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TIME RESOLUTION AND TDC PERFORMANCE

Tex file in ~ser/coherent_photon_beam/daq/tdc_resolution.tex

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Abstract

I have studied the time resolution we can obtain for a track using various assumptions about TDC performance and time resolution of the pulse at the output of the discriminator.

DEFINITIONS

The TIME RESOLUTION of the TDC is in units of the least significant bit (LSB). e.g. the LRS3377 can be in modes corresponding to LSB of .5, or 1., or 2., or 4. ns. Statistically this implies a sigma of LSB/$\sqrt{12}$.

The PULSE RESOLUTION is the jitter on the logic pulse coming out of the discriminator in units of standard deviations. This is caused by time slewing, phototube performance, scintallator performance etc.

TDC MODEL

I have assumed that 1)the clock on the TDC is free running so that the start can come anywhere within the time bucket of the LSB (e.g. .5ns) and the stop can come at another random time within a latter time bucket. This leads to a 250ps sigma for the time difference between start and stop, in agreement with the LRS manuel for typical performance.

2) A track has N hits (on different planes). I have assumed a worse case that each of the N hits is in a different TDC and the time variations due to randomness within the time buckets(see number 1) are uncorrelated between TDCs.

SUMMARY OF RESULTS

Table 1. is a summary of the results for selected values of TDC Least Significant Bit and Pulse Resolution for 1 hit and for 5 hits on a track. The full listing of results are in the next section.

A TDC LSB of 0.5ns is significantly better than 1.0ns at Pulse Resolutions up to and including 0.4ns. The loss of time resolutin is approximately 50% at 1ns. With 5 hits/track we can probably achieve a time resolution for a track of $\pm$ 0.20 ns.

TDC LSB	PULSE RESOLUTION sigma(ns)	NUMBER OF HITS per Track	TIME RESOLUTION sigma (ns)
.5	.2	1	.32
.5	.3	1	.39s
.5	.4	1	.47
1.0	.2	1	.54
1.0	.3	1	.59
1.0	.4	1	.65
.5	.2	5	.15
.5	.3	5	.18
.5	.4	5	.21
1.0	.2	5	.24
1.0	.3	5	.26
1.0	.4	5	.29

Table 1: Table 1. Summary of Time resolution dependence on TDC LSB (Least Significant Bit), Pulse Resolution(sigma) and number of hits on a track.

TABLES OF RESULTS

TDC TIME RESOLUTION PERFORMANCE FROM ser/coherent_photon_beam/daq/time_resolution.cc
Assume TDC start time is random within tdc resolution

TDC RESOLUTION(bin size)n= 0.5; PULSE RESOLUTION(sigma)=0.00
BIN POPULTION

0	1	2	3	4	5	6
0.000	0.000	0.502	0.498	0.000	0.000	0.000

Hits on track	Average time
1	1.248+/-0.250
2	1.248+/-0.176
3	1.248+/-0.142
4	1.249+/-0.124
5	1.249+/-0.112

TDC RESOLUTION(bin size)n= 0.5; PULSE RESOLUTION(sigma)=0.10
BIN POPULTION

0	1	2	3	4	5	6
0.000	0.009	0.492	0.489	0.009	0.000	0.000

Hits on track	Average time
1	1.248+/-0.269
2	1.250+/-0.190
3	1.249+/-0.154
4	1.248+/-0.134
5	1.249+/-0.121

TDC RESOLUTION(bin size)n= 0.5; PULSE RESOLUTION(sigma)=0.20

BIN POPULTION

	0	1	2	3	4	5	6
	0.000	0.042	0.460	0.459	0.039	0.000	0.000

Hits on track	Average time
1	1.247+/-0.322
2	1.248+/-0.226
3	1.249+/-0.185
4	1.249+/-0.160
5	1.248+/-0.145

TDC RESOLUTION(bin size)n= 0.5; PULSE RESOLUTION(sigma)=0.30

BIN POPULTION

	0	1	2	3	4	5	6
	0.003	0.080	0.416	0.415	0.084	0.003	0.000

Hits on track	Average time
1	1.252+/-0.391
2	1.255+/-0.274
3	1.255+/-0.225
4	1.253+/-0.195
5	1.252+/-0.175

TDC RESOLUTION(bin size)n= 0.5; PULSE RESOLUTION(sigma)=0.40

BIN POPULTION

	0	1	2	3	4	5	6
	0.013	0.121	0.368	0.365	0.120	0.012	0.000

Hits on track	Average time
1	1.251+/-0.471
2	1.250+/-0.332
3	1.248+/-0.270
4	1.247+/-0.235
5	1.248+/-0.210

TDC RESOLUTION(bin size)n= 0.5; PULSE RESOLUTION(sigma)=0.50

BIN POPULTION

	0	1	2	3	4	5	6
	0.031	0.144	0.326	0.325	0.143	0.028	0.003

Hits on track	Average time
1	1.247+/-0.550
2	1.250+/-0.383
3	1.252+/-0.313
4	1.251+/-0.272
5	1.251+/-0.243

TDC RESOLUTION(bin size)n= 1.0; PULSE RESOLUTION(sigma)=0.00

BIN POPULTION

	0	1	2	3	4	5	6
	0.000	0.000	0.498	0.502	0.000	0.000	0.000

Hits on track	Average time
1	2.501+/-0.500
2	2.501+/-0.353
3	2.501+/-0.287
4	2.501+/-0.251
5	2.502+/-0.227

TDC RESOLUTION(bin size)n= 1.0; PULSE RESOLUTION(sigma)=0.10

BIN POPULTION

	0	1	2	3	4	5	6
	0.000	0.003	0.496	0.499	0.003	0.000	0.000

Hits on track	Average time
1	2.502+/-0.511
2	2.500+/-0.360
3	2.503+/-0.295
4	2.502+/-0.255
5	2.502+/-0.229

TDC RESOLUTION(bin size)n= 1.0; PULSE RESOLUTION(sigma)=0.20

BIN POPULTION

	0	1	2	3	4	5	6
	0.000	0.010	0.492	0.489	0.009	0.000	0.000

Hits on track	Average time
1	2.489+/-0.536
2	2.496+/-0.382
3	2.498+/-0.310
4	2.499+/-0.268
5	2.498+/-0.240

TDC RESOLUTION(bin size)n= 1.0; PULSE RESOLUTION(sigma)=0.30

BIN POPULTION

	0	1	2	3	4	5	6
	0.000	0.023	0.480	0.474	0.023	0.000	0.000

Hits on track	Average time
1	2.487+/-0.588
2	2.492+/-0.413
3	2.494+/-0.338
4	2.497+/-0.294

5 2.497+/-0.264

TDC RESOLUTION(bin size)n= 1.0; PULSE RESOLUTION(sigma)=0.40

BIN POPULTION

0	1	2	3	4	5	6
0.000	0.040	0.458	0.461	0.041	0.000	0.000

Hits on track	Average time
1	2.508+/-0.645
2	2.502+/-0.459
3	2.504+/-0.377
4	2.504+/-0.324
5	2.504+/-0.292

TDC RESOLUTION(bin size)n= 1.0; PULSE RESOLUTION(sigma)=0.50

BIN POPULTION

0	1	2	3	4	5	6
0.001	0.060	0.434	0.443	0.062	0.001	0.000

Hits on track	Average time
1	2.518+/-0.709
2	2.510+/-0.502
3	2.507+/-0.408
4	2.507+/-0.352
5	2.507+/-0.314

TDC RESOLUTION(bin size)n= 1.5; PULSE RESOLUTION(sigma)=0.00

BIN POPULTION

0	1	2	3	4	5	6
0.000	0.000	0.500	0.500	0.000	0.000	0.000

Hits on track	Average time
1	3.738+/-0.750
2	3.746+/-0.533
3	3.747+/-0.436
4	3.751+/-0.379
5	3.750+/-0.341

TDC RESOLUTION(bin size)n= 1.5; PULSE RESOLUTION(sigma)=0.10

BIN POPULTION

0	1	2	3	4	5	6
0.000	0.001	0.499	0.499	0.001	0.000	0.000

Hits on track	Average time
1	3.752+/-0.754
2	3.750+/-0.535
3	3.750+/-0.433

4	3.753+/-0.377
5	3.749+/-0.335

TDC RESOLUTION(bin size)n= 1.5; PULSE RESOLUTION(sigma)=0.20

BIN POPULTION	0	1	2	3	4	5	6
	0.000	0.004	0.497	0.495	0.004	0.000	0.000

Hits on track	Average time
1	3.739+/-0.774
2	3.742+/-0.548
3	3.742+/-0.450
4	3.746+/-0.389
5	3.748+/-0.349

TDC RESOLUTION(bin size)n= 1.5; PULSE RESOLUTION(sigma)=0.30

BIN POPULTION	0	1	2	3	4	5	6
	0.000	0.010	0.495	0.486	0.010	0.000	0.000

Hits on track	Average time
1	3.743+/-0.806
2	3.744+/-0.567
3	3.747+/-0.467
4	3.743+/-0.406
5	3.743+/-0.362

TDC RESOLUTION(bin size)n= 1.5; PULSE RESOLUTION(sigma)=0.40

BIN POPULTION	0	1	2	3	4	5	6
	0.000	0.018	0.483	0.482	0.018	0.000	0.000

Hits on track	Average time
1	3.745+/-0.847
2	3.741+/-0.598
3	3.745+/-0.490
4	3.747+/-0.424
5	3.749+/-0.381

TDC RESOLUTION(bin size)n= 1.5; PULSE RESOLUTION(sigma)=0.50

BIN POPULTION	0	1	2	3	4	5	6
	0.000	0.028	0.471	0.473	0.028	0.000	0.000

Hits on track	Average time
1	3.751+/-0.903
2	3.750+/-0.641

3	3.749+/-0.518
4	3.750+/-0.451
5	3.751+/-0.402