Missing Energy Signatures at LEP and Tevatron

w/ Spencer Chang and Paddy Fox

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CERN TH Institute

Aug 24, 2007

We will find SUSY at the LHC!

VOLUME 49, NUMBER 18 PHYSICAL REVIEW LETTERS 1 NOVEMBER 1982

Fractionally Charged Particles as Evidence for Supersymmetry

VOLUME 77, NUMBER 17 PHYSICAL REVIEW LETTERS 21 OCTOBER 1996

Multilepton Signal for Supersymmetric Particles in the Fermilab Tevatron Data?

PHYSICAL REVIEW D VOLUME 55, NUMBER 8 15 APRIL 1997

Evidence for supersymmetric dark matter annihilations into γ rays

Dep

SIGNATURES AND POSSIBLE EVIDENCE FOR SUPERSYMMETRY AT THE CERN COLLIDER

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The ast

imaging at

Low-Energy Supersymmetry and the Tevatron Bottom-Quark Cross Section

E. L. Berger[1], B. W. Harris[1], D. E. Kaplan[1,2], Z. Sullivan[1], T. M. P. Tait[1] and C. E. M. Wagner[1,2]

Indirect Evidence for the Supersymmetric Nature of Dark Matter from the Combined Data on Galactic Positrons, Antiprotons and Gamma Rays

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March 25, 2006

Apr 2001

p 2003

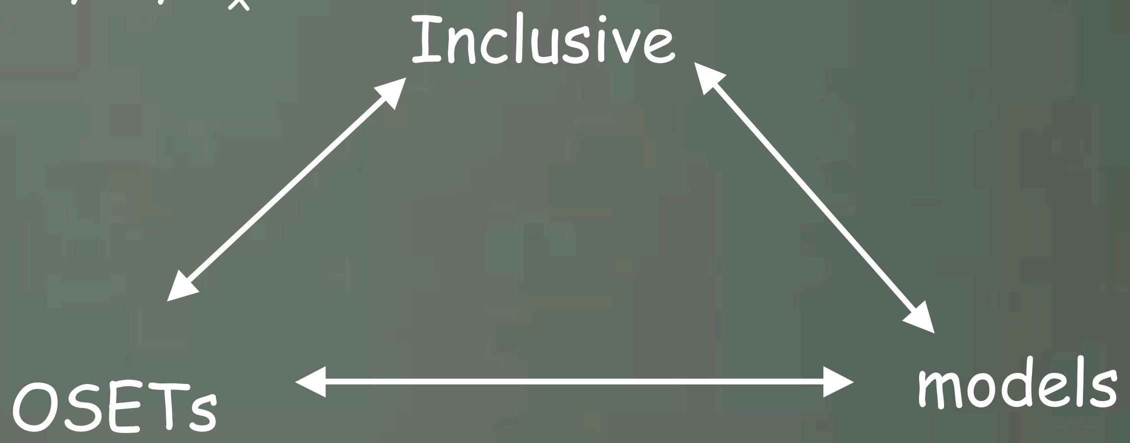
Motivation (see Jay's talk)

- What are the hidden or not-so-hidden assumptions that influence the strength of present (and future) limits?
- Naturalness suggests: light Higgs (<115 GeV?), light spartners
  - Should investigate whether these regions of parameter space open in non-mSUGRA, non-MSSM models

What Modifications?

- OSETs: Onshell Effective Theories
  (Arkani-Hamed, Knuteson, Mrenna, Schuster, Thaler, Toro, Wang)
  - Focus on physically relevant parameters:

    σ, m, Γ_x



Which OSETs

- Two basic modifications
  - UV modifications: new colored states, new gauge bosons, new directly produced particles
  - IR modifications: modify decay chaings
    - LEP constrains ≲ 100 GeV to be neutral

      -> consider light neutral particles
- Theoretical Motivation
  - Vectorlike matter: Higgsino, top partners
  - Hidden-valley models: other sectors with Λ<TeV
  - Theoretical problems NMSSM
  - RG effects drive neutrals down in mass (often)

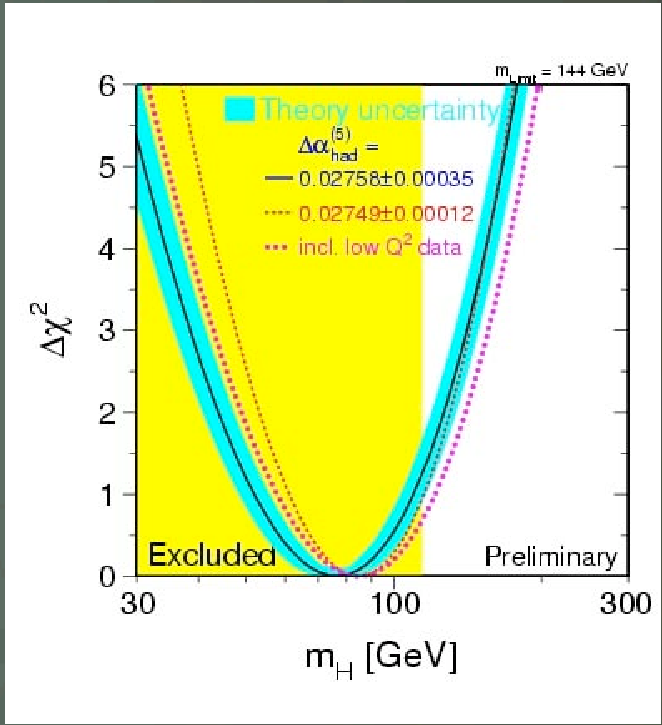
Appended OSETs

- Take known theory/model
- Modify IR with limited particles & decays

- Why?
  - Shows robustness of existing strategies
  - (More) “real” limits
  - Suggests new search strategies

Example: OSET SM Higgs

- EWPO prefer light Higgs (76 < 144/182 GeV)
- "Naturalness" prefers light Higgs
- Intriguing proposal: Suppose Higgs is light but missed (Dermisek & Gunsion; Carpenter, Kaplan, Rhee; Strassler, Zurek; Schuster, Toro; Graham, Pierce, Wacker; Chang, Fox, NW)



What do we know about Higgs decays?

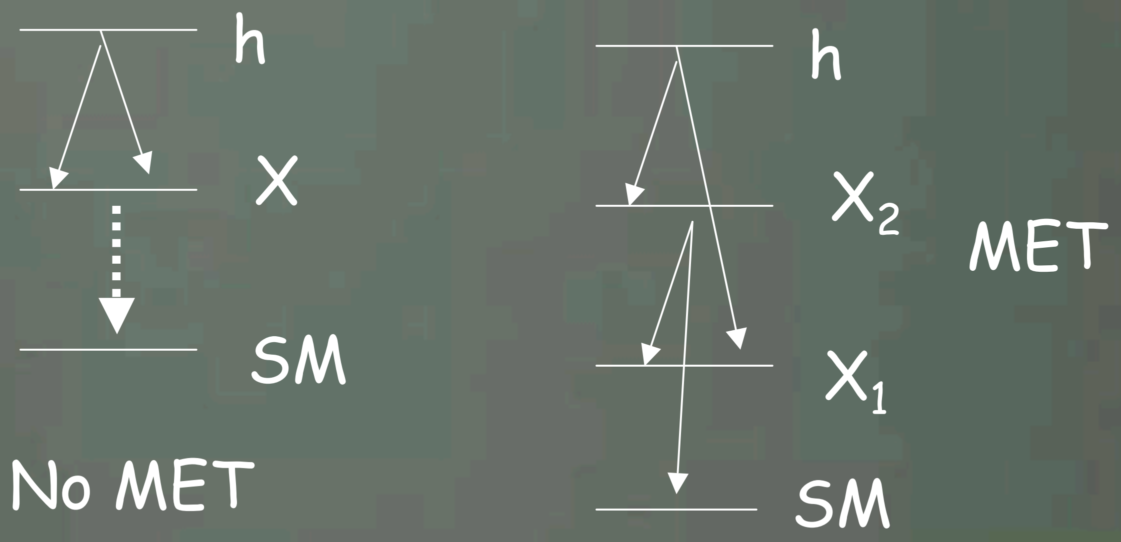
• H-> invisible	112.3 GeV
• H->2 jets	110.3 GeV
• H ->γ γ	117 GeV
• H->W W*	109.7 GeV
• H->$\tau\tau$	115 GeV

- Direct SM decays strongly constrained

  => new particles lighter than Higgs

Multibody Higgs Decays

- H-> XX -> SM (4b, 4 τ, 4 jet, 6 jet, 8 b, 4 τ 4b…)
  - 4b strong limits
  - Others (essentially) unanalyzed



27/08/07

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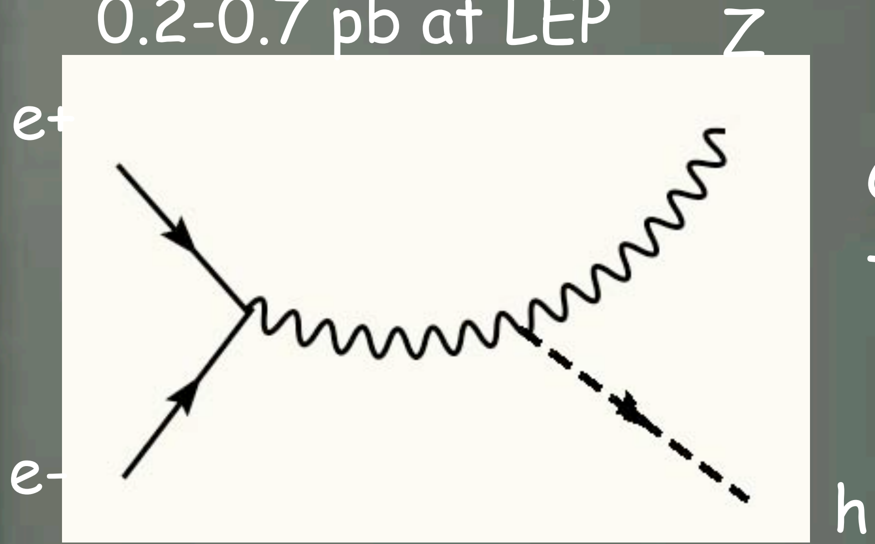
Constraints

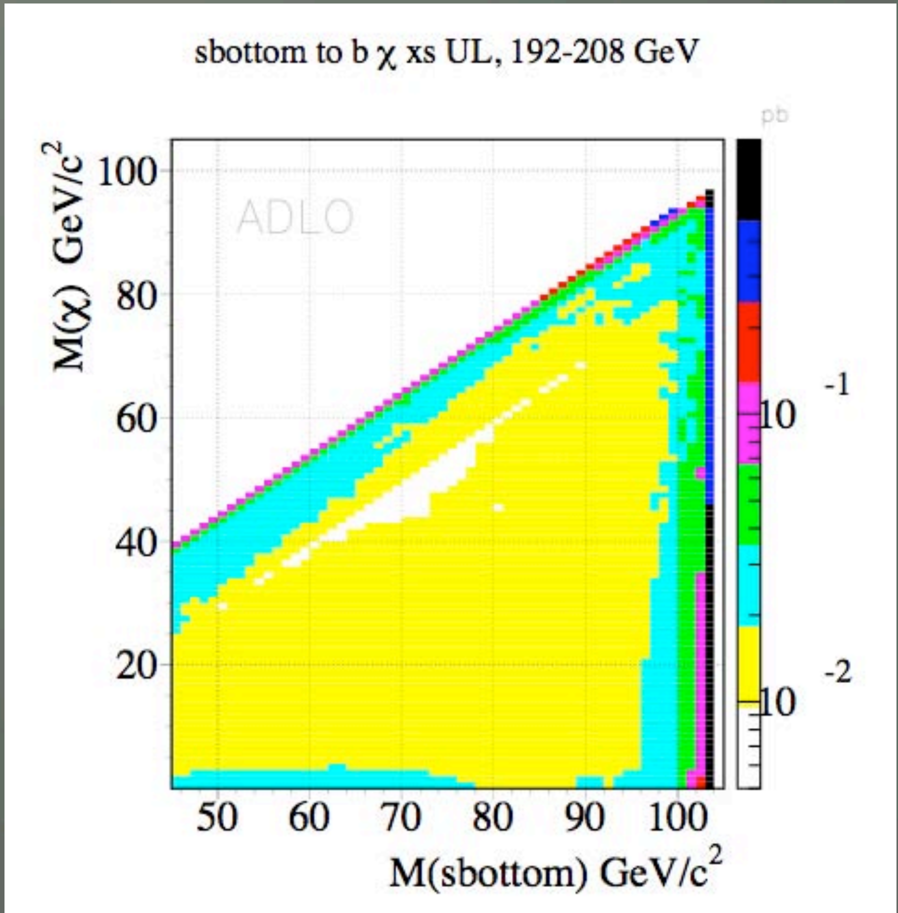
0.2-0.7 pb at LEP



Constraints depend on final topology

H-> MET+X	Z-> ?	Toplogy	Limits
X=any	2e,2μ	2l+X	OPAL indep
X=bb	inv	2b+MET	sbottom
X=qq	inv	2j+MET	squark
X=ll	inv	2l+MET	slepton
X=$\tau\tau$	inv	2τ+MET	stau

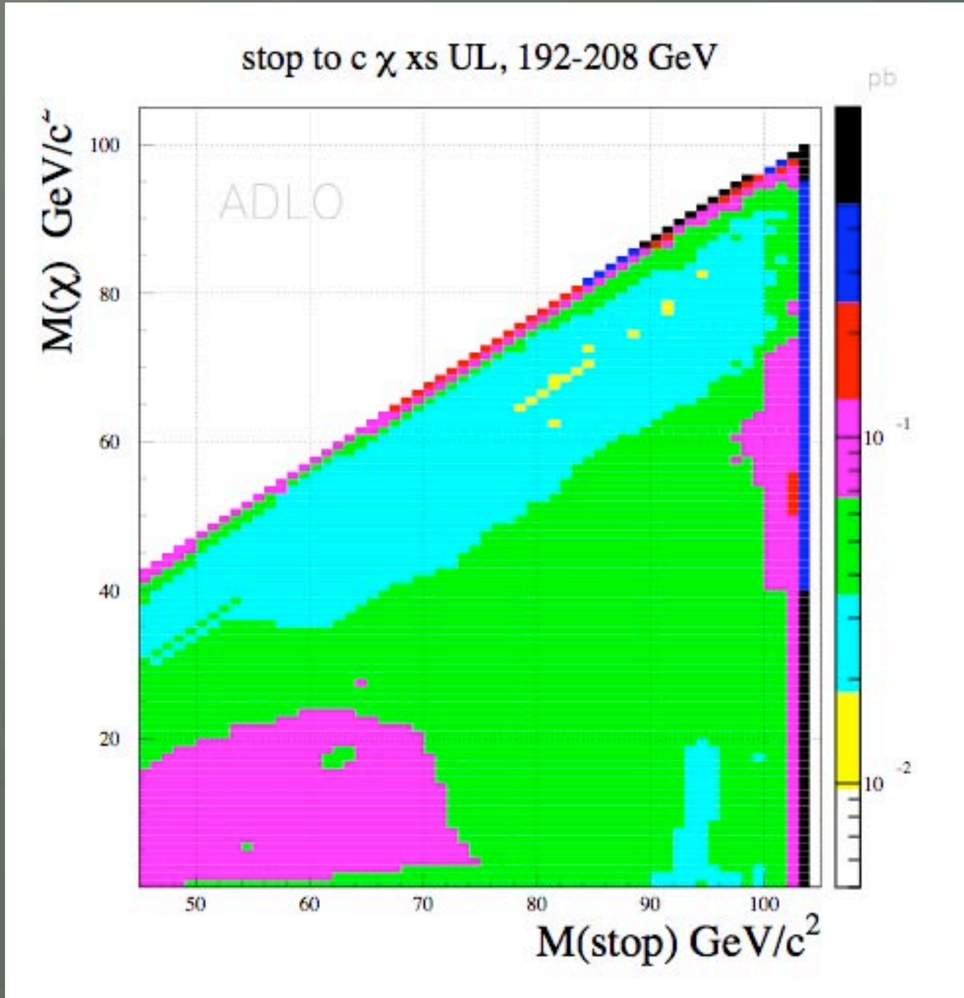
Sbottom searches: Strong



.01 - .02 pb limits

Efficiencies similar for "cuts"
- unknown for shape variables

Light jets: weaker



0.3-0.7 pb

Similar issues as sbottoms

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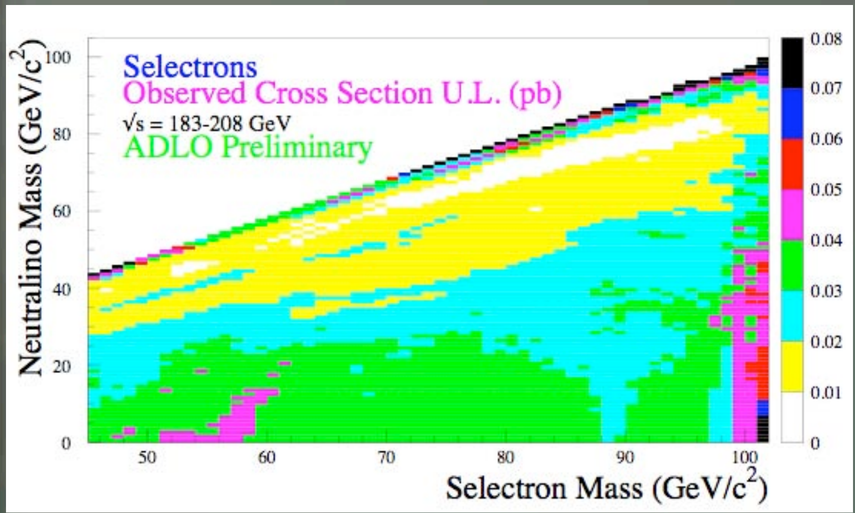
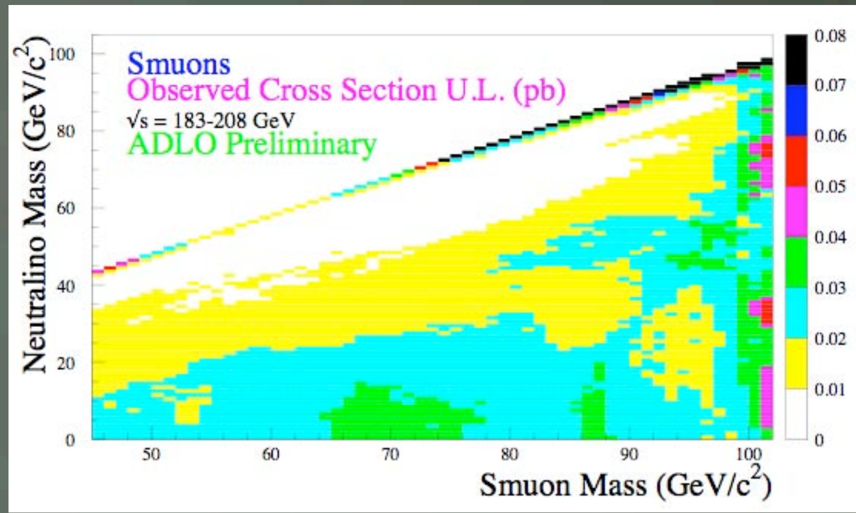
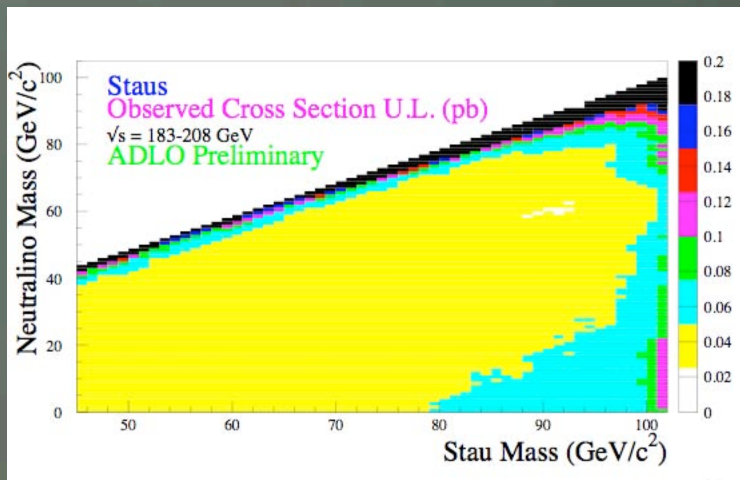
Electrons/Muons/Taus - weak





.01-.03pb

.01-.03pb



.02-.04pb

Sum: .04 - .1 pb

Comparison

H-> MET+X	Z-> ?	Toplogy	Limits	
X=any	$2e, 2\mu$	2l+X	OPAL indep	82 GeV
X=bb	inv	2b+MET	sbottom	.01-.02
X=qq	inv	2j+MET	squark	.3-.7
X=ll	inv	2l+MET	slepton	.01-.03
$X=\tau\tau$	inv	2τ+MET	stau	.02-.04
				(leps .04-.1)

For comparison, production is (0.2-0.7) x 1/5
= 0.04-0.14 pb

H->	MET+bb	excluded	
	MET+jj	OK	~ 90GeV
	MET+ll	borderline	Higgs
	MET + mixture	OK	

Squark/Gluino searches

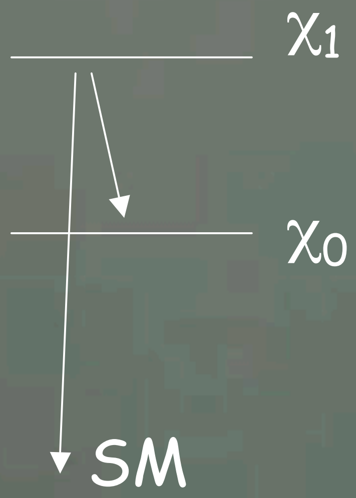
- Natural to consider consequences for colored particle searches
  - Heavy squarks/gluinos -> unnatural thoeries
    -> ugly DM (heavy Higgsino)
- What to compare? Pt in NMSSM to mSUGRA?

Appended OSETs!

- Take point in mSUGRA,
  - Append OSET
  - Study

mSUGRA'OSET

- Simplest approx: PLSP approx (pseudo-LSP)



Only question is mass and decay of final particle

D0 squark search

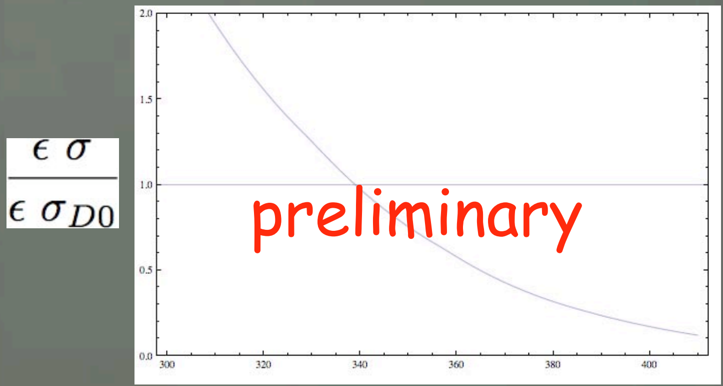
TABLE I: Selection criteria for the three analyses (all energies in GeV); see the text for further details.

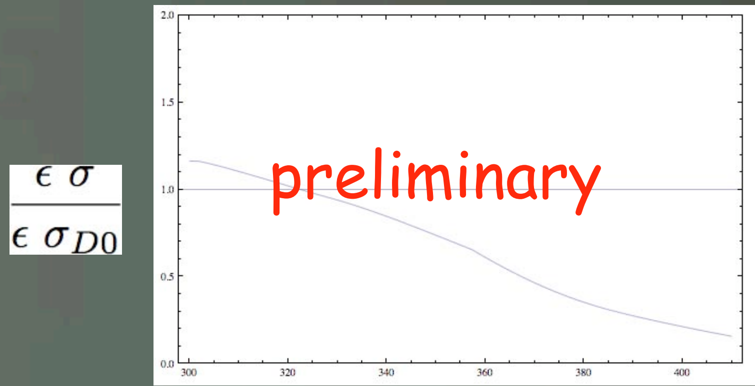
Preselection Cut	All Analyses		
1st jet E_T[a]		≥ 35	
2nd jet E_T[a]		≥ 35	
$\not\!\!E_T$		≥ 40	
Acoplanarity		$< 165°$	
|Vertex z pos.|		< 60 cm	
Selection Cut	**"dijet"**	**"3-jets"**	**"gluino"**
Trigger	acoplanar dijet	multijet	multijet
3rd jet E_T[b]	–	≥ 35	≥ 35
4th jet E_T[b]	–	–	≥ 20
$\not\!\!E_T$	≥ 75	≥ 75	≥ 75
Electron veto	yes	yes	yes
Muon veto	yes	yes	yes
$\Delta\phi(\not\!\!E_T,\text{jet}_1)$	$\geq 90°$	$\geq 90°$	$\geq 90°$
$\Delta\phi(\not\!\!E_T,\text{jet}_2)$	$\geq 50°$	$\geq 50°$	$\geq 50°$
$\Delta\phi_{\min}(\not\!\!E_T,\text{any jet})$	$\geq 40°$	–	–
H_T	≥ 300	≥ 400	≥ 300
$\not\!\!E_T$	≥ 225	≥ 150	≥ 100

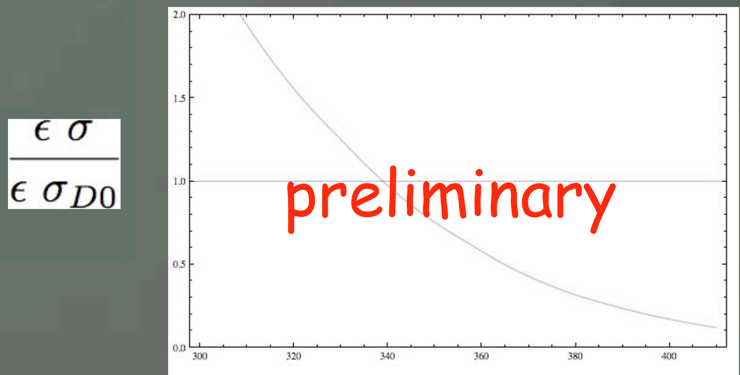
[a]The first and second leading jets were also required to be central ($|\eta_{\det}| < 0.8$), and to have $CPF \geq 0.85$.
[b]The $|\eta_{\det}|$ cut on the third and fourth jet was < 2.5 and no CPF requirement was imposed on those jets.

Calculate efficiency for D0 optimized points

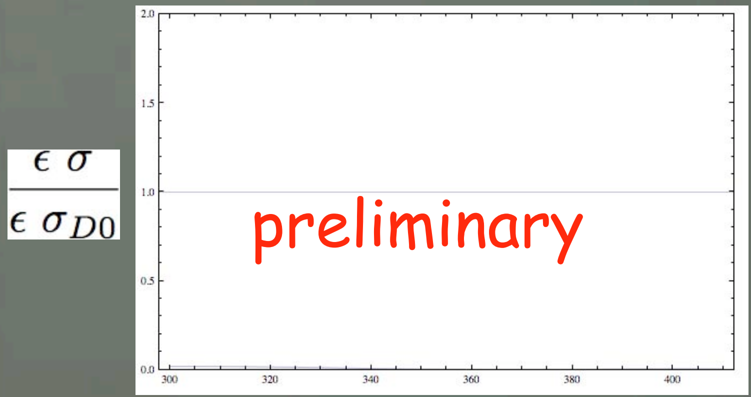
tau dominated decays (3jet benchmark)

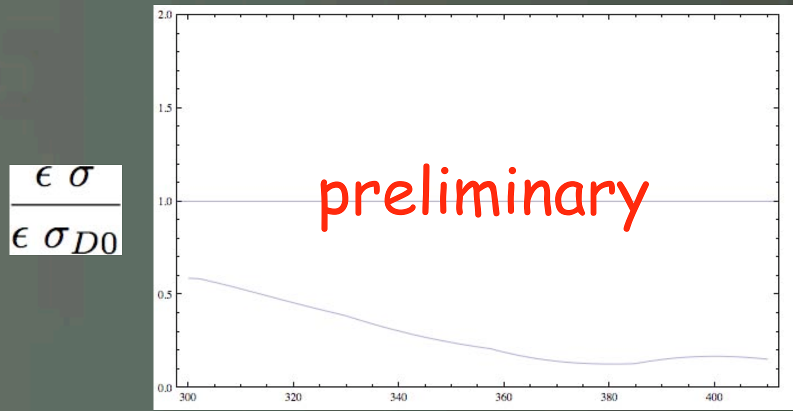


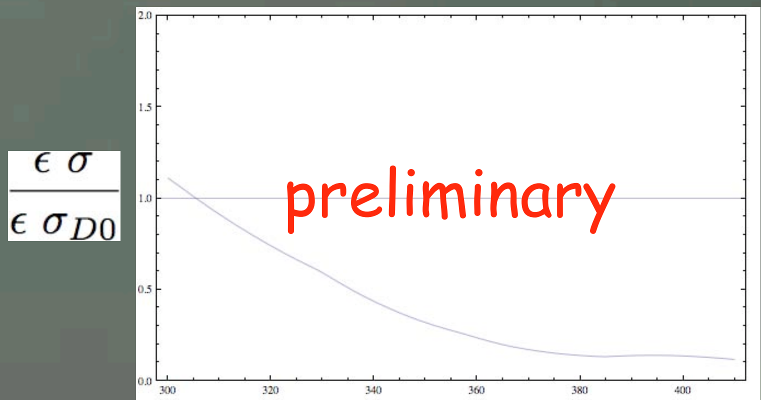




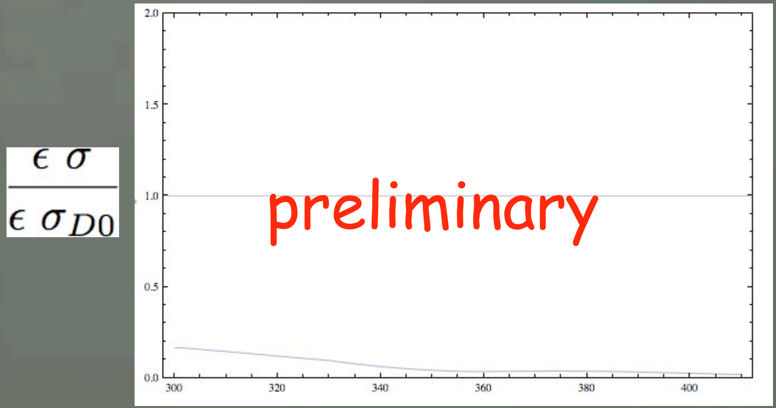
lepton dominated decays (3jet benchmark)

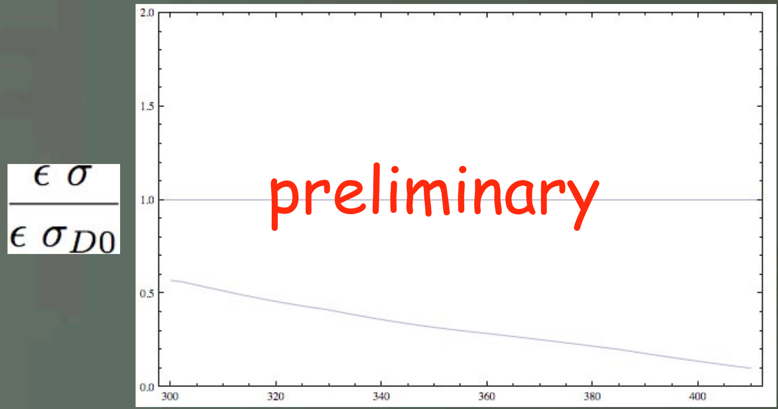


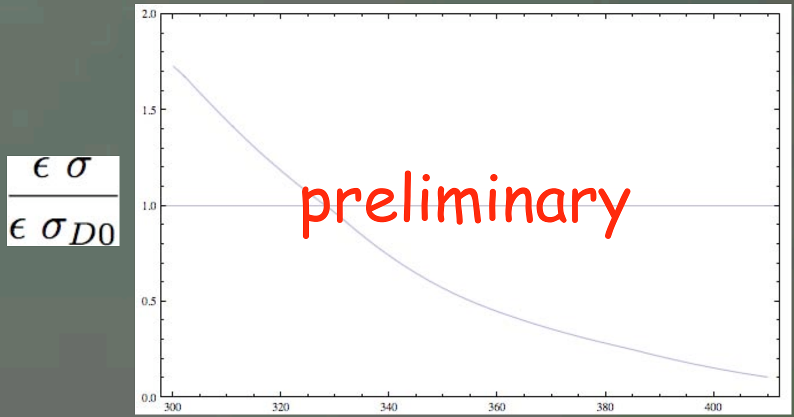




mixed decays (3jet benchmark)







Conclusions

- Not surprising: modifying IR of theory has important consequences for limits
- (Perhaps) more surprising: minor modifications lead to very significant results
  - Higgs well below LEP limits
  - Colored particles below Tevatron bounds
- Relevance for additional analyses