Detection Efficiency for the Hadronic Events in R Measurement

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Abstract

Detection efficiency for hadronic events is one of important factor in R measurement. Here we discuss the detection efficiency for hadronic events with Lund model(JETSET7.4), and then give the detection efficiency for hadronic events and its error at center-of-mass energy 2.6, 3.2, 3.4, 3.55, 4.6 and 5.0 GeV.

1 Introduction

Detection efficiency for hadronic events (ε_{had}) is defined as the probability that a hadronic final state is observed in the detector and passes all the selection criteria, so it depends on the particle multiplicity, the angular and momentum distributions. As a result, the uncertainty in the knowledge of this efficiency and its dependence on the c.m. energy was the main contributor to the systemic error in the determination of the total hadronic cross section. Generally speaking, detection efficiency for hadronic events can break down into two parts:

$$\varepsilon_{had} = \varepsilon_{flt} \cdot \varepsilon_{rsel} \tag{1}$$

where $\varepsilon_{flt}$is the filter efficiency of the events, which can be determined exactly with the expression :

$$\varepsilon_{flt} = \frac{N_{godflt}}{N_{godflt} + N_{badflt}} \tag{2}$$

The second term ε_{rsel} is the product of the efficicency of reconstruction and selection of the hadronic events. ε_{rsel} can be determined by Monte Carlo simulation with the help of the proper hadronic events generator. LUND model[2] is widely regarded as the best hadronic events generator to describe multihadronic event production in e^+e^- annihilation process at higher energy region, but how it works at low energy region, it remains a puzzle so far[3].

Using the hadronic events sample collected with BES near 3.55GeV at BEPC for a previous experiment [4] and the published data [5, 6, 7, 8, 9, 10, 11, 12], we studied the distributions characterizing the hadronic events produced from e^+e^- annihilation and the most sensitive parameters in LUND model. The parameters of the generator are adjusted to reproduce distributions of kinematic variables.

2 LUND model

The study of multihadron production in e^+e^- annihilation is an important field of high energy physics. It can generally be divided into four phases, explained respectively by different interaction theory. Among these phases, the fragmentation of partons into direct hadrons is a non-perturbatively QCD process and unable to be calculated precisely. So many phenomenological model, such as string fragmentation(LUND model), cluster fragmentation(HERWIG model) and independent fragmentation etc, have been put forward to explain the fragmentation mechanism. LUND model is the dominant one developed by LUND group, which can describe hadronic events production fairly well in high energy region ($> 10GeV$) [2]. There are two basic hypotheses in string fragment in LUND model, one is called high energy approximation , which can be expressed by the following equation

$$lim_{s\to\infty} f(z,s) = f(z) \tag{3}$$

The other one is left-right sysmmetry. According to above-mentioned two hypotheses, LUND Fragmentation function $f(z) \propto \frac{1}{z}(1-z)^a \cdot exp(-\frac{bm_\perp^2}{2})$ can be deduced. where, $z = \frac{(E+p_z)_{hadron}}{(E+p_z)_{q\bar{q}}}$; E, p_z is the energy and longitudinal momentum of the hadrons; a, b is two free parameters in LUND Fragmentation function; $m_\perp^2 = m^2 + p_T^2$ is transverse mass for hadronic events.

3 LUND model and parameter tunning

Monte Carlo techniques were used to estimated the detection efficicency for hadronic events. This task was twofold: it required the generation of events according to models for hadron production and the simulation of the response of the detector to these events. The resulting particle distributions were compared with experimental data to choose the most appropriate model and to adjust the free parameters in LUND model. So we take two steps to investigate LUND model both at generation level and detector simulation level. We began with the comparsion LUND model with the openly published data directly, such as MARKII, PLUTO, CLEO, DASP, etc)[5, 6, 7, 8, 9, 10, 11, 12](Fig. 1). Then, to study those distributions characterizing the hadronic events produced by jetset7.4 with default parameters at detection level, and compared those distributions with those of BES data at energy region 2-5GeV (Fig.2).

The comparsion at generator level(without detector simulation) between LUND model with default parameters and the openly published results was made as Fig1. We see the following distributions almost agree with the published results, such as multiplicities(n_{ch}); KNO distribution(KNO); transverse momentum ($P_{t(in)}$, $P_{t(out)}$); Feynman $x_p(x_p)$; pseudorapidity (y/η) distributions. But, when we comes to sphericity(S), great difference between Monte Carlo and data is observed. Namely, the feature of jetlike in LUND model is much more obvious than those of hadronic events.

Aside from the event generator, the Monte Carlo calculation included a complete simulation of the detector properties, such as geometrical acceptance, hardware inefficiciencies, trigger condition, and event selection criteria. Those events generated by the LUND model were passed through a complete BES detector simulation named SOBER program. The interaction of hadrons in the detector were simulated using the SOBER program.

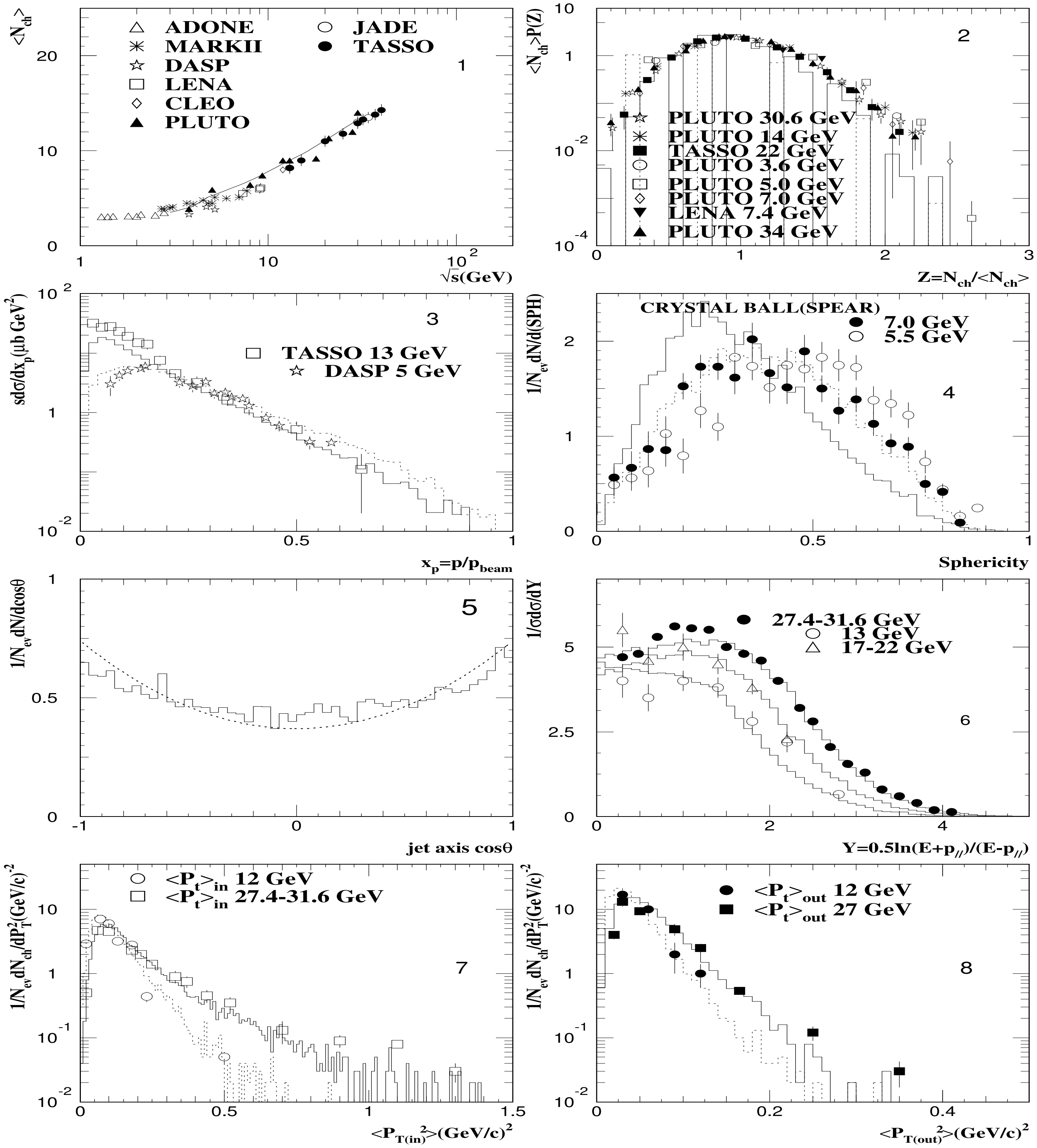

Figure 1: Comparison between the published data and model without simulation. Lines stand for LUND model(JETSET7.4) with default parameters; symbols are the published results.

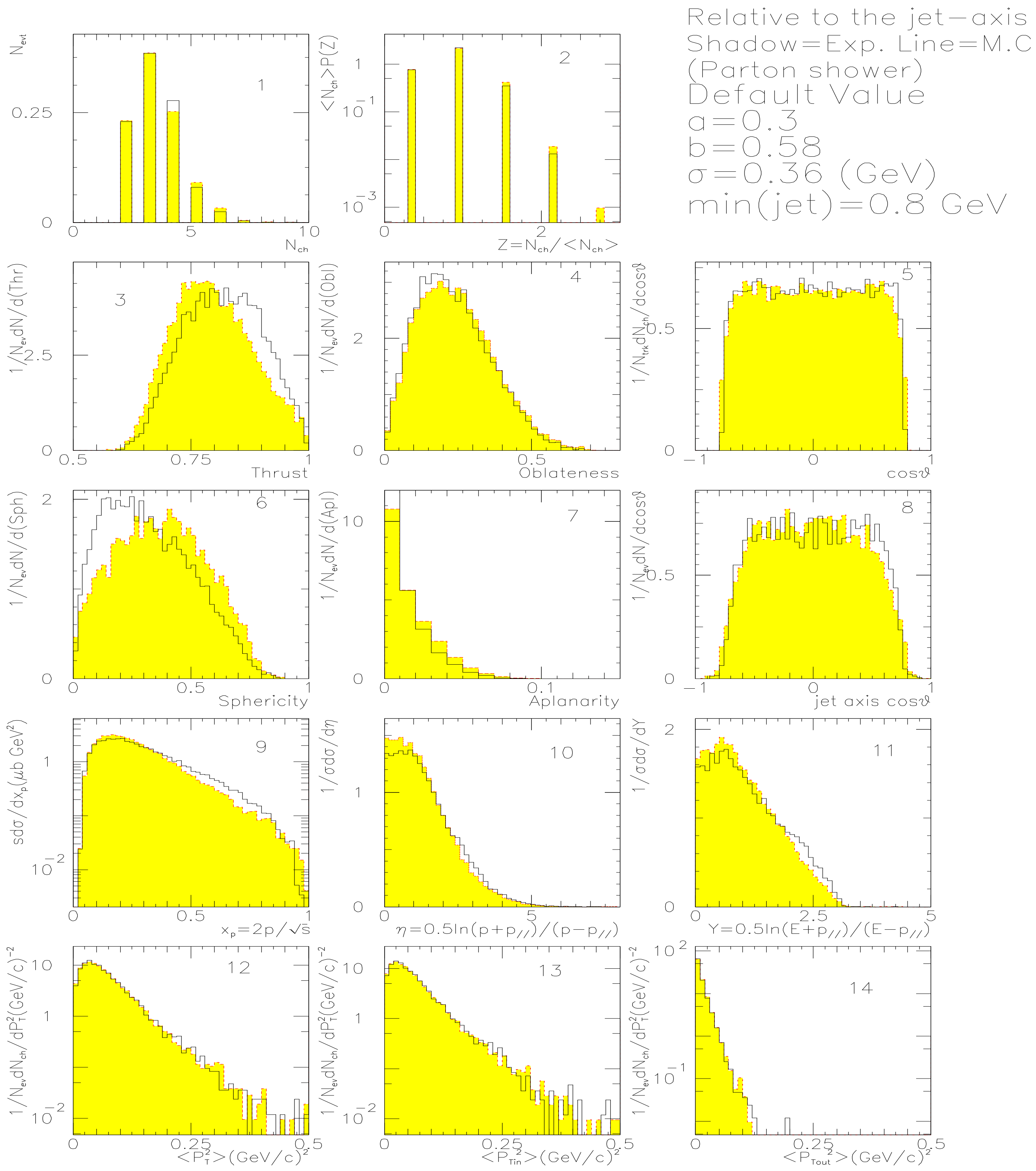

Figure 2: Comparison between BES data at 3.55GeV and model after detection simulation. Solid lines stand for the results of LUND model(JETSET7.4) with default parameters; shaded region represent the hadronic events obtained by BES

Those distributions such as multiplicities(n_{ch}); KNO distribution; polar angle($cos\theta$); transverse momentum($P_{t(in)}$,$P_{t(out)}$) are consistant each other ; and feynman $x_p(x_p)$; true/pseudorapidity(y/ planarity(A); oblateness(O) are nearly consistent. But sphericity(S) and thrust(T) differ greatly between LUND model and BES hadronic events sample.

From the comparsions between those distributions which characterized the hadronic events production in e^+e^- annihilation in Monte Carlo and data sample, we conclude that LUND string fragmentation still has its own reasonable mechanism at BES energy region.

In order to make LUND model(JETSET7.4) to reproduce the features of hadronic events at BES, we try to tune some sensitive parameters in JETSET7.4 to make it agree with the true hadronic sample. Fig. 3 and Fig.4 are two figures which show the comparsions between data and LUND model(JETSET7.4) after parameters tunning. The geometrical acceptance was well reproduced: the distributions in momentum, and polar angle angle agreed well within the statistical errors. The observed multiplicity of charged particles was in reasonably good agreement; transverse momentum($P_{t(in)}$, $P_{t(out)}$) are still consistent with each other. And true/pseudorapidity (y/η); aplanarity(A); oblateness(O); Feynman x_P also has improved, agree with data more exactly. Sphericity(S) and thrust(T) has greatly improved, nearly the same with Monte Carlo and data. It is the same with the level without detector simulation. The sphericity agree with Crystball results(¡5.0GeV) fairly well.

Table 1: Parameters & Values

Parameter	PARJ(41)	PARJ(42) (GeV^{-2})	PARJ(21) (GeV)	PARJ(33) (GeV)
Default	0.3	0.58	0.36	0.8
Tunning	1.5	0.78	0.45	0.5

where

$a = PARJ(41)$: a parameter of LUND fragmentation function;
$b = PARJ(42)$: a parameter of LUND fragmentation function(GeV^{-2});
$PARJ(21)$: the width in Gaussian p_x, p_y transverse momentum distributions for primary hadrons;
$PARJ(33)$: the remaining energy below which the fragmentation of a jet systemis stopped and two final hadrons formed.

4 Detection efficiecny & error estimation

The detection efficiency for hadronic events is determined via a Monte Carlo simulation using the jetset7.4 event generator, whose parameters are tuned. So, the detection efficiciency(ε_{had}) is given by:

$$\varepsilon_{had} = \frac{N_{had}}{N_{gen}} \tag{4}$$

where

N_{had} : the net hadronic events number after events selection;

N_{gen} : total hadronic events number produced by generator.

The detection efficiency at 2.6, 3.2, 3.4, 3.55, 4.6 and 5.0GeV is given in Table 2.

Table 2: **Detection efficicency for hadronic events**

E_{cm} (GeV)	$\epsilon_{had}(\geq 2pr)$ (%)	$\epsilon_{had}(\geq 3pr)$ (%)
2.6	55.90	41.52
3.2	64.69	51.35
3.4	69.91	57.67
3.55	68.64	56.46
4.6	81.82	73.00
5.0	84.34	76.00

Estimation of the systematic uncertainty in the hadron detection efficiency were obtained by studying its sensitivity to the choice of the Monte Carlo production model and the adjustable parameters(Source 1), the imperfectiong of BES detector simulation(Source 2) and the uncertainties by varying the event selection cuts(Source 3). A breakdown of contributions to the syssteatic errors is given in Table 3. Where the uncertainty from hadronic event selection(Source 3) has been taken into accounts when the hadronic selection error is given.

According to those comparisons of data and Monte Carlo distributions for different parameters, the uncertainty in R due to the choice of parameters used in the LUND model as Table 3.

To check the model dependence of the efficiency estimation, the LUND model is compared with a second, independent model which belong to cluster fragement named HERWIG model(Further investigation will be done with HERWIG model), or different set of parameters in LUND Model. We investigate the global features of real hadron sample and the data which are reasonably reproduced by the LUND Model with another set of parameters.

Contributions to the error of hadronic efficiency determination are as Table 2.

5 Summary

Hadronic event shapes are carefully investigated with the published data and BES data. Lund model with default parameters is fairly well down to about $10GeV$, but some small discrepancies are observed at the lower energy region. We concluded that LUND model(JETSET7.4) has its own reasonable mechanism at BES energy region. Using the hadronic events sample collected with BES at BEPC, we studied the distributions characterizing the hadronic events and sensitive parameters in LUND model and tune to

Table 3: Error sources of detection efficicency. All errors are in percentages(%).

E_{cm}(GeV)	Source 1	Source 2	Total
2.6	0.52	2.61	2.66
3.2	0.39	1.86	1.90
3.4	0.25	2.86	2.87
3.55	0.65	2.34	2.43
4.6	0.73	3.58	3.65
5.0	0.24	3.20	3.21

make it agree with BES data very well. After parameter tunning, the distributions are comparable to BES hadronic event sample. But some tiny discrepancies still exist.

Hadronic event detection efficiency is estimated by JETSET7.4 in which several sensitive parameters were tunned according to BES data. At the same time, another independent model — HERWIG model is used to estimate the error from model of detection efficiency ($\sim 2\%$).

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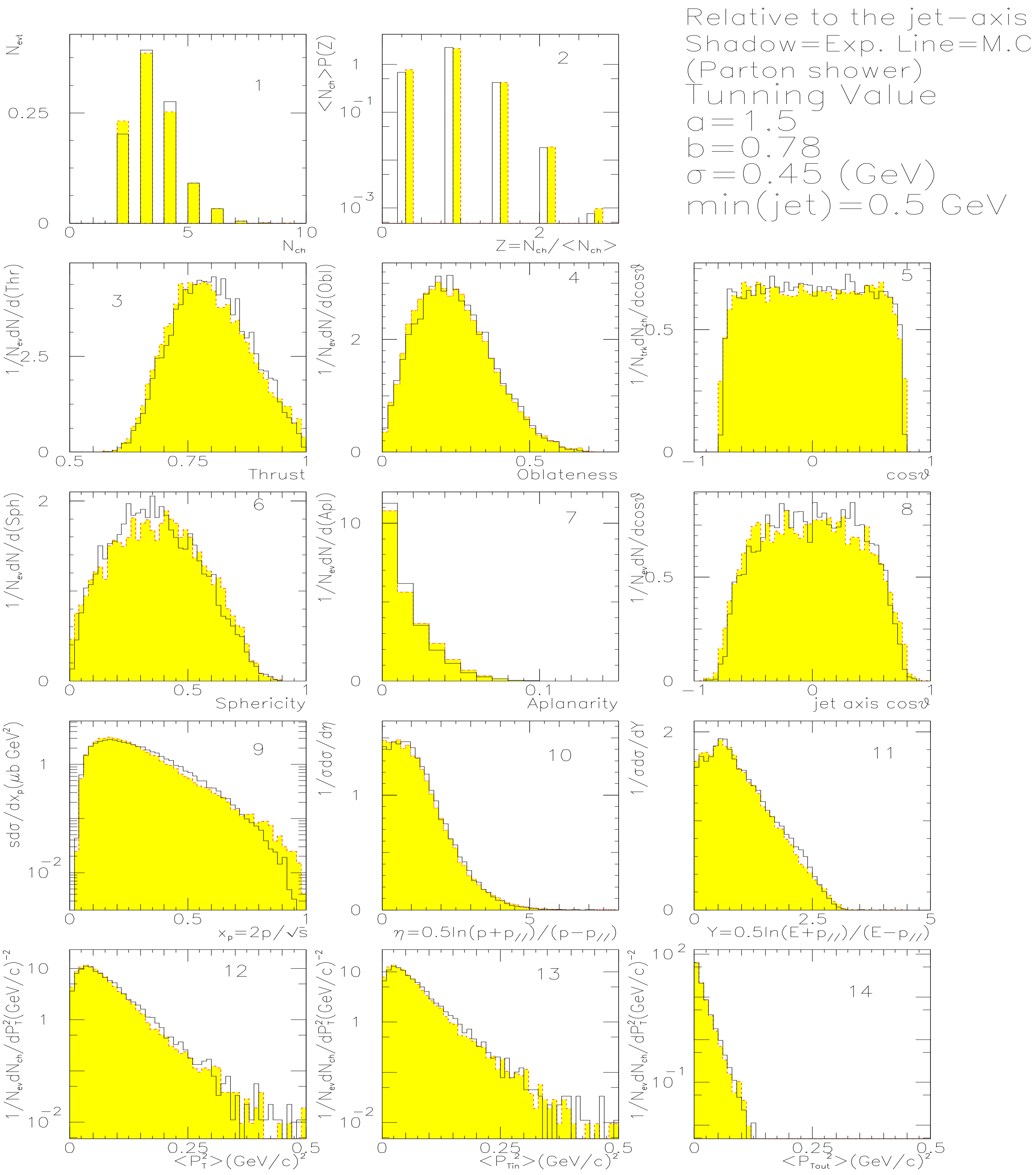

Figure 3: Comparsion between BES data and Monte Carlo hadronic events sample at Ecm=3.55GeV. Solid lines stand for LUND model(JETSET7.4) with tunning parameters; dashed line are the published results.

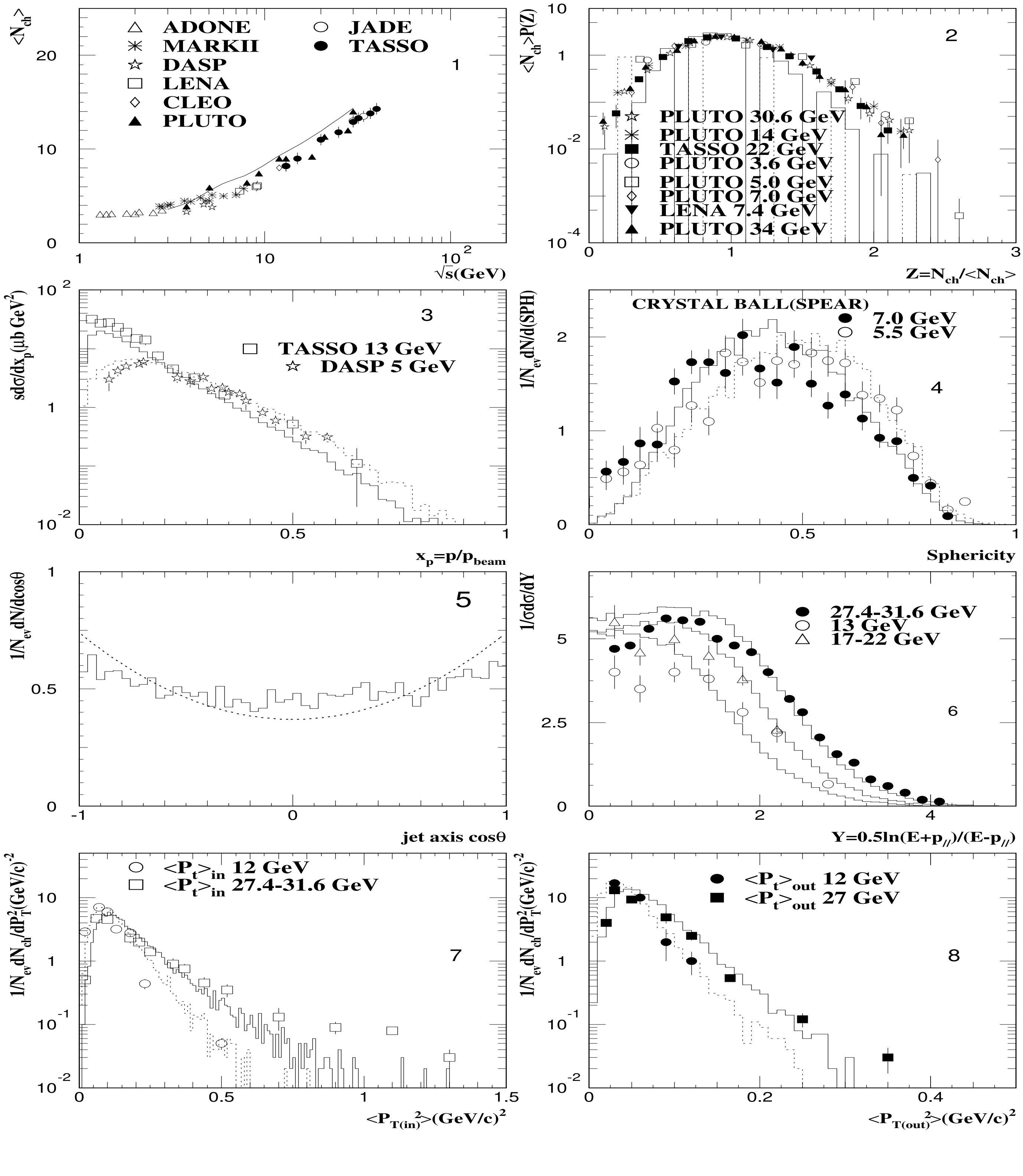

Figure 4: Comparsion between data and Monte Carlo. Lines stand for LUND model(JETSET7.4) with tunning parameters; symbols are the published results.