Outline:

- Expected cross-section during early DATA
- Inclusive Search Strategy - SuperSymmetry
- SUSY discovery potential
- Background estimation using “DATA”
- Summary and Outlook

Thanks to B. Mellado, Sau Lan Wu and ATLAS SUSY WG
Expected cross-section during early DATA

Standard Physics processes have relatively large uncertainties but with huge cross section

\[ 10 \text{ pb}^{-1} \sim 1 \text{ day at } 1/100 \text{ of the design lumi.} \]

- Total inelastic: \( \sim 0.1 \text{ barn} \)
- Inclusive QCD multijets: \( \sim 10^5 \text{ nb (10}^9 \text{/day)} \)
- Inclusive b\bar{b}: \( \sim 10^3 \text{ nb (10}^7 \text{/day)} \)
- Inclusive \( \gamma/Z/W \): \( \sim 100/1.5/10 \text{ nb (1- 100k /day)} \)
- Inclusive top: \( \sim 0.89 \text{ nb (8.9 k /day)} \)
- Z(vv) + Jets: \( \sim 0.3 \text{ nb (3 k /day)} \)

Compare this to 1 TeV Inclusive SUSY < 10 fb

Need to have an accurate understanding of the background – to claim a discovery
If Supersymmetry (SUSY) exists at electroweak scale:
LHC should be able to find it: sensitive to $\sim 2$ TeV for 10 fb$^{-1}$

**Typical signature (R-parity Conserved):**
Cascade decays into Multijets, leptons + E$_T^{Miss}$
QCD couplings $\rightarrow g\bar{q}q, q\bar{q}g, gg\bar{g}$
Jets + E$_T \rightarrow q\bar{q}^*, gg, q\bar{g}$
Interesting stops $\rightarrow \tilde{t}_1 \tilde{t}_1^*$
Like sign dileptons $\rightarrow \tilde{g}\tilde{g}$ $[\tilde{g} \rightarrow \tilde{u}u \rightarrow \tilde{t}_1^+\tilde{t}_1^0 \text{ or } \tilde{g} \rightarrow \tilde{u}^*u \rightarrow \tilde{t}_1^-\tilde{t}_1^0]$ Tri-leptons $\rightarrow \tilde{\chi}_2^0\tilde{\chi}_1^- \left[ \tilde{\chi}_2^0 \rightarrow \ell\ell \rightarrow \tilde{\chi}_1^0\ell\ell; \tilde{\chi}_1^- \rightarrow \tilde{\chi}_1^0\ell\ell \right]$
Step 1: Use a simple inclusive analysis to establish a deviation from the SM
   [In a model independent manner to establish “New Physics”]

   **Main idea behind this talk**

Step 2: Study the characteristic variables and show SUSY is a candidate
   for explanation

Step 3: Test the predictions of candidate for SUSY models

**Goal**: If SUSY exists, measure large number of characteristic distributions to
   perform a global fit to the data – as was done at LEP for $Z^0$

**Exclusive Search** (Not Covered in this talk):
- With enough statistics reconstruct kinematic endpoints in invariant mass
- Constrains mass spectrum and SUSY parameters
- Requires large statistics
The dominant production of SUSY at LHC is through pairs of gluinos and squarks.

Use mSUGRA as testing ground for methods.

Their cascade decays produces high $E_T$ jets and large $E_T^{\text{Miss}}$.

\[ \tilde{g} \rightarrow \tilde{q}_L + \bar{q} \quad \text{and} \quad + \tilde{g} \rightarrow \tilde{q}_R + \bar{q} \]

\[ \rightarrow \tilde{\chi}_2^0 + q \quad \text{and} \quad \rightarrow \tilde{\chi}_1^0 + q \]

\[ \rightarrow \tilde{\chi}_1^0 + h \]

Use a discriminant for inclusive SUSY searches like effective mass:

\[ \text{Meff} = E_T^{\text{Miss}} + \sum E_T(4 \text{ Jets}); \]

An excess of events with large effective mass

- could provide initial discovery of SUSY
Inclusive SuperSymmetry using mSUGRA

Main final states in Cascade decays ($E_T + \text{Jets}$): [No lepton Mode]

Current estimation using ALPGEN

M$_{\text{SUSY}}$ ~ 1 TeV

TDR Study 1999

M$_{\text{SUSY}}$ ~ 0.7 - 1.2 TeV

SU1: $m_0 = 70$ GeV, $m_{1/2} = 350$ GeV, $A_0 = 0$, $\tan\beta = 10$, & $\mu = +ve$

SU3: $m_0 = 100$ GeV, $m_{1/2} = 300$ GeV, $A_0 = -300$, $\tan\beta = 6$, & $\mu = +ve$

SU52: $m_0 = 250$ GeV, $m_{1/2} = 600$ GeV, $A_0 = 0$, $\tan\beta = 10$, & $\mu = +ve$

SU6: $m_0 = 320$ GeV, $m_{1/2} = 375$ GeV, $A_0 = 0$, $\tan\beta = 50$, & $\mu = +ve$

**Signal**

- Hard Jet is not emitted in a parton shower
- Parton shower works reasonable in collinear region
- For High Et region use: ME Calculations + Matching to Parton Shower
- Dominant backgrounds: Inclusive top, $Z \rightarrow \nu\nu + \text{N Jets}$, $W \rightarrow l\nu + \text{N Jets}$ & QCD MultiJets

10 - 15th Sept 2006  "PASCOS 2006, The Ohio State University"  6
Exclude the standard Model background using the $M_T$ cut

**One Lepton Mode:** Very clean discovery channel ...

Main final states in Cascade decays ($E_T + \text{Jets} + \text{Lepton}$): [One lepton Mode]
SUSY discovery potential: Significance using CL$_b$

Calculate significances using Likelihood Ratio:

- B-only: the number of expected events is given by a Poisson distribution
- S+B: Poisson distribution with P(n; S+B)
- Compute the probability density function of the Likelihood Ratio in B-only
- Compute the likelihood ratio for LR$_{\text{obs}}$
- If CL$_b$ $\sim$ 1; exclude the background only hypothesis
SUSY discovery potential: Significance using $\text{CL}_b$

- **SUSY: 0 Lepton Mode with 10 – 50 pb$^{-1}$**
  - Assuming 10 – 30 % uncertainty on understanding of the background
  - One lepton mode is not much sensitive to background uncertainties
  - Need to address background extraction and its uncertainties

- **SUSY: 1 Lepton Mode with 20 pb$^{-1}$**

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Sanjay Padhi
Assuming 10% uncertainty on understanding of the background

Need an accurate understanding of backgrounds

- Inclusive top, $Z \rightarrow \nu\nu + N$ Jets, $W \rightarrow l\nu + N$ Jets, QCD MultiJets

Important to extract backgrounds using DATA – See Next
Modeling \( tt \) background using control samples:

Important to find variable uncorrelated to Missing \( E_T \)
make control sample at lower Missing \( E_T \)
\[ \Rightarrow \] extrapolate it to higher Missing \( E_T \)

Top mass is reasonably uncorrelated to Missing \( E_T \)
Use it to isolate top sample
Select semi-leptonic top candidates
- Combinatorial from side bands

Control sample is normalized to data using low MET where SUSY contribution is small
Background estimation using "DATA"

Modeling tt background using control samples:

Background estimation using 10 fb-1 of DATA (low lumi.)
Large excess at Missing $E_T > 500$ GeV

Using high $P_T$ Validation sample:

High Missing $E_T$ region > 500 GeV

- $N_{\text{OBS}}$ (w SUSY) = $503 \pm 22$
- $N_{\text{ESTIMATED}}$ (w/o SUSY) = $7 \pm 35$

Clear $13\sigma$ excess !!!
⇒ the method proved to valid

Estimating top background from 'real DATA' looks promising

Other dominant SUSY background includes: $Z (\rightarrow \nu \nu) + N$ Jets
Background estimation using “DATA”

- Modeling $Z \rightarrow \nu\nu + \text{Jets}$ background using $Z \rightarrow \mu\mu + \text{N Jets}$

- Measure $Z^0$ mass peak using (ee or $\mu\mu$) channel
- Under the $Z^0$ mass peak study the events by replacing the $\mu$'s with $\nu$'s
- Recalculate the Missing $E_T$ distribution event by event

Note: $Z$ BR to $\nu$'s is 6 times that to leptons ⇒ important to study with fewer Jets
Use $W (\rightarrow l\nu) + \text{Jets}$ by replacing leptons with $\nu$'s
Background estimation using “DATA”

- Modeling $Z \rightarrow \nu \nu +$ Jets background using $W \rightarrow l \nu + N$ Jets

**Estimate the $Z(\nu\nu)$ background esp. in high Missing $E_T$ region**

Use $W(\mu \nu)+n$jets sample, replacing $\text{Pt} (\mu \nu)$ with Missing $E_T$

(same kinematics to $Z(\nu\nu)$, 10 times larger $\sigma$ than Drell-Yan)

![Graph showing $Z(\nu\nu)+n$jets Estimated vs Missing $E_T$](image)

- **SUSY cut**
  - $N_{\text{Jet}} \geq 4$ ($p_T^{1\text{st}}>100\,\text{GeV}$, $p_T^{4\text{th}}>50\,\text{GeV}$)
  - $\text{MET}>100\,\text{GeV}$ and $\text{MET}>0.2 \times \text{Meff}$
  - $N_\mu>0$ with $\text{Pt}(\mu)>10\,\text{GeV}$

**Normalization**

low Missing $E_T$ region (=100-150GeV)

**Result** (Missing $E_T>300\,\text{GeV}$, 1fb$^{-1}$)

$Z(\nu\nu)+n$jets : $157+/−13$

Estimated : $134+/−10$

Good agreement

- The method looks promising
- $W(\mu \nu)$ needs discrimination from the top events

**Major Issue : Scale Choice and related uncertainties**
The LHC will be THE PLACE to search for and 'hopefully' study SUSY from 2008

Inclusive search Strategy – based on observables independent of Model assumptions

Need to re-discover Standard Model in order to understand SUSY starting Day 1

Big challenge for discovery will be understanding of background systematics

Unavoidable tension between understanding inclusive samples for SM background + detector issues, Versus making initial discoveries.

There will be strong challenges from trigger and reconstruction

- the initial LHC discoveries will come from inclusive signature
Summary and Outlook

Be careful !!! Not for Amateurs

MET + MultiJets among the most challenging searches in Tevatron