Charged particle multiplicity in the CERES '2000 data

D. Miśkowiec

April 7, 2006

1 Introduction

The absolute multiplicity of charged particles in events of a given centrality was determined by counting reconstructed SD or TPC tracks. The following aspects were treated with special care:

single track efficiency
The analysis was restricted to a phi-range with all anodes alive (SD) or to the central 1/3 of each chamber and excluding chambers 9 and 15 (TPC). The obtained multiplicity was multiplied by $2\pi/\Delta\phi$.

additional inefficiency for low momenta
For the TPC the effect was estimated to be about 3%; the correction was not applied.

fake tracks
Fake tracks in the SD, estimated by rotating one of the detectors, were subtracted.

additional inefficiency for pairs of close tracks (two-track efficiency)
For the SD I suppressed tracks by requiring a certain minimum distance to neighbour hits. The relation between the track multiplicity and the size of the cut was then extrapolated to zero. For the TPC the the effect was estimated to be below 4%; the correction was not applied.

delta electrons
The multiplicity of delta electrons was obtained from the data taken with the beam trigger and was subtracted.

2 SD analysis in detail

The step2 output for 100 bursts of run 1424 (minb trigger, low beam intensity) was analyzed. The analysis was done separately in 5 bins of pseudorapidity, covering $2< \phi <3$, and separately for every centrality bin.

event cuts

centrality
reasonable amplitudes of BC1 and BC2
no other beam particle within $\pm$ 5 μs

hit cuts

SD1 hits within $-1.81 < \phi < -1.61$ and $+0.40 < \phi < +0.60$ (Fig. 1)
SD2 hits within $-1.83 < \phi < -1.58$ and $+0.38 < \phi < +0.62$
no neighbour within Δr and $\Delta\phi$

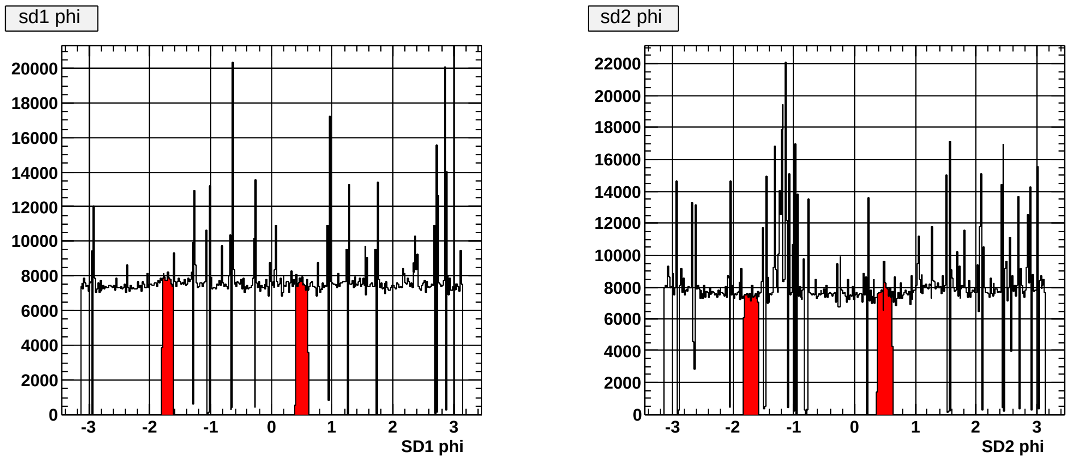

Figure 1: Azimuthal angle distributions of the hits in SD. The red filled areas represent the accepted hits.

background subtraction

For every combination of hits SD1 and SD2 the vertex z was calculated using the z-positions of the detectors and the r-coordinate of the two hits. The vertex z was then shifted to the event coordinate system, obtained in a standard way from the SD tracks. The resulting distribution exhibits a narrow peak sitting on a broad background of random hit combinations (Fig. 2). The background was determined by combining hits belonging to different ϕ regions: $-1.81 < \phi_{\mathrm{SD1}} < 1.61$ with $+0.38 < \phi_{\mathrm{SD2}} < 0.62$ and vice versa. The background was (slightly) adjusted such that the two matched in the range (-3.0,-1.2) and (1.2,3.0) (in cm), and then subtracted. The remaining peak was integrated from -1.2 cm to 1.2 cm, yielding the fake-free number of tracks from the target. This number was divided by the number of events and the ϕ-acceptance factor $0.4/2/\pi$=0.0637. This procedure, performed separately for each pseudorapidity bin, gave the $dN_{ch}/d\eta$ histogram.

two track efficiency

The procedure, described above, was repeated for different values of the two-hit separation cuts Δr and $\Delta\phi$. For a fixed $\Delta\phi$, $dN_{ch}/d\eta$ vs Δr was fit by an exponential in the range 0.07 cm $< \Delta r <$ 0.21 cm and extrapolated to zero (Fig. 3). The extrapolated $dN_{ch}/d\eta(0)$, obtained in this fashion for $\Delta\phi$=0.027, 0.036, and 0.045 are very similar. For the final result the histograms obtained with $\Delta\phi$=0.036 were used.

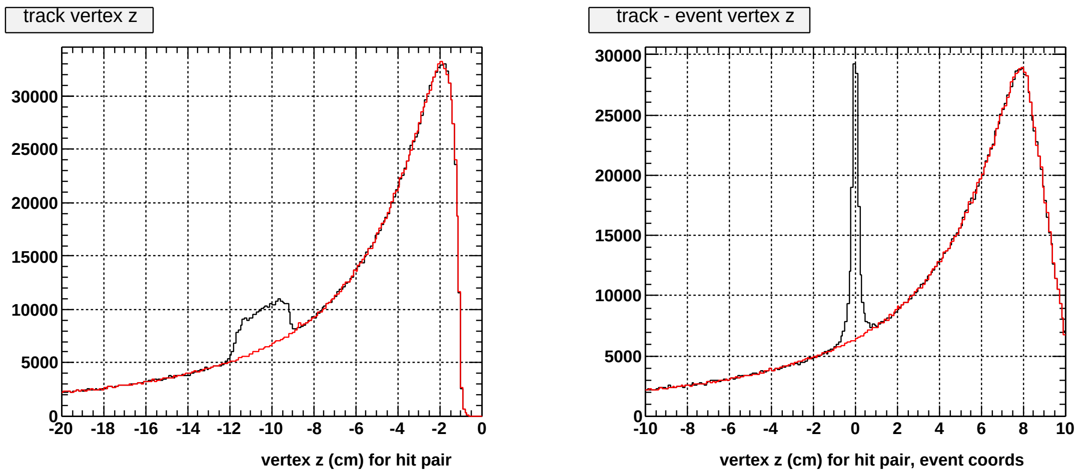

Figure 2: Vertex z distribution for the hit pairs SD1 x SD2 in LAB (left) and in event coordinates (right).

delta electrons

The delta electrons were estimated by applying the complete procedure for beam trigger data (100 bursts of run 1423). The result was 16 electrons on average into the η-interval from 2 to 3, or $dN_{ch}/dy(3.1)$=8. Half of this was then subtracted from the minimum bias run results to account for electrons knocked out of the targets preceding the one in which the interaction occured.

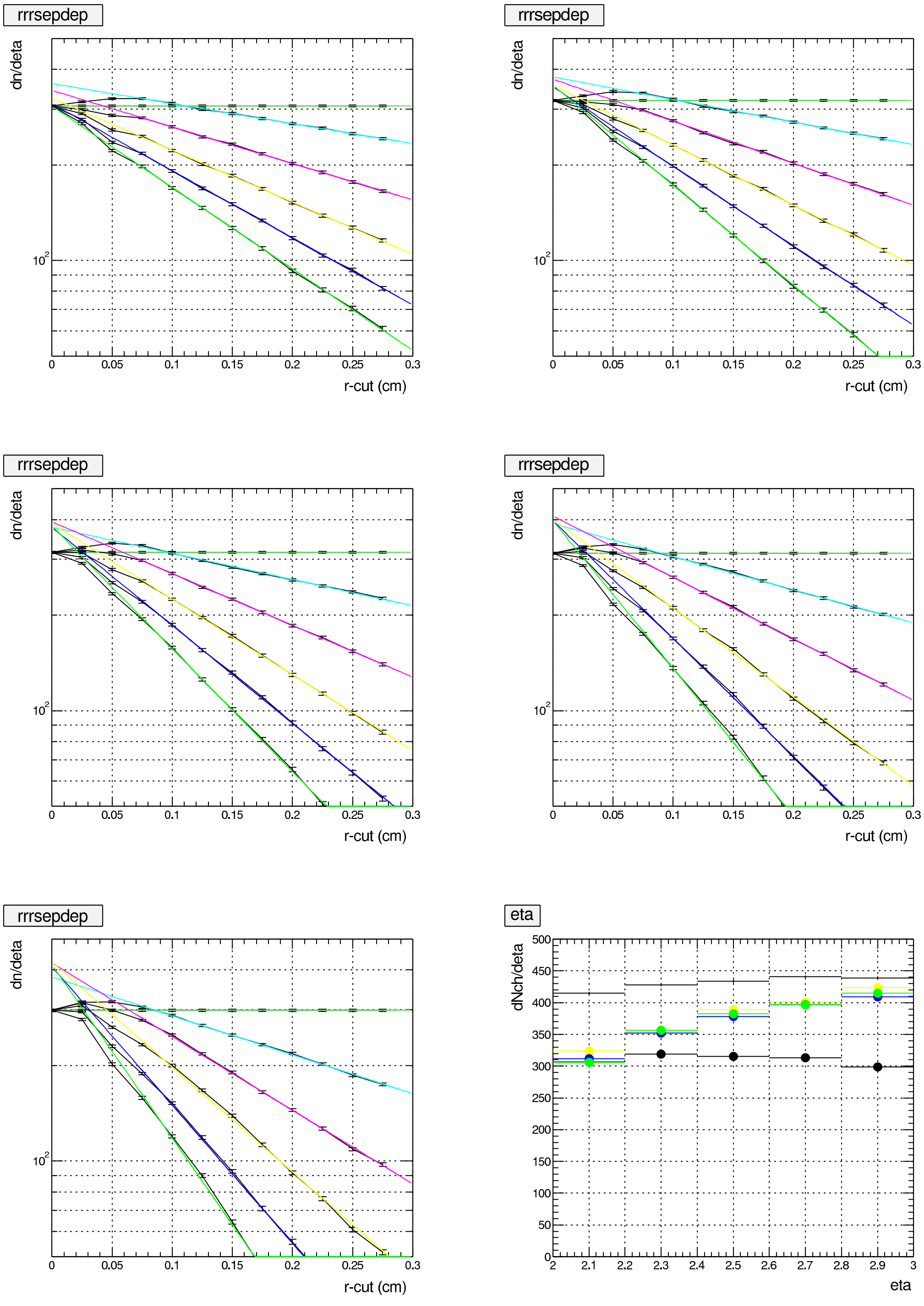

Figure 3: Circumventing the problem of two-track efficiency by looking at the dependence of the track multiplicity on the two-hit cuts, and extrapolating to zero (centrality 0-5%). The first five panels represent the five pseudorapidity bins. The sixth panel shows the raw charged particle multiplicity (black dots) as well as the values obtained from the extrapolation to $\Delta r = 0$ using $\Delta\phi$=0.027 (yellow), 0.036 (blue), and 0.045 (green). The $\Delta\phi$=0.036 were taken for the final result. For comparison, the result of a naive counting SD tracks, which with the loose default matching contain significant contamination of fakes, is shown as the black histogram.

3 TPC analysis in detail

event cuts

centrality
reasonable amplitudes of BC1 and BC2

track cuts

ϕ within the middle 0.33 of a radout-chamber
chambers 9 and 15 excluded (see Fig. 4)

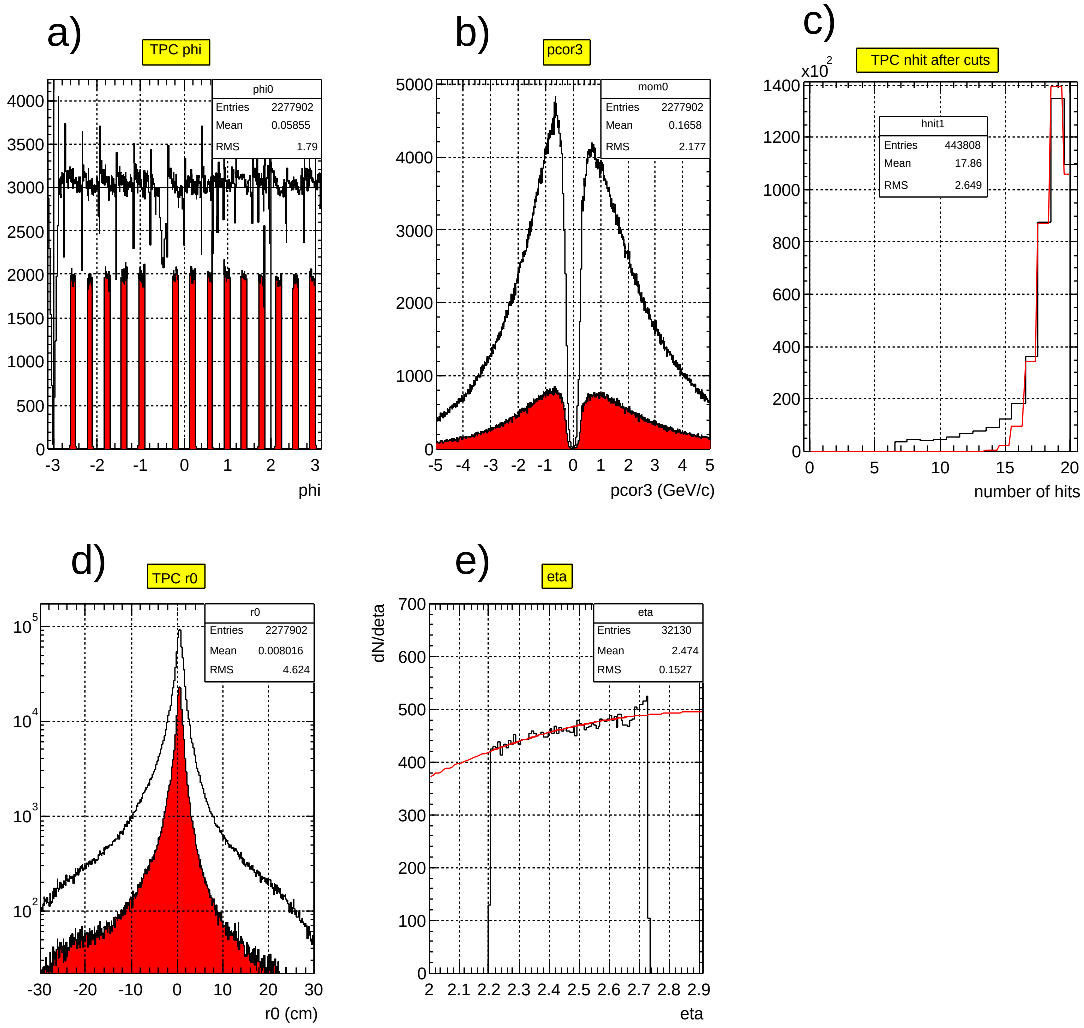

Figure 4: TPC track analysis, red filled areas are the tracks that passed the cuts. a) Azimuthal angle distribution; b) momentum p/Z; c) number of hits, compared to the binomial distribution; d) vertex; e) charge particle multiplicity vs pseudorapidity.

single track efficiency

The losses caused by the inefficiency at low momenta $|p| < 0.4$ GeV were estimated to be between 4 and 2% for the low and the high pseudorapidities, respectively. This estimate was obtained by comparing the data to the thermal distribution. The correction was NOT applied.

The efficiency for the tracks with higher momenta was estimated by comparing the measured number of hits per track (black histogram in Fig. 4c) with a binomial distribution (red). Based on the comparison one might say that the tracks with nhits<15 are fakes. Leaving them out leads to a multiplicity lower by 15%. On the other hand, accepting all of them and in addition accounting for the ones that might be missing in the range 0<nhits<6 leads to an increase of 7%. Both hypotheses being rather radical, I estimate the related systematical uncertainty to be -8 and +4%, respectively.

two-track efficiency

The influence of the two-track efficiency for pairs of close tracks was estimated by analyzing the shape of the opening angle distribution. The estimated net-loss of tracks was $< 4\%$ for the most central events. The correction was NOT applied.

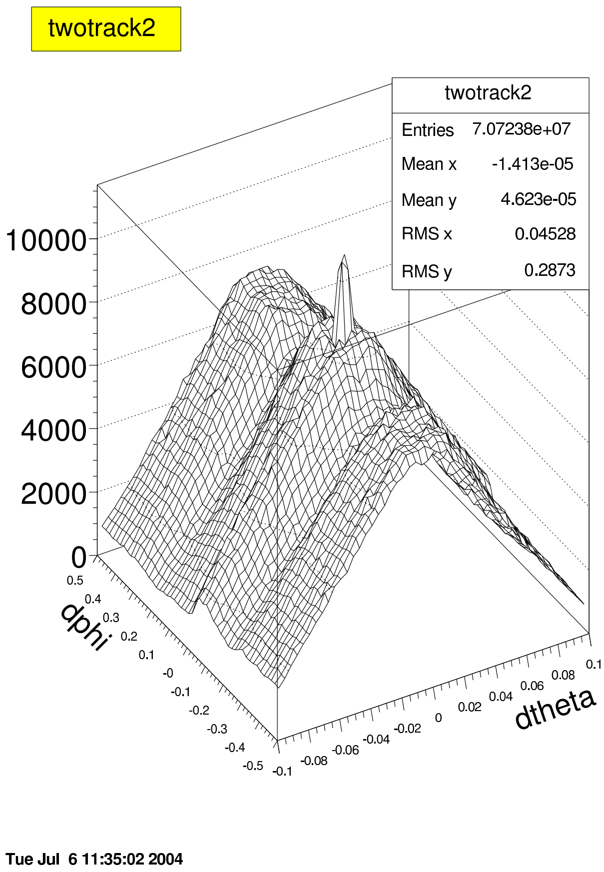

Figure 5: The relative-angle distribution between pairs of tracks in the TPC. A spike (fakes?) sits in a valley caused by the two-track inefficiency.

4 Results

The obtained pseudorapidity distributions are shown in Figs. 4-6. The peak value of the distributions was determined by fitting a Gaussian centered at 3.1. The results of this fit and of an integration within $2 < \eta < 3$, corrected for delta electrons ($dN_{ch}/dy(3.1)$=8, integral 16), are listed in the table below. In addition, dN_{ch}/dy was calculated as $1.02 \times dN_{ch}/d\eta$, based on the UrQMD (see below). The errors are statistical; see below for discussion of systematical uncertainties.

	SD	SD	SD	TPC	SD
centr	dNch/deta(3.1)	dNch/deta(2-3)	dNch/deta(2.1-2.65)	dNch/deta(3.1)	dNch/dy(2.91)
00-05	404.4+-4.4	359.3+-2.4	347.2+-2.4	504.9+-2.4	412.5+-4.5
05-10	340.1+-3.8	300.7+-2.1	291.6+-2.1	420.9+-2.2	346.9+-3.9
10-15	278.7+-3.3	253.8+-1.8	246.1+-1.8	353.2+-2.0	284.3+-3.3
15-20	230.5+-2.8	213.6+-1.6	209.0+-1.6	296.3+-1.8	235.1+-2.8
20-25	189.9+-2.4	177.7+-1.4	173.7+-1.4	251.8+-1.6	193.7+-2.5
25-30	157.8+-2.1	145.9+-1.2	144.2+-1.2	210.2+-1.5	161.0+-2.2
30-35	132.2+-1.9	120.5+-1.1	117.7+-1.1	174.7+-1.3	134.9+-1.9
35-40	107.6+-1.7	97.5+-1.0	94.2+-1.0	141.4+-1.2	109.8+-1.8
40-45	89.5+-1.5	78.1+-0.9	75.6+-0.9	115.1+-1.1	91.3+-1.5
45-50	69.9+-1.4	61.2+-0.8	58.8+-0.8	95.5+-1.0	71.3+-1.4
50-55	54.4+-1.2	47.9+-0.7	46.2+-0.7	77.4+-0.9	55.5+-1.2
55-60	43.9+-1.1	38.6+-0.6	37.5+-0.6	65.9+-0.9	44.8+-1.1
60-65	35.2+-1.0	31.0+-0.6	29.9+-0.6	57.2+-0.8	36.0+-1.0
65-70	30.0+-0.9	24.6+-0.5	22.6+-0.5	47.8+-0.7	30.6+-1.0
70-75	23.7+-0.9	18.9+-0.5	17.2+-0.5	38.3+-0.7	24.1+-0.9
75-80	16.1+-0.8	13.0+-0.4	12.0+-0.4	30.1+-0.6	16.4+-0.8
80-85	11.1+-0.8	6.3+-0.4	5.2+-0.4	21.2+-0.5	11.3+-0.8
85-90	329.2+-1215.9	0.4+-0.3	-0.1+-0.3	11.7+-0.5	335.8+-1240.2
cent	362.7+-5.7	328.0+-3.1	324.5+-3.1	11.7+-0.5	370.0+-5.8
00-04	412.3+-5.0	365.3+-2.7	352.4+-2.7	11.7+-0.5	420.6+-5.1

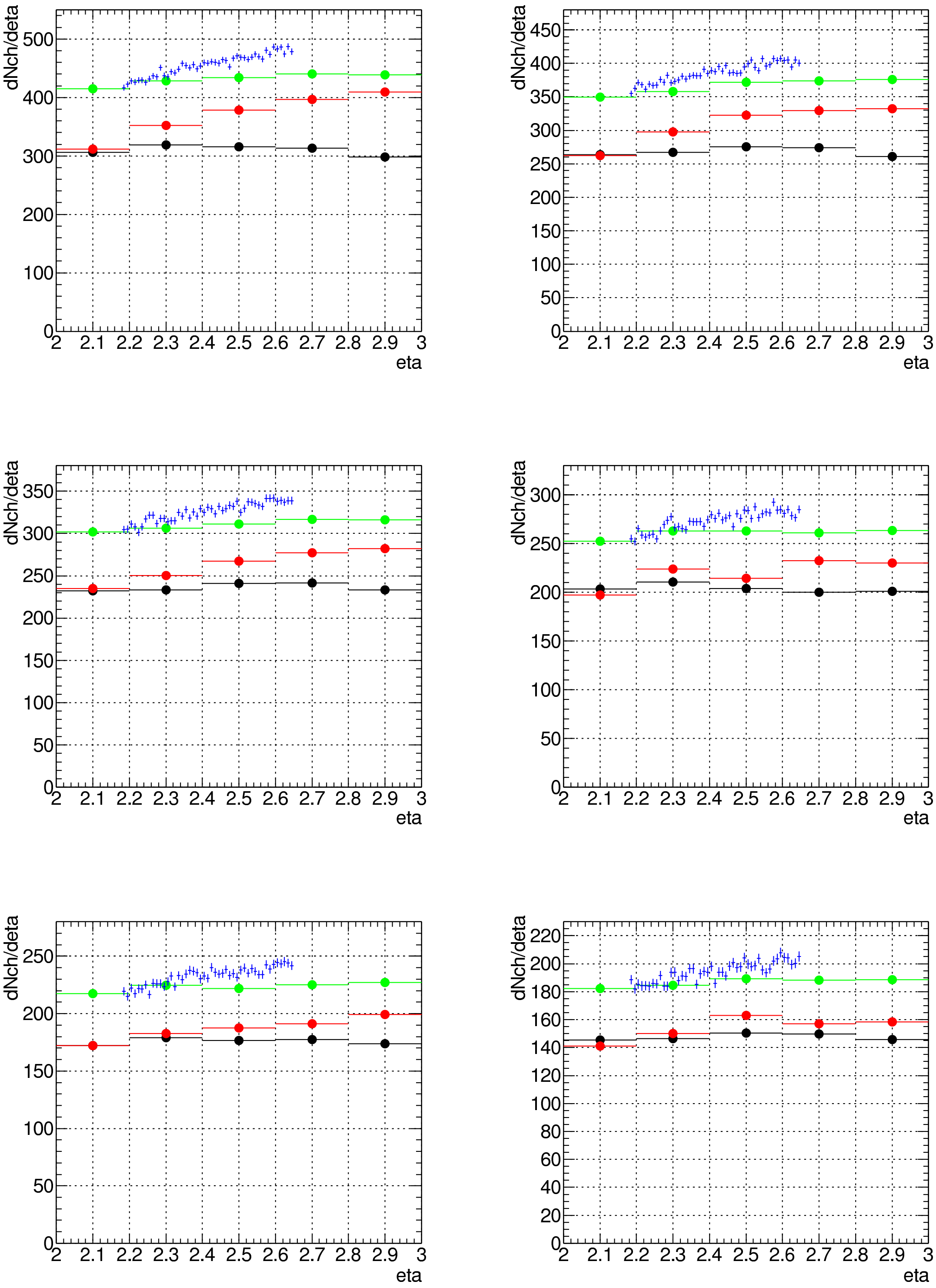

Figure 6: Pseudorapidity distributions of charged particles: raw (black), corrected for two-track efficiency (red), and naive (green). For comparison, the charged tracks in the TPC are shown in blue. The 6 panels represent centralities 00-05%, . . . , 25-30%.

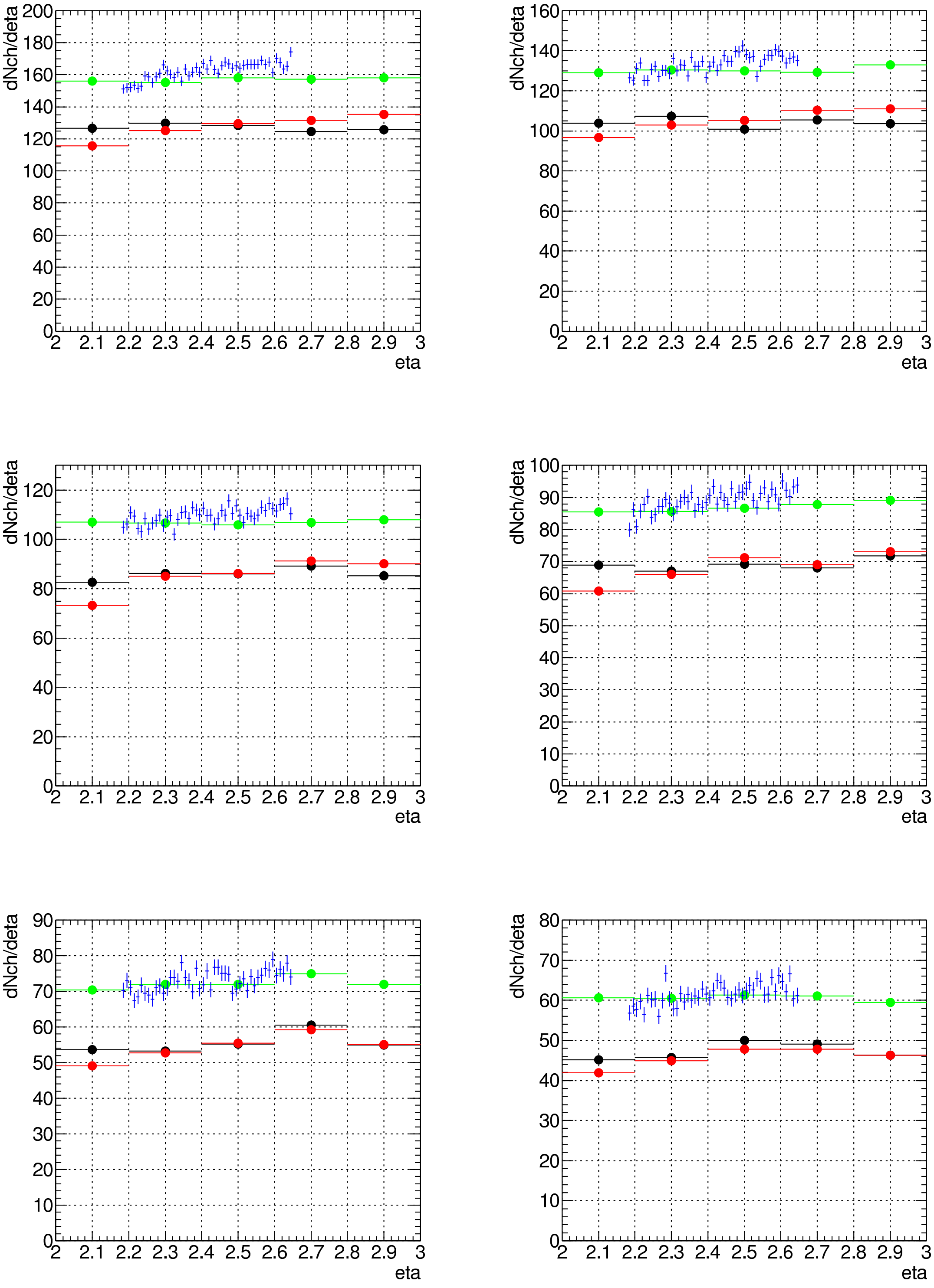

Figure 7: Pseudorapidity distributions of charged particles: raw (black), corrected for two-track efficiency (red), and naive (green). For comparison, the charged tracks in the TPC are shown in blue. The 6 panels represent centralities 30-35%, . . . , 55-60%.

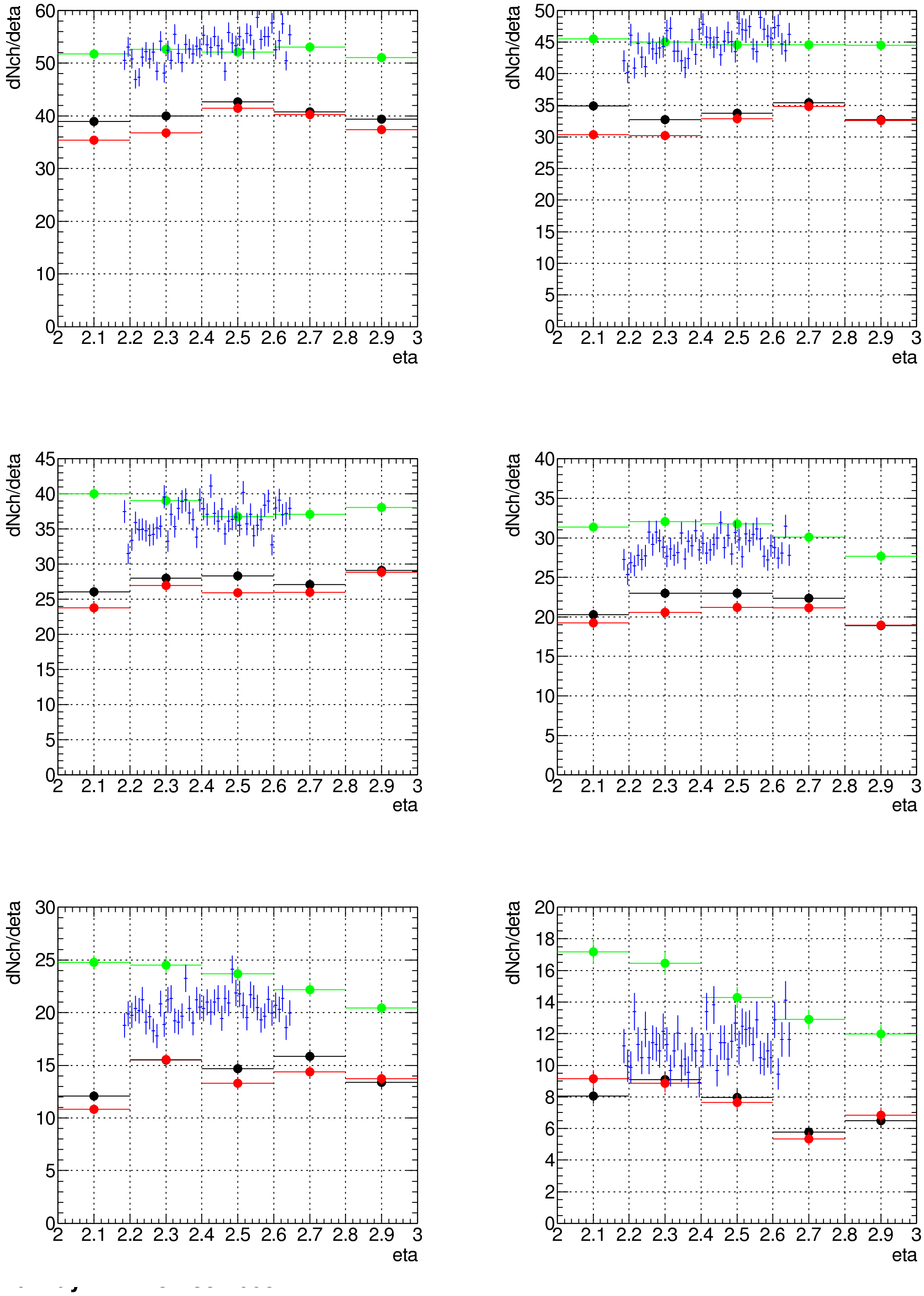

Figure 8: Pseudorapidity distributions of charged particles: raw (black), corrected for two-track efficiency (red), and naive (green). For comparison, the charged tracks in the TPC are shown in blue. The 6 panels represent centralities 60-65%, . . . , 85-90%.

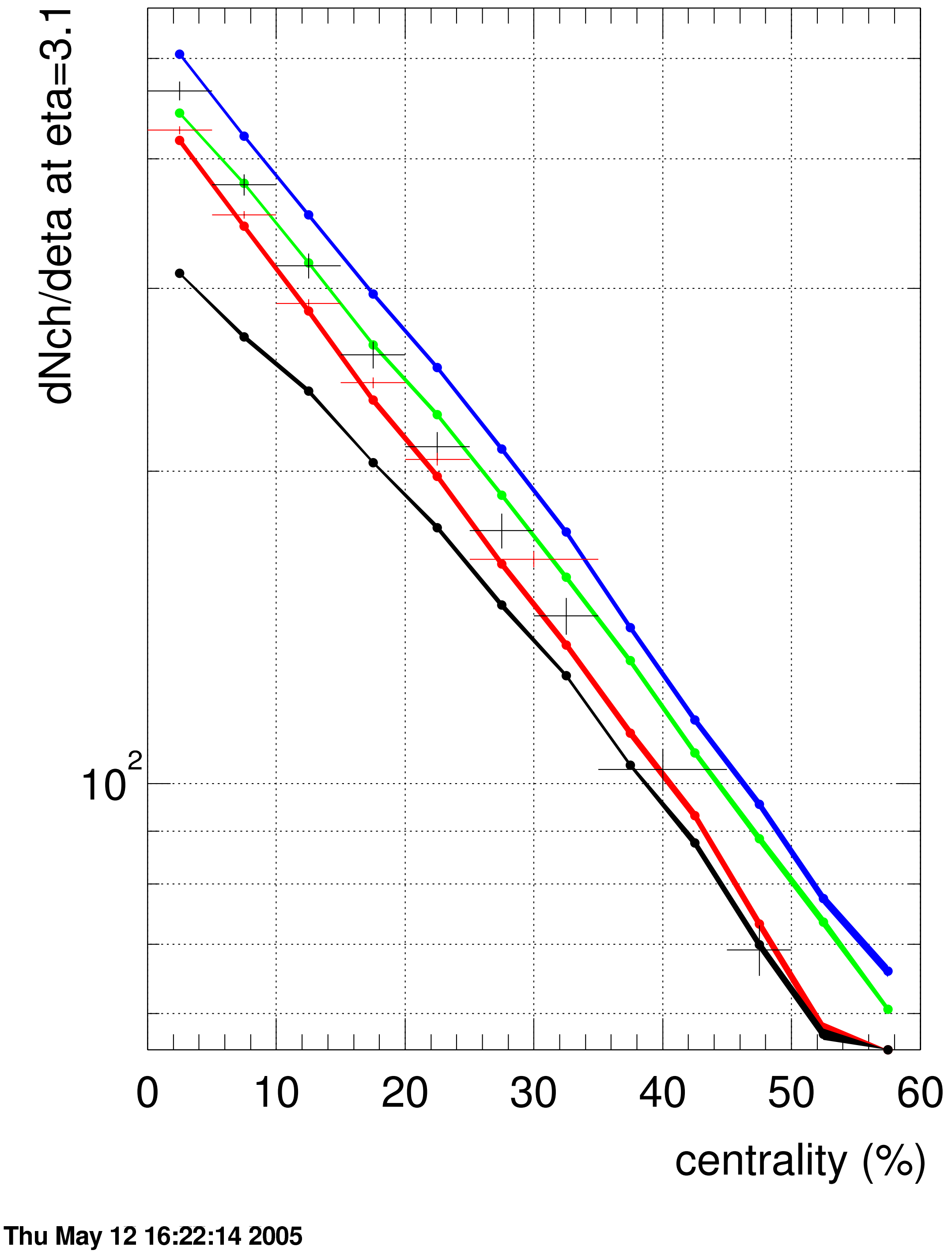

Figure 9: Centrality dependence of the $dN_{ch}/d\eta$ at $\eta = 3.1$. The black, red, green, and blue curves represent the raw, the two-track efficiency corrected, naive, and TPC track mulciplicities, respectively. The black and the red crosses show the data of NA57 and NA50.

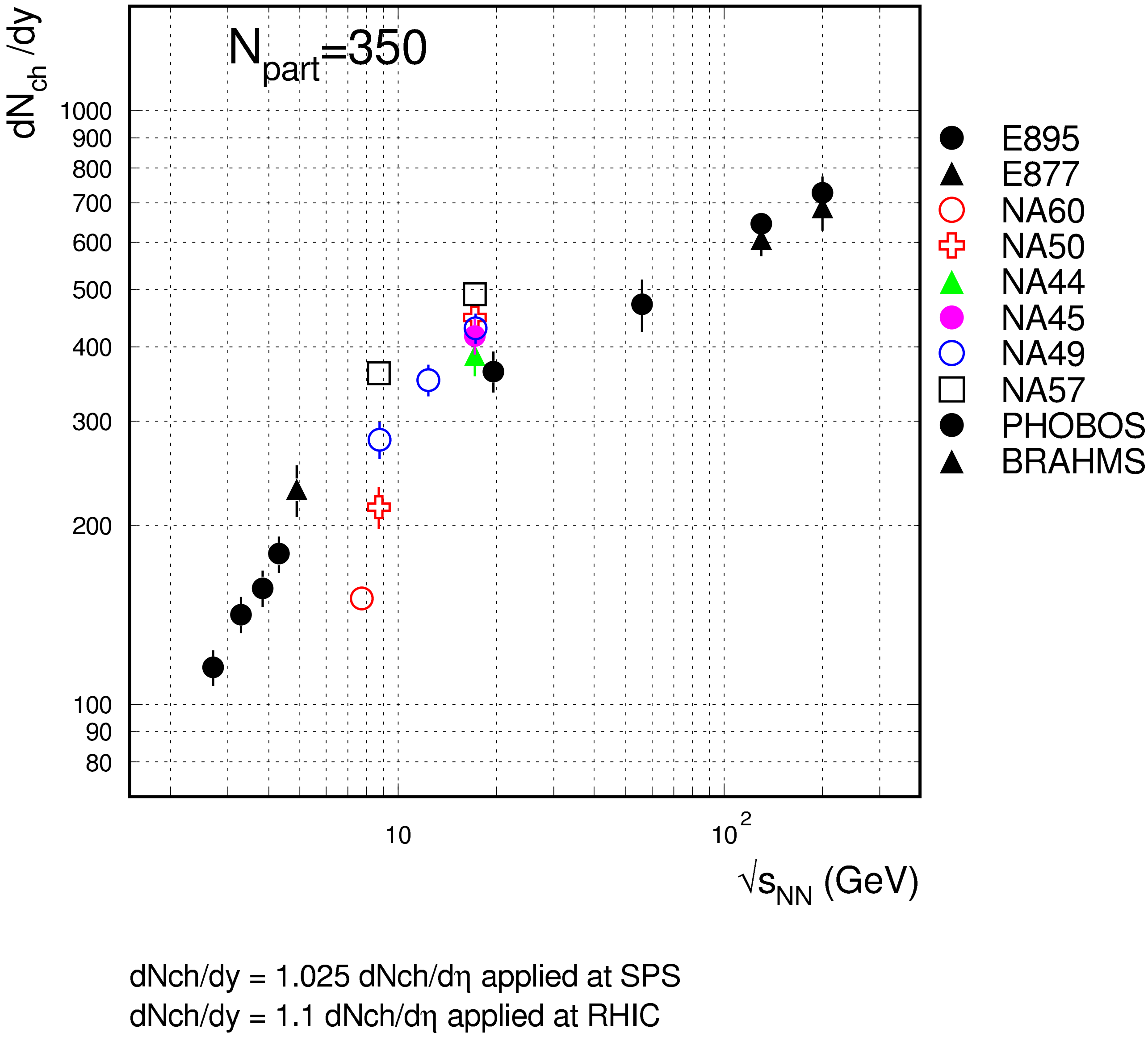

Figure 10: Energy dependence of dN_{ch}/dy (courtesy of Anton Andronic (AA)).

5 Systematical error estimate

The systematical errors in the SD analysis were estimated by checking the sensitivity of the result to small modification of the analysis procedure. In the case of the TPC, the quoted numbers represent the estimated magnitude of various effects not corrected for in the analysis.

SD analysis

vary the positions of the ϕ regions	$\pm 1\%$
vary the width of the ϕ regions	$\pm 1\%$
require dedx>200 for all SD hits	-5%
vary the range of normalization or integration during fake subtraction	$\pm 2\%$
fake subtraction using the LAB (instead of the event-) vertex coordinates	-4%
vary the range of the exponential fit in the two-track extrapolation	$\pm 5\%$
an additional degree of freedom in the two-track extrapolation	-8%
choice of $\Delta\phi$ in the two-track extrapolation	$\pm 2\%$
quadratic sum of all that	$\pm 12\%$

TPC analysis

efficiency	$+4\%$
fakes	-8%
efficiency for $\lvert p \rvert < 0.4$ GeV	$+4\%$
two-track efficiency	$+4\%$
quadratic sum of all that	$\pm ??\%$

6 UrQMD

For comparison, pseudorapidity and rapidity distributions of charged particles from UrQMD 1.3 were analyzed (Fig. 7). The pseudorapidity distributions peak at 3.1-3.2 and have a width of 1.5-2.0. The rapidity distributions are higher by 2-3% than the pseudorapidity.

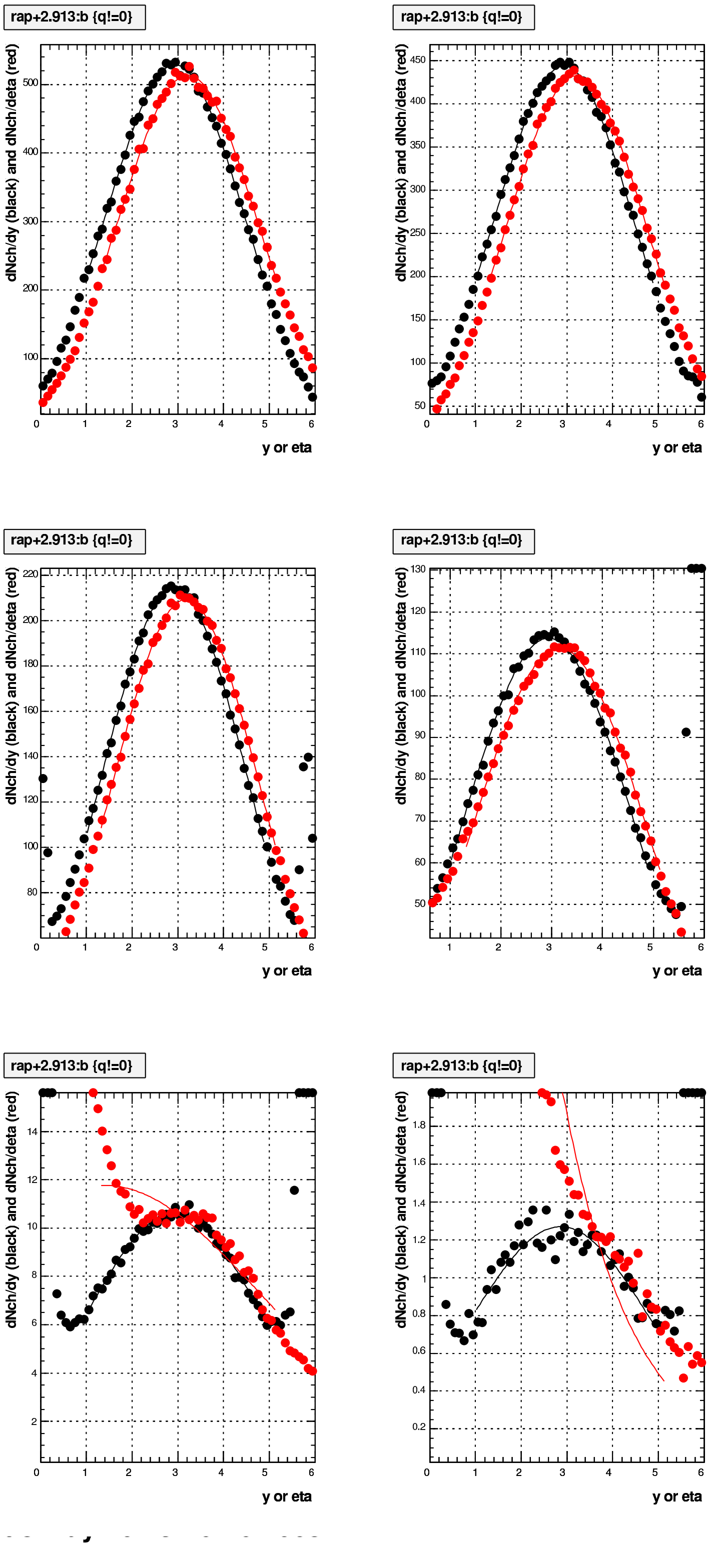

Figure 11: Rapidity (black) and pseudorapidity (red) distributions of charged particles from UrQMD 1.3. The 8 panels represent centralities $0< b <2$ fm, ..., 14 fm$< b <16$ fm.

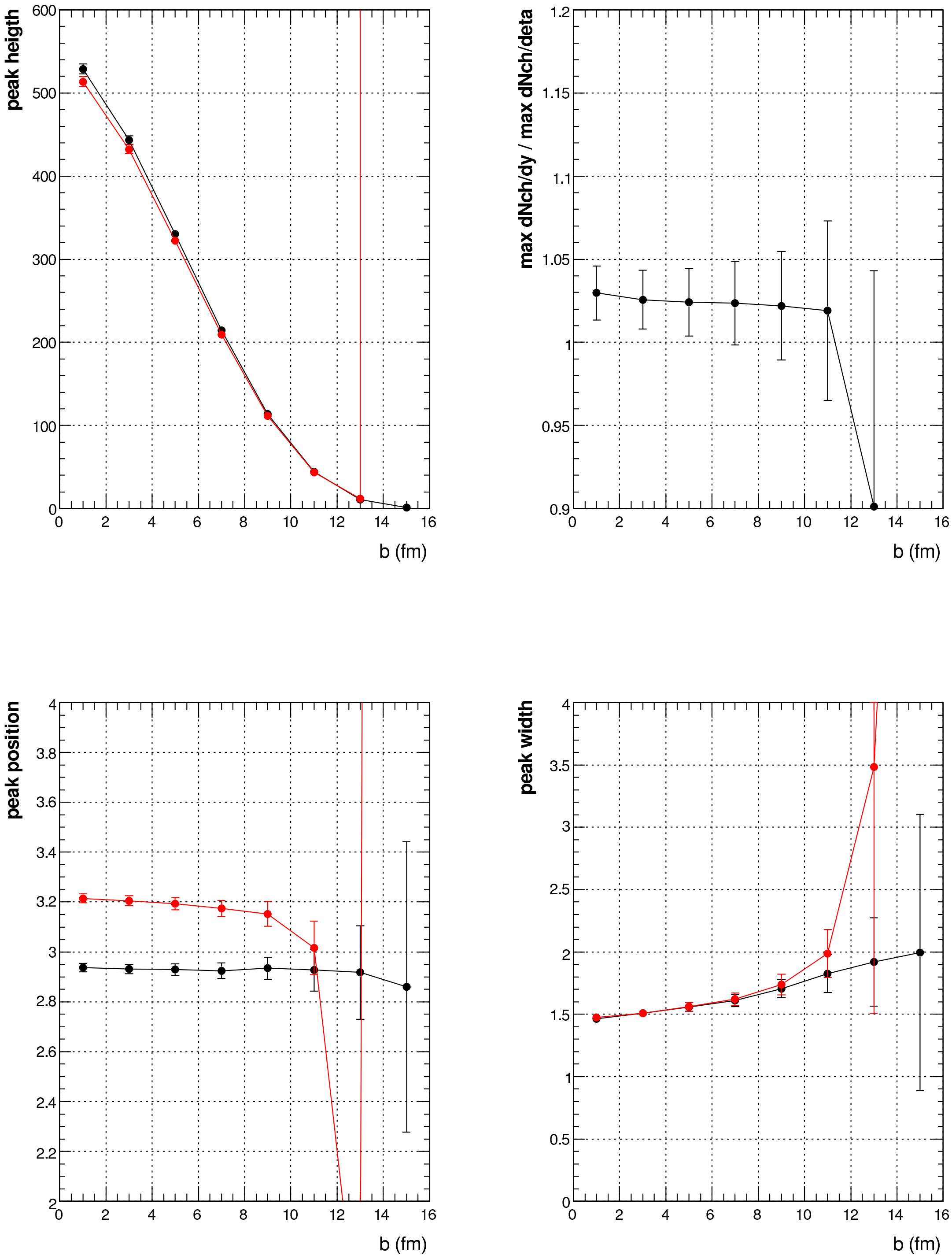

Figure 12: Comparison of rapidity (black) and pseudorapidity (red) distributions in UrQMD 1.3.