PHENO 08 – April 28, 2008

ZZ → llνν production with the DØ detector at the Tevatron collider

Gianluca Cerminara
on behalf of the DØ collaboration

INFN TORINO

Northeastern UNIVERSITY

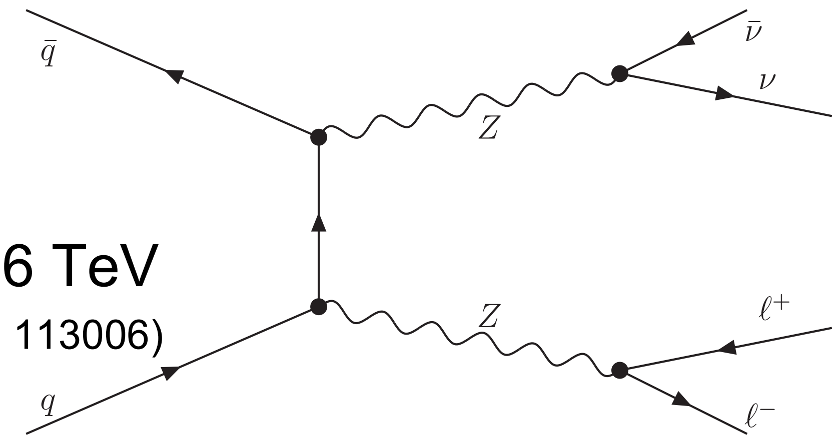
Overview

- ZZ production
  - why an interesting measurement
  - experimental challenge of the $ll\nu\nu$ final state
- Event pre-selection
  - luminosity used for the measurement
  - “tight” quality leptons to reject backgrounds from fakes
- Instrumental background treatment
  - an alternative approach to missing E_T (MET) selection
- Physics background discrimination
- Results:
  - significance estimate
  - cross section measurement

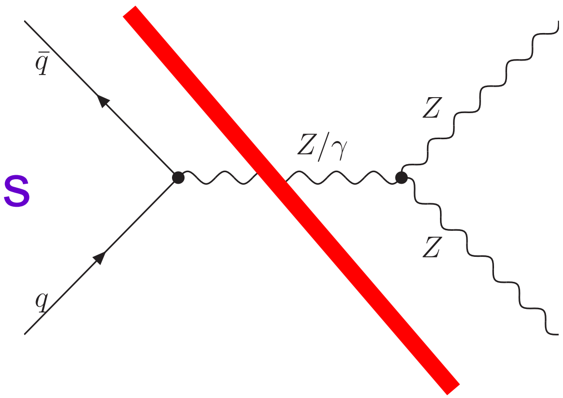
ZZ production at hadron collider

- ZZ production last unobserved di-boson process at Tevatron
  - small cross-section
    - $\sigma(ZZ) = 1.4 \pm 0.1$ pb @ $\sqrt{s} = 1.96$ TeV

    (J. M. Campbell and R. Ellis,Phys. Rev. D 60 (1999) 113006)



- interest of the measurement:
  - irreducible background to Higgs searches
  - no triple boson couplings in the SM → possible new physics = anomalous couplings



- experimental challenge
  - 4-lepton → clean signature but low statistics
  - 2l2ν → higher branching ratio but also higher backgrounds

Event pre-selection

- Data sample after data quality:
  - 2.2 fb^{-1} in the di-electron and di-muon final states respectively
- Trigger selection: OR of single μ/e triggers.
- Lepton selection

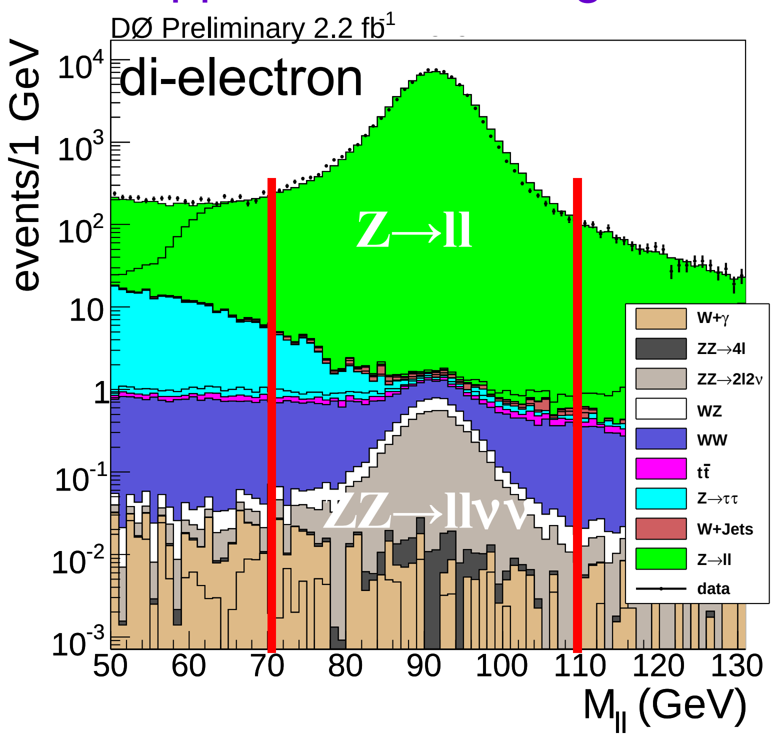
- 2 muons ($|\eta| < 2$) with :
  - $p_T > 15$ GeV
  - central track matched to stubs in the muon spectrometer
  - tight requirement on calorimeter and track scaled isolation

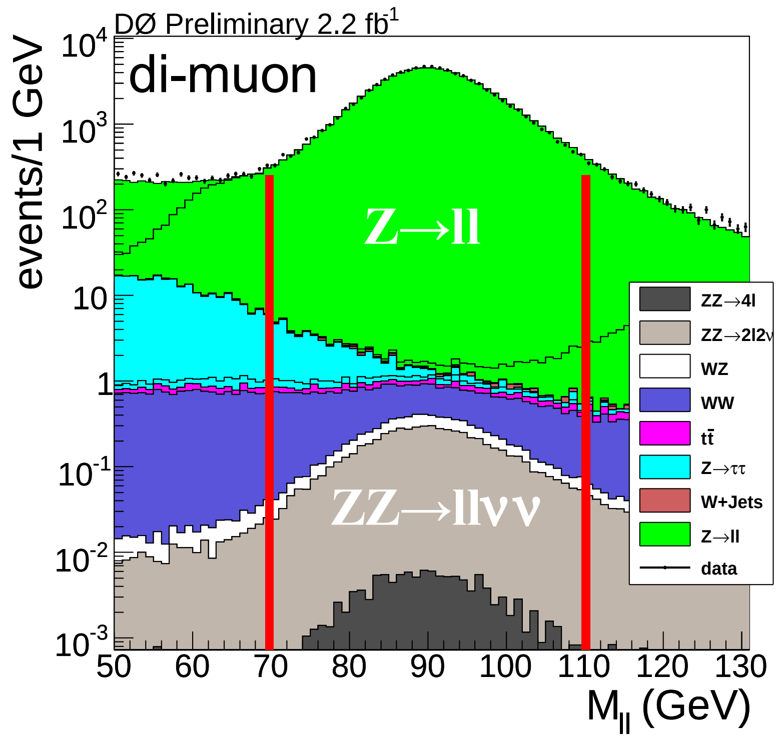
- 2 electrons ($|\eta|<1.1$ and $1.5<|\eta|< 2$) with:
  - $p_T > 15$ GeV
  - calorimeter cluster matched to a central track
    - isolation requirement
    - multivariate discriminant for the shower shape

- high quality leptons → high background rejection (W+jets)

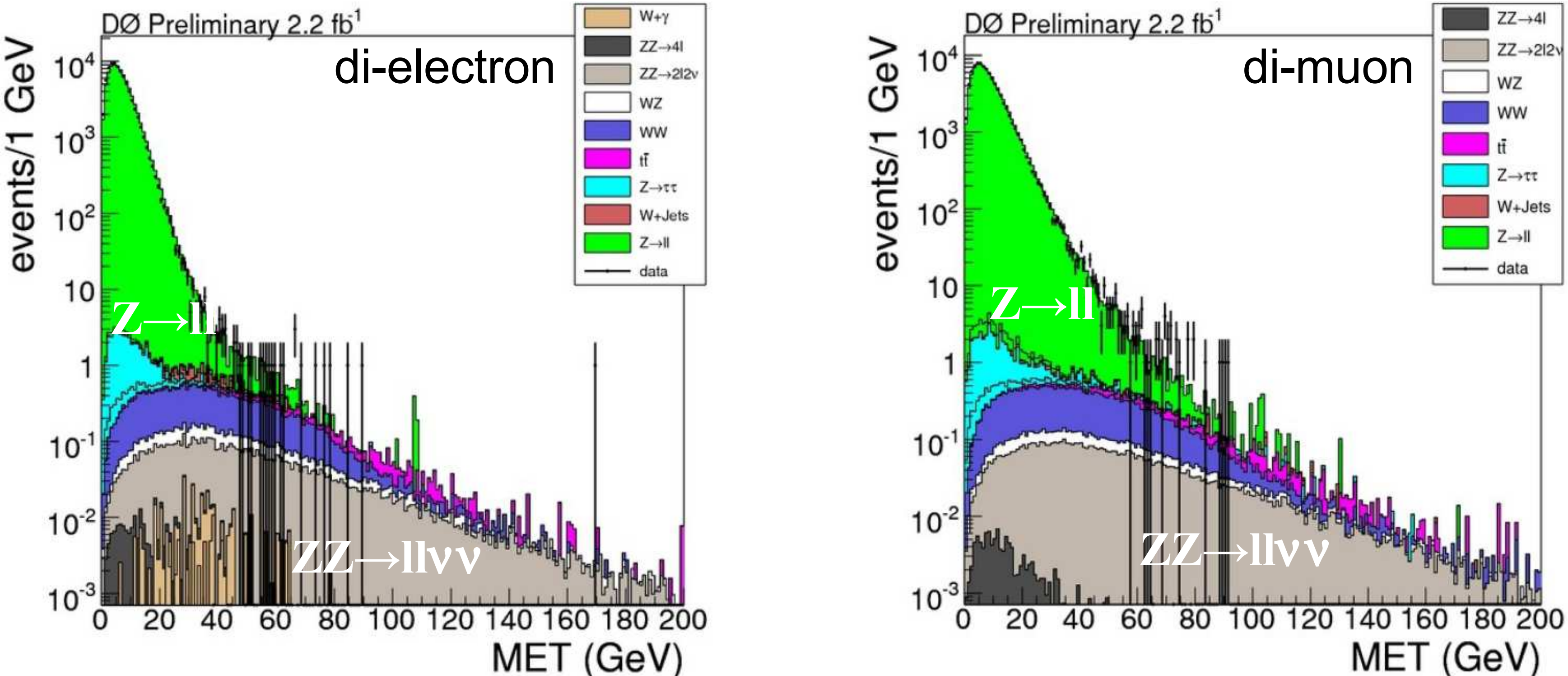
Selection of Z events

- require $70 < M_{ll} < 110$ GeV
- veto on additional lower quality leptons / isolated tracks
  - suppress WZ
- veto on the # of jets (≤ 2)
  - clean calorimeter events → improve MET resolution
  - suppress ttbar background





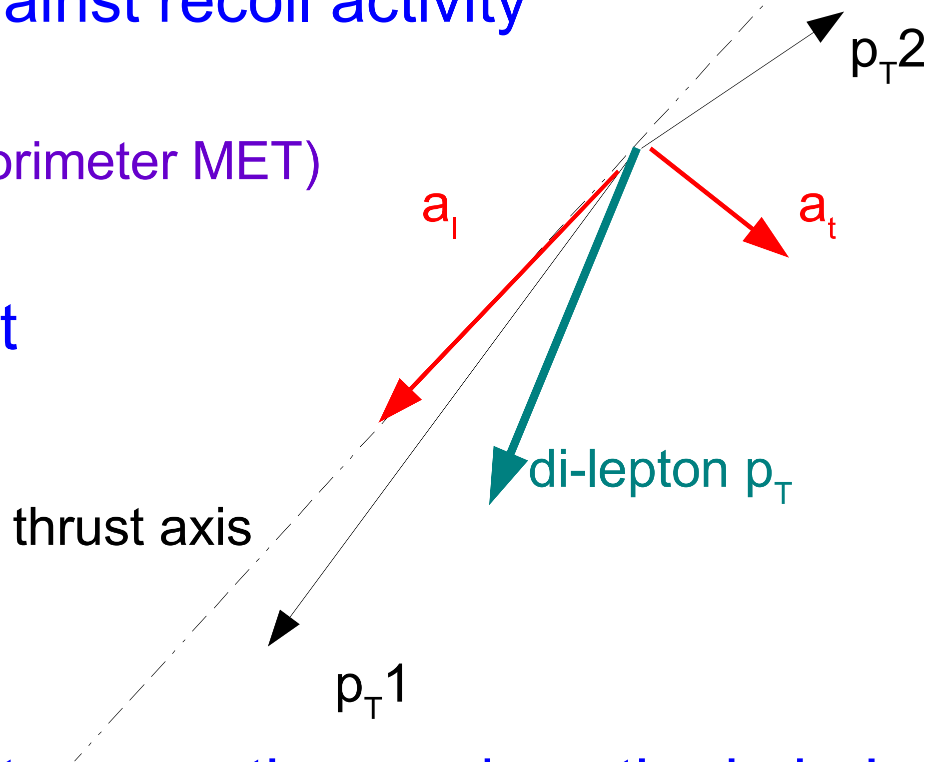
Rejection of Z+X events
(why no direct cut on MET)



- MET distribution dominated by resolution effects
  - no powerful discrimination of Z → ll events
- No direct cut on MET but build a new variable ($\hat{\not{E}}_T$):
  - sensitive to genuine p_T imbalance
  - less sensitive to resolution effects

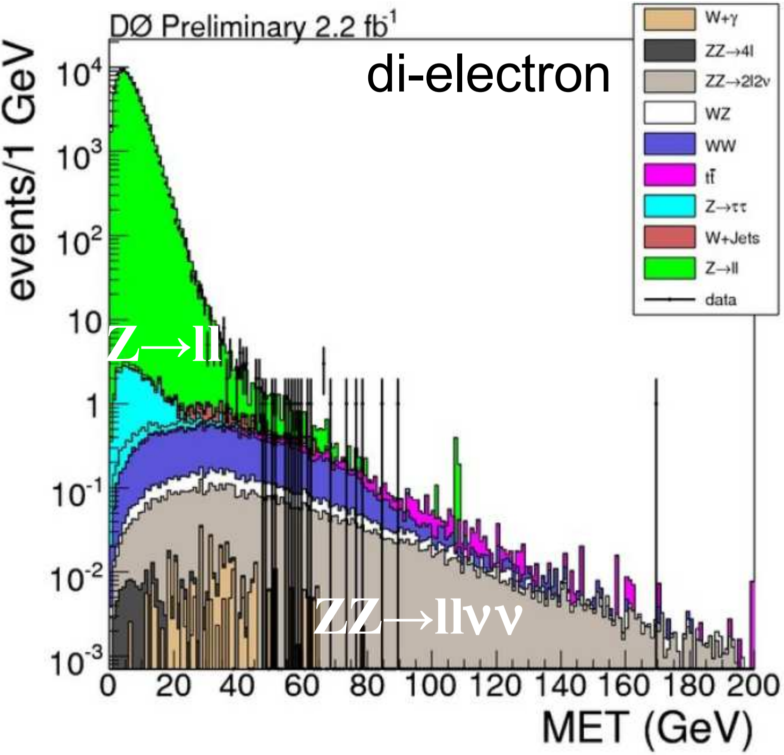
Selection based on p_T imbalance

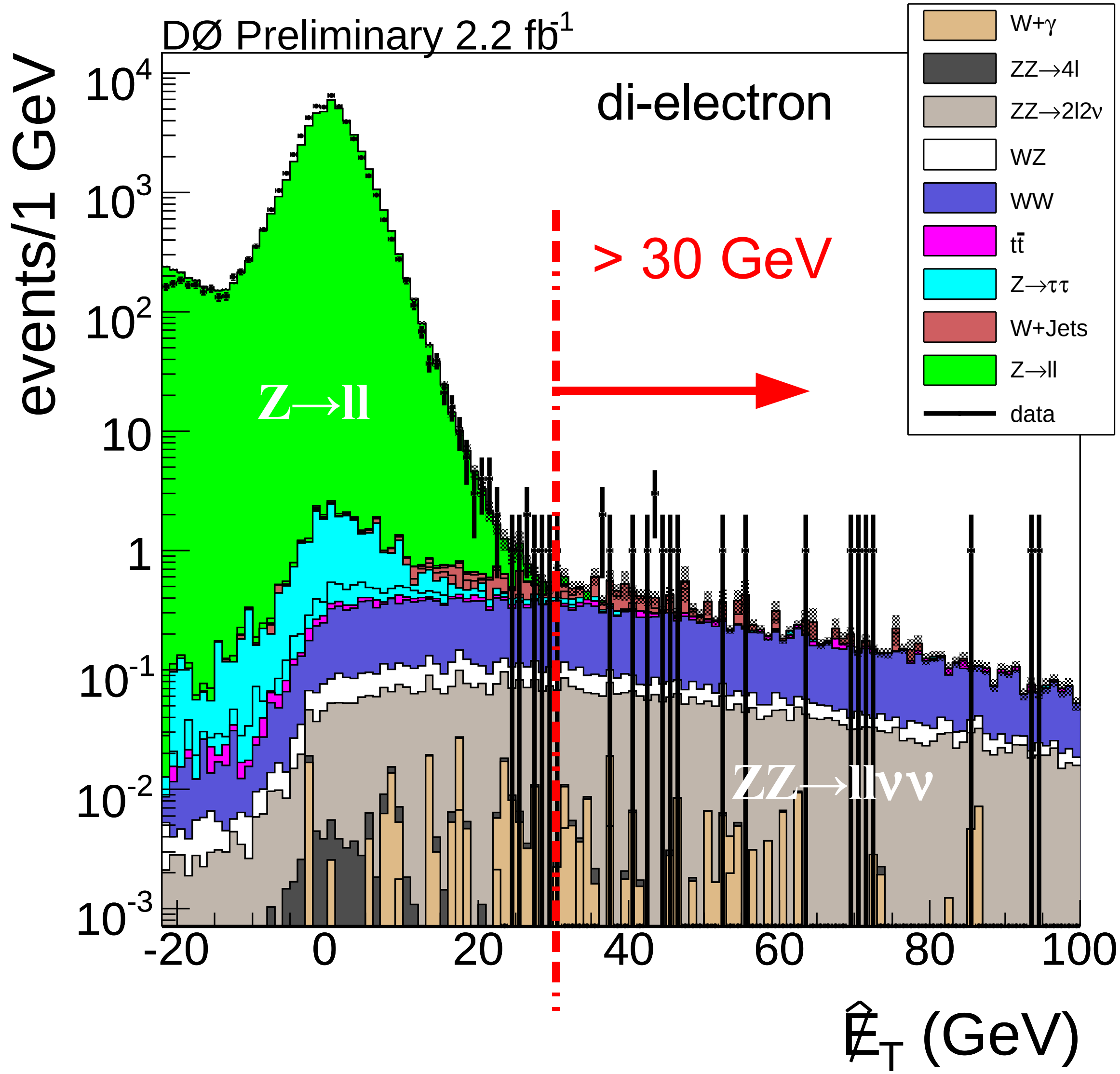
- di-lepton p_T decomposed with respect to the thrust axis
  - p_T balancing uses a metric which enhance the transverse component (less sensitive to lepton resolution)
- balance each component against recoil activity in the opposite hemisphere
  - calorimeter recoil (jets and calorimeter MET)
  - track recoil activity
- reduce imbalance to account for resolution effects



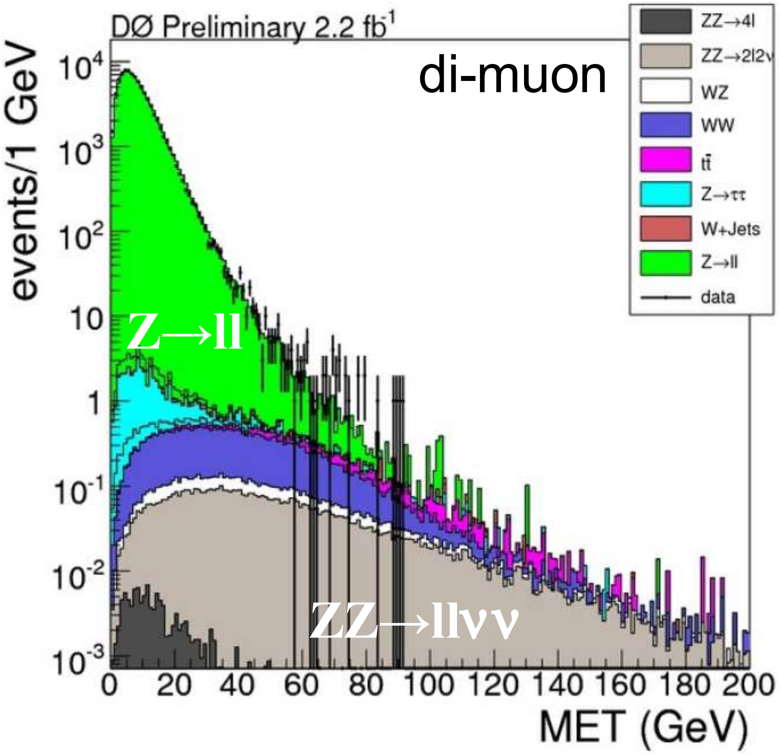
- By construction all uncertainty corrections reduce the imbalance

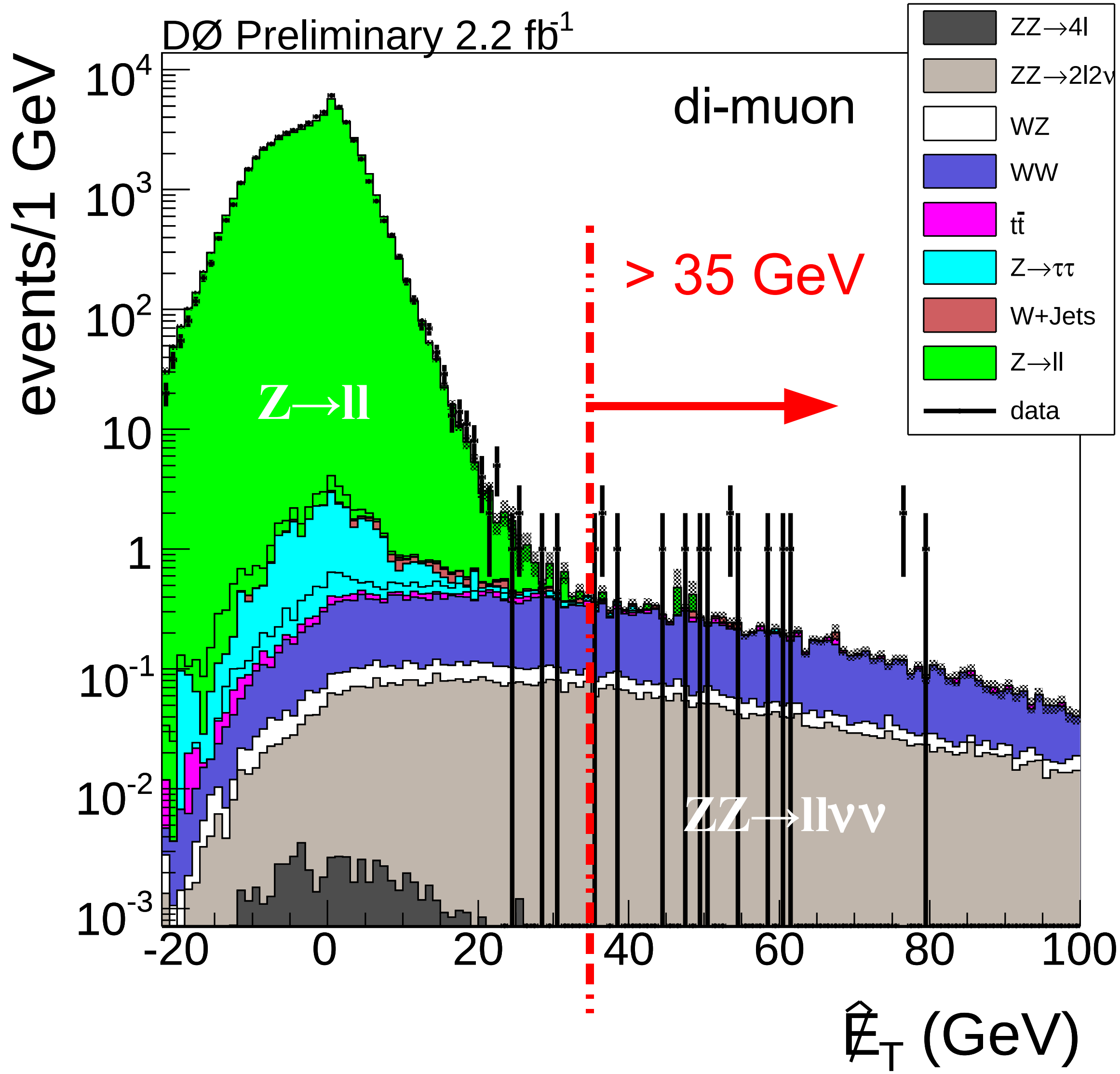
Reject instrumental backgrounds





Reject instrumental backgrounds





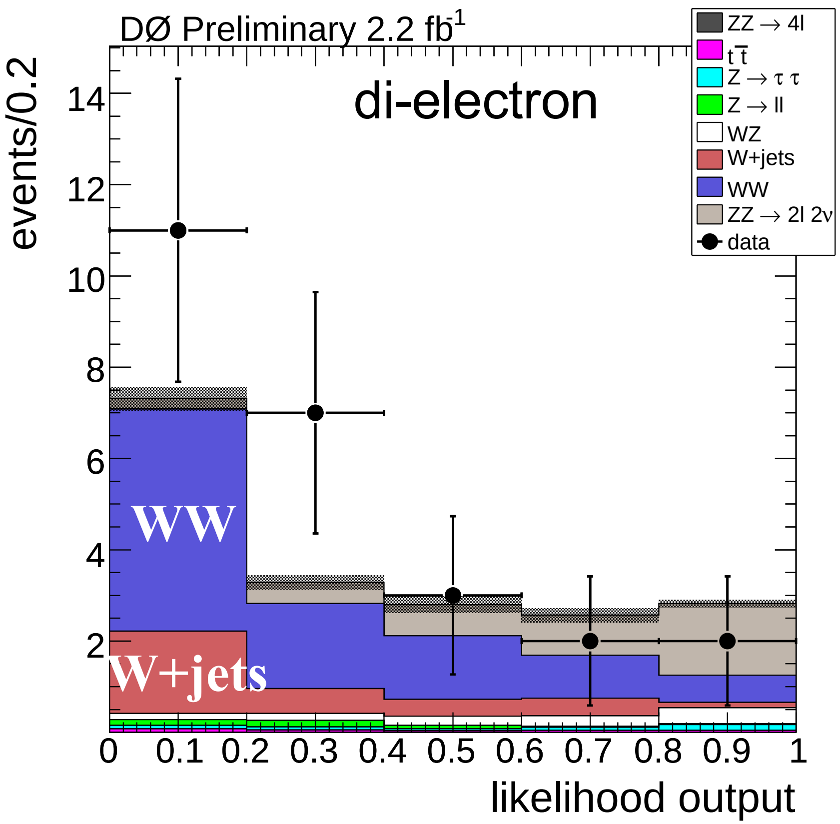
Event yield after the selection

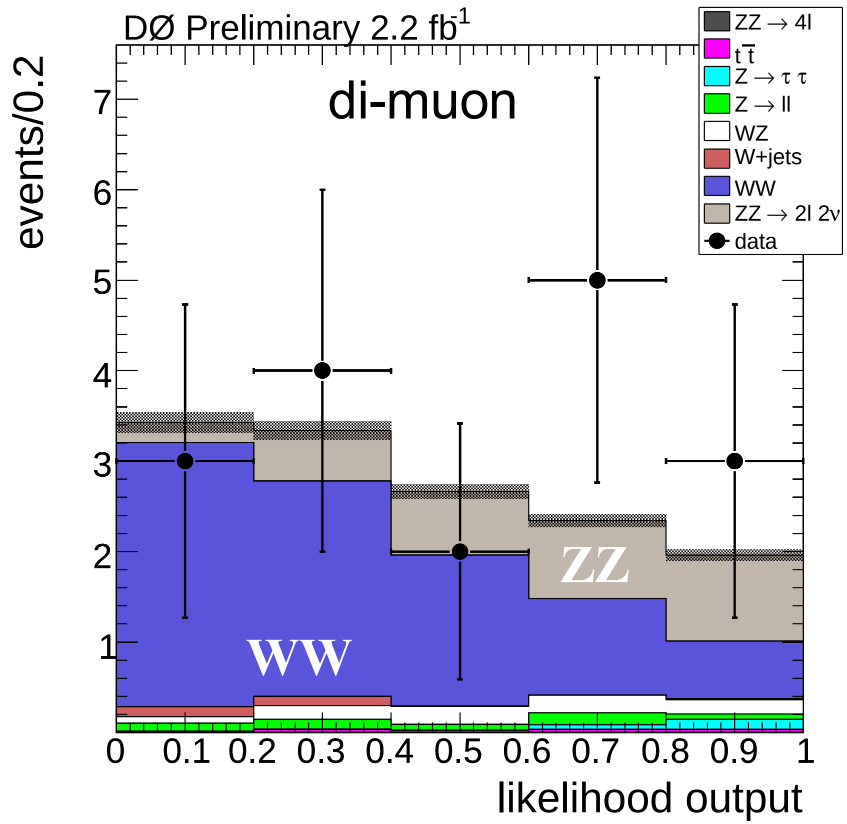
	di-electron	di-muon
Sample	# of events	# of events
$Z \to ll$	0.40 ± 0.32	0.45 ± 0.25
$Z \to \tau\tau$	0.36 ± 0.05	0.18 ± 0.04
$ZZ \to llll$	0.010 ± 0.001	0.010 ± 0.001
$t\bar{t}$	0.25 ± 0.03	0.14 ± 0.03
$WZ \to l\nu ll$	1.05 ± 0.06	0.77 ± 0.06
$W + jets$	3.22 ± 0.77	0.23 ± 0.15
$WW \to l\nu l\nu$	9.67 ± 0.68	8.67 ± 0.62
Tot MC bckg	14.87 ± 1.08	10.44 ± 0.69
$ZZ \to ll\nu\nu$	3.81 ± 0.19	3.30 ± 0.17
Tot MC	18.68 ± 1.09	13.73 ± 0.71
data	25	17

- WW → lνlν main irreducible background
- W+jets background → normalization from data

Separate WW from ZZ

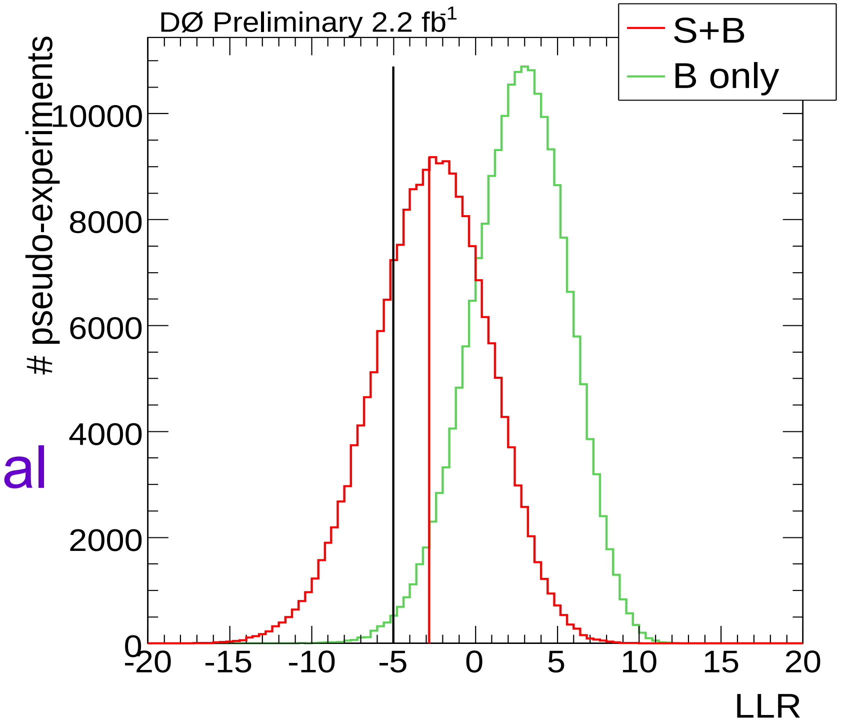
- Build a likelihood discriminant based on the following variables:
  - di-lepton invariant mass
  - leading lepton p_T
  - $\Delta\phi$ (leading lepton, di-lepton system)
  - $\cos(\theta^*)$ lepton (θ^* decay angle in the di-lepton rest frame)





Significance estimate

- Use output of likelihood discriminant to evaluate significance
  - negative log-likelihood ratio as test statistic
    - run signal + background (S+B) and background only (B only) pseudo-experiments
- Significance:
  - expected 1.8 σ (p-value = 0.0387)
  - observed 2.4 σ (p-value = 0.0082)
- Cross section measurement:
  - fit likelihood output with floating signal
    - determine fraction of signal (f) with respect to Z events (used for the normalization)



$$\sigma^{ZZ} = \sigma^{Z} \frac{A_Z}{A_{ZZ}} \frac{f N_{ZZ}^{MC}}{N_Z}$$

$$\sigma^{ZZ} = 2.1 \pm 1.1(stat.) \pm 0.4(sys.)\ \mathrm{pb}$$

Systematic uncertainties

- Main systematics on significance estimate:
  - W+jet normalization from data (limited statistics)
    - diem: 3.2 ± 0.8 events   dimu: 0.23 ± 0.15 events
  - WW and WZ theoretical cross-section
    - diem: 9.7±0.7 events   dimu: 8.7±0.6 events
  - lepton resolution (shape uncertainty)

  Main systematics on cross-section
  - $Z \rightarrow ll$ theoretical cross section +2% -5%
  - Systematics on the A_Z/A_{ZZ} acceptance ratio
    - modelling of the ZZ p_T spectrum (3.6%)
    - modelling of the veto efficiencies (3%)
    - *p.d.f.* uncertainty (1.7%)
- Systematics accounted in the LLR through Gaussian smearing and Likelihood profiling

Conclusions

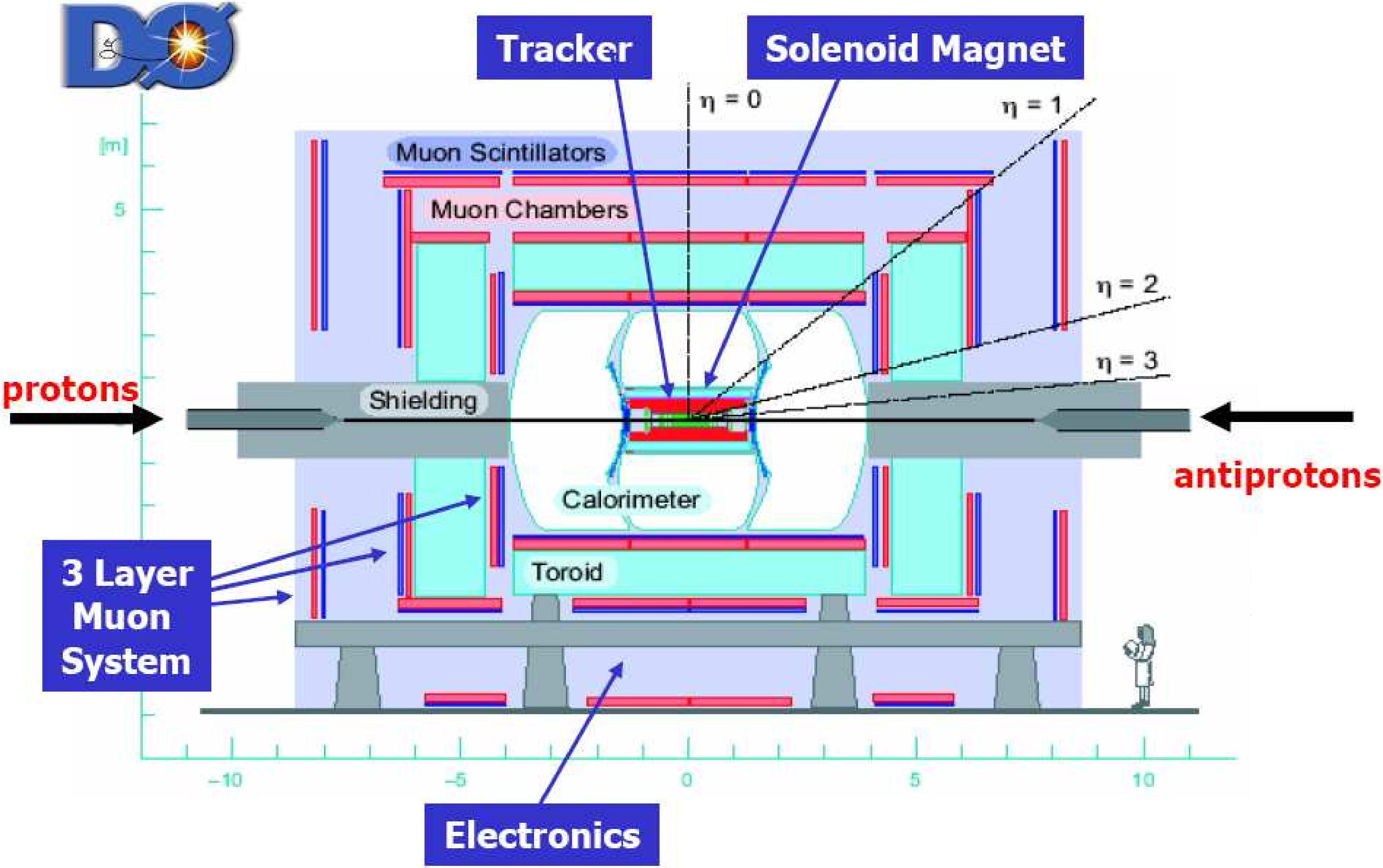
- 2.4 σ significance observed in the $ll\nu\nu$ channel
- measurement of the ZZ production cross section with the DØ experiment:
  - $\sigma^{ZZ} = 2.1 \pm 1.1(stat.) \pm 0.4(sys.)$ pb
  - compatible with the standard model prediction:
    - $\sigma^{ZZ} = 1.4 \pm 0.1$ pb

    (no evidence of anomalous ZZ production)

    - CDF measurement ($ZZ \rightarrow ll\nu\nu$ and $ZZ \rightarrow 4l$): $\sigma^{ZZ} = 1.4^{+0.7}_{-0.6}$(stat.+sys.) pb
- New tool for the discrimination of real MET developed

Backup

The D0 detector



Signal Significance

- Channel breakdown

	di-electron		di-muon		combined	
	expected	observed	expected	observed	expected	observed
p-value	0.0753	0.1140	0.1100	0.0052	0.0387	0.0082
significance	+1.44	+1.21	+1.23	+2.57	+1.77	+2.40

References

- The DØ Collaboration, *$ZZ \rightarrow ll\nu\nu$ production in ppbar collisions at $\sqrt{s}$ =1.96 TeV*, DØ note 5620 (2008). http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/EW/E24/
- J. M. Campbell and R. Ellis, *Update on vector pair production at hadron colliders*, Phys. Rev. D 60 (1999) 113006.
- The DØ Collaboration, *Search for ZZ and $Z\gamma^*$ production in ppbar collisions at $\sqrt{s}$ =1.96 TeV and limits on anomalous ZZZ and $ZZ\gamma^*$ couplings*, Phys. Rev. Lett. 100, 131801 (2008).
- The CDF Collaboration, *First Measurement of ZZ production in ppbar collisions at $\sqrt{s}$ =1.96 TeV, arXiv:0801.4806v1 (2008).*