Things decaying into top quarks, that are similar to top quarks, or that are produced with top quarks

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On behalf of the DØ and CDF collaborations

$t\bar{t}$ resonances — stop quarks — t' — $t\bar{t}H^0$

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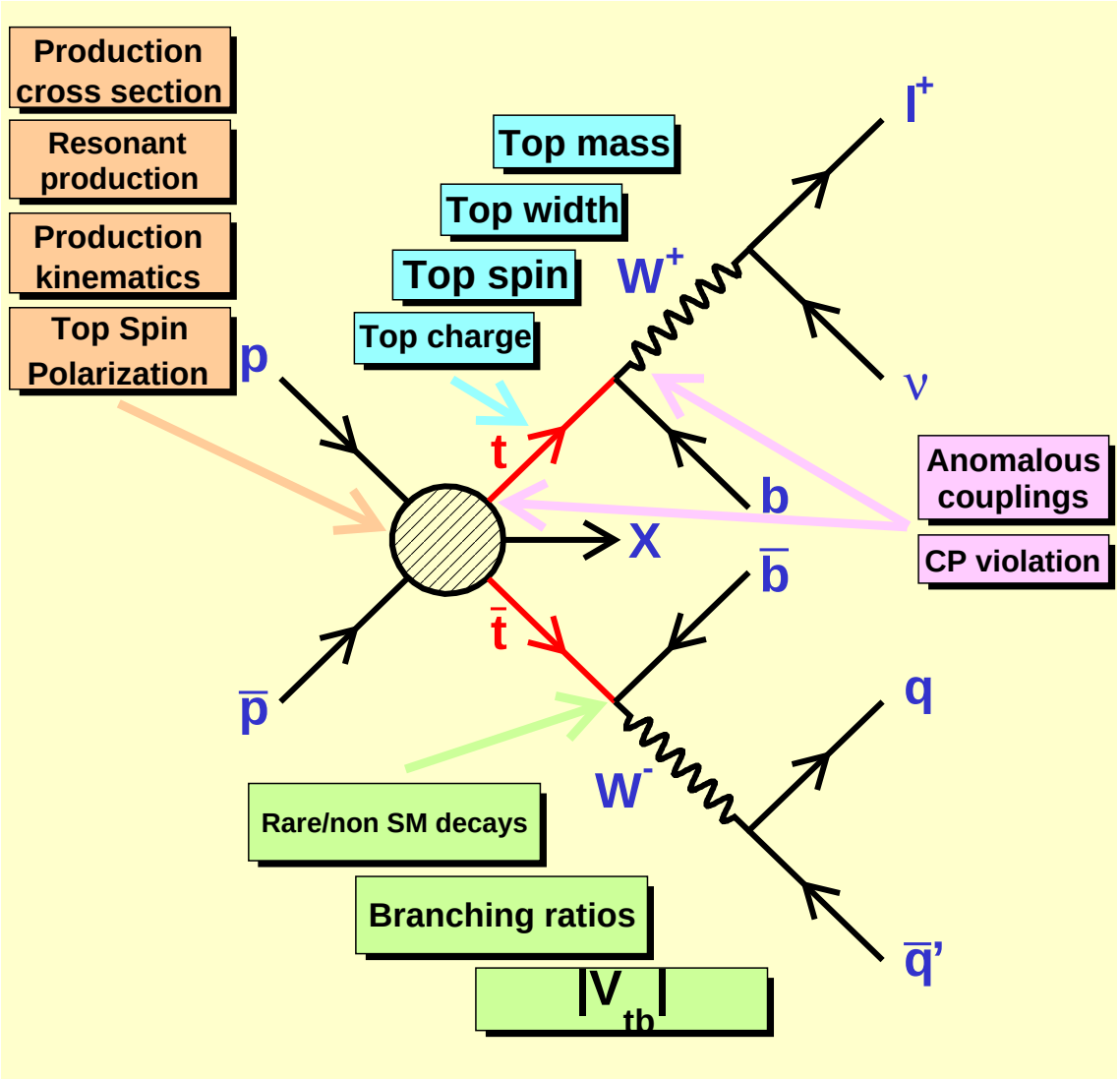
Introduction

- Top quark production and decays provide a wealth of interesting measurements.
- Several have reached high precision.

  Example: m_t known to 0.8 %

⇒ Deviations from standard model prediction would indicate new physics.

- Signature of new physics is often exactly the same as SM $t\bar{t} \rightarrow$ signal could be hidden in SM measurements.

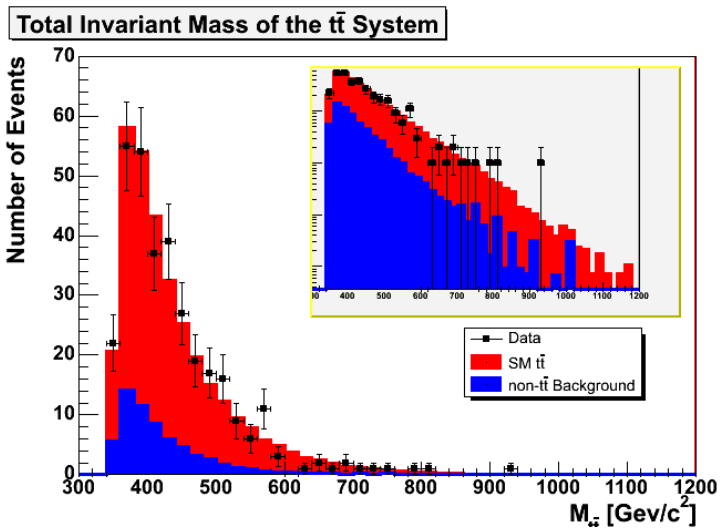


Note: In this talk I reference several techniques to reconstruct the top quark mass. See related talks for details.

$t\bar{t}$ resonances (CDF) – Analysis I

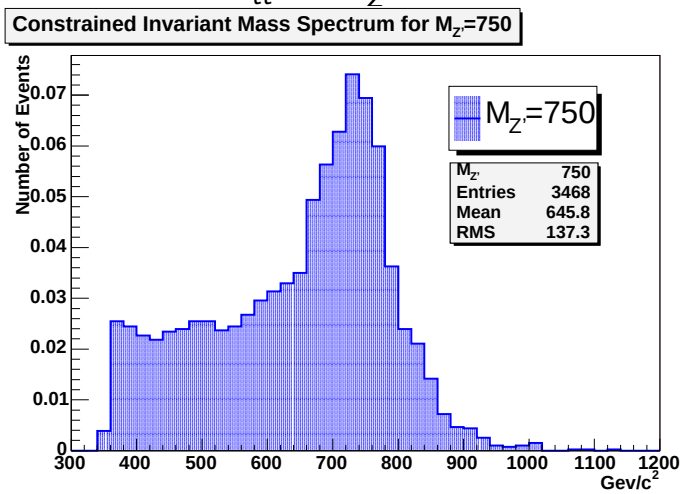
$\mathcal{L} = 1\ \mathrm{fb}^{-1}$

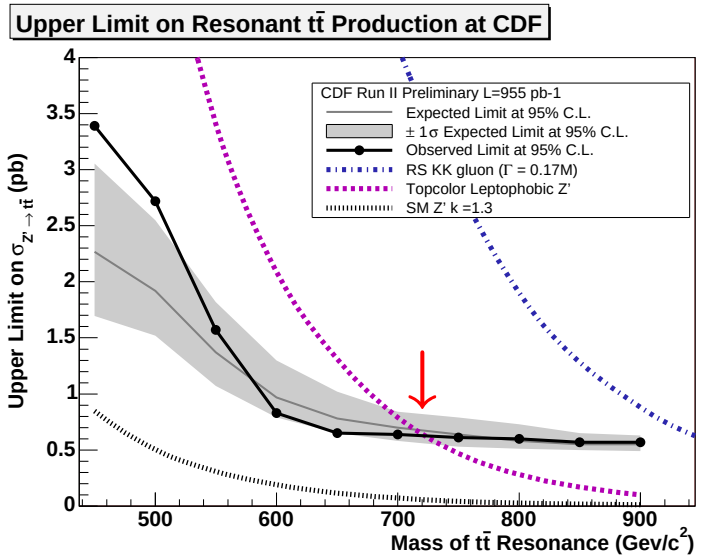
- Resonances from Z-like new objects, Kaluza-Klein states of Z or gluon, axigluons, topcolor.
- Assume narrow resonance with $\Gamma_{m_{Z'}} = 0.012 m_{Z'}$.
- ℓ+jets channel, ≥ 1 SVX b-tag.
- Choose combination with best χ^2 for m_{W_1}, m_{W_2}, m_{t_1}, m_{t_2}.



Binned MLL fit to extract signal fraction.

Reconstructed $m_{t\bar{t}}$ for $m_{Z'} = 750$ GeV



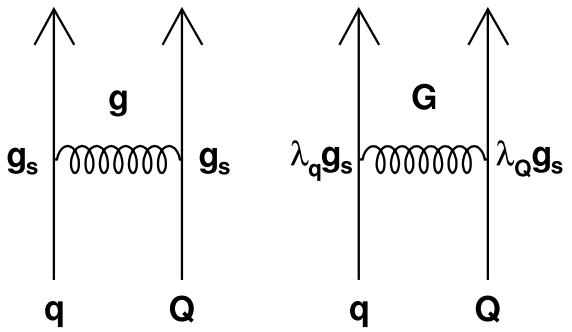


$\Rightarrow$ Exclude topcolor $Z' < 720$ GeV (PRD 77 051102)

$t\bar{t}$ resonances (CDF) – Analysis II

$\mathcal{L} = 1.9\ \text{fb}^{-1}$

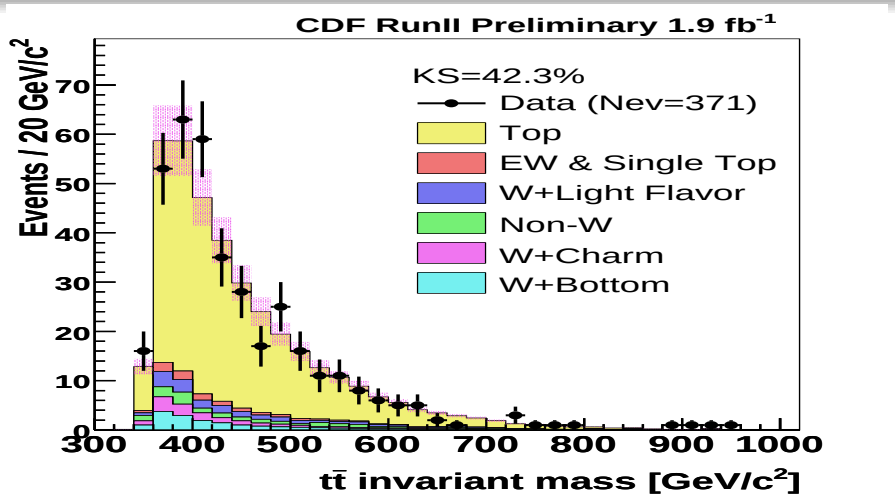
Assume massive gluons G $\longrightarrow t\bar{t}$



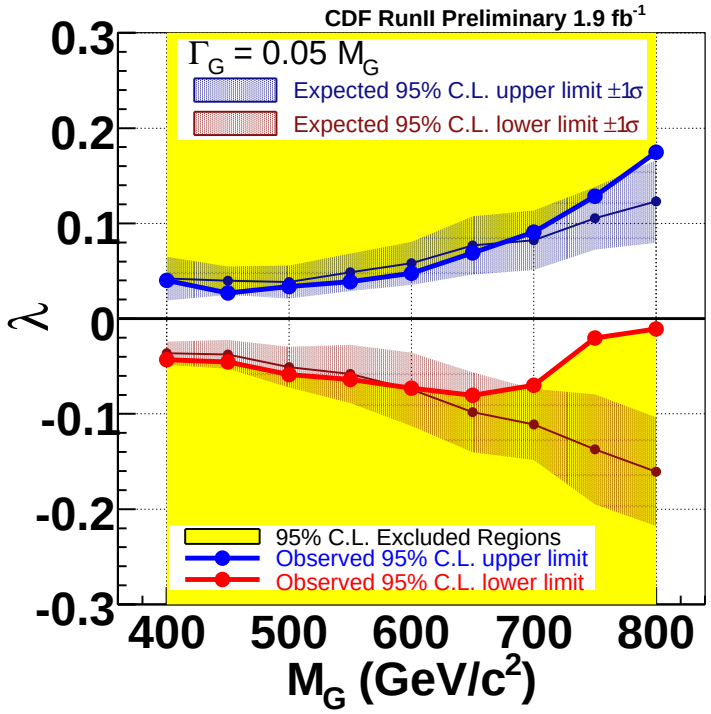
diagrams interfere

- ℓ+jets selection, $\geq$1 SVX b-tag.
- Final state reconstruction with Dynamical Likelihood Method (does not use the matrix element).
- No assumption about width.

$\Rightarrow$ Set limits on coupling λ in a range of widths $\Gamma_G = 0.05$–$0.5 \cdot M_G$.



Example: $\Gamma_G = 0.05 \cdot M_G$

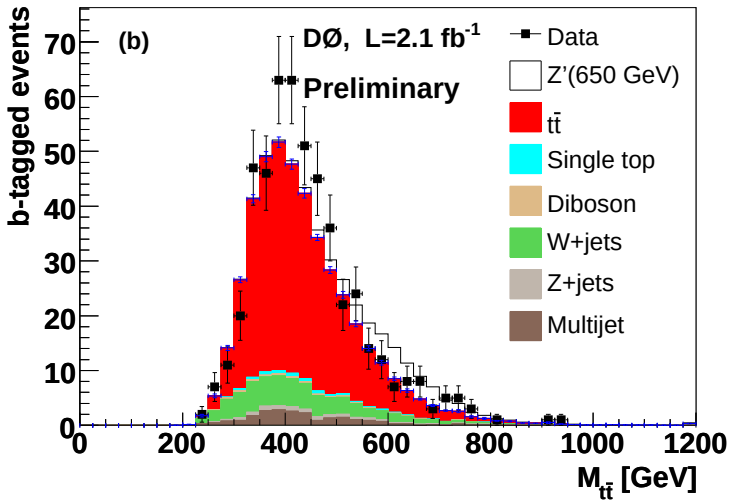


$t\bar{t}$ resonances (DØ)

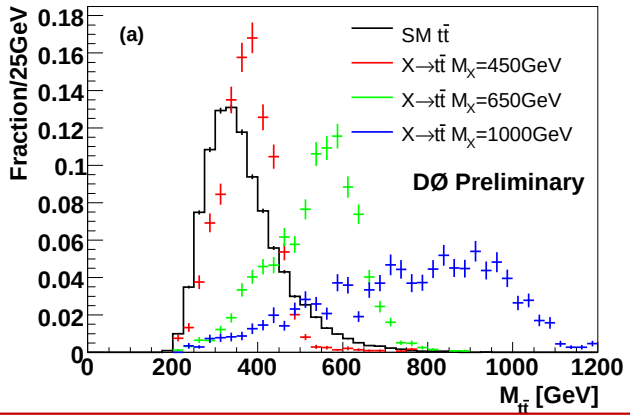
$\mathcal{L} = 2.1\ \text{fb}^{-1}$

- Assume narrow width $Z' \to t\bar{t}$, $\Gamma_{m_{Z'}} = 0.012 m_{Z'}$.
- Search in ℓ+jets final state.
- 4 or 3 jets (at high $m_{Z'}$ jets can be merged).
- $\geq$ 1 b-tagged jet (NN b-tagger).
- Direct reconstruction of $m_{t\bar{t}}$ from jets, lepton, E_T^{miss}.

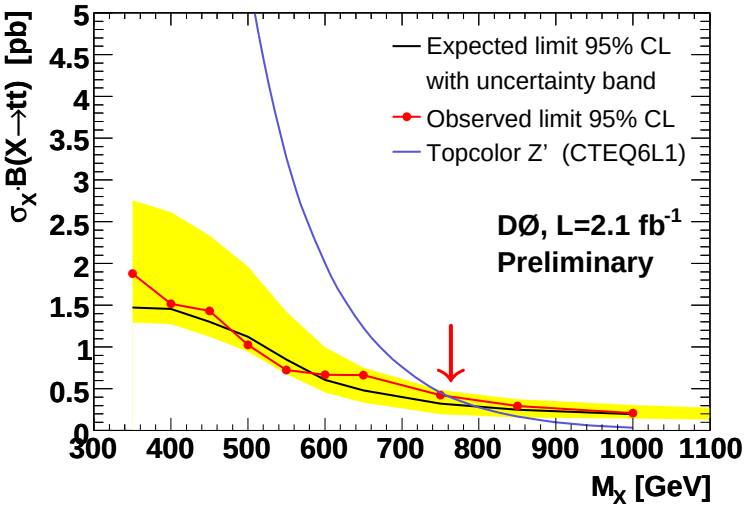
$\geq$ 4 jets



reconstructed $m_{t\bar{t}}$



3 and $\geq$ 4 jets



$\Rightarrow$ Exclude topcolor-assisted technicolor $Z' < 760$ GeV (subm. to PLB)

Supersymmetric top quark pairs (CDF)

$\mathcal{L} = 2.7\ \mathrm{fb}^{-1}$

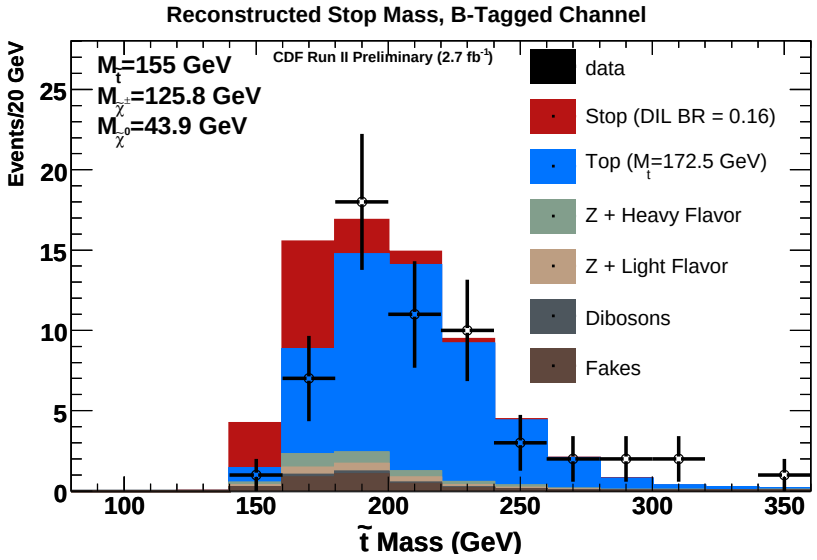
The scenario

- Supersymmetric top-pairs could lead to same final state signature as SM top-pairs.
- $m_{\tilde{t}_1} \leq m_t$ in supersymmetric electroweak baryogenesis scenarios. Assume $m_{\tilde{\chi}^\pm} < m_{\tilde{t}_1} - m_b$, so that $\tilde{t}_1 \to b\chi_1^+$ has 100 % BR; $\tilde{\chi}_1^0$ is LSP, $\tilde{q}, \tilde{\ell}, \tilde{\nu}$ are heavy.
- $\tilde{\chi}_1^\pm$ decays to $\tilde{\chi}_1^0 + \ell + \nu$ via

$$\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 + W^{\pm(*)} \to \tilde{\chi}_1^0 + \ell + \nu,$$
$$\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 + H^\pm \to \tilde{\chi}_1^0 + \ell + \nu,$$
$$\tilde{\chi}_1^\pm \to \ell + \tilde{\nu}_\ell \to \tilde{\chi}_1^0 + \ell + \nu,$$
$$\tilde{\chi}_1^\pm \to \nu + \tilde{\ell}_L \to \tilde{\chi}_1^0 + \ell + \nu,$$
$$\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0 + G^{\pm(*)} \to \tilde{\chi}_1^0 + \ell + \nu.$$

Analysis procedure

- Search for stop quarks in dilepton final states. Identical with $t\bar{t} \to$ dilepton siganture.
- Reconstruct stop mass à la top mass with neutrino weighting.
- Use stop mass as discriminant.
- B-tagged and anti-b-tagged samples.



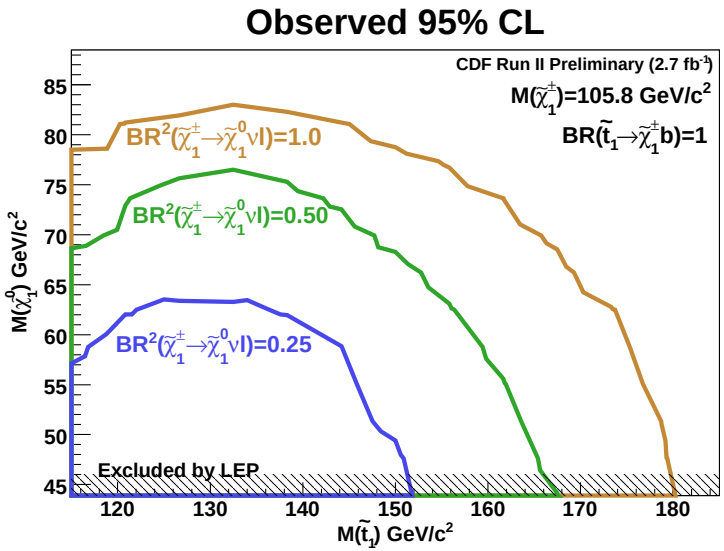
Supersymmetric top quark pairs (CDF)

Source	ee	$\mu\mu$	$e\mu$	$\ell\ell$
		anti-tagged		
stop	1.1 ± 0.5	1.3 ± 0.4	2.9 ± 0.6	5.4 ± 1.5
SM total	22.8 ± 4.3	18.3 ± 3.3	26.0 ± 4.0	67.2 ± 10.3
Data	24	10	25	59
		b-tagged		
stop	1.1 ± 0.3	1.4 ± 0.4	3.0 ± 0.7	5.5 ± 1.2
SM total	14.2 ± 2.0	12.4 ± 1.6	29.4 ± 3.8	56.0 ± 7.3
Data	15	12	30	57

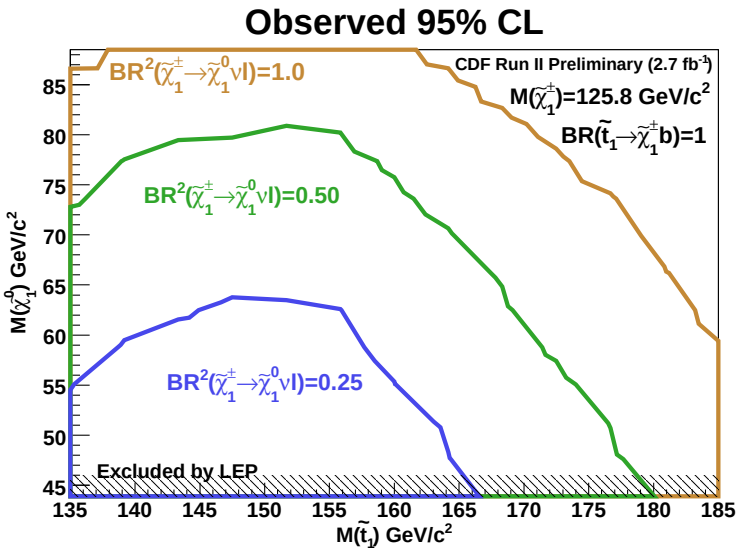
stop signal for $m_{\tilde{t}} = 135$ GeV, $m_{\tilde{\chi}^{\pm}} = 125.8$ GeV, $m_{\tilde{\chi}_1^0} = 58.8$ GeV, $BR = 0.3$

Using reconstructed mass, set limits for $115 \leq m_{\tilde{t}} \leq 185$ GeV, $43.9 \leq m_{\tilde{\nu}} \leq 88.5$ GeV, $105.8 \leq m_{\tilde{\chi}_1^{\pm}} \leq 125.8$ GeV in $m_{\tilde{t}}$–$m_{\tilde{\chi}_1^0}$ plane.

$m_{\tilde{\chi}_1^{\pm}} = 105.8$ GeV/c^2



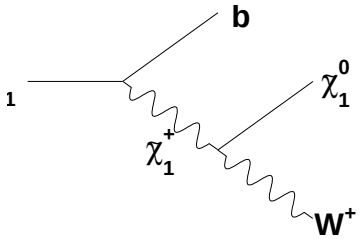
$m_{\tilde{\chi}_1^{\pm}} = 125.8$ GeV/c^2

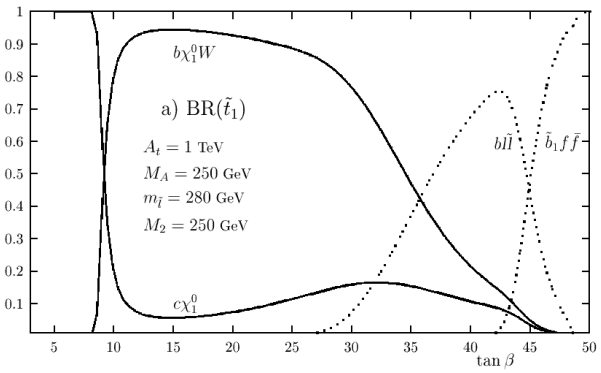


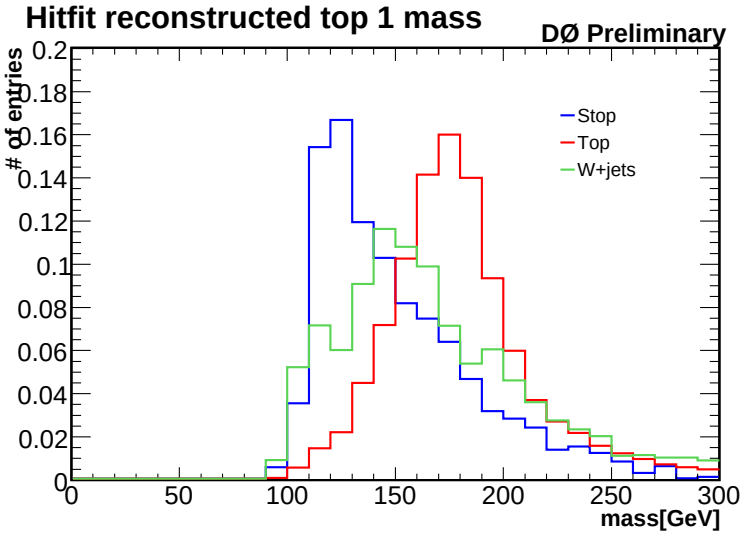
Supersymmetric top quark pairs (DØ)

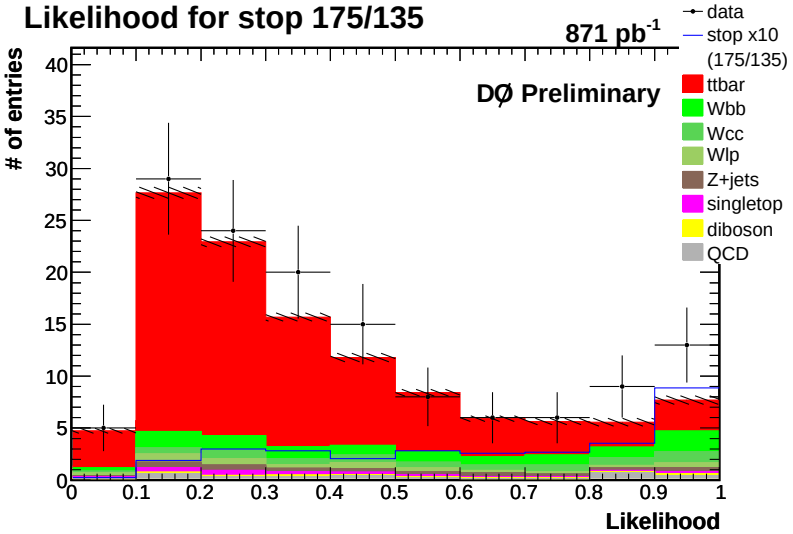
$\mathcal{L} = 1\ \mathrm{fb}^{-1}$

- Consider $m_{\tilde{t}} \leq m_t$, chargino and neutralino close to experimental limits.
- stop/chargino masses 175–145 GeV and 135–105 GeV.
- Lepton+jets final states.
- Kinematic fitter to reconstruct final states.
- Likelihood discriminant for signal/background.



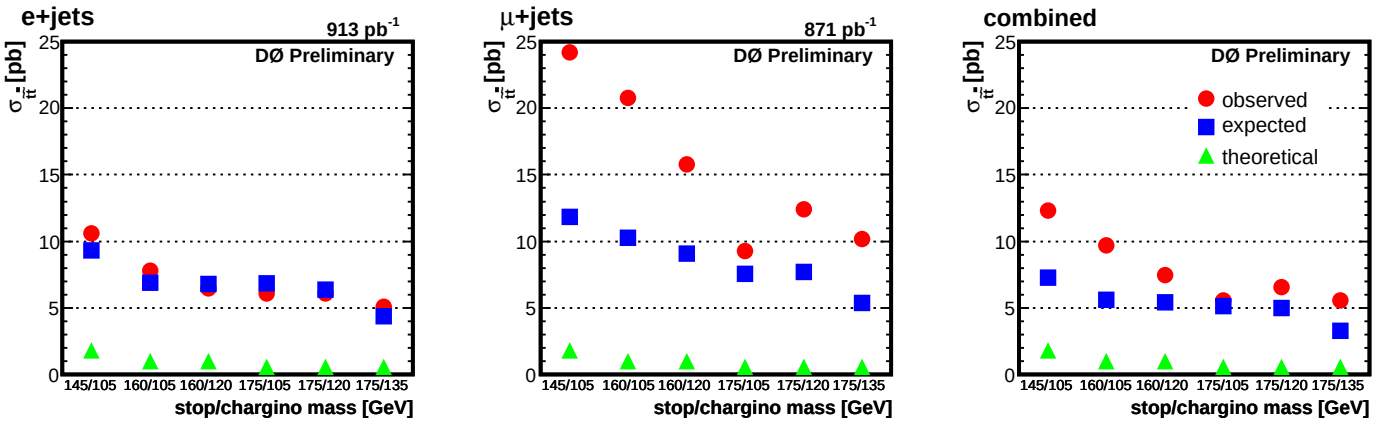




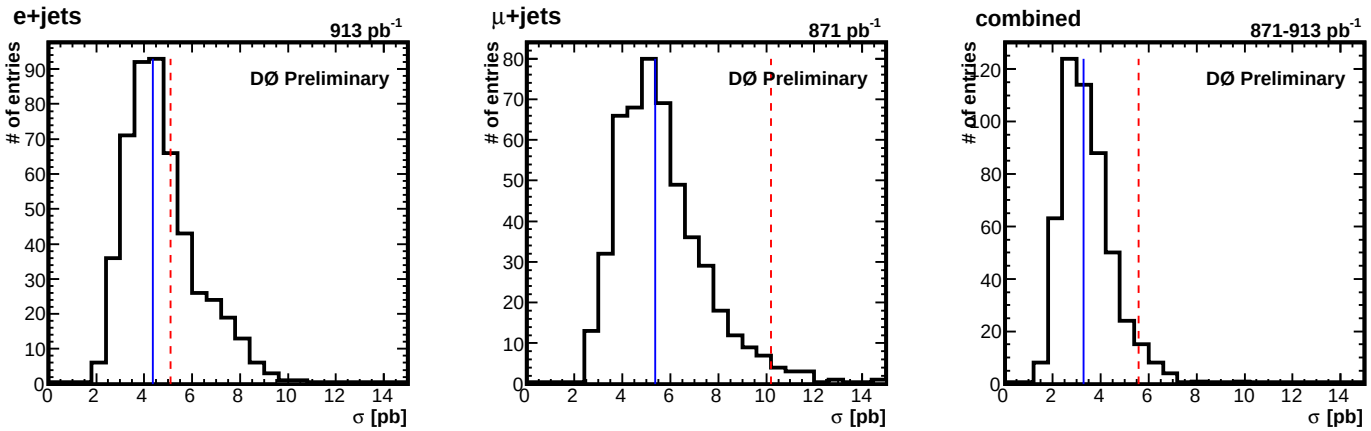


Supersymmetric top quark pairs (DØ)

- Set limits on cross section.



- Cross check with ensemble tests.



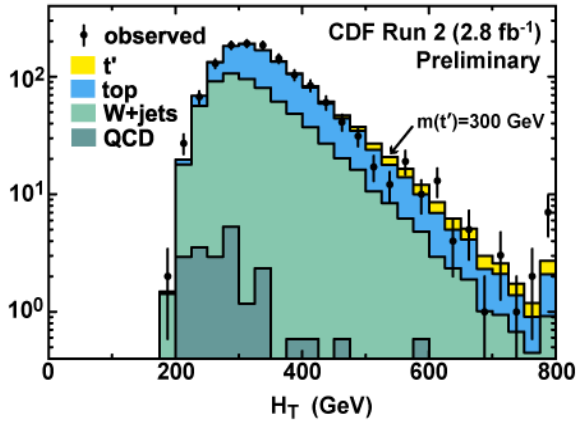
- Larger observed limit compatible with SM fluctuation.

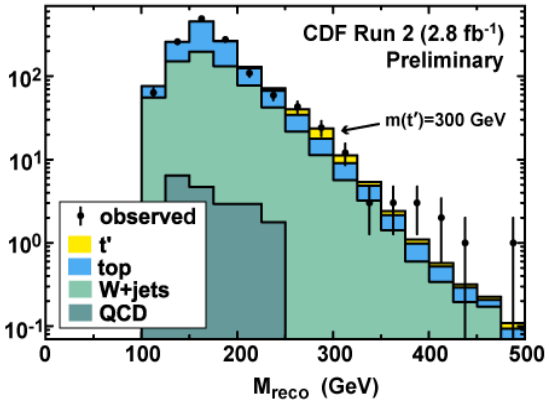
Top-like objects (t') (CDF)

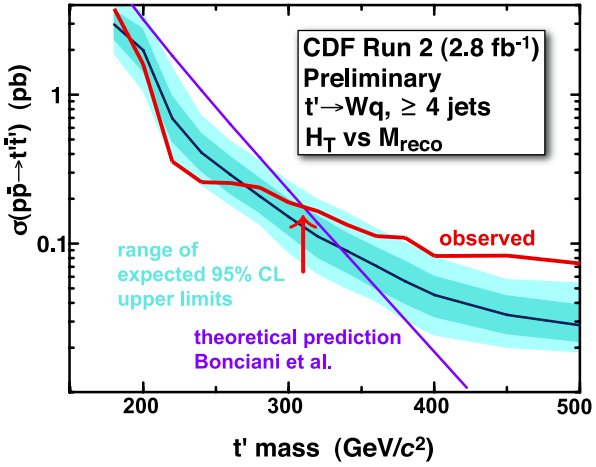
$\mathcal{L} = 2.8\ \text{fb}^{-1}$

Massive 4th-generation, top-like quark predicted in several models (Little Higgs, Beautiful Mirrors).

- Search for $t' \to Wq$ (no b-tagging)
  Assume $m_{t'} > m_t$, $m_{t'} - m_{b'} < M_W$.
- Template fit method based on minimal χ^2 to find correct combination of final state.
- Use M_{reco} and H_T in 2D binned MLL fit to extract t' signal.





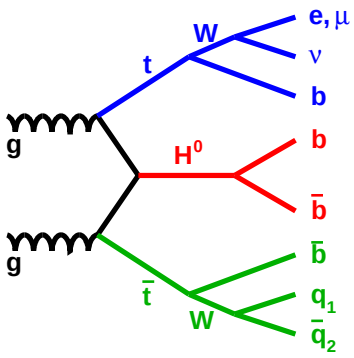


$\Rightarrow$ t' excluded up to 311 GeV @ 95% C.L.

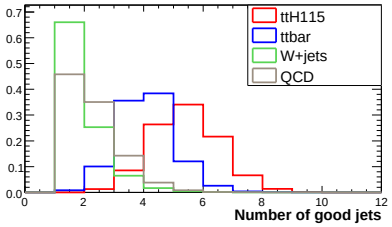
$t\bar{t}H^0$: Limits on a Light SM Higgs Boson (DØ)

$\mathcal{L} = 2.1\ \text{fb}^{-1}$

- $t\bar{t}H^0$ discovery channel at LHC for "low mass" Higgs.
- Can measure top Yukawa coupling.
- Tevatron: very small cross section, but contributes to overall sensitivity (at low masses).
- 4 and $\geq$5 jets; 1, 2, and 3 b-tagged jets (in ℓ+jets final state).
- $\sigma_{p\bar{p}\to t\bar{t}H^0} \approx 7$ fb ($m_{H^0} = 115$ GeV) but could be enhanced in BSM scenarios such as 2HDMs (MSSM).

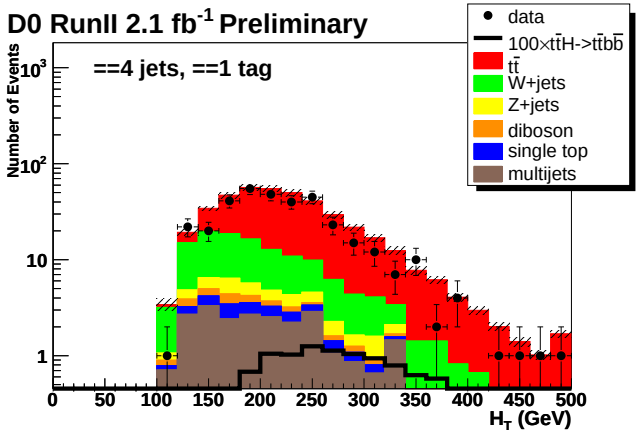


Number of jets

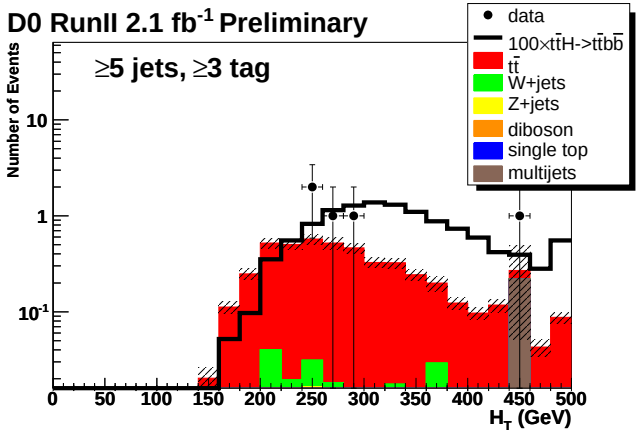


Use $H_T = \sum_{i\leq 4} p_T^{\text{jet}_i}$ to discriminate signal and background.

3 jet bin, 1 b-tag

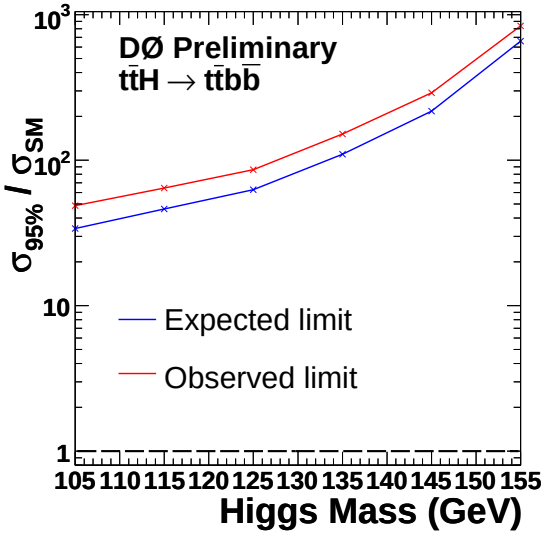


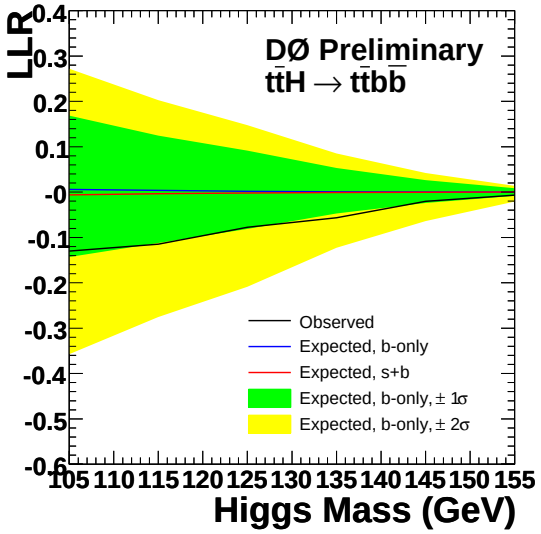
$\geq$5 jet bin, 3 b-tag



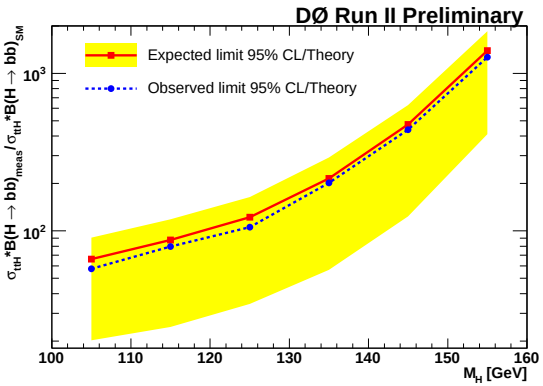
$t\bar{t}H^0$: Limits on a Light SM Higgs Boson (DØ)

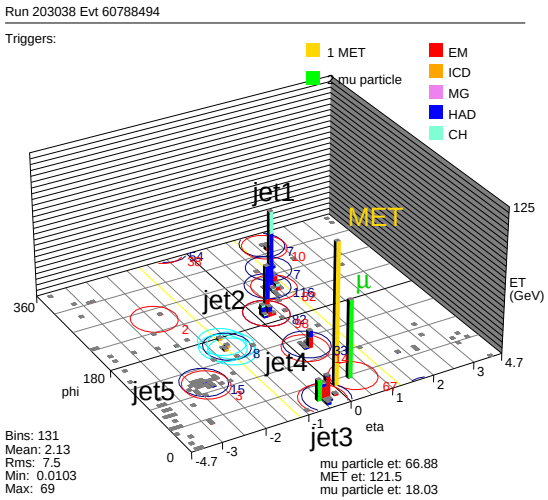
Set limits on cross section using modified frequentists approach with LLR test statistics.

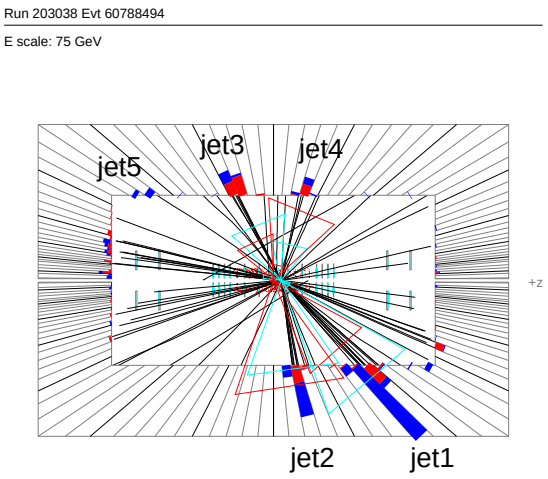


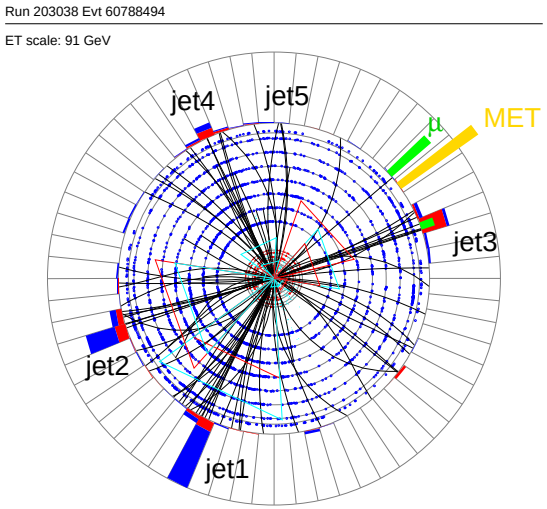


Cross check from simultaneous fit to $\sigma_{t\bar{t}}$ and $\sigma_{t\bar{t}H^0}$ using number of jets and b-tagged jets.









Summary

- A lot of interesting physics in $t\bar{t}$ production and decays.
- Current precision motivates to search for deviations from the SM.
- Plenty of room for new physics.

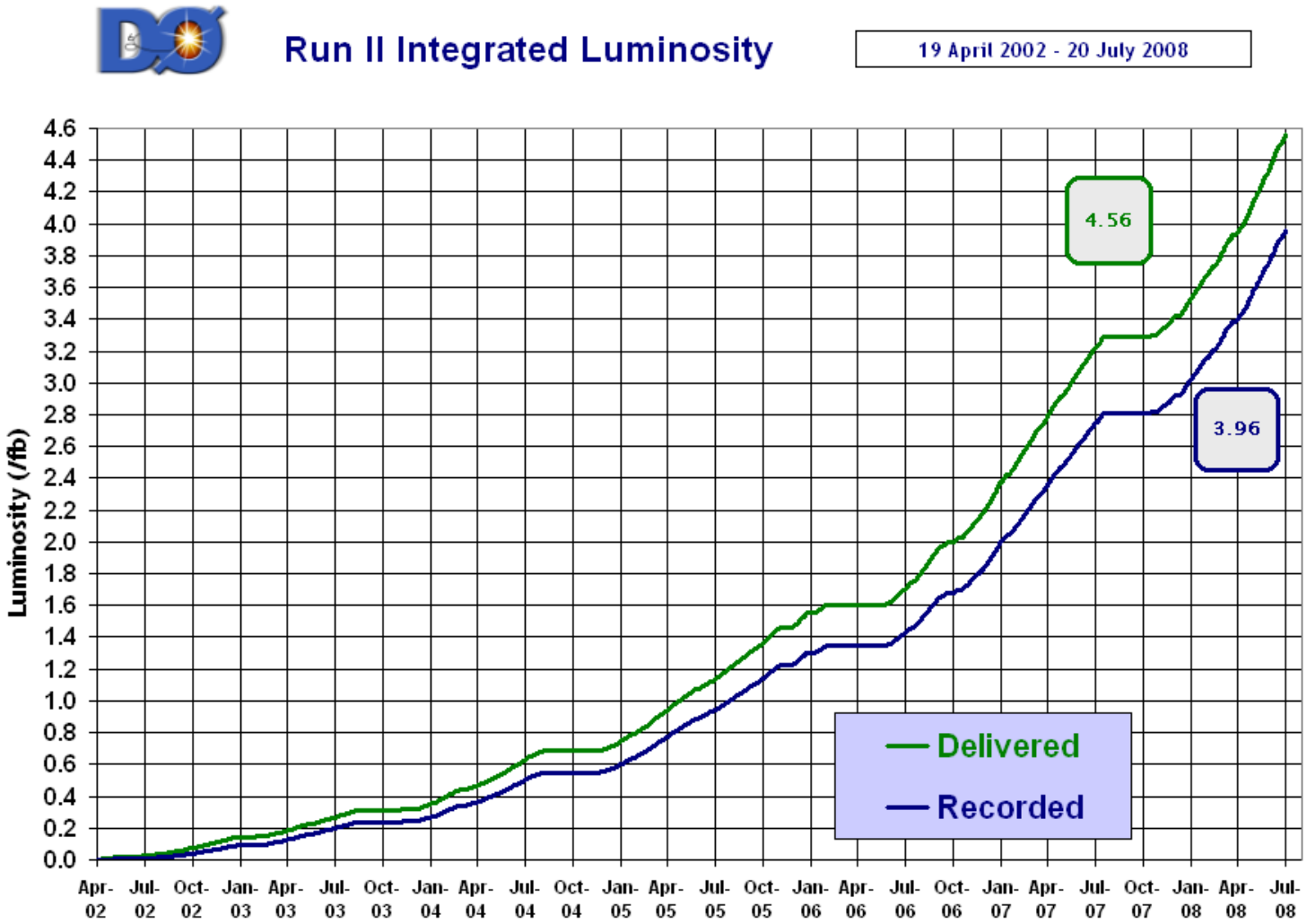
Analysis	Luminosity	Method	Results	Comment
$Z' \to t\bar{t}$ (DØ)	2.1 fb^{-1}	direct	$m_{Z'} < 760$ GeV	
$Z' \to t\bar{t}$ (CDF)	1.0 fb^{-1}	χ^2 fit	$m_{Z'} < 720$ GeV	(topcolor leptophobic Z')
$Z' \to t\bar{t}$ (CDF)	1.9 fb^{-1}	DLM	limits on λ	
stop (CDF)	2.7 fb^{-1}	ν weight	limits on $M_{\tilde{t}} - M_{\chi_1^0}$	dilepton
stop (DØ)	1.0 fb^{-1}	kin. fit	limits on $\sigma_{\tilde{t}\bar{\tilde{t}}}$	ℓ+j
t' (CDF)	2.8 fb^{-1}	χ^2 fit	$m_{t'} > 284$ GeV	
$t\bar{t}H^0(H \to b\bar{b})$ (DØ)	2.1 fb^{-1}	kinem. discr.	$\sigma_{t\bar{t}H^0 \times BR}/\sigma_{SM} < 64$	$m_{H^0} = 115$ GeV

(all limits given at 95% C.L.)

Tevatron Performance

$p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV

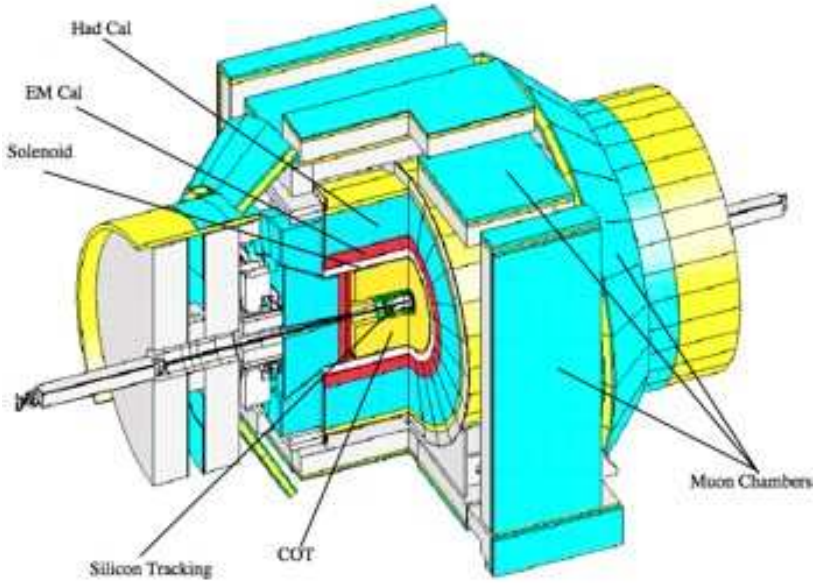
36x36 bunches, bunch crosssing 395ns
Peak luminosity: $2.85 \cdot 10^{32} \mathrm{cm}^{-2}\mathrm{s}^{-1}$

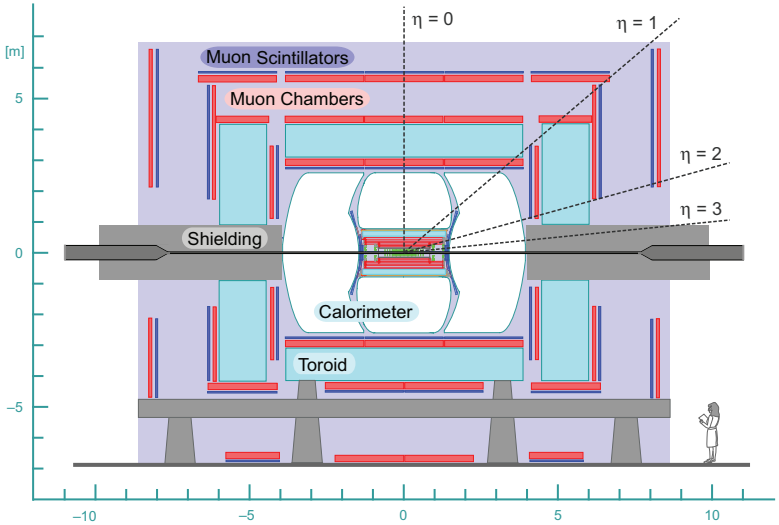


CDF and DØ Experiments

Both detectors significantly updated for RunII

- New silicon vertex detector
- New tracking system
- Upgraded muon chambers





DØ:

- New solenoid and preshower detectors
- New innermost SMT layer (RunIIb)
- Upgraded L1 triggers (RunIIb)

- CDF: New plug calorimeter and ToF