Dark Matter
FROM THE COSMOS TO THE LABORATORY

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Supersymmetry at the Tevatron

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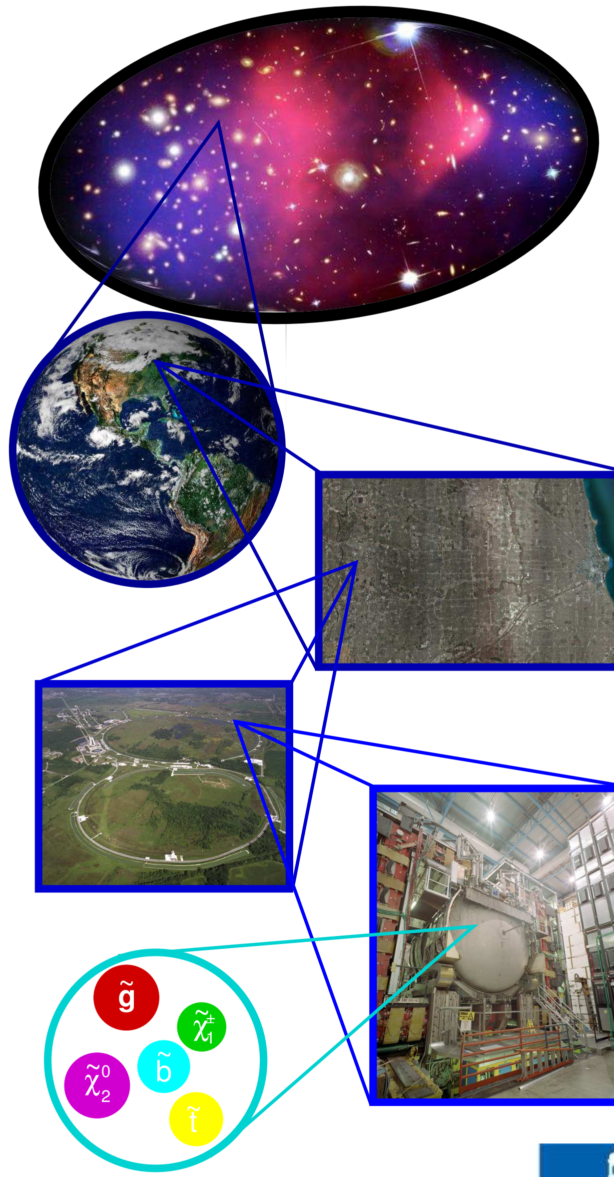
on behalf of the CDF and DØ experiments

http://www-conf.slac.stanford.edu/ssi/2007/reg

Outline

- Introduction
- Tevatron collider and detectors
- Physics at the Tevatron
- Search for Supersymmetry
  - Direct searches
    - Search for supersymmetric Higgs bosons
    - Search for Charginos and Neutralinos
    - Search for Squarks and Gluinos
    - Search for long lived particles
  - Indirect searches
    - Search for $\mathrm{B_s} \to \mu\mu$
- Summary and outlook



Particle Content

Particles in the Minimal Supersymmetric Model (MSSM)

R–parity = +1			R–parity = –1			R–parity = –1		
Particle	Symbol	Spin	Particle	Symbol	Spin	Particle	Symbol	Spin
Lepton	ℓ	$\frac{1}{2}$	Slepton	$\tilde{\ell}_L, \tilde{\ell}_R$	0			
Neutrino	ν	$\frac{1}{2}$	Sneutrino	$\tilde{\nu}$	0			
Quark	q	$\frac{1}{2}$	Squark	$\tilde{q}_L, \tilde{q}_R$	0			
Gluon	g	1	Gluino	$\tilde{g}$	$\frac{1}{2}$			
Photon	γ	1	Photino	$\tilde{\gamma}$	$\frac{1}{2}$			
Z Boson	Z	1	Zino	$\tilde{Z}$	$\frac{1}{2}$			
W Boson	$W^{\pm}$	1	Wino	$\tilde{W}^{\pm}$	$\frac{1}{2}$	4 Neutralinos	$\tilde{\chi}_i^0$	$\frac{1}{2}$
Higgs	$H^0, H^{\pm}$	0	Higgsino	$\tilde{H}_1^0, \tilde{H}_2^+$	$\frac{1}{2}$	2 Charginos	$\tilde{\chi}_i^{\pm}$	$\frac{1}{2}$
	h^0, A^0	0		$\tilde{H}_1^-, \tilde{H}_2^0$	$\frac{1}{2}$			

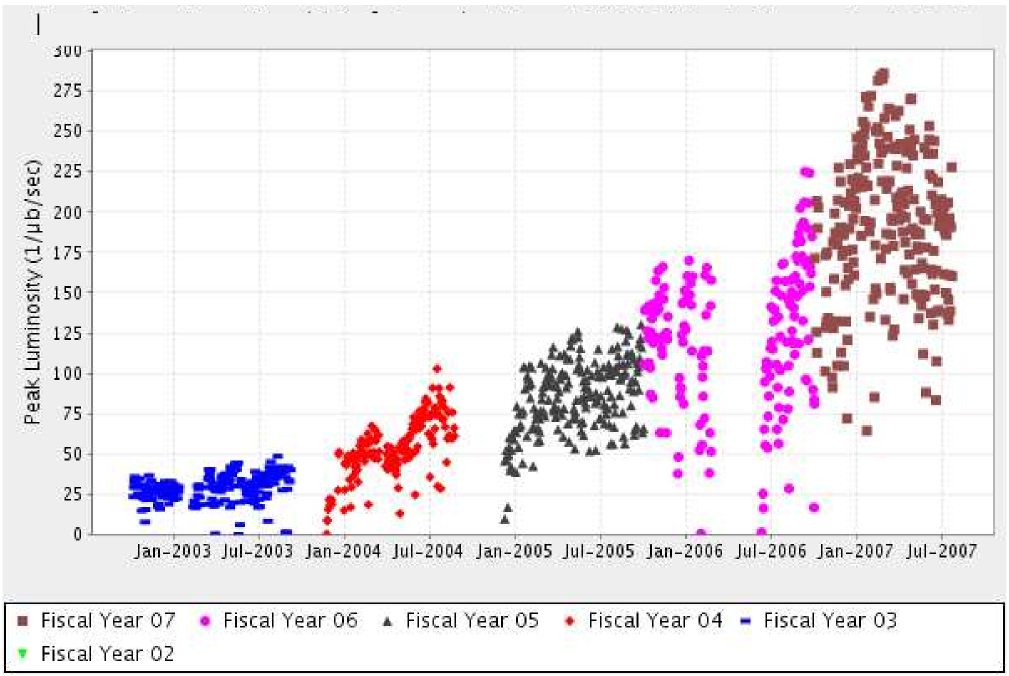
- Assumptions in this talk
  - Consider mSUGRA model
    - Relevant parameters: $\tan\beta$, m_0, $m_{1/2}$, A_0, sign(μ)
  - R–parity is conserved ⇒ LSP (Neutralino) is stable

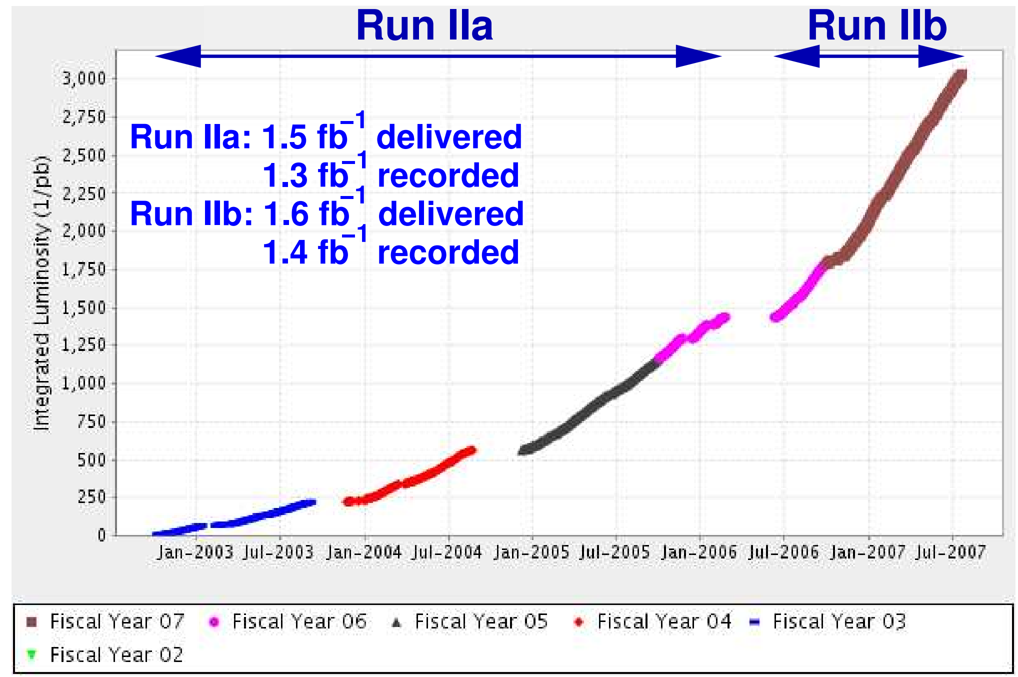
Tevatron Parameters

- $p\bar{p}$ collisions at center of mass energy of $\sqrt{s}$ = 1.96 TeV

	Run I	Run IIa	Run IIb
$\sqrt{s}$ (TeV)	1.8	1.96	1.96
Bunches	6×6	36×36	36×36
Bunch spacing (ns)	3500	396	396
Luminosity $(\mathrm{cm}^{-2}\mathrm{s}^{-1})$	$1.6 \cdot 10^{30}$	$9 \cdot 10^{31}$	$3 \cdot 10^{32}$

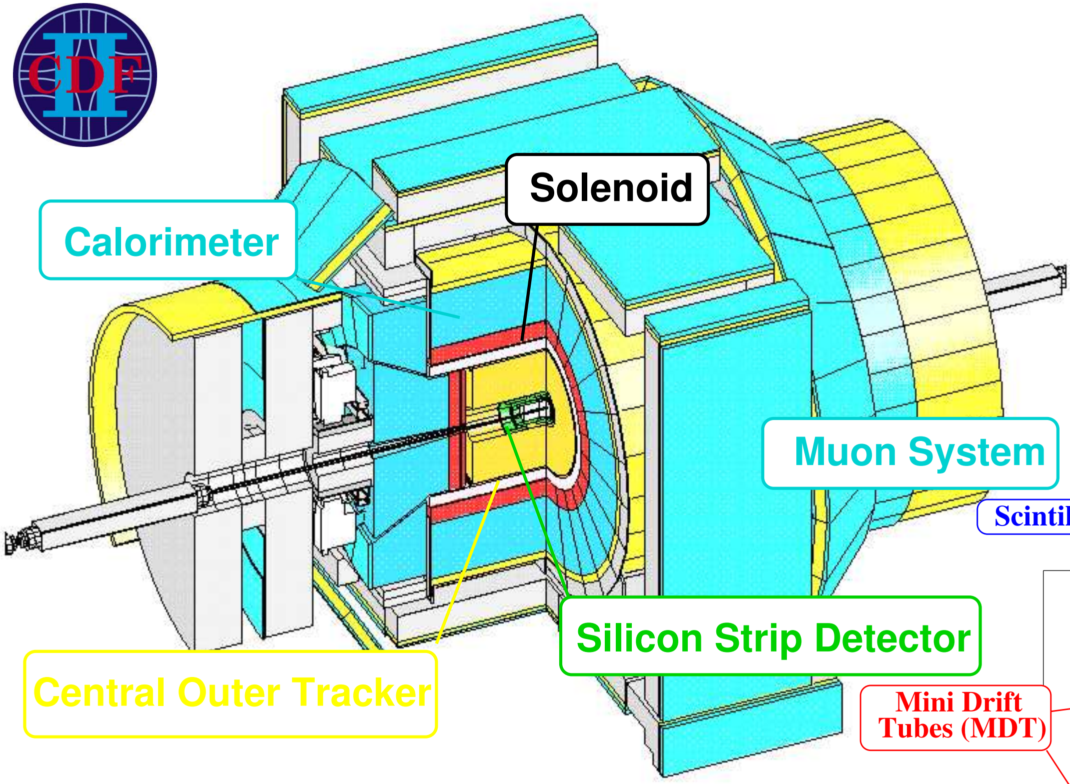
Tevatron Performance



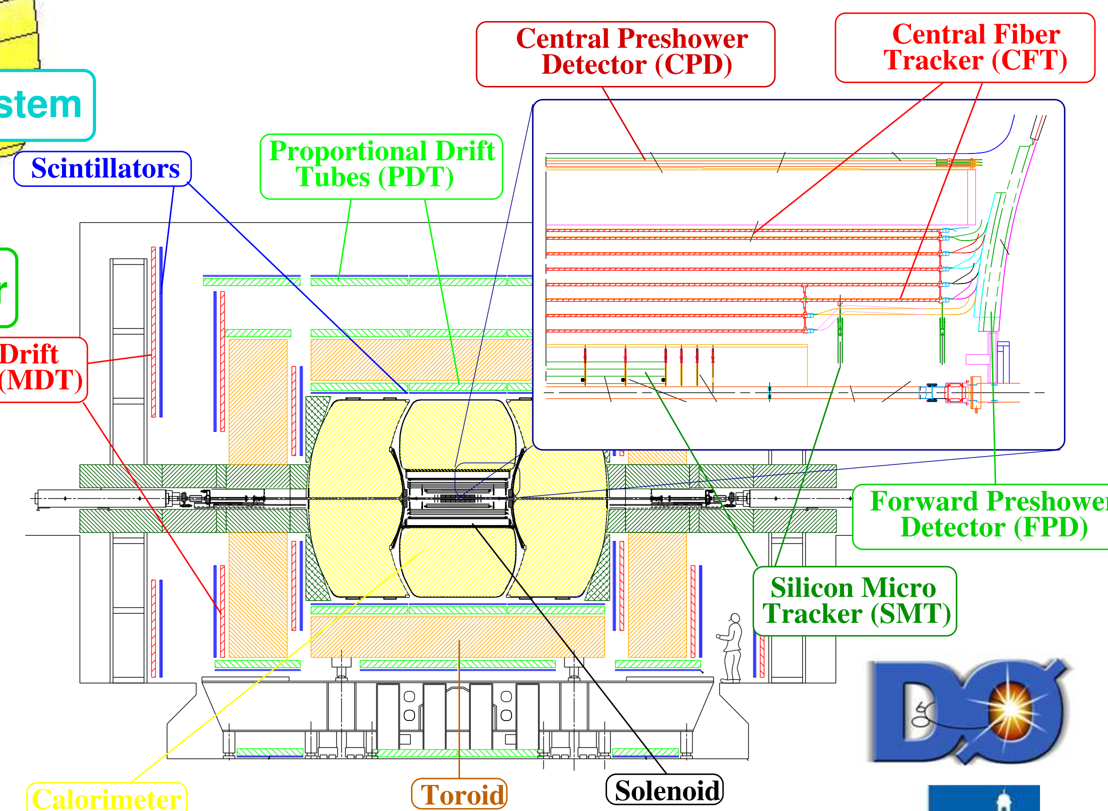


- Tevatron coming close to design luminosity for Run IIb
  - Improved antiproton stacking rate
  - Peak luminosity $\sim 300 \cdot 10^{30}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Integrated luminosity of 7–8 fb^{-1} by end of 2009 realistic projection

The Detectors

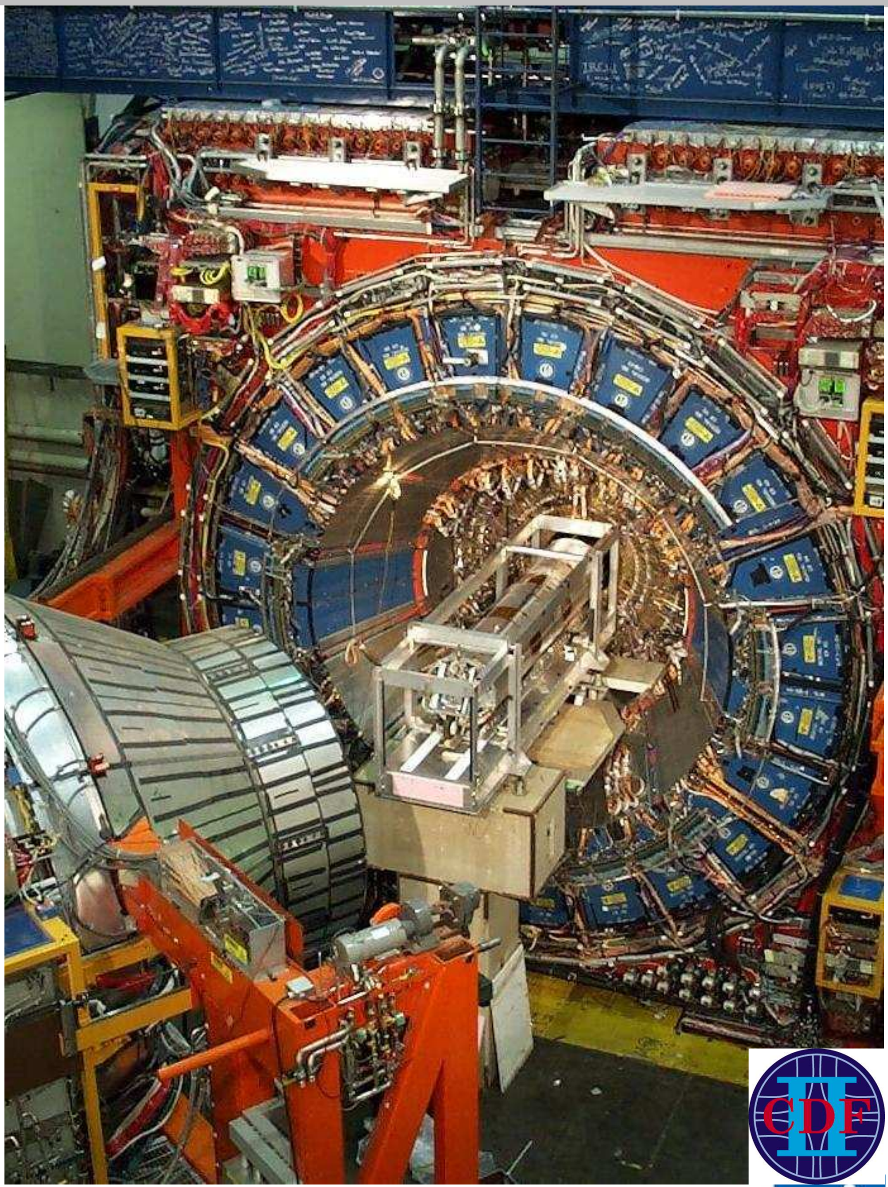


- Two multipurpose detectors
  - ▲ Identification of electrons, muons, taus, jets, missing transverse energy
- Fast readout electronics
  - ▲ Bunch spacing 396 ns
- Dedicated trigger systems
  - ▲ Rate reduction from 2.5MHz to 50Hz



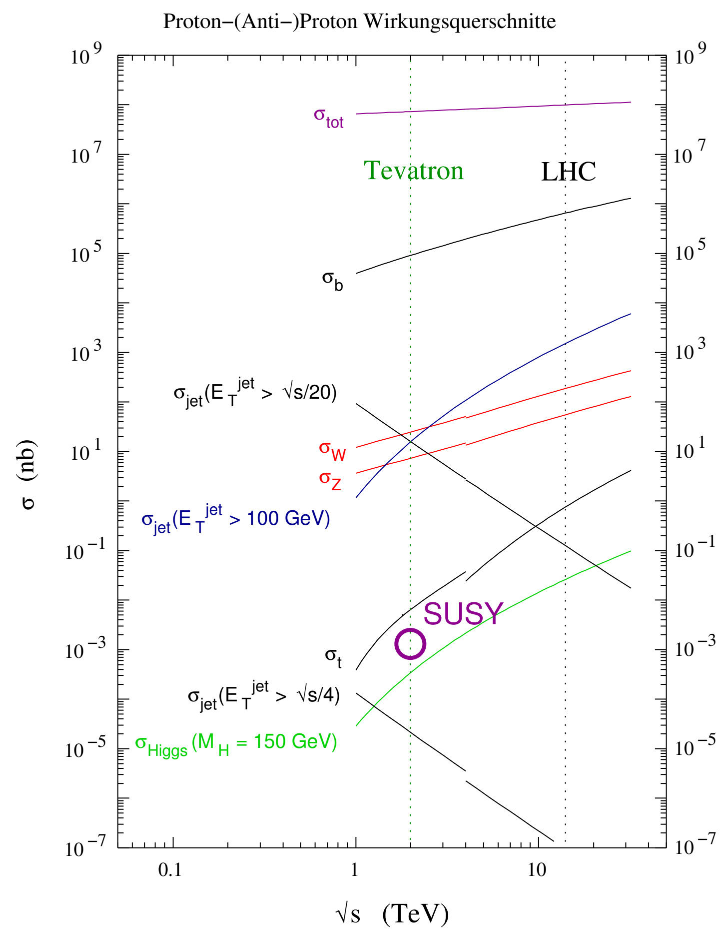
- CDF detector
  - ▲ Large tracking volume
- DØ detector
  - ▲ Large acceptance for electrons and muons

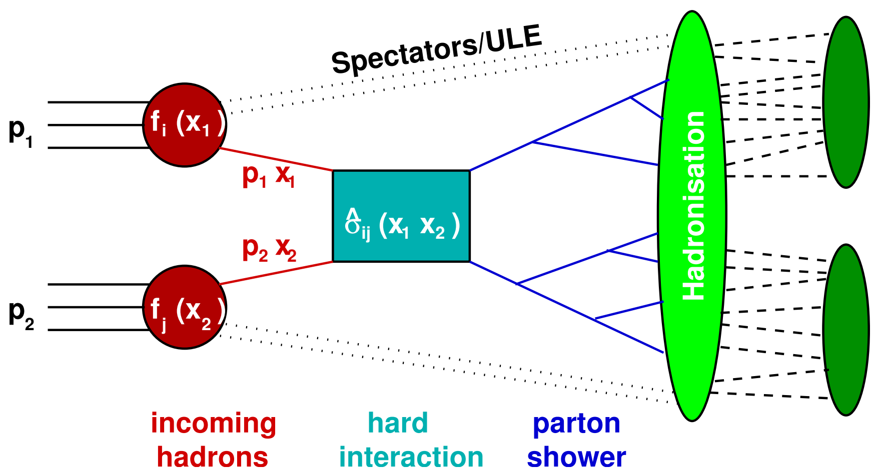
The Detectors (cont'd)



Physics at the Tevatron

- Physics at the Tevatron is characterized by
  - ▲ High center–of–mass energy of the collider
    - ▶ Production of massive particles possible
    - ▶ top–quark, Higgs, SUSY particles, heavy gauge boson,...
  - ▲ Particles are produced in strong interaction
    - ▶ Huge cross section for jet production
    - ▶ Need large reduction to see signals
  - ▲ 7 interactions/crossing at $3 \cdot 10^{32} \mathrm{cm}^{-2}\mathrm{s}^{-1}$





- ▲ Final states are complicated
  - ▶ Fragmentation of spectators
  - ▶ Additional jets due to gluon radiation

SUSY at the Tevatron

- There are three major areas to search for Supersymmetry at the Tevatron
  - Search for supersymmetric Higgs bosons
    - Search for Higgs bosons in τ final states
    - Higgs bosons searches using b–jets
  - Direct searches for other SUSY particles
    - Squarks and Gluinos
    - Charginos and Neutralinos
    - Long lived particles
  - Indirect searches
- Only a few selected topics will be covered in this talk
- For a comprehensive overview please refer to

CDF `http://www-cdf.fnal.gov/physics/physics.html`
DØ `http://www-d0.fnal.gov/Run2Physics/WWW/results.htm`

Search for SUSY Higgs Bosons

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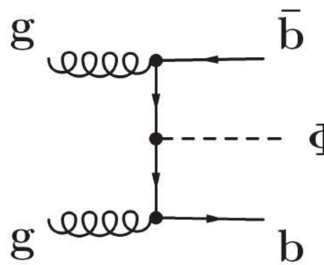
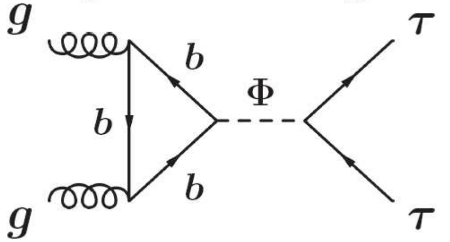
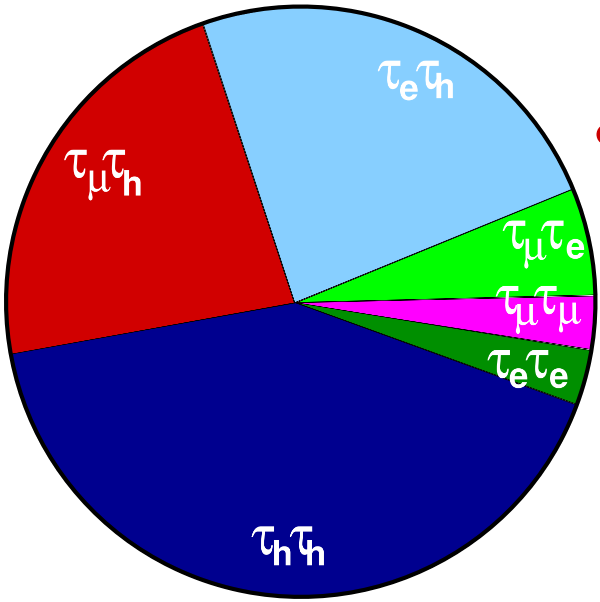
Search for SUSY Higgs Bosons

- 5 Higgs bosons are predicted in SUSY models
  - ▲ MSSM Higgs sector specified by $\tan\beta$, m_A
- Neutral Higgs bosons h/H/A can be produced via gluon fusion or in association with jets
  - ▲ Coupling increases with $\tan^2\beta \Rightarrow$ Large cross section
- At high $\tan\beta$ the main decay modes are
  - ▲ h/H/A$\rightarrow b\bar{b}$: 90%   h/H/A$\rightarrow \tau\tau$: 10%



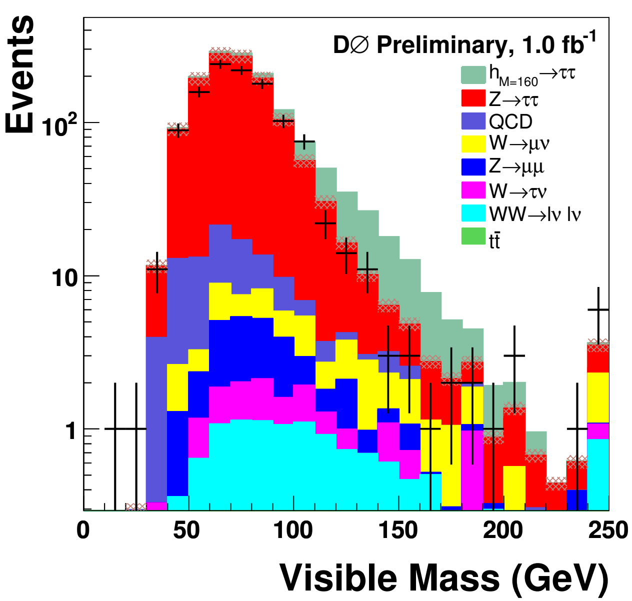


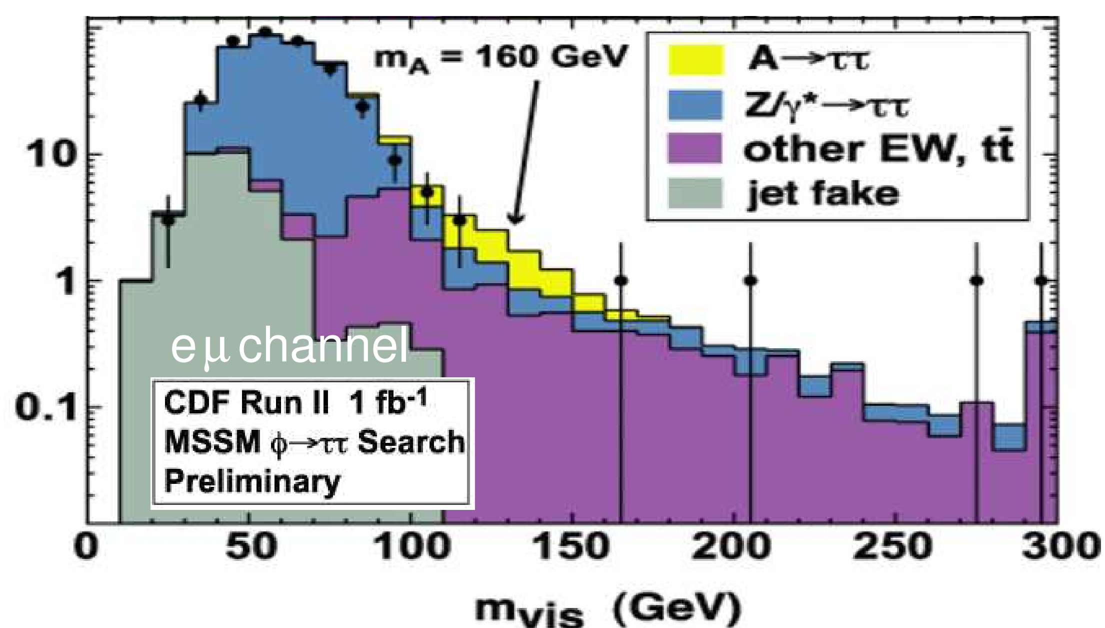


- Focus on $\tau\tau$ final state
  - ▲ Golden channels are $\tau_h\tau_e$ and $\tau_h\tau_\mu$
    - ▶ Large branching fraction, moderate background
  - ▲ Other channels are less important
    - ▶ Fully leptonic channels: small branching fraction
    - ▶ Fully hadronic mode: huge multijet background

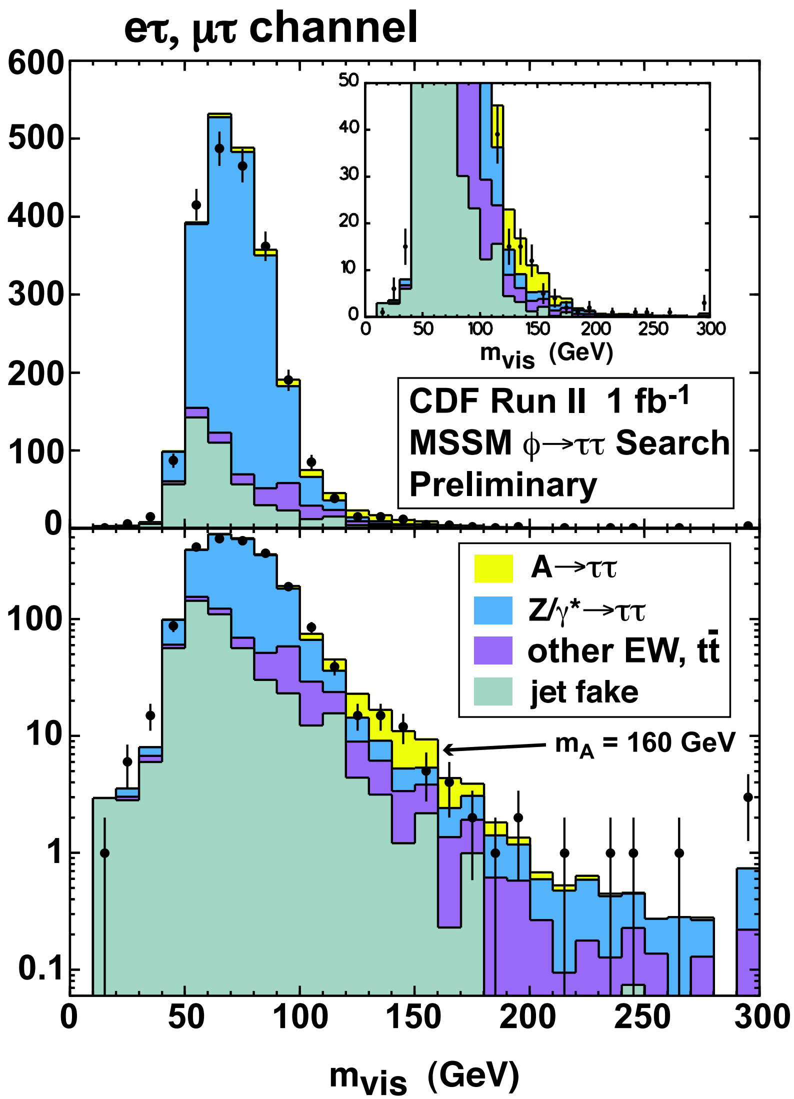
Search for SUSY Higgs Bosons (2)

- Major backgrounds are $Z/\gamma^* \to \tau\tau$ and multijet production
  - Require isolated lepton and isolated τ to reduce QCD contribution
  - Further reduce QCD by requiring large $H_T = \sum p_T$
  - Veto on events where $\not{E}_T$ is aligned with visible τ decay products to suppress W+jet events
- Finally reconstruct visible mass
  - $M_{vis} = \sqrt{(E_\ell + E_\tau + \not{E}_T)^2 - (p_x^\ell + p_x^\tau + \not{E}_T^x)^2 - (p_y^\ell + p_y^\tau + \not{E}_T^y)^2 - (p_z^\ell + p_z^\tau)^2}$

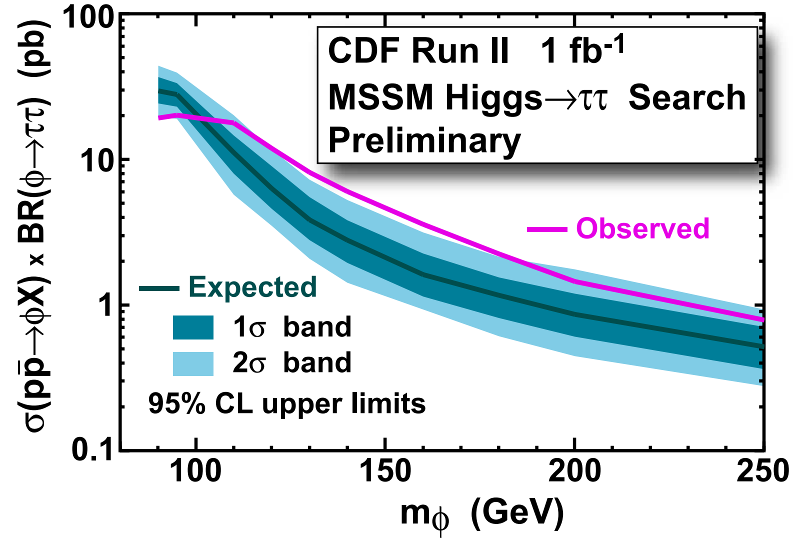




Search for SUSY Higgs Bosons (3)



- CDF (3 channels)
  - ▲ 2σ excess in $\tau_h\tau_e$ and $\tau_h\tau_\mu$ channels
    - ► $m_A \approx$ 150 GeV, $\tan\beta \approx$ 50
  - ▲ No excess in $\tau_e\tau_\mu$ channel
- DØ (1 channel)
  - ▲ No excess in $\tau_h\tau_\mu$ channel
  - ▲ Expect results in $\tau_h\tau_e$ and $\tau_e\tau_\mu$ channels later this summer



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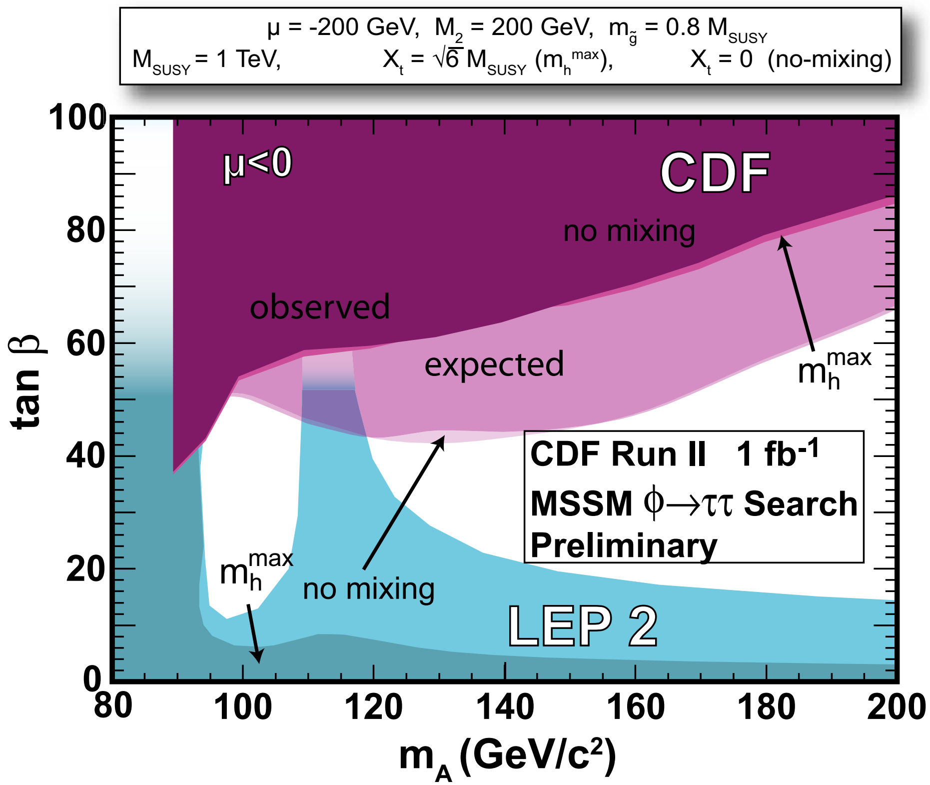
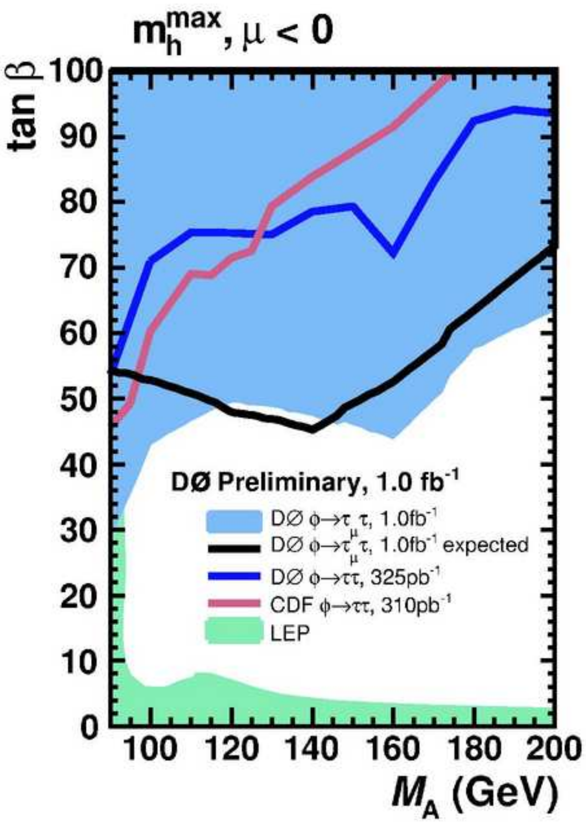
Limits

- Although there is excess seen by CDF, no evidence for Higgs production (yet)
  - Set limits in the $\tan\beta$–m_A–plane





- What to expect in the future
  - More data, more channels, combination with $bh \to bb\bar{b}$ result

Search for Charginos and Neutralinos

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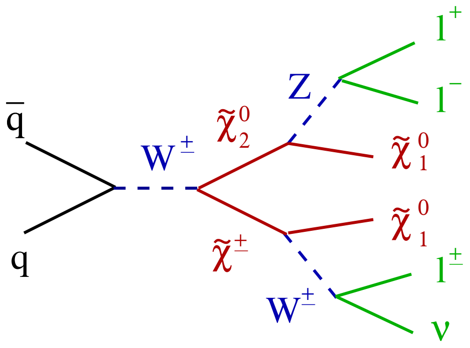
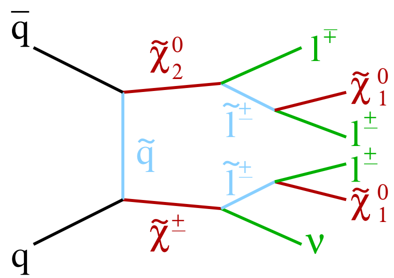
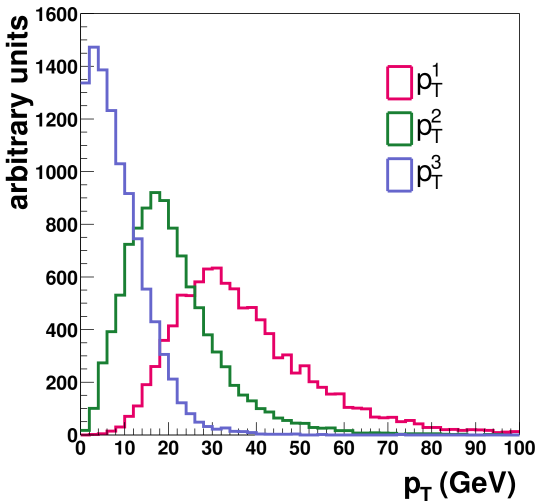
Search for Charginos and Neutralinos

- Associated production of Charginos and Neutralinos
  - ▲ Via W boson or Squark exchange
- Decay of Chargino
  - ▲ W bosons and lightest Neutralino
  - ▲ Slepton and neutrino
- Decay of Neutralino
  - ▲ Z bosons and lightest Neutralino
  - ▲ Slepton and lepton





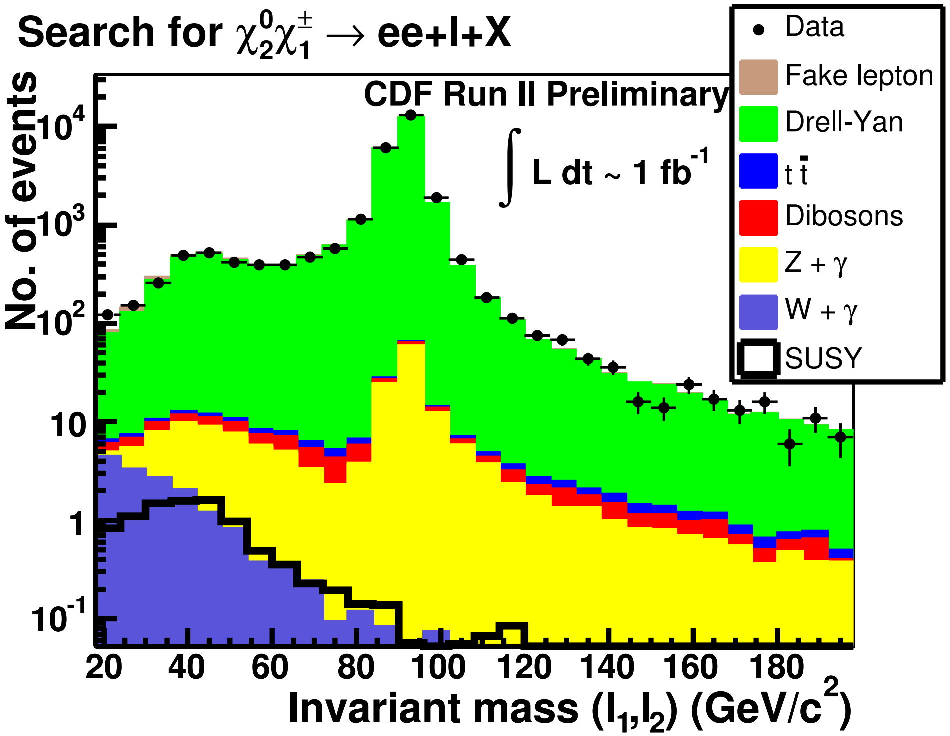
- Final state consists of three charged leptons, two Neutralinos and a neutrino

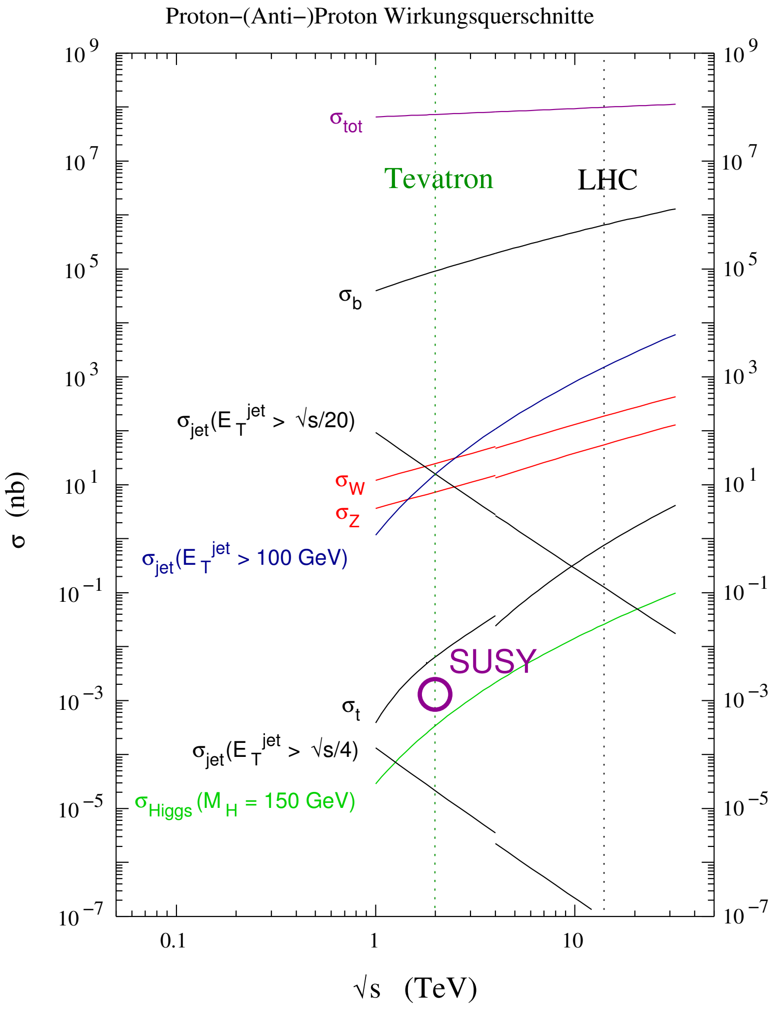


- Trilepton channel is the golden mode for the search of Charginos and Neutralinos
  - ▲ Signature: three charged leptons plus missing transverse energy
- Challenges
  - ▲ Leptons have low transverse momenta
  - ▲ Small cross sections: $\sigma \times BR < 0.5$ pb

Backgrounds and Selection

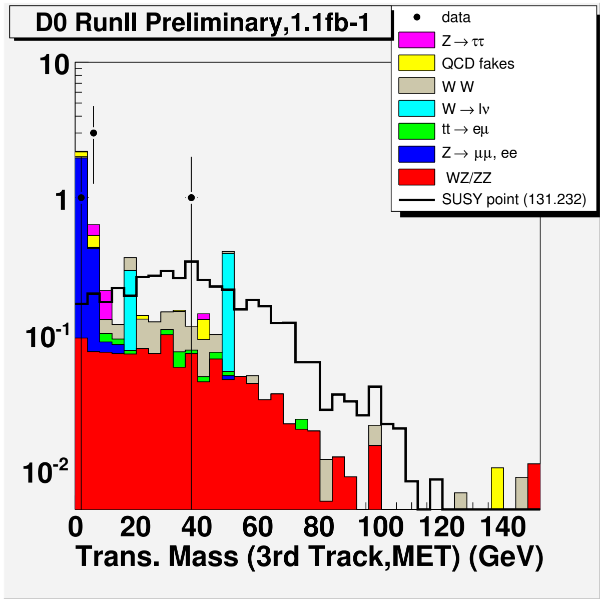
- Main background is QCD multijet production
  - Very large cross section
- Require two isolated leptons
  - Main contributions from Z/γ production

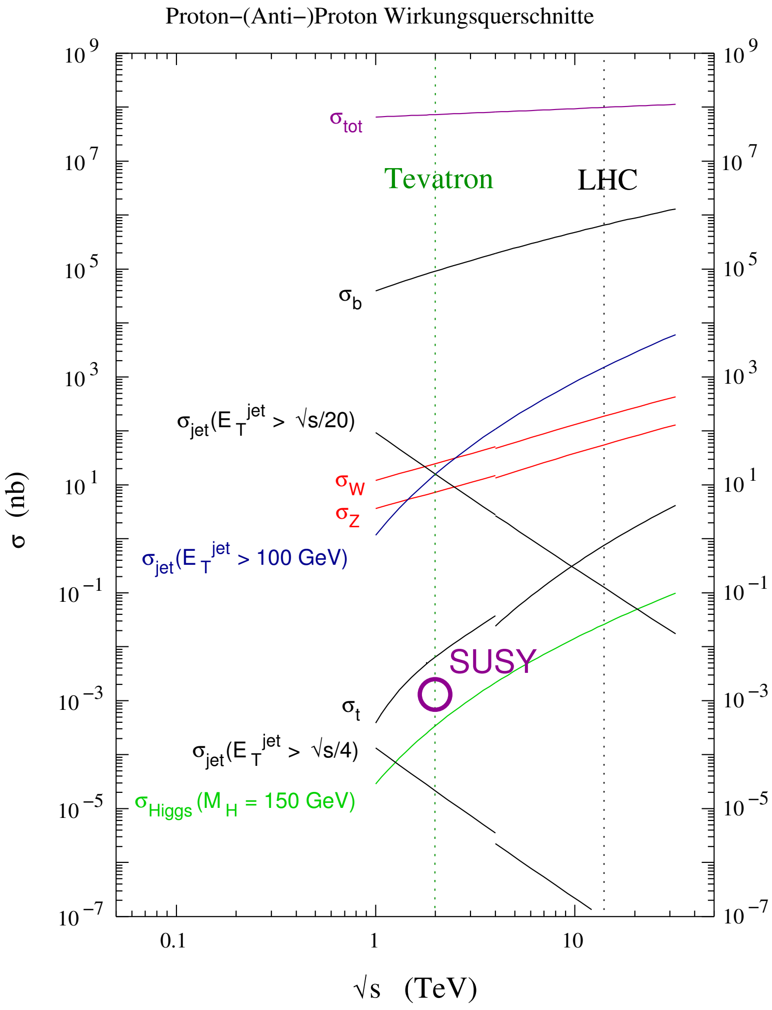




Backgrounds and Selection

- Main background is QCD multijet production
  - ▲ Very large cross section
- Require two isolated leptons
  - ▲ Main contributions from Z/γ production
- Further possibilities to suppress background
  - ▲ Require a third lepton or track
  - ▲ Leptons must have same charge
  - ▲ Diboson production main contributor





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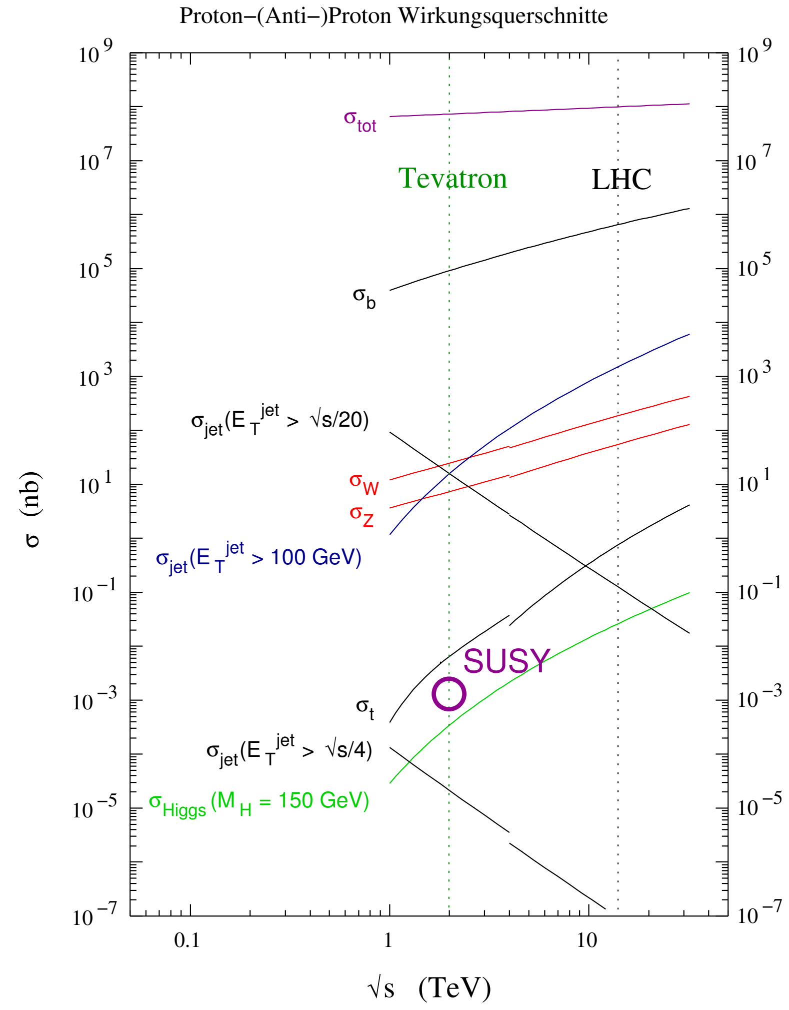
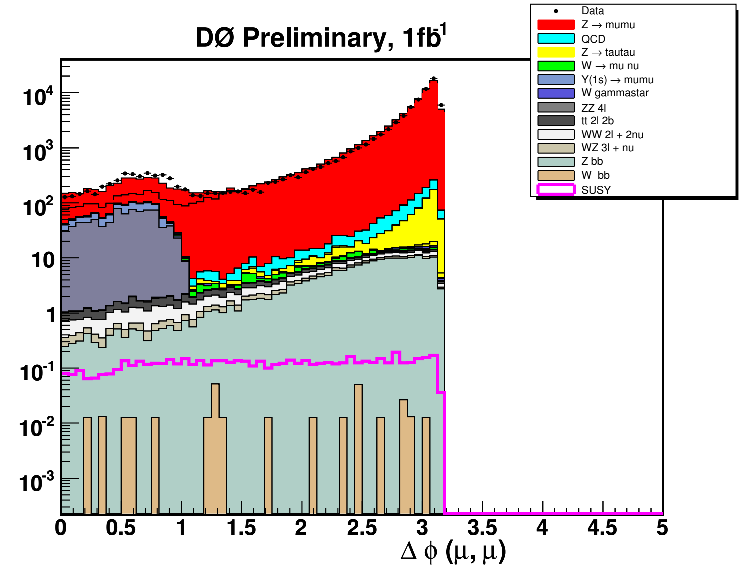
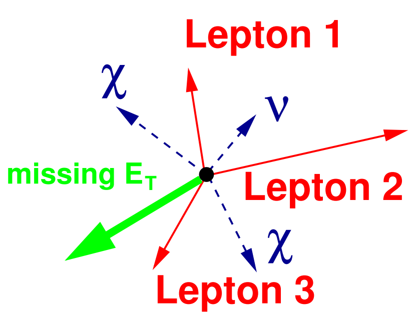
  - ▲ Diboson production main contributor
- Three different selection criteria
  - ▲ Three identified leptons
  - ▲ Two leptons plus additional track
    - ▶ Higher efficiency, but slightly more background
  - ▲ Likesign selection
    - ▶ Sensitive in regions with low p_T third lepton

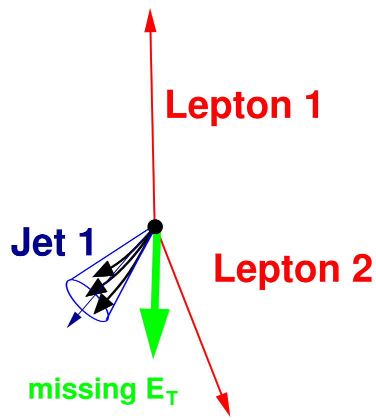


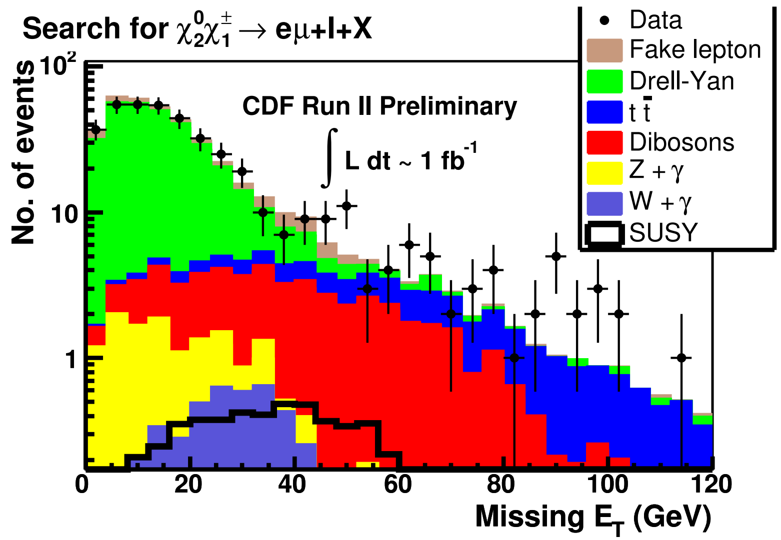
Selection with Two Leptons

- Preselection
  - ▲ Two good reconstructed leptons
- Anti–$Z/\gamma^* \to ee$, $Z/\gamma^* \to \mu\mu$ cuts
  - ▲ Small invariant mass
  - ▲ Not back–to–back leptons





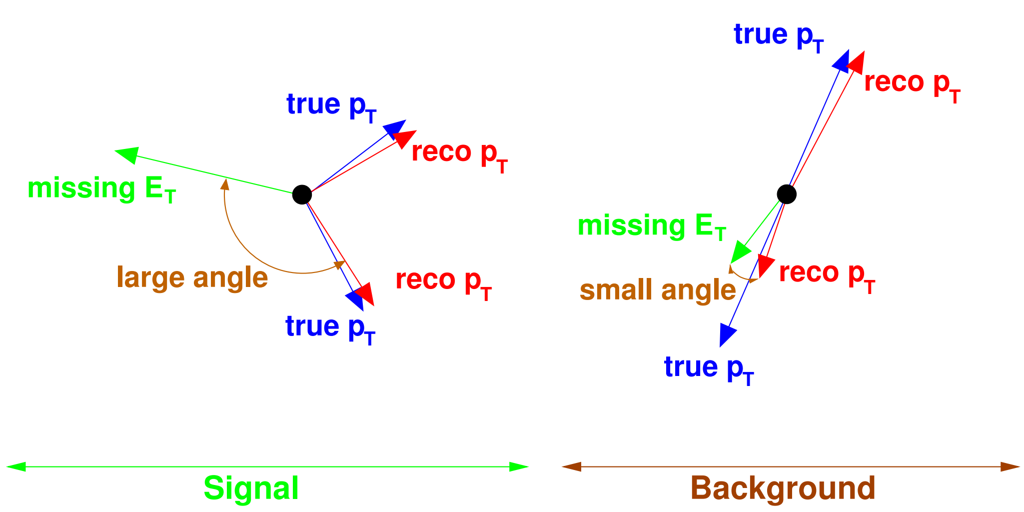


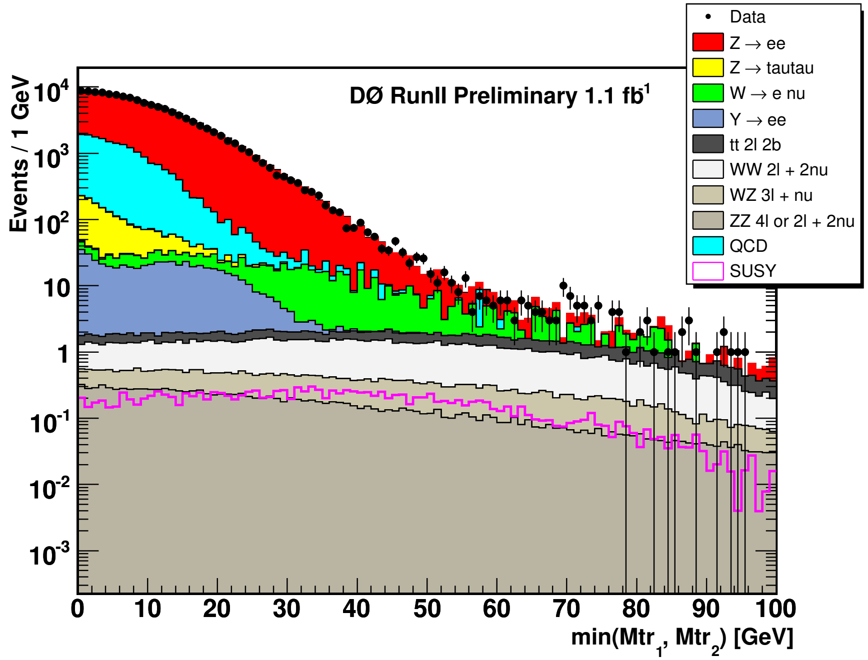


- Significant missing transverse energy

Cuts using $\not{E}_T$

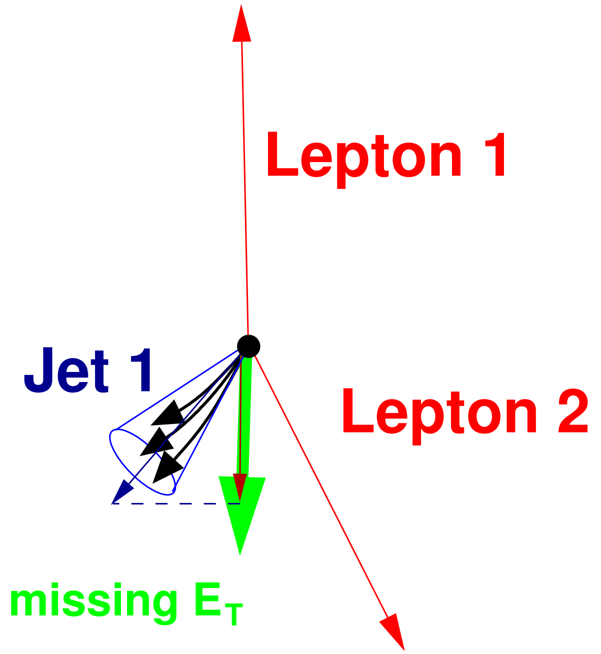
- $\not{E}_T$ related cuts
  - Cut on $\not{E}_T$ itself
  - Transverse mass cut: $m_T = \sqrt{p_T \cdot \not{E}_T \cdot (1 - \cos\Delta\Phi(e, \not{E}_T))}$
    - Rejects events with mismeasured lepton energies

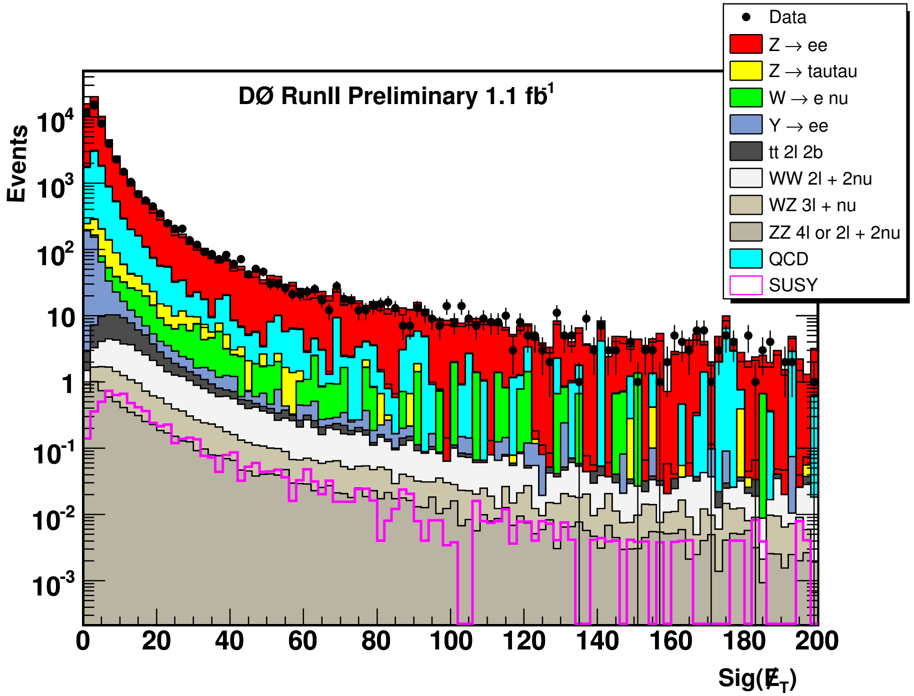




Cuts using $\not\!\!E_T$

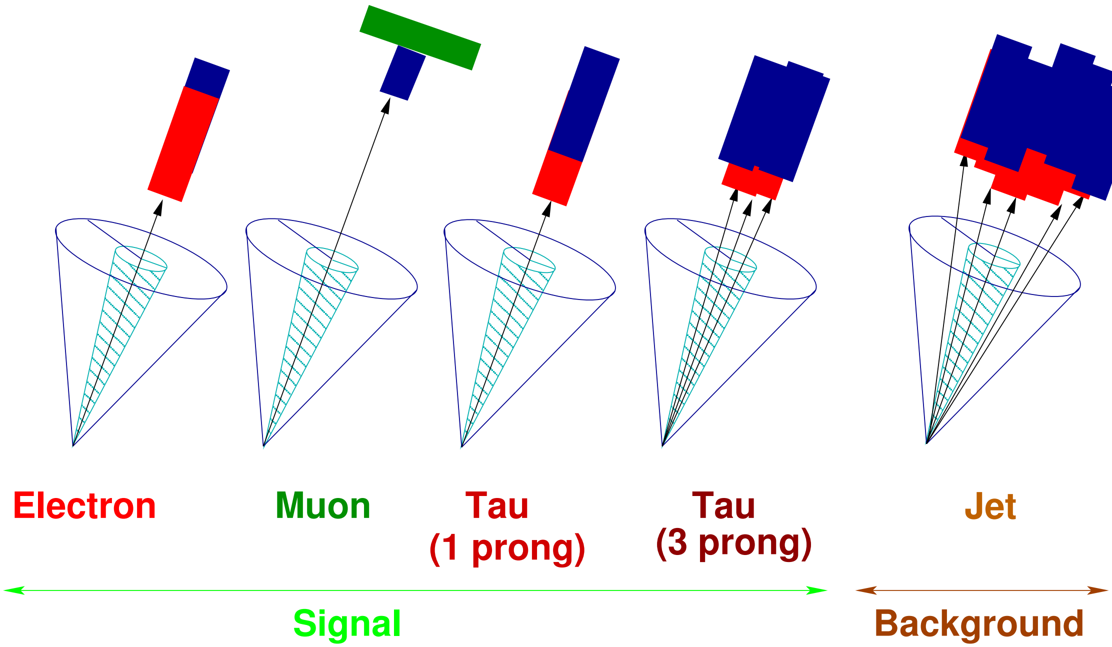
- $\not\!\!E_T$ related cuts
  - Cut on $\not\!\!E_T$ itself
  - Significance of $\not\!\!E_T$: $\mathrm{Sig}(\not\!\!E_T) = \dfrac{\not\!\!E_T}{\sqrt{\sum_{jets} \sigma^2(E_T^{jet} || \not\!\!E_T)}}$
    - Only defined for events with jets
    - Rejects events with mismeasured jet energies

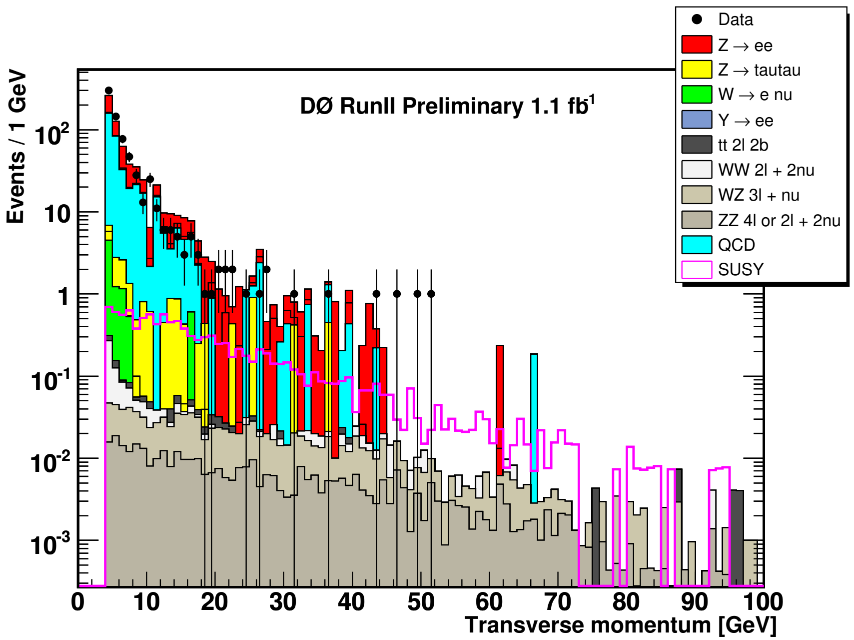




Third Track Selection

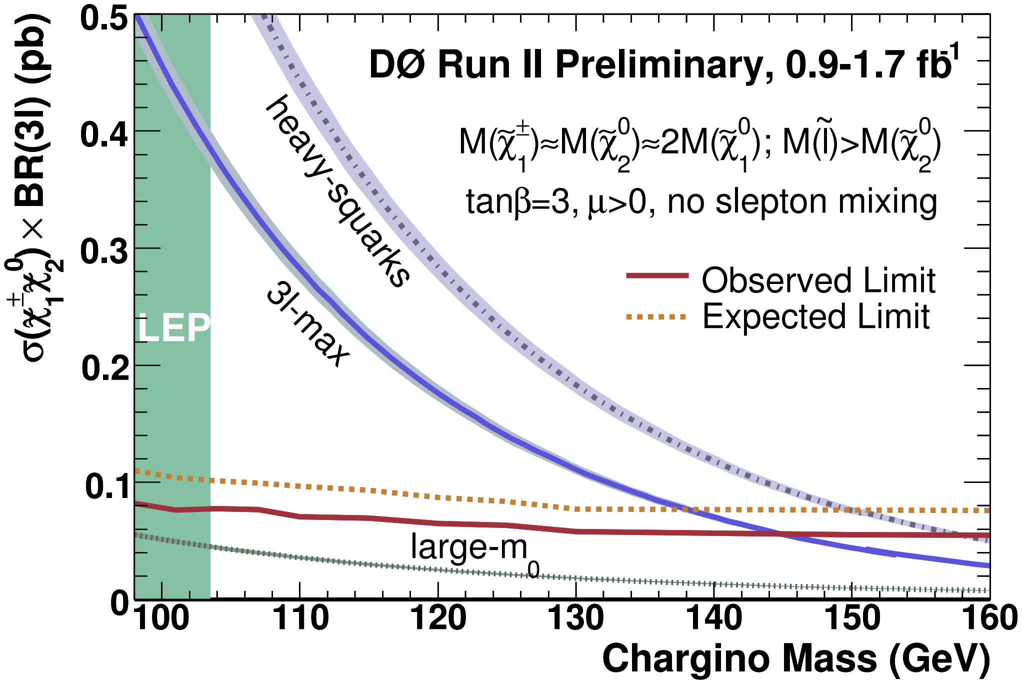
- Select high quality track to account for the third lepton
  - Track must be isolated in tracker and calorimeter
    - Efficient for electrons, muons and taus, suppresses tracks in jets
  - Use hollow cone for isolation
    - Also efficient for (3 prong) tau decays

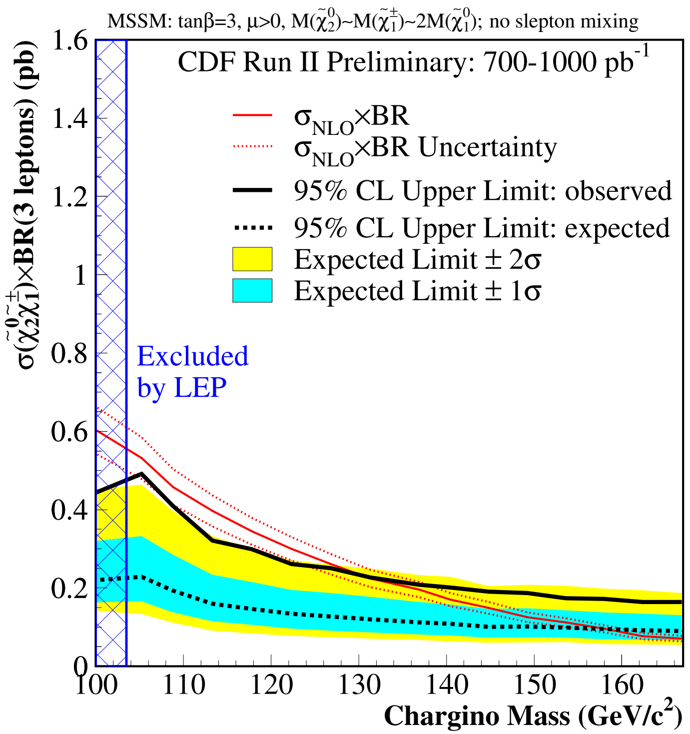




Result

- No evidence for Charginos and Neutralinos found
  - Set limits on the production cross section times branching ratio
  - Translate these limits in mass limits

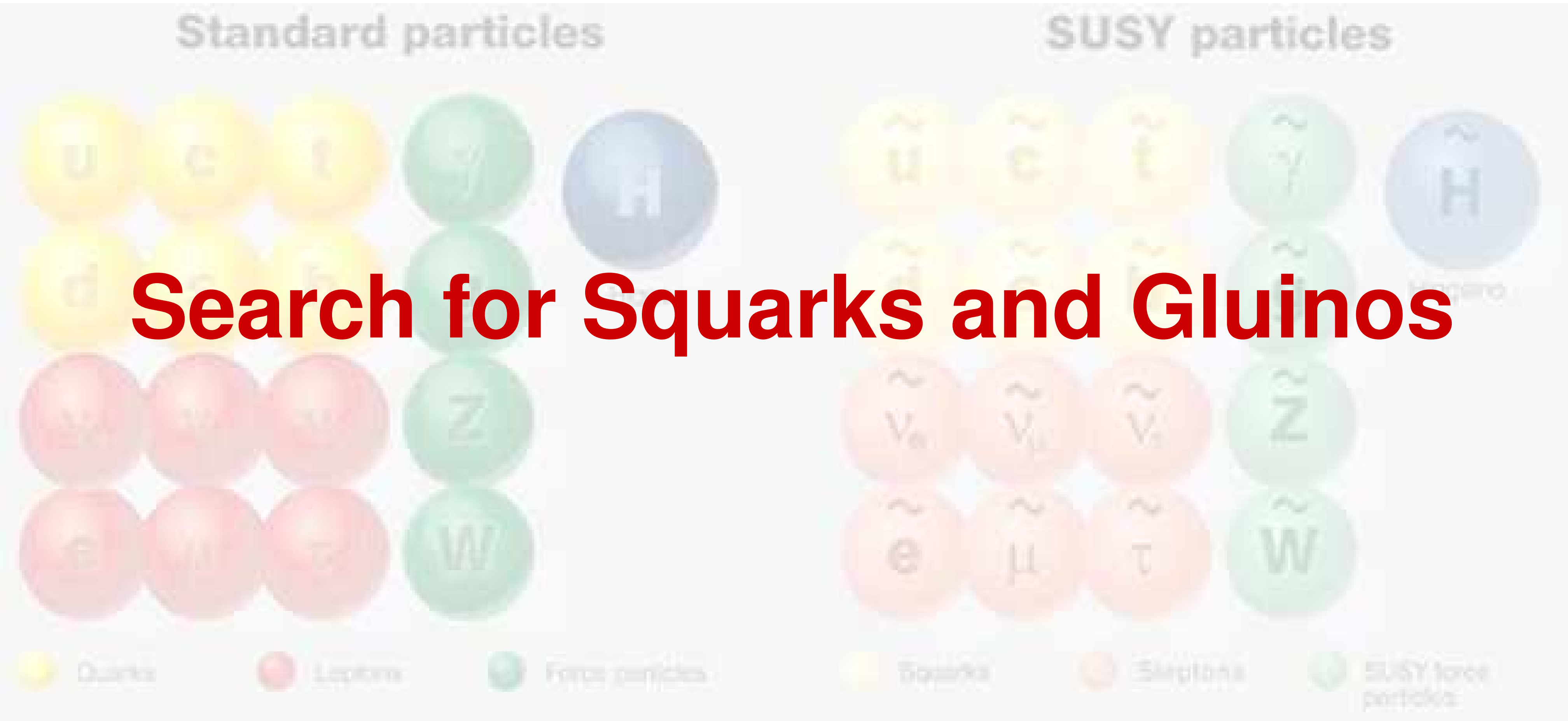




- Cross section limit: $\sigma \times$BR$\sim$0.06 pb
- 3ℓ–max scenario ($m_{\tilde{\ell}_R} \gtrsim m_{\tilde{\chi}_1^\pm}$)
  - $m_{\tilde{\chi}_1^\pm} > 145$ GeV

- Cross section limit: $\sigma \times$BR$\sim$0.2 pb
- mSUGRA model without $\tilde{\ell}$–mixing
  - $m_{\tilde{\chi}_1^\pm} > 130$ GeV

Search for Squarks and Gluinos

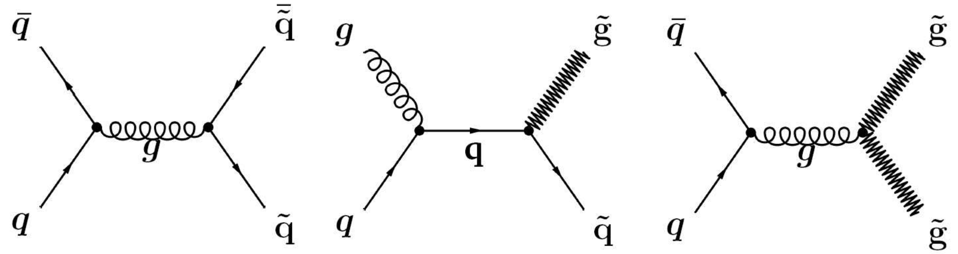


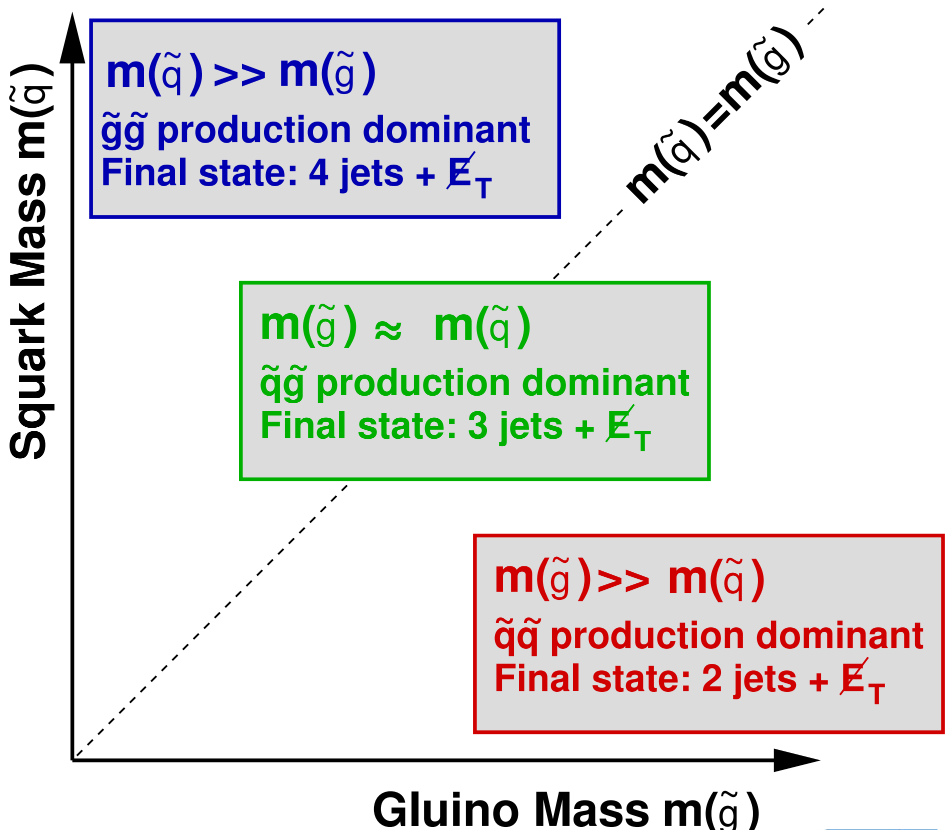
Search for Squarks and Gluinos

- Squarks and Gluinos can be produced via strong interaction
  - ▲ Production depends on the masses of the Squarks and Gluinos
    - ▶ Either $\tilde{g}\tilde{g}$, $\tilde{q}\tilde{g}$ or $\tilde{q}\tilde{q}$
  - ▲ Decays of Squarks and Gluinos
    - ▶ Squarks: $\tilde{q} \rightarrow q\tilde{\chi}^0$
    - ▶ Gluinos: $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}^0$

⇒ Three different analysis scenarios

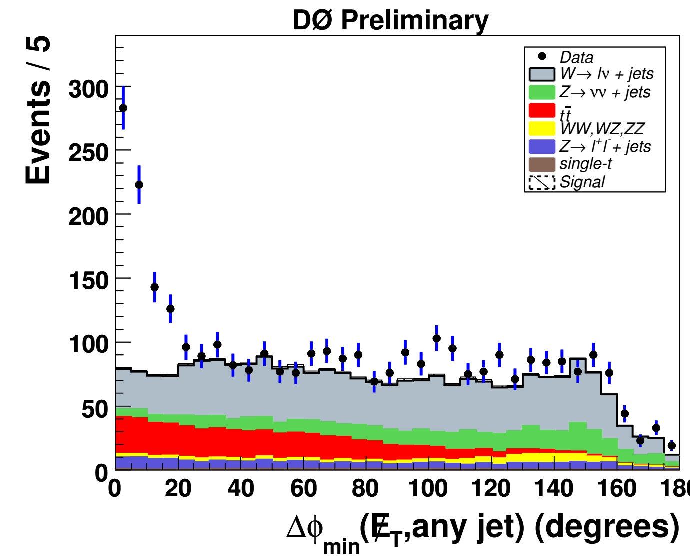
1 $\tilde{q}\tilde{q}$: 2 jets + $\not{E}_T$ (Dijet analysis)
2 $\tilde{q}\tilde{g}$,$\tilde{q}\tilde{q}$: 3 jets + $\not{E}_T$ (3–jet analysis)
3 $\tilde{g}\tilde{g}$: 4 jets + $\not{E}_T$ (Gluino analysis)

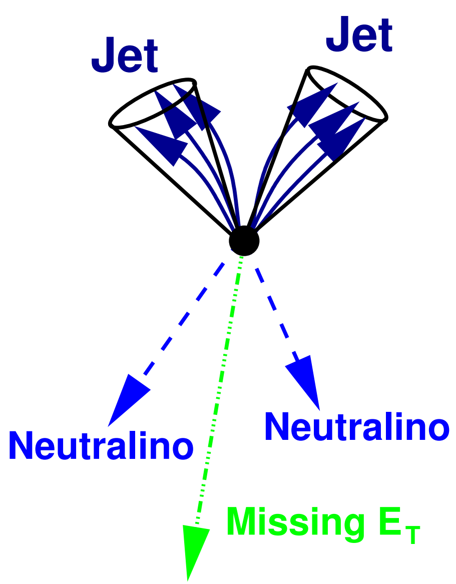




Squark and Gluino Selection

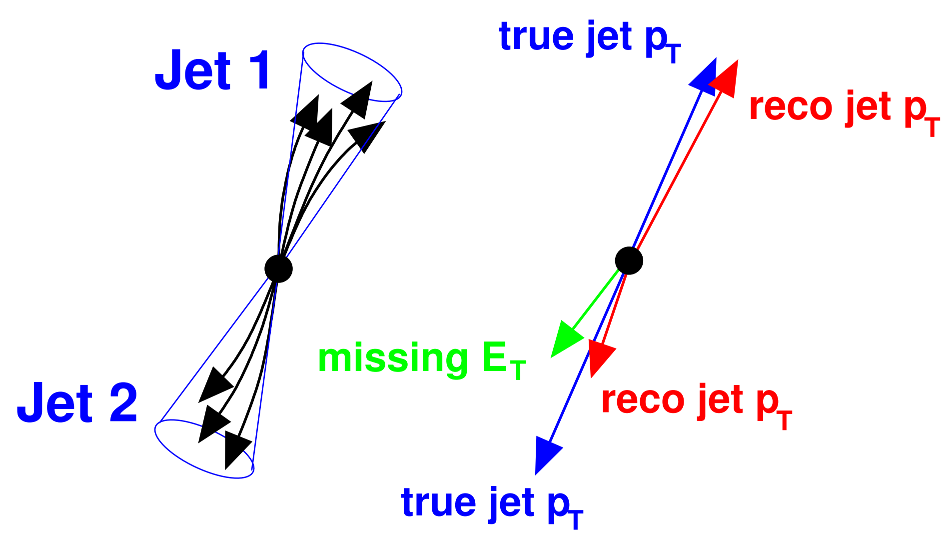
- Common selection for all three analyses
  - 2 acoplanar jets and large $\not{E}_T$
    - 1 or 2 additional jets (3–jet, Gluino analysis)
  - Reject events with electrons or muons
    - Suppress W and Z events
  - Veto on events where $\not{E}_T$ is aligned with jets
    - Reject events with mismeasured jets





⇐ Signal configuration

QCD background ⇒



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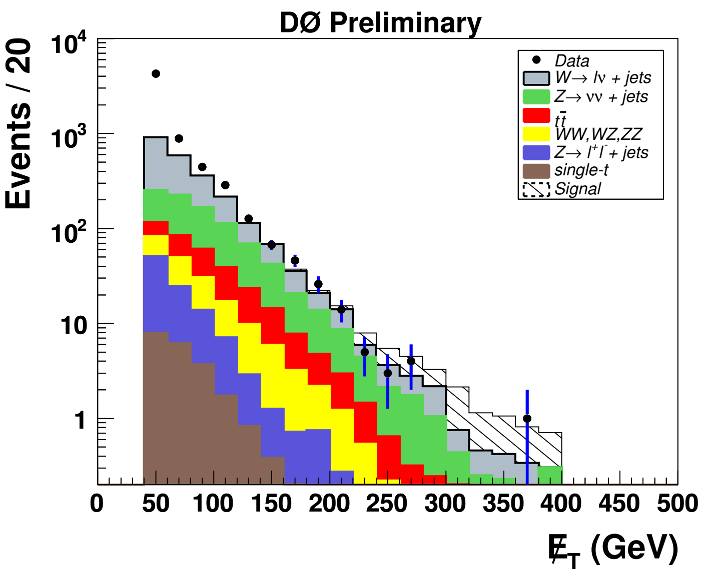
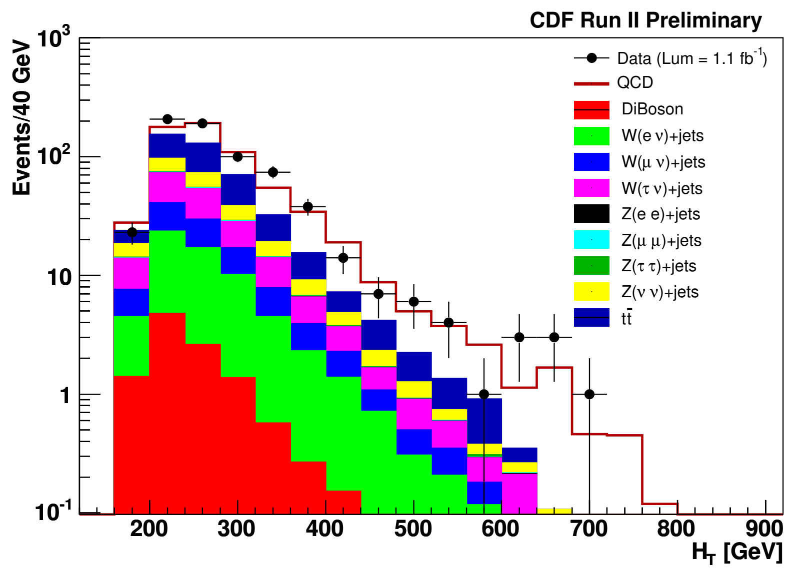
  - 2 acoplanar jets and large $\not\!\!E_T$
    - 1 or 2 additional jets (3–jet, Gluino analysis)
  - Reject events with electrons or muons
    - Suppress W and Z events
  - Veto on events where $\not\!\!E_T$ is aligned with jets
    - Reject events with mismeasured jets
- At the end cuts on $\not\!\!E_T$ and H_T are optimized for every selection



⇐ $\not\!\!E_T$ distribution

H_T distribution ⇒

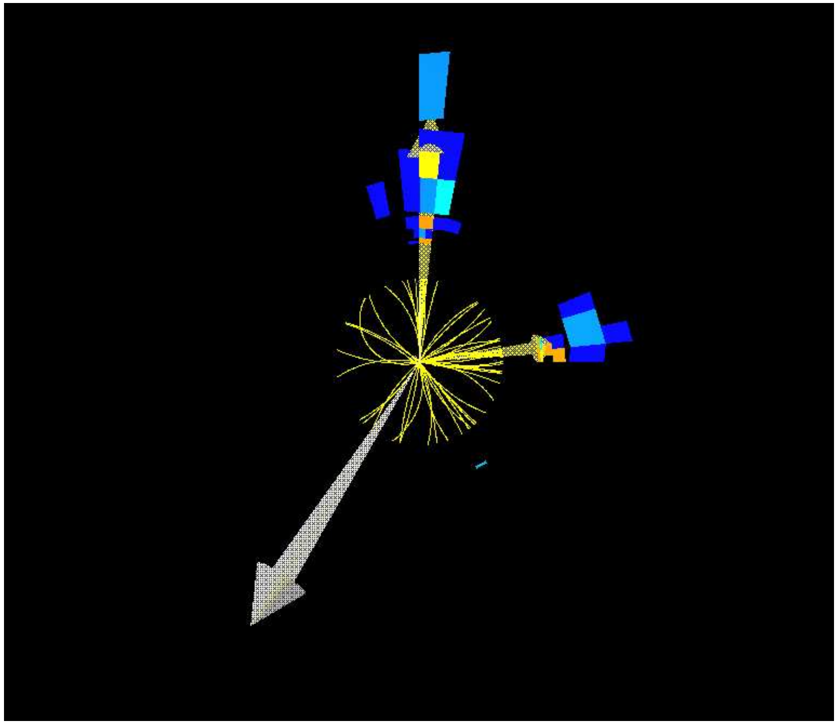


Event Displays

Highest $\not{E}_T$ events

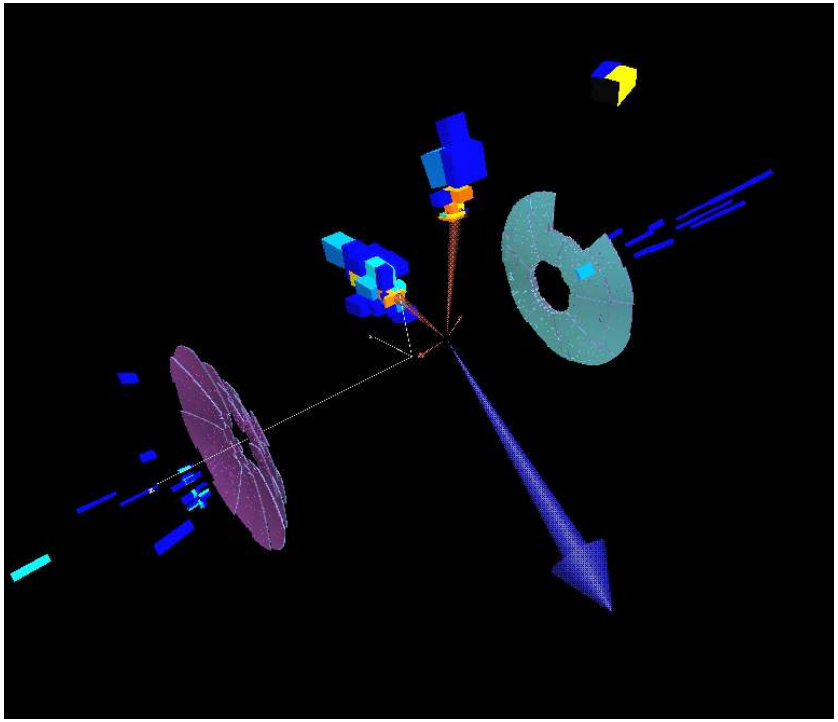
Dijet analysis

- $\not{E}_T$ = 368 GeV
- H_T = 489 GeV
- $p_T^{jet_1}$ = 282 GeV, $p_T^{jet_2}$ = 174 GeV
  $p_T^{jet_3}$ = 33 GeV



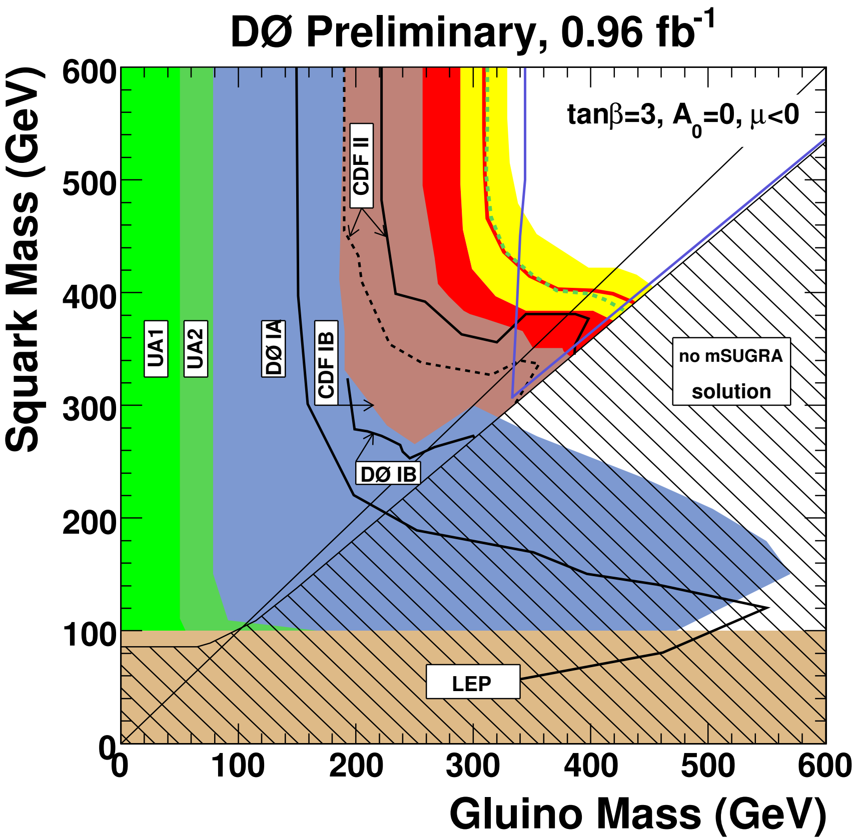
Gluino analysis

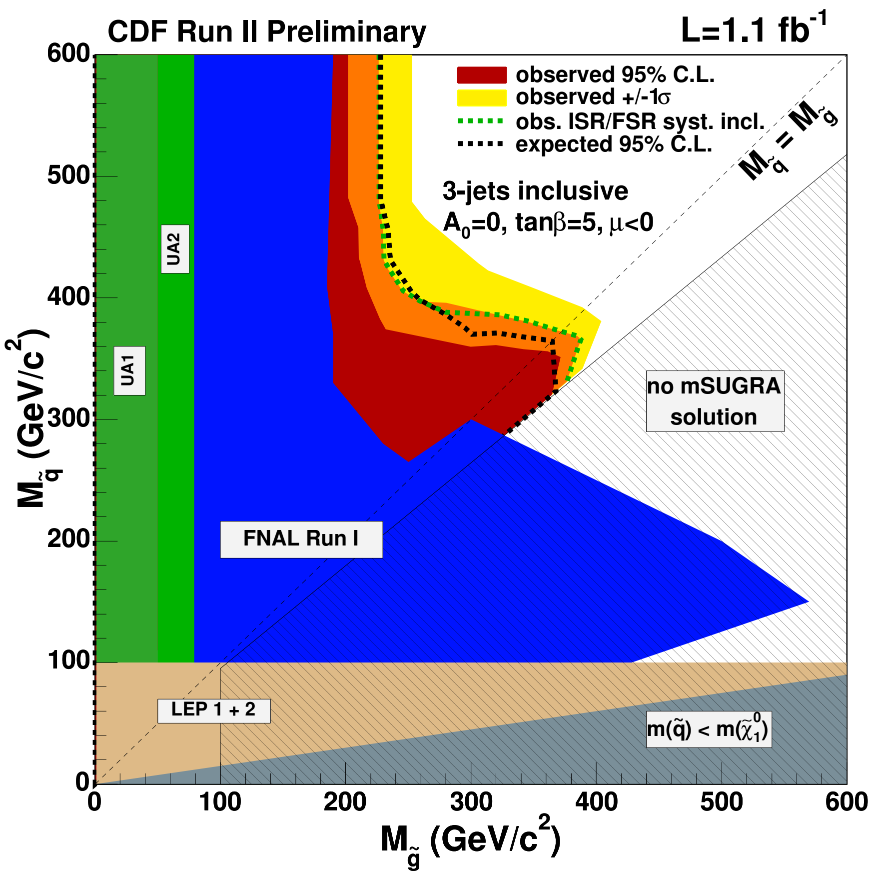
- $\not{E}_T$ = 321 GeV
- H_T = 464 GeV
- $p_T^{jet_1}$ = 254 GeV, $p_T^{jet_2}$ = 77 GeV,
  $p_T^{jet_3}$ = 67 GeV, $p_T^{jet_4}$ = 66 GeV



Results

- The analyses are optimized for three benchmark scenarios
  - Vary m_0 and $m_{1/2}$, other parameters constant: $A_0 = 0$, $\mu < 0$ and $\tan\beta = 3/5$



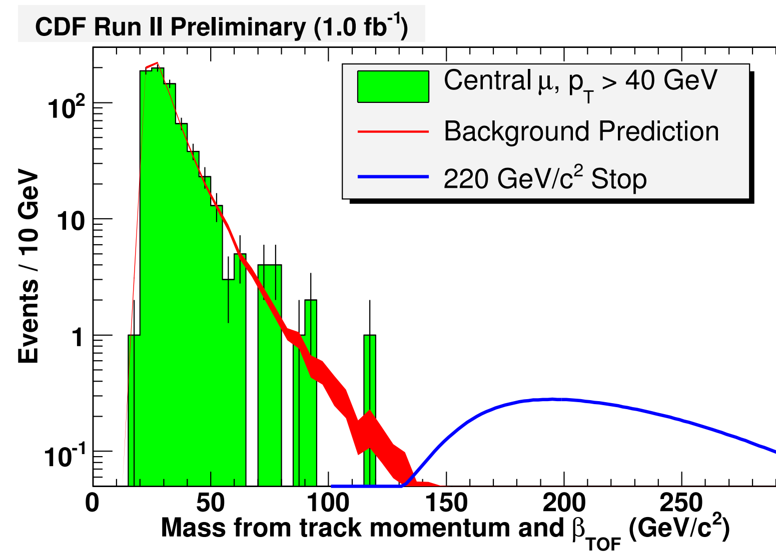


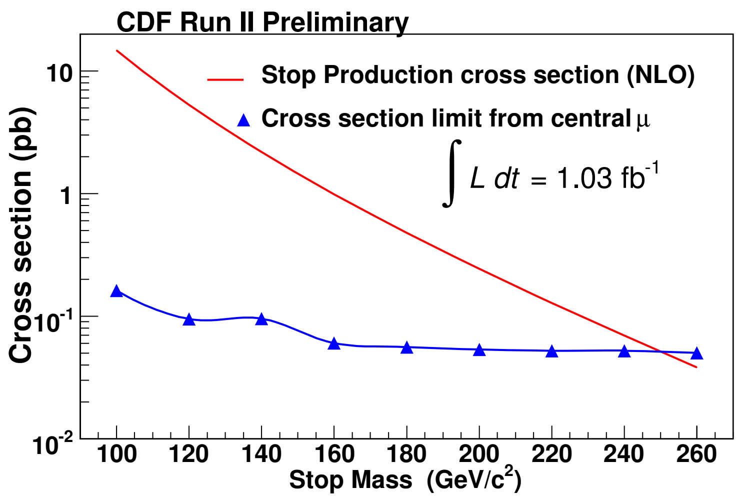
- Mass limits
  - Squarks: 391 (375) GeV   Gluinos: 309 (289) GeV

Search for long lived particles

Search for CHAMPS

- Search for long lived Charged Massive Particles
  - Particles do not decay inside the detector
  - Highly ionizing and penetrating
- Signature in the detector: "slow muon"
  - Particle penetrates cal and muon system
  - Use time–of–flight system to measure β
- Signal expected at high mass
  - Background sits at low mass

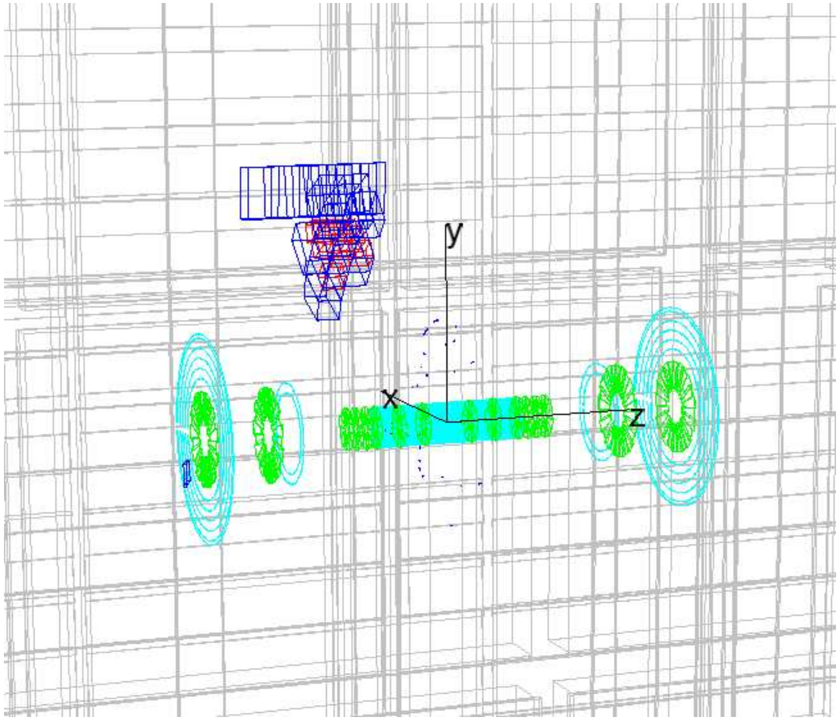




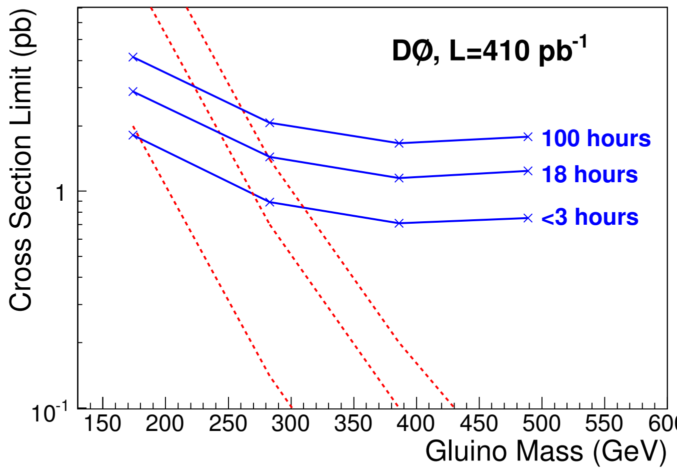
- Main background components
  - Cosmic muons and instrumental background
- Interpreted in SUSY models with one compactified extra dimension
  - In these models Stop is the LSP
- Mass limit: $m_{\tilde{t}} > 250$ GeV

Search for Long lived Gluinos

- Long lived Gluinos are predicted in several models
  - For example split SUSY
- Gluinos can stop inside the detector
  - Can decay at random times ⇒ Not related to any beam crossing
  - Decay can also occur if no beam is in the machine

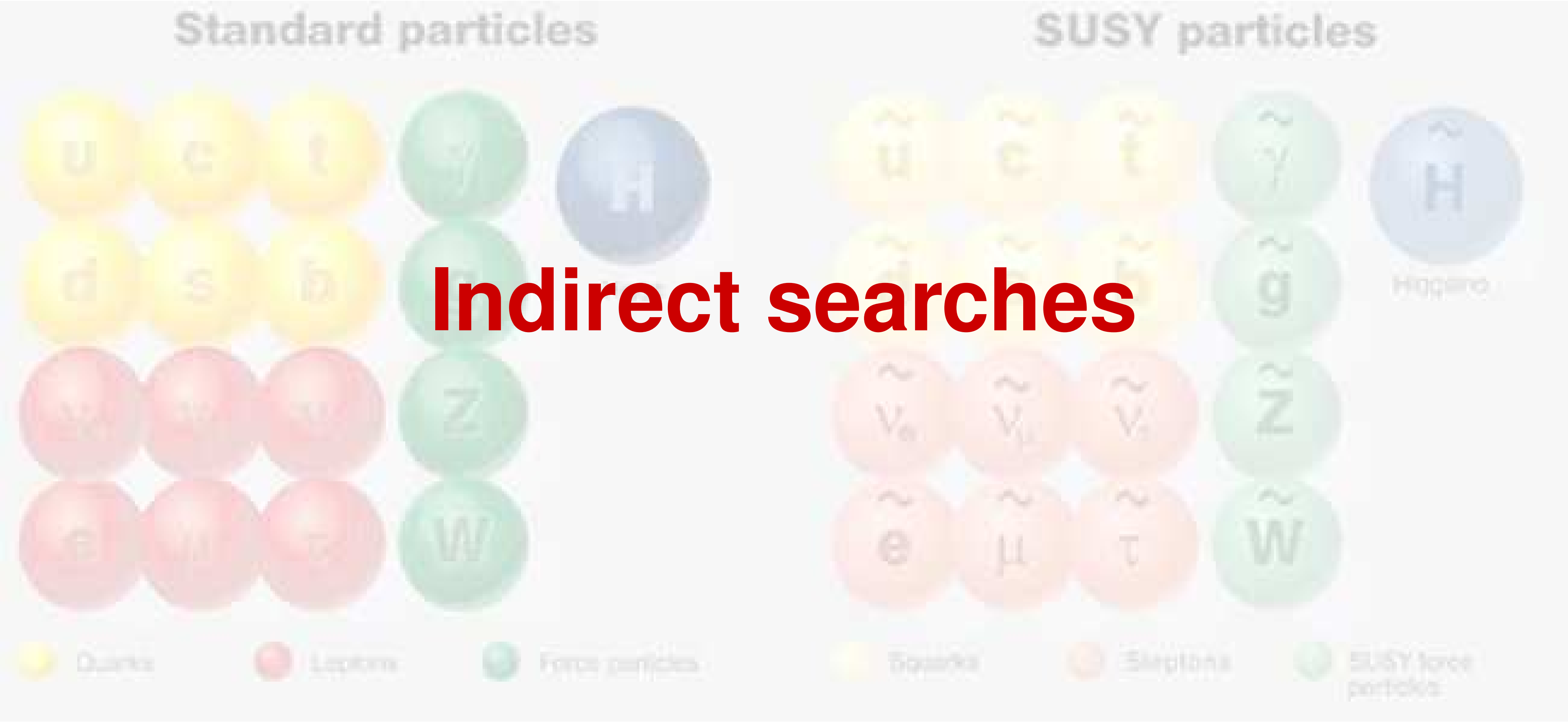


- Very hard to model trigger for these events
- Need a good model for the alive time of the detector



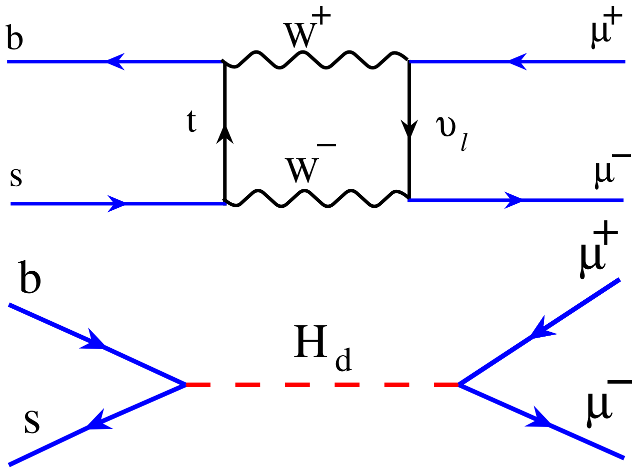
- No evidence for stopped Gluinos

Indirect searches

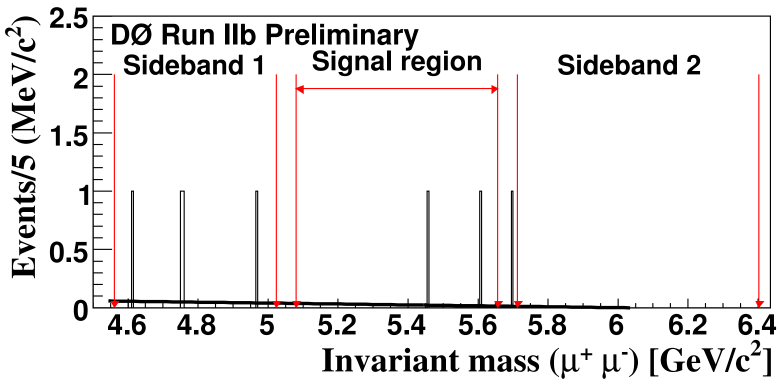


Search for $B_s \to \mu\mu$

- New physics can also be observed indirectly
- The decay $B_s \to \mu\mu$ is a very good candidate
  - Decay is a flavor changing neutral current
    - In the SM it is forbidden at tree level
      $\Rightarrow$ Small branching fraction:
      $BR(B_s \to \mu\mu) = (3.4 \pm 0.4) \cdot 10^{-9}$
  - Enhancement in SUSY models: $\sim (\tan\beta)^6$



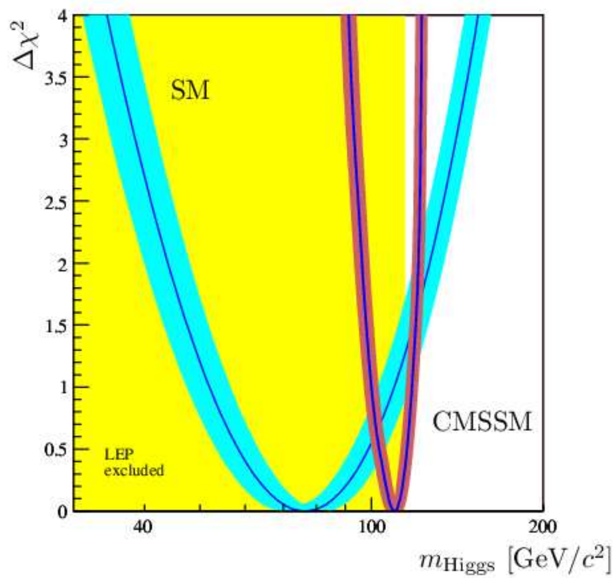
- Blind analysis $\Rightarrow$ Predict events in signal region from sidebands
  - Good agreement between number of events predicted and observed
  - No observation $\Rightarrow$ Upper limits on the branching fraction



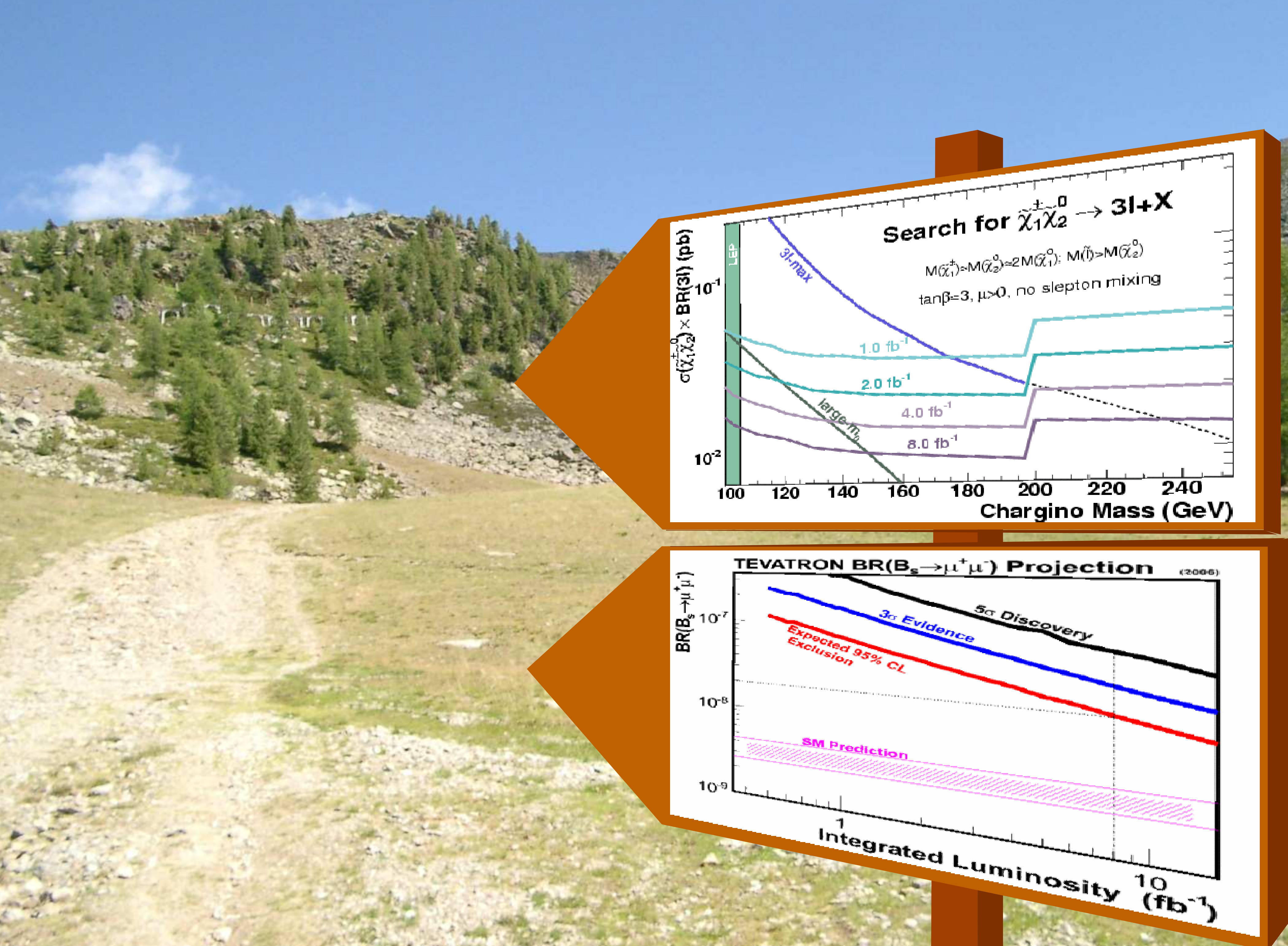
- Current limits
  - DØ ($2\ \mathrm{fb}^{-1}$): $BR(B_s \to \mu\mu) < 9.3 \cdot 10^{-8}$
  - CDF ($0.78\ \mathrm{fb}^{-1}$): $BR(B_s \to \mu\mu) < 1.0 \cdot 10^{-7}$

Conclusion

- Summary
  - Tevatron, CDF and DØ are performing well
    - Already collected more than 2.7 fb^{-1} of data
    - Nearly factor three more than the data used in the results presented here
  - SUSY searches probing new regions in phase space
    - New mass limits beyond LEP2 limits
- Tevatron will further probe Supersymmetry in so far uncovered territory



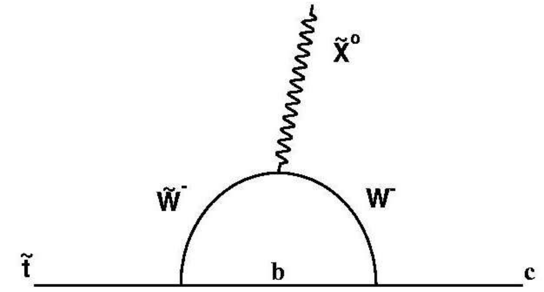
O. Buchmueller et al., arXiv:0707.3447v1

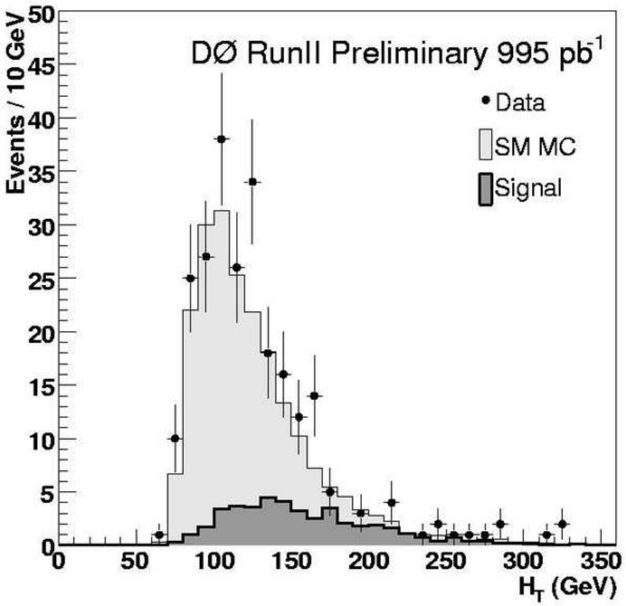

Search for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to 3l+X$
$M(\tilde{\chi}_1^{\pm}) \approx M(\tilde{\chi}_2^0) \approx 2M(\tilde{\chi}_1^0)$; $M(\tilde{l}) > M(\tilde{\chi}_2^0)$
$\tan\beta=3$, $\mu>0$, no slepton mixing
LEP
3l-max
large-m_0
1.0 fb^{-1}
2.0 fb^{-1}
4.0 fb^{-1}
8.0 fb^{-1}
$\sigma(\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0) \times BR(3l)$ (pb)
10^{-1}
10^{-2}
100 120 140 160 180 200 220 240
Chargino Mass (GeV)
TEVATRON $BR(B_s \to \mu^+\mu^-)$ Projection
(2006)
$BR(B_s \to \mu^+\mu^-)$
10^{-7}
10^{-8}
10^{-9}
5σ Discovery
3σ Evidence
Expected 95% CL Exclusion
SM Prediction
1
10
Integrated Luminosity (fb^{-1})

BACKUP SLIDES

Search for Stop Quarks

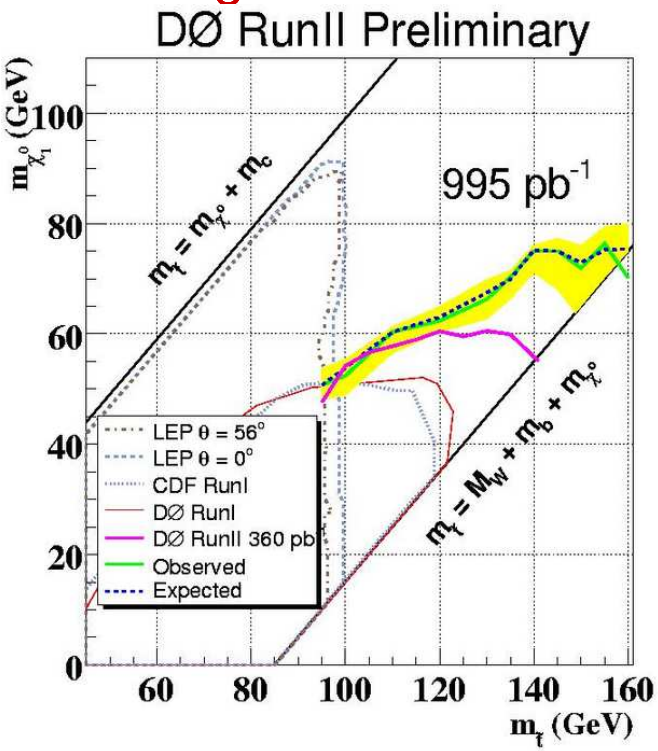
- Due to mixing in third generation, Stop can be light
  - ▲ Can be pair produced at the Tevatron
- If Stop is light enough it can only decay into cχ_1^0
  - ▲ The decays tχ_1^0 and b$\chi_1^\pm$ are forbidden
- Major background contributions are
  - ▲ W+jets, Z+jets and multijet production
- Selection strategy
  - ▲ Select events with acoplanar dijets
  - ▲ Reject events with isolated electrons, muons or tracks
  - ▲ Require large $\not{E}_T$ and $\not{H}_T$
  - ▲ Apply heavy flavor tagging to reduce light jet contributions from background
- Optimize selection for different mass points





Search for Stop Quarks (2)

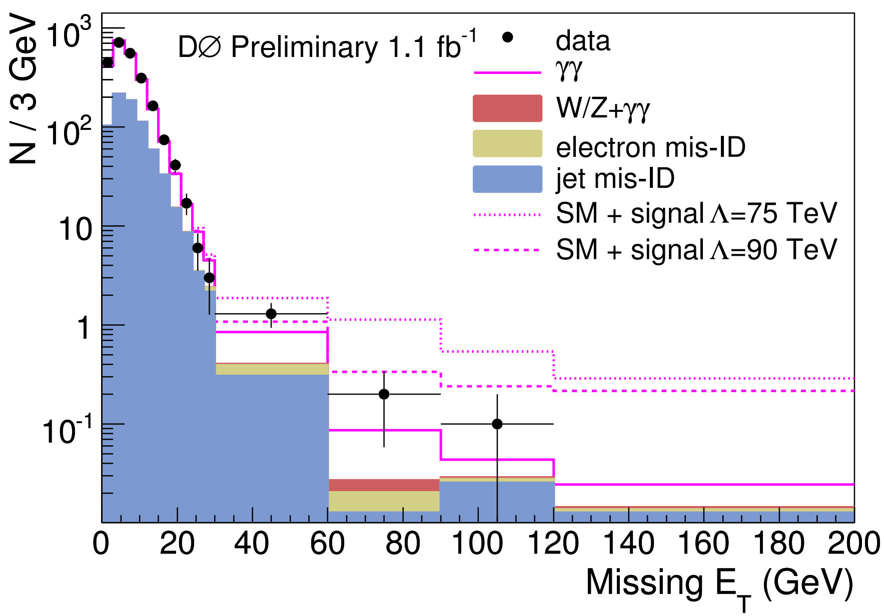
- Main background after final selection
  - ▲ W($\rightarrow \ell\nu$) = jets and Z($\rightarrow \nu\nu$) + jets
  - ▲ Background varies between 57 and 82 events depending on Stop mass
- Signal efficiencies
  - ▲ Range from 0.1% to 5% depending on Stop and Neutralinos mass
- Data is in agreement with the SM expectation



- Mass limits
  - ▲ Stop: $m_{\tilde{t}} >$ 160 GeV
  - ▲ Neutralino: $m_{\chi_1^0} >$ 75 GeV

Search for GMSB

- In Gauge Mediated SUSY Breaking (GMSB) models the Gravitino $\tilde{G}$ is the LSP
  - If the Chargino $\tilde{\chi}_1^0$ is the NLSP it decays to Gravitinos: $\tilde{\chi}_1^0 \to \gamma\tilde{G}$
  - Final state consists of two photons and $\not{E}_T$ due to escaping Gravitinos
- Search for inclusive $\gamma\gamma$+$\not{E}_T$ events with 1.1 fb^{-1} of data

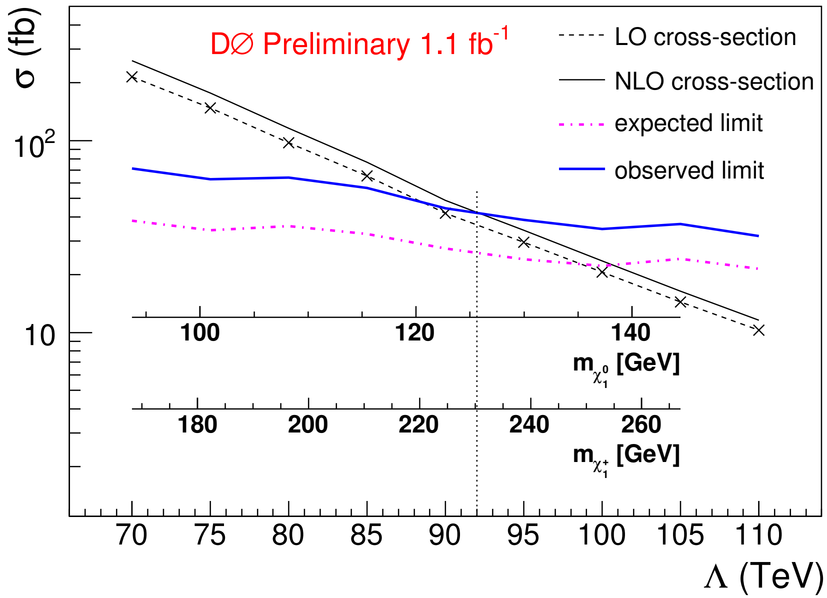


- Major background components
  - Events with true $\not{E}_T$
    - W+jets/γ, $t\bar{t}$
  - Events with instrumental $\not{E}_T$
    - Multijets and direct $\gamma\gamma$ production, $Z \to ee$
- Diphoton selection yields 2341 events

Search for GMSB (2)

- Search for the signal in the high $\not\!\!E_T$ region (for different energy scales Λ)

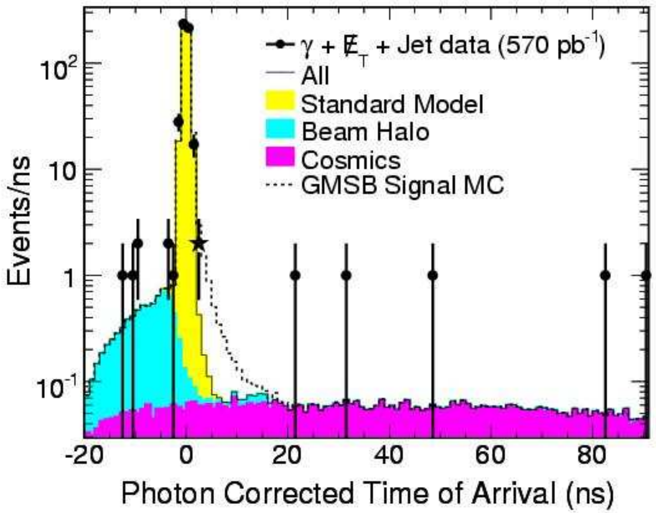
$\not\!\!E_T$ (GeV)	Background true $\not\!\!E_T$	fake $\not\!\!E_T$	Total	Data	Signal Λ = 75 TeV	Λ = 90 TeV
> 30	1.16 ± 0.14	9.62 ± 1.12	10.8 ± 1.1	16	28.3 ± 1.0	8.7 ± 0.3
> 60	0.19 ± 0.07	1.44 ± 0.43	1.6 ± 0.4	3	18.1 ± 0.8	6.4 ± 0.3

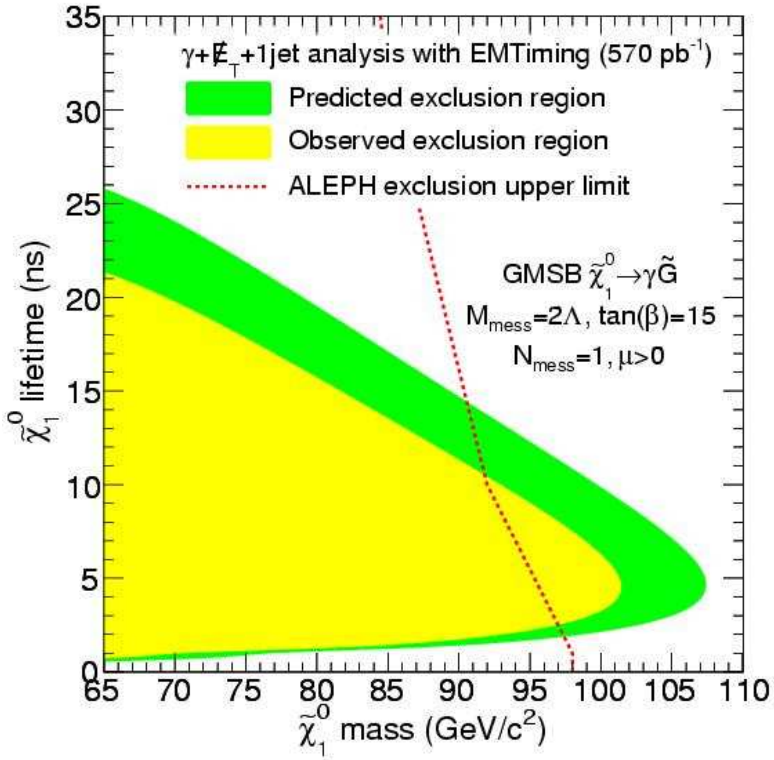


- No evidence for a signal
- Energy scale and mass limits
  - $\Lambda > 92$ TeV
  - $m_{\tilde{\chi}_1^\pm} > 231$ GeV, $m_{\tilde{\chi}_1^0} > 126$ GeV

Search for GMSB (3)

- Search for long lived Neutralinos
  - In GMSB models pair production of Gauginos is dominant
  - Gauginos decay into the lightest Neutralino
    - Final states consists of a delayed photon, jets and $\not{E}_T$
- Main selection criteria
  - Select events with time delayed photon
  - Require large $\not{E}_T$

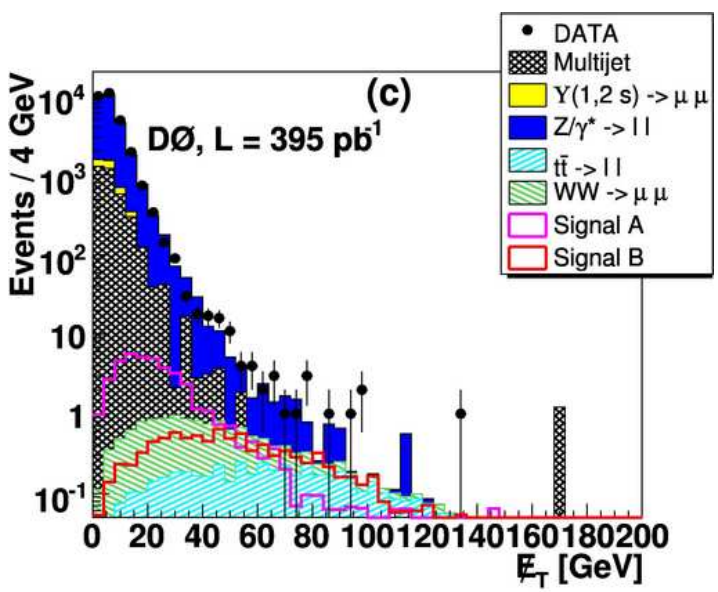


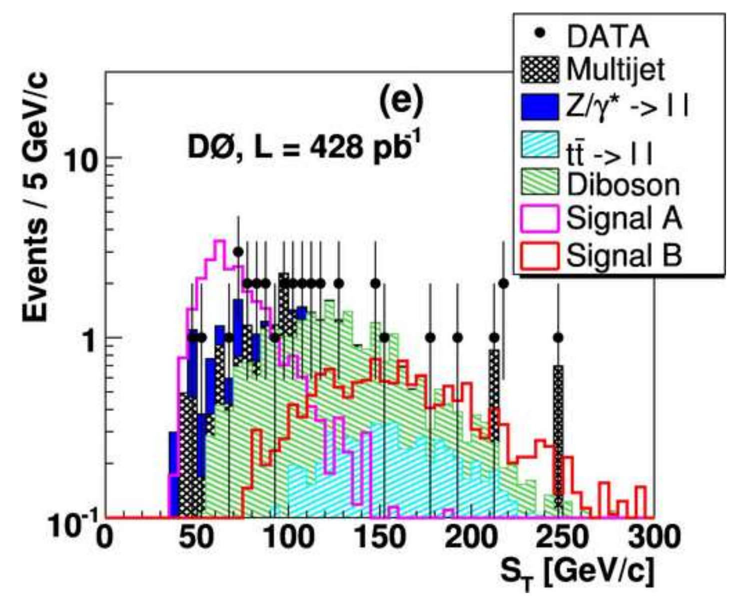


- Mass limit (depending on lifetime)
  - $m_{\tilde{\chi}_1^0} > 101$ GeV for τ = 5 ns

Search for Stops in the Dilepton Channel

- Search for scalar top quarks in final states with two leptons and two b–quarks
  - ▲ $\tilde{t}$ decays dominantly into $b\ell\tilde{\nu}$ if $\tilde{t} \rightarrow b\chi_1^{\pm}$ and $\tilde{t} \rightarrow b\chi_1^0$ are forbidden
- Main selection criteria
  - ▲ Two isolated leptons
  - ▲ At least two jets, highest $\mathrm{p_T}$ jet must be tagged as b–jet (only $\mu\mu$ channel)
  - ▲ Significant $\not{E}_{\mathrm{T}}$
  - ▲ Other kinematic variables: invariant mass, scalar sum of all $\mathrm{p_T}$

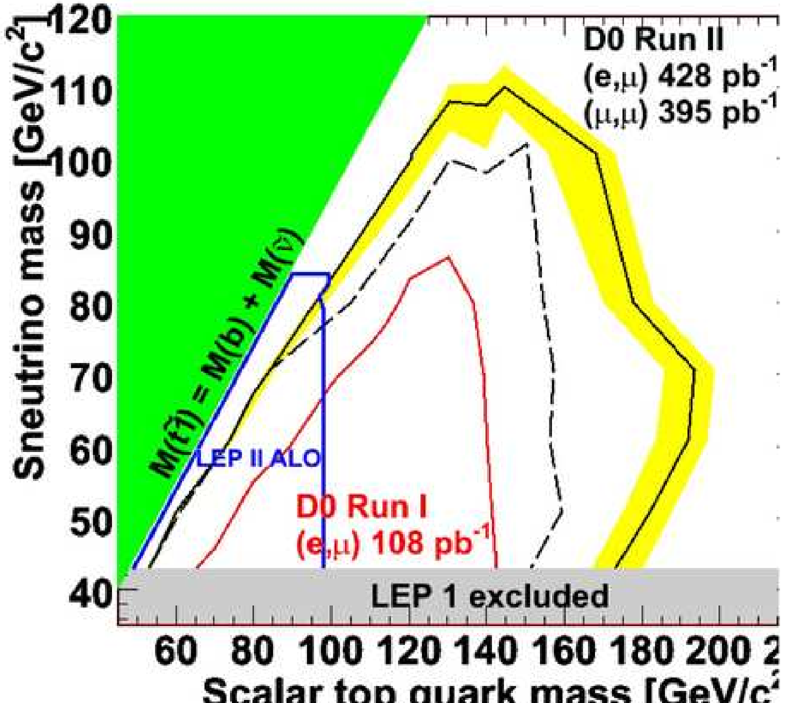




Search for Stops in the Dilepton Channel (2)

	Background			Data	Signal	
	$t\bar{t}$	Diboson	Total		Point A	Point B
ee	7.4	20.2	31.7 ± 2.7	34	26.0 ± 1.5	17.3 ± 0.6
$e\mu$	2.3	0	2.9 ± 0.4	1	3.1 ± 0.2	3.3 ± 0.4

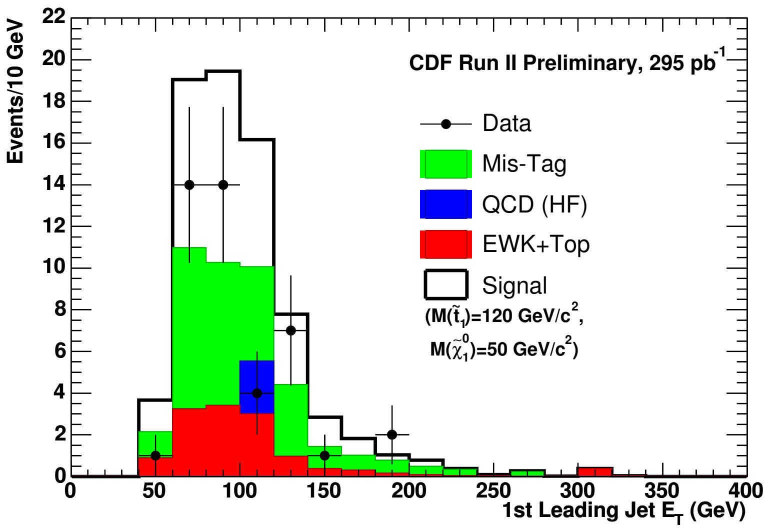
- Good agreement of data and SM prediction

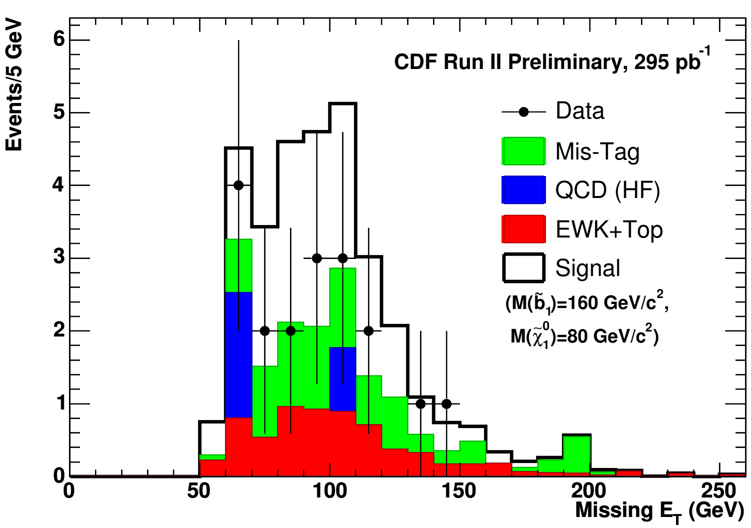


- Mass limits in $m_{\tilde{t}}$–$m_{\tilde{\nu}}$ plane
  - Largest $m_{\tilde{t}}$ limit: $m_{\tilde{t}} > 186$ GeV (for $m_{\tilde{\nu}}$ = 71 GeV)
  - Largest $m_{\tilde{\nu}}$ limit: $m_{\tilde{\nu}} > 107$ GeV (for $m_{\tilde{t}}$ = 145 GeV)

Search for Sbottom Quarks

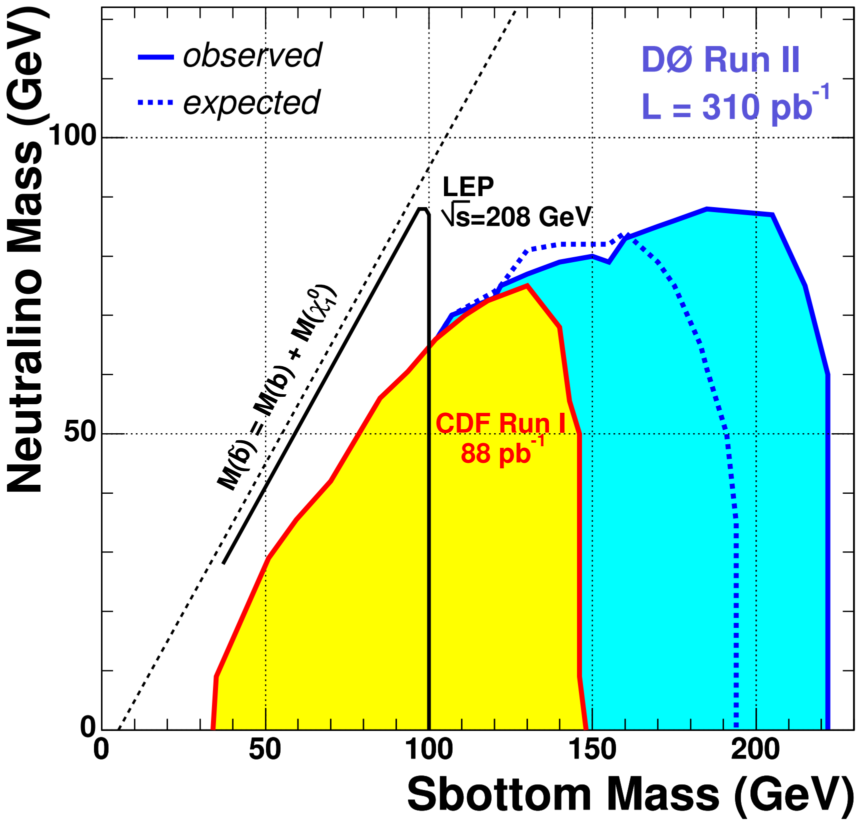
- For high $\tan\beta$ the $\tilde{b}$–mass eigenstates have large separation
  - Sbottom quarks might be light enough to be pair produced at the Tevatron
  - Assume 100% branching fraction of $\tilde{b}$ into $b\chi_1^0$
- Final state consists of two b–jets and $\not\!\!E_T$
- Event selection
  - At least two high p_T jets, one jet must be tagged as b–jet
  - Require significant $\not\!\!E_T$
  - Veto on isolated leptons

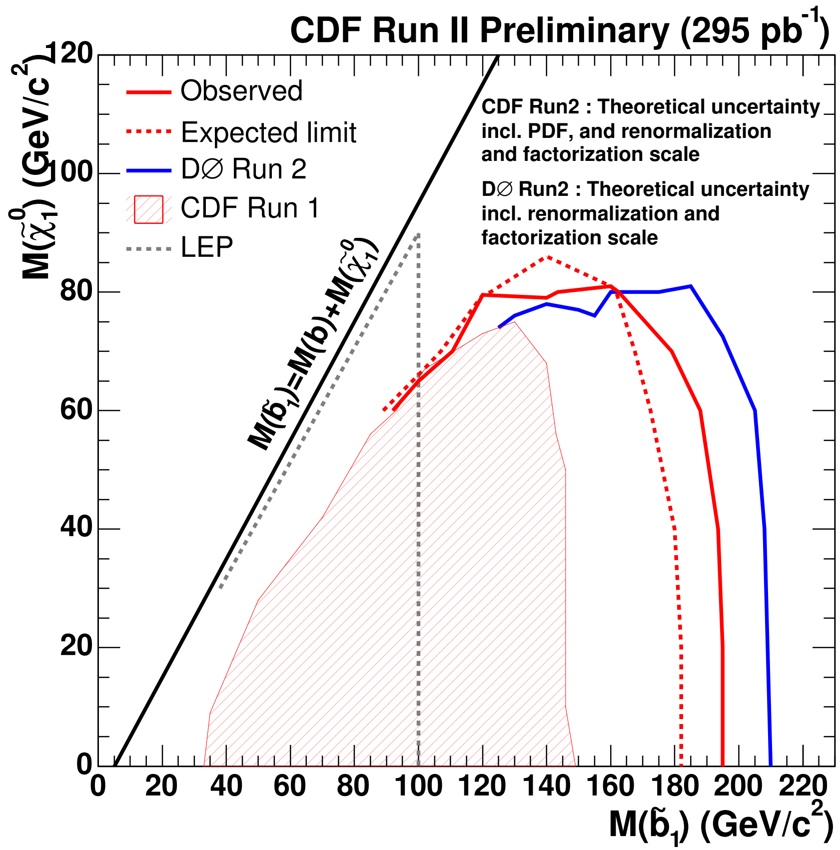




Search for Sbottom Quarks (2)

- Data is well described from SM prediction

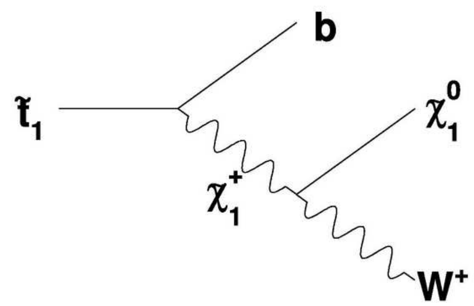




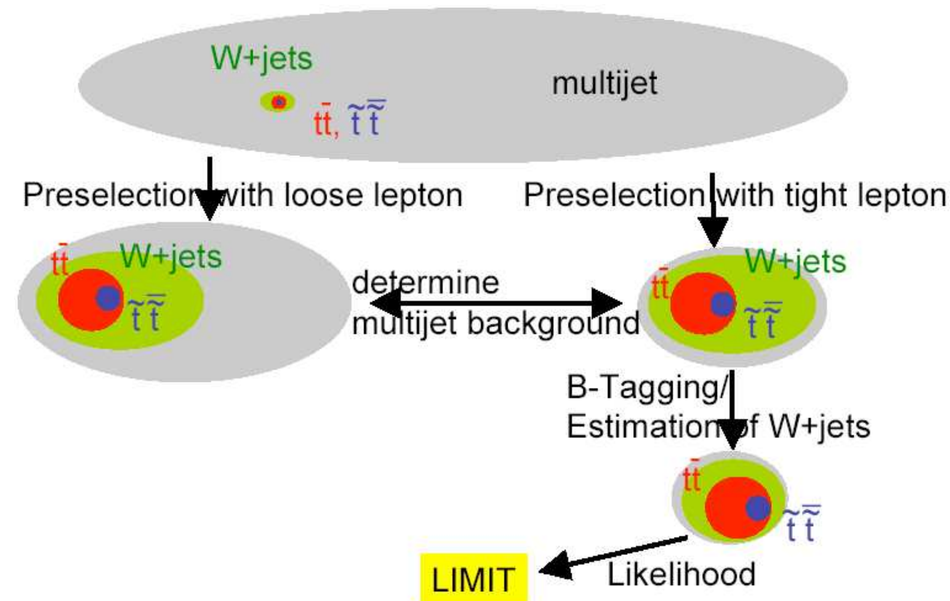
- Mass limits
  - DØ (310 pb^{-1}): $\mathrm{m}_{\tilde{b}} >$ 222 GeV
  - CDF (290 pb^{-1}): $\mathrm{m}_{\tilde{b}} >$ 195 GeV

Search for Stop Quarks

- Search for scalar top admixture in $t\bar{t}$ events in the lepton+jets channel
  - Stop quarks are pair produced
  - Decay channels
    - $\tilde{t}_1 \rightarrow b\chi_1^+ \rightarrow bW\chi_1^0$
    - $\tilde{t}_1 \rightarrow b\chi_1^+ \rightarrow c\chi_1^0$
  - $\sigma(\tilde{t}_1\tilde{t}_1) \approx 0.1 \times \sigma(t\bar{t})$ for masses of 175 GeV

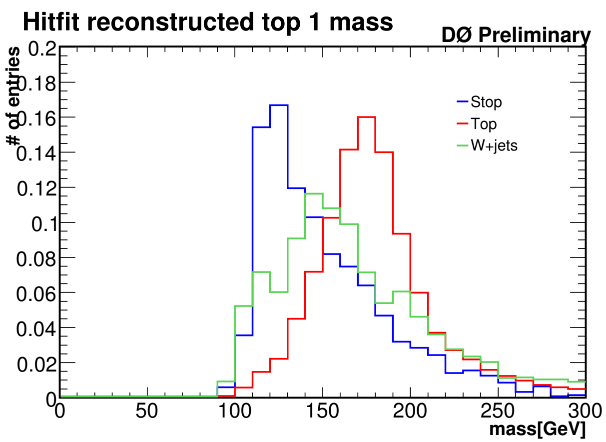


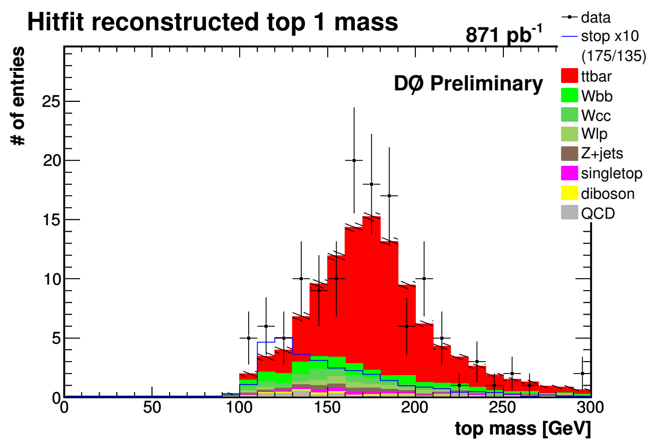
- Start from a selection that is similar to $t\bar{t}$ selection
  - Main backgrounds for $t\bar{t}$ measure–ments are W+jet and multijet events
  - $t\bar{t}$ events are of course the major (irreducible) background for stop search
    - Use Likelihood to discriminate top decays

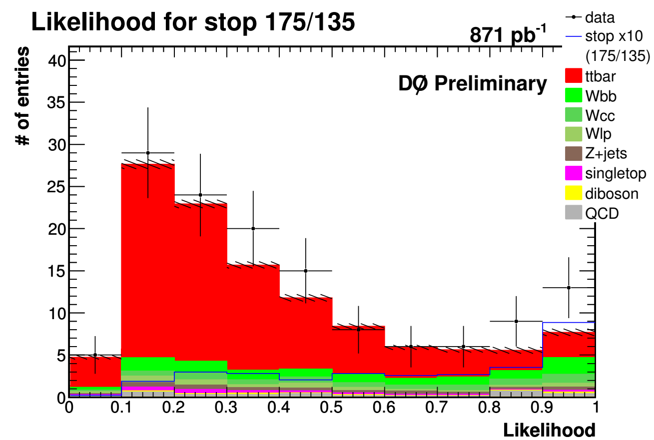


Search for Stop Quarks (2)

- Combine up to five variables in the Likelihood







- Events observed consistent with SM prediction
- No evidence for stop quark admixture
- Upper limits on stop quark production
  - $\sigma(\tilde{t}_1\tilde{t}_1) < 5.7$–$12.8$ pb (at 95% CL)
  - Factor 7–12 above the MSSM prediction