
The Search for Supersymmetry at CDF

Report of the SUSY Working Group

Dave Toback &
Monica D'Onofrio

CDF Collaboration Meeting
March 2008



The Search For Supersymmetry at CDF
David Toback, Texas A&M University



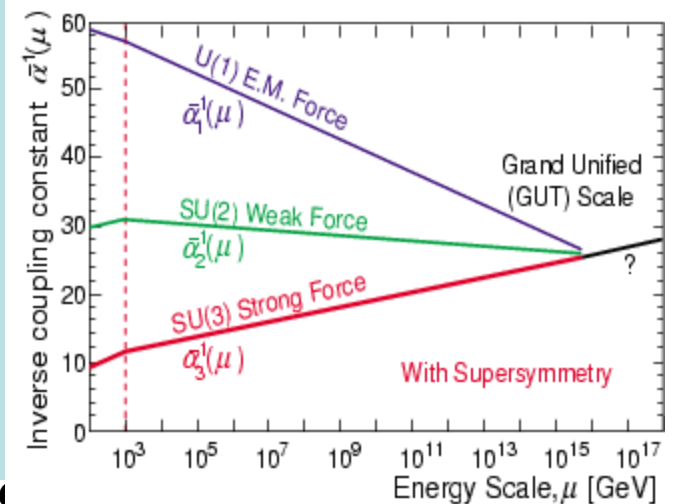
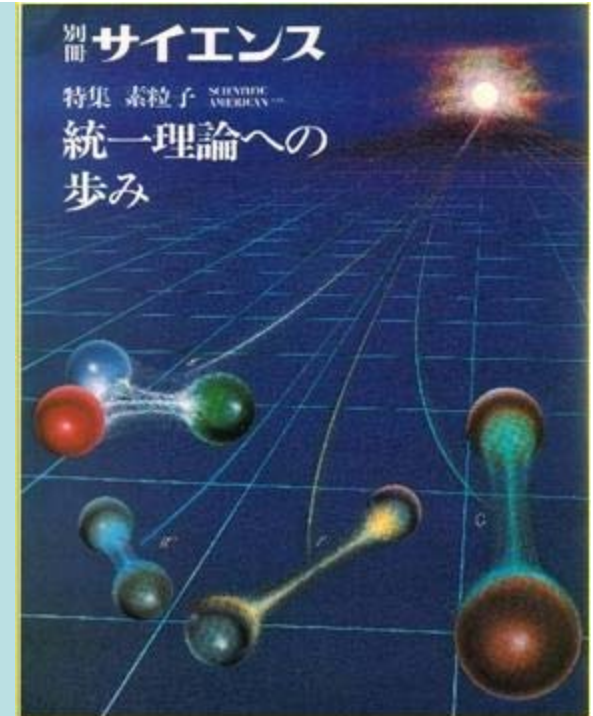
Outline

- **SUSY: The big picture**
 - Minimal and Non-Minimal Models
- **Golden Mode Searches**
 - Squarks & Gluinos
 - Gaugino Pairs
 - Indirect Searches
- **More exotic SUSY models**
- **Conclusions**

Overview of Supersymmetry

- There are some theories that are so compelling that it's worth doing a comprehensive and systematically deep set of searches to see if they are realized in nature

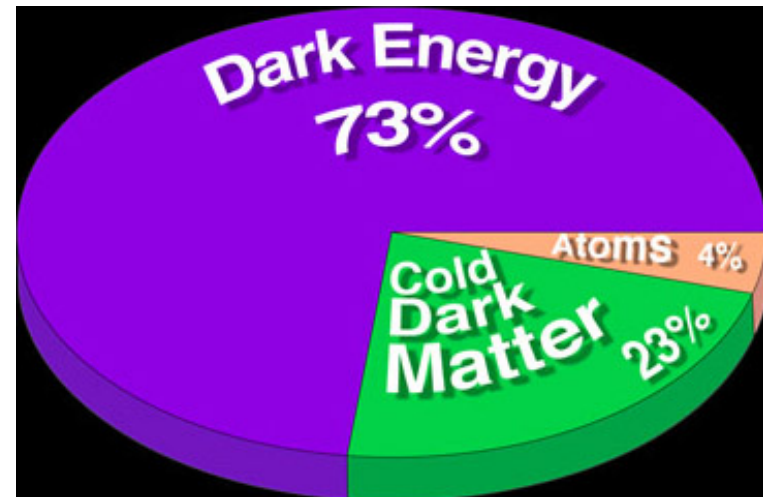
→ Supersymmetry is such a theory



Particle Physics and Cosmology?

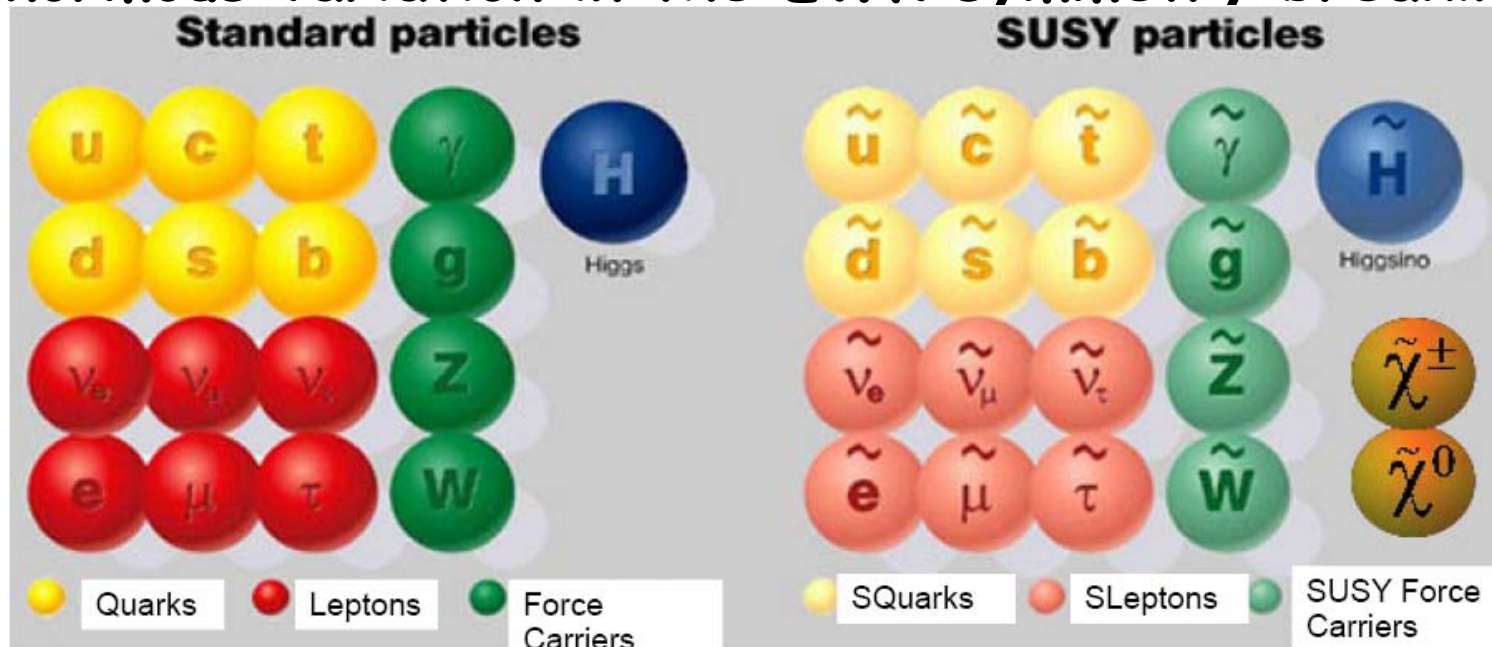
If SUSY is correct, then precision measurements from WMAP can help us narrow down the search

New possibilities of studying the early universe and particle physics at the same time



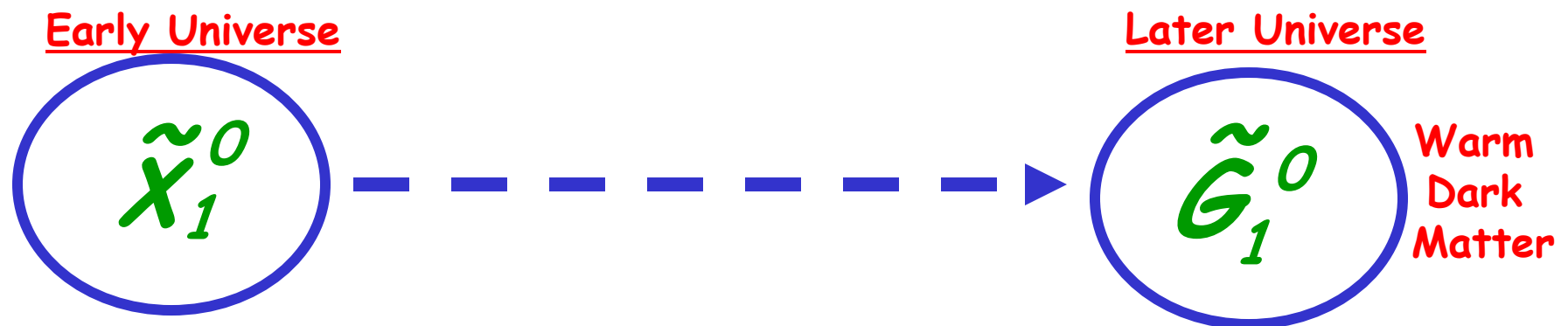
Minimal Models

- In minimal models, with R-parity conserved, the heavy sparticles would have quickly decayed to the lightest sparticle and the early universe would determine the relic dark matter density: *Cold Dark Matter*
- Most searches follow this type of model: Assume the lightest neutralino is the LSP
- Enormous variation in the EWK symmetry breaking



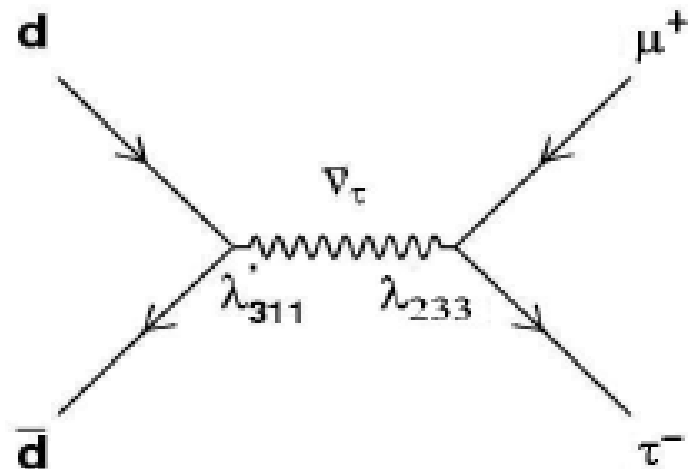
Non-Minimal Models

- However, there are other possibilities
- Here the Neutralinos or Charginos or Staus might have long-lifetimes
- Example: $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$ would provide a warm dark matter candidate, favored in some galaxy substructure models



A Third Possibility

- Perhaps Supersymmetry is correct but has nothing to do with the Dark Matter problem (Axions?)
- Still worth looking for, just harder to know where to look
 - E.g. R-Parity Violating SUSY



CDF SUSY Program

- **Our program at CDF is both broad and deep**
- **Golden Modes**
 - Neutralino-LSP scenarios
 - mSUGRA or similar type for simplicity
- **More exotic Models**
 - Gauge Mediated SUSY
 - CHAMPS
 - RPV SUSY

Golden Channels

Three ways to look for CDM Models

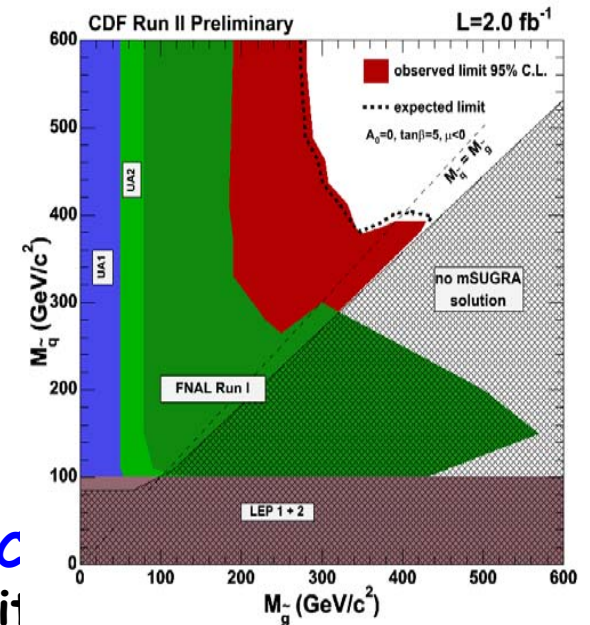
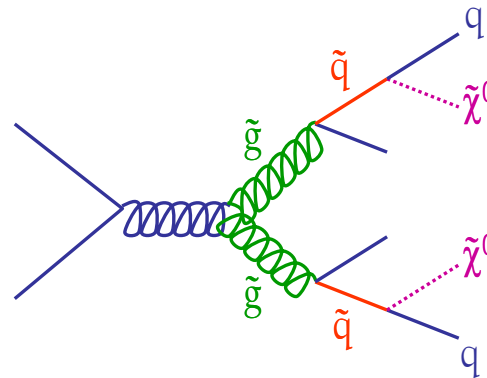
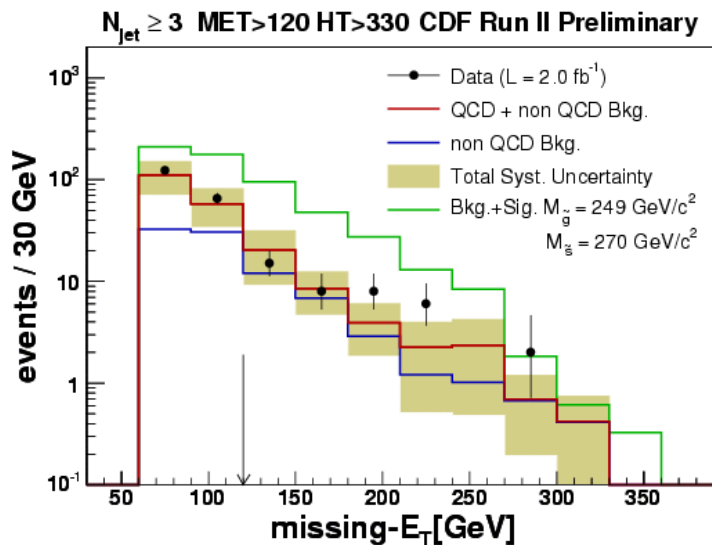
- Direct production of Squarks and Gluinos
 - Heavy, but strong production cross sections
- Direct production of the Gauginos
 - Lighter, but EWK production cross sections
- Indirect search via sparticles in loops
 - Branching Ratios

Light Squarks and Gluino Program

Squark-Gluino Search in Multijets+Met

Gianluca De Lorenzo, Monica D'Onofrio and Mario Martinez (IFAE Barcelona)

- 3 separate analyses \rightarrow best sensitivity for different squark/gluino mass combinations
 - 2, 3 or 4 jets required in the final state
- Optimized using M_{et} , $E_{\text{T}}(\text{jets})$ and $H_{\text{T}} = \Sigma E_{\text{T}}(\text{jets})$
- Just started Godparenting \rightarrow PRL



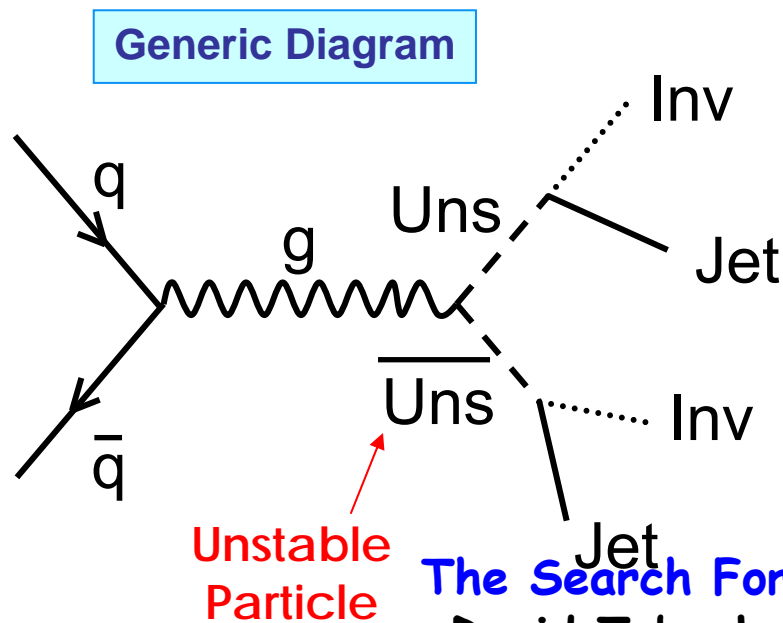
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Light Squarks in Dijets+Met

Look for squarks in the dijet+Met channel

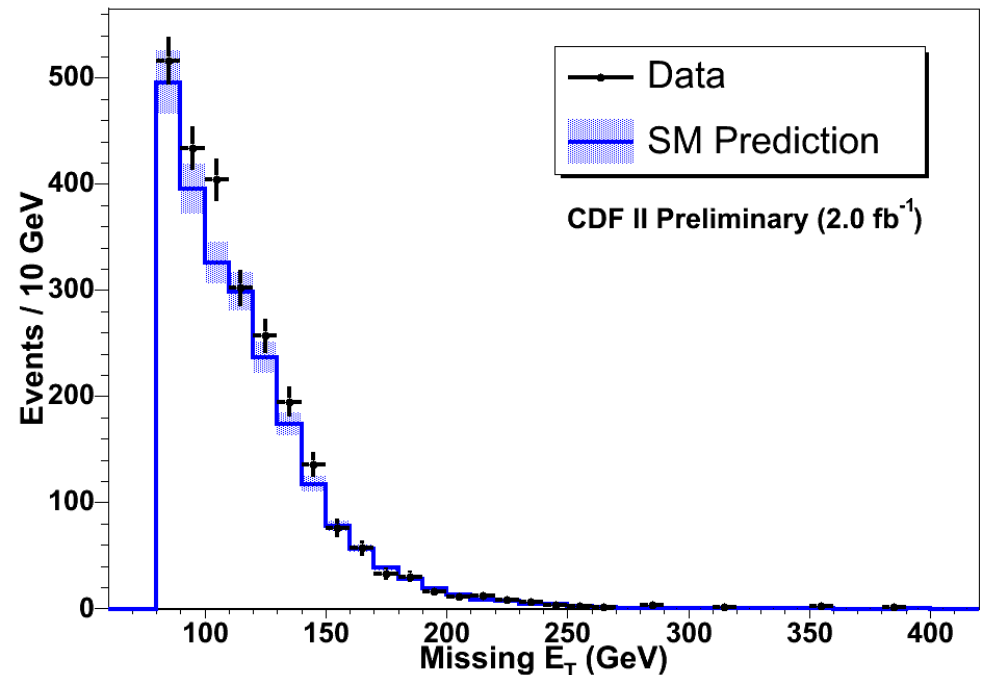
Hugo Beauchemin, Pier-Olivier Deviveiros, Dan MacQueen, and Pierre Savard (University of Toronto), Kevin Burkett and Eric James (FNAL)

- Analysis done, starting SUSY interpretation
- More in Dan McQueen's talk



The Search For S

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Sbottom Searches

Two Sbottom searches recently started

1. Gluino-Mediated Sbottom Production in the B-jets+Met final state

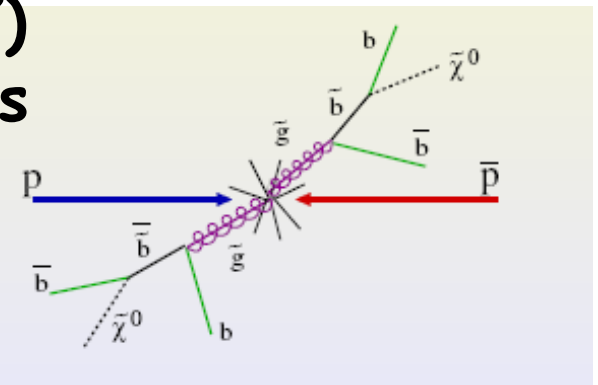
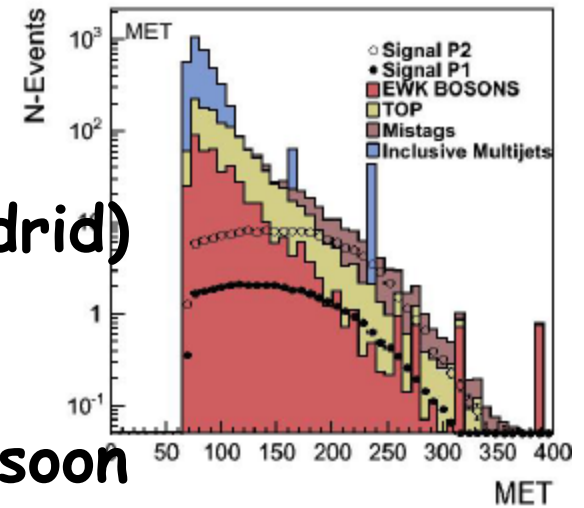
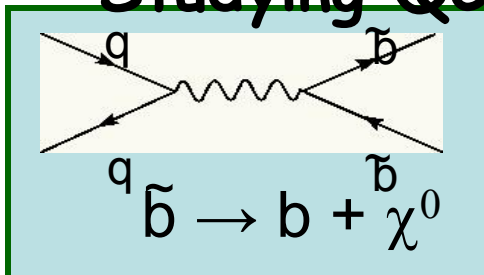
Miguel Vidal and Oscar Gonzalez (Madrid)

- Update from Rott *et al.*,
PRL 96, 171802 (2006)
- Planning to open their signal region soon

2. Direct sbottom pair production

- Alon Attal, Monica D'Onofrio, Gianluca DeLorenzo, Mario Martinez (IFAE Barcelona)
- Update from Wang *et al.*,
Phys. Rev. D76, 072010 (2007)

Studying QCD Background estimations



Stop Searches

Two Stop Searches:

1. Stop in Opposite-sign Dileptons

Virgil Barnes, Alvin Laasanen, Oscar Gonzalez, Else Lykten and Alexei Sedov (Purdue)

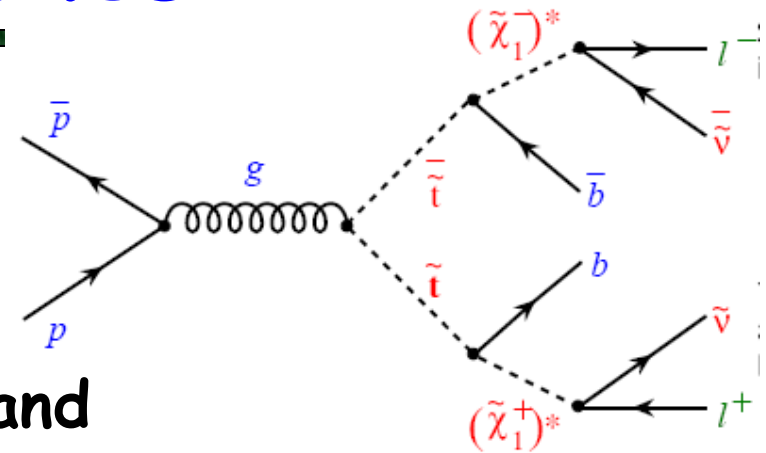
Optimization ongoing

2. Using the properties of the top sample events (dilepton and lepton+jets) to see if there is a stop component

Andrew Ivanov, Will Johnson and Robin Erbacher (UC Davis)

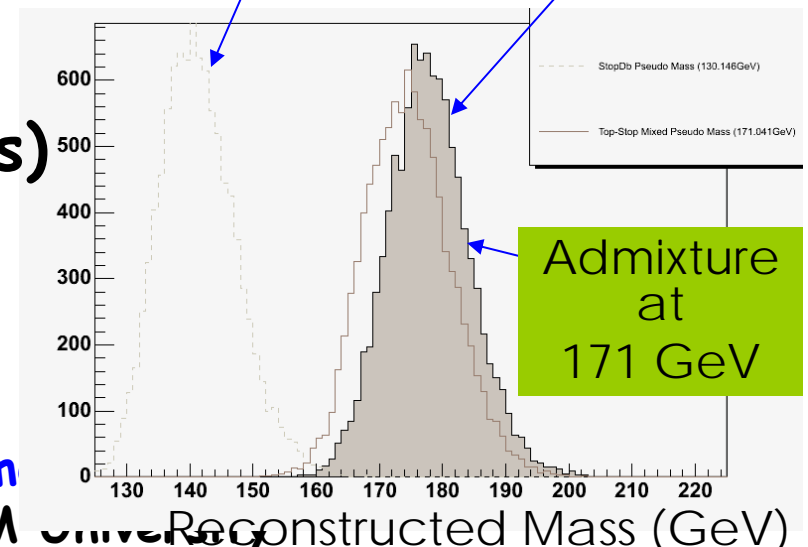
Stop admixture would lower the Measured top mass (w/Top Properties group)

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$M_{\text{Stop}} = 135 \text{ GeV}$

$M_{\text{top}} = 175 \text{ GeV}$



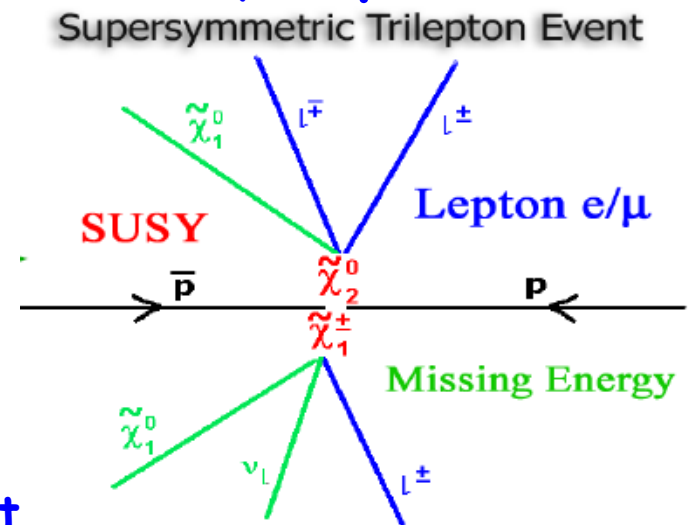
Gaugino Pair Production

Gaugino Pairs are lighter, but have electroweak production cross sections

Produce multi-leptons and Met in the final state

The first round of Run II Chargino/Neutralino papers are now either published or nearing publication.

- Phys. Rev. D 77, 052002 (2008) ***
- Phys. Rev. Lett. 99, 191806 (2007)
- Phys. Rev. Lett. 98, 221803 (2007)
- One more: Chargino-Neutralino in Low P_T Leptons
 - In the hands of the GPs
 - Should post first-reading soon
 - To be submitted to PRD



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Gaugino Pair Production

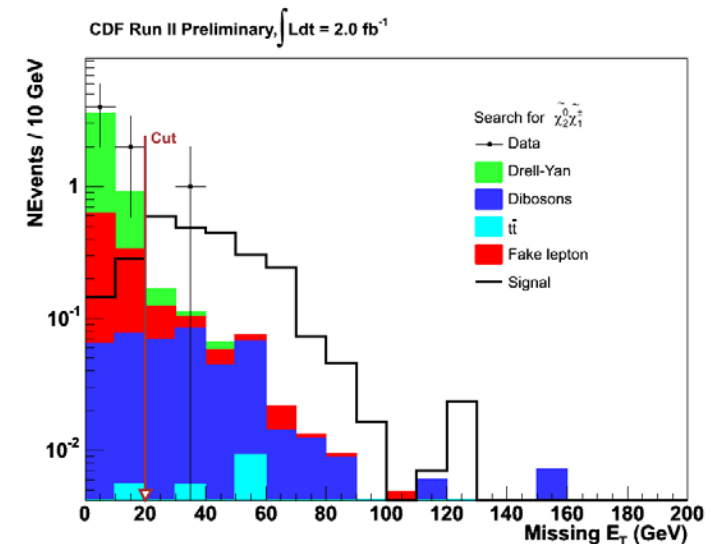
The next generation Chargino-Neutralino analysis was recently completed with 2fb^{-1}

Sourabh Dube and Sunil Somalwar (Rutgers)

This is a flagship analysis and was done as an integrated tri-lepton search

CDF RUN II Preliminary $\int \mathcal{L} dt = 2.0 \text{ fb}^{-1}$: Search for $\tilde{\chi}_2^\pm \tilde{\chi}_1^0$

Channel	Signal	Background	Observed
3tight	$2.25 \pm 0.13(\text{stat}) \pm 0.29(\text{syst})$	$0.49 \pm 0.04(\text{stat}) \pm 0.08(\text{syst})$	1
2tight,1loose	$1.61 \pm 0.11(\text{stat}) \pm 0.21(\text{syst})$	$0.25 \pm 0.03(\text{stat}) \pm 0.03(\text{syst})$	0
1tight,2loose	$0.68 \pm 0.07(\text{stat}) \pm 0.09(\text{syst})$	$0.14 \pm 0.02(\text{stat}) \pm 0.02(\text{syst})$	0
Total Trilepton	$4.5 \pm 0.2(\text{stat}) \pm 0.6(\text{syst})$	$0.88 \pm 0.05(\text{stat}) \pm 0.13(\text{syst})$	1
2tight,1Track	$4.44 \pm 0.19(\text{stat}) \pm 0.58(\text{syst})$	$3.22 \pm 0.48(\text{stat}) \pm 0.53(\text{syst})$	4
1tight,1loose,1Track	$2.42 \pm 0.14(\text{stat}) \pm 0.32(\text{syst})$	$2.28 \pm 0.47(\text{stat}) \pm 0.42(\text{syst})$	2
Total Dilepton+Track	$6.9 \pm 0.2(\text{stat}) \pm 0.9(\text{syst})$	$5.5 \pm 0.7(\text{stat}) \pm 0.9(\text{syst})$	6

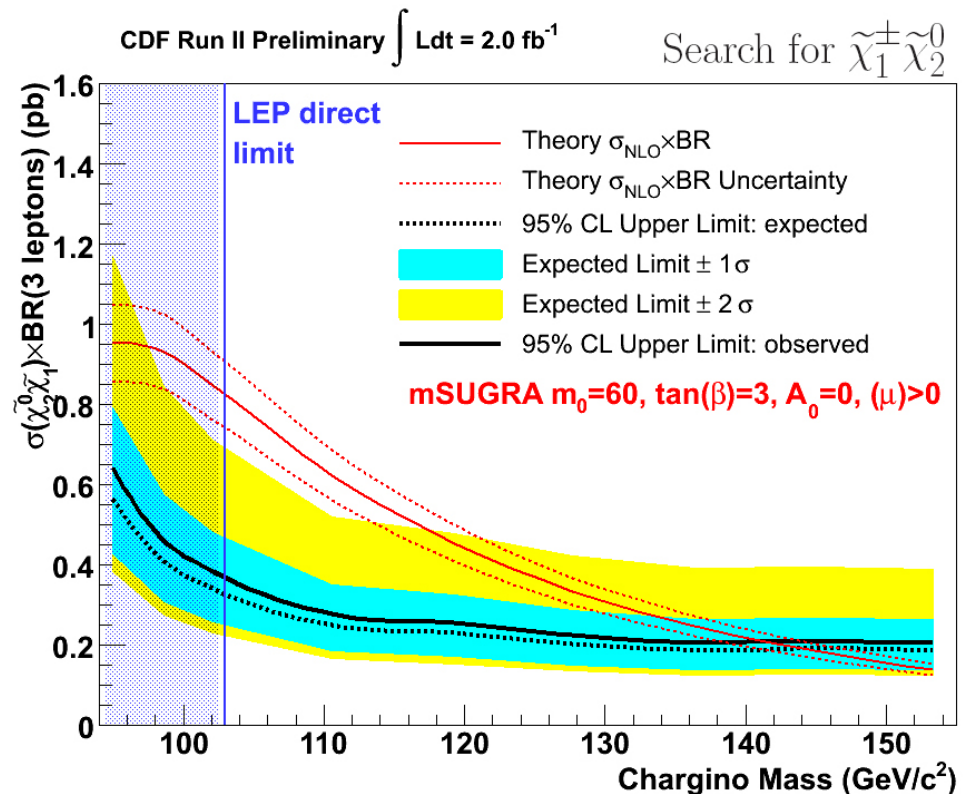


More on Tri-leptons

- This analysis was blessed and recently shown at a Wine and Cheese

- Working on PRL 1st draft with GPS

- Post first reading soon



Other Gaugino Pair Production Searches

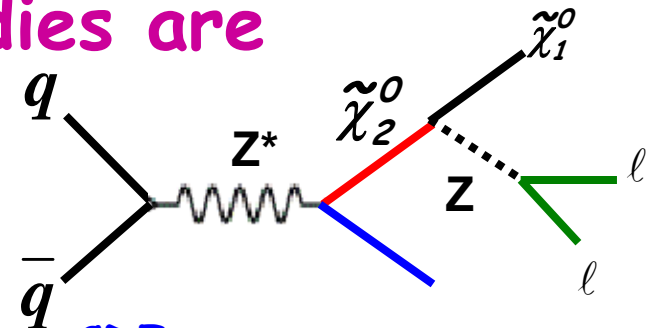
Other groups combining to work on the next-next generation analysis

- John Strologas, Marcelo Vogel and Mike Gold (New Mexico)
- Melisa Rossi, Giovanni Pauletta, Diego Cauz, Lorenzo Santi and Mapo Giordani (Udine)

Gaugino pairs in the Z+Met Final State

Seog Oh, ByeongRok Ko and Chiho Wang (Duke)

- This would require an unusual mass splitting, so sensitivity studies are underway
- New idea (just starting)



Gaugino Pair Production at High $\tan\beta$

Data from around the world suggests high $\tan\beta$ is favored so τ final states from gaugino pairs can dominate

Two new analyses just starting:

1. Multilepton Final States with Taus, Trileptons

Rob Forrest, Aron Soha and Max Chertok (UCDavis)

- Signal studies on-going, planning on showing Prospects for APS

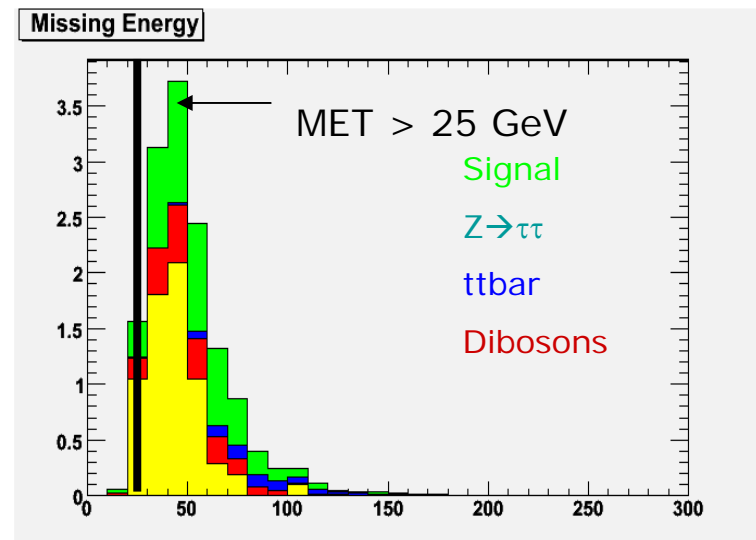
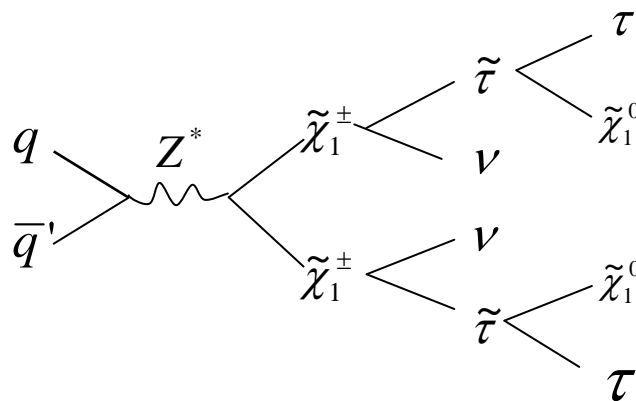
2. Co-annihilation Region Gaugino Pair Production

Adam Aurisano, Mike Weinberger and Dave Toback (Texas A&M)

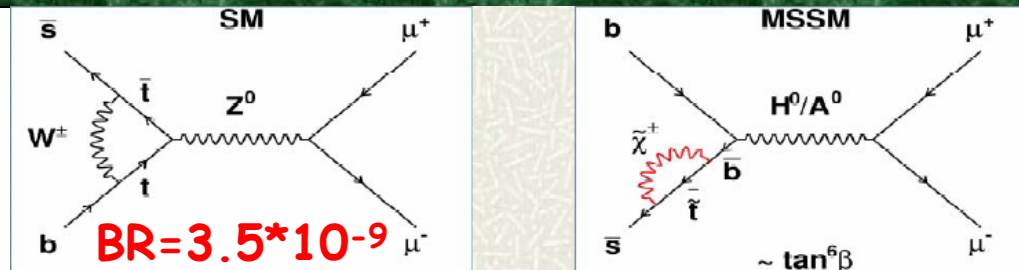
- If the $g-2$ excess is confirmed almost all of mSUGRA parameter space is excluded except for the co-annihilation region

- Stau and LSP are nearly mass degenerate

→ 2τ +Met to get Chargino pairs



Indirect Search $B_s \rightarrow \mu\mu$



- The search for $B_s \rightarrow \mu\mu$ is perhaps the most sensitive to SUSY since sparticles show up in loops. Especially sensitive at high $\tan\beta$ ($\propto \tan^6\beta$)

Doug Glenzinski (FNAL), Matt Herndon (Wisc), Teruki Kamon (TAMU), Cheng-Ju Lin (FNAL), Slava Krutelyov (TAMU→UCSB), Mike Weinberger (TAMU)

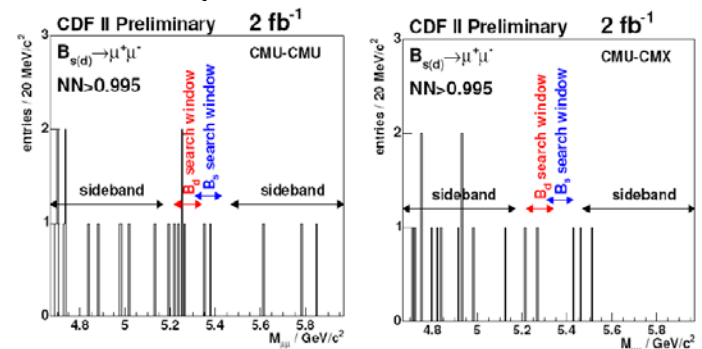
- To appear in Phys. Rev. Lett
March 21, 2008

- Current limit is $5.8 \cdot 10^{-8}$

- Next-next generation $B_s \rightarrow \mu\mu$

- Same team + Max Goncharov (TAMU)

- Improving NN methodology and other new tool. Use 2.5fb^{-1} for the summer conferences

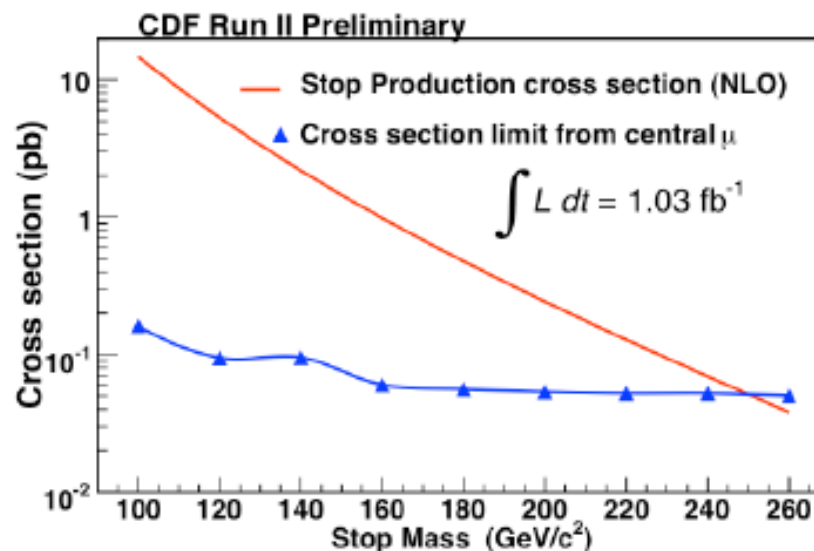
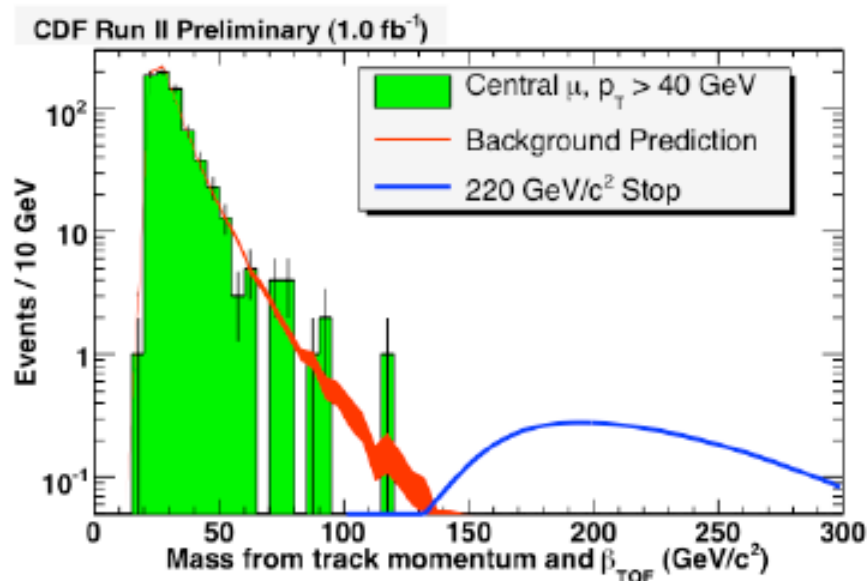


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Long-Lived Sparticles

- New emphasis among the theory community to think about long-lived sparticles
 - Early universe models
- CHAMPS Search
 - Tom Phillips (Duke) and Rick Snider (FNAL)
 - Use TOF and COT to measure the “mass” of weakly interacting charged particles
 - PRL Draft in progress, GPS assigned

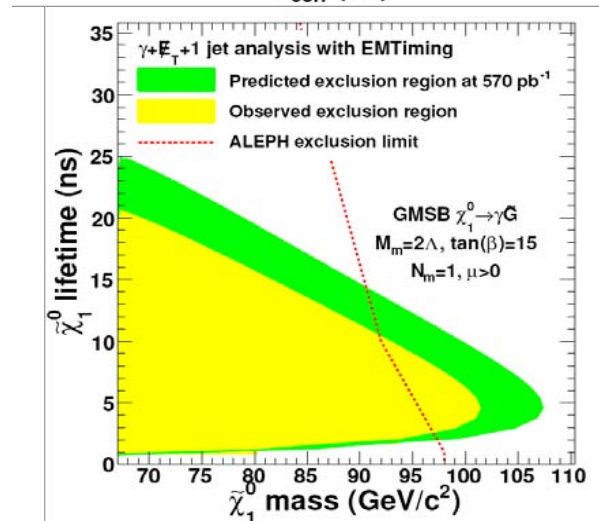
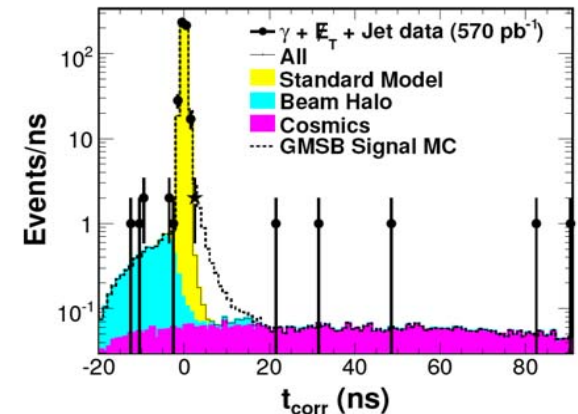


GMSB Models

GMSB models with $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ typically assume $\tau_{\tilde{\chi}_1^0} = 0$. Warm dark matter models

favor ns lifetimes

- $\gamma\gamma$ +Met analysis published in 2004, new data result recently blessed (Pronko, Culbertson *et al*), with GMSB interpretation coming soon
- Long-lifetime NLSP in γ +Met+jet published in PRL 99, 121801 (2007)
Goncharov, Lee, Krutelyov, Toback & Wagner (TAMU)
- PRD (Same + Geffert) in second reading
- Next generation GMSB (Delayed photons in γ +Met+jet, γ +Met+track & $\gamma\gamma$ +Met) in progress



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21

R-Parity Violating Scenarios

Two RPV Searches

1. Search for Stop quarks in RPV scenarios, $Stop \rightarrow \tau b$ in the $2\tau + 2jet$ decay mode

Teruki Kamon, Vadim Khotilovich and Alexei Safanov (TAMU), Max Chertok and Dick Lander (Davis)

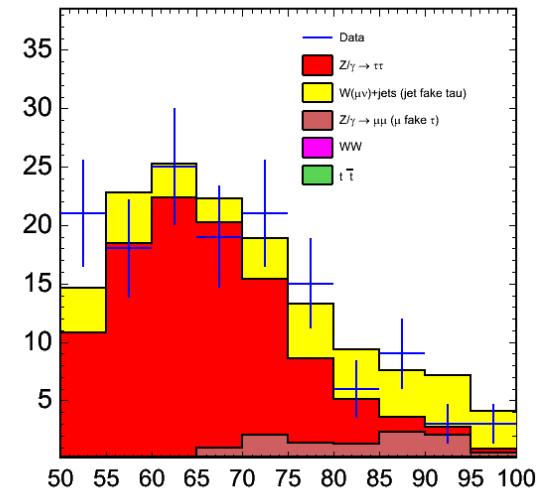
- Submitted to PRL (hep-ex arXiv:0802.3887)

2. RPV Sneutrino search

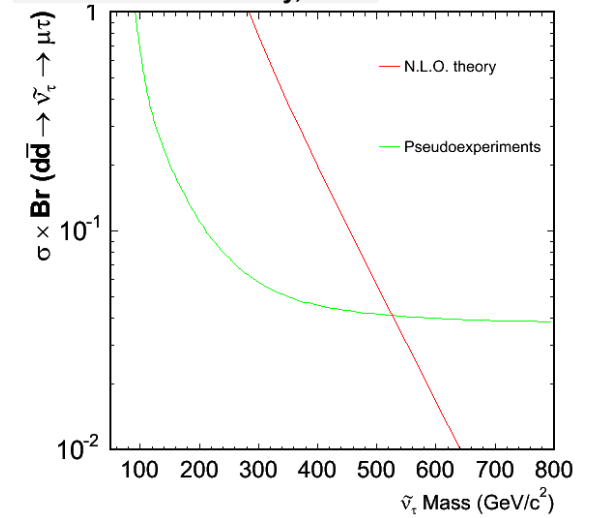
Yanjun Tu & Anadi Canepa (Penn) and Pasha Murat (FNAL)

- Look for mass resonances in the $e\mu$, $e\tau$ and $\mu\tau$ final states
- Many new useful tau tools
- Approaching pre-blessing

Mass_mutau ($\mu\tau$ channel)



CDF Run II Preliminary, 1 fb⁻¹



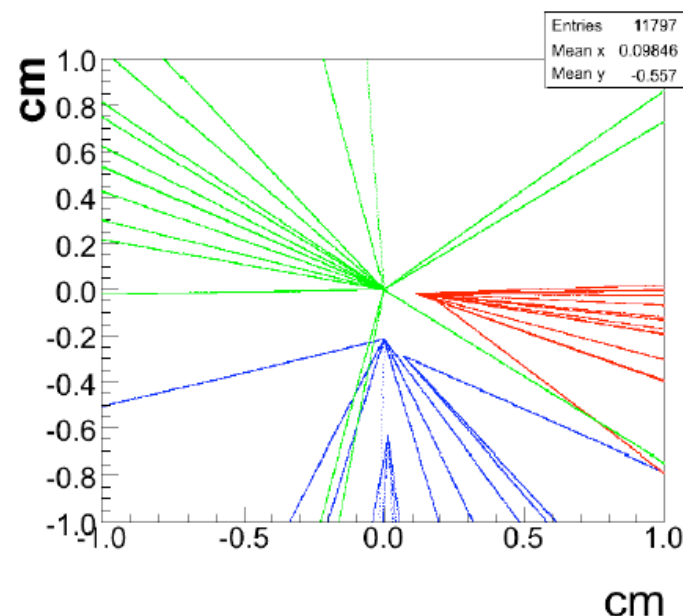
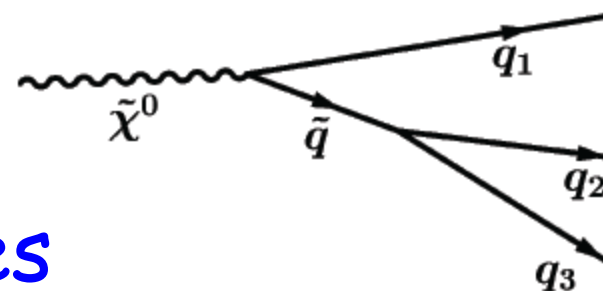
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New on the Scene

Long-Lived Neutralinos in RPV SUSY

Mark Mathis & Petar
Maksimovic (Hopkins)

- Heavy Squark Mass gives the neutralino a long lifetime
- Two-track trigger!
- Topological Vertexing
- Just starting, but interesting new tool!



Summary

- The *SUSY* group continues to be very productive
- 6 papers published/accepted in 2007/8, One more submitted
- 5 are in *Godparenting* at the moment
- 14 are in progress and moving nicely
- Stay tuned for a discovery near you
- Want more details?



<http://www-cdf.fnal.gov/internal/physics/exotic/susy/susy.html>

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