μs + Jets + MET Final State Review

as a signal for mSUGRA Discovery in CMS

A. Fahim

Sharif University of Technology
IPM (Institute for Research in Fundamental Sciences)

April 2009 / ISFAHAN

Outline

1. SUPERSYMMETRY
2. μs+Jets+MET
3. PREVIOUS STUDIES IN CMS
4. OUR APPROACH TO ATTACK THE PROBLEM
   - DATA SAMPLE
   - Pre-SELECTION
   - SELECTION
   - RESULTS
   - OUTLOOK

SUPERSYMMETRY

Of all the proposals for physics beyond the Standard Model, supersymmetry is the most popular, and the most likely to show up at the LHC.

SUSY can explain why the E.W. scale is so much lower than the Planck scale (the hierarchy problem) if and only if it is broken at a low enough scale to be detectable at the LHC. But there are no guarantees, so . . .

SUPERSYMMETRY

SUSY Particles

<table>
<tr><th>SM Particles</th><th colspan="3">SUSY Particles</th></tr>
<tr><td>Quarks: q</td><td colspan="3">Squarks: $\tilde{q}$</td></tr>
<tr><td>Leptons: l</td><td colspan="3">Sleptons: $\tilde{l}$</td></tr>
<tr><td>Gluons: g</td><td colspan="3">Gluino: $\tilde{g}$</td></tr>
<tr><td>Charged Bosons: $W^{\pm}$</td><td rowspan="2">$H^{\pm}$</td><td>Winos: $\tilde{W}^{\pm}$</td><td rowspan="2">Charginos: $\tilde{\chi}^{\pm}_{1,2}$</td></tr>
<tr><td rowspan="2">Higgs: H^0</td><td>Charged Higgsinos: $\tilde{H}^{\pm}$</td></tr>
<tr><td>h^0, A^0, H^0</td><td>Neutral Higgsinos: $\tilde{h}^0, \tilde{A}^0, \tilde{H}^0$</td><td rowspan="3">Neutralinos: $\tilde{\chi}^0_{1,2,3,4}$</td></tr>
<tr><td>Neutral Boson: Z^0</td><td rowspan="2"></td><td>Zino: $\tilde{Z}^0$</td></tr>
<tr><td>Photon: γ</td><td>Photino: $\tilde{\gamma}$</td></tr>
</table>

For each SM Fermion (Boson), there is a Bosonic (Fermionic) partner.

Supersymmetry
mSUGRA

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
  - LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

Supersymmetry
mSUGRA

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
  - LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
  - LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
  - LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

Supersymmetry
mSUGRA

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
  - LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

Supersymmetry
mSUGRA

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
  - LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

Supersymmetry
mSUGRA

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
    LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

Supersymmetry
mSUGRA

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
    LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

Supersymmetry
mSUGRA

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
    LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

Supersymmetry
mSUGRA

- MSSM Lagrangian depends on 105 parameters
  mSUGRA with radiative E.W. symmetry breaking requires only 5 parameters

m_0	the universal soft breaking mass parameter for all scalars at the unification scale
$m_{1/2}$	the common gaugino mass
A_0	a universal trilinear coupling
$tan(\beta)$	the ratio of the vacuum expectation values of the two neutral Higgs fields
$sign(\mu)$	the sign of the higgsino mixing mass parameter

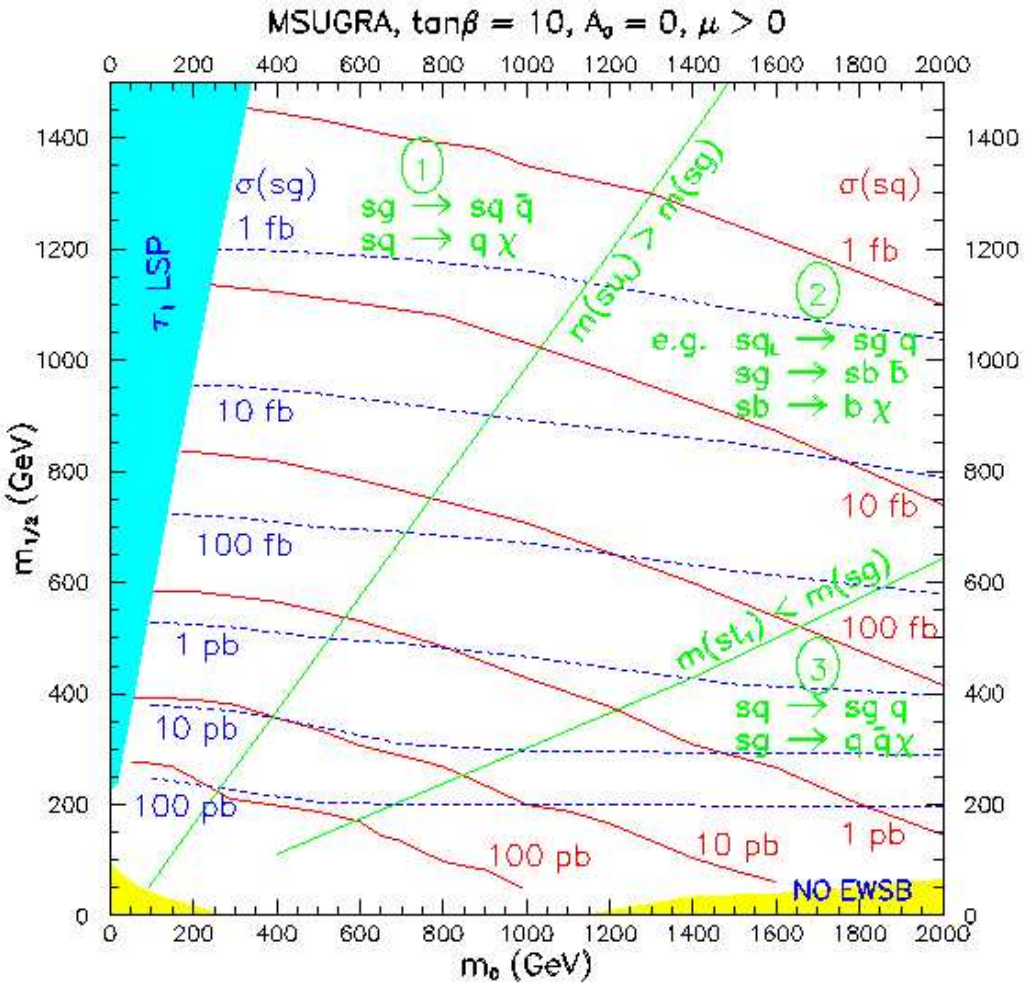
- R-parity $R = (-1)^{3(B-L)+2S}$ can be conserved and it implies:
  - SUSY particles are produced in pairs
  - The existence of a stable and neutral lightest SUSY particle (LSP)
    LSP is a good candidate for Cold Dark Matter
  - Avoiding the fast proton decay

SUPERSYMMETRY

$m_0, m_{1/2}$ plane for mSUGRA

In three regions:

- Region 1: $\tilde{g} \to \tilde{q}\bar{q}, \tilde{q} \to q\chi$
- Region 2: $\tilde{q}_L \to \tilde{g}q, \tilde{g} \to \tilde{b}\bar{b}, \tilde{b} \to b\chi$
- Region 3: $\tilde{q} \to \tilde{g}q, \tilde{g} \to q\bar{q}\chi$

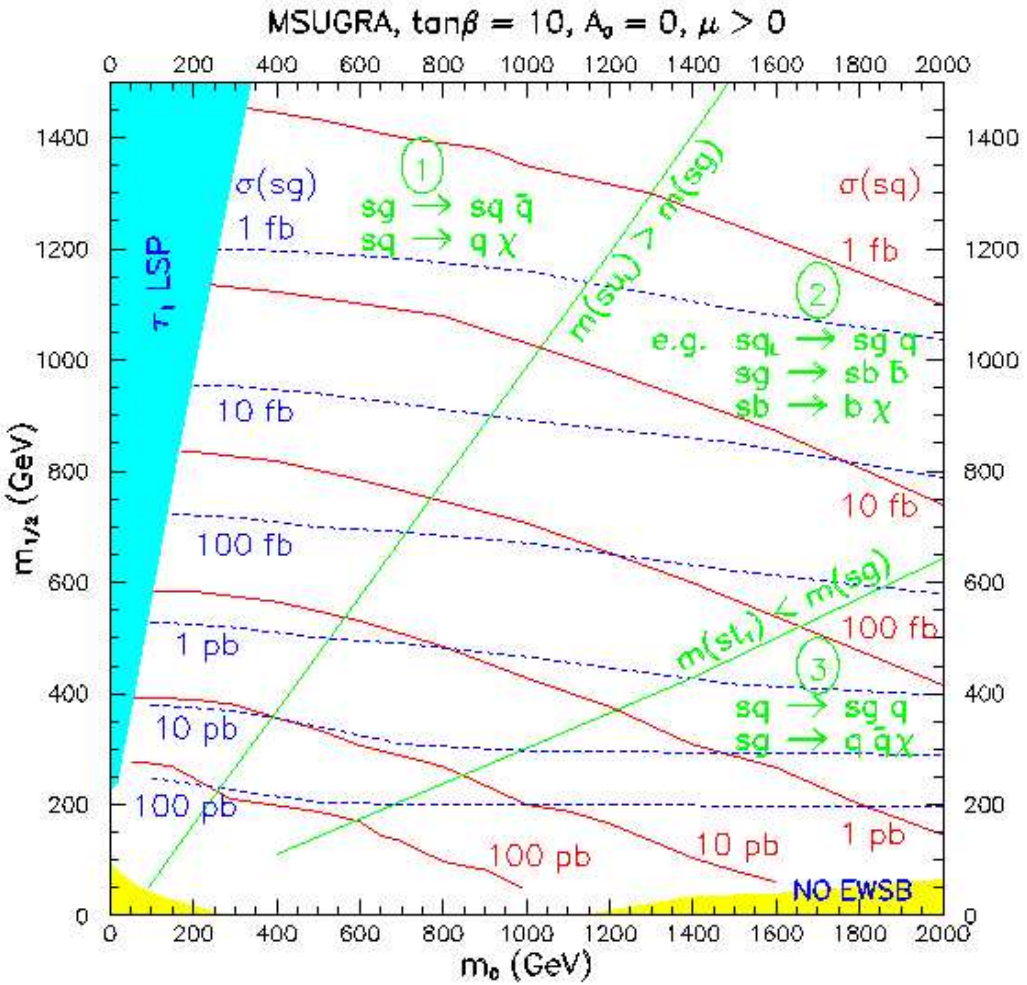


SUPERSYMMETRY

$m_0, m_{1/2}$ plane for mSUGRA

In three regions:

- Region 1: $\tilde{g} \to \tilde{q}\bar{q}, \tilde{q} \to q\chi$
- Region 2: $\tilde{q}_L \to \tilde{g}q, \tilde{g} \to \tilde{b}\bar{b}, \tilde{b} \to b\chi$
- Region 3: $\tilde{q} \to \tilde{g}q, \tilde{g} \to q\bar{q}\chi$

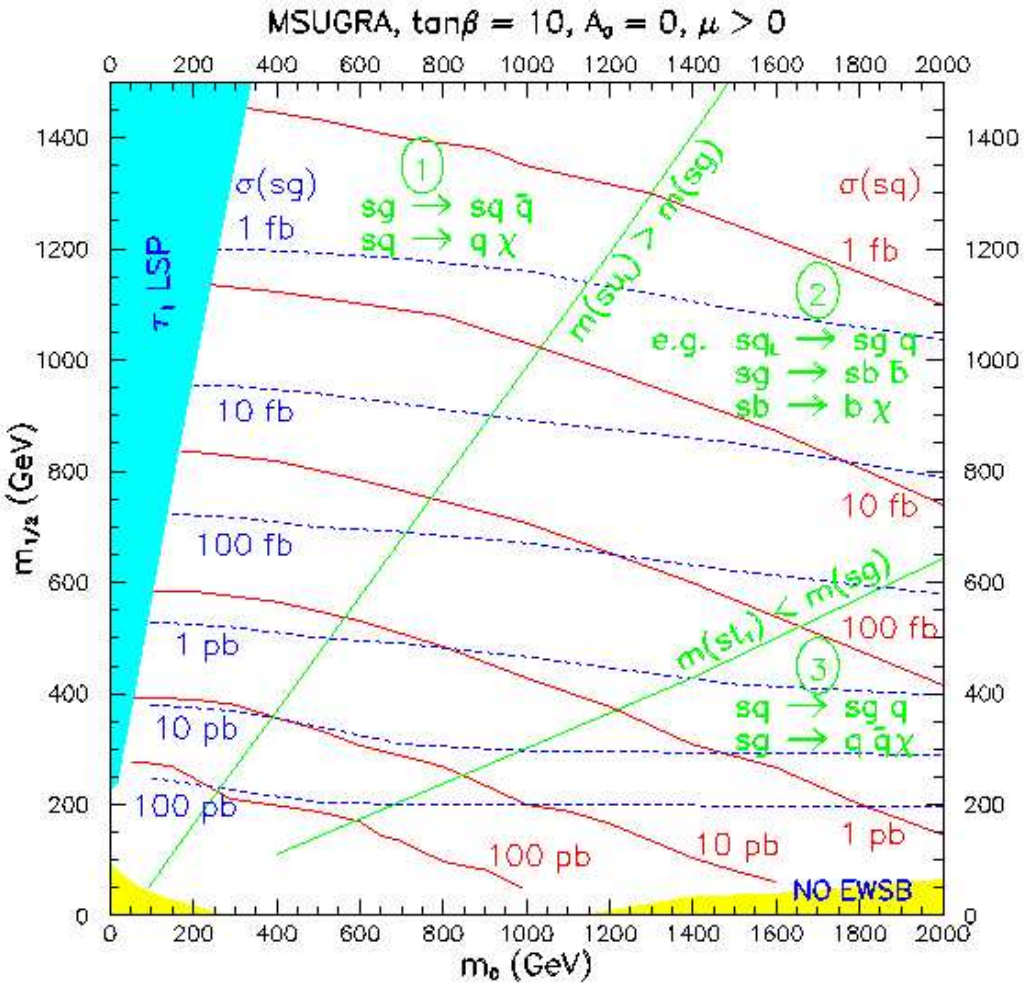


SUPERSYMMETRY

$m_0, m_{1/2}$ plane for mSUGRA

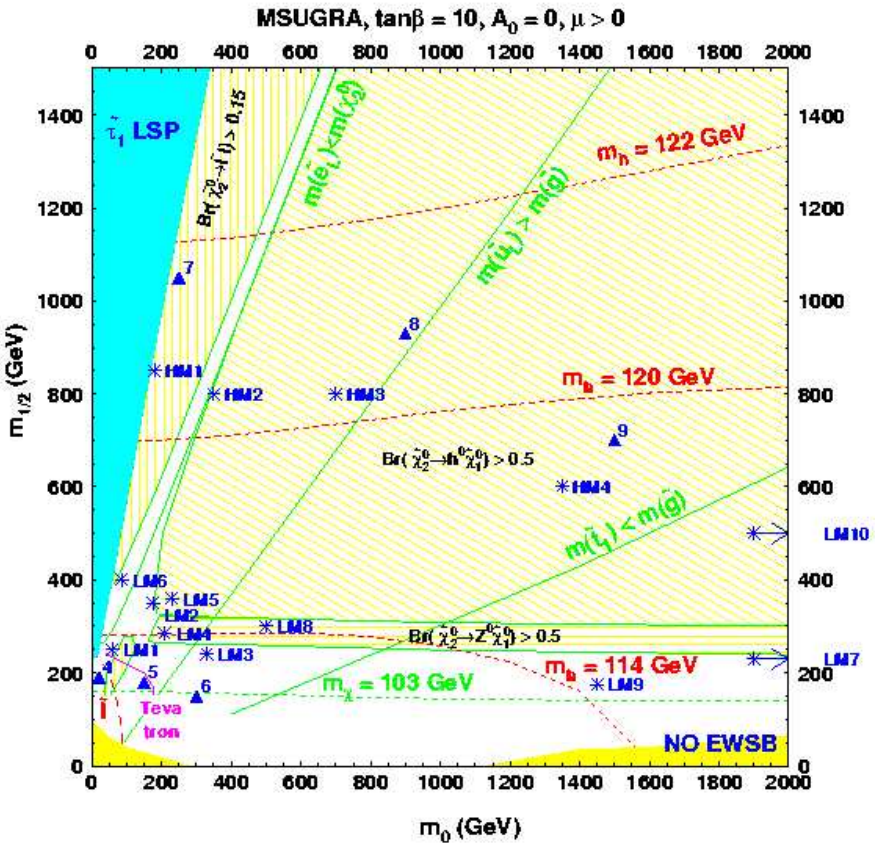
In three regions:

- Region 1: $\tilde{g} \to \tilde{q}\bar{q}, \tilde{q} \to q\chi$
- Region 2: $\tilde{q}_L \to \tilde{g}q, \tilde{g} \to \tilde{b}\bar{b}, \tilde{b} \to b\chi$
- Region 3: $\tilde{q} \to \tilde{g}q, \tilde{g} \to q\bar{q}\chi$



CMS has chosen several points in the $m_0, m_{1/2}$ plane to explore phenomenological signatures and scan phase space

Point	m_0	$m_{1/2}$	$\tan\beta$	sign(μ)	A_0
LM0	200	160	10	+	-400
LM1	60	250	10	+	0
LM2	185	350	35	+	0
LM3	330	240	20	+	0
LM4	210	285	10	+	0
LM5	230	360	10	+	0
LM6	85	400	10	+	0
LM7	3000	230	10	+	0
LM8	500	300	10	+	-300
LM9	1450	175	50	+	0
LM10	3000	500	10	+	0
HM1	180	850	10	+	0
HM2	350	800	35	+	0
HM3	700	800	10	+	0
HM4	1350	600	10	+	0



μs+Jets+MET as a signal for mSUGRA Discovery

μs+Jets+MET

MET

- SUSY predicts an unobservable particle, the χ^0, detectable only as MET.
- MET is very sensitive to detector inefficiencies.
  A need for presence of other particles to identify specific final states and suppress backgrounds.
- ISASUSY decay modes for LM0:

ISASUSY decay modes:

Parent	-->	daughters			Width	Branching ratio
TP	-->	MU+	NUM	ET	0.12742E+00	0.11111E+00
GLSS	-->	BB1	BT		0.32682E+00	0.23023E+00
GLSS	-->	BT1	BB		0.32682E+00	0.23023E+00
GLSS	-->	TB1	TP		0.32576E+00	0.22948E+00
GLSS	-->	TP1	TB		0.32576E+00	0.22948E+00
BT1	-->	Z2SS	BT		0.10052E+01	0.28326E+00
BT1	-->	W1SS-	TP		0.79678E+00	0.22452E+00
BT1	-->	W-	TP1		0.16133E+01	0.45459E+00
TP1	-->	W1SS+	BT		0.46801E+00	0.10000E+01
Z2SS	-->	Z1SS	UP	UB	0.20394E-06	0.10730E+00
Z2SS	-->	Z1SS	DN	DB	0.30547E-06	0.16072E+00
Z2SS	-->	Z1SS	ST	SB	0.30547E-06	0.16072E+00
Z2SS	-->	Z1SS	CH	CB	0.20394E-06	0.10730E+00
Z2SS	-->	Z1SS	BT	BB	0.34075E-06	0.17929E+00
W1SS+	-->	Z1SS	UP	DB	0.54390E-05	0.32393E+00
W1SS+	-->	Z1SS	CH	SB	0.54390E-05	0.32393E+00
W1SS+	-->	Z1SS	E+	NUE	0.19477E-05	0.11600E+00
W1SS+	-->	Z1SS	MU+	NUM	0.19477E-05	0.11600E+00
W1SS+	-->	Z1SS	TAU+	NUT	0.20175E-05	0.12015E+00

$\tilde{g}$ Decay is dominant and $Br(\tilde{g} \rightarrow \mu\, s + Jets + MET) \approx 0.17$

μs+Jets+MET

MET

- SUSY predicts an unobservable particle, the χ^0, detectable only as MET.
- MET is very sensitive to detector inefficiencies.
  A need for presence of other particles to identify specific final states and suppress backgrounds.
- ISASUSY decay modes for LM0:

ISASUSY decay modes:

Parent	-->	daughters			Width	Branching ratio
TP	-->	MU+	NUM	ET	0.12742E+00	0.11111E+00
GLSS	-->	BB1	BT		0.32682E+00	0.23023E+00
GLSS	-->	BT1	BB		0.32682E+00	0.23023E+00
GLSS	-->	TB1	TP		0.32576E+00	0.22948E+00
GLSS	-->	TP1	TB		0.32576E+00	0.22948E+00
BT1	-->	Z2SS	BT		0.10052E+01	0.28326E+00
BT1	-->	W1SS-	TP		0.79678E+00	0.22452E+00
BT1	-->	W-	TP1		0.16133E+01	0.45459E+00
TP1	-->	W1SS+	BT		0.46801E+00	0.10000E+01
Z2SS	-->	Z1SS	UP	UB	0.20394E-06	0.10730E+00
Z2SS	-->	Z1SS	DN	DB	0.30547E-06	0.16072E+00
Z2SS	-->	Z1SS	ST	SB	0.30547E-06	0.16072E+00
Z2SS	-->	Z1SS	CH	CB	0.20394E-06	0.10730E+00
Z2SS	-->	Z1SS	BT	BB	0.34075E-06	0.17929E+00
W1SS+	-->	Z1SS	UP	DB	0.54390E-05	0.32393E+00
W1SS+	-->	Z1SS	CH	SB	0.54390E-05	0.32393E+00
W1SS+	-->	Z1SS	E+	NUE	0.19477E-05	0.11600E+00
W1SS+	-->	Z1SS	MU+	NUM	0.19477E-05	0.11600E+00
W1SS+	-->	Z1SS	TAU+	NUT	0.20175E-05	0.12015E+00

$\tilde{g}$ Decay is dominant and $Br(\tilde{g} \rightarrow \mu\, s + Jets + MET) \approx 0.17$

μs+Jets+MET

MET

- SUSY predicts an unobservable particle, the χ^0, detectable only as MET.
- MET is very sensitive to detector inefficiencies.
  A need for presence of other particles to identify specific final states and suppress backgrounds.
- ISASUSY decay modes for LM0:

ISASUSY decay modes:

Parent	-->	daughters			Width	Branching ratio
TP	-->	MU+	NUM	ET	0.12742E+00	0.11111E+00
GLSS	-->	BB1	BT		0.32682E+00	0.23023E+00
GLSS	-->	BT1	BB		0.32682E+00	0.23023E+00
GLSS	-->	TB1	TP		0.32576E+00	0.22948E+00
GLSS	-->	TP1	TB		0.32576E+00	0.22948E+00
BT1	-->	Z2SS	BT		0.10052E+01	0.28326E+00
BT1	-->	W1SS-	TP		0.79678E+00	0.22452E+00
BT1	-->	W-	TP1		0.16133E+01	0.45459E+00
TP1	-->	W1SS+	BT		0.46801E+00	0.10000E+01
Z2SS	-->	Z1SS	UP	UB	0.20394E-06	0.10730E+00
Z2SS	-->	Z1SS	DN	DB	0.30547E-06	0.16072E+00
Z2SS	-->	Z1SS	ST	SB	0.30547E-06	0.16072E+00
Z2SS	-->	Z1SS	CH	CB	0.20394E-06	0.10730E+00
Z2SS	-->	Z1SS	BT	BB	0.34075E-06	0.17929E+00
W1SS+	-->	Z1SS	UP	DB	0.54390E-05	0.32393E+00
W1SS+	-->	Z1SS	CH	SB	0.54390E-05	0.32393E+00
W1SS+	-->	Z1SS	E+	NUE	0.19477E-05	0.11600E+00
W1SS+	-->	Z1SS	MU+	NUM	0.19477E-05	0.11600E+00
W1SS+	-->	Z1SS	TAU+	NUT	0.20175E-05	0.12015E+00

$\tilde{g}$ Decay is dominant and $Br(\tilde{g} \rightarrow \mu\, s + Jets + MET) \approx 0.17$

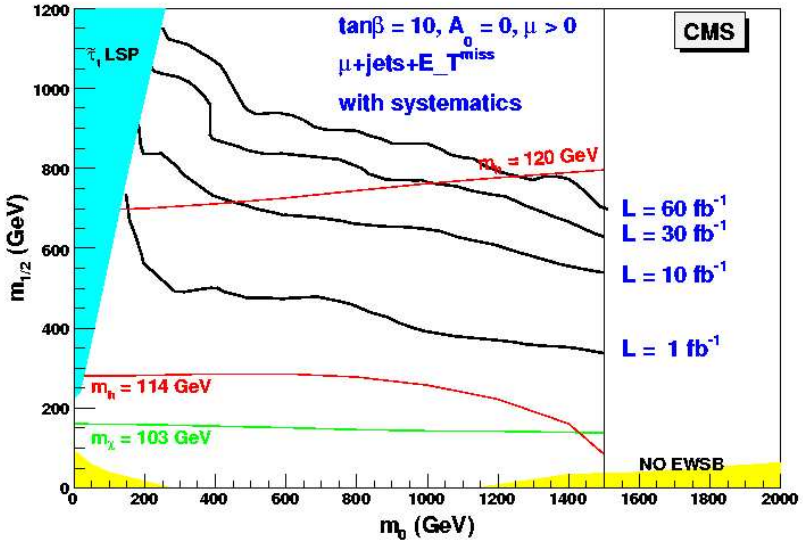
PREVIOUS STUDIES IN CMS

PREVIOUS STUDIES IN CMS

CMS Note 2006/134

D. Acosta et al., ”Potential to Discover SUSY in Events with Muons Jets and Large Missing Transverse Energy in pp Collisions at $\sqrt{s}$ = 14 TeV with the CMS Detector” CMS Note 2006/134 (2006).

They investigated Multi-jet QCD, $t\bar{t}$, W+jets, Z+jets, WW+jets, WZ+jets, ZZ+jets as background and LM1-HM2 as signal. And also optimized their cuts for $10fb^{-1}$ Integerated Luminosity by maximizing the significance by a generic algorithm tool, known as GARCON.



PREVIOUS STUDIES IN CMS

CMS Note 2006/134

	Cut Criteria			LM1	SM
Pre-selection	number of muons ≥ 1 "AND" p_T	$>$	30 GeV/c	45450 (10%)	7.383×10^7 (10^{-5}%)
	μ calo. iso. $(R = 0.3)$ E_T	$<$	10 GeV	24260 (53%)	5.26×10^7 (71%)
	number of jets ≥ 3 "AND" E_T	$>$	50 GeV	15660 (64%)	3.769×10^4 (0.07%)
Selection	leading jet (Jet1) E_T^{Jet1}	$>$	440 GeV	4062.0 (25%)	3271.0 (1%)
	next-to-leading jet (Jet2) E_T^{Jet2}	$>$	440 GeV	656.0 (16%)	536.1 (16%)
	$\lvert\eta^{\mathrm{Jet1}}\rvert$	$<$	1.9	639.2 (97%)	500.9 (93%)
	$\lvert\eta^{\mathrm{Jet2}}\rvert$	$<$	1.5	567.7 (88%)	445.9 (89%)
	$\lvert\eta^{\mathrm{Jet3}}\rvert$	$<$	3.0	559.3 (98%)	313.4 (70%)
	$-1 < \cos\left[\Delta\phi(\mathrm{Jet1},\ \mathrm{Jet2})\right]$	$<$	0.2	525.6 (93%)	311.3 (99%)
	$-0.95 < \cos\left[\Delta\phi(E_T^{\mathrm{miss}},\ \mathrm{Jet1})\right]$	$<$	0.3	407.9 (77%)	81.4 (26%)
	$-1 < \cos\left[\Delta\phi(E_T^{\mathrm{miss}},\ \mathrm{Jet2})\right]$	$<$	0.85	386.9 (94%)	34.0 (42%)
	E_T^{miss}	$>$	130 GeV	328.0 (84%)	3.7 (11%)
Trigger	single-μ "OR" di-μ	$=$	"Accept"	311.2 (94%)	2.5 (69%)

	Cut Criteria			LM1	SM
Pre-selection	2 same-sign muons with p_T	$>$	10 GeV/c	4813 (1.1%)	8×10^7 (10^{-5}%)
	number of hits per μ track ≥ 13 and χ^2_μ	$<$	3	4191 (87%)	2×10^6 (2.5%)
	isolation $\mathrm{Iso}_{\mu 1} < 10$ GeV and $\mathrm{Iso}_{\mu 2}$	$<$	6 GeV	1481 (35%)	29368 (1.5%)
	number of jets ≥ 3 with E_T	$>$	50 GeV	947 (64%)	636 (2.2%)
Selection	next-to-next-to-leading jet E_T^{Jet3}	$>$	55 GeV	883 (93%)	477 (75%)
	next-to-leading jet E_T^{Jet2}	$>$	130 GeV	555 (63%)	38 (8%)
	leading jet E_T^{Jet1}	$>$	175 GeV	529 (95%)	28 (74%)
	E_T^{miss}	$>$	200 GeV	341 (64%)	1.5 (5%)
Trigger	di-μ HLT	$=$	"Accept"	341 (100%)	1.5 (100%)

PREVIOUS STUDIES IN CMS

CMS AN-2008/034

P. Biallass et al., "Search Strategies for mSUGRA in the Muons + Jets + MET Final State." CMS AN-2008/034 (2008)

Cut	Background sample								Signal sample		
	$W+0$ jets	W+jets	Z+jets	$t\bar{t}$	Diboson	DY	QCD	All BG	LM1	LM2	LM4
NoCuts	$5.07e+07$	$1.48e+07$	$6.58e+06$	$8.28e+05$	$1.08e+05$	$1.75e+03$	$8.03e+13$	$8.03e+13$	$6.11e+04$	$1.05e+04$	$2.77e+04$
HLT	$6.67e+06$	$2.22e+06$	$1.44e+06$	$1.24e+05$	$1.07e+04$	$1.65e+03$	$2.21e+08$	$1.05e+07$	$8.88e+03$	$1.33e+03$	$3.33e+03$
Efficiency	13%	15%	22%	15%	9.9%	94%	0.0%	0.0%	15%	13%	12%
μ acceptance	$5.39e+06$	$1.85e+06$	$1.19e+06$	$1.04e+05$	$9.20e+03$	$1.63e+03$	$4.17e+06$	$8.56e+06$	$6.08e+03$	$9.77e+02$	$2.89e+03$
Efficiency	81%	84%	83%	84%	86%	99%	1.9%	82%	69%	73%	87%
μ identification	$5.33e+06$	$1.82e+06$	$1.18e+06$	$9.86e+04$	$9.04e+03$	$1.62e+03$	$3.17e+06$	$8.44e+06$	$5.42e+03$	$8.44e+02$	$2.61e+03$
Efficiency	99%	98%	99%	95%	98%	99%	76%	99%	89%	86%	91%
3 Jets, $p_T \geq 80$ GeV	$0.00e+00$	$4.13e+03$	$9.27e+02$	$1.01e+04$	$5.13e+01$	$2.74e+00$	$1.28e+03$	$1.53e+04$	$2.09e+03$	$4.42e+02$	$1.39e+03$
Efficiency	0.0%	0.23%	0.078%	10%	0.57%	0.17%	0.04%	0.18%	39%	52%	53%
$\not{E}_T \geq 100$ GeV	$0.00e+00$	$1.36e+03$	$9.19e+01$	$3.43e+03$	$1.79e+01$	$3.90e-01$	$1.13e+02$	$4.93e+03$	$1.91e+03$	$4.18e+02$	$1.24e+03$
Efficiency	0.0%	33%	9.9%	34%	35%	14%	8.8%	32%	91%	94%	89%
Angular correlations	$0.00e+00$	$2.47e+02$	$8.43e+00$	$8.62e+02$	$3.56e+00$	$1.43e-01$	$0.00e+00$	$1.12e+03$	$7.76e+02$	$1.80e+02$	$5.04e+02$
Efficiency	0.0%	18%	9.2%	25%	20%	37%	0.0%	23%	41%	43%	41%
1st Jet $p_T \geq 200$ GeV	$0.00e+00$	$1.31e+02$	$5.02e+00$	$3.10e+02$	$1.74e+00$	$1.22e-01$	$0.00e+00$	$4.47e+02$	$6.24e+02$	$1.57e+02$	$4.21e+02$
Efficiency	0.0%	53%	60%	36%	49%	85%	0.0%	40%	80%	88%	84%
2nd Jet $p_T \geq 150$ GeV	$0.00e+00$	$9.42e+01$	$4.26e+00$	$2.04e+02$	$9.11e-01$	$6.78e-02$	$0.00e+00$	$3.03e+02$	$4.85e+02$	$1.29e+02$	$3.26e+02$
Efficiency	0.0%	72%	85%	66%	52%	56%	0.0%	68%	78%	82%	77%
$\not{E}_T \geq 250$ GeV	$0.00e+00$	$8.33e+00$	$9.49e-02$	$9.16e+00$	$2.48e-01$	$1.25e-02$	$0.00e+00$	$1.79e+01$	$3.16e+02$	$9.73e+01$	$2.03e+02$
Efficiency	0.0%	8.8%	2.2%	4.5%	27%	18%	0.0%	5.9%	65%	75%	62%

Analysis is at $1fb^{-1}$ and $\sigma(LO)_{LM1} = 45.9[pb]$

OUR APPROACH TO ATTACK THE PROBLEM
Warming-up

DATA SAMPLE

		$\sigma[pb]$	**Events**	**Generator**
SIGNAL	**LM0**	110	110K	Pythia6
BACKGROUND	**TTJets**	317	31.7K	Madgraph
	ZJets	3.7E3	370K	
	WJets	40E3	2M	
	QCD1	15E6	35K	
	QCD2	400E3	1500K	
	QCD3	14E3	1400K	
	QCD4	370	37K	

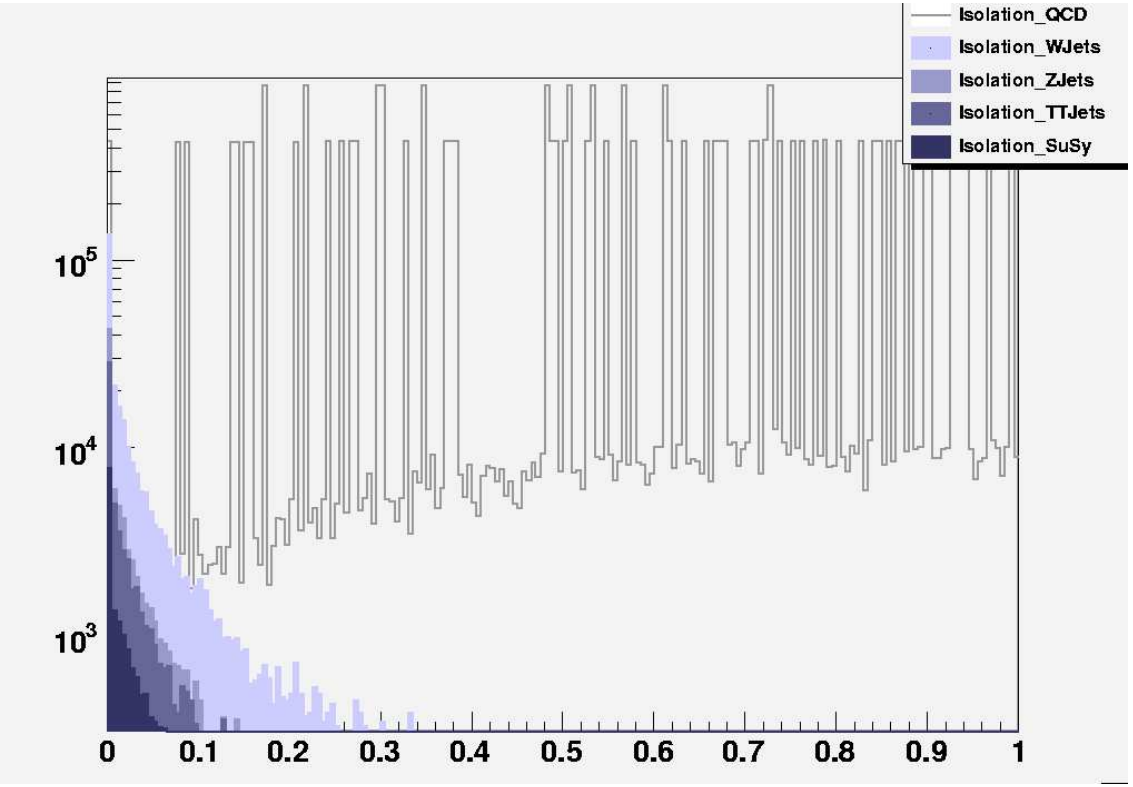
QCD1: QCD100to250
QCD2: QCD250to500
QCD3: QCD500to1000
QCD4: QCD1000toInf

Pre-SELECTION

μ Selection

At least one μ:

- Global & Tracker Muon
- $P_t^{\mu} > 10$ GeV
- $|\eta| < 2.5$
- Combined Relative Isolation = $\frac{\sum_{R<0.3} P_t^{Tr} + \sum_{R<0.3} E_t^{HCal}}{P_t^{\mu}} < 0.05$



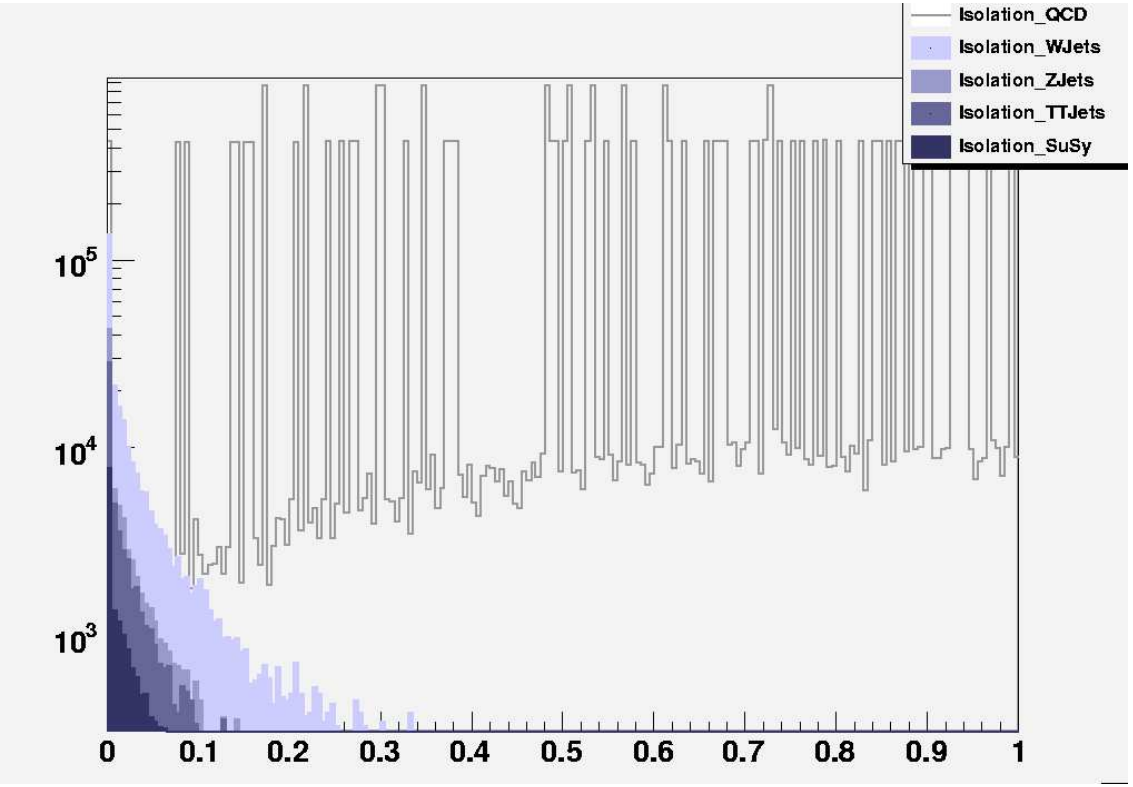
Isolation of μ

Pre-SELECTION

μ Selection

At least one μ:

- Global & Tracker Muon
- $P_t^{\mu} > 10$ GeV
- $|\eta| < 2.5$
- Combined Relative Isolation = $\frac{\sum_{R<0.3} P_t^{Tr} + \sum_{R<0.3} E_t^{HCal}}{P_t^{\mu}} < 0.05$



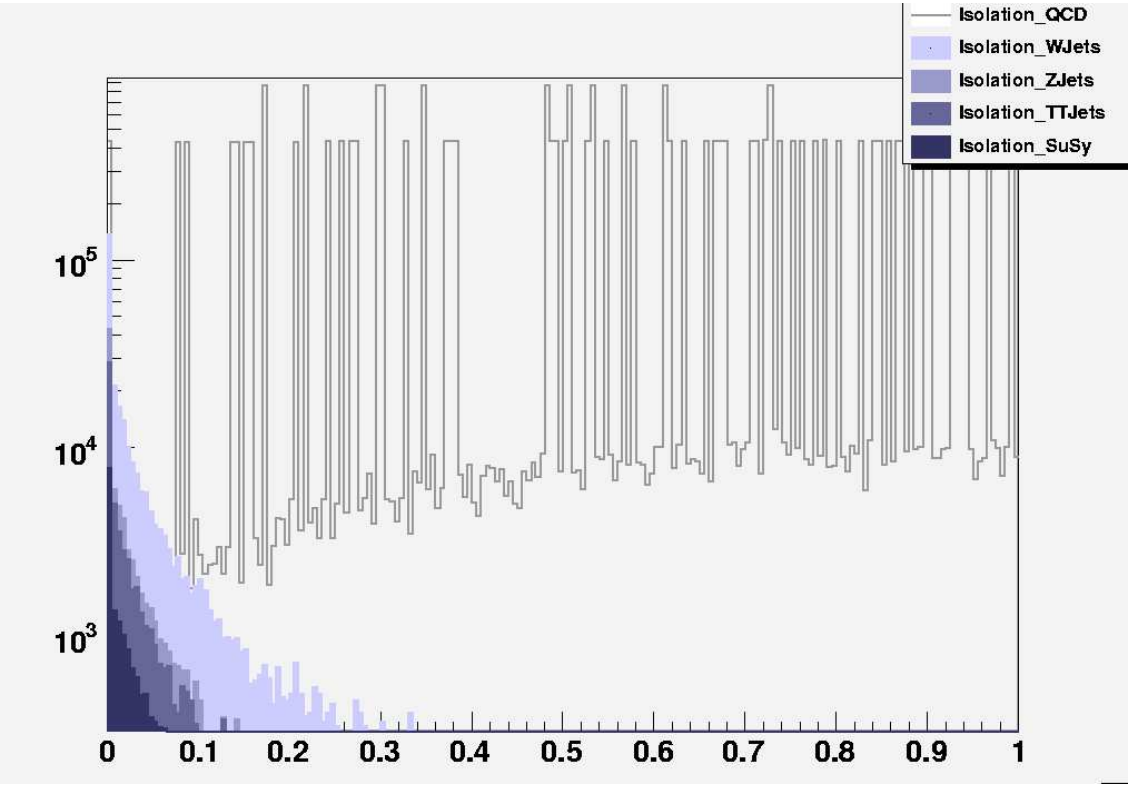
Isolation of μ

Pre-SELECTION

μ Selection

At least one μ:

- Global & Tracker Muon
- $P_t^{\mu} > 10$ GeV
- $|\eta| < 2.5$
- Combined Relative Isolation = $\frac{\sum_{R<0.3} P_t^{Tr} + \sum_{R<0.3} E_t^{HCal}}{P_t^{\mu}} < 0.05$



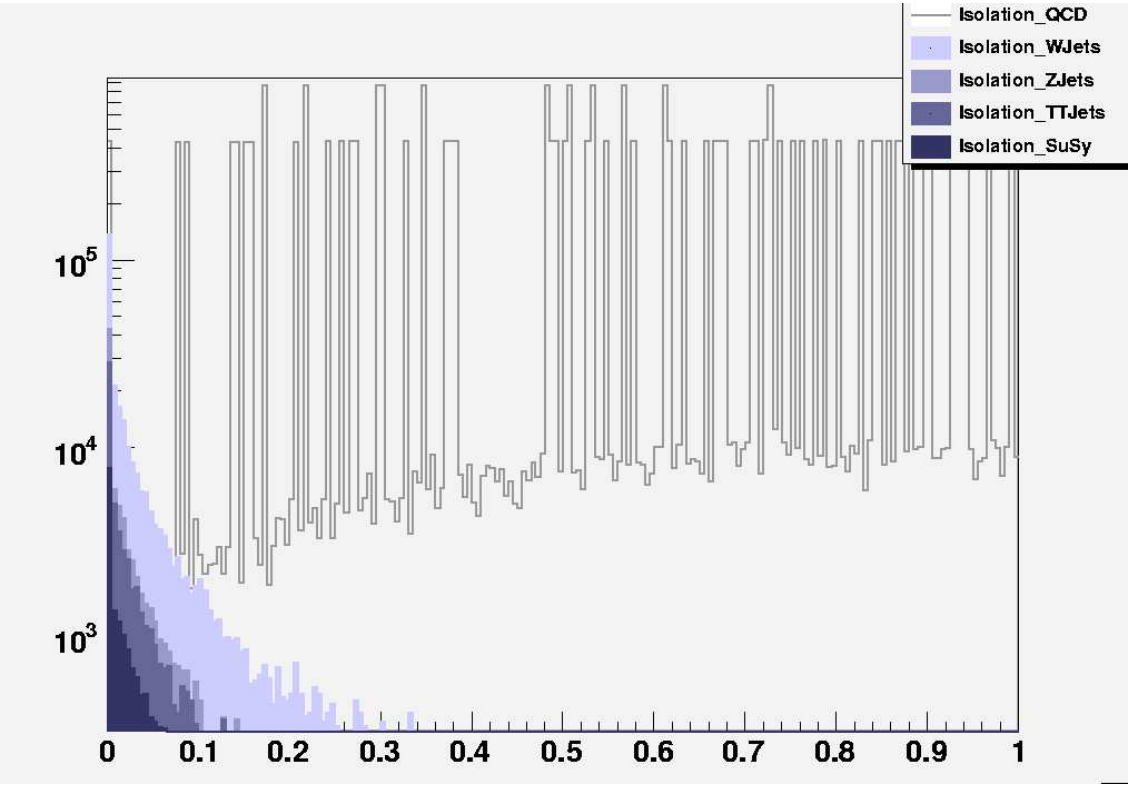
Isolation of μ

Pre-SELECTION

μ Selection

At least one μ:

- Global & Tracker Muon
- $P_t^{\mu} > 10$ GeV
- $|\eta| < 2.5$
- Combined Relative Isolation = $\frac{\sum_{R<0.3} P_t^{Tr} + \sum_{R<0.3} E_t^{HCal}}{P_t^{\mu}} < 0.05$



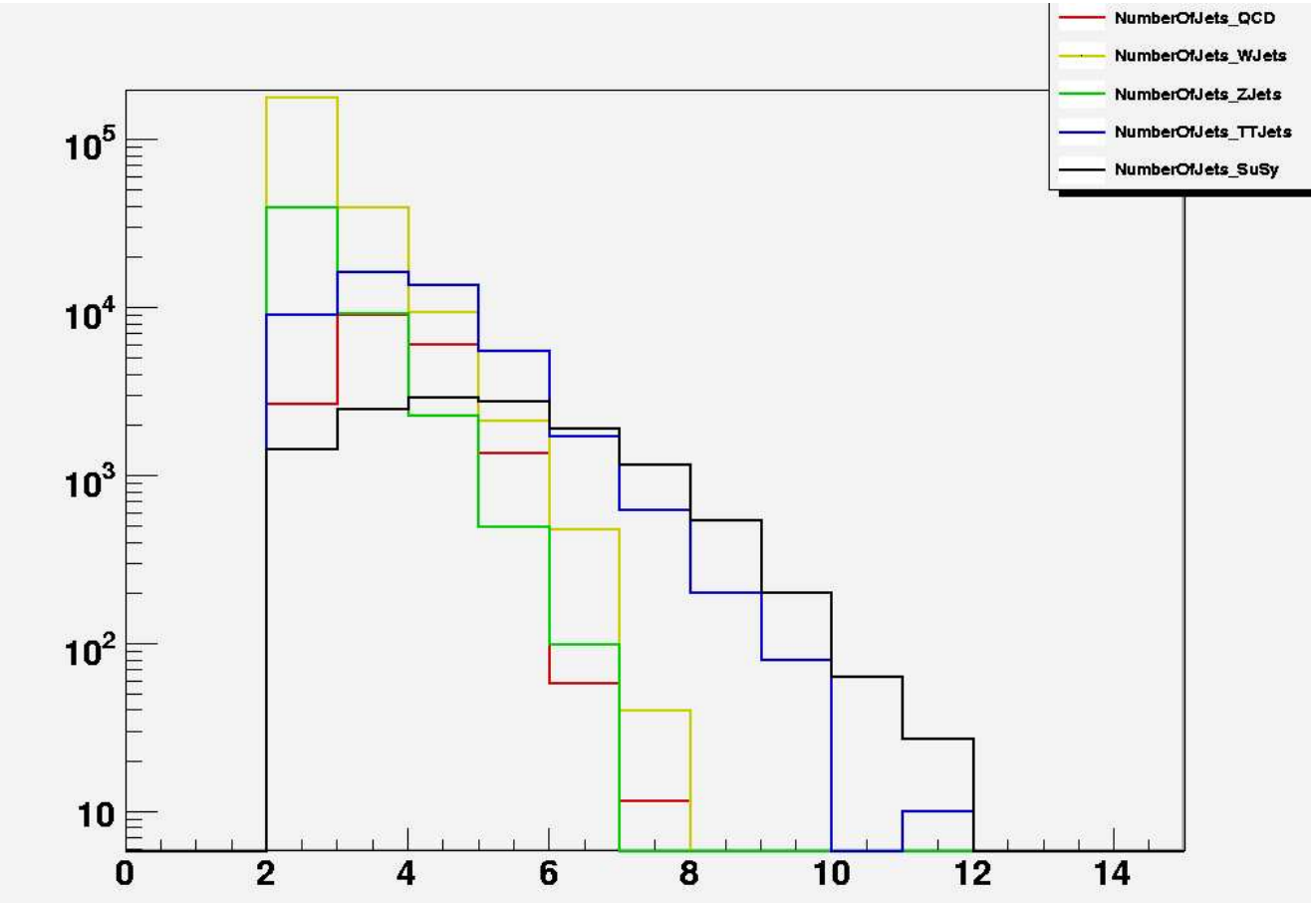
Isolation of μ

Pre-SELECTION

Jet Selection

At least three Jets:

- $E_t^{jet} > 30$ GeV
- $|\eta| < 3.0$



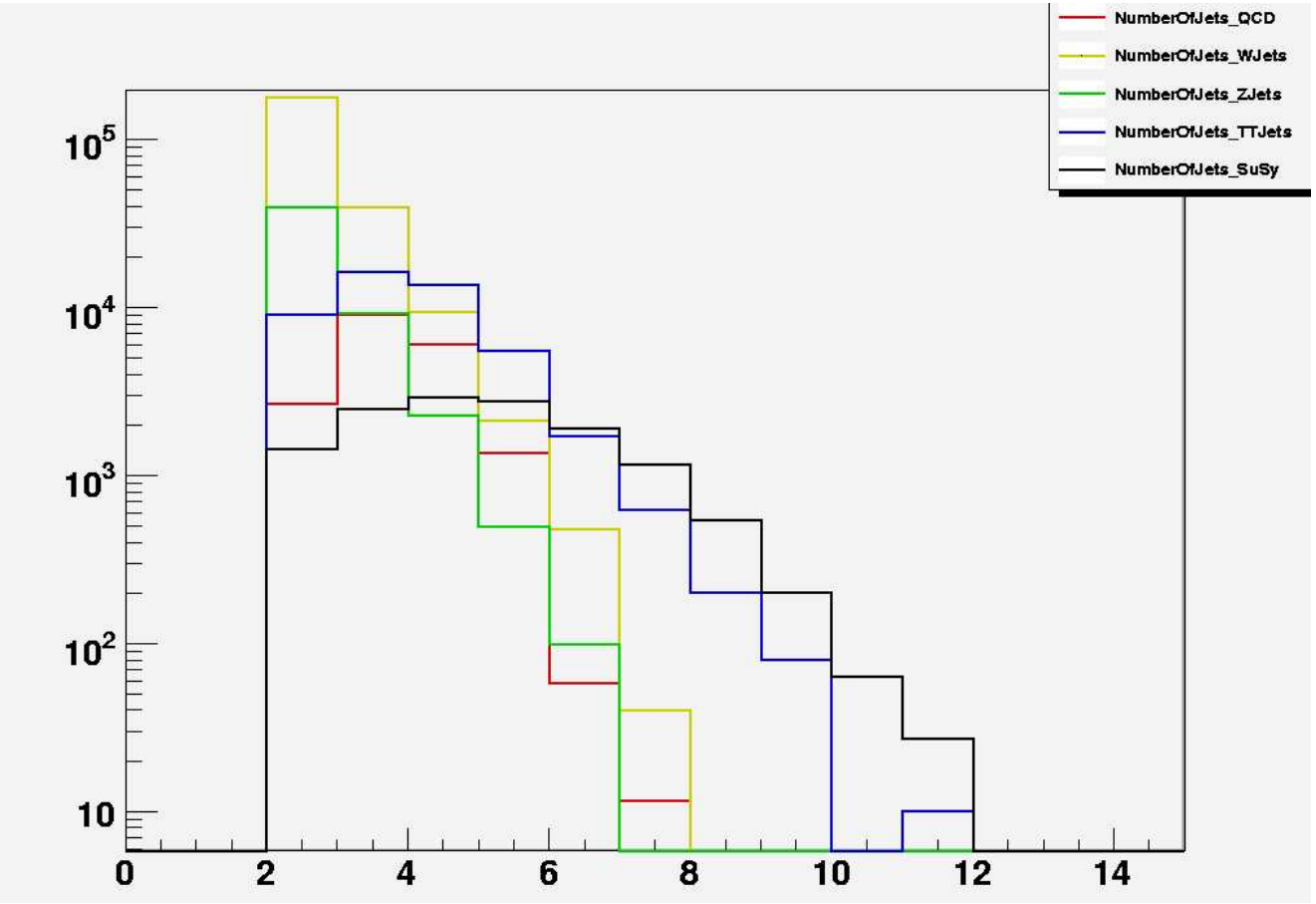
Number of Jets

Pre-SELECTION

Jet Selection

At least three Jets:

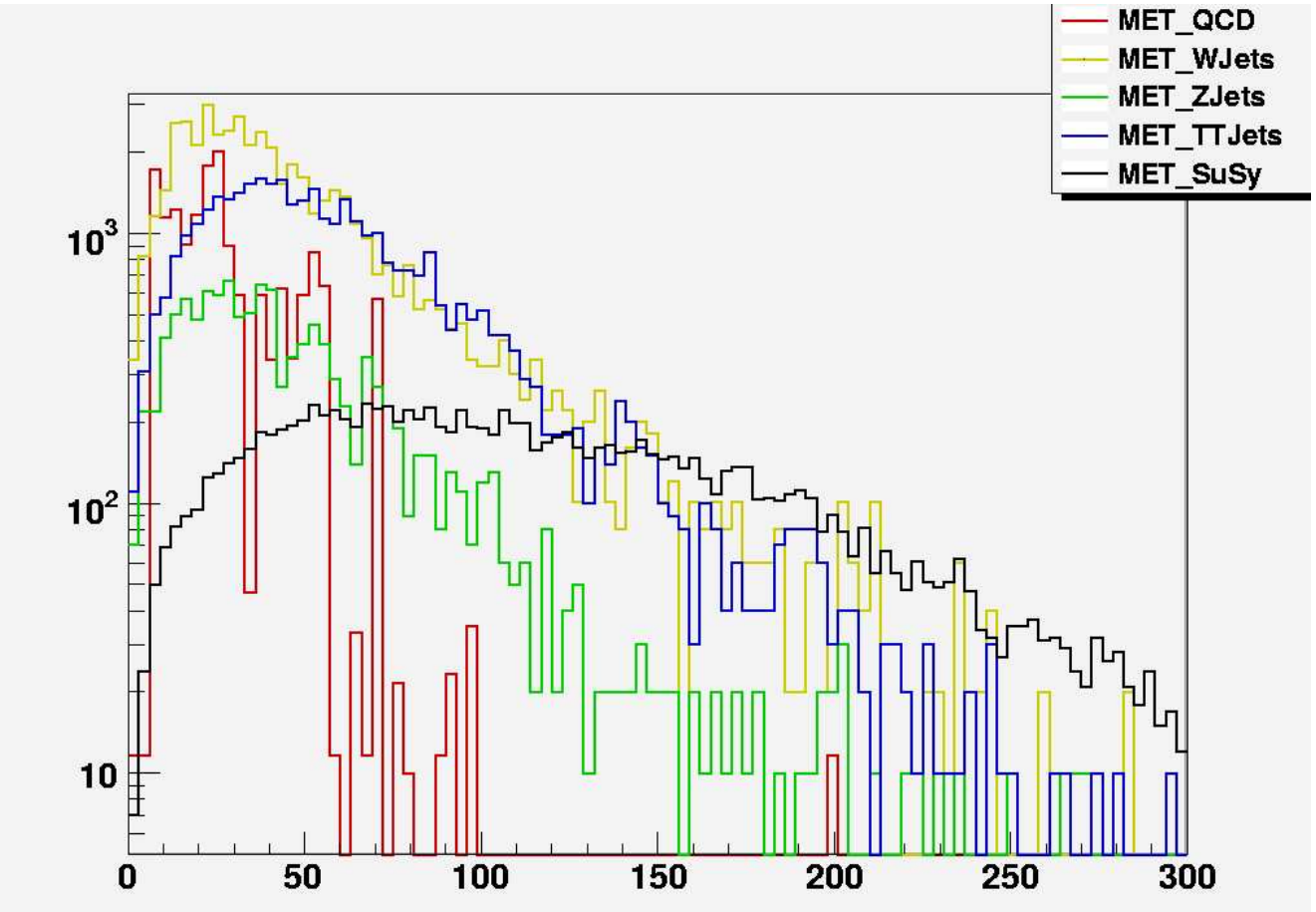
- $E_t^{jet} > 30$ GeV
- $|\eta| < 3.0$



Number of Jets

SELECTION

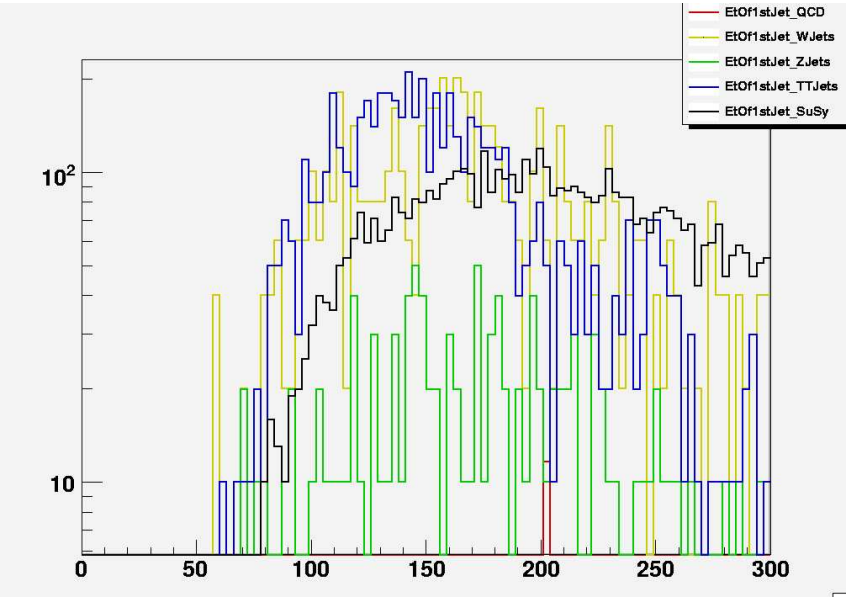
MET



MET > 95 Gev

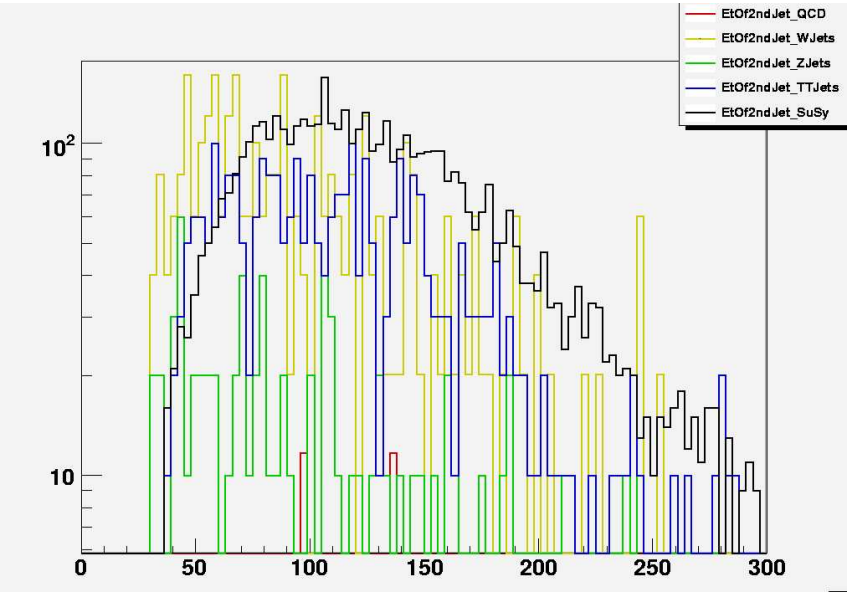
SELECTION

Et of 1st & 2nd Jet



Et of the fi rst Jet

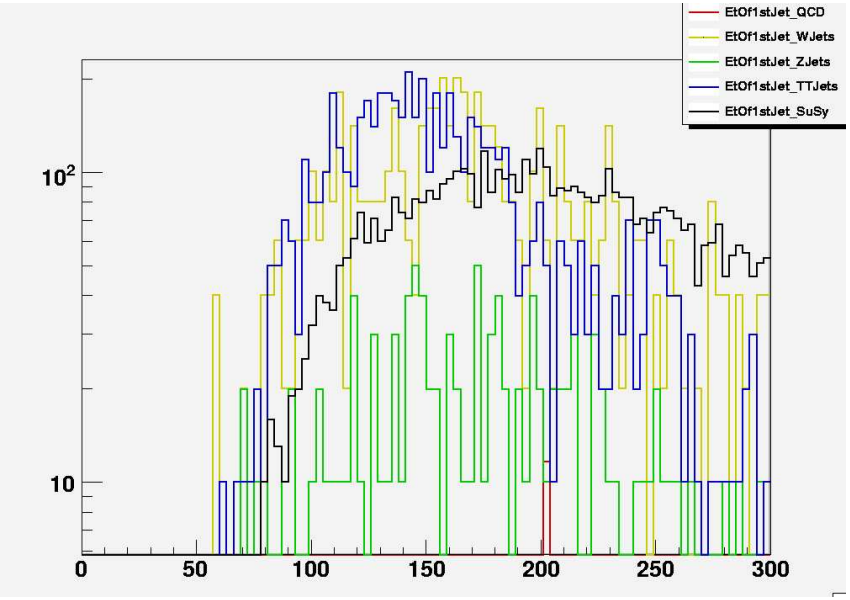
- $|\eta| < 3.0$
- $E_t^{1^{st}\,Jet} > 160$ GeV
- $|\eta| < 3.0$
- $E_t^{2^{nd}\,Jet} > 50$ GeV



Et of the second Jet

SELECTION

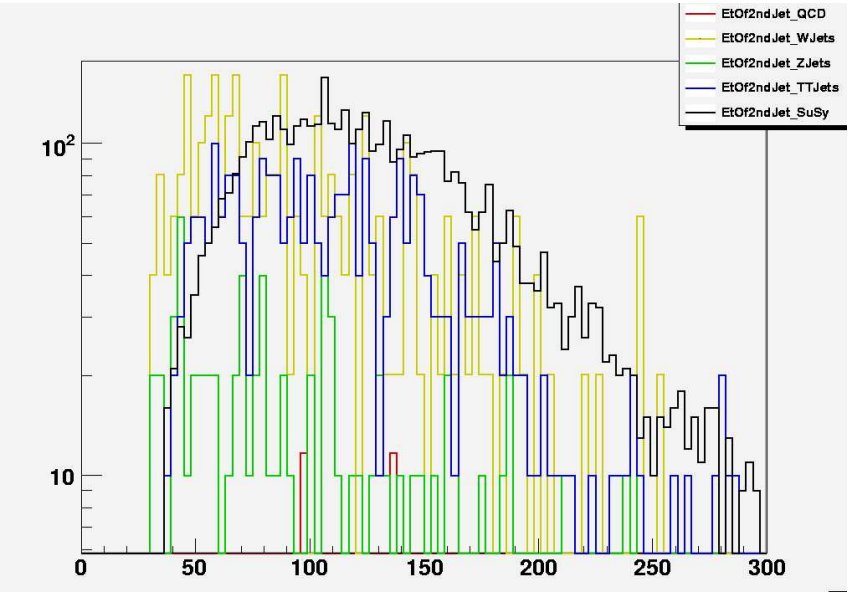
Et of 1st & 2nd Jet



Et of the fi rst Jet

- $|\eta| < 3.0$
- $E_t^{1^{st}\,Jet} > 160$ GeV

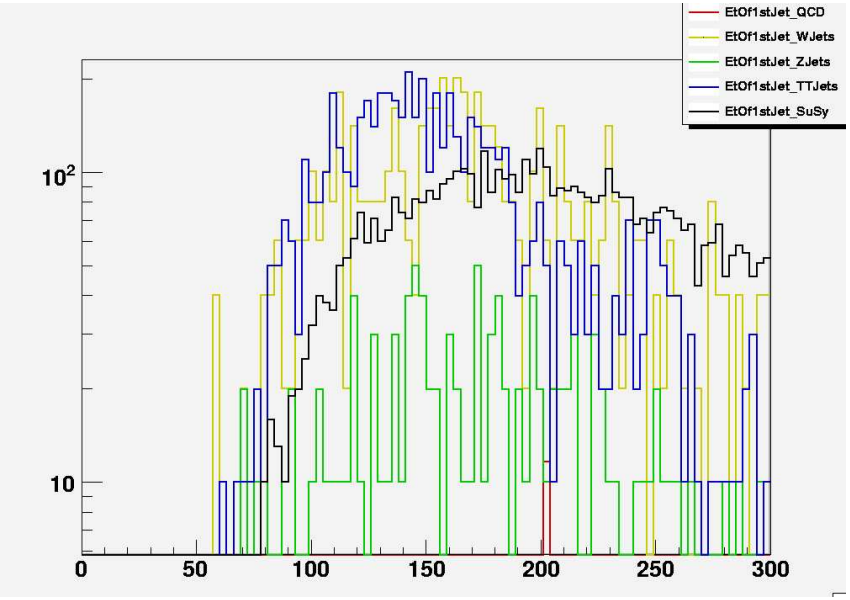
- $|\eta| < 3.0$
- $E_t^{2^{nd}\,Jet} > 50$ GeV



Et of the second Jet

SELECTION

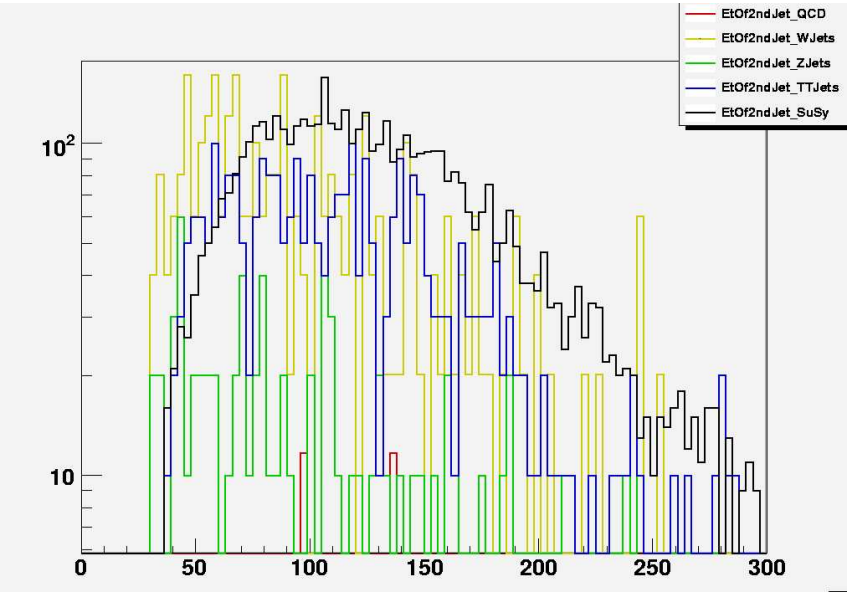
Et of 1st & 2nd Jet



Et of the fi rst Jet

- $|\eta| < 3.0$
- $E_t^{1^{st}\,Jet} > 160$ GeV

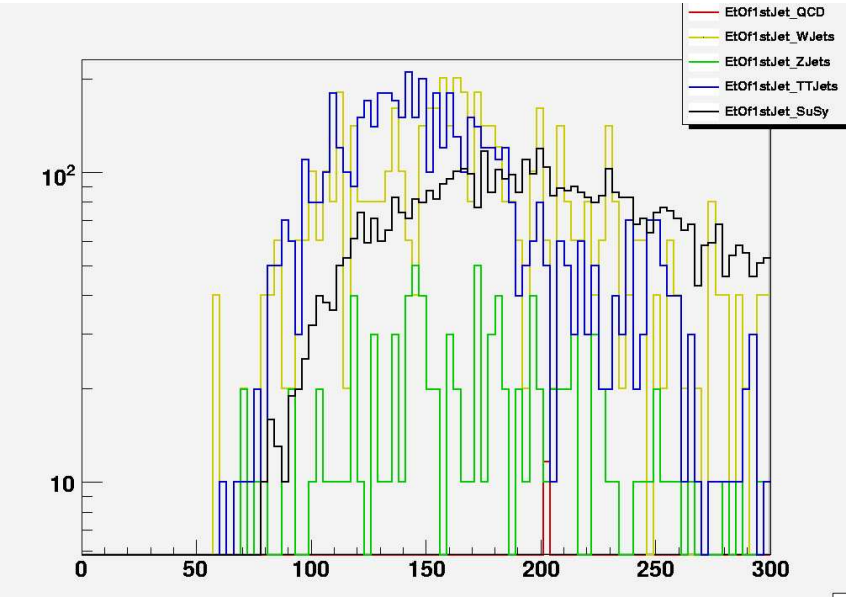
- $|\eta| < 3.0$
- $E_t^{2^{nd}\,Jet} > 50$ GeV



Et of the second Jet

SELECTION

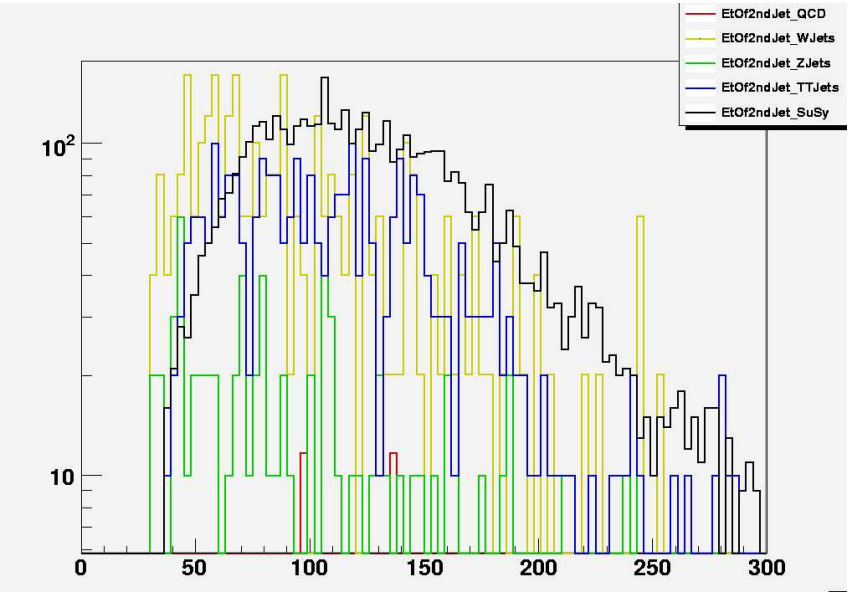
Et of 1st & 2nd Jet



Et of the fi rst Jet

- $|\eta| < 3.0$
- $E_t^{1^{st}\,Jet} > 160$ GeV

- $|\eta| < 3.0$
- $E_t^{2^{nd}\,Jet} > 50$ GeV

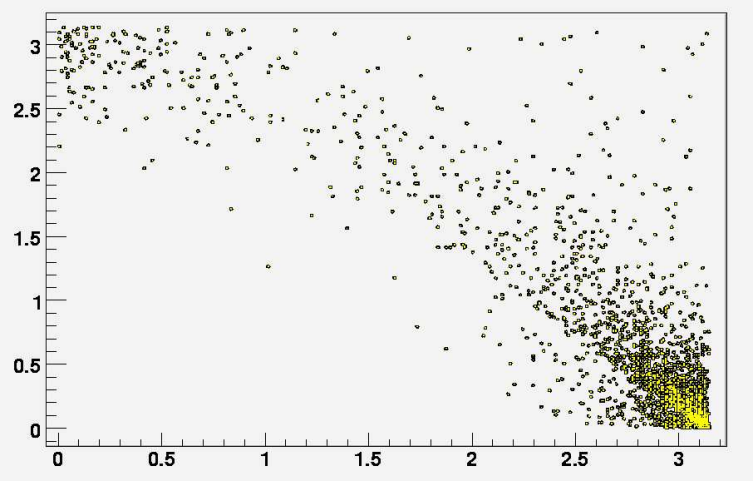


Et of the second Jet

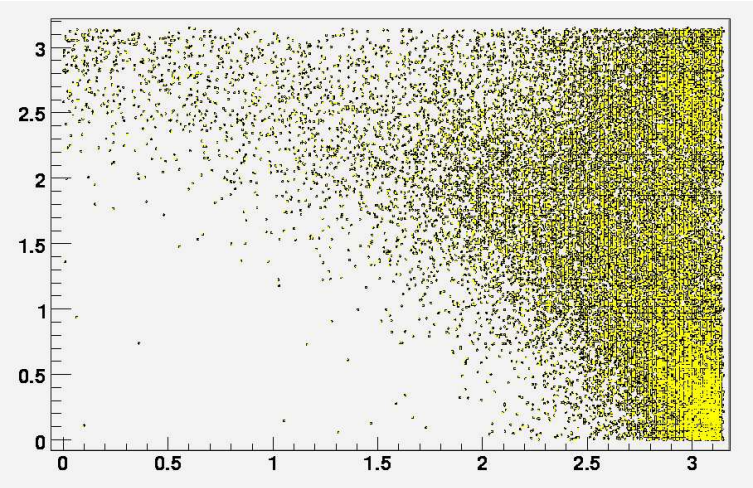
SELECTION

$\Delta\phi_1 - \Delta\phi_2$

- MET in QCD originates from mismeasured jets
- $\Delta\phi_{1,2} = |\phi_{j1,j2} - \phi_{MET}|$
- when $\Delta\phi_{1,2} = 0$ we have $\Delta\phi_{2,1} = \pi$



$\Delta\phi_1$ versus $\Delta\phi_2$ for QCD

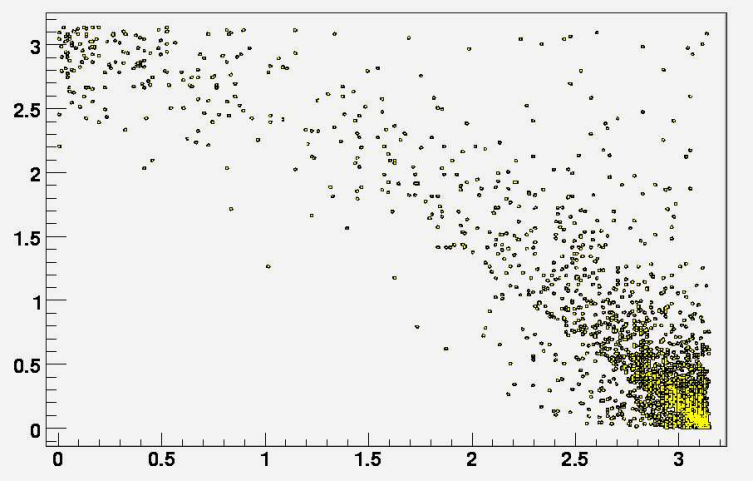


$\Delta\phi_1$ versus $\Delta\phi_2$ for SUSY

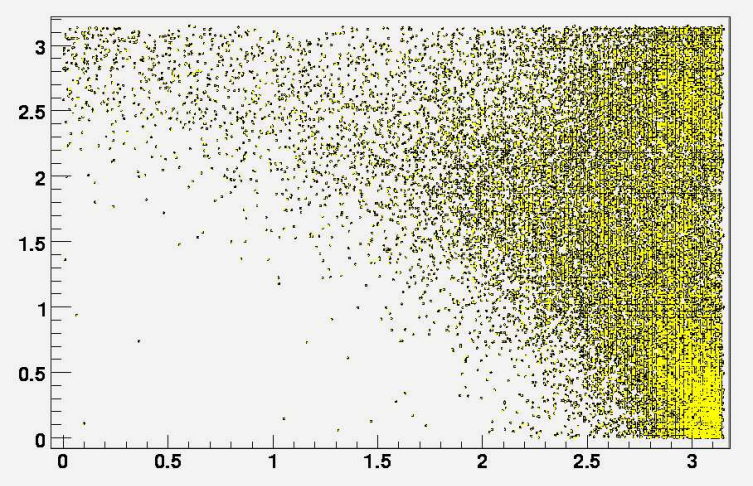
SELECTION

$\Delta\phi_1 - \Delta\phi_2$

- MET in QCD originates from mismeasured jets
- $\Delta\phi_{1,2} = |\phi_{j1,j2} - \phi_{MET}|$
- when $\Delta\phi_{1,2} = 0$ we have $\Delta\phi_{2,1} = \pi$



$\Delta\phi_1$ versus $\Delta\phi_2$ for QCD

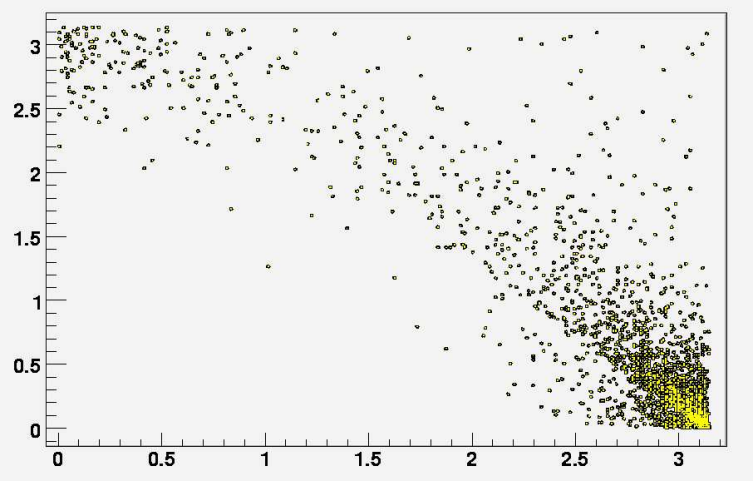


$\Delta\phi_1$ versus $\Delta\phi_2$ for SUSY

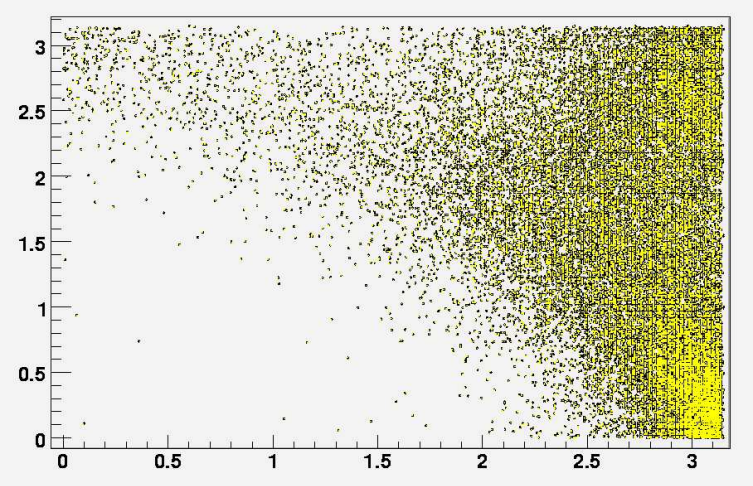
SELECTION

$\Delta\phi_1 - \Delta\phi_2$

- MET in QCD originates from mismeasured jets
- $\Delta\phi_{1,2} = |\phi_{j1,j2} - \phi_{MET}|$
- when $\Delta\phi_{1,2} = 0$ we have $\Delta\phi_{2,1} = \pi$



$\Delta\phi_1$ versus $\Delta\phi_2$ for QCD

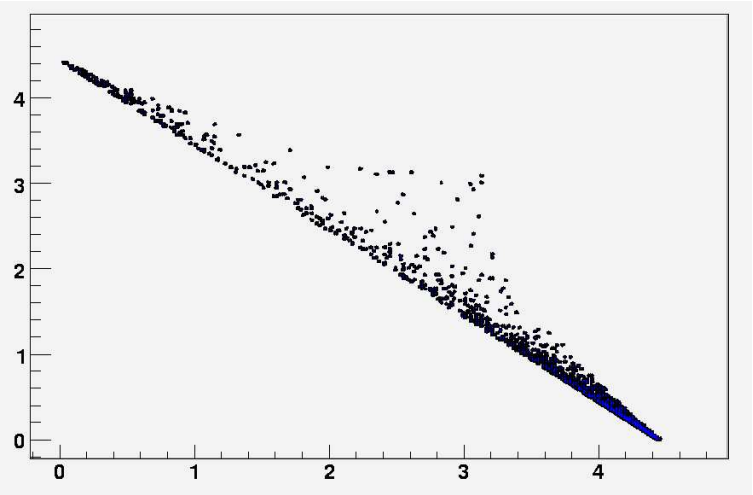


$\Delta\phi_1$ versus $\Delta\phi_2$ for SUSY

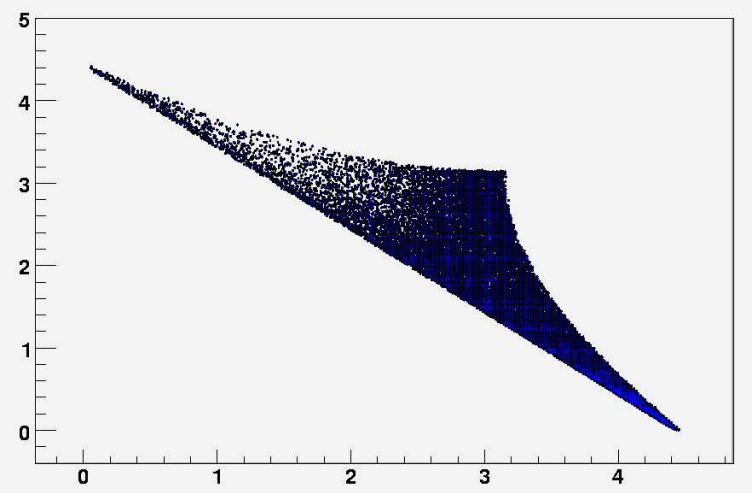
SELECTION

$\mathcal{R}_1 - \mathcal{R}_2$

- $\mathcal{R}_{1,2} = \sqrt{\Delta\phi_{1,2}^2 + (\pi - \Delta\phi_{2,1})^2}$



$\mathcal{R}_1$ versus $\mathcal{R}_2$ for QCD

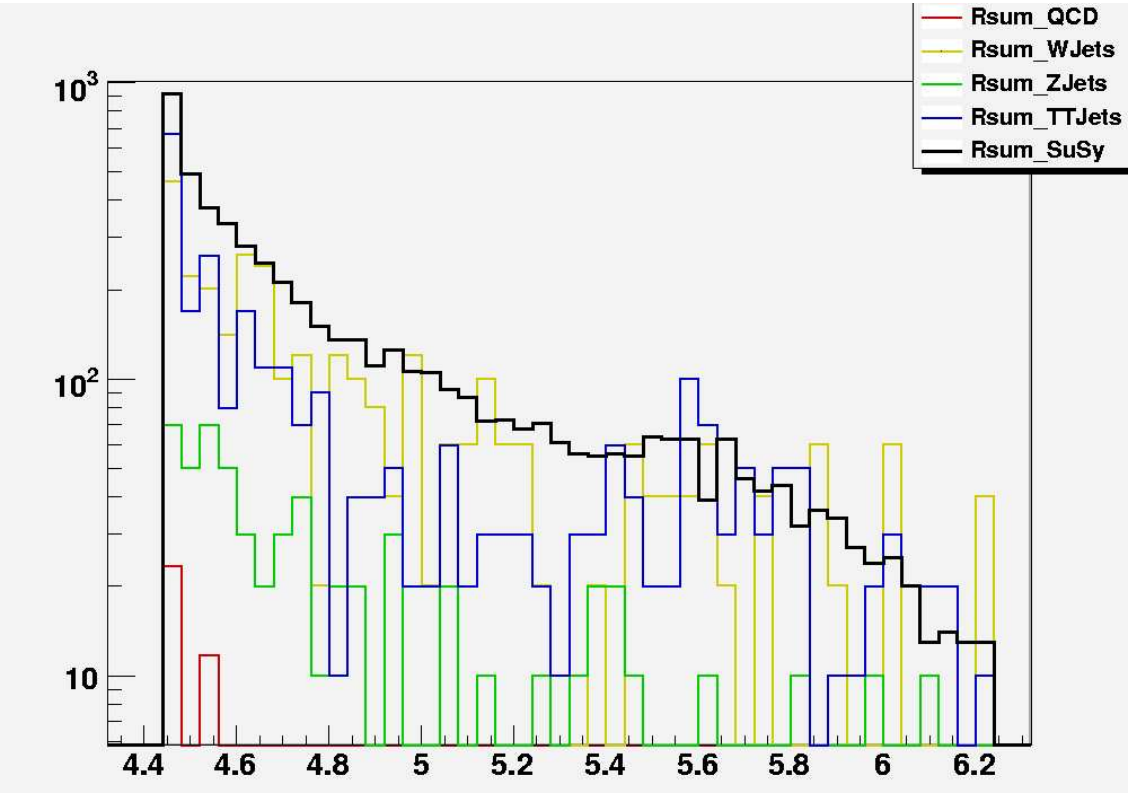


$\mathcal{R}_1$ versus $\mathcal{R}_2$ for SUSY

SELECTION

$\mathcal{R}_{sum}$

- $\mathcal{R}_{sum} = \mathcal{R}_1 + \mathcal{R}_2$
- $\mathcal{R}_{sum} > 4.5$

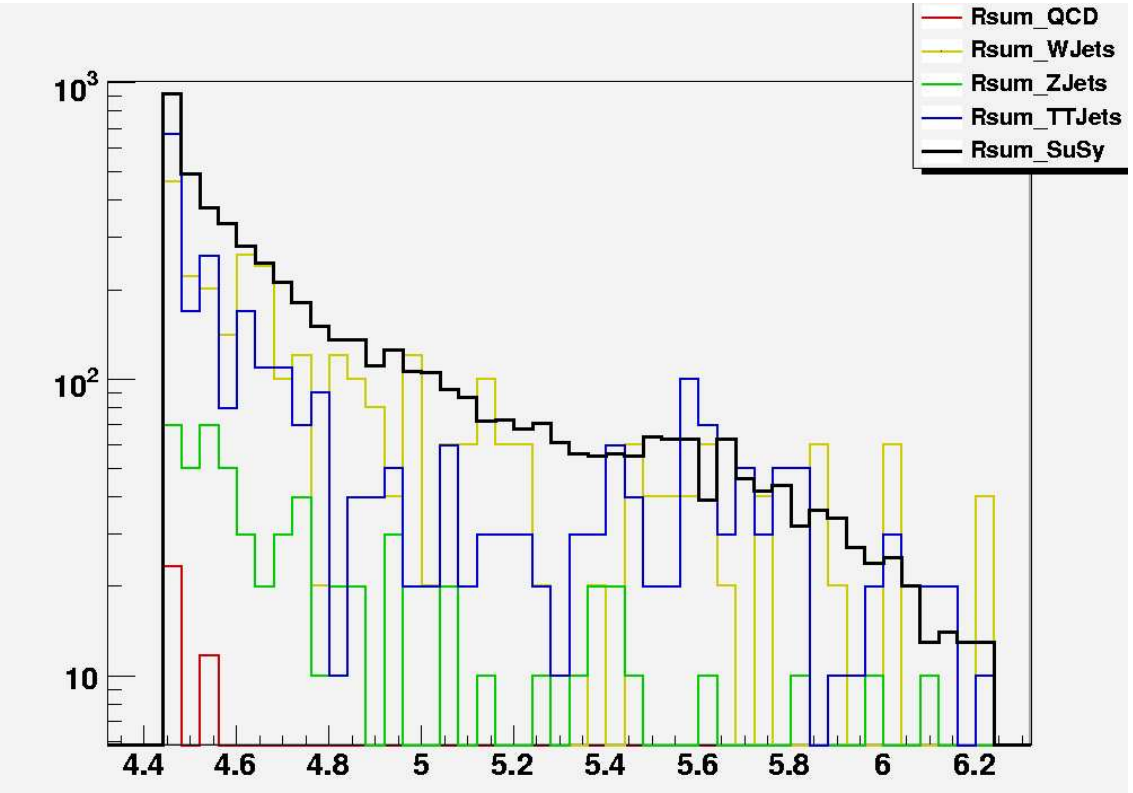


$\mathcal{R}_{sum}$

SELECTION

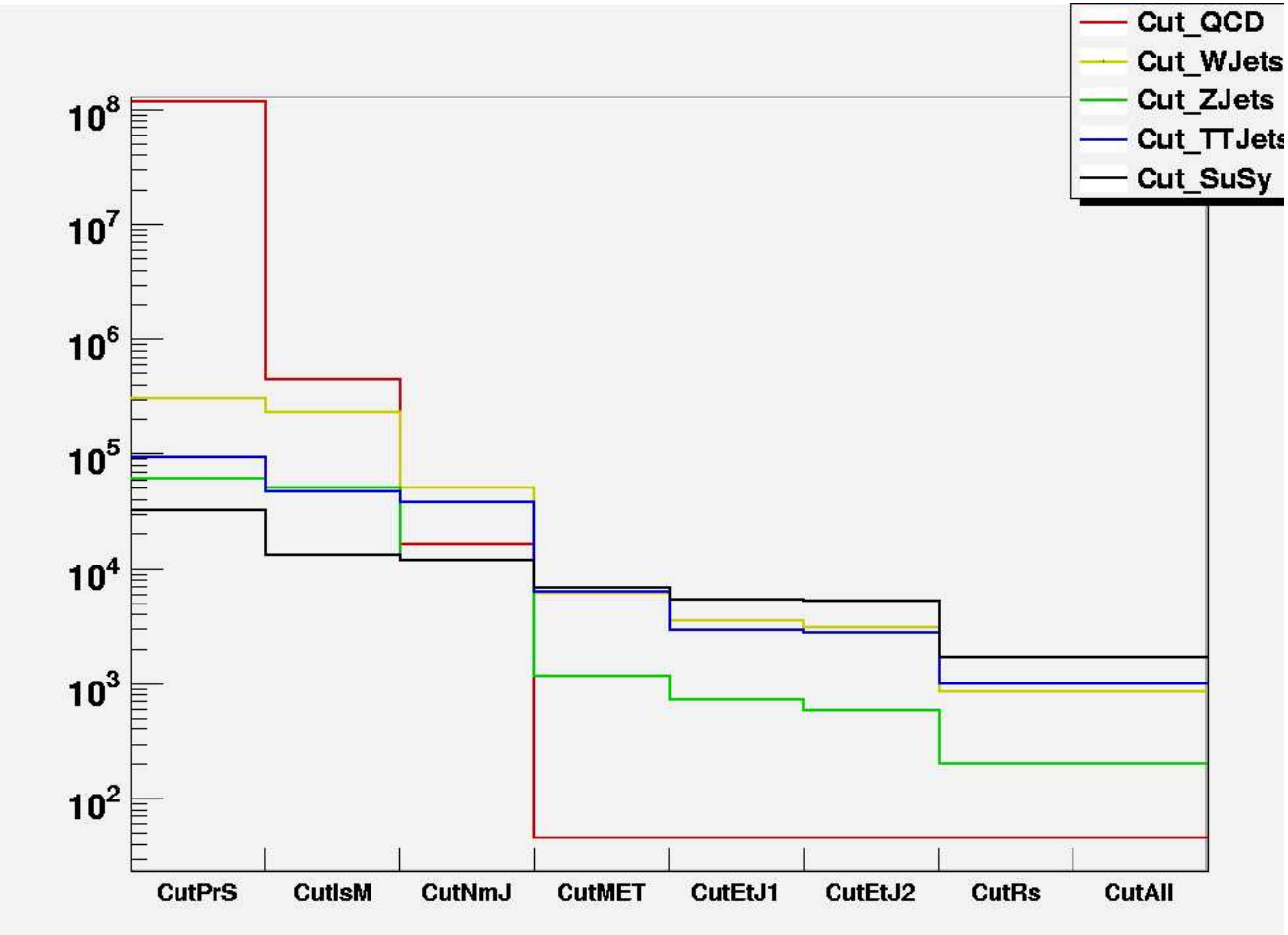
$\mathcal{R}_{sum}$

- $\mathcal{R}_{sum} = \mathcal{R}_1 + \mathcal{R}_2$
- $\mathcal{R}_{sum} > 4.5$



$\mathcal{R}_{sum}$

RESULTS



It seems that Et of Jet 2 can be removed.

RESULTS

Cut Name	#SuSy	#TTJets	#ZJets	#WJets	#QCD
Pre-Selection	3.330e+04	9.448e+04	6.254e+04	3.135e+05	1.184e+08
μIsolation	1.353e+04	4.733e+04	5.185e+04	2.317e+05	4.478e+05
Number of Jet$\geq$ 2	1.210e+04	3.820e+04	1.207e+04	5.176e+04	1.655e+04
$MET > 95$	6.902e+03	6.340e+03	1.190e+03	6.181e+03	4.670e+01
Et of J1 $>$ 160	5.451e+03	3.000e+03	7.400e+02	3.604e+03	4.670e+01
Et of J2$>$ 50	5.330e+03	2.840e+03	5.900e+02	3.141e+03	4.670e+01
$\mathcal{R}_{sum} > 4.5$	1.690e+03	1.020e+03	2.000e+02	8.658e+02	4.670e+01

- Weighted for 1 fb^{-1} Integrated Luminosity
- With 20 pb^{-1} Integrated Luminosity, significance will be 5
- $\frac{n_s}{n_b} = 0.79$

RESULTS

Cut Name	#SuSy	#TTJets	#ZJets	#WJets	#QCD
Pre-Selection	3.330e+04	9.448e+04	6.254e+04	3.135e+05	1.184e+08
μIsolation	1.353e+04	4.733e+04	5.185e+04	2.317e+05	4.478e+05
Number of Jet$\geq$ 2	1.210e+04	3.820e+04	1.207e+04	5.176e+04	1.655e+04
$MET > 95$	6.902e+03	6.340e+03	1.190e+03	6.181e+03	4.670e+01
Et of J1 $>$ 160	5.451e+03	3.000e+03	7.400e+02	3.604e+03	4.670e+01
Et of J2$>$ 50	5.330e+03	2.840e+03	5.900e+02	3.141e+03	4.670e+01
$\mathcal{R}_{sum} > 4.5$	1.690e+03	1.020e+03	2.000e+02	8.658e+02	4.670e+01

- Weighted for 1 fb^{-1} Integrated Luminosity
- With 20 pb^{-1} Integrated Luminosity, significance will be 5
- $\frac{n_s}{n_b} = 0.79$

RESULTS

Cut Name	#SuSy	#TTJets	#ZJets	#WJets	#QCD
Pre-Selection	3.330e+04	9.448e+04	6.254e+04	3.135e+05	1.184e+08
μIsolation	1.353e+04	4.733e+04	5.185e+04	2.317e+05	4.478e+05
Number of Jet$\geq$ 2	1.210e+04	3.820e+04	1.207e+04	5.176e+04	1.655e+04
$MET > 95$	6.902e+03	6.340e+03	1.190e+03	6.181e+03	4.670e+01
Et of J1 $>$ 160	5.451e+03	3.000e+03	7.400e+02	3.604e+03	4.670e+01
Et of J2$>$ 50	5.330e+03	2.840e+03	5.900e+02	3.141e+03	4.670e+01
$\mathcal{R}_{sum} > 4.5$	1.690e+03	1.020e+03	2.000e+02	8.658e+02	4.670e+01

- Weighted for 1 fb^{-1} Integrated Luminosity
- With 20 pb^{-1} Integrated Luminosity, significance will be 5
- $\frac{n_s}{n_b} = 0.79$

OUTLOOK

- Et of the second hardest jet seems does not have important effect on the analysis results. For a fi nal decision to remove or keep this cut, more investigations are needed.
- We need more statistics to analyze the backgrounds, specially QCD
- We only used pat Objects without Cross Cleaning implement, so we must carry out these algorithms on the objects.
- The analysis can be more completed by taking into account DiBosons as the backgrounds.
- SUSY is not necessarily placed at LM0 or . . . and maybe not even in the mSUGRA, so we should study and verify that the cuts are suffi ciently optimal throughout the plane.
- Estimates of backgrounds should be developed by the data-driven methods.
- Study to fi nd the best formula to estimate the discovery signifi cance of our analysis.

OUTLOOK

- Et of the second hardest jet seems does not have important effect on the analysis results. For a fi nal decision to remove or keep this cut, more investigations are needed.
- We need more statistics to analyze the backgrounds, specially QCD
- We only used pat Objects without Cross Cleaning implement, so we must carry out these algorithms on the objects.
- The analysis can be more completed by taking into account DiBosons as the backgrounds.
- SUSY is not necessarily placed at LM0 or . . . and maybe not even in the mSUGRA, so we should study and verify that the cuts are suffi ciently optimal throughout the plane.
- Estimates of backgrounds should be developed by the data-driven methods.
- Study to fi nd the best formula to estimate the discovery signifi cance of our analysis.

OUTLOOK

- Et of the second hardest jet seems does not have important effect on the analysis results. For a fi nal decision to remove or keep this cut, more investigations are needed.
- We need more statistics to analyze the backgrounds, specially QCD
- We only used pat Objects without Cross Cleaning implement, so we must carry out these algorithms on the objects.
- The analysis can be more completed by taking into account DiBosons as the backgrounds.
- SUSY is not necessarily placed at LM0 or . . . and maybe not even in the mSUGRA, so we should study and verify that the cuts are suffi ciently optimal throughout the plane.
- Estimates of backgrounds should be developed by the data-driven methods.
- Study to fi nd the best formula to estimate the discovery signifi cance of our analysis.

OUTLOOK

- Et of the second hardest jet seems does not have important effect on the analysis results. For a fi nal decision to remove or keep this cut, more investigations are needed.
- We need more statistics to analyze the backgrounds, specially QCD
- We only used pat Objects without Cross Cleaning implement, so we must carry out these algorithms on the objects.
- The analysis can be more completed by taking into account DiBosons as the backgrounds.
- SUSY is not necessarily placed at LM0 or . . . and maybe not even in the mSUGRA, so we should study and verify that the cuts are suffi ciently optimal throughout the plane.
- Estimates of backgrounds should be developed by the data-driven methods.
- Study to fi nd the best formula to estimate the discovery signifi cance of our analysis.

OUTLOOK

- Et of the second hardest jet seems does not have important effect on the analysis results. For a fi nal decision to remove or keep this cut, more investigations are needed.
- We need more statistics to analyze the backgrounds, specially QCD
- We only used pat Objects without Cross Cleaning implement, so we must carry out these algorithms on the objects.
- The analysis can be more completed by taking into account DiBosons as the backgrounds.
- SUSY is not necessarily placed at LM0 or . . . and maybe not even in the mSUGRA, so we should study and verify that the cuts are suffi ciently optimal throughout the plane.
- Estimates of backgrounds should be developed by the data-driven methods.
- Study to fi nd the best formula to estimate the discovery signifi cance of our analysis.

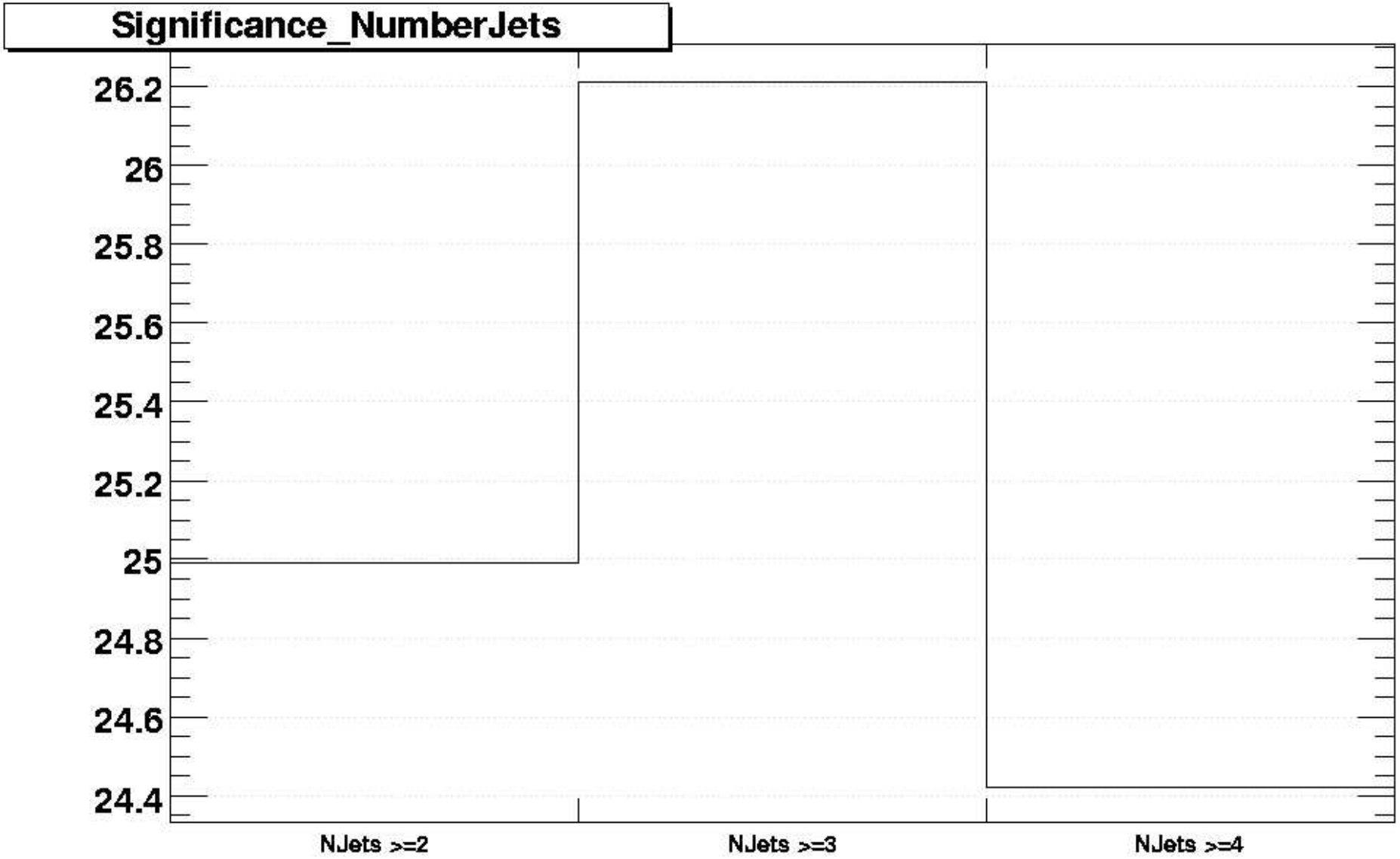
OUTLOOK

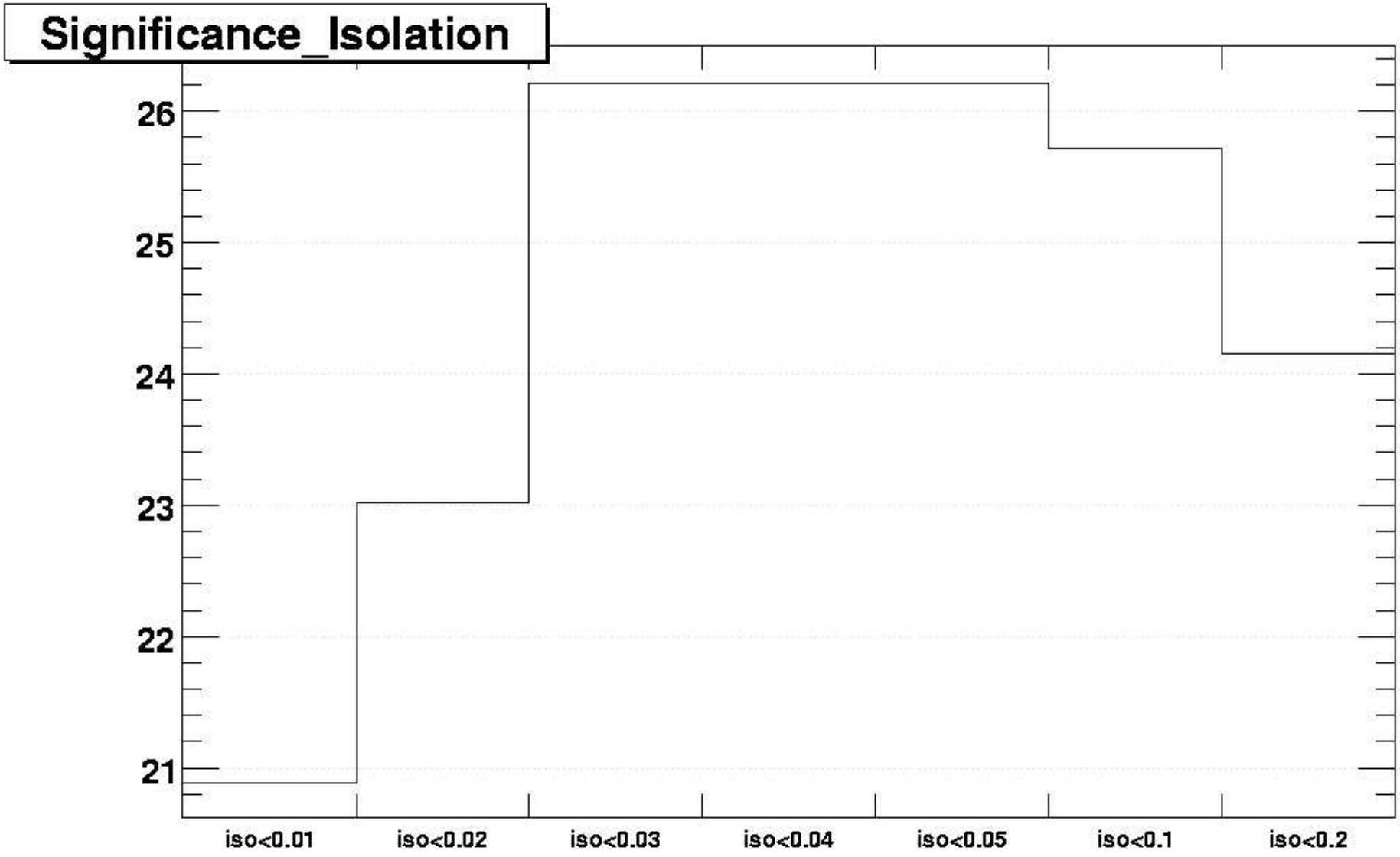
- Et of the second hardest jet seems does not have important effect on the analysis results. For a fi nal decision to remove or keep this cut, more investigations are needed.
- We need more statistics to analyze the backgrounds, specially QCD
- We only used pat Objects without Cross Cleaning implement, so we must carry out these algorithms on the objects.
- The analysis can be more completed by taking into account DiBosons as the backgrounds.
- SUSY is not necessarily placed at LM0 or . . . and maybe not even in the mSUGRA, so we should study and verify that the cuts are suffi ciently optimal throughout the plane.
- Estimates of backgrounds should be developed by the data-driven methods.
- Study to fi nd the best formula to estimate the discovery signifi cance of our analysis.

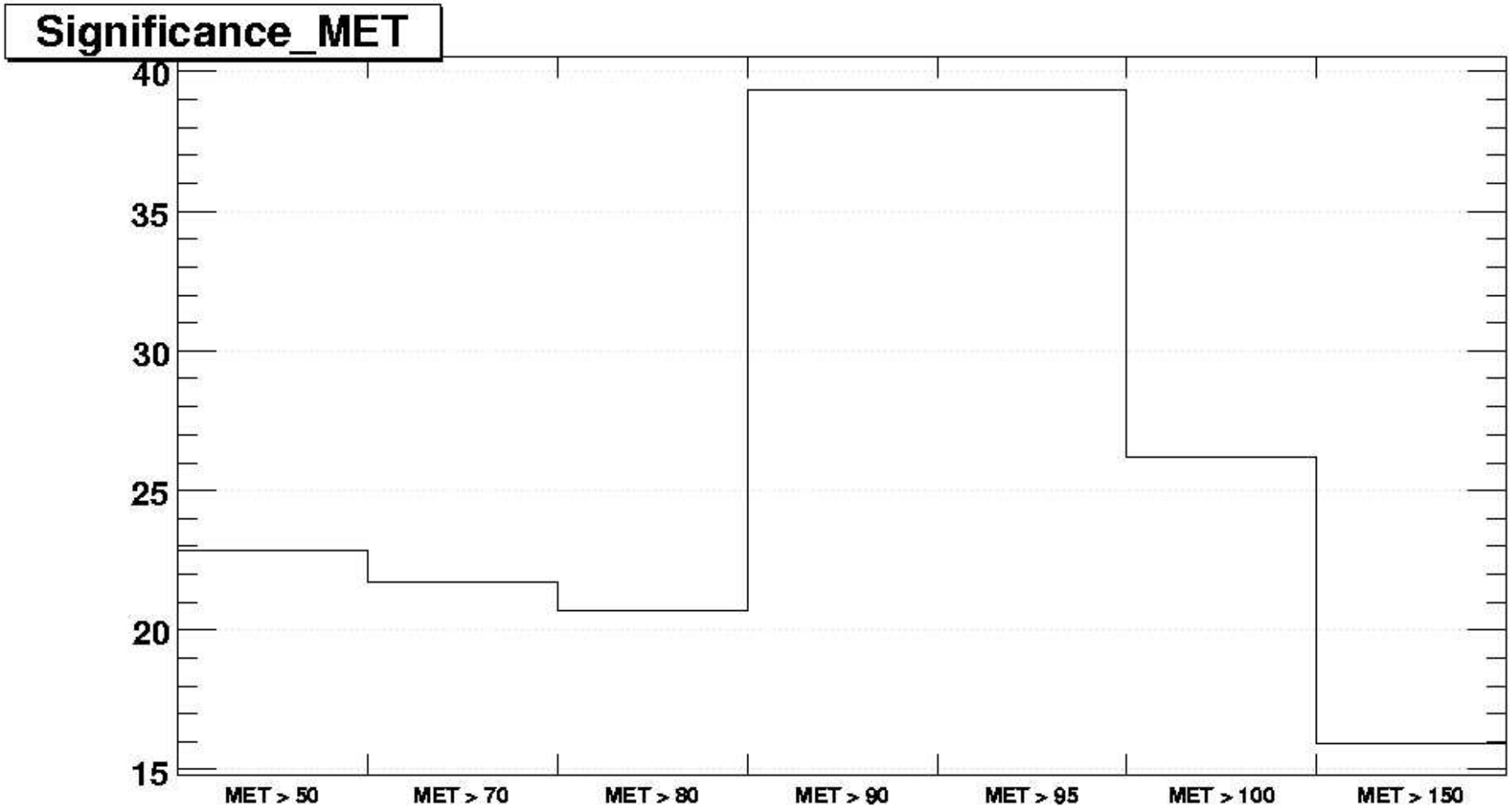
OUTLOOK

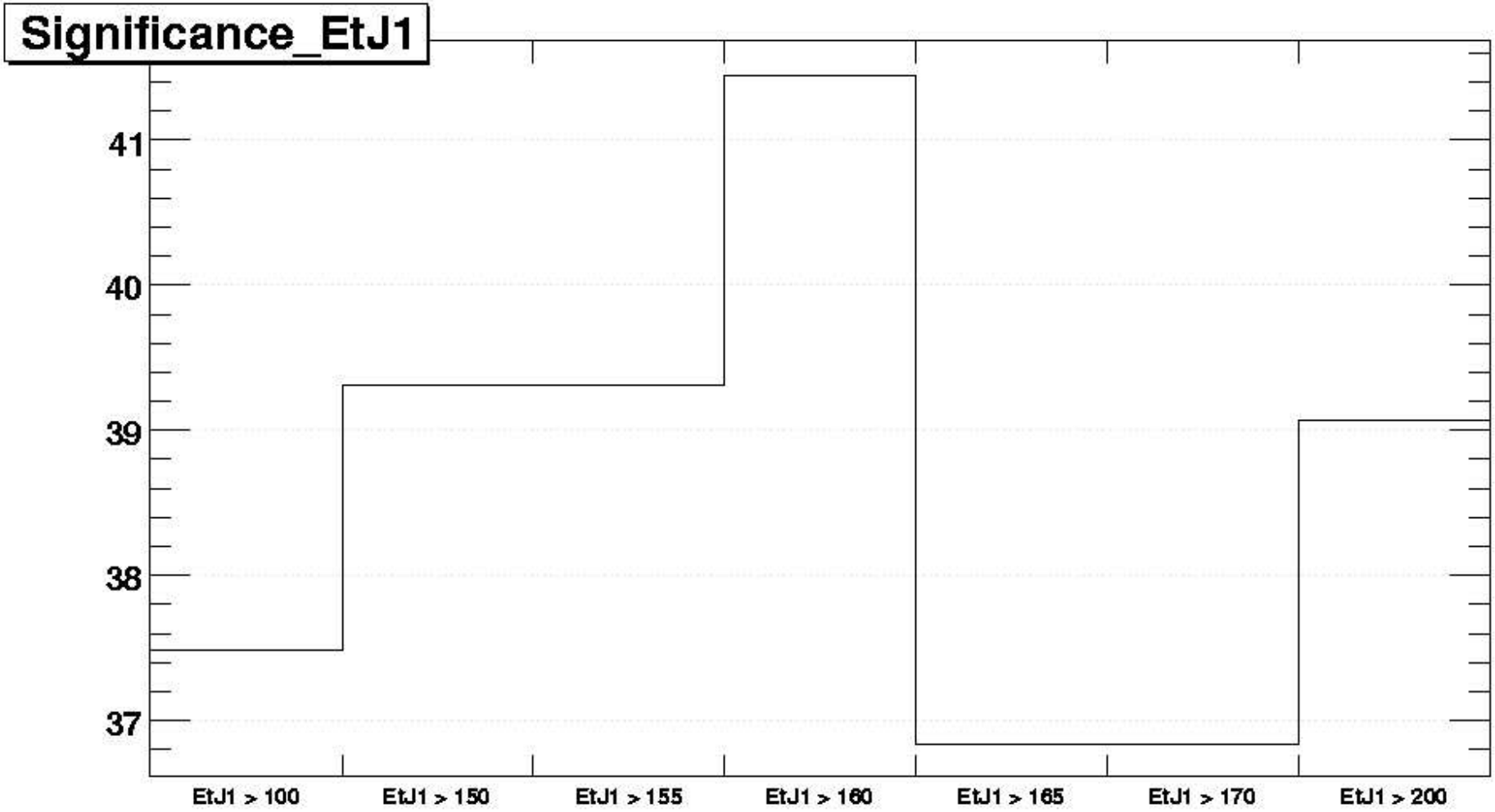
- Et of the second hardest jet seems does not have important effect on the analysis results. For a fi nal decision to remove or keep this cut, more investigations are needed.
- We need more statistics to analyze the backgrounds, specially QCD
- We only used pat Objects without Cross Cleaning implement, so we must carry out these algorithms on the objects.
- The analysis can be more completed by taking into account DiBosons as the backgrounds.
- SUSY is not necessarily placed at LM0 or . . . and maybe not even in the mSUGRA, so we should study and verify that the cuts are suffi ciently optimal throughout the plane.
- Estimates of backgrounds should be developed by the data-driven methods.
- Study to fi nd the best formula to estimate the discovery signifi cance of our analysis.

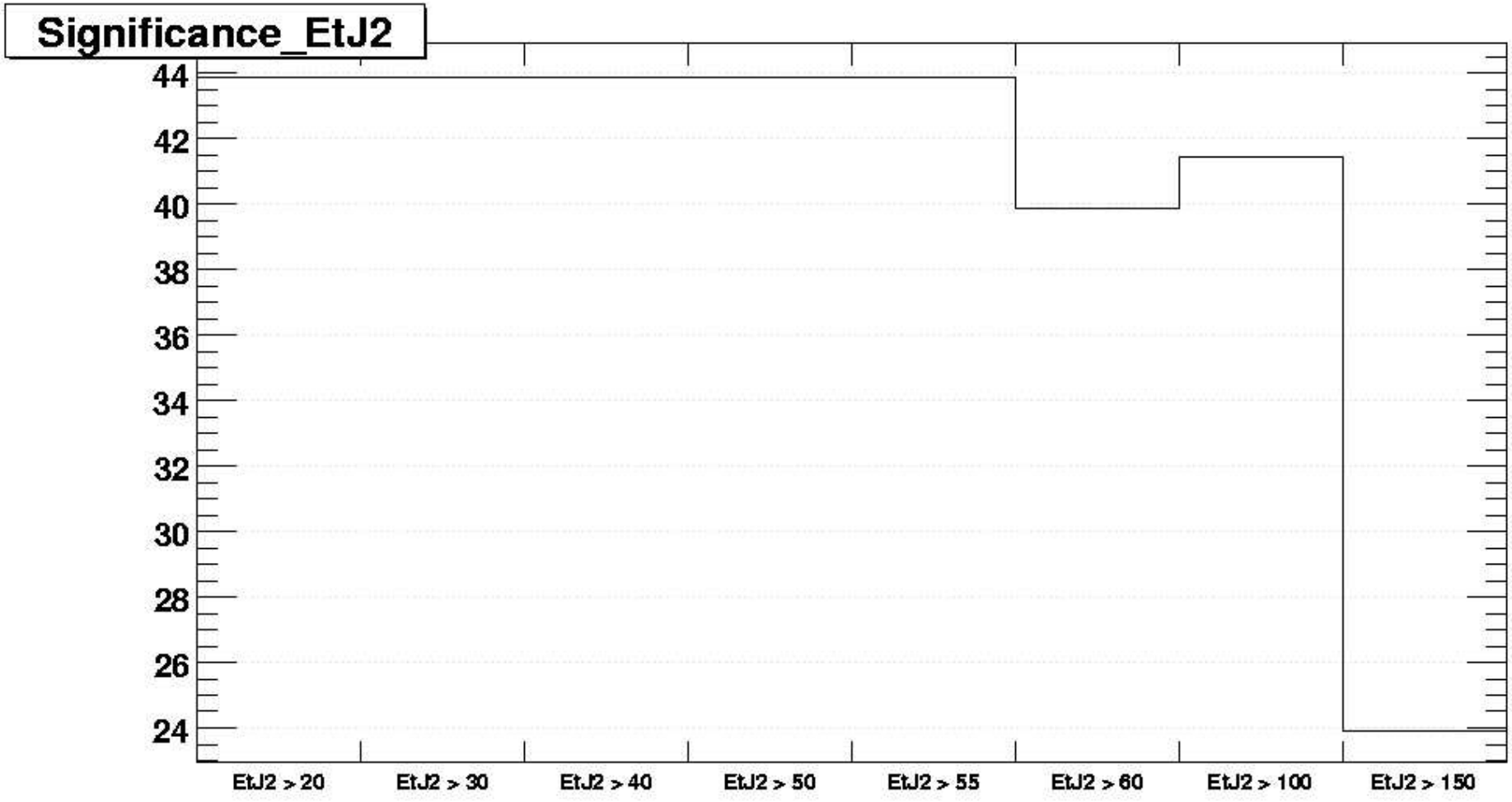
BACKUP

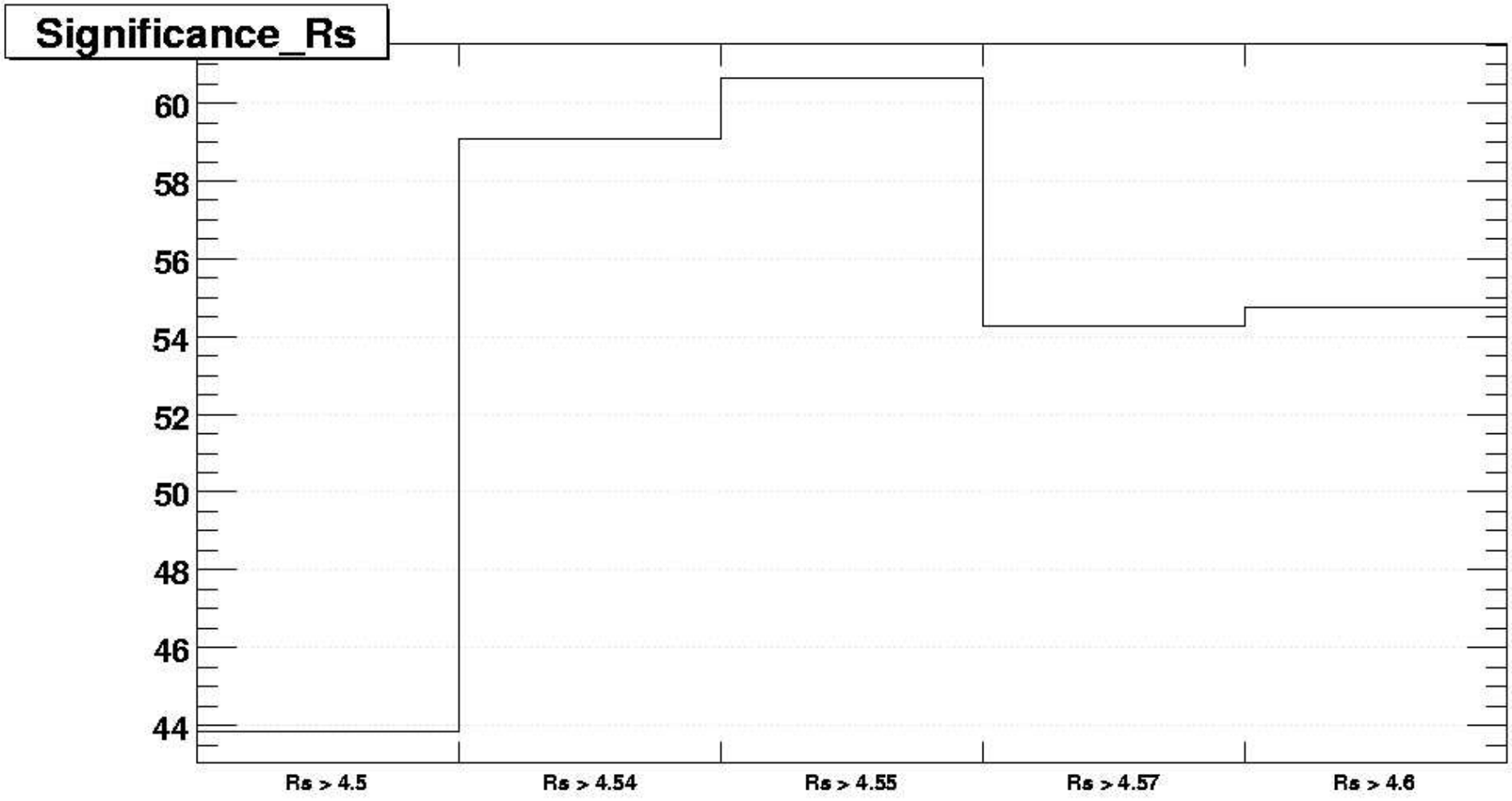

Significance_NumberJets
26.2
26
25.8
25.6
25.4
25.2
25
24.8
24.6
24.4
NJets >=2
NJets >=3
NJets >=4


Significance_Isolation
26
25
24
23
22
21
iso<0.01
iso<0.02
iso<0.03
iso<0.04
iso<0.05
iso<0.1
iso<0.2


Significance_MET
40
35
30
25
20
15
MET > 50
MET > 70
MET > 80
MET > 90
MET > 95
MET > 100
MET > 150


Significance_EtJ1
41
40
39
38
37
EtJ1 > 100
EtJ1 > 150
EtJ1 > 155
EtJ1 > 160
EtJ1 > 165
EtJ1 > 170
EtJ1 > 200


Significance_EtJ2
44
42
40
38
36
34
32
30
28
26
24
EtJ2 > 20
EtJ2 > 30
EtJ2 > 40
EtJ2 > 50
EtJ2 > 55
EtJ2 > 60
EtJ2 > 100
EtJ2 > 150


Significance_Rs
60
58
56
54
52
50
48
46
44
Rs > 4.5
Rs > 4.54
Rs > 4.55
Rs > 4.57
Rs > 4.6