New Physics Searches at CDF

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For the CDF Collaboration

Motivation

- The SM Higgs is yet to be found
- Many hints (Naturalness Problem, neutrino oscillations, ...) that the standard model is incomplete
- New theories (SUSY, Technicolor, ...) predict new, heavy particles to appear at energies which may be now accessible at the Fermilab Tevatron

$\Rightarrow$ Search strategies:

1) Search specifically for a particle predicted by a major model

2) Do a signature-based search where no-one has looked before

Outline

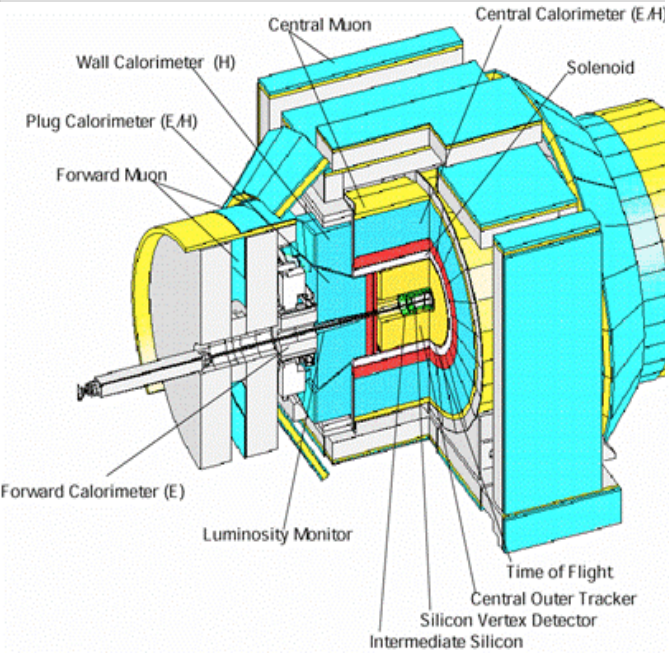
- Introduction
- Signature-based searches in $\gamma\gamma$ + ($\not{E}_T$,γ,μ, or e)
- High-Mass searches:
  Particles decaying into Z + jets, Z' $\rightarrow$ ee
- Searches for heavy, long-lived particles:
  Charged (CHAMPs) and neutral (GMSB neutralinos)
- SUSY searches in the golden mode:
  combined result for gaugino final states
- Higgs Searches: MSSM Higgs $\rightarrow\tau\tau$, SM h$\rightarrow$WW
- Conclusion

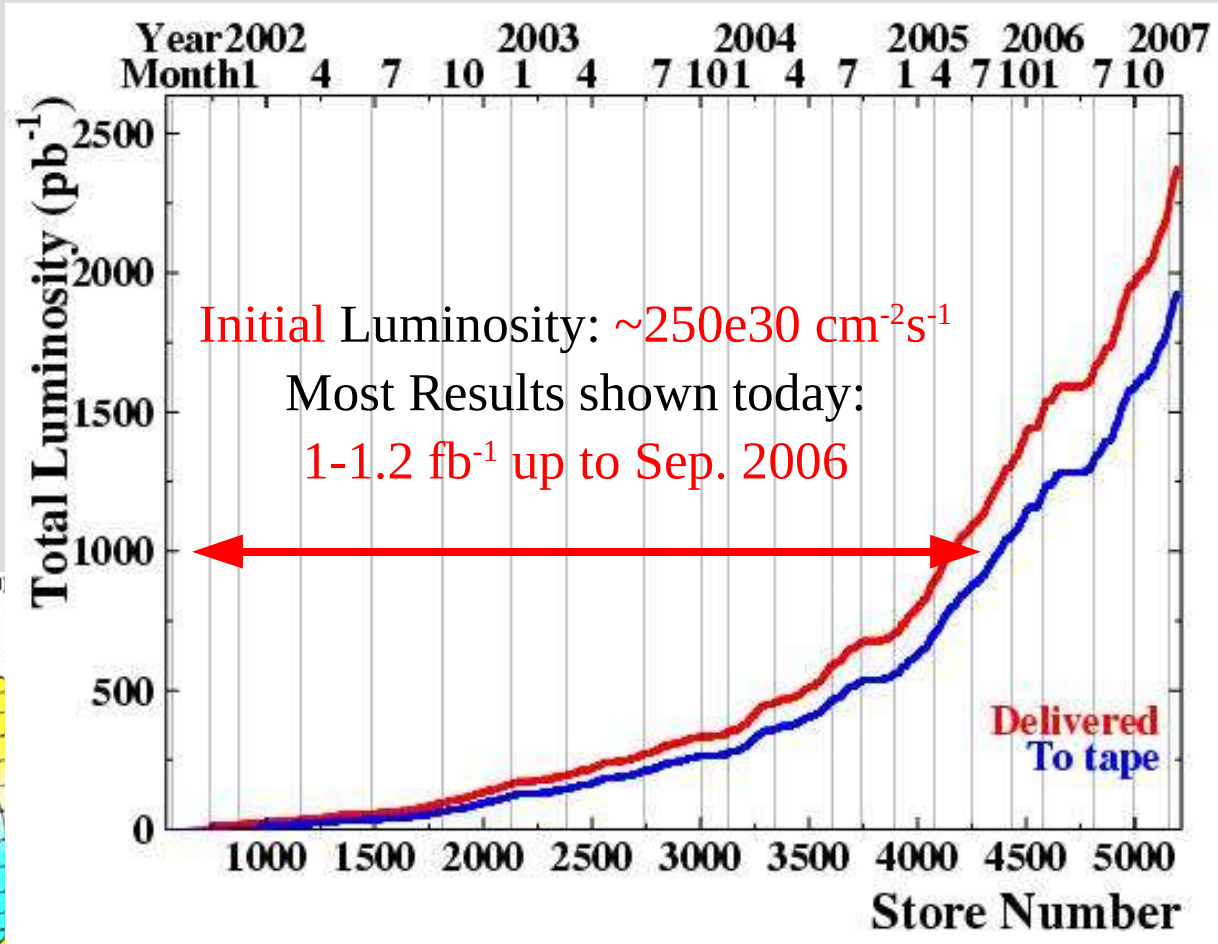
model-independent

model-specific

CDF II at the Tevatron

CDF





Data recorded at CDF: ~2 fb^{-1}

Signature-Based γγ+($\not\!\!E_T$, γ, μ or e)

L = ~1.2fb^{-1}

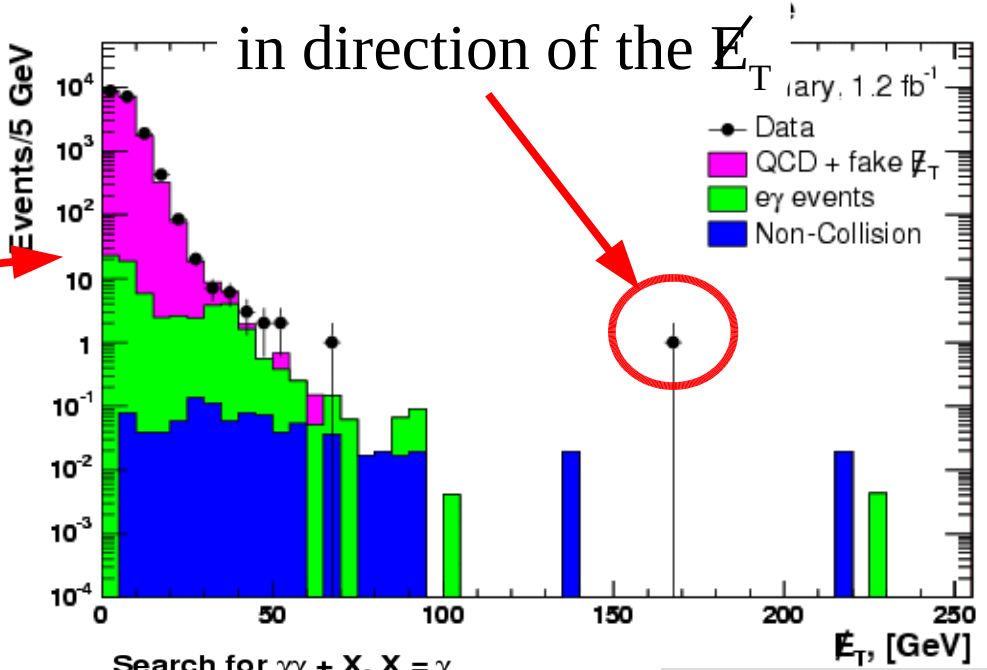
... τ and *b* coming soon!

Lots of models: SUSY $\tilde{\chi}_1^0 \to \gamma\tilde{G}$, $\tilde{\chi}_2^0 \to \gamma\tilde{\chi}_1^0$, Higgs→γγ, CDF eeγγ$\not\!\!E_T$ candidate event

$\not\!\!E_T$ > 50 GeV:

1.6±0.3 exp., 4 obs.

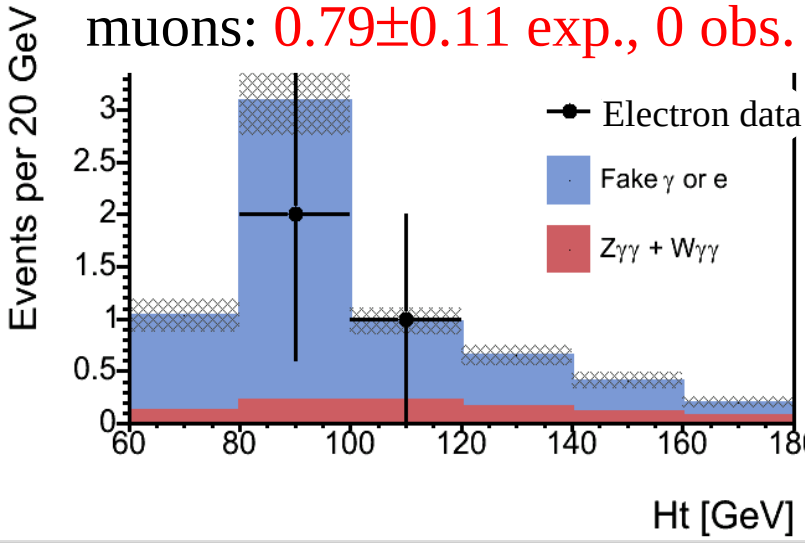
high-E_T jet points in direction of the $\not\!\!E_T$

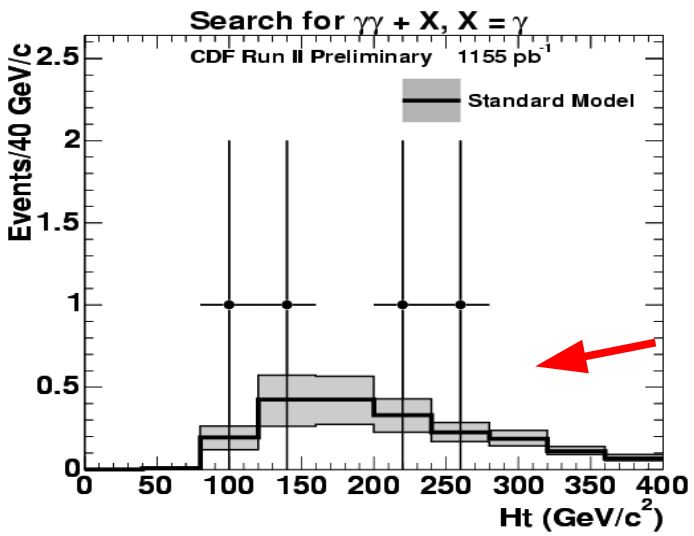


Lepton E_T > 20 GeV:

electrons: 6.82±0.75 exp., 3 obs.

muons: 0.79±0.11 exp., 0 obs.





3rd photon

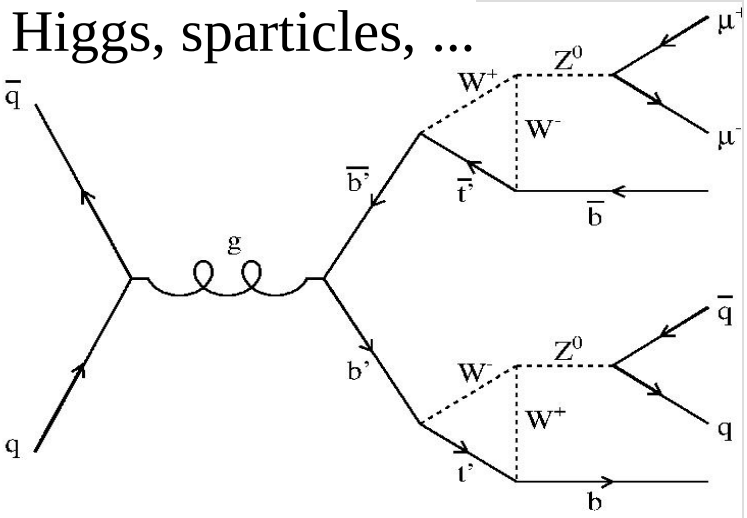
E_T > 13 GeV:

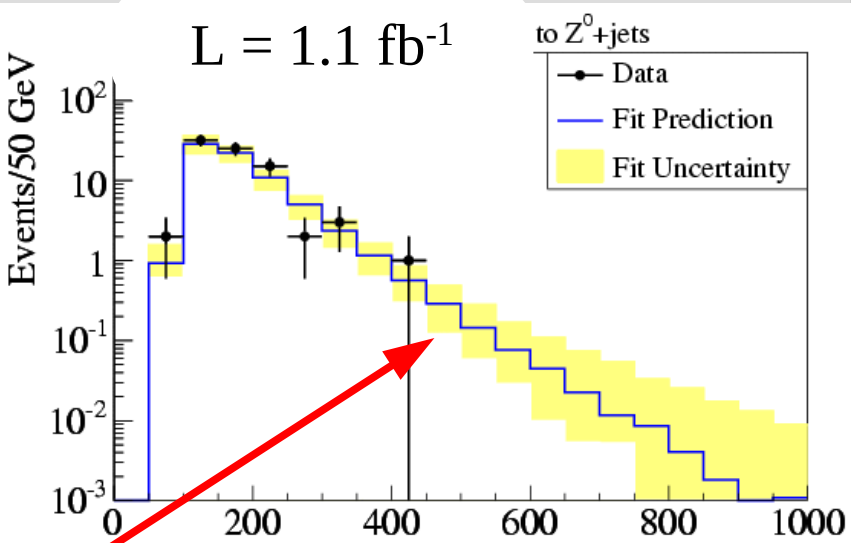
2.2±0.6 exp.,

4 obs.

High-Mass Decays to Z+jets

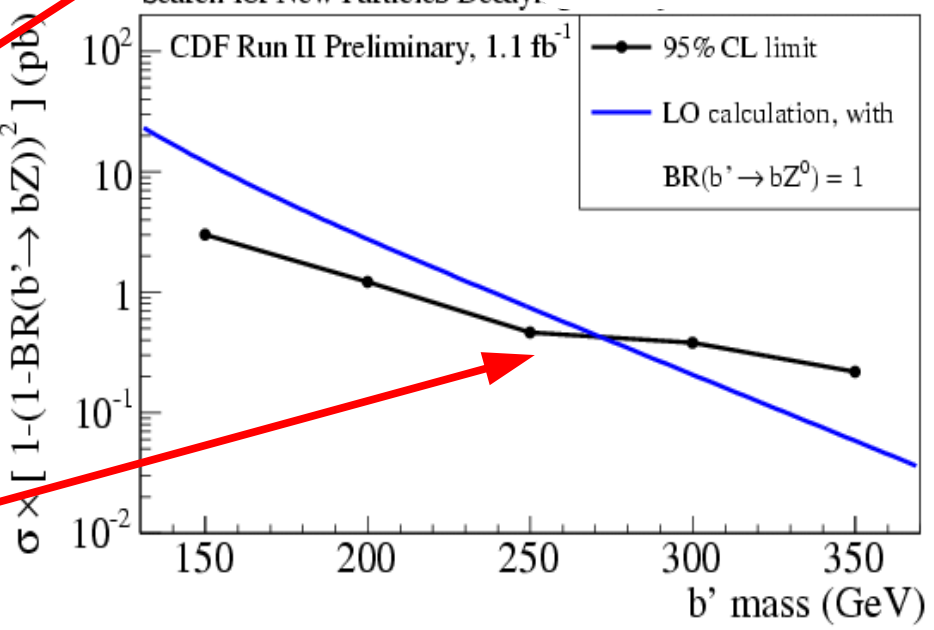
Could be *b'*, Higgs, sparticles, ...





1) e-pair or μ-pair consistent with the Z-mass
2) ≥3 additional jets with E_T>30 GeV
   suppress SM Z+jets production
3) Parametrize the jet E_T-distributions of events with 1 or 2 jets and extrapolate to the blinded signal region at ≥3
4) Set limits using *b'*-models with BR=100%:

m(*b'*)>270 GeV



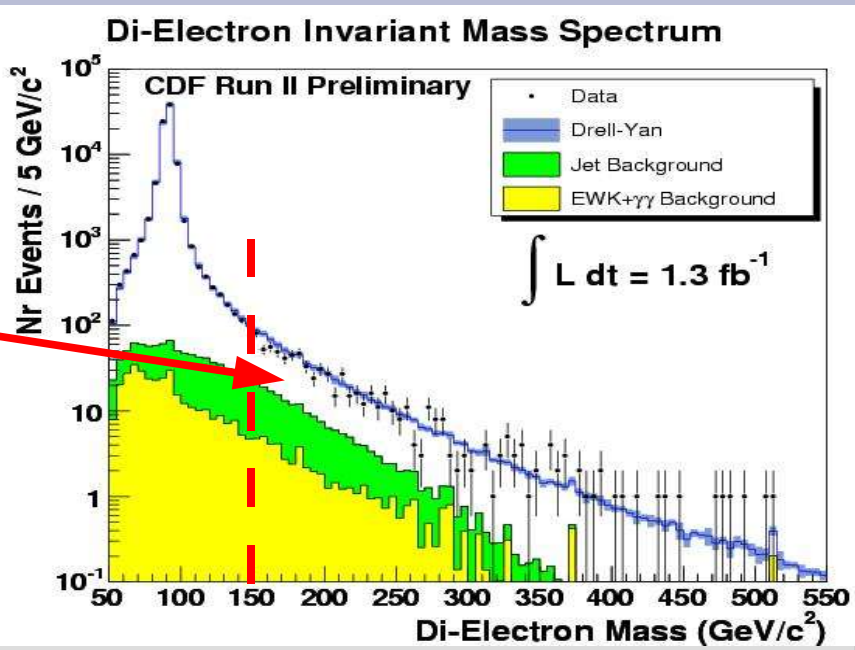
High Mass $Z' \rightarrow ee$

L = 1300 pb^{-1}

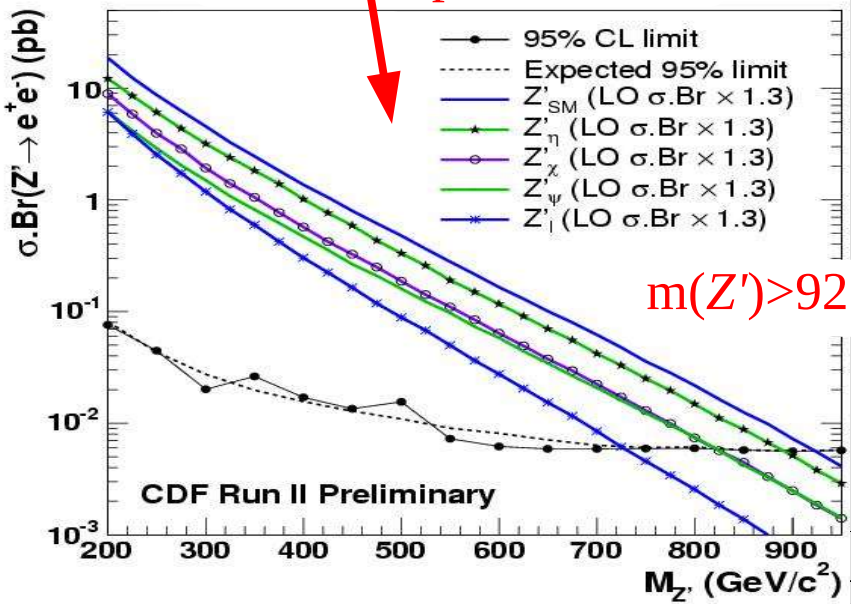
Could be Z', Randall-Sundrum Graviton...

- Require a high-E_T central electron and a high-E_T central or plug electron
- blind signal region: m_{ee} > 150 GeV
- scan the mass range in 1 GeV steps using the Z' mass resonance width (10-45 GeV)

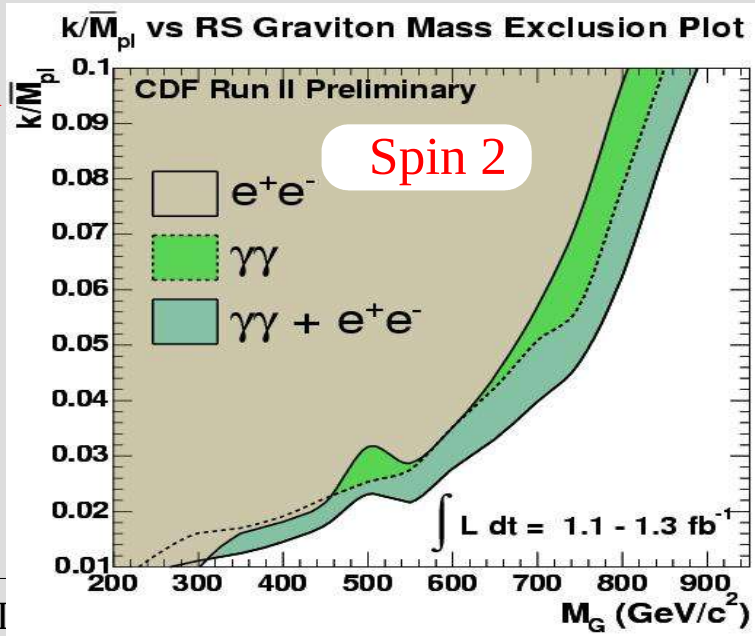
No stat. significant excess found ⇒ set limits on SM and E6 Z' and RS models



Spin 1



m(Z')>923 GeV



Neutral, Long-Lived Particle Decays to Photons

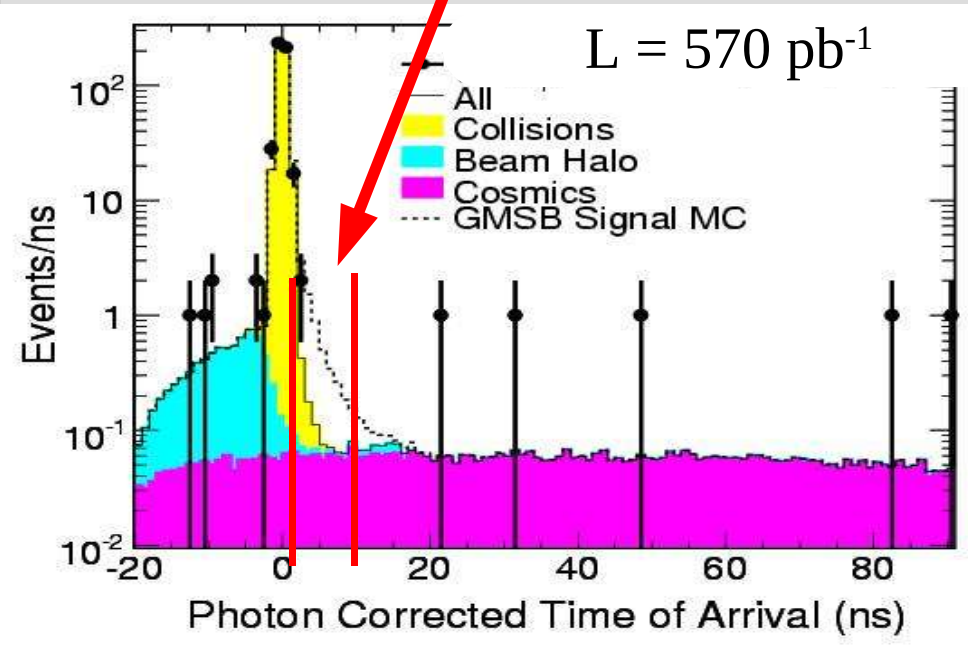
GMSB $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$ with ~nanosecond lifetime, Hidden Valley Models...

$E_T^\gamma > 30$ GeV, $\not{E}_T > 30$ GeV

and ≥1 jet to reduce non-collision bkg

Use calorimeter timing NEW to separate signal from SM photon background:

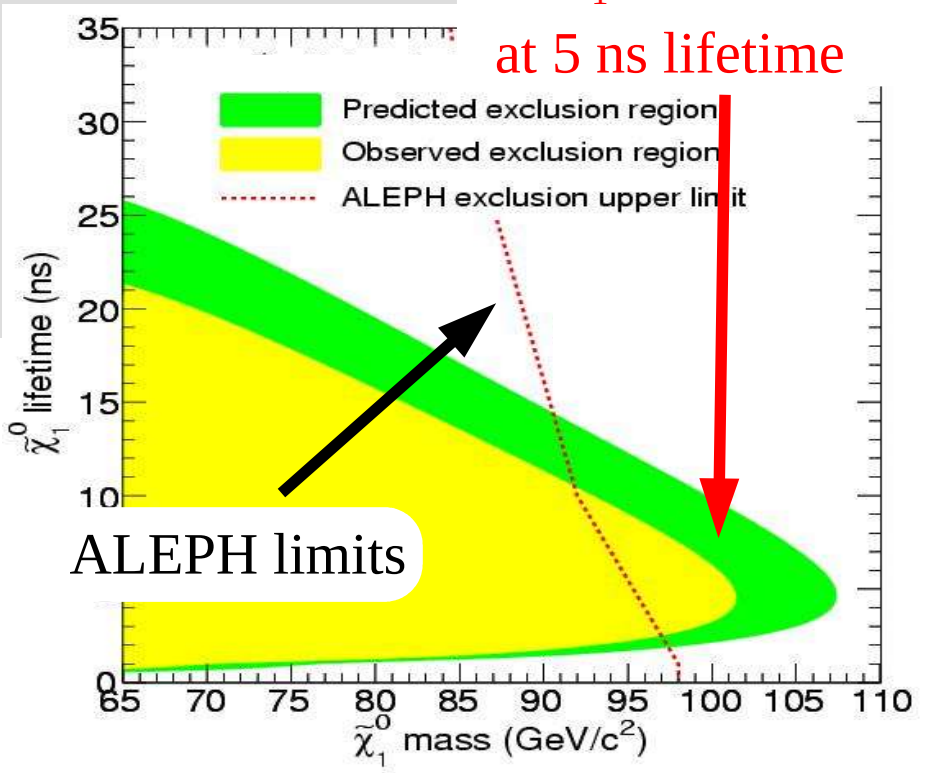
signal window $2 \text{ ns} < t^\gamma < 10 \text{ ns}$



Set GMSB limits:

$m(\tilde{\chi}_1^0) > 101$ GeV

at 5 ns lifetime



1.3±0.7 exp., 2 obs.

Model-independent limit: 5.5 events

Charged, Massive Particles (CHAMPS)

Search for slow-moving, massive particles with mass > 100 GeV

- Can e.g. occur in SUSY, GMSB with long-lived $\tilde{\tau}$ or $\tilde{t}$...
- Look at high-p_T muon or track
- Determine its mass from its velocity and its momentum

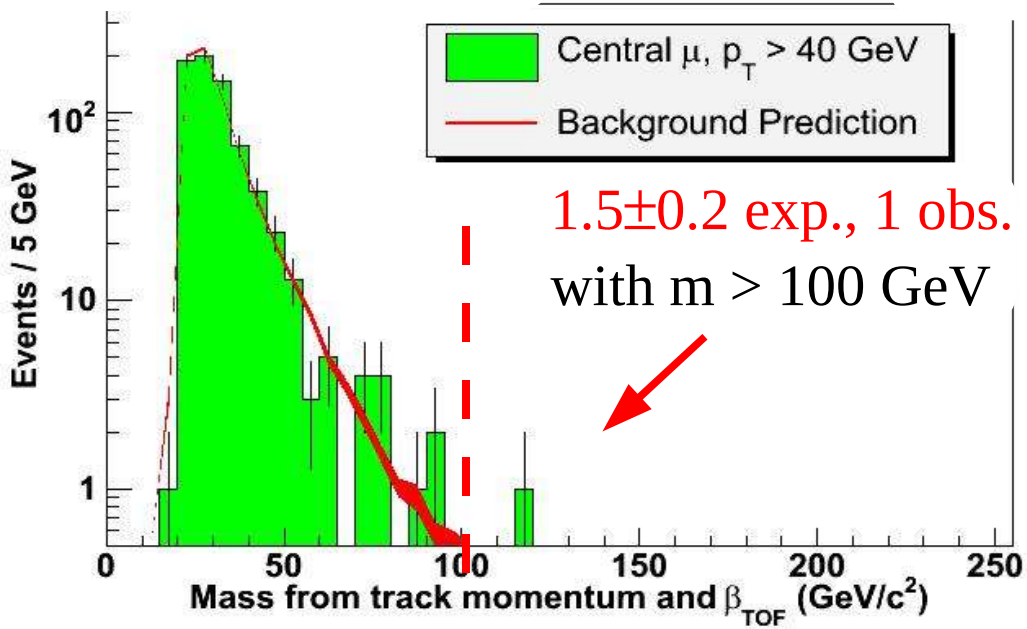
$$\frac{\text{track path length}}{\text{time of arrival} - \text{collision time}}$$

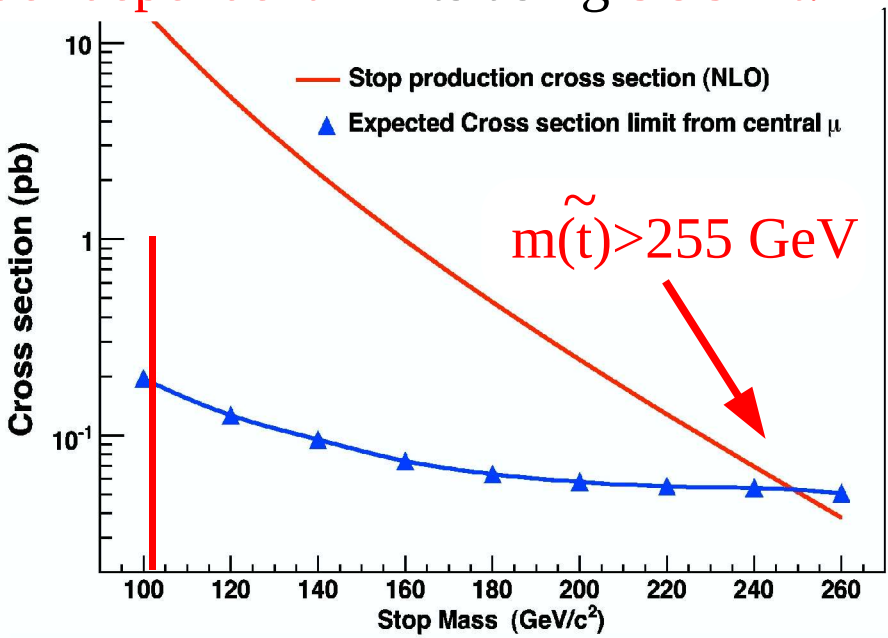
$\Rightarrow$ Model-independent limits $\sigma_{95} \cdot A_{kin} \cdot A_{fid}$

- strongly interacting CHAMPs: 48 fb
- weakly interacting CHAMPs: 10 fb

Model-dependent limits using SUSY $\tilde{t}$:

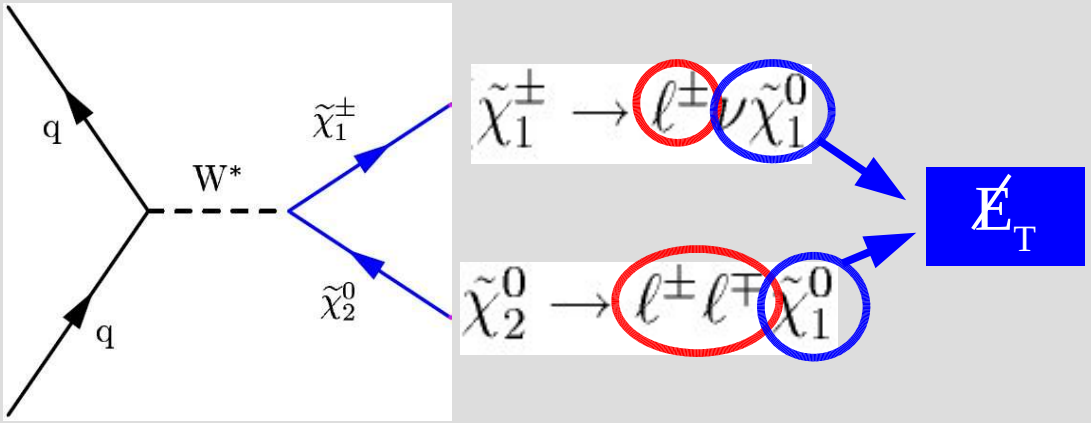
L = 1.03 fb^{-1}





SUSY Multilepton Searches

- mSUGRA is one of the most important SUSY models
- $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^{0}$ pair production is expected to be a golden mode at the Tevatron:



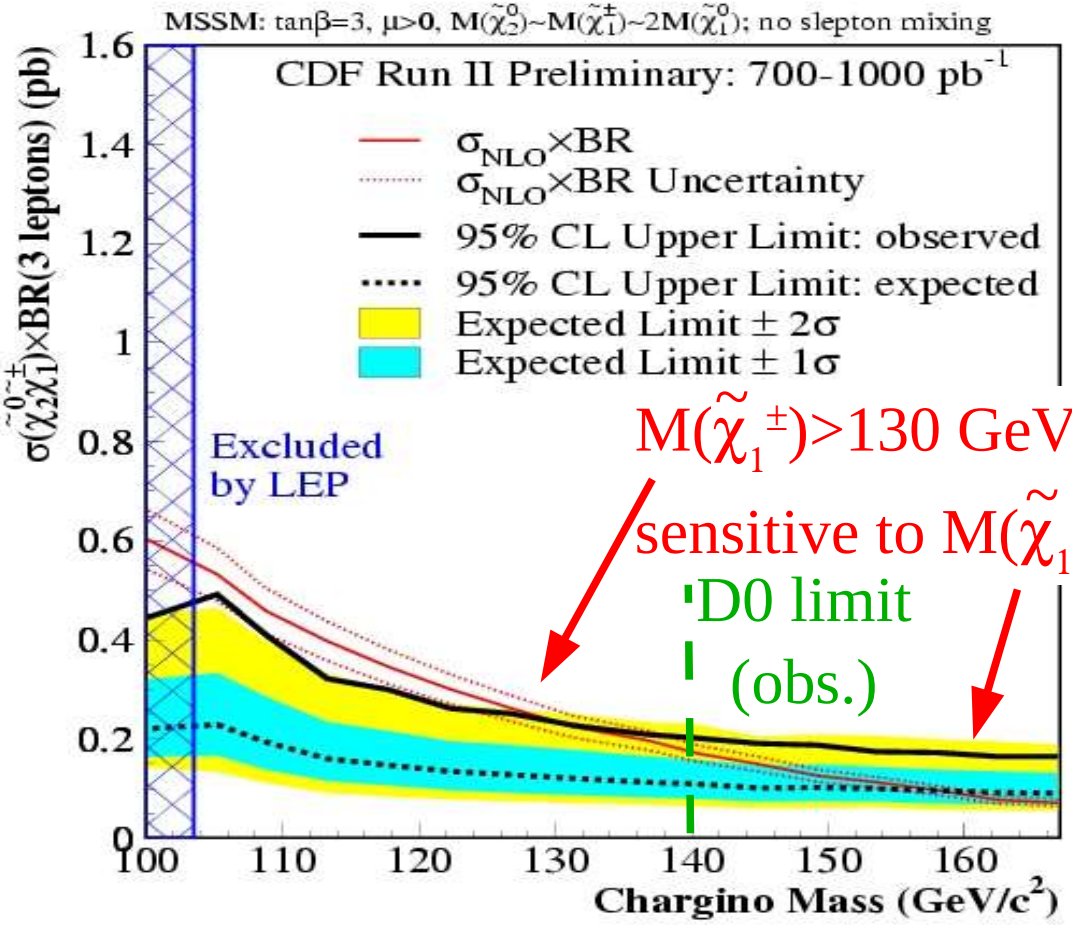
- Low σ_{prod} (~0.1-0.4 pb), however backgrounds very small
- Perform 14 blind searches that require high $\not{E}_T$ and either 2 (like-sign) or 3 isolated leptons (e or μ)

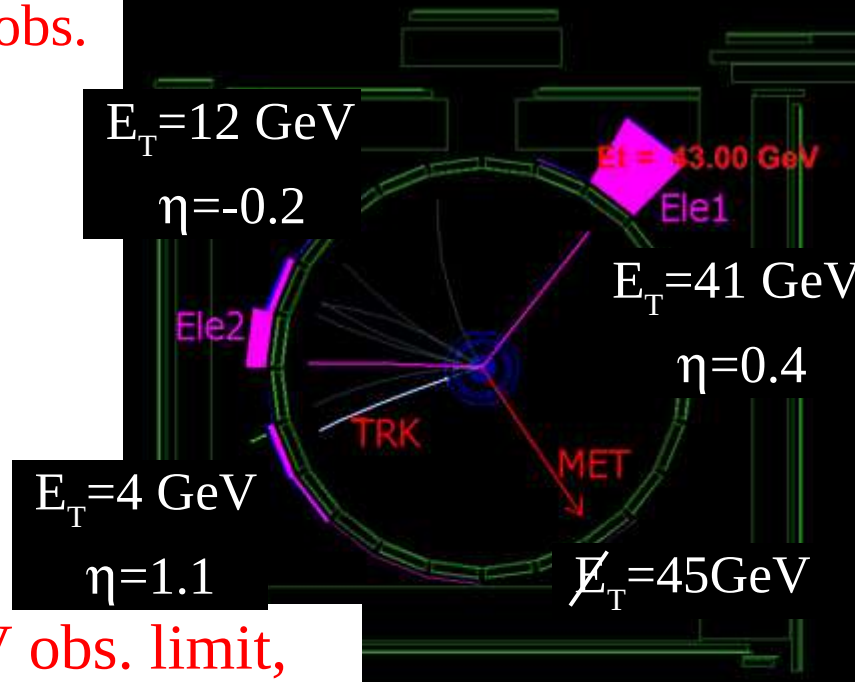
SUSY Multilepon: Combined Results

Interesting event in the ee+track search:

Largest excess in ee+track: 0.97±0.3 exp., 3 obs.

⇒ Limit-setting with mSUGRA-like MSSM without slepton mixing (same as D0)





$M(\tilde{\chi}_1^{\pm})$>130 GeV obs. limit,

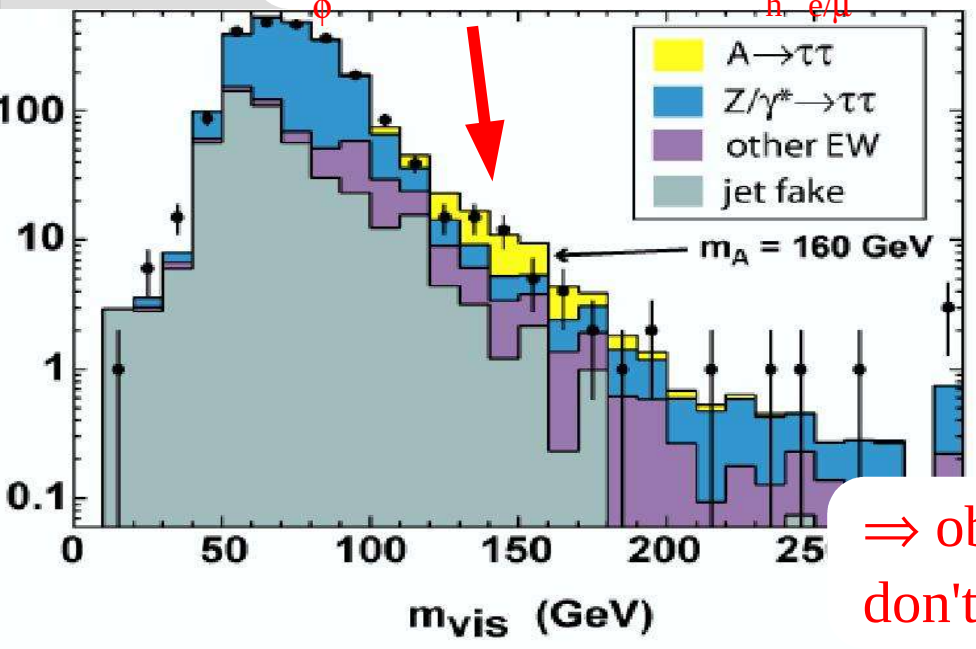
sensitive to $M(\tilde{\chi}_1^{\pm})\cong$160 GeV

MSSM Higgs $\rightarrow \tau^+\tau^-$

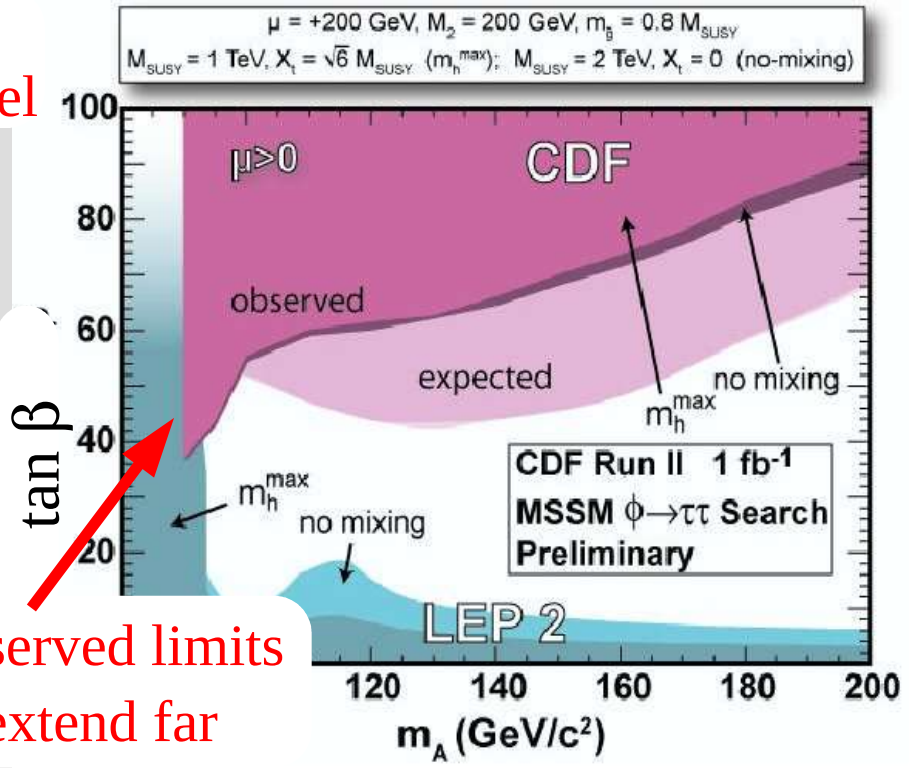
L = 1 fb^{-1}

- Dominant production of h,H,A ($\equiv\phi$) at the Tevatron is gg-fusion
- $\phi\rightarrow\tau^+\tau^-$ has BR ~10% (low compared to $b\bar{b}$), but can reduce both Z/γ and QCD background by selecting events with $\tau_h\tau_{e/\mu}$ or $\tau_e\tau_\mu$ NEW
- To have sensitivity to low mass ϕ don't reject the major Z bkg.
- Binned likelihood fit to the visible combined τ-mass and scan through Higgs masses

Slight excess (<2σ) for m_ϕ=160 GeV in the $\tau_h\tau_{e/\mu}$ channel



Set limits for MSSM scenarios:



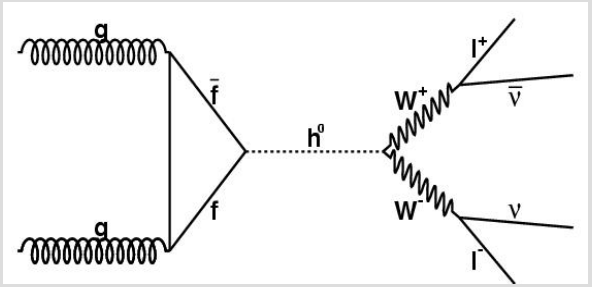
⇒ observed limits don't extend far

SM Higgs $h^0 \rightarrow WW^*$

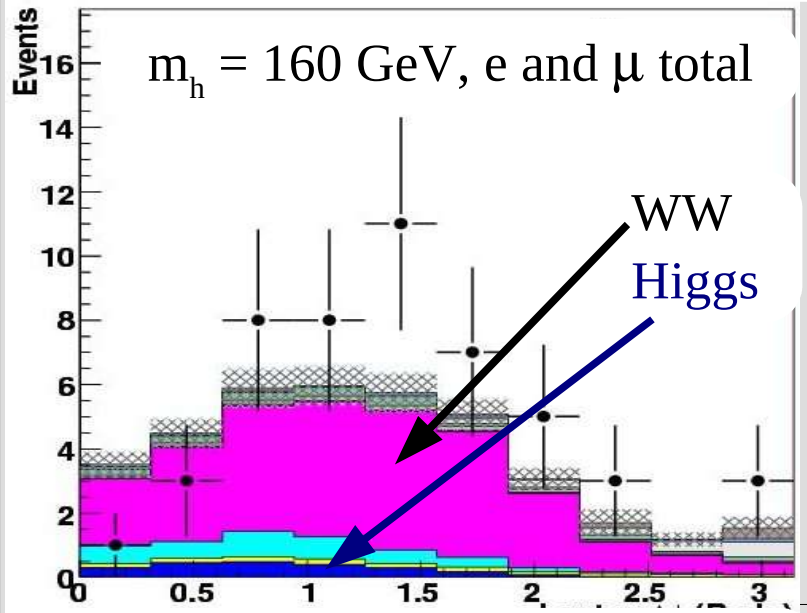
NEW

$L = 1\ fb^{-1}$

- At the Tevatron $gg \rightarrow h^0$ (σ_{prod} = 0.2-1pb) dominates, $h^0 \rightarrow WW^*$ is the dominant decay mode for $m_h \gtrsim 135$ GeV
- require one l=e or μ from each leptonic W decay
- Major background (30-70%): SM diboson (WW)

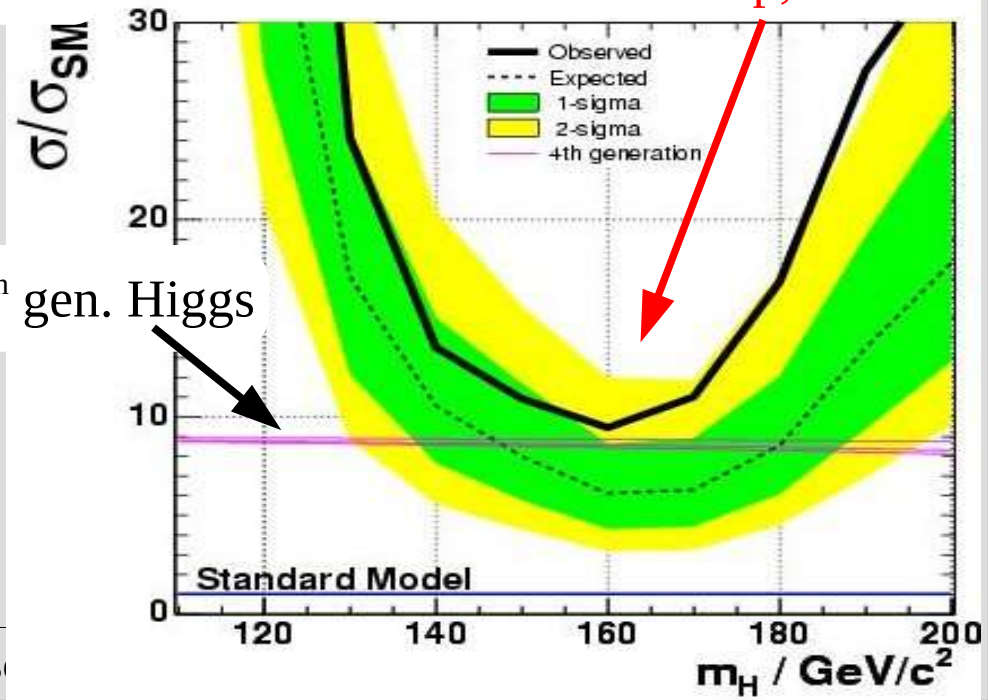


Leptons from resonant WW production are correlated ⇒ to discriminate signal from bkg use the azimuthal separation of the two leptons, for m_h = 110 ... 200 GeV



At m=160 GeV: σ(obs)=3.6pb

Limit / SM rate = 6.0 exp, 9.2 obs



Conclusion

- Lots of results from the recent new physics searches at CDF:

Signature-based $\gamma\gamma$+X: broad search for exotic photon production

Heavy objects:

- Decays to Z+jets: world best mass limits using b'
- High Mass Z'→ee: world best mass limits on Z' and RS models
- Charged, massive particles: $\tilde{t}$ mass limit at 255 GeV
- Neutral, long-lived particle-decays to photons: already world best mass-lifetime limits on GMSB $\tilde{\chi}_1^0$

SUSY in the "golden mode":

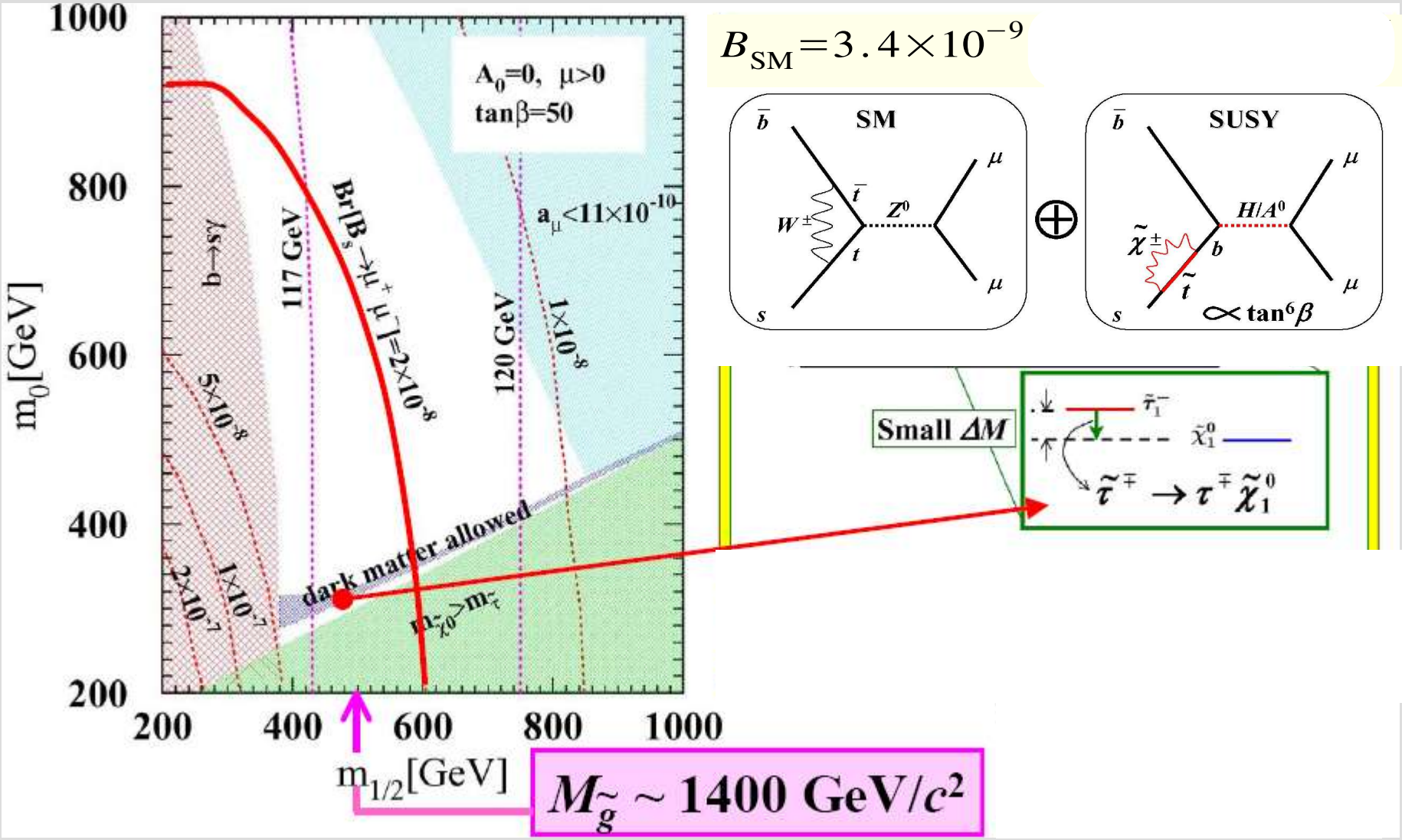
- Trileptons combined: most sensitive channel for mSUGRA
- MSSM Higgs $\rightarrow \tau\tau$: slight excess at ~160 GeV $\rightarrow$ investigate!

SM Higgs $h^0 \rightarrow WW^*$: sensitive to 4th gen. Higgs, only factor 6.0 away from the SM prediction, small excess

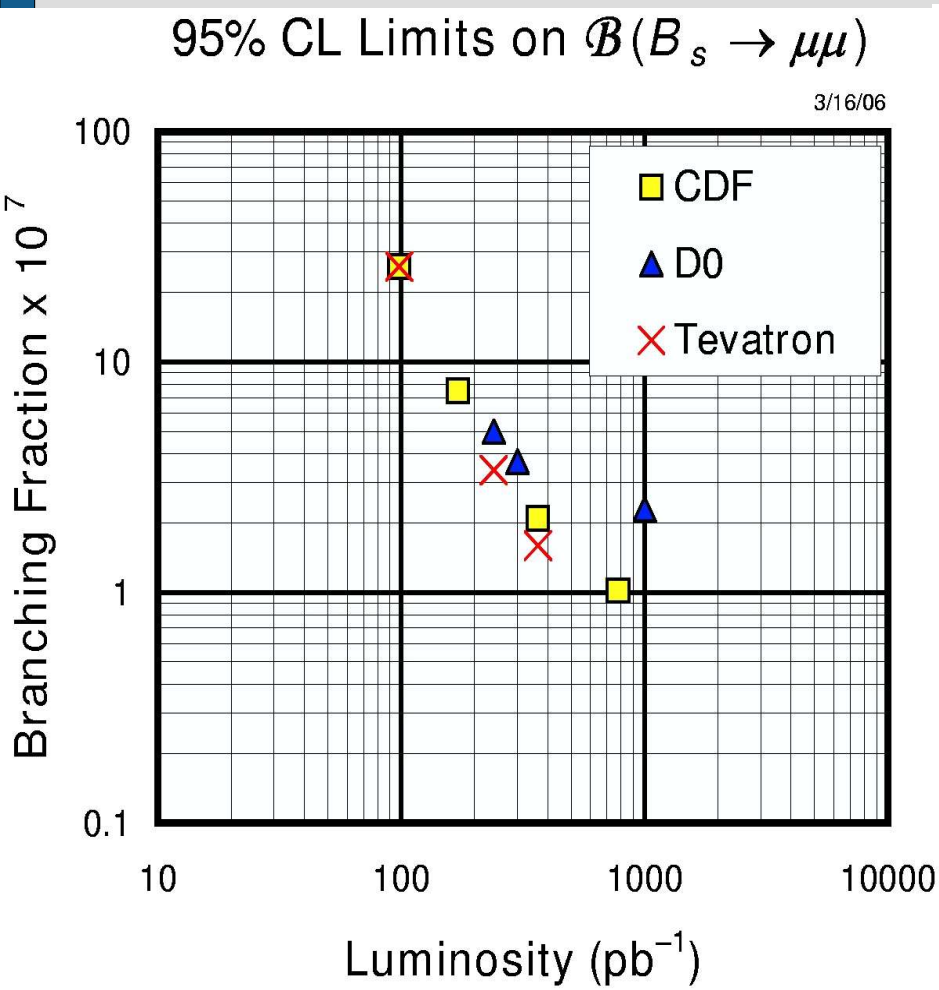
... stay tuned! We already doubled the data...

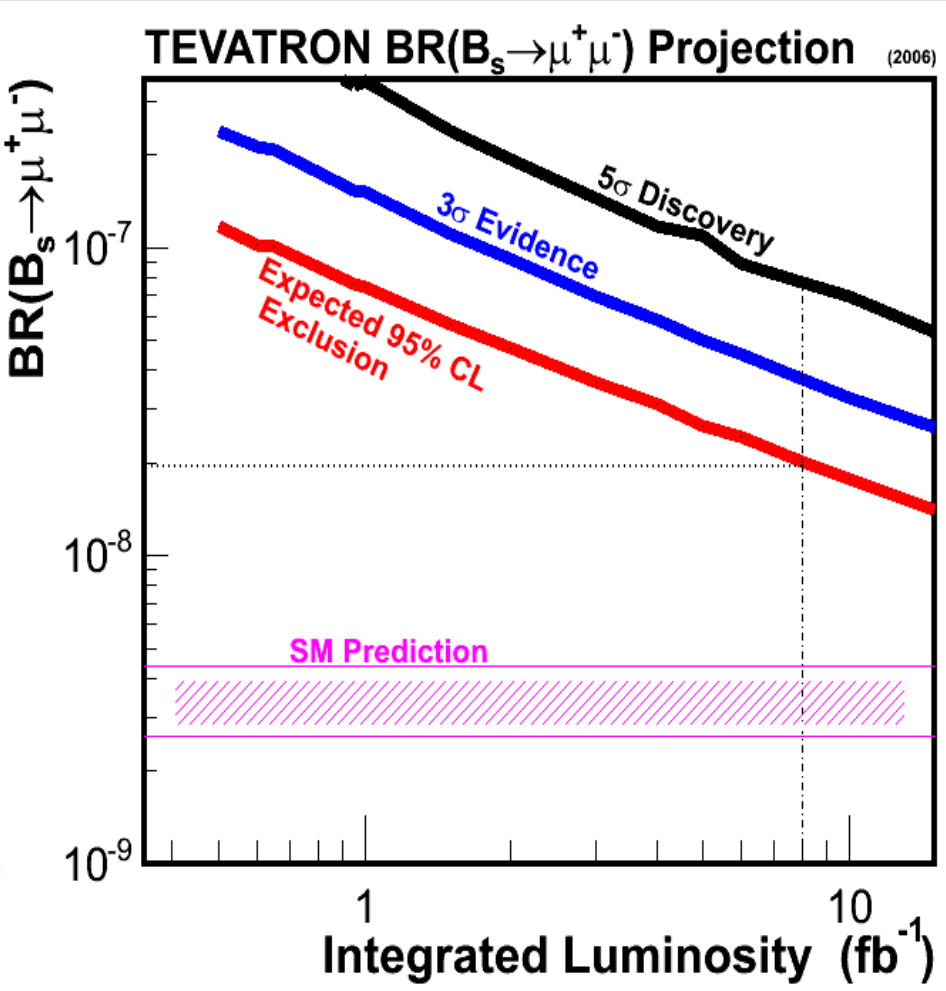
BACKUP

$B_s \rightarrow \mu\mu$



$B_s \rightarrow \mu\mu$





SUSY: Combined Results I

- Trilepton search results:

	$ee(CEM)+\ell$	$ee(PLUG)+\ell$	$e\mu+\ell$	$\mu\mu+\ell$ (high-p_T)	$\mu e(CEM)+\ell$	$\mu e(PLUG)+\ell$	$ee+track$	$\mu\mu+\ell$ (low-p_T)
Luminosity	1034 pb^{-1}	954 pb^{-1}	1034 pb^{-1}	745 pb^{-1}	745 pb^{-1}	680 pb^{-1}	1013 pb^{-1}	976 pb^{-1}
$p_T^{\ell_1}, p_T^{\ell_2}, p_T^{\ell_3,track}$ (GeV/c)	20,8,5	20,8,5	20,8,5	20,5,5	20,5,5	20,5,5	15,5,4	5,5,5
Expected number of SM background events	0.44± 0.08	0.34± 0.10	0.28± 0.09	0.64± 0.18	0.42± 0.08	0.36± 0.07	0.97± 0.28	0.42± 0.12
Number of observed events	0	0	0	1	0	0	3	1

- LS-dilepton search results:

	ee LS	$e_{si}e$ LS	$e_{si}e_{si}$ LS	$e_{si}\mu$ LS	$e\mu$ LS	$\mu\mu$ LS
Luminosity	993 pb^{-1}	993 pb^{-1}	993 pb^{-1}	971 pb^{-1}	971 pb^{-1}	1087 pb^{-1}
$p_T^{\ell_1}, p_T^{\ell_2}$ (GeV/c)	20,10	20,10	20,10	20,10	20,10	20,10
Expected number of SM background events	0.10± 0.10	1.50± 0.30	1.30± 0.30	1.70± 0.20	2.30± 0.50	0.90± 0.10
Number of observed events	1	2	1	4	4	1

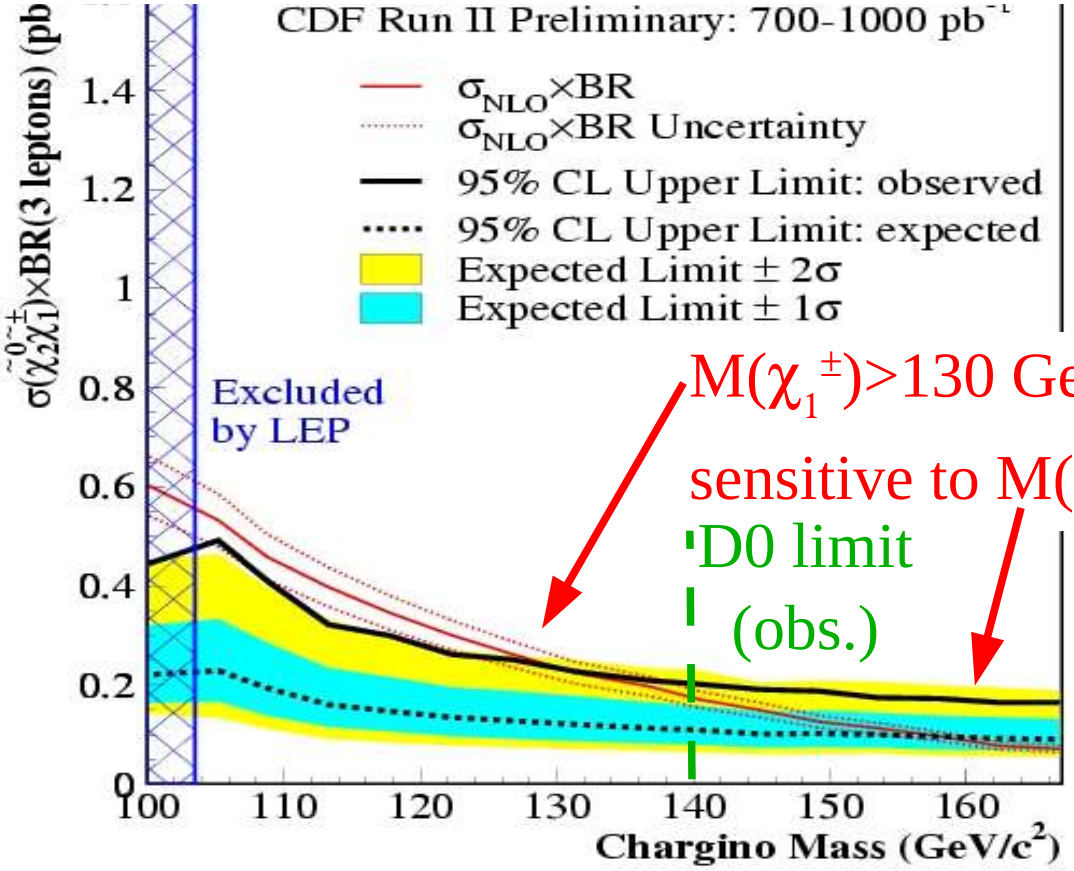
Backgrounds: mainly Drell-Yan, W/Zγ, dibosons and fake leptons

SUSY: Combined Results

- Each accepted event can only occur in one analysis only
- Both the requirement optimization in each analysis and the limit-setting are guided by the mSUGRA point:

  M_0=100 GeV, $M_{1/2}$=180 GeV/c, A_0=0, tan(β)=3, μ>0

  (⇒ $M(\chi_1^{\pm})\cong M(\chi_2^0)\cong 113$ GeV $\cong 2*M(\chi_1^0)$, $M(\sim q)\cong 400$ GeV)



- Limit-setting with mSUGRA-like MSSM without slepton mixing (same as D0)

$M(\chi_1^{\pm})$>130 GeV obs. limit,

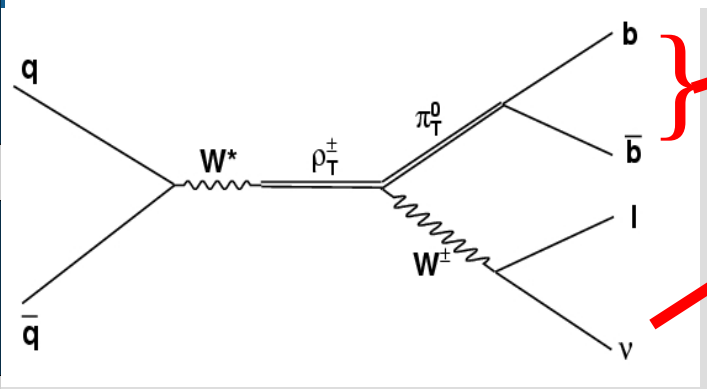
sensitive to $M(\chi_1^{\pm})\cong 160$ GeV

D0 limit (obs.)

Technicolor: $\rho_T \rightarrow \pi_T + W$

L = 955 pb^{-1}

At the Tevatron: σ_{prod} ~ 1-3 pb

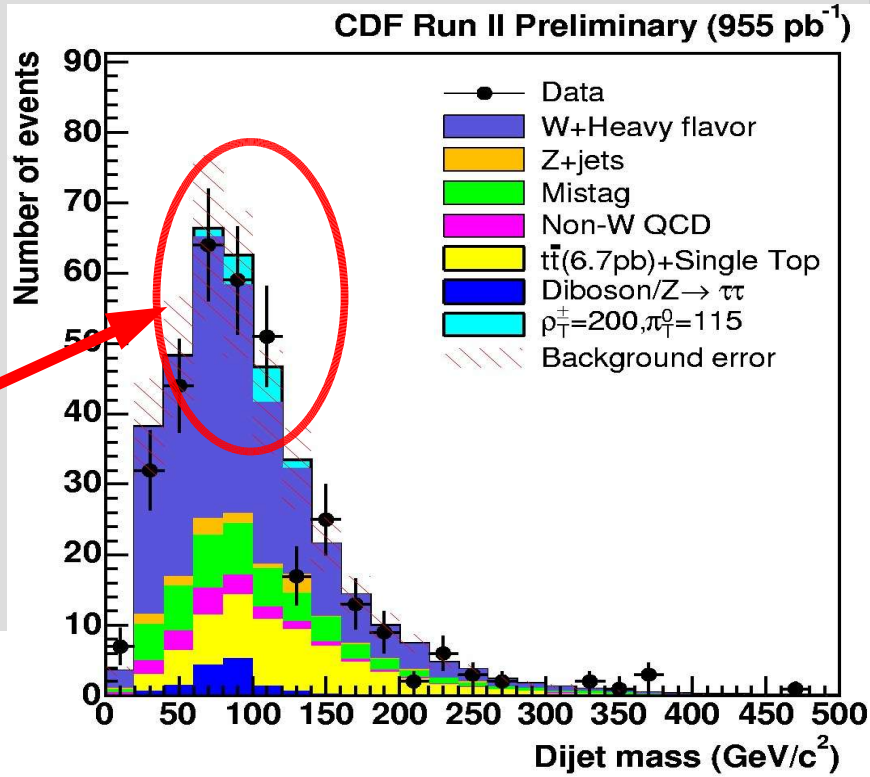


1) require exactly 2 jets, separate into a single (neural network) and a double *b*-tag analysis
2) combine results for limit calculation

$\not{E}_T$ > 25 GeV reduces QCD events with fake leptons

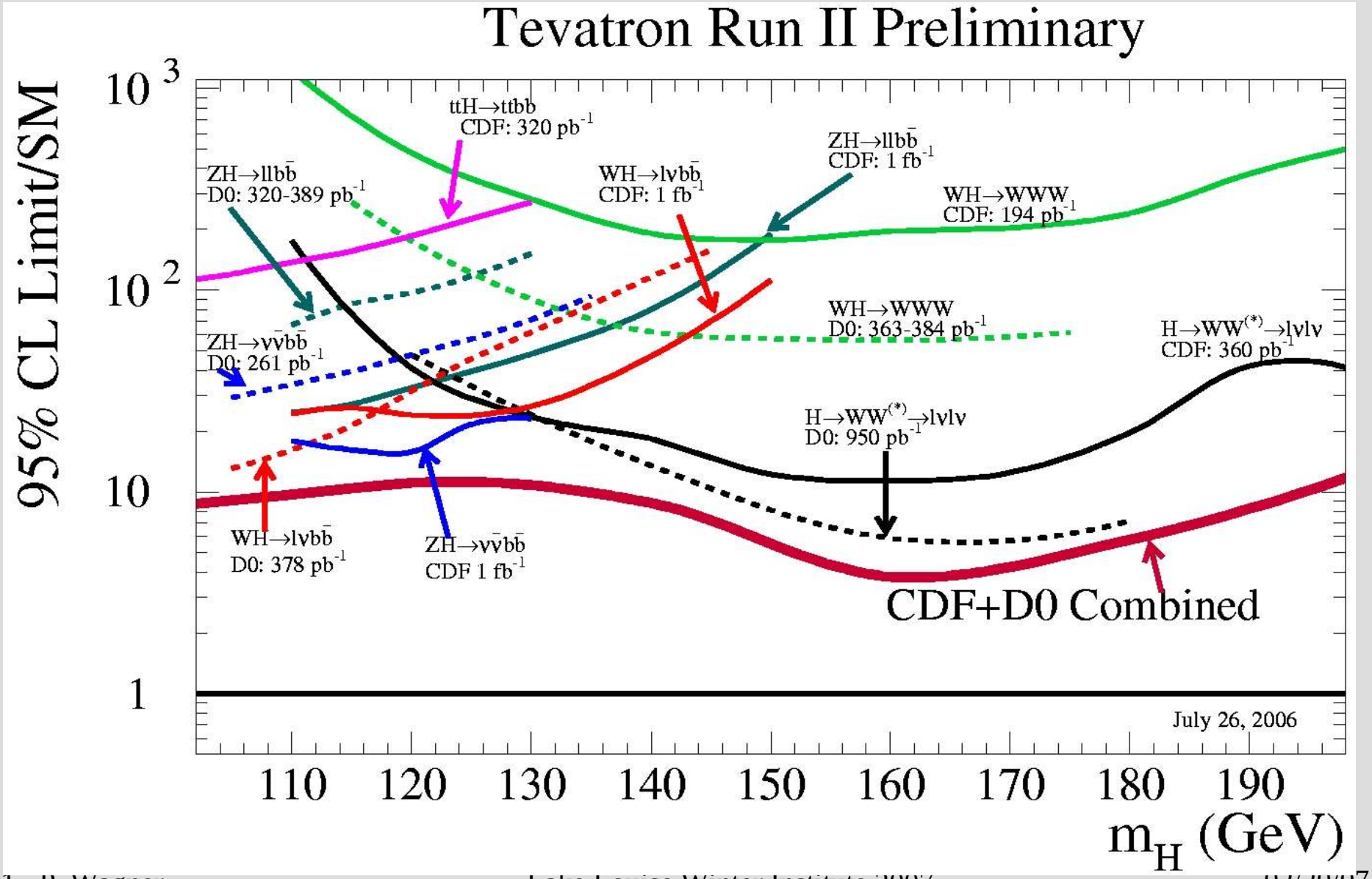
Method: Look for peaks in dijet and Q=m(W+2jet)-m(dijet)-m(W) distributions
Fit simultaneously with a 2D binned likelihood
→ Cross section limits at ~3-4pb

At m(π_T)=105 GeV, m(ρ_T)=210 GeV:
excess with p-value 2.6%!
BUT: it's mostly from single *b*-tag data

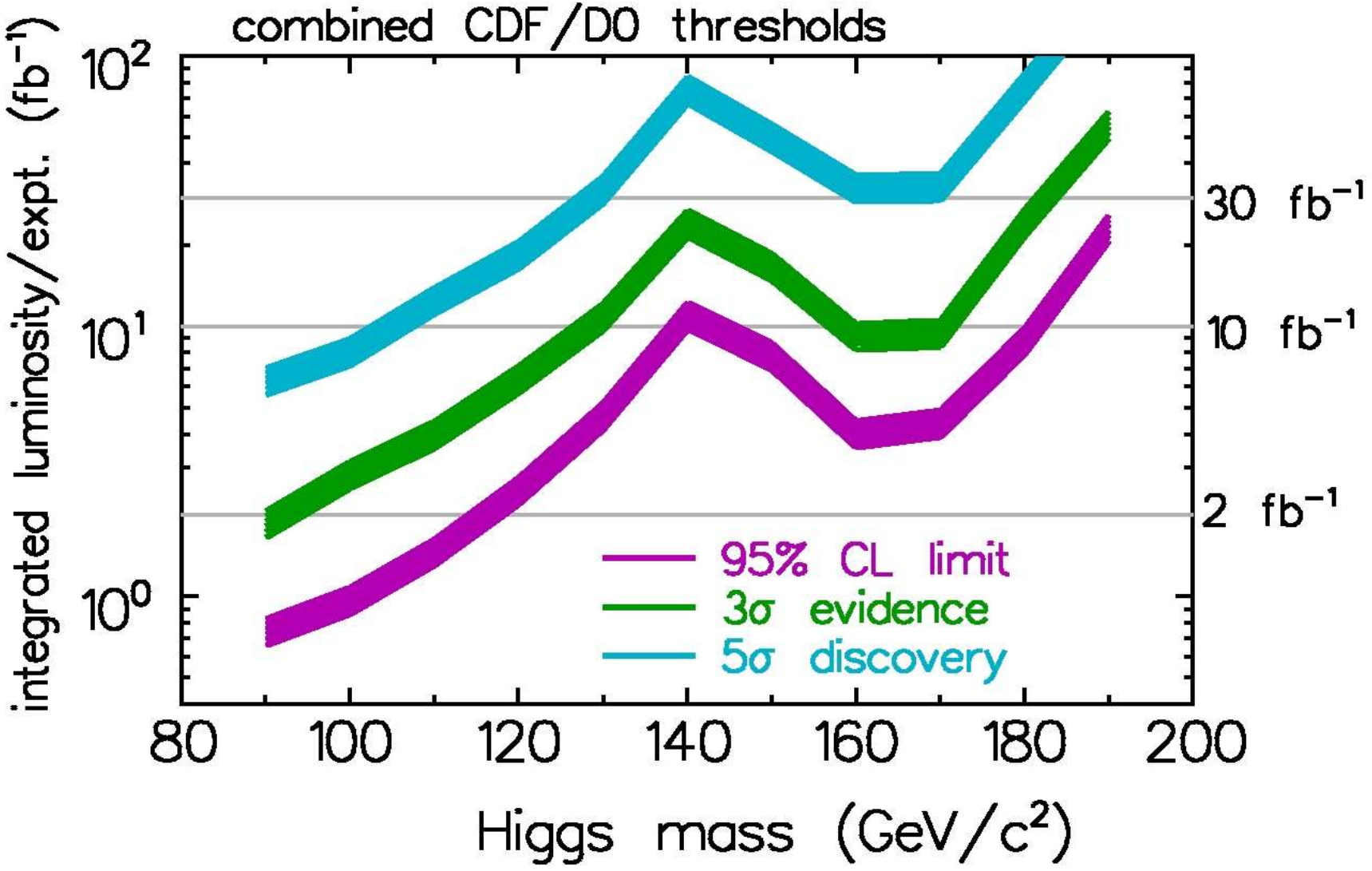


Plan: more data, optimize event selection...

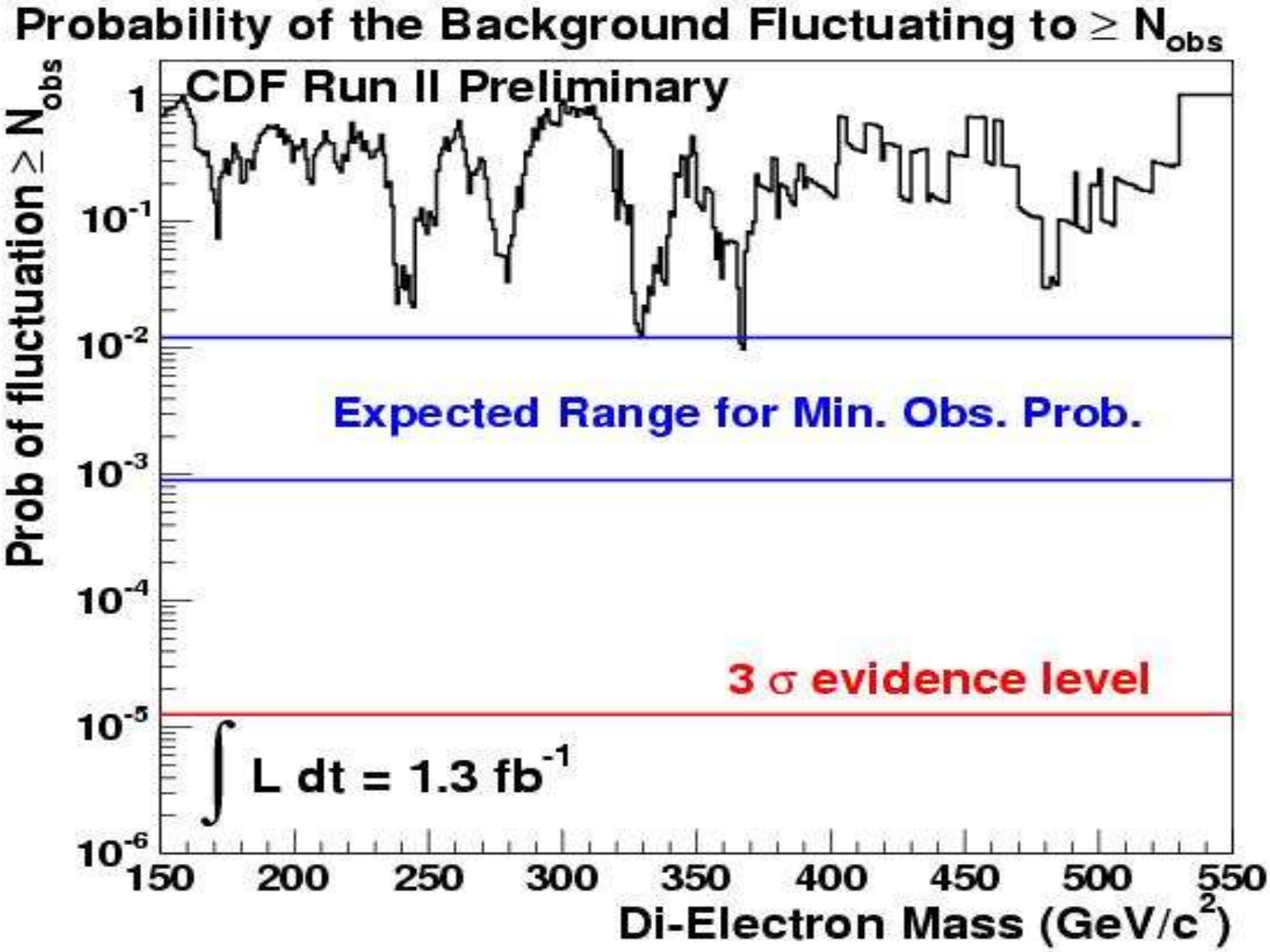
SM Higgs $h^0 \rightarrow WW^*$



SM Higgs $h^0 \rightarrow WW^*$



Dielectron Search



Dielectron Search