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FRONTIERS IN NUCLEAR PHYSICS

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Every four years we meet at these big conferences at which the entire broad spectrum of nuclear physics is represented. What is then the purpose of these conferences, for which many of us travel halfway around the world? Doubtlessly they serve as a platform for discussions, as a sounding board for latest results and ideas as well as a source of information for learning about the principal developments in areas not so close to our speciality. But if this was the purpose, it is largely served as well and maybe even better by many smaller conferences.

The outstanding role of a conference of the present format is a quite different one. Its unique and truly important role is that it permits us to gauge the development of nuclear physics as a whole in a broader perspective, to see the straws in the wind which indicate the future areas of main developments. It is the presence of experts representing all the varying special research lines and the differing national profiles which make such a perspective of special value. This necessity for self-examination at regular intervals is particularly important to a mature field like nuclear physics. In fact our field is so mature that its applications permeate our society in a wide number of fields. We are in daily contact with it in our everyday life, sometimes for good, sometimes for bad. I will not dwell on those important issues concerning our society; you are all aware of them. I will today confine myself to the specific topics of the present conference, those of nuclear structure.

If we look back for a moment, it is clear that nuclear physics in the last few decades has been profoundly and lastingly dominated by the remarkable breakthroughs associated with the understanding of how nuclei are organized in terms of valence nucleons and their couplings to the collective degrees of freedom. This picture opened up a goldmine of new research lines and has successively led us to a detailed understanding of the nature of the forces responsible, how they are generated and under what circumstances drastic new effects can occur. Of the many discoveries based on these ideas, I need only to mention two of the more recent ones: the discovery of the structure in the fission barrier with its isomers and the discovery of the sudden changes in the moment of inertia at higher rotations, what we call back-bending. This exploration of non-trivial consequences still continues actively and successfully; the remarkable discovery in the last few months of nuclear isomers of extremely high spin, decaying after 100 nsec by the emission of a cascade of 15 γ -rays, bears ample witness to this¹⁾. In spite of this we are at present in a transition period. Over the last few years, new areas of nuclear physics of qualitatively new nature have grown up. These are based on the realization that nuclei can have other degrees of freedom than neutrons and protons. This has made possible entirely new forms of nuclear objects and of nuclear matter.

Let us first rapidly examine which areas of nuclear physics we may expect on general grounds to change our concepts of nuclei and to give discoveries of importance in the next few years. Clearly these areas will be outside the standard frame of reference. Our understanding of nuclei at low excitation and in the stable regions of the periodic system is much too good by now to allow for drastic changes. Instead, new phenomena are much more likely to occur when the nuclei are in some extreme condition, or probed in some extreme or particularly delicate way. As for areas of qualitative surprises, I would list the following:

- 1) Particularly neutron rich and neutron poor elements at the edge of stability: in these regions the usual balance of the forces has been strongly changed.
- 2) High-mass nuclei beyond the presently known regions, in particular superheavy elements.
- 3) Nuclei forced into extremely rapid rotations: the centrifugal and Coriolis forces will force unusual rearrangements of the internal structure.
- 4) Short distances, i.e. exploration of nuclei with short wavelength probes which can reveal very fine details.
- 5) Structures of nuclear type formed by unconventional particles, and new forms of nuclear matter [hypernuclei, $\bar{p}$ systems, ...].
- 6) New nuclear degrees of freedom, in particular the pionic ones.

Now this is my personal list. Doubtlessly some of you have a few variants, but the principle is always the same: it is in the new areas that the qualitative surprises will occur.

Let me now illustrate these points in a more concrete fashion. It has been fortunate for me that the last few months have been rich in developments which in many cases have missed the deadlines for the Conference^{*)}.

It is becoming increasingly clear that high-energy accelerators, normally associated with elementary particle physics, are also extremely powerful producers of very neutron rich and proton rich nuclei of quite different composition than those near stability. The reason is a very simple one: the targets used are extremely thick with typically 300 g/cm^2 as compared to those of heavy ion machines with 10^{-3} g/cm^2 . In spite of more unfavourable cross-sections the gain is a factor of 10^3 . A beautiful example of the power of these machines is the discovery, in July, of a new region of deformed nuclei²⁾. A target of uranium was bombarded with 20 GeV protons, and the Na isotopes were analysed by a mass-spectrometer. These isotopes were observed up to ^{35}Na , which by itself is quite a record. The decay

*) By agreement with Dr. J.P. Schiffer my examples will mainly concern developments connected to intermediate energy physics or high-energy machines.

of these isotopes to Mg was then observed (Fig. 1). The most striking observation is that the energy of the first excited 2^+ state in the even Mg versus neutron number dramatically decreases at the "closed neutron shell" $N = 20$, i.e. $A = 32$ (Fig. 2). The obvious interpretation is a sudden increase of moment of inertia. Although most of the experiment is not yet analysed, a number of factors point in the same direction. The sophistication of the experiment is such that hyperfine studies of the Na isotopes with laser spectroscopy is carried out: these indicate an increase in $\langle r^2 \rangle$ in the same region. The later analysis should also give quadrupole moments. Stimulated by earlier data³⁾ from the group, several Hartree-Fock explorations have been performed. A spherical study⁴⁾ indicates that in these neutron rich nuclei the normal $N = 20$ closed shell is replaced by the shell numbers $N = 16$ and 32 , so that the anomaly is in the middle of a neutron shell, a good condition for deformation. A deformed study⁵⁾ indicates the possibility of strong deformations. Taken together with the anomalies observed in the Q -values by the group, the evidence that heavy Mg and Na are very deformed becomes a strong one.

A second example is provided by the recent observation⁶⁾ of the most proton rich nucleus ever seen, ^{32}Ar with a surplus of 4 protons (Fig. 3). In a certain sense such a nucleus is a challenge simple because it is there, just as the north wall of the Eiger is a challenge to the mountaineer, and there is a great joy in victory of such obstacles. It has however, already been put in use as the most accurate existing test of the electromagnetic mass formula $E = a + bT_z + cT_z^2 + dT_z^3$, with the coefficient of the cubic term being zero to high precision.

Electrons and muons have traditionally served as the best probe particles for the distribution of nuclear charges, since their interaction is weak and very well understood. In the past it was the habit of assuming arbitrarily that the nucleus had a "reasonable" shape, characterized by a few parameters and then adjust these to fit the experimental results. The last few years have witnessed the development of model independent methods of analysis which permit accurate mapping of both static and transition charge densities. At the present moment we are reaching a stage, in which we obtain, in certain cases, a vividly concrete image of the nucleus so direct that it is as if we had put it under a powerful microscope, which in a sense is exactly what we are using. In Fig. 4 static and transition densities for rotational bands have been combined in a nearly model independent way⁷⁾; one notices how it is actually possible to see the development of two regions of enhanced density inside the nucleus. It is obvious that such pictures will be a concrete guide to the better understanding of fission phenomena.

The great precision of the present electron experiment is illustrated by a submitted paper in which the cross-section on ^{208}Pb has been studied over not less than 11 magnitudes⁸⁾. This new level of precision reflects itself

remarkably in the corresponding charge distribution (Fig. 5) with errors of the order of 1 % even in the central region, and much more accurate elsewhere. For comparison, there is a theoretical density obtained from a mean field calculation which clearly disagrees with data. The mean field Hartree-Fock method used for the comparison is in a way a direct extension of the shell model with the collective adjustment of the nucleus included; in addition it systematically generates its own shell model potential from the force. Doubtlessly, the effective force can still be better understood from the remaining disagreements. Still, at present precisions, we have probably reached the end of the power of the mean field method: at the present level, mesic effects and nucleon size affect the charge density. While it may be possible to adjust parameters for an exact fit to data, the phenomenological forces will most likely be meaningless in their precision. Electron scattering of today breaks out from a description of nuclei consisting of point neutrons and protons, a basic assumption of the mean-field method. This point is seen more clearly in Fig. 6, which represents the charge density of ^3He with the proton size included and excluded⁹⁾. A very clear dip in the central charge is strongly changed by the proton charge cloud. For comparison, the two theoretical curves indicate the importance of including or excluding exchange currents.

It is thus clear that high precision electron-scattering data at present have reached the point at which it is now unavoidable to explicitly discuss relativistic effects, the nucleon extension in the nucleus, and the modification of the meson cloud by other nucleons.

It is interesting to contrast the electron-scattering data on charge distributions with our knowledge of neutron distributions. Traditionally all our information on neutron distributions of nuclei has been most disappointingly crude. This situation is now changing. Accurate experimental data on proton scattering in the GeV region is now available and, most important, begins to be quantitatively interpretable. Figure 7 shows such data for Ca and Ni isotopes from a contributed paper¹⁰⁾. Since the accuracy of the discussion is far from that of the charge density data, one can still assume the nucleus to consist of neutrons and protons. Insofar as their interaction with the fast proton is understood from the NN free interaction, it is possible to make a model independent analysis of the neutron distribution. This has now seriously been attempted^{10,11)} and it is claimed that the neutron charge radius can be determined to a few % precision. While conclusions are subject to caution, it seems that the uncertainties are not predominantly in the NN interaction, but in the experimental precision. Of course such an analysis neglects the possible mesic contributions. One may ask which region of the neutron distribution is probed in this way, and this is roughly illustrated in Fig. 8; it is mainly the surface region which is probed with precision. The importance of the present discussion is not whether one now learns about the neutrons with the claimed accuracy or not, but that this question is now clearly attacked on a quite new level of ambition.

Although this way of looking at proton data holds considerable promise for learning about neutron distributions, or at least about differences in neutron distributions between nuclei, one can also look at the data in a cruder, but radically different way. In the past decade, the theory of diffraction from a purely classical object has made strong advances which have only in part been applied to nuclei¹²⁾. In particular, outside a forward region of geometrical diffraction, it has been demonstrated that for any convex surface, the diffraction scattering is dominated by "creep waves" following geodesics on the surface. The "elementary bundles" of light associated with these eigenpaths are "eigenfunctions", in a way, for the system. If we now simply plot¹³⁾ the p-nuclear high energy cross-section versus the characteristic diffraction variable $kR\theta$ from ^{12}C to ^{208}Pb (not versus qR !) we find crudely the characteristic diffraction maxima and minima at the expected places (Fig. 9): this is rather trivial. What is not well known however, is that classical diffraction theory predicts a characteristic average fall-off $\propto \exp \{-c (kR)^{1/3} \theta\}$: the imaginary part of the Regge pole depends on the "crazy variable" $(kR)^{1/3}$ or more generally on the radius of curvature. A plot versus this variable shows that the curves indeed are remarkably parallel throughout the periodic system (Fig. 10). This result raises a number of interesting questions since diffraction clearly plays an extremely important role here:

- 1) Analytical relation between the multiple scattering approach and diffraction, at least in the limit of high k ? The two approaches should be complementary in the limit.
- 2) Which are the characteristic features in the angular distributions which determine the form factor beyond an effective R and a surface thickness?
- 3) Since inelastic phenomena of diffraction type are characteristic of nuclei as opposed to classical systems: are there general, rigorous results of similar type applicable to inelastic and coupled channel reactions for nuclei and in particular to heavy ion reactions?

At present beautiful studies of complex paths and Regge pole approaches to nuclei have been made, but to my knowledge they have not approached the problem in this spirit.

At this point let me turn to the question of the NN interaction, in which some important developments have recently been taking place. The interaction between pairs of nucleons, the NN force, plays traditionally a central role in nuclear physics. The origin is not only the wish to understand nuclear matter as well as neutron matter on this basis, but also the wish to make a direct contact between the properties of finite nuclei (or more realistically, the effective interaction in finite nuclei) and the force. The traditional viewpoint has been to see the NN potential as generated by a series of Yukawa like interactions due to single meson exchange (OBEP = one boson exchange potential) (Fig. 11).

Each one of the mesons I have indicated in the figure plays its crucial role in the description of the force, since each is responsible for a major, characteristic feature of the NN interaction (like spin-orbit with right sign). The inclusion of these mesons guarantees a qualitatively correct description of the force. The cuckoo in the nest is the light σ -meson with $J = 0^+$ and $T = 0$. Experimentally, there simply is no such light meson. This is embarrassing: the σ -meson gives a central, attractive potential which adds up coherently to a very major component in the nuclear binding energy. This is in contrast to the π -meson, which to leading order gives no contribution at all the binding energy, contrary to widespread popular belief.

It has been known for a long time that 2π exchange with isobar excitation simulates important features of the σ -exchange. In the last few years this view has been transformed into quantitative statements¹⁴⁾ and incorporated in the best NN potential presently available, the Paris potential¹⁵⁾. The new picture is one of dominance by the Δ isobar, whether excited once, or on both sides in the interaction (Fig. 12).

One might wonder why the 2π exchange should have such a privileged role. The reason is conceptually a most interesting one: it is a pionic van der Waals interaction as shown in a contributed paper¹⁶⁾. Consider the interaction between two neutral spinless atoms due to photon exchange: the interaction requires atomic excitation on both sides and 2γ exchange (Fig. 13): the virtually excited state (e.g. the induced dipole) polarizes the other atom and induces another dipole in it which reacts back with the first one. In this way characteristic interactions appear in the long range region like the atomic induced dipole-induced dipole one $\propto r^{-7}$, or the dipole-induced dipole one. It is important that the long range strength of the interaction is entirely described by a characteristic structure constant, the electric polarizability. The nucleon-nucleon case in Fig. 12 is exactly parallel in the physical mechanism: the photon is replaced by the pion, the Δ isobar excitation is only the simplest and most important contribution to the axial polarizability of the nucleon, i.e. to the πN scattering by the exchanged π . Of course the range of this force is governed by the usual exponential damping factor, since the π has to go to the other nucleon and then back again. In this way one finds that outside a range of 1 to 1.5 fm the 2π interaction is nearly model independent and that all the usual van der Waals forces (dipole-induced dipole, induced dipole-induced dipole, charge-induced charge, etc.) come into play, each with its characteristic, but model independent potential shape. It is indeed most remarkable that we now suddenly find that nuclei are bound, not be the traditional Yukawa mechanism, but by the van der Waals mechanism. The molecular binding of the ordinary matter around us and the way nuclei are kept together are fundamentally due to the same basic physical mechanism. It is no accident both are attractive.

From about 0.8 fm and inwards the NN forces are largely phenomenological concepts carefully adjusted to NN-scattering data. It would be wrong to attach too strong importance to their detailed properties there. This situation is particularly accentuated from 0.5 fm and inwards, since the very strong repulsion generated by ω -exchange prevents all explorations at present of this region. Indeed, inside this region we could very well have free quarks. It is interesting to note that one can generate both a strong short ranged repulsion and a short range tensor force of correct sign from the MIT quark bag picture.

Therefore, the long to medium range NN force is very well founded and understood, while it is mainly phenomenological in the inner regions. What are then its predictive powers in a novel physical situation? Can it be applied in radically new circumstances? Such a possibility exists in the low energy antinucleon-nucleon system. If we accept the one-boson-exchange picture for the sake of argument, we should be able to understand its properties, since the couplings are the same (Fig. 14). The only change (apart from annihilation) is that some of the potentials change sign: $V_{\pi} \rightarrow (-)V_{\pi}$ and $V_{\omega} \rightarrow (-)V_{\omega}$. In particular, the strong ω -repulsion becomes a strong attraction. This opens the possibility of numerous bound states in the $\bar{N}N$ system, if it can be suitably protected from too fast annihilation; the $\bar{N}N$ interaction indicates strongly the possibility of deuteron like, weakly bound or resonant systems near the threshold region of 2 nucleon masses¹⁷⁾. These systems would differ from the usual high-energy states mainly by the purity of their wavefunction which would be dominated by the nucleon-antinucleon aspect. Numerous states are predicted with spacings of 50-100 MeV and varying spins. Are they there? On the theoretical side there are various uncertainties, in particular due to the annihilation which is not well controlled. Experimentally it has become clear lately, and in particular during the year, that this region is very rich in structures. Apart from a previous clear narrow resonance at mass 1935 MeV¹⁸⁾, one has very recently found several new narrow resonances at somewhat higher energy¹⁹⁾ (Fig. 15). Perhaps even more exciting, a contribution reports²⁰⁾ the observation of 4 γ -rays in the several 100 MeV region from the stopped $\bar{p}p$ systems (Fig. 16). The 3 of these associated with possible bound states may be candidates for expected P states if the radiation is E1. At the present moment this area is in rapid development. The crucial task is now to establish the quantum numbers of the observed states so as to obtain a detailed quantitative comparison with theoretical possibilities. Although it is at present equally possible that the structures are more a branch of quark physics, it provides the first qualitatively new prediction of our picture of the NN force and it may very well turn out to be a natural extension of nuclear physics. Whatever the outcome, these new near stable states of matter and antimatter are quite exciting.

Traditionally nuclei are thought of as consisting primarily of neutrons and protons. Any ordinary nucleus is full of virtual mesons, however. Are these mesons just carried by the neutrons and protons? Nucleons are densely packed in the nucleus, and we must expect important deviations from that picture. Effects of nuclear mesons have always been there as exchange currents, usually small special effects, but at present this issue has come into focus for various reasons. Areas like electron scattering have now reached a precision at which meson effects are significant even in static charge distributions. In addition, the understanding of the interactions of physical pions with nuclei from intermediate energy physics now opens up the possibility of an entirely new view of the nuclear meson degrees of freedom. Of these the pionic one has a very privileged role because of its long range, low mass and easy excitability. How do nuclear states couple to this degree of freedom? By now it is clearly established that pions are closely linked to axial excitations of collective spin-isospin character, in other words to states characterized by strong Gamow-Teller type strength in β -decay. This is illustrated by the states populated in the radiative π capture process at rest ($\pi^- {}^{12}\text{C}, {}^{12}\text{B}^* \gamma$) with $E_\gamma \approx 130$ MeV [Fig. 17]²¹⁾.

The strong link to the nuclear axial current is a central aspect of the pion field. It has, in particular, consequences for the nuclear weak interactions. How nucleons change their properties like magnetic moments or couplings inside nuclear matter is an old question. It is now natural to see the weak axial coupling constant g_A of a nucleon renormalized in the nucleus, simply because the πN coupling is changed by the presence of other nucleons²²⁾. This raises a more basic question: is the nuclear axial current so closely linked to pions that it is identical to pion physics? In fact, it is likely that there is a very deep relation. From two simple statements: a) partial conservation of the axial current (PCAC) and b) axial locality²³⁾, namely that the axial current is locally determined by its source, the current becomes purely pionic. From this the usual theory of β -decay follows, including exchange currents²²⁾, but the consequences are far stronger and do not even assume the nucleus to consist of nucleons. This means a unification of the physical pion interaction with certain low-energy nuclear properties: axial β -decay, for example, can now be seen as a branch of π physics. We may speculate whether a similar unified view can be applied to magnetic effects.

The development at present of a clearer picture of the role of pions also changes our attitude to nuclear 3-body forces. The traditional attitude to nuclear 3-body forces was well expressed by Peierls in an earlier introduction to one of these conferences: "Push the hypothesis of 2-body forces as far as we possibly can. If we finally come to the conclusion that no form of 2-body forces will account for all the data, then we will have evidence for many-body forces." Here in Tokyo in 1977 this has become a most unnatural standpoint. From our present picture of the nuclear 2-body force, we are forced to have at least some 3-body force, since we otherwise will be logically inconsistent.

Consider in the NN force the diagrams which correspond to the pionic van der Waals mechanism (Fig. 18). If we apply the same picture to 3 nucleons we have naturally three different 3-body forces:

- a) π rescattering in the medium. This primarily renormalizes range and strength of the single π exchange potential²⁴⁾. (Fig. 19).
- b) The 3-body pionic van der Waals forces. The two processes in Fig. 20 have the pions mutually excite the internal degrees of freedom in the nucleons.

The real question is therefore the importance of these 3-body effects. Must we in practice include them or not? Present estimates^{24,25)}, which may not yet be final, indicate that both the π rescattering mechanism and the van der Waals mechanism contribute each about 1 MeV to the nuclear binding: they are certainly not negligible although small.

These long-ranged 3-body forces must therefore be included in the nuclear description, just as the corresponding molecular forces must be included in a molecular problem.

In the 3-body force the rescattering of the pion played as special role. It is clear that the same mechanism can give rise to a cooperative n-body force. If the nuclear density is increased beyond a critical value, these effects become so important that the entire nucleus readjusts and pion condensation occurs²⁶⁾. At present, we have no evidence that any actual nucleus shows such a collective phenomenon, but it has become quite clear that the nuclear density must be close to the critical value. The collective phenomenon has a "single particle" counterpart: the possibility that a physical pion added to a nucleus might bind in a Schrodinger type bound state²⁷⁾. How do such states occur? The π -nuclear optical potential is dominated by an attractive contribution to the kinetic energy. Normally the kinetic energy is always repulsive, and no bound states can appear. However, if the strength of the interaction (or the density) is sufficient, an over-all attractive kinetic energy can result. Since this will favour states with many nodes, we expect then an unusual level spectrum of bound states with an inverted level order: 1s, 2s, ... in order to increasing binding (Fig. 21). In principle, an infinite number of states occurs, but only the weakest bound states have physical significance, since the optical potential approach requires long wavelength. Can such states occur in realistic nuclei, and what are the most favourable conditions? The best conditions are for π^- added to nuclei with high central densities and with a substantial neutron excess in the central region. Most nuclei are not good candidates. Lighter nuclei like ^{16}O and ^{28}Si have 10-20% too weak attraction, and even in ^{208}Pb the attraction is probably slightly too weak. Strangely, the newly discovered heavy Na-isotopes²⁾ are excellent candidates. Their densities have been predicted in the literature⁵⁾. From the published densities we expect binding. Unfortunately these nuclei are all unstable with 10 msec lifetimes, making experimental

observation difficult. Still, this illustrates clearly that the empirical π -nuclear interaction is quite attractive, so attractive in fact, that binding might occur even in some stable nucleus.

It would clearly be of interest to establish a method which would allow direct studies of the virtual pion field. Most nuclear probes are very unsuited for this purpose: they have no selectivity for pions. If we were to ask a similar question about the electrons in deep orbits in an atom, we could consider the process: $e^+ + e^- \rightarrow 2\gamma$ with a reconstruction of binding energy and momentum of the electron from the annihilation photons. This process is highly allowed, apart from the unavoidable factor $(\alpha/\pi)^2 \approx 10^{-5}$. Similarly, for pions we could envisage the nuclear process $\pi^- + \pi^+ \rightarrow 2\gamma$ on a virtual π^+ in the nucleus. Once more the process is basically highly allowed, but suppressed trivially by the factor $(\alpha/\pi)^2$. A post deadline paper²⁸⁾ reports the first observation of this process in ^9Be and ^{12}C with a rate about a factor of three above crude estimates (Fig. 22). Note that the yield at $\approx 90^\circ$ is characteristic as opposed to 180° for π^0 decay. This measurement may well open a novel line of research.

Nuclear physics has always played a very particular role in the discussion of symmetries. It is interesting to ask: What makes nuclear physics so special? The nuclear superiority is mainly this: it selects quantum numbers. As a very striking example consider the $^4\text{H}-^4\text{He}$ isobar doublet. By hypernuclear γ -spectroscopy, the level scheme including the excited state has recently been observed²⁹⁾ (Fig. 23). From the observation that the 0^+-1^+ states are not degenerate, one immediately concludes that the ΛN force cannot be spin independent. From the splitting, the magnitude and sign of the term $\vec{\sigma}_\text{N} \cdot \vec{\sigma}_\Lambda$ in the force can be derived using weak additional assumptions. Further, the two γ -rays differ by $\approx 30\%$! If charge-symmetry was good, they should have identical energy. The large charge symmetry breaking in the spin-spin force is due to virtual excitation of Σ , mainly by 2π exchange: the mass of Σ is close to that of Λ , and there is a substantial mass-splitting between Σ^+ , Σ^0 and Σ^- breaking charge-symmetry. Since in addition the ΣN interaction is stronger than the ΛN interaction, the breaking becomes important.

The second example is that of parity violation by neutral currents on which nuclear physics presently has a word to say. One of the outstanding central questions of modern physics is the possible unification of weak and electromagnetic forces. The vehicle to reach this goal is hopefully provided by so-called gauge theories, which are not plagued by divergence difficulties. Any test of the validity of such pictures is of great significance. In particular, the simplest versions of such theories give specific predictions in the area of weak interactions. The usual weak interactions in nuclei, β decay, have the property that charge changes in the process: for example, in K-capture processes an electron is absorbed and a neutrino is emitted. These processes are due to charged weak

currents. In addition there are neutral weak currents, in which the lepton charge is unchanged as in neutrino scattering. Although such processes are not specific to gauge theories, they have a natural place within them.

One of the strongest probes into the structure of neutral currents as for charged currents is their behaviour under parity. Charged currents violate parity; it is natural to seek for parity violation also from neutral currents. Indeed, the cross-sections of high-energy neutrinos and antineutrinos suggest parity violation for neutral currents. This is however apparently contradicted by two experimental non-observations of parity breaking in atomic physics in Bi: there is no violation observed within a near magnitude of expectations³⁰⁾. Since in atomic physics one deals with electrons, the question is now: is the trouble with the coupling of the electron, or is it with all the neutral couplings?

What do nuclei say about parity for neutral currents? A submitted paper³¹⁾ studies experimentally the ^{18}F case with an expected strong enhancement (Fig. 24). Two close levels of spin 0^+ and 0^- with different isospin may mix by neutral currents. A highly forbidden $T = 0, E1$ γ -ray may have circular polarization from M1 admixture. The predicted level of about 3×10^{-3} , is about present experimental accuracy. Suppose it could be concluded from such an experiment that also nuclear physics has no parity violation by neutral currents, and that this is no nuclear effect, What is then the consequence? We would then have to abandon the present idea that neutral currents are mediated by a single neutral vector boson Z_0 , and at least two such bosons would be necessary. Although less simple than single vector boson exchange, this is a legitimate alternative.

The examples I have just discussed were all taken from very recent developments made during the last year, in fact mainly in the last few months. Indeed, a number of them missed the deadline of the present conference. This demonstrates how nuclear physics today once more develops quickly and vigorously along new frontiers. There are new discoveries, new phenomena with rapid changes both in outlook and concepts, and others are probably just around the corner. While I have particularly stressed the new frontiers of high-energy and nuclear meson structure, important developments and discoveries also happen in traditional areas, like the just discovered yrast traps. Nuclear physics is, in this way, both a very old and quite young field. This is what makes it so exciting and such a challenge. In this spirit of excitement in front of new developments and discoveries let us now go on to the discussions of the main part of the conference.

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Figure captions

- Fig. 1 : The ^{32}Mg excited state populated in $^{32}\text{Na}(\beta, \gamma)^{32}\text{Mg}$
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Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 10

Fig. 9

Fig. 11

Fig. 12

MOLECULES

NUCLEONS

Induced dipole - Induced dipole

$V \propto r^{-7}$; $V \propto$ (model independent
rather complicated)

Fig. 13

Fig. 14

Fig. 15

Fig. 16

Fig. 17

Fig. 18

Fig. 19

Fig. 20

Fig. 21

Fig. 22

Fig. 23

Fig. 24