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Experimental summary —XII DAE HEP symposium, Guwahati, 1997

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Abstract : The experimental talks presented at the XII DAE HEP Symposium, Guwahati 1997 are summarised here.

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Introduction

There have been 16 invited talks and 20 contributed papers in the field of experimental physics in this conference. These talks can be broadly divided into six physics categories—new particle searches, heavy flavour physics, electroweak physics, strong interaction physics and QCD, heavy ion interactions, future experiments and techniques. The break-up of the talks are summarised in Table 1. We have learnt new results from several current experiments from CESR, LEP/SLC, Tevatron Collider as well as fixed target facilities, heavy ion programme at the CERN SPS and some non-accelerator experiments. There have been some talks on future experimental activities with the Tevatron Collider (TEV 33) and the Large Hadron Collider (LHC) at CERN. Notable omissions are ν experiments, *ep* scattering at HERA and future experiments in the b-factories.

Table 1. Statistics of talks on experimental high energy physics in the conference

	New Particle	Heavy Flavour	Electroweak	QCD	Heavy Ion	Future Experiment
Long Invited	2	2	1	0	1	1
Short Invited	1	2	1	1	1	3
Contributed	6	1	5	3	2	3

The summary talk is organised as follows. The next section will deal with the discoveries in the recent past. This will be followed by precision measurements. Then the null results from a variety of searches will be described. There will be a brief mention of a few detailed measurements. Finally a couple of rather interesting but inconclusive observations will be discussed.

Discovery

This is the first DAE symposium where the discovery of the sixth quark flavour, **top**, has been reported [1]. The first hint of direct observation of top was reported by the CDF collaboration during the summer of 1994. During March 1995, both the Tevatron collider experiments, CDF and DØ, reported a ~5σ excess of the top signal. Since then, the statistics of the signal has almost doubled (> 100 pb^{-1} of integrated luminosity per experiment) and systematic errors are better understood by both the experiments.

Top is produced in pair in the pp collisions and top dominantly decays to a b-quark and W^+. Discovery channels for top are the ones where one or both the W's decay leptonically. Consequently one has the two following scenarios :

Signature	2 leptons + ≥ 2 jets + missing E_T	1 lepton + ≥ 4 jets + missing E_T
Fraction	~5%	~2 x 15%
Signal/BG	3 : 1 ($e^{\pm}\mu^{\pm}$) ; 1 : 1 ($e^+e^-/\mu^+\mu^-$)	~1 : 4

This indicates that additional handles are required to improve the signal to background ratio for one-lepton final state. This has been achieved using two distinctive features of top decays, namely,

1. top is heavy and its decay is symmetric. So cuts in global event shape variables would distinguish top decays from background.
2. top always decays to a b-quark. b-jets can be identified through displaced vertex and/or accompanied soft non-isolated lepton.

These additional cuts bring the signal to background ratio in the range 1.5 : 1 to 4 : 1.

The number of top candidates as seen by the two experiments in the various final states are summarised in Table 2. From the observed events, expected background events and the integrated luminosities, the cross section of top-pair production has been determined by CDF and DØ to be $7.7^{+1.9}_{-1.6}$ pb and 5.2 ± 1.8 pb respectively. They agree with the three possible estimates using next-to-leading-log QCD calculations. CDF has started to look for top in other channels where both W's decay hadronically.

Events belonging to lepton + four jet category have been used in estimating the top quark mass. Kinematic fits have been performed to events belonging to this category, constraining the lepton-neutrino and 2-jet mass (from W-decay) to W-mass and the two combinations of W and b-jet masses to be the same (t and $\bar{t}$ having the same mass). This gives rise to several combinatorics. A multi-variable discriminator is used to choose

Table 2. Number of top candidates found by the two experiments CDF and DØ together with estimated background and signal events.

Experiment	Channel	# Observed	Estimated BG	Expected Signal
CDF	$e^+e^- \cdot \mu^+\mu^-$	6	1.21 ± 0.36	~1.6
	$e^{\pm}\mu^{\pm}$	6	0.76 ± 0.21	~2.4
(SVX)	l + 4 Jet	16	2.80 ± 0.58	
DØ	e^+e^-	1	0.66 ± 0.17	~0.9
	$\mu^+\mu^-$	1	0.55 ± 0.28	~0.5
	$e^{\pm}\mu^{\pm}$	3	0.36 ± 0.09	~1.7
(Event Shape)	l + 4 Jet	21	9.23 ± 2.83	~12.8
(μ tag)	l + 4 jet	11	2.58 ± 0.07	~9.0

signal from background. The data are then fitted to the estimated background and signal using binned Poisson statistics and discrete top mass. Top mass is determinad by maximising the log likelihood function. The results are summarised in Table 3. One expects the top mass to be determined to an accuracy of ± 2 GeV with the high luminosity run at TEV33 [2].

Table 3. Top mass determined from direct reconstruction.

Experiment	Top Mass (GeV)	ΔM (Stat) (GeV)	ΔM (Syst) (GeV)
CDF	176.8	± 4 4	± 4.8
DØ	169	± 8	± 8
Combined	175	±6	

Precision measurements

Precise measurements on the properties of the vector bosons Z and W have been reported from LEP [3,4] and Tevatron [5]. LEP reported analysis of all their data till 1995 including the high energy run at 130–140 GeV whereas Tevatron reported analysis of the combined Run I data. Certain heavy flavour properties have been precisely measured at the Tevatron fixed target experiments [6], CLEO [7] and experiments at LEP and Tevatron collider [8].

Z Boson properties :

LEP [3] made a very precise measurement of the beam energy using several magnetic and resonant depolarisation measurements. This has been supplemented by very precise determination of cross section and forward-backward asymmetry in the final states $e^+e^- \rightarrow f\bar{f}$ by the four experiments ALEPH, DELPHI, L3 and OPAL. The measurements have made use of 14.4 million events in the hadronic final state and 1.6 million events in the leptonic final state. The systematic errors have been controlled to a very small level (for example the systematic error for hadronic cross section measurements is less than 0.2%). Using improved Born approximation for the Z-exchange contribution and assuming the photon exchange and Z-γ interference from the Standard Model, one gets:

Parameter	Average Value
m_Z (GeV)	91.1863 ± 0.0020
Γ_Z (GeV)	2.4946 ± 0.0027
σ_{had} (nb^{-1})	41.508 ± 0.056
Rz	20.778 ± 0.029
$A_{FB}^{0,l}$	0.0174 ± 0.0010

Mass of the Z-boson has been determined with an accuracy of 2 parts in 10^5. However, if one relaxes the assumption on the Z-γ interference term by introducing a scale factor, one finds a large correlation of m_Z with the scale factor for hadronic final state, J_{had}^{Tot}. This leads to a larger error on m_Z. If one now uses cross section measurements where the contribution of the interference term is relatively larger (at centre of mass energies away from m_Z), one gets significant improvement in the measurements. This has been achieved by using the cross section measurements at 130–140 GeV (LEP 1.5).

Measurement	m_Z (GeV)	J_{had}^{Tot}
LEP 1 + LEP 1.5	91.1936 ± 0.0040	−0.21 ± 0.20
LEP 1 + LEP 1.5 + TOPAZ	91.1912 ± 0.0035	−0.07 ± 0.16

Lepton universality has been tested in the charged as well as the neutral current sector to a high degree of precision from the measurements of asymmetries in production (for all 3 leptons) and decays (for τ's).

The ratio of *b* and *c* quark partial widths of the Z to its total hadronic partial width and the corresponding forward backward asymmetries have been measured. These measurements created a lot of interest to theorists in 1995 because they deviated from the Standard Model predictions by nearly 3σ's. These measurements have been done by tagging hadronic Z decays using heavy flavour characteristics (large life time, heavy mass of the b-quark, fast D*'s produced by c-quark). The 1996 analysis reveals

Parameter	Average Value
R_b^0	0.2179 ± 0.0012
R_c^0	0.1715 ± 0.0056
$A_{FB}^{0,b}$	0.0979 ± 0.0023
$A_{FB}^{0,c}$	0.0733 ± 0.0049

The disagreement with the Standard Model has been greatly reduced. Several things have contributed to this shift in the measurements. The main differences are due to (a) use of only multi-tag measurements, (b) attempt of using mostly the high energy measurements from LEP, (c) increased statistics, (d) improved tagging techniques.

The electroweak mixing angle has been determined from a variety of measurements as summarised in Table 4. As one sees, all the measurements are consistent with each other supporting the validity of the Standard Model.

Table 4. Determination of $\sin^2\theta_{eff}^{lept}$ from different measurements.

	$\sin^2\theta_{eff}^{lept}$	Average by group of observations	Cumulative average	χ^2/d.o.f.
$A_{FB}^{0,l}$	0.23085 ± 0.00056			
A_τ	0.23240 ± 0.00085			
A_e	0.23264 ± 0.00096	0.23157 ± 0.00042	0.23157 ± 0.00042	3.9/2
$A_{FB}^{0,b}$	0.23246 ± 0.00041			
$A_{FB}^{0,c}$	0 23155 ± 0.00112	0.23236 ± 0.00038	0.23200 ± 0.00028	6.3/4
$\langle Q_{FB}\rangle$	0.2320 ± 0.0010	0.2320 ± 0.0010	0.23200 ± 0.00027	6.3/5
A_{LR} (SLD)	0.23061 ± 0.00047	0.23061 ± 0.00047	0.23165 ± 0.00024	12.8/6

W Boson properties :

Measurement of the mass of the W-boson has been reported from the Tevatron collider [5] and LEP [4]. The $\bar{p}p$ colliders identify W's through the leptonic decays. The energy and directions of the lepton and the missing ν are measured and the transverse mass of the $l\nu$ system is determined. The transverse mass is calibrated against the mass of Z decaying to lepton pair and is then fitted to obtain m_W. DØ measures W-mass :

$$m_W = (80.38 \pm 0.07 \pm 0.08 \pm 0.17)\ \text{GeV}$$

where the first two errors are due to W and Z statistics and the third error is due to systematics. The systematic error includes errors due to transverse momentum of W and luminosity. Both these errors will significantly reduce when the analysis is finalised and one expects the systematic error to become ≈ 0.1 GeV.

Combining the measurements from UA2, CDF and DØ, one gets the current best estimate of W-mass from hadron colliders :

$$m_W = (80.356 \pm 0.125)\ \text{GeV}$$

The centre of mass energy of the e^+e^- system has gone above W-pair threshold in 1996. Preliminary results exist on W-mass from all LEP experiments from the threshold scan measurement of the cross section $\sigma(e^+e^- \to W^+W^-)$. Measurement of W-mass from direct reconstruction is expected soon. LEP measures

$$m_W = (80.4 \pm 0.2\ (\text{stat}) \pm 0.1\ (\text{LEP}))\ \text{GeV}$$

With the advent of high luminosity run at LEP and the Tevatron Collider, the following evolution of error on W-mass is expected [2] :

Tevatron run I	Tevatron run II	LEP 2	TEV 33
≤ 100 MeV	~40 MeV	~35 MeV	~20 MeV

Width of the W boson has been measured at the $\bar{p}p$ collider by two independent methods. In the indirect measurement, one uses the expression

$$\Gamma_W = \frac{\sigma_W}{\sigma_Z} \cdot \frac{\Gamma(W \rightarrow l\nu)}{B(Z \rightarrow l\bar{l})} \cdot \frac{1}{R}$$

where σ_W/σ_Z is obtained from theory (3.33 ± 0.03), $B(Z \rightarrow l\bar{l})$ is measured at LEP [(3.367 ± 0.006)%], $\Gamma(W \rightarrow l\nu)$ is taken from the Standard Model [(225.2 ± 1.5) MeV] and the ratio R defined as

$$R = \frac{\sigma_W B(W \rightarrow l\nu)}{\sigma_Z B(Z \rightarrow l\bar{l})}$$

is measured at the Tevatron collider. This gives

$$\Gamma_W = (2.062 \pm 0.059) \text{ GeV}$$

CDF has looked into the tail of the transverse mass distribution for W (m_T > 110 GeV). Using the measured p_T of the W's, CDF obtained

$$\Gamma_W = (2.11 \pm 0.28 \text{ (stat)} \pm 0.16 \text{ (sys)}) \text{ GeV}$$

The non-Standard Model contribution of W width is restricted to < 109 MeV at 95% confidence level. In future, the error on Γ_W is expected to go down to 45 MeV after Run II of Tevatron and to 20 MeV at TEV33.

Preliminary measurements exist on triple gauge boson couplings. Using CP conserving Lagrangian, one obtains two coupling constants each for WWγ and WWZ vertices. The parameters, denoted by κ and λ, are 1 and 0 respectively in the Standard Model calculations. One uses radiative W production in $\bar{p}p$ collisions and all W events in e^+e^- collisons to measure the anomalous coupling of W's. Event rates as well as kinematic distributions have been used. The current and future limits of the coupling constants are summarised in Table 5.

Table 5. Limits on anomalous coupling of W-boson.

95% CL Limit	Current	Run II	TEV 33	LEP 2	LHC
$\lvert\Delta\kappa_\gamma\rvert$	1.4	0.38	0.21	0.24	0.06
$\lvert\lambda_\gamma\rvert$	0.4	0.12	0.06	0.24	0.01

Physics with c Quarks :

The standard Model expects CP violation in D decays at the level of $\sim 10^{-3}$ in singly Cabibbo suppressed decays and to be non-existent in Cabibbo favoured and doubly suppressed decays. Experiments performed in the Tevatron fixed target facilities [6] have now reached a sensitivity level of $\sim 10^{-1}$. The two experiments E687 and E791 have measured the asymmetry function A_{CP} :

$$A_{CP} = \frac{\Gamma(D^+ \to f^+) - \Gamma(D^- \to f^-)}{\Gamma(D^+ \to f^+) + \Gamma(D^- \to f^-)}$$

All measured A_{CP}'s are compatible to 0 and the 90% CL upper limits are summarised in Table 6.

Table 6. Limits on CP violating asymmetries in D decays.

Decay mode	90% CL from E687	90% CL from E791
$K\bar{K}\pi$	$-14\% < A_{CP} < 8.1\%$	$-6.2\% < A_{CP} < 3.4\%$
$\phi\pi$	$-7.5\% < A_{CP} < 21\%$	$-8.7\% < A_{CP} < 3.1\%$
K^*K	$-33\% < A_{CP} < 9.4\%$	$-9.2\% < A_{CP} < 7.2\%$
$\pi\pi\pi$		$-8.6\% < A_{CP} < 5.2\%$

One expects, within the framework of the Standard Model, the mixing between $D^0 - \bar{D}^0$ to be small.

$$r_{mix} = \frac{\Gamma(D^0 \to \bar{D}^0 \to f)}{\Gamma(D^0 \to f')}$$

is expected to be in the range 10^{-10}–10^{-7}. The experiments have now reached the accuracy of 10^{-3}–10^{-2} E791 [6] has measured r_{mix} from semileptonic D^{*+} decays $\left(D^{*+} \to D^0\pi^+ \to (K^-l^+\nu l)\pi^+\right)$ where the rates of same-sign π/l (mixing) *versus* opposite sign π/l (no mixing) is compared. This measurement yields $r_{mix} < 0.5\%$ to 90% CL. E791 has made similar measurements from hadronic D decays where the corresponding limit is $r_{mix} < 0.4\%$.

Table 7. Limits on flavour changing neutral current from D^0 decays.

Decay Mode	90% CL Upper Bound obtained by		
	CLEO	E653	E791
$D^+ \to \pi^+e^+e^-$	$2-3\times10^{-3}$		6.6×10^{-5}
$D^+ \to \pi^+\mu^+\mu^-$		2×10^{-4}	1.8×10^{-5}
$D^0 \to \mu^+\mu^-$			3.1×10^{-5}

The experiment E791 [6] also reported on non-observation of flavour changing neutral current in D decays. The experiments have reached accuracy in the range of

10^{-5} whereas the Standard Model expectations are $< 10^{-8}$. The results are summarised in Table 7.

CLEO [7] has used data corresponding to integrated luminosity of 3.6 fb^{-1} to measure various rare decay modes of D_s. The measurements agree well with the theoretical expectation based on broken SU(3) model using factorisation hypothesis.

Physics with b Quarks :

CLEO [7] reported on their recent measurements of electromagnetic penguins in both inclusive and exclusive final states. CLEO measures the branching ratio for $(b \to s\gamma)$ to be $(2.32 \pm 0.57 \pm 0.35) \times 10^{-4}$ whereas the Standard Model expectation is $(2.8 \pm 0.8) \times 10^{-4}$. In the exclusive final states one measures

Final State	Branching Ratio
$B^0 \to K^{*0}\gamma$	$(4.4 \pm 1.0 \pm 0.6) \times 10^{-5}$
$B^- \to K^{*-}\gamma$	$(3.8^{+2.0}_{-1.7} \pm 0.5) \times 10^{-5}$
$B \to K^*\gamma$	$(4.2 \pm 0.8 \pm 0.6) \times 10^{-5}$

CLEO [7] also reported on the prospect of observation of the gluonic penguins ($b \to s + g$). CLEO studied final states with very heavy mesons where the meson is too heavy to come from $b \to c$ decays. They choose η' decaying to $\eta\pi\pi$ and study the rate of production as a function of the momentum fraction x. By comparing the rates on and off resonance, they obtained branching ratio of B to η'. The low x region would have admixture of gluonic penguin with B decays to $D^*\eta'$. The large x region ($x > 0.4$) will contain pure $b \to s + g$ decays. The data are consistent with Monte Carlo prediction and the data at large x region is at the moment limited by statistics.

The Tevatron experiments CDF and DØ have reported [8] observation of clear B signals in $J/\psi K^0_s$ channel. So there is the potentiality of CP violation studies in the b-system in the high luminosity runs of the Tevatron. CDF and DØ give limits on pure leptonic decay mode of B's at the level of 10^{-7} whereas Standard Model expectation is $< 10^{-9}$.

Several LEP experiments [8] have reported on the observation of time dependent $B^0 - \overline{B}^0$ oscillation. If the flavour eigenstates are not mass eigenstates and if the life times of the mass eigenstates are comparable, the flavour eigenstates are expected to oscillate with probability given by the difference in mass Δm and average life time τ. To study the oscillation, one needs to tag the b-flavour at production as well as at the decay. b-flavour at production is tagged through jet charge or lepton charge and at decay is tagged through lepton charge or D^* charge. The decay length of the B-meson is determined with the precise vertex detectors and the boost is measured from the energy measurements. After corrections due to background, mistags, combinatorics, one obtains

$$\Delta m_d = (0.468 \pm 0.019)\ \text{ps}^{-1}$$

$$\Delta m_s > 9.2\ \text{ps}^{-1} \text{ at } 95\%\ \text{CL}$$

Null results

There have been several searches for new phenomena in LEP [4,9] and Tevatron [11]. The searches have yielded null results so far giving rise to limits to various processes.

Higgs searches :

LEP experiments [3] have reported several electroweak measurements which agree with the Standard Model. So if one tries to fit all the measurements obtained from LEP, SLC, Tevatron and low energy experiments to the Standard Model, one obtains a fit corresponding to rather low mass of the Higgs boson. This can be translated to a 95% CL upper bound on Higgs boson mass of 650 GeV. However, some of the measurements are inconsistent giving rise to large χ^2. If one scale up the errors to make the measurements consistent, the limit loosens to 920 GeV.

LEP experiments [9] also looked for direct observation of Higgs bosons through the Bjorken process (associated production with Z). The associated Z will decay to a pair of fermions (search concentrates on leptonic decay mode of Z) and a Higgs above 10 GeV will decay dominantly to a pair of b-quarks. All LEP experiments reported on non-observation of signals for Higgs boson. An attempt has been made of combining the four LEP experiments [9]. One requires harder cuts thus lowering the efficiency of individual experiments. Taking tuned efficiency for 60 GeV Higgs and reducing the efficiency by 25%, one obtains 95% lower bound on Higgs mass :

$$m_H > 65.6\ \text{GeV}$$

At LEP2, one needs to produce the associated Z on shell to get appreciable cross section. This limits the reach of search to $\sqrt{s}$ – 100 GeV. With the new run at $\sqrt{s}$ = 161 GeV [4], Higgs of mass up to 60 GeV can be probed. OPAL has combined the results from LEP1 and LEP2 searches and improves the limit on lower bound from 59.6 GeV to 65.0 GeV.

LEP2 can look for Higgs up to a mass of 90 GeV. Beyond that mass, Higgs can be found in the high luminosity run of the Tevatron [2] or at the LHC [10]. In hadron collider, Higgs search is difficult in the mass range 90 – 130 GeV. For low Higgs mass, one needs to look for Higgs in the $\gamma\gamma$ decay mode. The signal to $\sqrt{\text{Background}}$ ratio, the discovery potential, of 10 can be reached with ~100 fb^{-1} of integrated luminosity. The background rate would be smaller if the 2γs are looked with associated ≥ 2 jets. There the signal to background is 1 : 1, and the discovery potential would be similar for 100 fb^{-1} integrated luminosity.

SUSY searches :

Signals for Supersymmetry has been looked into in e^+e^- and hadron colliders with the assumption of R-parity conservation. This hypothesis gives rise to the scenario that the super particles are produced in pair and that the lightest super particle (LSP) is stable. The LSP interacts weakly with matter and will thus avoid detection. So experimentally one would look for events with large missing energy. In hadron collider, missing energy is not measurable and hence one looks for large missing transverse energy. For gluino searches, one utilises the fact that gluinos are Majorana type [10,11] and it will give rise to excess of like sign dileptons.

In the SUGRA motivated SUSY models, the parameter space of SUSY is given by the scalar mass m_0, gaugino mass M, higgsino mixing μ, ratio of the vacuum expectation value tan β, and a soft trilinear coupling term A. The experiments develop search strategies which make use of generic topologies of SUSY signal and the parameter space provide a guideline for the expected signal level.

LEP experiments utilised their high energy runs [4] to look for chargino, neutralino, slepton and squarks. No signal has been observed above the level of expected background and this provides 95% CL upper bound on cross section of SUSY signal. One can scan parameter space and exclude the parameter space where the expected cross section is above the excluded cross section. This essentially rules out charginos and selectrons all the way to the kinematic limit.

Tevatron experiments [11] looked for squarks and gluinos through jets + missing E_T signature and also through same sign dileptons. Both CDF and DØ provide limits in squark-gluino mass plane. Gluinos of mass less than 180 GeV have been ruled out by the experiments.

Several search scenarios of SUSY signal in the future hadron collider have been reported [10,12] in this conference.

Test of QCD

There have been several results testing the theory of strong interaction from the $\bar{p}p$ collider [13] as well as from LEP [14]. Only a small selection of these results is included here.

Direct photon production :

CDF [13] has measured direct photon production in $\bar{p}p$ collisions in the fiducial range $|\eta| < 0.9$. The purity of the signal has been estimated to be within the range 25% to 80% for photon p_T of 20–60 GeV/c using Monte Carlo. One finds ≈ 20% excess in the data for p_T in the range of 20–30 GeV/c. The direct photons will be background to Higgs searches at LHC in the $H \rightarrow \gamma\gamma$ decay mode and have to be monitored carefully.

Strong coupling constant from LEP :

LEP [14] has used the high energy hadronic data to measure the strong coupling constant α_s. The global event shape variables, thrust, heavy jet mass, jet broadenings, are compared to analytical calculation to second order with complete resummed leading and next-to-leading log terms. The study has been extended to low $\sqrt{s}$ values by utilising events with direct photons. The hadronic events with high energetic isolated photons are due to an early radiation from initial or final state. The hadronic shower formation factorises out. So using such events and looking into the hadronic subsystem, one can measure α_s over a large centre of mass energies (from 30 to 172 GeV) from a single experiment. The measurements favour running of α_s ala QCD. The L3 measurements are consistent with $\alpha_s(m_Z)$ of 0.119 ± 0.002 where the error refers to experimental error only. The theoretical uncertainty is at the level of ± 0.006.

New physics

There have been a couple of observations which cannot be explained by standard processes. However, the signals are indicative only and not supported by statistics or other experiments.

ALEPH four jet events :

ALEPH [4] has reported excess of events in the four jet final state from their analysis of high energy data. From the 130–140 GeV data, ALEPH looked for events with two massive particles of approximately same mass each decaying to a pair of jets. Using energy rescaling to improve the mass resolution, they saw a peak in the distribution of ΣM for the four jets at 105 GeV. The peak corresponds to 9 entries where only 1 is expected from background. The integrated rates are 16 and 9 in data and Standard Model Monte Carlo. Combining with the high energy data at 161 and 172 GeV, the number of entries in the peak region has increased to 18 whereas background expectation is 3.1. Total number of events in the 4-jet category is now 34 with 24.5 events expected from background.

This excess was not reported by any of the other three LEP experiments. The position of the peak is at 106.1 ± 0.8 GeV with a Gaussian width of 2.1 ± 0.4 GeV. The width is compatible with detector resolution. All properties of these events are similar to normal hadronic events. For example, there is no large $b\bar{b}$ excess in these events. There is a working group set up by LEP to look into these four jet events. The preliminary work has shown that the other 3 LEP experiments have similar acceptance and resolution for such events. So they would have observed similar excess. One should wait for the final analysis of this working group to get a clearer picture of the situation.

CDF special event :

CDF [11] has reported one special event with two energetic isolated electrons, two energetic isolated photons and lots of missing transverse energy. The transverse energies of the two electrons are 59 and 36 GeV respectively and those for the photons are 38 and

30 GeV. Missing E_T is 53 GeV. Such an event cannot be explained by the Standard Model. One, however, expects such events in a SUSY scenario from slepton pair production. There, one also expects to see several events with energetic photons and missing E_T. Such events have not been reported by CDF or DØ as yet. One needs more data to sort this out.

Outlook

We got a glimpse of several excellent results from the work of many physicists in a variety of experiments. The current trend of results consolidates the standing of the Standard Model. We hope some of the hints on new physics can lead to physics beyond the Standard Model. May be in two years from now, one can hear more of such results in the future DAE symposium.

References

[1] M Narayan (Talk given at this conference)
[2] U Heintz (Talk given at this conference)
[3] S N Ganguli *Indian J. Phys.* **72A** 527 (1998)
[4] A Gurtu *Indian J. Phys.* **72A** 539 (1998)
[5] B Chaudhury (Talk given at this conference)
[6] S Mishra (Talk given at this conference)
[7] V Jain (Talk given at this conference)
[8] T Aziz *Indian J. Phys* **72A** 689 (1998)
[9] A Sopczak *Indian J. Phys.* **72A** 469 (1998)
[10] D P Roy *Indian J. Phys.* **72A** 587 (1998)
[11] N K Mondal *Indian J. Phys.* **72A** 505 (1998)
[12] K Maumdar (Talk given at this conference)
[13] M R Krishnaswamy *Indian J. Phys.* **72A** 671 (1998)
[14] S Sarkar (Talk given at this conference)