EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

L3 Note 2195
December 10, 1997

MC Study on R-parity violating neutralino decays into hadrons at 183 GeV

László Boldizsár, Pál Hidas, József Tóth

MTA KFKI Research Institute for Particle and Nuclear Physics

Budapest, Hungary

Contents

1 Introduction

One of the major candidates for the LSP in the MSSM is the lightest neutralino χ_1^0. In the R-parity conserving scenario the lowest threshold SUSY-process

$$e^+e^- \rightarrow \chi_1^0\chi_1^0$$

is invisible because the χ_1^0 is stable. This is not the case when R-parity ($R = (-1)^{3B+2S+L}$) is violated. The most general gauge- and SUSY-invariant Lagrangean includes the following R-parity violating Yukawa coupling terms :

$$\mathcal{L}_{RPV} = \lambda_{ijk} L_i L_j E_k^c + \lambda_{ijk}^{'} L_i Q_j D_k^c + \lambda_{ijk}^{''} U_i^c D_j^c D_k^c$$

The first two terms violate lepton number L and the third terms violate baryon number B. The stability of the proton restricts RPV scenarios : L and B can not be simultaneously violated.

1.1 The leptonic terms

These final states include four charged leptons and two neutrinos.

1.2 The semileptonic terms

These final states include :

- four quark jets + two neutrinos
- four quark jets + one neutrino + one charged lepton
- four quark jets + two charged leptons

1.3 The hadronic terms

These final states include six quark jets.

2 The hadronic case

2.1 MC simulation at $\sqrt{s} = 183GeV$

2.1.1 Signal events

- SUSYGEN 2.17/03 used
- includes string fragmentation of 6 quark jets
- sil3v220a applied
- setup 14
- χ_1^0 masses : (10,20,30),40,50,60,70,80 GeV
- $\chi_1^0 \rightarrow udd$ only
- np11 ntuples created from dvn

2.1.2 Backround events

- official np11 ntuples used

2.2 Analysis

- np11 ntuples were used
- the confidence level distribution derived from the kinematic fit χ^2 of np11 is not uniform (can not be safely used for selection)
- kinematic refit : 4C, 5C, 6C of 4 jets
- the momentum resolution of the official fit is OK, but the calculation of the χ^2 or the applied errors are not correct
- to earn 6 jets forced JETNOR (max. 8) jets merged (Durham y definiton)
- kinematic fit : 4C, 5C of 6 jets

2.3 Selection criteria

- Event multiplicity : $N_{trk} > 10$, $N_{src} > 30$
- Event energy : $E_{vis}/E_{cm} > 0.80$, $M_{event}/E_{cm} > 0.80$
- 4 jets : $N_{jet} \geq 4$ if $y_{cut} = 0.008$ then force 4 jets
- No electromagnetic jets : $E_{jet,EM}/E_{jet} < 0.95$, $N_{trk,jet} > 1$
- Off-beam : $|\cos\theta_{jet,beam}| < 0.95$
- No WW : $C.L._{6C,4jet} < 0.01$ (4-momentum + 2 M_W)
- 6 jet fit : $C.L._{4C} > 0.10$, $C.L._{5C} > 0.10$ (4-mom. + $M_{123} = M_{456}$)

2.4 Conclusions

- new selection criteria needed under 40 GeV
- perform mass scan
- 6 jet variable study (thrust, sphericity, y_{56}) is necessary
- χ_2^0,$\chi_1^\pm$
- NP ntuples should contain forced 6 jets
- NP ntuples need better kinematic fit χ^2s

$\lambda^{'}$	*Decay channels*	*Events needed*
(111)	$e^{-}u\bar{d} + \nu_e d\bar{d} + CC$	
(112)	$e^{-}u\bar{s} + \nu_e d\bar{s} + CC$	
(113)	$e^{-}u\bar{b} + \nu_e d\bar{b} + CC$	
(121)	$e^{-}c\bar{d} + \nu_e s\bar{d} + CC$	
(122)	$e^{-}c\bar{s} + \nu_e s\bar{s} + CC$	
(123)	$e^{-}c\bar{b} + \nu_e s\bar{b} + CC$	
(131)	$\nu_e b\bar{d} + CC$	
(132)	$\nu_e b\bar{s} + CC$	
(133)	$\nu_e b\bar{b} + CC$	
(211)	$\mu^{-}u\bar{d} + \nu_\mu d\bar{d} + CC$	
(212)	$\mu^{-}u\bar{s} + \nu_\mu d\bar{s} + CC$	
(213)	$\mu^{-}u\bar{b} + \nu_\mu d\bar{b} + CC$	
(221)	$\mu^{-}c\bar{d} + \nu_\mu s\bar{d} + CC$	
(222)	$\mu^{-}c\bar{s} + \nu_\mu s\bar{s} + CC$	
(223)	$\mu^{-}c\bar{b} + \nu_\mu s\bar{b} + CC$	
(231)	$\nu_\mu b\bar{d} + CC$	
(232)	$\nu_\mu b\bar{s} + CC$	
(233)	$\nu_\mu b\bar{b} + CC$	
(311)	$\tau^{-}u\bar{d} + \nu_\tau d\bar{d} + CC$	
(312)	$\tau^{-}u\bar{s} + \nu_\tau d\bar{s} + CC$	
(313)	$\tau^{-}u\bar{b} + \nu_\tau d\bar{b} + CC$	
(321)	$\tau^{-}c\bar{d} + \nu_\tau s\bar{d} + CC$	
(322)	$\tau^{-}c\bar{s} + \nu_\tau s\bar{s} + CC$	
(323)	$\tau^{-}c\bar{b} + \nu_\tau s\bar{b} + CC$	
(331)	$\nu_\tau b\bar{d} + CC$	
(332)	$\nu_\tau b\bar{s} + CC$	
(333)	$\nu_\tau b\bar{b} + CC$	

Table 1: Semileptonic decay channels (90 nodes)

Final state	$\lambda^{`}$ *(SUSYGEN)*	*Number of final states*
$e^{\pm}e^{\pm}+4jets$	(11i),(12i)	144 (24)
$\mu^{\pm}\mu^{\pm}+4jets$	(21i),(22i)	144 (24)
$e^{\pm}\mu^{\pm}+4jets$		288 (0)
$e^{\pm}\tau^{\pm}+4jets$		288 (0)
$\mu^{\pm}\tau^{\pm}+4jets$		288 (0)
$\tau^{\pm}\tau^{\pm}+4jets$	(31i),(32i)	144 (24)
$e^{\pm}+4jets+M_{missing}$	(11i),(12i)	1296 (48)
$\mu^{\pm}+4jets+M_{missing}$	(21i),(22i)	1296 (48)
$\tau^{\pm}+4jets+M_{missing}$	(31i),(32i)	1296 (48)
$4jets+M_{missing}$	*all*	2916 (108)

Table 2: Semileptonic final states (8100 channels)

$Process$		$q\bar{q}q\bar{q}$ (ZZ)	e^+e^-qq $(\gamma\gamma)$	WW $(\rightarrow all)$	$q\bar{q}$ (Z,γ)
Cross section		0.6775 pb	15392 pb	15.77 pb	105.75 pb
$N_{expect}(55.49pb^{-1})$		37.6	854102	875	5868
$Generator$	data	PYTHIA	PHOJET	KORALW	PYTHIA
Set		qpz45	pjq16	wk020	qpz40
All	3660799	29625	940906	29635	19992
$multiplicity$		21636		23111	13952
$energy$		15741		14561	5819
$4jets$	476	8983	15	10464	650
$noEM$	343	6945	0	9501	224
$off-beam$	319	6523	0	8822	203
$noWW$	190	5555	0	4428	182
$6jetfits$	120	4050	0	2975	110
$10GeV\,windows$					
$30GeV$	0	3	0	1	1
$40GeV$	0	12	0	9	0
$50GeV$	0	58	0	24	4
$60GeV$	11	183	0	126	12
$70GeV$	21	587	0	455	24
$80GeV$	53	1485	0	1533	40
$90GeV$	35	1722	0	827	29

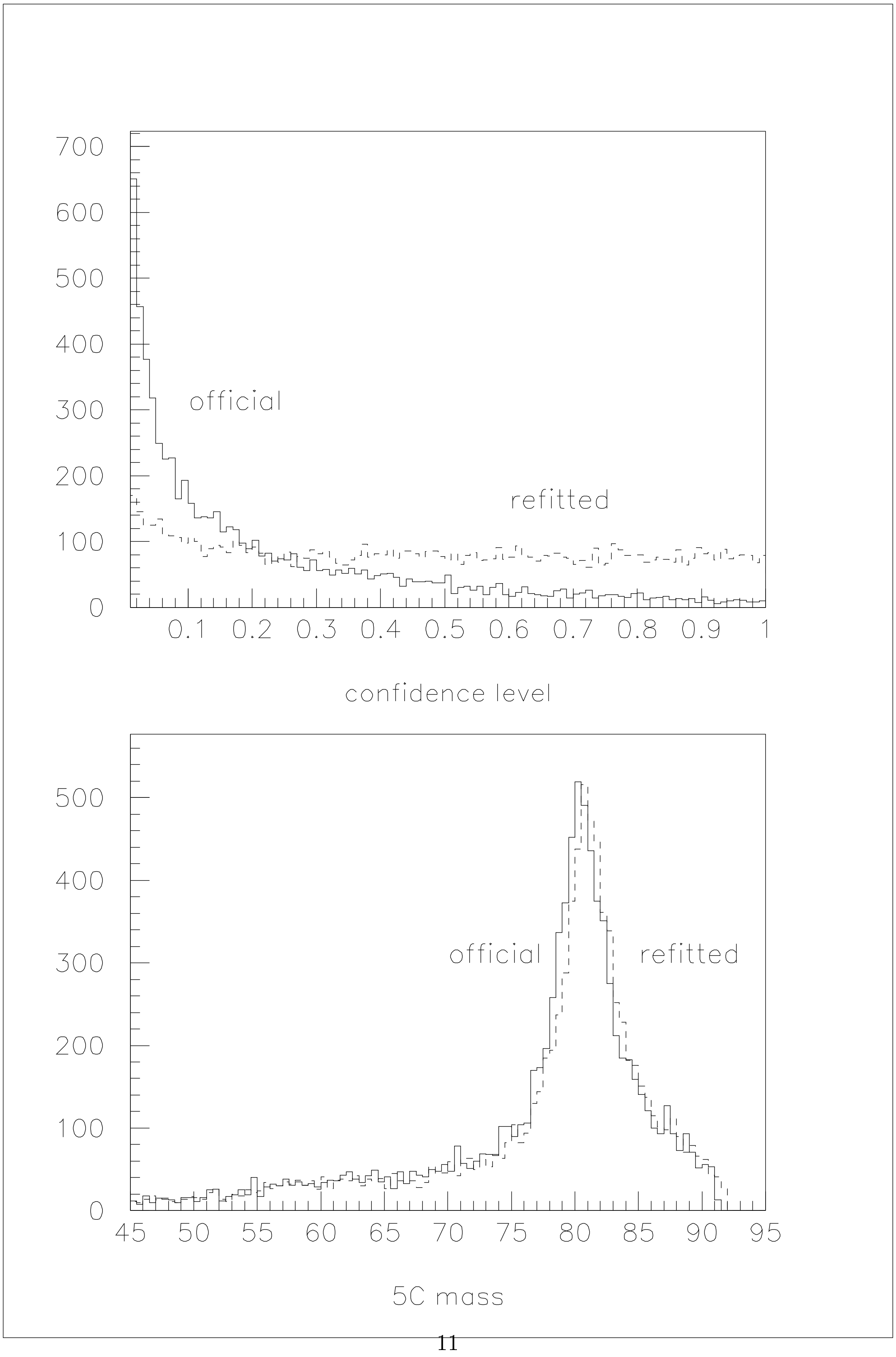
Table 3: The number of events remaining after the cuts applied

Table 4: The number of expected events

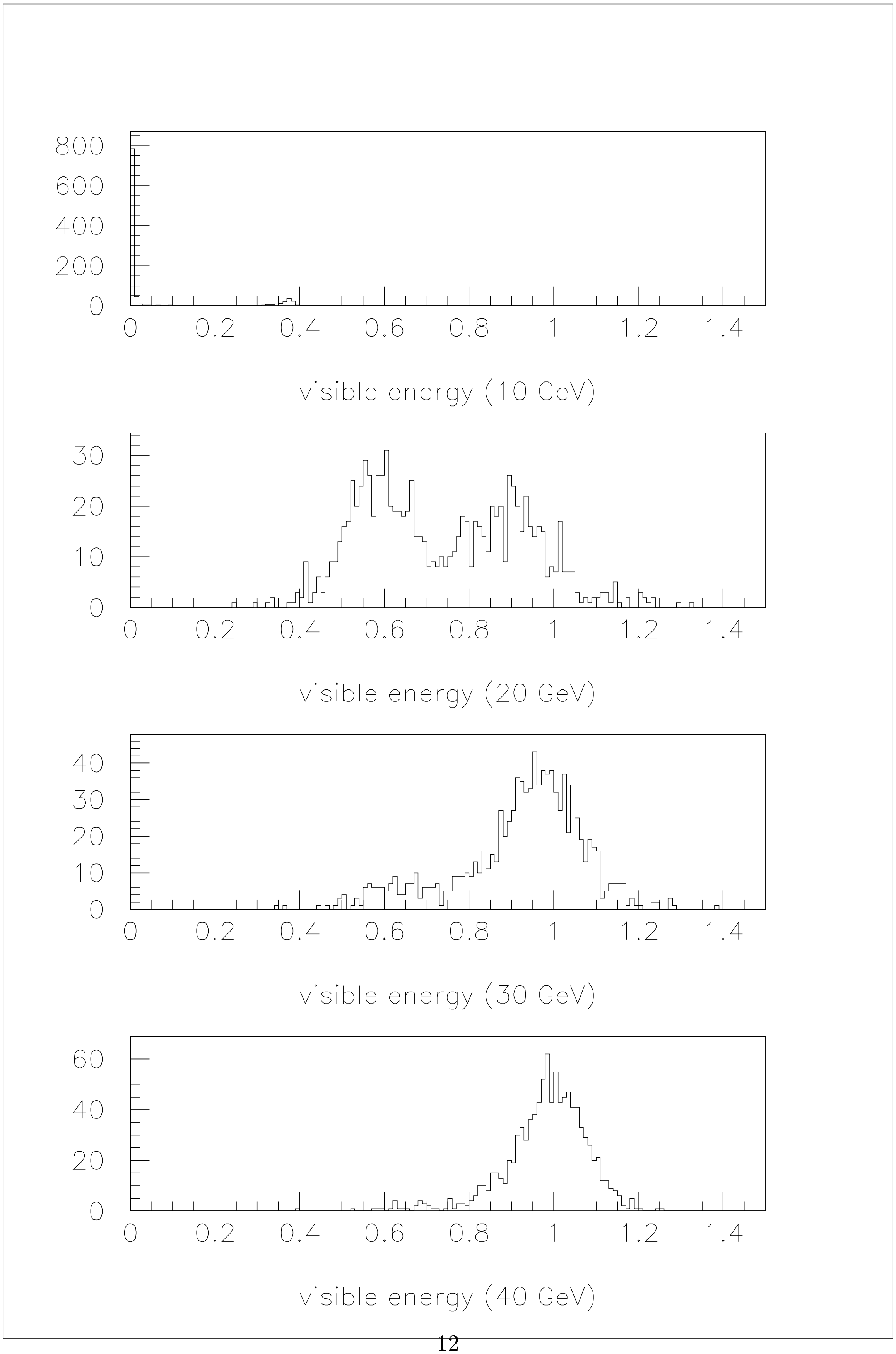
$Process$		$q\bar{q}q\bar{q}$ (ZZ)	e^+e^-qq $(\gamma\gamma)$	WW $(\rightarrow all)$	$q\bar{q}$ (Z,γ)	All $backgrounds$
Cross section		0.6775 pb		15.77 pb	105.77 pb	
$N_{expect}(55.49pb^{-1})$		37.6		875	5868	
$Generator$	data	PYTHIA	PHOJET	KORALW	PYTHIA	
All	3660799	37.6		875	5868	
$multiplicity$		27.5 ± 0.1		682.4 ± 2.1	4095.2 ± 19.1	
$energy$		20.0 ± 0.1		429.9 ± 2.5	1708.0 ± 18.9	
$4jets$	476 ± 21.8	11.4 ± 0.1	13.6 ± 3.5	309.0 ± 2.4	190.8 ± 7.4	
$noEM$	343 ± 18.5	8.8 ± 0.1	0	280.5 ± 2.4	65.7 ± 4.4	355.0 ± 5.0
$off-beam$	319 ± 17.9	8.3 ± 0.1	0	260.5 ± 2.3	59.6 ± 4.2	328.4 ± 4.8
$noWW$	190 ± 13.8	7.1 ± 0.1	0	130.7 ± 1.8	53.4 ± 3.9	191.2 ± 4.3
$6jetfits$	120 ± 11.0	5.1 ± 0.1	0	87.8 ± 1.5	32.3 ± 3.1	125.2 ± 3.4
$10GeV windows$						
$30GeV$	0	0	0	0.03 ± 0.03	0.29 ± 0.29	0.32 ± 0.29
$40GeV$	0	0.02	0	0.27 ± 0.09	0	0.29 ± 0.09
$50GeV$	0	0.07	0	0.71 ± 0.14	1.2 ± 0.6	2.0 ± 0.6
$60GeV$	11 ± 3.3	0.23 ± 0.02	0	3.7 ± 0.3	3.5 ± 1.0	7.4 ± 1.1
$70GeV$	21 ± 4.6	0.75 ± 0.03	0	13.4 ± 0.6	7.0 ± 1.4	21.2 ± 1.5
$80GeV$	53 ± 7.3	1.88 ± 0.05	0	45.3 ± 1.1	11.7 ± 1.9	58.9 ± 2.2
$90GeV$	35 ± 5.9	2.19 ± 0.05	0	24.4 ± 0.8	8.5 ± 1.6	35.1 ± 1.8

Process $\chi_0^0\chi_0^0 \to hadrons$	30 GeV	40 GeV	50 GeV	60 GeV	70 GeV	80 GeV
Cross section						
$N_{expect}(55.49pb^{-1})$						
All	999	999	999	999	999	998
multiplicity	884	975	993	995	999	998
energy	683	928	973	971	973	979
4 jets	130	486	768	861	890	912
no EM	87	410	654	746	752	793
off-beam	85	401	625	709	718	743
no WW	79	317	517	629	629	541
6 jet fits	38	249	386	446	460	418
global effectivity	0.038	0.249	0.386	0.446	0.460	0.419
expected background	125.2 ± 3.4	125.2 ± 3.4	125.2 ± 3.4	125.2 ± 3.4	125.2 ± 3.4	125.2 ± 3.4
data observed	120	120	120	120	120	120
95% upper limit	9.6	1.47	0.95	0.82	0.79	0.87
10 GeV window	9	55	80	111	157	232
effectivity	0.009	0.055	0.080	0.111	0.157	0.232
expected background	0.32 ± 0.29	0.29 ± 0.09	2.0 ± 0.6	7.4 ± 1.1	21.2 ± 1.5	58.9 ± 2.2
data observed	0	0	0	11	21	53
95% upper limit	6.00	0.98	0.67	1.78	1.23	1.01

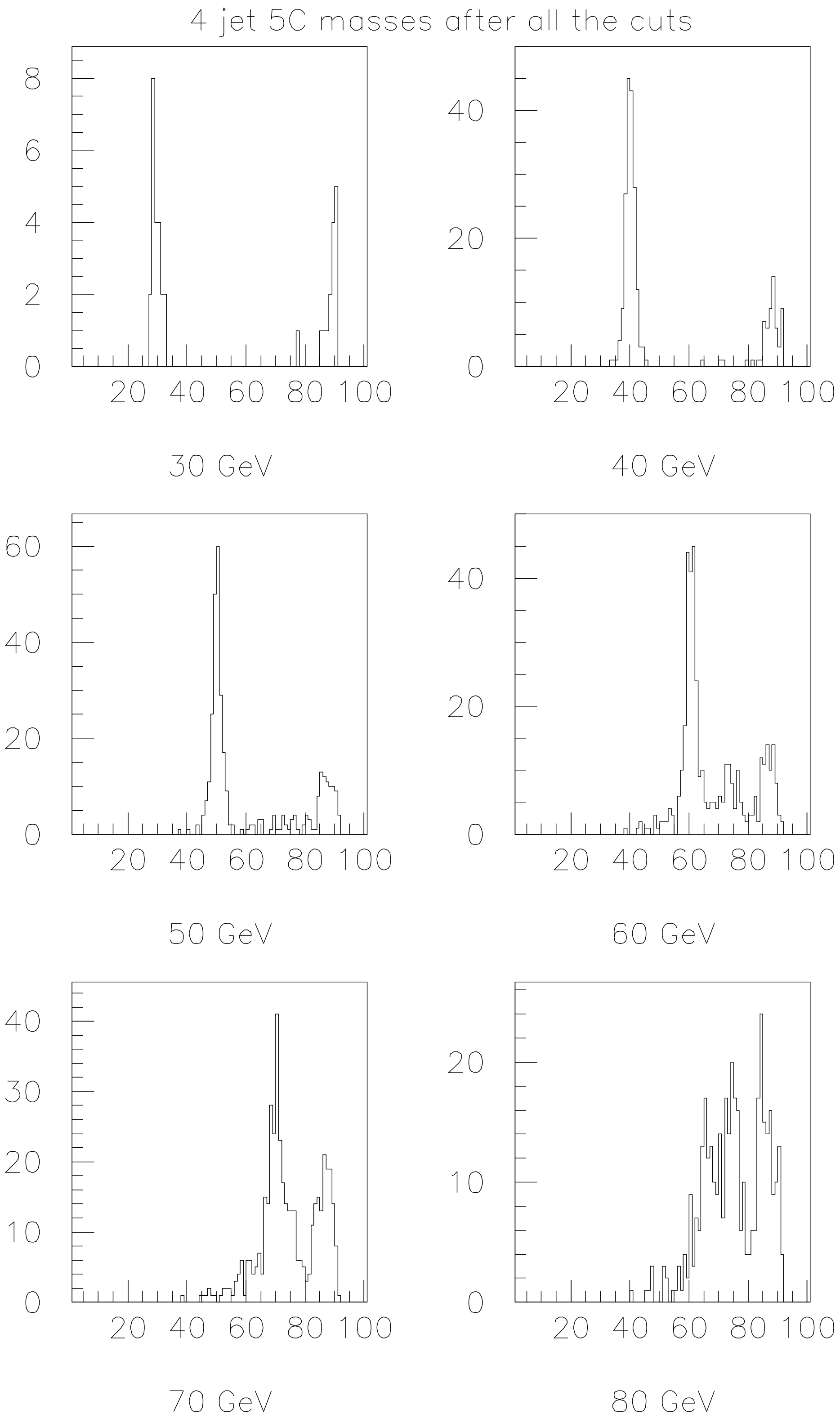
Table 5: Neutralino events after cuts for respective neutralino masses

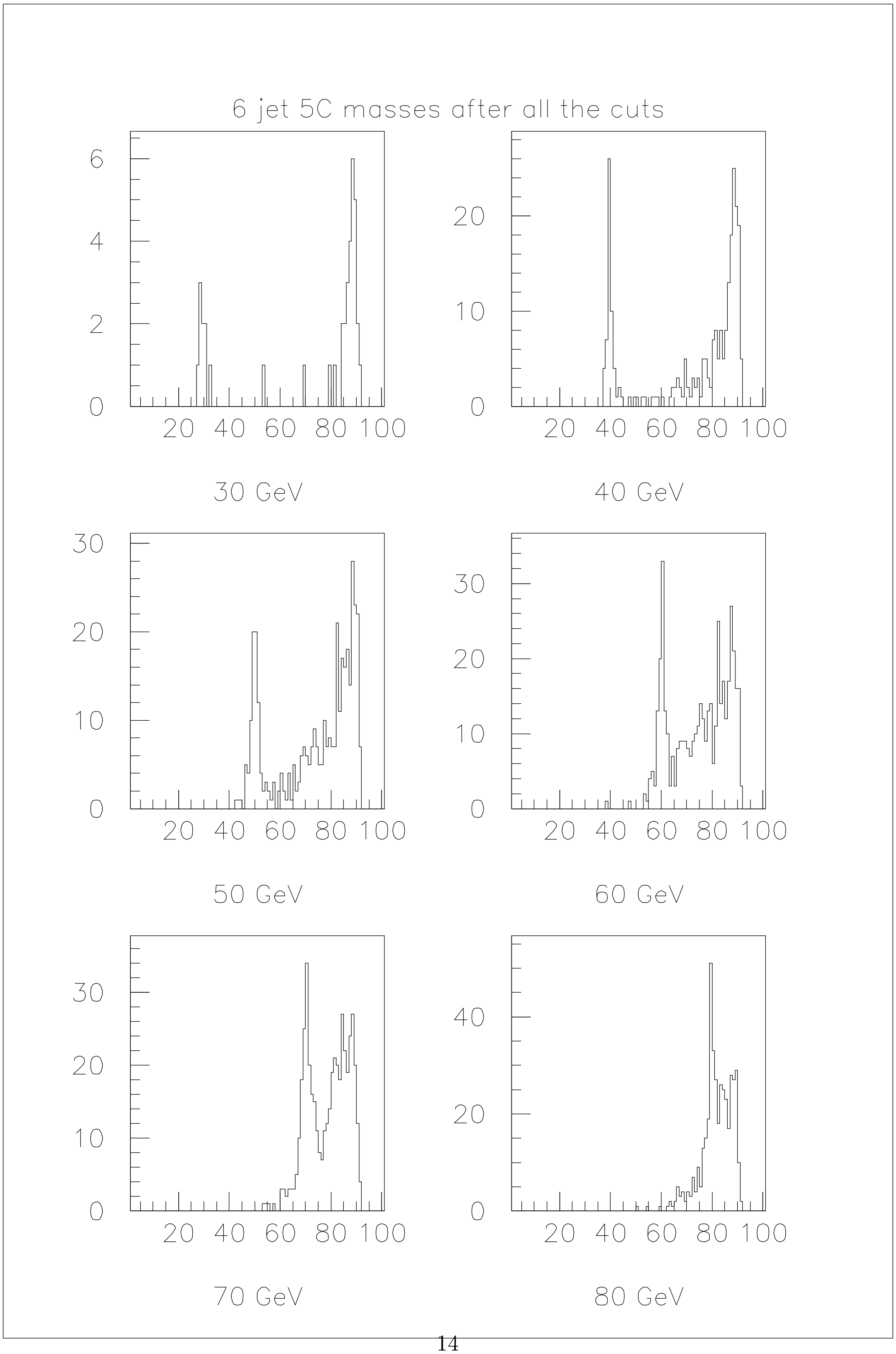


700
600
500
400
300
200
100
0
official
refitted
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
confidence level
500
400
300
200
100
0
official
refitted
45 50 55 60 65 70 75 80 85 90 95
5C mass

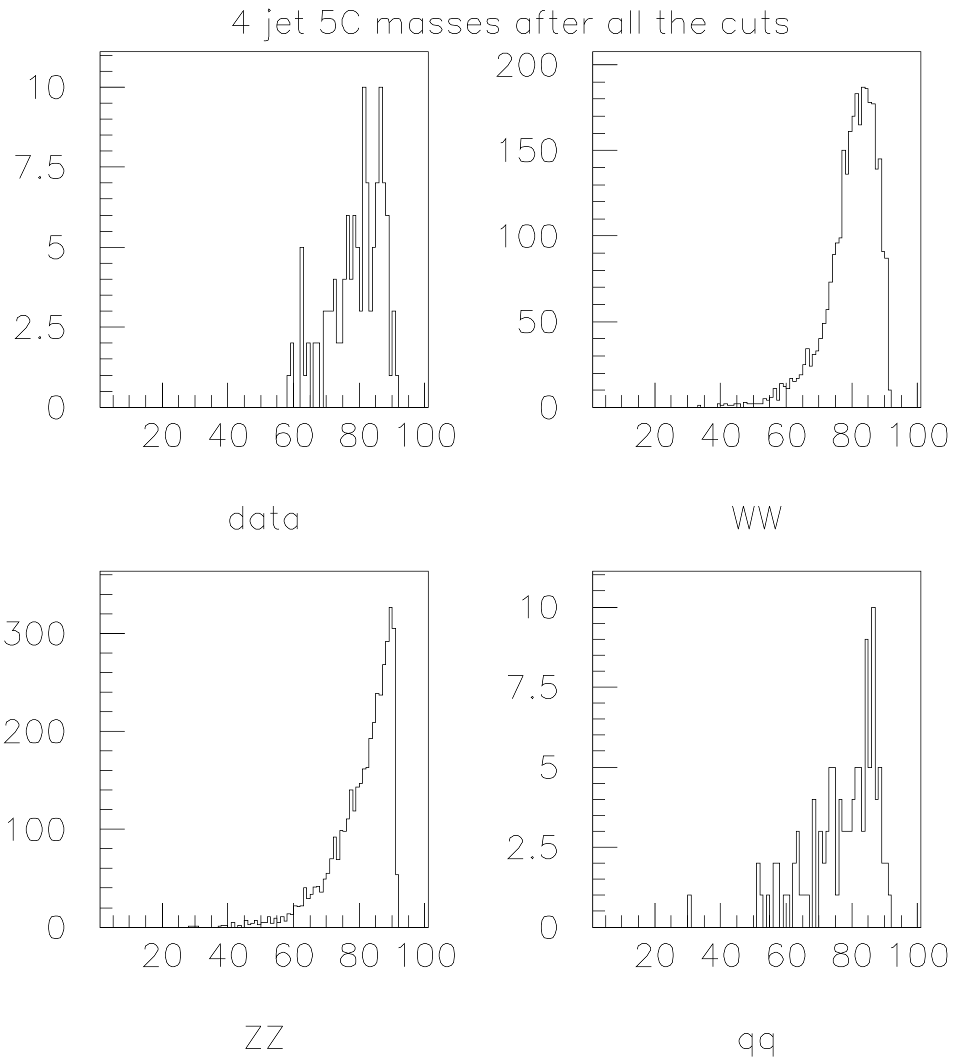


800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
visible energy (10 GeV)
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
visible energy (20 GeV)
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
visible energy (30 GeV)
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
visible energy (40 GeV)

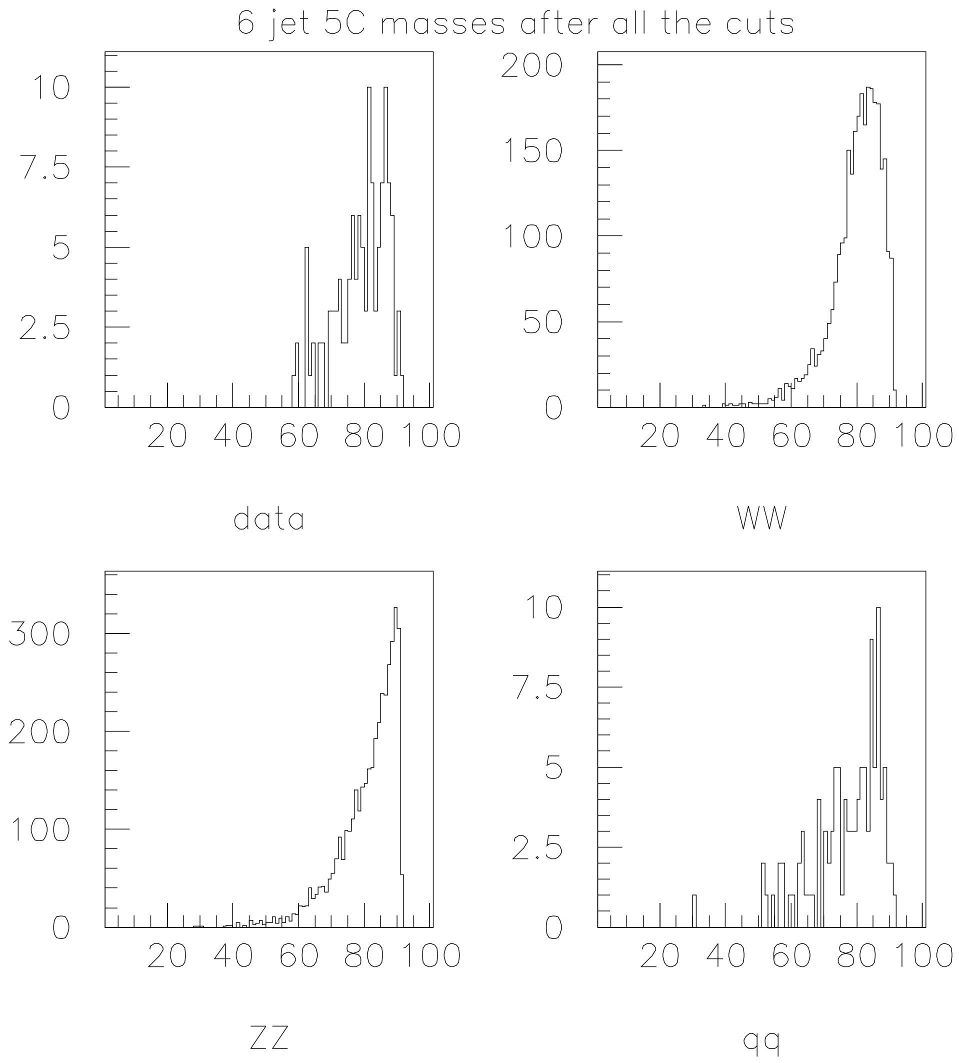

4 jet 5C masses after all the cuts
0
2
4
6
8
20 40 60 80 100
30 GeV
0
20
40
20 40 60 80 100
40 GeV
0
20
40
60
20 40 60 80 100
50 GeV
0
20
40
20 40 60 80 100
60 GeV
0
10
20
30
40
20 40 60 80 100
70 GeV
0
10
20
20 40 60 80 100
80 GeV



6 jet 5C masses after all the cuts
0
2
4
6
20
40
60
80
100
30 GeV
0
10
20
40 GeV
0
10
20
30
50 GeV
60 GeV
70 GeV
40
80 GeV



4 jet 5C masses after all the cuts
10
7.5
5
2.5
0
20 40 60 80 100
data
200
150
100
50
0
20 40 60 80 100
WW
300
200
100
0
20 40 60 80 100
ZZ
10
7.5
5
2.5
0
20 40 60 80 100
qq


6 jet 5C masses after all the cuts
10
7.5
5
2.5
0
20 40 60 80 100
data
200
150
100
50
0
20 40 60 80 100
WW
300
200
100
0
20 40 60 80 100
ZZ
10
7.5
5
2.5
0
20 40 60 80 100
qq