Electroweak Measurements (including Dibosons) at the Tevatron

Andrew Askew
Florida State University
for the:

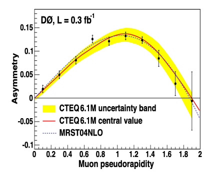
and

experiments.

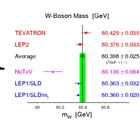
La Thuile 2008

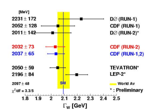
A Survey:

- I will provide an overview some of the most recent/most impressive results from the DØ and CDF experiments from Run II.
- Analyses use from 0.2-1.9 fb^{-1}.
  - W:
    - Charge Asymmetry

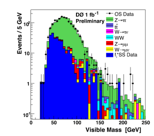


    - Mass/Width

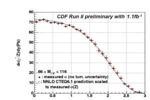




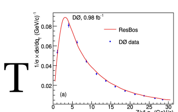
  - Z:
    - Z->ττ



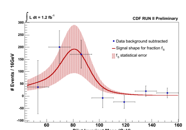
    - dσ/dy



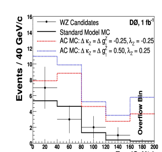
    - dσ/dp$_T$



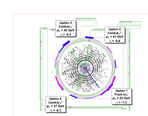
  - Diboson:
    - WW/WZ->lνjj



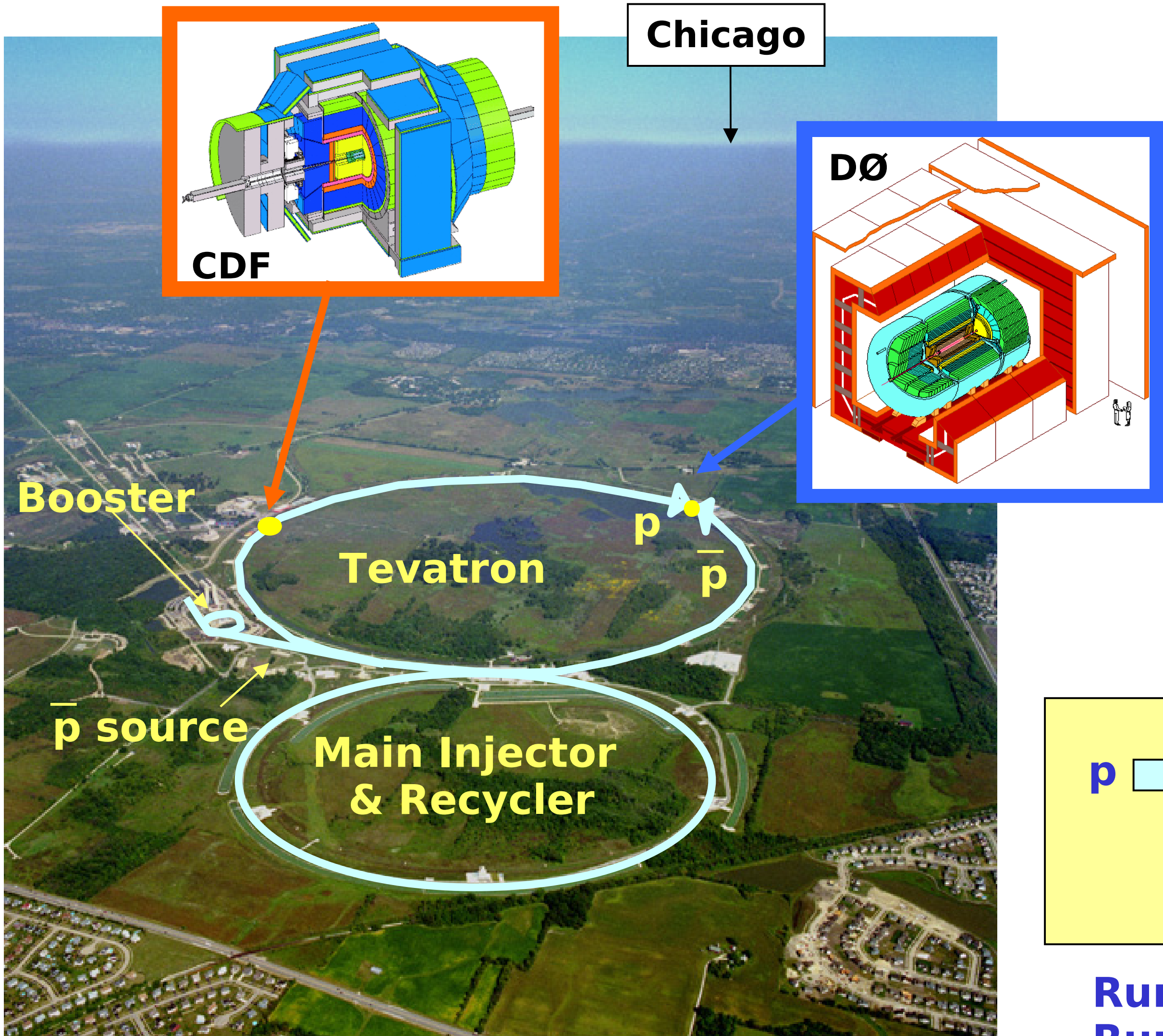
    - WZ



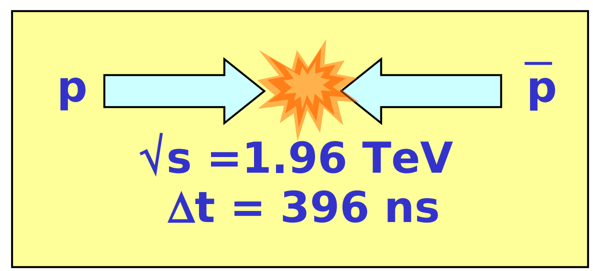
    - ZZ



The Tevatron:

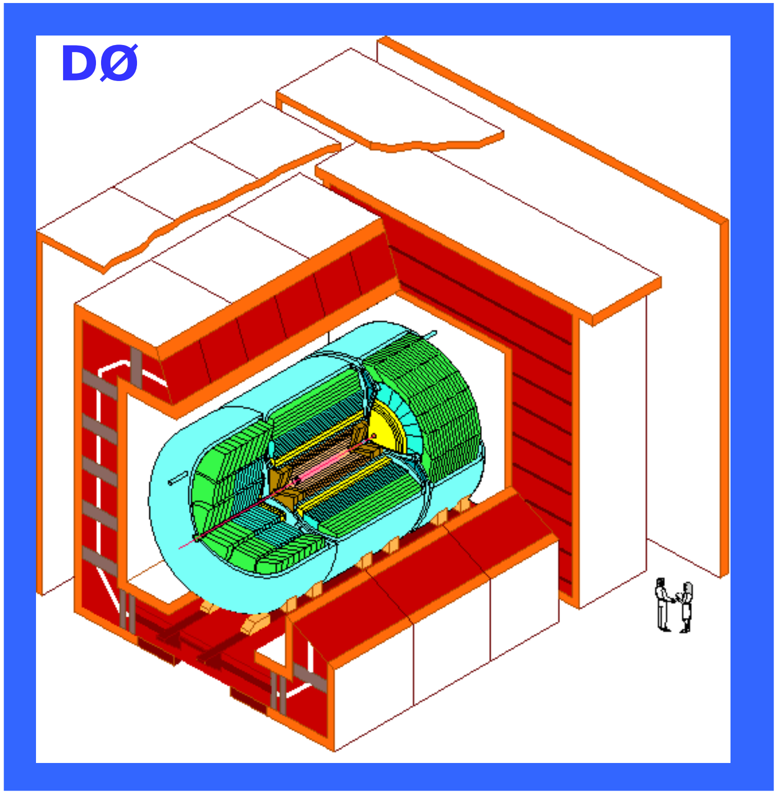


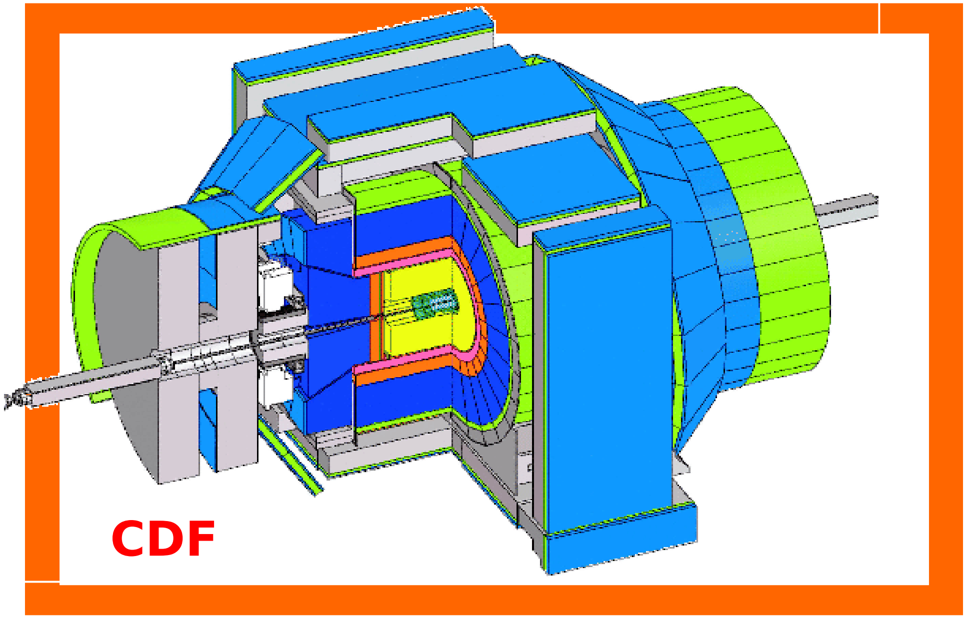
- Vector boson factory
- L~30pb^{-1}/ week:
  - ~700,000 W
  - ~150,000 Z
  - ~400 WW, ~120 WZ, ~50 ZZ



Run I 1992-96
Run II 2001-09

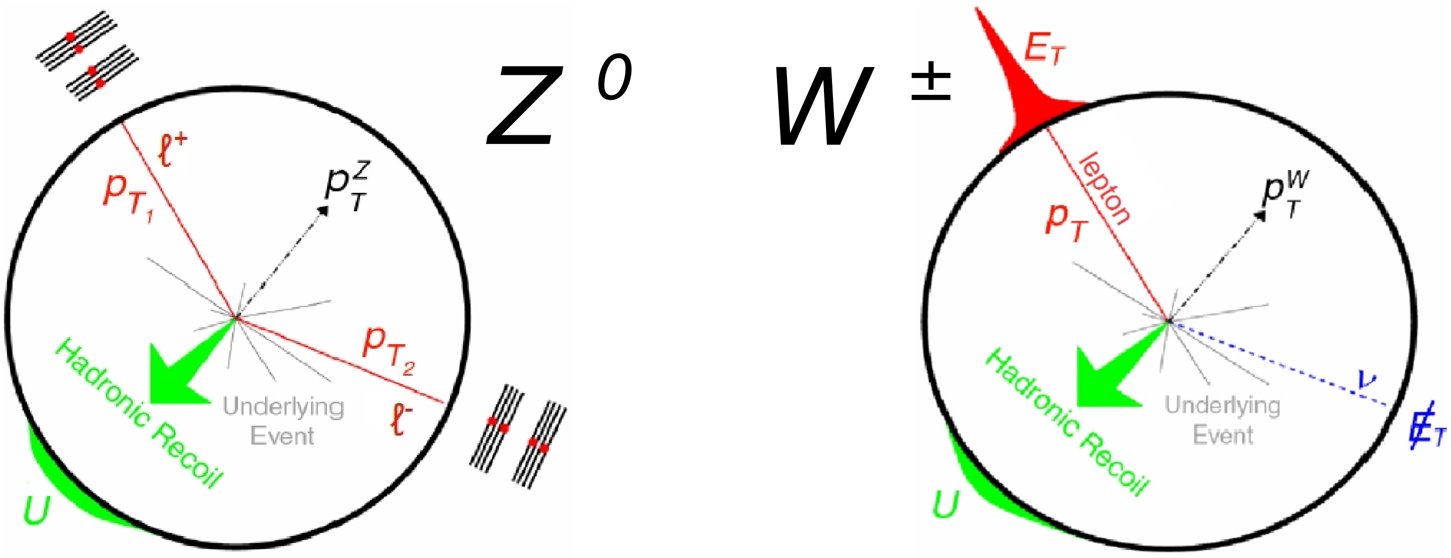
The Detectors:





- No talk is complete without at least the pictures of our beloved detectors.

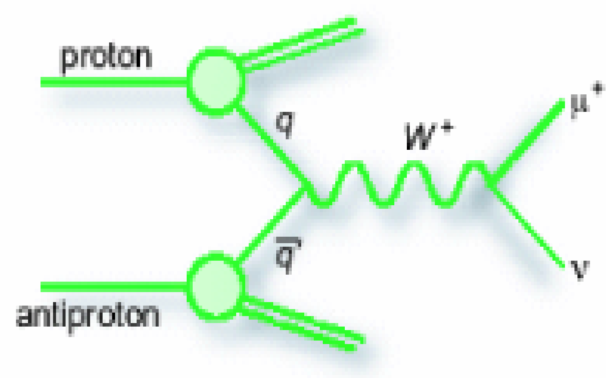
A Word about…

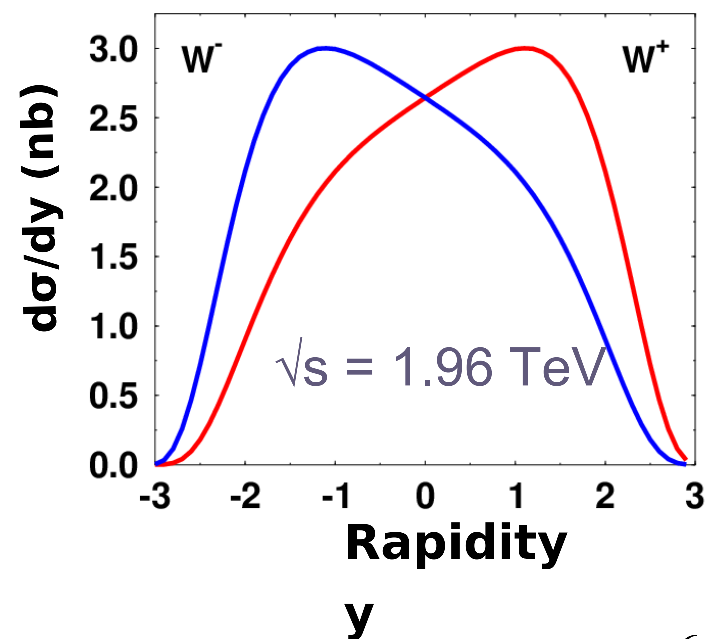


- Due to large backgrounds from hadronic jets, W and Z events are typically reconstructed in leptonic decays (e, μ, and sometimes τ).

W Charge Asymmetry:

- u-quark typically carries more of the proton momentum than d-quark.
- Asymmetry sensitive to the momentum distribution within proton.





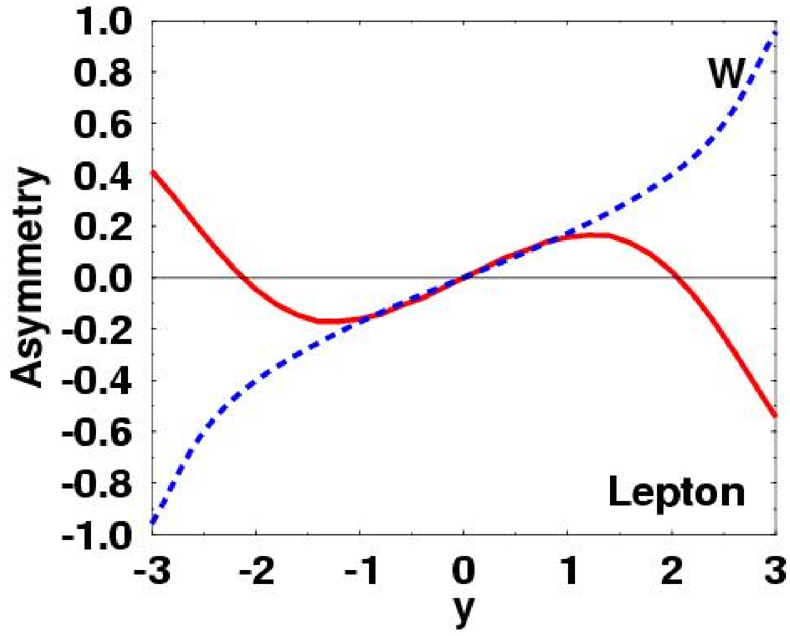
Two Different Approaches:

- One can make assumptions on ν_e p_Z, and solve for the W rapidity.

$$A(y) = \frac{d\sigma(W^+)/dy - d\sigma(W^-)/dy}{d\sigma(W^+)/dy + d\sigma(W^-)/dy}$$

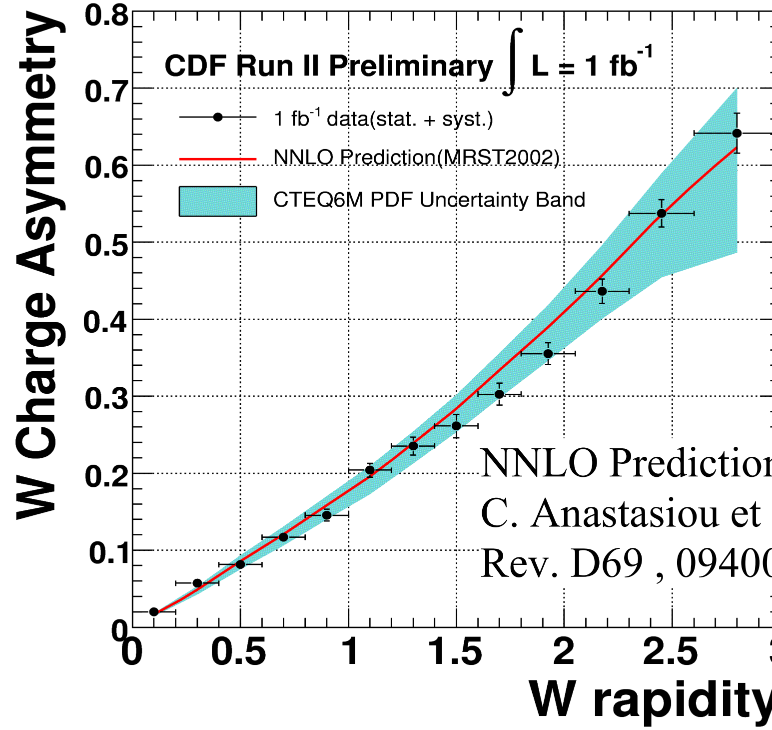
- Or one can simply form the lepton asymmetry.

$$A(\eta_l) = \frac{d\sigma(l^+)/d\eta - d\sigma(l^-)/d\eta}{d\sigma(l^+)/d\eta + d\sigma(l^-)/d\eta}$$

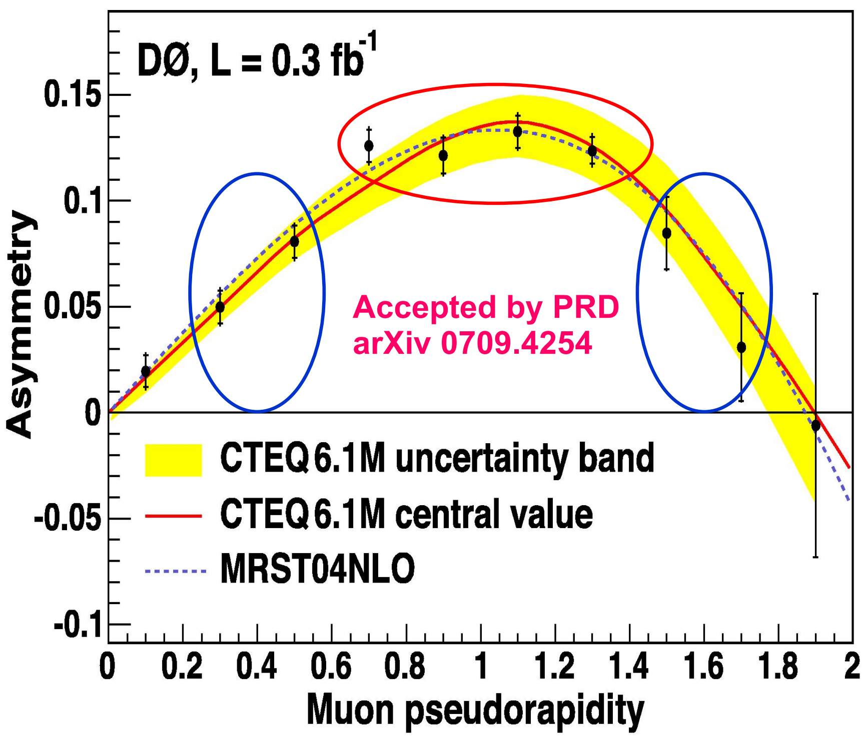


Two Different Results:

- CDF does the former, forming the W rapidity in electron channel.



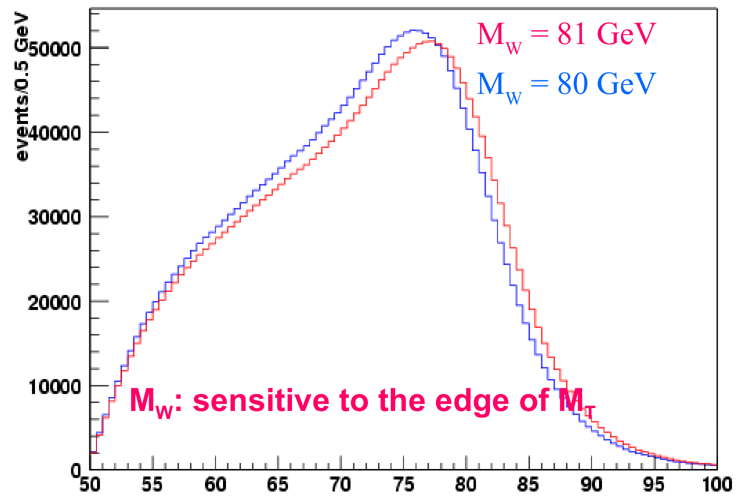
NNLO Prediction:
C. Anastasiou et al., Phys. Rev. D69 , 094008 (2004)

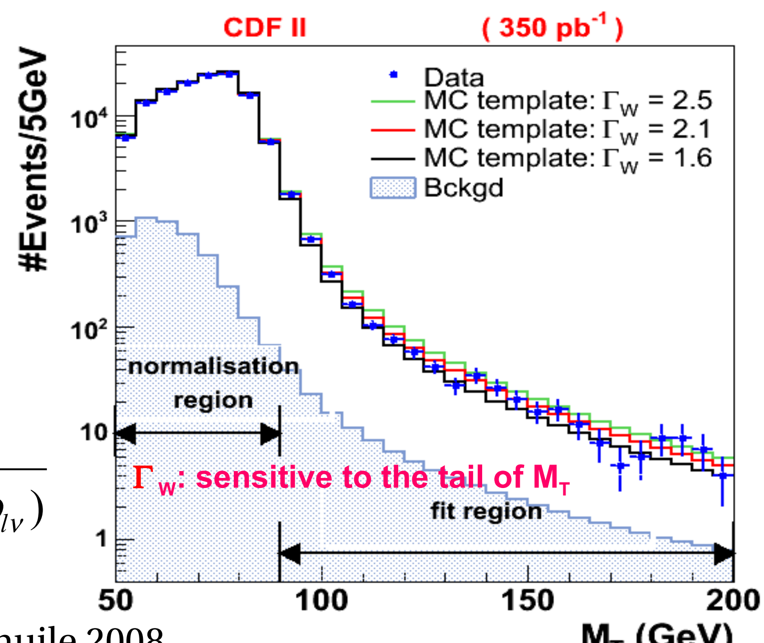


- DØ does the latter, lepton rapidity in μ channel.

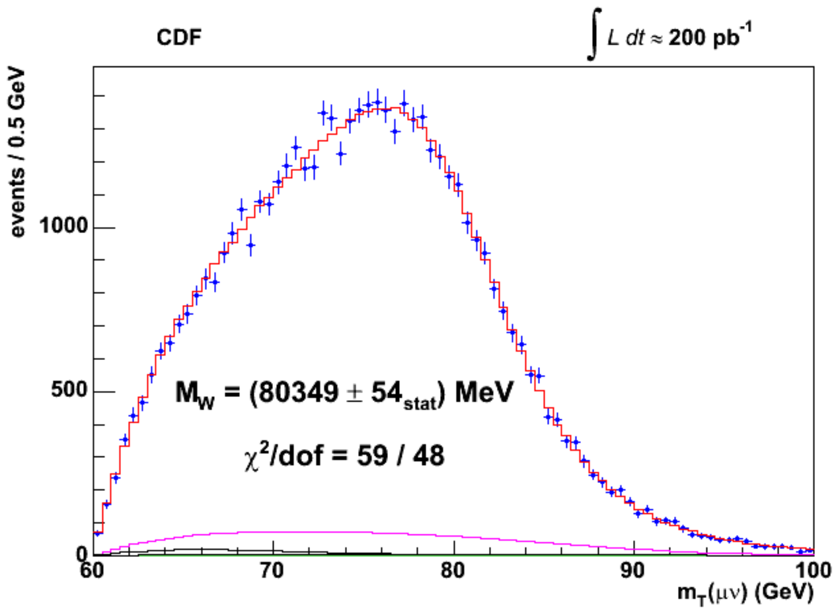
W Mass and Width:

- Sketch of method:
  - Build a parametrized simulation of the detector that incorporates all knowledge of both energy/momentum scale and resolution.
  - Generate distributions with different M_W, Γ_W.
  - Form W transverse mass distribution from the data. Compare. $M_T = \sqrt{2 p_T^{\,l} p_T^{\,\nu} (1 - \cos\phi_{l\nu})}$





Mass and Width Result



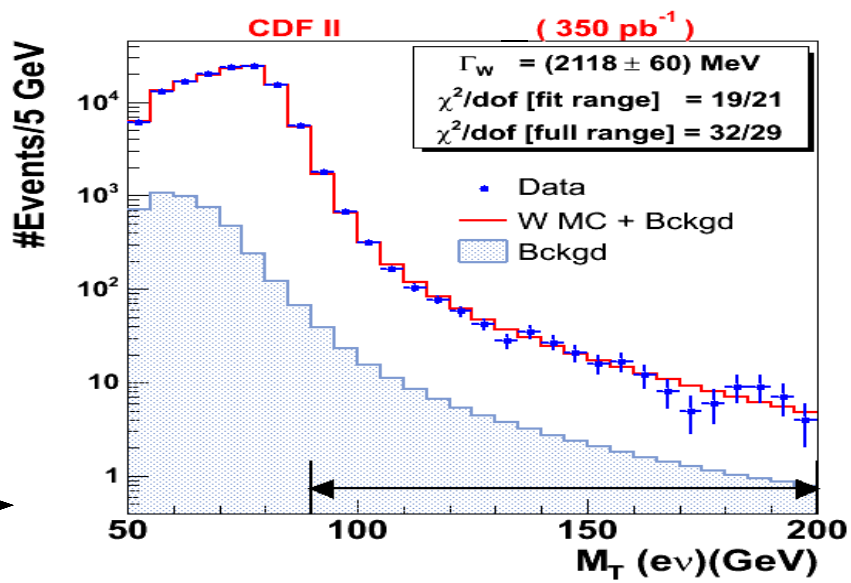
Transverse mass, μ channel

M_W = 80413±48 MeV

Single most precise measurement to date!

PRL 99, 151801 (2007)

Transverse mass, e channel

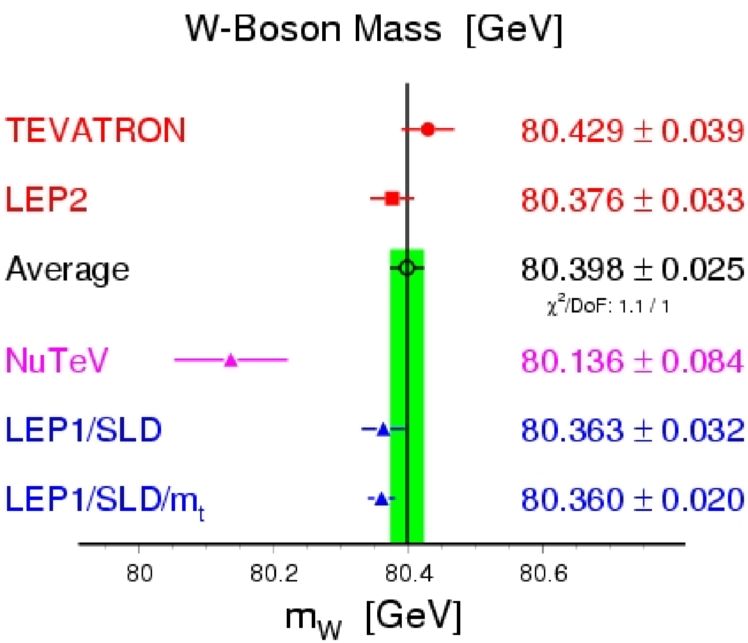


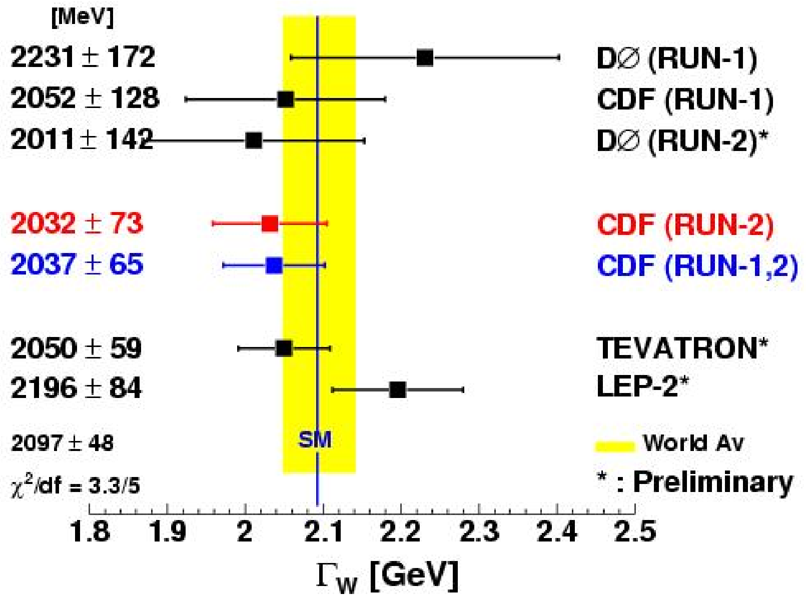
Γ_W = 2032 ± 73 (stat. + syst.) MeV

Most precise single direct measurement!

PRL 100, 071801 (2008)

Perspective:

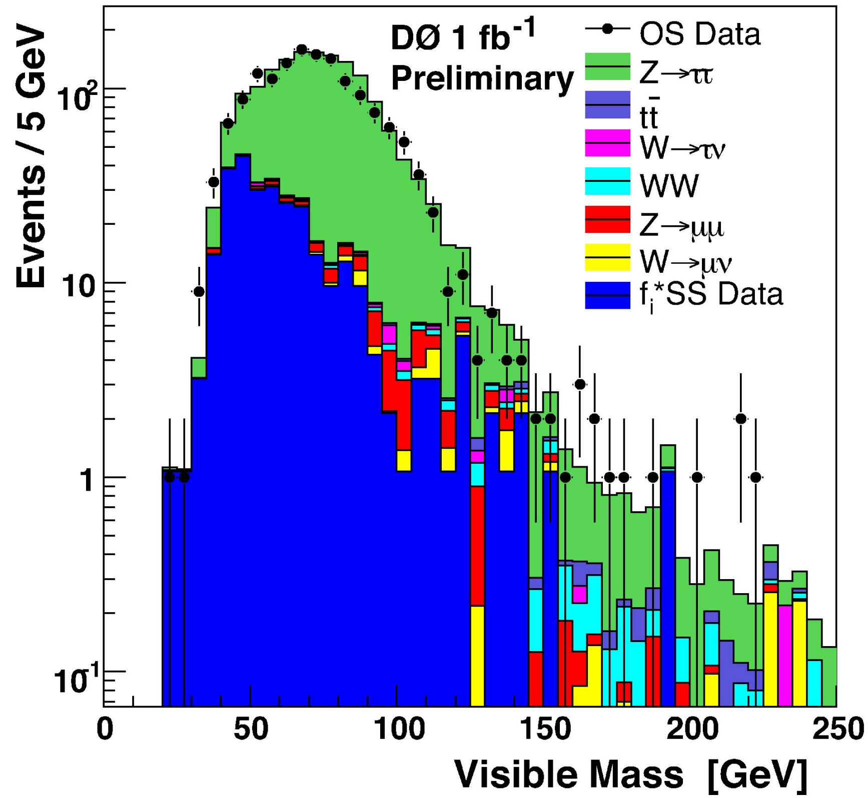




- The current state of the art.
  - Improvement in world average M_W by 15%.
  - Improvement in world average Γ_W by 22%.
  - And Run II isn't over yet...

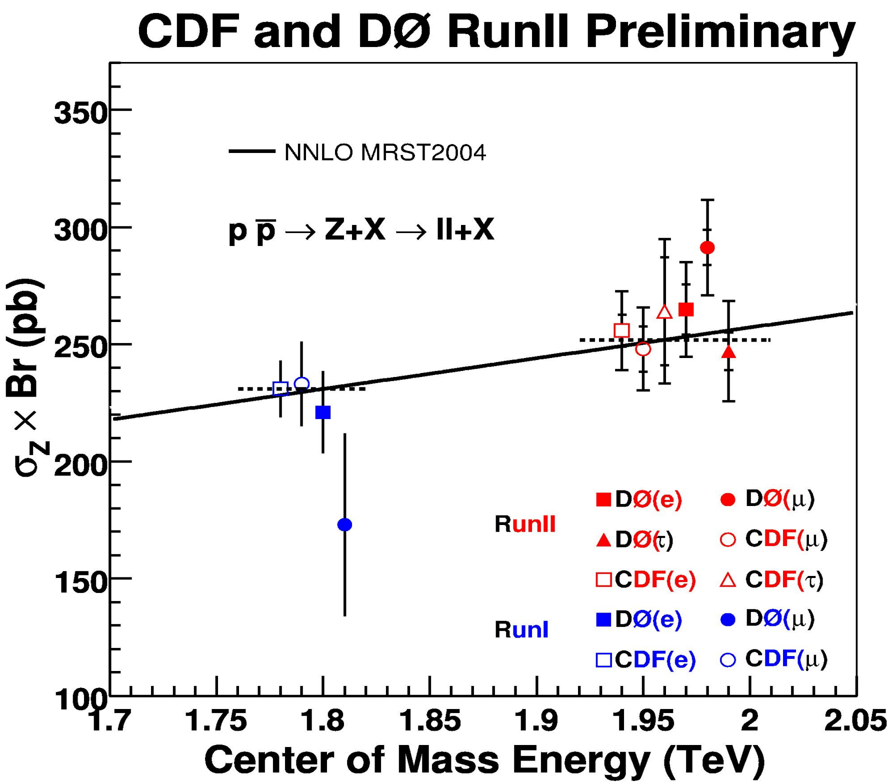
DØ Z->ττ

- Inclusive cross section measurement.
  - Require Z->ττ->$\mu\tau_{had}$.
- Important:
  - Verifies τ energy scale/efficiencies.
  - Provides sample of τ for triggering and systematic studies.
  - Important verification for, say, H->ττ.

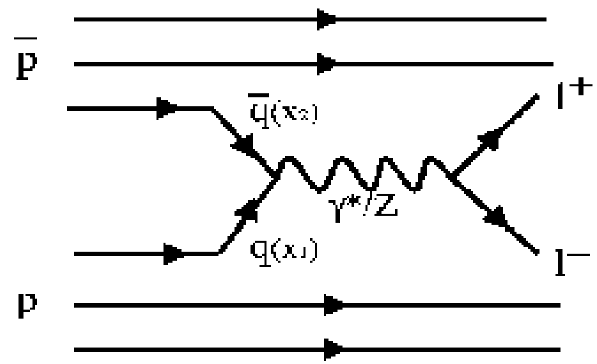


DØ Z->ττ (2)

- 1527 candidates, 20% background (1 fb^{-1}).
- $\sigma(p\bar{p}\to Z\to\tau\tau)$ = 247± 8 (stat.)± 13 (syst.)± 15 (lumi) pb.
- SM: $251.9^{+5}_{-11.8}$pb.

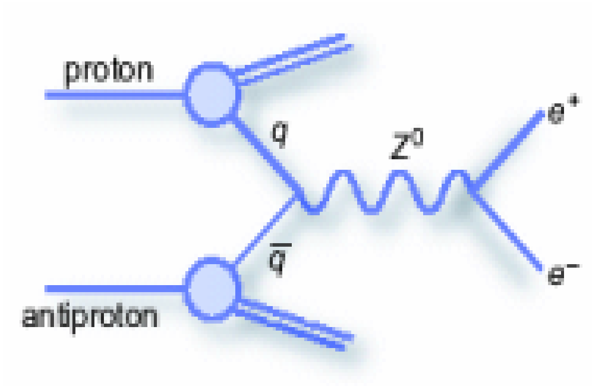


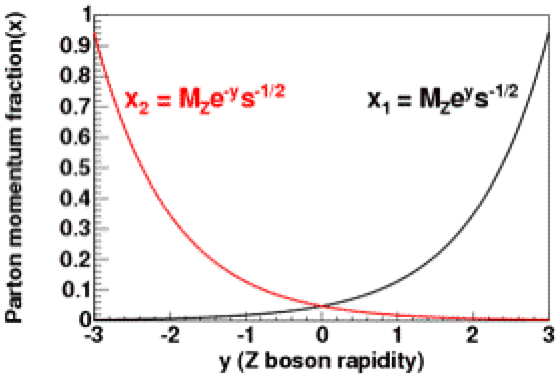
High Statistics of Z events:



- Through differential cross section measurements, one may probe different parts of the underlying production processes:
  - Z Rapidity: Parton distribution functions, and NLO calculations.
  - Z p_T: Theoretical prediction over the full range of p_T.
- Also: With high statistics of Z events, one can gain a better understanding of efficiencies and energy scale.

CDF Z rapidity:

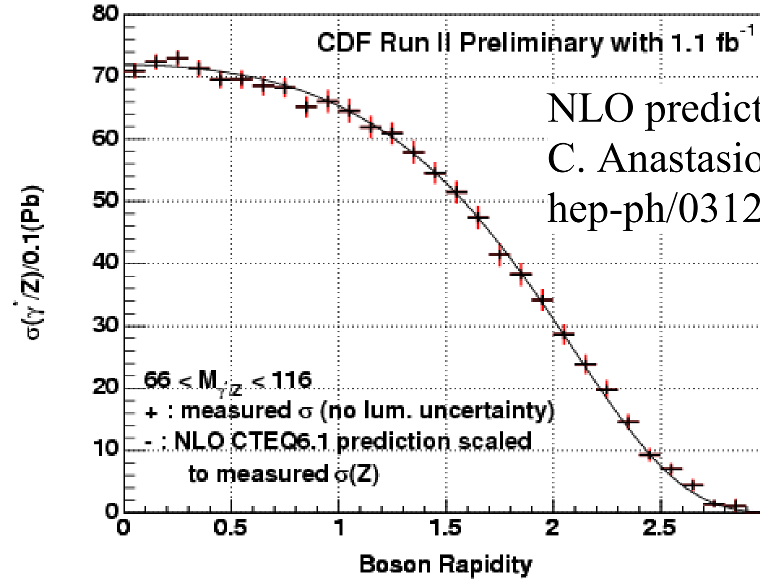




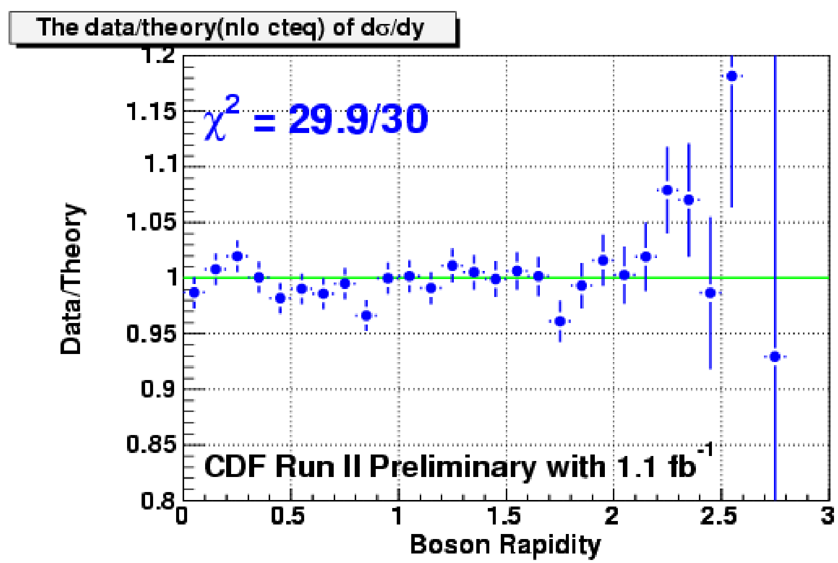
- At leading order, sensitive to PDFs:
  - Partons carry different momentum fractions, which then affect the rapidity of the produced γ^*/Z.
- At next-to-leading order, one starts including gluons in the initial state, which also alter the rapidity of the produced γ^*/Z, and thus this measurement gives a test of these calculations.

CDF Z Rapidity (2)

- ~91K γ^*/Z candidates $(66 < M_{ee} < 116)$, with small backgrounds.
- Coverage extending to 2.8 in y_Z.
- Most consistent with the NLO prediction (using CTEQ6.1 PDFs).

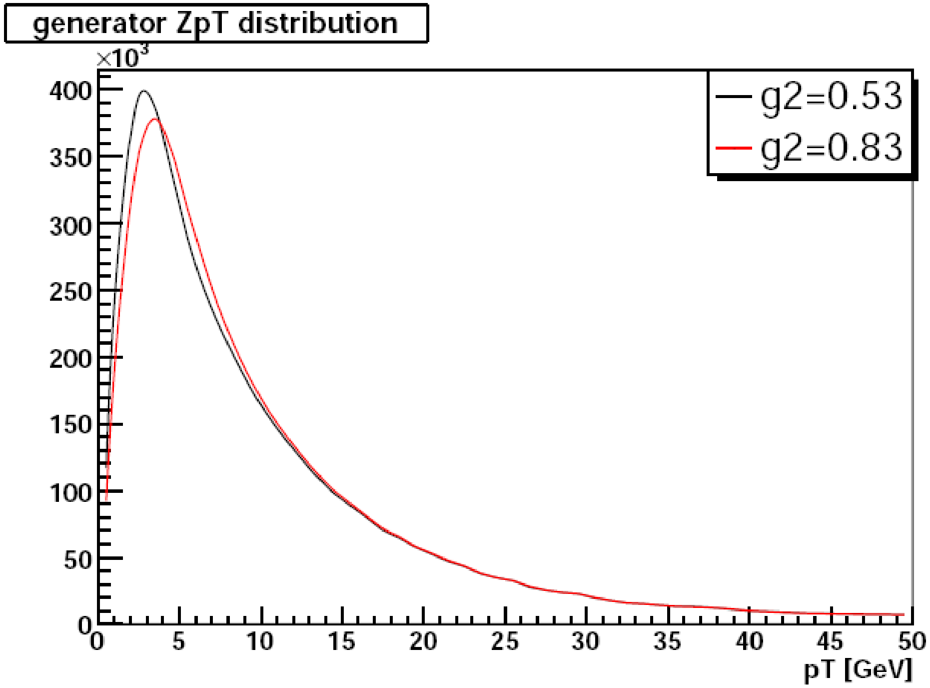


NLO prediction:
C. Anastasiou et. al,
hep-ph/0312266



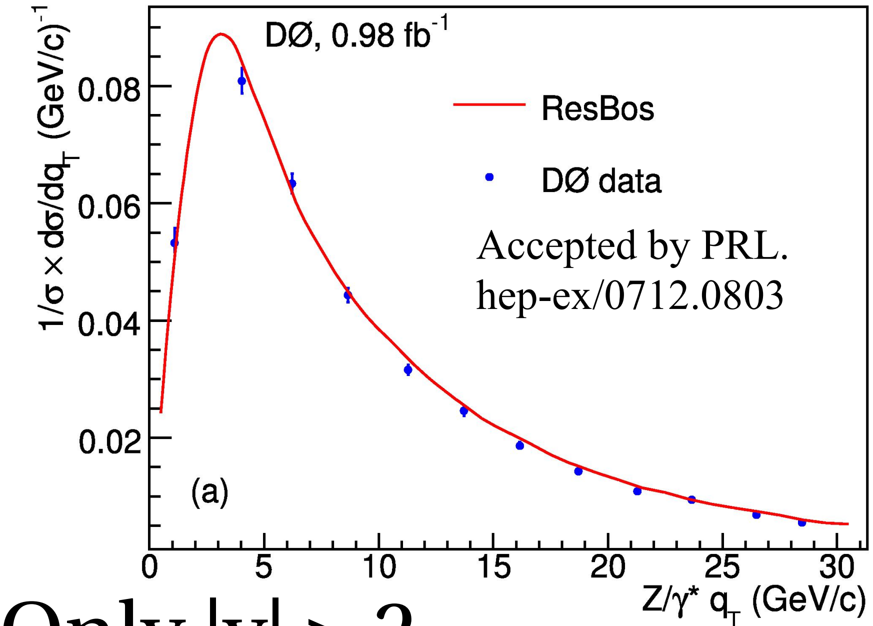
DØ Z p_T measurement

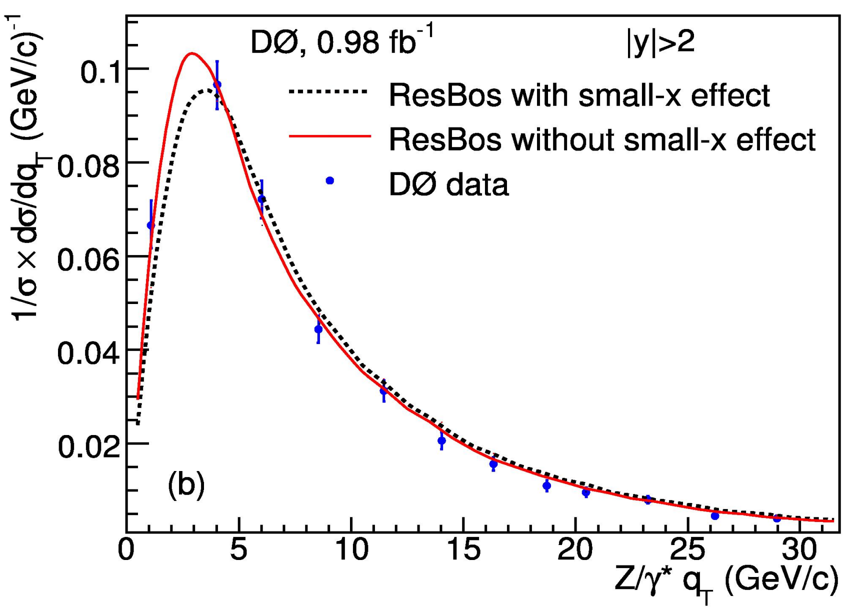
- Setting aside the rapidity, focusing only on the p_T, gives different information:
  - High p_T region is dominated by perturbation theory.
  - Low p_T region is the realm of resummation.



DØ Z p_T measurement (low p_T):

- All rapidity, comparison of data and ResBos NLO MC.

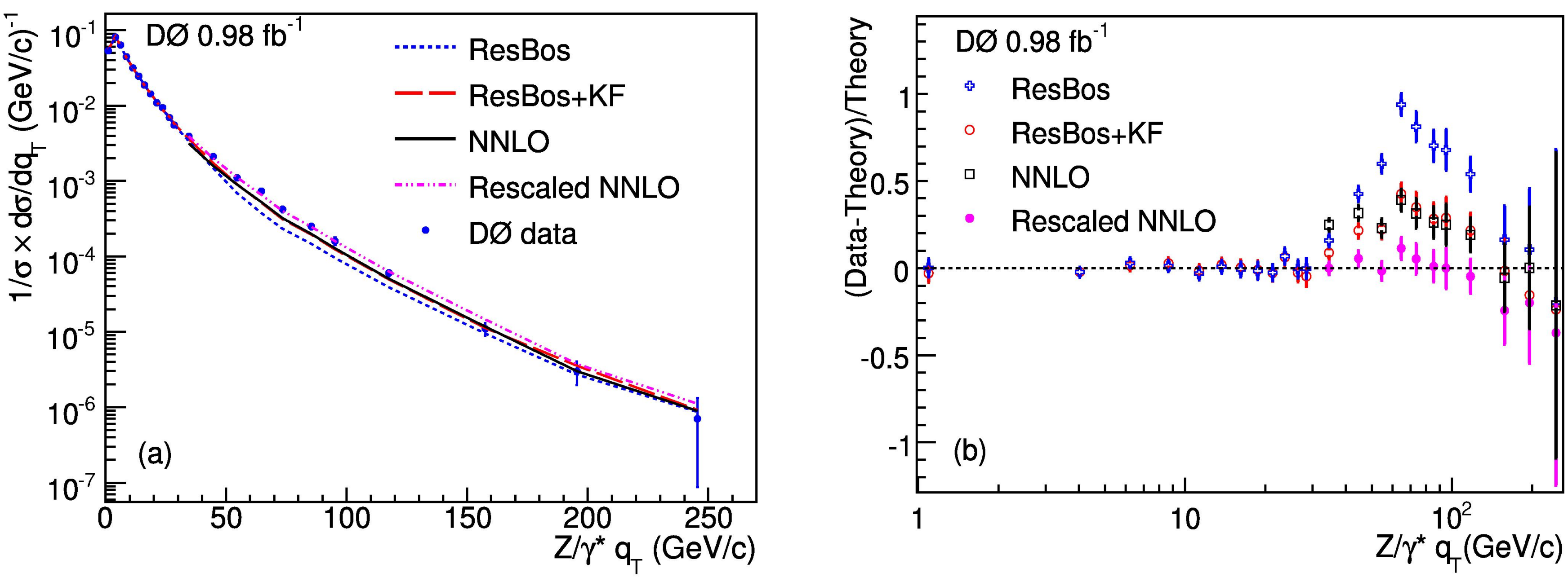




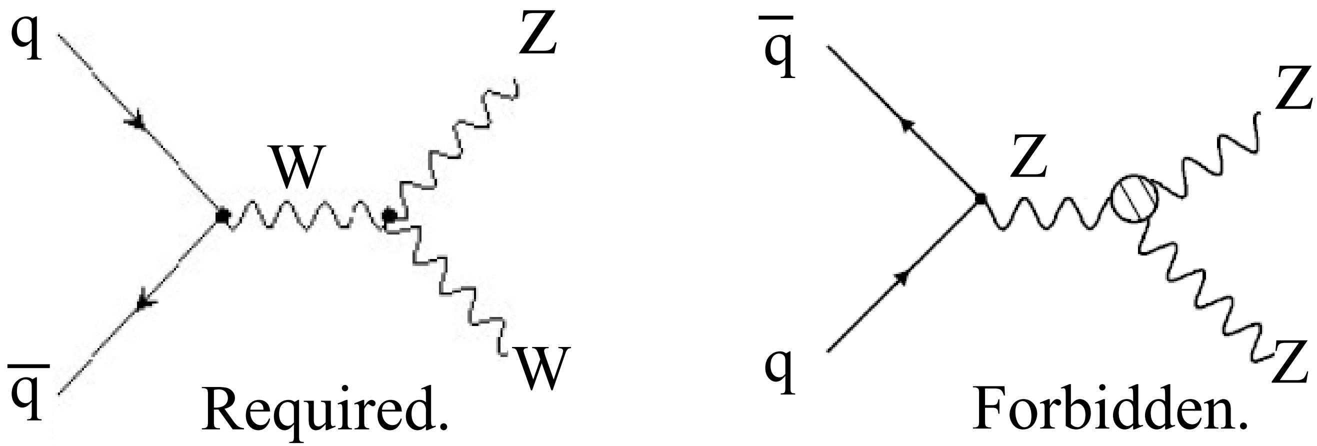
- Only |y| > 2, comparison of ResBos, and optional low x-broadening.

DØ Z p_T measurement (high p_T):

- Highest center of mass energy measurement of this cross section over this large phase space.
- Data agrees in shape with NNLO prediction.



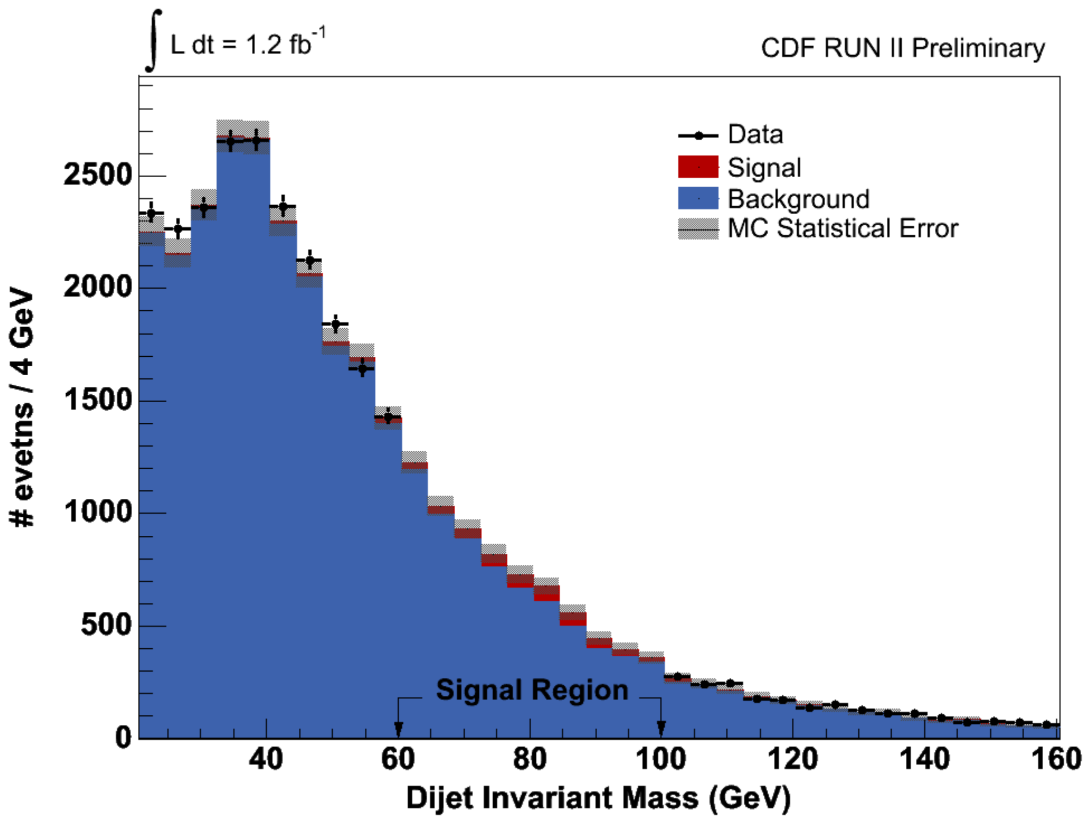
Diboson Production:



- Search for pairs of bosons:
  - Trilinear boson vertices (like $W\gamma$, WZ) are a feature of the Standard Model (required!).
  - There are also instances where these are forbidden (ZZ, $Z\gamma$).
  - Any deviation is new physics.

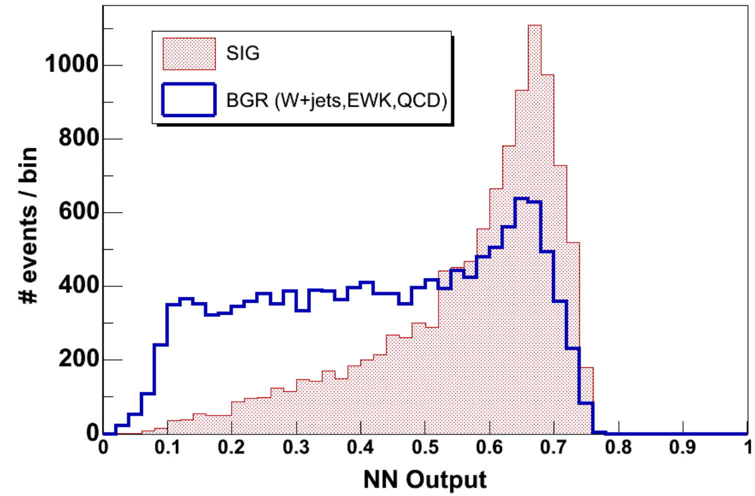
CDF WZ/WW->lνjj

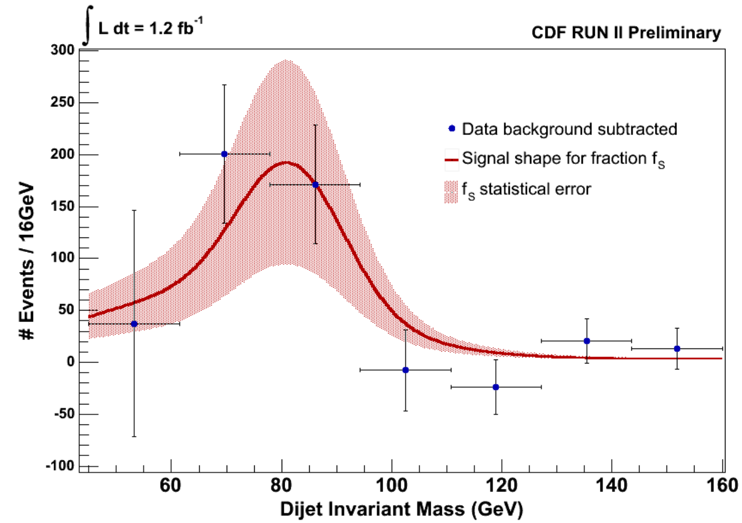
- Good: High branching fraction.
- Bad: HIGH backgrounds from W+jets.



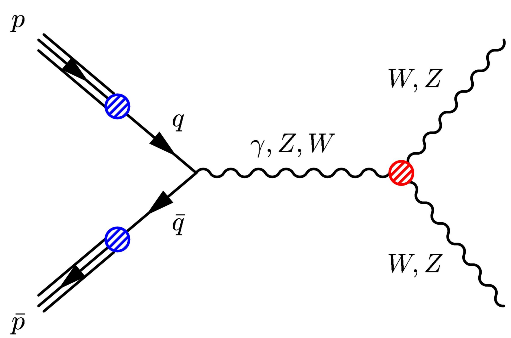
Dig into the background:

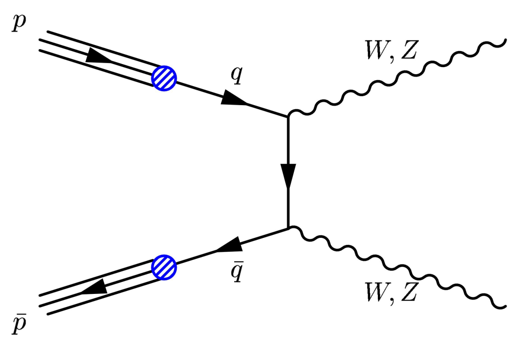
- Appeal to NN to extract as much as possible from data.
- Fit NN output to determine signal fraction.
- $N_{Signal} = 410 \pm 212(\text{stat}) \pm 107(\text{sys})$ signal events
- Cross section limit $\sigma_{WZ/WW} \times BR < 2.88$ pb.





WZ->lllν



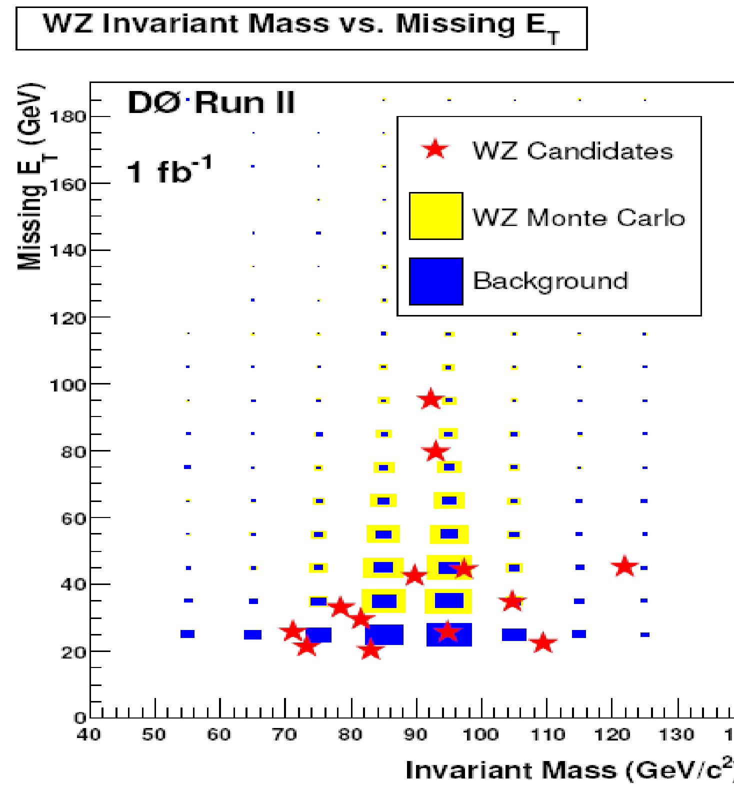


- WZ probes the WWZ coupling.
  - Very clean analysis, low backgrounds via leptonic Z peak.
  - Analysis is VERY dependent on lepton efficiency (ZZ will be as well).

DØ WZ Results

- 13 candidate events (1.0 fb^{-1}).
- $\sigma(WZ) = 2.7^{+1.7}_{-1.3}\,\text{pb}$

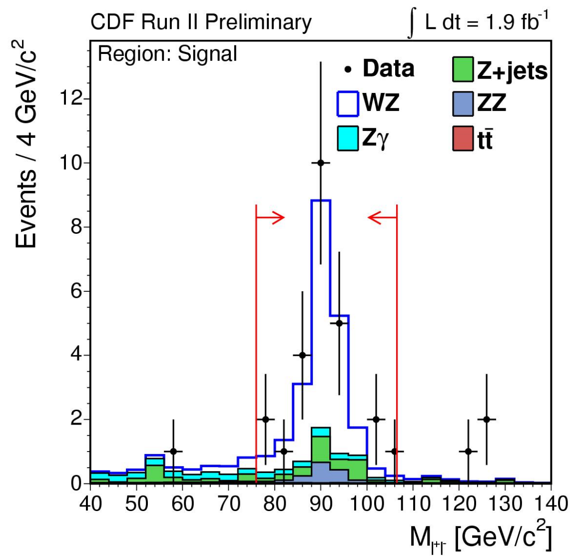
Final State	Number of Candidate Events	Expected Signal Events	Estimated Background Events	Overall Efficiency
eee	2	2.3 ± 0.2	1.2 ± 0.1	0.16 ± 0.02
$ee\mu$	1	2.2 ± 0.2	0.46 ± 0.03	0.17 ± 0.02
$\mu\mu e$	8	2.2 ± 0.3	2.0 ± 0.4	0.17 ± 0.03
$\mu\mu\mu$	2	2.5 ± 0.4	0.86 ± 0.06	0.21 ± 0.03
Total	13	9.2 ± 1.0	4.5 ± 0.6	–



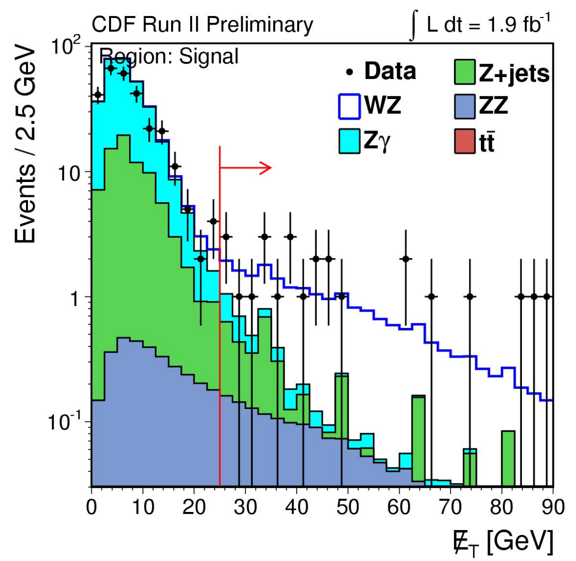
PRD 76, 111104(R) (2007)

CDF WZ results

- 25 candidate events (1.9 fb^{-1}).
- $\sigma = 4.3^{+1.3}_{-1.0}(\text{stat}) \pm 0.4(\text{syst.}+\text{lumi.})\text{pb}$

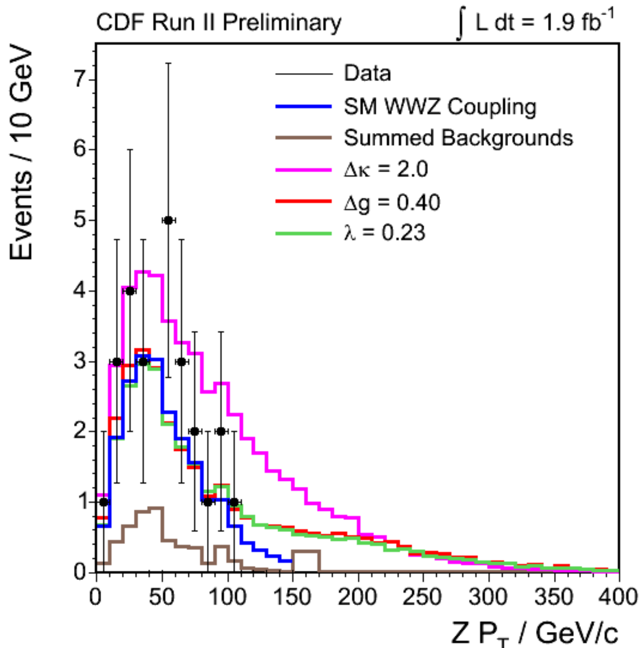


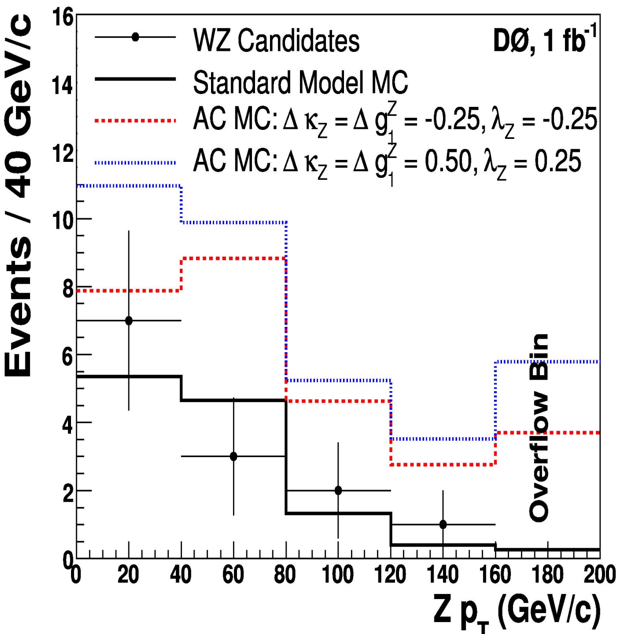
Source	Expected ± Stat ± Syst ± Lumi
Z+jets	2.45 ± 0.48 ± 0.48 ± 0.00
ZZ	1.53 ± 0.01 ± 0.16 ± 0.09
$Z\gamma$	1.03 ± 0.06 ± 0.35 ± 0.06
$t\bar{t}$	0.17 ± 0.01 ± 0.03 ± 0.01
WZ	16.45 ± 0.03 ± 1.74 ± 0.99
Total	21.63 ± 0.48 ± 2.25 ± 1.15
Observed	**25**



WZ AC Limits:

- Both experiments use the Z p_T spectrum to set limits on anomalous couplings.





CDF **Λ=2.0 TeV**

$-0.13<\lambda_Z<0.14$

$-0.15<\Delta g_1^Z<0.24$

$-0.82<\Delta\kappa_Z<1.27$

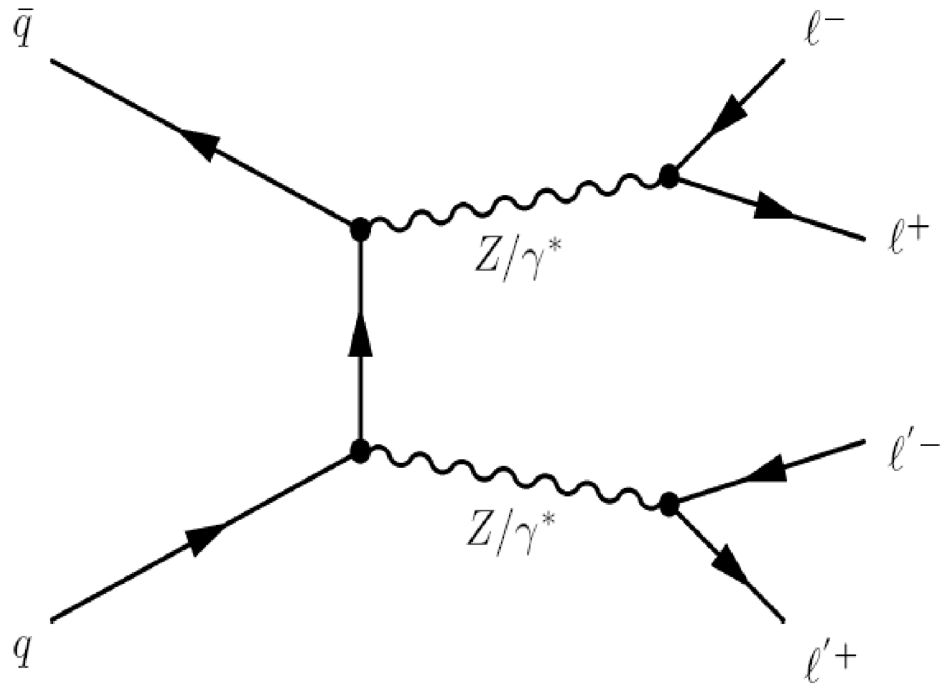
DØ **Λ=2.0 TeV**

$-0.17<\lambda_Z<0.21$

$-0.14<\Delta g_1^Z<0.34$

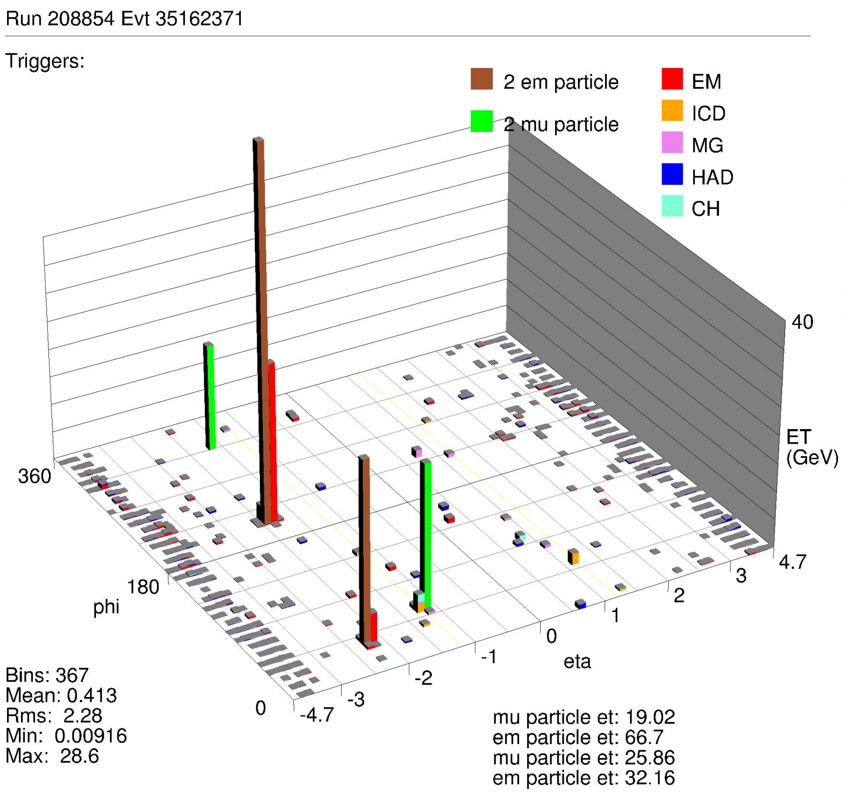
$-0.12<\Delta\kappa_Z=\Delta g_1^Z<0.29$

Turning to ZZ->llll:



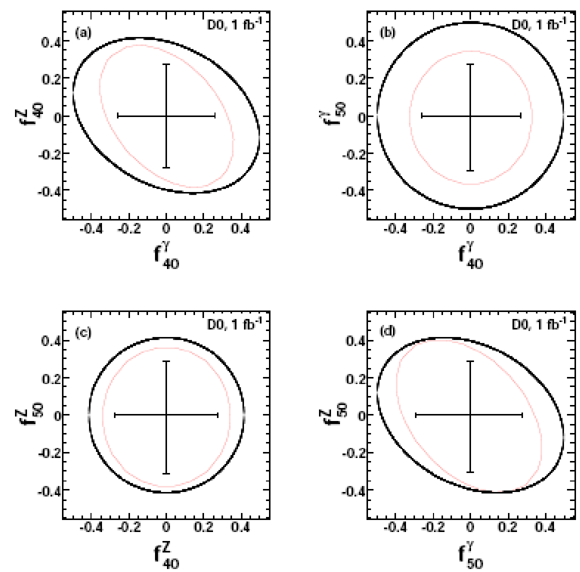
- Conceptually simple, take WZ analysis, remove missing E_T, and require an additional lepton.
- ZZ should have no trilinear term (whereas WZ does).

DØ ZZ->llll

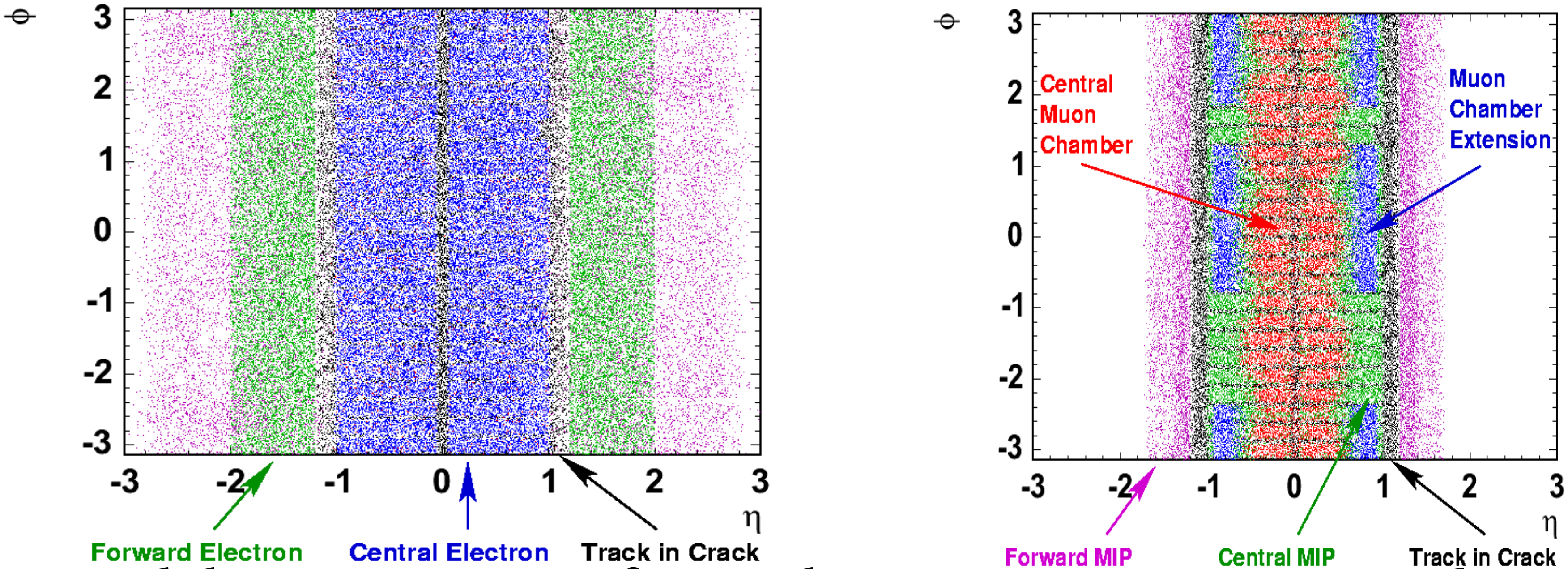


hep-ex/0712.0599

- DØ experiment observes one 4 lepton event after full selection cuts.
- $\sigma_{ZZ} < 4.4$ pb.
- First ZZ AC bounds from Tevatron:



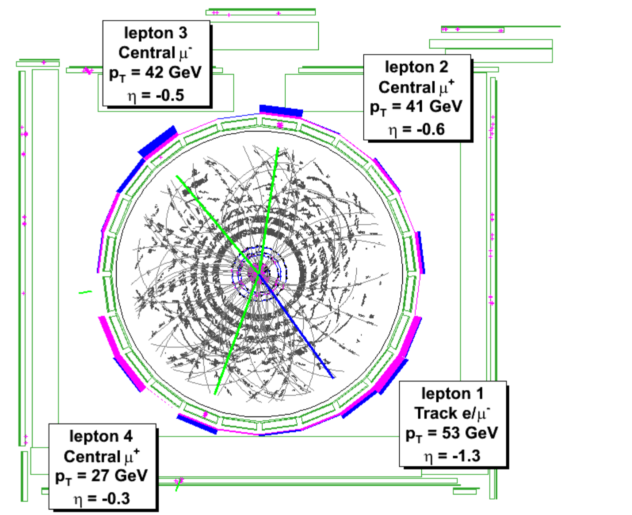
CDF ZZ results



- Build a more uniform lepton acceptance by forming leptons from all the available information.

CDF ZZ->llll

- 3 candidates, on less than 0.1 background.
- 4.2 σ significance!
- $\sigma_{ZZ} = 1.4^{+0.7}_{-0.6}$ pb.



hep-ex/0801.4806

Category	Candidates without a trackless electron	Candidates with a trackless electron
ZZ	$1.990 \pm 0.013 \pm 0.210$	$0.278 \pm 0.005 \pm 0.029$
Z+jets	$0.014^{+0.010}_{-0.007} \pm 0.003$	$0.082^{+0.089}_{-0.060} \pm 0.016$
Total	$2.004^{+0.016}_{-0.015} \pm 0.210$	$0.360^{+0.089}_{-0.060} \pm 0.033$
Observed	**2**	**1**

Conclusions:

- Exciting times:
  - High statistics analyses making serious statements about theory.
  - Low cross section observations.
- And the data keeps coming!