DØ Results on Electroweak Measurements

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Lake Louise Winter Institute 2007

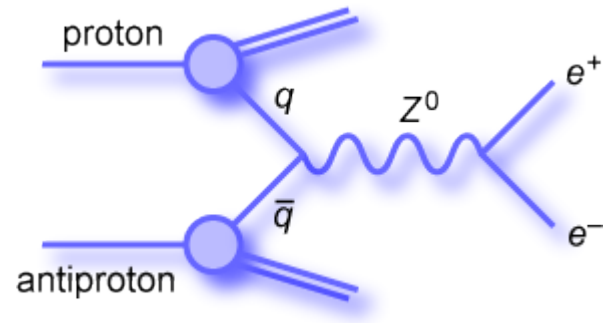
Outline

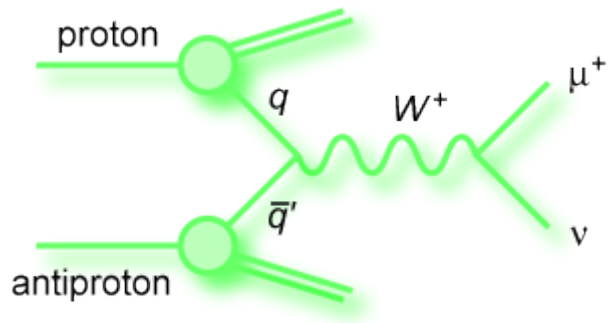
- Introduction
  - Electroweak physics at the Tevatron
  - The DØ detector
- Selected results
  - Z boson transverse momentum p_T
  - Z boson rapidity Y
  - WZ production
  - Wγ production
- Summary

Introduction

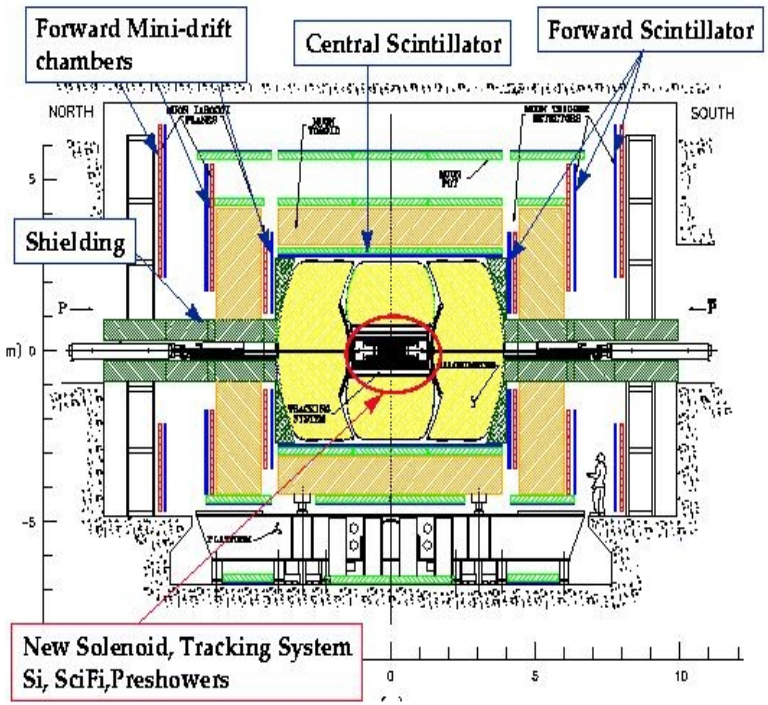
Electroweak Physics at the Tevatron

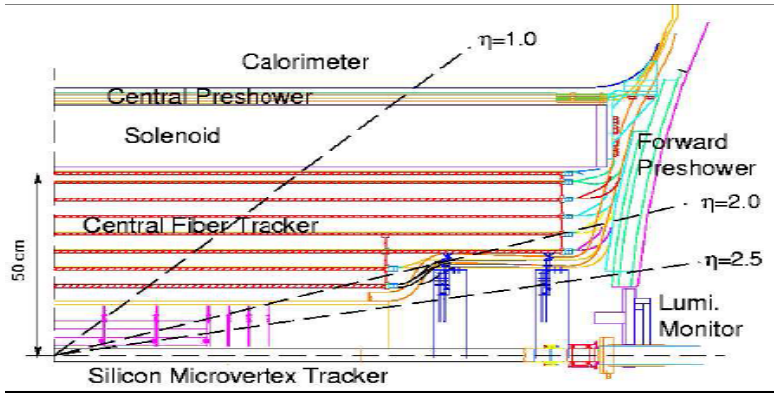
- test of the Standard Model
- higher order physics via Z p_T
- test of SM structure with di-bosons
- W mass constrains Higgs mass
- use W's and Z's for calibration
- reduce systematics in other measurements

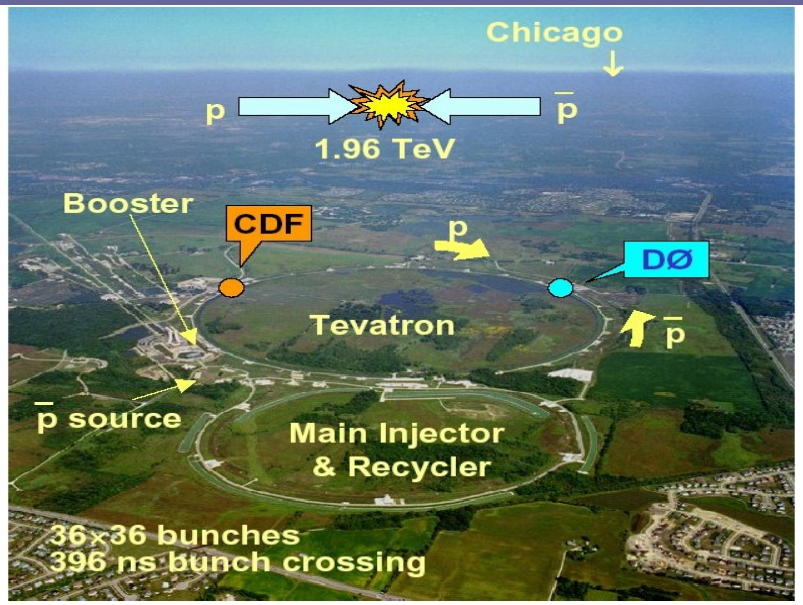




The DØ Detector



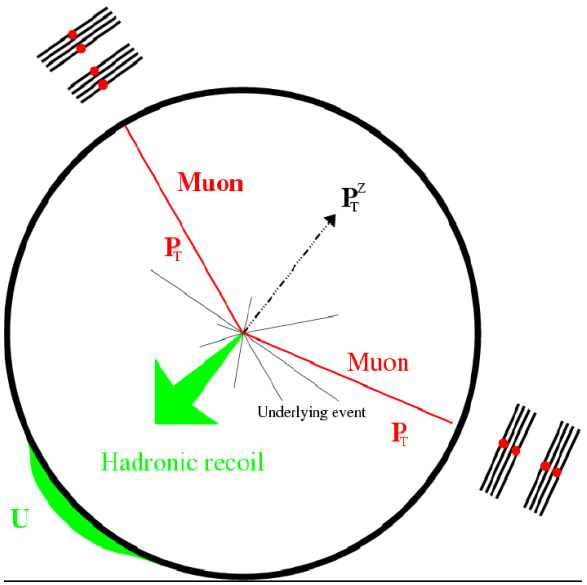


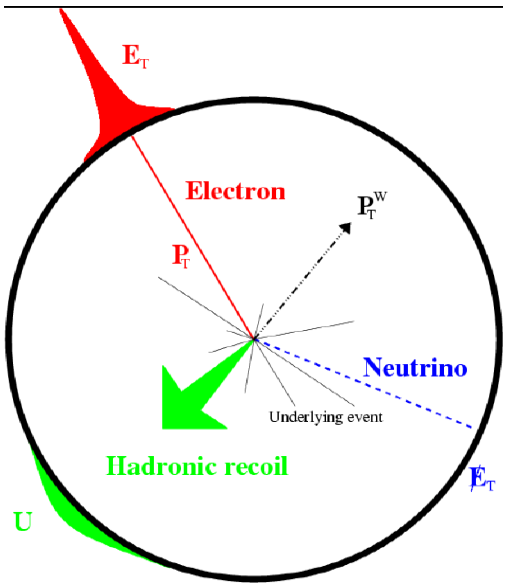


- silicon micro-strip VTX
- scintillating fiber central tracker
- 2T solenoid magnet
- liquid Ar cal
- 1.8 T toroid
- wire tracking/scint. counter muon system
- **e coverage: $|\eta| < 3.2$, μ coverage: $|\eta| < 2$**

W/Z Boson Signatures/Selection

- **Z boson selection**
  - single and di-muon/electron triggers
  - two reconstructed leptons
  - lepton p_T cut (20 GeV)
- **W boson selection**
  - single electron/muon trigger
  - one reconstructed lepton
  - lepton p_T cut (20 GeV)
  - MET (20 GeV)
- small background contribution
  - QCD (heavy flavor decays, electron- like jets)
  - boson decays (W/Z → taus)
  - cosmic muons





Results

Differential Cross-sections

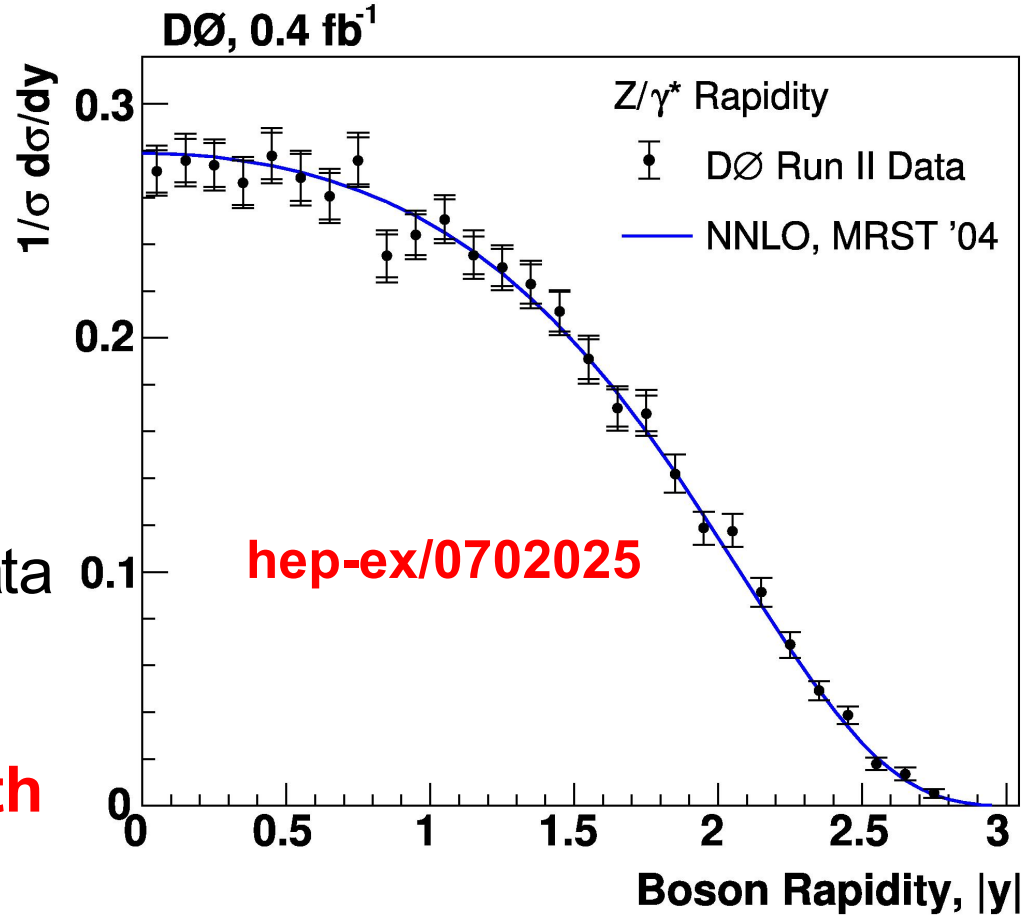
- **Z boson rapidity Y: $d\sigma/dY$**
  - precision electroweak measurements depend on theoretical calculations of W/Z boson cross-sections and their transverse momentum dist.
  - calculations limited by PDF uncertainties
  - study of di-lepton production offers alternative way handle PDFs (usually via high-momentum jet spectra)
  - Z/Drell-Yan process rapidity distributions can be calculated at NNLO
  - **important input for other measurements**
- **Z boson transverse momentum p_T: $d\sigma/dp_T$**
  - Z production is governed by strong force
  - $p_T > 0$ only in case of **gluon radiation** of incoming quark
  - perturbative QCD for large p_T, divergences for small p_T caught by resummation (CSS formalism)
  - **important test of model**

Z Boson Rapidity

$$\frac{1}{\sigma}\frac{d\sigma(p\bar{p}\to Z/\gamma^\star\to e^+e^-)}{dY} = \frac{1}{\sigma}\frac{N_i - B_i}{(\epsilon\times A)_i\Delta_i L}$$

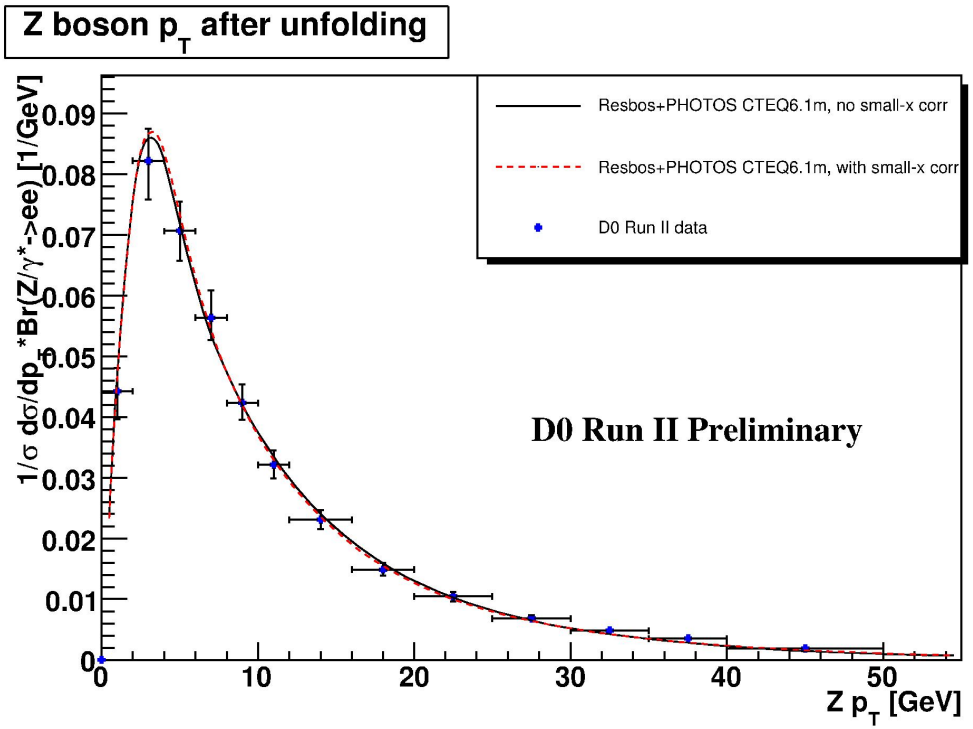
$$\left(Y = \frac{1}{2}\ln\frac{E^Z + p_z^Z}{E^Z - p_z^Z}\right)$$

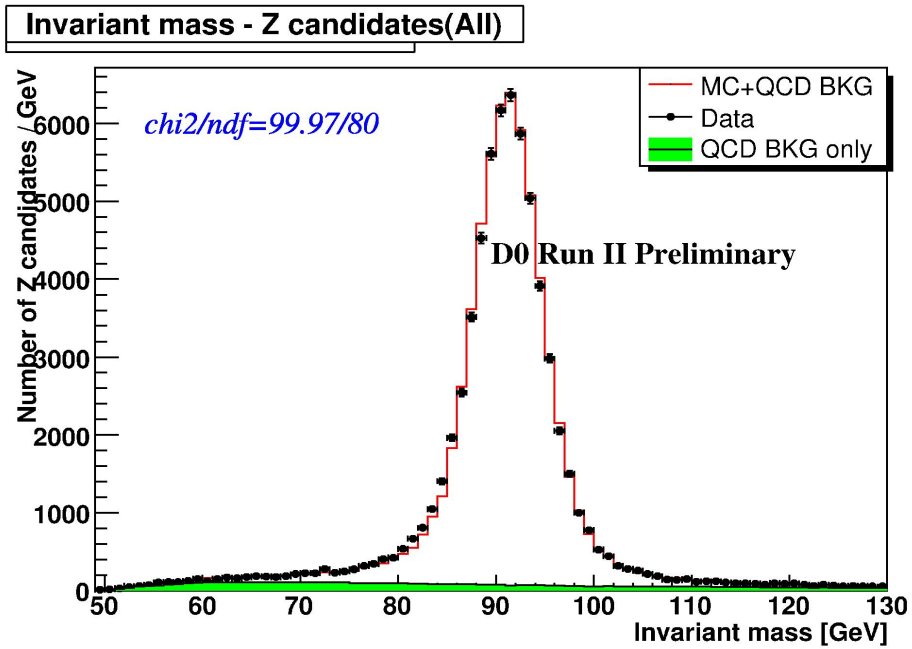
- select Z → ee with
  - $p_{T,1}$ > 25 GeV, $p_{T,2}$ > 15 GeV
  - electrons must be isolated
  - 71 GeV < M_{ee} < 111 GeV
- main backgrounds:
  - multi-jet events
  - W + jet events
- take background shapes from data
- results validate NNLO model
- **most precise measurement with largest rapidity coverage**



Z Boson Transverse Momentum

- test vector boson production formalism
- reduce theory uncertainties
- strategy:
  - measure p_T spectrum
  - detector resolution requires unfolding of spectrum

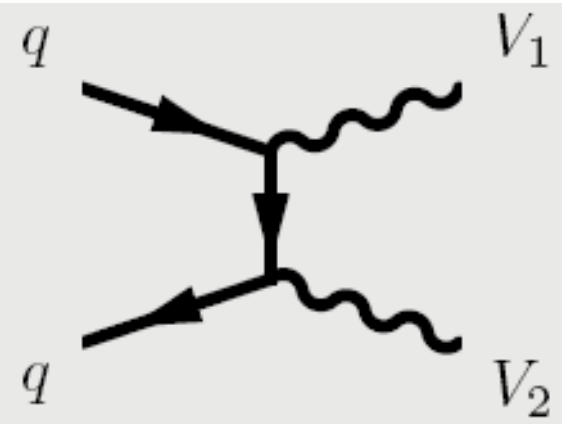


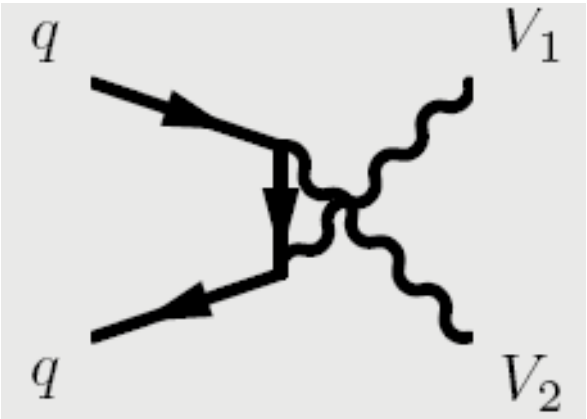


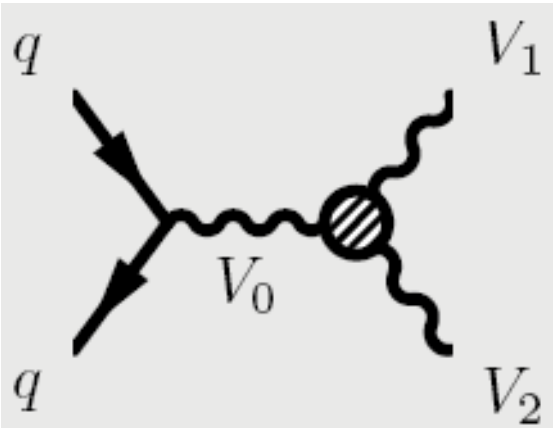
- main background: QCD (di-jet, EM + jet), $Z \to \tau^+\tau^-$, WZ events with $Z \to e^+e^-$
- 960 pb^{-1} → 64k events selected (70 GeV < M_{ee} < 110 GeV, $|\eta_e| < 3.2$)
- **results validate RESBOS+PHOTOS approach**

Di-boson Physics

- multiple vector boson production
  - high-p_T SM process with cross-section predictable with high precision
  - probe non-abelian structure of SM
  - SM parameter to measure: gauge boson self-couplings
  - cross-section measurement sensitive to physics beyond SM
  - major backgrounds/decay channels for scalar bosons (Higgs)



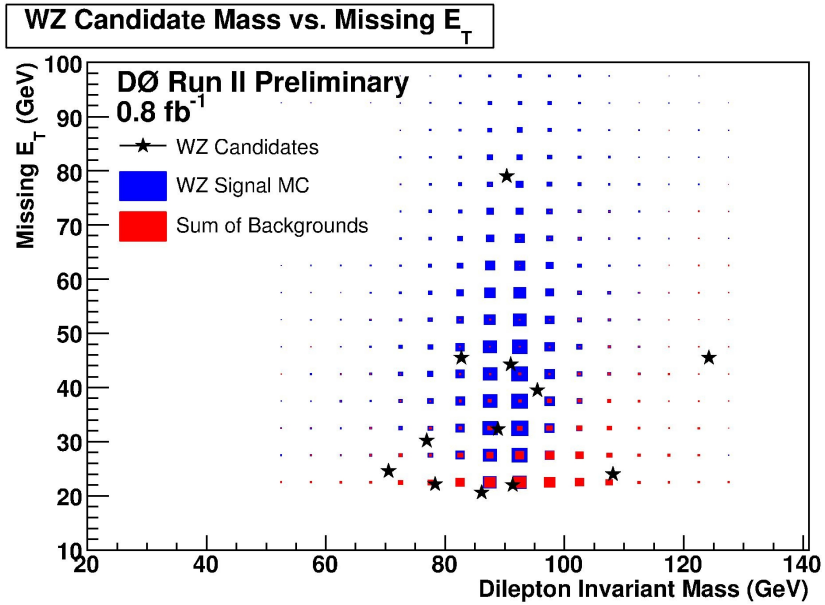


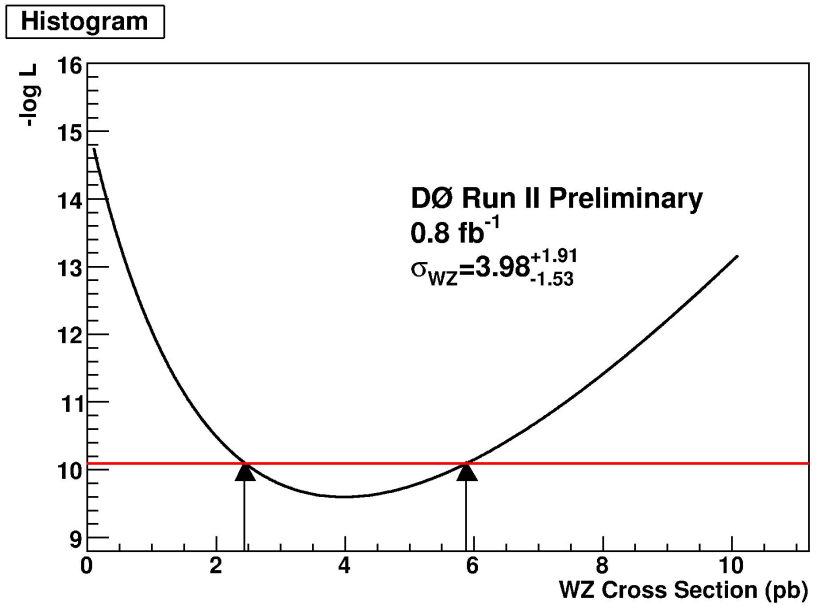


WZ Production

- analysis:
  - 4 channels: eee, eeμ, μμe, μμμ
  - cross-section calculated by combining likelihoods for each channel
- results:
  - L=0.8 fb^{-1}
  - observed candiates: 12
  - background: 3.61±0.21
  - P(bkg fluctuation) = 4.2 x 10^{-4}
    (**3.3 sigma evidence for WZ production**)
  - **$\sigma(WZ) = 3.98^{+1.91}_{-1.53}$ pb**

    ($\sigma_{SM}(WZ)$ = 3.68 ± 0.25 pb)



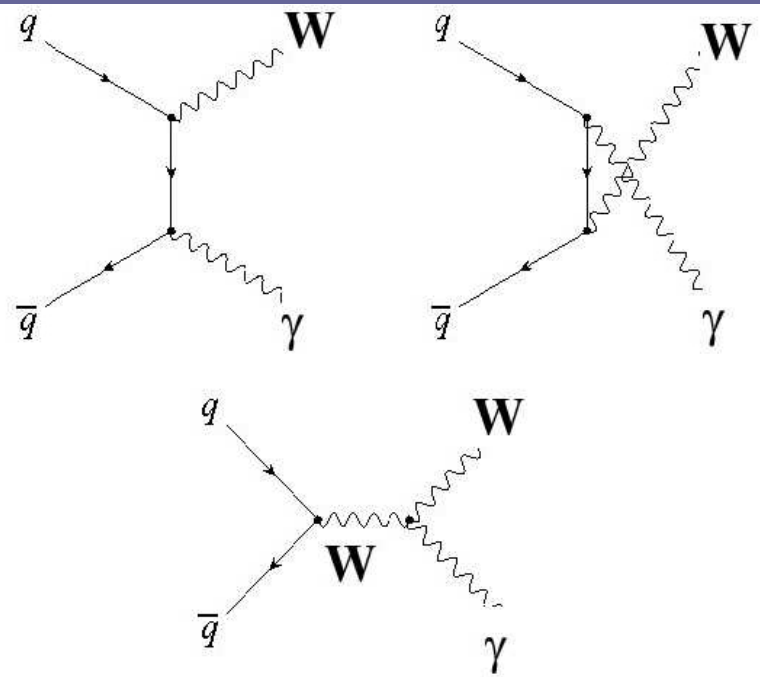


$W\gamma$ Production I

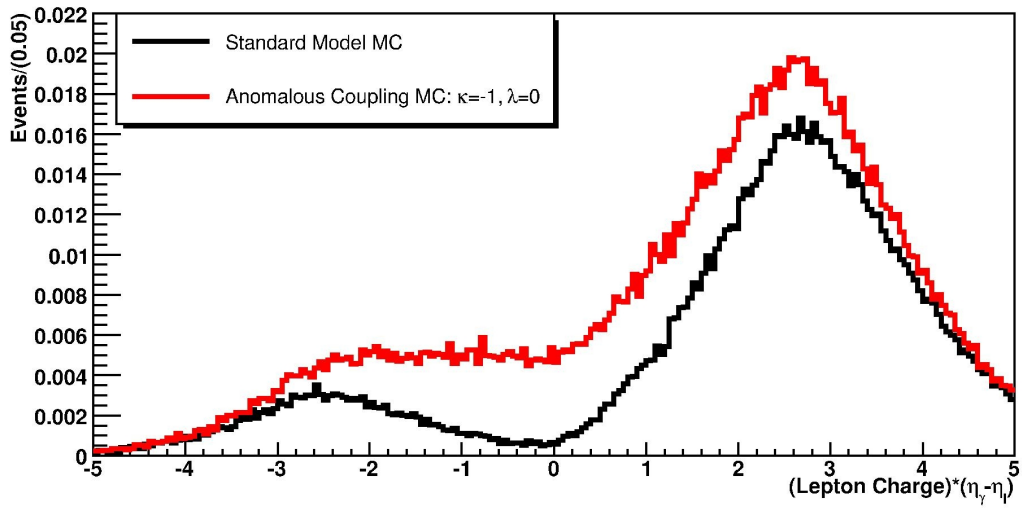
- interference among tree-level diagrams creates zero in center-of-mass angular distribution, θ*, between W and incoming quarks
- **radiation amplitude zero** manifest as dip at:

$$\mathrm{sign}(\ell) \times (Y(\gamma) - Y(\ell)) \approx -0.3$$

(Baur et al.: hep-ph/9402282)



- sensitive to **anomalous WWγ couplings**
- challenges:
  - final state radiation
  - NLO processes
  - poor rapidity resolution
  - poorly estimated background



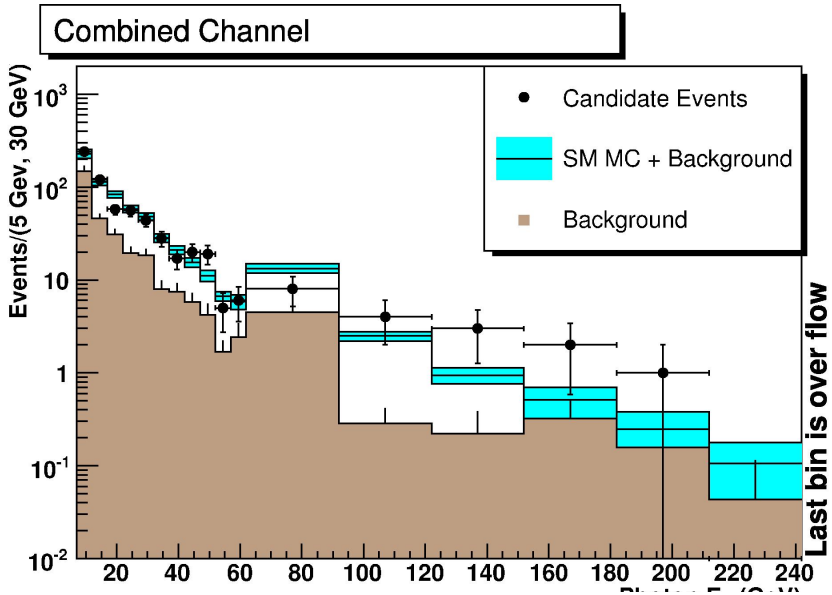
$W\gamma$ Production II

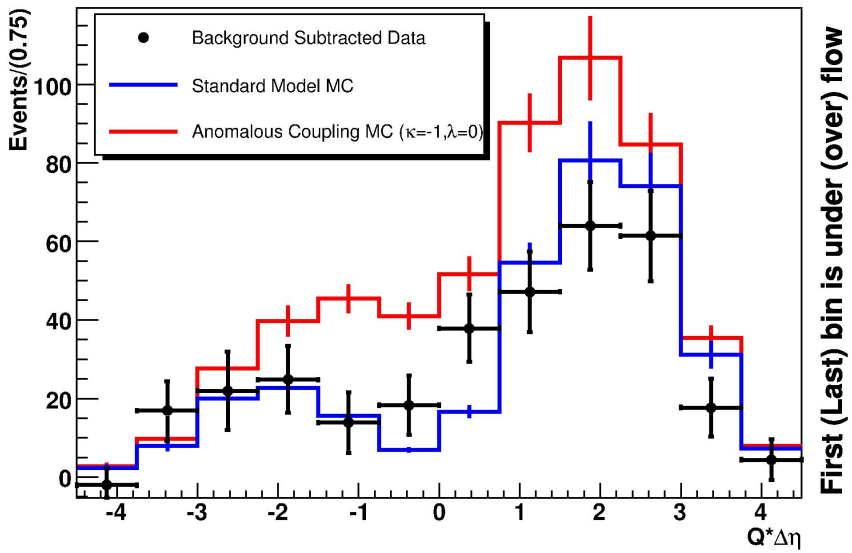
- reduce final state radiation contribution by threshold imposed on transverse mass of the lepton-photon-neutrino system M_T

	μ channel	e channel
L [pb-1]	878	933
cand.	130±18	205±26
σ x BR [pb]	**3.21±0.49±0.20**	**3.12±0.49±0.19**

(σ x BR(SM) = 3.21±0.08 pb)

- rapidity difference distribution shows **first indication of radiation amplitude zero**
  - **χ^2/ndf(SM) = 16 / 12**





Summary

- DØ has rich electroweak program
- selection of recent electroweak results presented
  - Z p_T and rapidity measurement
  - first evidence for WZ production
  - first indication of radiation amplitude zero
- more results and updates to be expected soon - stay tuned

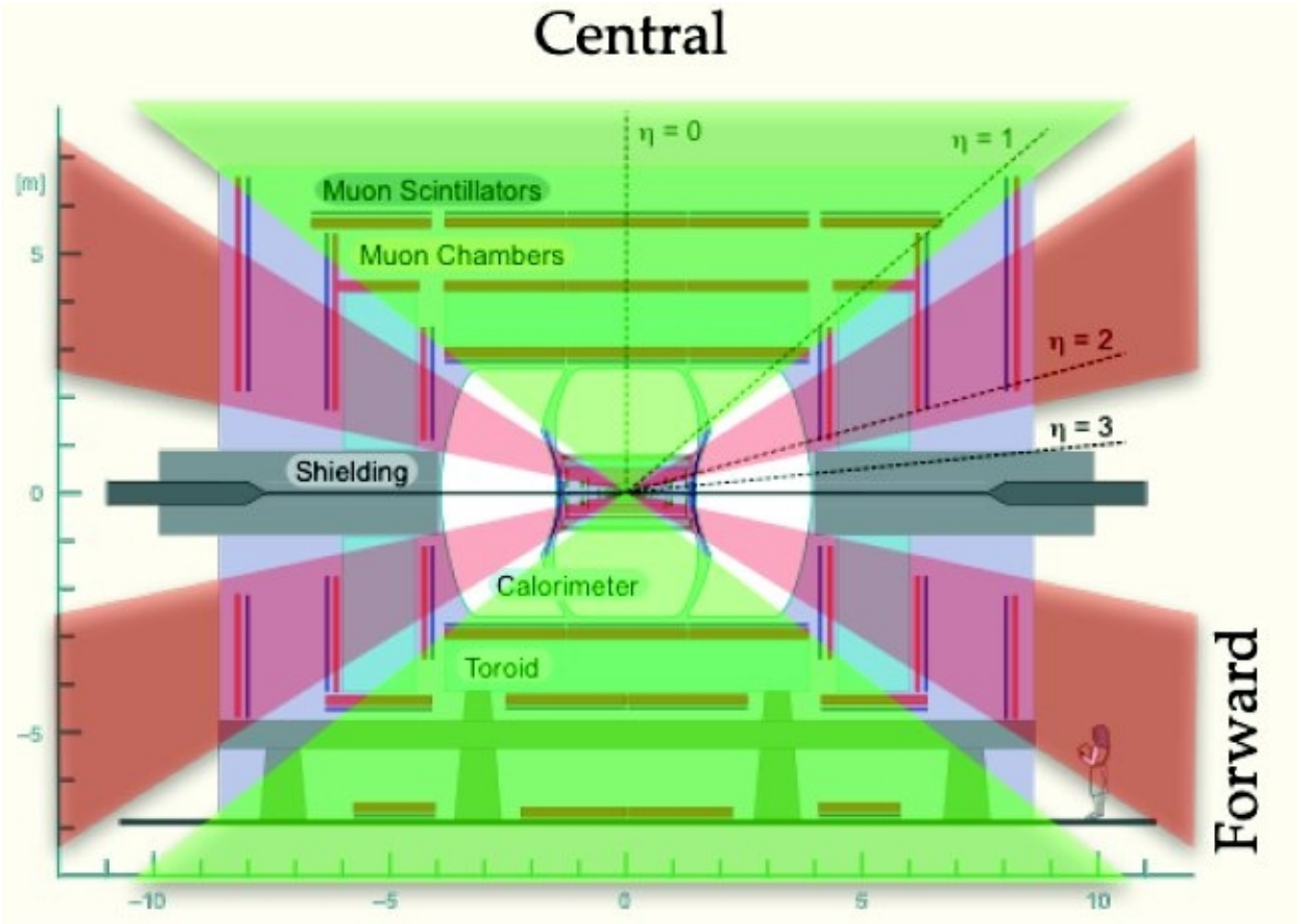
Acknowledgement

I would like to thank everyone who has contributed to this talk!

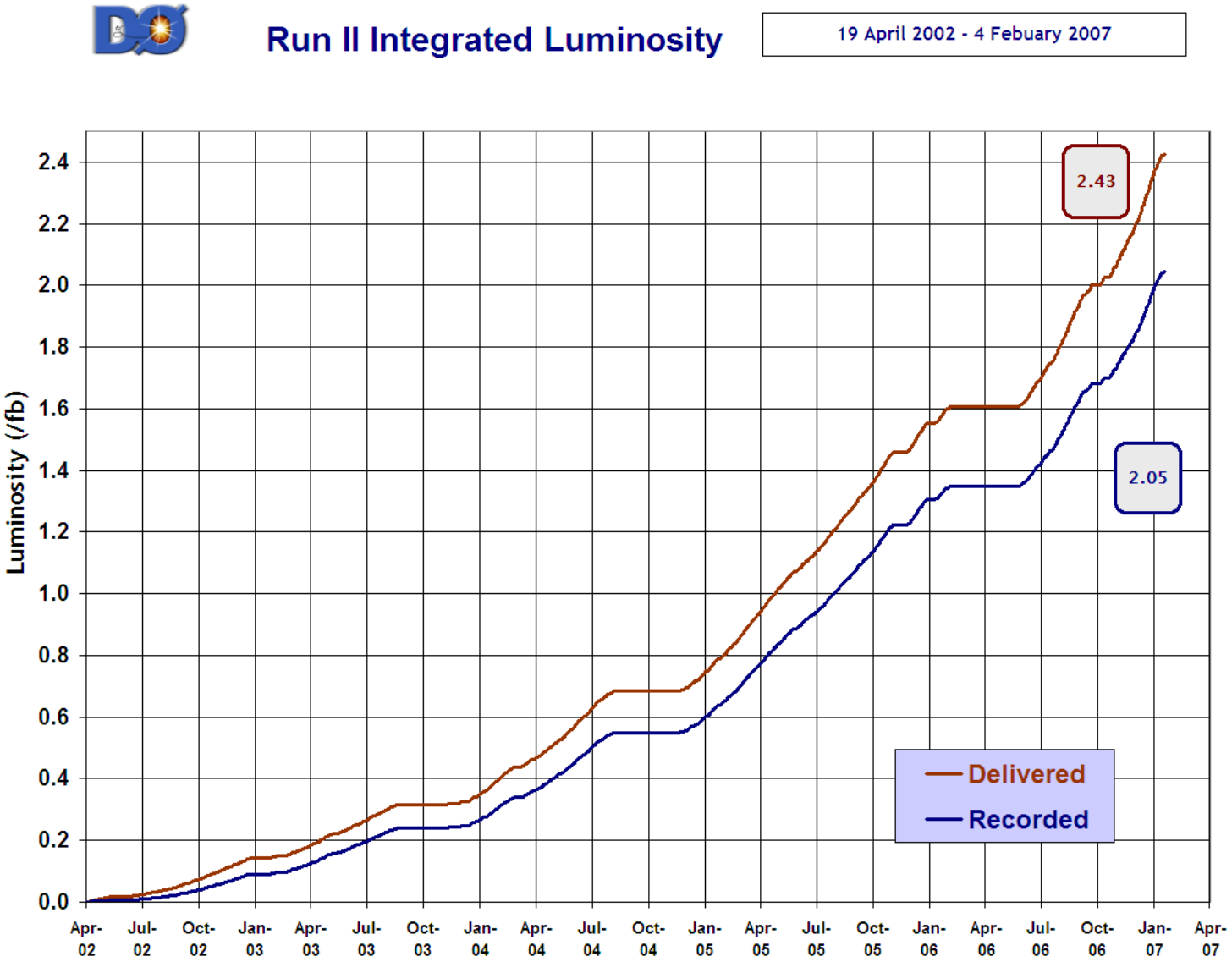
Backup

The DØ Detector

- excellent muon coverage
  |η| < 2
- excellent electron coverage
  |η| < 3.2



Luminosity


Run II Integrated Luminosity
19 April 2002 - 4 Febuary 2007
Luminosity (/fb)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
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Jan-04
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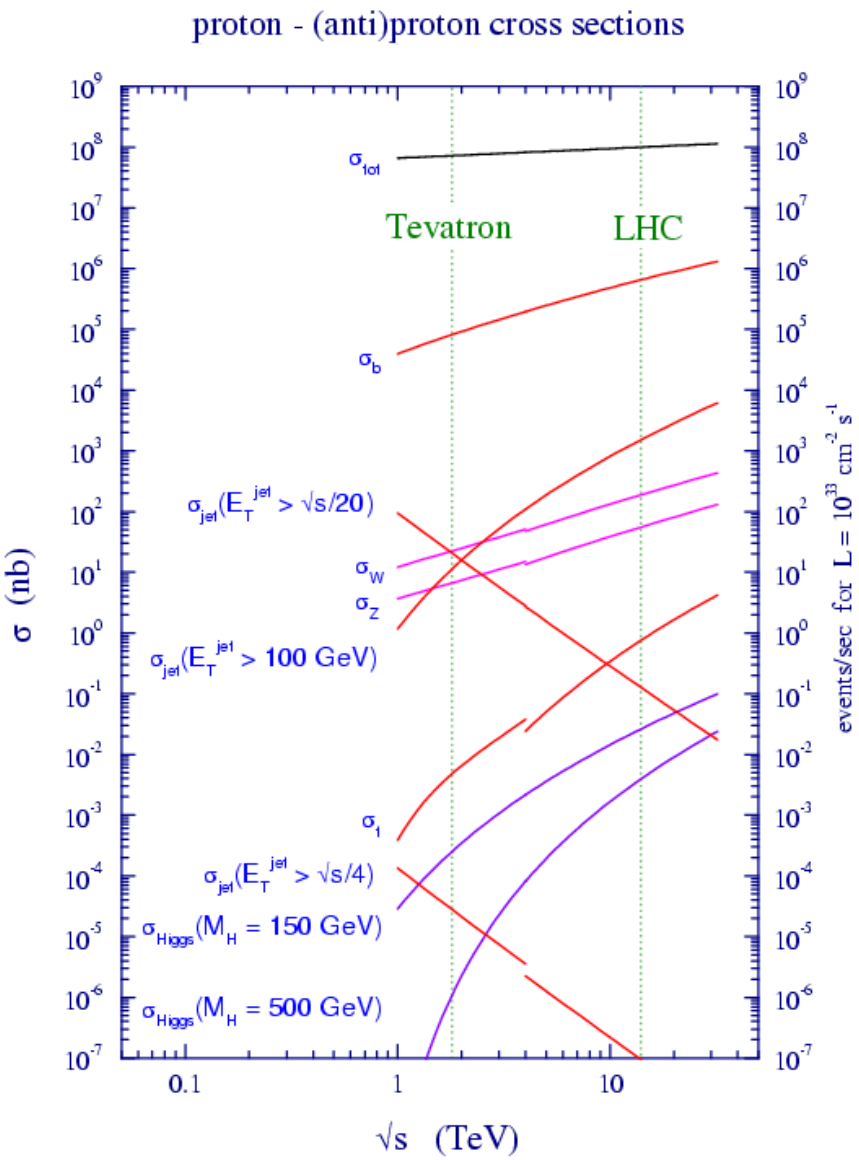
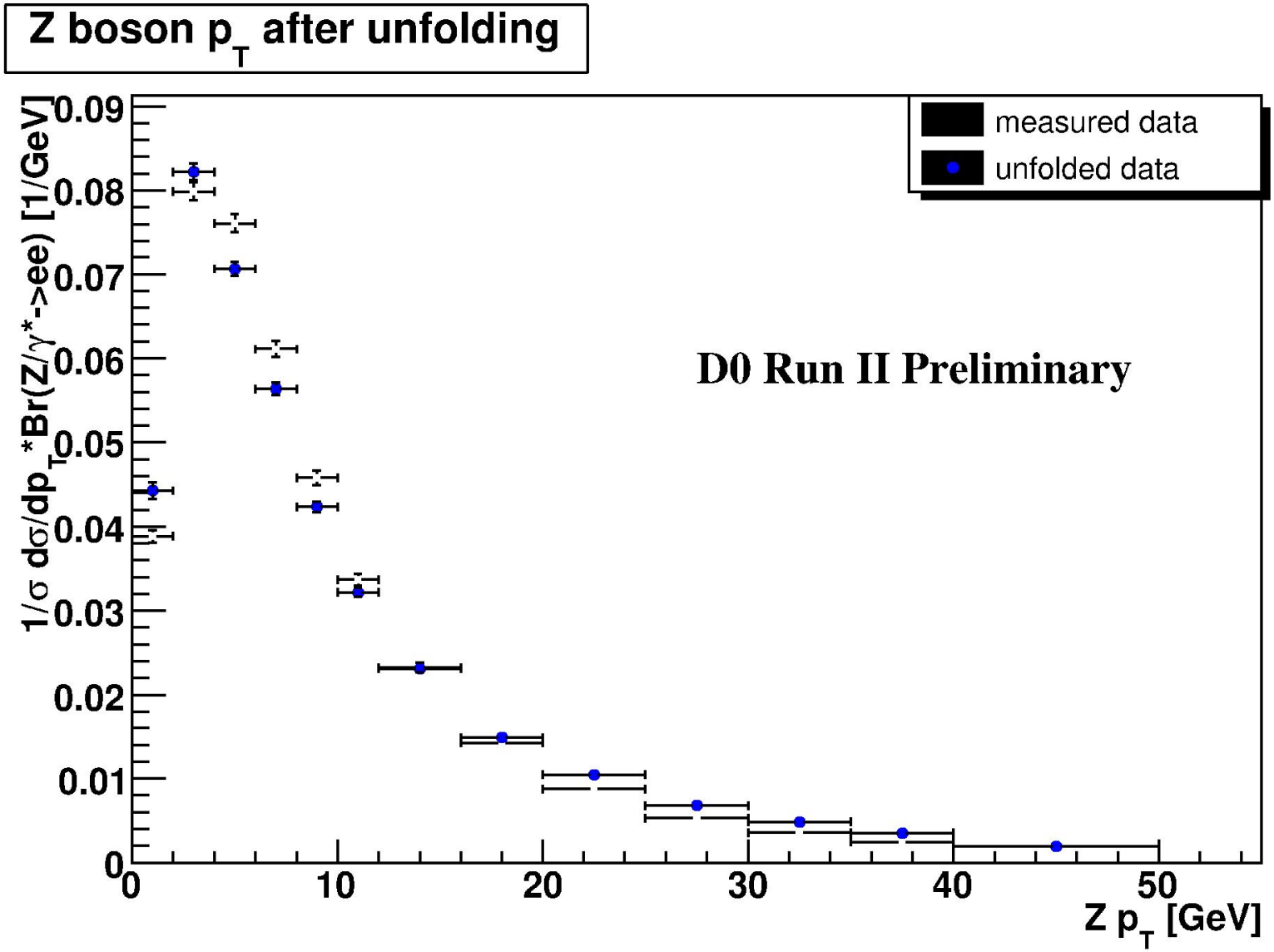
2.43
2.05
Delivered
Recorded

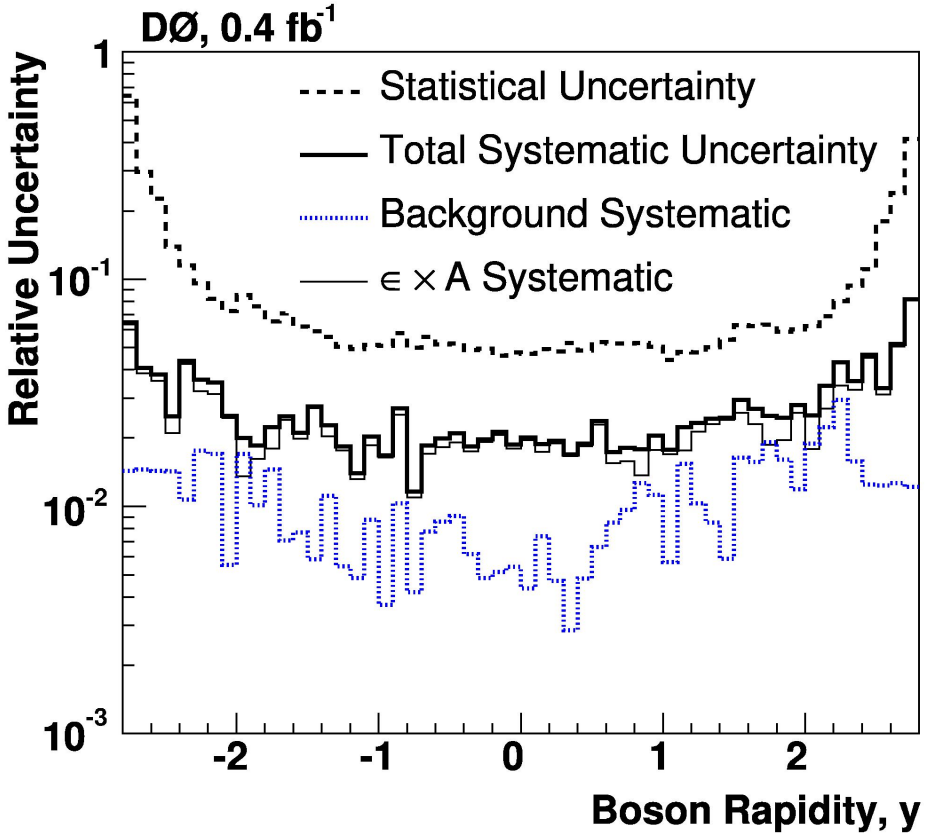
Cross-sections

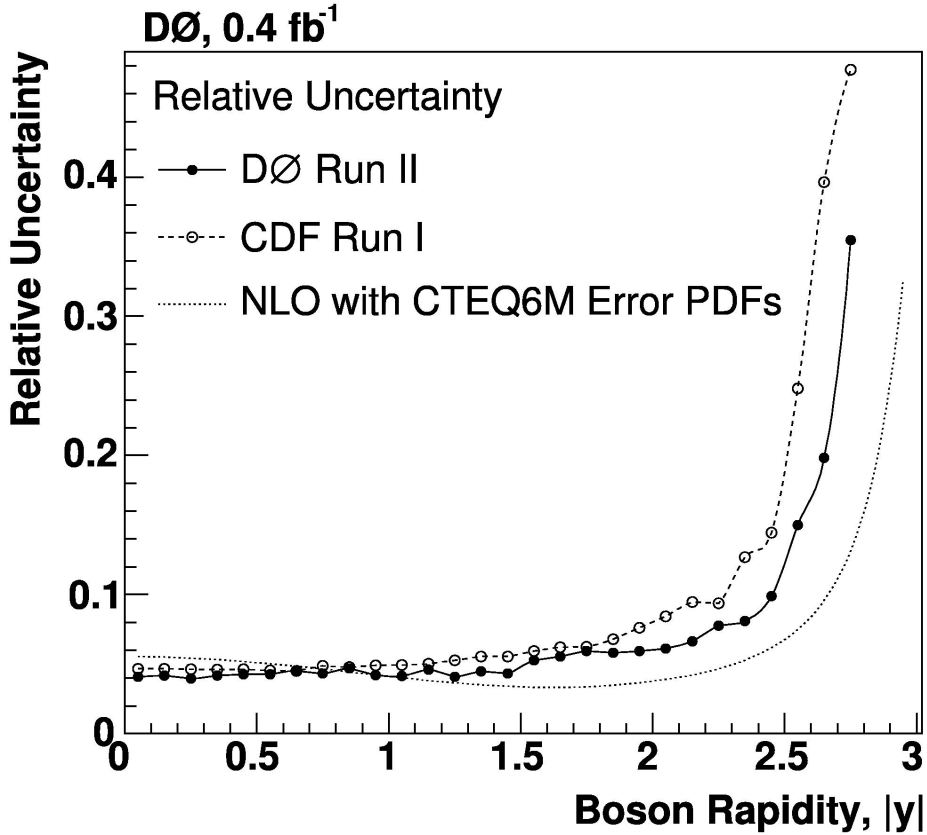
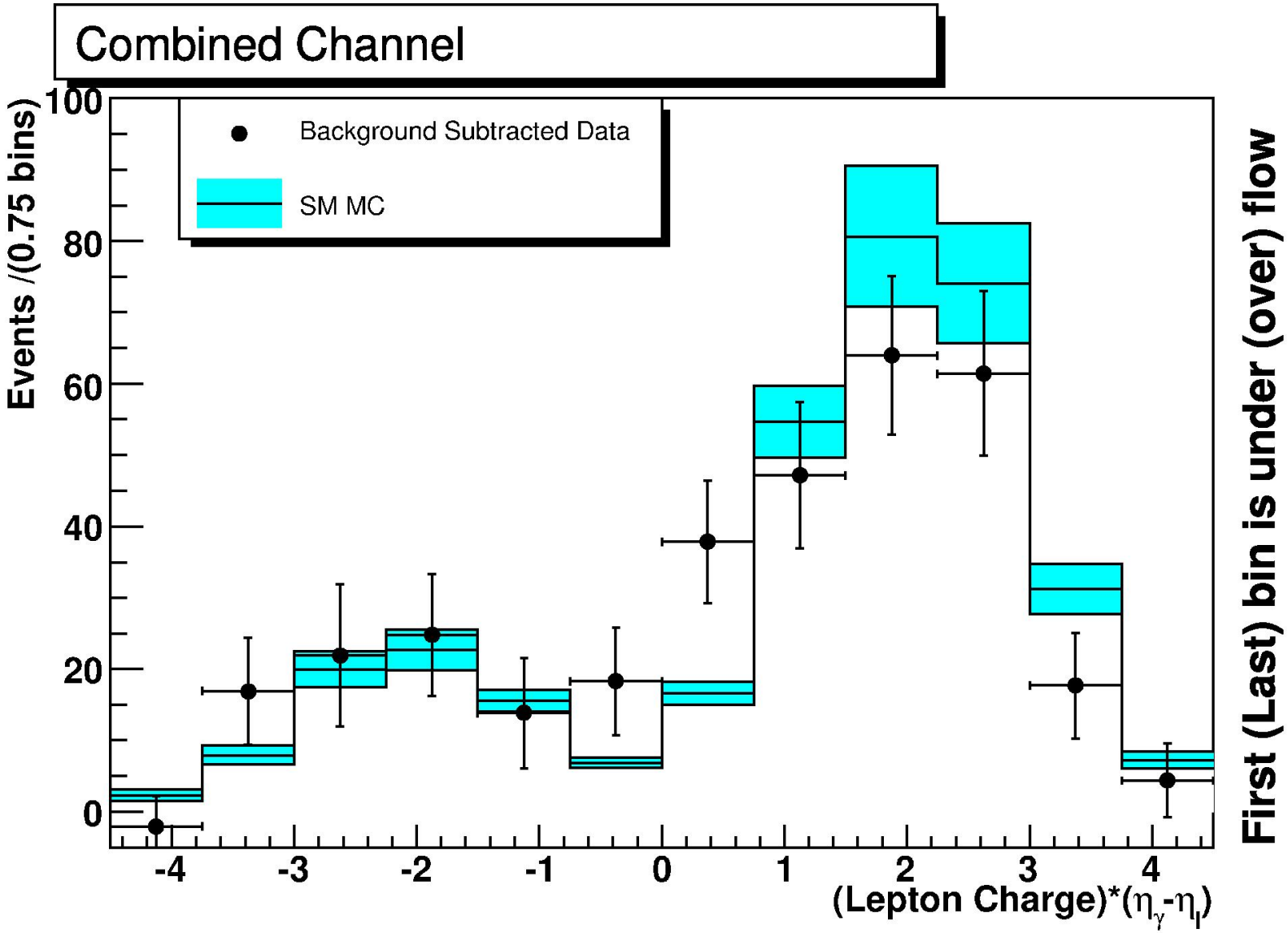


Z Boson p_T: Unfolding



Z Boson Rapidity: Uncertainties





$W\gamma$ Production