Search for universal extra dimensions in the like-sign dimuon events using 7.3 fb^{-1} of DØ data

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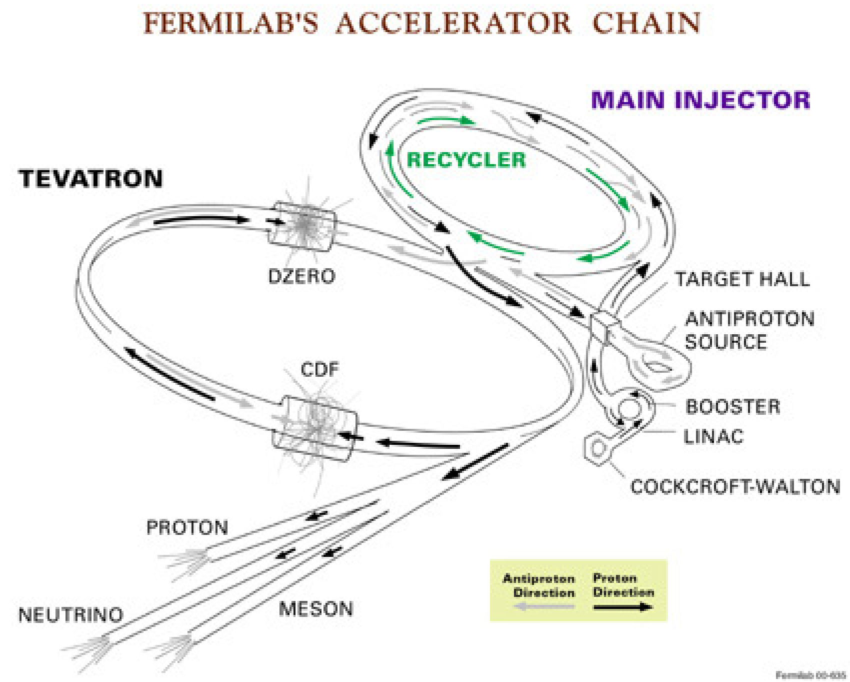
Overview

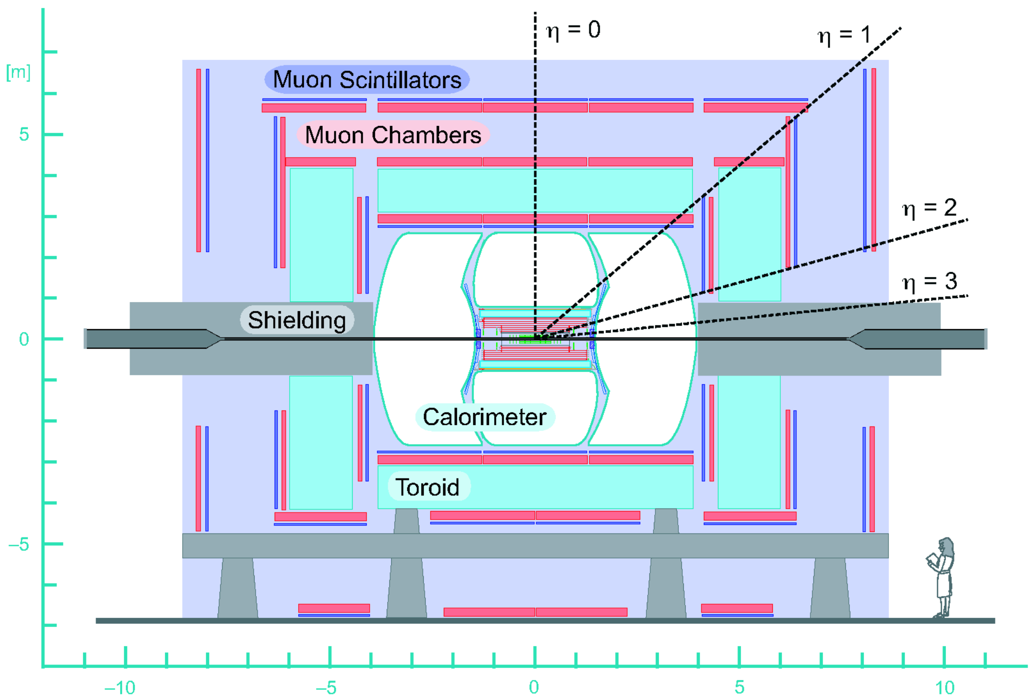
- Tevatron and DØ detector
- Universal Extra Dimensions
- Data sets used
- Backgrounds
    - multijet from QCD
    - charge mismeasurement
- Multivariate analysis
- Conclusions

Tevatron and DØ

Tevatron

- $p\bar{p}$ collider
- $\sqrt{s}$ = 1.96 TeV
- Integrated delivered luminosity ~ 11.7 fb^{-1}
- 2 multi-purpose detectors: DØ and CDF





The DØ detector

- Tracking:
  - Silicon Microstrip Tracker (SMT), |η| < 3
  - Central Fiber Tracker (CFT), |η| < 2
- Uranium liquid argon calorimeter
- Muon tracking and triggering systems
- Solenoid + Toroid magnets

Universal Extra Dimensions

- Attempt to unify electromagnetism and gravity – Kaluza & Klein (1921-26)
- Additional spatial dimension which we don't see since it is compactified (“rolled up”)
- Universal – all fields propagate in extra dimension, non just gravity
- Particles moving in extra dimension have higher E_{kin}
  - higher mass in 4D
  - Kaluza-Klein excitation

Universal Extra Dimensions

- Minimal UED (mUED) parameters:
  - assuming only 1 extra dimension
  - inverse radius $R^{-1} \approx 200..320$ GeV
  - cutoff scale $\Lambda \approx 10000$ GeV

Size of extra dimension:
$\hbar c/200\ \text{GeV}^{-1} \approx 10^{-3}$ fm

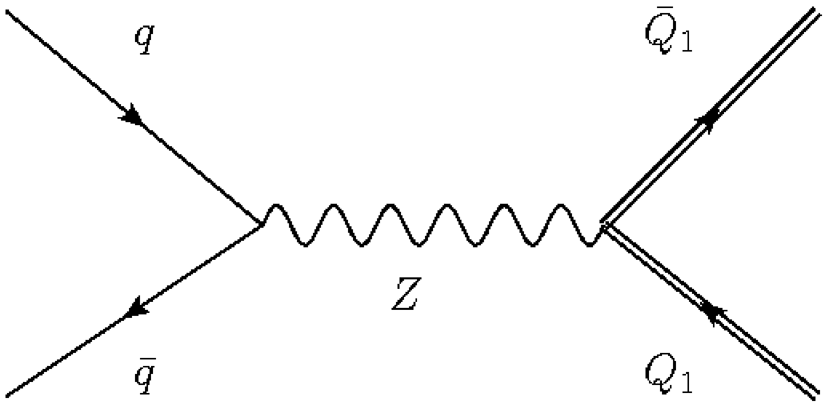
- Quantization
  - periodic boundary conditions
  - discrete masses, $m_n^2 = m_0^2 + (n/R)^2$

- Conservation of momentum in extra dimension
  - conversation of KK-excitation, KK-parity $P_{KK} = (-1)^n$
  - lightest KK-partner (LKP) stable - KK-photon
  - candidate for dark matter

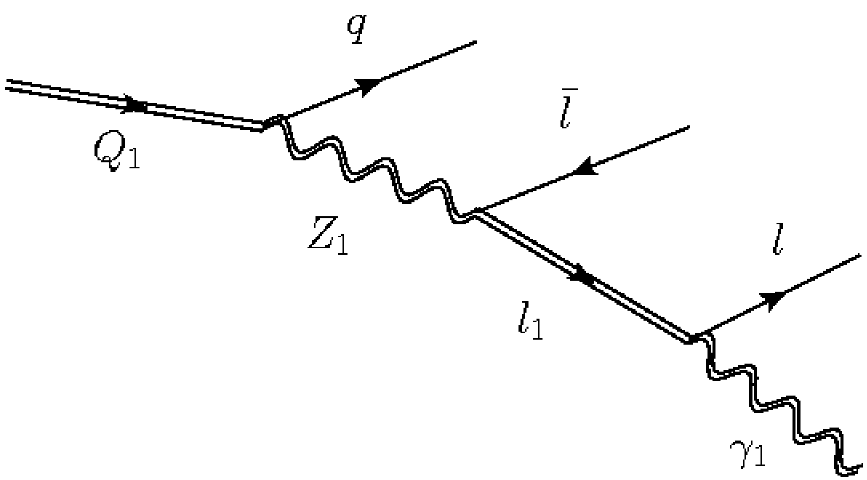
mUED production and decays

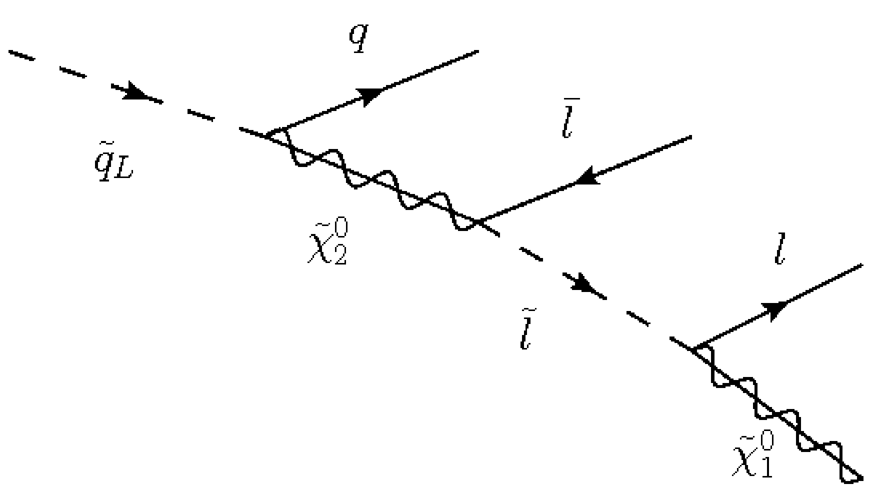
Possible leptonic decay chain:

$p\bar{p} \rightarrow Q_1Q_1 \rightarrow Z_1Z_1/W_1W_1/W_1Z_1 \rightarrow$ 2-4 leptons + MET



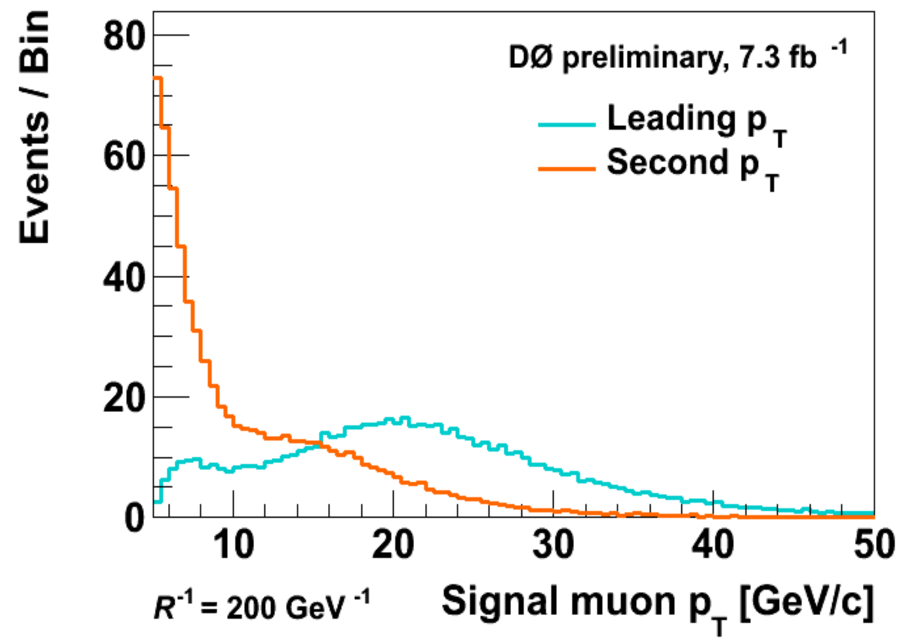
Phenomenology is very similar to R-parity conserving SUSY:





Why dimuons?

- **2-4 leptons + MET**
- If masses of KK-boson and KK-lepton are close then leptons can be very soft (undetectable)
- **2 leptons + MET** → large background because of Z→μμ
- **2 like-sign muons + MET**
  low SM background
  sensitivity to soft muons



Datasets used

DATA

- 7.3 fb^{-1} of DØ Run II data
- OR of single muon triggers

Background MC

- ALPGEN+PYTHIA for Z+jets, W+jets, $t\bar{t}$
- PYTHIA for diboson
- Normalized to NLO cross section
- Multijet estimated from data

Signal MC

- Generated with PYTHIA 6.421 using CTEQ5L PDF
- Generated points: R^{-1}=200..320 GeV

Physics

- Real like-sign muons
  Diboson (ZZ, WZ, WW)

Instrumental

- Muons from jets
  Z+jets, W+jets, QCD ($b\bar{b}$, $c\bar{c}$)
- Mismeasured charge
  $Z \rightarrow \mu^+\mu^- \rightarrow \mu^+\mu^+$

QCD modeling is hard:

- Perturbation theory breaks at low energies (α ≈ 1)

- Existing modelings do not agree with data
  ($b\bar{b}$ cross section, angular distributions)

- Small BR to like-sign dimuons – huge MC samples are needed

↓

Modeled from data

QCD modeling

Muons from signal

- 2 like-sign muons
- Prompt muons
- Muon angles non-correlated
- Jet and muon direction are non-correlated

Muons from multijet

- Jets + muons
- Non-prompt muons (from jets)
- Muons are back-to-back
- Jet and muon direction are correlated

Use muon isolation to separate signal from multijet background

QCD modeling

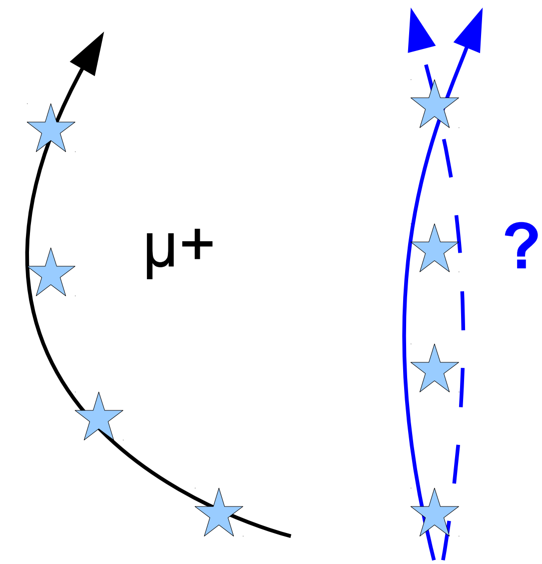
- Signal sample:
  both muons are isolated
- QCD enriched sample:
  one muon is not isolated

- Reweighted QCD sample is
  an estimation of multijet background in signal sample

- Determine reweighting for different jet multiplicities
  (0 jets, 1 jet, >1 jets) in the region where QCD is dominant
  background: $p_T<10$ GeV

- Electroweak "contamination" in QCD sample is estimated from MC and subtracted

Charge mismeasurement



- Charge flip (CF):
  $\mu^+\mu^-$ mismeasured as like-sign pair
- Mostly at high pT – straighter tracks
- Small fraction can lead to large contamination – Z peak
- Included in detector simulation – good enough?

Estimation of charge flip

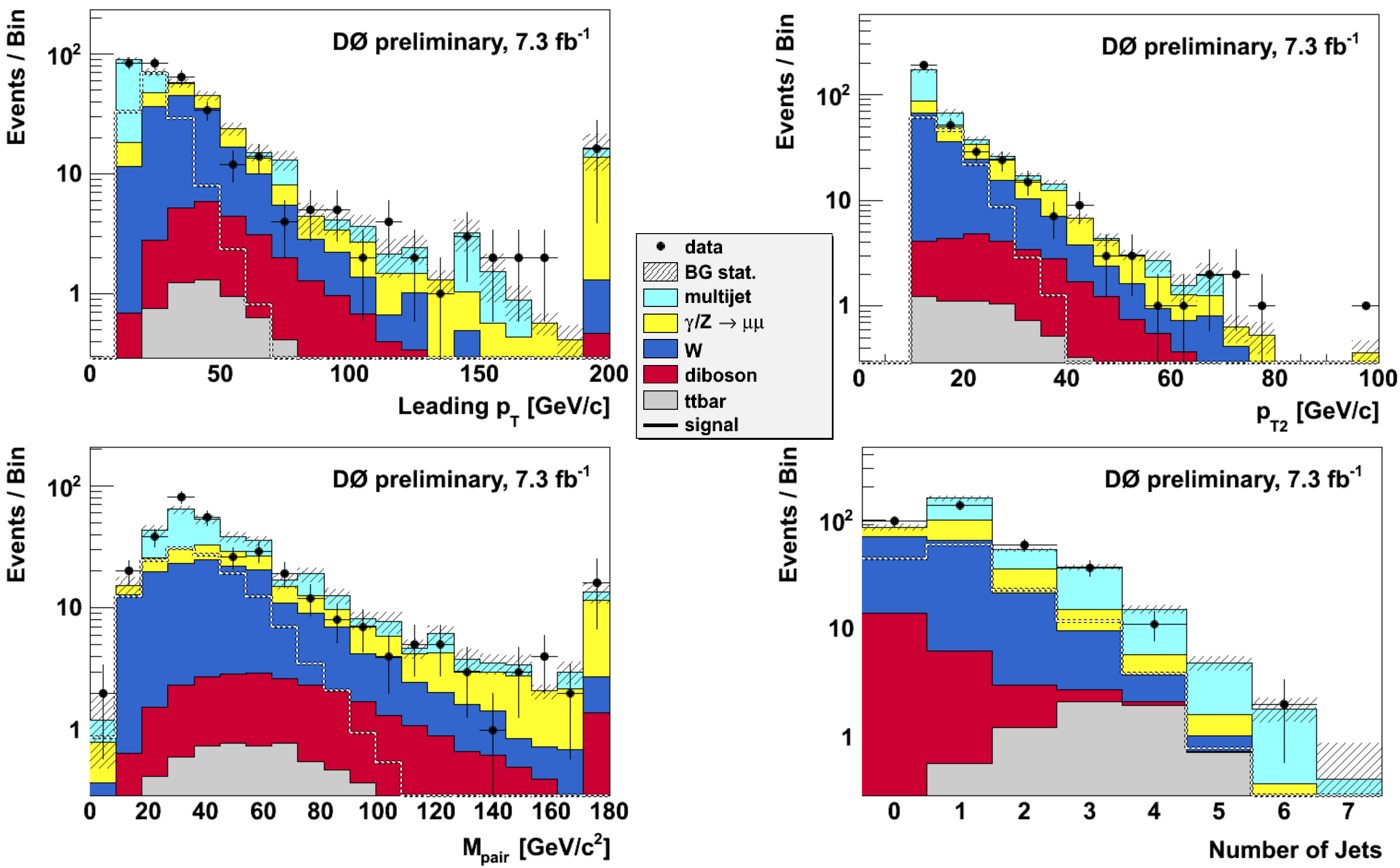
Use two measurements for CF estimation:

- charge measured in muon system
- charge measured in tracking system

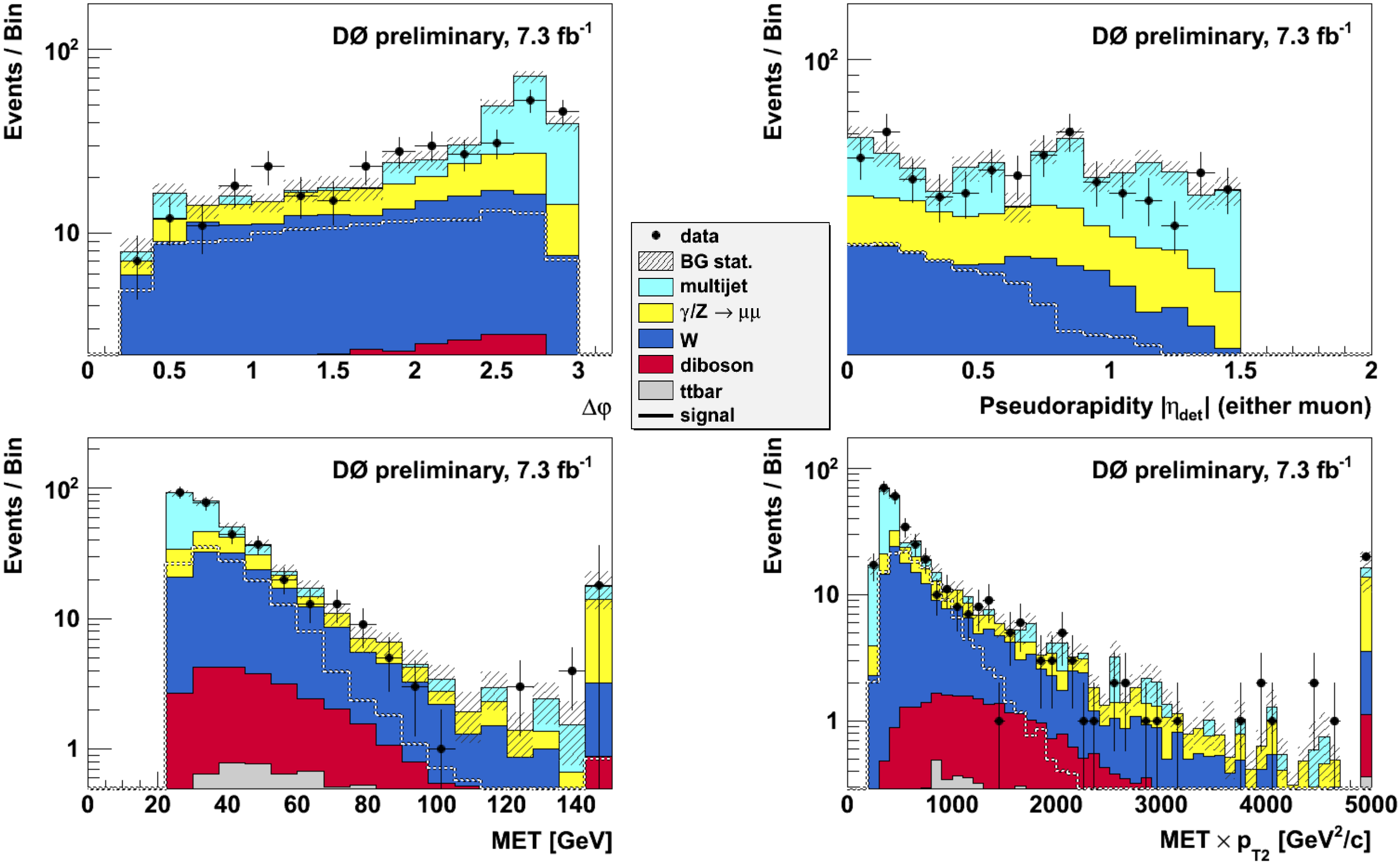
Taking into account efficiencies of charge measurements in tracking and muon systems and number of disagreements between these measurements we can estimate number of CF events and compare it with $Z \to \mu\mu$:

	CF estimation	$Z \to \mu\mu$ MC
Events	161.7±32.4	170.6

Data vs Background

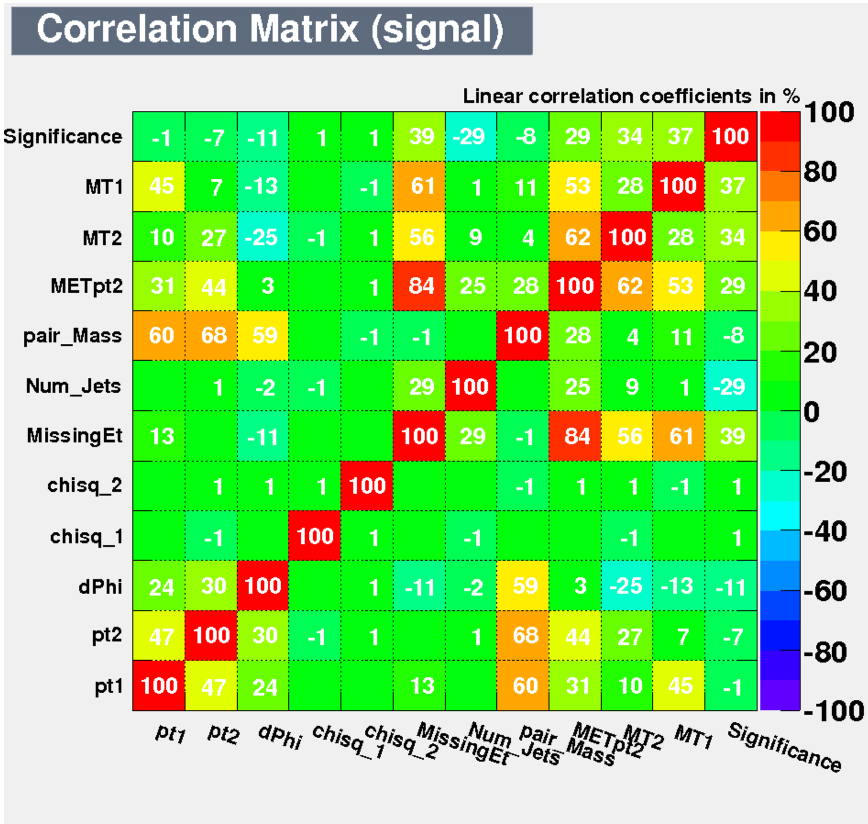


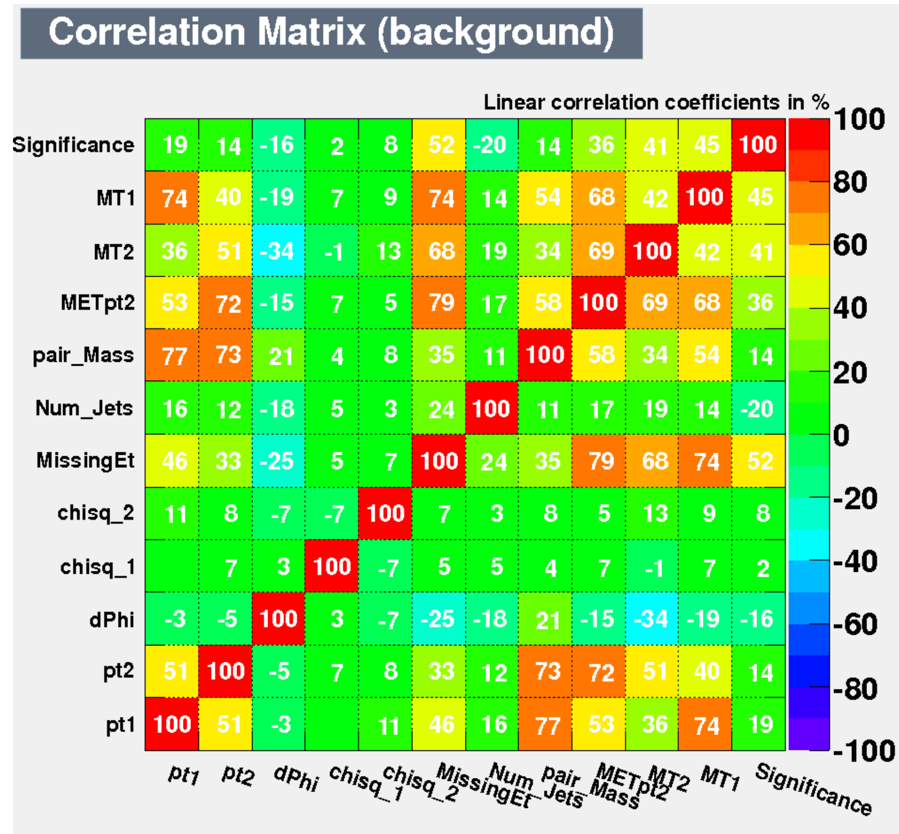
Data vs Background



Variables

Different correlations is signal and background



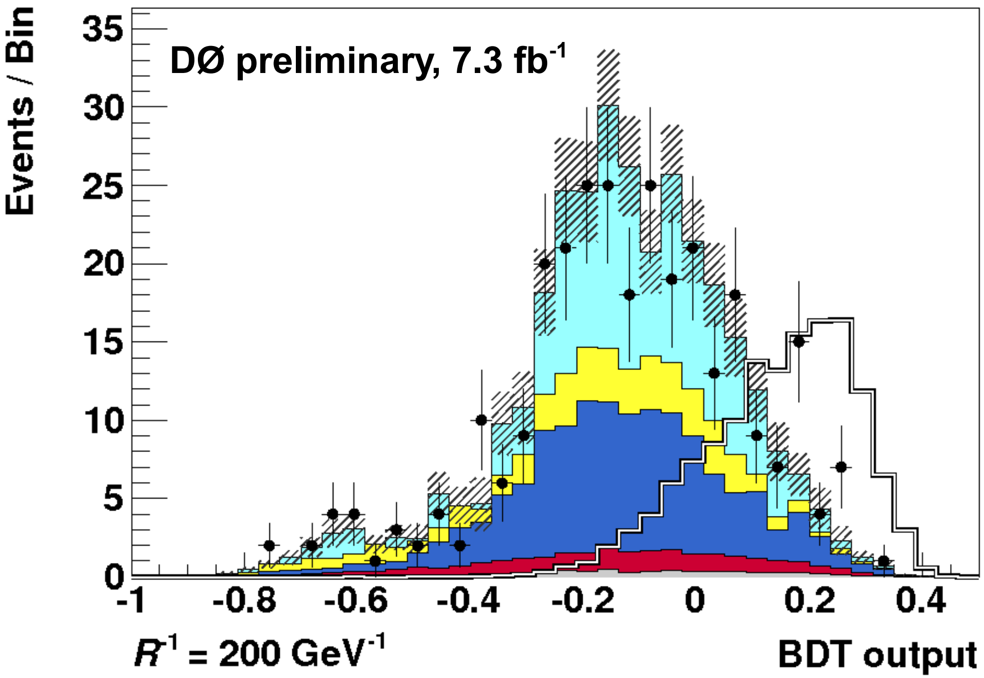


Most important variables:

- $\Delta\varphi$ – azimuthal opening angle between muons
- pT1 – transverse momentum of leading muon
- MT2 – transverse mass calculated using missing ET and transverse momentum of second muon

Multivariate analysis:

- Take correlations into account
- Boosted decision trees method is used
- One tree trained for each signal point
- Classifier



Systematics

Source	Uncertainty, %
Luminosity	6.1
PDF	2.0
Muon ID	2.0
QCD	35
W cross section	8.5
Z cross section	3.5
Diboson cross section	7.0
$t\bar{t}$ cross section	14.8

Largest contributions: Luminosity, QCD modeling, W cross section

Conclusion

- Performed search for UED using 7.3 fb^{-1} if DØ data
- QCD modeling works well
- Charge mismeasurement is understood
- No excess over background observed
  - proceed to set the limits
- Analysis is in review, expecting to submit to PRL soon

Thank you!