

Strange, Charm and Beauty Hadrons: concluding remarks

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1. INTRODUCTION

It is not that easy to summarize over 75 papers presented at this Conference, most of which very interesting and full of good new data. It is easy however to define my job as "Mission Impossible". Nonetheless, it is challenging to pin out the ideas and the results that might influence the future development of the field.

Actually, it comes to my mind a very old Conference that took place in Pisa in 1955, to celebrate the first 100 years of the journal "Il Nuovo Cimento" [at the time one of the most prestigious international journals in Physics]. There was a young theorist by the name of Murray Gell-Mann [1] who presented a talk by the title: *The Interpretation of the New Particles as Displaced Charge Multiplets*. To make it clear, it was the paper where Gell-Mann introduced the formula $\frac{Q}{e} = I_z + \frac{n}{2}$, with I_z the isospin third component, Q the charge operator, e the electron charge, n the baryon number prior to the introduction of the strangeness s . He emphasizes the fact that all particles can be "grouped" into: (A)- the heavy particles or "baryons", including protons and neutrons and all known "hyperons": all fermions that obey an overall conservation law [of their baryon number]; (B)- the light fermions or "leptons", including the muon, the electron and the neutrino [the author comments....*if K particles exist that are fermions, they presumably belong in this category*]; (C) the "mesons"; (D)- the photon.

Turning to the type of interactions, Gell-Mann underlines their natural classification into three types: (i)- the *strong interactions* confined to baryons, antibaryons and mesons; (ii)- the *electromagnetic interactions* through which the photon is linked to all charged particles, real or vir-

tual; (iii)- the *weak interactions* responsible for β decay, the slow decays of the hyperons etc. In continuing along the paper he speaks of "*slow, electromagnetic and rapid*" interactions. Neat and clear simplification of all our knowledge on elementary particles.

Compared to that situation, our present understanding doesn't change that much as far as the interactions are concerned: the *em* interactions are always there: quite "understandable" and understood; they have been unified to the weak interactions and that is good. The strong interactions are "brand new" in character as they are interaction among quarks and gluons.

We reinterpreted the "meaning" of the basic interactions but there are always three of them, reduced to two by the electroweak unification.

Where the scenario has completely changed is on the front of the particles: now we know [or we believe we know] we have six leptons and six quarks, plus the gluons that have to take the quarks stuck together. And that is it.

However the real life is much much more difficult than it was some 45 years ago. We have the Standard Model: it *might* not be right, but it is certainly very, very well set up; there are some 18-25 arbitrary parameters which make it somewhat uncomfortable, but it seems extremely hard to falsify it. It seems to work so well that it looks almost incredible. Why the electron, the muon, the proton have the mass they have? Why the mixing angles are what they are? Furthermore: why the *negative* quark of the lightest family is heavier than the *positive* one while it is the opposite for the heavy families? Simple and naive questions that have no answer yet, but that make life very exciting. We have Quantum Chromo Dynamics: QCD, as the *theory* of strong inter-

actions. It seems to work where there are no data but it is hard to make it work where data is plenty. However it is the only one we have to live with.

In this Conference we deal with 3 out of the 6 quarks: strange, charm and beauty [top is too heavy and the data are still very limited; u and d are *light* by all means]. The s quark -thanks in part to Mr. Gell-Mann- has been known for over half a Century now, but still a lot of activity is in progress and yet the question of CP violation is not solved; the c quark is now known since about a quarter of a Century and the results, though rather satisfactory for the meson sector is still lacking a lot of information in the baryon sector; the hierarchy of the charm baryon lifetimes has been settled no more than 5 years ago, but only very roughly; the b quark is in its flourishing season but the data on the b-baryons is still very scanty. It is not far from the truth the statement that well over one thousand physicists and students are working full time to disentangle a rather complicated and exciting scenario.

2. STRANGENESS

Although the title of the Conference refers to "hyperons" and not to strange mesons, very interesting material is expected to come also from its strange sector. The decay properties of the neutral kaons are not yet completely understood. The issue of CP violation is not yet completely settled. To tackle the CP issue, at Frascati a specific collider has been built -DAΦNE- and a specific experiment -KLOE- is rapidly reaching the stage of data collection. At Fermilab, kTeV[2] has already started the accumulation of very interesting data. The two experiments are well complementary, one running at low energy and consisting in a typical collider setup, the other being a fully dedicated high energy fixed target setup taking advantage of the $\beta\gamma$ at the Fermilab Tevatron. To see the CP non conservation problem solved we shall have to wait probably at least till the next Conference of this series. The data already existing have rather small errors, both systematic and statistics, but the effects are so tiny that the compatibility with zero is not yet ruled out.

In addition to these experiments, CPLEAR [3]

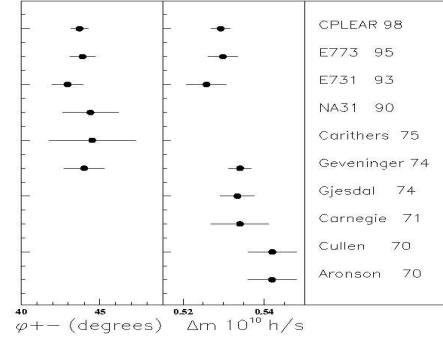


Figure 1. Values of ϕ_{+-} and Δm measured by CPLEAR compared to previous experiments.

presented to this Conference a "smart" identification of K^0 states at production by identifying the charged companion in the low energy annihilation channels $p\bar{p} \rightarrow K^+\pi^-\bar{K}^0$ or $\bar{p}p \rightarrow K^-\pi^+K^0$ to measure ϕ_{+-} and the Δm term of the mass matrix element. They provided also a direct measurement of the T violating component.

The measured values: $\phi_{+-} = (43.63 \pm 0.59)^\circ$ and $\Delta m = (529.5 \pm 2.0) \times 10^7 h s^{-1}$ are compared to previous results in fig.1: they show errors equal if not smaller than those of the world averages[4]. To underline the intrinsic difficulty of the measurements, it is worth to notice that, in about a quarter of a Century, the absolute value of the overall errors have improved by no more than a factor 2.5 for $\sigma(\phi_{+-})$ and a factor 2.0 for $\sigma(\Delta m)$.

The direct measurement of the time reversal violating amplitude $A_{T,t}$ for $t \gg \tau_s$ [where t is the decay time and τ_s the mean lifetime of the K_s^0] provided to the Conference by CPLEAR is also interesting and new. The experiment finds:

$$\begin{aligned} A(T, t \gg \tau_s) &= (8.0 \pm 1.7_{stat} \pm 1.0_{syst}) \times 10^{-3}; \\ Im(x_+) &= (-3.9 \pm 3.3_{stat} \pm 1.0_{syst}) \times 10^{-3}; \\ Re(x_-) &= (-1.2 \pm 0.7_{stat} \pm 0.1_{syst}) \times 10^{-2}. \end{aligned}$$

Assuming CPT conservation in semileptonic decays, CPLEAR obtains $A(T, t \gg \tau_s) = (7.2 \pm 1.5_{stat} \pm 1.0_{syst}) \times 10^{-3}$.

2.1. Hyperons

The experiment kTeV[5,6] provided hints on the capabilities of the experiment in the hyperon sector, by showing the first evidence for several previously undetected semileptonic decays of the

Ξ^0 and radiative decays of the Σ^0 . They find first evidence of 1200 events for $\Xi^0 \rightarrow \Sigma^+ e^- \bar{\nu}_e$, giving the branching fraction: $B.F. = (2.49 \pm 0.19 \pm 0.25)$; 60 events of the decay $\Xi^0 \rightarrow \Sigma^+ e^+ \nu_e$ and 10 events of the decay $\Xi^0 \rightarrow \Sigma^+ \mu^- \bar{\nu}_\mu$; the first 20 events of the radiative decays $\Xi^0 \rightarrow \Lambda^0 \pi^0 \gamma$ and $\Sigma^0 \rightarrow \Lambda^0 e^+ e^-$. The experiment is very promising in this field and it will provide samples of about 7000 $\Xi^0 \rightarrow \Sigma^0 \gamma$, about 1000 $\Xi^0 \rightarrow \Lambda^0 \gamma$ and about 7000 $\Lambda^0 \rightarrow p \pi^- \gamma$.

P. Ratcliffe [7] discussed in some details the role of SU(3) breaking in hyperons decay and P. Zenczykowski [8] presented an analysis of weak radiative decays of Λ^0 and Σ^\pm in connection with a detailed vector dominance model: both theoretical speculations will be soon confronted by the excellent experimental data.

2.2. Quark confinement and the s quark

Before moving to heavy quarks, it is worth mentioning, a somewhat related but general issue that very recently was brought to the attention of the scientific community: F.Close et al. [9] discussed the role played by the scalar mesons $f_0(980)$ and $a_0(990)$ in understanding the confinement of the strange quark. The question of what is the real mechanism responsible for the confinement of the different flavoured quarks into the real observed particles has not been deeply investigated neither experimentally nor theoretically. The paper by Close et al. calls into the game the role of glueballs and scalar mesons. At this conference, for instance, P.Blüm [10]b reported several very high statistic Dalitz plot analyses of the Crystal Ball experiment. The main target is to detect the contribution of the $f_0(1500)$ to the two channels $p\bar{p} \rightarrow 3\pi^0 \rightarrow 6\gamma$ (with a statistics of 712 kevents) and $p\bar{p} \rightarrow 2\eta^0 \pi^0 \rightarrow 6\gamma$ (with a statistics of 198 kevents). The data in fig.s 2 and 3 of ref. [10]a show how many scalar mesons contribute to the two channels, in particular in the second reaction where the $s\bar{s}$ state η is involved¹. The experimental observations in favour of the speculation by Close et al. come from two sources: one pertaining the field of the light quarks (i.e. the production of scalar mesons), one pertaining the

¹It has been impossible to reproduce in this paper those figures, and I apologize for that.

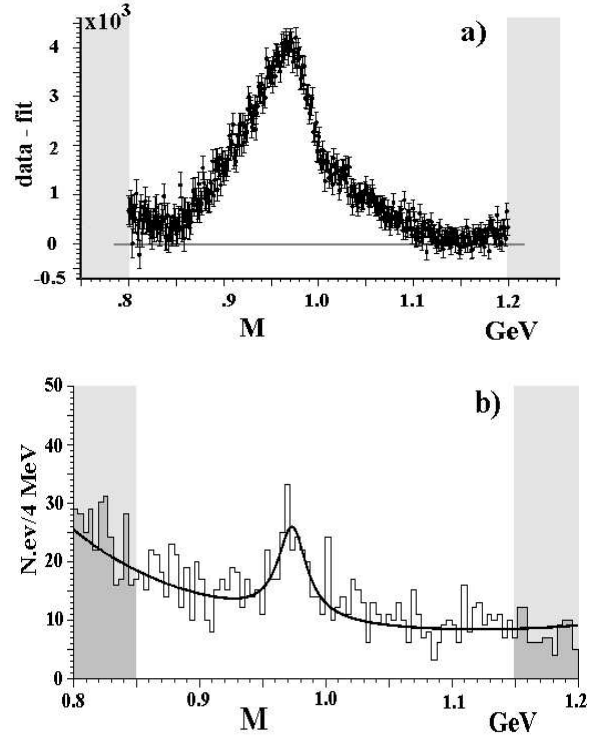


Figure 2. a- Residuals (data-fit) for $M_{2\pi}$ if the $f_0(980)$ amplitude is set to zero; b- E687 $M(2\pi)$ spectrum (4 MeV bin) associated to a $\phi(1020)$, fitted by Breit-Wigner plus background (3 parameters).

decay of D_s mesons into scalar mesons.

Here I wish to mention the recent observation by E687[11] of the photoproduction of the $f_0(980)$ scalar meson. Based on $\sim 1.4 \times 10^8$ triggers $\gamma N \rightarrow n_{ch} \pi + X$, with $n_{ch} = 2, 3, 4, 5, 6$, the $\pi^+ \pi^-$ mass plot for $\sim 3.3 \times 10^5$ events with $(0.8 < M(\pi^+ \pi^-) < 1.2)$ GeV shows evidence of a relevant signal below 1.0 GeV (about 1% of the events). The residuals of a fit to a continuous non resonant background plus a tail of the $\rho(770)$, shown in fig. 2a, leaves an excess of over 4×10^5 events above a non trivial background, hard to be accounted for without invoking a narrow $f_0(980)$. The fitted parameters in the mass range 0.85 – 1.15 GeV are: $m_{f_0(980)} = 968 \pm 0.5$ MeV and $\Gamma_{f_0(980)} = 50.0 \pm 2.4$ MeV. Furthermore, based on 100,510 events in the channel $K^+ K^- \pi^+ \pi^-$, (with the 2 "kaon" tracks having the mass of the ϕ) E687 searched for $f_0(980)$

$\phi(1020)$ photoproduction, finding (see fig.2b) a $\sim 3\sigma$ signal of (167 ± 47) events over background, a $\chi^2 = 73.45$ for 68 d.o.f., $m_{f_0(980)} = 973 \pm 2.5$ MeV, $\Gamma_{f_0(980)} = 28 \pm 10$ MeV (fit shown in fig. 2b). This is the first observation of quasi-exclusive $\phi(1020)f_0(980)$ associated photoproduction.

These data support the speculation by F. E. Close et al.[9] (in Section 4.2, further support to this idea comes from the Dalitz plot analysis for the D^+ and D_s^+ decays[12]).

3. HEAVY QUARK PRODUCTION

The production of light quarks seems to be well described by Montecarlo predictions of Models based on Quantum Chromo Dynamics. The situation seems to be not so satisfactory for charm and beauty quarks. The impression is that light quarks come at the very end of a multiplicative cascade process in which quarks emits gluons and/or gluons annihilate into a quark-antiquark pair followed by their hadronization into detectable hadrons.

The models based upon perturbative QCD exploited at *leading order* (hereafter LO) or *next to leading order* (hereafter NLO) seem to be sufficient to describe the general features of the total cross sections and the inclusive distributions[14]. The LUND model(s) -see e.g. ref.[14]- contains LO plus approximate NLO corrections to the description of the parton shower plus a *string fragmentation model*. HERWIG makes similar assumption *but* uses a *cluster fragmentation model*, in which clusters of undefined masses (i.e. not corresponding to resonant states) are allowed during the fragmentation process. Essentially the *primordial* $q\bar{q}$ states can be produced under different initial boundary conditions depending on whether the quark production is initiated by e^+e^- , γ -hadron or hadron-hadron states, say at the level of some ~ 18 cm. The subsequent production process then is exactly the same and undergoes identical steps for any high energy collision *but* the *initial* boundary process. In e^+e^- collisions a virtual photon is created and then converted, by vector dominance or by photon-gluon fusion, into $q\bar{q}$ pairs; in photoproduction the initial photon is real; in hadroproduction

also the projectile quarks are bound in a hadron state. After this "primordial" step that might be different for the different projectiles, the processes become identical: the two charge conjugate quarks give rise to a multiplicative cascade process which include gluon irradiation by a quark and gluon splitting into $q\bar{q}$ pairs (for instance, the $g \rightarrow b\bar{b}$ and $g \rightarrow c\bar{c}$ splittings have been discussed in the particular case of the Z^0 resonance, by T. Boccali [13]), at a level of 10^{-16} cm. After that, at a level, say, of about 10^{-15} cm, the "non-perturbative" QCD process of hadronization takes place in which quarks and gluons get together to form *colorless* hadrons. Finally, at distances (much) larger than 10^{-15} cm, all the *old physics* for strong resonance decays and weak decays of unstable particles are simulated to reproduce a final *zoo* of π 's, e's, γ 's, μ 's, k's, hyperons and nucleons. The study of $\pi\pi$, kk correlations

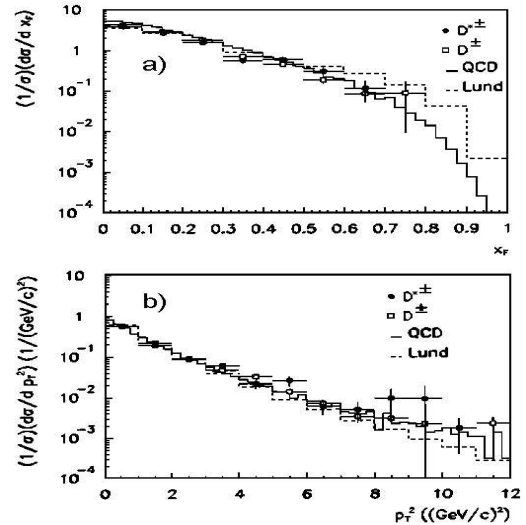


Figure 3. WA92. Comparison to QCD Models of: a- x_F distributions for D^* and D^\pm ; b- p_T^2 distributions for the same particles. [16]).

has been done some decades back in the past and have suggested the *tuning* of the models outlined above. Now the investigation of $c\bar{c}$ and $b\bar{b}$ correlations are an attempt to provide a picture of the primordial gluon splitting during the parton shower process (and not only at the initial state as done i.e. in the historical J/Ψ production in

Table 1
Comparison of the asymmetry parameter A for 3 experiments

	$\sigma(D^{*-})/\sigma(D^{*+})$	$\sigma(D^-)/\sigma(D^+)$
WA82 Cu, W, Si 340 GeV/c π^-	1.8 ± 0.3	1.34 ± 0.13
E769 Be, Al, Cu, W 250 GeV/c π^-	1.20 ± 0.14	1.44 ± 0.18
WA92 Cu, W 350 GeV/c π^-	1.35 ± 0.14	1.34 ± 0.06

e^+e^- at 3.05 GeV). These correlation studies provide unique information on the dynamics of the splitting process necessary for a decent formulation of a *non perturbative* QCD.

Marginal *inclusive* distributions -such as rapidity, Feynmann-x or p_t^2 - seem to be well reproduced by the LUND Model. However, the situation becomes unclear, mostly for the production of charm particles, when the experimental investigation comes to correlations. From a theoretical standpoint, the only reasonable calculations can be based on *perturbative* QCD, calculations that require high mass -if not infinite mass- of the produced quarks. From the experimental standpoint, data are indeed very scanty on the production mechanism of the top quark, where non perturbative QCD is supposed to be well valid, while the comparison of charm data on $c\bar{c}$ correlations to the Montecarlo models doesn't look at all satisfactory[14].

3.1. c quark production

Recently several *specific* models have been proposed to explain the observed $c\bar{c}$ production asymmetries[15] that include ideas like the initial or final state gluon bremsstrahlung or the *dragging* effect of the quark (antiquark) contained into the projectile or the target, or a *primordial* coalescence of the initial state due to fluctuations (an initial pion state might fluctuate into a 4 particle Fock state leading to a $D\bar{D}$ pair or an initial proton might degenerate into a 5 particle Fock state, leading to either a $\Sigma_c^{++}D^-$ or a $\Lambda_c^+D^0$ and the data are often compared to them [14].

At this Conference several new data were pre-

sented on charm production. WA92 presented[16] (see fig.3a,b) a comparison of marginal distributions (in x_F and p_t^2) for the hadroproduction of D^* 's, where the comparison with perturbative QCD and LUND predictions are adequate (however here the curves are *normalized* to the data). The same experiment finds that the behaviour of the asymmetry parameter $A = (N_{lead} - N_{non-lead})/(N_{lead} + N_{non-lead})$ vs. x_F for both D^* 's and D 's produced by 350 GeV/c π^- is not in disagreement with the predictions of the LUND Model. The average values of the asymmetry parameters of three experiments are compared in TABLE 1. The *leading* D^* asymmetry is larger than the D asymmetry, an intuitively understandable effect that may be diluted by the D^* decay process.

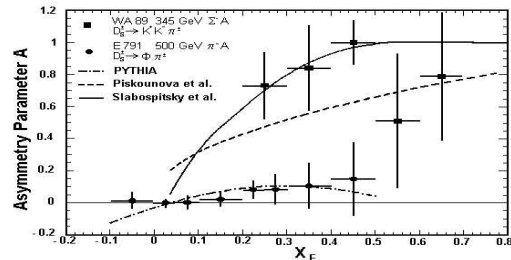


Figure 4. WA89. Comparison to QCD Models of the x_F distribution for D_s . For explanation of the curves see ref. [17]).

Contrary to that, WA89[17] discussed the parameter $A = (N_{lead} - N_{non-lead})/(N_{lead} + N_{non-lead})$ vs. x_F for D_s produced by 340 GeV/c Σ^- particles of 350 GeV/c, by comparing also the data of E791 to QCD. The perturbative QCD predictions have to be substantially modified. The data are shown in fig.4 and the curves are discussed in ref. [17] and [14].

Finally, CLEO[18] presented the first Ξ_c^+ x_F distribution for e^+e^- production -well reproduced by a NLO QCD model (see fig. 5)- as well as an interesting comparison of the x_p fragmentation functions for $L = 0$ and $L = 1$ baryons that seem to be different[18], the $L = 1$ charm baryons being more peaked towards larger values of x_p .

From this scenario the physics of charm production is providing more and more experimental information. As seen before, to recover a decent

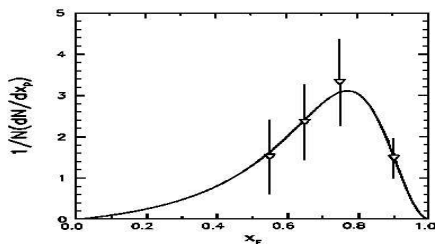


Figure 5. x_F distribution for Ξ_c^+ 's in CLEO.

accord with the $c\bar{c}$ data on asymmetry and correlations, ad hoc modifications are necessary in the standard QCD modeling: in hadroproduction it is the assumption of uncomfortable values of the charm mass or the average primordial p_t kick, in photoproduction it is a specific *hard* momentum partition function between the quarks that is needed. Definitely the non-perturbative part of the QCD modeling needs improvements.

3.2. b Quark Production

About the same situation is encountered in the comparison of QCD calculations to the b quark experimental data. In spite of the higher mass of the b quark, substantial kinematical corrections are due to NLO QCD calculations.

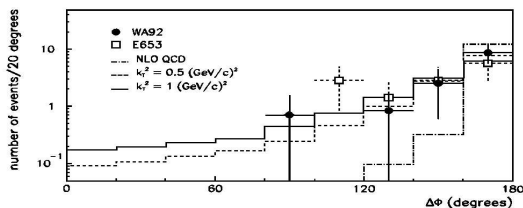


Figure 6. $b\bar{b}$ azimuthal correlation $\Delta\phi$ (see ref. [19] for details on the histograms).

WA92[19] presented the total production cross section of b quarks $\sigma(\pi^-Cu)$ at $350 \text{ GeV}/c^2$ as well as the $b\bar{b}$ azimuthal angular correlation. The total b production cross section is in agreement with a smooth logarithmic increase with incoming momentum but somewhat critically dependent upon the b mass. Theoretical uncertainties included, the data are consistent with any value of the b mass in the range $4.5 < m_b < 5.0$ (the higher the mass, the smaller the cross section).

The opening angle between the $B\bar{B}$ pairs $\Delta\phi$ is compared in fig.6 to NLO QCD calculations.

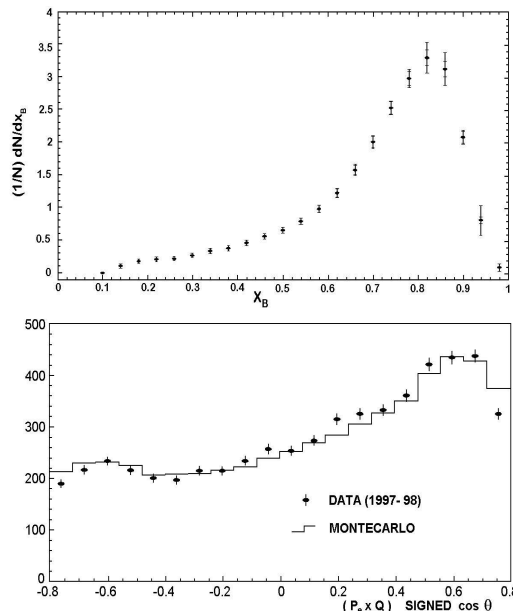


Figure 7. a- x_B distribution at SLD; b- distribution of the angle with the thrust axis for fwd-bwd asymmetry (see ref. [20] for details on the histogram).

NLO QCD again predicts too much back-to-back $b\bar{b}$ correlation. Also in this case a simple calculation is insufficient and a p_t kick of $\sim 1.0 \text{ GeV}^2$ works better in reproducing the data. Finally, SLD presented[20] a preliminary x_F distribution (fig. 7a) as well as the distribution of the θ angle that the B meson makes with the thrust axis of the collision (fig. 7b).

In summary, the first kinematical distributions for the production of b quarks are becoming available with good statistics and the models can be efficiently challenged. The p_t kick and the asymmetry diseases are common to both c and b quarks. The *non perturbative* part of the QCD simulations should improve. There is a general consensus that string fragmentation and cluster fragmentation are not very different at high energies, however the *non perturbative* fragmentation mechanism should be better investigated and understood. The parton shower is a multiplicative process and has automatically scaling properties that are not introduced into the modeling; the gaussian fluctuations used in Montmodelecarlos do *not* scale; intermittency [21] is a known phenomenon; several multifractal properties of multiparticle production have been detected[22] and

the multiple scaling of the probability distributions proven. P.Hoyer[23] has discussed the role that rescattering could play in this respect and specially in calculating $\sigma(\text{quarkonium})$.

4. CHARM

Moving to the decay of (hidden or open) charm particles, several nice preliminary results have been presented. Charm is the best laboratory to test non perturbative QCD effects since, on one side the mass is not that heavy, on the other side, data is reaching impressive statistics so that theories will be challenged severely by the very accurate results of the near future. The major contribution are related to: a- charmonium; b- charm mesons and c- charm baryons.

4.1. Charmonium

Charmonium Spectroscopy is a wealthy and flourishing field. New data have been presented on the two states $\eta'(2^1S_0)$ and $\chi_2(1^3P_2)$. E835[25] presented an upper limit $\text{BR}(\eta' \rightarrow p\bar{p})\text{BR}(\eta' \rightarrow \gamma\gamma) < 9 \times 10^{-8}$ at 95% c.l.

The $\gamma\gamma$ radiative decays widths of the χ_{c2} are still an issue. The data of several experiments, compared by B. de la Cruz[24] and summarized in Table 2, still show serious discrepancies. $\Gamma_{\gamma\gamma}(\eta_c)$ seem to converge to values $\sim 6 - 9$ keV.

L3[24] provided several new measurements of the η_c radiative widths such as:

$\Gamma_{\gamma\gamma}(\chi_{c2}) = .99_{-.37}^{+.43}(\text{stat}) \pm .36(\text{syst})$ keV (a value confirmed by preliminary results of E835);

$\Gamma_{\gamma\gamma}(\eta_c) = 9.5_{-1.9}^{+2.1}(\text{stat} + \text{sys}) \pm 2.7(\text{BR}_{J/\psi})$ keV, while the preliminary value of E835: $\Gamma_{\gamma\gamma}(\eta_c) = 3.7_{-1.3}^{+3.9}(\text{stat} + \text{sys}) \pm 1.2$ keV, is low[25] compared to that measured by L3.

The complexity of the charmonium spec-

Table 2
Radiative decay widths of the χ_{c2} .

Experim.	Prod. Mech.	$\Gamma(\chi_{c2})$ (keV)
R704	$p\bar{p} \rightarrow \gamma\gamma$	$2.9_{-1.0}^{+1.3} \pm 1.7$
E760	$p\bar{p} \rightarrow \gamma\gamma$	$.3 \pm .08 \pm .05$
TPC/2 γ	$\gamma\gamma \rightarrow \gamma J/\psi$	$3.4 \pm 1.7 \pm 0.9$
CLEO	$\gamma\gamma \rightarrow \gamma J/\psi$	$1.08 \pm .30 \pm .26$
PDG96		$.37 \pm .17$
L3	$\gamma\gamma \rightarrow \gamma J/\psi$	$.9_{-.37}^{+.43} \pm .36$
OPAL(pr.)	$\gamma\gamma \rightarrow \gamma J/\psi$	$1.76 \pm .47 \pm .27 \pm .15$

troscopy requires a hard experimentation that is being carried out by the current experiments.

4.2. Charm mesons

The major new results presented here in the charm sector are concentrated on charm baryons, however this is to be expected. Most of what we already know on charm comes from the study of charm mesons.

Each of the running experiments, particularly CLEO III and FOCUS-E831, are likely to provide soon more than one million fully reconstructed charm events. The laboratory *to chal-*

Table 3
Decay fractions for the D mesons: a- D_s^+ ; b- D^+ .

a)	$D_s^+ \rightarrow \pi^+\pi^+\pi^-$	
Decay mode	Decay fraction	Phase (degree)
<i>NR</i>	$0.121 \pm .115 \pm .044$	$235 \pm 22 \pm 2$
$\rho(770)\pi$	$0.023 \pm .027 \pm .011$	$53 \pm 44 \pm 10$
$f_2(1270)\pi$	$0.123 \pm .056 \pm .018$	$100 \pm 18 \pm 6$
$f_0(980)\pi$	$1.074 \pm .140 \pm .043$	0(fixed)
$S(1475)\pi$	$0.274 \pm .114 \pm .019$	$234 \pm 15 \pm 4$
b)	$D^+ \rightarrow \pi^+\pi^+\pi^-$	
Decay mode	Decay fraction	Phase (degree)
<i>NR</i>	$0.589 \pm .105 \pm .081$	0(fixed)
$\rho(770)\pi$	$0.289 \pm .055 \pm .058$	$27 \pm 14 \pm 11$
$f_2(1270)\pi$	$0.052 \pm .034 \pm .035$	$207 \pm 17 \pm 4$
$f_0(980)\pi$	$0.027 \pm .031 \pm .038$	$197 \pm 28 \pm 24$

lenge non perturbative QCD will provide very impressive data. There are always decay channels to be investigated, in particular the fully leptonic decays; there are always dynamical mechanisms to be studied, in particular the relative role played by the annihilation and the exchange diagrams; there is still the lifetime of the D_s not adequately measured. Nonetheless we know a lot more on charm mesons than on charm baryons. To this Conference E831[12] presented a preliminary new analysis of the Dalitz plots for the decays $D^+, D_s^+ \rightarrow \pi^+\pi^-\pi^+$ confirming the recently published data by E687[12]b. The results of the multi-amplitude analysis are summarized in Table 3. It can be clearly seen that the D_s^+ is dominated by the decay channel $D_s^+ \rightarrow f_0(980)\pi$ while

the D^+ is dominated by the $\rho(770)\pi$ channel. This also supports the idea of F. Close et al.[9] that the $f_0(980)$ be associated to the strangeness content of the physical state involved. Due to the limited space allotted to this report, the reader can refer to contributions by D. Pedrini[12]a and B. O'Reilly[12]c for the impressive evidence of charm mesons presented by E831.

4.3. Charm baryons

On charm particles, the issue of the lifetimes is still open. A new measurement of $\tau_{\Xi_c^+} = 0.34^{+0.07}_{-0.05} \pm .02$ ps at the Ξ_c^+ mass $m = 2465.8 \pm 1.9 \pm 2.5$ MeV has been presented here by E687 [26]b. For sake of brevity, the lifetimes of all charm particles measured by E687[12]a are compared to the PDG values[4] in fig. 8.

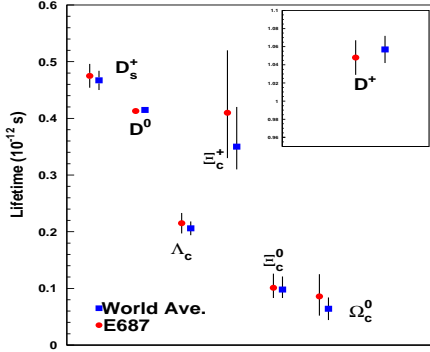


Figure 8. Charm particle lifetimes compared to the PDG values.

The meson's lifetimes are well measured at the level of $\sim 1\%$ for both statistical and systematic errors. Only τ_{D^+} has a 3.6% error and has to be improved in view of remeasuring the ratio $\tau(D_s^+)/\tau(D^0) = 1.15 \pm .05$ which is still compatible with 1.0 within 3σ and is important in order to estimate the importance of the exchange decay diagram relative to the annihilation diagram. For the charm baryons, only $\tau_{\Lambda_c^+}$ has been measured so far with an error below 10%, the are values are *estimates* rather than *measurements*, but the issue will be settled soon by E831.

To this Conference E687[26] presented new evidence for (47 ± 11) events of the excited state $\Xi_c^{*+} \rightarrow \Xi_c^0 \pi^+$ with two different decay channels of the Ξ_c^0 : i.e.: $\Xi_c^0 \rightarrow \Lambda_c^0 \bar{K}_s^0 \pi^+ \pi^- \pi^- \pi^+$ and

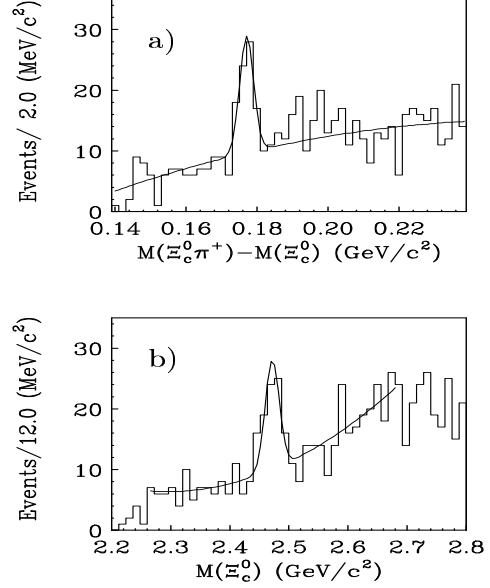


Figure 9. Evidence for a Ξ_c^{*+} excited state by E687. The shaded histograms refer to the "wrong" sign combinations.

$\Xi_c^0 \rightarrow \lambda^0 \bar{K}_s^0 \pi^+ \pi^-$ (see fig.9). The measured mass difference is $\Delta(M_{X_i^*} - M_{\Xi_c^0}) = 0.177 \pm .5 \pm 1.1$ MeV and the Ξ_c^0 mass is $m = 2470.0 \pm 2.8 \pm 2.6$ MeV. Our knowledge on charm baryons needs significant improvements in the near future and they will come from CLEO III and FOCUS-E831. As an indicator of the potential quality of E831 data[12]c, fig. 10 shows signals of the Σ_c baryons on 15% of the statistics. In the experiment not only the statistics has been increased by over a factor 10 compared to E687 but also the signal to noise ratio has been considerably improved.

I finally wish to conclude this subsection by making two general comments:

1- taking advantage of the presentation by CHORUS[27], I find it kind of nice, here, to suggest an *unorthodox* investigation to that experiment: being still a *new generation* emulsion experiment it might be worth searching for the possible *charm fragments*. In the old days, hyperfragments -nuclear objects in which a neutron is replaced by a Λ hyperon- were searched for. Today it cannot be excluded that a *proton* be replaced by a Λ_c^+ in a nucleus. Thus, instead of the *old style* ${}_{\Lambda}He^4$ hyperfragment, a state (p, p, Λ, n) , CHORUS might observe a ${}_{\Lambda_c}He^4$ *charm fragment* where a *proton* is replaced by a Λ_c^+ in a state

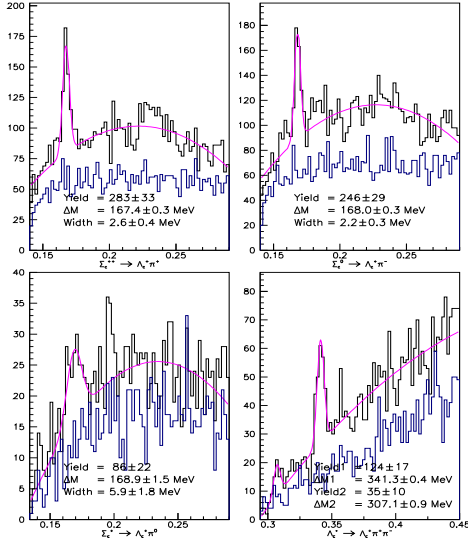


Figure 10. Charm baryon signals in E831-FOCUS with 15% of the statistics (shaded histograms are *wrong sign* combinations).

(Λ_c^+, p, n, n). The lifetime of the ΛH^3 hyperfragment[28] ($\tau = (0.70^{+.19}_{-.13})10^{-10}$ s) is of the same order of τ_{Λ^0} [4]. Similarly -should the sticking probability of the Λ_c^+ in a nucleus be not negligible- the charm fragment lifetime would be of the same order of the charm baryon lifetimes.

2- E687 gave definite evidence[29] for the existence of the *primordial neutron*, a neutral (css) state which contains no ordinary quarks. It is a challenge to FOCUS-E831 and SELEX to find the *primordial proton* i.e. the *double charm baryon* positive state (ccs) which also doesn't contain any of the natural quarks. J.M.Richard[30] predicts for Ω_{cc}^+ a mass of 3.4 – 3.8 GeV, a possible decay being: $\Omega_{cc}^+ \rightarrow \Xi^0 D^+$, a final state not easy to detect experimentally. But, just for this reason, a very attractive possibility.

5. BEAUTY

For the summary of the b sector, I can take advantage of the beautiful review delivered by Jacques Boucrot[31] who summarized something between 25 to 40 contributions on the very important issue of $B^0 - \bar{B}^0$ mixing. For sake of completeness I might only recall his final conclusions: Δm_d has been measured to about 4% at the value $\Delta m_d = 0.416 \pm .018 ps^{-1}$ and Δm_s

not yet measured but likely to be provided in a couple of years. At the moment only a lower limit has been set to $\Delta m_s > 10.2 ps^{-1}$ with 95% confidence level. The present situation seems to foresee the possibility of putting interesting constraints on the unitary triangle. At the Conference also CDF[32]a presented a measurement of Δm_d giving: $\Delta m_d = 0.4810 \pm .0289 \pm .026 ps^{-1}$, in good agreement with the previously value.

Important issues of the b quark sector are: lifetimes, Cabibbo-Kobayashi-Maskawa matrix elements and α, β, γ of the unitarity triangle.

CDF presented[32]b a measurement $\sin 2\beta = 1.8 \pm 1.1(stat) \pm 0.3(syst)$ excluding $\sin 2\beta < 0$ at 90% c.l. and $\sin 2\beta < -0.2$ at 95% c.l., compatible with the value presented by OPAL[33]: $\sin 2\beta = 3.2^{+1.8}_{-2.0} \pm 0.5(syst)$, obtained from the study of $B_c \rightarrow J/\psi K_s^0$ decays.

DELPHI[34] presented two new measurements: ($|V_{cb}| = 41.19 \pm 1.52(stat) \pm 1.77[syst] \pm 1.36(theory)10^{-3}$ obtained by using new experimental procedure and theoretical parameterisation, and: $|V_{cb}|F(1) = (37.5 \pm 1.4 \pm 1.8)10^{-3}$ for D^* 's. This value, for the first time, is consistent with the lifetime results. DELPHI measured also the ratio $|V_{ub}|/|V_{cb}| = 0.104 \pm .012(stat) \pm .015(syst) \pm .008(model)$ which leads to: $|V_{ub}| = (4.3 \pm 0.8)10^{-3}$, i.e. $(10.4 \pm 2.1)\%$ of V_{cb} , compatible with the PDG value and the measurements of competing experiments (see ref. [34]).

Several speakers have shown tables of measured values for τ_{B^0} , τ_{B^-} and for the ratio τ_{B^-}/τ_{B^0} . The values of τ_{B^-} are systematically larger than those of τ_{B^0} . However the world average of the ratio $\tau_{B^-}/\tau_{B^0} = 1.07 \pm .04$ is compatible with unity within two σ . SLD presented a value averaged over the years 1993-98 $\tau_{B^-}/\tau_{B^0} = 1.061^{+.031}_{-.029} \pm .027$ which doesn't differ much from the world average[4].

No new data on b baryons were presented here. Soon from CDF might come new discoveries as the b quark is the main tag for the top decays, but we shall have to wait several years before we may learn more on the b baryon's sector.

The clue issue of the Conference in b physics -beyond the $B^0 - \bar{B}^0$ oscillations- is the improvement in the knowledge of the gluon splitting factors R_c and R_b which are not simply and eas-

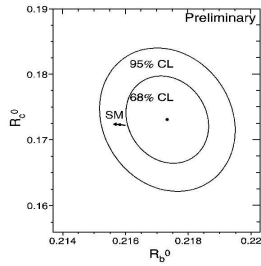


Figure 11. Correlation between R_c^0 and R_b^0 and comparison to Standard Model predictions.

ily linked to the detection efficiencies for charm ϵ_c beauty-bottom ϵ_b or light quarks ϵ_{uds} . Both SLD[35] and LEP[36] presented new measurements of these parameters which are derived by the rate of single and double tags determined experimentally: $F_s = \epsilon_b R_b + \epsilon_c R_c + \epsilon_{uds}(1 - R_b - R_c)$; $F_d = \epsilon_b^d R_b + \epsilon_c^d R_c + \epsilon_{uds}^d(1 - R_b - R_c)$ where the correlation ϵ^d is: $\epsilon^d = \epsilon^2 + \lambda(\epsilon - \epsilon^2)$. M. Caccia[36] presented (fig. 11), a preliminary estimate of the correlation between the two parameters and the comparison to the predictions of the Standard Model. The data are converging towards an agreement with the predictions of the Standard Model, thus confirming that the latter, if not right, it is anyhow a very well thought picture of the intimate structure of nature.

6. ACKNOWLEDGMENTS

I wrote this report having in front of me only the transparencies handed in during the Conference. I therefore apologize to all those I have been unable to properly quote and to those authors whose results have not been considered. I wish to thank the organizers for their hospitality and, most warmly, G. Gianini and M. Merlo, of my group, for their unvaluable contribution to the setting up of decent figures. Without their help this report could never appear.

REFERENCES

1. M.Gell-Mann, Nuovo Cim. Sup. **4** (1956) 848;
2. G.Thomson: these Proceedings;
3. A.Benelli: these Proceedings;
4. C.Caso et al.: Eur. Phys. Journ. **C3** (1998)1;
5. a- E.Monnier: these Proceedings;
6. E.Ramberg: these Proceedings;
7. P.Ratcliffe: these Proceedings;
8. P. Zenczkowski: these Proceedings;
9. F.E.Close *et al.*: Phys. Lett. **B319** (1993)291;
10. a- P. Blüm et al.: Phys. Lett.: **B355** (1995) 425; b- P. Blüm: these Proceedings;
11. S.P.Ratti: *Light Quark Photoproduction at Fermilab*, EPS-HEP97, Jerusalem (1998);
12. a- D.Pedrini: these Proc.; b- P.F.Frabetti et al., E687 coll. Phys. Lett. **B407** (1997) 79; c- B. O'Reilly: these Proceedings;
13. T.Boccali: these Proceedings;
14. S.P.Ratti: a- in Res. and Persp. in Part. Phys., (Ed. M.Greco, INFN,1996) p. 155; b- in Multiparticle Dynamics, (Ed. J. Dias De Deus, World Sci.,1996) p. 211;
15. a- R.Vogt, S.J.Brodsky: Nucl. Phys. **B478** (1996) 311; b- R.Hwa Phys.Rev. **D51** (1995) 85; c- O.Piskounova JINR prep. E2-95-275 (1995);
16. C.Lazzeroni: these Proceedings;
17. O.Thilman: these Proceedings;
18. J.O'Neill: these Proceedings;
19. C.Gemme: these Proceedings;
20. D.Jackson: these Proceedings;
21. E.A.De Wolf and W.Kittel: Phys. Rep. **270** (1996) 1;
22. a- S.P.Ratti et al.: Z. Phys. **C61** (1994) 229; b- V.Arena et al.: N. Cim. **108A** (1995) 417;
23. P.Hoyer: these Proceedings;
24. B.de la Cruz: these Proceedings;
25. M.Pallavicini: these Proceedings;
26. : a- G.L.Boca: these Proc.; b- P.L. Frabetti et al.: Phys. Lett. **B427** (1998) 211; c- P.L. Frabetti et al.: Phys. Lett. **B426** (1998) 403;
27. O.Melzer: these Proceedings;
28. a- M.M.Block, S.P.Ratti et al.: I.C.H.E.P. at CERN (Cern, 1962) p. 458; b- The Sienna Int. Conf. on El. Part., (EPS, 1963) p. 62;
29. P.L.Frabetti et al., E687 coll.: Phys. Lett. **B338** (1994) 106;
30. S.Fleck, J.M.Richard: Prog. Theor. Phys. **82** (1989) 760; Fermilab-Conf.-94-190 (1994);
31. J.Boucrot: these Proceedings;
32. a- K.Kelley: these Proceedings; b- CDF coll.: Fermilab-pub-98/188-E; 198-E;
33. R.Hawkins: these Proceedings;
34. P.Collins: these Proceedings;
35. V.Serbo: these Proceedings;
36. M.Caccia: these Proceedings.