AN OVERVIEW OF DELPHI AND ITS RESULTS

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ABSTRACT

A short description of the DELPHI detector and of its performances is followed by two sections devoted to the results on the Z-line shape obtained with 68,000 hadronic events collected in the first year of data taking at LEP. The last sections summarise a number of other results obtained in many different areas: particle searches, multiplicity distributions, QCD, heavy flavour decays.

1. The DELPHI detector.

A detailed description of the DELPHI detector, of the triggering conditions and of the analysis chain can be found in [1]. The charged tracks are measured in the 1.2 Tesla magnetic field by a set of four cylindrical tracking detectors: the Microvertex Detector (MD) which has layers at 9 cm and 11 cm from the vertex, the Inner Detector (ID) covering radii 12 to 28 cm, the Time Projection Chamber (TPC) from 30 to 122 cm, and the Outer Detector (OD) between 197 and 208 cm. The end caps are covered by the Forward Chambers A and B, at polar angles 10° to 36° on each side. A layer of Time-of-Flight (TOF) counters is installed beyond the magnet coil for triggering purposes. The 1.1 m thick Hadron Calorimeter is followed, both in the barrel and forward, by two or three layers of Muon Chambers.

The electromagnetic energy is measured by the High Density Projection Chamber (HPC), and by the Forward Electromagnetic Calorimeter (FEMC) in the end caps. The HPC is a high granularity gaseous calorimeter covering polar angles 40° to 140°. It is mounted inside the cryostat of the Superconducting Coil, which has a diameter of 5.2 m. The FEMC consists of 2 × 4500 lead glass blocks (granularity 1 × 1 degrees), covering polar angles from 10° to 36° on each side.

Two novel detectors are used to 'flavour tag' the events, one of the main aims of DELPHI, a Detector with Lepton, Photon and Hadron Identification. The two layers of the microvertex silicon detector contain ~ 50,000 channels. At present the measurement accuracy in the $r\varphi$ plane is 7 μm and the alignment error is ~ 15 μm for the external layer (at 11 cm from the vertex) and ~ 10 μm on the internal layer (at 9 cm from the vertex). In 1991 a new beryllium pipe of smaller diameter will allow the installation of an inner layer at ~ 6 cm from the vertex. The second novel detector is the Barrel RICH, which is described in [1]. Charged particles emit ultraviolet photons in a liquid radiator (C_6F_{14}) and in a gas radiator (C_5F_{12}). During the first months of running half of the liquid radiators were installed. Fig. 1 shows the rings due to muons coming from Z-decays. The number of photons per track is 10, in good agreement with the Montecarlo prediction [12]. When the temperature of the BRICH will be raised to ~ 40°C, the absorption of the ultraviolet photons in the detector drift volumes will increase by ~ 20%. At the beginning of 1991 all the liquid radiators and the final gas will be introduced and the BRICH will be fully operational.

2. Hadronic and leptonic decays of the Z-boson.

The results summarised in this and the following section are described in more detail in a paper submitted to this Conference [2]. They are based on approximately 68,000 hadronic events and about 4,000 electron, muon and tau-lepton pairs recorded between Sept. 89 and July 90.

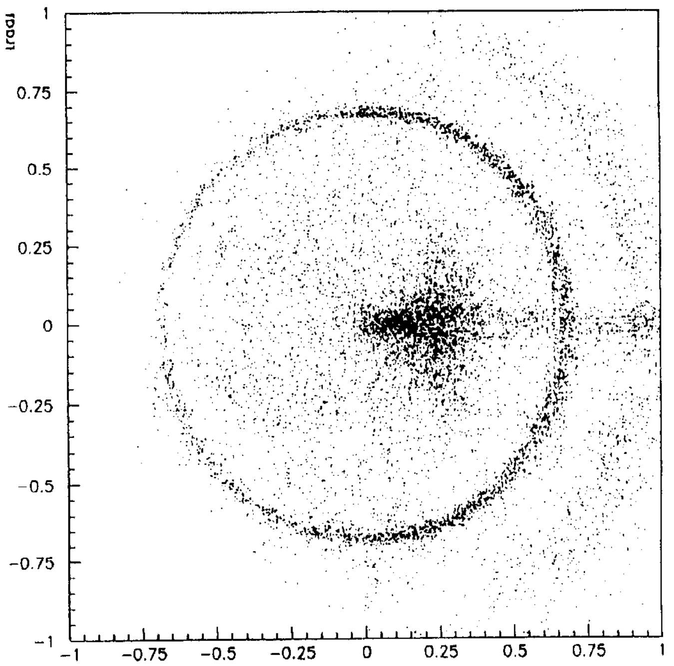

Figure 1 : Overlap of about 200 'liquid' rings due to muons from Z-decay. The spot at the center is due to the muons traversing the RICH detector.

The luminosity measurement has improved with respect to our previous publication [3] by the addition of a lead mask ("butterfly-wings") in front of one of the Small Angle Tagger (SAT) arms to cover a dead zone in the vertical plane. The overall systematic error on the 1990 luminosity measurement is 1.7%(expt.) $\pm$ 1.0%(theory).

The analysis of the 1990 data (about 58,000 *hadronic* events) is very similar to the one described in [3].

The hadronic event selection relies only on charged tracks measured in the barrel region. The track selection criteria are the same as for the 1989 data. The overall normalisation uncertainty for the 1989 data remains unchanged at 2.6%. For the 1990 data, the reduced systematic error on the luminosity measurement gives an overall normalisation uncertainty of 2.3% (i.e. 1.1% for the hadronic event selection and 2.0% for the luminosity).

For the *electron-positron channel* the present analysis follows closely the one described in [4] with some important improvements. In particular, the fiducial cuts (to avoid the border regions of the HPC modules) are better understood; the tau pair background is reduced to 2 $\pm$ 1%, the t-channel subtraction is made using the formulae of [5]. A total sample of 1389 events were selected, corresponding to an integrated luminosity of 2.6 pb^{-1}. The systematic error on the e^+e^- cross-section is estimated to be 1.6%, due to 0.1% from the trigger, 1.0% from the tau-lepton background subtraction, 0.8% for the selection efficiency and 1.0% for the t-channel subtraction.

The present analysis of the *muon-antimuon channel* has several significant changes from the one described in [4]. The main emphasis has been put on increasing the muon pair identification efficiency inside an "extended-barrel" region defined to lie in the polar angle range $43° < \theta < 137°$. A total sample of 1618 events were selected corresponding to an integrated luminosity of 2.5pb^{-1}. The systematic error on the $\mu^+\mu^-$ cross-section is (apart from the luminosity uncertainty) estimated to be 1.9%, due to 1.0% from the trigger, 1.35% from selection efficiency, 0.5% for particle identification, 1.0% from the tau-lepton background subtraction and 0.3% from the cosmic ray background. A 1.0% systematic error on the asymmetry is estimated from the number of like sign pairs and from the charge asymmetry in each hemisphere taken separately.

For the *tau-antitau* channel we follow very closely the analysis described in [4] but with a much better understanding of selection efficiencies and backgrounds. A total sample of 1016 events were selected corresponding to an integrated luminosity of 2.3 pb^{-1}. The systematic error on the $\tau^+\tau^-$ cross-section is (apart from the luminosity uncertainty) estimated to be 2.7%, due to 1.0% from the trigger 1.5% from selection efficiency, and 2.0% from hadronic background subtraction and secondary interactions. A 1.0% systematic error on the asymmetry is estimated from the charge asymmetry in each hemisphere taken separately.

In this new analysis we have also selected the leptonic pair final states without distinguishing the leptonic flavor *(blind analysis)* . The event selection depends only on the information from the TPC. A topology cut is applied to the selected events. The cuts are equivalent to requiring a two jet configuration with topology 1.vs.N (N=1,...5) and isolation angle of 150° between the isolated track and the jet. The efficiency for detecting each type of charged lepton with these cuts has been calculated with a Monte Carlo simulation giving 95% for e^+e^-, 96% for $\mu^+\mu^-$ and 84% for $\tau^+\tau^-$. A total sample of 3187 events were selected, for an integrated luminosity of 1.9 pb $^{-1}$. The systematic error on the flavour-blind lepton cross-section is (apart from the luminosity uncertainty) estimated to be 1.3%, due to 1.0% from the trigger, 0.5% from track selection efficiency and 0.6% from background subtraction.

3. Extraction of the Z-parameters.

The Z° resonance parameters were determined by fitting the hadronic and leptonic data with the theoretical cross-sections computed in [6]. A 3 parameter fit gives (with $\chi^2/d.o.f = 12.4/(17-3)$)

$$M_Z = 91.191 \pm 0.014(\text{stat}) \pm 0.030(\text{syst})\text{GeV}/c^2$$

$$\Gamma_Z = 2.466 \pm 0.027(\text{stat}) \pm 0.010(\text{syst})\text{GeV}/c^2$$

$$\sigma_0 = 42.38 \pm 0.30(\text{stat}) \pm 0.97(\text{syst})\text{nb}.$$

A 4 parameter fit gives

$$M_Z = 91.188 \pm 0.013(\text{stat}) \pm 0.030(E_{\text{cm}})\text{GeV}/c^2$$

$$\Gamma_Z = 2.476 \pm 0.026(\text{stat}) \pm 0.010(\text{syst})\text{GeV}/c^2$$

$$\Gamma_h = 1.756 \pm 0.023(\text{stat}) \pm 0.020(\text{syst})\text{GeV}/c^2$$

$$R = 21.00 \pm 0.38(\text{stat}) \pm 0.29(\text{syst}).$$

The corresponding values of the leptonic partial width (assuming lepton universality) and the invisible partial width are:

$$\Gamma_l = 83.7 \pm 1.0(\text{stat}) \pm 1.1(\text{syst})\text{MeV}/c^2,$$

$$\Gamma_{\text{inv}} = 469 \pm 19(\text{stat}) \pm 22(\text{syst})\text{MeV}/c^2.$$

These values are also in good agreement with the standard model predictions: $83.8 \pm 0.9\text{MeV}/c^2$ and $502 \pm 5\text{MeV}/c^2$ respectively. In the minimal standard model the leptonic partial width can be expressed in terms of an effective weak mixing angle $\sin^2(\overline{\theta_W})$. Using the measurement of Γ_l we find:

$$\sin^2(\overline{\theta_W}) = 0.2309 \pm 0.0048.$$

The number of light neutrino generations can be derived from Γ_{inv}:

$$N_\nu = 2.82 \pm 0.11(\text{stat}) \pm 0.13(\text{syst}).$$

With the values of the Z^0 mass and total width fixed to the values obtained above the individual leptonic widths were obtained:

$$\Gamma_e = 82.0 \pm 1.4(\text{stat}) \pm 1.3(\text{syst})\text{MeV}/c^2$$

$$\Gamma_\mu = 87.2 \pm 2.7(\text{stat}) \pm 2.2(\text{syst})\text{MeV}/c^2$$

$$\Gamma_\tau = 86.0 \pm 3.1(\text{stat}) \pm 2.7(\text{syst})\text{MeV}/c^2.$$

Fixing the mass and width of the Z^0 to the values given above, a one parameter fit to the "flavour-blind lepton" lineshape yields:

$$\Gamma_l = 82.6 \pm 0.80(\text{stat}) \pm 0.80(\Gamma_Z)$$
$$0.83(\text{lumi}) \pm 0.53(\text{syst})\text{MeV}/c^2.$$

This is in good agreement with the result of the 4 parameter fit. The hadronic cross-section was compared to the standard model expectations via a fit in which only M_Z and an overall normalisation factor K were left free to vary. The results are:

$$M_Z = 91.193 \pm 0.013(\text{stat}) \pm 0.030\text{GeV}/c^2$$

$$K = 1.019 \pm 0.005(\text{stat}).$$

The quality of the fit $[\chi^2/d.o.f = 13.1/(17-2)]$ shows that the standard model with 3 neutrinos reproduces the data well. A 2 parameter fit to the tau and muon pair cross-sections and *forward-backward charge asymmetries* with M_Z and Γ_Z fixed to the above values, yields a measurement of the vector and axial-vector couplings of the Z^0 to charged leptons (assuming universality). If we take the sign of these couplings to be negative, as determined by previous experiments, we obtain

$$v_l = -0.111 {}^{+0.049}_{-0.033}(\text{stat}) \pm 0.015(\text{syst})$$

$$a_l = -1.003 \pm 0.007(\text{stat}) \pm 0.01(\text{syst}).$$

These results agree well with standard model expectations of -0.998 to -1.007 for the axial coupling and -0.056 to -0.095 for the vector coupling (by varying the top quark mass from 50 to 230

GeV and the Higgs mass from 30 to 1000 GeV). The results of this fits are displayed in Fig. 2.

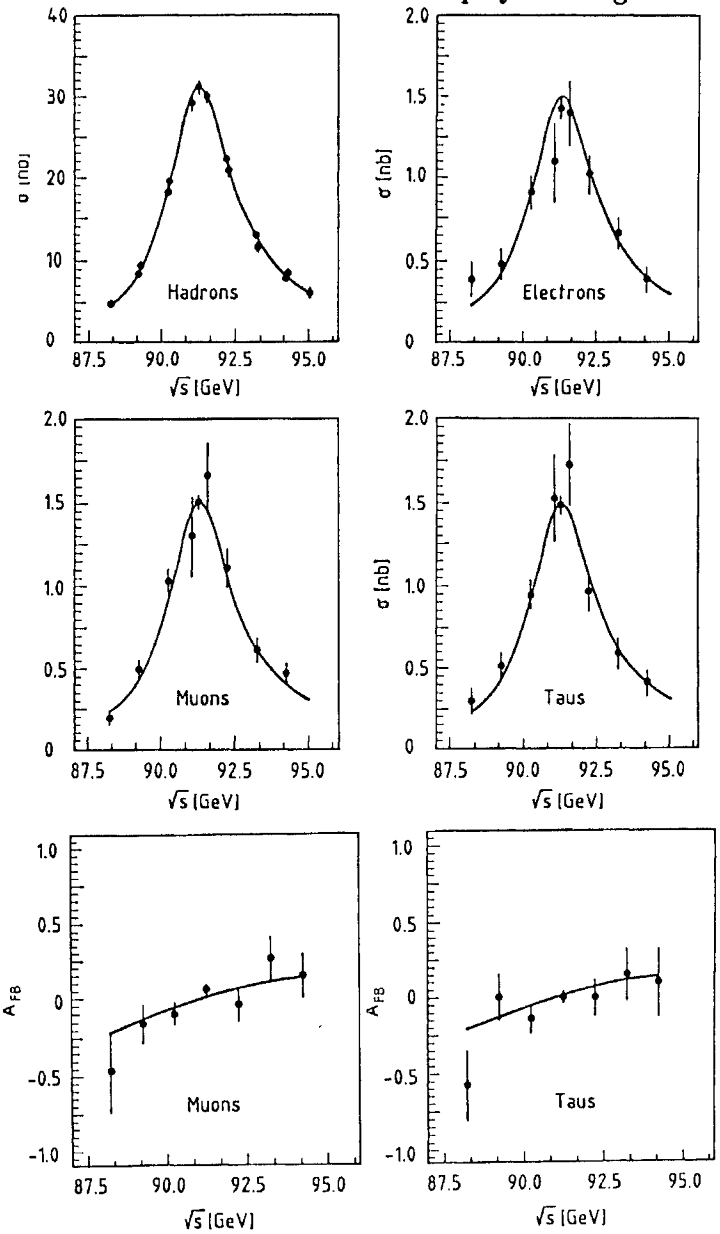

Figure 2 : Cross-sections of hadronic and leptonic decays of the Z-particle. The lower figures reproduce the forward-backward asymmetries in the muon- and tau- channels.

4. Searches for new particles and decays.

In the searches described below samples of up to 70,000 events were used.

4.1 Neutral standard higgsons.

Details of the search using the 1989 data have been published [7]. The mass range 210 MeV $\leq$ $m_H \leq$ 14 GeV/c^{2}was excluded (95% CL). An improvement in the upper limit has now been obtained from a study of the channels $e^+e^- \rightarrow H^\circ Z^*$ with $Z^* \rightarrow e^+e^-$, $\mu^+\mu^-$ and $\nu\bar{\nu}$. For the charged leptonic channels a search was made for 2 high energy leptons (at least one with energy above 10 GeV), well isolated from the decay products of the Higgs. One $e^+e^-H^\circ$ and no $\mu^+\mu^-H^\circ$ candidates remain after the cuts. The e^+e^- candidate has a missing mass of about 50 GeV/c^2, and is outside the current range of sensitivity. For the channel $\nu\bar{\nu}H^\circ$ the topology searched for was that of two misaligned jets, with a cut of $\cos\xi$ of 0.8 in both the acoplanarity and acollinearity angles. The new upper limit is 34 GeV/c^2. A new search was performed for a very light Higgs boson, below the $\mu\mu$ threshold. The search was conducted in two parts:

- a) $0 \leq m_H \lesssim 60$ MeV. In this range there is a large probability that the $H^\circ \rightarrow ee$ or $\gamma\gamma$ decay is outside the detector. The topology searched for was an acoplanar (> 5°) lepton-pair and nothing else.
- b) $60 \lesssim m_H \leq 210$ MeV. In this range the $H^\circ \rightarrow ee$ decay would frequently be inside the fiducial region of the tracking chambers. A search was made for an isolated V° with a lepton pair for the $H^\circ\ell^+\ell^-$ ($\ell = e$, μ or τ) channels. The V° search algorithm was successfully tested by finding K° and Λ° decays in normal hadronic events (with mass resolutions of 20 MeV and 7 MeV FWHM respectively).

There were no candidates remaining after cuts in either a) or b). This excludes a light Higgs in the mass range from zero to 210 MeV at the 95% confidence level.

4.2 Neutral higgsons in MSSM.

The results obtained with the 1989 sample data in the framework of the Minimal Supersymmetric Standard Model (MSSM) can be found in [8]. The new limits for m_h as a function of $\tan\beta$ are shown in Fig. 3. Different methods, corresponding to different decay modes and different topologies, are used in the different domains of the plot. They are described in detail in a paper submit-

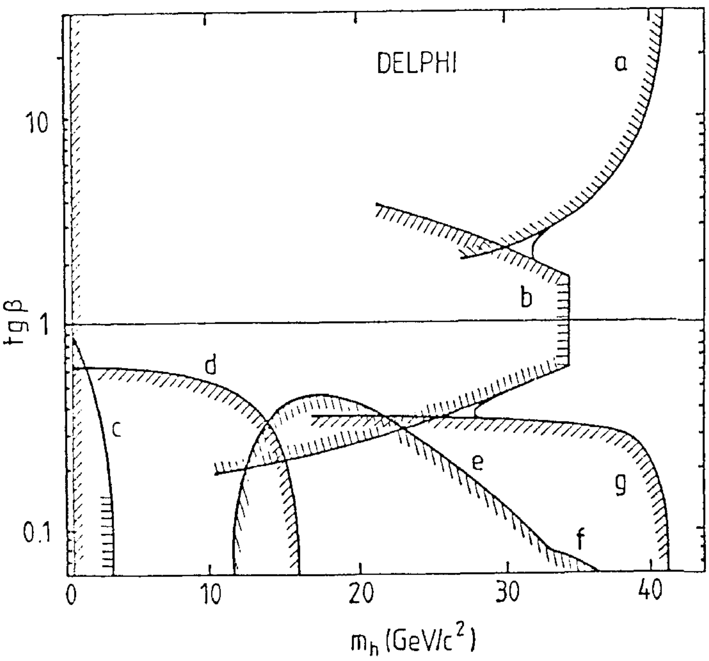

Figure 3 : Limits on the mass of the MSSM higgson h. The curves are explained in the text.

ted to the Conference [9]. The different curves in the plot correspond the following searches.

- a) $\tau^+\tau^-$+hadrons (mainly $\tau^+\tau^- + b\bar{b}$). The method is to search for two isolated tracks (from τ decays) accompanied by one or two jets. The 95% confidence level contour, taking into account the one candidate which survives the cuts, gives for $m_h \approx m_A$ the limit $m_h > 42$ GeV/c^2.
- b) This contour is obtained directly from the standard model search described in 4.1.
- c) This corresponds to the low mass domain where the decays are preferentially to pairs of μ, π or K[8].
- d) In this intermediate mass region the final state is mainly two hadronic jets. In hA events, unlike normal $q\bar{q}$ events, there is no coloured string connecting the two jets and hence fewer particles are expected at wide angles from the jet axis.
- e) and f) correspond to searches in the 4-jet final state, the first one being based on inclusive charm tagging through $D^{*\pm}$ production, the second on a global shape analysis [8].
- g) This contour corresponds to a new 4-jet analysis in which energy and momentum constraints are used to improve the mass resolution on heavy objects decaying into two hadronic jets.

In summary m_h > 28 GeV for all values to $tg\beta$, while $m_h \geq$ 32 GeV for $tg\beta$ > 0.

4.3 Charged higgsons.

Charged higgsons can decay to either a pair of jets, mainly $c\bar{s}$, or to $\tau\nu_\tau$. The H^+H^- pair will therefore give rise to 4 jets, 2 prongs, or 2 jets-1 prong final states. The branching fraction into hadrons is treated as a free parameter, in order to produce model independent limits. The analyses concerning the 2 prong and the 2 jets-1 prong final states described in detail in [10] were applied to the 1990 data sample and no positive signal was obtained. For the 4-jets case, for the considered mass range (above 30 GeV/c^2), the jet with the lowest energy was combined with the one with the highest energy. The resulting limits are [9]:

$m_{H^\pm} > 43$ GeV/c^2 for $Br(H^\pm \to \text{hadrons}) \simeq 0$,
$m_{H^\pm} > 42$ GeV/c^2 for $Br(H^\pm \to \text{hadrons}) \simeq 0.5$,
$m_{H^\pm} > 37$ GeV/c^2 for $Br(H^\pm \to \text{hadrons}) \simeq 1$.

4.4 Squarks produced with non-interacting heavy stable particles.

We have recently [11] applied a new method to the search of heavy unstable charged particles which are pair created and decay immediately producing a neutral and non-interacting stable particle together with a standard quark. Decays of this type are to be expected in some theories beyond the Standard Model. Previous searches for these types of processes were based on the signature of a momentum imbalance appearing. Such approaches require a large difference between the masses. In the case of a *heavy* invisible object, close in mass to the decaying particle, the experimental signature changes from a clearly distinguishable acollinear jet topology to events of small visible energy.

The DELPHI search was based on two different analysis. The *first* one applies to heavy invis-

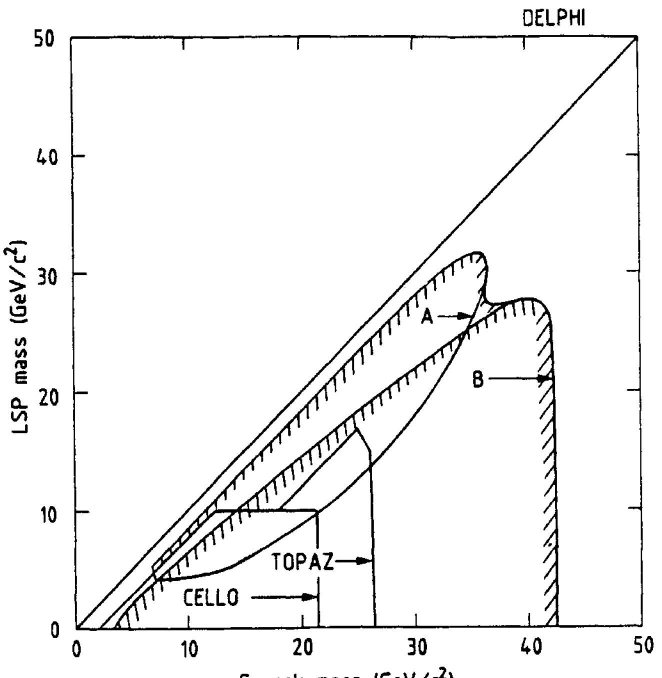

Figure 4 : Mass limits (95% C.L.) for non-degenerate up-squarks decaying into LSP's. The first and second method are labelled A and B.

ible objects and is new. It utilises e^+e^- annihilations at center-of-mass energies around the Z^0 boson mass. The cross section of the new process is expected to follow the standard line shape of the Z^0 boson and, thus, to exceed on the peak the cross section due to s-channel photon exchange by several orders of magnitude. Data points at center-of-mass energies around the Z^0 pole are a direct experimental check of the estimates for the backgrounds which are decoupled from the Z^0. The *second* analysis was based on searching, as usual, for acollinear jets. The results of the search for up-squarks are compared in Fig. 4 with previous limits. Note how close to the 45° line the exclusion contour lies. Similar limits are obtained for down-squarks.

4.5 Search for Z→ $\pi\gamma$, and $\eta\gamma$.

We have performed and submitted an analysis of the e^+e^- annihilation into two photons [12]. The main contribution to this reaction comes from a pure QED process, since the decay of the Z^0 into two photons is forbidden by the Landau-Yang theorem. However, several allowed decays of the Z^0, notably $Z^0 \to \pi^0\gamma$ and $Z^0 \to \eta\gamma$, could lead to events with this topology. Through the analysis of the energy dependence of the cross-section, it is possible to identify the resonant contribution to this channel, and thus detect these decays.

Upper limits on Z^0 decays into $\pi^0\gamma$ and $\eta\gamma$ can then be obtained by a likelihood analysis. We obtained the following limits at 95% confidence level :

$$BR\,(Z^0 \to \pi^0\gamma) < \left(3.0 \times 10^{-4}\right)$$
$$BR\,(Z^0 \to \eta^0\gamma) < \left(4.8 \times 10^{-4}\right).$$

4.6 Search for sleptons and charginos.

In the minimal supersymmetric scheme, one expects two charged and three neutral higgsons particles. Accordingly there should be two pairs of charginos formed by mixing the weak eigenstates associated to W bosons (winos) and to charged higgsons (higgsinos). The lightest chargino pair is called $\chi^\pm$. The two heavy scalar particles, called sleptons, associated with the standard chiral leptonic states are denoted $\tilde{\ell}^\pm_R$ and $\tilde{\ell}^\pm_L$. The $\tilde{\ell}_R$ is expected to be the lightest but we have also tested the case of degenerate masses. Charginos and sleptons will decay into the lightest supersymmetric particle. The photino is assumed to be stable and to escape undetected since it has only weak interactions. A review of the production cross-sections for these particles, and of their decay properties, can be found in the previous DELPHI paper [13].

The events used to search for *unstable* sleptons and charginos correspond to about 40.000 hadronic Z^0 's. We required events with two oppositely charged tracks, both of them with a momentum higher than 2 GeV/c, at more than 30° with respect to the beam axis and with acoplanarity larger than 15°. As we have found no candidate for supersymmetric channels, we can derive limits in terms of $m_{\tilde{\ell}}$ and m_χ with two assumptions:

$$m_{\tilde{\ell}_R} = m_{\tilde{\ell}_L} \qquad \text{or} \qquad m_{\tilde{\ell}_L} >> m_{\tilde{\ell}_R}.$$

We have determined the limits at 95% confidence level corresponding to the three slepton families [12]. These limits are above 44 GeV/c² for selectrons and smuons in the case of degenerate masses, and above 43 GeV/c^2 if the masses are different. For staus the corresponding values are 42.5 and 40.5 GeV/c^2. The coupling of the Z° to $\chi^+\chi^-$ depends on the proportion of the wino and higgsino components. It is smallest for the case of pure higgsino. For the pure higgsino and pure gaugino cases we reach the kinematical limit.

If the lightest supersymmetric particle is not neutral, one could observe Z^0 's decaying into two heavy *stable* charged particles. The final state is identified kinematically by looking for collinear two prongs where both measured momenta are equal and differ significantly from the beam momentum. For very high masses, close to the kinematical limit, the particles become non-relativistic. In this case the analysis of the momenta is not adequate. We have therefore searched for pairs of highly ionizing particles by looking for anomalous ionization in the TPC [12]. For stable sleptons, the absence of any candidate allows us to exclude the mass domain between 25 GeV/c^2 and 44.8 GeV/c^2 in the degenerate case, and up to 44.5 GeV/c^2 in the non-degenerate case. For stable charginos the limit is 45 GeV/c^2.

5. Properties of hadronic events and QCD.

5.1 Multiplicity distributions and intermittency.

From a study of the multiplicity distributions we conclude that in the energy range 20-90 GeV approximate KN0 scaling is valid [14]. In particular the value of the dispersion $D = 6.28 \pm 0.03 \pm 0.43$ of the distribution is equal to the one at lower energies. It was also shown that the Lund Parton Shower model describes the data reasonably well. The multiplicity distributions show positive forward-backward correlations that are strongest in the central region of rapidity and for particles of opposite charge. Later, we reached the same conclusion in [15], which is based on a data sample ten times larger.

Intermittency is a measure of the sporadic appearance of more hadrons in small volume of the available phase space. In the first paper on the subject, we have found that the relevant factorial moments in rapidity space are well described by the JETSET parton shower model [16]. This conclusion does not support the finding of the TASSO collaboration [17]. Our later work, with much increased statistics, showed that the agreement is there also in 2-dimensional and 3-dimensional phase-space [18]. In conclusion, there is *no* need for physics beyond the one which is included in the best MC generators to explain the factorial moments of the multiplicity distributions at LEP energies.

5.2 Measurements of α_S.

DELPHI performed two independent measurements of the strong coupling constant by using the multijet rate [19] and the asymmetry of the energy-energy correlation [20]. The results are :

$$\alpha_S(91\mathrm{GeV}) = 0.114 \pm .003(\mathrm{stat}) \pm .004(\mathrm{syst}) \pm .012(\mathrm{th})$$

$$\alpha_S(91\mathrm{GeV}) = 0.106 \pm .003(\mathrm{stat}) \pm .003(\mathrm{syst})\,{}^{+.003}_{-.000}\,\mathrm{th}.$$

The systematic errors are mainly due to hadronisation effects. The last error is due to the uncertainty in the choice of the renormalization scale. The asymmetry of the energy-energy correlation is much less sensitive to this choice [20] so that we can quote our best result on the QCD scale parameter :

$$\Lambda^{(5)}_{\overline{\mathrm{MS}}} = \left[104\,{}^{+20}_{-20}(\mathrm{stat})\,{}^{+25}_{-20}(\mathrm{syst})\,{}^{+30}_{-0}(\mathrm{th})\right] \mathrm{MeV}.$$

5.3 Measurements of the triple gluon vertex.

DELPHI has submitted to the Conference the first measurement of a quantity which *measures* directly the triple gluon vertex. We have studied the bi-dimensional angular distributions of four jet events; previously only one-dimensional distribution had been used. Following R.K. Ellis et al [21], the transition probabilities to order α_S^2 can be grouped into gauge-invariant classes. For QCD the various probabilities are determined by the fermionic Casimir operation C_F=4/3 and the number of colors N_C=3. By fitting the expected bi-dimensional distribution to the data we deduced [22]:

$$N_C/C_F = 2.05 \pm 0.4(\mathrm{stat})\,{}^{+0.7}_{-0.1}(\mathrm{simul}) \pm 0.4(\mathrm{frag}),$$

which is in agreement with the QCD expectation 2.25. Abelian theories would give N_C/C_F=0.

6. Partial widths in heavy flavours.

We have determined the partial width $\Gamma_{c\bar{c}}$ of the Z^0 boson into charm quark pairs, based on a total sample of 36 900 Z^0 hadronic decays [23]. The production rate of $c\bar{c}$ events was derived from the inclusive analysis of charged pions coming from the decay of charmed meson $D^{*+} \rightarrow D^0\pi^+$ and $D^{*-} \rightarrow \bar{D}^0\pi^-$ where the $\pi^{\pm}$ is constrained by kinematics to have a low p_T with respect to the jet axis. The probability to produce these $\pi^{\pm}$ from $D^{*\pm}$ decay in $c\bar{c}$ events was taken to be 0.31 ± 0.05 as measured at $\sqrt{s} = 10.55$ GeV. The measured relative partial width

$$\Gamma_{c\bar{c}}/\Gamma_h = 0.162 \pm 0.030(\text{stat}) \pm 0.050(\text{syst})$$

is in good agreement with the Standard Model value of 0.171.

The $b\bar{b}$ decay channel has a special event shape because of the high mass of the decaying particles. By using a technique based on a separation in boosted sphericity product, from a sample of Z^0 events corresponding to an integrated luminosity of $\sim 0.9\ pb^{-1}$ the fraction of $b\bar{b}$ decays has been measured to be $0.209 \pm 0.030(\text{stat}) \pm 0.031(\text{syst})$ [24]. The systematic error comes mainly from the uncertainty on b fragmentation function. Using our determination of the hadronic Z^0 width, this corresponds to a partial width $\Gamma_{b\bar{b}} = 367 \pm 76$ MeV, in good agreement with the Standard Model prediction of $\simeq 380$ MeV.

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