Adding Stereo Hits in Final COT Fit

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Overview

- COT Pattern Recognition (CDF 6992)
  - Two linking algorithms: Segment-L and Histogram-L
  - The two sets of tracks are merged at the end; duplicates removed
    - Merging favors the SL; SL tracks has lower effic for high-p_T tracks.
      - An SL track with $\geq 3/3$ stereo/axial SLs each with at least 6 hits, at least 20/20 stereo/axial hits is always kept against the any duplicate HL track
  - There are tracks with no hits in the inner superlayers (overlapping hits, busy events)
    - Try to recover missing stereo segments (SL1, SL3):
      - Add hits, refit and keep the hits if they pass quality criteria
      - Done just before the merging
- Various studies using $Z \to \mu^+\mu^-$ (high-pt) and $J/\Psi \to \mu^+\mu^-$ (low-pt) to evaluate the effect of the hits recovery

Study Overview

Compare COT tracks in 4 cases:

- default: using 5.3.1 CT Tracking .
- 6h400mc: recover ST SL hits iff $\geq$ 6 hits/SL, road $<$ 400 μm.
- 5h400mc: recover ST SL hits iff $\geq$ 5 hits/SL, road $<$ 400 μm.
- 5h500mc: recover ST SL hits iff $\geq$ 5 hits/SL, road $<$ 500 μm.

Compare the effect of the hit recovery on various track quality cuts applied to COT-tracks (See JPM, Tracking Quality Cuts, Nov 22nd, 2004.).

- default: defTrack: $\geq$ 2/2 axial/stereo SL's with $\geq$ 5 hits each
- loose: $\geq$ 3 axial SL, $\chi^2/dof < 4$
- tight: $\geq$ 3/3 axial/stereo SL's, $\chi^2/dof < 3$

Type of tracks used:

- Use COT-BC tracks for $Z \rightarrow \mu^+\mu^-$ studies
- Use COT-NONBC tracks for $J/\Psi \rightarrow \mu^+\mu^-$ studies

$Z \to \mu^+\mu^-$ Selection

Apply the baseline selection described in CDF 7031.

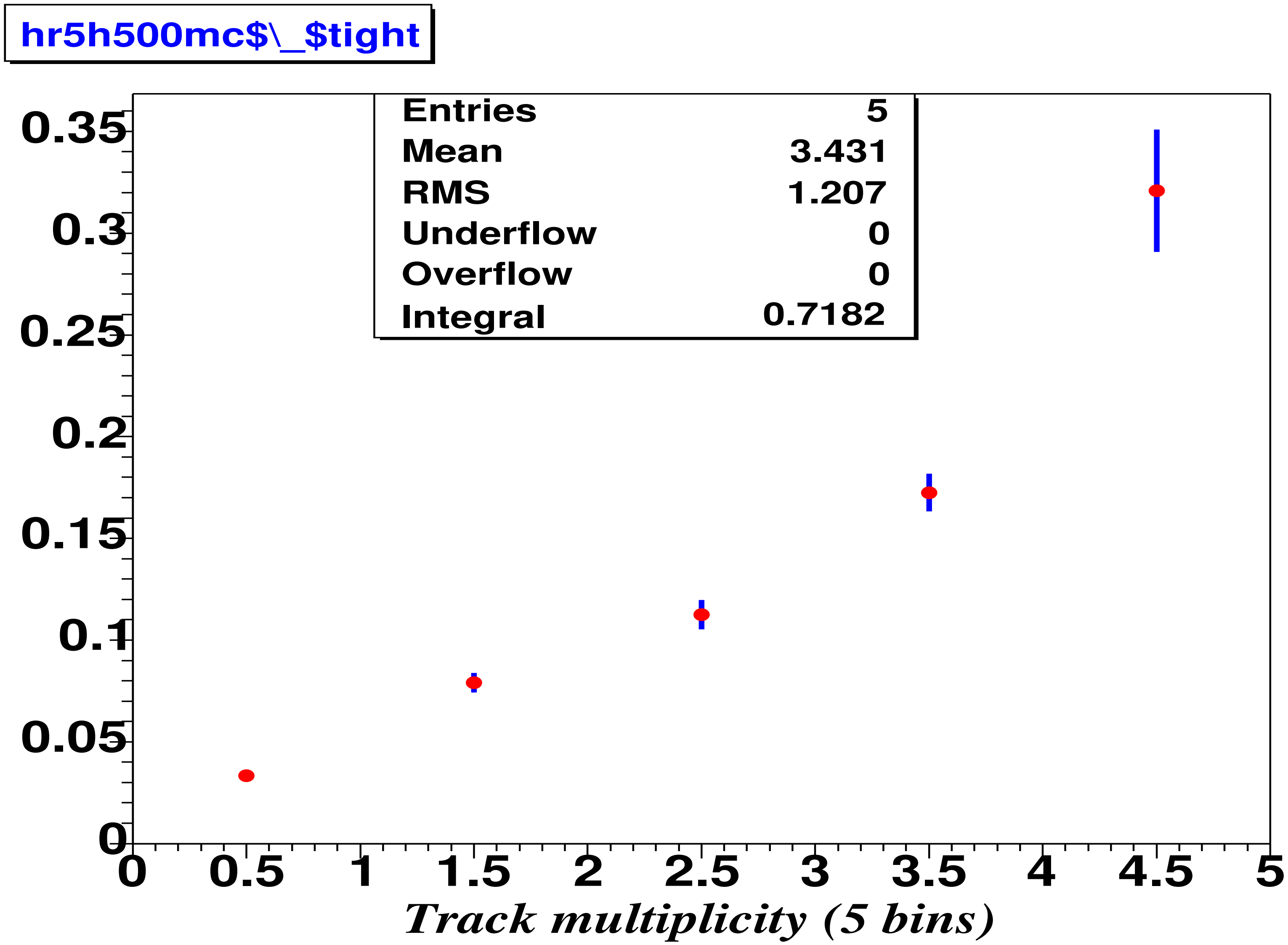
- A CMUP or CMX + a STUBLESS muon
  - $P_T > 25$ GeV
  - opposite-sign
  - COT exit radius cut for CMX muons
  - in the mass window (75, 105) GeV
- For COT-BC tracks apply "Larry Corrections" CDF 6971
- List of good runs, version 6.0
- Use the dataset zewk2d (stripped Z loose sample)

$J/\Psi \to \mu^+\mu^-$ Selection

Apply the baseline selection described in CDF 6663.

- 2 muons (CMUP or CMX)
  - $p_T > 1.4$ GeV
  - opposite-sign
  - mass window (3.01, 3.15) GeV
  - sideband subtraction: (2.85, 2.99) GeV and (3.17, 3.31) GeV
- Use COT-NONBC tracks
- List of good runs, version 6

$Z \to \mu^+\mu^-$- Frac of tracks w/o hits in SL1 vs trk. mult.

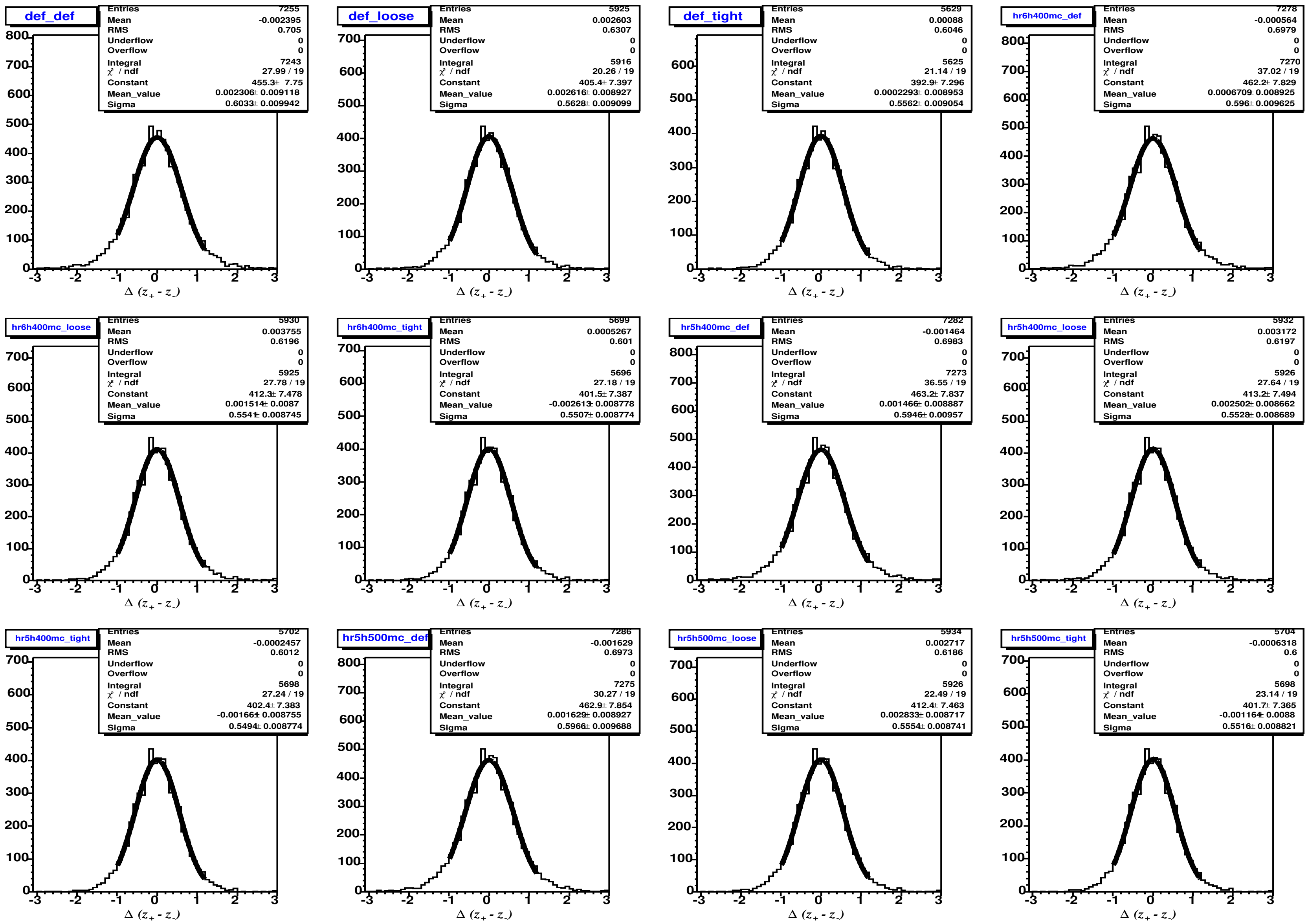


$Z \rightarrow \mu^+\mu^-$- Frac of tracks w/o hits in SL1 vs trk. mult.- defTracks

TrackRec/TrackQual	Trks 1	Trks 2	Trks 3	Trks 4	Trks 5
def_def	0.0422 ± 0.0026	0.0976 ± 0.0048	0.144 ± 0.0071	0.239 ± 0.0093	0.446 ± 0.029
def_loose	0.0457 ± 0.0031	0.105 ± 0.0054	0.159 ± 0.0081	0.263 ± 0.011	0.493 ± 0.03
def_tight	0.0429 ± 0.003	0.0968 ± 0.0053	0.147 ± 0.008	0.234 ± 0.011	0.424 ± 0.035
hr6h400mc_def	0.0342 ± 0.0024	0.0807 ± 0.0044	0.115 ± 0.0064	0.194 ± 0.0086	0.344 ± 0.027
hr6h400mc_loose	0.0368 ± 0.0028	0.088 ± 0.005	0.126 ± 0.0073	0.214 ± 0.0097	0.393 ± 0.029
hr6h400mc_tight	0.0348 ± 0.0027	0.08 ± 0.0049	0.115 ± 0.0072	0.188 ± 0.0096	0.343 ± 0.031
hr5h400mc_def	0.0332 ± 0.0024	0.0795 ± 0.0043	0.112 ± 0.0063	0.186 ± 0.0085	0.327 ± 0.026
hr5h400mc_loose	0.0359 ± 0.0028	0.0868 ± 0.005	0.123 ± 0.0072	0.206 ± 0.0096	0.366 ± 0.028
hr5h400mc_tight	0.034 ± 0.0027	0.0791 ± 0.0048	0.112 ± 0.0071	0.18 ± 0.0094	0.319 ± 0.03
hr5h500mc_def	0.0327 ± 0.0024	0.0792 ± 0.0043	0.112 ± 0.0063	0.181 ± 0.0083	0.33 ± 0.026
hr5h500mc_loose	0.0353 ± 0.0028	0.0864 ± 0.005	0.123 ± 0.0072	0.199 ± 0.0094	0.367 ± 0.028
hr5h500mc_tight	0.0334 ± 0.0027	0.079 ± 0.0048	0.112 ± 0.0071	0.172 ± 0.0093	0.321 ± 0.03

- def $\rightarrow$ hr6h400mc: $\approx 20\%$ segment recovery
- hr6h400mc $\rightarrow$ hr5h400mc: $\approx 2\%$ segment recovery
- hr5h400mc $\rightarrow$ hr5h500mc: $\approx 2\%$ segment recovery

$Z \to \mu^+\mu^-\ \Delta(z_+ - z_-)$ - Comparisons

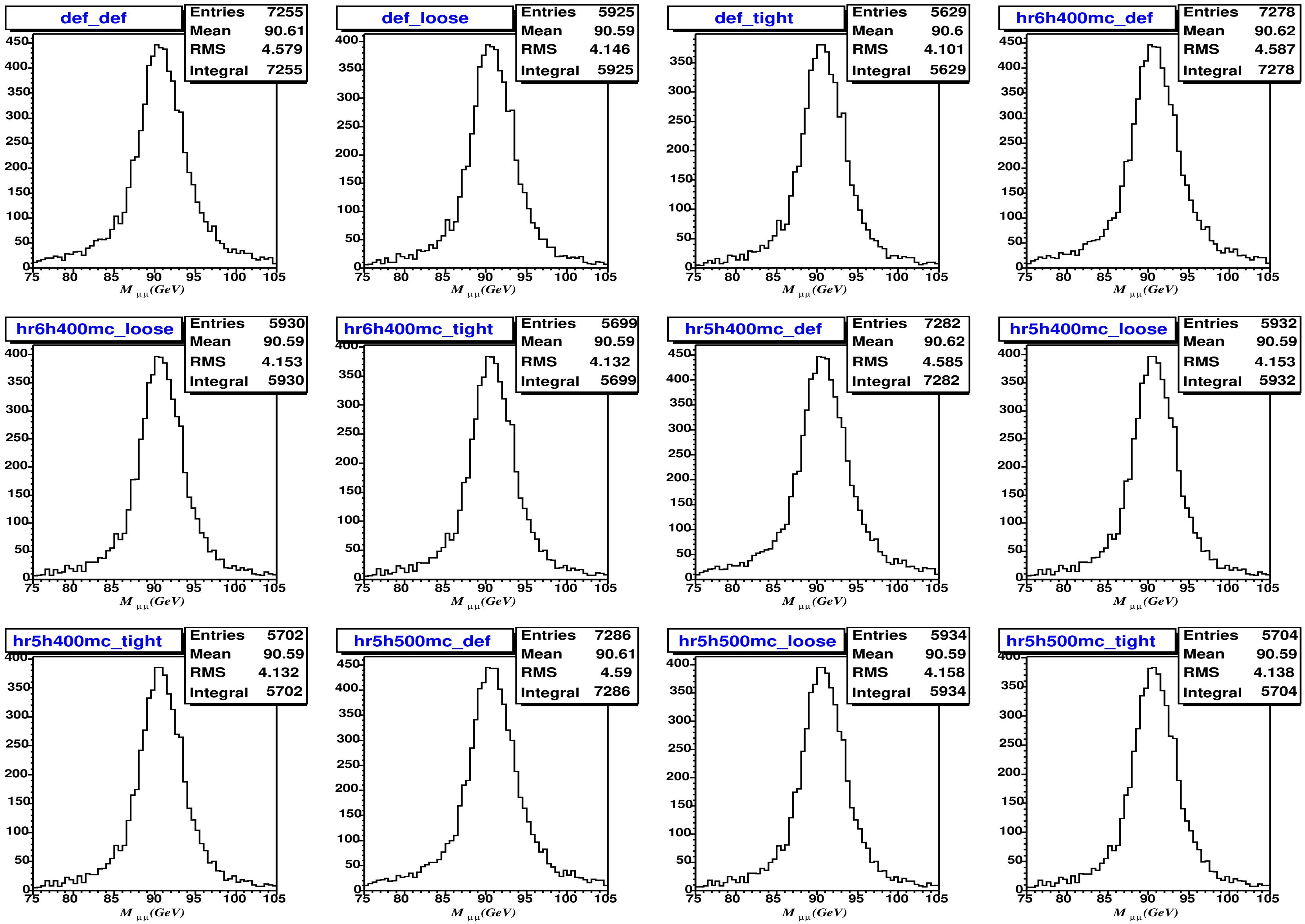


$Z \to \mu^+\mu^-$ $\Delta(z_+ - z_-)$ - Comparisons

TrackRec/Track Quality	Mean	Sigma	# Z's	Fraction events in $\pm 3\sigma (\%)$
def_def	-0.0024	0.705	7243	98.26
def_loose	0.0026	0.631	5916	98.63
def_tight	0.00088	0.605	5625	99.08
hr6h400mc_def	-0.000564	0.698	7270	97.96
hr6h400mc_loose	0.00376	0.62	5925	98.77
hr6h400mc_tight	0.000527	0.601	5696	99.1
hr5h400mc_def	-0.00146	0.698	7273	97.92
hr5h400mc_loose	0.00317	0.62	5926	98.73
hr5h400mc_tight	-0.000246	0.601	5698	99.07
hr5h500mc_def	-0.00163	0.697	7275	97.97
hr5h500mc_loose	0.00272	0.619	5926	98.77
hr5h500mc_tight	-0.000632	0.6	5698	99.1

- Resolution: a small improvement: 1-2 %
- Number of recovered events: 1%
- Reduce the number of events in the tails by 1%

$Z \rightarrow \mu^+\mu^-$ Invariant Mass - (75, 105) GeV

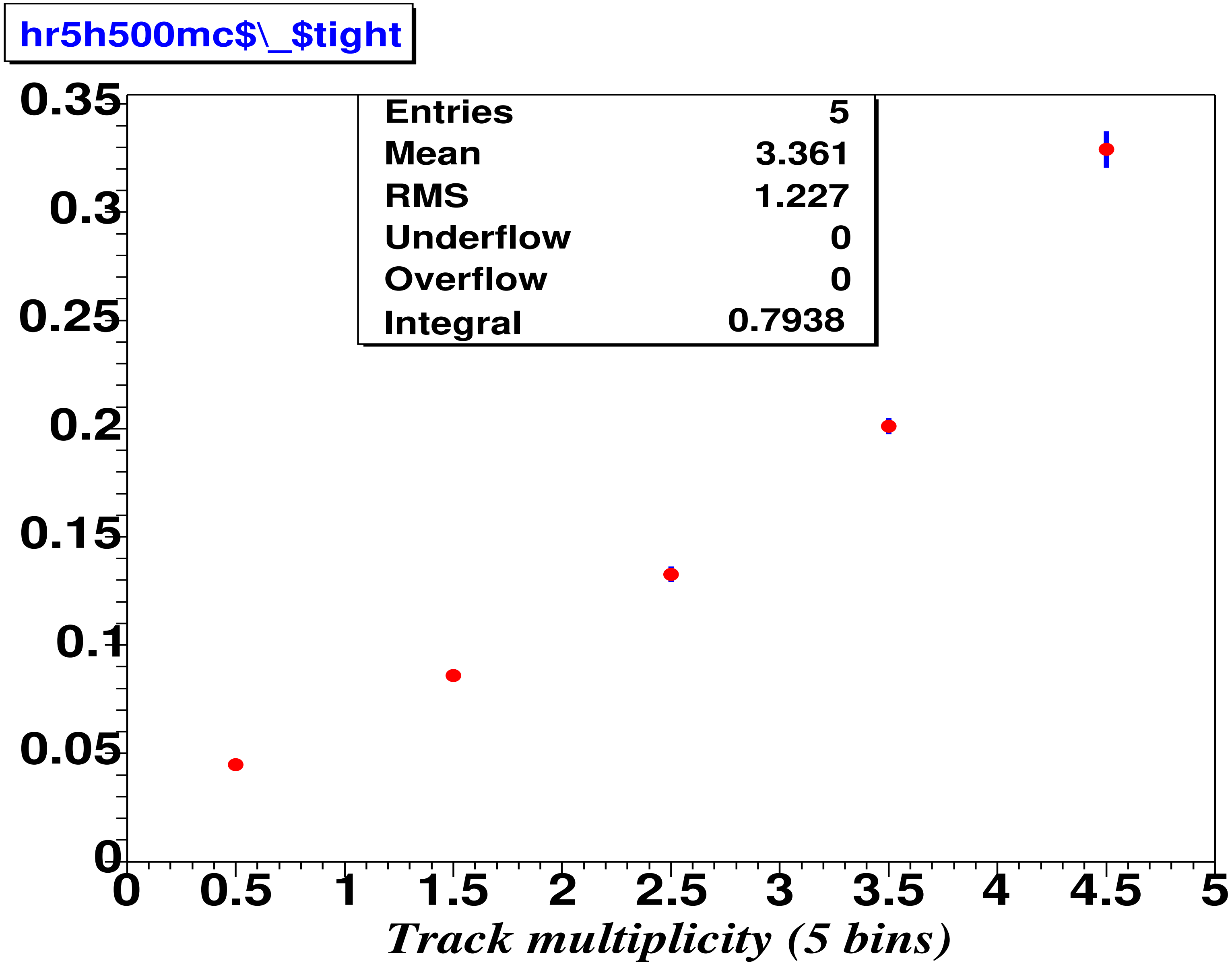


$Z \to \mu^+\mu^-$ Invariant Mass - Comparisons

TrackRec/Track Quality	Mean	RMS	# Z's	Fraction events in $\pm 3\sigma(\%)$
def_def	90.609	4.579	7255	99.3
def_loose	90.588	4.146	5925	98.46
def_tight	90.598	4.101	5629	98.42
hr6h400mc_def	90.616	4.587	7278	99.31
hr6h400mc_loose	90.585	4.153	5930	98.41
hr6h400mc_tight	90.59	4.132	5699	98.32
hr5h400mc_def	90.619	4.585	7282	99.31
hr5h400mc_loose	90.589	4.153	5932	98.38
hr5h400mc_tight	90.595	4.132	5702	98.3
hr5h500mc_def	90.615	4.59	7286	99.3
hr5h500mc_loose	90.586	4.158	5934	98.37
hr5h500mc_tight	90.592	4.138	5704	98.4

- Resolution: very small degradation ($< 1\%$)
- Number of recovered events: (1-2% tight)
- Increase the number of events in the tails by 1%

$J/\Psi \rightarrow \mu^+\mu^-$- Frac of tracks w/o hits in SL1 vs trk. mult.

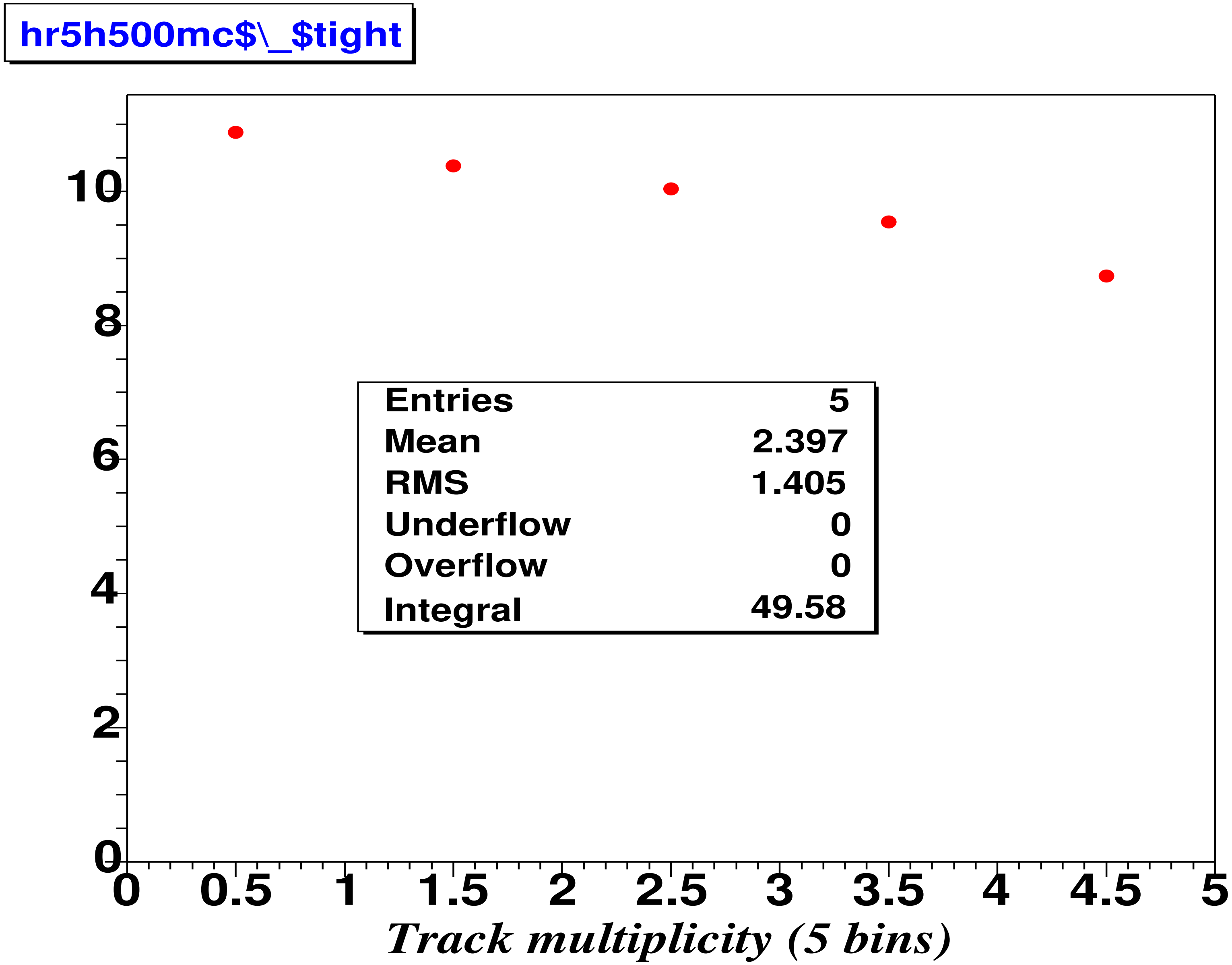


$J/\Psi \to \mu^+\mu^-$- Frac of tracks w/o hits in SL1 vs trk. mult.

TrackRec/TrackQual	Trks 1	Trks 2	Trks 3	Trks 4	Trks 5
def_def	0.0607 ± 0.0026	0.122 ± 0.0032	0.196 ± 0.004	0.312 ± 0.004	0.534 ± 0.0072
def_loose	0.0608 ± 0.0026	0.122 ± 0.0032	0.195 ± 0.004	0.311 ± 0.004	0.533 ± 0.0072
def_tight	0.0576 ± 0.0025	0.113 ± 0.0032	0.179 ± 0.004	0.275 ± 0.0041	0.458 ± 0.0086
hr6h400mc_def	0.0492 ± 0.0023	0.0959 ± 0.0029	0.153 ± 0.0036	0.248 ± 0.0038	0.43 ± 0.0077
hr6h400mc_loose	0.0492 ± 0.0023	0.0959 ± 0.0029	0.153 ± 0.0036	0.248 ± 0.0038	0.43 ± 0.0078
hr6h400mc_tight	0.0469 ± 0.0023	0.0899 ± 0.0029	0.141 ± 0.0036	0.218 ± 0.0038	0.363 ± 0.0087
hr5h400mc_def	0.0477 ± 0.0023	0.0929 ± 0.0029	0.147 ± 0.0036	0.237 ± 0.0037	0.406 ± 0.0076
hr5h400mc_loose	0.0478 ± 0.0023	0.0929 ± 0.0029	0.147 ± 0.0036	0.237 ± 0.0037	0.406 ± 0.0077
hr5h400mc_tight	0.0454 ± 0.0023	0.0873 ± 0.0028	0.136 ± 0.0035	0.208 ± 0.0037	0.339 ± 0.0084
hr5h500mc_def	0.0472 ± 0.0023	0.0914 ± 0.0029	0.145 ± 0.0036	0.23 ± 0.0037	0.396 ± 0.0077
hr5h500mc_loose	0.0472 ± 0.0023	0.0914 ± 0.0029	0.145 ± 0.0036	0.23 ± 0.0037	0.395 ± 0.0077
hr5h500mc_tight	0.0449 ± 0.0023	0.086 ± 0.0028	0.133 ± 0.0035	0.201 ± 0.0037	0.329 ± 0.0084

- def $\to$ hr6h400mc: $\approx$ 20% segment recovery
- hr6h400mc $\to$ hr5h400mc: $\approx$ 2-3% segment recovery
- hr5h400mc $\to$ hr5h500mc: $\approx$ 1-2% segment recovery

$J/\Psi \to \mu^+\mu^-$- Mean # of hits in SL1 vs trk. mult. Exclude 0 hits tracks.

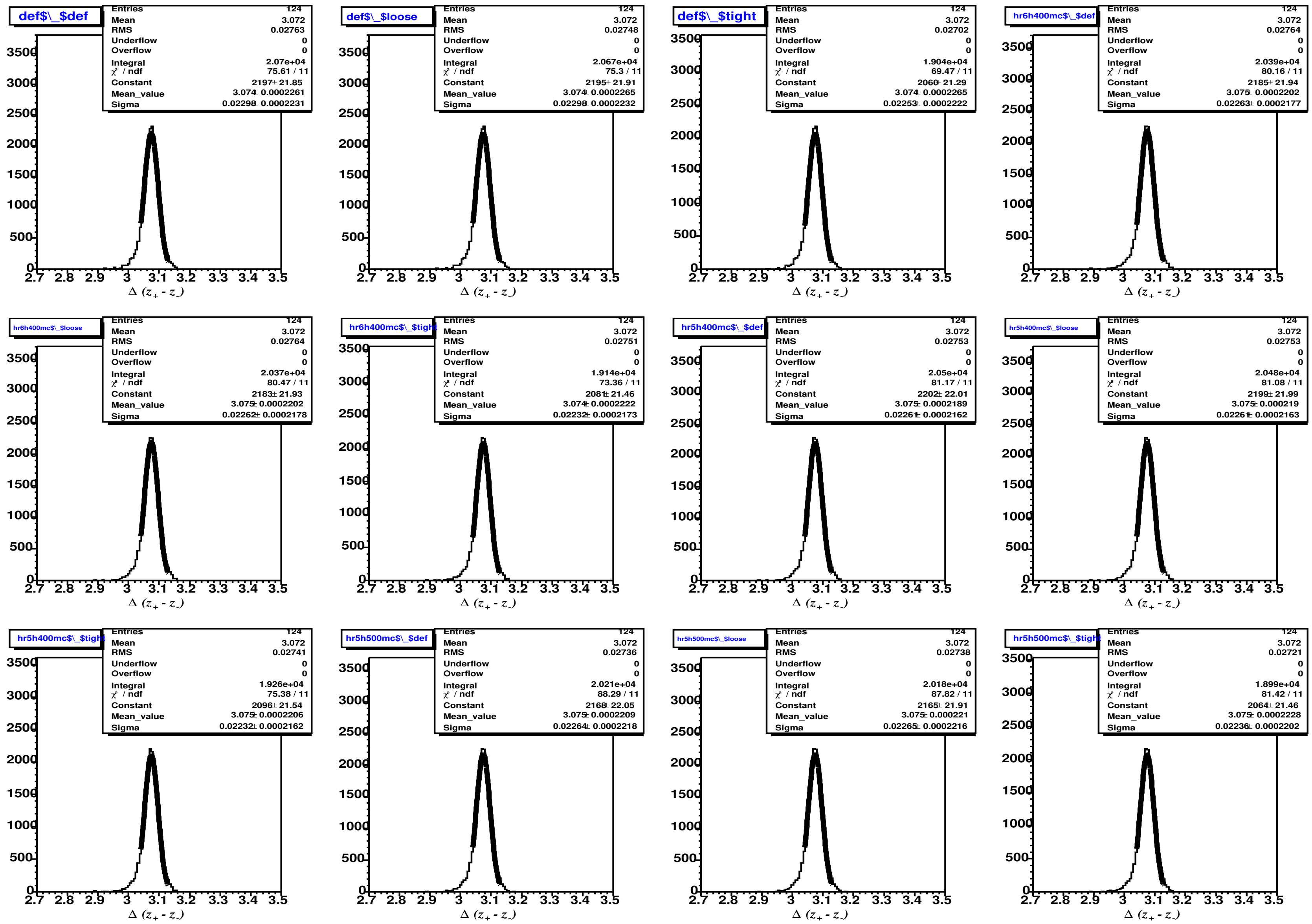


$J/\Psi \to \mu^+\mu^-$- Mean # of hits in SL1 vs trk. mult. Exclude 0 hits tracks.

TrackRec/TrackQual	Trks 1	Trks 2	Trks 3	Trks 4	Trks 5
def_def	10.89 ± 0.018	10.45 ± 0.018	10.14 ± 0.02	9.706 ± 0.018	8.997 ± 0.032
def_loose	10.89 ± 0.018	10.45 ± 0.018	10.14 ± 0.02	9.707 ± 0.018	8.996 ± 0.032
def_tight	10.9 ± 0.018	10.46 ± 0.018	10.16 ± 0.02	9.738 ± 0.019	9.088 ± 0.037
hr6h400mc_def	10.87 ± 0.018	10.38 ± 0.018	10.03 ± 0.02	9.547 ± 0.018	8.793 ± 0.034
hr6h400mc_loose	10.87 ± 0.018	10.38 ± 0.018	10.03 ± 0.02	9.549 ± 0.018	8.795 ± 0.034
hr6h400mc_tight	10.88 ± 0.018	10.39 ± 0.018	10.05 ± 0.02	9.577 ± 0.019	8.848 ± 0.038
hr5h400mc_def	10.86 ± 0.018	10.37 ± 0.018	10 ± 0.02	9.494 ± 0.018	8.651 ± 0.034
hr5h400mc_loose	10.86 ± 0.018	10.37 ± 0.018	10 ± 0.02	9.497 ± 0.018	8.652 ± 0.035
hr5h400mc_tight	10.87 ± 0.018	10.38 ± 0.018	10.02 ± 0.02	9.525 ± 0.019	8.705 ± 0.039
hr5h500mc_def	10.87 ± 0.018	10.37 ± 0.018	10.02 ± 0.02	9.518 ± 0.018	8.689 ± 0.034
hr5h500mc_loose	10.87 ± 0.018	10.37 ± 0.018	10.02 ± 0.02	9.522 ± 0.018	8.691 ± 0.034
hr5h500mc_tight	10.88 ± 0.018	10.38 ± 0.019	10.04 ± 0.02	9.547 ± 0.019	8.733 ± 0.039

- No gain al low luminosity.
- 2 % lower at high luminosity

$J/\Psi \to \mu^+\mu^-$ Invariant Mass-(3.01, 3.15) GeV

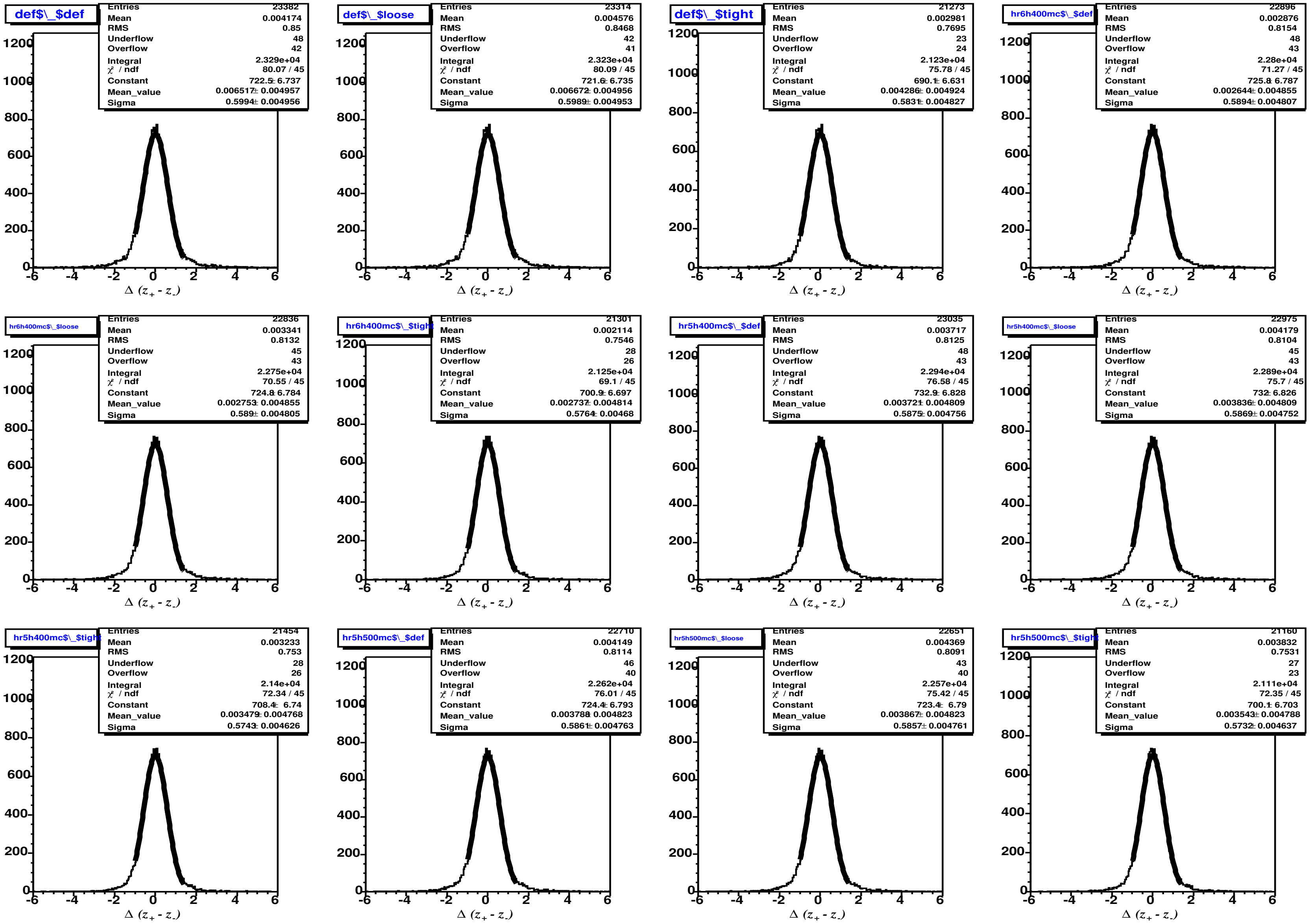


$J/\Psi \to \mu^+\mu^-$ Invariant Mass - Comparisons

TrackRec/Track Quality	Mean	Sigma	$\#$ J/Ψ's	Fraction events in $\pm 3\sigma(\%)$
def_def	3.07	0.0276	20704.7	97.99
def_loose	3.07	0.0275	20668.2	98.05
def_tight	3.07	0.027	19039.6	98.2
hr6h400mc_def	3.07	0.0276	20389	97.95
hr6h400mc_loose	3.07	0.0276	20365.9	97.95
hr6h400mc_tight	3.07	0.0275	19140.8	98.02
hr5h400mc_def	3.07	0.0275	20501.7	98.02
hr5h400mc_loose	3.07	0.0275	20476.8	98.01
hr5h400mc_tight	3.07	0.0274	19264	98.1
hr5h500mc_def	3.07	0.0274	20206.8	98.02
hr5h500mc_loose	3.07	0.0274	20183.1	98
hr5h500mc_tight	3.07	0.0272	18985.8	98.12

- Resolution: very small degradation
- The number of events in the tails: no change.
  - Caution: The initial $\#$ events is the same only for def and hr5h400mc.

$J/\Psi \to \mu^+\mu^-$ $\Delta(z_+ - z_-)$ - Comparisons



$J/\Psi \to \mu^+\mu^-$ $\Delta(z_+ - z_-)$ - Comparisons

TrackRec/TrackQual	Mean	Sigma	# Z's	Frac evts $\pm 3\sigma (\%)$	B
def_def	-0.00165	0.786	20607.5	97.14	2684.5
def_loose	5.93e-05	0.784	20573	97.15	2658
def_tight	-0.00179	0.729	18938.5	98.16	2287.5
hr6h400mc_def	-0.00114	0.756	20235.5	97.6	2569.5
hr6h400mc_loose	1.48e-05	0.754	20201	97.58	2547
hr6h400mc_tight	0.00157	0.715	18969.5	98.13	2277.5
hr5h400mc_def	-0.000291	0.748	20360	97.69	2584
hr5h400mc_loose	0.000957	0.747	20325.5	97.67	2561.5
hr5h400mc_tight	0.00294	0.712	19105	98.16	2295
hr5h500mc_def	0.000739	0.752	20082.5	97.68	2541.5
hr5h500mc_loose	0.00147	0.748	20049	97.67	2519
hr5h500mc_tight	0.00429	0.71	18852.5	98.15	2257.5

- Resolution: a small improvement: 2-4 % (loose/tight)
- Number of recovered events: too small
  - Better background rejection (?) 4% smaller (def vs hr5h400mc)
- No change in the number of events in the tails

CPU Time - Comparisons

Tested on a file with 9913 events.

Module name:	# Calls:	Mean cpu time:	Mean clk time:	Total CPU
$def : CT_TrackingModule$	9913	0.150255+/-0.001799	0.156188+/-0.001884	1489.480
$hr5h400mc : CT_TrackingModule$	9913	0.178975+/-0.002171	0.185435+/-0.002257	1774.180
$hr5h500mc : CT_TrackingModule$	9913	0.179149+/-0.002165	0.185612+/-0.002261	1775.900
$hr6h400mc : CT_TrackingModule$	9913	0.178130+/-0.002154	0.183759+/-0.002249	1765.800

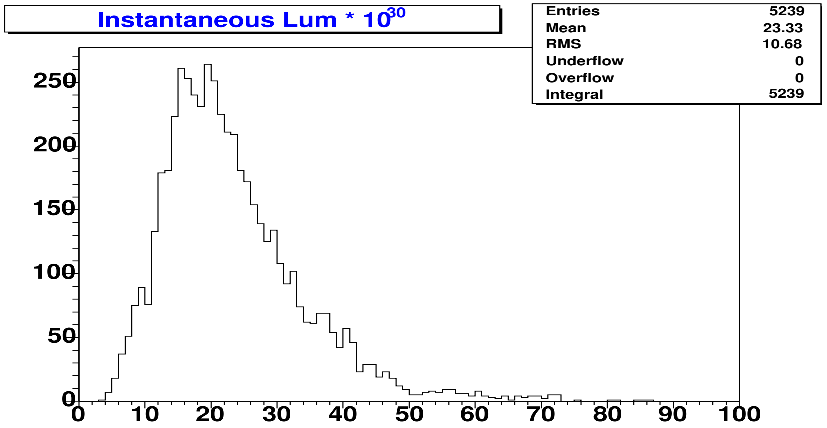
- It takes 19% longer when running the hit recovery.
- However the CT_TrackingModule takes 12% of the total event processing time (ProductionExe).
- If running hit recovery the CT_TrackingModule spending goes up to 13.5%, an overall increase by 2%.

Conclusions

- The good quality tracks are already good.
- At low luminosity (5% of hit-less tracks) the potential improvement is low (1%)
  - Maybe for high track multiplicity events might get a larger improvement?
- Also if the hit recovery helps predominantly the HL tracks, might not see it as the SL are favor
  - Try the hit recovery after the tracks are merged.
- Improvement versus CPU consumption !?

Extra - Backup

$Z \rightarrow \mu^+\mu^-$ - # events vs trk mult



TrackRec/TrackQual	Trks 1	Trks 2	Trks 3	Trks 4	Trks 5
def_def	5422	3642	2348	2022	292
def_loose	4206	2974	1926	1664	256
def_tight	4134	2868	1818	1478	180
hr6h400mc_def	5376	3674	2348	2064	314
hr6h400mc_loose	4172	2980	1918	1700	264
hr6h400mc_tight	4110	2888	1822	1568	218
hr5h400mc_def	5374	3670	2352	2070	316
hr5h400mc_loose	4168	2978	1924	1702	266
hr5h400mc_tight	4106	2886	1828	1572	220
hr5h500mc_def	5368	3668	2354	2080	320
hr5h500mc_loose	4162	2978	1922	1712	268
hr5h500mc_tight	4100	2886	1826	1582	222

- 40% of events in 1^{st} track mult bin, 65% in $1^{st}+2^{nd}$, 83% in the 1^{st} 3 bins

$Z \to \mu^+\mu^-$ Invariant Mass, Low Track Multiplicity

TrackRec/Track Quality	Mean	Sigma	# Z's	Fraction events in $\pm 3\sigma (\%)$
def_def	90.593	4.518	4651	99.12
def_loose	90.558	4.069	3693	98.54
def_tight	90.562	4.07	3601	98.56
hr6h400mc_def	90.6	4.522	4630	99.14
hr6h400mc_loose	90.563	4.07	3662	98.55
hr6h400mc_tight	90.561	4.065	3581	98.58
hr5h400mc_def	90.604	4.519	4628	99.18
hr5h400mc_loose	90.568	4.065	3659	98.58
hr5h400mc_tight	90.566	4.061	3578	98.6
hr5h500mc_def	90.602	4.521	4626	99.14
hr5h500mc_loose	90.56	4.072	3659	98.55
hr5h500mc_tight	90.557	4.068	3577	98.57

- Resolution: small changes after hit recovery
- Resolution improves by 1-2% comparing with the overall inv mas

$Z \to \mu^+\mu^-$ Invariant Mass, High Track Multiplicity

TrackRec/Track Quality	Mean	Sigma	# Z's	Fraction events in $\pm 3\sigma$(%)
def_def	90.634	4.867	2212	99.55
def_loose	90.595	4.301	1820	98.3
def_tight	90.623	4.166	1638	98.05
hr6h400mc_def	90.64	4.876	2258	99.69
hr6h400mc_loose	90.583	4.316	1855	98.49
hr6h400mc_tight	90.602	4.27	1722	98.14
hr5h400mc_def	90.64	4.876	2263	99.69
hr5h400mc_loose	90.585	4.32	1860	98.44
hr5h400mc_tight	90.605	4.275	1728	98.09
hr5h500mc_def	90.629	4.884	2269	99.82
hr5h500mc_loose	90.592	4.325	1862	98.39
hr5h500mc_tight	90.615	4.28	1731	98.04

- Resolution:degradation from def to hr6h400mc: 2.5% (tight)
- Compare σ high vs low trk mult: worsen by (8/6/2)% (def/loose/tight)

$Z \to \mu^+\mu^-$ $\Delta(z_+ - z_-)$ - Low Track Multiplicity

TrackRec/Track Quality	Mean	Sigma	# Z's	Fraction events in $\pm 3\sigma (\%)$
def_def	-0.0113	0.675	4649	98.39
def_loose	-0.0055	0.586	3692	99.3
def_tight	-0.00212	0.578	3601	99.42
hr6h400mc_def	-0.00855	0.675	4627	98.38
hr6h400mc_loose	-0.00335	0.582	3661	99.32
hr6h400mc_tight	-0.0018	0.573	3581	99.44
hr5h400mc_def	-0.00859	0.675	4625	98.36
hr5h400mc_loose	-0.00284	0.581	3658	99.32
hr5h400mc_tight	-0.00151	0.573	3578	99.44
hr5h500mc_def	-0.0088	0.676	4624	98.33
hr5h500mc_loose	-0.00249	0.581	3658	99.32
hr5h500mc_tight	-0.00105	0.573	3577	99.44

- Resolution improves slightly.

$Z \to \mu^+\mu^-$ $\Delta(z_+ - z_-)$ - High Track Multiplicity

TrackRec/Track Quality	Mean	Sigma	# Z's	Fraction events in $\pm 3\sigma (\%)$
def_def	0.0122	0.778	2201	97.91
def_loose	0.0222	0.709	1813	97.85
def_tight	0.012	0.656	1635	98.59
hr6h400mc_def	0.0108	0.76	2251	97.87
hr6h400mc_loose	0.019	0.685	1852	98
hr6h400mc_tight	0.00953	0.65	1720	98.6
hr5h400mc_def	0.00894	0.762	2255	97.25
hr5h400mc_loose	0.0162	0.688	1856	97.9
hr5h400mc_tight	0.00681	0.652	1725	98.55
hr5h500mc_def	0.00688	0.759	2259	97.3
hr5h500mc_loose	0.0136	0.684	1856	98.01
hr5h500mc_tight	0.004	0.648	1726	98.67

- Resolution improves 2.4-3.4 % from def to hr6h400mc (def, loose). Not much for tight.
- Compare the resolution b/w low-high: 13-20 % degradation;