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Fiducial Cut For Positive Hadrons in CLAS/E2 data at 4.4 GeV

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Abstract

The procedure of deriving the geometrical fiducial cut for positive hadrons at 4.4 GeV (I_B=2250 A) for E2 run data is discussed.

1 Introduction

The CEBAF Large Acceptance Spectrometer (CLAS) is designed to measure multi-particle final states[1]. It is based on six iron free superconducting coils that generate a toroidal magnetic field in between. Each of the six gaps between the coils is equipped with a set of drift chambers (DC)[2] and scintillator counters (SC)[3] from 10° to 145° in polar angle, Cerenkov counters (CC)[4] and electromagnetic calorimeters (EC)[5] from 10° to 45°. In electron scattering experiments with CLAS, the triggered event is accepted for physics analysis if the scattered electron and the other particles in event are identified. Due to the complicated readout structures (EC), (CC), detection and reconstruction efficiencies are not well understood in the regions close to the magnet, or close to any dead channels (DC,SC,CC,EC). In order to minimize systematic uncertainties in the physics analysis it is important to accept events in the fiducial region of the detector, where efficiencies are understood. The fiducial cut for electrons (for CLAS/E2) is discussed in ref. [6]. We use the same data and the same method to derive fiducial cuts for positive hadrons (protons, pions), so we are going to follow the steps described in [6].

The Fiducial Cut Procedure is defined by three steps:

1. Applying cuts

2. Determining the flat acceptance regions in ϕ space for small bins of θ and momentum

3. Fitting the boundaries of the flat acceptance region as a function of θ and ϕ

Web-based documentation that contains description of the procedure, plots, including a complete set of histograms and routines is given in [7].

2 Selecting good events

We applied cuts that helps to make better fit:

1. Selecting events with an electron and a good positive hadron (good DC, SC status).

2. Cut on χ^2 from DCPB bank

We cut out events with bad tracks (with χ^2 >13.2). That allows us to keep 99% of the integral of DC χ^2 distribution.

3. Cut on Energy transfer

We apply that cut to eliminate protons from quasi-free reactions. These protons are not uniformly distributed in ϕ and could not be fit by the trapezoid method. The quasielastic peak results from the electron interacting with a single nucleon of mass m_N and knocking it out of the nucleus. The energy transfer for those events defined by:

$$\omega = \frac{Q^2}{2m_N} + \frac{\vec{q} \cdot \vec{p}}{m_N}$$

We cut out energy transfer in the range:

$$\frac{Q^2 - 2 \cdot q \cdot p_{init}}{2m_N} < \omega < \frac{Q^2 + 2 \cdot q \cdot p_{init}}{2m_N};$$

where $p_{init} = 200$ MeV/c is the initial momentum of the struck nucleon. The 6 sectors (θ,ϕ) distribution plots with the quasielastic peak are shown in Fig.1.

3 Finding the Flat Acceptance Region

We divide the momentum range of the protons and pions in small bins and plot for each momentum bin a two-dimensional histogram of counts versus angles (θ and ϕ) for each sector. We use two momentum ranges $0.2 < p < 0.6$ GeV/c (protons only) and $0.6 < p < 4.4$ GeV/c (protons and pions). Table 1 shows the momentum binning for our plots. Fig.2 and Fig.3 show some typical (θ,ϕ) plots at different momentum for 6 sectors using E2 run ^3He data at 4.4 GeV.

Table 1: Momentum Bins

Momentum Range MeV/c	**Hadrons**	**Bin Size MeV/C**	**Number of Bins**
0 – 600	p	50	12
600 – 1000	$p\,\pi$	50	8
1000 – 2000	$p\,\pi$	100	10
2000 – 4400	$p\,\pi$	200	12

The histograms in Fig.2 and Fig.3 exhibit a well contoured semicircular region, surrounded by a fuzzy region. We want to select this solid area of the histogram, which is the flat acceptance region and discard the blurred area surrounding it. For this, we will fit its contour with a function $\Phi(\theta, p)$ for every sector. To define the flat area we slice the two-dimensional plots in theta bins of $2°$ at $11° < \theta < 45°$ (Forward region) and $2-10°$ at $45° < \theta < 140°$ (Backward region). We fit each sliced histogram with a trapezoid + background function, defined by:

$$y = \begin{cases} p0, & \text{if } x < p2 - p1; \\ (p6 - p0) \cdot (x - p2 + p1)/p1 + p0, & \text{if } p2 - p1 < x < p2; \\ p6, & \text{if } p2 < x < p3; \\ (p6 - p5) \cdot (p3 + p4 - x)/p4 + p5, & \text{if } p3 < x < p3 + p4; \\ p5, & \text{if } x < p3 + p4. \end{cases}$$

Each parameter is described in Fig.4. Some typical trapezoids (fitted θ slices) are shown in Fig.5 and Fig.6. The plateau of the trapezoid (parameters $p2, p3$) defines our "flat" acceptance region. The automatic fitting procedure gives us reliable results in over 90% of the fits. Some of the "bad" θ slices are shown in Fig.7. Bad fits are "fixed" manually by increasing the error bar of the resulting parameters.

The coordinates of the edges of the trapezoid plateau for each momentum bin and sector are written to a file and fitted with a function $\phi = \Phi(\theta, p)$ for every momentum bin and sector. The procedure is completely automatic. We use the CERN two-dimensional Minuit fit routine for fitting non-equidistant data points. An example of that fitting function is given in [8].

We chose two different functions to fit the Forward and Backward regions and also we fit separately 2 momentum regions using the range of momenta $0.2 < p < 0.6$ GeV/c and $0.6 < p < 4.4$ GeV/C.

For the Forward region we used a hyperbolic function for the theta dependence and a $1/p$ function for the momentum dependence:

For $\phi < 0$: $\quad \Phi(\theta, p) = a \cdot (c - \theta)/(\theta - c + (b/a))$
For $\phi > 0$: $\quad \Phi(\theta, p) = a' \cdot (\theta - c')/(\theta - c' + (b'/a'))$

where,

$$a = a_0 + a_1/p$$
$$b = b_0 + b_1/p$$
$$c = c_0 + c_1/p$$

and similarly for a',b' and c'.
To avoid discontinuity at $\phi = 0$ we introduce θ_{min} variable. We cut out events with $\theta < \theta_{min}$. For $0.2 < p < 0.6$ GeV/c $\theta_{min} = 20.6 - 11.4 \cdot p$. For $0.6 < p < 1.5$ GeV/c θ_{min} determined visually for Sectors 1,4,5 and 6.

We divided the Backward region into two regions BackwardA ($45° < \theta < 60°$) and BackwardB ($60° < \theta < 140°$). For the BackwardA region we used a quadratic function and for the BackwardB region we used a constant ($60° < \theta < \theta_{flat}$) +straight line ($\theta_{flat} < \theta < \theta_{max}$) (see Fig. 8) with a $1/p$ function for the momentum dependence:

For $45° < \theta < 60°$:

$\phi < 0$: $\quad \Phi(\theta, p) = (d + e \cdot \theta + f \cdot \theta^2)$

$\phi > 0$: $\quad \Phi(\theta, p) = -(d' + e' \cdot \theta + f' \cdot \theta^2)$

where,

$$d = d_0 + d_1/p$$
$$e = e_0 + e_1/p$$
$$f = f_0 + f_1/p$$

and similarly for d',e' and f'.

For $60° < \theta < \theta_{flat}$:

$$\Phi(\theta, p) = \Phi(60°, p)$$

(no free parameters)

For $\theta_{flat} < \theta < \theta_{max}$:

$$\Phi(\theta, p) = (140° - \theta) \cdot (\Phi(60°, p) - \phi_{edge})/(140° - \theta_{flat}) + \theta_{flat}$$

where, θ_{flat} and ϕ_{edge} are determined from fitting and θ_{max} is determined visually from (θ, ϕ) distributions and parameterized using a linear function in p.

$$\theta_{flat} = g_0 + g_1/p;$$

$$\phi_{edge} = h_0 + h_1/p;$$

$$\theta_{max} = i_0 + i_1 \cdot p$$

BackwardB region parameters $\theta_{flat}, \phi_{edge}$ and θ_{max} are shown in Fig.8. These fits were necessary due to the lack of the data in the BackwardB region. For $p > 0.6$ GeV/c the $\theta_{flat}, \phi_{edge}$ and θ_{max} at $p = 0.575$ GeV/c were used (last momentum bin of $p < 0.6$ GeV/c region). To avoid discontinuity at $\theta = 45°$ we fit the BackwardA region θ range starting from $\theta = 30°$ instead of $\theta = 45°$. Also, we replace the $\Phi(40°, p)$ edge points with values defined from the Forward region fiducial function with error=0.05. That forced the BackwardA region curves to start from the end point of the Forward region curves.
The list of fit parameters is given in Table 2.

Table 2: List of the fit parameters

P[GeV/c]	ϕ	*Forward* $\theta < 45°$	*BackwardA* $45° < \theta < 60°$	*BackwardB* $60° < \theta < 140°$
$p < 0.6$	$\phi < 0$	$a_0, a_1, b_0, b_1, c_0, c_1$	$d_0, d_1, e_0, e_1, f_0, e_1$	$g_0, g_1, h_0, h_1, i_0, i_1$
	$\phi > 0$	$a'_0, a'_1, b'_0, b'_1, c'_0, c'_1$	$d'_0, d'_1, e'_0, e'_1, f'_0, e'_1$	$g'_0, g'_1, h'_0, h'_1, i'_0, i'_1$
$p > 0.6$	$\phi > 0$	$a''_0, a''_1, b''_0, b''_1, c''_0, c''_1$	$d''_0, d''_1, e''_0, e''_1, f''_0, e''_1$	
	$\phi > 0$	$a'''_0, a'''_1, b'''_0, b'''_1, c'''_0, c'''_1$	$d'''_0, d'''_1, e'''_0, e'''_1, f'''_0, f'''_1$	

Some typical plots of 2D fits of the data points with corresponding $\Phi(\theta, p)$ function for Forward and Backward regions are shown in Fig.9 and Fig.10, respectively. The fitting procedure gives us the final set of parameters, that is included to the **PFiducialCut** subroutine of **E2AnaTool** package. Fig.11 shows the overall result of the fiducial cut as made by using the derived **PFiducialCut** function for 4.4 GeV data.

4 Summary

We determined the fiducial region for positive hadrons by the following techniques: We eliminated events with bad tracks and events that generate quasielastic peaks. We split the angle-momentum range into small bins and found the contour of the regions of CLAS where acceptance is flat. We get from this a set of curves. What is inside the contour passes as OK, what is out is discarded. We fit the parameters that defines flat acceptance and insert them to **PFiducialCut(***Pr3Vect)* subroutine together with the functions that define the fiducial cut.

5 Acknowledgments

We would like to thank Bin Zhang (MIT) for discussions and work he has done to obtain fiducial cuts for positive hadrons at 2.2 Gev [9]. Also we want to thank Dan Protopopescu (UNH) for nice description of fiducial cut procedure [6] for electrons at 4.4 GeV.

References

[1] B.Mecking et al., CLAS detector, In preparation, to be submitted to Nucl.Instr. and Meth.

[2] M.D.Mestayer et al., The CLAS drift chamber system, Nucl.Instr. and Meth. **A449** (2000) 81

[3] E.S. Smith et al., The time-of-flight system for CLAS, Nucl.Instr. and Meth. **A432** (1999) 265

[4] The Cherenkov counter system for CLAS , In preparation, to be submitted to Nucl.Instr. and Meth.

[5] L.C. Smith et al., The CLAS forward electromagnetic calorimeter, Accepted for publication in Nucl.Instr. and Meth.

[6] D.Protopopescu et al., Fiducial Cuts for electrons in CLAS/E2 data at 4.4 GeV CLAS-NOTE 01-008

[7] http://www.physics.odu.edu/~rust/clas/fidp.html

[8] http://root.cern.ch/root/html/examples/Ifit.C.html

[9] http://www.jlab.org/Hall-B/secure/e2/bzh/pfiducialcut.html

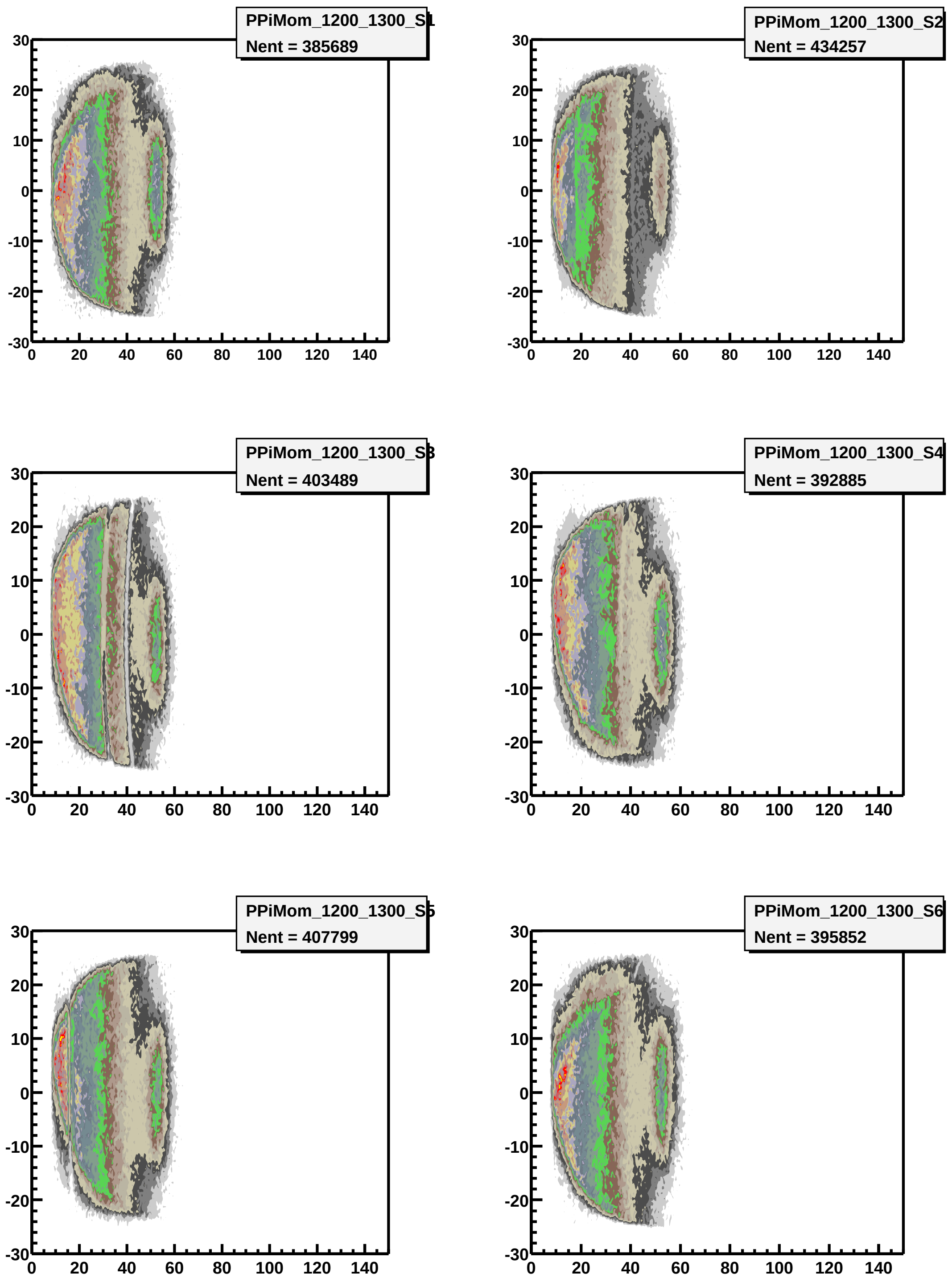

Figure 1: Plots of (θ,ϕ) distribution with quasielastic peak. The peak is at $\theta = 50°$ at proton momentum (1200< p <1300 MeV/c). The 6 plots are for the 6 sectors. Vertical axis is defined by ϕ, horizontal axis is defined by θ.

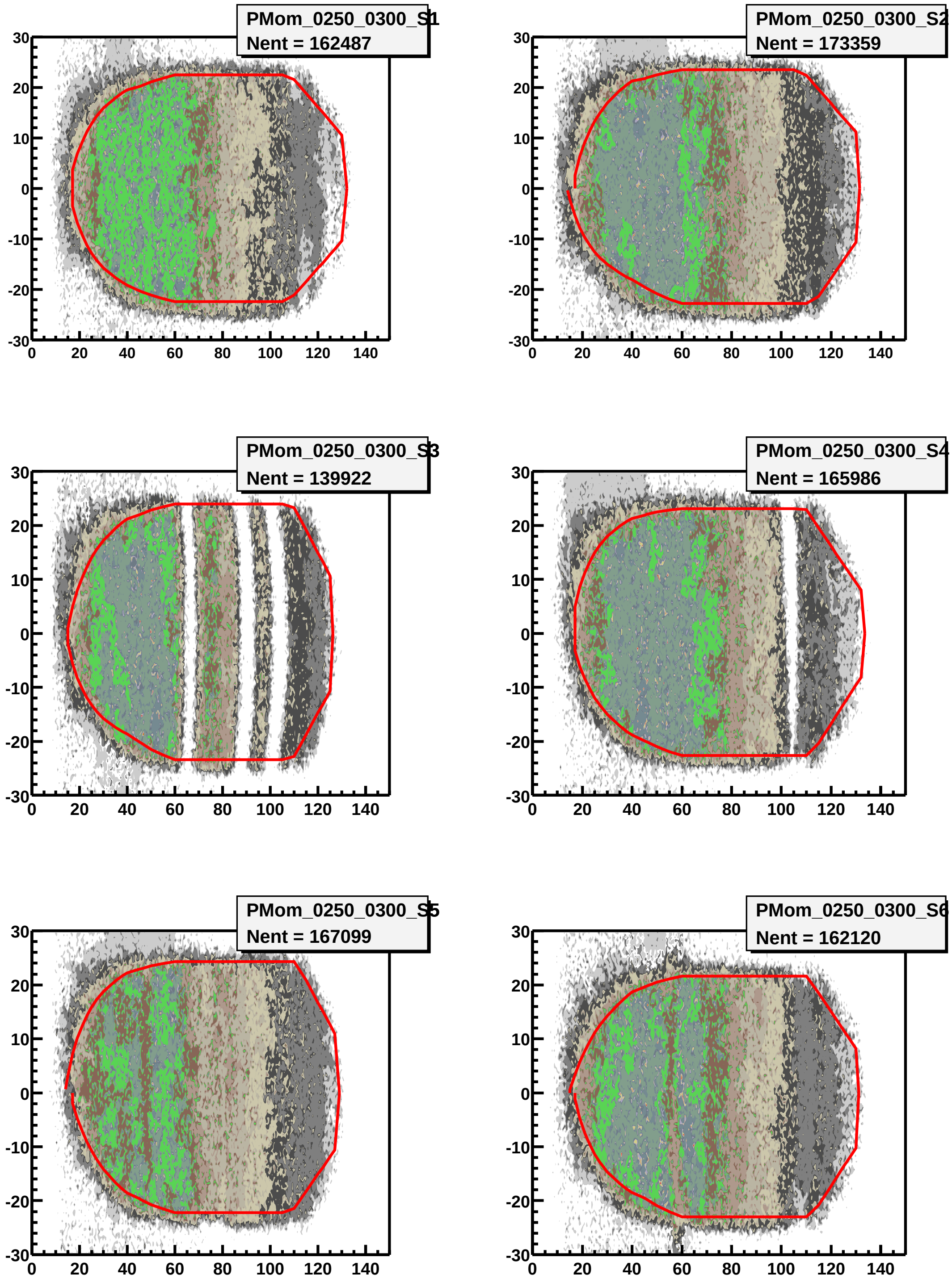

Figure 2: Some typical plots of (θ,ϕ) distribution at 250$< p <$300 MeV/c for all 6 sectors. Red line on the top of the distribution is defined by fiducial cut function. Vertical axis is defined by ϕ, horizontal axis is defined by θ.

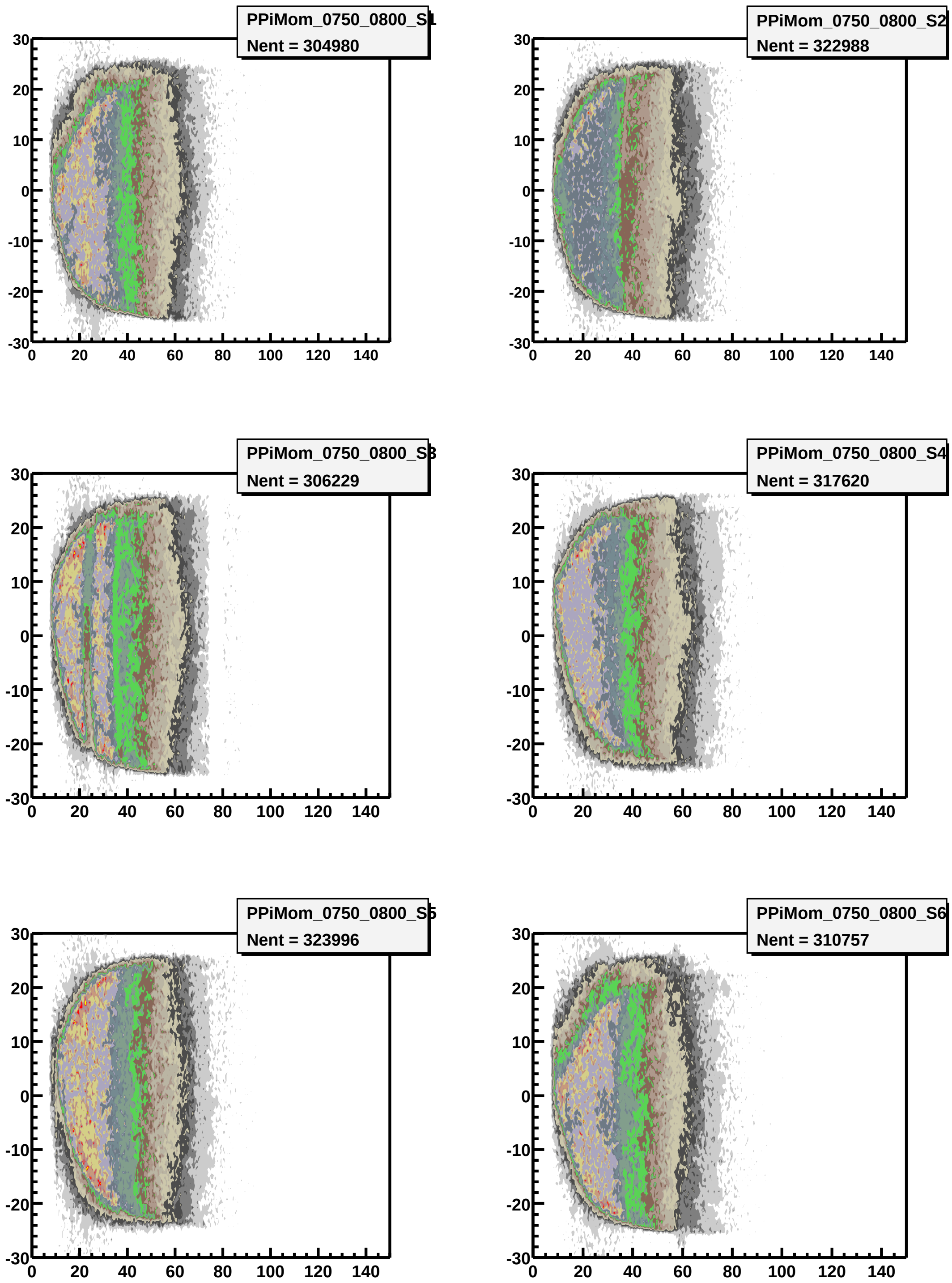

Figure 3: Plots of (θ,ϕ) distribution at 750< p <800 MeV/c for all 6 sectors.

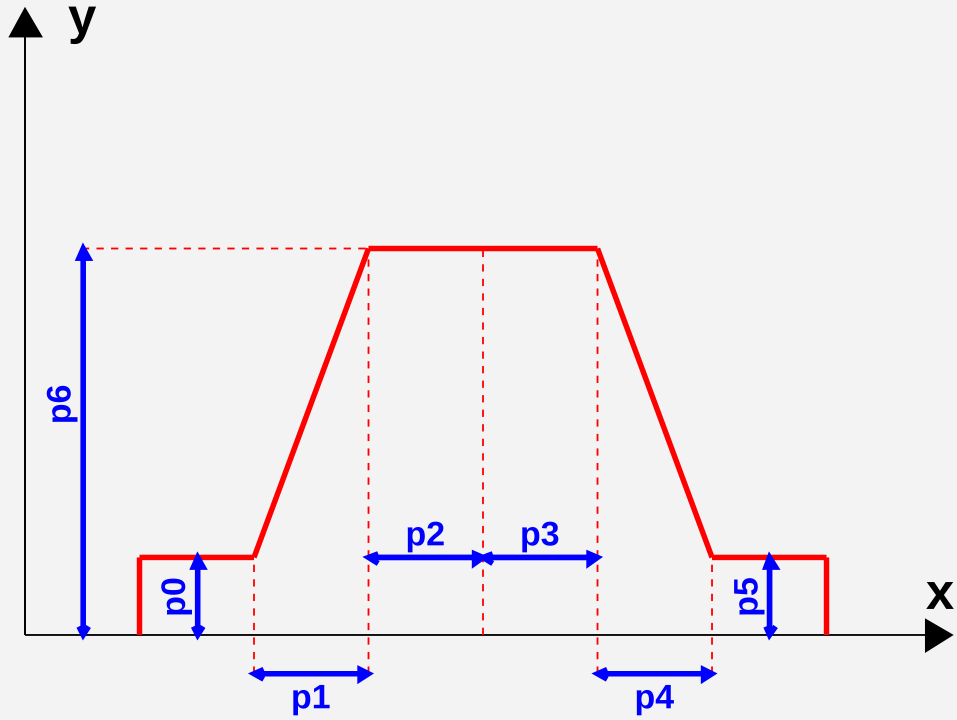

Figure 4: Parameters used for fitting trapezoid+background function.

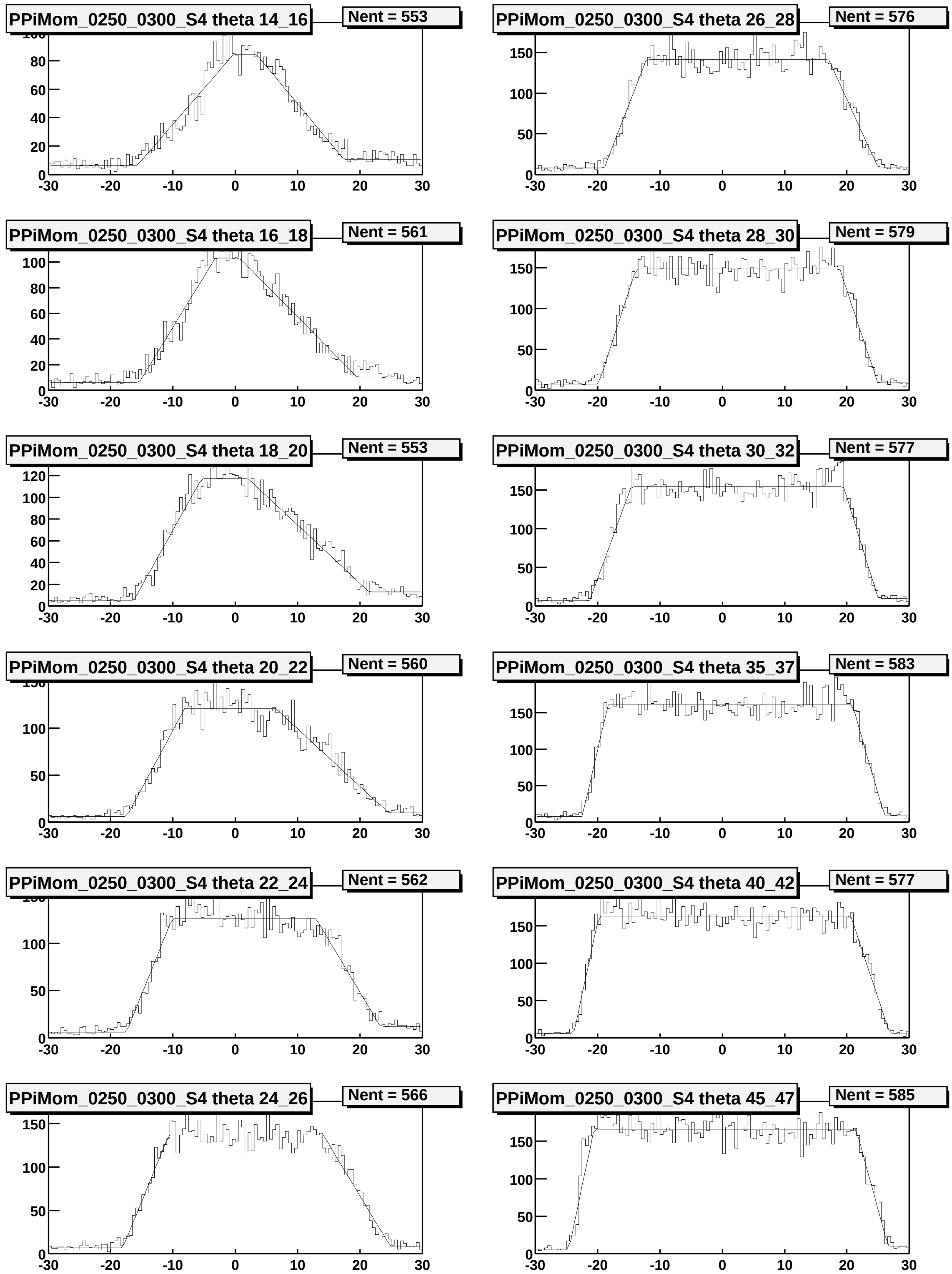

Figure 5: Trapezoid+background function fitted on histogram counts vs ϕ angle. The top defines our "flat" region. These are for Sector 4, 250< p <300 MeV/c.

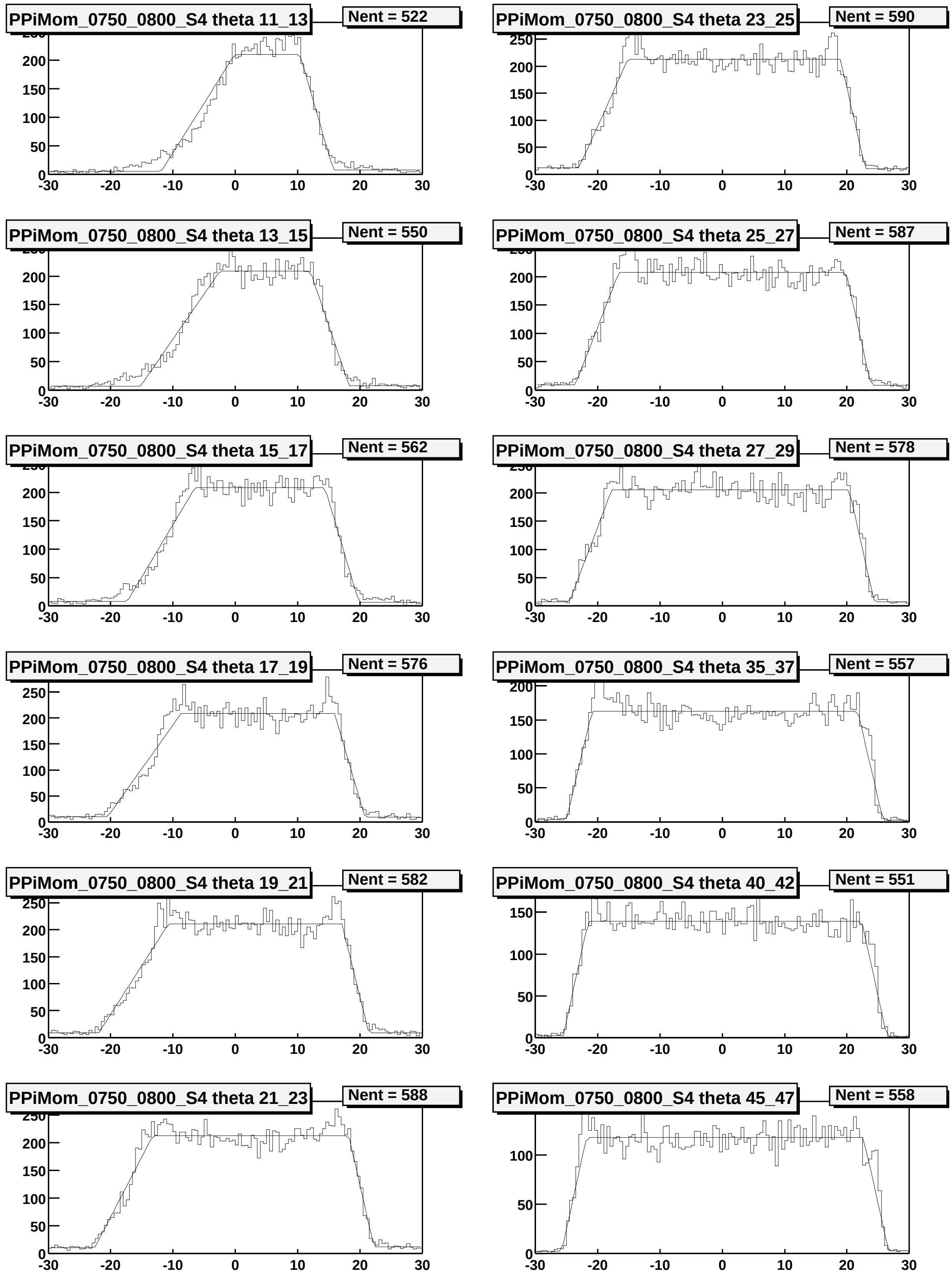

Figure 6: Trapezoid+background function fitted on histogram counts vs ϕ angle. These are for Sector 4, 750< p <800 MeV/c.

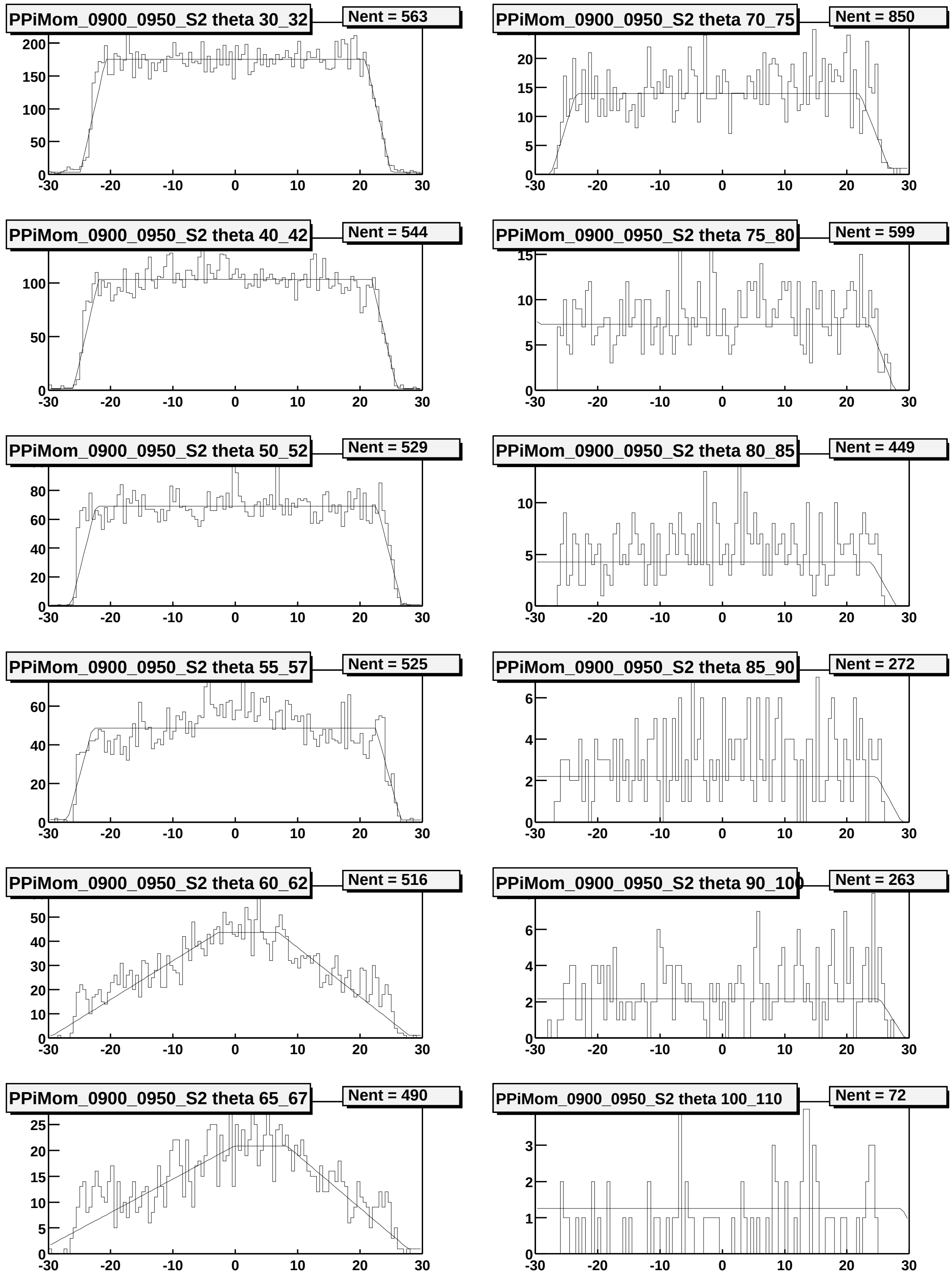

Figure 7: Typical bad θ slice. These are for Sector 2, 900< p <950 MeV/c. Vertical axis is defined by counts, horizontal axis is defined by ϕ.

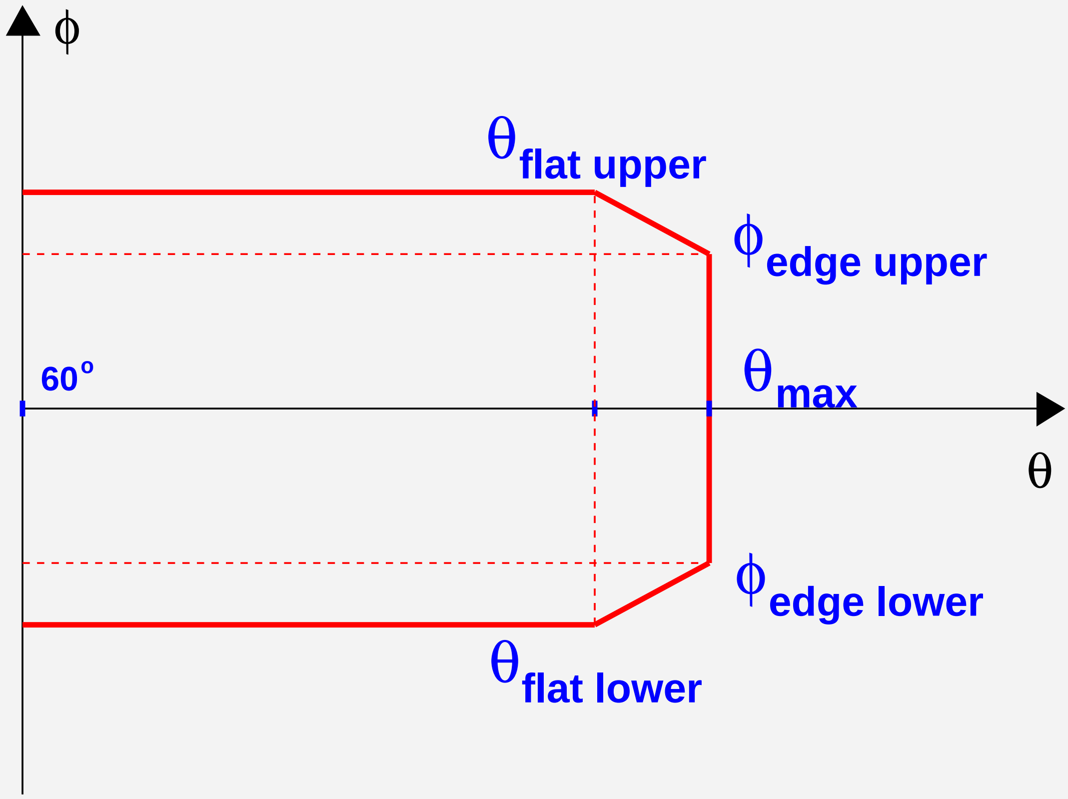

Figure 8: Backward region parameters $\theta_{flat}, \phi_{edge}$ and θ_{max}.

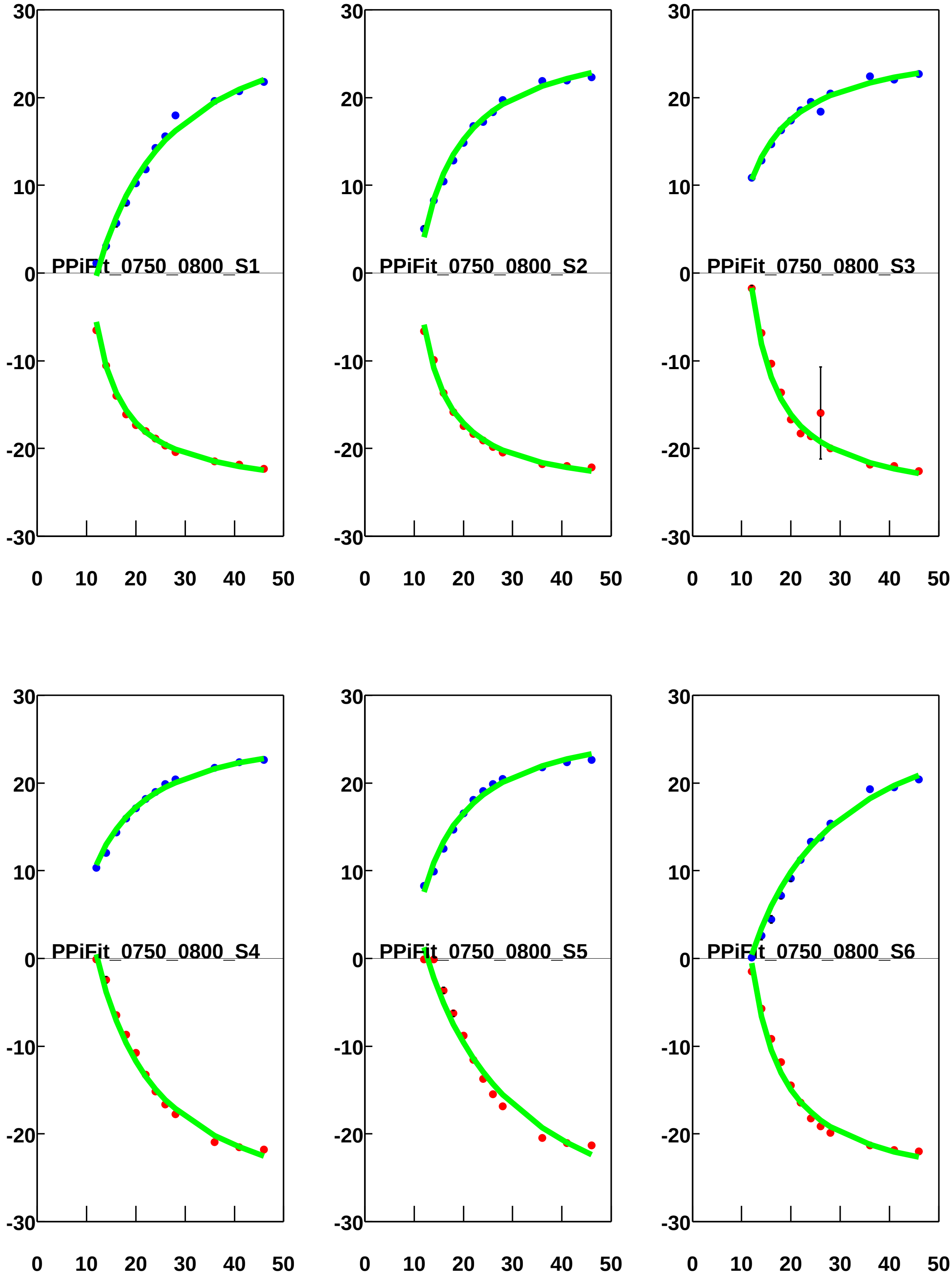

Figure 9: Forward region $\Phi(\theta, p)$ fit at 750< p <800 MeV/c. 6 graphs are for 6 sectors. Vertical axis is defined by ϕ, horizontal axis is defined by θ.

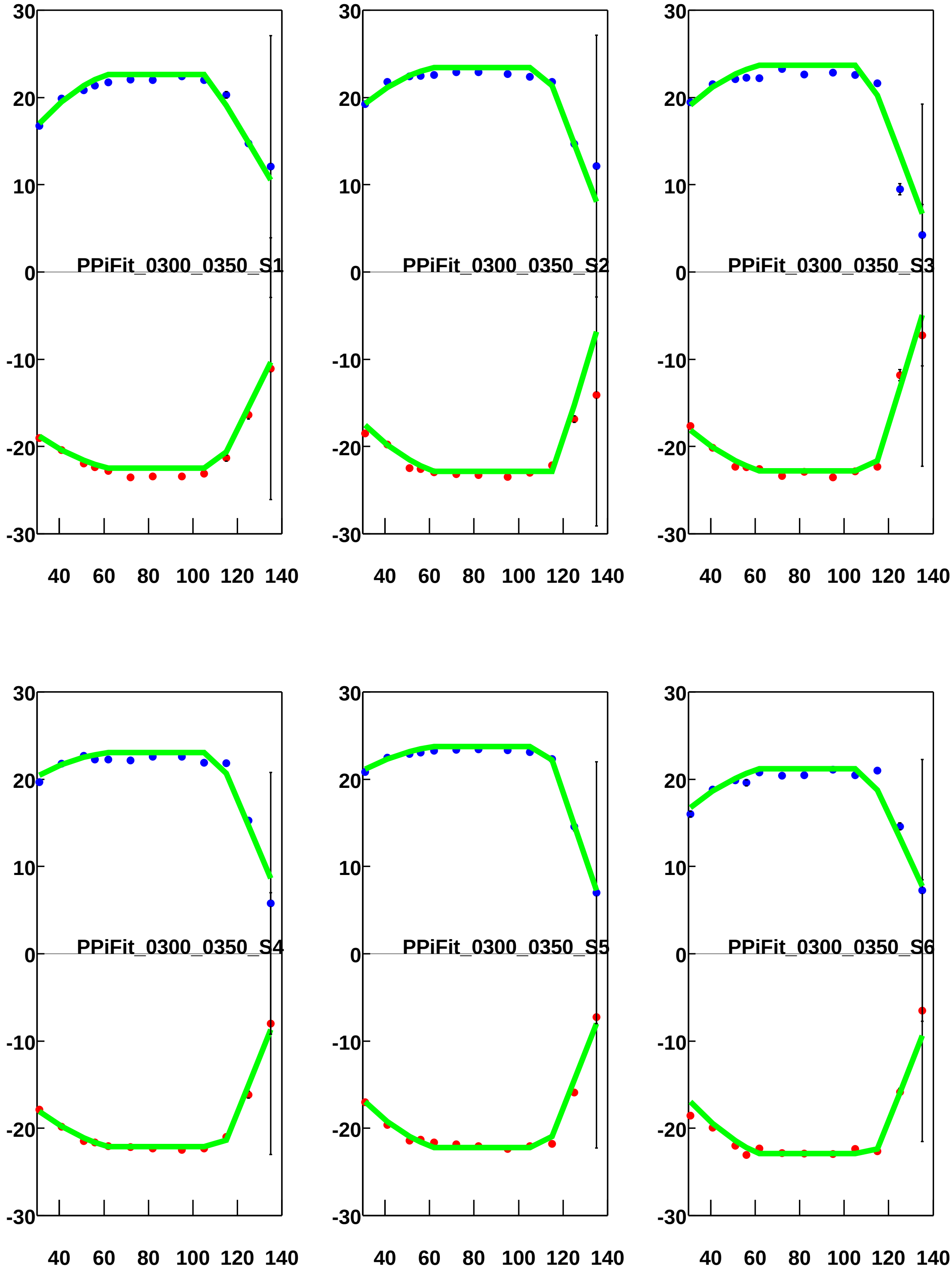

Figure 10: Backward region $\Phi(\theta, p)$ fit at 300< p <350 MeV/c. 6 graphs are for 6 sectors. Vertical axis is defined by ϕ, horizontal axis is defined by θ.

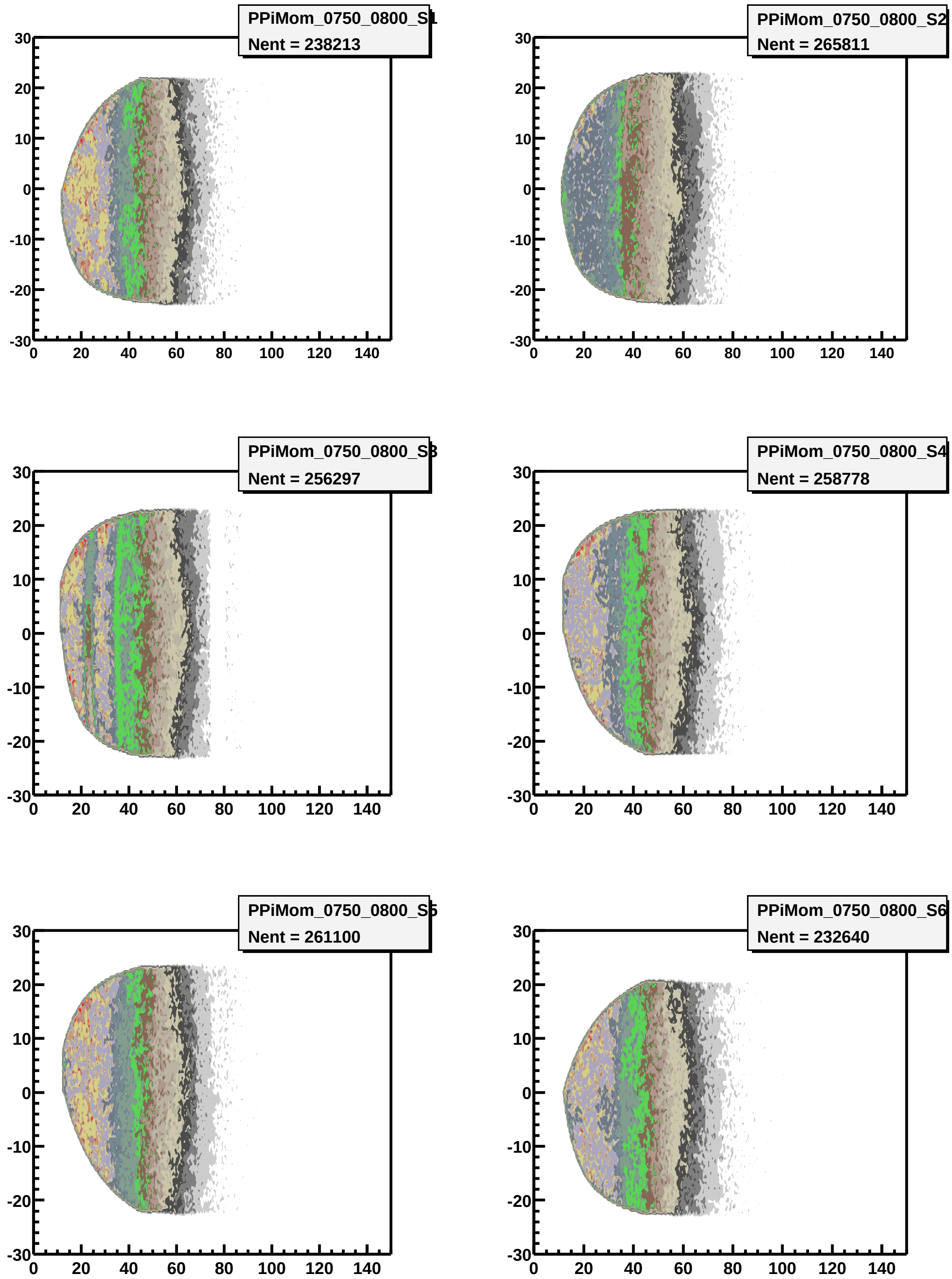

Figure 11: Plots illustrating the result of the cut at 750< p <800 MeV/c for all 6 sectors. Vertical axis is defined by ϕ, horizontal axis is defined by θ.