SUSY in di-tau final states

CMS France
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CEA Saclay, Paris

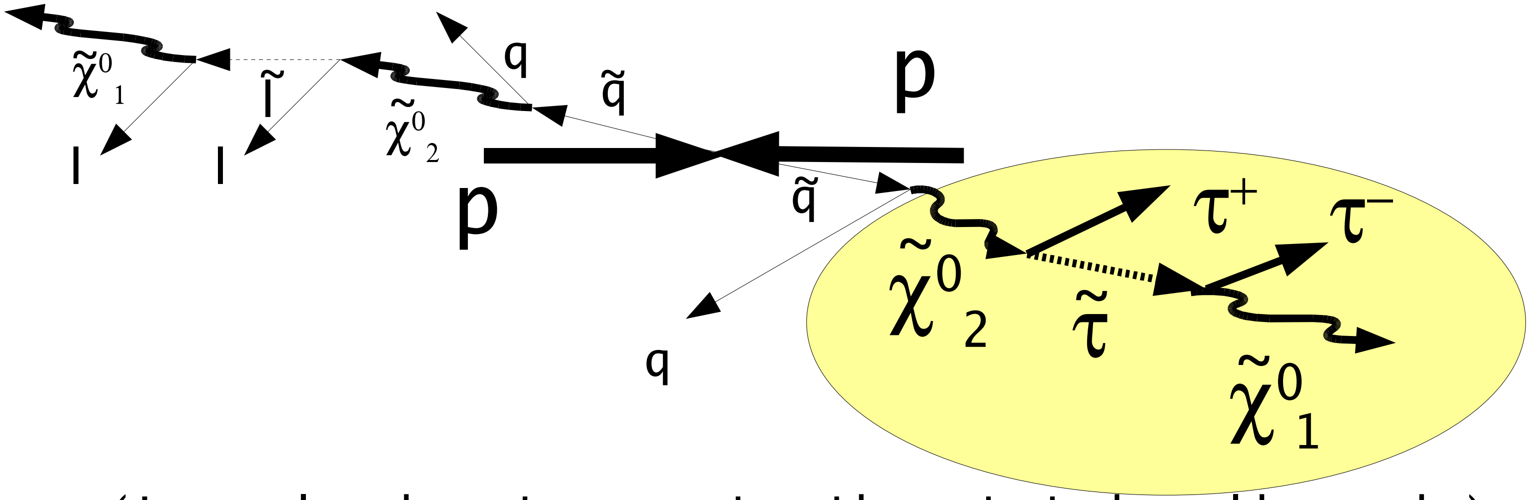
Yoshinari Mikami
IPHC / CNRS Strasbourg

Ulrich Goerlach,
IPHC / Universite de Strasbourg

Brief outline

- Strasbourg has interests in di-tau final states.

e.x)



(Just replaced μ pairs or e pairs with τ pairs in the golden mode.)

- Outline
  - Basic distributions (still in 10TeV MC)
  - Event selection optimization test
  - ABCD method test
  - Status summary

MC samples

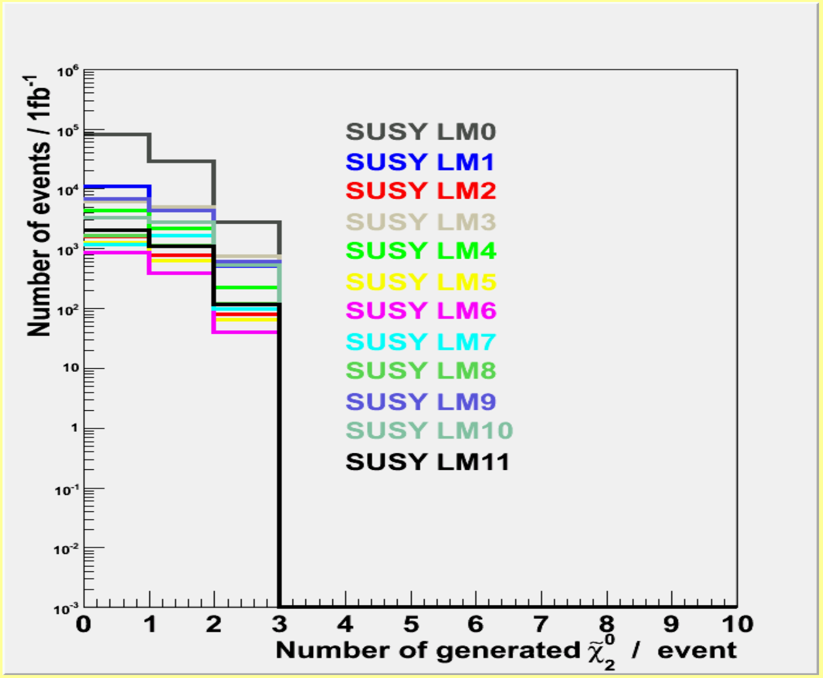
Sample	Cross section	Events used	Luminosity correspond
LM0	110 pb	203 k	1.8 fb^{-1}
LM1	16.1 pb	105 k	6.5 fb^{-1}
LM2	2.4 pb	130 k	54 fb^{-1}
LM3	11.8 pb	153 k	13 fb^{-1}
LM4	6.7 pb	110 k	16 fb^{-1}
LM5	1.9 pb	172 k	88 fb^{-1}
LM6	1.3 pb	134 k	105 fb^{-1}
LM7	2.9 pb	82 k	28 fb^{-1}
LM8	2.9 pb	211 k	74 fb^{-1}
LM9	11.6 pb	200 k	17 fb^{-1}
LM10	6.6 pb	203 k	31 fb^{-1}
LM11	3.2 pb	208 k	64 fb^{-1}
ttbar	317 pb	1.0 M	3.0 fb^{-1}
WJets	40000 pb	9.2 M	0.23 fb^{-1}
ZJets	3700 pb	1.3 M	0.34 fb^{-1}
QCDHt100to250	15 μb	12.7 M	0.8 pb^{-1}
QCDHt250to500	400 nb	5.1 M	13 pb^{-1}
QCDHt500to1000	14000 pb	4.7 M	0.33 fb^{-1}
QCDHt1000toInf	370 pb	1.1 M	2.9 fb^{-1}

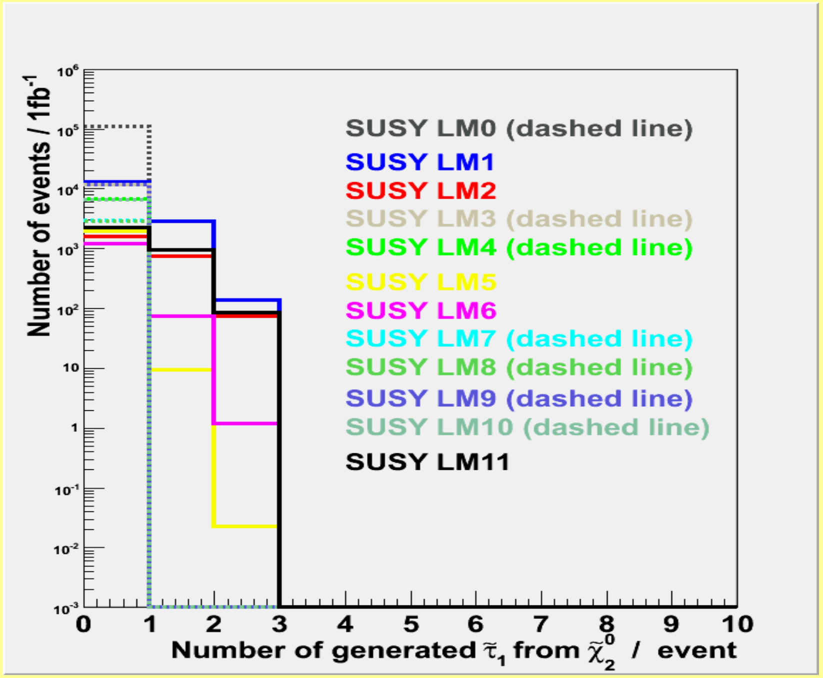
Note.1: 10 TeV samples

Note.2: Summer08 Pythia6 for signal SUSY Light Mass test points (LMX), Fall08 MadGraph for the ttbar, Summer08 MadGraph for the Wjets and the Zjets, Fall08 MadGraph for QCDs

Note.3: PAT Layer 1 Files produced with V5.

Generated particles

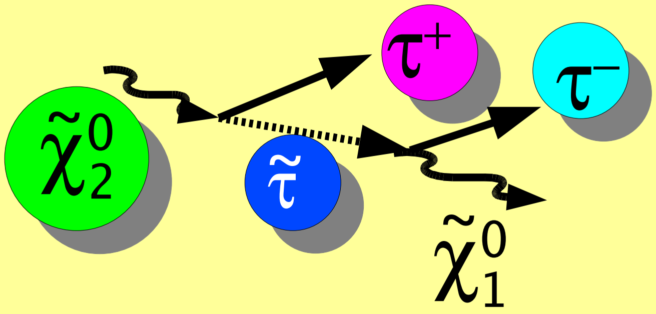


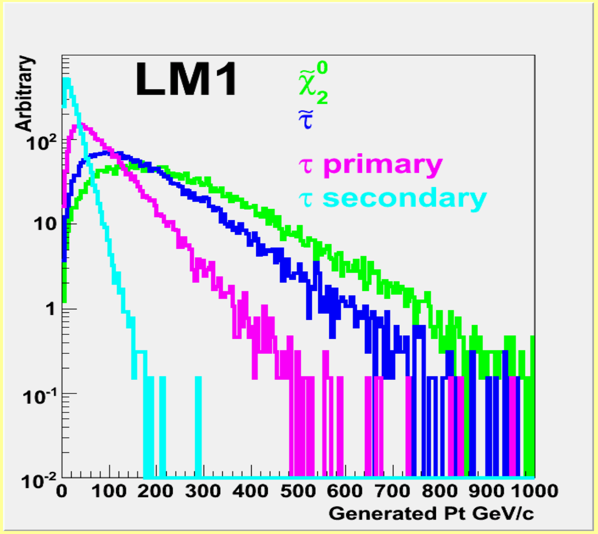


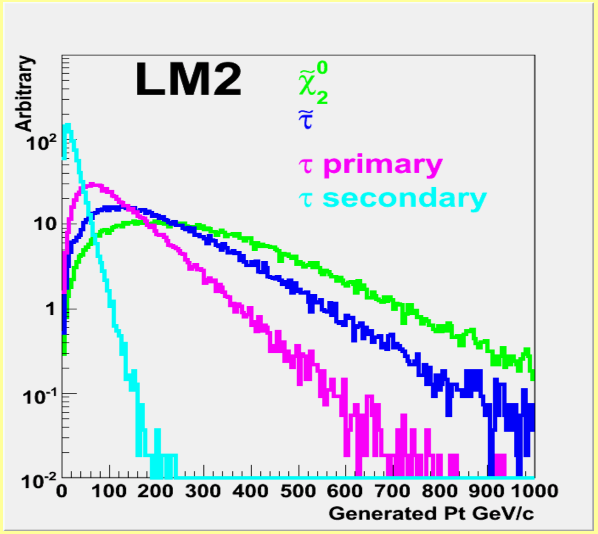
Light mass test points	m0	m1/2	tanβ	sign(μ)	A0
LM1	60 GeV	250 GeV	10	+	0
LM2	185 GeV	350 GeV	35	+	0

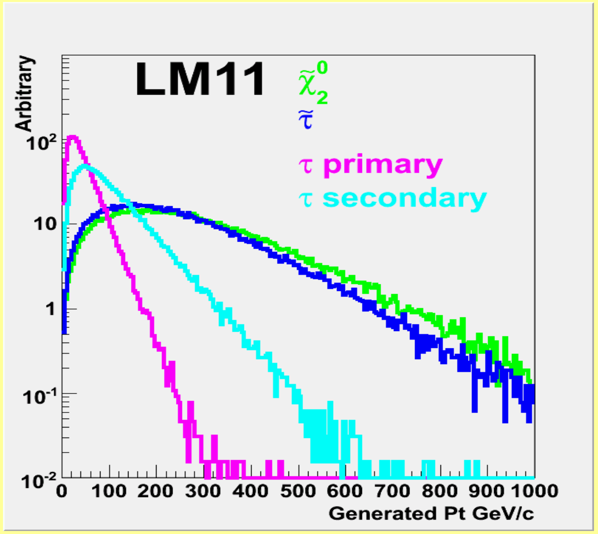
Note1; Just counting numbers of the generated particles (who has some daughters).
Note2; Br($\tilde{\chi}^0$ -> $\tilde{\tau}\,\tau$) = 96% in the LM2
Note3; $\tau^+\tau^-$ pair can be generated without stau. (e.x. $\tilde{\chi}^0_2$ -> $\tau^+\tau^-\,\tilde{\chi}^0_1$)

Generated Pt spectrum in the signal decay chain





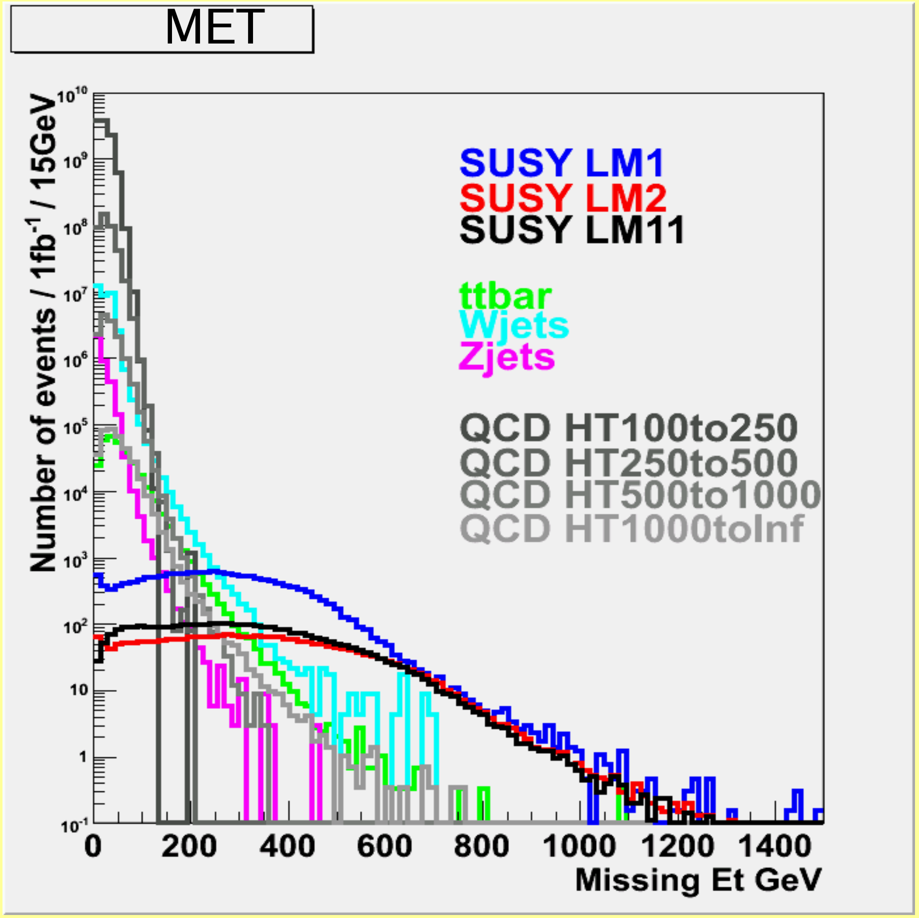


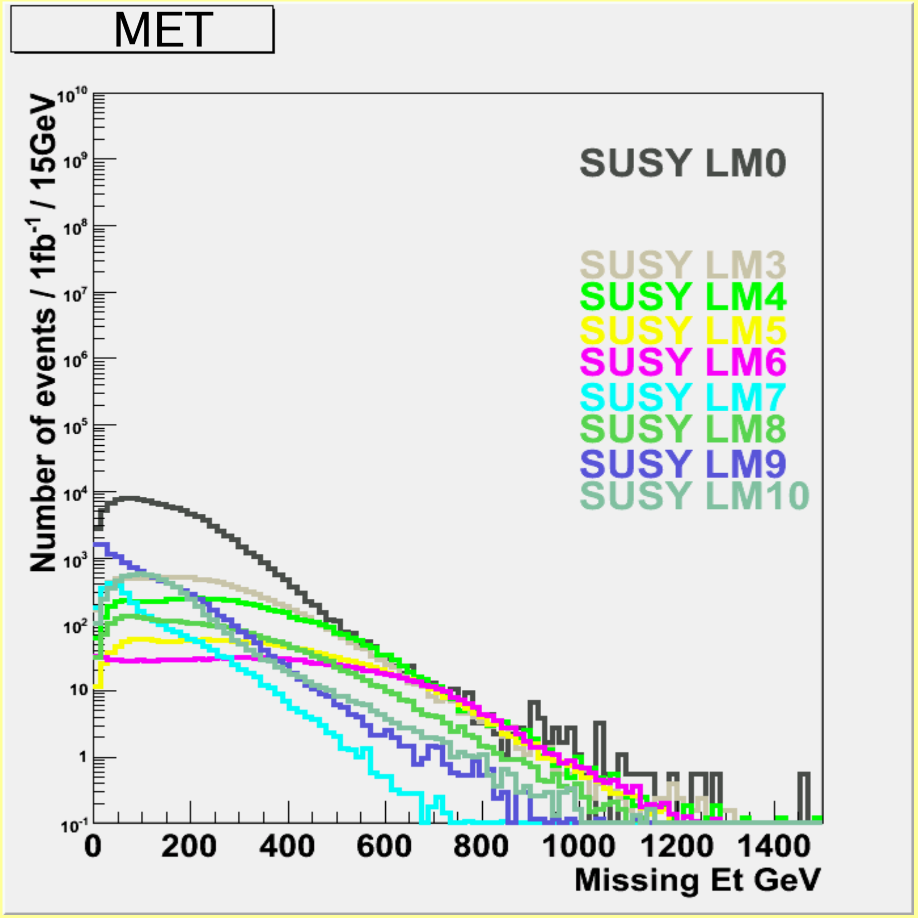


Note: τ momentum are the generated Pt. (It is NOT the visible Pt.)

Reconstructed Missing Et (1)

Without any cut
(They are PAT default outputs.)

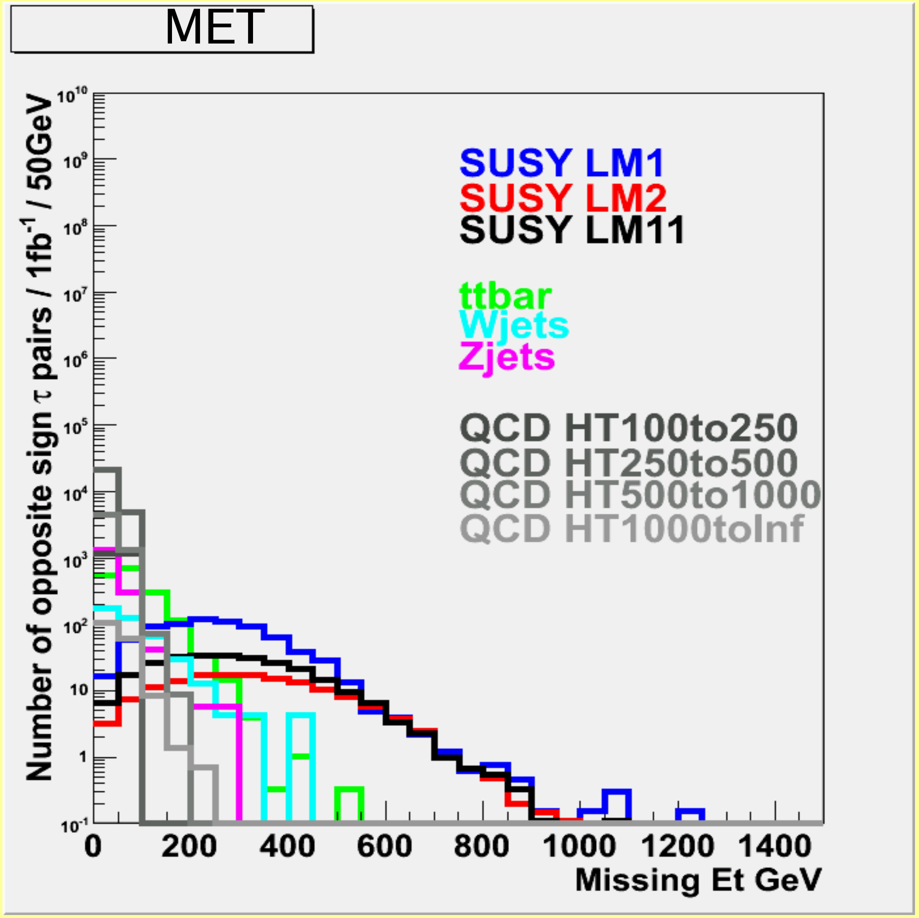


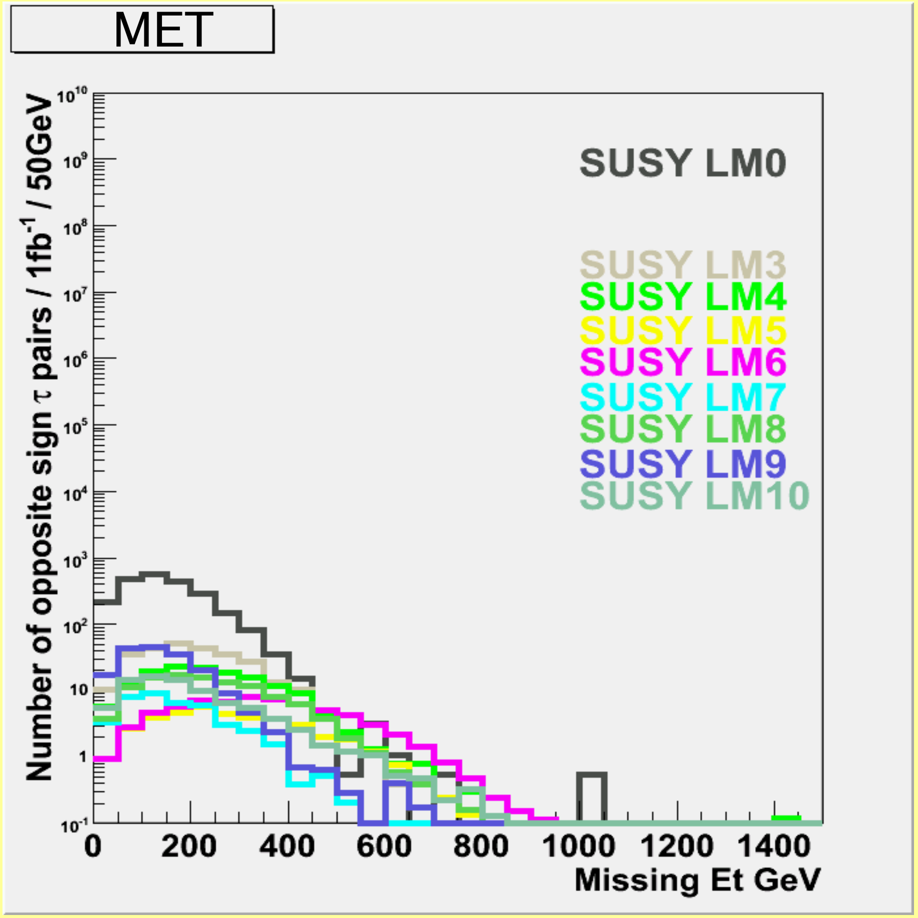


Reconstructed Missing Et (2)

With basic criteria:

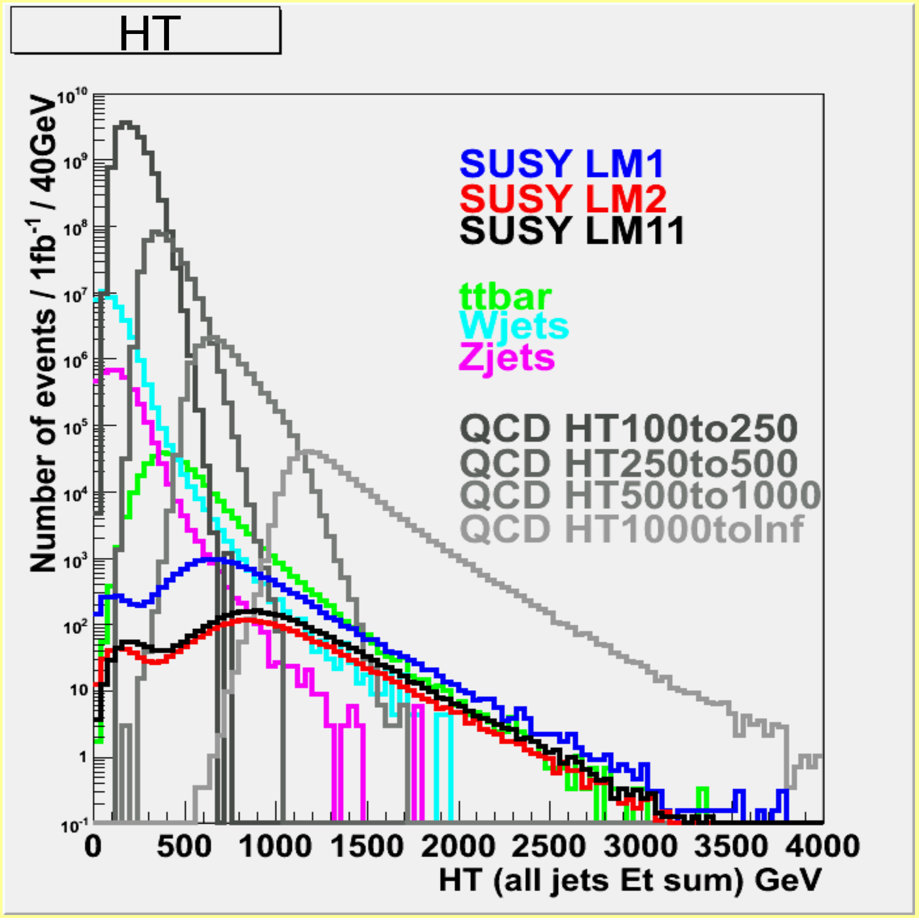
- τ pair requirement, both with Pt > 5 GeV/c (PAT default) and |η| < 2.0
- HT > 500 GeV (HT = All jets Et sum in the default PAT)
- Leading jet Et > 50 GeV

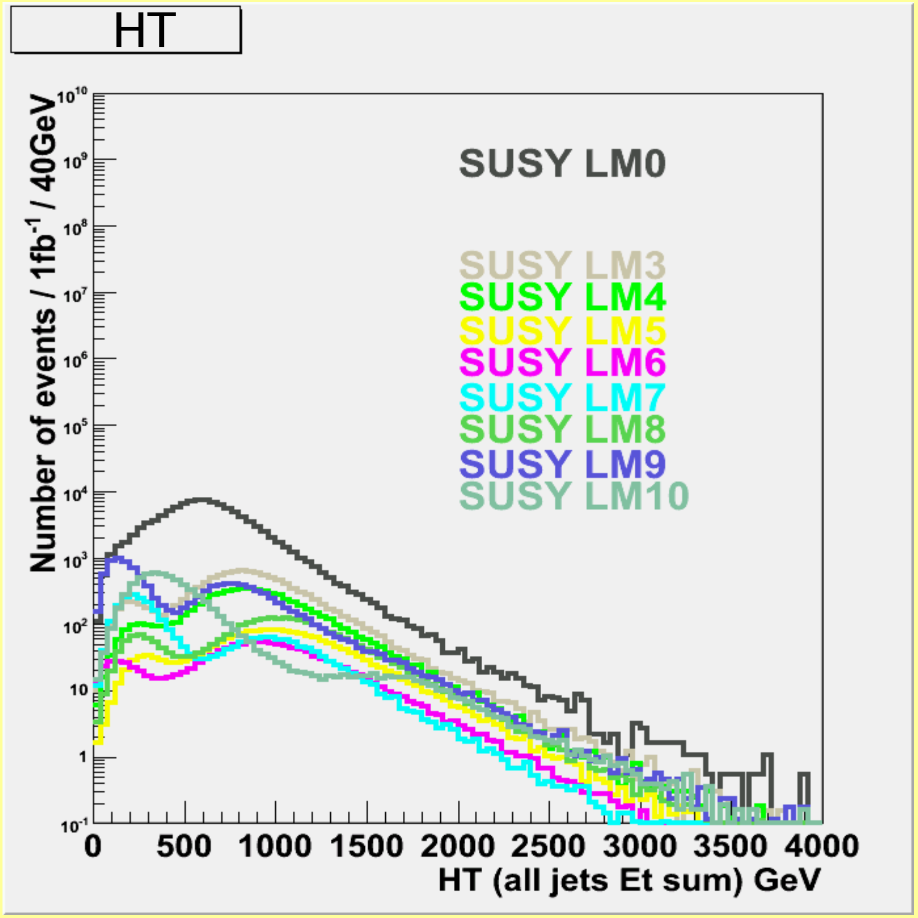




Reconstructed HT (1)
(all jets Et sum in default PAT)

Without any cut
(They are PAT default outputs.)

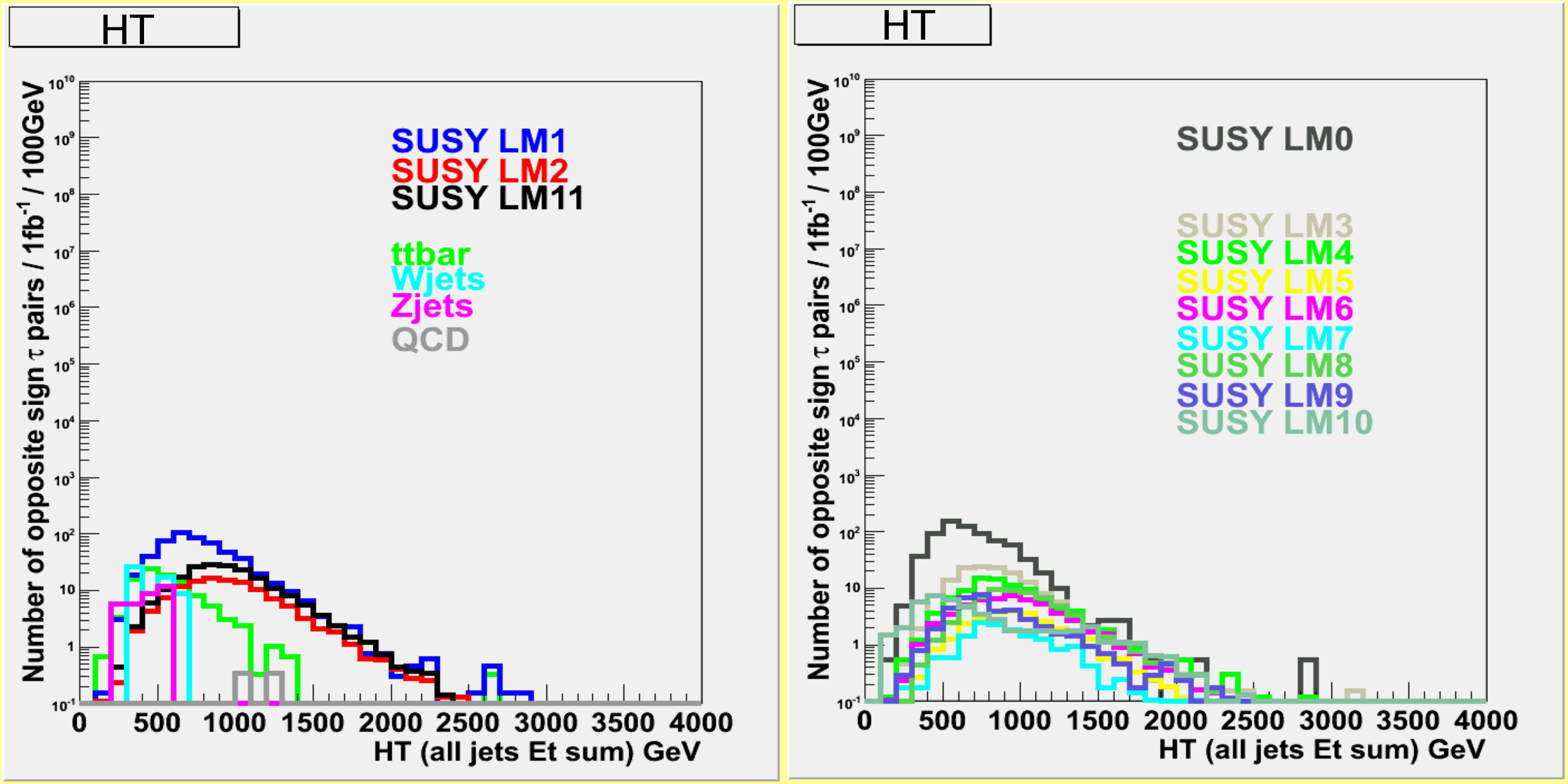




Reconstructed HT (2)
(all jets Et sum in default PAT)

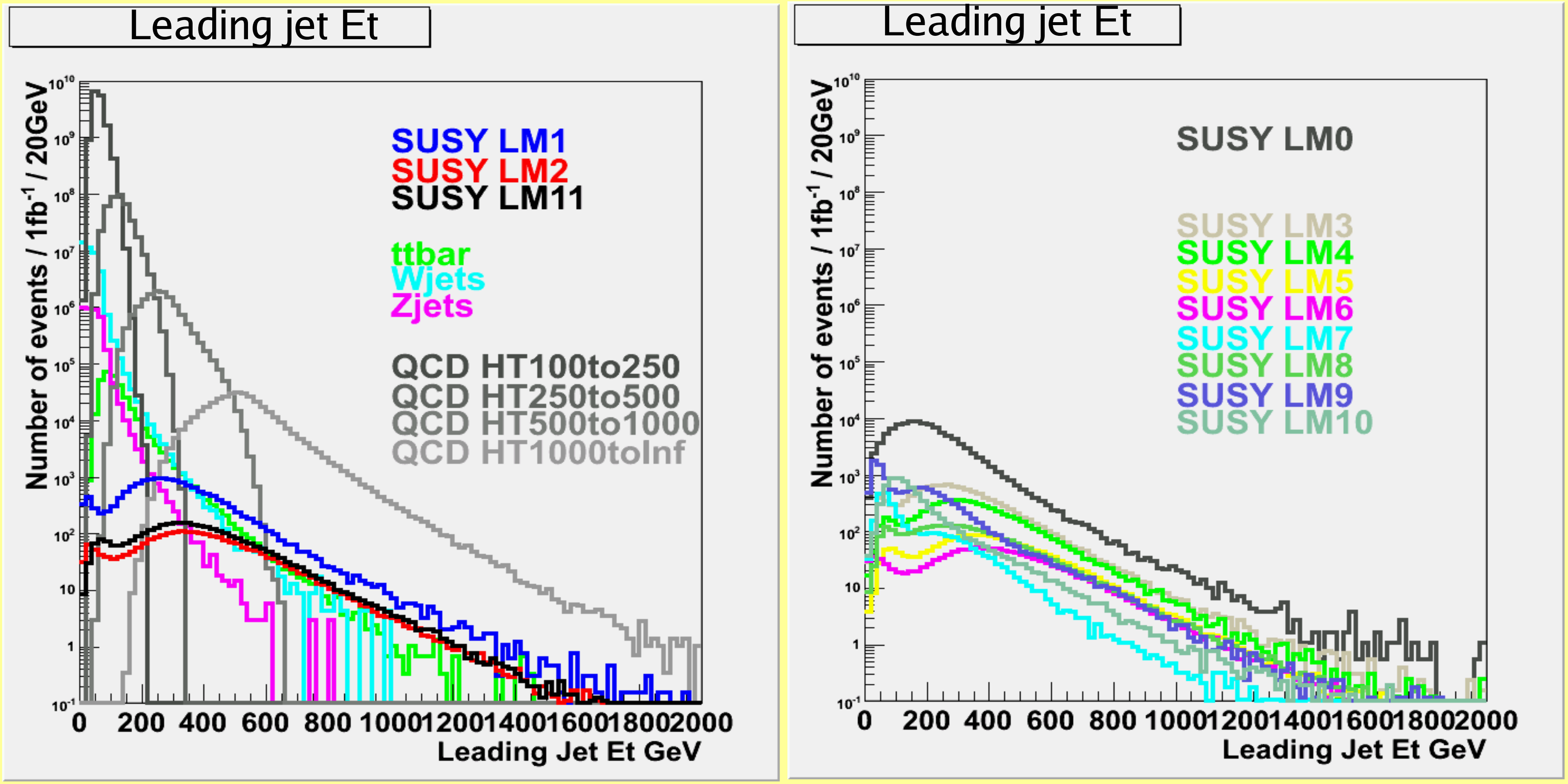
With basic criteria:

- **τ pair requirement, both with Pt > 5 GeV/c (PAT default) and $|\eta|$ < 2.0**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**



Reconstructed Leading Jet Et (1)

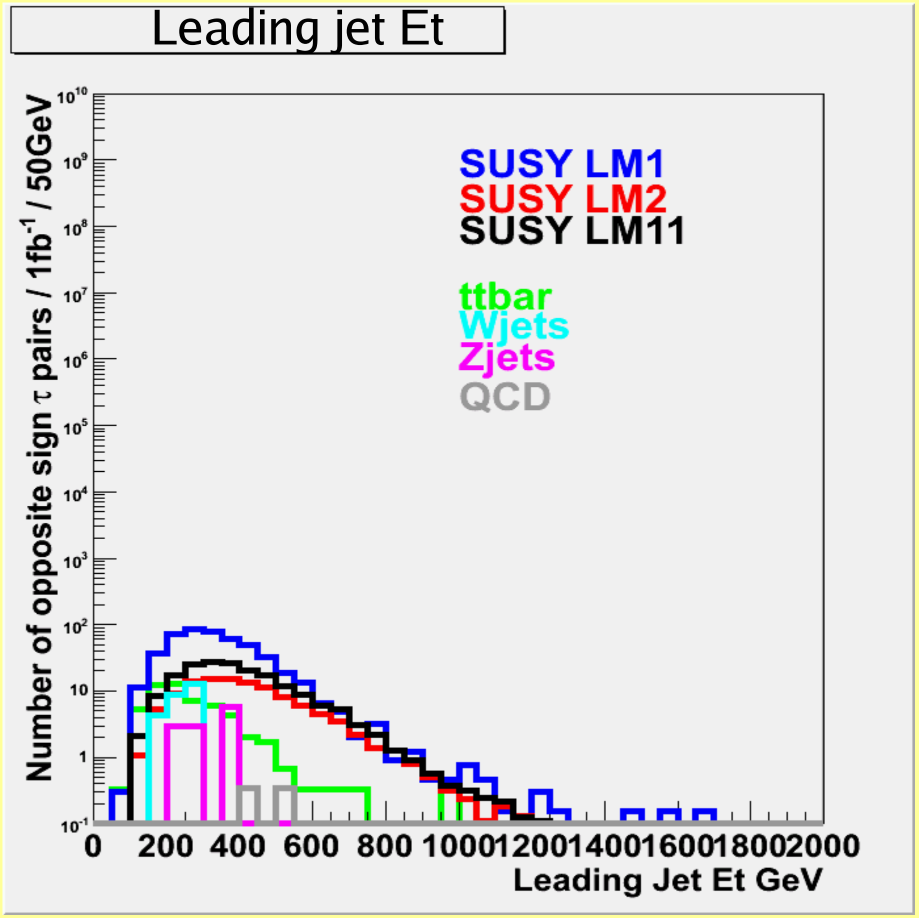
Without any cut
(They are the leading jet in PAT default outputs.)

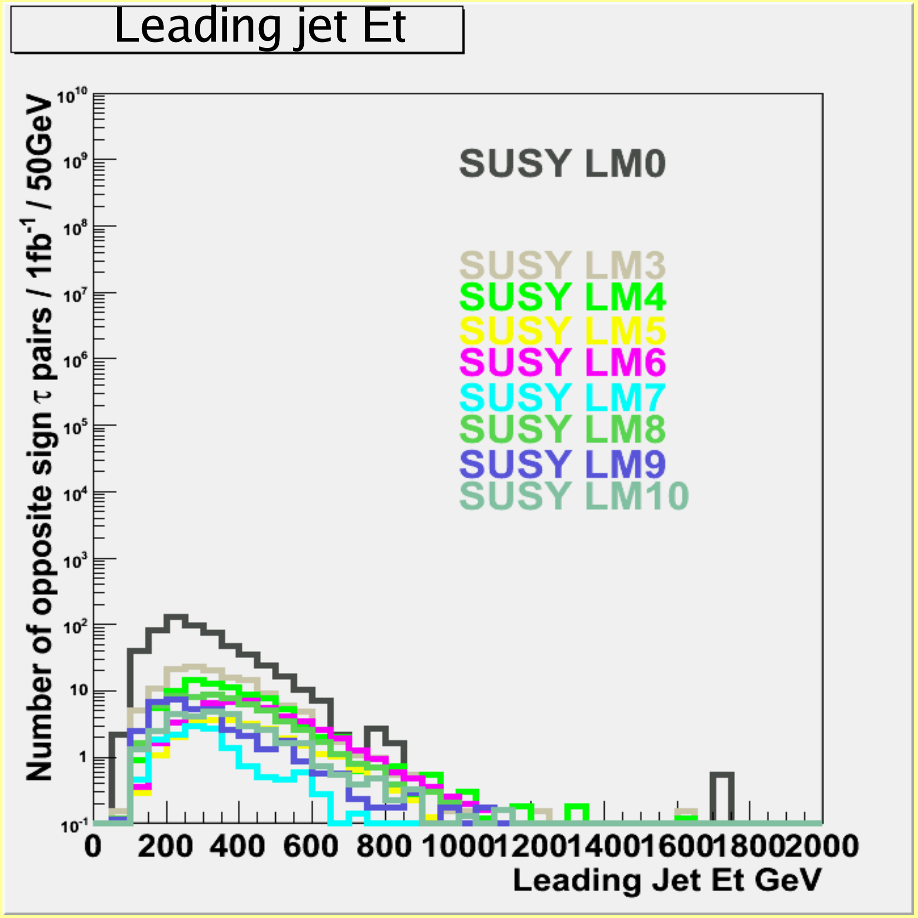


Reconstructed Leading Jet Et (2)

With basic criteria:

- **τ pair requirement, both with Pt > 5 GeV/c (PAT default) and |η| < 2.0**
- **MET > 200 GeV**
- **HT > 500 GeV**





Optimization method (tests for statistical effects)

S = #(LMx opposite sign τ pairs) - #(LMx same sign τ pairs)

S + B = #(LMx opposite sign τ pairs) + #(LMx same sign τ pairs)
+ #(ttbar opposite sign τ pairs) + #(ttbar same sign τ pairs)
+ #(Wjets opposite sign τ pairs) + #(Wjets same sign τ pairs)
+ #(Zjets opposite sign τ pairs) + #(Zjets same sign τ pairs)
+ #(QCD opposite sign τ pairs) + #(QCD same sign τ pairs)

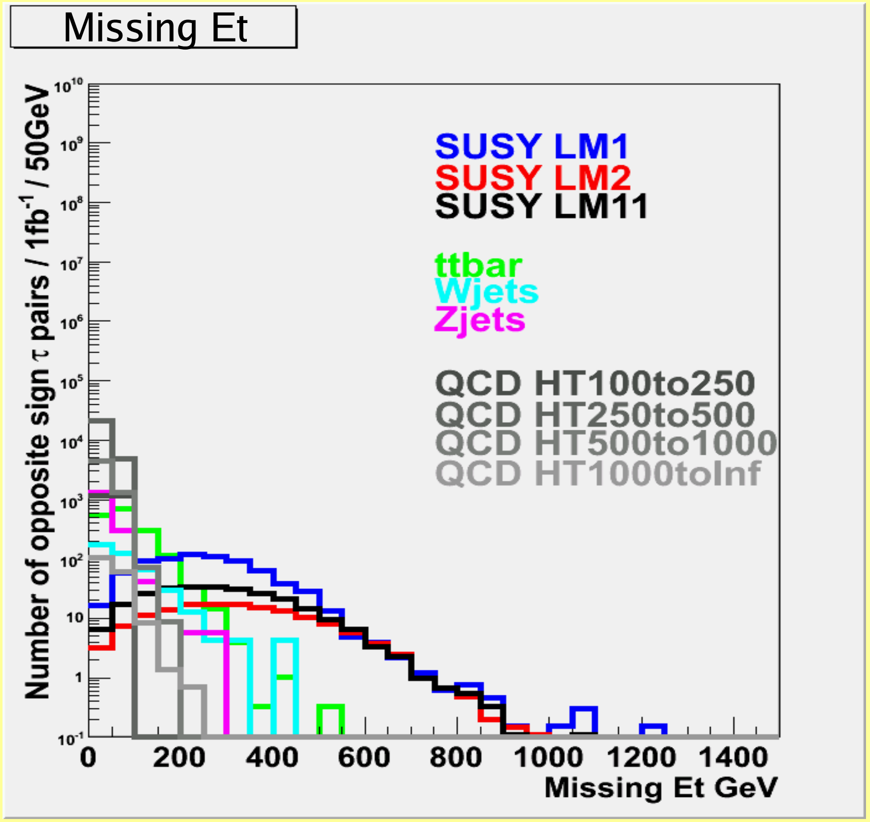
Maximizing the significance, S / sqrt(S+B).

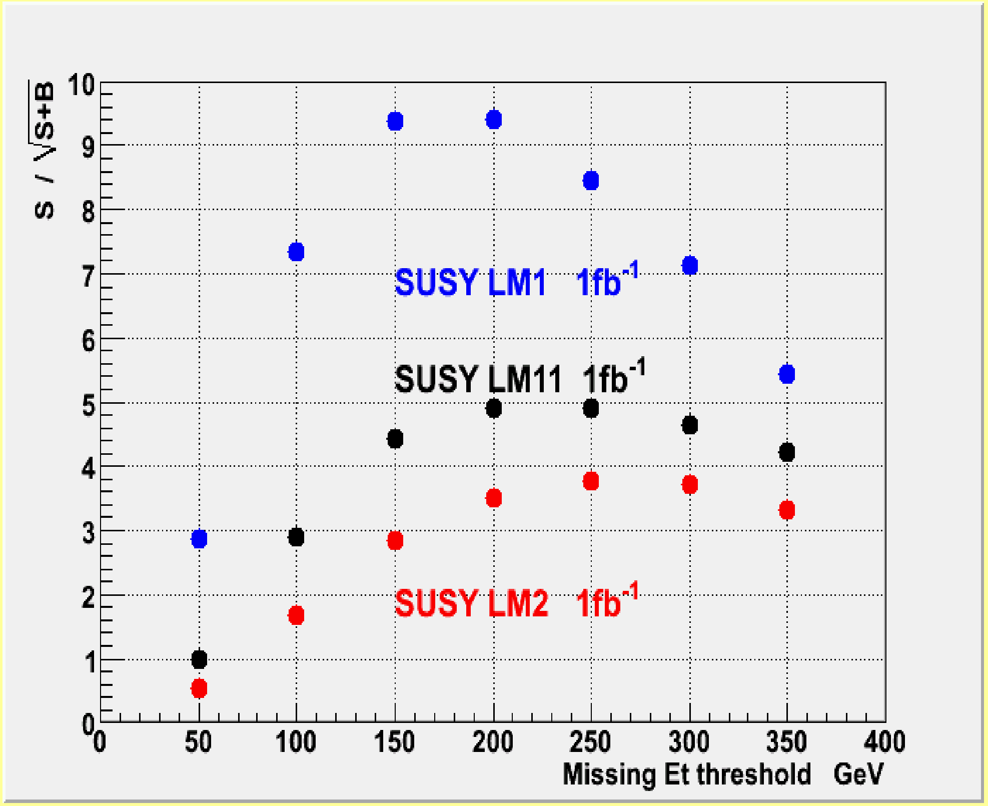
Note.0: This is not taking other $\tau^+\tau^-$ pair backgrounds (in signal LMx) into account. (e.x. Z^0 -> $\tau^+\tau^-$ etc.)
Note.1: This is assuming that the same sign pair roughly corresponds to the combinatorial background.
(Please see backup slides)
Note.2: All MC are normalized to $1fb^{-1}$
Note.3: This considers only statistical uncertainty.

Missing Et optimization test

With basic cuts:

- Tau pair requirement, both with Pt > 5 GeV/c (PAT default), |η| < 2.0
- HT > 500 GeV
- Leading jet Et > 50 GeV

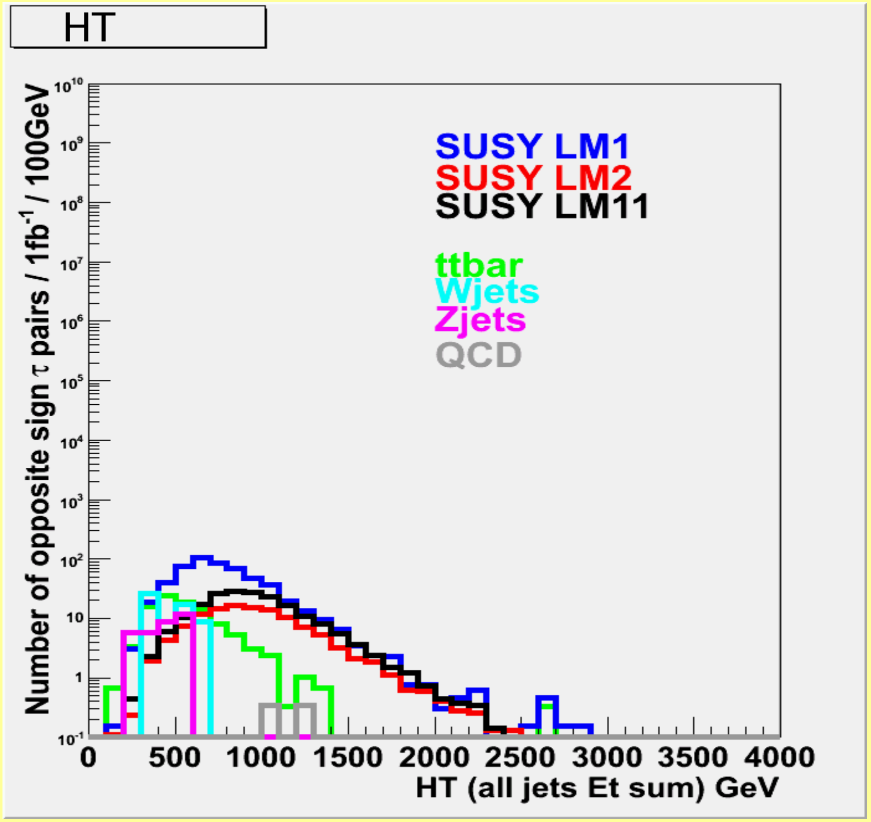


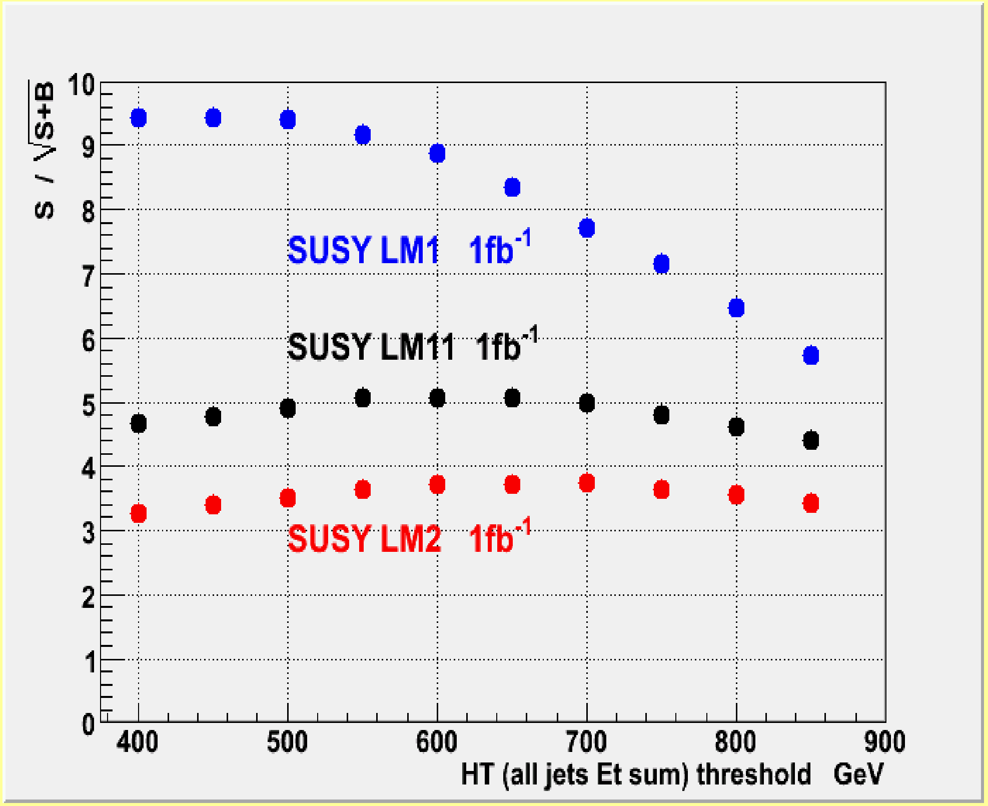


HT optimization test

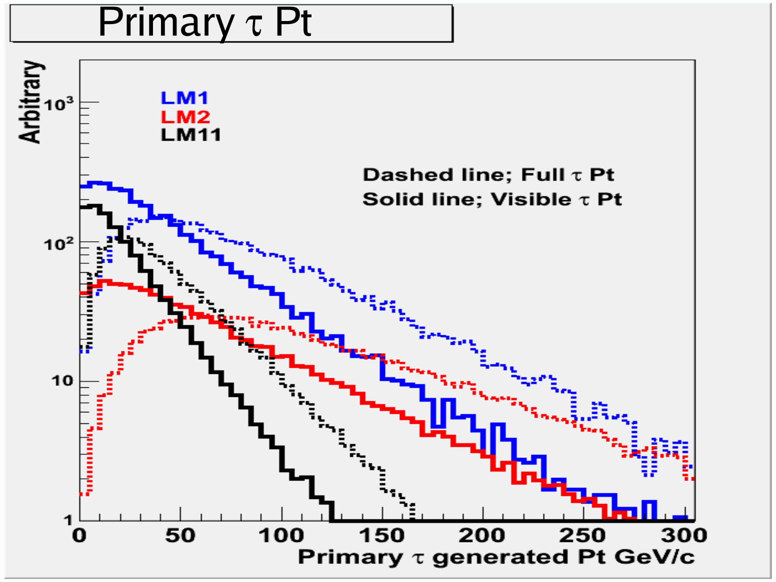
With basic cuts:

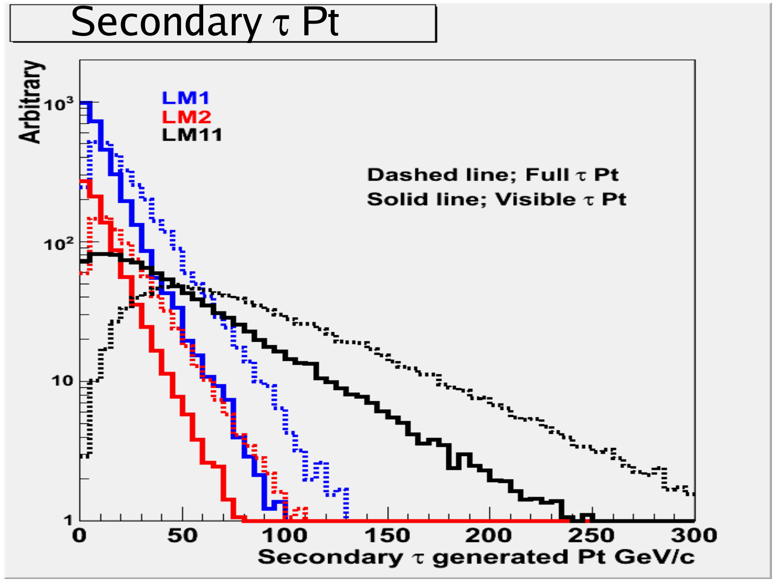
- Tau pair requirement, both with Pt > 5 GeV/c (PAT default), |η| < 2.0
- MET > 200 GeV
- Leading jet Et > 50 GeV





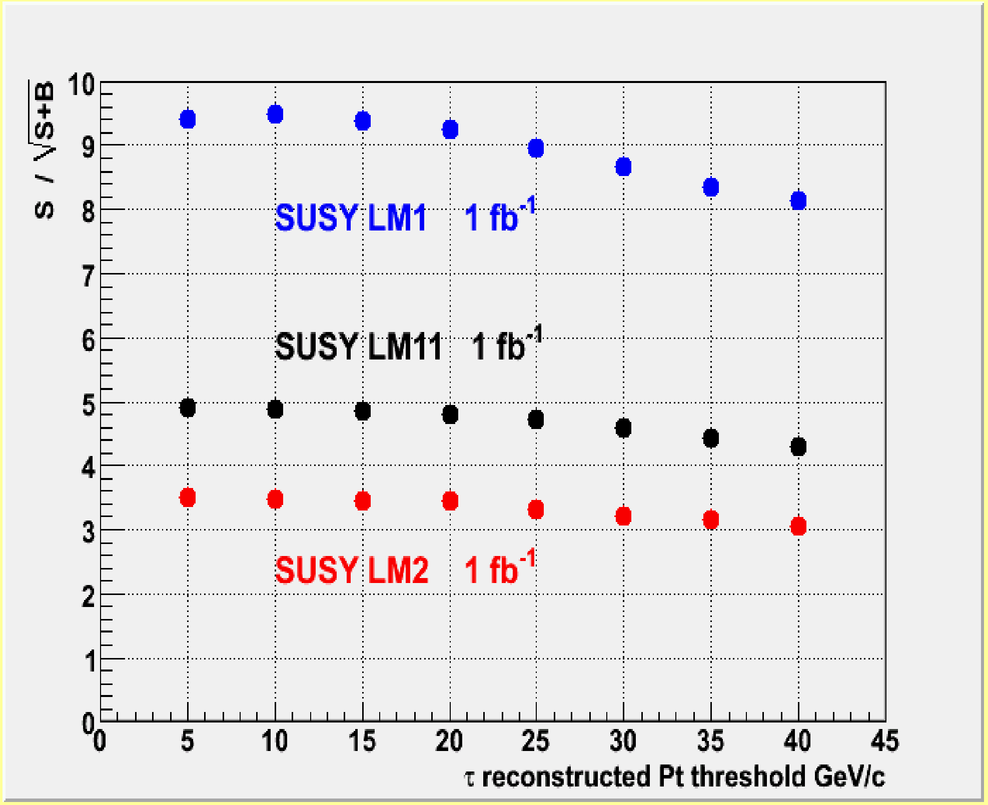
τ Pt optimization test





With basic cuts:

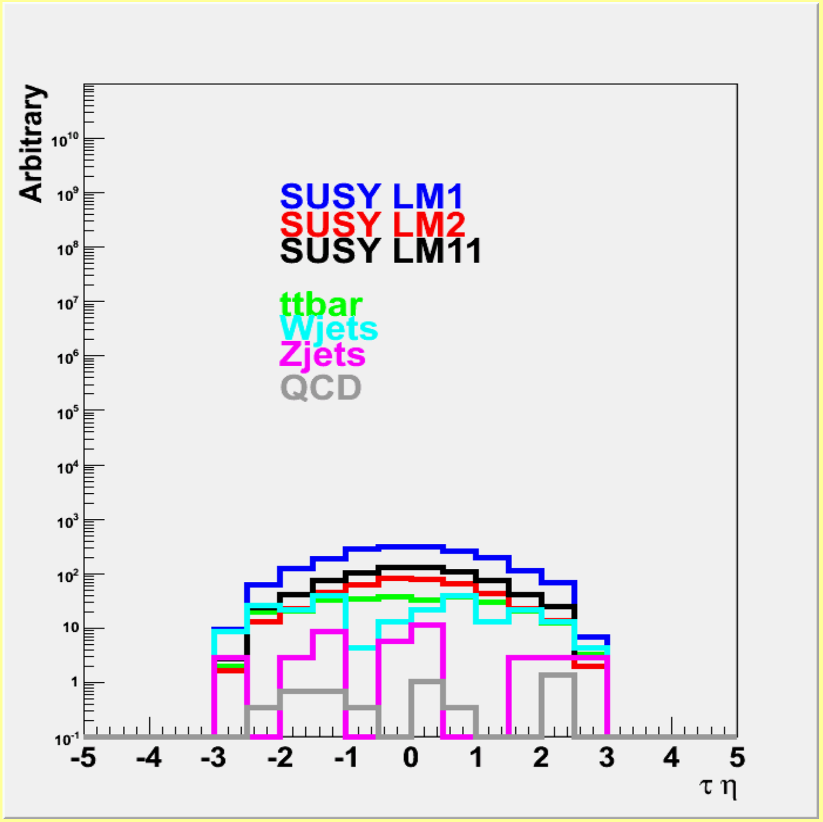
- Tau pair requirement, both with |η| < 2.0
- Another τ Pt > 5 GeV/c (PAT default)
- MET > 200 GeV
- HT > 500 GeV
- Leading jet Et > 50 GeV

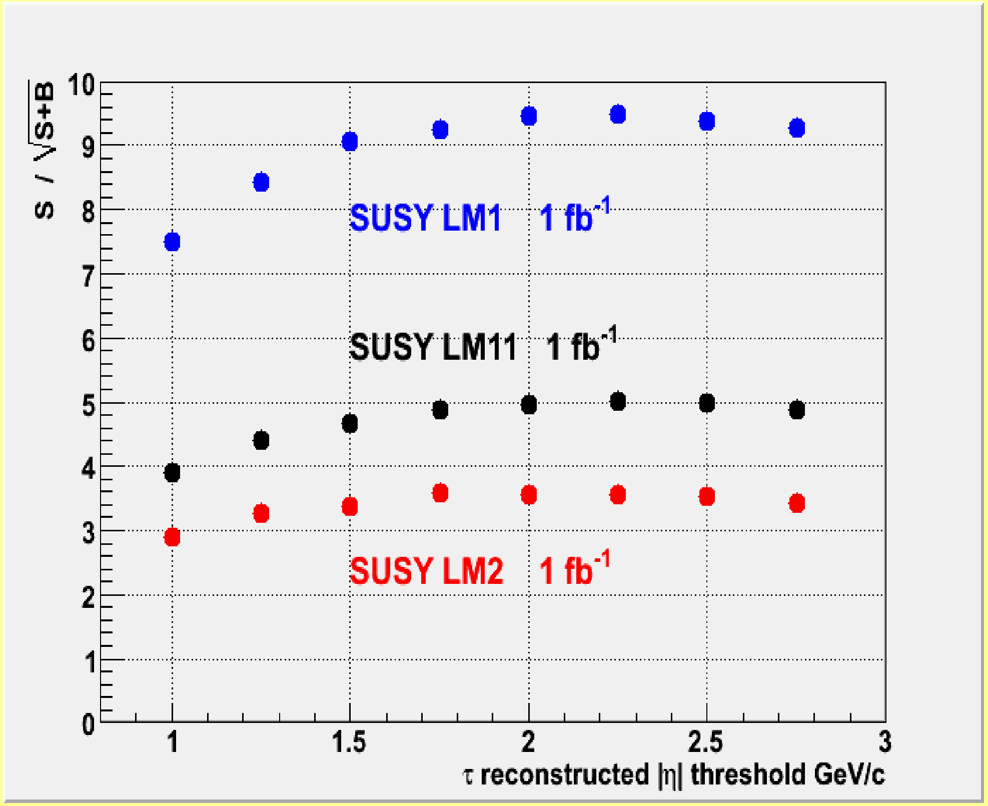


τ pseudo-rapidity optimization test

With basic cuts:

- Tau pair requirement, both with Pt > 5 GeV/c (PAT default)
- MET > 200 GeV
- HT > 500 GeV
- Leading jet Et > 50 GeV





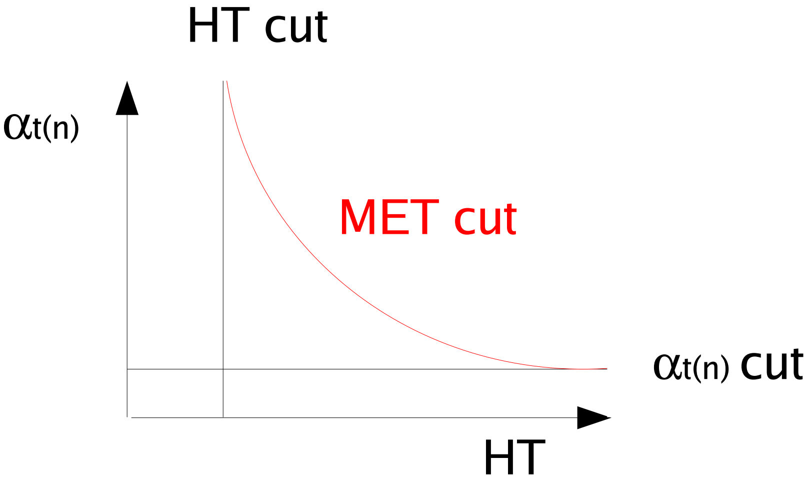
α_t for n-jets (1)

The α_t for n-jets is effectively just a function of HT and MET.

$$\alpha_t(n) = HT / \mathrm{sqrt}\,(HT^2 - MET^2)$$
$$= 1 / \mathrm{sqrt}\,(1 - (MET / HT)^2)$$

→ In fact, this is effectively just MET/HT.

Schematic view

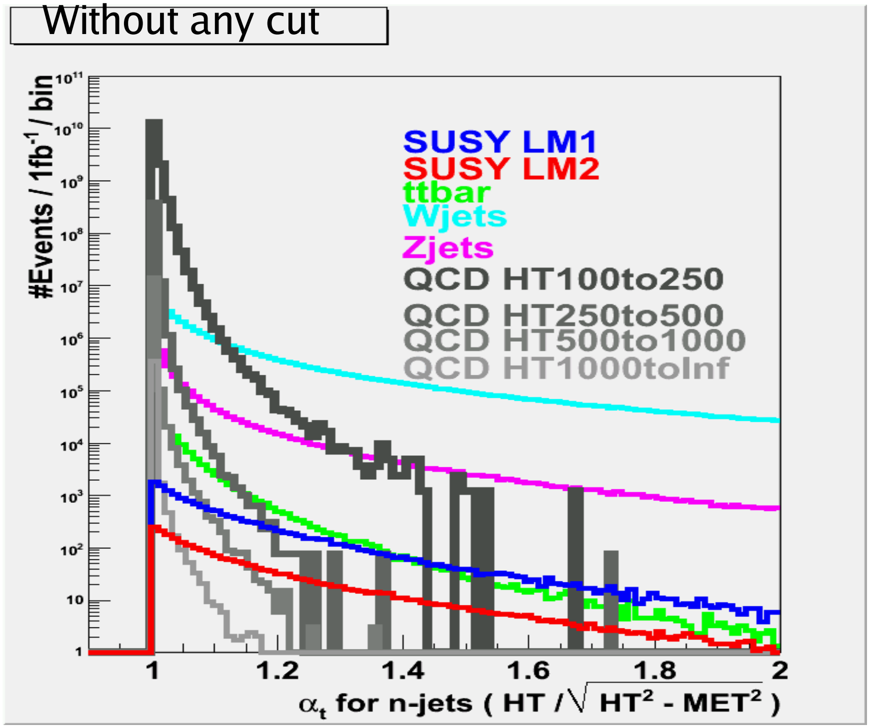


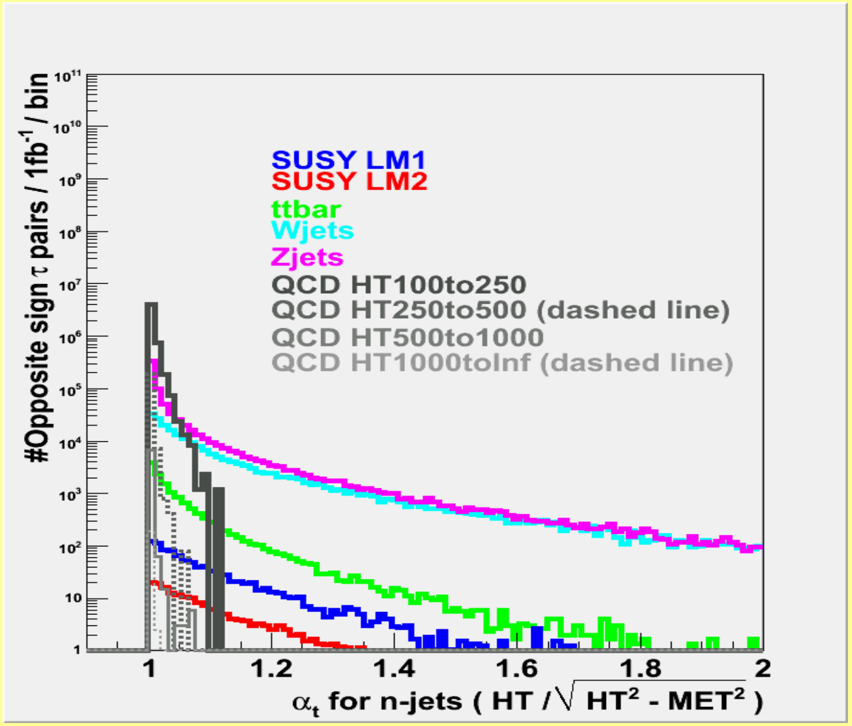
Note: A mis-measurement of the leading Et will change both the MET and the HT with the same direction.
Thus, a variable which divides one by the other is stable somehow.

α_t for n-jets (2)

With basic cuts:

$|\eta(\tau)| < 2.5$, one $Pt(\tau) > 20$ GeV/c and another $Pt(\tau) > 5$ GeV/c,



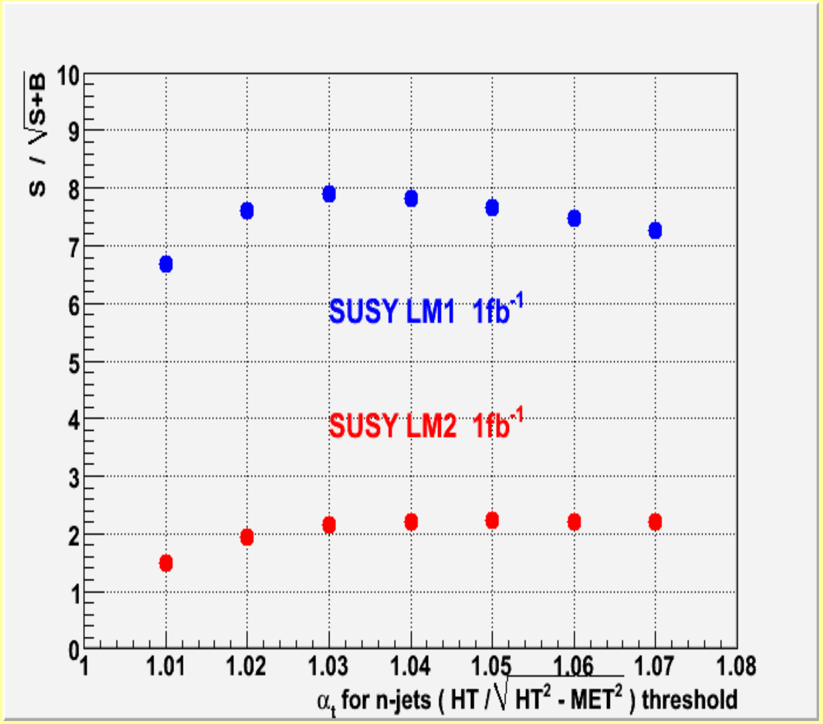


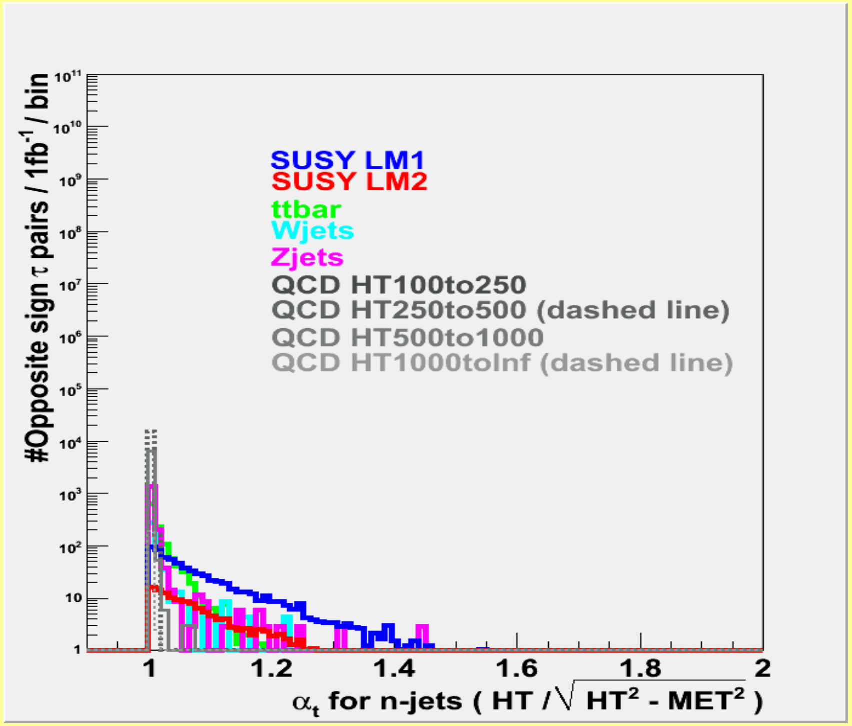
α_t for n-jets (3)

With HT cut:

$|\eta(\tau)| < 2.5$, one $Pt(\tau) > 20$ GeV/c and another $Pt(\tau) > 5$ GeV/c,

Leading jet Et > 150 GeV, HT > 500 GeV

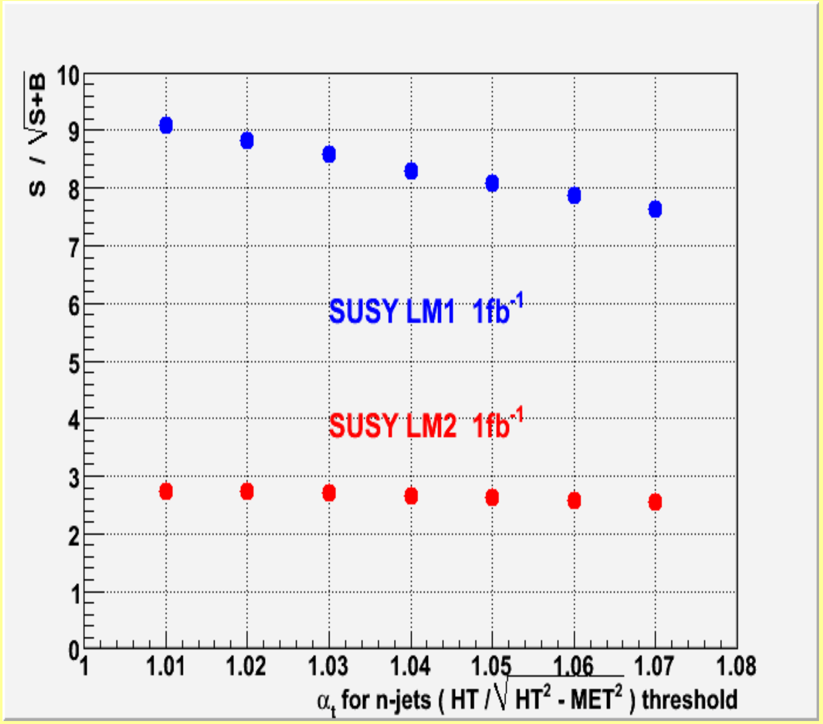


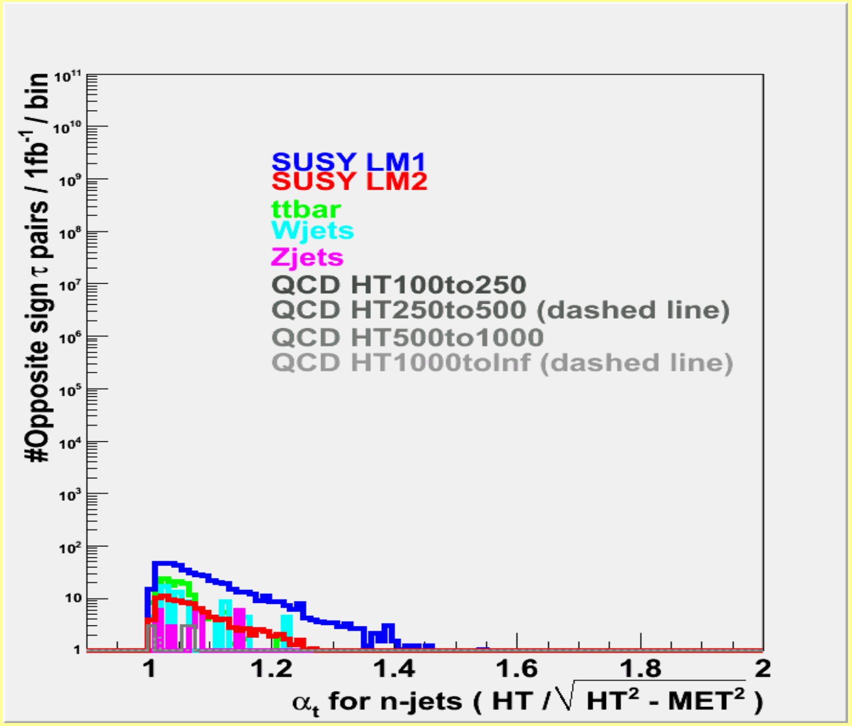


α_t for n-jets (4)

With HT cut and after MET cut:

$|\eta(\tau)| < 2.5$, one $Pt(\tau) > 20$ GeV/c and
another $Pt(\tau) > 5$ GeV/c,
Leading jet Et > 150 GeV, HT > 500 GeV
MET > 150GeV





Statistical point of view, the α_t (n) does not gain (compared with the MET cut).

Backup; Summary table (SUSY LMx)

	LM1		LM2		LM11	
#events used	105k events		130k events		208k events	
Cross section	16.1 pb		2.4 pb		3.2 pb	
Luminosity correspond	6.51 fb^{-1}		54.3 fb^{-1}		64 fb^{-1}	
Generated #signal decay	20094		47526		72281	
	opposite sign τ pairs	same sign τ pairs	Opposite sign τ pairs	Same sign τ pairs	Opposite sign τ pairs	Same sign τ pairs
PATτ pairs	8127	3683	12191	6045	26698	13179
$\lvert eta(\tau) \rvert < 2.0$	(86%)6956	(81%)2986	(88%)10761	(85%)5125	(87%)23203	(84%)11035
MET > 200 GeV	(51%)3521	(52%)1552	(61%)6541	(61%)3114	(54%)12506	(54%)5961
HT > 500 GeV	(88%)3112	(89%)1379	(94%)6163	(95%)2965	(95%)11932	(96%)5738
Leading Jet Et > 50 GeV	(100%)3112	(100%)1379	(100%)6163	(100%)2965	(100%)11932	(100%)5738
Normalized to 1 fb^{-1}	478 +/- 9	212 +/- 6	113 +/- 2	55 +/- 1	186 +/- 2	90 +/- 2

Note; The leading jet Et requirement is not effective after the HT cut. (please see backup slides.)
I'm applying a minimum cut since I suppose that a standard trigger will be using some cut

Backup;
Summary table (backgrounds (1))

	TT Jets		Wjets		Zjets	
#events used	947 k events		9.26 M events		1.26 M events	
Cross section	317 pb		40000 pb		3700 pb	
Luminosity correspond	3.0 fb^{-1}		0.23 fb^{-1}		0.34 fb^{-1}	
	TT Jets opposite sign	TT Jets same sign	Wjets opposite sign	Wjets same sign	Zjets opposite sign	Zjets same sign
PAT τ pairs	44762	13897	68328	42784	273434	17462
$\lvert eta(\tau)\rvert < 2.0$	(78%)34751	(67%)9260	(62%)42337	(59%)25304	(70%)190478	(59%)10331
MET > 200 GeV	(0.8%) 294	(1.1%)98	(0.04%)14	(0.03%)6	(0.006%)11	(<0.03%) 0
HT > 500 GeV	(55%) 162	(63%)62	(43%)6	0	(40%)4	0
Leading Jet Et > 50 GeV	(100%)162	(100%)62	(100%)6	0	(100%)4	0
Normalized to 1 fb^{-1}	54 +/- 5	21 +/- 3	26 +/- 11	(<10)	12 +/- 6	(<7)

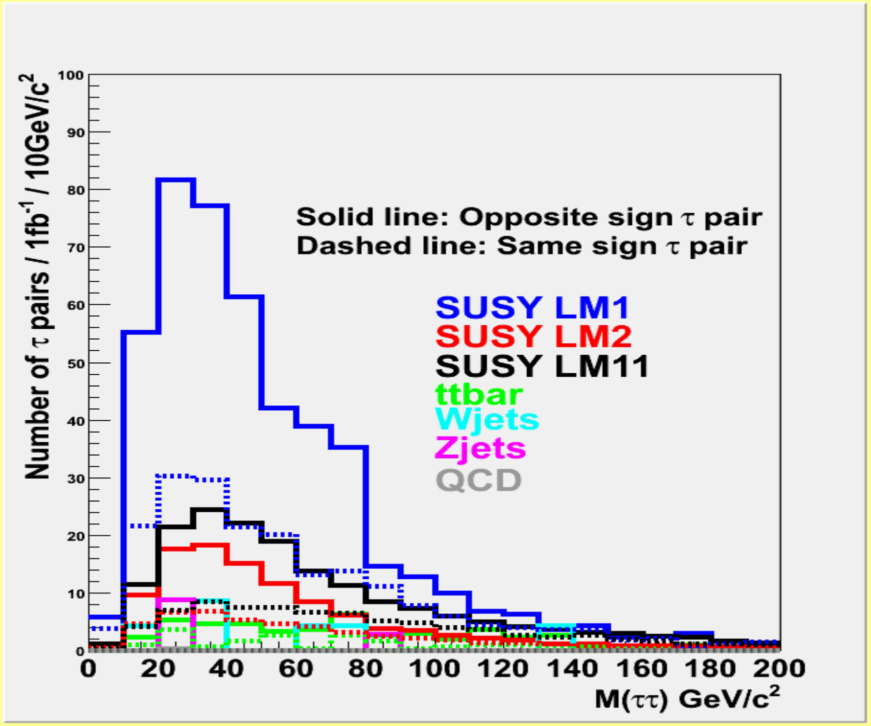
Backup;
Summary table (backgrounds (2))

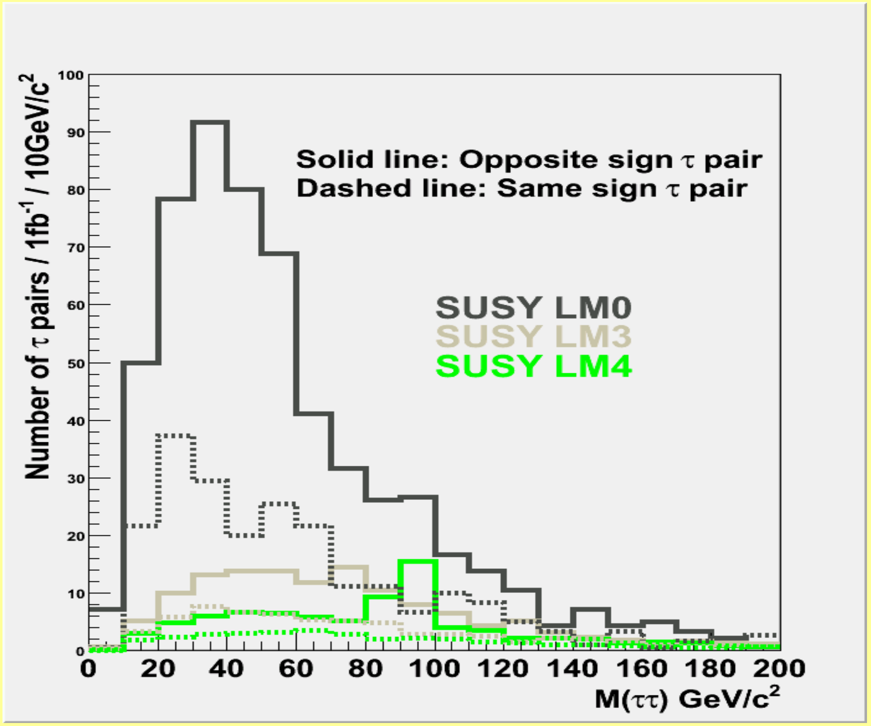
	QCD100to250		QCD250to500		QCD500to1000		QCD1000toInf	
#events used	12.7 M events		5.06 M events		4.69 M events		1.07 M events	
Cross section	15 μb		400 nb		14000 pb		370 pb	
Luminosity correspond	0.84 pb^{-1}		13 pb^{-1}		335 pb^{-1}		2.88 fb^{-1}	
	Opposite sign	Same sign	Opposite sign	Same sign	Opposite sign	Same sign	Opposite sign	Same sign
PAT τ pairs	8382	7606	4314	3917	3737	3577	845	767
|eta(τ)| < 2.0	(52%) 4372	(50%) 3815	(51%) 2219	(50%) 1972	(52%) 1956	(51%) 1837	(60%) 510	(54%) 416
MET > 200 GeV	(<0.06%) 0	(<0.07%) 0	(<0.2%) 0	(<0.2%) 0	(<0.2%) 0	(<0.2%) 0	(0.4%) 2	(<0.6%) 0
HT > 500 GeV	0	0	0	0	0	0	2	0
Leading Jet Et > 50 GeV	0	0	0	0	0	0	2	0
Normalized to 1 fb^{-1}	(<1)	(<1)	(<1)	(<1)	(<1)	(<1)	1	(<1)

Note: In order to normalize to 1fb^{-1}, I estimated by probabilities from Missing Et distributions without τ requirement.
It means that this assumes less correlation between τ events and general events. (Please see backup slides.)

M($\tau\tau$) distributions

- $|\eta(\tau)| < 2.0$, Pt(τ) > 5 GeV/c,
- HT > 500 GeV,
- MET > 200 GeV,
- Leading jet Et > 50 GeV





Note.1; The peak around 90 GeV in the LM4 would be a double misidentification of Z^0 -> e^+e^- (or Z^0 -> $\mu^+\mu^-$) as Z^0 -> $\tau^+\tau^-$. Those fake τ contaminations should be estimated.

Note.2; $\tau^+\tau^-$ pair can be generated without stau. (For example, $\tilde{\chi}^0_2$ -> $\tau^+\tau^-$ $\tilde{\chi}^0_1$ or Z^0–>$\tau^+\tau^-$ etc.)
For the exclusive stau search, we have to estimate these backgrounds.

ABCD method test (under study) (1)

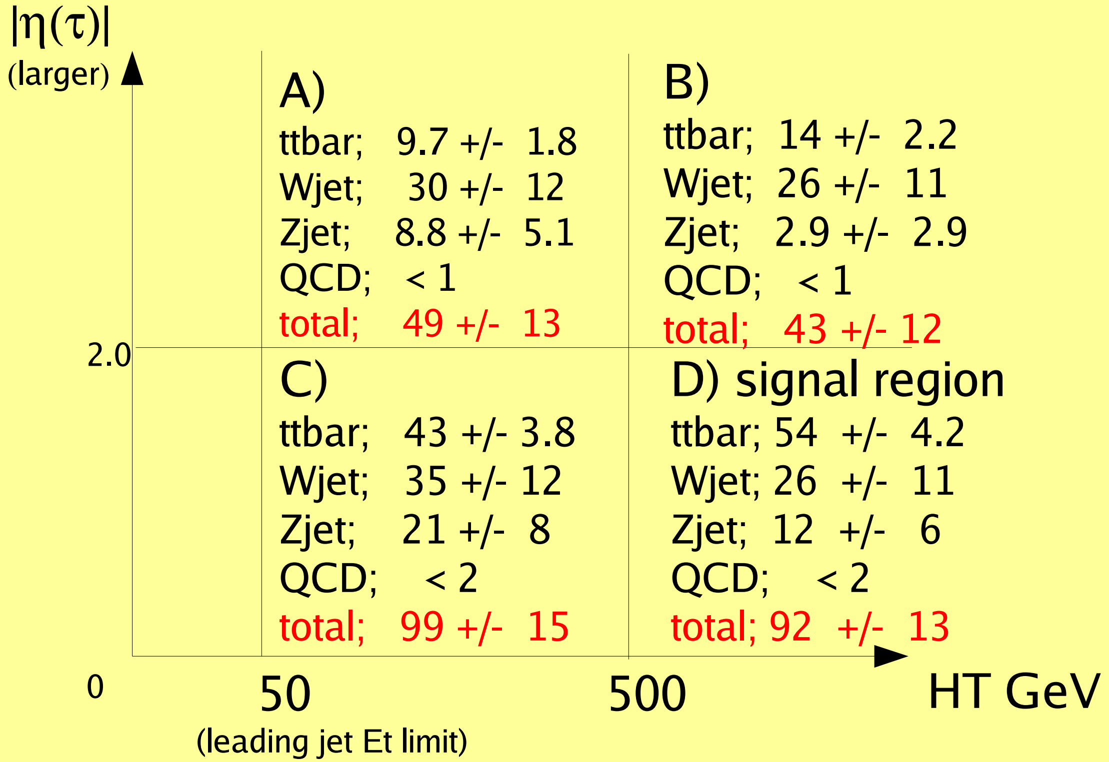
[ttbar, W jets, Z jets and QCD at $1fb^{-1}$]

$1.0fb^{-1}$

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**

Control region definitions are not yet optimized at all.



A)
ttbar; 9.7 +/- 1.8
Wjet; 30 +/- 12
Zjet; 8.8 +/- 5.1
QCD; < 1
total; 49 +/- 13

B)
ttbar; 14 +/- 2.2
Wjet; 26 +/- 11
Zjet; 2.9 +/- 2.9
QCD; < 1
total; 43 +/- 12

C)
ttbar; 43 +/- 3.8
Wjet; 35 +/- 12
Zjet; 21 +/- 8
QCD; < 2
total; 99 +/- 15

D) signal region
ttbar; 54 +/- 4.2
Wjet; 26 +/- 11
Zjet; 12 +/- 6
QCD; < 2
total; 92 +/- 13

The estimated number in the signal region D is,
D = B/A x C = 43/49 x 99 = 87 +/- 35
(Good agreement with the true number 92 +/- 13)

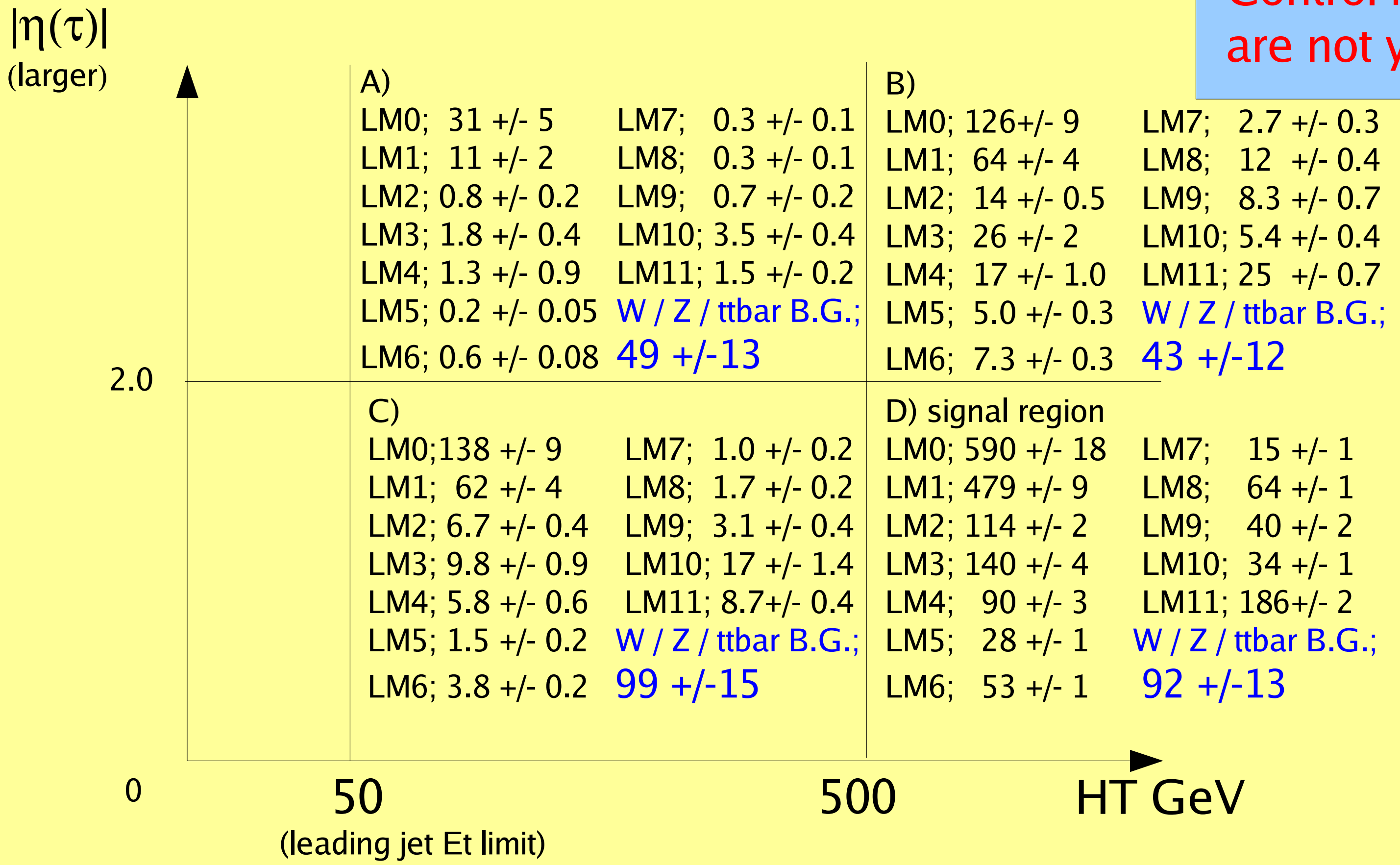
ABCD method test (under study) (2)
[SUSY signal contamination]

SUSY 1.0fb^{-1}

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**

Control region definitions are not yet optimized at all.



A)

LM0; 31 +/- 5	LM7; 0.3 +/- 0.1
LM1; 11 +/- 2	LM8; 0.3 +/- 0.1
LM2; 0.8 +/- 0.2	LM9; 0.7 +/- 0.2
LM3; 1.8 +/- 0.4	LM10; 3.5 +/- 0.4
LM4; 1.3 +/- 0.9	LM11; 1.5 +/- 0.2
LM5; 0.2 +/- 0.05	W / Z / ttbar B.G.;
LM6; 0.6 +/- 0.08	49 +/-13

B)

LM0; 126+/- 9	LM7; 2.7 +/- 0.3
LM1; 64 +/- 4	LM8; 12 +/- 0.4
LM2; 14 +/- 0.5	LM9; 8.3 +/- 0.7
LM3; 26 +/- 2	LM10; 5.4 +/- 0.4
LM4; 17 +/- 1.0	LM11; 25 +/- 0.7
LM5; 5.0 +/- 0.3	W / Z / ttbar B.G.;
LM6; 7.3 +/- 0.3	43 +/-12

C)

LM0;138 +/- 9	LM7; 1.0 +/- 0.2
LM1; 62 +/- 4	LM8; 1.7 +/- 0.2
LM2; 6.7 +/- 0.4	LM9; 3.1 +/- 0.4
LM3; 9.8 +/- 0.9	LM10; 17 +/- 1.4
LM4; 5.8 +/- 0.6	LM11; 8.7+/- 0.4
LM5; 1.5 +/- 0.2	W / Z / ttbar B.G.;
LM6; 3.8 +/- 0.2	99 +/-15

D) signal region

LM0; 590 +/- 18	LM7; 15 +/- 1
LM1; 479 +/- 9	LM8; 64 +/- 1
LM2; 114 +/- 2	LM9; 40 +/- 2
LM3; 140 +/- 4	LM10; 34 +/- 1
LM4; 90 +/- 3	LM11; 186+/- 2
LM5; 28 +/- 1	W / Z / ttbar B.G.;
LM6; 53 +/- 1	92 +/-13

Signal SUSY contaminate control regions. (It depends on the mSUGRA parameter points.)

Status summary

- We tested basic criteria in di-tau final states. (in 10 TeV MC)
- We testes a less correlated ABCD method, $\eta(\tau)$ vs HT.
  - It works well for SM backgrounds. However, signal SUSY events contaminate backgrounds control regions.
- Next interests
  - Optimization of control region definition
  - Using other variable combination for an ABCD method
  - Estimation of $Z^0 \to \tau^+\tau^-$ background in signal SUSY events
  - Updating with 7 TeV MC

Backups slides

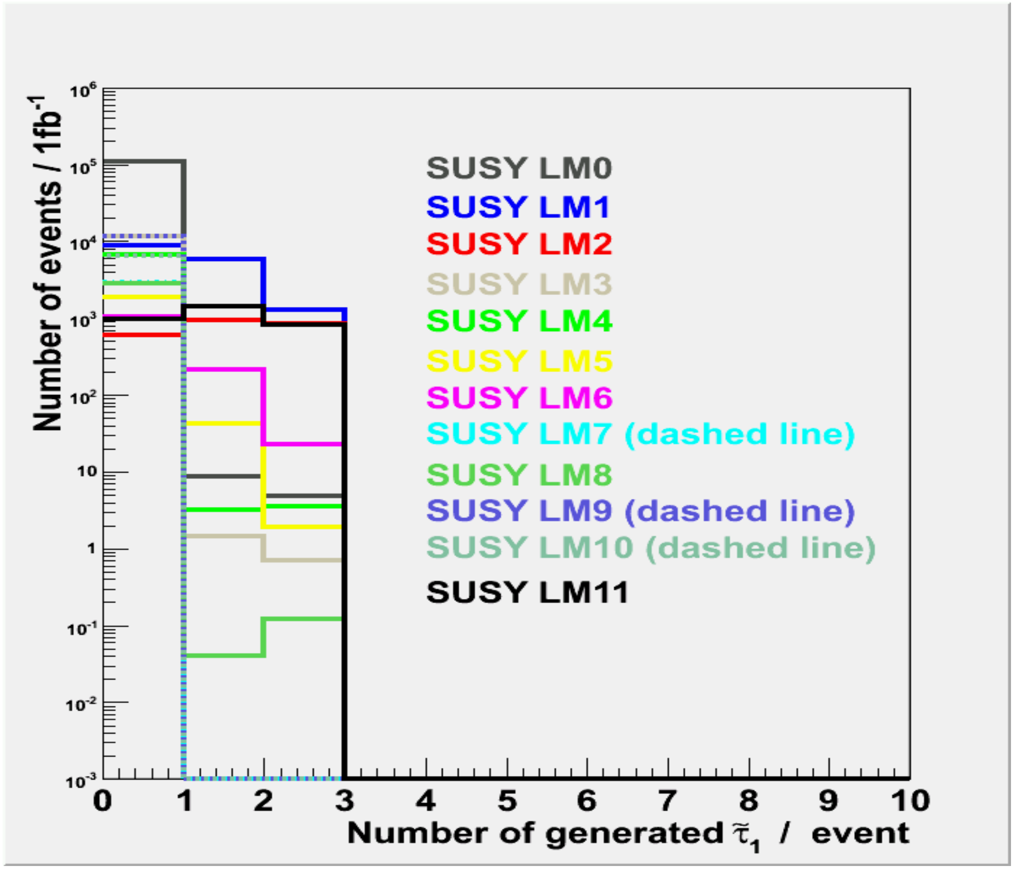
Summary table

(very preliminary, just a current status)

	Reconstructed SUSY	Reconstructed ttbar/W/Z	Reconstructed SUSY + ttbar/W/Z	Estimated ttbar/W/Z with SUSY contamination	Excess	Sigma (stat.)
LM0	590 +/- 18	92 +/- 13	682 +/- 22	501 +/- 103	181 +/- 105	1.7
LM1	479 +/- 9	92 +/- 13	581 +/- 16	287 +/- 77	294 +/- 79	3.7
LM2	114 +/- 2	92 +/- 13	206 +/- 13	121 +/- 43	85 +/- 45	1.9
LM3	140 +/- 4	92 +/- 13	232 +/- 14	148 +/- 50	84 +/- 52	1.6
LM4	90 +/- 3	92 +/- 13	182 +/- 14	125 +/- 45	57 +/- 47	1.2
LM11	186 +/- 2	92 +/- 13	278 +/- 13	145 +/- 50	133 +/- 52	2.6

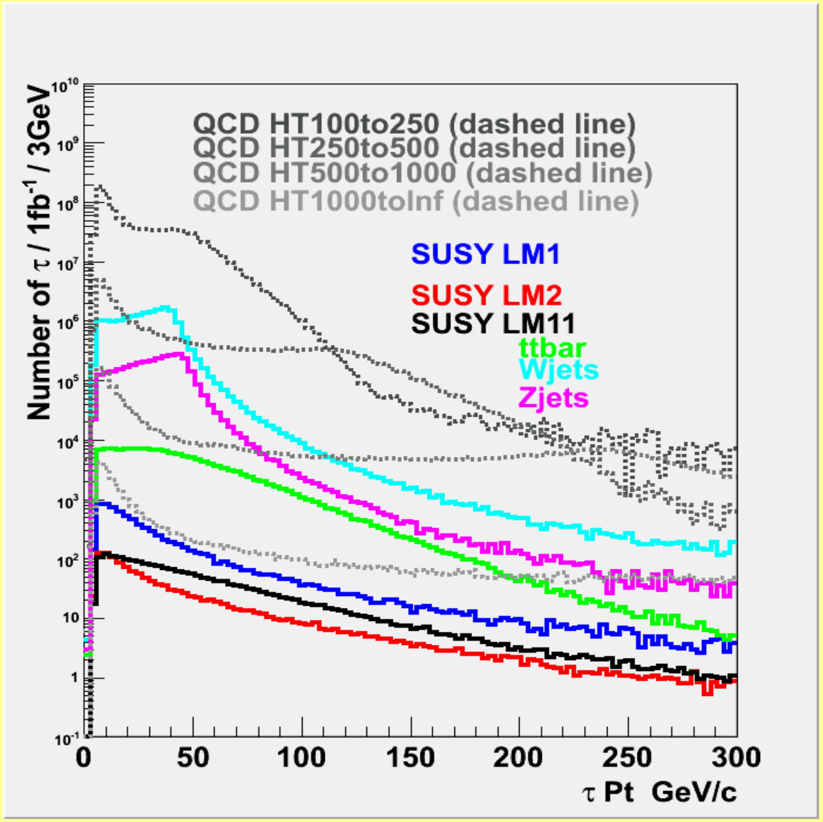
Note.1; Uncertainties of excess are dominant by W jet and Z jet MC statistics.
(Therefore, significances are not prospects at 1fb^{-1} in real data.)
Note.2; The cut values (HT etc.) are optimized for the LM1 signal MC.
Note.3; Control regions are not yet optimized at all.

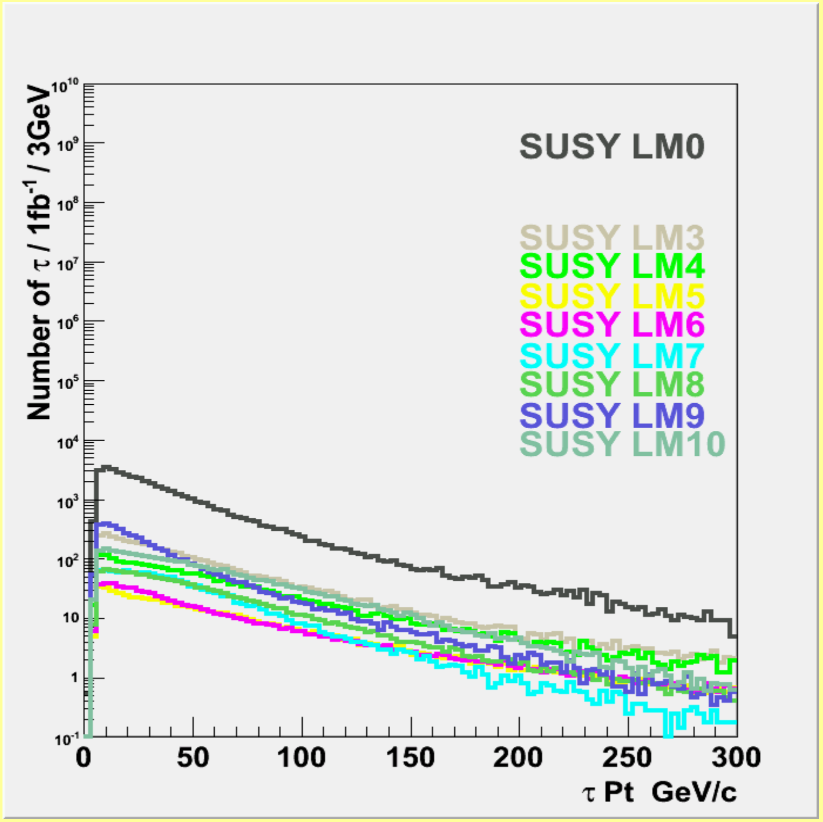
Backup; All generated stau$_1$



Reconstructed PAT τ Pt spectrum (1)

Without any cut
(They are PAT default outputs.)

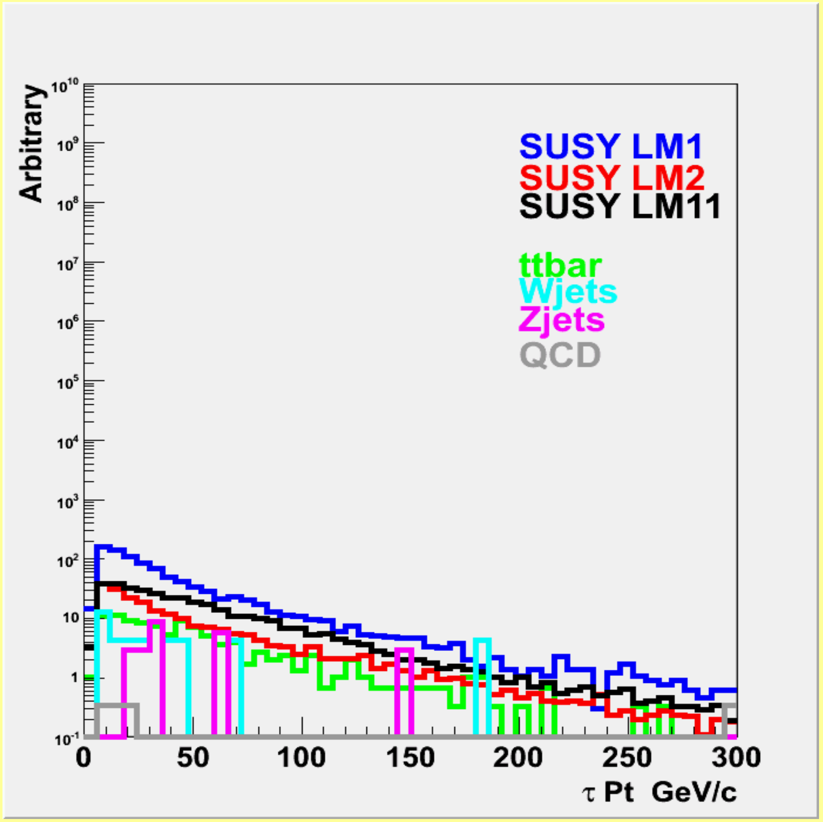


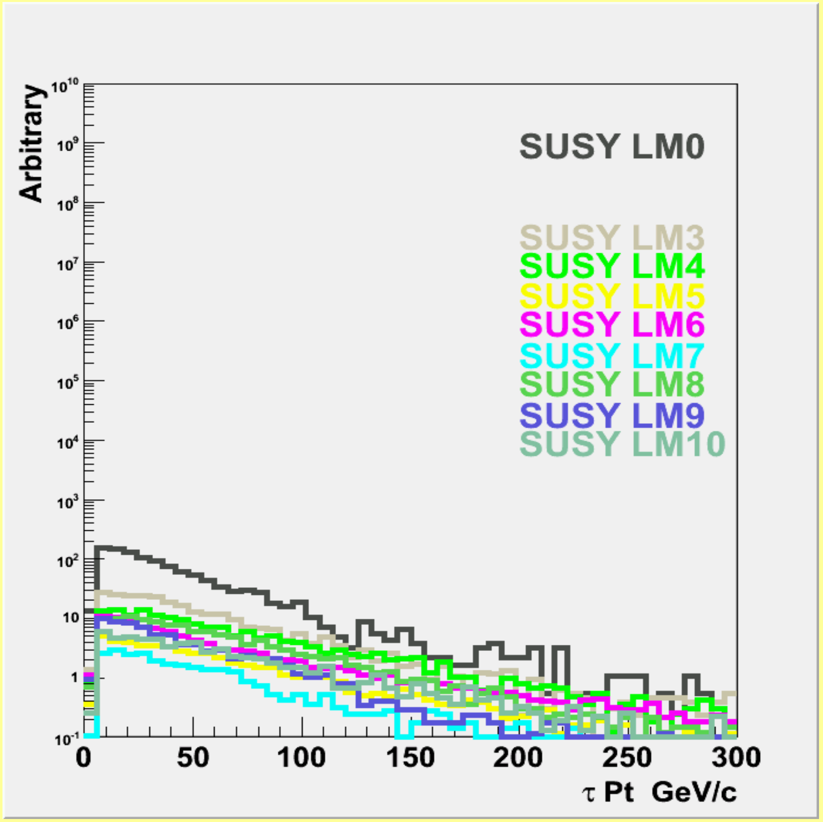


Reconstructed PAT τ Pt spectrum (2)

With basic criteria:

- **τ pair requirement, both with $|\eta(\tau)| < 2.0$**
- **MET > 200 GeV,**
- **HT > 500 GeV**
- **Leading Jet Et > 50 GeV**

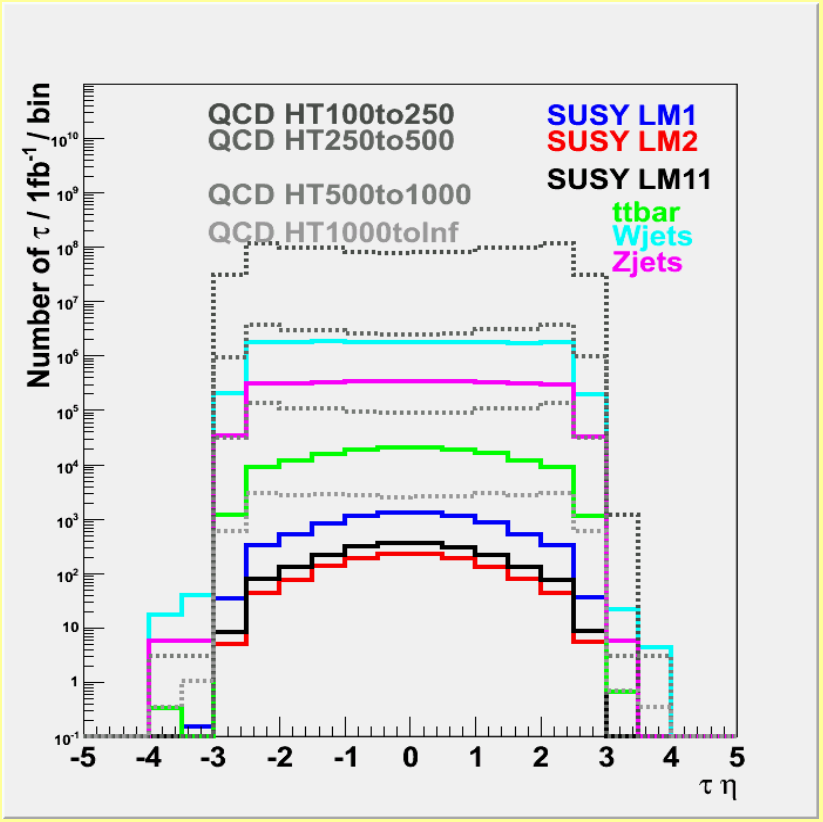


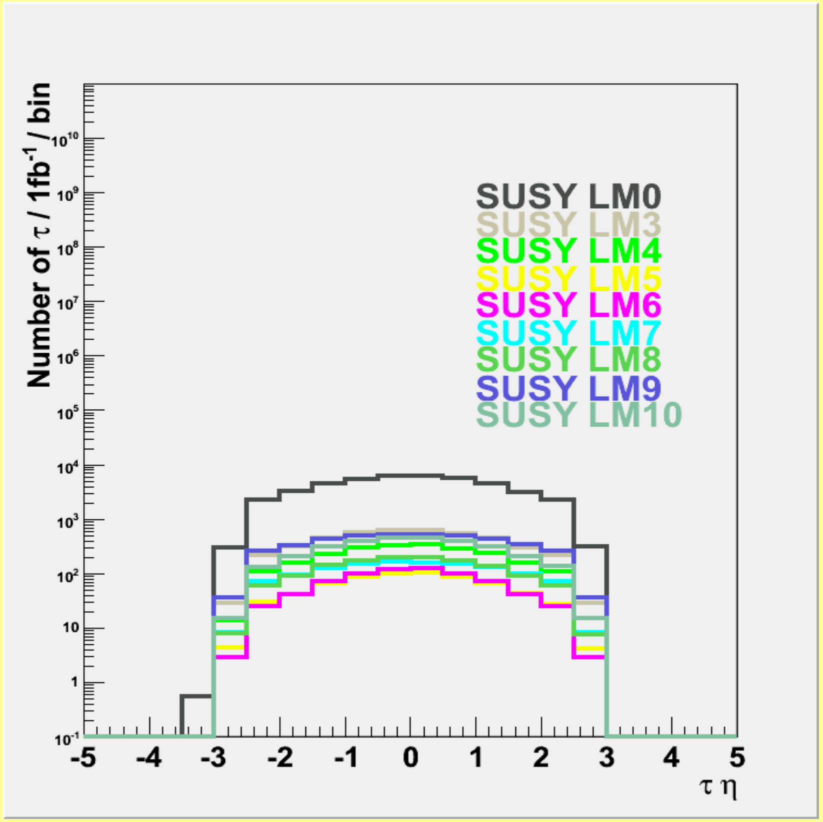


Note: Each di-tau has two different entries.

Reconstructed PAT τ pseudo-rapidity (1)

Without any cut
(They are PAT default outputs.)

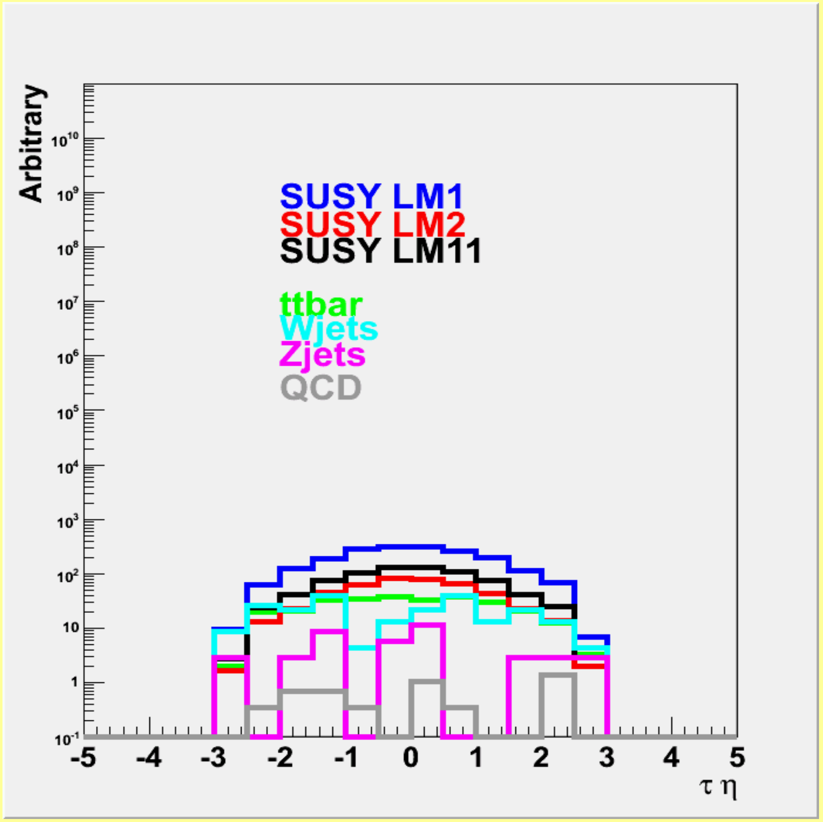


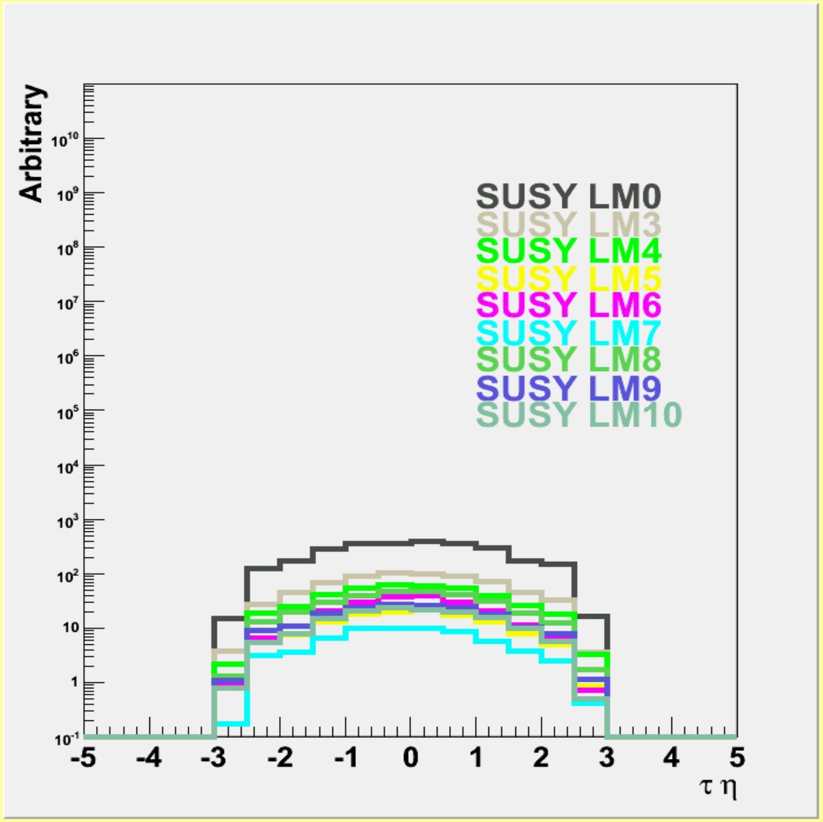


Reconstructed PAT τ pseudo-rapidity (2)

With basic criteria:

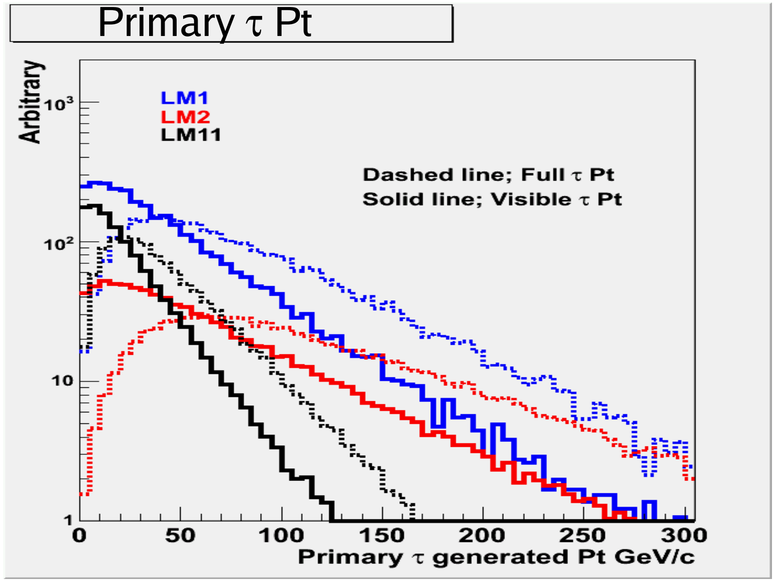
- **τ pair requirement, both with Pt > 5.0 GeV/c (PAT default)**
- **MET > 200 GeV,**
- **HT > 500 GeV**
- **Leading Jet Et > 50 GeV**

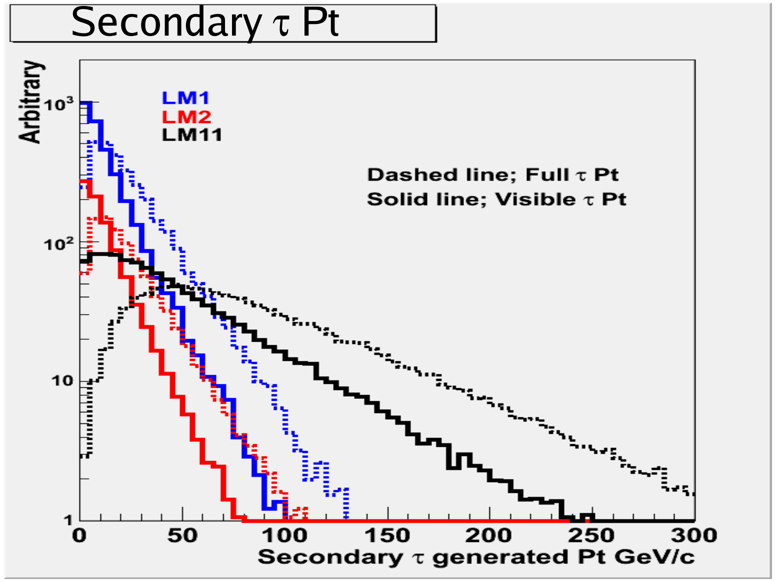




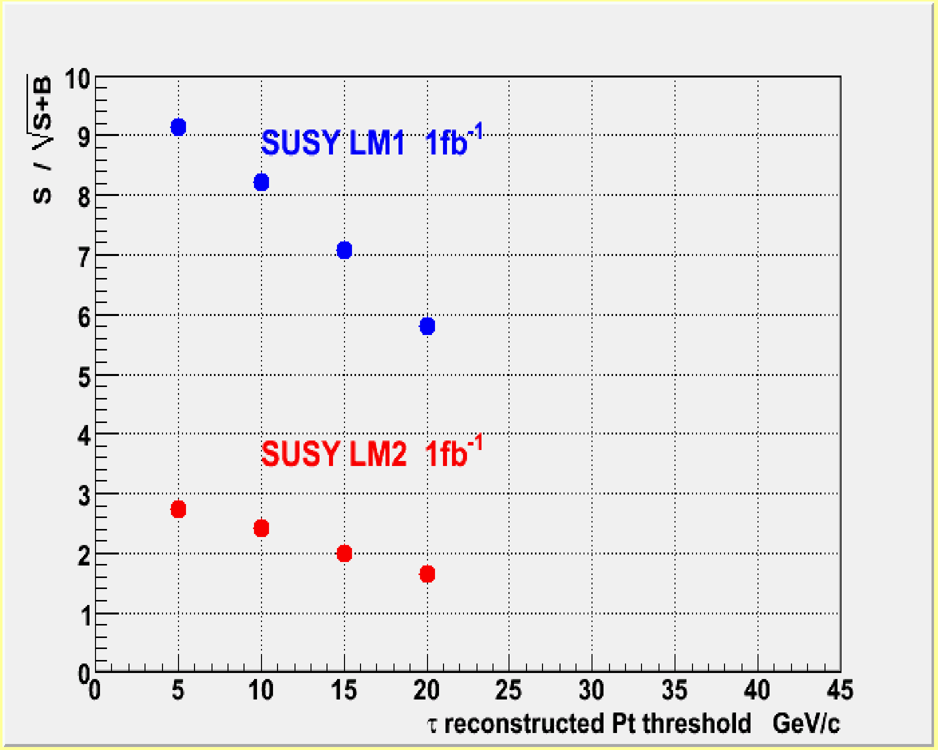
Note: Each di-tau has two different entries.

Backup;
One tighter τ Pt help ?





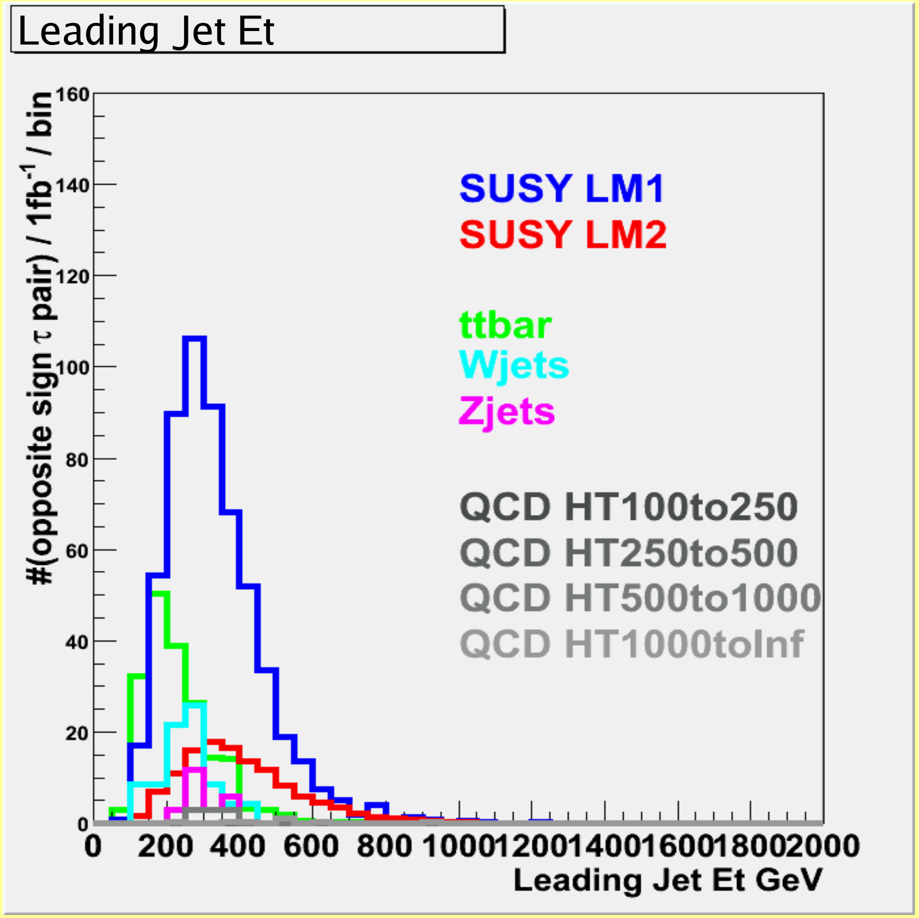
With basic cuts:
$|\eta(\tau)| < 2.5$, another $Pt(\tau) > 20$ GeV/c,
HT > 500 GeV, MET > 150 GeV,
Leading jet Et > 150 GeV

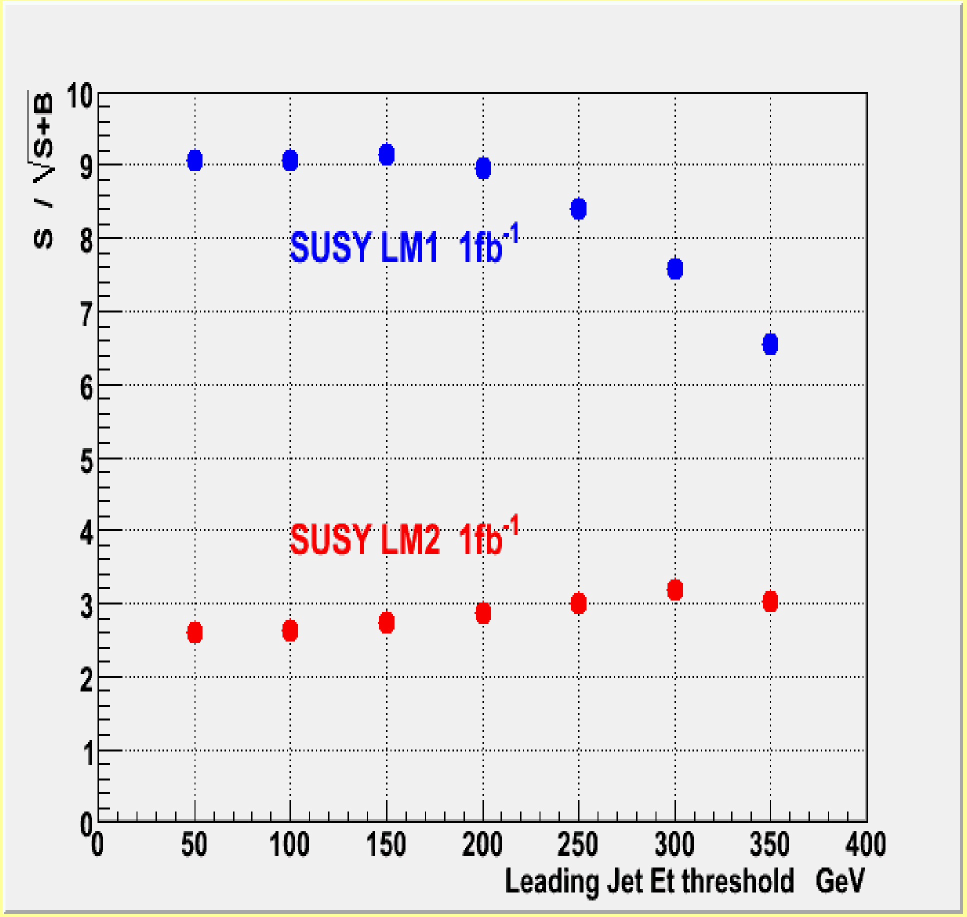


Note; Systematic uncertainty will increase.

Backup; Leading jet (after HT cut) help ? (1)

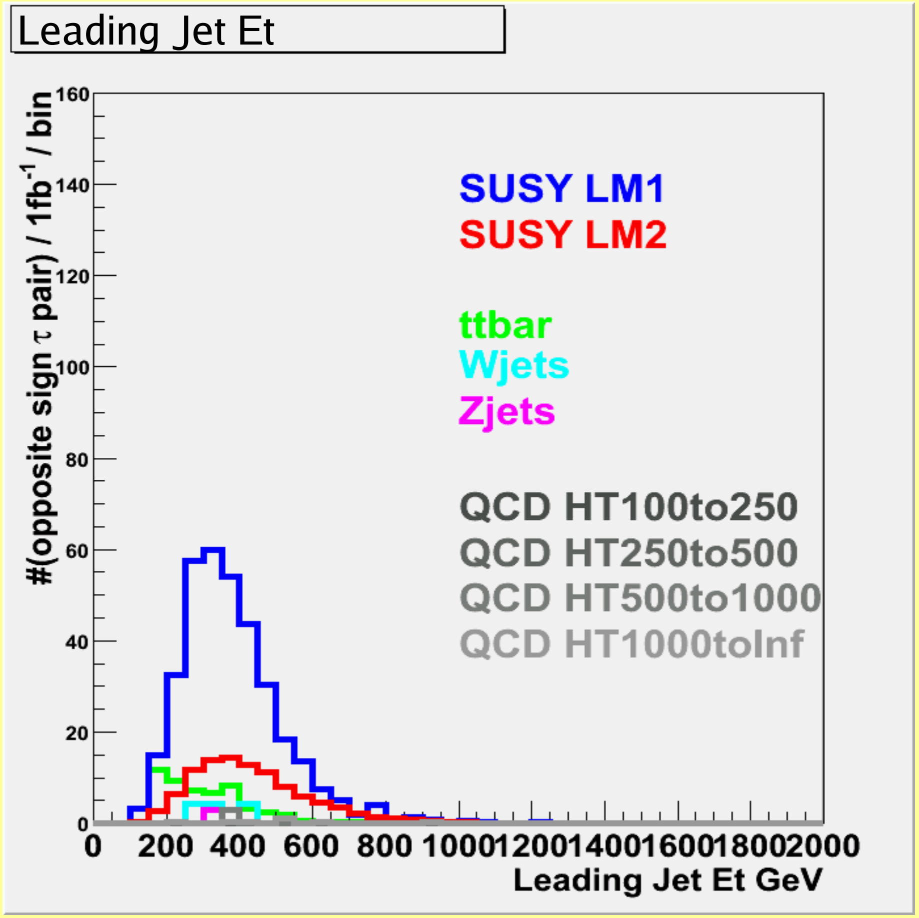
With very basic cuts: $|\eta(\tau)| < 2.5$, one $Pt(\tau) > 20$ GeV/c and another $Pt(\tau) > 5$ GeV/c, HT > 500 GeV (optimized for LM1, not for LM2), MET > 150 GeV

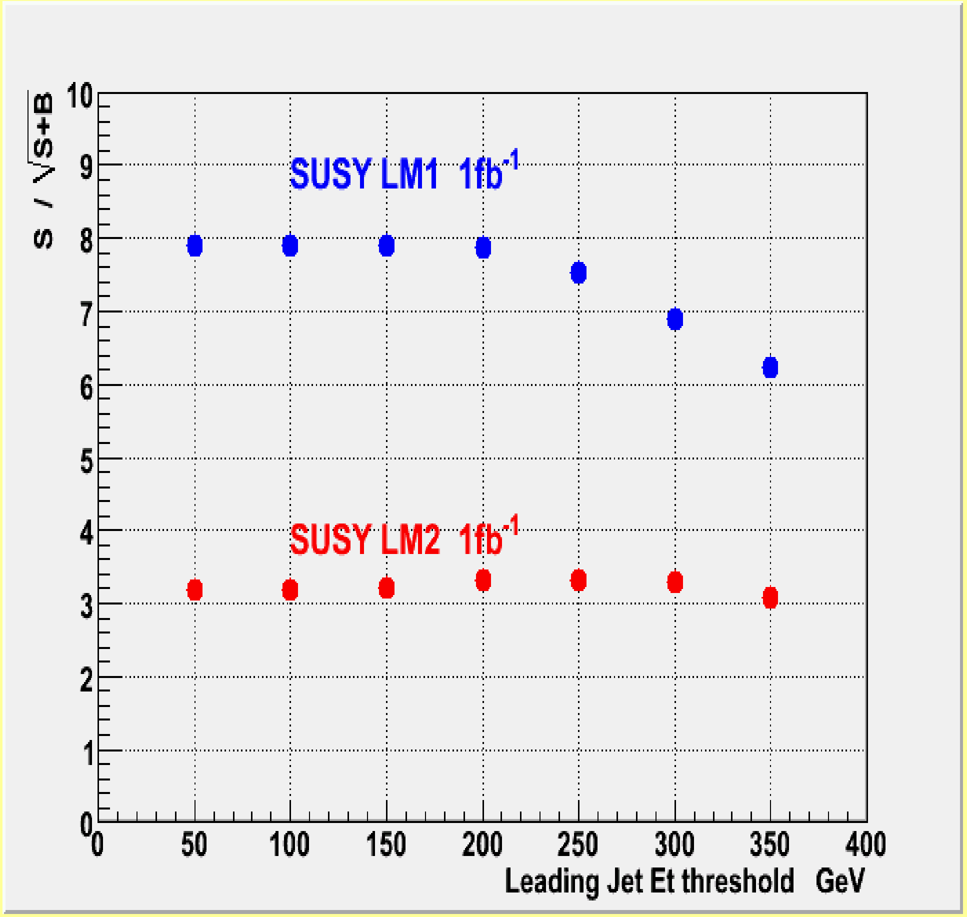




Backup;
Leading jet (after HT cut) help ? (2)

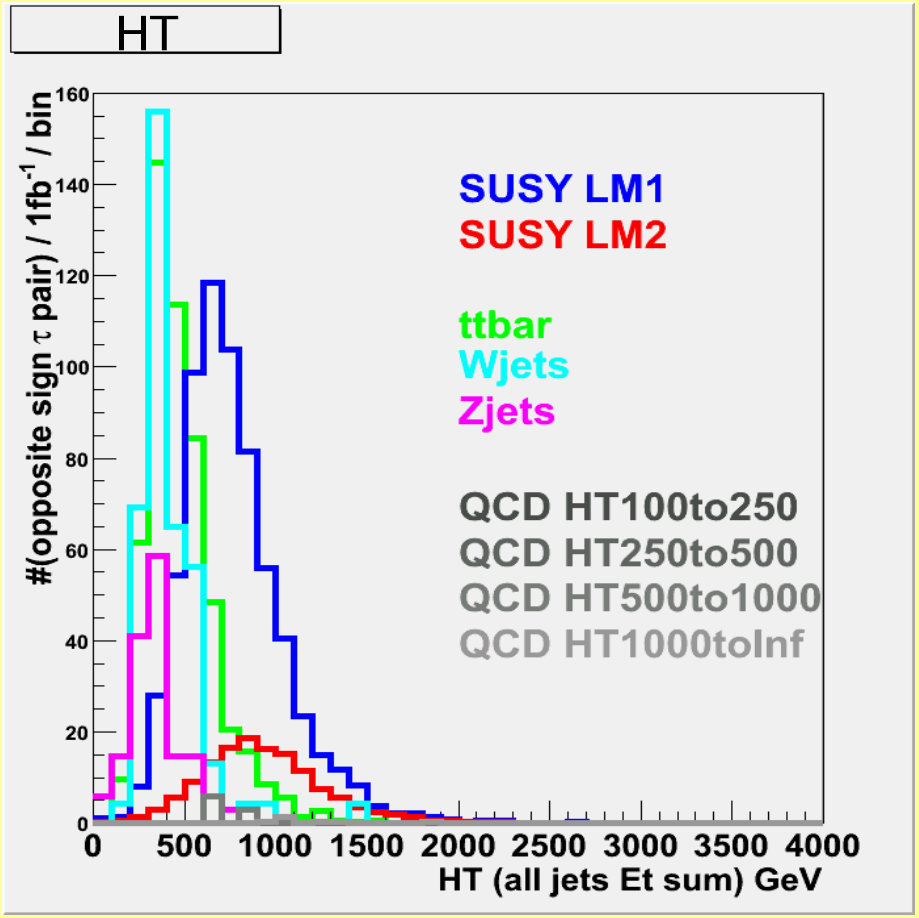
With very basic cuts: $|\eta(\tau)| < 2.5$, one $Pt(\tau) > 20$ GeV/c and another $Pt(\tau) > 5$ GeV/c, HT > 700 GeV (optimized for LM2, not for LM1), MET > 150 GeV

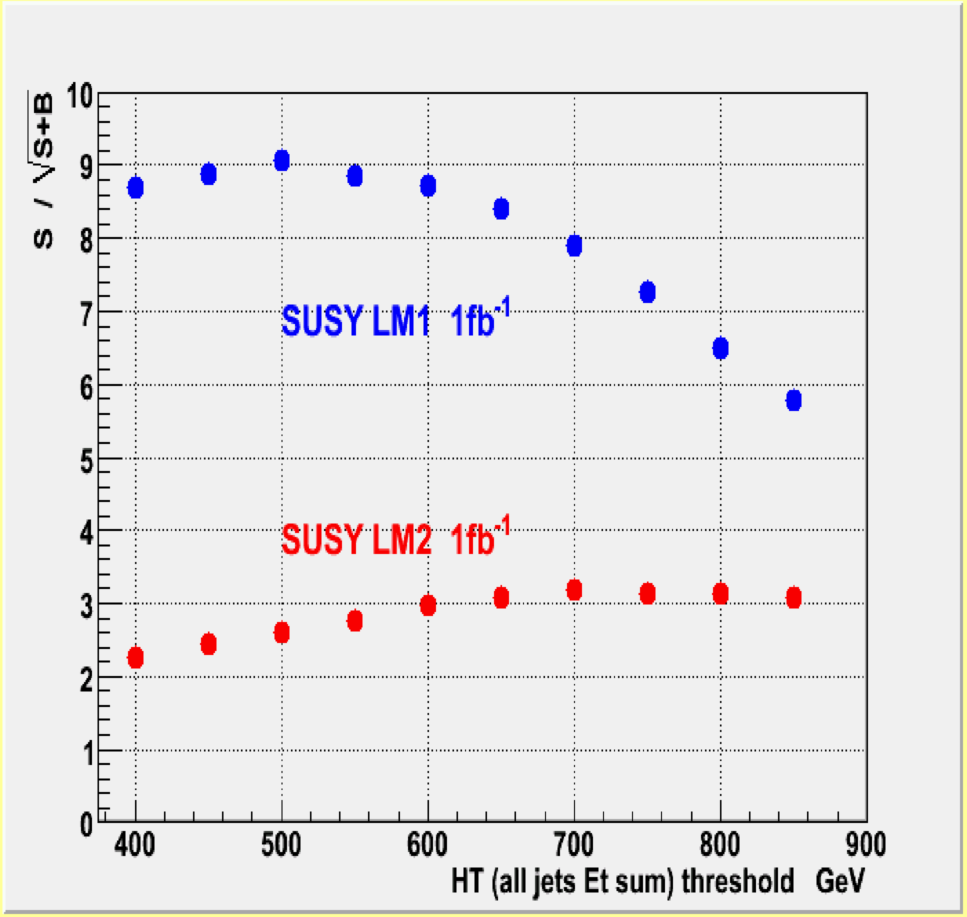




Backup;
Leading jet (after HT cut) help ? (3)

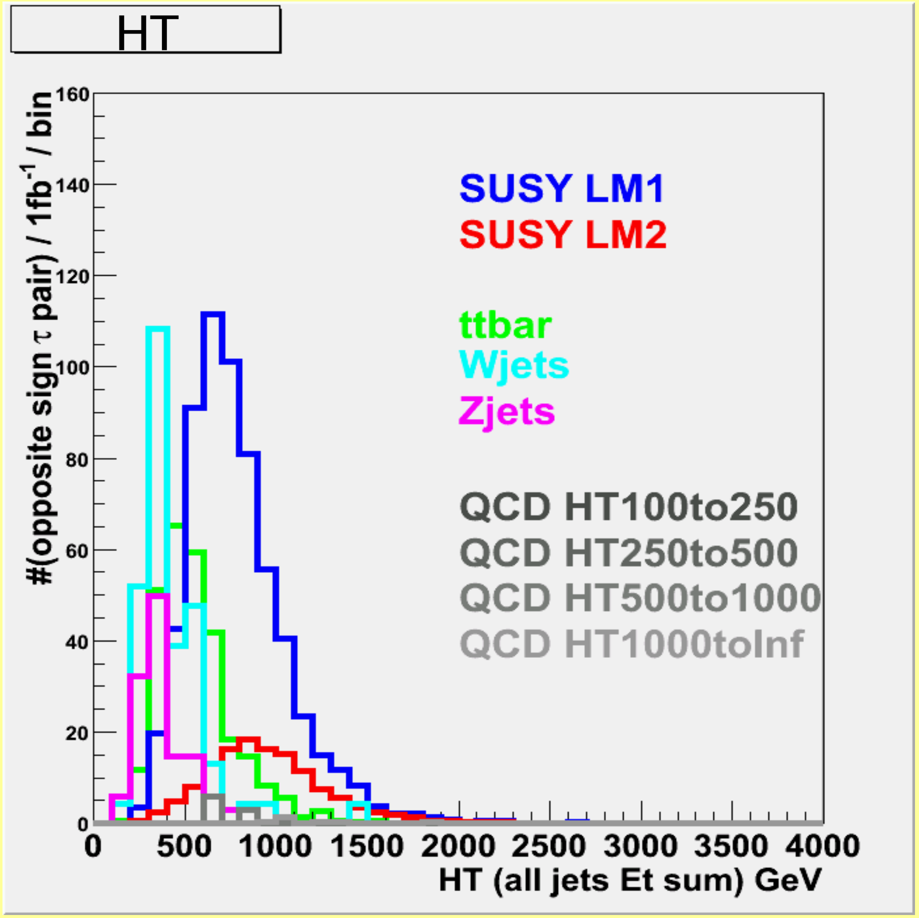
Without leading jet Et: $|\eta(\tau)| < 2.5$, one $Pt(\tau) > 20$ GeV/c and another $Pt(\tau) > 5$ GeV/c, MET > 150 GeV

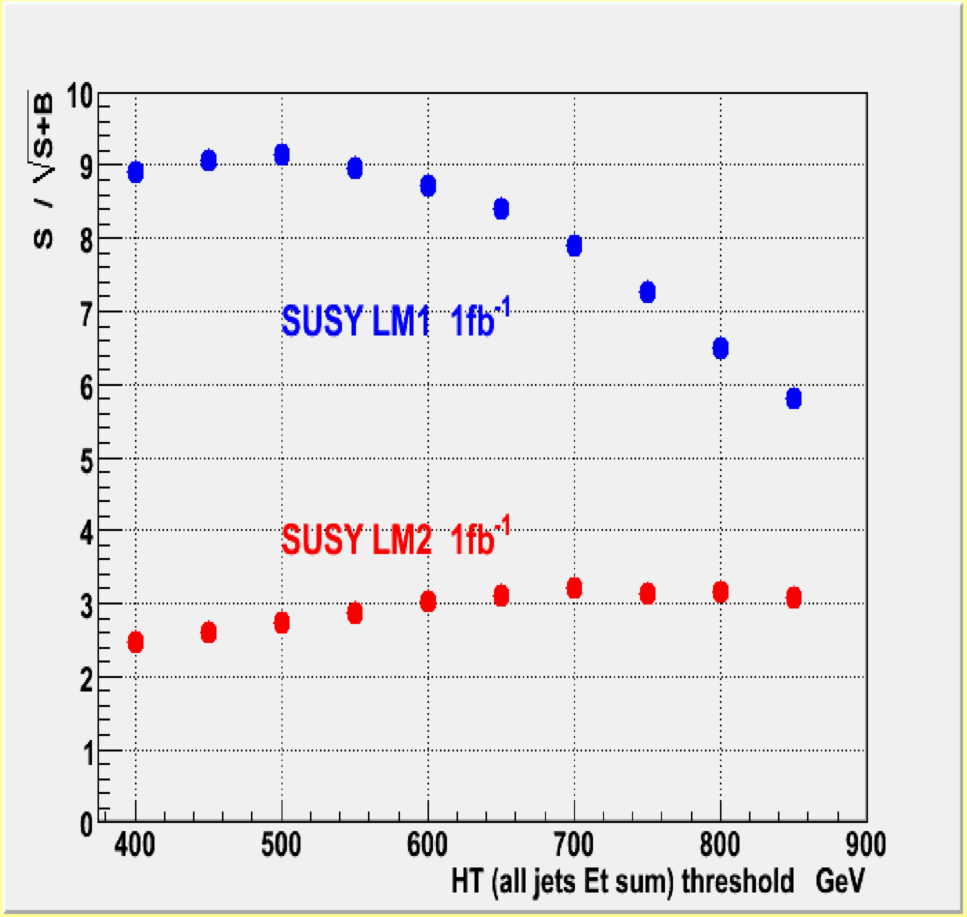




Backup; Leading jet (after HT cut) help ? (4)

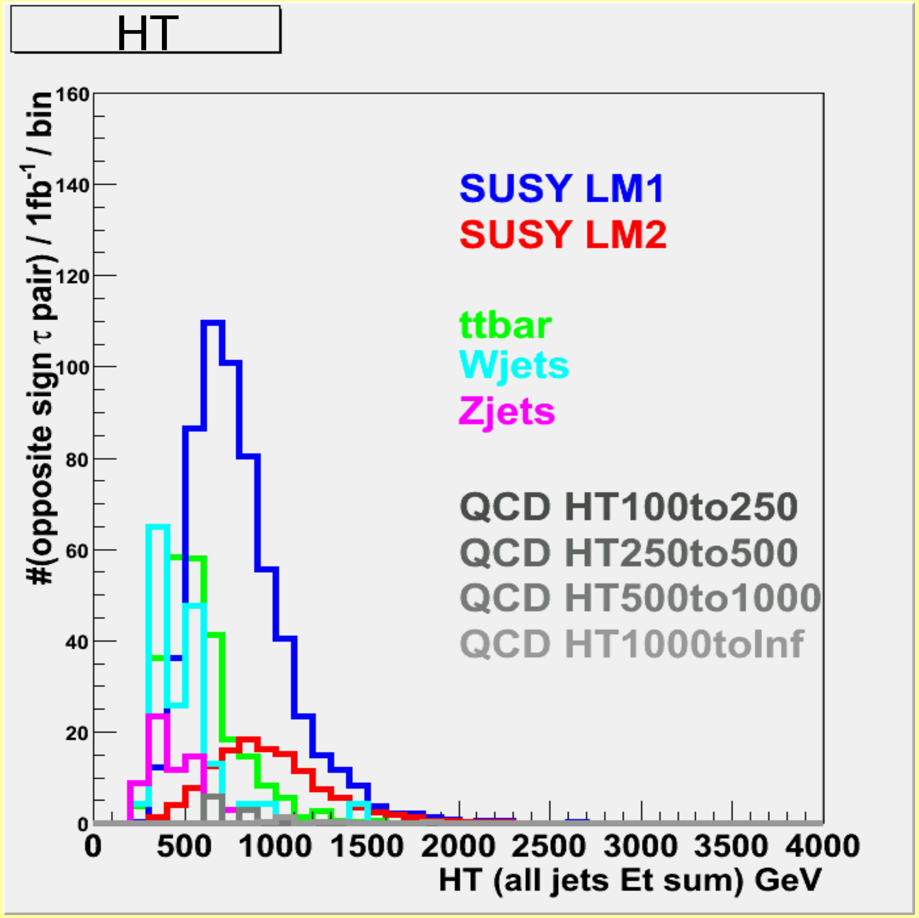
With leading jet Et: $|\eta(\tau)| < 2.5$, one $Pt(\tau) > 20$ GeV/c and another $Pt(\tau) > 5$ GeV/c, MET > 150 GeV, Leading jet Et > 150 GeV

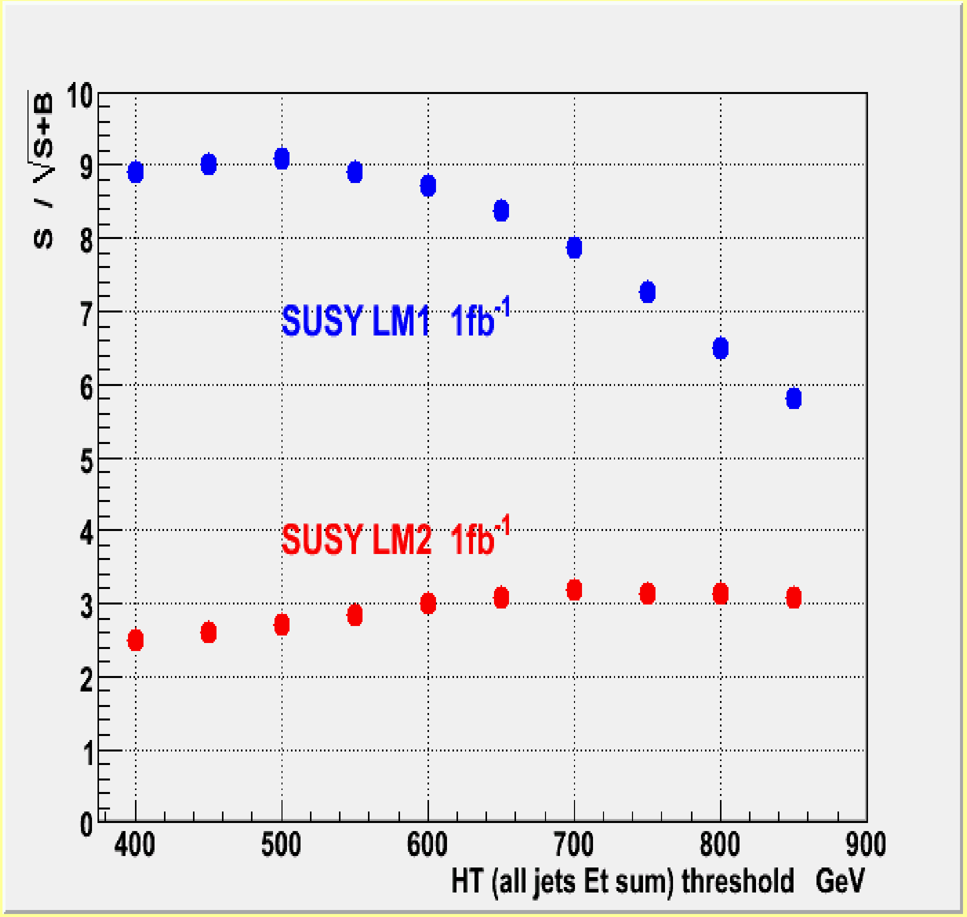




Backup;
Jet multiplicity help ? (1)

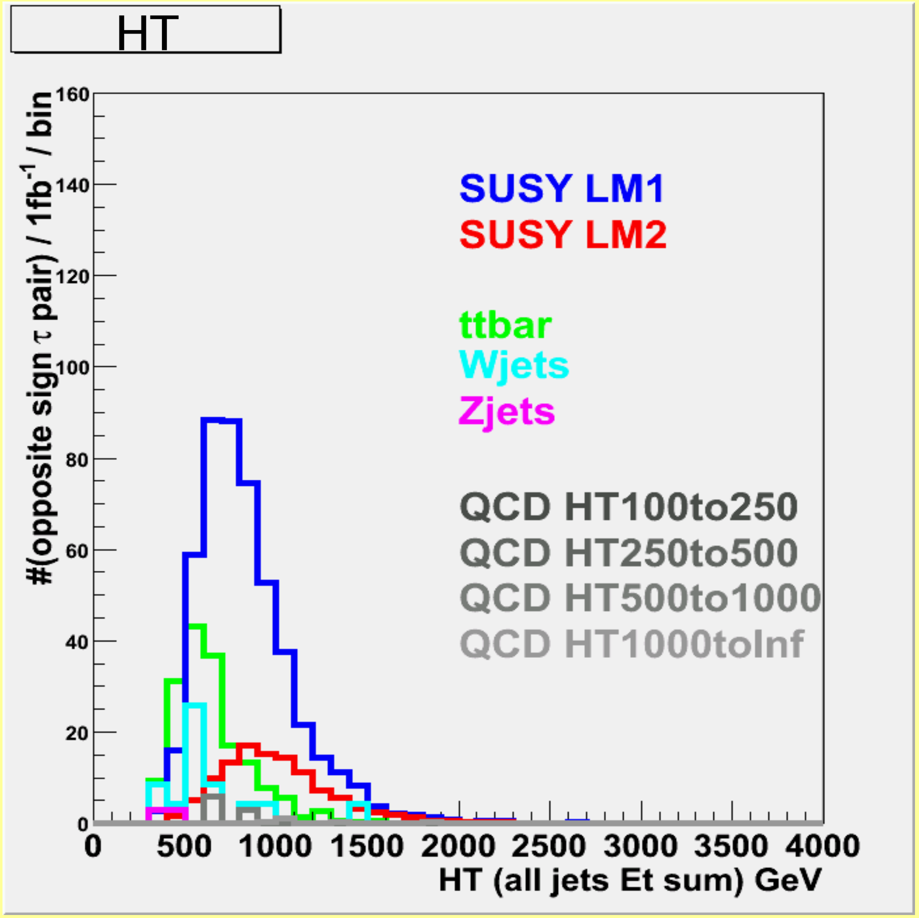
With jet multiplicity: |η(τ)| < 2.5, one Pt(τ) > 20 GeV/c and another Pt(τ) > 5 GeV/c, MET > 150 GeV, Leading jet Et > 150 GeV, #Jets(Et >50GeV) >=2

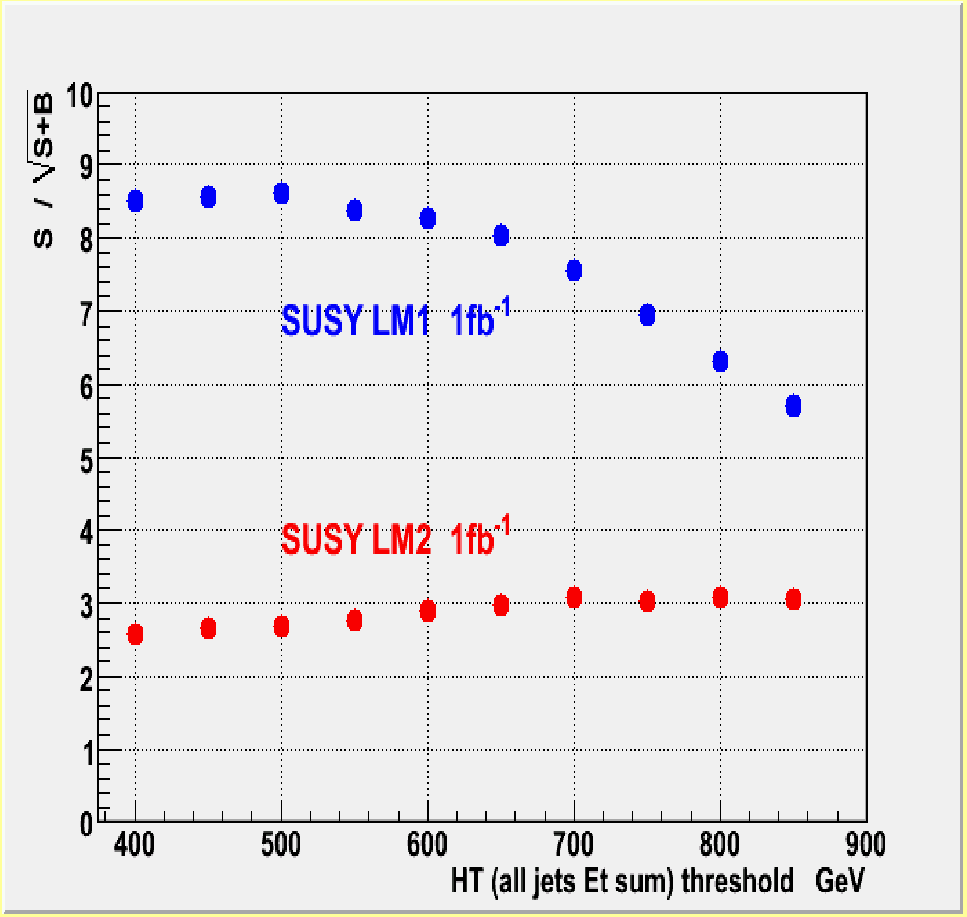




Backup;
Jet multiplicity help ? (2)

With additional cut: $|\eta(\tau)| < 2.5$, one $Pt(\tau) > 20$ GeV/c and another $Pt(\tau) > 5$ GeV/c,
MET > 150 GeV, Leading jet Et > 150 GeV, #Jets(Et >50GeV) >=3





Backup; Reconstructed Jet (Et > 50 GeV) multiplicity

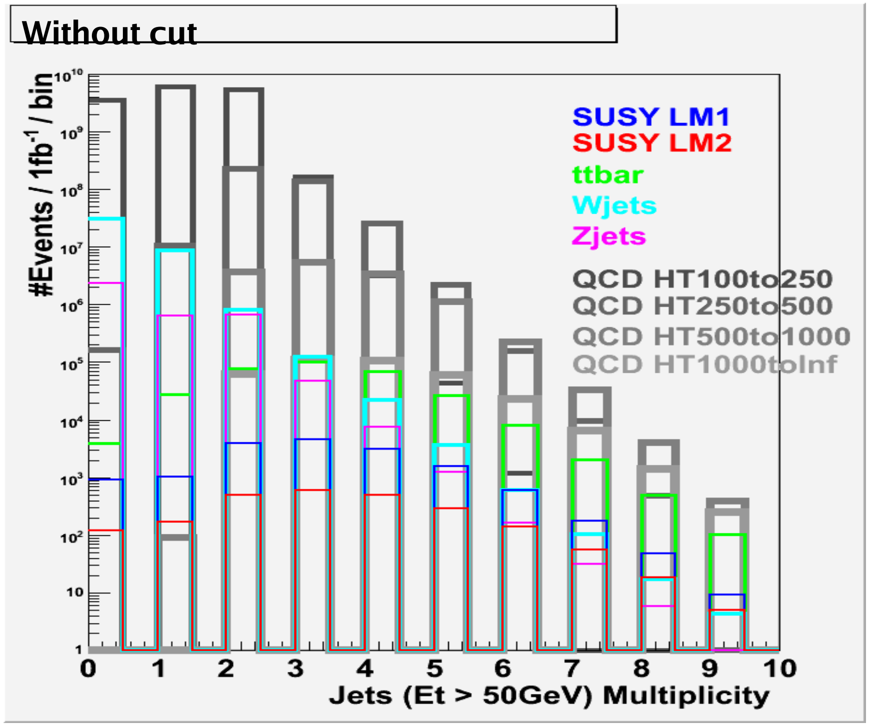
With basic cuts:

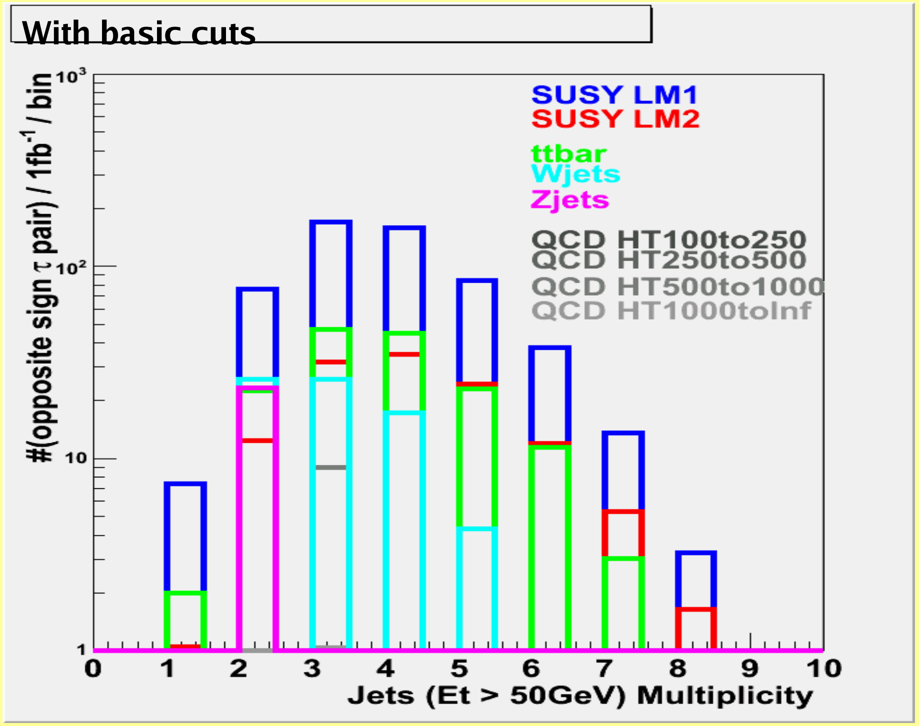
$|\eta(\tau)| < 2.5$,

one $Pt(\tau) > 20$ GeV/c and another $Pt(\tau) > 5$ GeV/c,

HT > 500 GeV, MET > 150 GeV,

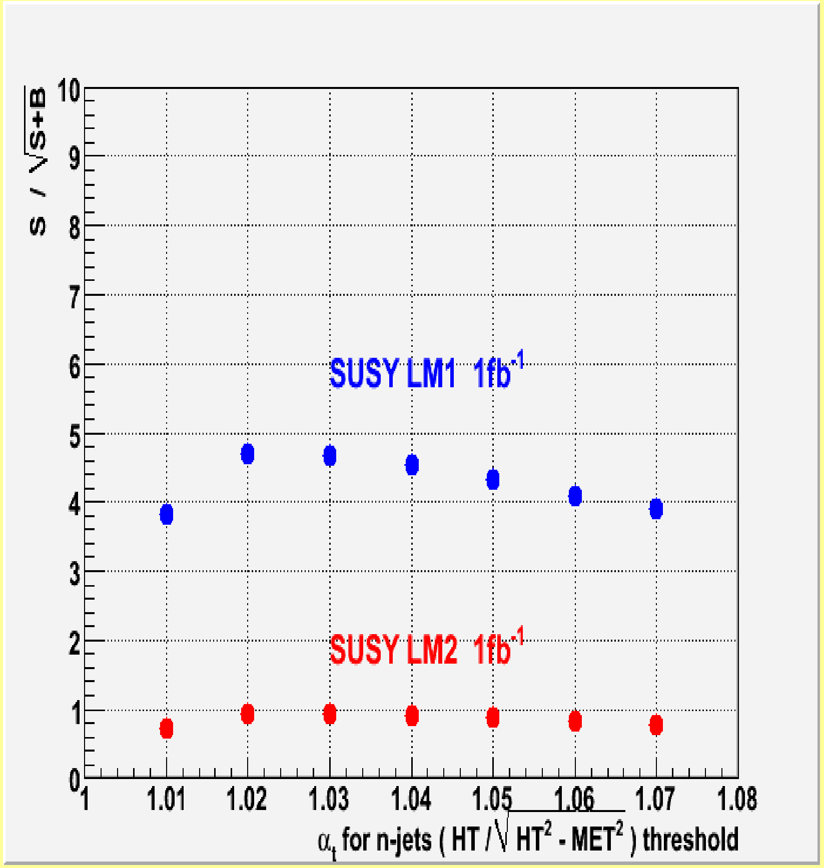
Leading jet Et > 150 GeV





Note; The Z jet events survived only 4 events after cut.
(It was normalized by a factor ~3.)

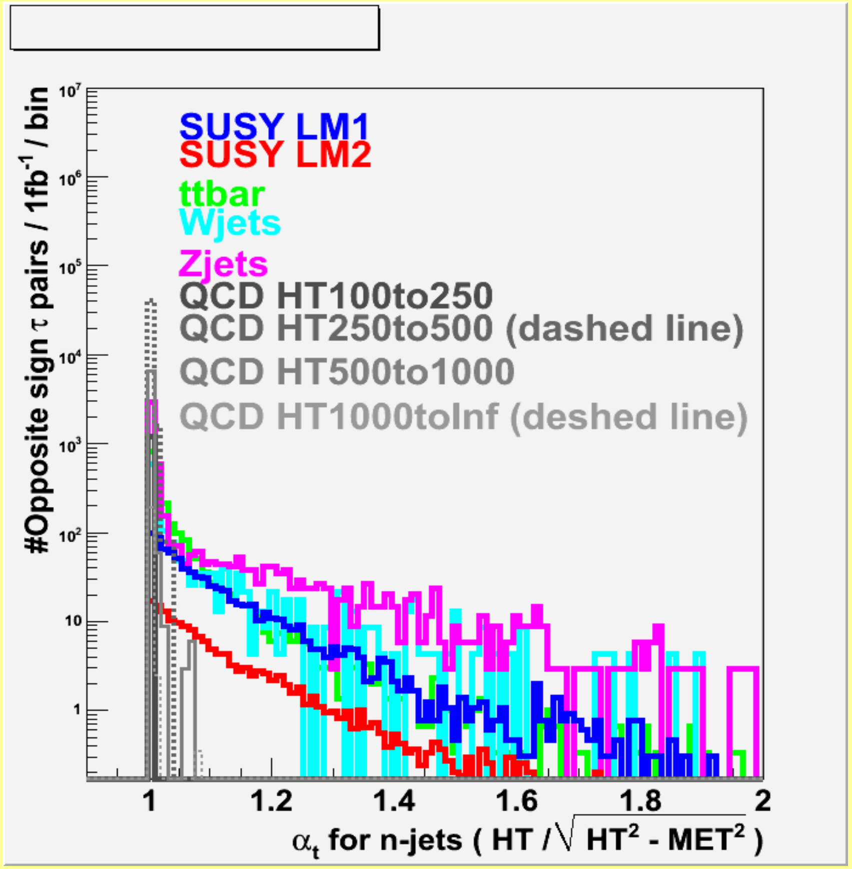
Backup; α_t for n-jets (5)



Without HT and MET:

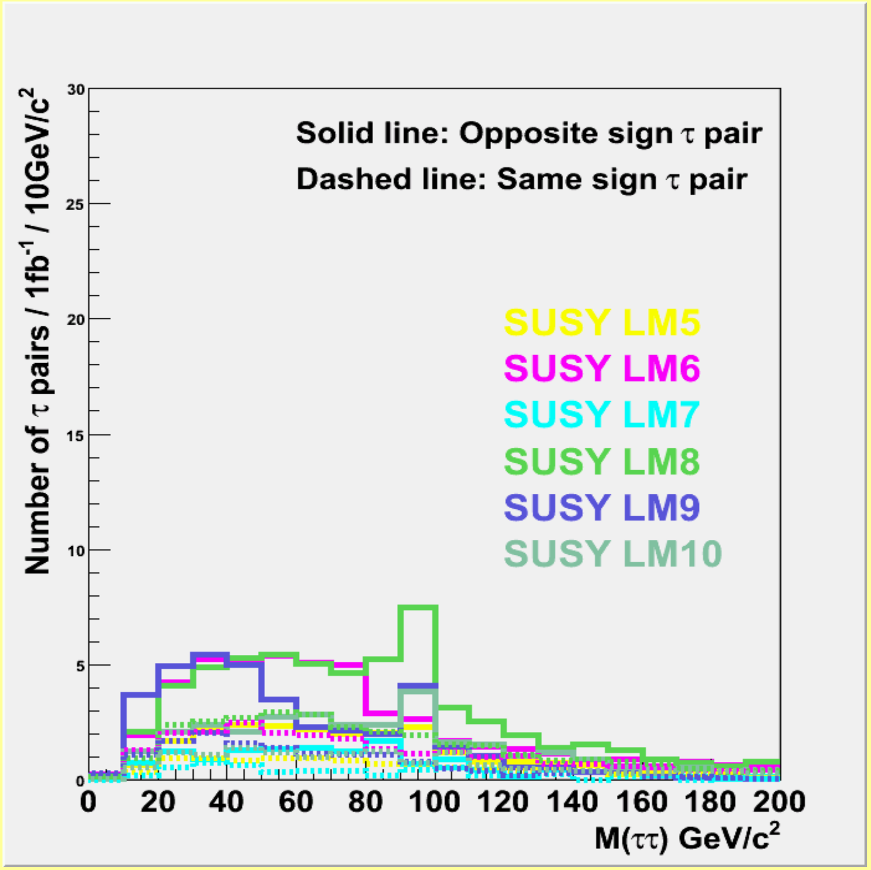
$|\eta(\tau)| < 2.5$, one $Pt(\tau) > 20$ GeV/c and another $Pt(\tau) > 5$ GeV/c,

Leading jet Et > 150 GeV

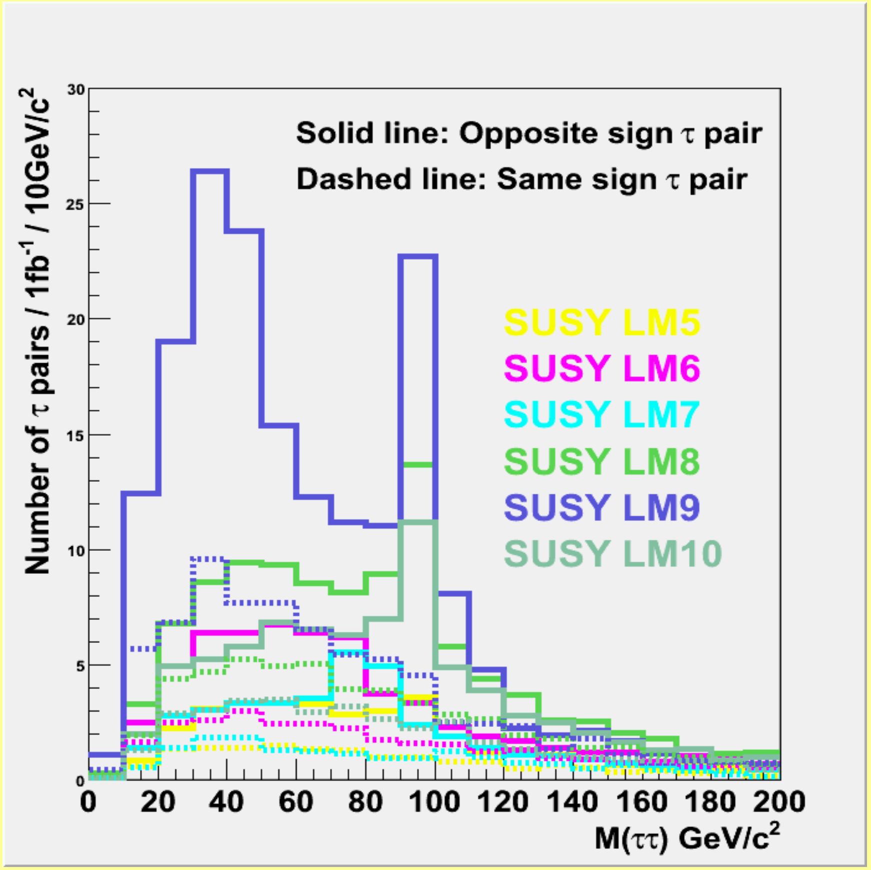


Backup; $M(\tau^+\tau^-)$ distributions

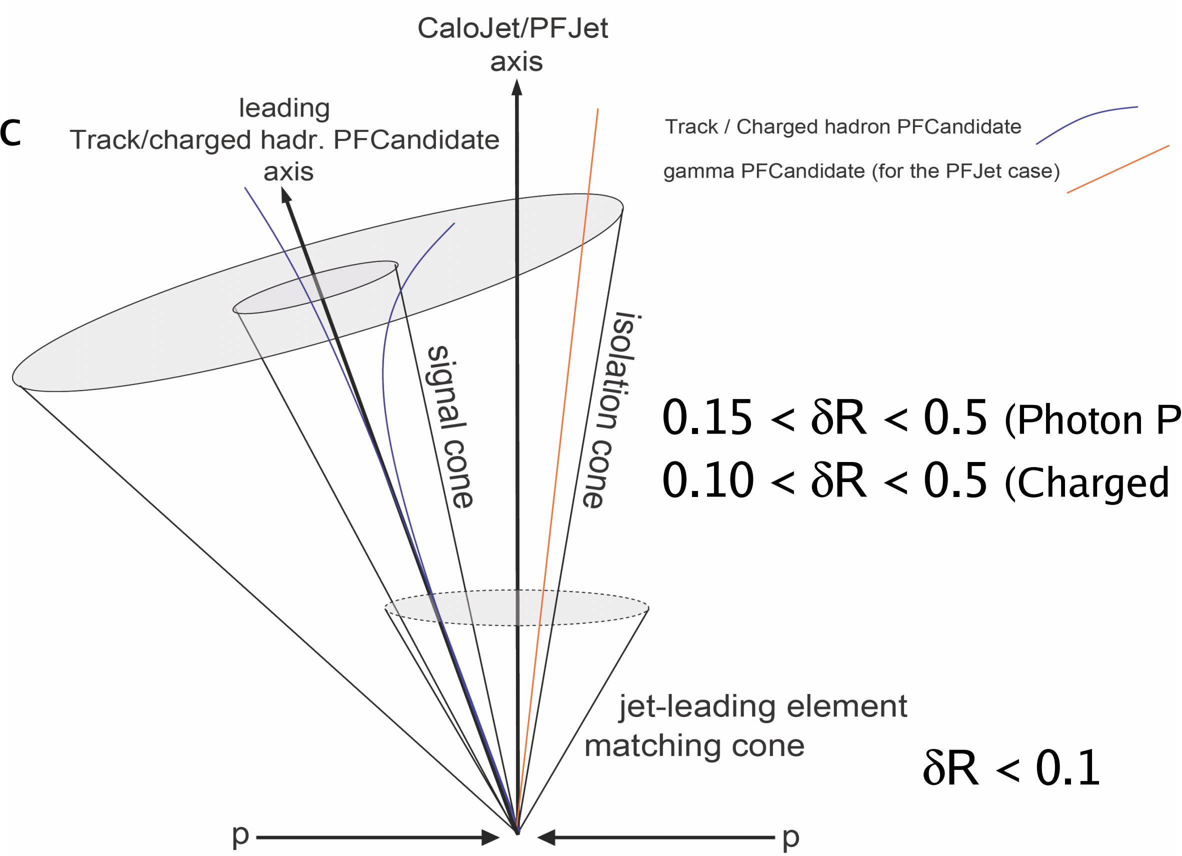
- $|\eta(\tau)| < 2.0$, $Pt(\tau) > 5$ GeV/c,
- HT > 500 GeV,
- MET > 200 GeV,
- Leading jet Et > 50 GeV



- $|\eta(\tau)| < 2.0$, $Pt(\tau) > 5$ GeV/c,
- HT > 500 GeV,
- Without MET cut
- Leading jet Et > 50 GeV



CMS Standard tau reconstruction



5 GeV/c

$0.15 < \delta R < 0.5$ (Photon Pt > 1.5 GeV)

$0.10 < \delta R < 0.5$ (Charged track Pt > 1 GeV)

$\delta R < 0.1$

ABCD method discussion; Which variable is better ?

Basic cuts (please see backup slides for the optimization)

- **$|\eta(\tau)| < 2.0$**
- **$Pt(\tau) > 5$ GeV/c** [PAT default]
- **HT > 500 GeV**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**

[This leading jet Et requirement is not effective after the HT cut. (please see backup slides as well.)
I'm applying a minimum cut since I suppose that a standard trigger will be using some cut.]

- ✓ In order to estimate ttbar/Wjet/Zjets which survive eventually, QCD backgrounds should be suppressed even in control regions. Then, the MET cut would be applied even for control regions. Therefore, I don't use the MET as the ABCD method variable.
- ✓ $Pt(\tau)$ is using the PAT minimum value. I don't have a control region.
- ✓ HT and the leading jet Et are highly correlated. I can use only one of them.
- ✓ The leading jet η is highly correlated with the leading jet Et. It means that the leading jet η is also highly correlated with the HT. Therefore I did not use the leading jet η in this time.

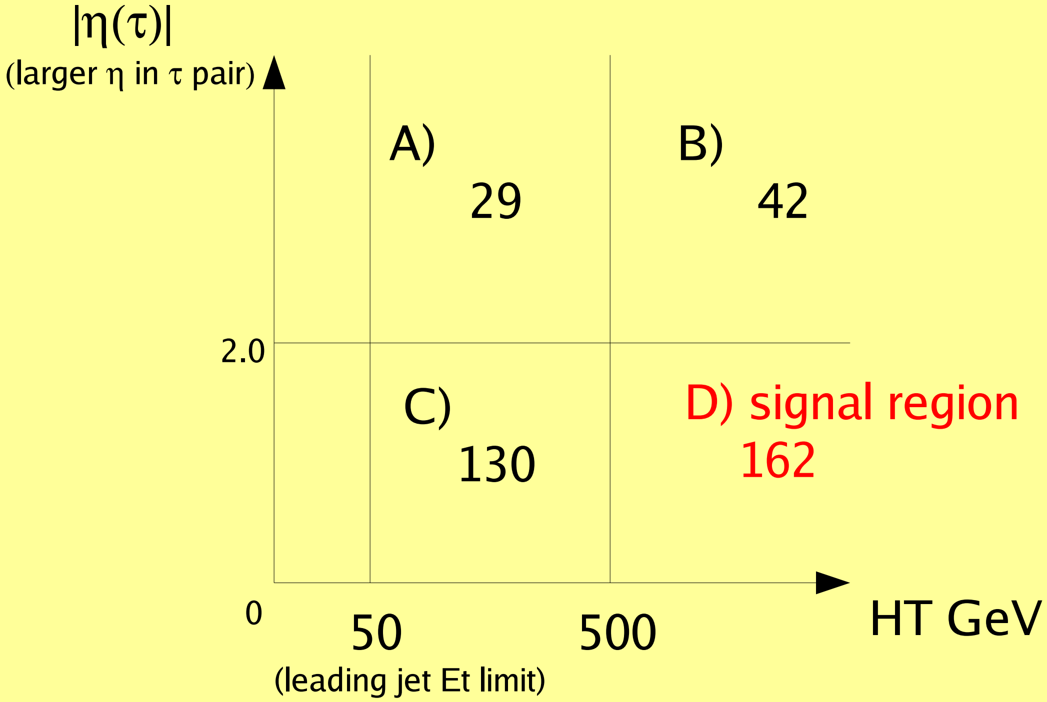
➔Tested "**$\eta(\tau)$ vs HT**"

ABCD method test (1) [ttbar]

$3.0\mathrm{fb}^{-1}$ ttbar

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**



Control region definitions are not yet optimized at all.

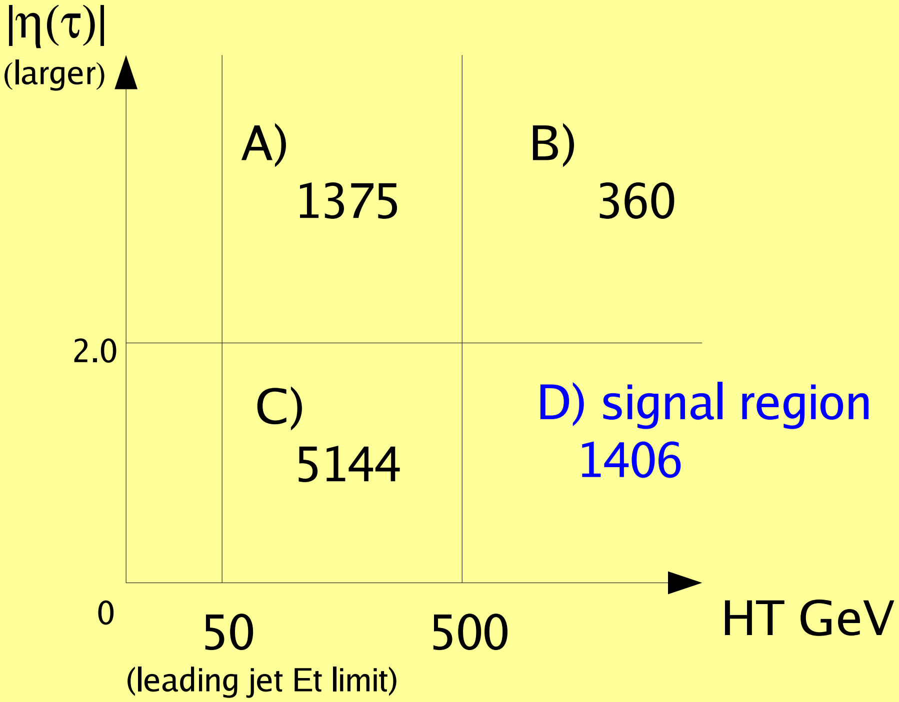
By assuming the ratio A:B = C:D,
the estimated number in the signal region D is,
D = B/A x C = 42/29 x 130 = 188 +/- 48.
(Good agreement with the true number 162.)

ABCD method test (2) [ttbar consistency check]

3.0fb^{-1} ttbar

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 100 GeV**
- **Leading jet Et > 50 GeV**



|η(τ)|
(larger)

A)
1375

B)
360

2.0

C)
5144

D) signal region
1406

0

50
(leading jet Et limit)

500

HT GeV

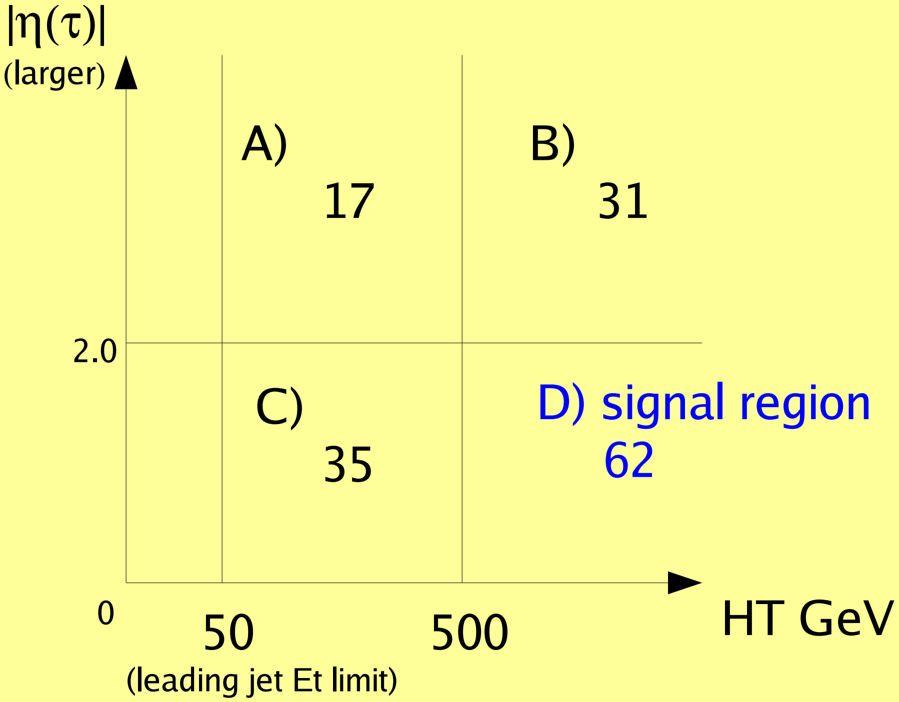
The estimated number in the signal region D is,
D = B/A x C = 360/1375 x 5144 = 1347 +/- 82.
(Good agreement with the true number 1406.)

ABCD method test (3) [ttbar consistency check]

$3.0fb^{-1}$ ttbar

#same sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**



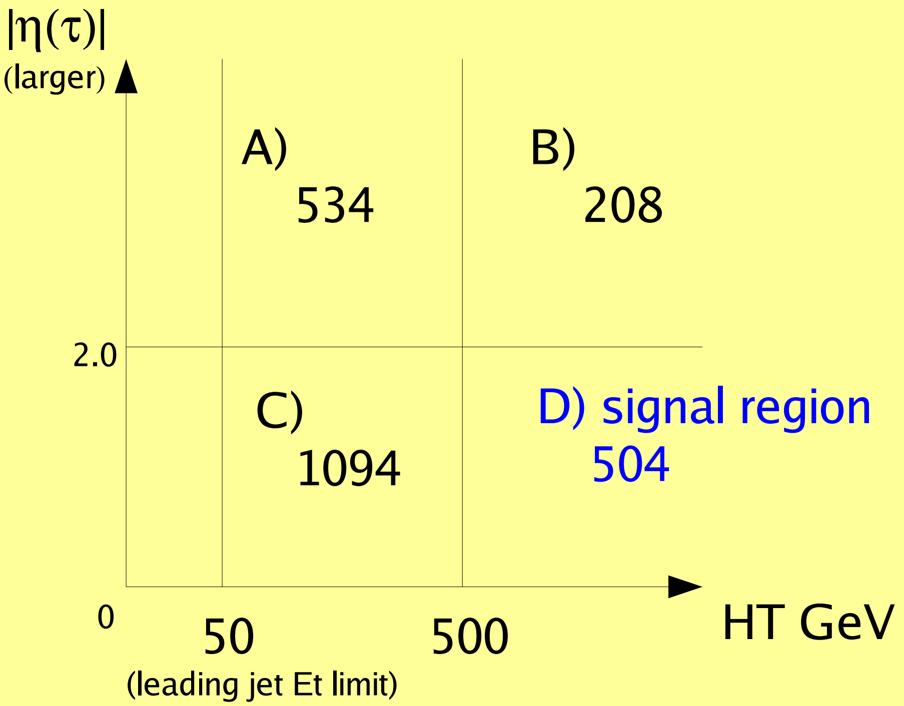
The estimated number in the signal region D is,
D = B/A x C = 31/17 x 35 = 64 +/- 22.
(Good agreement with the true number 62.)

ABCD method test (4) [ttbar consistency check]

$3.0\mathrm{fb}^{-1}$ ttbar

#same sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 100 GeV**
- **Leading jet Et > 50 GeV**



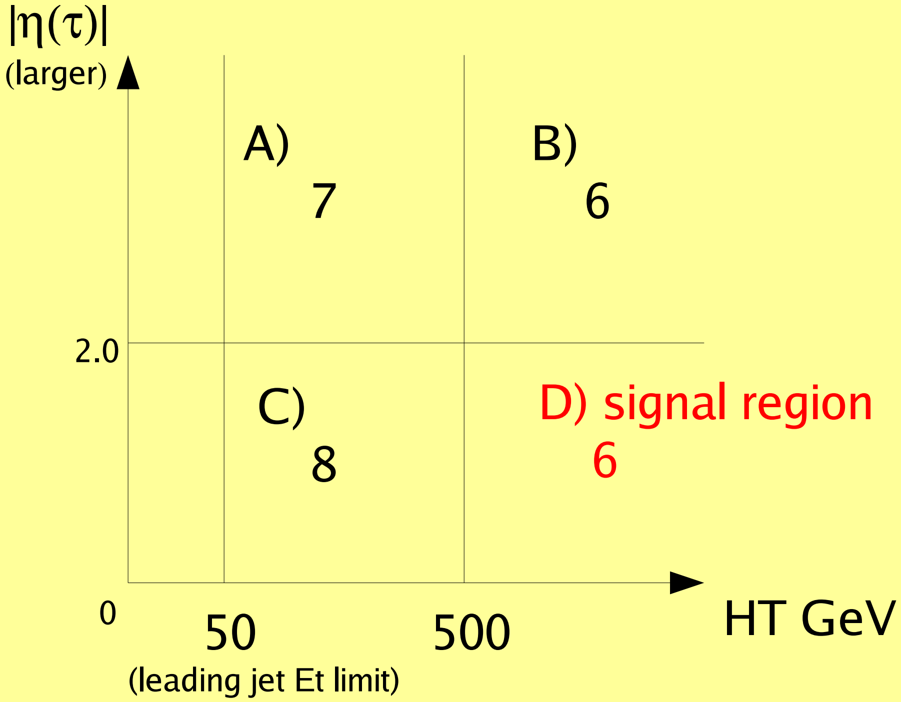
The estimated number in the signal region D is,
D = B/A x C = 208/534 x 1094 = 426 +/- 37.
(Fair (2.1σ) from the true number 504.)

ABCD method test (5) [W jets]

0.23fb^{-1} W jets

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**



|η(τ)|
(larger)

A) 7

B) 6

2.0

C) 8

D) signal region 6

0

50
(leading jet Et limit)

500

HT GeV

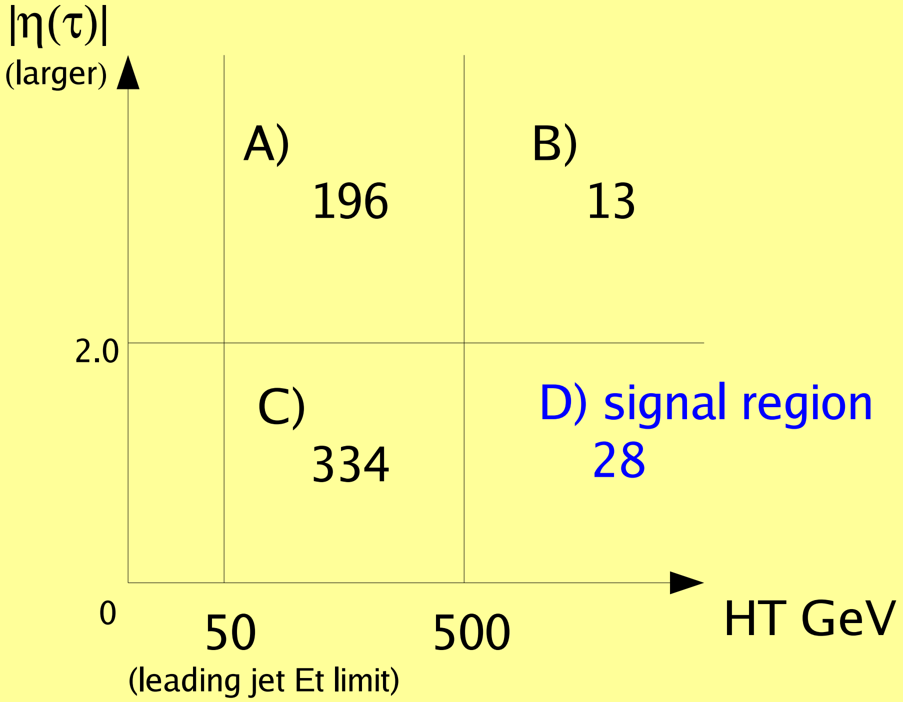
The estimated number in the signal region D is,
D = B/A x C = 6/7 x 8 = 6.9 +/- 4.5.
(Less statistics, but looks reasonable.)

ABCD method test (6) [W jets consistency check]

$0.23\,\text{fb}^{-1}$ W jets

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 100 GeV**
- **Leading jet Et > 50 GeV**



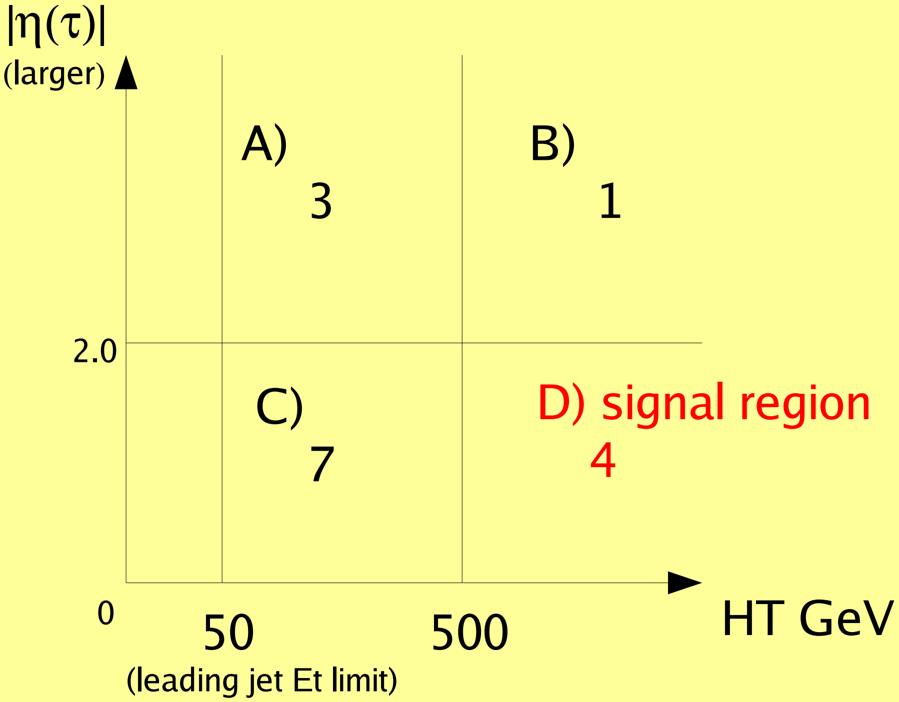
The estimated number in the signal region D is,
D = B/A x C = 13/196 x 334 = 22.2 +/- 6.5
(Good agreement with the true number 28.)

ABCD method test (7) [Z jets]

0.34fb^{-1} Z jets

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**



|η(τ)| (larger)

A) 3

B) 1

2.0

C) 7

D) signal region 4

0

50 (leading jet Et limit)

500

HT GeV

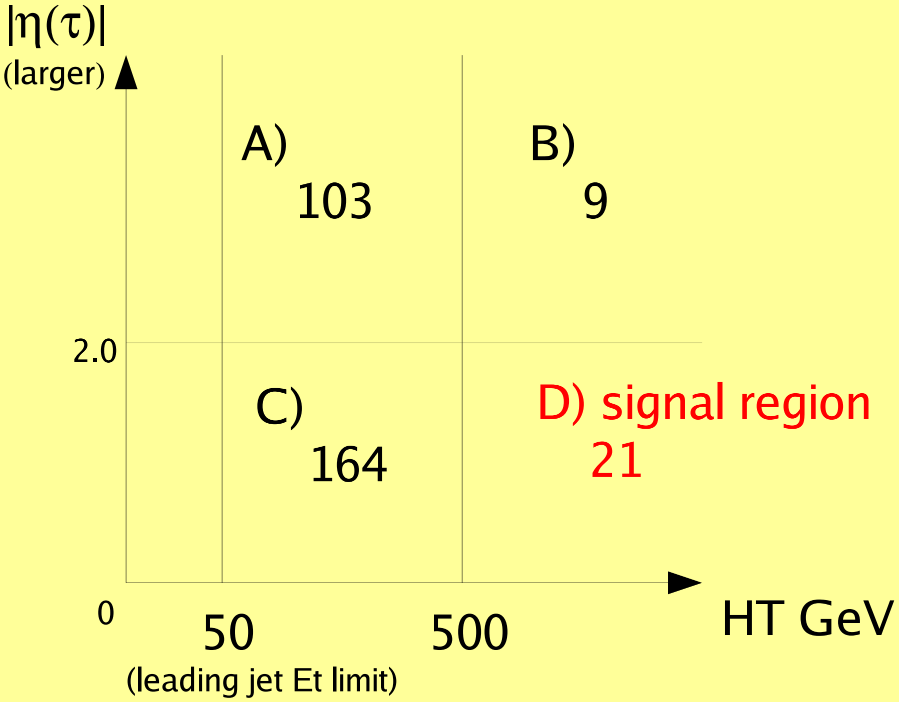
The estimated number in the signal region D is,
D = B/A x C = 1/3 x 7 = 2.3 +/- 2.8.
(Less statistics, but looks reasonable.)

ABCD method test (8) [Z jets consistency check]

0.34fb^{-1} Z jets

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 100 GeV**
- **Leading jet Et > 50 GeV**



The estimated number in the signal region D is,
D = B/A x C = 9/103 x 164 = 14.3 +/- 5.1
(Fair (1.3σ) agreement with the true number 21.)

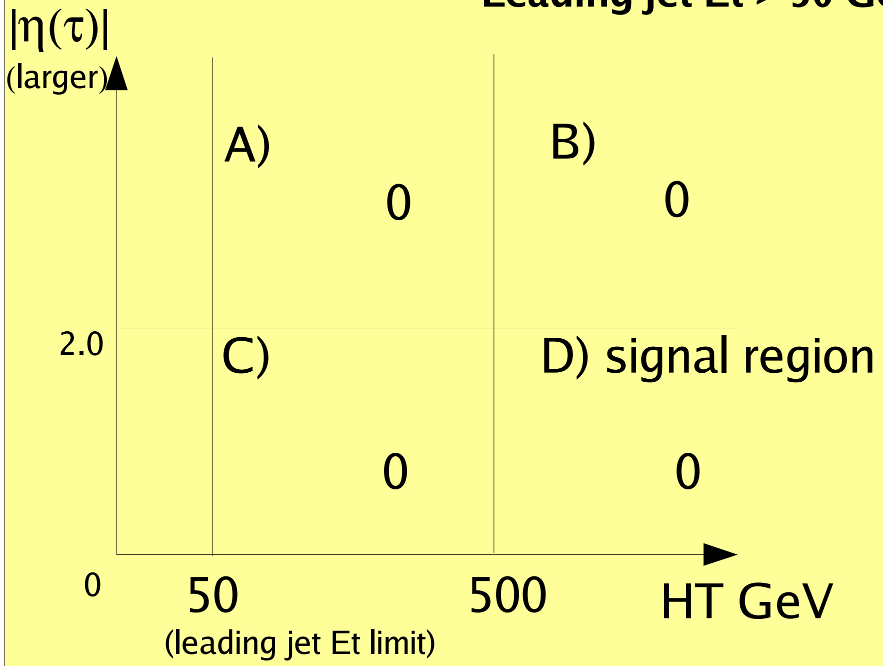
ABCD method test (10)

[QCD (100GeV<HT<250GeV) contamination]

QCD100to250
$0.84\mathrm{pb}^{-1}$

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**



$|\eta(\tau)|$
(larger)

A) 0

B) 0

C) 0

D) signal region 0

2.0

0

50
(leading jet Et limit)

500

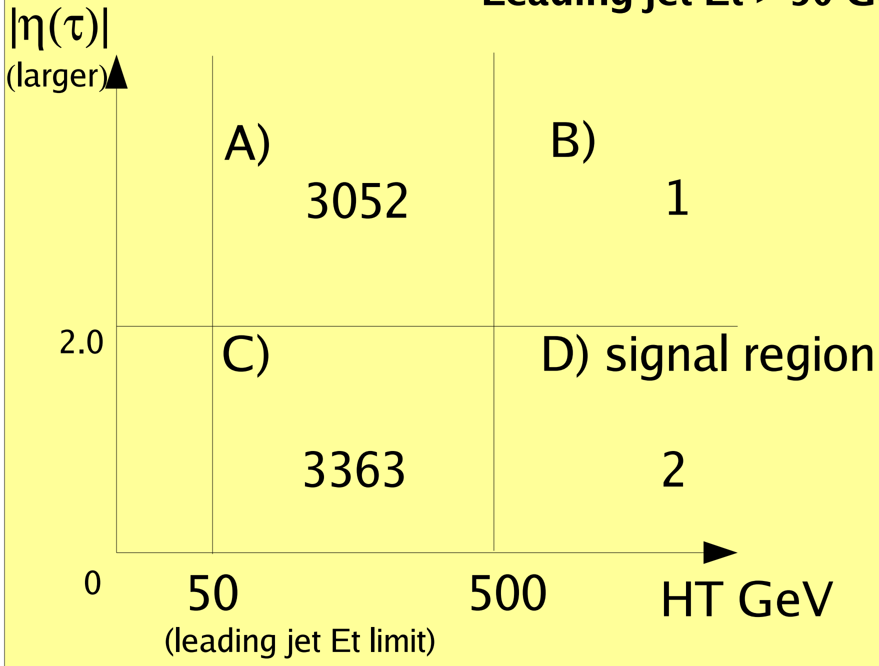
HT GeV

ABCD method test (10)

[QCD (100GeV<HT<250GeV) contamination]

QCD100to250
0.84pb^{-1}
#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Without MET cut**
- **Leading jet Et > 50 GeV**



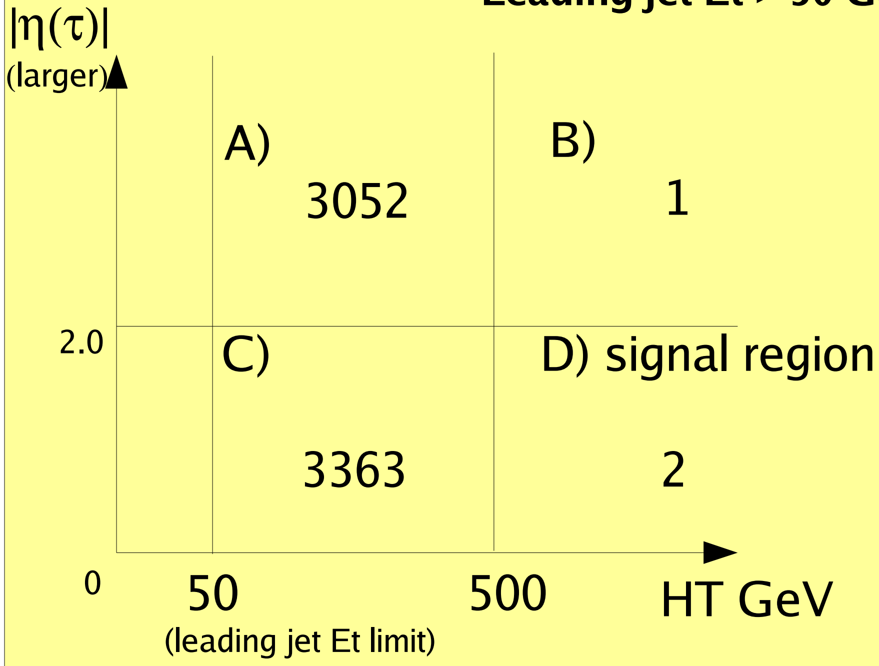
A) 3052	B) 1
C) 3363	D) signal region 2

ABCD method test (10)

[QCD (100GeV<HT<250GeV) contamination]

QCD100to250
0.84pb^{-1}
#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Without MET cut**
- **Leading jet Et > 50 GeV**



|η(τ)|
(larger)

A) 3052

B) 1

C) 3363

D) signal region 2

2.0

0

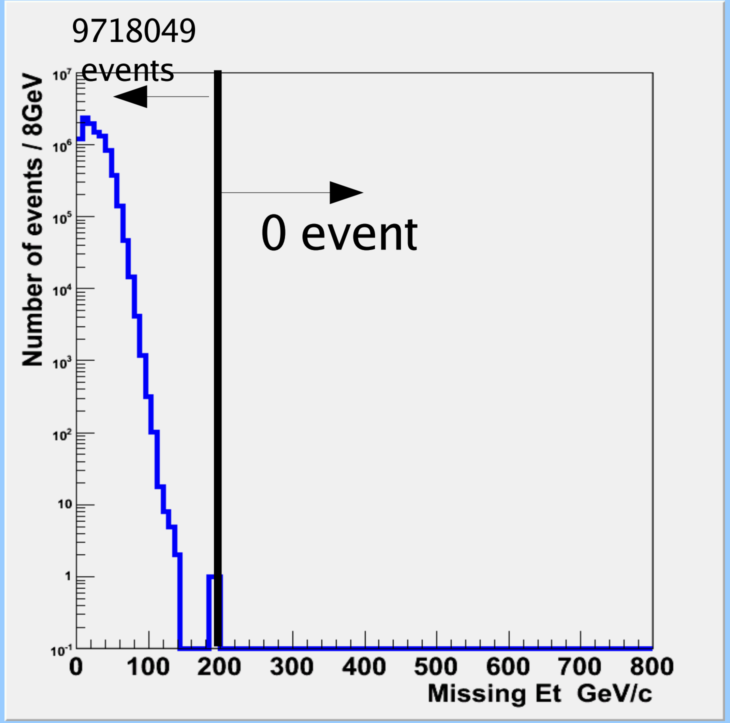
50
(leading jet Et limit)

500

HT GeV

QCD100to250
0.84pb^{-1}

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



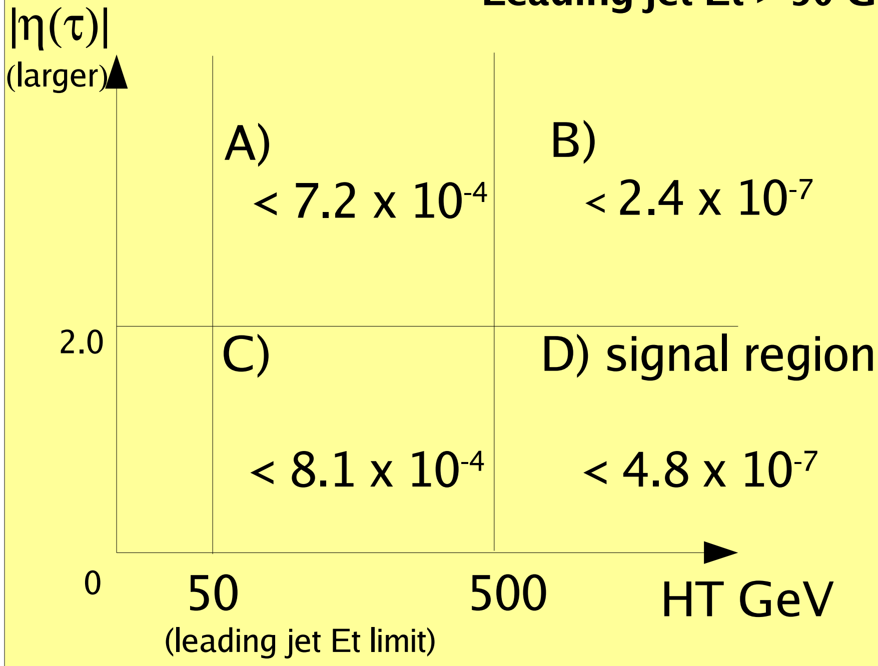
“MET > 200 GeV probability”,
2.3 / 9718049 = 2.4 x 10^{-7} (90% C.L.)

ABCD method test (10)

[QCD (100GeV<HT<250GeV) contamination]

QCD100to250
$0.84pb^{-1}$
#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Applied MET > 200 GeV probability”**
- **Leading jet Et > 50 GeV**



|η(τ)|
(larger)

A)
< 7.2 x 10^{-4}

B)
< 2.4 x 10^{-7}

2.0

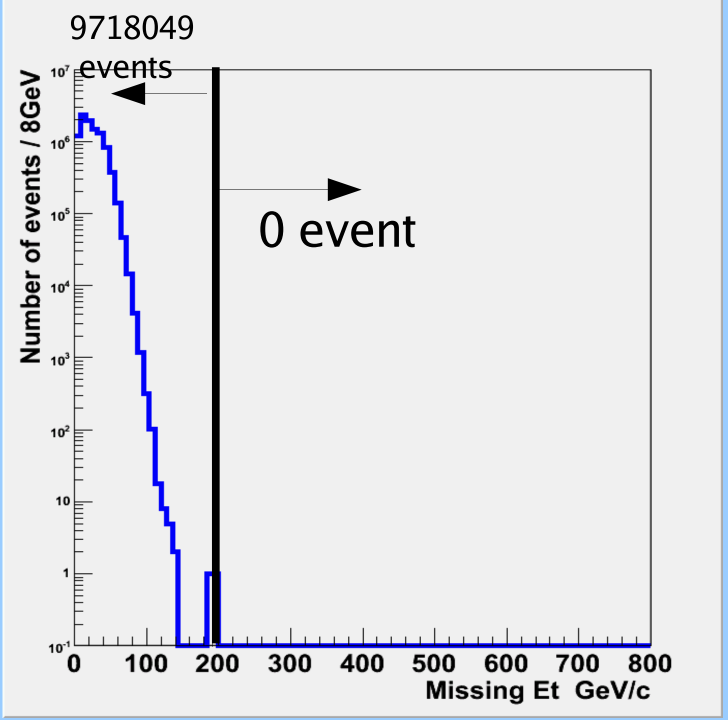
C)
< 8.1 x 10^{-4}

D) signal region
< 4.8 x 10^{-7}

0
50
(leading jet Et limit)
500
HT GeV

QCD100to250
$0.84pb^{-1}$

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



Note; This is very rough estimation.
(Not taking any correlation into accounts.)

“MET > 200 GeV probability”,
2.3 / 9718049 = 2.4 x 10^{-7} (90% C.L.)

ABCD method test (10)

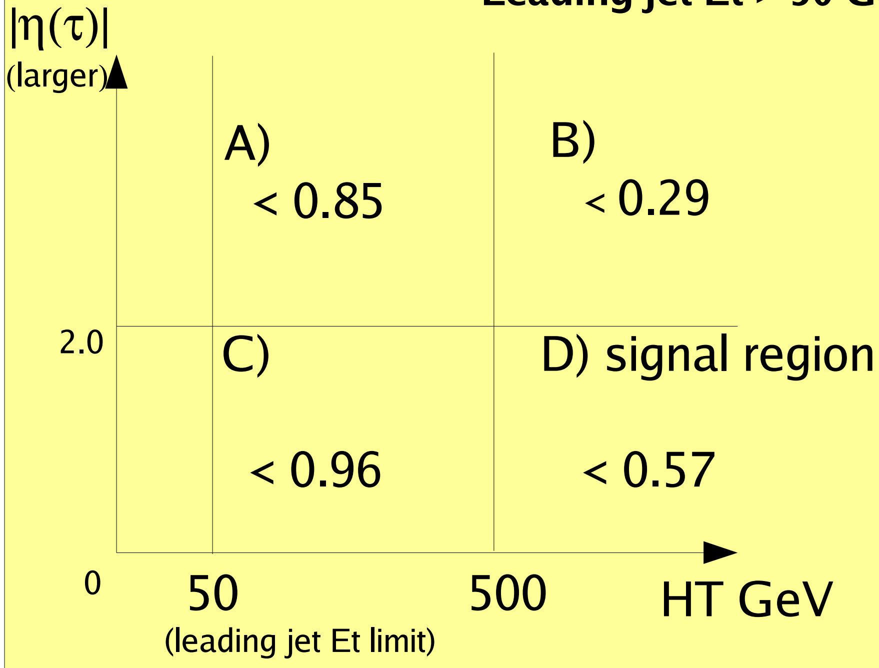
[QCD (100GeV<HT<250GeV) contamination]

QCD100to250

$1.0fb^{-1}$

#opposite sign τ pairs

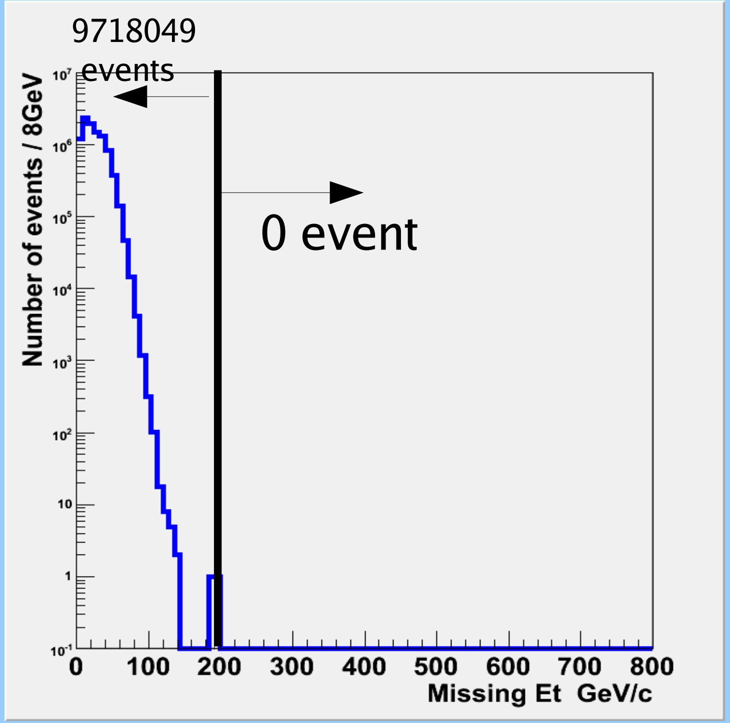
- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Applied MET > 200 GeV probability”**
- **Leading jet Et > 50 GeV**



QCD100to250

$0.84pb^{-1}$

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



Note; This is very rough estimation.
(Not taking any correlation into accounts.)

“MET > 200 GeV probability”,

$2.3 / 9718049 = 2.4 \times 10^{-7}$ (90% C.L.)

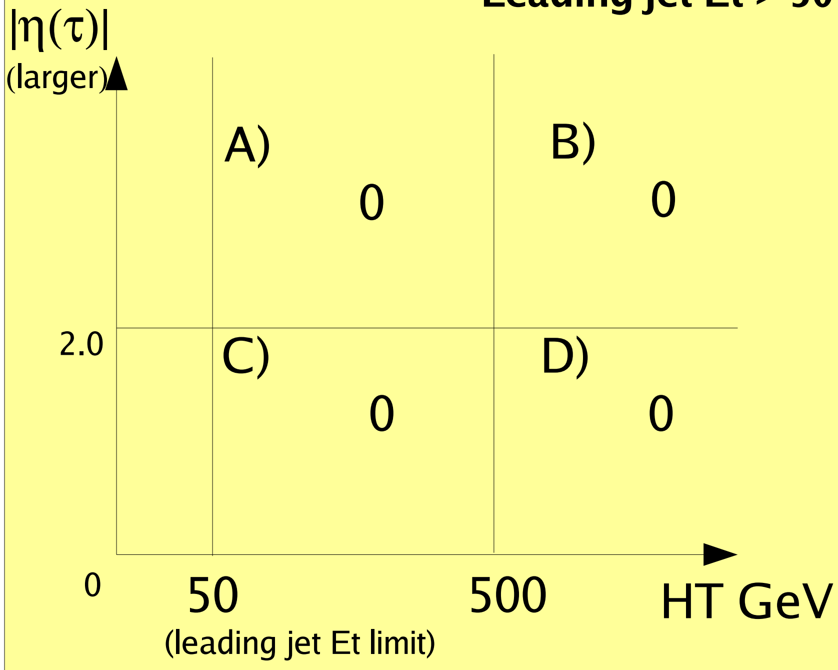
Backup; ABCD method test (11)

[QCD (250GeV<HT<500GeV) contamination]

QCD250to500
$13pb^{-1}$

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**



Backup; ABCD method test (11)

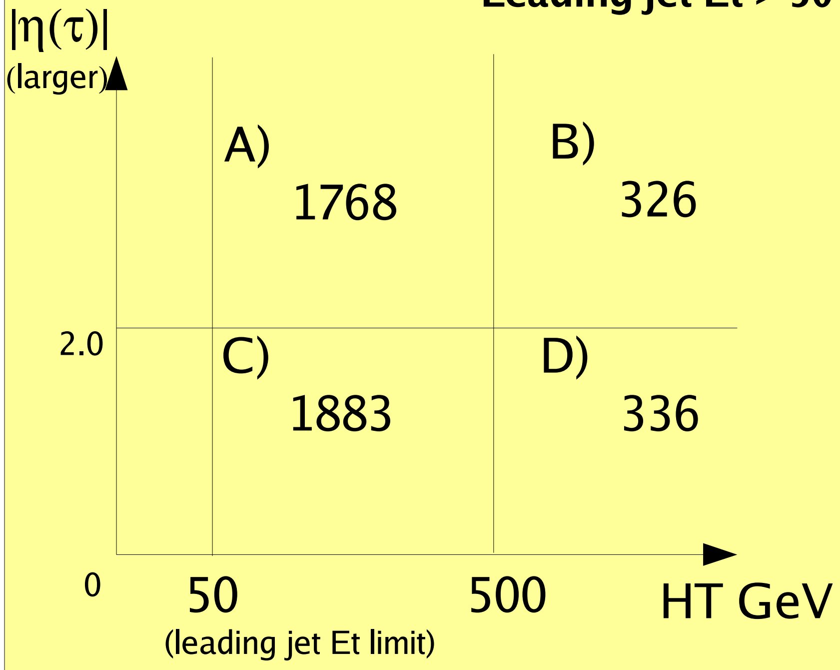
[QCD (250GeV<HT<500GeV) contamination]

QCD250to500

$13pb^{-1}$

#opposite sign τ pairs

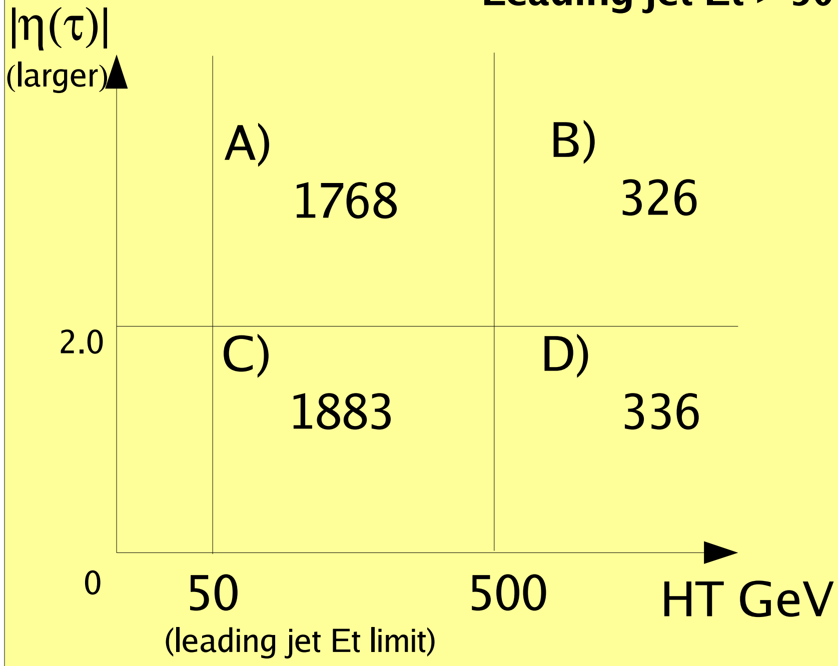
- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Without MET cut**
- **Leading jet Et > 50 GeV**



Backup; ABCD method test (11)
[QCD (250GeV<HT<500GeV) contamination]

QCD250to500
$13pb^{-1}$
#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Without MET cut**
- **Leading jet Et > 50 GeV**



|η(τ)|
(larger)

A) 1768

B) 326

C) 1883

D) 336

2.0

0

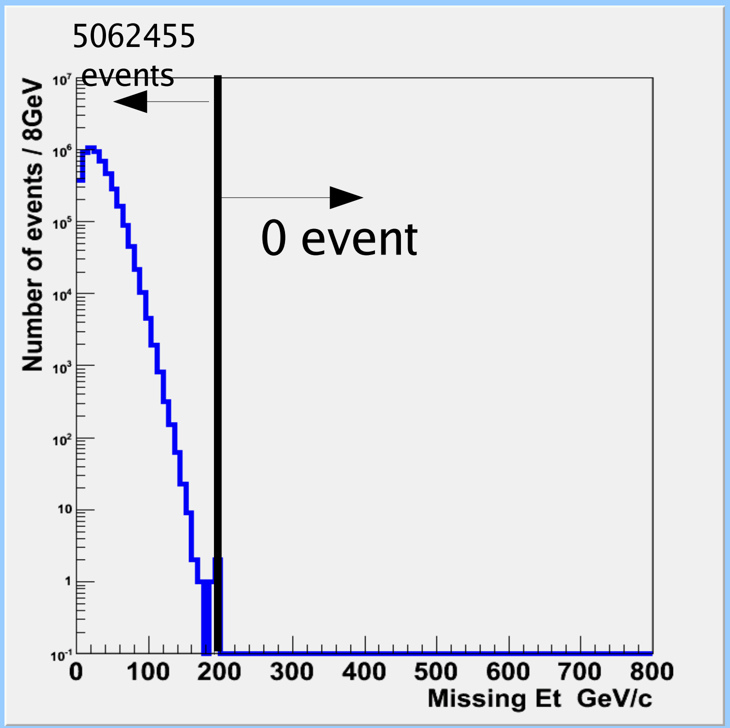
50
(leading jet Et limit)

500

HT GeV

QCD250to500
$13pb^{-1}$

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



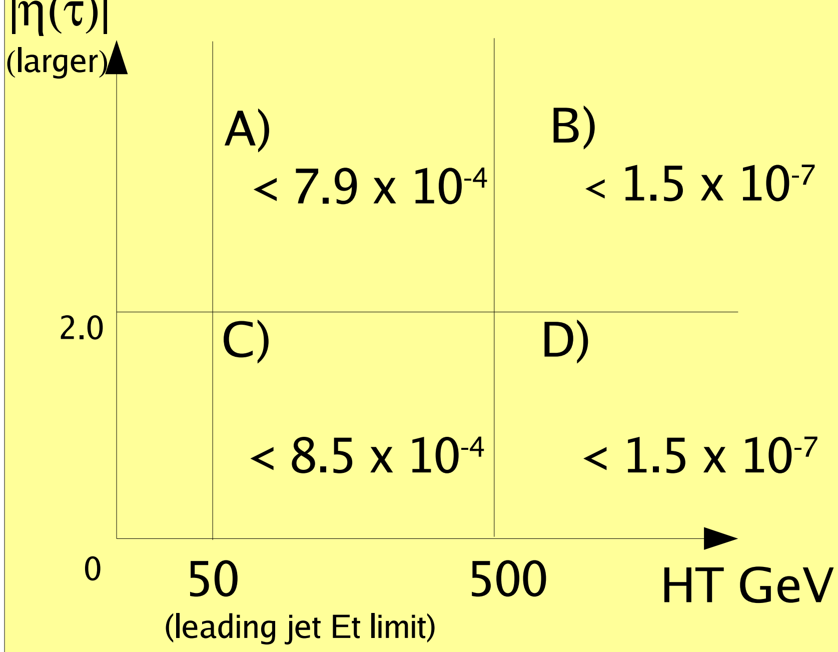
"MET > 200 GeV probability,"
2.3 / 5062455 = 4.5 x 10^{-7} (90% C.L.)

Backup;   ABCD method test (11)

[QCD (250GeV<HT<500GeV) contamination]

QCD250to500
$13 pb^{-1}$
#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Applied MET > 200 GeV probability”**
- **Leading jet Et > 50 GeV**



|η(τ)|
(larger)

A) $< 7.9 \times 10^{-4}$

B) $< 1.5 \times 10^{-7}$

C) $< 8.5 \times 10^{-4}$

D) $< 1.5 \times 10^{-7}$

2.0

0

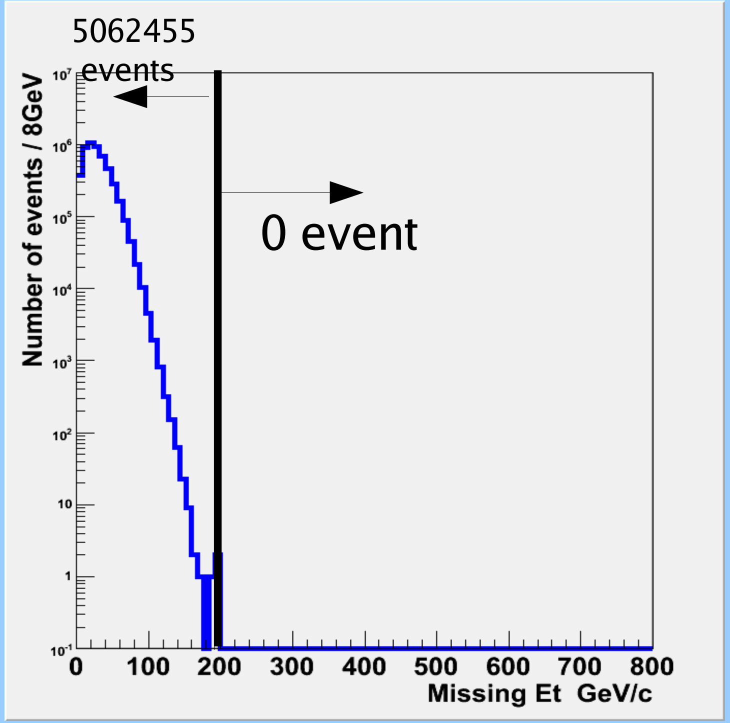
50
(leading jet Et limit)

500

HT GeV

QCD250to500
$13 pb^{-1}$

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



Note; This is very rough estimation.
(Not taking any correlation into accounts.)

“MET > 200 GeV probability”,
$2.3 / 5062455 = 4.5 \times 10^{-7}$ (90% C.L.)

Backup; ABCD method test (11)

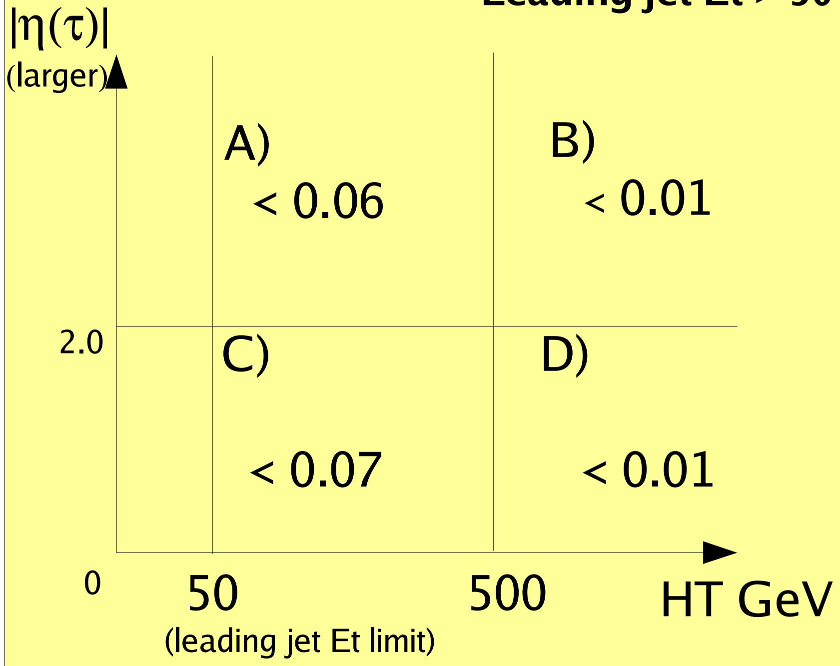
[QCD (250GeV<HT<500GeV) contamination]

QCD250to500

$1.0 fb^{-1}$

#opposite sign τ pairs

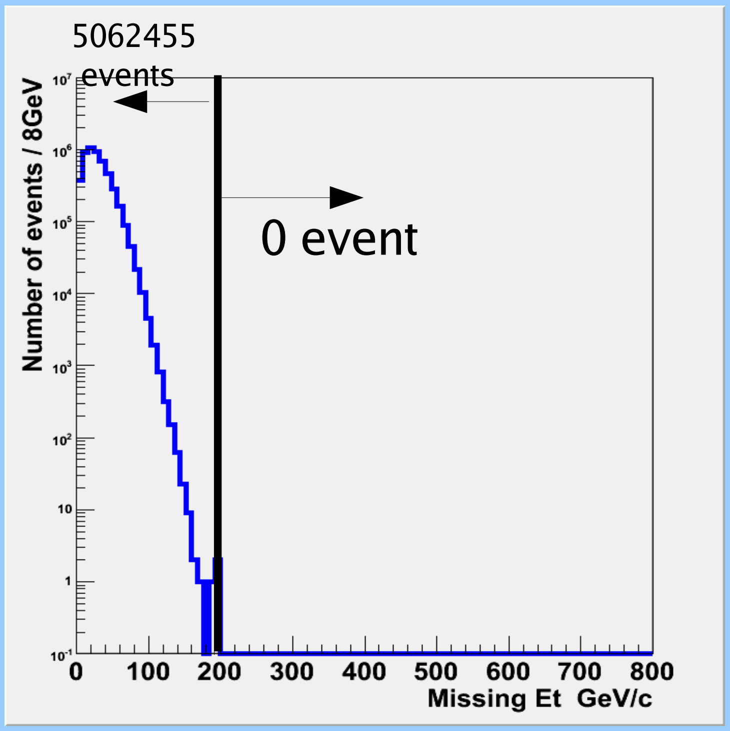
- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Applied MET > 200 GeV probability”**
- **Leading jet Et > 50 GeV**



QCD250to500

$13 pb^{-1}$

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



Note; This is very rough estimation.
(Not taking any correlation into accounts.)

“MET > 200 GeV probability”,
$2.3 / 5062455 = 4.5 \times 10^{-7}$ (90% C.L.)

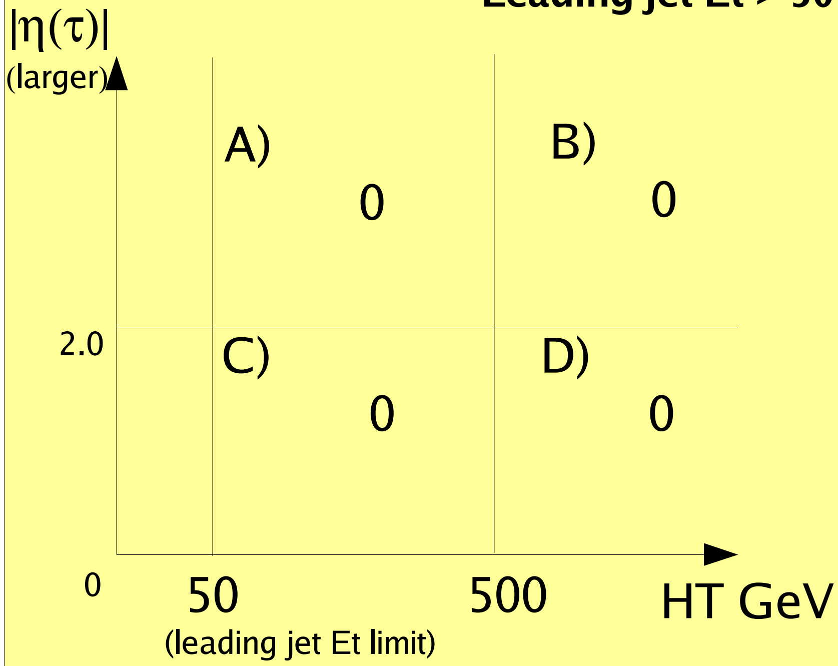
Backup; ABCD method test (12)

[QCD (500GeV<HT<1000GeV) contamination]

QCD500to1000
$0.33 fb^{-1}$

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**



$|\eta(\tau)|$
(larger)

A)
0

B)
0

2.0

C)
0

D)
0

0

50
(leading jet Et limit)

500

HT GeV

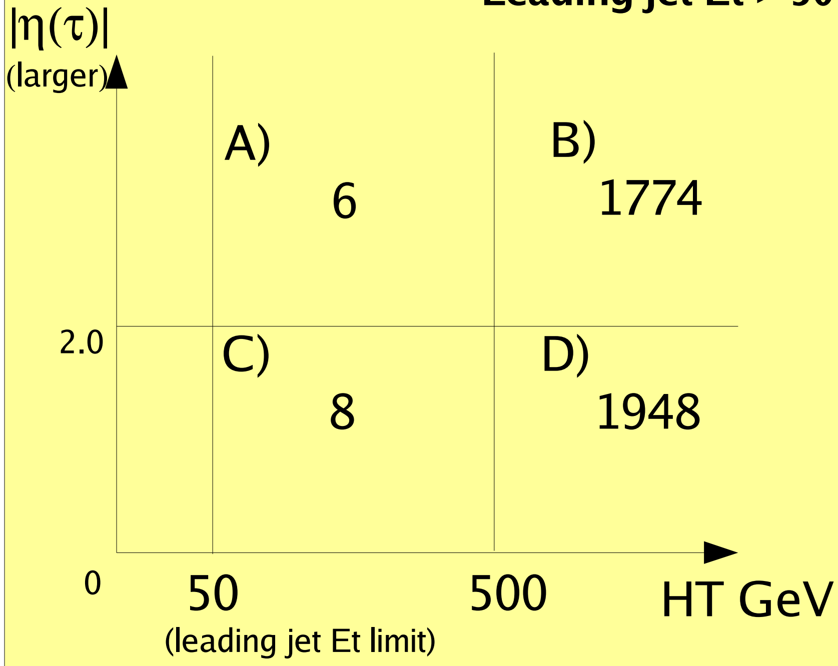
Backup; ABCD method test (12)

[QCD (500GeV<HT<1000GeV) contamination]

QCD500to1000
$0.33 fb^{-1}$

#opposite sign τ pairs

- **Tau pairs with $Pt(\tau) > 5$ GeV/c**
- **Without MET cut**
- **Leading jet Et > 50 GeV**



A) 6	B) 1774
C) 8	D) 1948

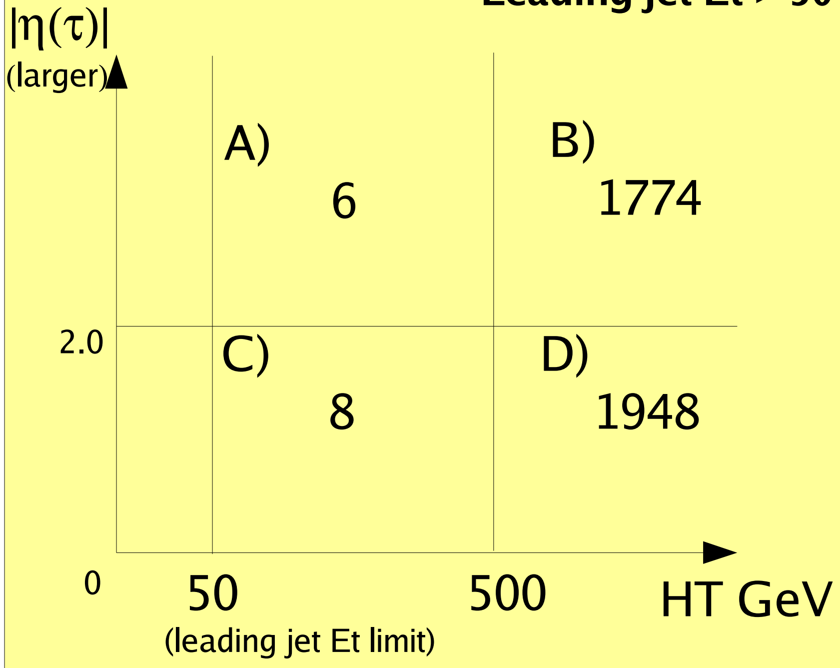
Backup; ABCD method test (12)

[QCD (500GeV<HT<1000GeV) contamination]

QCD500to1000
$0.33\mathrm{fb}^{-1}$

#opposite sign τ pairs

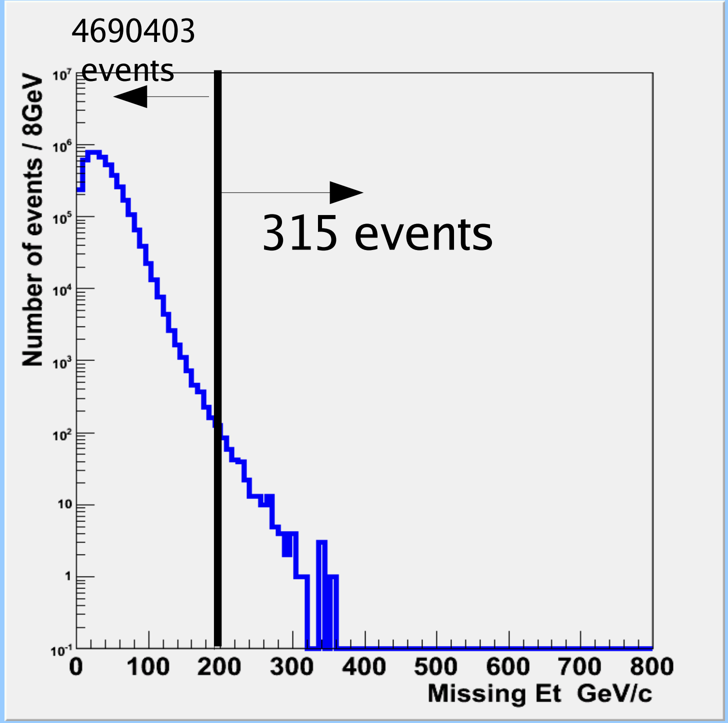
- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Without MET cut**
- **Leading jet Et > 50 GeV**



	HT < 500	HT > 500
|η(τ)| > 2.0	A) 6	B) 1774
|η(τ)| < 2.0	C) 8	D) 1948

QCD500to1000
$0.33\mathrm{fb}^{-1}$

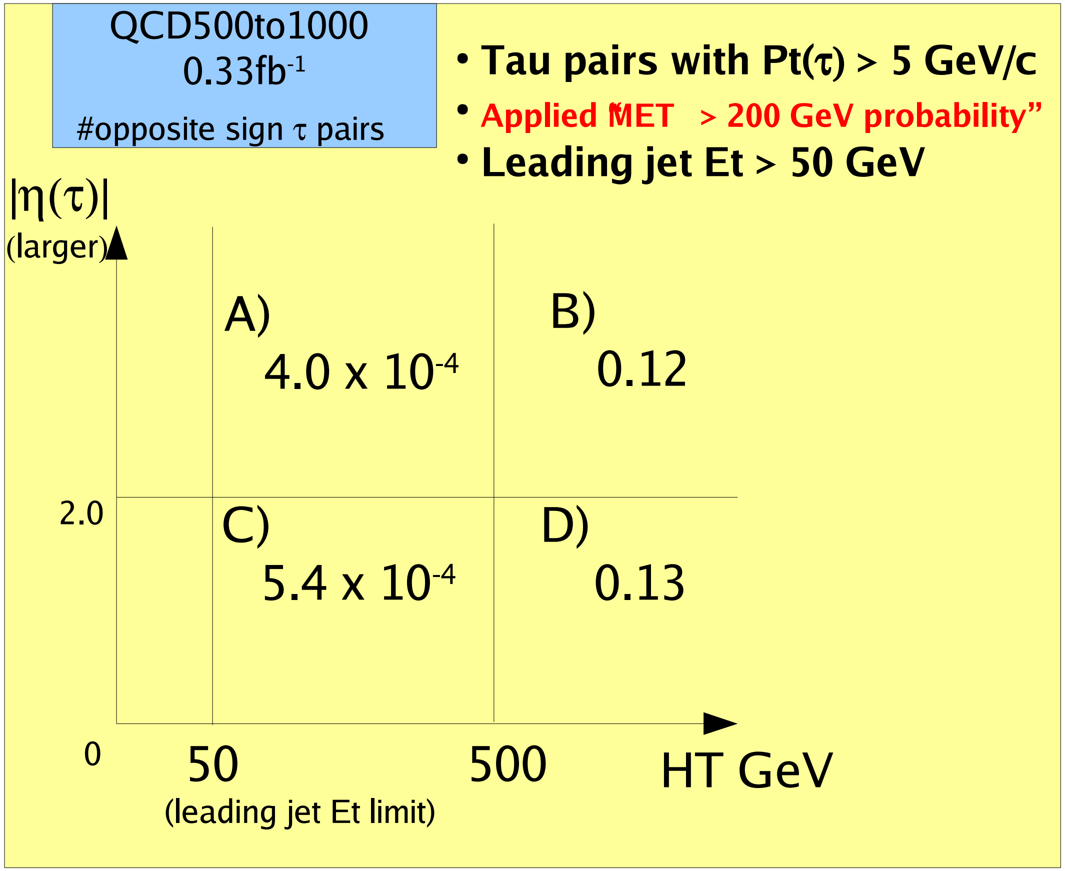
- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



"MET > 200 GeV probability",
$315 / 4690403 = 6.7 \times 10^{-5}$

Backup; ABCD method test (12)

[QCD (500GeV<HT<1000GeV) contamination]

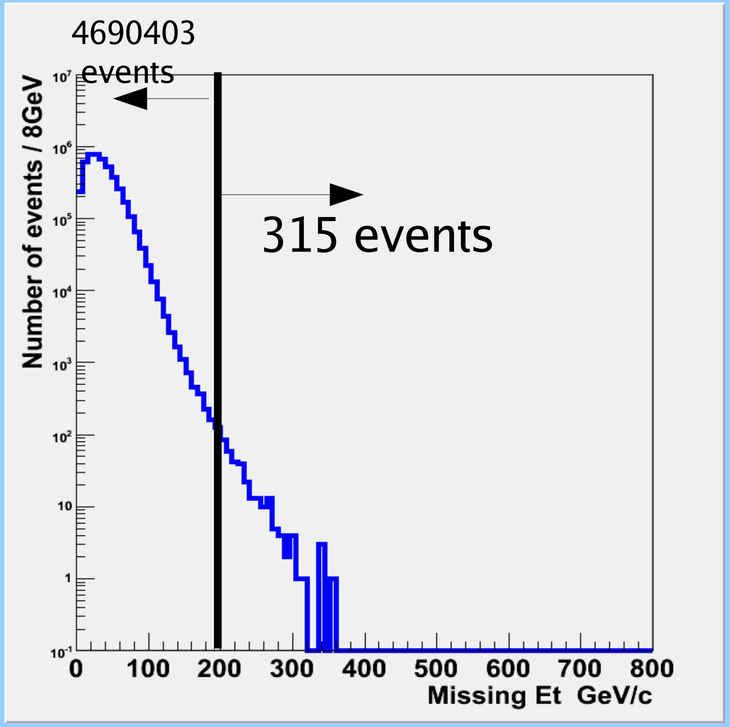


QCD500to1000
$0.33fb^{-1}$
#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Applied MET > 200 GeV probability”**
- **Leading jet Et > 50 GeV**

QCD500to1000
$0.33fb^{-1}$

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



Note; This is very rough estimation.
(Not taking any correlation into accounts.)

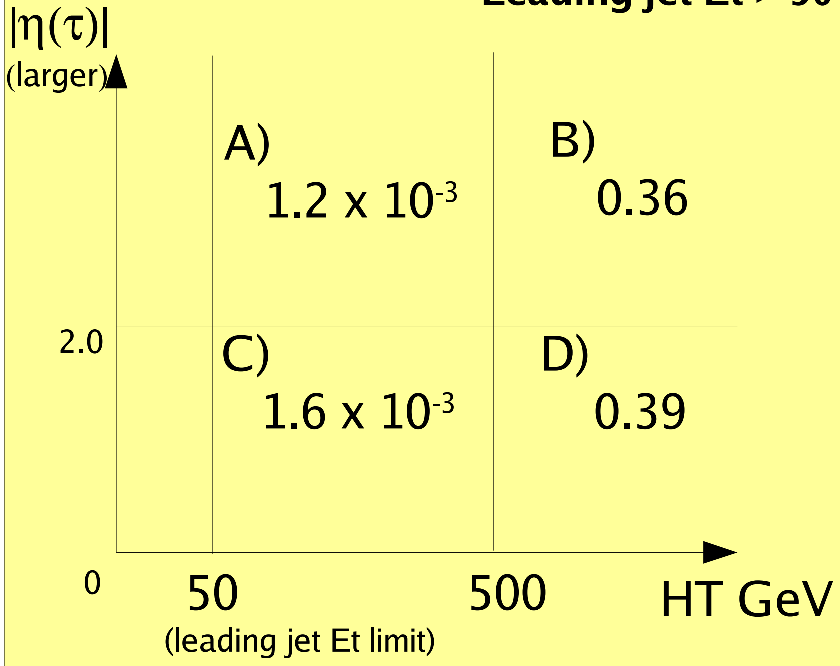
“MET > 200 GeV probability”,
$315 / 4690403 = 6.7 \times 10^{-5}$

Backup; ABCD method (12)

[QCD (500GeV<HT<1000GeV) contamination]

QCD500to1000
1.0fb^{-1}
#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Applied MET > 200 GeV probability”**
- **Leading jet Et > 50 GeV**



$|\eta(\tau)|$ (larger)

A) 1.2×10^{-3}

B) 0.36

C) 1.6×10^{-3}

D) 0.39

2.0

0

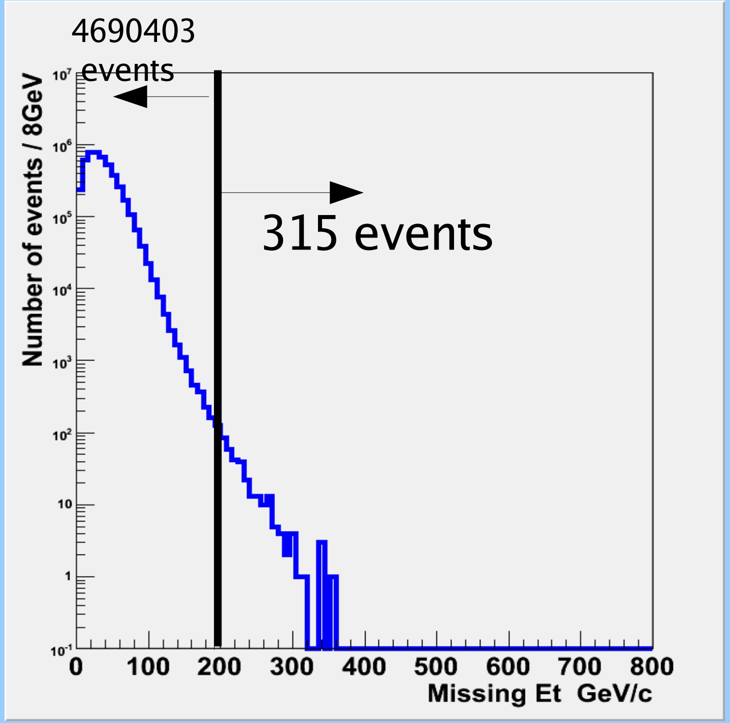
50 (leading jet Et limit)

500

HT GeV

QCD500to1000
0.33fb^{-1}

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



4690403 events

315 events

Note; This is very rough estimation.
(Not taking any correlation into accounts.)

“MET > 200 GeV probability”,
315 / 4690403 = 6.7×10^{-5}

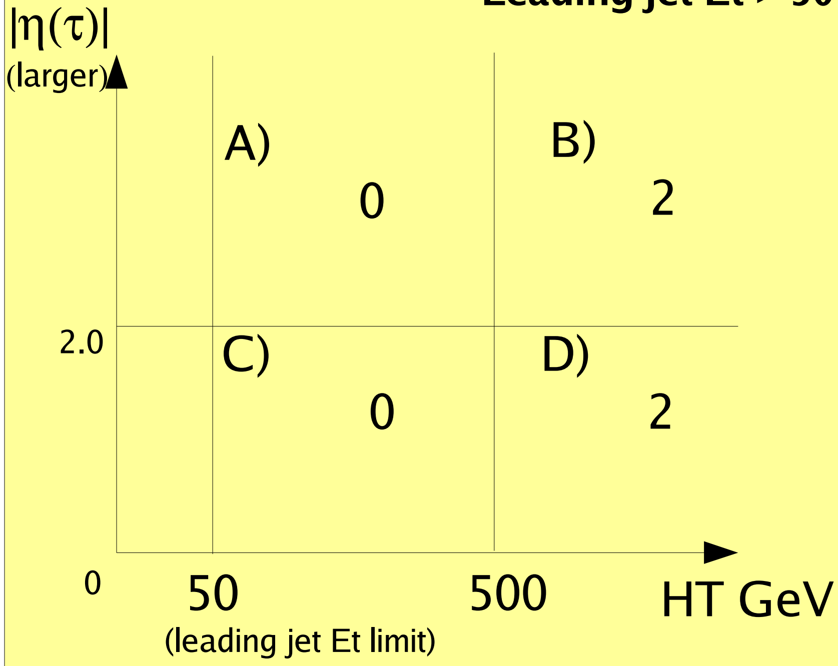
Backup; ABCD method test (13)

[QCD (1000GeV<HT<Infinity) contamination]

QCD1000toInf
2.9fb^{-1}

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **MET > 200 GeV**
- **Leading jet Et > 50 GeV**



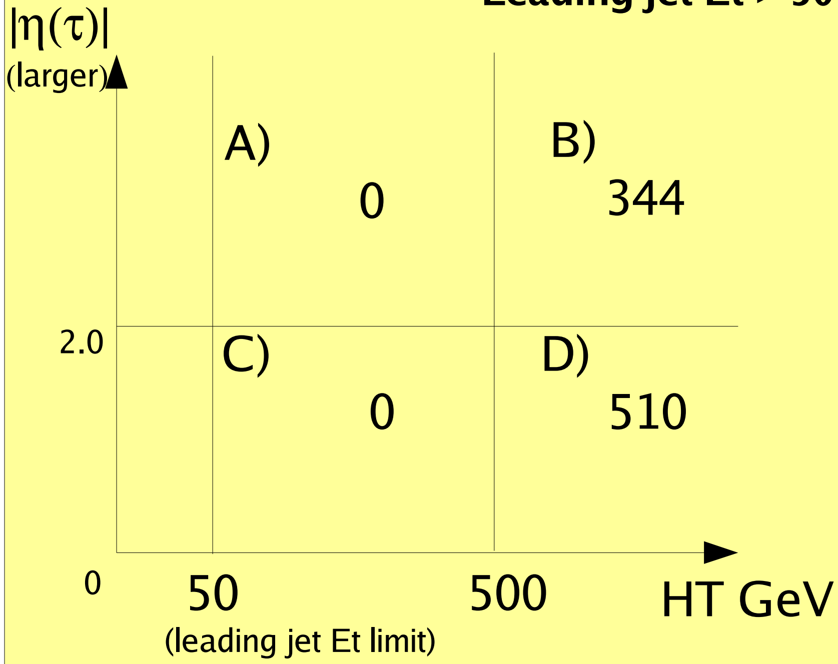
Backup; ABCD method test (13)

[QCD (1000GeV<HT<Infinity) contamination]

QCD1000toInf
$2.9 fb^{-1}$

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Without MET cut**
- **Leading jet Et > 50 GeV**

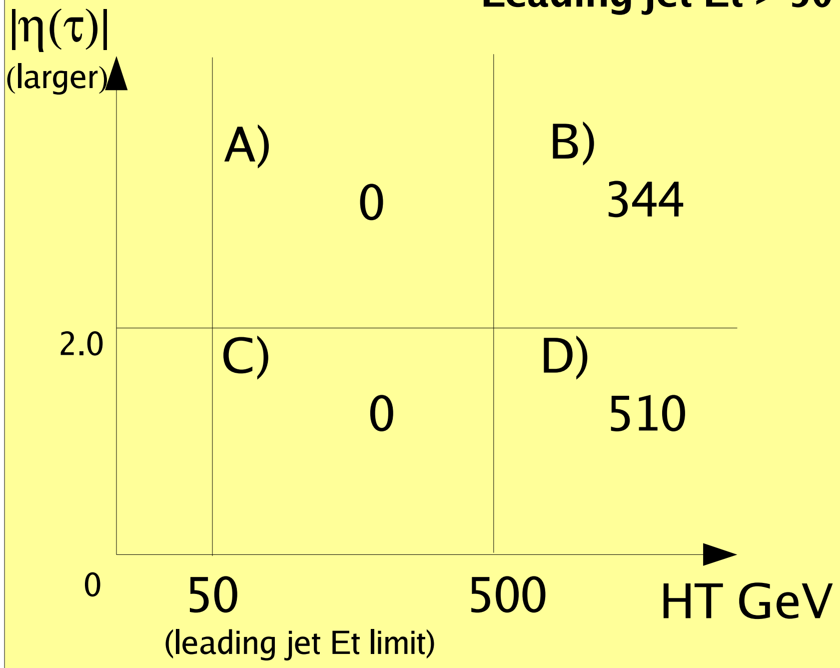


Backup; ABCD method test (13)

[QCD (1000GeV<HT<Infinity) contamination]

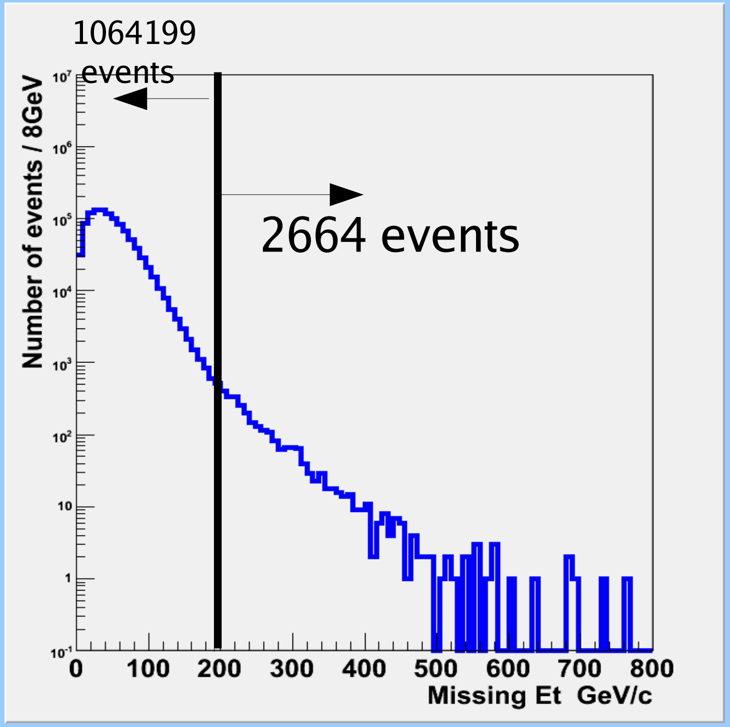
QCD1000toInf
$2.9fb^{-1}$
#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Without MET cut**
- **Leading jet Et > 50 GeV**



QCD1000toInf
$2.9fb^{-1}$

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



“MET > 200 GeV probability,”
$2664 / 1064199 = 2.5 \times 10^{-3}$

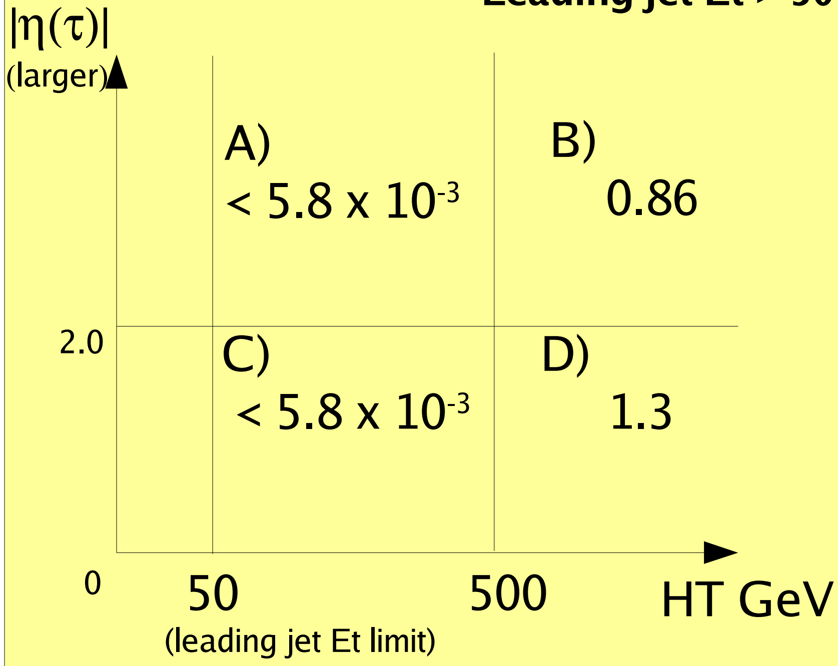
Backup; ABCD method test (13)

[QCD (1000GeV<HT<Infinity) contamination]

QCD1000toInf
2.9fb^{-1}

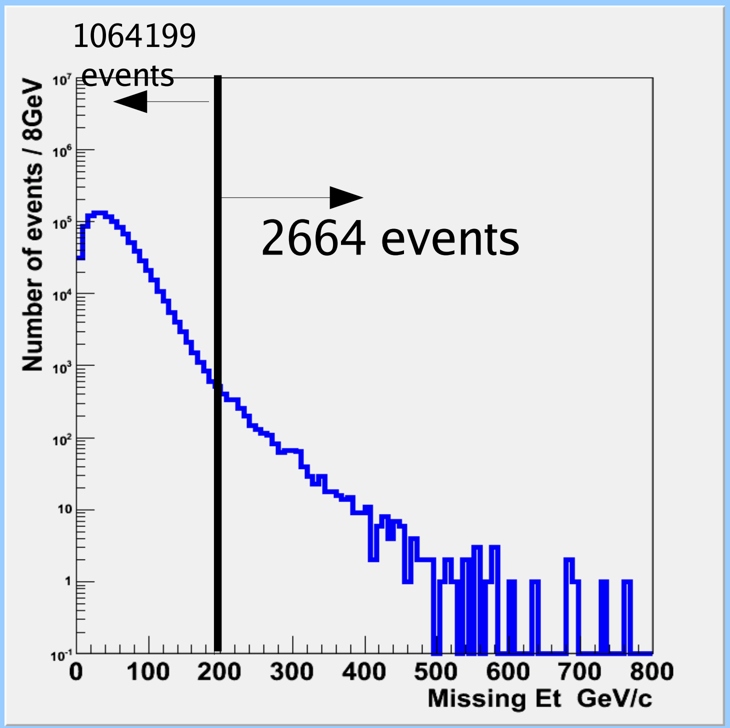
#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Applied MET > 200 GeV probability”**
- **Leading jet Et > 50 GeV**



QCD1000toInf
2.9fb^{-1}

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



Note; This is very rough estimation.
(Not taking any correlation into accounts.)

“MET > 200 GeV probability”,
2664 / 1064199 = 2.5 x 10^{-3}

Backup; ABCD method test (13)

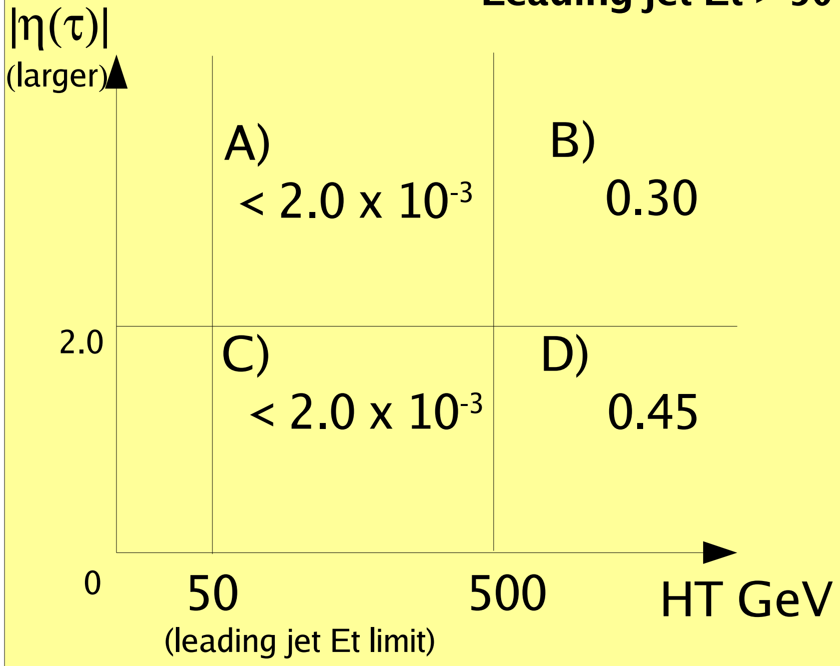
[QCD (1000GeV<HT<Infinity) contamination]

QCD1000toInf

1.0fb^{-1}

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Applied MET > 200 GeV probability"**
- **Leading jet Et > 50 GeV**



$|\eta(\tau)|$ (larger)

A) < 2.0 x 10^{-3}

B) 0.30

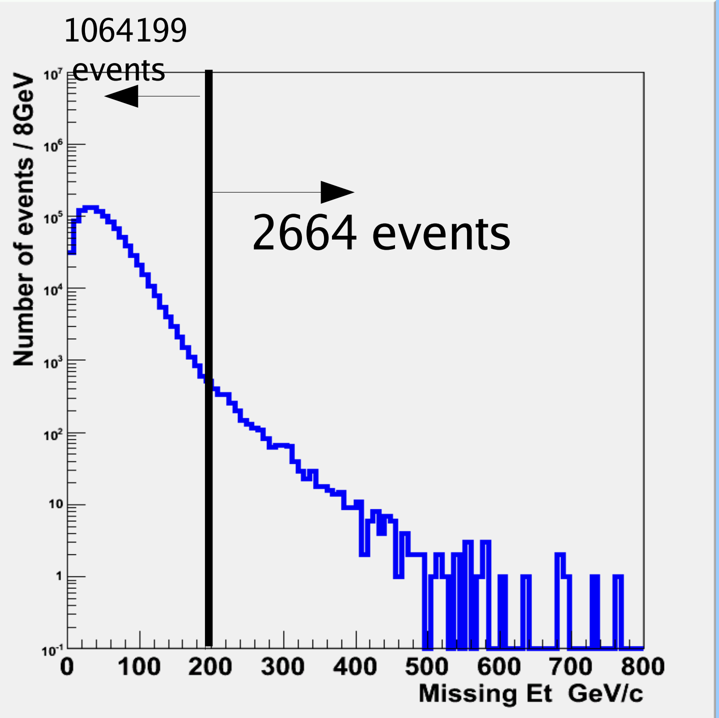
C) < 2.0 x 10^{-3}

D) 0.45

QCD1000toInf

2.9fb^{-1}

- **Without τ pair requirement**
- **Leading jet Et > 50 GeV**



1064199 events

2664 events

Note; This is very rough estimation.
(Not taking any correlation into accounts.)

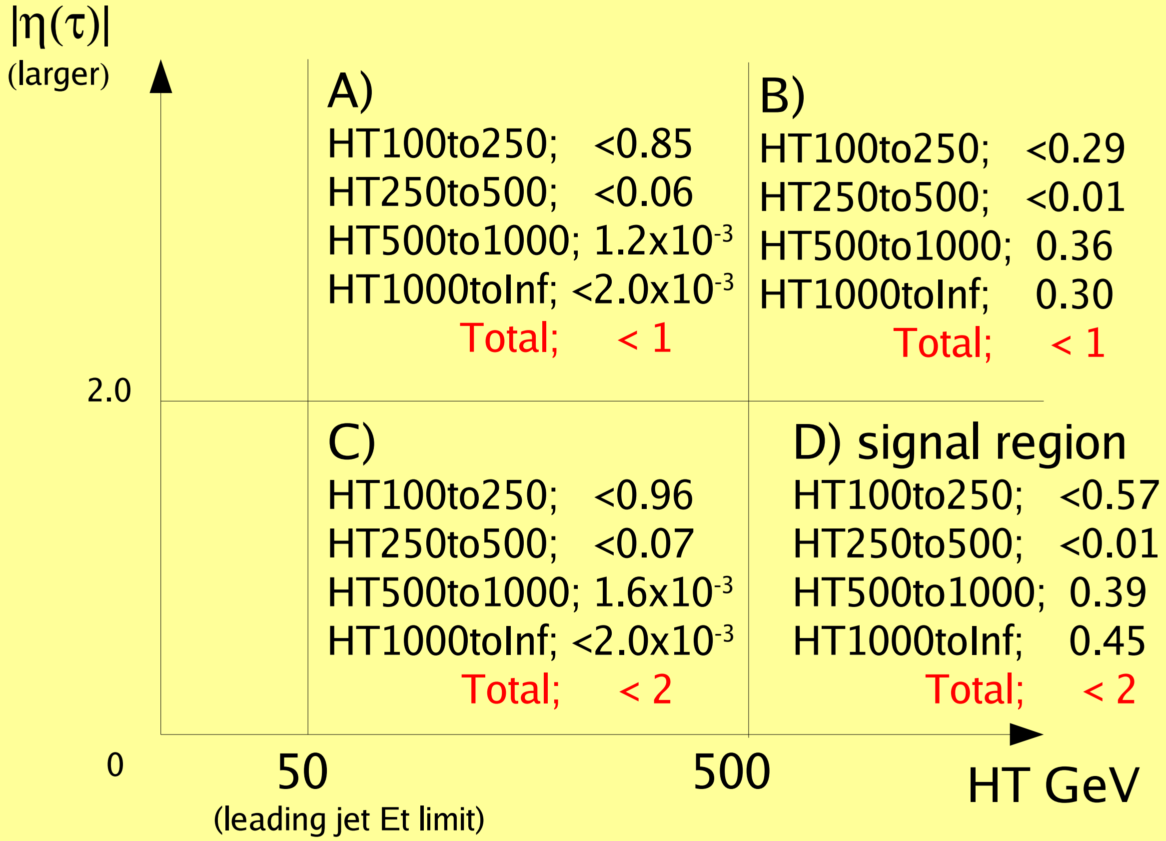
"MET > 200 GeV probability",
2664 / 1064199 = 2.5 x 10^{-3}

ABCD method test (11) [QCD at 1fb^{-1}]

QCD 1.0fb^{-1}

#opposite sign τ pairs

- **Tau pairs with Pt(τ) > 5 GeV/c**
- **Applied "MET > 200 GeV probability"**
- **Leading jet Et > 50 GeV**



A)
HT100to250; <0.85
HT250to500; <0.06
HT500to1000; 1.2x10^{-3}
HT1000toInf; <2.0x10^{-3}
Total; < 1

B)
HT100to250; <0.29
HT250to500; <0.01
HT500to1000; 0.36
HT1000toInf; 0.30
Total; < 1

C)
HT100to250; <0.96
HT250to500; <0.07
HT500to1000; 1.6x10^{-3}
HT1000toInf; <2.0x10^{-3}
Total; < 2

D) signal region
HT100to250; <0.57
HT250to500; <0.01
HT500to1000; 0.39
HT1000toInf; 0.45
Total; < 2

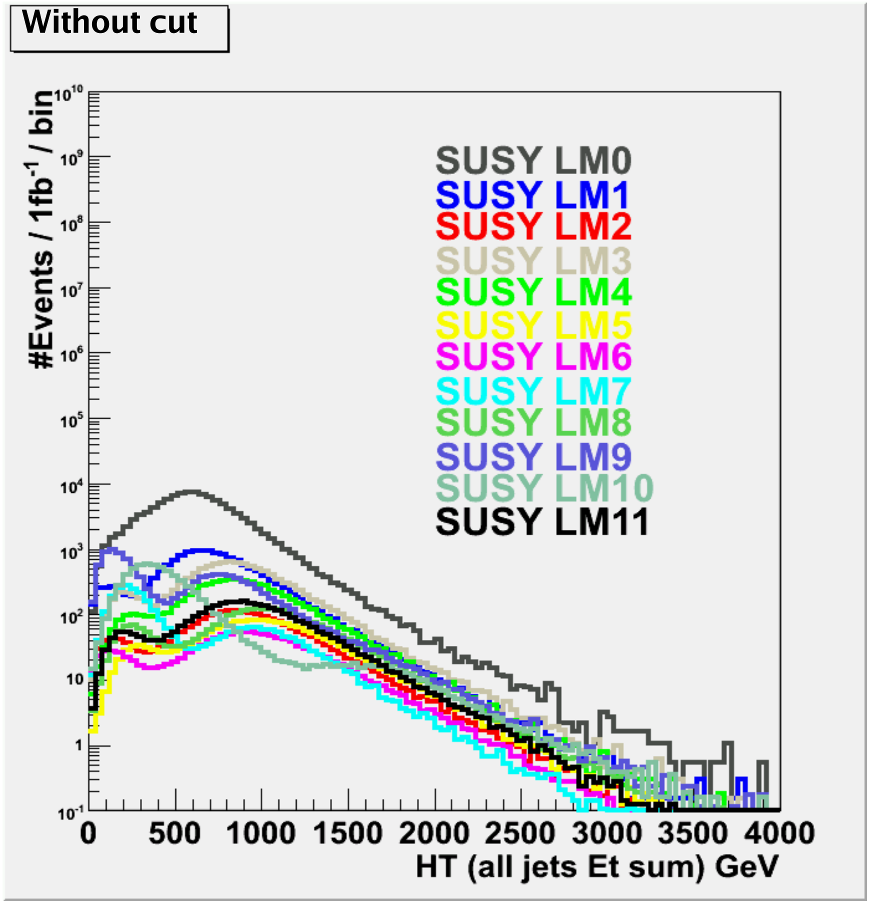
Control region definitions are not yet optimized at all.

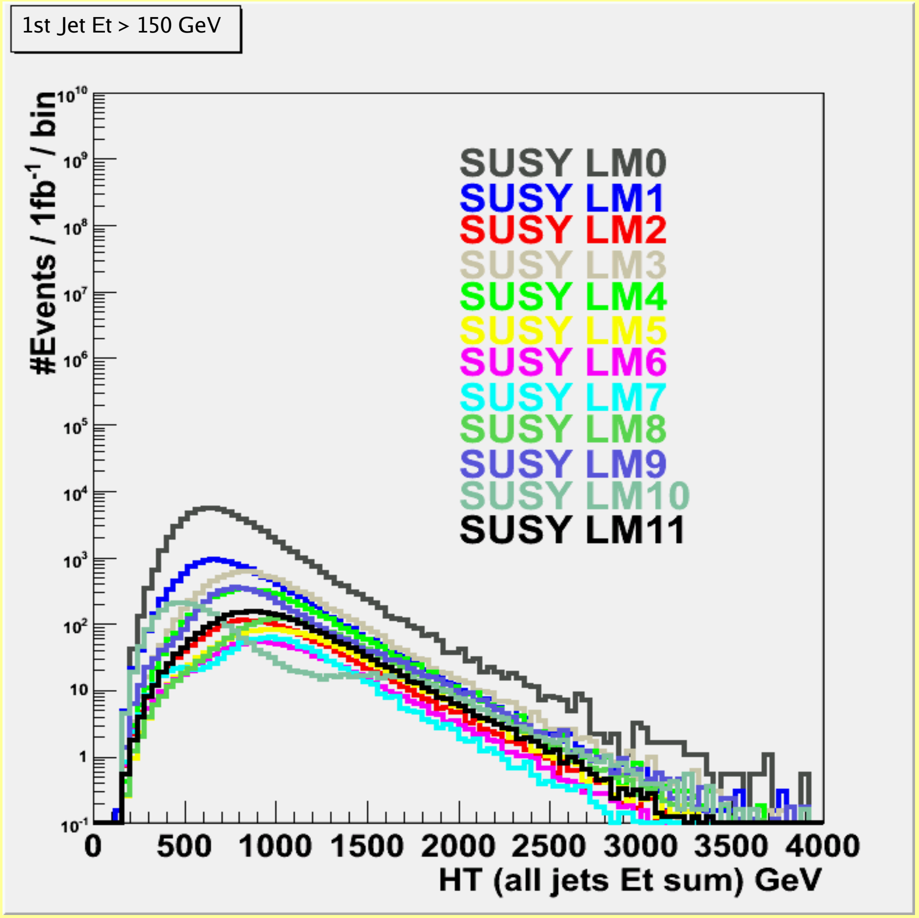
Note; This is very rough estimation for individual A, B, C or D, since MET and HT are correlated.
However, ABCD sum is not so bad estimation. (though just in this MC)

Backup;   HT low energy bump

Only with leading jet Et cut:

Leading jet Et > 150 GeV

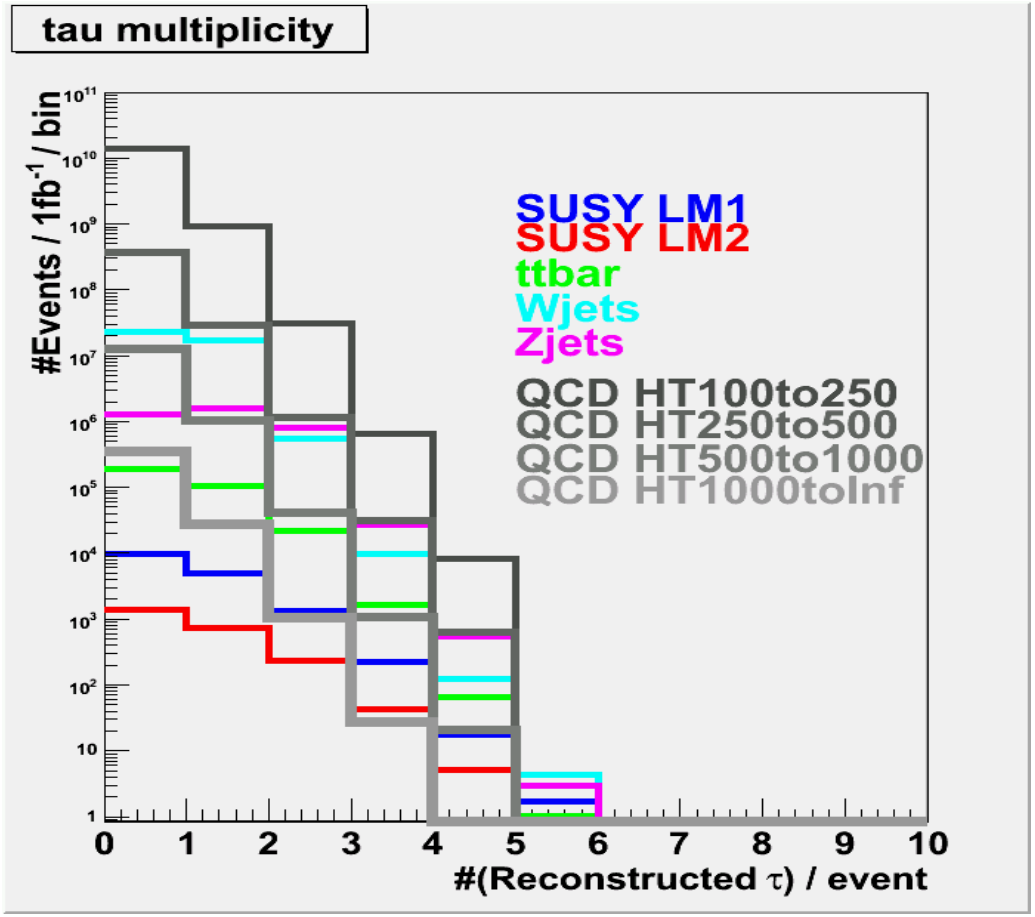




Note: The bump would be the case of that the real leading jet is out of the detector acceptance.

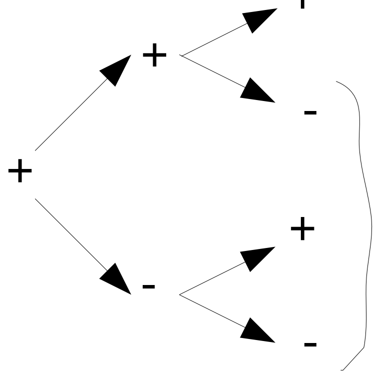
Backup;
Reconstructed τ multiplicity

Without any cut
(It is PAT-τ default.)



Backup:
Discussion for combinatorics
(Case of three charged tracks)

Three uniform charged tracks,



(and charge conjugate)

combination	probability	#opposite sign pairs	#same sign pairs
+++	1/4	0	3
++- or +--	3/4	2	1

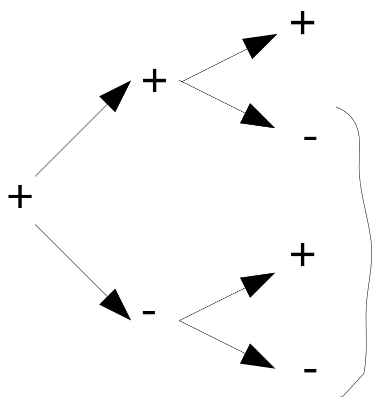
normalized

	#opposite sign pairs	#same sign pairs
	0	3/4
	3/2	3/4
sum	3/2	3/2

This is equal only when
P(+++):P(++- or +--) = 1/4:3/4.

Backup:
Discussion for combinatorics
(Case of three charged tracks)

Three uniform charged tracks,



(and charge conjugate)

combination	probability	#opposite sign pairs	#same sign pairs
+++	1/4	0	3
++- or +--	3/4	2	1

normalized

	#opposite sign pairs	#same sign pairs
	0	3/4
	3/2	3/4
sum	3/2	3/2

This is equal only when P(+++):P(++- or +--) = 1/4:3/4.

In fact, this probability assumption may not be correct due to the initial pp charge constraint.

Backup:
Discussion for combinatorics (general case)

Just repeated the same calculation with the previous slide for different cases.

- #tracks = 2 case, #opposite sign pair = 1
  #same sign pair = 1
- #tracks = 3 case, #opposite sign pair = 3 [Twice (charge conjugate) of
  #same sign pair = 3 the previous slide.]
- #tracks = 4 case, #opposite sign pair = 6
  #same sign pair = 6
- #tracks = 5 case, #opposite sign pair = 10
  #same sign pair = 10

In any case, #opposite sign pairs = #same sign pairs.