Fermilab Start of Run II schedule

PHENO2000, Madison , WI
April 19, 2000; H.Weerts

October 15, 1999

October 1999 to March 2001 Schedule

CY	1999			2000								
Month	Oct	Nov	Dec	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
Proton Source		M&D	Operation		M&D	Operation					M&D	
Main Injector		M&D	Operation		M&D	Operation					M&D	Run II Commissioning Run
Recycler		Bake out	Installation and Commissioning		M&D	Commissioning		Engineering Run			M&D	
Pbar Source		M&D	Commissioning a)	E835 Run	M&D	E835 Run		c)			E-835 Removal	
Tevatron		1 TeV test	Operation		Changeover to Collider Configuration			Run II Engineering Run			Detector Roll-in	
Switchyard		M&D	Operation	b)	OFF							

1/17

now

CY	2000			2001		
Month	Oct.	Nov.	Dec.	Jan.	Feb.	March
Proton Source	Run II Comm. Run	M&D/Studies/Commissioning				Run II
Main Injector		M&D/Studies/Commissioning				
Recycler		M&D/Studies/Commissioning				
Pbar Source		M&D/Studies/Commissioning				
Tevatron		CDF Roll-out & Roll-in and D0 Roll-in				
Switchyard	OFF					

a) Band 1 & 2 Installation and E835 installation

b) Possible KAMI Test

c) Operation for Pbar Source Commissioning, Recycler Engineering Run, and parasitic Run of E835

Beam energy: 1000^{+5}_{-20} GeV

not fixed yet

Run II parameters

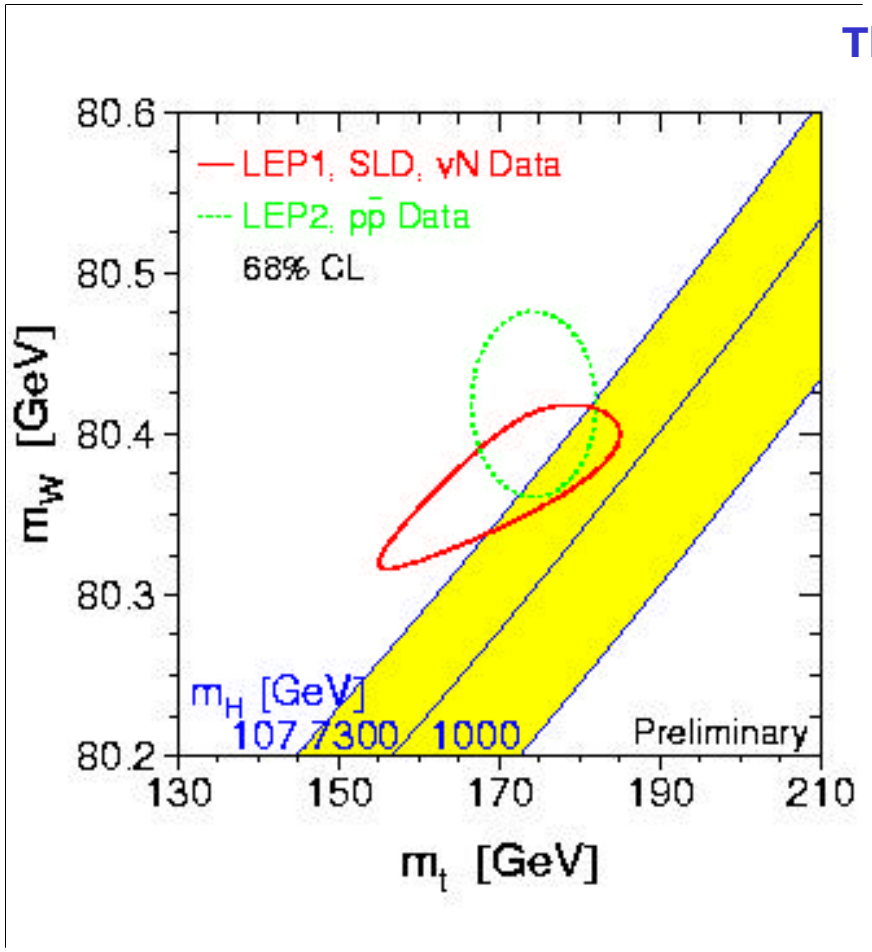
RUN	Ib (1993-95) (6x6)	Run IIa (36x36)	Run IIa (140x105)	Run IIb (140x105)	
Protons/bunch	2.3×10^{11}	2.7×10^{11}	2.7×10^{11}	2.7×10^{11}	
Antiprotons/bunch*	5.5×10^{10}	3.0×10^{10}	4.0×10^{10}	1.0×10^{11}	
Total Antiprotons	3.3×10^{11}	1.1×10^{12}	4.2×10^{12}	1.1×10^{13}	
Pbar Production Rate	6.0×10^{10}	1.0×10^{11}	2.1×10^{11}	5.2×10^{11}	hr^{-1}
Proton emittance	23π	20π	20π	20π	mm-mrad
Antiproton emittance	13π	15π	15π	15π	mm-mrad
β^*	35	35	35	35	cm
Energy	900	1000	1000	1000	GeV
Antiproton Bunches	6	36	103	103	
Bunch length (rms)	0.60	0.37	0.37	0.37	m
Crossing Angle	0	0	136	136	μrad
Typical Luminosity	0.16×10^{31}	0.86×10^{32}	2.1×10^{32}	5.2×10^{32}	$cm^{-2}sec^{-1}$
Integrated Luminosity†	3.2	17.3	42	105	pb^{-1}/week
Bunch Spacing	~3500	396	132	132	nsec
Interactions/crossing	2.5	2.3	1.9	4.8	

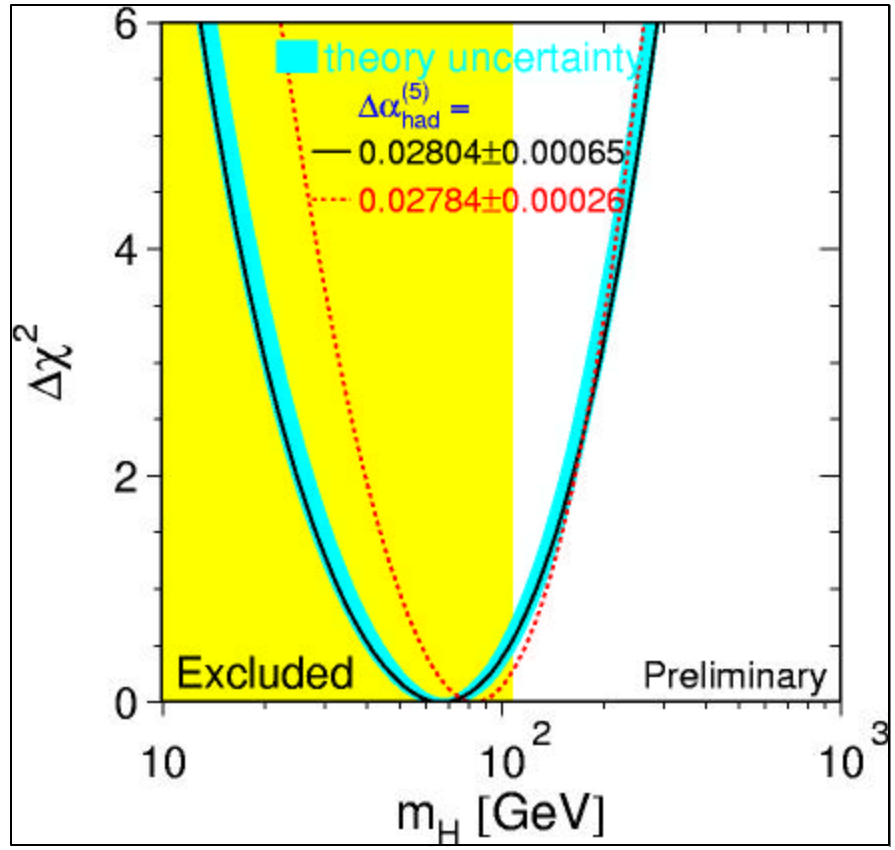
†The typical luminosity at the beginning of a store has traditionally translated to integrated luminosity with a 33% duty factor. Operation with antiproton recycling may be somewhat different.

Beyond the Standard Model

Where will we stand, circa 2001, 2002?

The Standard Model works at the 10^{-3} level





- **All observations are consistent with a single light SM Higgs, though no such beast has yet been observed**
  - m_H > 107.7 GeV (LEP) and m_H < 188 GeV (95% CL) will improve before end of LEP; good

Beyond the Standard Model

So far.....

- General arguments for new physics at the EW scale (250 GeV)
- Standard Model fits suggest the new physics is weakly coupled
- Indirect pointers to supersymmetry
- Direct searches all negative so far

- LEP2
  - squarks (stop, sbottom) > 80-90 GeV
  - sleptons (selectron, smuon, stau) > 70-90 GeV
  - charginos > 70-90 GeV
  - lightest neutralino > 36 GeV
- Tevatron Run I
  - squarks and gluinos
  - stop, sbottom
  - charginos and neutralinos

The Run II mission

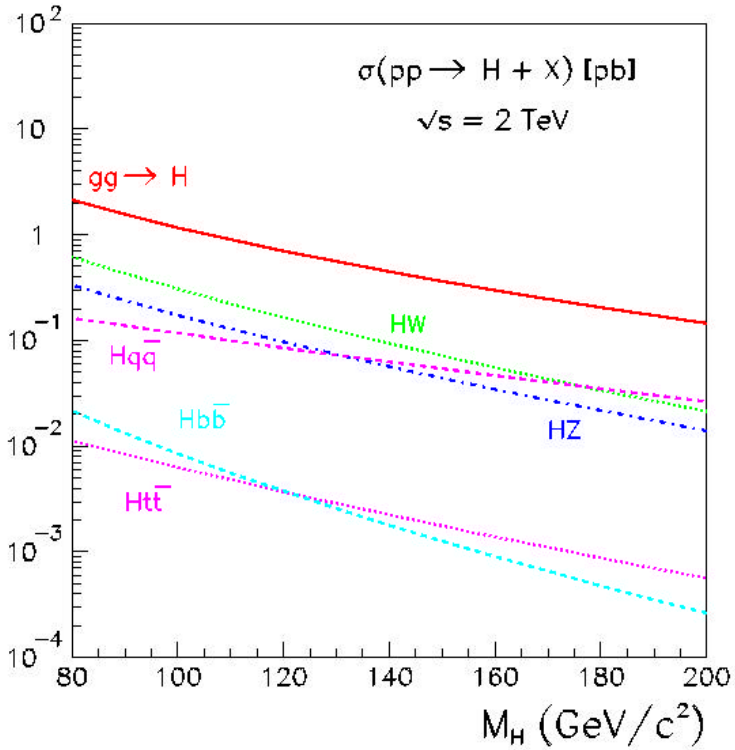
At your earliest convenience, please carry out one or more of the following challenges:

- Discover the SM Higgs
- Discover or exclude lightest SUSY Higgs with masses up to ~ 130 GeV
- Discover one or more superpartners
- Exclude supersymmetry at the TeV scale by discovering some other new physics

- Can any of this be done in the next five years?

Sounds like movie:"Mission: Impossible "

Higgs Production at the Tevatron



- *gg* ® *H* dominates, but huge QCD background
- *WH* and *ZH* seem to offer the best potential
- SUSY enhances associated *b* production

- Run II SUSY/Higgs workshop
- repeated and extended previous studies, combining all possible channels
- simulated "average" of CDF and DØ (SHW parameterized simulation) program

SM Higgs Channels

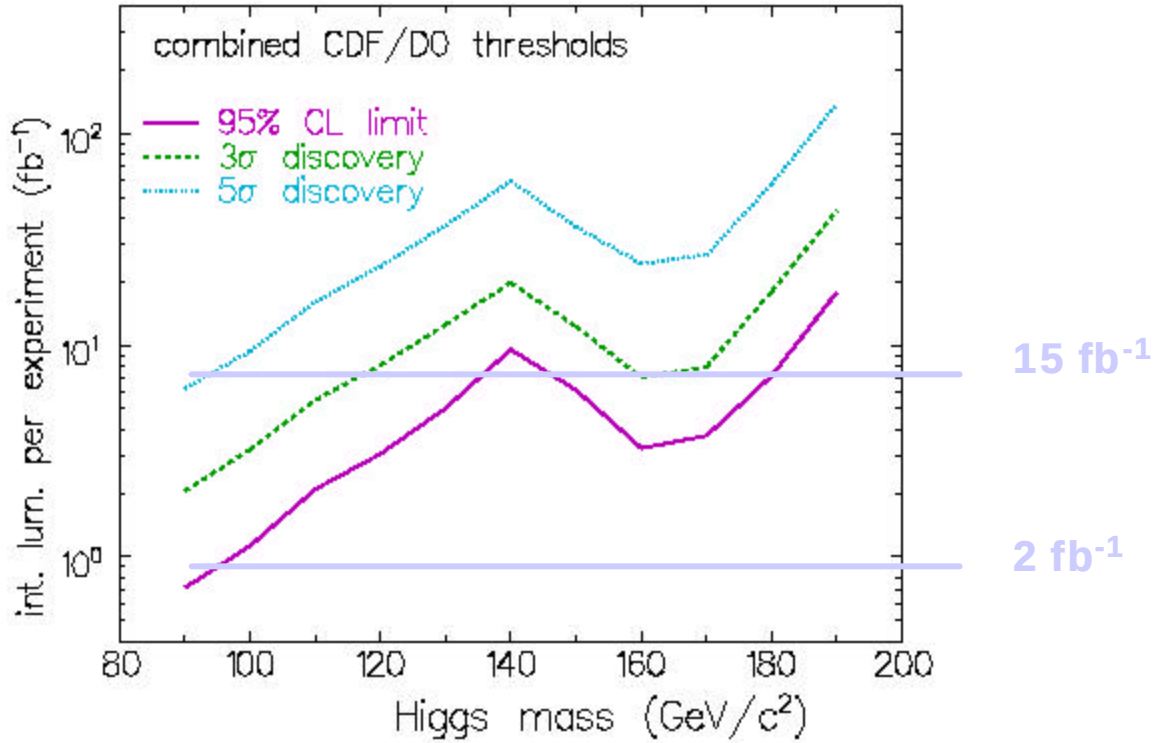
m_H < 130-140 GeV

- $WH \rightarrow l\nu\, bb$ backgrounds Wbb, WZ, tt, single top
  - factor ~ 1.3 improvement in S/B with neural network
  - possibility to exploit angular distributions (WH vs. Wbb) Parke and Veseli, hep-ph/9903231
- $WH \rightarrow qq\, bb$ overwhelmed by QCD background
- $ZH \rightarrow l\, l\, bb$ backgrounds Zbb, ZZ, tt
- $ZH \rightarrow \nu\nu\, bb$ backgrounds QCD, Zbb, ZZ, tt
  - requires relatively soft missing E_T trigger (35 GeV?)

m_H > 130-140 GeV

- $gg \rightarrow H \rightarrow WW^*$ backgrounds Drell-Yan, WW, WZ, ZZ, tt, tW, $\tau\tau$
  signal:background ratio ~ 7×10^{-3}!
  - Angular cuts to separate signal from “irreducible” WW background

Combined CDF & DØ reach



- Bayesian combination of two experiments
- 30% improvement in *bb* mass resolution over Run I
- SHW acceptance but no neural network improvement assumed
- 10% systematic error on backgrounds

Run II SM Higgs: Issues

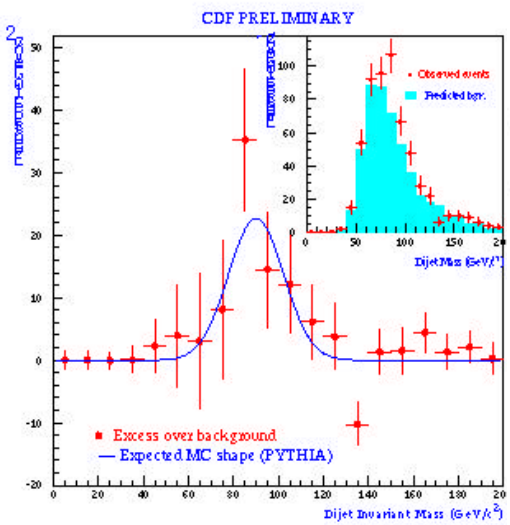
- LEP2 analysis is clear-cut, and the reach is predictable

- The Tevatron analysis is an exciting prospect. Is it credible?
  - Yes: it is an exercise similar in scale to the top discovery, with a similar number of backgrounds and requiring similar level of detector understanding.
  - but it will be harder: the irreducible signal:background is worse
  - it has caught the imagination of experimenters
  - the single biggest problem with the studies so far (in my opinion) is the assumptions about the bb dijet mass resolution
    - can the assumed resolution really be achieved (and in a high luminosity environment)?
    - can it be improved (through the use of "smarter" algorithms)? e.g. k_T?

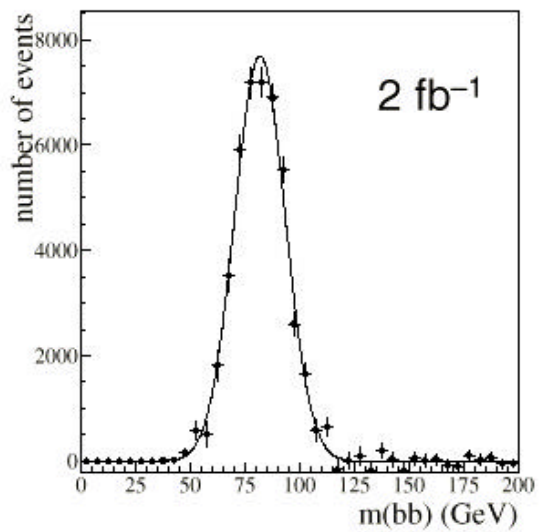
Mass resolution

- Directly influences signal significance
- Requires corrections for missing E_T and muon
- $Z \rightarrow bb$ will be a calibration signal

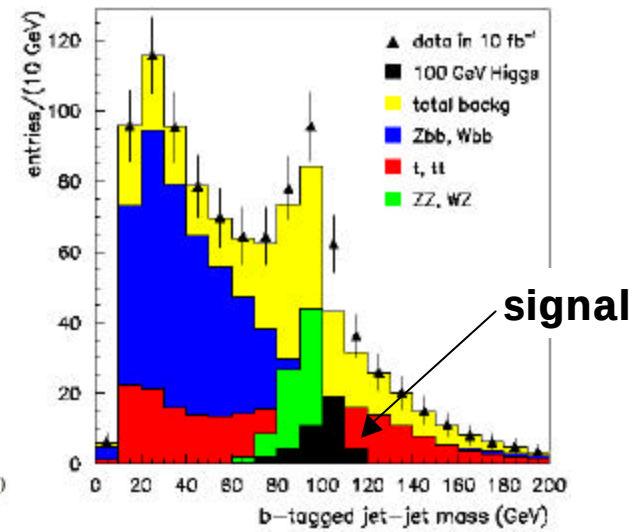
CDF observation in Run I



DØ simulation for 2fb^{-1}



Higgs simulation for 10fb^{-1}



Minimal Supersymmetric Standard Model

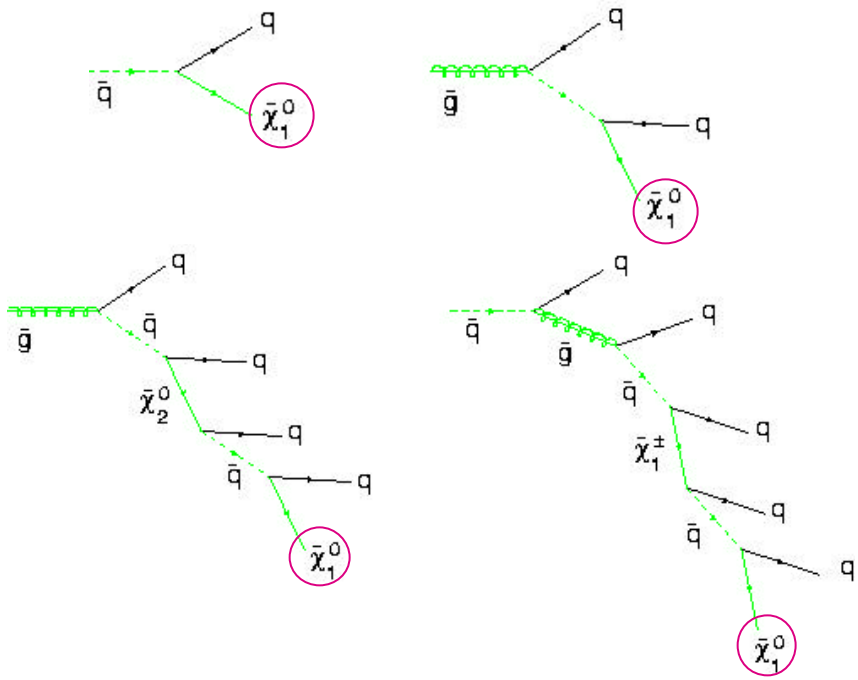
i.e. SM particles plus two Higgs doublets and their SUSY partners

Even this minimal spectrum can have many faces:

- Is *R*-parity conserved?
  - Is the LSP (lightest supersymmetric particle) stable?
- How is supersymmetry broken?
  - Supergravity-inspired (mSUGRA): the typical benchmark
    - parameters $m_{1/2}$, m_0, A_0, $\tan b$, $sign(m)$
    - radiative EWSB occurs naturally from large top mass
    - the χ^0_1 is the LSP
    - χ^0_1, χ^0_2, $\chi^\pm_1$, sleptons and h are "light"
    - χ^0_3, χ^0_4, $\chi^\pm_2$, squarks and gluinos are "heavy"
  - Gauge-mediated (GMSB): LSP can be Gravitino
    - signatures with photons and/or slow-moving particles which may decay within or outside detector
  - Anomaly mediated
    - lightest chargino and neutralino almost degenerate

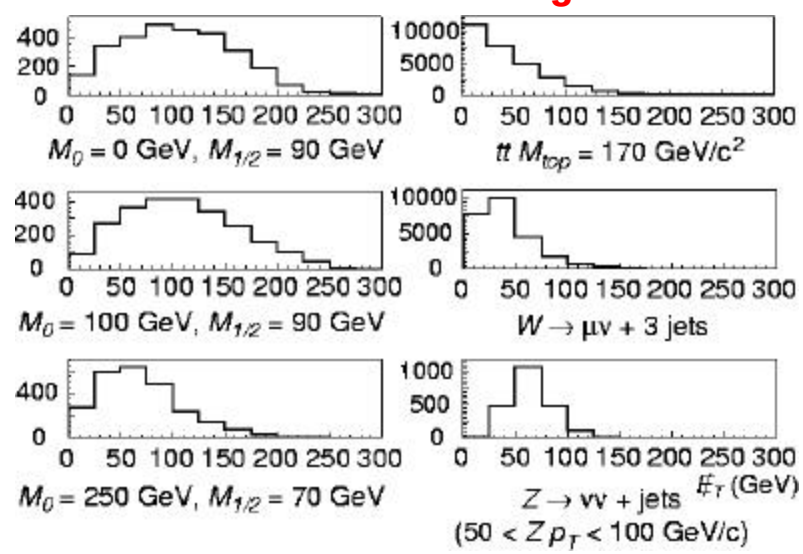
Hadron collider SUSY signatures

- The highest production cross section at a hadron collider is for the pair production of squarks and gluinos
- As long as R-parity is conserved, jets + missing transverse energy:



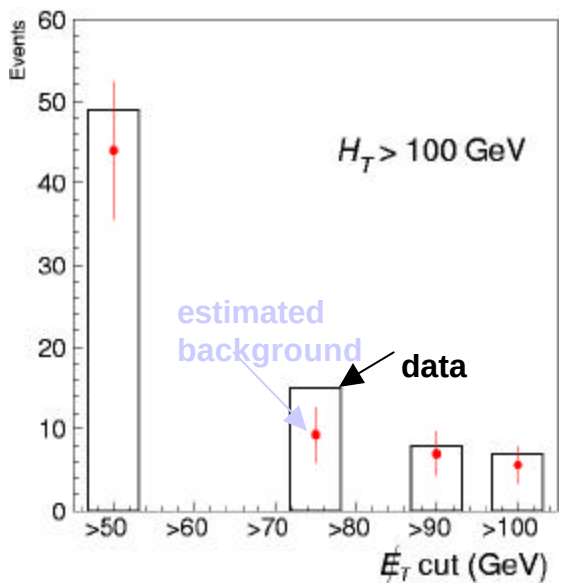
Missing E_T

SUSY **backgrounds**

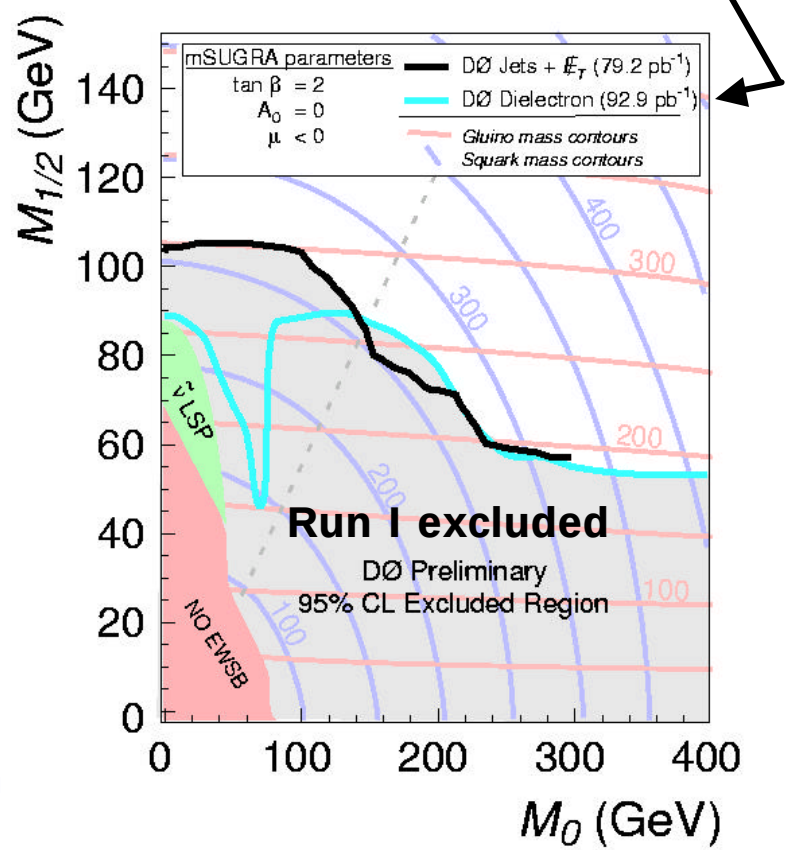


DØ search for squarks and gluinos

- Demand
  - 3 jets, E_T > 25 GeV, one jet E_T > 115 GeV
  - H_T > 100 GeV
  - veto electrons, muons
- Main Backgrounds: top, QCD jets, W/Z+jets



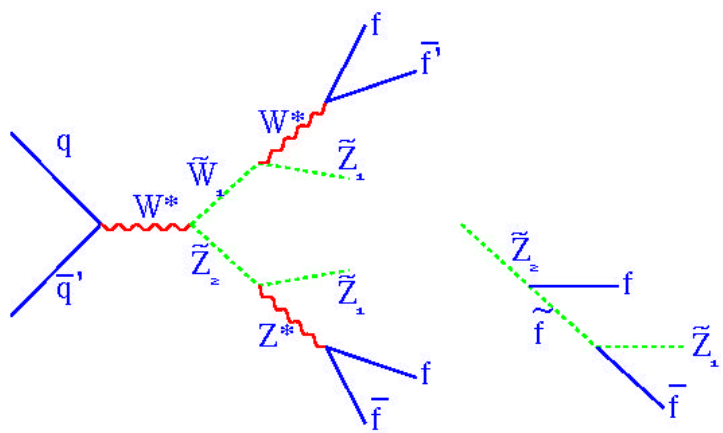
Run II limit:
gluino mass ~ 400 GeV

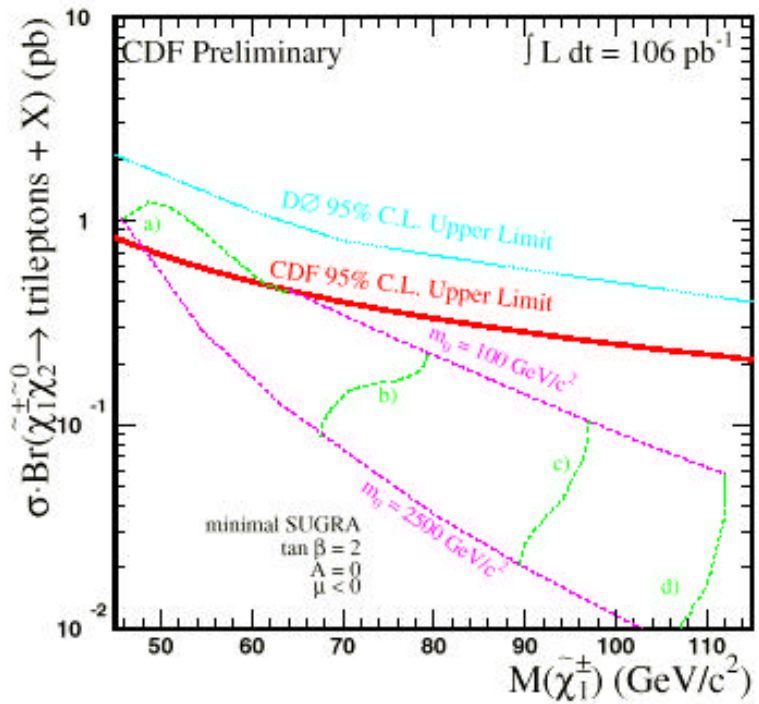


- Cascade decays to charginos can give leptons in final state: complementary analysis requiring
  - 2 electrons, 2 jets + Missing E_T

Chargino/neutralino production

- "golden" trilepton signature

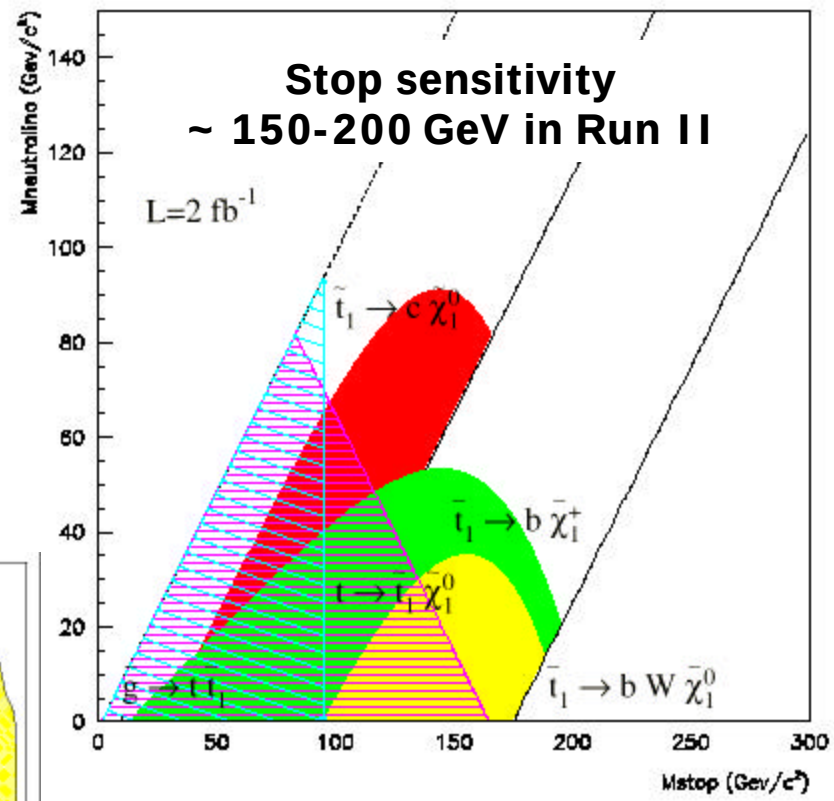




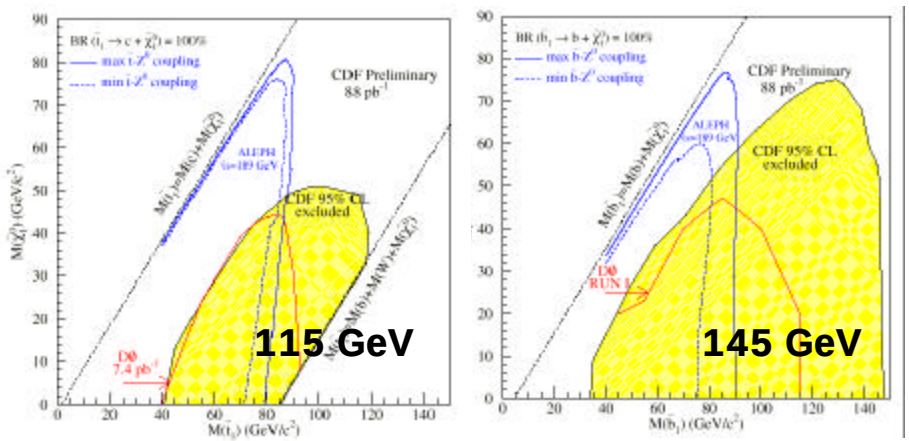
- Run II reach on $\chi^{\pm}$ mass ~ 180 GeV ($\tan\beta = 2$, $\mu < 0$)
  ~ 150 GeV (large $\tan\beta$)
  - this channel becomes increasingly important as squark/gluino production reaches its kinematic limits (masses 400-500 GeV)
- Low p_T triggering?
- Can we include tau modes?

Stop and Sbottom

- Stop
  - stop → b + chargino or W (top like signatures)
  - stop → c + neutralino
  - top → stop and gluino → stop
- Sbottom
  - 2 acollinear b-jets + E_T^{miss}



CDF Run I stop and sbottom limits

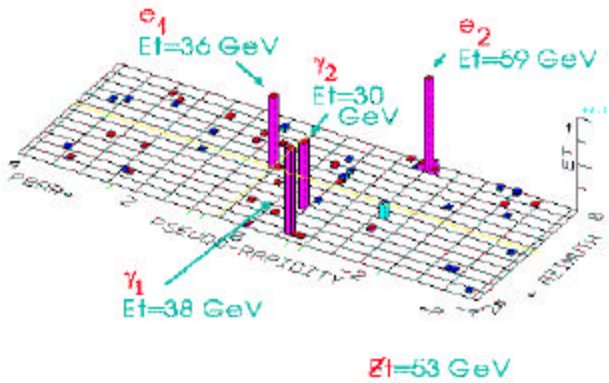


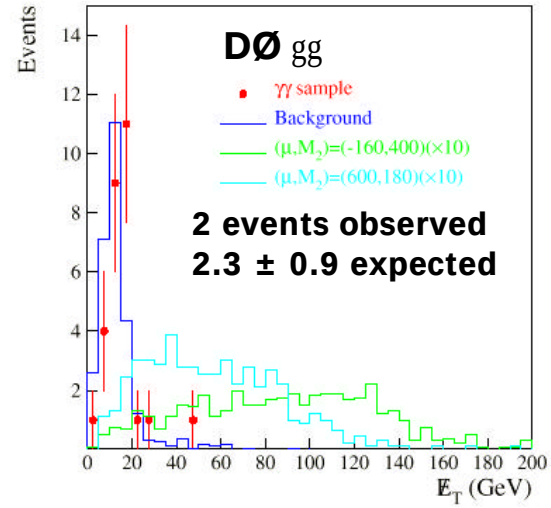
Sbottom sensitivity
~ 200 GeV in Run II

Gauge Mediated SUSY

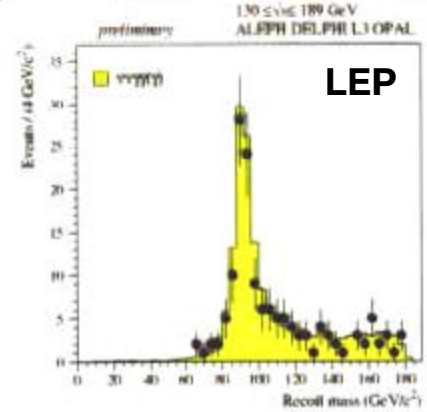
- Is this selectron pair production?

Event: $2\ e + 2\ \gamma + \not{E}_t$





$$\sigma\left(e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 \to \gamma\gamma\tilde{G}\tilde{G}\right) \sim O(pb)$$



- All we can say is that searches for related signatures have all been negative
  - CDF and DØ $\gamma\gamma$ + missing E_T
  - DØ γ + jets + missing E_T
  - LEP

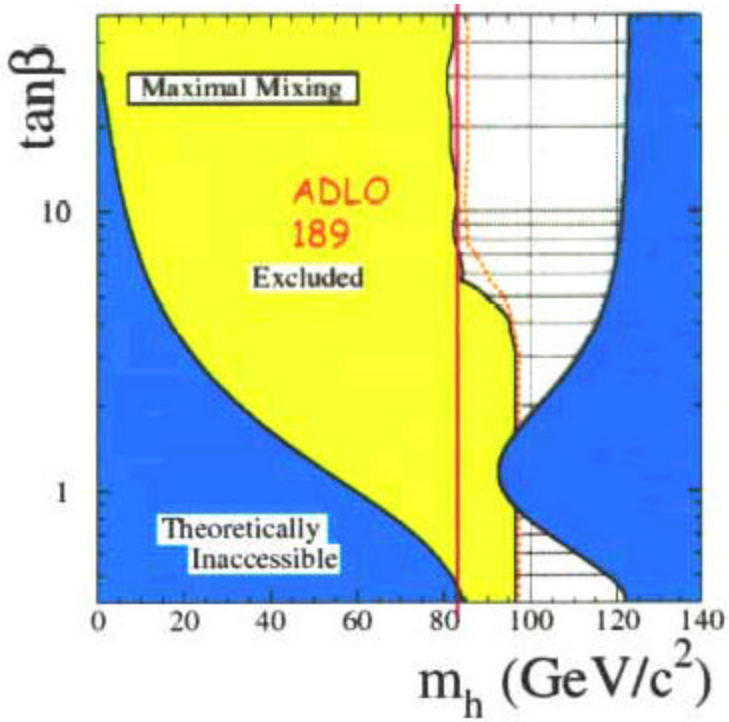
Large extra dimensions.....

- Gravitons propagate into higher dimensional space?
- Direct searches for
  - $e^+e^- \rightarrow \gamma$ + nothing
  - $pp \rightarrow \gamma\gamma$ + nothing, ee+ nothing, jet+nothing
  - $pp \rightarrow \gamma\gamma$, ee angular distribution vs. M_{ee} , $M_{\gamma\gamma}$
- Indirect effects in $e^+e^- \rightarrow \gamma\gamma, \mu\mu, \tau\tau$

- Do event generators exist? Yes LO, now.

MSSM Higgs at LEP2

- Complementary processes: $e^+e^- \rightarrow (h/H)Z$ and $(h/H)A$



Summer 1999:
m_h > 81 GeV
m_A > 81 GeV

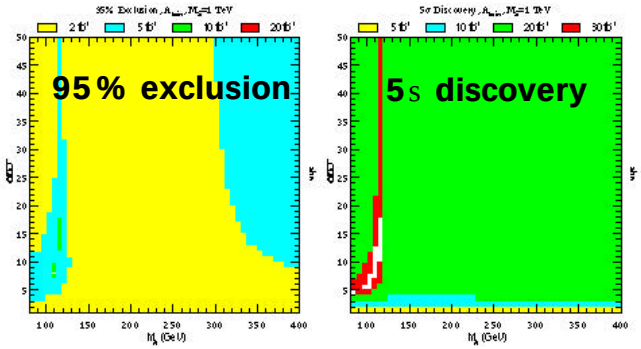
<u>Excludes</u>
0.9 < tan b < 1.6 max mixing
0.6 < tan b < 2.6 no mixing
but no exclusion if m_{top} = 180 GeV

- General MSSM scans find a few points that can evade limits
- Invisible Higgs decays included in searches

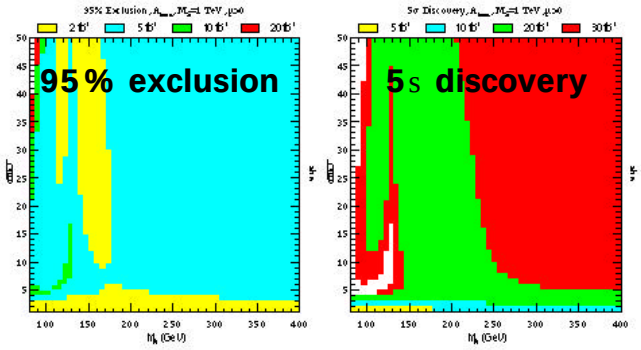
MSSM Higgs sector at the Tevatron

Assuming 1 TeV sparticle masses, $\mu < 0$

minimal stop mixing

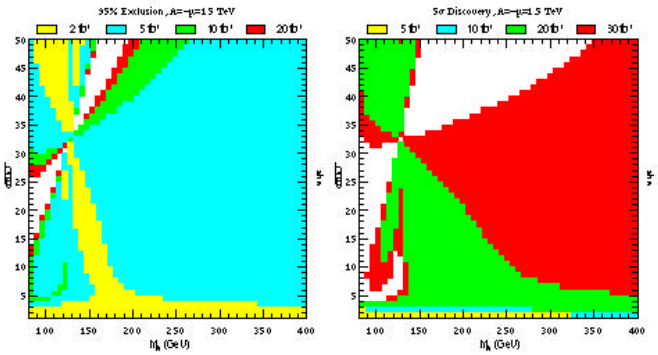


maximal stop mixing (heaviest h)



But not always so straightforward:

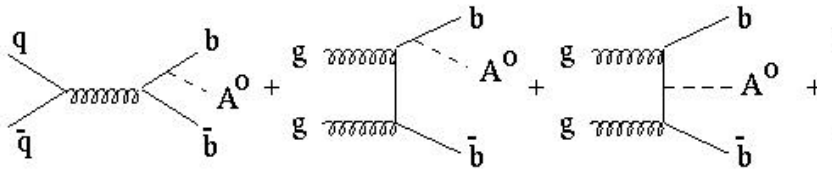
Fixed A (= $-\mu$ = 1.5 TeV here) suppresses hbb, h$\tau\tau$ couplings for



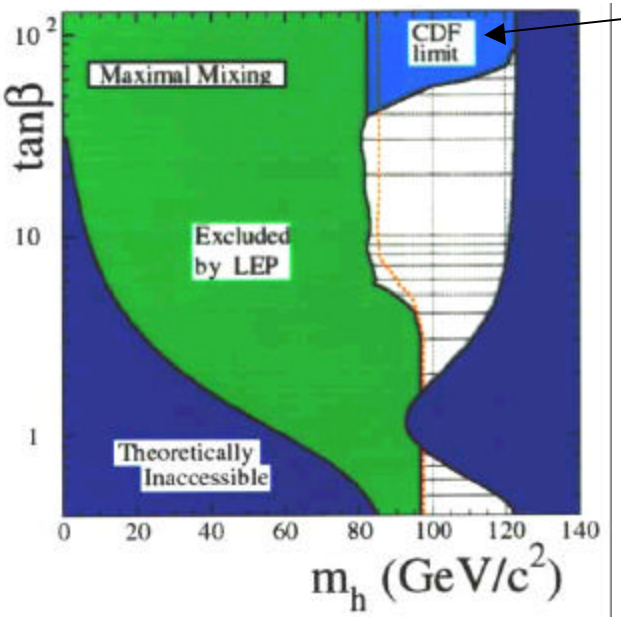
Enhances h ® gg
(branching ratio as high as 10%?)

Strong SUSY Higgs Production

- bb(h/H/A) enhanced at large tan β:

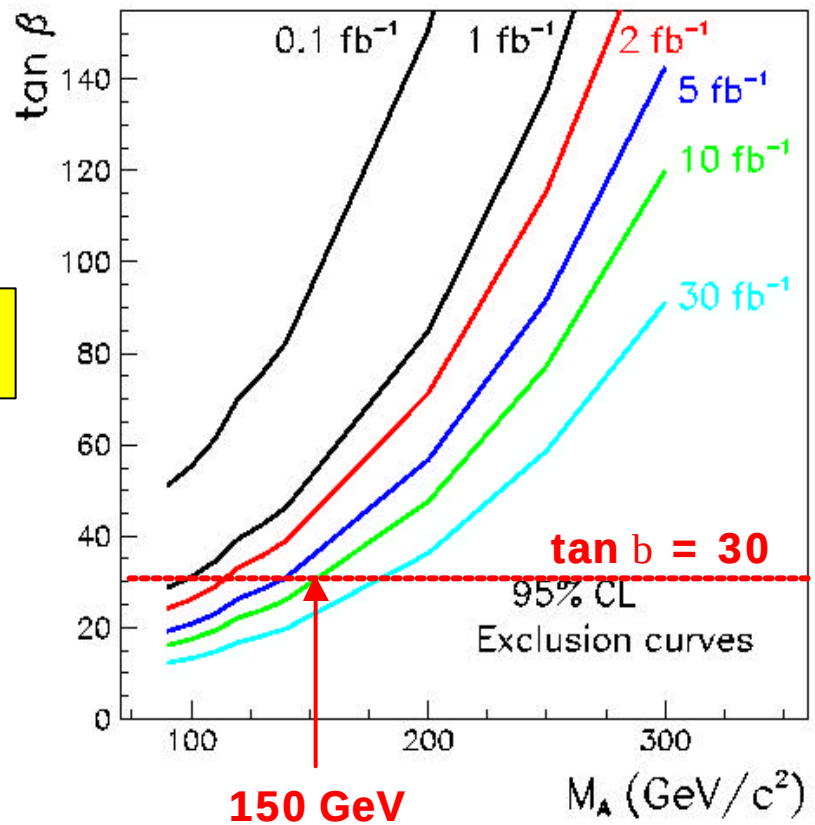


- σ ~ 1 pb for tanβ = 30 and m_h = 130 GeV



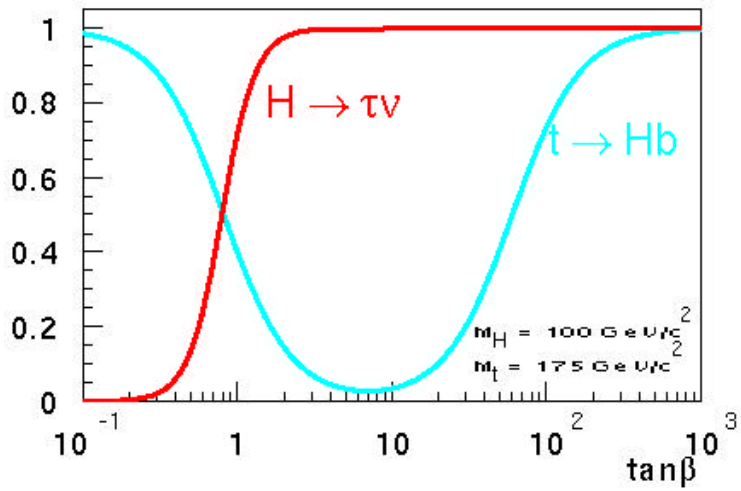
CDF Run I
3 b tags

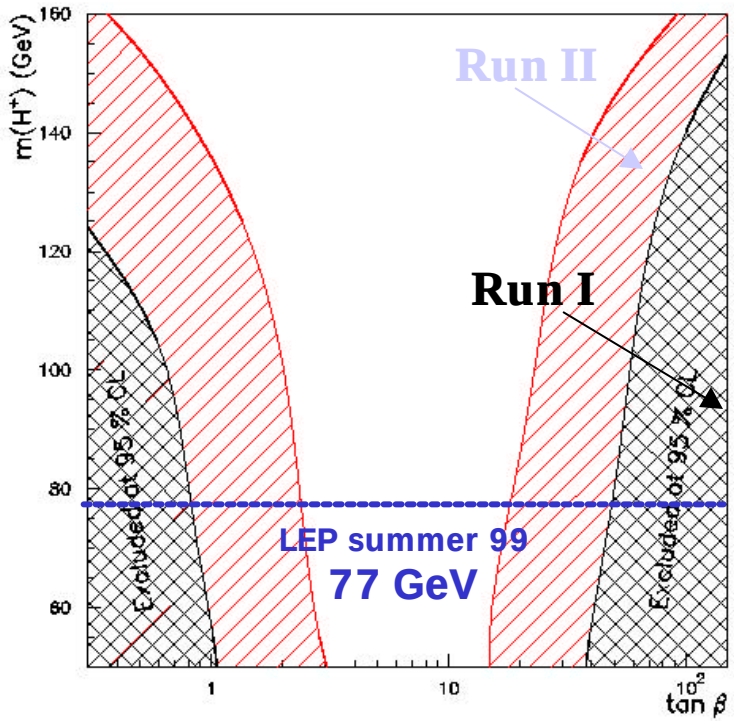
bb(h/A) ® 4b



Charged Higgs

- Tevatron search in top decays
- Standard tt analysis, rule out competing decay mode *t* ® $H^{\pm}b$
- Assumes 2 fb^{-1}, n_{obs} = 600, background = 50 ± 5





- LEP not really sensitive to MSSM region (expect $m_H > m_W$)