Honorary Doctorate Ceremony for Jonathan Dorfan, 6 July 2009

Laudation, Klaus R. Schubert (TU Dresden)

Magnifizenz, Herr Dekan, liebe Kolleginnen und Kollegen, meine Damen und Herren, dear Jonathan and Renee,

Our University is very proud that you, Jonathan, accepted the offer to receive the academic degree of a Doctor rerum naturalium honoris causa, and I am very happy to present the laudation today. You were the essential person in the BABAR experiment and its preparation. The name BABAR is well known in our University since this project dominated the activity of the University's Particle Physics Group since its foundation in October 1993.

In the same week when I started here the new field of Particle Physics, the United States Parliament approved construction of the project which you had developed for investigating B-meson decays, the electron-positron collider PEP-II at the Stanford Linear Accelerator Laboratory SLAC. The approval included construction of a new detector which we named BABAR two years later. In our University we profited very much from the work with BABAR. We were challenged by detector construction work, we placed orders in local industry, we developed computer code for analyzing data, and we gave very ambitious physics questions into the hands of our students. We successfully completed 24 Diploma and 15 PhD Theses in Dresden, many of them leading to BABAR publications in Physics Letters and Physical Review. The intensive work in a large international collaboration was of additional benefit for our students; this experience helped them in finding very good positions later.

However, the benefits for our University are not the primary motivation for Jonathan's distinction today. Of much higher importance is his contribution to the history of elementary particle physics. As a result of the measurements with BABAR, physicists have understood how Nature can succeed to break the symmetry between matter and antimatter. The efforts for gaining this understanding were tremendous. They required a new particle accelerator, here an electron-positron collider, a new detector, 600 highly motivated and knowledgeable engineers and physicists, and a personality who can steer them: a personality with great enthusiasm for the physics question, with wide experience in solving the experimental problems, and able to steer with an always consequent view onto the goal to be reached. Jonathan had all these properties, this talent, and this experience. He has developed the project, has convinced all decision makers to start it, and he has led the construction of collider and detector. He is the father of the project‘s success.

To show where he gained his experience, let me present a short biography. Jonathan Dorfan was born 1947 in Cape Town, South Africa. He studied physics at the University of Cape Town until the Bachelor degree and then moved to California where he continued his studies until the Ph D degree 1976 at Irvine. He found his first post-doc position at SLAC working on the MARK-I detector. Two years later he became Staff Scientist there, responsible for operating the new MARK-II detector and for data analysis in tau-lepton decays. As young staff member, he was free to select which SLAC group to join. He chose to work 200% of his time and joined the groups of both Burton Richter and Martin Perl. From Burton he learned accelerator physics (and leading a large group, I guess), from Martin he learned all the essentials of data analysis. Burton received the Nobel Prize for the discovery of the c quark, Martin for that of the tau lepton. Both results were found by the MARK-I group, a few years before Jonathan joined it.

Two more years later, in 1980 when MARK-II had moved to the electron-positron collider PEP, Jonathan became Scientific Spokesman of the MARK-II Collaboration, and in 1982 Spokesman for the upgraded MARK-II detector to be installed at the new higher-energy electron-positron collider SLC. Academic honors followed: in 1984 he became Associate Professor and 1989 Full Professor at

Stanford University. Let me mention his next two career steps before I come to his major contribution to Physics. From 1994 to 1999 he was SLAC Associate Director and from 1999 to 2007 the third Director of SLAC.

When I met Jonathan for the first time, around 1989 at the Paul Scherrer Institute in Switzerland, I was very much impressed how quantitatively he could argue what type of collider with what amount of intensity we need for answering the big question which moved us both independently at that time. What is the origin of, what is the explanation for the asymmetry between matter and antimatter?

In 1989 we knew only two places where Nature breaks the matter-antimatter symmetry, our Universe and in particle physics the decay of K mesons. The evolution of the Universe after the Big Bang requires an equal amount of matter and antimatter, and this remains equal until an age of a few minutes if there are no symmetry-breaking effects. Matter and antimatter would then annihilate, extinguish each other, with only photons and neutrinos remaining. This disagrees with the later history of the Universe and with our existence. We have a precise measure of the amount of matter which remained after the annihilation time: The number of protons in the Universe today is 6×10^{-10} of the number of photons. That means, three minutes after the Big Bang the ratio of quarks to antiquarks, the building blocks of matter and antimatter, was around 1,000 000 001 : 1. What is the physical origin of this asymmetry?

Particle physics must have an answer to this question. Antimatter in form of the positron (the antiparticle of the electron) has been observed since 1933; Carl Anderson received the 1936 Nobel Prize for its discovery. The existence of antimatter and especially of the positron had been predicted by Paul Dirac 1928 using a beautiful mathematical argument. The antiparticle of the proton was discovered in 1955. Let me now jump to 1964. Three important and quickly accepted achievements of particle physics happened during that year: Murray Gell-Mann and George Zweig uncovered the quark structure of matter (made out of three types of quarks; u, d, and s) and antimatter (made from their antiparticles $\bar{u}$, $\bar{d}$, $\bar{s}$). In addition to bound states of quarks (e. g. proton = uud) and bound antiquarks (antiproton = $\bar{u}\bar{u}\bar{d}$), there are bound states of one quark and one antiquark in Nature, neither belonging to matter nor to antimatter. We call them mesons. In this laudation I will only introduce four mesons to you, $s\bar{d}$, $d\bar{s}$, called K mesons and $b\bar{d}$, $d\bar{b}$, called B mesons. The second achievement in 1964 was the hypothesis of Peter Higgs that a yet undiscovered particle of well-defined properties is responsible for the mass of the quarks. The third achievement in that year was the discovery of Val Fitch and Jim Cronin that the K mesons mesons $s\bar{d}$ and $d\bar{s}$ behave differently in their decays.

To illustrate that, I show you a later result from 1999 in Figure 1. The Figure shows clearly the essence of the 1964 discovery. For the first time, matter and antimatter showed an asymmetric behavior in a human laboratory. The effect remained unexplained for many years; the Nobel Prize for Fitch and Cronin was awarded only 16 years later. The obvious but also unresolved question was if the asymmetries in the Universe and in $s\bar{d}$ and $d\bar{s}$ decays may have a common origin.

A possible answer emerged in 1973 when Makoto Kobayashi und Toshihide Maskawa published a mathematically very simple argument, for me only comparable to that of Dirac 1928 in its beauty, its simplicity, and its importance. It is based on Higg's hypothetical particle and its coupling to quarks. If Nature has six types of quarks (soon called d, u, s, c, b, and t) instead of three and if the Higgs particle has the most general allowed coupling to them and to the six antiquarks, then Nature can break the quark-antiquark symmetry. This kind of symmetry breaking is not possible with three or four or five types of quarks. An essential property of the Kobayashi-Maskawa (KM) hypothesis is quark mixing. That means, the Higgs particle H has not only couplings of the type dHd but also of the type dHs. One consequence of quark mixing is the effect that a K meson $s\bar{d}$ can transform itself spontaneously into its antiparticle $d\bar{s}$, a known effect since 1961 before the quark structure of mesons was uncovered.

The c quark was discovered in 1974 (I mentioned it already before), the b quark in 1977, and the t quark in 1995. The B mesons $b\bar{d}$ and $d\bar{b}$ were found in 1982. Their decay rate (corresponding to a mean lifetime of 10^{-12} seconds) was first measured in 1983 at SLAC by the experiments MAC and Jonathan Dorfan's MARK-II. In 1987, the ARGUS group at DESY in Hamburg discovered a new consequence of quark mixing: a B meson $b\bar{d}$ transforms itself into its antiparticle $d\bar{b}$. The rate of the transformation was found to be of the same order as the B meson decay rate. This observation, together with the finding of Kobayashi and Maskawa what Nature can do with six quarks, opened the possibility that a large asymmetry between $b\bar{d}$ and $d\bar{b}$ decays could be observable. Only five quarks had been observed up to that year, but the PETRA experiments at DESY strongly suggested that the fifth quark b must have a sixth heavy partner t.

The year 1987 was the starting time of many ideas and plans for experiments to discover this expected large asymmetry in $b\bar{d}$ and $d\bar{b}$ decays. From that year onwards, Jonathan was one of the leading persons who worked for transforming dreams into ideas, into plans, into projects. The experiment was in principle easy; the difficulty was the production of a sufficiently large number of B mesons in a special configuration. Here I remember Jonathan as the first person who calculated and convincingly showed that we need around 10^8 B mesons. No electron-positron collider in the world at that time could produce this number in a period of a few years; the records at DESY and Cornell were between 10^5 and 10^6 per year.

We needed a new type of machine, which meant for Jonathan that he started to work as an accelerator physicist and contributed significantly to the design of the collider which we now call PEP-II. The design was ready around 1990; the expected intensity was 3×10^7 B mesons per year. I should also mention that quantum mechanics required the B mesons to be produced in an energy-asymmetric collider with e. g. electrons of 9 GeV colliding with positrons of 3 GeV. This was the smaller problem compared to the big one of high intensity. In 1991 there were seven proposals in the world for high-intensity B-meson producing machines, we called them B-meson factories. Only two of them were built, one at SLAC and the other one in the KEK laboratory in Japan. Both decisions were taken in the fall of 1993, and I do not want to elaborate here how many convincing efforts were necessary for Jonathan and for the project leader in KEK to reach the decisions. Besides all the physics motivation, Jonathan always had one very strong argument: he was not the only accelerator physicist at SLAC, he had a very strong and very experienced crew of specialists around him.

Jonathan will show you in his lecture the essential steps which were necessary for constructing the collider PEP-II and the detector BABAR between 1993 and 1999. The two pieces of the project were completed at the same time, and with them also the collider KEK-B and the detector BELLE in Japan. In 1999 we started to take data, and already two years later we had the first significant result. I remember well that it was Jonathan who was chosen by the BABAR collaboration to present it at the Lepton Photon Conference in July 2001 at Rome. BELLE showed their first observation with a comparable result and a comparable significance in the same session of the Conference. Seven years later, BABAR finished to take data, and I show you here only the final result of the observed asymmetry in Figure 2, as published in the summer of 2008. This final result is only one out of many observed b-quark b-antiquark asymmetries in BABAR, but it is the most significant one. It is so precise that we can proudly say that it confirms the KM prediction much better than we had thought around 1990. The main reason is that the B-meson production rate of PEP-II was 3 to 4 times higher than it was designed.

In 2008, Kobayashi and Maskawa obtained the Physics Nobel Prize for – quoting the Nobel Committee – "the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature". I did not introduce the concept of families in my short laudation, the Committee means six quarks. In Figure 3, I show the words of gratitude which the two laureates addressed to the B-Factory measurements. They mean the results obtained by the two B-meson projects PEP-II / BABAR at SLAC and KEK-B / BELLE in Japan. The BABAR Collaboration consists of about 600 physicists, BELLE of about 400. But the worldwide particle-physics community knows very well who are the initiators and the leading personalities of the two collaborations. Thus, Jonathan had the honour to be invited to the Nobel award ceremony in December 2008, see Figure 4.

Before I conclude, I must mention the weak point of the KM explanation for the observed matter-antimatter asymmetry. It is only successful in explaining all observations in the particle-physics laboratory, so far limited to K mesons and B mesons. It cannot explain what happened in the first minutes of the Universe, which mechanism created the small asymmetry in the number of quarks and antiquarks before the big annihilation. If it were around 10^{-20} and not around 10^{-9}, then the KM mechanism could be responsible for the asymmetry in the Universe. But we know from precise measurements in cosmology that the asymmetry is 6×10^{-10}. Nature needs more particles or/and more forces than we know now in particle physics for creating the asymmetry. Jonathan and BABAR have not helped to solve this puzzle; we neither found a new fundamental particle nor a new fundamental force. But the intense theoretical studies which accompanied our experiments have shown us a set of conditions which are necessary for creating a matter-antimatter asymmetry. With whatever new particles or new forces, a principle called the CPT theorem requires the interference of at least two contributions to the asymmetry-producing mechanism.

Life goes on. The BABAR experiment has stopped to take data, we only continue with data analysis. Jonathan is no longer Director of SLAC, his activities and the main activity of his Laboratory have drastically changed. Jonathan is now working together with cancer-therapy specialists in the Medical Faculty of Stanford University on the development of a proton or heavy-ion accelerator for therapy, and he chairs Stanford’s Task Force for the feasibility studies. In addition, his activity in our particle-physics community remains highly visible. He chairs the Machine Advisory Committee for a new B-meson project “Super-B” in Italy, he is Board-of-Governors member of the Weizmann Institute in Israel, member of the Advisory Board of the Max-Planck-Institut für Physik in München, member of the Advisory Committee for TRIUMF in Canada, and this is not a complete list all of his present obligations in particle physics.

Our award today contributes to writing your name into the history of particle physics, Jonathan, for your leading role in obtaining the asymmetry results of BABAR. Our University says “thank you” for opening us the chance to contribute to these results, and with us the particle physics groups of the Universities in Bochum, Rostock, Dortmund, Heidelberg, Karlsruhe, Berlin, and Mainz. Our best wishes from all of us for your future, good health, continuing scientific achievements in cancer therapy, in further B-meson studies with Super-B, or in both! And last not least our best wishes go also to your family and especially to Renee.

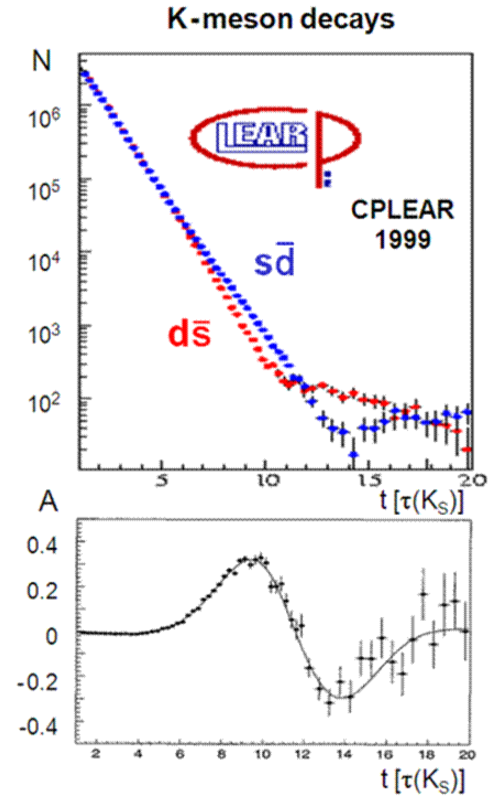

Figure 1: The 1964 discovery of V. Fitch and J. Cronin that K mesons $d\bar{s}$ have a decay law which is different from that of their antiparticles $s\bar{d}$, illustrated by a more recent result of the CPLEAR group in 1999. The upper plot shows the time dependence of the rates N of $s\bar{d}$ and $d\bar{s}$ mesons decaying into a pair of lighter mesons $u\bar{d}$ and $d\bar{u}$; the time t is given in a unit close to 10^{-10} s. The lower plot shows the rate asymmetry,
$A = [N(s\bar{d}) - N(d\bar{s})] / [N(s\bar{d}) + N(d\bar{s})]$.

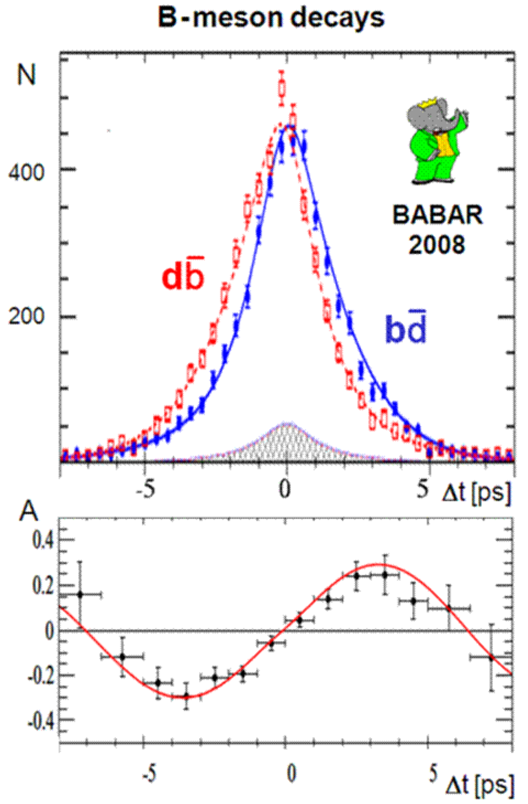

Figure 2: The final BABAR result of 2008 showing the decay laws of $b\bar{d}$ and $d\bar{b}$ mesons decaying into $c\bar{c}$ $u\bar{d}$ $d\bar{u}$, where the $u\bar{d}$ $d\bar{u}$ pair originates from the sequential decay of a K meson. The upper plot shows the rates N as function of the time t in units of 10^{-12} s. Negative times appear since the identity of the decaying B meson ($b\bar{d}$ or $d\bar{b}$) is determined before or after its decay. The lower plot shows the rate asymmetry A as defined in Figure 1.

"Please accept our deepest respect and gratitude for the B factory achievements. In particular, the high-precision measurement of CP violation and the determination of the mixing parameters are great accomplishments, without which we would not have been able to earn the Prize."

小林誠 (Makoto Kobayashi)

益川敏英 (Toshihide Maskawa)

Figure 3: Words of gratitude addressed by the two Physics Nobel Laureates of 2008 to the achievements of the two B-meson Factories PEP-II / BABAR at SLAC (USA) and KEK-B / BELLE at KEK (Japan).

Figure 4: Toshihide Maskawa, Makoto Kobayashi, and Jonathan Dorfan at a December 2008 reception in Stockholm.