HADRON CROSS-SECTIONS IN $\gamma\gamma$ COLLISIONS AT LEP

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The reaction $e^+e^- \to e^+e^-\gamma\gamma \to e^+e^- hadrons$ is analysed for quasi-real photons using data collected at LEP for $\sqrt{s} = 130 - 202$ GeV. Results on the total cross-sections are compared to the universal Regge parametrisation. We observe a steeper rise with energy as compared to hadron-hadron cross-sections. The data are also compared to the expectations of different theoretical models. Inclusive charged hadrons, π^0 and K^0_S productions are measured as function of the transverse momentum p_T.

1 The $e^+e^- \to e^+e^-\gamma\gamma \to e^+e^- hadrons$ total cross-section

The $\gamma\gamma$ total cross-section has been measured at LEP: by L3[1] at intermediate energies $\sqrt{s} = 130-161$ GeV with an integrated luminosity of $\mathcal{L} \simeq 15.4\,pb^{-1}$; by OPAL[2] at $\sqrt{s} = 161-183$ GeV with $\mathcal{L} \simeq 74.3\,pb^{-1}$. Preliminary L3 results are here presented at $\sqrt{s} = 189 - 202$ GeV with $\mathcal{L} \simeq 392.6\,pb^{-1}$.

The $\gamma\gamma$ events are selected by energy and multiplicity cuts. An anti-tag selection keeps only quasi-real photon interactions. The main remaining backgrounds are annihilation events (< 15 %) and $\gamma\gamma \to \tau\tau$ events (< 5 %). The hadronic mass ($W_{\gamma\gamma}$) is calculated from the visible mass in the detector ($W_{\rm vis}$) using unfolding programs : BAYES[3] for L3 and GURU[4] for OPAL. Both experiments use as input for unfolding PHOJET[5] and PYTHIA[6] Monte-Carlos with JETSET[7] hadronization. The results obtained with the two Monte-Carlos are averaged. To extract the $\sigma(\gamma\gamma \to hadrons)$ cross-section from $\sigma(e^+e^- \to e^+e^- hadrons)$, the luminosity function $\mathcal{L}_{\gamma\gamma}$ is calculated and the process is extrapolated to zero Q^2.
The results are shown on fig.1 with statistical and detector related systematic errors added in quadrature. OPAL and L3 data, as well as 1998 and 1999 data are consistent with each other. The main uncertainty is the MC dependence of the unfolding procedure. This changes the absolute normalisation, but not the $W_{\gamma\gamma}$ dependence of the measurement.

A Regge fit[8] $\sigma_{\gamma\gamma} = As^{\varepsilon} + Bs^{\eta}$, with $s = W^2_{\gamma\gamma}$, using the universal values[9] $\varepsilon = 0.095$ and $\eta = 0.34$, doesn't reproduce the high $W_{\gamma\gamma}$ data. Relaxing the Pomeron intercept in the fit gives $\varepsilon = 0.263 \pm 0.014$. Different theoretical model are also tested. Those[10] which are too close to hadron-hadron or γ-hadron phenomenology also fail to reproduce the data. Models[11] which take

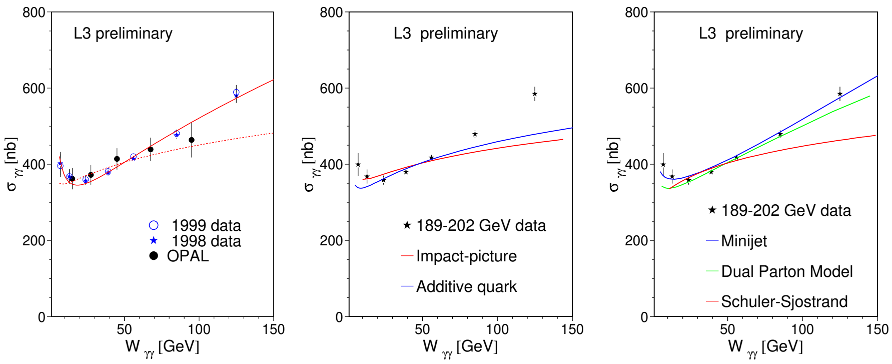

Figure 1: The $\gamma\gamma$ cross-section, using the average of PYTHIA and PHOJET corrections, is compared to Regge fits and to various theoretical models.

into account the specific $\gamma\gamma$ direct and hard-QCD subprocesses, show a better agreement with the data.

2 The single particle inclusive cross-section

The specific $\gamma\gamma$ behaviour can be analysed through single particle inclusive production. OPAL published[12] cross-sections for charged hadrons and K^0_S production at $\sqrt{s}=$ 161-172 GeV and L3 measured π^0 and K^0_S cross-sections at 189-202 GeV. The results are shown on fig.2. The L3 and OPAL results are in good agreement in the K^0_S channel. The p_T dependance of the cross-sections shows a soft-interaction part which can be fitted by an exponential and a hard-interaction part starting above 2 GeV. The first part is similar to other hadronic processes. The second is specific to $\gamma\gamma$ processes; the direct and hard-QCD subprocesses are well explained by NLO calculations[13].

3 Conclusions

L3 and OPAL measured the total $\gamma\gamma$ cross-section and single particle inclusive production at high energies. Their results are in agreement with each other. The main source of uncertainities comes from the Monte-Carlo model dependence. In all channels, $\gamma\gamma$ collisions present a specific behaviour, distinct from γ-hadron and hadron-hadron collisions.

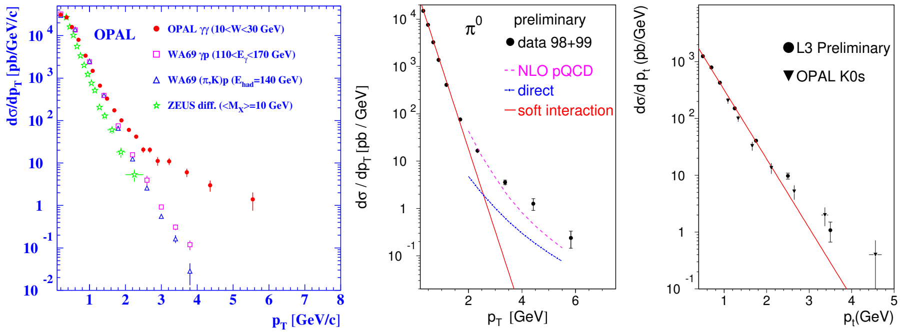

Figure 2: Inclusive single particle transverse momentum distributions for: charged hadrons in OPAL, π^0 in L3 and K^0_S in L3 and in OPAL. In the first figure, the $\gamma\gamma$ events are compared to other hadronic processes. In the last two, an exponential fit describes the soft part. NLO-QCD calculations are compared to the π^0 high-p_T differential cross-section.

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