Search for R-parity Violating Scalar Top Decays in e^+e^- Collisions at $\sqrt{s} = 189$ GeV

Archil Garishvili
Deutsches Elektronen Synchrotron, DESY Zeuthen
Platanenallee 6, Zeuthen,
Germany

Abstract

A search for scalar top quarks in the R-parity violating decay channel $\tilde{t}_1 \rightarrow$ b τ is carried out on a luminosity of 176.4 pb^{-1} using the data sample collected by L3 at a center-of-mass energy of 189 GeV. A two step selection procedure was developed and performed.

1 L3 Detector

L3 was one of the four LEP experiments. LEP was the CERN e^+e^- collider, which was located near CERN and was working from 1989 - 2000.

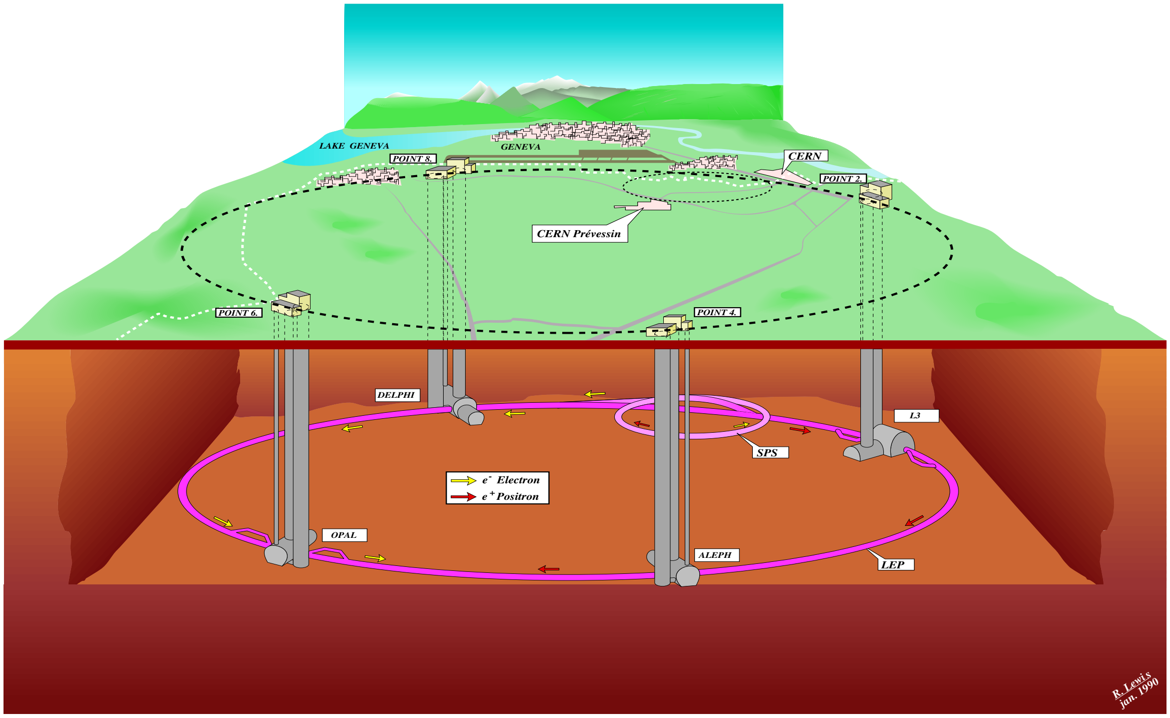

Figure 1: LEP View

The main objective of L3 is to understand some of the fundamental laws of particle physics. The way of getting some insight on these problems is to take some particles we know, like electrons and positrins, give them enough energy and make them collide to produce new particles and study the process.

The L3 detector is build as follows: Starting from the interaction point outside of the beam pipe, we first find the SMD (Silicon Microvertex Detector) and the TEC (Time Expansion Chamber). These two sub-detectors trace the paths of charged particles produced in the collision. Both gathers information about the momenta of the particles by measuring their deflection on the magnetic field present at detector. The three main outer detectors are the Electro-Magnetic-Calorimeter (BGO), the hadronic calorimeter (HCAL) and the Muon detector. Both calorimeters are inside the coin of the magnet. A set of scintillation counters is placed between the Electro-Magnetic and Hadronic calorimeters. One of their function is to help in recognising and rejecting signals from cosmic ray muons, very high energetic particles which come from the space and can disturb the measurement. The Electro-Magnetic-Calorimeter is BGO, what means Bismuth Germanium Oxide. BGO detects electrons and photons. Both leave most of their energy in the BGO. The difference

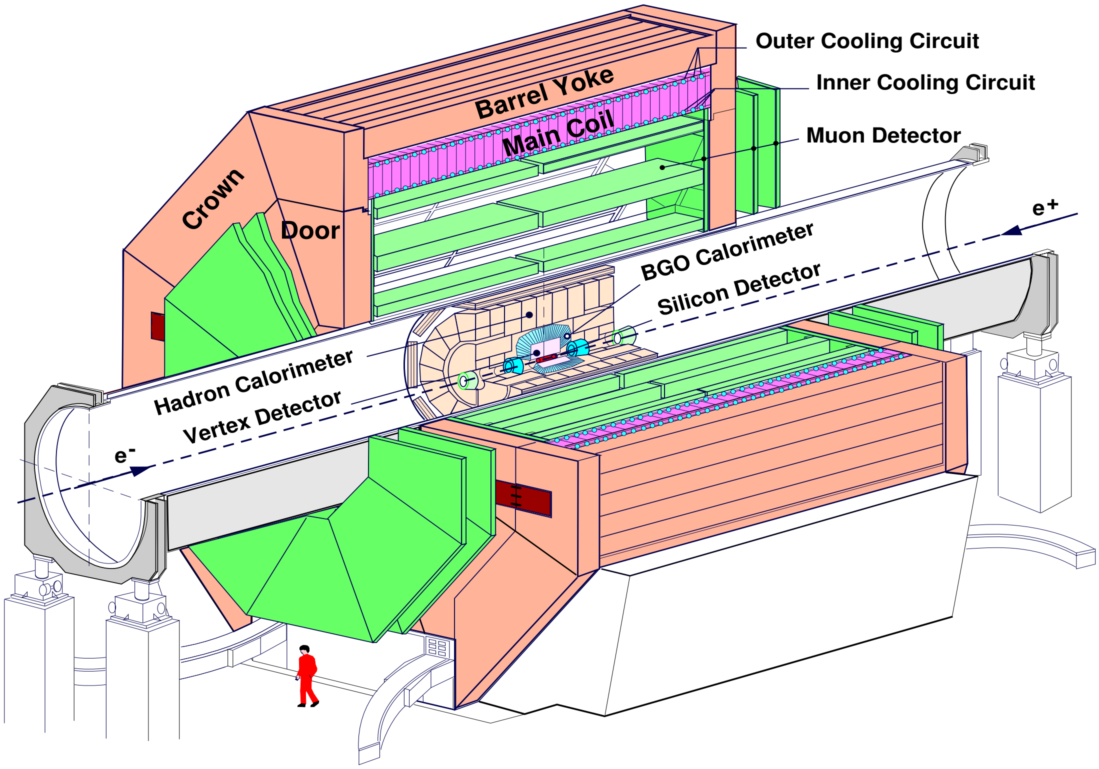

Figure 2: L3 Detector

between photons and electrons is that electrons have a charge and photons not so they do not trace their path in the TEL. HCAL detect hadrons and usually they stop in the calorimeter. Muons with an energy greate of 2 GeV have a very small energy loss in the calorimeters and so they can reach the muon detector where they are finally detected.

The while detector is surrounded by the magnet (the largest in the world: about the same weight of the Eiffel tower!) which generates inside the detector a magnetic field about 10000 times the average field on the surface of the Earth, (0.5 Tesla).

Another important part of the detector are the two luminosity monitors, placed along the beam on both sides of the interaction point. They measure the ”luminosity” of the beam, which is a way of quantifying the rate of interactions produced. The reaction $e^+e^- \rightarrow e^+e^-$ is used to measure this luminosity.

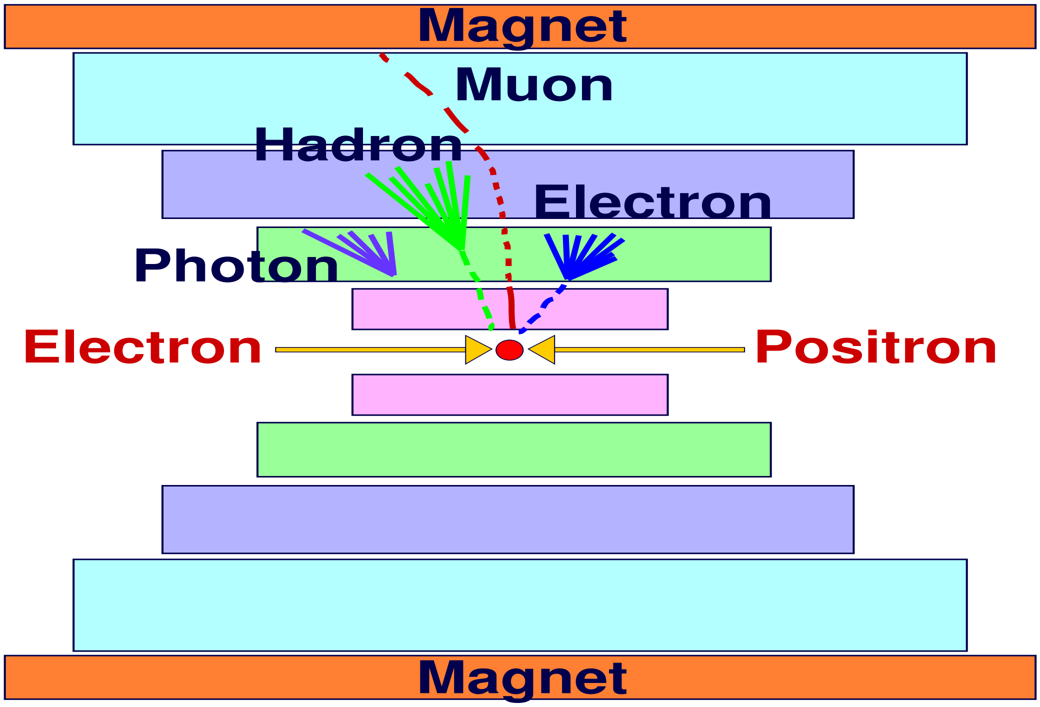

Figure 3: Particles in the Detector

2 Introduction to SUSY

The supersymmetric theories were introduced as a generalization of the concept of symmetry for high energy physics in order to join the bosonic and fermionic worlds. The supersymmetry describes the transformation of fermionic states in bosonic and vice versa. The most general superpotential of the Minimal Supersymmetric Standard Model (MSSM), which describes a supersymmetric, renormalizable and gauge invariant theory, with minimal particle content, includes the term W_R

$$W_R = \lambda_{ijk} L_i L_j \overline{E}_k + \lambda'_{ijk} L_i Q_j \overline{D}_k + \lambda''_{ijk} \overline{U}_i \overline{D}_j \overline{D}_k + \epsilon_i L_i H_2 \tag{1}$$

where ϵ_i, λ_{ijk}, λ'_{ijk} and λ''_{ijk} are the Yukawa couplings and i, j and k are the generation indices. L_i and Q_j are the left-handed lepton and quark-doublet superfields. E_k, D_j and U_i are the right-handed singlet superfields for charged leptons, down and up type quarks, respectively. The $L_i L_j \overline{E}_k$, $L_i Q_j \overline{D}_k$ and $L_i H_2$ terms violate the leptonic quantum number L, while the $\overline{U}_i \overline{D}_j \overline{D}_k$ terms violate the baryonic quantum number B. The R-parity is the quantum number which distinguishes the ordinary and the SUSY particles:

$$R = (-1)^{3B+L+2S} \tag{2}$$

Here S is the spin, B and L baryonic and leptonic number respectively. R is +1 for all ordinary particles, and -1 for their supersymmetric partners. If R-parity is conserved, supersymmetric particles can be produced only in pairs and they decay in cascades to the lightest supersymmetric particle, which is stable. However, the assumption of R-parity conservation lead us to a fast proton decay. Stop mixing leads to a light scalar top: No reason that R is conserved. It is enough that one of the Yukawa Coupling is non zero, that means that L or B is not conserved. Another possibility called Spontanius symmetry breaking leads to a non zero ϵ_i. In this case the scalar top decay couple to the τ and a decay like $\tilde{t}_1 \rightarrow$ b τ is allowed.

3 Data and Monte Carlo samples

The data used correspond to an integrated luminosity of 176.4 pb^{-1} collected by the L3 detector at the center-of-mass energy of 189 GeV in the year 1998. At LEP scalar tops are produced in e^+ e^- collisions, through a virtual photon or a virtual Z_0^0 boson exchange. For scalar top decays Monte Carlo samples of signal events are generated using a PYTHIA based event generator varying the scalar top mass from 40 to 93 GeV. For every one of the 14 different masses about 5000 events are generated.

All generated signal and background data were introduced into the detector simulator package GEANT, which takes into account all possible effects of the detector. This information is processed in the same way as the real data. The number of simulated events corresponds to at least 50 times the luminosity of the data. The same criteria are then applied also to the data. The detector response is simulated using the GEANT package. It takes into account effects of energy loss, multiple scattering and showering in the detector materials.

Reaction	L3 Name	Type	Simulated events	Generator
$e^+e^- \rightarrow \tau^+\tau^-$	KAT45	2f	94800	KORALZ
$e^+e^- \rightarrow e^+e^-q\bar{q}$	PJQ32	2γ	5940000	PYTHIA
$e^+e^- \rightarrow q\bar{q}$	QPZ56	2f	2930000	PYTHIA
$e^+e^- \rightarrow Ze^+e^-$	QPZ57	4f	29500	PYTHIA
$e^+e^- \rightarrow ZZ$	QPZ58	4f	196000	PYTHIA
$e^+e^- \rightarrow We\nu$	WBE46	4f	7900	EXCALIBUR
$e^+e^- \rightarrow W\mu\nu$	WBM45	4f	84000	EXCALIBUR
$e^+e^- \rightarrow W^+W^-$	WK029	4f	294500	KORALW
$e^+e^- \rightarrow \tau^+\tau^-bb$	WBT19	4f	9770	EXCALIBUR

Table 1: Monte Carlo samples

4 Selection of Events

In order to remove from our samples the highest possible number of background events, some selection criteria are required for the signal and Monte Carlo. These conditions are chosen in such a way that the highest number of signal events reminds for the highest loss of events in the background set. Two different sets of preselection were defined. With a luminosity of 176.4 pb^{-1}, we have a high statistics. We cut our events three times. After the first selection we still had too much backgrounds for the two reactions $e^+e^- \rightarrow W^+W^-$ and $e^+e^- \rightarrow ZZ$. After the last selection we got a very good signal to background ration at all difference stop masses $M_{\tilde{t}}$. The Monte Carlo background had to be normalized to the integrated luminosity of our experimental data, to be able to compare it with the data sample. The efficiency for the different stop masses varies between 14 and 27 percents. Any double counting of events avoided in the Monte Carlo.

NAME	VARIABLE	LOWER	UPPER	LOWER	UPPER
NSCT	Numb of scintillators	5	20	5	20
NGTK	Numb of good tracks	5	30	5	26
NCLCA	Numb of clusters	14	50	14	50
EVIS/ENCM	Norm. visible energy	0.3	0.85	0.36	0.85
EMIS	Missing energy		70		70
EMIS*SIN(THPM)	$P_{Tmissing}$	7		7	
SJET	θ for 3 jets	5.5	6.3	6	6.3
NJET08	Jets with Ycut	3	5	3	5
NLPT	Numb of leptons	1	6	2	6
XMVI/ENCM	Norm. visible mass	0.3	0.9	0.34	0.9
UCSDBT4		1	10	1.5	10
THJET0	θ for jets	0.5	2.64	0.5	2.64
THPM	θ total momentum	0.5	2.64	0.5	2.64
ABS(Y34)		0	0	0	0
NJET08+NLPT	Jets plus leptons	4	11	4	11
ACOP	Acoplanarity	2	3.2	2.4	3.2
ACOL	Acollinearity	1.6	3.1	1.6	3.1
CTHT	Cosinus θ thrust	-0.75	0.75	-0.75	0.75
XOV1+XOV2	Width jet1 + jet2	0.2	1.4	0.3	1.4
XMJ1	Mass of jet1	5	70	5	70
XMJ2	Mass of jet2	3	80	5	80

Table 2: Lower and upper cuts for selection 1(column 3 and 4) and selection 3 (column 5 and 6).

Reaction	L3 Name	Total events	Pres. events	Norm. pres. events
$e^+e^- \rightarrow \tau^+\tau^-$	KAT45	94800	1	0.02±0.02
$e^+e^- \rightarrow e^+e^-q\bar{q}$	PJQ32	5940000	0	0.00±0.00
$e^+e^- \rightarrow q\bar{q}$	QPZ56	2930000	12	0.07±0.02
$e^+e^- \rightarrow Ze^+e^-$	QPZ57	29500	5	0.10±0.04
$e^+e^- \rightarrow ZZ$	QPZ58	196000	812	0.71±0.02
$e^+e^- \rightarrow We\nu$	WBE46	7900	15	0.24±0.06
$e^+e^- \rightarrow W\mu\nu$	WBM45	84000	184	0.22±0.02
$e^+e^- \rightarrow W^+W^-$	WK029	294500	575	5.70±0.24
$e^+e^- \rightarrow \tau^+\tau^-b\bar{b}$	WBT19	9770	151	0.13±0.01

Table 3: normalized of preselected events after Selection 3

5 Results

After a two step selection 10 data events were found, but we don't observe any excess of events. Data events are consistent with the background (7 events). The MC results are given in table 3.

6 Outlook

Further investigation will contain a optimization procedure and a determination of mass limits as well as a study of the same reactions at higher energies with the L3 data of the 1999 and 2000.

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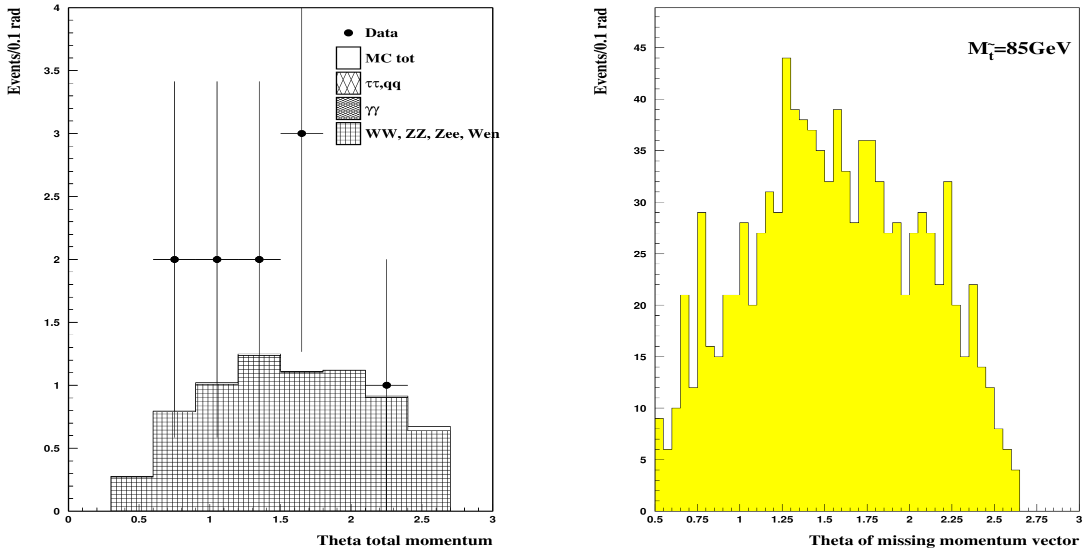

Figure 4: At this picture on left side is data and MC and on right side is signal of 85 GeV mass for Theha Total momentum

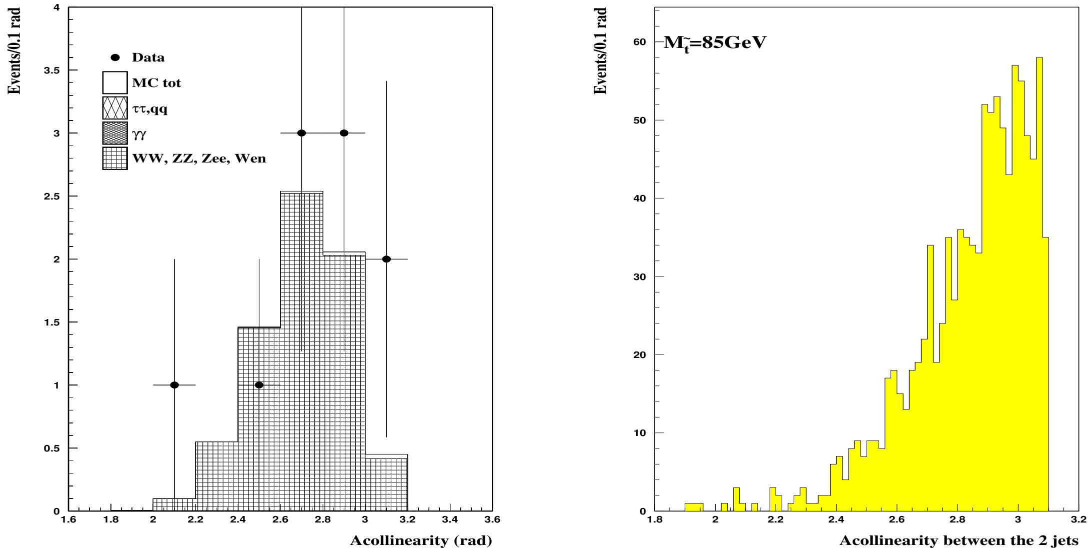

Figure 5: At this picture on left side is data and MC and on right side is signal of 85 GeV mass for The Acollinearity between the 2 jets

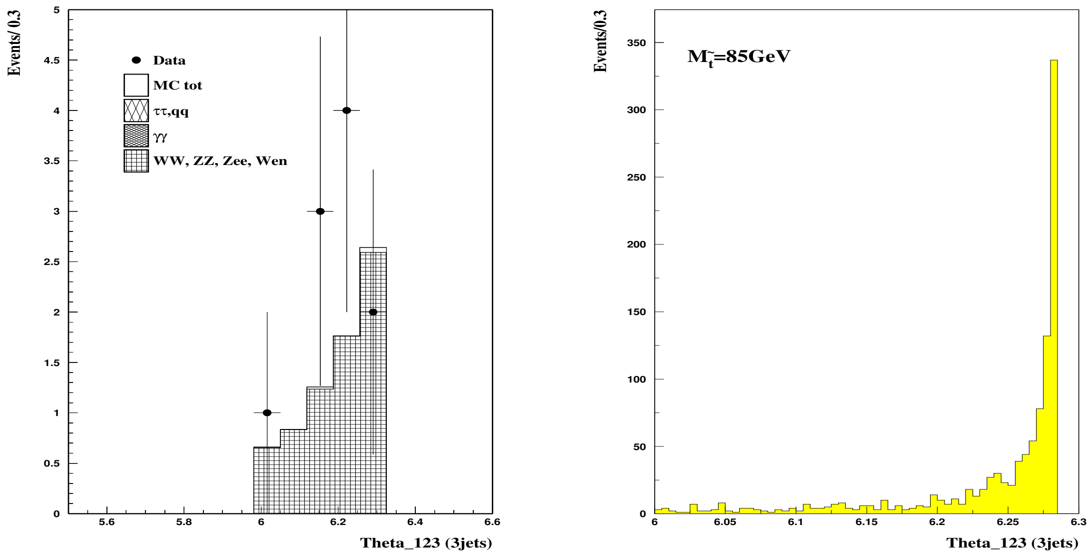

Figure 6: At this picture on left side is data and MC and on right side is signal of 85 GeV mass for Theha for 3 jets

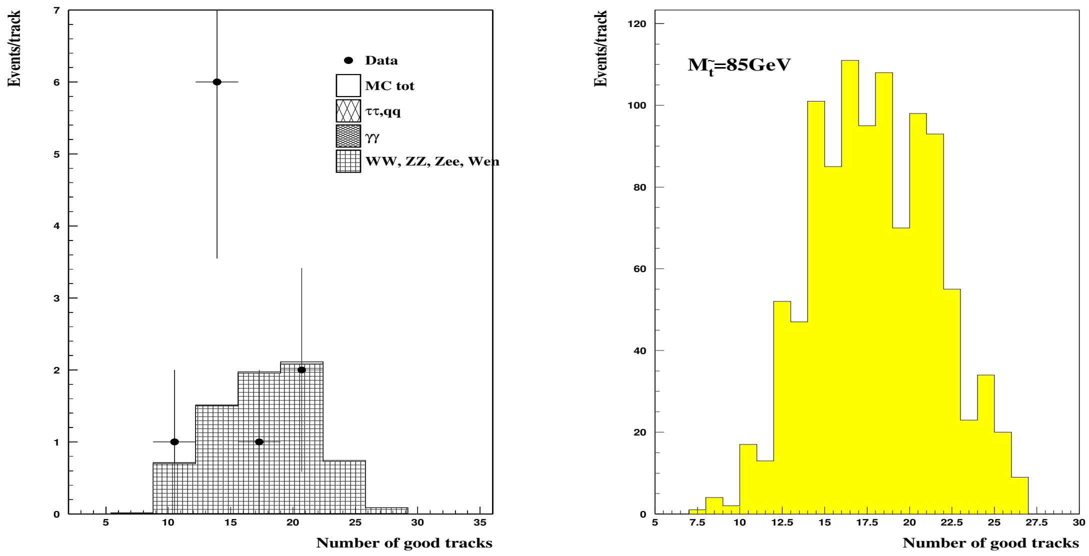

Figure 7: At this picture on left side is data and MC and on right side is signal of 85 GeV mass for number of Good Tracks

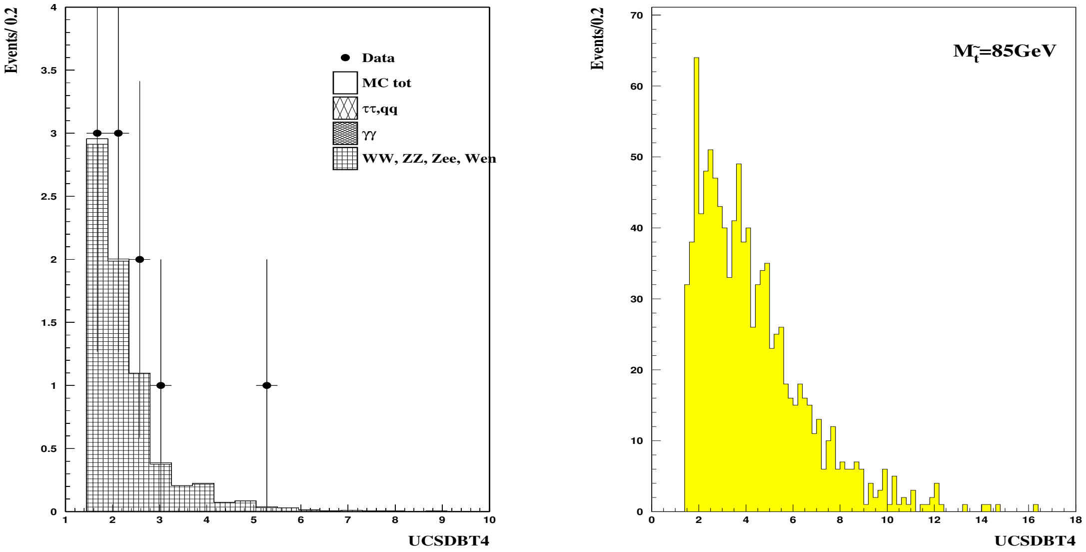

Figure 8: At this picture on left side is data and MC and on right side is signal of 85 GeV mass for UCSDBT4