Finding SUSY Without Using Missing E_T

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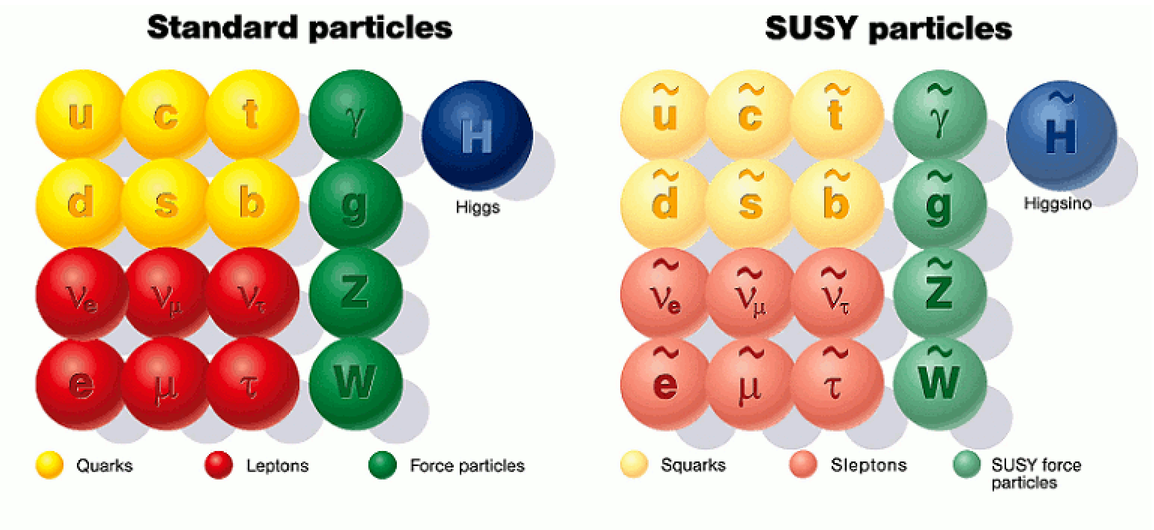
Outline

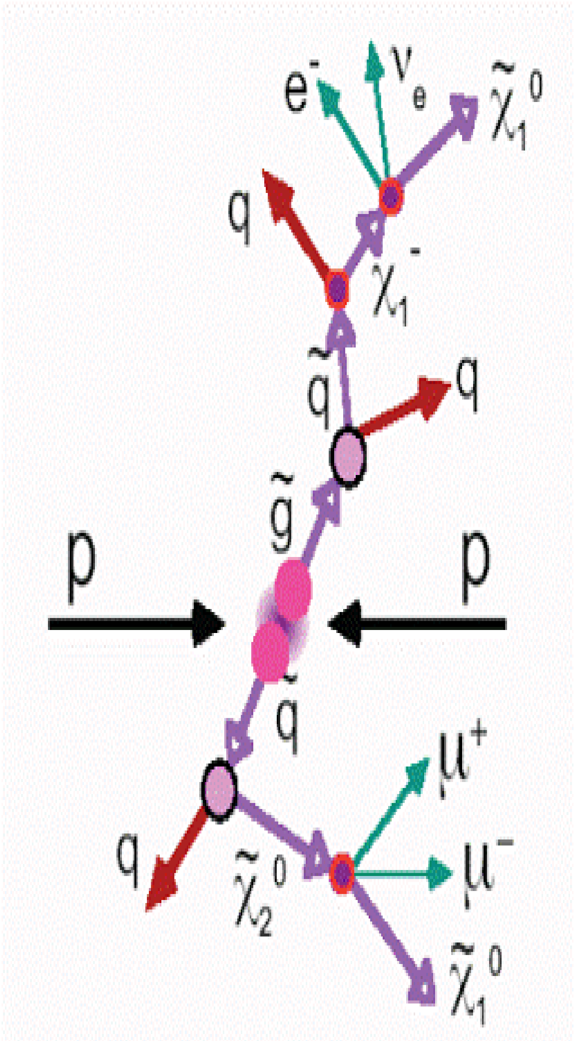
- Supersymmetry overview
- Motivation
- Details of analysis
- Results
- Conclusions
- Future Plans

Supersymmetry (SUSY)

- SUSY requires each SM particle to have a supersymmetric partner.
  - Sparticles have the same charge as SM particles, however
  - Sparticles differ from their SM partner in spin by half a unit,
    - Example: SUSY partner of an electron (a fermion) is a selectron (a boson).
  - Sparticle types: squarks, sleptons, gluino, charginos, neutralinos and SUSY Higgses.



Characteristics of SUSY Events



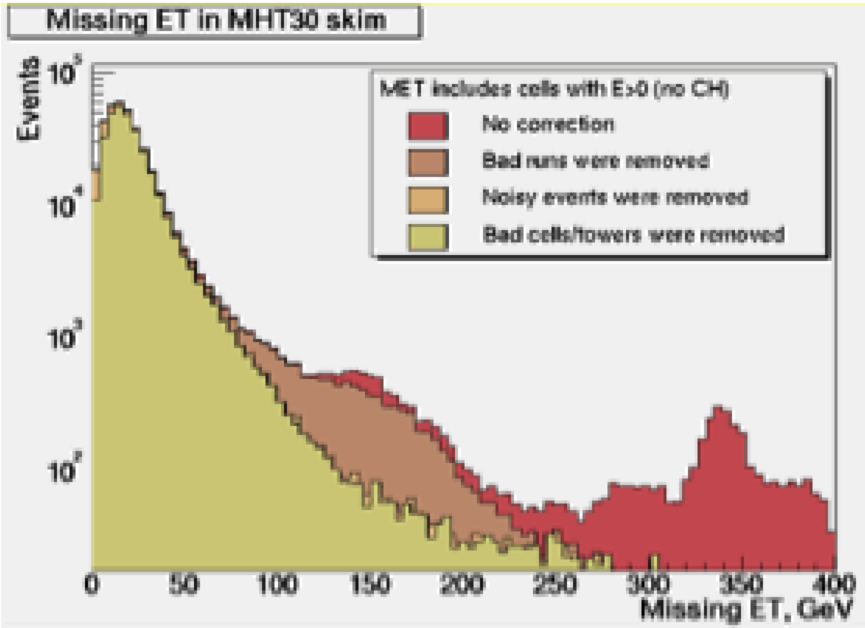
- Long cascade decays.
- SUSY events are expected to be rich in jets, isolated leptons, isolated photons and missing transverse energy (MET).
- Introduce a quantum number R-parity
  - R-parity for SM is -1, while for SUSY it is +1,
- When R-parity is conserved
  - Sparticles are produced in pairs,
  - Sparticle decay yields at least one SUSY daughter particle,
  - The lightest sparticle (LSP) is stable, since there is no particle for it to decay into.

Expected SUSY Signatures

- Long cascade decay chains lead to
  - High multiplicity of leptons and jets,
  - Low p_T leptons late in the decay chain,
  - High p_T jets due to central jets early in the decay chain.
- MET correlates with the mass of the LSP.
- Thus, the standard way to search for SUSY is to look for an excess in
  - MET + Jets,
  - MET + Leptons,
  - MET + Jets + Leptons.

Motivation

- Wish to develop an analysis for possible early detection of SUSY.
- As experience at the Tevatron shows, MET is a complicated global variable which takes time to understand, due to:
  - Mis-measurement in calorimeters,
    - Causes uncertainty in jet energy measurement,
  - Cracks and un-instrumented regions,
  - Dead cells,
  - Hot cells,
  - Mis-identified cosmic rays in the event.



Dan Green

Early SUSY Discovery

Early SUSY discovery at LHC without missing E_T: the role of multi-leptons

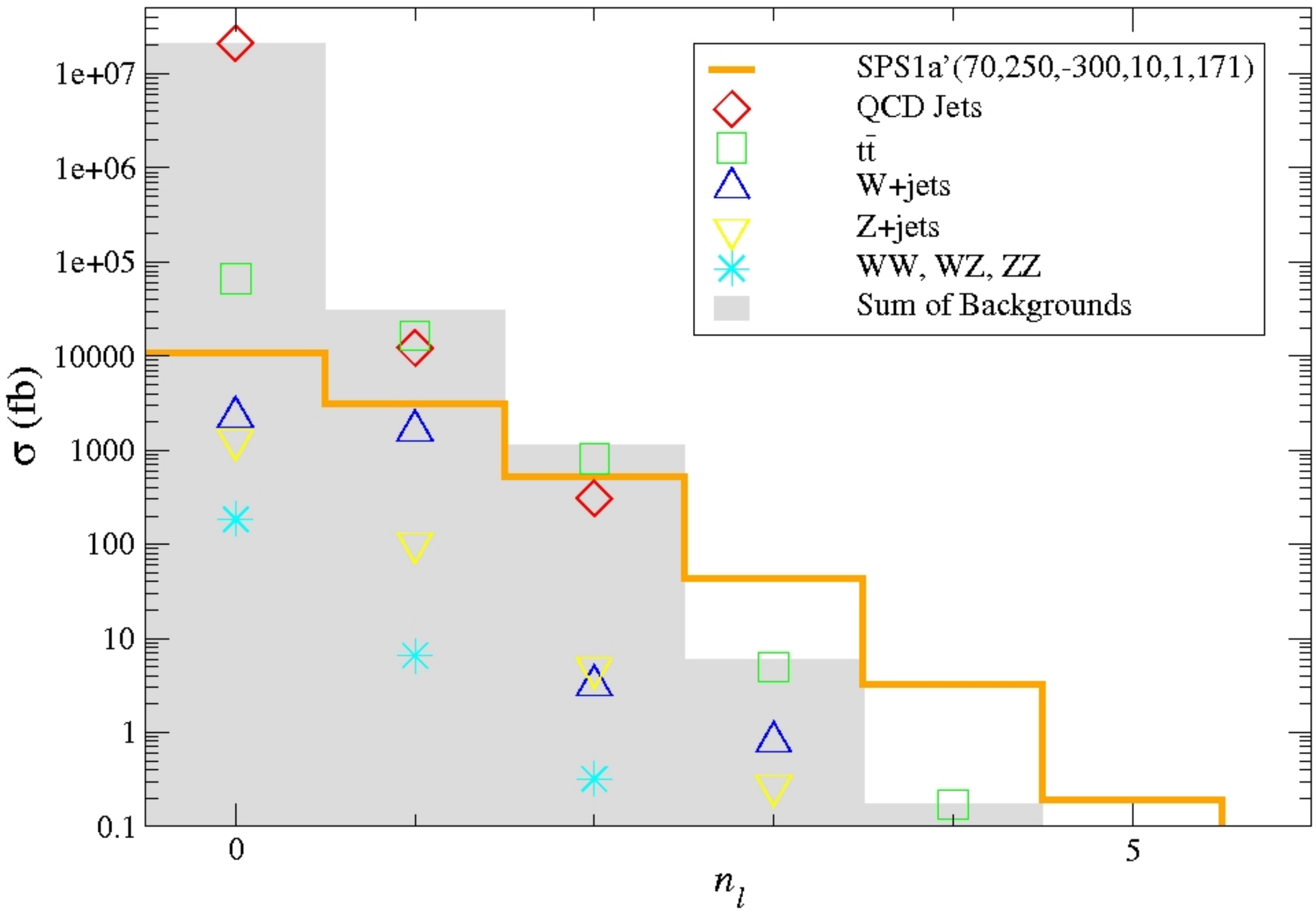
Howard Baer, Harrison Prosper, Heaya Summy.

Phys.Rev.D77:055017, 2008

- mSUGRA benchmark point (BM) SPS1a' (specific SUSY model)
  - m_0 = 70 GeV, $m_{1/2}$ = 250 GeV, $\tan(\beta) = 10$, A_0 = -300, $\mathrm{sign}(\mu) > 0$, m_t = 171 GeV.
- Cuts applied
  - $n(\mathrm{jets}) \geq 4$,
  - E_T (j1, j2, j3, j4) $\geq$ 100, 50, 50, 50 GeV,
  - $S_T \geq 0.2$.

Sphericity, $S_T = 3/2\min[\sum_j (p_{jT})^2] / [\sum_j p_j^2]$

Conclusions of Paper



SUSY is discoverable for lepton multiplicity > 2 without using MET!

Details of Analysis

- The PRD paper
  - Used ISAJET 7.76 and a toy detector simulation,
  - Investigated BM points SPS1a' and SO10ptA.
- Our goals
  - Before seeing data, verify whether this approach is a viable one.
    - Extend analysis to include mSUGRA bench mark points with different final states.
    - We have chosen, LM0, LM1, LM7, LM8, BM points.

Monte Carlo Samples Generated

- Process at 10 TeV
- Isajet and SUSYHIT were used to compute SUSY masses and branching ratios.
- PYTHIA 6.4 was used for generation, parton showers and hadronization.
  - Signal: LM0 , LM1, LM7, LM8 at 0.28M events each

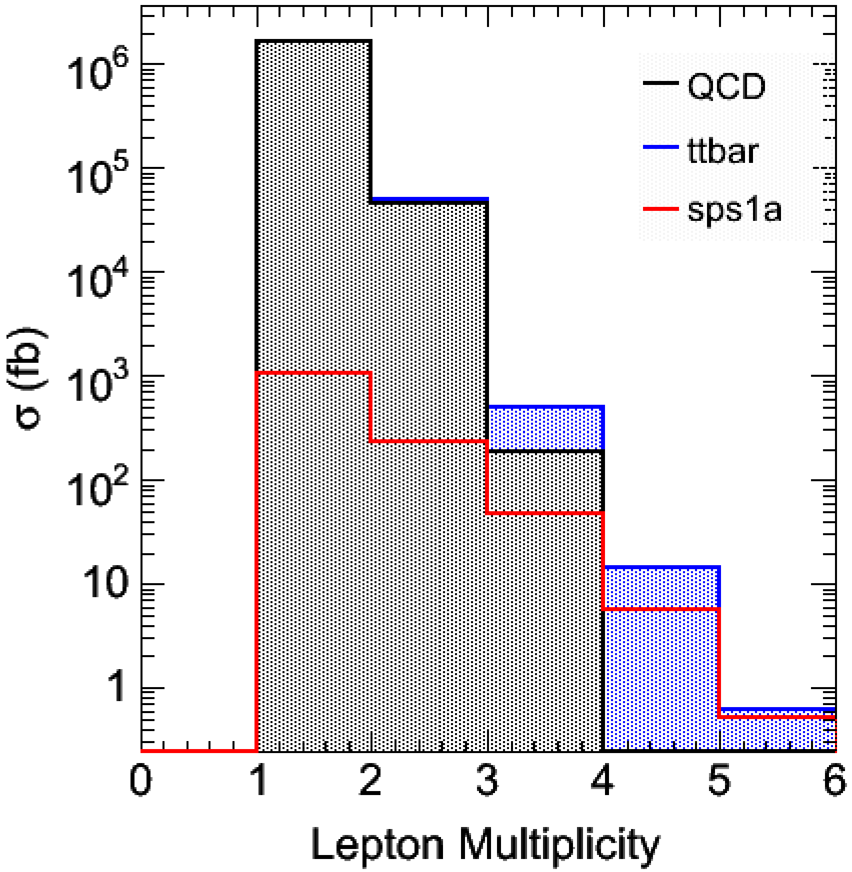
BM Point	m_0 (GeV)	$m_{1/2}$ (GeV)	tan(β)	sign(μ)	A_0	m_t (GeV)
LM0	200	160	10	+	-400	172.5
LM1	60	250	10	+	0	172.5
LM7	3000	230	10	+	0	172.5
LM8	500	300	10	+	-300	172.5
SPS1a'	70	250	10	+	-300	171 PRD

  - Background
    - QCD with p_T 50 - 2400 GeV 1M events,
    - ttbar 3M events.

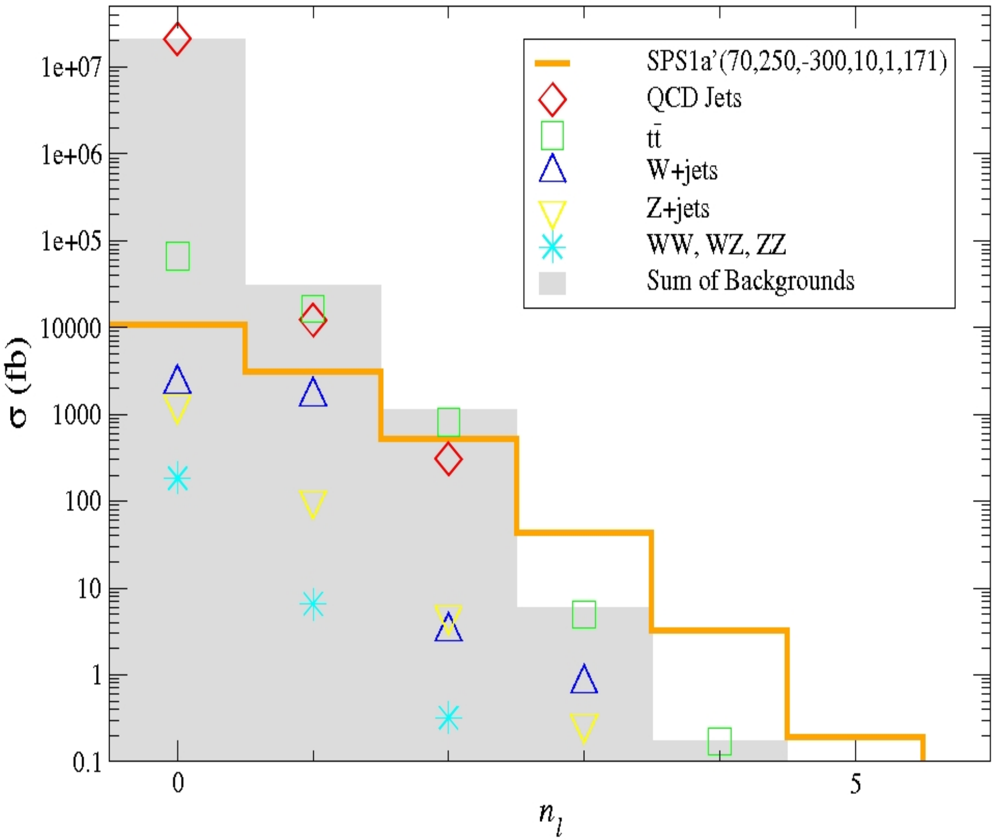
Detector Simulation

- PGS 4, Pretty Good Simulation is the work of many people!*
  - A fast approximate detector simulation.
  - It is an approximate simulation due to items which are not considered,
    - Secondary and nuclear interactions, bremsstrahlung, pair production, multiple scattering and pileup.
  - We are in the process of tuning PGS to match the CMS detector performance.
    - *John Conway (UC Davis), Ray Culbertson (FNAL), Regina Demina (U. Rochester), Ben Kilminster (Ohio State), Mark Kruse (Duke), Steve Mrenna (FNAL), Jason Nielsen (LBNL), Maria Roco (now at Lucent), Aaron Pierce and Jesse Thaler (Harvard), Natalia Toro (Harvard), Chris Tully (Princeton).
    - http://www.physics.ucdavis.edu/~conway/research/software/pgs/pgs4-general.htm

SPS1a'



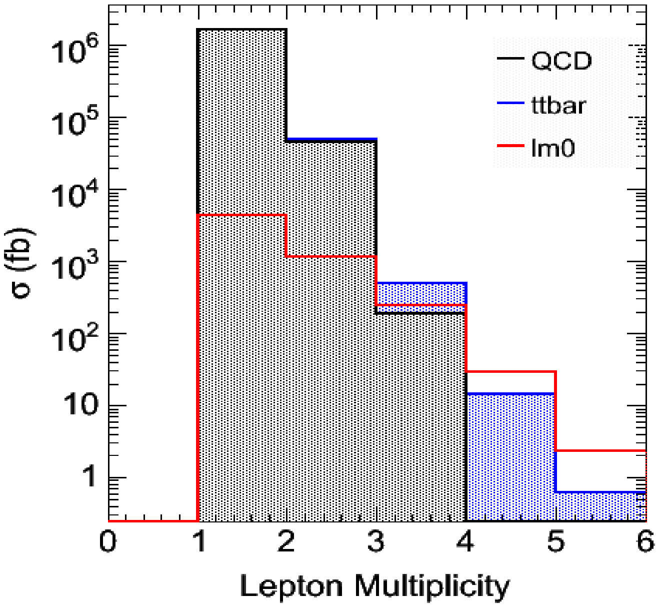
10 TeV



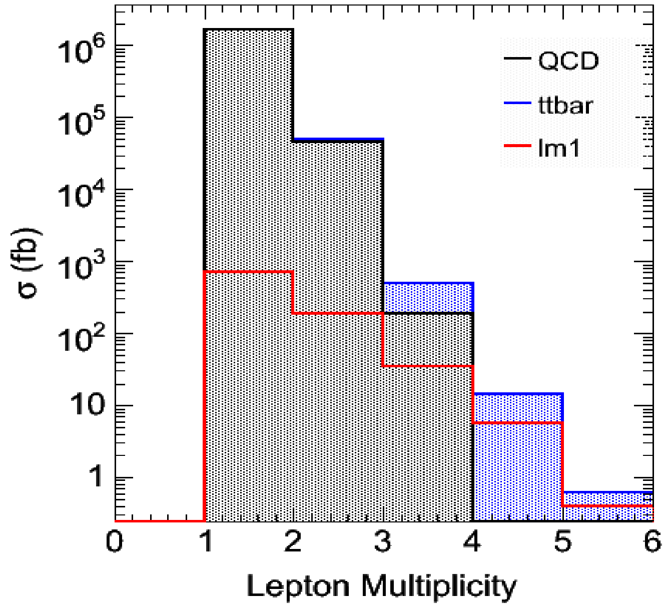
14 TeV

Lepton Multiplicity Results

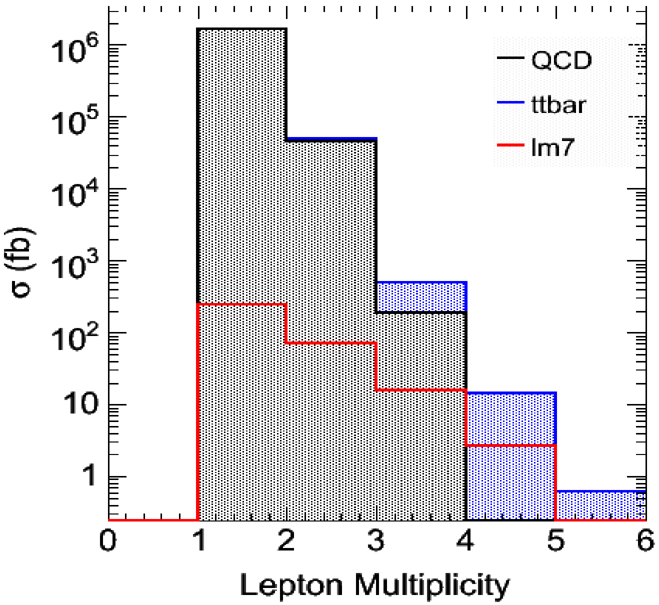
LM0



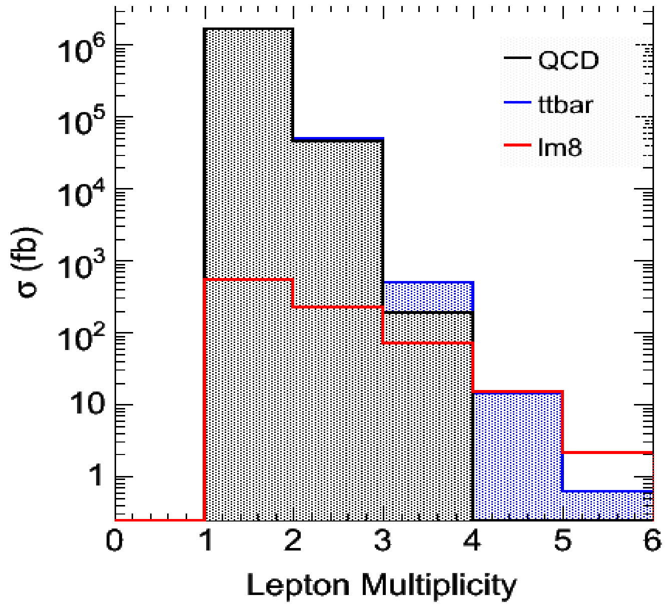
LM1



LM7



LM8



Conclusions

- This approach needs further investigation and inspiration,
  - Investigate,
    - Understand the differences between the current study and the PRD,
  - Inspiration,
    - Apply other known or new methods to reduce background,
  - If the background can not be sufficiently reduced,
    - Look for other variables which do not require using MET.

Future Plans

- Complete the tuning of PGS to match CMS detector performance.
- Search for signals of 5 σ significance
  - Explore a broader class of SUSY models,
  - Develop an automated search strategy for SUSY to use with the early LHC data.

Thank You

Backup Slides

Cross Section (pb)

Process	10TeV	14TeV	
LM0	110		
LM1	16	43.5	2.7
LM7	2.92	7.3	2.5
LM8	2.85	9	3.2
SPS1a'	16	47	2.9
QCD 50-100 GeV	1.28E+007	2.60E+007	2.0
QCD 100-200 GeV	6.76E+005	1.50E+006	2.2
QCD 200-400 GeV	27663	73000	2.6
QCD 400-1000 GeV	810	2700	3.3
QCD 1000-2400 GeV	2.75	15	5.5
ttbar	233	510	2.2

parameter	A	B	C	D	E
m_{16}	9202.9	9202.9	5018.8	2976.5	5877.3
$m_{1/2}$	62.5	62.5	160	107.0	113.6
A_0	-19964.5	-19964.5	-10624.2	-6060.3	-12052.6
m_{10}	10966.1	10966.1	6082.1	3787.9	—
$\tan\beta$	49.1	49.1	47.8	49.05	47.4
M_D	3504.4	3504.4	1530.1	1020.8	—
M_1	—	195	—	—	—
$m_{16}(1,2)$	—	—	603.8	—	—
f_t	0.51	0.51	0.49	0.48	0.49
f_b	0.51	0.51	0.41	0.47	0.49
f_τ	0.52	0.52	0.47	0.52	0.49
μ	4179.8	4186.3	1882.6	331.0	865.3
$m_{\tilde{g}}$	395.6	395.4	495.5	387.7	466.6
$m_{\tilde{u}_L}$	9185.4	9185.4	622.1	2970.8	5863.0
$m_{\tilde{u}_R}$	9104.1	9104.2	98.3	2951.4	5819.2
$m_{\tilde{t}_1}$	2315.1	2310.5	1048.4	434.5	944.7
$m_{\tilde{b}_1}$	2723.1	2714.9	1894.0	849.3	1452.7
$m_{\tilde{e}_L}$	9131.9	9132.0	311.9	2955.8	5833.6
$m_{\tilde{e}_R}$	9323.7	9323.9	891.8	3009.0	5945.8
$m_{\tilde{\chi}_1^\pm}$	128.8	128.8	165.7	105.7	141.3
$m_{\tilde{\chi}_2^0}$	128.6	128.1	165.1	105.1	140.9
$m_{\tilde{\chi}_1^0}$	55.6	115.9	80.2	52.6	65.7
m_A	3273.6	3266.0	1939.9	776.8	177.8
m_h	125.4	125.4	123.2	111.1	113.4
$\Omega_{\tilde{\chi}_1^0}h^2$	423 220	0.09 0.08	0.11 0.11	0.10 0.06	0.15 0.08
$BF(b\to s\gamma)$	3.0×10^{-4} 3.3×10^{-4}	3.0×10^{-4} 3.3×10^{-4}	6.2×10^{-4} 3.7×10^{-4}	1.9×10^{-4} 4.0×10^{-4}	2.5×10^{-4} 2.2×10^{-4}
Δa_μ	5.0×10^{-12} 5.1×10^{-12}	5.0×10^{-12} 5.0×10^{-12}	3.0×10^{-10} 2.8×10^{-10}	2.2×10^{-10} 2.2×10^{-10}	4.1×10^{-11} 4.1×10^{-11}
$BF(B_s\to\mu^+\mu^-)$	5.0×10^{-9} 4.4×10^{-9}	5.0×10^{-9} 4.4×10^{-9}	11.8×10^{-9} 6.9×10^{-9}	5.8×10^{-8} 6.2×10^{-8}	2.0×10^{-5} 2.0×10^{-5}
$\sigma_{sc}(\tilde{\chi}_1^0 p)$ [pb]	1.3×10^{-15}	1.9×10^{-17}	1.5×10^{-6}	2.7×10^{-9}	5.3×10^{-8}

Table 1: Masses and parameters in GeV units for five benchmark Yukawa unified points using Isajet 7.75 and $m_t = 171.0$ GeV. The upper entry for the $\Omega_{\tilde{\chi}_1^0}h^2$ etc. come from IsaReD/Isatools, while the lower entry comes from micrOMEGAs; $\sigma(\tilde{\chi}_1^0 p)$ is computed with Isatools.

Standard Model	Supersymmetry
$\gamma,\ Z^0,\ h^0,\ H^0$	$\tilde{\chi}^0_1,\ \tilde{\chi}^0_2,\ \tilde{\chi}^0_3,\ \tilde{\chi}^0_4$
$W^+,\ H^+$	$\tilde{\chi}^+_1,\ \tilde{\chi}^+_2$
$e^-,\ \nu_e,\ \mu^-,\ \nu_\mu,\ \nu_\tau$	$\tilde{e}^-_R,\ \tilde{e}^-_L,\ \tilde{\nu}_e,\ \tilde{\mu}^-_R,\ \tilde{\mu}^-_L,\ \tilde{\nu}_\mu,\ \tilde{\nu}_\tau$
τ^-	$\tilde{\tau}_1,\ \tilde{\tau}_2$
$u,\ d,\ s,\ c$	$\tilde{u}_R,\ \tilde{u}_L,\ \tilde{d}_R,\ \tilde{d}_L,\ \tilde{s}_R,\ \tilde{s}_L,\ \tilde{c}_R,\ \tilde{c}_L$
b	$\tilde{b}_1,\ \tilde{b}_2$
t	$\tilde{t}_1,\ \tilde{t}_2$

mSUGRA Parameters

- m_0 common mass of scalar sparticles (at GUT scale),
- $m_{1/2}$ common mass of gauginos (at GUT scale),
- A_0 tri-linear coupling constant,
- $\tan\beta$ ratio of the Higgs doublets,
- Sign(μ) is the sign of the Higgsino mass parameter.