Search for $t\bar{t}$-Resonances in the Lepton+Jets Final State

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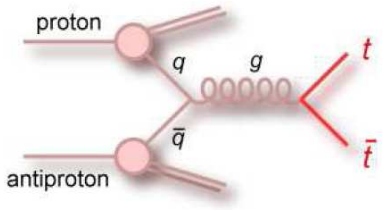
for the DØ collaboration

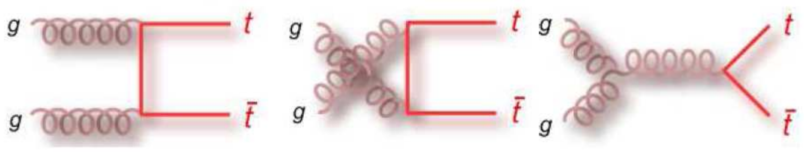
- Selection & background estimation
- Invariant mass distributions
- Limit

Top Quark Pair Production and Decay

Strong Top Production



$$85\% \quad q\bar{q} \rightarrow t\bar{t}$$
$$15\% \quad gg \rightarrow t\bar{t}$$

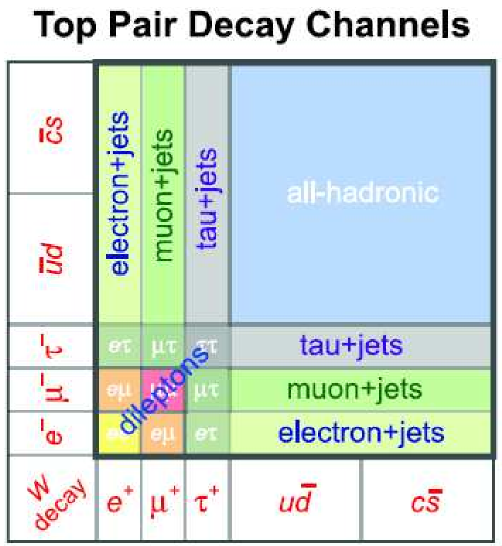


- $\sigma(t\bar{t}) = 7.3 \pm 0.7$ pb ($m_t = 172.5$ GeV)
- Around 7k $t\bar{t}$ per 1 fb^{-1} expected

Decay Modes

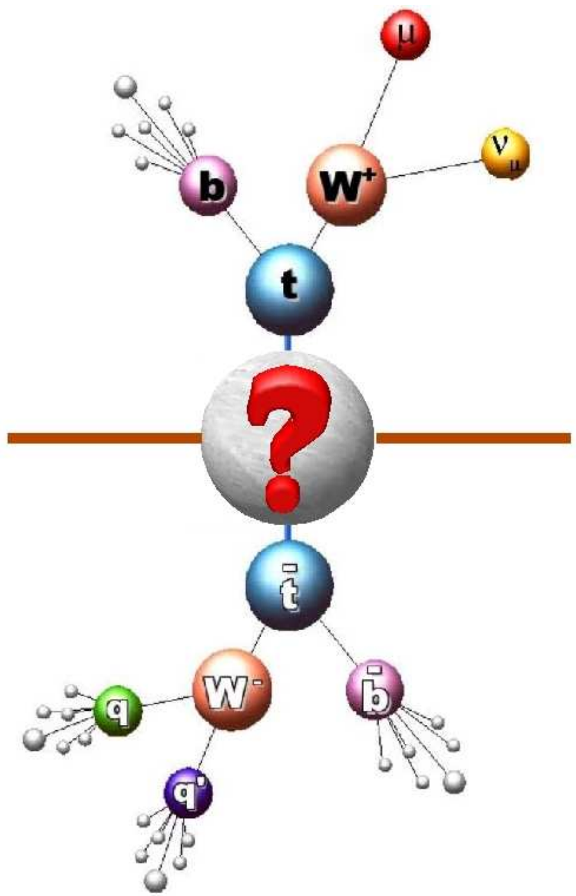
Top quarks decay to bW ($\sim$ 100%)

- Dilepton (2b + 2l + 2ν)
- Lepton+jets (2b + 2q + l + ν)
- Alljets (2b + 4q)



Resonant Production of Top Pairs

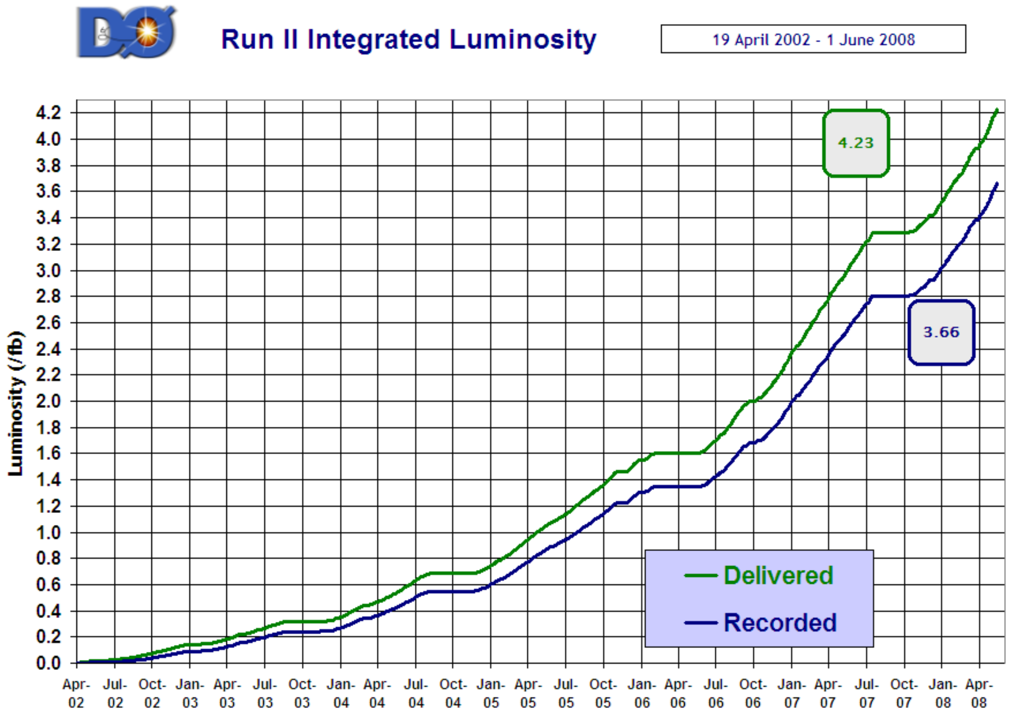
- No resonance production in $t\bar{t}$ expected in SM, but some models predict bound $t\bar{t}$-states
  - Axigluon
  - Coloron / KK-gluon
  - Top-color assisted technicolor: Z'
  - Graviton
  - ...
- Such a resonance should create a bump in differential cross-section $\frac{\mathrm{d}\sigma}{\mathrm{d}m_{t\bar{t}}}$



- Assume its width is smaller than detector mass resolution

Tevatron

- $p\bar{p}$-accelerator:
  - Circumference: 7 km
  - Run II since 2001
  - $\sqrt{s} = 1.96\,\mathrm{TeV}$
  - 2 Experiments:
    - CDF
    - DØ



$> 4\,\mathrm{fb}^{-1}$ integrated luminosity delivered

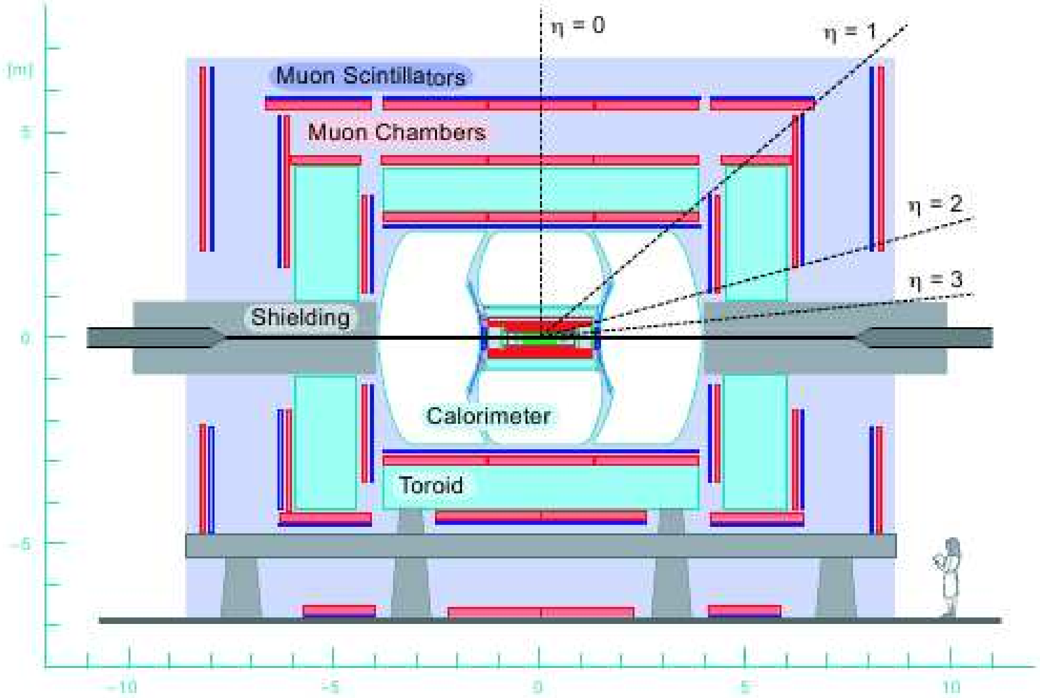
almost $4\,\mathrm{fb}^{-1}$ on disk

The DØ Detector

- 4π-detector
  $(20\,\mathrm{m} \cdot 12\,\mathrm{m} \cdot 12\,\mathrm{m})$

- Tracking: SMT & CFT
  - Tracks of charged particles
  - Secondary vertices

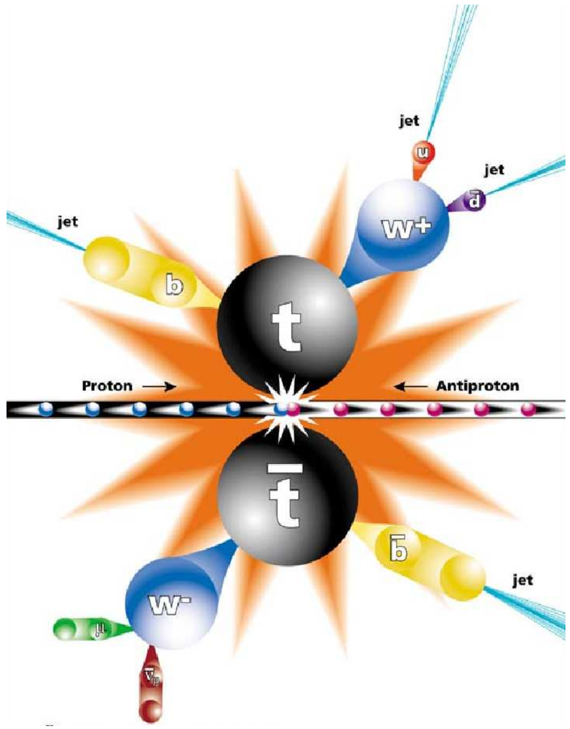
- Calorimeter: Sampling Ur/LAr
  - Energy of jets, electrons



- Muon spectrometer:
  3 layers of drift tubes & scintillators
  - Identification of μ's

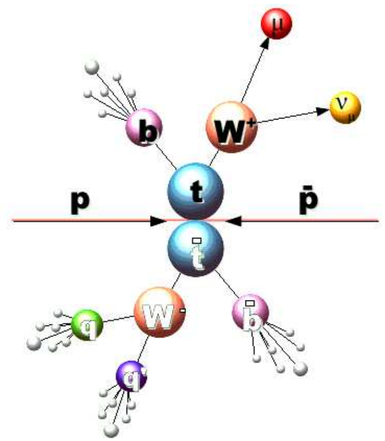
Selection of Data set

- Data set: $\sim 2.1\,\mathrm{fb}^{-1}$
- l+jets physics signature:
  lepton + neutrino + $\geq$ 4 jets
- Cuts for $t\bar{t}$ cross-section:
  - $\geq$ 3 jets with $p_T \geq 20$ GeV, $|\eta| < 2.5$
  - Leading jet $p_T \geq 40$ GeV
  - $\geq$ 1 b-tag
  - $\not{E}_T \geq$ 20 (25) GeV for e+jets (μ+jets)
  - One isolated lepton
    - Electron with $p_T \geq$ 20 GeV
    - μ with $p_T \geq$ 25 GeV

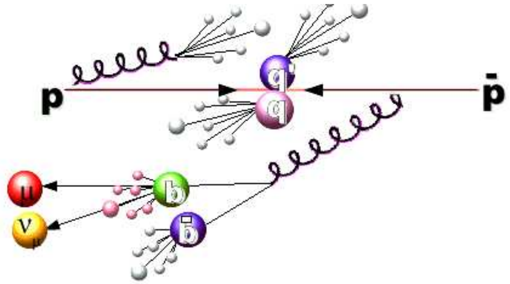


Background Estimation

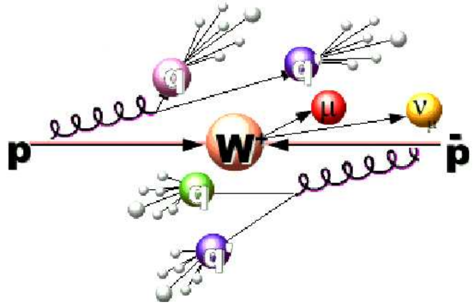
• $t\bar{t}$, Z+jets, single top and diboson:
MC normalized to NLO theoretical cross-section



• Multijet:
taken from data with depleted signal

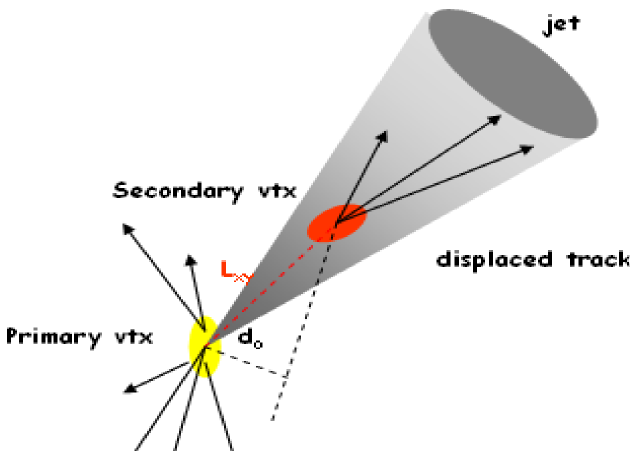


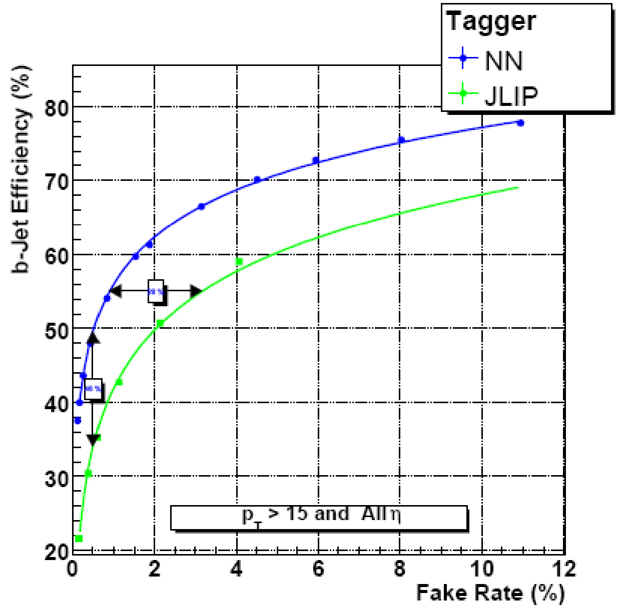
• W+jets:
cross-section normalised to data,
shape from Monte Carlo

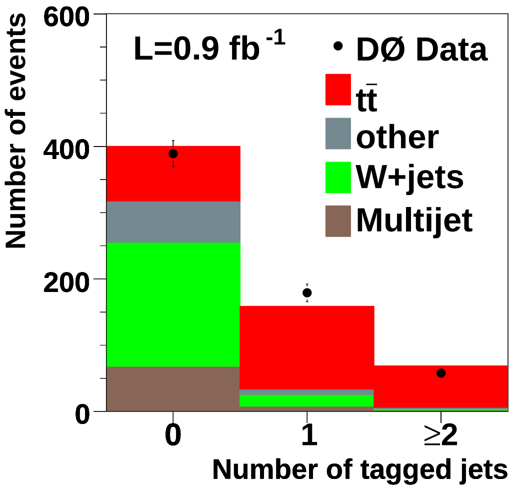


Neural Network b-tag Algorithm

- Use high lifetime of b of ∼1.6 ps
- Variables from several tagging algorithms:
  - Impact parameter significance of tracks
  - Probability jet originates from primary vertex
  - Secondary vertices properties
- Efficiency for tagging b-jets ∼ 54 % with a fake rate of ∼ 1.2 %

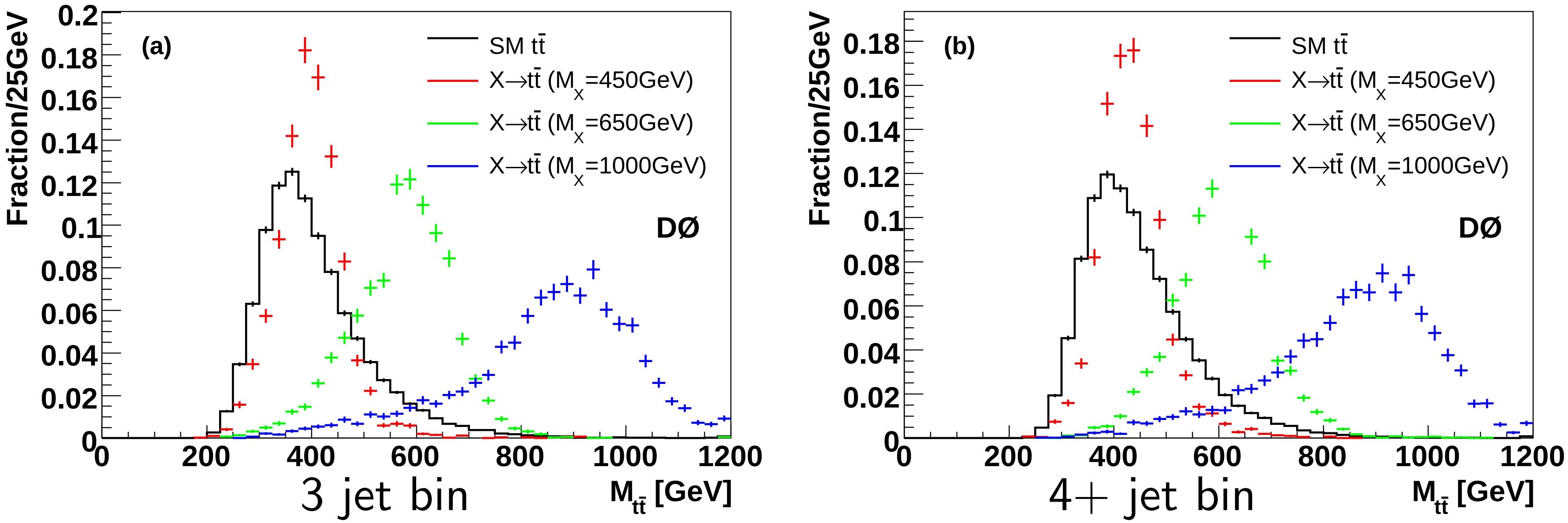






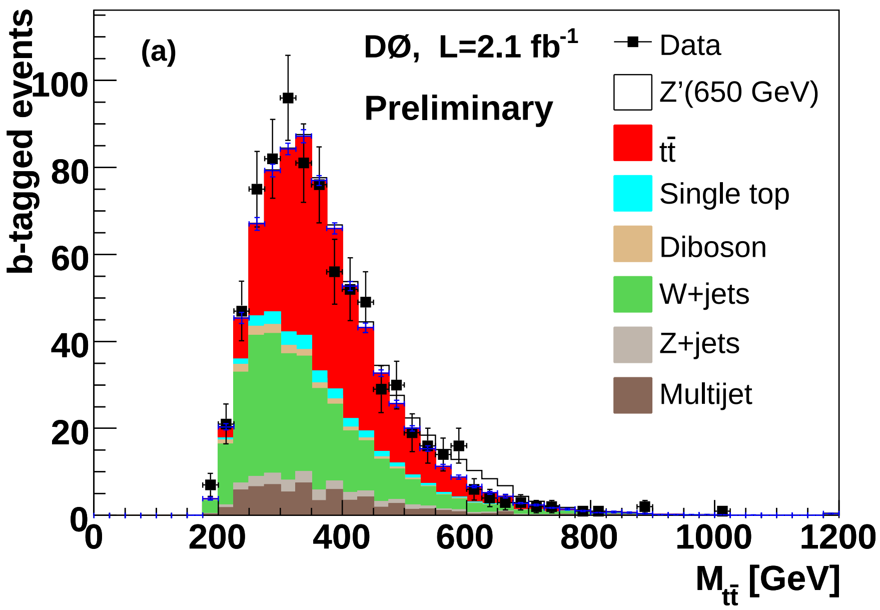
Reconstruction of Invariant Mass of the $t\bar{t}$ System

- Reconstruct $m_{t\bar{t}}$ directly from ℓ, ν and up to 4 leading jets (no constraint fit)
- Neutrino: p_x, p_y components from $\not{E}_T$ and p_z^ν from $M_W^2 = (p^\nu + p^l)^2$

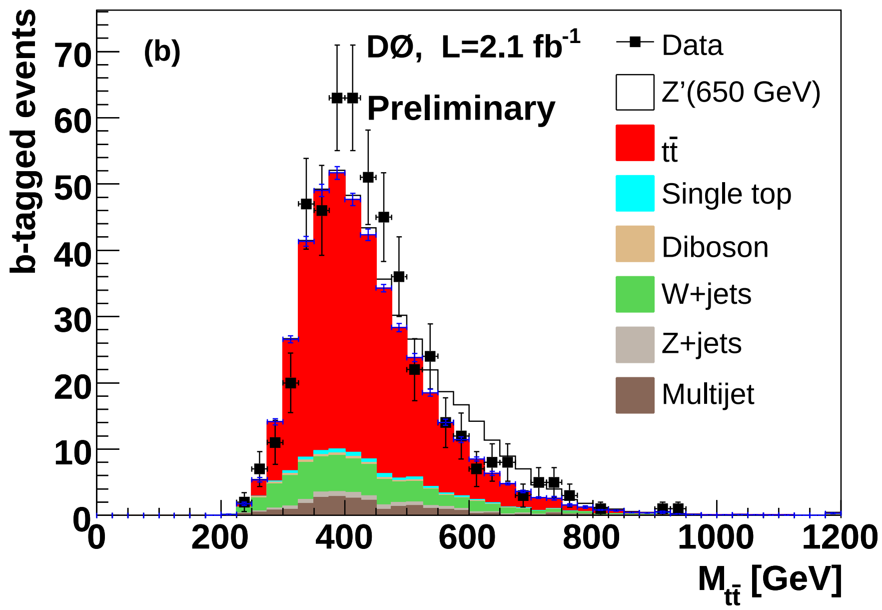


- Resonant production shows more narrow $M_{t\bar{t}}$ distributions than SM $t\bar{t}$
- With increasing resonance mass discrimination gets better, though resolution gets worse

Top Pair Invariant Mass Distribution



3 jet bin



4+ jet bin

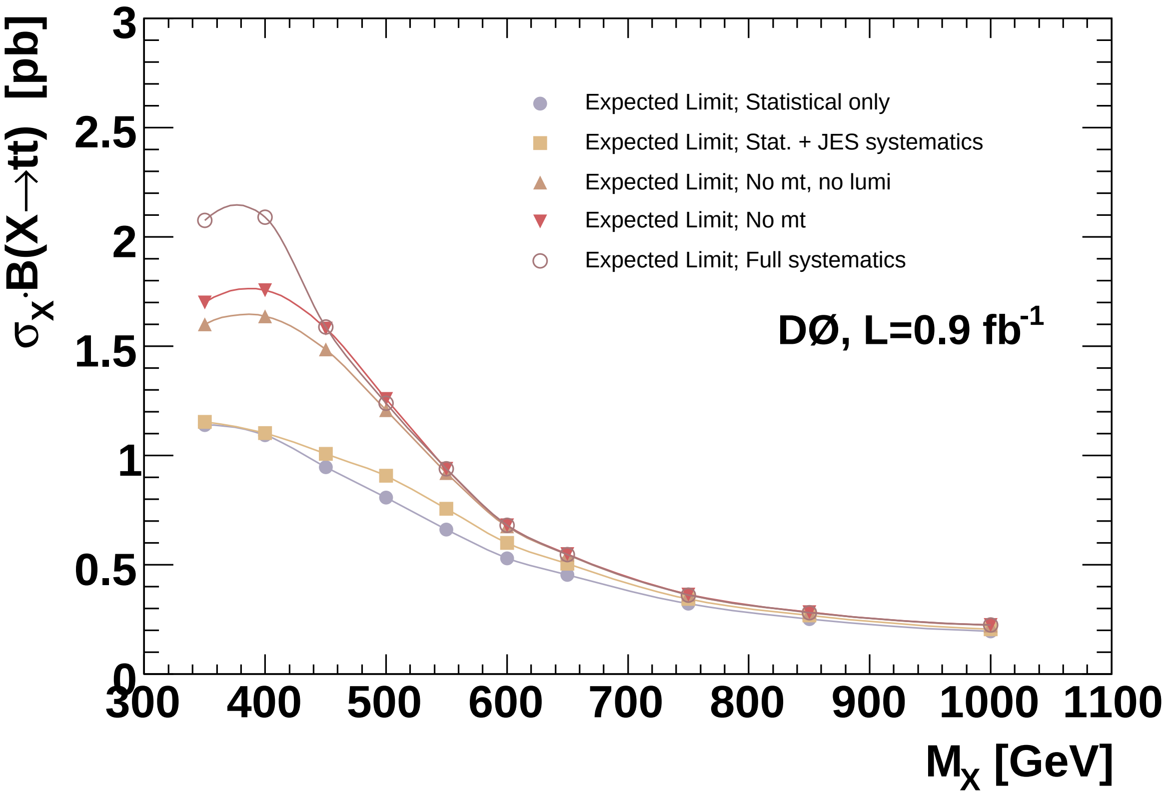
- No resonance signal is observed
- Set limits on resonance production

Limit calculation

- Invariant mass spectrum used for binned likelihood fit
- Bayesian approach used:
  - Use flat prior in $\sigma_X \times B(X \to t\bar{t}) \geq 0$
  - Keep upper bound of prior large enough stay away from boundary
  - Scan through resonance masses (350 - 1000 GeV)
  - Assume Poisson distributed events
  - Use multivariate Gaussian for systematics
  - Use posterior to calculate 95 % C.L. limit

Systematic Uncertainties (Expected Limits)

Expected limits are computed by using background prediction as “observation”

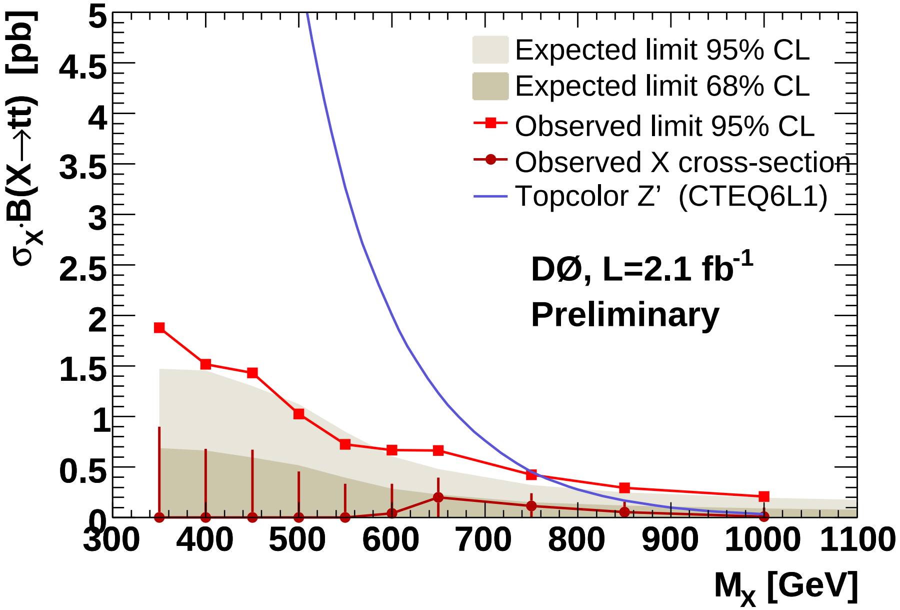


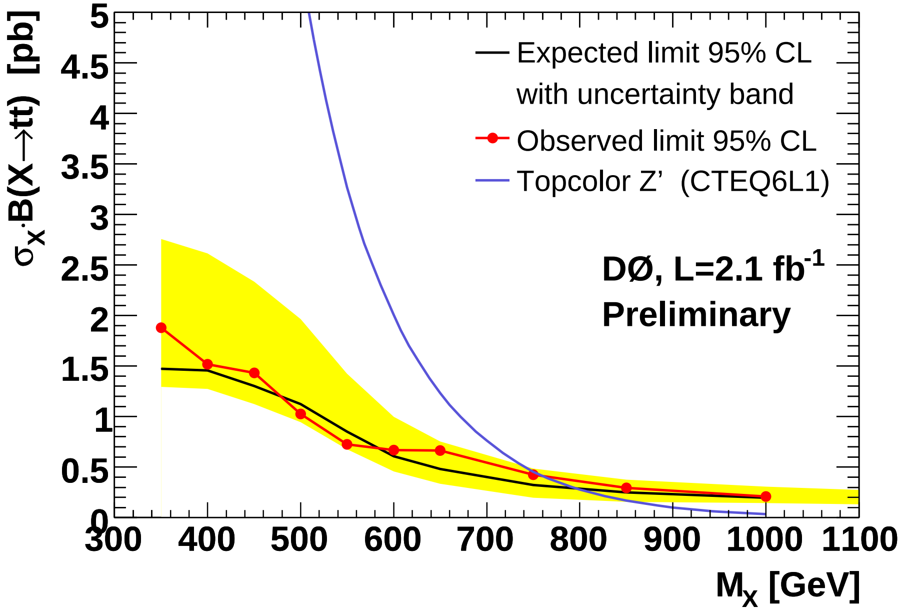
Systematics scale and/or change the background shape:

- JES affects medium M_X
- Luminosity, efficenies, ... scale like bkg shape
- m_t affects low M_X

High M_X stat. dominated

Top Resonance Results ($2.1\,\mathrm{fb}^{-1}$)





- All measured $\sigma_X \cdot B(X \to t\bar{t})$ close to zero (max. deviation $\sim 1\sigma$)
- Thus we set limits on $\sigma_X \cdot B(X \to t\bar{t})$ below 2 pb for all masses
- Benchmark Top-color assisted technicolor Z': Expected Limit: $M_{Z'} > 795$ GeV

Observed Limit: $M_{Z'} > 760$ GeV

CDF Observed Limit: $M_{Z'} > 725$ GeV

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Conclusion

- Search for $t\bar{t}$ resonances in the l+jets channel performed
- Measured distribution of $M_{t\bar{t}}$ in 2.1 fb^{-1} of DØ data
- No deviation from SM was observed, yet
- Limits are set for $\sigma \times BR(X \rightarrow t\bar{t})$
  - Topcolor assisted technicolor Z' yields:
    - Observed Limit: $M_{Z'} > 760\,\text{GeV}$
    - Cross-sections limits $\Rightarrow$