Searches for Higgs bosons and New Physics at the Tevatron

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DESY Seminar, March 18/19, 2008

- Indirect constraints from precision measurements
- The SM Higgs boson
- MSSM Higgs bosons
- Supersymmetry: Squarks, Gluinos, Charginos
- Heavy Resonances

Full set of Tevatron results available at:

http://www-d0.fnal.gov/Run2Physics/WWW/results.htm

http://www-cdf.fnal.gov/physics/physics.html

The Tevatron Collider

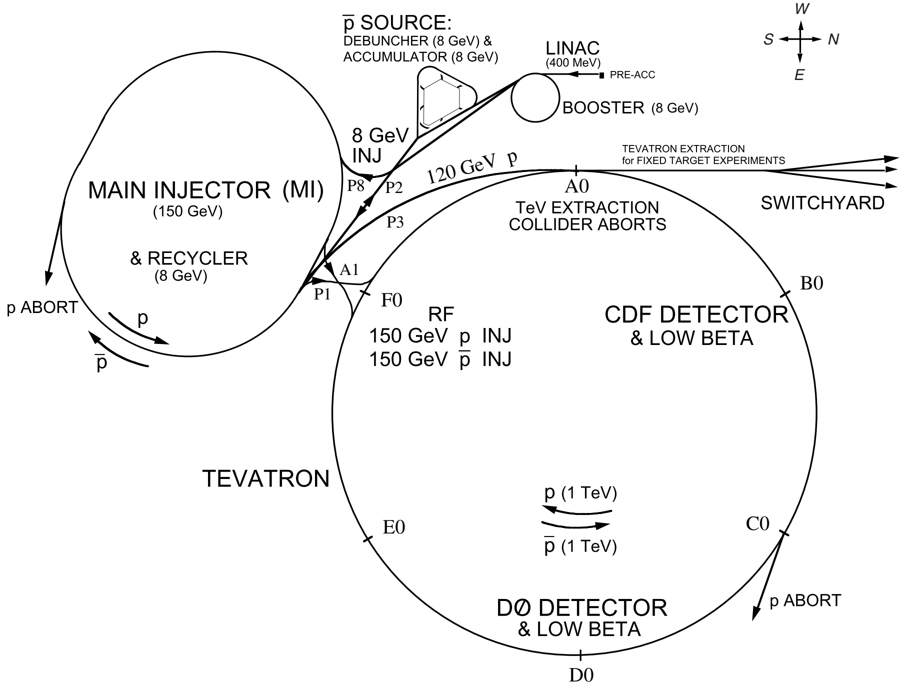
Proton Antiproton Collider

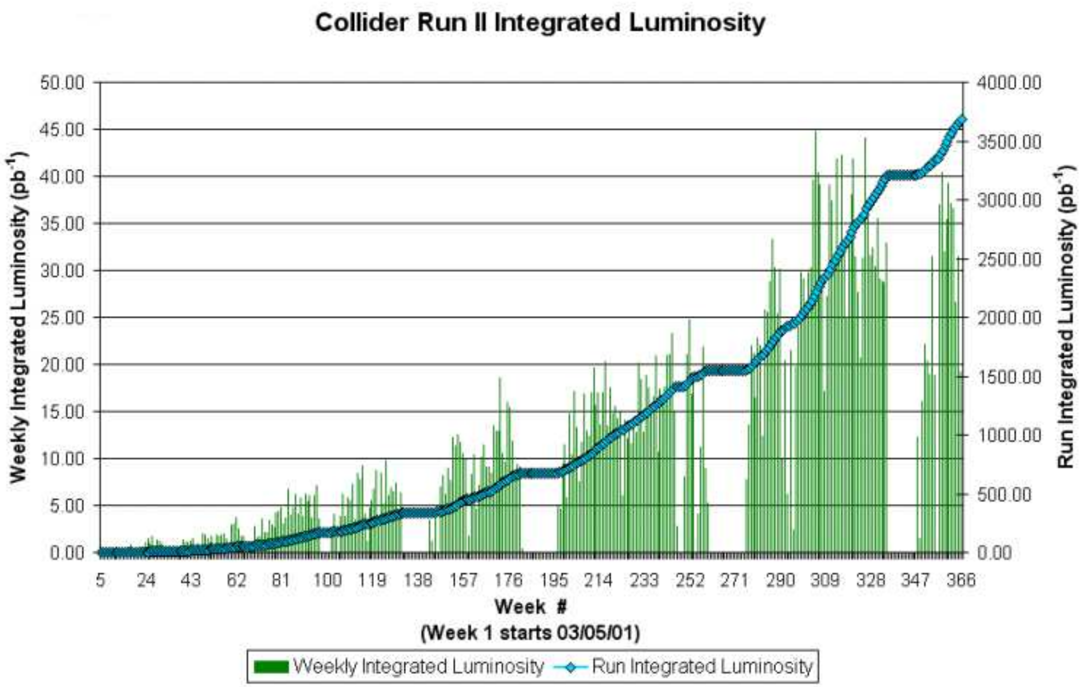
Centre-of-mass energy: 1.96 TeV

Integrated Luminosity: 3.8 fb^{-1} so far

Peak luminosity: 2.8×10^{32} $\text{cm}^{-2}\text{s}^{-1}$

Expecting to accumulate 6-9 fb^{-1} by 2009/10





Electron Cooling in operation

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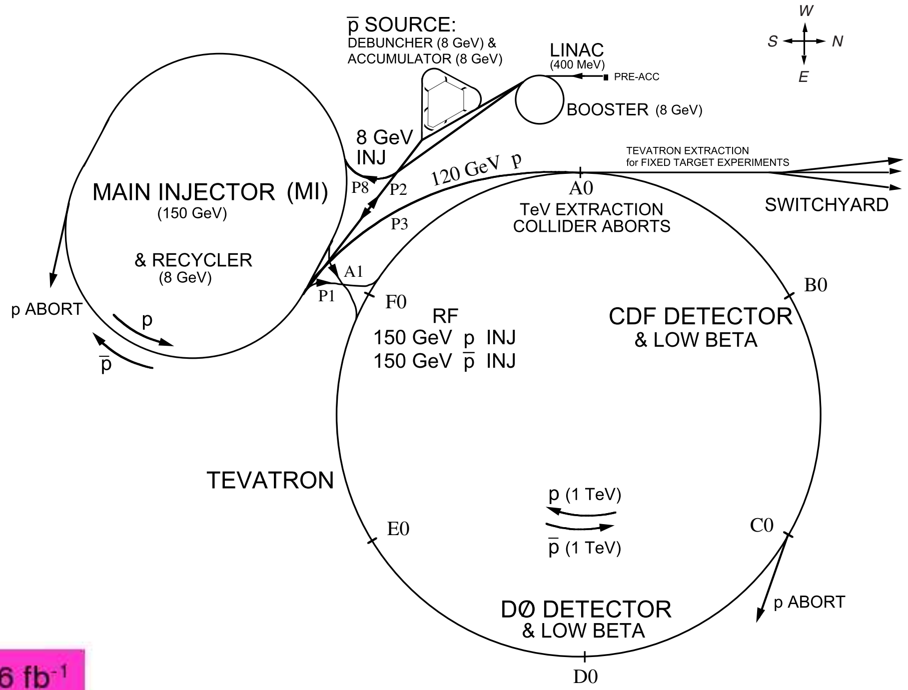
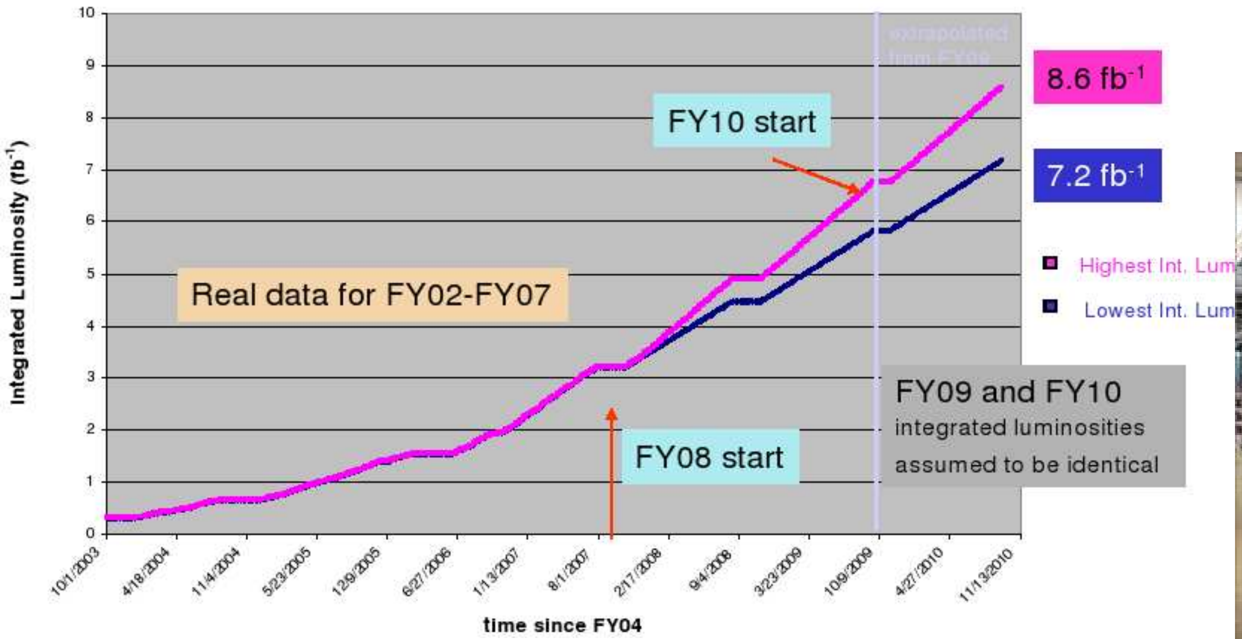




Electron Cooling in operation

Physics at Hadron Colliders

Tevatron: Proton-Antiproton Collider at $\sqrt{s} = 1.96$ TeV, collisions every 396 ns

- **Advantage: High centre-of-mass energy**

  $\longrightarrow$ production of massive particles (LEP: m $\lesssim$ 100 GeV)

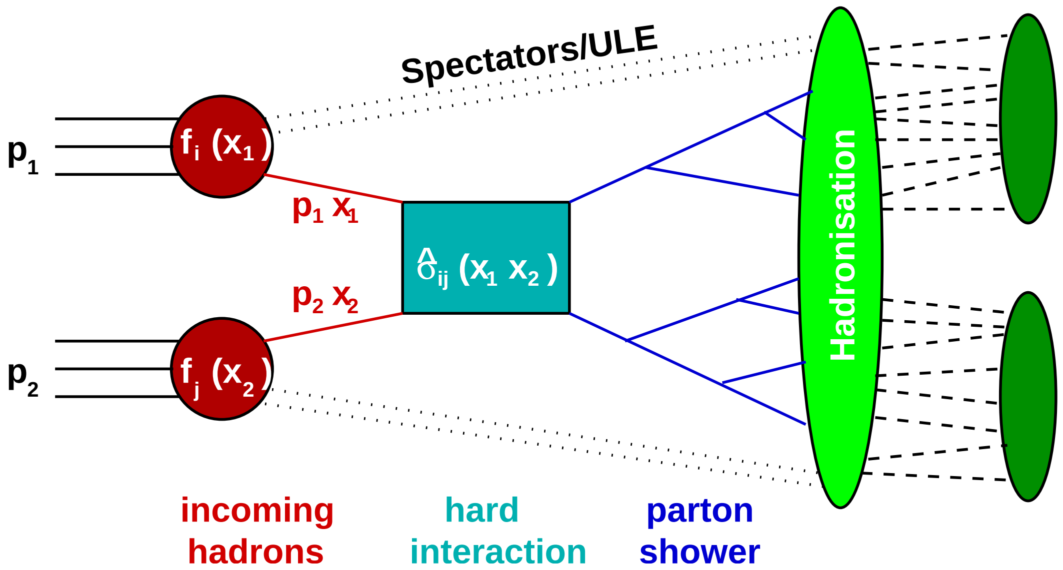
- **Disadvantage: Strong Interaction**

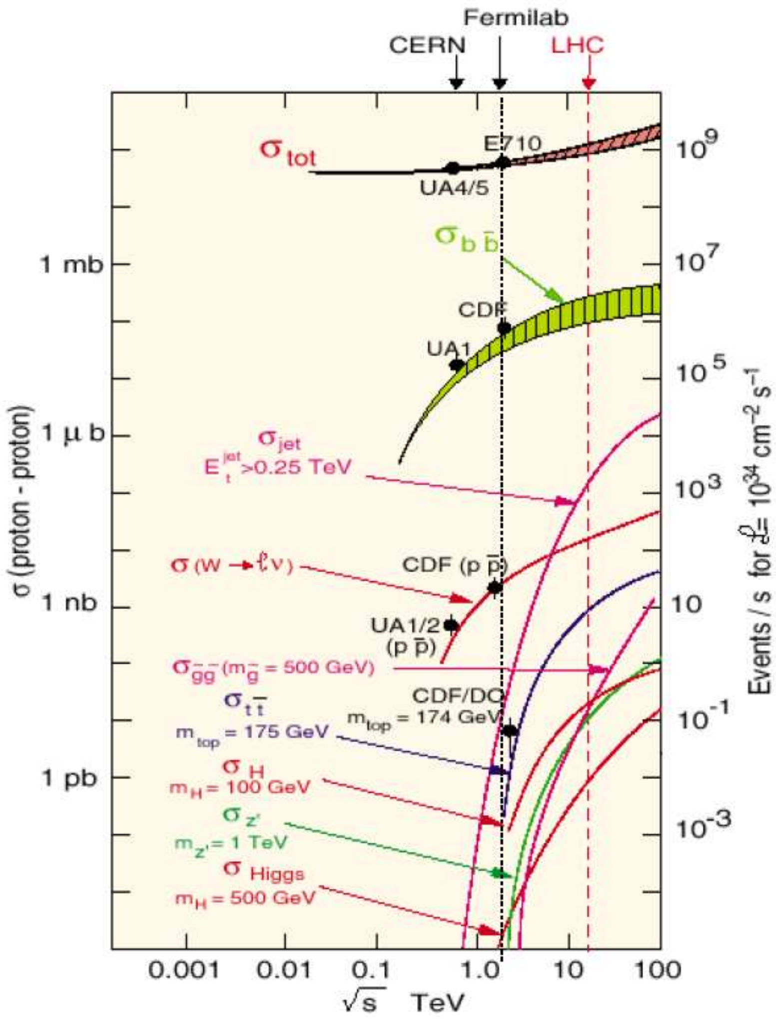
  $\longrightarrow$ huge event rates for jet production

  $\longrightarrow$ multiple interactions per crossing

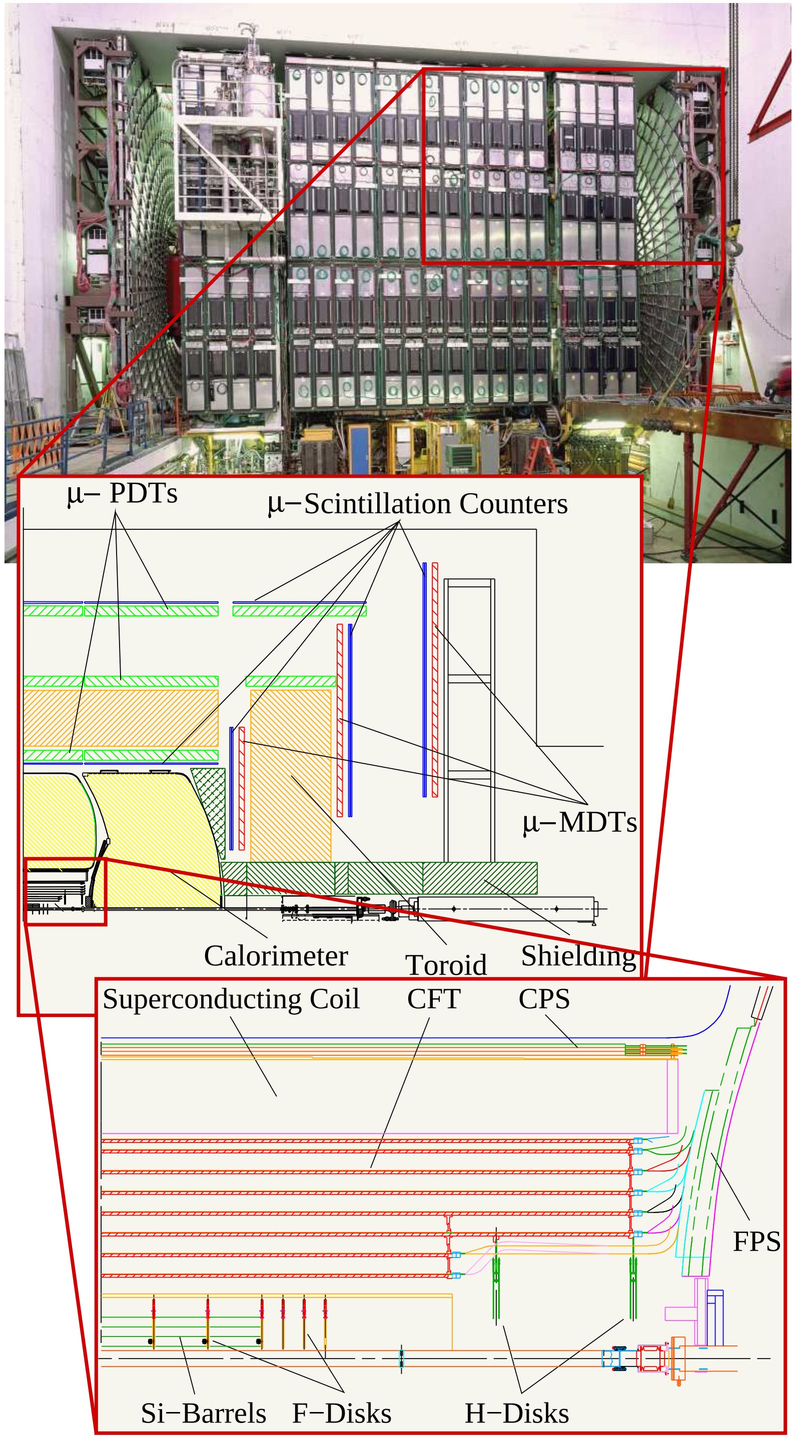
  $\longrightarrow$ complicated final states:

  - particles from fragmentation of $p/\bar{p}$ remnants
  - gluon radiation $\longrightarrow$ jets





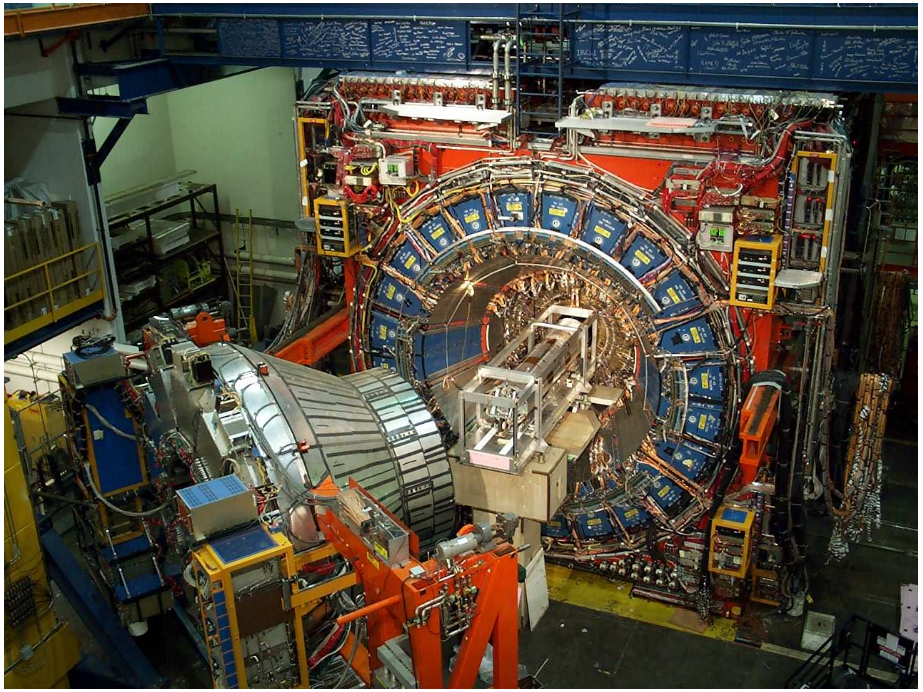
The Tevatron Experiments



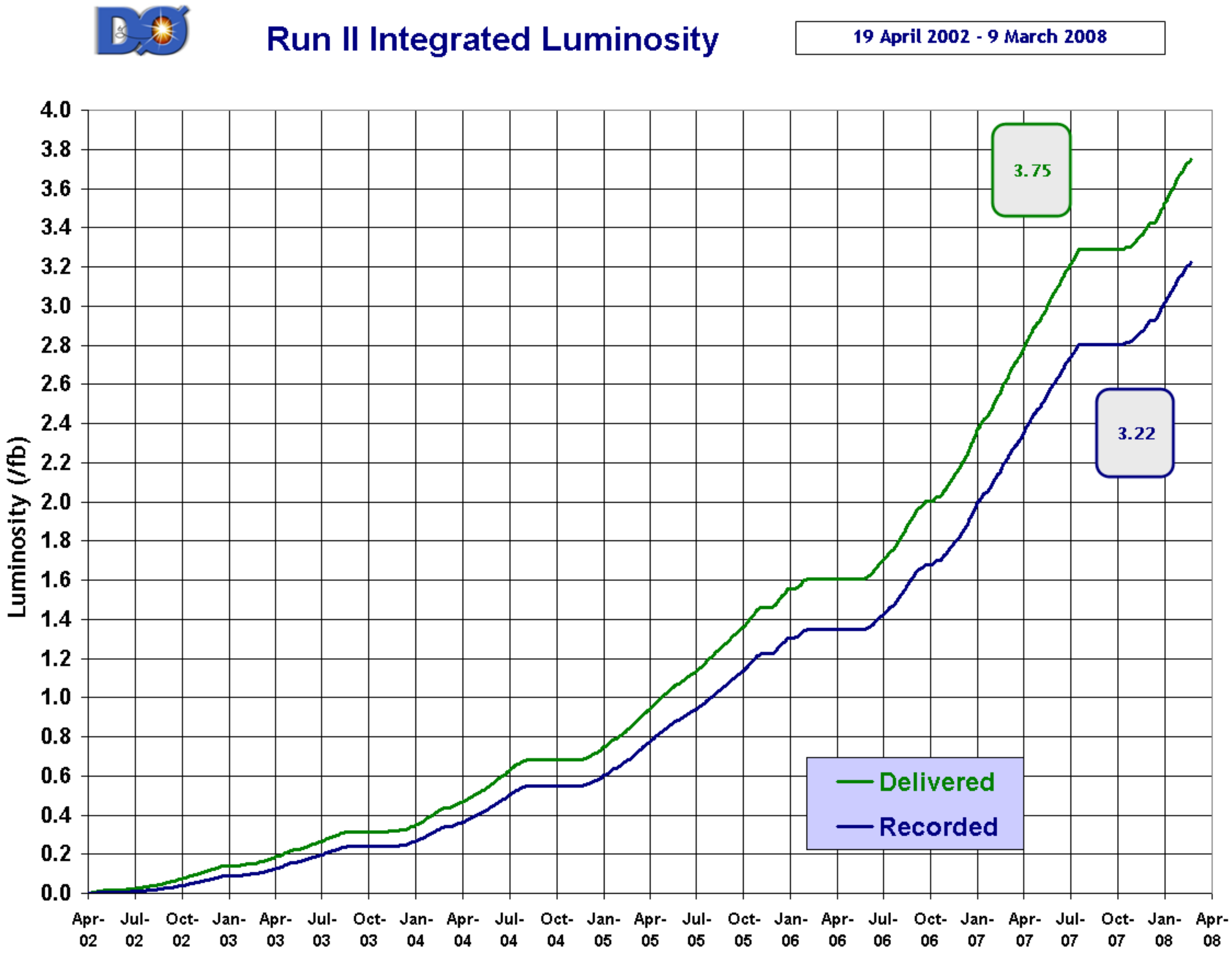
Two General-Purpose Detectors:	CDF	DØ
Electron acceptance	$\|\eta\| < 2.0$	$\|\eta\| < 3.0$
Muon acceptance	$\|\eta\| < 1.5$	$\|\eta\| < 2.0$
Silicon Precision tracking	$\|\eta\| < 2.0$	$\|\eta\| < 3.0$
Hermetic Calorimeter	$\|\eta\| < 3.6$	$\|\eta\| < 4.2$

Powerful trigger systems (2.5 MHz→100 Hz)

- Dilepton triggers starting at $p_T > 4$ GeV
- Jets+$\not{E}_T$ triggers with $\not{E}_T > 25$ GeV



The Tevatron Experiments – Dataset

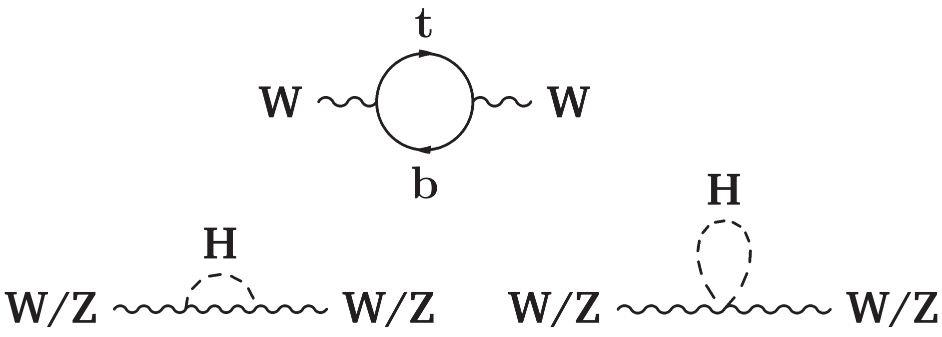


– $3.2 + 3.0\ \text{fb}^{-1}$ recorded by DØ + CDF

– Most results presented here based on $2\ \text{fb}^{-1}$

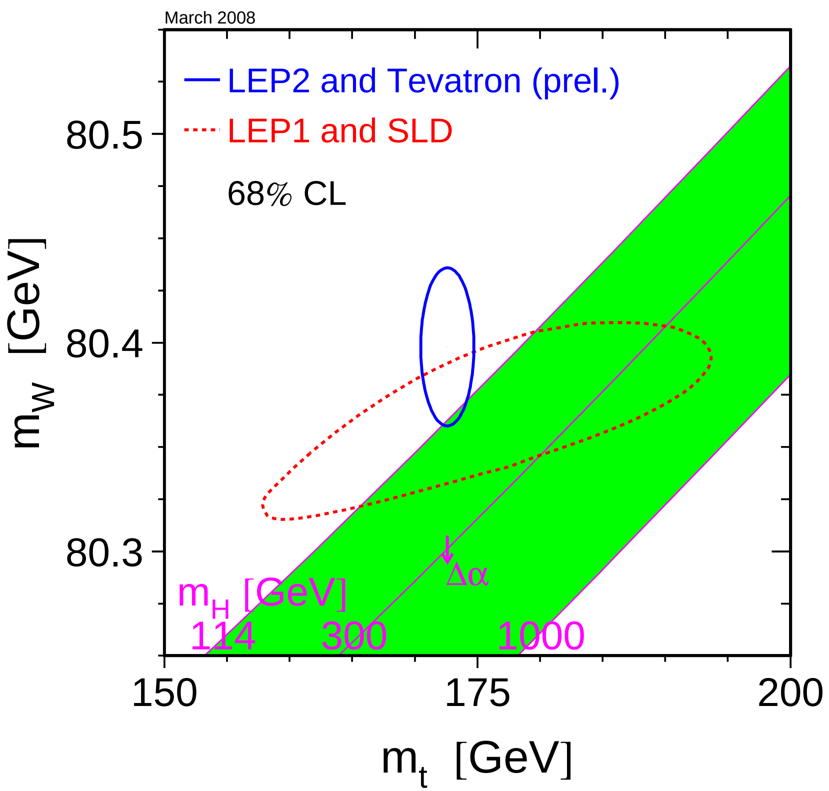
Pinning down EWSB at the Tevatron

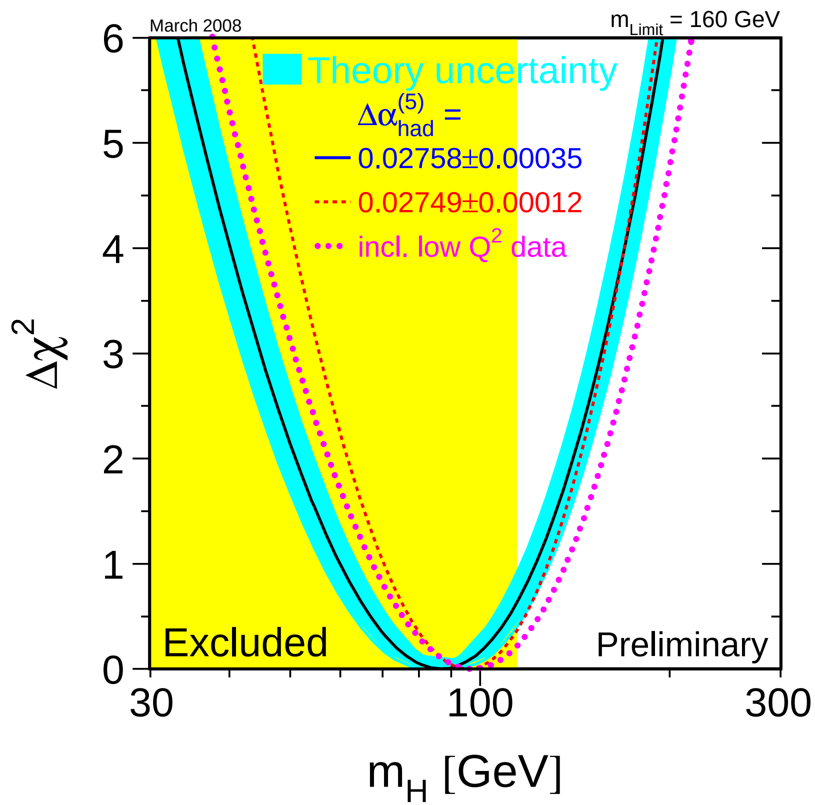
Standard Model relates m_H, m_t, m_W via radiative corrections:



$\sim m_{\rm top}^2$

$\sim \ln \frac{m_{\rm H}}{m_{\rm W}}$





→ Indirect constraints on Higgs boson mass:

$m_H = 87^{+36}_{-27}$ **GeV and** $m_H < 160$ **GeV at 95% C.L.**

Pinning down EWSB at the Tevatron

Combined top mass measurement from CDF+DØ:

m_t = 172.6±0.8(stat)±1.1(syst) GeV

New CDF W mass measurement (200 pb^{-1}):

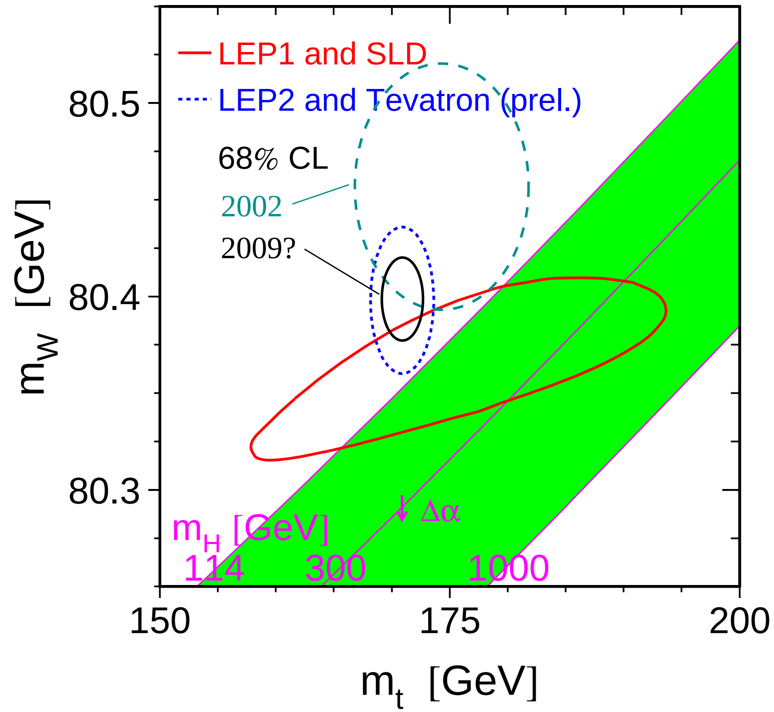
m_W = 80.413±0.048 GeV

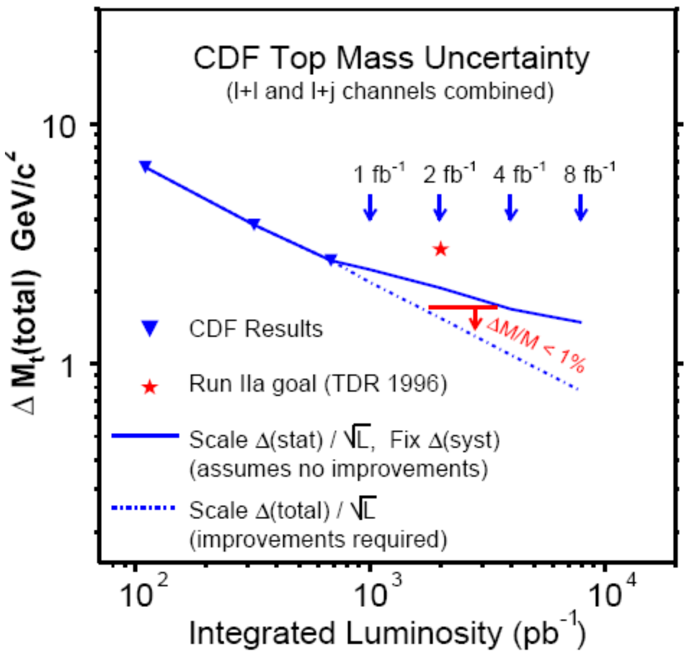
new world average: m_W = 80.398±0.025 GeV

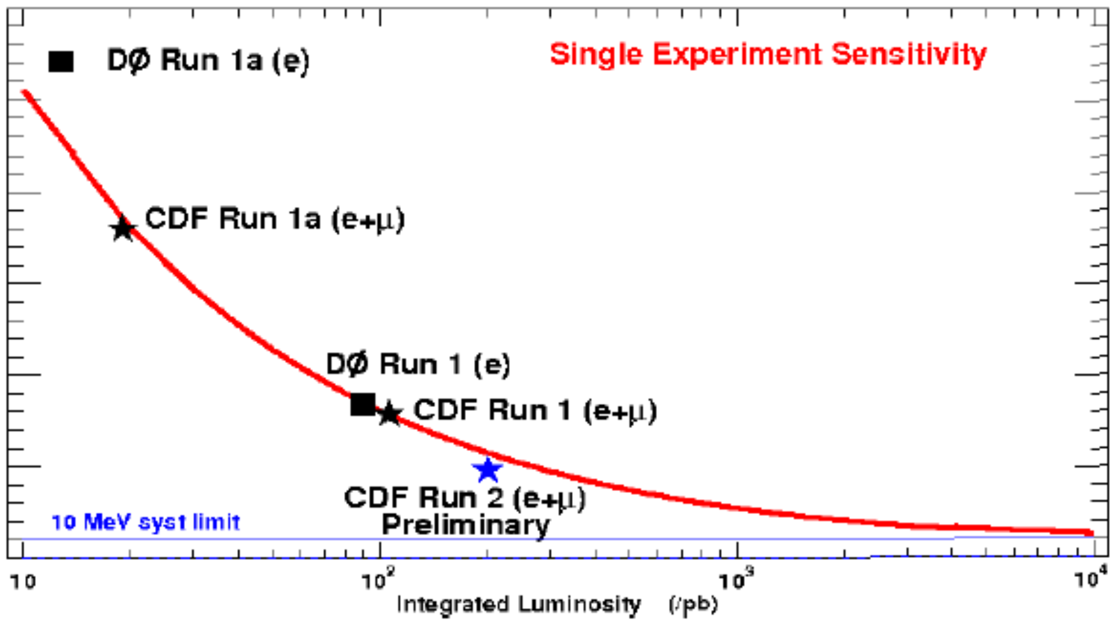
Projected uncertainties for 8 fb^{-1}:

m_t: ±1.2 GeV

m_W: ±15-20 MeV

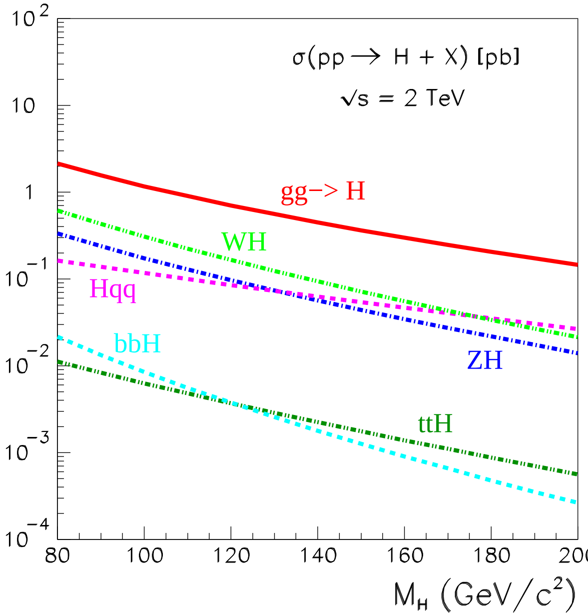




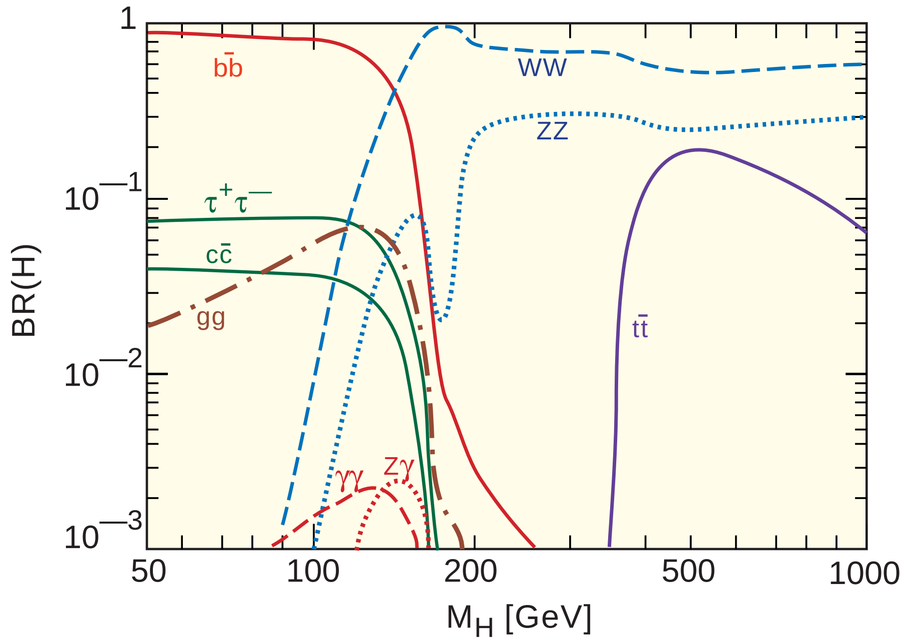


Search for Higgs Bosons – Production and Decay

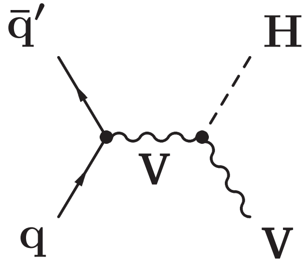
Production Cross-Sections



Branching Ratios



Light Higgs bosons ($m_H \lesssim 135$ GeV):



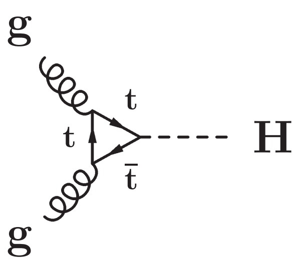
Dominant decay mode: $H \rightarrow b\bar{b}$

Production: in association with W,Z

→ leptonic W,Z-decays provide best signature

→ b-tagging to suppress background from W/Z+jets

Heavy Higgs bosons ($m_H \gtrsim 135$ GeV):



Dominant decay mode: $H \rightarrow WW$

Production: Gluon-Gluon Fusion

→ relatively high cross-section

→ clean 2-lepton+$\not{E}_T$ signature via $H \rightarrow WW \rightarrow l\nu l\nu$

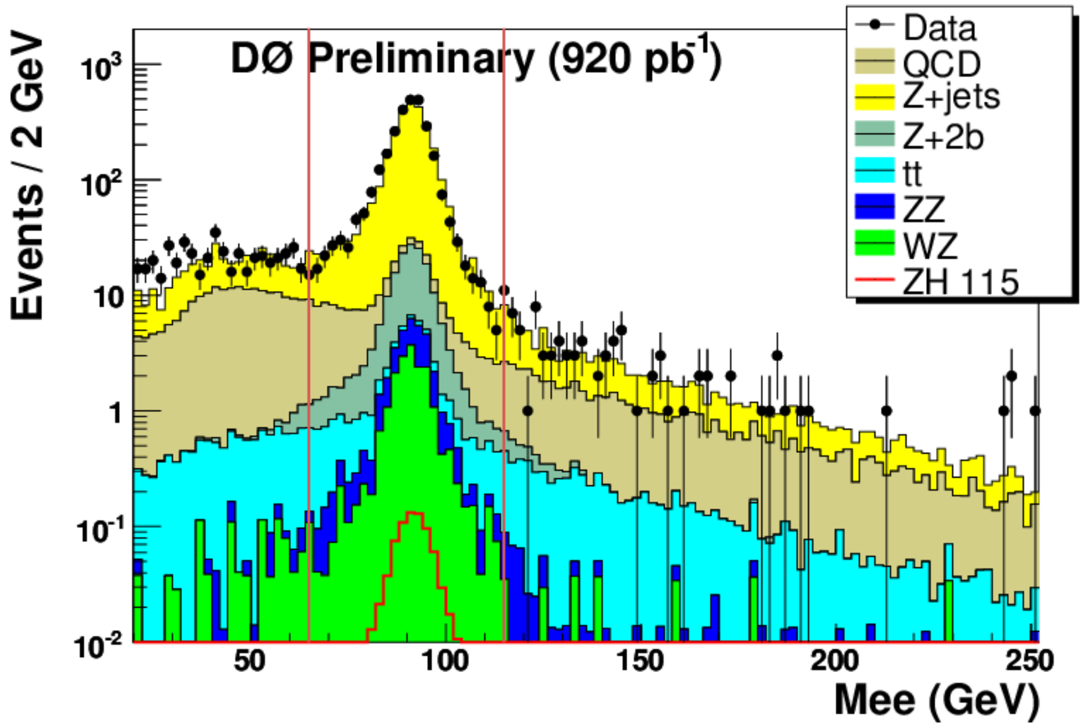
Search for low-mass Higgs Boson

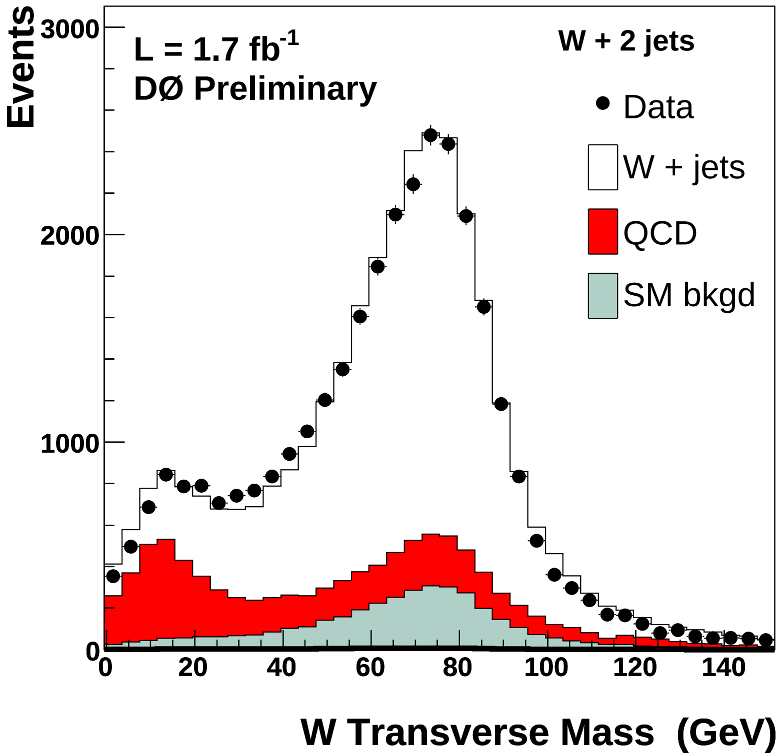
For best sensitivity, need to combine many channels:

$$WH \to \ell\nu b\bar{b},\ ZH \to \nu\bar{\nu}b\bar{b},\ ZH \to \ell^+\ell^- b\bar{b}\ (\text{with}\ \ell\text{=e},\mu)$$

Challenge: very low signal rates, massive backgrounds from V+jets

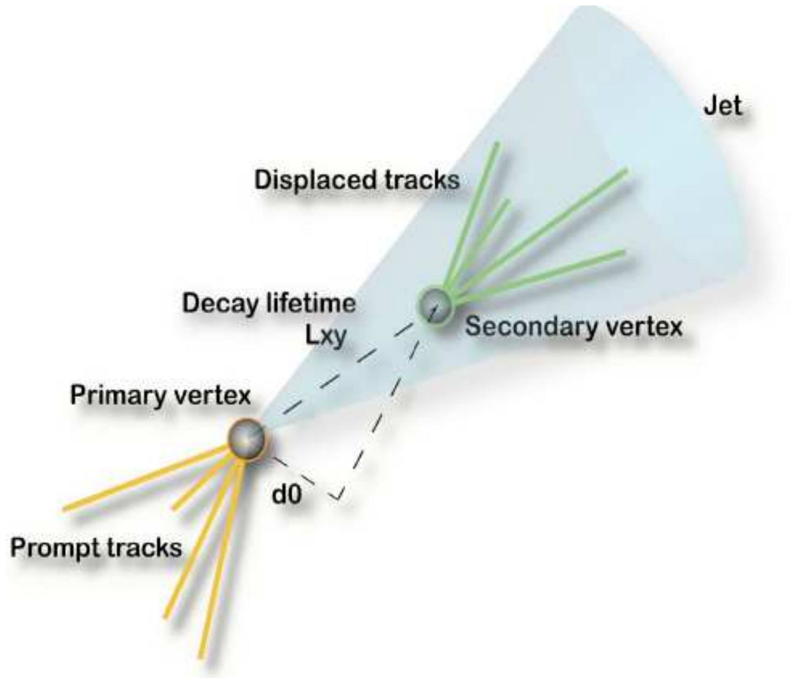
First step: select events consistent with W/Z+2 jets





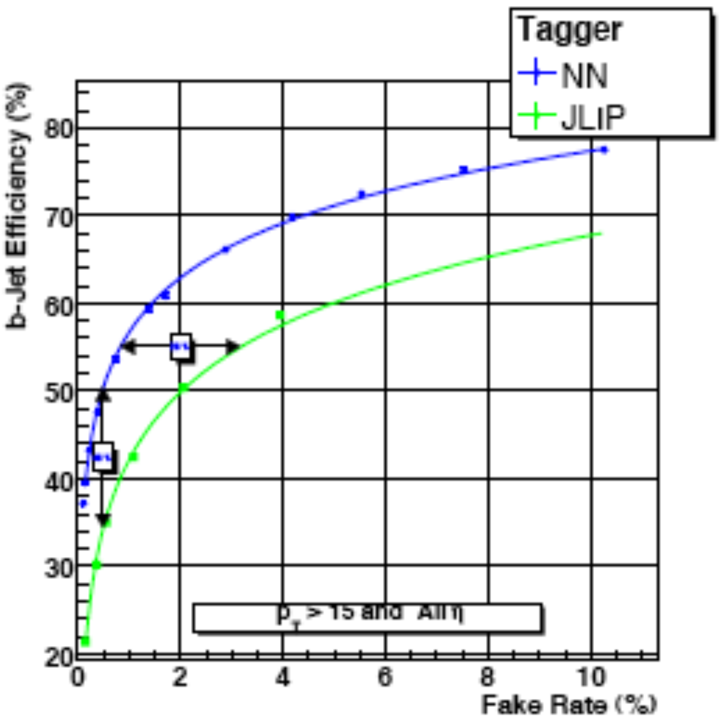
Search for low-mass Higgs Boson

Second step: b-tagging



Exploiting B-meson lifetime, mass and decay modes to separate b- from light-quark jets:

- impact parameter
- secondary vertices
- vertex mass
- vertex track multiplicity
- soft leptons

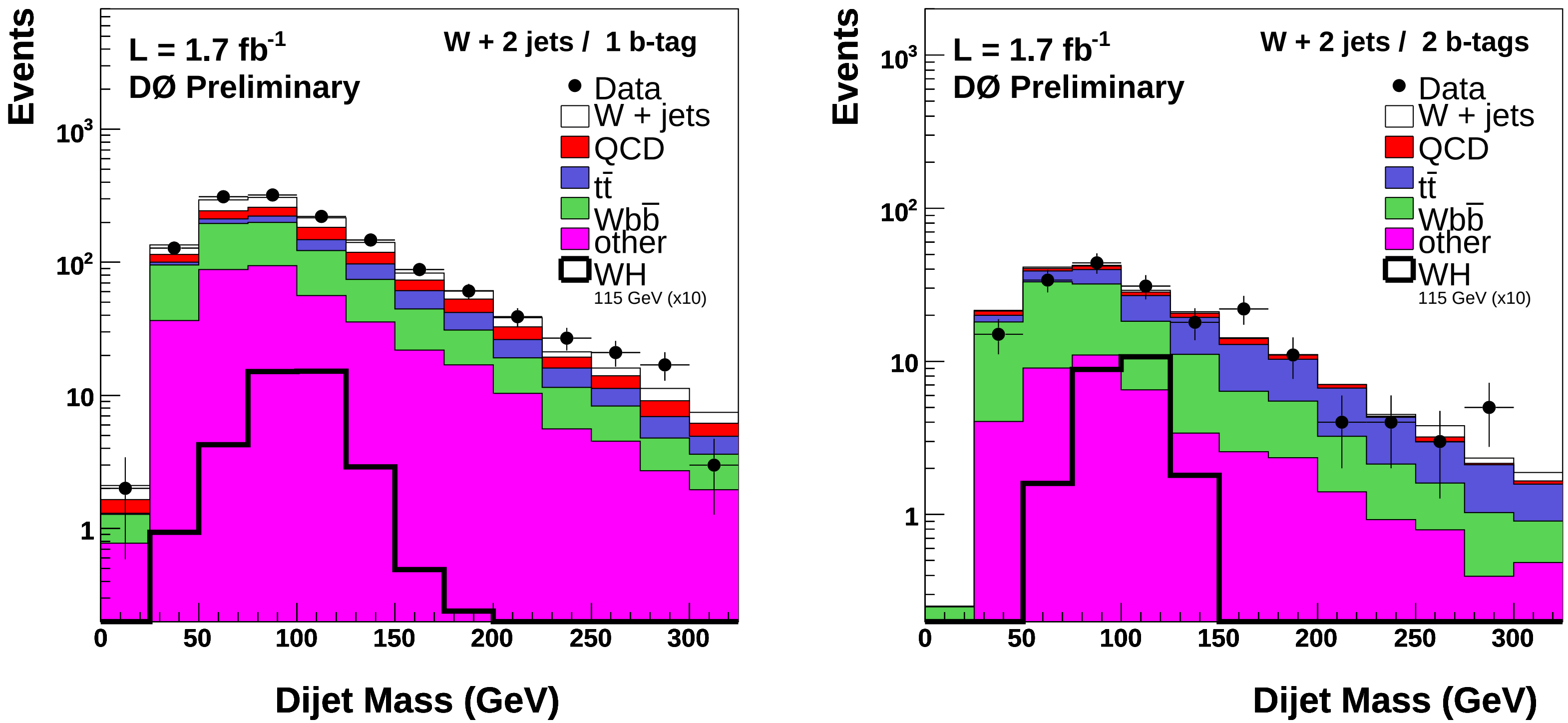


Similar strategies in both experiments:

- use neural networks for optimal combination of tagging information
- use several NN operating points to define channels with high/low s/b:
  - 1 tight b-tag (low s/b, “single tag”),
  - 2 loose b-tags (high s/b, “double tag”)

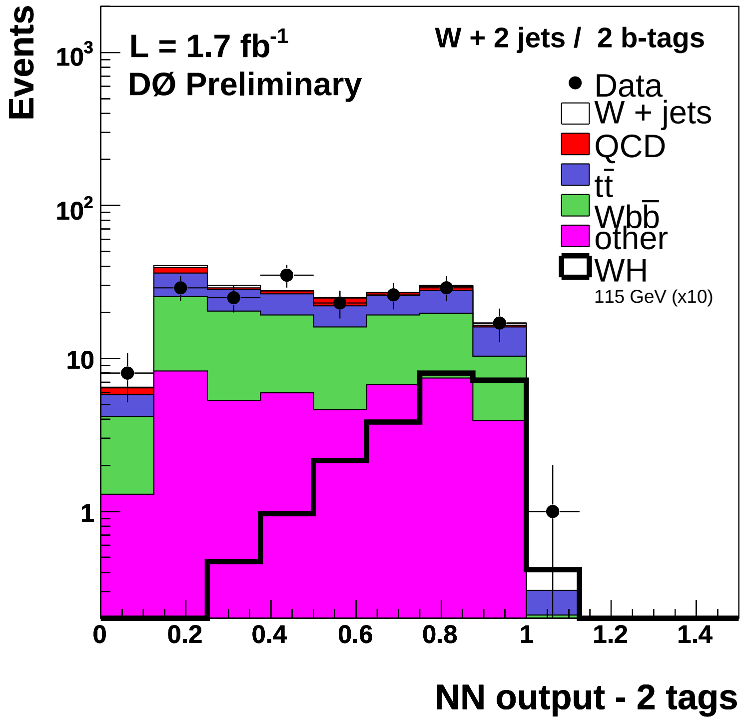
Search for low-mass Higgs Boson

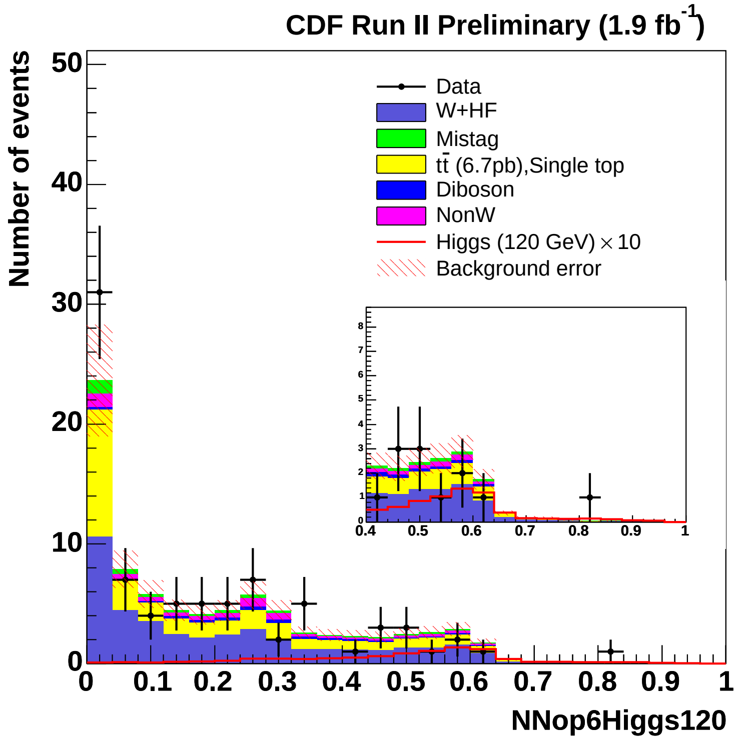
- Backgrounds dominated by W/Z+bb, $t\bar{t}$
- Main handle: invariant mass of two b-jets



Search for low-mass Higgs Boson

– For optimal separation power, use neural networks:





Note: signal-to-background ratios are at most 10-20%

$\longrightarrow$ need full combination of all channels to reach sensitivity

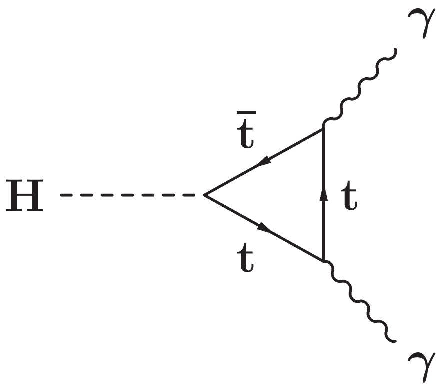
$\longrightarrow$ need to control systematics at a level $\ll$10%!

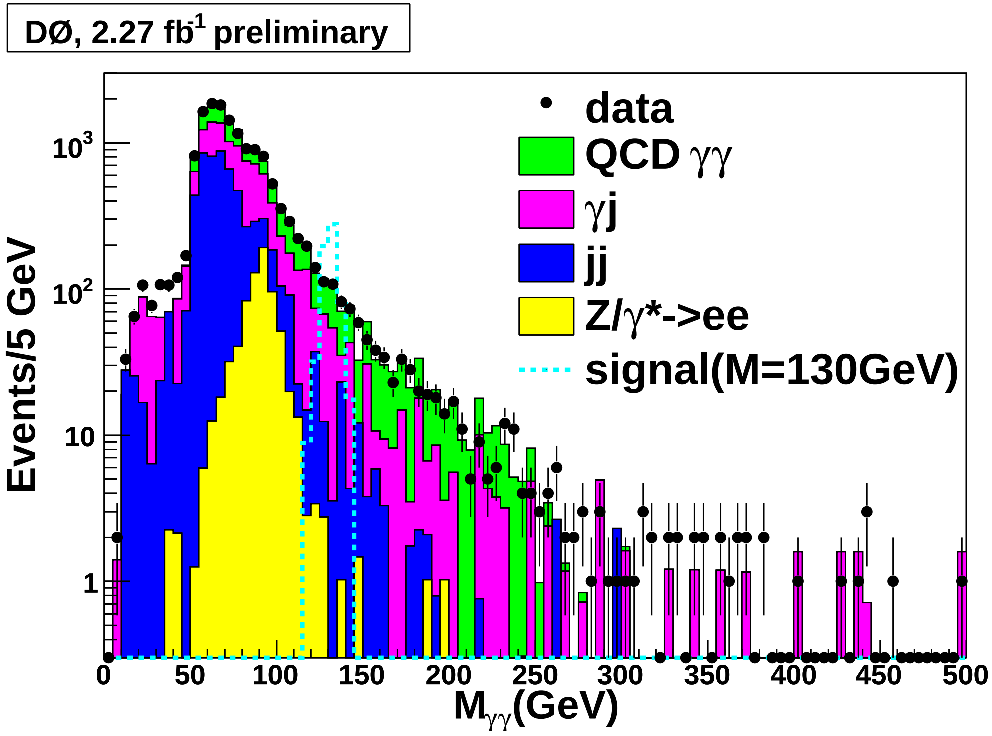
Main concern: modeling of V+jets backgrounds

- shapes: from MC (alpgen, MCFM, CKKW)
- normalisation: combination of (N)NLO cross-sections and sideband-fitting

New channels added for Winter 2008

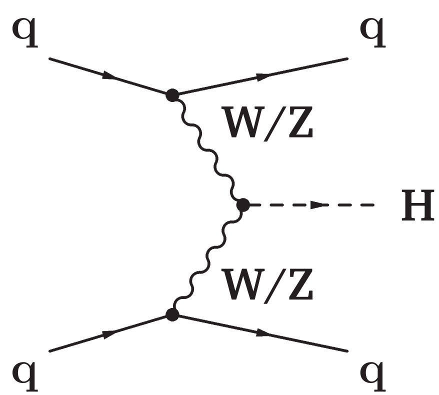
DØ: H→ $\gamma\gamma$

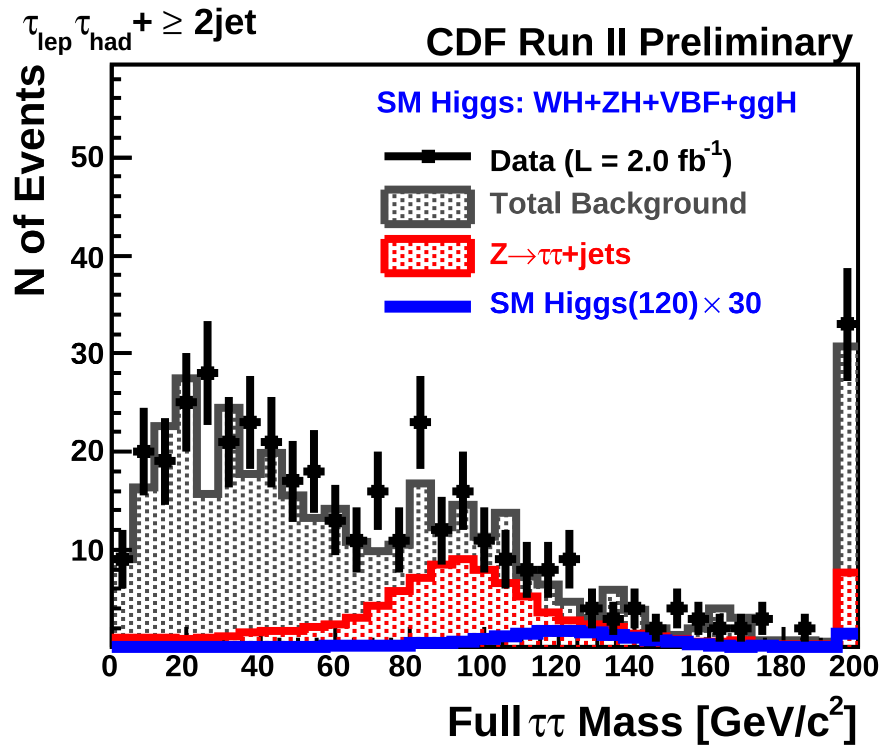




Expected Limit: 40 x σ_{SM} (m_H=120 GeV)

CDF: H+jj with H→ $\tau\tau$



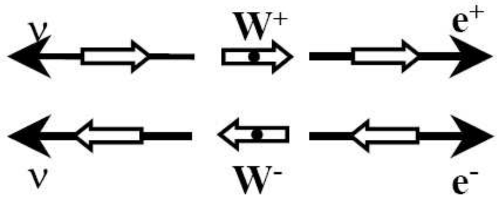


Expected Limit: 25 x σ_{SM} (m_H=120 GeV)

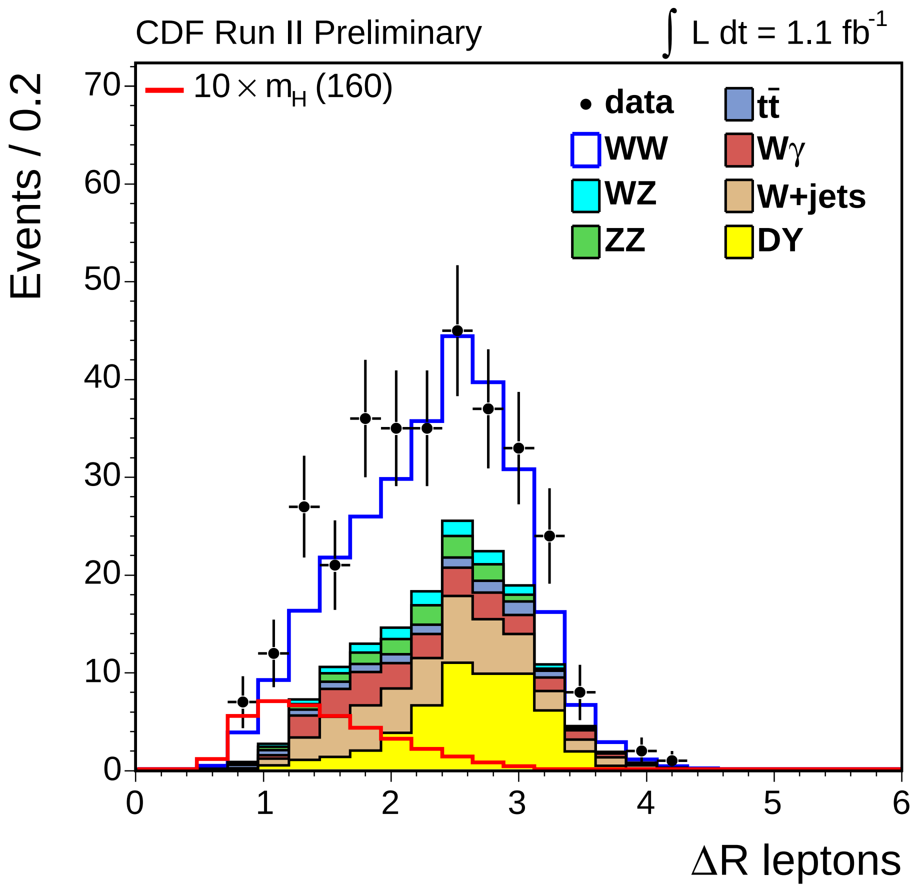
Search for high-mass Higgs Boson: H⟶WW

Main irreducible background: WW⟶ $\ell\nu\ell\nu$

Additional information: angular correlations exploiting spin of Higgs boson



⟶ Charged leptons from Higgs decay tend to have small opening angle ΔΦ



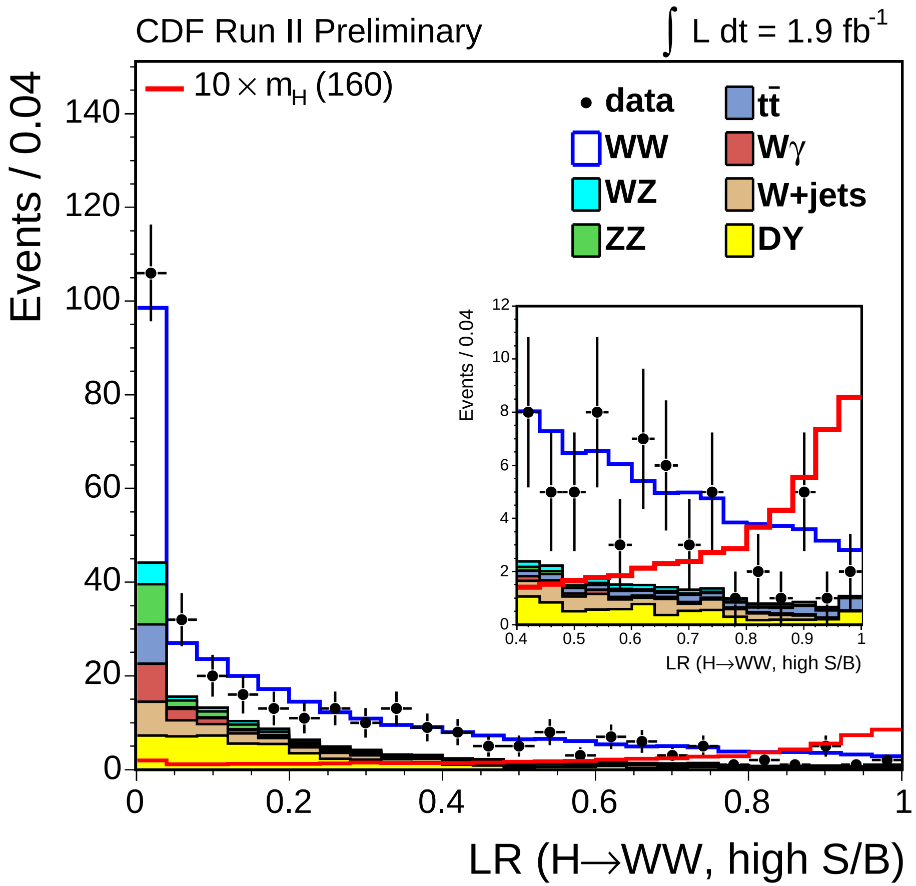
For best sensitivity, use multivariate techniques

Search for high-mass Higgs Boson: H→WW

- For each event, use full kinematic information x_{obs} to calculate probabilities that event comes from signal (P_H) and background (P_B):

$$P_{H/B}(x_{obs}) = \frac{1}{\sigma_{H/B}} \int dy^n_{true}\, \sigma^{theory}_{H/B}(y_{true})\, \epsilon(y_{true})\, G(x_{obs}, y_{true})$$

- Then calculate likelihood ratio $\frac{P_H}{P_H+P_B}$ for optimal separation of signal and background:



Search for high-mass Higgs Boson: H⟶WW

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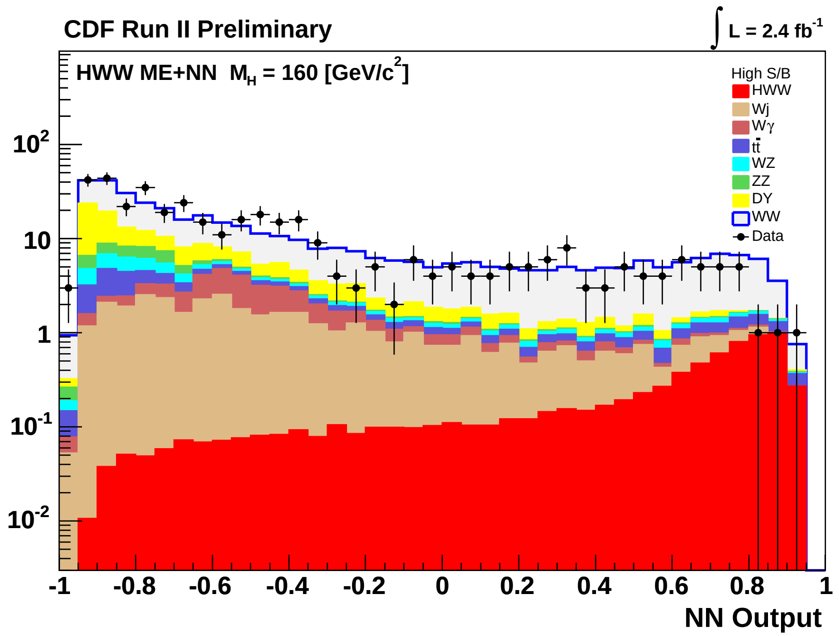
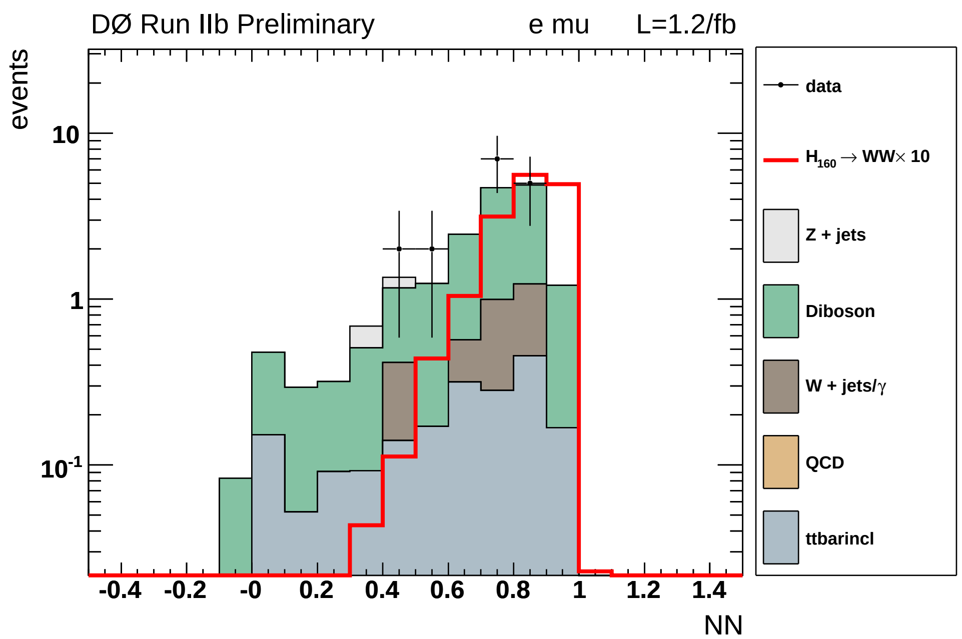
- Then calculate likelihood ratio $\frac{P_H}{P_H+P_B}$ for optimal separation of signal and background

- Finally, combine with other kinematic variables in a neural network:





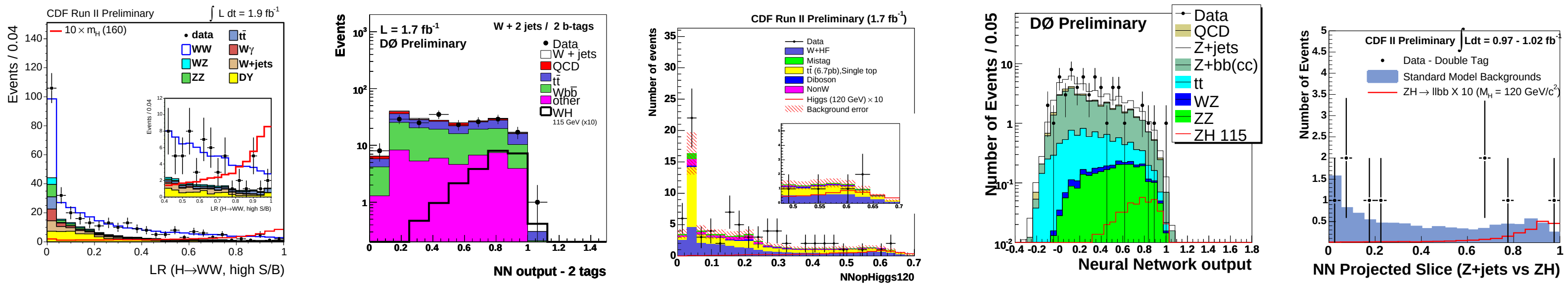
Tevatron Full Combination

Massive exercise in advanced statistics

– currently combining 28 different channels

– full distributions of final variables are analyzed

→ 28 NN/LR/Mass distributions



> 50 different sources of systematic uncertainties are considered

– taking into account correlations bin-to-bin and channel-to-channel

→ >50 300x300 covariance matrices...

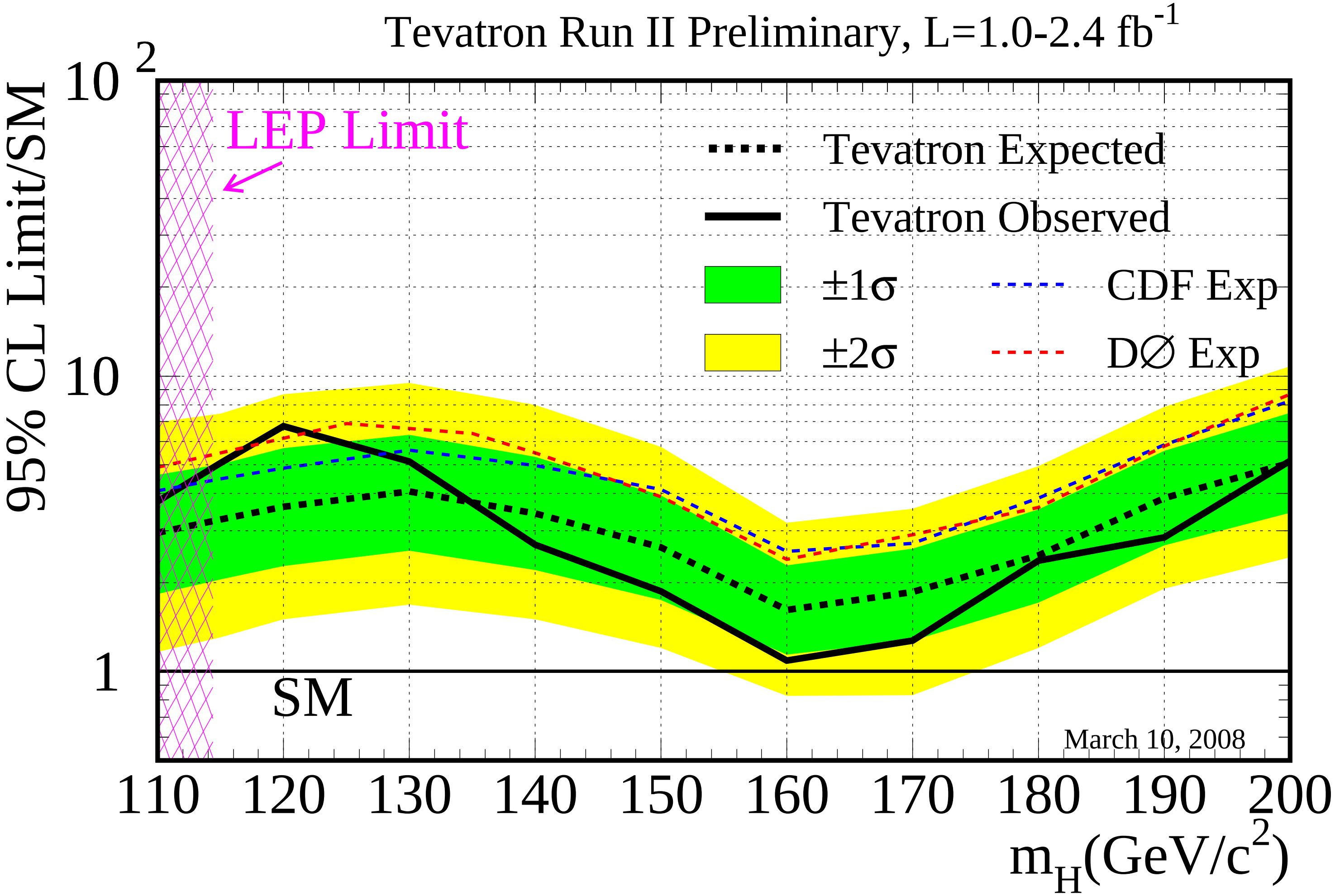
Systematic uncertainties need to be constrained in sidebands

→ very complicated procedure...

– used several techniques (Bayesian, mod. frequentist) and 4 independent programs to cross-check calculations

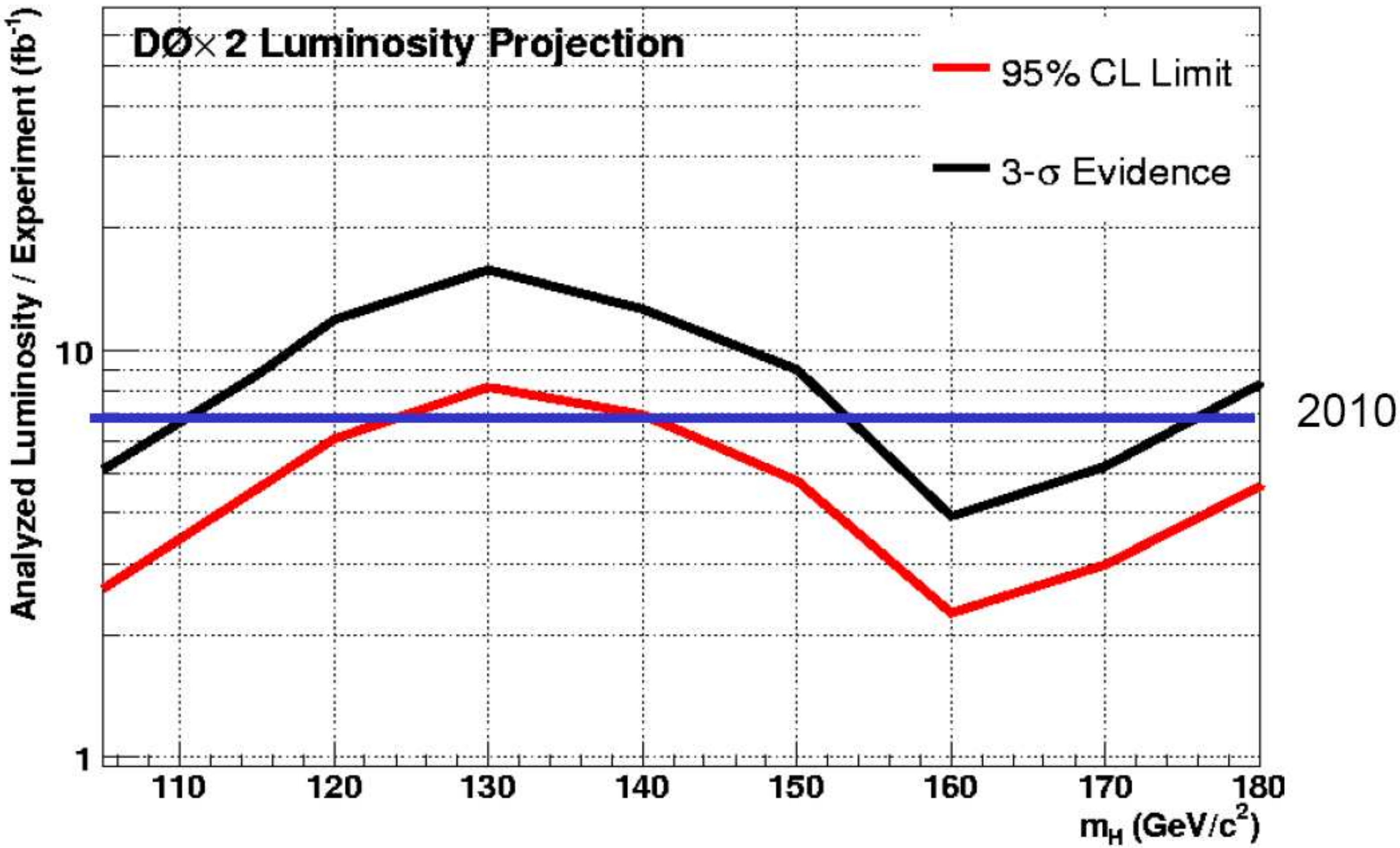
→ results agree within 10%

Tevatron Full Combination



- **Sensitivity improvement still scaling faster than luminosity**
- **Exciting times are ahead!**

Tevatron Full Combination



- Sensitivity improvement still scaling faster than luminosity
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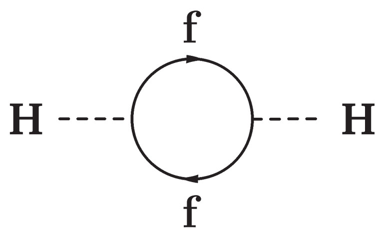
Beyond the Standard Model

Strong hint for new physics: The hierarchy problem

– fermion loop corrections to Higgs mass are divergent

$\longrightarrow$ Higgs mass should be of the order of the cutoff scale Λ (e.g. M_{Planck})



$$\Delta M_H^2 = N_f \frac{\lambda_f^2}{8\pi^2}\left[-\Lambda^2 + 6m_f^2 \log\frac{\Lambda}{m_f} - 2m_f^2 \right] + \mathcal{O}(1/\Lambda^2)$$

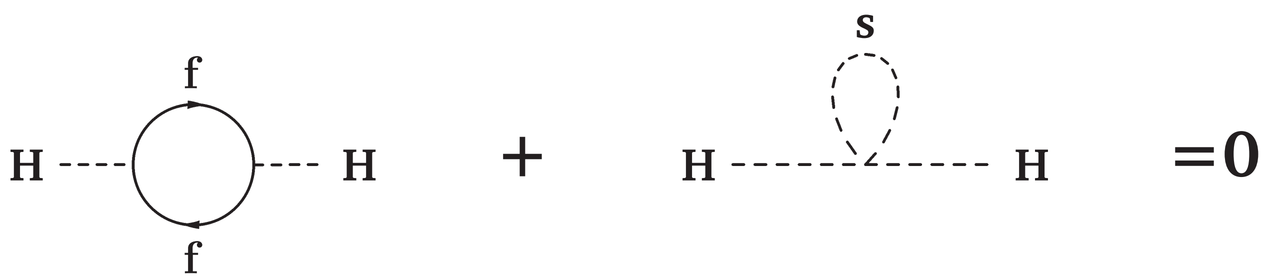
– in contradiction to indirect evidence for a light SM Higgs boson

$\longrightarrow$ there must be something beyond the SM that modifies these corrections

Two main options:

1. New physics at O(1 TeV) $\longrightarrow$ loop corrections stay “reasonably” small
2. New symmetry that suppresses loop corrections

   Most straightforward way: cancel fermion loops with boson loops



Cancellation exact for equal couplings and mass

Supersymmetry

The idea: particle physics is symmetric under transformation fermion ↔ boson

→ implies one supersymmetric partner for each SM particle

Superpartners are heavy → SUSY must be broken

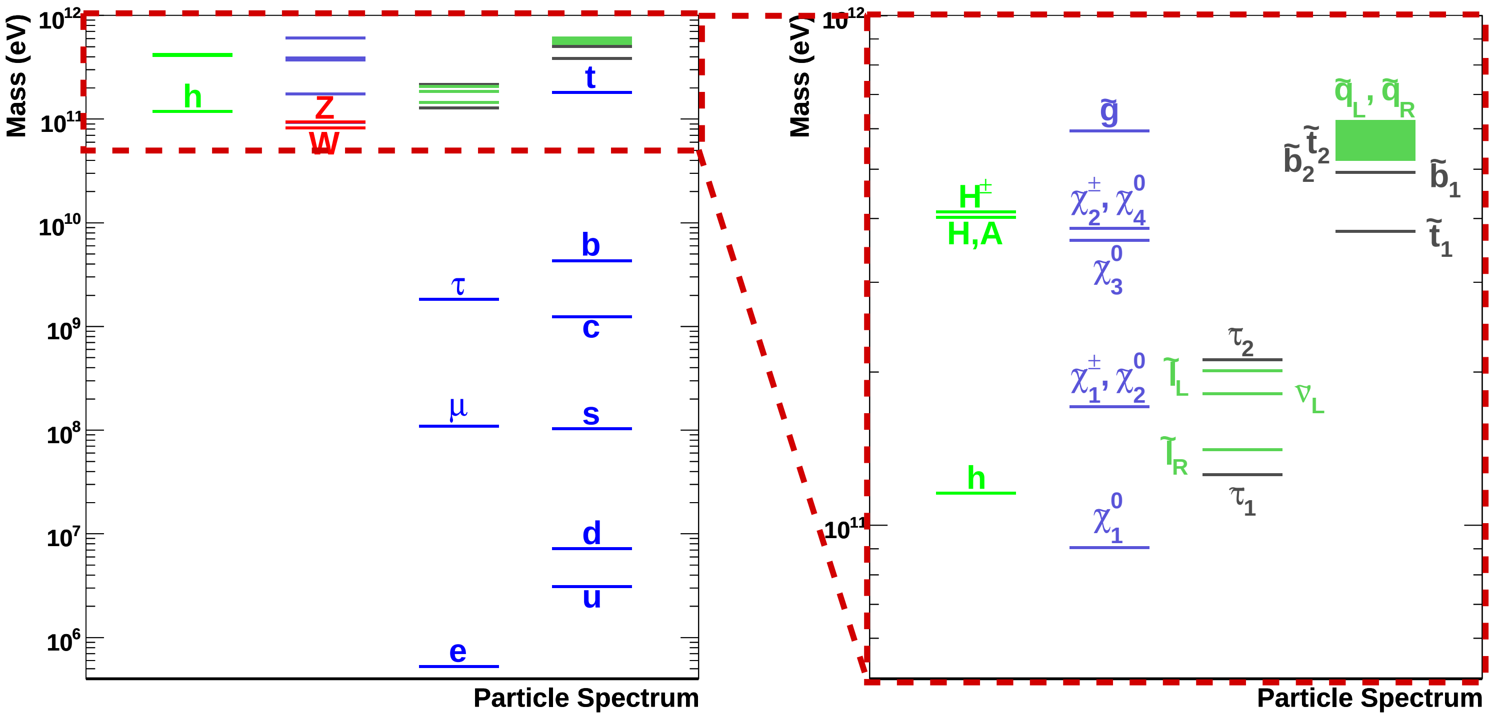
– Details of SUSY breaking mechanism unknown

→ need to consider several models: gravity-, gauge-, anomaly-mediated breaking

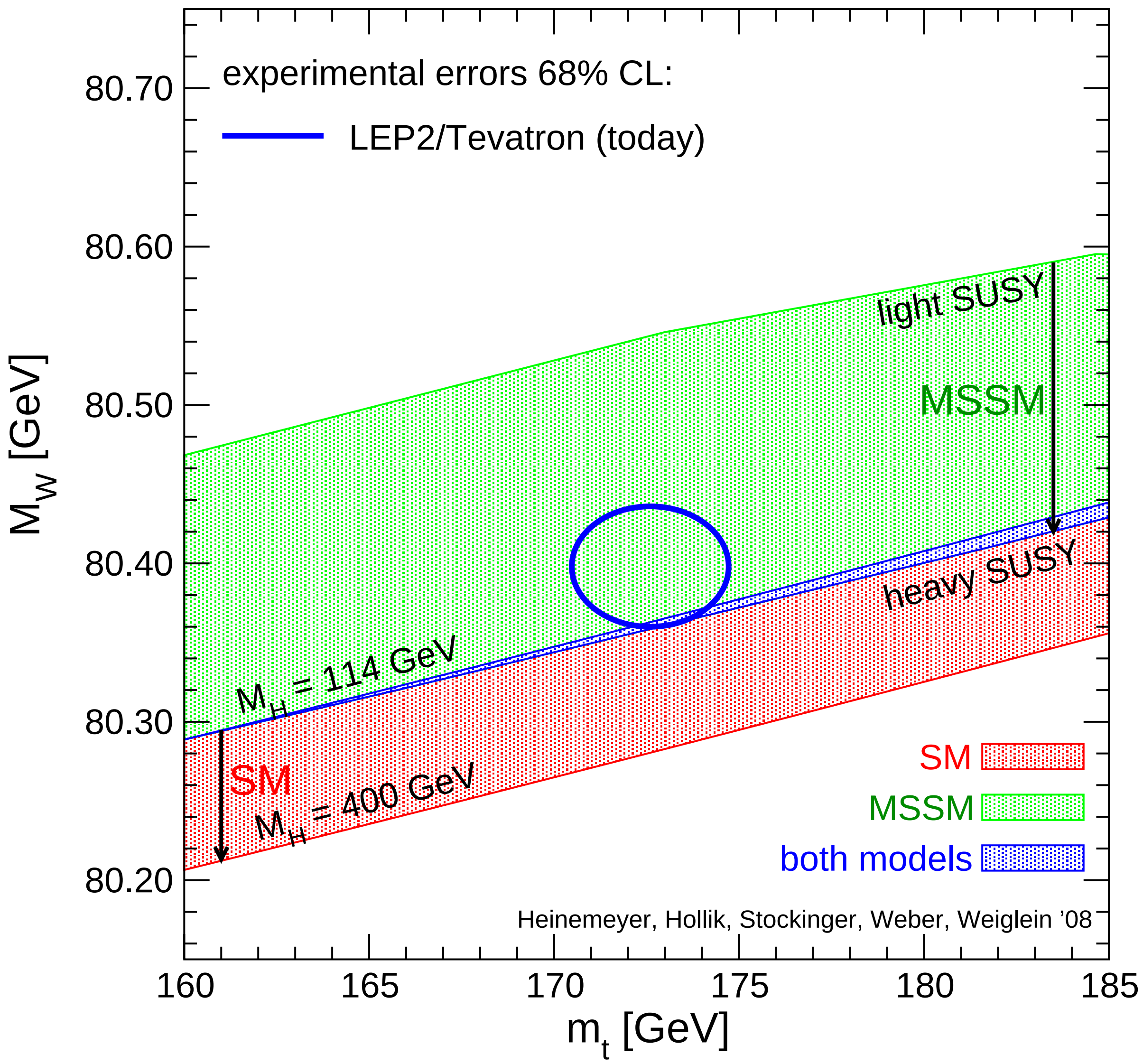
Predictions:

– Many new SUSY particles: Charginos/Neutralinos/Gluinos, Squarks, Sleptons

– Extended Higgs sector: 5 physical Higgs bosons h,H,A,$H^{\pm}$



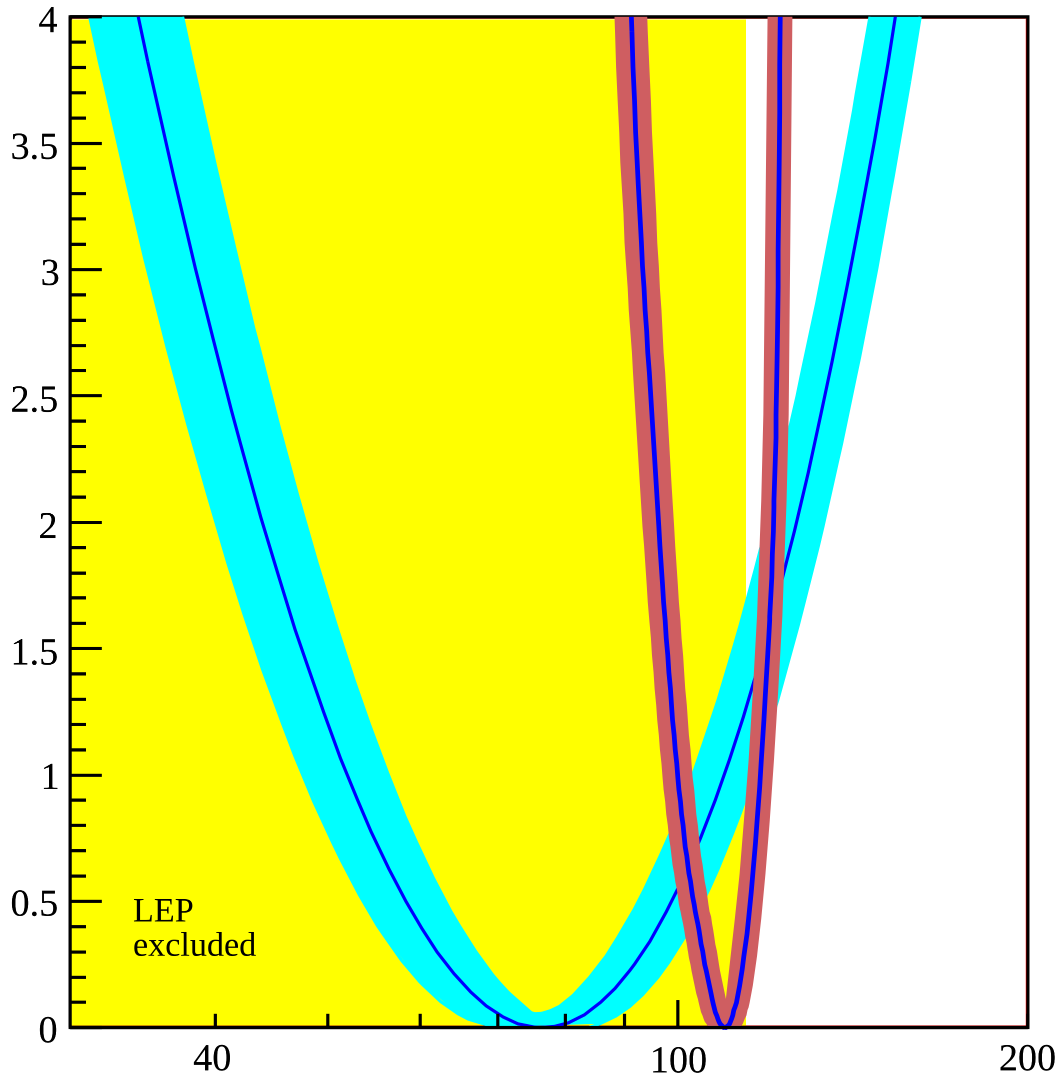
M_W vs. m_t for SM vs. MSSM



- Supersymmetric theories predict additional particles that modify loop corrections
- Lightest MSSM Higgs boson: $m_h \lesssim 135$ GeV

Blue Band Plot for SM vs. MSSM

O. Buchmueller et al., arXiv:0707.3447



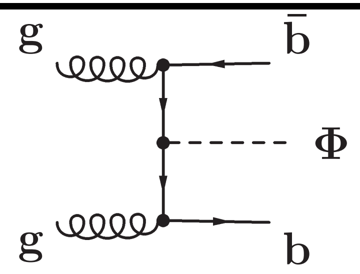
Adding constraints from CDM, b⟶sγ etc. allows prediction of m_h in MSSM:

$$m_h = 110\ ^{+8}_{-10}\ (\text{exp})\ \pm 3\ (\text{theo})\ \text{GeV}$$

Search for SUSY Higgs

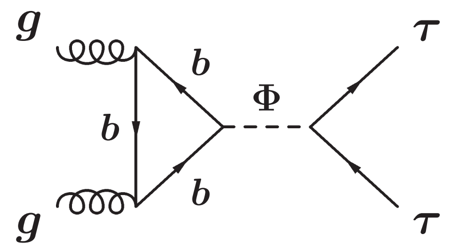
Important: Higgs-$b\bar{b}$-coupling depends on tanβ

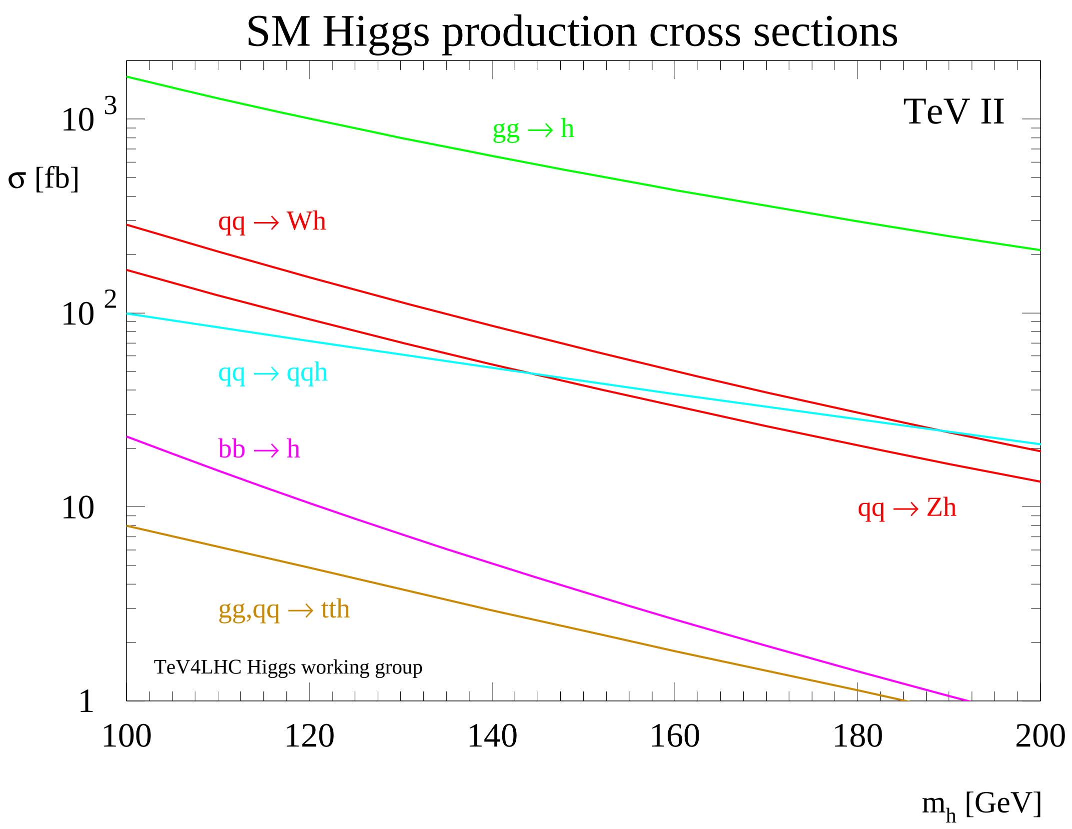
$\longrightarrow$ **large cross-sections for Higgs production at high tanβ**

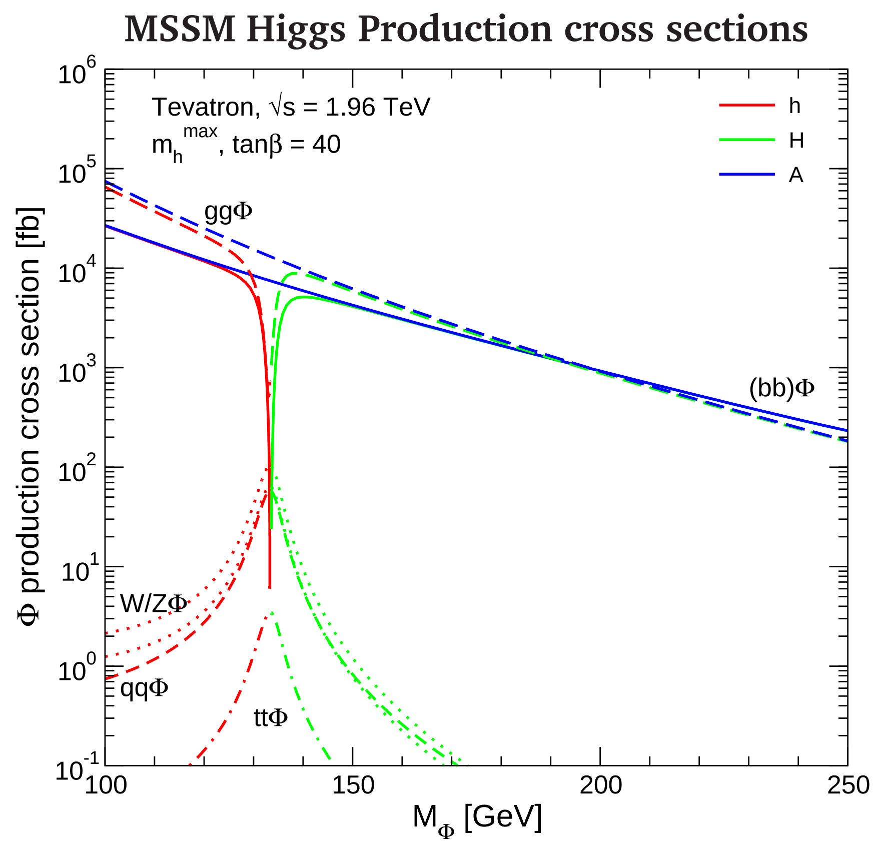


Additional search channels at high tanβ:

- **associated production with bb: bbΦ with Φ $\rightarrow$bb,$\tau\tau$**
- **enhanced gluon fusion cross-section: gg$\rightarrow$ Φ $\rightarrow$ $\tau\tau$**







Search for SUSY Higgs: $\Phi \rightarrow \tau\tau$

Mode	Fraction (%)	Comments
$\tau_e\tau_e$	3	Large DY BGND
$\tau_\mu\tau_\mu$	3	Large DY BGND
$\tau_e\tau_\mu$	6	Small QCD BGND
$\tau_e\tau_h$	23	Golden
$\tau_\mu\tau_h$	23	Golden
$\tau_h\tau_h$	41	Large QCD BGND

Selections:

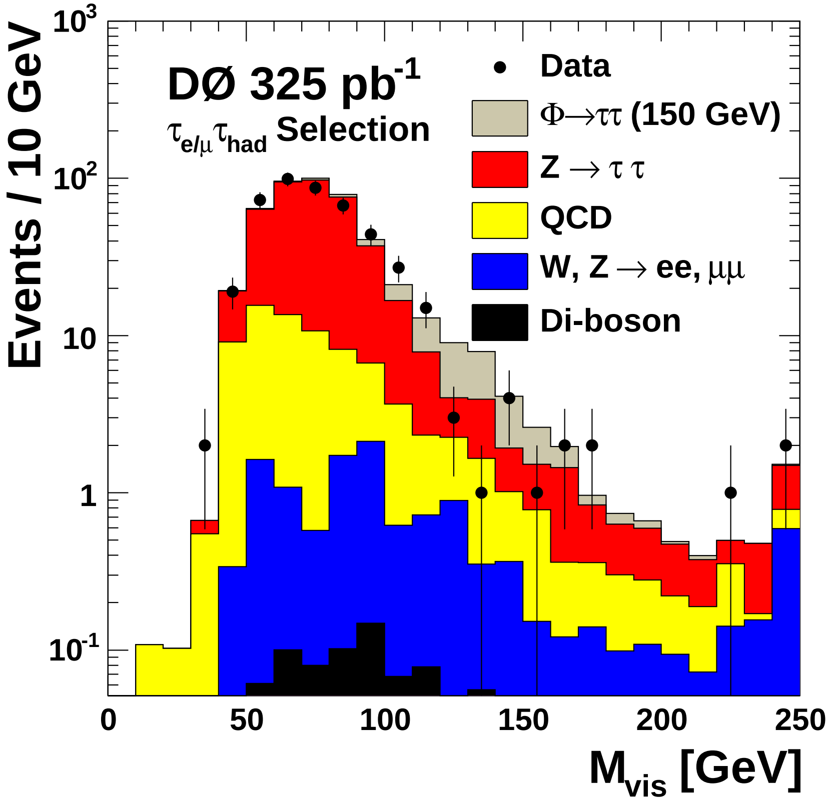
A) two isolated taus with one leptonic tau decay

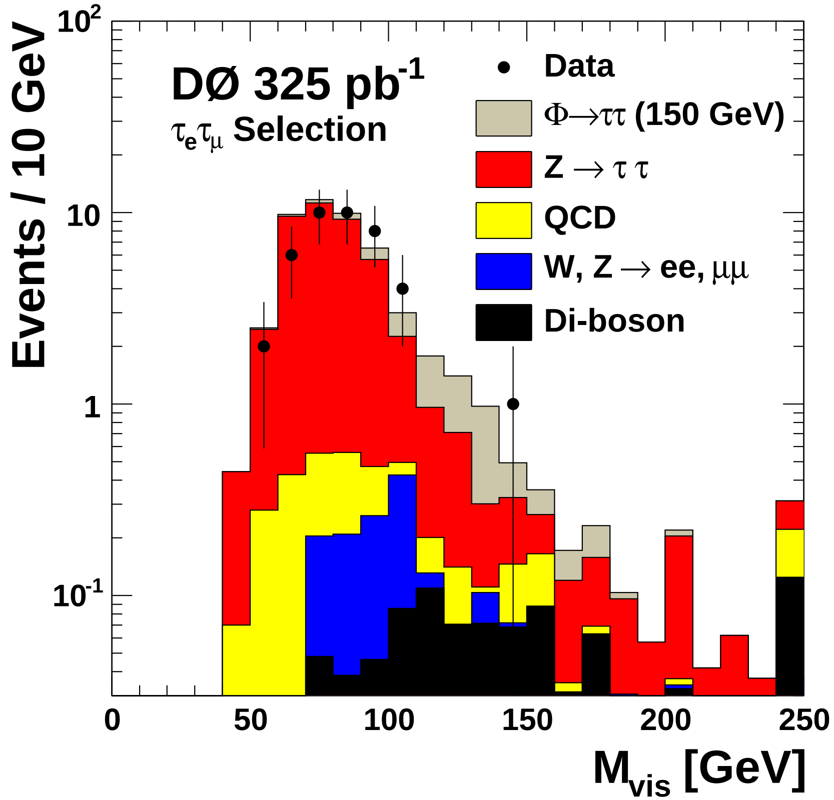
B) isolated electron and muon

– Irreducible background from $Z \rightarrow \tau^+\tau^-$

– Reconstruction of effective mass from visible tau decay products and $\not{E}_T$

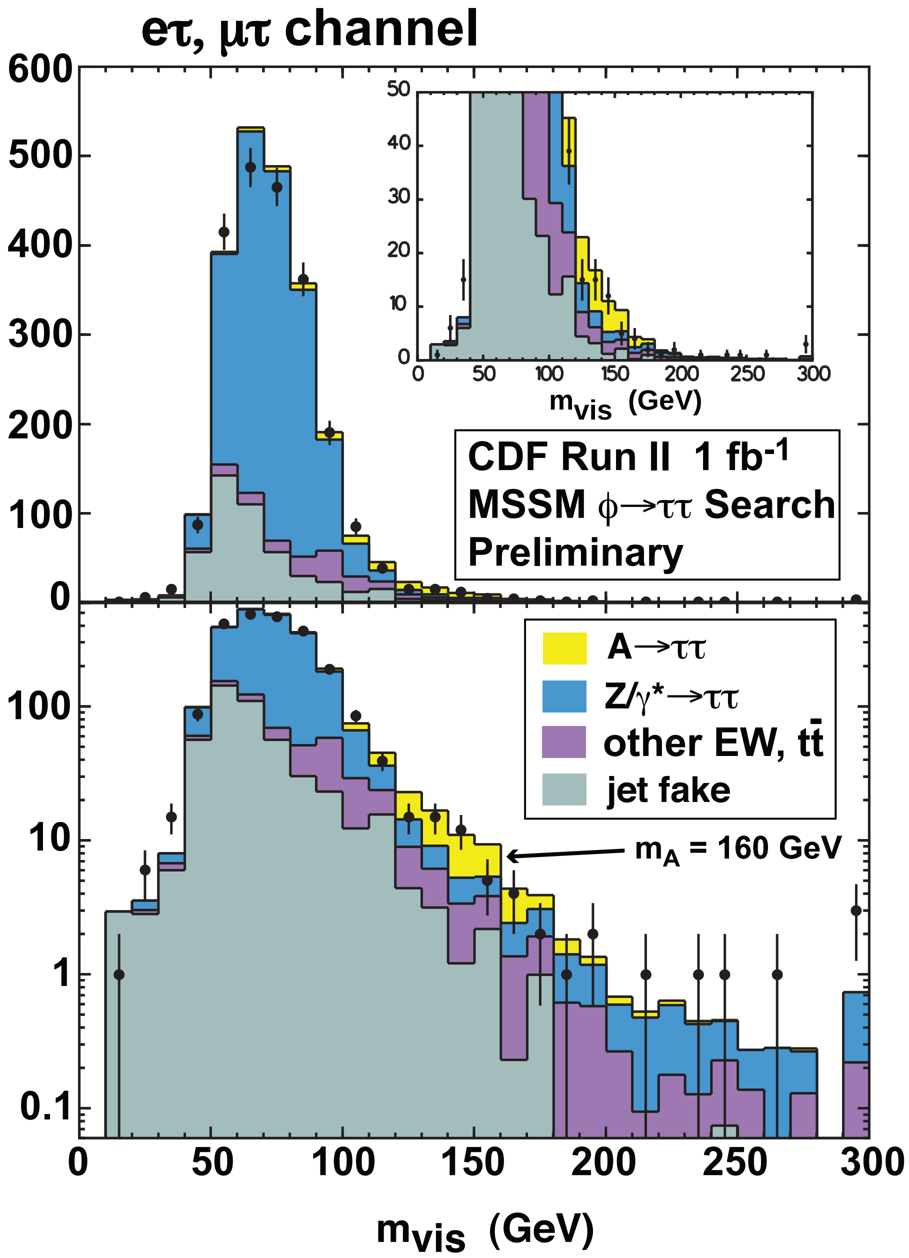
Summer 2006

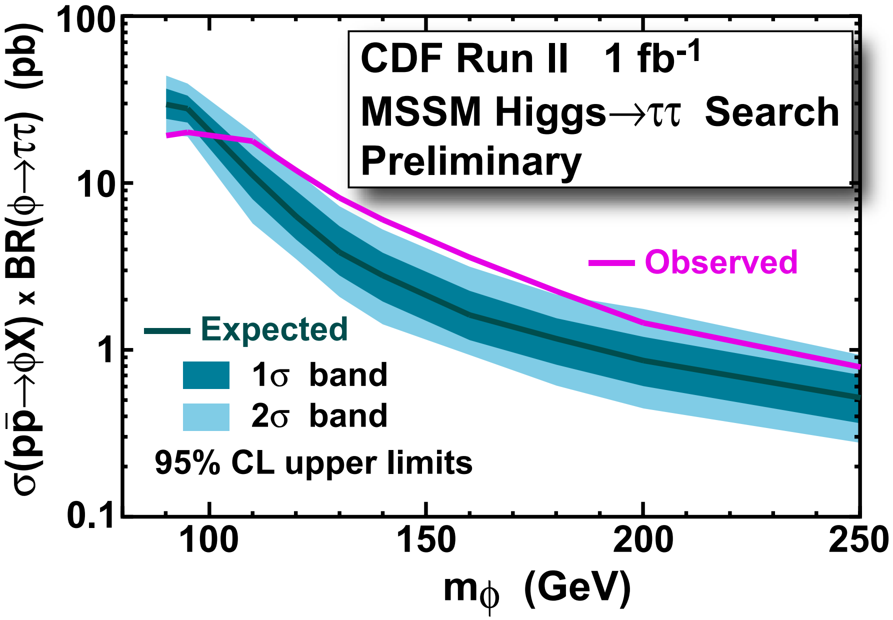




Search for SUSY Higgs: $\Phi \to \tau\tau$

January 2007: new CDF results with 1 fb^{-1}

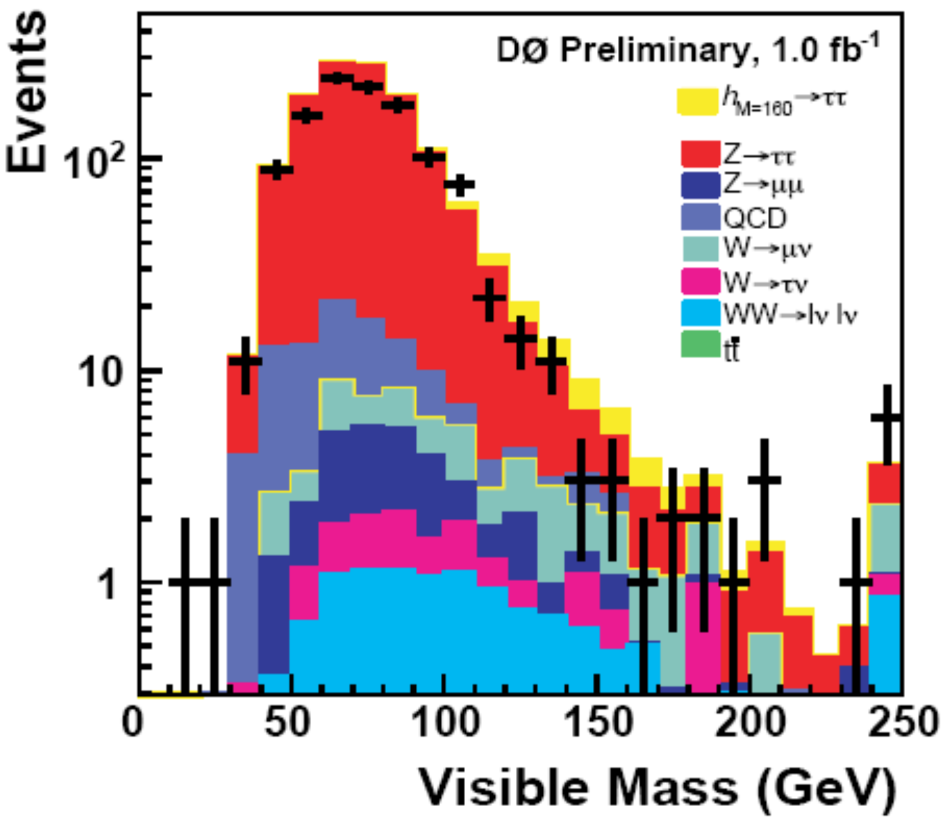


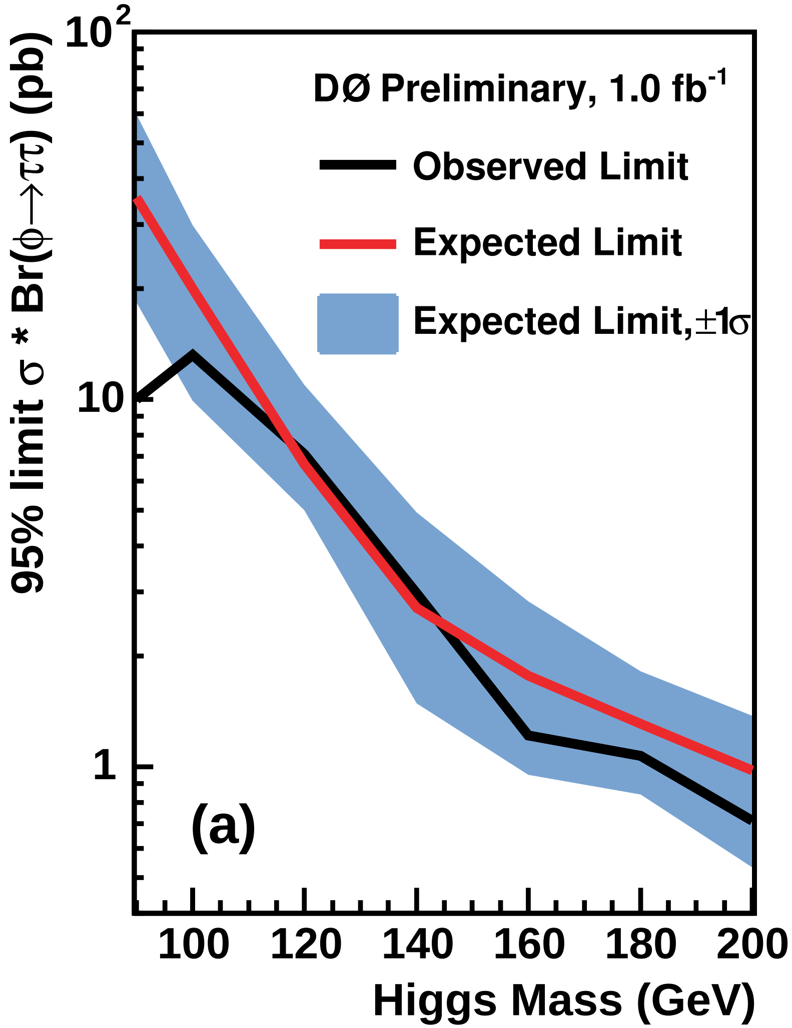


- 2σ excess at $m_A \approx$150 GeV
- would correspond to tan$\beta\approx$50
- confirmed by DØ?

Search for SUSY Higgs: $\Phi \rightarrow \tau\tau$

February 2007: new DØ results with 1 fb^{-1}

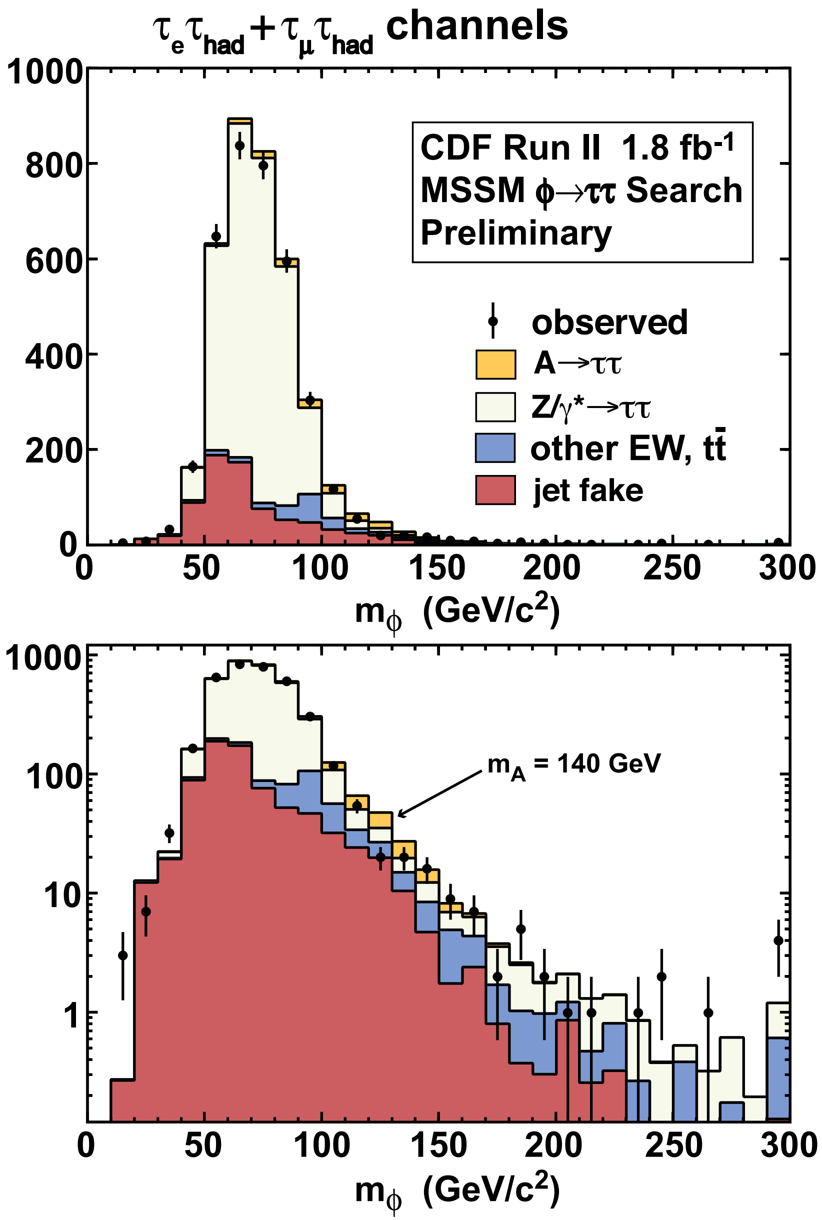


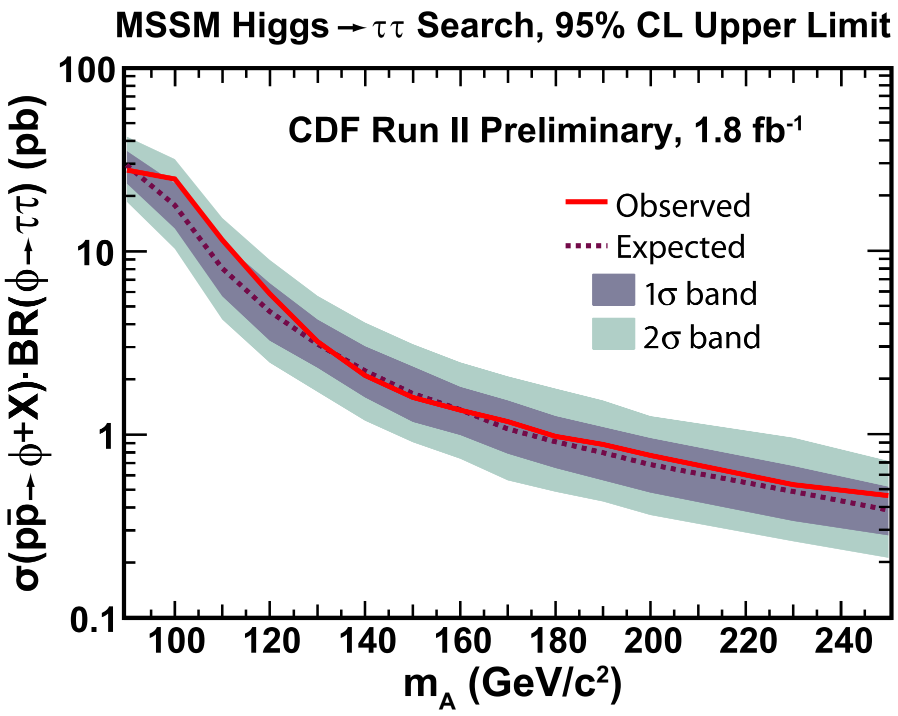


→ unfortunately no confirmation of signal

Search for SUSY Higgs: $\Phi \rightarrow \tau\tau$

October 2007: new CDF results with 1.8 fb^{-1}



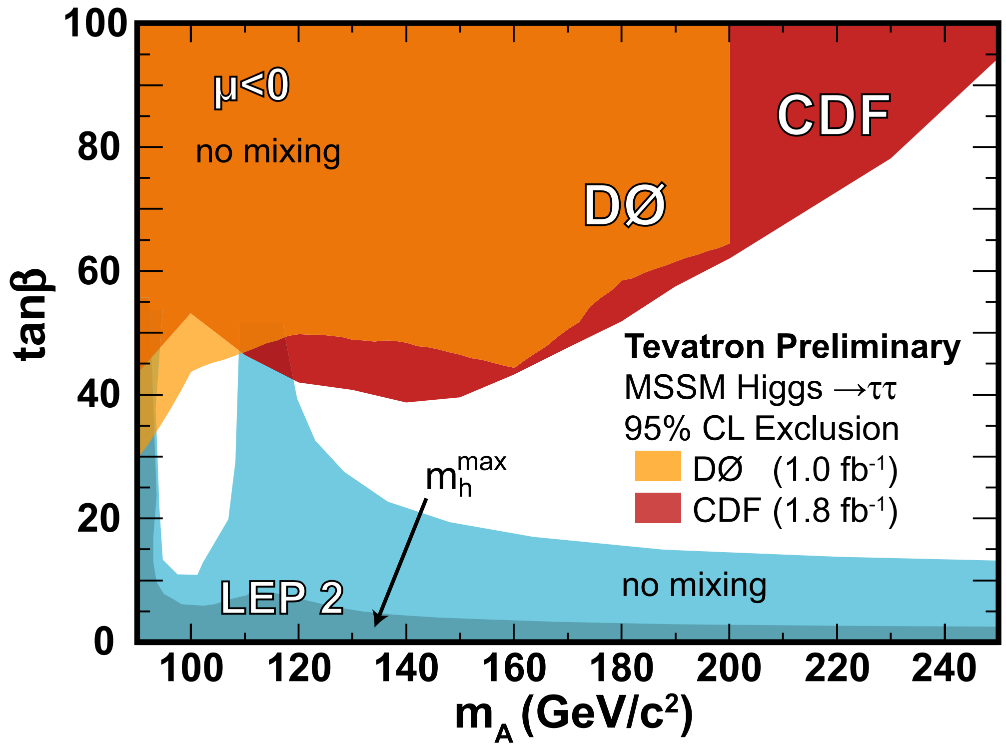


– Excess is gone

Search for SUSY Higgs: $\Phi \rightarrow \tau\tau$

Interpretation within MSSM: limits on tanβ as a function of m_A

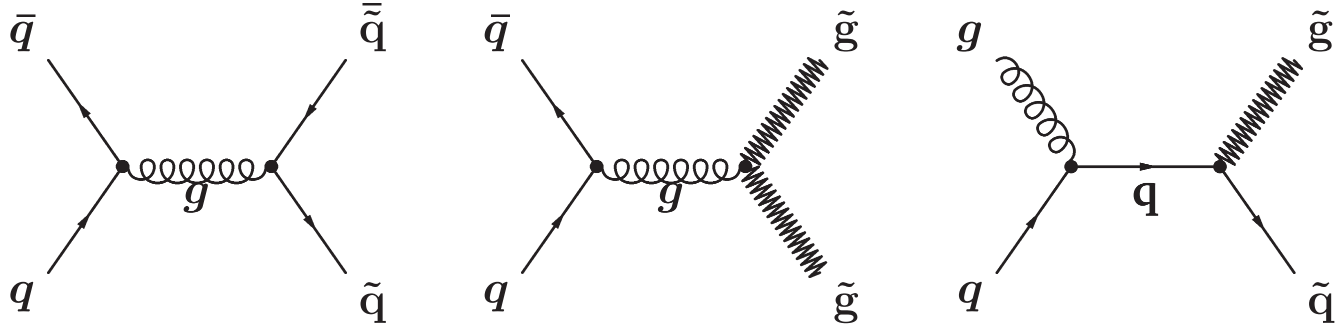
- based on DØ 1 fb^{-1} $\mu\tau_h$, CDF 1.8 fb^{-1} $\mu\tau_h$, $e\tau_h$, $e\mu$
- limits from bbh channels currently not competitive
- no Tevatron combination yet
- benchmark scenarios: no-mixing and mhmax



Expect to reach sensitivity to tan$\beta\approx$20 with full Run II dataset

In addition: expect to probe large m_A with WH/ZH channels

Search for Supersymmetry – Squarks/Gluinos

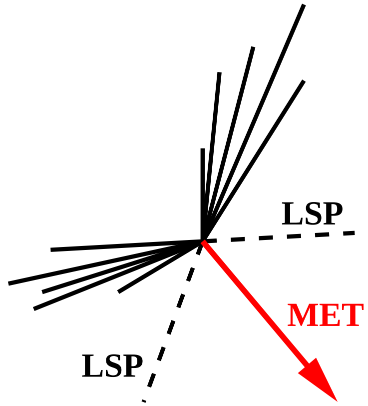


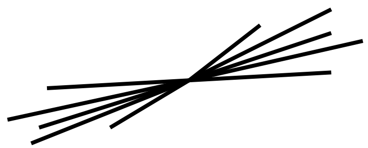
- **Squarks/Gluinos produced via strong interaction**
  $\longrightarrow$ **large cross sections at hadron colliders**
- **Decays: jets + LSP**
  - **LSP assumed to be stable (R_p conserved)**

  $\longrightarrow$ **Signature: jets + $\not{E}_T$**
- **Data collected with dedicated triggers:**
  acoplanar jets + $\not{E}_T$

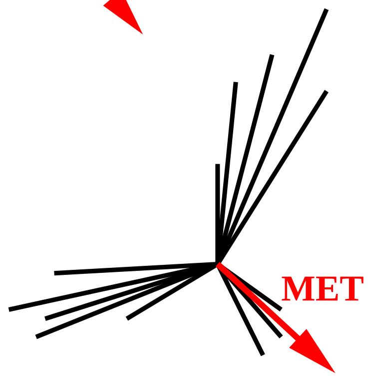
Mass region	Main Channel	Signature
$m_{\tilde{q}} < m_{\tilde{g}}$	$\tilde{q}\tilde{q}$	2j + $\not{E}_T$
$m_{\tilde{q}} > m_{\tilde{g}}$	$\tilde{g}\tilde{g}$	4j + $\not{E}_T$
$m_{\tilde{q}} \approx m_{\tilde{g}}$	$\tilde{q}\tilde{q}$,$\tilde{q}\tilde{g}$	3j + $\not{E}_T$

$\tilde{q}\tilde{q} \longrightarrow qq + \not{E}_T$





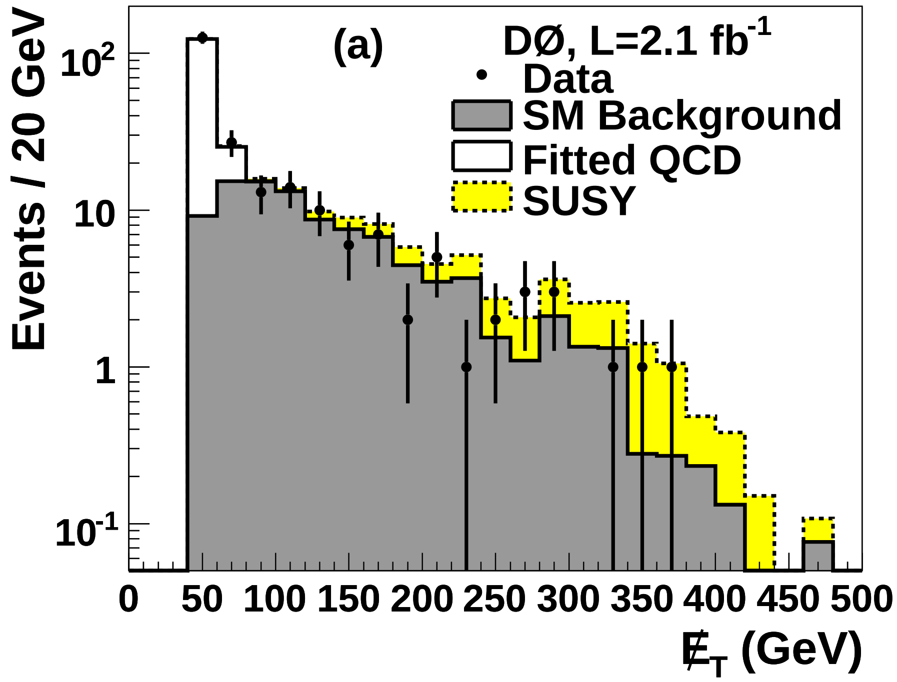
Dijet Background



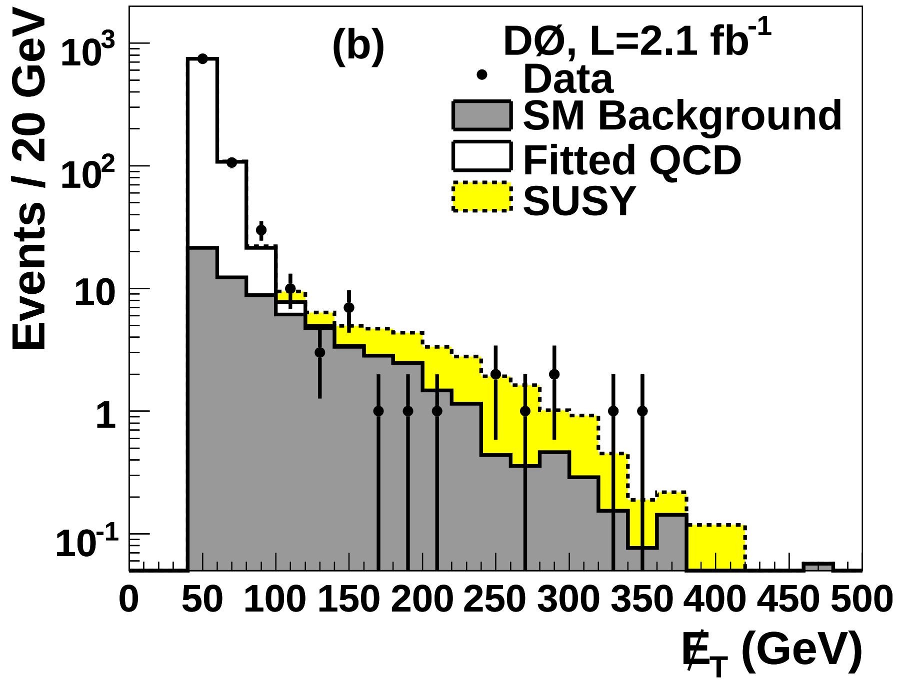
3-jet Background

Search for Supersymmetry – Squarks/Gluinos

2j+$\not\!\!E_T$ analysis



3j+$\not\!\!E_T$ analysis

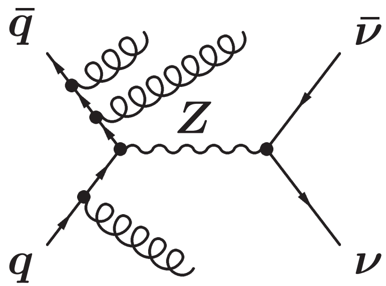


Main backgrounds:

– Multijets with fake $\not\!\!E_T$

– W+jets with W$\to e\nu, \mu\nu, \tau\nu$

– Z+jets with Z$\to \nu\bar{\nu}$



Main selection cuts:

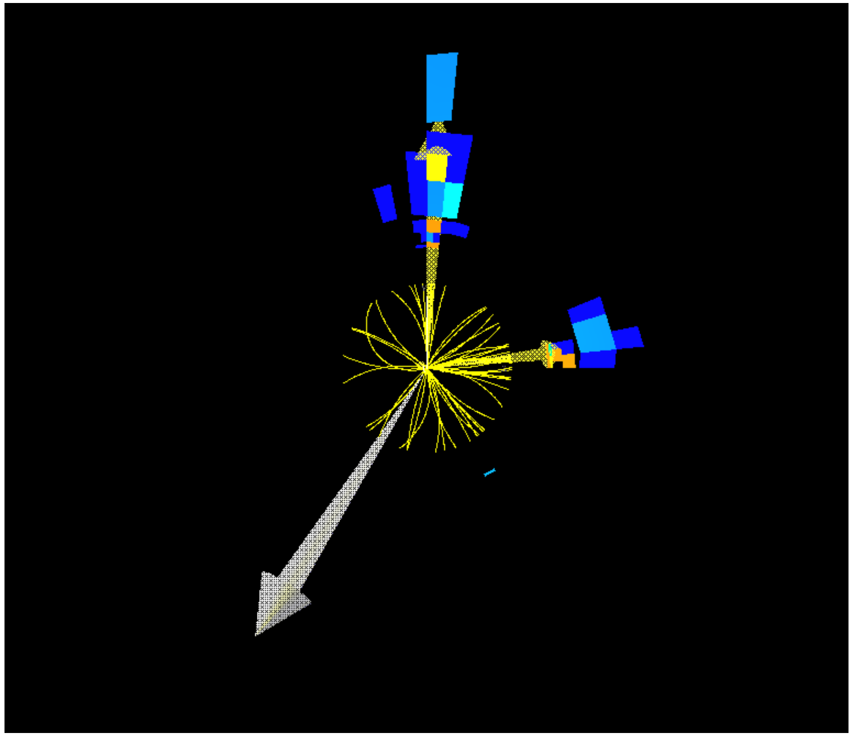
– 2/3/4 jets and large $\not\!\!E_T$

– angular separation $\not\!\!E_T$, jets

– isolated lepton veto

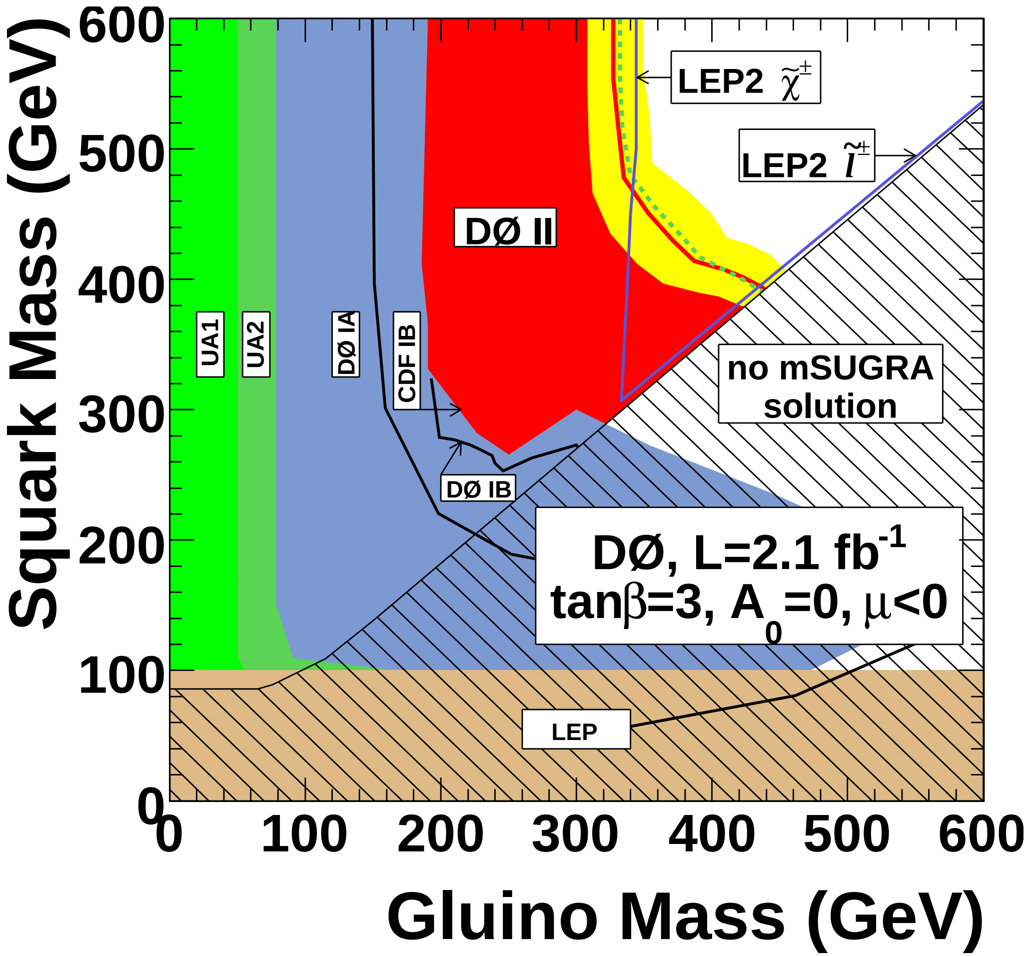
Mass region	Main Channel	Signature	$\not\!\!E_T$	$H_T = \sum p_T^{jet}$	Exp. Bckgd.	Data
$m_{\tilde{q}} < m_{\tilde{g}}$	$\tilde{q}\tilde{q}$	2j + $\not\!\!E_T$	>225 GeV	>325 GeV	11±3	11
$m_{\tilde{q}} > m_{\tilde{g}}$	$\tilde{g}\tilde{g}$	4j + $\not\!\!E_T$	>100 GeV	>400 GeV	18±5	20
$m_{\tilde{q}} \approx m_{\tilde{g}}$	$\tilde{q}\tilde{q}$,$\tilde{q}\tilde{g}$	3j + $\not\!\!E_T$	>175 GeV	>375 GeV	11±3	9

Search for Supersymmetry – Squarks/Gluinos



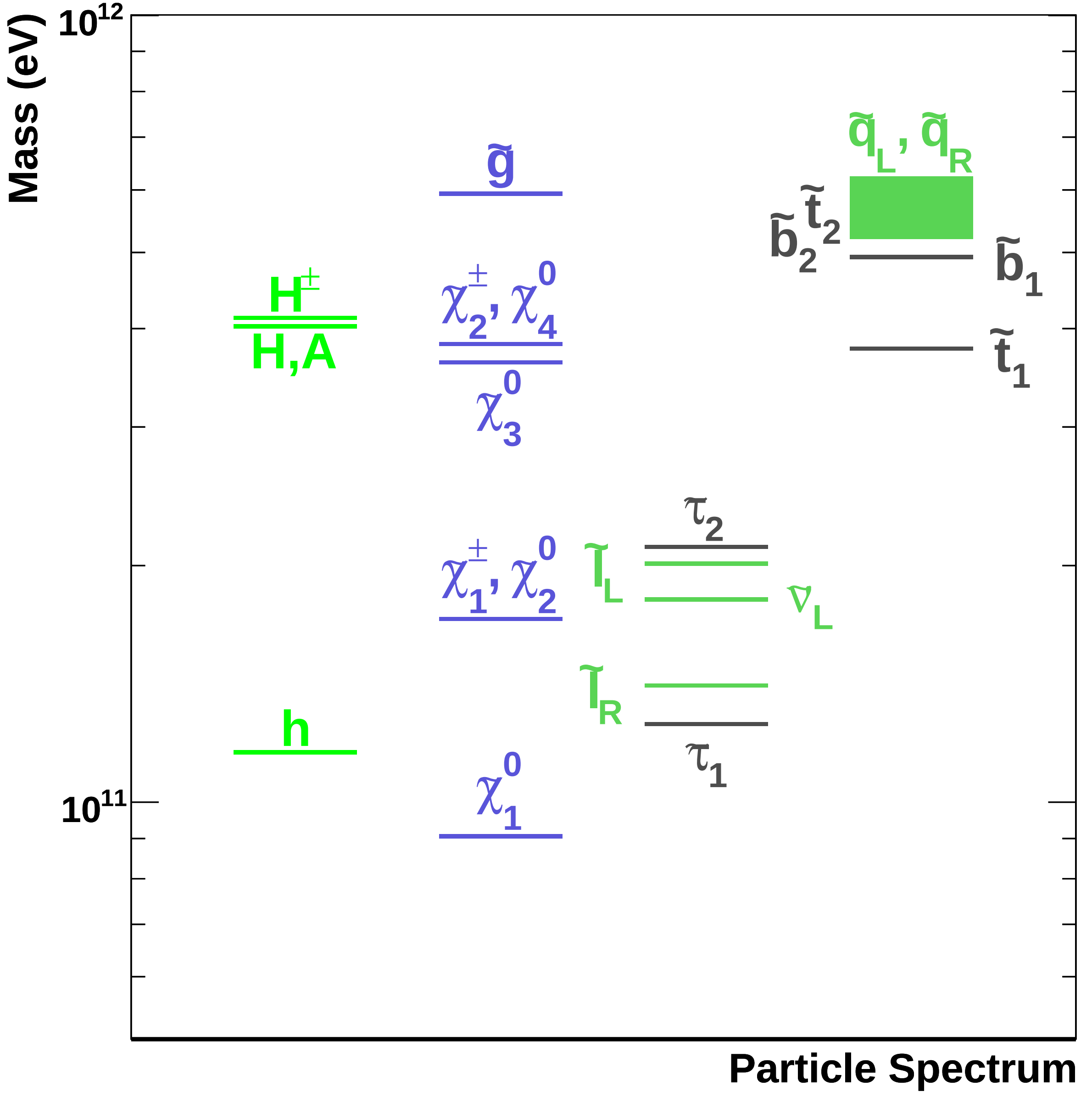
$\tilde{q}\tilde{q}$ candidate event

($\not{E}_T$=368 GeV, p_T^{j1}=282 GeV, p_T^{j2}=174 GeV)



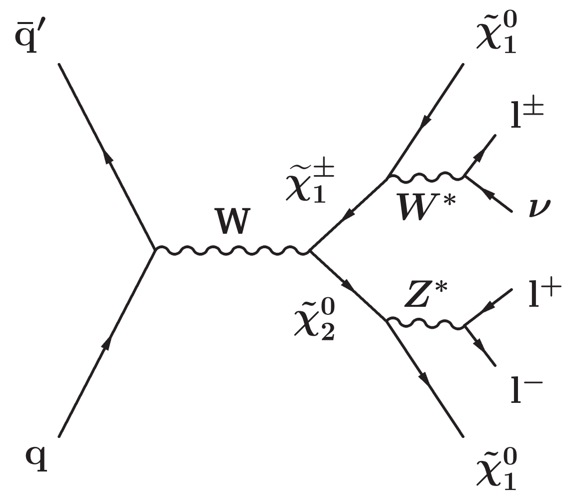
- No evidence for squark/gluino production at the Tevatron
- New limits in squark/gluino mass plane (mSUGRA: tanβ=3, $A_0 = 0$, $\mu < 0$)
- Sensitivity beyond indirect limits from LEP

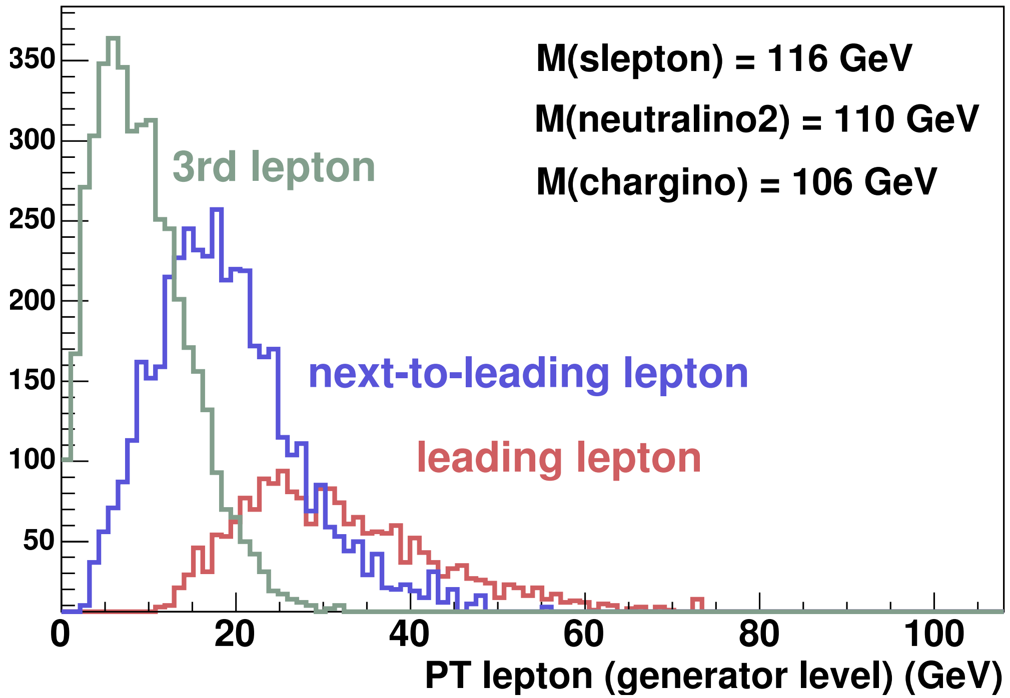
What other particles does SUSY predict?



Search for Charginos and Neutralinos

- **Production cross section (electroweak) relatively small**
  $\longrightarrow$ need clean leptonic signature to suppress backgrounds
- **Golden channel: $\tilde{\chi}^{\pm}\tilde{\chi}^0_2 \longrightarrow 3\ell + \not{E}_T$**
- **Experimental Challenge: low-p_T leptons**
  $\longrightarrow$ need multilepton triggers with low thresholds
  $\longrightarrow$ need efficient lepton identification at low p_T





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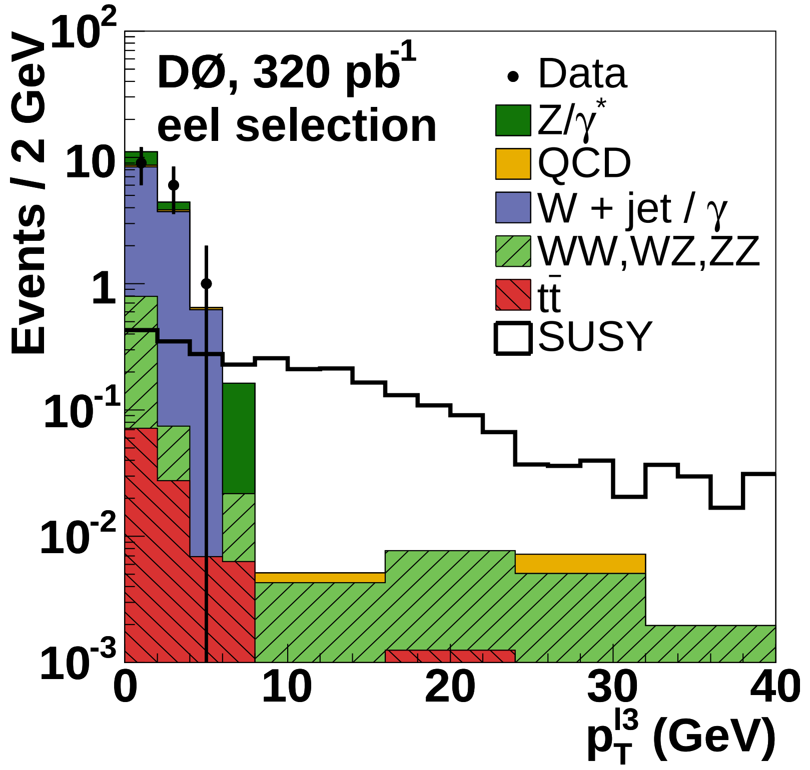
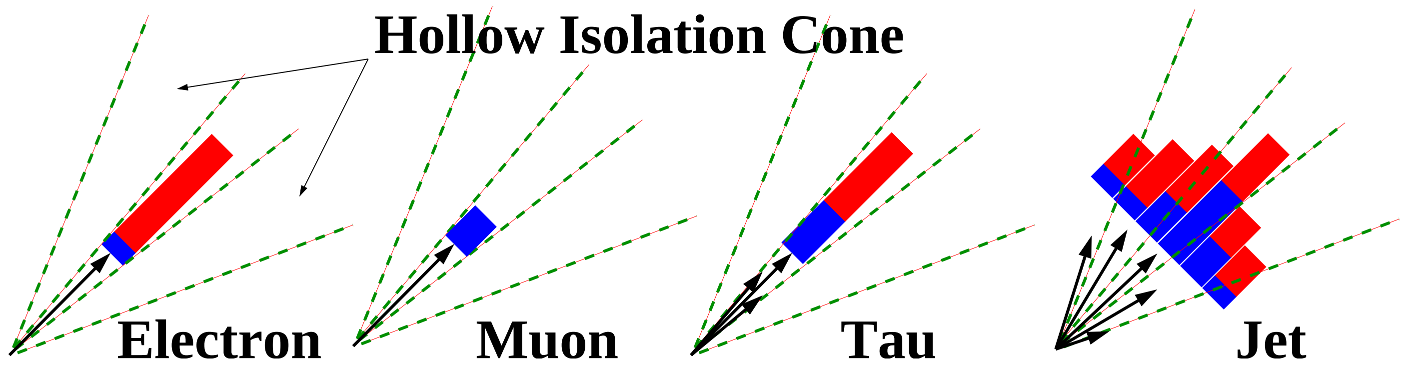


Analysis Strategy:

- two identified leptons plus isolated track
- isolation criteria designed to be efficient for electrons, muons and hadronic τ-decays

Transverse momentum thresholds (DØ):

Selection	$p_T^{\ell 1}$	$p_T^{\ell 2}$	$p_T^{\ell 3}$
$ee\ell$	$>$12 GeV	$>$8 GeV	$>$4 GeV
$e\mu\ell$	$>$12 GeV	$>$8 GeV	$>$5 GeV
$\mu\mu\ell$	$>$12 GeV	$>$8 GeV	$>$4 GeV
ls-$\mu\mu$	$>$11 GeV	$>$5 GeV	–



Search for Charginos and Neutralinos

DØ Results (0.9–1.7 fb^{-1}):

Selection	Expected Background	Observed	Signal ($m_{\tilde{\chi}^\pm}$=110 GeV)
$ee\ell$	1.8±0.7	0	6.8±0.4
$e\mu\ell$	0.9±0.4	0	4.0±0.2
$\mu\mu\ell$	0.3±0.8	2	2.5±0.2
ls-$\mu\mu$	1.1±0.4	1	4.2±0.7
Combined	4.1±1.2	3	17.5±0.8

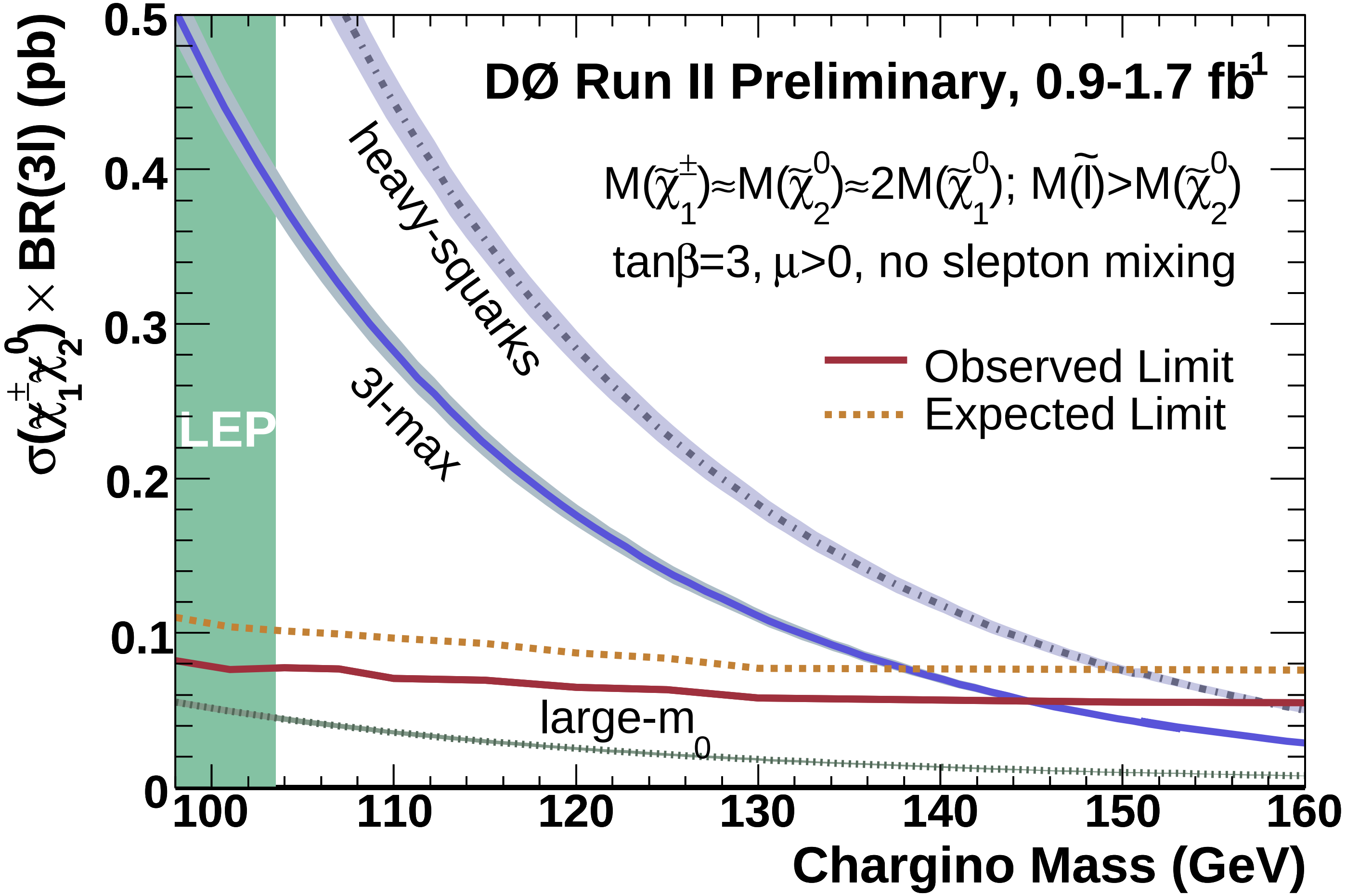
CDF Results (2 fb^{-1}):

(t=tight,l=loose)	3t	2t,1l	1t,2l	2t+trk	1t,1l+trk
Expected Background	0.5±0.1	0.25±0.04	0.14±0.03	3.2±0.7	2.3±0.6
Observed	1	0	0	4	2
Signal ($m_{\tilde{\chi}^\pm}$=120 GeV)	2.3±0.3	1.6±0.2	0.7±0.1	4.4±0.7	2.4±0.4

→ No evidence for chargino/neutralino production

→ Limits on product of cross section and leptonic branching fraction

Search for Charginos and Neutralinos

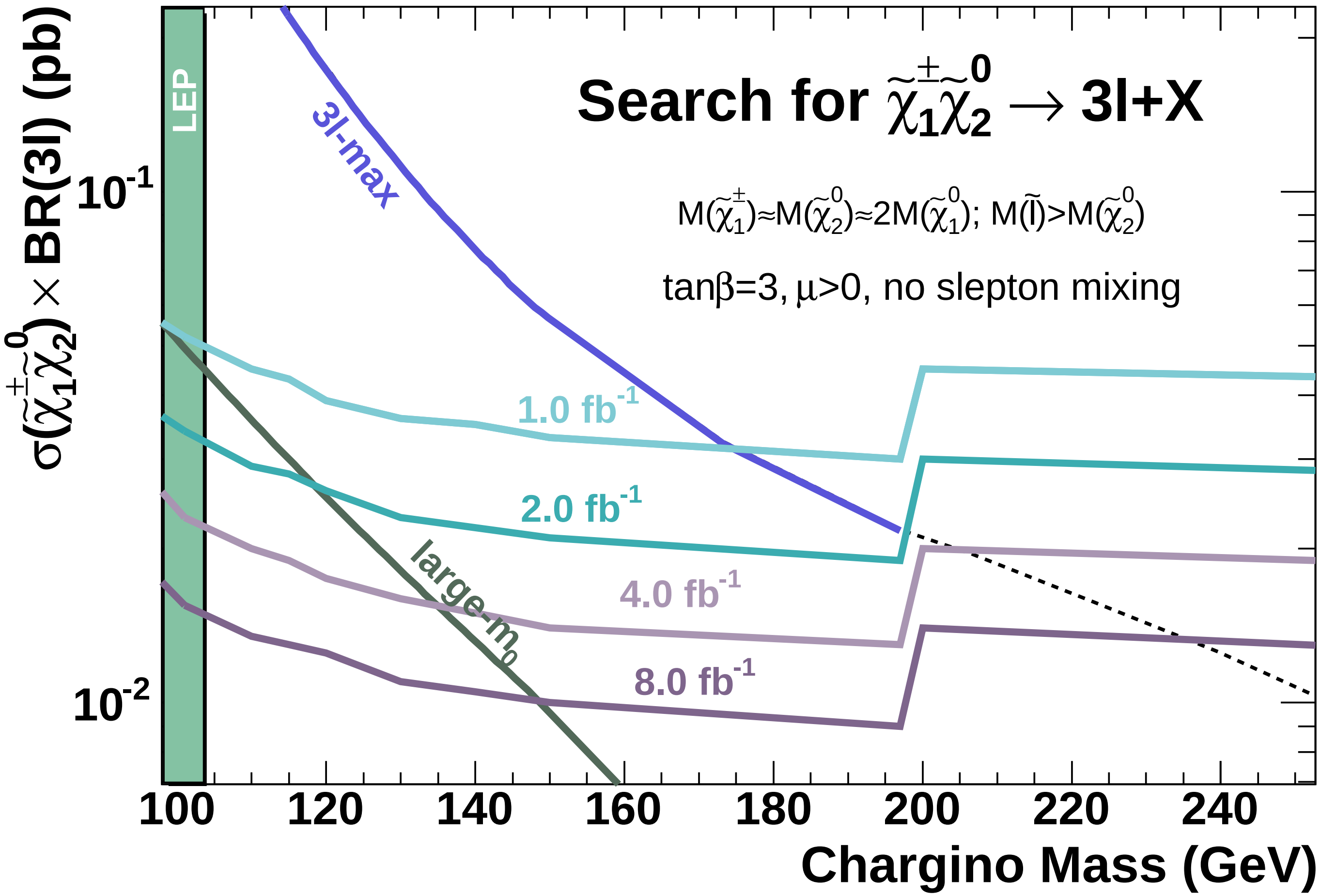


Limits constrain SUSY beyond LEP chargino limits:

- **3ℓ-max scenario: $m_{\tilde{\chi}^\pm} > 145$ GeV**

Updates with 3 fb^{-1} datasets currently in progress

Search for Charginos and Neutralinos



Run II projections (combining CDF and DØ):

- 3ℓ-max scenario: will probe $m_{\tilde{\chi}^{\pm}} > 200$ GeV
- large-m_0 scenario: sensitive up to $m_{\tilde{\chi}^{\pm}} \approx 150$ GeV

Updates with 3 fb^{-1} datasets currently in progress

Beyond mSUGRA

Many other SUSY models on the market → large variety of SUSY searches at the Tevatron

Gauge-Mediated SUSY Breaking

- Inclusive $\gamma\gamma + \not{E}_T$: charginos excluded up to 229 GeV (DØ)
- Long-lived neutralinos: limits up to 101 GeV (CDF)

Anomaly-Mediated SUSY Breaking

- Stable charginos: excluded up to 174 GeV (DØ)

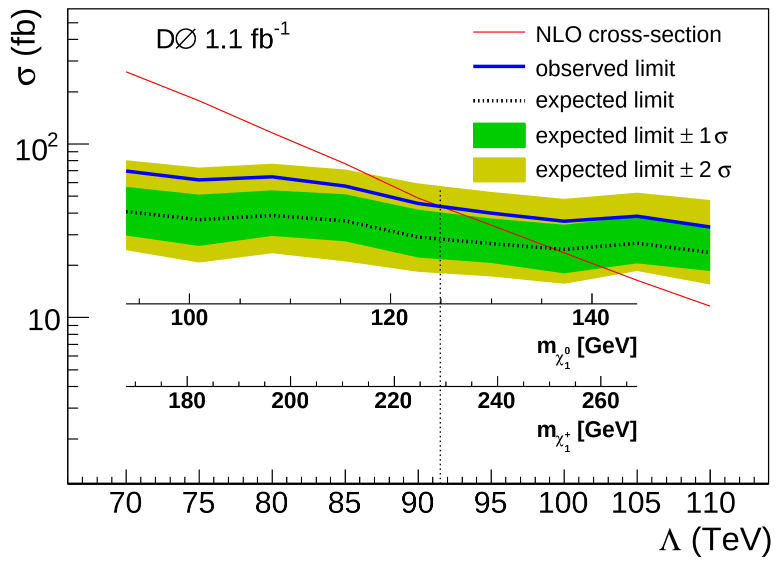
Split Supersymmetry

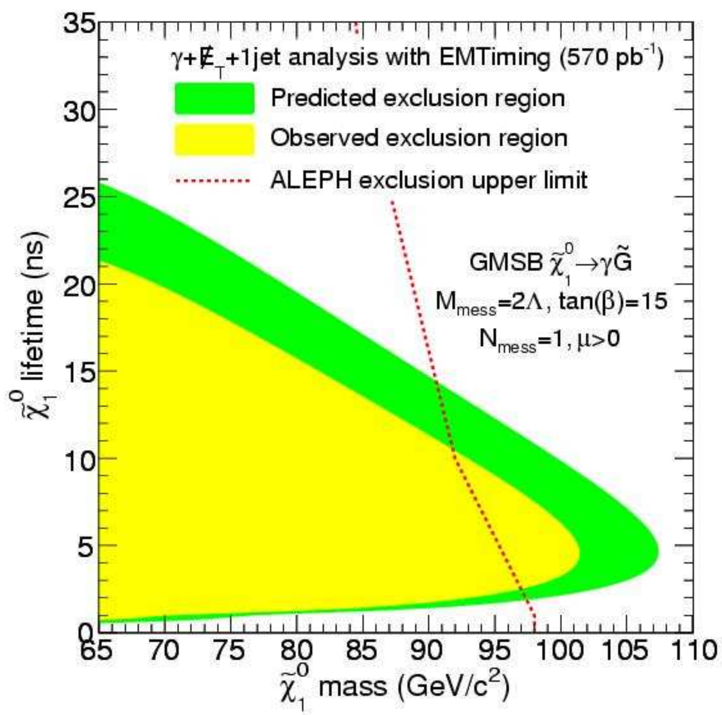
- Long-lived Gluinos $\tilde{g} \rightarrow g\tilde{\chi}_1^0$:

  limits up to 320 GeV for lifetimes up to 100 hours (DØ)

R-Parity Violation

- LLE couplings: limits on charginos up to 234 GeV (DØ)





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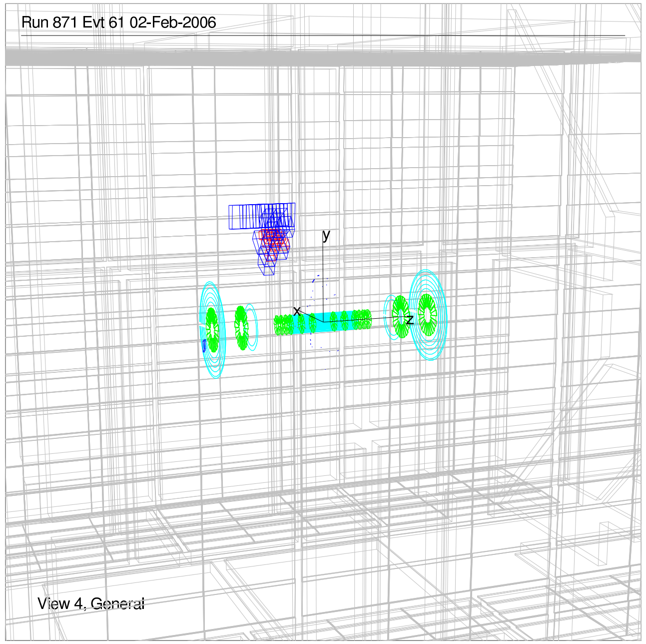

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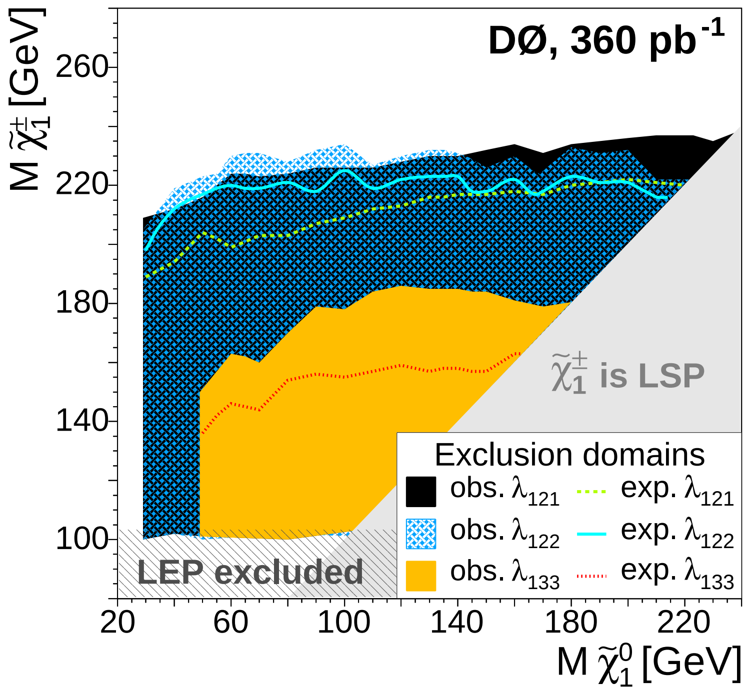
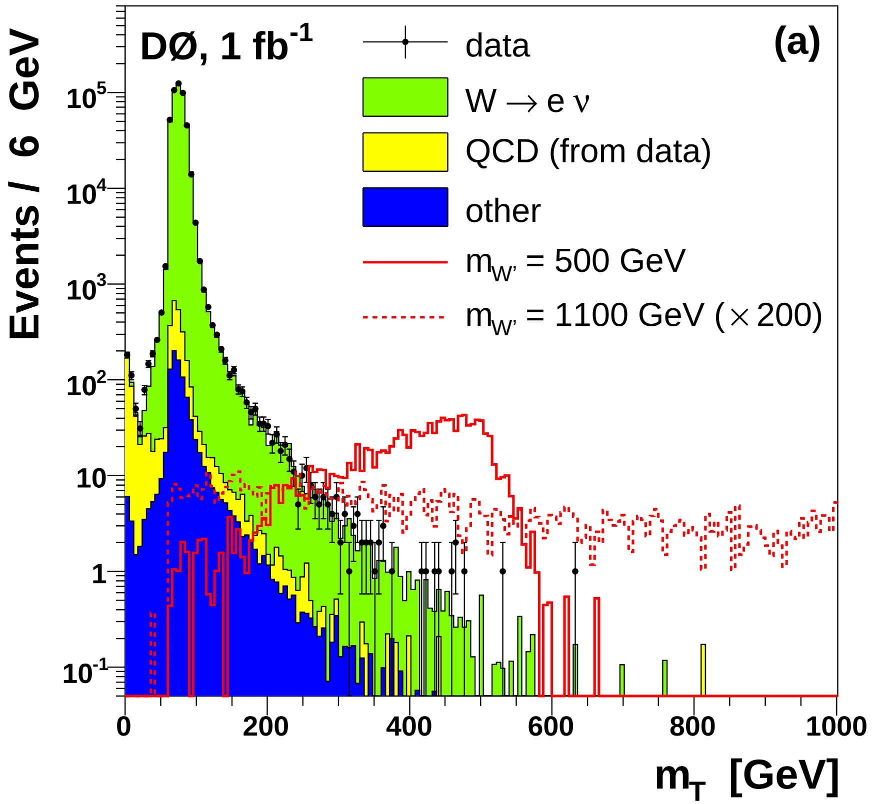


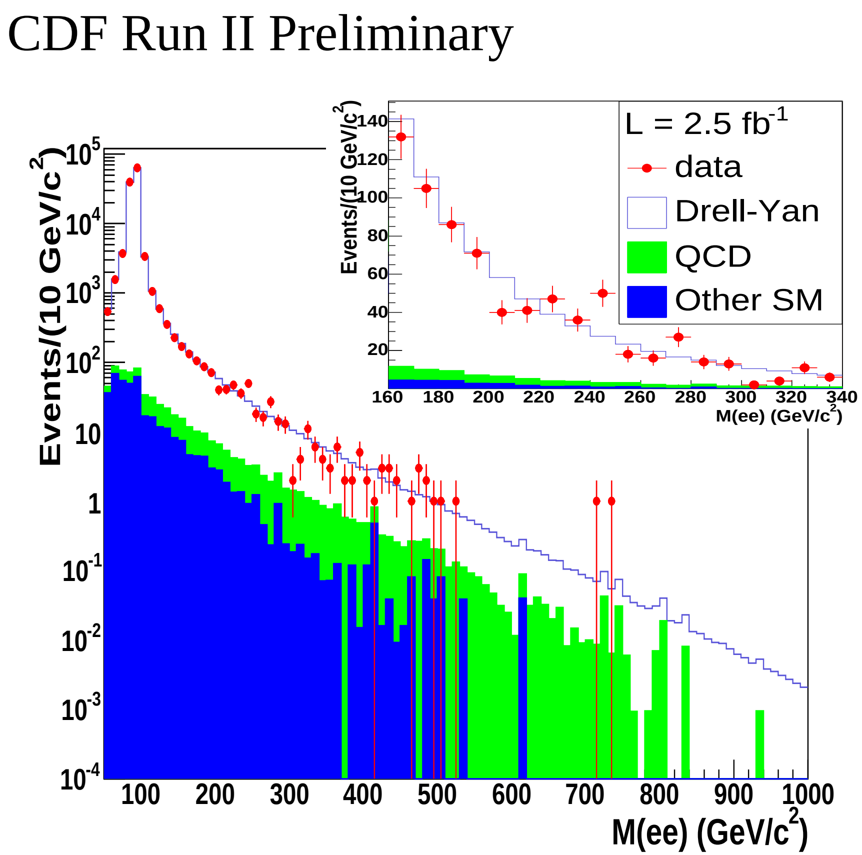
Beyond Supersymmetry – Heavy Resonances

Searches for heavy charged or neutral difermion resonance X:

- **Channels considered for $X^0 \rightarrow f\bar{f}$: ee, $\mu\mu$, $\tau\tau$, $q\bar{q}$, $t\bar{t}$ (plus eμ, $\gamma\gamma$)**
- **Channels considered for $X^{\pm} \rightarrow f f'$: eν, $q\bar{q}$, tb**



DØ: $M_{W'} > 1.0$ TeV



CDF: $M_{Z'} > 966$ GeV

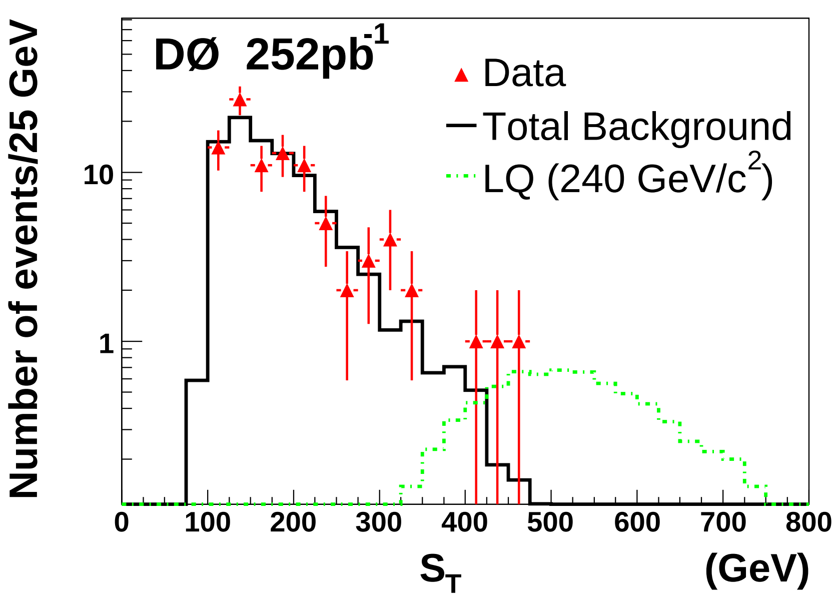
Beyond Supersymmetry – Heavy Resonances

Searches for Leptoquarks LQ$\to$lq:

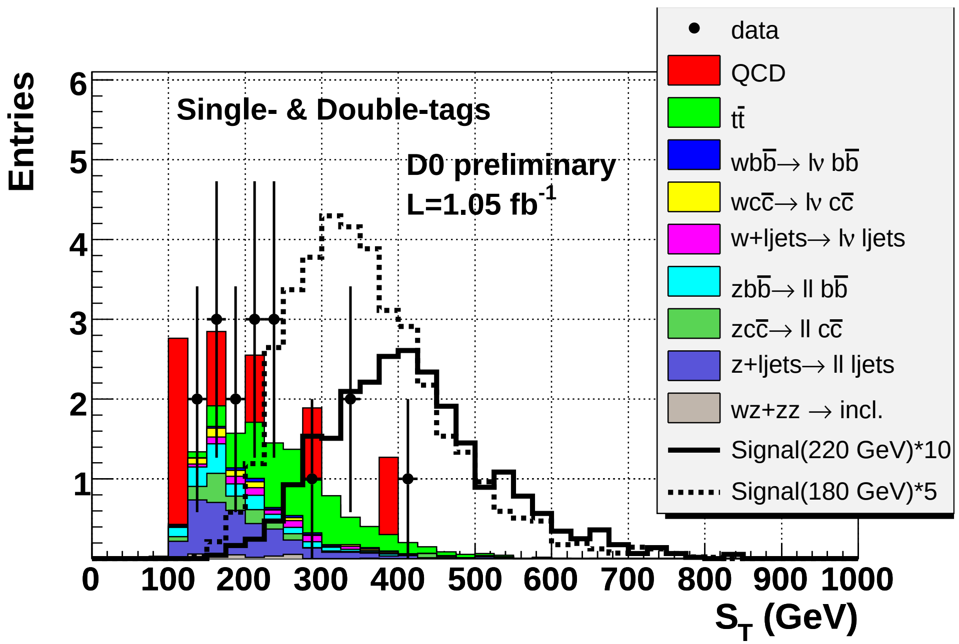
- Final states considered: eeqq, eνqq, $\mu\mu$qq, $\mu\nu$qq, $\nu\nu$qq, $\tau\tau$bb, $\nu\nu$bb
- High LQ mass $\to$ decay products with high transverse momenta

  $\to$ check for excess at high $S_T = p_T^1 + p_T^2 + p_T^3 + p_T^4$

1st Generation (eeqq)



3rd Generation ($\tau\tau$bb)



Mass limits for BR(LQ$\to$lq)=1:

- 1st Generation: M>256 GeV
- 2nd Generation: M>251 GeV
- 3rd Generation: M>180 GeV

Conclusions

Tevatron is running very well: 3 fb^{-1} on tape, good prospects for 8 fb^{-1} by 2010

Precision measurements of Top and W mass pinpoint SM Higgs boson mass

SM Higgs search finally reaching sensitivity

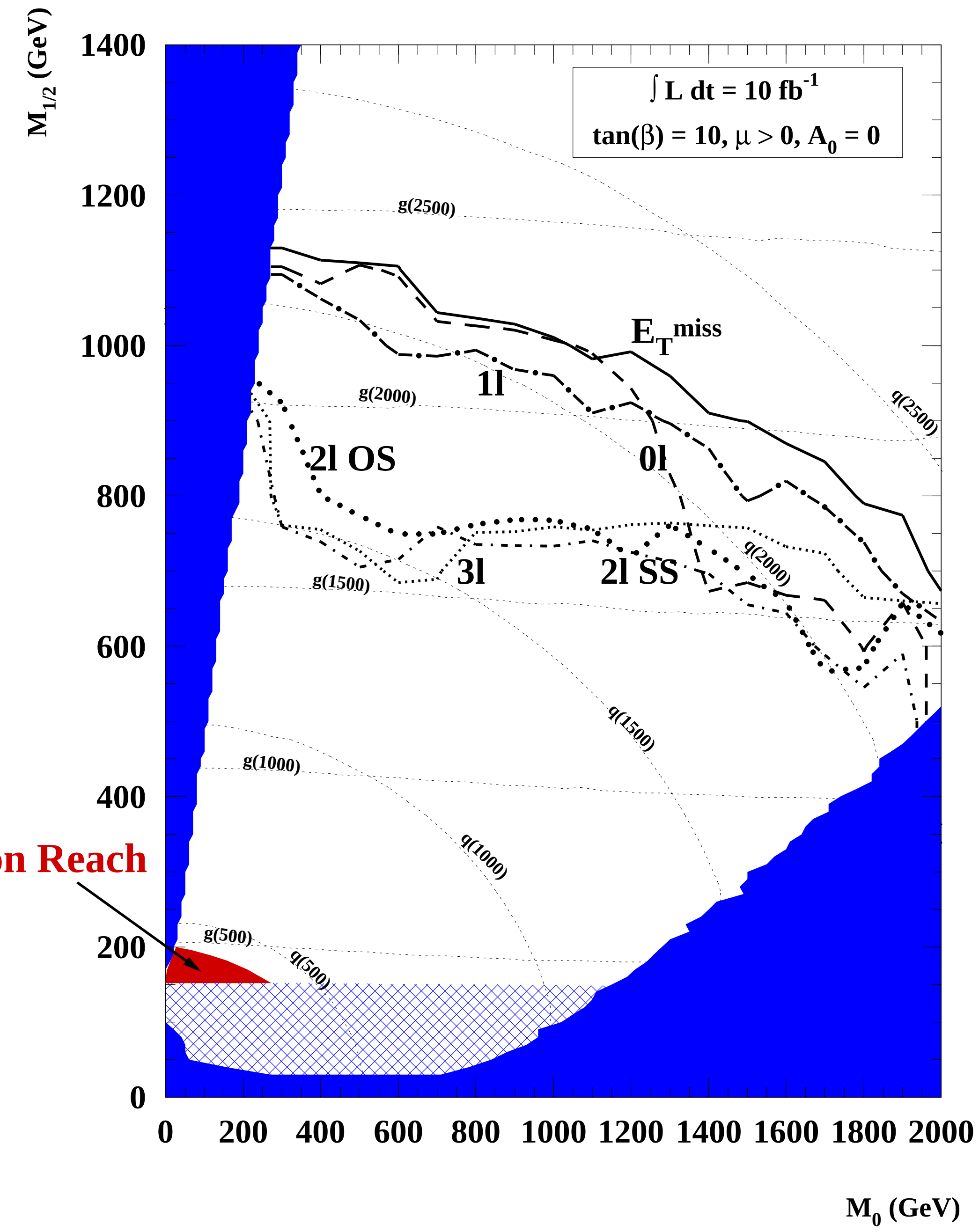
SUSY Higgs: limits on tanβ at low m_A (consistent with $B_s \rightarrow \mu\mu$)

Direct searches for Supersymmetry:

- Squarks, Gluinos: excluded below about 380 GeV, 310 GeV
- Charginos: excluded below 145 GeV (in favourable scenarios)
- numerous signatures and models beyond mSUGRA have been investigated

Searches for heavy resonances probing masses up to 1 TeV

Conclusions



Tevatron Reach

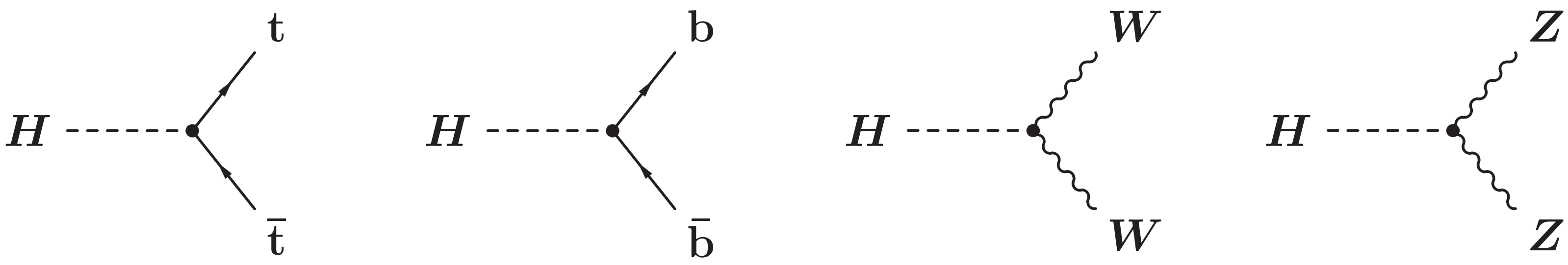
Still plenty of room for SUSY discovery at LHC!

BACKUP

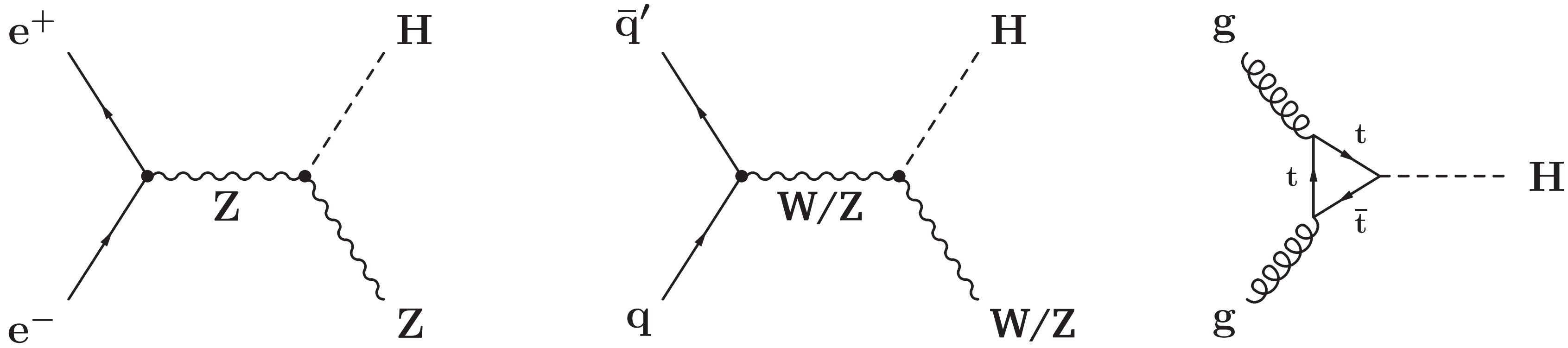
Direct Searches for the Higgs Boson

Direct detection of Higgs bosons requires large enough production rates

$\rightarrow$ **connect initial state (ee, qq, gg) with H using vertices with large couplings:**



Selection of good choices for e^+e^- and Hadron-Collider:



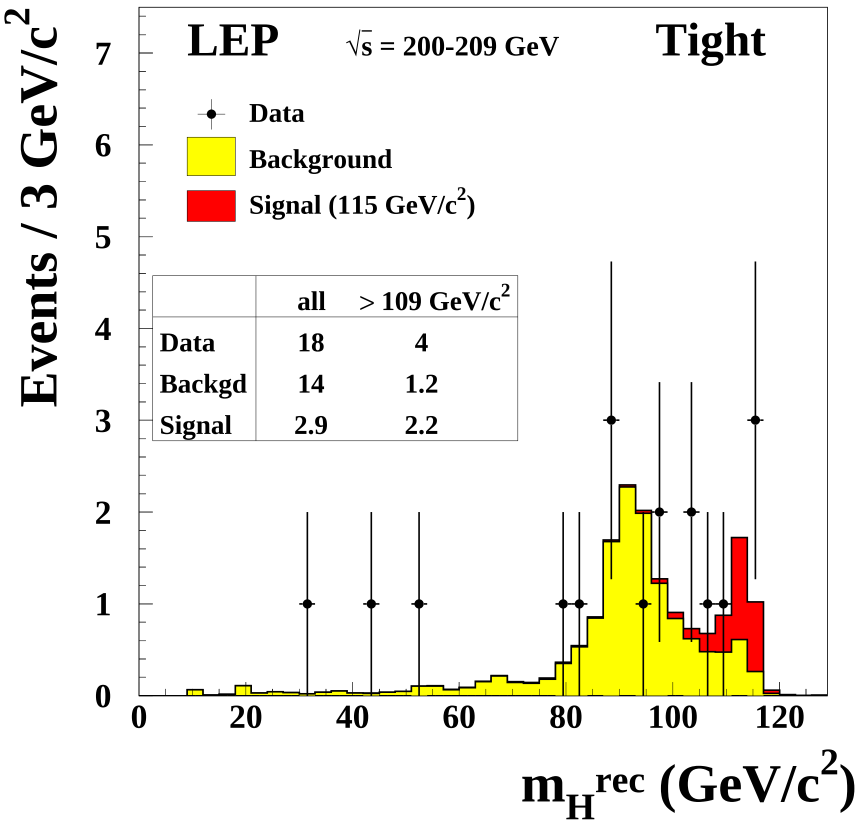
History: Higgs searches at LEP

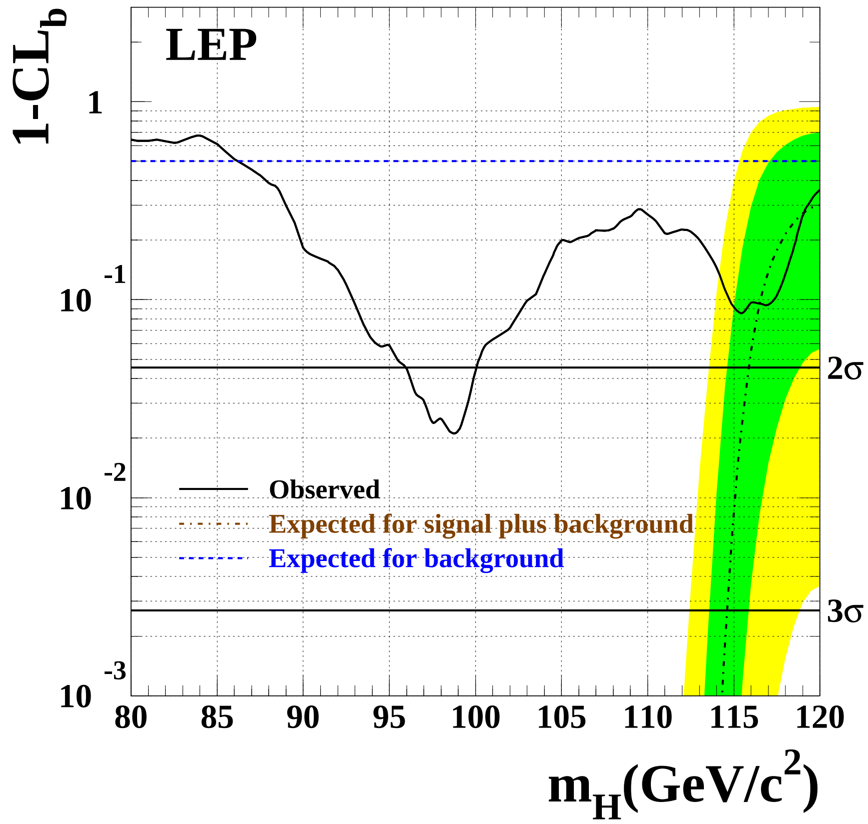
LEP: e^+e^- collider with centre-of-mass energy of up to 206–209 GeV

$\longrightarrow$ **kinematic limit for ZH production at about m_H = 116 GeV**

Slight excess (1.7 σ) at 115 GeV (mainly driven by ALEPH 4-jet channel)

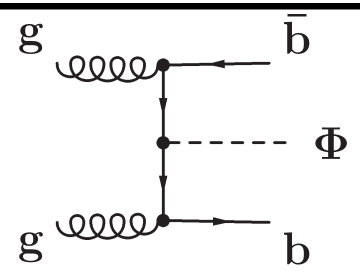
Limit on m_H at 95% C.L.: 114.4 GeV

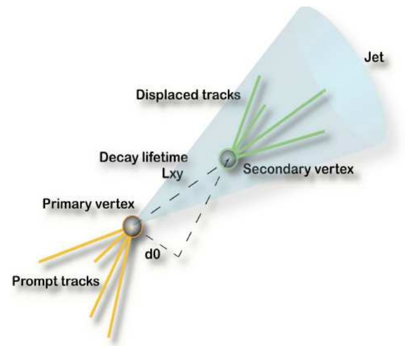


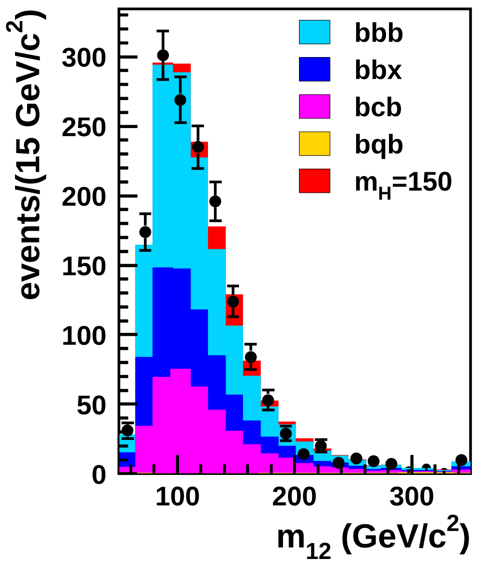


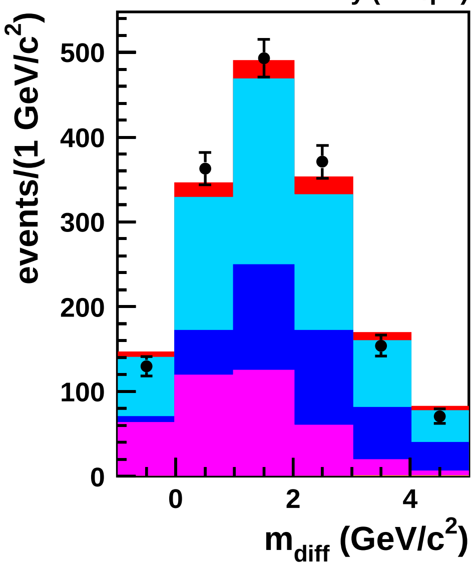
Search for SUSY Higgs: Φb(b)→bbb(b)

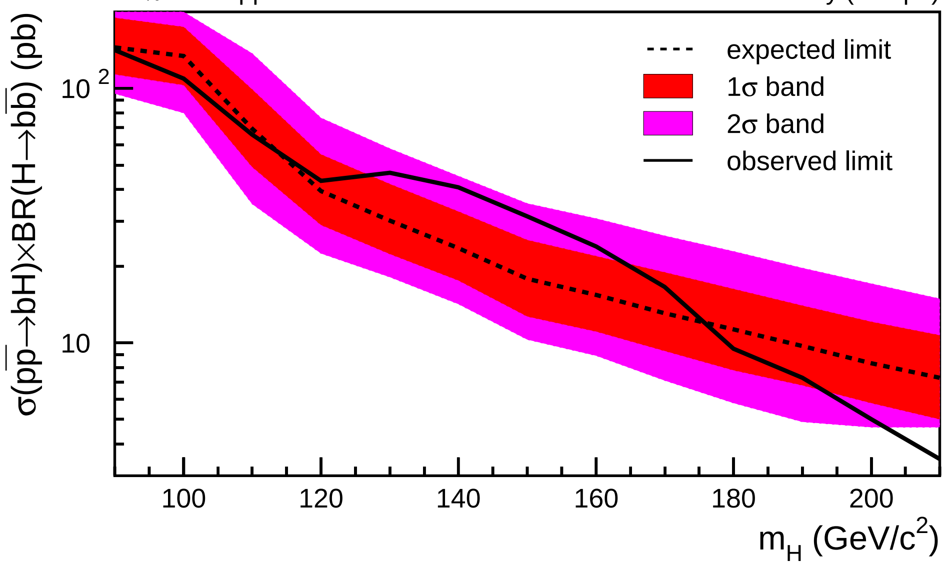
- Selection: at least 3 b-jets
- Backgrounds: multijet production
  - modelled extrapolating from 2-tag data
- Reconstruction of Higgs boson mass in $b\bar{b}$ spectrum
- Additional variable: $m_{diff} = m_{SV}^{j1} + m_{SV}^{j2} - m_{SV}^{j3}$
  - sensitive to flavour composition of the 3 b-tagged jets
- Limits derived from 2D-template fits to both variables



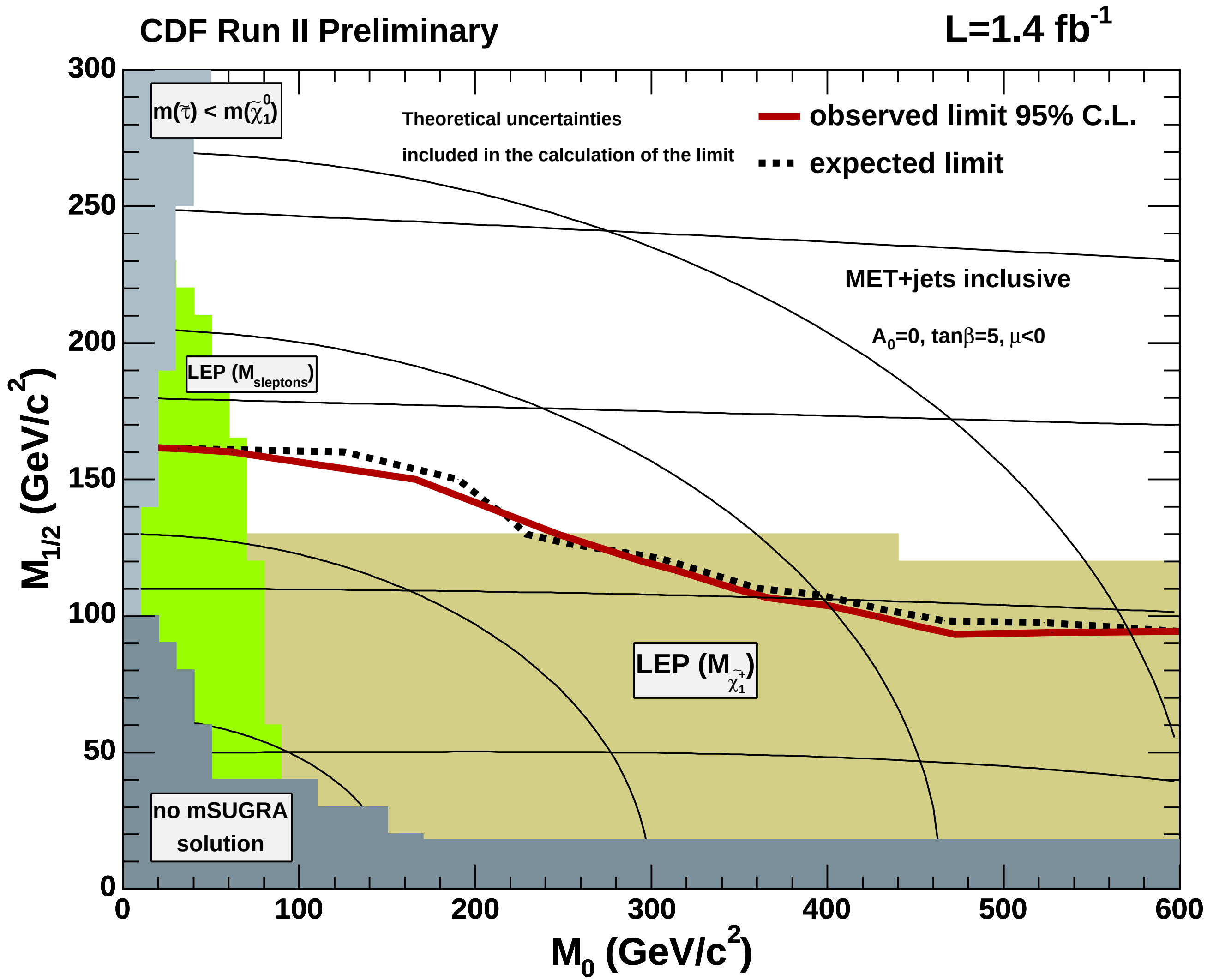






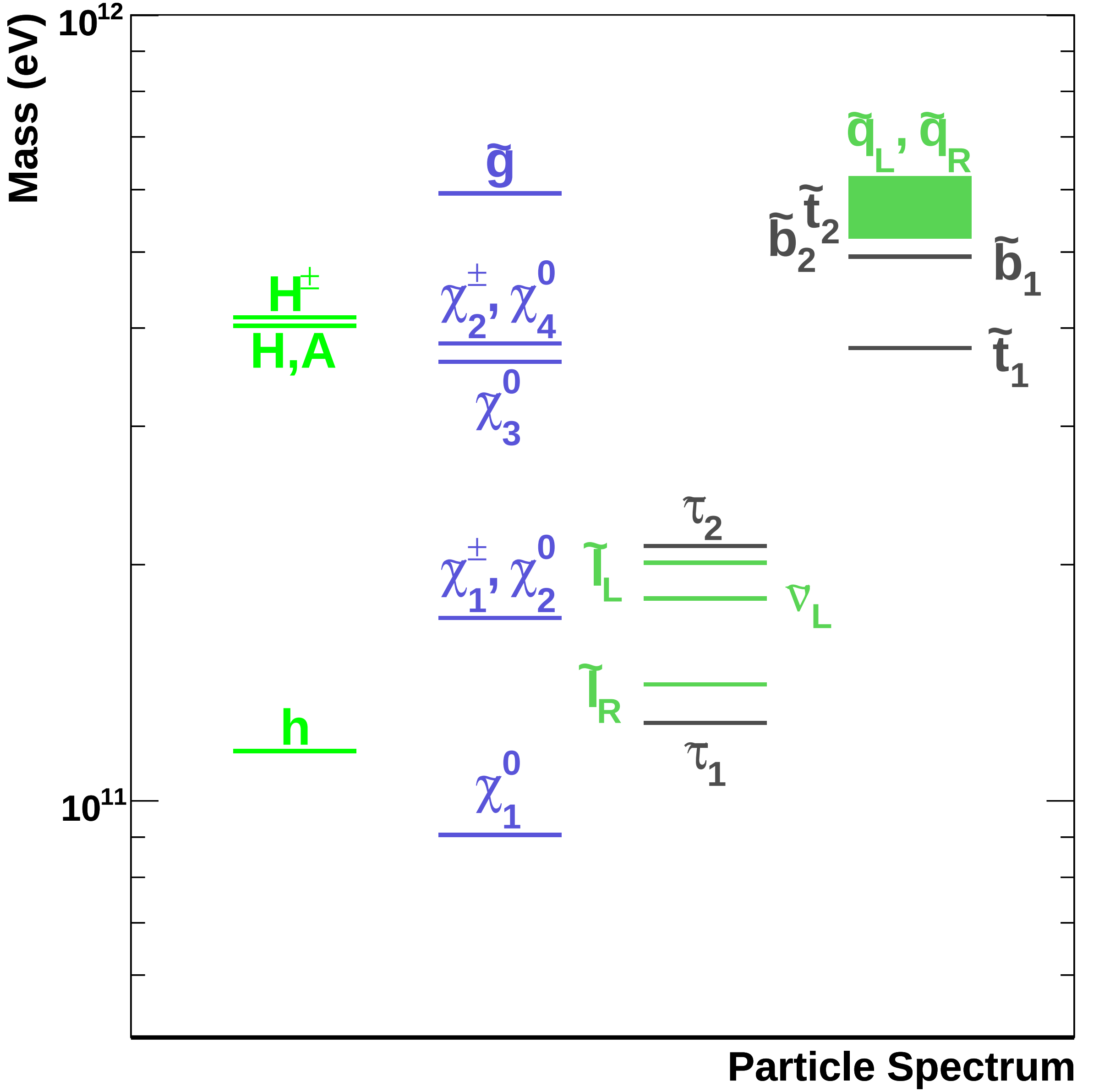


Search for Supersymmetry – Squarks/Gluinos



- No evidence for squark/gluino production at the Tevatron
- New limits in squark/gluino mass plane (mSUGRA: $tan\beta = 3$, $A_0 = 0$, $\mu < 0$)
- Sensitivity beyond indirect limits from LEP

What other particles does SUSY predict?

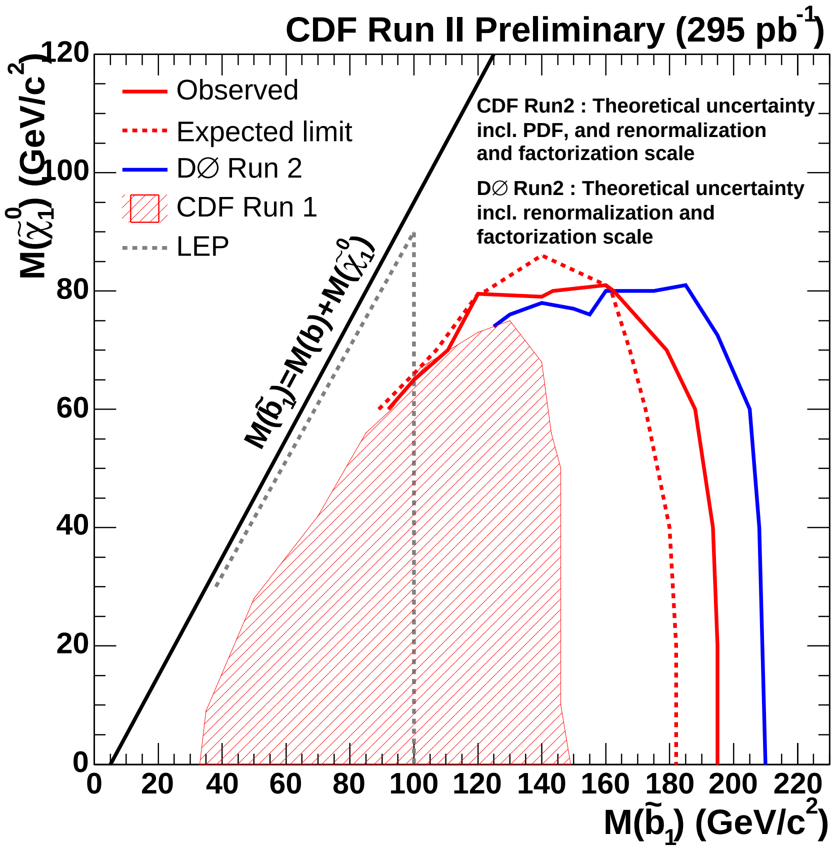


Search for Supersymmetry – Sbottoms/Stops

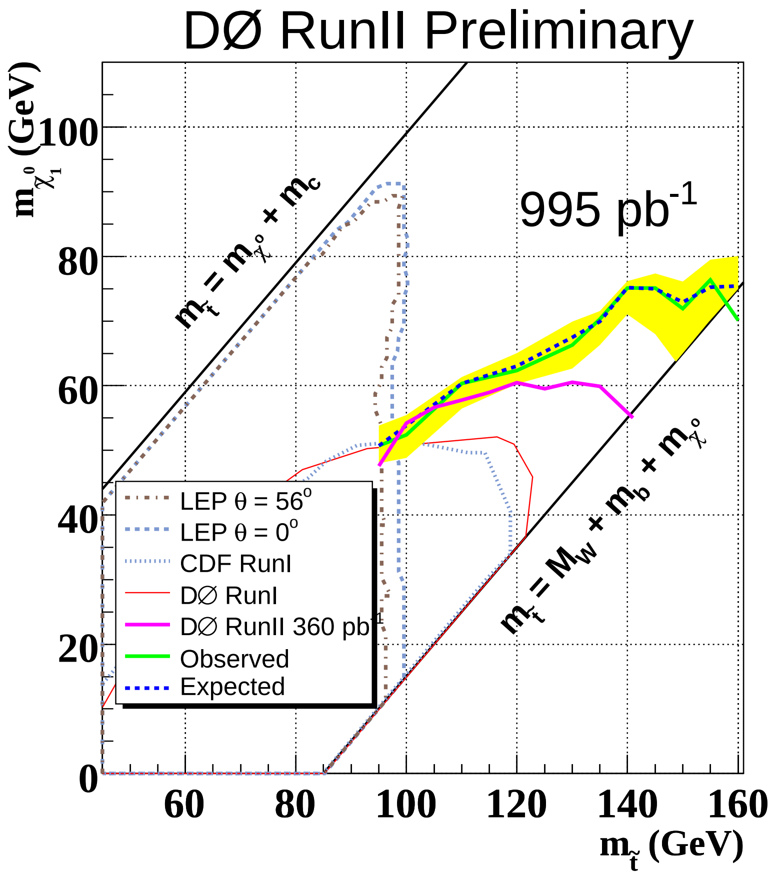
Dedicated searches for light sbottom or stop quarks

- can use b- and charm-tagging to substantially reduce backgrounds
- still significant potential with more integrated luminosity

$$\tilde{b} \rightarrow b + \tilde{\chi}_1^0$$



$$\tilde{t} \rightarrow c + \tilde{\chi}_1^0$$



Search for Supersymmetry – Sbottoms/Stops

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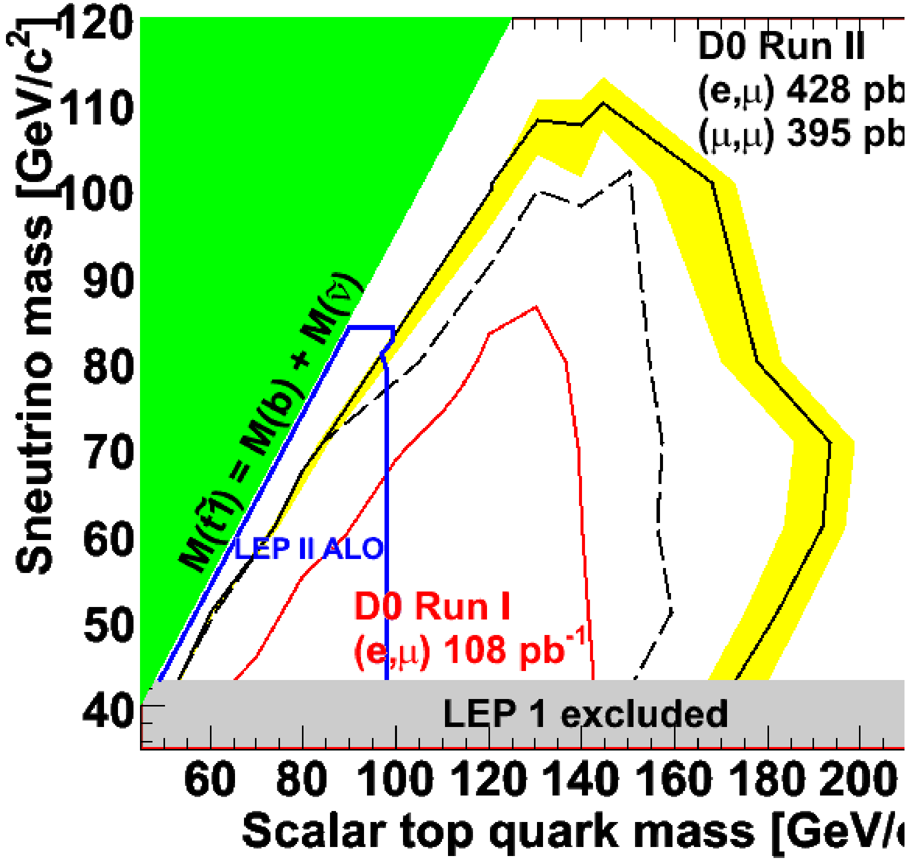
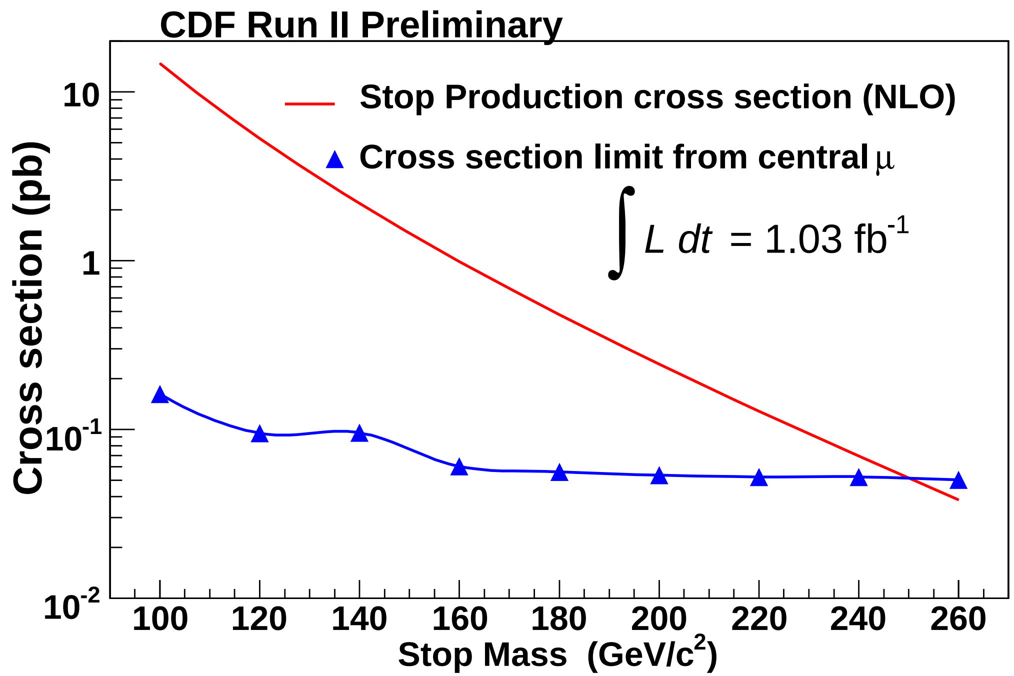
- still significant potential with more integrated luminosity

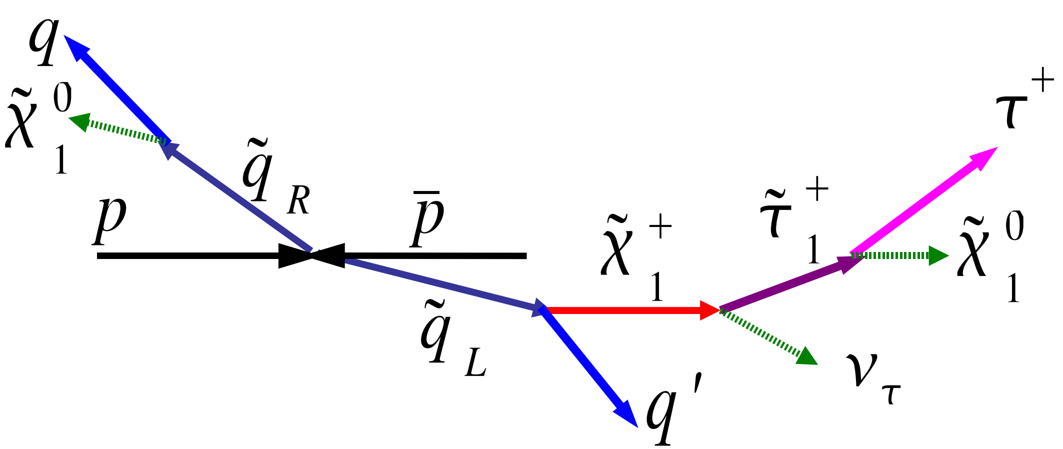
$\tilde{t} \rightarrow b + \ell + \tilde{\nu}$



stable stop quarks



Search for Supersymmetry – Squarks/Gluinos



High tan$\beta \longrightarrow$ light staus

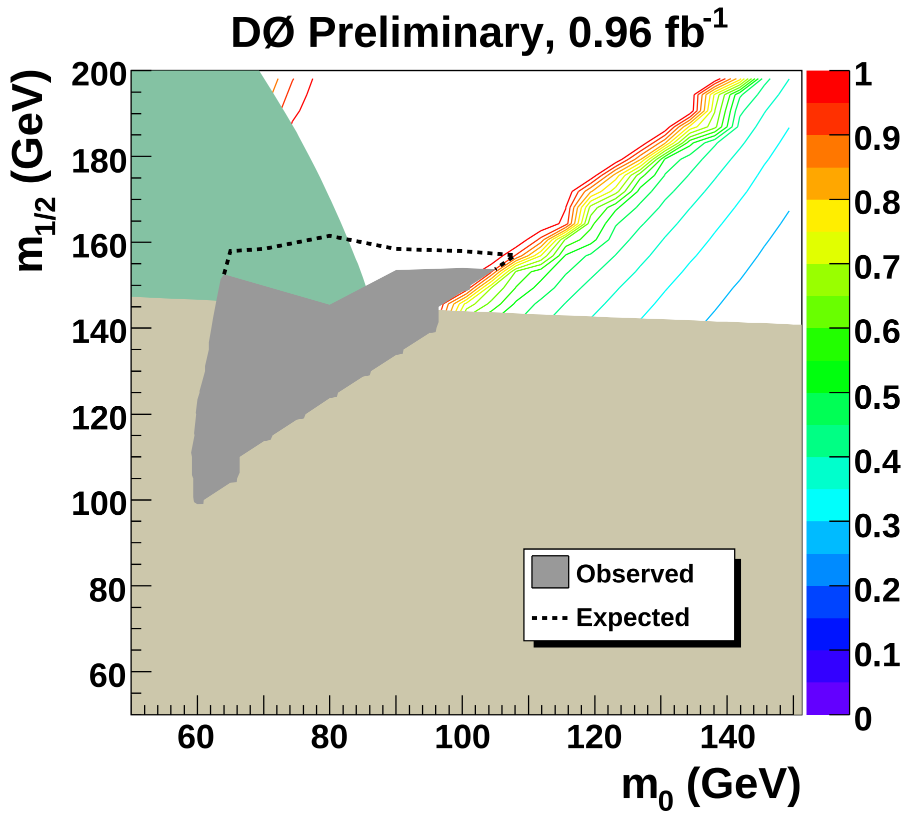
$\longrightarrow$ cascade decays of squarks to taus

DØ (1 fb^{-1}):

- dedicated search in τ+jets+$\not\!\!E_T$
- 1.7 events expected, 2 observed

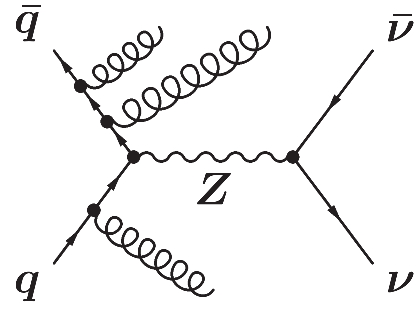
$\longrightarrow$ mSUGRA exclusion contour:

tanβ=15, A_0=-2m_0, $\mu < 0$

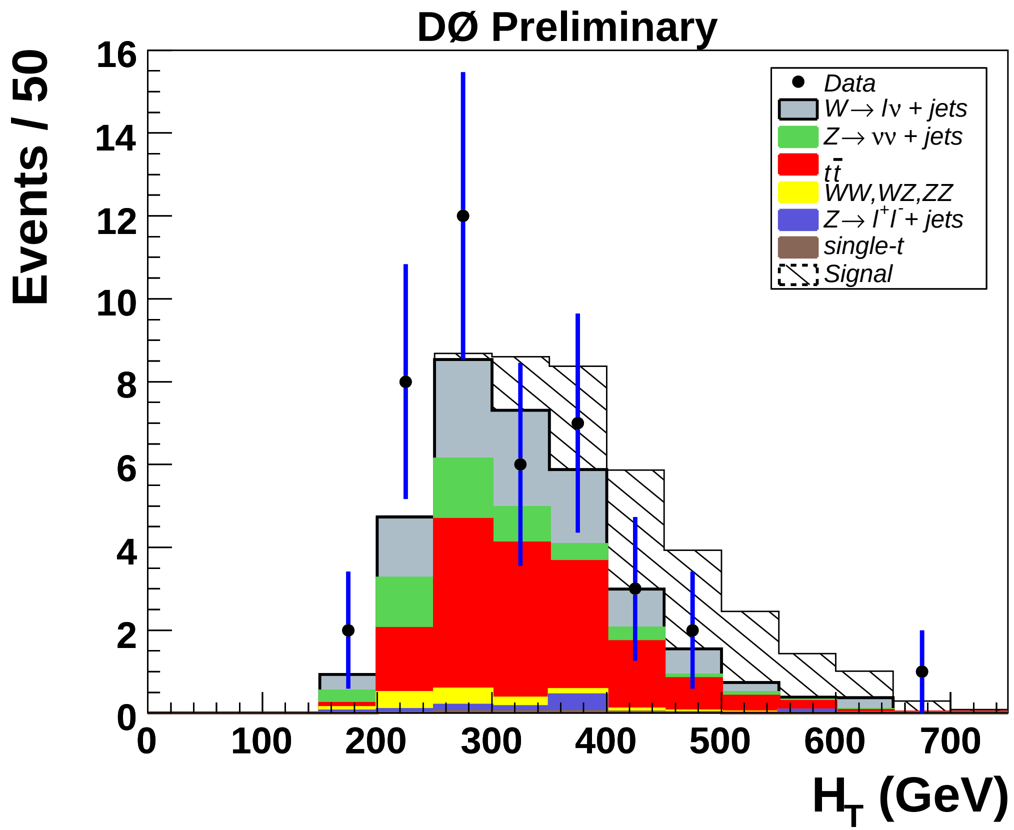


Search for Supersymmetry at LHC – V+jets Background

- Search for SUSY in Jets+$\not{E}_T$ is flagship analysis at the LHC
- Modelling of V+jets backgrounds is crucial
- Default pythia modelling is not adequate



DØ Squark/Gluino Search



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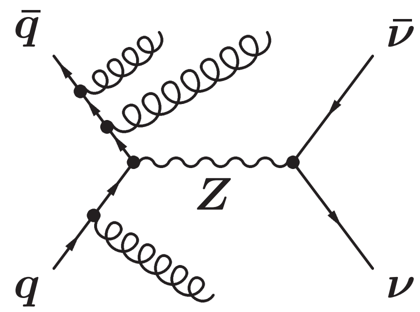
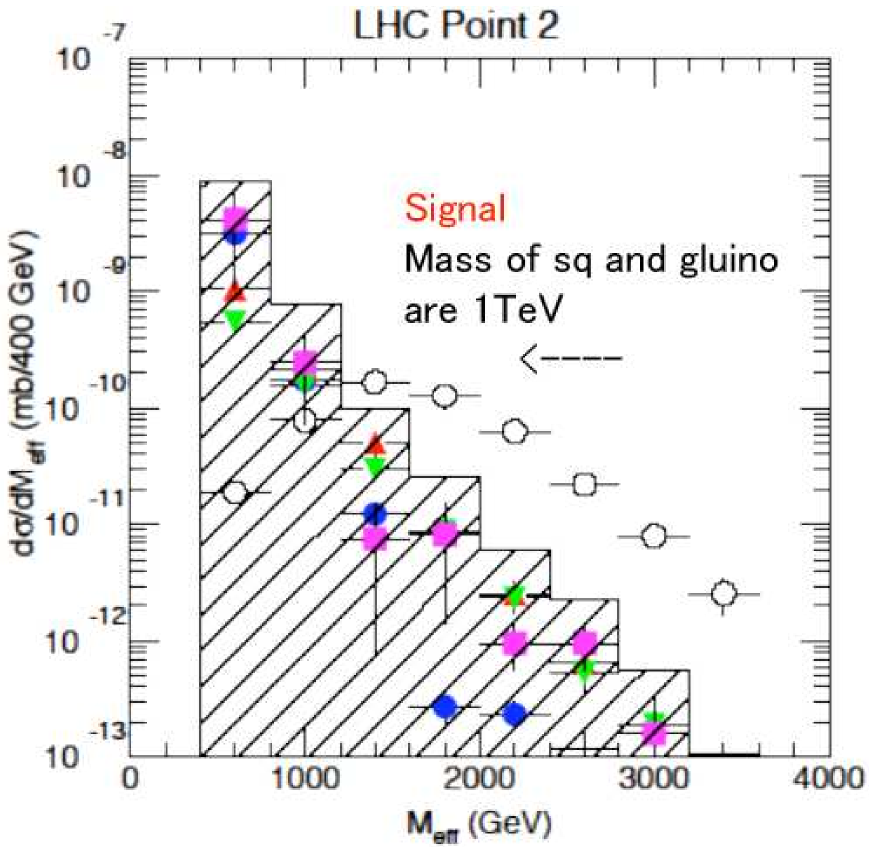
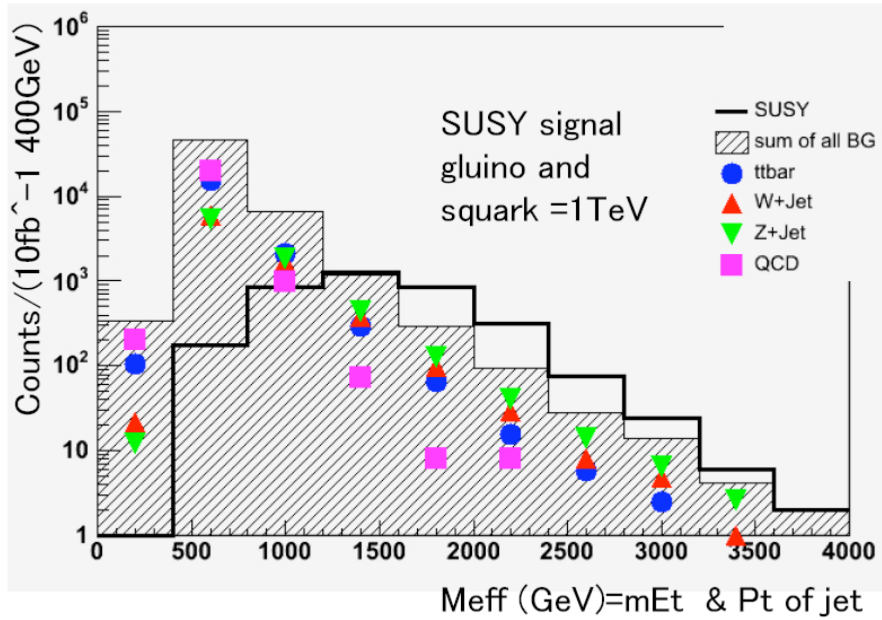


ATLAS TDR Study (Parton Shower MC)



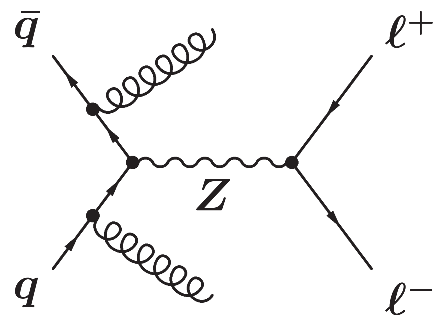
New Study (Matrix Element MC)



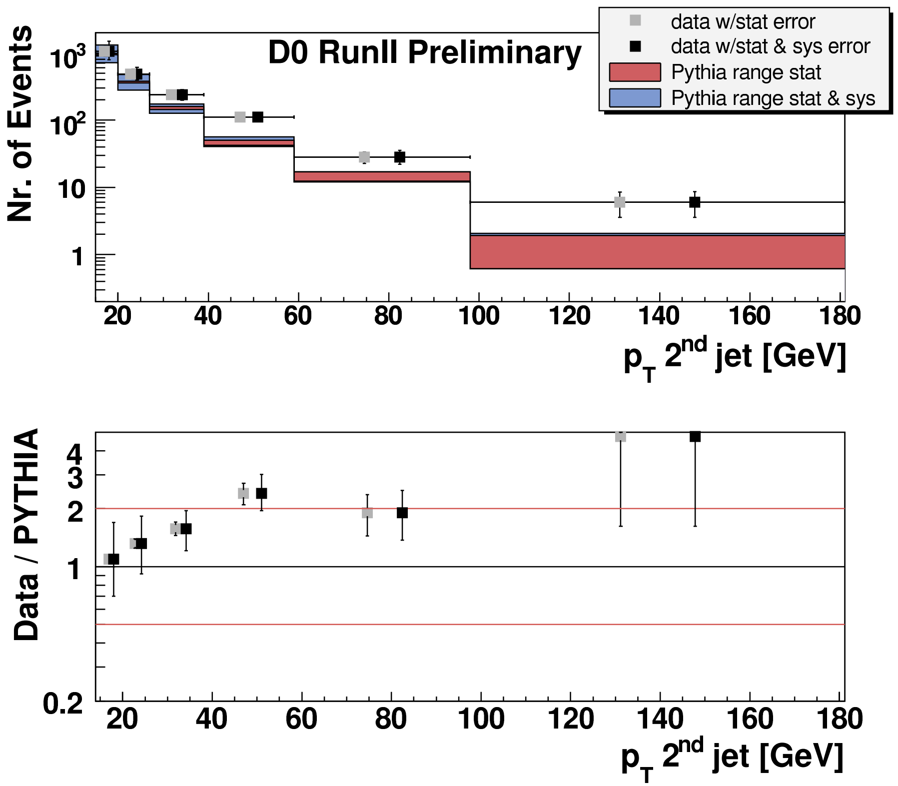
(S. Asai et al.)

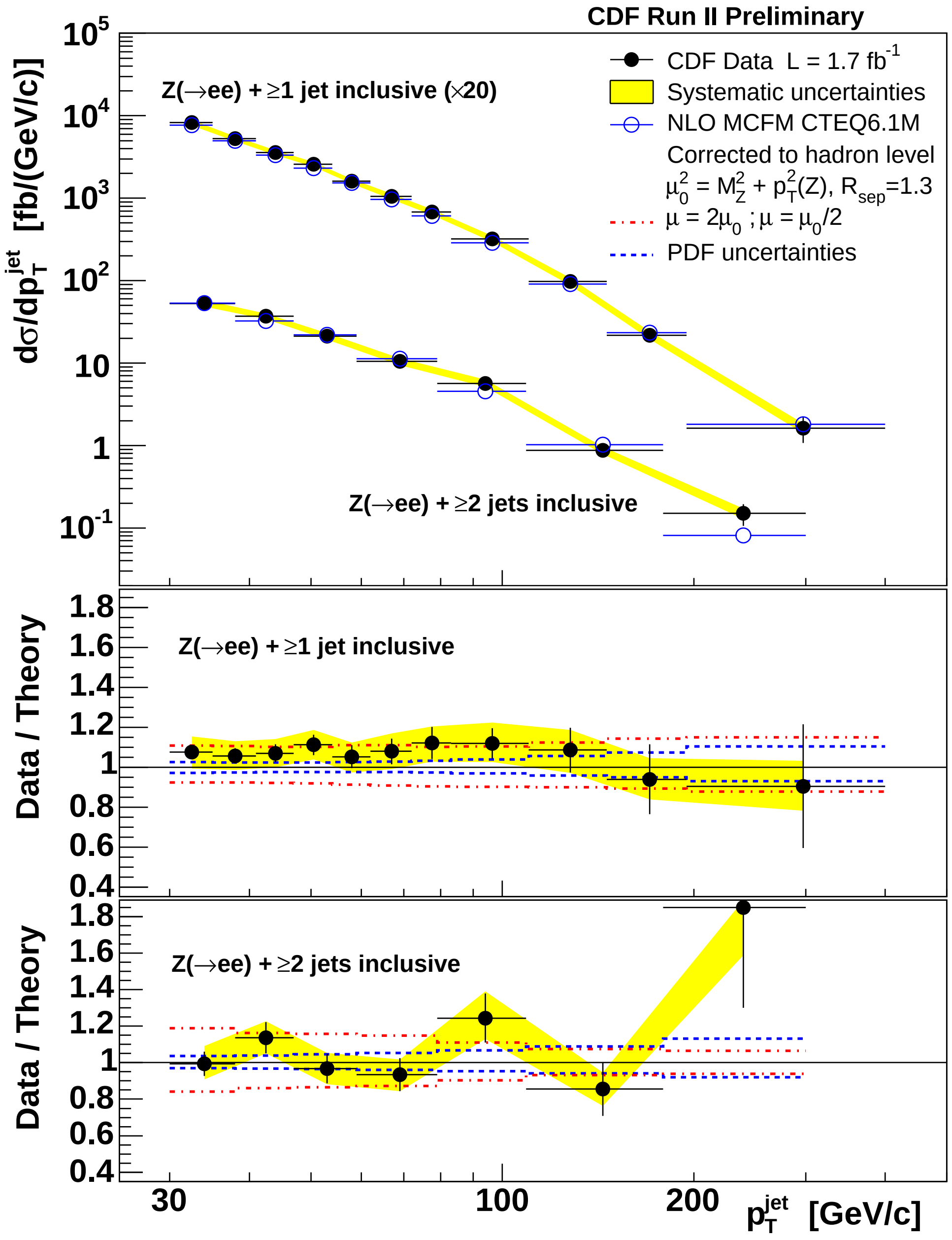
Vector Boson plus Jet Production at the Tevatron

Dedicated Analyses to test new MC Generators in Z+jets data



DØ Data vs. PYTHIA





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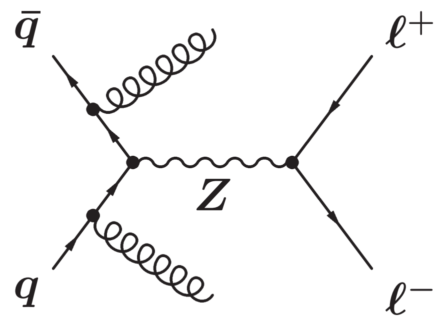
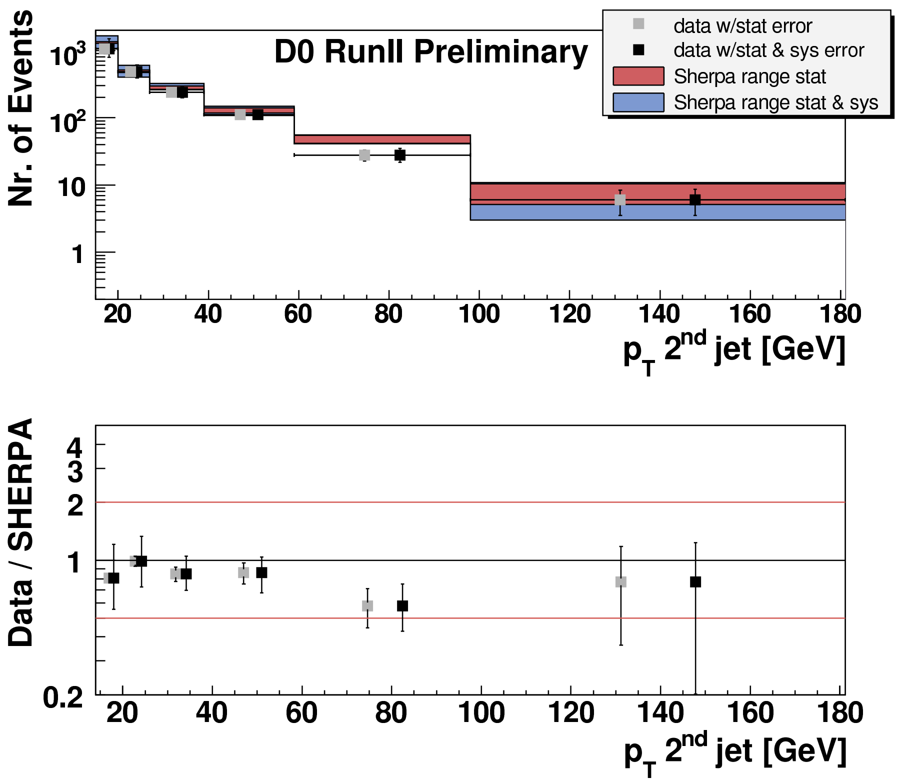
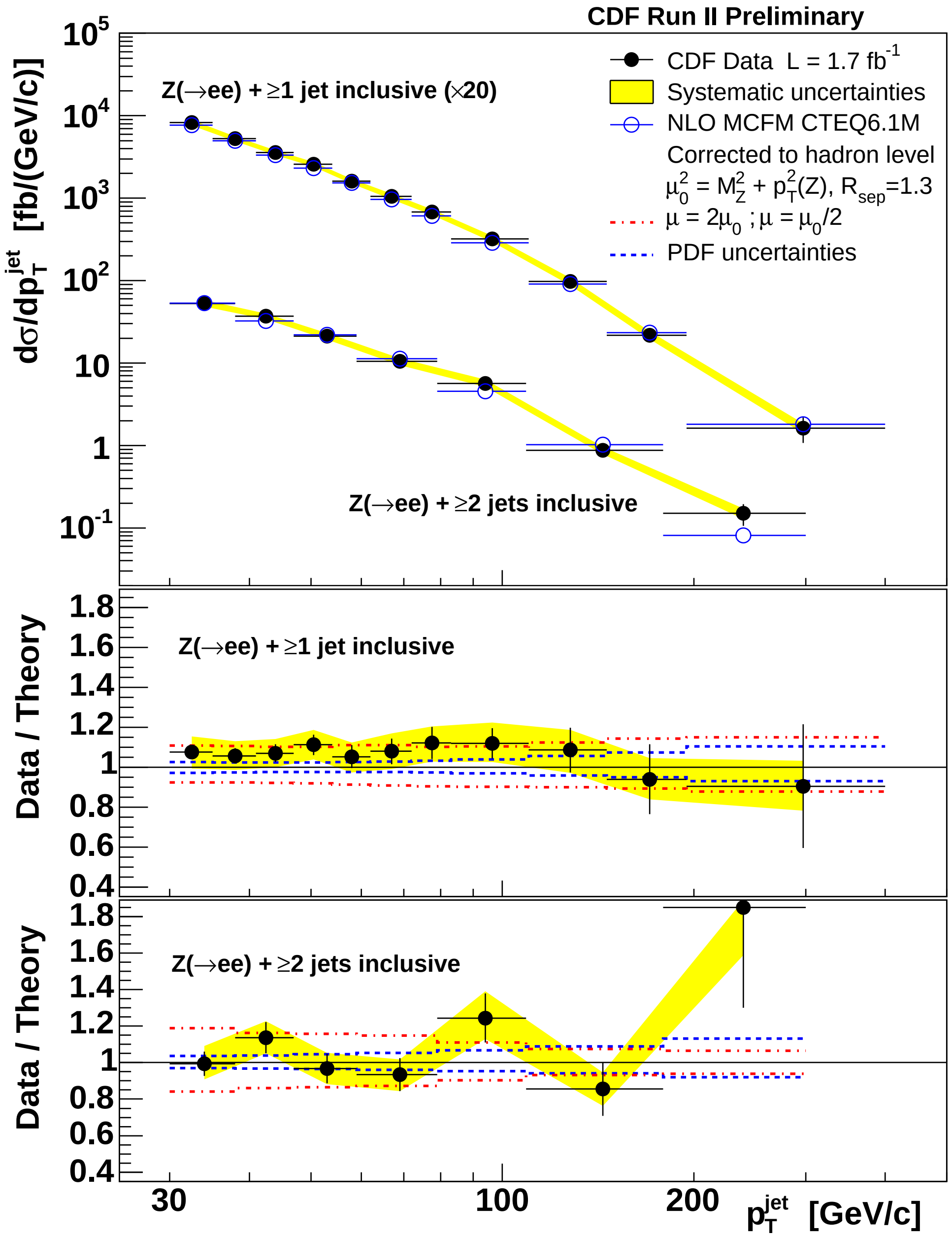


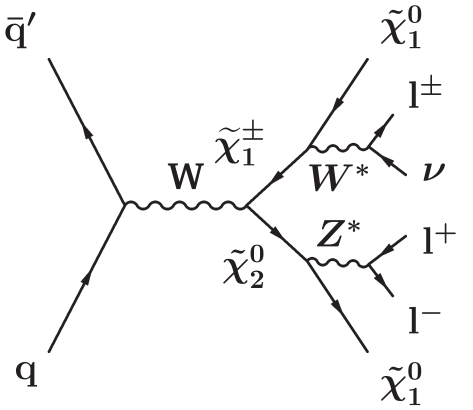
DØ Data vs. SHERPA



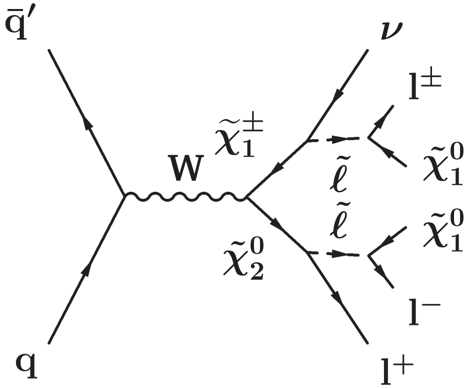


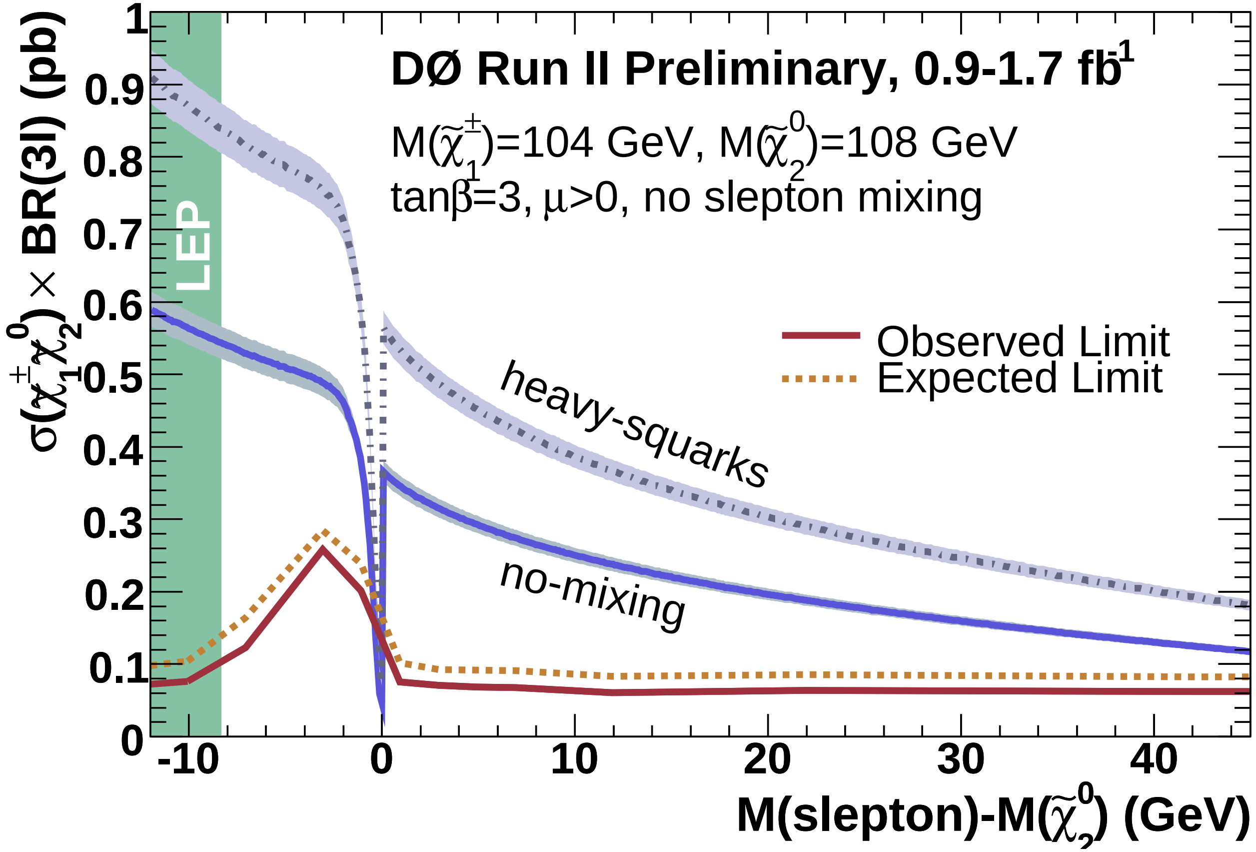
Search for Charginos and Neutralinos

Heavy sleptons:



Light sleptons:





ΔM$<$0: two-body decays into real sleptons

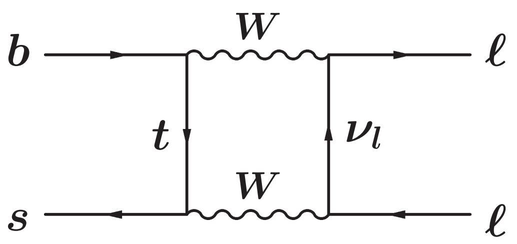
- ΔM$<$-6 GeV: good efficiency, high branching fractions
- -6 GeV$<\Delta$M$<$0: very soft third lepton $\rightarrow$ limit set by ls-$\mu\mu$-analysis

ΔM$>$0: three-body decays via slepton- and W/Z-exchange

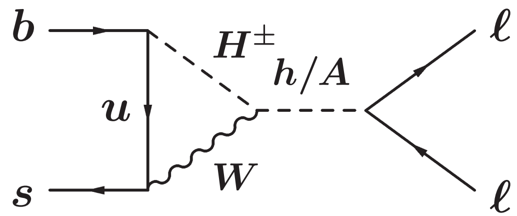
- ΔM$\gtrsim$0: slepton-exchange maximal $\rightarrow$ large BR(3ℓ): *"3l-max scenario"*
- ΔM$\gg$0: W/Z-exchange dominates $\rightarrow$ small BR(3ℓ): *"large-m_0 scenario"*

Supersymmetry and rare decays: $B_s \to \mu^+\mu^-$

SM prediction: $BR(B_s \to \mu^+\mu^-) = 3.8 \times 10^{-9}$



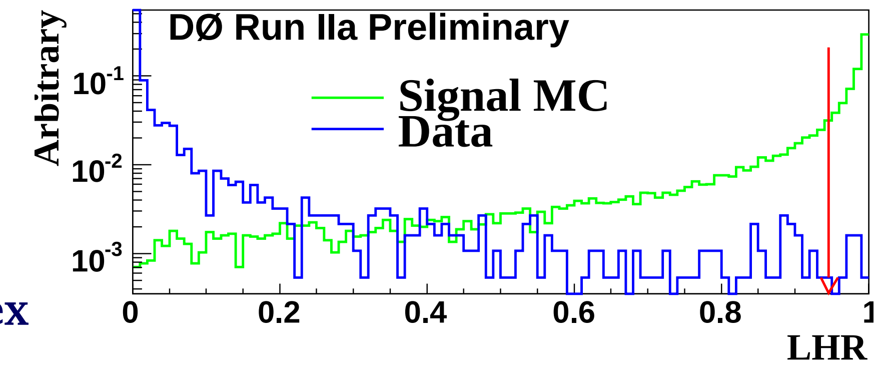
MSSM: enhancement $\sim(\tan\beta)^6$

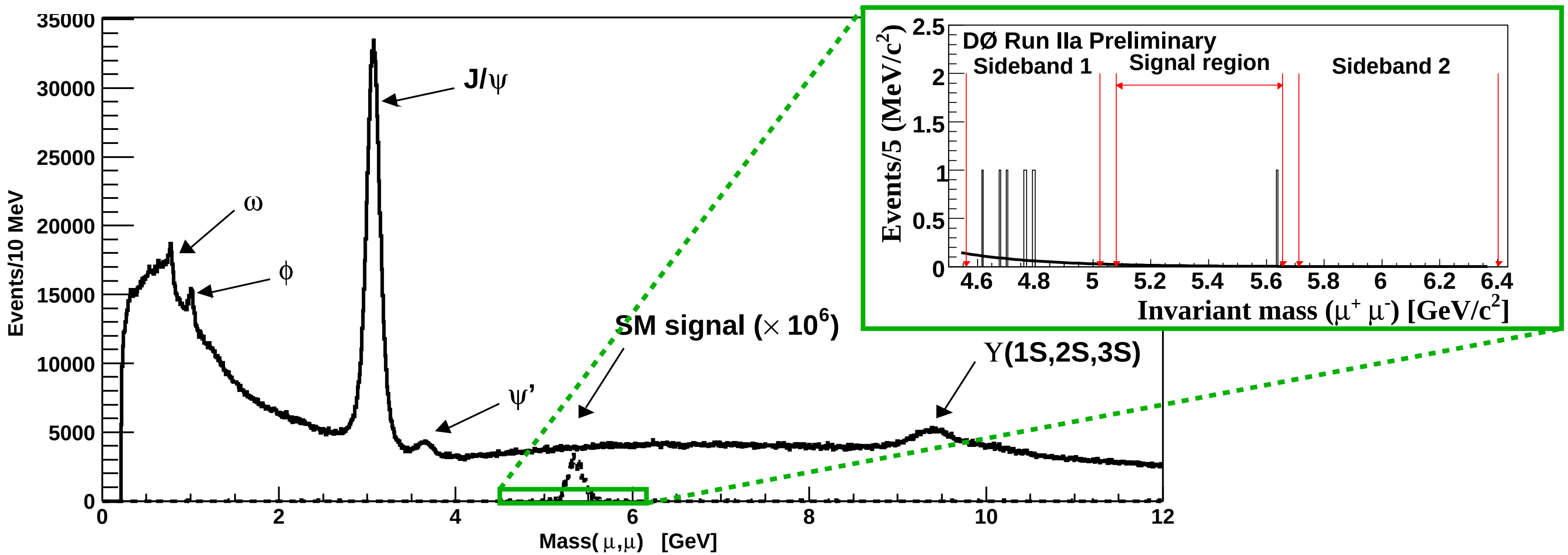


→ significant at high $\tan\beta$: $BR = O(10^{-7})$

→ complementary to trilepton search

- Tevatron: large production rate for B_s
- Selection: two isolated muons, displaced vertex





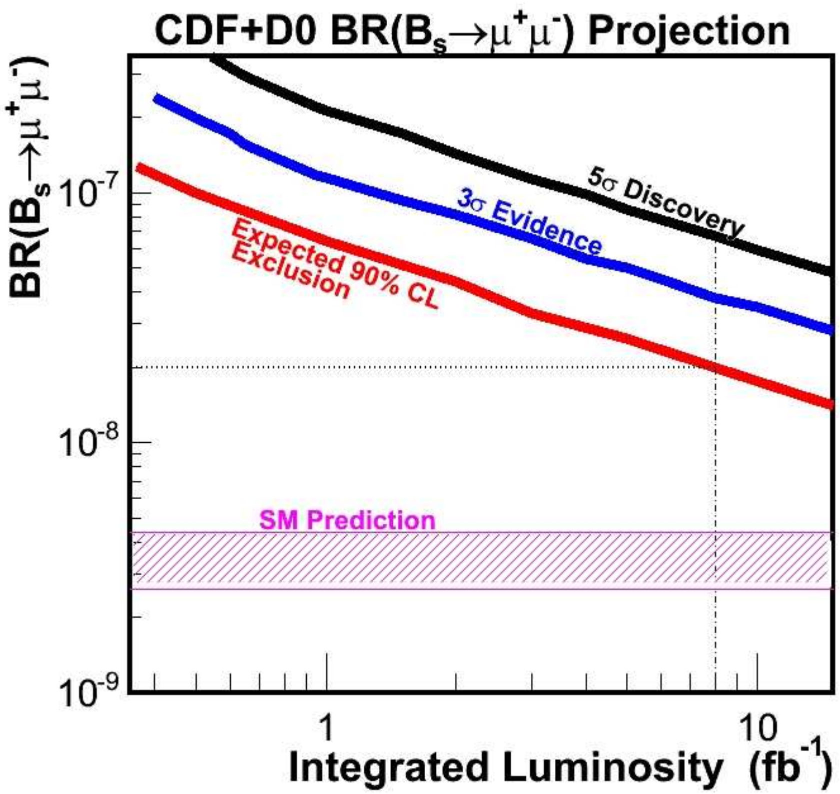
Supersymmetry and rare decays: $B_s \to \mu^+\mu^-$

Results (limits at 95% C.L.):

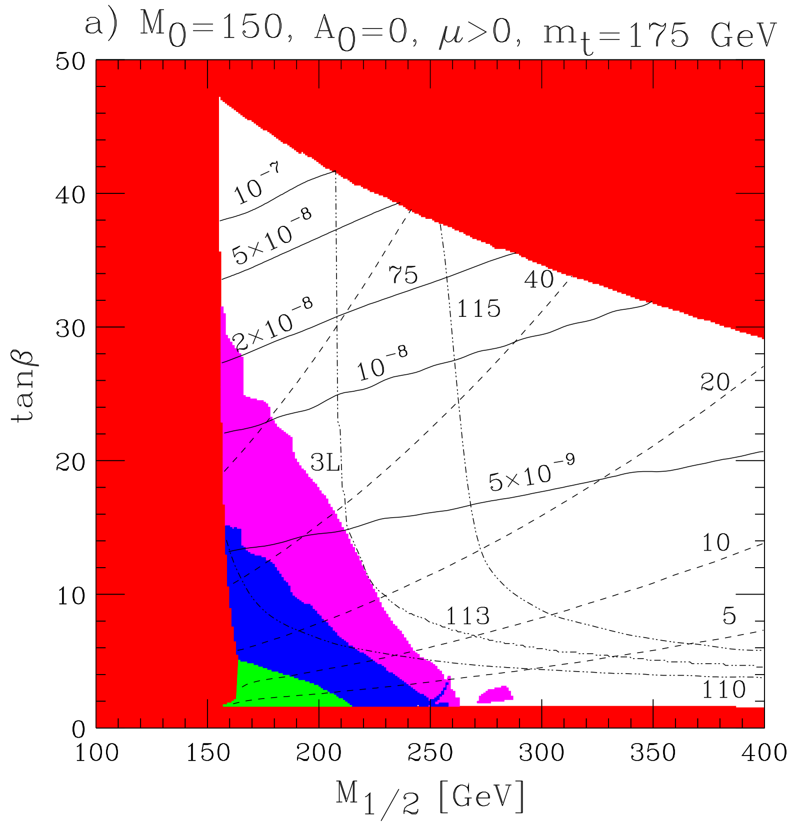
DØ (2 fb^{-1}): 2.3±0.5 expected, 3 observed → $BR(B_s \to \mu^+\mu^-) < 9.3\times10^{-8}$
CDF (2 fb^{-1}): 3.7±1.0 expected, 3 observed → $BR(B_s \to \mu^+\mu^-) < 5.8\times10^{-8}$

Projection for Run IIb: sensitivity will approach 10^{-8}

→ will test large part of SUGRA parameter space



Dedes, Dreiner, Nierste, Richardson
(hep-ph/0207026)



More B_s Physics: CP Violation

CP violation in B_s^0 system:

- SM prediction for CPV phase $\Phi_S = (4.2 \pm 1.4) \times 10^{-3}$
- potentially modified by new physics

DØ: new combined constraint extracted from 4 measurements

- time-dependent angular distributions in $B_s^0 \to J/\Psi\Phi$
- effective mean lifetime from flavour-specific B_s^0 decays
- charge asymmetry in semileptonic B_s^0 decays

(Still) 4 solutions, including:

$$\Delta\Gamma_s = 0.13 \pm 0.09 \text{ ps}^{-1}$$

$$\Phi_s = -0.70^{+0.47}_{-0.39}$$