FUTURE PLANS AND POSSIBILITIES FOR HIGH ENERGY PHYSICS RESEARCH AT D E S Y

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Elementary particle physics research at DESY in the ongoing decade will be based on the exploitation of the existing e^+e^- storage rings DORIS and PETRA. DORIS just has obtained a face lift with a complete rebuilt, and PETRA is being upgraded in several steps. Both machines therefore provide new research potential for the coming years. Our long-term program will be based on the ep colliding beam facility HERA which we expect to be operational around 1990. In the first part of my talk I will describe the DORIS and PETRA programs. In the second part I will give a brief description of HERA and tell you where we stand now with this project.

D O R I S

DORIS was originally built as a two-ring machine with two beam crossings, operated with many bunches in each ring. In this mode, DORIS was used for about four years mainly for research in the charm region and for investigations of the τ-lepton. The detectors installed at DORIS were DASP in one intersection and PLUTO and the non-magnetic DESY-Heidelberg-detector, for a short time also the BONANZA-detector in the other intersection. When the interest turned towards higher beam energies, in particular after the discovery of the Υ-family, DORIS was operated as a one-ring machine with one bunch each of e^+ and e^- like SPEAR and ADONE. In this mode of operation a luminosity of 10^{31} $cm^{-2}s^{-1}$ was achieved at the Υ-peak. This led to the first observation of the Υ- and the Υ'resonances in e^+e^- collisions soon after their discovery at Fermilab, and all three detectors then operational at DORIS made interesting contributions to the physics of b-quarks.

In 1980 the newly formed LENA-collaboration which used the original DESY-Heidelberg-detector, took still interesting data in the Υ-region at DORIS until the end of 1980. DORIS was a unique machine in this energy range up to the moment when CESR was turned on with CLEO and CUSP.

Early in 1981 it was decided to give DORIS a face lift and to make it a dedicated machine for Υ spectroscopy and for open beauty physics. This decision was taken after a workshop on 'the future of high energy physics at DORIS' held at DESY in February 1981 where the strong demand for another e^+e^- machine - besides CESR - capable to reach all four Υ resonances with good luminosity became apparent.

DORIS, which in 1981 served exclusively as a synchrotron radiation source, had a six months shut down from November 2nd 1981 until beginning of May this year. In this time the old machine was completely taken apart, and a new single storage ring was built in the old tunnel. Many of the old components were used, in particular the main parts of the magnets. The new machine which is called DORIS II - for nostalgia, since there is no double ring any more - is expected to have the following characteristics:

maximum cms energy	11.2 GeV (DORIS I 10.1)
luminosity	$2\cdot 10^{31}$ cm^{-2} sec^{-1} at 10 GeV (factor 20 higher than DORIS I)

with one bunch each of e^+ and e^- of 30 mA.

The power consumption will be about half that of the old machine (now about 5 MW at 5 GeV beam energy), a very important factor for our electricity bill. The radius of the machine has been kept, the beam position is that of the previous upper ring. This point is important for the Synchrotron Radiation Laboratory.

Let me now briefly describe what was done technically: the dipoles were modified, a slap of iron was put into the yoke to widen the gap so that improved pole-pieces could be placed which are smaller in radial extension and therefore allow a higher field before the yoke starts to saturate (saturation was in fact a limitation in DORIS I). The space gained in the yoke was further used to put in the coils of the magnets of the removed second ring thereby doubling the copper in each magnet - and this is the main factor for the reduced power consumption. The pole pieces of the quadrupoles and of the injection elements were also modified. A complete set of sextupoles was added to the lattice. DORIS II has obtained a completely new vacuum system. A mini-beta-scheme was installed in the two intersections. The machine has a new control system following the scheme in use at PETRA. There are good beam monitors which should allow a more reliable operation of the machine.

There will be two high energy physics detectors installed at DORIS II: The Crystal Ball and ARGUS. Their physics interest is complementary: The Ball wants to do photon spectroscopy in the bottonium system mainly; ARGUS' main interest is the investigation of open beauty decays, and they want to take the bulk of their data at the 4S-resonance.

The Crystal Ball, well known to everybody here, arrived safely in Hamburg with all its parts by end of April. After some weeks of preparation in the DORIS experimental hall it was moved into the beam position on Monday, June 21st. One week from now on July 12, the installation, the cabling and the calibration of the detectors with nuclear γ-rays should be finished and Crystal Ball should be ready for e^+e^- collisions.

The other detector, ARGUS, is a new general purpose detector. It has an axial field with a copper coil, a drift chamber vertex detector with inclined wires for Z read-out, a good photon calorimeter with leed-scintillator sandwich counters, and is covered by μ-chambers. ARGUS is foreseen to be installed in September during the summer shut down of all our machines.

DORIS II has been operated already as a synchrotron radiation source in June. Next week when the Crystal Ball installation is complete, K. Wille and his machine crew will start to tune the machine for luminosity. (At the moment where the report is written, DORIS II has already obtained a luminosity of $8\cdot 10^{31}$ cm^{-2} sec^{-1} and the Crystal Ball has seen a nice Υ-resonance.)

The two detectors have been approved to stay in the intersections for three years from the start of operation; this means until about August 1985. An extension is certainly possible but there will be in due time a thorough discussion of the DORIS high energy program in the Physics Research Committee of DESY for the time beyond 1985.

DORIS is jointly used by the high energy groups and the various groups doing research with synchrotron radiation. It is the present DESY policy that one third of the physics time at DORIS is dedicated synchrotron radiation time. We expect to run about 7÷7.5 months for physics in a normal year so that the Crystal Ball and ARGUS may get some 5 months running time. If the luminosity anticipated will really be achieved, the experience from PETRA tells us that it is not unrealistic to expect about 500 nb^{-1} per day as an average and more than 50 000 nb^{-1} in a year - a figure which is certainly encouraging and will allow for a very exciting program.

Let me conclude on DORIS II that we will have a new facility which allows for an interesting program - in friendly and stimulating competition with Cornell, I hope.

P E T R A

PETRA is in operation since 1978. It works now steadily with luminosities around $10^{31}\ cm^{-2}\ sec^{-1}$. The best value recorded was $1.7 \cdot 10^{31}\ cm^{-2}\ sec^{-1}$. PETRA operates with four bunches, two each of electrons and of positrons; at filling each bunch has about 5 mA. The luminosity values I quoted have been achieved last year after the mini β-scheme was installed in all four intersections. The highest energy where data have been taken up to now is 37 GeV cms. At the moment PETRA runs at 17.3 GeV where the highest luminosity is achieved. The present data taking period started in October 1981. There are four experiments installed, three of them have since accumulated more than 50 000 nb^{-1}. PLUTO, the dedicated two photon experiment with special forward spectrometers, had to debug the new parts of the detector during the initial weeks of that run and therefore has somewhat less accumulated luminosity, about 35 000 nb^{-1} for good data. The other three experiments presently taking data are TASSO, MARK J and JADE. During the summer shut down in August, PLUTO will move out of the intersection NE to give way to CELLO which will start data taking again when PETRA starts up in October.

Let me show you one physics result before discussing the future: the charge asymmetry in μ-pairs, averaged over the results of four PETRA-experiments. The latest average was reported at Stockholm by Beate Naroska a few weeks ago, $A_\mu \simeq -(11.8 \pm 1.5)$ % to be compared with the expectation of the standard model, A_μ(GSW) = 9.2 %.

For PETRA we have now an upgrading program which will bring the cms energy to 45 GeV. This will be achieved by doubling the 500 MHz RF-system both in the number of clystrons and in active cavity lengths. The 45 GeV will be the limit with warm cavities.

Let me briefly describe what will be done: PETRA has 8 straight sections. Four of them are used for the experiments, two - the south and the north section - are now used for RF-cavities; east and west have been empty so far.

Without going into details I just tell you that the upgrading will essentially mean to install additional radiofrequency in the halls east and west.

We will install four 500 MHz clystrons in each of these halls, thus doubling the number of clystrons and the available RF-power. Furthermore, we will install 48 7-cell cavities in addition to the existing 64 5-cell cavities.

The upgrading will be done in three steps: In the first step this year only clystrons are added and some of the cavities from south and north are moved to east and west. In the second and third step the new cavities will be added.

The bunch current in PETRA is limited to 5 mA. The limitation is caused by instabilities which are due to higher order mode excitations of the cavities. With increased number of cavities the bunch current would be even lower and this of course would reduce the luminosity which can be obtained. We have consequently to do something against these instabilities, and our weapon is a beam lengthening device which compensates for the additional cavities. Beam lengthening is achieved by a super-position of a 1000 MHz wave to the 500 MHz wave of the accelerating system, with the proper phase and amplitude. It was shown last year with a test installation that a beam lengthening by a factor of 3 and an increase in the bunch current by the same factor of 3 could be achieved, in fact bunches of 15 mA have been brought up to 9 GeV with this test system. We will now take advantage of this possibility and install a 1000 MHz system powerful enough as to bring the long bunch up to 14 or 15 GeV. At that energy the 500 MHz system can take over and continue the acceleration up to the desired energy. With the 1000 MHz system installed we expect to maintain 5 mA bunch currents with all cavities installed and to achieve at the higher energies about the same luminosity in PETRA as we have now.

The present mini-beta-scheme is capable to go right up to 23 GeV provided the two short quadrupoles in each intersection are replaced by long ones, which will be done in one of the forthcoming shut downs.

It is our present planning to complete the PETRA-upgrading by September 1983.

There are two options for a further upgrading of PETRA. The one is the so-called 'micro-beta-scheme' with superconducting quadrupoles in all four intersection regions, leaving a free space of only 1.8 m. With this scheme a luminosity increase by a factor 2-3 could be achieved. A scheme has been worked out which would be compatible with the detectors, but there is no decision to go ahead with its installation.

There is also the option to go up with the energy of PETRA beyond 23 GeV per beam by installing superconducting cavities. The highest energy which could be achieved assuming 3 MV per m would be 30 GeV per beam. This upgrading would only make sense if also the micro-beta-quadrupoles would be installed, of course. I will later talk about our development program of superconducting cavities.

The main physics goals as seen today for the upgraded PETRA will be the search for top and the measurement of the electroweak interference. Let me remind you that for a Z^0 mass of 90 GeV the propagator term will increase the charge asymmetry by 25 % at 45 GeV cms.

The experimental program of PETRA will also in future be based on four intersections, and it is the present policy to have in the long term only one detector per intersection.

We looked into the question of a 5th intersection. This would cost one GeV in the maximum energy to be achieved because we could install less cavities. It would also reduce the luminosity per intersection by about a factor of two and, as a consequence, the overall luminosity around the machine. Therefore we will stay with four intersections.

Detectors

PLUTO which is a dedicated detector for two photon physics is going to move out in August to give place to CELLO. The other detectors, MARK J, TASSO and JADE, will remain. For all detectors, there are minor improvement programs in progress: precision vertex detectors, improved shower detectors, improvement in the capability for two photon physics. It is presently under study whether after the removal of PLUTO one of the other detectors could have a major upgrading with special emphasis on two photon physics.

Development program for superconducting cavities

PETRA could go beyond 23 GeV with superconducting cavities. DESY has a development program jointly with Karlsruhe, Wuppertal and CERN for the development of superconducting cavities. Here are the steps of the program:

In May this year a one-cell 500 MHz cavity developed and built in Karlsruhe has been tested in PETRA. A beam of 5 GeV was stored with this cavity alone. It achieved 2.5 MW per m and was equipped with higher mode copplers. The cavity maintained its qualities also after an installation of four weeks during which it was kept in PETRA at liquid Helium temperature. This experiment is very encouraging for the future use of superconducting cavities in storage rings.

The next step will be the test of a 5-cell 500 MHz structure built at CERN. This structure will be installed in PETRA towards the end of the year and will be tested early 1983.

The main development at DESY goes into a 1000 MHz system. Here we aim to have two 9-cell structures installed in PETRA in summer 1983 which should be capable to store a beam of 10 GeV. Here the same clystrons as for the bunch lengthening will be used. This device could be a prototype for a later system to be installed in PETRA.

The development program should in 1984 reach a status, where a decision can be taken whether to install superconducting cavities as the main system in PETRA. Let me mention that superconducting cavities may also be interesting just to safe electrical power, without rising the energy.

Polarization

Rossmanith et al. have achieved early this year a transverse polarization of 80 % in PETRA at an energy of 16.5 GeV by the use of correction coils to get around depolarizing resonances. The polarization could be maintained with e^+e^- collisions at a luminosity of $4 \cdot 10^{30}$ cm^{-2}sec^{-1}.
From March 22-27 this year we had a workshop on 'polarized electron acceleration and storage' in Hamburg (DESY-M-82/09, April 1982).
On August 25 we will have a discussion on physics with transversely polarized e^+e^- in DORIS and PETRA.

This concludes the discussion of the PETRA-program. I expect that PETRA will be an exciting machine for the years in front of us.

Long Term Program

At around 1990 the high energy program at DESY is expected to turn towards the investigation of electron proton collisions at high energy. DESY proposes to build an ep collider called HERA in which protons of 820 GeV will collide with electrons or positrons of 30 GeV. The move to a new area of research was primarily motivated by physics interest, but was of course not independent of the development in high energy physics around the world. It was in particular influenced by the fact that CERN is building LEP. ECFA was much behind the idea to build an ep collider at DESY. It moreover emphasized the point that two high energy labs should be maintained in Europe with complementary programs. The decision to go ahead with a proposal for an ep collider at DESY is based on a broad consensus in the high energy physics community all around Europe.

W. Lee has in this meeting already given an enthusiastic pladoyer for ep physics to which I have little to add. Let me just repeat the main physics goals we have in mind with HERA: we would like to study the electron quark interaction via space like currents - charged and neutral - at high momentum transfers. The HERA machine with the energy chosen will allow a maximum q^2 of close to 100 000 GeV^2.
The three main topics of research we have in mind are:

- to study the properties of space like currents at momentum transfers large compared to the W, and Z^o masses,
- to study the structure of the proton and its constituents down to dimensions 10^{-17} cm, and
- to search for new particles.

We are convinced that ep physics is a very exciting field with unique features which deserves a special effort and will be very rewarding. We are sure that the study of ep collisions at high energy deserves a dedicated effort and requires a dedicated machine which allows for the long running needed to investigate these interesting processes.

In summer last year the technical proposal for HERA was completed by a group headed by Bjorn Wiik. The group included many participants from DESY, members from German universities, and from university and research labs from many foreign countries.

The proposed machine has the following characteristics:

E_p	820 GeV
E_e	30 GeV
crossing angle at intersections	20 mr
luminosity	$6 \cdot 10^{31}$ cm^{-2}sec^{-1}
longitudinal polarization of e^+,e^-	$\pm$ 0.60

There are four intersections; the experimental halls have an area of 875 m^2, the free space for experiments is 15 m.

HERA will be built as two independent storage rings for protons and electrons. They will be located in an underground tunnel of 6.3 km circumference, adjacent to the DESY site. The bending radius of protons and electrons is slightly different, $r_p \approx 603.8$ m, $r_e \approx 540.9$ m. The proton ring is built with superconducting bending and focussing magnets, the dipole field at 820 GeV will be 4.53 T.

PETRA will be used as injector for protons at $E_p \approx 40$ GeV and electrons at $E_e \approx 14$ GeV.

There will be 210 bunches circulating each of protons and electrons with $3 \cdot 10^{11}$ protons per bunch and $3.6 \cdot 10^{10}$ electrons per bunch.

As compared to head on collisions, the crossing angle offers the advantage that there are no common beam transport elements of the protons and the electrons and therefore their energy can be chosen independently.

In all four intersections spin rotators are foreseen. The encouraging results for polarization in PETRA make us optimistic that we will also succeed to have good e^+ and e^- polarization in HERA.

In what follows I will give a brief status report of the project, addressing myself to six points:

status of proposal
finance
international collaboration
sites and buildings
superconducting magnet development
schedule.

Status of proposal

Here is the calendar of events:

March 1981:	recommendation by Pinkau Committee
July 1981:	HERA proposal completed
Dec. 1981:	HERA proposal submitted to 'Verwaltungsrat' with endorsement of scientific council
Febr. 1982:	presentation to the German Minister for Research and Technology, A. von Bülow.

The previous Minister, V. Hauff, had in 1980 installed a committee to review the large projects in Germany for basic research proposed for the 80's. K. Pinkau was the chairman of this committtee, which came out with a clear recommendation that HERA should be built.

The 'Verwaltungsrat' is the body which takes the final decision. It is composed of representatives of the two governments funding DESY, the German federal government at Bonn and the government of the Hanseatic City Hamburg.

We are now waiting for a decision by the Verwaltungsrat which is hoped for in the course of 1983.

Finance

The estimated material cost of HERA is 654 Mio DM in prices of January 1st, 1981. The break up in three major items is as follows:

general cost	260.5 Mio DM
of which tunnel and experimental halls is 195.6 Mio DM	
electron ring	112.0 Mio DM
proton ring	281.5 Mio DM
of which the superconducting magnet system is 226.0 Mio DM.	

To the material cost must be added 3000 men years, out of which 2000 will be provided by DESY staff; 1000 men years are expected from outside, German and foreign laboratories.

International collaboration

In a very early state of the discussions with German government officials it became apparent that international collaboration in the construction of HERA with sizeable foreign participation will be essential for an approval of the project. In summer last year the DESY management has now approached several foreign laboratories in Europe to explore the possibilities for such a collaboration. In May 1982 a meeting was held at DESY to discuss the international collaboration in the construction of HERA, where two participants of each of the following countries were present: Canada, France, Great Britain, Italy, Netherlands and Norway. The participants came from countries where within the high energy physics community there is strong interest in ep collisions and where an active participation in the experimental program at HERA could be expected on one hand, and which on the other hand do not have their own high energy accelerator project.

As an outcome of these discussions it appears to be not unrealistic that about one third of the material cost of HERA will be contributed by foreign countries. These contributions are expected to be in the form of components to the machine rather than in cash money. In this way, we hope to form a real collaboration for the construction of HERA.

Sites and buildings

The planning for the tunnel and for the experimental halls is completed. The plans and the cost estimates are now submitted for verification by the Oberfinanzdirektion.

The proposed site has been carefully investigated with the result that it appears to be well suited for tunneling.

The parliament of the City of Hamburg passed in April 1982 a law on the 'Bebauungsplan Bahrenfeld' which foresees the construction of the HERA buildings on the proposed site. Before, the HERA-plans were made publicly available so that all neighbours could see them and make their comments and objections. The law became effective in the beginning of May. The situation is now that a building permit for HERA can be given by the administration provided the conditions which are formulated in the law are fulfilled by DESY. These conditions are mainly concerned with environmental aspects and radiation safety - both easily fulfilled.

DESY finds itself now in the outstanding situation that it can obtain the permission for the construction of an accelerator of the size of HERA in the midth of a big city!

Superconducting magnets

DESY has a development program for superconducting magnets which I will briefly describe:

First we started to build some short magnets, 1 m long with 100 mm diameter warm bore, just to learn the technique. Two coils had been successfully tested earlier this year; they achieved 5.3 T where 4.53 T would be needed for HERA. There was practically no training, and the field quality is good, up to specification. So this part of the program was rather successful.

Our next step will be the construction of 6 m long magnets with 75 mm cold bore. These magnets are of the length foreseen for HERA. The present design follows closely the FNAL design. The first coil should be ready for test in January '83, we expect to have 3 magnets completed in autumn 1983 completely assembled with cryostates and iron yokes.

Parallel to the 6 m magnets we want to build short magnets (1 m long) with 75 mm bore to test various modifications and improvements and then go on to build more 6 m magnets with the improvements incorporated.

The development of the quadrupoles is carried out at SACLAY in collaboration with DESY. The first quadrupole should be ready in November this year, the second in middle '83.

We foresee that the first half cell of the HERA proton lattice consisting of 3 dipoles and 1 quadrupole can be installed towards the end of next year and then be tested as a unit.

There is another independent program for dipole development in German industry. DESY has a contract with a firm for the construction of three prototype magnets with cold iron; the first of those should be delivered in November '83, the third one in May '84.

The design of the HERA-dipole should be finalized one year after the beginning of the HERA construction, this is in our present planning at the end of '84. This would leave sufficient time to build up a production line and to produce the 624 magnets for the proton ring in time to be ready for installation in the years 1988-1989.

Schedule

We hope for an approval of HERA in the middle of 1983. This would allow a start of the construction in the beginning of 1984. One year later at the end of 1984, the design of the proton magnets should be finalized so that the production line can be set up. The electron ring should be finished by the end of 1987, and in the years 1988 and 1989 the proton ring should be installed in the tunnel. First ep collisions are then expected in 1990. The total construction time of HERA should be 6.5 years.

The next steps foreseen are:

a continuation of the superconducting magnet development,

prototype work on components for the electron ring,

a continuation of the polarization studies, both experimental in PETRA and theoretical,

negotiations with foreign laboratories and governments on participation and collaboration in the construction of the HERA machine.

At DESY we are confident that we will obtain approval to build HERA. If our schedule will be followed - and there are good indications for that - DESY will offer to the high energy physics community in the 90's four intersection regions for ep collisions at high cms energy.