HARP Collaboration

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Water data: bad TPC pads, 3.6 μs and 100 ns problems

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Abstract

Out of the 3972 pads of the HARP TPC, about 9% are 'bad' and not useful for the correct reconstruction of clusters. Bad pads comprise dead pads, noisy pads, and pads with low or undefined amplification. Pads may be bad at one time, but not at another. This memo discusses the sources of information which were used to declare a pad 'bad', and gives the list of bad pads for the water data (runs 19146 – 19301). Also, the 3.6 μs and 100 ns problems of the TPC readout are discussed, including the corrective measures which have been taken.

1 Introduction

The HARP TPC has $6 \times 662 = 3972$ pads. A few percent of these pads do not perform like the grand majority, and are not useful for the correct reconstruction of clusters. They require special software action, and therefore the list of bad pads must be known for each data set.

Pads may behave differently at different times. Therefore, the list of bad pads is *a priori* time-dependent. Throughout this paper, the time dependence of the list of bad pads is realized as dependence on run numbers. No finer time quantization is attempted.

The declaration 'bad' comprises three different categories:

1. **'dead'**: pads are considered dead if they give no signal, or an abnormally low signal;
2. **'noisy'**: pads are considered noisy if they show an abnormally high number of 'hits' (i.e. groups of contiguous 100 ns charge samplings above threshold), or an abnormally high time-integrated charge per event;
3. **'abnormal'**: pads are considered abnormal if no non-zero krypton equalization constant could be determined (for details of the procedure, see Ref. [1]).

The list of bad pads stems from different origins:

1. in the course of the analysis of the pulser data taken by V. Serdyuk, during the development of the CERN–Dubna–Milano (CDM) crosstalk correction algorithm [2], dead and noisy pads and, if applicable, their noisy satellites, were identified;
2. further pads with an abnormally low signal were identified during the development of the pad equalization algorithm using clusters from radioactive krypton decays in the TPC gas [1];
3. further noisy pads were identified by a dedicated run-by-run search for an abnormally high number of 'hits' in the water data (runs 19146 — 19301).

The lists of bad pads derived from the crosstalk correction and from the pad equalization are considered stable, while the dedicated run-by-run search may result in lists of bad pads which depend on the run number.

All pad numbers given in this memo are in line with the numbering scheme of Vidal-Sitjes and Prior [3].

2 Noisy parent and satellite pads from crosstalk correction

The analysis of pulser data with a view to developing the CDM crosstalk algorithm, contributed to the list of bad pads the following 273 entries:

Sector 1:
55 107 120 154 170 180 201 361 382 412 426 442 447 474 501 502 537 617 656

Sector 2:
23 24 73 74 75 76 77 78 79 129 130 178 179 220 221 225 226 236 241 253 265 267 268 270 271 282 308 309 313 314 322 350 352 353 361 382 406 408 409 410 411 412 413 442 443 444 445 446 447 454 457 458 474 475 476 477 478 479 486 504 505 506 507 508 509 528 560 569 570 571 572 573 574 575 591 592 593 594 595 596 611 612 613 614 615 616 628 629 630 631 632 633 645 646 652 653 654 655 656 657 658 659 660

Sector 3:
38 39 43 92 148 186 189 308 309 349 361 381 382 418 419 484 518 519 520 521 522 523 538 544 545 546 547

Sector 4:
59 88 122 221 223 224 225 226 267 268 269 270 271 310 311 312 314 352 354 480 568 613 616 630

Sector 5:
1 2 3 4 5 6 56 57 58 59 60 61 66 109 110 111 112 113 114 116 153 159 160 161 162 163 164 165 168 201 242 243 278 329 368 374 376 377 390 401 402 405 406 407 414 436 439 441 469 470 472 473 500 501 502 503 510 511 514 515 529 537 538 563 568 569 571 572 573 574 575 586 591 593 594 595 596 611 612 613 614 615 616 628 629 630 631 632 633 645 657 658

Sector 6:
280 301 473 519 532 659 660 661

3 Pads with an abnormally low signal

The analysis of krypton data with a view to providing pad equalization constants [1], contributed to the list of bad pads the following 147 entries (notice that there is a sizeable overlap with the bad pads listed already in Section 2).

Sector 1:
55 107 118 119 120 154 170 196 201 412 426 442 447 474 501 537 617 656

Sector 2:
23 24 77 78 130 154 178 179 220 227 236 241 253 282 309 313 314 322 352 361 406 447 454 457 458 486 528 560 615 632

Sector 3:
38 39 43 55 92 108 148 189 309 377 418 448 480 484 549 609 623 626

Sector 4:
118 119 120 151 152 153 154 155 156 314 354 393 410 429 430 431 444 445 476 477 480 507 528 529 555 556 568 581 582 583 613 616

Sector 5:
56 66 116 153 154 155 165 168 201 242 243 329 332 333 334 335 336 368 374 376 377 381

382 414 418 419 438 472 510 511 537 538 562 568 639 652

Sector 6:
118 119 120 280 301 473 519 528 529 532 554 555 556

4 Summary list of bad pads

We present below the OR of all stable bad pads. Their total number is 336 (that is 8.5% of all pads of the HARP TPC).

Sector 1:
55 107 118 119 120 154 170 180 196 201 361 382 412 426 442 447 474 501 502 537 617 656

Sector 2:
23 24 73 74 75 76 77 78 79 129 130 154 178 179 220 221 225 226 227 236 241 253 265 267 268 270 271 282 308 309 313 314 322 350 352 353 361 382 406 408 409 410 411 412 413 442 443 444 445 446 447 454 457 458 474 475 476 477 478 479 486 504 505 506 507 508 509 528 560 569 570 571 572 573 574 575 591 592 593 594 595 596 611 612 613 614 615 616 628 629 630 631 632 633 645 646 652 653 654 655 656 657 658 659 660

Sector 3:
38 39 43 55 92 108 148 186 189 308 309 349 361 377 381 382 418 419 448 480 484 518 519 520 521 522 523 538 544 545 546 547 549 609 623 626

Sector 4:
59 88 118 119 120 122 151 152 153 154 155 156 221 223 224 225 226 267 268 269 270 271 310 311 312 314 352 354 393 410 429 430 431 444 445 476 477 480 507 528 529 555 556 568 581 582 583 613 616 630

Sector 5:
1 2 3 4 5 6 56 57 58 59 60 61 66 109 110 111 112 113 114 116 153 154 155 159 160 161 162 163 164 165 168 201 242 243 278 329 332 333 334 335 336 368 374 376 377 381 382 390 401 402 405 406 407 414 418 419 436 438 439 441 469 470 472 473 500 501 502 503 510 511 514 515 529 537 538 562 563 568 569 571 572 573 574 575 586 591 593 594 595 596 611 612 613 614 615 616 628 629 630 631 632 633 639 645 652 657 658

Sector 6:
118 119 120 280 301 473 519 528 529 532 554 555 556 659 660 661

Table 1 gives the total number of stable bad pads for every TPC sector, for the bad pads determined from the crosstalk correction, and from the krypton pad equalization. It also gives the OR of both lists of bad pads.

Figure 1 shows the location of the OR of stable bad pads in the six TPC sectors.

The OR of all stable bad pads is available as text file at the location

http://cern.ch/dydak/ORofbadpads.ca

Table 1: Summary list of stable bad pads for the six TPC sectors.

	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Sum
Crosstalk	19	103	27	24	92	8	273
Krypton	18	30	18	32	36	13	147
OR	22	105	36	50	107	16	336

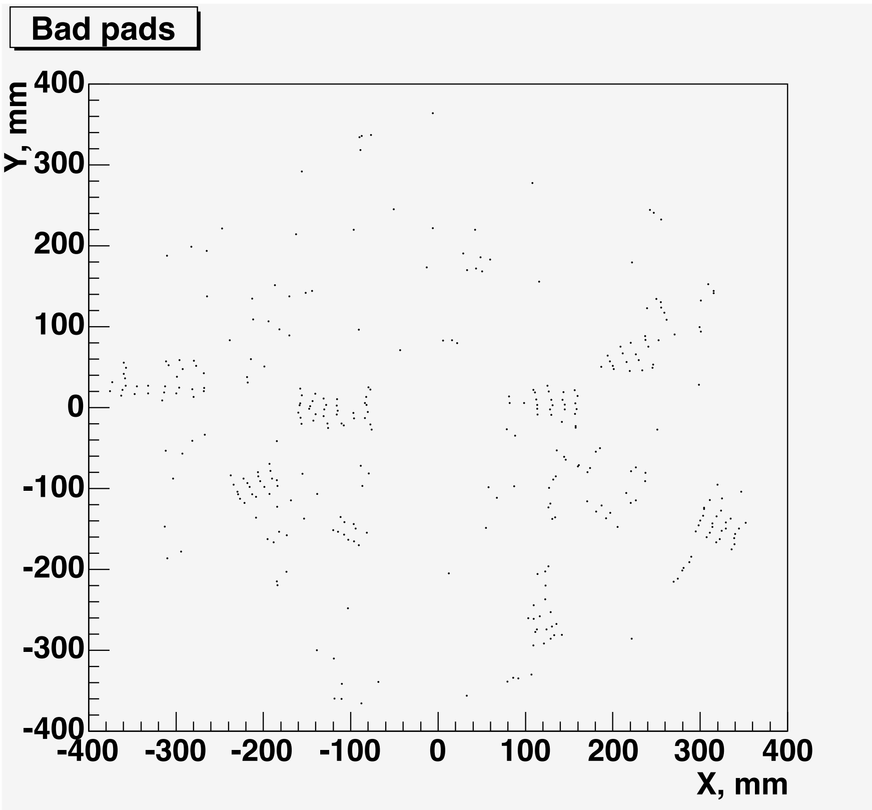

Figure 1: Looking upstream: location of the OR of stable bad pads; sector 1 is top left.

5 Noisy pads in the water data set

A dedicated scan for noisy pads specifically in the thin-water and thick-water data was performed. Pads were declared noisy if they showed a run-averaged number of hits per event at least ten times higher than the typical number of hits per event for 'good' pads. The latter is defined as the run-averaged number of hits per event and pad, from all pads whose number of hits per event is between 0. and 0.1 .

We give here the list of 22 pads (in the format 'sector#/pad#') which were found noisy in **all** water-data runs:

1/111 1/112 1/117 1/334 2/155 2/333 2/334 3/068 3/335 4/103 4/104 4/105 4/106 4/107 4/157 4/203 5/156 5/157 6/107 6/117 6/151 6/334

It is perhaps instructive to give also the list of pads, for each water-data run, which are **not** noisy in all runs:

Run 19146
2/335 3/332 4/201 4/628 5/295 6/333 6/335

Run 19147
1/335 2/335 3/332 4/201 4/628 5/295 6/157 6/333 6/335 6/450

Run 19148
2/335 3/332 4/201 4/628 5/295 6/333 6/335

Run 19149
2/335 3/332 4/201 4/333 5/295 6/104 6/157 6/333 6/335

Run 19151
2/335 3/332 4/201 5/295 6/333 6/335

Run 19152
2/335 3/332 4/201 4/628 5/295 6/333 6/335

Run 19153
2/335 3/332 4/201 4/628 5/295 6/333 6/335 6/450

Run 19154
1/335 2/335 3/332 4/201 4/334 4/628 5/295 6/157 6/333 6/335

Run 19155
2/335 3/332 4/201 4/628 5/295 6/157 6/333 6/335

Run 19156
2/335 3/332 4/201 4/628 5/295 6/157 6/333 6/335

Run 19157
2/335 3/332 4/201 4/628 5/295 6/157 6/333 6/335

Run 19158
2/335 3/332 4/201 4/333 5/295 6/157 6/333 6/335

Run 19159
2/335 3/332 4/201 4/333 4/628 5/295 6/157 6/333 6/335 6/450

Run 19160
2/335 3/332 4/201 4/628 5/295 6/333 6/335

Run 19161
2/335 3/332 4/201 4/628 5/295 6/333 6/335

Run 19162
2/335 3/332 4/201 4/333 4/628 5/295 6/333 6/335

Run 19163
2/335 3/332 4/201 4/333 4/628 5/295 6/157 6/333 6/335

Run 19164
1/335 2/335 3/332 4/201 4/333 4/628 5/295 6/157 6/333 6/335

Run 19165
1/335 2/335 3/332 4/201 4/334 4/628 5/295 6/157 6/333 6/335

Run 19166
2/335 3/332 4/201 4/628 5/295 6/157 6/333 6/335

Run 19167
1/335 2/335 3/332 4/201 4/333 5/295 6/157 6/333 6/335

Run 19168
1/333 1/335 2/335 3/332 4/201 4/333 4/628 5/295 6/157 6/333 6/335

Run 19169
1/333 1/335 2/335 3/332 4/201 4/334 4/628 5/295 6/157 6/333 6/335

Run 19170
1/333 1/335 2/335 3/332 4/201 4/333 4/628 5/295 6/157 6/333 6/335

Run 19209
2/335 3/332 4/201 4/333 5/295 6/157 6/333 6/335

Run 19211
2/335 3/332 4/201 4/333 4/628 5/295 6/104 6/335

Run 19212
2/335 3/332 4/201 4/628 6/335

Run 19213
2/335 3/332 4/201 4/628 6/335

Run 19216
2/335 3/332 4/201 4/628 5/295 6/333 6/335

Run 19219
2/335 3/332 4/201 4/628 6/104 6/333 6/335

Run 19220
2/335 4/201 4/628

Run 19221
2/335 3/332 4/201 6/335

Run 19223
2/335 3/332 4/201 4/628 6/335

Run 19224
2/335 3/332 4/201

Run 19225
2/335 3/332 4/201 4/628

Run 19226
2/335 3/332 4/201 4/628

Run 19227
2/335 4/628 6/335

Run 19228
2/335 3/332 4/201 4/628 6/335

Run 19229
2/335 4/201 4/628 6/333 6/335

Run 19230
2/335 4/201 4/628 6/335

Run 19231
2/335 4/201 4/628 6/335

Run 19233
2/335 4/201 4/628 6/333 6/335

Run 19234
2/335 3/332 4/201 4/628 6/333 6/335

Run 19235
2/335 4/201 4/628 6/335

Run 19237
1/335 2/335 4/201 4/628 6/333 6/335

Run 19238
2/335 4/201 4/628 6/335

Run 19239
2/335 4/201 4/628 6/335

Run 19240
2/335 3/332 4/201 6/335

Run 19241
2/335 4/201 4/628 6/333 6/335

Run 19242
2/335 4/201 4/628 6/335

Run 19243
2/335 4/201 4/628 6/104 6/335

Run 19244
2/335 3/332 4/201 4/628 6/335

Run 19245
2/335 3/332 4/201 4/628 6/335

Run 19246
2/335 3/332 4/201 4/628 6/333 6/335

Run 19247
1/335 2/335 4/201 4/628 5/295 6/333 6/335

Run 19248
2/335 4/201 4/628 6/335

Run 19249
4/628 5/295 6/335

Run 19250
2/335 4/201 4/628 6/335

Run 19251
2/335 4/201 6/335

Run 19252
1/335 2/335 4/201 5/295 6/333 6/335

Run 19253
1/333 1/335 2/335 3/332 4/201 4/333 4/334 5/295 6/104 6/157 6/333 6/335 6/450

Run 19299
1/335 2/335 3/332 4/ 53 4/201 4/333 4/334 5/257 5/295 6/104 6/157 6/333 6/335 6/450

Run 19300
1/113 1/335 2/335 3/332 4/201 4/333 4/628 5/257 5/295 6/104 6/155 6/157 6/333 6/335 6/450

Run 19301
1/113 1/335 2/335 3/332 4/ 53 4/201 4/333 4/628 5/257 5/295 6/104 6/157 6/333 6/335 6/450

The above list of noisy pads specifically in the water data is available as text file at the location

http://cern.ch/dydak/badpadswater.ca

6 The 3.6 μs problem

The sampling of pad charges every 100 ns starts when a gate opens $\sim$ 3.6 μs after the time of the event trigger. The sampling itself is driven by a free-running 10 MHz clock. In order to avoid a random time difference between zero and 100 ns between the trigger and the first sampling, this time difference is measured in a TDC.

Unfortunately, in $\sim$ 17% of the events, this measurement the normal result of which is shown in Fig. 2, failed and returned 'zero'. This hardware failure became known as the '3.6 μs problem'.

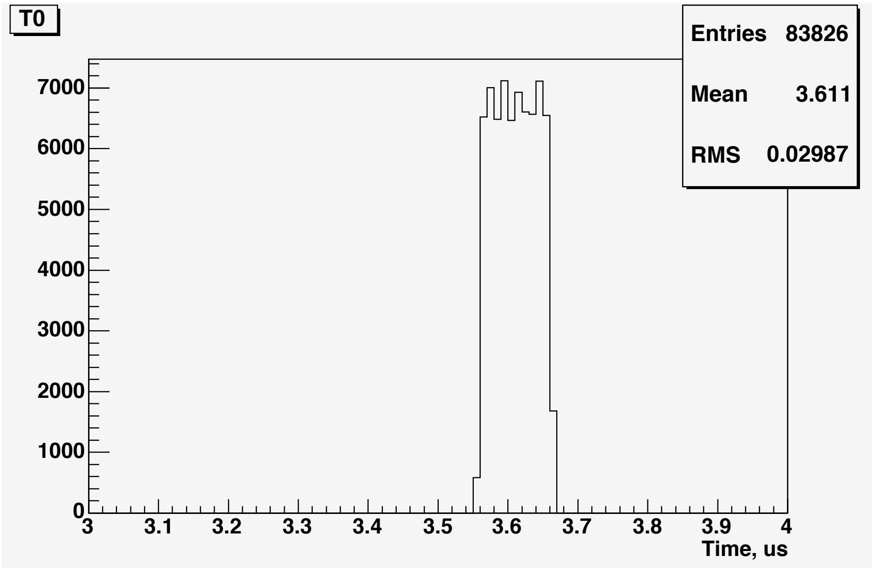

Figure 2: Time delay of the start of charge sampling with respect to the trigger time.

The solution is that whenever 'zero' is found for this time, it is replaced by the average of 3.61 μs. This introduces for these events a jitter in the z coordinate of up to ± 50 ns, with a $\sigma = 29$ ns or 1.4 mm. While keeping this problem in mind, it is considered of minor importance for physics data analysis.

7 The 100 ns problem

In the pulser data campaign carried out by V. Serdyuk, it was noticed that the pulses of some pads were systematically advanced by 100 ns. Figure 3 shows the evidence for this problem in the plot of the start of the pulse versus the TPC pad number from 1 to 3972.

The 100 ns problem is a real advance in time and not an artefact caused, perhaps, by a baseline shift. This can be concluded from Fig. 4 which shows from pulser data in the TPC sector 1 the correlation between the r.m.s. pulse width and the average time of the pulse; two parallel bands shifted by 100 ns with respect to each other are clearly visible (the attentive reader will also notice the clustering of the r.m.s. pulse width into three distinct regions: the Type1, Type2 and Type3 pulseshapes reflecting different self-crosstalk behaviour, see Ref. [4]).

The problem is strongly correlated with groups of 24 pads the signals of which are transmitted by 'microflex' cables from the TPC pad plane to the FADC's. That can be concluded from Fig. 5 which shows the location of pads affected (upper plot) and not affected (lower plot), respectively, by the 100 ns problem.

We note that each FADC unit receives two such microflex cables. Especially Sector 1 (left top sector in Fig. 5) invites the conclusion that the 100 ns problem is actually correlated with FADC units, since pad islands from **both** pad regions connected by the two microflex

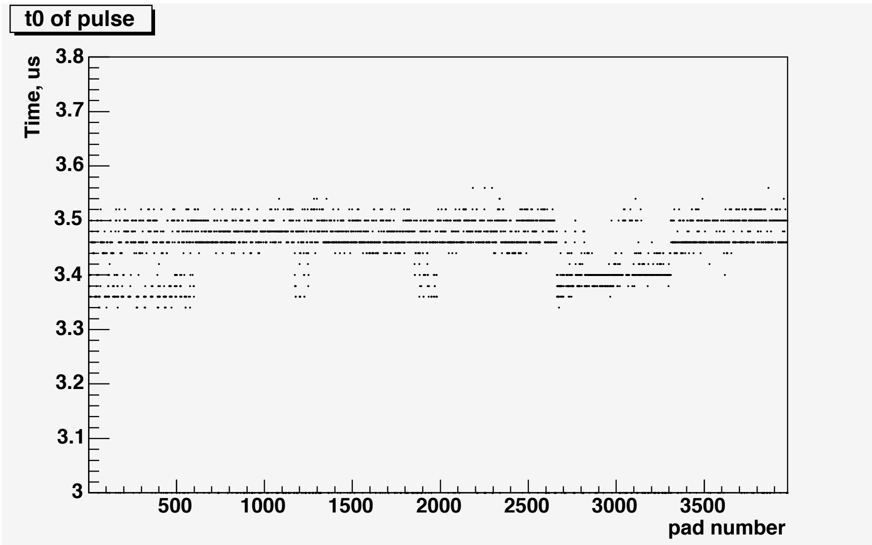

Figure 3: Time of start of pulse as a function of TPC pad number; from pulser data.

cables of the FADC unit are affected. However, there is also some evidence against this conclusion from a few pad islands connected to single microflex cables, in Sectors 2 to 5.

The 100 ns problem is conjectured to be rooted in the circuitry inside the FADC which latches the (random) trigger signal to the (free-running) 10 MHz clock which governs the 100 ns sampling sequence. This circuitry, although identical in design, physically exists separately for the inputs connected to the upper and lower microflex cables [5].

The suspicion that the 100 ns problem may be an artefact of the pulser data only, caused for example by a correlation between the pulser trigger and the 100 MHz clock of the Flash ADC's, is ruled out: Fig. 2 demonstrates that the trigger was randomly distributed over 100 ns in time with respect to the 10 MHz clock.

In order to prove that the 100 ns problem is also present in physics data, and therefore needs to be corrected, we show in Fig. 6 the reconstruction of the z position of a 20.3 mm thick Be target in +8.9 GeV/c data. We wish to stress at this stage of our work that no TPC distortion correction is yet applied, by contrast to the CDM crosstalk correction which is applied to the data. Therefore, the global z correction has not yet been applied and the absolute z coordinate has no precise meaning yet. Rather, the intention is to demonstrate that the reconstructed target position from tracks in sector 5 is **relatively** shifted by approximately 5 mm (= 100 ns) to smaller z values with respect to other sectors. We remind that sector 5 sticks out as the sector which is almost completely beset with the 100 ns problem, by contrast to other sectors.

We give below the list of pads which are affected by the 100 ns problem:

Sector 1:
1 2 3 4 5 6 7 8 9 10 11 12 13 37 38 39 40 41 42 43 44 45 46 47 48 49 55 56 57 58 59 60 61 62 63 64 65 66 92 93 94 95 96 98 99 100 101 102 107 109 110 111 112 113 114 115 116 117 118 119 120 138 140 142 143 144 145 146 147 148 149 150 151 152 154 159 160 161 162 163 164 165 166 167 168 169 170 180 187 188 190 191 192 193 194 195 196 197 198 199 200 201 227

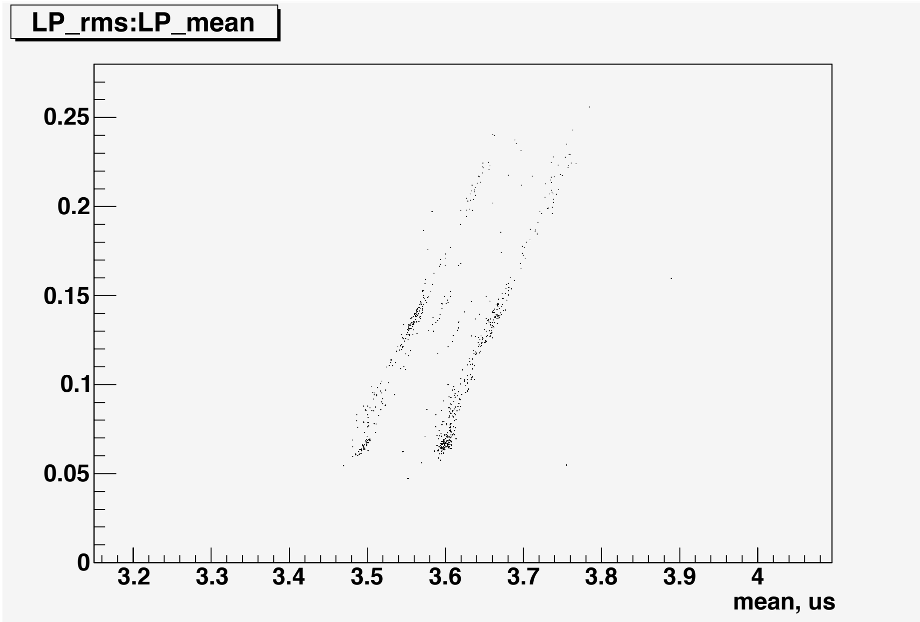

Figure 4: RMS pulse width versus average time of pulses in the pulser data of Sector 1.

228 229 230 231 232 233 234 235 236 237 238 239 256 272 273 274 275 276 277 278 279 280 281 282 283 284 290 314 315 316 317 318 319 320 321 322 323 324 325 354 355 356 357 358 359 360 361 362 363 364 365 382 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 412 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 447 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 490 491 492 493 494 495 496 497 498 499 500 501 502 503 517 518 519 520 521 522 523 524 525 526 527 528 529 537 544 545 546 547 548 549 550 551 552 553 554 565 566 570 576 577 578 579 592 597 598 599 617 656

Sector 2:
23 24 73 74 75 76 77 78 79 129 130 154 178 179 189 201 220 221 225 226 236 241 253 265 266 267 268 270 271 282 308 309 313 314 322 350 352 353 361 382 406 408 409 410 411 412 413 418 442 443 444 445 446 447 454 457 458 463 474 475 476 477 478 479 486 504 505 506 507 508 509 511 512 513 514 515 516 520 521 524 525 528 537 538 540 541 542 550 551 560 563 564 565 566 569 570 571 572 573 574 575 586 588 589 591 592 593 594 595 596 611 612 613 614 615 616 628 629 630 631 632 633 645 646 647 652 653 654 655 656 657 658 659 660

Sector 3:
38 39 43 58 92 107 108 148 163 164 186 189 234 278 308 309 333 334 349 361 379 380 381 382 416 417 418 419 429 448 450 451 452 453 475 480 481 482 483 484 490 493 513 518 519 520 521 522 523 530 531 532 533 538 544 545 546 547 548 549 556 557 558 559 560 565 566 567 570 574 580 581 582 583 584 590 591 592 603 604 605 606 607 608 609 610 623 624 625 626 627 639 640 641 642 643 644 652 653 654 655 656

Sector 4:
59 88 98 122 221 222 223 224 225 226 265 267 268 269 270 271 310 311 312 314 352 354 480 520 568 613 614 615 616 622 630 632 633

Sector 5:
1 2 3 4 5 6 10 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 66 67 68 69 70 71 72 73 74 75 77 78 79 80 81 82 83 85 86 87 88 89 90 91 92 93 94 95 96 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 116 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 156 157 158 159 160 161 162 163 164 165 168 172 173 174 175 176 177 178 179 180 181 182 183 184 185 187 188 190 191 193 194 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 347 348 349 350 352 353 354 355 356 357 358 359 360 361 362 363 364 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 382 383 384 385 386 387 388 389 390 401 402 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 436 439 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 460 464 465 466 467 469 470 472 473 474 475 476 477 480 481 482 483 484 485 486 489 490 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 556 557 558 559 560 561 562 563 564 565 566 568 569 570 571 572 573 574 575 576 577 578 580 581 582 584 585 586 587 588 589 591 592 593 594 595 596 597 599 600 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 620 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 656 657 658 659 661 662

Sector 6:
4 37 39 44 59 109 145 214 218 225 226 270 271 280 301 306 399 403 418 419 434 460 465 468 473 496 519 520 521 527 530 531 532 545 546 547 549 562 563 565 587 622 659 660 661

The list of pads with the 100 ns problem is available as text file at the location

http://cern.ch/dydak/100nsproblempads.ca

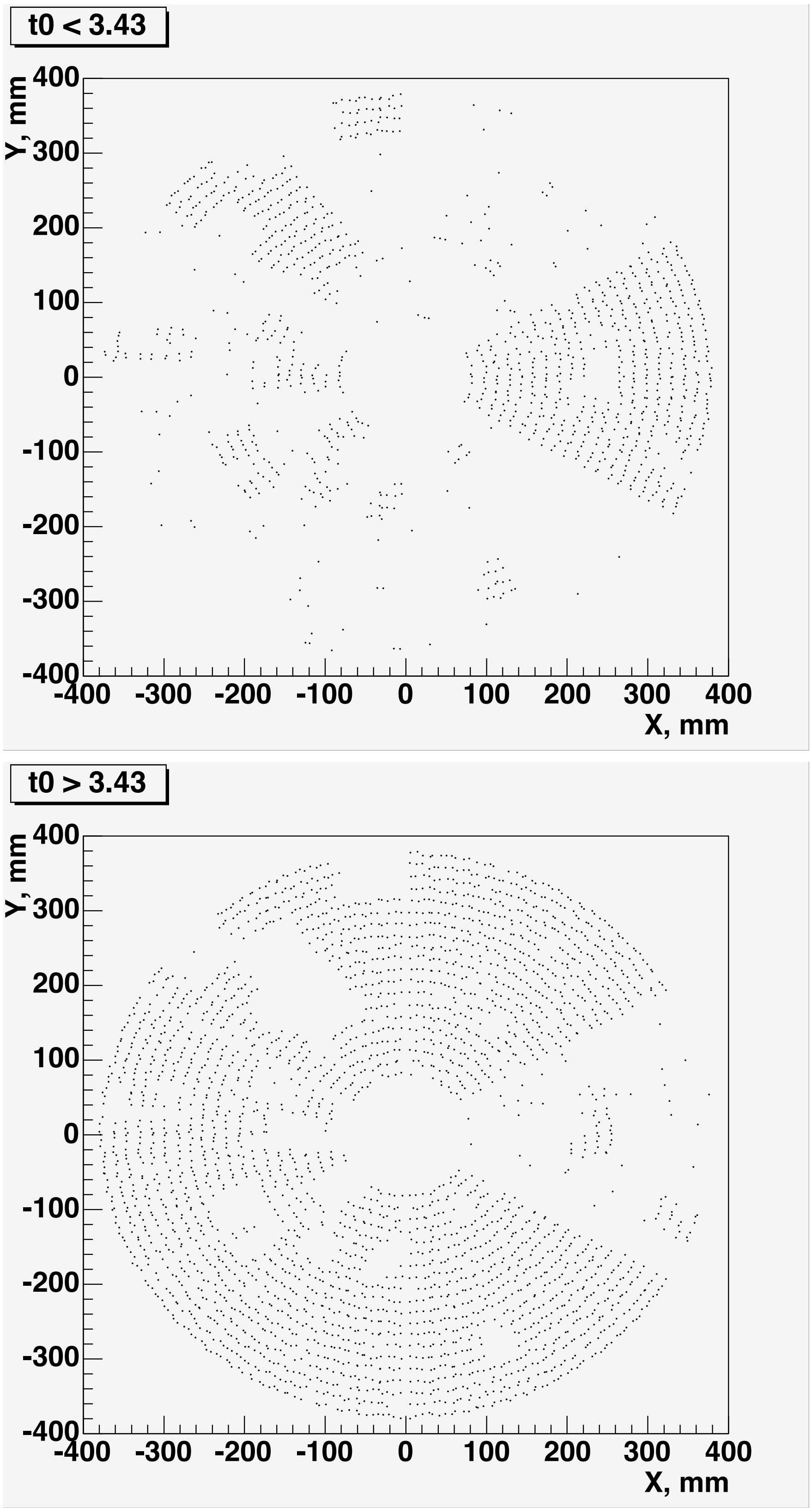

Figure 5: Looking upstream: position of pads affected by the 100 ns problem (top), and not affected by the 100 ns problem (bottom); sector 1 is top left.

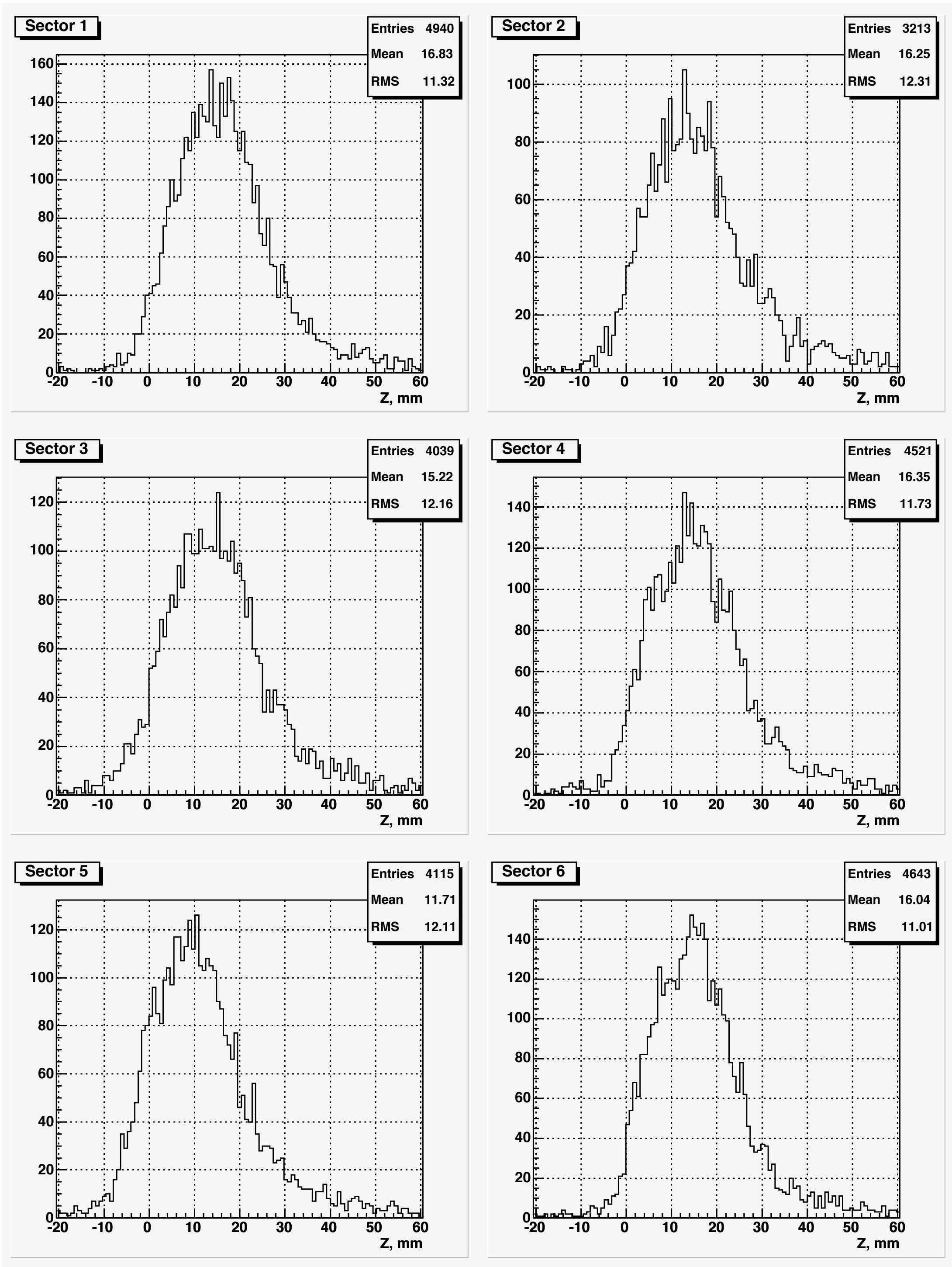

Figure 6: Reconstructed thin-target positions from tracks in the six TPC sectors.

References

[1] A. De Min and F. Dydak, Analysis of HARP TPC krypton data, HARP Memo 04-xxx (submitted 28 April 2004), *http://cern.ch/dydak/kryptonCalib.ps*

[2] A. De Min *et al.*, TPC cross-talk correction: CERN–Dubna–Milano algorithm and results, HARP Memo 03-003, *http://cern.ch/dydak/crosstalk3.ps*

[3] G. Vidal-Sitjes and G. Prior, TPC mapping and data packing conventions, HARP TPC note (DEAFT), dated 3.3.2004.

[4] F. Dydak *et al.*, On TPC cluster reconstruction, HARP Memo (in preparation).

[5] L. Musa, private communication.