Analysis of W→μν+jets

Introduction

The detection of leptons (muons and electrons) is very important for physics at the current and higher energy regimes. The study of intermediate vector bosons decaying into leptons will give precise measurement of the mass of W, results on forward and backward asymmetry and the measurement of anomalous gauge boson couplings. Multileptons are a signature of supersymmetric particles in many models. The search for stable particles that can appear like slowing moving muon like objects gives us information about new physics. Muons are also used to tag b-jets for B physics and also higgs searches. The important search channel for higgs decay is the WH channel at the current and future colliders. Therefore it is important for us to understand the W decay with jets in the final states which can be the signature of higgs.

Data Set

The dataset consists of Electroweak working group's D0reco ver.p13.05 skimmed muon samples [1]. The p13.05 reconstructed data is stored in thumbnail format [2] in 206 files with 8866142 skimmed events for analysis. The dataset definition [3] keyword for accessing these skimmed events through SAM [4,5] is **wzskim1305.mu**. For the analysis about 408K events were selected. The event selection criteria for skimmed events is the presence of at least one muon with p_T > 8 GeV in addition to dimuon events with one loose muon (p_T >1 GeV) quality requirement. The offline run quality database was queried for bad muon, bad missing E_T, bad jet run numbers and the results are shown in Table 1. Only reasonable or good runs for muons are chosen. The definitions of quality words are given in table 2. The luminosity for the trigger used to skim muon data is 24.3/pb [6]. The muon selection criteria are based on the trigger MU_W_L2M5_TRK10.

File Name	Run #	#Events	Muon_quality	Met quality	Jet_quality
WZskim-muStream-20030110-145203.raw_p13.05.00	169988	47256	REASONABLE	GOOD	GOOD
WZskim-muStream-20030112-012201.raw_p13.05.00	167882	43987	REASONABLE	GOOD	GOOD
WZskim-muStream-20030105-140711.raw_p13.05.00	168023	44975	REASONABLE	BAD	BAD
WZskim-muStream-20030112-162415.raw_p13.05.00	167807	45065	REASONABLE	GOOD	GOOD
WZskim-muStream-20030110-135933.raw_p13.05.00	167882	41758	REASONABLE	GOOD	GOOD
WZskim-muStream-20021221-171855.raw_p13.05.00	165241	45450	REASONABLE	GOOD	GOOD
WZskim-muStream-20021222-020109.raw_p13.05.00	169224	46888	BAD	GOOD	GOOD
WZskim-muStream-20021227-100513.raw_p13.05.00	169260	45385	BAD	GOOD	GOOD
WZskim-muStream-20030112-200818.raw_p13.05.00	167827	47944	REASONABLE	GOOD	GOOD

Table 1. Data Set description

Flag	
BAD	This run should not be used

GOOD	A physics run with no known problems, which can likely be used for physics analysis/publication
REASONABLE	A physics run with minor problems which can perhaps be used for physics analysis, but needs to be treated with care

Table 2. Definition of quality words

DØ Muon System at Fermilab

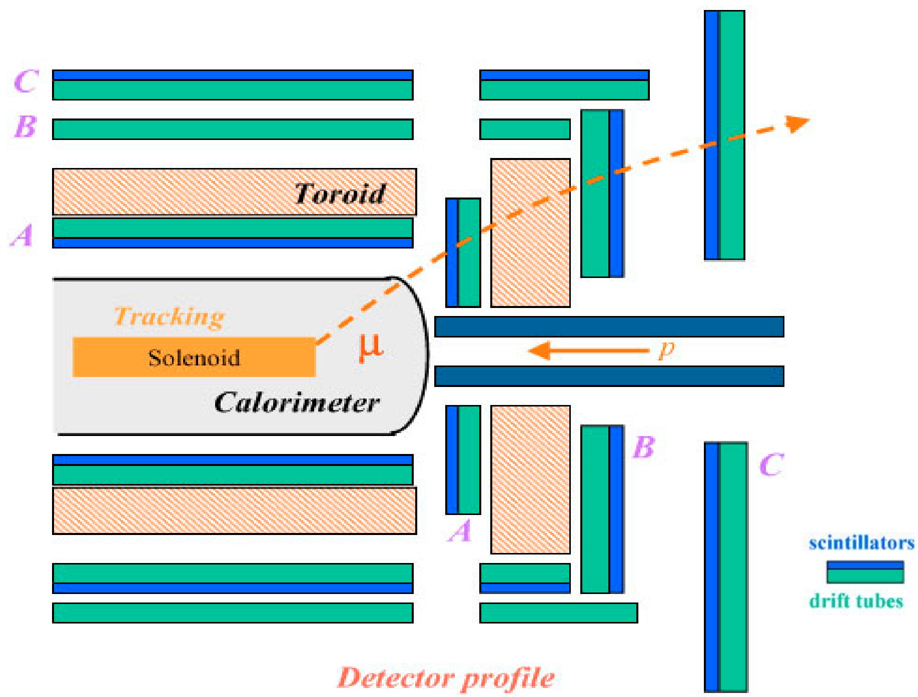

Fig 1

The understanding muon detection system is crucial in analysis of data, especially uncertainties resulting from the measuring device and also rejection of background. This section describes the muon detection system in brief. The central muon tracking system with pseudorapidity coverage $|\eta|\leq1.0$, consists of proportional drift tube (PDT) chambers. The A layer is between the calorimeter cryostat and the toroid magnet (Fig 1). The B and C layers outside the toroid have three decks each. The momentum resolution of the central muon is improved dramatically if these PDTs are used with central tracking. The forward angle muon detection system consists of mini-drift tubes (MDT) and pixel scintillators. The MDT system covers the region $1.0\leq|\eta|\leq 2.0$. The A-layer chambers are in front of the toroid magnet and the B and C layers are behind it. There are layers of scintillators on the top and upper sides of the central muon detector to reject cosmic rays. In addition there is another layer of scintillators (called the AØ counters) between the A layer and the calorimeter. The AØ counters are used for muon triggering, rejection of out-of-time [7] scattered particles and identifying low p_T muons that do not penetrate the toroid magnet.

Selection Criteria

The selection of good muon events with the presence of neutrinos is a challenging task. The idea is to select events that have a Central Tracking Chamber (CTC) track which are well matched to the track segment in the muon chambers. The signal in the electromagnetic and hadronic calorimeters must be consistent with the passage of a minimum-ionizing particle. To ensure good measurements in the drift chamber and calorimeters, muons must originate from an event vertex located within 50 cm of the detector center along z-axis. Events consistent with cosmic rays must be removed. Efficiencies must be calculated and background estimates of events that mimic W decay must be performed. Based on the above information the definition of good muon object for analysis is as follows.

Good muon
- $p_T > 20.0$ GeV
- Match to a central track with $|z_o| < 50$cm

Central muon
- $|\eta| \leq 1.5$
- > 1 A layer wire hits
- > 1 BC layer wire hits
- > 0 A layer scintillators hits
- > 0 BC layer scintillators hits

Not a cosmic muon
- A layer scintillators time < 10ns
- BC layer scintillators time < 15ns

Isolated Muon
- EinCone4 – EinCone1 < 2.5 GeV
- Track $p_T < 2.5$ GeV

Good neutrino
- $E_{T\nu} = \sqrt{(E_{x\nu})^2 + (E_{y\nu})^2}$
- Corrected $E_{T\nu} = \sqrt{(E_{x\nu} \pm p_{Tx})^2 + (E_{y\nu} \pm p_{Ty})^2} \pm 2.0$ GeV

Based on the above information the cuts are applied on the data sample. Muons contained entirely in the central region are considered for analysis.

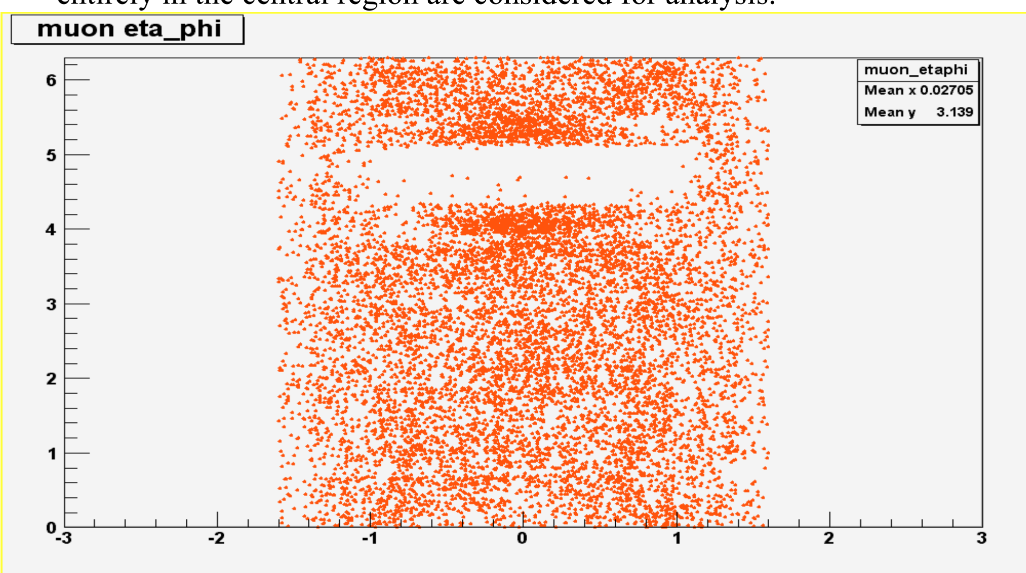

Fig 2. Geometric Acceptance cut

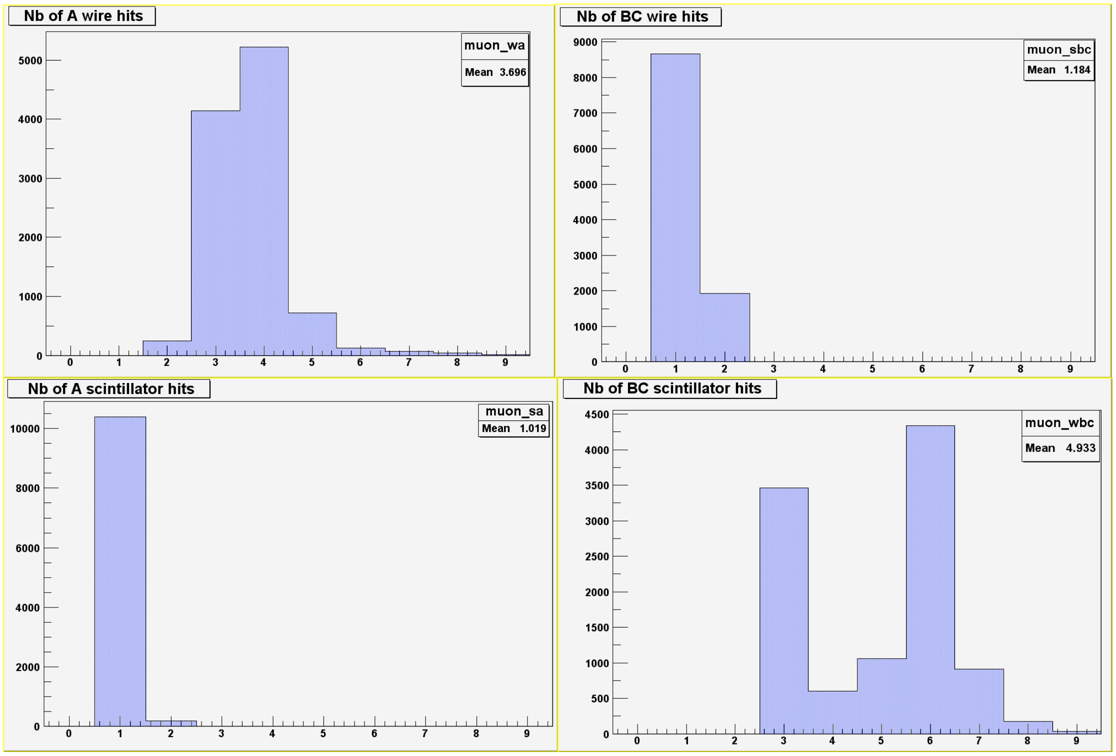

Fig 3. Kinematic cuts

Background Estimate

- Physics Background

➢ W → τν → *l*ννν
This background is not distinguishable from the signal. The way to minimize this background is the difference in kinematics. Since the background lepton comes from the decay of τ, it will have a lower p_T distribution than the signal. Kinematic cuts for p_T of muons keep this background under control. Monte Carlo simulations can be done to estimate geometric and kinematic acceptance. That study is not done here. The W → μν Monte Carlo distribution is shown in filled histogram and the data are shown as points.

➢ Z → *ll*
One of the two leptons from the Z decay may escape detection or poorly reconstructed. This can be a background because the missing lepton can be understood as neutrino. Assuming the σ (Z → *ll)* / σ (W → μν) = 0.10, Monte Carlo simulation can be used to estimate this background. This study is excluded here.

➢ Z → ττ → *l*νν *l*νν
This process has the same rate as Z → *ll.* The lepton will have a lower p_T distribution than the signal. So kinematic cuts should eliminate this background.

➢ QCD

The QCD background consists of muons decayed from particles associated with jets. The isolation cuts eliminate this background considerably.

- ➢ Drell-Yan production

  This occurs when a quark and an antiquark annihilate to form a high-energy photon intermediate, which decays into two leptons. If two muons are produced and one escapes detection, it be a background.

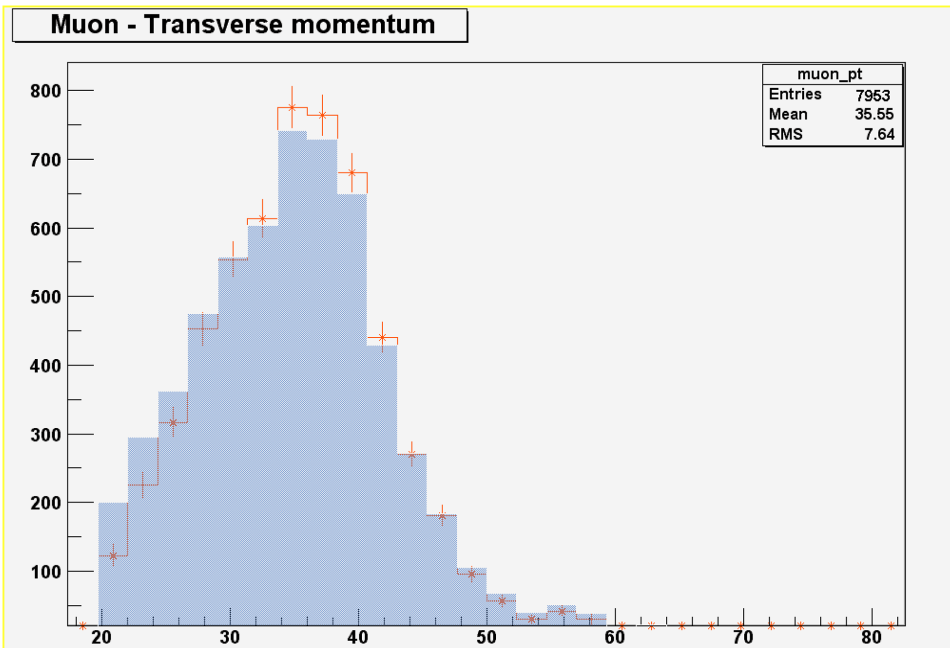

Fig 4. Kinematic cut on muon p_T

- Systematic Uncertainties
- ➢ Punchthrough effects:

  A significant number of muons produced by punchthroughs. Central track matching can eliminate this. The energy deposit along their trajectories in the calorimeter must confirm candidate muon tracks found in the PDTs. For a good muon, the energy deposit in the calorimeter is a minimum ionizing particle (MIP) signal with ~3GeV of energy. This is confirmed by the isolation cut (EinCone4 – EinCone1 < 2.5 GeV). The energy of a 5x5 calorimeter tower around the central track matches the MIP signal.

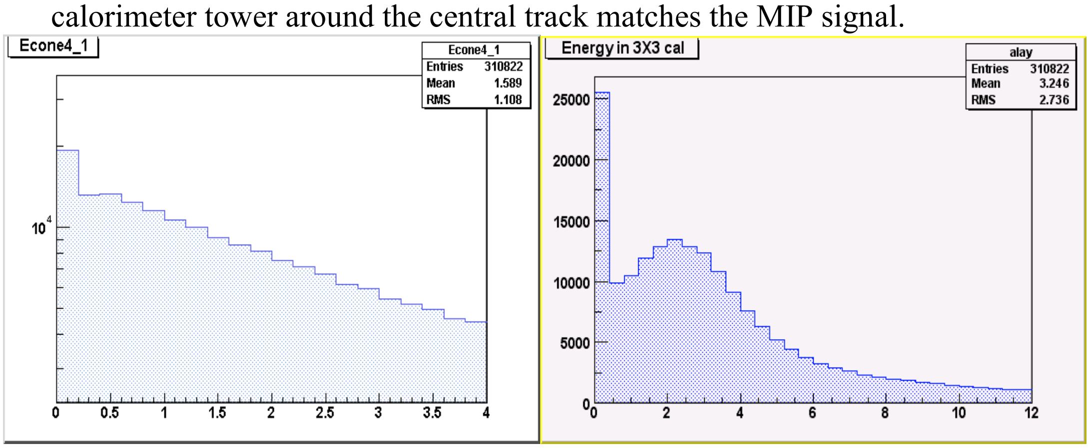

Fig 5. Isolation Cuts

- Rejection of Cosmic Rays:

Cosmic ray muon backgrounds are reduced for isolated muons by scintillator timing cuts and central tracking match cut. The muon track has to originate within 50 cm of the event vertex ($|z_o| < 50$cm). The muon timing is an important parameter in eliminating cosmic ray muons. The drift times of all muon hits should vary consistently. The timing between the hits in A segment is a few nanoseconds (A layer scintillators time < 10ns) and for the BC segment it is of the same order of magnitude (BC layer scintillators time < 15ns). The time interval between the beam crossing and the time that gives the best fit for muon track is almost negligible, because they are produced in coincidence with beam crossings[8].

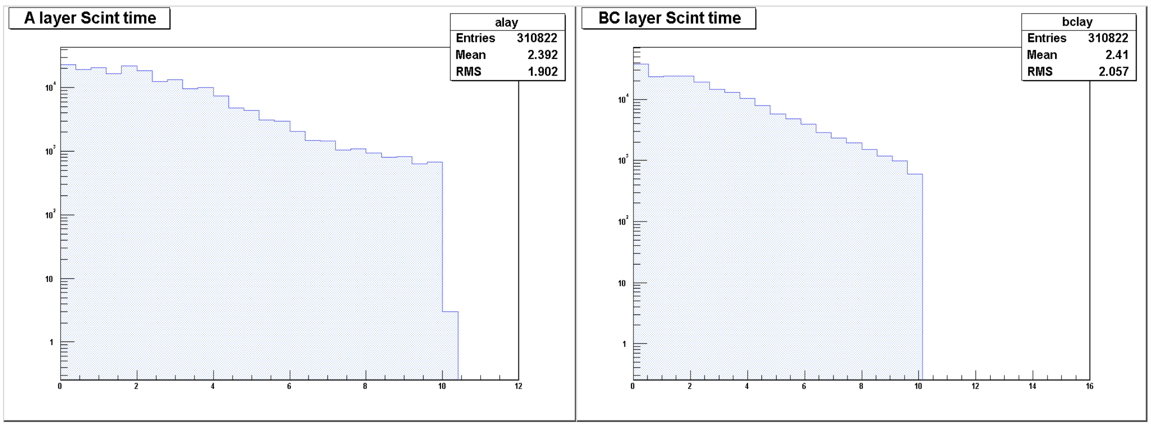

Fig 6. Muon Timing Cut

Good Neutrinos

Good neutrinos are identified by the presence of missing transverse energy given as above. There is a correction applied to the x and y components owing to muon being a MIP signal and the missing $E_{T\nu}$ based on calorimeter. The muon momentum in the x and y directions are vectorially added to the E_{Tx} and E_{Ty} and the MIP signal of 2GeV is vectorially subtracted. This is only a first order estimation of neutrino energy. The missing transverse energy spectrum is shown below. The points are the data and the filled histogram is the Monte Carlo missing transverse energy.

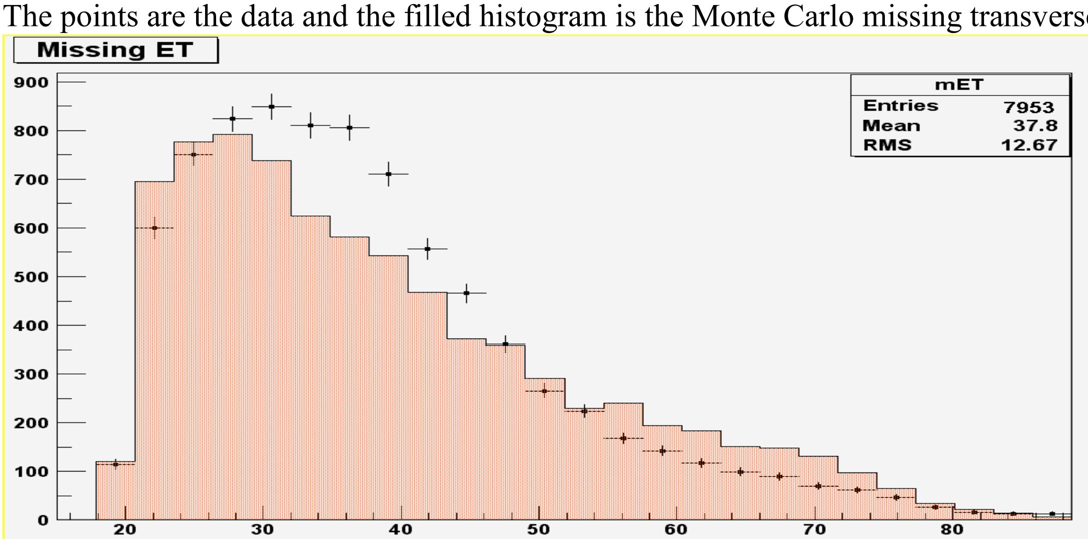

Fig 7. Corrected Missing Transverse Energy

The Φ distribution of the missing transverse energy has no preferential direction. So we must observe a flat distribution. The distribution is shown below.

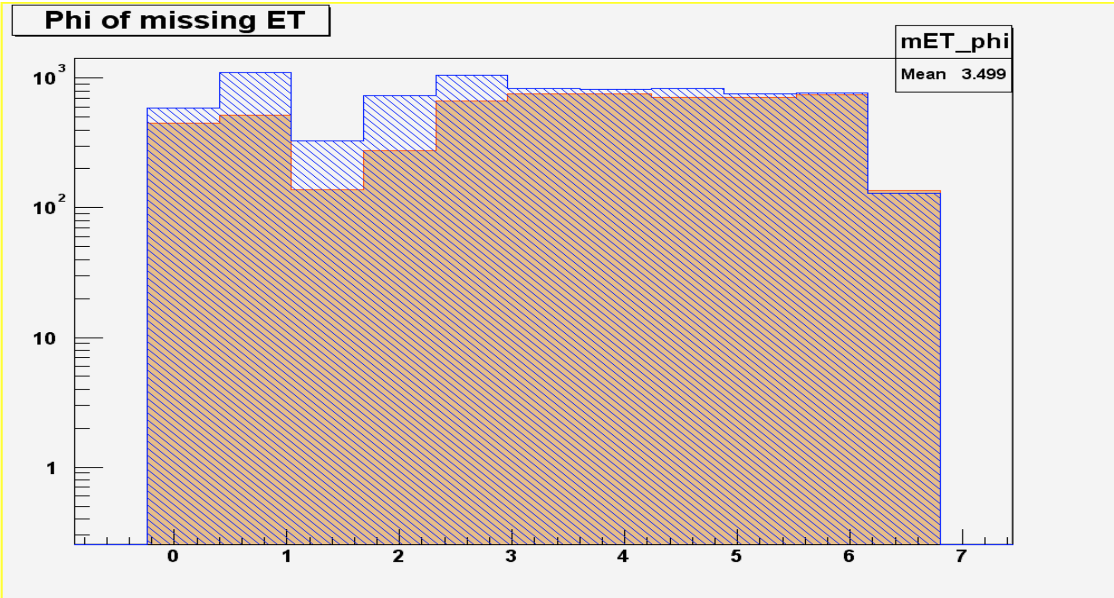

Fig 9. Φ of Missing Transverse Energy

Signal Events

The presence of the signal is tested by the W transverse mass distribution and the presence of neutrino and muon back to back in such events. The W transverse mass is given by $M_{Tw} = \sqrt{2 E_{T\nu} E_{T\mu} (1 - \cos\Phi_{\mu\nu})}$. The $\Phi_{\mu\nu}$ is the included angle between the muon direction and the neutrino direction. Closer the $\cos\Phi_{\mu\nu}$ to -1, the better. The distribution is shown in Fig 8.

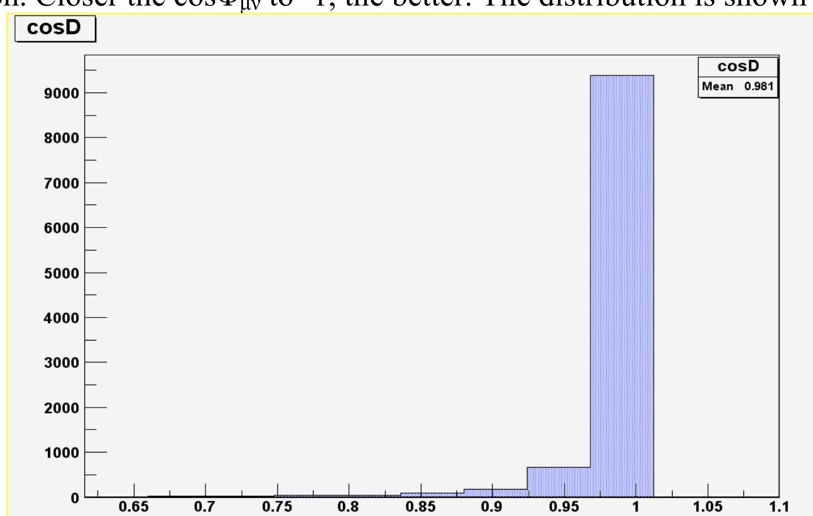

Fig 8. $\cos\Phi_{\mu\nu}$ Distribution (absolute value)

The W transverse mass distribution confirms the presence of muon and neutrino. The data is shown as points and the Monte Carlo W transverse mass is shown in filled histogram. If there are other leptons in the sample, it would be a good check to compute the Z invariant mass to reject events with Z background.

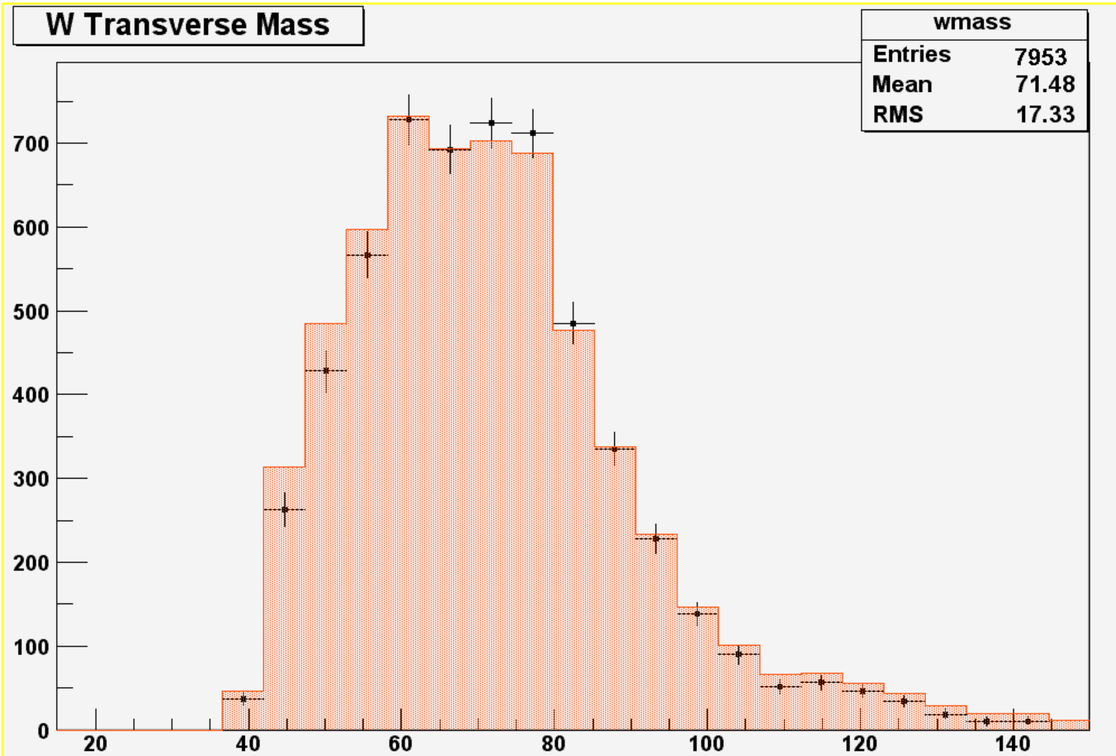

Fig 9. W transverse mass distribution

Cross-Section calculation

- Luminosity = 24.3/pb
- NLO cross section for W → μν = 1342 pb [9]
- BR = 0.1
- L1 trigger efficiency = 0.92
- L2 trigger efficiency = 0.81
- L3 tracking efficiency = 0.73

Expected number of events = 24.3 * 2 * 1342 *0.92 *0.81 * 0.73 *0.1 = 3550 events
The number of events obtained after all the cuts = 4205 events.

W + jets

The jet is confined within a cone of 0.5 and satisfies the following criteria. Energies are corrected using JetCorr v4.1[10]

- $|\eta| \leq 2.5$
- 0.05 < EMF < 0.95
- CHF < 0.4
- $r_{hot} < 10.0$
- n90 > 1
- CHF <0.05 or f90 +0.5 < 0.8
- (CHF <0.025 or f90 +0.5 < 0.7) if $p_T < 20.0$ GeV

The jet distribution is shown in Fig10.

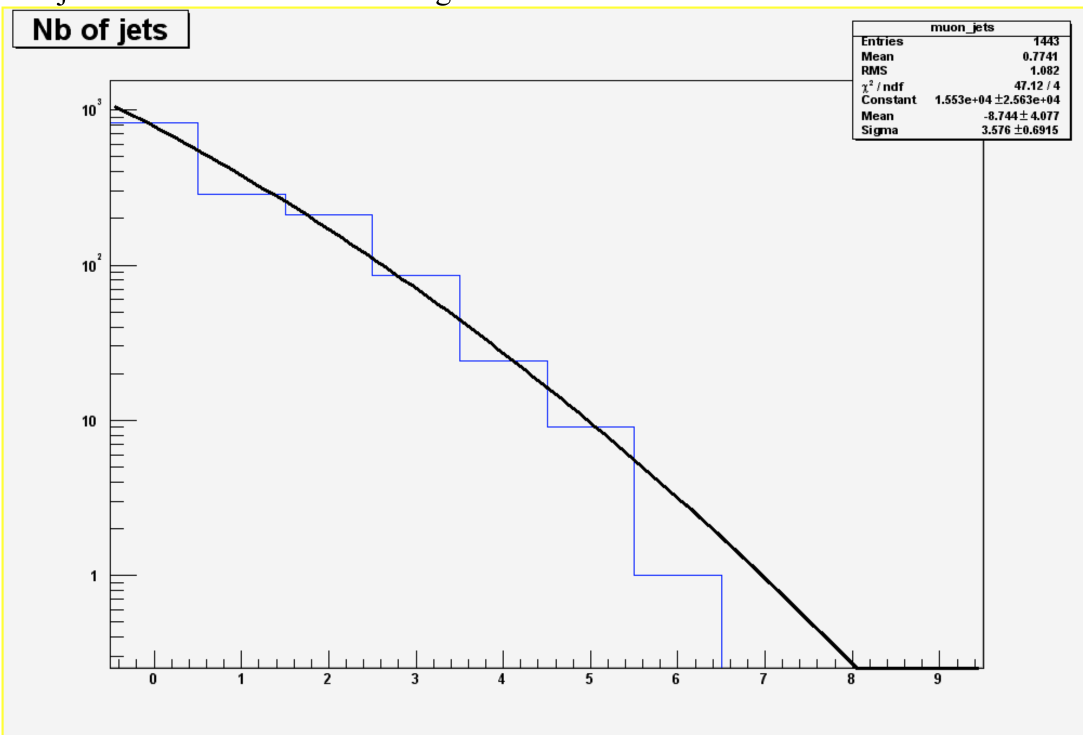

Fig 10. The jet distribution in W → μν samples

Conclusion

The best discovery for Standard Model (SM) higgs or the minimal supersymmetric higgs (MSSM) are the channels of WH and ZH. The study of jets in association with decay of W is vital in higgs searches. The multijet + W final states give important information about the presence of Higgs. This project aimed at understanding data analysis with importance to backgrounds, underlying physics and method of estimation. The number of events logarithmically decreases with the number of jets per event. The closeness in agreement of the number of events with the expected number is a good indication of signal events. However efficiency studies have to be done on jets. Statistical error dominates the sample. The requirement for W+multijet final states is the presence of good jets (> 20GeV). The number of such jets is small. Also it would be a worthwhile effort to study the QCD background for good estimation.

References

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