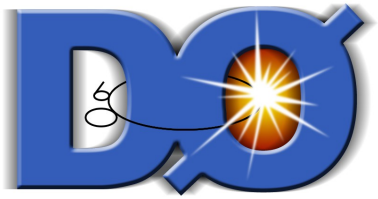


Top Quark Results at the Tevatron

Ernest Aguiló

York University

on behalf of the CDF & DØ collaborations

YORK UNIVERSITÉ UNIVERSITY

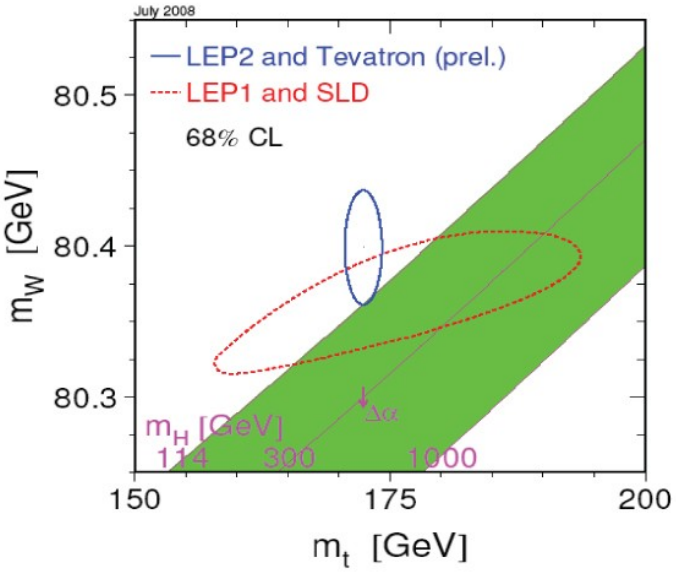
Outline

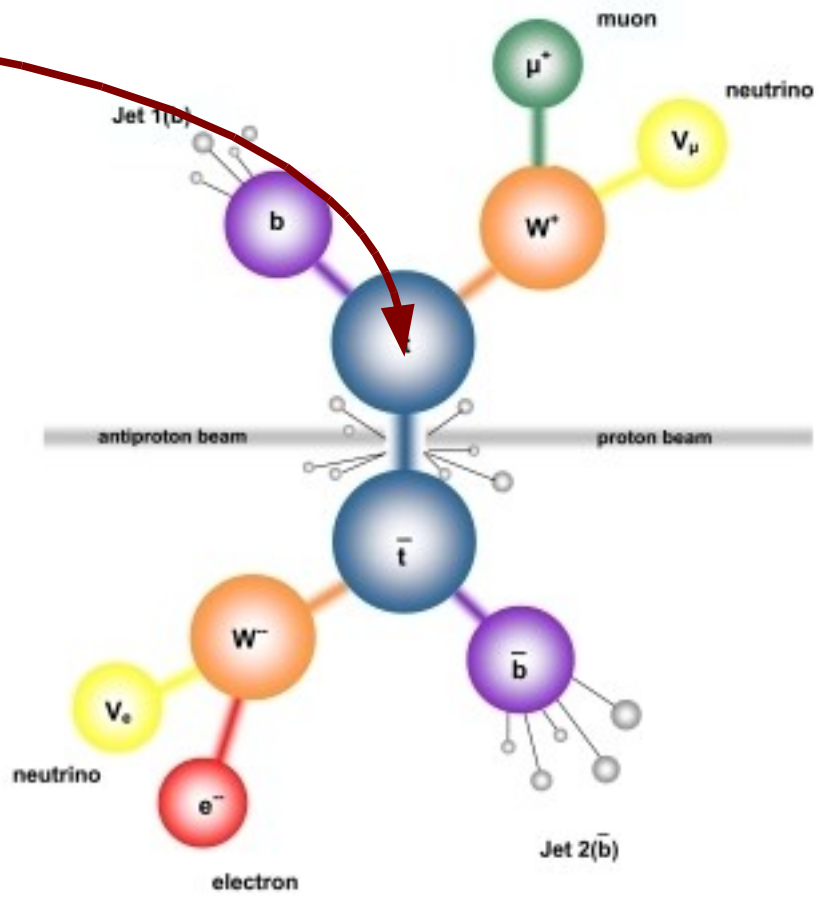
- Introduction & motivation
- Top pair results:
  - Mass
  - Cross section
  - Properties
- Single top observation
- Summary

Introduction & Motivation

Introduction & Motivation

- Top quark discovery in 1995 by CDF & DØ
- Mass
  - Heaviest elementary particle
  - Important SM parameter

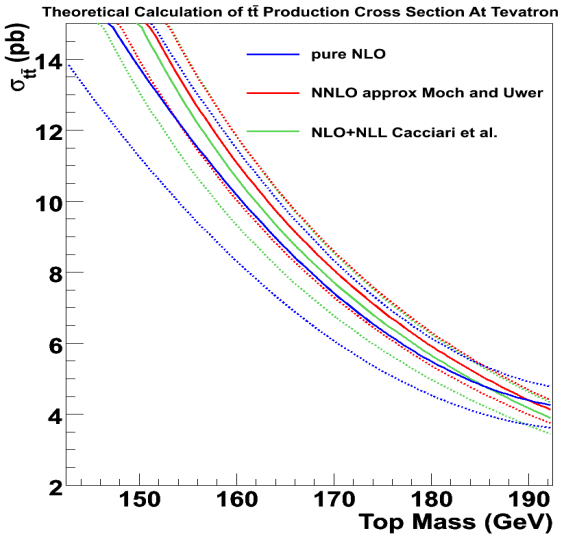


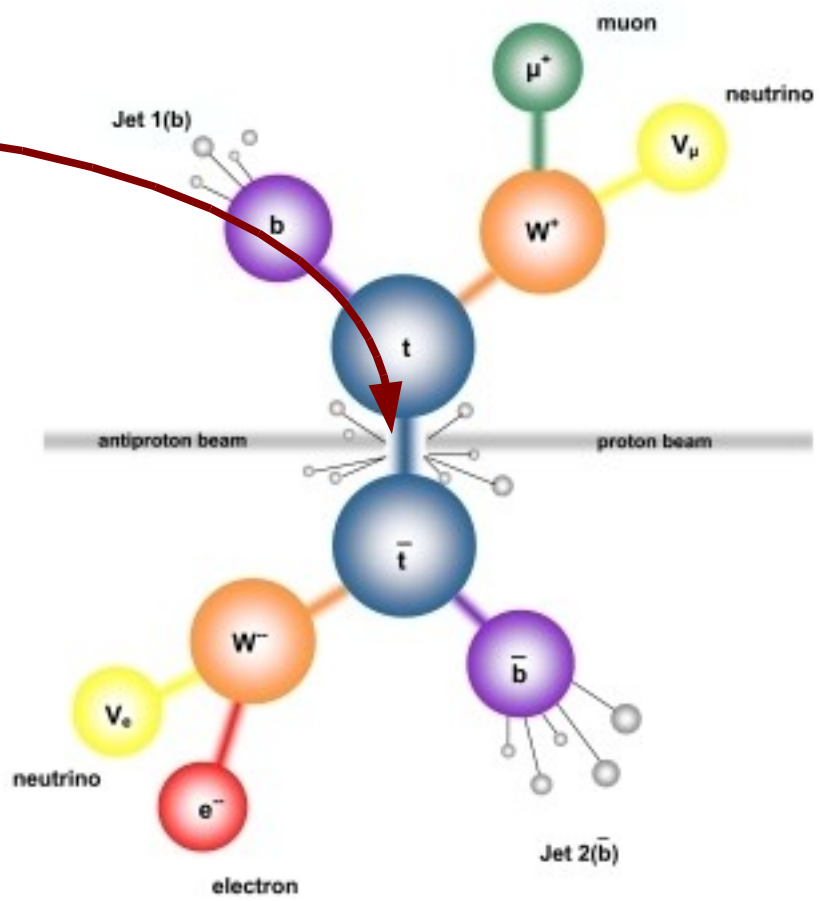


- Cross section
- Properties & other

Introduction & Motivation

- Top quark discovery in 1995 by CDF & DØ
- Mass
- Cross section
  - SM test

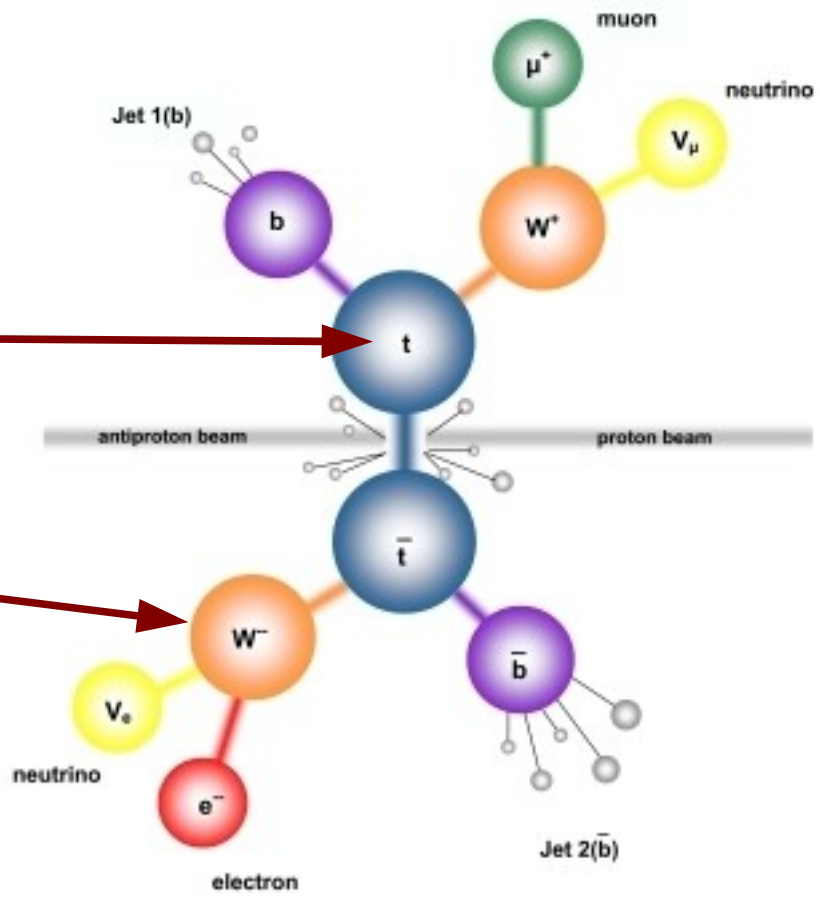




  - Background to Higgs & PBSM
  - Resonance production
  - FB asymmetry
- Properties & other

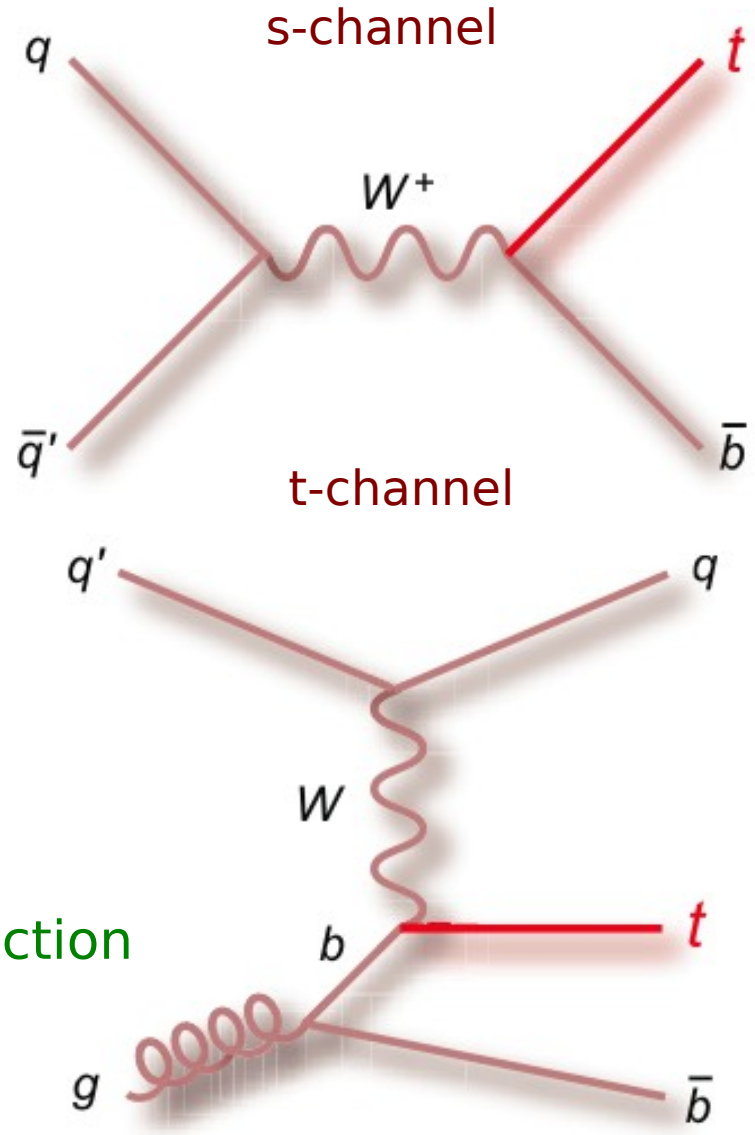
Introduction & Motivation

- Top quark discovery in 1995 by CDF & DØ
- Mass
- Cross section
- Properties & Beyond SM
  - Charge
  - Lifetime
  - W helicity
  - Non SM decay
  - 4^{th} generation
  - FCNC, W'
  - Charged Higgs H^+

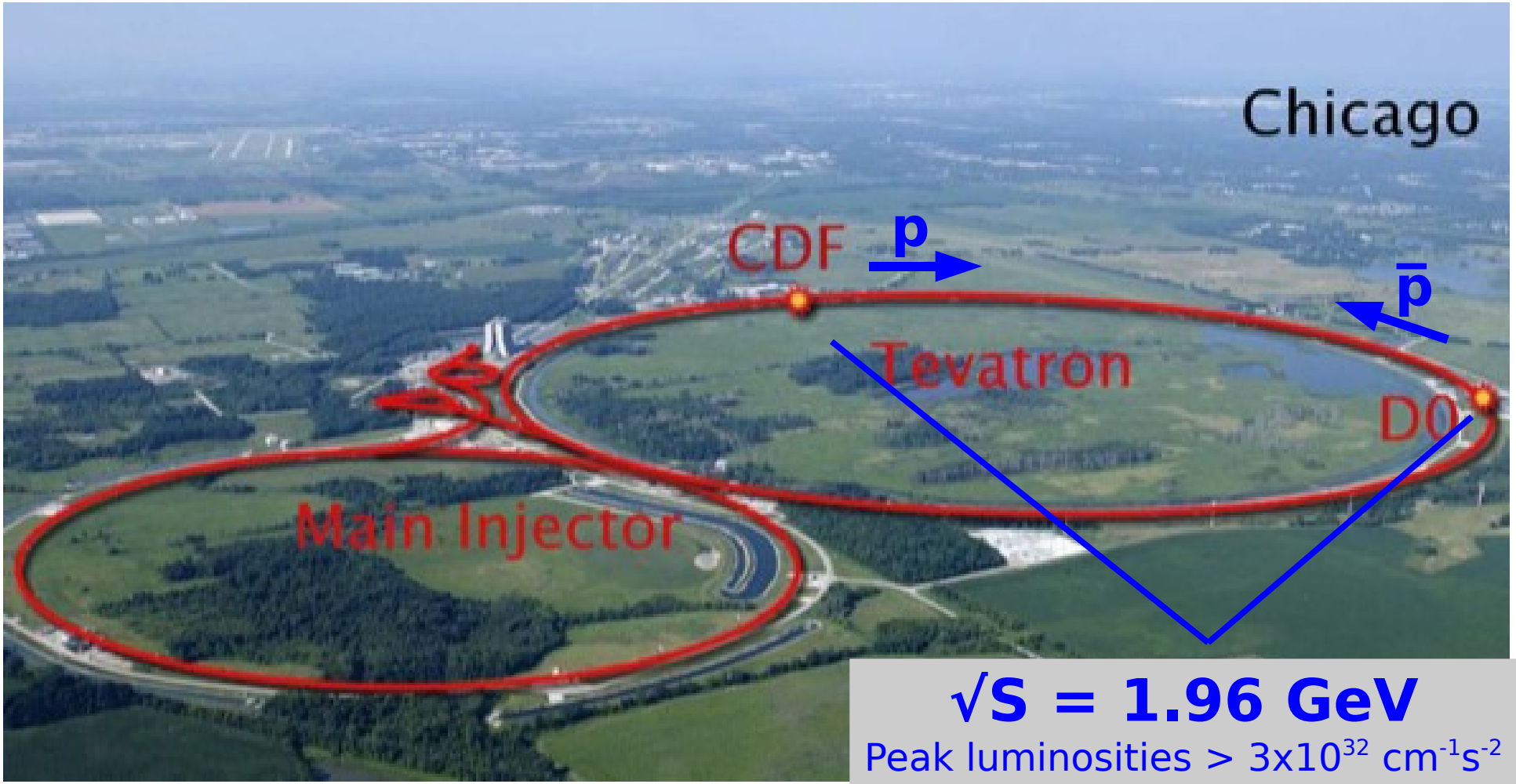


Introduction & Motivation

- Single top electroweak production mechanism predicted by SM
- Evidence in 2006
- Very Challenging:
  - High backgrounds & few jets
  - Need sophisticated discriminants
- Interest:
  - Access to Wtb coupling:
    - Direct measurement of $|V_{tb}|$
  - Top properties
  - Background to WH associated production
  - Sensible to New Phenomena:
    - FCNC, t', W', H^+,



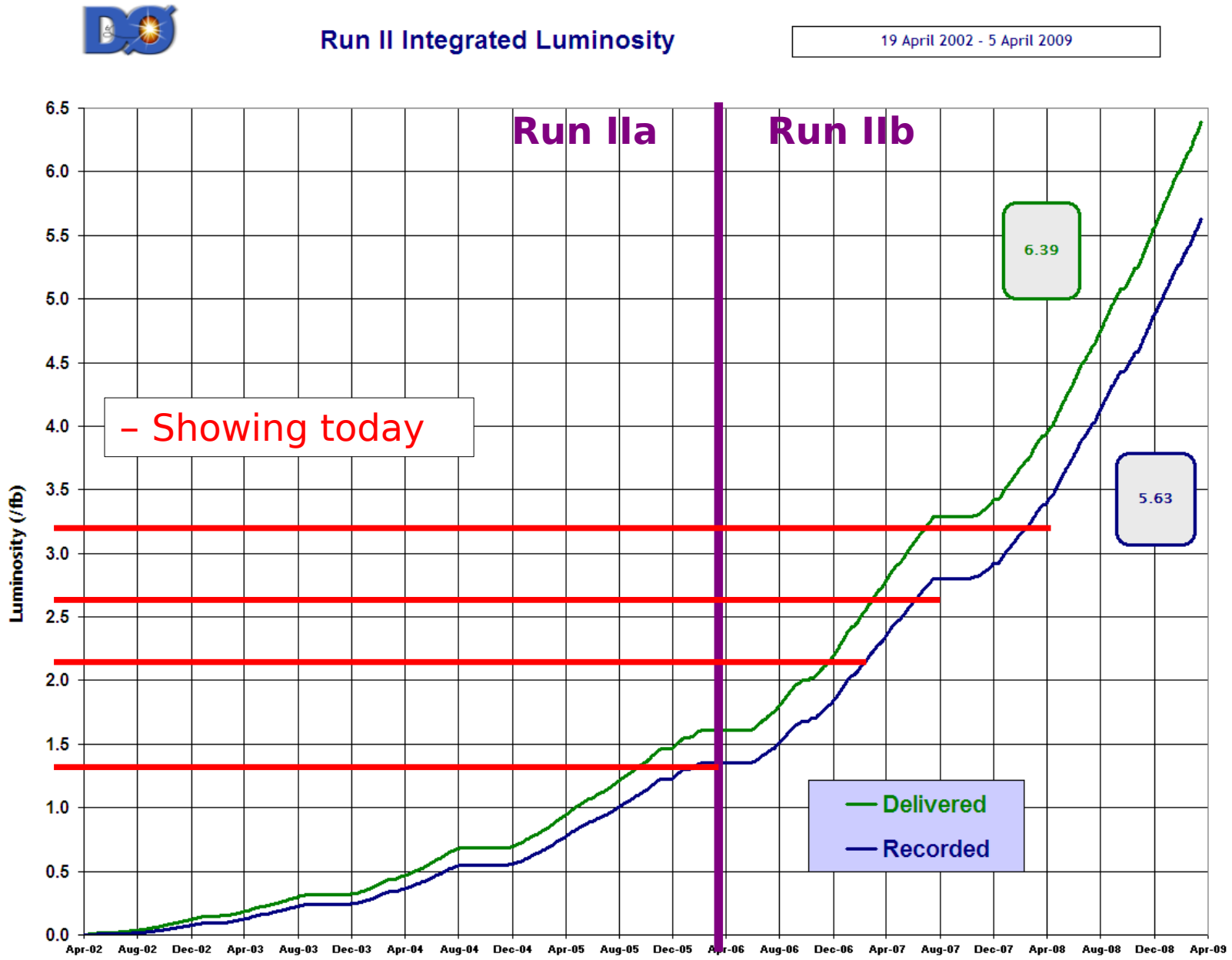
Introduction: the Tevatron



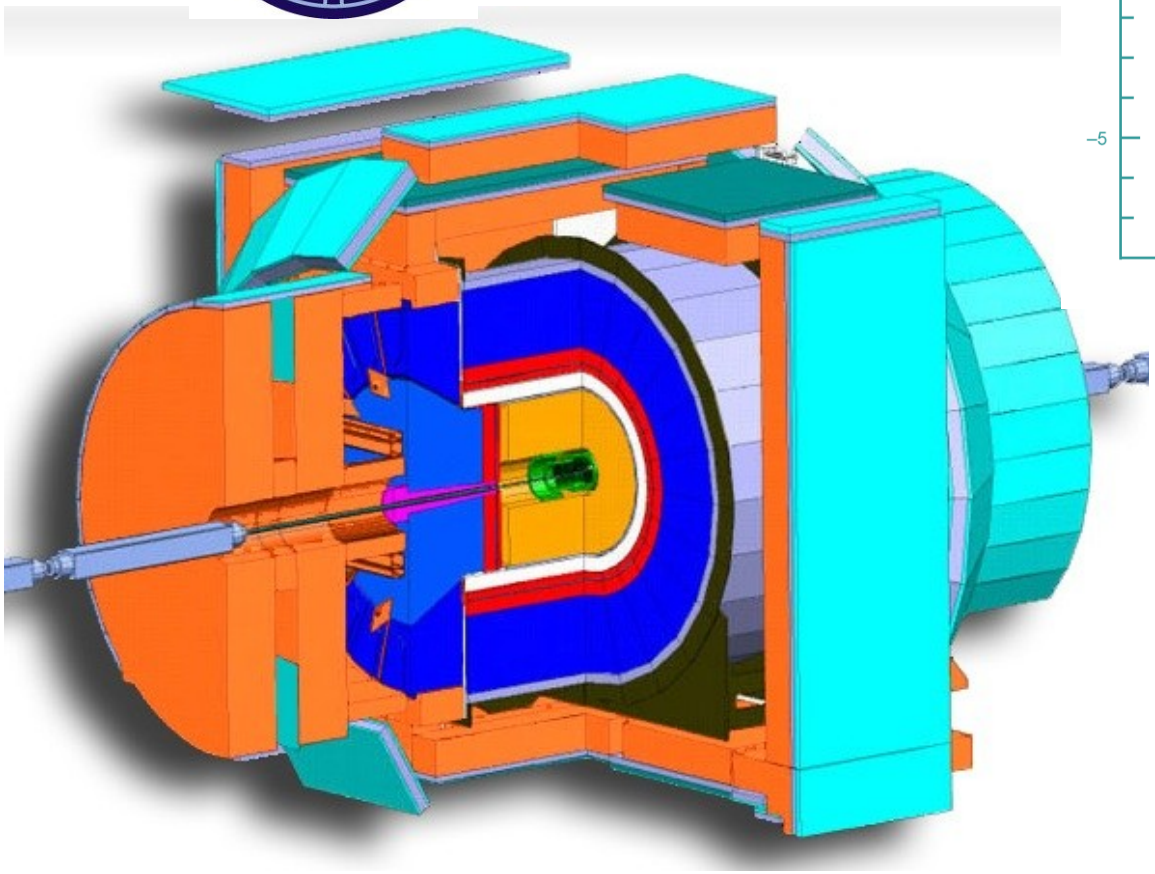
√S = 1.96 GeV

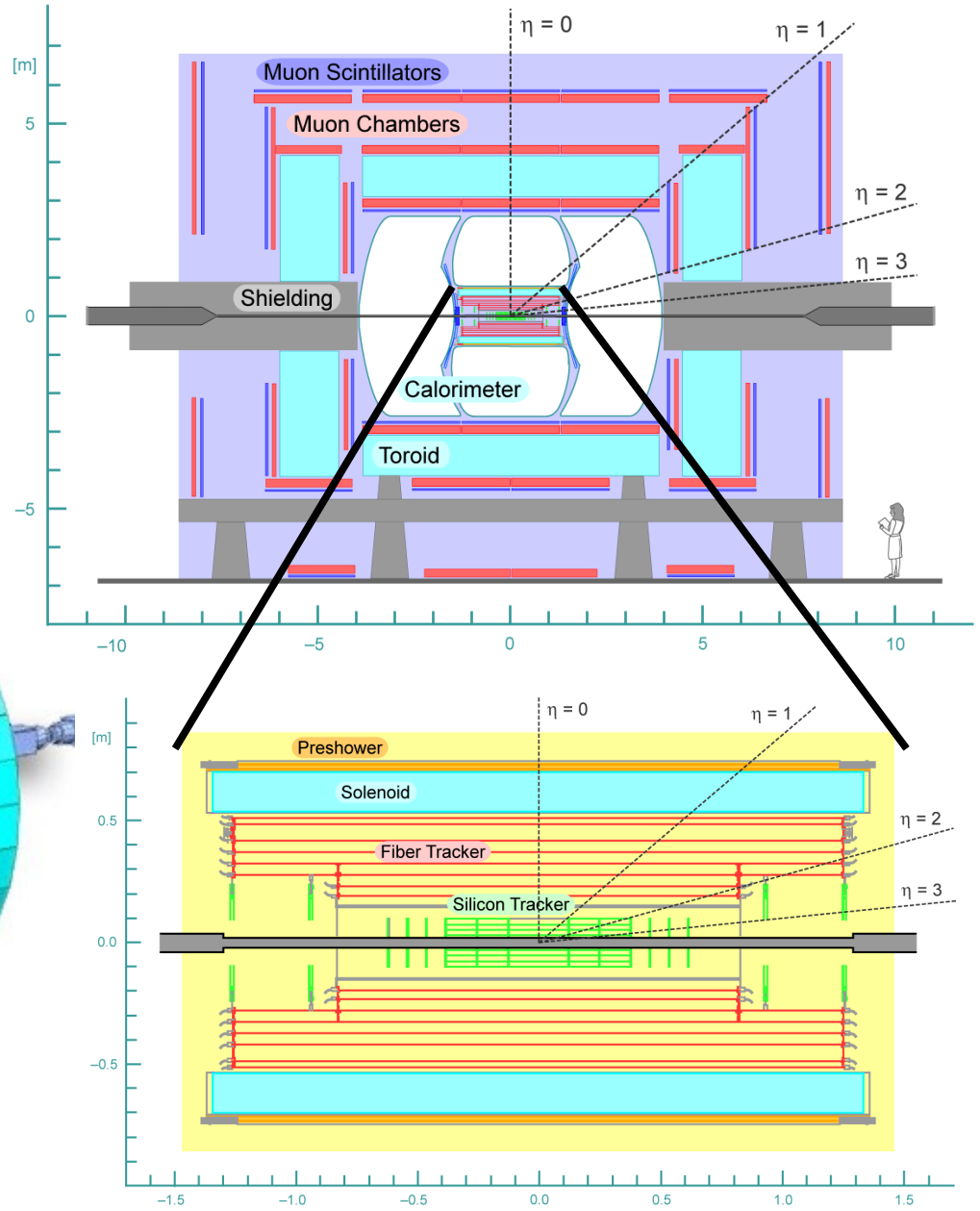
Peak luminosities > 3×10^{32} $cm^{-1}s^{-2}$

Introduction: the Tevatron



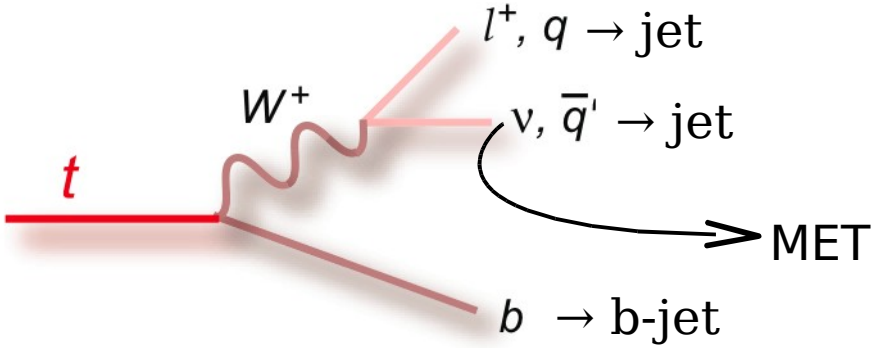
Introduction: the Detectors





Introduction: Top Signatures

- Top decays:



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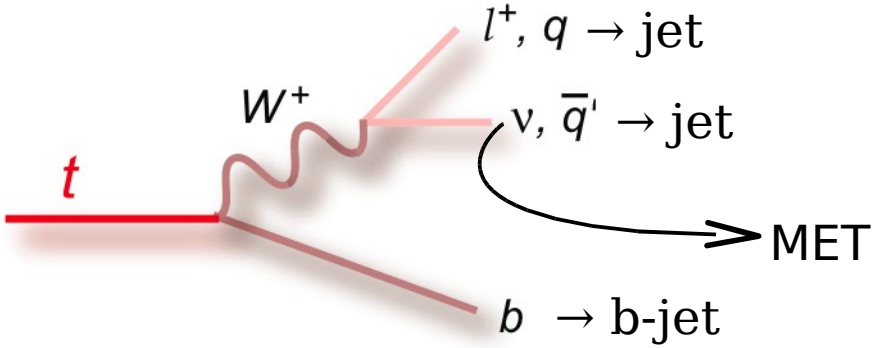
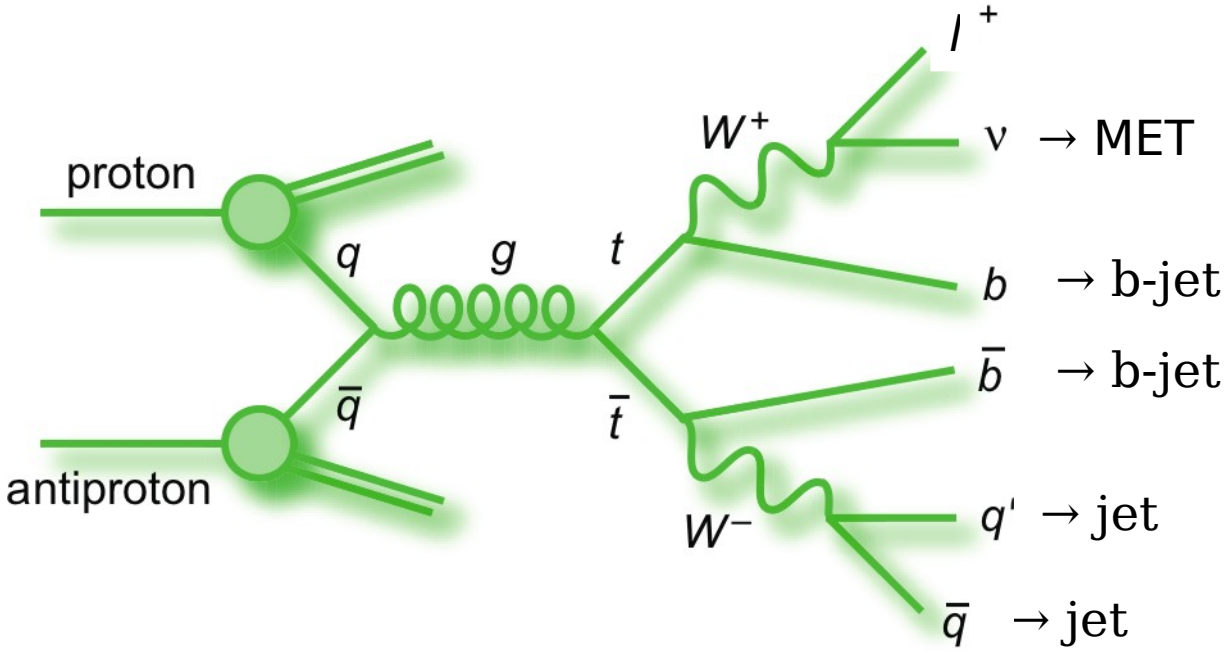
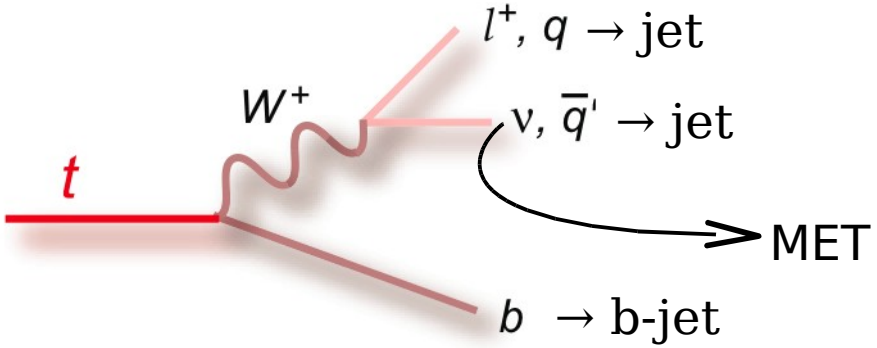


- Top pair signatures:
  - lepton + jets

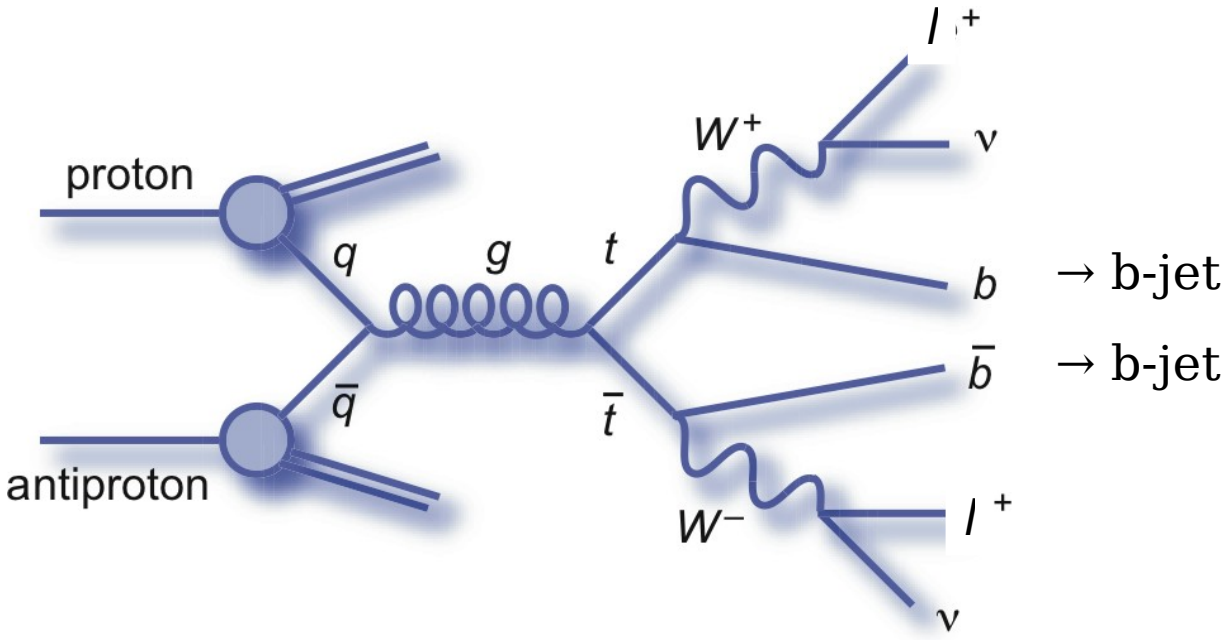


Introduction: Top Signatures

- Top decays:



- Top pair signatures:
  - lepton + jets
  - dilepton



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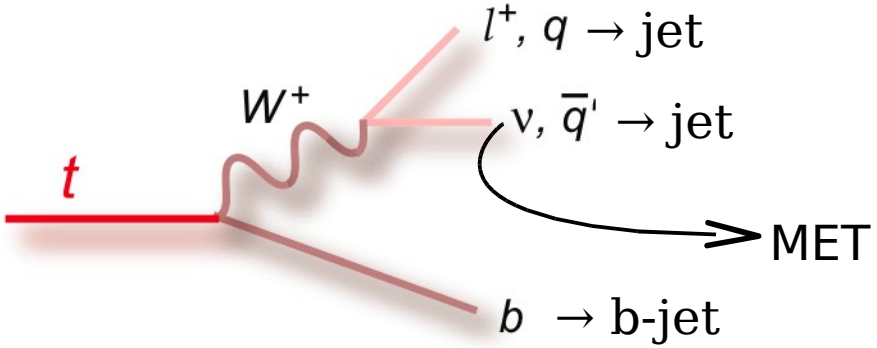
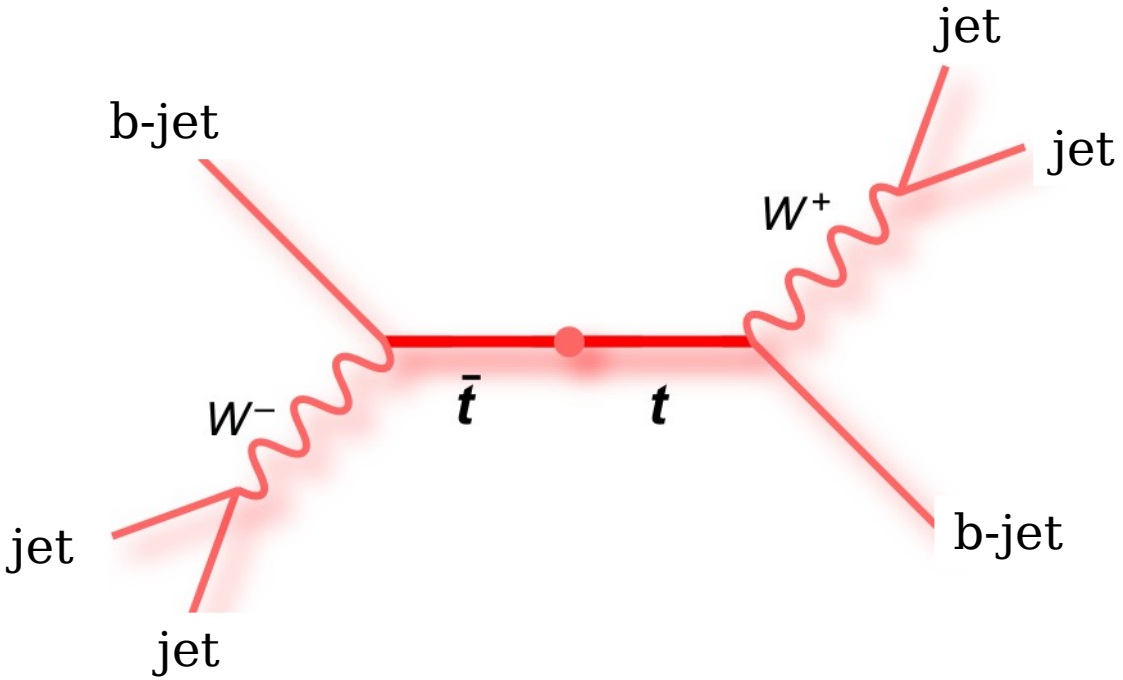
- Top decays:

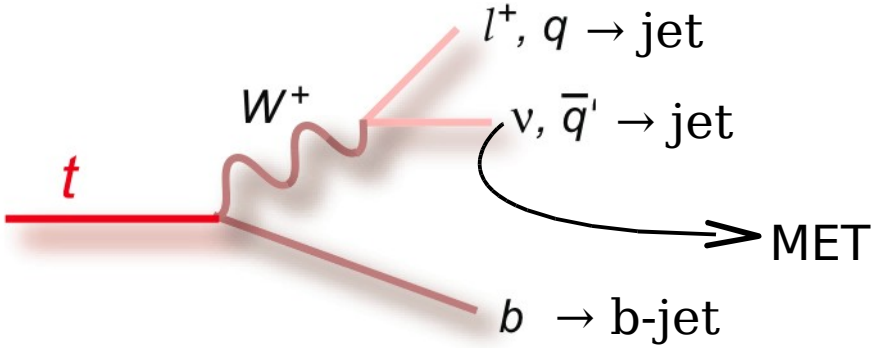


- Top pair signatures:
  - lepton + jets
  - dilepton
  - all jets



Introduction: Top Signatures

- Top decays:



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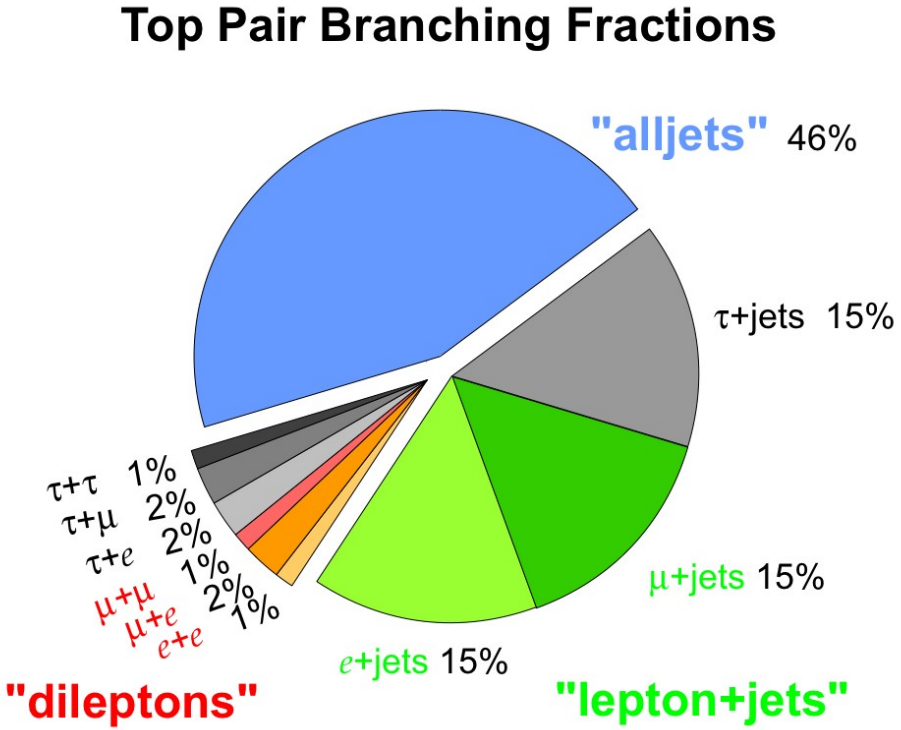
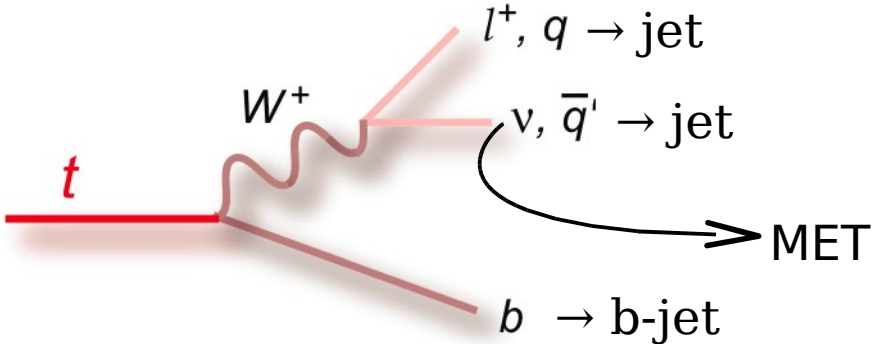
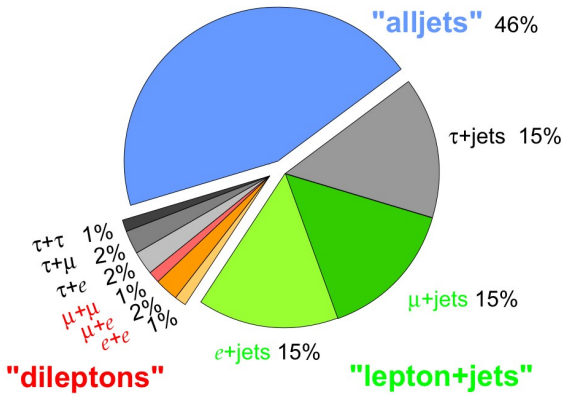


Introduction: Top Signatures

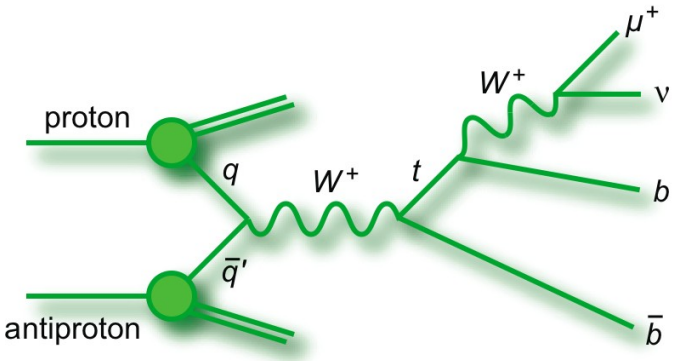
- Top decays:

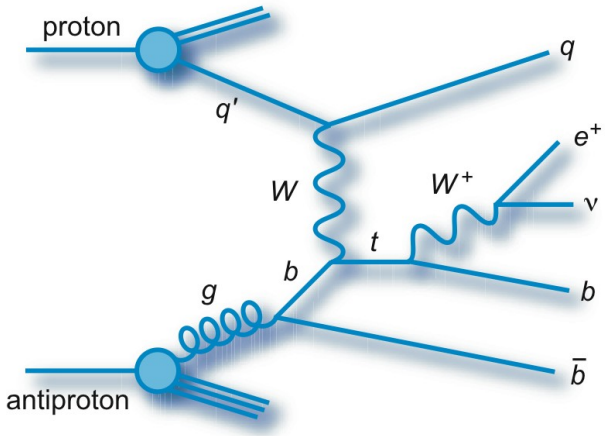


- Top pair signatures:
  - lepton + jets
  - dilepton
  - all jets



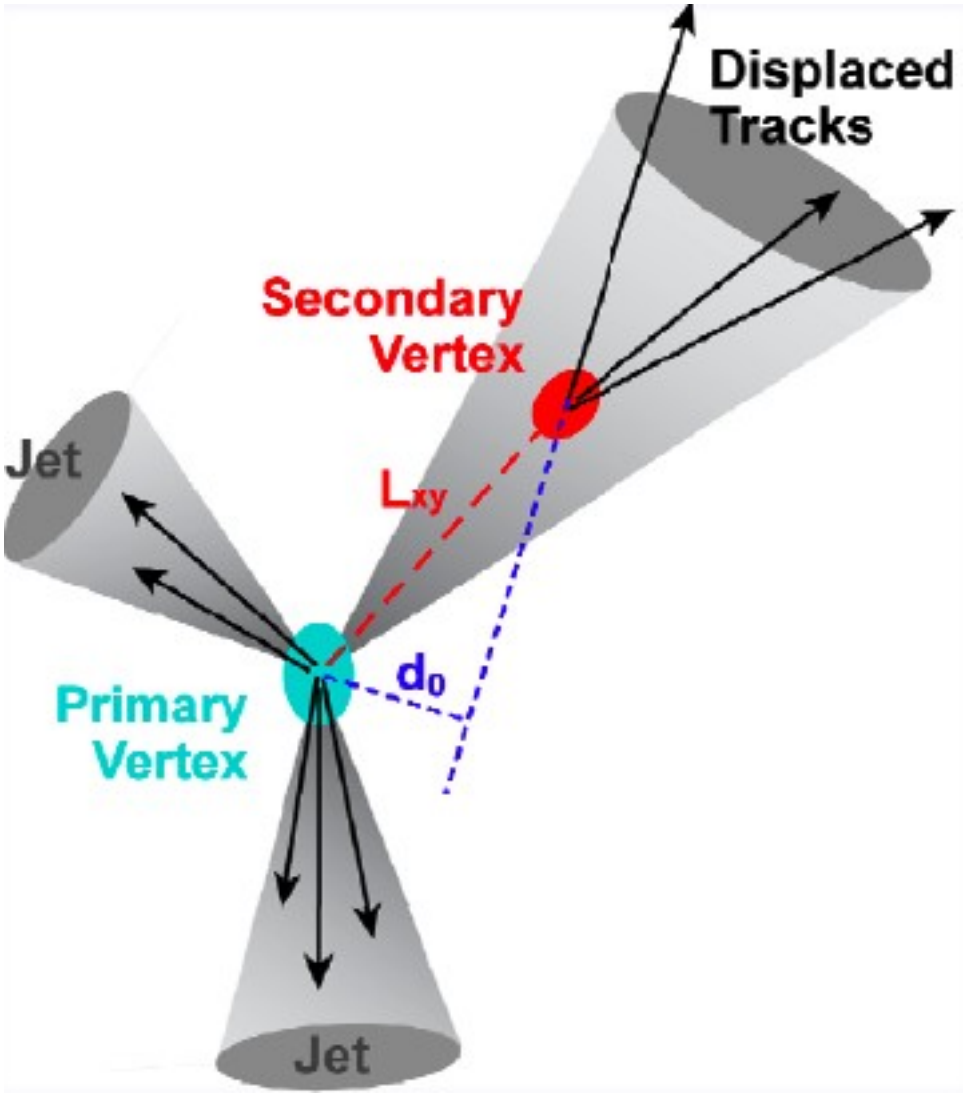
- Single Top Signatures:





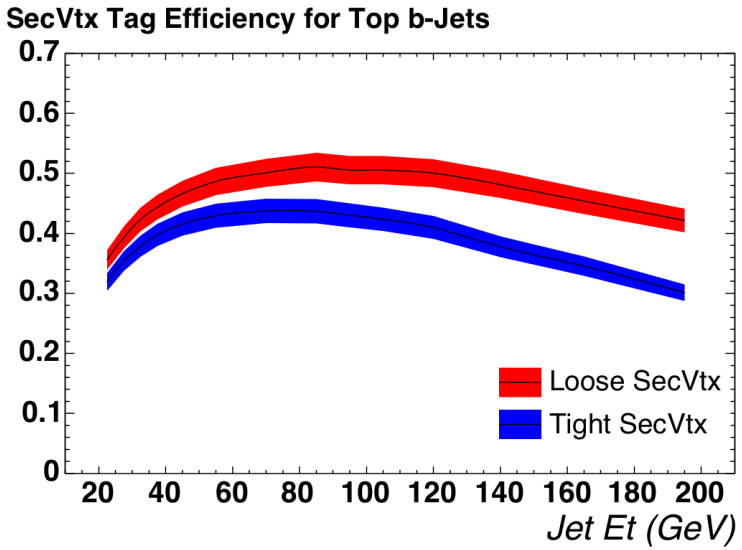
Introduction: B-Tagging

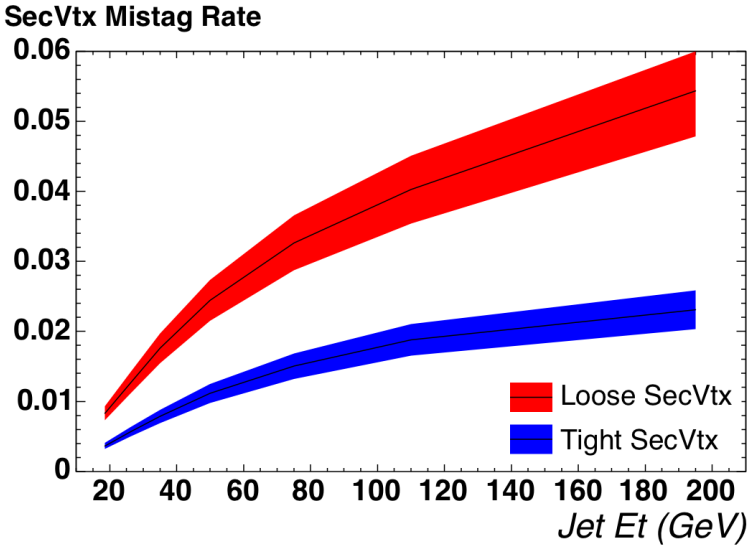
- How to identify b-jets: apply b-tagging
  - B mesons longer lifetime secondary vertex
  - b larger mass
  - Large track IP significance

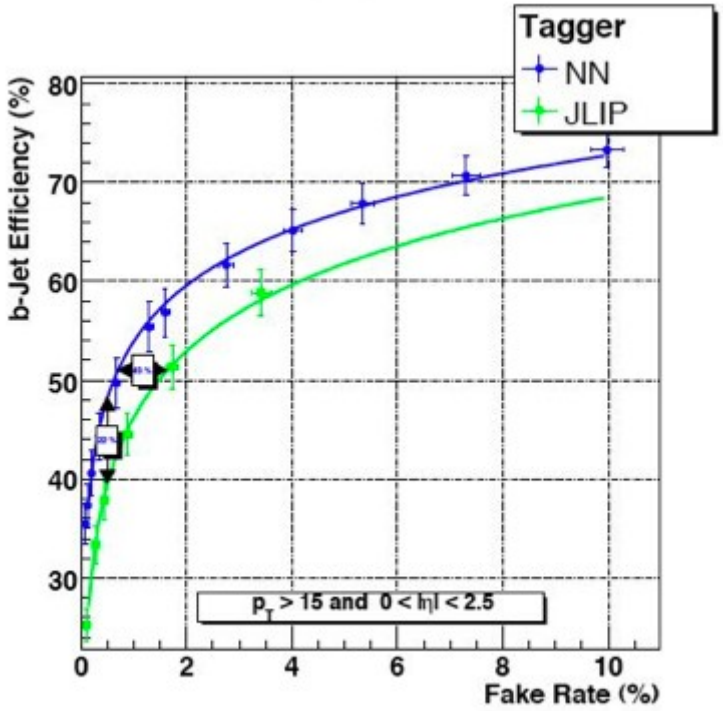


Introduction: B-Tagging

- How to identify b-jets: apply b-tagging

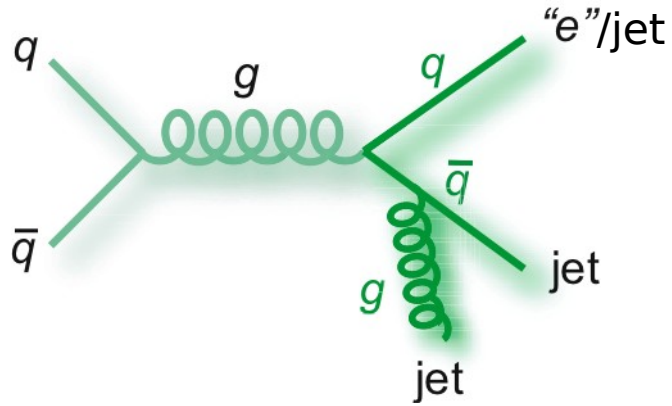




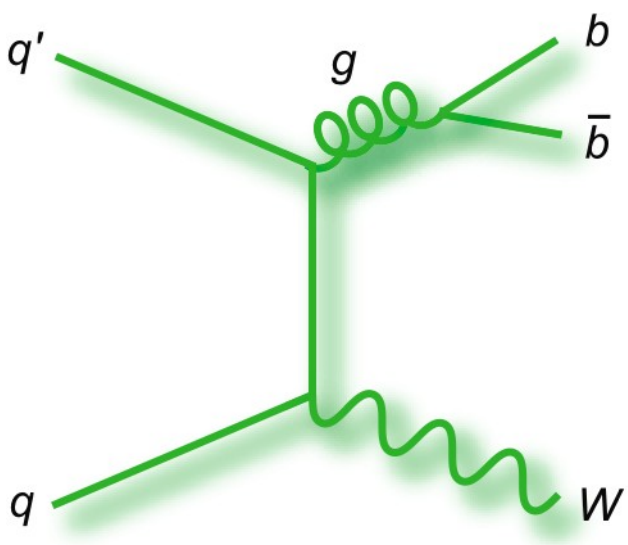


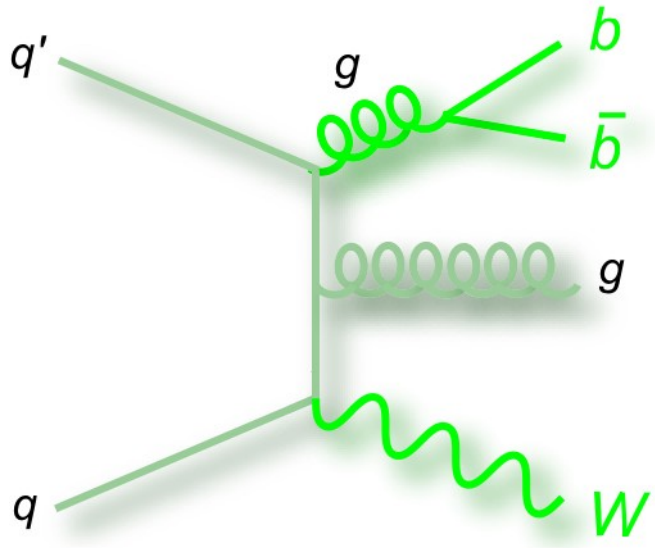
Introduction: Backgrounds

- Multi-jet



- W+jets

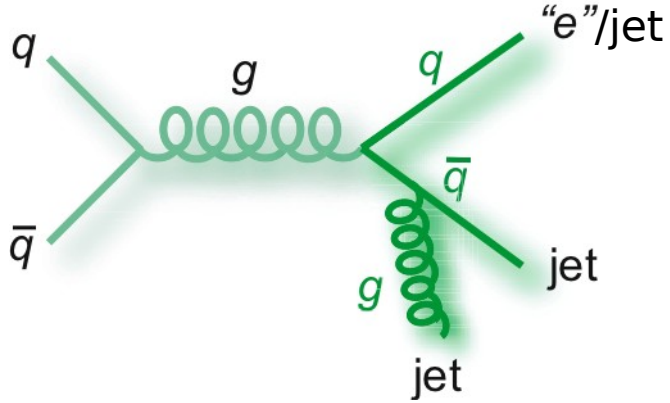




- Z+jets, diboson (WW,ZZ,WZ)
- Top pair is a background to single top!

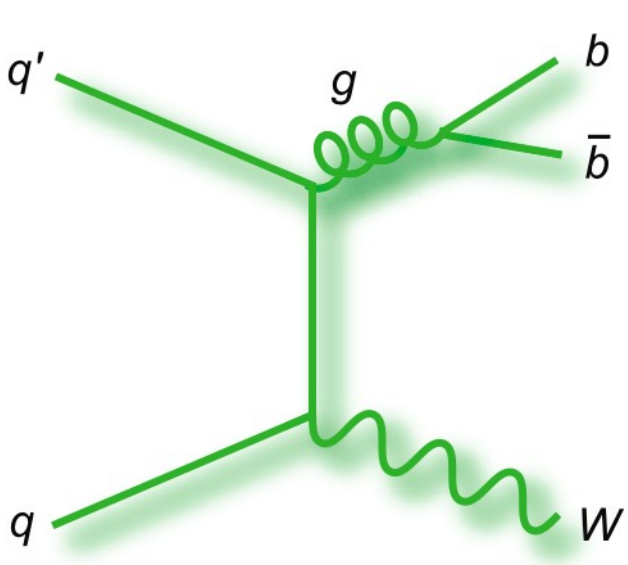
Introduction: Backgrounds

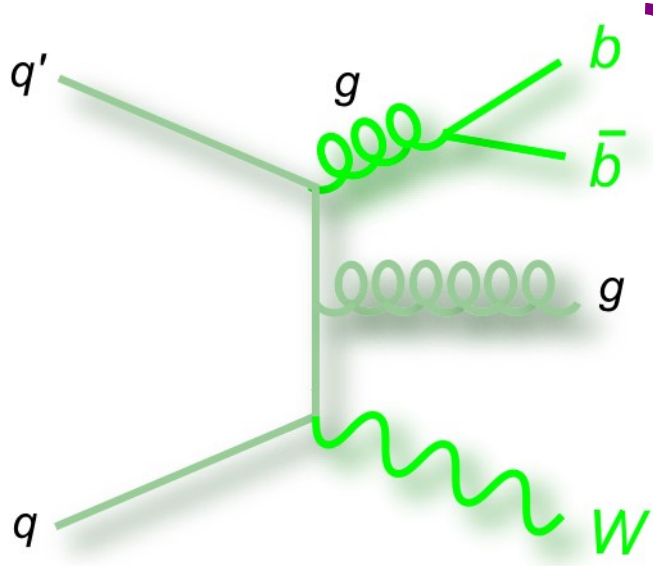
- Multi-jet



→ **From data**

- W+jets



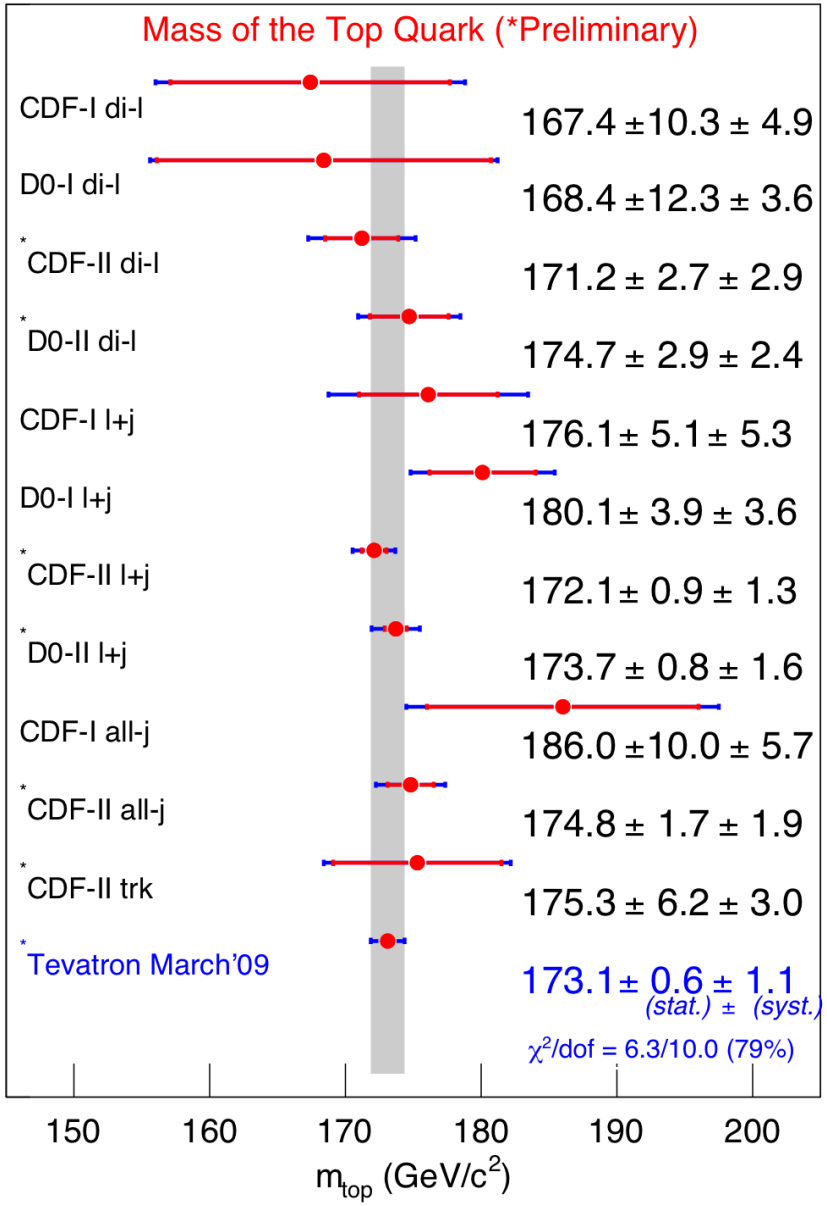


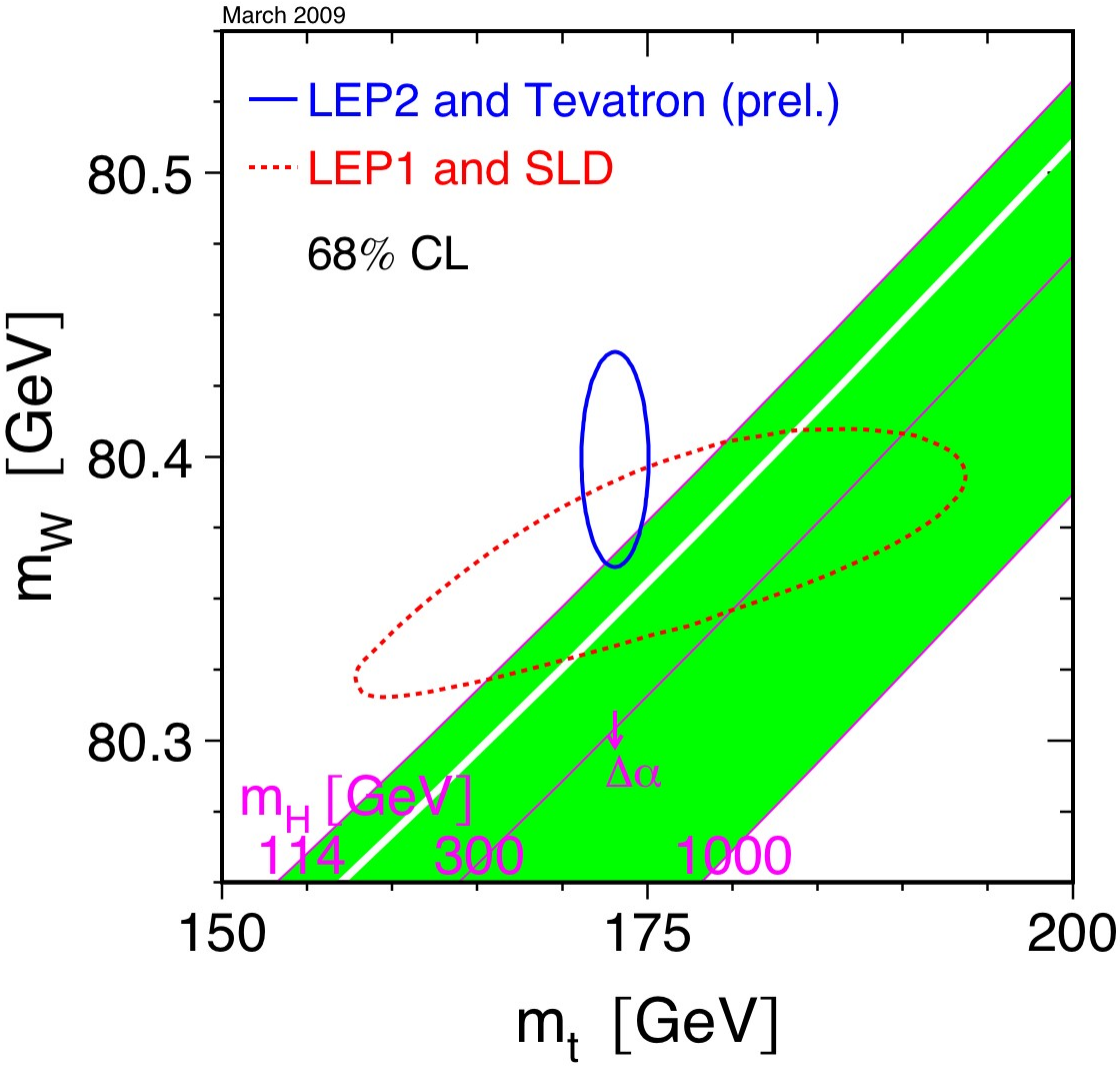
MC

- Z+jets, diboson (WW,ZZ,WZ)
- Top pair is a background to single top!

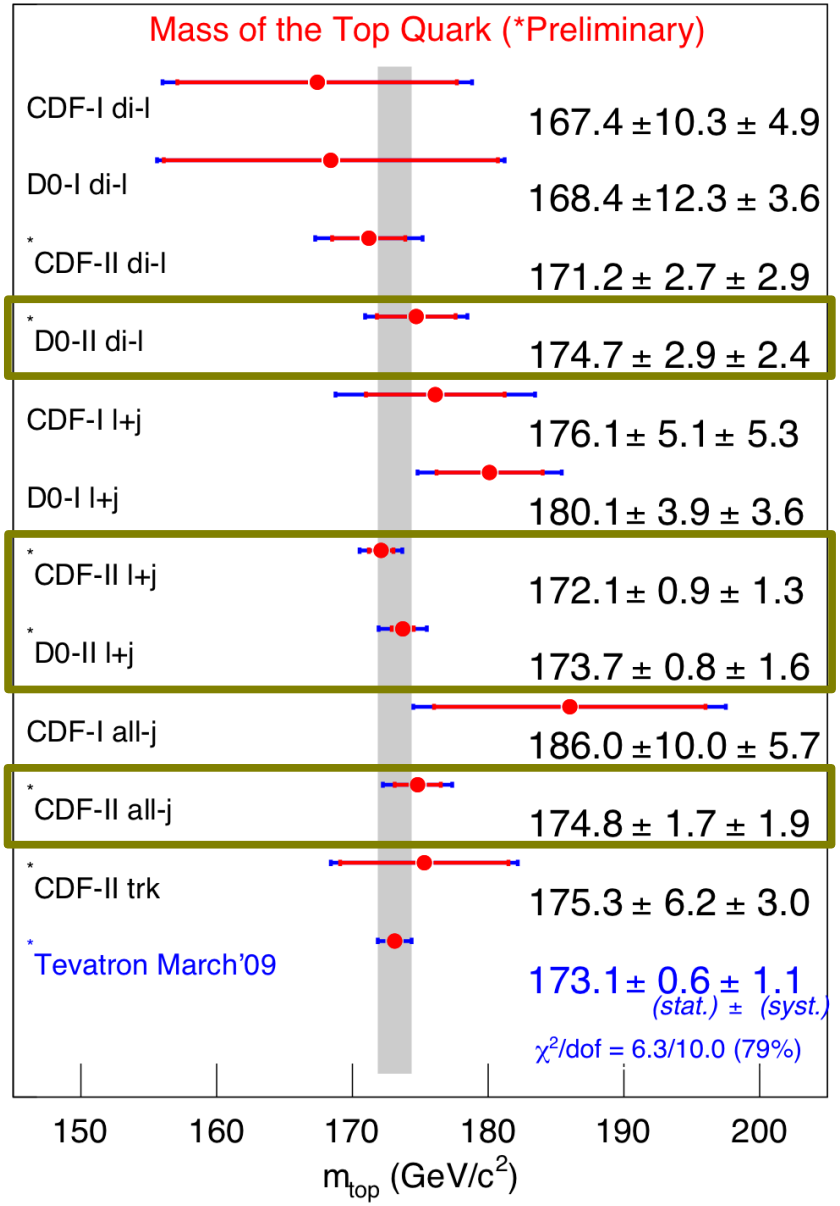
Top Mass

Top Mass


Mass of the Top Quark (*Preliminary)
CDF-I di-l
167.4 ±10.3 ± 4.9
D0-I di-l
168.4 ±12.3 ± 3.6
*CDF-II di-l
171.2 ± 2.7 ± 2.9
*D0-II di-l
174.7 ± 2.9 ± 2.4
CDF-I l+j
176.1± 5.1± 5.3
D0-I l+j
180.1± 3.9 ± 3.6
*CDF-II l+j
172.1± 0.9 ± 1.3
*D0-II l+j
173.7 ± 0.8 ± 1.6
CDF-I all-j
186.0 ±10.0 ± 5.7
*CDF-II all-j
174.8 ± 1.7 ± 1.9
*CDF-II trk
175.3 ± 6.2 ± 3.0
*Tevatron March'09
173.1± 0.6 ± 1.1
(stat.) ± (syst.)
χ²/dof = 6.3/10.0 (79%)
150
160
170
180
190
200
m_top (GeV/c²)


March 2009
LEP2 and Tevatron (prel.)
LEP1 and SLD
68% CL
80.5
80.4
80.3
m_W [GeV]
m_H [GeV]
114
300
1000
Δα
150
175
200
m_t [GeV]

Top Mass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(stat.) ± (syst.)
χ²/dof = 6.3/10.0 (79%)
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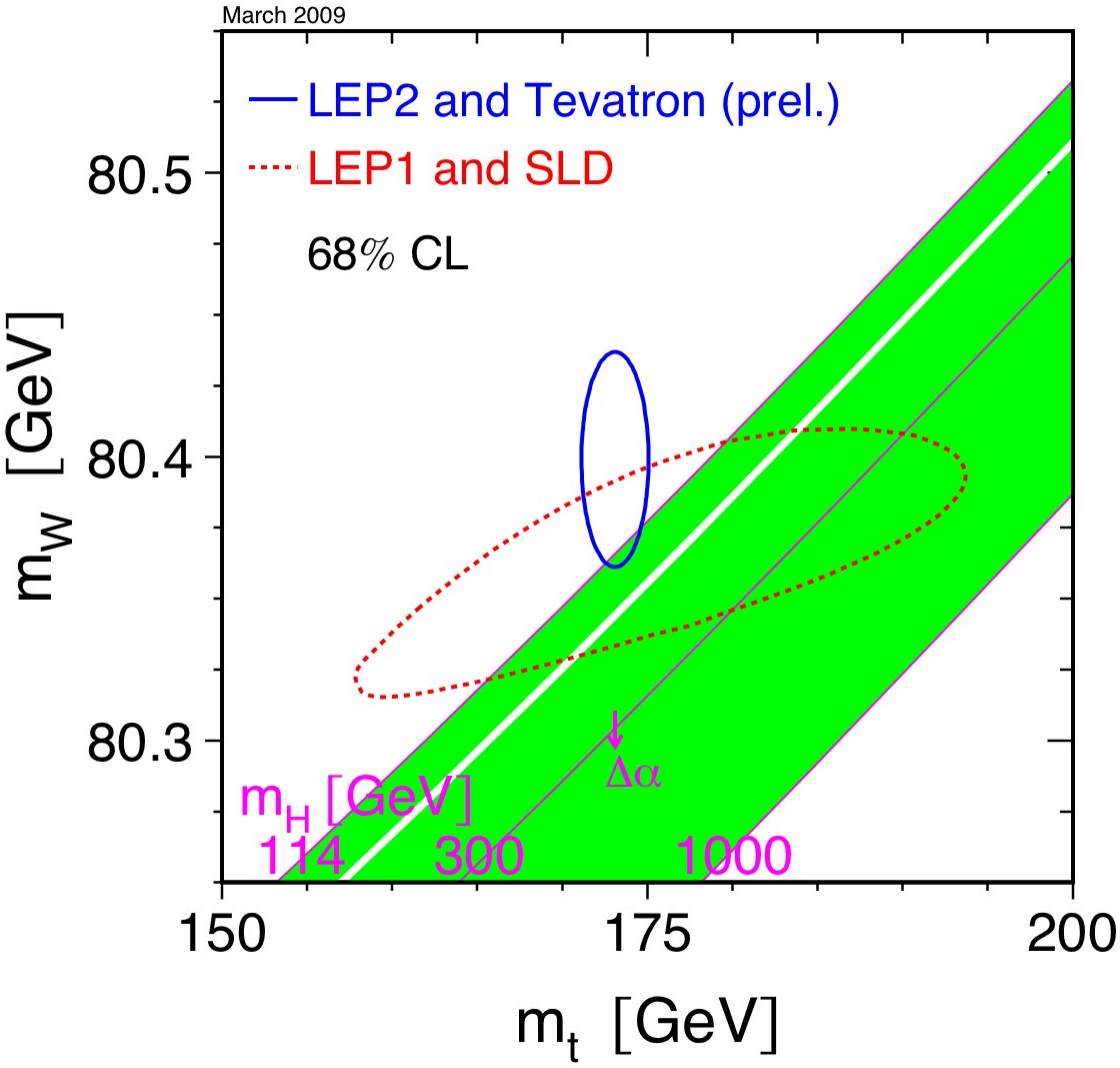
m_top (GeV/c²)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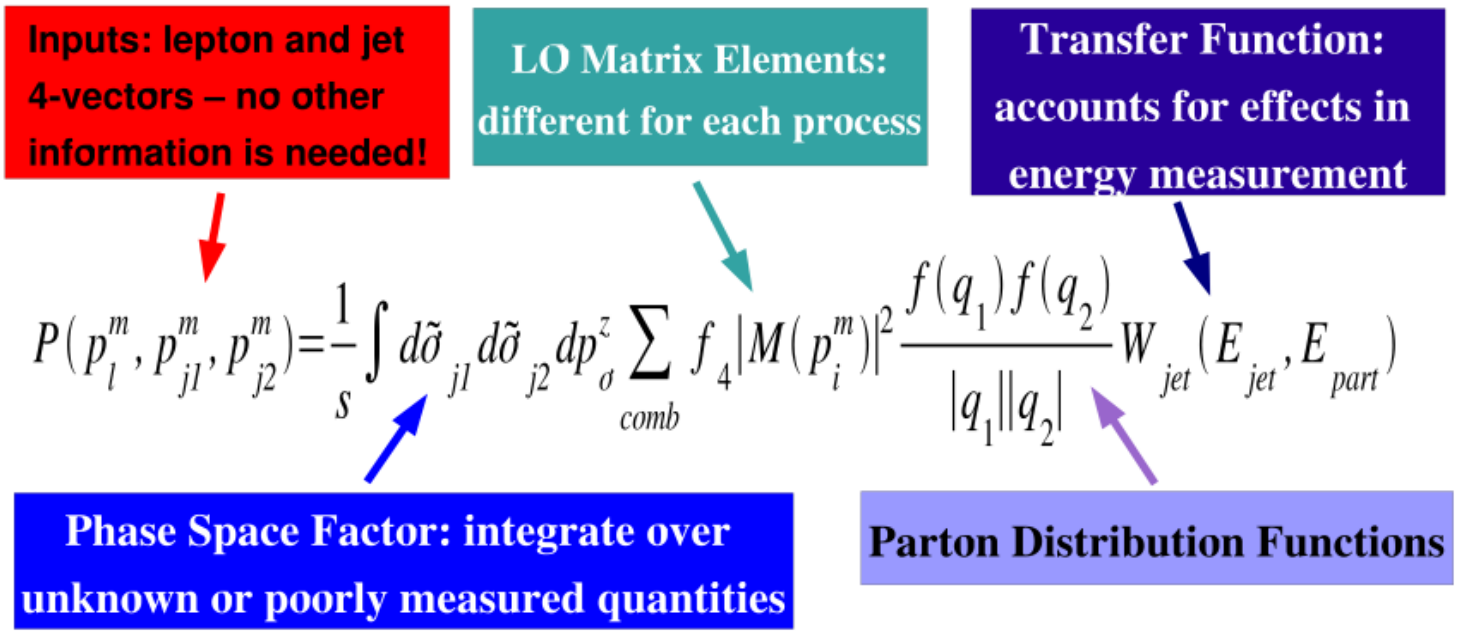
LEP2 and Tevatron (prel.)
LEP1 and SLD
68% CL
80.5
80.4
80.3
m_W [GeV]
m_H [GeV]
114
300
1000
Δα
150
175
200
m_t [GeV]

Top Mass

- Matrix Element with in-situ JES calibration in Lepton+jets
  - Matrix Element



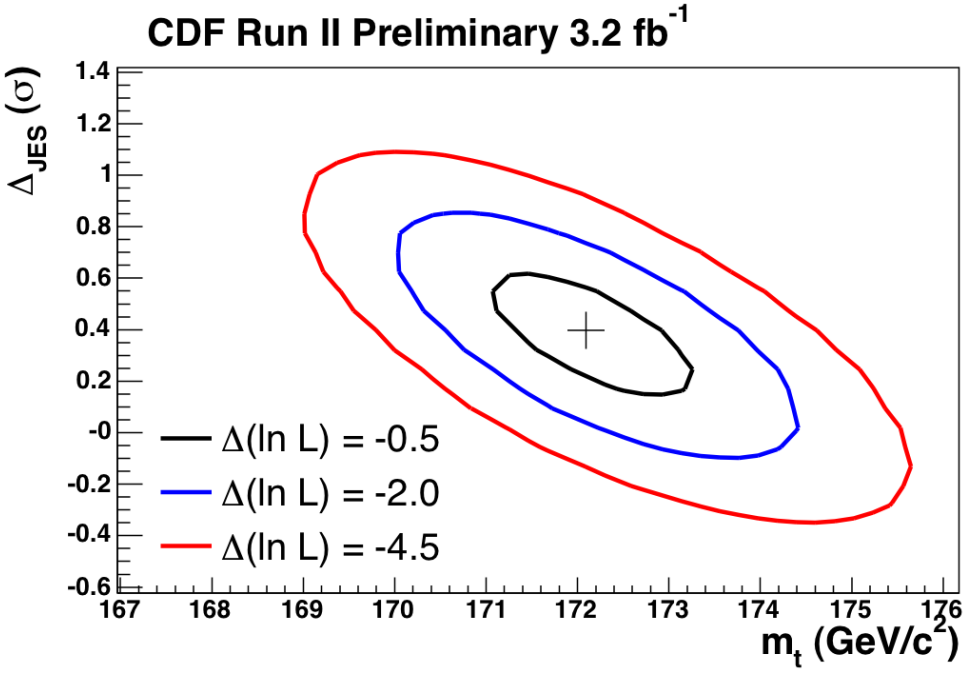
  - Event by event likelihood vs. m_t & ΔJES (fit to W mass)

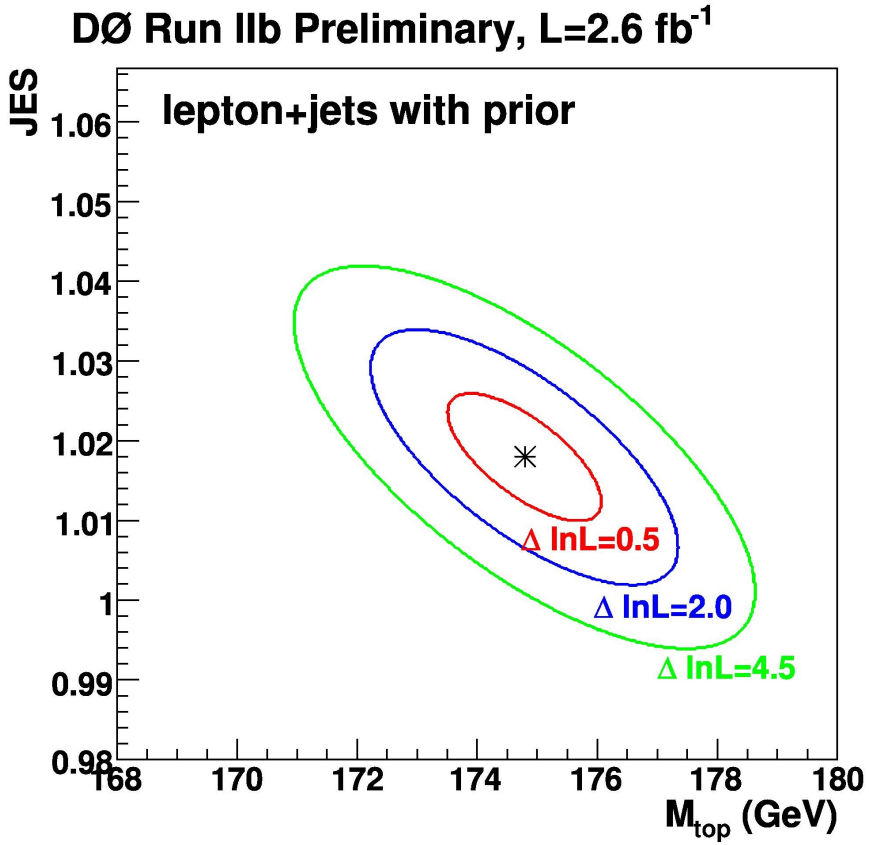
    $P(m_t,\Delta JES) = f_{top} \cdot P_{top}(m_t,\Delta JES) + f_{bkg} \cdot P_{bkg}(\Delta JES)$

  - Top mass at likelihood maximum

Top Mass

- Matrix Element with in-situ JES calibration in Lepton+jets





- CDF(3.2 fb^{-1}): 172.1± 0.9(stat) ±0.7(jes)±1.1(syst) GeV
- DØ (3.6 fb^{-1}): 173.7±0.8(stat)±1.6(syst⊕jes) GeV

Top Mass

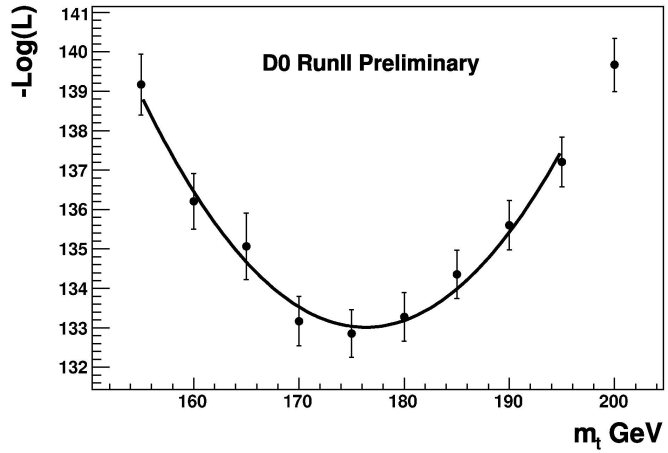
- Dilepton ($e\mu$) with ME by DØ with 3.6 fb^{-1}

  174.8 ±3.3 (stat) ±2.6 (syst) GeV

- Dilepton with template fits by DØ with 1.0 fb^{-1}
  - Neutrino weighting (ll,l+t):

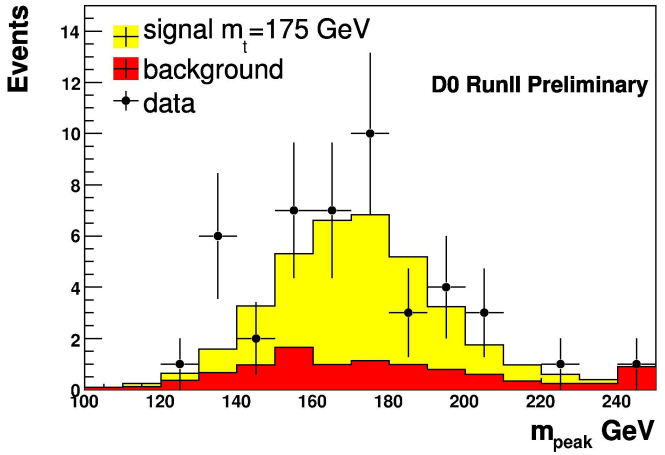
  176.0 ±5.3 (stat) ±2.0 (syst) GeV
  - Matrix weighting (ll):

  175.2 ±6.1 (stat) ±3.4 (syst) GeV



- Combination:

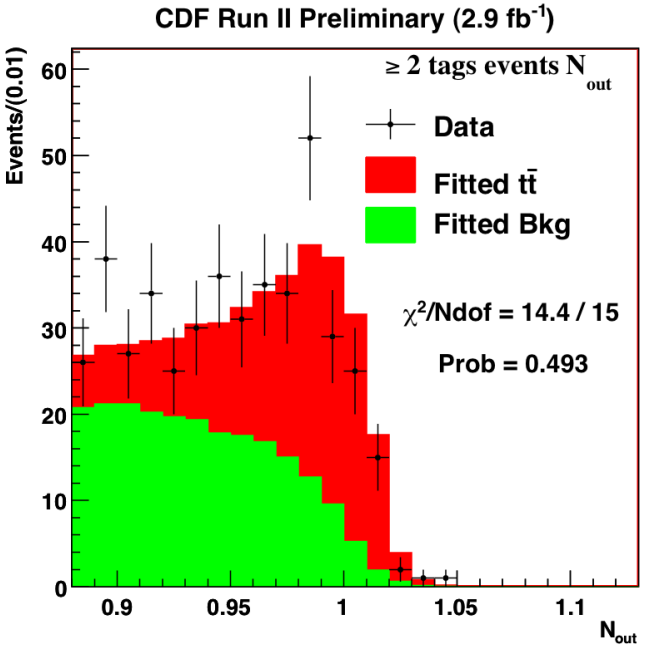
  174.7 ±2.9 (stat) ±2.4 (syst) GeV

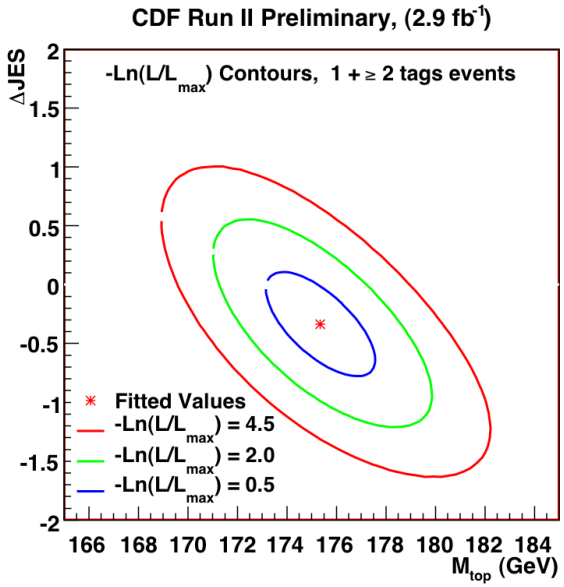


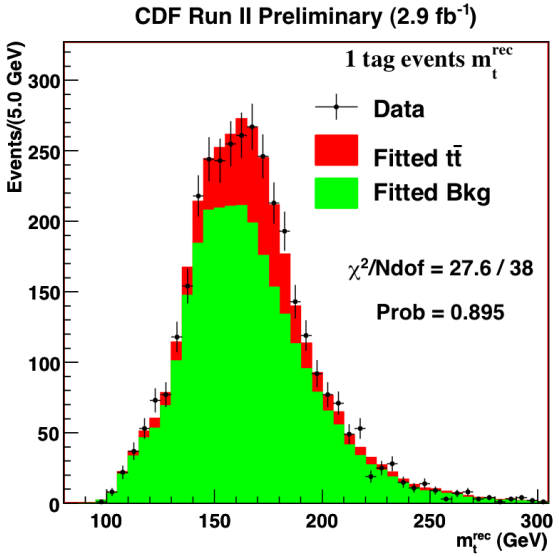
Top Mass

- All jets by CDF with 2.9 fb^{-1}:
  - Selection with NN
  - In-situ JES calibration
  - Extract m_t from χ^2 of 6 jets
  - Mass template fits

$174.8 \pm 1.7(stat) \pm 1.6(JES)\ ^{+1.2}_{-1.0}(syst)$

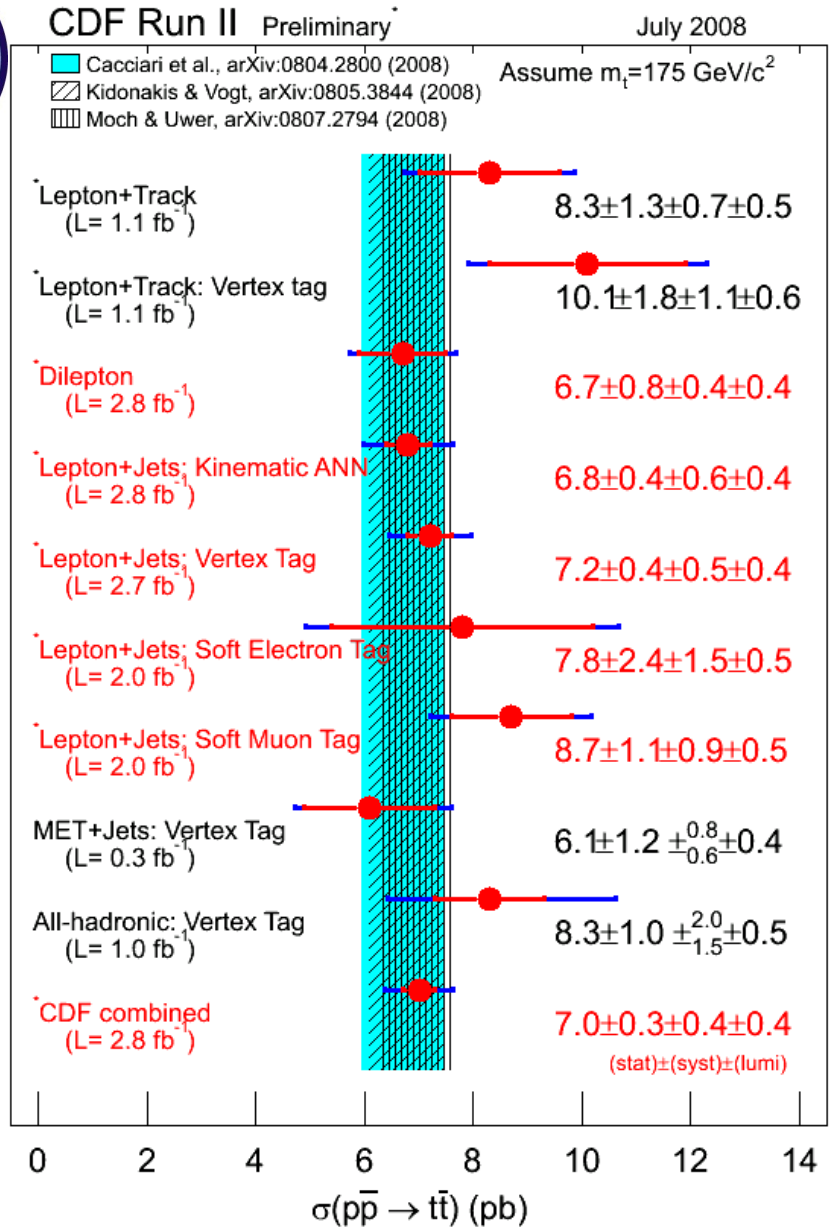


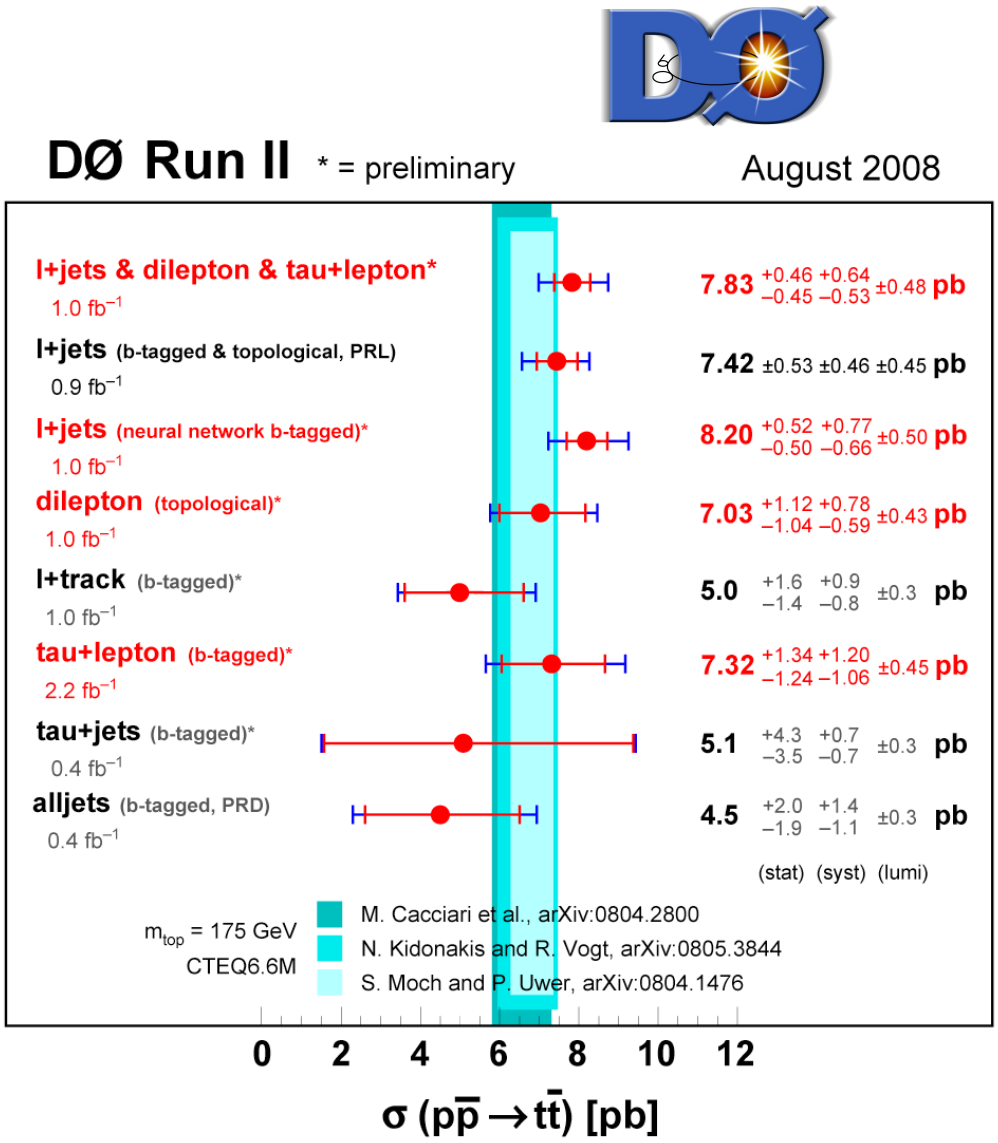




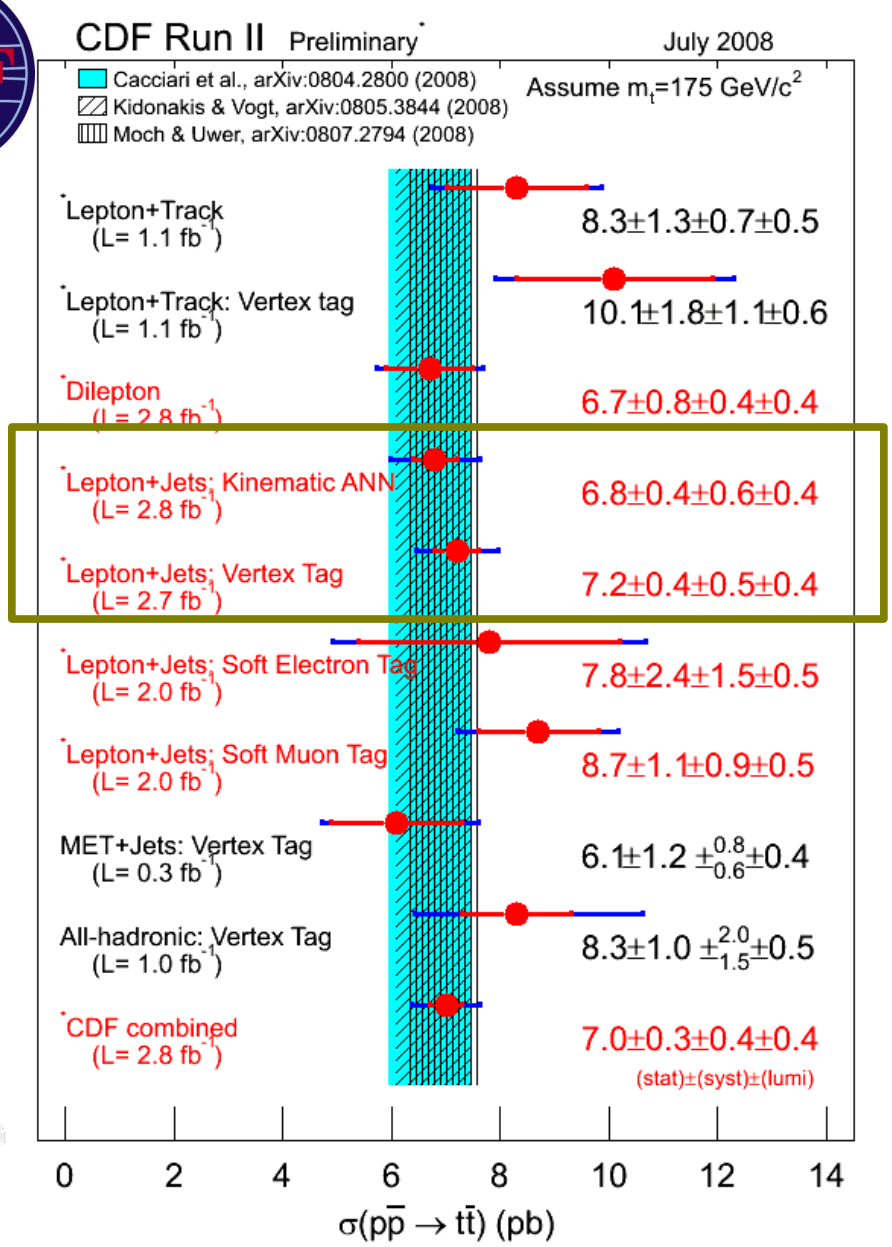
Top Pair Cross-section

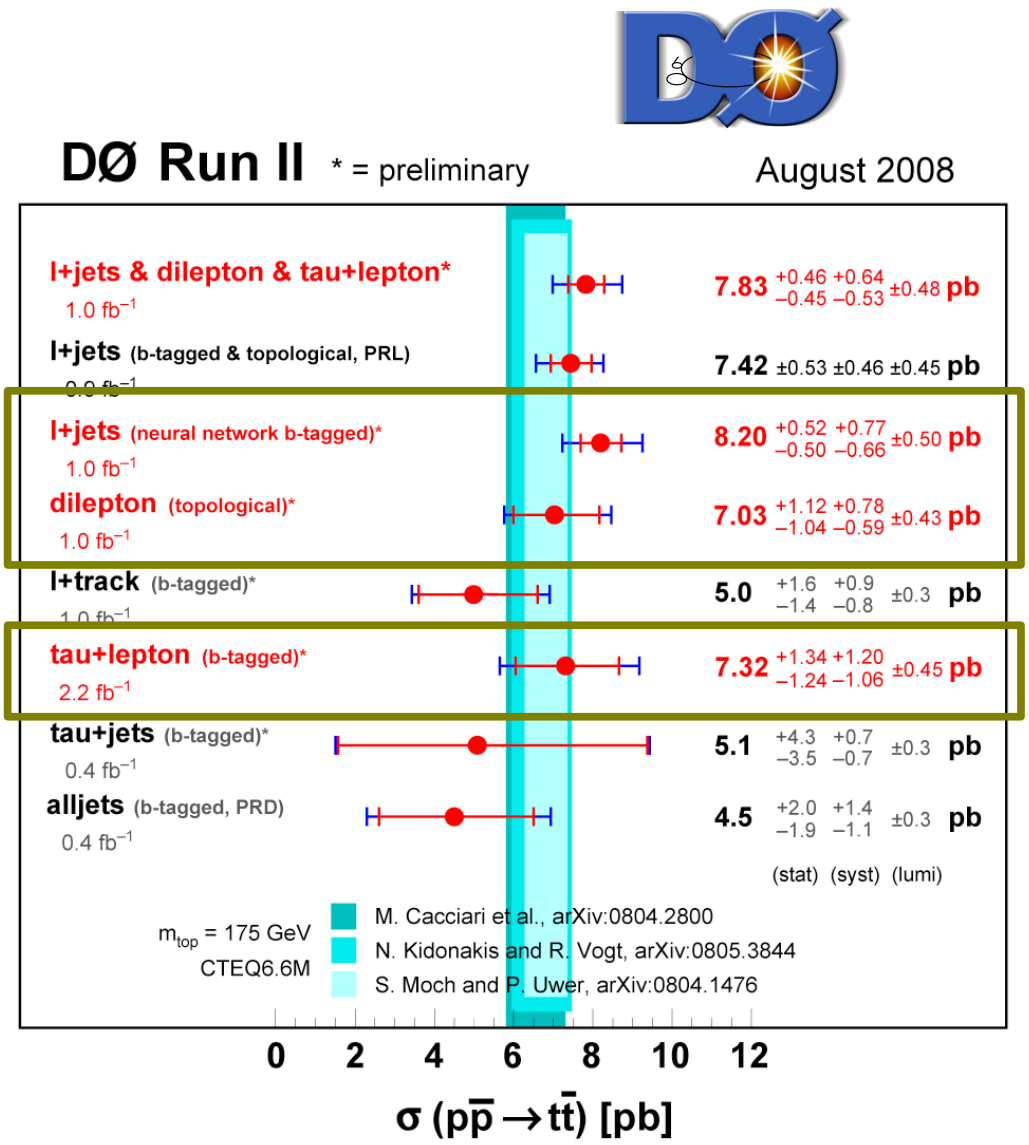
Top Pair Cross-section





Top Pair Cross-section





Top Pair Cross-section

- Lepton + jets by CDF with 2.7 fb^{-1} (@m_t=175 GeV):
  - Using b-tagging

$\sigma = 7.2 \pm 0.4(stat) \pm 0.5(syst) \pm 0.4(lumi)$ pb

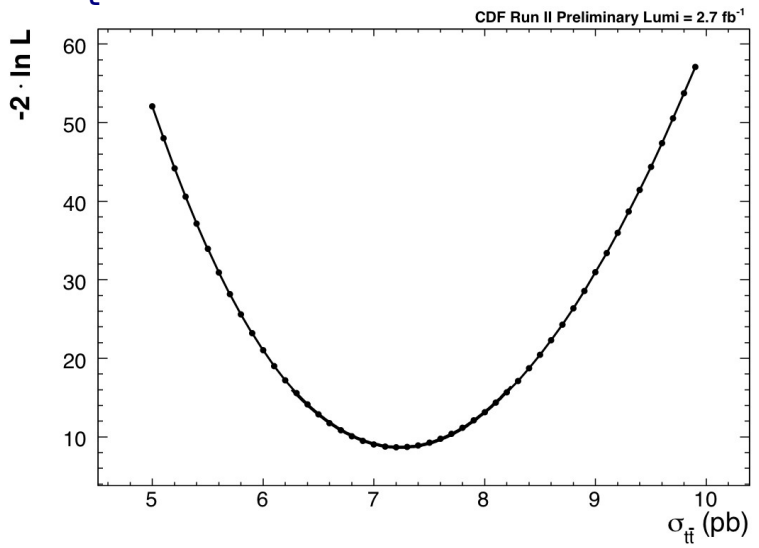
  - Using topological NN

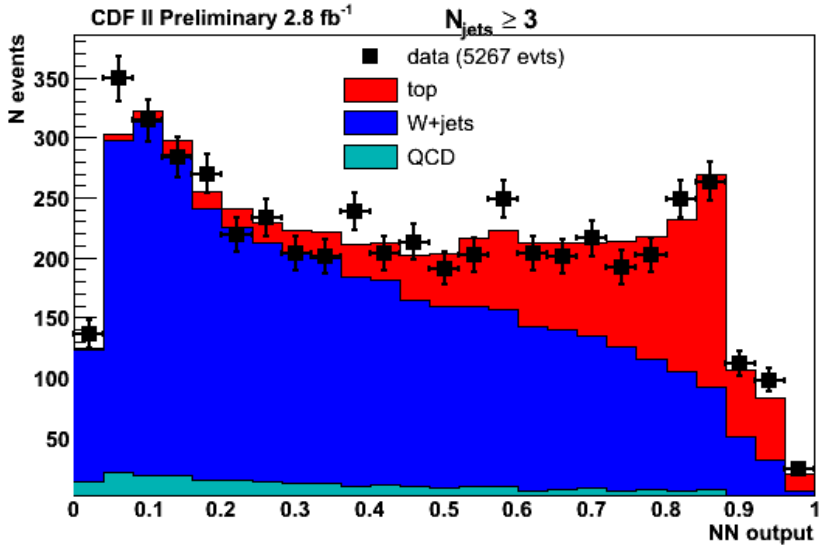
$\sigma = 7.1 \pm 0.4(stat) \pm 0.4(syst) \pm 0.4(lumi)$ pb

  - Largest systematics:
    - JES (3%)
    - MC HF correction factor (3%)
    - B-tagging on MC (5%)
    - Luminosity (6%)
  - Get rid of luminosity systematic:
    - Measure ratio to Z cross-section compare to theory

$\sigma = 7.0 \pm 0.4(stat) \pm 0.6(syst) \pm 0.1(th)$ pb

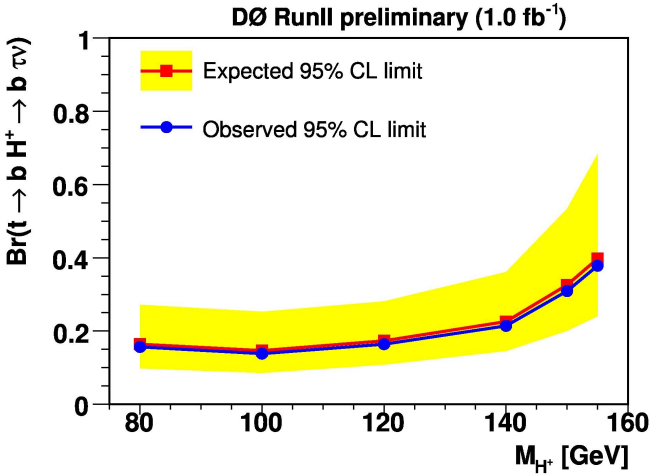
$\sigma = 6.9 \pm 0.4(stat) \pm 0.4(syst) \pm 0.1(th)$ pb

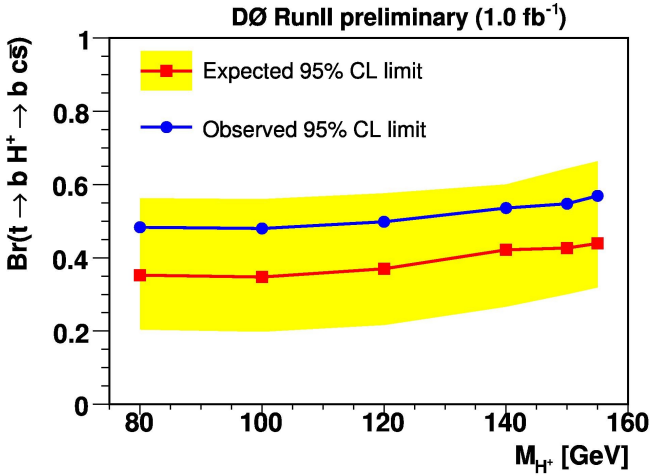


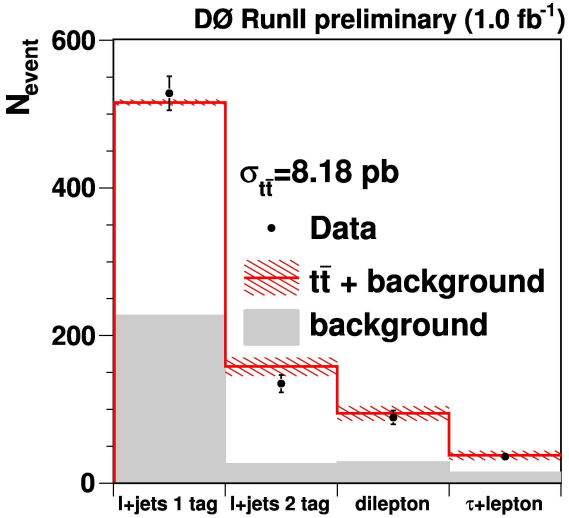


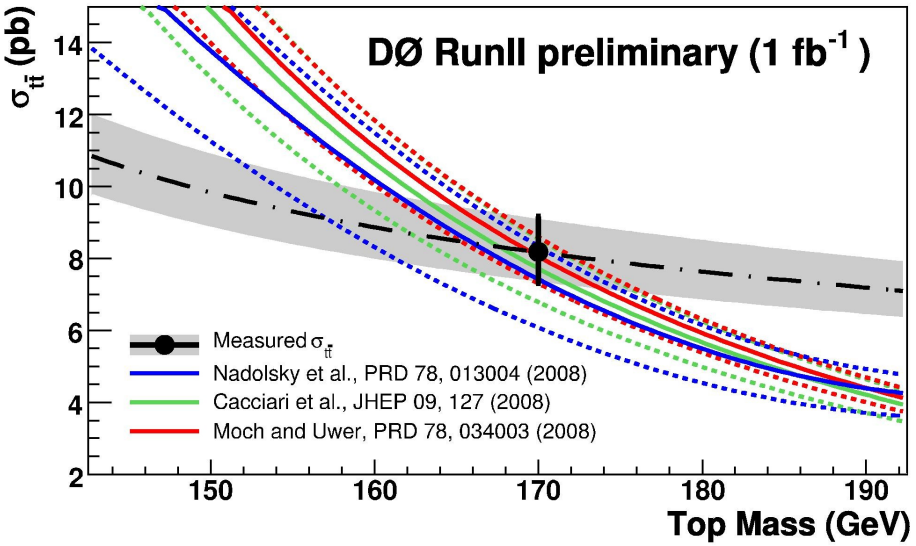
Top Pair Cross-section

- DØ combination of l+jets, l+l & τ+l:
  - Extract mass comparing to theory
  - From channel ratios set limits to H^+ mass





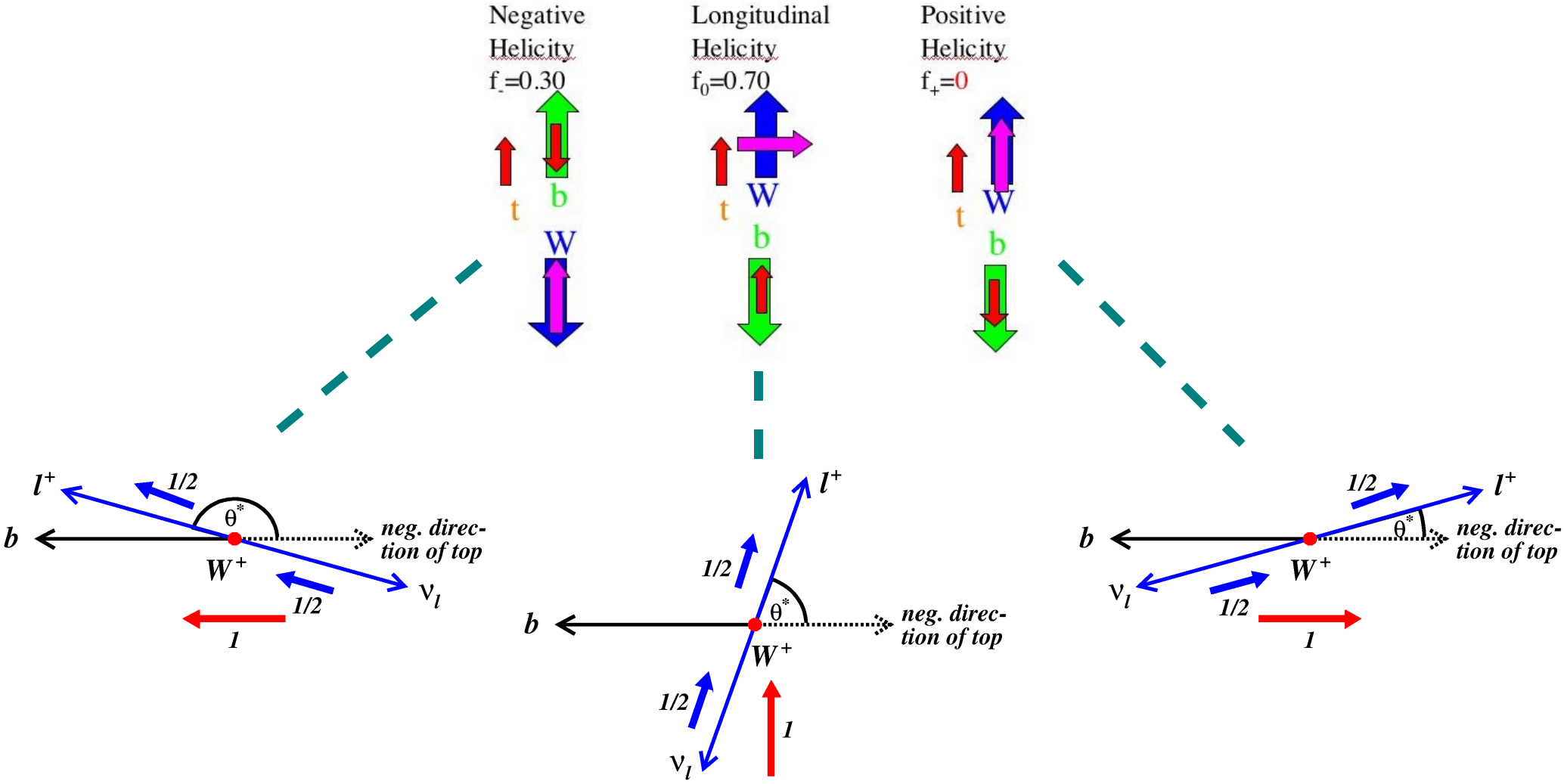




Top Properties

Top Properties

- W helicity:



Top Properties

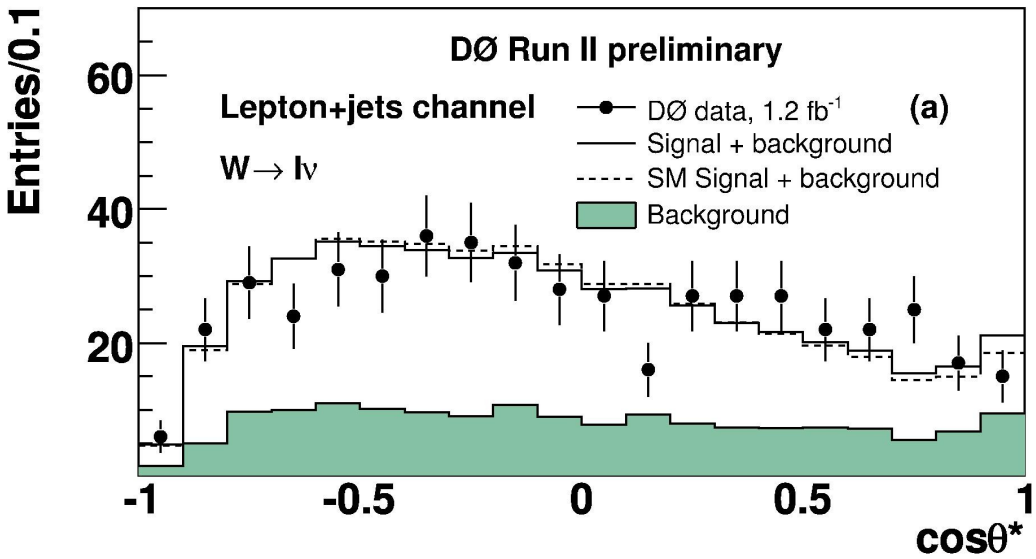
- W helicity:
  - $f_+ + f_0 + f_- = 1$
    - Likelihood fit by DØ (2.2-2.7 fb^{-1}):

$f_0 = 0.490 \pm 0.106\ (stat) \pm 0.085\ (syst)$

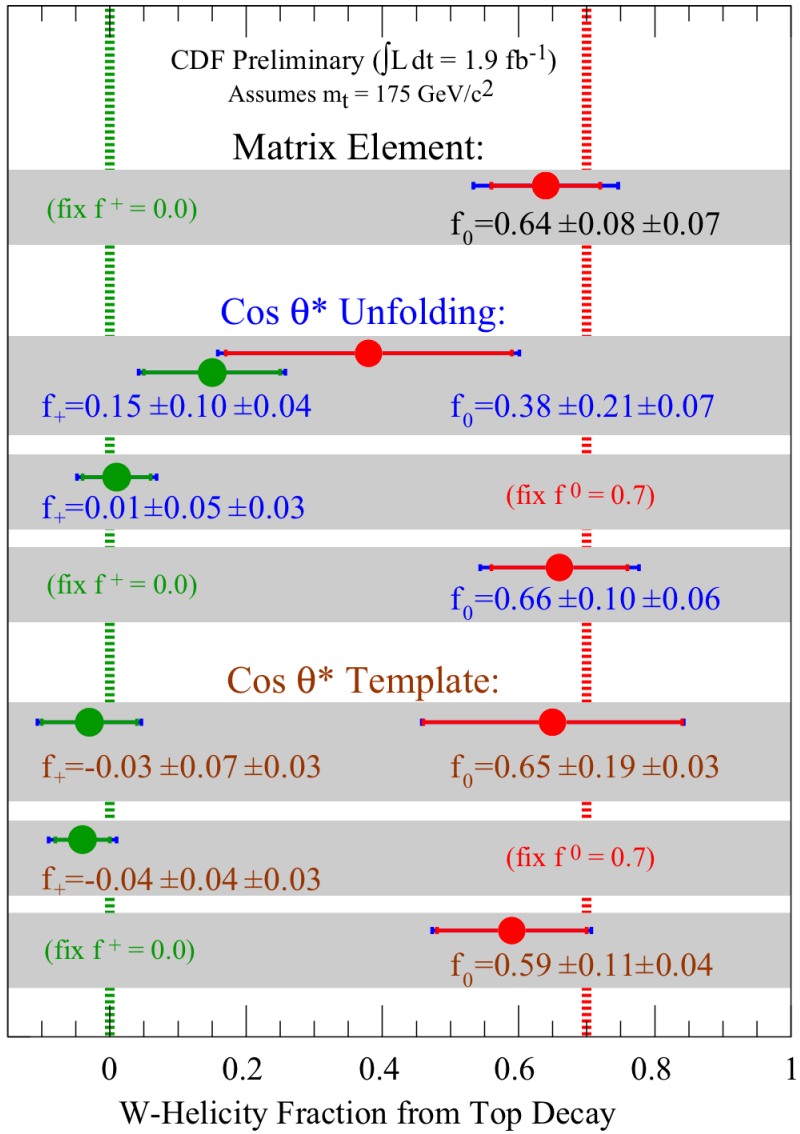
$f_+ = 0.110 \pm 0.059\ (stat) \pm 0.052\ (syst)$

  - Constraining $f_0=0.7$

$f_+ = 0.019 \pm 0.031\ (stat) \pm 0.047\ (syst)$

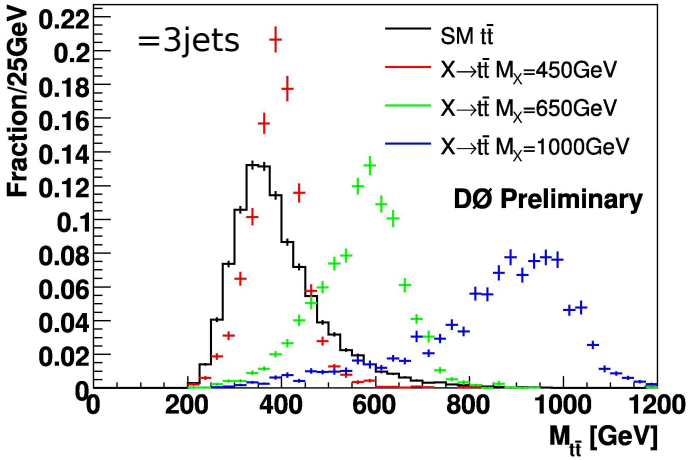


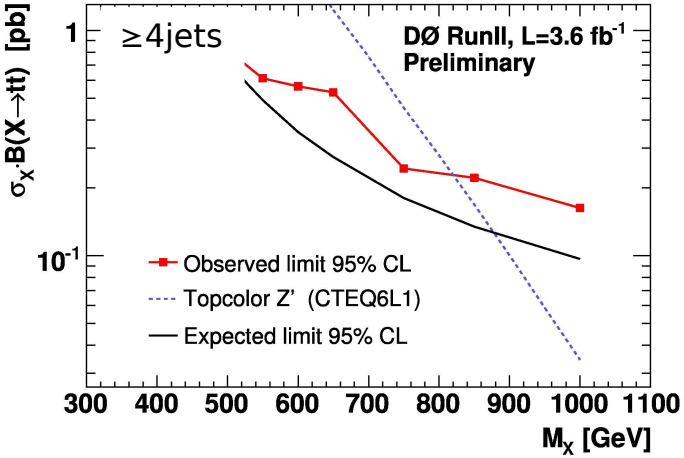
By CDF (1.9 fb^{-1}):

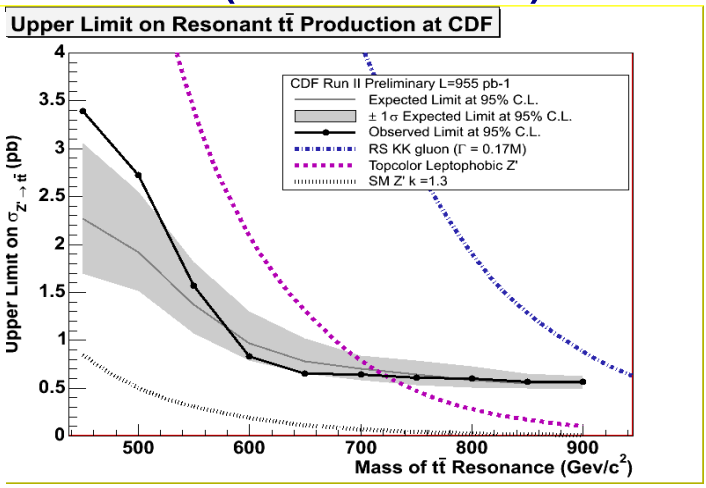


Top Properties

- Resonant top pair production by DØ with 3.6 fb^{-1} (CDF 1 fb^{-1}):

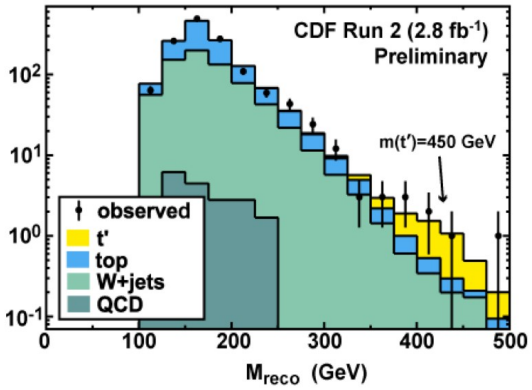


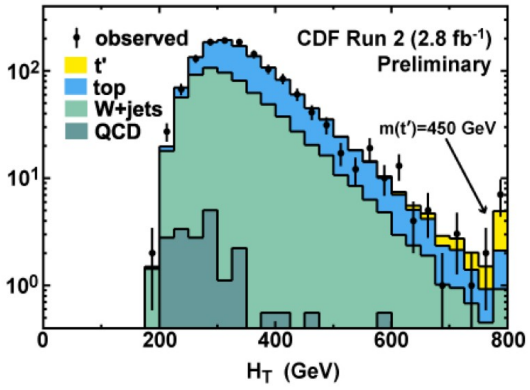


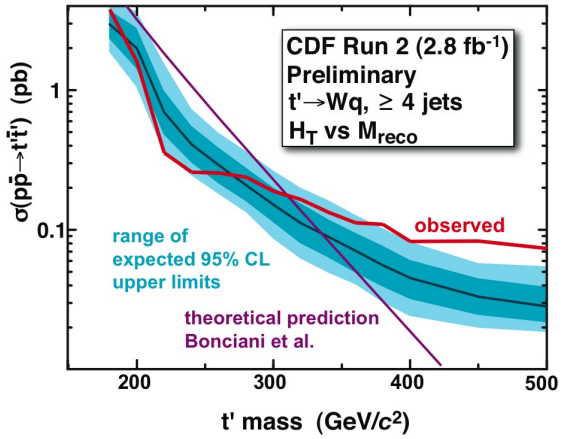


Exclude $M_{Z'}$ < 820 GeV @ 95% C.L. (CDF: 720 GeV)

- 4th generation quark by CDF with 2.8 fb^{-1}:







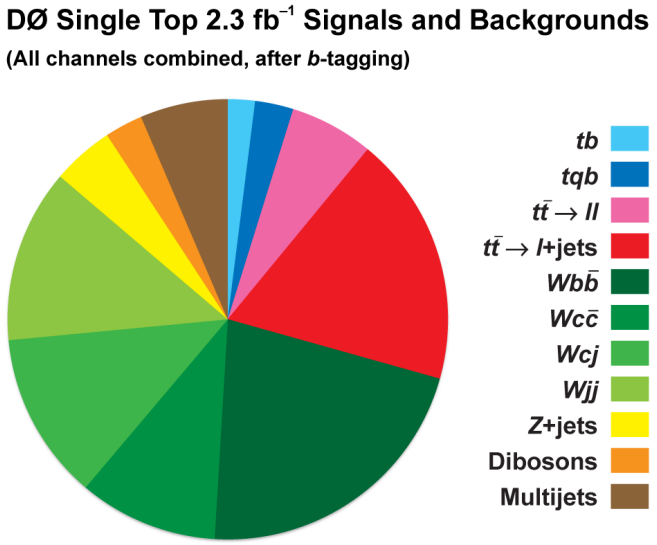
Exclude $M_{t'}$ < 311 GeV @ 95% C.L.

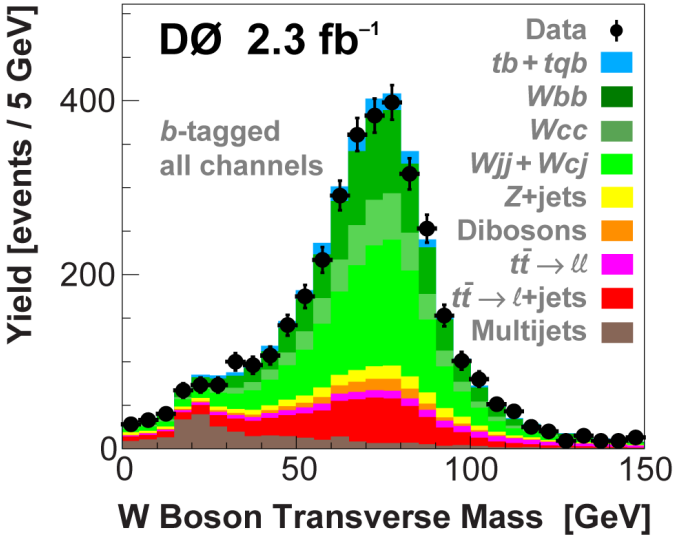
Single Top

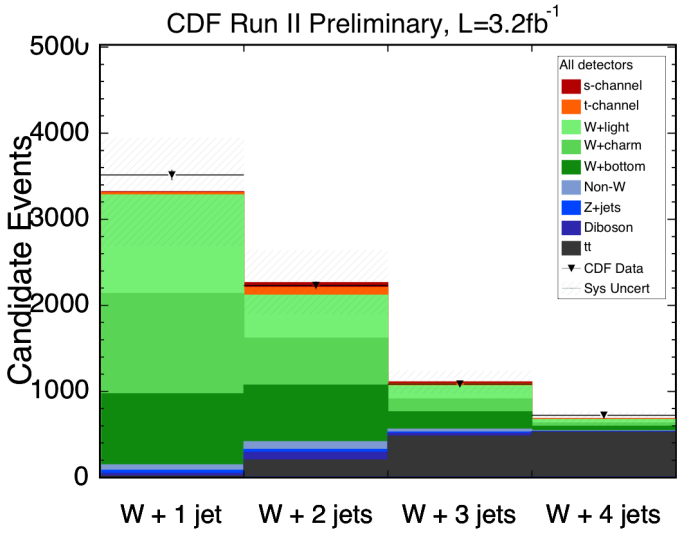
Single Top Observation

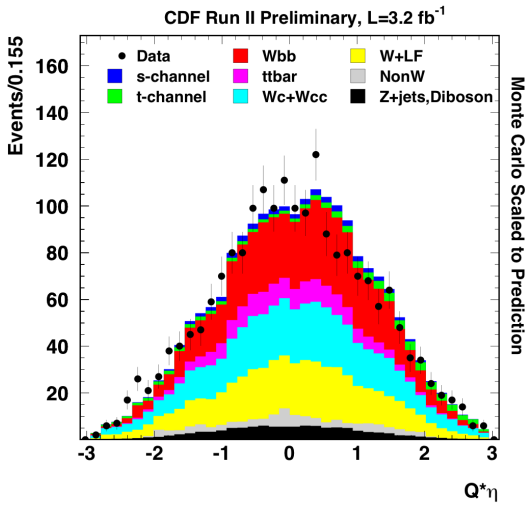
- By CDF (3.2 fb^{-1}) and DØ (2.3 fb^{-1})
  - CDF: m_t = 175 GeV
  - DØ: m_t = 170 GeV
- Event Selection:
  - lepton+jets
  - MET+jets (CDF)

  } & ≥1 b-tag
- S:B ≈ 1:20





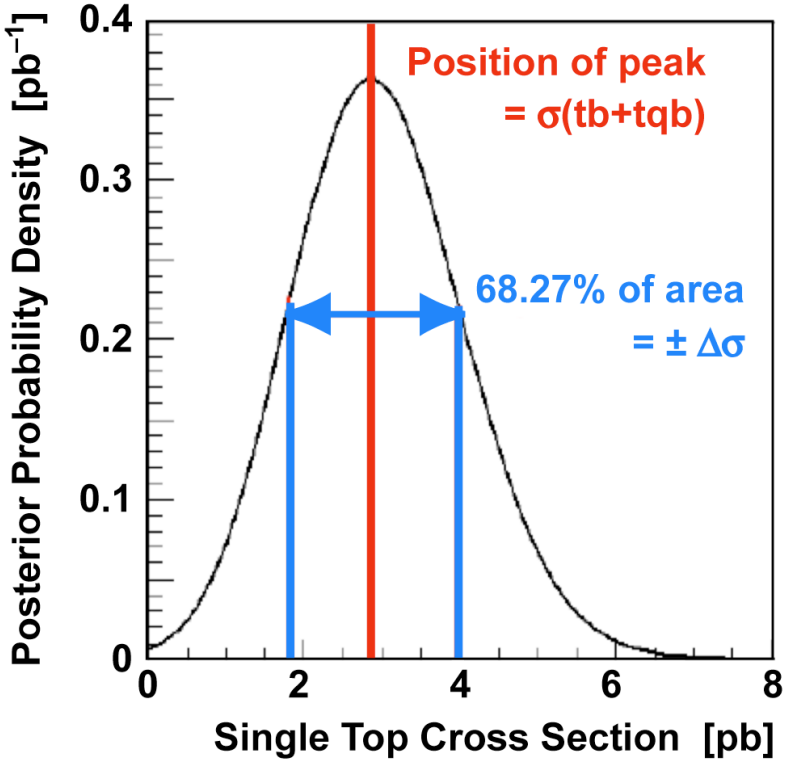


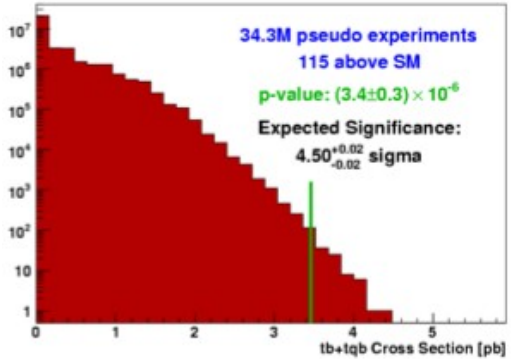


Single Top Observation

- By CDF (3.2 fb^{-1}) and DØ (2.3 fb^{-1})
  - CDF: m_t = 175 GeV
  - DØ: m_t = 170 GeV
- Event Selection:
  - lepton+jets
  - MET+jets (CDF)

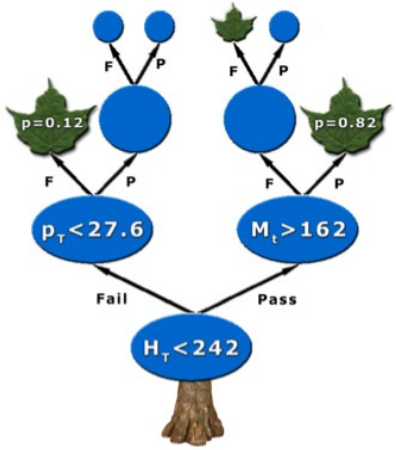
  } & ≥1 b-tag
- S:B ≈ 1:20
- Need sophisticated discriminants!
- Cross-section calculation:
  - Data & model discriminant distribution bayesian posterior
- Significance:
  - p-value from pseudo-experiments





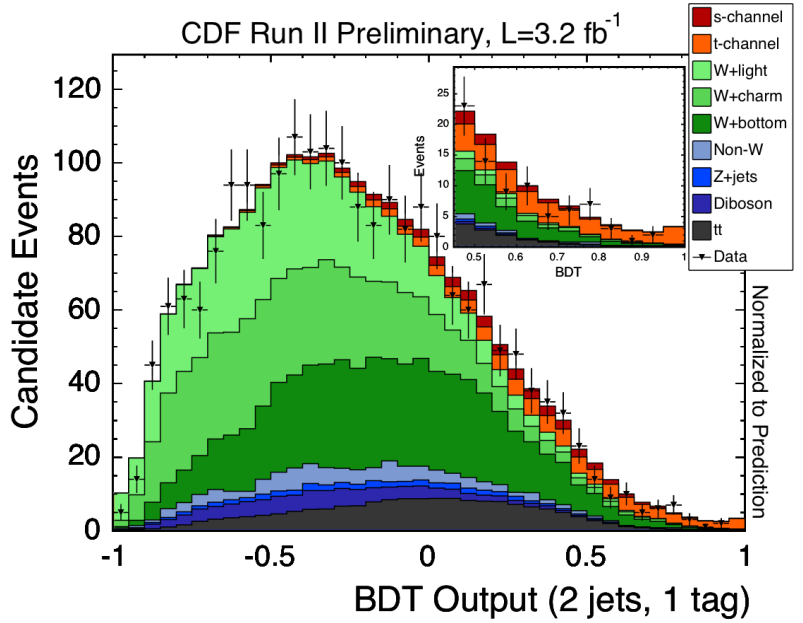
Single Top Observation

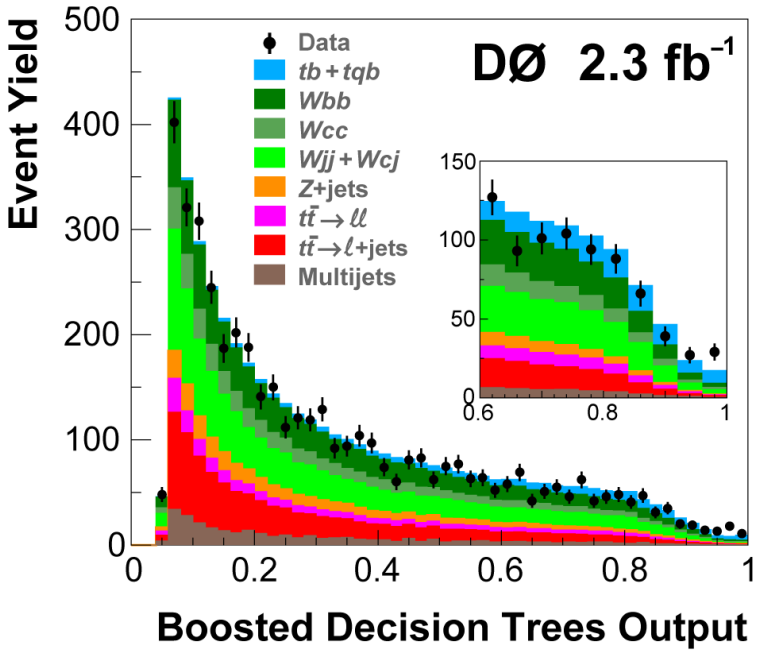
- Need sophisticated discriminants:
  - Boosted Decision Trees:
    - DT: sequence of cuts
    - Boosting: forest of trees with higher weights for failed signal events
    - Variables: 20 (CDF), 64 (DØ)



BDT Results

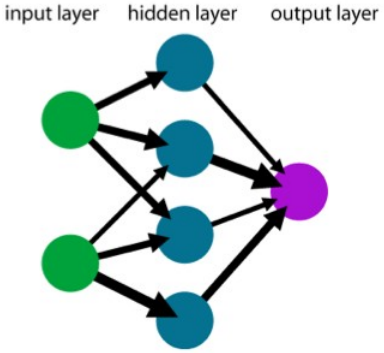
	$\mathcal{L}$ [fb^{-1}]	Significance Exp.	Obs.	σ_{s+t} [pb]
DØ	2.3	4.3σ	4.6σ	$3.7^{+1.0}_{-0.8}$
CDF	3.2	5.2σ	3.5σ	$2.1^{+0.7}_{-0.6}$





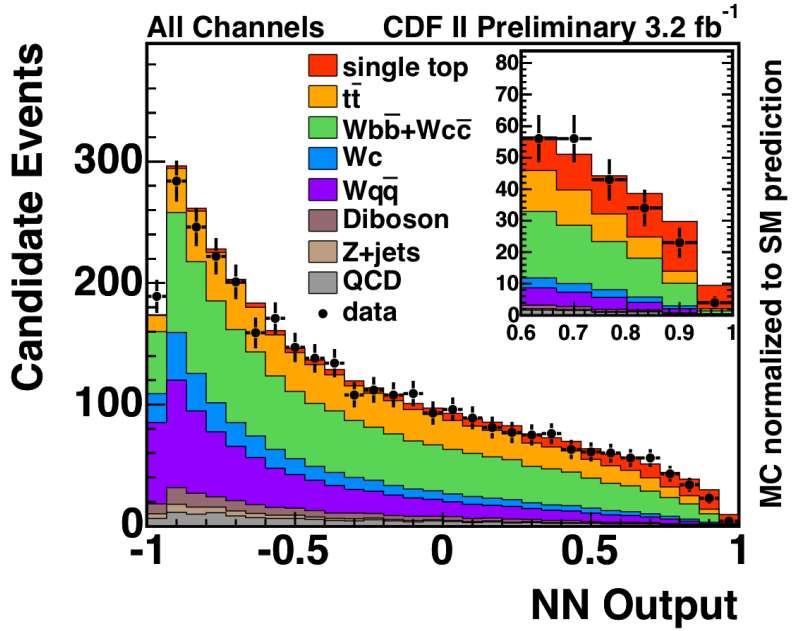
Single Top Observation

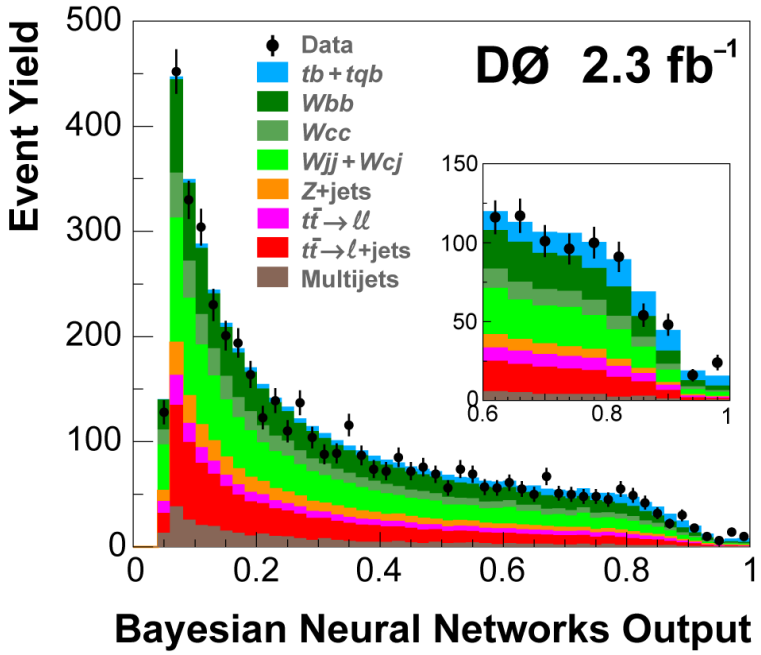
- Need sophisticated discriminants:
  - Neural Networks:
    - DØ: Bayesian NN. Many NN's averaged according to a bayesian posterior
    - CDF: 4 NN's with 11-18 variables including a jet flavor separator



NN Results

	$\mathcal{L}$ [fb^{-1}]	Significance Exp.	Obs.	σ_{s+t} [pb]
DØ	2.3	4.1σ	5.2σ	$4.7^{+1.2}_{-0.9}$
CDF	3.2	5.2σ	3.5σ	$1.8^{+0.6}_{-0.6}$





Single Top Observation

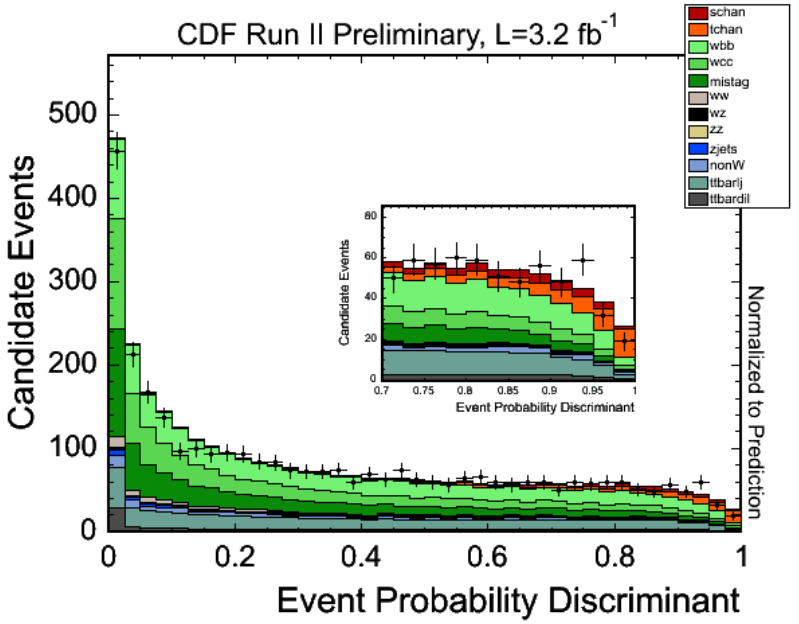
- Need sophisticated discriminants:
  - Matrix Element

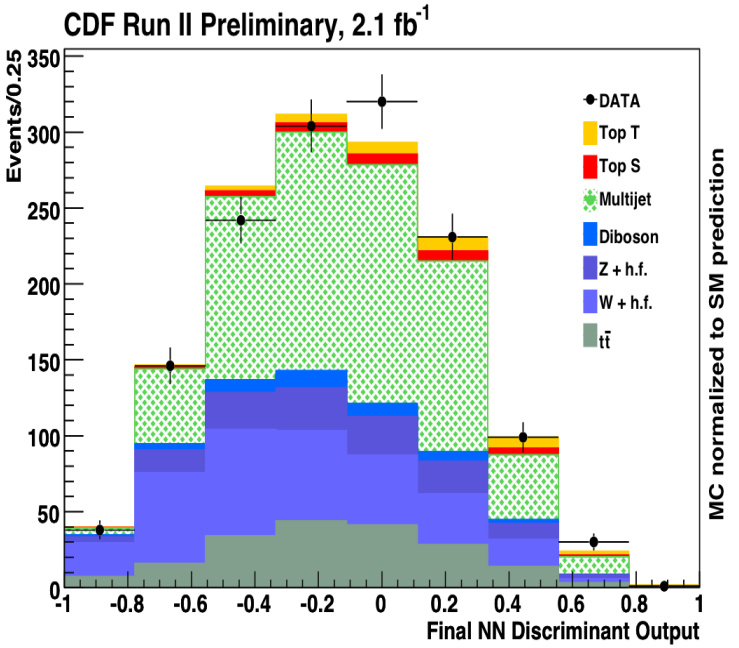
ME Results

	$\mathcal{L}$ [fb^{-1}]	Significance Exp.	Obs.	σ_{s+t} [pb]
DØ	2.3	4.1σ	5.0σ	$\mathbf{4.3^{+1.0}_{-1.2}}$
CDF	3.2	4.9σ	4.3σ	$\mathbf{2.5^{+0.7}_{-0.6}}$

  - Likelihood Function (only CDF)
    - Also optimized for s-channel
  - MET+jets with NN (only CDF)
    - Recover non-reconstructed leptons

	$\mathcal{L}$ [fb^{-1}]	Significance Exp.	Obs.	σ_{s+t} [pb]
$\not\!\!E_T$+jets	2.1	1.4σ	2.1σ	$\mathbf{4.9^{+2.5}_{-2.2}}$
LF	3.2	4.0σ	2.4σ	$\mathbf{1.6^{+1.0}_{-0.8}}$
LFS [†]	3.2	1.1σ	2.0σ	$\mathbf{1.5^{+0.9}_{-0.8}}$



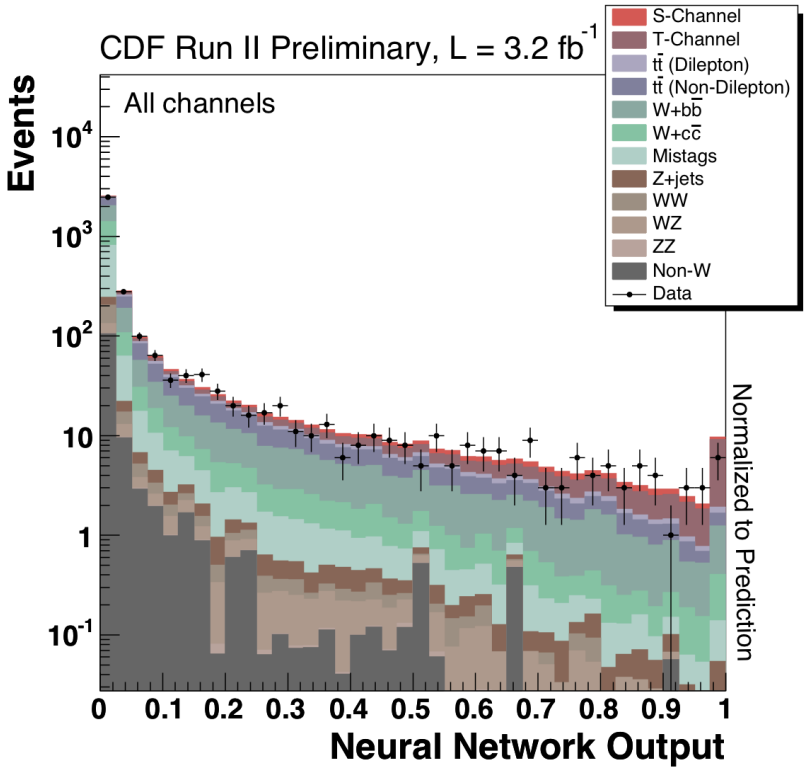


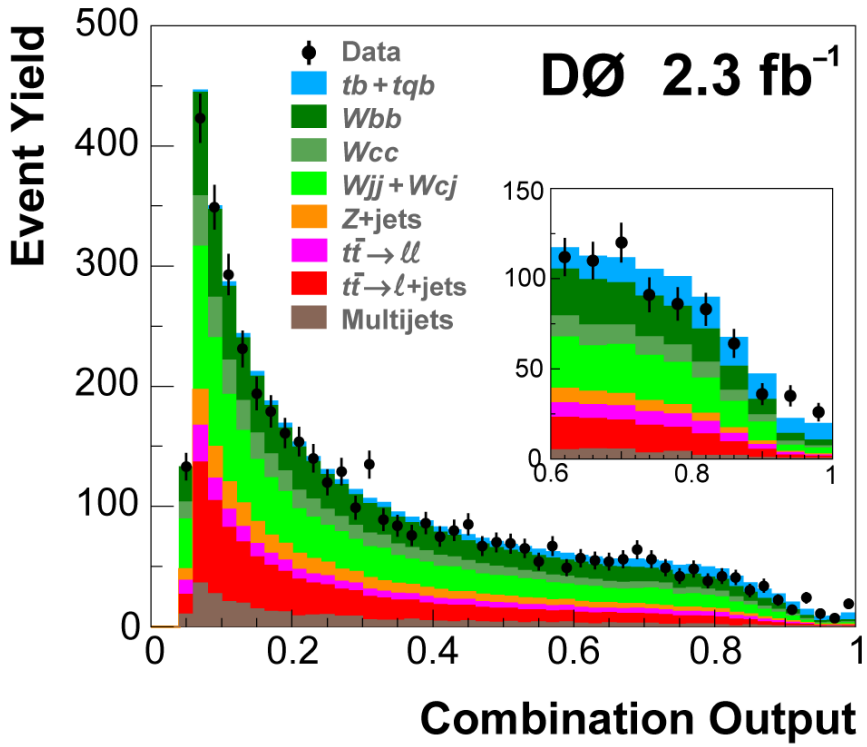
Single Top Observation

- Combination: **OBSERVATION!!!**
  - Combine the individual discriminants
    - DØ: use BNN
    - CDF: use NN optimized with "Neuro-Evolution of Augmenting Topologies"

Combined Results

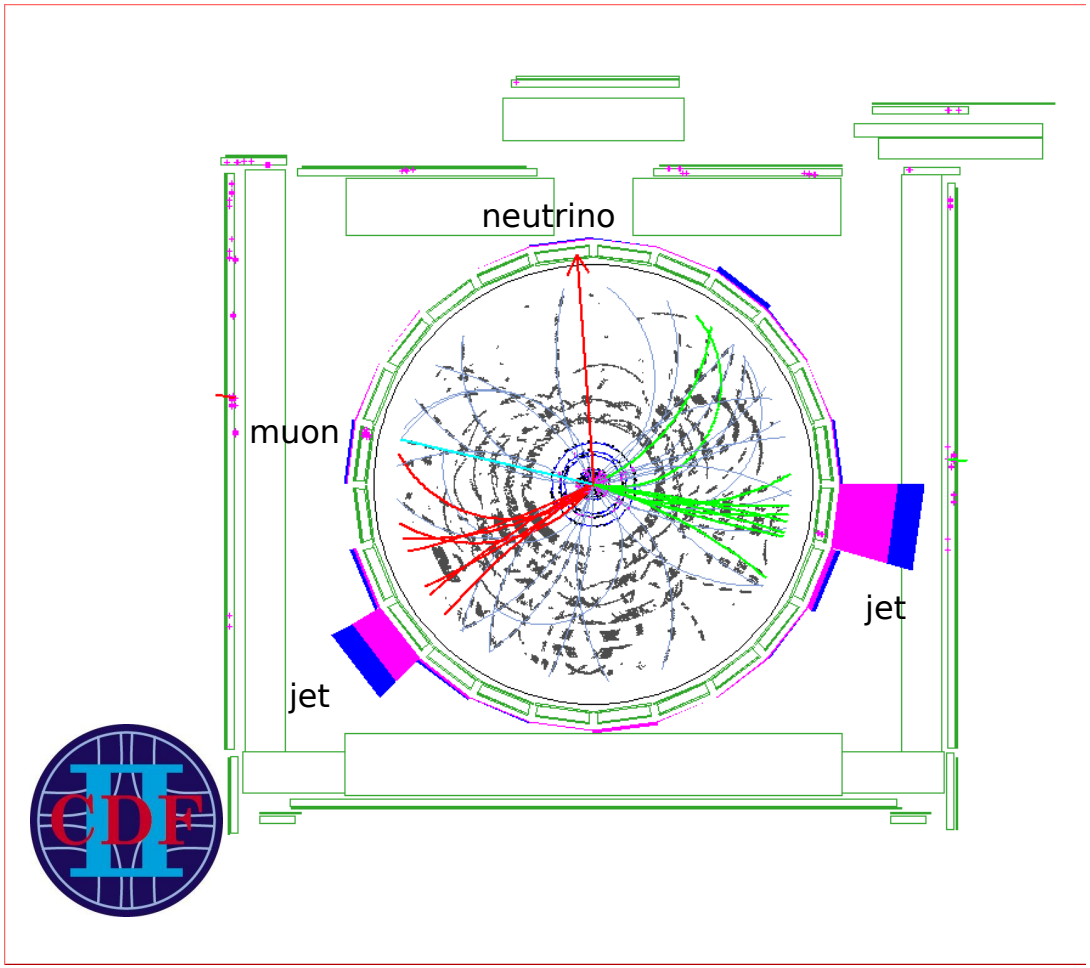
	$\mathcal{L}$ [fb^{-1}]	Significance Exp.	Obs.	σ_{s+t} [pb]
DØ	2.3	4.5σ	5.0σ	$3.9^{+0.9}_{-0.9}$
CDF	3.2	5.9σ	5.0σ	$2.3^{+0.6}_{-0.5}$

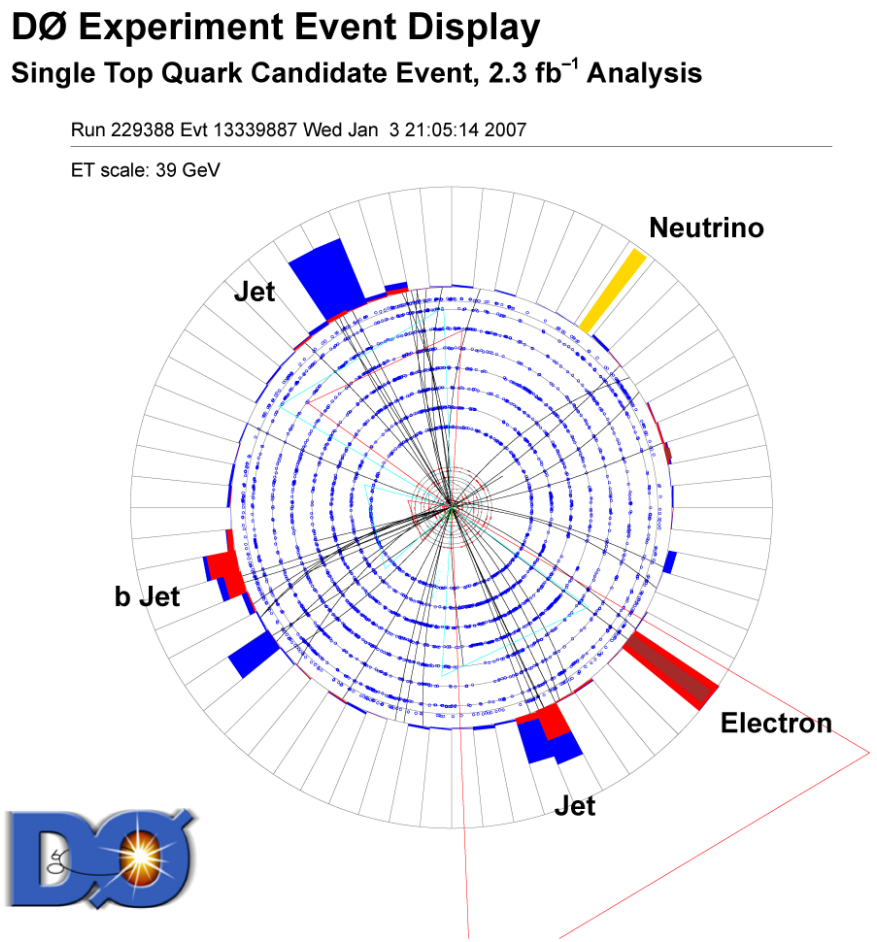




Single Top Observation

- Event displays

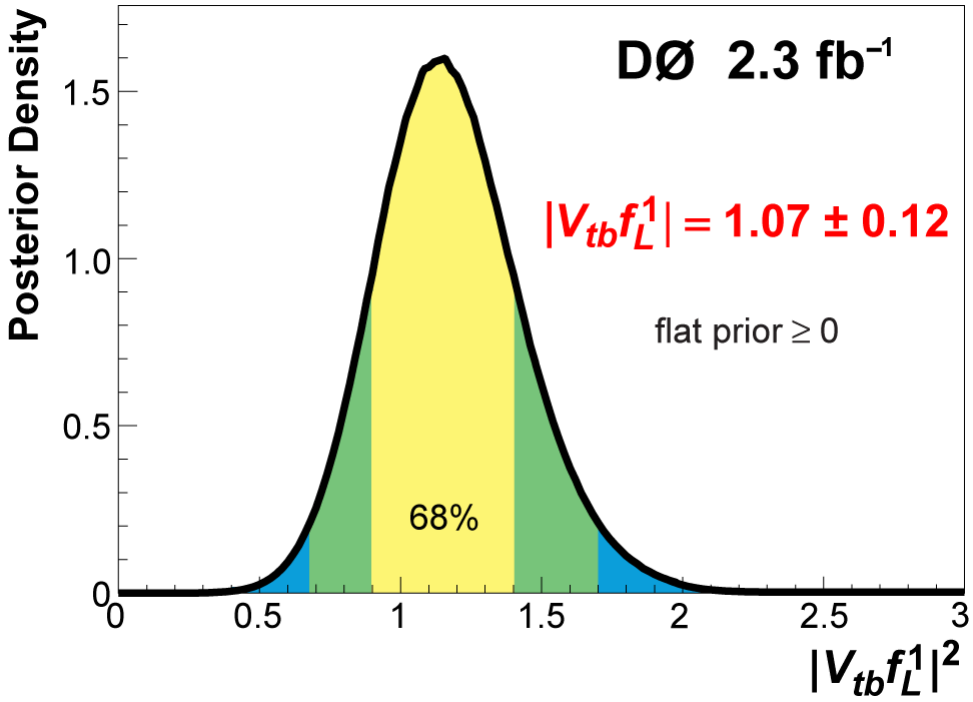




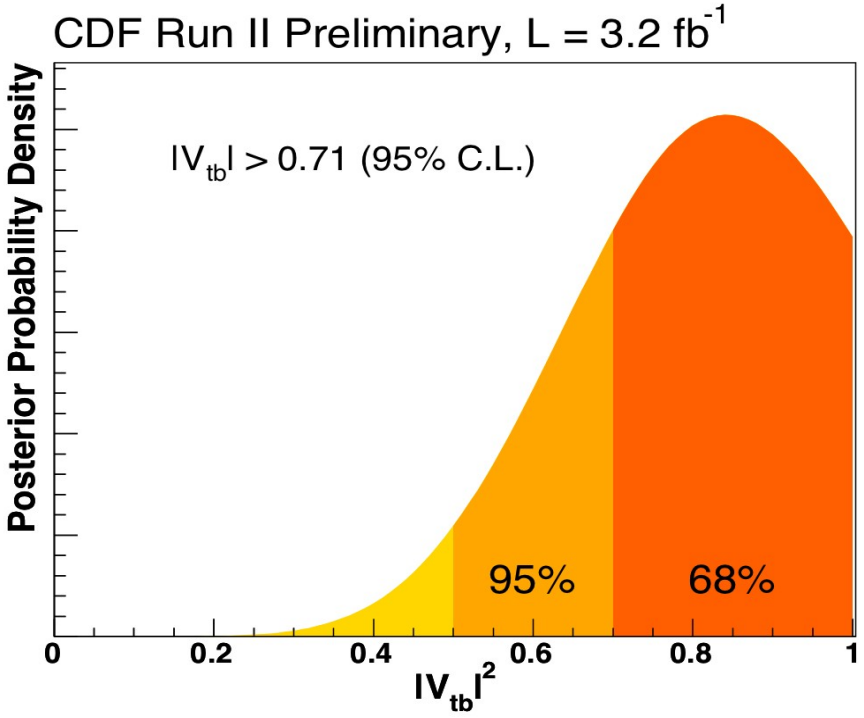
Single Top Observation

- Direct measurement of $|V_{tb}|$

$$\Gamma^{\mu}_{Wtb} = -\frac{g}{\sqrt{2}} V_{tb} \left\{ \gamma^{\mu} \left[f_1^L P_L + f_1^R P_R \right] - \frac{i\sigma^{\mu\nu}}{M_W} (p_t - p_b)_{\nu} \left[f_2^L P_L + f_2^R P_R \right] \right\}$$



$|V_{tb}f_{L^1}| = 1.07 \pm 0.12$,
$|V_{tb}| > 0.78$ at 95% CL



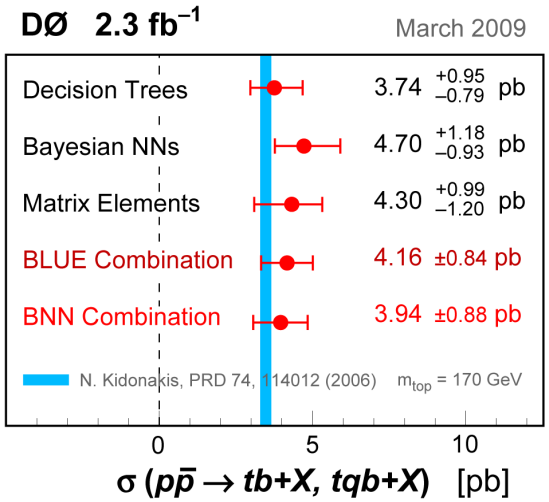
$|V_{tb}| = 0.91 \pm 0.11$,
$|V_{tb}| > 0.71$ at 95% CL

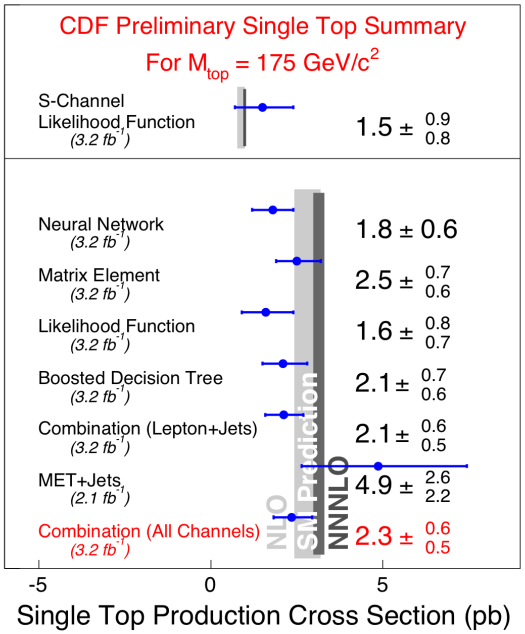
Summary

- Top mass: latest CDF & DØ combination:

  173.1 ± 0.6(stat) ± 1.1(syst) GeV

- Improvements in top pair cross section measurement. Interesting properties can be extracted
- Measured top properties still consistent with the SM.
- Physics beyond the SM being searched.
- Single top observed by CDF and DØ
- Improved direct measurements of |Vtb|

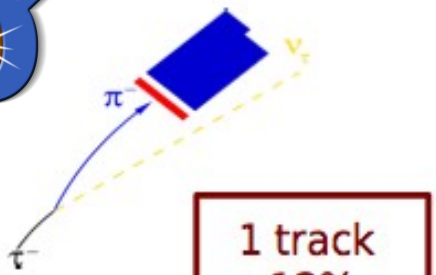


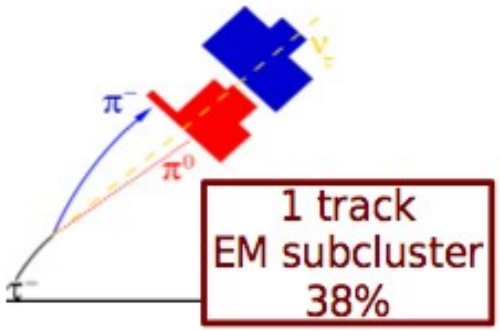


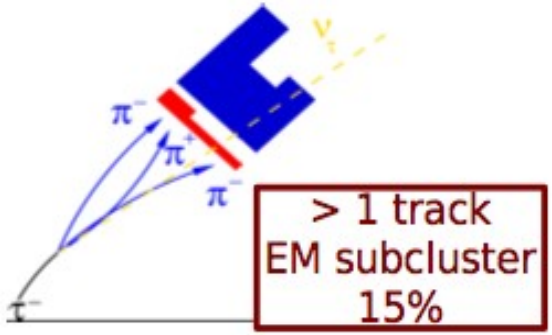
http://www-cdf.fnal.gov/physics/new/top/public.html
http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html

Back-up

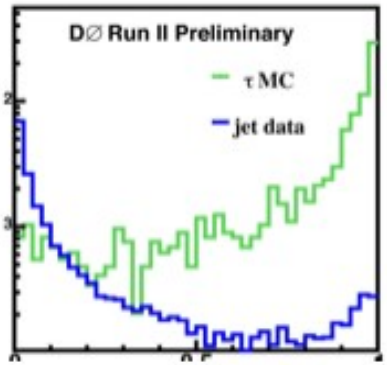
Tau identification

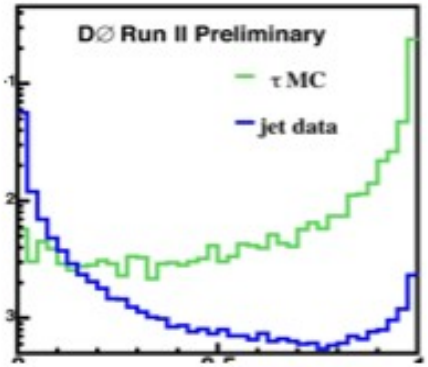


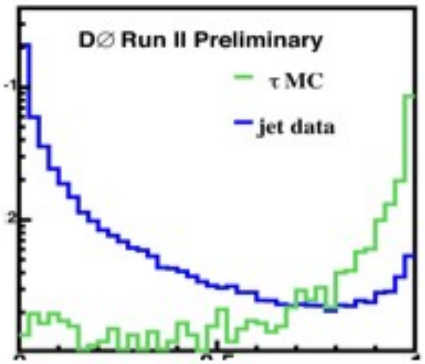




- Tau candidates is a narrow jets (dR = 0.3) + one or more tracks
- For each tau type a neural network has been trained to distinguish between true taus (from MC) and from fakes (from data).
- NN inputs: isolation, energy deposition profiles, track / calorimeter correlation variables. NN performance has been verified with $Z \Rightarrow \tau\tau$ data







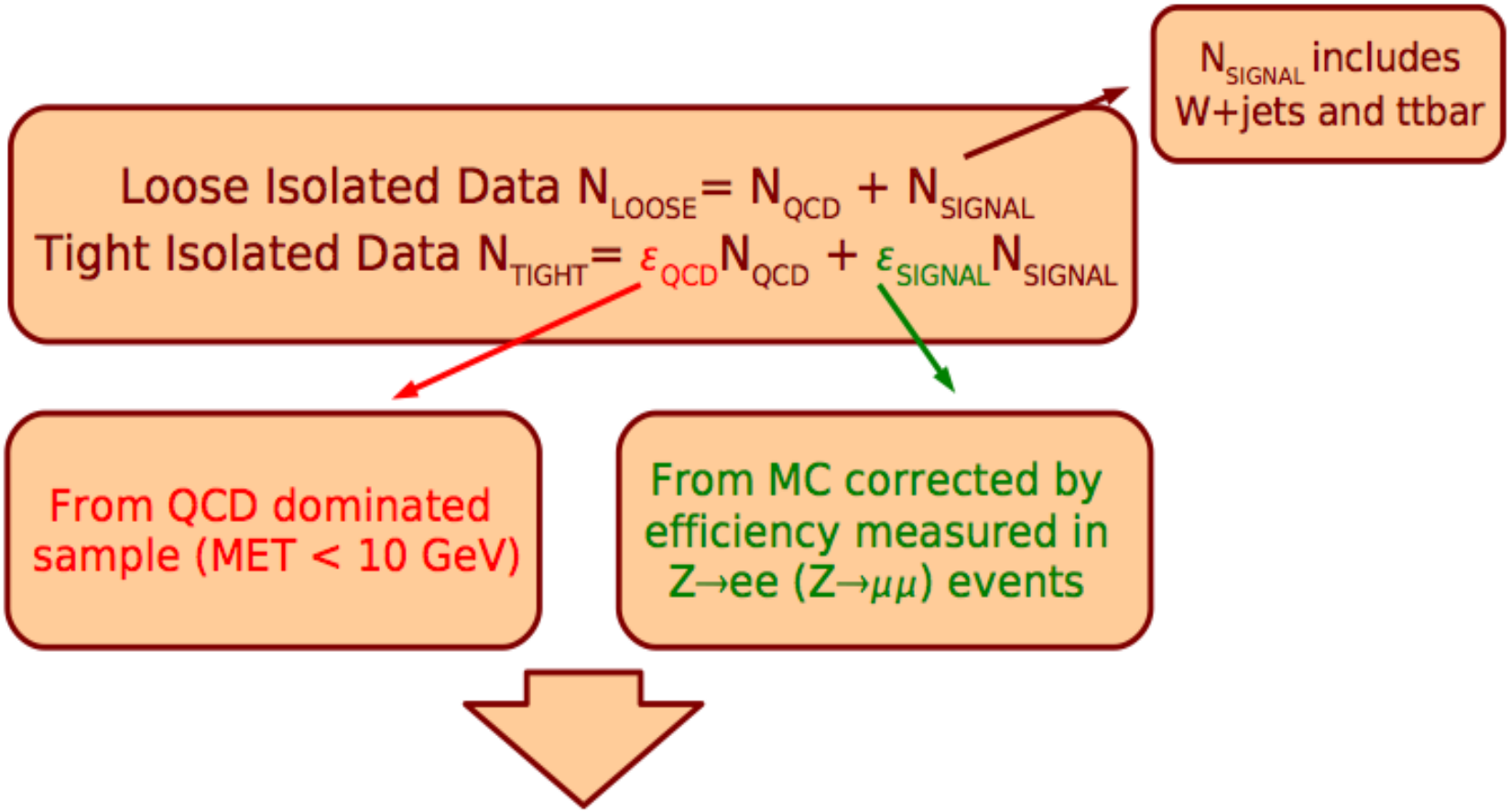
Lepton+jets selection

	D0	CDF
electron:	isolated cluster in EM calo, p_T>20 GeV, track match, $\|\eta\| \in$ 0 – 1.1	isolated cluster in EM calo, p_T>20 GeV, track match,
muon:	track in muon system, track in central tracker isolated in calo and tracker p_T>20 GeV, $\|\eta\| < 2$	track in muon system, trak in central tracker isolated in calo and tracker p_T>20 GeV
jet:	dR=0.5 cone, JES corrected for muons from b-quark decays, at least 2 jets with p_T > 40 (leading), 20 GeV, $\|\eta\| < 2.5$	dR=0.4 cone, JES corrected, at least 3 jets with p_T > 30 (leading), 20 GeV, $\|\eta\| < 2.5$
MET:	corrected for electrons, muons, jets. MET >20 (e+jets), 25 (μ+jets) GeV. MET vector and lepton p_T separted in azimuth	corrected for electrons, muons, jets, MET > 35 GeV
Final:	topological, with b-tagging	topological (neural network), with b-tagging

Dilepton selection

	D0	CDF
electron:	isolated cluster in EM calo, p_T>15 GeV, track match, $\|\eta\| \in$ 0 – 1.1, 1.5 – 2.5	isolated cluster in EM calo, p_T>20 GeV, track match,
muon:	track in muon system, track in central tracker isolated in calo and tracker p_T>15 GeV, $\|\eta\| < 2$	track in muon system and in central tracker isolated in calo and tracker p_T>20 GeV,
jet:	dR=0.5 cone, JES corrected for muons from b-quark decays, p_T > 30, 20 GeV, $\|\eta\| < 2.5$	dR=0.4 cone, JES corrected, p_T > 30, 15 GeV, $\|\eta\| < 2.5$
MET:	corrected for electrons, muons, jets, MET > 0, 35, 45 GeV	corrected for electrons, muons, jets, MET > 25 GeV
Final:	topological	topological, with b-tagging

Matrix Method



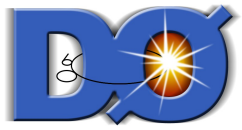
$$N_{QCD} = \frac{\varepsilon_{SIGNAL} N_{LOOSE} - N_{TIGHT}}{\varepsilon_{SIGNAL} - \varepsilon_{QCD}}$$

Mass ME l+jets systematics

Source	Uncertainty (GeV)
Higher Order Effects	±0.25
ISR/FSR	±0.26
Hadronization and UE	±0.58
Color Reconnection	±0.50
PDF uncertainty	±0.24
Residual JES uncertainty	±0.21
Relative b/light response	±0.81
Sample-dependent JES	±0.56
Jet ID efficiency	±0.26
Jet energy resolution	±0.32
Plus a few smaller sys <0.2	
Total	±1.44

Systematic source	Systematic uncertainty (GeV)
Calibration	0.2
MC generator	0.5
ISR and FSR	0.3
Residual JES	0.5
b-JES	0.4
Lepton P_T	0.2
Multiple hadron interactions	0.1
PDFs	0.2
Background	0.5
Color reconnection	0.4
Total	1.1

Mass dilepton systematics



Uncertainty	$e\mu$ Run IIb [GeV]
JES up	-1.5
JES down	$+1.8$
b quark JES	$+1.4$
jet resolution up	-0.7
jet resolution down	$+0.7$
jssr shifting	$+0.1$
muon smearing up	-0.0
muon smearing down	$+0.3$
b quark fragmentation	± 0.3
PDF uncertainty up	-0.2
PDF uncertainty down	$+0.1$
fit uncertainty	± 0.4
signal modeling	± 0.4
background fraction up	-0.1
background fraction down	$+0.2$
TOTAL	$^{+2.5}_{-1.8}$

Uncertainty	$e\mu$ Run IIa [GeV]	$e\mu$ Run IIb [GeV]
JES	$^{+1.2}_{-1.3}$	$^{+1.5}_{-1.6}$
b/light quark response	± 1.4	± 1.6
jet resolution	$^{+0.6}_{-0.6}$	$^{+0.2}_{-0.3}$
sample-dependent JES	± 0.2	± 0.1
muon smearing	$^{+0.3}_{-0.0}$	± 0.3
b quark modeling	± 0.1	± 0.3
PDF uncertainty	$^{+0.3}_{-0.0}$	$^{+0.1}_{-0.2}$
MC calibration	± 0.4	± 0.4
signal fraction	$^{+0.2}_{-0.0}$	± 0.3
QCD background modeling	± 0.6	± 0.6
electron energy scale	± 0.1	± 0.1
muon momentum scale	± 0.2	± 0.2
hadronization and UE	± 1.0	± 1.0
ISR/FSR	± 0.6	± 0.6
Color reconnection	± 0.4	± 0.4
TOTAL	± 2.4	± 2.6

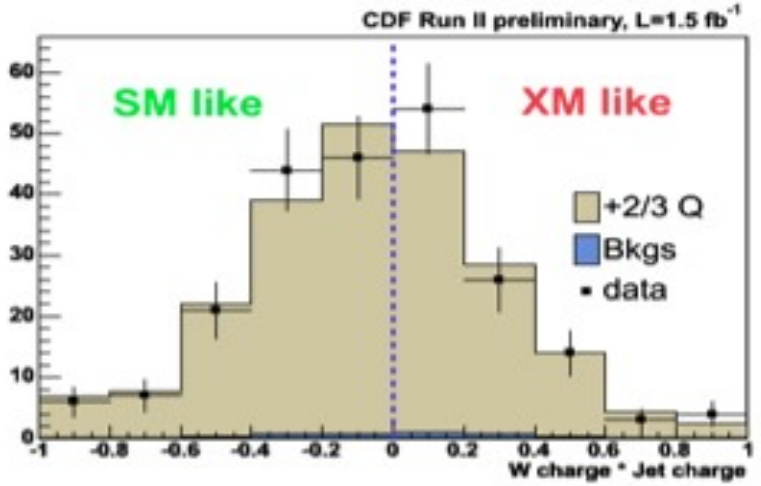
TABLE II: Summary of systematic uncertainties.

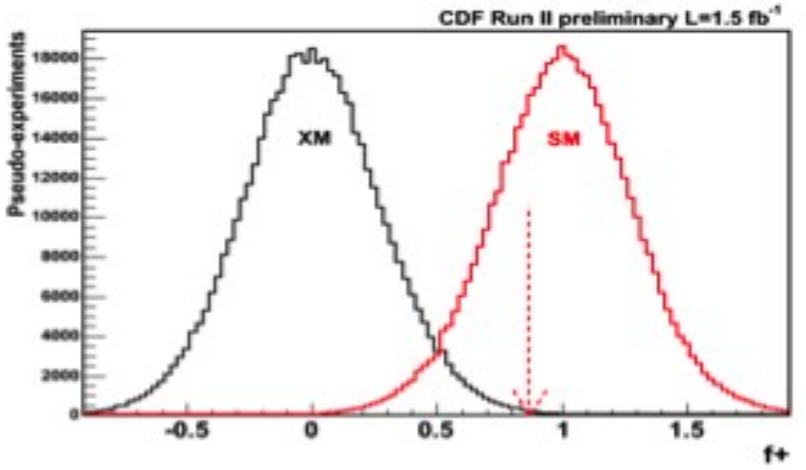
Mass alljets systematics

Source	δM_{top}^{syst} (GeV/c^2)	$\delta\Delta\text{JES}^{syst}$
Residual bias	$^{+0.8}_{-0.4}$	$^{+0.18}_{-0.24}$
2D calibration	< 0.1	< 0.01
Generator	0.3	0.25
ISR/FSR	0.1	0.06
b-jets energy scale	0.2	0.04
SF E_T dependence	0.1	0.01
Residual JES	0.5	$--$
PDF	$^{+0.3}_{-0.2}$	$^{+0.05}_{-0.04}$
Multiple Hadron Interactions	0.2	0.01
Color Reconnections	0.4	0.08
Templates Statistics	0.3	0.07
Background Shape	0.1	0.02
Background Normalization	0.2	0.05
Total	$^{+1.2}_{-1.0}$	$^{+0.34}_{-0.37}$

top quark charge

- is it
  - $t \rightarrow W^{+}b$ (Q_{top} = 2/3 e)
  - $t \rightarrow W^{-}b$ (Q_{top} = -4/3 e)
- Exotic model
  - doublet (–1/3e,–4/3e) ?
  - D. Chang et al., PRD59 (1999) 091503
- D0 PRL 98, 041801 (2007)
  - 4/3e excluded at 92% CL
  - fraction of exotic quark pairs < 0.80 (90% CL)
- CDF result with 1.5/fb
  - p-value for SM: 0.31
  - exotic model XM excluded with 87% CL





Single top event selection

DØ

- One isolated lepton with $p_T > 15$ and $|\eta| < 1.1$ (2.0) for e (μ)
- Veto events with additional leptons
- 2-4 jets, with $p_T > 15$ GeV and $|\eta_{\rm det}| < 3.4$
- 1-2 b-tagged jets
- Leading jet $p_T > 25$ GeV
  Leading b-tagged jet $p_T > 20$ GeV
- $\not\!\!E_T > 20$ (25) for events with 2 (3 or 4) jets
- Remove events with low $H_T(\text{alljets}, \mu, \not\!\!E_T)$ ($\sim <$ 120 GeV) to reduce QCD
- Remove events where ℓ aligned/anti-aligned with $\vec{\not\!\!E}_T$

CDF

- One isolated lepton with $p_T > 20$ and $|\eta| < 1.6$ (not for MJ)
- Veto additional leptons
- 2-3 jets, with $p_T > 20$ GeV and $|\eta_{\rm det}| < 2.8$
- At least one b-tagged jet
- $\not\!\!E_T > 25$ (50) for LJ (MJ)
- MJ only: leading jet $p_T > 35$, second jet $p_T > 25$ GeV
- MJ only: Cut on NN trained to chareterize QCD

Single top event yields

Process	Number of Events in 3.2 fb^{-1}	
	W + 2 jets	W + 3 jets
s-channel	58.1 ± 8.4	19.2 ± 2.8
t-channel	87.6 ± 13.0	26.2 ± 3.9
$Wb\bar{b}$	656.9 ± 198.0	201.3 ± 60.8
$Wc\bar{c}$	292.2 ± 90.1	98.1 ± 30.2
Wcj	250.4 ± 77.2	52.1 ± 16.0
Mistags	501.3 ± 69.6	151.9 ± 21.4
non-W	89.6 ± 35.8	35.1 ± 14.0
WW	58.5 ± 6.6	21.2 ± 2.4
WZ	28.9 ± 2.4	8.5 ± 0.7
ZZ	0.9 ± 0.1	0.4 ± 0.0
$Z + jets$	36.5 ± 5.6	15.6 ± 2.4
$t\bar{t}$ dilepton	69.2 ± 10.0	60.2 ± 8.7
$t\bar{t}$ non-dilepton	134.9 ± 19.6	421.8 ± 61.1
Total signal	145.7 ± 21.4	45.4 ± 6.7
Total prediction	2265.0 ± 375.4	1111.5 ± 129.5
Observed in data	2229	1086

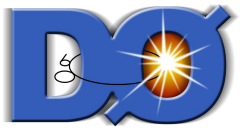
Event Yields in 2.3 fb^{-1} of DØ Data

Electron + muon, 1 tag + 2 tags combined

Source	2 jets	3 jets	4 jets
s-channel *tb*	62 ± 9	24 ± 4	7 ± 2
t-channel *tqb*	77 ± 10	39 ± 6	14 ± 3
$W+b\bar{b}$	678 ± 104	254 ± 39	73 ± 11
$W+c\bar{c}$	303 ± 48	130 ± 21	42 ± 7
$W+cj$	435 ± 27	113 ± 7	24 ± 2
$W+jj$	413 ± 26	140 ± 9	41 ± 3
Z+jets	141 ± 33	54 ± 14	17 ± 5
Dibosons	89 ± 11	32 ± 5	9 ± 2
$t\bar{t} \to \ell\ell$	149 ± 23	105 ± 16	32 ± 6
$t\bar{t} \to \ell$+jets	72 ± 13	331 ± 51	452 ± 66
Multijets	196 ± 50	73 ± 17	30 ± 6
Total prediction	2,615 ± 192	1,294 ± 107	742 ± 80
Data	2,579	1,216	724

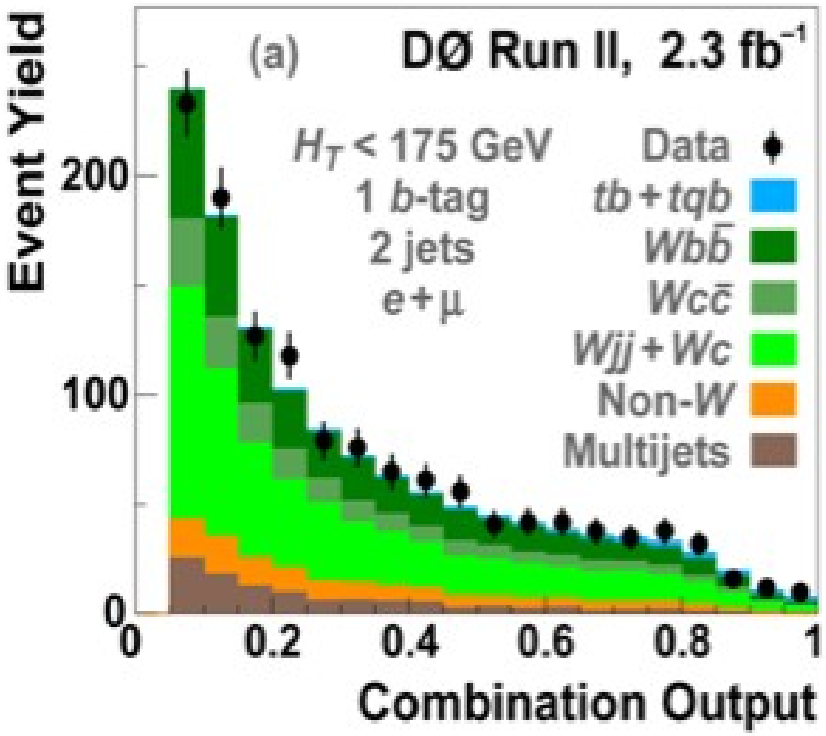
Single top systematics

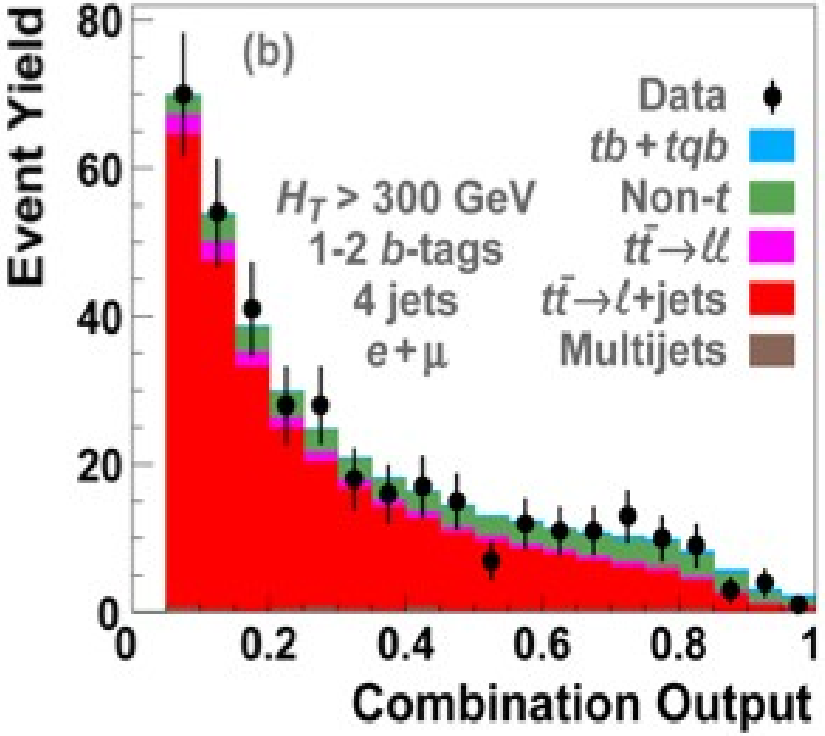
Systematic	Rate	Shape
Jet energy scale	0...16%	✓
Initial state radiation	0...11%	✓
Final state radiation	0...15%	✓
Parton distribution functions	2...3%	✓
Monte Carlo generator	1...5%	—
Event detection efficiency	0...9%	—
Luminosity	6%	—
NN flavor separator	—	✓
Mistag model	—	✓
Non-W model	—	✓
ALPGEN Q^2	—	✓
MC Modeling $(\Delta R, \eta(j_2))$	—	✓
$Wb\bar{b}$+$Wc\bar{c}$ normalization	30%	—
Wc normalization	30%	—
Mistag normalization	17...29%	—
Top Mass - top-pair normalization	23%	✓



Systematic Uncertainties	
Components for normalization	
Integrated luminosity	6.1%
$t\bar{t}$ cross section	12.7%
Z+jets and dibosons cross section	5.8%
Branching fractions	1.5%
Parton distribution functions (signal only)	3.0%
Triggers	5.0%
Instantaneous luminosity reweighting	1.0%
Primary vertex selection	1.4%
Lepton identification	2.5%
Jet fragmentation	(0.7–4.0)%
Initial-state and final-state radiation	(0.6–12.6)%
b-jet fragmentation	2.0%
Jet reconstruction and identification	1.0%
Jet energy resolution	4.0%
W+jets and Z+jets heavy flavor correction	13.7%
Multijets normalization to data	(30–54)%
Monte Carlo and multijets statistics	(0.5–16)%
Components for normalization and shape	
Jet energy scale for signal	(1.1–13.1)%
Jet energy scale for total background	(0.1–2.1)%
b tagging for single-tagged	(2.1–7.0)%
b tagging for double-tagged	(9.0–11.4)%
Component for shape only	
ALPGEN reweighting	–

Single top cross-check samples

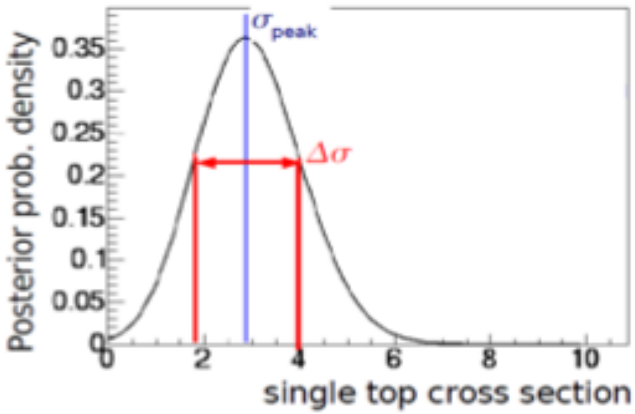




Probability to observe data distribution D, expecting y:

$$y = \alpha l \sigma + \sum_{s=1}^{N} b_s \equiv a\sigma + \sum_{s=1}^{N} b_s$$

$$P(D|y) \equiv P(D|\sigma, a, b) = \prod_{i=1}^{nbins} P(D_i|y_i)$$



The cross section is obtained

$$Post(\sigma|D) \equiv P(\sigma|D) \propto \int_a \int_b P(D|\sigma, a, b) Prior(\sigma) Prior(a, b)$$

- Bayesian posterior probability density
- Shape and normalization systematics treated as nuisance parameters
- Correlations between uncertainties properly accounted for
- Flat prior in signal cross section