Measurement of the $t\bar{t}$ production cross section at DØ using kinematic information and a search for resonant $t\bar{t}$ production

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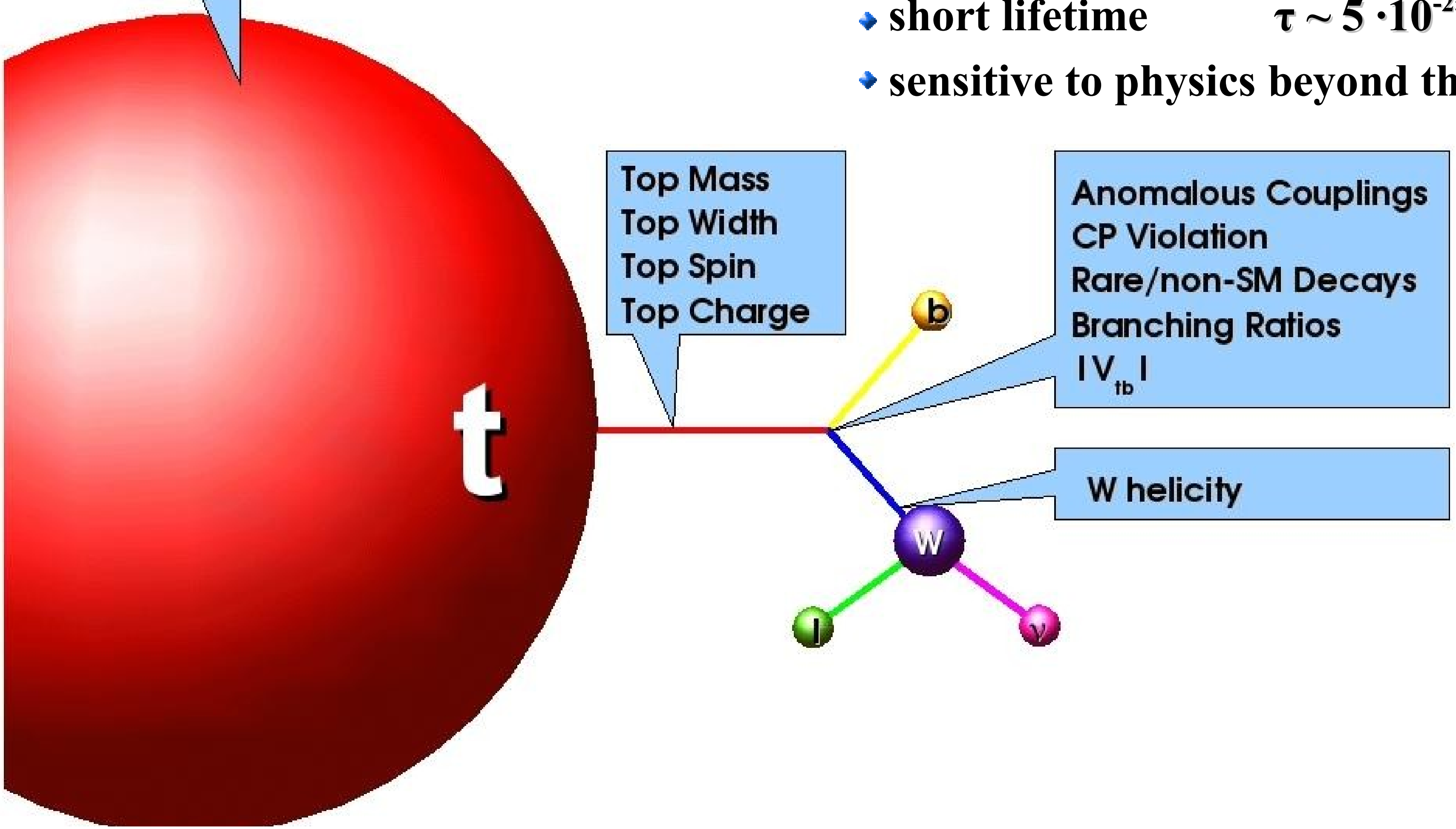
on behalf of the DØ collaboration

- Introduction
- Cross section measurement
- Search for $t\bar{t}$ resonance
- Conclusion

Top quark physics

Why is the top quark so interesting ?

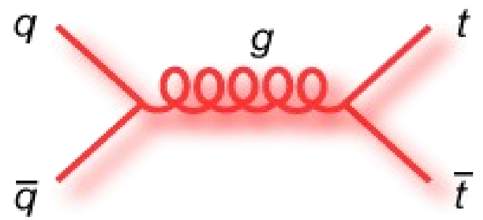
- completes the quark sector
- large mass $m_{top} = 171.4\ \mathrm{GeV}/c^2$
- short lifetime $\tau \sim 5 \cdot 10^{-25}\mathrm{s} \ll \Lambda^{-1}_{QCD}$
- sensitive to physics beyond the SM



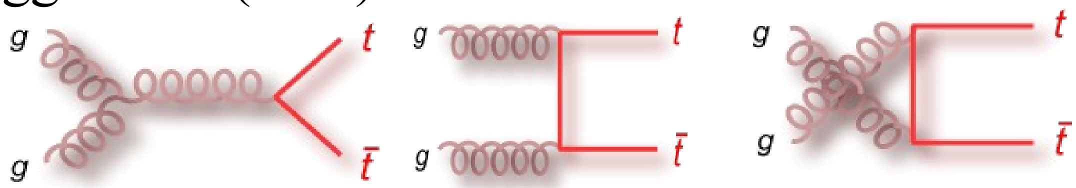
Production and Decay of $t\bar{t}$

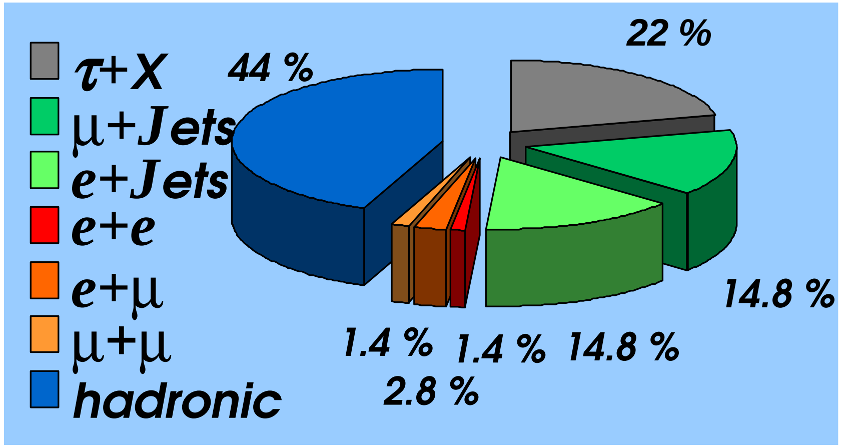
production:

$q\bar{q}$ annihilation (85%)



gg fusion (15%)





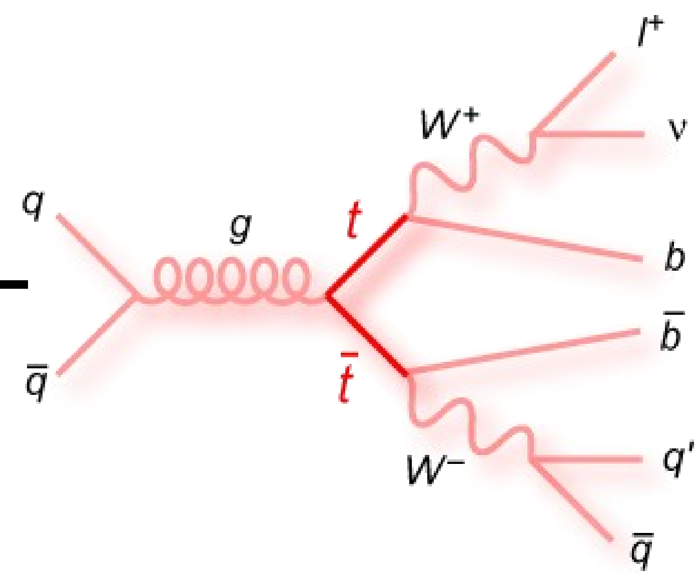
decay: top quarks decay in ~100% to a W boson and a b-quark

<u>$t\bar{t}$ decay signatures:</u>

`Dilepton channel'
5% : 2 jets, 2 charged leptons, 2 neutrinos

'Lepton+Jets channel'
30%: 4 jets, 1 electron or muon, 1 neutrino

'All jets channel'
44%: 6 jets

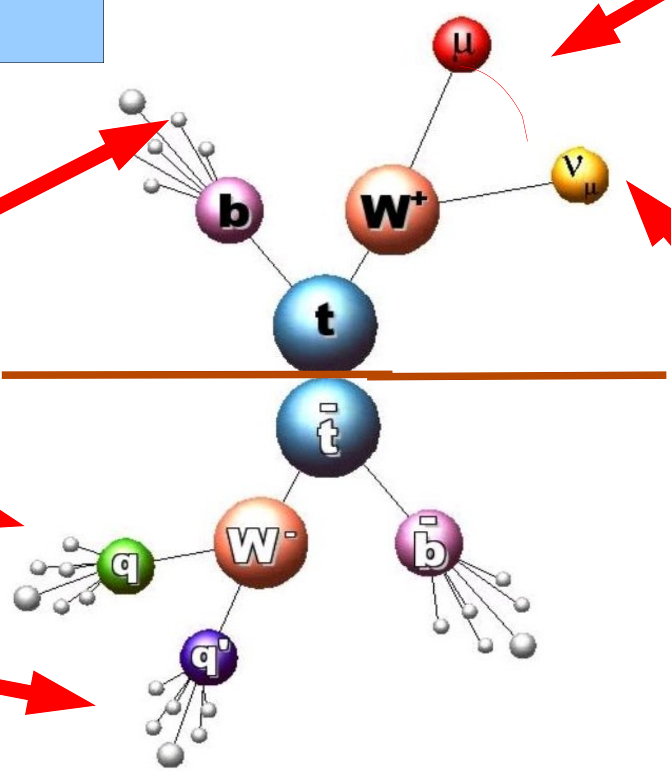


always 2 jets are b-jets

Event selection

loose lepton selection:
isolated e (μ), $p_T > 20$ GeV,
$|\eta| < 1.1$ (2.0),
no second high p_T lepton
additional tight quality cut

minimal angle $\Delta\varphi$



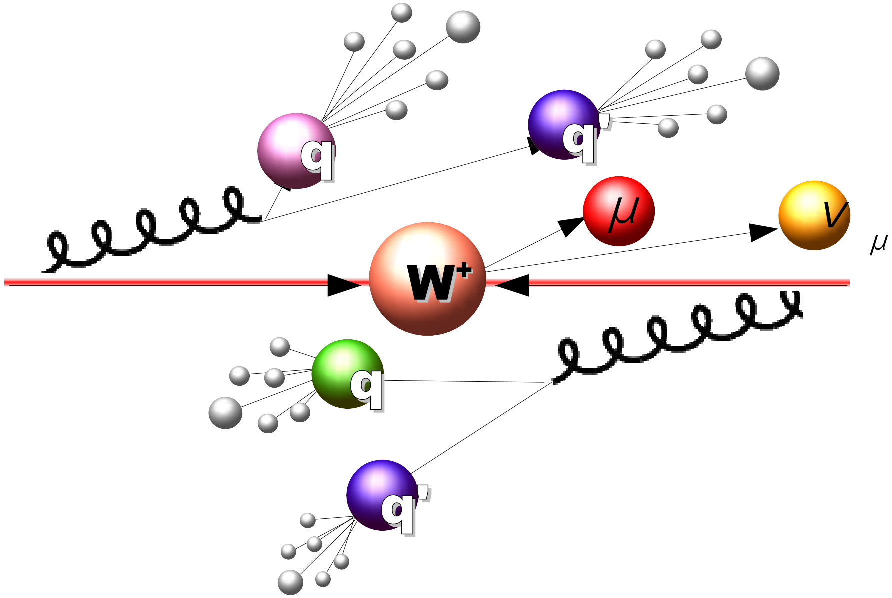
missing $E_T > 20$ GeV

at least 4 Jets,
$p_T > 20$ GeV,
$|\eta| < 2.5$

Background processes

- Physics background
  - electroweak W production
    + gluon radiation

$W \rightarrow l\nu + \geq 4$ Jets

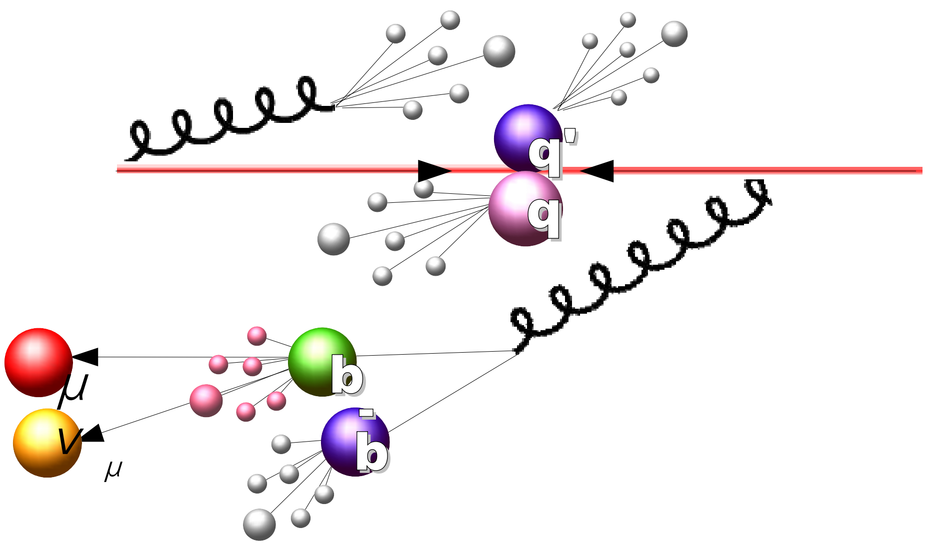


- Instrumental background

  multijet production

  + fake electrons or fake
    isolated muons

  + misreconstructed MET



Estimation of multijet background

- multijet background is estimated from data
  - loose and tight lepton selection

$$N_{loose} = N_{multijet} + N_{Wjet+t\bar{t}}$$

ε (loose → tight)

$\varepsilon_{multijet}$ = 0.18 for e+jets, 0.24 for μ+jets, estimated from data

$\varepsilon_{Wjet+t\bar{t}}$ = 0.84 for e+jets, 0.85 for μ+jets, estimated from MC

$$N_{tight} = \varepsilon_{multijet} * N_{multijet} + \varepsilon_{Wjet+t\bar{t}} * N_{Wjet+t\bar{t}}$$

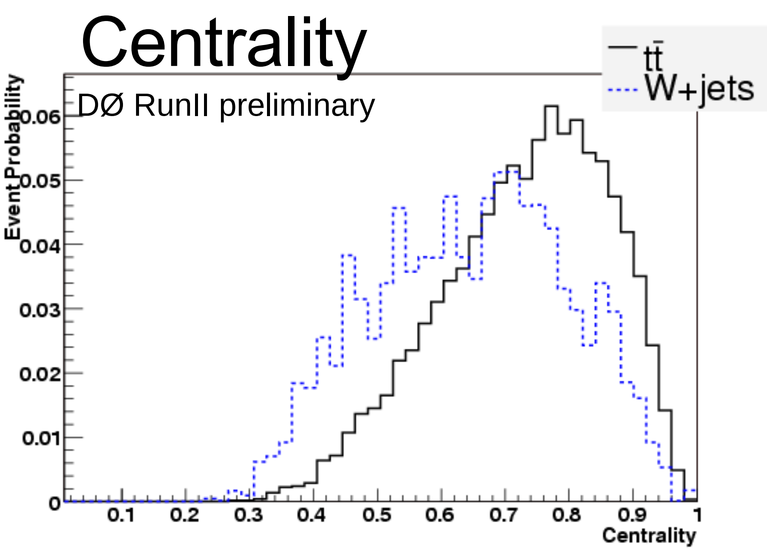
- solve system of linear equations for $N_{multijet}$ and $N_{Wjet+t\bar{t}}$
- fixes the ratio between multijet and W+jets background

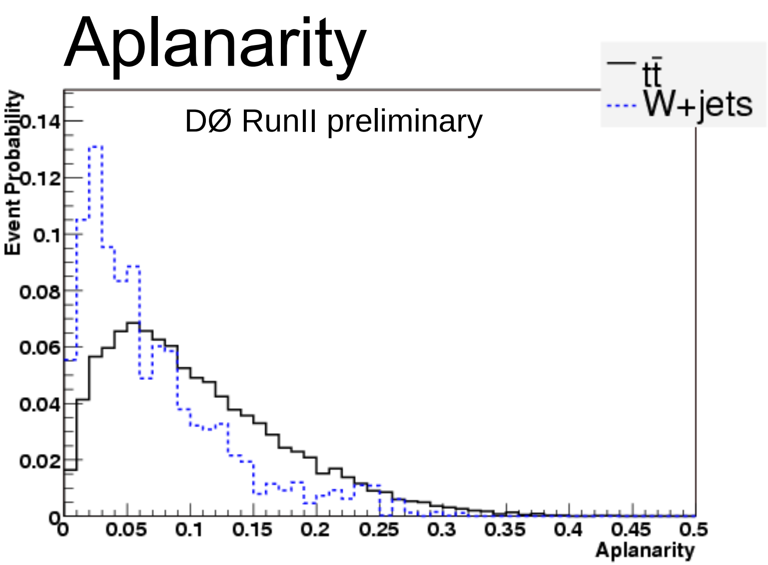
Topological variables

- use topological event information to separate $t\bar{t}$ from the background
  - use variables with good discrimination power
  - low sensitivity to the jet energy scale

➔variables describing angular distributions of final state objects

➔ratios of energy dependent variables

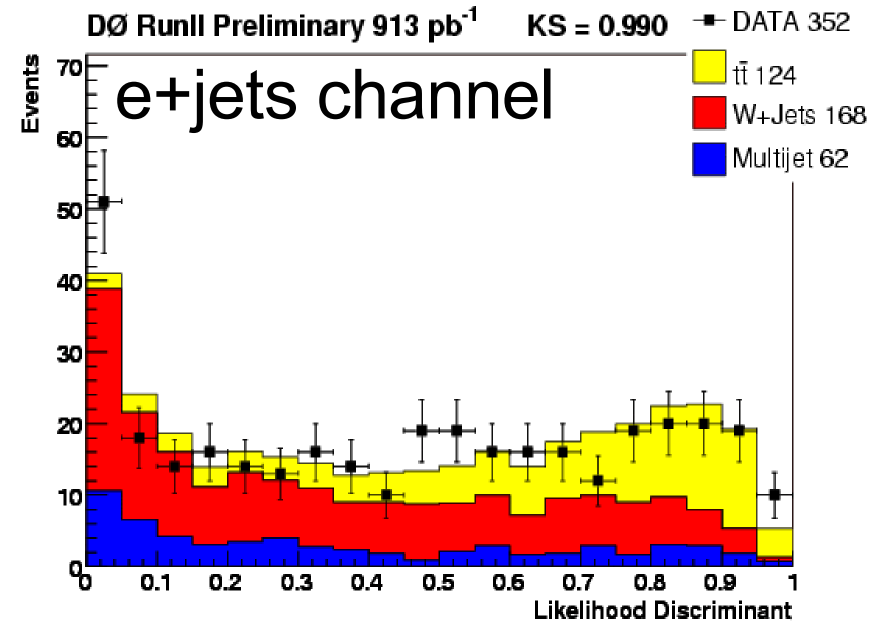


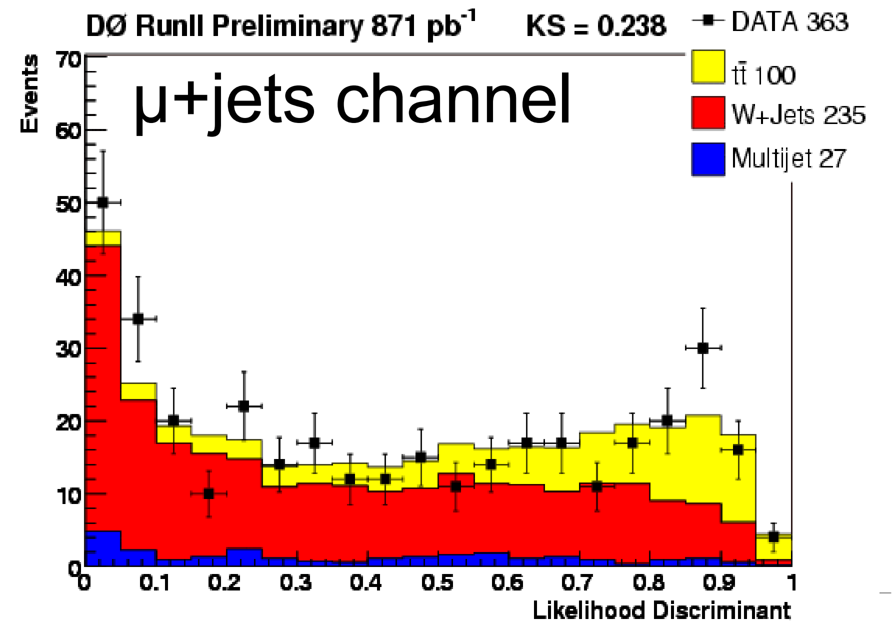


Likelihood

- combine topological variables in a likelihood discriminant
- perform a fit to the data to extract the number of $t\bar{t}$ events

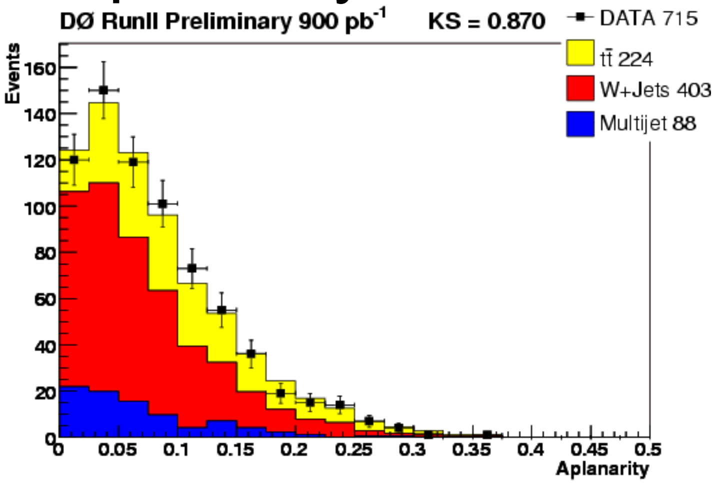
	e + jets	μ + jets
L	913 pb^{-1}	871 pb^{-1}
N_{total}	352	363
$f_{t\bar{t}}$	35 ± 6 %	28 ± 6 %
f_{W+jet}	48 ± 7 %	65 ± 7 %
$f_{multijet}$	17 ± 1 %	7 ± 1 %



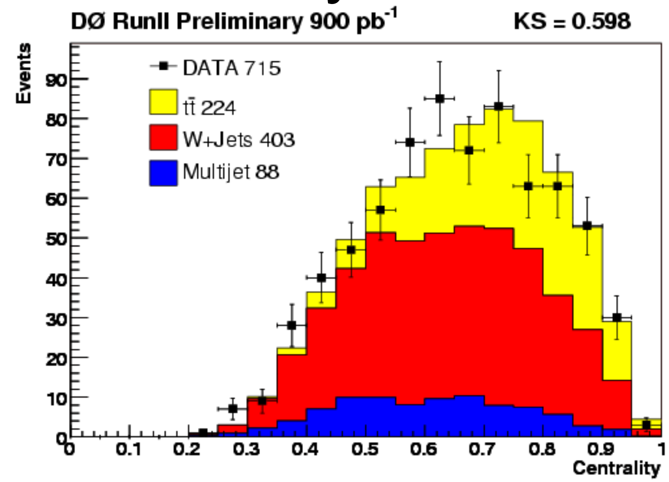


Control Plots l+jets

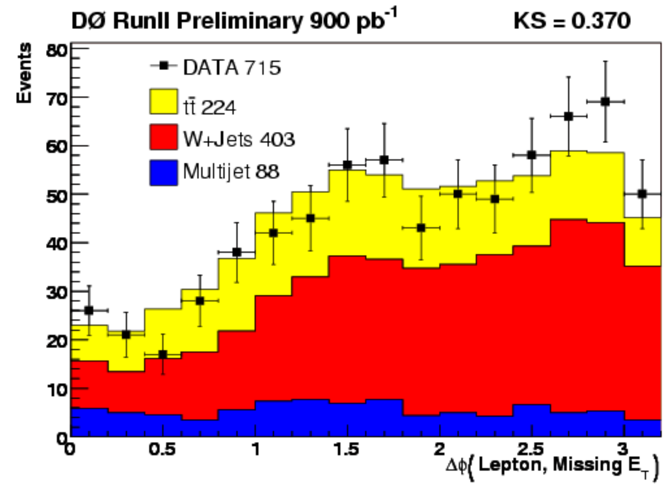
Aplanarity



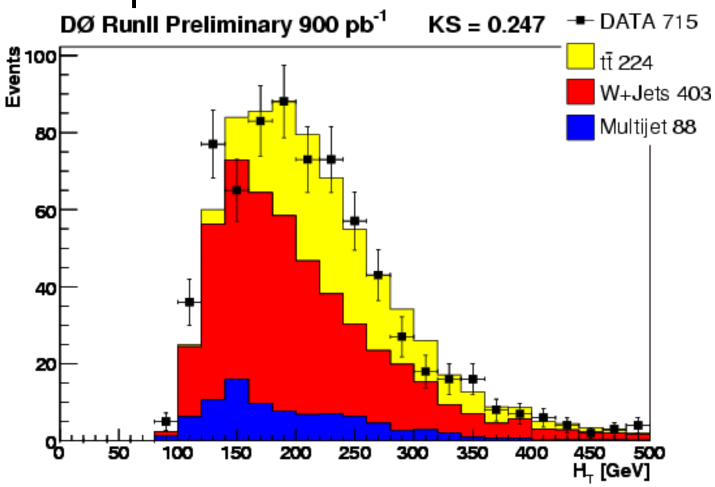
Centrality



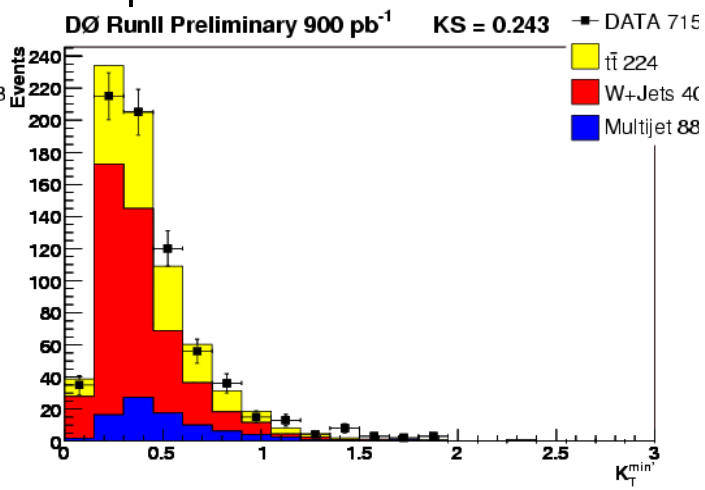
Δφ(lepton,met)



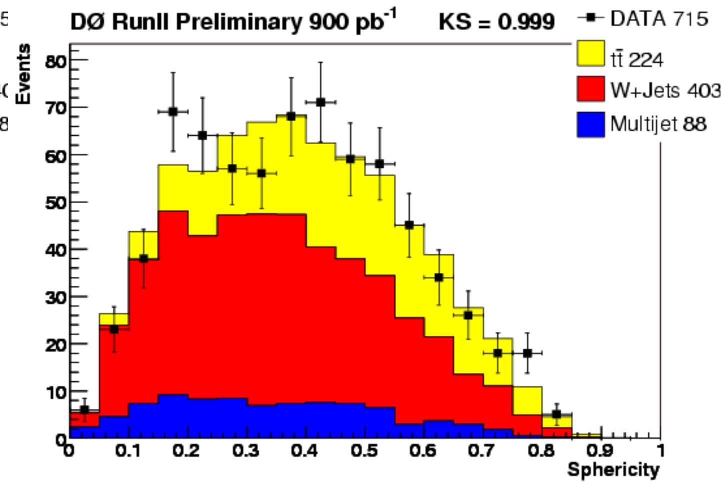
H_T



$K_T^{min'}$



Sphericity



Results

- cross section for m_{top} = 175 GeV
- dominating systematic uncertainties:
  - W+jet background modeling ~ ± 0.5 pb
  - Lepton identification ~ ± 0.3 pb
  - MC statistics ~ ± 0.3 pb

e + jets $\sigma_{p\bar{p}\to t\bar{t}+X} = 6.6\,^{+1.2}_{-1.1}\,(\text{stat}) \pm 0.8\,(\text{syst}) \pm 0.4\,(\text{lumi})$ pb

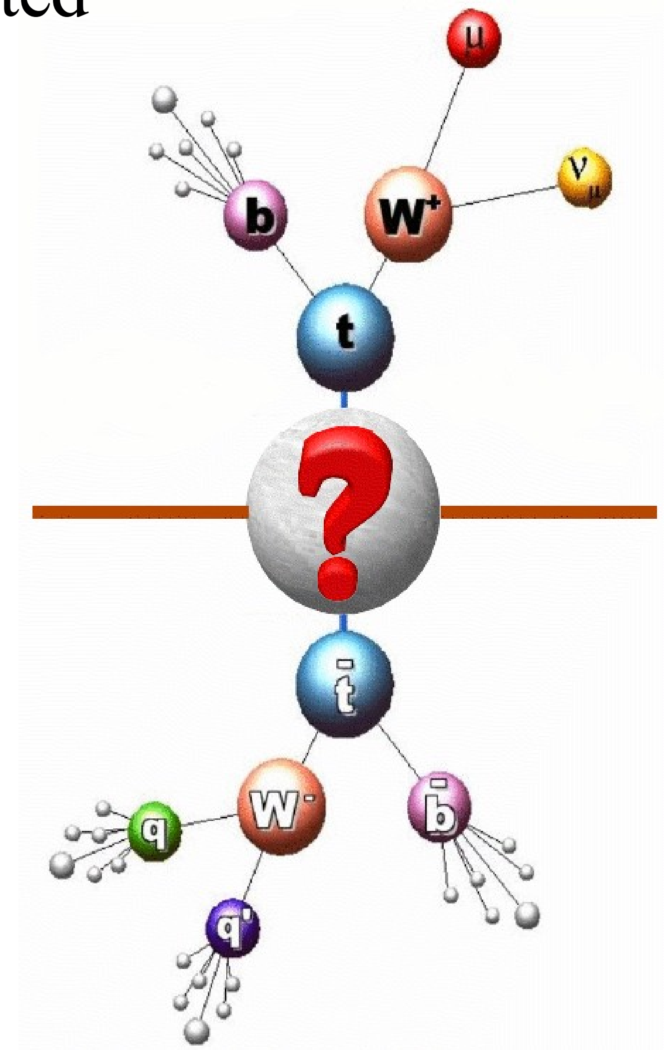
μ + jets $\sigma_{p\bar{p}\to t\bar{t}+X} = 5.9\,^{+1.3}_{-1.2}\,(\text{stat})\,^{+0.9}_{-0.8}\,(\text{syst}) \pm 0.4\,(\text{lumi})$ pb

combined $\sigma_{p\bar{p}\to t\bar{t}+X} = 6.3\,^{+0.9}_{-0.8}\,(\text{stat}) \pm 0.7\,(\text{syst}) \pm 0.4\,(\text{lumi})$ pb

- agrees with theoretical SM prediction of σ_{theo} =6.8 ± 0.6pb

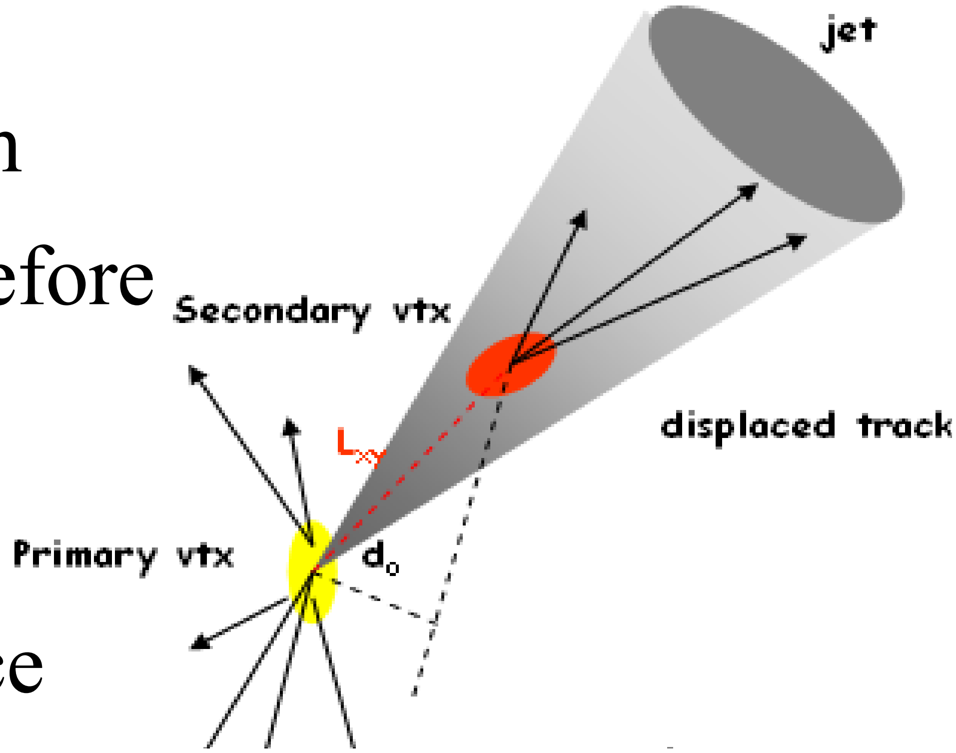
$t\bar{t}$ Resonances

- no resonance production in $t\bar{t}$ system is expected in SM
  - would result in larger $\sigma_{p\bar{p}\rightarrow t\bar{t}+X}$ than predicted
  - uncertainties leave room for a resonance
- some models predict $t\bar{t}$ bound states
  - e.g. topcolor-assisted technicolor predicts leptophobic Z'
    Harris, Hill, Parke hep-ph 9911288
- search for resonance signal in invariant mass distribution of the $t\bar{t}$ decay products in l+jets channel
- $X\rightarrow t\bar{t}$ with narrow width i.e. smaller than mass resolution of the detector



b-Jet Identification

- use b-tagging instead of event kinematics
  - good for background reduction
- lifetime of B hadrons ~ 450 μm
- B hadrons travel L_{xy} ~ 3 mm before they decay
- reconstruction of 3D vertices
- cut on decay length significance
- require at least one b-tagged jet per event
  - efficiency in a $t\bar{t}$ event is ~ 60 %, in a W+jets event only ~ 5 %

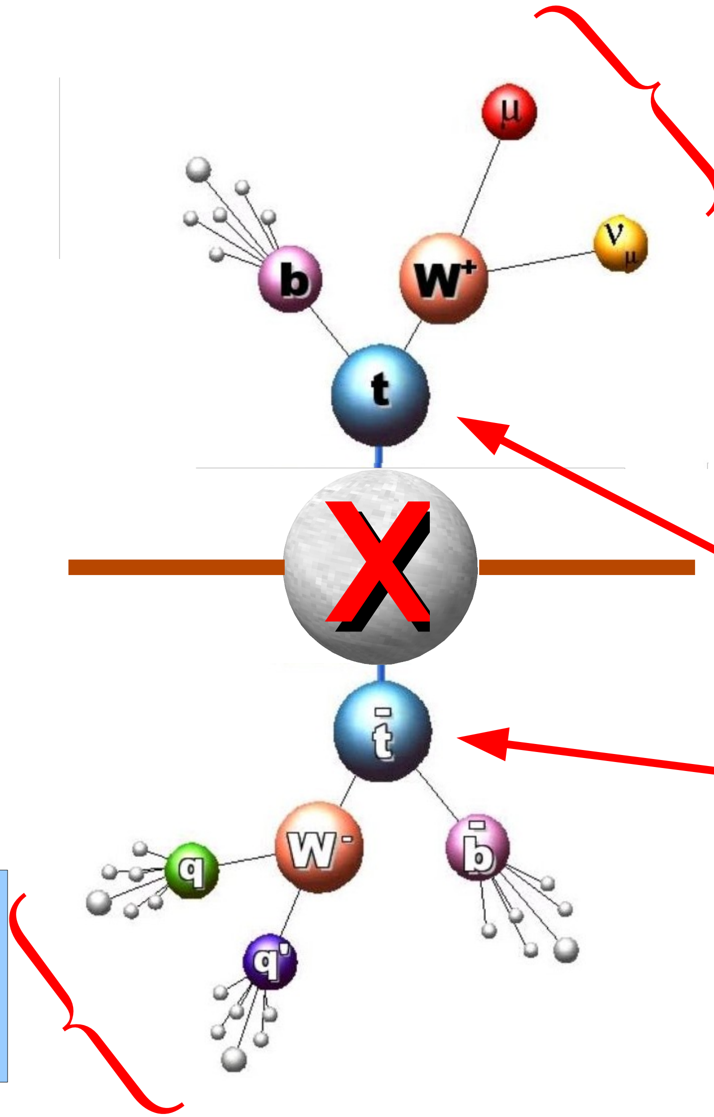


Reconstruction of the invariant $t\bar{t}$ mass

<u>12 jet-parton assignments:</u>

kinematic fit

lowest χ^2



mass of the W Boson

(2 ν solutions)

m_{top} = 175 GeV

mass constraint

mass of the W boson

Results for l+jets

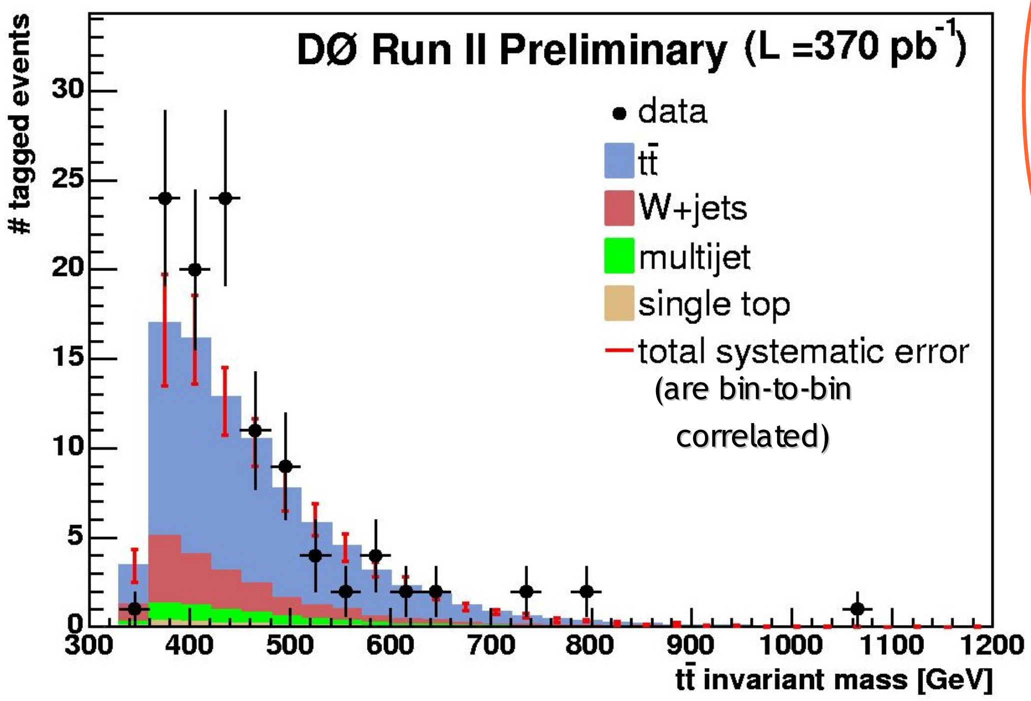
Data and SM:

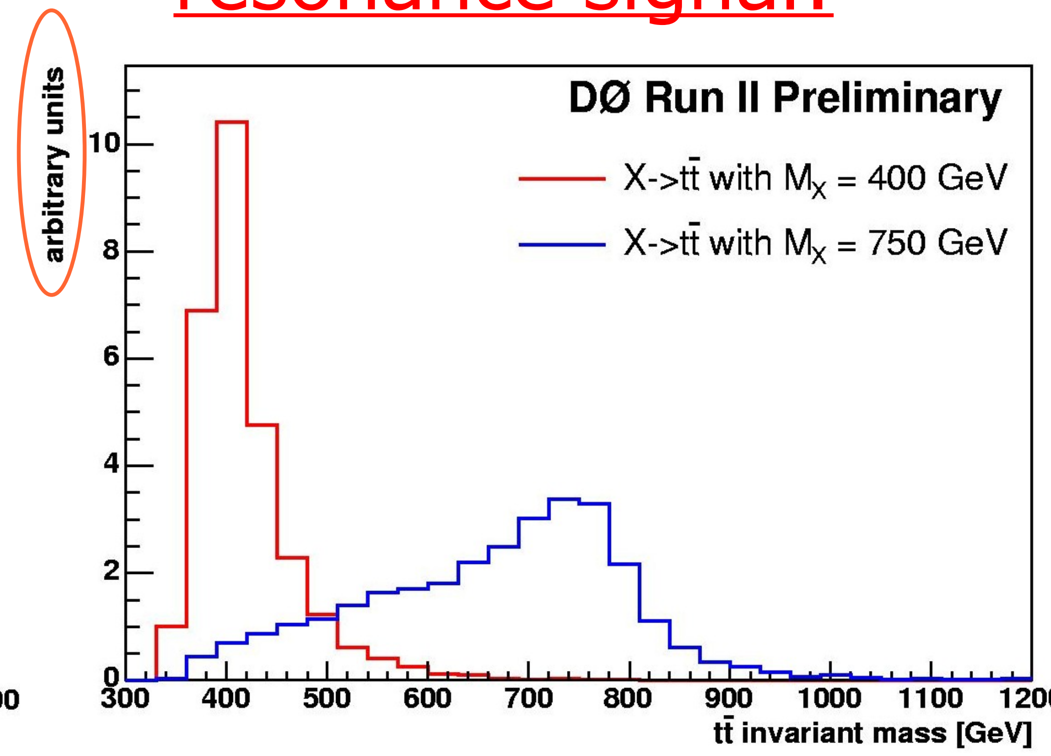
L=370pb^{-1}

SM: use $t\bar{t}$ cross section

6.8 ± 0.6 pb (NNLO)

MC expectation for resonance signal:





⇒ e, μ+jets combined: 108 events, $89.2^{+11.7}_{-13.2}$ expected

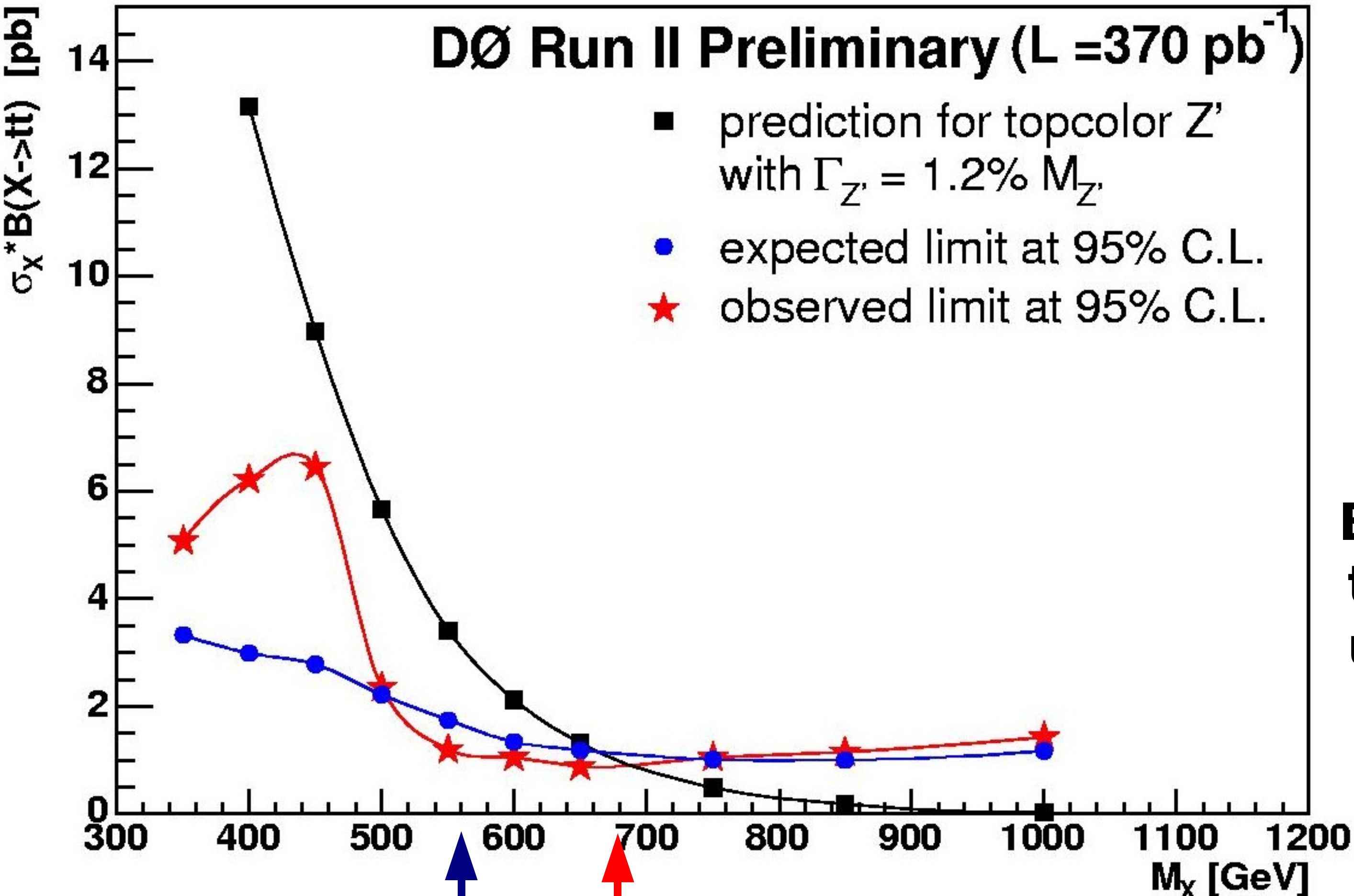
Systematic uncertainties

- relative systematic change on overall normalization of SM background:

source	rel. syst. uncertainty (%)	
	σ^+	σ^-
Top quark mass (includes effect on $\sigma_{t\bar{t}}$)	+8.7	−7.6
Signal subtraction from W+jets background estimate	+0.0	−6.6
Jet reconstruction	+5.6	−6.9
Luminosity	+4.6	−4.6
Theoretical uncertainty on $\sigma_{t\bar{t}}$	+4.2	−4.2
W+jets flavor composition	+2.9	−3.0
Jet energy calibration	+2.7	−3.2
b-tagging rate	+2.6	−2.6
MC-to-data correction factors	+2.5	−2.5
Theoretical uncertainty on $\sigma_{singletop}$	+0.2	−0.2
Total	+13.2	−14.8

- uncertainties which change shape of invariant mass distribution are also taken into account

Limits for l+jets



$\Gamma_X = 0.012\ M_X$

Bayesian approach to calculate 95% C.L. upper limits

DØ Run I **DØ Run II**

⇒ $M_{Z'}$ > 680 GeV

Conclusion

- Measurement of $t\bar{t}$ cross section in l + jets events with nearly 1 fb^{-1} of data

$$\sigma_{p\bar{p}\rightarrow t\bar{t}+X} = 6.3 \,^{+0.9}_{-0.8}\,(\text{stat}) \pm 0.7\,(\text{syst}) \pm 0.4\,(\text{lumi})\ \text{pb}$$

DØ RunII preliminary

- Search for $t\bar{t}$ production via intermediate resonance with 370 pb^{-1} of data
  - no evidence for a new resonance
  - cross section limits
  - leptophobic Z': $M_{Z'} > 680$ GeV