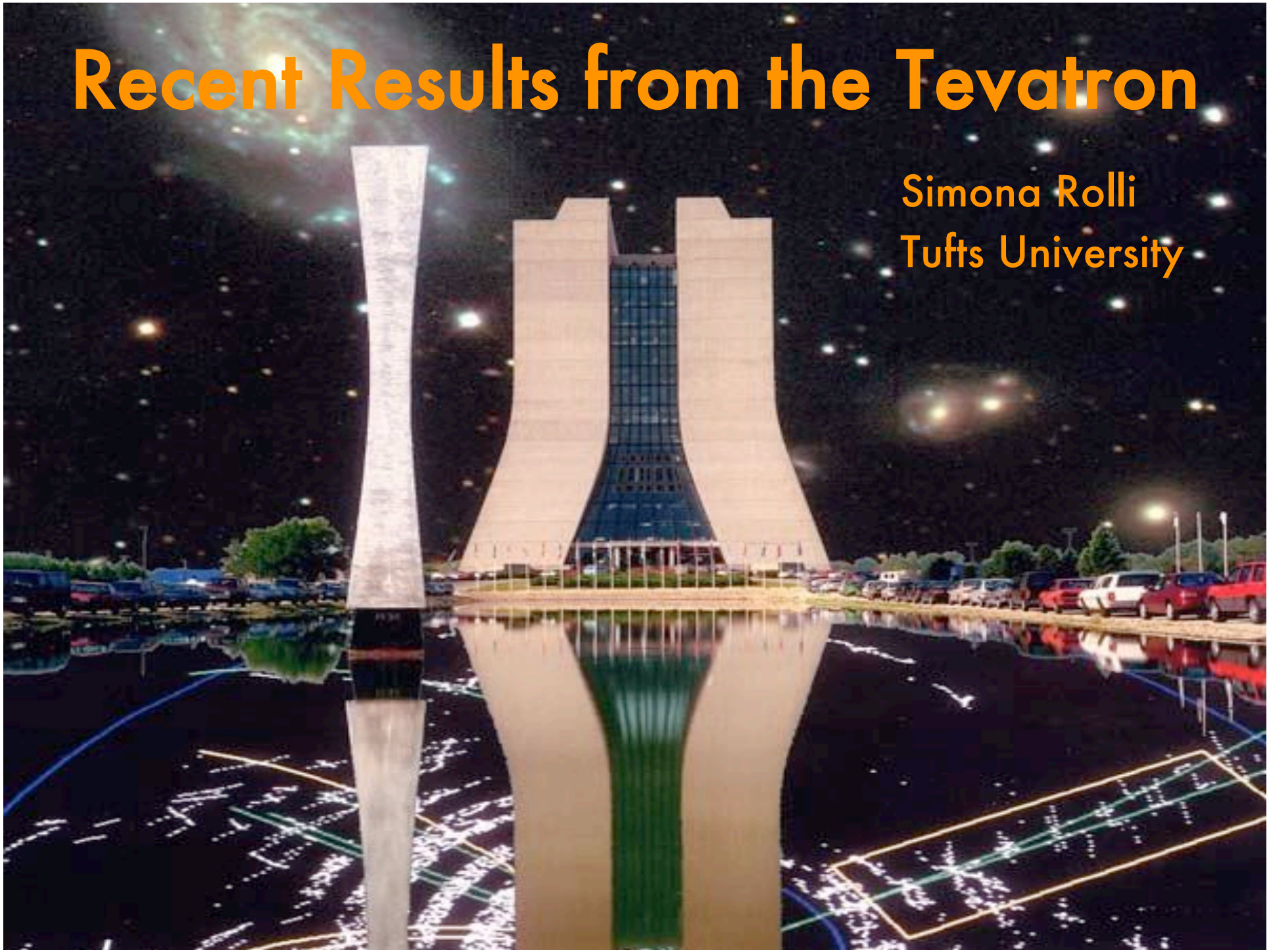
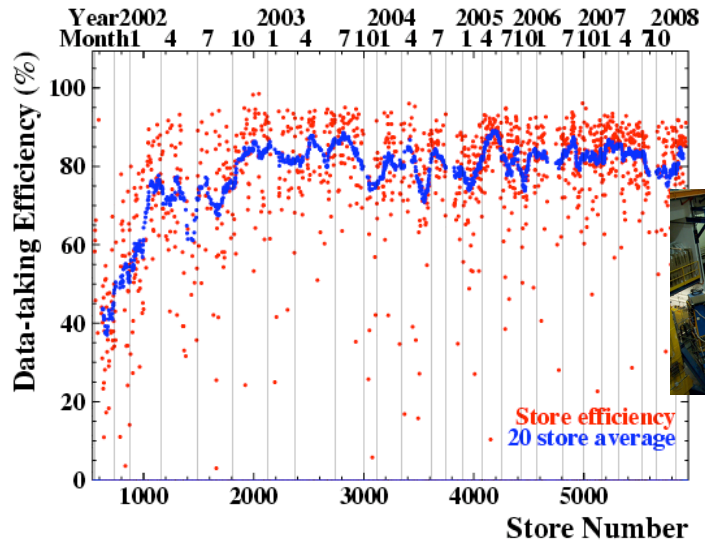
Recent Results from the Tevatron

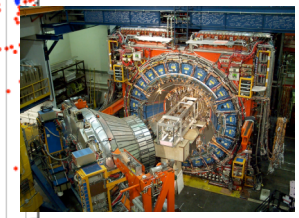
Simona Rolli
Tufts University



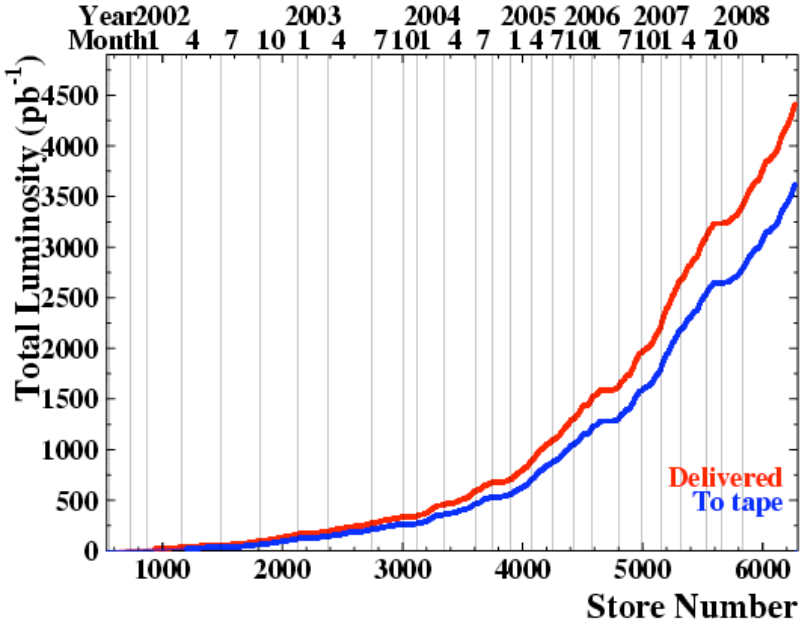
TeVatron Status

The TeVatron is doing very well!

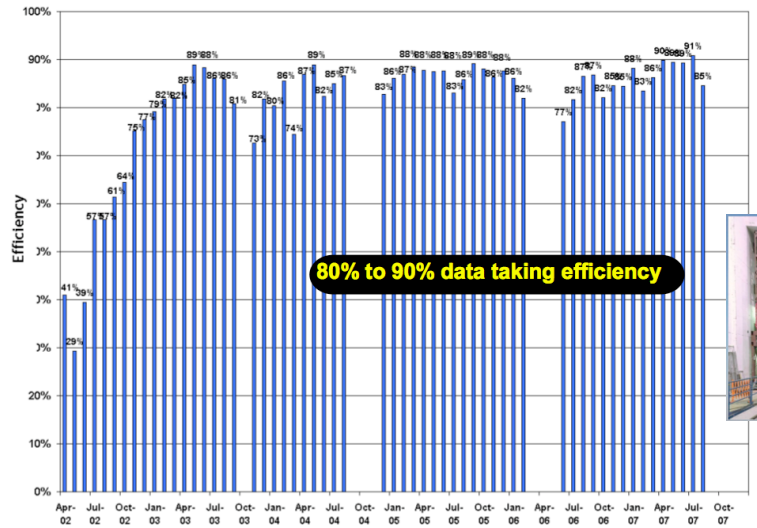


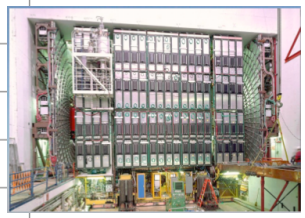


Luminosity Profile



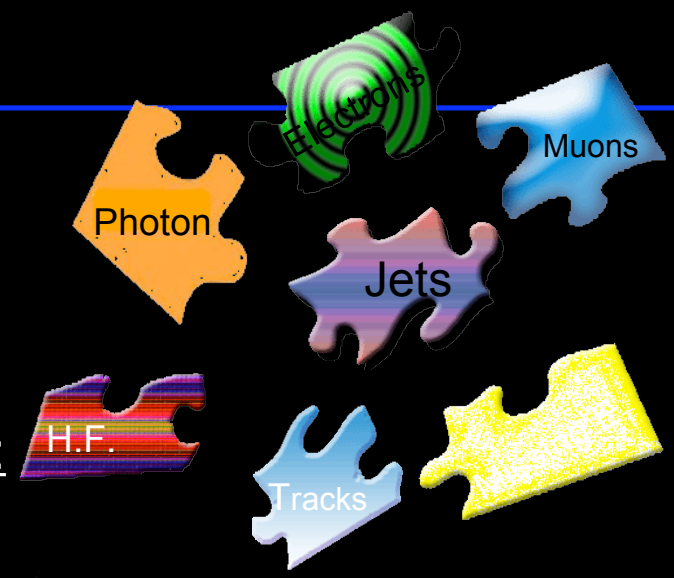
Delivered Lumi. > 4.5 fb^{-1}
Good for analysis ~ 3. fb^{-1}

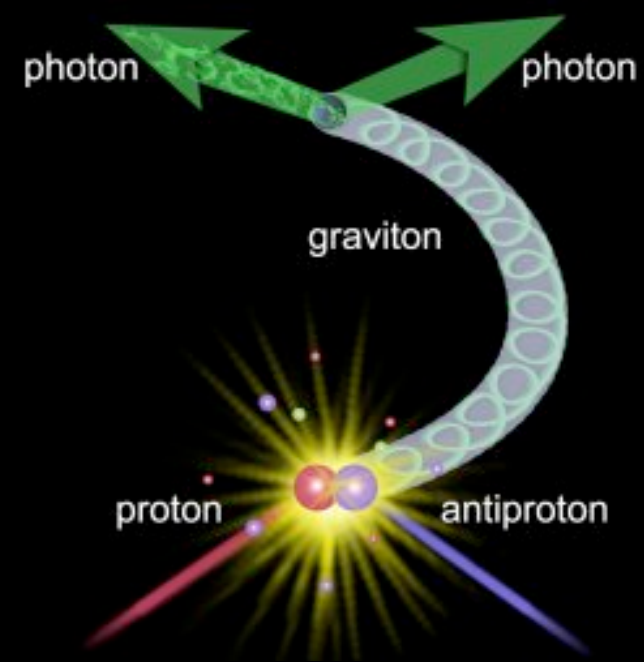




Outline of the talk

- Testing the Standard Model
  - jet physics
  - b-physics
  - Top physics
- Search for Physics beyond the Standard Model:
  - Searching for SUSY
  - Searching for exotic particles
- The search for the Higgs
  - Low mass Higgs
  - High Mass Higgs
  - Perspectives





–from simple objects to complex final states

- leptons-only final states (and isolated tracks)
- … + Missing Energy and Photons E_T
- … + Jets and heavy flavors

Testing the Standard Model

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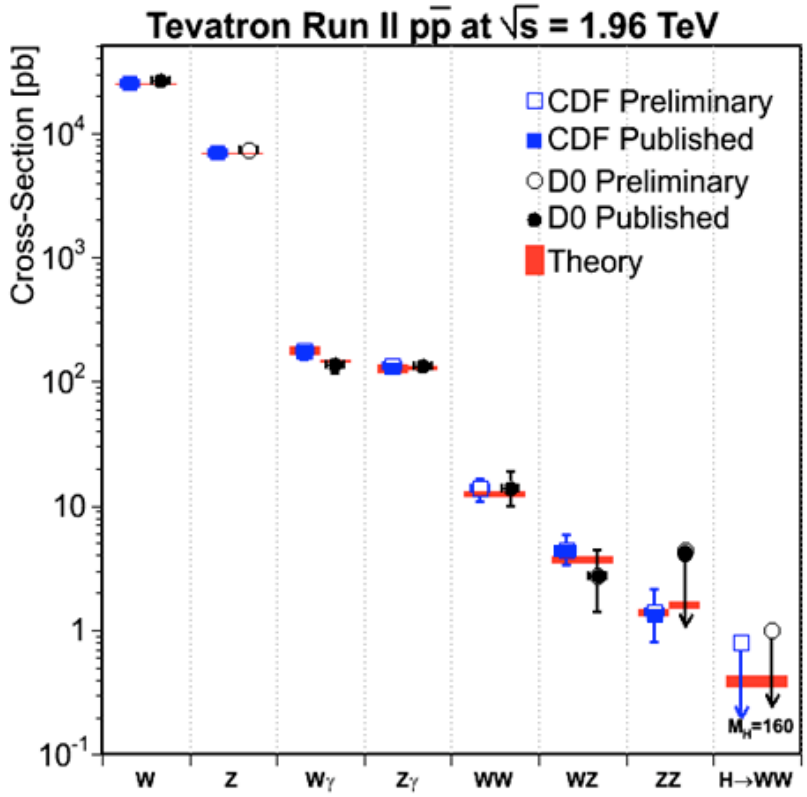
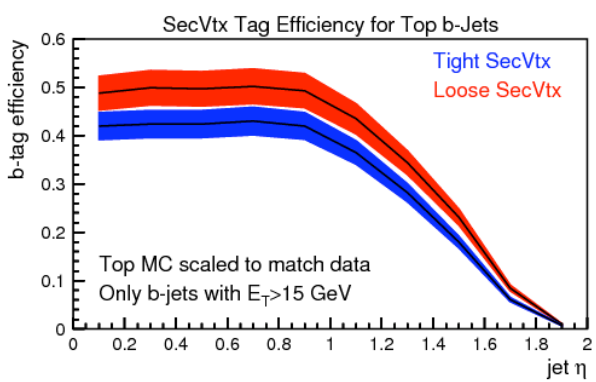
- Simple signatures:
  - Z and W physics - lepton signatures
    - Lepton ID
  - Jets cross section
    - Jet Energy Scale
- Complex signatures
  - B-physics
  - Top Quark
    - Btagging
    - Multivariate techniques

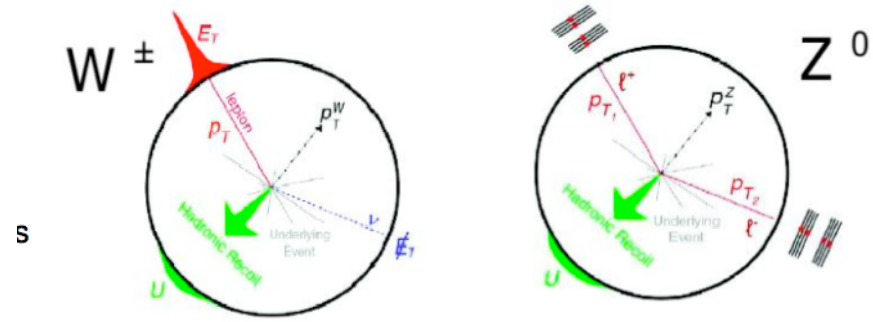


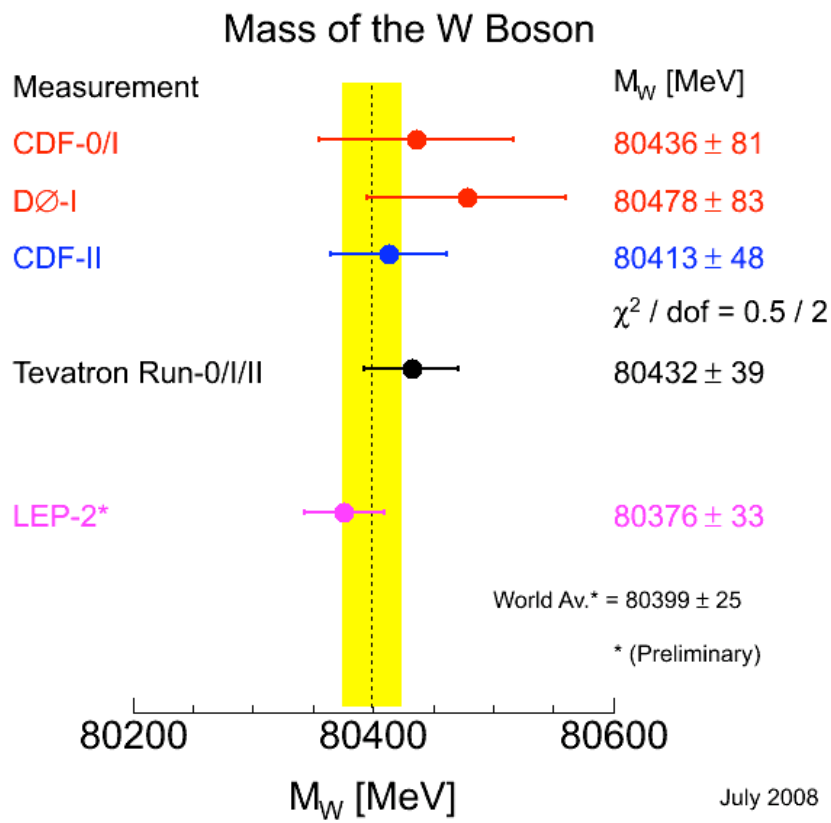


Precision measurements and new ones

W/Z Physics

- At the Tevatron, W and Z bosons are produced by quark-antiquark annihilation
- EW bosons are also fundamental tools for calibrations and checks:
  - EM energy scale
  - momentum scale in tracker
  - resolution in missing transverse energy
  - calorimeter response to low E_t hadronic activity (boson recoil)
  - input to PDF at low x from W charge asymmetry measurements

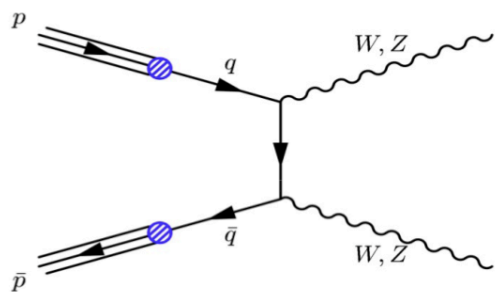




We are using the millions of W and Z boson decays collected in high-P_t lepton samples to produce excellent measurements of electroweak observables

ZZ Cross section

The smallest cross section measured!

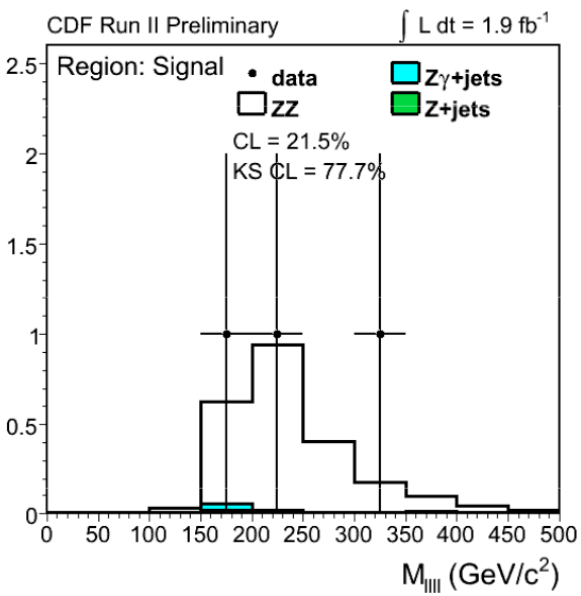


$$\sigma(ZZ) = 1.6 \pm 0.1 \text{ pb (SM)}$$

CDF combines events with 4 charged leptons (e,μ), and 2 charged leptons and 2 neutrinos. Based on 3 llll and 5 llνν candidates:

$$\sigma(ZZ) = 1.4^{+0.7}_{-0.6}(stat + syst)\, pb$$

4.4σ observed significance



- D0 uses seven orthogonal channels:
  - 4e (3 categories)
  - 4μ
  - 2e+2μ (3 categories)
- $M(Z_1)>70$ GeV, $M(Z_2)>50$ GeV

$$\sigma(ZZ) = 1.75^{+1.27}_{-0.86}(stat) \pm 0.13(syst)\ \text{pb}$$

5.42σ significance

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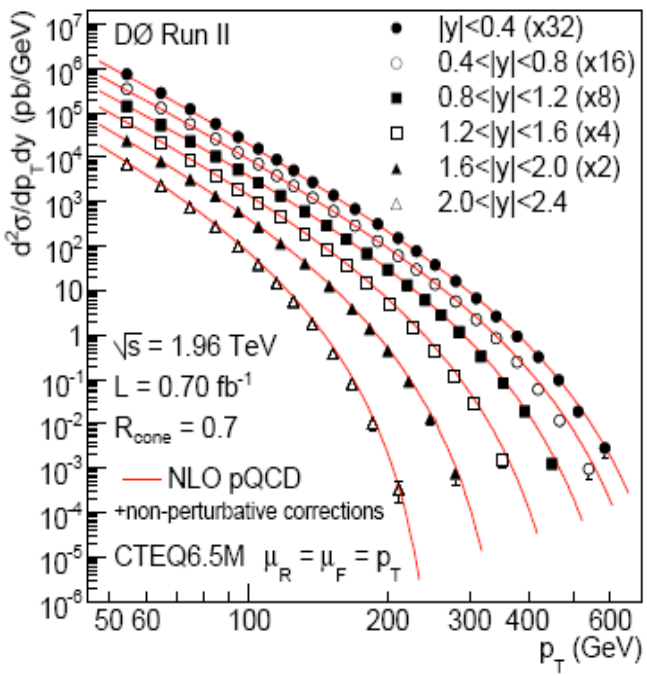
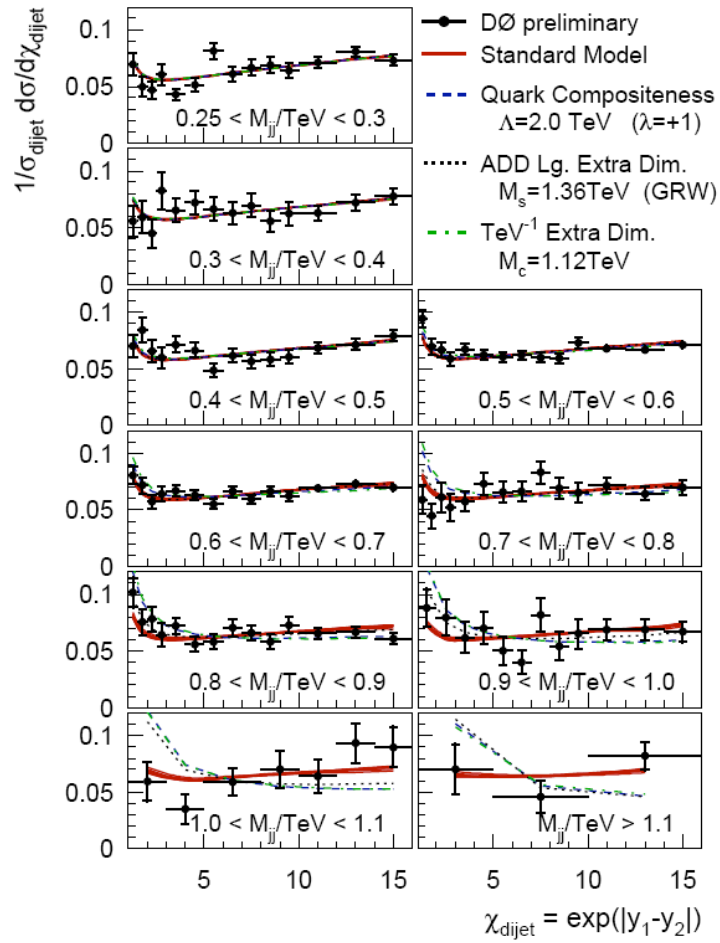
Jets Measurements

arXiv:0802.2400 [hep-ex]



The Jet cross section is measured over a wide range of energy and great accuracy

Data agree well with NLO theory over the whole p_T range

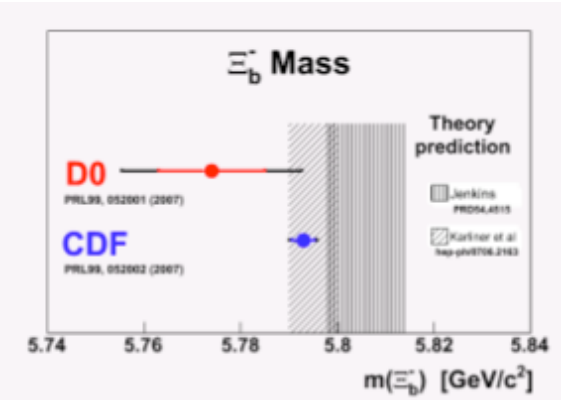


Dijet angular distributions in bins of dijet mass:

- First differential cross section measurement at partonic energies >1 TeV!
- Small experimental and theoretical uncertainties.
- Sensitive to New Physics (95% CL limits):

B-physics

- B hadrons are produced copiously in proton-antiproton collisions
- D0 and CDF collect large samples of B decays
  - CDF uses inclusive lepton triggers
    dimuon triggers
    impact parameter-based triggers (SVT)



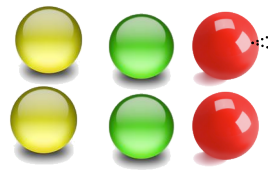
- Long string of successes:
  - B_s mixing measured: $\Delta M_s = 17.77 \pm 0.12\ ps^{-1}$
  - New Σ_b Ξ_b baryons discovered
  - B_c observation
  - Lifetime measurements competitive with B factories even on non-strange B hadrons
  - Stringent limits on rare decays

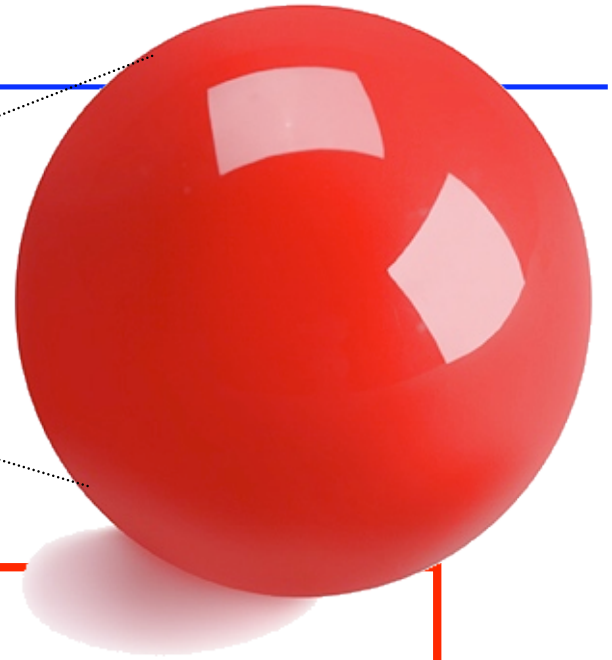
http://www-cdf.fnal.gov/physics/new/bottom/bottom.html

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

Top Physics

Discovered in 1995 at the TeVatron, flurry of measurements still ongoing





We still don't know all about it….

- Mass	Precision <2%
- Top width ~1.5 GeV	?
- Electric charge ⅔	-4/3 excluded @ 94% C.L. (preliminary)
- Spin ½	Not really tested – spin correlations
- BR(t→Wb) ~ 100%	At 20% level in 3 generations case
	FCNC: probed at the 10% level
- Production mechanisms	Single Top : just observed

Top Quark at the TeVatron

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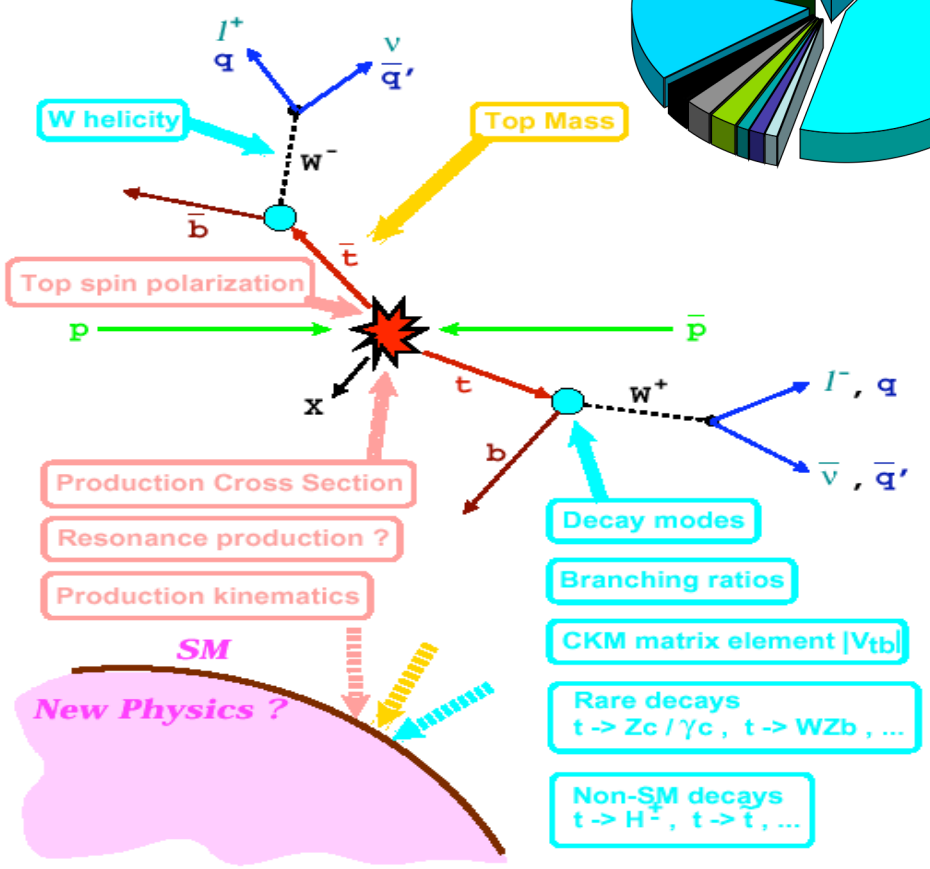
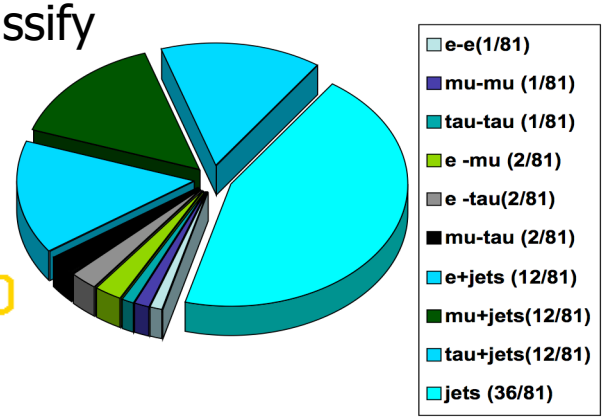
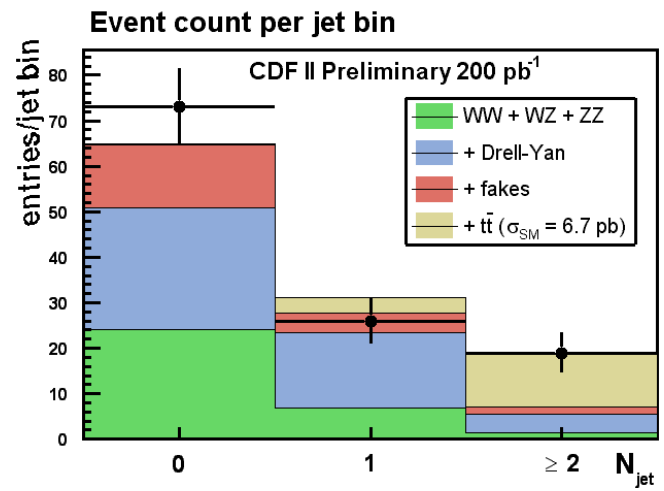
Complex final state including leptons, missing energy, jets and heavy flavors
W decay mode is used to classify the final state







Signal is well visible in ≥ 2 jets bin

A host of measurements

- -Mass and CrossSection
- -Wtb coupling
- -Searches for $H^+ \rightarrow tb, t \rightarrow H^+ b$
- -Search for FCNC
- -Forward-backward asymmetry
- -M_{tt} distribution
- -Search for 4th generation top
- -W boson helicity

……..

Top Cross Section Measurement

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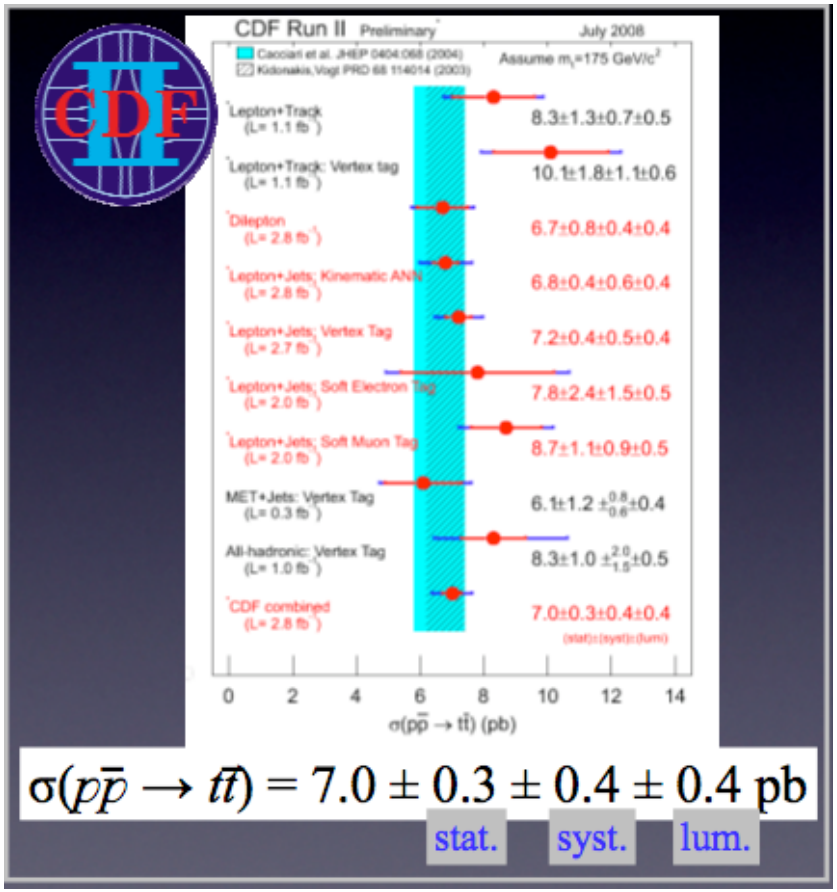
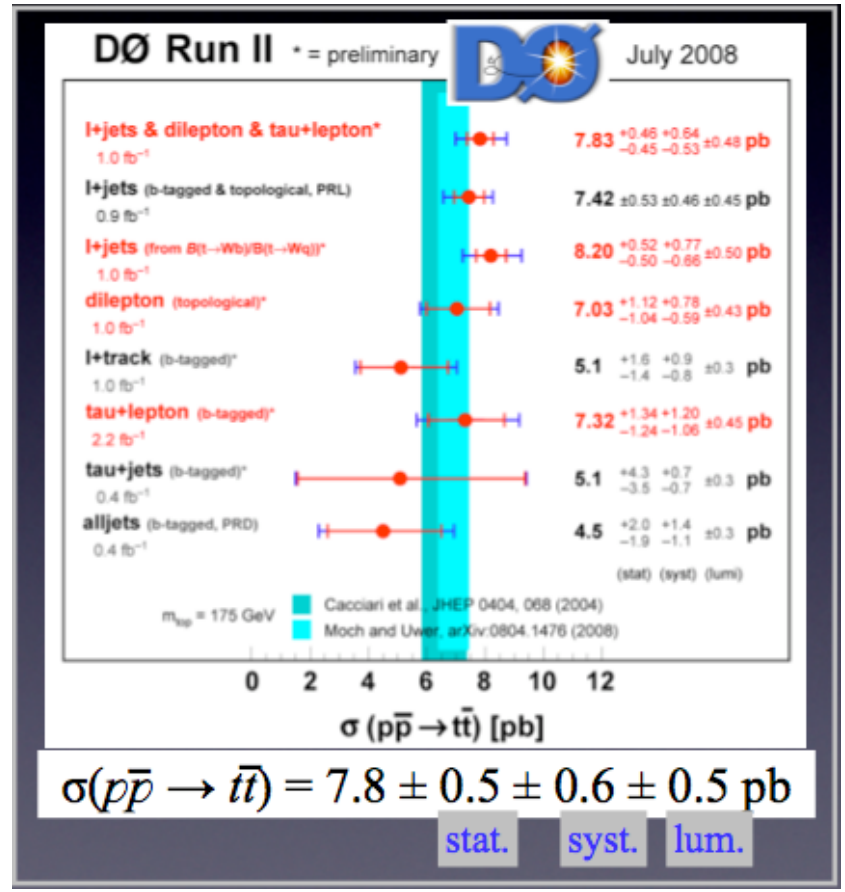
The cross section is measured in all final states: it is the first step of any study of the details of top quark properties.

σ_{tt}=6.8±0.6 pb (Kidonakis, Vogt)
σ_{tt}=6.7+0.7-0.9 pb (Cacciari et al.)



$\sigma(p\bar{p} \to t\bar{t}) = 7.0 \pm 0.3 \pm 0.4 \pm 0.4$ pb

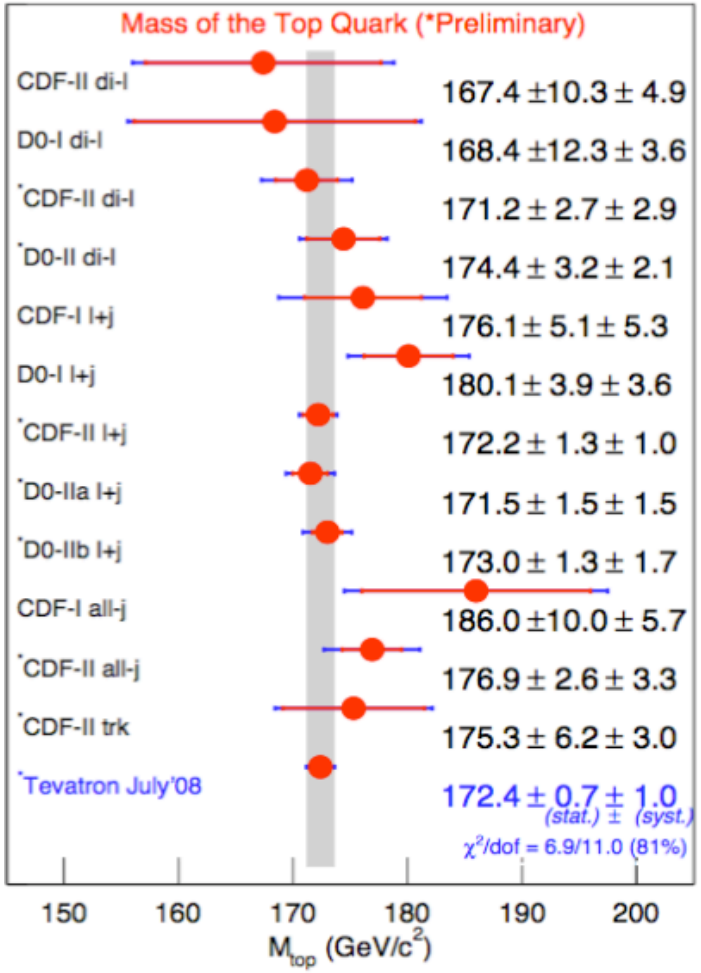
stat. syst. lum.



$\sigma(p\bar{p} \to t\bar{t}) = 7.8 \pm 0.5 \pm 0.6 \pm 0.5$ pb

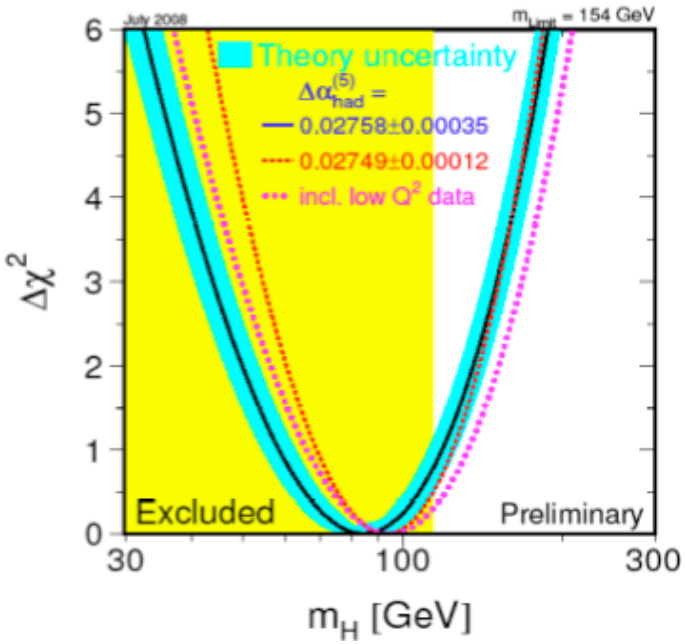
stat. syst. lum.

Top Mass Measurement

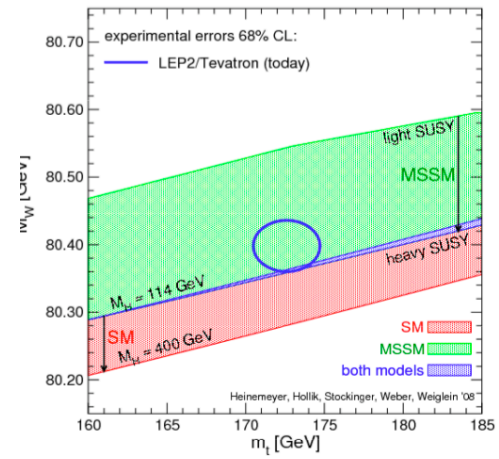


$$m_t = 172.4 \pm 0.7 \pm 1.0 \text{ GeV}$$

0.7% precision!



$$m_H < 154 \text{ GeV @ } 95\% \text{ C.L.}$$

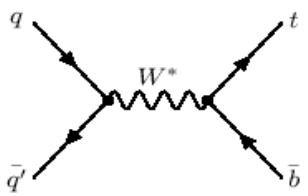


Light Higgs preferred

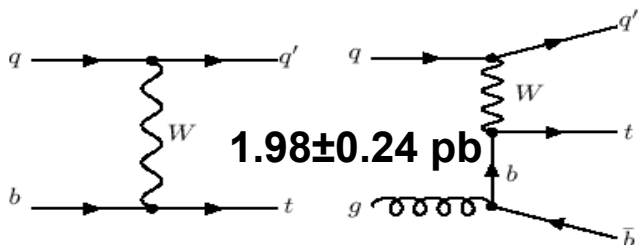
→ *will be a legacy to LHC for the* ***calibration of the jet E scale*** *of the Atlas and CMS detectors*

Single Top Production

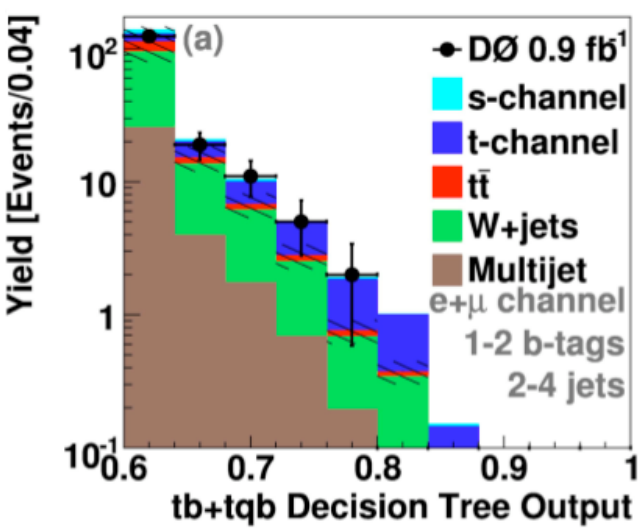
The TeVatron data show evidence for single top production by now (small EW cross section)

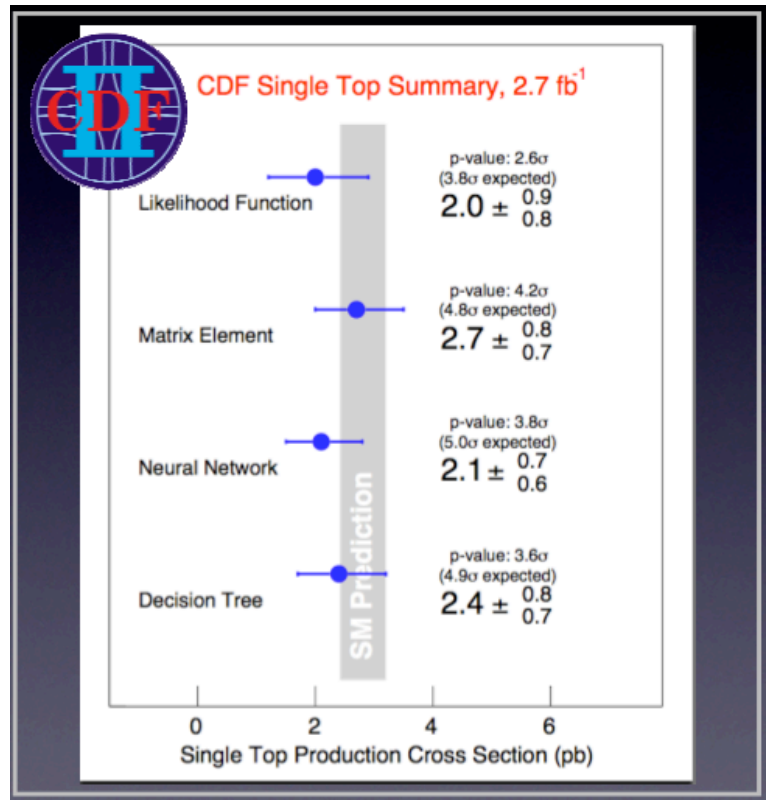


0.88±0.11 pb



1.98±0.24 pb



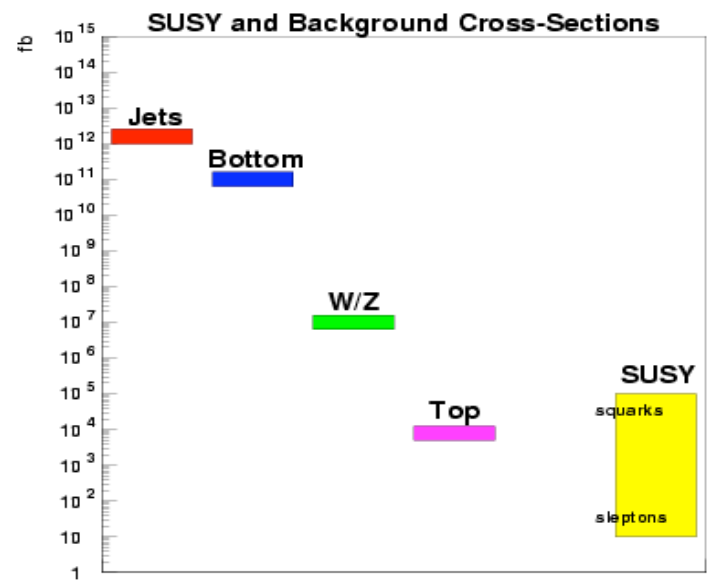


DØ: $\sigma = 4.7 \pm 1.3$ pb
3.6σ significance (obs)
2.3σ significance (exp)
$|V_{tb}| > 0.68$ @ 95% C.L.

Heavy use of multivariate methods

Beyond the SM

- Simple signatures:
  - High mass dileptons
  - High mass diphotons
  - SUSY in multileptons
- Complex Signatures:
  - Search for Leptoquarks
  - SUSY in multijets (squarks and gluinos)
  - Sbottom and stop searches
  - Many more
- Multi objects scans and global searches



Cross sections for various physics processes vary over many orders of magnitude:
processes of interest are often buried under heavy background
need good rejection factors, selection and analysis strategies

Searches in dilepton final states

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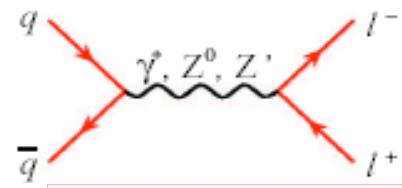
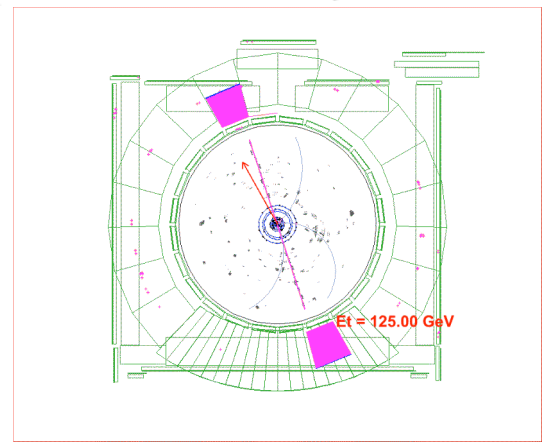
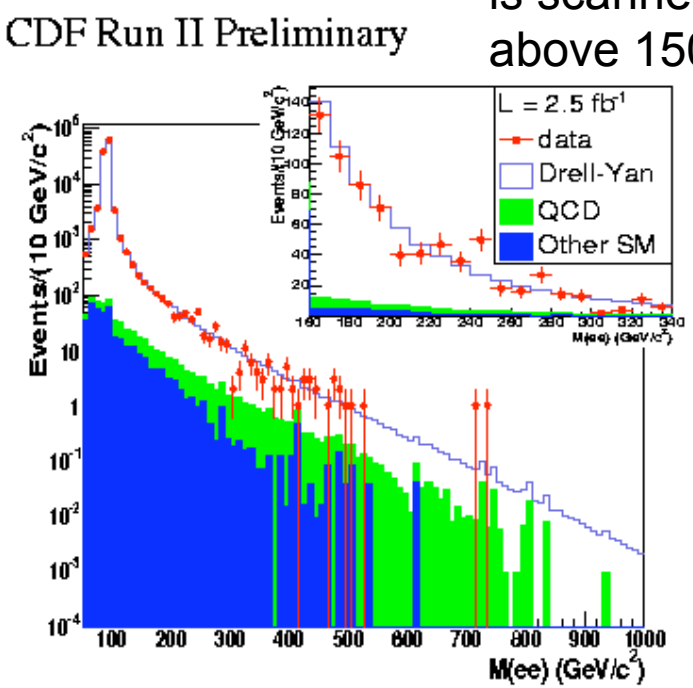
Old-fashioned mass bump hunt..

-Z production and decay into ee/μμ precisely measured
-Lepton ID/Reco and Trigger efficiencies high and very well understood
-Background low and easily determined (QCD fakes)
-Clean events





At CDF the dielectron mass spectrum is scanned in search for excesses in above 150 GeV/c^2



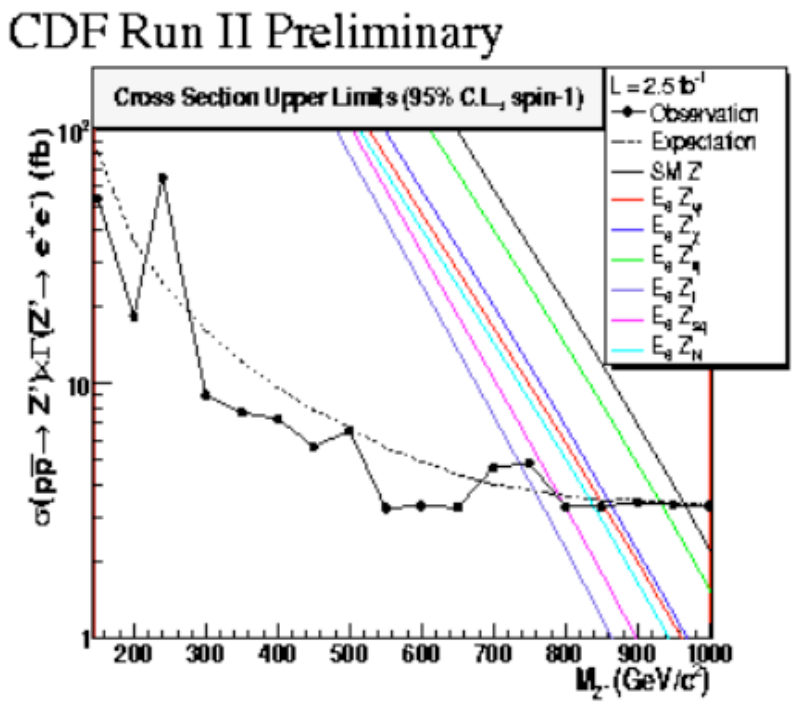
The most significant region of excess for an e^+e^- invariant mass window of 240 GeV/c^2

3.8 standard deviations above the SM prediction
Excess is monitored (data period) Cross-check in muons

The probability of observing a background fluctuation with significance equal to or greater than 3.8 anywhere in the mass range of 150-1,000 GeV/c^2 is about 0.6%, corresponding to a 2.5 σ significance.

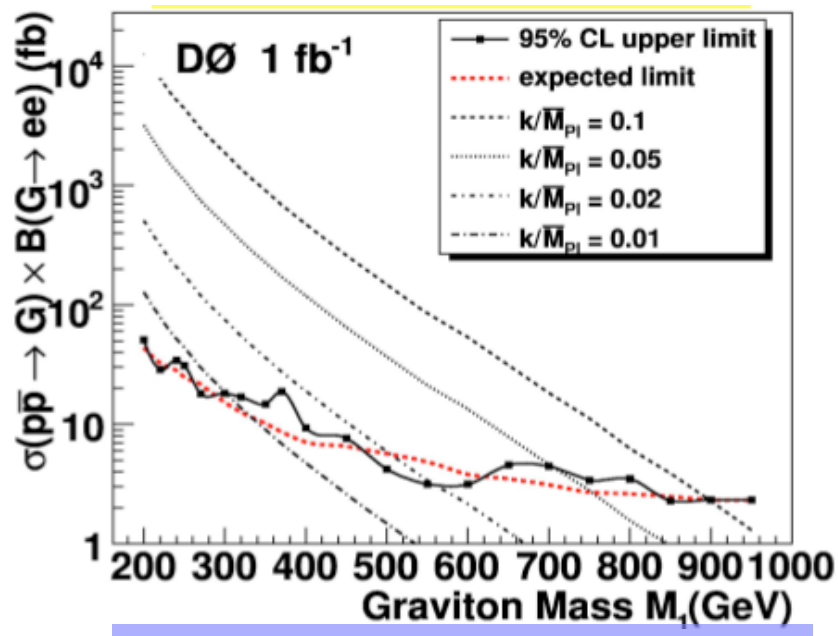
Testing different models

Once the data spectrum is well understood in terms of SM background, from MC, the acceptances for resonant states for different spin particles are derived (Z', RS Graviton) and the expected number of BSM events is calculated.
In the absence of an excess of data, 95% CL limits on production cross-sections and mass of the particles are set.



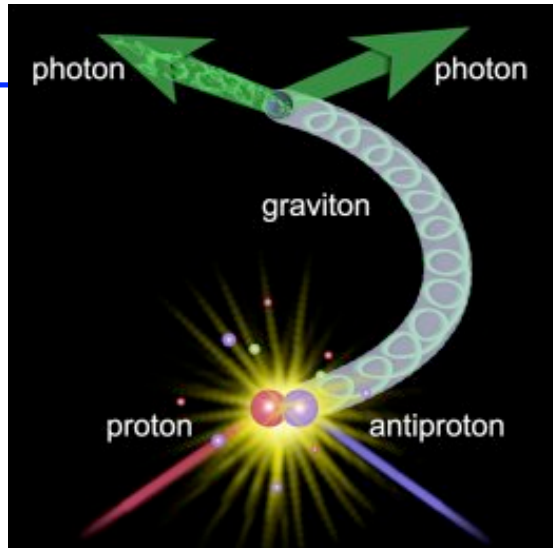
Exclude (at 95% CL) Z' with SM coupling below 966 GeV

PRL 100, 091802 (2008)

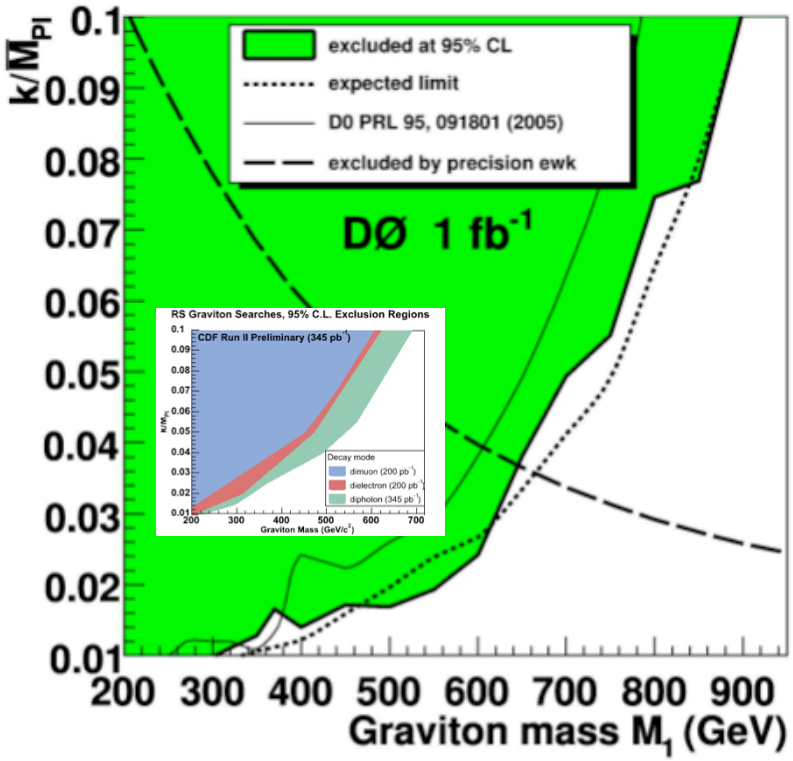


Exclude at 95% CL RS Gravitons below 900 GeV for k/M_{Pl} = 0.1
(CDF limit 850 GeV)

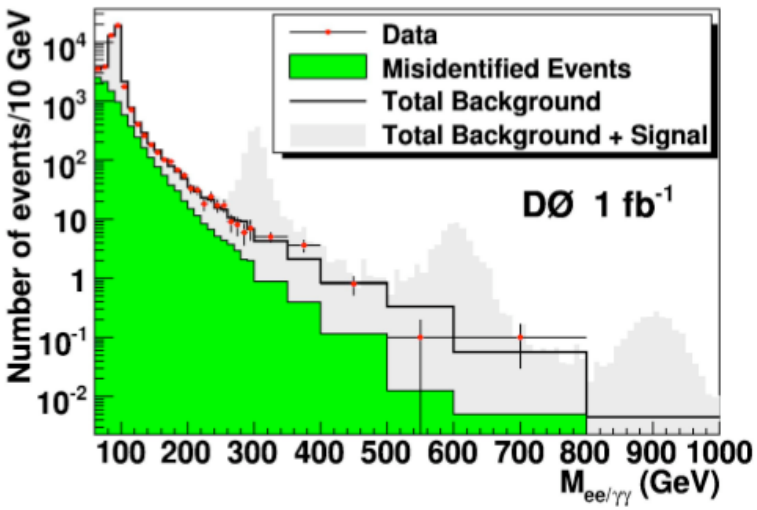
Search for LED in diphoton



The search for new particles decaying to diphotons uses the RS graviton model to express sensitivity to Kaluza-Klein graviton resonances (spin 2 resonance)



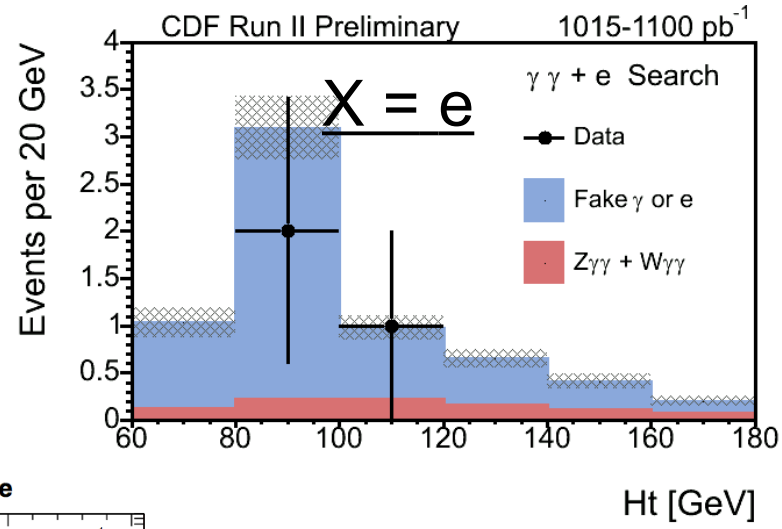
PRL **100**, 091802 (2008)

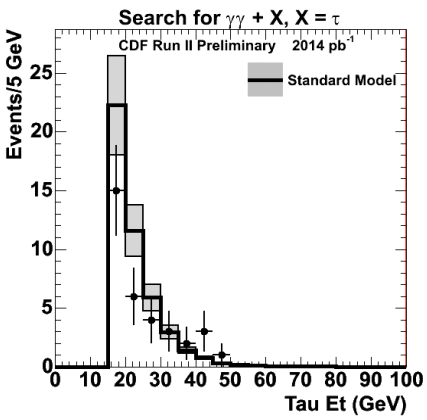


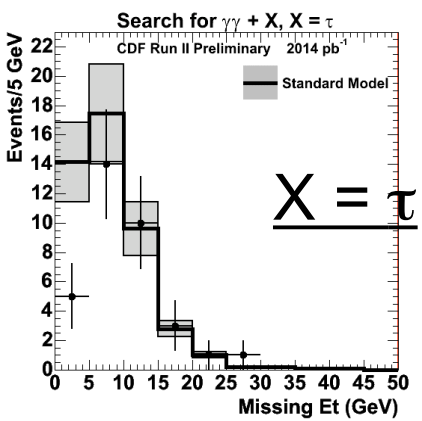
Combined with dilepton searches

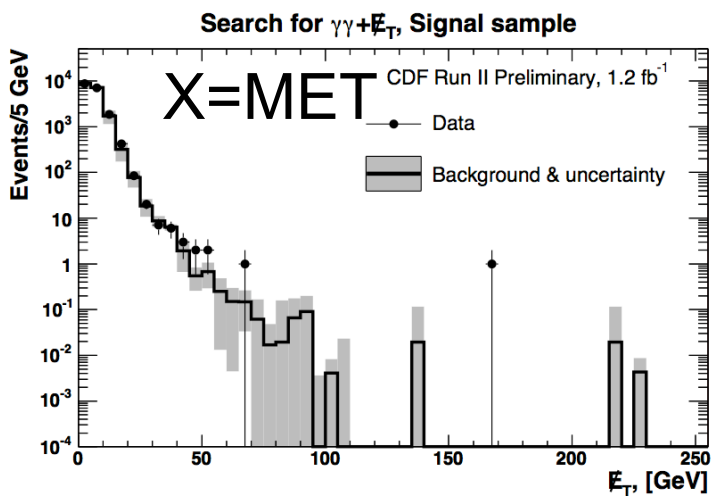
Diphoton+X

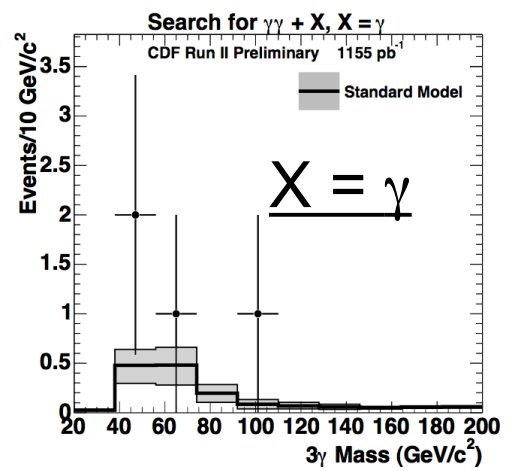
Nominal high E_T object identification and kinematic selections are used.
The observed event counts is reported as well as SM prediction for various kinematic distributions





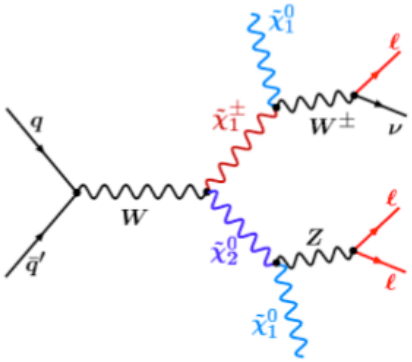




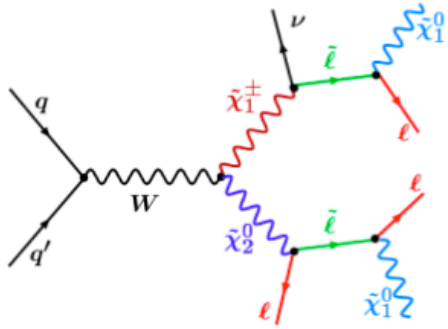


Good agreement between data and SM predictions

Multileptons final states: SUSY in Trileptons

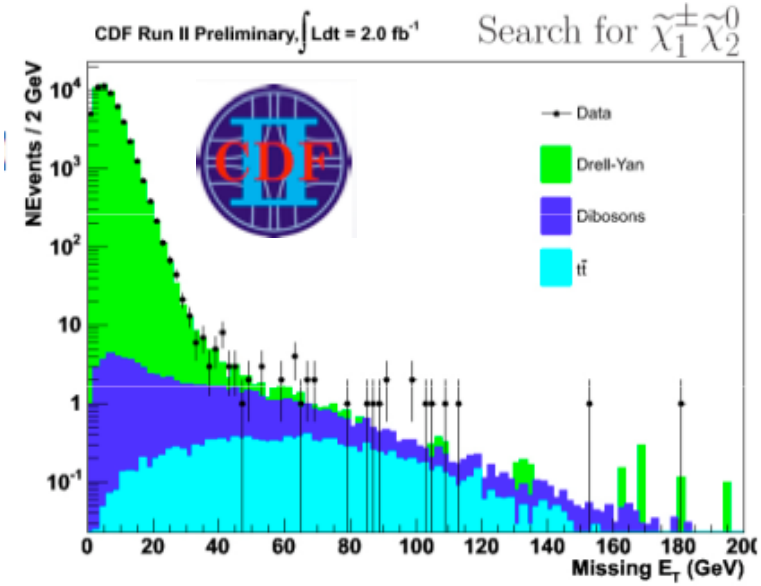


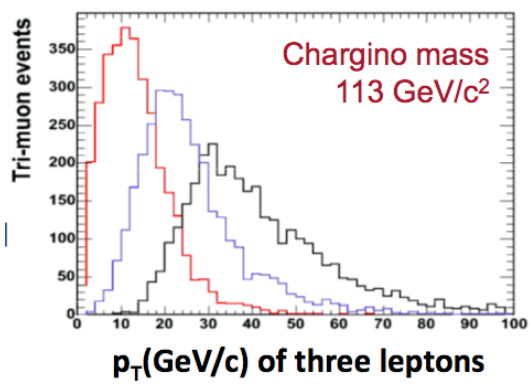
Decays through W/Z favorable for heavy sleptons, but BR to leptons low



Decays through sleptons guarantee final leptons, but also preference to $\tilde{\tau} \rightarrow \tau$

Chargino Neutralino cascade decay results in a signature of
(3 leptons or 2 leptons + track) and MET





- Selection (signal region):
  - p_T (15,10/5,5) GeV/c
  - MET>20 GeV (DY and QCD rejection)
  - $N_{jets} \leq 1$ and $H_T < 80$ (top rejection)
  - Z-mass veto (DY rejection)
  - Dilepton Mass above 20 GeV/c² (QCD and resonance rejection)
- Trilepton backgrounds:
  - DY+fake, Z+γ, diboson

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

- Signal region is investigated only after validating backgrounds in control regions (a blind analysis)

Similar cuts at D0

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SUSY in Trileptons

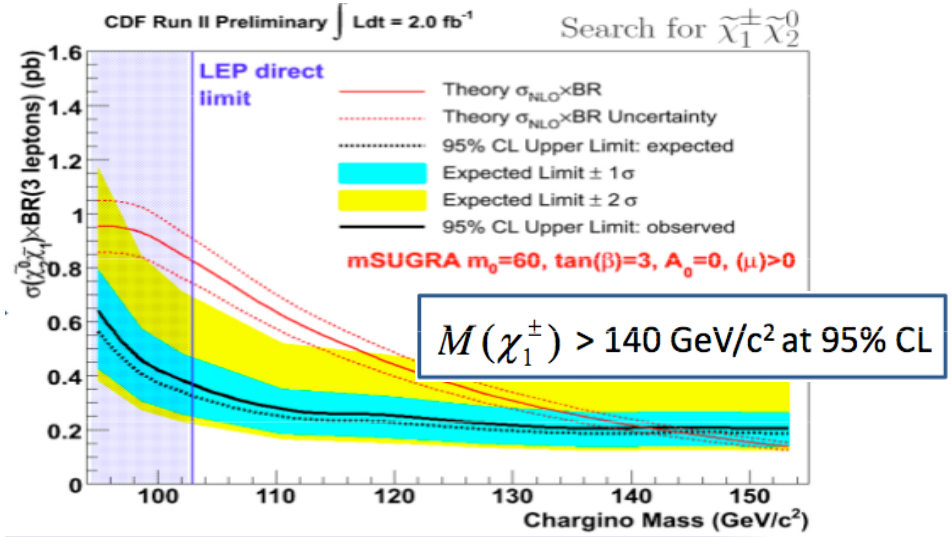
- Signal region is investigated only after validating backgrounds in control regions (a blind analysis)
- Good agreement with SM background

CDF Run II Preliminary, $\mathcal{L}$ = 2.0 fb^{-1}

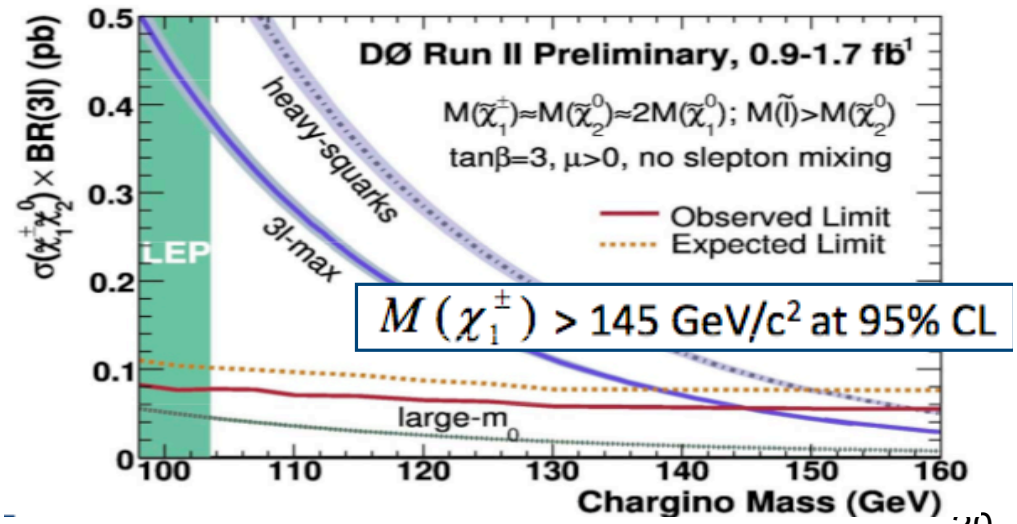
Analysis	Backg.	Signal	DATA
Trilepton	0.9 ± 0.1	4.5 ± 0.6	1
Dilepton+Track	6.9 ± 0.9	5.5 ± 1.1	6

DØ Run II Preliminary,

Analysis	$\mathcal{L}$ (fb)	Backg.	Signal	DATA
ee+ℓ	0.6	1.0 ± 0.3	0.5 – 0.2	0
μμ+ℓ	1	$0.3^{+0.7}_{-0.03}$	0.5 – 2.5	2
eμ+ℓ	1	$0.9^{+0.4}_{-0.1}$	1 – 4	0
ee+ℓ	1.1	0.8 ± 0.7	1.7 – 4.7	0
$\mu^\pm\mu^\pm$	0.9	1.1 ± 0.4	0.6 – 3.7	1



$M(\chi_1^\pm)$ > 140 GeV/c^2 at 95% CL



$M(\chi_1^\pm)$ > 145 GeV/c^2 at 95% CL

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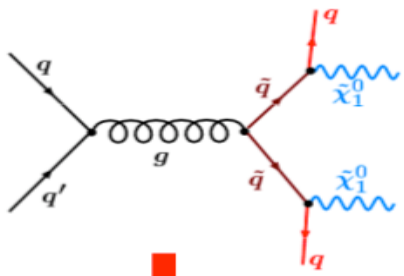
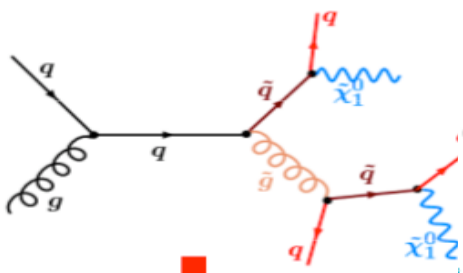
SUSY in MET + jets

- Although the production is strong, the analyses are challenging due to QCD-multijet and W/Z+jet backgrounds
  - Solution: break-down analyses in jet-multiplicity bins and optimize separately (using MET and HT ← Sum of jet E_T)

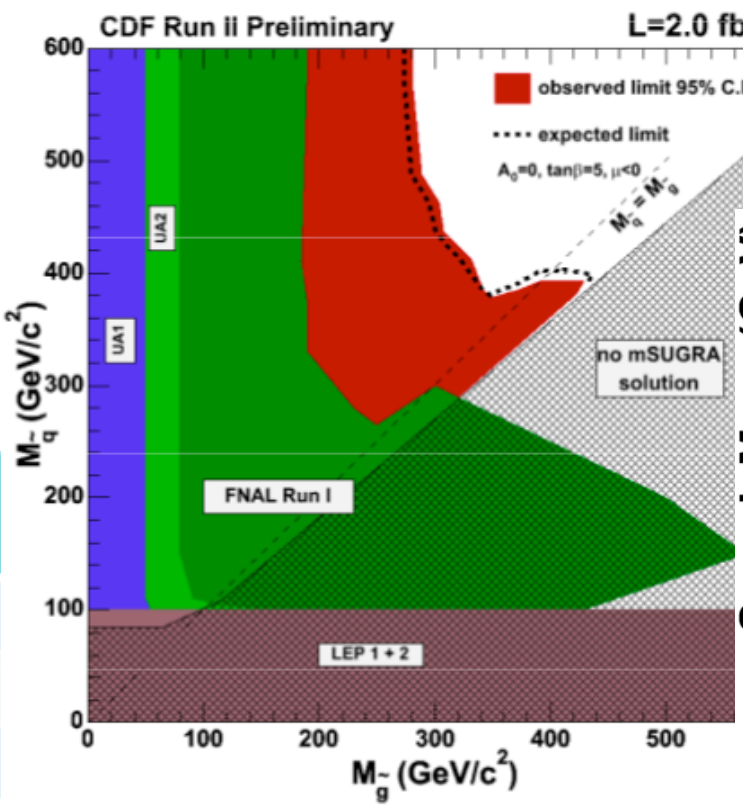


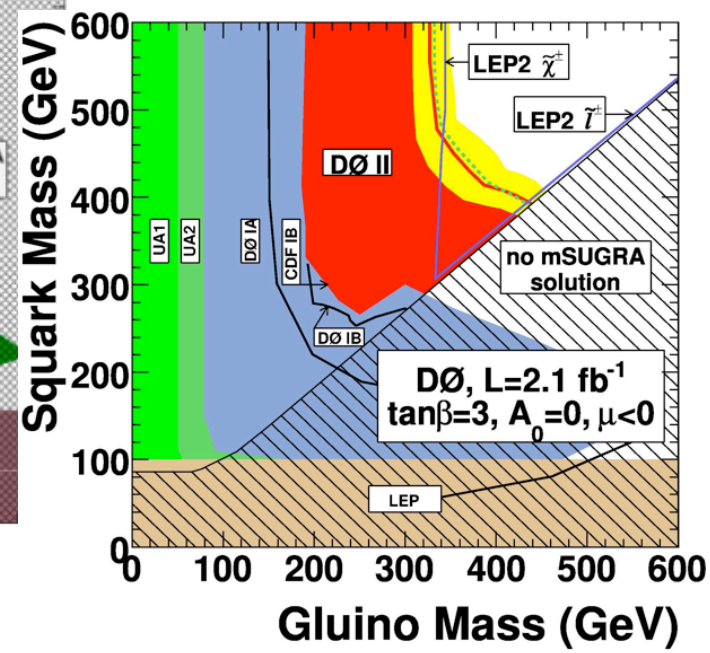
Result: 2 jets and MET



Result: 3 jets and MET

Result: 4 jets and MET





Dijets final state: mass bumps

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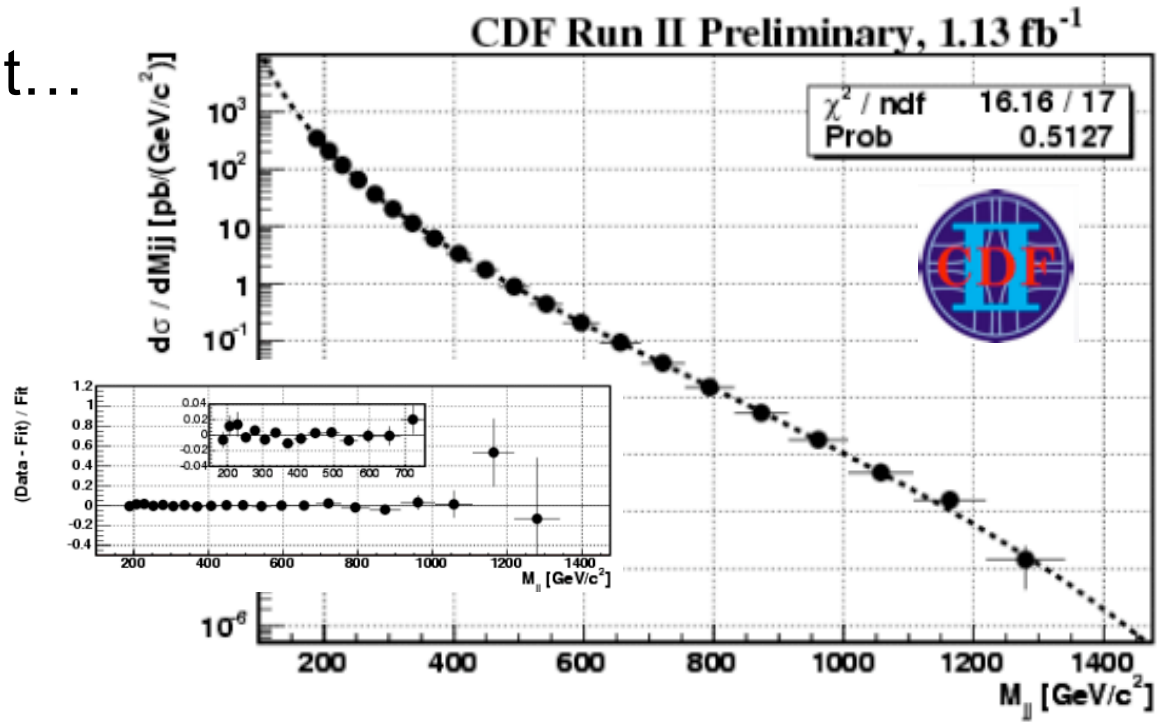
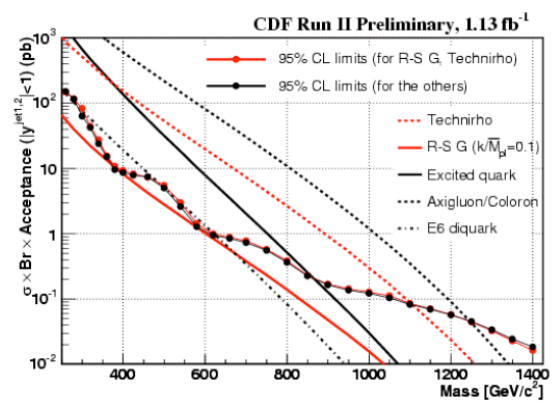
Another mass bump hunt…

- Choose events with two high-p_T jets with rapidity less than 1.0. Look for an excess in the dijet mass spectrum for masses above 180 GeV
- Possible signals include excited quarks, W', Z', and Randall-Sundrum gravitons
- Find functional form of of dijet spectrum in pythia and herwig, fit to data. Look for "bumps" in the data minus fit plot



- No significant resonant structure is observed, so limits are set on various models
- Excludes (at 95% CL) excited quarks from 260-870 GeV, W' from 280-840 GeV, and Z' from 320-740 GeV



Jets+MET final state: Leptoquarks

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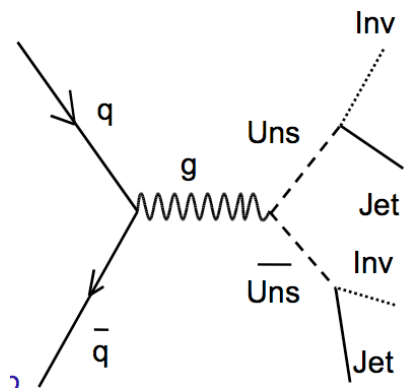
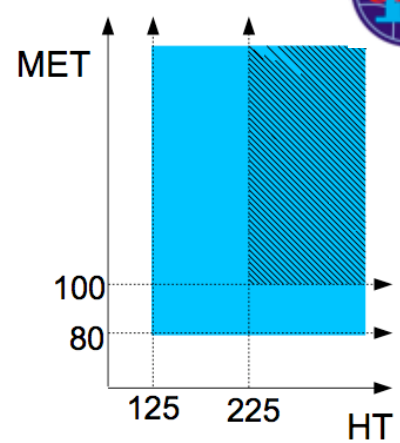


The analysis is a counting experiment examining two different kinematic regions (each region being more sensitive to different models). Cuts are not optimized for a specific model.

Main backgrounds:

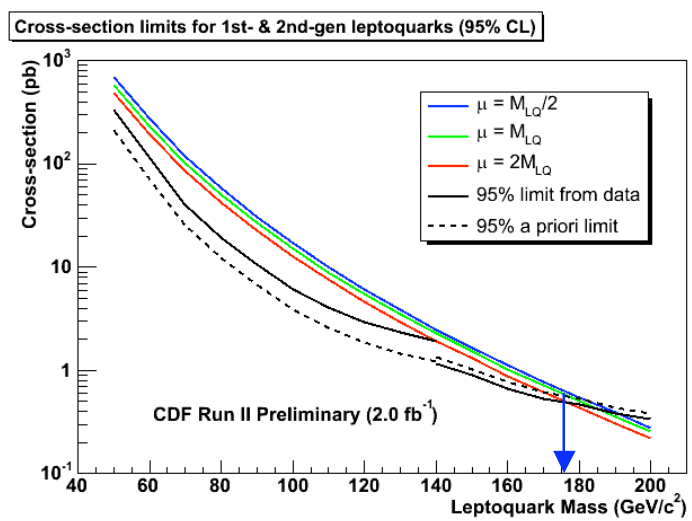
- $Z \rightarrow \nu\nu$ + jets (irreducible background)
- $W \rightarrow l\nu$ + jets (with charged lepton lost)
- Residual QCD and non-collision backgrounds.

Data driven prediction



CDF Run II Preliminary, $2fb^{-1}$

Background	125/80	225/100
$Z \rightarrow \nu\nu$	777 ± 49	71 ± 12
$W \rightarrow \tau\nu$	669 ± 42	50 ± 8
$W \rightarrow \mu\nu$	399 ± 25	33 ± 5
$W \rightarrow e\nu$	256 ± 16	14 ± 2
$Z \rightarrow ll$	29 ± 4	2 ± 0
QCD	49 ± 30	9 ± 9
γ + jets	55 ± 13	5 ± 3
top	74 ± 9	11 ± 2
non-collision	4 ± 4	1 ± 1
Total	2312 ± 140	196 ± 29
Observed	2506	186



Other LeptoQuarks Results

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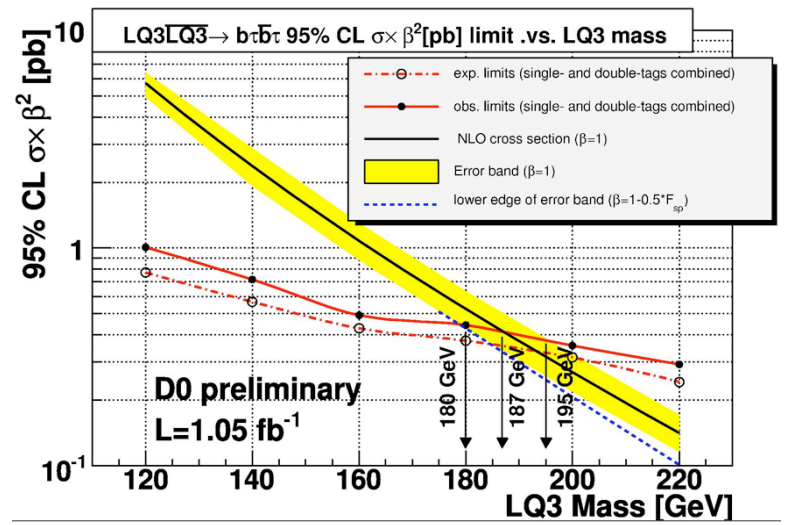
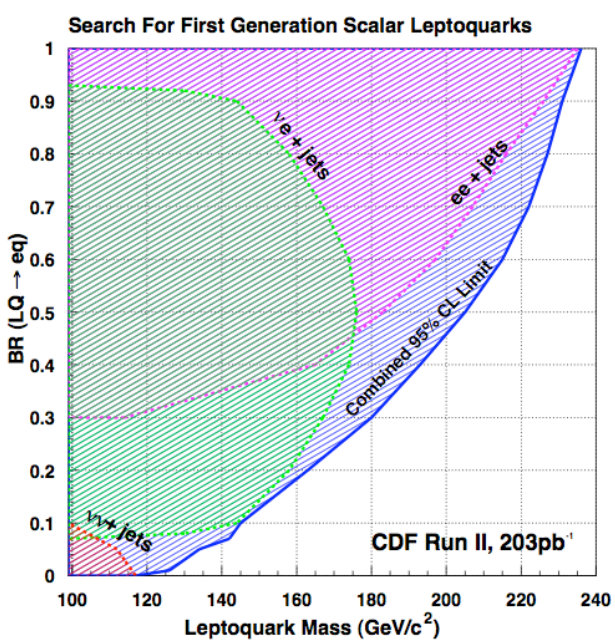
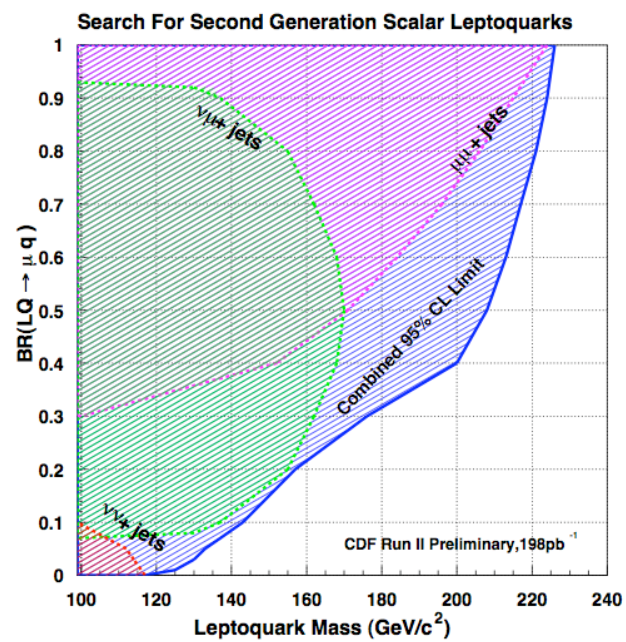
1st Generation	2nd Generation	3rd Generation
$LQ\,\overline{LQ} \to e^- e^+ q\bar{q}$	$LQ\,\overline{LQ} \to \mu^+\mu^- q\bar{q}$	$LQ\,\overline{LQ} \to \tau^+\tau^- q\bar{q}$
$LQ\,\overline{LQ} \to e^\pm \nu_e q_i q_j$	$LQ\,\overline{LQ} \to \mu^\pm \nu_\mu q_i q_j$	$LQ\,\overline{LQ} \to \tau^\pm \nu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

$\beta = Br(LQ \to lq)$







More complex signatures: γ+b+jets+MET

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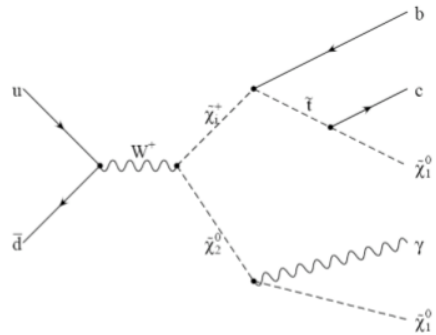
A handful of exotic processes would give rise to a final state signature comprising γ+b+jets+MET
Many anomalies could be reduced to detector mis-measurements.



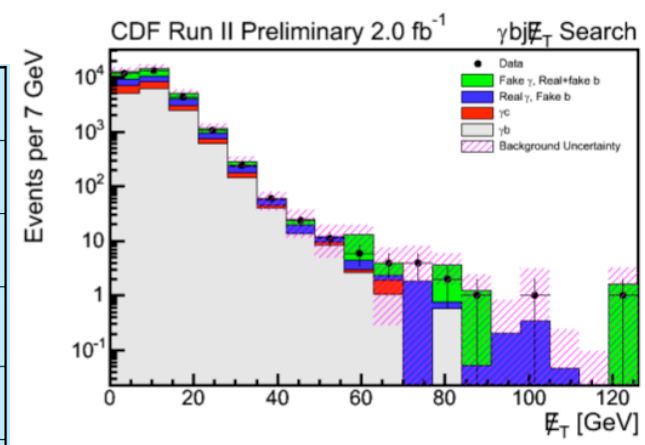
Low energy SUSY with radiative decay of the neutralino

<u>Selection:</u>
One high E_T photon
≥ 2 jets
≥ 1 tagged jet
Large MET (> 25 GeV)
Topological cuts

Main background is dominated by fake γ or b. Calculated using MC or data

CDF Run II Preliminary, 2 fb^{-1}

Source	Number
γb	291 ± 7 (stat.) ± 50 (syst.)
γc	92 ± 25 (stat.) ± 45 (syst.)
Fake b, real γ	141 ± 6 (stat.) ± 30 (syst.)
Fake γ	113 ± 49 (stat.) ± 54 (syst.)
Total	637 ± 54 (stat.) ± 128 (syst.)
Data	617

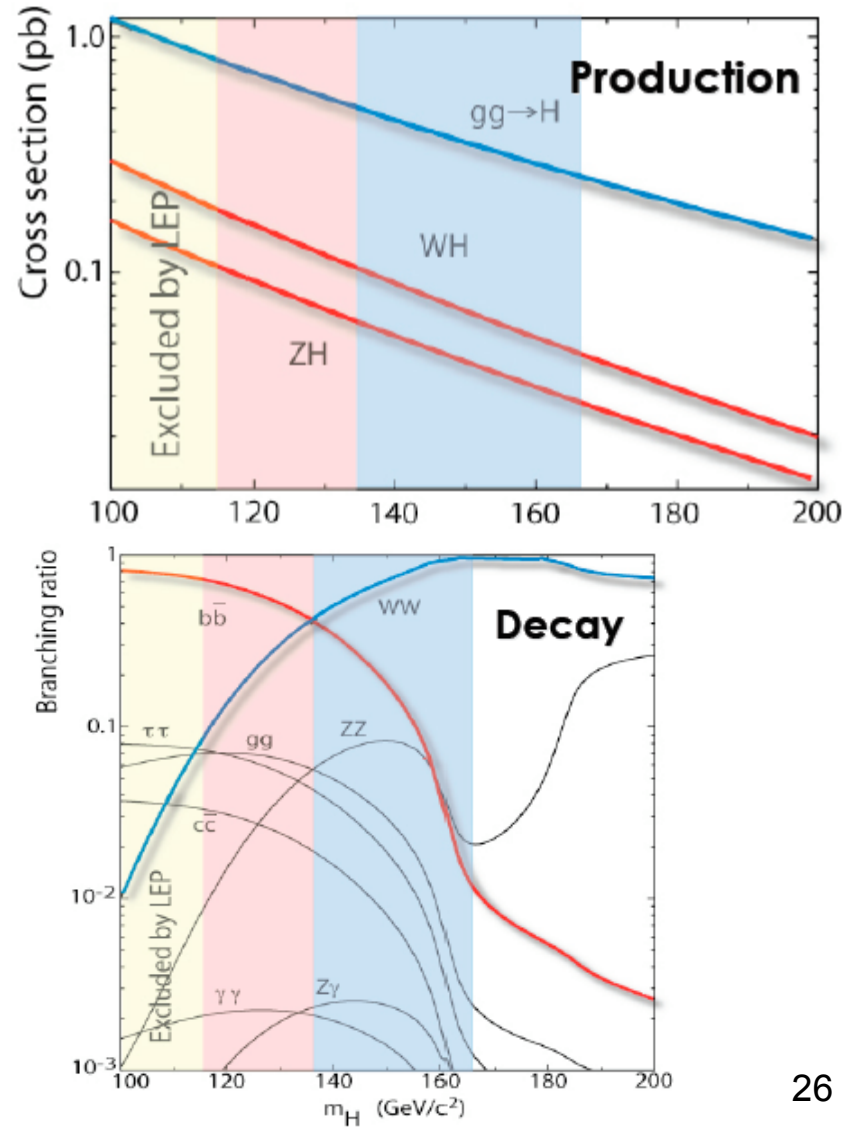


The Search for the Higgs

SM Higgs

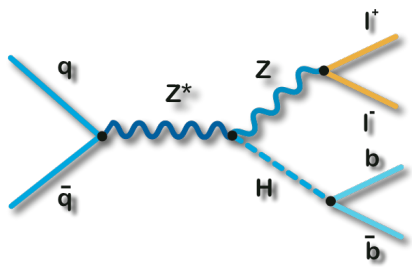
- Different production mechanisms
- Large backgrounds

- Low Mass Higgs
  - H→bb, QCD bb background overwhelming
  - Use associated production to reduce background
- High Mass Higgs
  - H→WW→lνlν decay available
  - Take advantage of large gg→H production cross section



SM Higgs: ZH→llbb

ZH→llbb - signature: two leptons and b jets



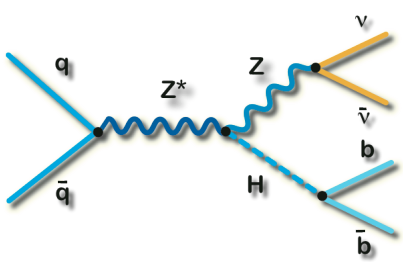
- Primary background: Z + b jets
- Key issue: Maximize lepton acceptance and b tagging efficiency
- Innovations:
  - CDF/DØ: Extensive use of loose b tagging
    - CDF:
      - » Use of isolated tracks and calorimeter only electrons
      - » MET used to correct jet energies, New ME analysis
    - DØ :
      - » Multiple advanced discriminates, NN and BDT

Analysis	Lum (fb^{-1})	Higgs Events	Exp. Limit	Obs. Limit
CDF NN	2.4	1.8	11.8	11.6
CDF ME(120)	2.0	1.4	15.0	14.2
DØ NN,BDT	2.3	2.0	12.3	11.0

Results at m(H) = 115GeV: 95%CL Limits/SM

SM Higgs: VH→METbb

ZH→ννbb, WH→lνbb(l not detected) - signature: MET and b jets



- Primary backgrounds: QCD b jets and mistagged light quark jets
- Key issue: Building a model of the QCD background
  - Shape from 0 and 1 b tagged data samples with tag and mistag rates applied
- Innovations:

  CDF/DØ : Use of track missing p_T to define control regions and suppress backgrounds

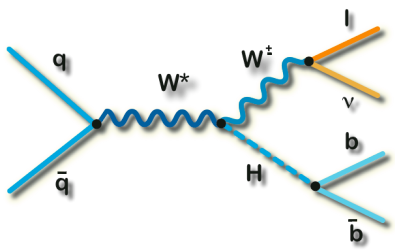
CDF: Uses of H1 Jet Algorithm combining tracking and calorimeter information
3 jet events including W→τμ acceptance
DØ also performs a dedicated W→τμ

Analysis	Lum (fb^{-1})	Higgs Events	Exp. Limit	Obs. Limit
CDF NN	2.1	7.3	6.3	7.9
DØ BDT	2.1	3.7	8.4	7.5

Results at m(H) = 115GeV: 95%CL Limits/SM

SM Higgs: WH→lνbb

WH→lνbb - signature: high pT lepton, MET and b jets



- Backgrounds: W+bb, W+qq(mistagged), single top, Non W(QCD)
- Key issue: estimating W+bb background
  - Shape from MC with normalization from data control regions
- Innovations:
  - CDF: 20% acceptance from isolated tracks, ME with NN jet corrections
  - DØ : 20% acceptance from forward leptons, use 3 jet events

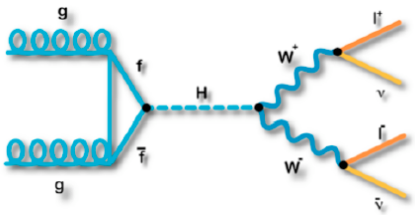
Analysis	Lum (fb^{-1})	Higgs Events	Exp. Limit	Obs. Limit
CDF NN	2.7	8.3	5.8	5.0
CDF ME+BDT	2.7	7.8	5.6	5.7
DØ NN	1.7	7.5	8.5	9.3

Results at m(H) = 115GeV: 95%CL Limits/SM

SM Higgs: H→WW

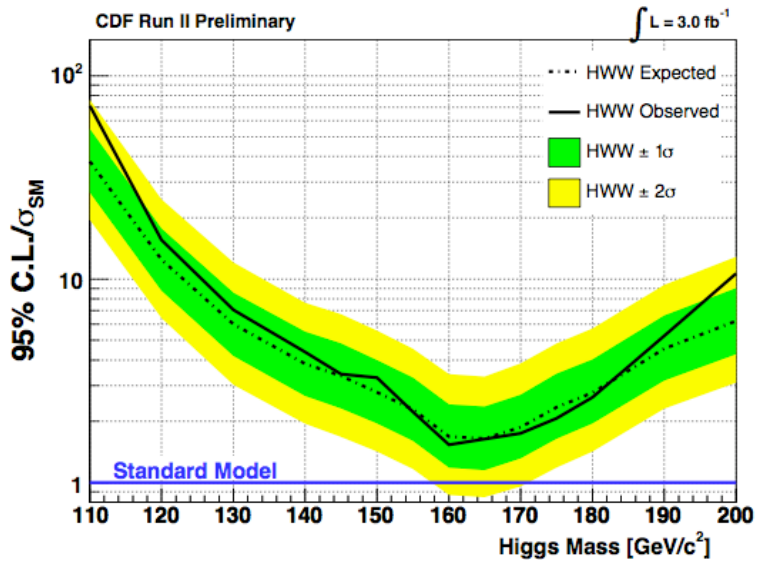
H→WW→lνlν - signature: Two high p_T leptons and MET

- Primary backgrounds: WW and top in di-lepton decay channel
- Key issue: Maximizing lepton acceptance
- Innovations:
  - CDF/DØ : Inclusion of acceptance from VH(CDF) and VBF
    - CDF : Combination of ME and NN approaches,
    - DØ : optimized NN



Analysis	Lum (fb^{-1})	Higgs Events	Exp. Limit	Obs. Limit
CDF ME+NN	3.0	17.2	1.6	1.6
DØ NN	3.0	15.6	1.9	2.0

Results at mH = 165GeV : 95%CL Limits/SM



Most sensitive Higgs search channel at the Tevatron

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Backup: other SM searches

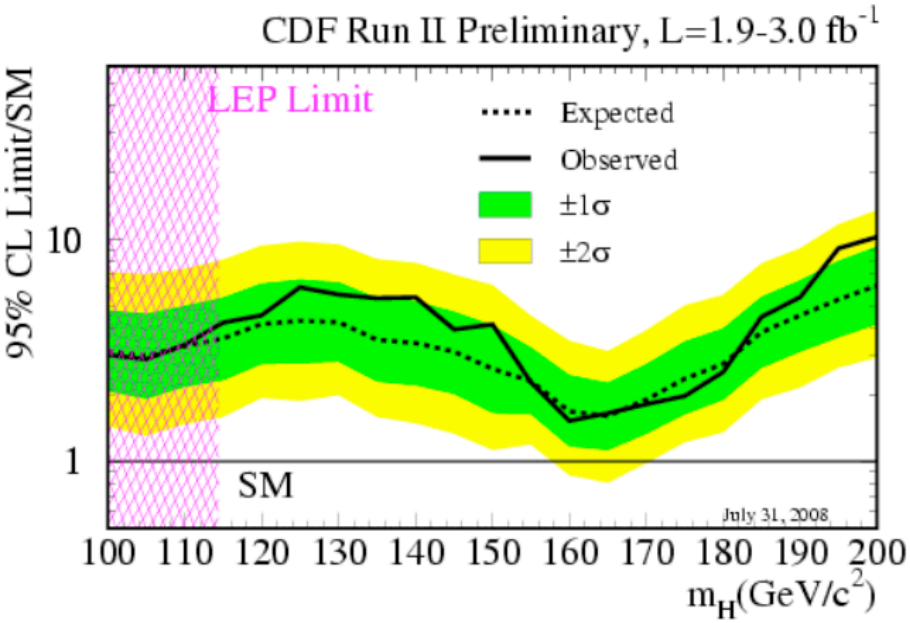
- CDF and DØ are performing searches in every viable mode
  - CDF/DØ: WH→WWW: same sign leptons
    - Adds sensitivity at high and middle masses
    - Also Fermiophobic Higgs search
  - CDF: VH→qqbb: 4 Jet mode.
  - CDF: H→ττ with 2jets
    - Simultaneous search for Higgs in VH, VBF and gg→H production modes
    - Interesting benchmark for LHC
  - DØ: H→ γγ
    - Also model independent and fermiophobic search
  - DØ: WH→τνbb, new mode
    - Dedicated search with hadronic τ decays
  - DØ: ttH, new mode

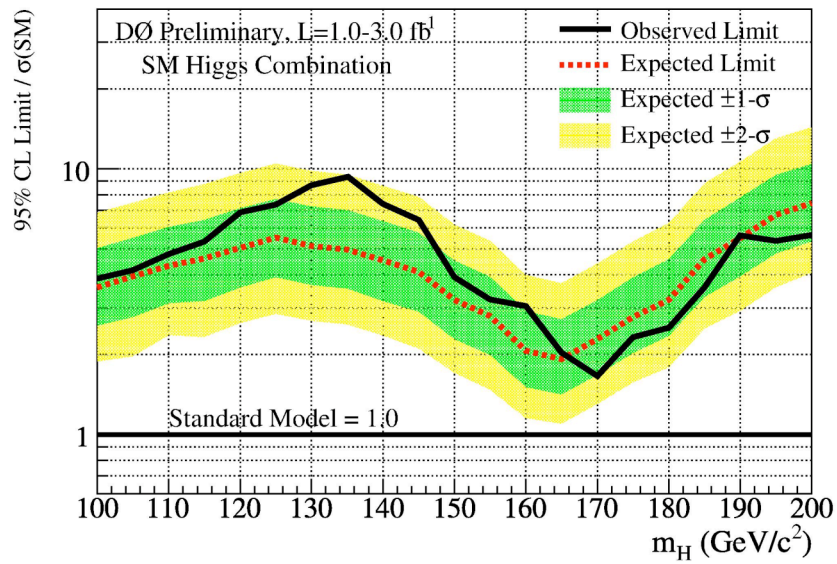
Analysis: Limits at 160 and 115GeV	Exp. Limit	obs. Limit
CDF WH→WWW	33	31
DØ WH→WWW	20	26
CDF VH→qqbb	37	37
CDF H→ττ	25	31
DØ WH→τνbb	42	35
DØ H→γγ	23	31
DØ ttH	45	64

SM Higgs Combination

Limits calculation and combination

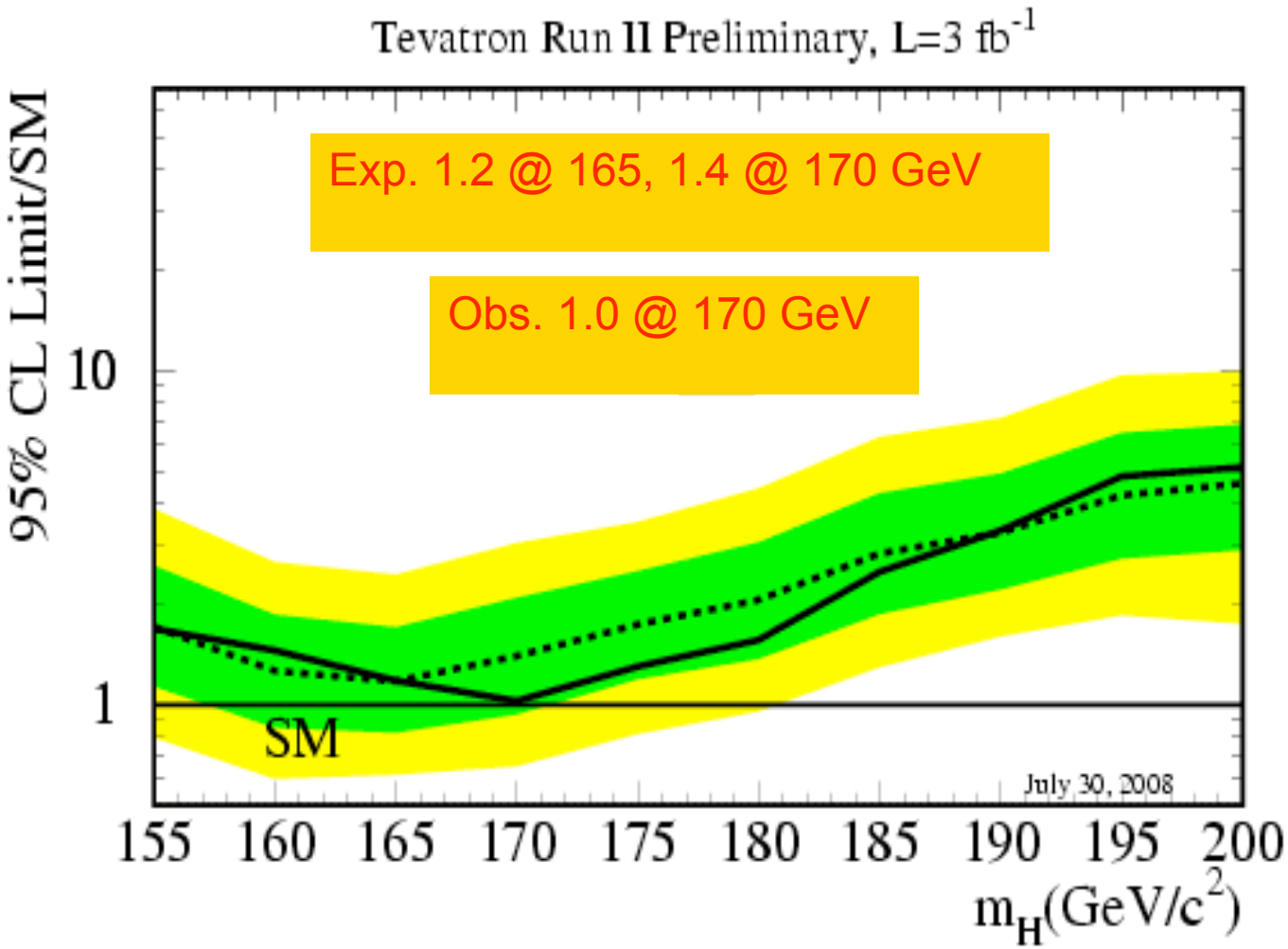
- Bayesian and CLs methodologies.
- Systematic uncertainties incorporated using pseudo-experiments (shape and rate included) (correlations taken into account between experiments)
- Backgrounds can be constrained in the fit





- Low mass combination difficult due to ~70 channels
  - Expected sensitivity of CDF/DØ combined: <3.0xSM @ 115GeV

SM Higgs Combined Limits



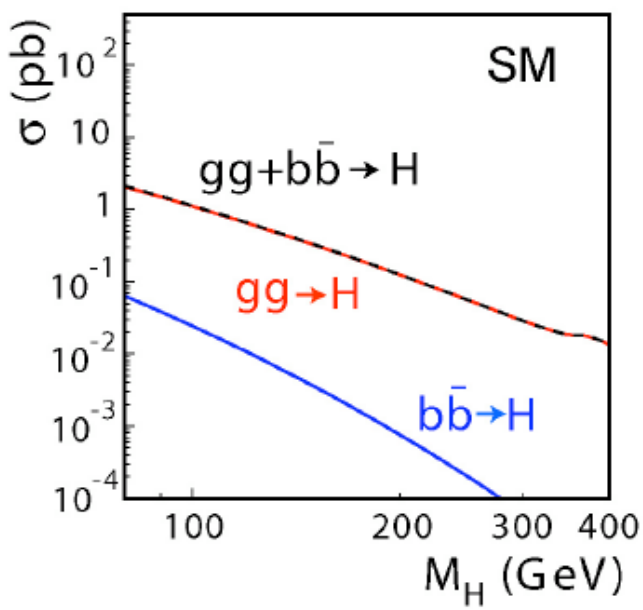
Exp. 1.2 @ 165, 1.4 @ 170 GeV

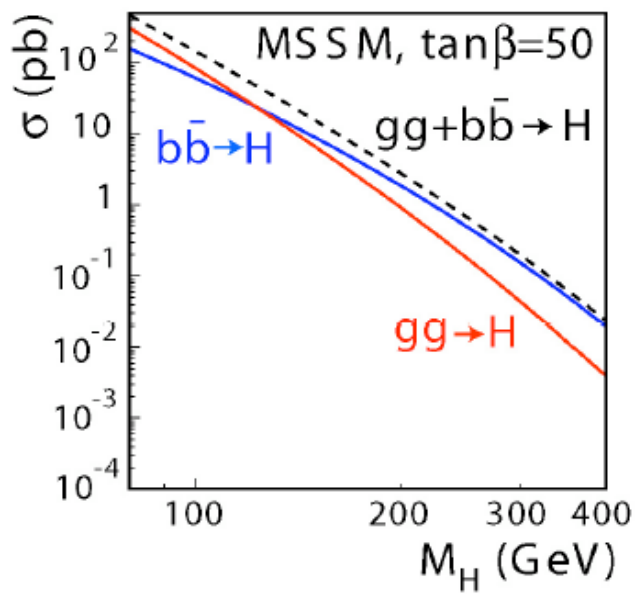
Obs. 1.0 @ 170 GeV

SM Higgs Excluded: m_H = 170 GeV at 95% CL

The Search for Higgs: BSM

- Many Beyond the Standard Model Higgs Possibilities
  - SUSY Higgs: tanβ enhanced couplings to b quarks and tau leptons
  - h, H, A, H^+, H^- or alternative models with doubly charged Higgs
  - Fermiophobic Higgs with enhanced couplings to W bosons or photons





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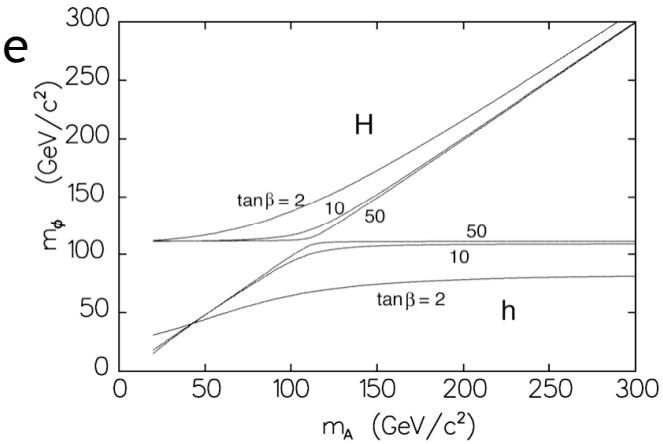
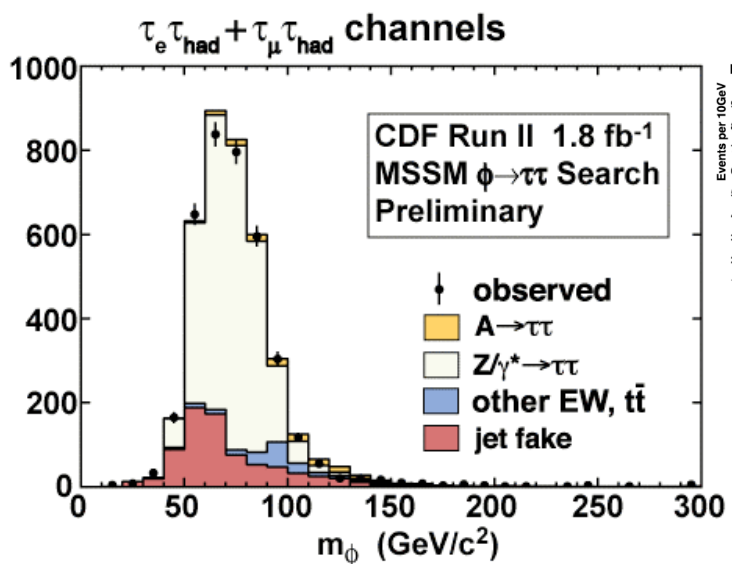
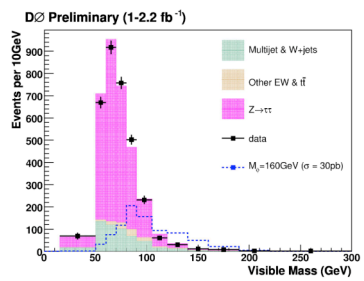
MSSM Higgs $\phi \rightarrow \tau\tau$

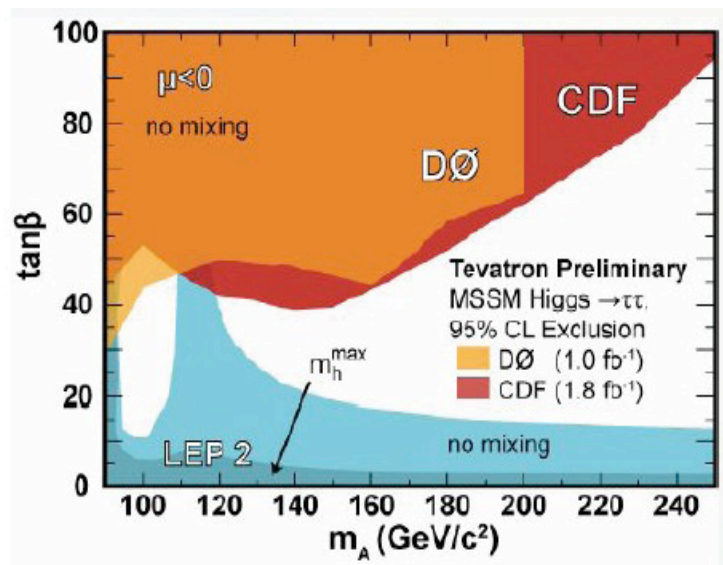
- In the MSSM framework the Higgs neutral sector simplifies at high tanβ
- A and h/H become degenerate
- Other scalar SM-like, low cross section



- Only need to search for a single mass peak (ϕ)
- For the A and its twin h/H, at high tanβ decays into $b\bar{b}$ (90%) and ττ (10%) dominate



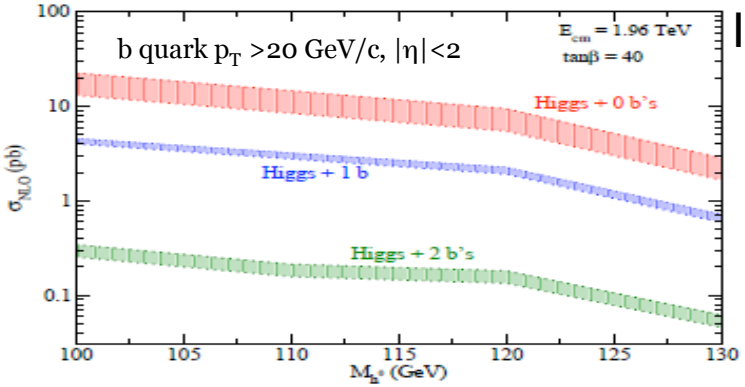




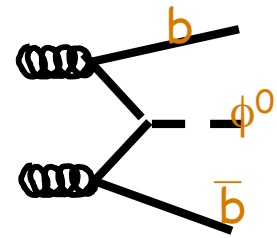
- No excess in e/μ + τ_{had} channel (similarly for D0)

Interpret σ x BR limits as limits on tanβ vs m_A in MSSM benchmark scenarios

BSM Higgs: $\phi \rightarrow bb$

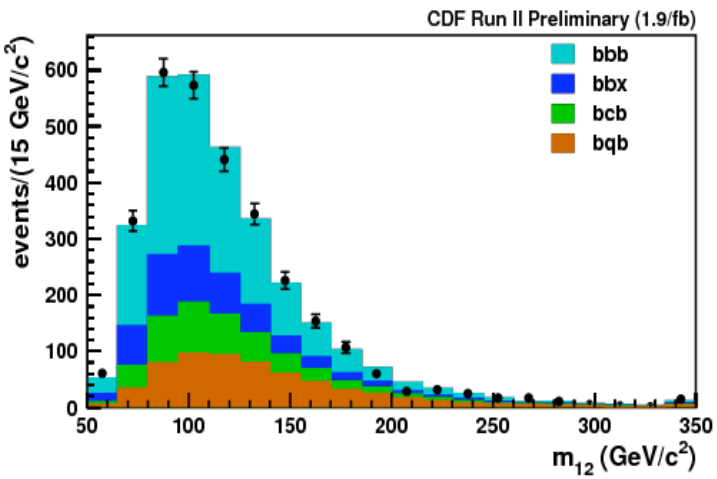


Inclusive H → b$\underline{b}$ is too hard due to QCD background

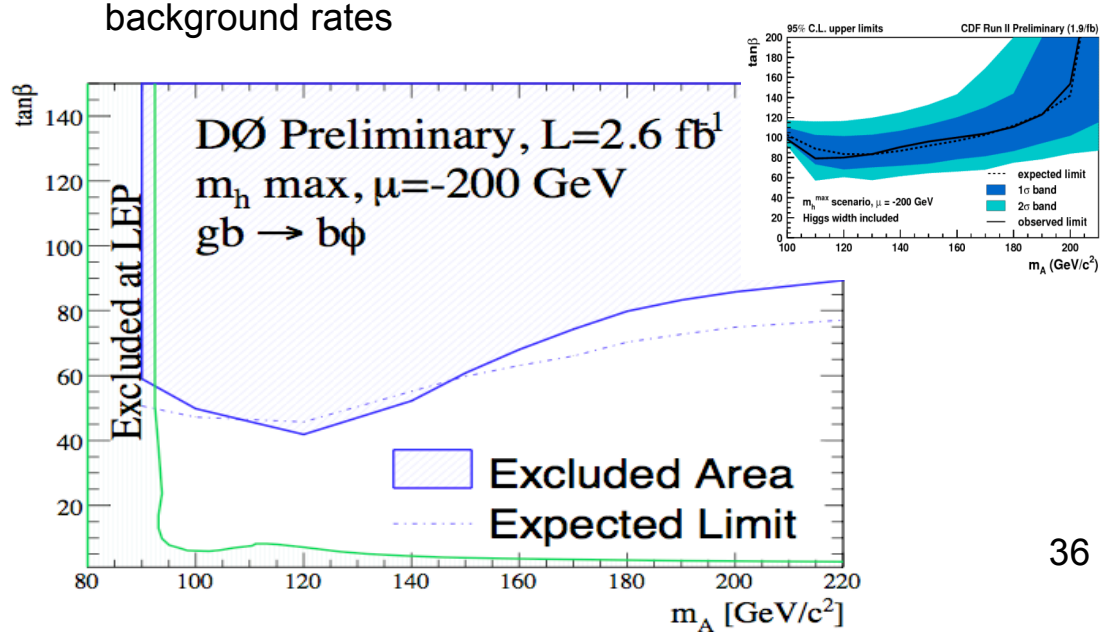


Require one additional bottom quark jet besides the two from Higgs decay

"3b" channel best compromise between signal and background rates



Search in mass of two lead jets m_{12}
No excess observed



Conclusions

Many exciting results are continuously produced at the Tevatron!

We are still the place of interest and will be for a few more years!

- machine stable
- detectors well known
- We are producing precision measurements
- and extending new particles reaches

A bump can be around the corner before the LHC turns on….

Backup

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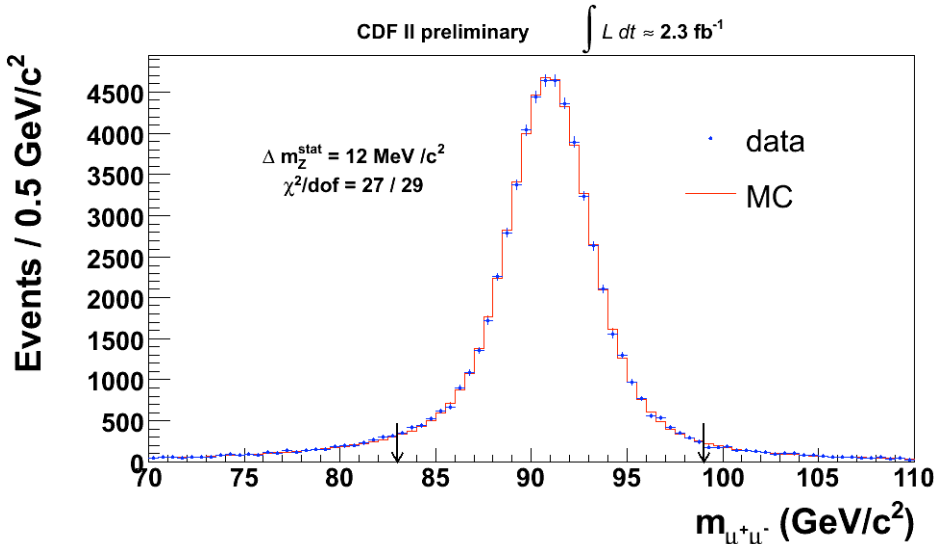
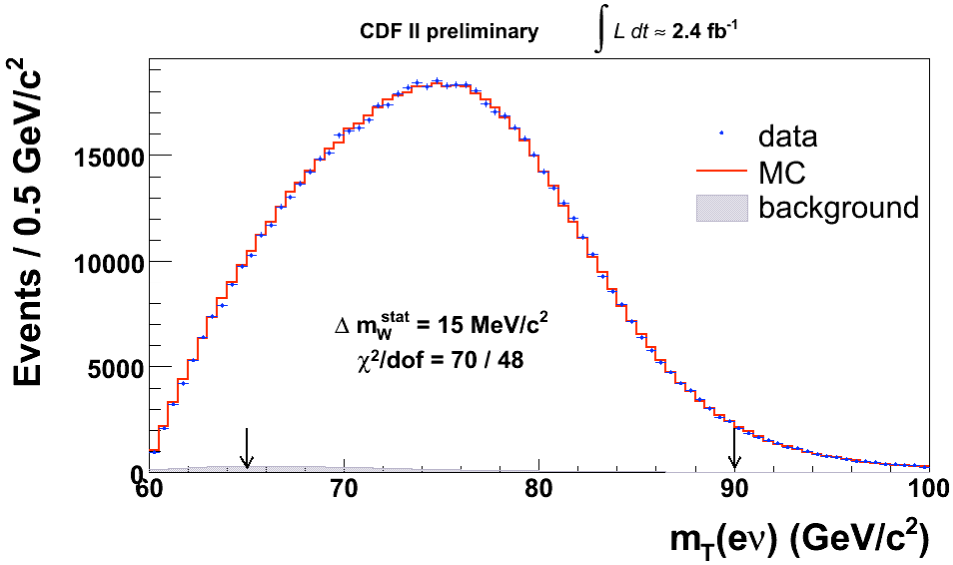
Backup: Mass measurements



	Δm_Z^{stat}
published (200pb^{-1})	43 MeV/c^2
expected (2.3fb^{-1})	13 MeV/c^2
fit (2.3fb^{-1})	12 MeV/c^2

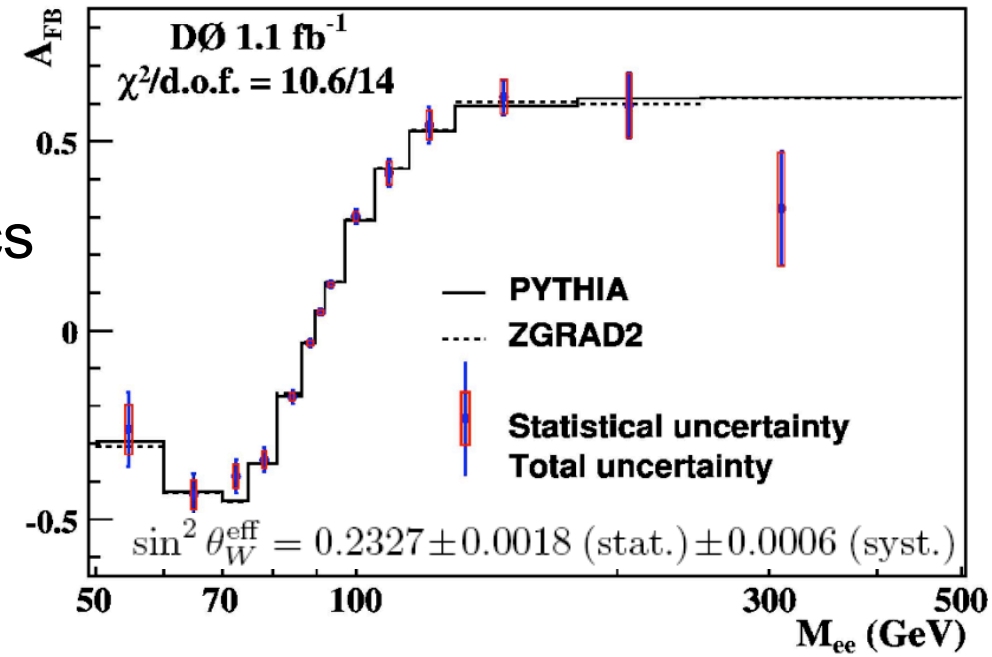


	Δm_W^{stat}
published (200pb^{-1})	48 MeV/c^2
expected (2.4fb^{-1})	14 MeV/c^2
fit (2.4fb^{-1})	15 MeV/c^2

Backup: Differential distributions

arXiv:0804.3220 [hep-ex]

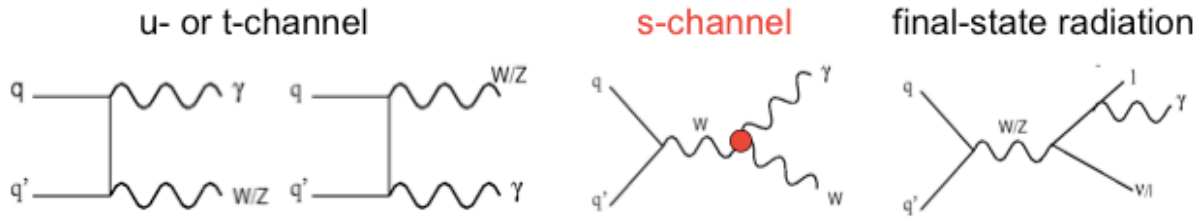
A good test for BSM physics

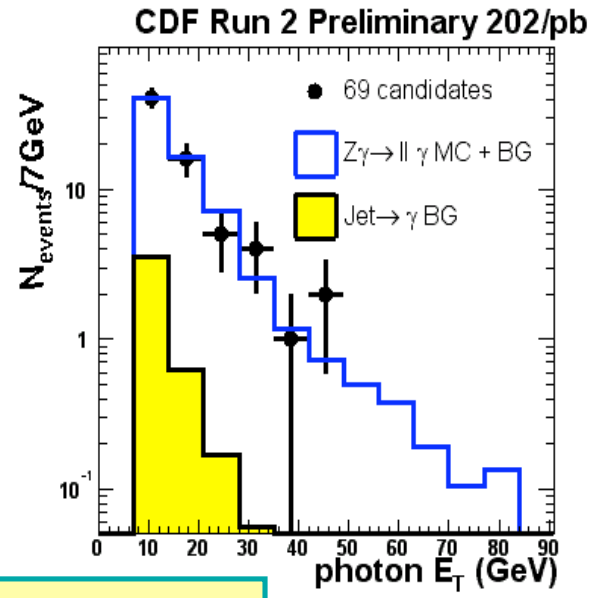


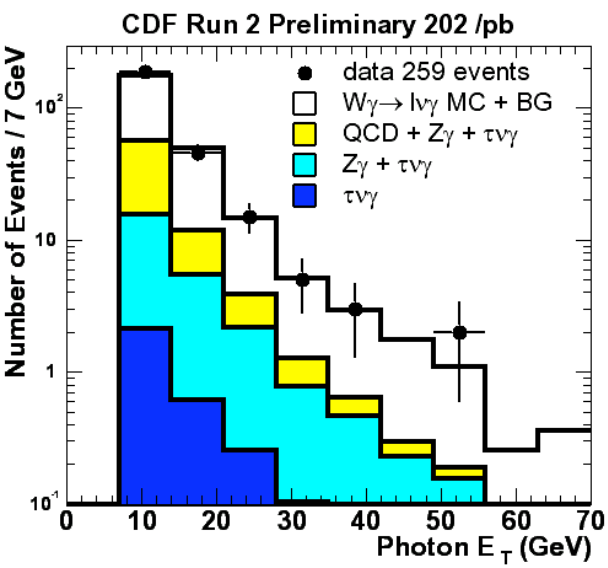
$$\sin^2\theta_W^{eff} = 0.2327 \pm 0.0018\ (\text{stat.}) \pm 0.0006\ (\text{syst.})$$

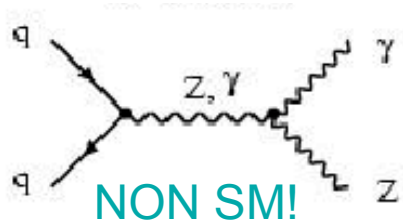
Backup: Wγ and Zγ

Test of gauge couplings (as predicted by the SM) and a window on new physics



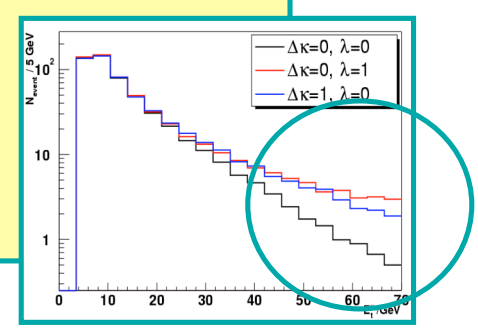






Now V+γ cross-sections well established, we are:

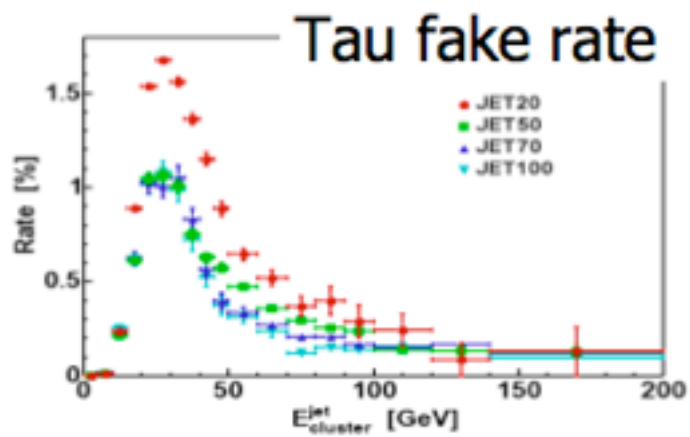
- optimizing sensitivity to anomalous coupling and new physics
- testing the Standard Model in ways unique to the TeVatron (e.g. observing RAZ in W γ production)



Lepton Efficiencies

- Compare "typical" high-pt (>20 GeV) isolated lepton efficiency and fake rates

Lepton	Efficiency	Fake Rate
electron	~80%	~0.01%
muon	~85%	~0.01%
tau (box cuts)	~45%	~1-0.1%
tau (neural net)	~80%	~5-1%



Backup:Jets and Heavy Flavor

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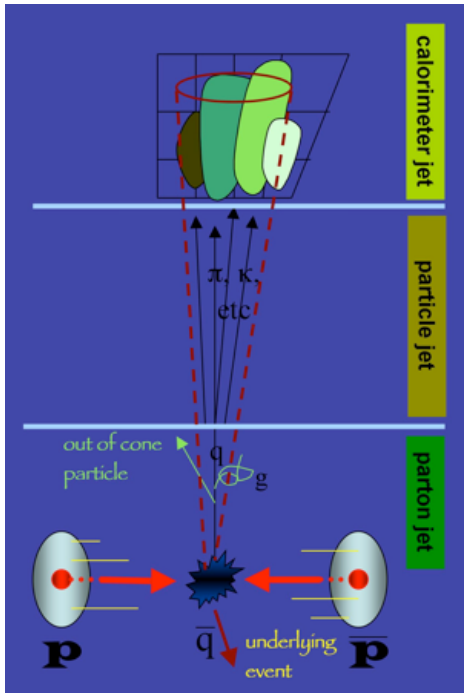
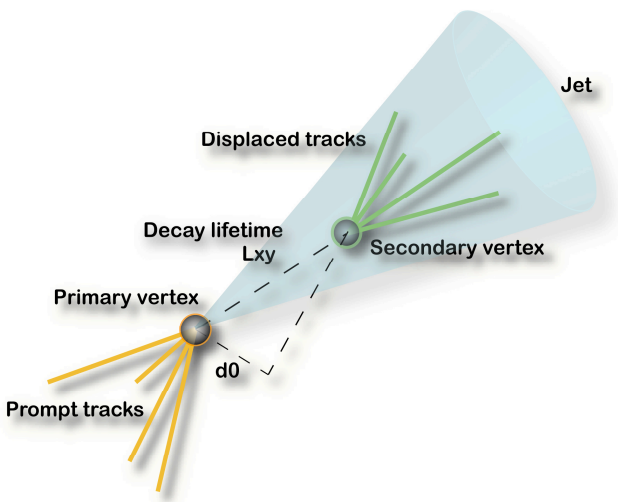
Hadronic jets are reconstructed using several algorithms: Cone,Midpoint, KT etc..

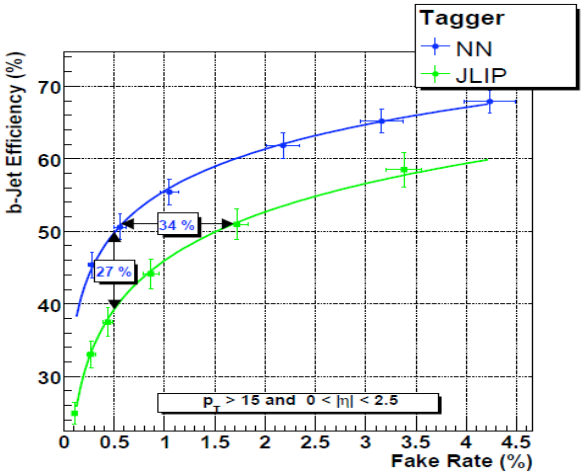
Measured jet energies are corrected to scale them back to the final state particle level jet . Additionally there are corrections to associate the measured jet energy to the parent parton energy, so that direct comparison to the theory can be made. Currently the jet energy scale is the major source of uncertainty in the measurement of the top quark mass and inclusive jet cross section

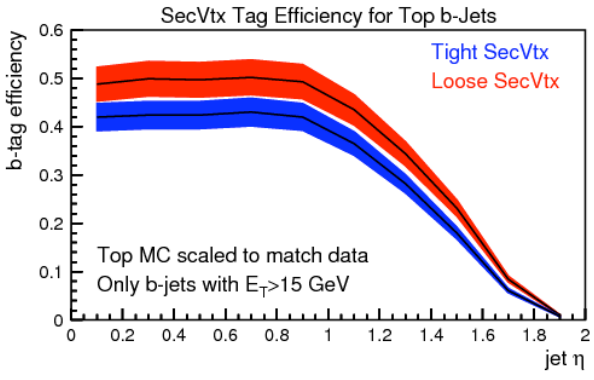


B-jet identification is implemented via:

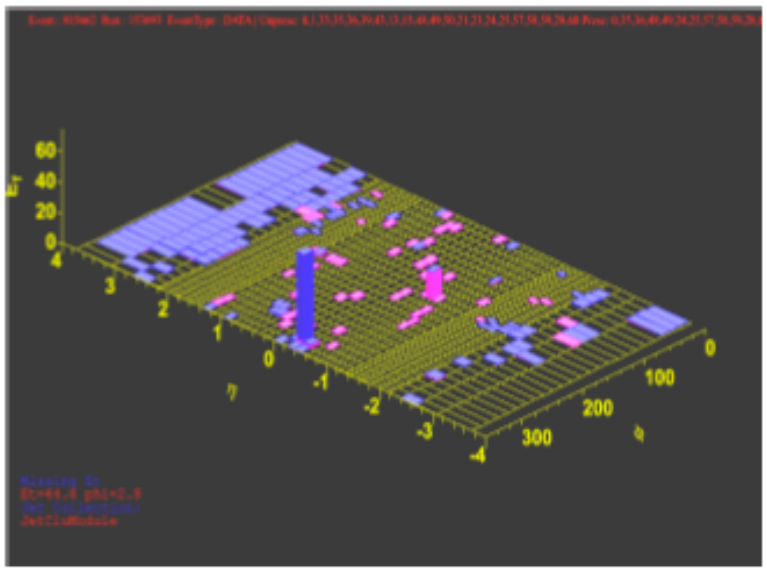
- -displaced vertices with L_{xy}/σ cut (CDF)
- -Vertex mass separation (CDF)
- -combining vertex properties and displaced track info with NN (D0)
  - -Tag to η beyond 2

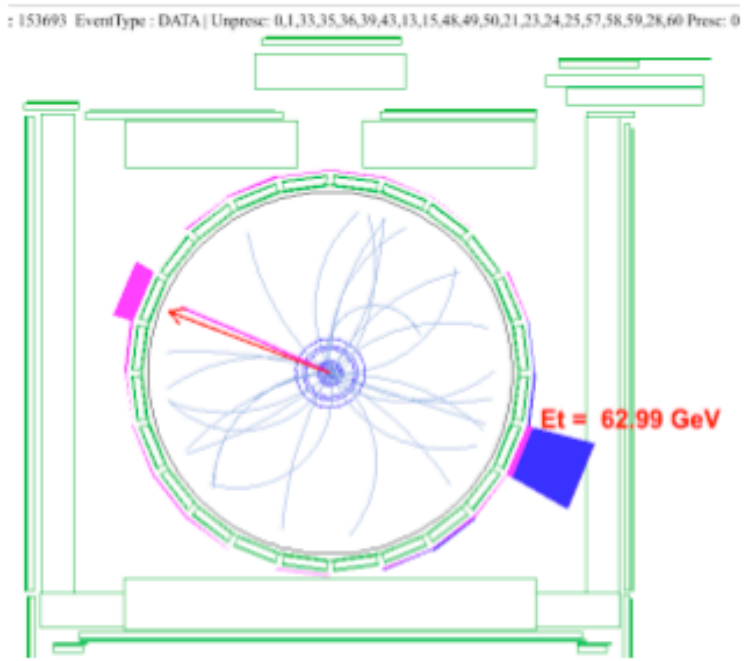






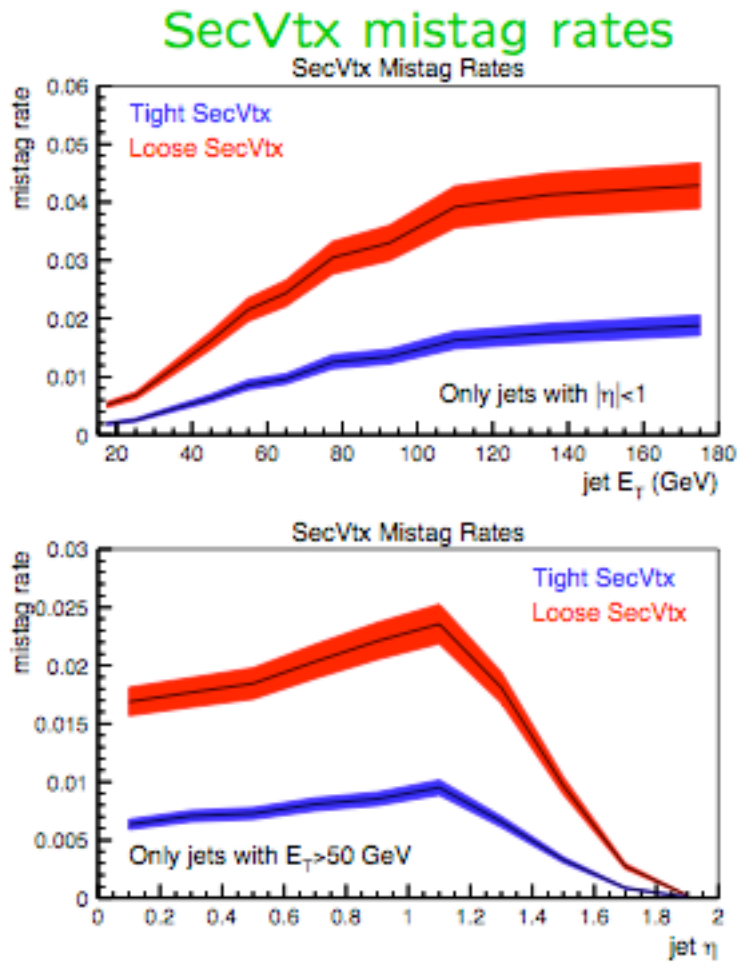
Z Tau event



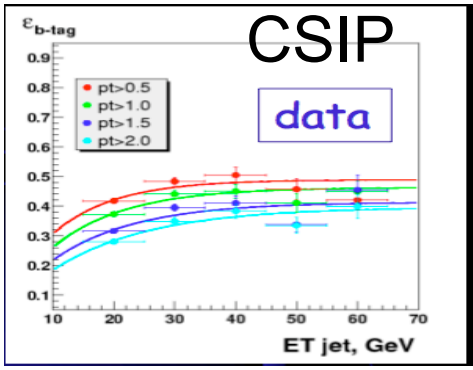


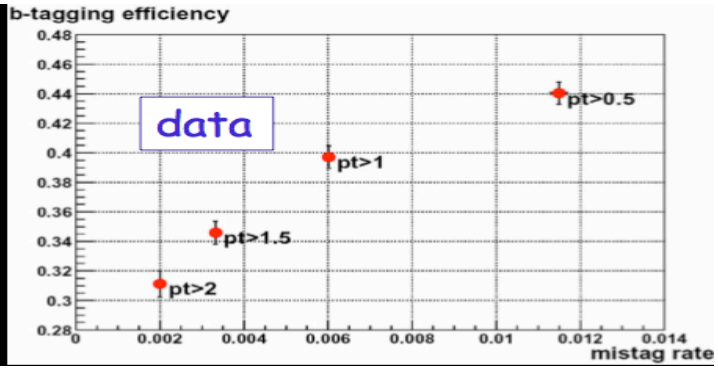
Mass ($\tau_e + \tau_h$ + MET) = 129 GeV/c^2

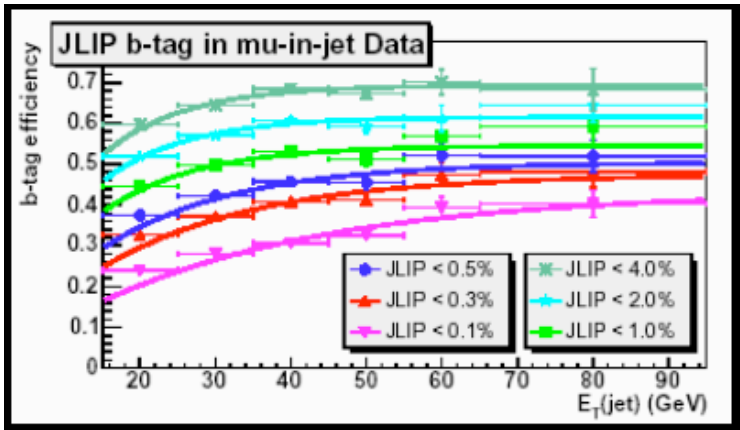
Btagging Mistag Rate



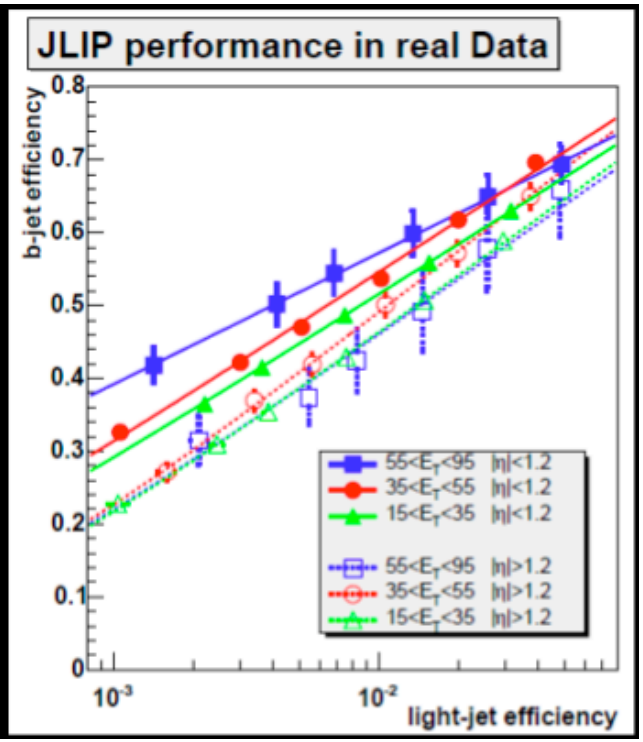
D0 btagging







- 6 operating points



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Backup: a host of other measurements

Color code :	< 1 fb^{-1}	1-1.9 fb^{-1}	1.9-2.8 fb^{-1}

Channel	Description (Link to web-page)	Measurement	Integrated Luminosity (pb^{-1})	Publication
Z+jets	Search for FCNC t->Zq	BR(t->Zq) < 3.7% at 95% C.L.	1.9 fb^{-1}	2/17/2008 Conf. Note 9202
Z+jets New!	Invisible search	BR(t->Zc) < 13%, BR(t->gc) < 12%, BR(t->gamma c) < 18%	1.9 fb^{-1}	07/17/2008 Conf. Note 9496
Lepton+jets	Search for resonances in ttbar mass spectrum, template method	95% C.L. on σ ×BR(X->ttbar)	1 fb^{-1}	03/12/2008 PRD 77 051102
Lepton+jets	Search for resonances in ttbar mass spectrum, matrix element + template	95% C.L. on σ ×BR(X->ttbar)	680 pb^{-1}	6/13/2008 PRL 100 231801
Lepton+jets	Search for resonances in ttbar mass spectrum using DLM method	Limits on the Massive Gluon strength of coupling	1.9 pb^{-1}	12/13/2007 Conf. Note 9164
Lepton+jets	Measurement of dSigma/Mttbar	no evidence beond the SM, measures a p-value = 0.45	1.9 pb^{-1}	12/13/2007 Conf. Note 9157
Lepton+jets New!	Search for charged Higgs	no significant excess of H+, set upper limit BR at 95% C.L. for H+ mass of 90 GeV/c^2 to 150 GeV/c^2	2.2 pb^{-1}	05/08/2008 Conf. Note 9322
Dilepton New!	Search for Stop quarks	no significant excess of Stop quarks, set upper limit BR at 95% C.L. for stop masses of 115 GeV/c^2 to 185 GeV/c^2	2.7 pb^{-1}	07/17/2008 Conf. Note 9439
Lepton+jets New!	Search for a Massive t' Quark	t' mass > 311 GeV at 95% CL	2.8 fb^{-1}	03/07/2008 Conf. Note 9446 760 pb^{-1} PRL 100 161803
Lepton+jets	Top Quark Width	Γ_{top} < 12.7 GeV at 95% C.L.	1 fb^{-1}	08/02/2007 Conf. Note 8953
Lepton+jets	Top Quark Lifetime	$c\tau_{top}$ < 52.5 μm @ 95% C.L.	320 pb^{-1}	02/14/2006 Conf. Note 8104

Backup: Other Top Measurements

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Dilepton	Search for Anomalous Kinematics	1.0-4.5%	190 pb^{-1}	**PRL 95 022001**
Dilepton, Lepton+jets, Single and double Vertex b-tags	**BR(t->Wb)/BR(t->Wq)**	1.12 + 0.21 - 0.19 (stat) + 0.17 -0.13 (syst) > 0.61 @ 95% C.L.	160 pb^{-1}	**PRL 95 102002**
Dilepton, Lepton+tau, Lepton+jets single and double Vertex b-tags	**Search for Charged Higgs in top decays**	Limits on BR(t->H^+b)	190, 160 pb^{-1}	**PRL 96 042003**
Lepton+jets	**Top Production Mechanism using low Pt Tracks**	0.07± 0.14(stat)± 0.07(syst) for xs(gg->ttbar)/xs(ppbar->ttbar)	1 fb^{-1}	03/05/2007 **Preprint**
Lepton+jets	**Top Production Mechanism using a Neural Network**	Fraction of ttbar events produced by gluon fusion < 0.33 at 68% CL	1 fb^{-1}	05/10/2007 **Preprint**
Lepton+jets	**Top Production Mechanism combination**	0.07+0.15-0.07(stat+sys)	1 fb^{-1}	11/29/2007 **Preprint**
Dilepton *New!*	**Top Production Mechanism using Azimuthal Correlation of Charged Leptons**	Fgg = 0.53 +0.36 -0.38 +0.35 +0.07		7/10/2008
Lepton+jets, dilepton	**Top Charge**	Observe Exclude top chai Bayes Factor valu		
Lepton+jets	**Charge Asymmetry A_{FB} (ttbar rest frame)**	A_{FB} = 0.24 ±		
Lepton+jets	**Charge Asymmetry A_{FB} (ppbar rest frame)**	A_{FB} = 0.17 ±		
Lepton+jets	**W helicity cosθ ***	**1-pa** F_0= 0.59 ± 0 F_+ = -0.04 ± F_+ < 0.		
Dilepton, Lepton+jets	**W helicity M_{lb}^2**	F_+ < 0.09 @ 95% C.L.	750 pb^{-1}	05/11/2006 **PRL 98 072001**
Lepton+jets	**W helicity matrix element**	0.64 ± 0.08(stat) ± 0.07(sys)	1.9 fb^{-1}	11/15/2007 **Conf. Note 9144**
Lepton+jets	**W helicity cosθ * (full reco)**	**1-parameter fit:** F_0= 0.66 ± 0.10(stat) ± 0.06(syst) F_+= 0.01 ± 0.05(stat) ± 0.03(syst) **2-parameter fit:** F_0= 0.38 ± 0.21(stat) ± 0.07(syst) F_+= 0.15 ± 0.10(stat) ± 0.04(syst)	1.9 fb^{-1}	11/29/2007 **Conf. Note 9114** 320 pb^{-1} **PRD 75 052001**
Lepton+jets *New!*	**Combination of W helicity cosθ * (full reco) and cosθ * from above**	**1-parameter fit:** F_0 = 0.62 ± 0.11 F_+ = -0.04 ± 0.05 **2-parameter fit:** F_0 = 0.66 ± 0.16 F_+ = -0.03 ± 0.07 correlation coeff = -0.82 with no assumption	1.9 fb^{-1}	7/17/2008 **Conf. Note 9431**
Lepton+jets	**Combined W helicity cosθ * and Lepton Pt spectrum**	F_0= 0.74 +0.22 -0.34 (stat+syst) F_+ < 0.27 @ 95% C.L.	160 pb^{-1}	**PRD 73 111103**

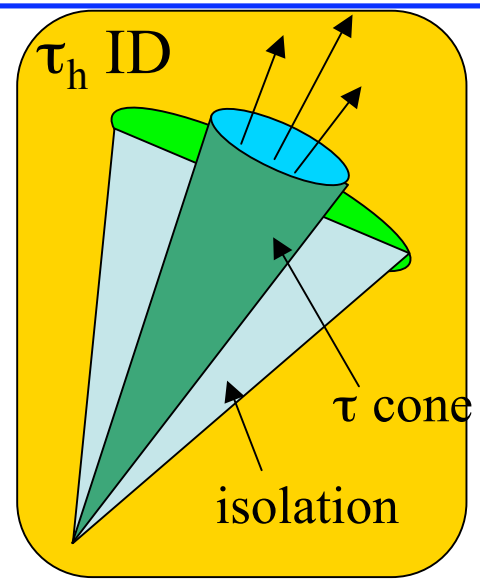
Backup: Tau final states

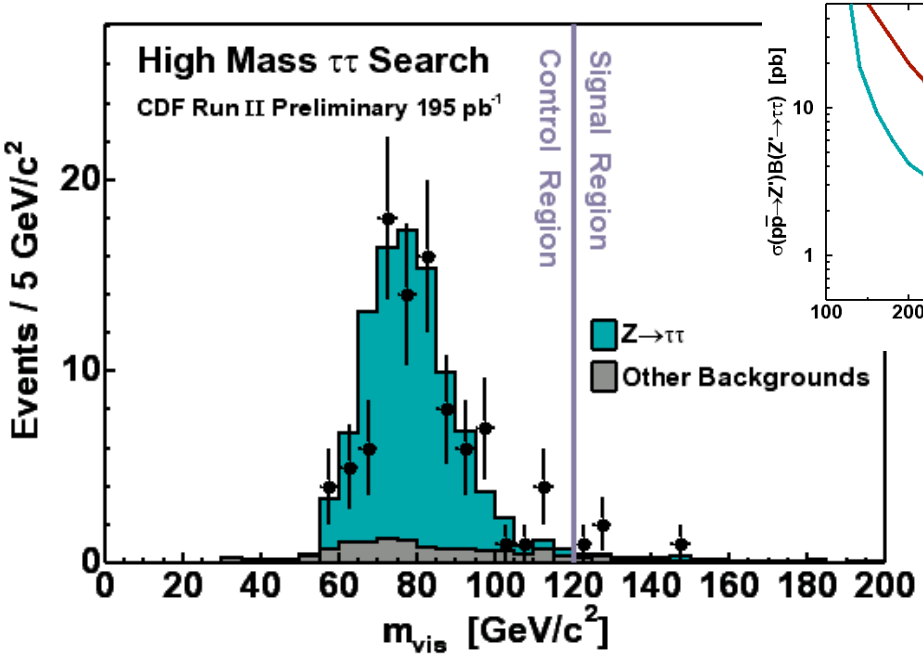
Ditaus final states are selected where

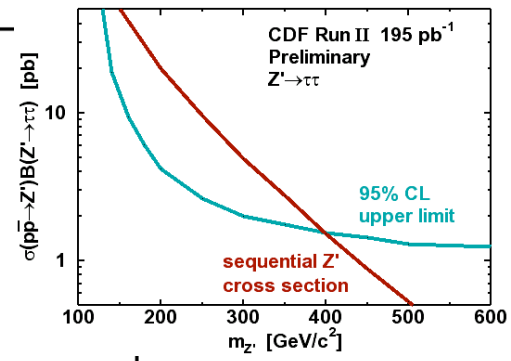
- One tau decays leptonically: e/μ (CDF) μ (DØ) (plus ν's)
- p_T > 10 GeV/c (CDF), p_T > 15 GeV/c (DØ)

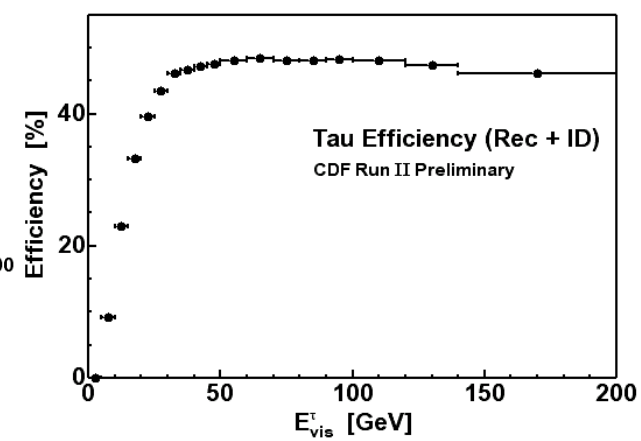
-Other tau hadronic (and ν_τ)

- -One or three tracks ($\Sigma q_{trk} = \pm 1$), opposite to lepton
- -CDF : isolation 30°, shrinking τ cone (10° → 3°)
- -DØ : three types ($\pi^\pm$, $\pi^\pm\pi^0$, 3-prong), NN score
  - No electron veto (allows eμ)
- -p_T > 15 GeV/c (1-prong), 20 GeV/c (3-prong)









Backup: SUSY squarks and gluinos

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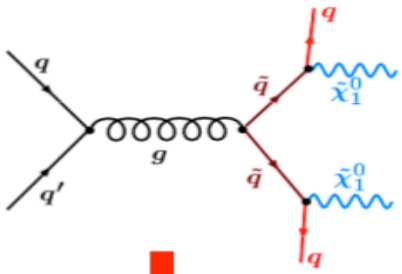
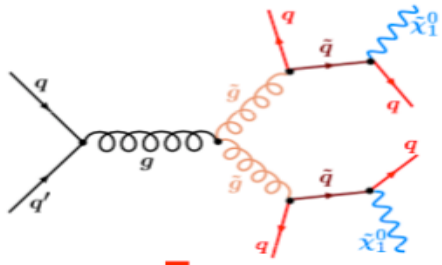
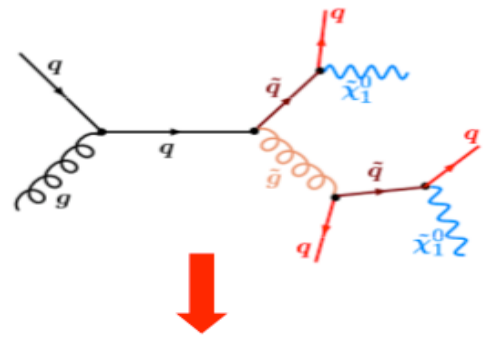


Result: 2 jets and MET

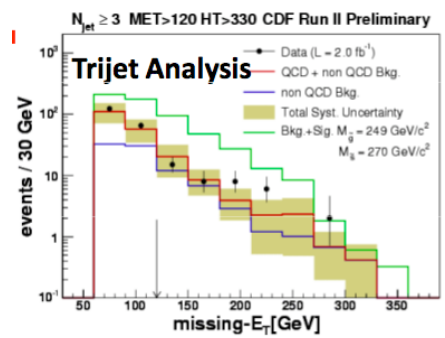


Result: 4 jets and MET



Result: 3 jets and MET

- Although the production is strong, the analyses are challenging due to QCD-multijet and W/Z+jet backgrounds
  - Solution: break-down analyses in jet-multiplicity bins and optimize separately (using MET and HT ← Sum of jet E_T)



D0,PLB 660, 449 (2008), $\mathcal{L}$=2.1fb^{-1}

Analysis	HT cut (GeV)	MET cut (GeV)	Jet Et (GeV)	Bckg.	DATA
Dijet	325	225	35,35	11 ± 1 +3/-2	11
Trijet	375	175	35,35,35	11 ± 1 +3/-2	9
4-jet	400	100	35,35,35,20	18± 1 +6/-3	20

CDF Run II Preliminary, $\mathcal{L}$ = 2.0 fb^{-1}

Analysis	HT cut (GeV)	MET cut (GeV)	Jet Et (GeV)	Bckg.	DATA
Dijet	330	180	165,100	16 ± 5	18
Trijet	330	120	140,100,25	37± 12	38
4-jet	280	90	95,55,55,25	48 ± 17	45

Backup: SUSY in MET + jets

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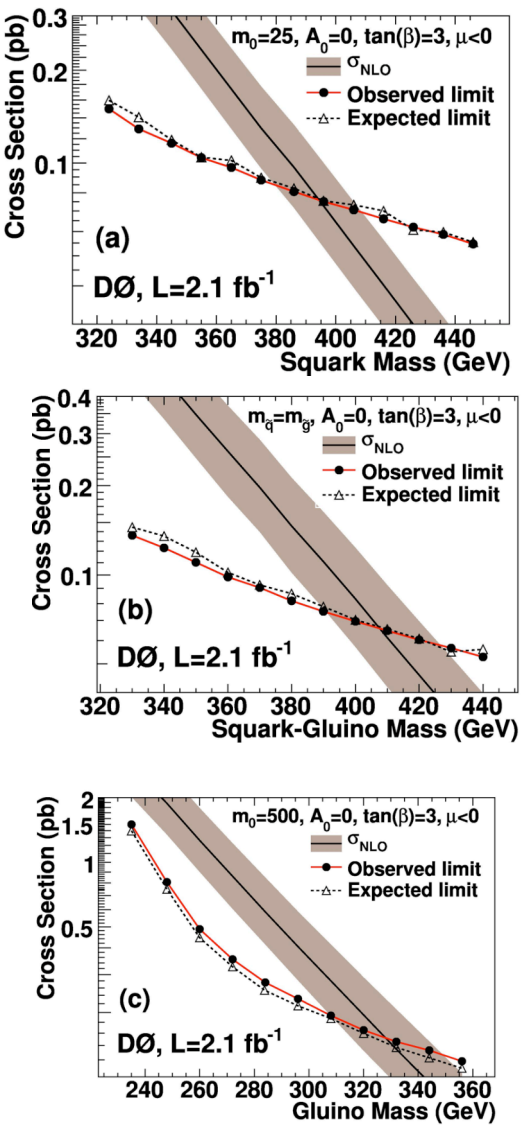
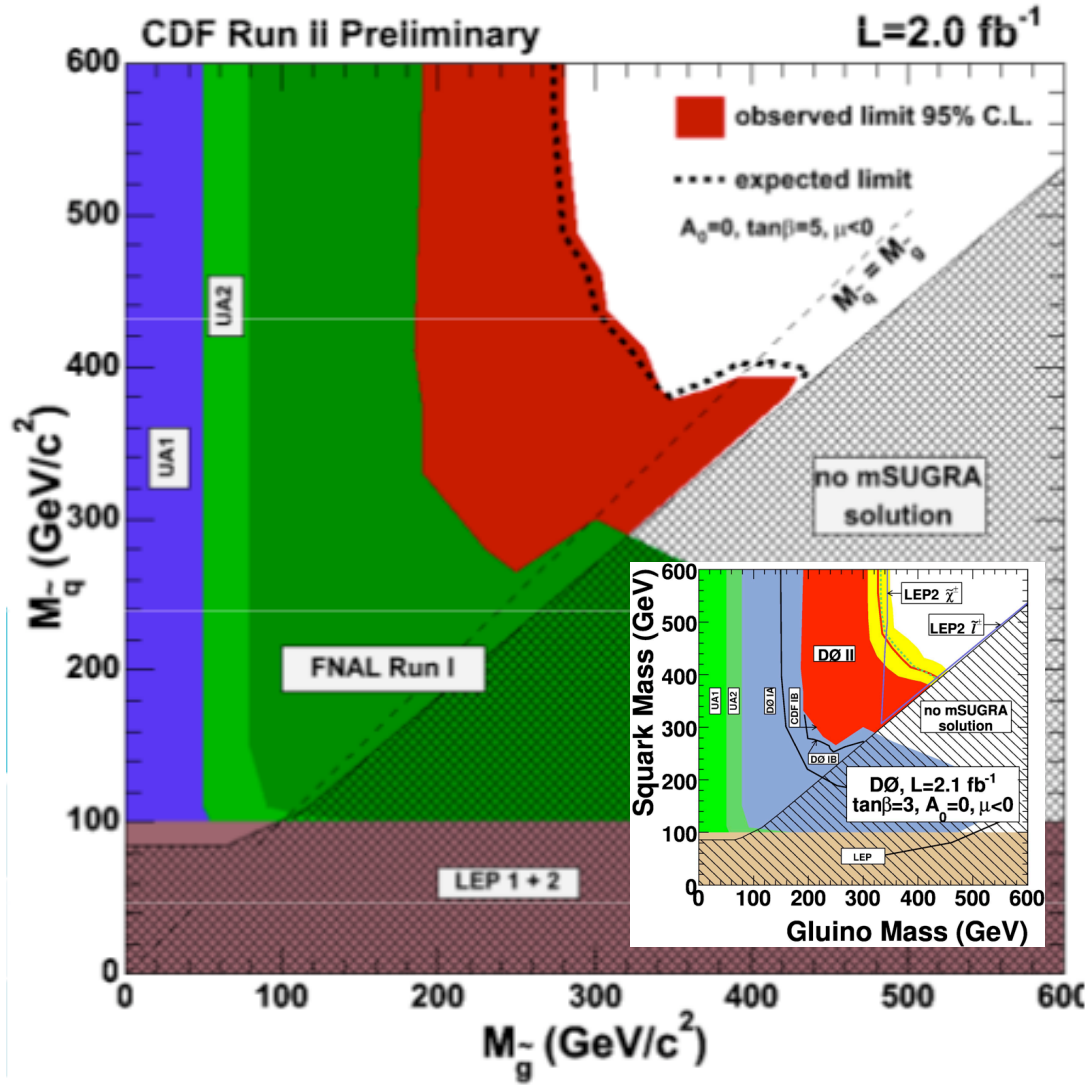
Phys. Lett. B 660 , 449 (2008)

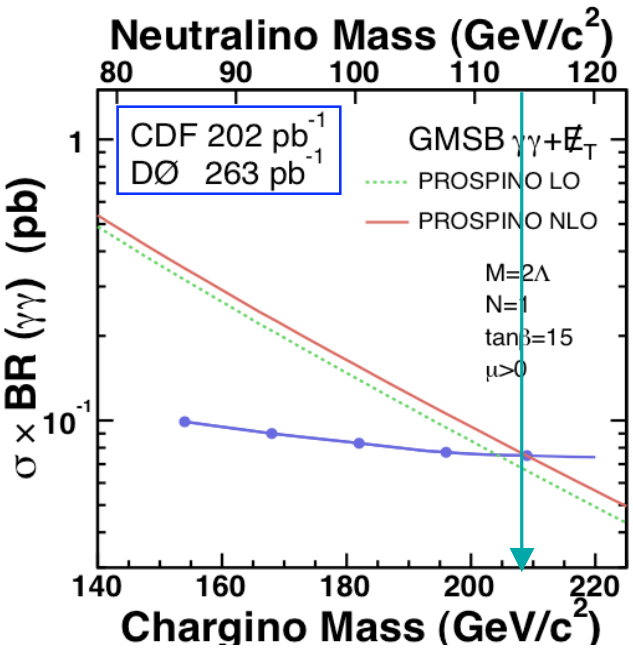


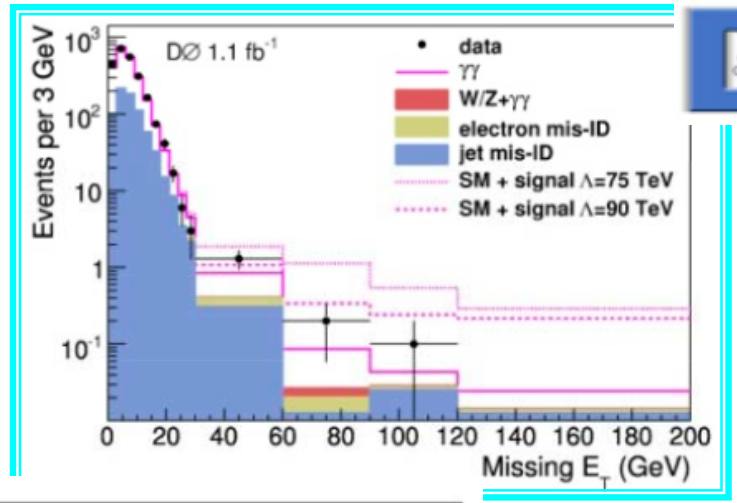


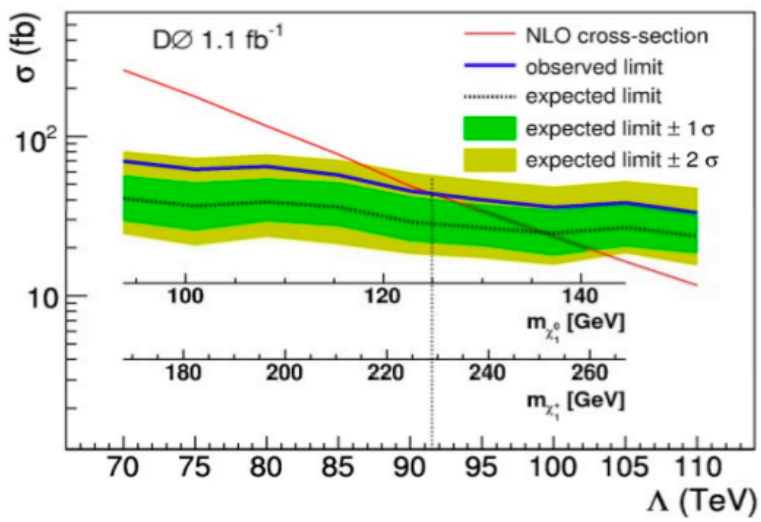
Backup: diphoton + MET: GMSB SUSY

GMSB scenario
NLSP = $\chi^0_1 \to \gamma \tilde{G}$

$p\bar{p} \to (X \to) \chi^0_1 \chi^0_1$ → $2\gamma + \not{E}_T$

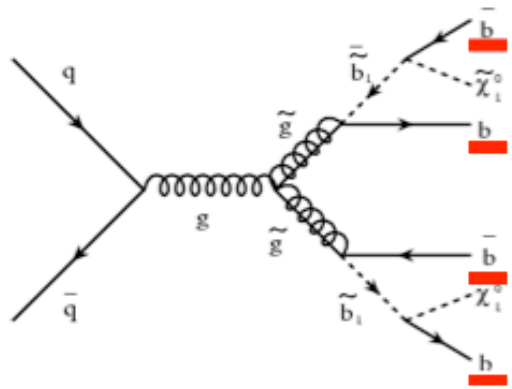






Backup:sbottom from gluinos

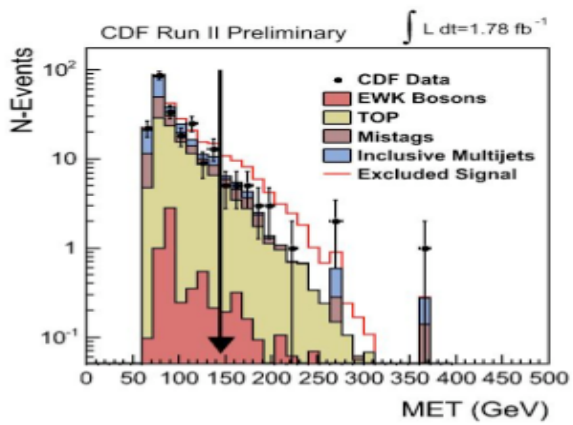
If the sbottom is significantly lighter than the other squarks, the two body decay of gluino into bottom/sbottom is kinematically allowed

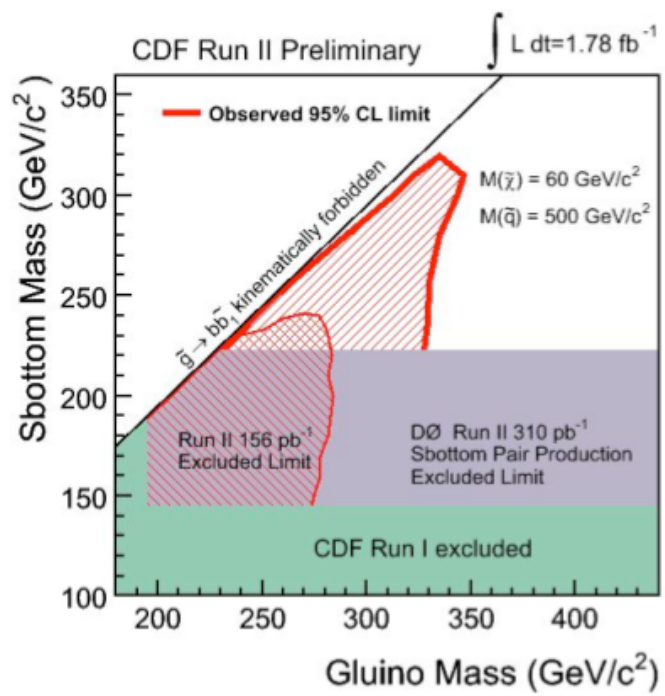


The sbottom decays into a bottom and LSP, giving rise to a final state with <u>4 b-jets and missing energy</u>

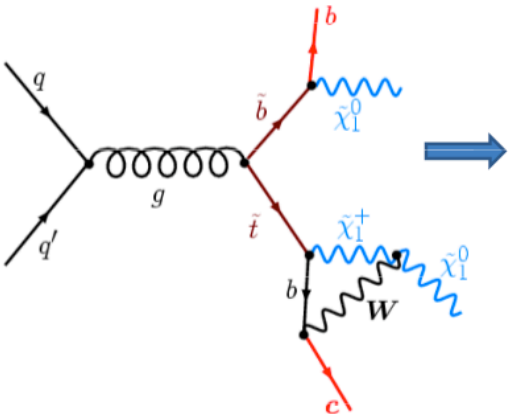
The analysis is optimized for 2 points in the SUSY parameter space:

Large Δm between $\tilde{g}$ and $\tilde{b}$
$M(\tilde{g})$ = 320 GeV/c^2, $M(\tilde{b})$ = 250 GeV/c^2, $M(\tilde{\chi})$ = 60 GeV/c^2
Small Δm between $\tilde{g}$ and $\tilde{b}$
$M(\tilde{g})$ = 300 GeV/c^2, $M(\tilde{b})$ = 280 GeV/c^2, $M(\tilde{\chi})$ = 60 GeV/c^2





Backup:Stop searches



Light stop and sbottom production and decay

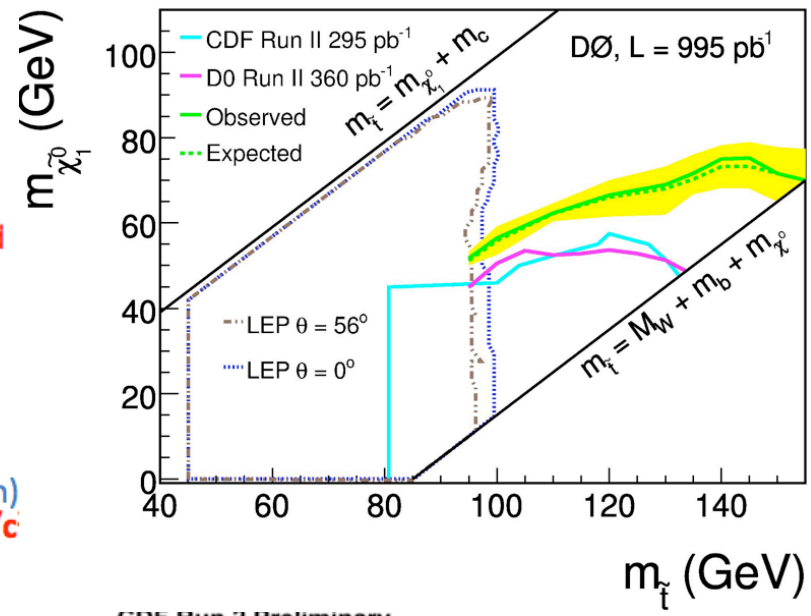
Stops to charm

- Exactly 2 jets (reduction of QCD)
- Jet pt cuts (20,40 GeV/c) and angular separation of jets (reduces QCD and W+jets)
- Angle between jets and met (reduction of QCD)
- Flavor tagging using Neural Network (impact parameter, secondary vertex information)

Exclusion: stop mass <149 GeV/c
neutralino mass of 63 GeV/c²

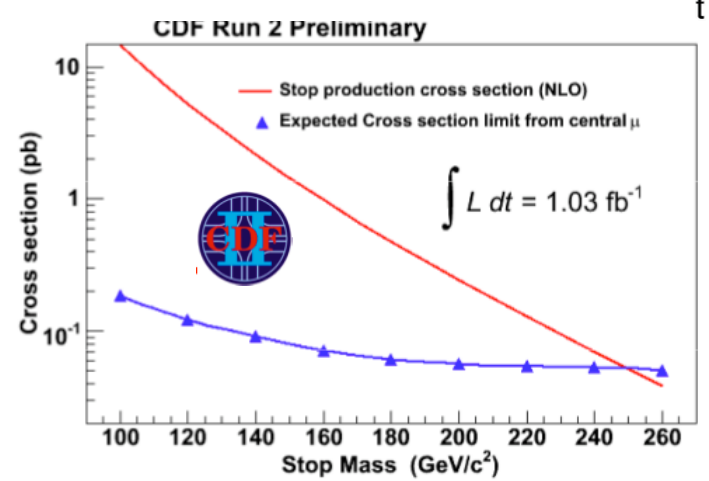
Other option is that stop does not decay in the detector (CHAMP)

Fermilab-PUB-08/063-E



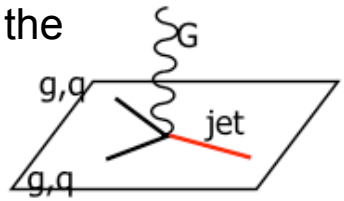
- Slow particle signature : slowly-moving highly-ionizing highly-penetrating particle
  - Will look like muon with possible calorimetry energy deposition
- Particle mass is measured using Time of Flight

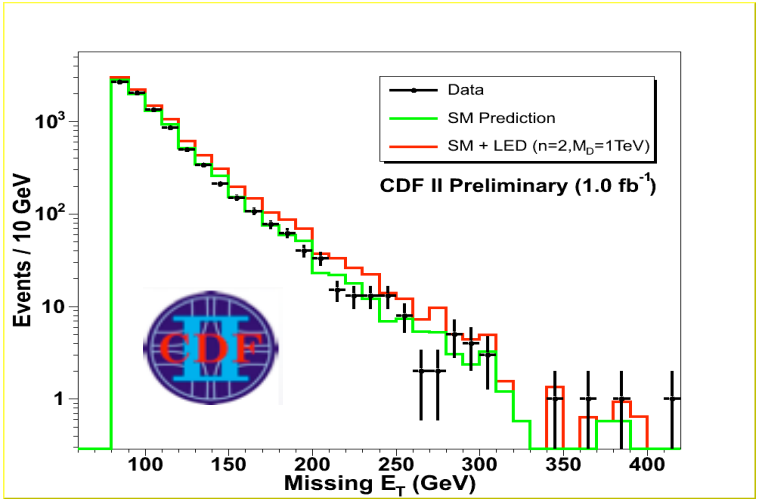
Stable stop mass > 250 GeV/c² at 95% CL

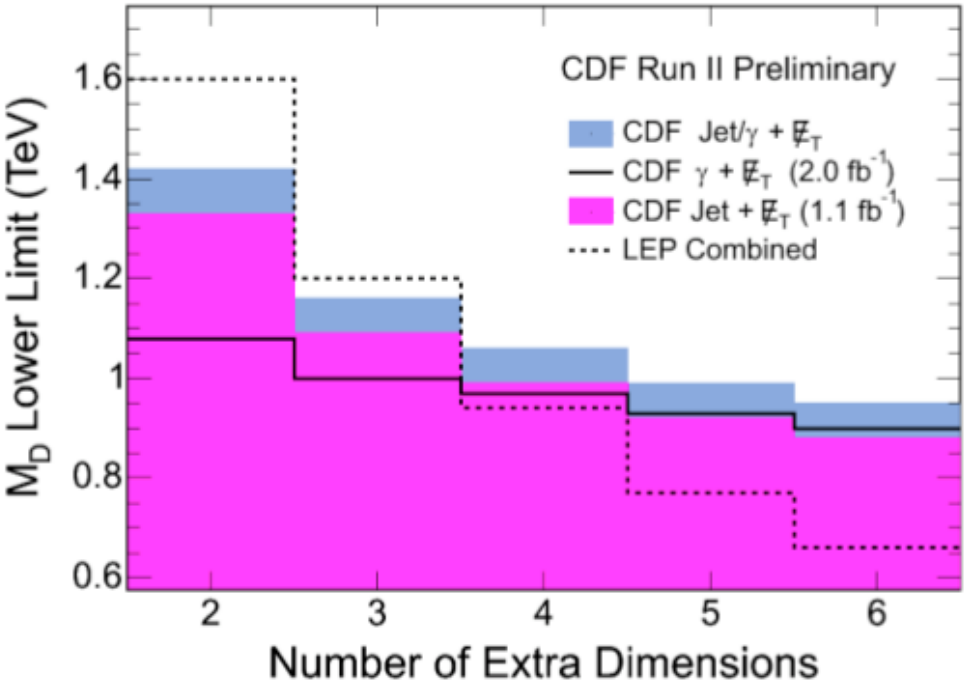


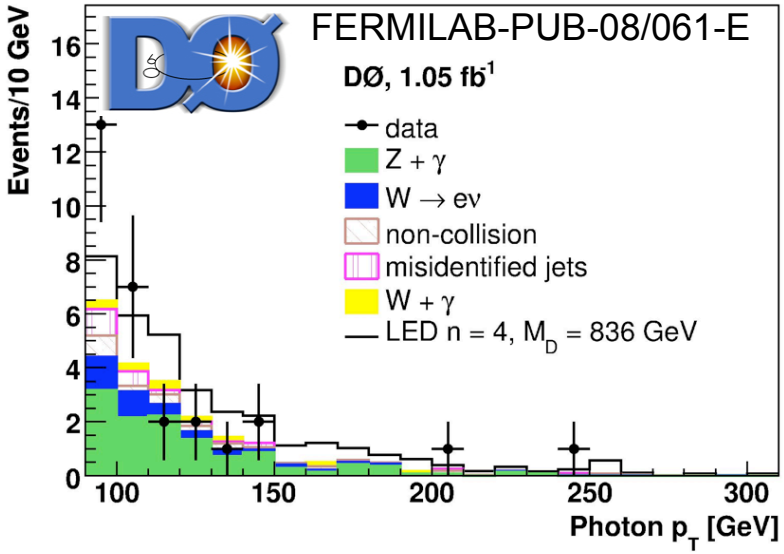
Backup: Single jet + MET: LED

A Kaluza-Klein graviton is produced in association with a jet (or photon). The graviton escapes detection, leaving a monojet (monophoton) signature in the detector









SUSY current status

Sparticle	Low mass limit (GeV/c^2)
Chargino (mSUGRA)	~140-150
NL Neutralino (mSUGRA)	~140-150
Chargino (GMSB)	~230
LSP Neutralino (GMSB)	~125
Chargino mSUGRA, RPV	~200
Neutralino mSUGRA, RPV	~100
Squark	~400
Gluino	~300
Light stop or RPV stop	~150
Stop as CHAMP	~250

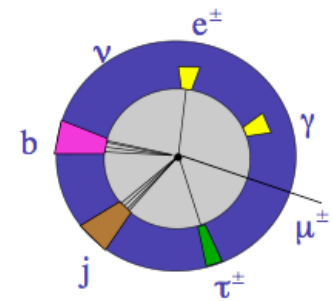
http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

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

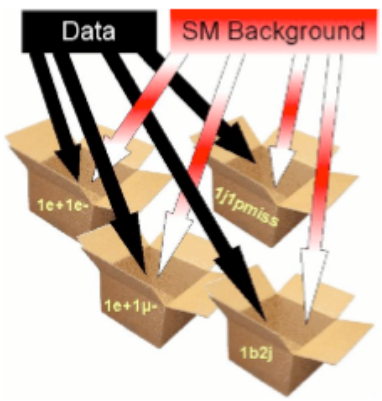
Backup: Global Searches

The goal is to perform a model-independent global search of high P_T data:

- -study bulk features of high P_T data;
- -search for resonances invariant mass distributions
- -search for significant excesses at high sum-p_T



Physics objects are categorized and events selected and partitioned into ~400 exclusive final states



The whole high P_T region is monitored at once

Pythia and MadEvent are used to implement the SM theoretical prediction (CdfSim emulates the detector response)

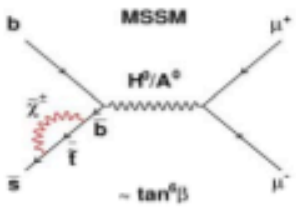
Many correction factors are used to obtain the *true* SM predictions (shouldn't a global search work globally?)

- theory k-factors etc
- experimental efficiencies and Scale Factors, fake rates etc

Currently observed discrepancies are explained in terms of incorrect MC modeling

$B_s \to \mu\mu$

Sensitive to new physics: if no observation, it can strongly constraint SUSY models



SM prediction:
BR = 3.42×10^{-9}

SUSY enhancement
~$(\tan\beta)^6$

- Data sample dominated by random combinatorial background
- Extract signal with Neural Net based discrimina

B_s and B_d considered separately:

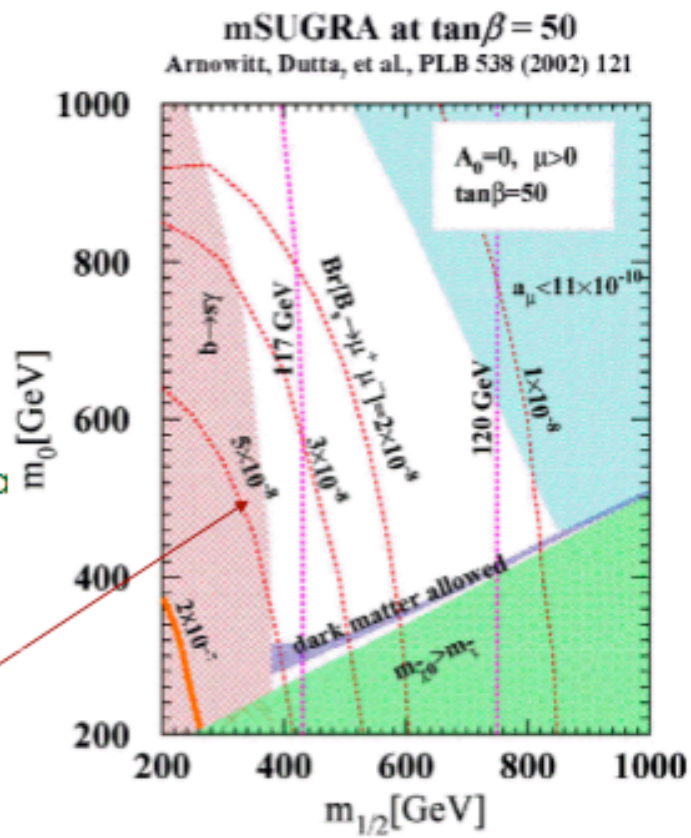
$Bs \to \mu\mu$ 3 observed events (3.6+/-0.3 exp.bkg.)

$Bd \to \mu\mu$ 6 observed events (4.3+/-0.3 exp.bkg.)

No significant excess → exclusion limit

$Br(B_s \to \mu\mu) < 5.8 \times 10^{-8}$ @ 95% CL
$Br(B_d \to \mu\mu) < 1.8 \times 10^{-8}$ @ 95%CL

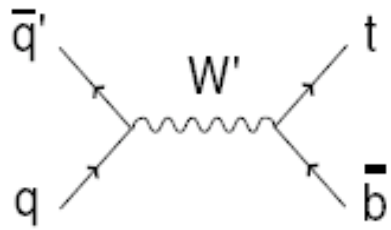
Comb CDF/D0



BR($B_s \to \mu\mu$) < 1.5×10^{-7} @95% CL

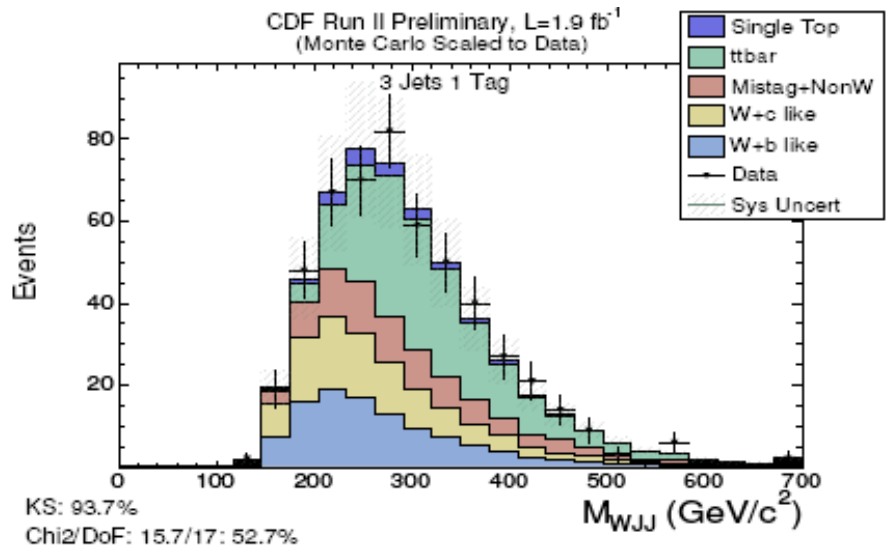
hep-ex/0508058

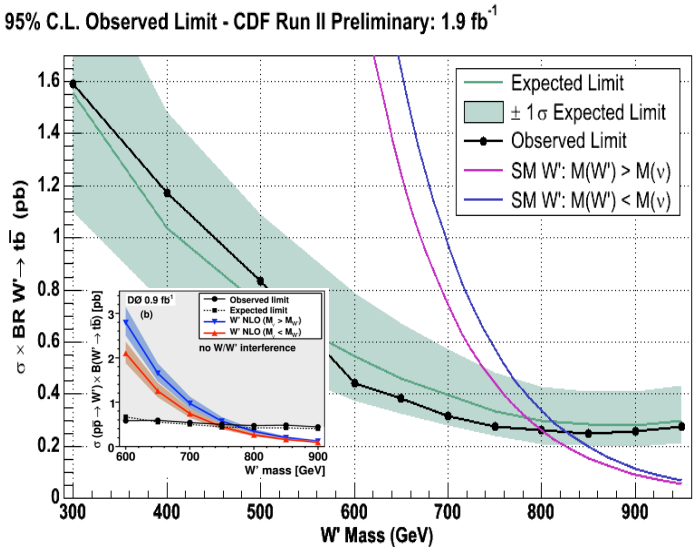
Backup:W'→ tb



Search for resonant tb*(+cc)* pair production

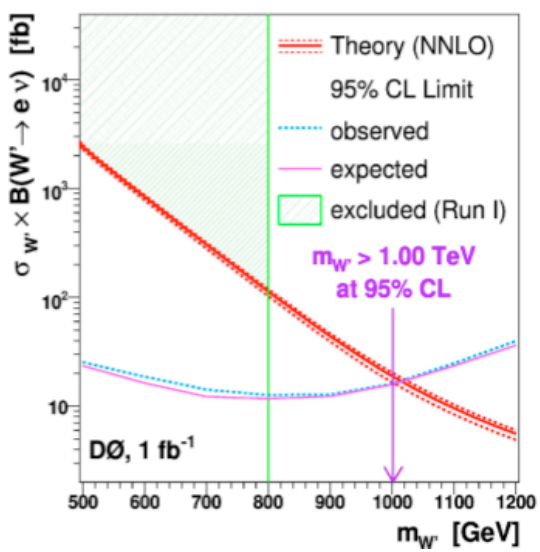
In W+2 jets and +3 jets channels (semileptonic W), look for unexpected structure in M(Wjj)

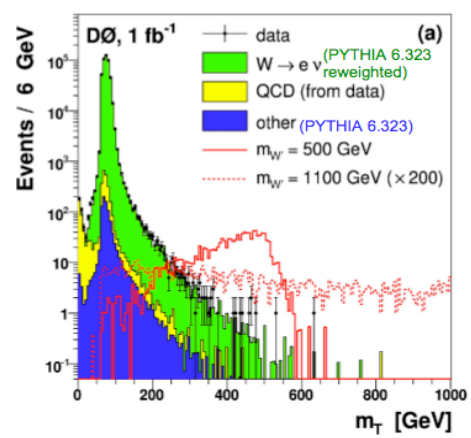


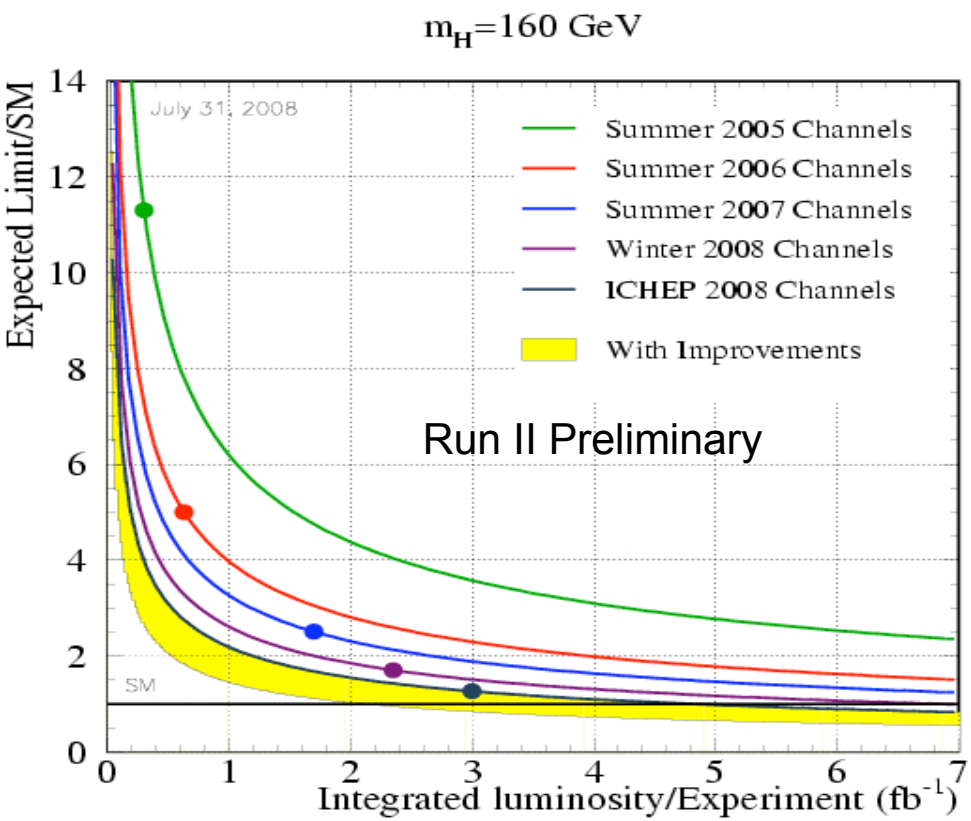
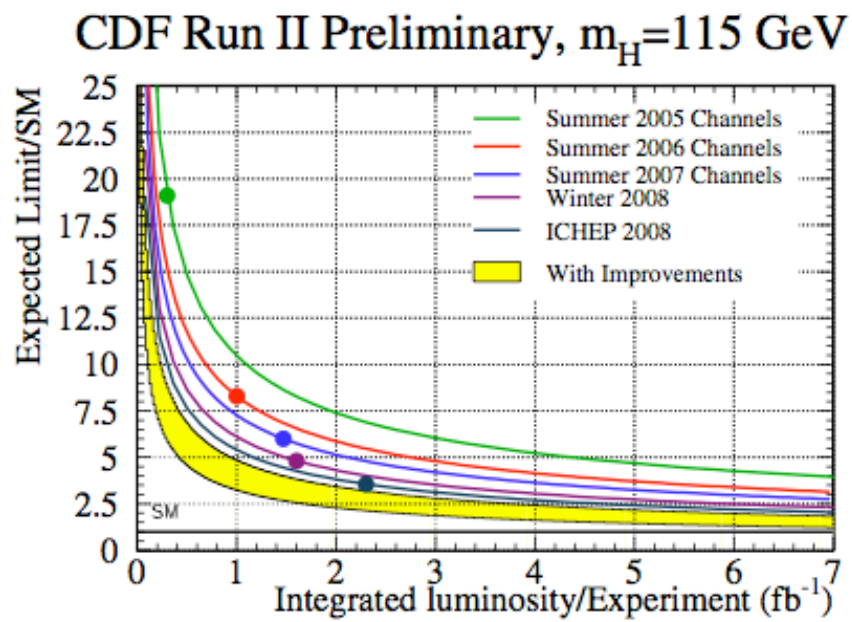


Extra W gauge boson decaying into eν

Phys. Rev. Lett. 100 , 031804 (2008





Backup: Projections

- Goals for increased sensitivity achieved
- Expect large exclusion, or evidence, with full Tevatron dataset and further improvements.