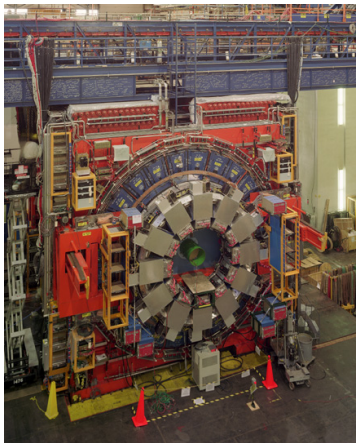


Searches For New Physics at CDF



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Lake Louise, Feb 2005

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[**New** Physics vs. **Old** Physics]

- **Higgs**
 - SM
 - MSSM
- **SUSY**
- **Z', W'**
- **Large Extra Dimensions**
- **Leptoquarks, etc**

*~ few fb
to 10⁴ fb*

- **QCD** (quarks, gluons → jets)
 - 10¹² fb
- **Bottom quarks**
 - 10¹¹ fb
- **W, Z Bosons**
 - 10⁷ fb
- **Top quark**
 - 10⁴ fb

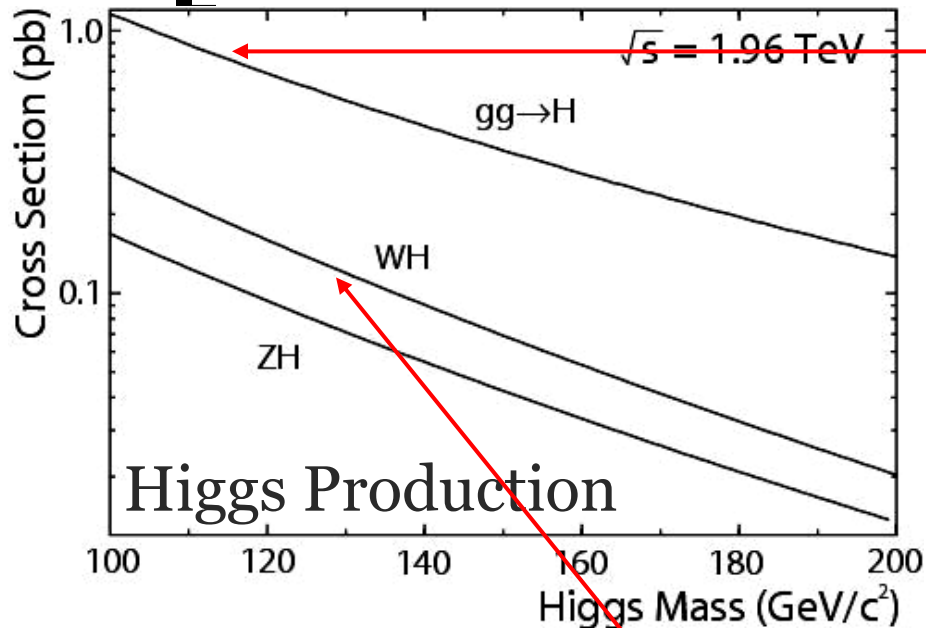
Old swamps New!

We need to be clever.

Objects Needed for Searches

- **Higgs** → 3rd gen objects
 - SM → b, leptons
 - MSSM → b, τ
- **SUSY** → \cancel{E}_T , leptons, γ
- **Z', W'** → lepton pairs, lepton + \cancel{E}_T
- **Large Extra Dimensions** → lepton, γ pairs
- **Leptoquarks, etc** → lept(\cancel{E}_T) + jets ...

Searches for Higgs



Higgs production $\sim 10^3$ fb

90% decay to bb

Backgrounds:

Swamped by 10^{11} fb of direct bb production.

10% decay to $\tau\tau$

Backgrounds:

$Z \rightarrow \tau\tau$ irreducible: 10^2 fb

Higgs produced with W at $\sim 10^2$ fb

$W \rightarrow \text{lepton} + \nu$, $H \rightarrow bb$.

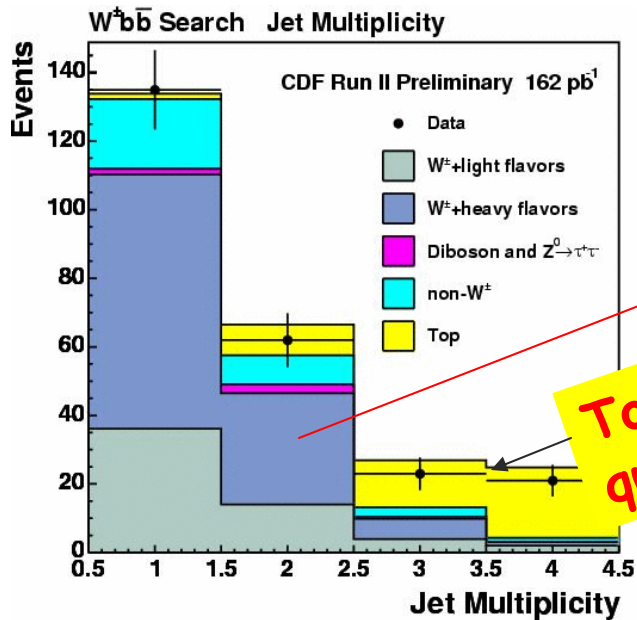
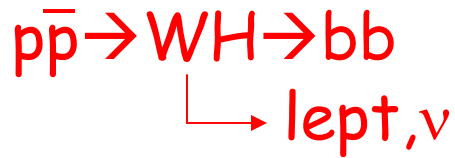
Backgrounds:

W + quark/gluon jet,

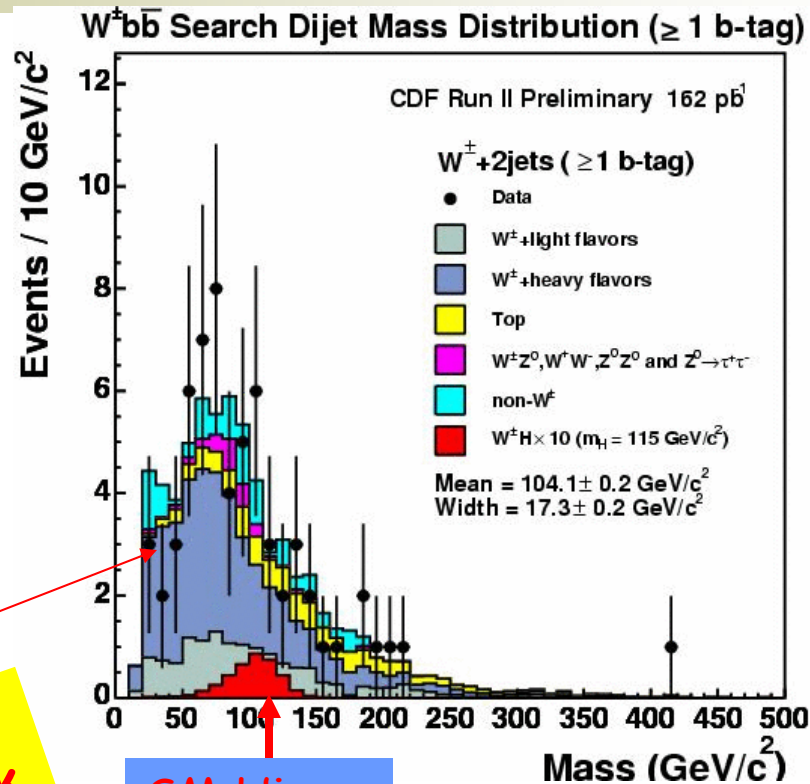
either real b quark jet,

or light quark jet that looks like a b jet

Higgs Produced with W



Top quark

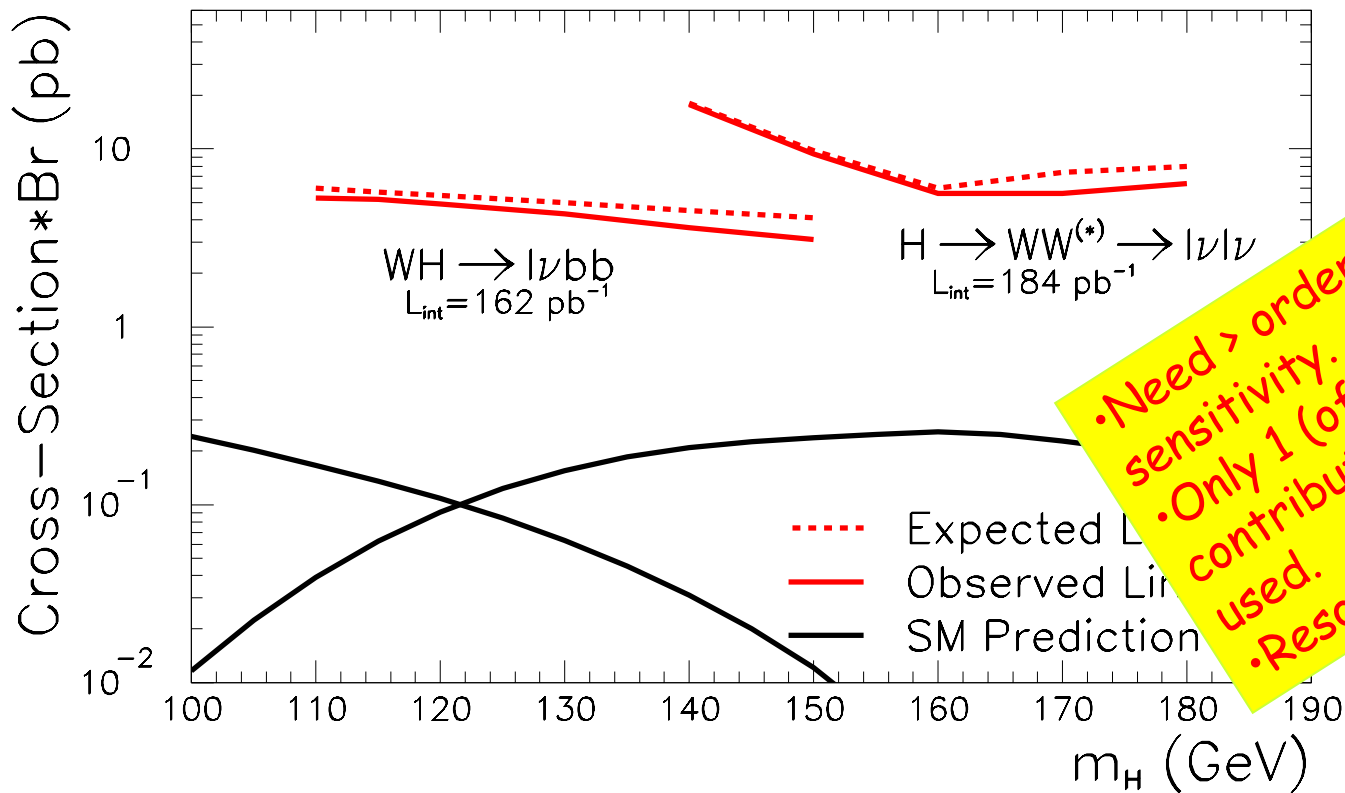


SM Higgs Signal x10

Biggest background:
A real W +
real or fake b-quarks

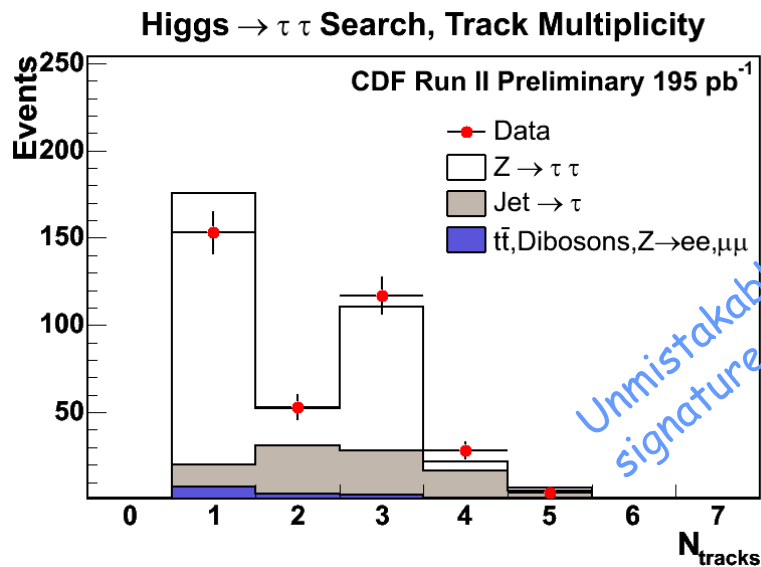
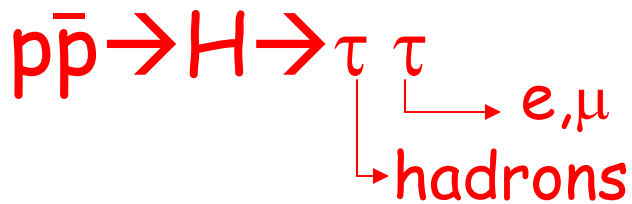
Standard Model Higgs Limits

CDF Run II Preliminary



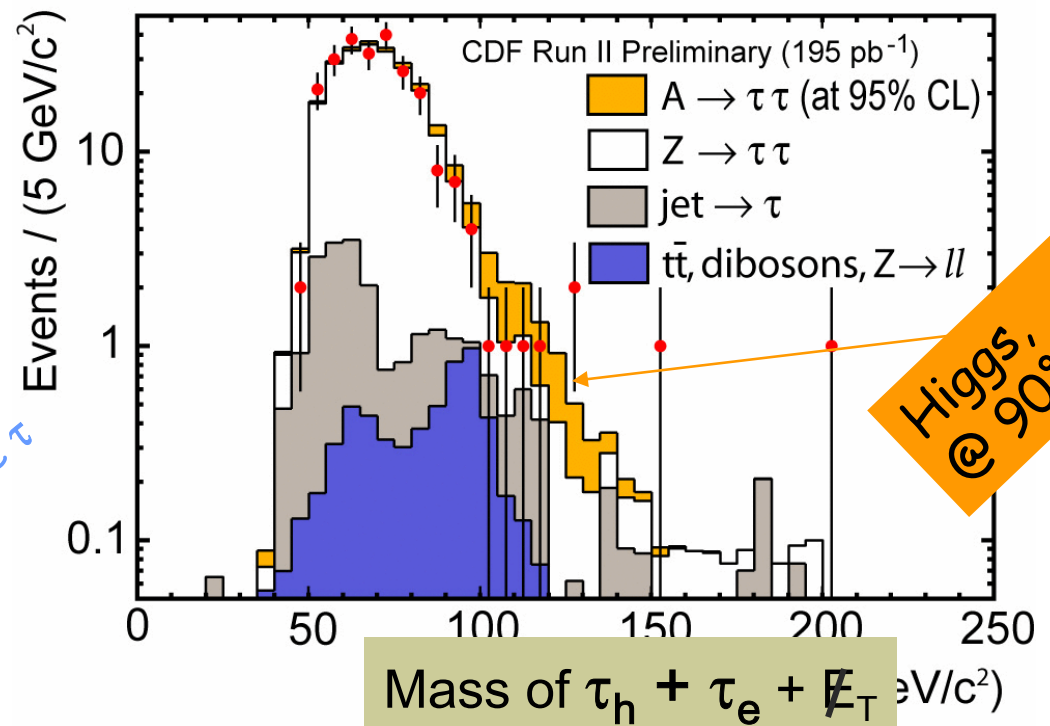
- Need > order of magnitude sensitivity.
- Only 1 (of 3) chans that contribute to low mass higgs used.
- Resolution not yet optimised.

MSSM Higgs (τ channel)



Unmistakable τ signature

Higgs $\rightarrow \tau\tau$ Search, Example Fit for $m_A = 130 \text{ GeV}/c^2$

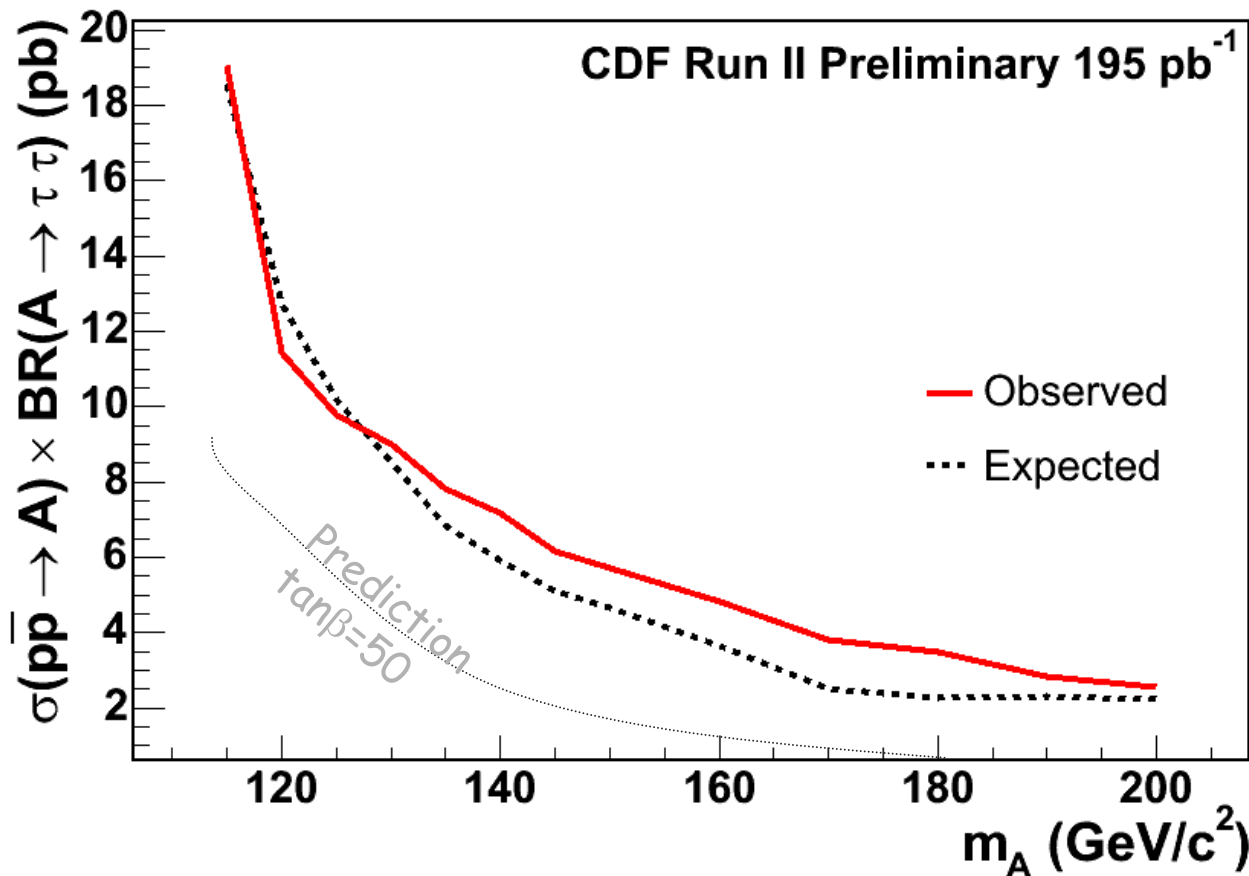


Higgs, @ 90% CL

Biggest background: Z $\rightarrow \tau\tau$
 Irreducible, looks *just* like signal!

Higgs Decaying to $\tau\tau$

Higgs $\rightarrow \tau\tau$ Search, 95% CL Upper Limit



- $\tau\tau$ channel sensitive to inclusive production
- MSSM Higgs production enhanced with $\tan\beta$.
- Competes well with 4b (exclusive) analyses.

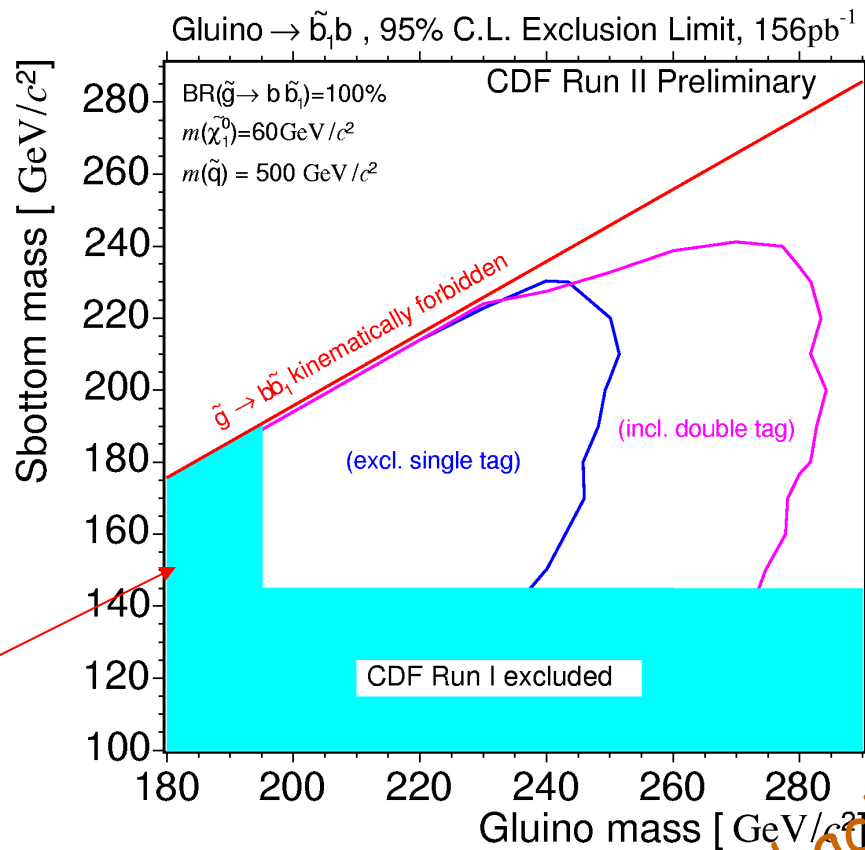
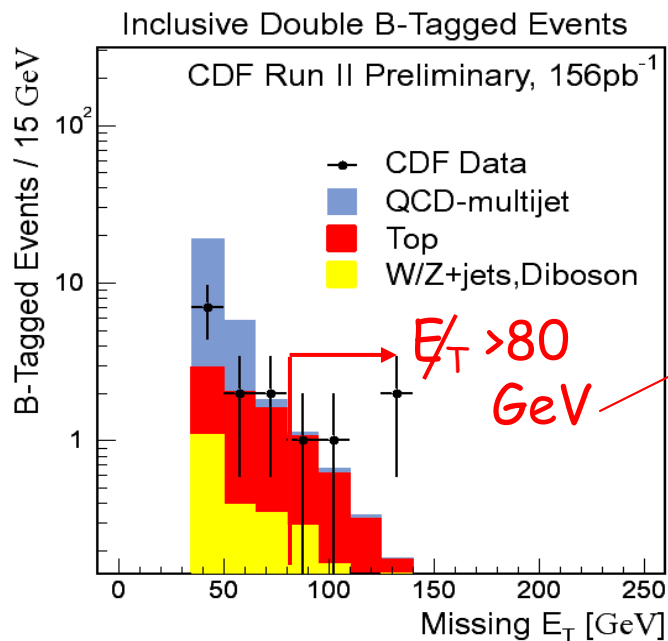
[Searches for Supersymmetry]

- Every SM particle has a *super-partner*.
- SUSY particles decay to SM partners...
 - Look for lepton, photon, top or b-quark...
 - Backgrounds: same, from plain-vanilla decays
- ...Plus the Lightest SUSY particle (LSP), which escapes the detector.
 - Look for Missing Energy, \cancel{E}_T
 - Backgrounds: Neutrinos from W,Z

SuperSymmetry (SUGRA)

$$p\bar{p} \rightarrow \tilde{g}\tilde{g} \rightarrow \tilde{b}_1 b \tilde{b}_1 \bar{b}$$

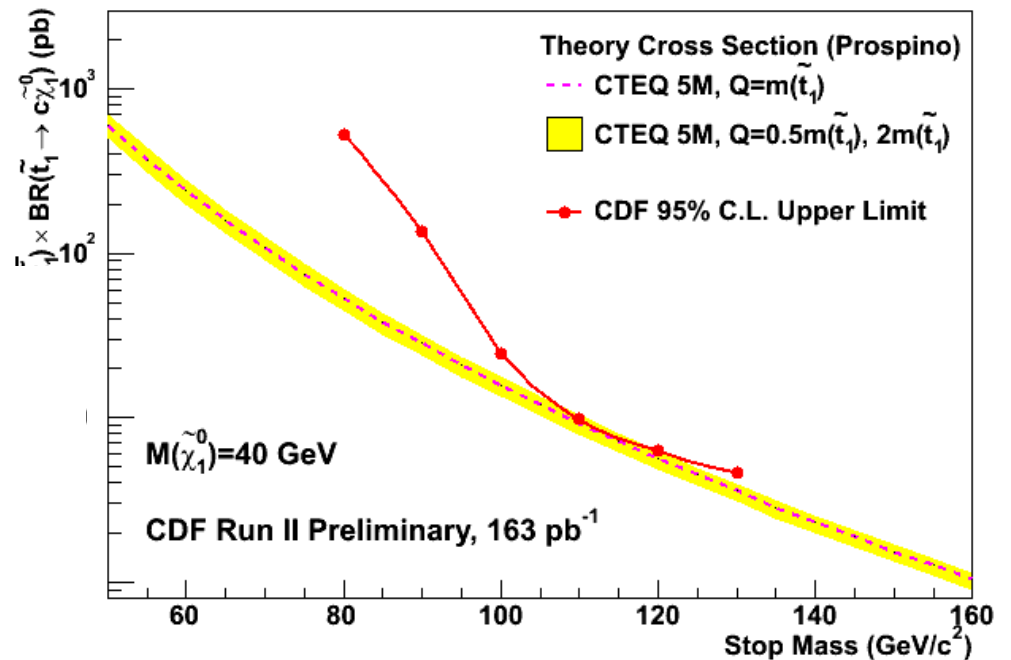
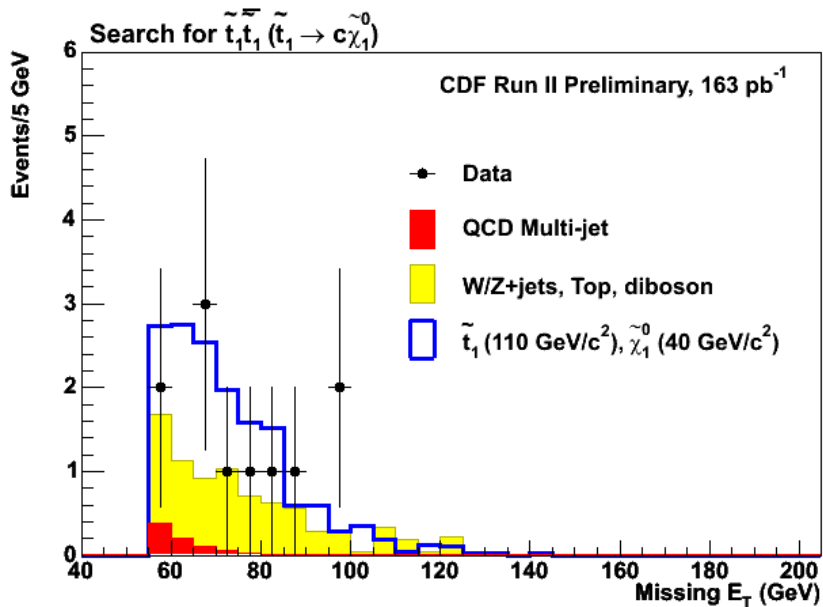
$$\rightarrow \chi_1^0 b \bar{b} \chi_1^0 b \bar{b}$$



Biggest background:
Top quarks

SuperSymmetry (SUGRA)

$$pp \rightarrow \tilde{t} \tilde{t}^* \rightarrow c \chi_1^0 c \chi_1^0$$

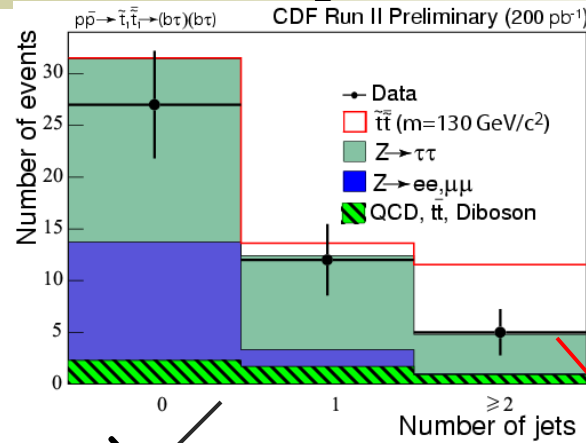


Biggest background:
A real W +
real or fake charm quark

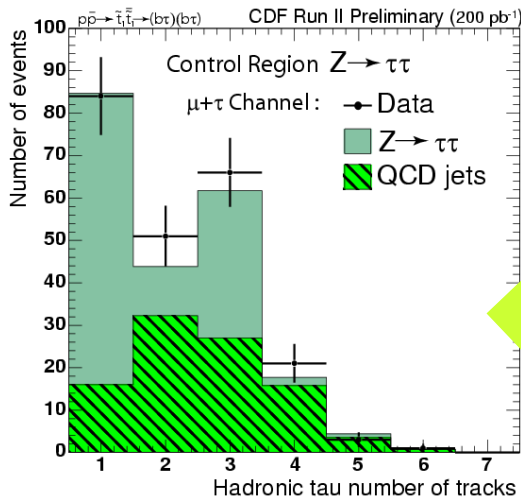
SuperSymmetry (RPV)

No large E_T requirement possible!

$$pp \rightarrow \tilde{t} \tilde{t}^* \rightarrow b\tau b\tau$$

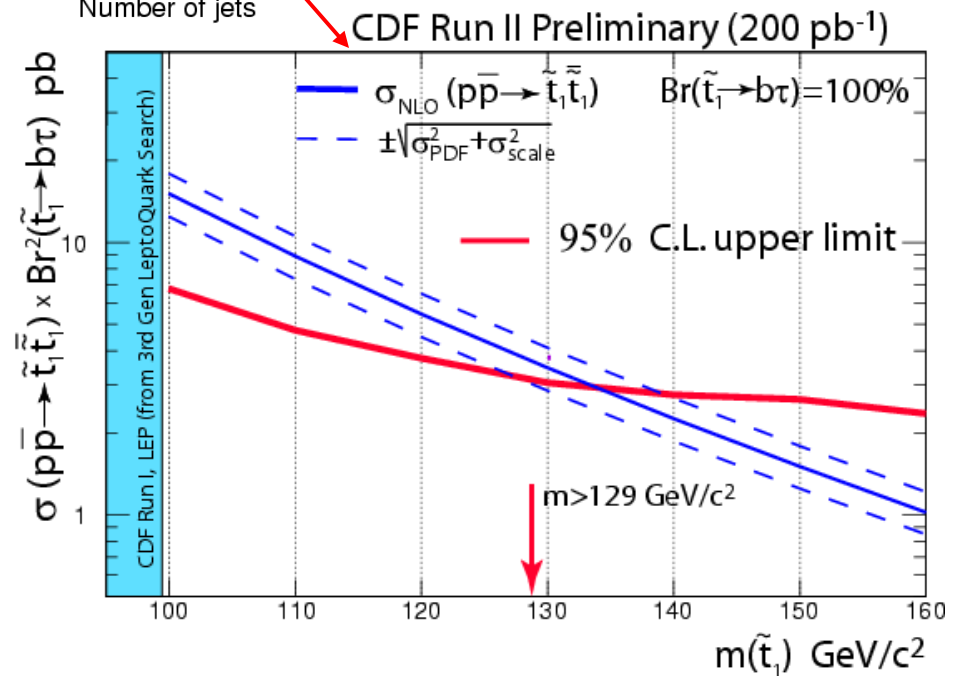


Biggest background: Real τ from Z → ττ



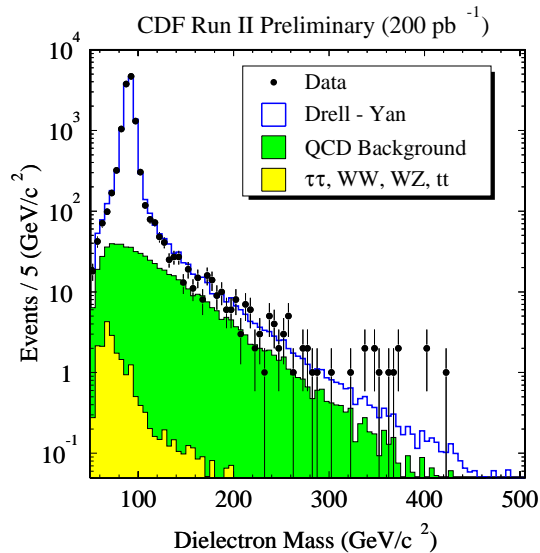
Control

Z → ττ visible

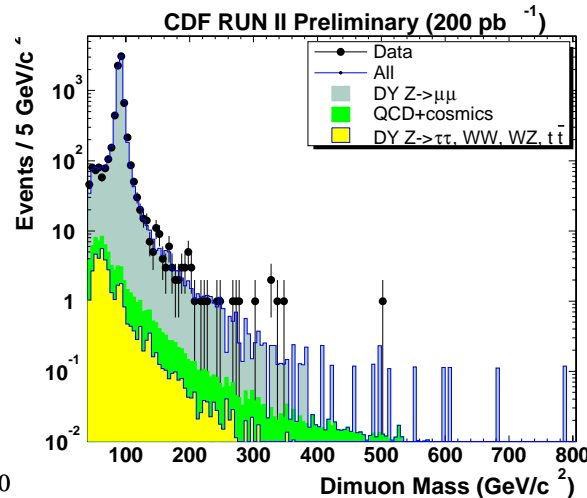


High Mass Dilepton Searches (All 3 Generations)

$$p\bar{p} \rightarrow Z' \rightarrow l^+l^-$$

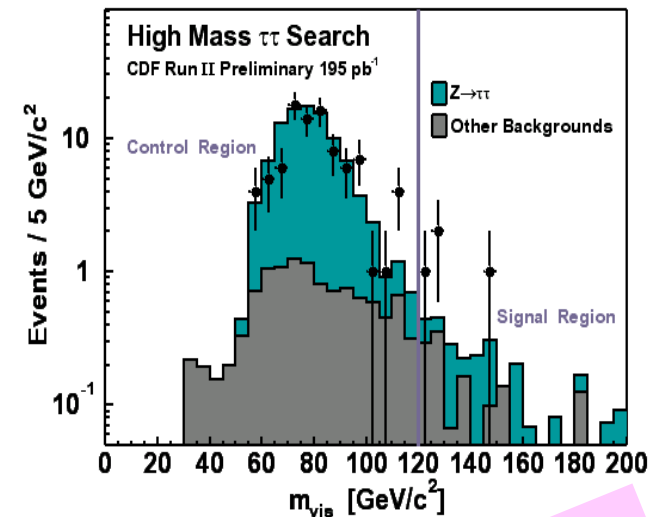


e^+e^-



$\mu^+\mu^-$

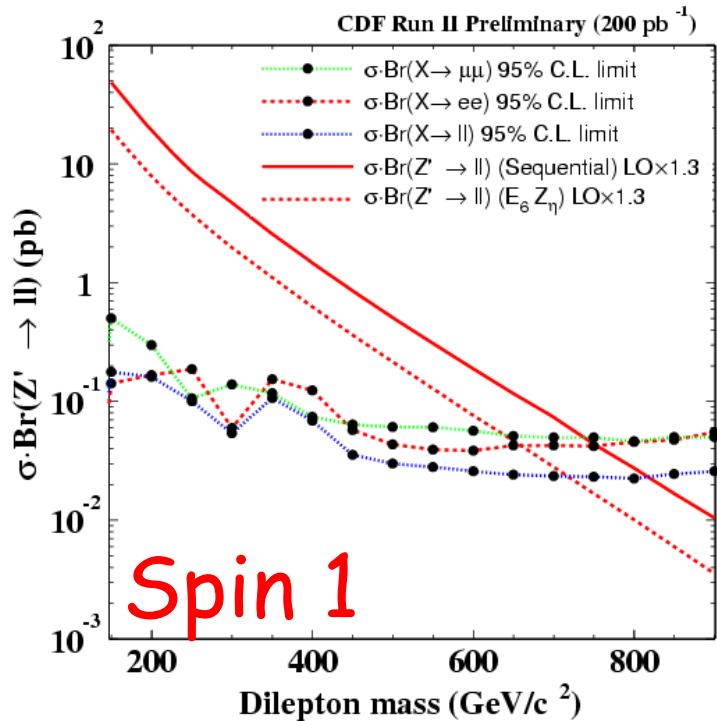
Excellent agreement over
3 orders of magnitude!



$\tau^+\tau^-$

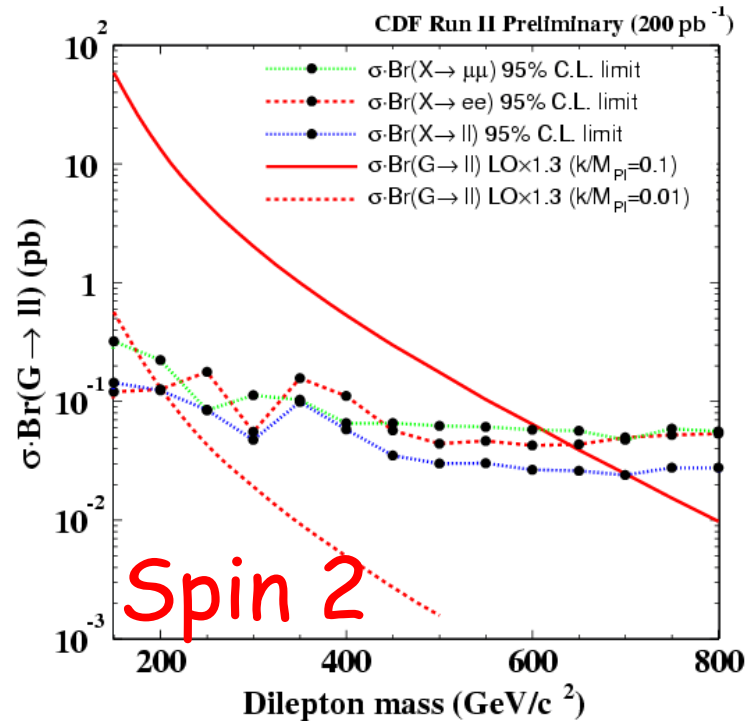
Includes BOTH τ
decaying to hadrons

High Mass Dilepton Search Limits (ee, $\mu\mu$ combined)



Spin 1

Ex: Z' bosons

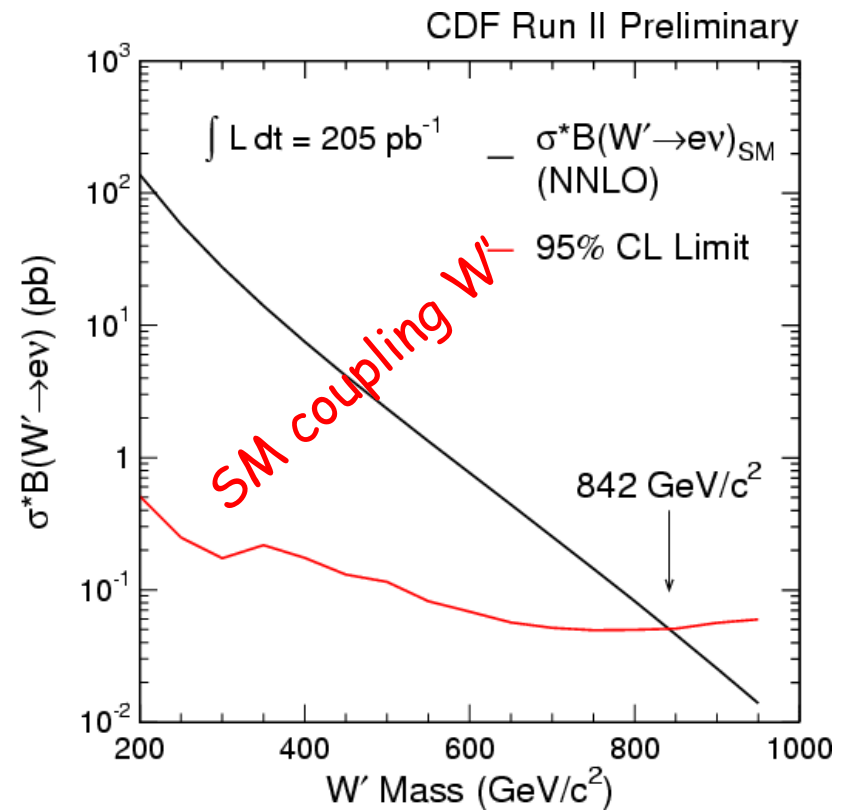
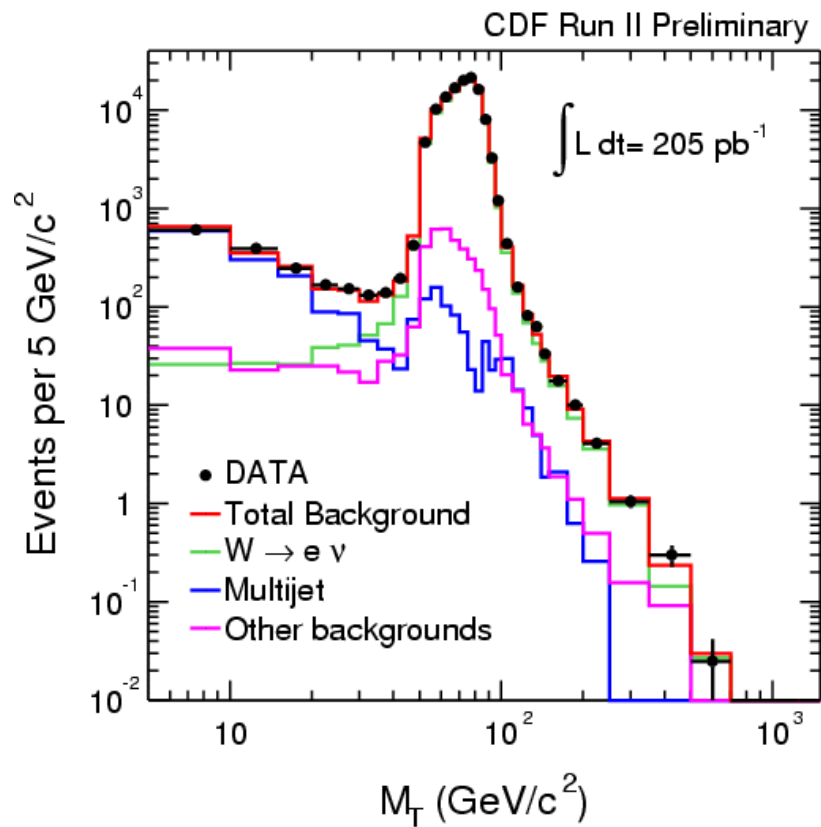


Spin 2

Ex: Gravitons

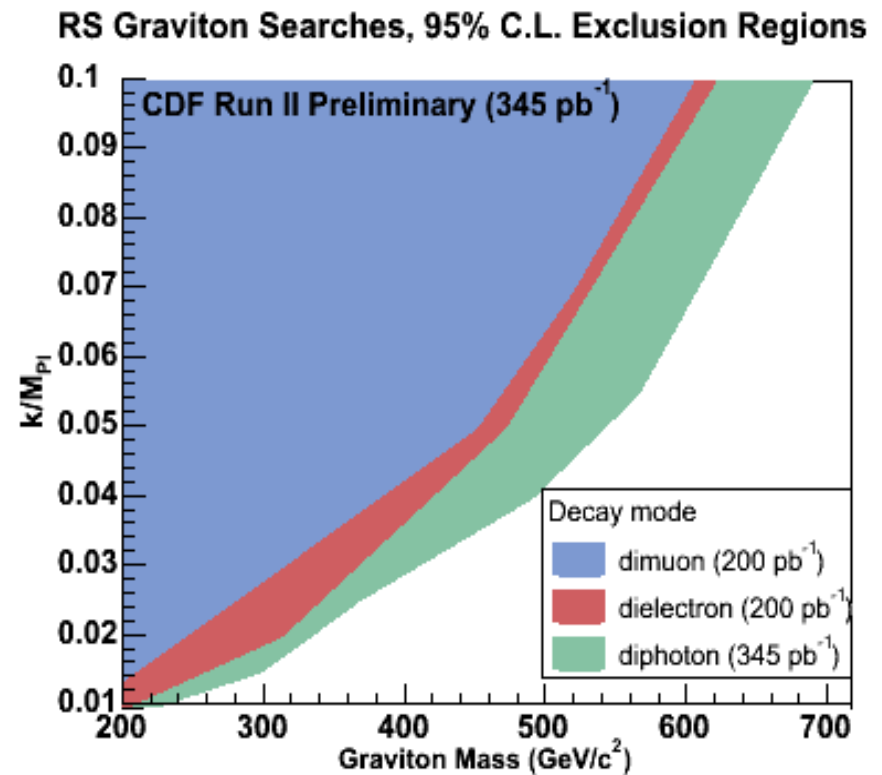
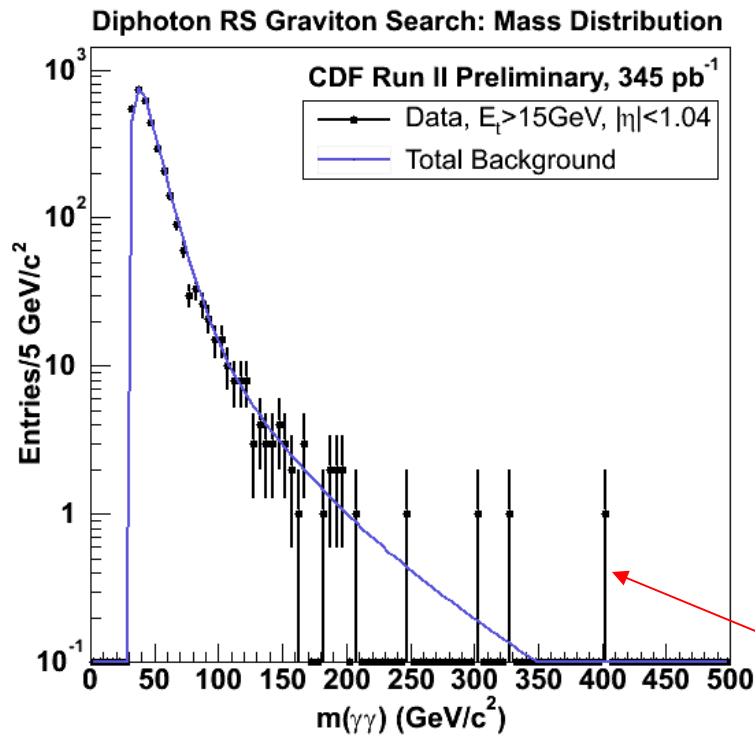
W' Search

$$p\bar{p} \rightarrow W' \rightarrow e \nu$$



Searches for Large Extra Dimensions (di-photons)

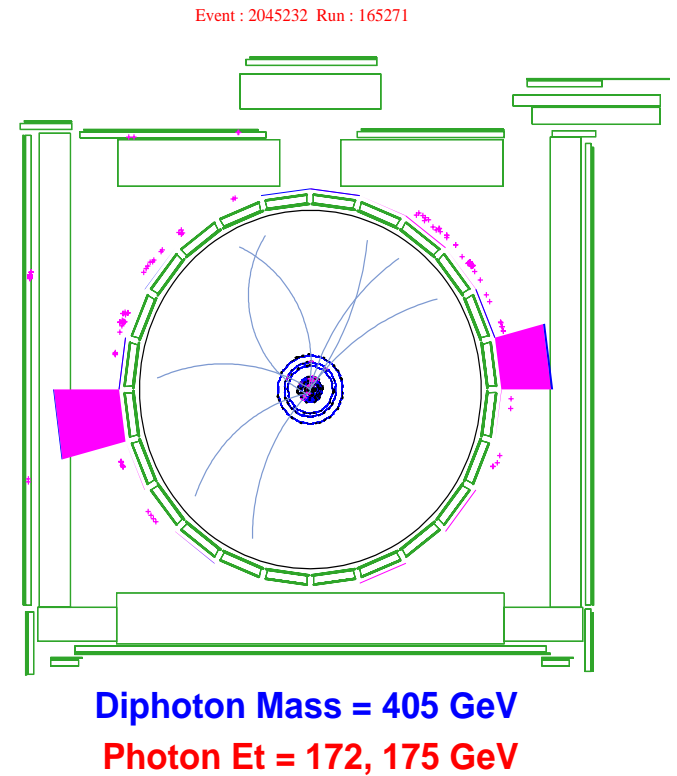
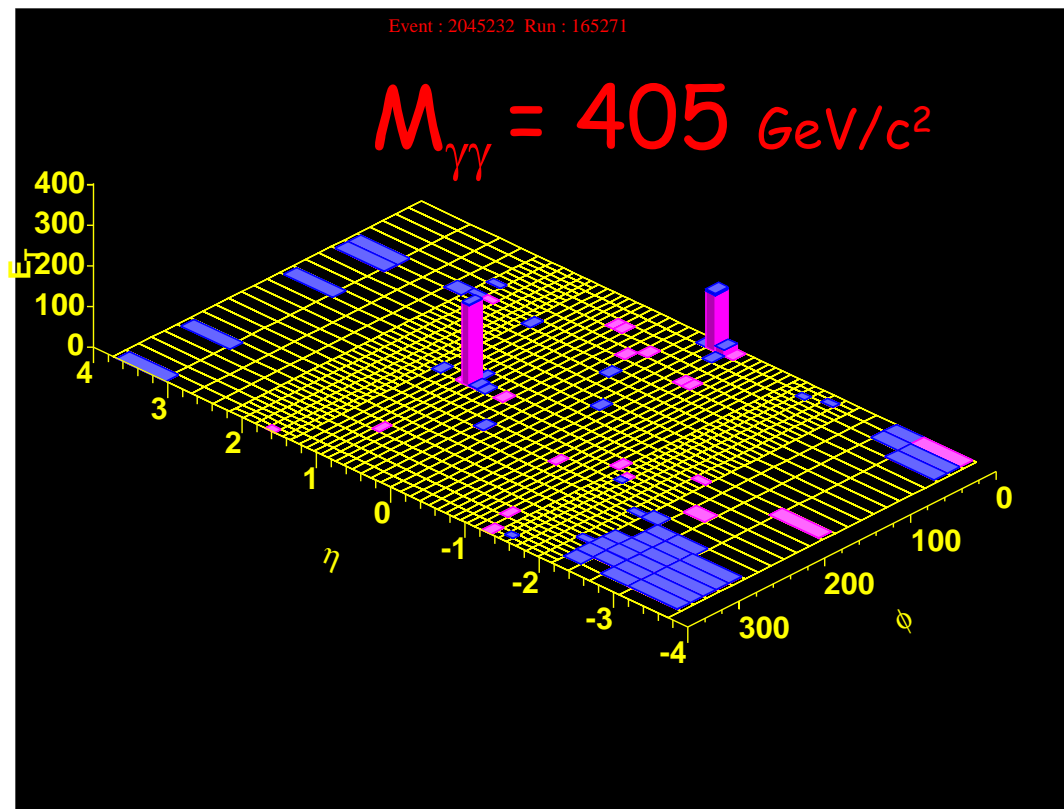
$$p\bar{p} \rightarrow G \rightarrow \gamma\gamma$$



What do these look like?

[Highest Mass di-photon events]

Clean event!



Summary

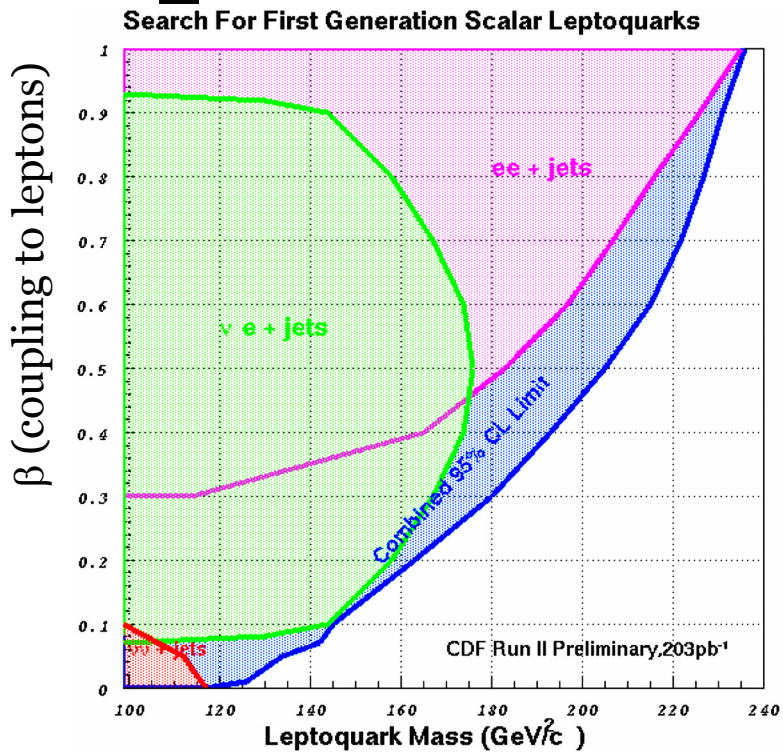
Order of magnitude

Signature	Physics	Limit x BR (fb)	Cross-sect Limit (fb)
di-lepton	Z', extra dimensions	30	900 (SM couplings)
di-photon	Extra Dimensions	100	1000 (0.1 G → $\gamma\gamma$)
lept + \cancel{E}_T	W'	100	1000 (SM couplings)
$e\bar{e}\gamma\gamma + \cancel{E}$	GM SUSY, Gravitino LSP	100 CDF+D0	110 (0.95 $\chi^0 \rightarrow \gamma$)
$\cancel{E}_T + 2b$ -tagged jets	SUSY, gluino to sbottom+bottom	500	500* 100% BR
$\cancel{E}_T +$ "charm" tag	SUSY, stop to charm	8,000	8,000* assumed
Lept + $\cancel{E}_T + b$ -tagged jet	WH → lνbb	5,000	5,000 (0.9 bb)
τ -pairs	MSSM Higgs	5,000	50,000 (0.1 $\tau\tau$)

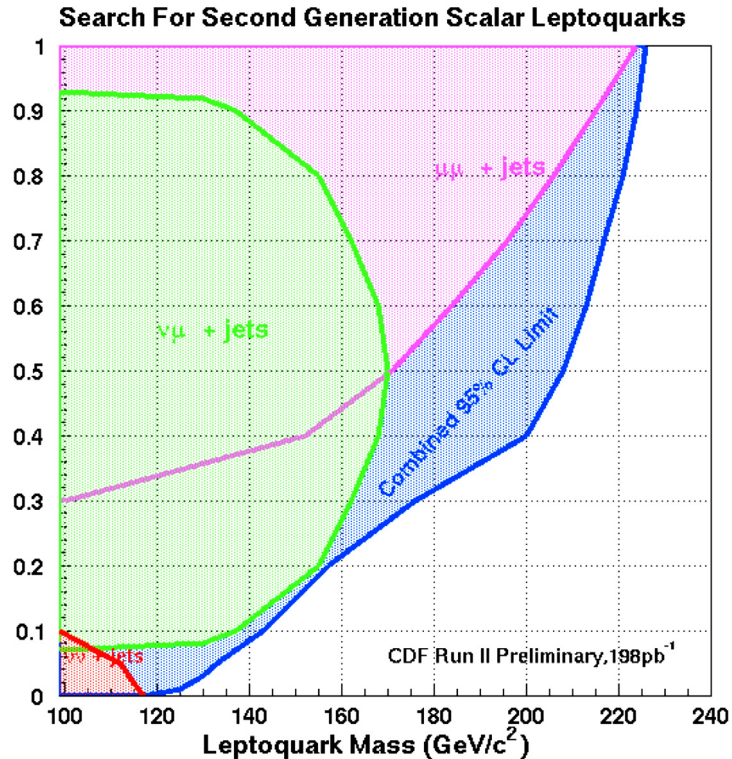
Conclusion

- **Best sensitivity with lepton, photon signatures.**
 - Limits degrade somewhat as we require \cancel{E}_T , jets, jets tagged as b-quarks, τ . This is to be expected.
 - Most cases limits surpass Run 1.
(ex: MSSM Higgs to $\tau\tau$: **8 times** better!)
- **Goals: More luminosity (4fb^{-1} ?)**
 - Improve, and combine: (different channels, CDF & D0)
 - If SM-Like Higgs $> 130 \text{ GeV}/c^2$ → **kills MSSM?**
- **Many analyses not covered here:**
 - H^{++} ($\rightarrow l^+l^+$, stable), e^* , γ +jet/ E_T , CHAMPS, monopoles..
 - <http://www-cdf.fnal.gov/physics/exotic/exotic.html>

Leptoquarks (All 3 Generations)



1st Gen

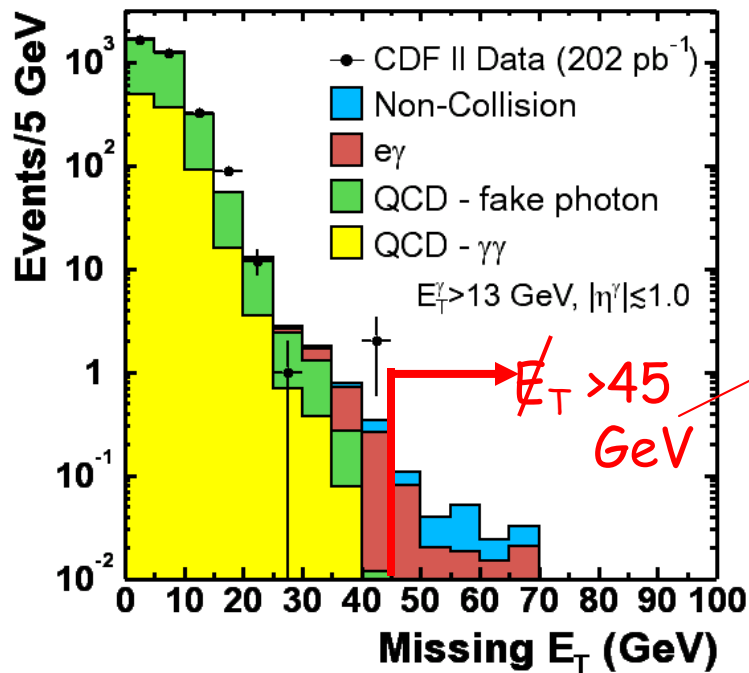


2nd Gen

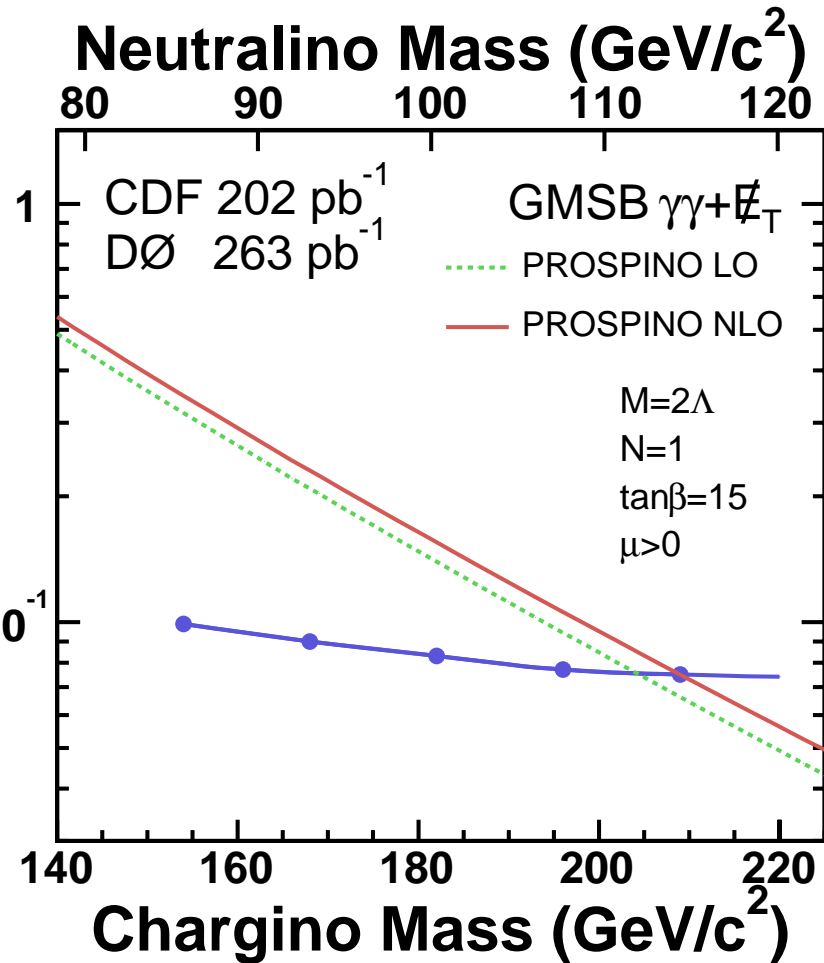
3rd Gen LQ
 same as RPV
 SUSY search,
 $m(\text{LQ}_3) >$
 $129 \text{ GeV}/c^2$

SuperSymmetry (Gauge Med)

$$\begin{aligned}
 p\bar{p} &\rightarrow \chi\chi \rightarrow \chi_1^0 \chi_1^0 \\
 &\rightarrow \gamma\gamma \tilde{G}\tilde{G} + X
 \end{aligned}$$



$\sigma \times \text{BR}(\gamma\gamma)$ (pb)



[CDF-D0 Combined $e\bar{e}\gamma\gamma E_T$]

