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CONFERENCE SUMMARY

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ABSTRACT

I summarize the new results presented during the hadronic session of the XXVI Rencontre de Moriond.

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1. INTRODUCTION

On this twenty-fifth anniversary of the Rencontres de Moriond, I want to begin my talk by saluting the marvelous spirit of common cause that has characterized this series of meetings. Again in this anniversary year, our friends—*gentils organisateurs,* conference staff, and *patron* Jean Trân Thanh Vân—have welcomed us with an inspired mixture of colleagues, topics, and entertainments. Diversity in the service of scientific excellence has been the hallmark of Moriond. Year after year, promising young physicists arrive in force to make their first presentations to an international audience that includes distinguished elders. Hot new subjects share the stage with old standbys. We participants are obliged to listen to—and even think about—research topics we didn't know could be interesting. Sometimes we find our prejudices confirmed, but sometimes we are treated to delicious surprises. To the pioneers of Moriond, to the veterans of many *Rencontres,* and to this year's first-time participants, I offer my thanks and congratulations for the atmosphere of support, encouragement, and curiosity about Nature that animates these encounters.

The Moriond years have spanned the development of the standard model: the establishment of quarks and leptons as basic constituents, the discovery of neutral weak currents, the proof that spontaneously broken gauge theories are renormalizable, the invention of asymptotic freedom, the rise of perturbative QCD, the discoveries of the ψ/J and charm, the tau lepton, the Υ and the b-quark, the $W^{\pm}$ and Z^0. Key experimental results have come from a succession of new machines: Serpukhov, SLAC, the ISR, Fermilab's Main Ring, CERN's SPS, the CEA Bypass, SPEAR, ADONE, ACO/DCI, DORIS, CESR, PETRA, PEP, the S$\bar{p}$pS collider, the Tevatron, TRISTAN, SLC, and LEP; from grand old machines like the AGS, the PS, and the KEK synchrotron; and from nonaccelerator experiments. Experimental techniques have ranged from emulsions and silicon microstrips to mammoth bubble chambers, water Cerenkov detectors, and 4π-solenoidal detectors. Theory has embraced the ancient wisdom of the complex angular momentum plane, the creation and application of the Lagrangian of the standard model, lattice gauge theory, supersymmetry, and dreams of superstrings. We have discovered common ground with cosmologists, astrophysicists, and nuclear physicists. Moriond has provided a forum for all these developments and has helped nurture the new links with other fields.

2. Z^0 PHYSICS

The largest quantity of new results this year come from the four LEP experiments, summarized here in a talk by Klaus Tittel.[1] The principal parameters of the Z^0 resonance are summarized in Table 1.

Table 1. Z^0 Parameters determined by experiments at LEP.

Observable	LEP Average	Standard Model
$M(Z)$	91.174 ± 0.02 GeV/c^2	
$\Gamma(Z)$	2.485 ± 0.009 GeV	2.497 ± 0.025 GeV
σ^0(hadrons)	41.43 ± 0.25 nb	41.43 ± 0.07 nb
$\Gamma(Z \to \text{hadrons})$	1740 ± 9 MeV	1744 ± 18 MeV
$\Gamma(Z \to e^+e^-)$	83.2 ± 0.5 MeV	83.9 ± 0.8 MeV
$\Gamma(Z \to \mu^+\mu^-)$	83.5 ± 0.9 MeV	83.9 ± 0.8 MeV
$\Gamma(Z \to \tau^+\tau^-)$	83.1 ± 1.0 MeV	83.9 ± 0.8 MeV
$\Gamma(Z \to \ell^+\ell^-)$	83.31 ± 0.40 MeV	83.9 ± 0.8 MeV
$\Gamma(Z \to \text{hadrons})/\Gamma(Z \to \ell^+\ell^-)$	20.90 ± 0.12	20.79 ± 0.08
$\Gamma(Z \to \text{invisible})$	494 ± 8 MeV	502 ± 4 MeV
Number of neutrinos	$2.97 \pm 0.05 \pm 0.05$	3

One new measurement I greatly enjoyed seeing is the first determination of the polarization of fermions produced on the Z^0, using self-analyzing decays of the τ-lepton to infer the polarization $P(\tau)$. In terms of the chiral couplings of the electroweak theory,

$$\begin{aligned} L &= \tau_3 - 2Qx_W \\ R &= -2Qx_W \end{aligned} , \tag{1}$$

where τ_3 is the weak-isospin projection, $x_W = \sin^2\theta_W$ is the weak mixing parameter, and Q is the electric charge, we may express the polarization of the tau as

$$P = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = \frac{R^2 - L^2}{R^2 + L^2} = \frac{4x_W - 1}{1 - 4x_W + 8x_W^2} . \tag{2}$$

The ALEPH Collaboration has measured the tau polarization in five decay modes, with the results shown in Table 2. The $\pi\nu_\tau$ and $\rho\nu_\tau$ channels have the greatest statistical weight. Within errors, all the channels give consistent determinations of the polarization. The mean value corresponds to a weak mixing parameter of $x_W = 0.2319 \pm 0.0057$, in good agreement with measurements by the L3 Collaboration ($x_W = 0.230 \pm 0.015$) and by the OPAL Collaboration ($x_W = 0.245 \pm 0.012$).

Table 2. ℵ Measurements of Tau Polarization on the Z^0 Peak.

Decay Mode	$P(\tau)$
$e\nu_e\nu_\tau$	$-0.193 \pm 0.162 \pm 0.061$
$\mu\nu_\mu\nu_\tau$	$-0.192 \pm 0.118 \pm 0.046$
$\pi\nu_\tau$	$-0.130 \pm 0.065 \pm 0.044$
$\rho\nu_\tau$	$-0.124 \pm 0.047 \pm 0.051$
$A_1\nu_\tau$	$-0.150 \pm 0.150 \pm 0.070$
Average	-0.143 ± 0.045

What is particularly noteworthy about the complex of measurements of Z^0 properties carried out at LEP is the consistency among the four experiments, and among many observables. This can be seen in the compilation[1] of ℵ measurements of the weak mixing parameter x_W shown in Table 3 and compared there with the overall LEP average. The LEP measurements significantly extend our tests of the standard model and enable us to place meaningful constraints on extensions to the standard model. Some of our colleagues are occasionally heard to claim that LEP is a disappointment because no "new" discoveries have been made and because the standard model has not (yet) been demolished. Let me be very clear: LEP is not a failure! Precisely these precision tests of standard-model predictions have been the stuff of our dreams for a decade. They will form a permanent part of the culture of our discipline.

Table 3. ℵ Measurements of the Weak Mixing Parameter.

Observable	$\sin^2\bar{\theta}_W$
Line shape, Γ_μ	0.2330 ± 0.0025
F-B asymmetry: leptons	0.2295 ± 0.0038
—: hadron charges	0.2300 ± 0.0052
—: $b\bar{b}$	0.2262 ± 0.0054
—: $c\bar{c}$	0.2310 ± 0.0110
Polarization: τ	0.2319 ± 0.0057
Average	0.2311 ± 0.0017
LEP Average	0.2320 ± 0.0017
	(0.0007 common systematics)

3. THE HIGGS BOSON

The Higgs boson arises naturally through the spontaneous breaking of electroweak symmetry in the minimal standard model. An important independent argument assures us that—in any acceptable theory—something like the Higgs boson must exist. Consider the role that the Higgs boson plays in the cancellation of high-energy divergences. An illuminating example is provided by the reaction

$$e^+e^- \rightarrow W^+W^- \ , \tag{3}$$

which is described in lowest order in the Weinberg-Salam theory by four Feynman graphs. The leading divergence in the $J=1$ amplitude of the t-channel neutrino-exchange diagram is cancelled by the contributions of the direct-channel γ- and Z^0-exchange diagrams. However, the $J=0$ scattering amplitude, which exists in this case because the electrons are massive and may therefore be found in the "wrong" helicity state, grows as $\sqrt{s}$ for the production of longitudinally polarized gauge bosons. The resulting divergence is precisely cancelled by the direct-channel Higgs-boson graph. From the point of view of S-matrix theory, the Higgs-electron-electron coupling must be proportional to the electron mass because the strength of "wrong-helicity" amplitudes is proportional to the fermion mass.

Let us summarize: Without spontaneous symmetry breaking in the standard model, there would be no Higgs boson, no longitudinal gauge bosons, and no extreme divergence difficulties. (Nor would there be a viable low-energy phenomenology of the weak interactions.) The most severe divergences are eliminated by the gauge structure of the couplings among gauge bosons and leptons. A lesser, but still potentially fatal, divergence arises because the electron has acquired mass—because of the Higgs mechanism. Spontaneous symmetry breaking provides its own cure by supplying a Higgs boson to remove the last divergence. A similar interplay and compensation must exist in any satisfactory theory.

The limited ability of the standard model to make definite predictions for the properties of the Higgs boson is well known. In the standard model, we expect a single, massive, spinless particle whose coupling to fermion-antifermion pairs is proportional to the fermion mass, but there is no definite prediction for the Higgs scalar's mass. Lower bounds on the Higgs mass can be derived by considering quantum corrections to the Higgs potential and requiring that the vacuum expectation value $<\phi>_0$ of the Higgs field be nonzero and that the Higgs potential $V(<\phi>_0)$ at that point be bounded from below. If $<\phi>_0$ is not an absolute minimum of the potential, it is reasonable to require that its false-vacuum lifetime exceed the age of the universe. The resulting bounds[2] require that $M_H \gtrsim \sqrt{1 - (m_t/79.5 \text{ GeV}/c^2)^4}$ or, for larger top-quark masses, that $M_H \gtrsim \frac{5}{3}(m_t - 95 \text{ GeV}/c^2)$. The CDF Collaboration's limit on the mass of the top quark, $m_t > 89 \text{ GeV}/c^2$, presented at this meeting by Rick Snider,[3] does not place a useful lower bound on the Higgs-boson mass.

Unitarity arguments lead to a conditional upper bound on the Higgs-boson mass.[4] It is straightforward to compute the s-wave amplitudes for scattering of the gauge-boson pairs $W_L^+W_L^-$, $Z_L^0Z_L^0$, HH, and HZ_L^0, where the subscript L denotes longitudinal gauge bosons, at high energies. All are proportional to $G_FM_H^2$ as $s \to \infty$. If we impose the minimal requirement of partial-wave unitarity that the magnitude of the s-wave amplitude be less than unity, an eigenchannel analysis leads to the constraint

$$M_H \lesssim \left(\frac{8\pi\sqrt{2}}{3G_F}\right)^{1/2} = 1 \text{ TeV}/c^2 \quad . \tag{4}$$

If this "upper bound" is exceeded, the weak interactions among gauge bosons become strong on the 1-TeV scale. The triviality of strongly coupled scalar field theory on the lattice leads by a different path to an estimate[5] $M_H \lesssim 600\ \mathrm{GeV}/c^2$.

Much effort has been devoted to searches for the standard-model Higgs boson in the fermion-antifermion, two-photon, and two-gauge-boson channels. A splendid survey of LEP searches in the process $e^+e^- \to HZ^*$, with the virtual Z tagged in lepton pairs, was presented by Ehud Duchovni.[6] The best current limit is

$$M_H > 48\ \mathrm{GeV}/c^2 \ . \tag{5}$$

If the Higgs boson is heavy ($M_H > 2M_W$), it will decay principally into pairs of gauge bosons. Strategies for detecting the "gold-plated" $ZZ \to \ell^+\ell^-\ell^+\ell^-$ signal in hadron supercolliders have been discussed in detail by Nigel Glover.[7] Giulia Pancheri[8] addressed the difficult region ($M_W \lesssim M_H \lesssim 2M_W$) in which rare decays seem the best bet for identifying a Higgs-boson peak. Although it will clearly be challenging to discover an intermediate-mass Higgs, we have reason to be optimistic about the prospects of high-luminosity pp colliders. The outstanding issues are the high resolution required to purify and reconstruct a $\gamma\gamma$ resonance and the fearsome interaction rates (10^8 – 10^9 Hz) a supercollider detector will have to survive. Finally, D. P. Roy[9] surveyed charged-Higgs-boson signatures and thereby reminded us that a single neutral Higgs scalar is but the simplest possibility.

4. STRONG INTERACTIONS AMONG GAUGE BOSONS[10]

We have seen that, in the standard model, the partial-wave amplitudes for gauge-boson scattering become large at high energies if the Higgs-boson mass is large. What might be the consequences of a strongly interacting gauge sector? How might we apply to this problem what Daniele Amati in his Moriond retrospective called the cultural capital of hadron physics? Can we give meaning to the mapping

$$\begin{array}{c} \pi \leftrightarrow W \\ \mathrm{GeV} \leftrightarrow \mathrm{TeV} \end{array} \quad ? \tag{6}$$

The beginning observation for all investigations is the low-energy behavior of the partial-wave amplitudes a_{ij} for gauge-boson scattering, which are determined by symmetry as

$$\begin{array}{ll} a_{00} \sim G_F s/8\pi\sqrt{2} & \text{attractive} \\ a_{11} \sim G_F s/48\pi\sqrt{2} & \text{attractive} \\ a_{20} \sim -G_F s/16\pi\sqrt{2} & \text{repulsive} \end{array} \quad . \tag{7}$$

Several approaches have been presented in talks at this meeting. Keiji Igi[11] showed us an N/D (elastic) unitarization of the low-energy amplitudes, an attempt to draw on the methods, as well as the intuition, of low-energy $\pi\pi$ scattering. His results give an example of a featureless amplitude that saturates unitarity. If you think about reasonable outcomes before doing a calculation, this is not the first possibility that comes to (my) mind. It seems to me more plausible, in light of the hadron spectrum, to anticipate a W^+W^- resonance as the means by which unitarity is preserved. How can we tell when a reasonable—but approximate and arbitrary—unitarization procedure gives us not just a possible answer, but the right one?

A second strategy is to construct explicit models of dynamical symmetry breaking, such as technicolor, and to solve these directly or by analogy with QCD. Kyungsik Kang[12] presented a variation on this theme in which the origin of electroweak symmetry breaking is the chiral phase transition in QCD with color-sextet or color-octet quarks.

The methods of chiral perturbation theory, or effective Lagrangians, which have enjoyed great recent popularity, were the topic of reports by R. Casalbuoni and Stefanie DeCurtis.[13] They emphasized the BESS (Breaking

Electroweak Symmetry Strongly) approach, in which one supposes that the essential feature is an I=1, J=1 resonance decaying into a pair of gauge bosons. The more general applications of chiral perturbation theory endeavor to learn from the effective Lagrangian for $\pi\pi$ scattering, or to capture the essence of the full standard model. The appeal of these methods derives from the successful application of chiral Lagrangians to $\pi\pi$ scattering and from the hope that symmetries might control gauge-boson dynamics at energies relevant to sorting out the nature of electroweak symmetry breaking.

Several problems arise in the application of chiral Lagrangians to gauge-boson scattering. First, the $O(s^2)$ effective Lagrangian necessarily produces featureless amplitudes and no longer makes sense in the interesting region around 1 TeV. Second, the results are highly sensitive to the unitarization procedure. This is clearly illustrated by the work of Dobado, Herrero, and Terron,[14] who compared K-matrix and Padé-approximant methods. For a Higgs-like model with $M_H \gg 1\ \mathrm{TeV}/c^2$, the Padé method may produce an s-wave resonance peak in the neighborhood of $1\ \mathrm{TeV}/c^2$, while the K-matrix yields featureless amplitudes. Finally, everyone who has ever worked on technicolor will understand the appeal of capturing the essence of the idea without being burdened by the details of a flawed explicit model. But without a complete theory, how can we impose constraints from other data, such as the restrictions on new degrees of freedom from LEP observables? Although I like the economy and generality of the effective-Lagrangian approach, I wonder whether it is not time to move on—but where?

The last issue I want to raise concerns the criteria we set for a strongly interacting gauge sector. Consider for definiteness the $(I,J) = (2,0)$ partial wave, to be observed in the exotic W^+W^+ channel. To estimate the yield of W^+W^+ events in a strongly interacting gauge sector, many authors have extrapolated the threshold behavior (7) set by low-energy theorems up to the energy at which unitarity (in the form of $|a_{20}| < 1/2$) is saturated. Such a theory, which corresponds to $M_H \to \infty$ in the Lagrangian, is surely strongly interacting; but so is its counterpart with M_H = 4, or 2, or even 1 TeV/c^2. (I consider a theory in which $|a_{00}|$ = 1, or 1/2, strongly interacting.) The a_{20} partial-wave amplitude in a strongly interacting theory—by my definition—may be considerably smaller than extrapolation of the low-energy theorem would suggest, and the yield of W^+W^+ events will be correspondingly smaller. A large value of $|a_{20}|$ is therefore not an infallible diagnostic of a strongly interacting theory: it is sufficient, but not necessary. We have to aspire to a comprehensive study of the (0,0), (1,1), and (2,0) partial waves.

5. QCD STUDIES AT THE Z^0

The LEP experiments have carried out extensive fits to event shapes and kinematical distributions on the Z^0 resonance. The observations are consistent with the predictions of QCD and lead to determinations of the strong coupling constant at the Z^0 mass that are consistent among the experiments and the different observables. The best values are summarized in Table 4. Comparing with earlier work, it is possible to believe that measured values of α_s run, but belief is not yet obligatory.

Table 4. LEP Measurements of the strong coupling constant.

Experiment	$\alpha_s(M_Z^2)$
ℵ[15]	0.117 ± 0.005
DELPHI[16]	0.106 ± 0.005
L3[17]	0.115 ± 0.004 (exp) ± 0.008 (theory)
OPAL[18]	0.120 ± 0.008

6. RUNNING TOWARD UNIFICATION

Why unify the gauge theories of the strong, weak, and electromagnetic interactions? We are motivated by the similarity of quarks and leptons as pointlike, Dirac particles, by the requirement of anomaly cancellation in the electroweak theory (which suggests a link between quarks and leptons), by the hope of understanding the equality of proton and positron charges, and by the running of the gauge couplings α_1, α_2, and α_3, which suggests that they might approach a common value at very high energy. The paradigm for unification is the SU(5) theory,[19] which breaks down according to $SU(5) \rightarrow SU(3)_c \otimes SU(2)_L \otimes U(1)_Y \rightarrow SU(3)_c \otimes U(1)_{em}$. Hermann Fürstenau[20] presented an analysis of the evolution of the coupling constants tied to the DELPHI determination of $\alpha_s(M_Z^2)$ that shows α_1 and α_2 crossing at 10^{13} GeV, but missing α_3 by many standard deviations. Going beyond the standard model by adding supersymmetric partners at around 1 TeV/c^2 changes the evolution so that all three coupling constants meet at around 10^{16} GeV. This has led some enthusiasts to announce that LEP has discovered supersymmetry!

Leaving aside the question of where the relevant knowledge of the coupling constants actually comes from, it strikes me that this is the sort of result that is really interesting only if it turns out to be true. Moreover, it is important to remember that nothing we know requires the $SU(3)_c$, $SU(2)_L$, and $U(1)_Y$ couplings to meet at a single point, even if the strong, weak, and electromagnetic interactions are unified without gravitation. I offer as a counterexample to the SU(5) paradigm the notion of petite unification advanced nearly a decade ago by Hung, Buras, and Bjorken.[21] In their scheme, electroweak unification is completed at an intermediate energy and the single electroweak coupling runs into the strong coupling at a higher energy.

7. HEAVY FLAVORS

New data were presented on the production and decay of charmed particles. Andrew Kirk[22] reported on the study of production dynamics and charm spectroscopy in the Ω-spectrometer experiment WA82 at CERN. Charm production is a difficult case for perturbative QCD, but the systematics of x-, $p_\perp$-, and energy-dependence are in reasonable agreement with experiment. Among the goals of WA82 are a study of the A-dependence of charm production, characterized by a power-law A^α, with $\alpha(D) = 0.88^{+0.04}_{-0.05}$ for charmed mesons produced with $\langle x \rangle = 0.24$, and an investigation of the leading-particle effect found in NA27. The theory of heavy-flavor production on complex targets was discussed by Kaidalov.[23] Laura Perasso showed lifetimes and branching ratios from E687 in the broadband photon beam at Fermilab.[24] Current data are comparable in statistics to E691 and NA32: a few thousand reconstructed events per decay mode for charmed mesons and about a hundred events per channel for the Λ_c. The 1990–1991 run is optimized (with an electron beam energy of 350 GeV) for the photoproduction of b-quarks, but will have a rich harvest of charms. I view the study of b-quarks in a photon beam as a long shot, because the high-energy cross section is expected to be quite small—perhaps a nanobarn at Fermilab energies[25] and no more than 75 nb at very high energies.[26]

New experimental results on b-quarks were presented in three talks to the conference. J. Gronberg[27] reported a new analysis of UA1 muon data. A Monte Carlo program based on the Nason-Dawson-Ellis calculation[28] accounts for the transverse-momentum distribution of muons and leads to an inclusive cross section of $\sigma(\bar{p}p \to b + X) = 12.8^{+7.0}_{-5.4}$ nb. A study of same-sign and opposite-sign dimuons yields a measure of the average mixing parameter, $\chi \equiv f_d\chi_d + f_s\chi_s$, of $\chi = 0.148 \pm 0.029 \pm 0.017$. A. Sansoni, representing the CDF Collaboration, showed for the first time evidence for B-$\overline{B}$ mixing from like-sign $e\mu$ events.[29] CDF's preliminary result is $\chi = 0.176 \pm 0.049$. A. Stocchi[30] reported the DELPHI measurement of the average b-quark lifetime, $\tau_b = 1.31 \pm 0.13 \pm 0.12$ ps, which leads to an estimate of the quark-mixing matrix element $V_{bc} \approx 0.041$. DELPHI has also been able to estimate the partial widths for Z^0 decays into heavy flavors, $\Gamma(Z \rightarrow c\bar{c}) = 282 \pm 53 \pm 88$ MeV and $\Gamma(Z \rightarrow b\bar{b}) = 350 \pm 41$ MeV, in agreement with standard model expectations.

8. STRUCTURE FUNCTIONS

Theoretical and experimental work continues on the problem of nucleon structure. Antje Brüll[31] presented the NMC Collaboration's measurements of the ratio $F_2^{\mu n}/F_2^{\mu p}$ in the range $0.002 < x < 0.8$ and $0.1\ \mathrm{GeV}^2 < Q^2 < 190\ \mathrm{GeV}^2$, which are important for determining the relative importance of valence up and down quarks in the proton. Ewa Rondio[32] reported the extraction of the gluon distribution from NMC data on the reaction $\mu N \rightarrow \psi X$.

Jan Kwiecinski[33] discussed the behavior of parton distributions in the limit of small values of x and large values of Q^2. At very small values of x, the normal QCD evolution of the gluon distribution $G(x,Q^2)$ and the sea-quark distribution $q_s(x,Q^2)$ causes a rapid growth with Q^2 of the parton density that can be computed using the methods of Gribov, Levin, and Ryskin.[34] If the density becomes so large that partons overlap within the proton, the impulse approximation that is the basis of the (renormalization-group-improved) parton model becomes nonsensical. Where—in x and Q^2—this effect sets in depends on the x-dependence of the input structure functions at low Q^2. It may be possible to look for the breakdown of the impulse approximation in ep collisions at HERA and in the production of $W^{\pm}$ and Z^0

at supercollider energies. The rapid growth in the sea-quark distribution at small x significantly enhances the cross sections for ultrahigh-energy νN interactions.[35] Because of the damping effect of the W-propagator, the range $x \lesssim 10^{-4}$ becomes extremely important for incident neutrino energies greater than about 10^{15} eV. Above this energy, the charged-current cross section may be boosted by more than an order of magnitude by the growth of the quark-antiquark sea.[36] It may be possible to measure these cross sections by instrumenting the ocean or the Antarctic ice.

9. HARD COLLISIONS / PERTURBATIVE QCD

The transverse-momentum distribution of gauge bosons produced in $\bar{p}p$ collisions has been the subject of very fruitful interplay between theory and experiment. J. Ng[37] showed the excellent agreement between the CDF measurements of the $p_\perp^W$-distribution and the beyond-leading-order calculation of Arnold and Kauffman.[38] The theory of gauge boson production was reviewed by Erwin Mirkes,[39] who emphasized the possibility of seeing the influence of higher-order contributions upon the $W^\pm$ polarization—hence the decay angular distribution. The UA2 analysis of W + jets was presented by Elisabetta Pennacchio.[40]

The data on direct photon production in hadron collisions from UA2,[41] CDF,[42] E706,[43] E705,[44] and UA6[45] are in good general agreement with the theory,[46,47] but the role of isolation cuts in defining the measured cross section needs continued careful attention, to ensure that theory and experiment are referring to the same quantity. P. Perez[48] reported the ℵ studies of prompt photons at LEP.

"What is a jet?" is a question that can—and must be—asked with increasing precision, if we are to take best advantage of advances in higher-order calculations and improved experimental sensitivity. Dave Soper[49] presented the perturbative-QCD answer, while Naor Wainer[42] reported CDF's jet-shape studies and the dependence of $d\sigma/dE_T$ on jet definition. The measured cross section is in excellent agreement with QCD over nearly four decades. Patrizia Cenci[50] discussed the analysis-in-progress of UA2's 1990 jet sample and reviewed their current limit on quark compositeness, $\Lambda^* > 825$ GeV.

10. PARTICLE PRODUCTION

We heard many talks on particle production in hadron collisions and in electron-positron annihilations. I was particularly struck during Brigitte Buschbeck's talk on intermittency[51] and Wolfram Kittel's review of particle production[52] by the continuing need to devise *differential* diagnostics of the production dynamics. In trying to make sense of multiplicity distributions and multiparticle correlation functions or rapidity-interval distributions, there is always a tension between the desire for a statistically sound result—which favors global, integrated quantities—and the hope for discrimination among competing dynamical ideas—which favors the most differential observables. It is important that we not neglect the lessons of the seventies, when it was found that two-particle correlations measured between particles of known charge could begin to distinguish among the many dynamical schemes that could reproduce topological cross sections. I am pleased to see critical examination of the methods used for the study of intermittency, so we can learn how best to unravel the dynamics of both commonplace and unusual events.

11. CONCLUDING REMARKS

At this twenty-fifth anniversary meeting, the traditions of Moriond have been much on the minds of all of us. With some embarrassment, I close my summary talk without reviewing all the contributions of this

Rencontre. It is small comfort to know that I am following a well-established Moriond tradition that finds the haggard summary speaker in his room in a state of considerable panic, surrounded by photocopies of talks and little piles of incomplete transparencies, instead of attending the last sessions.

In thinking of what participation in Moriond conferences has meant to me over the years, I find myself returning to the notion of *une embellie.* The literal meaning is the calm after a storm, or between two storms, or what I think the English call a bright interval. Poetically, *l'embellie* evokes a moment of rest and repose away from workaday cares, a time for reflection and appreciation and metamorphosis. With its emphasis on lively participation, opportunity to spend a week with colleagues in informal settings, and focus on the excitement of trying to understand Nature, Moriond gives us all a moment to learn, to savor, to reflect. To the founders and their successors, I offer the heartfelt thanks of participants past, present, and future.

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