outline

Today's talk will cover following topics:

- there is a non-zero Bottom vs Top time difference
- do we need to do the temperature corrections?
- what is light speed in bar?
- what is the final time balance?
- make consistency check

the event/track selection requirements

- Run analysis codes on the frozen release: R07.04.21
- Runs: 14083 - 14300
- Momentum - 59 GeV/c, thin targets
- Trigger: π, K and p beams and interactions
- Event/track selection cuts:
  - use proper T0 summed charge and T0 time differences (Andre codes)
  - select clean events, nTrks$<$20
  - use events with single beam track
  - select at least 3 track vertices
  - the vertex should be within the target sizes
  - the vertex should be associated with beam track
  - require the good quality tracks in the vertex: reasonable nTPC hits, timing

first issue

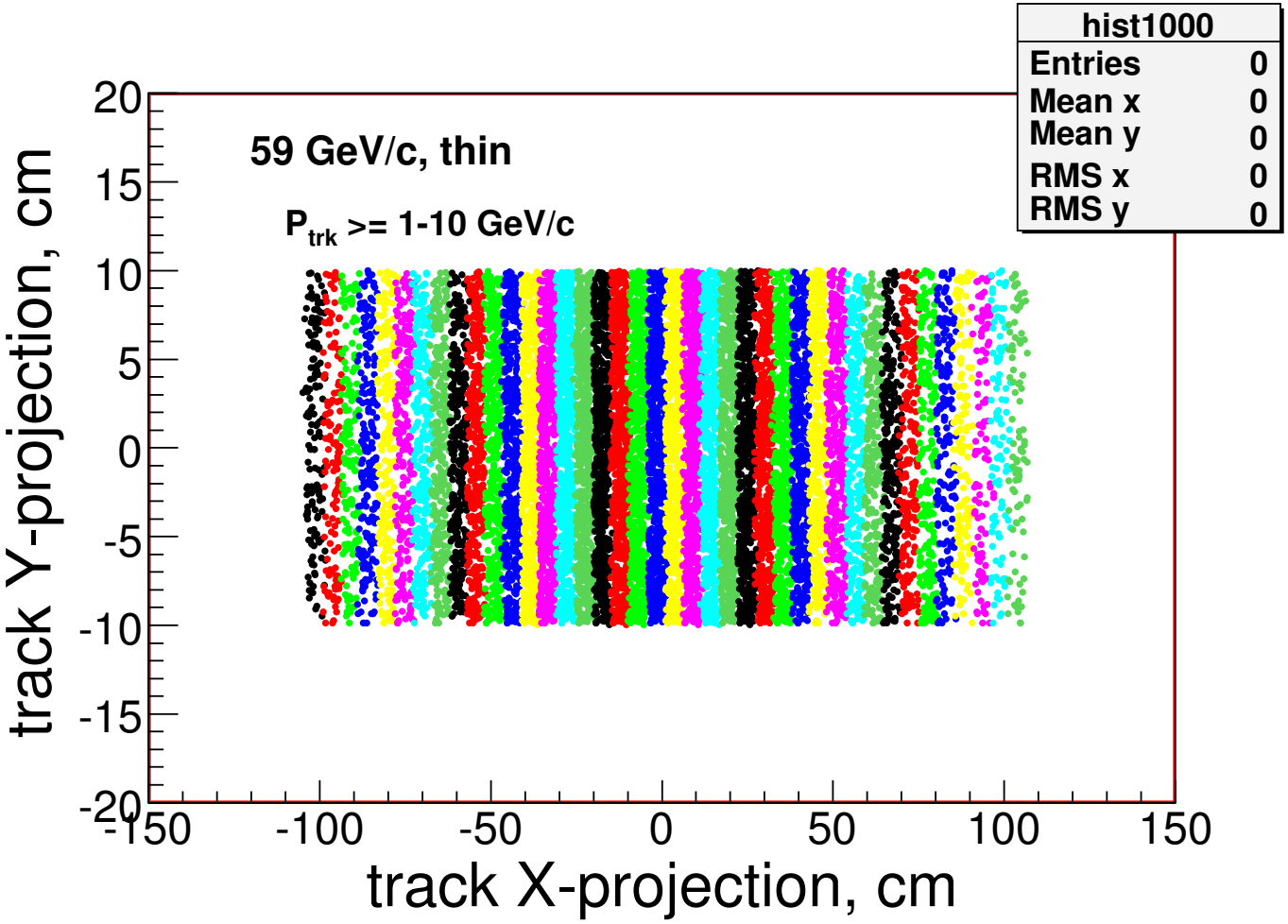
How to find the ToF Bottom-Top time differences?

- option 1: measuring actual cable length
- option 2: in analysis it can be done by making the Bottom-Top time difference plots:
  - use narrow particles spot at the center of bar
  - make Bottom-Top time difference plot for each bar
  - fit distributions
  - the mean value is a Bottom-Top delay difference
  - after applying correction the difference will be at 0.
  - use track momentum within 1 - 10 GeV/c

requirements on ToF variables

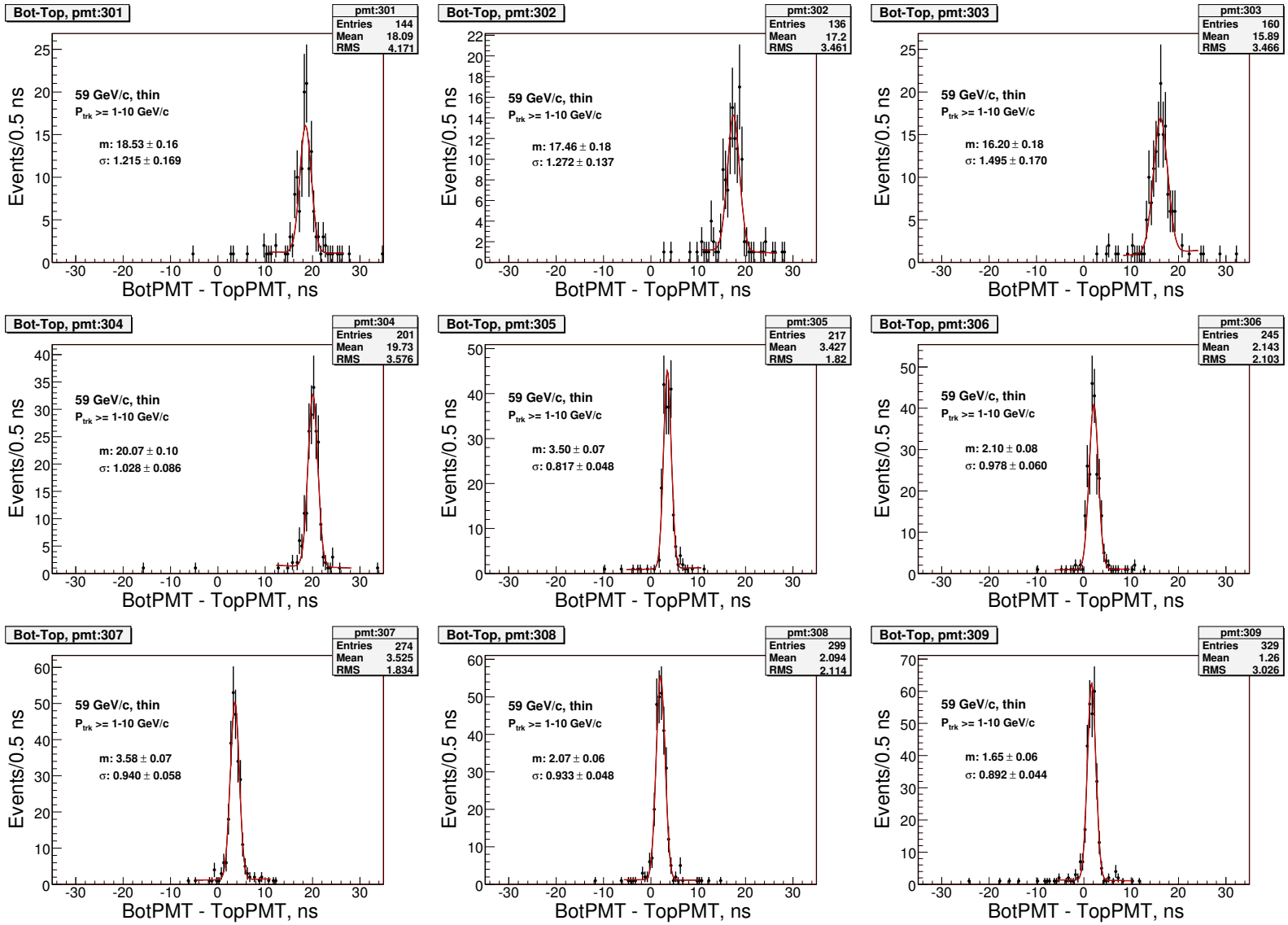
- PMT channels: 301 - 340
- Use the narrow beam spot: 0$\pm$10 cm in Y direction
- ToF match with track
- Bottom and top PMTs should be associated with given track
- Single track for bottom and top PMT's
- Use given TDC if time is within 5-100 ns range

track Y vs X scatter plot at ToF wall

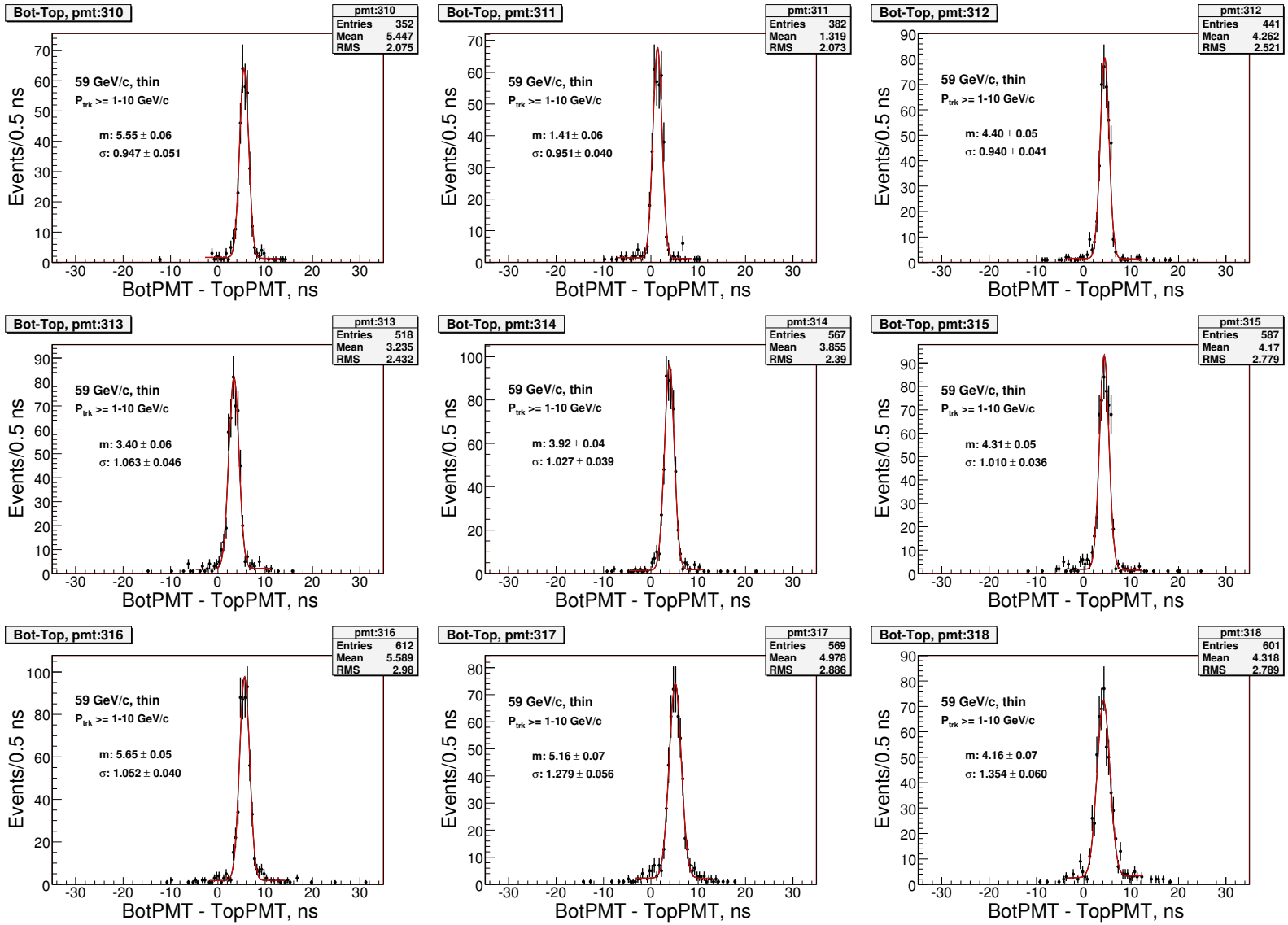


The track Y vs X scatter plot at ToF wall used for making the Bot-Top time difference plots. Each colored strip represents the single bar. Most left black strip is PMT number 301. Most right the green strip represents the PMT 340.

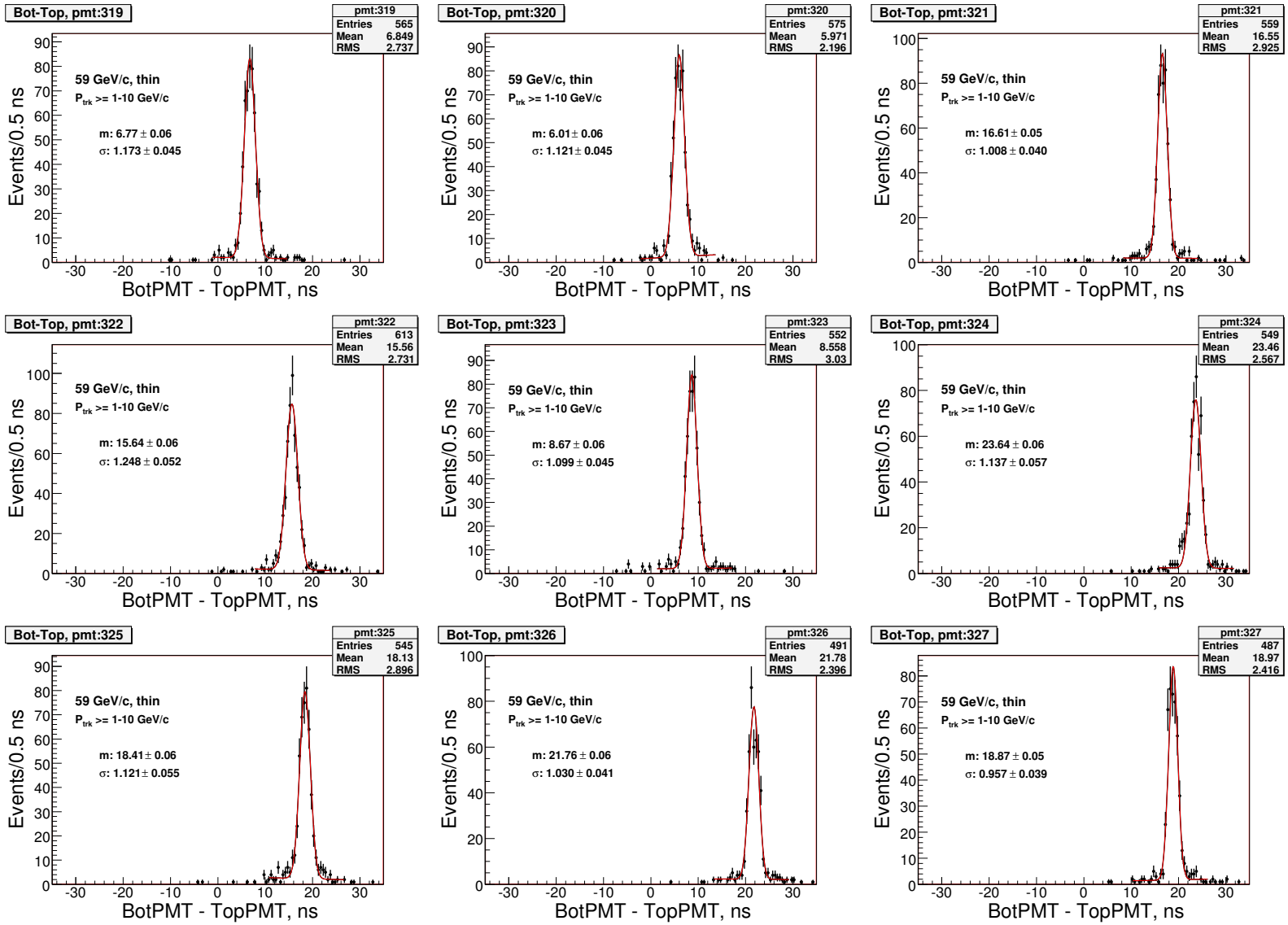
PMT's: 301 - 309


Bot-Top, pmt:301
pmt:301
Entries 144
Mean 18.09
RMS 4.171
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 18.53 ± 0.16
σ: 1.215 ± 0.169
Bot-Top, pmt:302
pmt:302
Entries 136
Mean 17.2
RMS 3.461
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 17.46 ± 0.18
σ: 1.272 ± 0.137
Bot-Top, pmt:303
pmt:303
Entries 160
Mean 15.89
RMS 3.466
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 16.20 ± 0.18
σ: 1.495 ± 0.170
Bot-Top, pmt:304
pmt:304
Entries 201
Mean 19.73
RMS 3.576
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 20.07 ± 0.10
σ: 1.028 ± 0.086
Bot-Top, pmt:305
pmt:305
Entries 217
Mean 3.427
RMS 1.82
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 3.50 ± 0.07
σ: 0.817 ± 0.048
Bot-Top, pmt:306
pmt:306
Entries 245
Mean 2.143
RMS 2.103
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 2.10 ± 0.08
σ: 0.978 ± 0.060
Bot-Top, pmt:307
pmt:307
Entries 274
Mean 3.525
RMS 1.834
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 3.58 ± 0.07
σ: 0.940 ± 0.058
Bot-Top, pmt:308
pmt:308
Entries 299
Mean 2.094
RMS 2.114
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 2.07 ± 0.06
σ: 0.933 ± 0.048
Bot-Top, pmt:309
pmt:309
Entries 329
Mean 1.26
RMS 3.026
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 1.65 ± 0.06
σ: 0.892 ± 0.044
Events/0.5 ns
BotPMT - TopPMT, ns

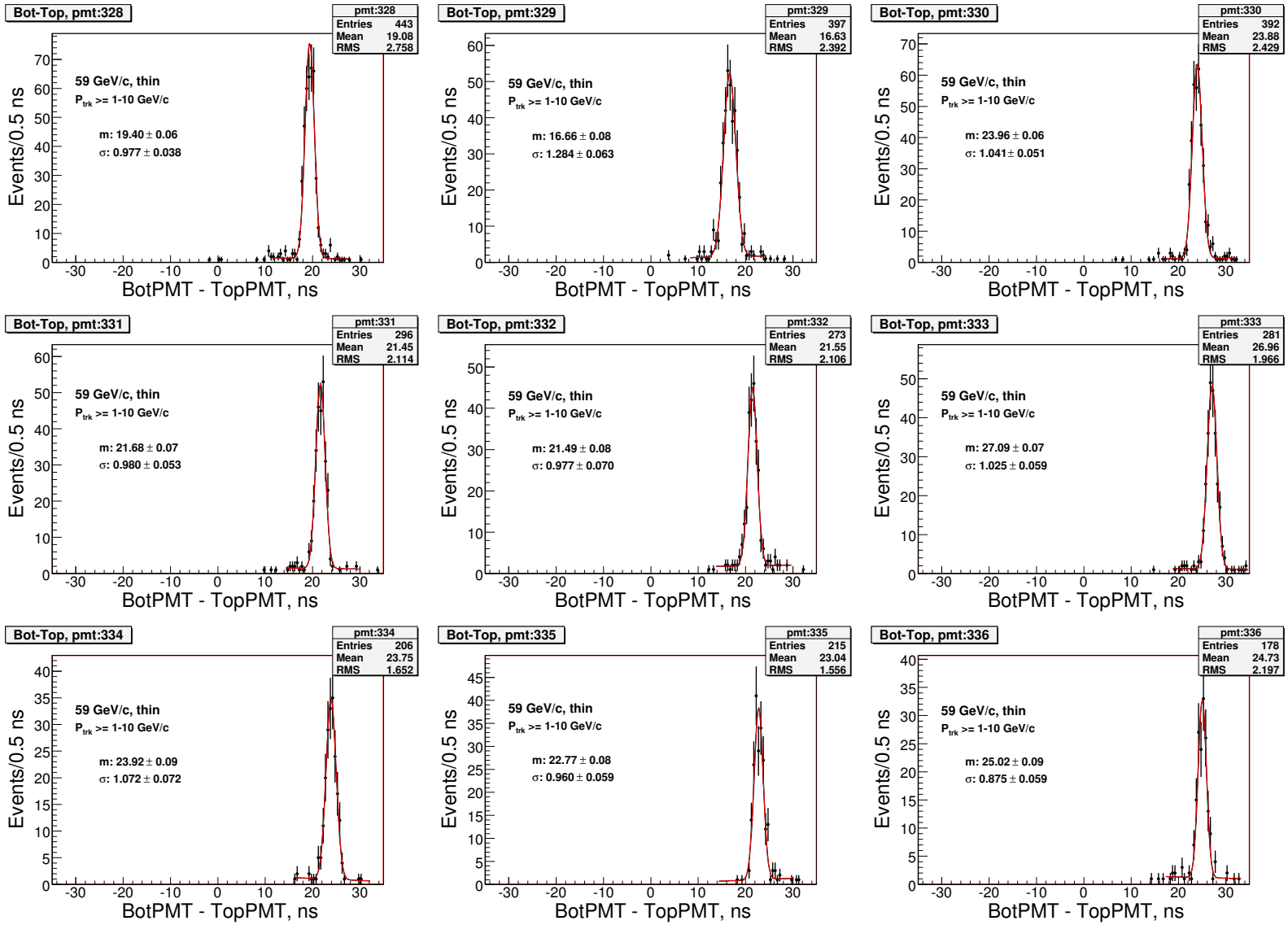
PMT's: 310 - 318


Bot-Top, pmt:310
pmt:310
Entries 352
Mean 5.447
RMS 2.075
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 5.55 ± 0.06
σ: 0.947 ± 0.051
Bot-Top, pmt:311
pmt:311
Entries 382
Mean 1.319
RMS 2.073
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 1.41 ± 0.06
σ: 0.951 ± 0.040
Bot-Top, pmt:312
pmt:312
Entries 441
Mean 4.262
RMS 2.521
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 4.40 ± 0.05
σ: 0.940 ± 0.041
Bot-Top, pmt:313
pmt:313
Entries 518
Mean 3.235
RMS 2.432
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 3.40 ± 0.06
σ: 1.063 ± 0.046
Bot-Top, pmt:314
pmt:314
Entries 567
Mean 3.855
RMS 2.39
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 3.92 ± 0.04
σ: 1.027 ± 0.039
Bot-Top, pmt:315
pmt:315
Entries 587
Mean 4.17
RMS 2.779
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 4.31 ± 0.05
σ: 1.010 ± 0.036
Bot-Top, pmt:316
pmt:316
Entries 612
Mean 5.589
RMS 2.98
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 5.65 ± 0.05
σ: 1.052 ± 0.040
Bot-Top, pmt:317
pmt:317
Entries 569
Mean 4.978
RMS 2.886
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 5.16 ± 0.07
σ: 1.279 ± 0.056
Bot-Top, pmt:318
pmt:318
Entries 601
Mean 4.318
RMS 2.789
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 4.16 ± 0.07
σ: 1.354 ± 0.060
Events/0.5 ns
BotPMT - TopPMT, ns

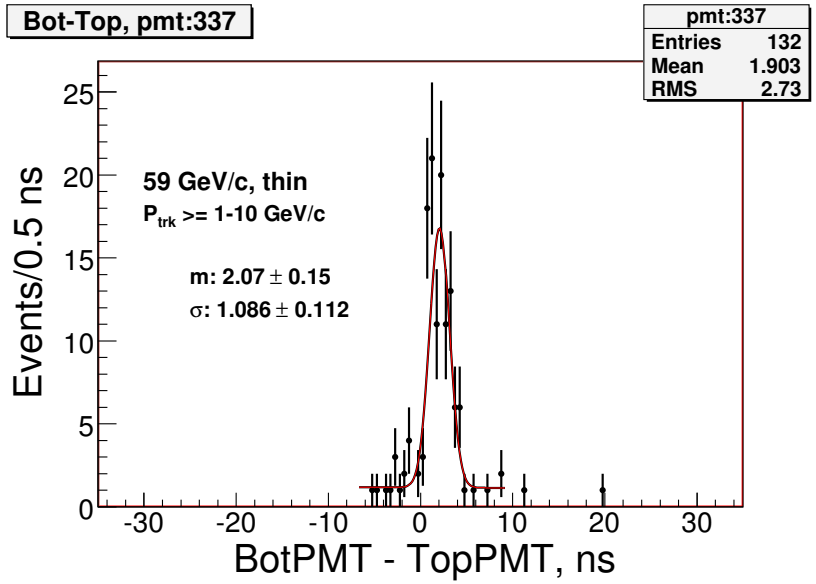
PMT's: 319 - 327

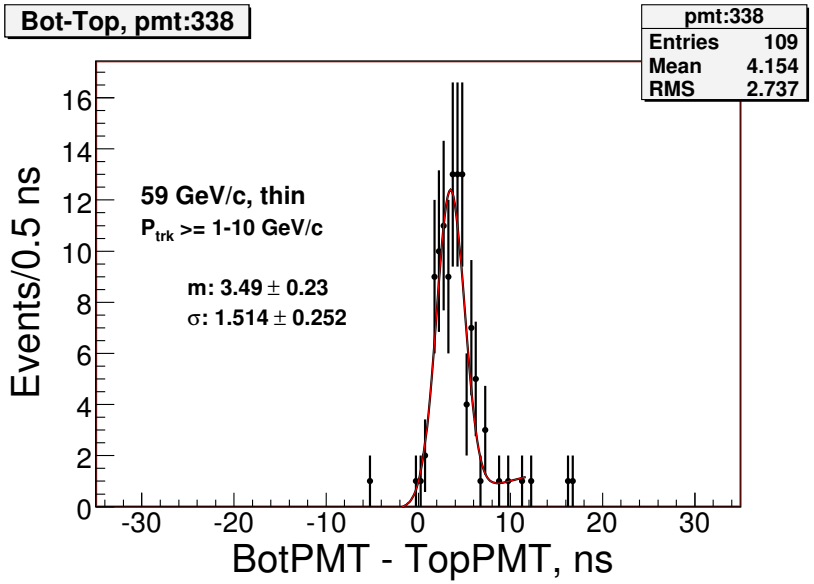

Bot-Top, pmt:319
pmt:319
Entries 565
Mean 6.849
RMS 2.737
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 6.77 ± 0.06
σ: 1.173 ± 0.045
Bot-Top, pmt:320
pmt:320
Entries 575
Mean 5.971
RMS 2.196
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 6.01 ± 0.06
σ: 1.121 ± 0.045
Bot-Top, pmt:321
pmt:321
Entries 559
Mean 16.55
RMS 2.925
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 16.61 ± 0.05
σ: 1.008 ± 0.040
Bot-Top, pmt:322
pmt:322
Entries 613
Mean 15.56
RMS 2.731
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 15.64 ± 0.06
σ: 1.248 ± 0.052
Bot-Top, pmt:323
pmt:323
Entries 552
Mean 8.558
RMS 3.03
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 8.67 ± 0.06
σ: 1.099 ± 0.045
Bot-Top, pmt:324
pmt:324
Entries 549
Mean 23.46
RMS 2.567
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 23.64 ± 0.06
σ: 1.137 ± 0.057
Bot-Top, pmt:325
pmt:325
Entries 545
Mean 18.13
RMS 2.896
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 18.41 ± 0.06
σ: 1.121 ± 0.055
Bot-Top, pmt:326
pmt:326
Entries 491
Mean 21.78
RMS 2.396
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 21.76 ± 0.06
σ: 1.030 ± 0.041
Bot-Top, pmt:327
pmt:327
Entries 487
Mean 18.97
RMS 2.416
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 18.87 ± 0.05
σ: 0.957 ± 0.039
Events/0.5 ns
BotPMT - TopPMT, ns

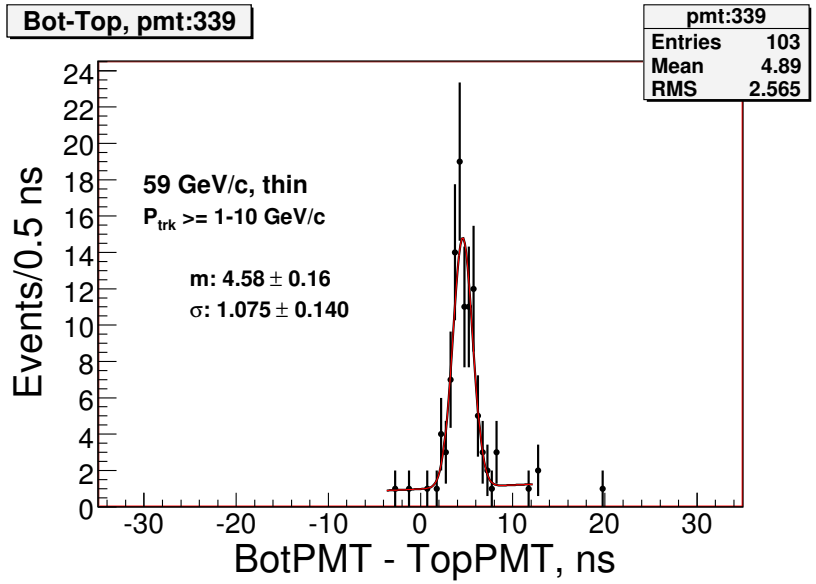
PMT's: 328 - 336

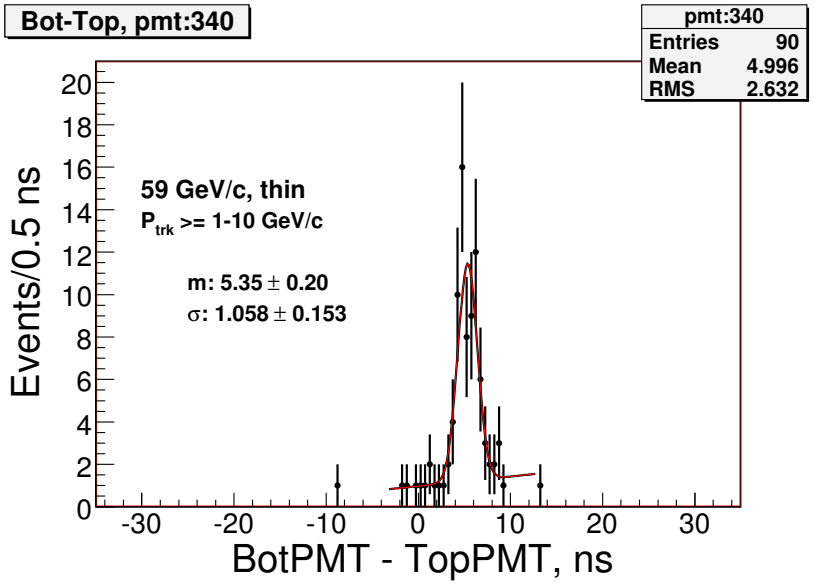

Bot-Top, pmt:328
pmt:328
Entries 443
Mean 19.08
RMS 2.758
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 19.40 ± 0.06
σ: 0.977 ± 0.038
Bot-Top, pmt:329
pmt:329
Entries 397
Mean 16.63
RMS 2.392
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 16.66 ± 0.08
σ: 1.284 ± 0.063
Bot-Top, pmt:330
pmt:330
Entries 392
Mean 23.88
RMS 2.429
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 23.96 ± 0.06
σ: 1.041 ± 0.051
Bot-Top, pmt:331
pmt:331
Entries 296
Mean 21.45
RMS 2.114
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 21.68 ± 0.07
σ: 0.980 ± 0.053
Bot-Top, pmt:332
pmt:332
Entries 273
Mean 21.55
RMS 2.106
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 21.49 ± 0.08
σ: 0.977 ± 0.070
Bot-Top, pmt:333
pmt:333
Entries 281
Mean 26.96
RMS 1.966
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 27.09 ± 0.07
σ: 1.025 ± 0.059
Bot-Top, pmt:334
pmt:334
Entries 206
Mean 23.75
RMS 1.652
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 23.92 ± 0.09
σ: 1.072 ± 0.072
Bot-Top, pmt:335
pmt:335
Entries 215
Mean 23.04
RMS 1.556
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 22.77 ± 0.08
σ: 0.960 ± 0.059
Bot-Top, pmt:336
pmt:336
Entries 178
Mean 24.73
RMS 2.197
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 25.02 ± 0.09
σ: 0.875 ± 0.059
Events/0.5 ns
BotPMT - TopPMT, ns

PMT's: 337 - 340


Bot-Top, pmt:337
pmt:337
Entries 132
Mean 1.903
RMS 2.73
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 2.07 ± 0.15
σ: 1.086 ± 0.112
Events/0.5 ns
BotPMT - TopPMT, ns


Bot-Top, pmt:338
pmt:338
Entries 109
Mean 4.154
RMS 2.737
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 3.49 ± 0.23
σ: 1.514 ± 0.252
Events/0.5 ns
BotPMT - TopPMT, ns


Bot-Top, pmt:339
pmt:339
Entries 103
Mean 4.89
RMS 2.565
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 4.58 ± 0.16
σ: 1.075 ± 0.140
Events/0.5 ns
BotPMT - TopPMT, ns


Bot-Top, pmt:340
pmt:340
Entries 90
Mean 4.996
RMS 2.632
59 GeV/c, thin
P_{trk} >= 1-10 GeV/c
m: 5.35 ± 0.20
σ: 1.058 ± 0.153
Events/0.5 ns
BotPMT - TopPMT, ns

summary of the Bottom-Top time differences

nPMT	mean, ns	widths, ns	nPMT	mean, ns	widths, ns
301	18.52±0.16	1.21±0.16	321	16.60±0.05	1.00±0.04
302	17.46±0.18	1.27±0.13	322	15.64±0.05	1.24±0.05
303	16.20±0.17	1.49±0.16	323	8.66±0.05	1.09±0.04
304	20.07±0.09	1.02±0.08	324	23.64±0.06	1.13±0.05
305	3.50±0.06	0.81±0.04	325	18.41±0.05	1.12±0.05
306	2.09±0.08	0.97±0.06	326	21.76±0.05	1.02±0.04
307	3.58±0.06	0.93±0.05	327	18.87±0.05	0.95±0.03
308	2.06±0.06	0.93±0.04	328	19.40±0.05	0.97±0.03
309	1.65±0.05	0.89±0.04	329	16.65±0.07	1.28±0.06
310	5.55±0.05	0.94±0.05	330	23.96±0.06	1.04±0.05
311	1.40±0.05	0.95±0.03	331	21.67±0.07	0.98±0.05
312	4.40±0.05	0.94±0.04	332	21.49±0.07	0.97±0.07
313	3.39±0.05	1.06±0.04	333	27.08±0.07	1.02±0.05
314	3.91±0.04	1.02±0.03	334	23.91±0.08	1.07±0.07
315	4.30±0.05	1.00±0.03	335	22.76±0.08	0.96±0.05
316	5.64±0.05	1.05±0.04	336	25.02±0.08	0.87±0.05
317	5.15±0.06	1.27±0.05	337	2.07±0.14	1.08±0.11
318	4.16±0.07	1.35±0.06	338	3.48±0.23	1.51±0.25
319	6.76±0.05	1.17±0.04	339	4.58±0.15	1.07±0.13
320	6.00±0.05	1.12±0.04	340	5.35±0.20	1.05±0.15

Table 1: Summary of the Bottom-Top pmt time differences for channels 301 - 340 using 0±10 cm beam size.

after subtracting above $\triangle$t values from the Bottom pmt

nPMT	mean, ns	nPMT	mean, ns	nPMT	mean, ns	nPMT	mean, ns
301	0.067± 0.067	311	0.011±0.059	321	0.059±0.059	331	0.002±0.071
302	0.020± 0.020	312	0.005±0.050	322	0.050±0.050	332	0.020±0.075
303	-0.017±-0.017	313	0.014±0.056	323	0.056±0.056	333	0.011±0.073
304	-0.034±-0.034	314	-0.005±0.049	324	0.049±0.049	334	-0.013±0.087
305	0.004± 0.004	315	0.018±0.052	325	0.052±0.052	335	0.052±0.085
306	-0.023±-0.023	316	-0.030±0.050	326	0.050±0.050	336	-0.003±0.087
307	-0.048±-0.048	317	0.005±0.065	327	0.065±0.065	337	-0.073±0.147
308	-0.029±-0.029	318	0.036±0.073	328	0.073±0.073	338	-0.010±0.234
309	0.012± 0.012	319	0.039±0.058	329	0.058±0.058	339	-0.046±0.148
310	-0.031±-0.031	320	0.005±0.058	330	0.058±0.058	340	0.019±0.217

Table 2: Resulting Bottom$_{corr}$-Top pmt time differences.

temperature variations?

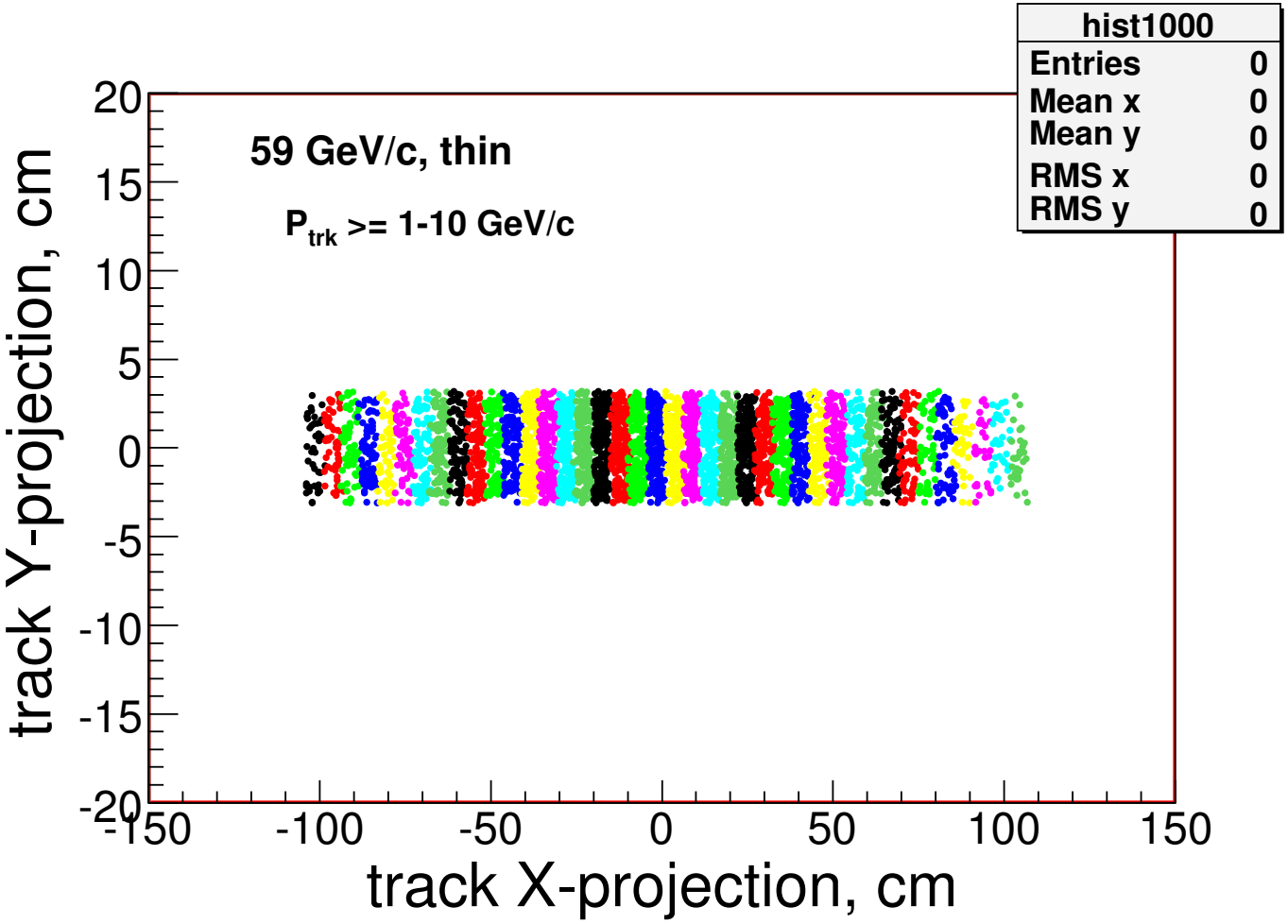
Do we need to do the temperature corrections?

Top and Bottom pmts and cables are in the different temperature conditions. Used data (200 runs) covers about 14 days and nights in May 2005. If this effect exist then it should be seen in Bottom-Top time differences.

What we see from the previous pages that the width distributions are consistent with the size of beam spot. In another words there is no room for presence of the temperature effects.

What will happen if we will use narrower beam size? Are the widths will shrink or remains same?

0±3 cm beam size



The track Y vs X scatter plot at ToF wall used for making the Bottom-Top time difference plots. Each colored strip represents the single bar. Most left black strip is PMT number 301. Most right the green strip represents the PMT 340.

beam size: 0±10 cm vs 0±3 cm

nPMT	0±10 cm	0±3 cm	nPMT	0±10 cm	0±3 cm
311	0.95±0.03	0.52±0.07	321	1.00±0.04	0.53±0.04
312	0.94±0.04	0.51±0.05	322	1.24±0.05	0.67±0.08
313	1.06±0.04	0.57±0.06	323	1.09±0.04	0.39±0.03
314	1.02±0.03	0.44±0.04	324	1.13±0.05	0.51±0.07
315	1.00±0.03	0.51±0.05	325	1.12±0.05	0.64±0.08
316	1.05±0.04	0.51±0.05	326	1.02±0.04	0.54±0.07
317	1.27±0.05	0.55±0.07	327	0.95±0.03	0.52±0.04
318	1.35±0.06	0.96±0.09	328	0.97±0.03	0.55±0.06
319	1.17±0.04	0.84±0.09	329	1.28±0.06	0.97±0.14
320	1.12±0.04	0.58±0.05	330	1.04±0.05	0.49±0.06

Table 3: Comparison of the widths for 0±10 cm beam size vs 0±3 cm. The beam size was reduced by factor 3, while the Δt widths became narrower only by factor ≈2 (except for pmt's 318,319 and 329). There is a contribution from the track resolution, especially for the low momentum tracks Results show that the widths of Δt distribution mainly defined by the size of beam. There is no room for the great temperature corrections. If some one will find a reason to make such corrections, then it might be in level of 0.3 ns.

third issue

How to find the speed of light in bar?

Bottom-Top time difference is a particles position in the time units.

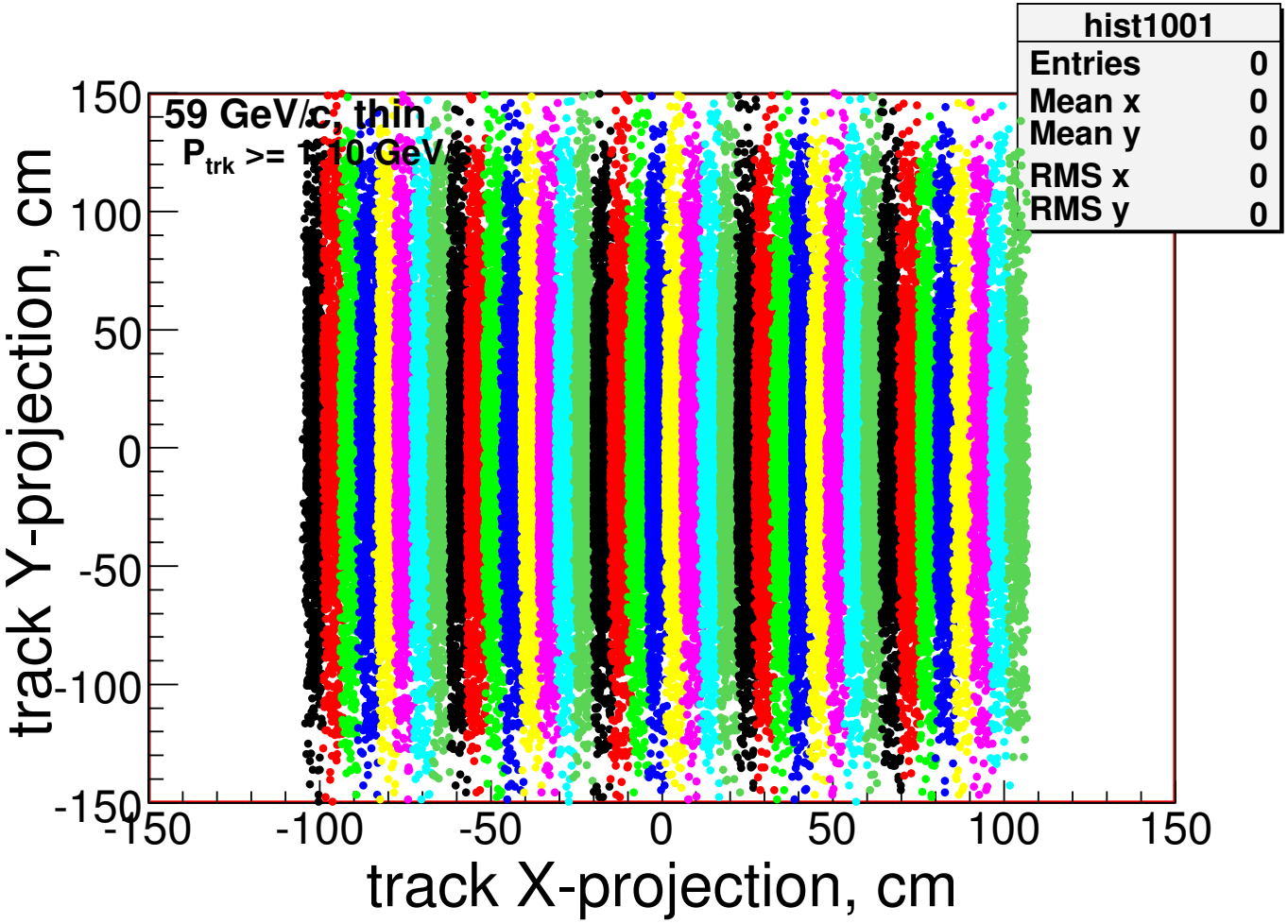
tofbar$\rightarrow$y gives Y coordinate of track at ToF wall

The ratio Y coordinate / Bottom-Top is a light speed in bar.

- use tracks in wide Y coordinate ranges: 0$\pm$150 cm.
- use track momentum within 1 - 10 GeV/c
- make scatter plot: Y coordinate vs Bottom$_{corr}$-Top time
- drop the events out of the reasonable area
- fit distributions
- the slope represents the speed of light in bar

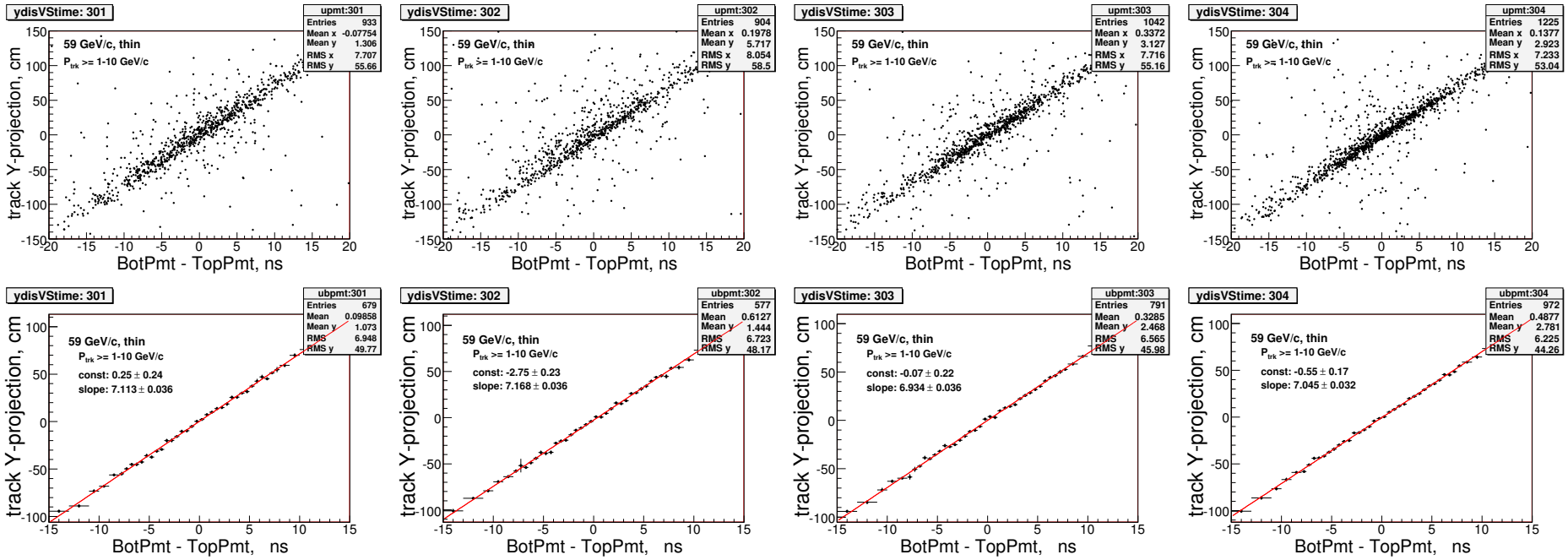
Assumption: TDC counts to time converting coefficient is true.

track Y vs X scatter plot at ToF wall



The track Y vs X scatter plot at ToF wall used for making the track Y coordinate vs the Bottom$_{corr}$-Top time difference scatter plots. Each colored strip represents the single bar. Most left black strip is PMT 301. Most right the green strip is PMT 340.

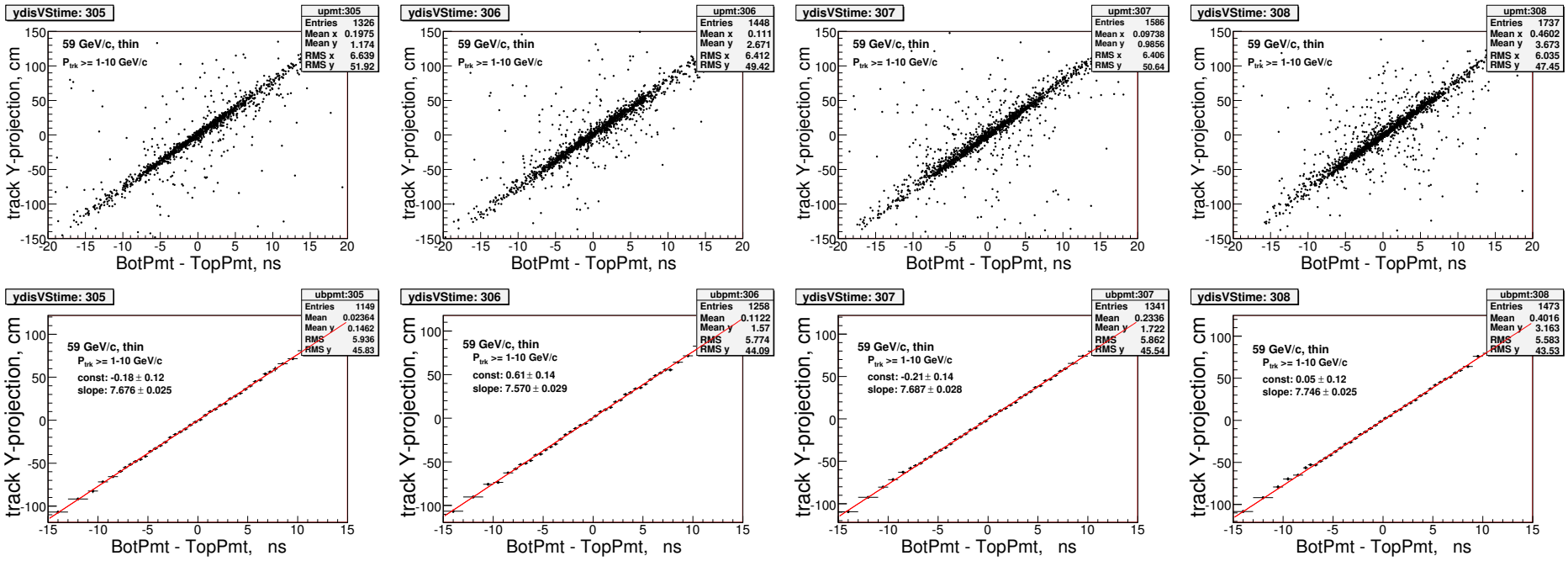
track Y coordinate vs Bottom$_{corr}$-Top time: 301 - 304



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

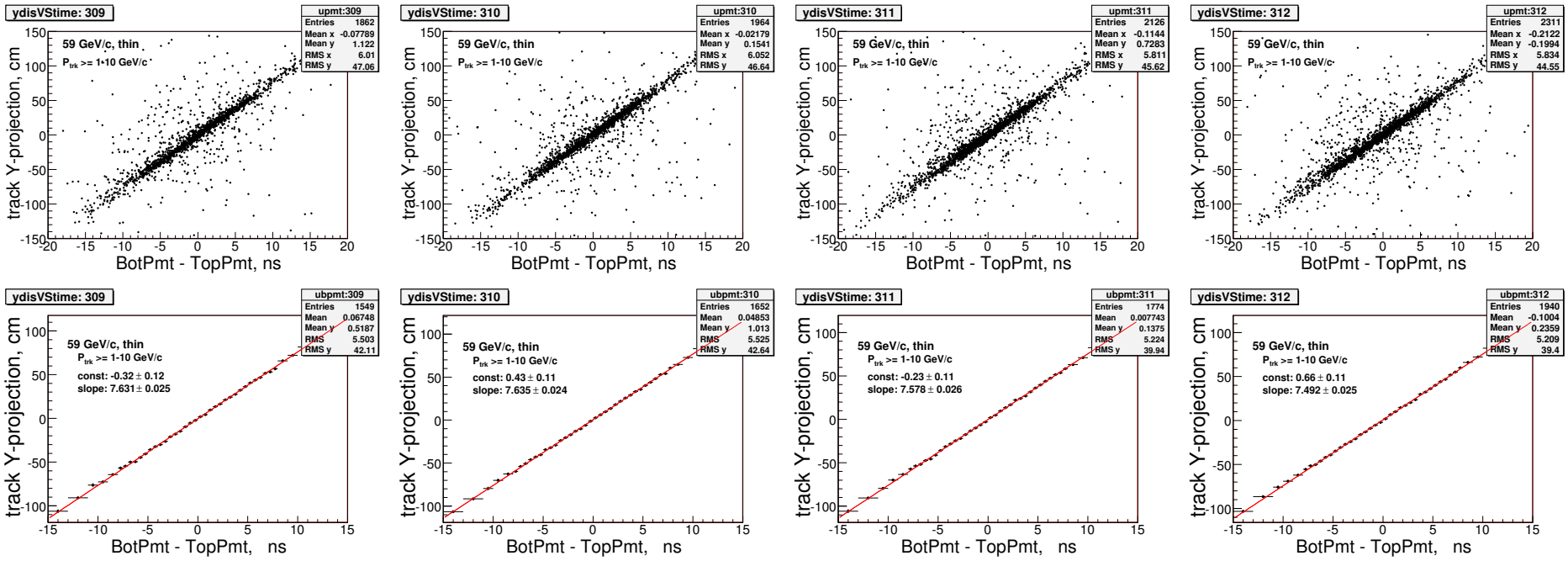
track Y coordinate vs Bottom$_{corr}$-Top time: 305 - 308



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

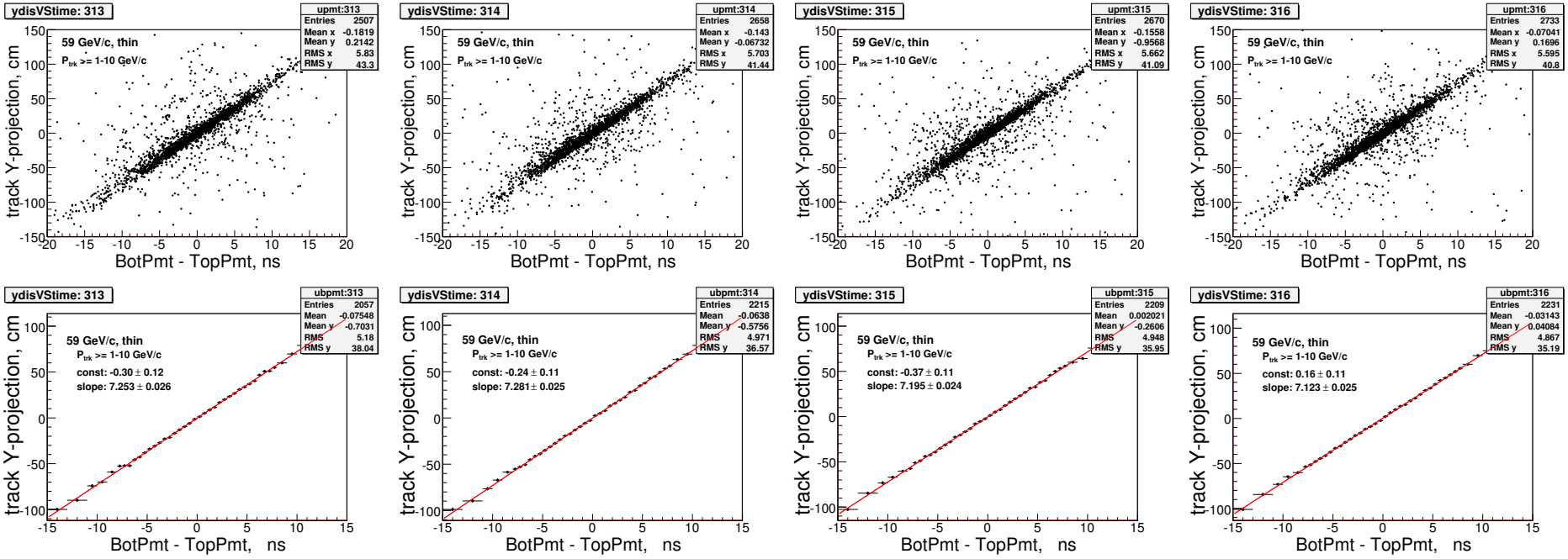
track Y coordinate vs Bottom$_{corr}$-Top time: 309 - 312



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

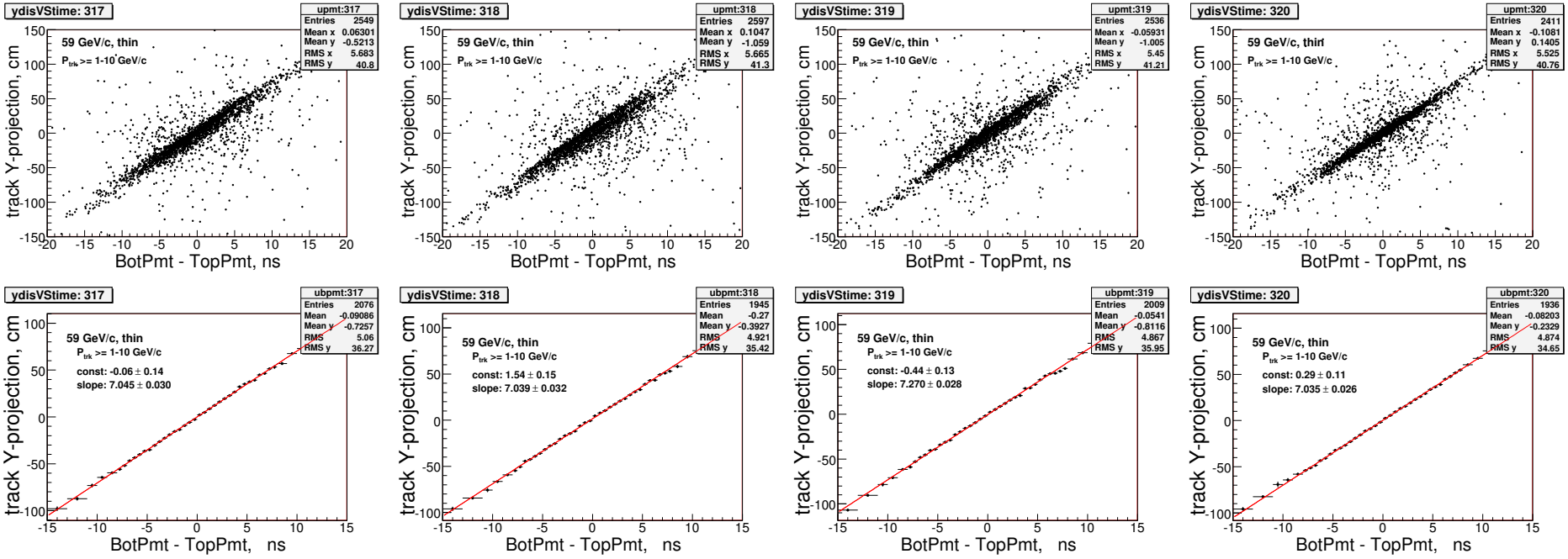
track Y coordinate vs Bottom$_{corr}$-Top time: 313 - 316



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

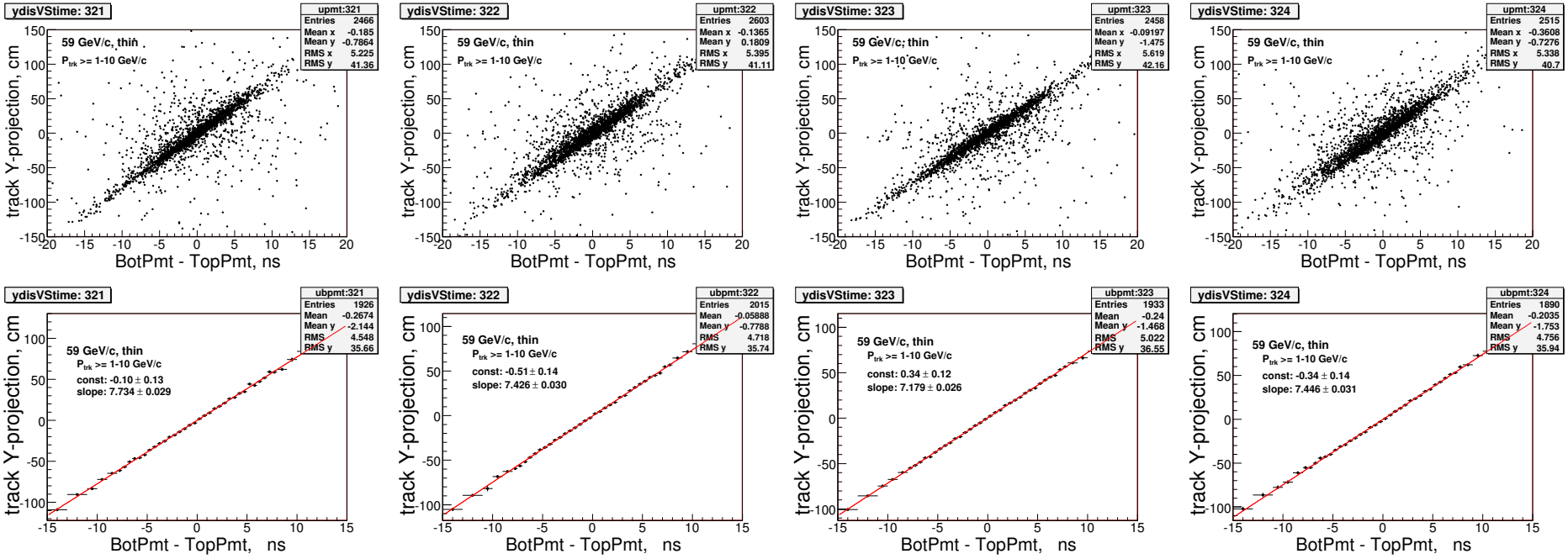
track Y coordinate vs Bottom$_{corr}$-Top time: 317 - 320



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

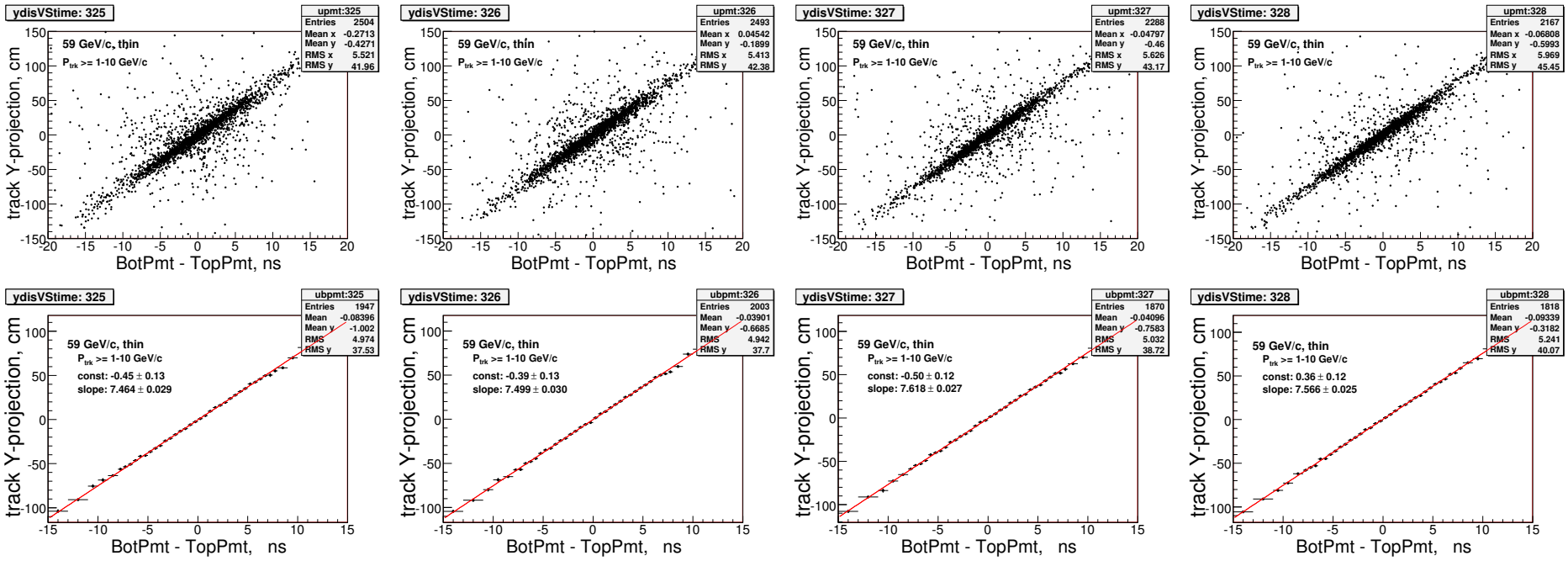
track Y coordinate vs Bottom$_{corr}$-Top time: 321 - 324



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

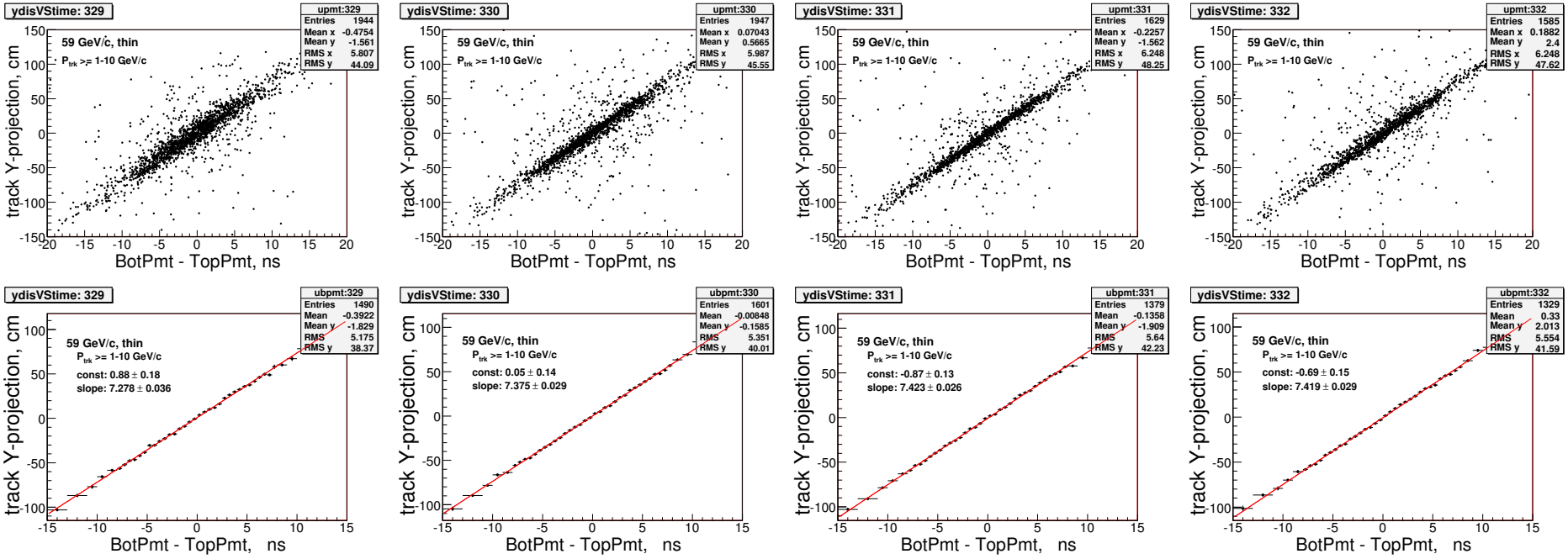
track Y coordinate vs Bottom$_{corr}$-Top time: 325 - 328



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

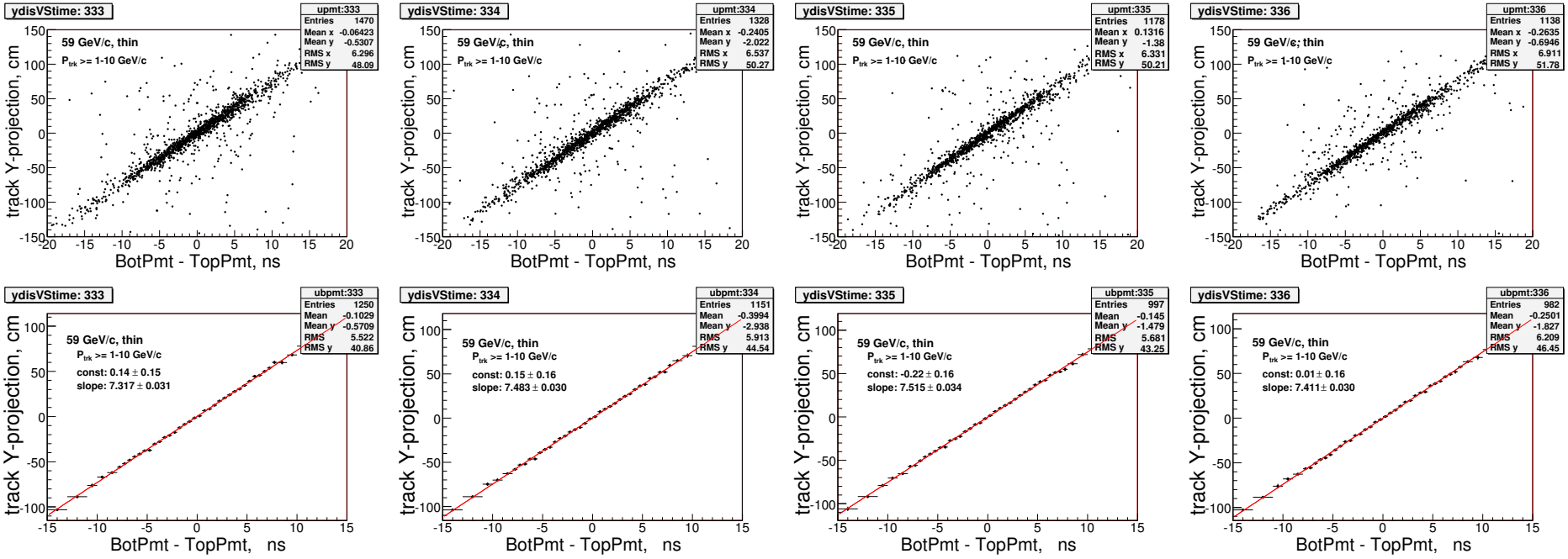
track Y coordinate vs Bottom$_{corr}$-Top time: 329 - 332



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

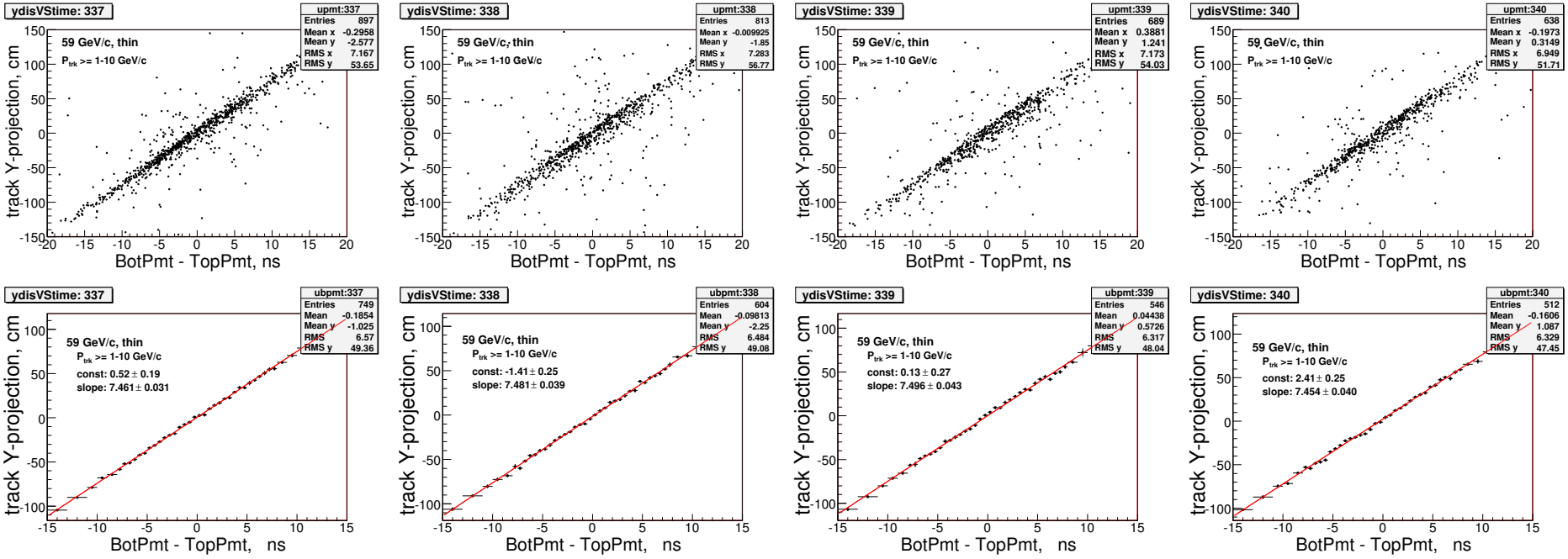
track Y coordinate vs Bottom$_{corr}$-Top time: 333 - 336



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

track Y coordinate vs Bottom$_{corr}$-Top time: 337 - 340



Top plots - the scatter plots of the track Y coordinate vs the Bottom$_{corr}$-Top time differences.

Bottom plots - linear fit results of the above data.

summary of the speed of light in ToF bars

PMT	speed, cm/ns	PMT	speed, cm/ns	PMT	speed, cm/ns	PMT	speed, cm/ns
301	7.112±0.036	311	7.577±0.025	321	7.733±0.029	331	7.422±0.025
302	7.168±0.035	312	7.491±0.024	322	7.425±0.029	332	7.418±0.028
303	6.933±0.035	313	7.253±0.026	323	7.178±0.026	333	7.316±0.031
304	7.045±0.031	314	7.281±0.024	324	7.445±0.031	334	7.483±0.029
305	7.675±0.025	315	7.195±0.024	325	7.463±0.029	335	7.514±0.034
306	7.570±0.028	316	7.123±0.025	326	7.498±0.029	336	7.411±0.030
307	7.687±0.027	317	7.045±0.029	327	7.618±0.026	337	7.460±0.030
308	7.745±0.024	318	7.039±0.031	328	7.565±0.025	338	7.480±0.039
309	7.630±0.024	319	7.270±0.027	329	7.278±0.035	339	7.496±0.043
310	7.634±0.024	320	7.034±0.026	330	7.375±0.029	340	7.453±0.040

Table 4: Summary of the speed of light in ToF bars: speed = track Y position / Bottom$_{corr}$-Top time difference. The speed of light in bar appears to be factor 2 less that expected. Is light traveling back-forward several time? Is TDC counts→time coefficient correct?

fourth issue

How to calculate the time balance?

time balance = $time_{average}$ - t_o - $t_{arrival}$ - t_{light}

$time_{average}$ = (Bottom $_{corr}$ + Top)/2: $\approx$ 25 ns

t_o - start time: $\approx$ 0 ns

$t_{arrival}$ is a particles arrival time = travel distance / speed of light in vacuum : $\approx$ 507cm/30=16.9 ns

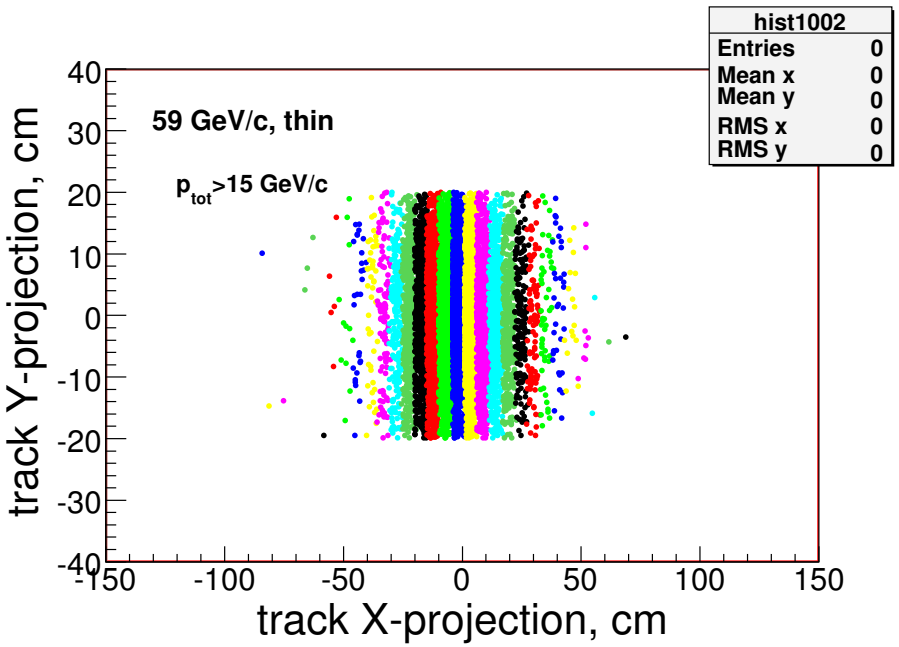
t_{light} is a light travel time in bar = half bar length / speed of light in bar: $\approx$ 155/7.2=21.5 ns

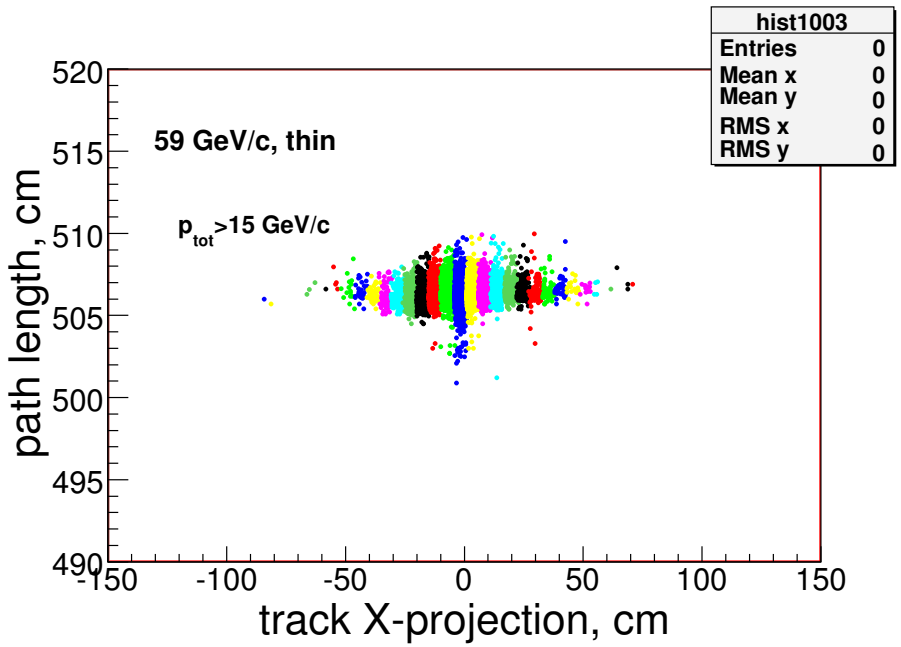
select the high momentum tracks, p_{tot} $>$15 GeV/c

select particles travel distance within 500 - 510 cm

expected time balance: 25 - 0 - 16.9 - 21.5 = -13.4 ns

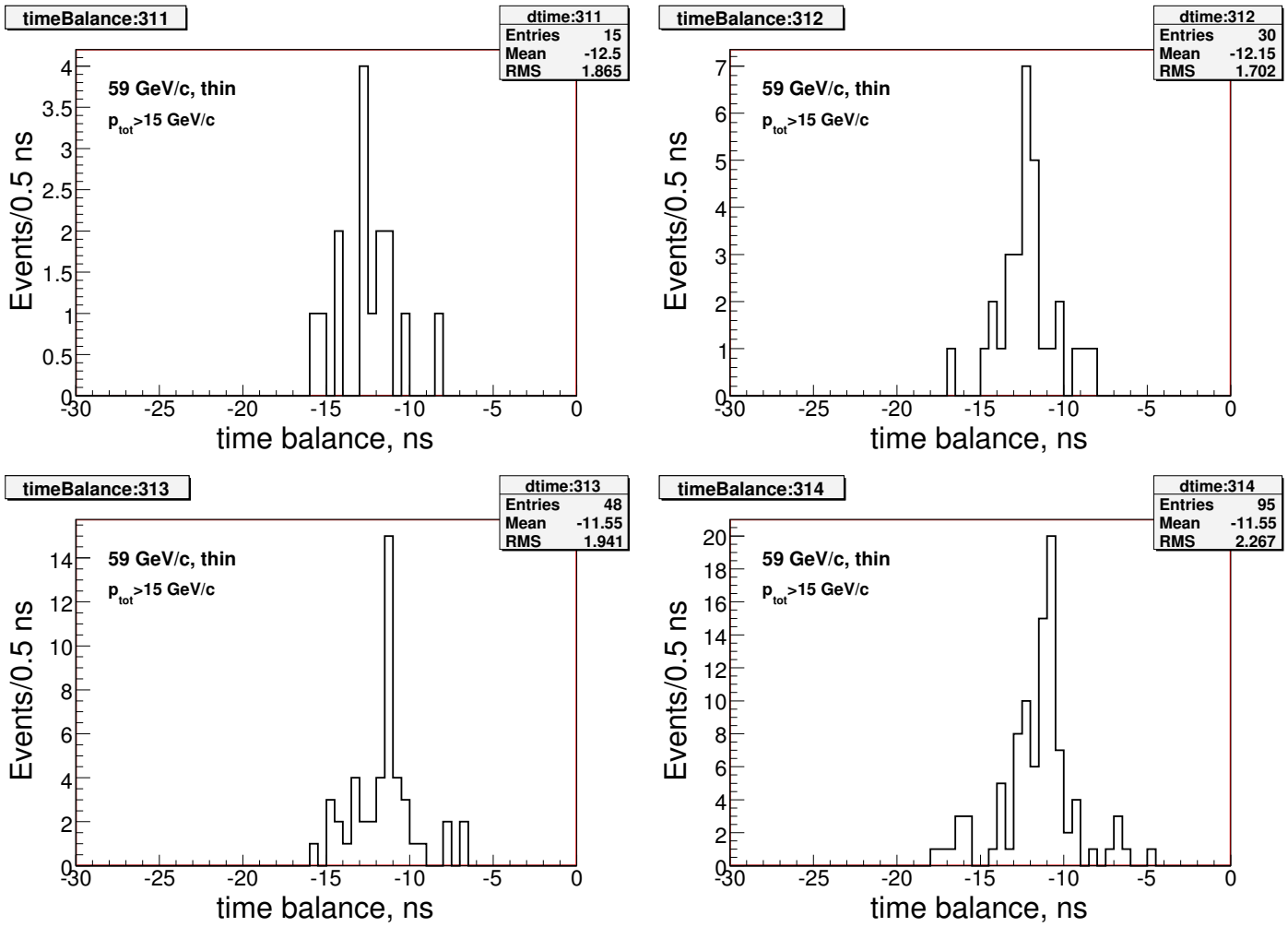
tracks at ToF wall





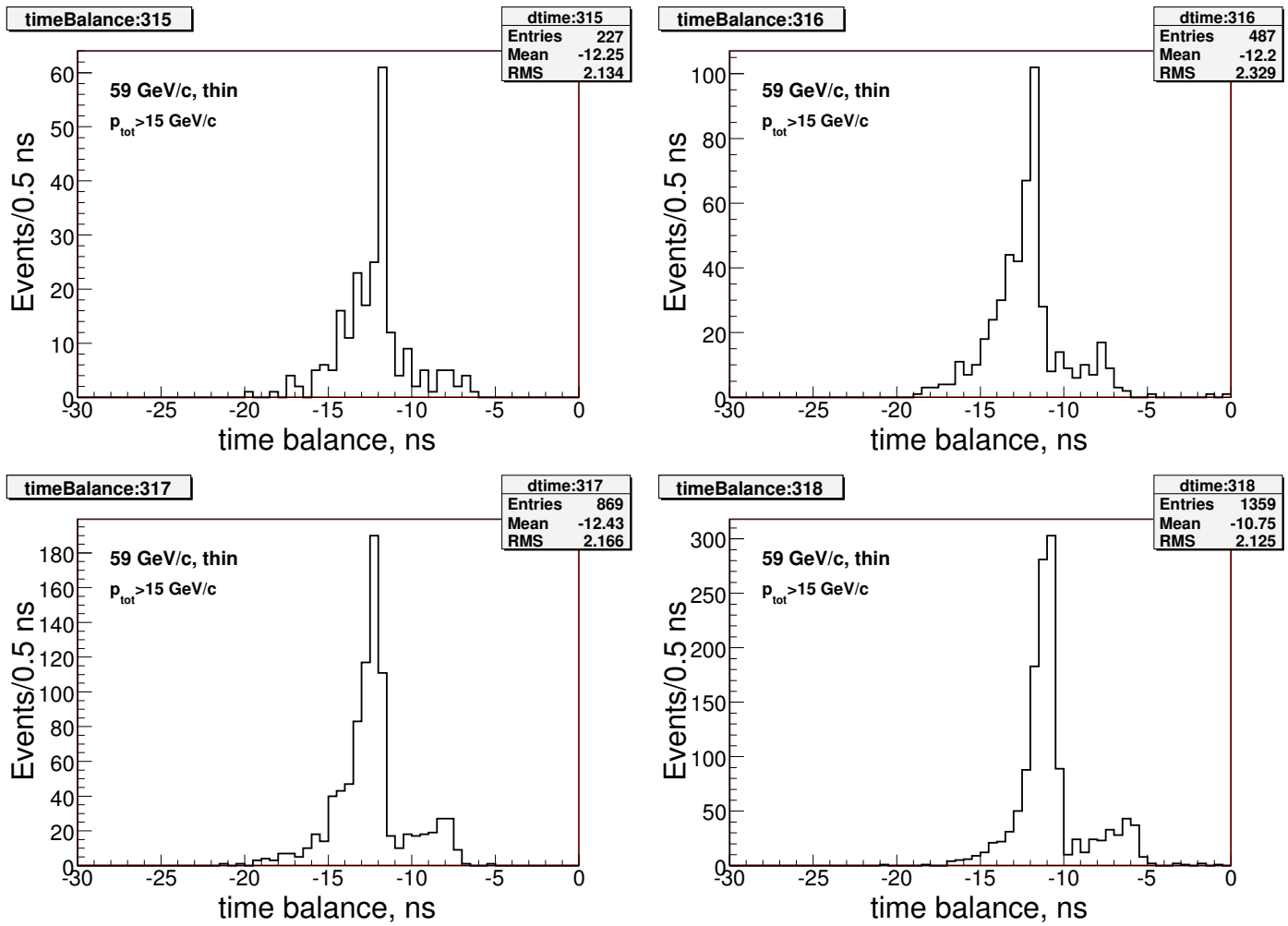
Left graph - track Y vs X scatter plot. Right - path length vs track X projection.

time balance: 311 - 314



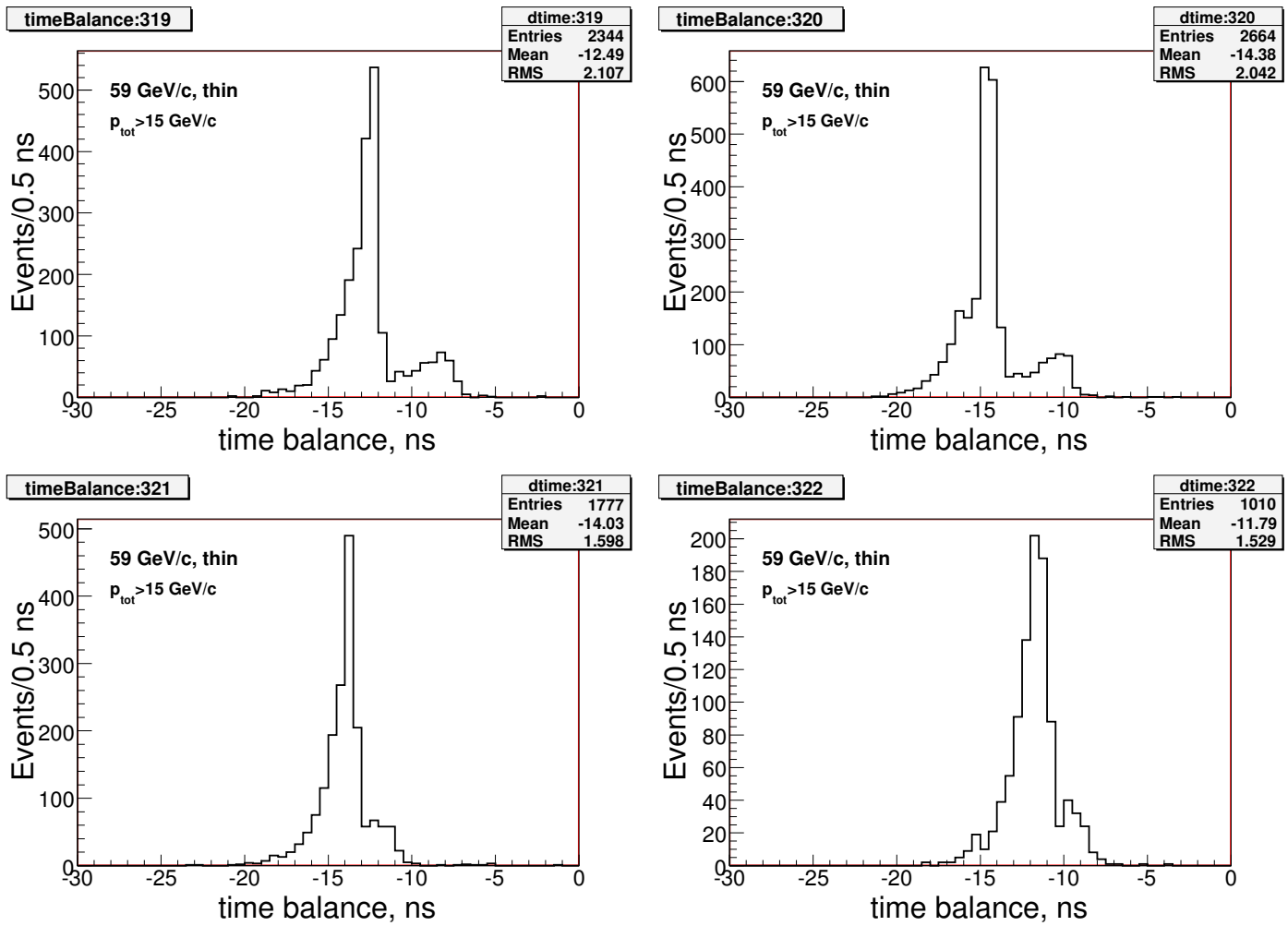
The resulting time balance distributions. Time balance = average Time - t_o - particles arrival time - light travel time from middle of bar to its end.

time balance: 315 - 318



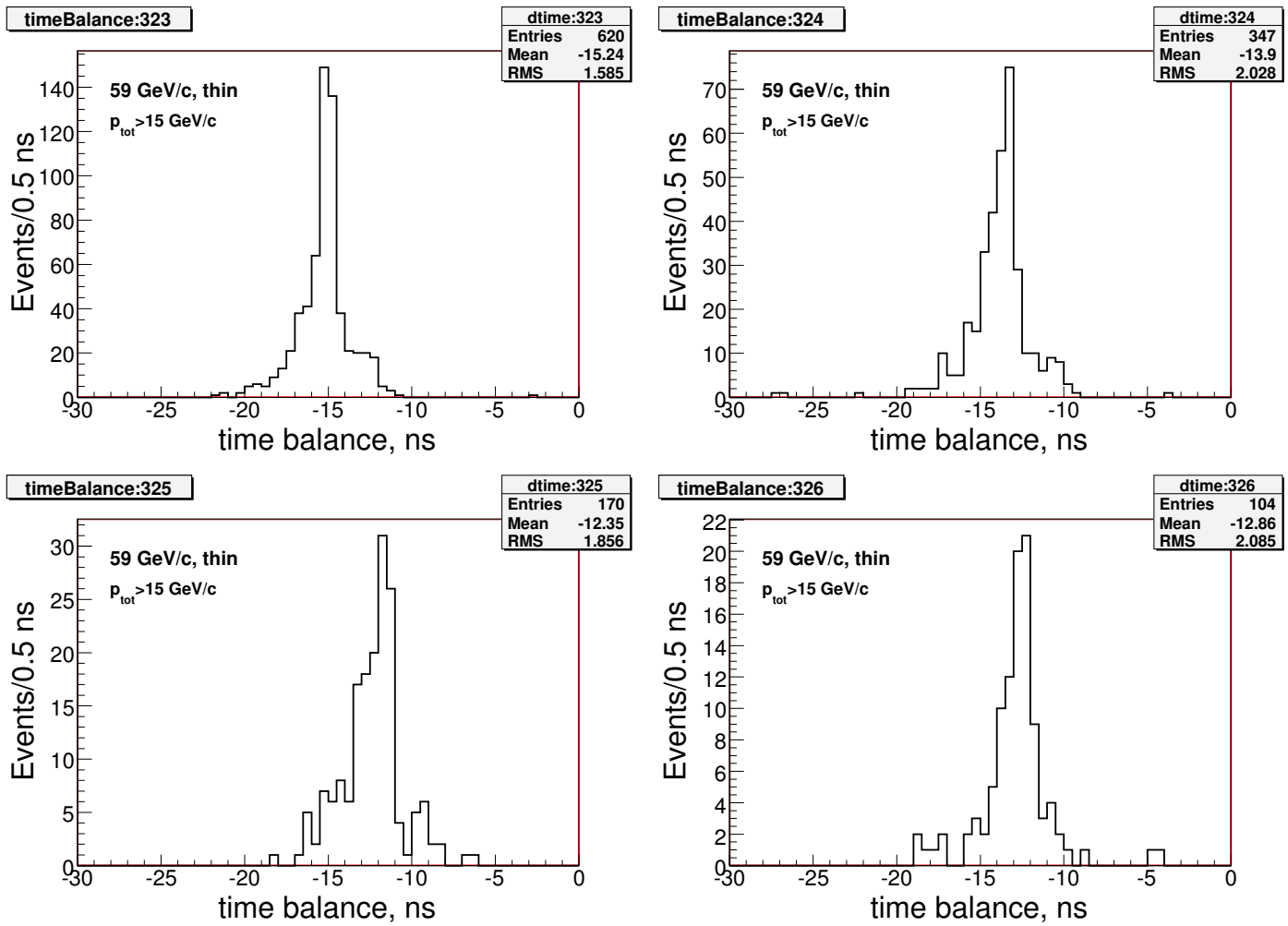
The resulting time balance distributions. Time balance = average Time - t_o - particles arrival time - light travel time from middle of bar to its end.

time balance: 319 - 322



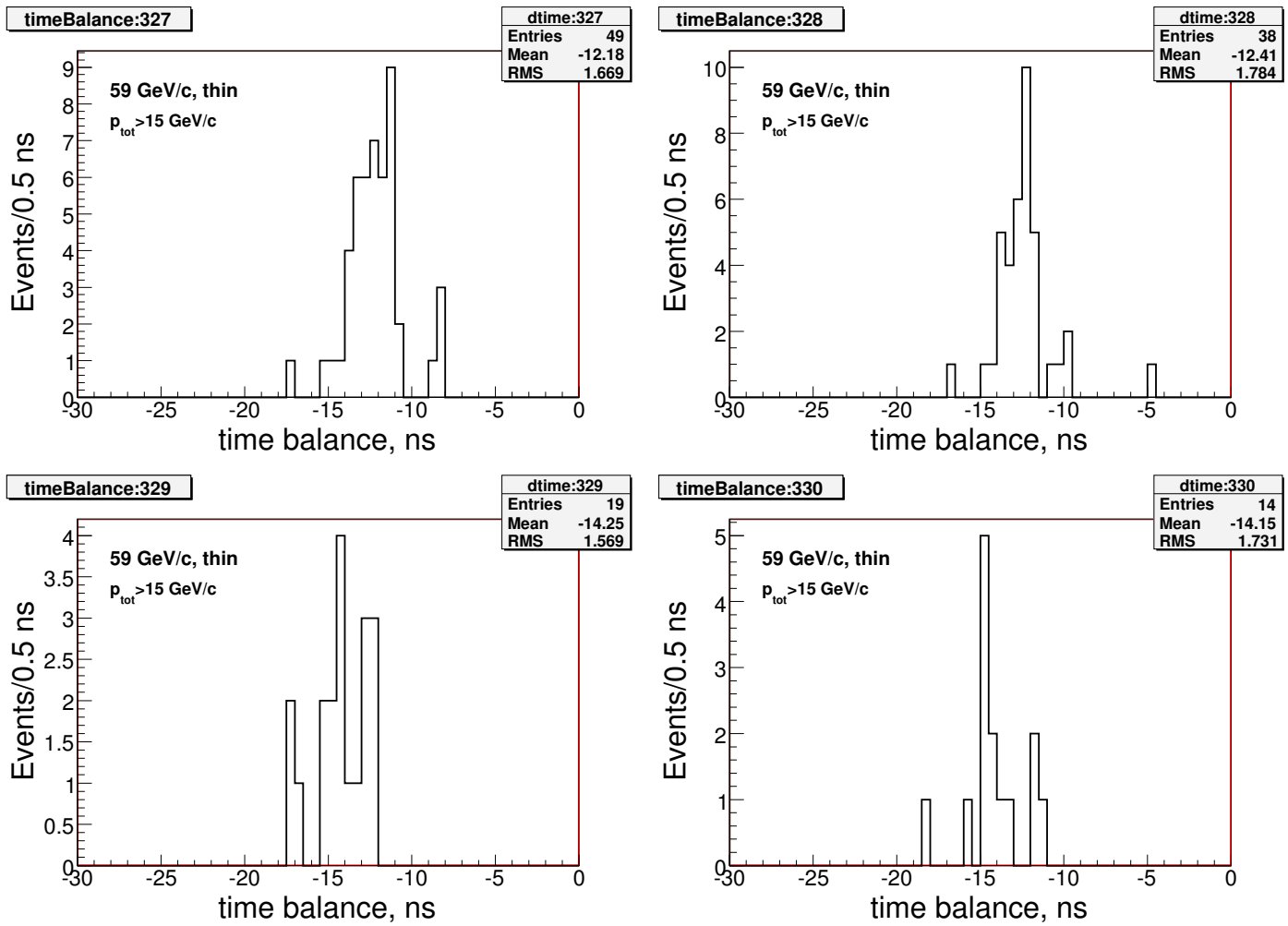
The resulting time balance distributions. Time balance = average Time - t_o - particles arrival time - light travel time from middle of bar to its end.

time balance: 323 - 326



The resulting time balance distributions. Time balance = average Time - t_o - particles arrival time - light travel time from middle of bar to its end.

time balance: 327 - 330



The resulting time balance distributions. Time balance = average Time - t_o - particles arrival time - light travel time from middle of bar to its end.

cross-check

How to calculate the bar length?

bar length = (time$_{total}$ - 2*t$_o$ - 2*t$_{arrival}$ - 2*t$_{deficit}$) * speed

time$_{total}$ = Bottom$_{corr}$ + Top pmt times

t$_o$: the start time

t$_{arrival}$: the particles arrival time = travel distance / speed of light in vacuum

t$_{deficit}$: the time deficit, see time balance plots

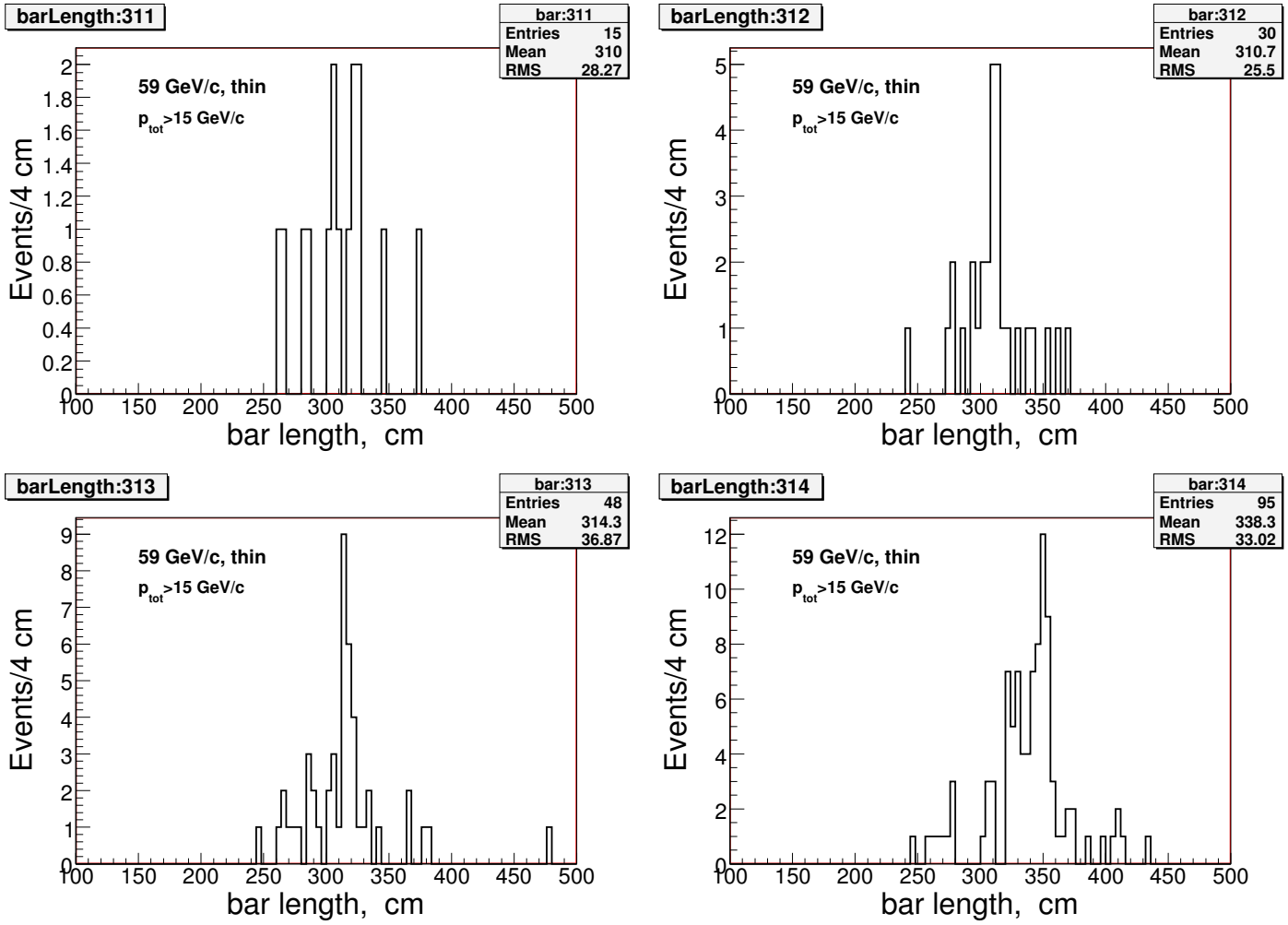
speed: the speed of light in bar, use above calculated values

select the high momentum tracks, p$_{tot}$ $>$15 GeV/c

select particles travel distance within 500 - 510 cm

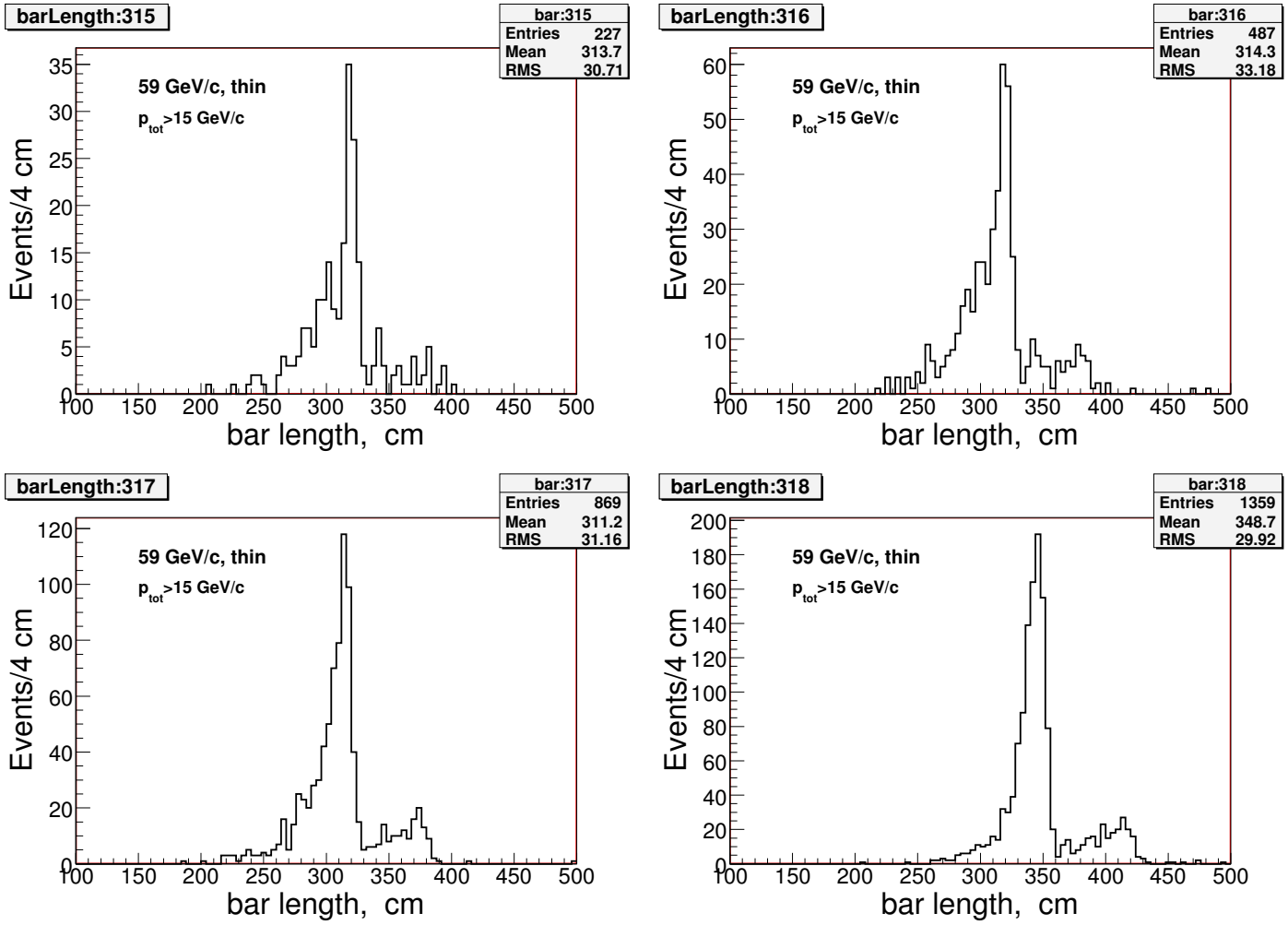
expected bar length: (2*25 - 2*0 - 2*16.9 + 2*13.4)*7.2 = 310 cm

bar length: 311 - 314



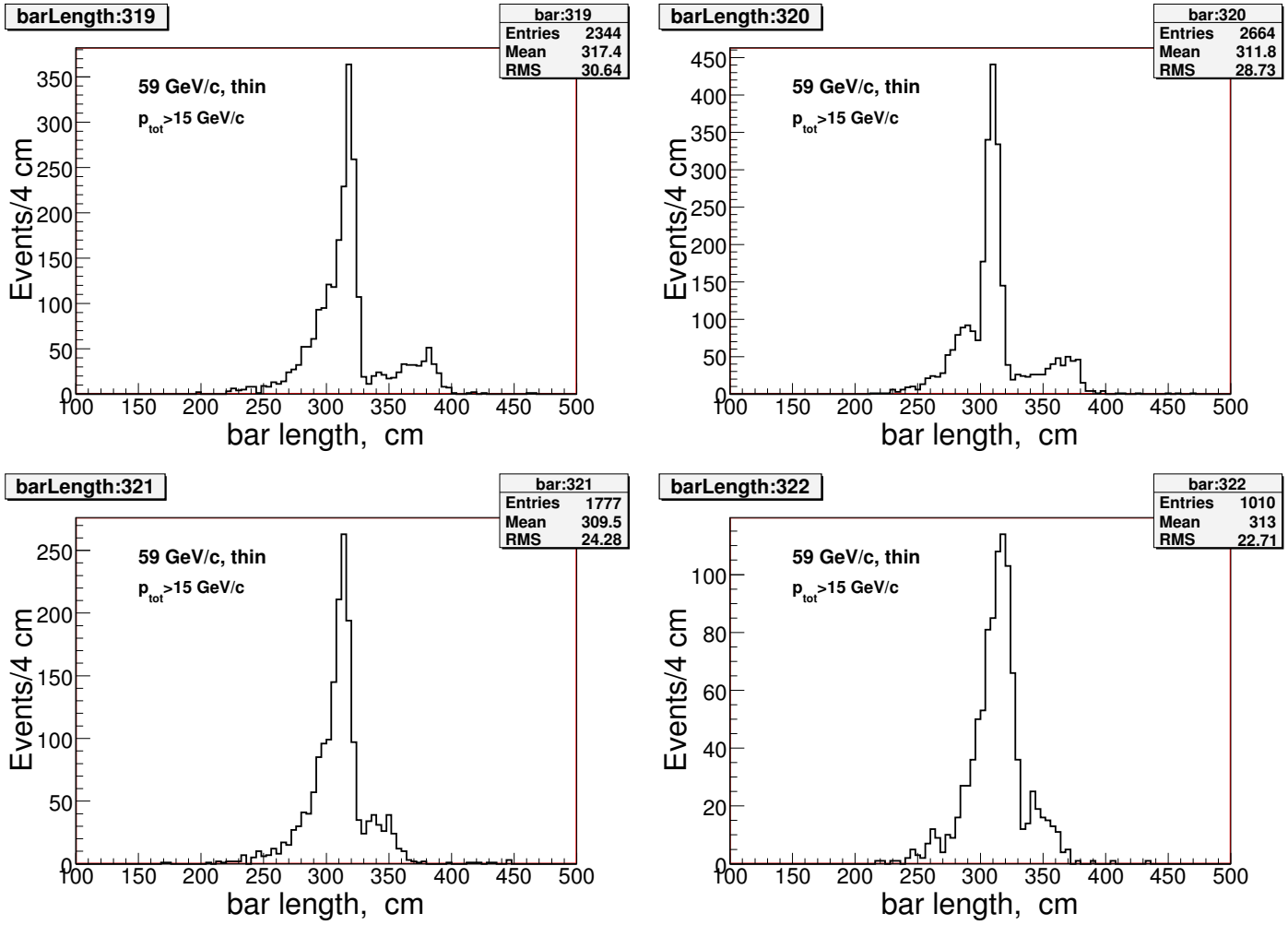
Calculated bar length distributions. Bar length = (time$_{total}$ - 2*t$_o$ - 2*t$_{arrival}$ - 2*t$_{deficit}$) * speed

bar length: 315 - 318



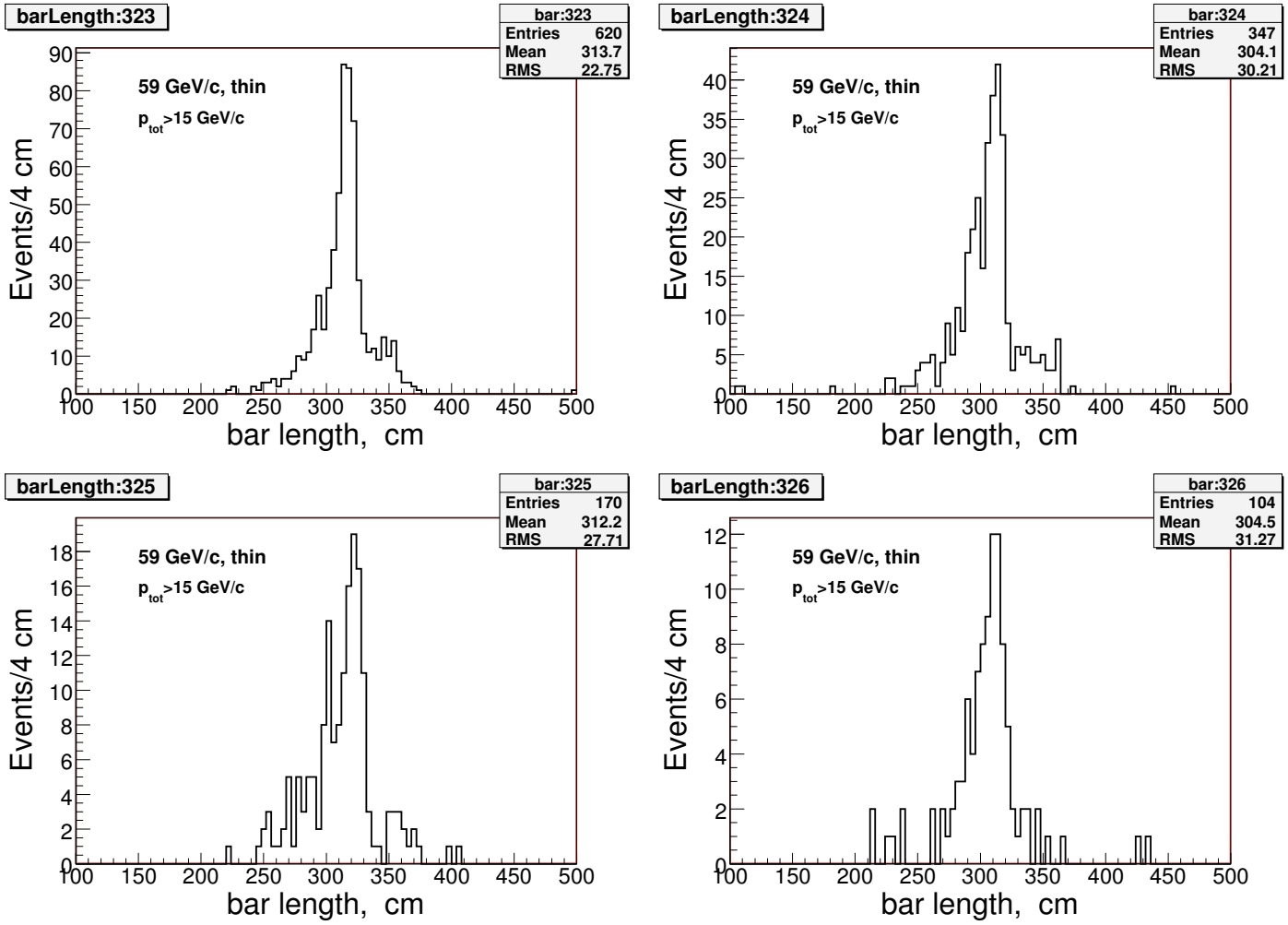
Calculated bar length distributions. Bar length = (time$_{total}$ - 2*t$_o$ - 2*t$_{arrival}$ - 2*t$_{deficit}$) * speed

bar length: 319 - 322



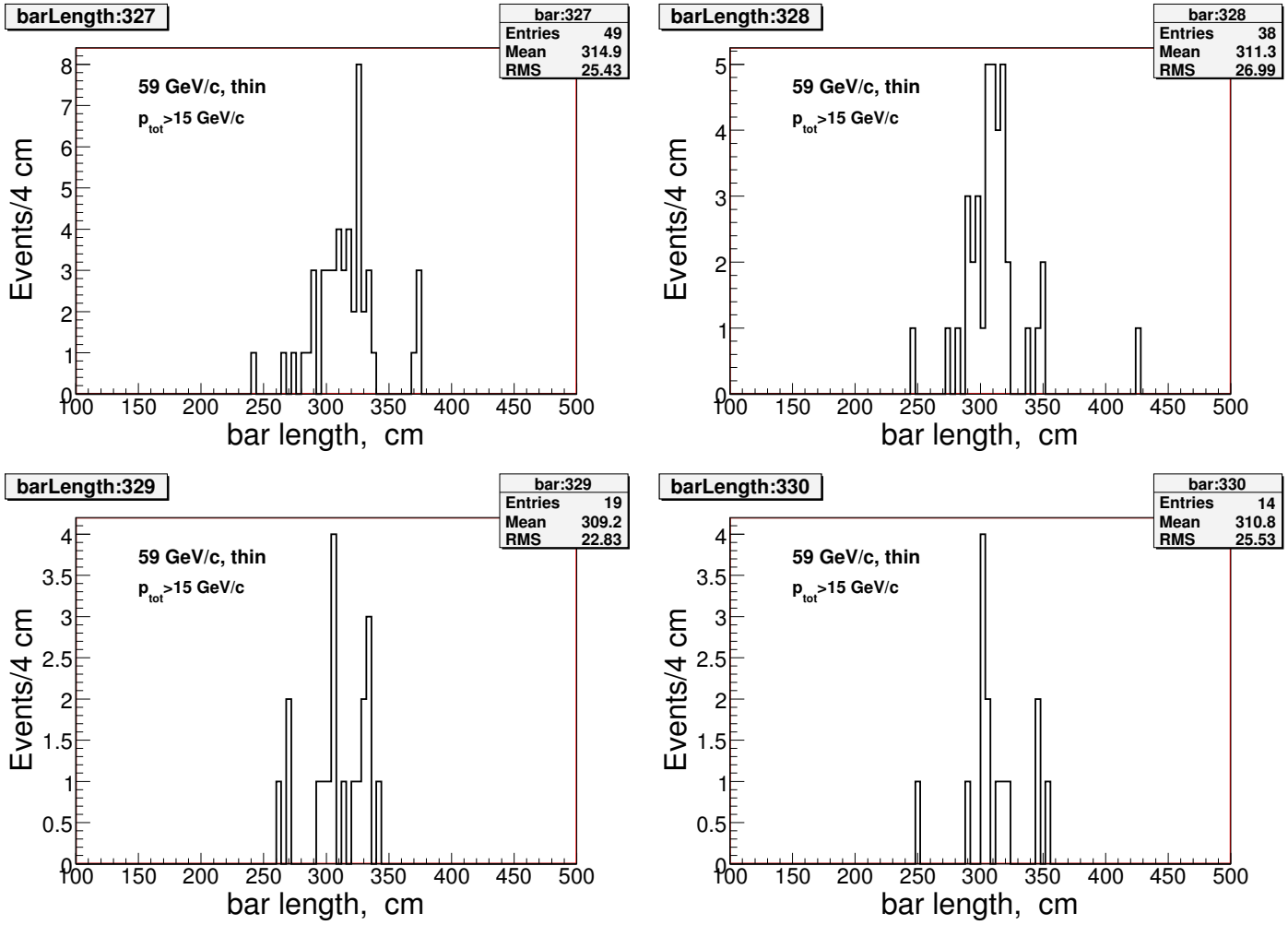
Calculated bar length distributions. Bar length = (time$_{total}$ - 2*t$_o$ - 2*t$_{arrival}$ - 2*t$_{deficit}$) * speed

bar length: 323 - 326



Calculated bar length distributions. Bar length = (time$_{total}$ - 2*t$_o$ - 2*t$_{arrival}$ - 2*t$_{deficit}$) * speed

bar length: 327 - 330



Calculated bar length distributions. Bar length = (time$_{total}$ - 2*t$_o$ - 2*t$_{arrival}$ - 2*t$_{deficit}$) * speed

summary

- Using narrow beam projections at center of bar (0$\pm$10 cm) we found the Bottom - Top pmt's time differences. Resulting Δt values are within 1 - 30 ns range. Bottom pmt time always is greater that Top pmt.
- The widths of Δt distributions can be totally explained by the size of used beam with accuracy in level of 0.3 ns. If there is a temperature dependence then it $\leq$ 0.3 ns.
- The light speed in bar was found by fitting the track Y position vs the Δt time scatter plots. The speed values found to be within 7.0 - 7.6 cm per ns.
- The time balance was calculated for certain bars. Considered pmt's have a time deficit in level of around -13 ns, the full range is from -15ns up to -11ns.
- The bad things (it is not a news): the time balance distribution is broad - about 10 ns wide. Andre's t_o temperature dependence studies shows that the total variation is about 1 ns. How to explain rest 9 ns? Uncertainties with t_o settings? We need the external time source.
- As a cross-check we calculated the bar length. Derived values are consistent with the actual sizes.