Tevatron Results 2: Electroweak, top, and Exotic Physics

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Fermilab

LHC PhenoNet Winter School 2012
22-29 January
Ascona, Switzerland

- W Mass Measurements
- Top Mass Measurements
- Single Top and Associated Measurements
- Top spin correlations
- ttbar Forward-Backward Asymmetry
- Search for Dark matter in Monojets+MET

D0's Measurement of the W mass in W→eν Events

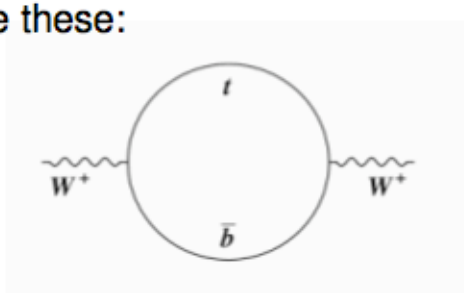
Data Sample: 1 fb^{-1}. D0 Collaboration, Phys. Rev. Lett **103**, 141801 (2009)

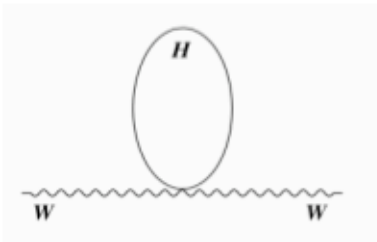
Motivation

W mass is a key parameter in the Standard Model. This model does not predict the value of th W mass, but it predicts this relation between the W mass and other experimental observables:

$$M_W = \sqrt{\frac{\pi\alpha}{\sqrt{2}G_F}} \frac{1}{\sin\theta_W \sqrt{1-\Delta r}}$$

Radiative corrections (Δr) depend on M_t as ~M_t^2 and on M_H as ~log M_H. They include diagram like these:



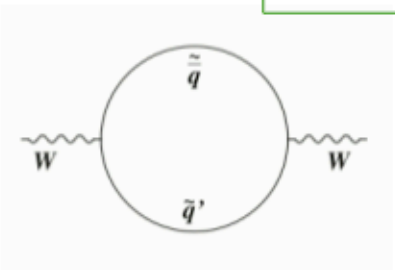


Precise measurements of M_W and M_t constrain SM Higgs mass.

For equal contribution to the Higgs mass uncertainty need:
$\Delta M_W \approx 0.006\ \Delta M_t$.

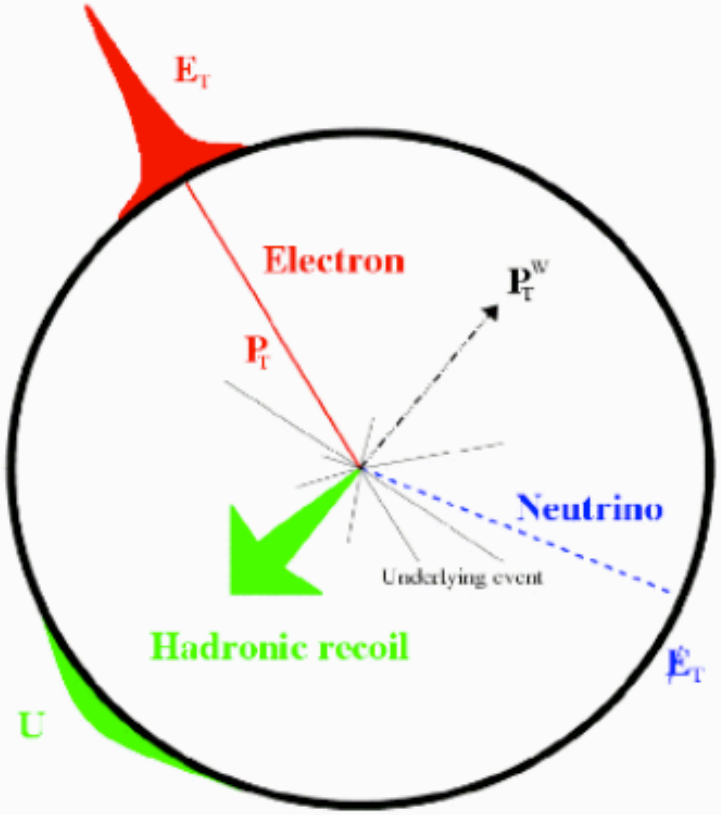
The limiting factor here will be ΔM_W, not ΔM_t !

Additional contributions to Δr arise in various extensions to the Standard Model, *e.g.* in SUSY:

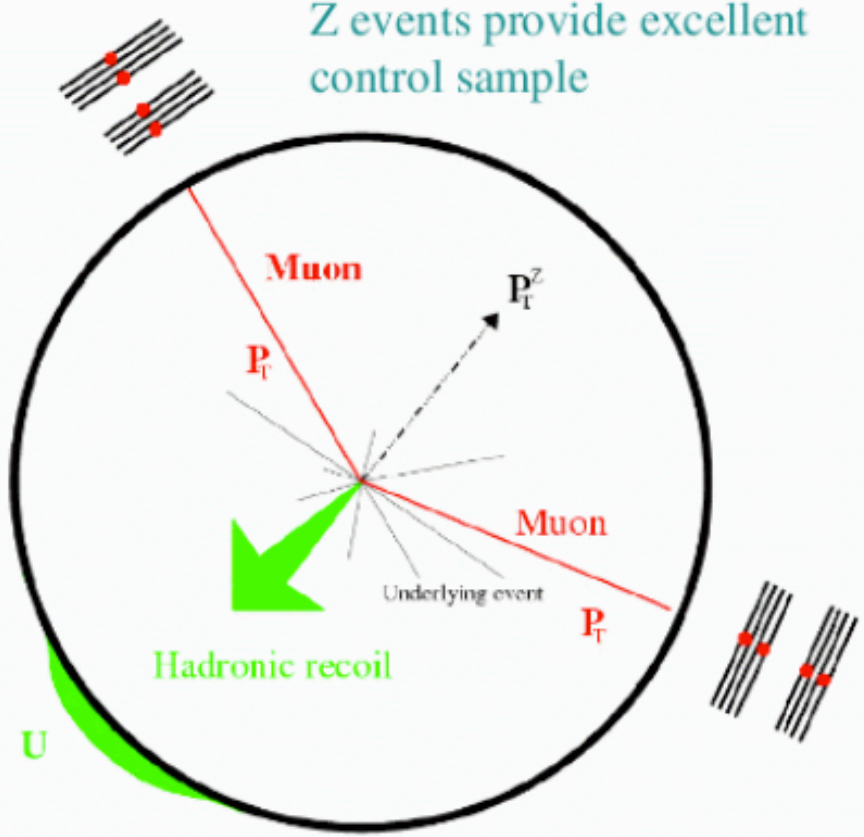


Signature in the detector

Isolated, high p_T leptons,
missing transverse momentum in W's

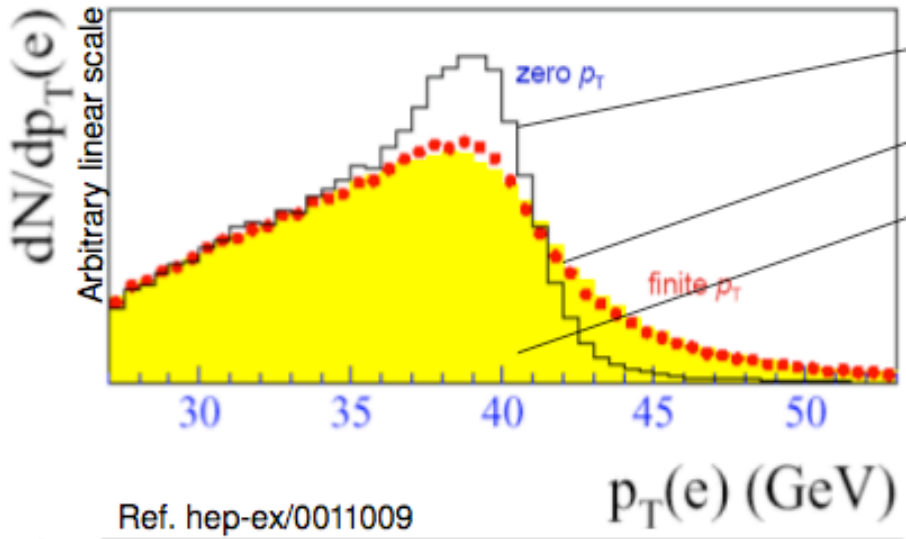


Z events provide excellent control sample



In a nutshell, measure two objects in the detector:
- Lepton (in principle e or μ; e in our analysis), need energy measurement with 0.2 per-mil precision (!!)
- Hadronic recoil, need ~ 1% precision

Experimental observables



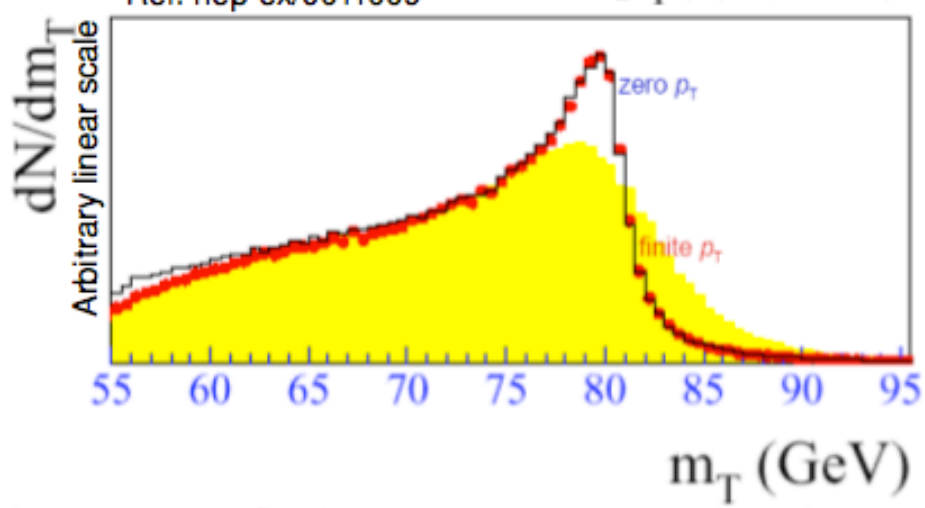
No $P_T(W)$

$P_T(W)$ included

Detector Effects added

$p_T(e)$ most affected by $p_T(W)$

Ref. hep-ex/0011009

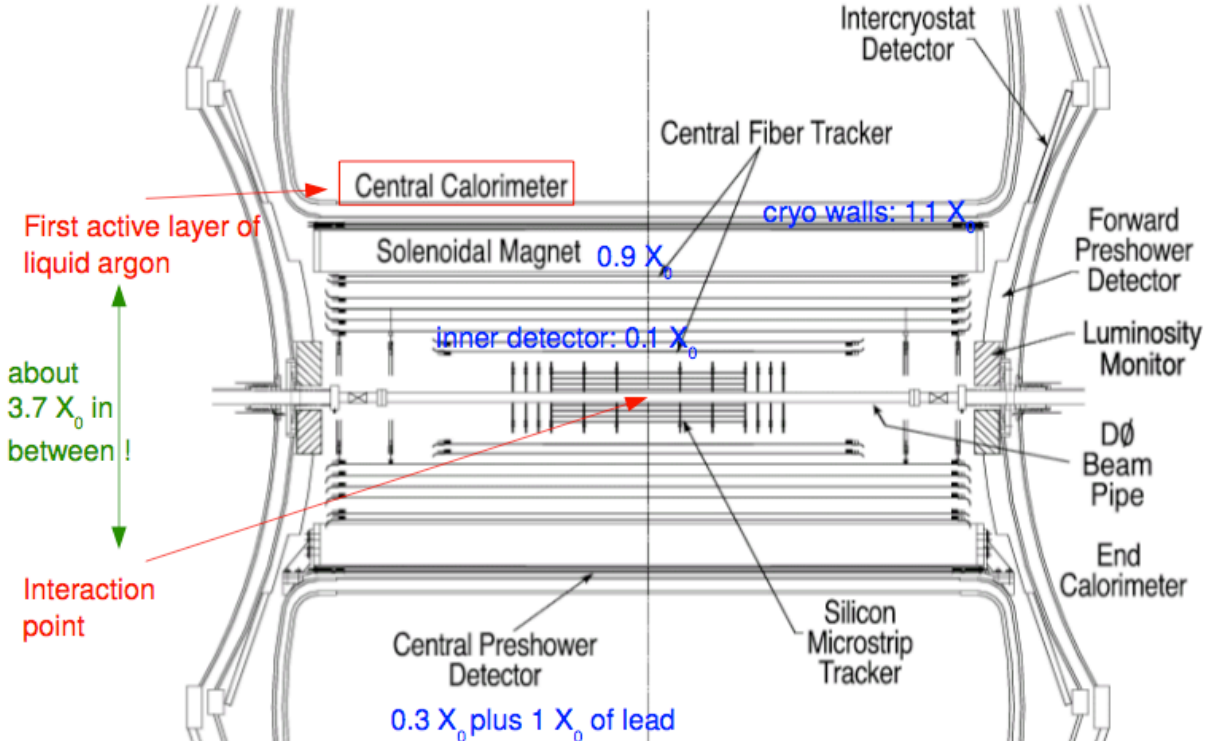


$$M_T = \sqrt{2E_T^l \not{E}_T (1 - \cos\Delta\phi)}$$

M_T most affected by measurement of missing transverse momentum

Need Monte Carlo simulation to predict shapes of these observables for given mass hypothesis. DØ use **ResBos** [Balazs, Yuan; Phys Rev D56, 5558] + **Photos** [Barbiero, Was, Comp Phys Com 79, 291] for W/Z production and decay, plus **parameterised detector model**.

D0 Tracking and Calorimetry Geometry



- Liquid argon active medium and (mostly) uranium absorber
- Hermetic with full coverage :$|\eta| < 4.2$
- Segmentation (towers): $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$

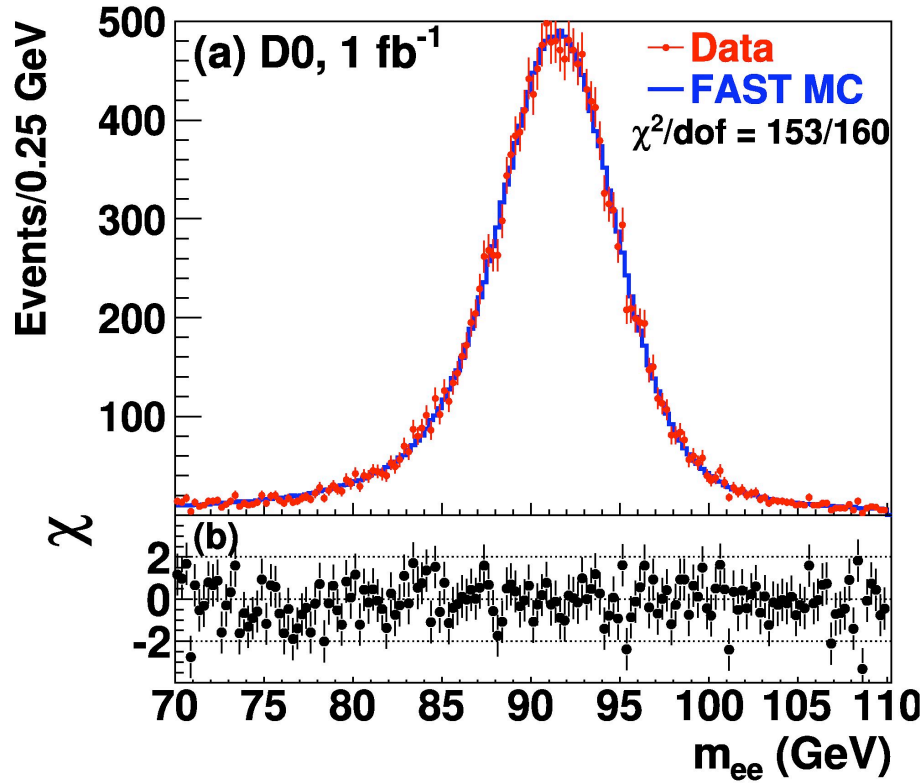
  (0.05x0.05 in third EM layer, near shower maximum)

Calibration of Detector Response

- m_Z known very precisely from LEP
- Z→ee lepton rapidity and momentum spectrum similar to W→eν

Z+hadronic recoil events used to calibrate hadronic response, and electron ID efficiency vs. P_T and proximity to the hadronic recoil

Material tuned in a fast simulation to make electron energies match in Z→ee in each calorimeter layer.



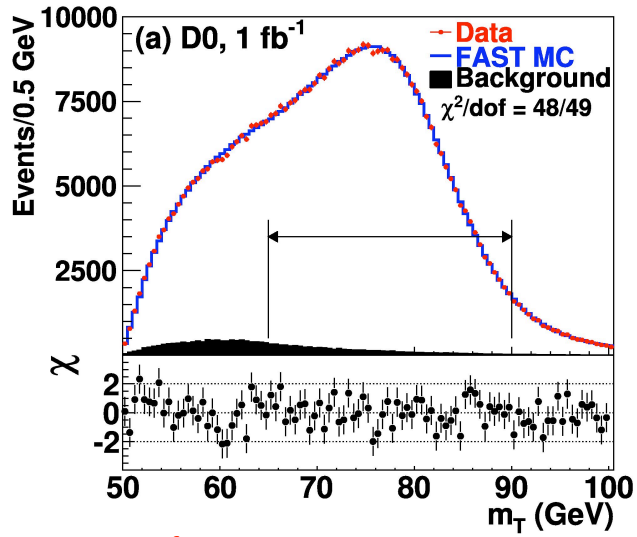
18,725 Z→ee candidates selected – negligible backgrounds

D0's Measurement of the W mass in W→eν Events

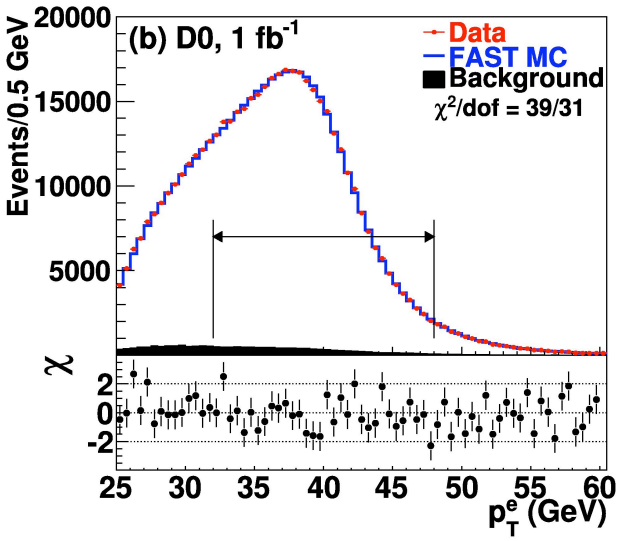
499830 candidate events

Background consists of

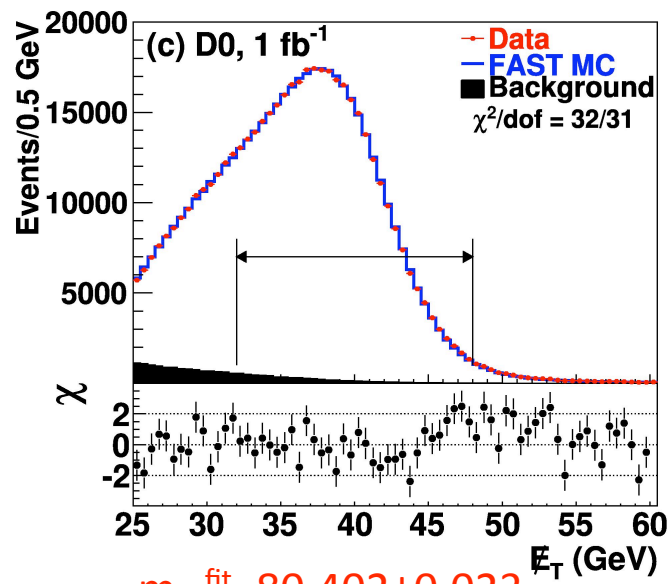
- Z→ee with a missing electron (inter-cryostat crack for example)
- Multijets
- W→τν→eνν



m_W^{fit}=80.401±0.023



m_W^{fit}=80.400±0.027



m_W^{fit}=80.402±0.023

D0 Collaboration, Phys. Rev. Lett **103**, 141801 (2009)

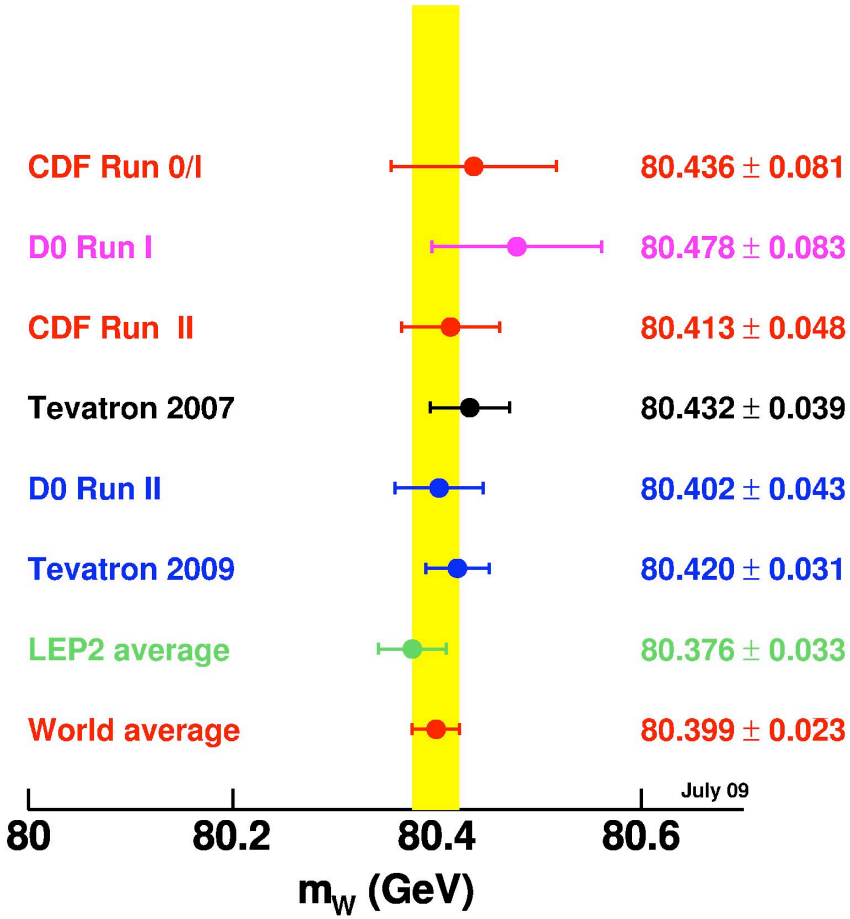
W mass Systematic Uncertainty Summary

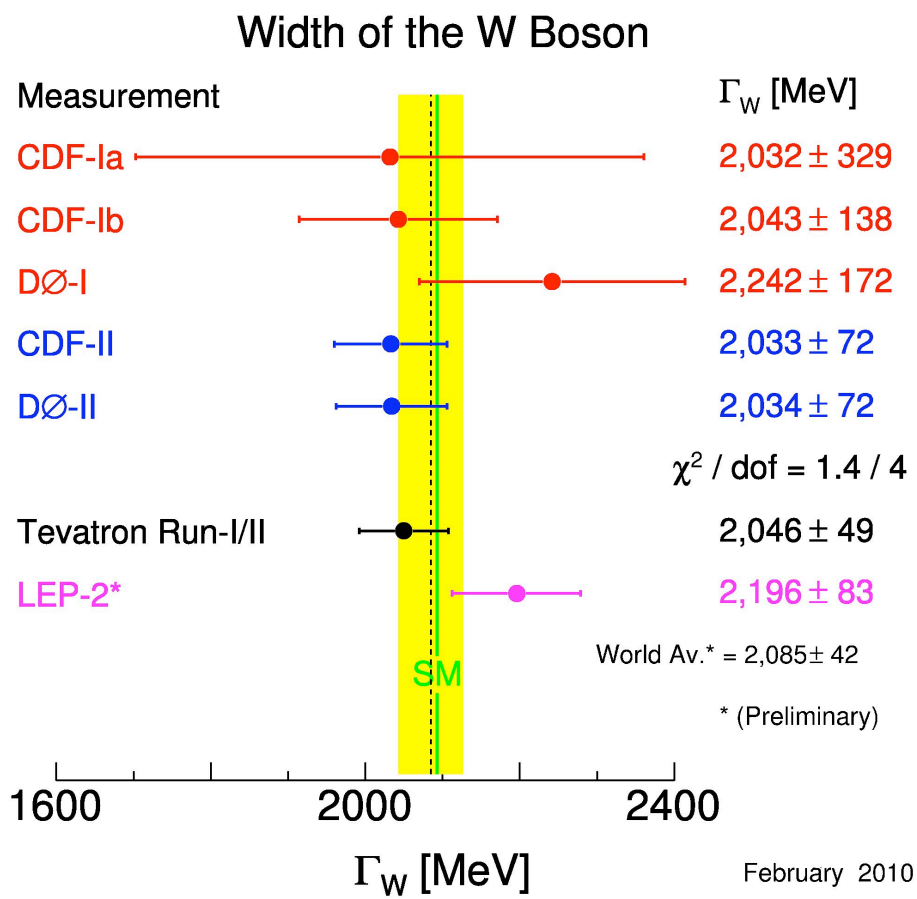
Source	ΔM_W (MeV) m_T	p_T^e	$\not{E}_T$
Electron energy calibration	34	34	34
Electron resolution model	2	2	3
Electron shower modeling	4	6	7
Electron energy loss model	4	4	4
Hadronic recoil model	6	12	20
Electron efficiencies	5	6	5
Backgrounds	2	5	4
Experimental Subtotal	35	37	41
PDF	10	11	11
QED	7	7	9
Boson p_T	2	5	2
Production Subtotal	12	14	14
Total	37	40	43

$$\begin{aligned} M_W &= 80.401 \pm 0.021\ (\text{stat}) \pm 0.038\ (\text{syst})\ \text{GeV} \\ &= 80.401 \pm 0.043\ \text{GeV}. \end{aligned}$$

D0 Collaboration, Phys. Rev. Lett **103**, 141801 (2009)

Tevatron W Mass and Width Combinations





Preliminary 80.402 GeV number used for D0 in this plot.

Matrix Element Basics

Predictions given by QM matrix element, PDF's and phase space.

Many processes (signal and background) give the same observable quantities in the detector -- cannot assign an event to be signal or background (if we could, we would!)

Instead, ask what the ratio of chances of getting an event from signal or background processes. Need to incorporate experimental resolution effects.

Imperfect Reconstruction

- Missing neutrinos! Missing E_T resolution not perfect.
- Jet energies not perfectly measured. Directions are pretty good, and leptons are measured well.
- What parton 4-vectors could have given us the measured events?

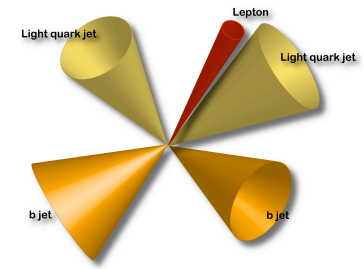
ME PDFs transfer function

$$P(x) = \frac{1}{\sigma} \int 2\pi^4 |M|^2 \frac{f(y_1)}{|E_{q_1}|} \frac{f(y_2)}{|E_{q_2}|} W(y,x) d\Phi_4 dE_{q_1} dE_{q_2}$$

y=parton (or neutrino momenta), *x*=measured jet quantities.

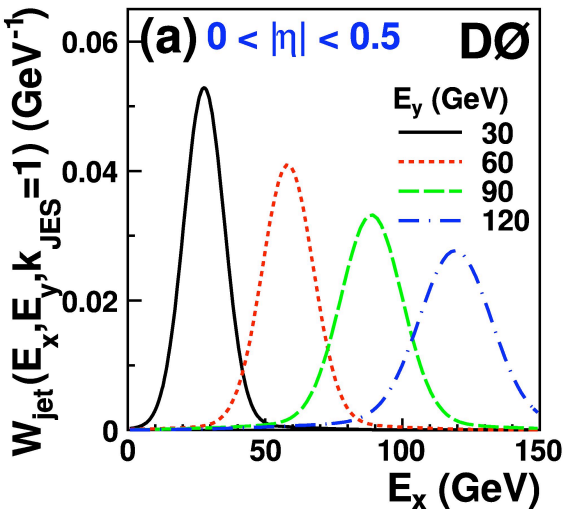
Do this for each physics process -- form a likelihood ratio from them

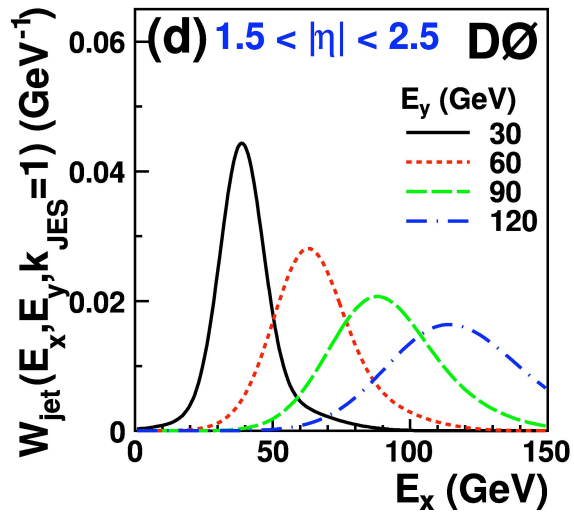
D0's Matrix-Element Lepton+jets m_{top} Measurement



Select events with one e or μ, large Missing E_T, exactly four jets, at least one b-tag. Selects 825 e+jets, and 737 μ+jets events in 3.6 fb^{-1}

$$P_{\rm sig} = \frac{1}{\sigma^{t\bar{t}}_{\rm obs}} \sum_{i=1}^{24} w_i \int d\rho\, dm_1^2\, dM_1^2\, dm_2^2\, dM_2^2\, d\rho_\ell\, dq_1^{\rm x}\, dq_1^{\rm y}\, dq_2^{\rm x}\, dq_2^{\rm y} \sum_{\rm flavors,\nu} |\mathcal{M}_{t\bar{t}}|^2 \frac{f'(q_1) f'(q_2)}{\sqrt{(\eta_{\alpha\beta} q_1^\alpha q_2^\beta)^2 - m_{q_1}^2 m_{q_2}^2}} \Phi_6 W(x, y;\, k_{\rm JES})$$





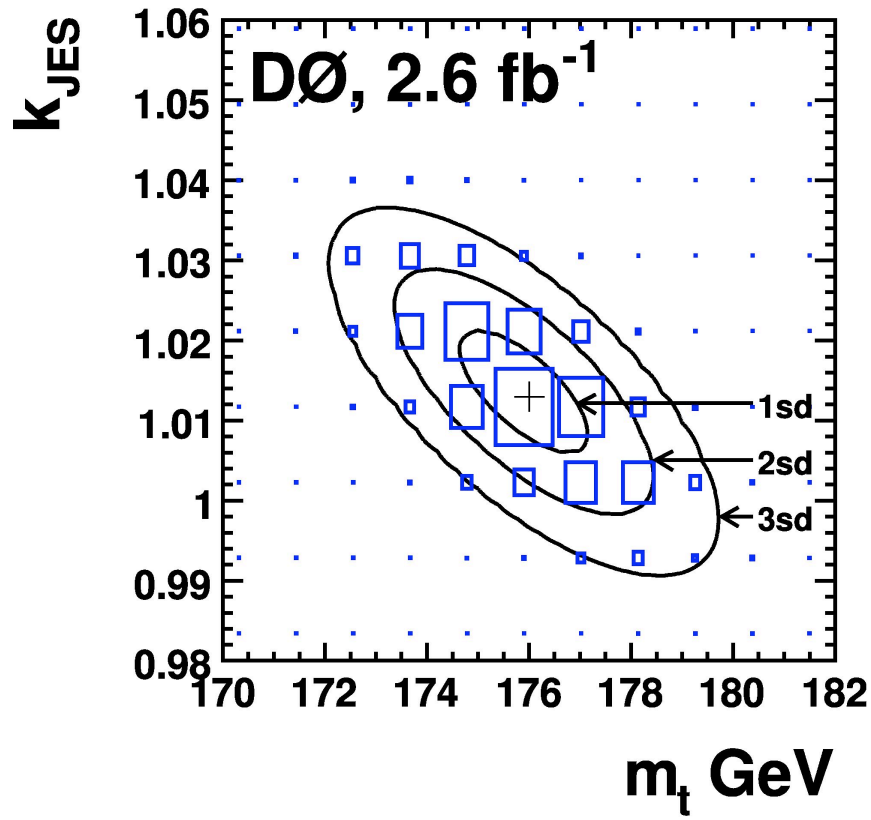
Background rates fit *in situ* using W+jets background matrix elements

$$P_{\rm evt} = A(x)[f P_{\rm sig}(x; m_{\rm t}, k_{\rm JES}) + (1-f) P_{\rm bkg}(x; k_{\rm JES})].$$

D0 Collab, Phys. Rev. D **84**, 032004 (2011).

D0's Matrix-Element Lepton+jets m_{top} Measurement

Source	Uncertainty (GeV)
Modeling of production:	
Modeling of signal:	
Higher-order effects	±0.25
ISR/FSR	±0.26
Hadronization and UE	±0.58
Color reconnection	±0.28
Multiple $p\bar{p}$ interactions	±0.07
Modeling of background	±0.16
W+jets heavy-flavor scale factor	±0.07
Modeling of b jets	±0.09
Choice of PDF	±0.24
Modeling of detector:	
Residual jet energy scale	±0.21
Data-MC jet response difference	±0.28
b-tagging efficiency	±0.08
Trigger efficiency	±0.01
Lepton momentum scale	±0.17
Jet energy resolution	±0.32
Jet ID efficiency	±0.26
Method:	
Multijet contamination	±0.14
Signal fraction	±0.10
MC calibration	±0.20
Total	±1.02

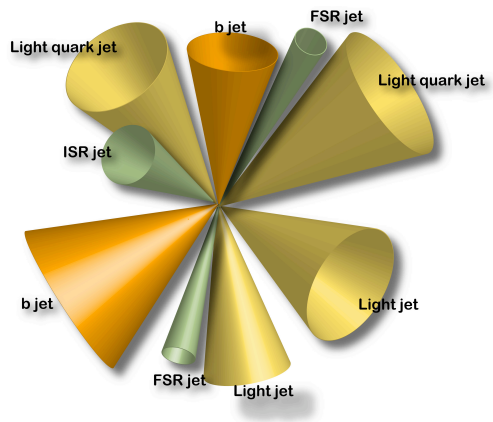


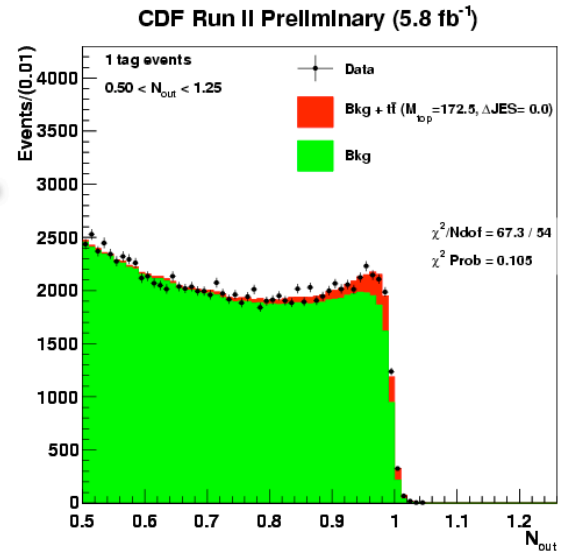
m_t = 176.01 ± 1.01 (stat) ± 0.79 (JES) ± 1.02 (syst) GeV = 176.01 ± 1.64 (GeV)

CDF's All Hadronic Top Quark Mass Measurement

Select events enriched in hadronically-decaying ttbar:

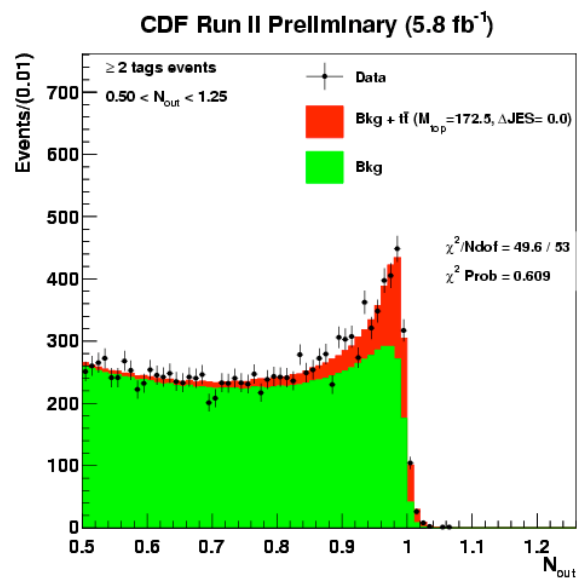
- 6-8 jets separated with ΔR>0.5
- 1 or more b-tags
- No identified leptons





NN built on these variables

1) Sum of the tight jets E_T;
2) Sum of the subleading tight jets E_T, obtained by removing the two leading jets;
3) Aplanarity;
4) Centrality;
5) Minimum of the invariant masses of dijet systems;
6) Maximum of the invariant masses of dijet systems;
7) Minimum of the invariant masses of trijet systems;
8) Maximum of the invariant masses of trijet systems;
9) $E_T^{1*} = E_T^1 \sin^2(\theta_1^*)$ where E_T^1 is the transverse energy of the leading jet and θ_1^* its polar angle in the center-of-mass system of the tight jets;
10) E_T^{2*};
11) $< E_T^* >_{3N}$ (geometric average of E_T^* over the 3rd, 4th...Nth jets);
12) geometric average of the untagged jets η-moments in the calorimeter
13) geometric average of the untagged jets ϕ-moments in the calorimeter



CDF's All Hadronic Top Quark Mass Measurement

Best-fit m_t^{rec} computed for each event, along with goodness-of-fit

$$\chi^2 = \frac{\left(m_{jj}^{(1)} - M_W\right)^2}{\Gamma_W^2} + \frac{\left(m_{jj}^{(2)} - M_W\right)^2}{\Gamma_W^2} + \frac{\left(m_{jjb}^{(1)} - m_t^{rec}\right)^2}{\Gamma_t^2} + \frac{\left(m_{jjb}^{(2)} - m_t^{rec}\right)^2}{\Gamma_t^2} + \sum_{i=1}^{6} \frac{\left(p_{T,i}^{fit} - p_{T,i}^{meas}\right)^2}{\sigma_i^2}$$

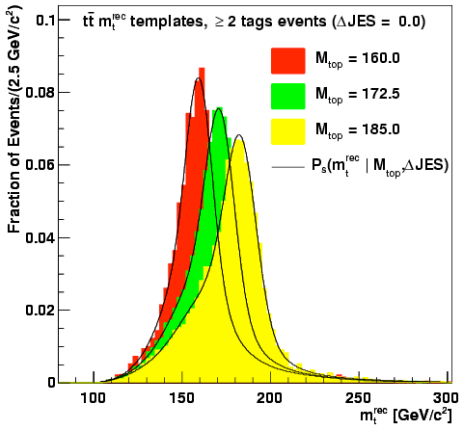
$\{N_{out} > 0.97, \chi^2(m_W^{rec}) < 2, \chi^2(m_t^{rec}) < 3\}$ for 1-tag events
$\{N_{out} > 0.94, \chi^2(m_W^{rec}) < 3, \chi^2(m_t^{rec}) < 4\}$ for ≥2-tag events

Sample		N_{obs}	Exp Bkg (B)	Exp $t\bar{t}$ (S) $(M_{top} = 172.5, \Delta\text{JES} = 0)$	S/B
1-tag	S_{JES}	4368	3652 ± 181	881 ± 73	0.24
	S_{Mtop}	2256	1712 ± 77	604 ± 50	0.35
$\geq$ 2-tags	S_{JES}	1196	718 ± 14	468 ± 38	0.65
	S_{Mtop}	600	305 ± 22	316 ± 26	1.04

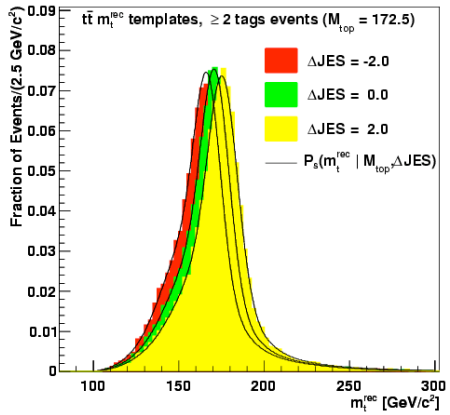
Background rate constrained in 5-jet data with data-calibrated tag rates

CDF's All Hadronic Top Quark Mass Measurement

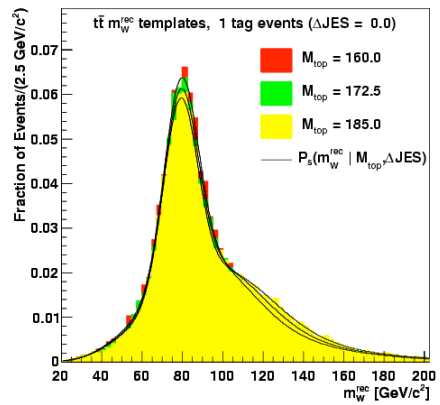
Templates for fitting (m_{top},JES)



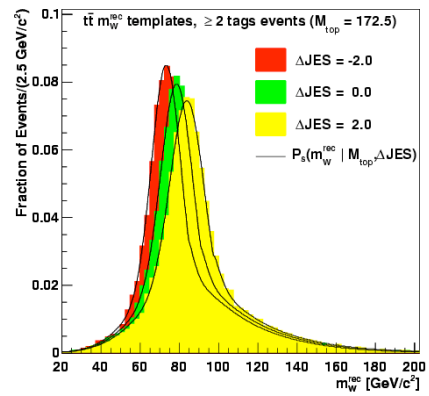
$m_{t,rec}$ vs. $m_{t,input}$



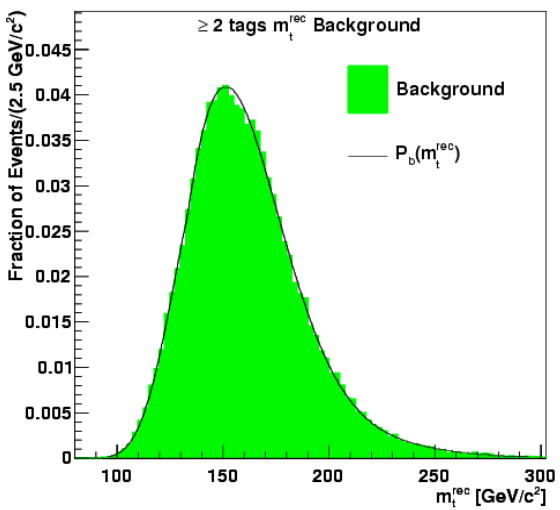
$m_{t,rec}$ vs. JES

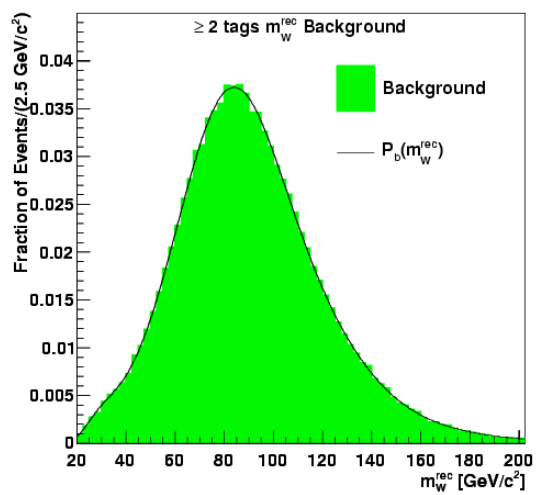


$m_{W,rec}$ vs. $m_{t,input}$



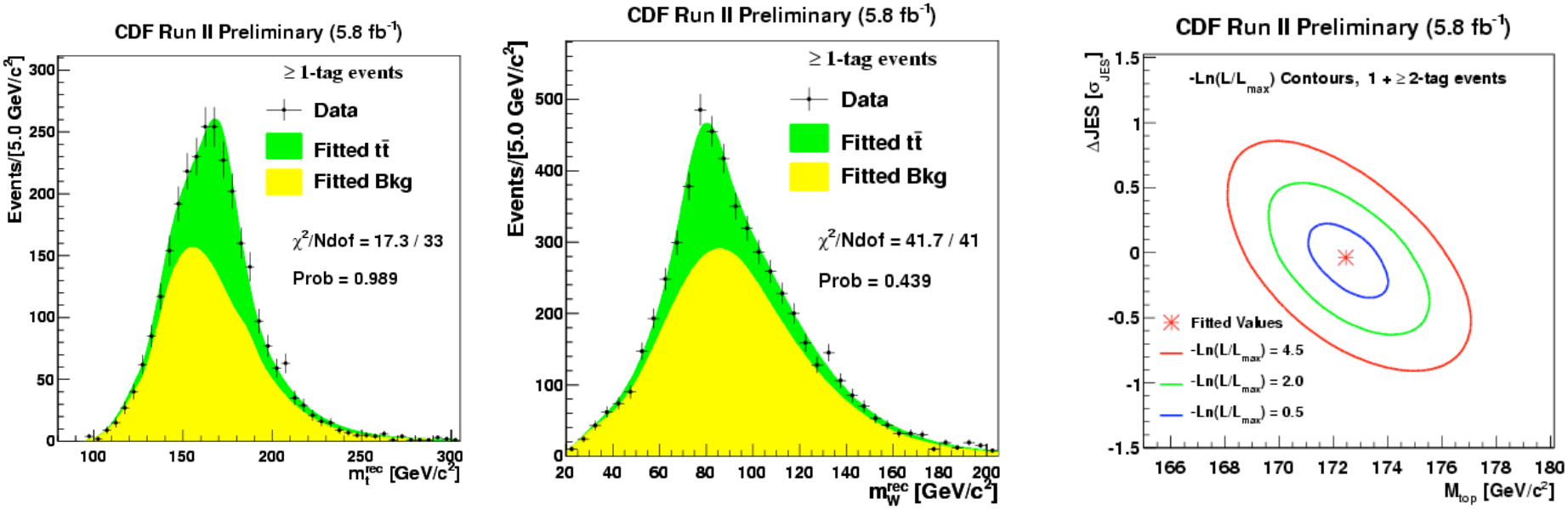
$m_{W,rec}$ vs. JES



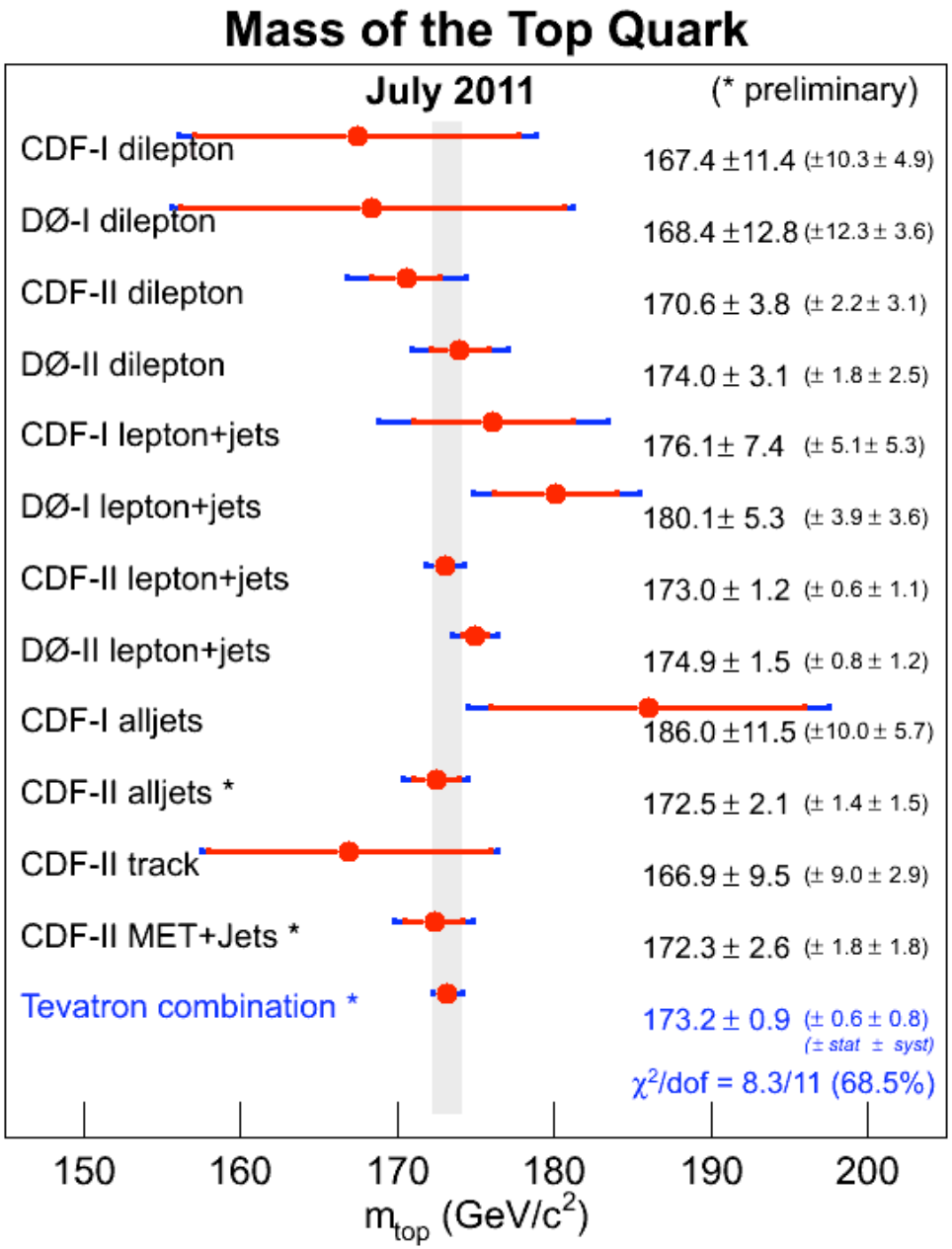


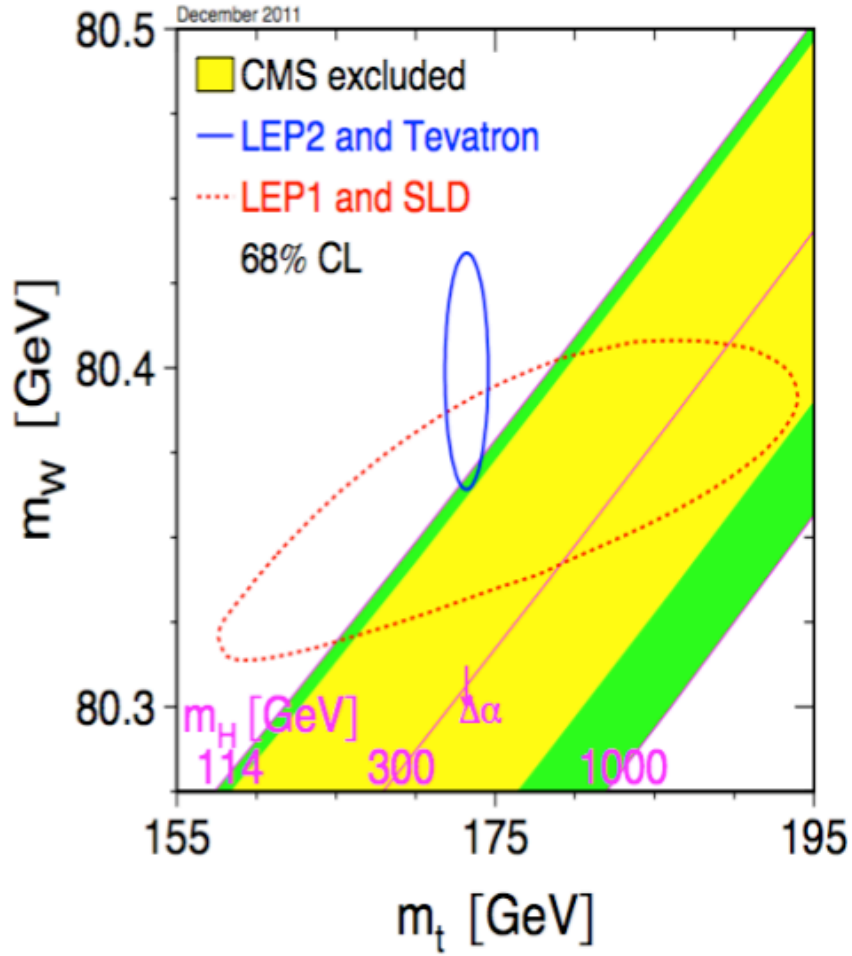
Background Templates

CDF's All Hadronic Top Quark Mass Measurement



M_{top} = 172.5 ± 1.4(stat) ± 1.4(syst) GeV/c^2





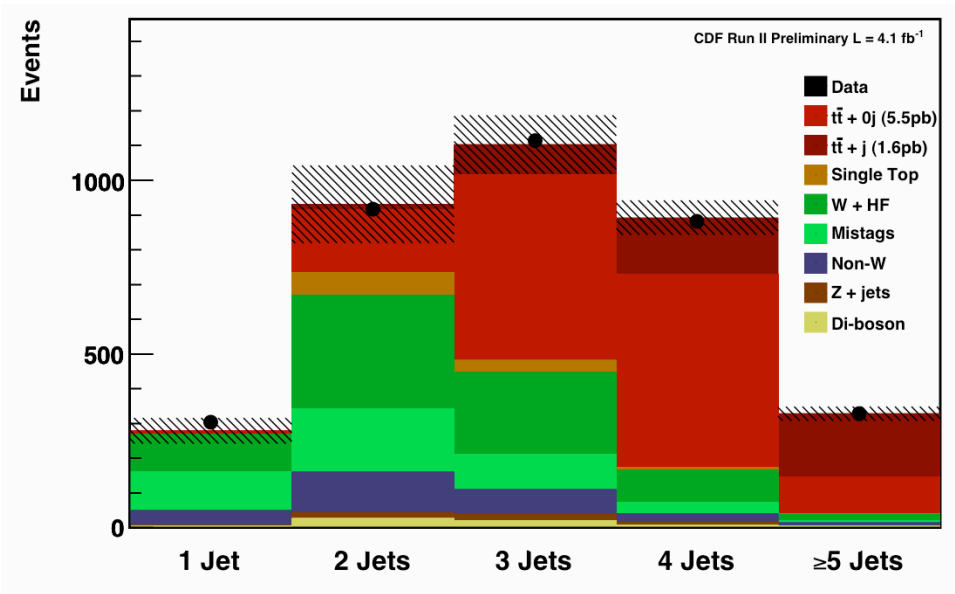
From G. Tonelli's CERN seminar, 13 December 2011

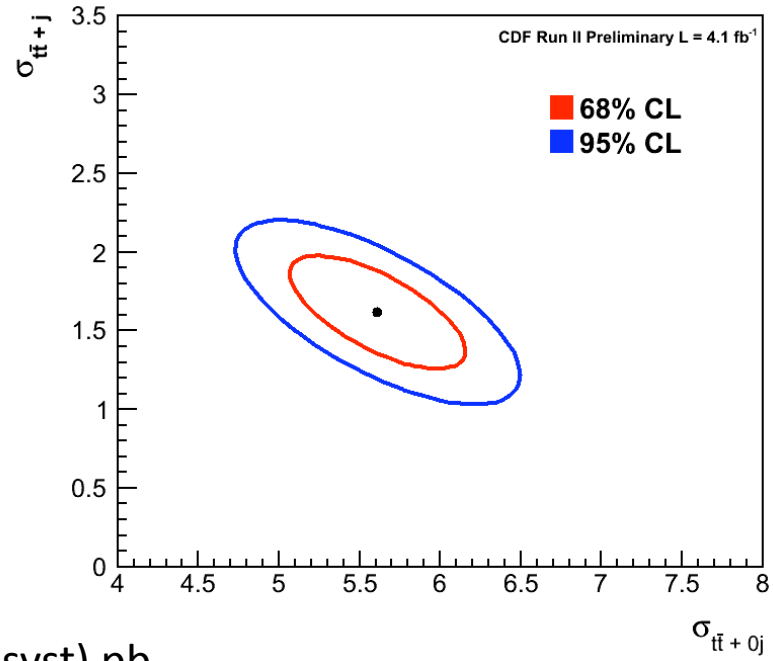
Measuring the rate of ttbar+jet(s)

CDF Public Note 9850 (2009)

CDF, 4.1 fb^{-1}
Require: 20 GeV isolated lepton
20 GeV Missing Transverse Energy
At least one b-tag
H_T>220 GeV

Jet E_T>20 GeV
$|\eta|$<2.0





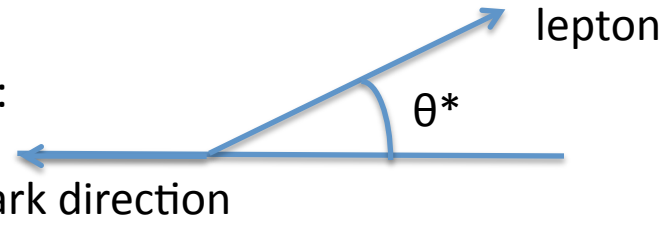
Measured: σ(ttbar+j) = 1.6± 0.2 (stat) ± 0.5 (syst) pb

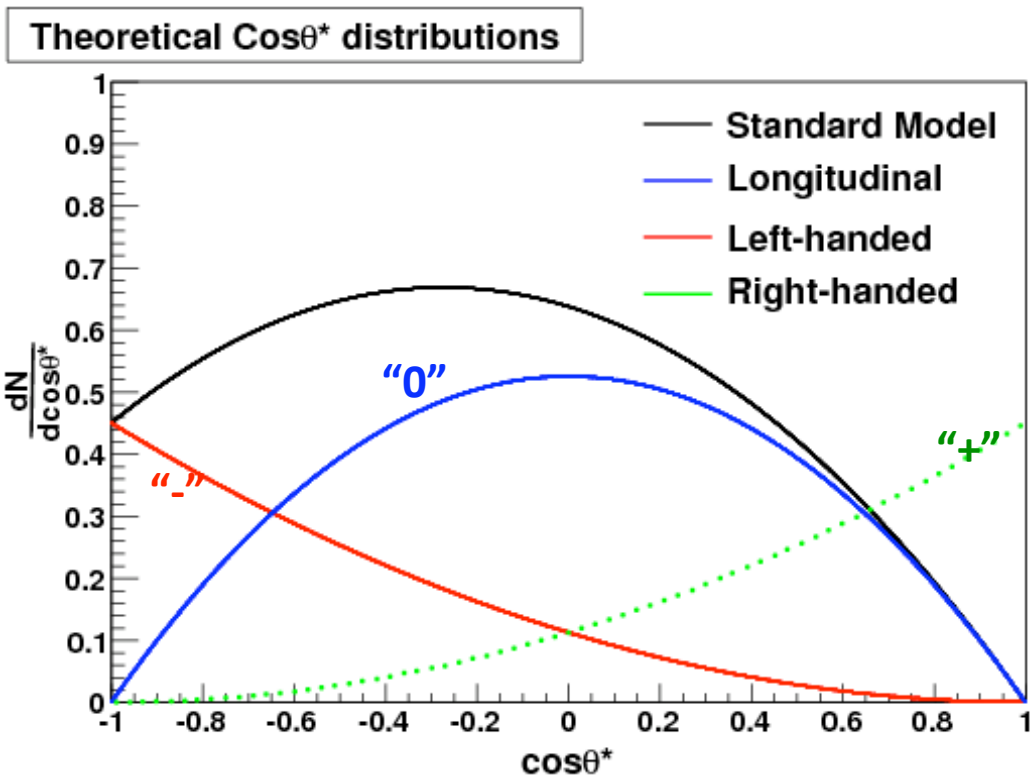
NLO Prediction: $1.79^{+0.16}_{-0.31}$ pb S. Dittmaier, P.Uwer, and S.Weinzierl, arXiv:0810.0452v2 [hep-ph].

Measurements like this can help constrain exotic particles decaying to top + jet(s)
See Eleni Vryonidou's talk yesterday

W Helicity in Top Quark Decay

In the W decay frame:





Sensitive to:

- Exotic Wtb couplings
- Non-standard top quarks
- Exotic W bosons (charged Higgs?)

SM Predictions:

f_0=0.698

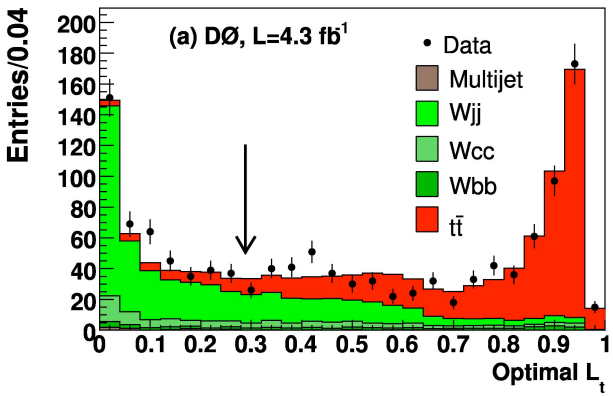
f_-=0.301

f_+=4.1×10^{-4}

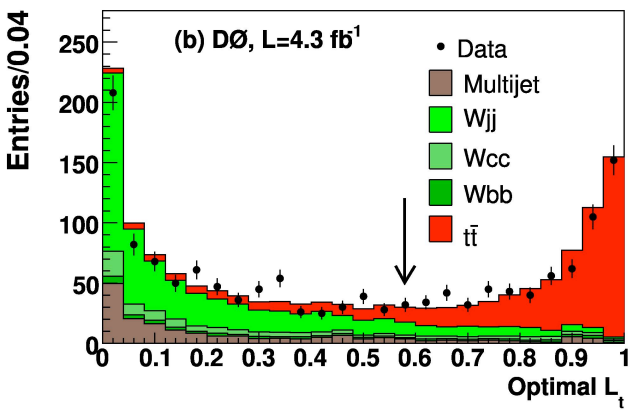
D0 Collab., arXiv:1011.6549 [hep-ex], Submitted to Phys. Rev. D

Selection of ttbar Events

Lepton + jets
Require e or μ, >=4 jets,
two b-tags, Missing Energy



μ+jets



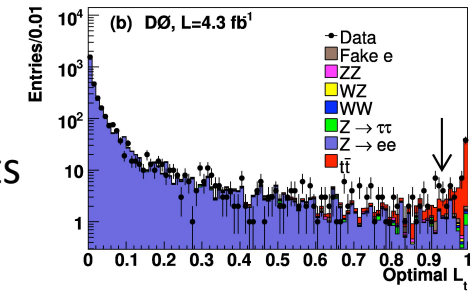
e+jets

[arXiv:1011.6549 [hep-ex]]

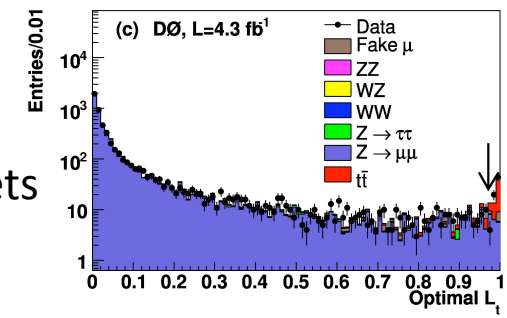
Selection likelihoods based on kinematic variables like H_T, and b-tag variables. Try not to sculpt cosθ* too much

Lepton + jets
Require e or μ, >=2 jets,
two b-tags, Missing Energy

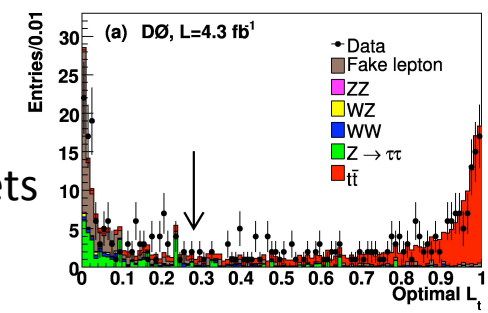
ee+jets



μμ+jets



eμ+jets

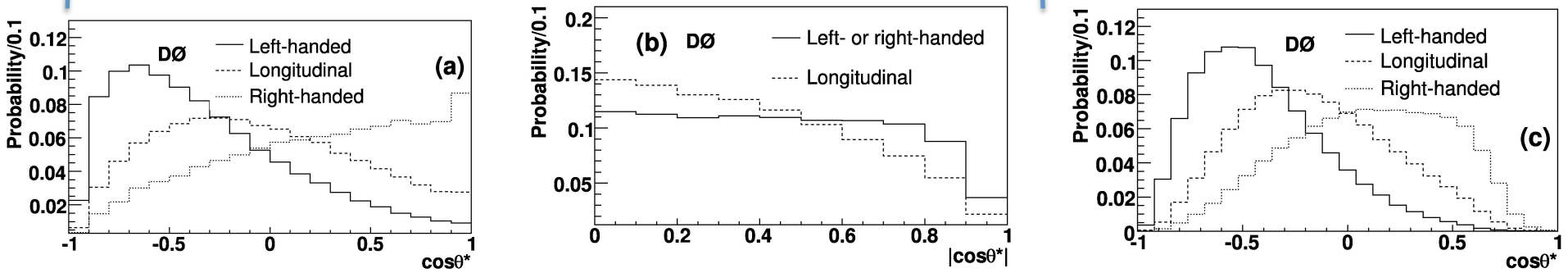


D0's lepton+jets W Helicity Measurement in 5.4 fb^{-1} of Data

$\cos\theta^*$ Distributions after Detector, Trigger, Reconstruction and Selection requirements

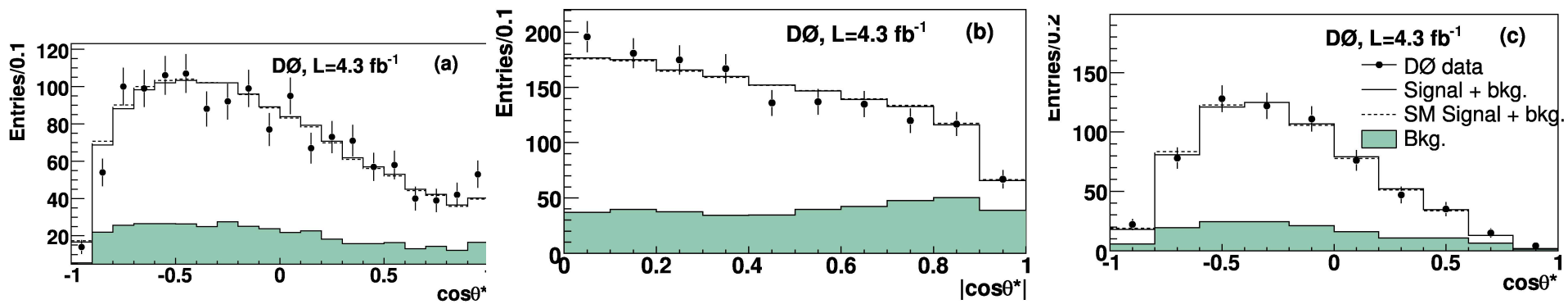
Lepton + Jets Channel

Dilepton Channel



leptonically decaying W

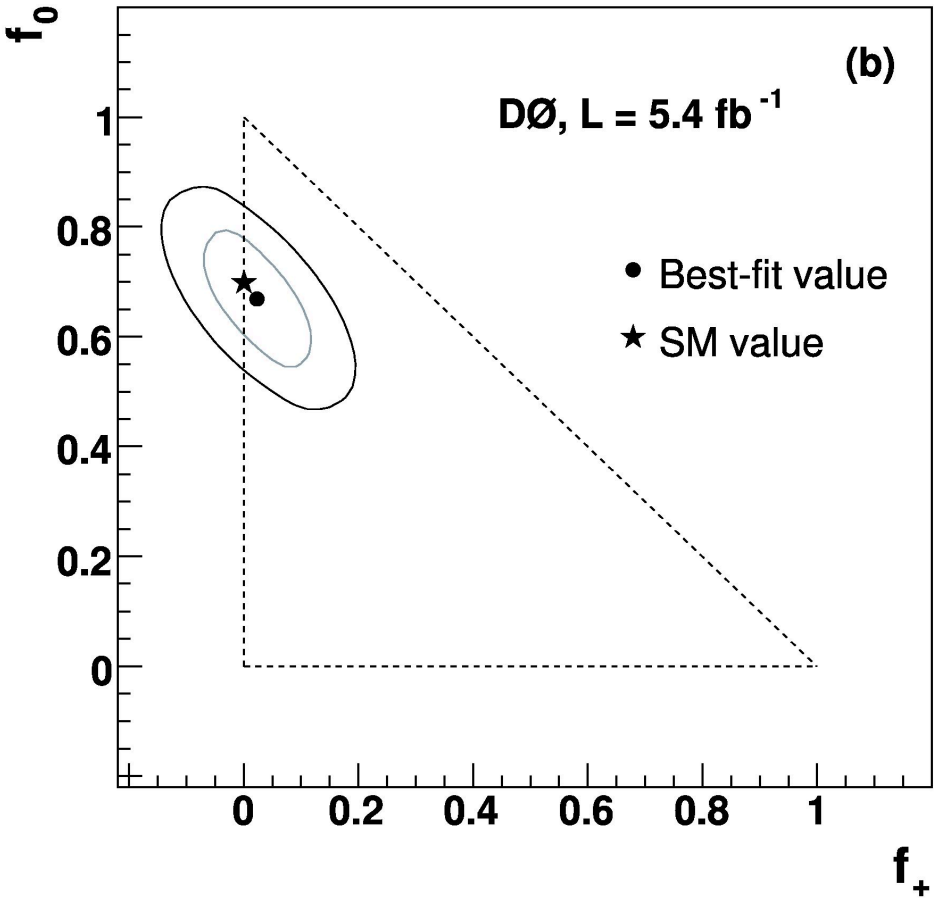
Hadronically decaying W



[arXiv:1011.6549 [hep-ex]](#)

Each event counts twice.

Fitted Helicity Fractions



SM Predictions:

f_0=0.698
f_-=0.301
f_+=4.1x10^{-4}

arXiv:1011.6549 [hep-ex]

$$f_0 = 0.739 \pm 0.091\ (\text{stat.}) \pm 0.060\ (\text{syst.})$$
$$f_+ = -0.002 \pm 0.045\ (\text{stat.}) \pm 0.032\ (\text{syst.})$$

CDF's Dilepton W Helicity Measurement

Select dilepton + MIssing E_T + 2 or more jets events in 5.1 fb^{-1} of data

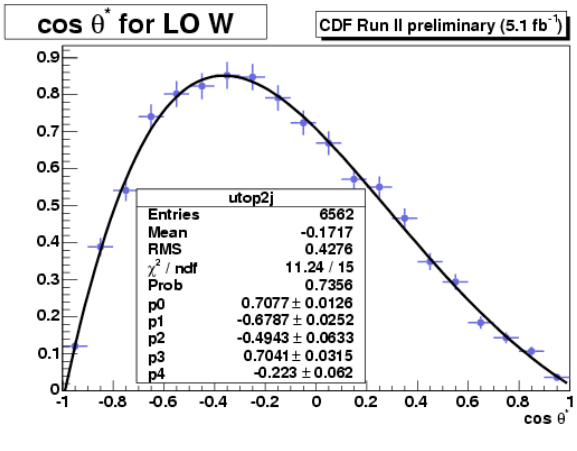
Combining results from events with a b-tag and events without

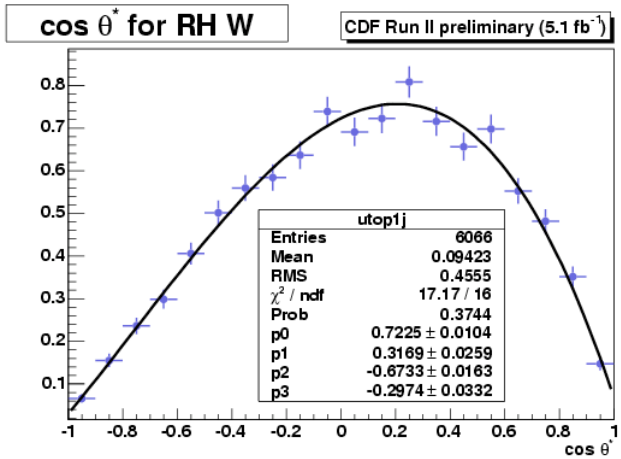
Non-tagged Signal Events	
Source	$\ell\ell$
WW	11.35±2.36
WZ	3.40±0.55
ZZ	2.08±1.76
Wγ	0.42±0.44
DY$\rightarrow \tau\tau$	11.78±2.18
DY$\rightarrow ee + \mu\mu$	21.49±3.24
Fakes	47.81±14.79
Total background	96.05 ±17.32
$t\bar{t}$ ($\sigma = 7.4$ pb)	107.17±13.90
Total SM expectation	203.22±29.90
Observed	206

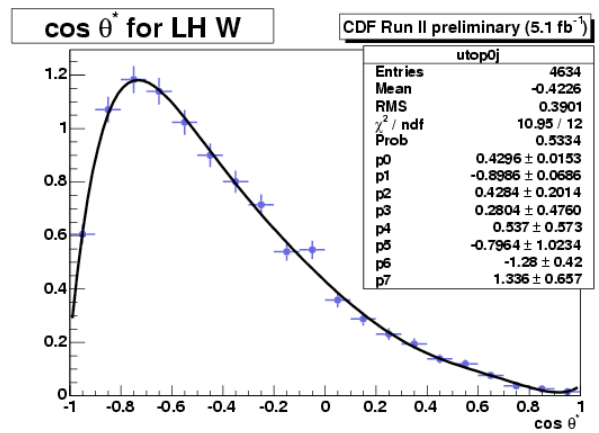
b-tagged Signal Events	
Source	$\ell\ell$
WW	0.37±0.10
WZ	0.08±0.02
ZZ	0.17±0.14
DY+LF	1.39±0.12
DY+HF	2.28±0.18
Fakes	5.46±1.59
Total background	9.75±1.68
$t\bar{t}$ ($\sigma = 7.4$ pb)	129.96±8.10
Total SM expectation	139.71±9.66
Observed	137

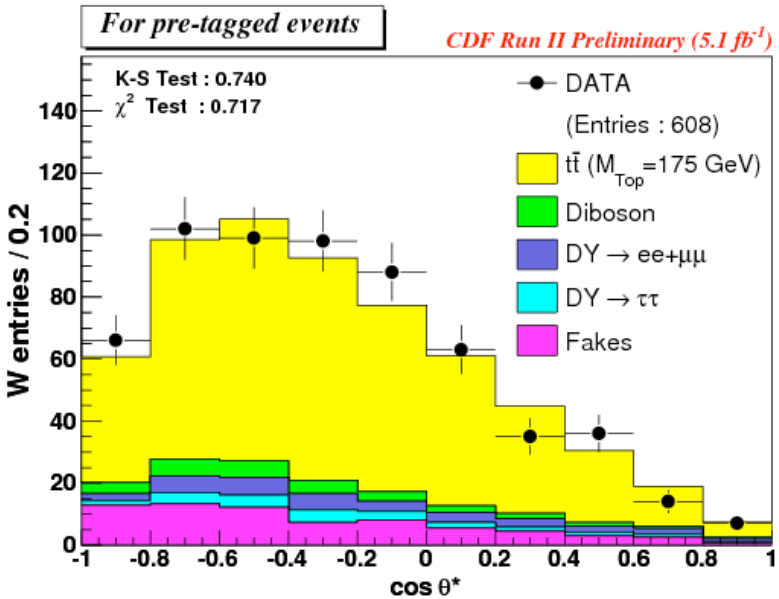
http://www-cdf.fnal.gov/physics/new/top/2011/WhelDil/cdf10543_WhelDilPub_Combo_v5.ps

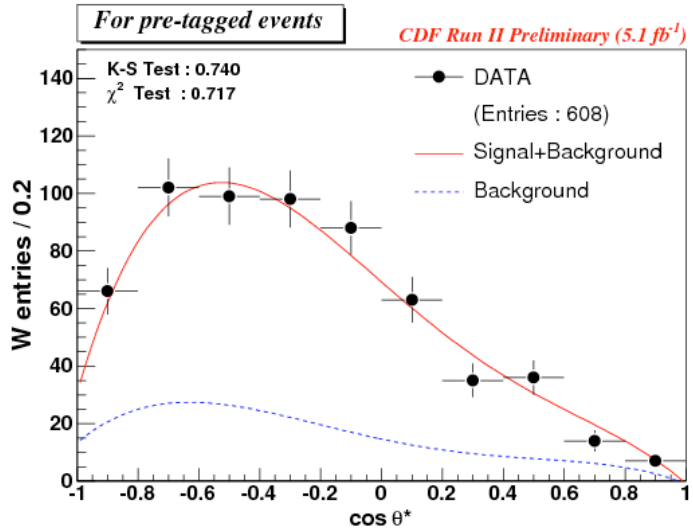
CDF's Dilepton W Helicity Measurement



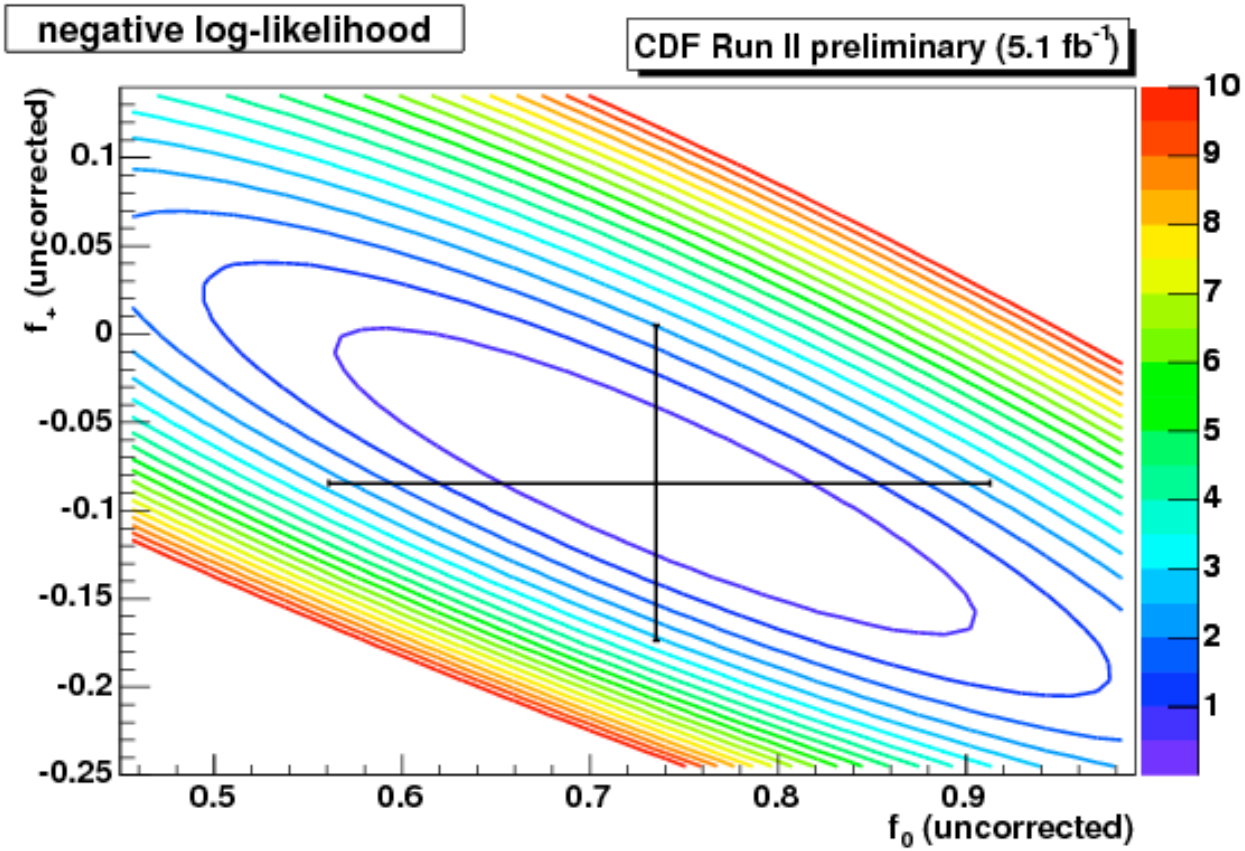








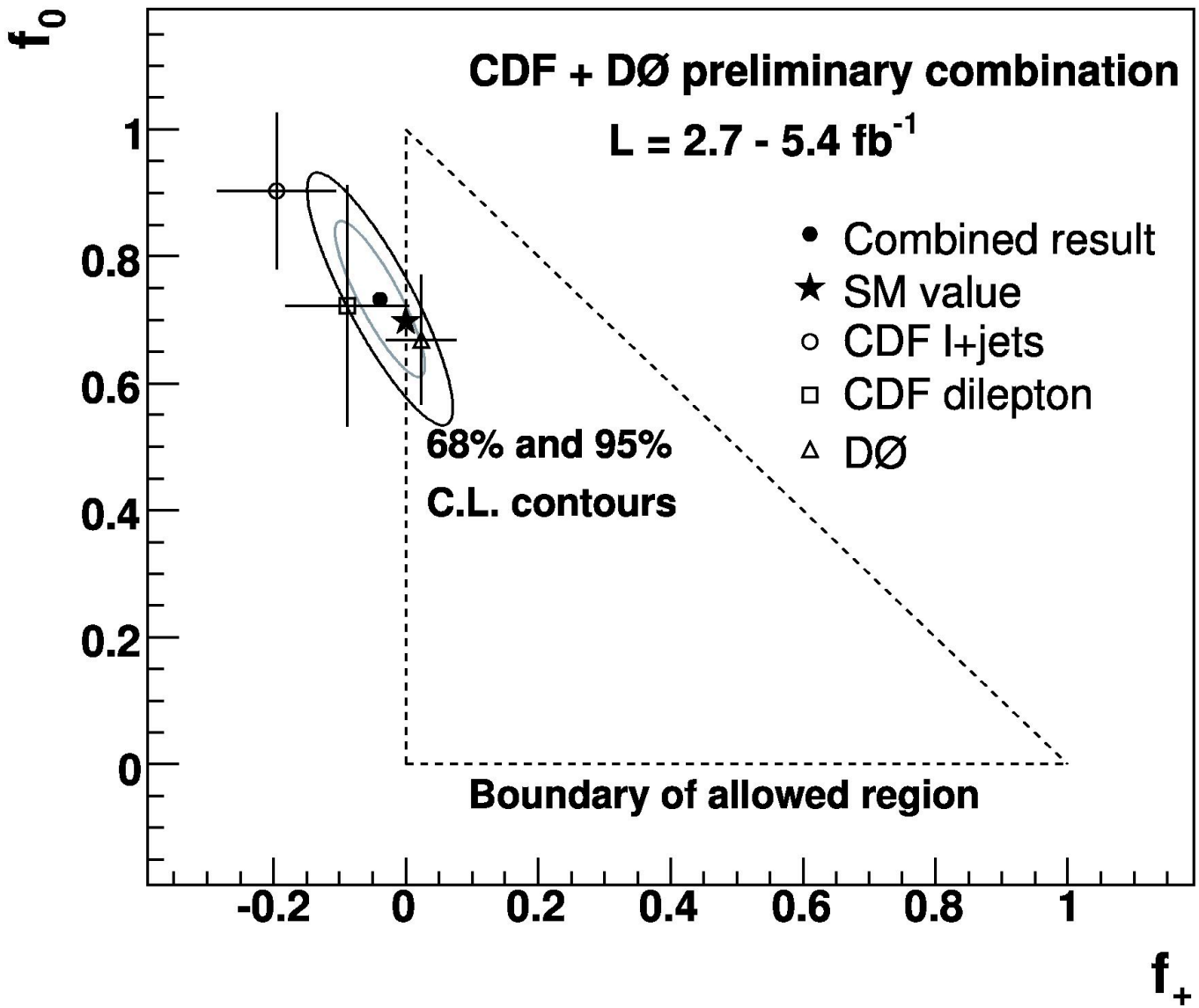
CDF's Dilepton W Helicity Measurement



Joint fit of f_0 and f_+:
$f_0 = 0.71\ ^{+0.18}_{-0.17}$ (stat) ± 0.06 (syst)
$f_+ = -0.07 \pm 0.09$ (stat) ± 0.04 (syst)

Constraining $f_+ = 0$ Yields $f_0 = 0.59 \pm 0.09$ (stat) ± 0.06 (syst)
Constraining $f_0 = 0.7$ yields $f_+ = -0.07 \pm 0.04$ (stat) ± 0.03 (syst)

Combined W Helicity in Top Quark Decay Measurements



Spin Correlation in ttbar Decay

Top quarks are unpolarized at the Tevatron

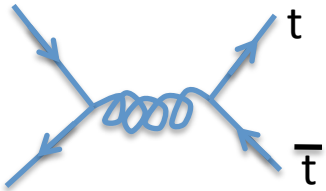
Nonetheless, spin is expected to be correlated between the two top quarks.

Top quark decays before it hadronizes – almost all of the polarization remains in the decay.

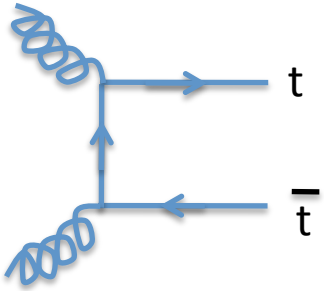
Maximally parity-violating tWb decay analyzes spin.

SM Predicted correlation: $C=0.78^{+0.03}_{-0.04}$ at NLO in QCD, using the beam axis as the spin quantization axis, and 100% spin analyzing power (true for leptons)
(Bernreuther, Brandenburg, Si and Uwer, 2004)

~85% of the cross section at the Tevatron



~15%



$$\mathrm{d}^2\sigma_{t\bar{t}}/\mathrm{d}\cos\theta_1\,\mathrm{d}\cos\theta_2 = \sigma_{t\bar{t}}(1 - C\cos\theta_1\cos\theta_2)/4$$

Spin Correlation in ttbar Decay

D0 Measurement in 5.3 fb^{-1} of data arXiv:1110.4194 [hep-ex], submitted to Phys. Rev. Lett

Event Selection:
- lepton (e or μ), p_T>20 GeV
- Missing Transverse Energy > 20 GeV (e), 25 GeV (μ)
- 4 or more jets with p_T>20 GeV, |η|<2.5
- Reject cosmics, conversions, dileptons (rejects Z, diboson)

Matrix-element technique used to test the hypotheses of uncorrelated spins and correlated spins.

H=u (uncorrelated)
c (correlated)

$$P_{\rm sgn}(x;H) = \frac{1}{\sigma_{\rm obs}} \int f_{\rm PDF}(q_1)\, f_{\rm PDF}(q_2) {\rm d}q_1 {\rm d}q_2 \times \frac{(2\pi)^4 \left|\mathcal{M}(y,H)\right|^2}{q_1 q_2 s} W(x,y)\, {\rm d}\Phi_6,$$

W: Jet transfer functions.
Probabilities summed over reconstruction ambiguity (jet assignments)

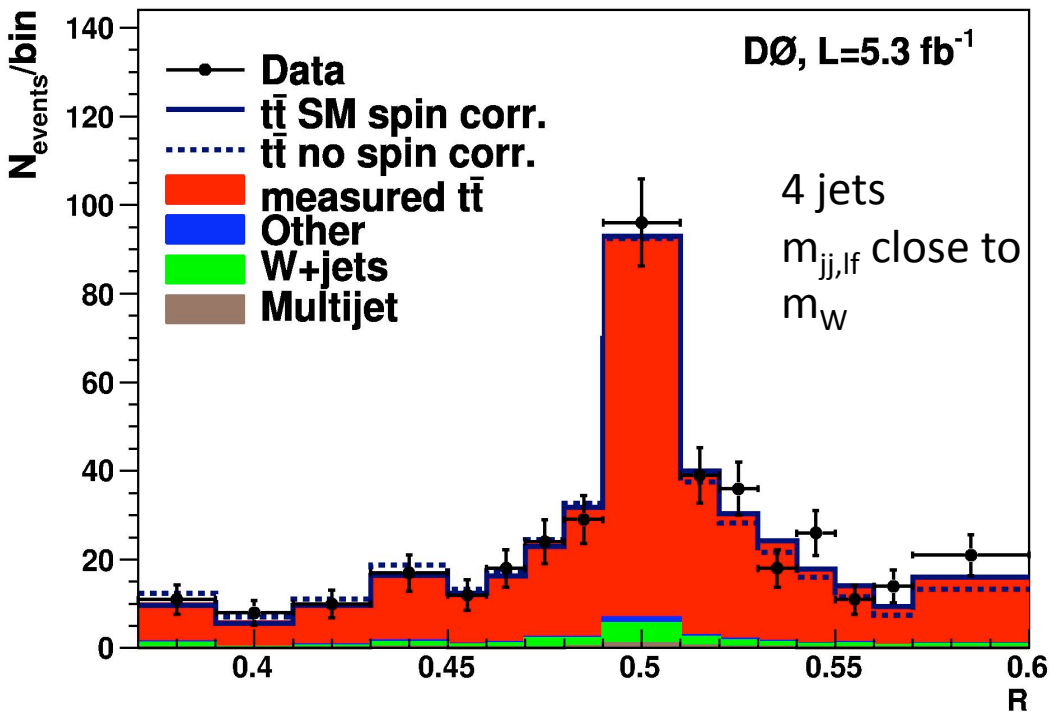
Define a likelihood ratio

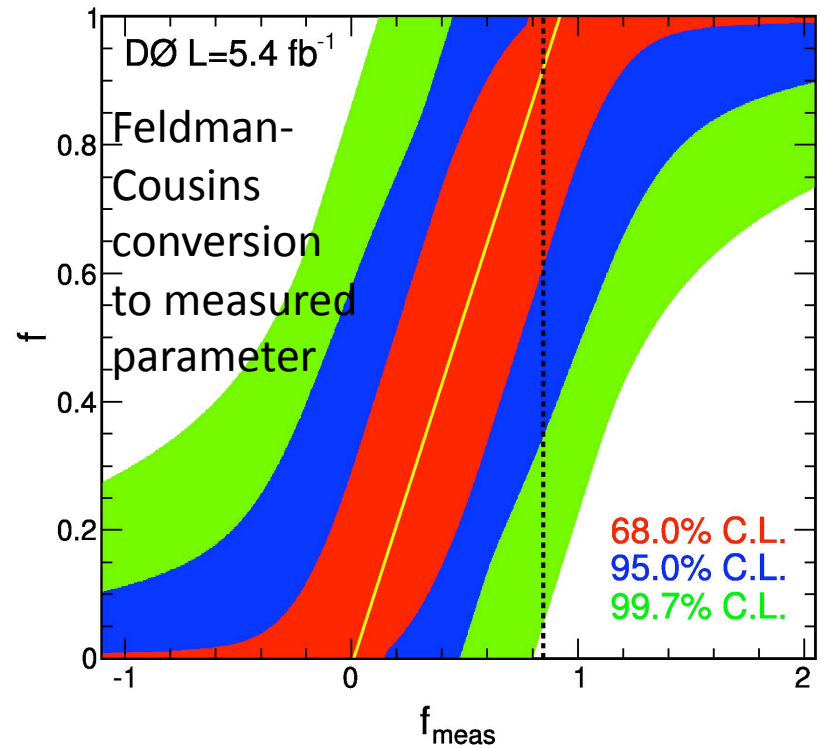
$$R = \frac{P_{\rm sgn}(x;H=c)}{P_{\rm sgn}(x;H=u) + P_{\rm sgn}(x;H=c)}$$

Evidence for Spin Correlation in Top Decay

Optimizations for sensitivity:

- Analyze l+4 jets events separately from l+5 or more jets (reduced combinations)
- Analyze events with m_{jj} for the untagged jets close to m_W or not (±25 GeV)





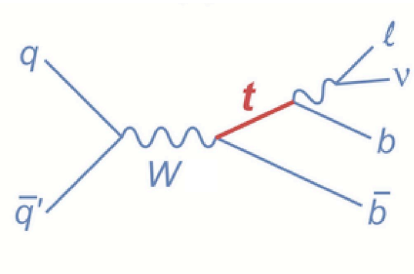
D0's "f" is just a scaling to their MC sample which is generated with the SM correlation

A_{meas}=0.66±0.23 (stat+syst), accounting for all dilutions

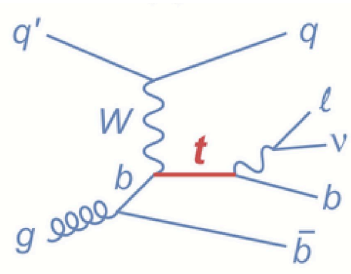
arXiv:1110.4194 [hep-ex], submitted to Phys. Rev. Lett

Measurements of Single Top Production

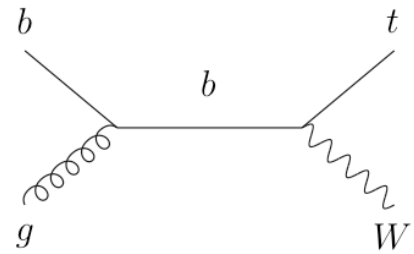
Signals



s-channel
(~ 1 pb)

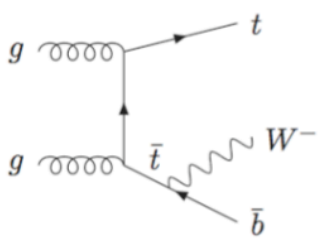


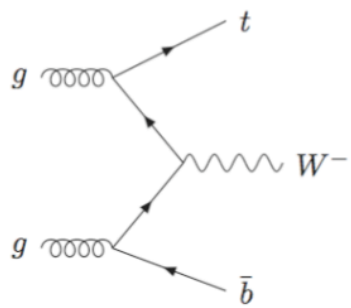
t-channel
(~2 pb)

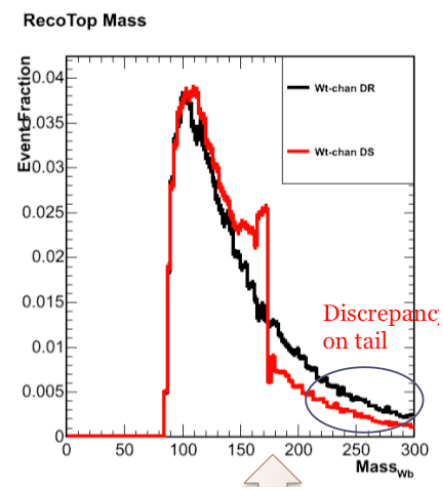


Associated tW
Production (~0.2 pb)

- Well known problem of interference between Wt and ttbar production.



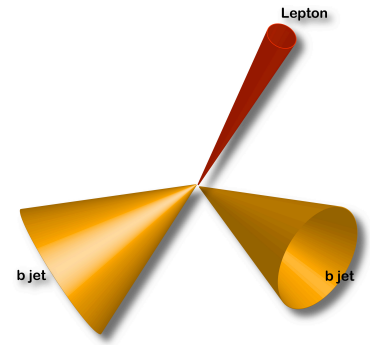




See talk of Mohammed Assadsolimani yesterday

Measurements of Single Top Production

Event Selection:



An s-channel signal event looks like this

Typically:

Selects events with a leptonically decaying W boson, rejects multijets

- A high-P_T lepton, P_T>20 GeV, |η| within detector acceptance
- Missing E_T (>25 GeV)

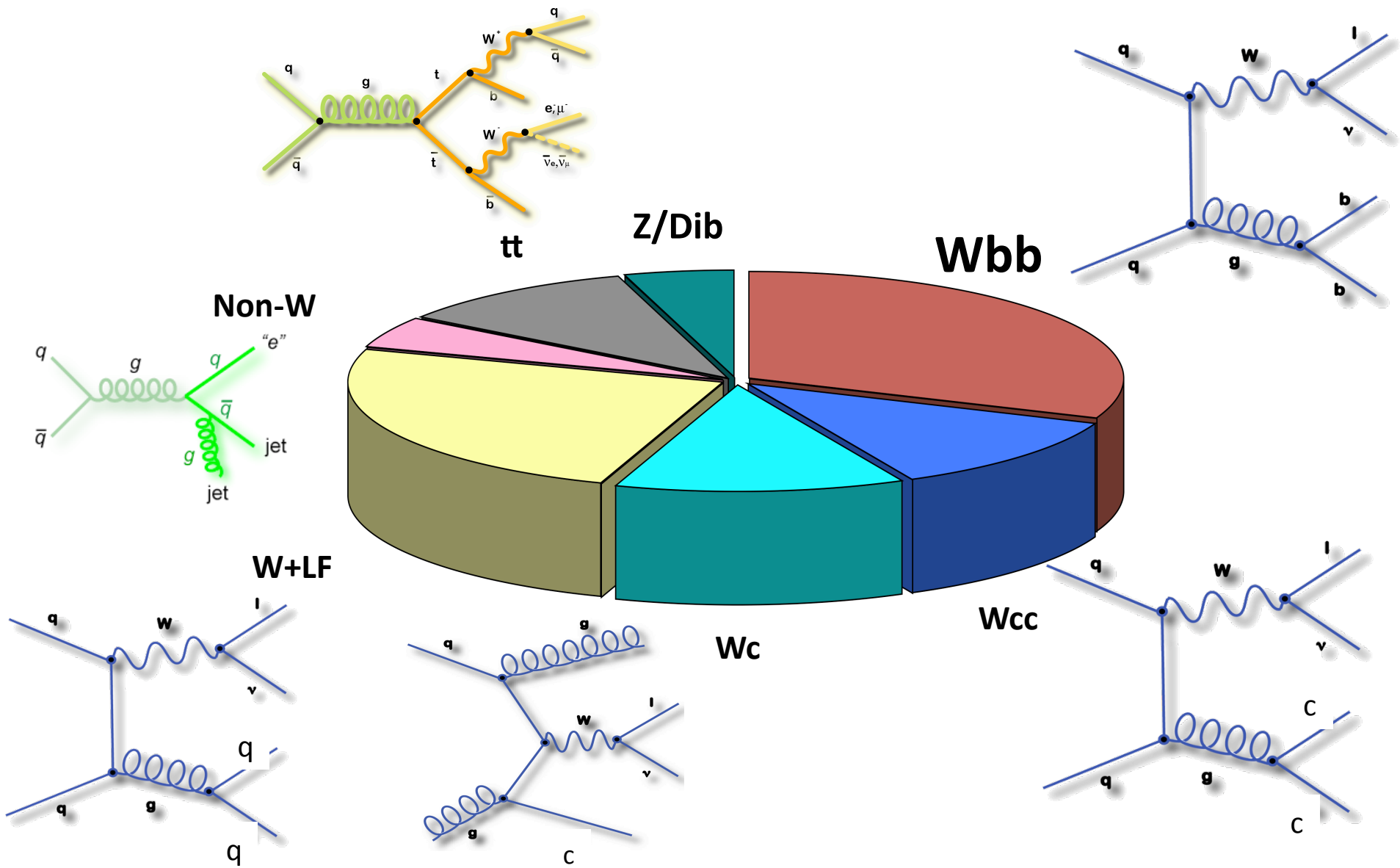
Reduces W+light flavor and W+charm while keeping single top.

Jet requirements reduce ttbar

- One or more b-tagged jets
- Two, three, or four total jets -- |η| out to 2.8, jet E_T cut at 20 GeV

- Veto dileptons (reduce Z+jets)
- Veto cosmics
- Special multijet vetos based on M_T(lν) and Missing E_T

Backgrounds in the b-tagged W+2, 3 jet sample



Expected Yields in D0's 5.4 fb^{-1} Single Top Measurement

Source	2 jets	3 jets	4 jets
tb	104 ± 16	44 ± 7.8	13 ± 3.5
tqb	140 ± 13	72 ± 9.4	26 ± 6.4
$t\bar{t}$	433 ± 87	830 ± 133	860 ± 163
W+jets	$3{,}560 \pm 354$	$1{,}099 \pm 169$	284 ± 76
Z+jets & dibosons	400 ± 55	142 ± 41	35 ± 18
Multijets	277 ± 34	130 ± 17	43 ± 5.2
Sum of above sources	$4{,}914 \pm 558$	$2{,}317 \pm 377$	$1{,}261 \pm 272$
Data	4,881	2,307	1,283

Modeling:

Single top: MC (SingleTop) normalized to Kidonakis's NNNLO+NNLL cross section

ttbar: Pythia normalized to Moch and Uwer's (~)NNLO cross section

W+jets: Untagged Alpgen MC scaled to data (minus non-Wjets). W+HF K-factor computed with MCFM. CDF uses HF K-factor from W+1 jet sample, but it is an extrapolation to use that in the 2+ jet samples, so larger uncertainty

Z+jets, dibosons: NLO cross sections * MC

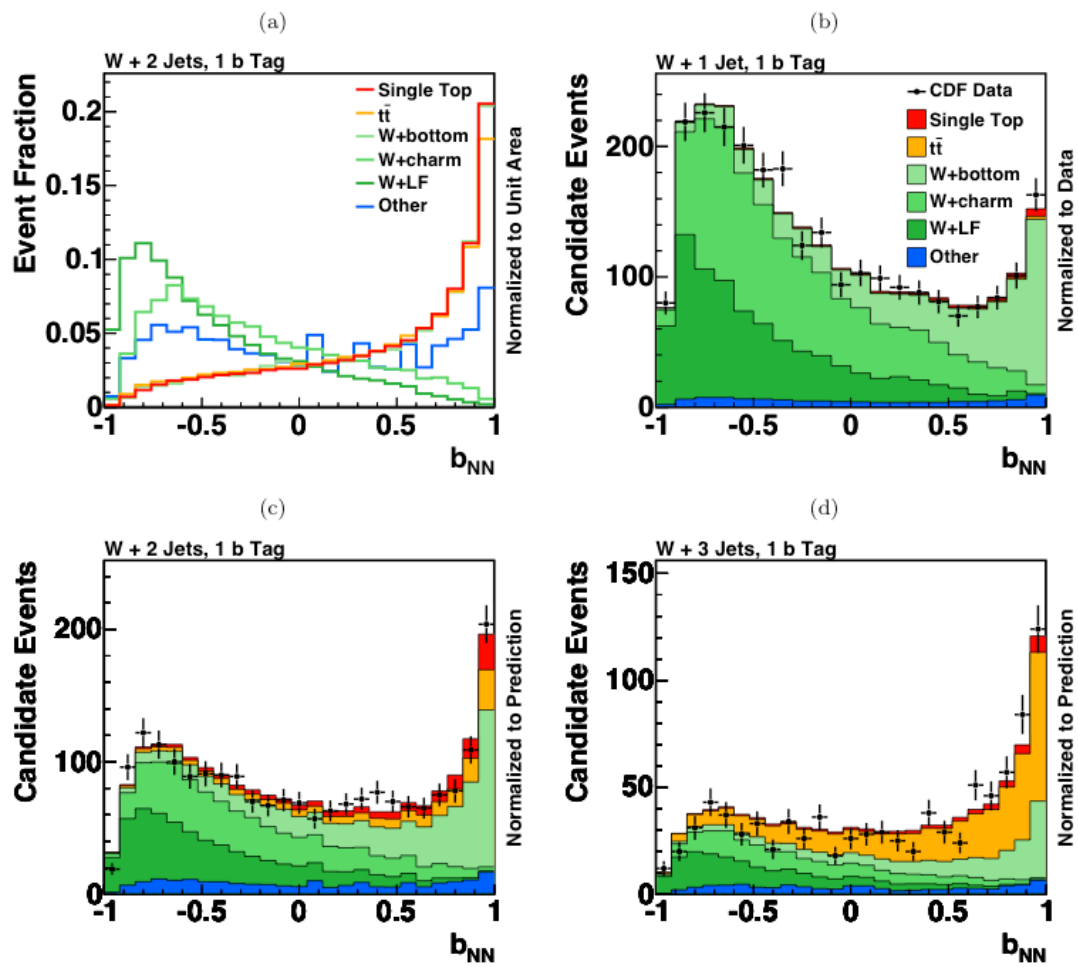
Multijets: Constrained in data sidebands

A Neural Network Flavor Separator for Jets Tagged with a Displaced Vertex

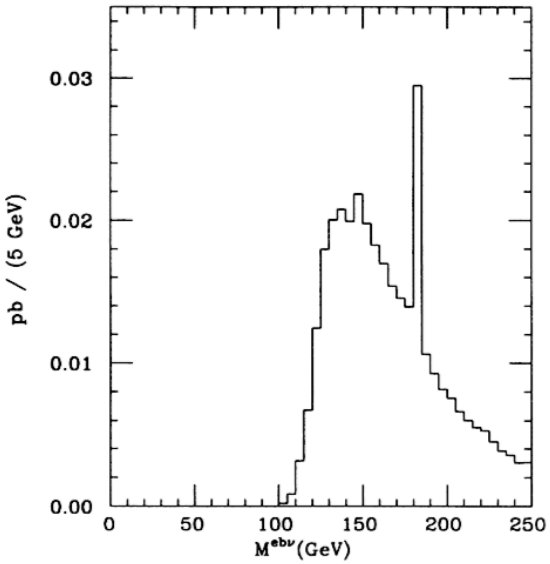
Inputs used:

Take advantage of long B hadron lifetime (~1.4 ps) and large mass (~5 GeV), compared to light flavor jets and charm jets

- Invariant mass of tracks in reconstructed displaced vertex
- Reconstructed decay length
- Decay length significance
- Track impact parameters
- Track Impact parameter significance
- Track p_T relative to jet axis
- Presence of lepton candidates



A Powerful Separation Variable -- Invariant Mass

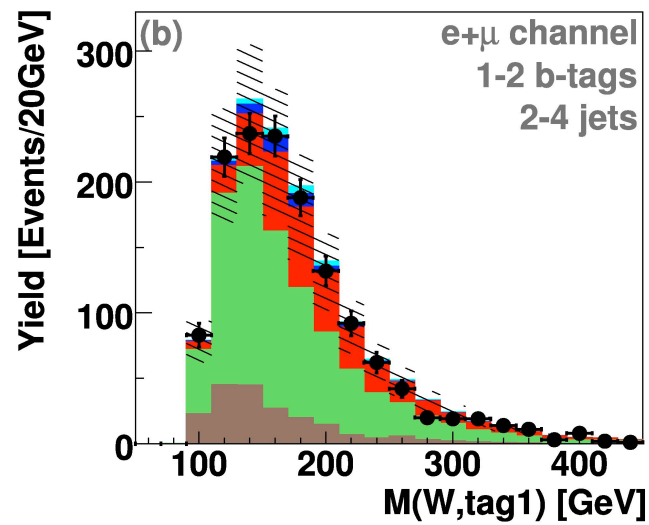


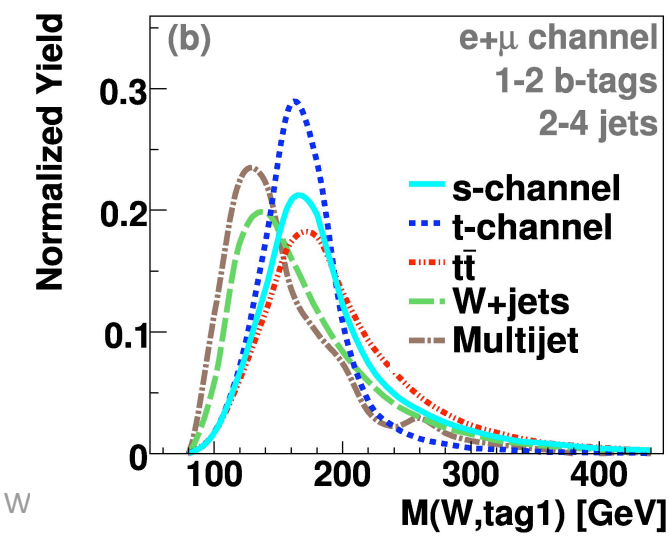
Well, maybe a little too powerful!

C.P. Yuan
Phys. Rev. **D41**, 42 (1990)

No experimental resolution effects taken into account.

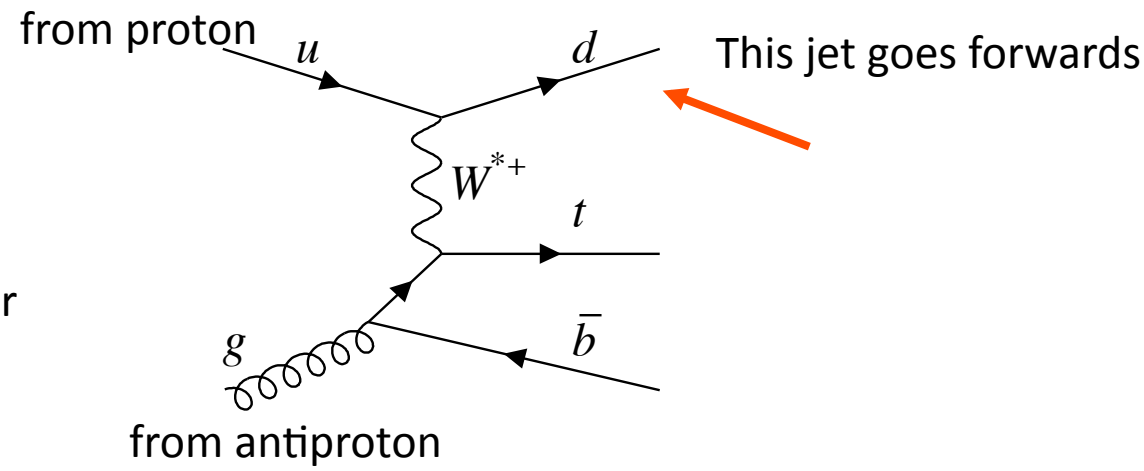
Reality sets in: MET and jet resolution, wrong jet assignment, wrong $p_{z,\nu}$ choice all degrade signal peak

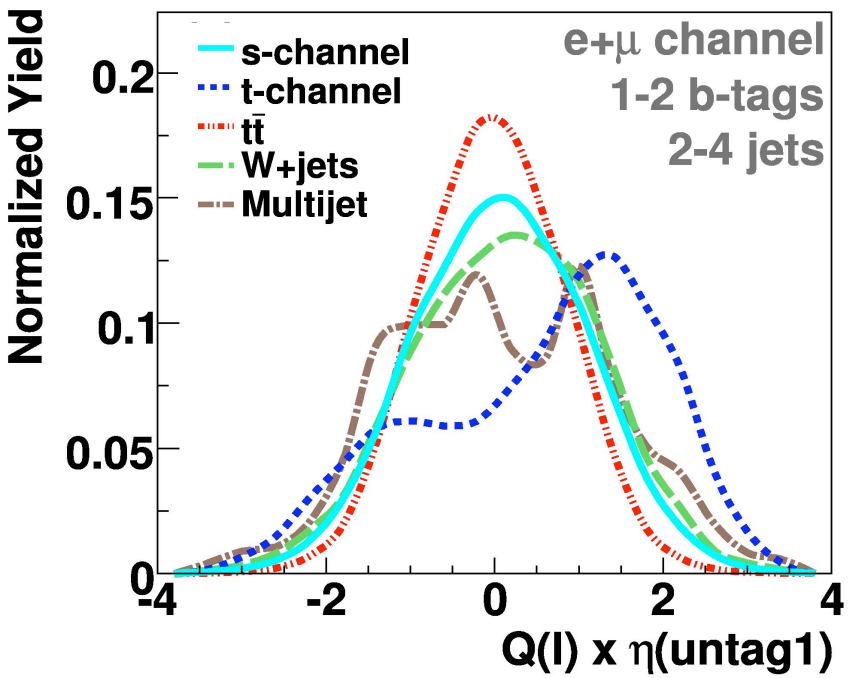


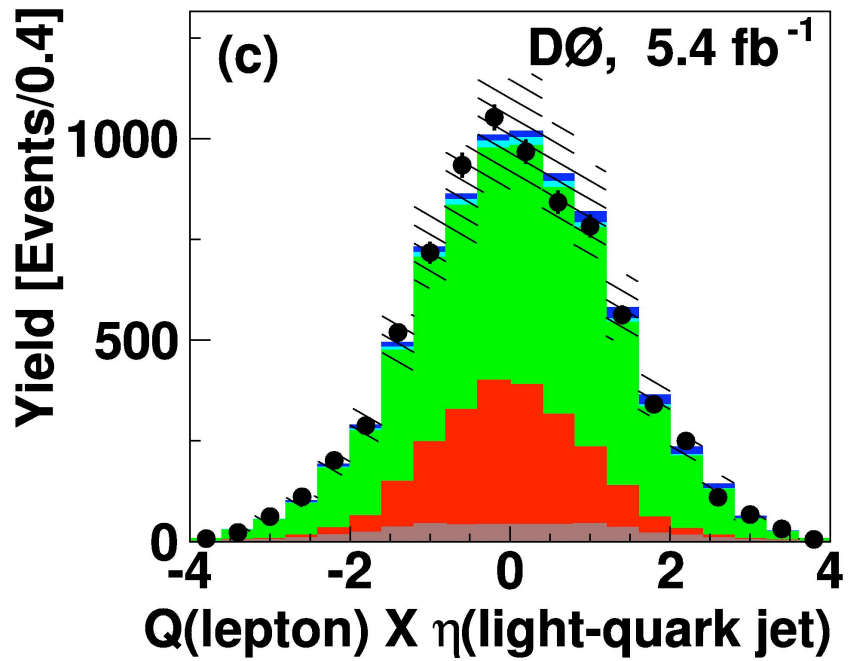


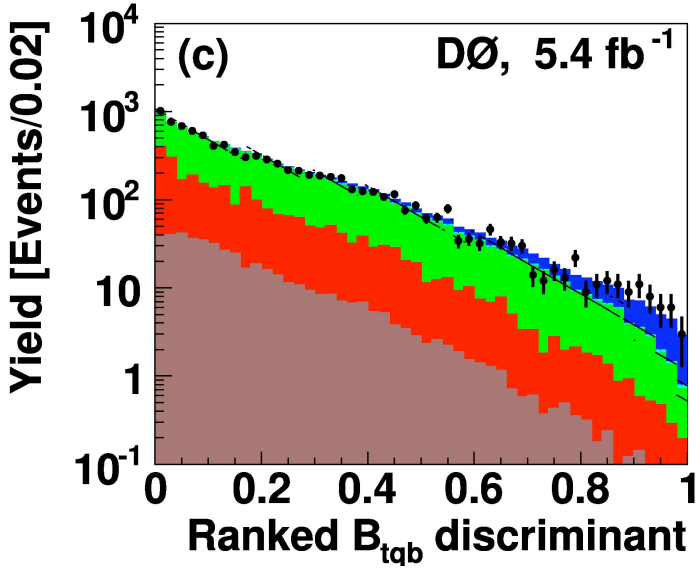
$Q \times \eta$

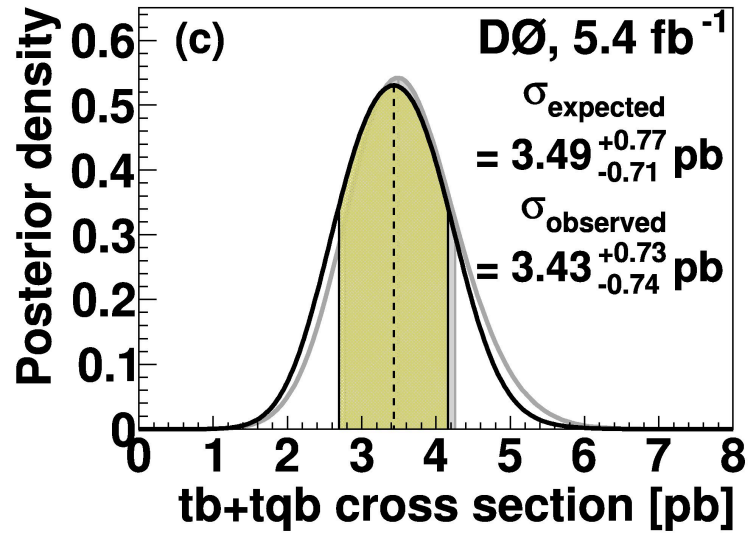
Excellent t-channel signal/background separator Yuan, 1990.





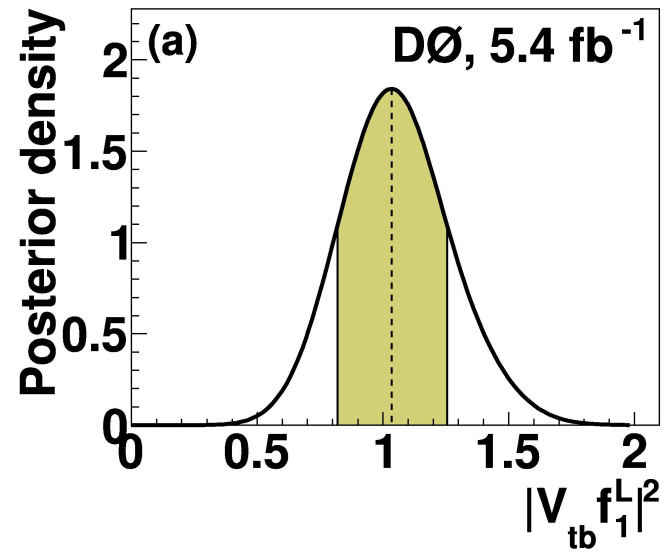






$|V_{tb}|^2$ posterior differs from the cross section posterior because of inclusion of theory uncertainties on the tb+tqb cross section.

Arise from m_{top}, PDF, and factorization and renormalization scale uncertainties.
The m_{top} part is correlated with the acceptance.



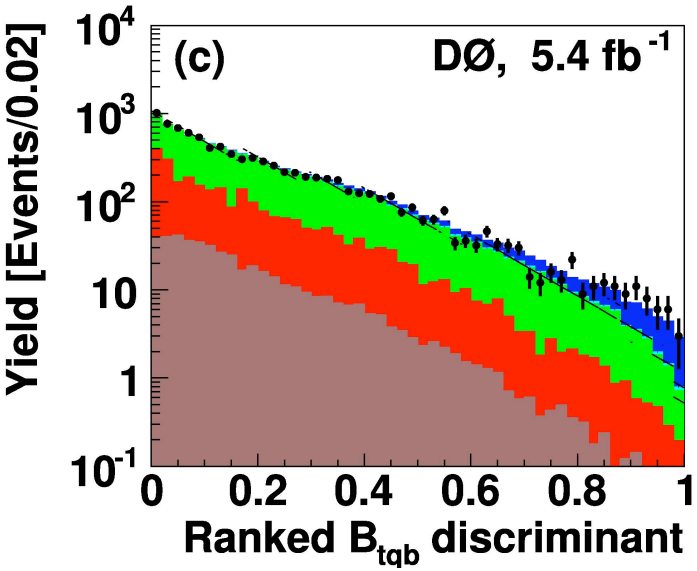
$$|V_{tb}^{meas}|^2 = \frac{|V_{tb}^{SM}|^2 \, \sigma_{tb+tqb}^{meas}}{\sigma_{tb+tqb}^{SM}}$$

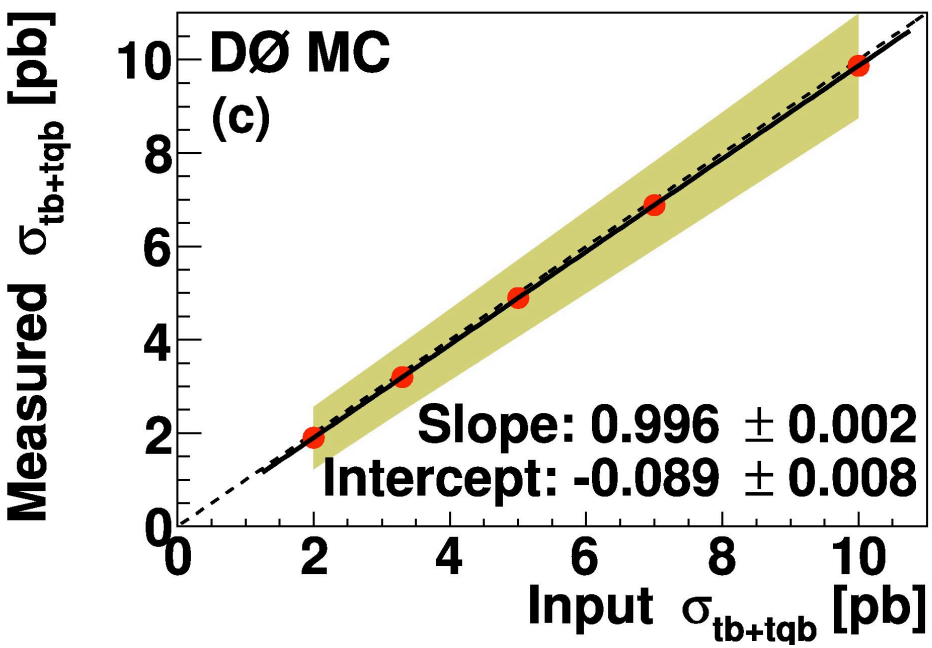
Denominator is Kidonakis's calculation.
See also M. Assadsolimani's talk

D0 Collab., Phys. Rev. D **84**, 112001 (2011)

Checking the Linearity of the Cross Section Fit and the Expected Uncertainty

- Inject signal to a model
- Run Pseudoexperiments with each value of injected signal
- Fit the pseudoexperiments and plot the distribution of fit values.

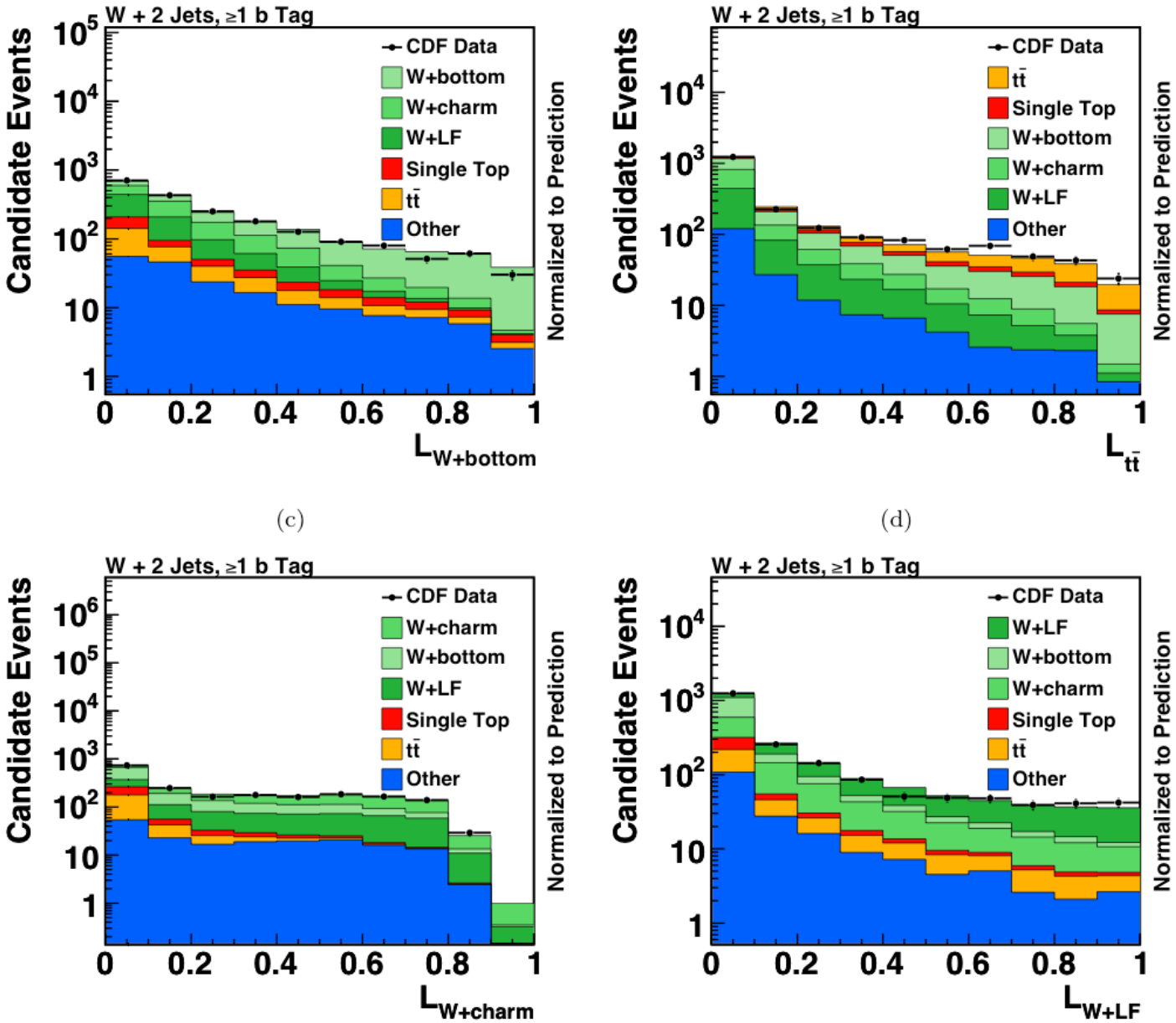




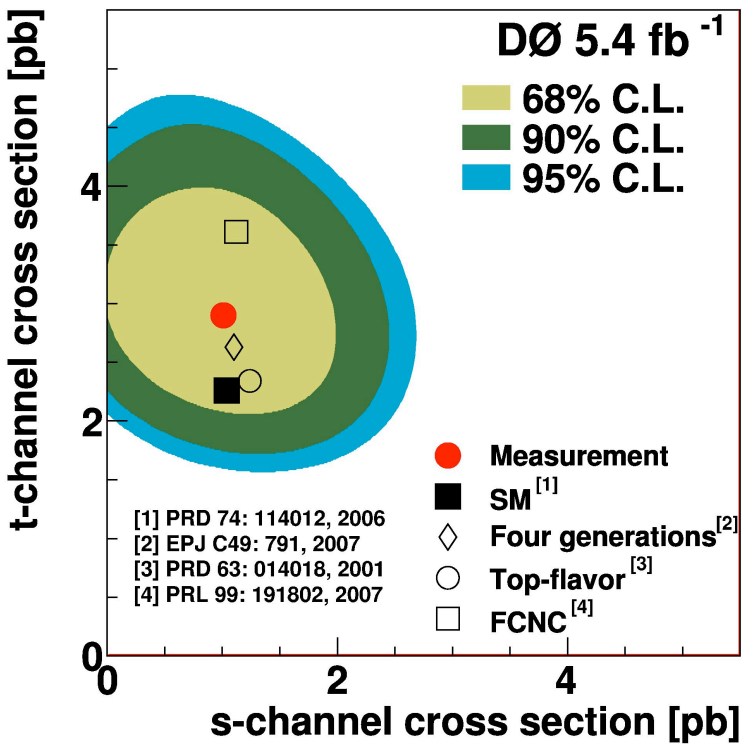
Fit uncertainty relatively independent of the fit value
(green band does not collapse to a point at a signal rate of 0)
A consequence of low s/b in much of the range contributing to the cross section fit.

Train a Discriminant Treating Each Background as the Signal

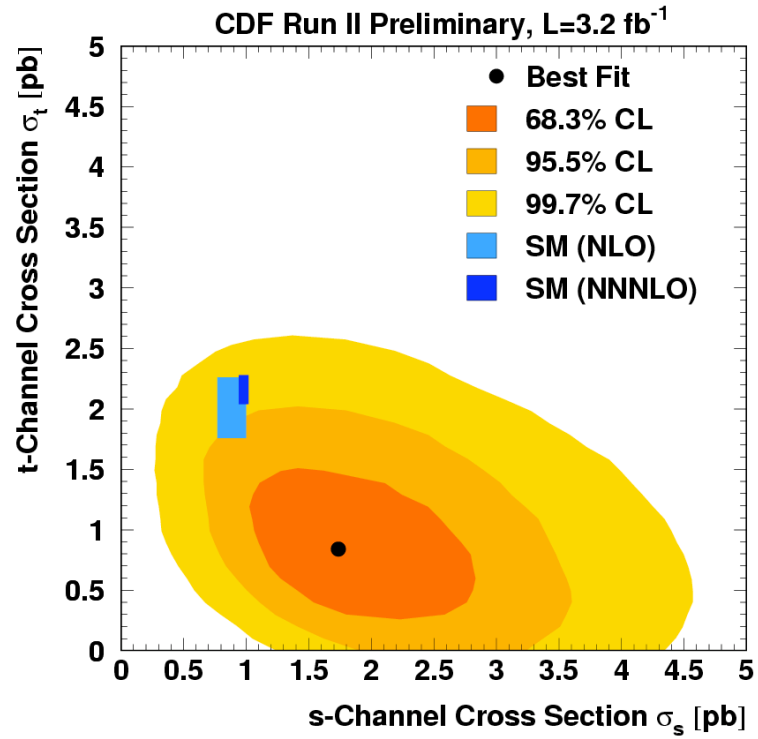
CDF,
3,2 fb^{-1}



Measuring s-channel vs. t-channel Single top Cross Sections



D0 Collab, arXiv:1105.2788v1 [hep-ex]



CDF Collab., PRD **82**, 112005 (2010)

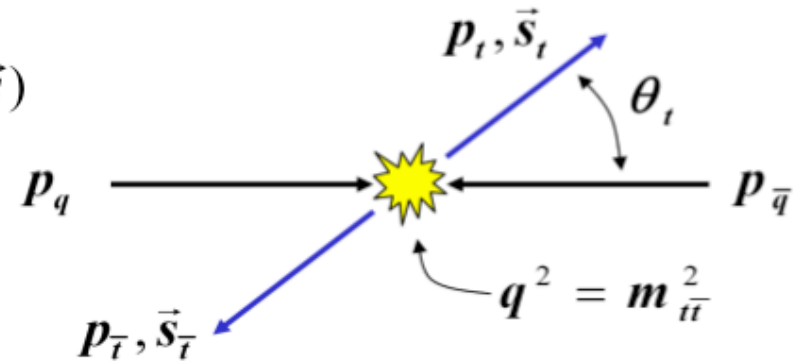
Lots of good work by R. Frederix (And Campbell, Maltoni, and Tramontano) to get us a fully NLO t-channel prediction in MCFM
JHEP 0910 (2009) 042

Top-Quark Pair Production Charge A_{FB}

top quark pair production

- hard scatter cm-frame cross-section

$$\frac{d\sigma}{d\cos\theta} \propto \frac{\alpha_s^2}{q^2}\left[1+\cos^2\theta^* + (1-\beta^2)\sin^2\theta^*\right] f(\vec{s})$$



- the final state is specified by
  $\alpha,\ q^2,\ \theta^*,\ \vec{s}$

- $\alpha,\ q^2$ well measured in total σ and M_{tt} spectrum. SM like.

- here: production angle
  - dependence on $q^2,\ \theta^*$
  - asymmetry in production angle with respect to beamline

D. Amidei

Possible New Physics interactions affecting the ttbar Forward-Backward Asymmetry

- exotic gluons
  - massive chiral color
  - RS gluon
  - color sextets, anti-triplets
- IVB´
  - Z´
  - FV W´Z´ t-channel
- FV scalars
- effective Lagrangians

- nice theoretical review by Cao et al. PRD 81,014016, arXiv:1003.3461

- model building must contend with
  - total σ in good agreement with SM
  - $d\sigma/dM_{tt}$ in good agreement with SM

D. Amidei

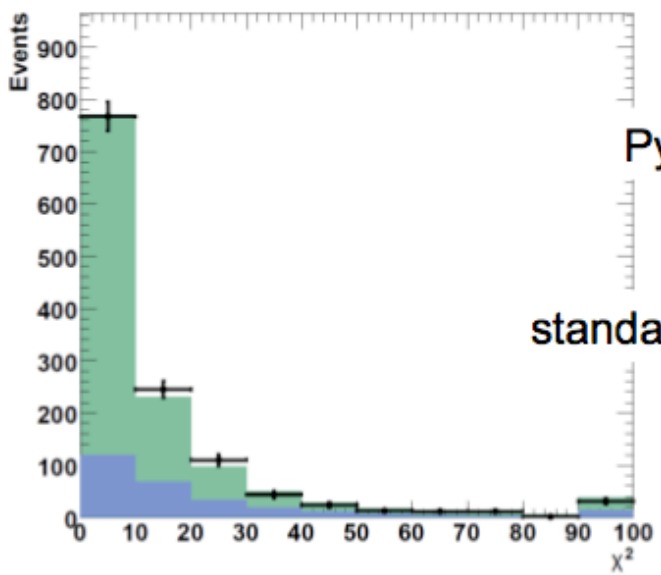
top reconstruction

$$l^+ + \not{E}_T + 4j + \geq 1\ btag \rightarrow (l^+ \upsilon b)(q\bar{q}\bar{b}) \rightarrow (W^+ b)(W^- \bar{b}) \rightarrow t\bar{t}$$

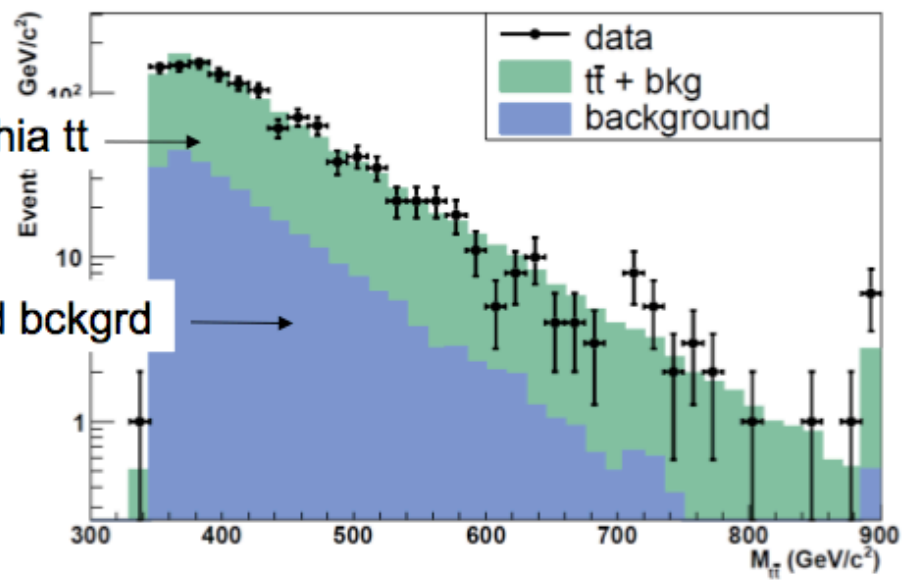
- Jet-parton assignment, $p_z(\nu)$ via minimum of simple χ^2
  - Constraints: M_W = 80.4 GeV/c2, Mt = 175 GeV/c^2, btag = b
  - Float jet p_t within errors

$$\chi^2 = \sum_{lep,\,jets} \frac{(p_t^{i,meas} - p_t^{i,fit})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_j^{UE,meas} - p_j^{UE,fit})^2}{\sigma_j^2} + \frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{l\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - M_{top})^2}{\Gamma_t^2} + \frac{(M_{bl\nu} - M_{top})^2}{\Gamma_t^2}$$

χ^2



$M_{t\bar{t}}$



Pythia tt

standard bckgrd

No resonances found in the ttbar spectrum

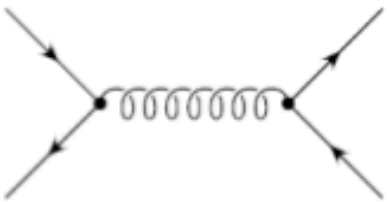
D. Amidei

tt charge asymmetry in QCD

D. Amidei

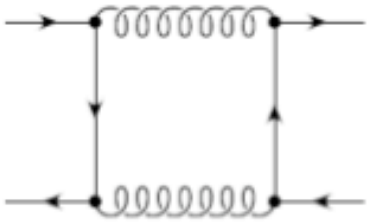
- Halzen, Hoyer, Kim; Brown, Sadhev, Mikaelian; Kuhn, Rodrigo; Ellis, Dawson, Nason; Almeida, Sterman, Vogelsang; Bowen, Ellis, Rainwater

$t\bar{t}$



C = - 1

+

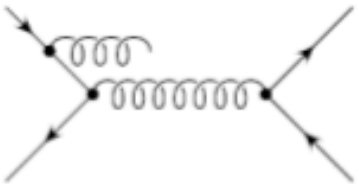


C = +1

tt frame asymmetries

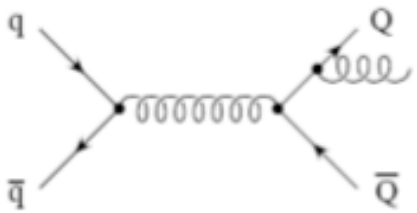
A_{FB} ~ +10-12 % NLO

$t\bar{t}j$



C = + 1

+



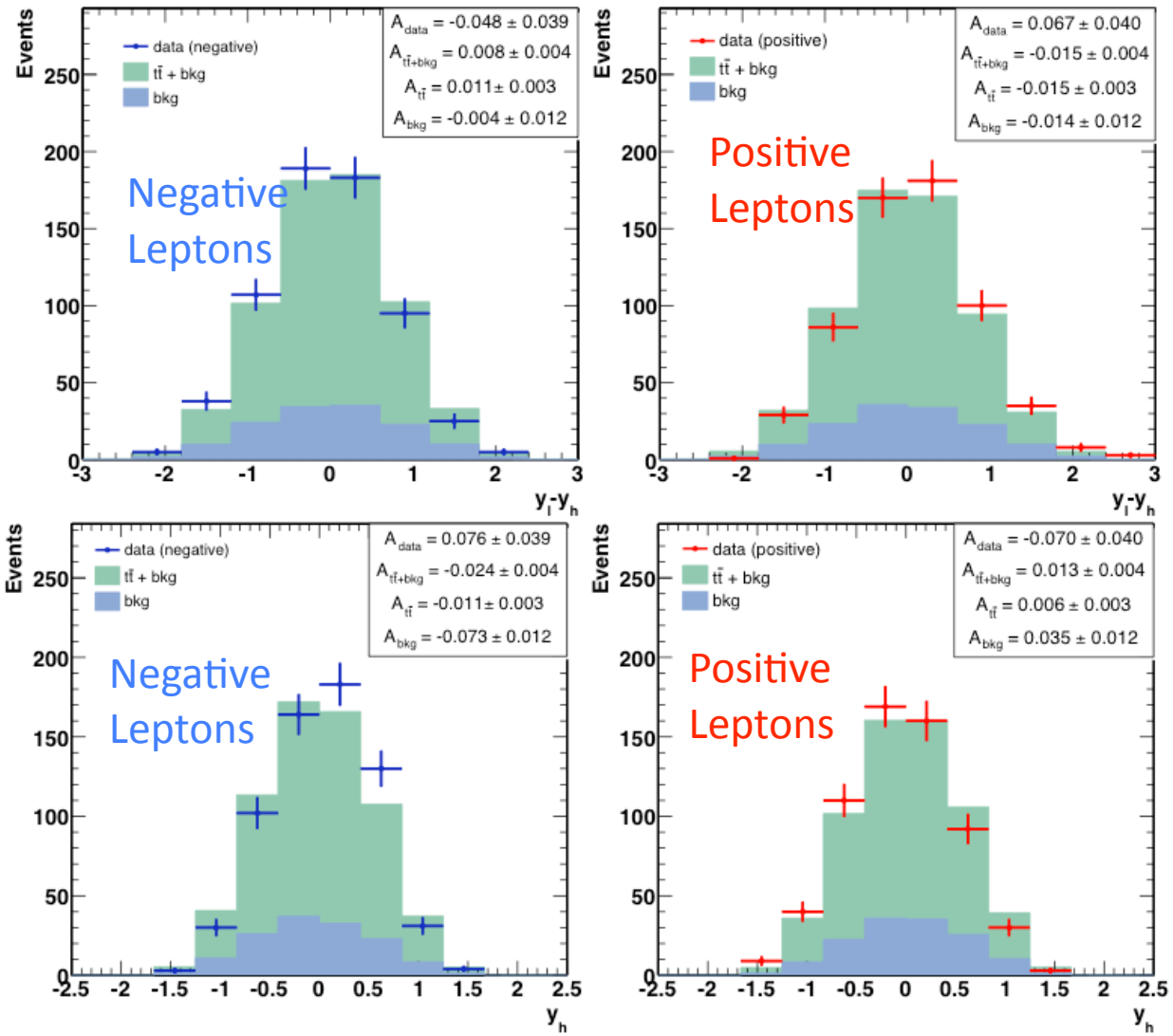
C = -1

A_{FB} ~ -7 % NLO

A_{FB} ~ 6 +- 1.0 % net

Idea after listening to Davide Pagani's talk: AFB in ttbar+1jet events

Rapidity and Δy Distributions – CDF 5.4 fb^{-1}



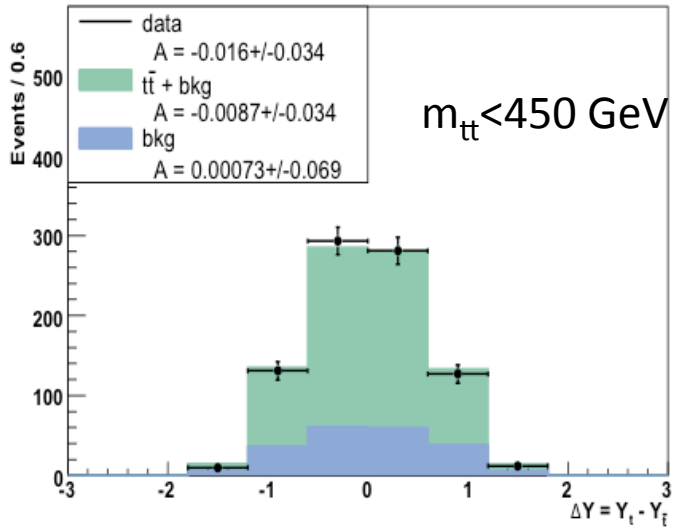
lepton+jets
ttbar selection

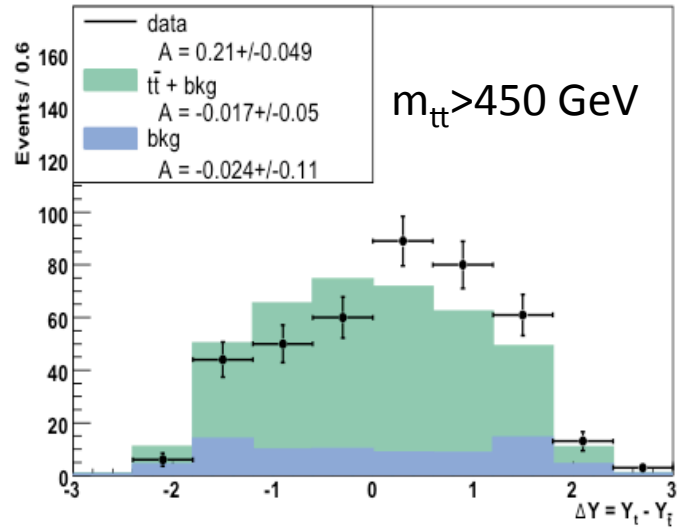
y_l: leptonic top rapidity

y_h: hadronic top rapidity

CDF Collab., Phys. Rev. D **83** 112003 (2011)

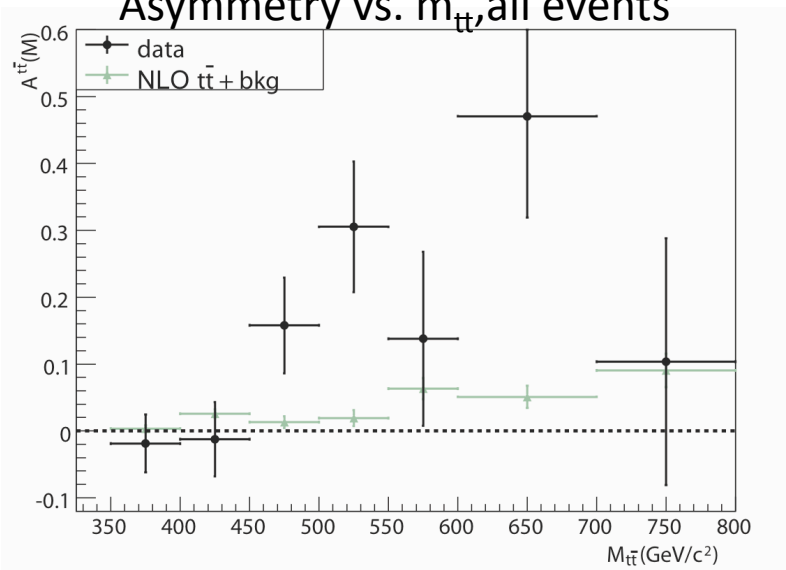
Mass Dependence of Observed Asymmetry



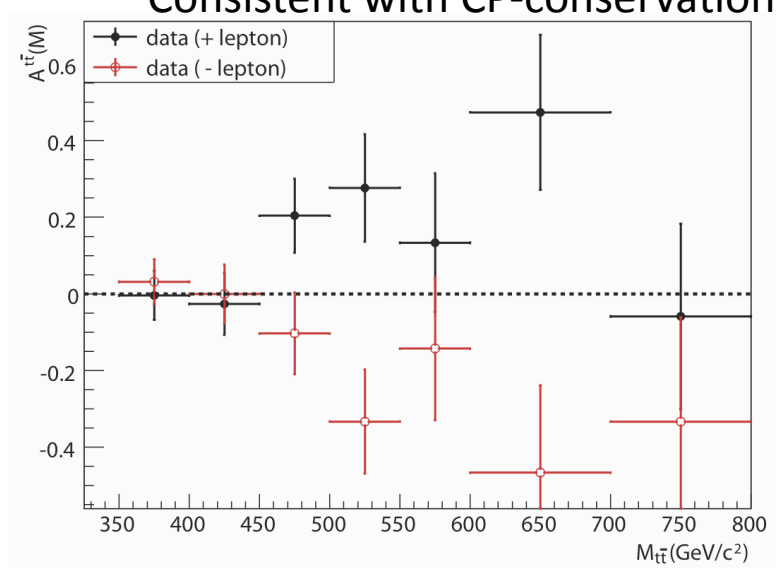


lepton+jets
ttbar selection

Asymmetry vs. m_{tt},all events

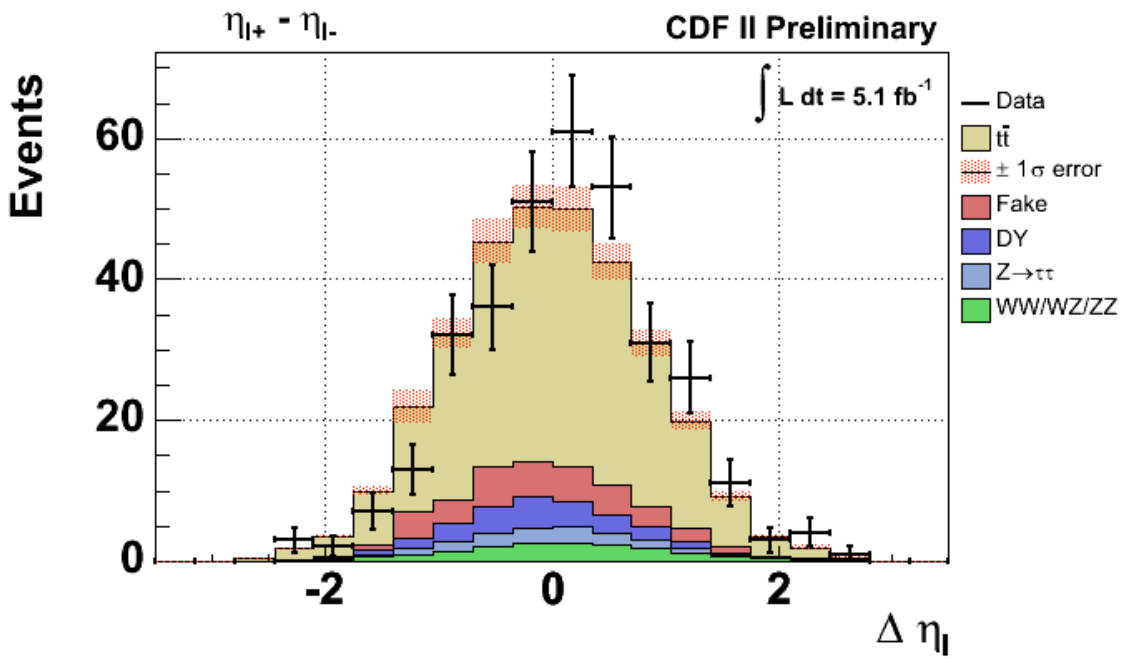


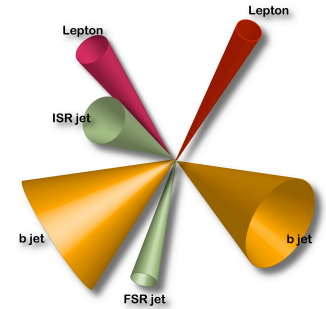
Separated out by lepton charge
Consistent with CP-conservation



Phys.Rev.D83:112003,2011

CDF's Dilepton Selection also sees a Large A_{FB}





CDF II Preliminary

Δy_t:

$$A_{\rm obs} = 0.14 \pm 0.05({\rm stat.})$$

$$A_{\rm sub} = 0.21 \pm 0.07({\rm stat.}) \pm 0.02({\rm bkg.\ shape})$$

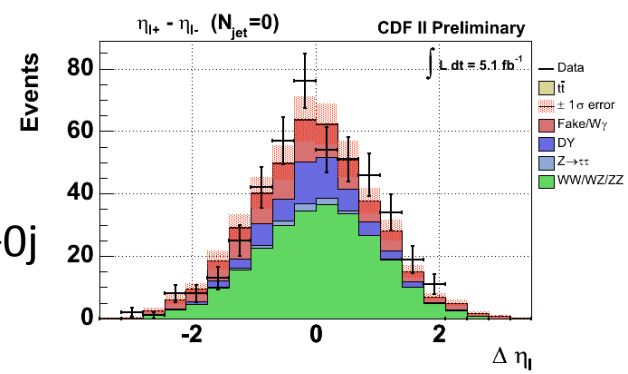
$$A_{\rm true} = 0.42 \pm 0.15({\rm stat.}) \pm 0.05({\rm syst.}) = 0.42 \pm 0.16$$

$\Delta\eta_\ell$:

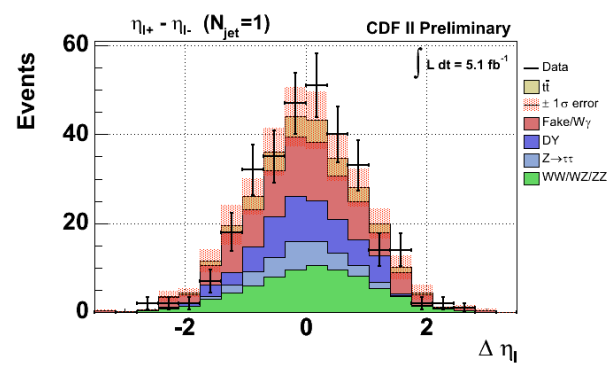
$$A_{\rm obs}^{\Delta\eta_\ell} = 0.14 \pm 0.05({\rm stat.})$$

$$A_{\rm sub}^{\Delta\eta_\ell} = 0.21 \pm 0.07({\rm stat.}) \pm 0.02({\rm bkg.\ shape})$$

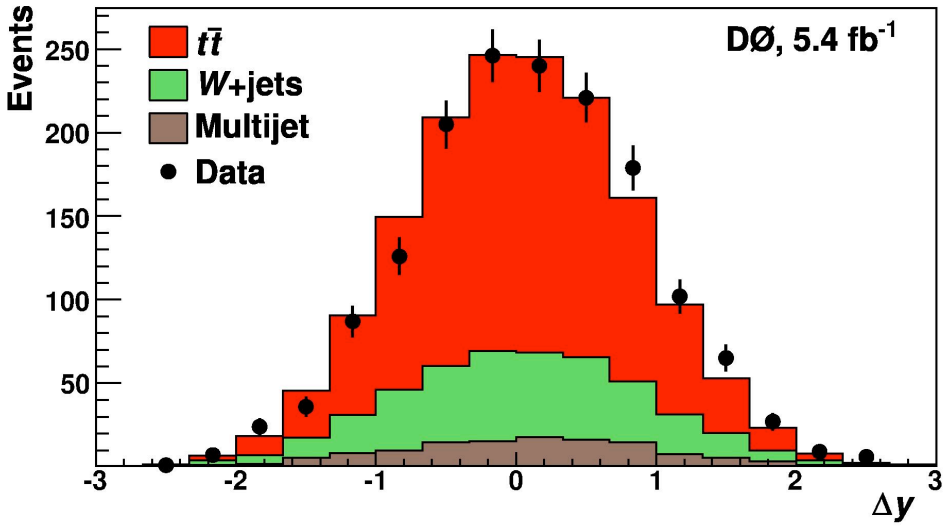
Control sample: dileptons+MET+0j



Control sample: dileptons+ MET+1j

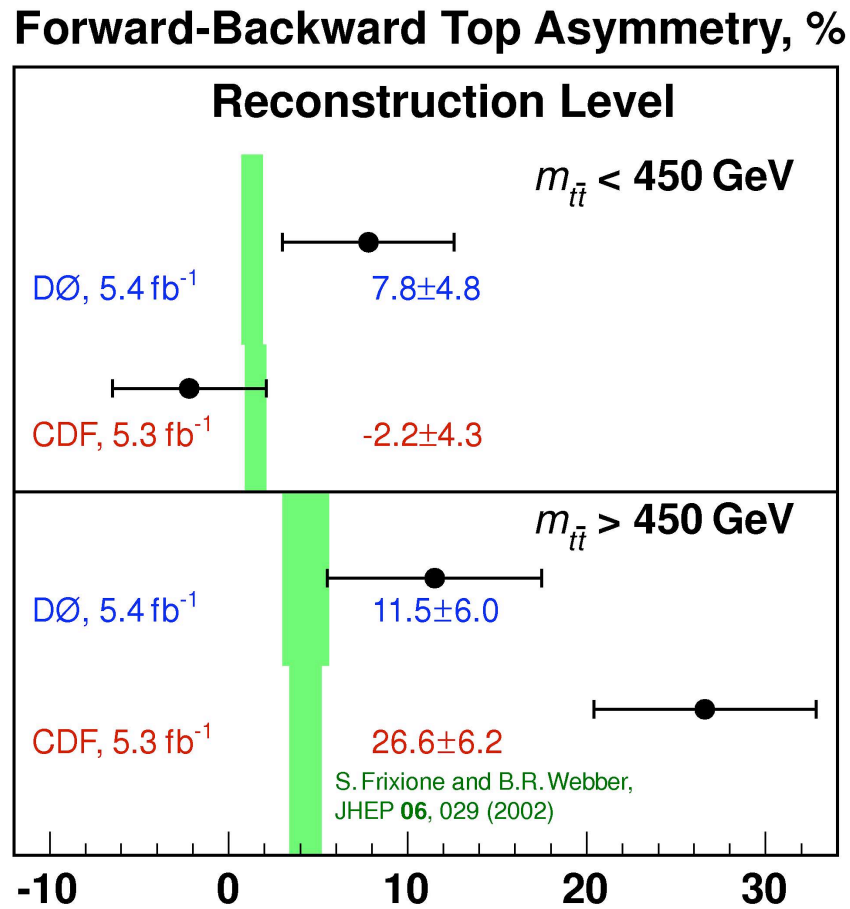


D0 Sees A Similar Asymmetry



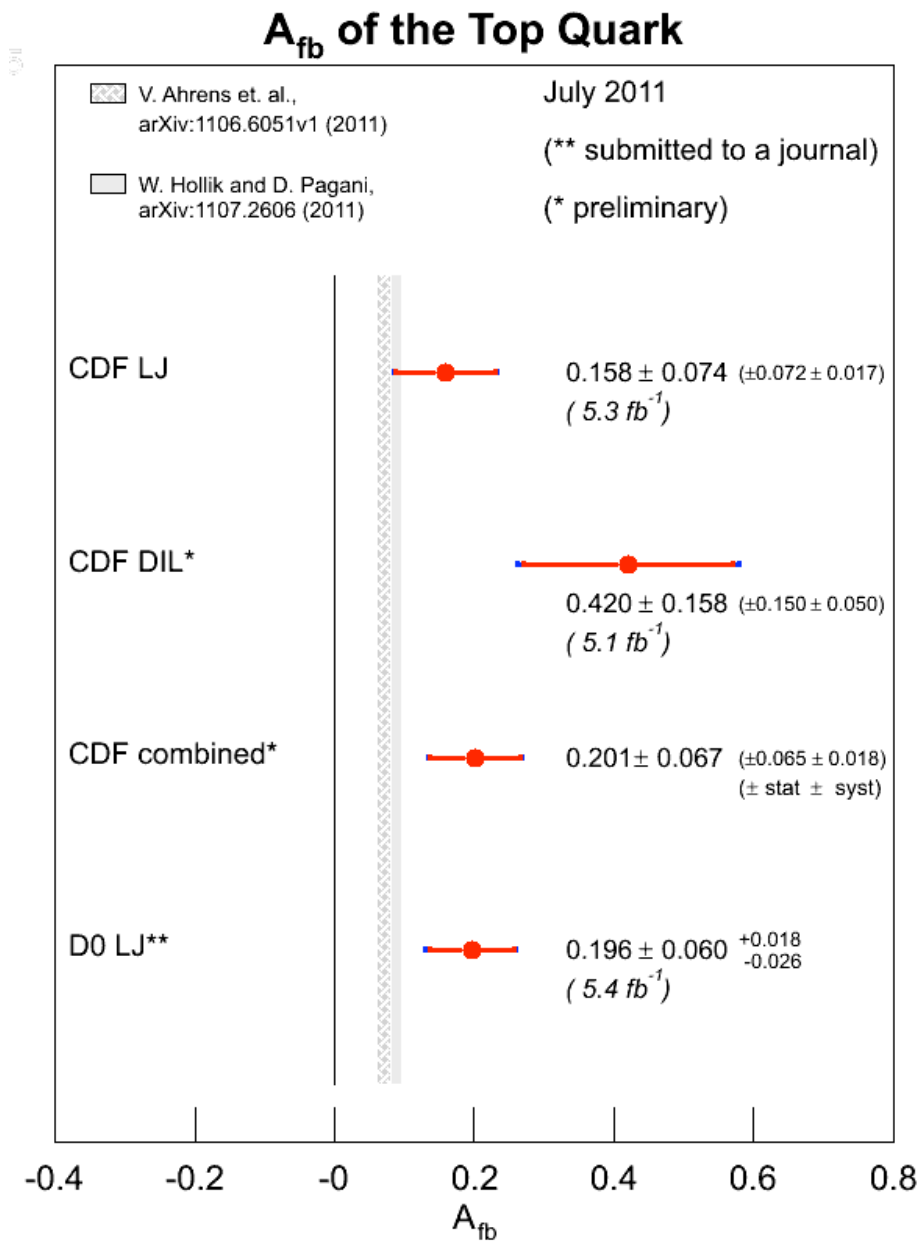
D0 Collab., Phys. Rev. D 84, 112005 (2011)

But no significant mass dependence is seen.



Tevatron ttbar Forward-Backward Asymmetry Measurement Summary

See D. Pagani's talk yesterday – EW corrections to top A_{FB} prediction can be a 25% increase



CDF's Measurement of $t\bar{t}\gamma$

Phys. Rev. D **84**, 031104 (2011)

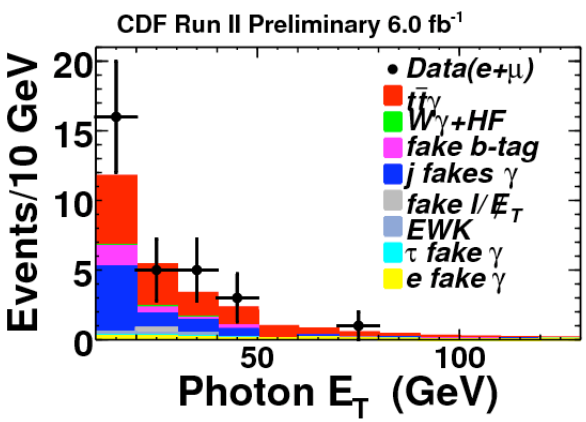
6.0 fb^{-1} of data used

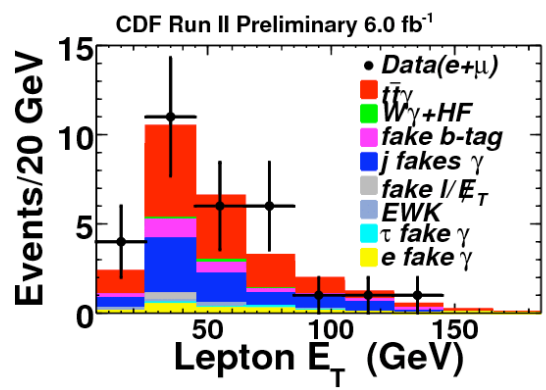
Select: High P_T isolated e or μ (> 20 GeV),
Large Missing Transverse Energy (> 20 GeV)
3 or more jets
H_T>200 GeV
One or more b-tags
Isolated photon, with E_T>10 GeV

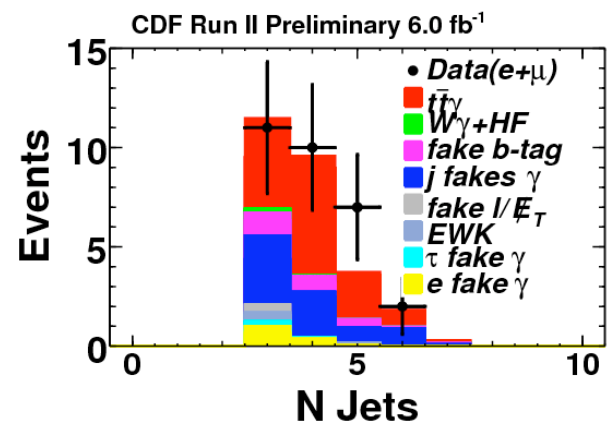
Jet-faking-photon background extrapolated in from the unisolated sample.

Electron-faking-photon background extrapolated from the $\ell + \not{E}_T + b + e + \text{large } H_T + \geq 3 \text{ jets}$ sample, using Z→ee events to measure the e→γ fake rate.
Other backgounds estimated with simulation

30 events selected (out of 4429 without the photon requirement)





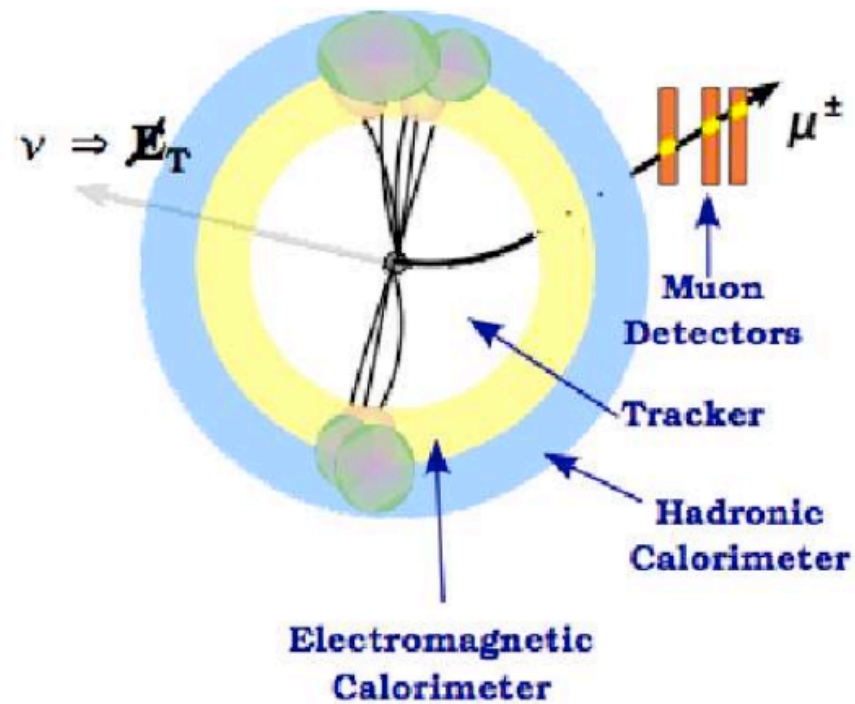


Measured: $\sigma_{t\bar{t}\gamma} = 0.18 \pm 0.07 \text{ pb}$

Prediction: $\sigma_{t\bar{t}\gamma} = 0.17 \pm 0.03 \text{ pb}$

D. Peng-Fei et al., arXiv:0907.1324

A Bump in the CDF lvjj Spectrum



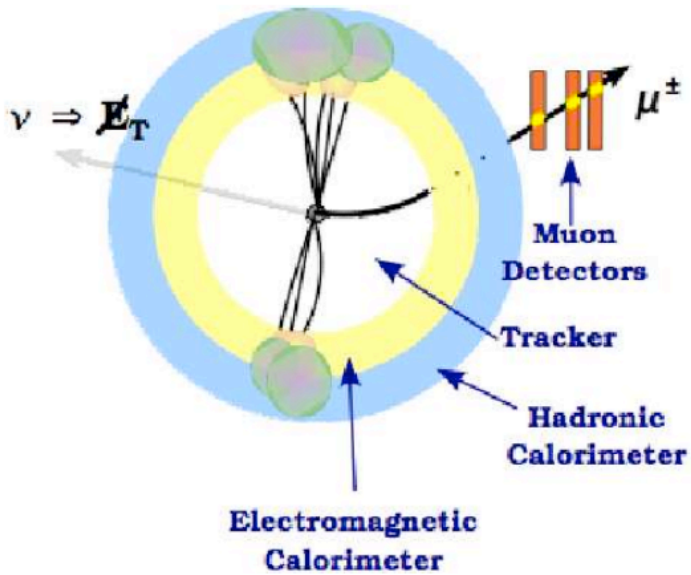
Seek events in 4.3 fb^{-1} of data with

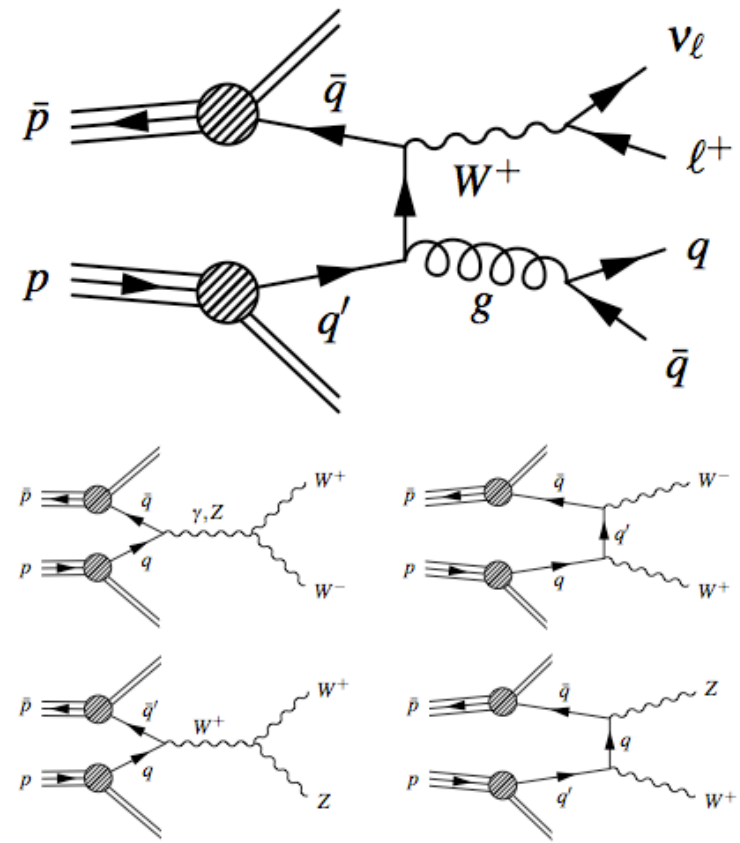
- An Identified Lepton (electron or muon) p_T>20 GeV, |η|<1 (electron p measured with calorimeter
- Reject dileptons, conversions, cosmics
- Missing E_T>25 GeV
- M_T^W>30 GeV to suppress multijets
- Select events with exactly two jets with E_T>30 GeV and |η|<2.4.
- Require $p_{T,jj}$>40 GeV
- Require $\Delta\eta_{jj}$<2.5
- Require $\Delta\Phi_{MET,J1}$>0.4
- Jets with a lepton inside a cone of ΔR<0.52

are removed (but the event is retained if it now has two jets).

CDF Collab., Phys. Rev. Lett **106**, 171801 (2011)

Main Standard Model Processes Selected





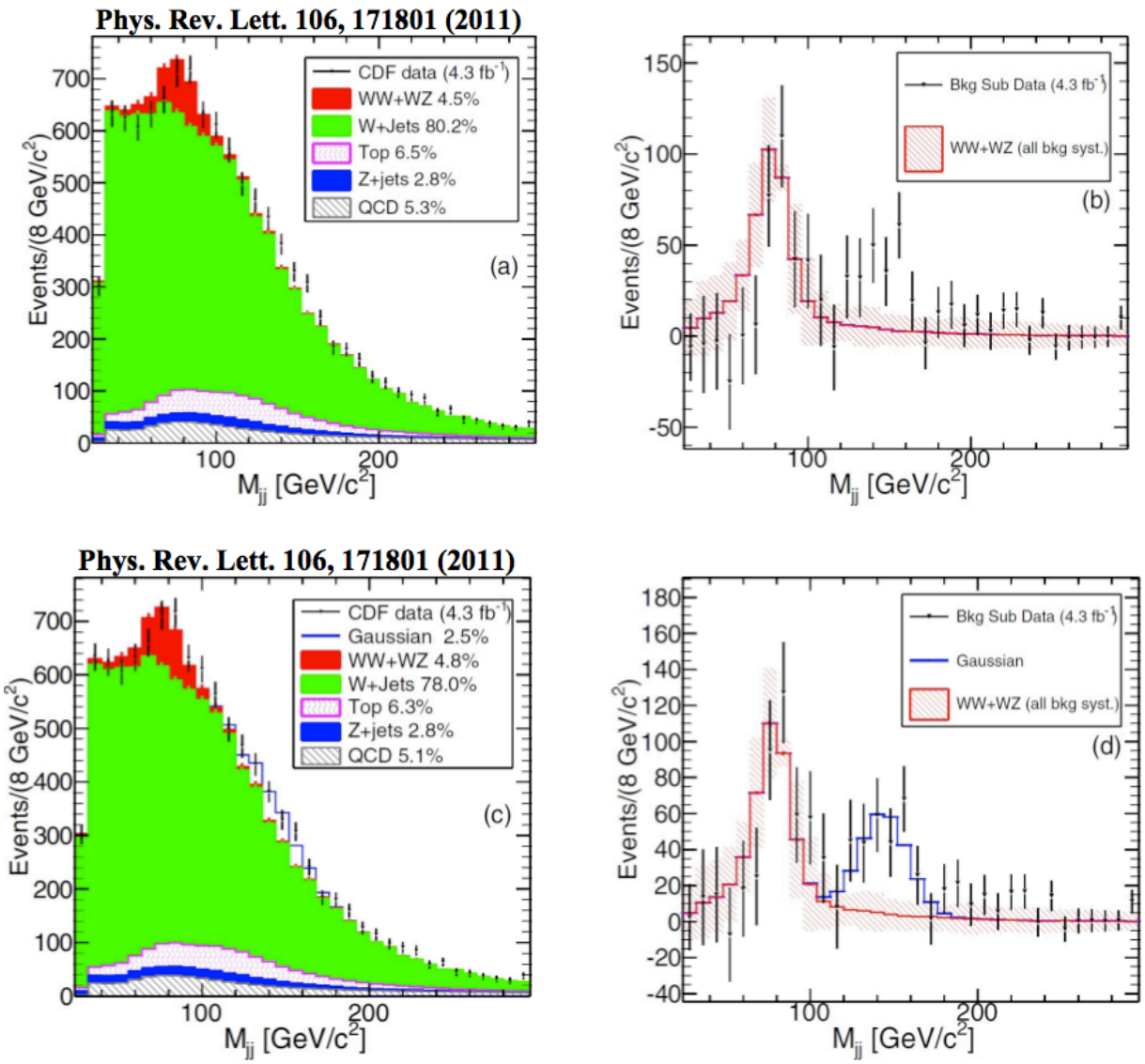
Also multijet production

- Need a fake lepton
- And Fake Missing E_T

Sometimes called "instrumental" background or Non-W background

W+jets simulated with ALPGEN
Diboson processes simulated with PYTHIA
Non-W background rates and shapes constrained with data. (low MET and low $\Delta\phi_{jet,MET}$, and $\Delta\phi_{MET,missningPT}$)

Two Fits to the Data – Assuming Background, and Allowing for a Gaussian Signal



Also allowing nuisance parameters such as background rate, jet energy scale, etc. to float in both fits.

Excess not seen when one or more jets is b-tagged

Excess not consistent with SM WH cross section

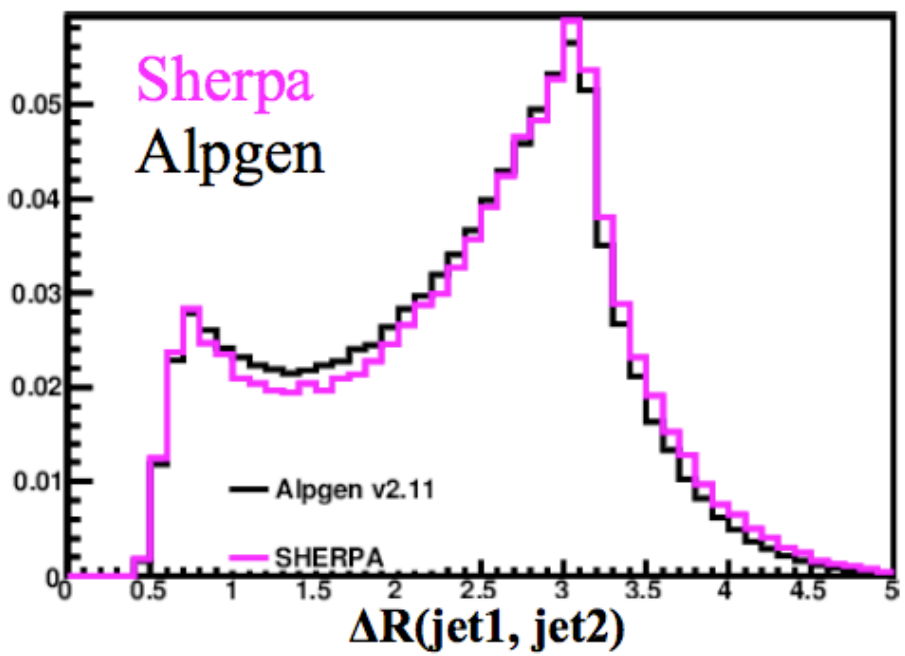
Does D0 See the Bump?

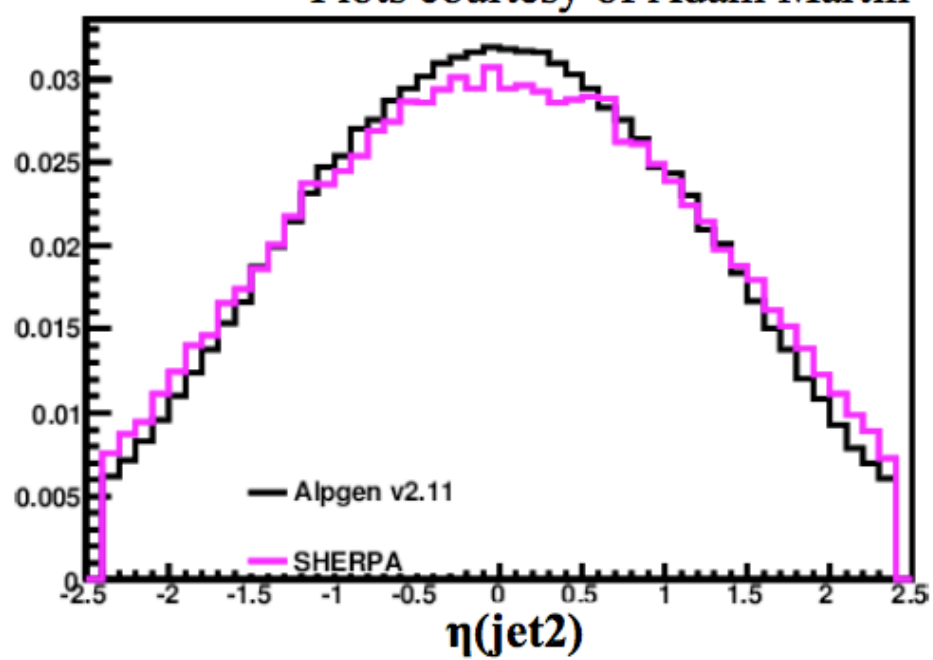
- Reproduced the CDF event selection requirements in 4.3 fb^{-1} of data
- Careful study of W+jets modeling

D0 Collaboration,
Phys. Rev. Lett. **107** (2011) 011804

ALPGEN is not the only model – different MC's predict different distributions

Plots courtesy of Adam Martin



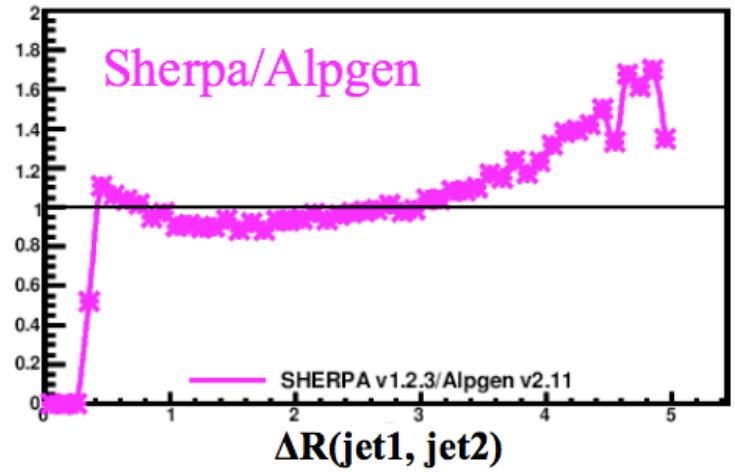


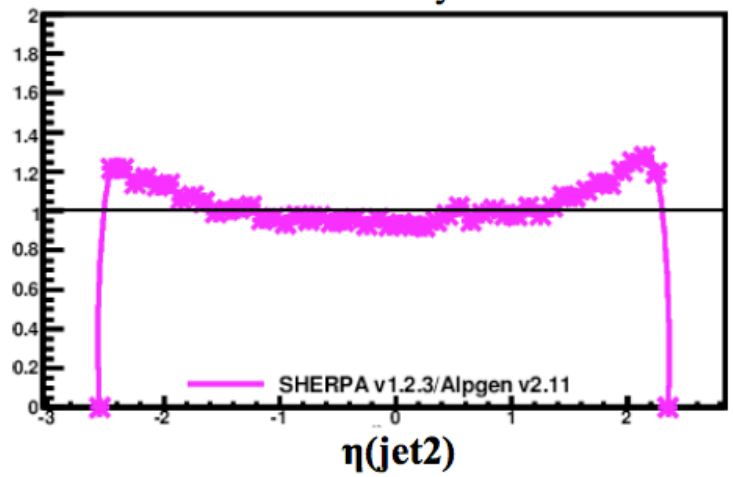
Discrepancies between Data and ALPGEN are of this type

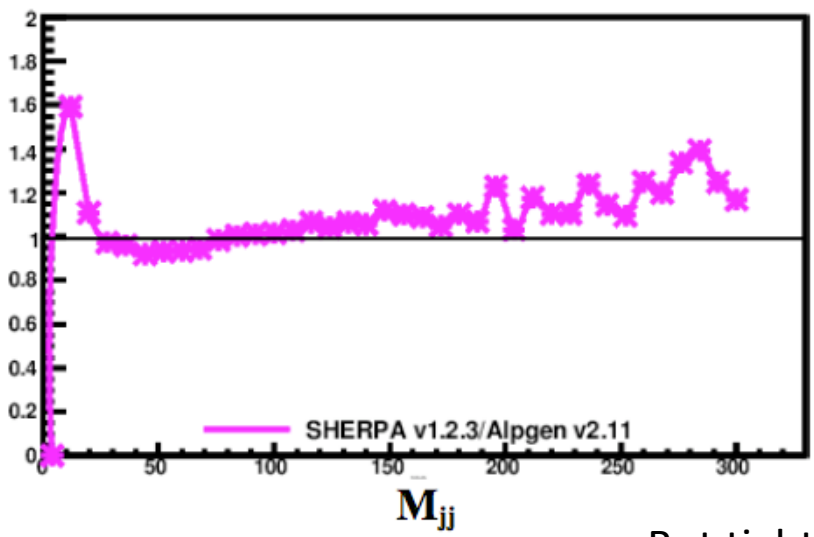
J. Haley, June 10, 2011

Comparing SHERPA to ALPGEN

Plots courtesy of Adam Martin







No bumps, but there are continuous distortions

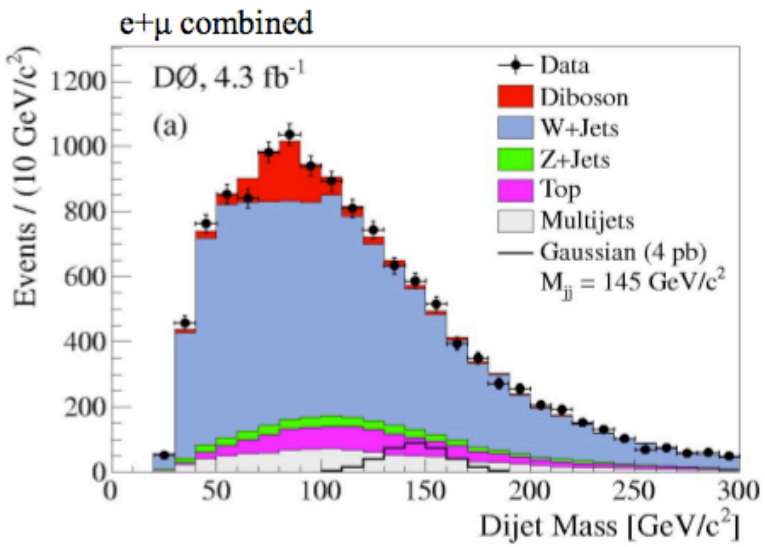
Low $P_{T,W}$ region is difficult to model.

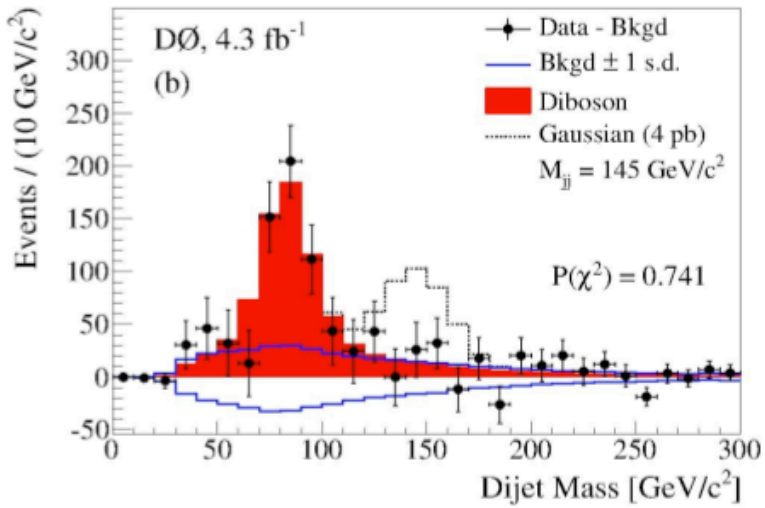
Corrections applied to MC to improve modeling of jet η, ΔR_{jj}, and $P_{T,W}$

But tight selection (high P_T jets, W) reduces the need for these corrections. (Corrections are very small)
CDF does not apply corrections

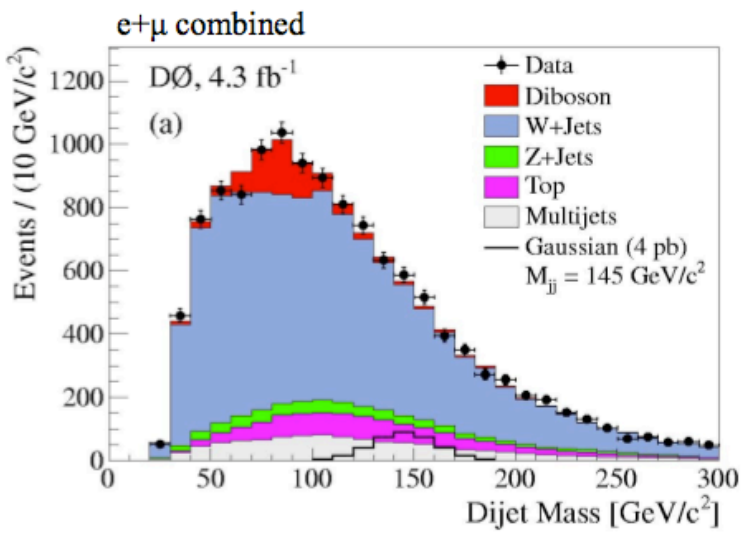
- **With** Alpgen modeling corrections applied

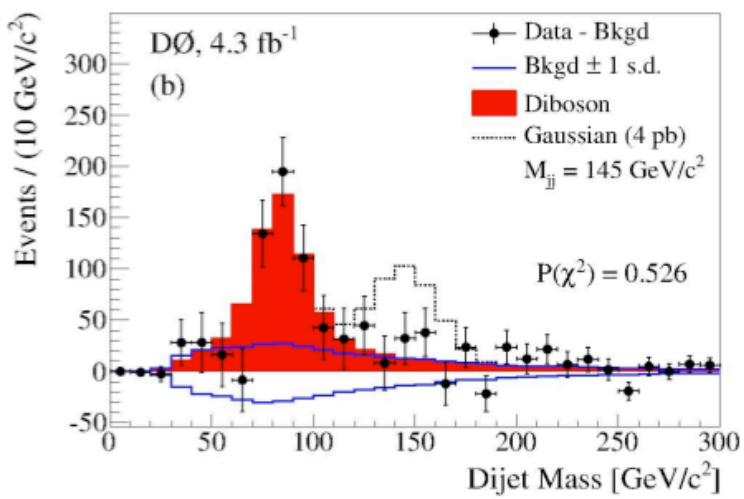
D0 Does Not See a Bump!





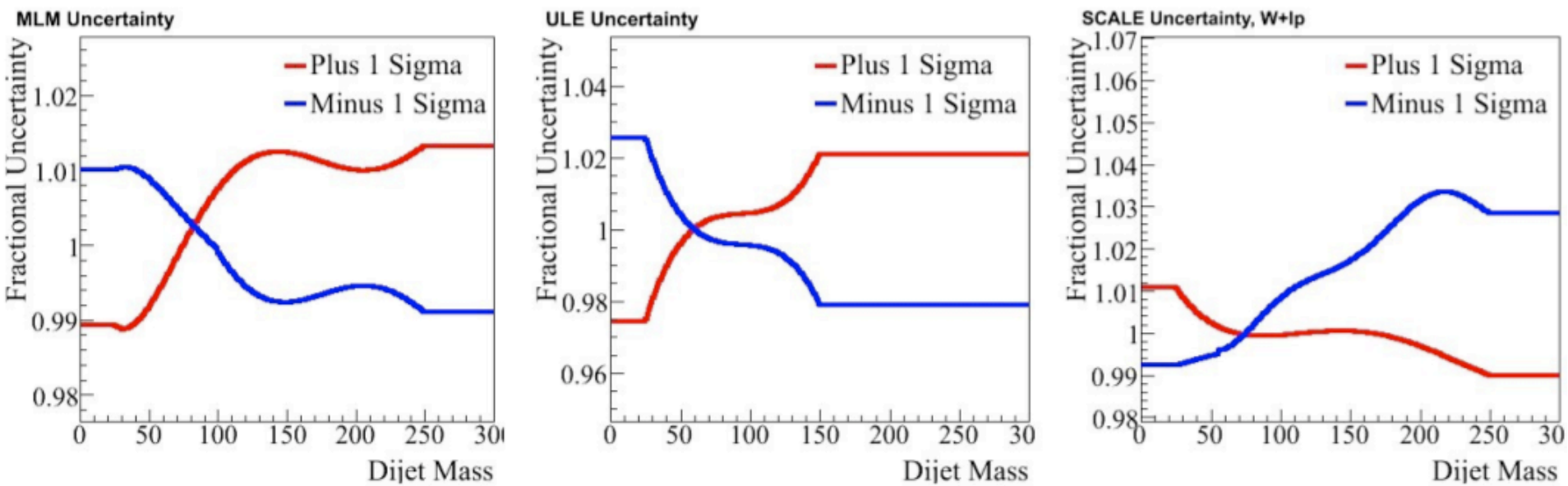
- Without Alpgen modeling corrections applied





Systematic Uncertainties Needed to Make an Interpretation

- Large NLO/LO k-factor
- Uncertainties due to:
  - P_T threshold for Alpgen MLM matching prescription
  - Parton shower model (Pythia vs. Herwig) and underlying event model (tunes)
  - Renormalization/Factorization scale choice

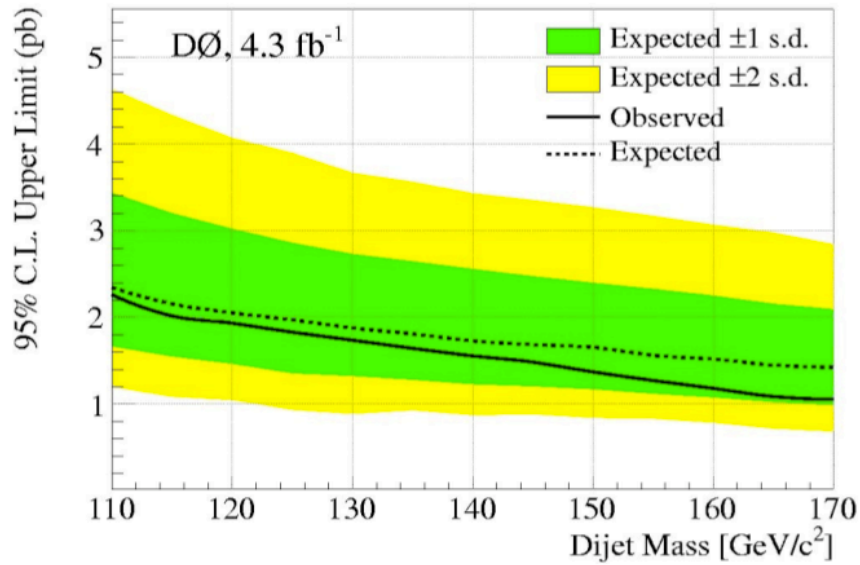


J. Haley, June 10, 2011

Cross Section Upper LImits

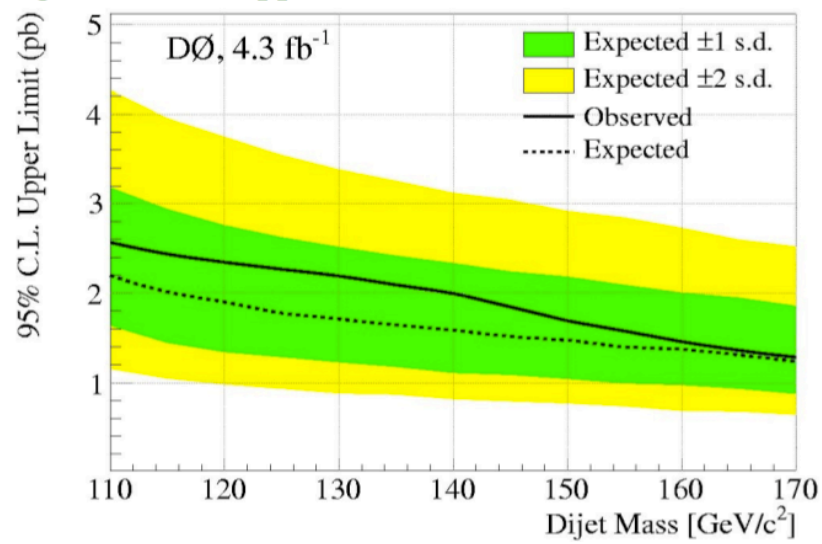
- **With** Alpgen modeling corrections applied

- For Mjj = 145 GeV
  - 95% CL exclusion for cross sections greater than 1.5 pb



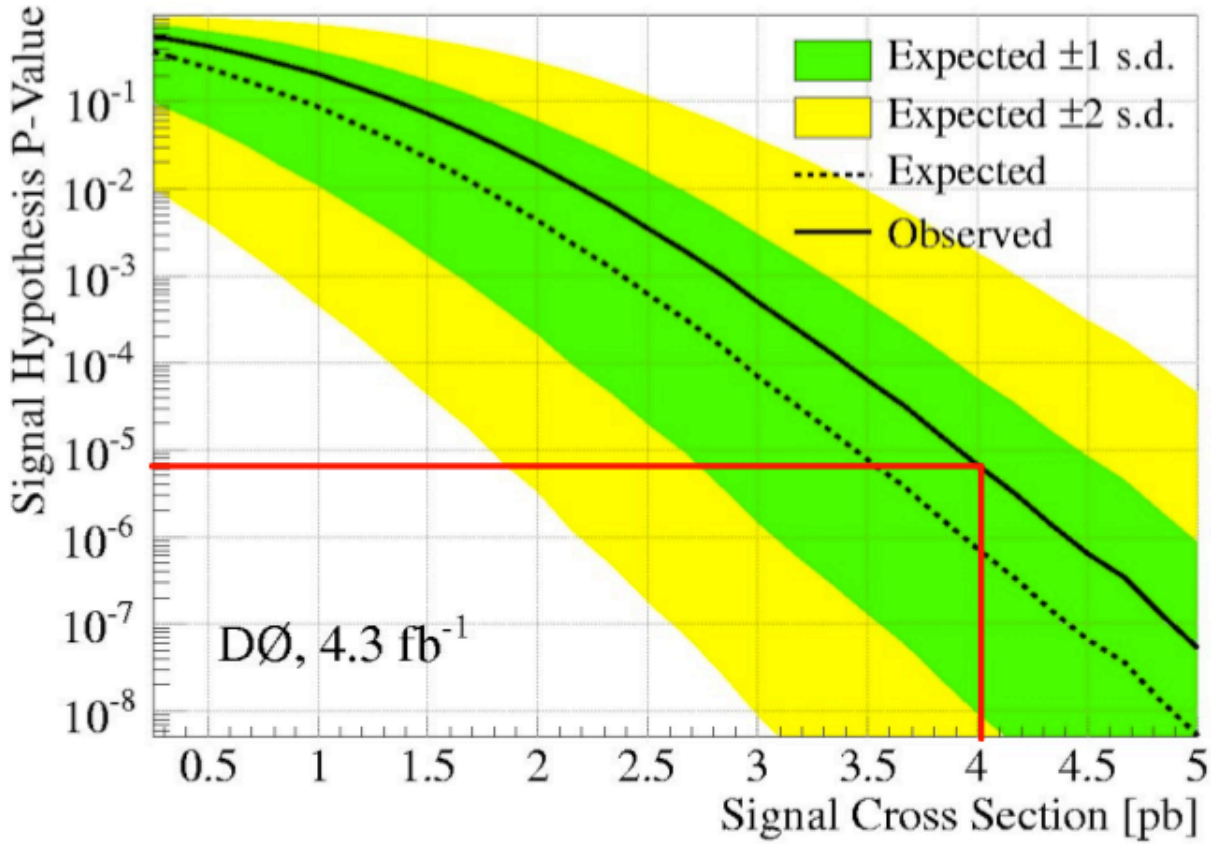
- Without Alpgen modeling corrections applied

- For Mjj = 145 GeV
  - 95% CL exclusion for cross sections greater than 1.9 pb



- How strongly do the DØ data rule out an excess at 145 GeV?

  - For a cross section of 4 pb as reported by CDF
    - Exclude at 99.999% CL
    - 4 standard deviations

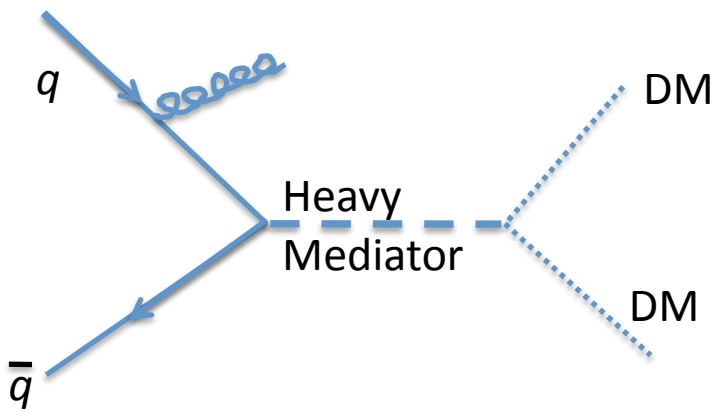


⇒ The DØ data are not consistent with the excess seen by CDF

D0 Collaboration, Phys. Rev. Lett. **107** (2011) 011804

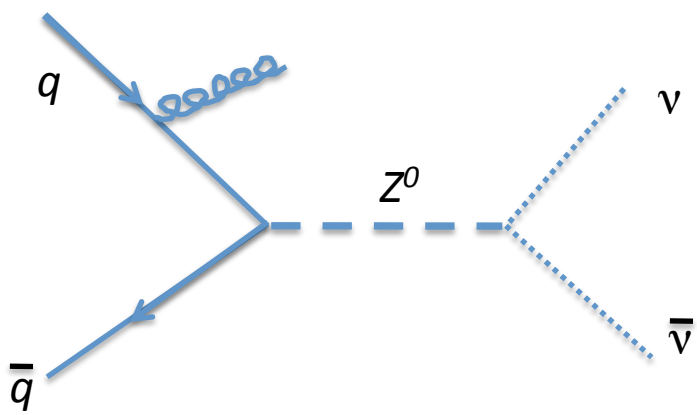
Search for Dark Matter in the Monojet + MET Signature

CDF Search in 6.7 fb^{-1} of data



The signal –

- One high E_T jet, and possibly a lower E_T jet
- Missing E_T



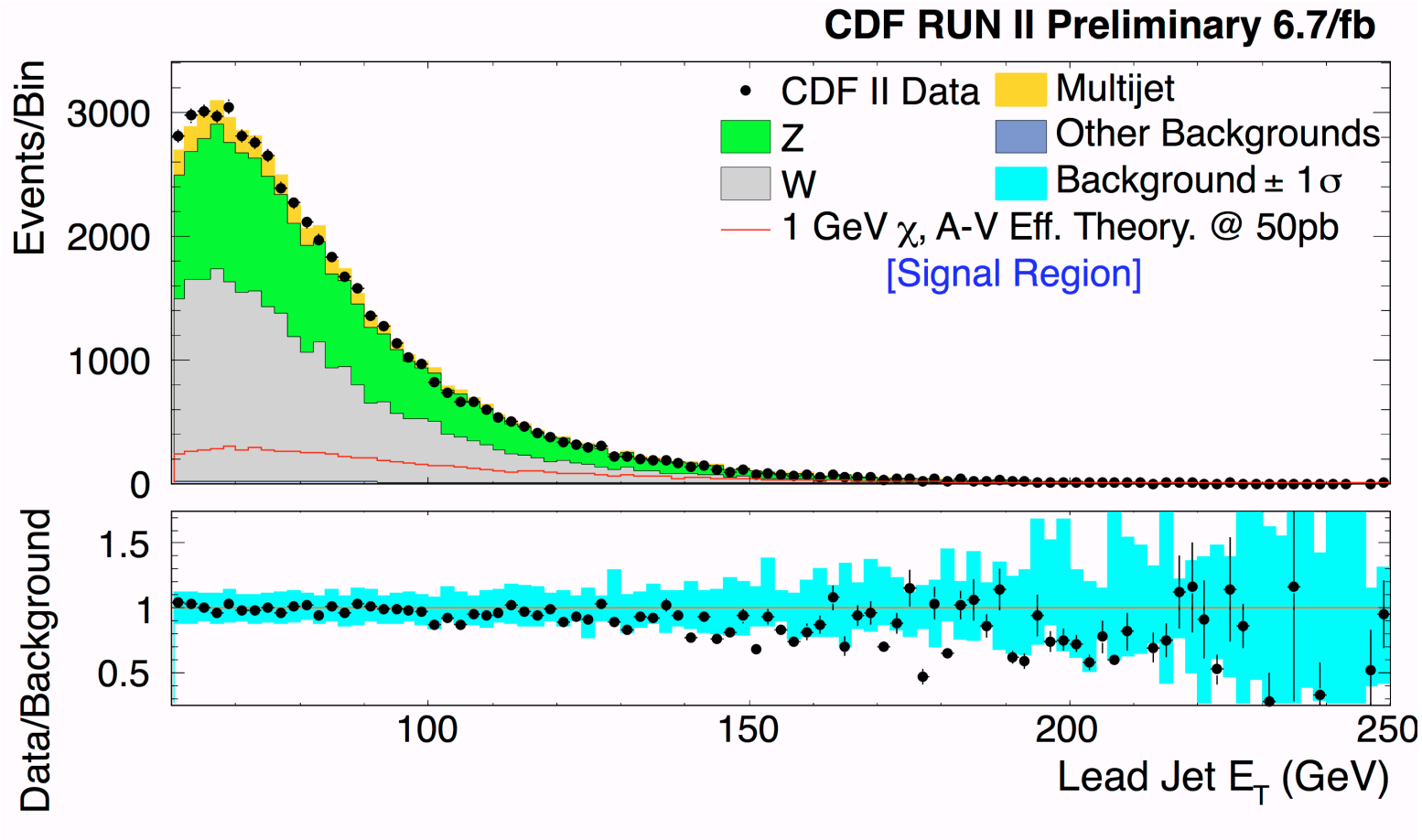
The Backgrounds

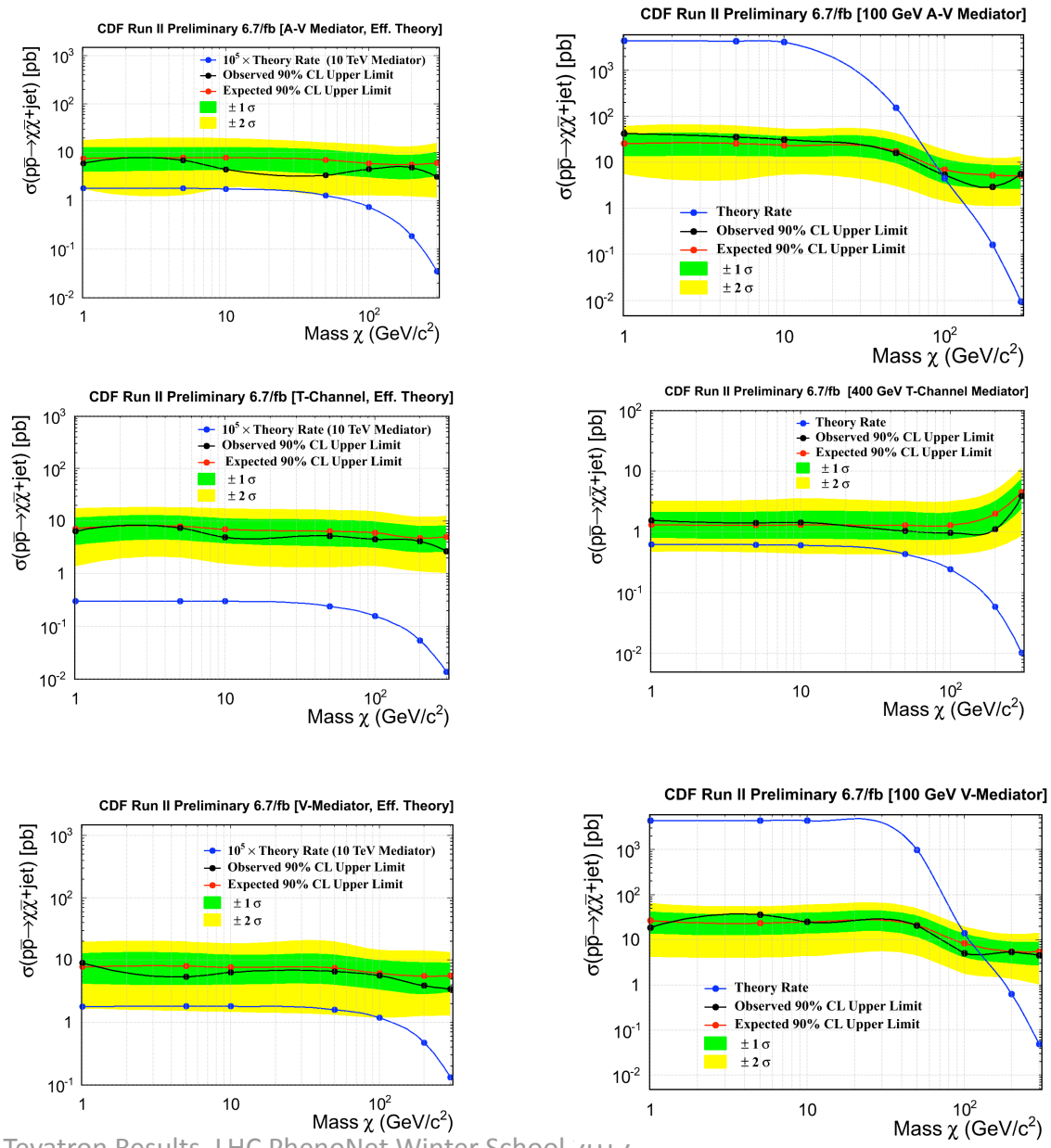
- Z+jets
- W+jets (with an unreconstructed lepton)
- Multijets

Discrimination:

- Multijets are balanced – MET is fake
- Jet E_T is higher on average for signal due to heavy mediator mass scale

Search for Dark Matter in the Monojet + MET Signature



Search for Dark Matter in the Monojet + MET Signature

Comparison with Different models mediating the DMqqbar interaction