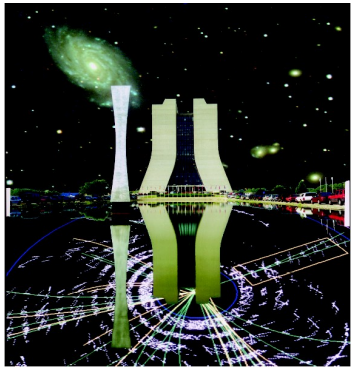


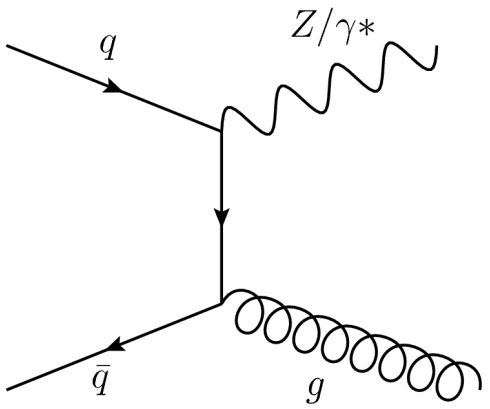
W/Z+Jets and W/Z+HF Production at the Tevatron

Stefano Camarda

IFAE - Barcelona

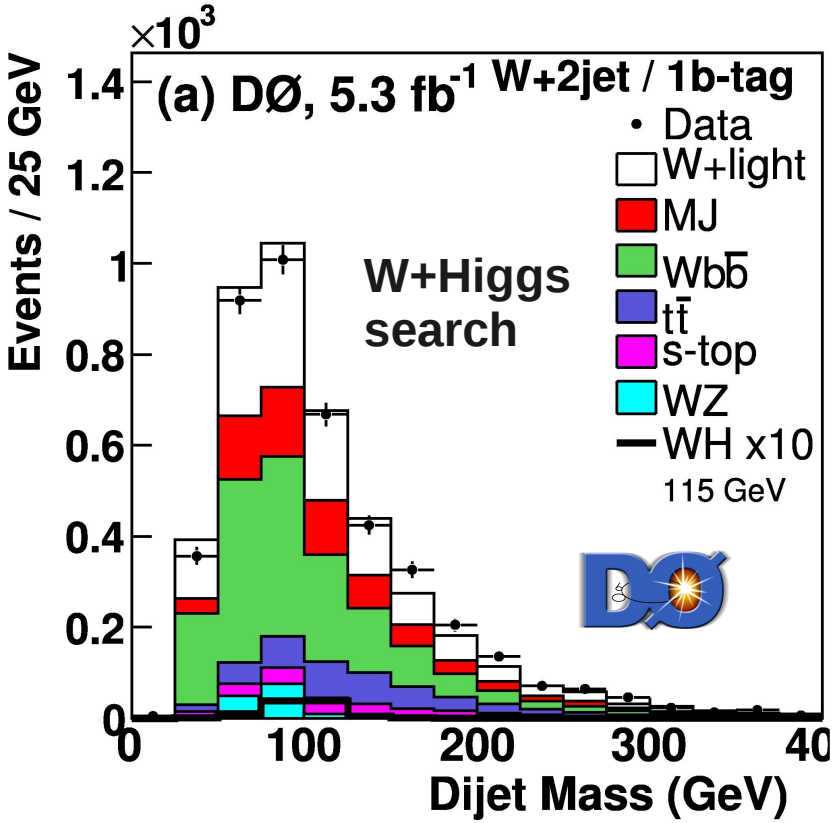
On behalf of the
CDF and DØ Collaborations

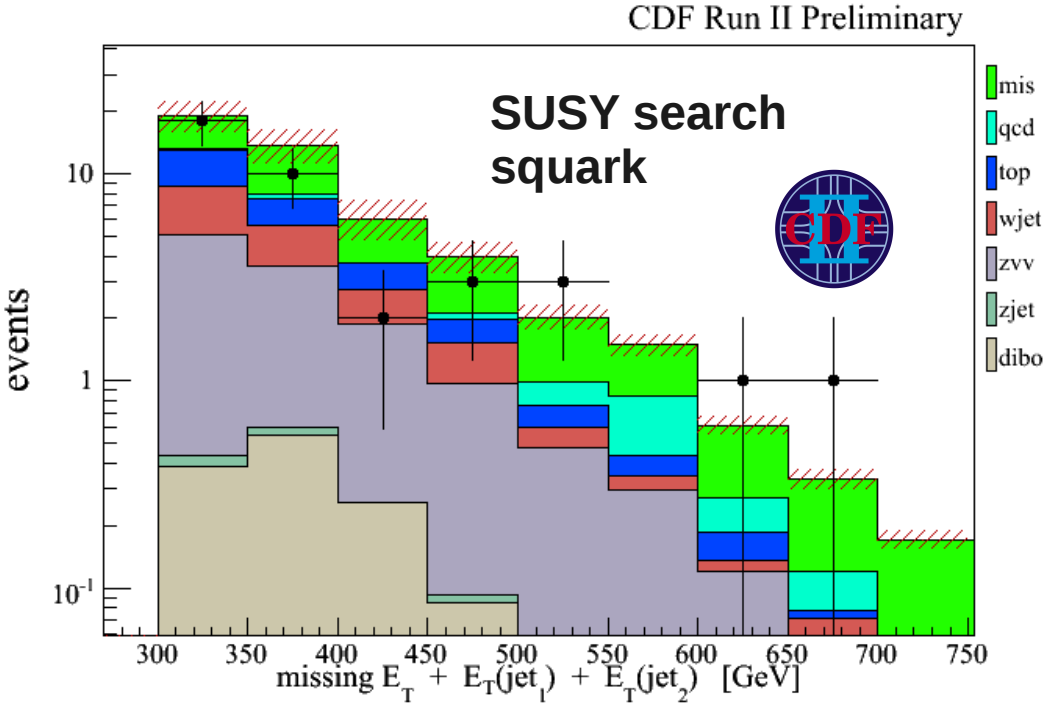
Moriond QCD
March 20-27, 2011
La Thuile



Motivation

- Test perturbative QCD at high Q^2
- Background for top measurements and new Physics searches
- 30% - 40% uncertainty in some of the processes (boson + HF)





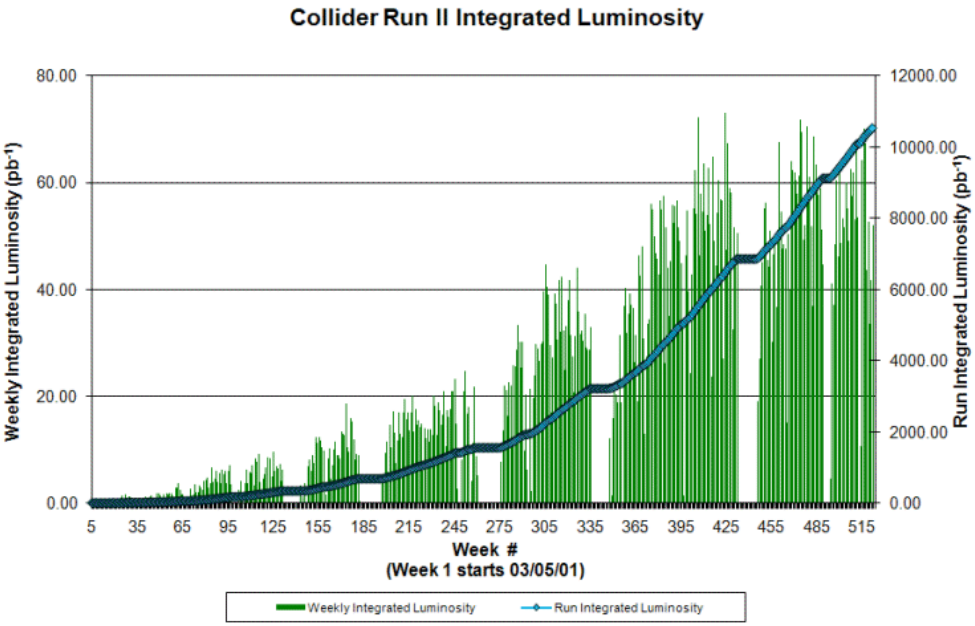
W/Z + Jets results from the Tevatron

Measurements with associated luminosity

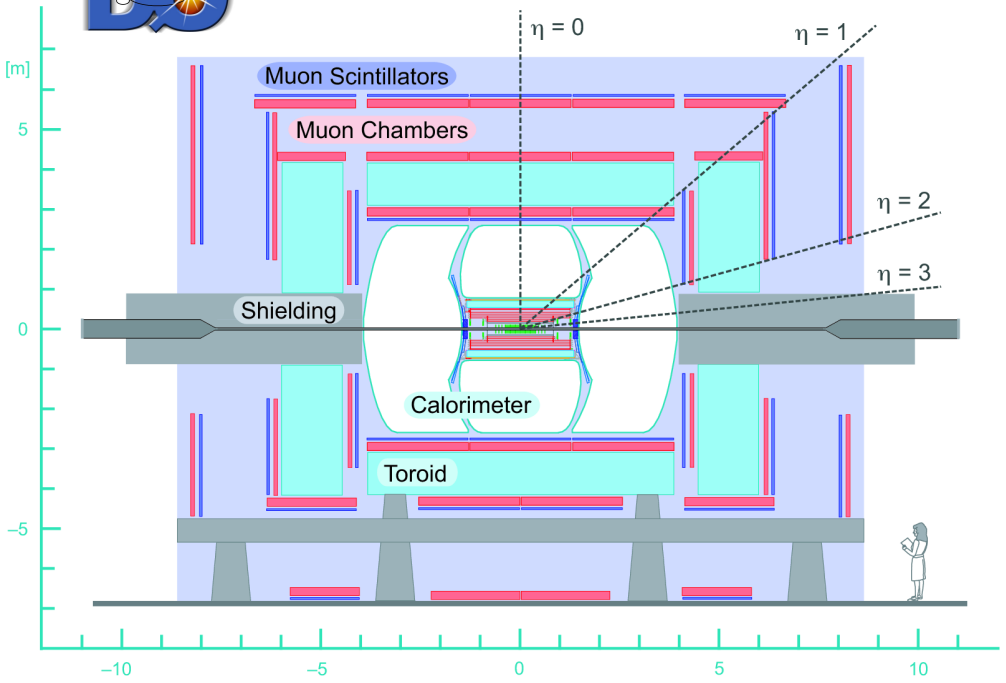
	Final State	DØ	CDF II
W/Z + Jets	$Z \rightarrow e^+e^- + Jets$	1.0 fb^{-1}	6.2 fb^{-1}
	$Z \rightarrow \mu^+\mu^- + Jets$	1.0 fb^{-1}	6.0 fb^{-1}
	W + Jets	–	2.8 fb^{-1}
W/Z + HF	Z + b	4.2 fb^{-1}	2.0 fb^{-1}
	W + b	–	1.9 fb^{-1}
	W + c (μ channel)	1.0 fb^{-1}	1.8 fb^{-1}
	W + c (e channel)	–	4.3 fb^{-1}

Tevatron

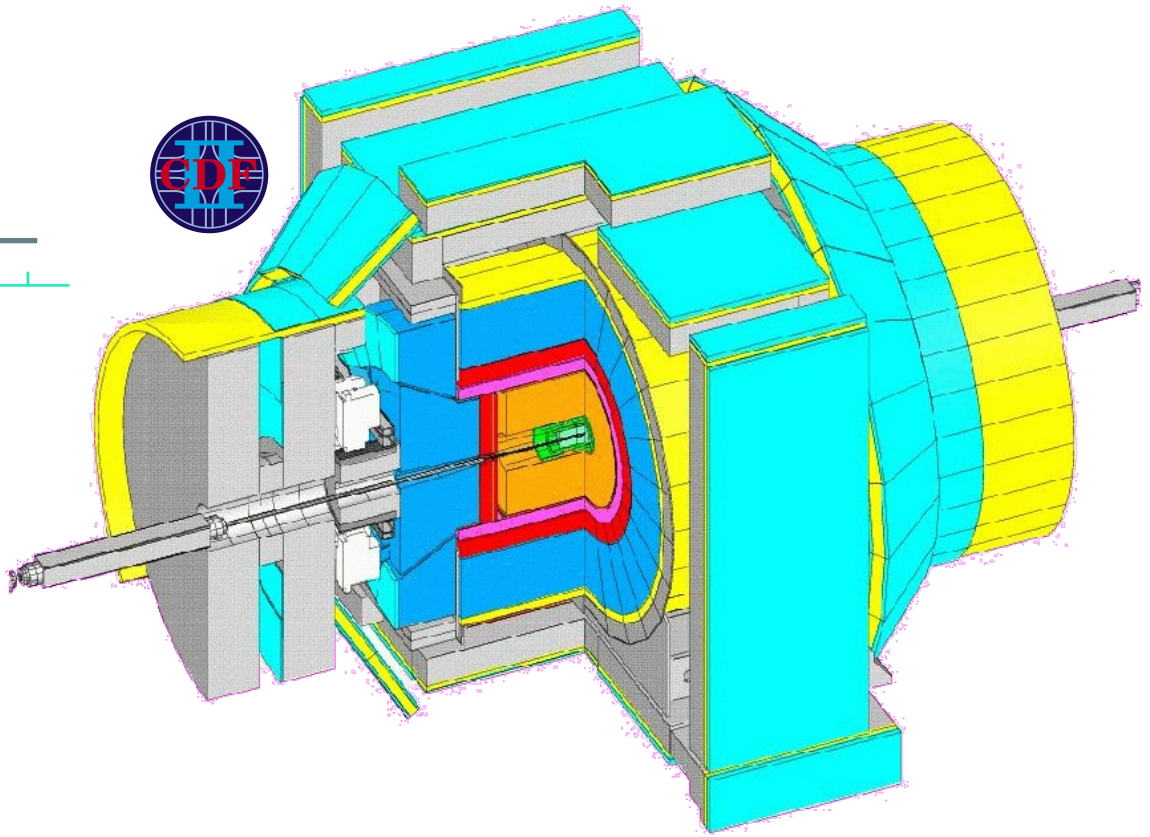
- $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV
- Peak instantaneous luminosity ~ 4 x 10^{32} cm^{-2} s^{-1}
- > 10 fb^{-1} of delivered luminosity



DØ and CDF detectors



Multi purpose detectors



- Central Tracking systems
- Calorimeters
- Muon detectors

Z Kinematic region

$66 < M_Z < 116$ GeV/c²

$P_T^{\mu} > 25$ GeV, $|\eta^{\mu}| < 1$

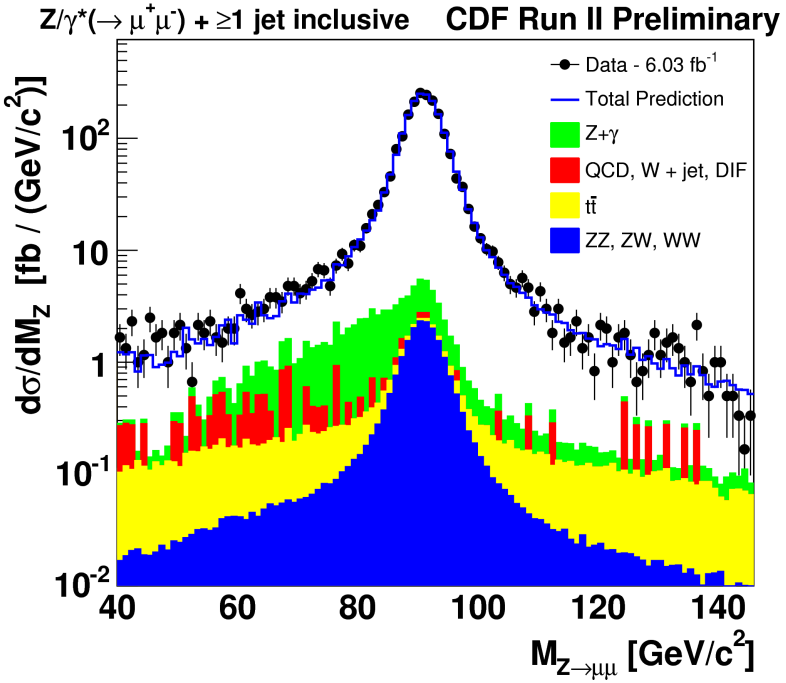
$Z/\gamma^* \rightarrow \mu^+\mu^- +$ jets

$\mathcal{L} = 6$ fb^{-1}

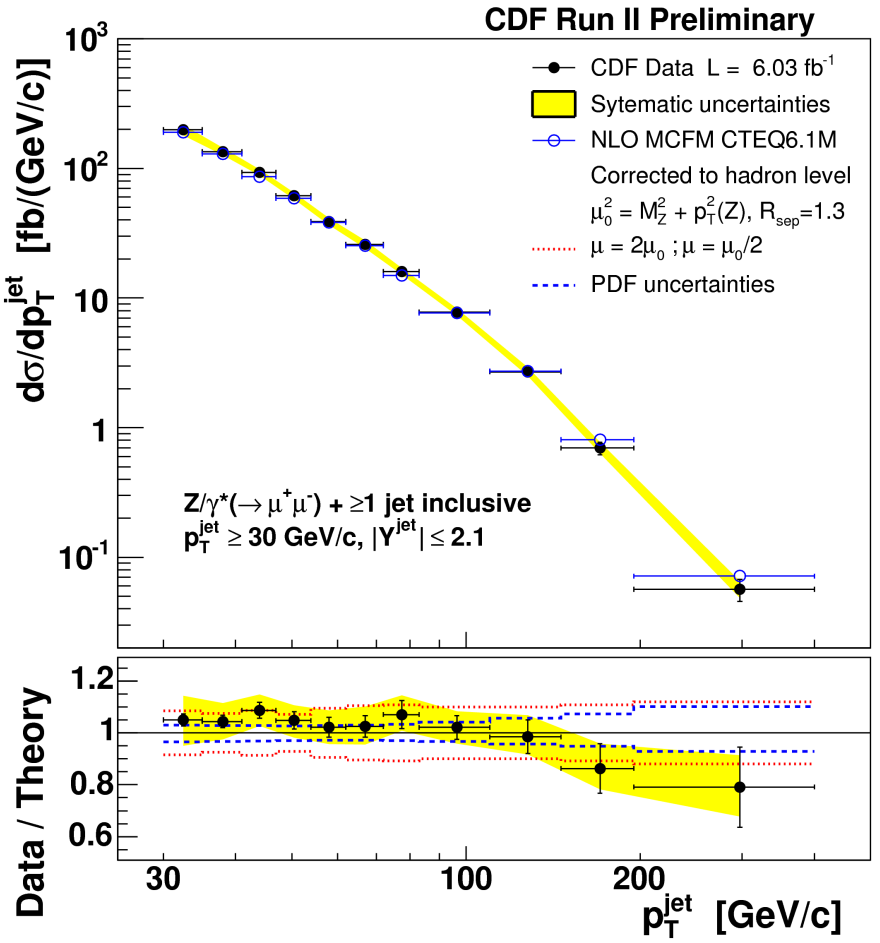
MIDPOINT R=0.7 jet

$p_T > 30$ GeV/c, $|Y| < 2.1$

Same Charge tracks and MC are used to estimate background



Jet Energy Scale is the main systematic uncertainty



Theory prediction and measured Xs corrected to Hadron level

Good Agreement between data and NLO prediction (MCFM)

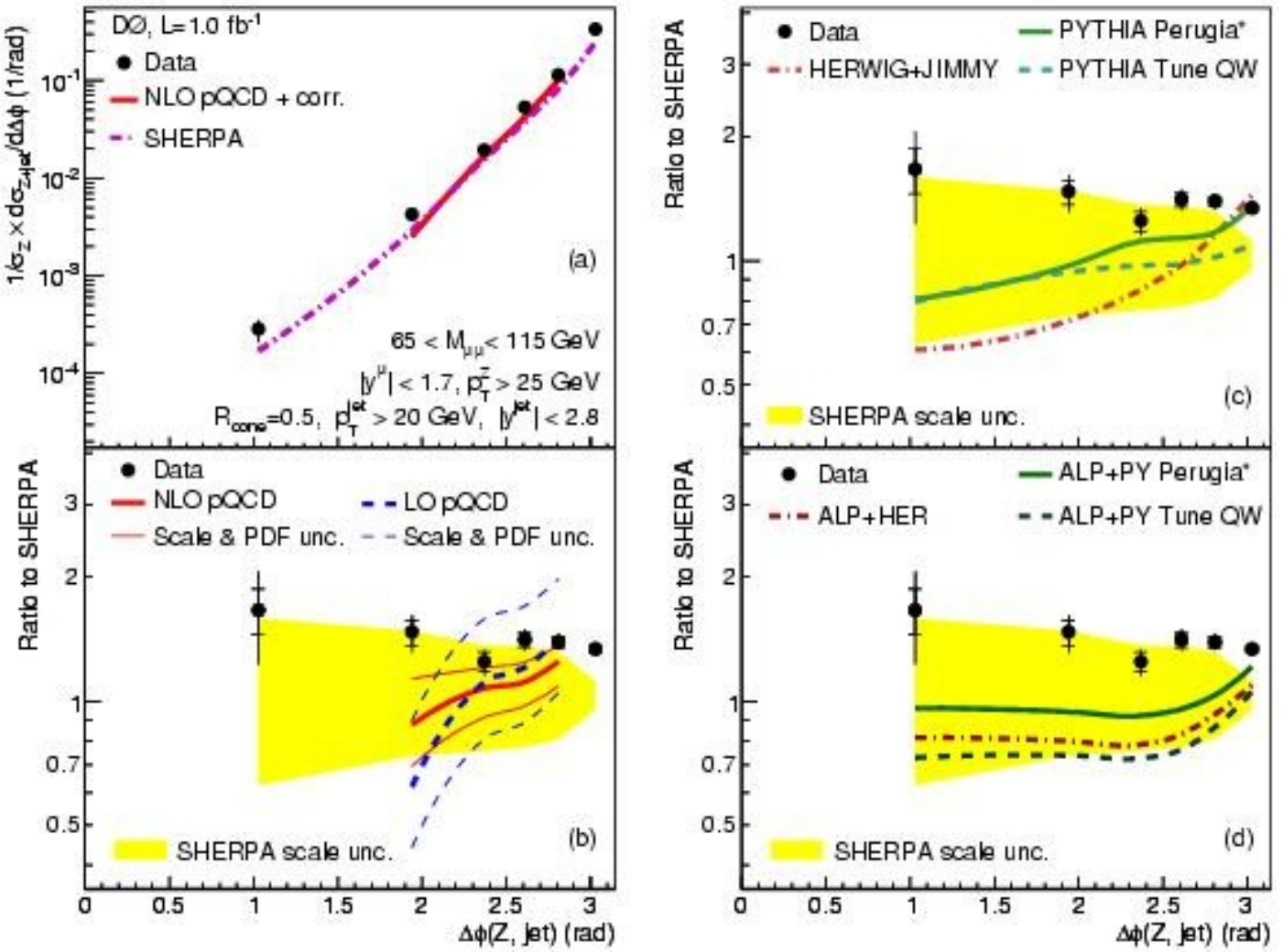
Angular distributions

$Z/\gamma^* \rightarrow \mu^+\mu^- + jets$

$\mathcal{L} = 1\ fb^{-1}$

MIDPOINT R=0.5 jet
$p_T > 20$ GeV/c, $|Y| < 2.8$

Measurements are normalized to σ_Z to reduce systematic uncertainties



Sherpa MC well describes shape but not normalization

Phys. Lett. B 682, 370 (2010)

Z Kinematic region

$66 < M_Z < 116$ GeV/c²

$E_T^e > 25$ GeV, $|\eta_1^e| < 1$

$|\eta_2^e| < 1 \;||\; 1.2 < |\eta_2^e| < 2.8$

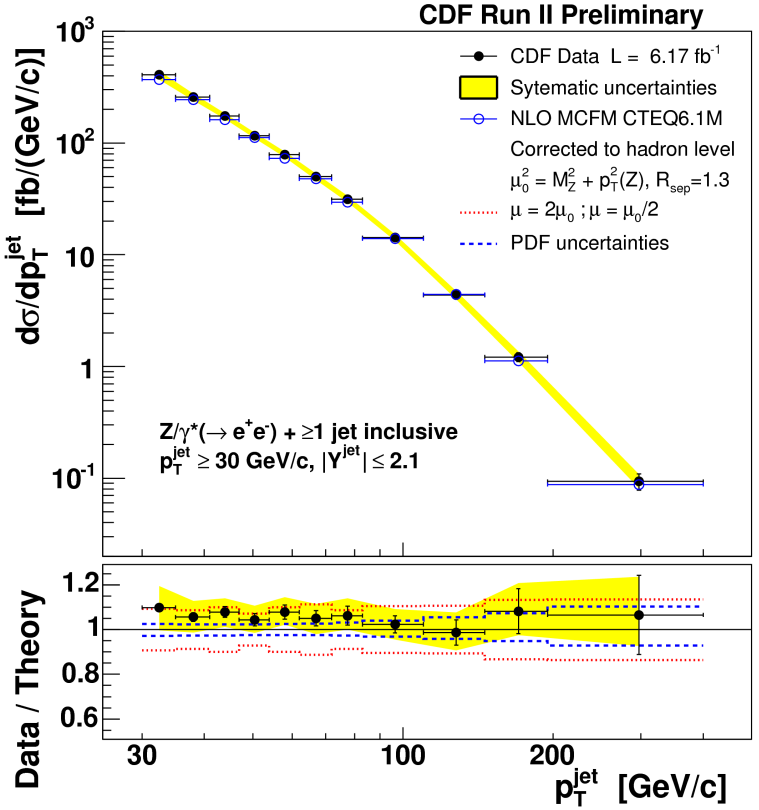
$Z/\gamma^* \rightarrow e^+e^- + \text{jets}$

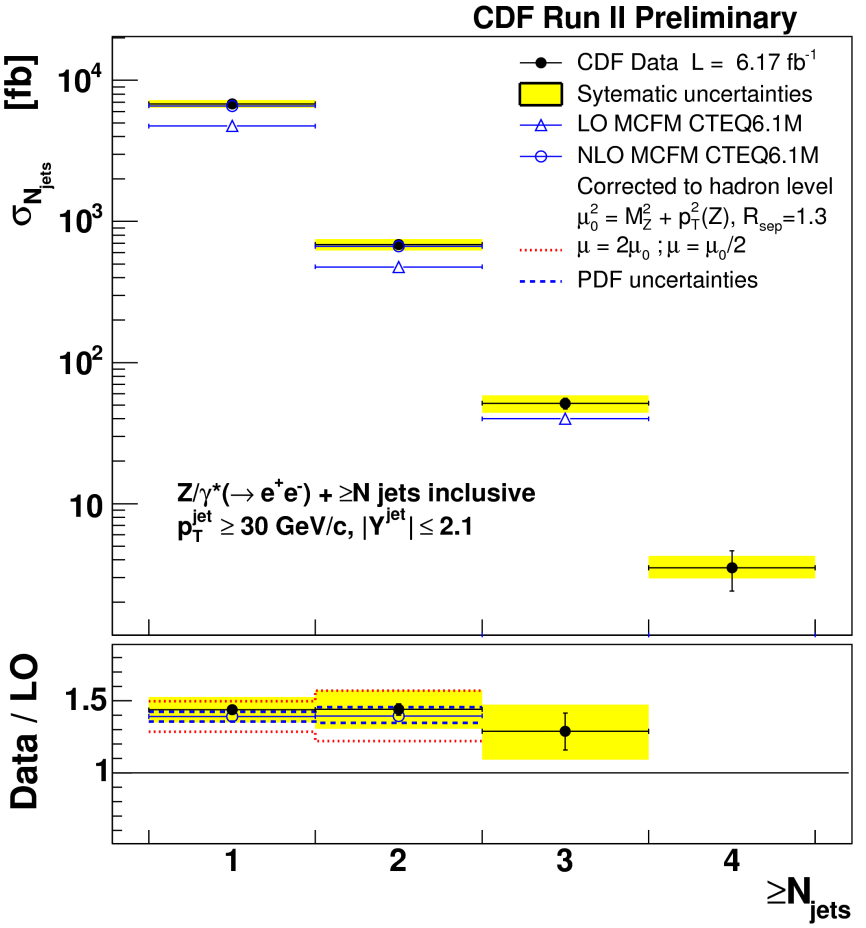
$\mathcal{L} = 6.2\ \text{fb}^{-1}$

MIDPOINT R=0.7 jet

$p_T > 30$ GeV/c, $|Y| < 2.1$

Measurement on the e^+e^- channel published in PRL 100, 102001 (2008) with 1.7 fb^{-1}





Same kinematic region of $Z \rightarrow \mu\mu$ + jets to allow combination

First Measurement of Z + ≥4 Jets

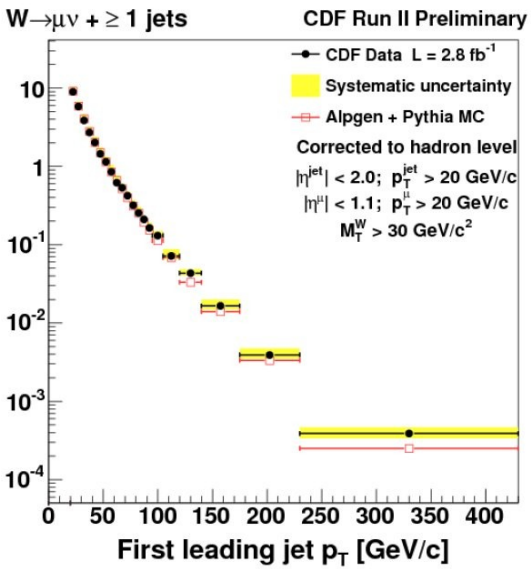
W Kinematic region

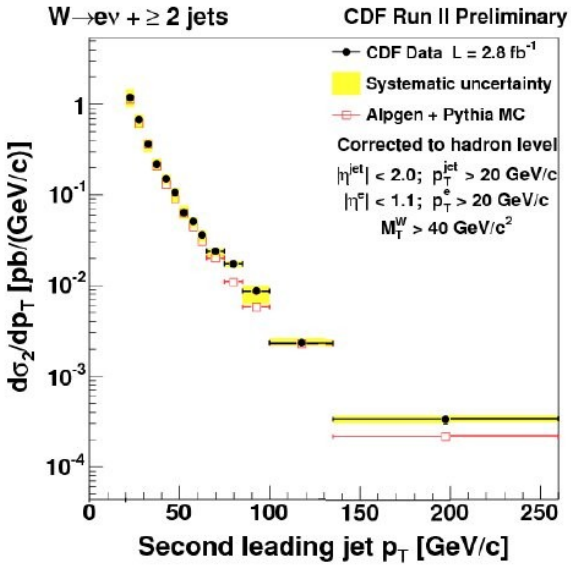
M_T^W > 30 / 40 GeV/c² (μ/e)

P_T^l > 20 GeV, $|\eta_1^l|$ < 1.1

W + jets

$\mathcal{L}$ = 2.8 fb^{-1}





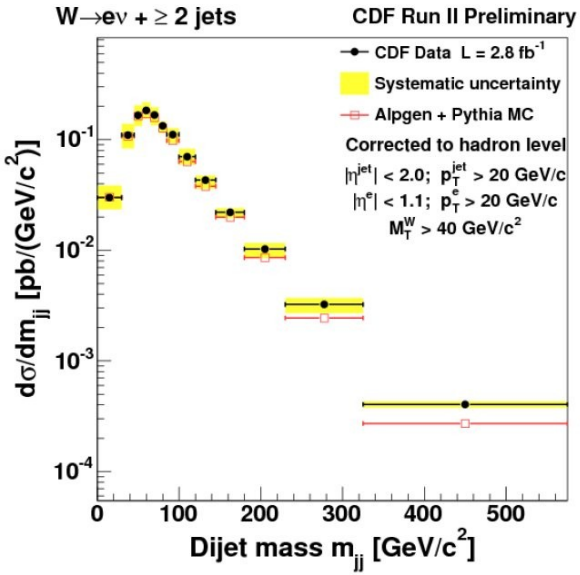
MIDPOINT R=0.4 jet

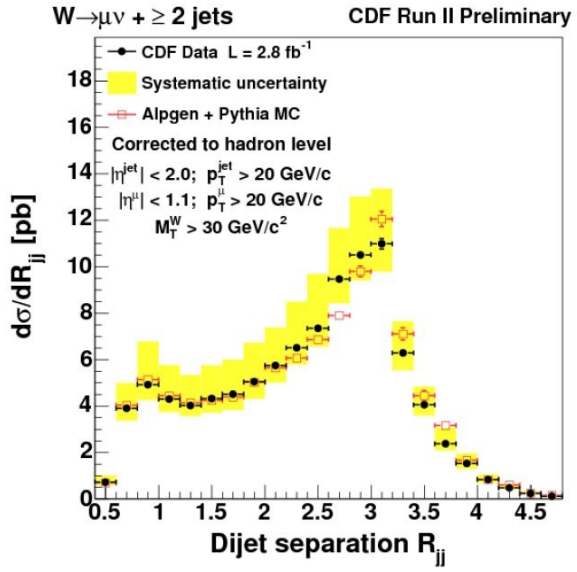
Separate measurements in
W → μν and W → eν channels

Measured differential cross sections in several kinematic variables

Alpgen+Pythia MC normalized to data for each Njet bin in control region M_T>20 GeV

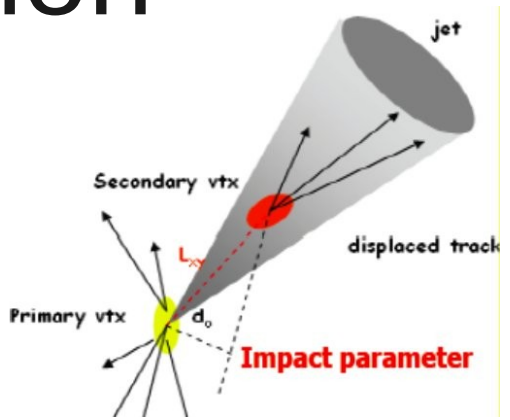
Comparison with NLO prediction will be soon available





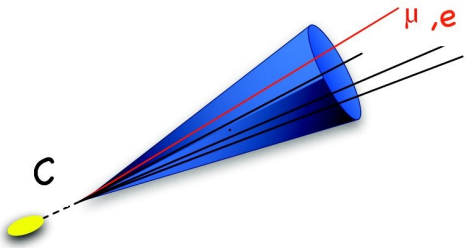
W/Z + HF jets production

Secondary vertex tag
based on large B lifetime

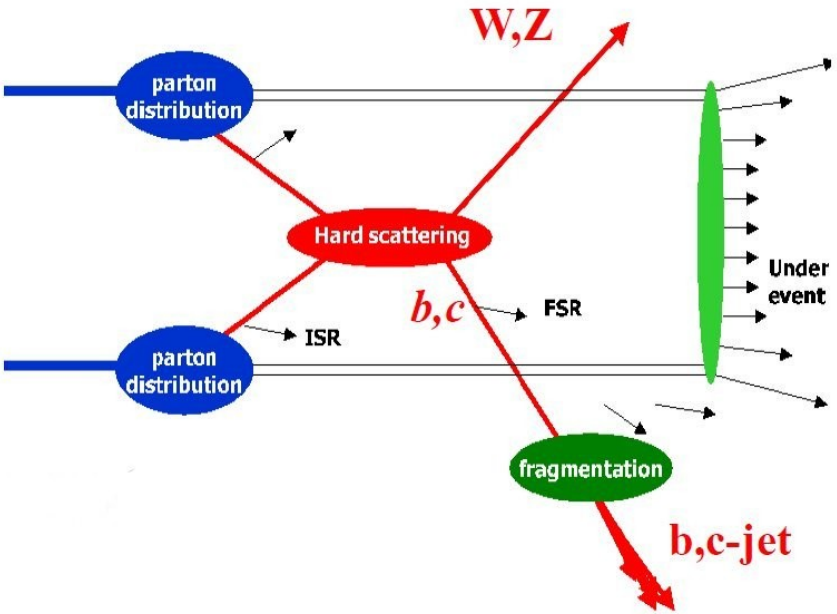


Challenging experimental measurements

- b and c identification
- Low statistics



Soft Lepton tag
(20% Branching ratio)



Challenging theory predictions

- Large variation wrt to scale choice
- PDF uncertainties at high momentum fraction x

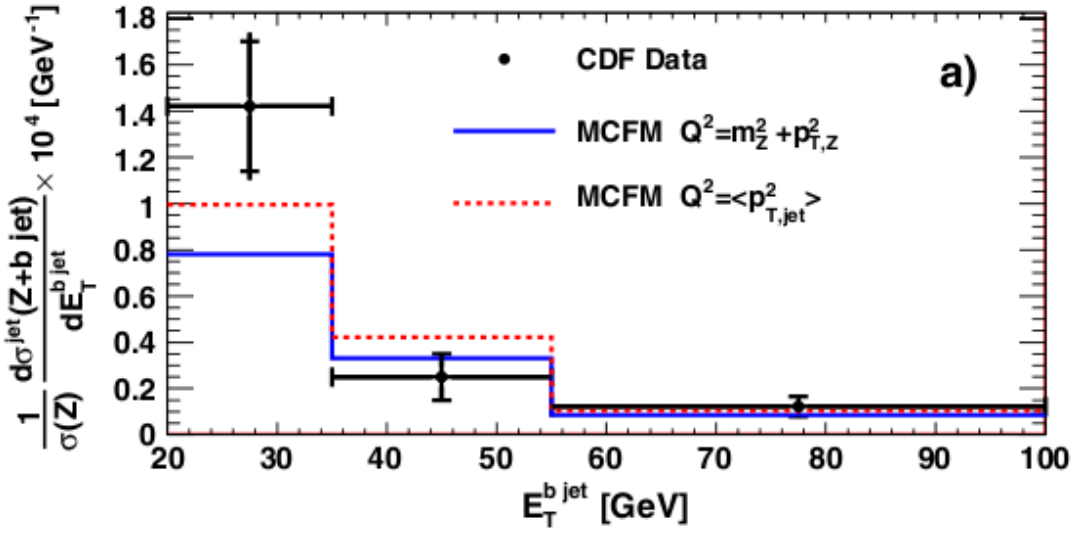
Z + b-jets

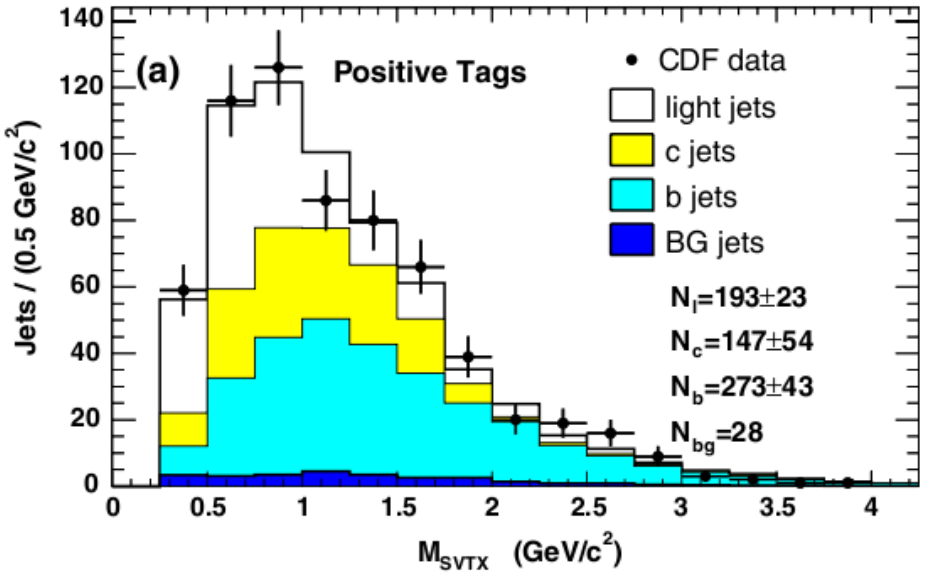
JETCLU R = 0.7 jet
E_T > 20 GeV, |η| < 1.5

$\mathcal{L}$ = 2 fb^{-1}

e and μ channel combination

b-quark composition extracted from fit to secondary vertex mass





$$\frac{\sigma_{Z+b-jet}}{\sigma_Z} = 3.32 \pm 0.53 \pm 0.42 \times 10^{-3}$$

NLO (MCFM)

$2.3\times10^{-3}\,(Q^2 = M_Z^2 + P_{T,Z}^2)$

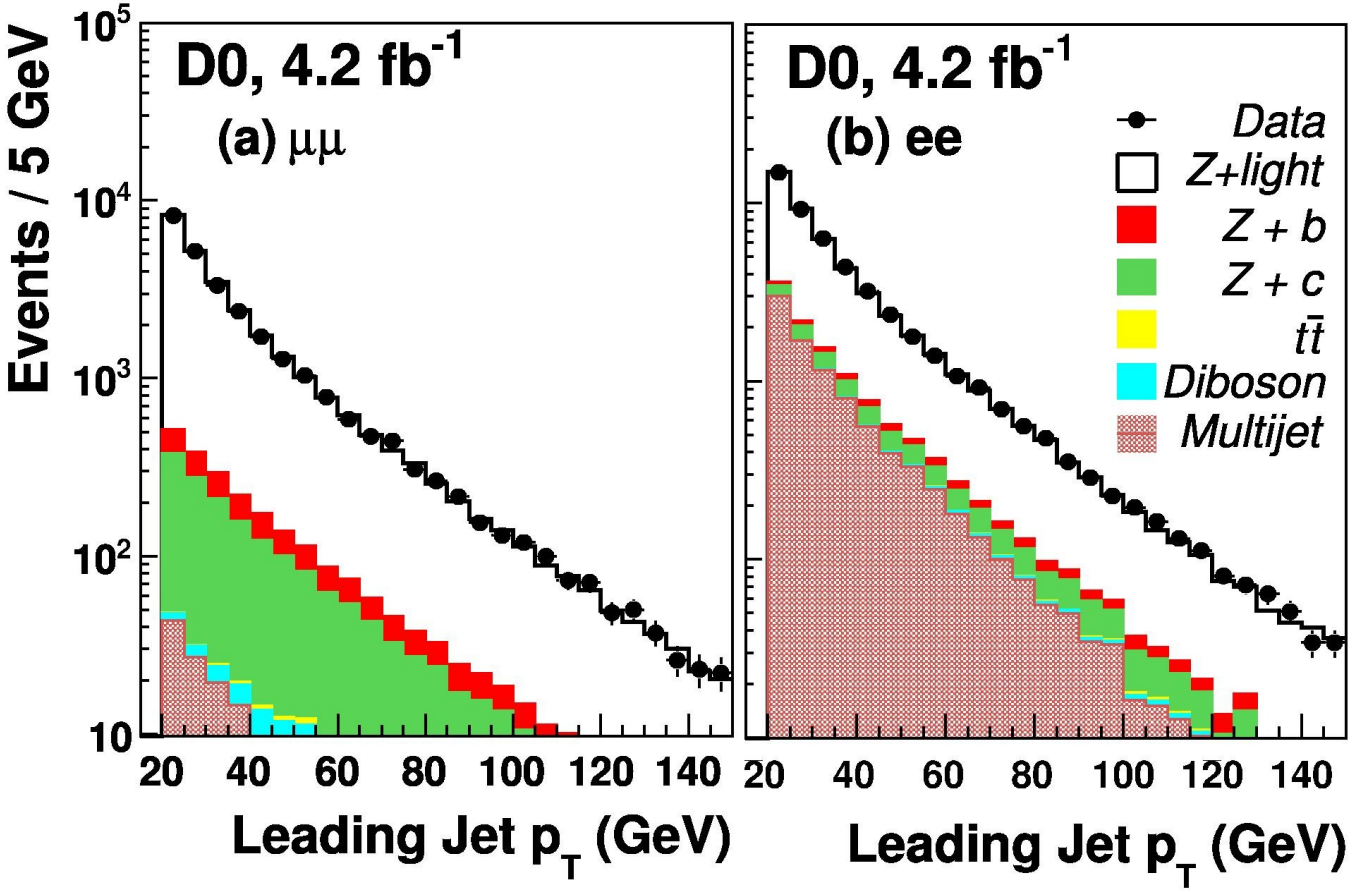
$2.8\times10^{-3}\,(Q^2 = <P_{T,Jet}^2>)$

Measurement in agreement with NLO prediction (large uncertainties in both data and theory)

PRD 79, 052008 (2009)

Z + b-jets

$\mathcal{L}$ = 4.2 fb^{-1}



MIDPOINT R = 0.5 jet
P_T > 20 GeV/c, |η| < 2.5

NN b tagging based on lifetimes

$$\frac{\sigma_{Z+b-jet}}{\sigma_{Z+jet}} = 0.0193 \pm 0.0022 \pm 0.0015$$

NLO prediction (MCFM)

$$0.0192 \pm 0.0022 \left(Q^2 = M_Z^2\right)$$

PRD 83, 031105 (2011)

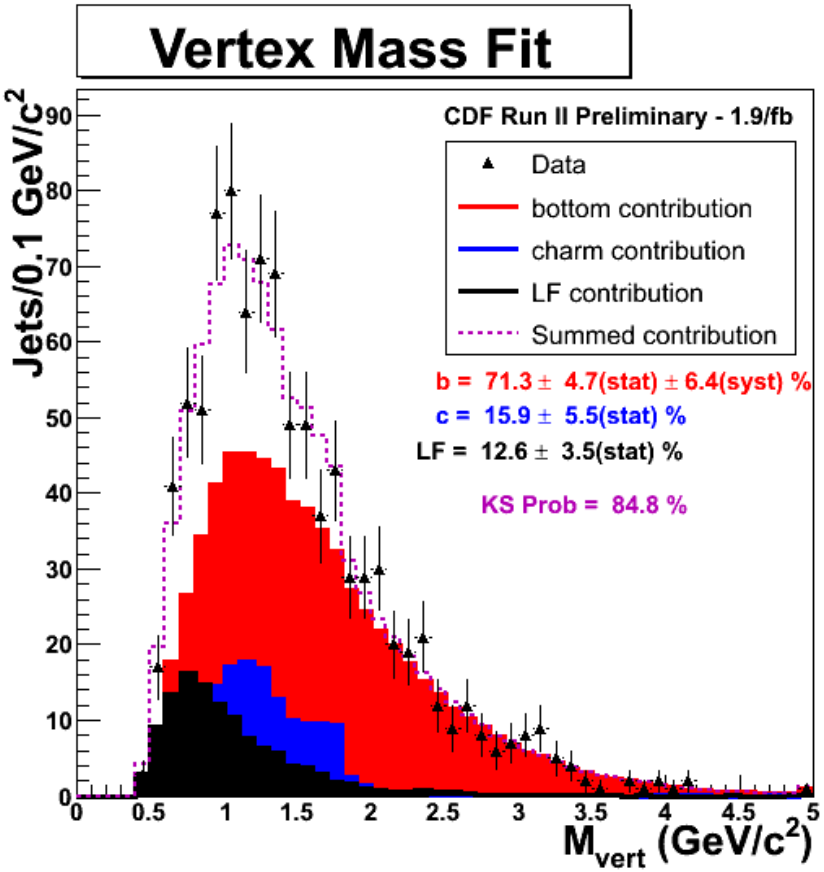
W Kinematic region
Combined e and μ channels
$P_T^{l} > 20$ GeV, $|\eta_1^{l}| < 1.1$
MET > 25 GeV

W + b-jets

$\mathcal{L} = 1.9\ fb^{-1}$

JETCLU R=0.4 jet
$E_T > 20$ GeV, $|\eta| < 2.0$

b-quark composition extracted from fit to secondary vertex mass



$$\sigma_{W+b} \times Br(W \to l\nu)$$
$$2.74 \pm 0.27 \pm 0.42\ pb$$

$$ALPGEN = 0.78\ pb$$
$$NLO\ pQCD = 1.22 \pm 0.14\ pb$$

Measured Xs is higher than NLO prediction

PRL 104, 131801 (2010)

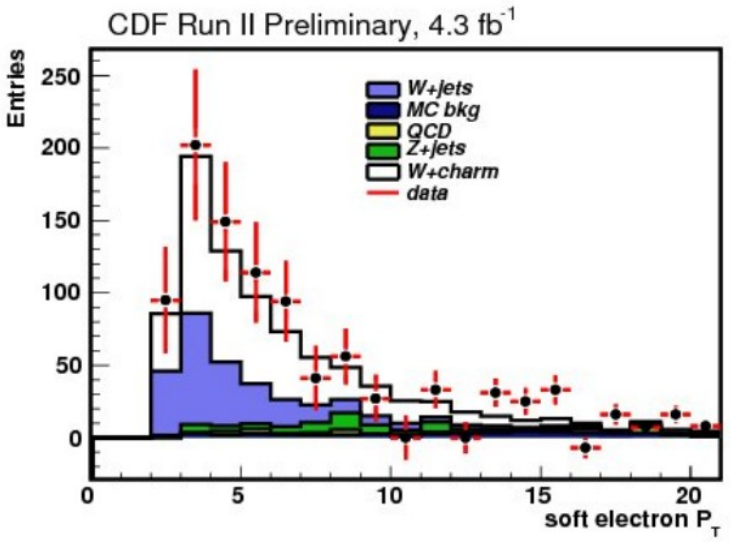
JETCLU R = 0.4 jet
E_T > 20 GeV/c, |η| < 2.0

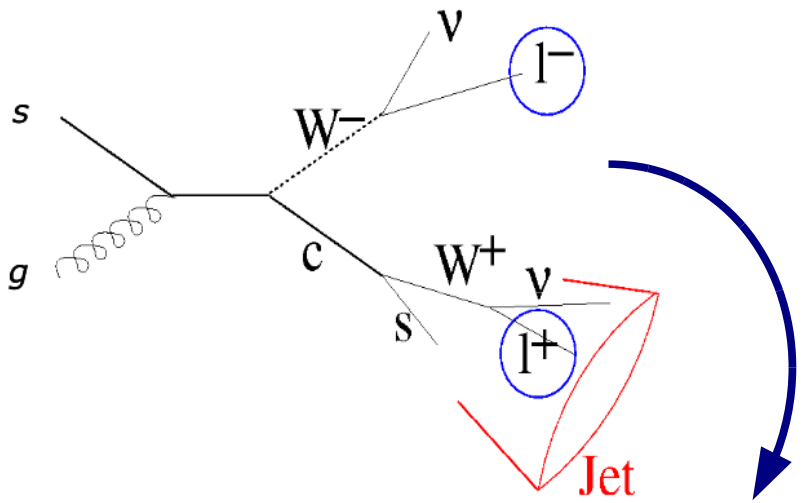
W + c (e channel)

$\mathcal{L}$ = 4.3 fb^{-1}

Probe s-content of proton at high Q²

Charm-jet identified by soft electron tagging (SLT$_e$) algorithm





Exploit opposite charge correlation between W lepton and SLT electron

$$\sigma_{W+c} \times Br(W \to l\,\nu) = 21.1 \pm 7.1(stat) \pm 4.6(syst)\ pb$$

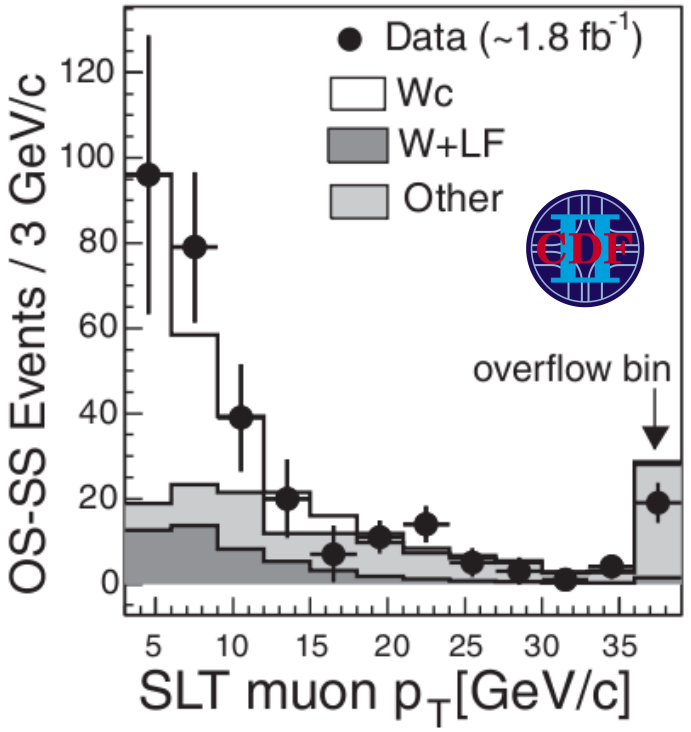
$$NLO\ prediction\ (MCFM): 11.0^{+\,1.4}_{-\,3.0}\ pb$$

Data and NLO in reasonable agreement

W + c (μ channel)

JETCLU R=0.4 jet
$p_T^C > 20$ GeV/c, $|\eta^C| < 1.5$

$\mathcal{L} = 1.8$ fb^{-1}



Soft muon tagger

$$\sigma_{W+c} \times Br(W \to l\nu)$$

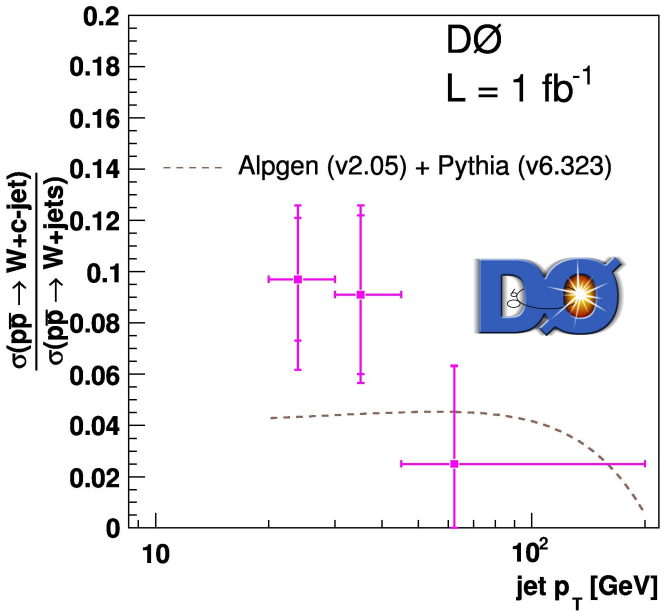
$$9.8 \pm 2.8\,(stat)^{+1.4}_{-1.6}\,(syst) \pm 0.6\,(lum)\ pb$$

$$NLO\,(MCFM): 11.0^{+1.4}_{-3.0}\ pb$$

PRL 100, 091893 (2008)

MIDPOINT R=0.5 jet
$p_T^C > 20$ GeV/c, $|\eta^C| < 2.5$

$\mathcal{L} = 1$ fb^{-1}



$$\frac{\sigma_{W+c}}{\sigma_{W+jets}} = 0.074 \pm 0.019\,(stat)^{+0.012}_{-0.014}\,(syst)$$

LO (Alpgen + Pythia) 0.044 ± 0.003

Phys. Lett. B 666, 23 (2008)

Summary

- New results on Z+jets, W+jets, Z+b
- Good agreement with NLO predictions
- Prospects for more precise W/Z + HF measurements and Z+jets e-μ combinations

More details at:

- http://www-cdf.fnal.gov/internal/physics/qcd/qcd.html
- http://www-d0.fnal.gov/Run2Physics/WWW/results/qcd.htm