SUSY in top final states at mSUGRA point LM1 with CMS

Saeid Paktinat (IPM, Tehran)

Luc Pape (ETH, Zurich)

Maria Spiropulu (CERN)

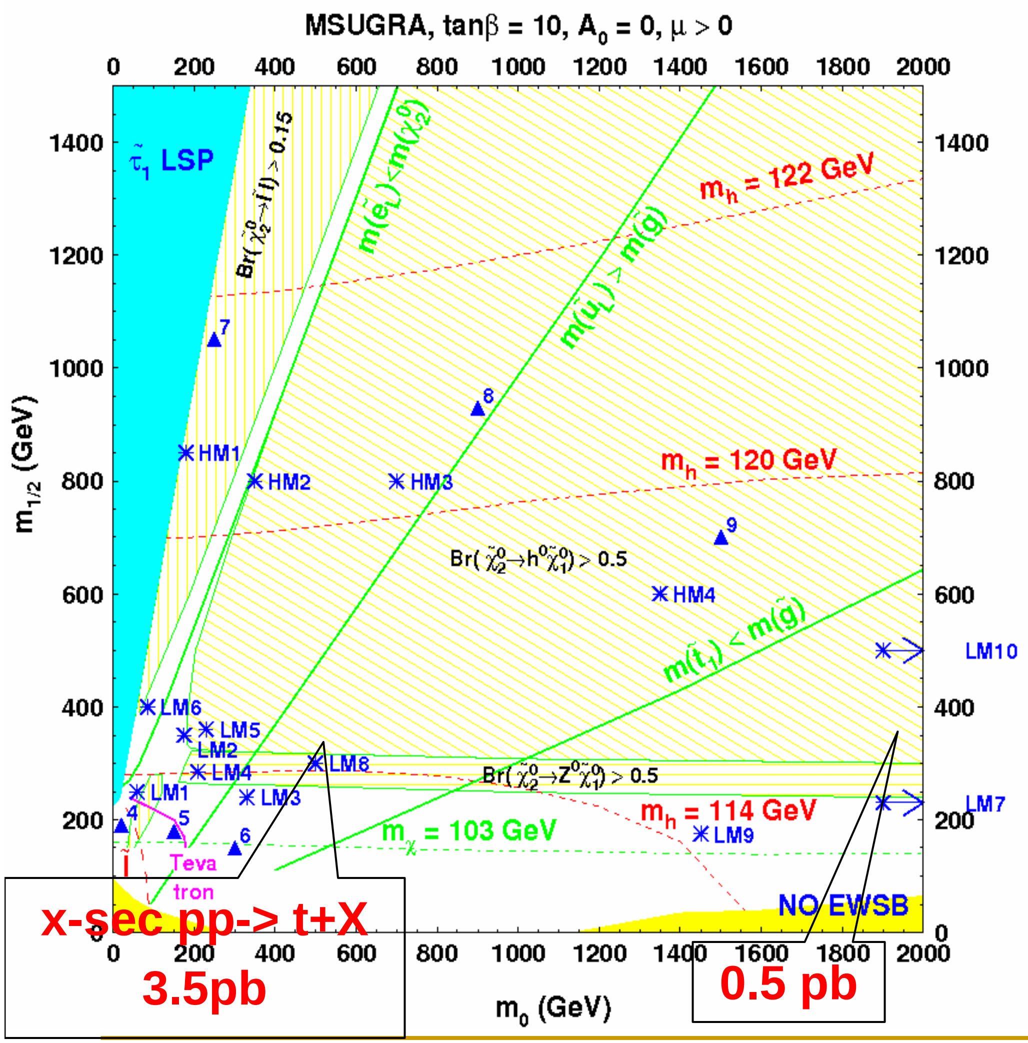
Outline

- Motivation/Objectives
- Signal and Background characterization and MC samples used
- Kinematic fit for top extraction
- Selection Requirements
- Results
- CMS reach
- Conclusion

Motivation/Objectives

- Examine low mass SUSY observability in final states containing top
- Use CMS test point LM1 where gluino cross section is high (35 pb)
- Target the decays to stop and sbottom
- Because they are heavier than the top
  - a lot of top quarks are generated via SUSY production/decays.
- The 2 neutralinos result in events with high MET.
- The inclusive SUSY signature is top+MET.

LM1: spectrum and branching ratios



LM1 parameters: $M_{1/2}$ = 250, M_0 = 60, tanβ = 10, sign(μ) = +

$\tilde{u}_R, \tilde{c}_R$	541.52	$\tilde{u}_L, \tilde{c}_L$	557.99
$\tilde{d}_R, \tilde{s}_R$	541.18	$\tilde{d}_L, \tilde{s}_L$	563.99
$\tilde{b}_2$	534.96	$\tilde{b}_1$	514.17
$\tilde{t}_2$	575.85	$\tilde{t}_1$	411.91
$\tilde{g}$	611.32	$\chi^\pm_2$	360.99
$\chi^\pm_1$	179.50	χ^0_4	361.81
χ^0_3	341.29	χ^0_2	179.56
χ^0_1	94.93	h_0	112.87

$\tilde{g} \to \bar{t} + \tilde{t}_1$	6.16	$\tilde{g} \to \bar{b} + \tilde{b}_1$	18.09
$\tilde{g} \to \bar{b} + \tilde{b}_2$	12.67	$\tilde{t}_2 \to Z^0 + \tilde{t}_1$	12.17
$\tilde{t}_2 \to h_0 + \tilde{t}_1$	2.62	$\tilde{b}_2 \to W^- + \tilde{t}_1$	16.33
$\tilde{b}_1 \to W^- + \tilde{t}_1$	6.64	$\tilde{t}_1 \to \chi^0_2 + t$	12.53
$\tilde{t}_1 \to \chi^0_1 + t$	17.70	$\tilde{t}_2 \to \chi^0_{all} + t$	40.58
$\tilde{b}_1 \to \chi^+_1 + t$	48.36	$\tilde{b}_2 \to \chi^+_1 + t$	23.85

Objects and Algorithms

- ORCA_8_7_1 (Jets from ORCA_8_7_4)
- IterCone 0.5 SplittedUELowLumEPHTInput
- Isolated electrons are removed from the list of the input for the jetFinder.
- Gamma/Jet calibrated jets:

  $E_T^{raw} > 30$ GeV $|\eta| < 2.5$
- TrackCountingBTagging
- METfromECALPlusHCALTowers + muon correction
- Isolated e/μ $P_T > 5.0$ and $|\eta| < 2.5$, ($\Delta R(l\text{-}j) > 0.2$)
- 2C kinematic fit to extract top quark (CMS NOTE-2006/023)

2 Constraints Kinematic Fit

- The purpose of this analysis is not to measure the top mass → top mass is used with *W* mass as the 2 constraints to find the best jet combination.
  1. To reject non-SUSY backgrounds (W+X)
  2. To reject SUSY combinatorial backgrounds
- Only energy of Jets is smeared in the detector

  (checked that directional errors have a small effect.)

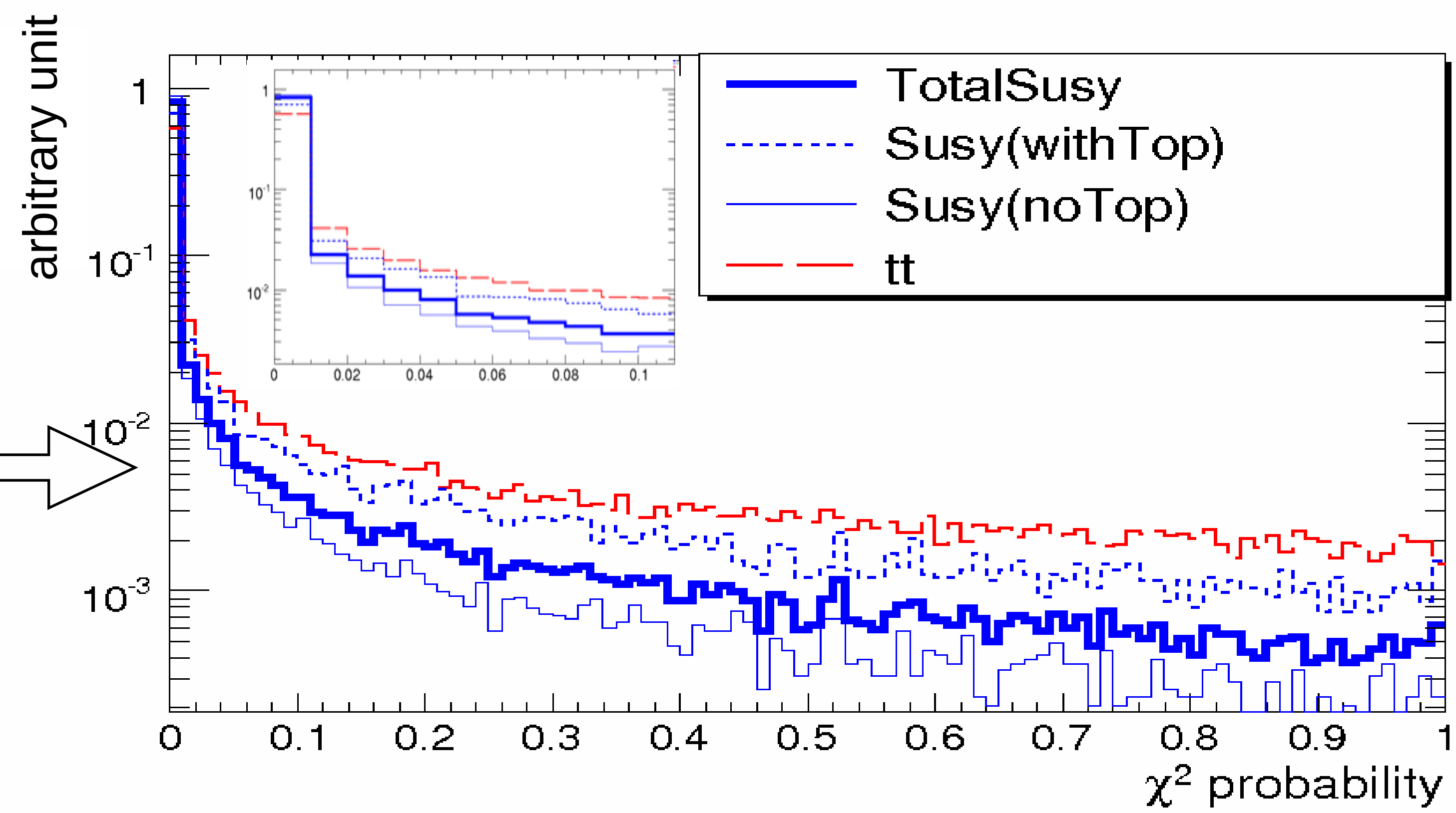
$$\chi^2 = \sum_{i=1}^{3} \frac{(E_i - E_i^m)^2}{\sigma_i^2} + \frac{(m_W - M_W)^2}{(\Gamma_W/2)^2} + \frac{(m_{Top} - M_{Top})^2}{(\Gamma_{Top}/2)^2}$$

- Last 2 terms: take into account the width of the particles. (Breit-Wigner approximated by Gaussian.)
- m_W and m_{Top} computed from jets. The third jet is a *b*-jet.
- Error parameterization from the CMS Note AN2005-005

2 Constraints Kinematic Fit

uses the (χ^2probability) as quantitative criterion to reject "fake" top

Peak at low probability is partly because of parameterization of jet energy uncertainty



In THIS SLIDE TotalSusy= 200 k LM1 (inclusive), tt=100 k (inclusive)

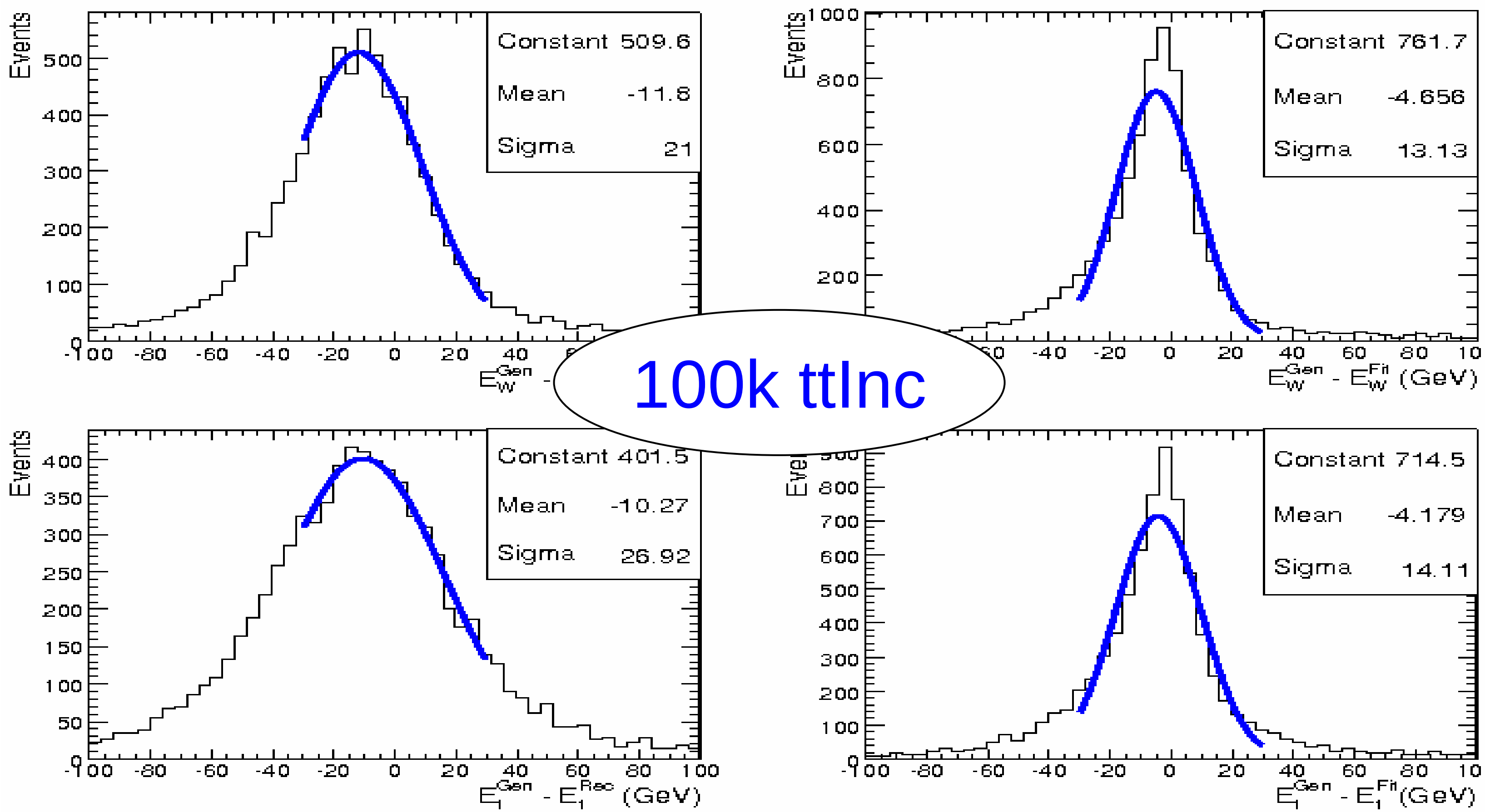
all normalized to 1

2 Constraints Kinematic Fit

Improves the kinematic features of reconstructed top and *W*

Improved energy resolution for *W* and top by ~40% and ~50%

Improved bias

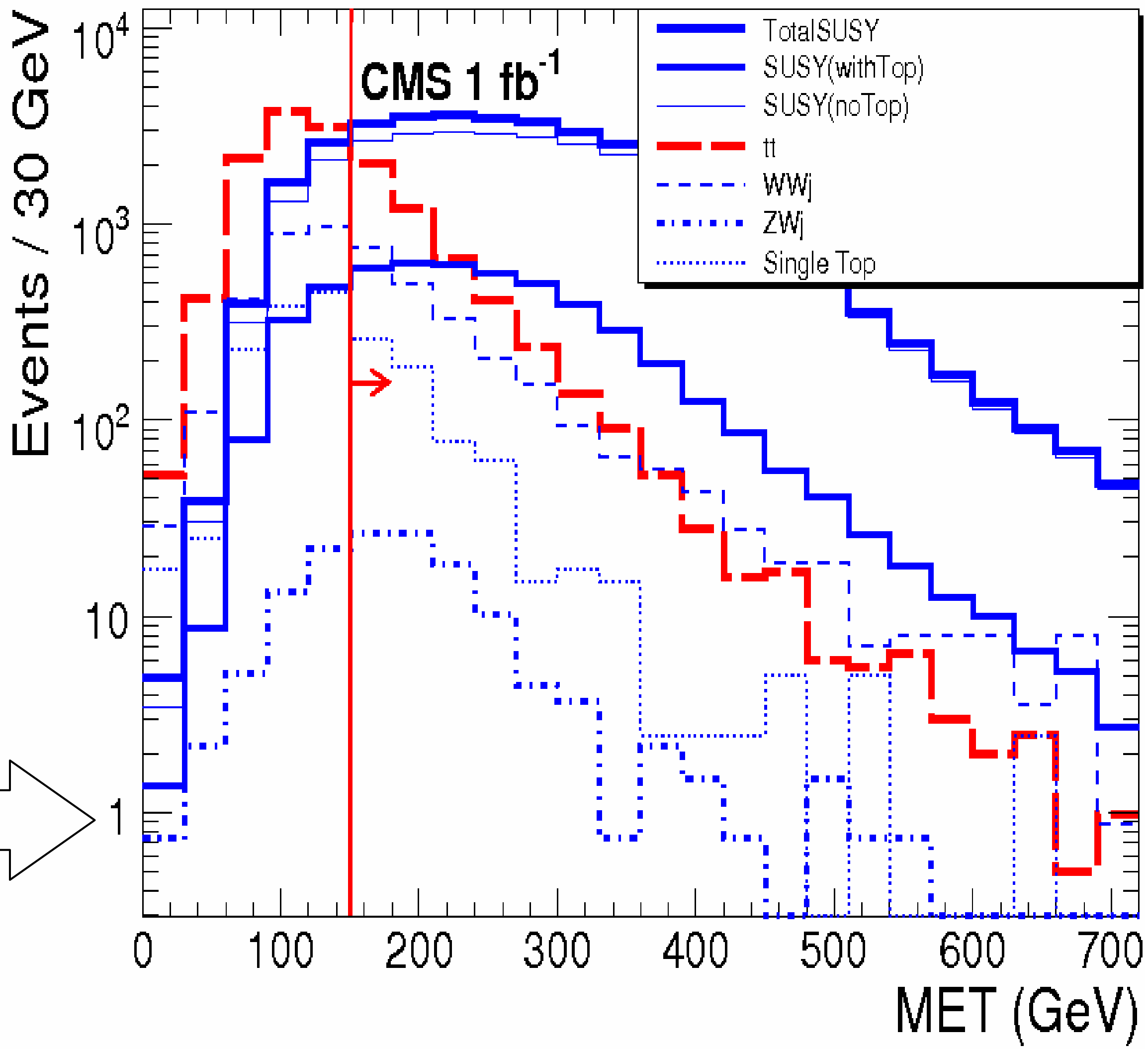


Selection requirements (1)

1)Jet/MET L1+HLT

2) MET > 150 GeV

After Previous Cuts



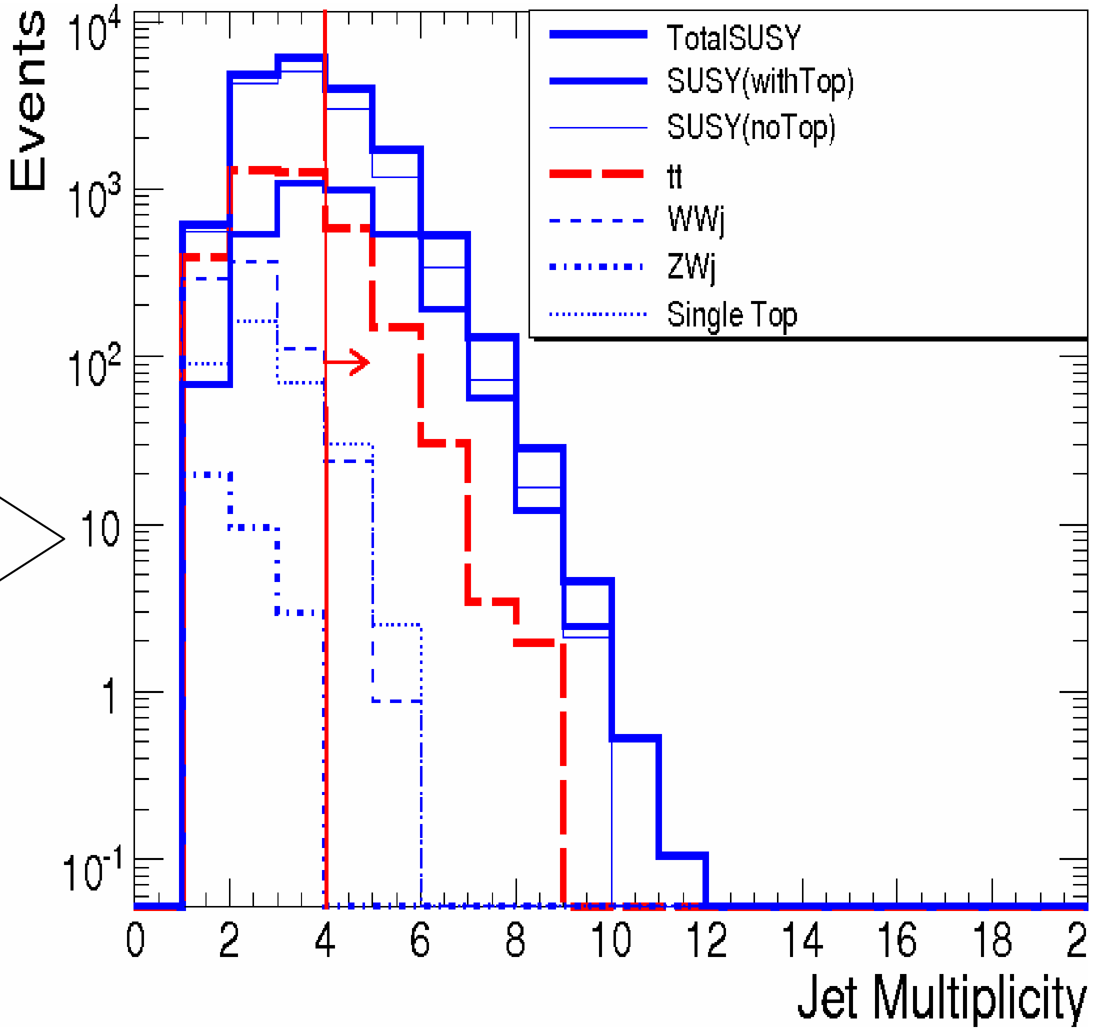
Selection requirements (2)

3) At least 1 *b*-jet.

4) At least 4 light or b-jets.

(to eliminate QCD, *W/ZW)*

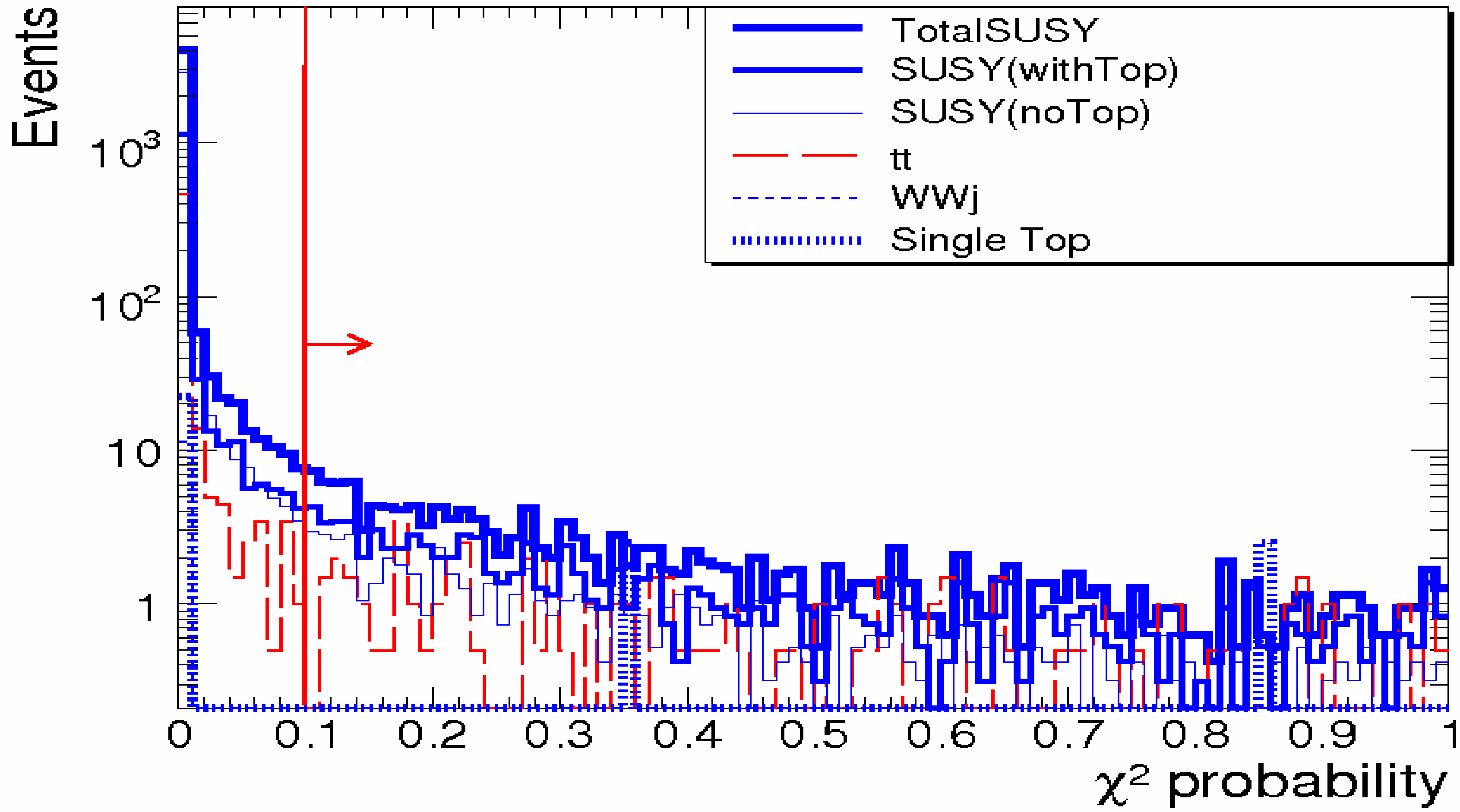
After Previous Cuts



5) A Convergent Fit

Selection requirements (3)

6) χ^2 probability > 0.1 (eliminates fake top: SUSY combinatorics)



Selection requirements (4)

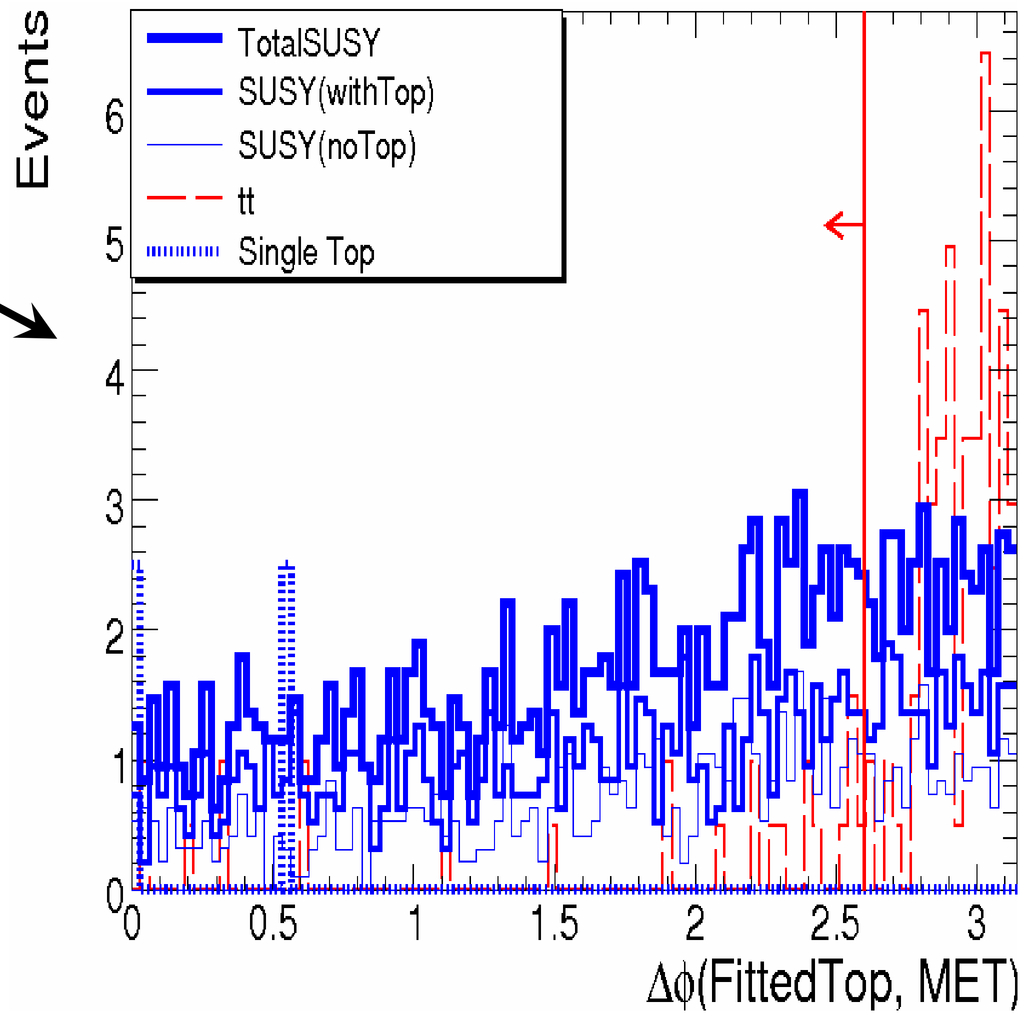
7) Δϕ (fittedTop, MET)<2.6
(eliminates tt)

8) At least one IsoLep
(eliminates QCD)

Cuts were optimized to:

- Reduce SM Bkg
- Maximize SUSY(wT/noT)=

$$\frac{\text{SUSY events with a generated top}}{\text{SUSY events without a gen top}}$$

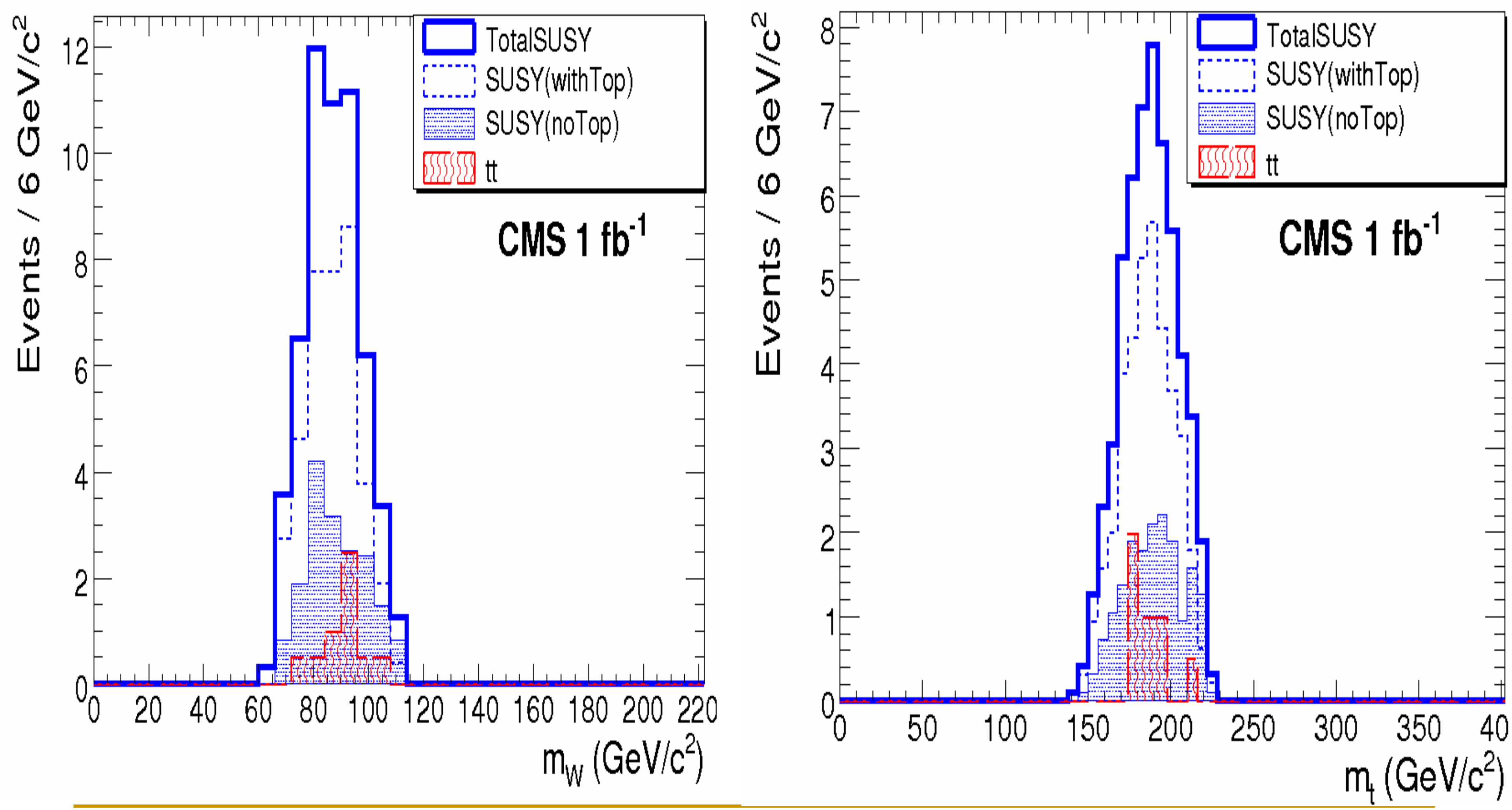


Selection Requirements Summary

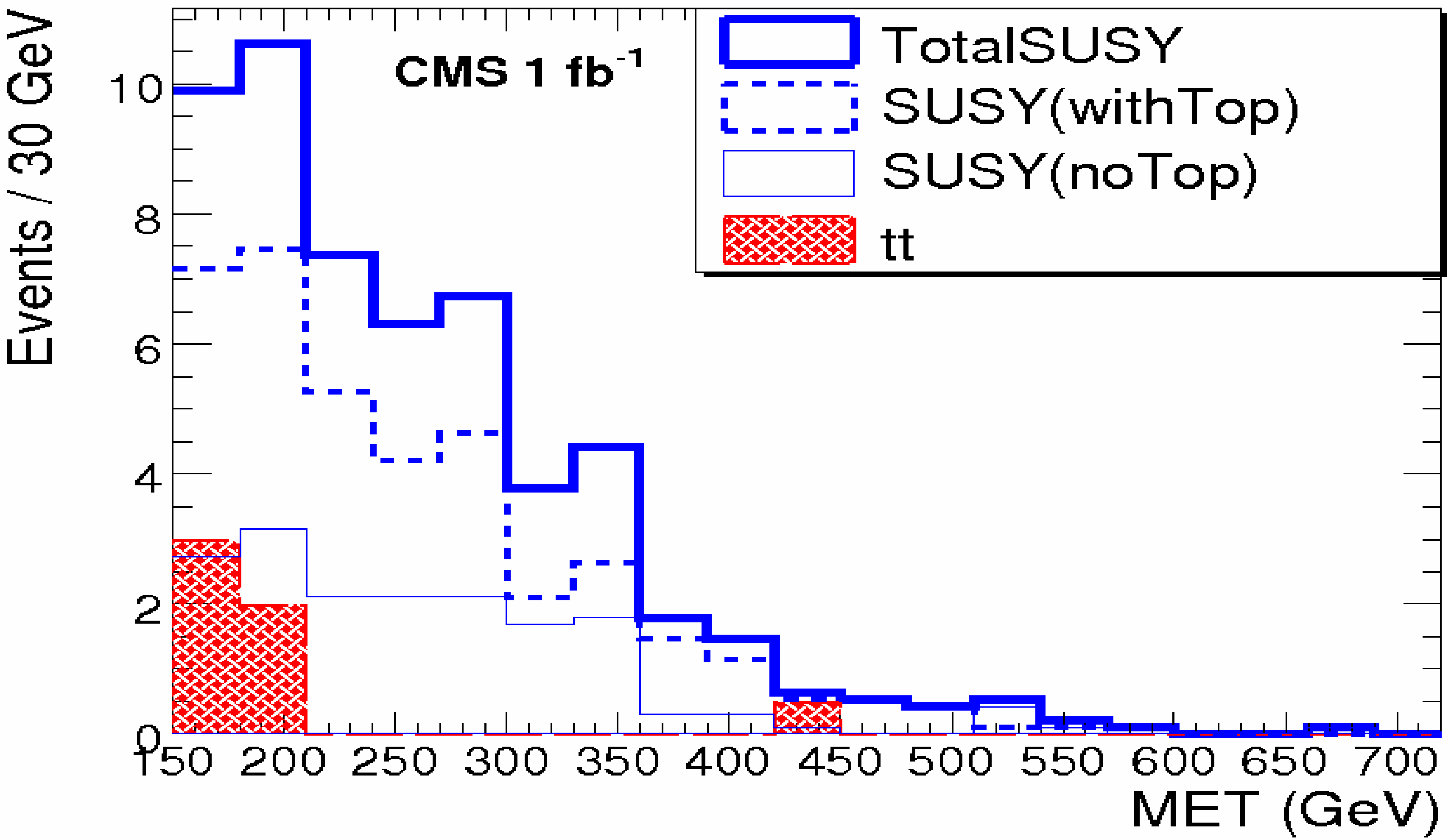
cut	SUSY(withTop)	SUSY(noTop)	ttInc	WWj	ZWj	Single Top	wT/noT
x-sec(pb) NLO	52		830	269.91	51.5	250	-
No.of.used.events	494261		1674500	305000	70000	100000	-
NEve(Nor.xsec)1 fb^{-1}	8375	43625	830000	269910	51500	250000	0.19
L1T (Jet/Met)	6269	33582	75806	18498	598	10875	0.19
HLT (Jet/Met)	5070	29427	14430	4733	142	1750	0.17
MET$\geq$ 150 GeV	4183	25677	4930	2312	99	653	0.16
$n_{bj} \geq 1$	3457	14388	3718	792	32	355	0.24
$n_j^{b\ or\ light} \geq 4$	1789	4576	769	25	0	33	0.39
A convergent Fit	1335	3062	557	12	0	28	0.44
χ^2 probability >0.1	105	69	56	0	0	5	1.52
$\Delta\phi$ <2.6	79	52	12	0	0	5	1.51
$n_l > 0$	38	17	5	0	0	0	2.19

The most efficient requirement to increase SUSY(wTop/noTop) is the χ^2 probability > 0.1

W and top after selection



MET after selection



Selection on QCD background

$\hat{P}_T$ range	x-sec(pb)	No.Used	L1T	HLT	MET	n_{bj}	n_j	χ^2	$\Delta\phi$	n_l
QCD-80-120	3.0e+6	242486	874	0	0	0	0	0	0	0
QCD-120-170	5.0e+5	213842	9189	29	1	0	0	0	0	0
QCD-170-230	1.0e+5	338478	48009	495	12	3	0	0	0	0
QCD-230-300	23800	389978	108256	1866	78	42	2	0	0	0
QCD-300-380	6400	283983	114690	2984	241	152	22	0	0	0
QCD-380-470	1880	191989	97488	4056	466	350	40	1	1	0
QCD-470-600	690	175987	104025	6759	905	740	156	0	0	0
QCD-600-800	202	94957	64547	6758	1031	907	222	0	0	0
QCD-800-1000	35.7	49499	38539	5602	976	908	262	1	1	0
QCD-1000-1400	10.8	23250	19869	3761	841	812	269	0	0	0
QCD-1400-1800	1.06	2700	2476	570	155	145	57	1	1	0

Selection on W+jets background

sample	x-sec(pb)	No.Used	L1T	HLT	MET	n_{bj}	n_j	χ^2	$\Delta\phi$	n_l
Wbb_lν	106.59 (LO)	224000	1437	593	349	271	1	0	0	0
Wj_lν_25-170	10069 (LO)	757936	6057	423	67	9	0	0	0	0
Wj_lν_200-1400	48.86 (LO)	86000	55203	39839	25376	7142	124	3	0	0

- Although the new analysis is more powerful against QCD and W+ jets, but
- Low statistics in low P_T (high cross section) bins cause a high statistical uncertainty.
- Could benefit from higher statistics for low P_T bins

Results

- Selection efficiency SUSY(withTop) $4.5*10^{-3}$
- Selection efficiency SUSY(noTop) $3.9*10^{-4}$
- Selection efficiency tt $6.0*10^{-6}$
- S = SUSY events (withTop + noTop)

$$\frac{S}{B} = \frac{\text{SUSY(withTop)} + \text{SUSY(noTop)}}{t\bar{t}} = \frac{38+17}{5} = 11$$

- SUSY events: withTop > 2 * noTop

Systematics

Systematic	Value%
JES (Jets)	**5.1**
JES (Met)	**18.3**
b-tagging	**8**
Total	**20**

Considered dominant systematics (from det-PRS) for tt:

- Jet Energy Scale
  (Jets, 5% 1fb$^{-1,}$)
  (MET, 5% 1fb$^{-1,}$)
- *b*-tagging (b-tau)

5 sigma discovery

Using Bityukov-Krasnikov formulae for significance,

$$Significance = 2 \times (\sqrt{S+B} - \sqrt{B})$$

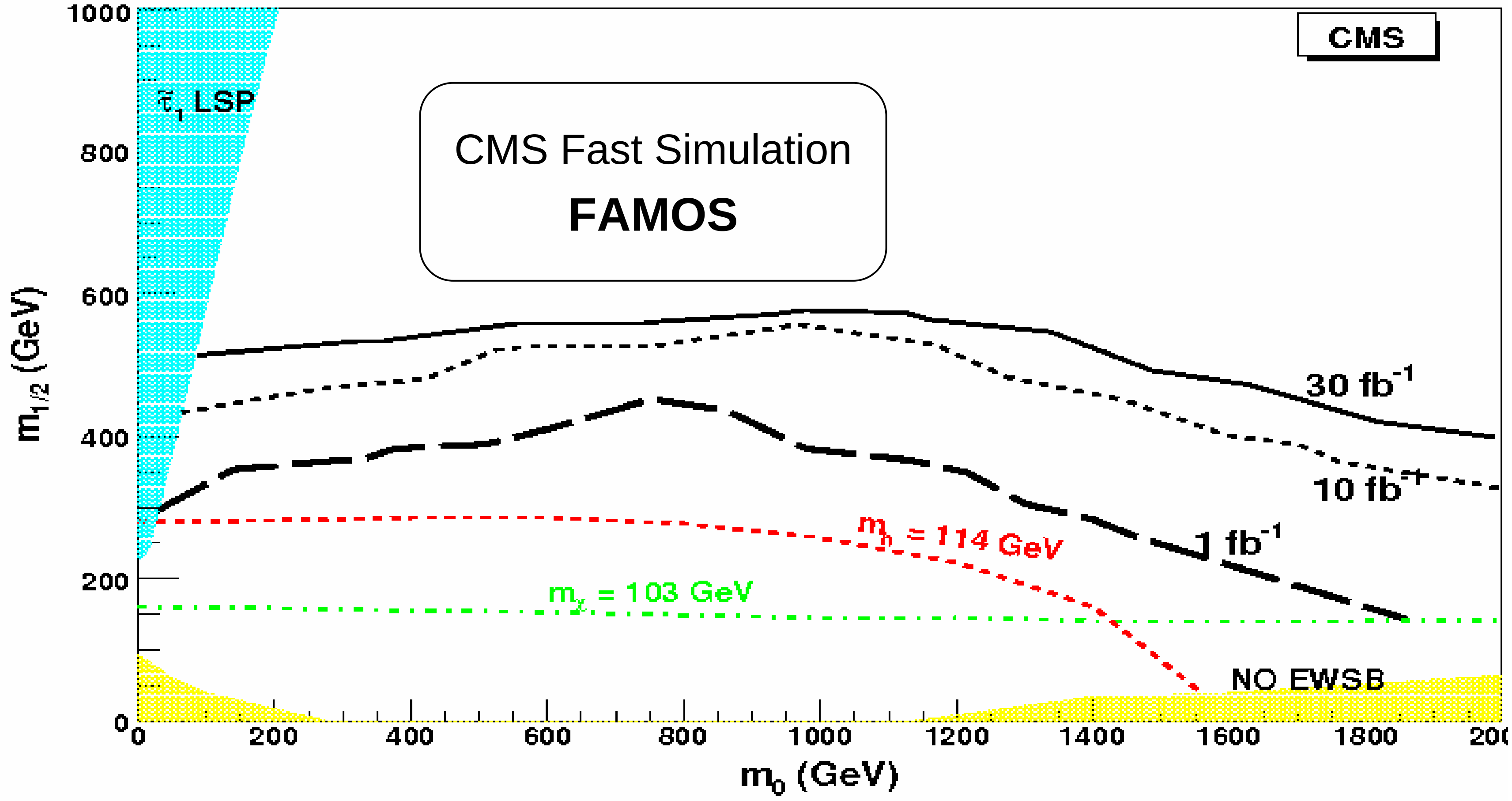
the minimum Integrated Luminosity for a 5 sigma discovery is

$$5 = \sqrt{IL} \times 2 \times (\sqrt{55+5} - \sqrt{5}) \Rightarrow IL = 0.21\, fb^{-1}$$

In this IL, S and B are 11 and 1, respectively. It means that the statistical uncertainty is dominant, so the systematics are neglected.

Reach in m_0-$m_{1/2}$ plane

Ntuples are generated for ≤200 GeV steps in both m0 and m1/2.
Total points are 36 points. NLO x-sec from prospino1.



Conclusion

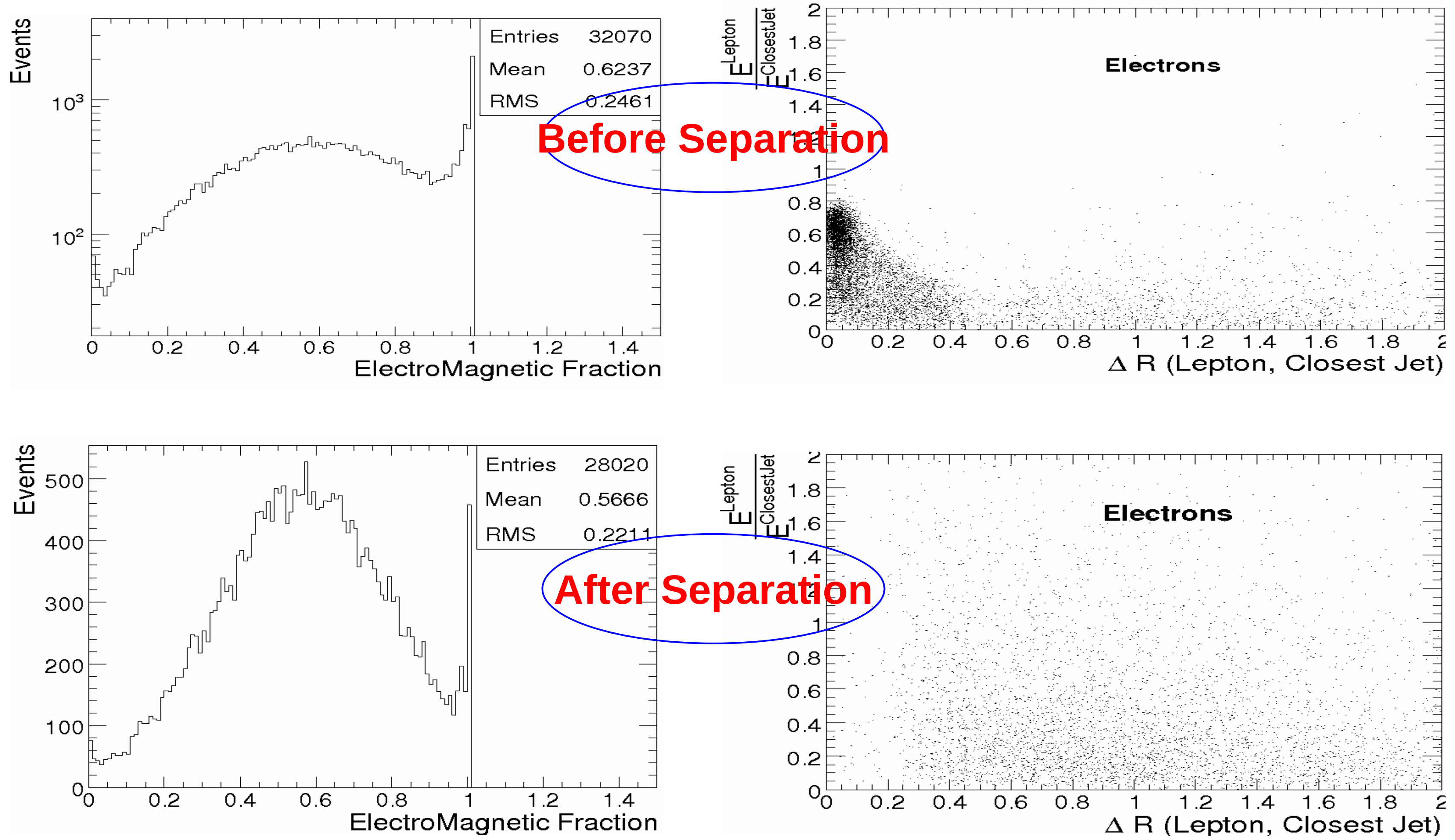
- A 2C kinematic fit is adopted that improves the top quark extraction in the LM1 SUSY sample.
- The observability of SUSY in inclusive top+MET final state is studied.
- CMS reach in m0-m1/2 plane is studied by using FAMOS.

Back up Slides

Summary for KinFit:

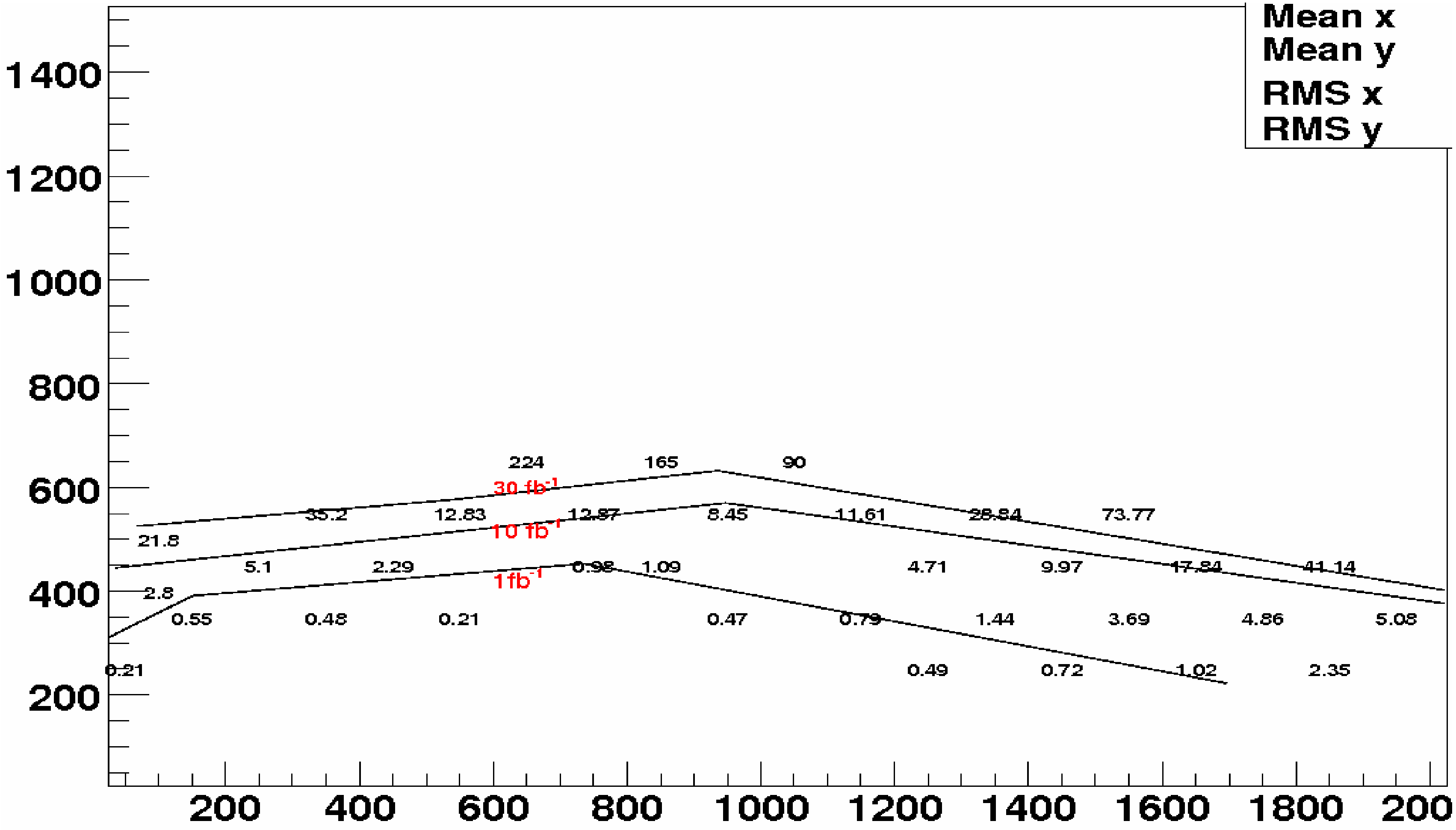
- **Efficiency:** 46% of tt events with a *b*-jet and 2 light jets have a convergent fit with χ^2 probability > 0.05
- (92% if χ^2 probability > 0.0)
- **Fake rate:** 4.5% of SUSY(noTop) events with a *b*-jet and 2 light jets have a convergent fit with χ^2 probability > 0.05
- (27% if χ^2 probability > 0.0)
- **Purity:** 33% of the fitted top quarks have a generated top closer than $\Delta R = 0.5$ that decays in *W(jj)b* and all *j,j* and *b* have $|\eta|<2.5$ and $E_T > 30$ GeV with χ^2 probability > 0.05
- (44% if χ^2 probability > 0.05)

Jet/Lepton Separation

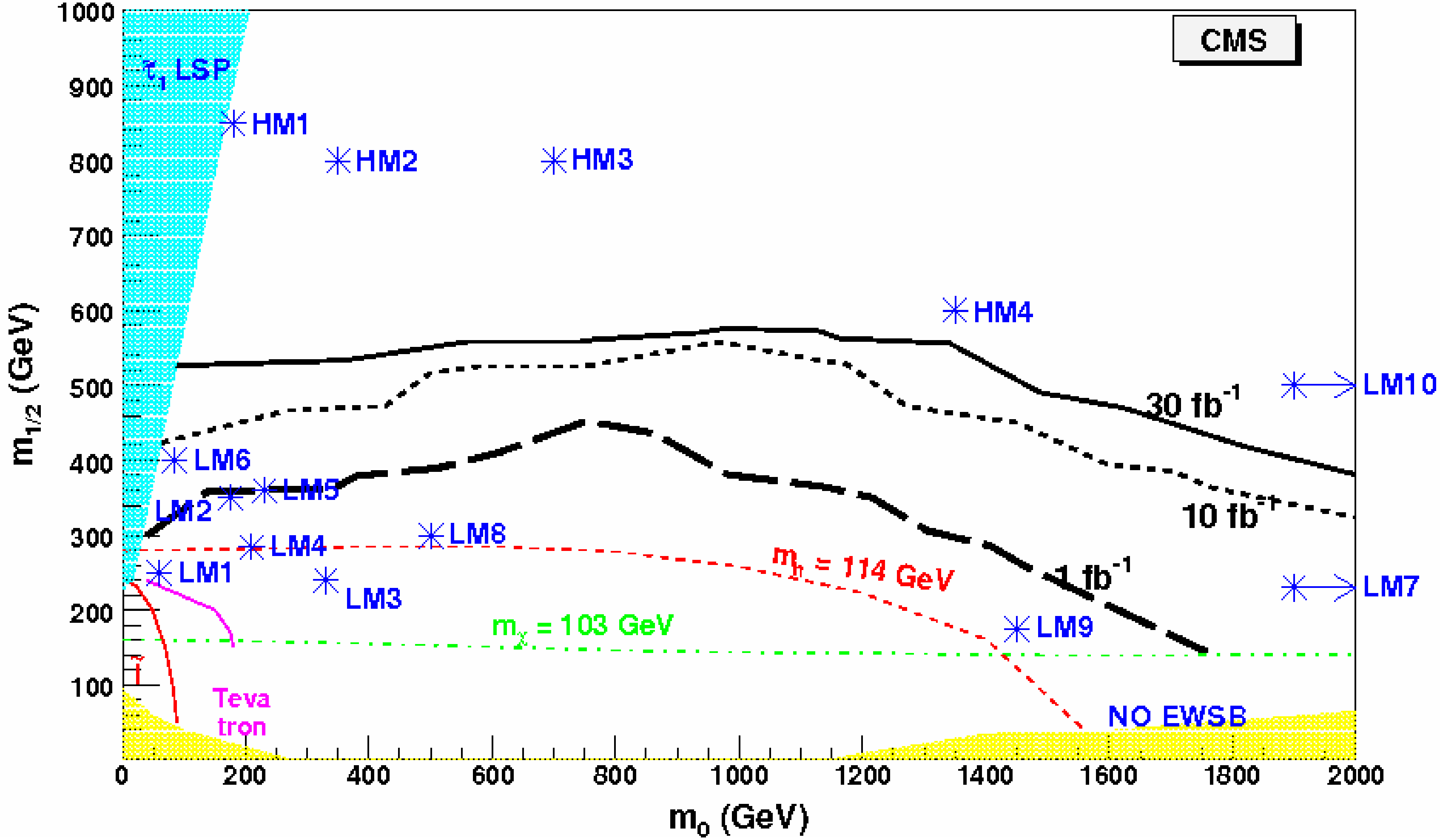


Points for scan

In every point the minimum IL for 5 sigma discovery is shown



Reach in m_0-$m_{1/2}$ plane



MC data samples and cross sections

- su05-LM1: NLO x-sec 52 pb (Prospino/SUSYBSM Group) (signal)
- jm03b-ZWj: NLO x-sec 51.5 pb (Generators PRS Group) (background)
- jm03b-WWj: NLO x-sec 270 pb (ditto) (background)
- jm03b-tt: NLO x-sec 830 pb (ditto) (background)
- jm03b-qcd LO x-sec from pythia (background)

  published DC04 samples PYTHIA 6.215 & Low Luminosity Pileup
- mSUGRA LM1 IsaPythia: ISAJET 7.69+ PYTHIA 6.225

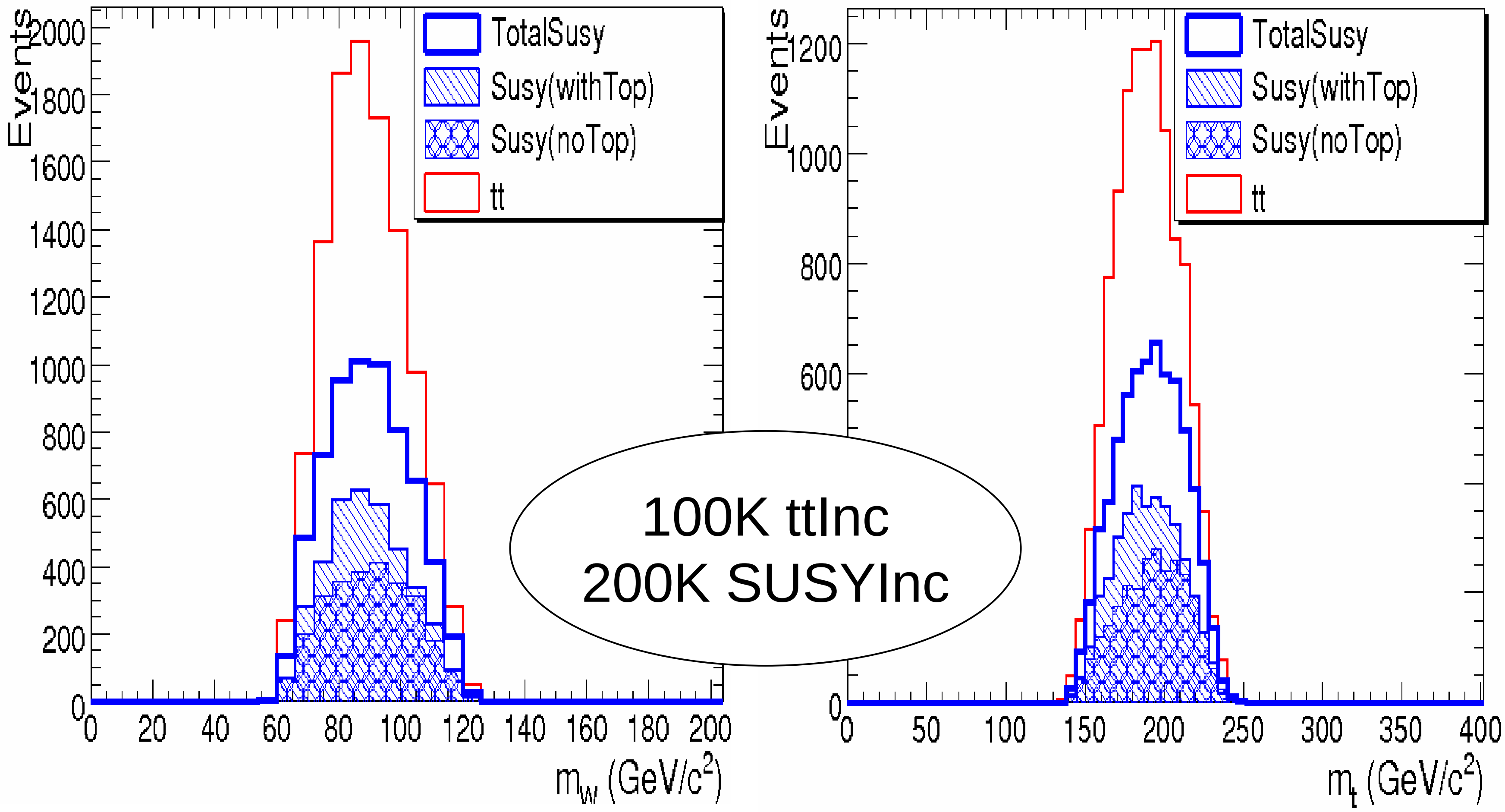
MC data samples and cross sections

(newly considered backgrounds)

- Single Top (t-channel) NLO x-sec 250 pb
  - Generated by TopRex 4.11, W decays inclusively.
- Wbb LO x-sec 107 pb
  - Generated by TopRex 4.11, W decays leptonically.
- Wj (25<P_T<170) LO x-sec 10069 pb
- Wj (200<P_T<1400) LO x-sec 48.86 pb
  - Both Generated by PYTHIA, W decays leptonically.

Extracted *W* and top by the fit

(χ^2 probability > 0.05)



Some x-sec, BR

- m0-m1/2 1850.000 250.000 X-SEC = 6.5 pb (NLO)
- M(GL) = 696.10
- M(UL) = 1900.77 M(UR) = 1903.69 M(DL) = 1902.46 M(DR) = 1904.68
- M(B1) = 1560.51 M(B2) = 1862.23 M(T1) = 1137.35 M(T2) = 1570.48
- M(Z1) = -99.37 M(Z2) = -195.12 M(Z3) = 380.84 M(Z4) = -398.38
- M(W1) = -195.94 M(W2) = -397.64
- M(HL) = 116.14 M(HH) = 1878.02 M(HA) = 1865.65 M(H+) = 1879.65
- GLSS --> W1SS+ BT TB 0.42630E-04 0.64082E-01
- GLSS --> W1SS- TP BB 0.42630E-04 0.64082E-01
- GLSS --> W2SS+ BT TB 0.18323E-04 0.27543E-01
- GLSS --> W2SS- TP BB 0.18323E-04 0.27543E-01
- GLSS --> Z1SS TP TB 0.45796E-04 0.68841E-01
- GLSS --> Z2SS TP TB 0.43684E-05 0.65667E-02

Some x-sec, BR

- m0-m1/2 1950.000 350.000 X-SEC = 1pb (NLO)
- ISAJET masses (with signs):
- M(GL) = 927.28
- M(UL) = 2058.29 M(UR) = 2057.18 M(DL) = 2059.84 M(DR) = 2057.66
- M(B1) = 1703.06 M(B2) = 2012.35 M(T1) = 1259.72 M(T2) = 1713.83
- M(SN) = 1956.90 M(EL) = 1960.57 M(ER) = 1951.69
- M(NTAU)= 1949.01 M(TAU1)= 1935.69 M(TAU2)= 1953.05
- M(Z1) = -141.90 M(Z2) = -278.97 M(Z3) = 473.38 M(Z4) = -490.39
- M(W1) = -279.85 M(W2) = -489.73
- GLSS --> W1SS+ BT TB 0.18788E-03 0.68487E-01
- GLSS --> W1SS- TP BB 0.18788E-03 0.68487E-01
- GLSS --> W2SS+ BT TB 0.23320E-03 0.85011E-01
- GLSS --> W2SS- TP BB 0.23320E-03 0.85011E-01
- GLSS --> Z1SS TP TB 0.27985E-03 0.10202E+00
- GLSS --> Z2SS TP TB 0.41819E-04 0.15245E-01
- GLSS --> Z3SS TP TB 0.33028E-04 0.12040E-01
- GLSS --> Z4SS TP TB 0.78771E-04 0.28715E-01

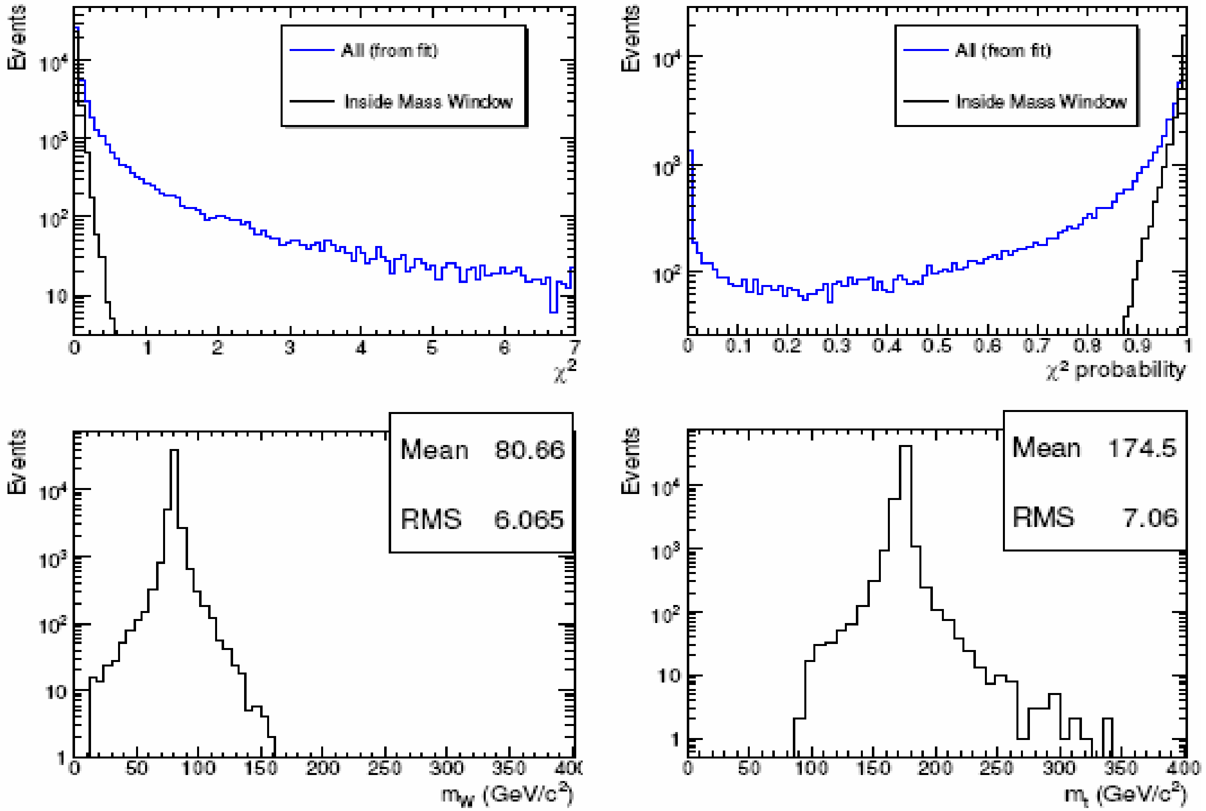
Some x-sec, BR

- m0-m1/2 550.000   350.000   XSEC = 5.1 pb (NLO)
- ISAJET masses (with signs):
- M(GL) =   857.27
- M(UL) =   930.12   M(UR) =   912.29   M(DL) =   933.60   M(DR) =   911.05
- M(B1) =   823.46   M(B2) =   890.61   M(T1) =   665.12   M(T2) =   857.23
- M(SN) =   592.36   M(EL) =   599.98   M(ER) =   565.46
- M(NTAU)=   589.95   M(TAU1)=   559.14   M(TAU2)=   598.71
- M(Z1) = -139.13   M(Z2) = -268.11   M(Z3) =   464.84   M(Z4) = -481.81
- M(W1) = -268.51   M(W2) = -481.27
- GLSS   --> TB1   TP   0.29033E+00   0.38523E+00
- GLSS   --> TP1   TB   0.29033E+00   0.38523E+00

Fit Validation(1)

- Starting from the right hypothesis
- Matched Partons
  - No fragmentation-hadronization
  - No detector effects
- **3%** have a χ^2 probability less than 0.01

Inside window:
$|M_W - 80| < 2.5$ GeV
$|M_t - 175| < 2.5$ GeV

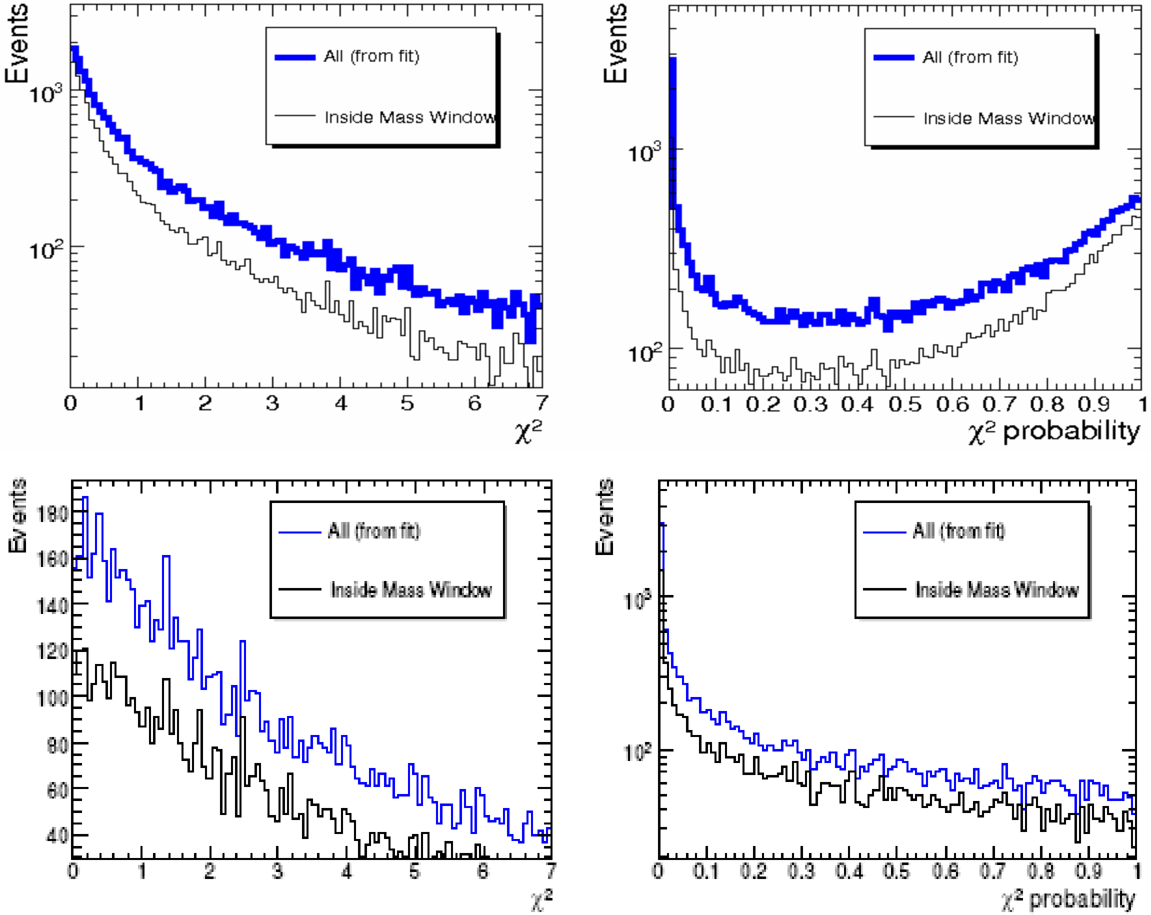


Fit Validation (2)

•Matched GenJets
(clusterized stable particles)

after fragmentation-hadronization
No Detector effects
11% have a χ^2 probability less than 0.01

•Matched RecJets
fragmentation-hadronization and detector effects are in.
15% have a χ^2 probability less than 0.01



The main sources of the large peak close to zero are the fragmentation-hadronization effects.

FAMOS vs ORCA(1)

- We run ORCA on a sample of LM1 and tt. ORCA_LM1 and ORCA_tt are the number of the remaining events.
- Do the same with FAMOS. FAMOS_LM1 and FAMOS_tt are the number of the remaining events.
- We check if

  FAMOS_tt /ORCA_tt = FAMOS_LM1/ORCA_LM1
- To increase the statistics, some cuts are relaxed.

FAMOS vs ORCA(2)

- 230k tt for ORCA 46k tt for FAMOS
- 75k LM1 for ORCA 30k LM1 for FAMOS

sample	ORCA	FAMOS	Famos/Orca
All cuts			
LM1	31.6(22+9.6)	41(28+13)	1.30±0.25
No Trigger, No Cut on MET			
LM1	64.8	77	1.18±0.16
$t\bar{t}$	100.6	121	1.21±0.13
Only b-jet cut			
LM1	16346.8	12644	0.77
$t\bar{t}$	27413.2	28184	1.03
Only b-jet and n_j cut			
LM1	5807.2	5085	0.88
$t\bar{t}$	4847.6	4669	0.96
Only b-jet, n_j and χ^2 cut			
LM1	203.2	216	1.06±0.09
$t\bar{t}$	724.2	780	1.08±0.05

- We use 1.3 as the (conservative) scale factor for FAMOS