Recent results from EW and Top Quark Physics at DØ

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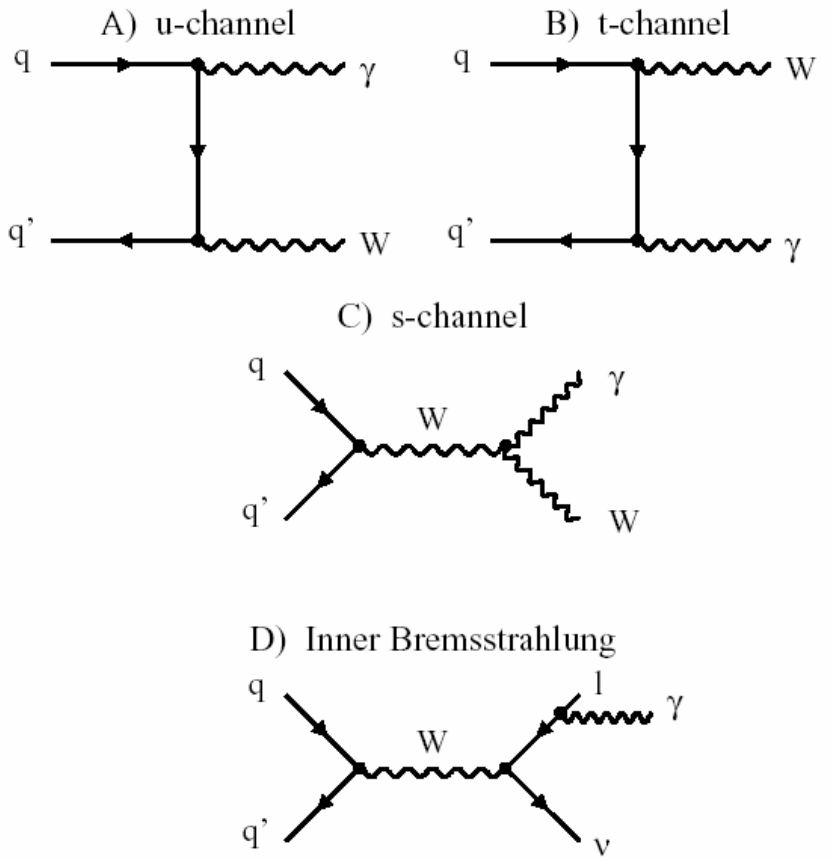
On behalf of the DØ Collaboration

Gauge Boson Couplings

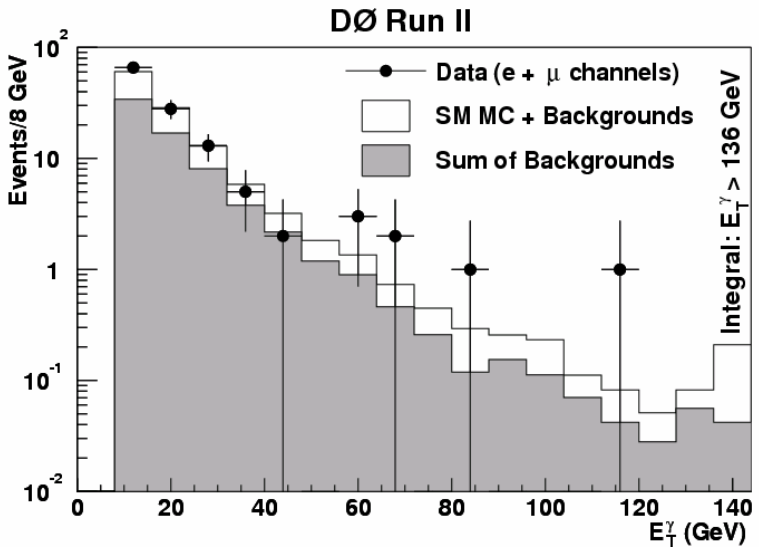
- The standard model makes very stringent predictions for (i.e. uniquely determines) the trilinear couplings of the gauge bosons: W, Z, and γ.
- These couplings can be investigated by measuring Wγ and Zγ production, as well as WW, WZ, and ZZ pair production.
- The presence of anomalous couplings would indicate physics beyond the standard model.
- Parameterized by an effective Lagrangian. Spin 1 boson will have four parameters.

Wγ Production

- Requires efficient photon identification.
- Event selection:
  - High P_T isolated electron or muon,
  - Missing transverse energy,
  - Isolated photon with $E_T > 8$ GeV $|\eta| < 1.1$ and $\Delta R(l,\gamma) > 0.7$.
- Photon ID efficiency $= 81 \pm 1$ %.
- Main background is W+jets production where the jet mimics a photon. Estimated from data.
- Background for important high P_T analyses: H→WW, top, trileptons.



Wγ Production Cross Section



Fermilab-Pub-05-046-E

	$e\nu\gamma$ Channel	$\mu\nu\gamma$ Channel
Luminosity	162 pb^{-1}	134 pb^{-1}
$W+$ jet background events	58.7 ± 4.5	61.8 ± 5.1
ℓeX background events	1.7 ± 0.5	0.7 ± 0.2
$W\gamma \to \tau\nu\gamma$ background events	0.42 ± 0.02	1.9 ± 0.2
$Z\gamma \to \ell\ell\gamma$ background events	-	6.9 ± 0.7
Total background events	60.8 ± 4.5	71.3 ± 5.2
Selected events	112	161
Total signal events	51.2 ± 11.5	89.7 ± 13.7

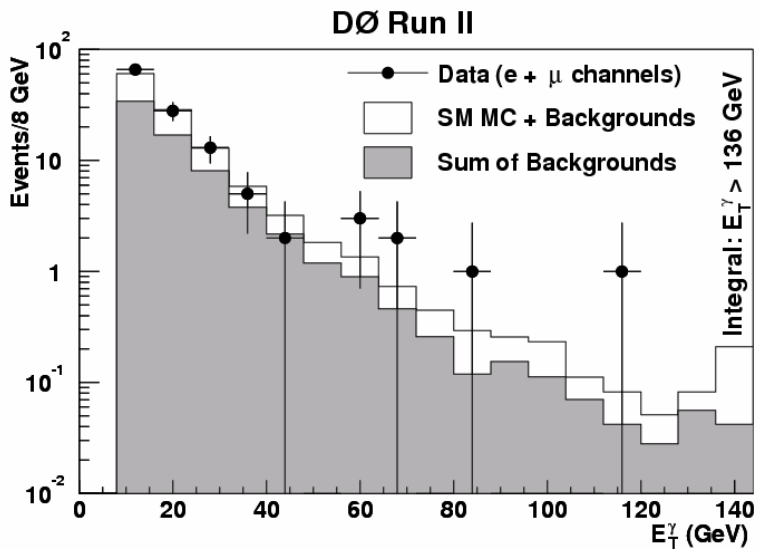
- Theory cross section: $\sigma(pp \to W\gamma \to l\nu\gamma) = 16.0 \pm 0.4$ pb.
- Combined electron and muon cross section: L = 162 (134) pb^{-1}

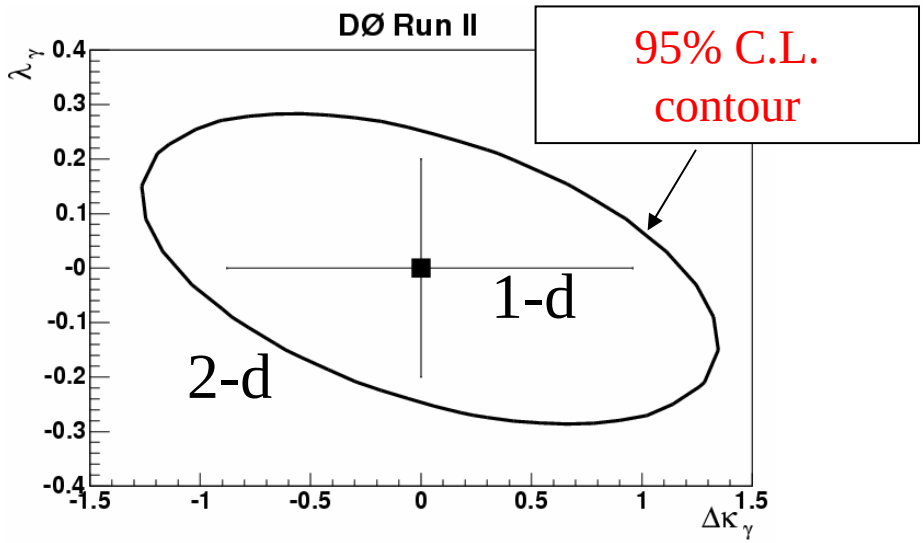
$\sigma(pp \to W\gamma \to l\nu\gamma) = 14.8 \pm 1.6(stat) \pm 1.0(syst) \pm 1.0(lumi)$ pb.

- In the absence of an excess of large E_T photons, extract limits on the anomalous couplings.

Wγ Anomalous Couplings

Fermilab-Pub-05-046-E

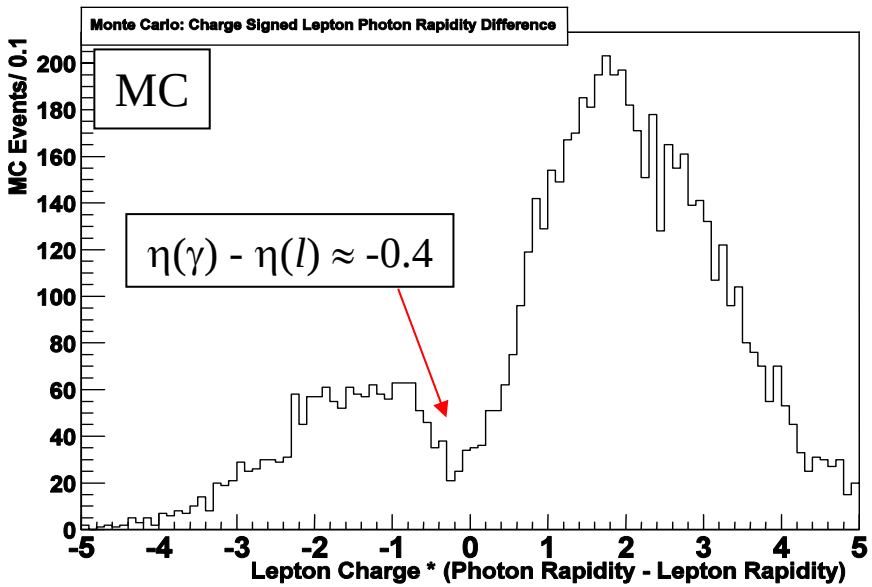


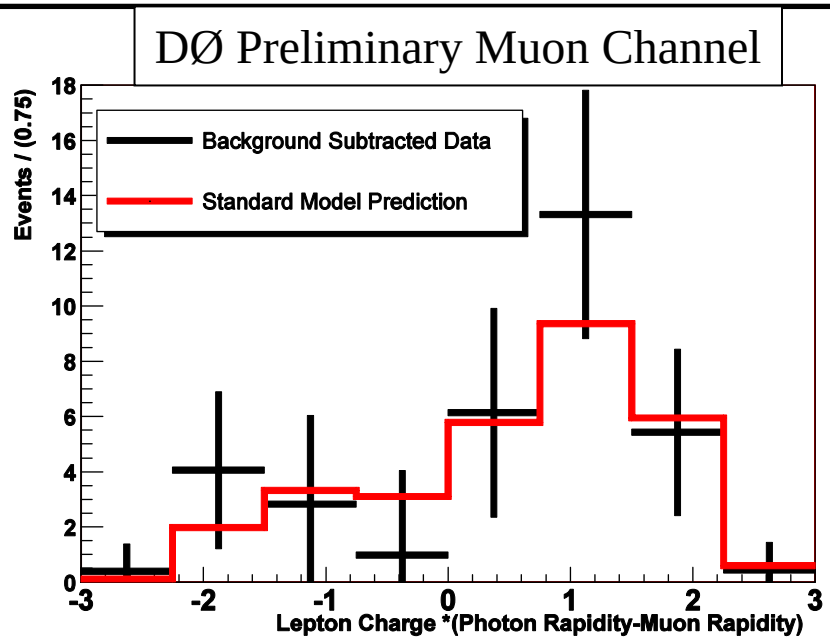


- Binned maximum likelihood fit to the photon E_T spectrum.
- Limits on CP conserving couplings (Λ = 2 TeV):

  $-0.88 < \Delta\kappa_\gamma < 0.96$ $-0.20 < \lambda_\gamma < 0.20$
- Limits on non-CP conserving couplings in progress.

Radiation Amplitude Zero

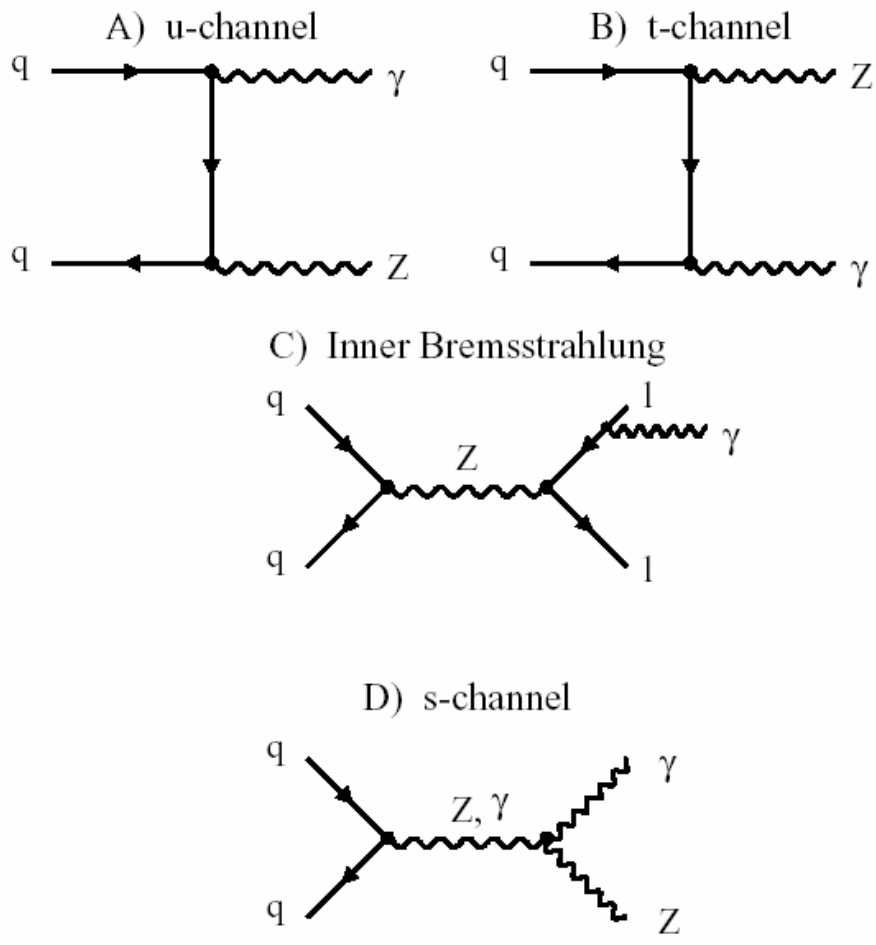




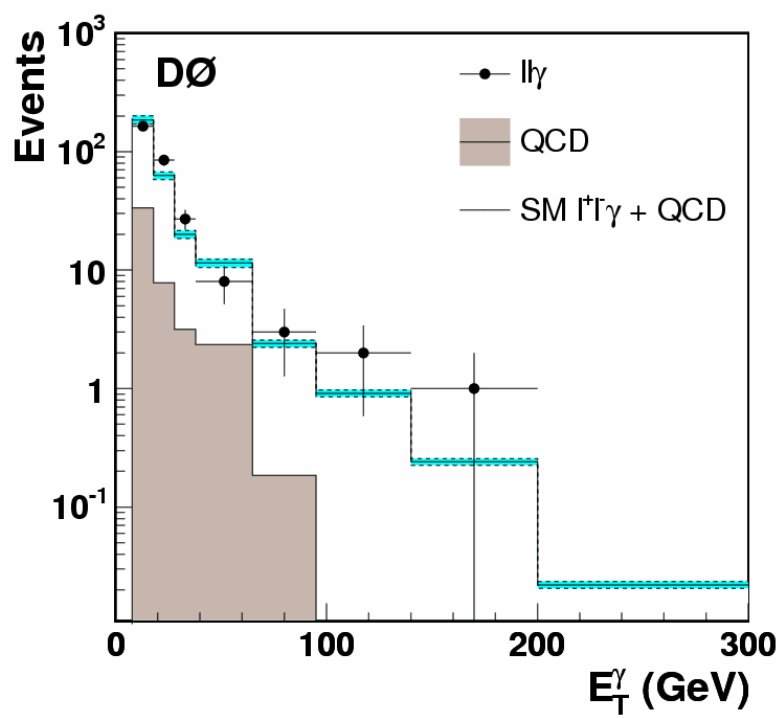
- For cos θ*, the angle between incoming quark and photon in the Wγ rest frame, equal to 1/3, the differential cross section goes to zero. This is a radiation amplitude zero.
- Endcap photon identification necessary to get a statistically significant signal. In progress…
- Background subtraction important (M(W,γ) > 90 GeV/c^2).

Zγ Production

- Requires efficient photon identification.
- Event selection:
  - Two high P_T isolated electrons or muons (oppositely charged),
  - Isolated photon with $P_T > 8$ GeV, $|\eta| < 1.1$ and $\Delta R(l,\gamma) > 0.7$.
- Photon ID efficiency = 81 ± 1 %.
- Main background is Z+jets production where the jet mimics a photon. Estimated from data.



Zγ Production Cross Section



Zγ Event Yields

	Electron	**Muon**
SM	95.3 ± 4.9	126.0 ± 7.8
Bkgd	23.6 ± 2.3	22.4 ± 3.0
Data	138	152

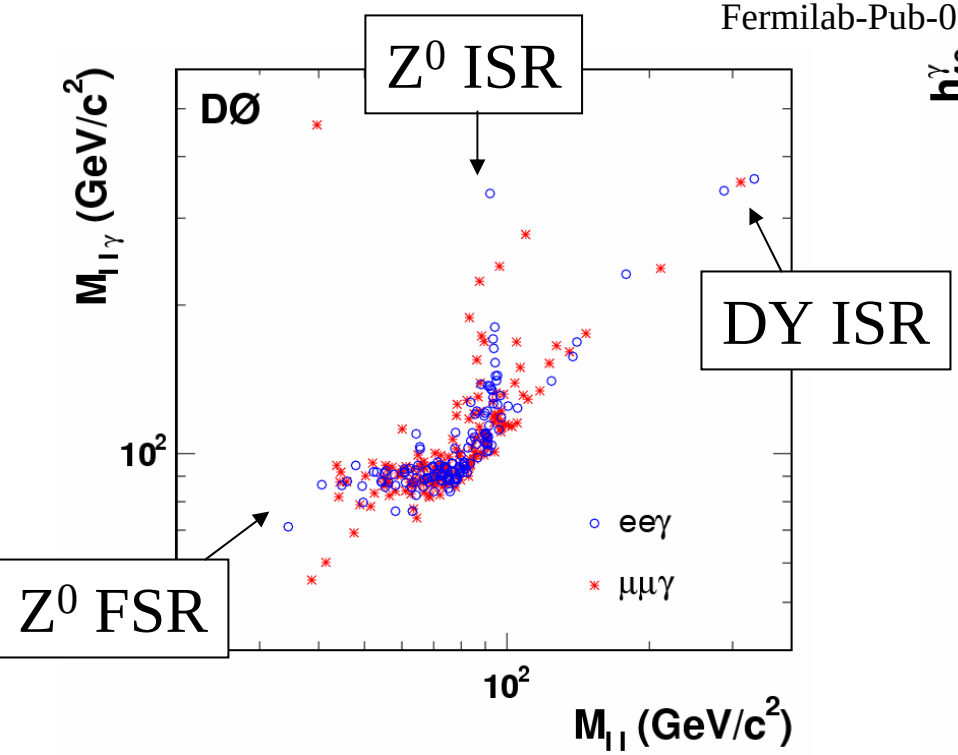
Fermilab-Pub-05/023-E

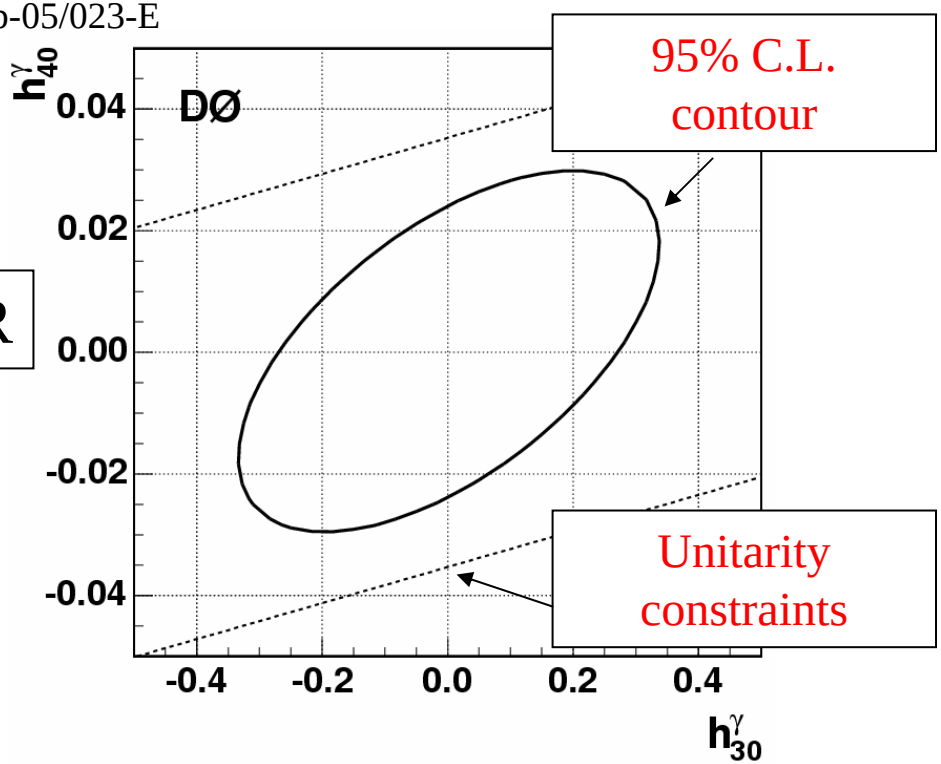
- Theory cross section: $\sigma(pp \rightarrow Z\gamma \rightarrow ll\gamma) = 3.9 + 0.1 - 0.2$ pb.
- Combined electron and muon cross section: L = 320(290) pb^{-1}

$\sigma(pp \rightarrow Z\gamma \rightarrow ll\gamma) = 4.2 \pm 0.4$ (stat+sys) ± 0.3 (lumi) pb.

Zγ Anomalous Couplings

Fermilab-Pub-05/023-E





- Limits on CP even and CP odd couplings for ZZγ (Λ = 1000 GeV):

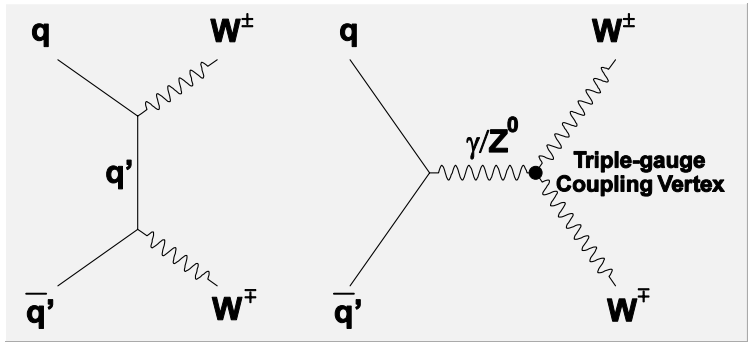
$$|\, h^{Z}_{10,30} \,| < 0.23, \qquad |\, h^{Z}_{20,40} \,| < 0.020$$

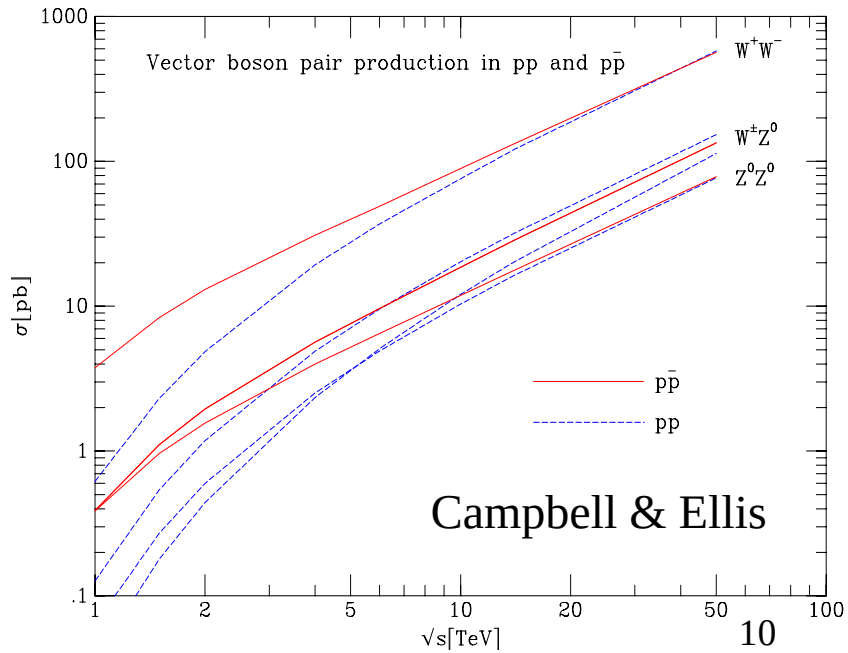
- Limits on CP even and CP odd couplings for Zγγ (Λ = 1000 GeV):

$$|\, h^{\gamma}_{10,30} \,| < 0.23, \qquad |\, h^{\gamma}_{20,40} \,| < 0.019$$

WW Production

- WW production is major background for searches (Higgs, SUSY).
- Provides another channel to search for anomalous couplings (WWγ and WWZ).
- Theoretical prediction:
  - σ(WW) = 13.5 pb @ 1.96 TeV
- Main backgrounds:
  - Z/γ, top pair production, WZ, ZZ, W+jet/γ, multijets.

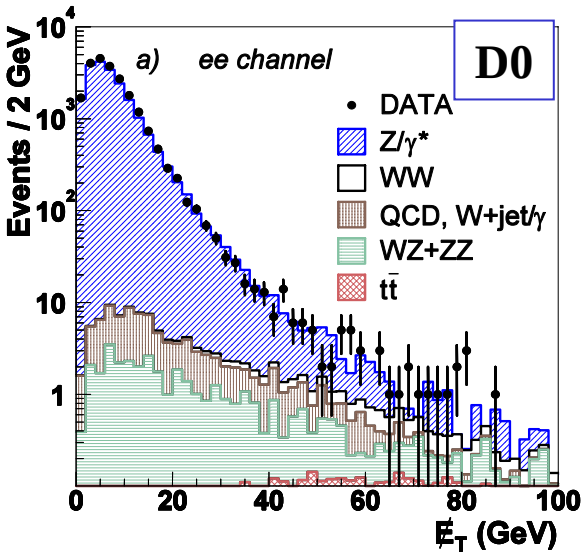




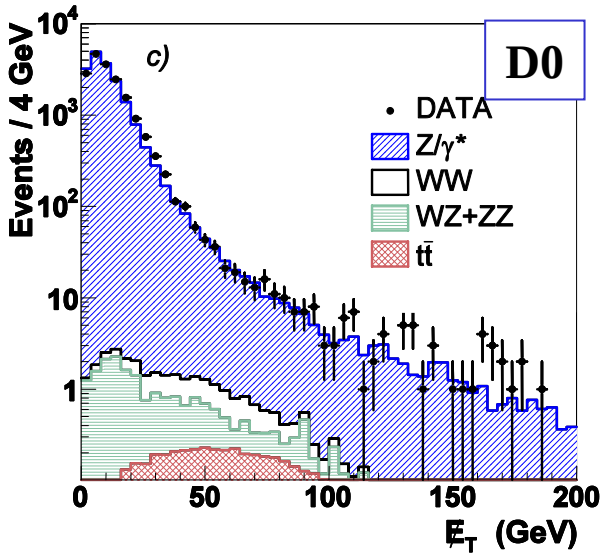
WW Production

- Event selection:
  - Two high P_T isolated oppositely charged electrons or muons,
  - With $P_T > 20$ GeV and $P_T > 15$ GeV,
  - MET > 30, 40, 20 GeV in ee, μμ, eμ to remove Z/γ^*.

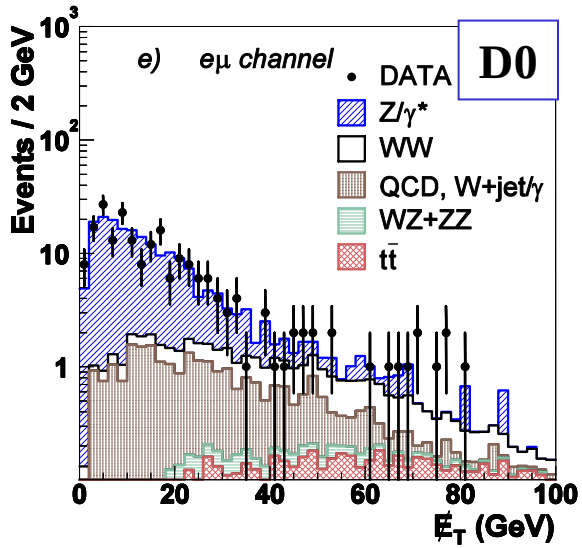
Missing transverse energy after event selection.



ee Channel



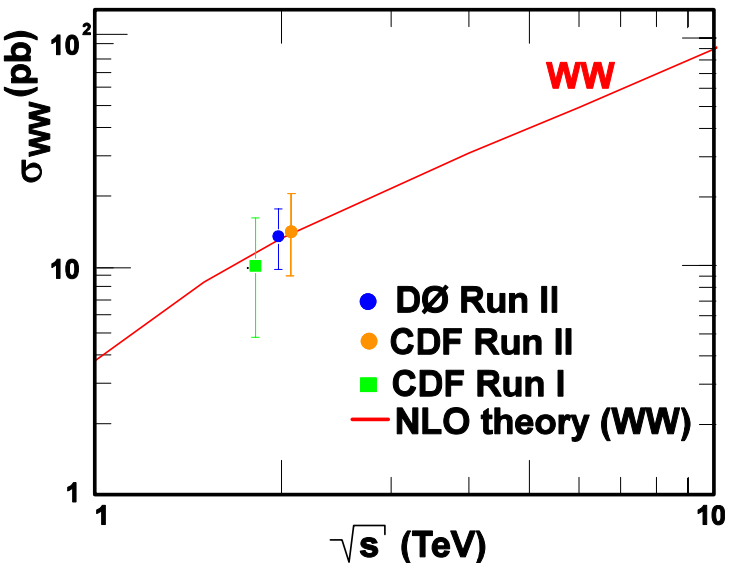
μμ Channel

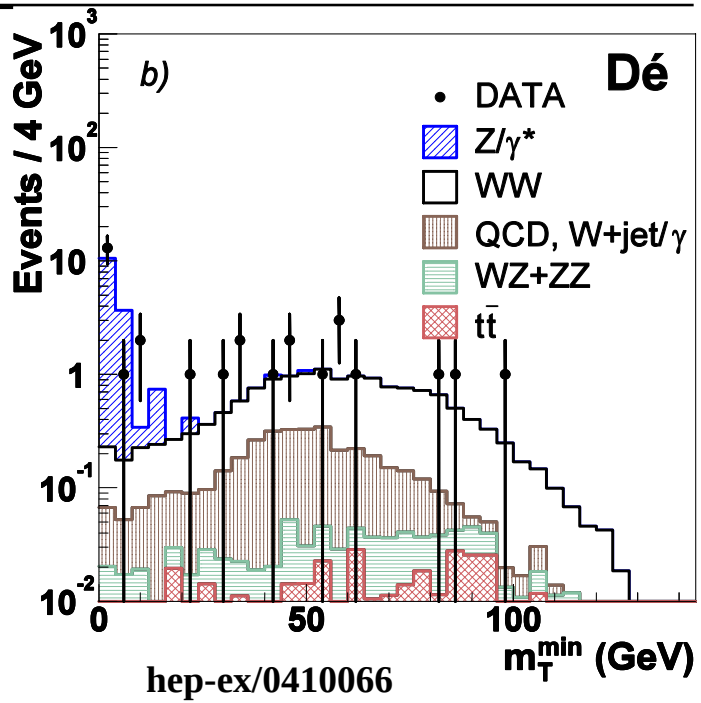


eμ Channel

WW Production Cross Section

- eμ channel:
  - no third lepton such that 61 < M(l+l-) < 121 GeV/c^2.
  - minimal transverse mass > 20 GeV/c^2.
  - H_T (jets w/E_T > 20 and |η| < 2.5) < 50 GeV.
- Summary:
  - 6 eevv candidates, exp. signal/background: 3.4 and 2.3.
  - 4 μμvv candidates, exp. signal/background: 2.1 and 1.9.
  - 15 eμvv candidates, exp. signal/background: 11.1 and 3.8.
- Anomalous coupling extraction in progress:
  - $|\Delta\kappa| < 1.2 \quad |\lambda| < 1.0$ 95% C.L. $\Lambda = 1000$ GeV (Run I).

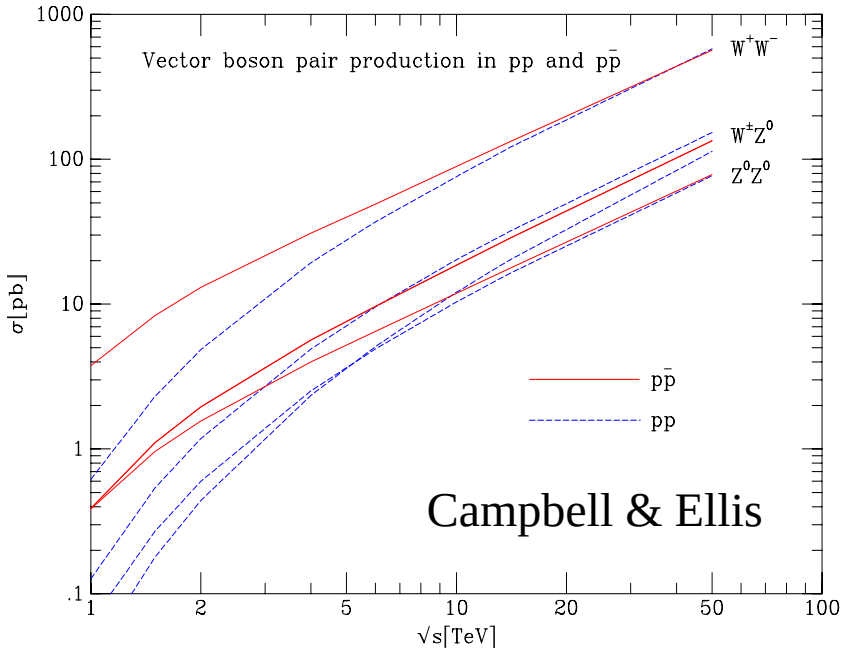


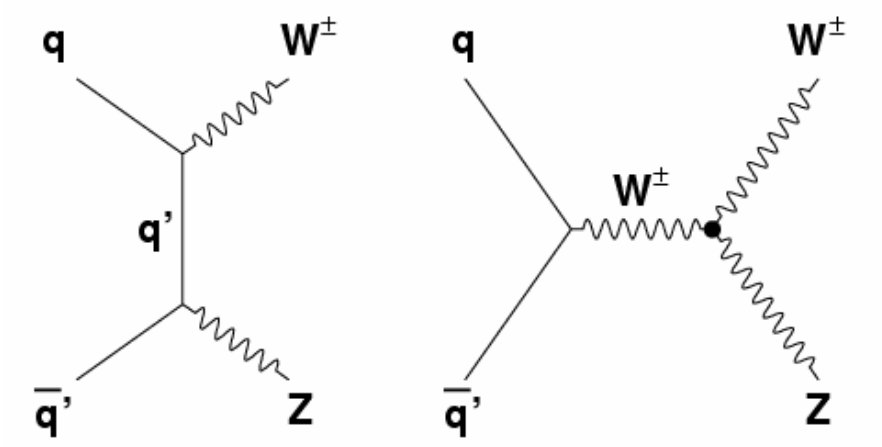


P(background fluctuation) = 2.3 × 10^{-7}
Corresponds to 5.2 σ significance.

$$\sigma(WW) = 13.8^{+4.3}_{-3.8}(stat.)^{+1.2}_{-0.9}(sys.) \pm 0.9(lum.)\ \text{pb}$$

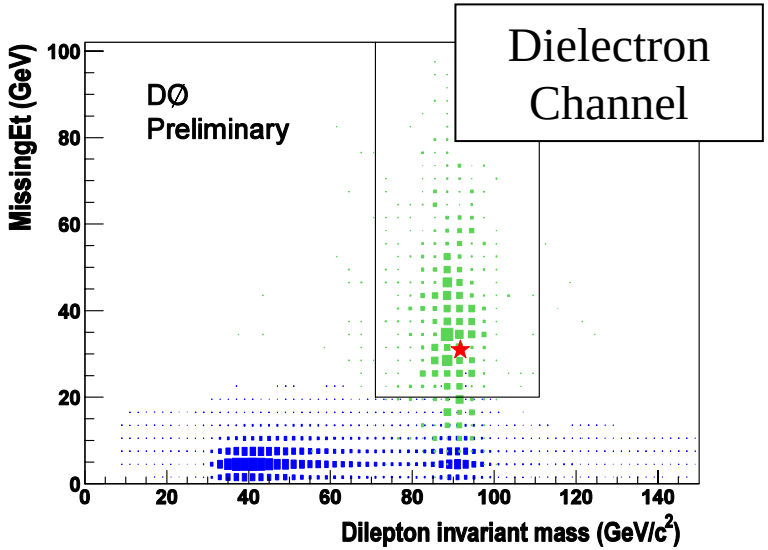
WZ Production

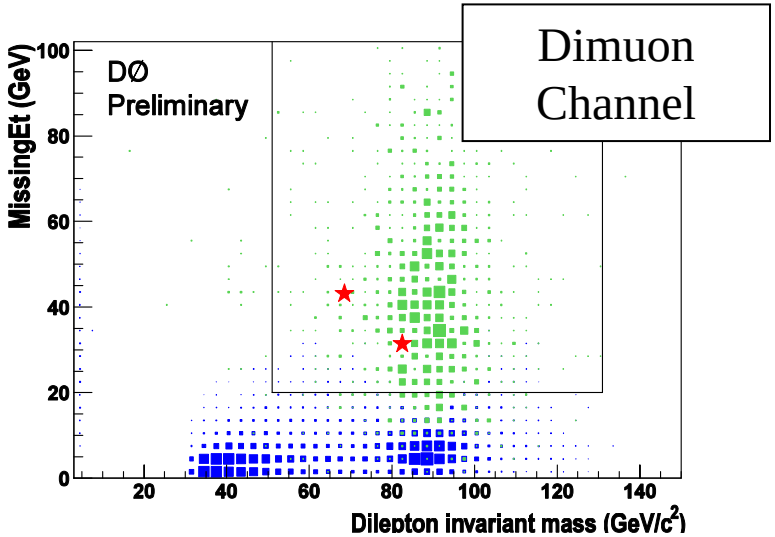




- Trilepton events:
  - At least two high P_T >15 GeV/c isolated electrons or muons that make a Z boson,
  - A third isolated *e* or μ with high P_T,
  - Missing transverse energy > 20 GeV.
- σ (WZ) ~ 4.0 pb @ 1.96 GeV.
- Only sensitive to WWZ coupling.

WZ Production Cross Section





- Main background is Z+X (X = j, γ, or Z).
- 2 μμμν and 1 *eee*ν candidates.
- P(0.71 bkgd) → 3 signal events is 3.5%.
- Cross section $\sigma(WZ) = 4.5^{+3.5}_{-2.6}$ pb
- standard model cross section:
  - $\sigma(WZ) = 3.7 \pm 0.1$ pb

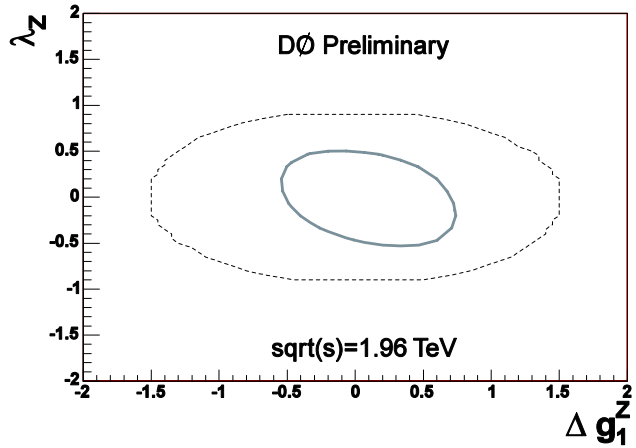
$$\sigma(p\bar{p} \rightarrow W^{\pm}Z) = \frac{N_{obs} - N_{bkgd}}{L \cdot Br \cdot \varepsilon} = 4.5^{+3.5}_{-2.6} \text{ pb}$$

D0 Preliminary

WWZ Anomalous Couplings

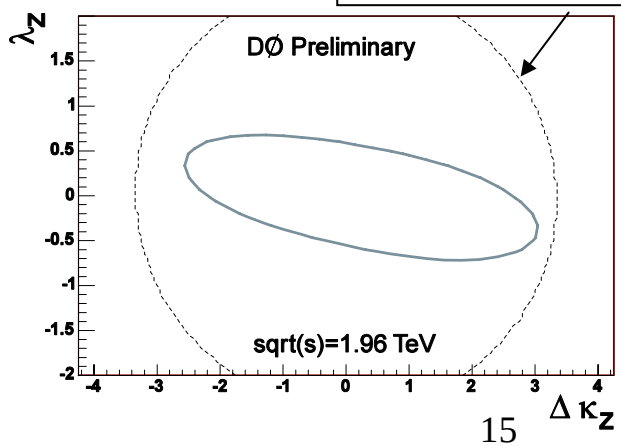
DØ Preliminary

$\Lambda = 1.0$ TeV	95% C.L.	$\Lambda = 1.5$ GeV
$-0.53 < \lambda_Z < 0.56$		$-0.48 < \lambda_Z < 0.48$
$-0.57 < \Delta g_1^Z < 0.76$		$-0.49 < \Delta g_1^Z < 0.66$
$-2.0 < \Delta\kappa_Z < 2.4$		-



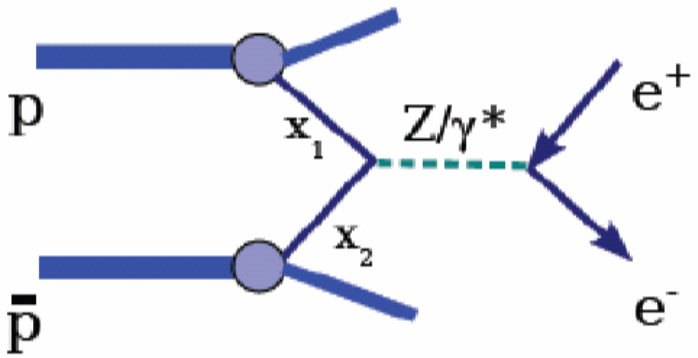
- Best limits in WZ final states.
- First 2-d limits in $\Delta\kappa_Z$ vs λ_Z using WZ.
- Best limits available on g_1^Z, $\Delta\kappa_Z$, and λ_Z from direct, model independent measurements.
- Factor of 2-3 improvement of Run I.

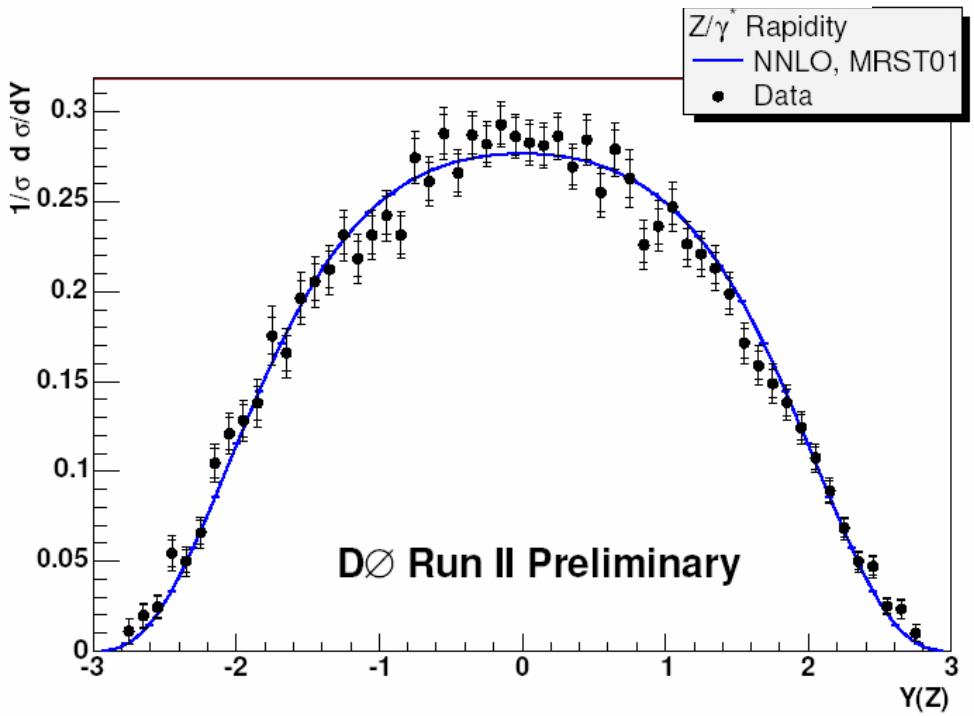
Unitary boundary



Z Boson Rapidity Distribution

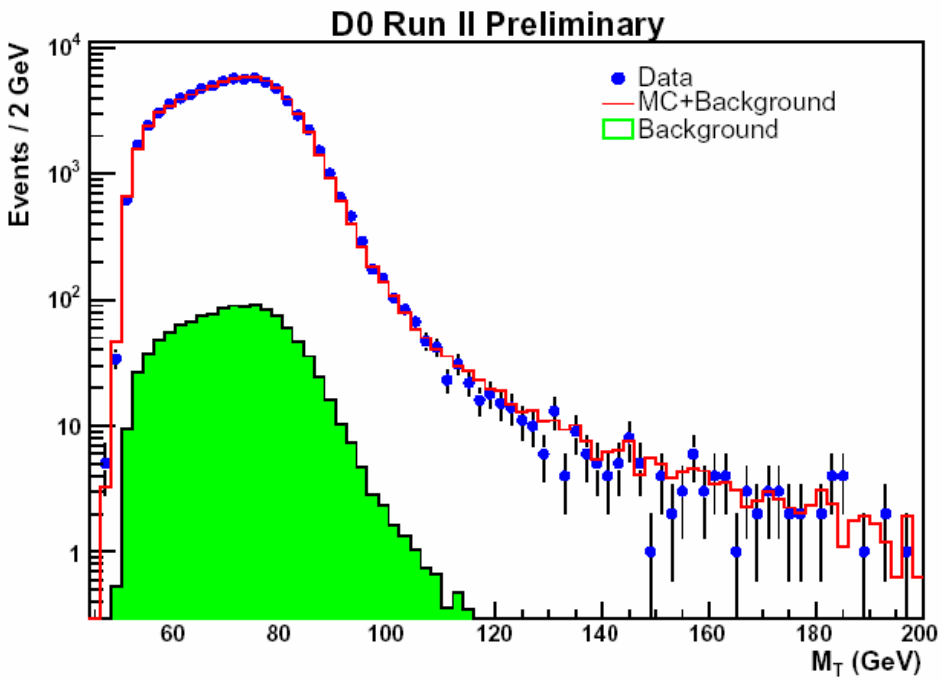
- Complimentary measurement to high-momentum jet spectrum PDF's.
- Advantage: Z/DY process rapidity distributions calculated at NNLO.
- Measure at high Q^2 , large and small Bjorken x in the initiating quark and antiquark.
- Can be used to constrain the parton distribution functions.
- Two high P_T isolated electrons that make a Z boson:
  - 71 GeV/c^2 < M(ee) < 111 GeV/c^2
- Integrated luminosity = 337 pb^{-1}
- Good agreement with prediction.





W Boson Width

- W boson width is predicted precisely to be $\Gamma_W = 2.090 \pm 0.008$ GeV (Hagiwara et al. D66 (2002)).
- High values of M_T are sensitive to the width of the W boson (Breit-Wigner lineshape).
- Integrated luminosity = 177 pb^{-1}
- Event selection:
  - High P_T electron
  - Missing transverse energy
- Backgrounds:
  - Multijets
  - $Z \rightarrow ee$, one electron undetected
  - $W \rightarrow \tau\nu \rightarrow e\nu\nu\nu$
- Binned maximum likelihood fit:
  - 100 GeV < M_T < 200 GeV



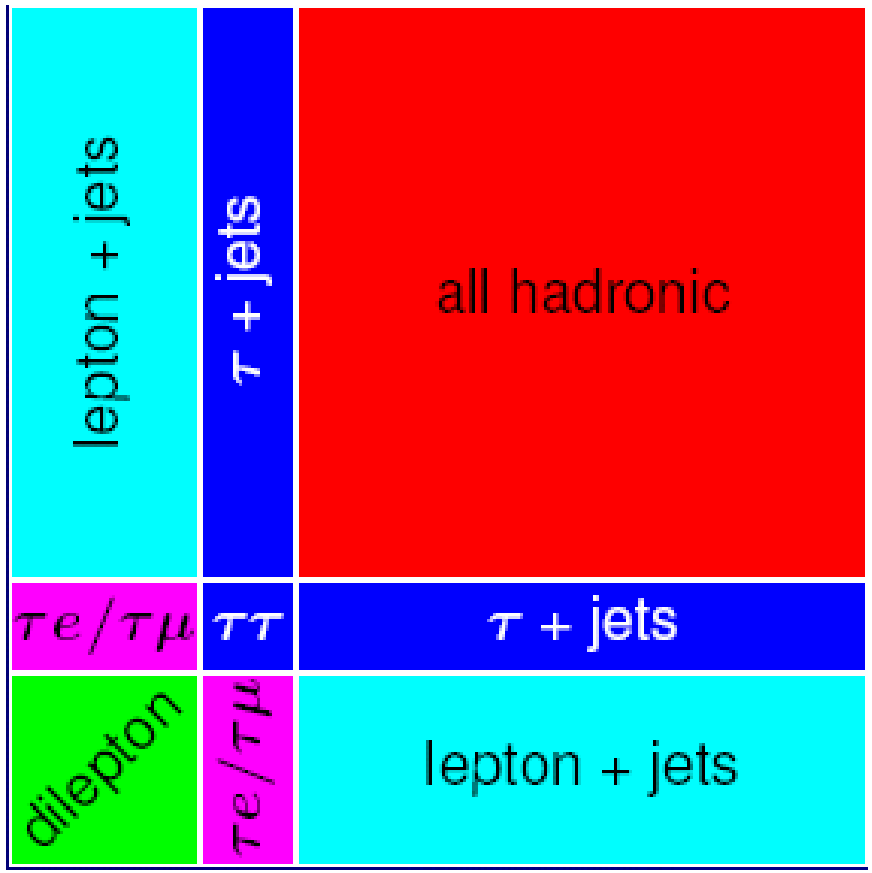
$\Gamma_W = 2.011 \pm 0.093$ (stat) ± 0.107 (syst)

Calorimeter calibration in progress. One inverse femtobarn can give ~25 GeV (stat.) and ~45 MeV (syst.) totaling ~50 MeV.

The Top Quark Event Signatures

- At Tevatron, top pair production mainly from qq (85%) and gg (15%).
- In standard model, top decays 99.9% of the time to Wb. It decays before it hadronizes.
- Event classification:
  - all hadronic (all jets), lepton plus jets, dileptons.
- Need to identify and reconstruct:
  - electrons, muons, jets from b-quarks, jets from light quarks, missing transverse energy.

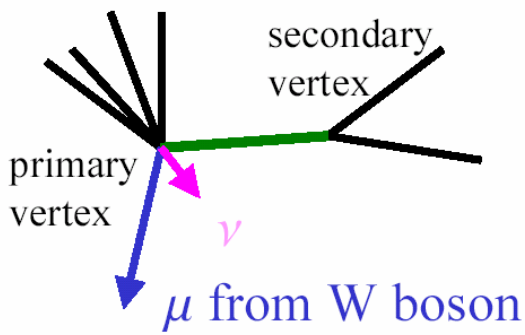
Top pair decay modes



Top Quark Event Signatures

- Dilepton:
  - Signal selection:
    - Two high P_T leptons
    - Missing transverse energy
    - Two or more high P_T jets
  - Backgrounds:
    - Diboson (WW, WZ, ZZ)
    - Drell-Yan
    - $Z \rightarrow \tau\tau$
    - W + jets with fake lepton

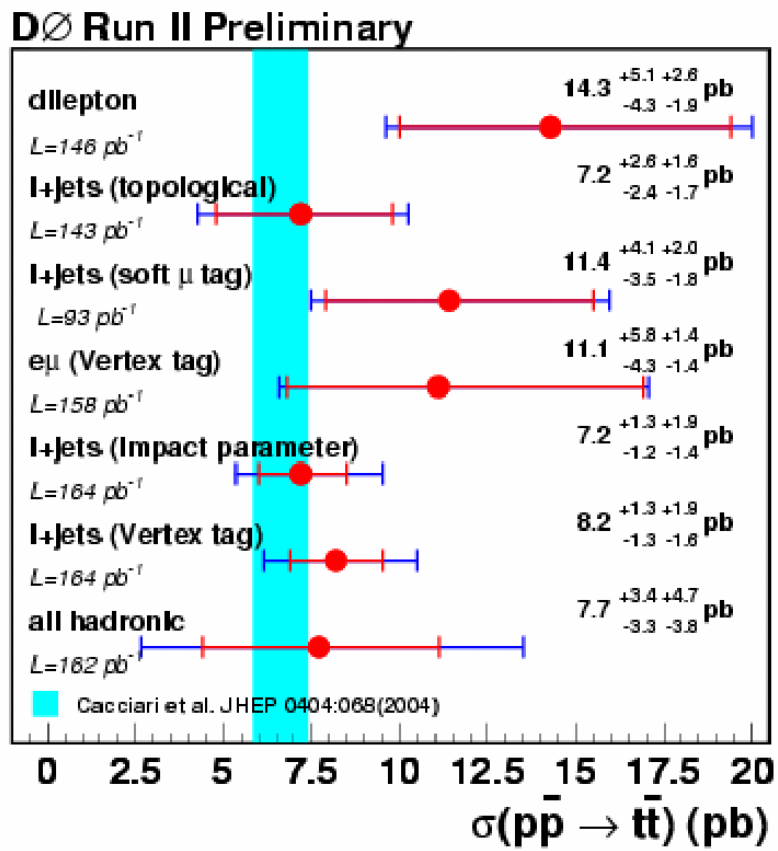
- Lepton plus jets:
  - Signal selection:
    - One high P_T leptons
    - Missing transverse energy
    - Four or more high P_T jets
  - Backgrounds:
    - W + jets
    - Multijet with fake lepton

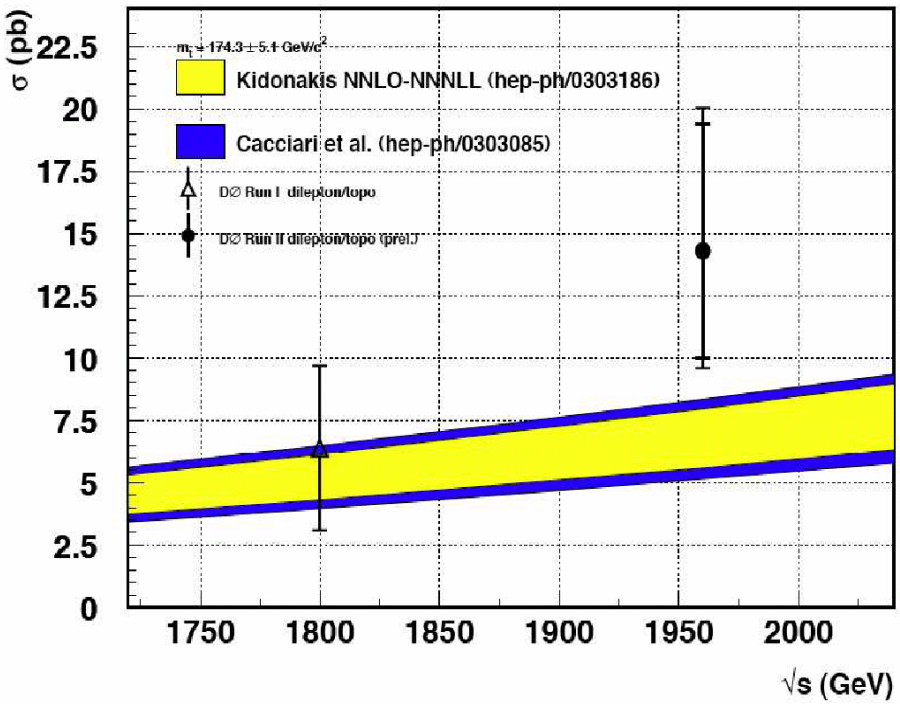


Secondary Vertex Tag

Use b tagging to increase S/B.

Top Pair Production Cross Section



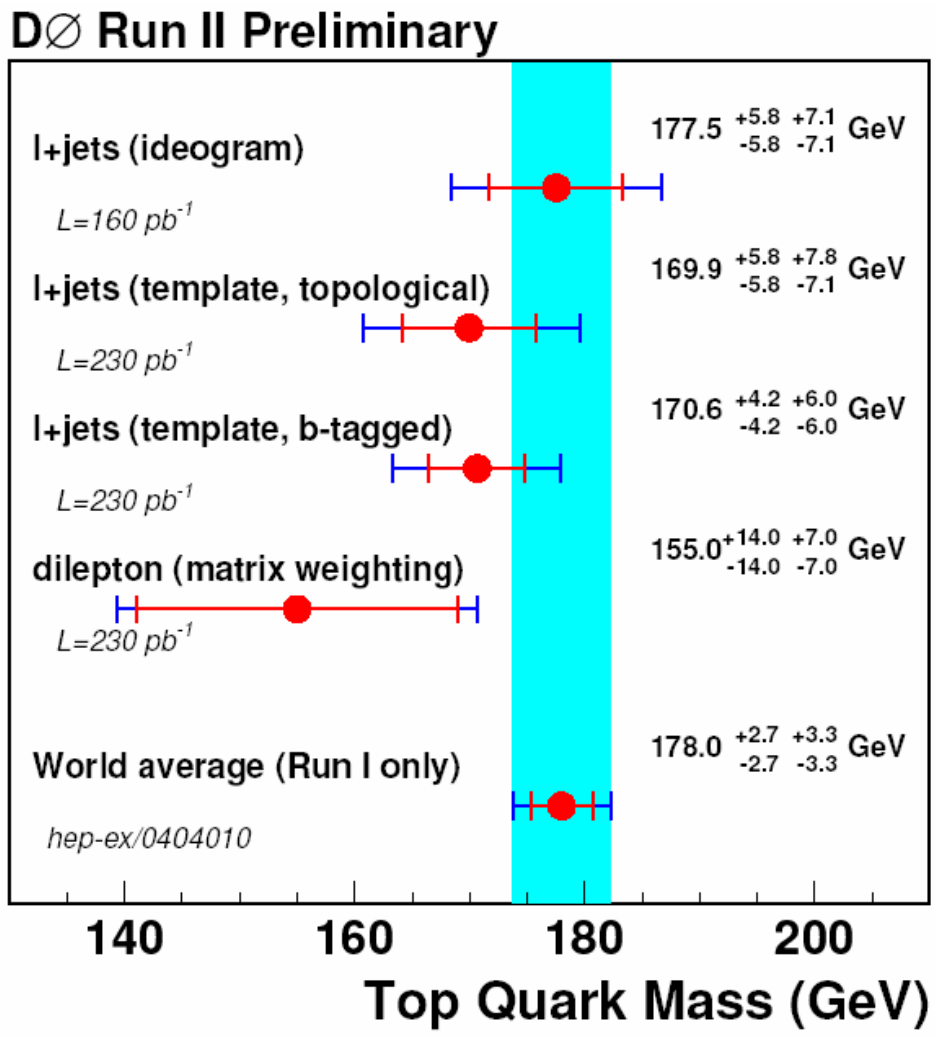


Top Quark Mass

Top mass measured in two channels with 0.25 fb $^{-1}$.

Currently improving measurement of jet energy calibration.

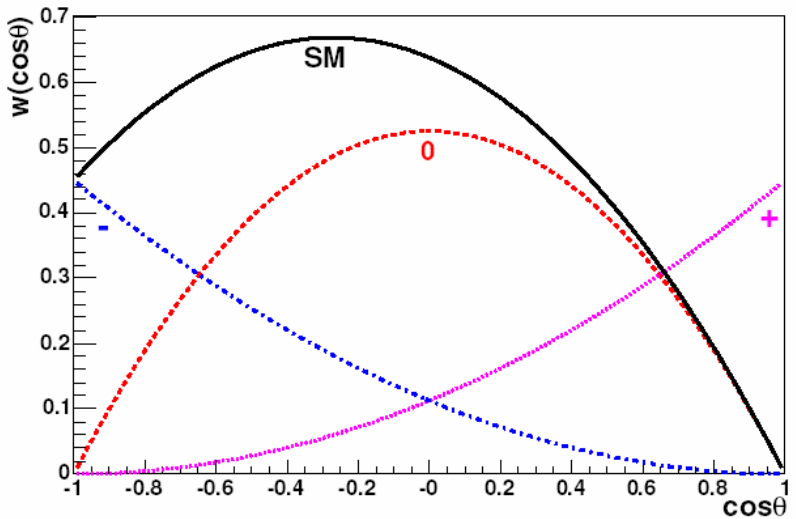
Expect improved results soon.



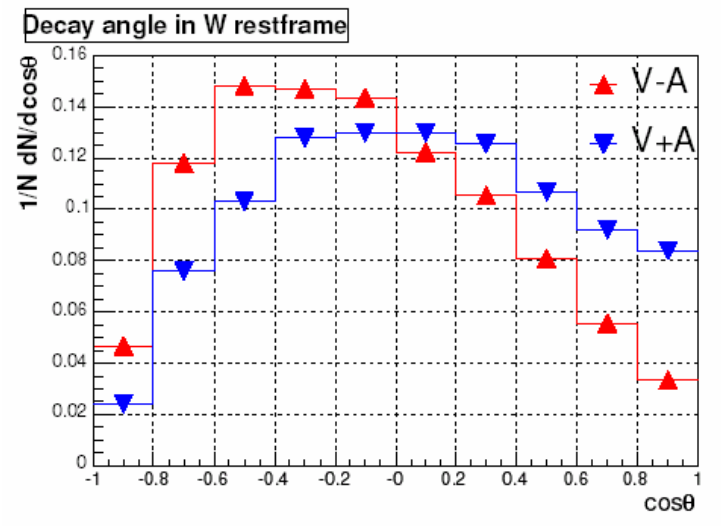
W Helicity Top Quark Decays

- In standard model, W helicity depends on the top quark and W boson masses:
  - Predicted 70% longitudinal, 30% left-handed, and 0% right-handed.
  - We measure right-handed fraction f_+ or V+A component.
- Any deviation is a signal for new physics:
  - $SU(2)_L \times SU(2)_R \times U(1)_Y$ models [PRL **38**, 1252 (1977)].

- Use the angular distribution cos θ^*:
  - –Angle between the charge lepton and top quark direction in the W boson rest frame.
- Event selection:
  - –High P_T isolated electron or muon, ≥ four jets, missing E_T.
  - –Two parallel analyses: topological, which uses only topological information, and b-tag, which requires at least one jet tagged by the SVT.

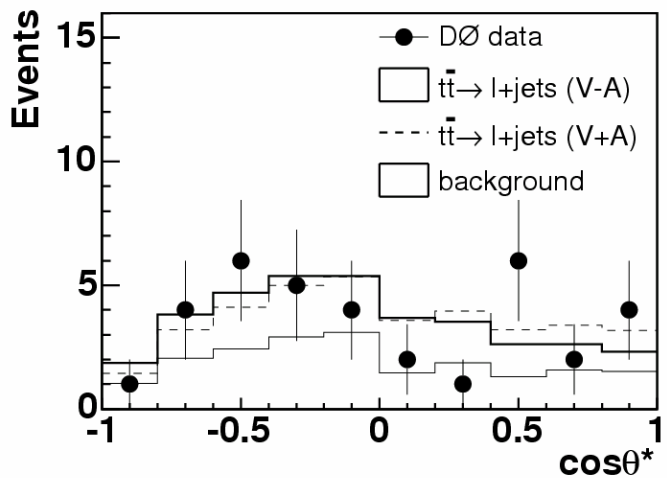


W Helicity in Top Quark Decays

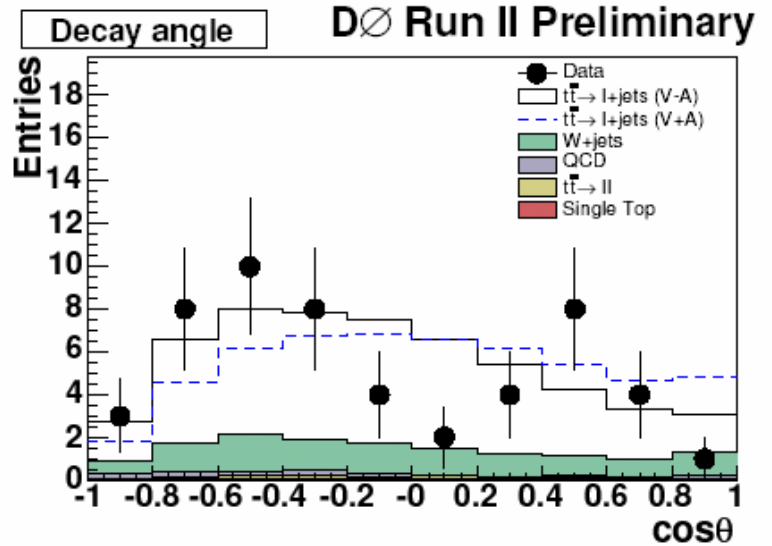


- Analyses use binned maximum likelihood fit to extract f_+ : cos θ* from data, cos θ* from signal and background contributions.
- Topological analysis (230 pb^{-1}):
  - 35 events observed in data
  - Expected yield for signal and background: 17 and 19, respectively.
- b-tag analysis (230 pb^{-1}):
  - 52 events observed in data
  - Expected yield for signal and background: 41 and 13, respectively.

Topological



b-tag



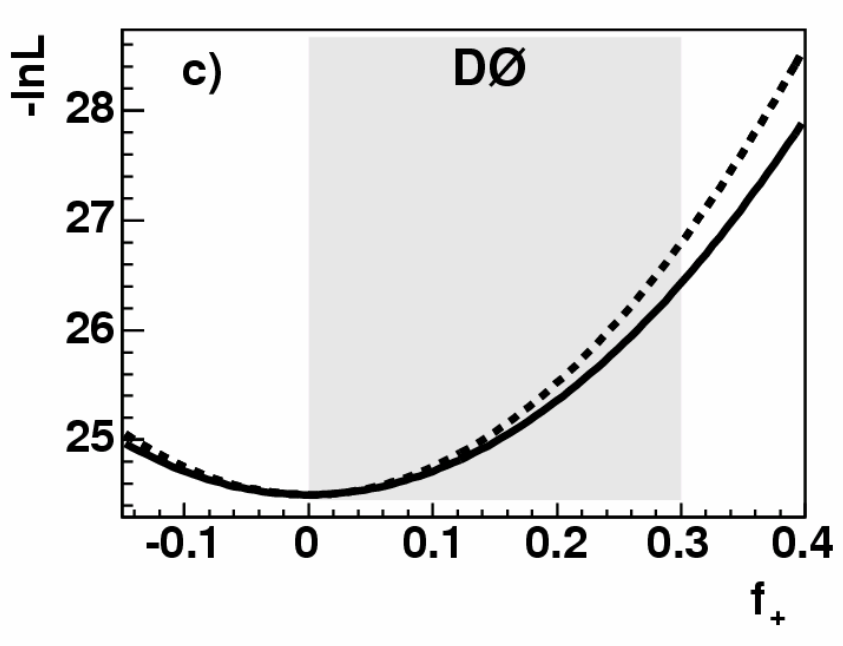
W Helicity in Top Quark Decays

- Systematics include:
  - jet energy calibration,
  - top quark mass,
  - signal and background MC.

- Topological analysis:
  $f_+ < 0.25$ @ 95% Bayesian C.L.

- b-tag analysis:
  $f_+ < 0.25$ @ 95% Bayesian C.L.

- Dilepton analysis now under collaboration review.

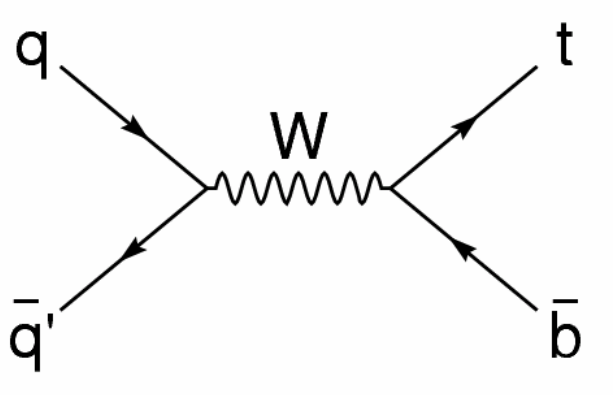


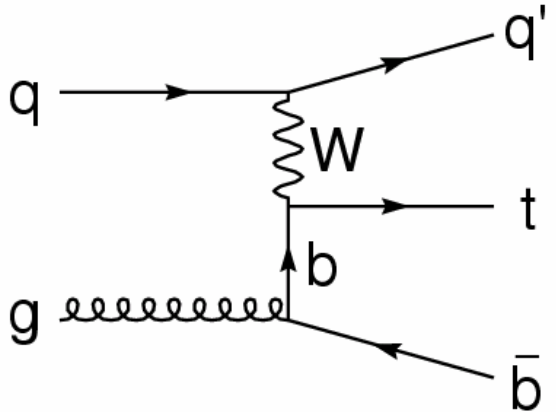
Combined result:

$f_+ = 0.00 \pm 0.13$ (stat) ± 0.07 (syst)

$f_+ < 0.25$ @ 95% Bayesian C.L.

Single Top Quark Production



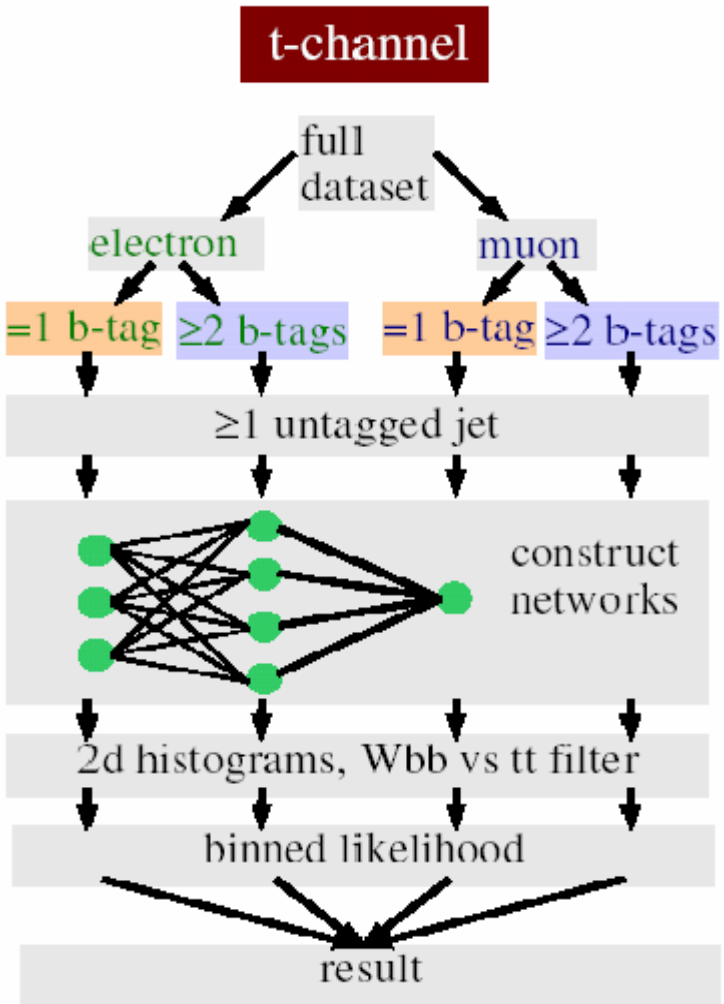


s-channel $\sigma_{NLO} \sim 0.88$ pb

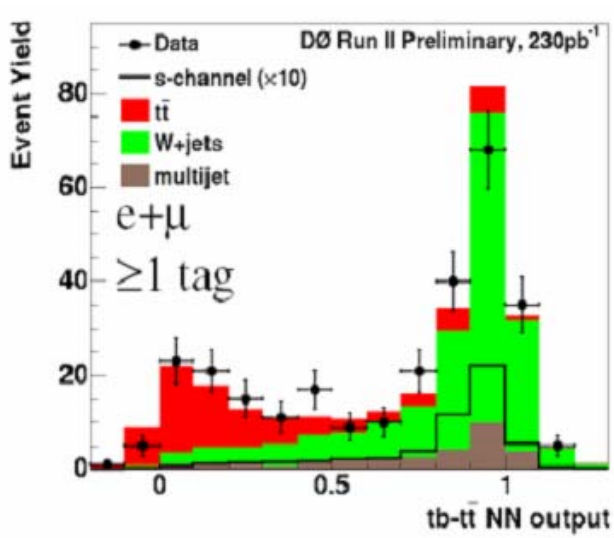
t-channel $\sigma_{NLO} \sim 1.98$ pb

- Event Selection:
  - One high P_T isolated lepton,
  - From 2 to 4 jets:
    Leading jet > 25 GeV,
    P_T > 15 GeV $|\eta|$ > 25 GeV.
- s-channel 1 or more b-tagged jets,
- t-channel 1 or more b-tagged jets and 1 or more untagged jets.

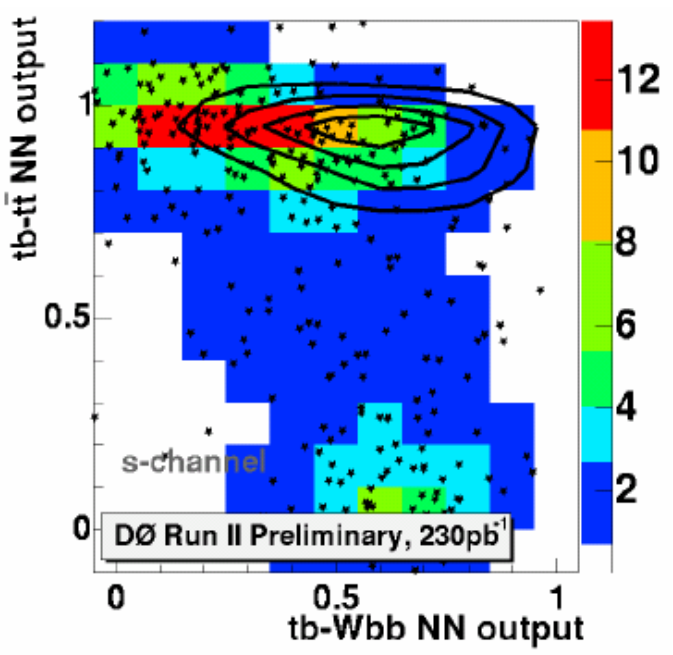
Single Top Quark Production

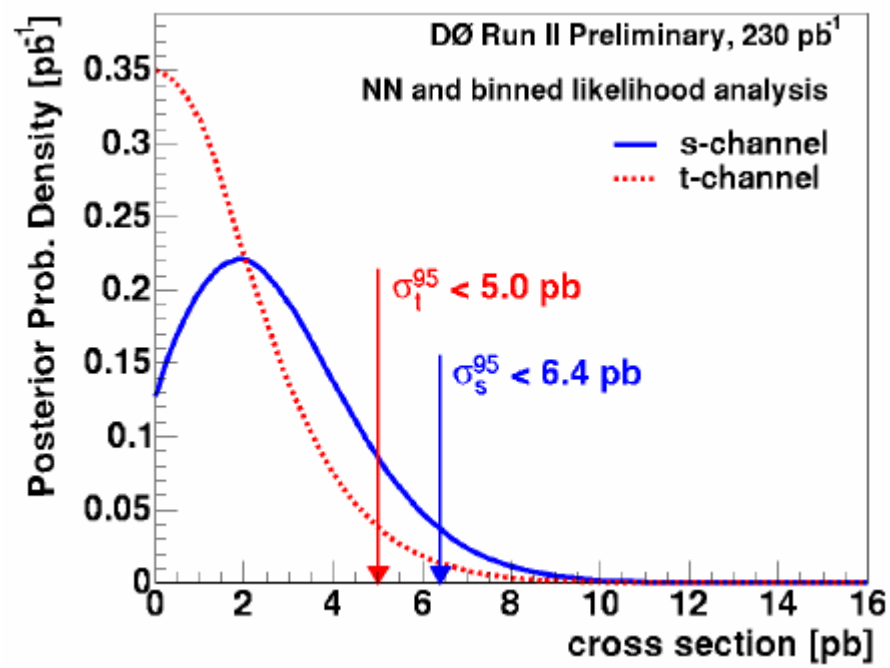


- Backgrounds:
  - W/Z + jets production,
  - Multijet production
  - Top pair production,
  - Diboson (WZ, WW).
- Use neural networks to improve sensitivity.



Single Top Quark Production





- No evidence for single top quark production.
- Set Bayesian 95% C.L. upper cross section limits:

  $\sigma_s < 6.4$ pb $\sigma_t < 5.0$ pb
- Presently, most sensitive limit in the world.

Summary

- This is just the beginning:
  - Electroweak analyses in progress:
    - W charge asymmetry in e + μ, Z P_T distribution, $W \rightarrow \tau\nu$ cross section, etc…($Z \rightarrow \tau\tau$ cross section, $W \rightarrow \mu\nu$ and $W \rightarrow e\nu$ cross sections)
  - Top quark analyses in progress:
    - Top charge, top pair resonances, top decay to charged Higgs, anomalous kinematics (P_T of top quark), top mass in all jets channel, etc…
- Reached one inverse femtobarn: $1fb^{-1}$.
- For more details on results available:
  - http://www-d0.fnal.gov/Run2Physics/WWW/results.htm