Precision Gluino Mass Measurement at the LHC

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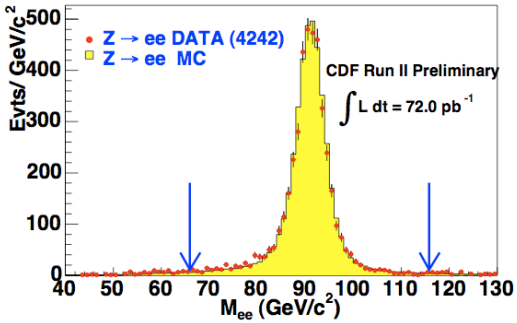
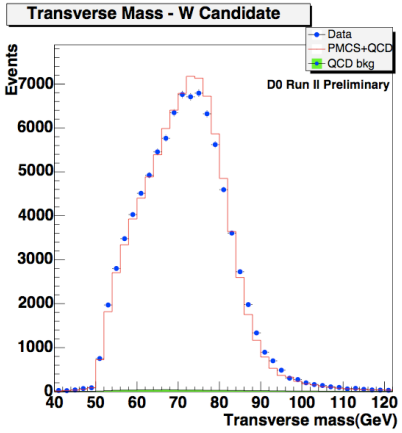
Mass Measurements

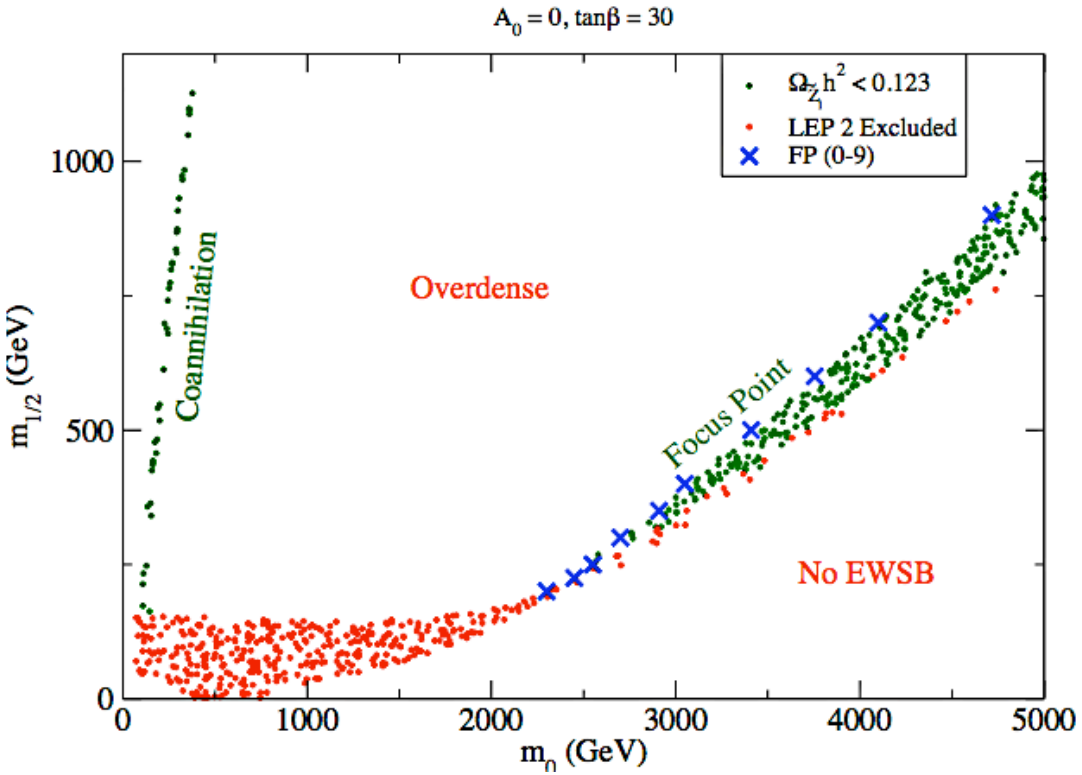
- Mass measurements rely on
  - Bump hunting - invariant mass
  - Kinematic endpoints if missing energy is present
    - Difficult if cascade decays are long
- Total rate can also be used to determine mass
  - Can be used in Focus Point region of mSUGRA





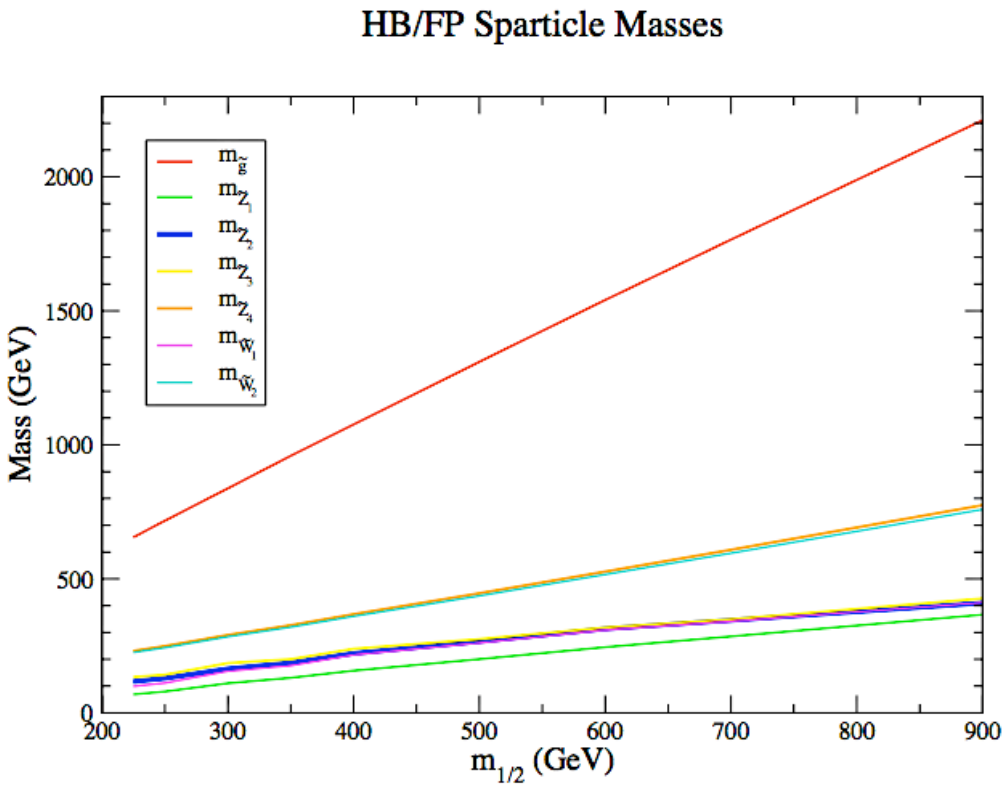
mSUGRA Parameter Space

- Relic density observations favors specific regions
  - $\tilde{Z}_1 - \tilde{\tau}$ coannihilation
  - Focus Point
    - Decoupled scalars & mixed higgsino-gaugino DM



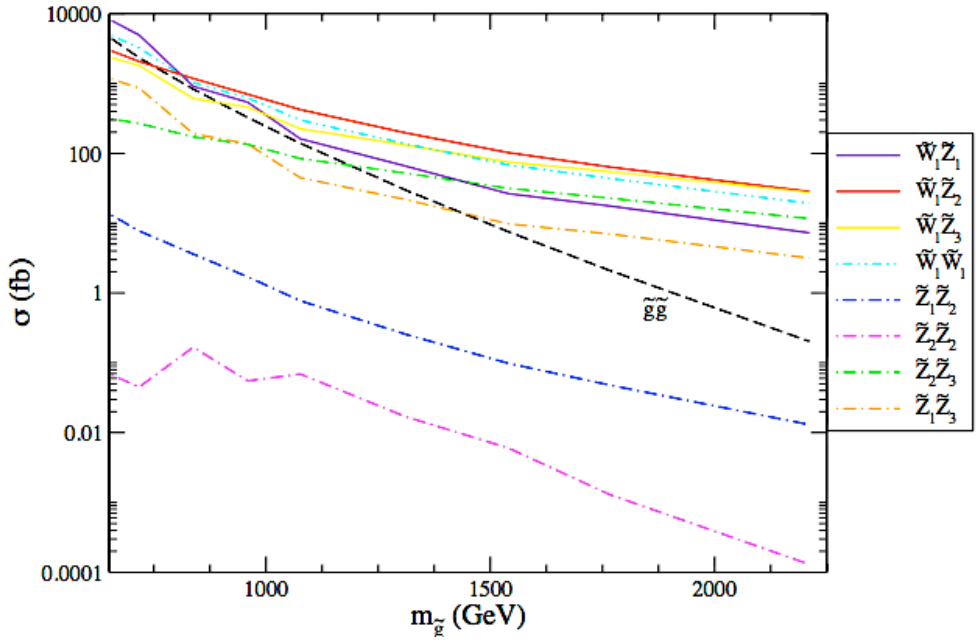
Focus Point Region Spectra

- Neutralinos and charginos typically light
  - soft component of event
- Scalar fermions decoupled (few TeV or more)
- Gluino is heaviest gaugino
  - Hard component of event



Gaugino Production Cross Section

- Dominated by Neutralino-Chargino production
  - Soft events with high lepton multiplicity
- Gluino pair production rate falls rapidly
  - (key to gluino mass measurement)



Minimal SUSY Cuts

- Apply C1 cuts:

$$
\begin{array}{ccc}
E_T^{miss} & > & \min(100\ \text{GeV},\ 0.2\ M_{eff}) \\
n(jets) & \geq & 4 \\
E_T(j1, j2, j3, j4) & > & 100,\ 50,\ 50,\ 50\ \text{GeV} \\
S_T & > & 0.2
\end{array}
$$

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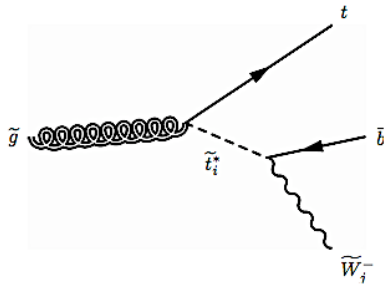
$$M_{eff} = E_T^{miss} + E_T(j1) + E_T(j2) + E_T(j3) + E_T(j4)$$

Characteristics of Gluino signal

- Large jet & b-jet multiplicity

mode	BF
$\tilde{g} \to t\bar{t}\tilde{Z}_1$	3.9%
$\tilde{g} \to t\bar{t}\tilde{Z}_2$	14.2%
$\tilde{g} \to t\bar{t}\tilde{Z}_3$	15.0%
$\tilde{g} \to t\bar{t}\tilde{Z}_4$	5.6%
$\tilde{g} \to t\bar{b}\tilde{W}_1 + c.c$	26.8%
$\tilde{g} \to t\bar{b}\tilde{W}_2 + c.c.$	13.9%



Apply jet cuts:

$$n(jets) \geq 7$$

$$n(b-jets) \geq 2$$

- b-tagging: 60% of jets that contains B-meson with $p_T(B) > 15$ GeV and $|\eta(B)| < 1.5$ with $E_T(j) > 50$ GeV and $|\eta(j)| < 3$
  - mistag rate: interpolated between

    0.7% for $E_T(j) < 100$ GeV

    2% for $E_T(j) > 250$ GeV

SM Backgrounds

- Many SM backgrounds

process	events	σ (fb)	cuts C1 (fb)
QCD ($p_T : 50 - 100$ GeV)	10^6	2.6×10^{10}	–
QCD ($p_T : 100 - 200$ GeV)	10^6	1.5×10^9	1513.3
QCD ($p_T : 200 - 400$ GeV)	10^6	7.3×10^7	3873.7
QCD ($p_T : 400 - 1000$ GeV)	10^6	2.7×10^6	486.0
QCD ($p_T : 1000 - 2400$ GeV)	10^6	1.5×10^4	4.4
$W + jets; W \to e, \mu, \tau$ ($p_T(W) : 100 - 4000$ GeV)	5×10^5	3.9×10^5	1815.9
$Z + jets; Z \to \tau\bar{\tau},\ \nu s$ ($p_T(Z) : 100 - 3000$ GeV)	5×10^5	1.4×10^5	845.3
$t\bar{t}$	3×10^6	4.6×10^5	6415.8
WW, ZZ, WZ	5×10^5	8.0×10^4	9.3
signal (FP5: $m_{\tilde{g}} = 1076$ GeV)	2×10^5	1.2×10^3	77.5

Most trouble-some backgrounds:
top pair production & QCD jets

Event Generation

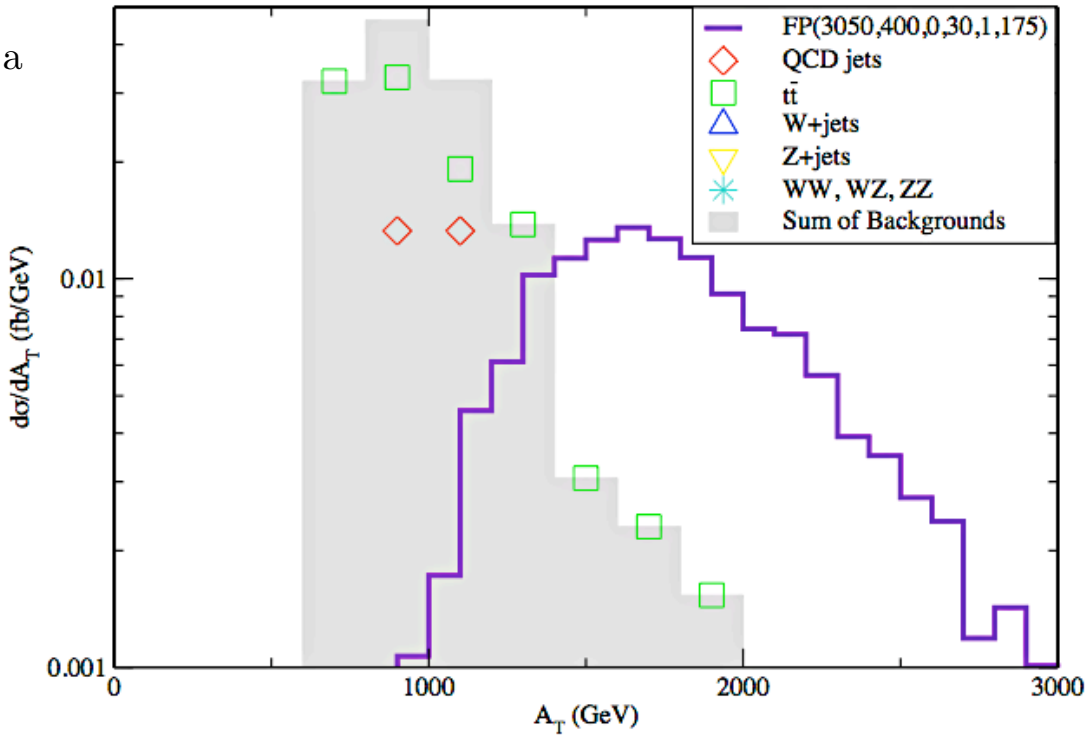
$n(jets) \geq 7$, $n(b\text{-}jets) \geq 2$

Use Isajet-7.74 to produce 100 fb^{-1} of data

Gluino signal isolated with:

- C1 cuts
- $n(jets) \geq 7$, $n(b\text{-}jets) \geq 2$
- $A_T \geq 1400$ GeV

Optimized for $M_{\tilde{g}} \approx 1$ TeV



Augmented effective mass: $A_T = E_T^{miss} + \sum_{leptons} E_T + \sum_{jets} E_T$

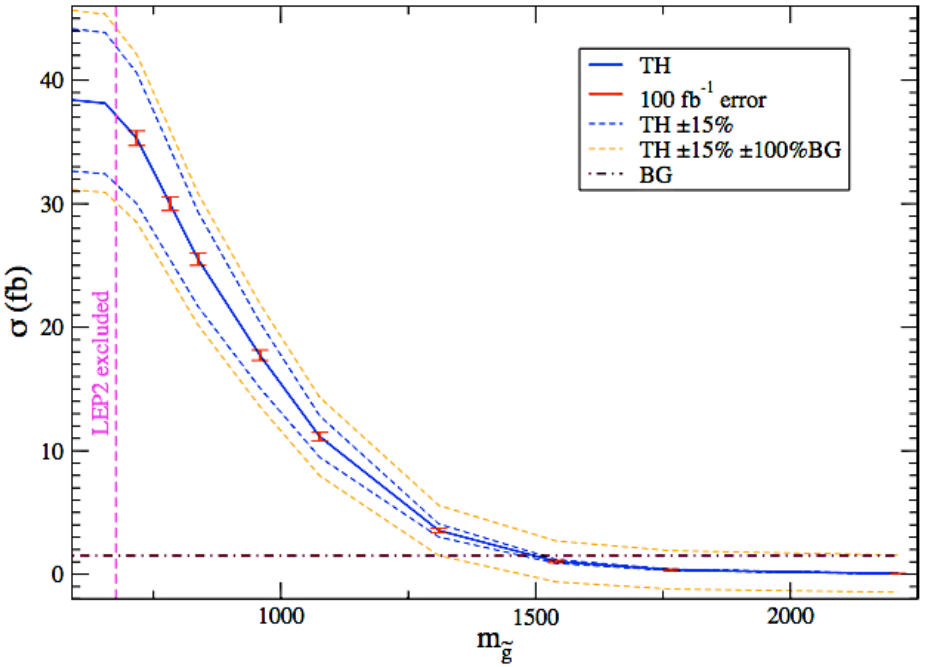
Gluino mass extraction

- Signal rate strongly dependent on gluino mass

Total rate uncertainties:

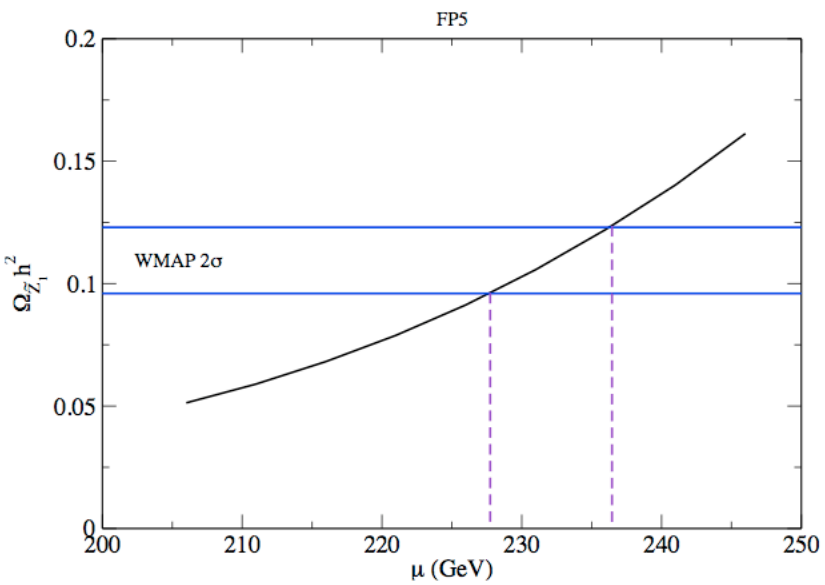
~3% 100 fb^{-1} finite statistics uncertainty
15% Theory uncertainty (NLO calculation / squark decoupling)
100% Background uncertainty

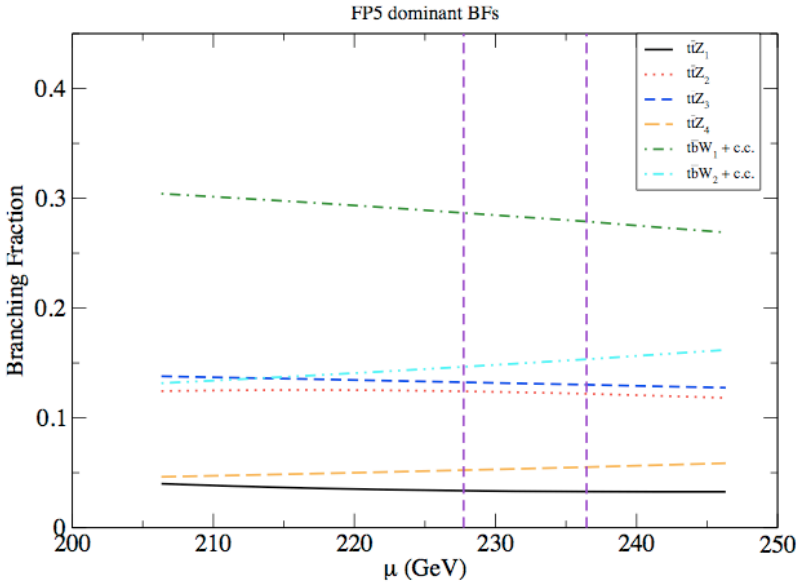
⇒ 7-10% uncertainty in gluino mass!



Other sources of uncertainty

- Variability of μ within allowed ranges of Ω_{DM}





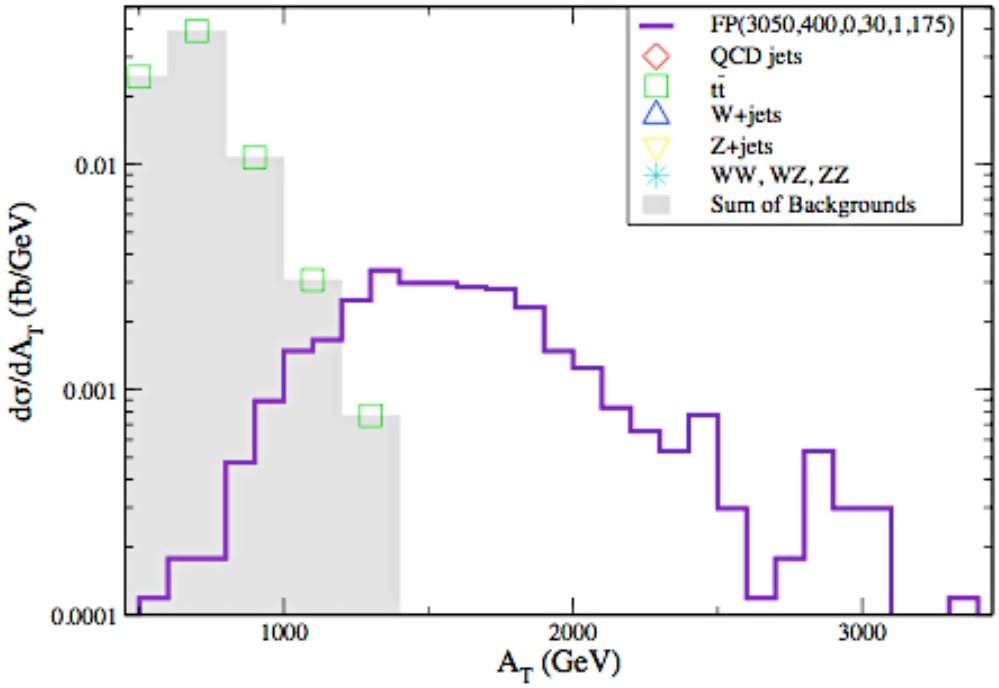
Percent variation in BF of typical modes

- Variability of $\tan\beta$:

m_0	$\tan\beta$	σ(C2) (fb)
4090	10	9.92
3150	20	10.45
3050	30	11.15
3000	40	11.04
2970	50	11.17

Leptonic signatures of FP region

- Leptons are typically soft
  - From lighter Neutralino and Chargino cascade decays
- Isolate leptonic signature by:
  - C1 cuts
  - $n(isolated\ leptons) \geq 2$
  - $n(jets) \geq 4$
  - $n(b\text{-}jets) \geq 2$
  - $A_T > 1200$ GeV

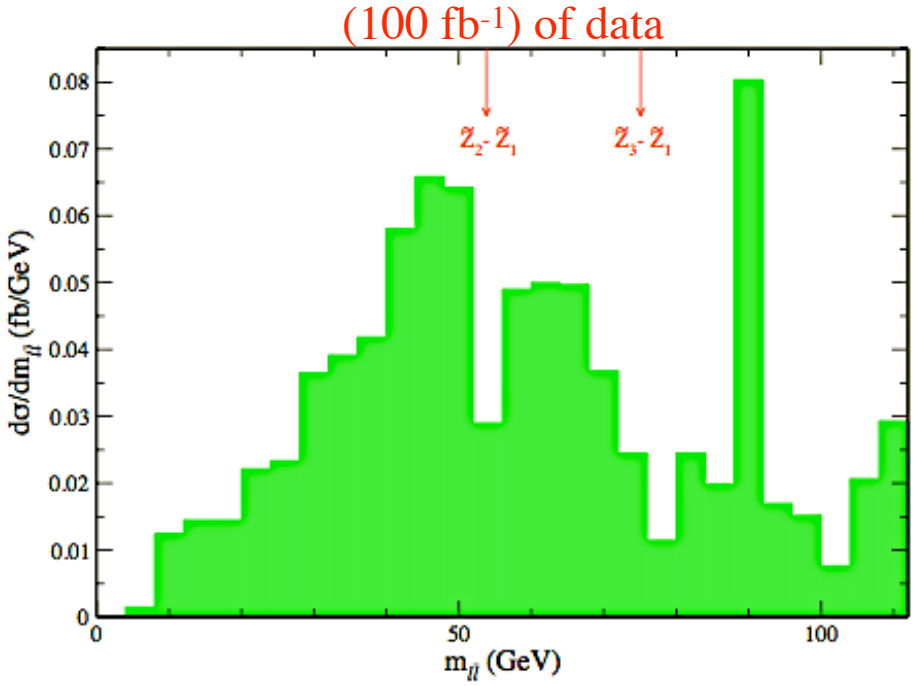


Neutralino decays

- Neutralino mass splitting below Z threshold in FP region
  - Dilepton invariant mass has edge
- Edge begins to appear with 100 fb^{-1} of data
- More well defined with more data

- Verify soft lepton component of signal with hard gluino component

  $\Rightarrow$ in FP region



Conclusions

- Events in Focus Point region characterized by
  - Hard events - gluino pair production
    - Many jets and b-jets
    - Large Augmented effective mass
  - Soft events - chargino/neutralino production
    - Many jets and leptons
    - $m_{\tilde{Z}_2} - m_{\tilde{Z}_1}$ and $m_{\tilde{Z}_3} - m_{\tilde{Z}_1}$ below Z resonance

- Gluino mass can be determined to 7-10% from total rate after isolating hard signal