Physics with W and Z bosons at Tevatron

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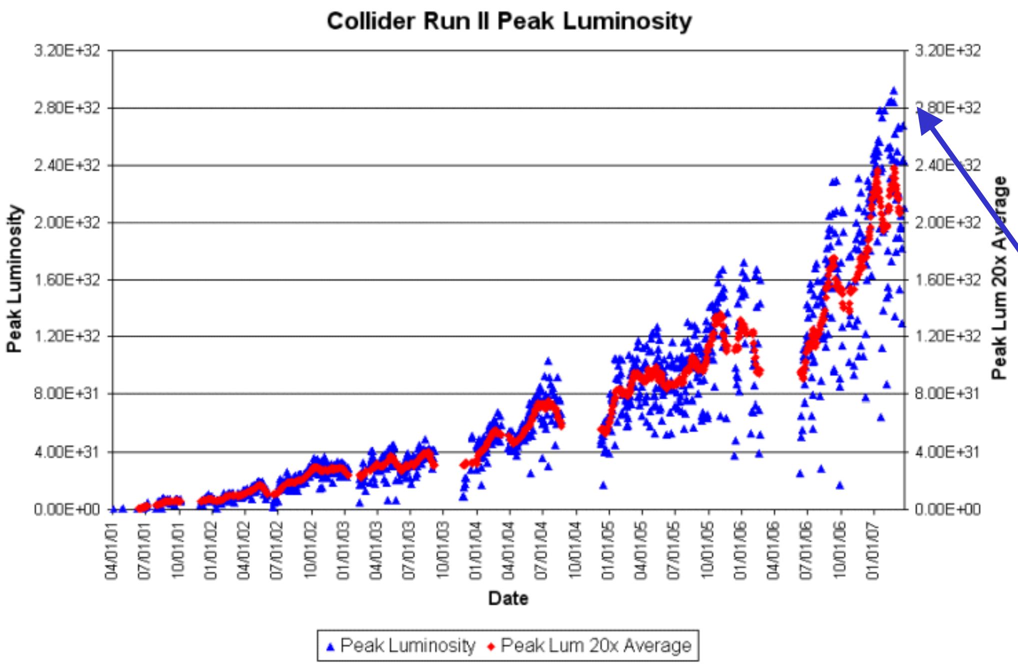
IFAE 2007 *Napoli 11 / 4 / 2007*

Outlines

- Introduction
- W Mass and Width
- W+jets
- Z+jets
- Z+b
- Diboson
- Conclusions

Tevatron

- p-pbar collisions at $\sqrt{s}$ = 1.96 TeV
- ~ 2.5 fb^{-1} delivered
- ~ 2.0 fb^{-1} on tape
- Results shown here use up to 1.1 fb^{-1}



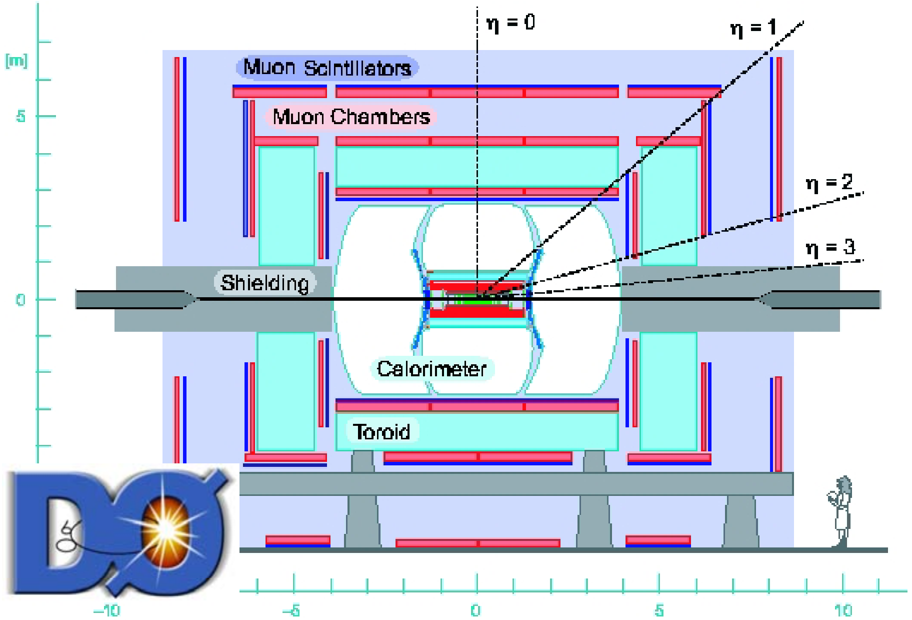
Initial Luminosity record:

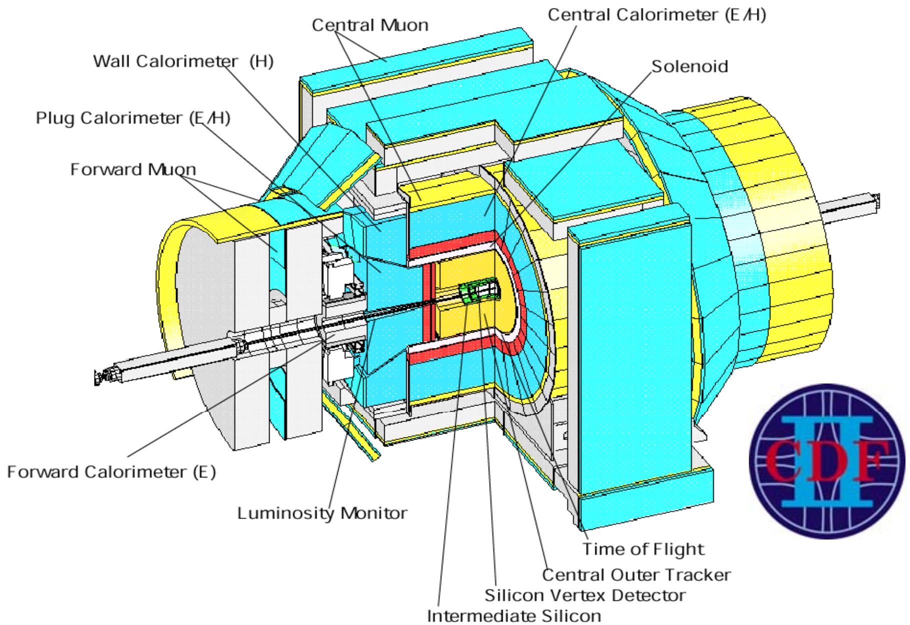
2.85 * 10^{32} $cm^{-2}s^{-1}$

18 February 2007

CDF and D0 detectors

- Both CDFII and D0 detectors are running with good efficiency (≥ 80% at high luminosity)
- Only CDF results today, D0 similar analysis and performances





Lepton identification

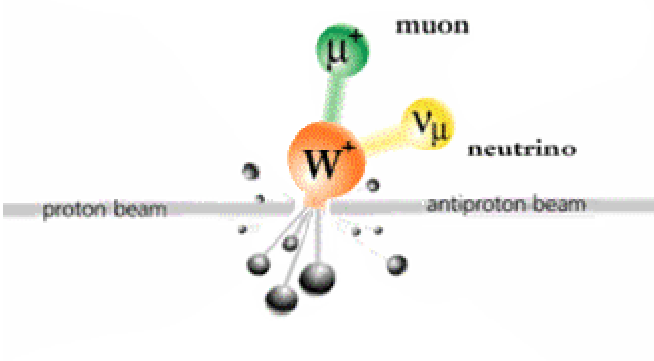
- W and Z bosons mainly reconstructed by their leptonic decay
- Electrons cut based selection on tracking and calorimeter informations: E_T, E_{em}/E_{had}, shower max shape, Isol, track matching, track P_T
- Muon selection: tracking and matching track with stubs

- W reconstruction: tight sets of cuts
- Z and diboson analyses: looser cuts to improve acceptance

W Mass

200 pb^{-1}

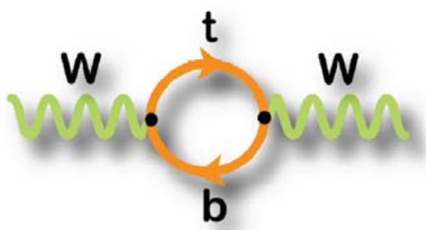
- W Mass can be derived using precisely measured electroweak quantities:



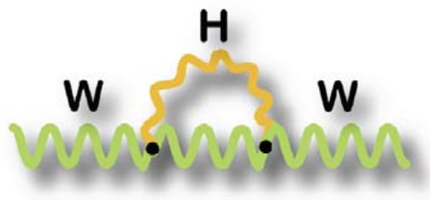
$$m_W^{\ 2} = \frac{\pi \alpha_{em}}{\sqrt{2} G_F \sin^2 \theta_W (1 - \Delta r)}$$

$$\cos \theta_W = \frac{m_W}{m_Z}$$

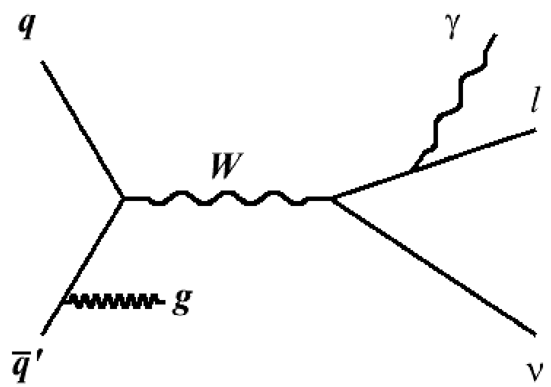
- Radiative corrections (Δr) dominated by top and Higgs loops



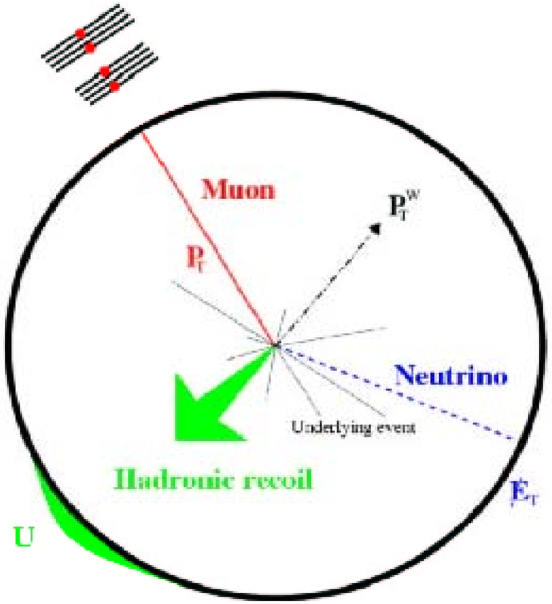
- Mass of the SM Higgs boson is constrained by precisely measured M_{top} and M_W



W Mass



$$m_T = \sqrt{2 p_T^{\,l} p_T^{\,\nu} (1 - \cos\phi_{l\nu})}$$

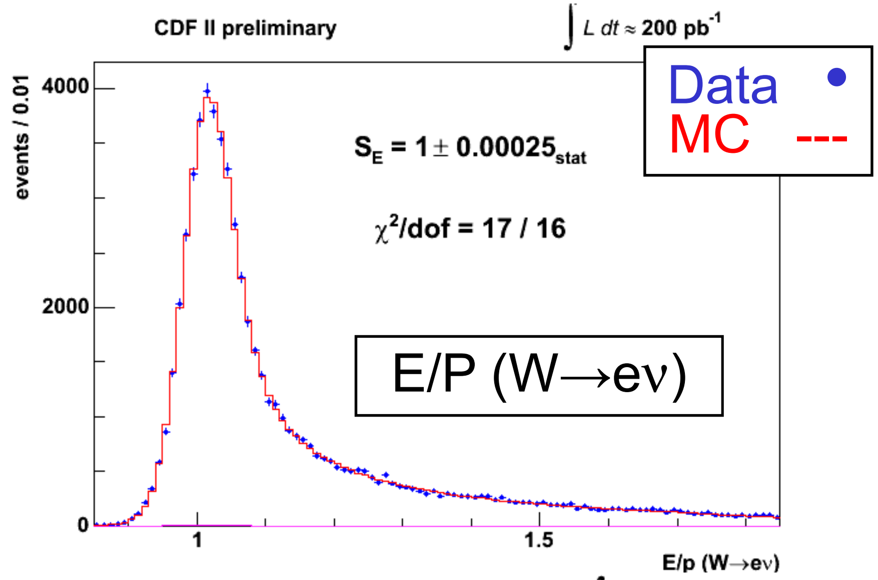


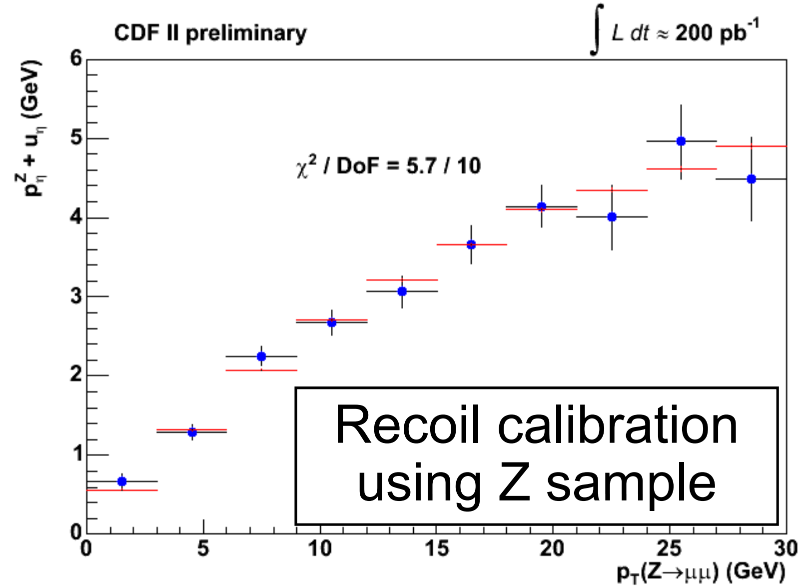
- M_W is extracted from binned Likelihood template fits to the m_T, p_T and $\not{E}_T$ distribution (combined using BLUE)
- A fast Monte Carlo simulation incorporating all known detector effects is used to predict the lineshape of the template distribution
- These predictions depend on several physics and detector effects constrained from control samples or simulation

W Mass

- Important detector effects
  - – external bremsstrahlung
  - – ionization energy loss in the detector material
  - – tracker momentum scale
  - – calorimeter energy scale and resolutions

- Important physics effects
  - – internal QED radiation
  - – intrinsic W boson p_T
  - – proton *pdf*





W Mass - M_T fit and uncertainties

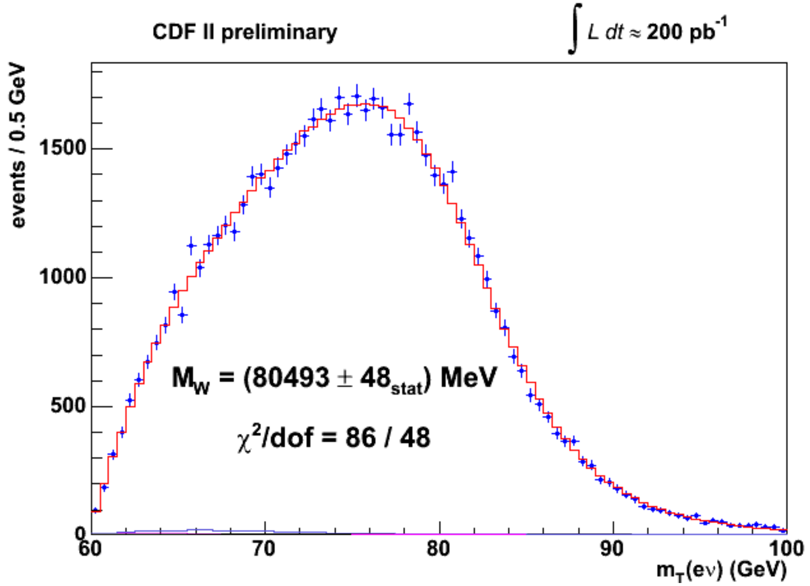
Combining all the fits to m_T, p_T, $\not{E}_T$

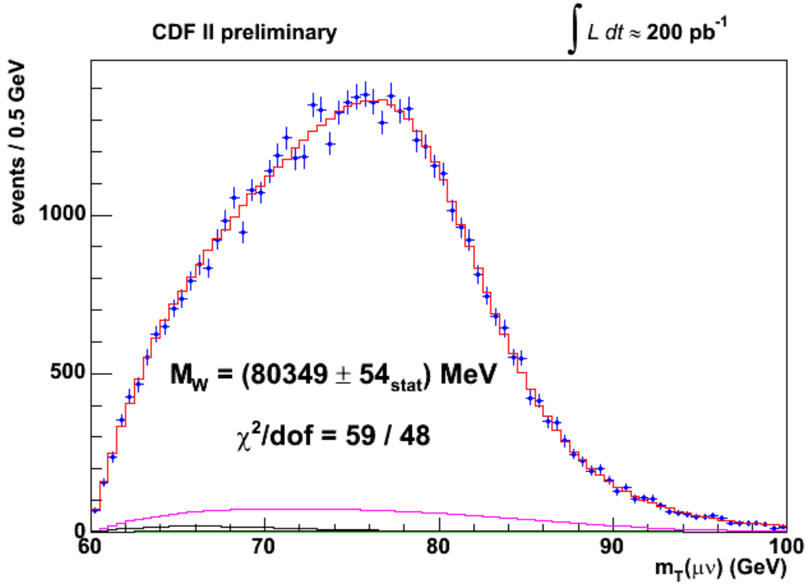
M_W = 80413 ± 34 (stat) ± 34 (syst) MeV

M_W = 80413 ± 48 MeV

CDF II preliminary $L = 200\ pb^{-1}$

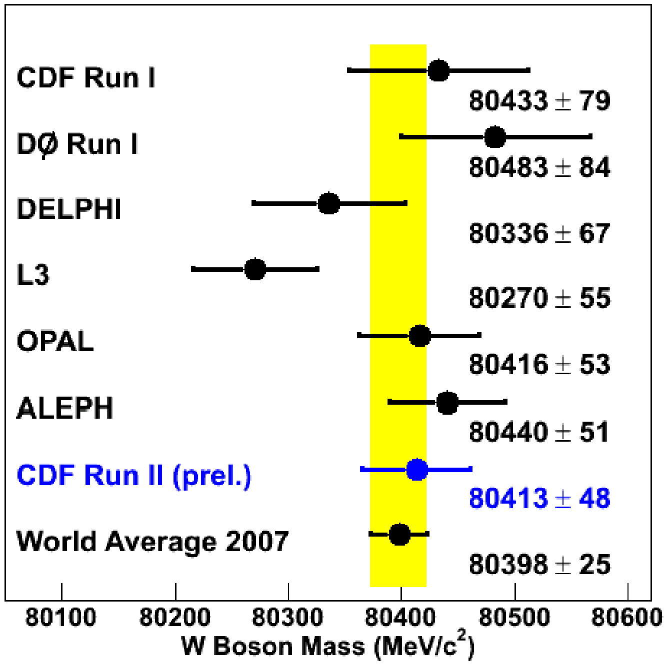
m_T Uncertainty [MeV]	Electrons	Muons	Common
Lepton Scale	30	17	17
Lepton Resolution	9	3	0
Recoil Scale	9	9	9
Recoil Resolution	7	7	7
$u_{\|\|}$ Efficiency	3	1	0
Lepton Removal	8	5	5
Backgrounds	8	9	0
$p_T(W)$	3	3	3
PDF	11	11	11
QED	11	12	11
Total Systematic	39	27	26
Statistical	48	54	0
Total	62	60	26

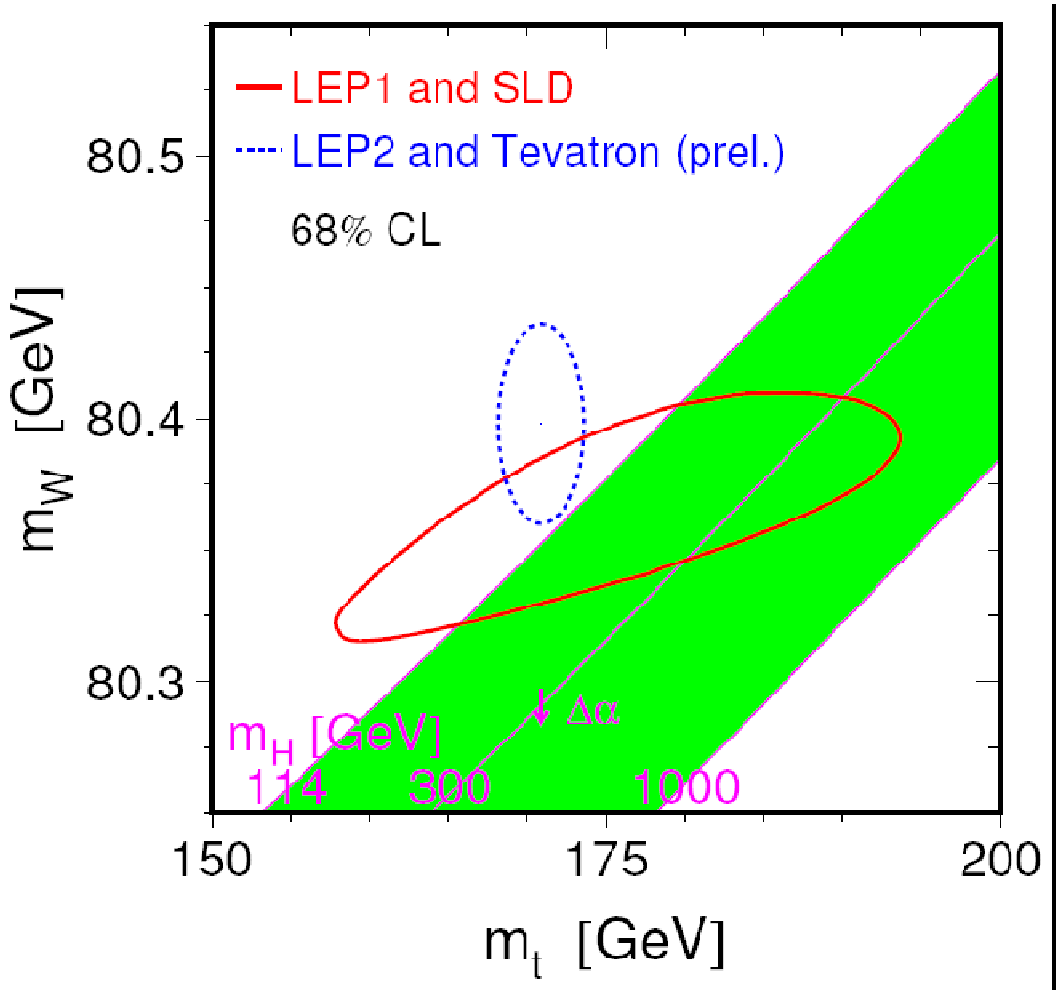




W Mass - M_H costraint

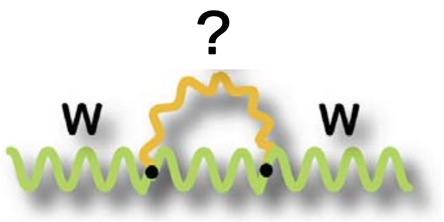
- Single most precise M_W measurement up to date
- Exploiting the whole dateset available expect to get a precision better than 25 MeV

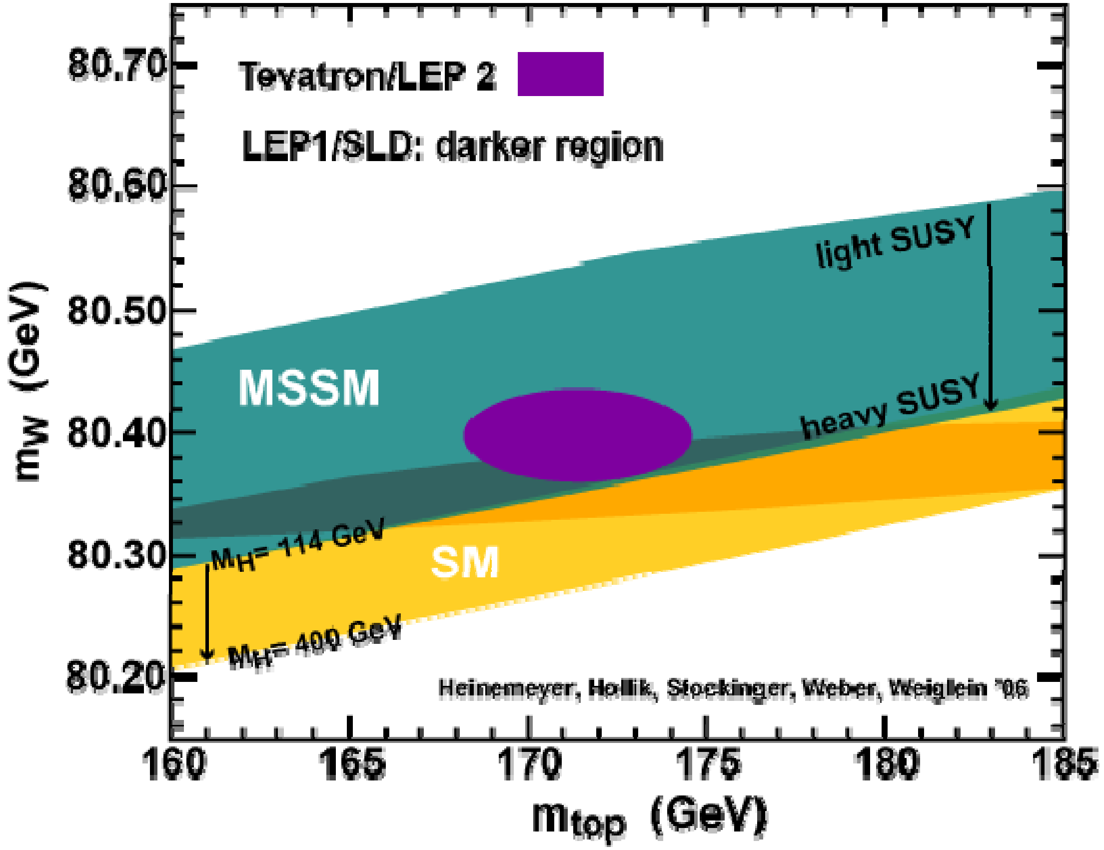




W Mass - Impact on New Physics

- Improving precision also sensitive to beyond SM radiative corrections, like SUSY

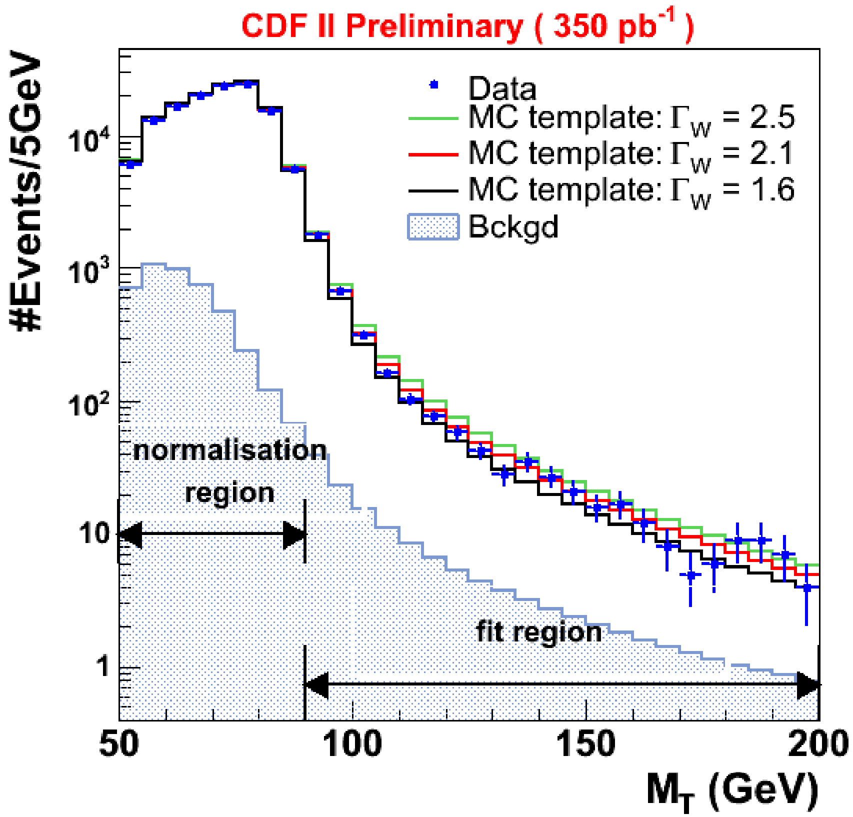




W Width

350 pb^{-1}

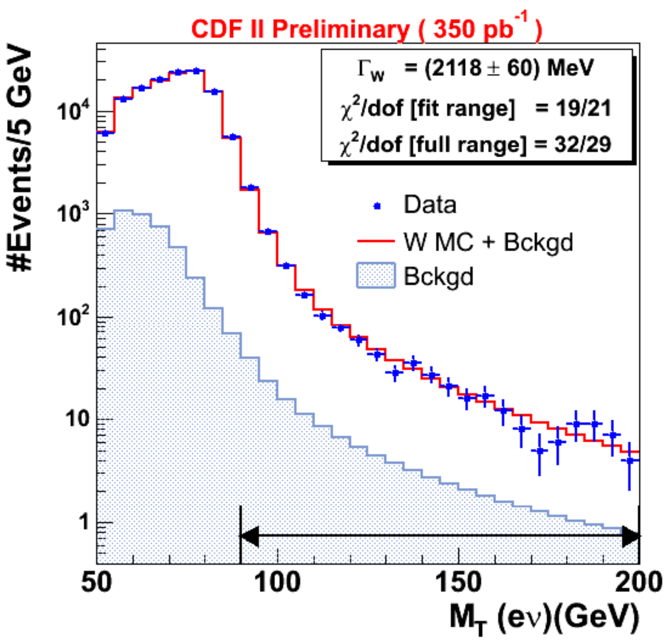
- Measuring Γ_W tests the SM
- M_W fit region used for normalization

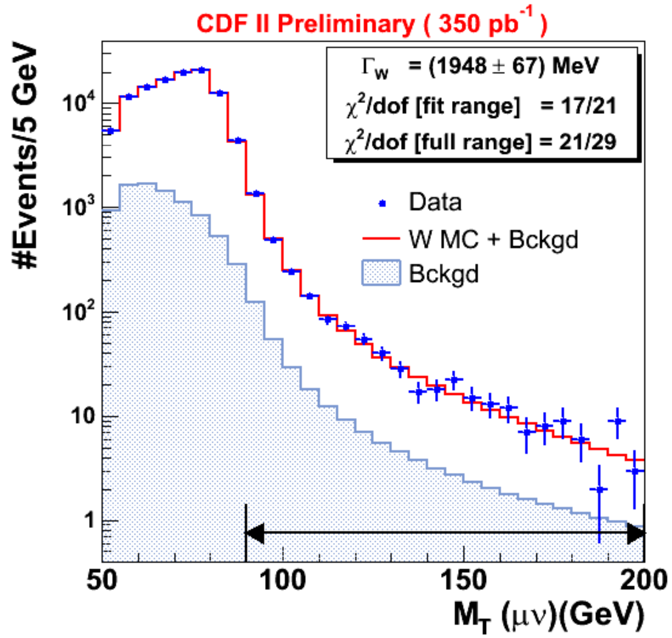


CDF Run II Preliminary (350 pb^{-1})

	$\Delta\Gamma_W$ [MeV]		
	Electrons	Muons	Common
Lepton Scale	21	17	12
Lepton Resolution	31	26	0
Simulation	13	0	0
Recoil	54	49	0
Lepton ID	10	7	0
Backgrounds	32	33	0
$p_T(W)$	7	7	7
PDF	16	17	16
QED	8	1	1
W mass	9	9	9
Total systematic	78	70	23
Statistical	60	67	0
Total	98	97	23

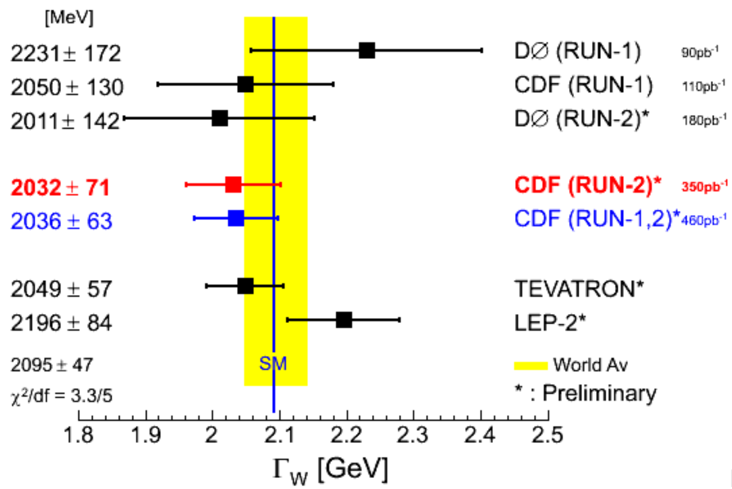
W Width





- Single most precise direct Γ_W measure up to date

Γ_W = 2032 ± 71 MeV

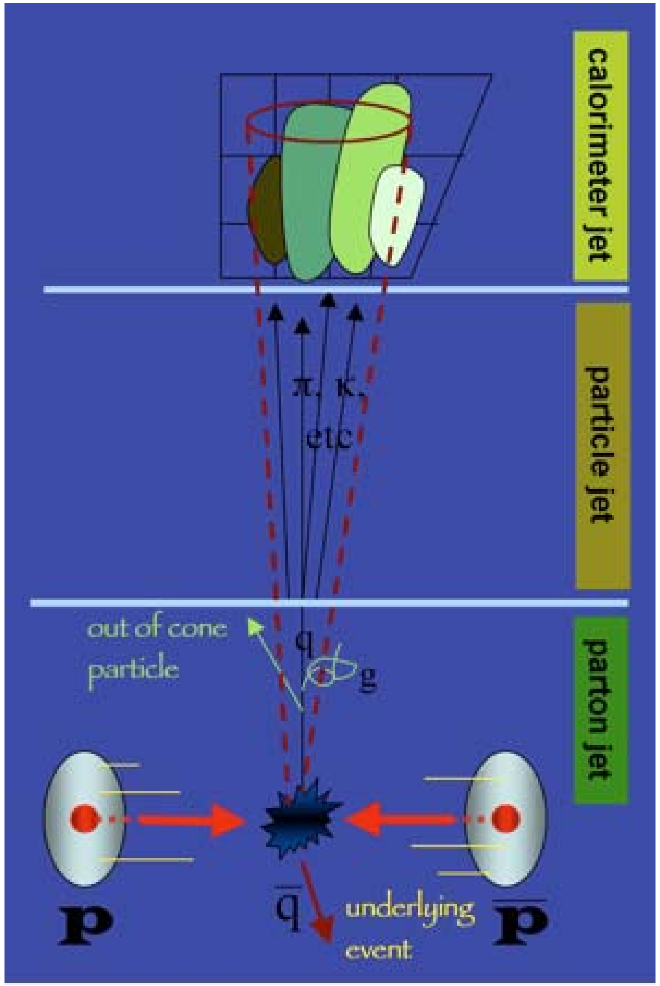


W/Z + jets

- Important backgrounds for top, Higgs and SUSY events
- *pdf* studies
- Test ground for pQCD in multijet environment:
  - the presence of a boson ensures high Q^2
  - large BR into leptons - easy to detect experimentally
- Validation of new matrix element MC event generators and matching algorithm to parton showers

Jets reconstruction

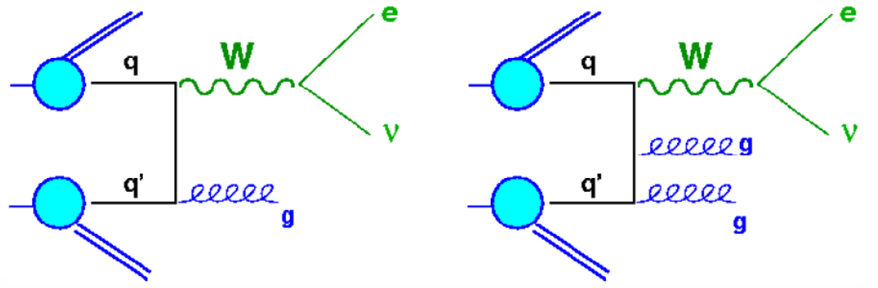
- A jet is a composite object:
  - complex underlying physics
  - depends on the clustering algorithm
  - depends on detector properties
- Particle jets:
  - calorimeter response to hadron
  - detector resolution and efficiency
  - pile-up interactions
- Parton jets:
  - underlying event
  - fragmentation / hadronization (Monte Carlo model based - needs to be tuned on data, using many different observables)

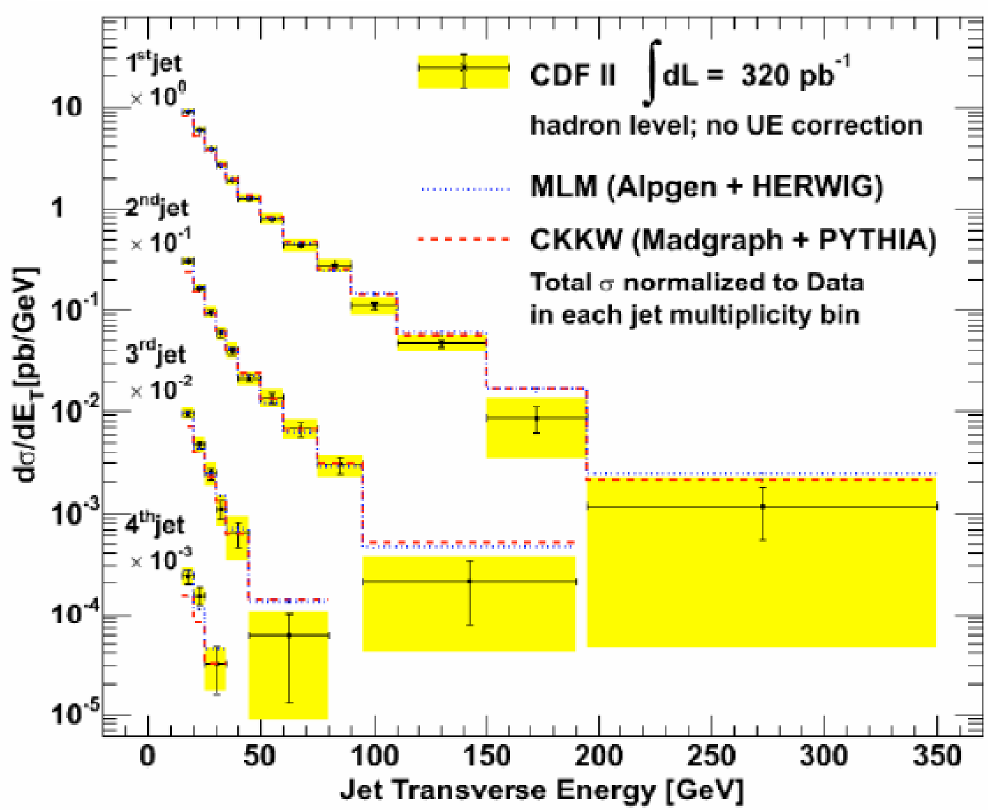


W+jets

320 pb^{-1}

- Key sample to test LO and NLO calculations
- Jets reconstructed using JetClu algorithm (R = 0.4)
- Jets corrected for detector effect to particle level
- $E_T^{jet} > 15$ GeV
- $|\eta^{jet}| < 2.0$

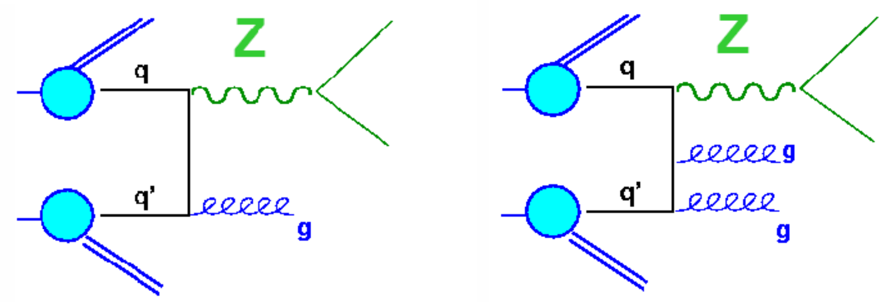


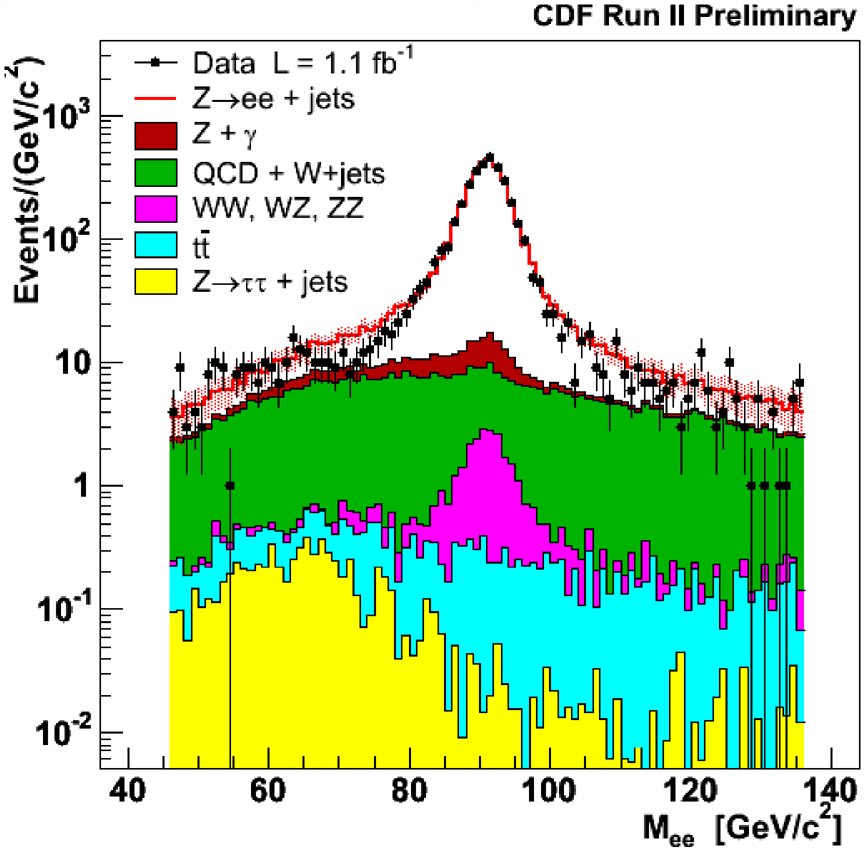


Z+jets

1.1 fb^{-1}

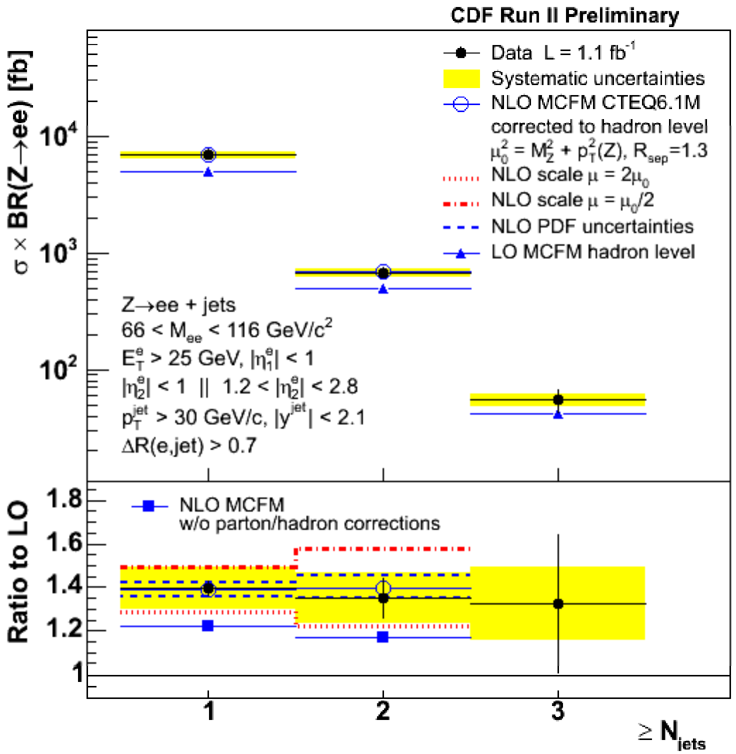
- Ten times smaller cross section than W+jet, but almost background free sample
- Jets reconstructed using MidPoint algorithm (R = 0.7)
- Data corrected to hadron level
- $p_T^{jet} > 30$ GeV/c
- $| y^{jet} | < 2.1$

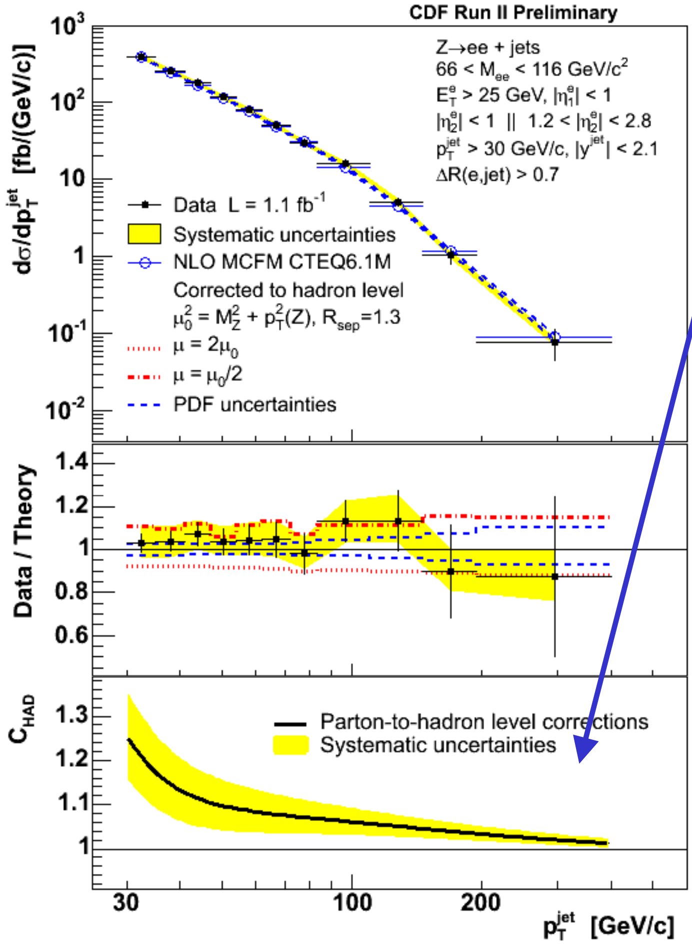




Z+jets

- Good agreement with NLO predictions with non-perturbative contributions
- NLO predictions up to 2 jets in final state (LO for 3 jets)
- Constant k-factor NLO/LO with the jet multiplicity

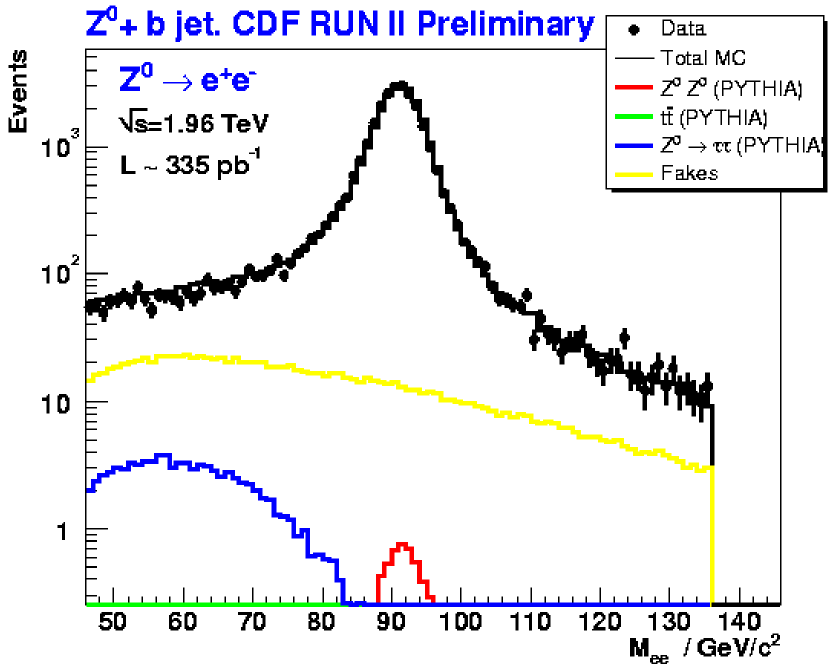


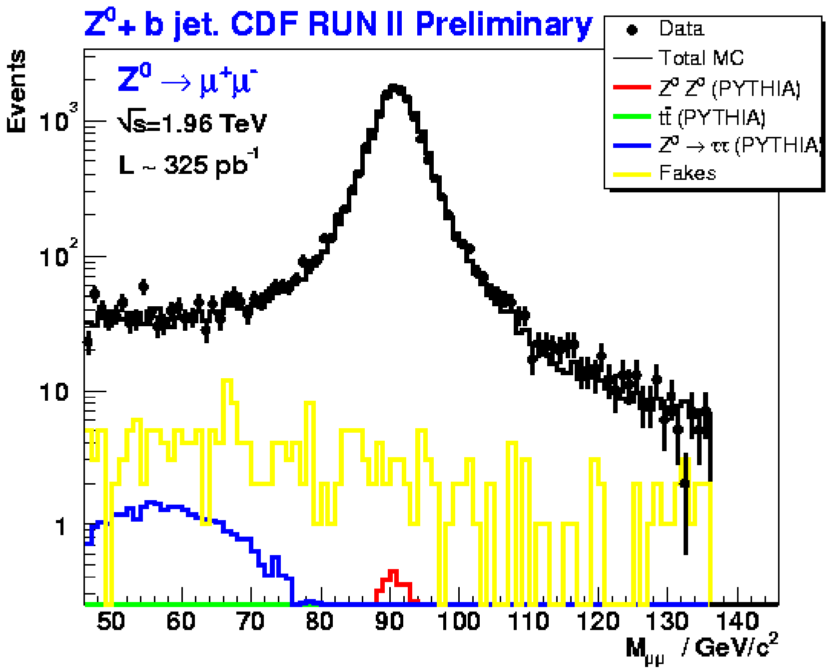


Z+b

320 pb^{-1}

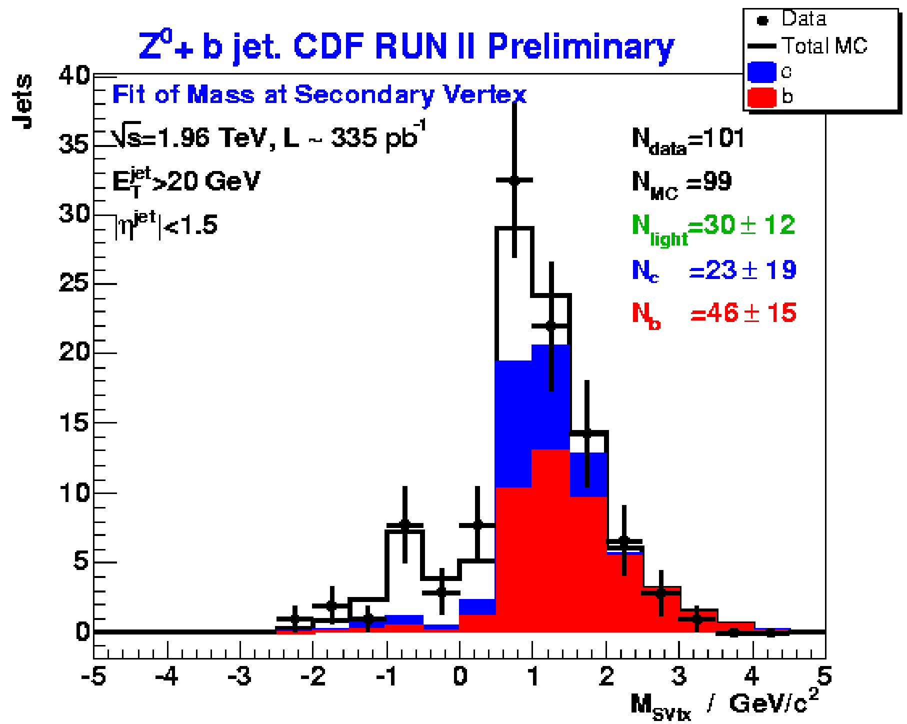
- Theoretical progress in calculation of Z + hf (hep-ph/0312024 Maltoni et al.)
- Z reconstructed in both e and μ channels





Z+b

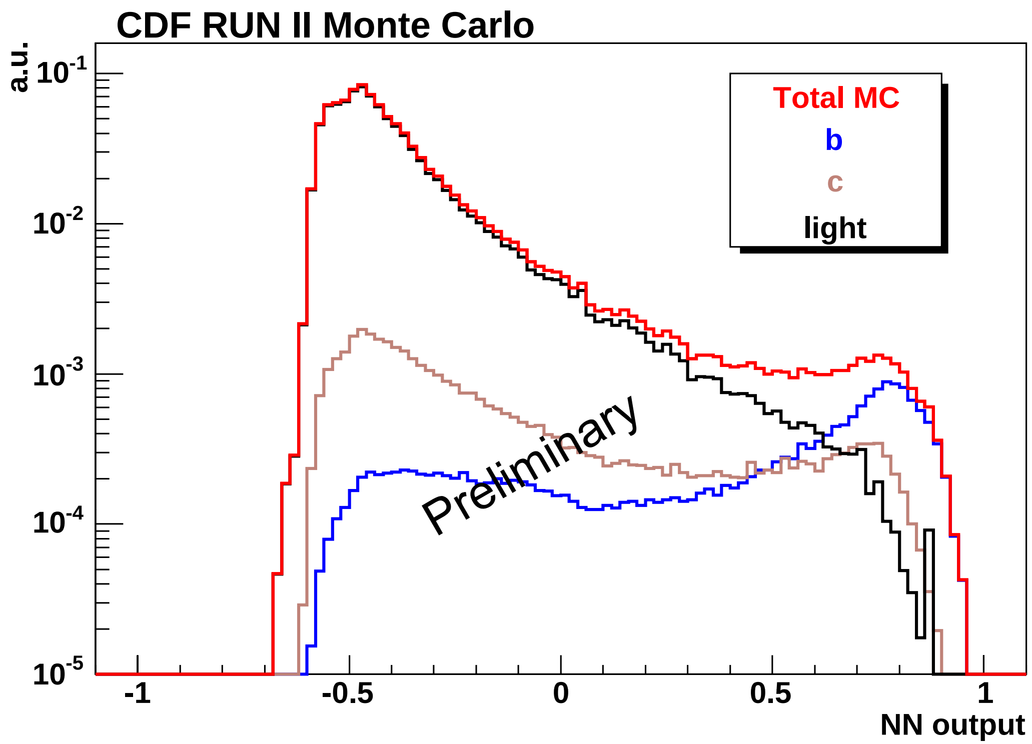
- Jets reconstructed using MidPoint algorithm (R = 0.7)
- Secondary vertex reconstructed inside the jet cone by SecVtx algorithm
- Extracting the Z+b events by a fraction fit to secondary vertex mass



Cone0.7, $E_T^{jet} > 20$ GeV, $\|\eta^{jet}\| < 1.5$, $\sqrt{s} = 1.96$ TeV, $L \sim 335\,pb^{-1}$	CDF RUN II Preliminary Data	PYTHIA TuneA (CTEQ5L)	NLO J. Campbell	NLO with Had, UE
$\sigma(Z^0 + b\ jet)$	$0.96 \pm 0.32 \pm 0.14$ pb	0.53 pb	0.45 pb	0.52 pb
$\sigma(Z^0 + b\ jet)/\sigma(Z^0)$	$0.0035 \pm 0.0012 \pm 0.0005$	0.0034	0.0019	0.0021
$\sigma(Z^0 + b\ jet)/\sigma(Z^0 + jet)$	$0.0237 \pm 0.0078 \pm 0.0033$	0.0207	0.0185	0.0185

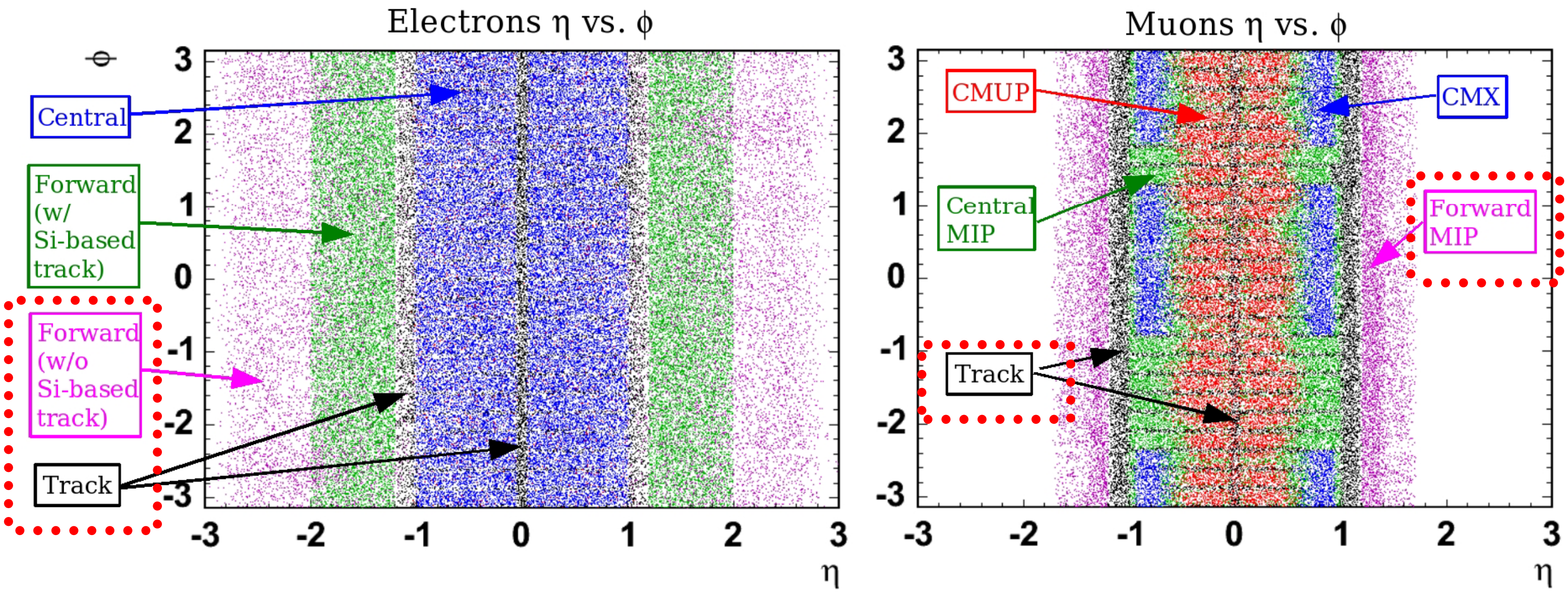
Improvements: better HF tagging

- Use a tagging algorithm which exploits as much as information possible - not only the secondary vertex
- Good test frame for tuning of new algorithm in Higgs and New Physics perspectives
- Statistical separation of b and c components to exploit the whole distribution shapes
- Fit b & c jet fractions with expected stat. relative uncertainty for 1 fb^{-1} of 18% and 35%



Improvements: new leptons categories

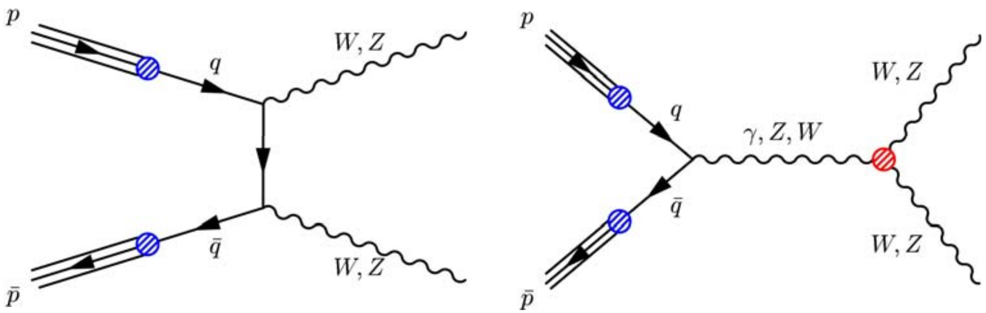
- All leptons final states: cope with small signals extending acceptance (important also for Higgs searches)
- Loosen requirements (i.e. use stiff & isolated tracks) for leptons in less instrumented regions
- Gain 15/30% in acceptance depending on the channel



Diboson

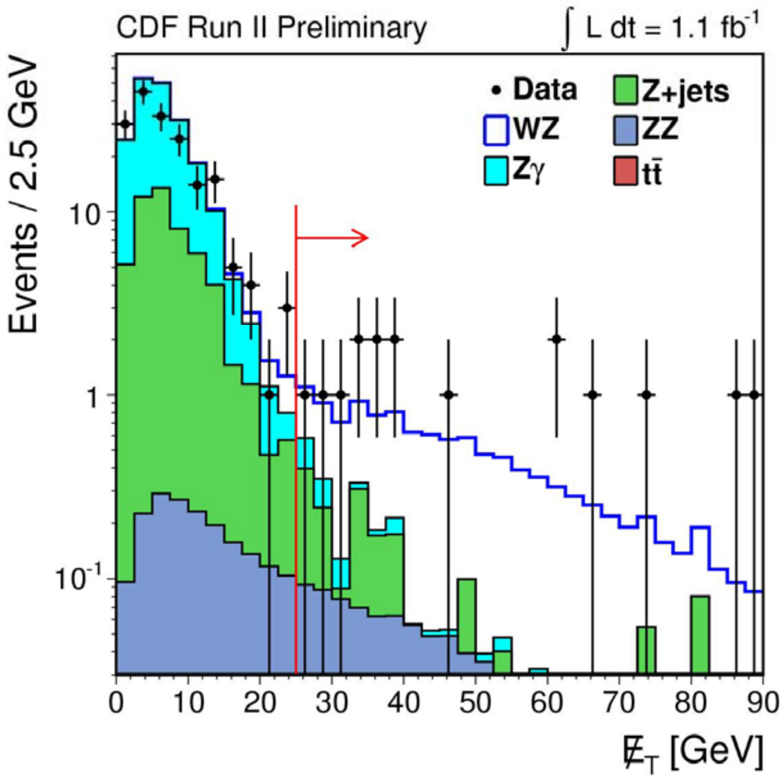
1.1 fb^{-1}

- Search $W^{\pm}Z$ in final state with 3 leptons and $\not{E}_T$
- The s-channel diagram provides sensitivity to the WWZ vertex coupling



$\sigma(\text{ppbar} \rightarrow WZ) = 5.0^{+1.8}_{-1.6}$ pb

5.9 σ significance



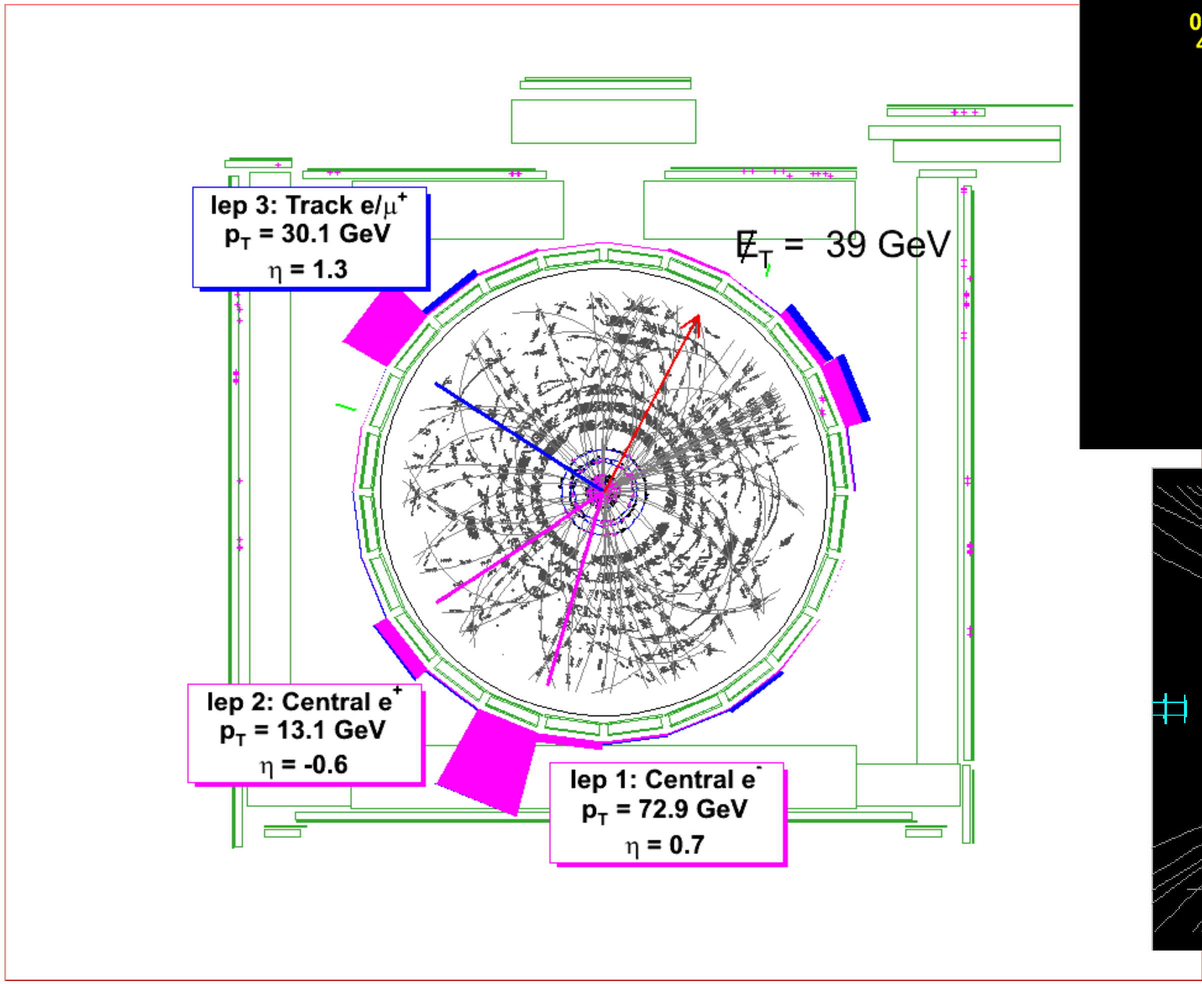
- Search ZZ in both 4l and 2l+2ν final states

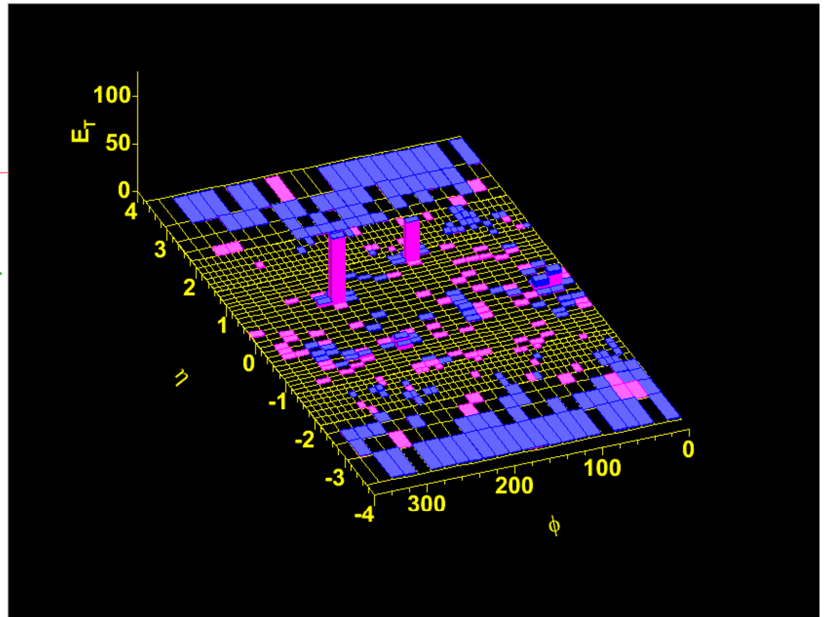
$\sigma(\text{ppbar} \rightarrow ZZ) = 0.75^{+0.71}_{-0.54}$ pb

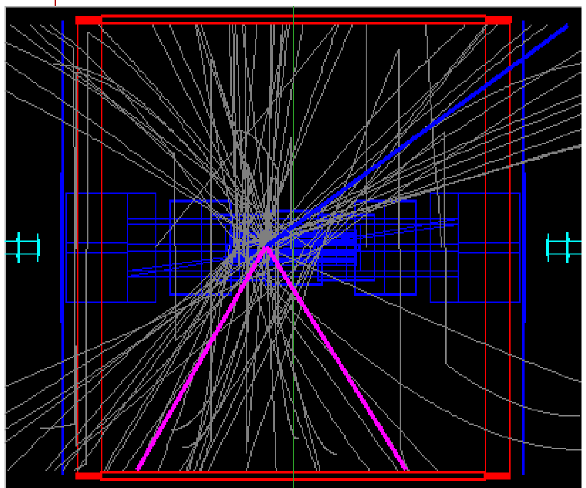
3.0 σ significance

Diboson: WZ event

Run = 202135   Event = 2529864



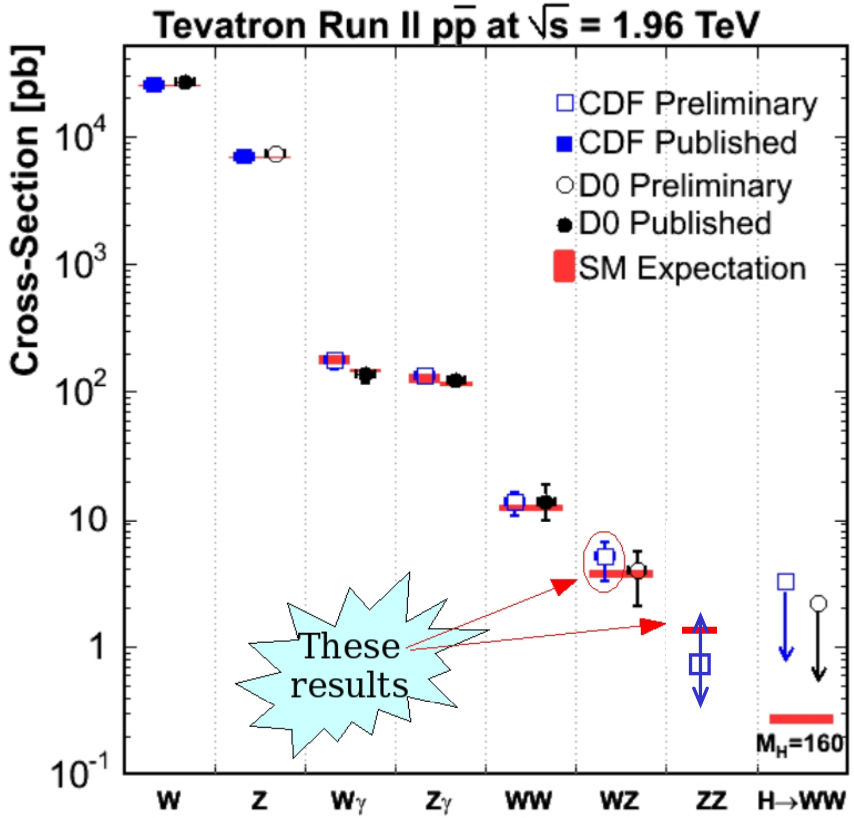




Diboson

Source	Expectation ± Stat ± Syst ± Lumi
Z+jets	1.22 ± 0.27 ± 0.28 ± -
ZZ	0.89 ± 0.01 ± 0.09 ± 0.05
$Z\gamma$	0.48 ± 0.06 ± 0.15 ± 0.03
$t\bar{t}$	0.12 ± 0.01 ± 0.01 ± 0.01
WZ	9.79 ± 0.03 ± 0.31 ± 0.59
Total Background	2.70 ± 0.28 ± 0.33 ± 0.09
Total Expected	12.50 ± 0.28 ± 0.46 ± 0.68
Observed	**16**

Source	Expectation ± Stat ± Syst ± Lumi
Z+jets	0.007 ± 0.007 ± 0.004 ± -
$Z\gamma\gamma$	0.002 ± 0.001 ± 0.000 ± 0.000
ZZ	1.884 ± 0.015 ± 0.061 ± 0.113
Total Background	0.009 ± 0.007 ± 0.004 ± 0.000
Total Expected	1.893 ± 0.017 ± 0.062 ± 0.113
Observed	**1**



Togheter with Z+b these are the smallest cross sections measured at Tevatron to date

... waiting to discover the Higgs!

Conclusions

- Tevatron is providing excellent data to study Physics with W and Z bosons
- These kind of studies are of particular interest in Higgs and New Physics searches
- Significant improvements expected with increased integrated luminosity and applying fine tuned tools to next generation of analysis

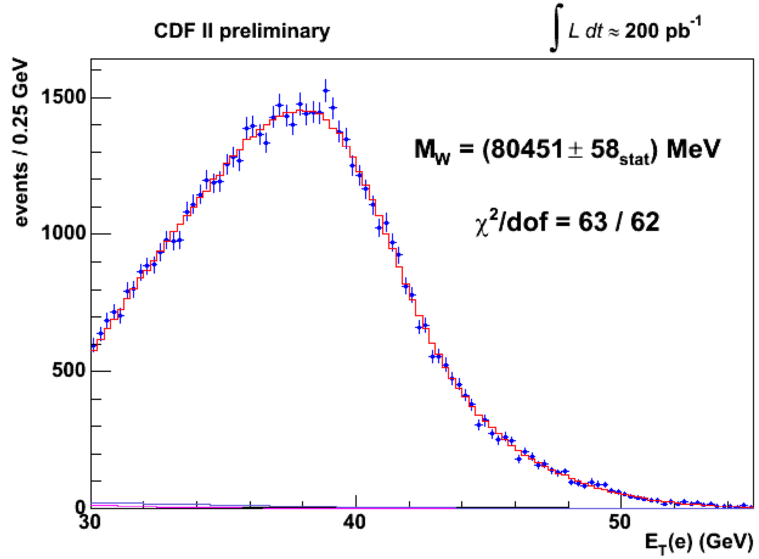
Backup

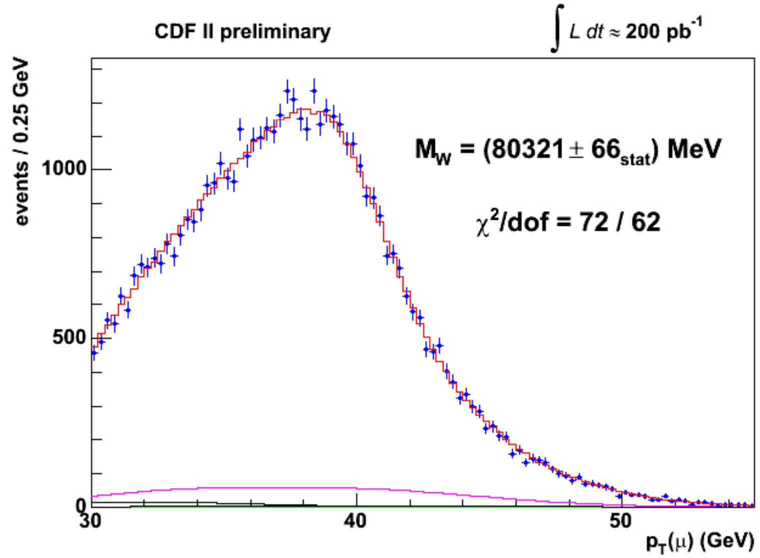
W Mass - P_T fit and uncertainties

M_W = 80388 ± 59 MeV

CDF II preliminary $L = 200\ pb^{-1}$

p_T Uncertainty [MeV]	Electrons	Muons	Common
Lepton Scale	30	17	17
Lepton Resolution	9	3	0
Recoil Scale	17	17	17
Recoil Resolution	3	3	3
$u_{\parallel}$ Efficiency	5	6	0
Lepton Removal	0	0	0
Backgrounds	9	19	0
$p_T(W)$	9	9	9
PDF	20	20	20
QED	13	13	13
Total Systematic	45	40	35
Statistical	58	66	0
Total	73	77	35





W Mass - $\not{E}_T$ fit and uncertainties

M_W = 80434 ± 65 MeV

CDF II preliminary L = 200 pb^{-1}

MET Uncertainty [MeV]	Electrons	Muons	Common
Lepton Scale	30	17	17
Lepton Resolution	9	5	0
Recoil Scale	15	15	15
Recoil Resolution	30	30	30
$u_{\|\|}$ Efficiency	16	13	0
Lepton Removal	16	10	10
Backgrounds	7	11	0
$p_T(W)$	5	5	5
PDF	13	13	13
QED	9	10	9
Total Systematic	54	46	42
Statistical	57	66	0
Total	79	80	42