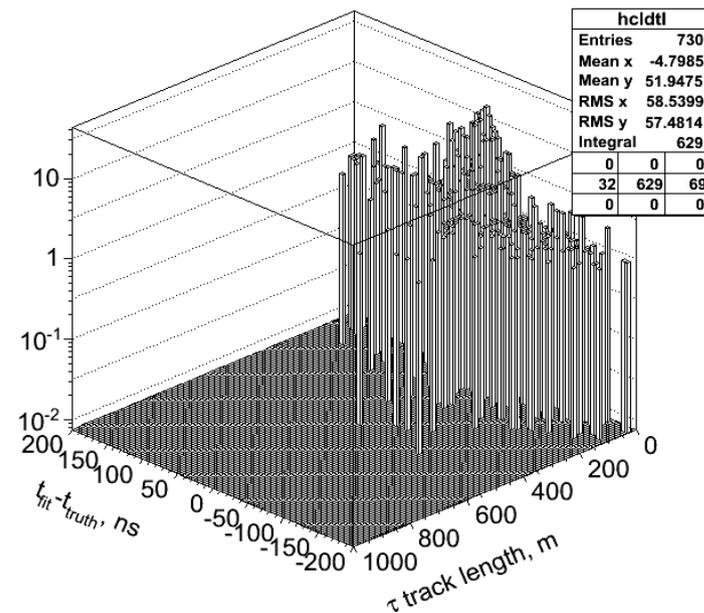| hmcdtl		
Entries		730
Mean x		-3.6514
Mean y		68.1704
RMS x		28.5032
RMS y		93.8762
Integral		719
0	0	0
1	719	10
0	0	0

Event time difference-track length, clast seed

hcldtl		
Entries		730
Mean x		-4.7985
Mean y		51.9475
RMS x		58.5399
RMS y		57.4814
Integral		629
0	0	0
32	629	69
0	0	0

x-axis is time difference
y-axis is track length
$L_{track} > 10m$

Event time difference-track length, time split seed

hspldtl		
Entries		535
Mean x		7.8343
Mean y		52.7125
RMS x		52.0826
RMS y		73.3863
Integral		475
0	0	0
5	475	55
0	0	0
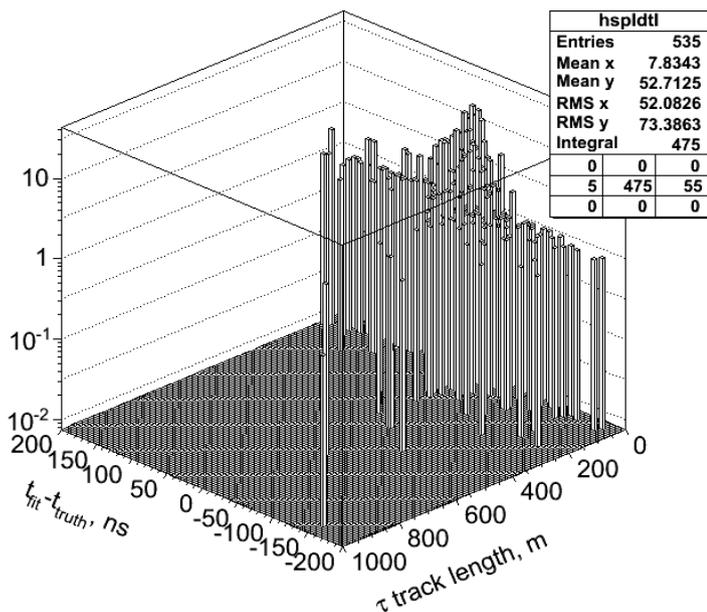
Event time difference-track length, track split seed

hprjdtl		
Entries		535
Mean x		7.8343
Mean y		52.7125
RMS x		52.0826
RMS y		73.3863
Integral		475
0	0	0
5	475	55
0	0	0
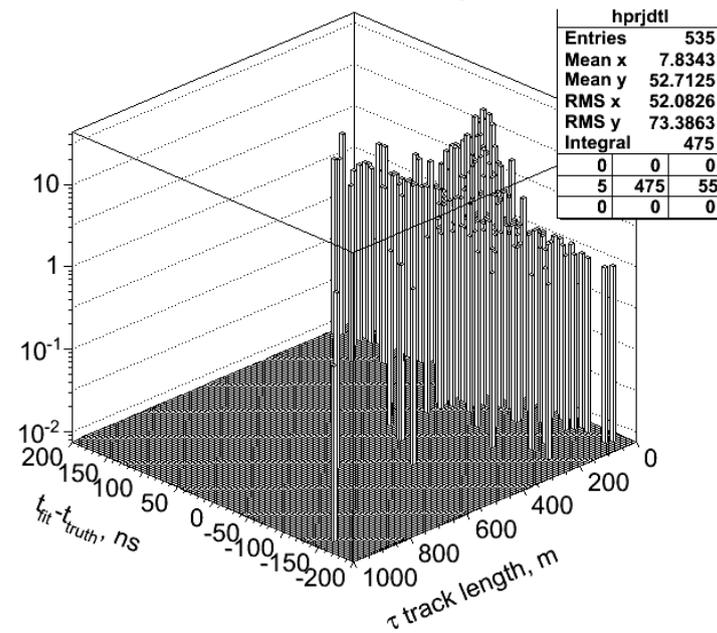
Position difference, first cascade

Distance-track length, mc seed

hmcdrl		
Entries		730
Mean x		9.6314
Mean y		68.2717
RMS x		13.0580
RMS y		93.4562
Integral		726

0	0	0
0	726	4
0	0	0

Distance-track length, clast seed

hcldrl		
Entries		730
Mean x		30.4731
Mean y		55.2814
RMS x		31.9338
RMS y		58.4829
Integral		682

0	0	0
0	682	48
0	0	0
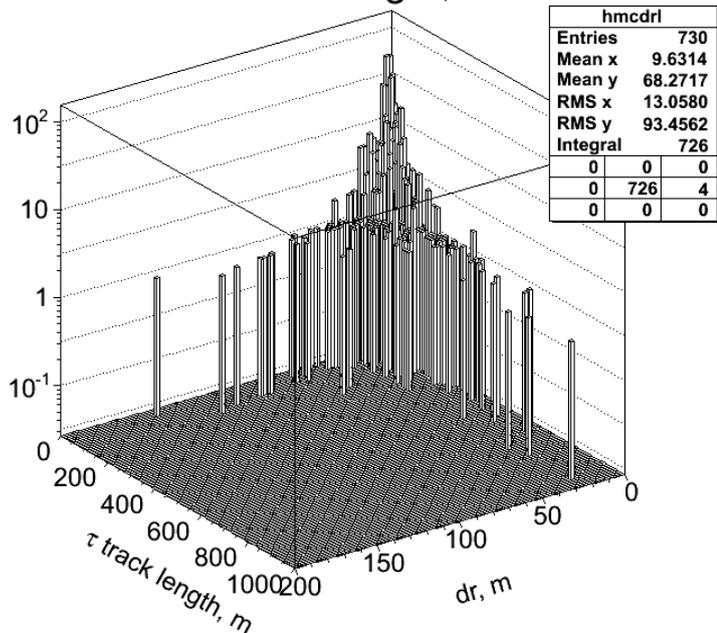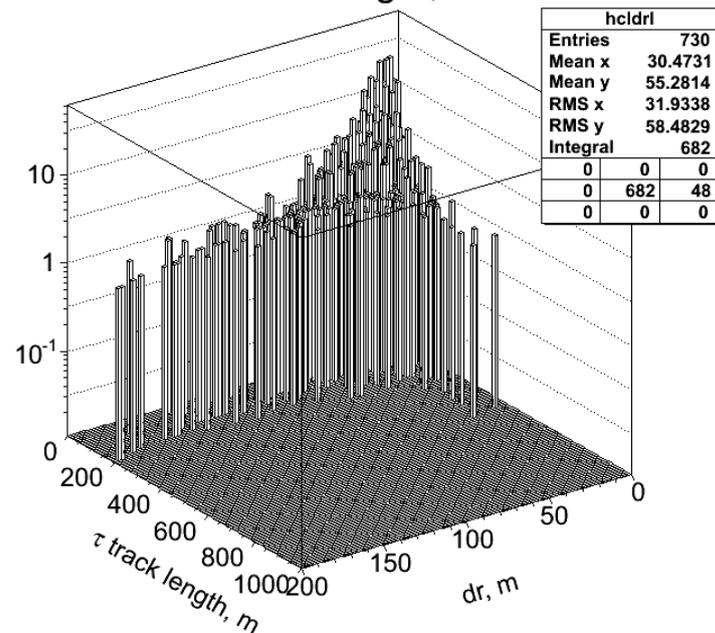
x-axis is position difference
y-axis is track length

Distance-track length, time split seed

hspldrl		
Entries		535
Mean x		26.7426
Mean y		57.2747
RMS x		32.3110
RMS y		73.9327
Integral		510

0	0	0
0	510	25
0	0	0

Distance-track length, track projection split seed

hprjdrl		
Entries		700
Mean x		28.5256
Mean y		57.7743
RMS x		31.7044
RMS y		71.6469
Integral		658

0	0	0
0	658	42
0	0	0
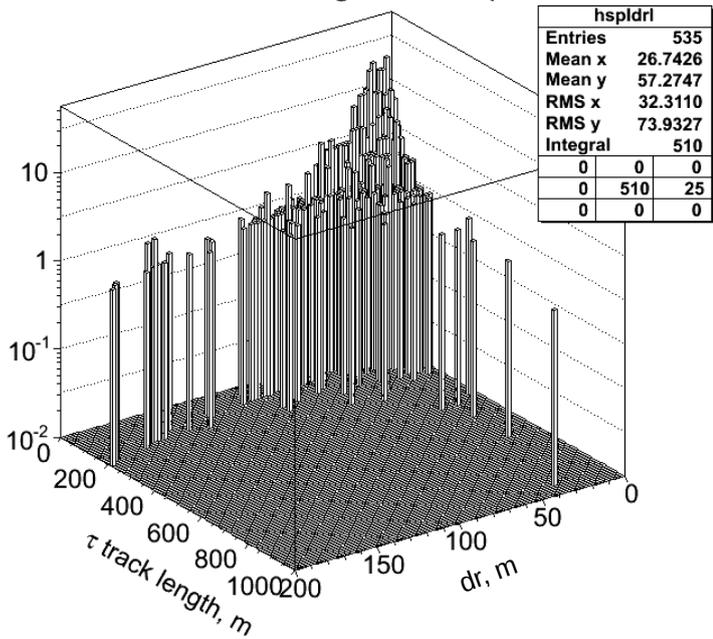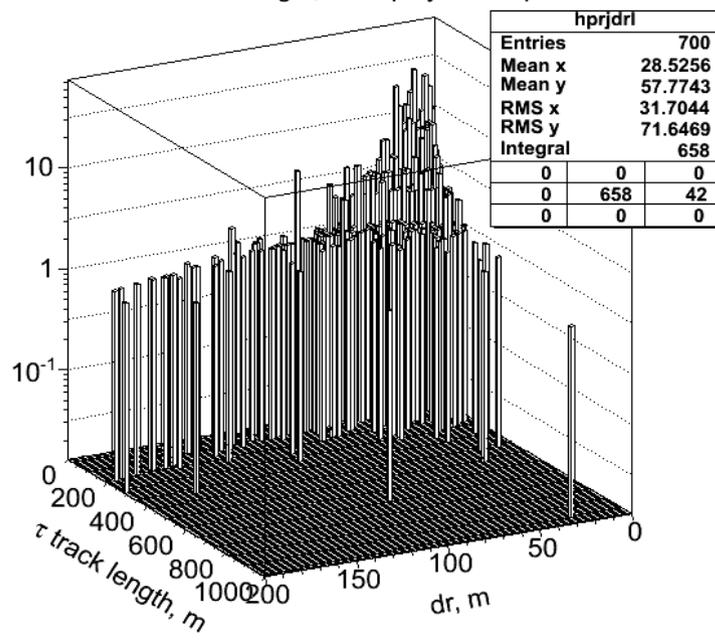
Position difference, second cascade

Distance-track length, mc seed
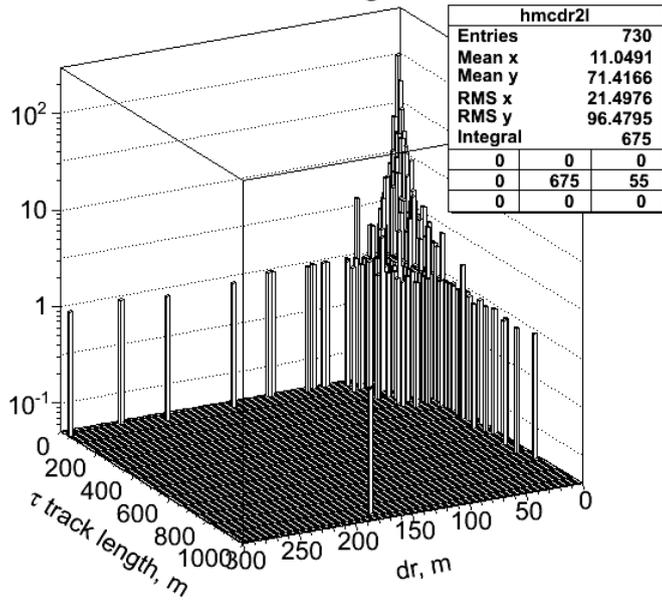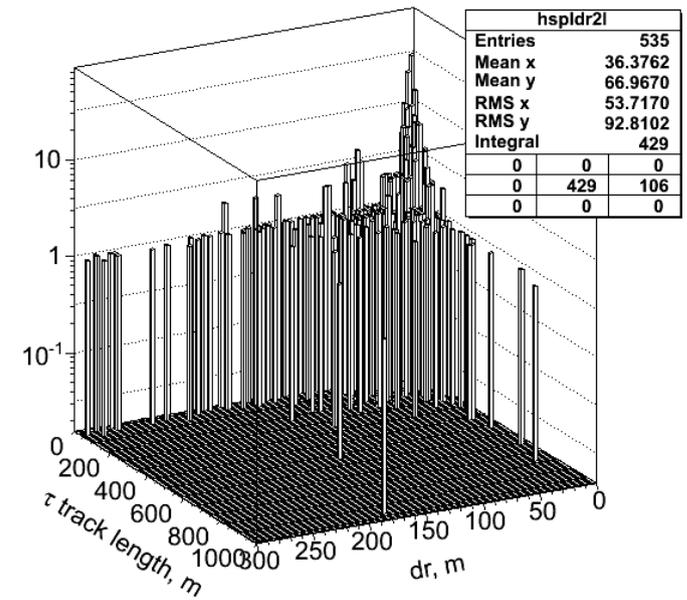
hmcdr2l		
Entries		730
Mean x		11.0491
Mean y		71.4166
RMS x		21.4976
RMS y		96.4795
Integral		675
0	0	0
0	675	55
0	0	0

Distance-track length, time split seed

hspldr2l		
Entries		535
Mean x		36.3762
Mean y		66.9670
RMS x		53.7170
RMS y		92.8102
Integral		429
0	0	0
0	429	106
0	0	0

Distance-track length, clast seed

hcldr2l		
Entries		730
Mean x		36.0654
Mean y		67.7993
RMS x		53.5285
RMS y		83.6297
Integral		475
0	0	0
0	475	255
0	0	0
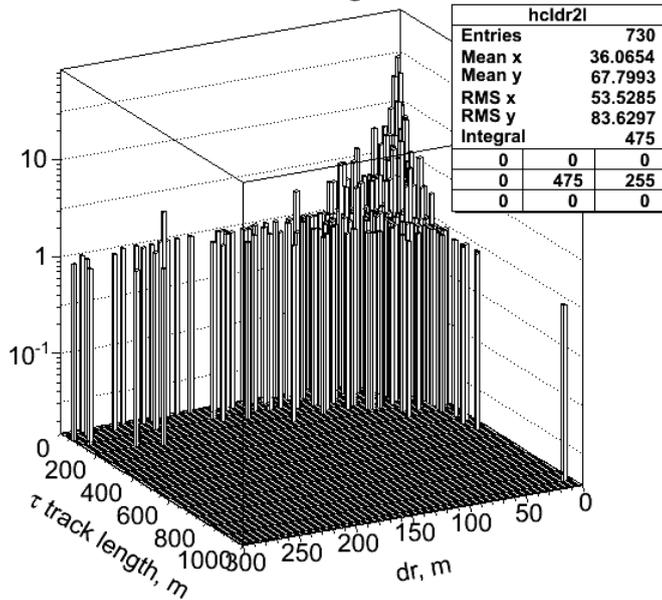
x-axis is position difference
y-axis is track length
$L_{track} > 10$m
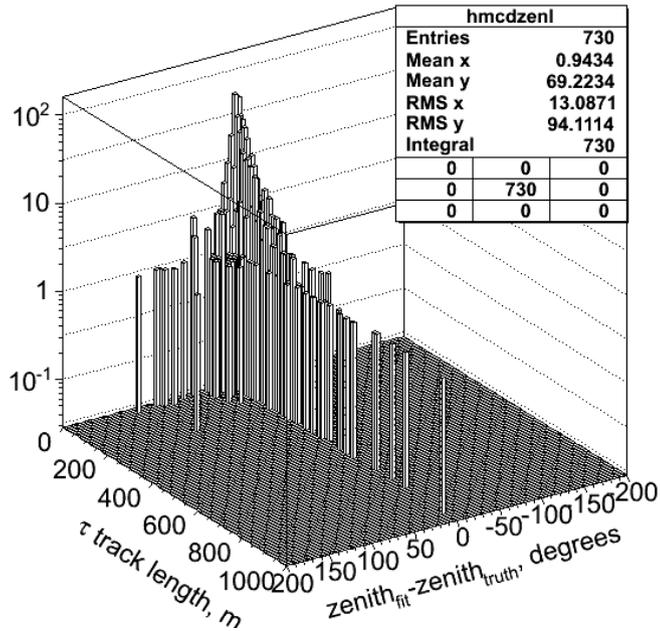
Distance-track length, track projection split seed

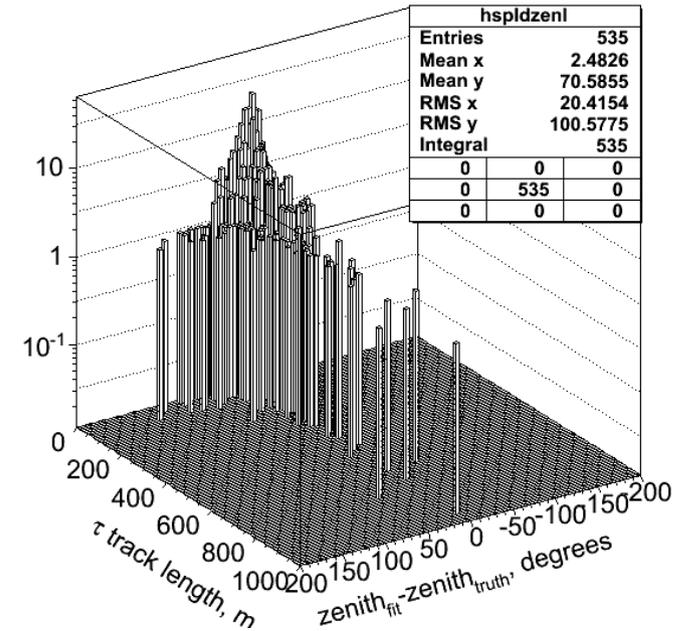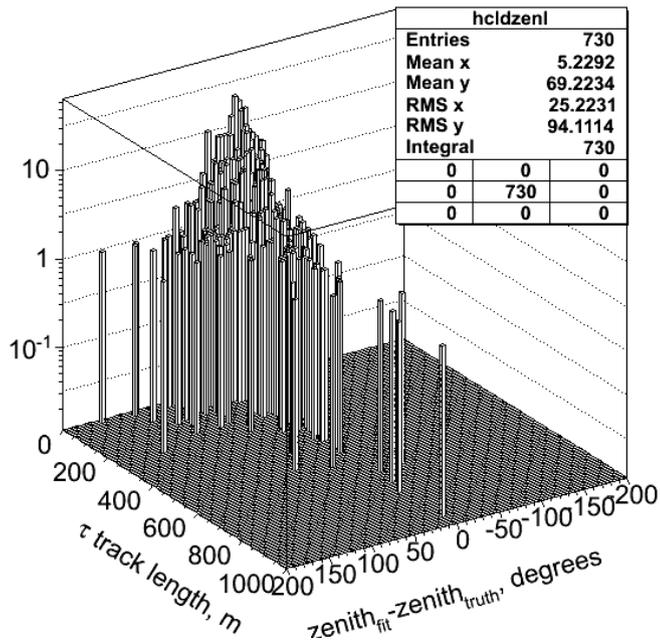| hprjdr2l		
Entries		700
Mean x		37.8416
Mean y		70.4704
RMS x		53.2474
RMS y		85.6514
Integral		512
0	0	0
0	512	188
0	0	0
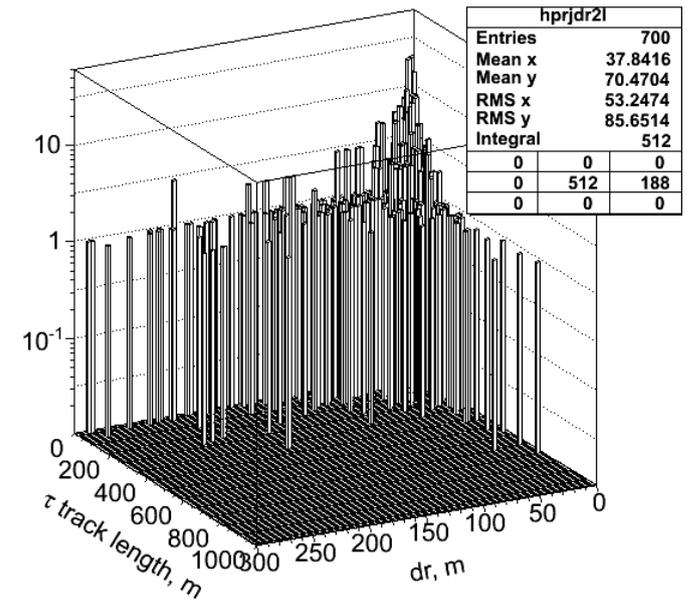
Zenith difference

Zenith difference-track length, mc seed

hmcdzenl		
Entries		730
Mean x		0.9434
Mean y		69.2234
RMS x		13.0871
RMS y		94.1114
Integral		730
0	0	0
0	730	0
0	0	0

Zenith difference-track length, time split seed

hspldzenl		
Entries		535
Mean x		2.4826
Mean y		70.5855
RMS x		20.4154
RMS y		100.5775
Integral		535
0	0	0
0	535	0
0	0	0

x-axis is zenith difference
y-axis is track length
L_{track}>10m

Zenith difference-track length, clast seed

hcldzenl		
Entries		730
Mean x		5.2292
Mean y		69.2234
RMS x		25.2231
RMS y		94.1114
Integral		730
0	0	0
0	730	0
0	0	0

Zenith difference-track length, track projection split seed

hprjdzenl		
Entries		700
Mean x		4.4267
Mean y		67.7943
RMS x		27.0585
RMS y		93.2155
Integral		700
0	0	0
0	700	0
0	0	0
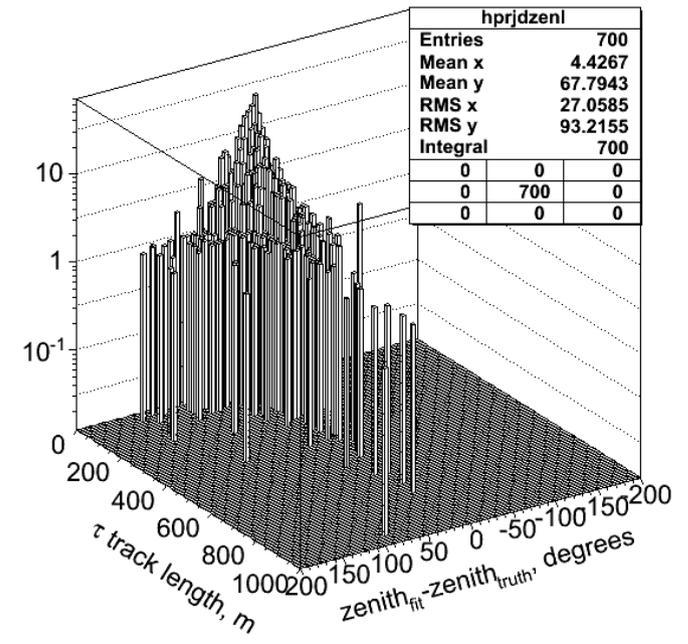
Azimuth difference

Azimuth difference-track length, mc seed

hmcdazl		
Entries		730
Mean x		0.8038
Mean y		69.2234
RMS x		61.6384
RMS y		94.1114
Integral		730
0	0	0
0	730	0
0	0	0

Azimuth difference-track length, time split seed

hspldazl		
Entries		535
Mean x		-2.9400
Mean y		70.5855
RMS x		93.3740
RMS y		100.5775
Integral		535
0	0	0
0	535	0
0	0	0
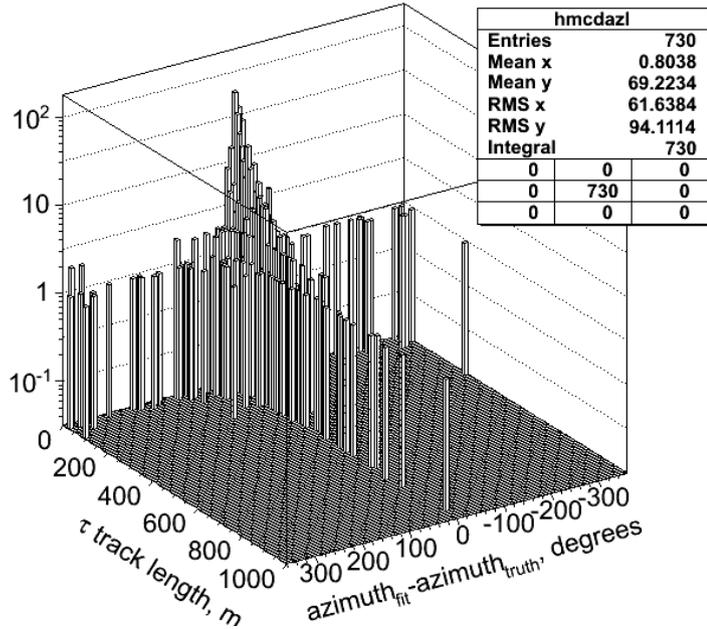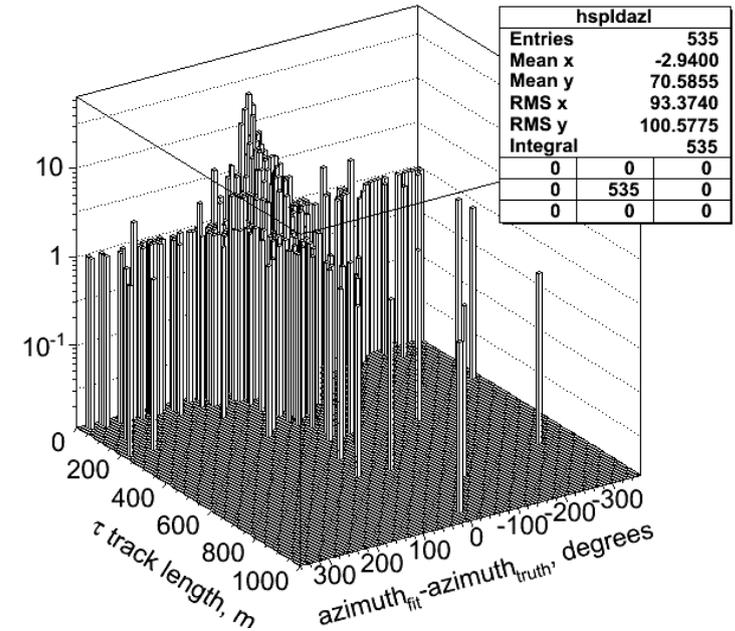
x-axis is azimuth difference
y-axis is track length
$L_{track} > 10m$

Azimuth difference-track length, clast seed

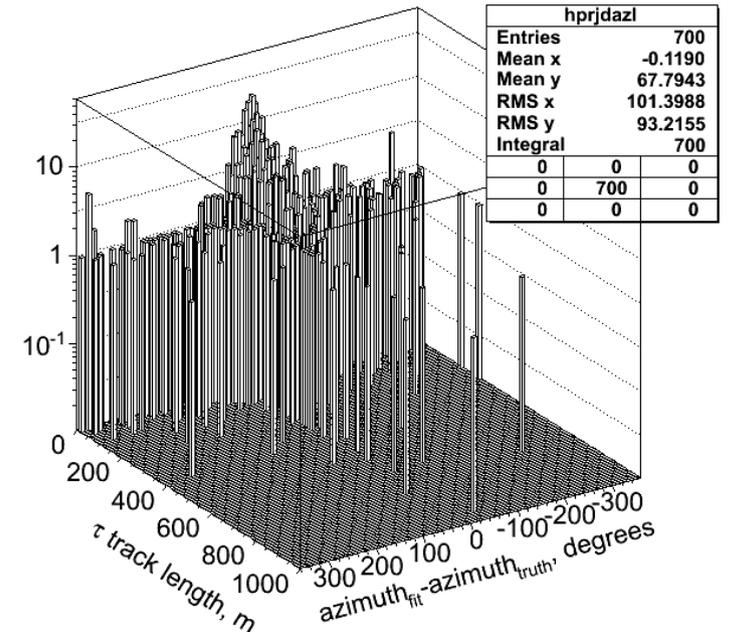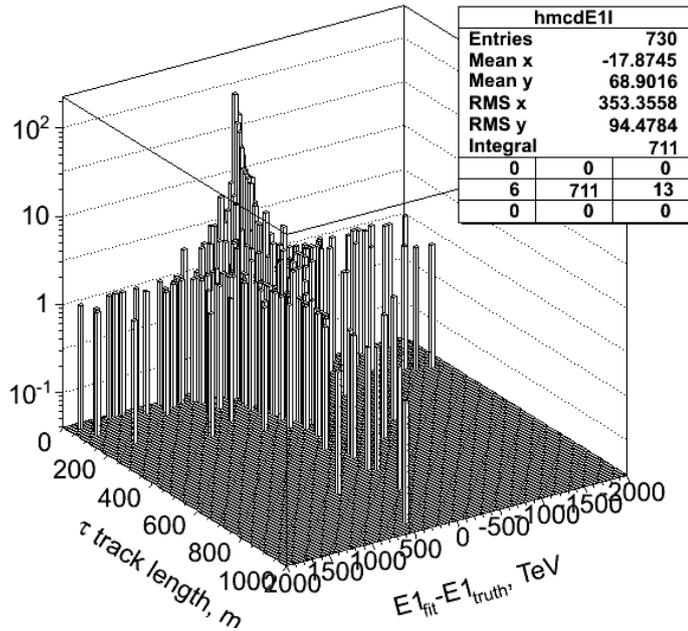| hcldazl		
Entries		730
Mean x		2.8606
Mean y		69.2234
RMS x		106.2293
RMS y		94.1114
Integral		730
0	0	0
0	730	0
0	0	0

Azimuth difference-track length, track projection split seed

hprjdazl		
Entries		700
Mean x		-0.1190
Mean y		67.7943
RMS x		101.3988
RMS y		93.2155
Integral		700
0	0	0
0	700	0
0	0	0

Energy difference

Energy difference for the first particle-track length, mc seed

hmcdE1l	
Entries	730
Mean x	-17.8745
Mean y	68.9016
RMS x	353.3558
RMS y	94.4784
Integral	711

0	0	0
6	711	13
0	0	0

Energy difference for the first particle-track length, time split seed

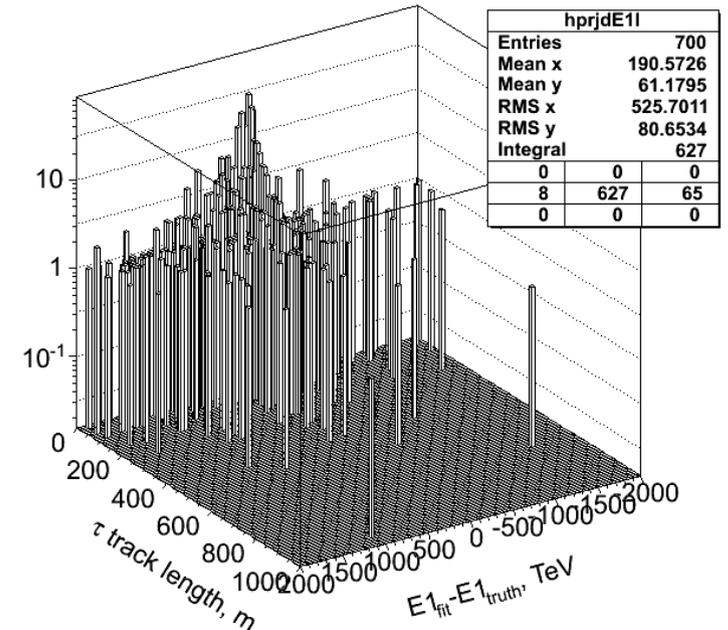| hspldE1l	
Entries	535
Mean x	223.8872
Mean y	66.1121
RMS x	500.1927
RMS y	95.1094
Integral	491

0	0	0
7	491	37
0	0	0

x-axis is energy difference
y-axis is track length
$L_{track} > 10m$

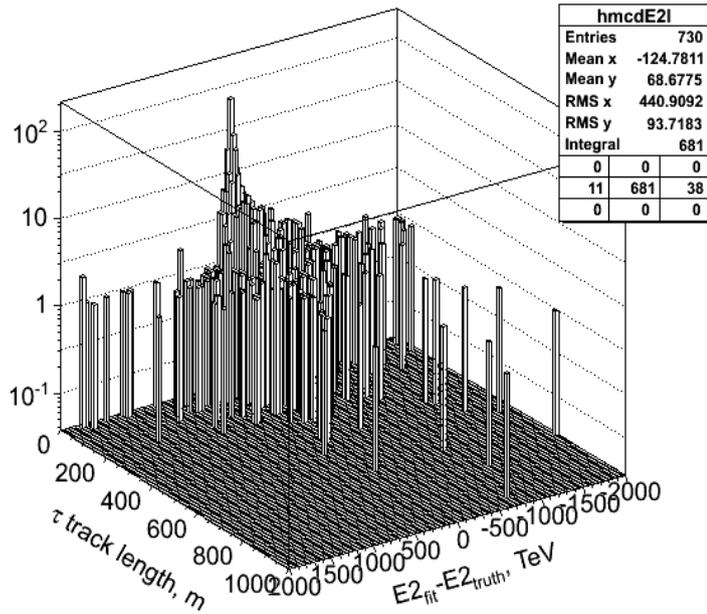Energy difference for the first particle-track length, clast seed

hcldE1l	
Entries	730
Mean x	271.6816
Mean y	63.5718
RMS x	560.2599
RMS y	85.1442
Integral	662

0	0	0
6	662	62
0	0	0

Energy difference for the first particle-track length, track projection split seed

hprjdE1l	
Entries	700
Mean x	190.5726
Mean y	61.1795
RMS x	525.7011
RMS y	80.6534
Integral	627

0	0	0
8	627	65
0	0	0

Energy difference

Energy difference for the second particle-track length, mc seed

hmcdE2l	
Entries	730
Mean x	-124.7811
Mean y	68.6775
RMS x	440.9092
RMS y	93.7183
Integral	681

0	0	0
11	681	38
0	0	0

Energy difference for the second particle-track length, time split seed

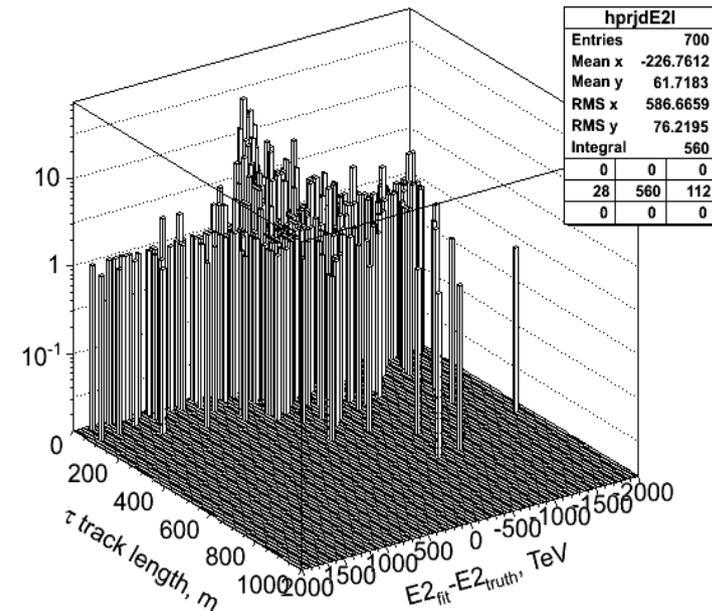| hspldE2l	
Entries	535
Mean x	-218.0241
Mean y	61.4994
RMS x	511.5098
RMS y	87.3143
Integral	450

0	0	0
27	450	58
0	0	0

x-axis is energy difference
y-axis is track length
L_{track} >10m

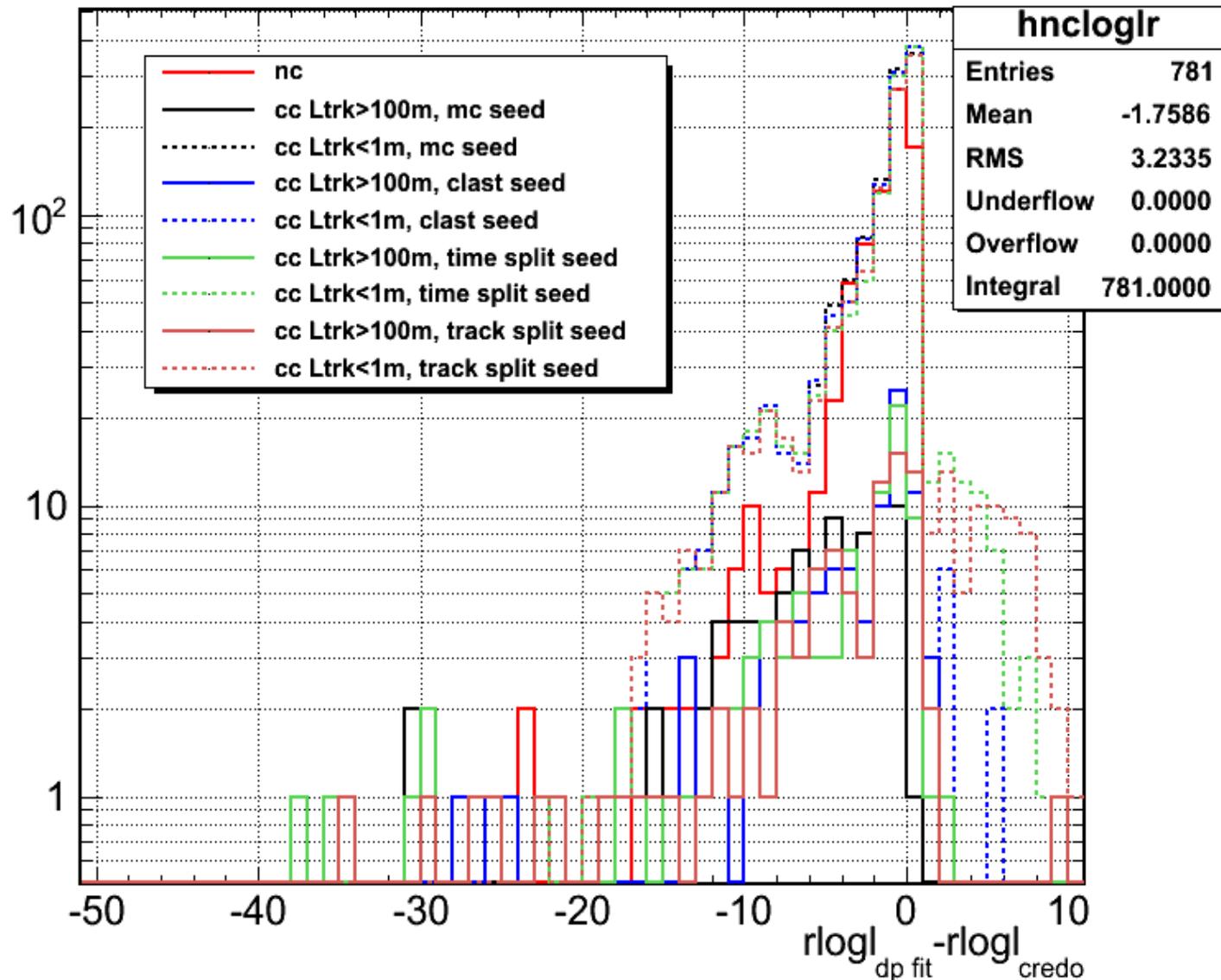Energy difference for the second particle-track length, clast seed

hcldE2l	
Entries	730
Mean x	-139.9900
Mean y	64.3244
RMS x	588.4436
RMS y	81.8200
Integral	507

0	0	0
18	507	205
0	0	0

Energy difference for the second particle-track length, track projection split seed

hprjdE2l	
Entries	700
Mean x	-226.7612
Mean y	61.7183
RMS x	586.6659
RMS y	76.2195
Integral	560

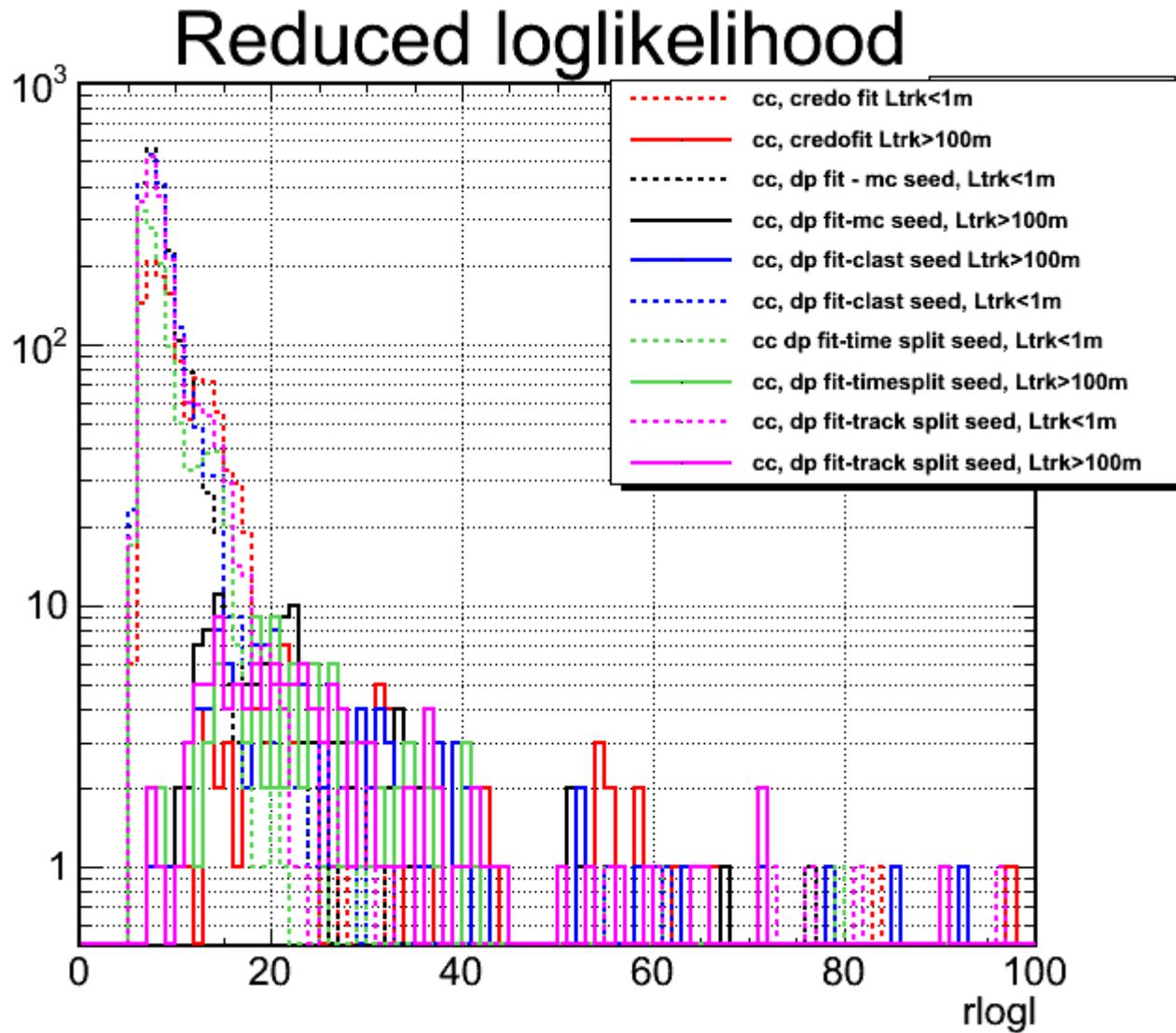| 0	0	0
28	560	112
0	0	0

Reduced loglikelihood distributions

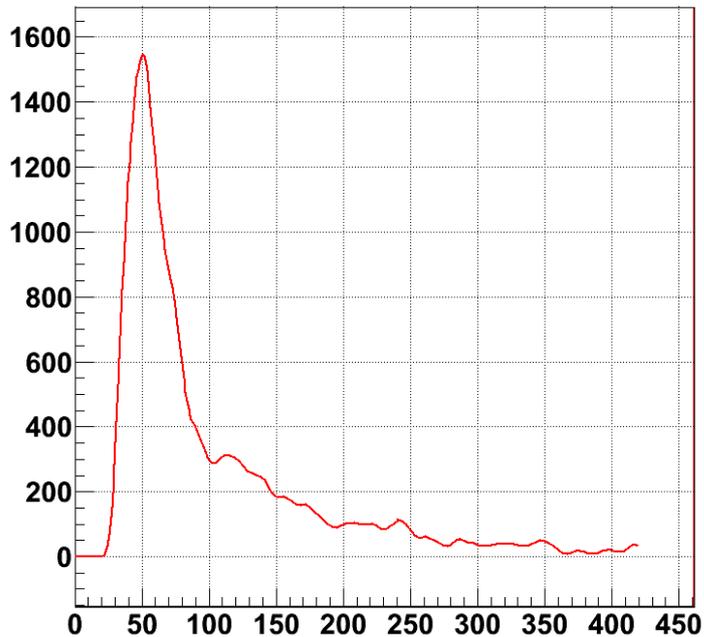Ratio of the loglikelihood between mcfit and credofit

Reduced loglikelihood distributions


Reduced loglikelihood

Type 2 waveforms

Normal IceCube waveform has one peak at the start of the event.

In case of charged current ν_τ event two cascades are produced. In this case double pulse waveform might be made when light from both cascades is detected in one waveform time window.

If one of the pulses is brighter then the other, type 2 waveform can be produced. In this case a low pulse starts the waveform and a bright pulse arrives later, producing a waveform that has maximum later then normal.
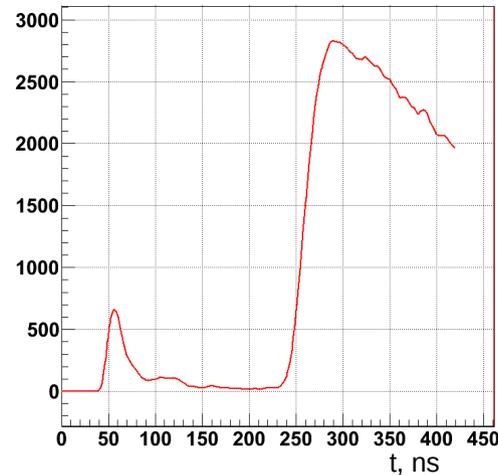

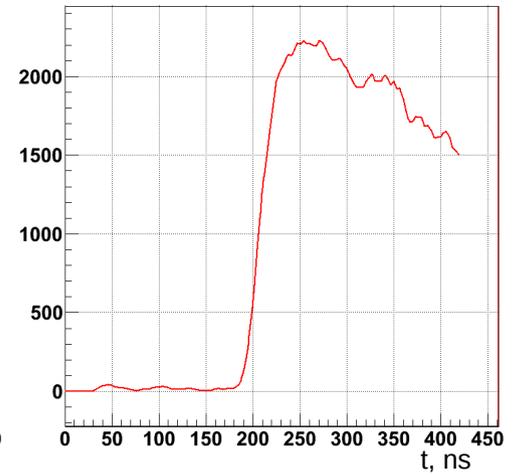Type 2 wfm example, track length 61m.
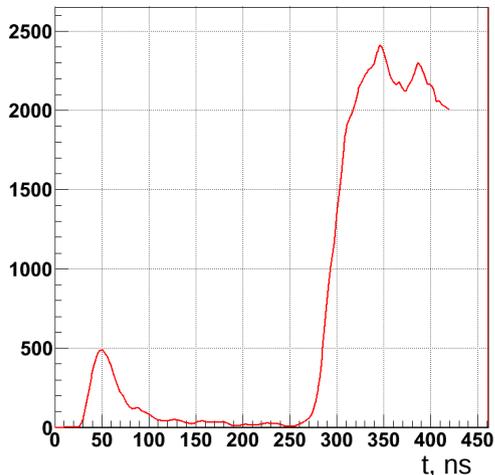
Type 2 wfm example, track length 61m.
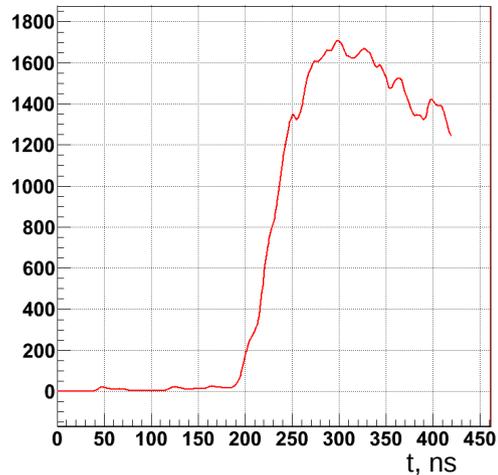
Type 2 wfm example, track length 636m.

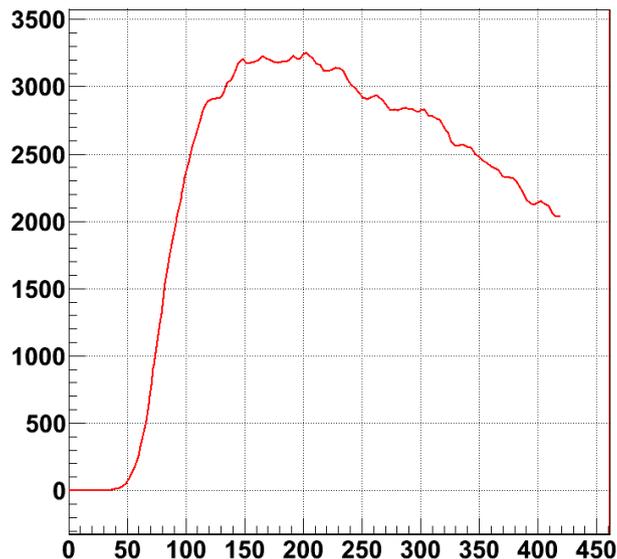Type 2 wfm example, track length 636m.

Type 2 waveforms

Type 2 waveform selection:

➢ waveform maximum should be after 198 ns
➢ maximum itself should be higher then 1000 mV

  Type 2 waveforms can be produced by neutral current events as well, but there is much less of them and they look different.
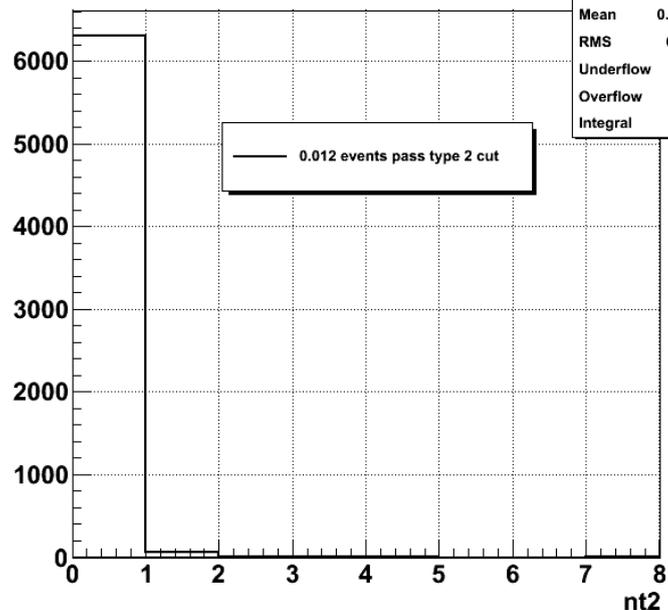 Large amount of low charge noise waveforms is cut down by the maximum cut
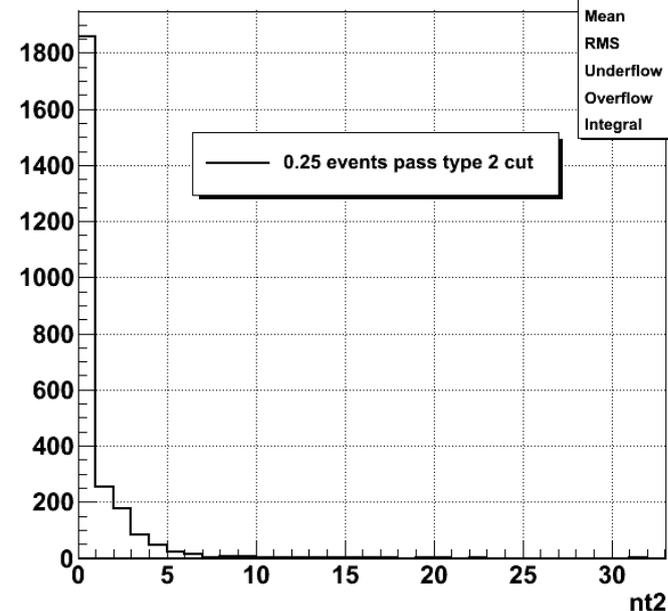
Type 2 wfm example, nc events.
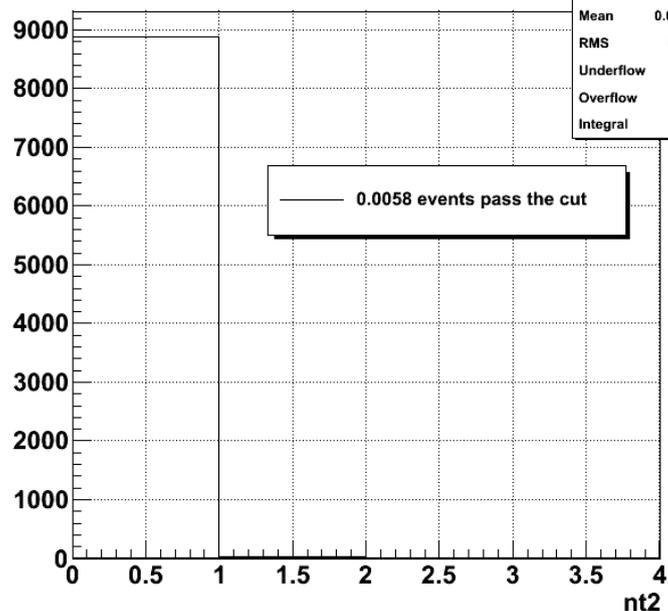
Type 2 cut

Number of type 2 wfms for nc events

htemp	
Entries	6378
Mean	0.01646
RMS	0.1829
Underflow	0
Overflow	0
Integral	6378

0.012 events pass type 2 cut

nt2

Number of type 2 wfms for medium traks (10m <trkL< 300m)

htemp	
Entries	2482
Mean	0.6471
RMS	1.785
Underflow	0
Overflow	0
Integral	2482

0.25 events pass type 2 cut

nt2

Type 2 cut means that event has at least one type 2 waveform

Number of type 2 wfms for short track (<10m) events

htemp	
Entries	8928
Mean	0.008513
RMS	0.1204
Underflow	0
Overflow	0
Integral	8928

0.0058 events pass the cut

nt2

Number of type 2 wfms for long tracks (>300m)

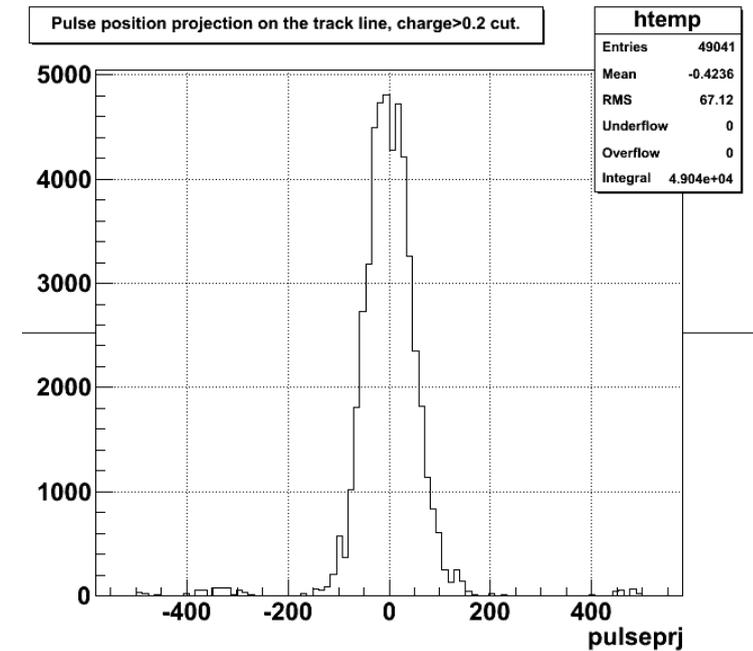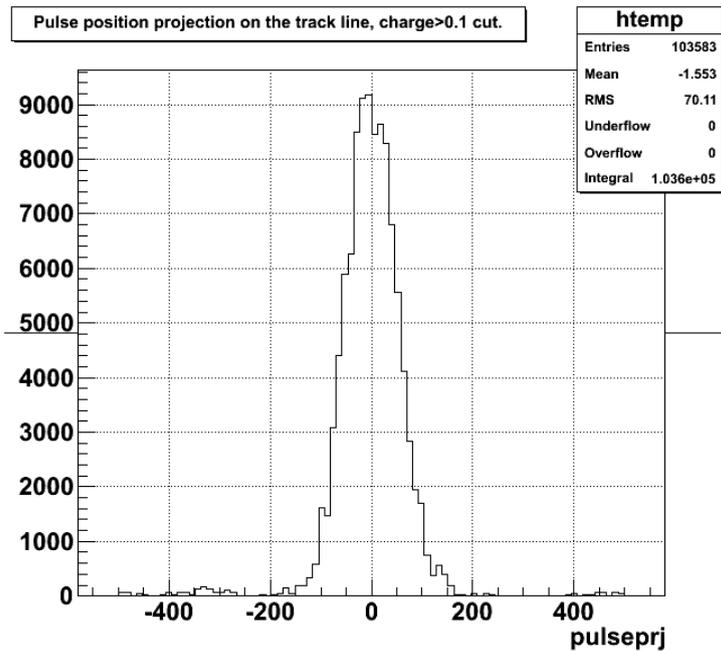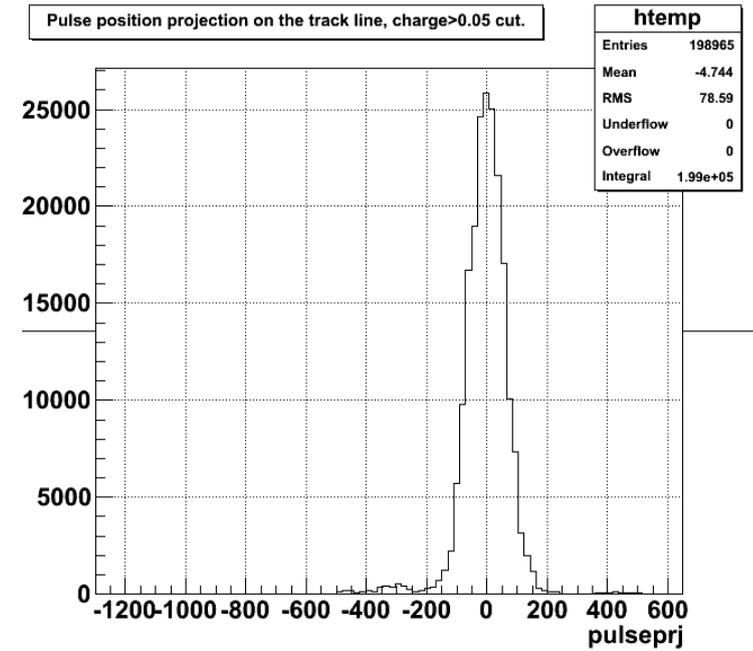| htemp	
Entries	95
Mean	2.126
RMS	2.502
Underflow	0
Overflow	0
Integral	95

0.69 events pass type 2 cut

nt2
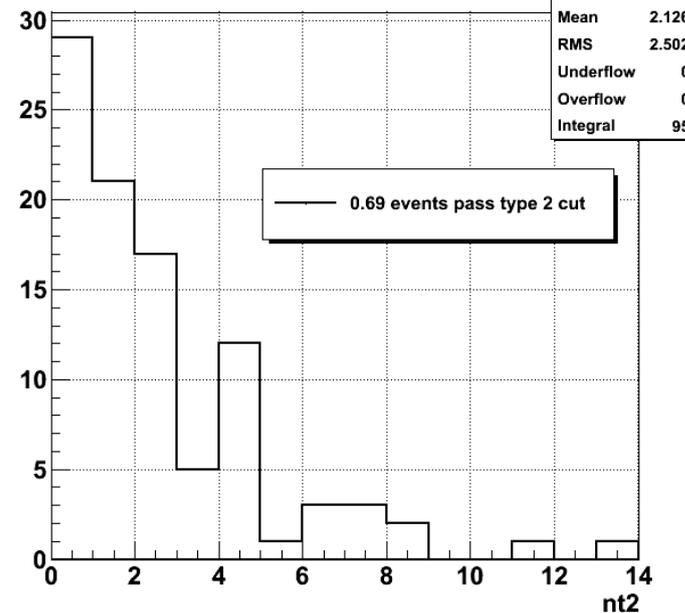
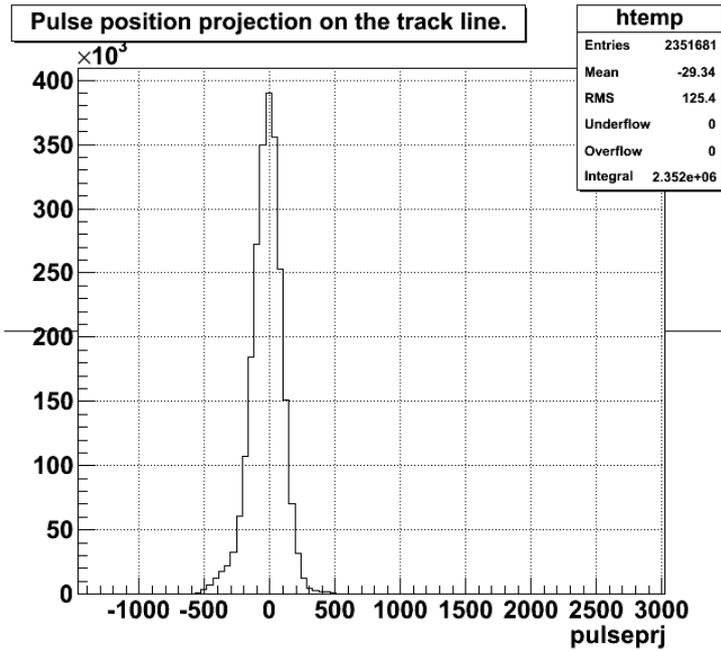# Summary and conclusions

- ➢ fit seeded with split seeds produces slightly better results
- ➢ both seed splitting methods produce very similar results
- ➢ Loglikelihood distributions are not very different for double pulse fit and credo fit

- ➢ Type 2 waveform cut provides a good discriminating power but not very good efficiency.

Backup

Position projection for all tracks ($I_{\tau\ track} > 30m$)

Pulse time for all tracks (l$_{\tau \, track}$> 30m)

Pulse time.

htemp	
Entries	2351681
Mean	3275
RMS	2838
Underflow	0
Overflow	0
Integral	2.352e+06

Pulse time, charge>0.05 cut.

htemp	
Entries	198965
Mean	1084
RMS	809.1
Underflow	0
Overflow	0
Integral	1.99e+05

Pulse time, charge>0.1 cut.

htemp	
Entries	103583
Mean	886.5
RMS	591.7
Underflow	0
Overflow	0
Integral	1.036e+05

Pulse time, charge>0.2 cut.

htemp	
Entries	49041
Mean	765.8
RMS	497.5
Underflow	0
Overflow	0
Integral	4.904e+04