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Physics at SuperLEAR

Conclusions of the Zurich Workshop
9 - 12 October 1991

Compiled by C. Amsler from the transparencies of the Workshop, 26/11/1991.

1 Introduction

One of the key issues in Particle Physics is whether Quantum Chromodynamics is the appropriate theory to describe the strong interaction force which binds hadrons in the non-perturbative low energy regime. The relevant questions are:

- Do glueballs and hybrid mesons made of $q\overline{q}$ pairs and constituent gluons exist?
- Are there multiquark states?
- Can we predict the observed hadron spectrum of light and heavy quarks?
- Is there a signal for glue in low energy interaction and in particular in $\overline{p}p$ annihilation?

Several mesons which do not appear to be consistent with $q\overline{q}$ states (exotic mesons) have recently been reported in πN, $K^- N$ and $\gamma\gamma$ interactions, in radiative J/ψ decay and in central collisions [1,2]. An experimental programme in $\overline{p}p$ annihilation is underway at LEAR (Crystal Barrel, Obelix, Jetset) [3] and already three candidates for exotic mesons have been reported [4,5,6,7]. However,

- The maximum $\overline{p}$ momentum of the LEAR facility (2 GeV/c), although adequate to study the mass spectrum below 2 GeV, **does not allow the higher mass range to be covered** where most glueballs, hybrids and the still missing $q\overline{q}$ states are predicted.
- The theoretical prediction for **charmonium and charmed hybrids** is believed to be much more reliable than for states made of light quarks since we have a reliable model for the charmonium spectrum. An experimental investigation of the charmonium spectrum requires $\overline{p}$ beams up to 12 GeV/c ($\sqrt{s}$=4.9 GeV).

The interaction of charm with nuclear matter addresses topics of interest to both Particle and Nuclear Physics. The questions debated at the workshop were:

- Can colour transparency be observed in $\overline{p}p$ annihilation on nuclei?
- Can one observe $c\overline{c}$-nucleus bound states?
- How is the charmonium spectrum modified in the presence of nuclear matter?
- Can supernuclei (the analog of hypernuclei in the strange sector) be produced?

Those were the major themes of the Workshop, the purpose of which was to identify the experimental programme for a 2 to 15 GeV/c $\overline{p}$ storage ring at CERN and to determine the required machine specifications.

The Workshop was held from 9 to 12 October 1991 at the Physik-Institut of the University of Zurich and was attended by 120 participants. The conference was sponsored by CERN, the Physik-Institut and the Swiss National Science Foundation. The advisory panel consisted of C. Amsler (Zurich, Conference Chairman), C. Batty (RAL), T. Bressani (Turin), C. Guaraldo (Frascati), M. Huber (Bonn), T. Johansson (Stockholm), K. Kilan (Jülich),

H. Koch (Bochum), R. Landua (CERN), D. Möhl (CERN), L. Montanet (CERN), R. Ricci (Legnaro), J.M. Richard (Grenoble) and Y. Simonov (ITEP). The scientific programme was divided into plenary talks involving 30 invited speakers and two parallel sessions with 19 contributed papers (appendix).

This report summarizes the outcome of the Workshop. For details, we refer to the Proceedings (and in particular to the conference summary talk [8]), which will be published in Spring 1992 by the UK Institute of Physics (Adam Hilger, Bristol).

2 The Machine

SuperLEAR would be built in the East Hall. The antiprotons would be accelerated or decelerated in the PS from 3.5 GeV/c to the energy required by the experiments and injected in SuperLEAR, a storage ring with superconductive magnets and stochastic beam cooling. It would use the present stacking rate of the ACOL/AA complex, $\sim 10^7$ $\overline{p}$/sec, if three cycles per PS supercycle are used for $\overline{p}$ production. In conjunction with the operation of an internal jet target (4×10^{13} atoms/cm^2), a luminosity of 10^{32} cm^{-2}s^{-1} and a momentum bite of about $\sigma/p=2\times10^{-4}$ would be achieved, matching $\overline{p}$ production with $\overline{p}$ consumption. The maximum luminosity would be reached in the momentum range above 3.5 GeV/c, while momenta as low as 2 GeV/c could be reached albeit at somewhat reduced luminosity or resolution, due to the limited acceptance of the PS at low energy.

SuperLEAR would run in parallel with the other (present and anticipated) programmes (SPS, LEP, IONS, LHC) during which two to three cycles per PS supercycle would be available for $\overline{p}$ production [9]. SuperLEAR would be refilled to 10^{12} $\overline{p}$ by feeding $\sim 3\times10^{11}$ $\overline{p}$ from the AA every ~8 hours.

Several versions were presented [10] which, in contrast to the earlier concept [11], now also include extracted beams with a flux of $\sim 10^7$ $\overline{p}$/s. The most suitable version will of course depend on the experimental programme:

- SL42, a ring with 126 m circumference, allowing the operation of two jet targets.
- SL44, a ring of similar dimensions but with one jet and one extraction feeding two to three beam lines.
- SL50, a ring with 157 m circumference with 2 (possibly 3) jets and one extraction (leading to two to three external beams, see fig. 1).
- SL205, a pear shaped ring with 157 m circumference, 2 jets and one extraction (leading to two to three external beams). This version, still under study, provides more floor space for the extracted beams.

The extraction would require an extension of the area into building 156. Versions SL205 and especially SL50 need a large fraction of the space presently occupied by the test beams in the East Hall.

For the operation at 12 GeV/c one needs 6 T magnets whilst the extension to 15 GeV/c would require 7.5 T. The 15 GeV/c option has however not been studied in details yet. The twelve curved superconducting dipoles require research and development. Two versions are being considered, one based on the HERA magnets [12], the other using strongly saturated ferromagnetic material which has successfully been developed for compact synchrotron light sources and ϕ factories both at TAC (Texas A&M) [13] and INP (Novosibirsk) [14].

If a positive decision is taken in late 1992, SuperLEAR could be running for physics in late 1996.

3 Charmonium Formation

The charmonium spectrum and the transitions between the $c\bar{c}$ levels are usually described by solving the Schrödinger equation with a flavor independent central potential, supplemented by a Breit-Fermi Hamiltonian mediated by one gluon exchange. This approach is actually also relatively successful in describing light quark mesons [15] but relativistic corrections and confinement forces are expected to be less important for the heavier quarkonia. The go[illegible] of charmonium spectroscopy is to test the $c\bar{c}$ potential in the 0.5 fm range. It is therefore important to observe and measure accurately the charmonium spectrum. SuperLEAR would offer such a possibility.

The partial width for decay into a given final state of mass M is given by

$$\Gamma_f \sim \alpha_s(M)^n |\psi(o)|^2 (1 + x\alpha_s) \qquad (1)$$

where $x\alpha_s$ is the radiative correction and n, x depend on quantum numbers. To obtain the partial width Γ_f one needs both the **total width** of the state and the decay branching ratio.

Charmonium formation in $\bar{p}p$ collisions was pioneered at the ISR by experiment R704 and is now being studied at FNAL by experiment E760. The idea is to vary the incident $\bar{p}$ momentum of a beam impinging on a jet hydrogen target in fine steps, using the excellent resolution of the internal beam, and to look for the resonant formation of charmonium states viz. $\bar{p}p \rightarrow X(c\bar{c}) \rightarrow$ final state, as a function of $\bar{p}$ momentum. The main advantage of $\bar{p}p$ over e^+e^- collisions is that the latter forms only $J^{PC}=1^{--}$ (e.g J/ψ and its radial excitations), while the former accesses all charmonium states, and that **the width and the mass [illegible] the resonance can be measured precisely** since the resolution is not determined by the detector, but by the beam momentum resolution. The disadvantage is the huge background from elastic and inelastic scattering and annihilation into light quarks (60 mb in the charmonium region). Thus a trigger on specific charmonium decays must be used, for instance $X(c\bar{c}) \rightarrow Y(c\bar{c})\gamma$, $\pi^0, \pi^+\pi^-$ etc, where $Y(c\bar{c}) \rightarrow e^+e^-$ or $\gamma\gamma$.

To illustrate the enormous improvement in background and in resolution, we show in fig. 2 the inclusive γ spectrum measured by Crystal Ball from $e^+e^- \rightarrow \psi(3685)$ at SPEAR [16], compared with the excitation spectrum for $\chi_1, \chi_2 \rightarrow J/\psi(\rightarrow e^+e^-)\gamma$ from E760 [17]. E760 is now publishing the final results [17]:

$$\Gamma(\chi_1) = 0.88 \pm 0.11 \pm 0.08 MeV \qquad (2)$$

$$\Gamma(\chi_2) = 1.98 \pm 0.17 \pm 0.07 MeV. \qquad (3)$$

Currently E760 gets an integrated luminosity of 0.3 pb^{-1}/day while SuperLEAR would deliver 4 pb^{-1}/day (already including 50% inefficiency). The cross section at the resonance maximum is given by

$$\sigma(M) = \frac{\pi}{p^2} B_i(X \to \overline{p}p) B_f(X \to f.s.)(2J+1) F(\frac{\sigma_b}{\Gamma}) \tag{4}$$

where p is the c.m. momentum, B the branching ratios, J, M, Γ are the resonance spin, mass and width, and F a function which describes the signal reduction due to the beam resolution σ_b (fig. 3). Table 1 gives the expected rates for charmonium formation and decay at SuperLEAR for $\sigma_b = 210$ keV [18]. The background for the present E760 detector is about 15 pb [19] for the final states listed in Table 1.

A charmonium spectroscopy programme would include [18]

- A measurement of the width of χ_0 and of the partial widths for $\gamma\gamma$ decay of χ_0 and χ_2. The ratio $\Gamma_{gg}/\Gamma_{\gamma\gamma}$ yields $\alpha_s(M_\chi)$. The same argument applies to η_c. Note from Table 1 that a χ_0 scan is time consuming due to its large hadronic width.

- Search for the missing $({}^1P_1)$ $h_c \to \gamma\eta_c, J/\psi\pi^0, J/\psi\pi\pi$. Its mass determination tests the very short range spin-spin interaction. Its mass could lie up to 30 MeV above the center of gravity of the χ triplet [20].

- Search for the η_c' observed so far only by Crystal Ball (fig. 2) [21].

- The comparison of η_c and $\eta_c' \to \phi\phi$ and $\overline{p}p$ gives information on pseudoscalar glueballs near η_c.

- Search for the missing D-wave $c\overline{c}$ states. ${}^1D_2$ and ${}^3D_2$ are expected to be narrow since parity conservation prevents them decaying into $D\overline{D}$ and they lie below the $D\overline{D}^*$ threshold. The relevant decay modes are:

$$ {}^3D_2(2^{--}) \to \gamma\chi_{1,2}, \pi\pi\psi, \pi^0\psi \tag{5}$$

$$ {}^1D_2(2^{-+}) \to \gamma\psi, \pi\pi\eta_c, \omega\psi, \gamma h_c. \tag{6}$$

Undoubtedly some of this programme will be covered by E760. However, **the gain in luminosity with SuperLEAR - of an order of magnitude - is substantial since charmonium scans are extremly time consuming** due to the weak signals and the uncertainty in the precise location of some of the states (h_c and D states). Multipole analyses of the decay angular distributions also require large statistical samples. This can only be achieved with a high luminosity dedicated machine.

Another useful comparison can be made with the production rates at a tau-charm factory running at the same luminosity of 10^{32} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$. With a mass resolution of $\sigma \sim 1$ MeV one would produce ~300 J/ψ or ~80 ψ' /s while SuperLEAR would deliver 100 J/ψ and 12 ψ' /s. Since the other charmonium states are only accessible indirectly through their decay, one would for instance produce 4 η_c, 6 χ_2 and ~0.4 η_c' /s at the tau-charm factory, but form 90, 20 and 20, respectively, at SuperLEAR. The two machines therefore nicely complement each other.

A major point of concern at SuperLEAR will be the high rate of 6×10^6 interactions /s which requires a fast and radiation resistant electromagnetic calorimeter. Lead glass (used by E760) is inadequate due to its low radiation resistance (200 rad). Preliminary investigations of CsI-CsBr crystals, which are commercially available from the USSR, have been made [22,23,24]. Its slowest decay time component (36 ns, fig.4), with nearly no afterglow and its high radiation resistance (more than 1 Mrad) make it an attractive candidate for calorimetry at SuperLEAR. Figure 4 also summarizes the properties of this new compound. In addition, the energy resolution would be improved by a factor of two, leading to a substantial combinatorial background reduction. Figure 5 shows the E760 detector which could be upgraded by replacing the lead glass calorimeter by a barrel of CsI-CsBr crystals.

4 Formation of Charmonium Exotics

In contrast to light quark spectroscopy, where many broad states cluster and overlap bel[illegible] 3 GeV, the charmonium spectrum is finite and predictable. The observation of addition[illegible] relatively narrow states, formed in $\bar{p}p$ collisions would unambiguously signal the existence of non-$q\bar{q}$ exotics, charmed hybrids, 4 quark-states or bound states of charmed mesons.

One may also expect the formation of $(c\bar{c}g)$ charmed hybrids (fig. 6a). The cross section is however unknown. A reasonable guess is between 5 μb and 0.25 μb, the cross sections for J/ψ and χ_2 productions (fig. 6b,c) [25]. Assuming 1.5 GeV for the mass of the ground state glueball G, one predicts ground state charmed hybrids to lie around $m(c\bar{c}g) \sim m(c\bar{c}) + 1/2m(G) \sim 3.7$ GeV i.e. near the $D\overline{D}$ threshold. Coupling a transverse electric gluon (1^{+-}) (which is lightest in the bag model) to the 0^{-+} and 1^{--} charmonium ground states one expects the sequence [25]

$$0^{-+} < 1^{-+} < 1^{--} < 2^{-+}. \tag{7}$$

The decay into $D\overline{D}$ or $D\overline{D^*}$ is hindered by angular momentum ($L \geq 1$) around threshold and hence these states are expected to be narrow below $D\overline{D^{**}}$ threshold (4.3 GeV). They would then mainly decay through transitions to charmonium states:

$$0^{-+} \rightarrow \chi_0\eta, \chi_0(\pi\pi)_S$$

$$1^{-+} \rightarrow \chi_1\eta, \chi_1(\pi\pi)_S \tag{9}$$

$$1^{--} \rightarrow J/\psi\ (\pi\pi)_S, J/\psi\ \eta \tag{10}$$

$$2^{-+} \rightarrow \chi_2\eta, \chi_2(\pi\pi)_S \tag{11}$$

which can be investigated with the charmonium apparatus and beam momenta up to at least 9 GeV/c. Note that 1^{-+} has exotic quantum numbers and hence can only be produced associated with the emission of another particle.

One does not expect a proliferation of $c\bar{c}q\bar{q}$ states, since these states are highly unstable and decay into $q\bar{q}$ pairs, with the exception of $cc\overline{qq}$ (tetraquark, note the charmed quark pair) and $\bar{c}sqqq$ (pentaquark) [26] which could be produced at the highest SuperLEAR energy or in the collider option (see section 9.2). Nonetheless, a clean signature of $c\bar{c}q\bar{q}$ states would be the observation of a peak in $\bar{p}n \to X^- \to \psi\pi^-$ which is pure isotriplet and hence not a member of the charmonium or charmed hybrid family.

Deuteron-like molecules made of $D\overline{D}$, $D\overline{D^*}$ or $D^*\overline{D^*}$ are also expected, akin to $K\overline{K}$ or $K\overline{K^*}$ molecules like $a_0(980)$ (and possibly $f_1(1420)$) in light quark spectroscopy [27]. For instance the formation and decay of

$$0^{++}(D\overline{D}, m < 3740 MeV) \to \gamma J/\psi, \eta_c\eta \tag{12}$$

$$1^{+-}(D\overline{D^*}, m < 3870 MeV) \to J/\psi\ \eta \tag{13}$$

could also be studied with the charmonium apparatus.

5 Light Quark Spectroscopy

Figure 7 shows the experimental status of light quark $q\bar{q}$ mesons. We now have well established candidates for the L=0 and L=1 ground state $q\bar{q}$ mesons. In contrast, many of the radial and L$\geq$2 excitations are still missing. Their masses lie above $\sim$ 1.7 GeV [28]. There are also established mesons which do not fit in the SU(3) scheme, either because the corresponding slot is already occupied ($f_0(1590)$, $f_1(1420)$, $f_2(1515)$), or because their masses and/or decay modes are not consistent with the properties of an SU(3) nonet ($a_0(980)$, $f_0(975)$ and possibly $\eta(1420)$). Further "excess" states have also been reported which need experimental confirmation. Some of these mesons might be glueballs, hybrids or multiquark states. Table 2 summarizes some of the meson states which have been recently reported [29,30].

There are three main reasons for investigating the meson spectrum above 1.7 GeV in $\bar{p}p$ annihilation:

- Higher orbital or radial excitations correspond to larger interquark distances. Therefore the mass spectrum leads to information about the confinement region.

- Glueballs, hybrids and multiquark states are predicted in the 1.7 to 3 GeV mass region. The ground state 0^{++} glueball is predicted around 1500 MeV by lattice gauge theories but we have little theoretical guidance for the excited states (0^{-+}, 2^{++}...) except that they should be heavier, with masses in the 1.5 to 2.5 GeV range. Gluonic matter is believed to couple strongly to η and η'. In the bag model, hybrid mesons lie above 1.2 GeV, most of them however above 1.5 GeV [31]. In the flux tube model, hybrids are predicted around 2.0 GeV [32]. These states can be understood as the QCD analog of the $\mathbf{H}_2^+$ molecular ion: the potential energy of the first excited state of the electron decreases as a function of the distance between the protons and hence no bound state is possible. For hybrids, however, the first excited state of the gluon flux tube has a minimum which leads to bound states. These states are predicted to decay into a $q\bar{q}$ S-wave and a P-wave mesons (fig.8). For instance:

$$2^{+-}(M = 1900\ MeV, \Gamma = 500\ MeV) \to (b_1\pi)_P \tag{14}$$

$$1^{-+}(M = 1900\ MeV, \Gamma = 130\ MeV) \to (b_1\pi)_S, (f_1\pi)_S \tag{15}$$

$$0^{+-}(M = 1900\ MeV, \Gamma = 250\ MeV) \rightarrow (b_1\pi)_P. \qquad (16)$$

Note that these states have "exotic" quantum numbers which do not couple to $q\overline{q}$ and can therefore be unambiguously distinguished from $q\overline{q}$ mesons.

- Peripheral reactions (eg $\pi p \rightarrow Xp, X \rightarrow$ mesons) enhance the production of low mass states X (through OBE). In contrast, there is no particular mechanism in $\overline{p}p$ annihilation so that events of the type $\overline{p}p \rightarrow \pi X$ populate the m_X mass plot up to the end of the available phase space. This process is similar to e^+e^- annihilation into J/ψ ($\rightarrow \gamma X$) which populates the mass plot up to the J/ψ or to $e^+e^- \rightarrow \psi' \rightarrow \gamma X$ which led to the discovery of the χ states.

As underlined in the previous section, the QCD spectroscopy of light quarks is extremely difficult to interpret with our present theoretical tools and one may argue that the profusion of states (exotic or non-exotic) already at hand is so confusing that little progress will be made by searching for further states. However, most observations made so far, for instance [illegible] radiative J/ψ decay, central collisions and $\gamma\gamma$ interaction are limited in statistical significance and restricted to few final states, i.e. one experiment observing only final state involving π^0, η or η', the other only $\pi^+\pi^-$ or K^+K^-.

So far, only small data samples scattered at several energies have been collected for $\overline{p}p$ annihilation in flight to study mainly the cross sections as a function of incident momentum. A spin-parity analysis of the produced resonances requires however large statistical samples (10^8 events) at one given energy on many different channels, rather than small data samples at various incident momenta, allowing a systematic coupled channel analysis of the S matrix. This is to some extend the programme in progress at LEAR (Crystal Barrel, Obelix, Jetset) but a limitation is the total energy available, whereas a consensus agrees that the most interesting region is the mass range between 2 and 3 GeV. Glueballs and hybrids could be produced in $\overline{p}p$ annihilation, associated with the production of one or two pions (kaons), provided that sufficient phase space is available. With LEAR running at its maximum momentum (2.0 GeV/c corresponding to a center of mass energy of 2.43 GeV), phase space suppression already limits the useful mass range to below 2 GeV. A typical two-body cro[illegible] section behaves like

$$\sigma \approx p\ exp(-A(s - (m_1 + m_2)^2)^{1/2}) \qquad (17)$$

A good match to the cross section is therefore obtained with $\overline{p}$ beams of typically 3-4 GeV/c for resonances lying below 2.5 GeV [8].

Based on the results achieved so far by the GAMS and Crystal Barrel collaborations (see Table 2), a good neutral detector is required. Annihilation into $\phi\phi$, which is sensitive to glueballs, is currently under investigation by the Jetset collaboration, although the $\phi\phi$ mass window is only 400 MeV at LEAR! Thus there is a genuine motivation to extend the spectroscopy programme currently performed at LEAR to SuperLEAR energies. There are two possible experimental approaches: a Jetset like detector [35] around an internal gas jet (fig. 9a) or a Crystal Barrel like detector supplemented by a forward spectrometer for both charged and neutral particles (fig. 9b) [33,34].

The first approach [35] uses the optimum luminosity required to study rare annihilation channels like

$$\bar{p}p \to \phi\phi, \phi\omega\, \phi\eta' \tag{18}$$

or

$$\bar{p}p \to \phi\phi X \tag{19}$$

where $X = \pi^0, \eta, \eta', \omega$. Four-quark states can be produced by annihilating one $q\bar{q}$ pair into e^+e^- e.g. $\bar{p}p \to e^+e^-X$. The cross section for Drell-Yan processes is small and hence this experiment is best done on the internal gas jet.

The second approach [33,34] is more adequate to study final states involving charged pions and kaons viz.

$$\bar{p}p \to X\pi^+\pi^-, X \to \eta\eta, \eta\pi^0, \eta'\pi^0, K\bar{K}\pi, etc. \tag{20}$$

6 Nuclear Physics Programme

6.1 J/ψ-nucleon cross section

A measurement of the J/ψ-nucleon cross section is of interest in the context of J/ψ suppression in high energy heavy ion reactions. A large cross section would reduce the J/ψ signal in heavy ion collisions. This would argue against the formation of the quark-gluon plasma [36]. For the cross section to be meaningful, the J/ψ should retain its identity and normal size in the scattering process. This means that the relative momentum between J/ψ and nucleon should be small. This is not achievable in high energy reactions like photoproduction but in $\bar{p}p$ annihilation in nuclei, viz. $\bar{p}A \to J/\psi(A-1)$.

To determine the cross section, one would look for $J/\psi \to e^+e^-$ for various mass numbers A. At high energy, the phenomenon of colour transparency may reduce the cross section and hence the nucleus may become transparent [37]. The cross section then varies as A, in contrast to $A^{2/3}$ for $\bar{p}p$ annihilation (which occurs on the surface of the nucleus). It is not clear whether colour transparency occurs in the energy regime of SuperLEAR, but this could be measured. Whether the $c\bar{c}$ system retains its geometrical size can be probed by comparing J/ψ and ψ' productions which should scale like the squares of the respective radii. A caveat is the Fermi motion which reduces J/ψ formation by a factor of 50 [36]. These experiments then require the highest possible luminosity.

6.2 Charmonium-nucleus bound states

. According to ref [38] the $c\bar{c}$ system should bind to the nucleus if the mass number is high enough, due to the absence of Pauli blocking and the pure gluon exchange force. This may already occur for the $\eta_c H^3$ system which has a binding energy of 19 MeV. The reaction to study is $\bar{p}He^4 \to \eta_c H^3$ where $\eta_c \to \gamma\gamma$. The ideal momentum is 2.3 GeV/c for which the final products are at rest in the c.m. system. The forward emitted tritium would be tagged and the mass of the $\eta_c H^3$ system would appear 19 MeV below its nominal (unbound) value.

There is a large uncertainty in the rates which depend crucially on formfactors. Estimates presented at the Workshop vary from 1 event/day [39] at SuperLEAR to the hopeless rate of 10^{-4} events/day [36].

6.3 Charmonium in nuclear matter

Another interesting effect which could be studied at SuperLEAR is related to the question as to whether external gluons can influence the size of hadrons. The gluon string tension of the free $c\bar{c}$ system could be modified in the presence of nuclear matter due to the additional gluon fields. There is however no agreement on the sign of the resulting mass shifts. The state ψ'' could be shifted downwards below $D\bar{D}$ threshold and become narrow. Conversely, ψ' could be shifted upwards beyond threshold and become broad. Again, for a meaningful test, the charmonium states should be produced at small momenta. This can be achieved for ψ' or ψ'' by detecting e^+e^- pairs that are emitted with large opening angles [40].

6.4 Subthreshold charm production

Charmed baryons (e.g. Λ_c) can be produced on nuclei by rescattering [41]:

$$\bar{p}N_1 \to c\bar{c}, c\bar{c}N_2 \to \Lambda_c\bar{D} \tag{21}$$

If the propagation time of charmonium in nuclear matter is large so that the energy uncertainty is much smaller than the charmonium level spacings, resonant production of Λ_c will occur at a $\bar{p}$ momentum of about 4 GeV/c. If on the other hand the propagation time is short, the charmonium levels will mix and the cross section for Λ_c production will be determined by the coherent superposition of several charmonium resonances leading to a broad excitation spectrum. Hence subthreshold Λ_c provides a quantum chronometer to the study the space-time structure of formation processes [40].

An interesting application is the production of so-called supernuclei [40] where the Λ_c replaces a proton, in analogy to hypernuclei where the Λ replaces a neutron. The binding energy, smaller for supernuclei than for hypernuclei due to the Coulomb repulsion, reach[illegible] a maximum around the atomic weight 40. Supernuclei could be produced with 3.5 GeV/c [illegible] impinging on an argon gas jet through the reaction

$$\bar{p}N_1 \to \eta_c, \eta_c N_2 \to \Lambda_c\bar{D} \tag{22}$$

which is kinematically advantageous due to the low (smaller than 2 GeV/c) Λ_c recoil momentum. The signature for supernuclei production would be the decay mode $\Lambda_c N \to \Lambda_s p$ leading to a proton and a back-to-back $\Lambda_s \to \pi^- p$. At SuperLEAR, the rate would be around 10 events/day [40].

6.5 Exotic state of nuclear matter

It has been conjectured that enhanced Λ production on nuclei (compared to $\bar{p}p$) could be explained by the formation of quark-gluon plasma or by simultaneous annihilation on multinucleon quark clusters. Indeed the Λ/K_S ratio at 4 GeV/c increases from 0.3 in $\bar{p}p$ to 2.3

in $\overline{p}Ta$ [42]. According to the intranuclear cascade model [43], the excess of Λ production can however be explained by kaon rescattering in the nuclear medium, viz. $\overline{K}N \to \Lambda X$ and hence no exotic process needs to be invoked. For Ξ production, however, the situation is different since Ξ can only be produced by rescattering together with the emission of a kaon (viz. $\overline{K}N \to \Xi K X$). The cross section is expected to be rather small so that any high rate of S = - 2 production in nuclei, compared to $\overline{p}p$, would signal unusual annihilation processes [44]. The rate for inclusive Ξ production in $\overline{p}p$ annihilation has to be measured before nuclei are investigated.

7 Hyperon-Antihyperon Production

7.1 CP violation in Λ decay

CP violation in Λ decay was also discussed at the Workshop. The conclusion was that the $\overline{p}p \to \Lambda\overline{\Lambda}$ experiment could be performed at the present LEAR facility and is therfore not part of the SuperLEAR programme. We nevertheless include a summary of the presentations [45,46] for completeness. However, a measurement of the Λ polarization in Ξ decay, which is also sensitive to CP violation (section 7.2), requires SuperLEAR.

CP violation in $\Lambda \to p\pi^-$ manifests itself through

- an asymmetry in the Λ and $\overline{\Lambda}$ decay rates
- an asymmetry A in the decay asymmetries for Λ and $\overline{\Lambda}$. The angular distribution of the decay proton (antiproton) is

  $$I = I_0[1 + \alpha(\overline{\alpha})P_{\Lambda(\overline{\Lambda})}cos\theta] \qquad (23)$$

  where $P_{\Lambda(\overline{\Lambda})}$ are the polarizations of the hyperons, equal by C conservation in $\Lambda\overline{\Lambda}$ production, and θ the emission angle of the proton (antiproton) with respect to the $\Lambda(\overline{\Lambda})$ spin in the hyperon rest frame. CP violation introduces the asymmetry

  $$A = \frac{\alpha + \overline{\alpha}}{\alpha - \overline{\alpha}} \neq 0 \qquad (24)$$

- an asymmetry in the final state polarization expressed by

  $$B = \frac{\beta + \overline{\beta}}{\alpha - \overline{\alpha}} \neq 0 \qquad (25)$$

  where $\beta(\overline{\beta})$ is related to the $p(\overline{p})$ polarization.

CP violation in the $\Lambda\overline{\Lambda}$ system occurs through the interference of the (dominantly $\Delta I = 1/2$) S and P waves amplitudes [45] and is relatively insensitive to the top quark mass, in contrast to ϵ'/ϵ in the $K\overline{K}$ system which depends on the delicate cancellation of strong and electroweak ($\Delta I = 3/2$) penguins. Thus A is non-zero even if ϵ' is zero. The magnitude of A is in the range 10^{-5} to 5×10^{-5} [45]. To obtain a (modest) 1 σ upper limit of 10^{-4}, one needs 2×10^9 events at an incident momentum of 1.63 GeV/c [46]. The present value for A (-0.013±0.029) has been obtained by PS185 at LEAR with 60'000 events.

This experiment could be performed on LEAR with a jet target at a luminosity of 7×10^{31} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ since the $\bar{p}$ momentum (1.63 GeV/c. just below the $\bar{\Lambda}\Sigma^0$ threshold) is outside the optimum range of SuperLEAR and the high statistics require dedicated operation of the storage ring. To reach a (statistical) sensitivity of 10^{-4} one would need one year of data taking.

7.2 CP violation in $\bar{p}p \to \Xi^-\overline{\Xi^-}$

On the other hand. B is expected to be at least 10 times larger than A. A measurement of B is however difficult since it involves measuring the proton and antiproton polarizations. With the reaction

$$\bar{p}p \to \Xi^-\overline{\Xi^-} \to \Lambda\pi^-\bar{\Lambda}\pi^+ \tag{26}$$

one would measure the polarization of the $\Lambda(\bar{\Lambda})$ (through its decay asymmetry) to obtain B. The threshold is 2.62 GeV/c and the peak cross section $2\mu b$. reached at about 3.5 GeV/c. A possible detector has been described in ref.[47]. Unfortunately, the differential cross section and Ξ polarization are not known. SuperLEAR would be ideally suited for a pilot investigation of this reaction (à la PS185 on an external beam) to determine the feasibility of a CP violation experiment and determine the cross section, polarizations (and get A(Ξ) as a byproduct).

7.3 $\bar{p}p \to Y_s^*\overline{Y_s^*}$

A natural extension of this programme is to investigate the reactions $\bar{p}p \to \Sigma^-\overline{\Sigma^-}$, $\Xi^0\overline{\Xi^0}$, $\Sigma^{-*}\overline{\Sigma^{-*}}$, $\Xi^{-*}\overline{\Xi^{-*}}$, $\Xi^{0*}\overline{\Xi^{0*}}$, all within the range of superLEAR, which yield information on double quark annihilation processes [48].

A particularly interesting one is $\Omega^-\overline{\Omega^-}$ for which all quarks are annihilated. This reaction can be compared to $\bar{p}p \to \phi\phi$ for which the angular distribution is symmetric around 90°. For $\Omega^-\overline{\Omega^-}$, two processes compete: pure gluon exchange in the s-channel and three-kaon exchange in the t-channel which breaks the forward/backward symmetry [49]. Hence a measurement of the angular distribution gives information on the relative contribution of gluon vs. K exchange. One would detect the decay $\Omega \to \Lambda K^-$ ($c\tau$=2.5 cm) with an extracted beam and an apparatus similar to PS185. The reaction threshold is 4.9 GeV/c. With an estimated rate of $1\mu b$ one would get 200 detected events/day. In addition, one could determine, through the measurement of the Λ polarization, the badly known asymmetry parameter in $\Omega^- \to \Lambda K^-$ decay.

8 $\bar{p}p$ Scattering and Annihilation

Very few data are available for elastic scattering and annihilation in the SuperLEAR momentum range [50,51]. Low energy $\bar{p}p$ scattering has been studied at LEAR in the low energy region (below 1 GeV/c). The upper energy range (1 - 2 GeV/c) has however not been investigated systematically. Two broad enhancements were observed earlier in the total, elastic, charge exchange and annihilation cross sections. Most of the evidence actually rests on the total cross section data [52] where one I=0 resonance and two I=1 resonances are reported in the mass range 2150 to 2400 MeV from $\bar{p}p$ and $\bar{p}d$ data. The experimental situation should be clarified by remeasuring the cross sections and measuring spin observables, in particular the analyzing power, which is a sensitive probe of fast moving phases in the presence of resonances. The lower peak occurs around 1.26 GeV/c and can thus be investigated at LEAR while the higher peak occurs around 1.88 GeV/c, marginally close to the LEAR upper momentum limit.

There is no satisfactory explanation as to the nature of these enhancements (genuine $\bar{p}p$ resonances or threshold effects due to the opening of inelastic channels like ΔN). Due to the large number of contributing partial waves and the resulting strong non-resonating background, it is unlikely that much progress will be achieved, unless exclusive annihilation final states, especially two-body final states, are studied as a function of $\bar{p}$ momentum, possibly with a polarized target. Among the contenders are the channels $\eta\eta$, $\pi^0\eta$, $\eta\omega$, $\omega\omega$, K_SK_S and K_SK_L which strongly reduce the number of contributing partial waves. We have nearly no data on two-body annihilation in flight with the exception of $\pi\pi$ (and K^+K^-) [53] which resonates in most partial waves at low energy.

Elastic scattering and two-body annihilation could be studied on an extracted beam with SuperLEAR running at very low momentum (2 GeV/c or below). There is no stringent requirement on beam quality nor intensity. The KAON factory is also a suitable facility for this programme with, however, the serious disadvantage that no beam line will cover a sufficiently broad momentum range.

Moving to higher energies, there is a serious discrepancy between the prediction for the ρ-parameter (ratio of real to imaginary spin-averaged forward amplitude) predicted from the low energy LEAR data and the few sparse data points in the 2 to 10 GeV/c momentum range. These predictions, based on dispersion relations, imply the existence of a structure below $\bar{p}p$ threshold [54]. This is an important point to check by measuring ρ in the SuperLEAR momentum range.

In the 10 GeV/c range, one expects to observe the onset of perturbative QCD. The differential cross section $d\sigma/dt$ is much steeper than the expected fixed angle s^{-10} power law, which correctly describes the pp cross section. It actually decreases even faster than s^{-12} predicted by QCD, and the ratio of pp to $\bar{p}p$ scattering cross sections at large angles seems to suddenly rise above s = 9 GeV^2, but the data are limited [55]. An important point to check is whether large spin effects (e.g. polarization asymmetries) which are reported in pp scattering are also observed in $\bar{p}p$ at large momentum transfers.

Perturbative QCD also predicts the differential cross sections $d\sigma/d\Omega$ for $\bar{p}p \rightarrow \gamma\gamma$, γM and MM (where M is a meson) to scale like $\alpha^2 f(\theta)/p_T^{10}$, $\alpha f(\theta)/p_T^{12}$ and $f(\theta)/p_T^{14}$, respectively [56]. The phenomenon of color transparency for these reactions will help disentangle the various contributions, in particular those dominated by short distance phenomena vs. those which are infrared sensitive [57]. A high luminosity and a good γ detector are required to measure the rather small cross sections for the first two reactions.

9 Future Options

9.1 Charmed Baryons

From the 15 expected *cqq* ground state charmed baryons, one (Λ_c^+) is well known and four (Σ_c^{++}, Σ_c^0, Ξ_c^0 and Ξ_c^+) have been seen. None of the spin 3/2 states has been observed so far. Apart from Λ_c^+, the world's supply consists of a few events only. Not counting Ω_c^0, which has been reported in one experiment at 2740 MeV [58], there are thus still nine states to discover.

The expected mass spectrum is shown in fig. 10a. All but the two S=-2 states can be observed at SuperLEAR energies. Actually, a fit of the quark masses to the known hadron spectrum yields m(Ω_c^0)= 2505 MeV [41], and if so, even Ω_c^0 could be observed at SuperLEAR. This is however in contradiction with the reported mass [58].

The idea [49,59] is to scan the thresholds of the reactions $\bar{p}p \rightarrow Y_c\overline{Y_c}$ which strongly constrain the kinematics if both decay final states are detected (fig. 10b). The rates for pair production of some of the baryons have been predicted [60]. For Λ_c^+, for instance, the cross section reaches its maximum of 20 nb at 12 GeV/c. Detecting the semileptonic dec[illegible] of one Λ_c^+ (1% b.r.) while tagging on the hadronic decay $\bar{p}K^+\pi^-$ of the other (2.8% b.r.), one would obtain 7 events a day [59]. This rate is quite competitive when compared to the rate expected from the SPS hyperon beam experiment [61]. It was also argued that the rates for pair production are uncertain by one order of magnitude and probably larger than 20 nb. The production of the other charmed baryons require SuperLEAR to run at 15 GeV/c.

9.2 Formation of Bottomonium

An exciting possibilty is to form the $b\bar{b}$ states and to repeat the charmonium programme in the bottomonium region [62]. Scaling for example the charmonium cross sections by the 8th power of the quark masses, one estimates 10 pb for the formation of χ_{b2}. In fixed target mode, the required $\bar{p}$ momentum is about 50 GeV/c and the signal/background ratio of the order 10^{-8}. A minicollider could be built by adding a proton ring to SuperLEAR. Since background events are mostly confined to the very forward or backward regions, a trigger on high transverse momentum would improve the signal/background ratio to a manageab[illegible] level [62]. With a luminosity of 10^{32} cm^{-2}s^{-1}, one would then form some 80 χ_{b2}/day. Th[illegible] however would require a major modification of SuperLEAR, including strong electron cooling ($\delta p/p \sim 10^{-5}$) and very high RF voltages to achieve short beam bunches [10].

10 A Likely Scenario

The high priority items for which SuperLEAR should be built were thus identified at the Workshop. They are:

- **Charmonium and charmed hybrid spectroscopy**
- **Light quark spectroscopy in the 2 to 3 GeV mass range**
- **Pair production of strange hyperons**

The interesting nuclear physics programme on charm interaction in nuclei could also be performed at SuperLEAR. The CP violation experiment could be performed at LEAR. Thus one could imagine that, after completion of the current programme, LEAR would be dedicated to CP and to the very low energy experiments (atomic physics, antihydrogen, gravitation, $\bar{p}$ mass, etc) while the rest of the present community would move to SuperLEAR. The most attractive option is SL50 (or SL205) with [64]

1. one jet target devoted to charmonium spectroscopy surrounded by a comprehensive detector.
2. one extracted beam and a detector of the kind shown in fig. 9b to study the light quark mass spectrum.
3. a second extracted beam with a forward detector similar to the PS185 apparatus.

Three essential questions must be resolved:

1. Does the glueball search in $\phi\phi$, $\phi\omega$, $\phi\eta'$, etc require the second jet target or could it be performed with the external detector (trade-off between luminosity and space required by the jet apparatus)?
2. Does the charmonium detector require a magnetic field and if yes, could the light quark spectroscopy programme with a jet also be performed with this detector?
3. Does the nuclear physics programme require a jet or could it be performed on an external beam (again a trade-off between luminosity and space)?

In any case, SL50 provides at least a second " spare" jet and a third extracted beam. The latter could also be used for $\bar{p}p$ scattering experiments.

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Table 1: Expected rates for $\bar{p}p \rightarrow c\bar{c} \rightarrow$ final state, assuming a beam momentum resolution of 500 keV (FWHM) and a luminosity of $10^{32}\text{cm}^{-2}\text{s}^{-1}$. An overall efficiency factor of 50 % is assumed (from the contribution of K. Königsmann).

p_L MeV/c	$c\bar{c}$	Final state	$B(\bar{p}p)$ 10^{-4}	B(f) 10^{-4}	$\sigma(M)$ pb	N_f /day
3676	η_c	$\gamma\gamma$	10.4	5.7	550	2'200
5870	η_c'	$\gamma\gamma$	4.6	5	120	480
4066	J/ψ	e^+e^-	22	590	63'000	250'000
6232	ψ'	e^+e^-	1.9	84	1'120	4'500
5192	χ_0	$\gamma J/\psi(e^+e^-)$	1.1	3.9	26	100
5192	χ_0	$\gamma\gamma$	1.1	4.5	30	120
5552	χ_1	$\gamma J/\psi(e^+e^-)$	0.8	161	1'800	7'200
5552	χ_2	$\gamma J/\psi(e^+e^-)$	0.9	80	1'850	7'400
5724	χ_2	$\gamma\gamma$	0.9	9.5	220	880
$\sim$ 5605	h_c	$\gamma\eta_c$	4.8	5	250	960

Table 2: Recently reported non-strange mesons with masses above 1.5 GeV. The nature of the states is debatable.

State	$J^{PC}(I^G)$	Mass MeV	Width MeV	Decay	Experiment	Nature
$f_2(1515)$	$2^{++}(0^+)$	1515	120	$\pi^0\pi^0$	Crystal Barrel	$\overline{N}N$
$f_2(1515)$	$2^{++}(0^+)$	1520	~100	$\pi^0\pi^0$	E760	$\overline{N}N$
$f_0(1525)$	$0^{++}(0^+)$	1525	90	K_SK_S	LASS	$^3P_0$
$f_0(1560)$	$0^{++}(0^+)$	1560	200	$\eta\eta$	Crystal Barrel	Glueball
$f_0(1590)$	$0^{++}(0^+)$	1587	175	$\eta\eta(\eta'), 4\pi^0$	GAMS	Glueball
$f_2(1565)$	$2^{++}(0^+)$	1565	170	$\pi^+\pi^-$	Asterix	$\overline{N}N$
$\omega(1600)$	$1^{--}(0^-)$	1594	100	$\rho\pi$	e^+e^-	$^3D_1$
$f_2(1640)$	$2^{++}(0^+)$	1640	<50	$\omega\omega$	GAMS	
$\rho(1700)$	$1^{--}(1^+)$	1712	213	$\rho\pi\pi$	e^+e^-	$^3D_1$
$f_2(1720)$	$2^{++}(0^+)$	1710	140	K^+K^-, K_SK_S	WA76	
$X(1750)$	$0^{++}?(0^+)$	1750	50	$\eta\eta$	GAMS	2^3P_0
$\eta(1760)$	$0^{-+}(0^+)$	1760	60	4π	DM2	3^1S_0
$\eta_2(1900)$	$2^{-+}(0^+)$	1876	228	$\eta\pi^0\pi^0$	Crystal Ball	$^1D_2$
$X(1910)$	$1^{-+}, 3^{-+}(0^+)$	1910	90	$\eta\eta'$	GAMS	CP exotic
$f_2(1920)$	$2^{++}(0^+)$	1924	91	$\omega\omega$	GAMS	2^3P_2
$f_2(2010)$	$2^{++}(0^+)$	2011	202	$\phi\phi$	MPS	Glueball
$G(2180)$	$2^{++}(0^+)$	2180		$\eta\eta$	GAMS	Glueball
$\xi(2220)$	$J>2$	2220		$\eta\eta'$	GAMS	$^3F_4$
	$4^{++}(0^+)$	2209	60	K^+K^-	LASS	$^3F_4$
	$2^{++}?(0^+)$	2230	~20	K^+K^-, K_SK_S	MarkIII	
$f_2(2300)$	$2^{++}(0^+)$	2297	149	$\phi\phi$	MPS	Glueball
$f_2(2340)$	$2^{++}(0^+)$	2339	319	$\phi\phi$	MPS	Glueball

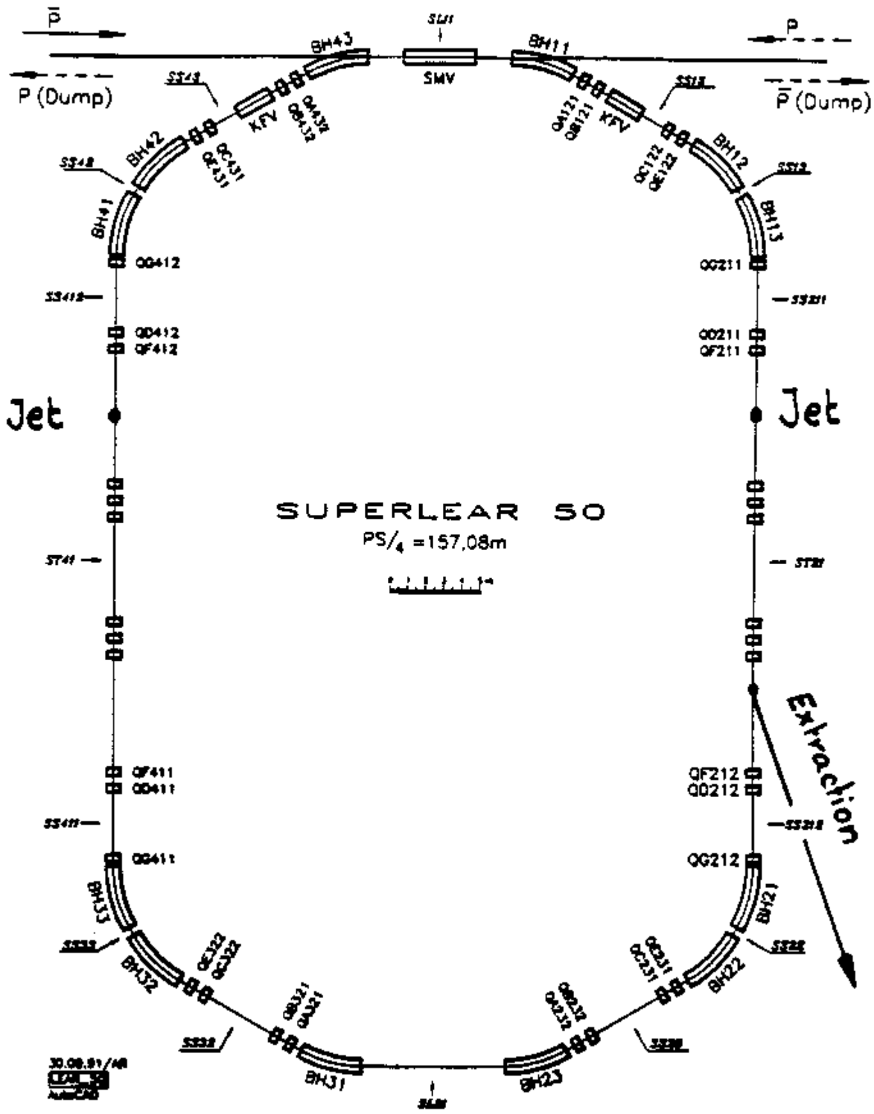


Fig. 1: SuperLEAR version SL50 with two jets and one extraction.

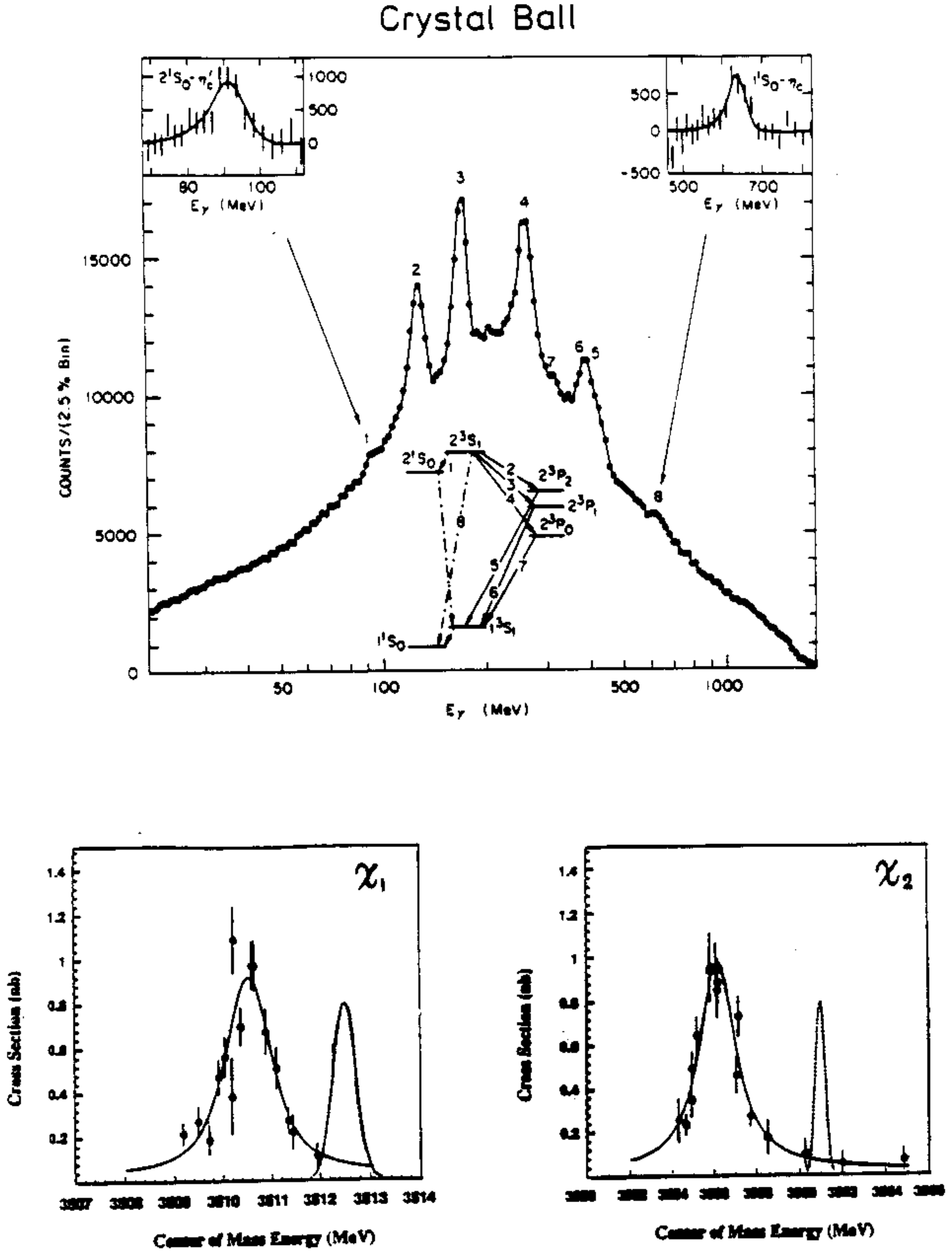


Fig. 2 Inclusive γ spectrum from ψ' decay [16] (top); excitation function of χ_1 and χ_2 at E760 [17] (bottom). The dotted peak shows the beam resolution.

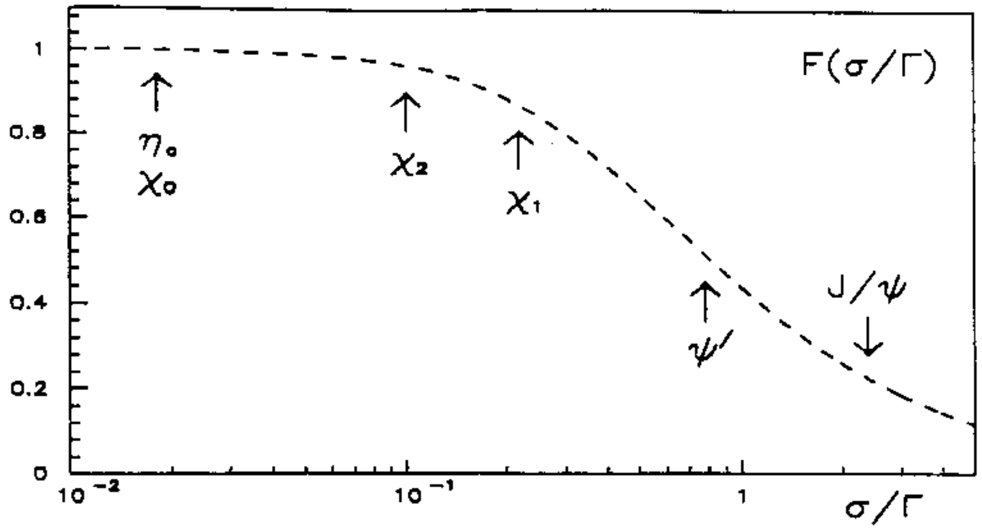
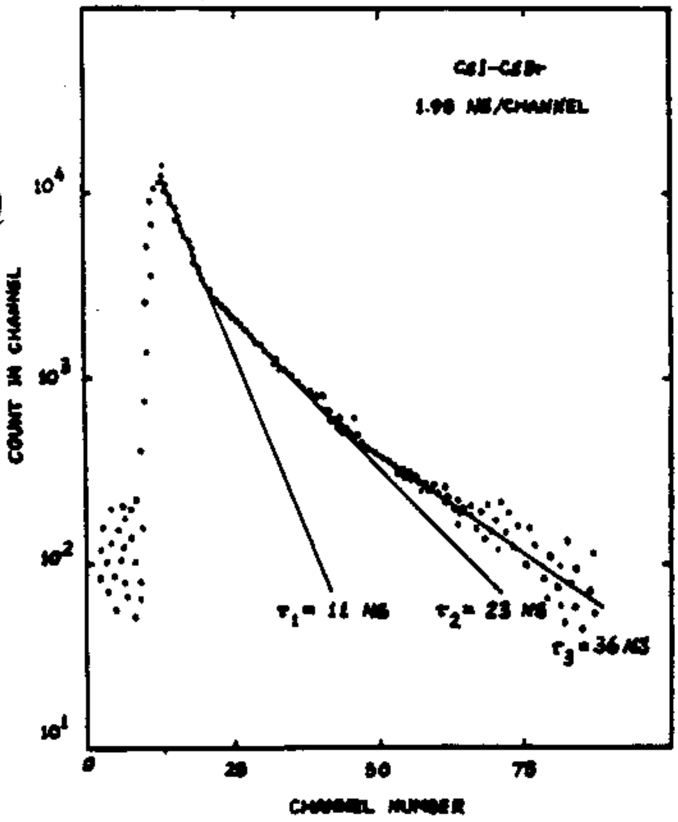


Fig. 3: Function F versus σ_b/Γ (see equ. 4). The arrows show the values of F for a mass resolution $\sigma_b = 210$ keV.



		Pure CsI	CsI-CsBr Mix
Density	g/cm^3	4.41	4.41
Rad. Len.	cm	1.86	1.86
Molière Rad.	cm	3.8	3.8
Hygroscopic		Slight	Slight
Emission Max.	nm	305	310
Decay time	ns	≈ 10,1000	10-30
After Glow	% after 3ms		≈ 1
Light Yield	N/MeV	$2 \cdot 10^4$	
Light Yield	% NaI	4*	18
Rad. Hardness	Rad	> CsI(Tl)	> 10^6

* The fast component.

Fig. 4 Decay time distribution of CsI-CsBr (left, from [24]). One channel corresponds to 1.95 ns; (b) Properties of CsI-CsBr (right, from [23]).

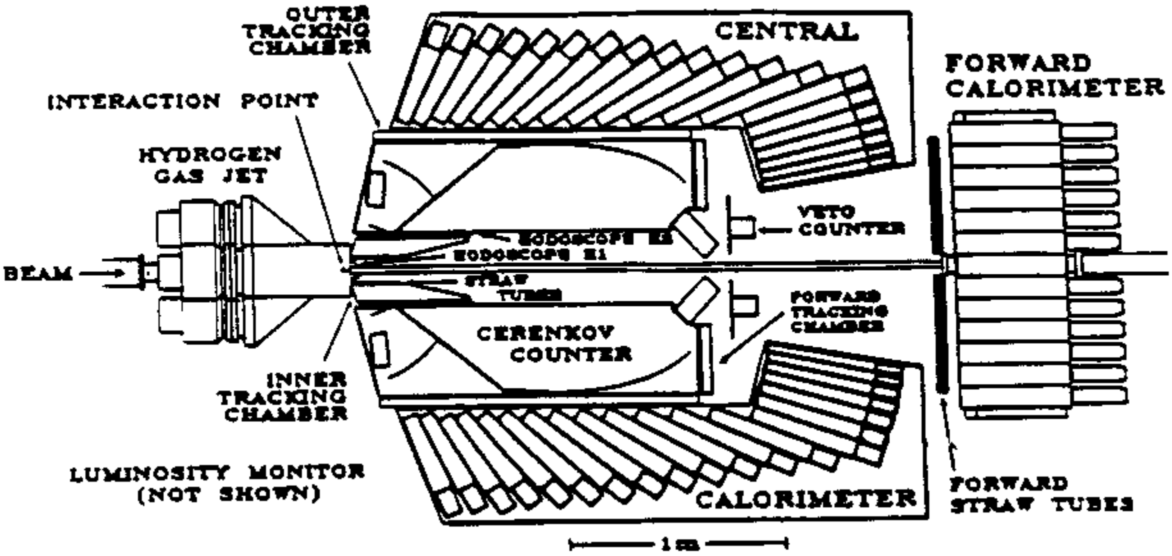


Fig. 5: The E760 detector for which the lead-glass calorimeter would be replaced by CsI-CsBr.

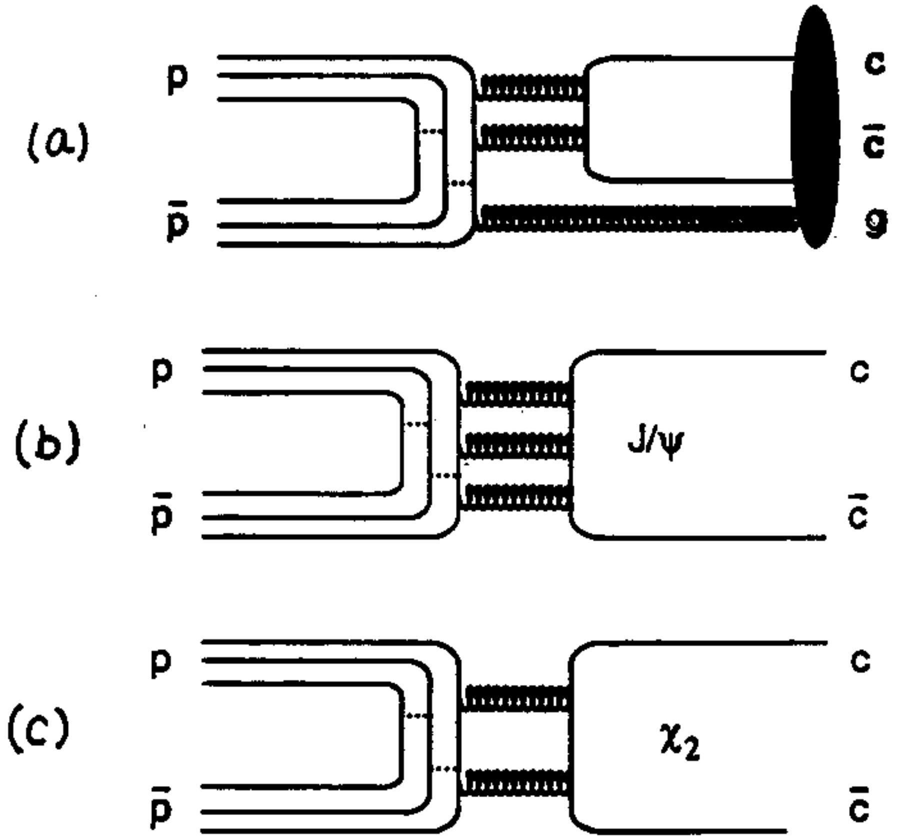


Fig. 6: Formation of hybrids (a), J/ψ (b) and $\chi_{0,2}$ states (c).

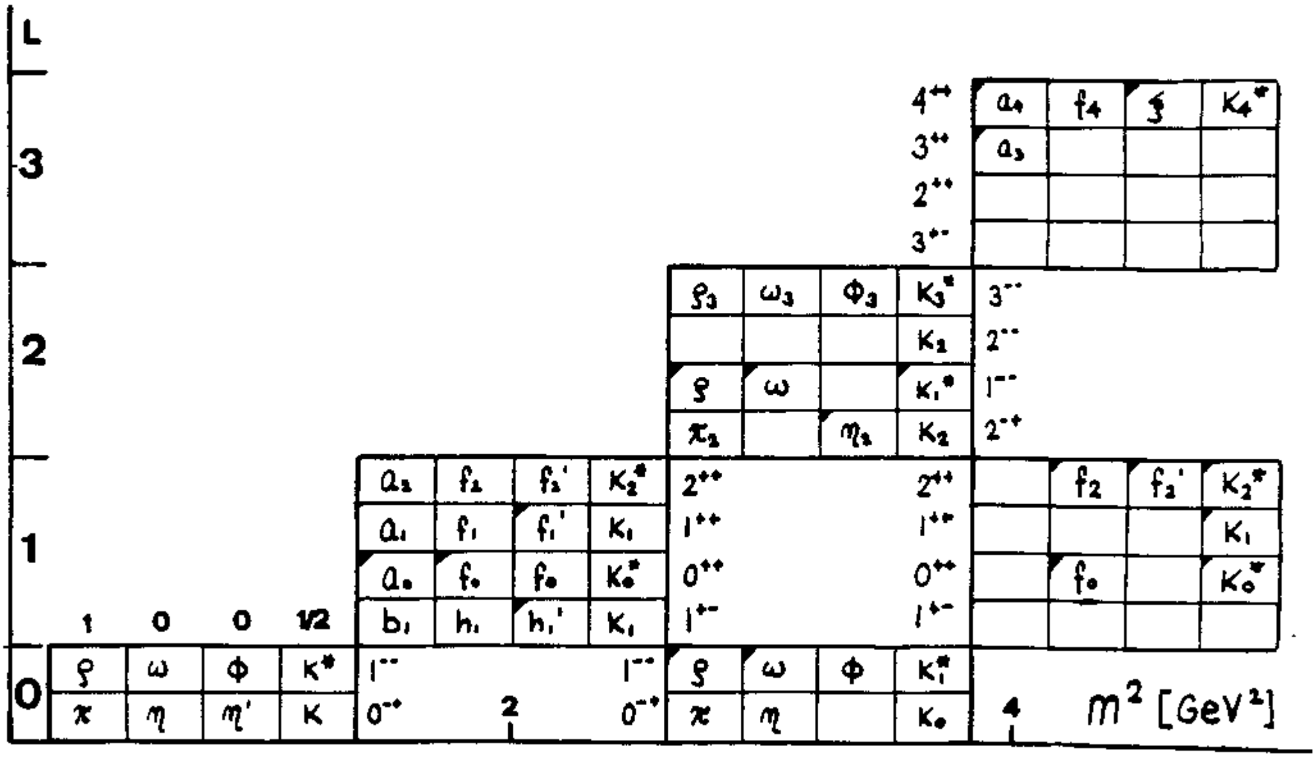


Fig. 7: Summary of $q\overline{q}$ mesonic states. Shown is the angular momentum versus m^2. Boxes marked with a wedge indicate states which are either not established (not included in the PDG summary table) or for which the classification is controversial.

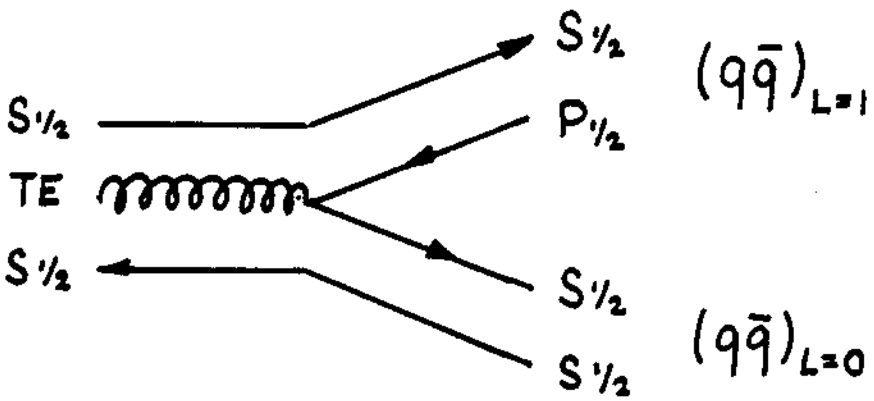
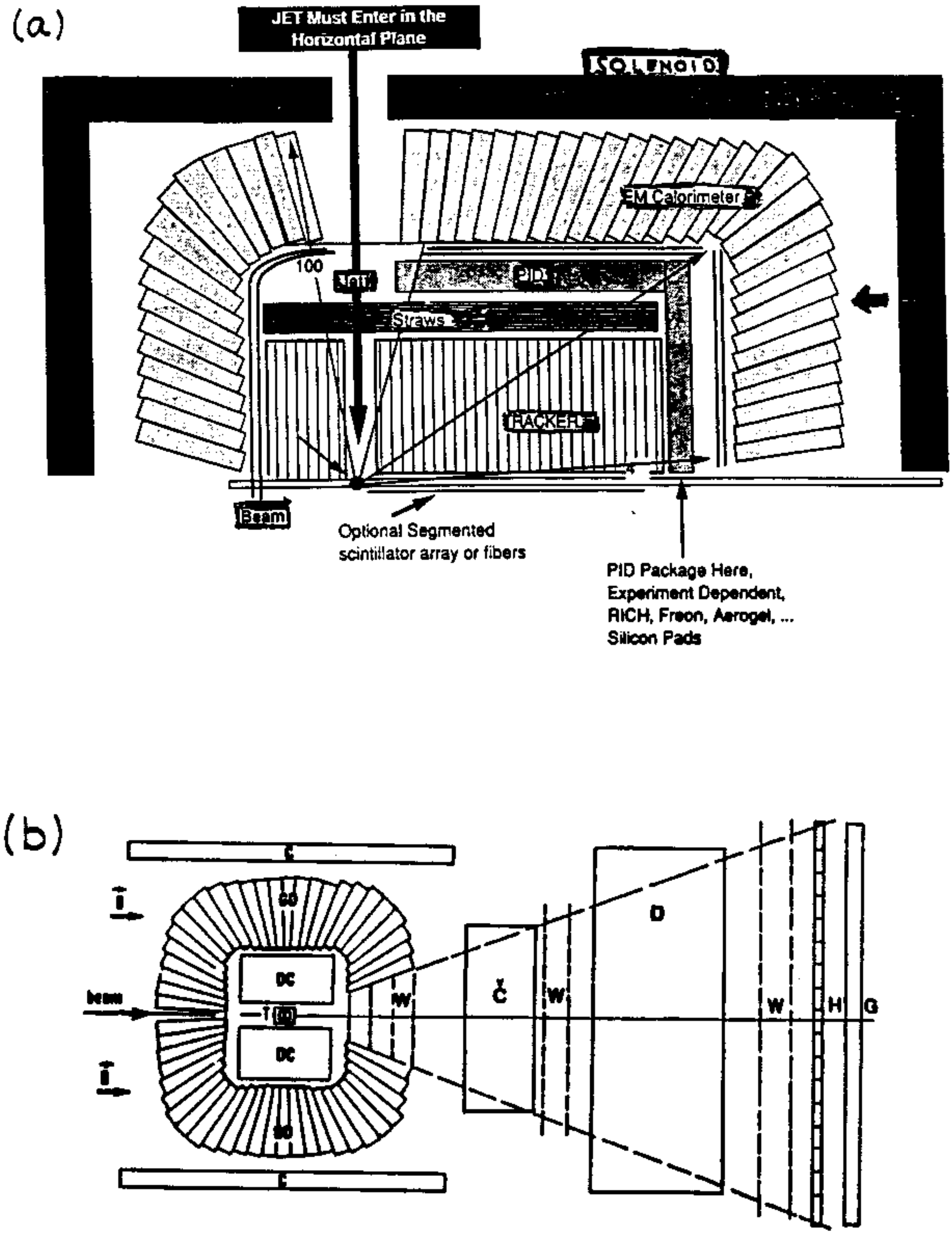


Fig. 8: Decay of a hybrid meson into S- and P-wave mesons



A possible layout of Hadron Spectrometer - Major elements are solenoid magnet (C), crystal barrel (GD), drift chambers (DC), proportional wire chambers (W), Cerenkov counter (Č), dipole magnet (D), hodoscope counter (H), and lead-glass detector (G).

Fig. 9 (a) A possible detector for light quark spectroscopy around a jet target (from [35]). The detector shown in (b) would be installed on the extracted beam (from [33]).

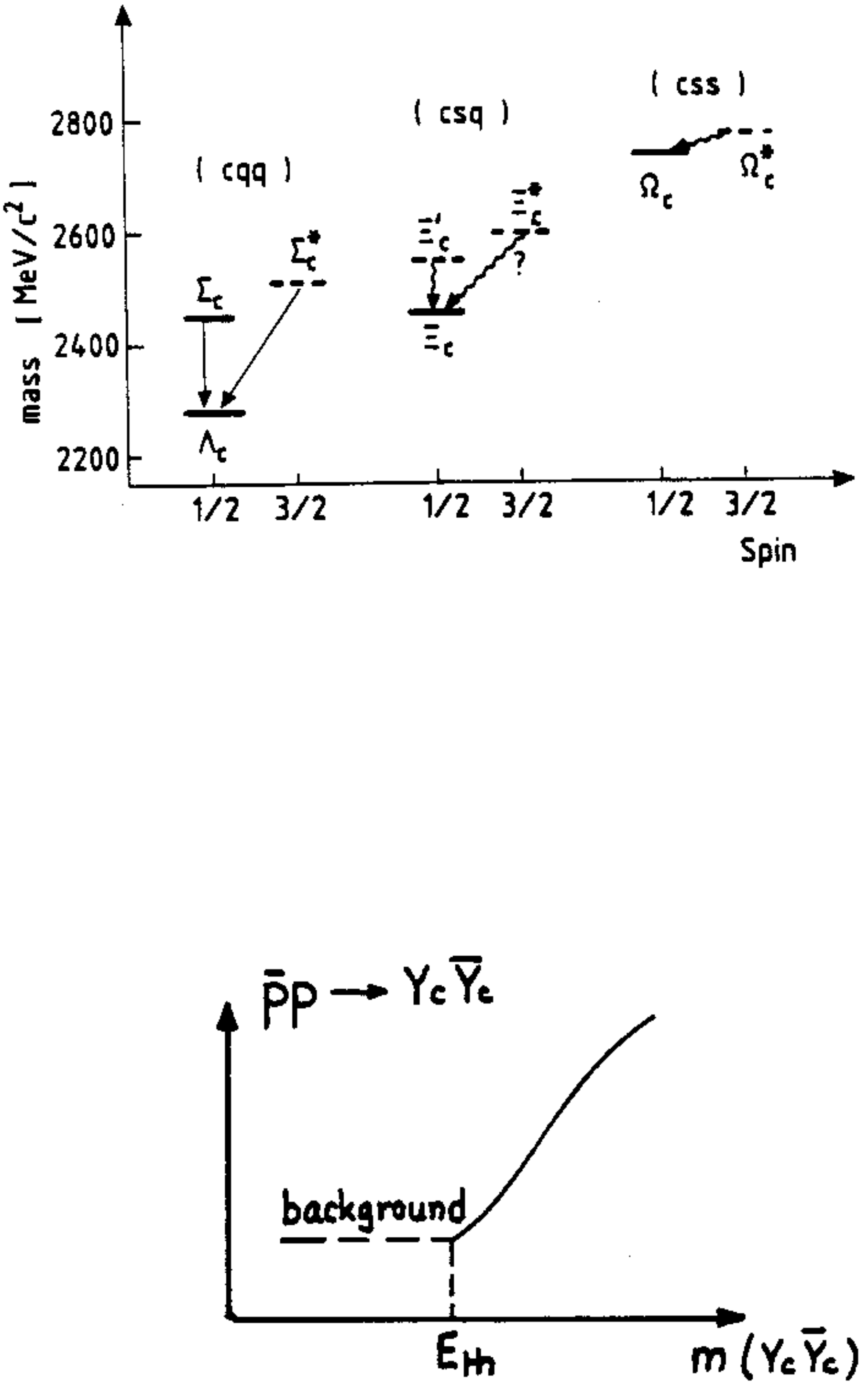


Fig. 10 (a) Level scheme of the charmed baryon ground states. Straight arrows denote pionic decays, wavy lines radiative decays (reproduced from [63]. (b) Threshold production of charmed baryons at SuperLEAR.

APPENDIX: Workshop Programme

P. Darriulat	CERN	Introductory remarks
		Machine Aspects
P. Lefèvre	CERN	SuperLEAR
S. Maury	CERN	Status of the antiproton source
H. Kaiser	DESY	The HERA superconducting magnets and their extrapolation to smaller rings
P. McIntyre	Texas A&M	Superferric SuperLEAR
P. Vobly	Novosibirsk	Superconductive magnets for SuperLEAR
M. Macri	Genova	Jet targets
		Quarkonium
F. Close	RAL	Gluonic charmonium
K. Königsmann	Munich	Open problems in charmonium spectroscopy
A. Martin	CERN	Where are the 1^1P_1 states in heavy quarkonia?
R. Cester	Torino	Charmonium at Fermilab
S.Y. Hsueh	FNAL	Charmonium physics in Fermilab E760
J.K. Bienlein*	ETH	Estimates for $\psi(3.77)$ formation at SuperLEAR
M. Faessler	Munich	Experimental search for charmonium hybrids
A. Noble	Zurich	Fast crystals
P. Dalpiaz	Legnaro	Bottomonium, a future option for SuperLEAR
		Charmed Baryons
P. Kroll	Wuppertal	Exclusive production of heavy flavors
P. Volkovitsky	ITEP	Masses of low-lying and excited charmed baryons
J.P. Stroot	IISN Belgium	Experimental study of charmed baryons
S. Paul	Heidelberg	Charm in hyperon beam experiments
		$\bar{N}N$ Scattering
C. Leluc	Geneva	Nucleon-antinucleon scattering
B. Pire	Palaiseau	Elastic scattering at large momentum transfer
R. Bertini*	Saclay	Energy dependence of Ay in $\bar{p}p$ elastic scattering
F. Iazzi	Torino	Lifetime of the antineutron
		CP Violation in Λ Decay
H. Steger	CERN	CP violation in hyperon decay
N. Hamann	CERN	Experimental approach to CP violation in hyperon decay
		Charm in Nuclei
B. Kopeliovich	Dubna	Color transparency
D. Kharzeev	Moskow	Charm in nuclear matter
D. Kharzeev	Moskow	Production of supernuclei by $\bar{p}$ beams
P. Volkovitsky	ITEP	Subthreshold charm production
K. Maruyama	Tokyo	Search for nuclear bound charmonium
K. Seth	Northwestern	$\bar{p}$-nucleus experiments
F. Nichitiu	Dubna	Multinucleon annihilation in $\bar{d}d$ annihilation
J.M. Richard	Grenoble	Multiquark states

		$\overline{N}N$ Reactions
J. Vandermeulen	Liège	Strangeness production in $\overline{p}p$ annihilation
B. Kopeliovich	Dubna	$\overline{p}$-annihilation on protons and nuclei at intermediate energies
V. Simak	Prag	$\overline{p}p$ annihilation above 2 GeV/c
W. Oelert	Jülich	Heavy hyperon-antihyperon production
B. Kerbikov	ITEP	$\overline{p}p \rightarrow \Xi\overline{\Xi}, \Omega\overline{\Omega}$ close to threshold
D. Woitschitzky	Karlsruhe	$\overline{p}p$ reactions via double annihilation
F. Myhrer*	South Carolina	The phenomenal maximum asymmetry in the reactions $\overline{p}p \rightarrow \pi^+\pi^-$ and K^+K^-
U. Wiedner	Hamburg	Experimental tests for strangeness in the proton
		Light Quark Spectroscopy
S. Godfrey	Carlton	The meson spectrum in the 2-3 GeV mass range
E. Klempt	Mainz	Non $q\overline{q}$ states in light meson spectroscopy
J.P. Stroot	IISN Belgium	New states from GAMS in the 2 GeV mass region
S.U. Chung	BNL	Current status of mesons with masses greater than 2 GeV
D. Hertzog	Illinois	Experimental search for exotics
M. Kunze	Bochum	Meson spectroscopy experiments above 2 GeV/c
H. Noya	Hosei	An analysis of the heavy exotic mesons
A. Green	Helsinki	Gluon degrees of freedom in the $q^2\overline{q}^2$ system
U. Gastaldi	Legnaro	Meson spectroscopy via differential measurements
C. Dover	BNL	Conference summary

* Written contribution only