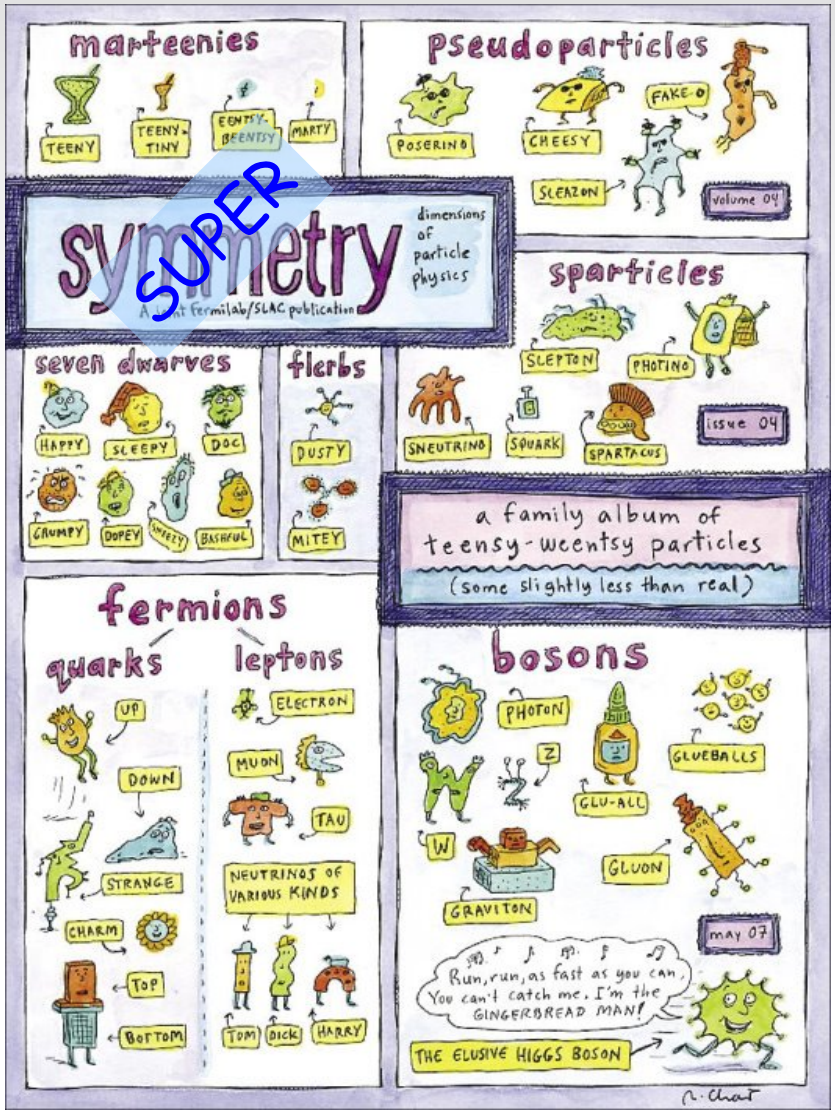
Search for new Physics at CDF

Outline:

- Introduction
- Search for new Physics
  - ✔ Model driven
  - ✔ Signature based
  - ✔ General searches

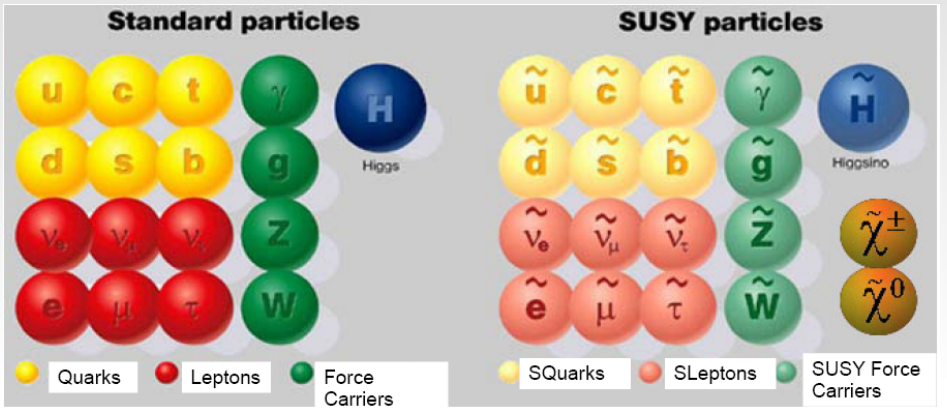


SUperSYmmetry

- Standard Model is theoretically incomplete
- SUSY: spin-based symmetry that relates Fermions to Bosons

Q|Boson> = Fermion

Q|Fermion> = Boson



gaugino/higgsino mixing

- Define R parity: $(-1)^{3(B-L)+2s}$

  R=1 SM particles

  R=-1 MSSM partners

If conserved, provides Dark Matter Candidate (Lightest Supersymmetric Particle)

- No SUSY particles found yet
  - SUSY must be broken -> models depend on many parameters even in "minimal" models

Search for New Physics

The breaking mechanism determines the phenomenology and the search strategies:

Model Driven,

- theory driven, optimize analysis to the searches
- explore large region of parameter space

Signature Based:

- search for unusual final states (not SM)
- optimize selections to minimize background
- interpret the results in term of several models

Global Searches:

- maximize the parameter space coverage
- less sensitivity but can give hint on possible deviation from SM

Experimental Approach

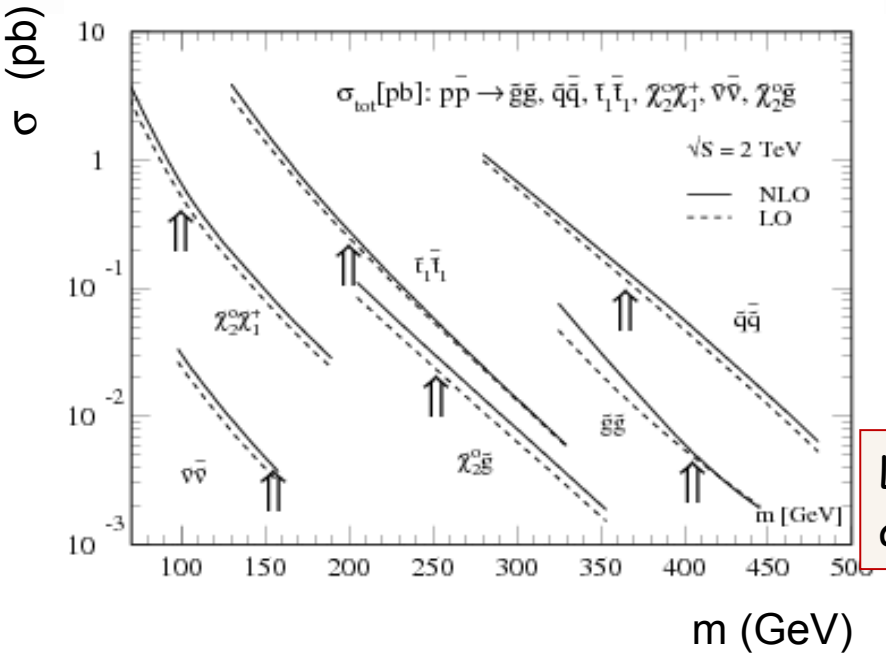
- Lepton-only final states
  - e/μ identification well understood
  - τ id more complex
  - Straightforward and efficient approach to search for anomalies
- ...+ MET and Photons
  - wealth of models and exotic process
  - detector effect are important, need to be understood
- ...+ Jets and Heavy Flavor
  - more complex signatures
  - Need to maintain high S/B

Model Driven Searches

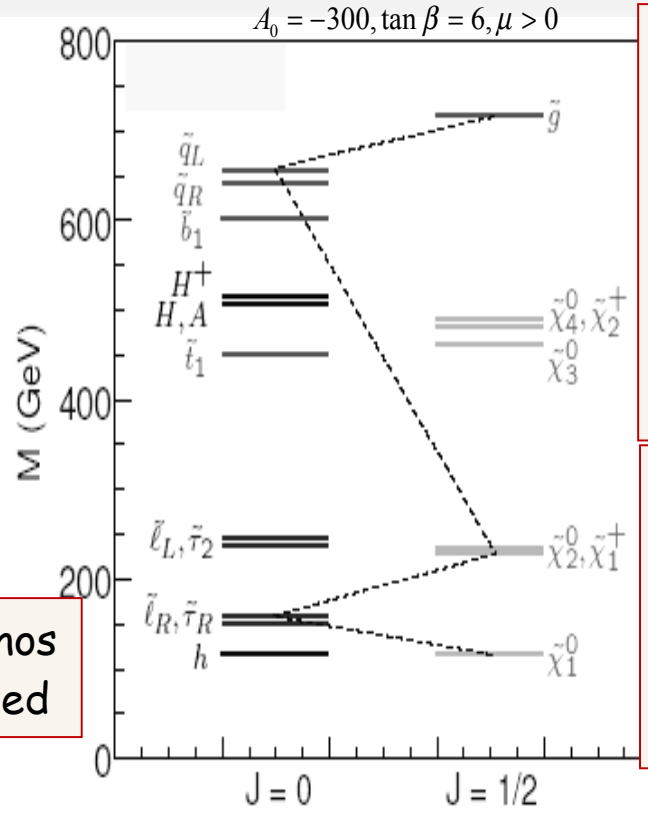
Standard SuSy: mSUGRA

- ✔ mSUGRA: minimal supergravity grand unification model provides a good reference model (5 parameters)
- ✔ Consider production with highest cross sections
  - Small masses (chargino/neutralinos) or large couplings (squark/gluino)

$m_0 = 100GeV, m_{1/2} = 300GeV$
$A_0 = -300, \tan\beta = 6, \mu > 0$



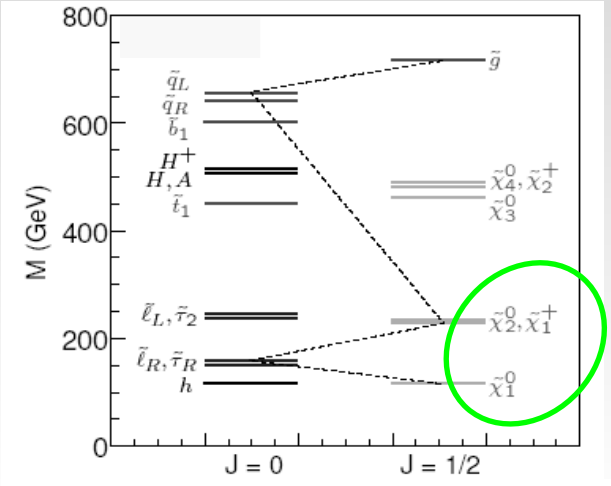
Light gauginos also expected



- Squarks and gluinos heavy
- 1st and 2nd generation squarks are mass degenerate

mixing of 3rd generation leads to light stop, sbottom and stau mass

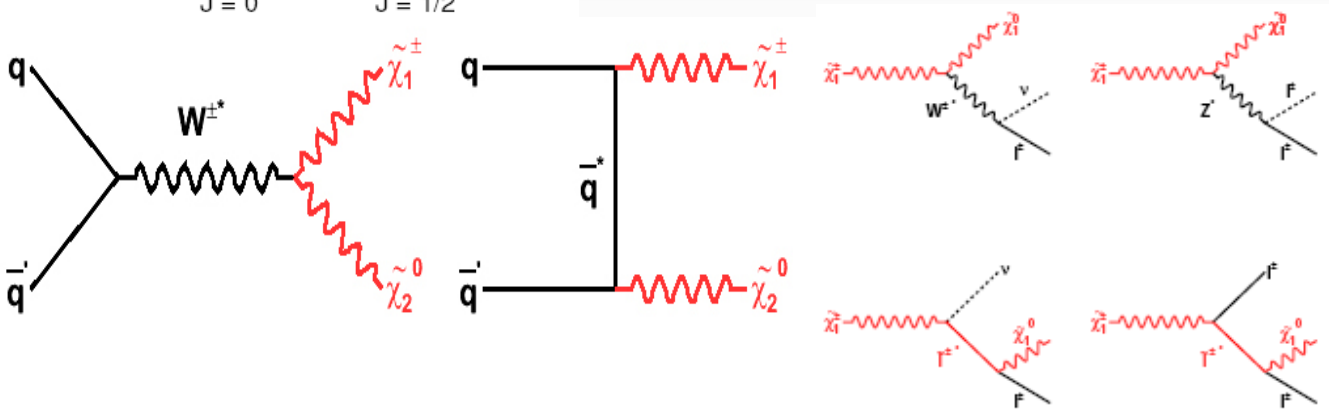
$\tilde{\chi}^0_2\tilde{\chi}^\pm_1$ Production: Trileptons



Assume R^p conservation and

$\tilde{\chi}^0_1$ is LSP (light stable particle)

Low cross section: $\sigma \times Br < 0.5$ pb



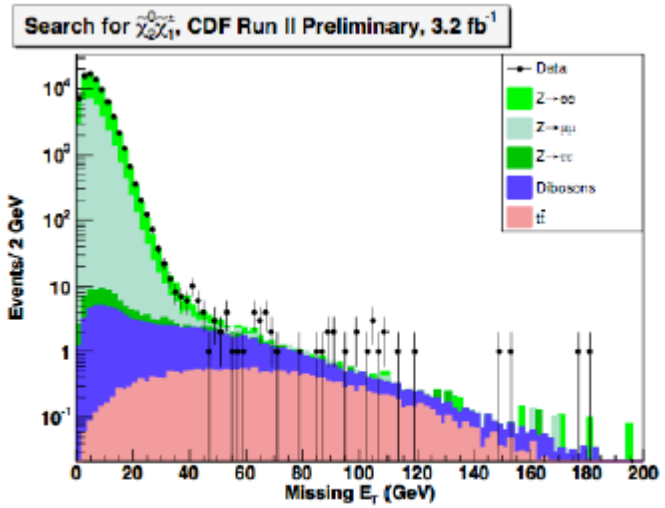
Clean signature:

- 3 isolated leptons
- MET due to ν
- no jets
- Z veto

Main Background:

Z+γ, DY, di-bosons

$\tilde{\chi}^0_2\tilde{\chi}^\pm_1$ Production: Trileptons



Control regions in MET vs $M_{\ell\ell}$ phase-space

- Good agreement with SM background

DØ $\int \mathcal{L}dt = 2.3$ fb^{-1}	Background	Data	CDF $\int \mathcal{L}dt = 2.0$ fb^{-1}	Background	Data
low p_T	5.4±0.6	9	Trilepton	1.47± 0.21	1
high p_T	3.3±0.4	4	Lepton+track	9.38±1.44	6

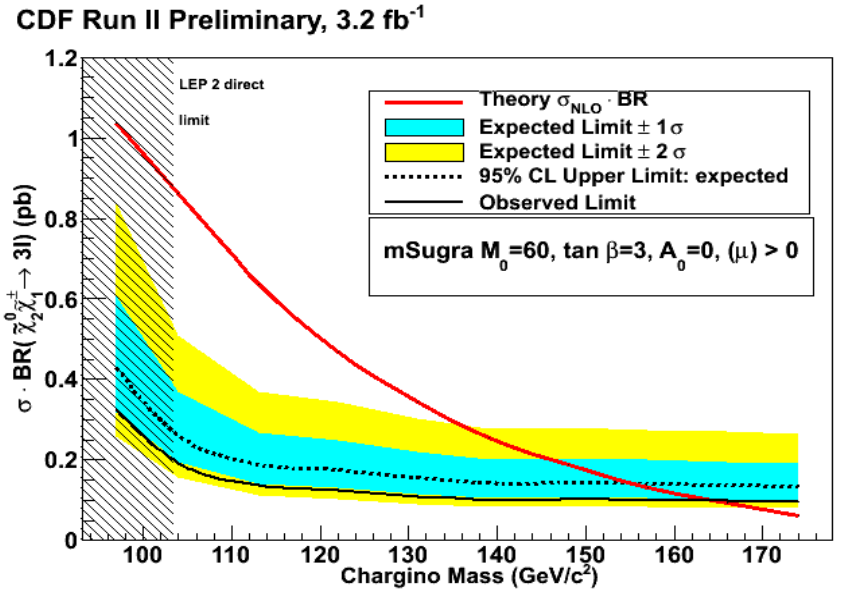
Data compatible with SM

Set limits in the mSUGRA model

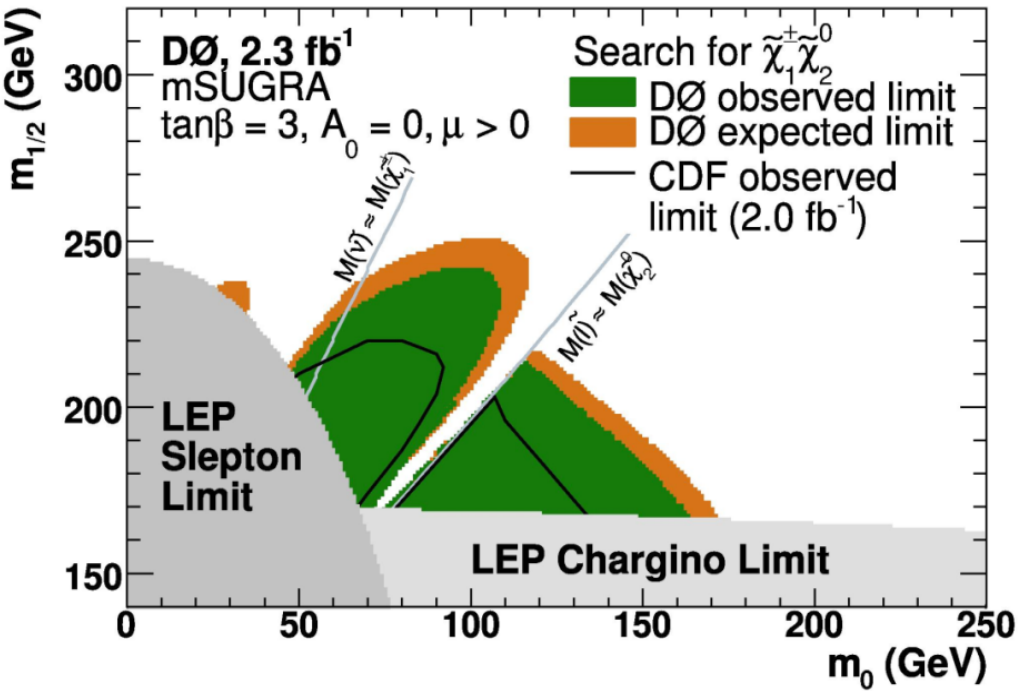
Benchmark scenario:
$A^0=0$, $\tan\beta=3$, $\mu > 0$

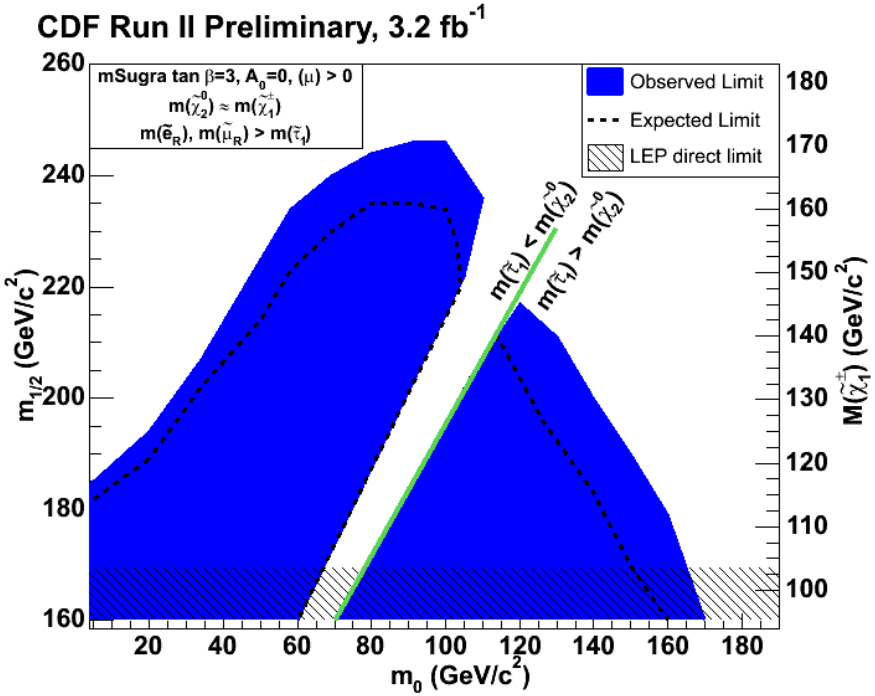
Background validation done in the control region $76<M_{ll}<106$

Chargino $m\chi^\pm_1<164$ (155 Exp.) GeV is excluded



$\tilde{\chi}^0_2\tilde{\chi}^\pm_1$ mSUGRA limit



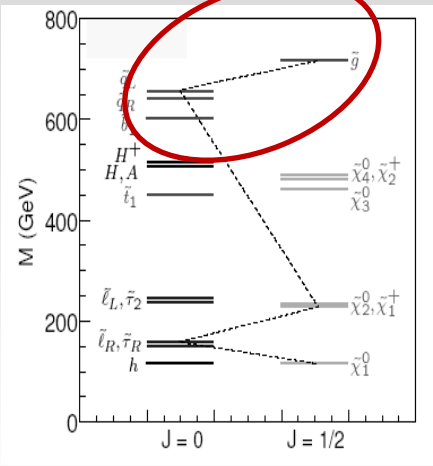


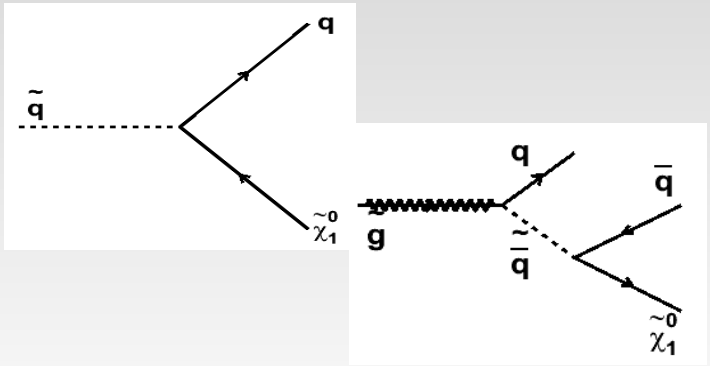
Use common scenario tan(β)=3, A_0=0, μ>0

Limits depend on the relative masses:

- $m_{\tilde{\chi}^0_2} > m_{\tilde{l}}$ increases BR to e/μ
- $m_{\tilde{\chi}^0_2} \approx m_{\tilde{l}}$ reduces acceptance to lowest-p_T lepton

Search for squark and gluino





Process:

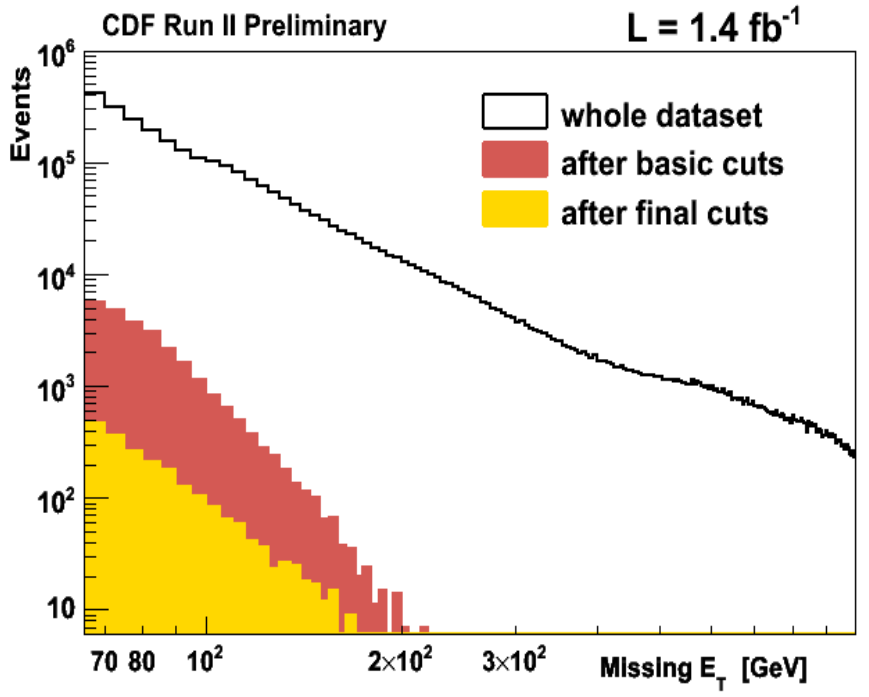
$\tilde{q}\tilde{q} \rightarrow qq\tilde{\chi}_1^0\tilde{\chi}_1^0$ ($m_q < m_g$)

$\tilde{q}\tilde{g} \rightarrow qqq\tilde{\chi}_1^0\tilde{\chi}_1^0$ ($m_q \sim m_g$)

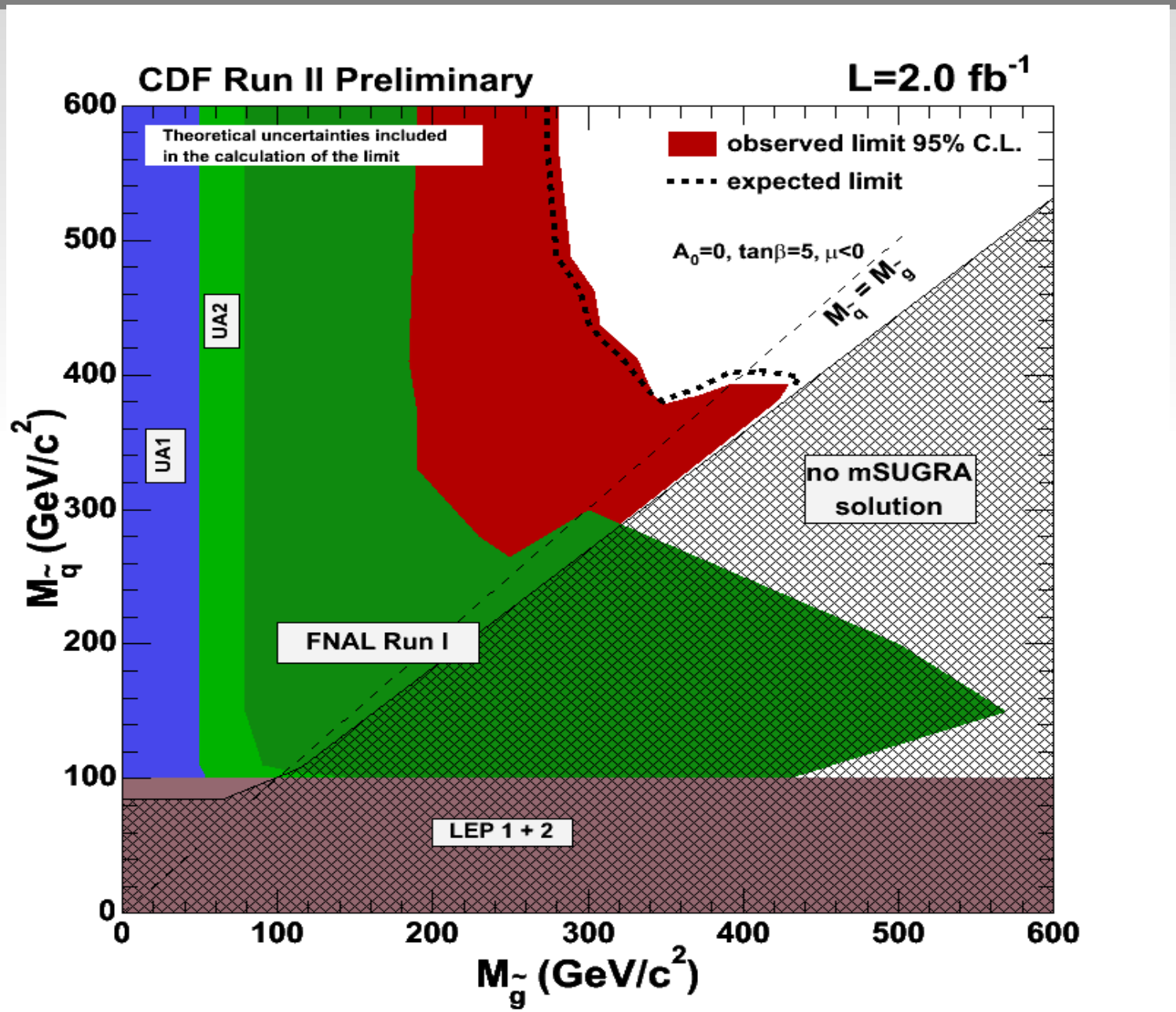
$\tilde{g}\tilde{g} \rightarrow qqqq\tilde{\chi}_1^0\tilde{\chi}_1^0$ ($m_q > m_g$)

Final states with Jets+MET

- MET > 70 GeV
- At least two/three/four jets with ET > 25 GeV
- Δφ (MET-jet)> 0.7 (first two/three leading jets)
- No reconstructed Z from tracks



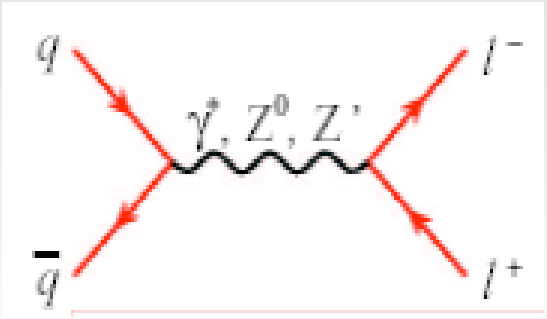
Search for squark and gluino: Results



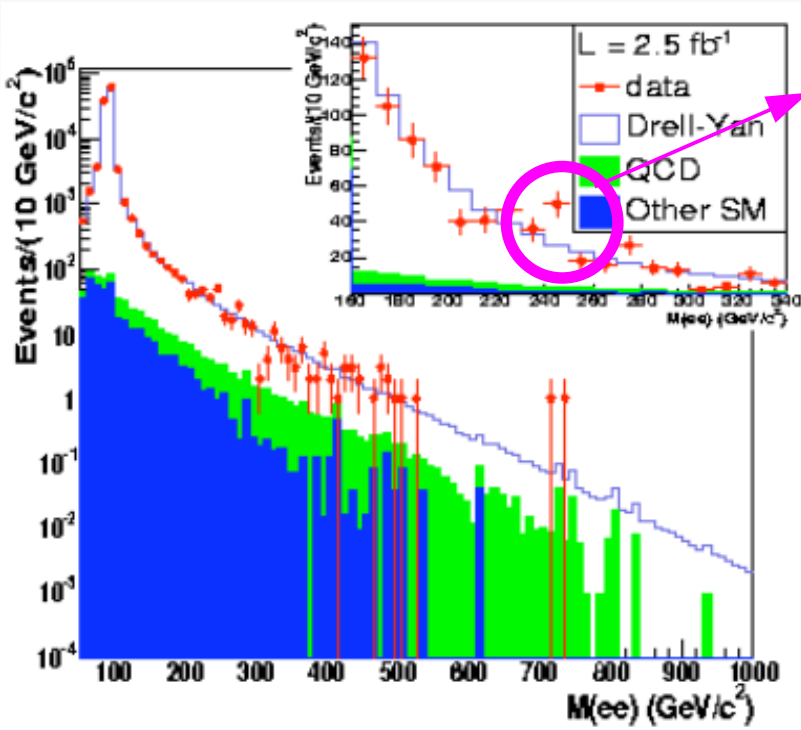
Signature Based Searches

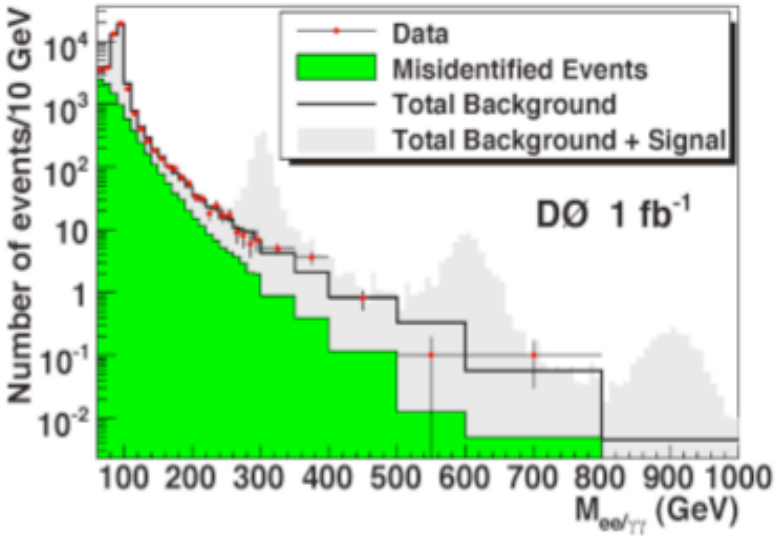
Di-leptons searches:Starting Point

Search for resonances in ee/μμ above 150 GeV
- lepton id well under control
- Z peak used as reference
- clean events



Excess?
3.8 standard deviations over SM.
Keep monitoring

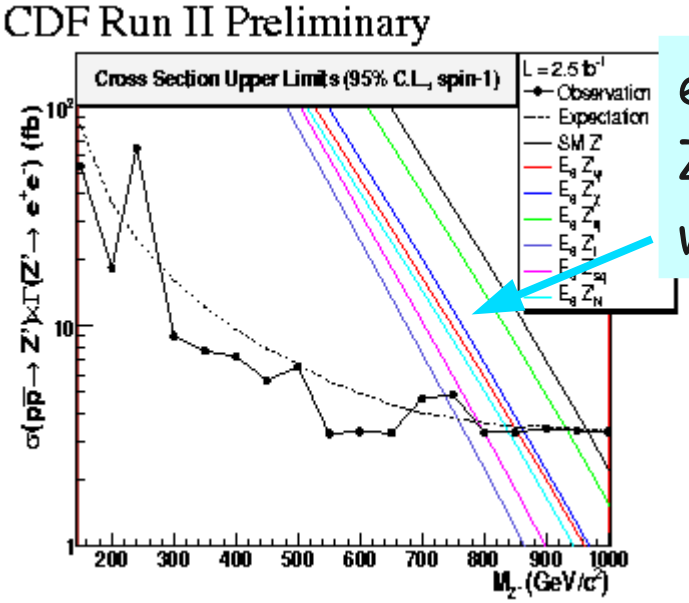




Di-leptons searches:New Phyiscs searches

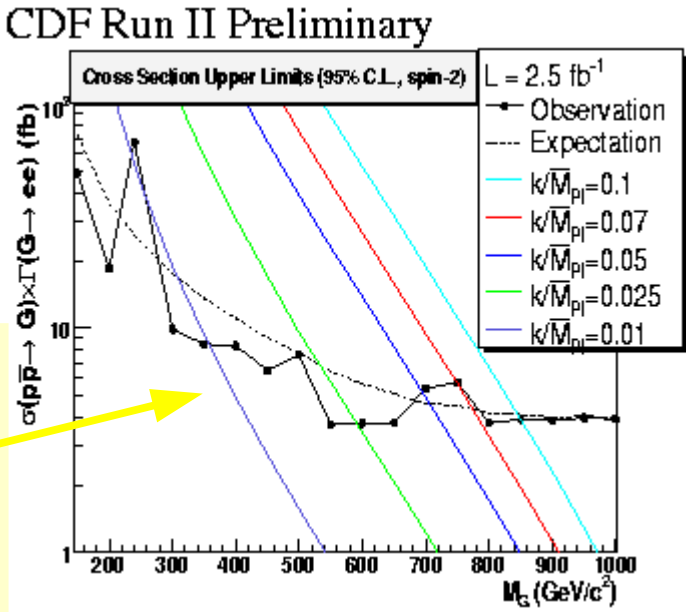
New Physics limits

- understand very well data spectrum in term of SM process
- calculate new signal acceptances and trigger efficiencies
- derive the number of expected new physics events
- if no events found in data calculate 95% CL cross section limit and set particle mass limit



exclude 95%CL
Z' with SM coupling
with mass <966 GeV

Randall-Sundrum
graviton with
mass< 850 GeV
excluded at 95%CL



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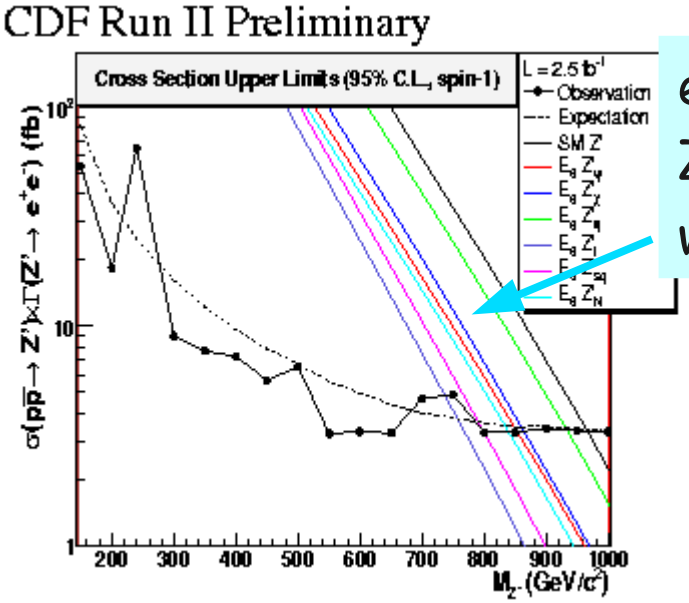

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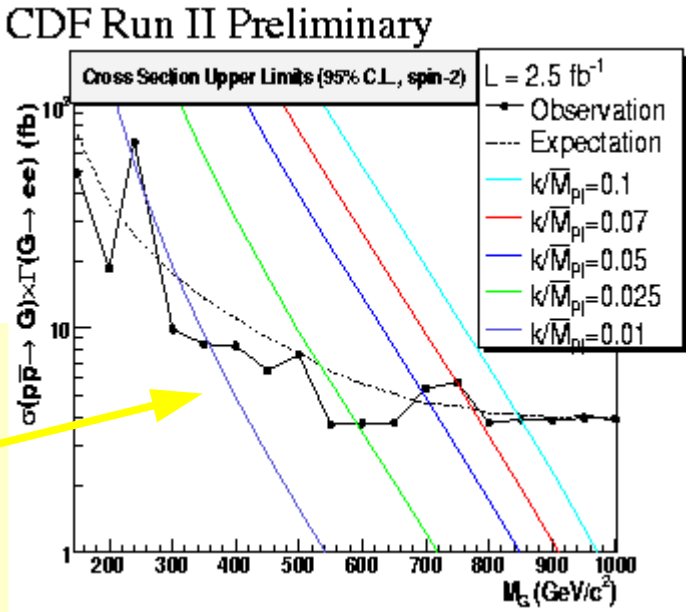
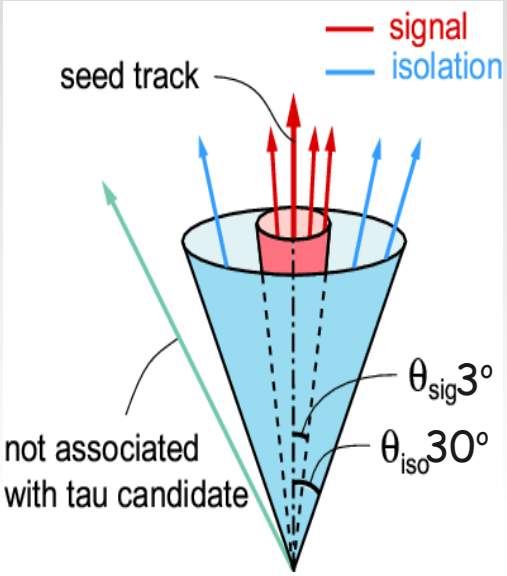


Tau final states searches

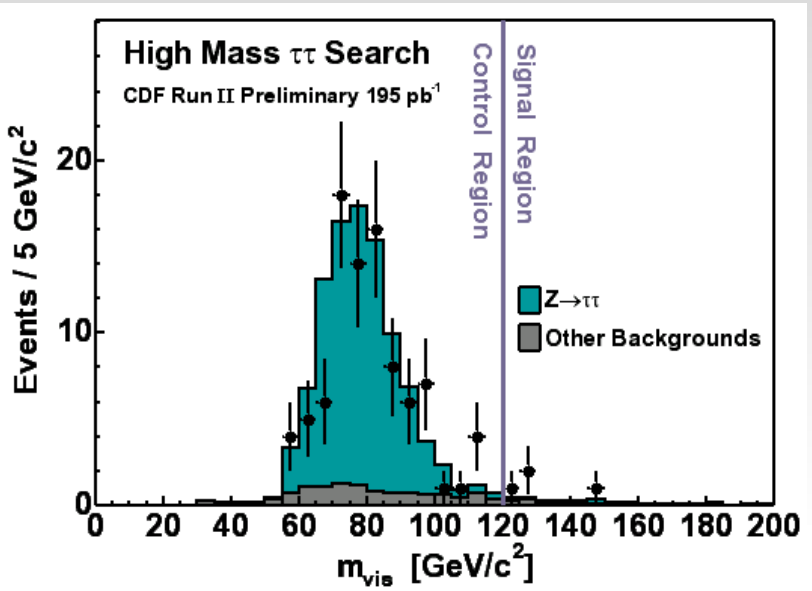


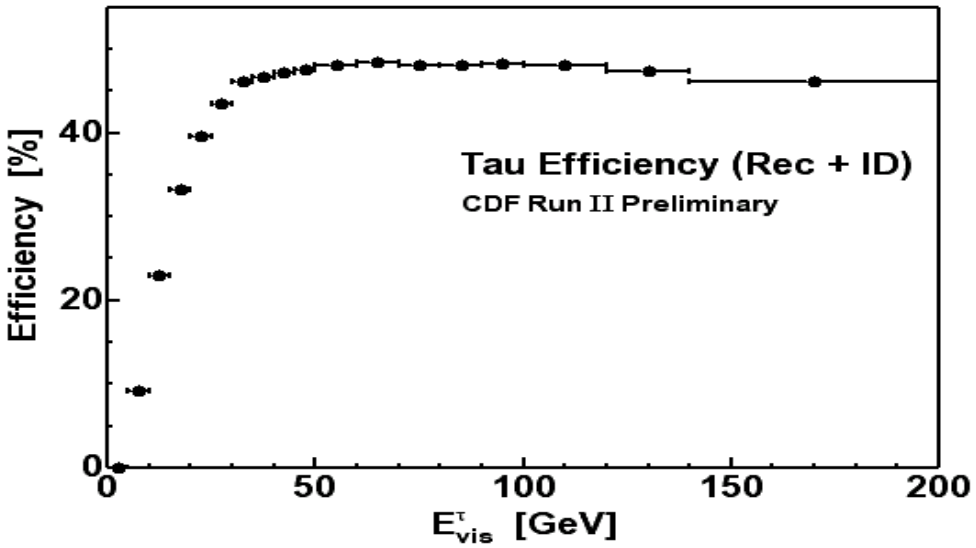
Di-taus:

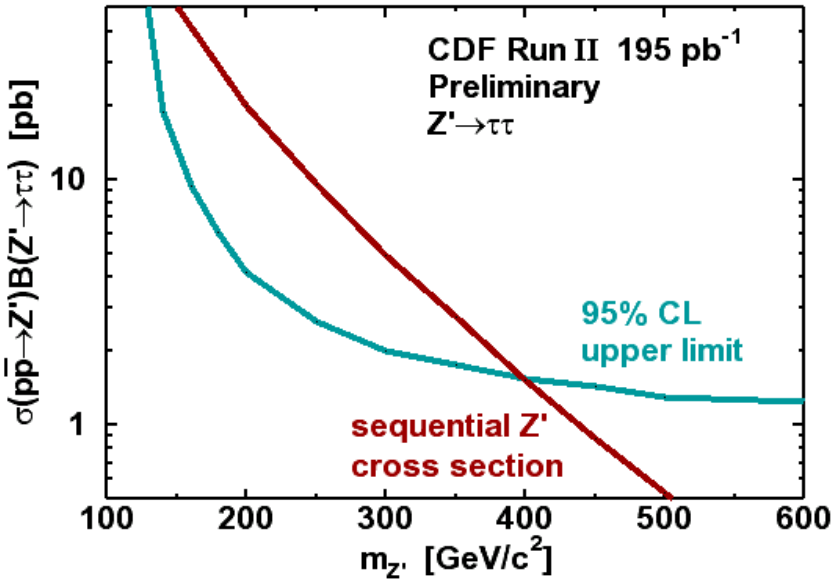
one τ decays leptonically

one τ decays hadronically:

1 or 3 tracks in an isolated cone



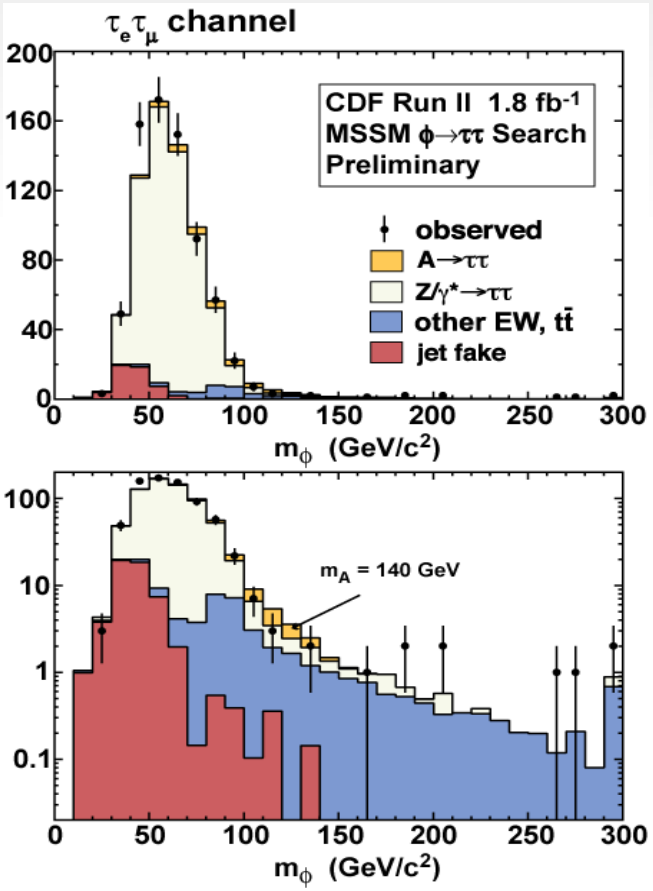


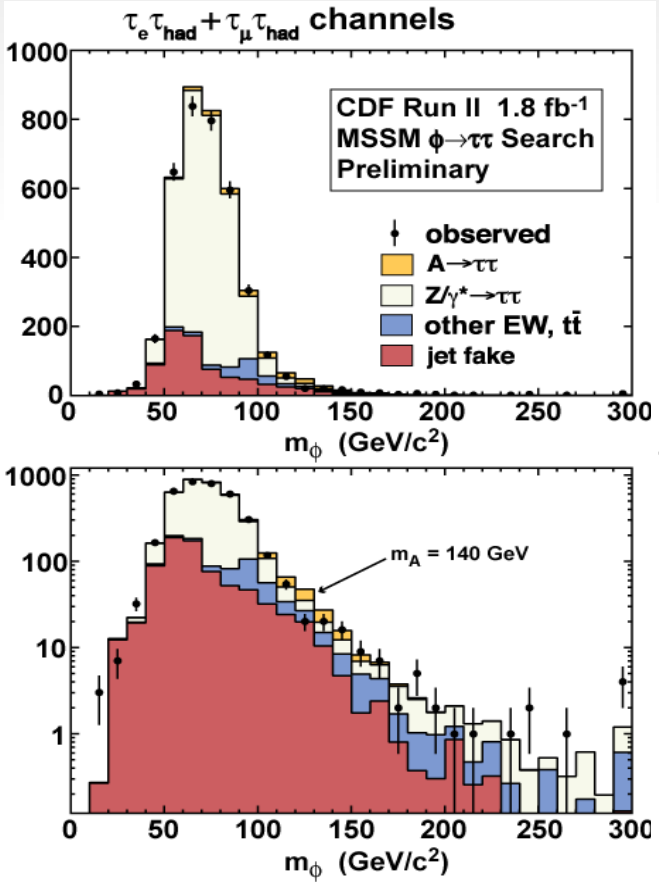


Φ→ττ searches

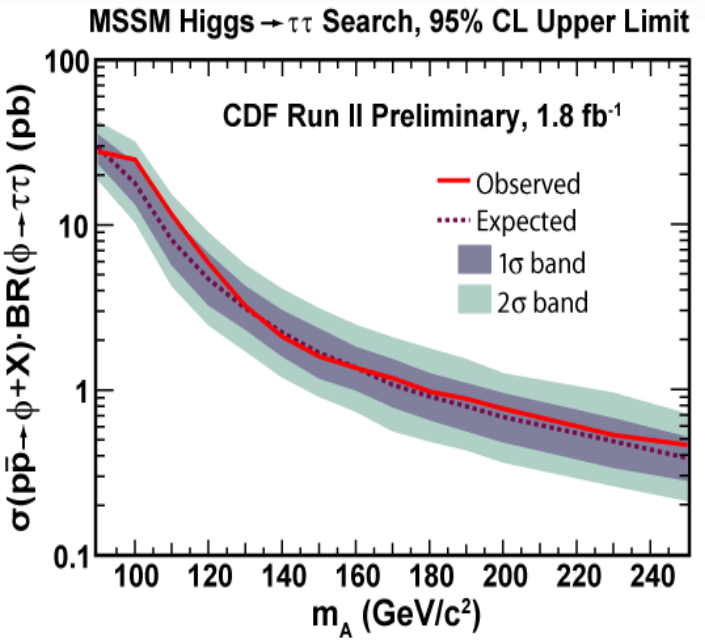
In the Minimal Supersymmetric Standard Model at high tan(β) higgs neutral sector simplifies: A and h/H become degenerate = Φ

Φ->$b\bar{b}$ (90%), Φ->$\tau^+\tau^-$ (10%). Φ->$\tau^+\tau^-$ searched looking at visible mass:





combined limit

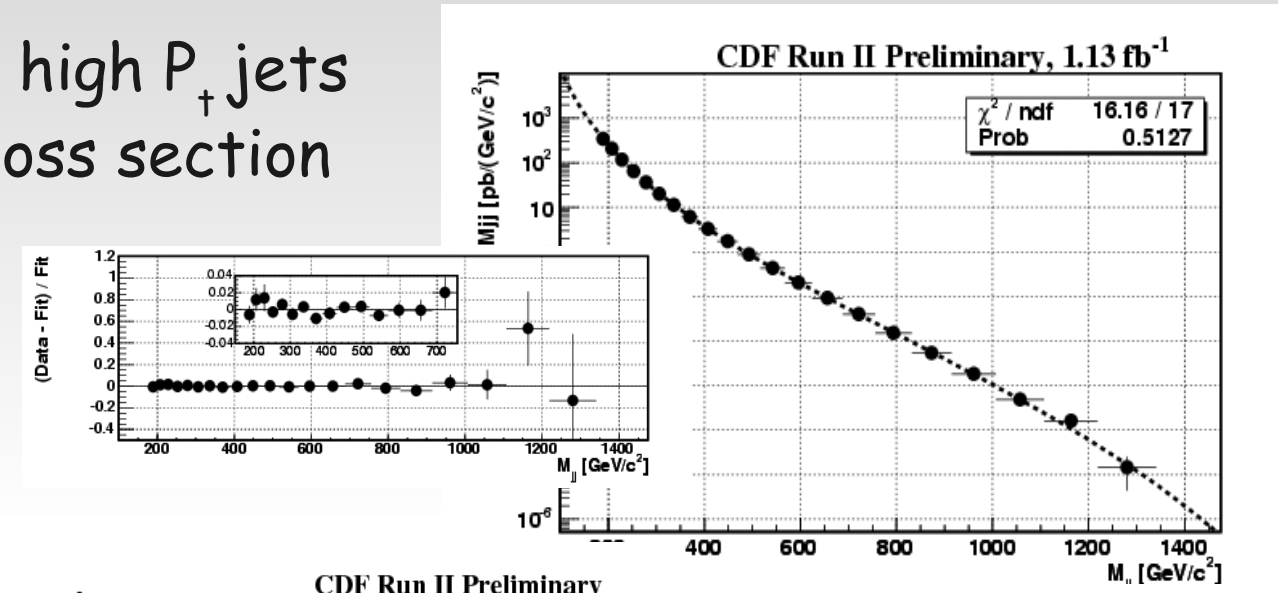


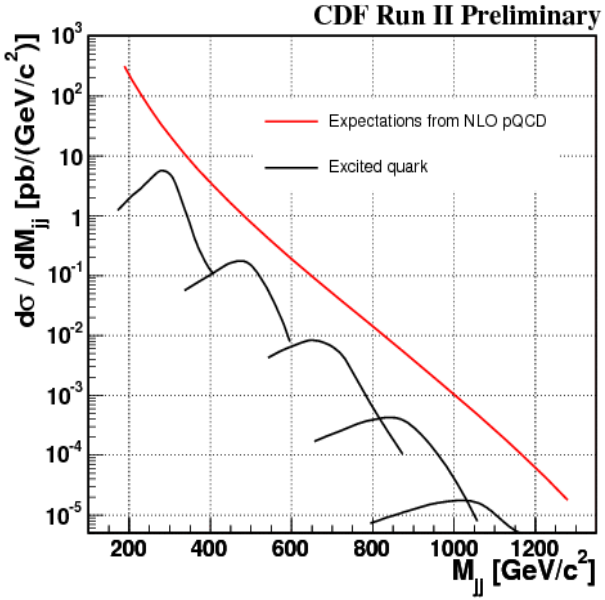
Di-jets Final States:mass bumps

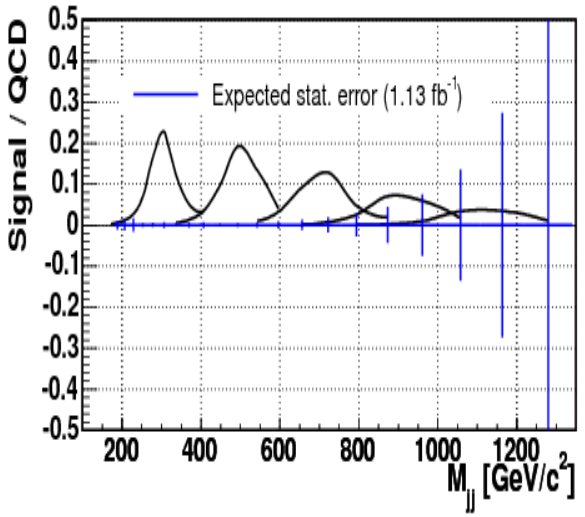
Selects events with two high P_t jets
Look for bumps in M_{jj} cross section

Excited quarks

Dijet mass spectrum from QCD and excited quark production.
Excited quark mass=300, 500, 700, 900, 1100 GeV/c^2.
Excited quark decaying to a quark-gluon pair simulated with Pythia







Di-jets Final States:mass bumps cont'd

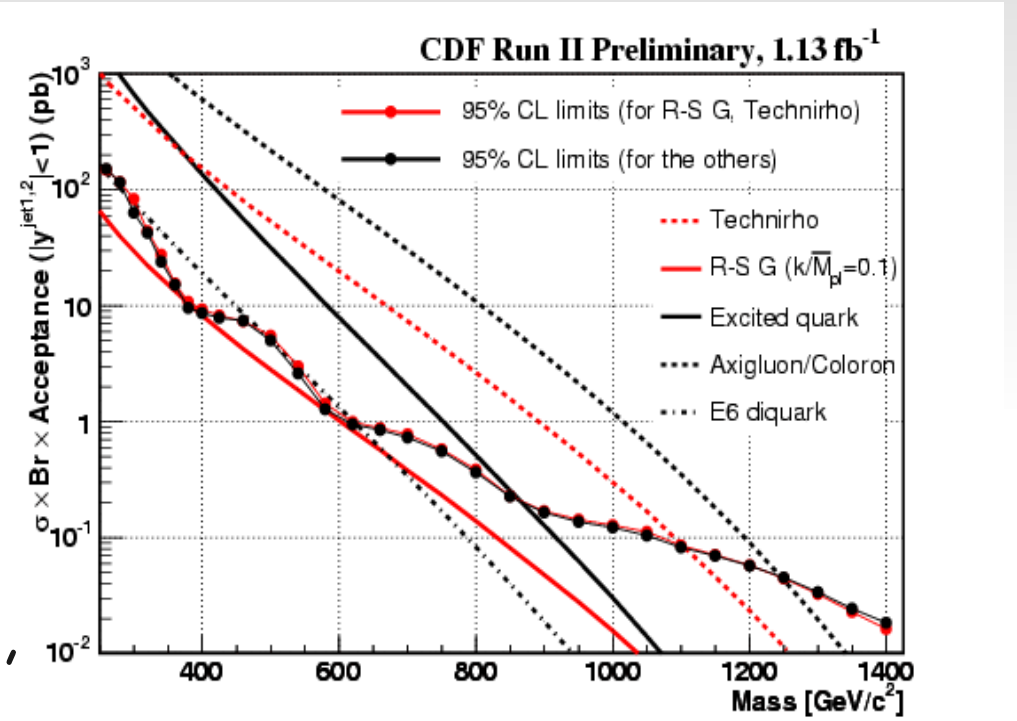
New particles

Red:

limits on the Randall-Sundrum graviton and color-octet technirho

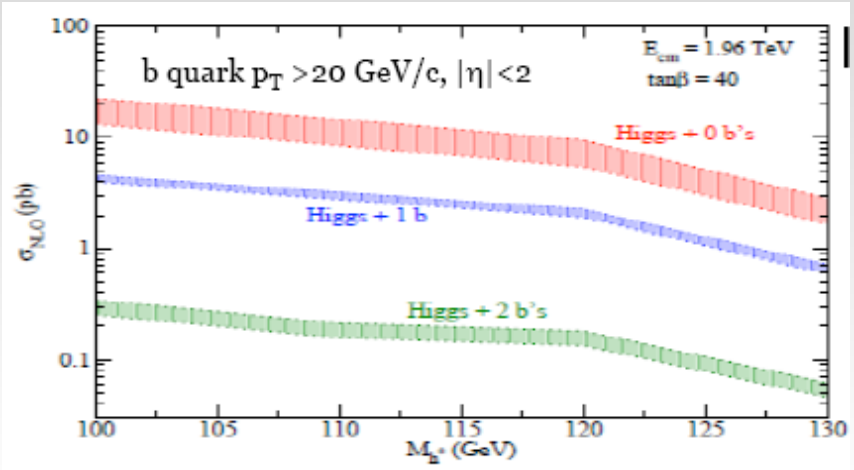
Black

limits on the excited quark, axigluon, flavor-universal coloron, and E6 diquark



These limits are compared with theoretical predictions for these particles production.

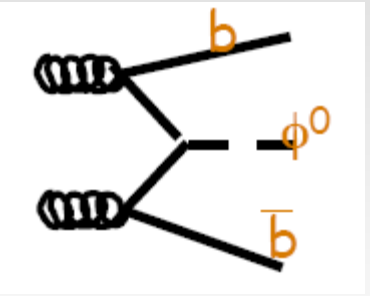
Di-jets Final States:$b\bar{b}$



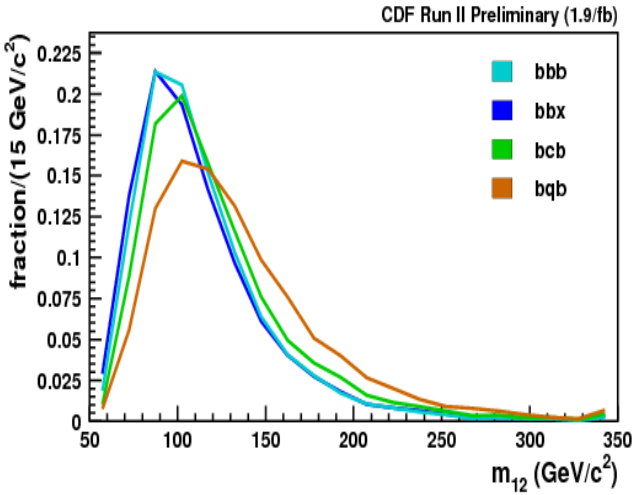
Inclusive bb is hard due to QCD background

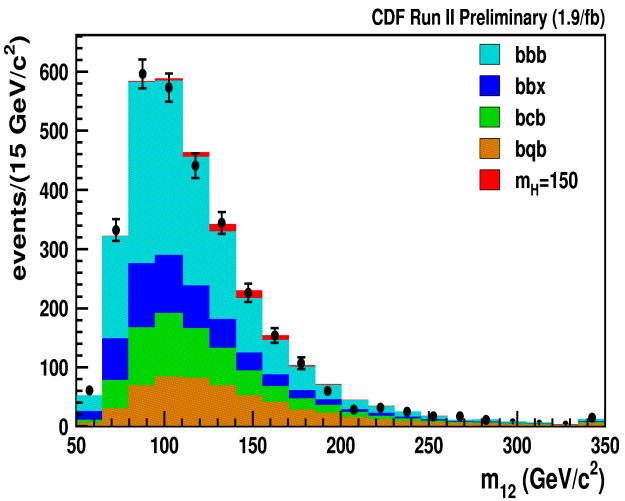
Require a 3^d b-jets

Good compromise between signal and background rate

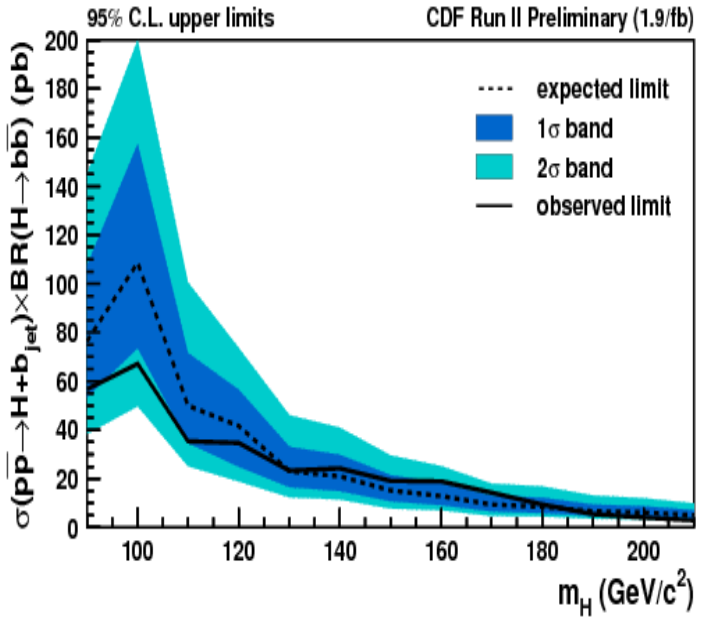


M_{12}, inv. mass of 2 leading jets used to separate signal from background





Result:



Photon + MET

Photon+MET rare in Standard Model ➡ sensitive to new high-energy invisible particles. Photons can be radiated by incoming parton or be produced in the decay chains of new particles.

One model: Large Extra Dimensions.

Large Extra Dimensions (LED) by Arkani-Hamed, Dimopoulos, and Dvali (ADD): $q\bar{q}$->γG, $q\bar{q}$->gG,qg->qG,gg->qG

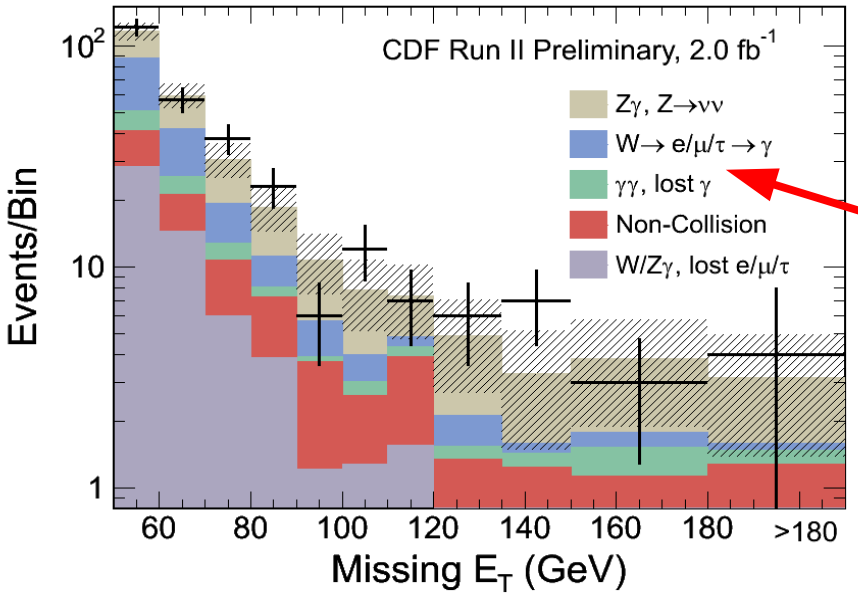
Data Selection:

Central Photon E_T >50 GeV

Missing Et >50 GeV

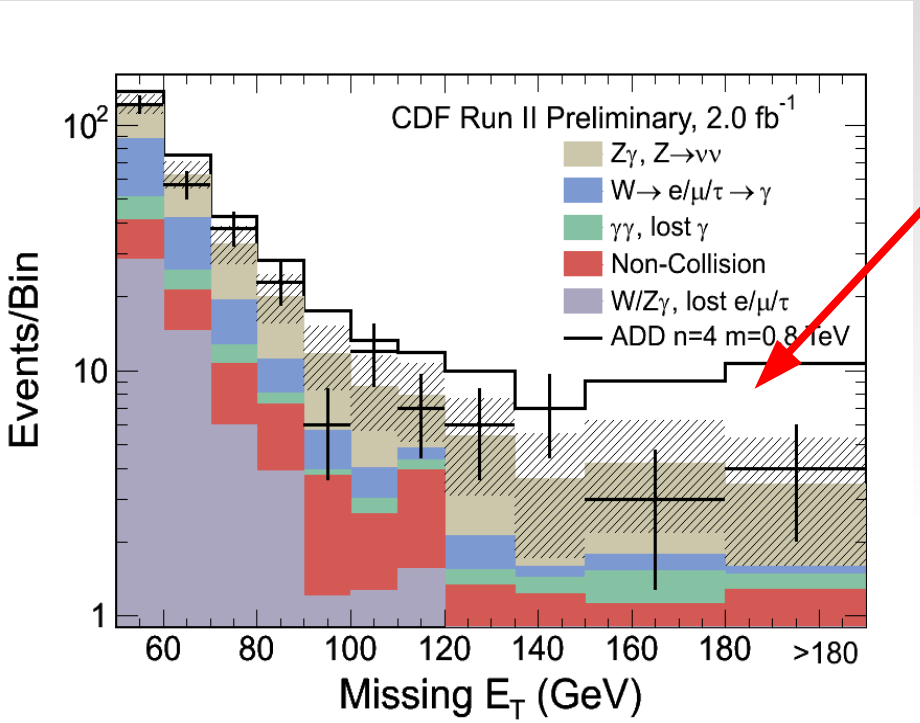
No jets with Et > 15 GeV

No tracks

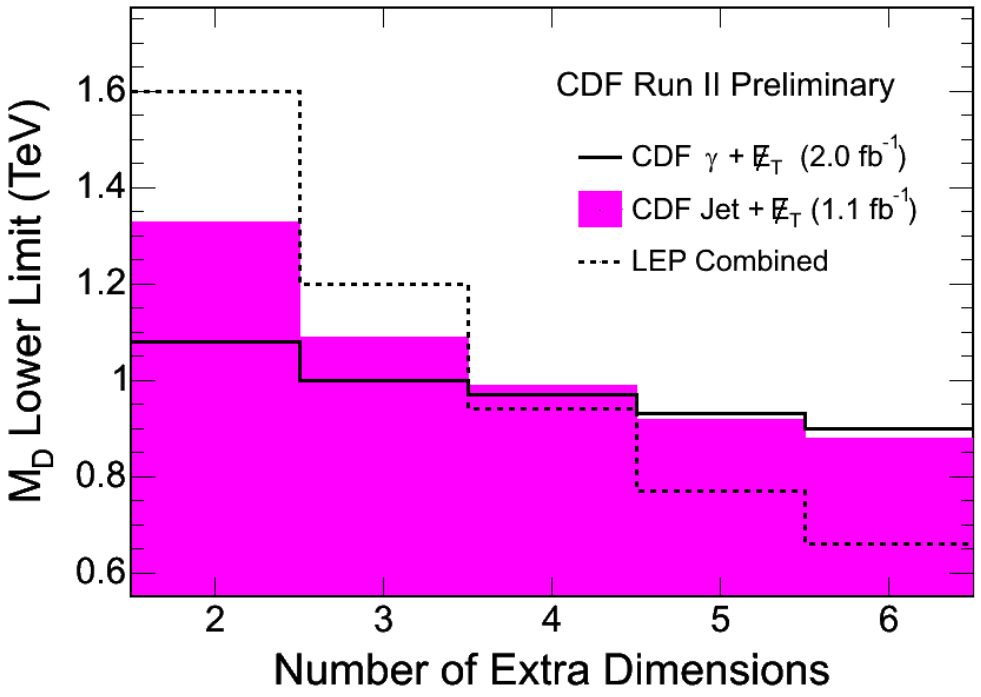


Main backgrounds

Photon + MET:Results



MET distribution including extradimensions, n=4



M_D=4+n dimensional Planck scale

n=N of extra dimensions

Leptoquarks searches

Leptoquarks are proposed as link among quarks and leptons, with fractionally-charged color-triplet bosons carrying both lepton and baryon quantum numbers. Leptoquarks appear in a wide range of theories, including SU(5) grand unification, superstrings, SU(4) Pati-Salam, and compositeness models.

1st Generation	2nd Generation	3rd Generation
$LQ\,\overline{LQ} \to e^- e^+ q\bar{q}$	$LQ\,\overline{LQ} \to \mu^+\mu^- q\bar{q}$	$LQ\,\overline{LQ} \to \tau^+\tau^- q\bar{q}$
$LQ\,\overline{LQ} \to e^{\pm}\nu_e q_i q_j$	$LQ\,\overline{LQ} \to \mu^{\pm}\nu_\mu q_i q_j$	$LQ\,\overline{LQ} \to \tau^{\pm}\nu q_i q_j$
$LQ\,\overline{LQ} \to \nu_e \nu_e q\bar{q}$	$LQ\,\overline{LQ} \to \nu_\mu \nu_\mu q\bar{q}$	$LQ\,\overline{LQ} \to \nu_\tau \nu_\tau q\bar{q}$

Final states with:
-jets
-leptons
-neutrinos (MET)

Leptoquarks searches cont'd

First generation:

* di-electrons + jets
* electron + MET + jets
* MET + jets

Main background:
W+jets, top, Z+jets

Second generation:

* di-muons + jets
* muon + MET + jets
* MET + jets

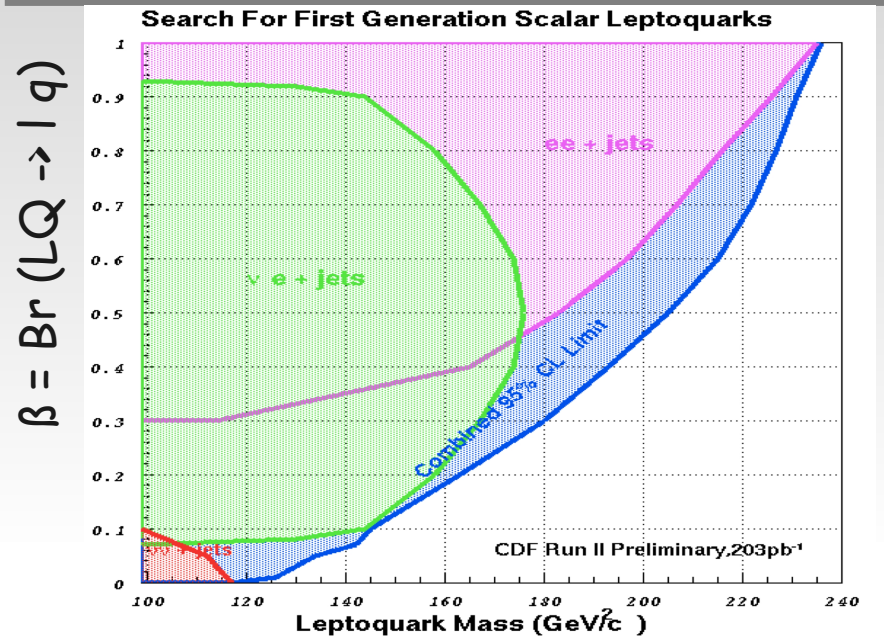
Main background:
W+jets, top, Z+jets

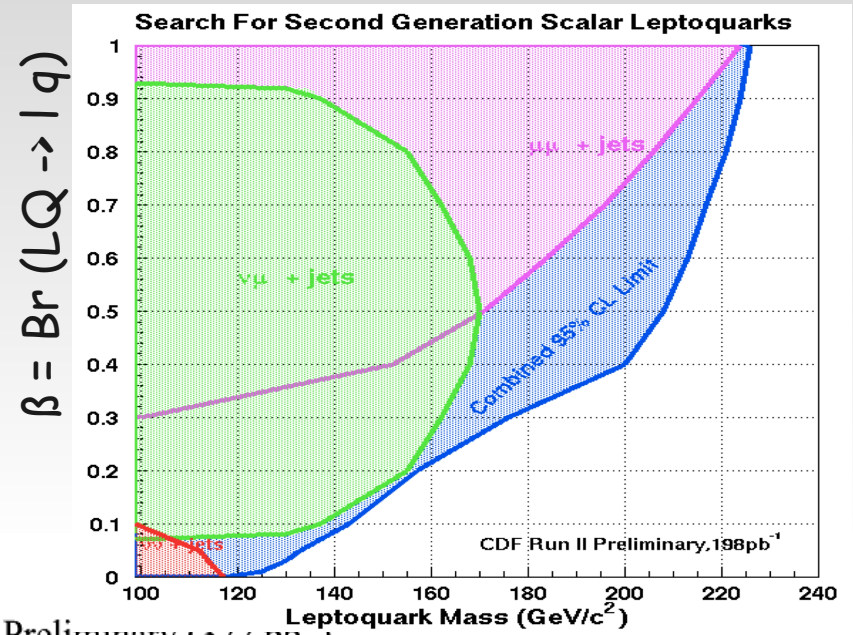
Third generation:

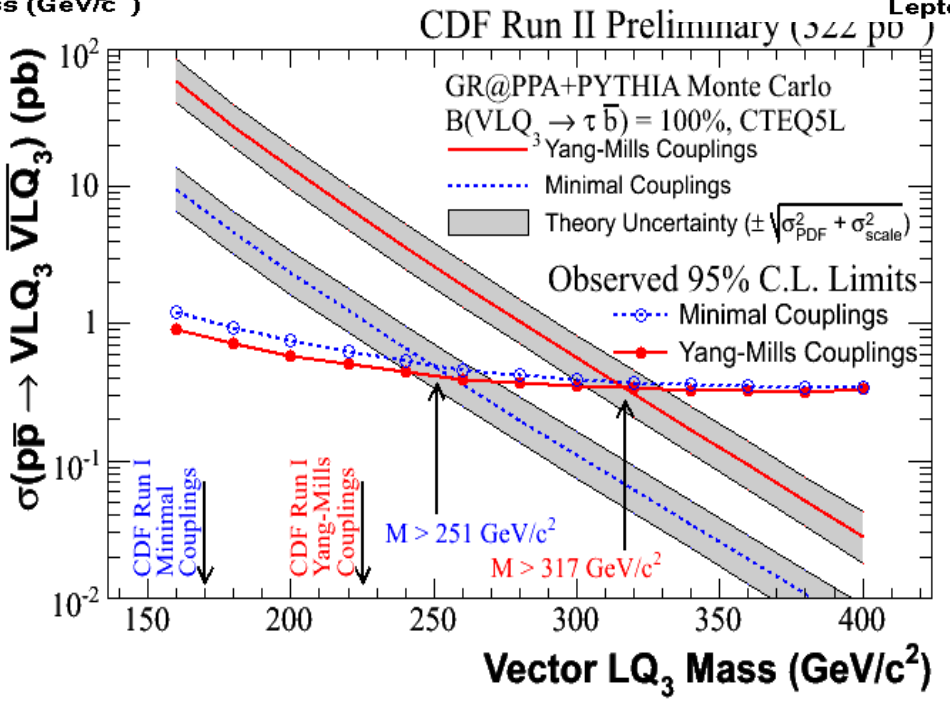
* di-taus + jets
* tau + MET + jets
* MET + jets

Main background:
W+jets, Z, QCD

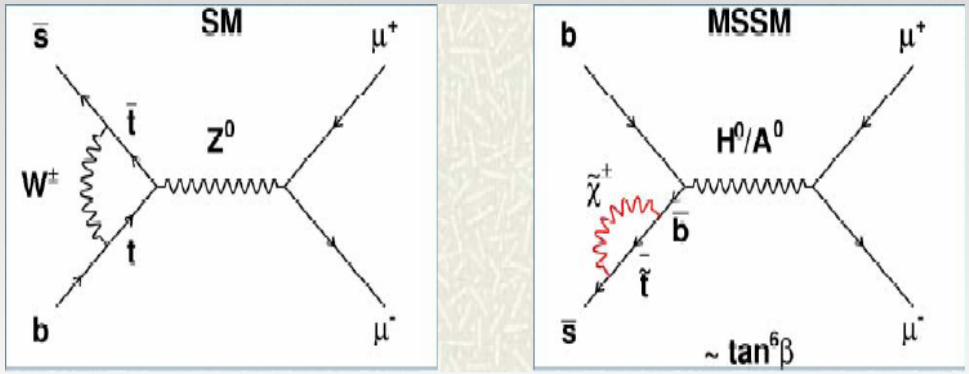
Leptoquarks searches: Results







Non Standard SuSy Searches: $B_s \to \mu\mu$



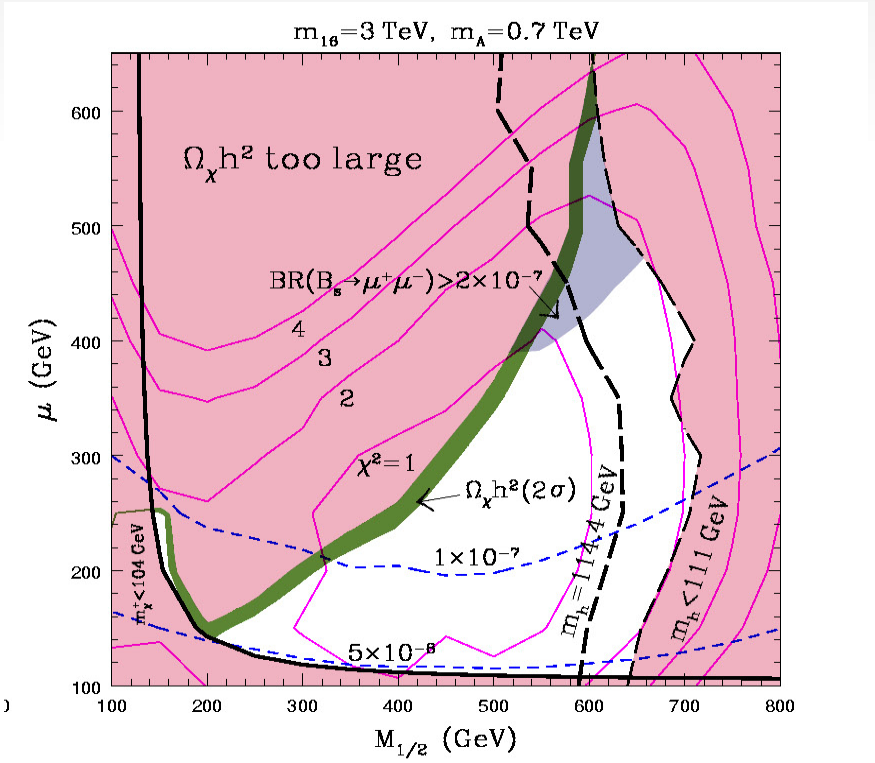
SM: BR = 3.42×10^{-9} SUSY enhance $\sim(\tan\beta)^6$

Sensitive to new physics:

SUSY particles show up in loops

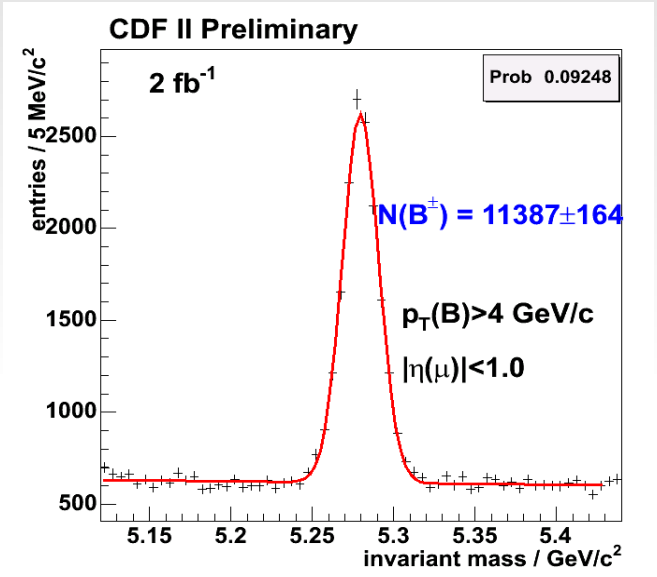
(or direct decays if R_p violation)

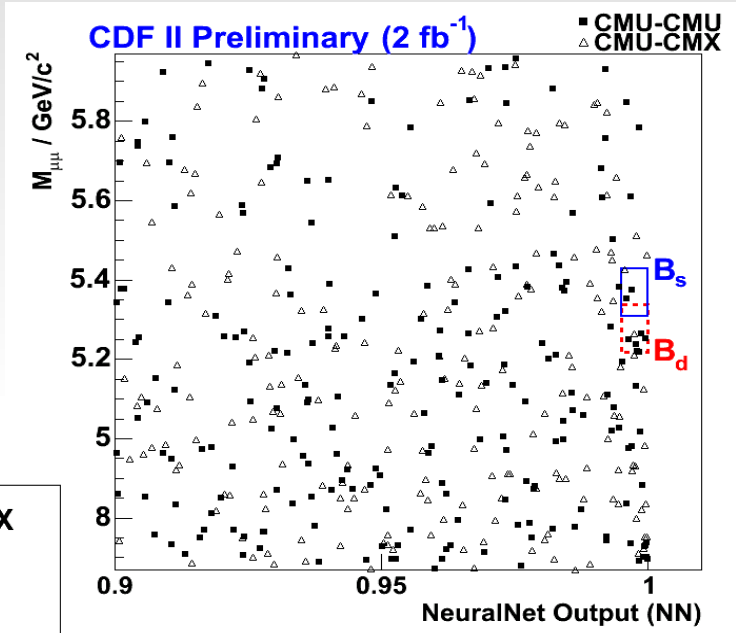
A second interesting class of models that predicts enhanced rates of Bs → μμ decay are SO(10) symmetry breaking models

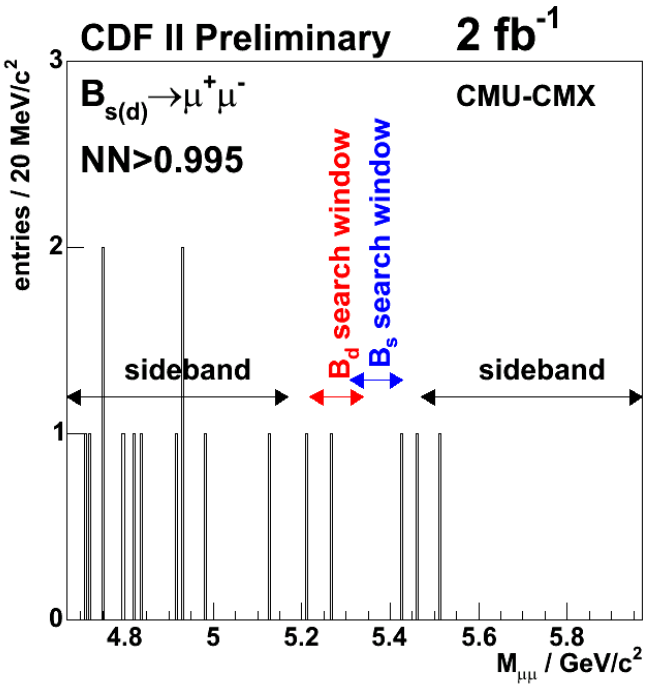


Non Standard SuSy Searches: B_s->μμ

Number of candidates B_s->μμ normalized to the number of B^+->J/ψK^+



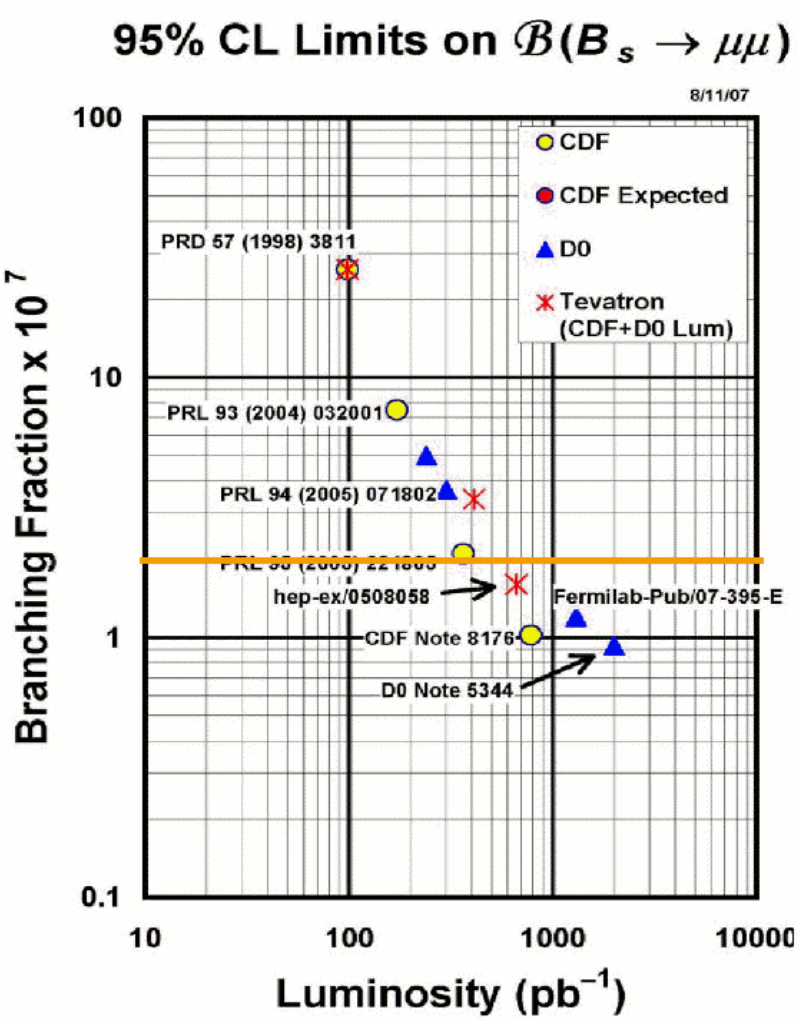


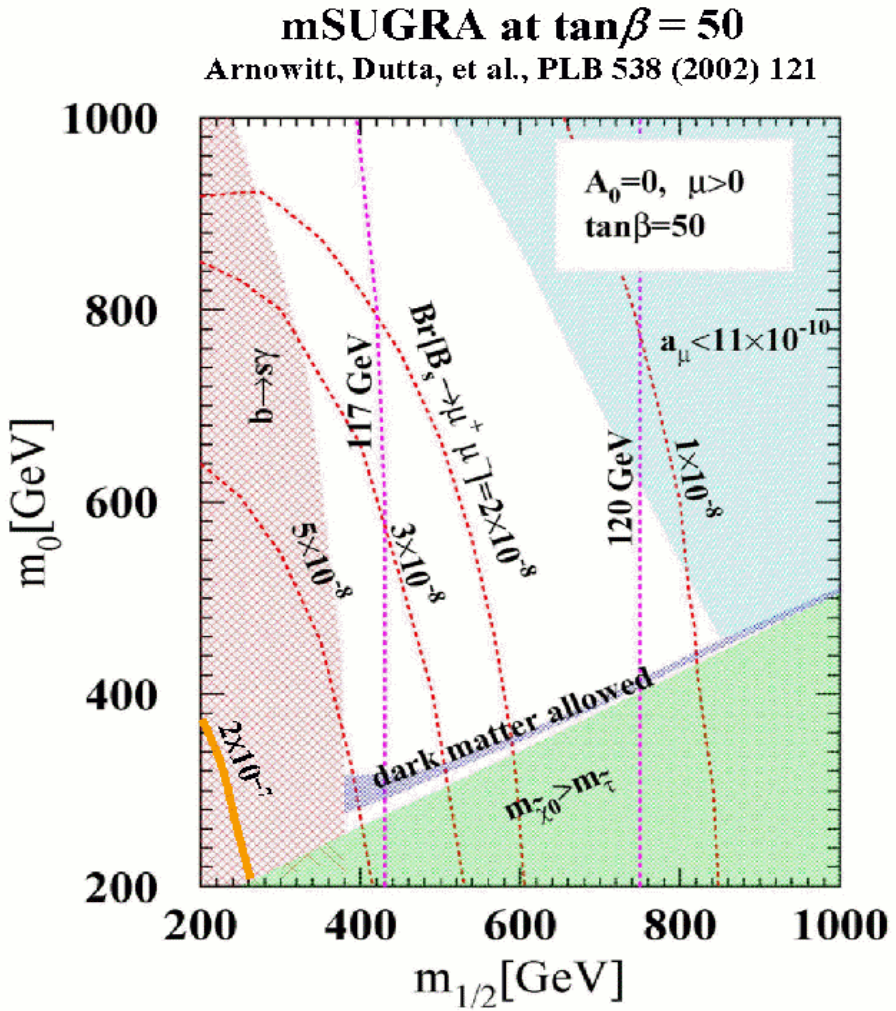


After the cut NN>0.995

B_s ->μμ Results

$\mathcal{B}(B_s \to \mu\mu)$ and Cosmological Connection





Model Independent Searches

Model Independent Searches

Wide searches for deviation from Standard Model:
Vista (model independent), Sleuth(quasi model indepent)

CDF Run II Preliminary ($2.0\ \text{fb}^{-1}$)

Final State	Data	Background	σ	σ_t
$be^{\pm}\not{p}$	690	817.7 ± 9.2	-4.3	-2.7
$\gamma\tau^{\pm}$	1371	1217.6 ± 13.3	$+4.0$	$+2.2$
$\mu^{\pm}\tau^{\pm}$	63	35.2 ± 2.8	$+3.7$	$+1.7$
b2j$\not{p}$ high-Σp_T	255	327.2 ± 8.9	-3.7	-1.7
2j$\tau^{\pm}$ low-Σp_T	574	670.3 ± 8.6	-3.6	-1.5
3j$\tau^{\pm}$ low-Σp_T	148	199.8 ± 5.2	-3.5	-1.4
$e^{\pm}\not{p}\tau^{\pm}$	36	17.2 ± 1.7	$+3.5$	$+1.4$
2j$\tau^{\pm}\tau^{\mp}$	33	62.1 ± 4.3	-3.5	-1.3
$e^{\pm}$j	741710	764832 ± 6447.2	-3.5	-1.3
j2$\tau^{\pm}$	105	150.8 ± 6.3	-3.4	-1.2

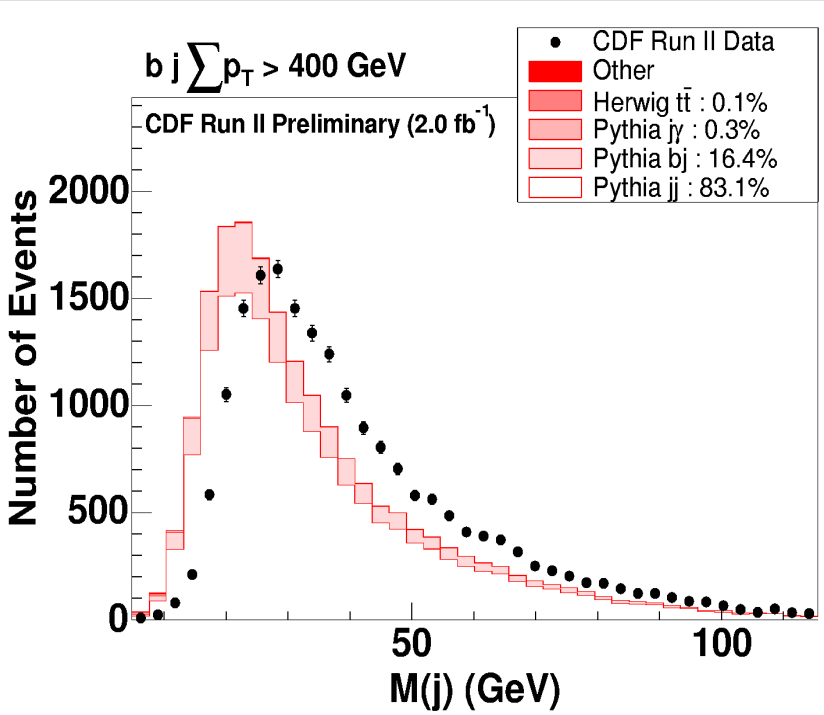
CDF Run II Preliminary ($2.0\ \text{fb}^{-1}$)

SLEUTH Final State	$\mathcal{P}$
$\ell^+\ell'^+$	0.00055
$\ell^+\ell'^+\not{p}jj$	0.0021
$\ell^+\ell'^+\not{p}$	0.0042
$\ell^+\ell^-\ell'\not{p}$	0.0047
$\ell^+\tau^+\not{p}$	0.0065

Most discrepant final states

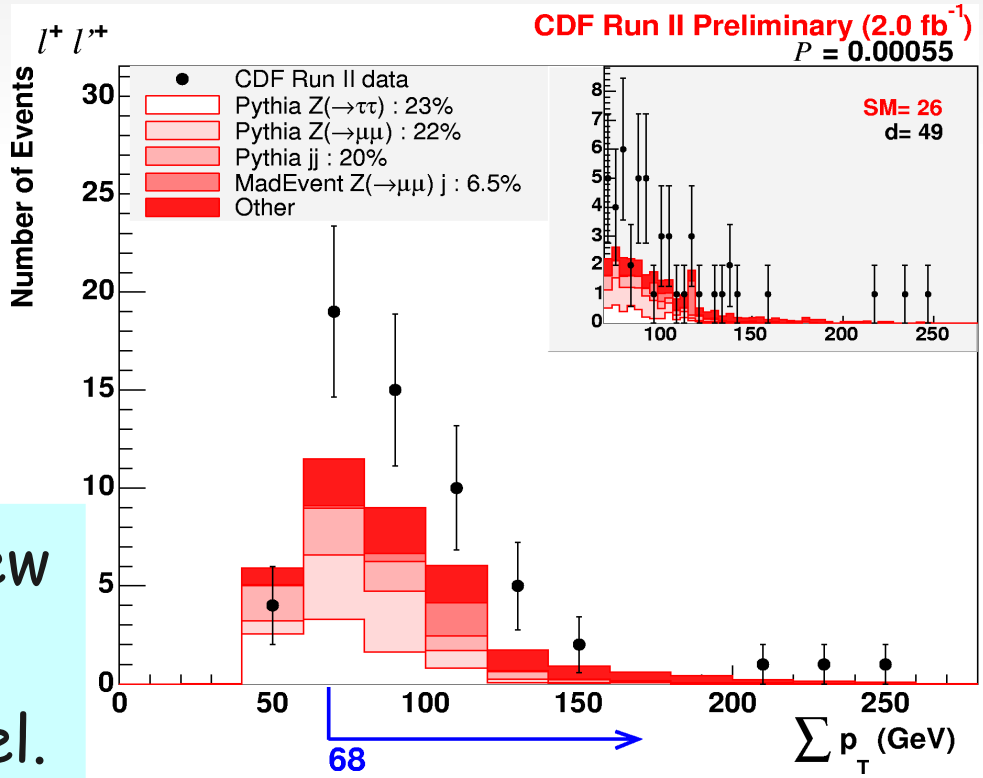
Most relevant searches

Model Independent Searches: Results



MC does not reproduce data

Jet mass in events with
1 btagged jet
2 jets
Σpt>400 GeV



This combined global search for new physics reveals no indication of physics beyond the Standard Model.