ZZ→llvv

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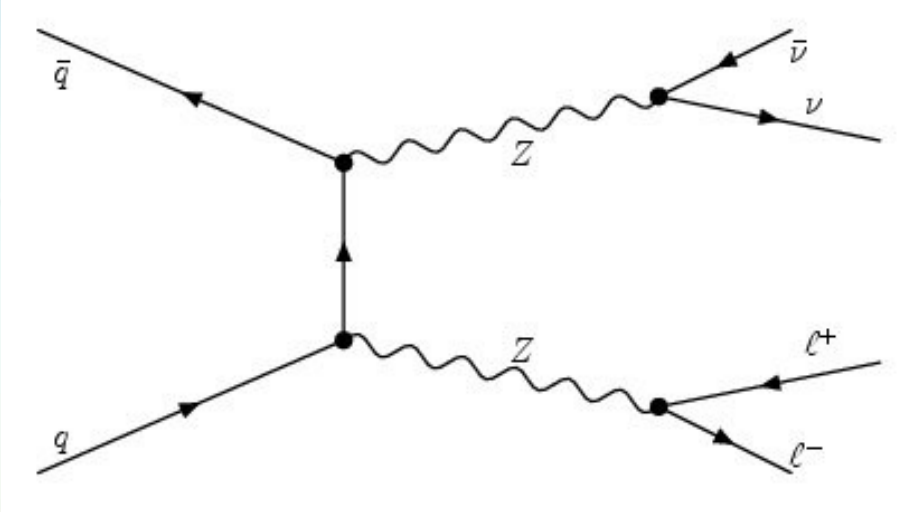
April 13, 2008

Outline

- Motivation
- Events selection and Monte Carlo modeling
- Inclusive Z Rejection
- Likelihood
- Significance and Cross Section measurement
- Conclusion

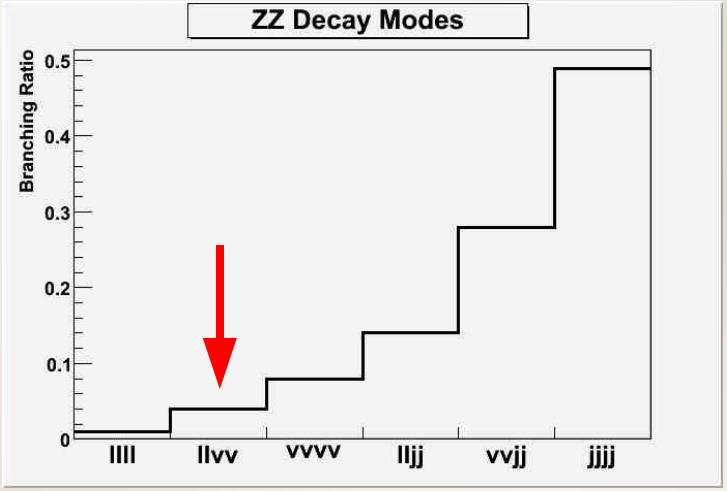
Motivation

Aside from production with a Higgs boson, the ZZ di-boson process has the lowest cross section and is the last remaining unobserved di-boson process at the Tevatron.



Use the fully leptonic mode ZZ→llvv (where l = electrons and muons):

- Small branching fractions w.r.t jet modes
- Larger branching fractions than the ZZ→llll
- Manageable Backgrounds
- Requires a large amount of data



Event Selection

Use an OR of single electron (muon) triggers for the di-electron (di-muon) channel.

Di-Electron Cuts:

- p_T > 15 GeV
- Within the central ($|\eta| < 1.1$) or forward ($1.5 < |\eta| < 2.5$) calorimeter regions
- Tight Isolation
- Tight cut on multi-variate parameter of energy and shower distribution

Di-Muon Cuts:

- p_T > 15 GeV
- Central track match with
  - at least 1 hit in the Silicon Microstrip Tracker (SMT)
  - A distance of closest approach < 0.02 cm
- Tight calorimeter isolation

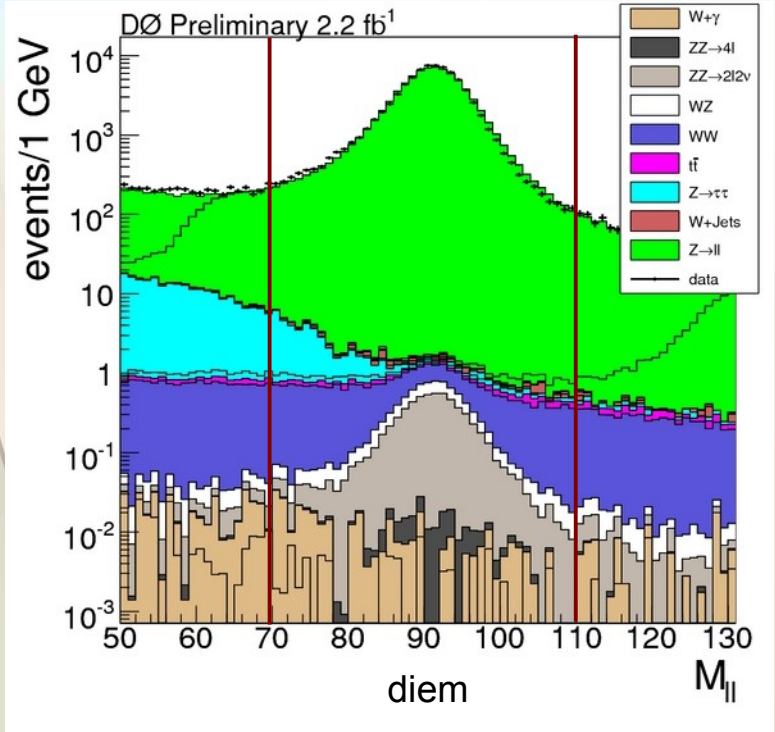
Additionally, require that there be ≤ 2 jets and no additional charged leptons

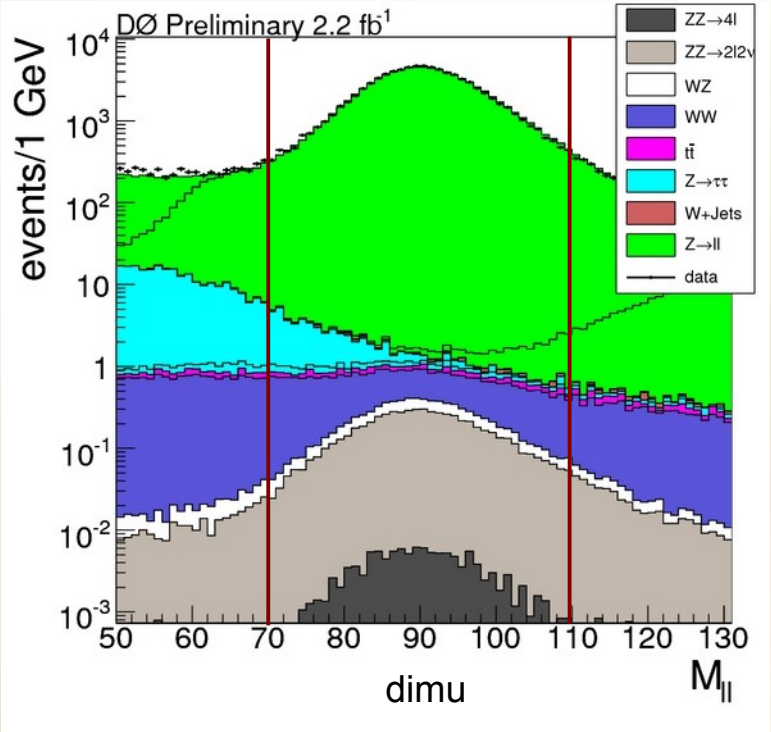
Two data taking periods (RunIIa and RunIIb) are combined for 2.2 fb^{-1} of data

Monte Carlo Modeling

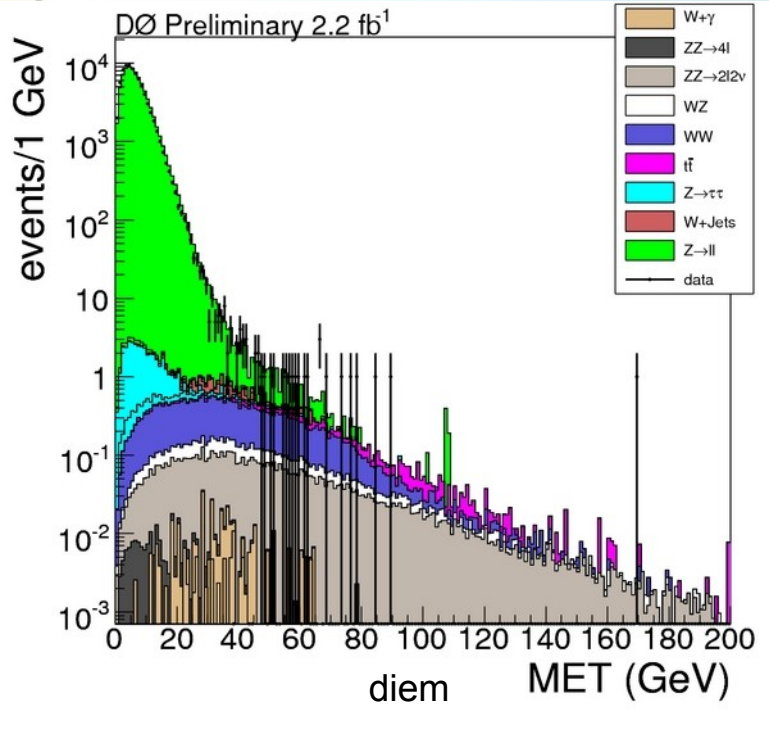
The W+Jets background is generated using ALPGEN and is normalized using a jet to lepton mis-identification rate measured in data.

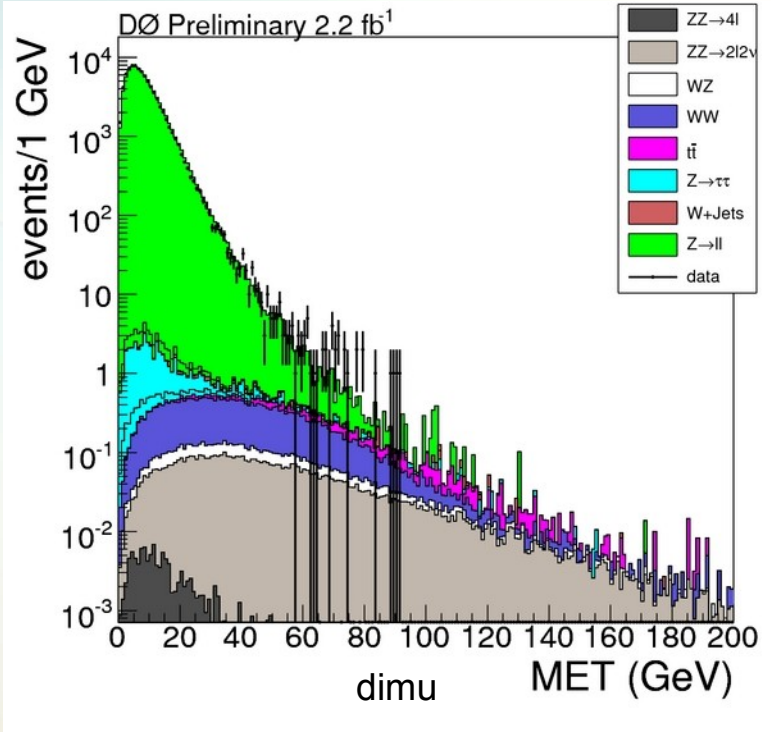
All other backgrounds are generated using PYTHIA and are normalized to the Z peak in data (70 to 110 GeV) using their relative NLO theoretical cross sections after correcting for the luminosity profile, trigger efficiency, and lepton id efficiency.





Missing E_T





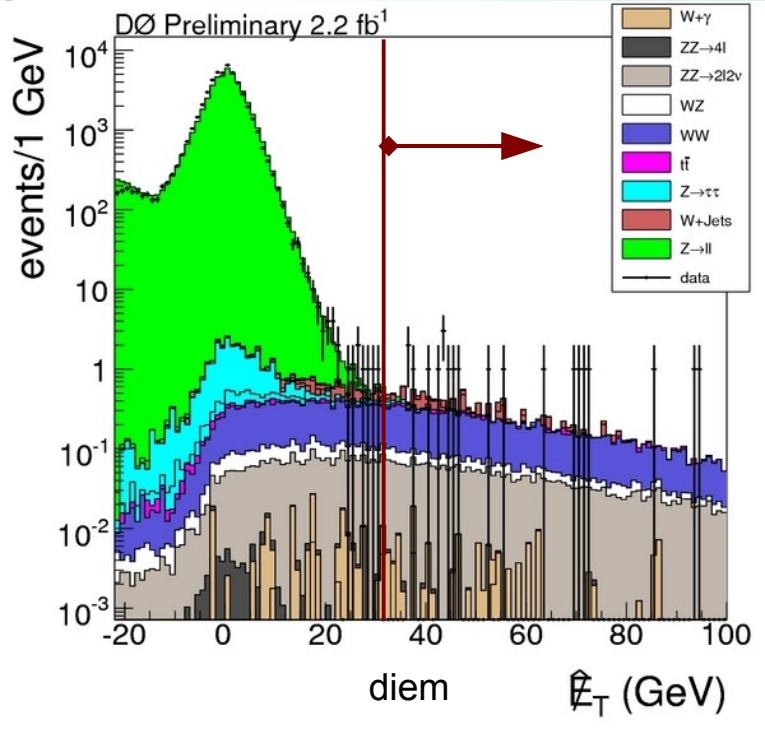
To reduce the contribution of mis-measured MET build a variable sensitive to "true MET"

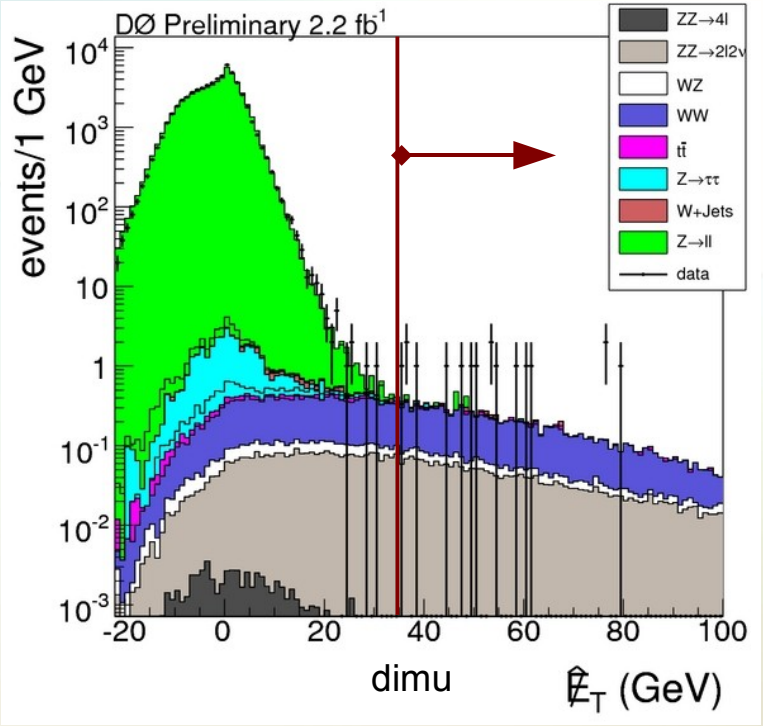
Define the recoil activity as a combination of:

- Uncertainty of the di-lepton p_T
- MET
- Jet Activity
- Track Activity

Inclusive Z Rejection

Recoil Activity





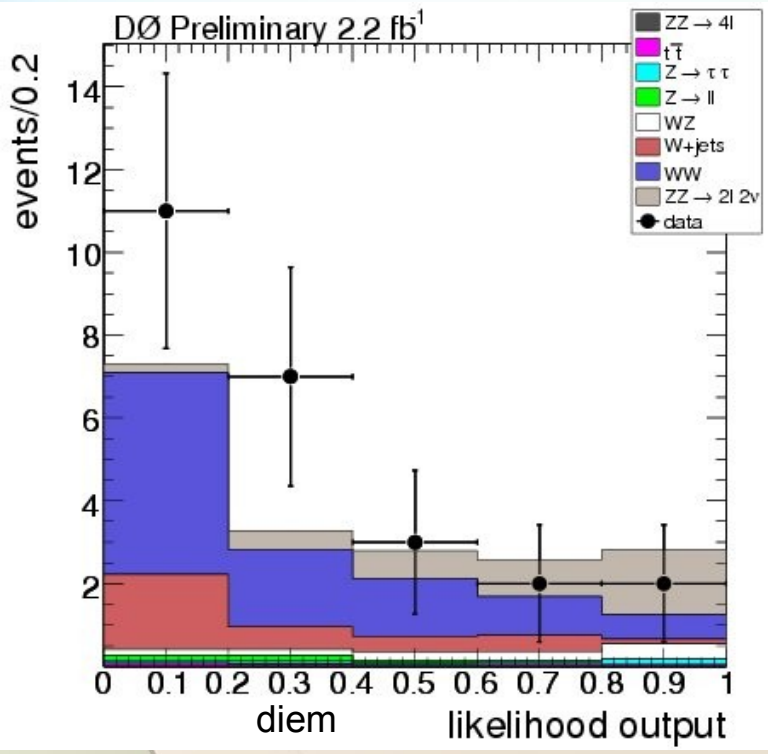
Event yields after the cut:

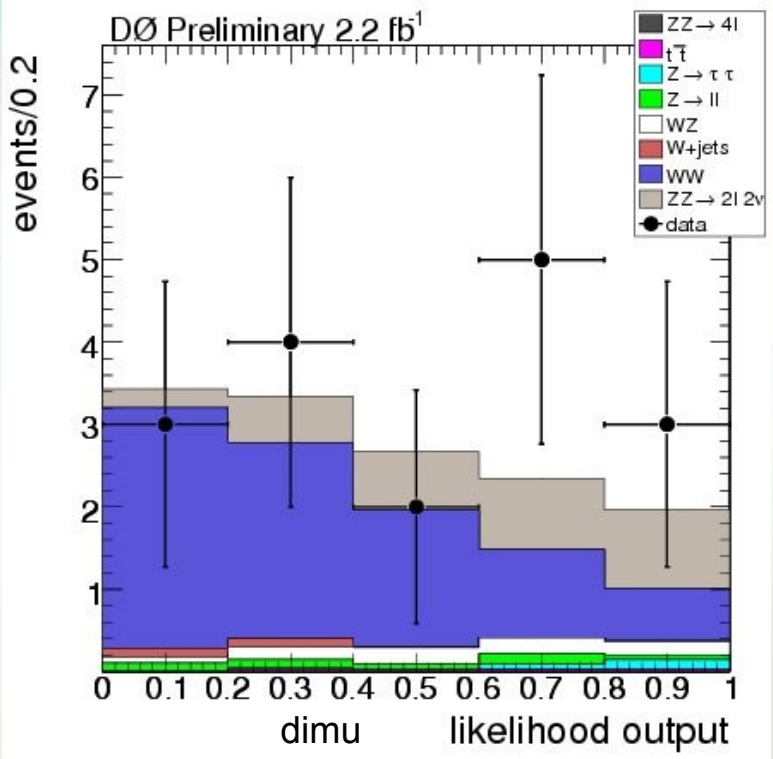
Sample	diem	dimu
Z->ll	0.3 ± 0.15	0.45 ± 0.24
ZZ->llvv	3.81 ± 0.03	3.30 ± 0.03
Tot Bckg	14.87 ± 0.4	10.4 ± 0.3
Tot MC	18.69 ± 0.4	13.7 ± 0.3
Data	25	17

WW is the largest remaining background

Likelihood Performance

Construct a likelihood to discriminate between the ZZ and the main remaining irreducible backgrounds (WW and W+Jets)

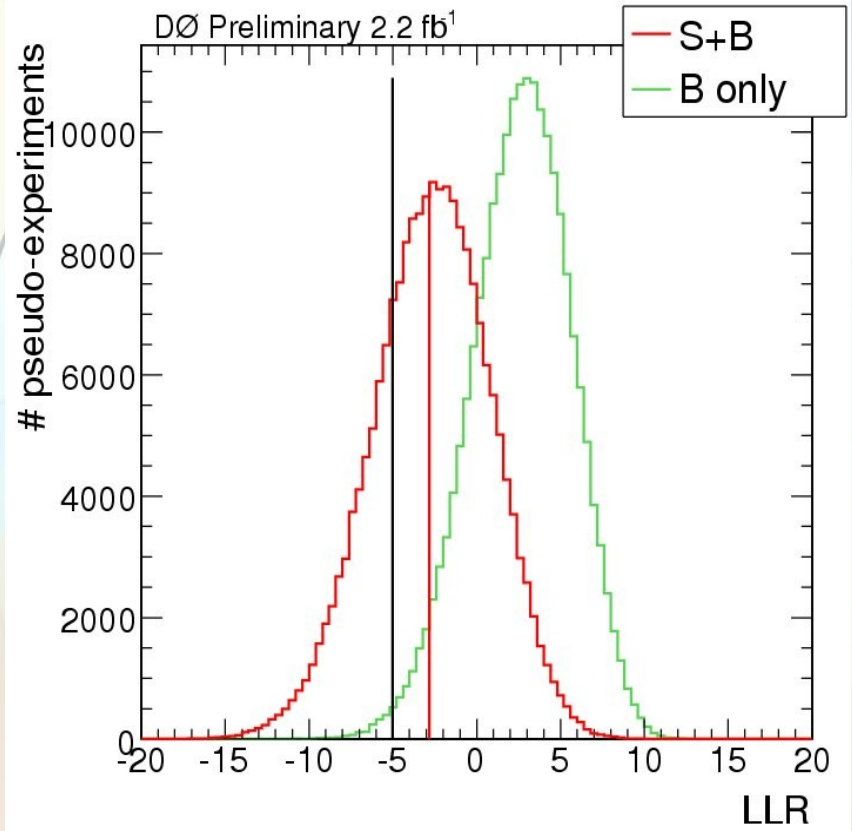




The variables used are:

- Di-lepton Mass
- Leading Lepton p_T
- $\Delta\Phi$(lead lepton, di-lepton pair)
- Cosine of the scattering angle of the negative lepton in the di-lepton rest frame

Calculating the Significance



The significance is determined by calculating the probability that the background fluctuate up to our observed values from 20000 pseudo-experiments.

We Find:

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

Predicted Standard Model cross section: 1.6 ± 0.1 pb

	di-electron		di-muon		combined	
	expected	observed	expected	observed	expected	observed
CL_b	0.9247	0.8860	0.8900	0.9948	0.9613	0.9918
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

vertical red line: median of the S+B distributions

vertical black line: value observed from data

Conclusion

- 2.4 σ measurement of ZZ→llvv using 2.2 fb^{-1} of data
- Demonstrated the effectiveness of using the Recoil Activity as a measure of the “true” Missing E_T
- Find σ(ZZ) = 2.1 ± 1.1 ± 0.4 pb

Backup Slides

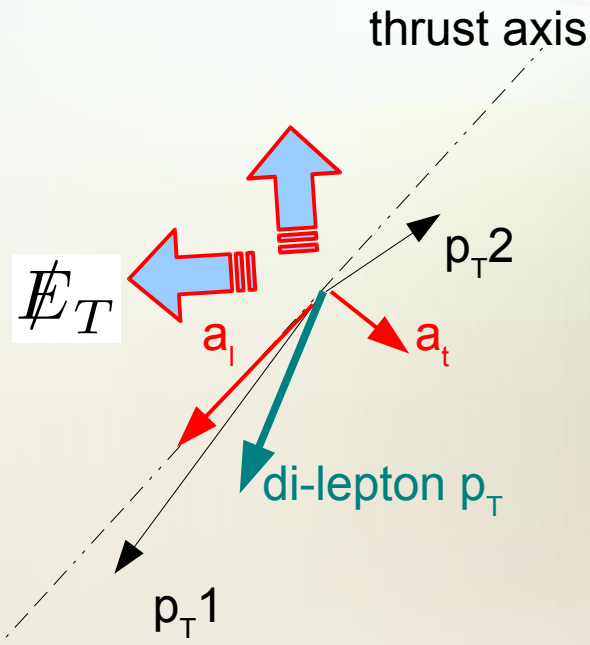
Recoil Activity

To reduce the contribution of fake MET no direct cut on MET → build a variable sensitive to "true MET"

- decompose di-lepton p_T in 2 components with respect to thrust axis:
  - a_l: sensible to p_T mis-measurement
  - a_t: sensible to recoil activity mis-measurment
- build a variable which gives more weight to a_t (add in quadrature with different weights) →
- balance against activity in the opposite hemisphere and correct using the corresponding uncertainties

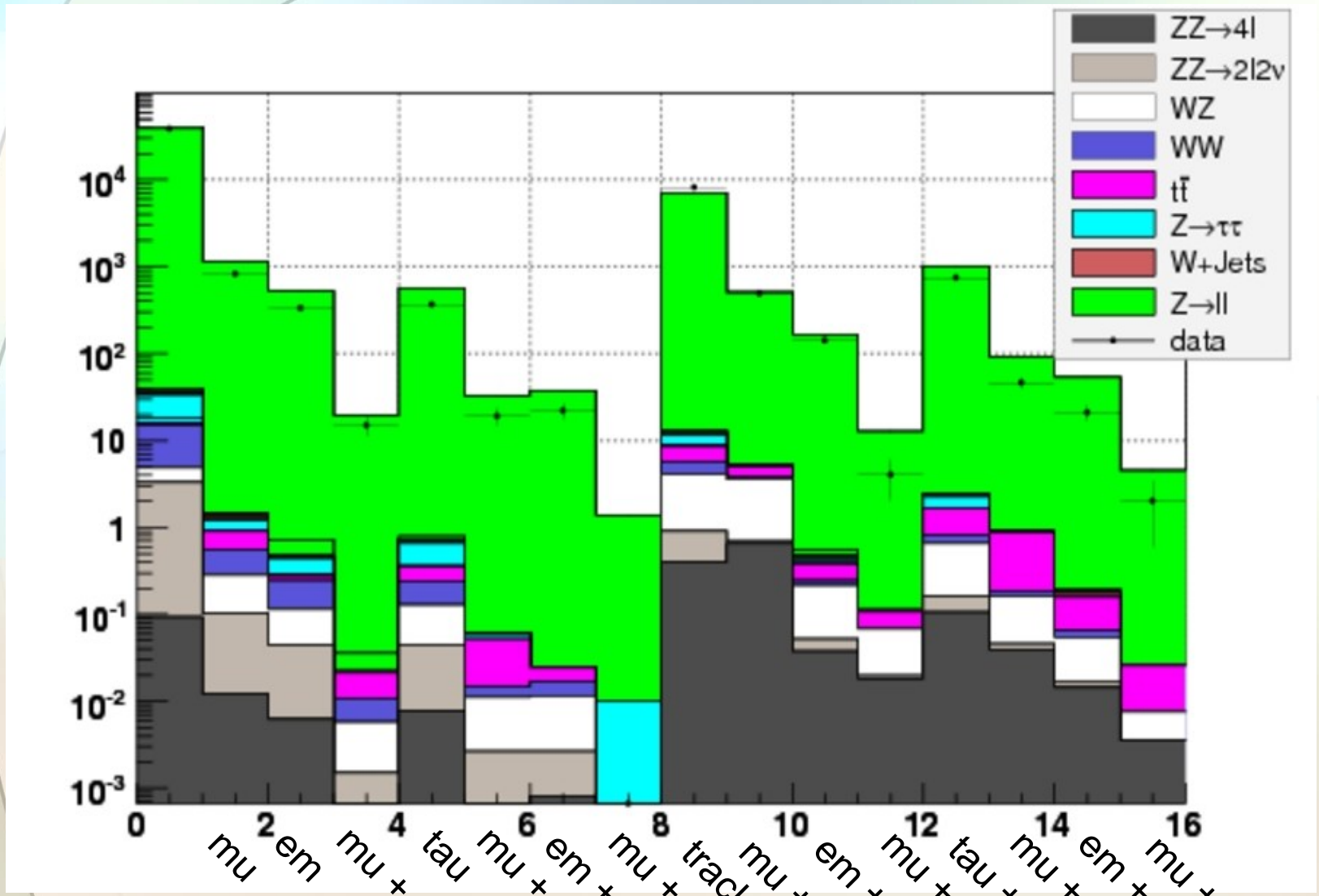
Result:

- by construction all uncertainties and mis-reconstruction can ONLY reduce the value of $\not\!\!E_T$



Systematics

- Not sensitive to global MC scale factor (normalize to data under the Z peak)
- JET related uncertainties:
  - absolute value of JES
  - relative JES data/MC
  - Jet Energy Resolution
  - Jet efficiency in JSSR
- Lepton resolution
- Modeling of the “Corrected MET variable”
  - the falling edge is integrated in data and MC and extrapolated to the threshold -> scale factor for the background
- Uncertainties on $Z/\gamma^* \rightarrow ll$ cross section
- Uncertainties on the acceptance ratio A_Z / A_{ZZ}
- Normalization of the W+jet background from the matrix method
  - limited statistics after cut on “corrected MET”
  - uncertainties on the fake rate


ZZ→4l
ZZ→2l2ν
WZ
WW
tt̄
Z→ττ
W+Jets
Z→ll
data
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
0
2
4
6
8
10
12
14
16
mu
em
mu + em
tau
mu + tau
em + tau
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track
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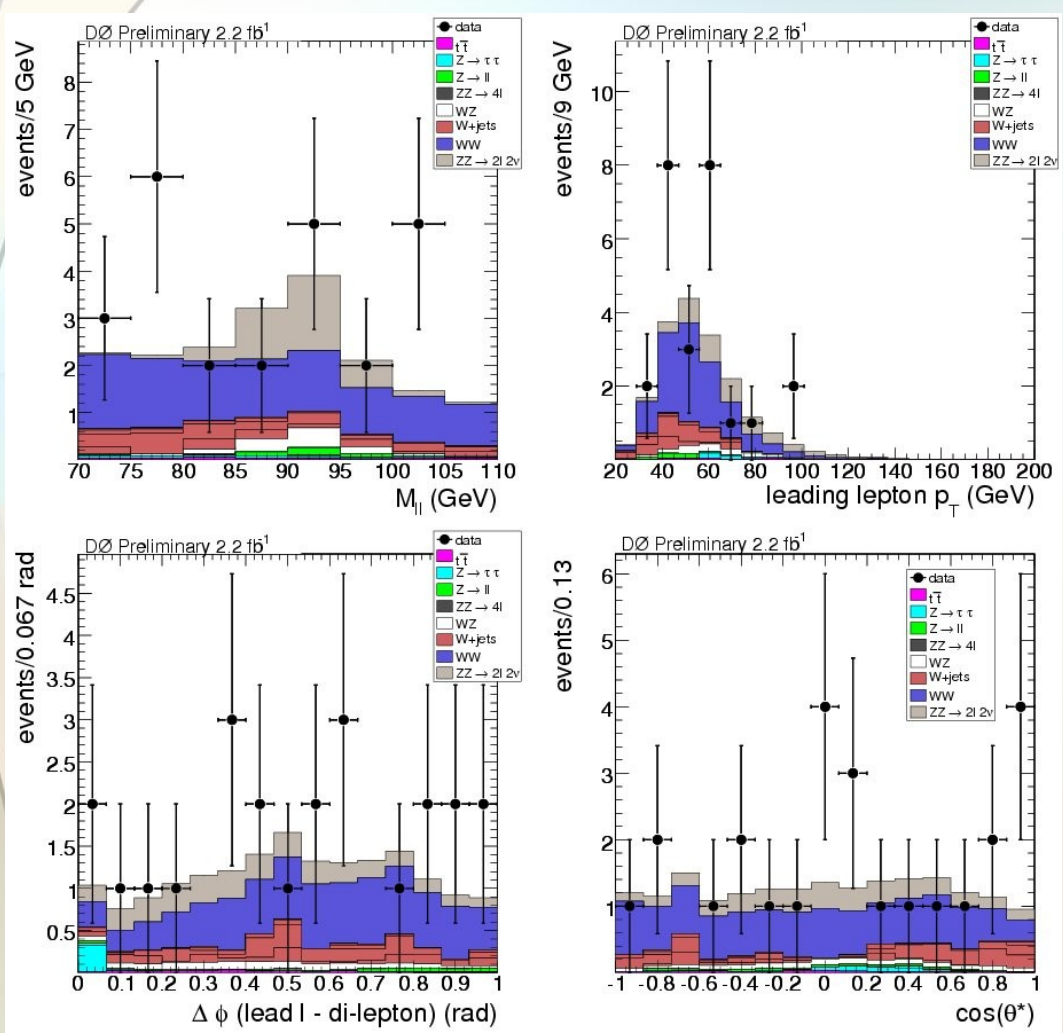
Likelihood Variables



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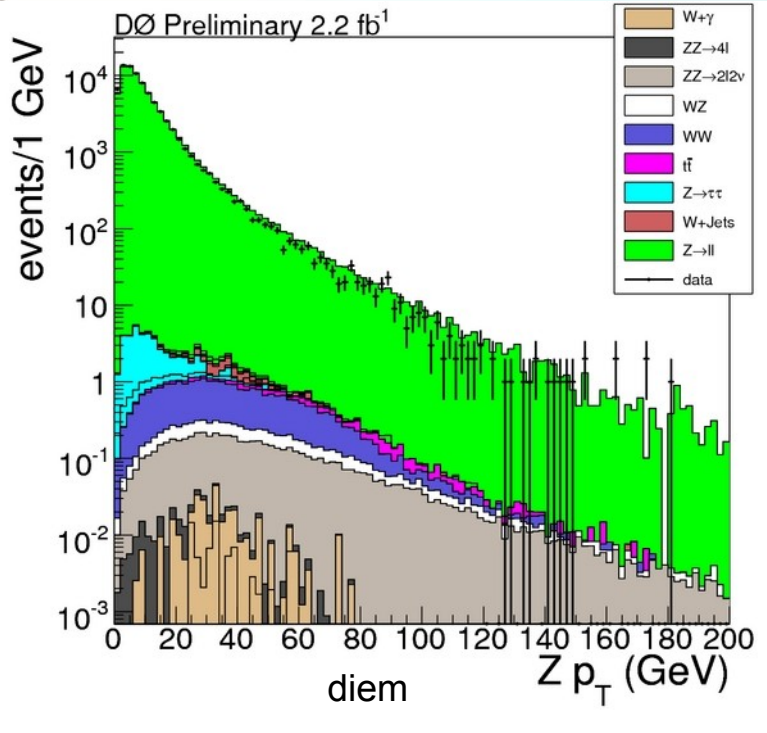
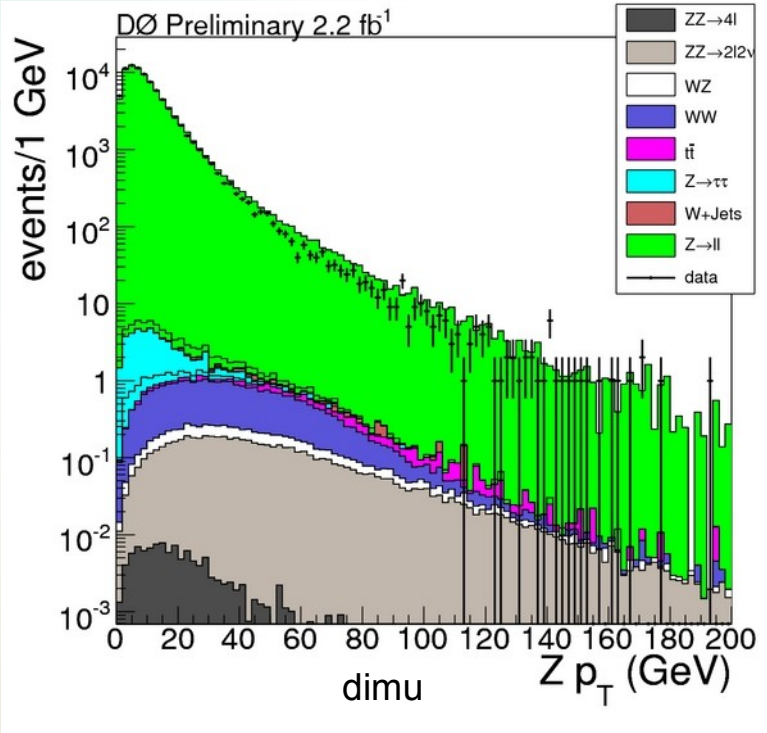
diem

Dilepton pT


DØ Preliminary 2.2 fb^{-1}
events/1 GeV
Z p_T (GeV)
W+γ
ZZ→4l
ZZ→2l2ν
WZ
WW
tt̄
Z→ττ
W+Jets
Z→ll
data
diem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events/1 GeV
Z p_T (GeV)
ZZ→4l
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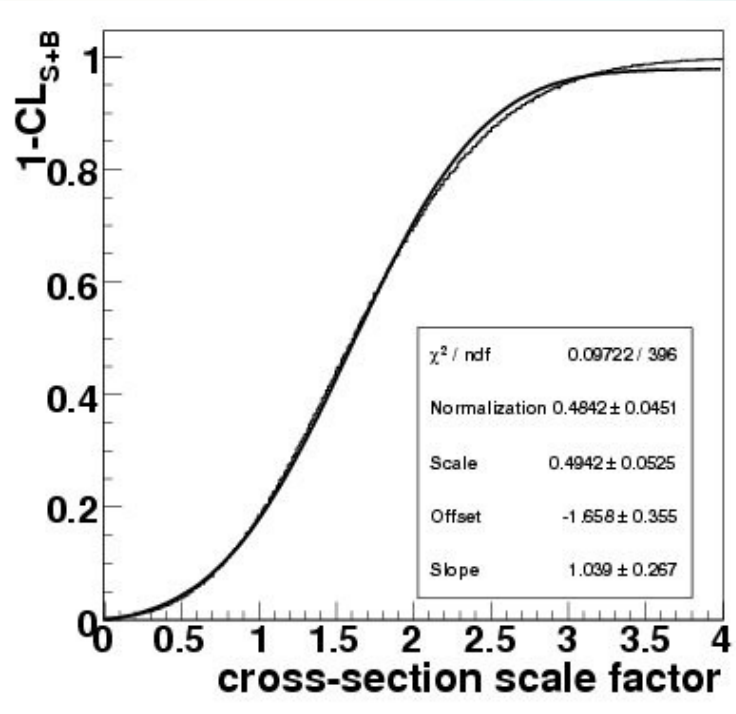
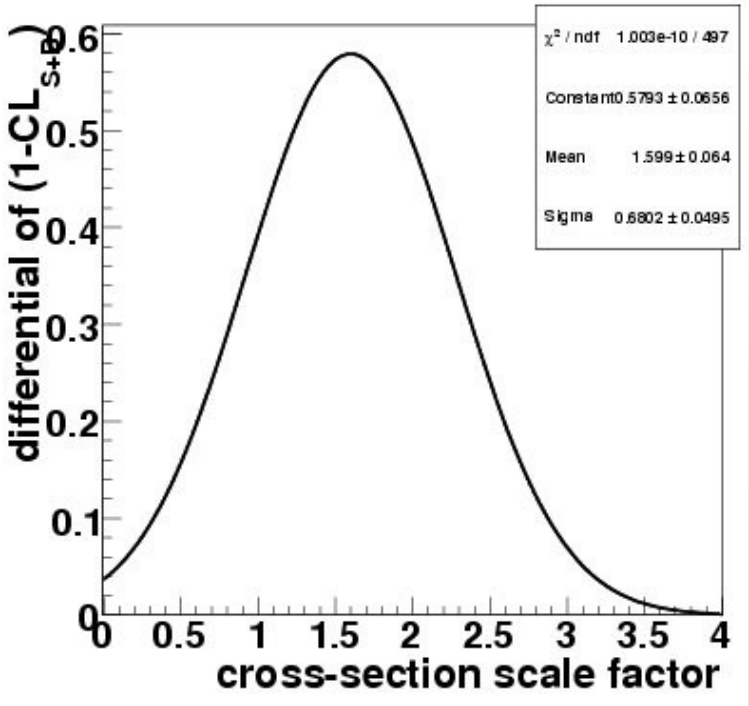
WZ
WW
tt̄
Z→ττ
W+Jets
Z→ll
data
dimu

Cross Section

- Fit 1-CL_{S+B} distribution as a function of a xsection scale factor
- Evaluate differential distribution of 1-CL_{S+B}





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

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