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OVERVIEW OF THE COMPETE PROGRAM†

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COMPETE◊ collaboration

Introduction

Nowadays, scientific databases have become the bread-and-butter of particle physicists. They are used not only for citation and publication [1, 2, 3, 4], but also for access to data compilations [5, 6, 7] and for the determination of the best parameters of currently accepted models [5, 6, 8]. These databases provide inestimable tools as they organize our knowledge in a coherent and trustworthy picture. They have lead not only to published works such as the Review of Particle Physics [9], but also to web interfaces, and reference data compilations available in a computerized format readily usable by physicists. It should be pointed out at this point that one is far from using the full power of the web, as cross-linking between various databases and interactive interfaces are only sketchy. Part of the problem comes from the absence of a

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◊COmputerised Models, Parameter Evaluation for Theory and Experiment.

common repository or environment.

One must also stress that this crucial activity is not a given, and that these databases must be maintained and checked repeatedly to insure the accuracy of their content. In fact, we run the risk to loose some or all of the information contained in them, as the maintainers are getting older. There is a need for teaching the systematization and evaluation of data in the standard physics curriculum, need which so far has totally been overlooked. We stress the importance of summer schools and workshops dedicated to data systematization.

The COMPETE collaboration aims at motivating data maintenance via the interfacing of theory and experiment at the database level, thus providing a complete picture of the phenomenology describing a given subclass of phenomena. The database concept then needs to be supplemented by a "model-base" [10]. Such an object enables one not only to decide what the best description may be, but also to discern what potential problems exist in the data. The systematization of such a cross-fertilization between models and data, which is at the core of physics, results in what we shall call an "object of knowledge", containing both factual and theoretical information, and presumably becoming the point at which all existing information resources on a given problem could converge.

There are many advantages to such a global approach. First of all, the maintenance of a data set is not a static task: it needs to be motivated by physics. Discrepancies between models and data call for checks, and often those checks lead to a new data set, where published errata in data are fixed and preliminary data are removed. A clear example of such improvements can be found in the total cross section data set. Furthermore, at times such studies show that there may be problems in the experimental analysis itself. For instance, in the analysis of the ρ parameter, the systematic error resulting from the use of a specific model is usually neglected. A general re-analysis of these data is therefore needed, or a different treatment of systematic errors may be brought in.

The second advantage is obviously that one can have a common testing ground for theories and models, so that all the details of the comparison are under control. This means that it becomes possible, for a given set of assumptions, to define the best models reproducing a given set of data. In this respect, as many models have to be tested, and as the usual "best fit" criterion, i.e. lowest χ^2/dof, is not fully satisfactory, we have developed a set of procedures that enable artificial intelligence decisions, simulating to some extent a physicist's intuition and taste.

Thirdly, it is obvious that an extensive theoretical database can be used to plan new experiments, and to predict various quantities. The automated treatment of a large number of models and theories enables us to quote a theoretical error, which gives the interval in which existing models can reproduce experimental results, and to determine the sensitivity needed to discriminate between various models.

Finally, as new data come in, one can very quickly decide on their theoretical impact, and hence immediately evaluate the need for new physics ideas.

As we want to treat a large amount of data and many models, computer technology constitutes an important part of our activity. We have concentrated on the elaboration of artificial intelligence decision-making algorithms, as well as on the delivery of computer tools for the end-user: these include web summaries of results, web calculators of various quantities for the best models, and of course computer-readable data-sets and Fortran codes. Finally, the consideration of several different physics problems brings in the need to interface various objects of knowledge. The interconnection and compatibility of these is an important constraint. Further linkage with existing databases, such as PDG [5], COMPAS [6], and HEPDATA [7] is being developed or planned.

Methodology

Our work is based on the following information model: theoretical descriptions and data are arranged in bases, which are then interfaced. This cross assessment leads to a ranking of models, and to an evaluation of data: some models globally reproduce data and some don't, some data seem incompatible with all models or with similar data. At this point, a selection of acceptable models and of acceptable data is made. The models are then ranked according not only to their χ^2/dof, but also to their number of parameters, stability, extendability to other data, etc. The best models are kept, and organized into an object of knowledge. One can then make predictions based on these few best models, and evaluate theoretical errors from all acceptable models. The data set can also be re-evaluated, and after a new data set is produced, one can re-iterate the above procedure. The next step is then to find models that can accommodate more data and once such new models are proposed, one can iterate again.

It is worth pointing out here the problems directly linked with data and parameters. First of all, contradictory data lead to sizable uncertainties. One way to handle these is to use a Birge factor, renormalizing the χ^2/dof to 1. Another way is to re-normalize a given data set, and assign to this operation a penalty factor. Finally, it is also possible to shift data sets within their systematic errors in order to obtain the best data set overall. Each method has its problems and advantages, and no overall best method has been found so far. Secondly, one must stress that, besides the usual statistical and systematic errors, one should independently quote a theoretical error which may not be combined with the experimental systematics. Finally, it is important for a given set of parameters to indicate their area of applicability, *e.g.* often high-Q^2 or high-s models are used outside their area of validity.

The organization of work within the collaboration is similar to that of the Particle Data Group: each member of the collaboration has access to the current object of knowledge which gets released to the community once a year, in the form of computer-usable files, and web-accessible notes. Part of the collaboration is devoted to the finding of new data and models in the literature, as well as to their encoding. Other people check the accuracy of the encoding. The study and elaboration of the object of knowledge is done under the guidance of a few developers, whose work then gets partially or fully verified by the rest of the team in charge of that study. The web interface and tools are then developed or updated by another part of the collaboration.

The organization of the object of knowledge itself goes as follows: a compilation of data is interfaced with a compilation of models, typically kept as a set of Mathematica routines (which can then be used to produce Fortran or C). The conclusions of the cross-assessment are then fed into a program devoted to predictions, and freely executable via the web. Tables of predictions then become available. Another module gathers the information obtained from the cross-assessment and makes it available to the collaboration for cross-checks. Finally, another module uses the citation databases to track new work that refers to our existing databases.

Results

The results we have obtained so far fall within two main categories: the first concerns the tools that we have developed, which could be used by others in a wide variety of tasks, the second concerns the physics conclusions which we have reached.

Tools

Elements of the artificial intelligence

The usual indicator χ^2/dof is certainly an important measure of the quality of a fit. However, it does not give us all the relevant information to choose the best models. We have developed [11, 12], in the context of fits to soft data, a series of other indicators that enable us to study numerically some of the aspects of fits which so far had only received a qualitative treatment. Models usually rely on some approximation which breaks down in some region. For instance, in DIS, the starting value of Q_0 is an indication of the area of applicability of a given parameterisation. Within a common area of applicability, fits with a better χ^2/dof are to be preferred. If the parameters of a fit have physical meaning, then their values must be stable when one restricts the fit to a sub-set of the full data set, or if one limits the area of applicability, *e.g.* but modifying the starting Q_0 of a DIS fit. Similarly, fits that use a handful of parameters are usually preferred to those that use many. All these features can be studied numerically, and details can be found in refs. [11, 12]. The use of these indicators then enables one to decide which model may be preferred to describe some set of data.

Web

We have also developed an automatic generation of results which are then gathered in postscript files available on the web [13], as well as a calculational interface that predicts values of observables for the first few best parameterisations [14]. Furthermore, computer-readable files [15], as well as Fortran code for the best models [16], are also given. As we shall see, this is only a first step as a full interface between different objects of knowledge still needs to be built.

Physics

Soft Forward data: FORWARD2.1

We started our activities a few years ago [17], concentrating on analytic fits to total cross sections and to the ρ parameter. Such studies first revealed a few problems with the data set, and then proved the equivalence of simple, double and triple pole parameterisations in the region $\sqrt{s} \geq 9$ GeV. This resulted in the first version of the object of knowledge concerned with soft forward physics, FORWARD1.0. Its second version [11], dating from last year, came when it was realized that some fits could be extended down to $\sqrt{s} \geq 4$ GeV. The latter models thus became favored, and constitute the second version of the object of knowledge, FORWARD2.0. It now contains 3092 points (742 above 4 GeV), and 37 adjusted and ranked models. We have recently used it to produce predictions at present and future colliders [18], and included cosmic ray data to obtain FORWARD2.1, which is detailed in J.R. Cudell's contribution to these proceedings.

This object of knowledge has demonstrated that ρ parameter data were poorly reproduced. Some experiments at low energy seem to have systematic shifts with respect to other experiments, and the χ^2/dof of the ρ data is very bad for some data sets (pp, $p\pi^+$, pK^-). Although some of the problems can be understood as coming from the use of derivative dispersion relations (see O.V. Selyugin's contribution to these proceedings), discrepancies between data nevertheless make a good fit impossible.

The only clean way out is to perform the experimental analysis again, or part of it, either through a check (and correction) of the theoretical input used, or through a re-analysis of the data in the Coulomb-nuclear interference region. One thus needs a common parameterisation of electromagnetic form factors, a common procedure to analyse data in the Coulomb-nuclear interference region, a common set of strong interaction elastic scattering parameterisations, and a common study of Regge trajectories. The next few objects of knowledge are devoted to the systematization of such information.

Regge trajectories: RT1.0β

First of all the long way of modelling the forms of Regge trajectories for positive and negative values of t should be systemized. Even the good old idea of linearity at positive t should be tested and maintained.

We have extracted from the RPP-2002 database a new set of hadronic states (213 mesons and 123 baryons), including their masses, widths and quantum numbers. Corresponding isotopic multiplets (one isomultiplet – one point) are all presented in a log-linear Chew-Frautschi plot with different markers for different flavors to show the similarities and differences of the (M^2, J) populations for different hadron classes, see Fig.1.

There is only one linear meson trajectory (a_2, a_4, a_6) that give the acceptable fit quality with weights constructed from the errors in masses. This trajectory is placed on the Fig. 1 together with longest baryon trajectory (5 Δ members) with good fit quality.

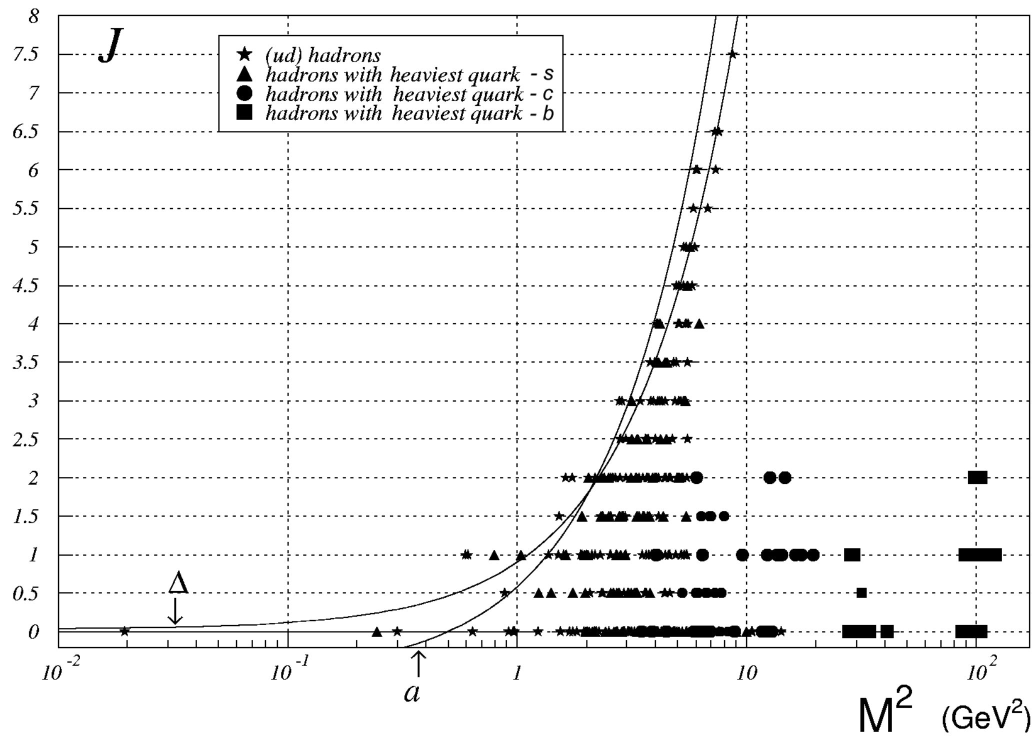

Figure 1: Chew-Frautschi plot for all hadrons from RPP-2002

Preliminary fits of the RPP-2000 data to linear trajectories (in the approximation where weights in the fits are constructed from $\Delta(M^2) = M\Gamma$, instead of $\Delta(M^2) = 2M\Delta M$) show a clear systematic flavor dependence of the slope for mesons, as shown in Table I. Such a dependence of the slopes on flavor does not seem to be present in the baryon case.

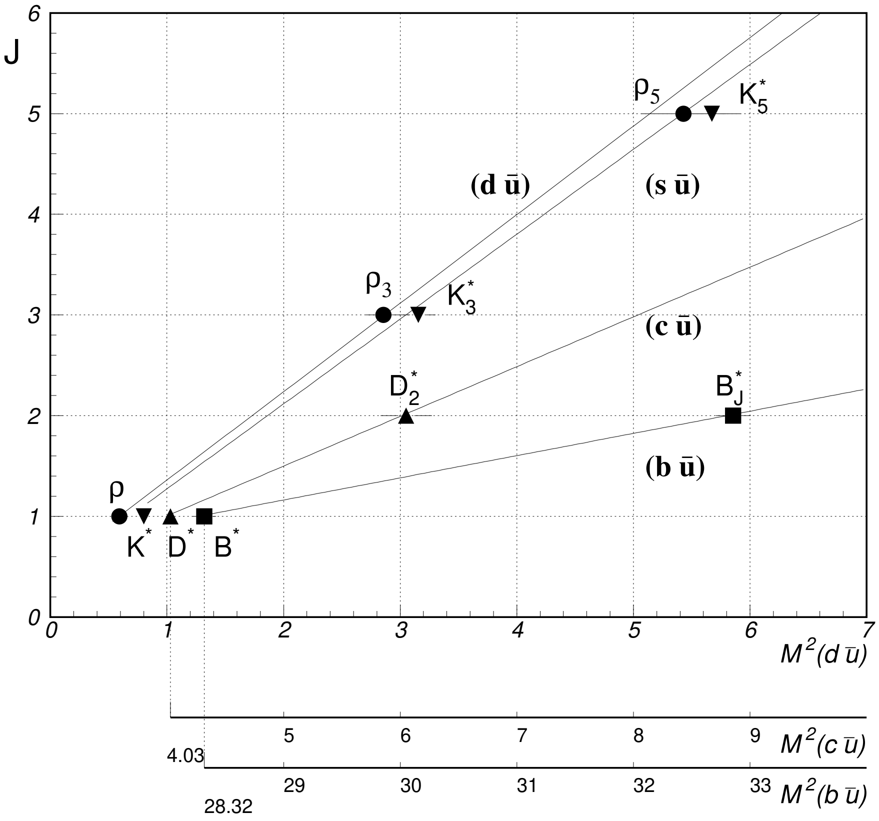

Figure 2: Linear Regge trajectories slopes for different meson flavors

Slopes of meson Regge trajectories as a function of their flavor content (obtained from the 2000 data)

	q	s	c	b
$\bar{q}$	0.84 ± 0.09	0.86 ± 0.02	0.49 ± 0.08	0.22 ± 0.01
$\bar{s}$		0.82 ± 0.01	0.55 ± 0.01	0.22 ± 0.02
$\bar{c}$			0.40 ± 0.01	
$\bar{b}$				0.11 ± 0.01

We plan to reiterate fits in this approximation on the 2002 RPP data to see if the regularity is stable and we will then proceed to collect and compare different functional forms of the trajectories on a regular basis using the: spectroscopic data together with the elastic scattering data; data on two body reactions; decay properties data to see if the decision rule for the dichotomy "quark model hadrons – exotic hadrons" can be constructed.

Electromagnetic form factors of hadrons: EFFH1.0β

This object of knowledge is also under construction. So far only nucleon emff were considered. Its data set consists of 785 values of $d\sigma_{ep}/d\Omega$, 29 values of G_e/G_m and 31 values of σ_{tot} for $\overline{p}p \to e^+e^-$, for a total of 845 points. We ignore derived data on emff and produce fits only to the directly measured observables and then compare fits. The base of models consists of 4 adjusted and maintained parameterizations.

Recently the extended Gari-Kruempelmann [19] parameterization for the nucleon emff were fitted [20] to the most complete data set of the derived data with inclusion of the new data on G_E/G_M [21]. To include this extension of the Gari-Kruempelmann parameterization to the model base we started to check if it could be reasonably fitted to our database.

It turns out that in the VMD part of parameterization it is enough to include only one vector meson ($\rho(770)$) to obtain a reasonable fit to the $d\sigma/dt$ and G_E/G_M data.

However it leads to the determination of the electric and magnetic radii of the nucleons that are incompatible with that determined from the Lamb shift in hydrogen atom measurements.

Table 1: Fit to the $d\sigma/dt$ data: $\chi^2/d.o.f. = 0.91$

$\langle r^2\rangle$ fm^2	Value	σ^2 fm^2	Correlations			
$\langle(r_E^p)^2\rangle$	0.6906	2.7E-03	1.00	−0.01	0.22	−0.26
$\langle(r_M^p)^2\rangle$	0.6926	3.1E-03	−0.01	1.00	−0.44	0.95
$\langle(r_E^n)^2\rangle$	−0.4266	3.2E-03	0.22	−0.44	1.00	−0.65
$\langle(r_M^n)^2\rangle$	0.9003	5.3E-03	−0.26	0.95	−0.65	1.00

Table 2: Fit to the $d\sigma/dt$ and G_E/G_M data: $\chi^2/d.o.f. = 1.03$

$\langle r^2\rangle$ fm^2	Value	σ^2 fm^2	Correlations			
$\langle(r_E^p)^2\rangle$	0.6650	1.7E-03	1.00	0.32	−0.24	0.69
$\langle(r_M^p)^2\rangle$	0.7153	4.7E-03	0.32	1.00	0.73	0.28
$\langle(r_E^n)^2\rangle$	−0.3411	15.6E-03	−0.24	0.73	1.00	−0.46
$\langle(r_M^n)^2\rangle$	0.8965	4.7E-03	0.69	0.28	−0.46	1.00

We see from Tables , that estimates of the physical parameters changed markedly with the addition of new observables measured in the same range of kinematic variables.

It should be noted that the mean square proton radii $\langle (r_E^p)^2 \rangle = 0.61$ fm^2, $\langle (r_M^p)^2 \rangle = 1.82$ fm^2 calculated from the fit obtained in [20] for the same model but with a VMD part containing ρ, ω, and ϕ contributions are even worse in comparison with estimates from the Lamb shift data. This is a signal for possible problems with the database and/or with parameterizations (see also [22]). Further cross-assessment iterations with models ranking are needed.

Forward elastic scattering of hadrons: FESH1.0β

This database contains the measured differential distribution $d\sigma/dt$ for $|t| < 0.6$ GeV^2 for $\pi^{\pm}p$ (438 points at 73 energies), $K^{\pm}p$ (204 points at 34 energies) and $\bar{p}p$, pp (564 points at 94 energies). The associated object of knowledge is interfaced with the FORWARD, EFFH and RT objects of knowledge as

$$\frac{d\sigma}{dt} = \pi \left(|f_c|^2 + 2Re(f_c^* f_h) + |f_h^2|^2 \right) \qquad (1)$$

with f_c the Coulomb amplitude, which depends on the form factors of EFFH, f_h the hard-interaction amplitude, which depends on σ_{tot} and ρ (from FORWARD), and on Regge trajectories (from RT).

So far, we have done a preliminary study trying to find regularity in energy of the several claimed evidences for oscillations on the diffraction cone. The method to reveal the oscillations is illustrated in the Figure 3

Using the naïve models for the diffractive cone description ($A(s)e^{B(s)\alpha(t)}$) and the standard Coulomb amplitude with popular dipole(pole) charge form-factors for nucleons(mesons), we calculate the normalized autocorrelation $R(s)$ of the difference $T(s,t) = (\frac{d\sigma^{data}/dt}{d\sigma^{theory}/dt} - 1)$ for 195 experimental distributions $d\sigma/dt$ at different values of $P_{lab} \geq 10$ GeV/c and having more than 7 data points in the region $|t| < 0.6$ GeV^2.

$$R(s) = \sum_i \frac{T(s,t_i)T(s,t_{i+1})}{\sigma_i^2 \sigma_{i+1}^2} \left(\sum_i \frac{1}{\sigma_i^2 \sigma_{i+1}^2} \right)^{-1},$$

where $\sigma_i = \frac{\sigma_i^{data}}{d\sigma^{theory}(s,t_i)/dt}$.

Large (> 1) values of the autocorrelator are signals for oscillations or fit biases, large negative values (< -1) are signals that we have problems with data (the errors are over-estimated).

Figure 4 shows that almost all values of the autocorrelations for the three intervals $|t| < 0.1$ GeV^2, $|t| < 0.2$ GeV^2, and $|t| < 0.3$ GeV^2 are close to the normal distribution. There are some outstanding points but the data on the corresponding scatter plots do not show any stable regularity in energy dependence of the scatter plots structures. These outstanding autocorrelation values may be due hidden t-dependent systematic effects, or to biases in the fits on the diffraction cone.

Furthermore, the possible oscillation pattern seems to be model-dependent, as seen on the same figure. For example, the Figure 3 clearly show absence of the oscillations claimed in some phenomenological papers. Our preliminary conclusion is based on the analyses of two different forms of the t-dependence of the pomeron trajectory: linear and square root dependence with branch point at $t = 4m_\pi^2$. The optical points also were calculated with use different models of the energy dependence of the total cross sections.

To make unambiguous conclusions we need more iterations of cross-assessments to find a parameterization that give good description of the diffractive cones and their evolution with energy. Having such a parameterisation it will be possible to clarify the situation with claimed oscillations.

Cross section in $e^+e^- \to hadrons$, R, QCD tests: CSEE1.0

As a parallel activity, we have gathered [23] the data for the annihilation cross sections $\sigma_{e^+e^-\to hadrons}$ and for their ratio R to $\sigma_{ee\to\mu\mu}$ for 0.36 GeV $\leq \sqrt{s} \leq$ 188.7 GeV. The database consists of 1066 points rescaled to the hadronic R. The QCD fit to the hadronic part clearly shows that a 3-loop calculation is preferred with respect to the naïve Born formula, and leads to the following value of α_S:

$$\alpha_S(M_Z^2) = 0.128 \pm 0.032 \tag{2}$$

All available data on the total cross section and the R ratio of $e^+e^- \to$ h$adrons$ are compiled from the PPDS(DataGuide, ReacData) (IHEP, Protvino, Russia) and HEPDATA(Reaction) (Durham, UK) databases and transformed to a compilation of data on the ratio $R = \frac{\sigma(e^+e^-\to q\bar{q}\to \mathrm{hadrons})}{\sigma(e^+e^-\to\mu^+\mu^-)}$, with the full set of radiative corrections. This compilation is the most complete set of evaluated hadronic R ratio data publicly available to date. The current status of the data is shown in Fig. 5. The compilation is continuously maintained so that new experimental data are added as they become available.

The compilation is intended for tests of pQCD calculations as well as for a precise evaluation of hadronic contributions to $\Delta\alpha_{QED}(M_Z)$, $a_\mu = (g_\mu - 2)$, *etc.* The results we obtained so far are as follows: current theoretical predictions from the parton model and pQCD are well supported by the world "continuum" data on $\sigma_{tot}(e^+e^- \to \mathrm{h}adrons)$. Our preliminary value of $\Delta\alpha^{had}_{QED}(M_Z)$ is $0.02736 \pm 0.00040(exp)$, in agreement with the results of other groups [25]. The refinement of the $\Delta\alpha^{had}_{QED}(M_Z)$ calculation and the evaluation of $a_{\mu}{}^{had}_{LO}$ are in progress.

Computer-readable data files are accessible on the Web at
`http://pdg.lbl.gov/2002/contents_plots.html` (see also [24]) and
`http://wwwppds.ihep.su:8001/eehadron.html`

Prospects for the future

The various objects of knowledge described in this report should be released to the community within a year. The FORWARD object of knowledge will also probably be renewed in light of the analysis of ρ. We also plan soon to build objects of knowledge devoted to 2-body processes at large s and t, to photoproduction of vector mesons, and to hadronic multiplicities.

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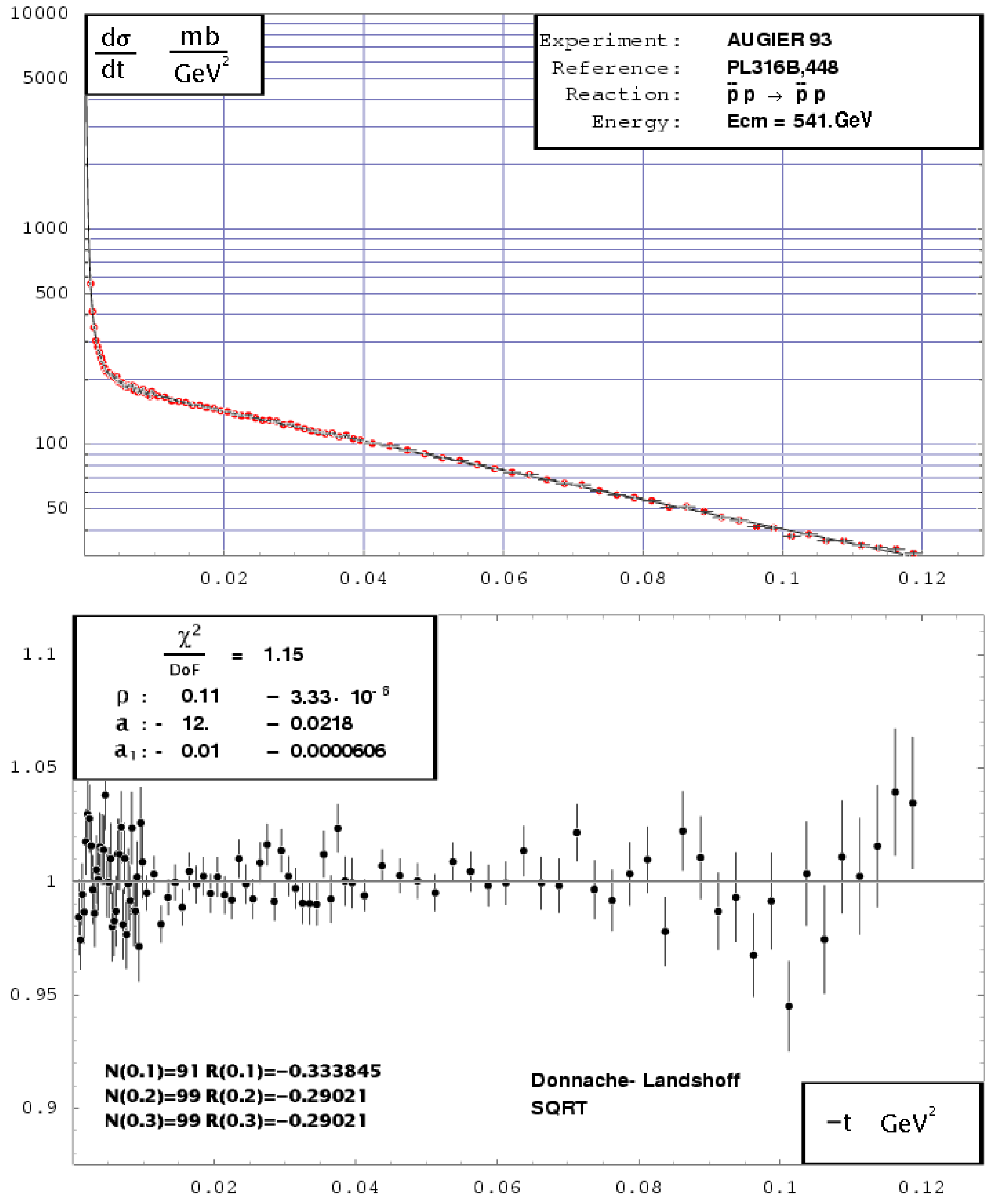

Figure 3: Fit to the $d\sigma/dt$ and results of autocorrelation function calculation

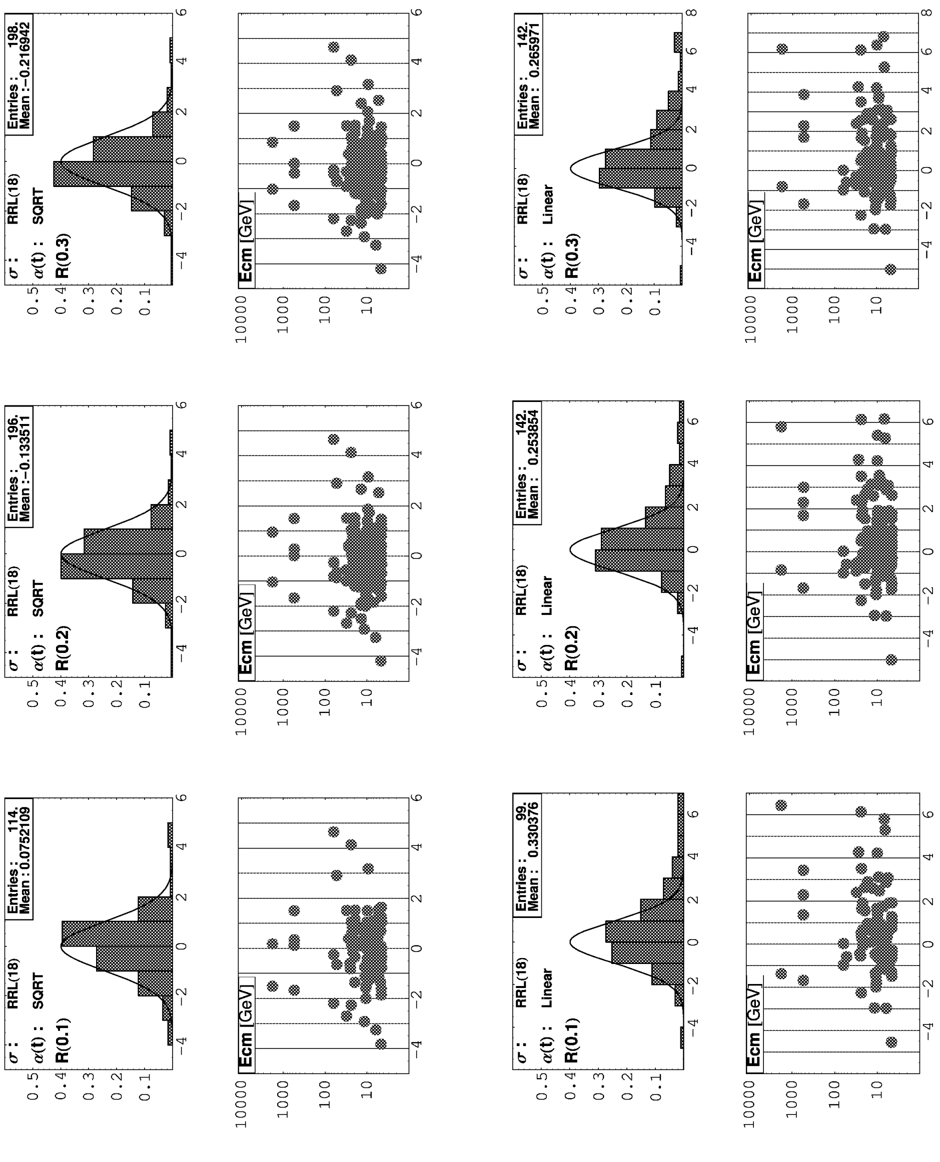

Figure 4: "Statistical pattern" of the autocorrelations as the indicator for the fine structure on the diffractive cone

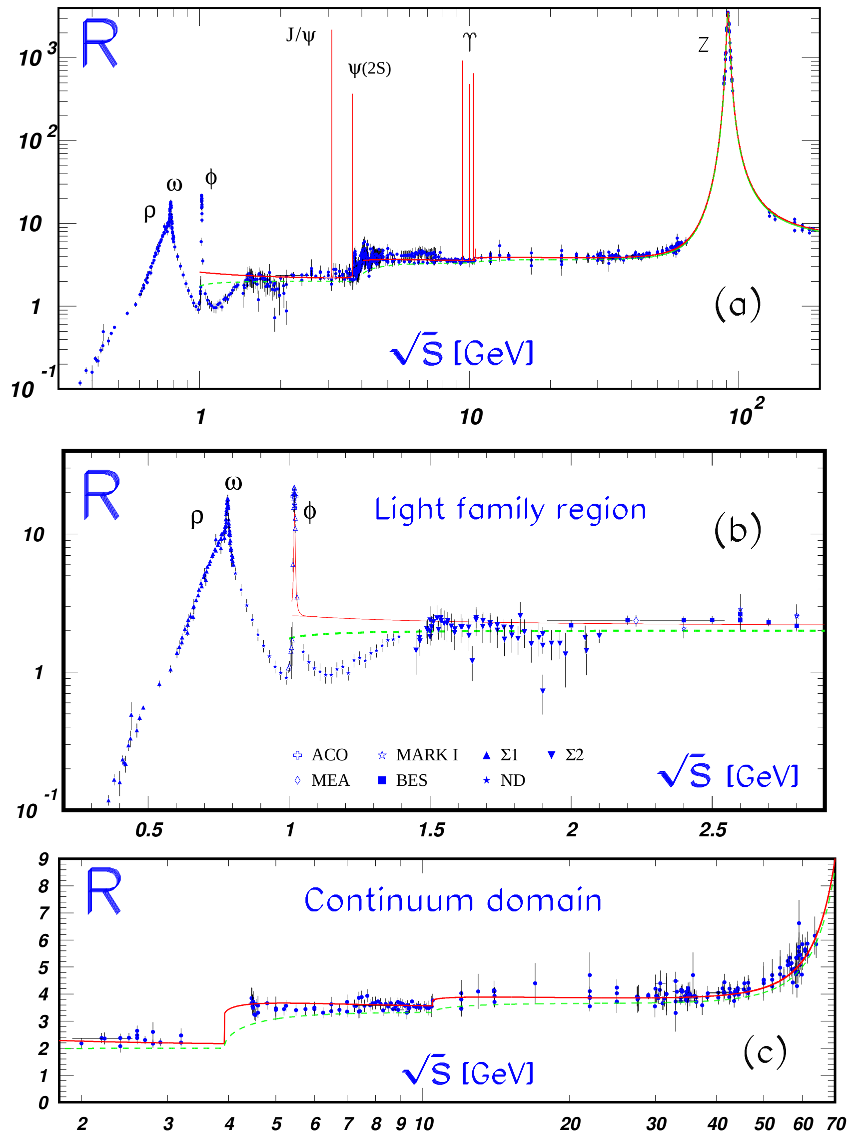

Figure 5: (a) World data on the ratio $R = \frac{\sigma(e^+e^- \to q\bar{q} \to \mathrm{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)}$. (b) Low $\sqrt{s}$ region crucial for the evaluation of $\Delta\alpha_{QED}^{had}(M_Z)$, $a_{\mu LO}^{had}$, *etc.* (c) Applicability domain of 3-loop pQCD. Solid curves are 3-loop pQCD predictions (plus Breit-Wigner for narrow resonances on (a) and (b)). Broken curves show the "naïve" parton model prediction. Masses of c and b quarks are taken into account. The full set of radiative corrections is applied to all data. Further details and references to the original experimental data can be found in [23]. See also [24].