Current status of the TPC simulation and reconstruction software

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Motivation

1. The “realistic” TPC simulation (“microsimulation”) is “a must” (all experiments do it)
2. Some regions of the covered phase space are very sensitive to the detector response details (e.g., forward region)
3. Physics predictions gain the confidence level if obtained from the “realistic” simulations

Simulation procedure (digitization)

1. Primary ionization (ionization clusters)
2. Drift and diffusion of ionization electrons
3. Gas gain fluctuations (Polya distribution)
4. Pad response (charge distribution on pad plane)
5. Electronics shaping
6. Signal digitization (ADC overflow)

TPC parameters

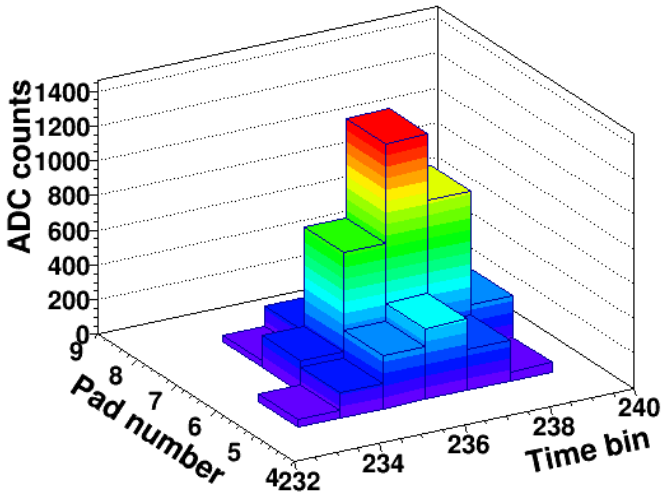
Parameter	Value
Magnetic field	0.5 T
Drift gas	P10 (90% Ar + 10% CH_4)
Drift velocity	5.45 cm/μs
Transverse diffusion at 0.5 T	185 μm/√cm
Longitudinal diffusion	320 μm/√cm
Pad size	5x12 mm^2 (27 rows) + 5x18 mm^2 (26 rows)
Charge spread σ	0.196 mm
Electronics shaping time	180 ns (FWHM)
ADC dynamic range	12 bits
ADC sampling frequency	10 MHz

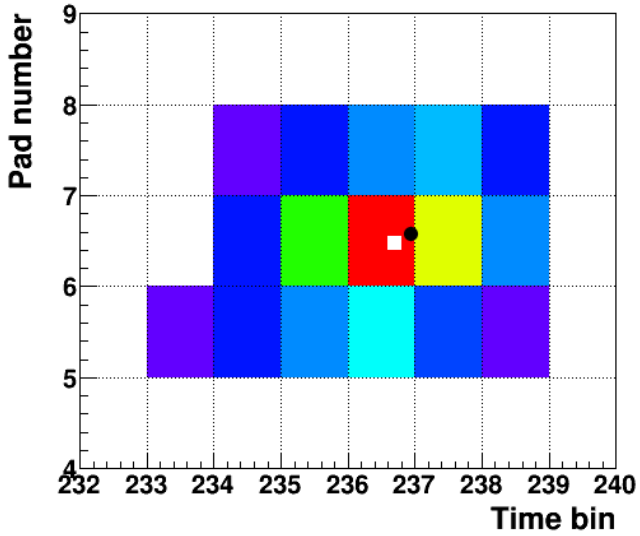
Cluster / hit reconstruction

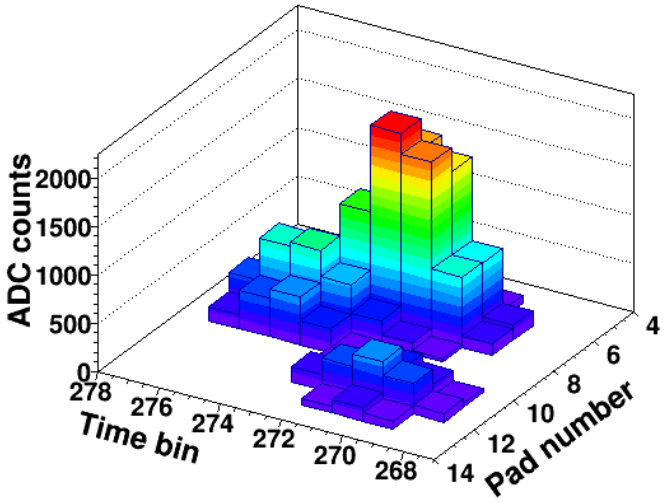
1. Precluster finder (group of adjacent pixels in time bin – pad space)
2. Hit finder (“peak-and-valley” algorithm either in time bin – pad space (for simple topologies) or in time-transverse coordinate pixel space (for more complicated topologies)) → COG around local maxima

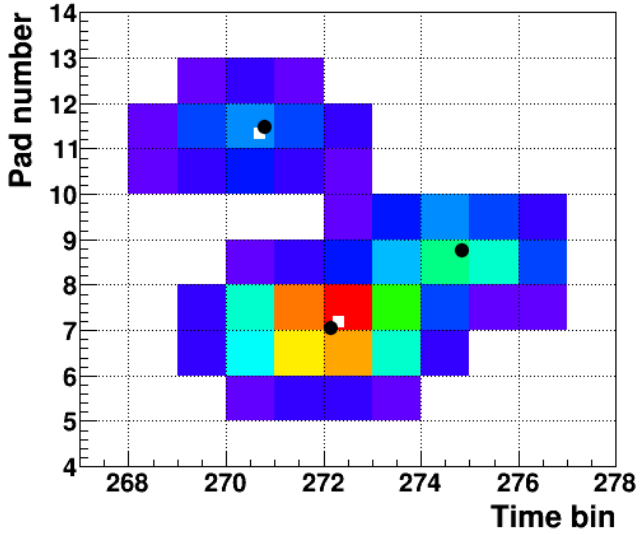
Digitization and reconstruction are quite time consuming packages.

Cluster topologies

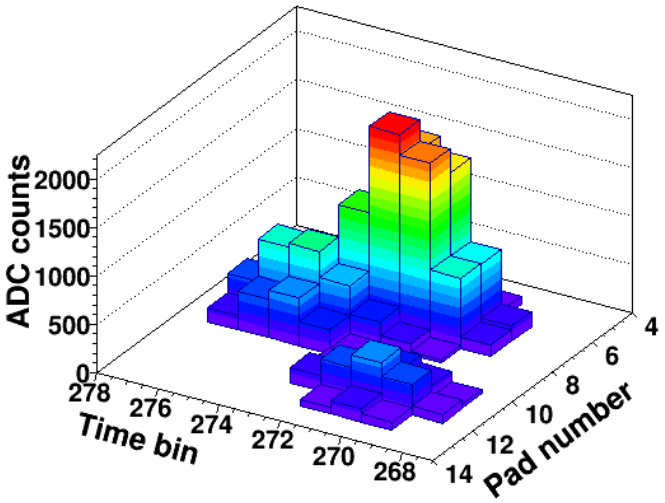


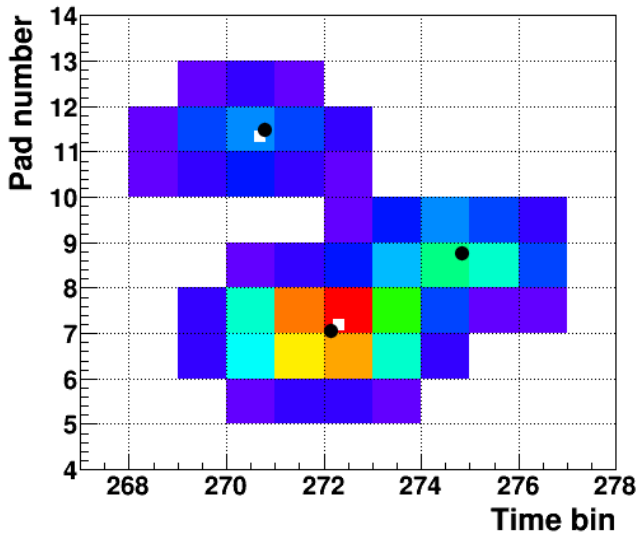


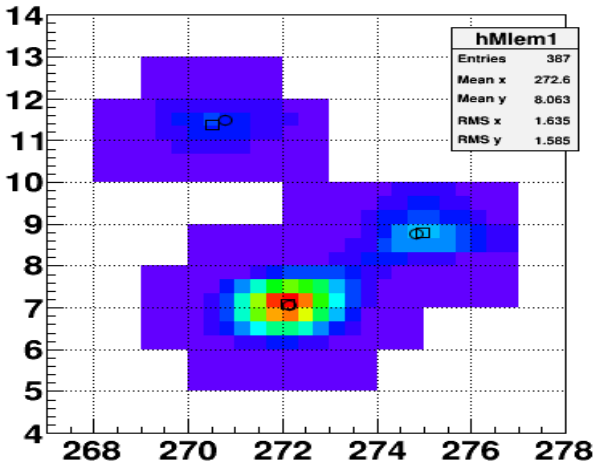


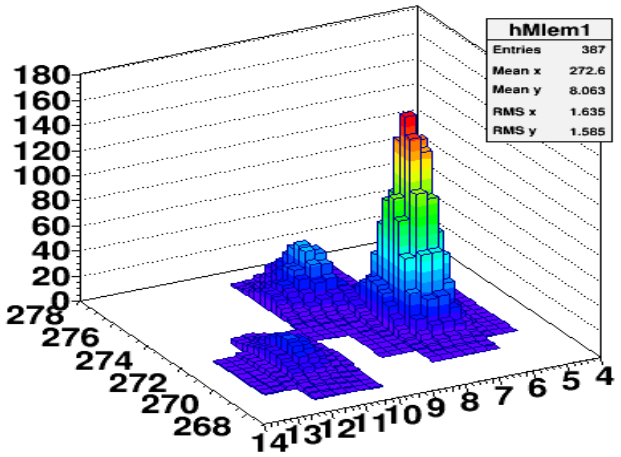


MLEM procedure - Bayesian unfolding

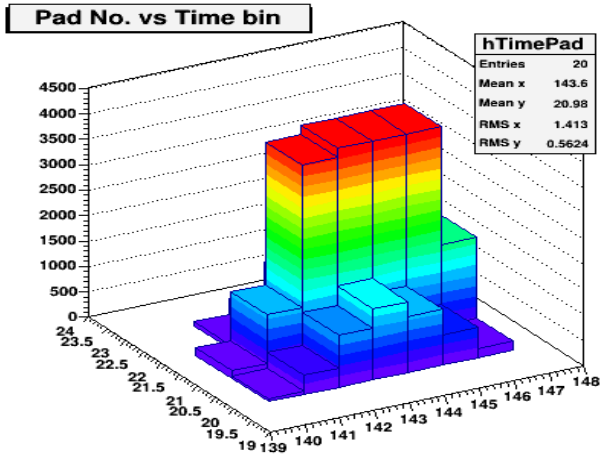


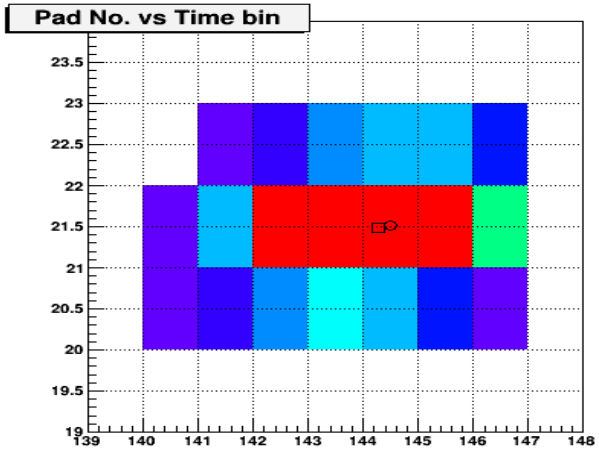


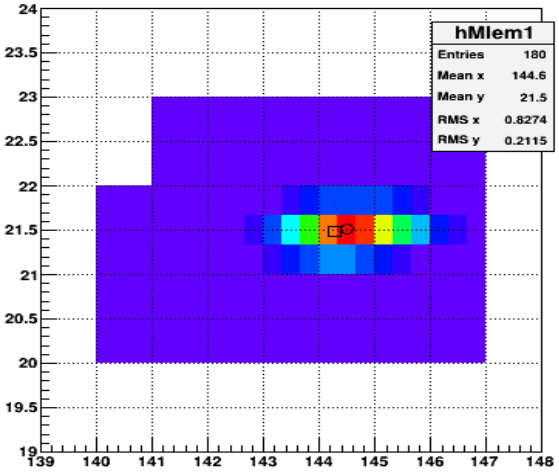


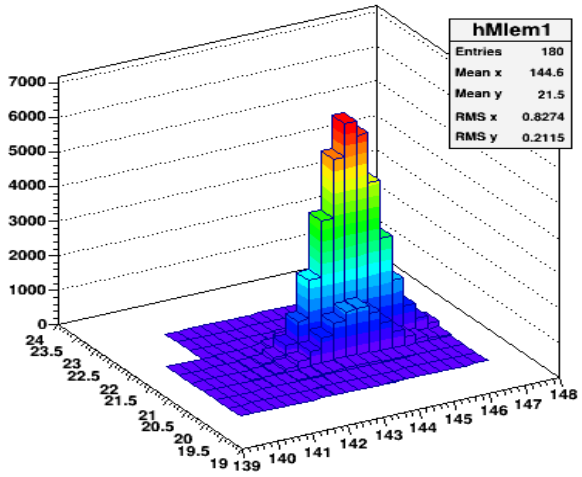


MLEM procedure – information recovery









Processing time

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[INFO   ] [  1.728670 s/ev |  0.635080 % ]  116M "  TPC Hit Producer"
[INFO   ] [  0.000109 s/ev |  0.000040 % ]    0B "  MpdVertexZfinder"
[INFO   ] [ 22.598266 s/ev |  8.302164 % ]   14M "  Kalman filter"
[INFO   ] [  0.012341 s/ev |  0.004534 % ]    0B "    MpdTpcDedxTask"
[INFO   ] [  0.321459 s/ev |  0.118098 % ]    0B "  Vertex finder"
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[INFO   ] ----------------------------------------
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[INFO   ] [ 32.988010 s/ev | 40.717104 % ]  159M "  TPC digitizerAZ"
[INFO   ] [ 36.064723 s/ev | 44.514691 % ]  247M "  TPC Cluster finder Mlem"
[INFO   ] [  0.659859 s/ev |  0.814464 % ]  117M "  TPC Hit Producer"
[INFO   ] [  0.000044 s/ev |  0.000054 % ]    0B "  MpdVertexZfinder"
[INFO   ] [ 11.138358 s/ev | 13.748077 % ]   14M "  Kalman filter"
[INFO   ] [  0.006390 s/ev |  0.007887 % ]    0B "    MpdTpcDedxTask"
[INFO   ] [  0.158190 s/ev |  0.195254 % ]    0B "  Vertex finder"
[INFO   ] [  0.001931 s/ev |  0.002384 % ]    0B "  MpdDst task"
[INFO   ] ----------------------------------------
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[INFO   ] [  0.000011 s/ev |  0.000026 % ]    4k "  Kalman Filter engine"
[INFO   ] [ 12.012464 s/ev | 28.728122 % ]  155M "  TPC digitizerAZ"
[INFO   ] [ 19.528689 s/ev | 46.703373 % ]  254M "  TPC Cluster finder Mlem"
[INFO   ] [  0.670510 s/ev |  1.603542 % ]  105M "  TPC Hit Producer"
[INFO   ] [  0.000044 s/ev |  0.000105 % ]    0B "  MpdVertexZfinder"
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[INFO   ] [  0.150484 s/ev |  0.359887 % ]    0B "  Vertex finder"
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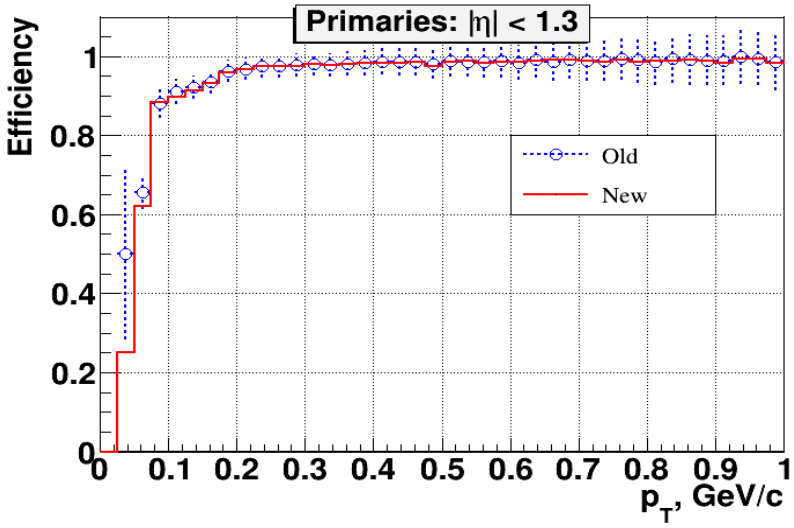
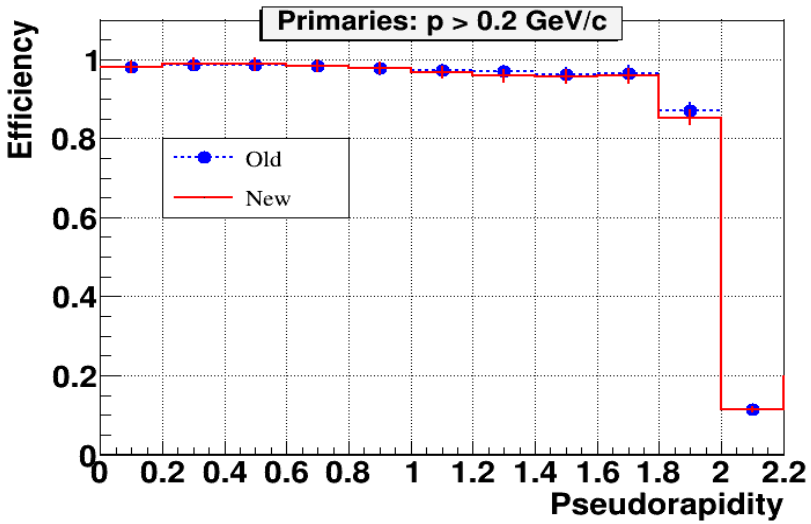
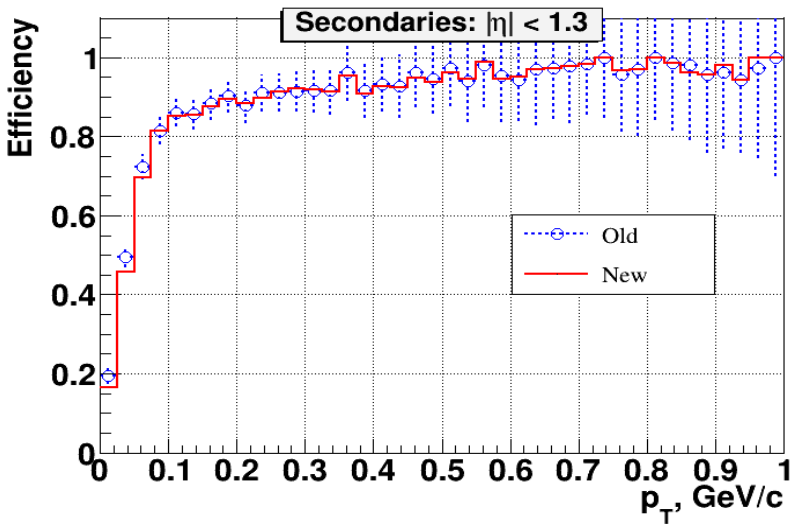
Track reconstruction efficiency

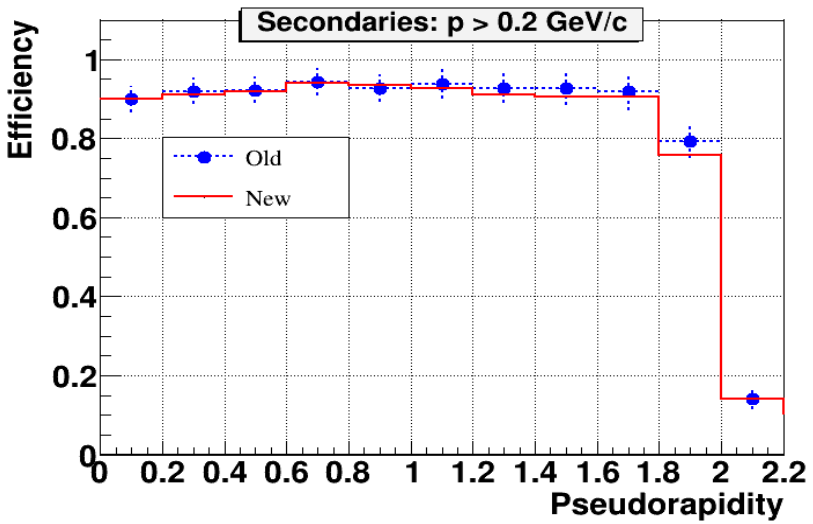
Primary



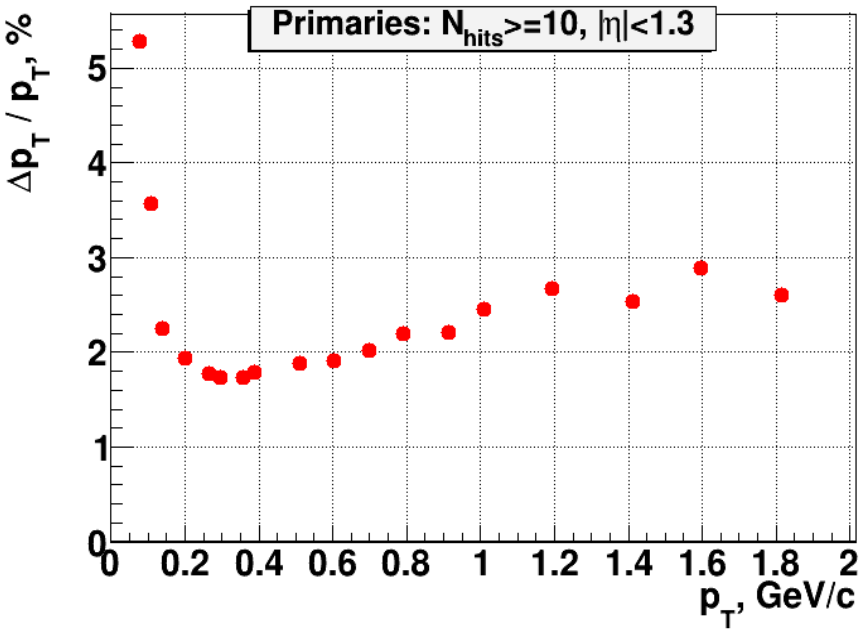


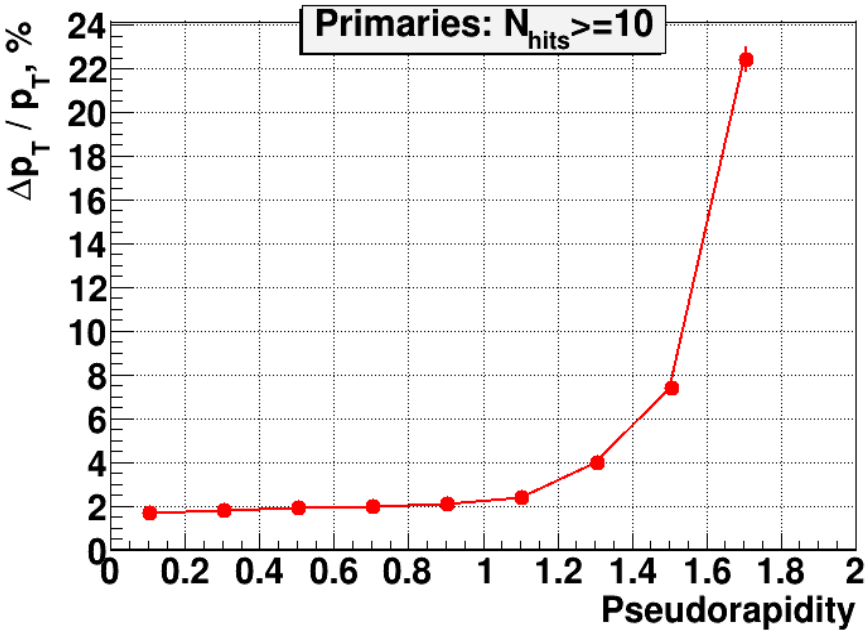
Secondary



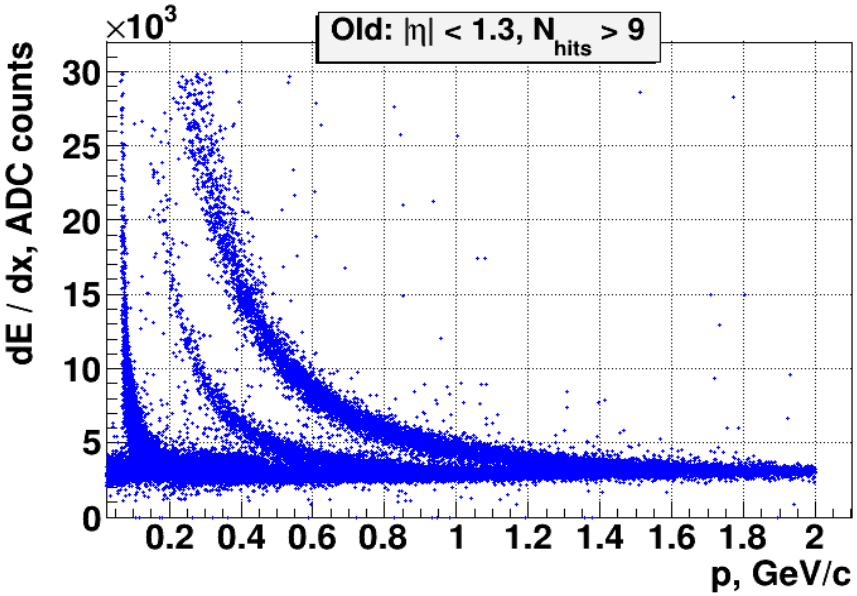


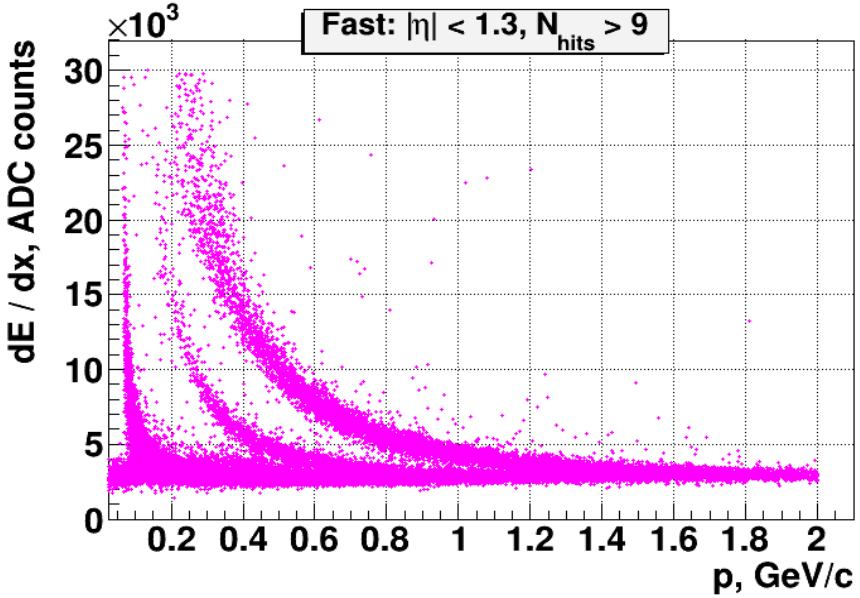
Momentum resolution



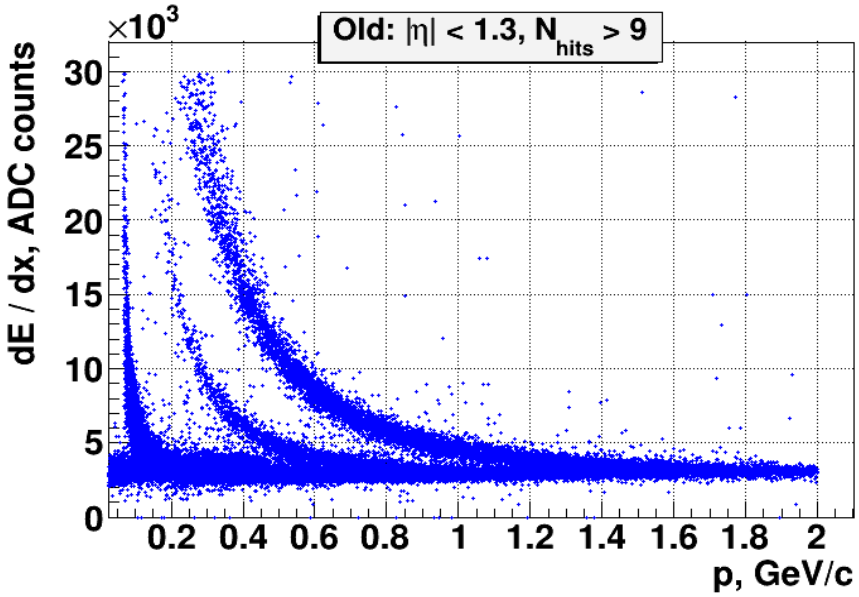


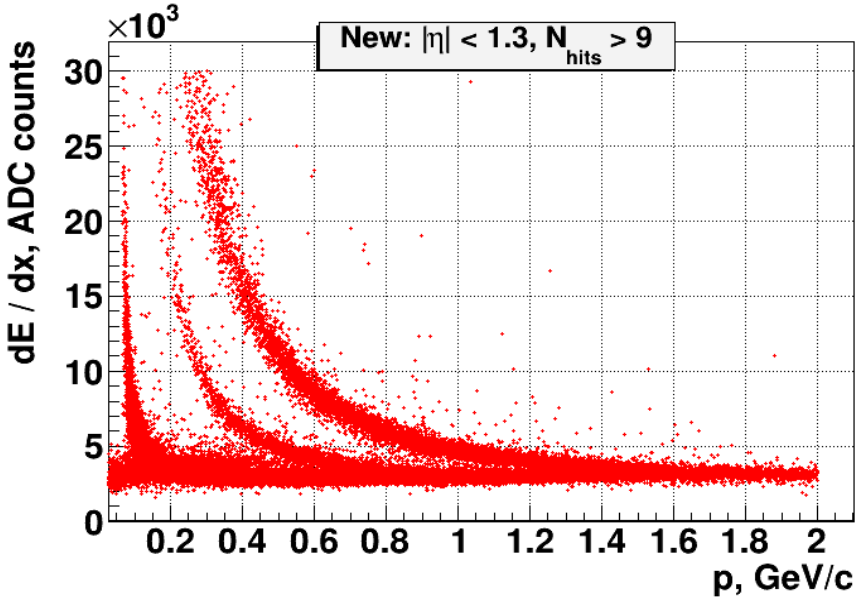
dE/dx: UrQMD generator (9 GeV)





dE/dx: UrQMD generator (9 GeV)





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<DartMeasurement name="MaxMemory" type="numeric/double">941.176</DartMeasurement>
<DartMeasurement name="CpuLoad" type="numeric/double">0.998584</DartMeasurement>
[INFO   ] - Total Run Time: 8101.76 s ------------------------------------------------------------
[INFO   ] [  0.000058 s/ev |  0.000071 % ]  440k "FairTaskList"
[INFO   ] [  0.000011 s/ev |  0.000014 % ]    4k "  Kalman Filter engine"
[INFO   ] [ 32.988010 s/ev | 40.717104 % ]  159M "  TPC digitizerAZ"
[INFO   ] [ 36.064723 s/ev | 44.514691 % ]  247M "  TPC Cluster finder Mlem"
[INFO   ] [  0.659859 s/ev |  0.814464 % ]  117M "  TPC Hit Producer"
[INFO   ] [  0.000044 s/ev |  0.000054 % ]    0B "  MpdVertexZfinder"
[INFO   ] [ 11.138358 s/ev | 13.748077 % ]   14M "  Kalman filter"
[INFO   ] [  0.006390 s/ev |  0.007887 % ]    0B "    MpdTpcDedxTask"
[INFO   ] [  0.158190 s/ev |  0.195254 % ]    0B "  Vertex finder"
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[INFO   ] ----------------------
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[INFO   ] [ 12.012464 s/ev | 28.728122 % ]  155M "  TPC digitizerAZ"
[INFO   ] [ 19.528689 s/ev | 46.703373 % ]  254M "  TPC Cluster finder Mlem"
[INFO   ] [  0.670510 s/ev |  1.603542 % ]  105M "  TPC Hit Producer"
[INFO   ] [  0.000044 s/ev |  0.000105 % ]    0B "  MpdVertexZfinder"
[INFO   ] [  9.443983 s/ev | 22.585532 % ]   10M "  Kalman filter"
[INFO   ] [  0.006225 s/ev |  0.014887 % ]    0B "    MpdTpcDedxTask"
[INFO   ] [  0.150484 s/ev |  0.359887 % ]    0B "  Vertex finder"
[INFO   ] [  0.001834 s/ev |  0.004387 % ]    0B "  MpdDst task"
[INFO   ] ------------------------------------------------------------------------------------
```

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[INFO   ] [ 18.252037 s/ev | 35.876751 % ]  153M "  TPC digitizerAZlt"
[INFO   ] [ 22.505010 s/ev | 44.236522 % ]  314M "  TPC Cluster finder Mlem"
[INFO   ] [  0.665787 s/ev |  1.308690 % ]  115M "  TPC Hit Producer"
[INFO   ] [  0.000041 s/ev |  0.000080 % ]    0B "  MpdVertexZfinder"
[INFO   ] [  9.294152 s/ev | 18.268864 % ]    8M "  Kalman filter"
[INFO   ] [  0.006232 s/ev |  0.012249 % ]    0B "    MpdTpcDedxTask"
[INFO   ] [  0.149118 s/ev |  0.293111 % ]    0B "  Vertex finder"
[INFO   ] [  0.001829 s/ev |  0.003595 % ]    0B "  MpdDst task"
[INFO   ] ------------------------------------------------------------------------------------
```

Summary

The MPD TPC “realistic” simulation procedures have been optimized with respect to the processing time – whether or not the processing can be further speeded up is not clear.