Top Quark Background in SUSY Searches @ LHC

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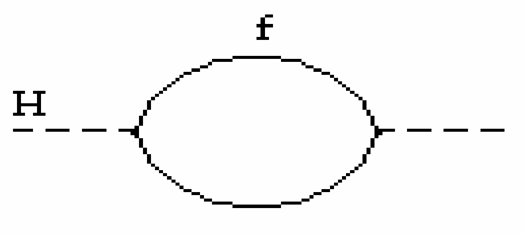
Why SUperSYmmetry(1)

SM describes a lot of experimental results very precisely, but



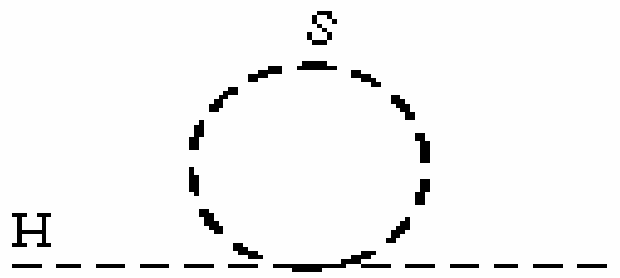
Fermionic loop corrections to higgs mass diverge quadratically:

$$\Delta m_H^2 = c\lambda_f^2[-\Lambda^2 + b]$$

Λ is a cut-off scale (upper limit for SM validity
→ $M_{pl} = 2.4*10^{18}$ GeV).
Huge disparity between *EW* scale and M_{pl} is not natural (Hierarchy Problem)

Why SUperSYmmetry(2)

If another scalar couples to higgs



new correction is

$$\Delta m_H^2 = c_2 \lambda_S [\Lambda^2 + b_2]$$

Proper couplings → This correction can cancel the quadratic divergencies.

SUSY introduces new particles that cancel quadratic div and fill the scale between EW and M_{pl} (solves the hierarchy problem).

SUSY particle content

Every SM particle has a SUSY partner (sparticle) that are exactly same, but differ in spin by ½ .

Names		spin 0	spin 1/2	$SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$
squarks, quarks (×3 families)	Q	$(\tilde{u}_L \quad \tilde{d}_L)$	$(u_L \quad d_L)$	$(3,\ 2,\ \frac{1}{6})$
	U^c	$\tilde{u}_R^*$	$u_R^\dagger$	$(\bar{3},\ 1,\ -\frac{2}{3})$
	D^c	$\tilde{d}_R^*$	$d_R^\dagger$	$(\bar{3},\ 1,\ \frac{1}{3})$
sleptons, leptons (×3 families)	L	$(\tilde{\nu} \quad \tilde{e}_L)$	$(\nu \quad e_L)$	$(1,\ 2,\ -\frac{1}{2})$
	E^c	$\tilde{e}_R^*$	$e_R^\dagger$	$(1,\ 1,\ 1)$
Higgs, higgsinos	H_u	$(H_u^+ \quad H_u^0)$	$(\tilde{H}_u^+ \quad \tilde{H}_u^0)$	$(1,\ 2,\ \frac{1}{2})$
	H_d	$(H_d^0 \quad H_d^-)$	$(\tilde{H}_d^0 \quad \tilde{H}_d^-)$	$(1,\ 2,\ -\frac{1}{2})$

Names	spin 1/2	spin 1	$SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$
gluino, gluon	$\tilde{g}$	g	(8, 1, 0)
wino, W	$\tilde{W}^\pm,\ \tilde{W}^0$	$W^\pm,\ W^0$	(1, 3, 0)
bino, B	$\tilde{B}^0$	B^0	(1, 1, 0)

SUSY & mSUGRA

- SUSY particles have not been discovered, so they don't have exactly same mass as their SM partners. SUSY is a broken symmetry.
- The mSUGRA, reduces the 127 parameters of general SUSY models to 5 parameters:

m_0, $m_{1/2}$:(common scalar and gaugino mass at GUT scale)
A: (common gaugino coupling at GUT scale)
$tan(\beta)$: ratio of vev of H_u and H_d
sign(μ): μ being the higgs mixing parameter.

- χ^2_0 is stable ➔ Missing Transverse Energy (MET)

mass measurement in stop sample (1)

- In benchmark SPS5, $\tilde{g}\tilde{q}$ production is considered when:

$$\tilde{g} \to \tilde{t}_1 t \to tb\tilde{\chi}_1^{\pm} \text{(38\%BR)} \qquad \tilde{q} \to q + (\chi_1^{\pm} \text{or} \, \chi_{1or2}^0)$$

- Relevant masses (all in GeV):

m_g=719, m_{X+1}=m_{X02}=226, m_{X01}= 120,

m_{qR}=620, m_{qL}=640, m_{t1}=236

- hadronic decay of top is considered.
- tt, SUSY background are relevant.
- Other SM backgrounds are eliminated by cuts.

mass measurement in stop sample (2)

- Cuts:

E_T^{miss} > 200 GeV. (kills SM backgrounds)

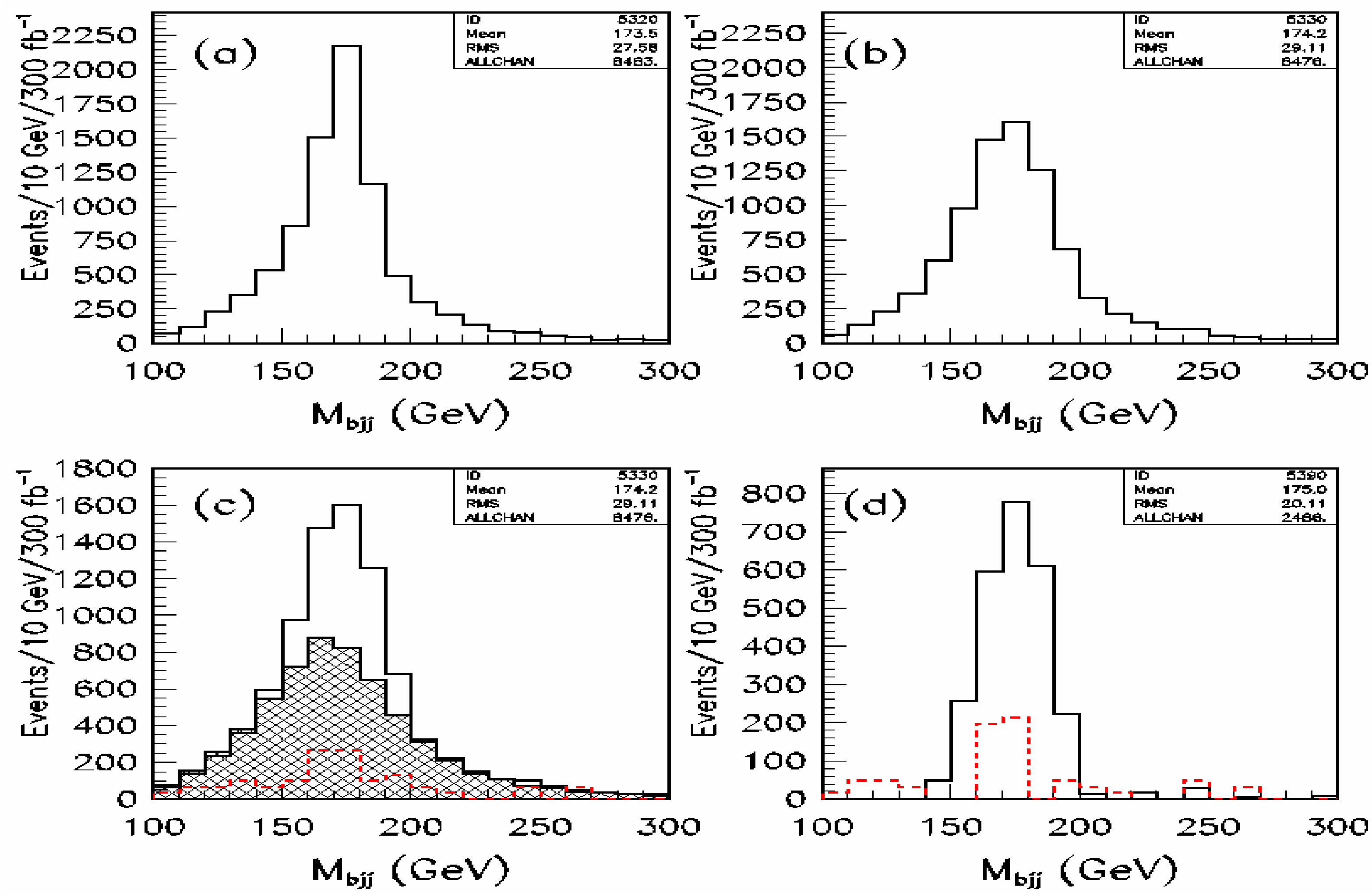
No isolated leptons

>=3 light jets $P_T(J_1) > 300$, $P_T(J_2,J_3,\ldots) > 30$ and $|\eta| < 3$

Only 2 b-jets $30 < P_T(b_1) < 50$ and $30 < P_T(b_2) < 150$ (upper limit kills SUSY backgrounds)

- Top Extraction: Excluding the most energetic jet, all m(jj) combinations are made, if $|m(jj) - m_W| < 15$, jj is selected as W, the closest m(bjj) to m_t is selected. jj are scaled to have m(jj)=80 GeV, if $|m(bjj) - m_t| < 30$, bjj is used as top.
- W sideband subtraction is used to estimate the combinatorial backgrounds

Top Extraction in mass measurement in stop sample



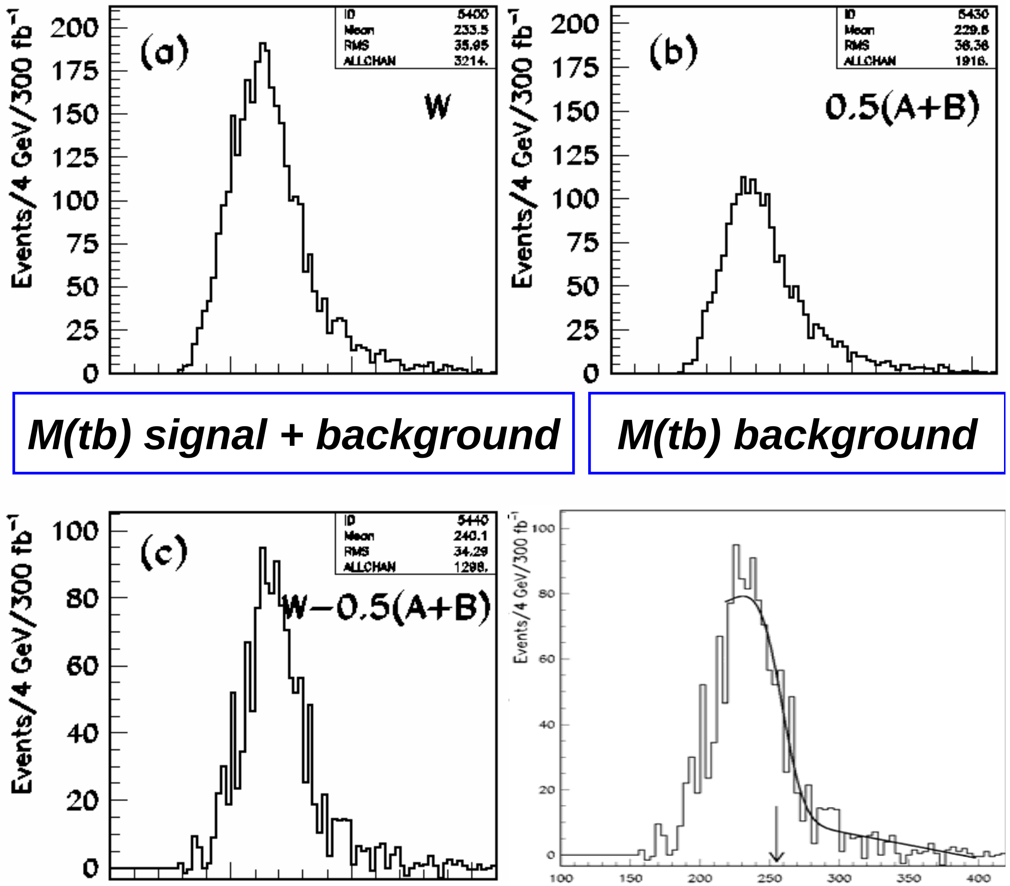
mass measurement in stop sample (3)

After cuts and W sideband subtraction

Signal/tt = 12
Signal/SUSY(Bkg) = 3

- Extracted top quark is combined with the remaining b.
- Theoretically m(tb) has an endpoint at 255 GeV.
- Extracted endpoint by fit:

258.6 +/- 0.3(stat) +/- 2.6 (sys)
(only 1% jet energy scale uncertainty)



Invariant mass of *tb after subtracting backgrounds*

Work done by I. Borjanovic, J.Krstic, D.Popovic

SUSY in top+MET final states in CMS

- gluino cross section is high (35 pb@LM1), it can decay to stop and sbottom, which are heavier than top ➔ a lot of top quarks are generated via SUSY production/decay.
- SUSY events have 2 neutralinos ➔ high MET events.

➔ The inclusive SUSY signature is top+MET

- Point LM1 MSUGRA

$M_{1/2} = 250$, $M_0 = 60$, $\tan\beta = 10$, $A_0 = 0$ $\text{sign}(\mu) = +$

m_g=611, m_{X01}= 94, m_{b1}=514, m_{b2}=535, m_{t1}=236

2 Constraints Kinematic Fit

- The purpose of this analysis is not to measure the top mass → Top mass is used with W mass as 2 constraints to find the best jet combination.

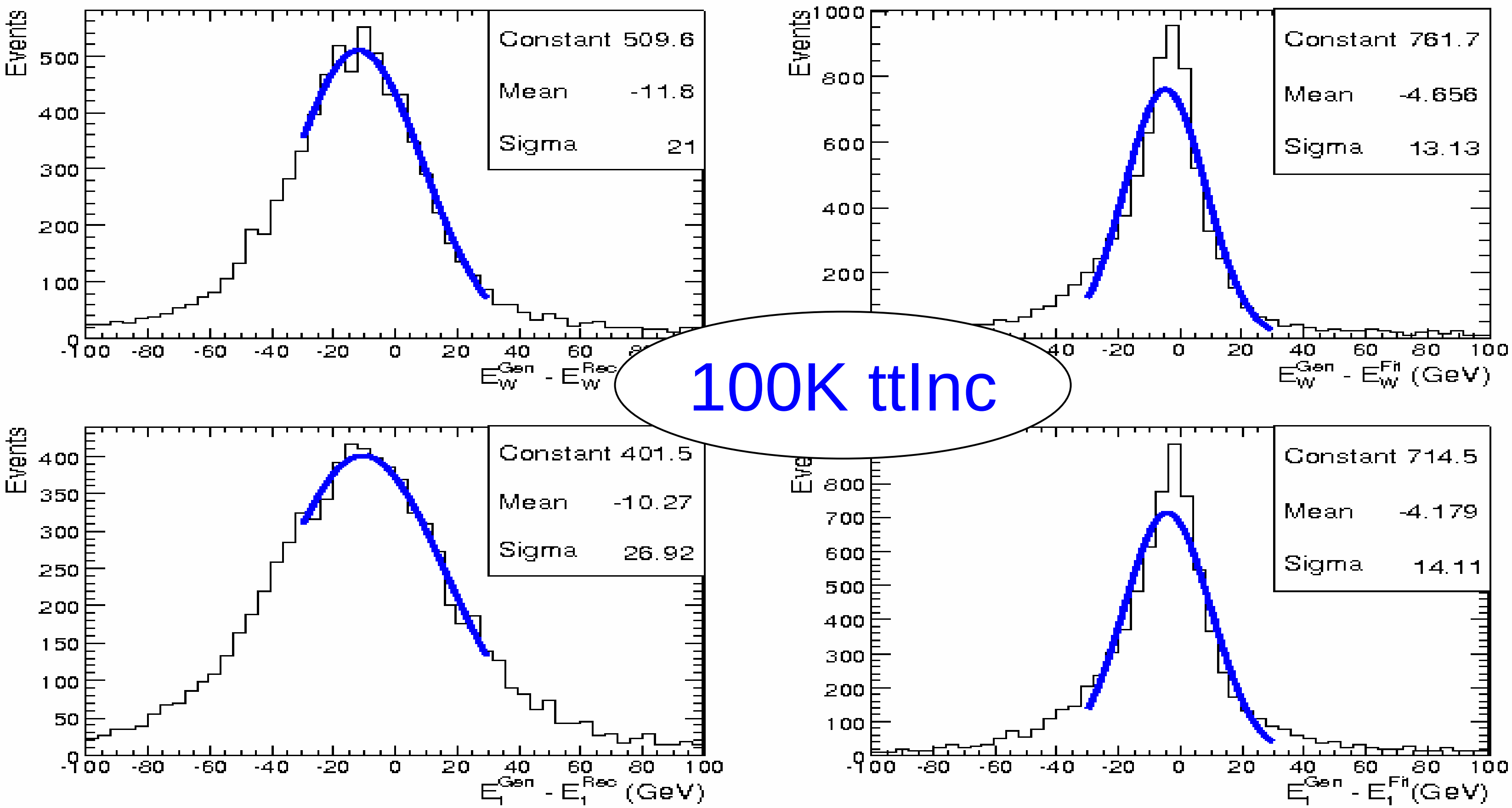
- Only energy of Jets are smeared in the detector (checked that directional errors have a small effect)

2 Constraints Kinematic Fit

Have a quantitative criteria to reject fake top (χ^2probability)

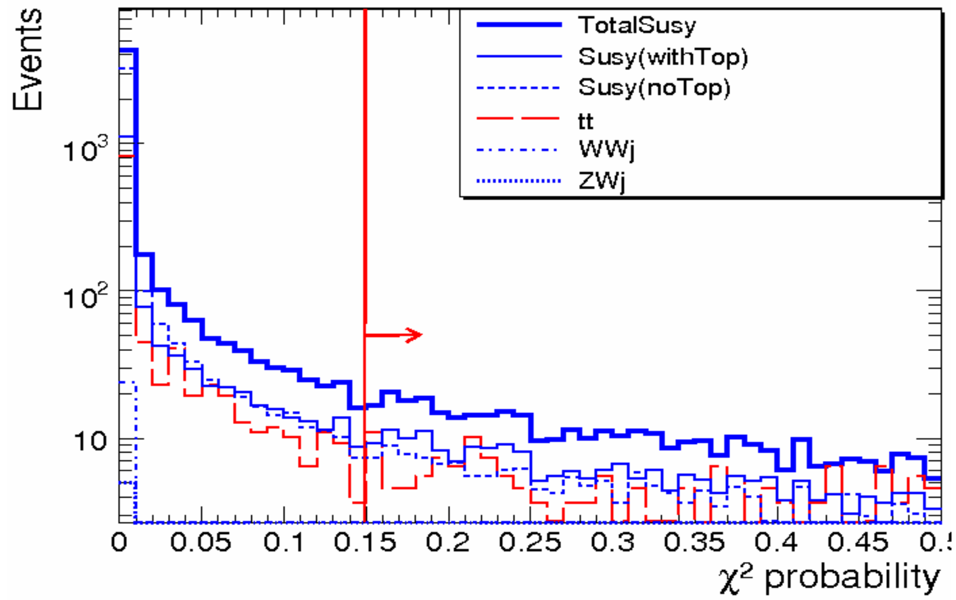
Improves the kinematical features of reconstructed top

(37% and 48% better energy resolution for W and Top, **Reduced bias**)

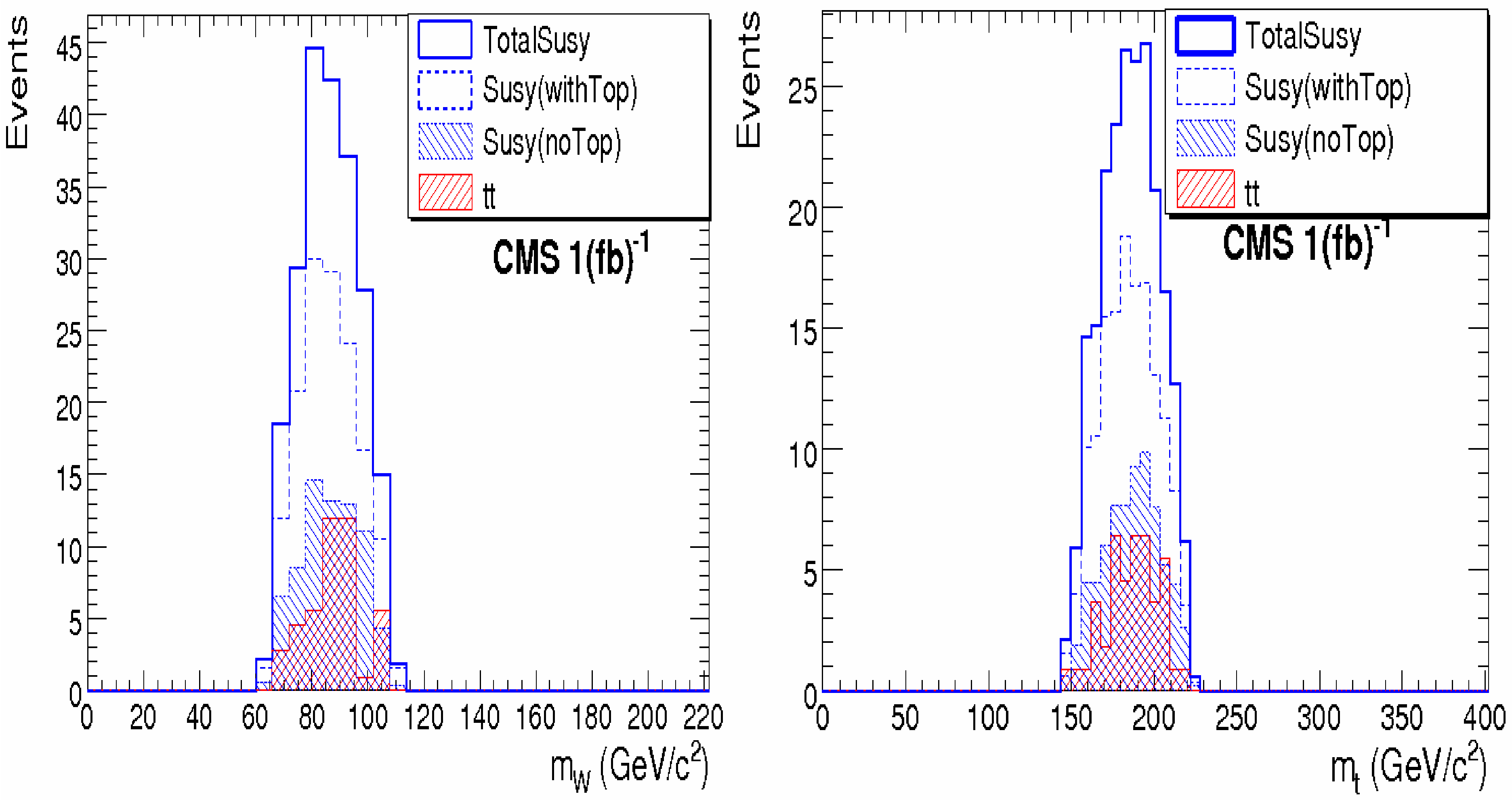


Cuts and selections

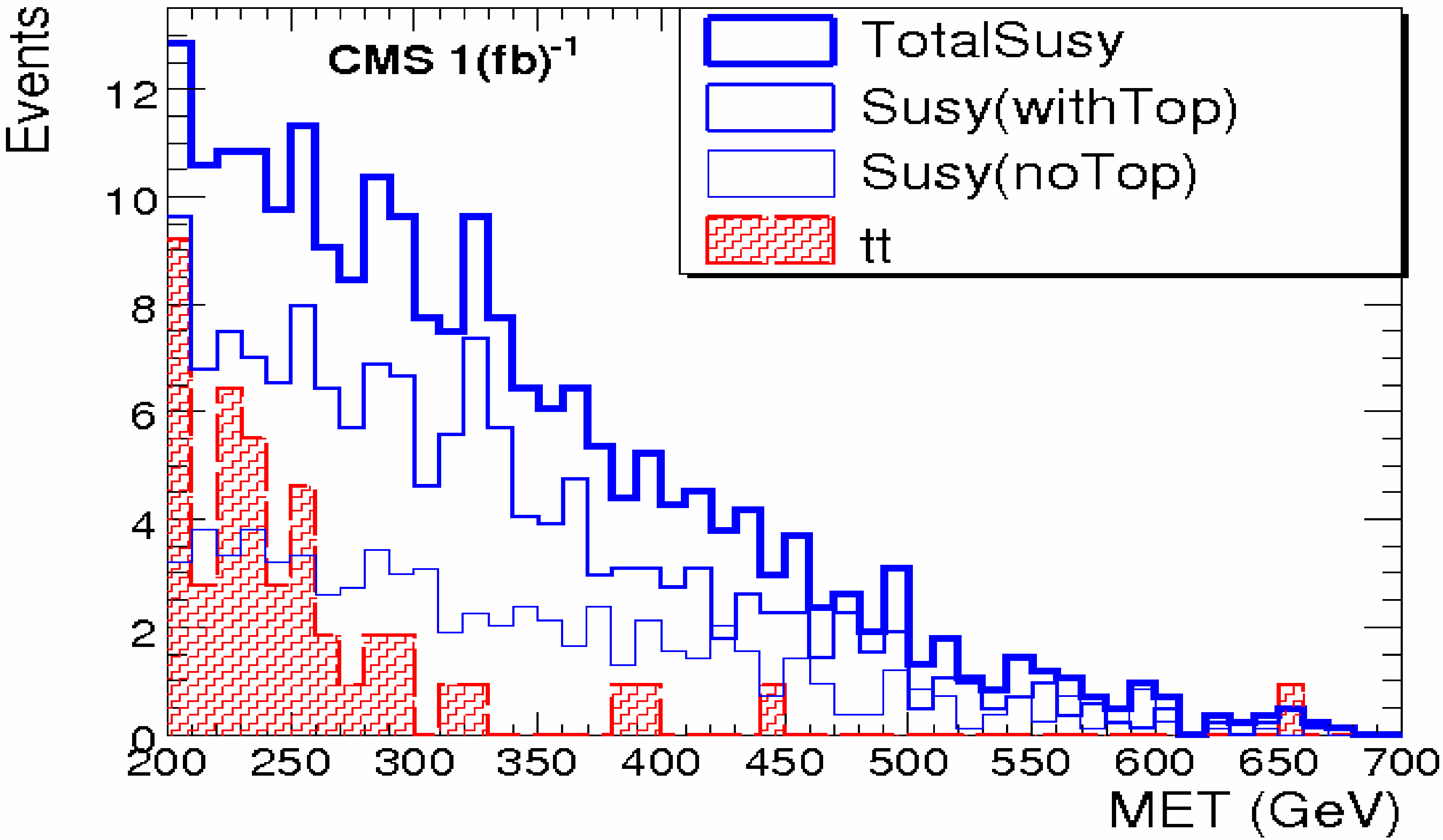
- Global High Level Trigger
- At least 1 b-jet. (E_T^{corr} > 30 GeV (E_T^{raw} > 20 GeV) |h| < 2.5)
- At least 3 light-jets (cuts same as *b*-jet). (to reduce qcd, W/ZW)
- MET > 200 GeV
- A Convergent Fit with χ^2 probability > 0.15
  (reduces fake top)
- $\Delta\phi$ (FittedTop, MET)<2.6
  (reduces tt)
- $\geq$ one isolated (e,μ) with $P_T > 5$ and $|\eta| < 2.5$
- **Only remaining Bkg is tt**



W and Top after all cuts



MET After All Cuts:



Results

- Efficiency Susy(withTop) $1.8*10^{-2}$
- Efficiency Susy(noTop) $1.6*10^{-3}$
- Efficiency tt $5.2*10^{-5}$
- SUSY(withTop) > 2 SUSY(noTop)
- Signal (SUSY(withTop) + SUSY(noTop)) > 3 SM Background
- Significance **(excess of SUSY over SM Bkg)** =11 σ
- Results will be revised to include QCD/W+Njets/single top but we do not expect dramatic changes.

Work done by S. Paktinat, L. Pape, M. Spiropulu

Conclusion

- Different approaches are being tried in both experiments to search for any evidence of BSM.

- Precise understanding of the top quark physics is vital for most of them both as a background and as signal.

Back up slides

Summary for KinFit

- Efficiency: 92% of tt events with a b-jet and 2 light jets have a convergent fit (46% if χ^2 probability > 0.05)

- Fake rate: 27% of SUSY(noTop) events with a b-jet and 2 light jets have a convergent fit (4.5% after cut)

- Purity: 44% of the fitted top quarks have a generated top closer than $\Delta R = 0.5$ that decays hadronically and all of its partons have $|\eta|<2.5$ and $E_T > 30$ GeV (33% after cut)

Extracted W and Top by Fit

(χ^2 probability > 0.05)