Signals in the Co-annihilation Region of Supersymmetry at the LHC

- Supersymmetry and Dark Matter -

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Outline

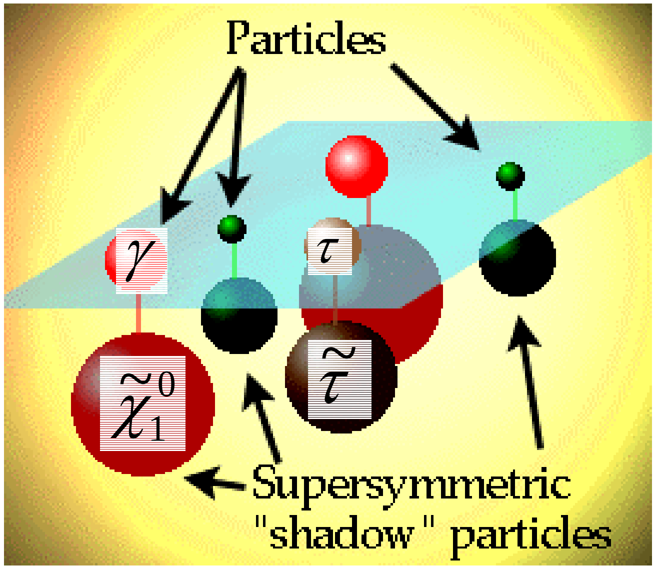
- Supersymmetry (SUSY) and Cosmology
  - Supersymmetric particles
  - Dark matter
- How to measure a small $\tilde{\tau} - \chi_1^0$ mass difference (ΔM)
  - Counting
  - Invariant mass
- Results
- Conclusions

Introduction

- Cosmology says: ~24% of universe's energy content is cold dark matter
- Supersymmetry for Grand Unification of forces : new Supersymmetric particles
- There are many candidates for dark matter.
- The lightest SUSY particle provides a well motivated dark matter candidate : $\tilde{\chi}_1^0$

Supersymmetric Particles

- Every standard model particle has a corresponding SUSY particle
- Recent cosmological data (WMAP) point to parameters in the "co-annihilation" region (also: LEP, b->sγ, g-2, Higgs mass)
- In "co-annihilation" region, $\tilde{\tau}$ and $\tilde{\chi}_1^0$ are nearly mass degenerate
- Can we measure ΔM = $\tilde{\tau} - \chi_1^0$ at the LHC?

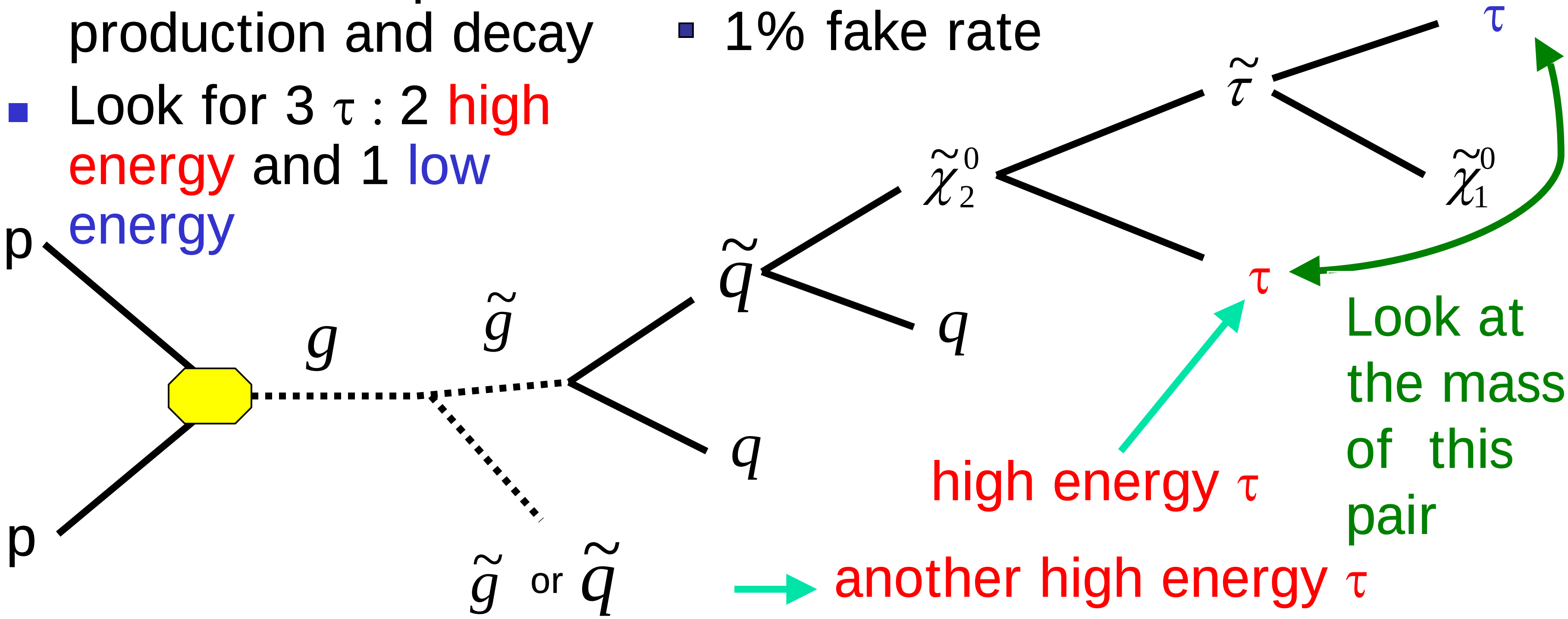


3τ Final State Provides Unique Signal of Co-annihilation

- Produce SUSY events in pp collisions at LHC
- Look at SUSY particle production and decay
- Look for 3 τ : 2 high energy and 1 low energy

Assume:

- 50% tau efficency
- 1% fake rate

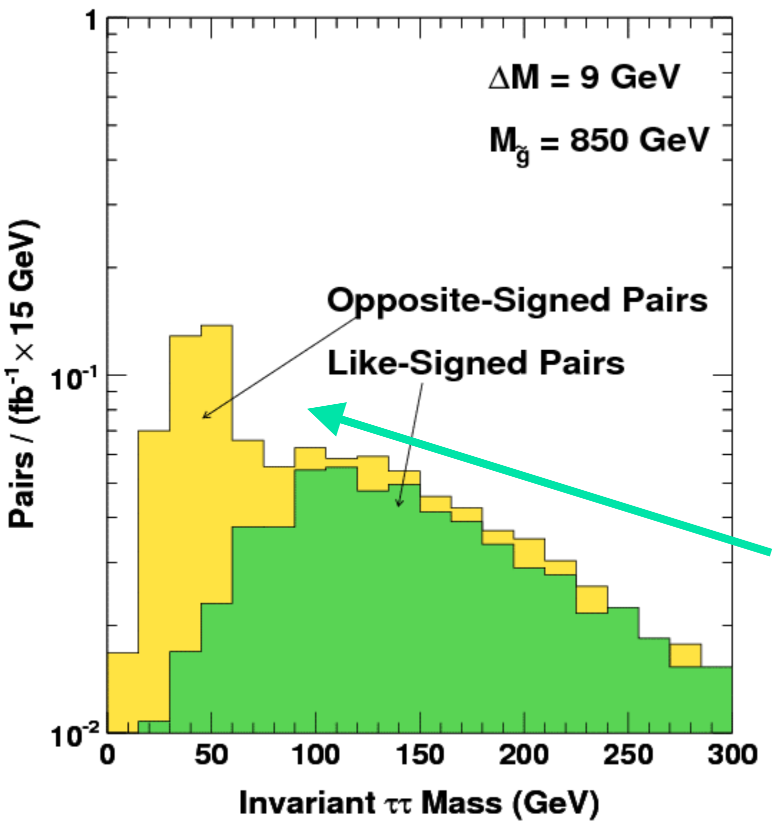


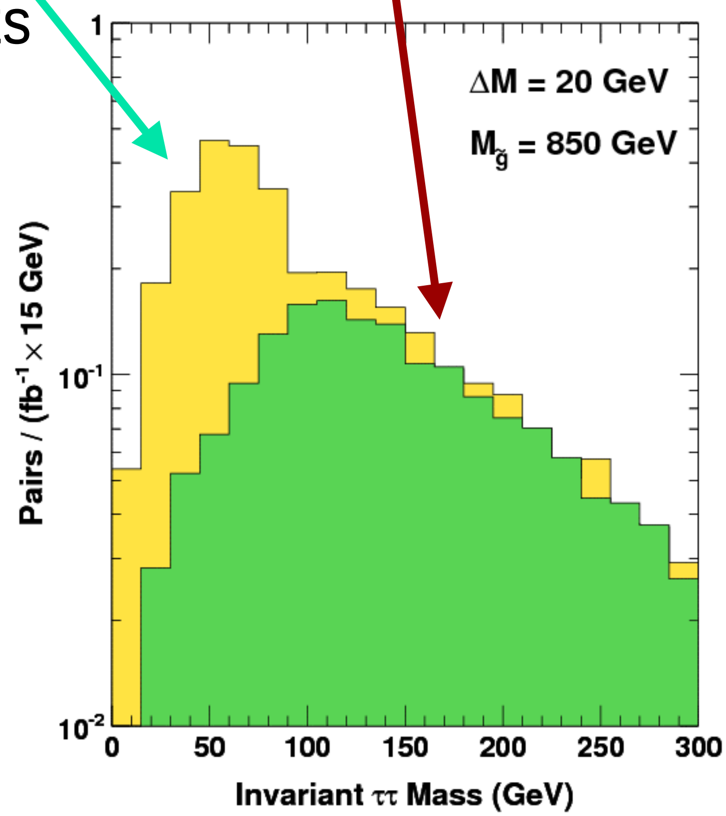
ττ Invariant Mass

Large ΔM:

- Many events
- Large mass

Background easy to subtract off

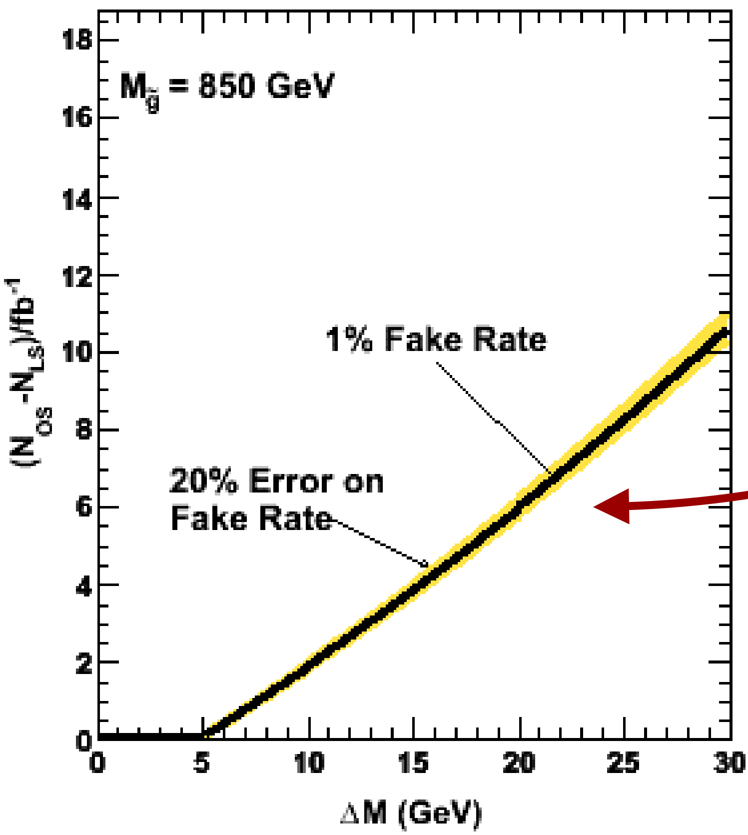




Small ΔM:

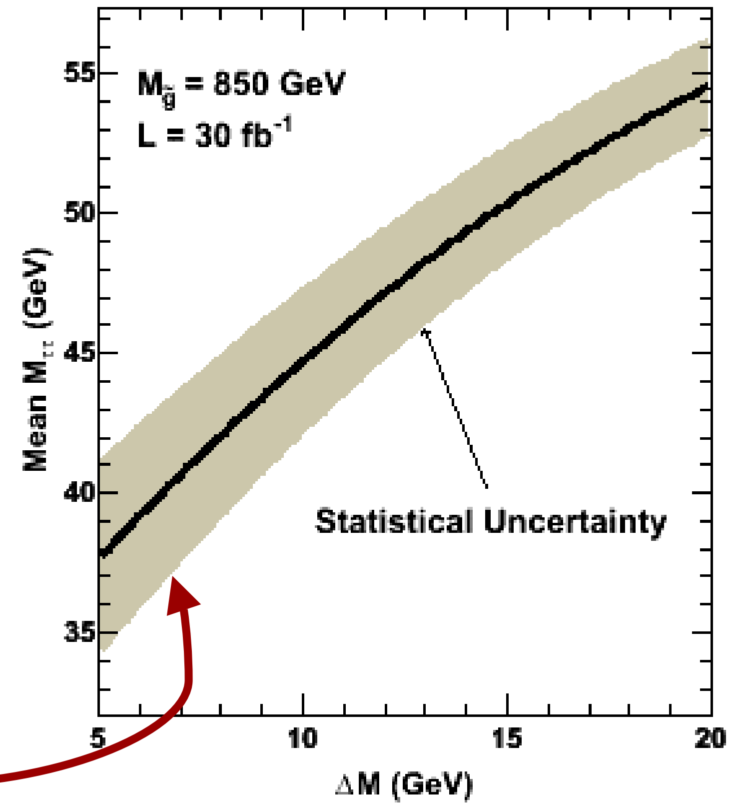
- Few events
- Small mass

Use Both Relationships to Measure ΔM



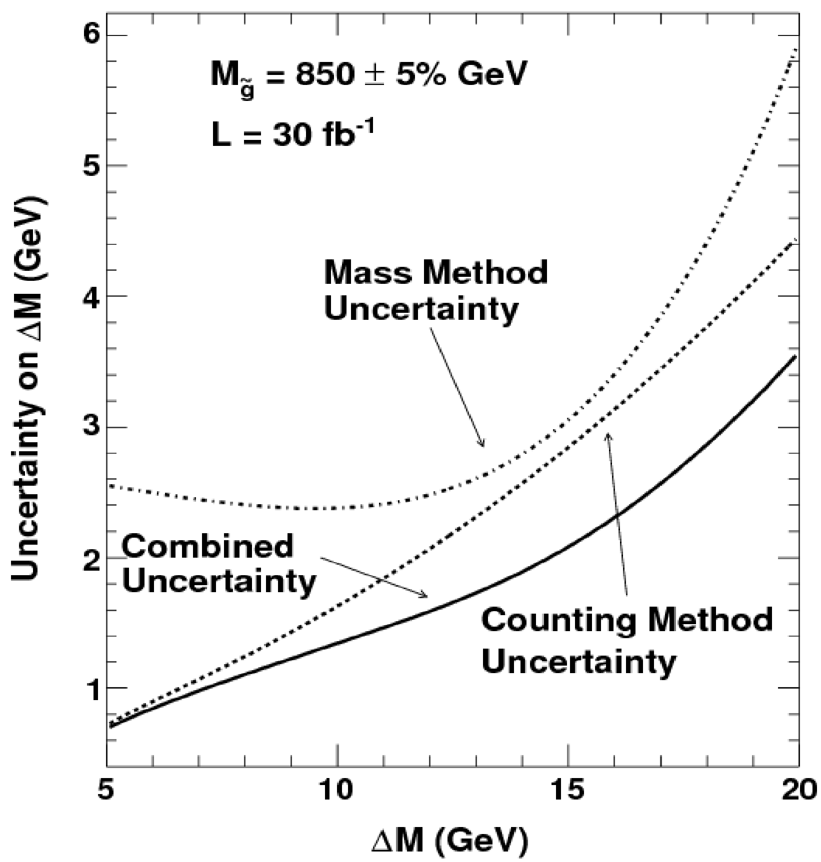
Counts rise with ΔM

Mass rises with ΔM



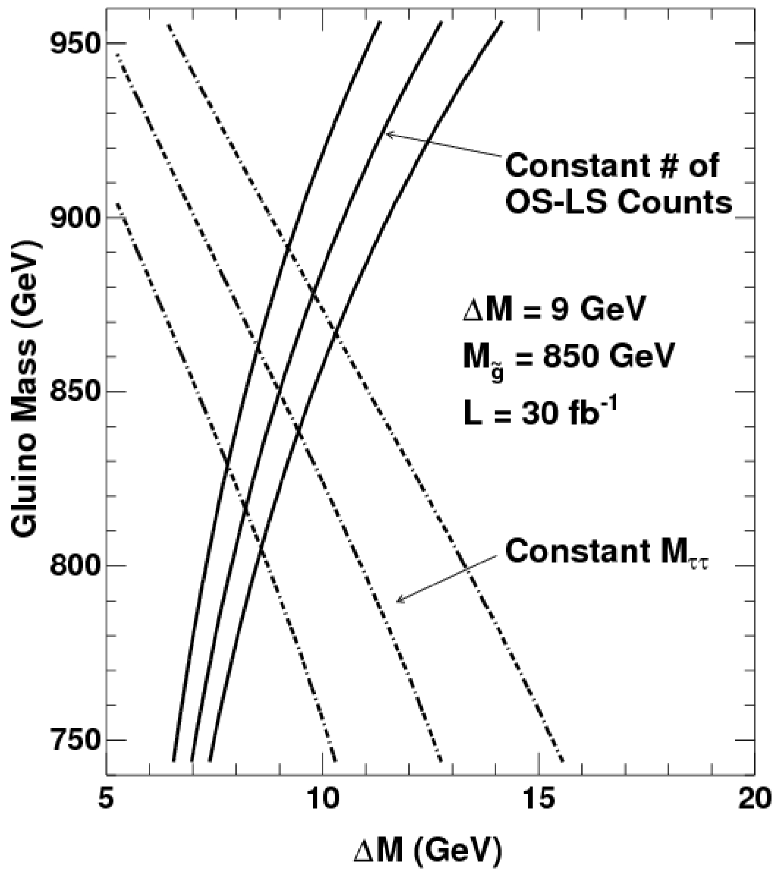
Individual and Combined Results

- Both produce high quality measurements
- Need to assume a gluino mass measured elsewhere
- 5% on gluino mass
- Dominates uncertainty



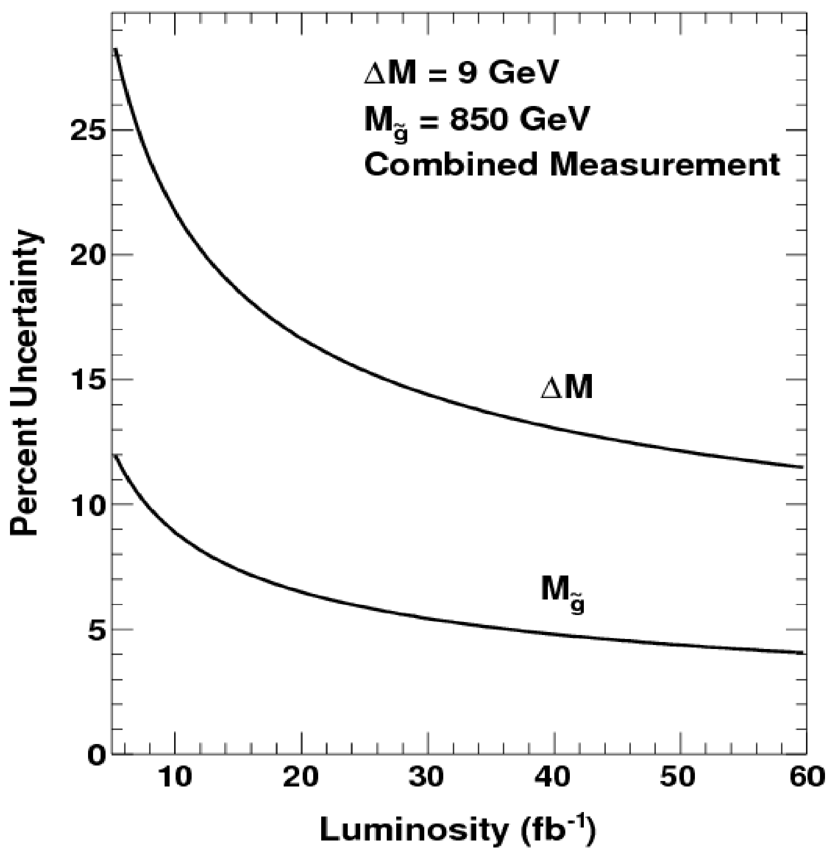
Gluino Mass

- Counts and mass have inverse relationships
- Use this to indirectly measure the gluino mass



Final Results

- We should be able to measure ΔM and the gluino mass simultaeously
- Our gluino mass measurement should be comparable to direct measurements at 30 fb^{-1}
- Excellent consistency check



Conclusions

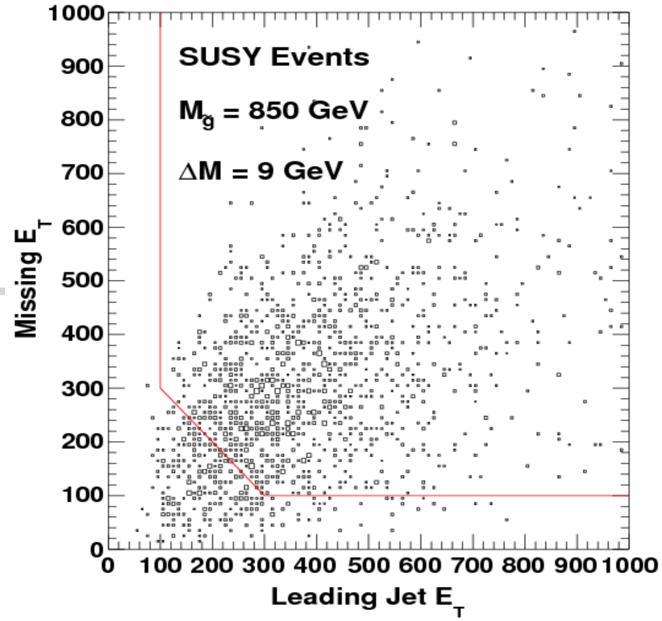
- For cosmological reasons, the co-annihilation region of supersymmetry is an important place to study
- Our new methods may help us measure the $\tilde{\tau} - \tilde{\chi}_1^0$ mass well at the LHC
- The combination of our methods allow us to measure the gluino mass for consistency checks with direct measurements

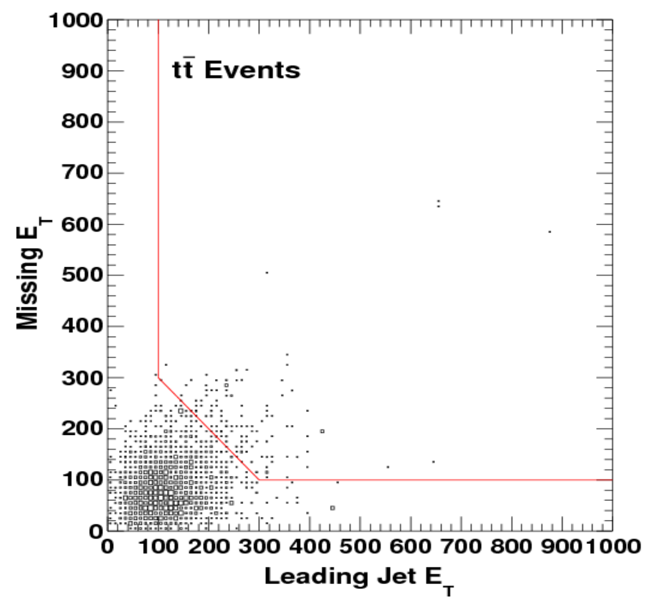
END OF TALK

Back-up Slides

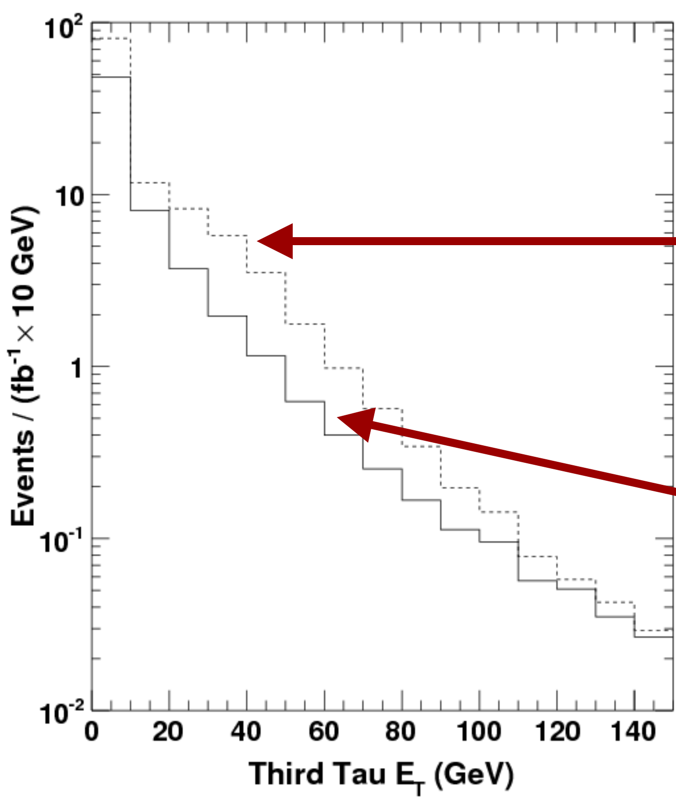
Analysis (cont.)

- Very little standard model background with 3 τ's
  - Require an extra jet from squarks and large missing E_T from $\tilde{\chi}_1^0$ just in case
- Leading jet E_T + missing E_T > 400 GeV, jet E_T > 100 GeV, and missing E_T > 100 GeV





E_T Spectrum of Third τ



- The third τ contains the mass difference information

<u>Large ΔM</u>

→ large τ energy

→ lots of events pass threshold

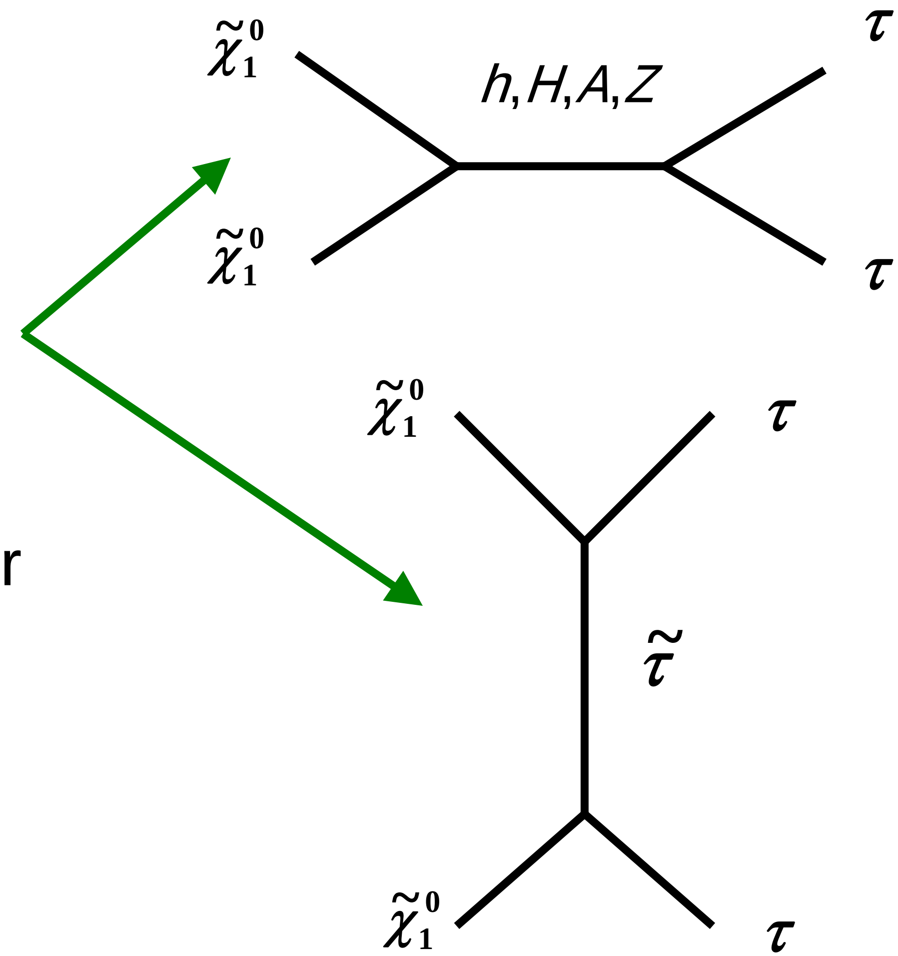
<u>Small ΔM</u>

→ small τ energy

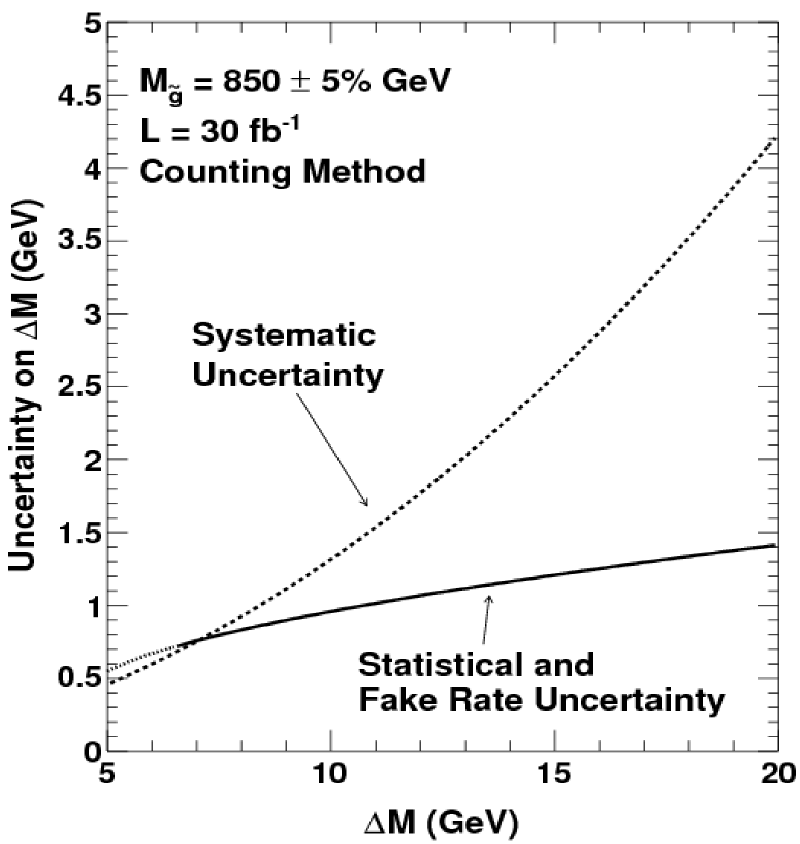
→ few events pass threshold

Co-annihilation Region

- The $\tilde{\tau}$ and $\tilde{\chi}_1^0$ are nearly degenerate: ΔM < 15 GeV
- Two Feynman diagrams determine the amount of the CDM ($\tilde{\chi}_1^0$) in the universe
- We can measure ΔM down to ~3 GeV at a future e^+e^- linear collider
- Can we measure ΔM at the LHC?

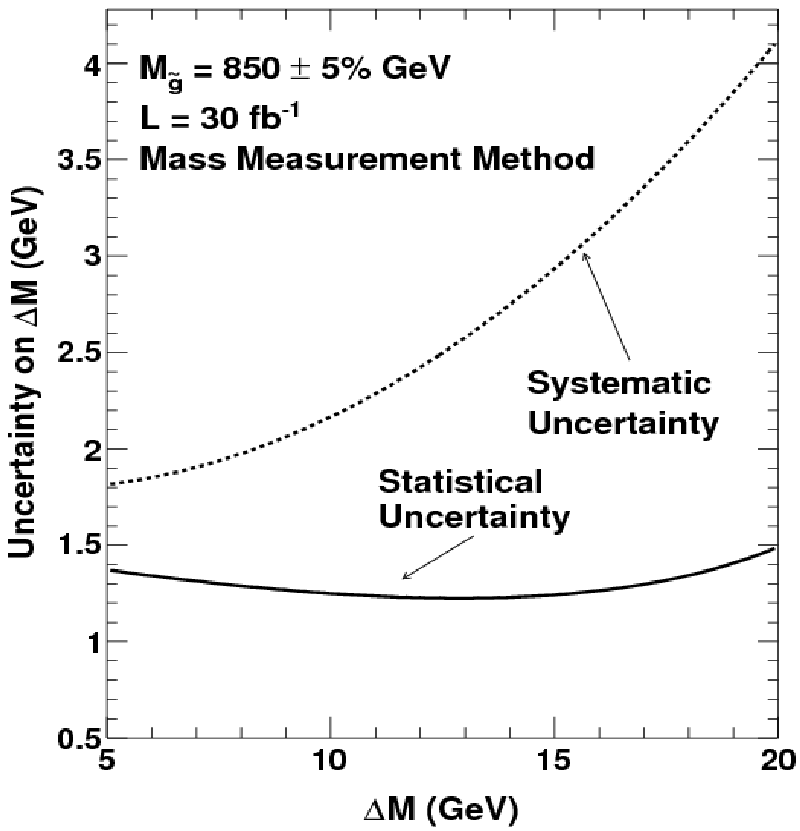


ΔM Measurement



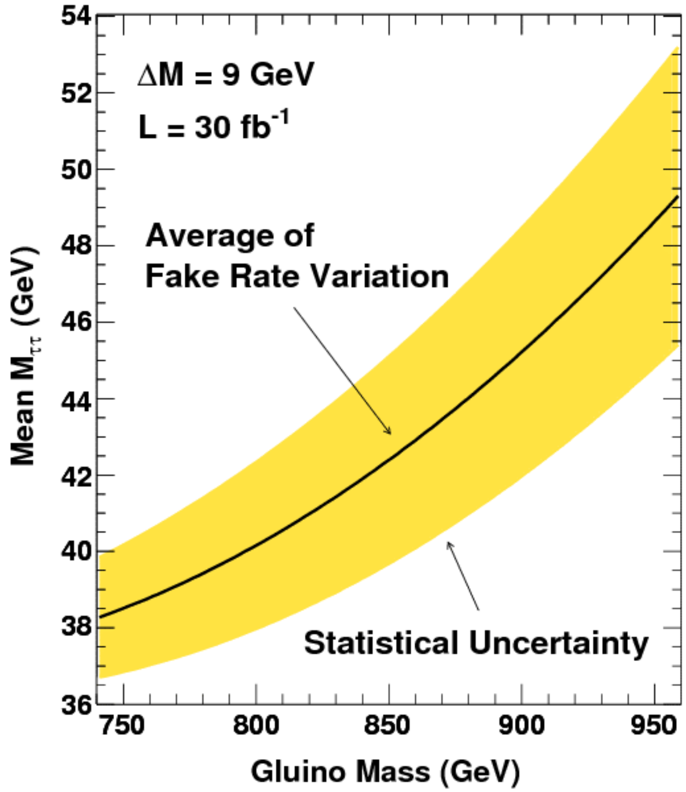
- Systematic uncertainty based on 5% variation in gluino mass
- We assume a 1% fake rate with 20% uncertainty
- For all luminosities with significance > 3σ, we are systematic dominated

ΔM Measurement (MM)

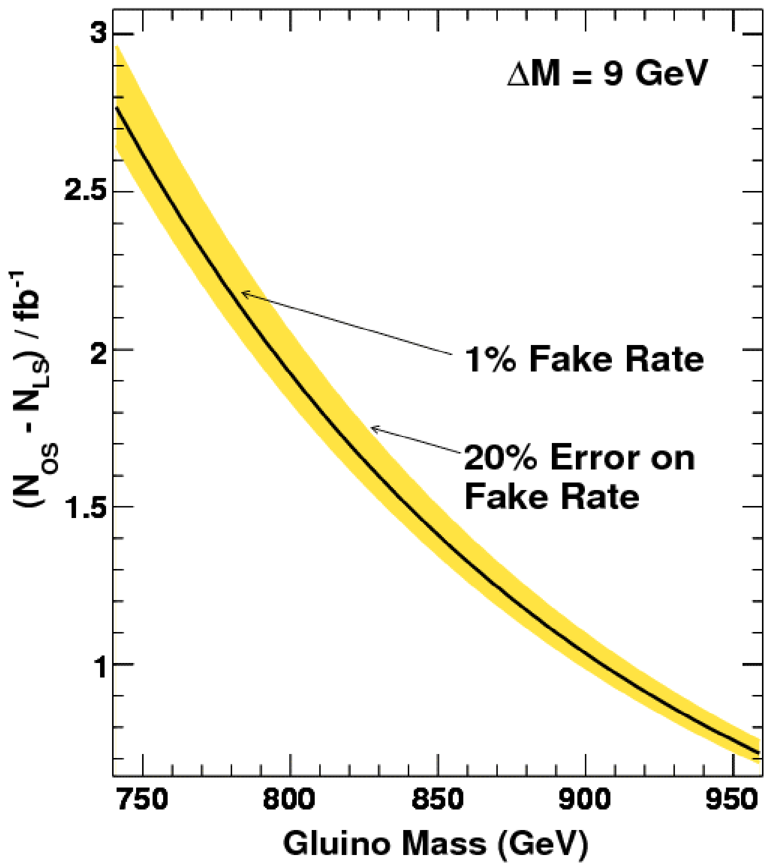


- Like the counting method, we are always in a systematic dominated region.

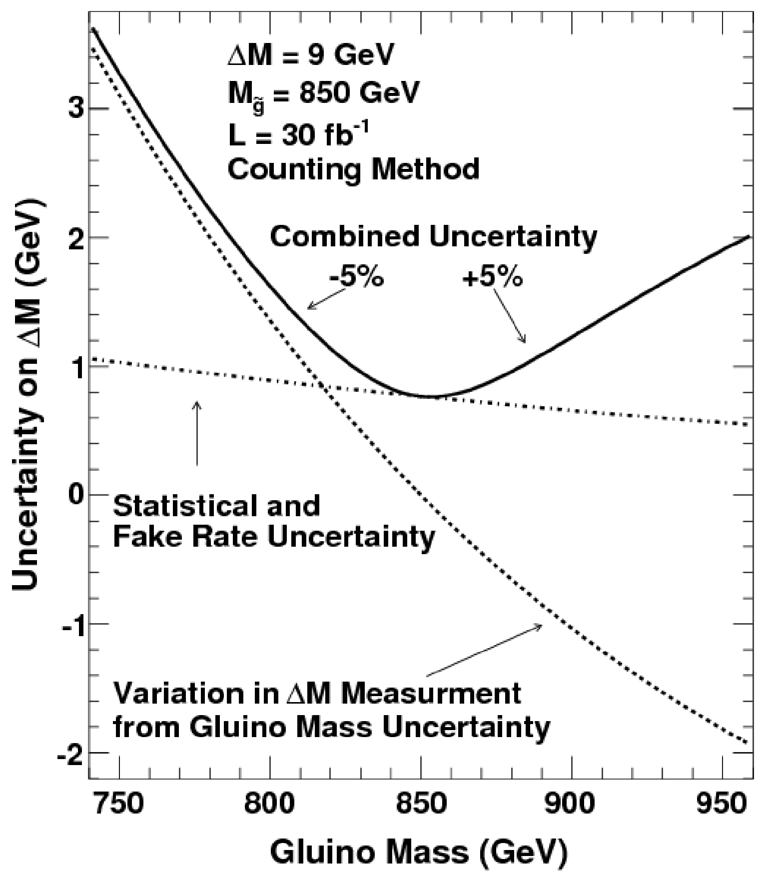
Back-up: Mean vs. Mg



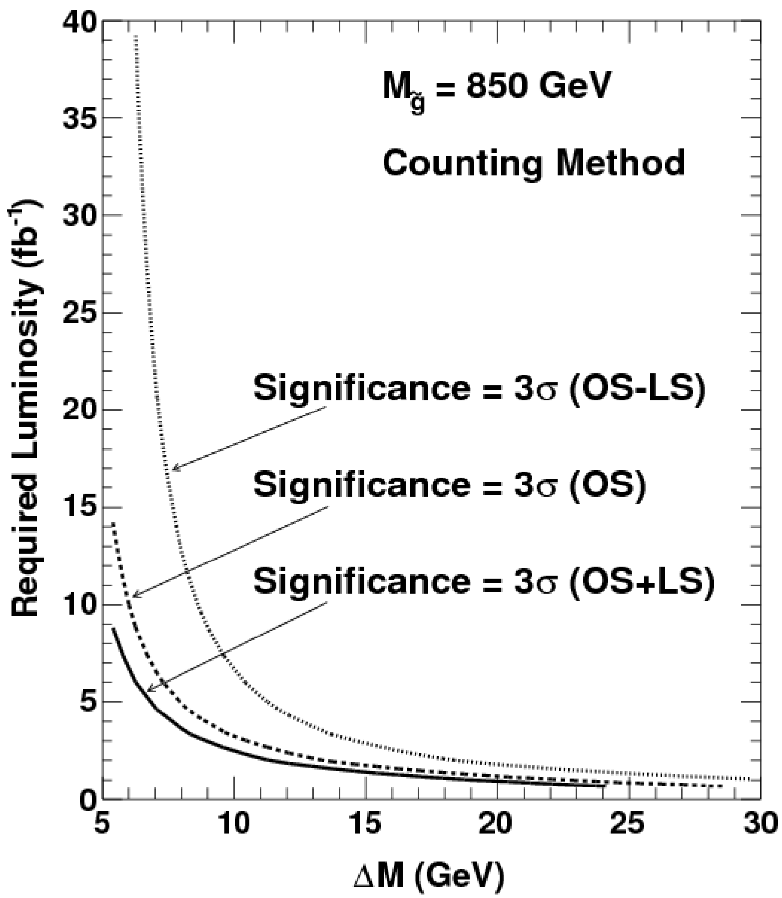
Back-up: Counts vs. Mg



Back-up: Systematics



Back-up: Significance



Back-up: Uncertainty vs. Luminosity