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THE ELECTRON-POSITRON STORAGE RING PETRA, PLANS AND STATUS

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Summary

Construction of the Electron-Positron Storage Ring PETRA was authorized October 20, 1975. At present most of the civil engineering work is completed and ring installation work is under way. All major components are on order and series production of bending magnets, quadrupoles, vacuum chambers and rf-resonators has started. Start-up of the machine is planned with a fourfold symmetry configuration with four active beam-beam interaction points. Five experimental facilities have been recommended for the first round of experiments scheduled to begin mid 79.

Introduction

The 19 GeV-storage ring PETRA has been described previously (1), (2), (3), (4). The description as given at the 1975 National Accelerator Conference (3) is, with a few exceptions, still up to date. The main changes in the machine design since that time are described in the PETRA up-date (2) and include the plans for two more experimental halls (Fig. 1), an rf-cavity structure with a higher shunt impedance per unit length which makes it possible to shorten the total length of rf-structure from 134 m to 96 m and an increase of total rf-power from 4 to 4.8 MW. This report summarizes the present status of machine design and construction, plans for commissioning of the machine and the first round of experiments.

Beam Optics and Machine Dynamics

The storage ring consists of eight 45° arcs with bending magnets and quadrupoles arranged in a FODO structure, four 65 m long straight sections with the experimental halls NW, NE, SE and SW and four 108 m long straight sections for the rf-areas N and S, and the experimental halls E and W (Fig. 1). A decision was taken to use a fourfold symmetry for the first round of experiments, in which the straight sections E and W have the same optics as the rf-straights N and S. Only for the second round of experiments will halls E and W also be used with low beta interaction points.

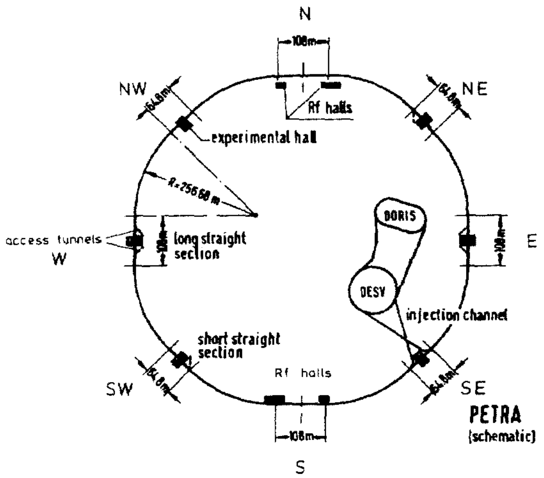

Fig. 1 PETRA (schematic)

The principal parameters of PETRA are:

Energy in each beam	5-19 GeV
Max. luminosity per interaction point	$10^{32}\,cm^{-2}s^{-1}$
Max. beam current in each beam	4x20 mA
rf power/max. voltage	4.8 MW/105 MV
Free length for experiments	15 m
Circumference	2304 m
Bending radius	192 m
Ampl. functions at interaction point	3.00/0.15 m
Injection energy	7 GeV

The beam emittance will be kept constant and independent of energy by variation of the optics: A system of aluminium bus bars allows 28 groups of quadrupole and sextupole magnets to be independently powered from centrally located power supplies. While variation of the optics affects mostly the dispersion in the arcs and thereby the beam emittance, the dispersion is always zero in all 8 straight sections. Zero dispersion at the experimental interaction points assures that electron and positron beams will always collide correctly, even if the energy variation due to synchrotron radiation around the ring cannot be neglected. Zero dispersion at the rf-accelerating straight sections will suppress one type of satellite resonance. Since satellite resonances are expected to be a major problem in a large electron-positron storage ring, care is also taken to make the linear and quadratic dependence of the ν-value on energy zero and to minimize the dependence of beta function on energy at the places of rf-cavities. This is done with a system of 168 sextupoles powered in 6 different groups. Two beam tracking programs are being used to determine the machine acceptance for different sextupole arrangements. One of these programs includes phase oscillations and thereby determines the strength of satellite resonances (5), (6).
A newly developed optics program PETROS calculates the equilibrium orbit and the linear optics about this orbit, taking into account the effects of sextupoles, energy variation along the circumferential path, energy deviation of the equilibrium particle, and field and alignment errors in bending magnets and quadrupole lenses. The program fully includes linear coupling and accurately calculates vertical dispersion, vertical quantum excitation and damping parameters in both planes. These results have been used to determine the effects of different orbit correction schemes, particularly on the vertical beam emittance (7).

Magnets

PETRA will employ 232 bending magnets of 5.317 m length each, 308 quadrupole magnets and 168 sextupole magnets. Steel laminations of 1.5 mm thickness are used for all magnet yokes, aluminium conductors for all coils. Homogenuity of the field in the bending magnets (gap width x height = 200x70 mm^2) is measured to be better than $\pm$ 3x10^{-4} over the beam aperture (100x54 mm^2), field errors in the quadrupoles are measured to be smaller than 10^{-3} over the aperture of the bore (100 mm Ø for the standard quadrupole, 160 mm Ø for the interaction region quadrupoles). All magnets go through an extensive measurement program before installation. Series production of bending

magnets, quadrupoles and sextupoles started at the beginning of 1977.
Fig. 2 shows the ring tunnel, bus bar circuits and magnet assembly.

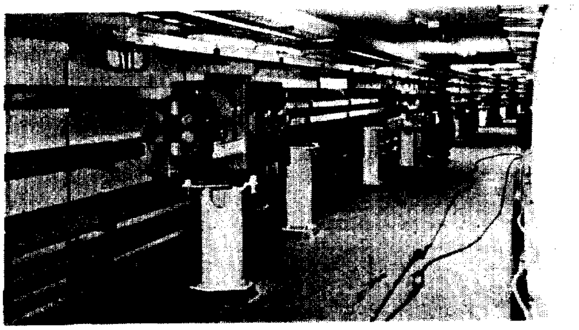

Fig. 2 Magnet assembly in the tunnel

Radiofrequency

A frequency of 500 MHz was chosen for the accelerating system, equal to that used for the DESY and DORIS rf-system. Considerations of energy losses due to higher order mode excitation in the vacuum and cavity system would suggest lower frequencies resulting in longer bunch length, but an extensive program of higher order mode loss measurements (8) showed that this problem will not be as serious as originally thought. Also, newer theories on bunch lengthening (9), (10), (11), (12) predict a significant lengthening of the core of the bunches, which will make higher order mode losses even smaller. Eight 600 kW klystrons, developed by industry, will power 64 five-cell resonators, evenly distributed in the long straight sections North and South. Magic tees and circulators will decouple the klystron transmitters and all cavity resonators from each other. Four 5-cell resonators were made out of aluminium and were powered without any difficulties to levels as high as 200 kW each, more than twice as high as will be used in PETRA. In January 1977 series production of the first 32 five-cell units has started. These resonators are made out of copper (Fig. 3), and the first measurements on these show even higher power handling capability than the aluminium prototypes.

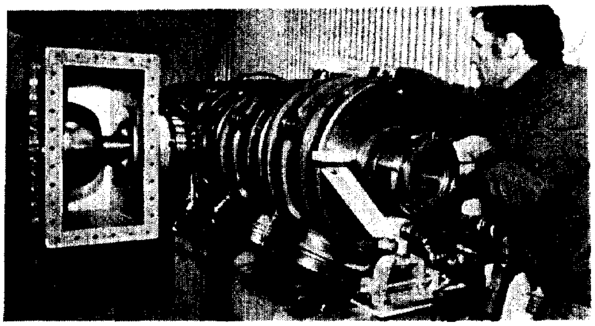

Fig. 3 Accelerating cavity

Vacuum

The PETRA vacuum system is described in more detail in a separate paper at this conference (13). In designing the vacuum system great emphasis was placed on the smoothness of the vacuum chamber walls as seen by the beam and the economical aspects of the construction. Smoothness of chamber walls is necessary to keep the longitudinal wall impedance small, which is responsible for higher order mode losses, bunch lengthening and phase instabilities. All component designs used for the vacuum system were tested with wire-measurements to determine energy losses of high density particle bunches (8). Special attention was given to chamber connections: Sliding rf-joints, tested with peak rf-currents larger than 2000 amp and rms currents larger than 100 amp, assure smooth transitions between chambers.
For reasons of economy, extruded aluminium chambers are used for the larger part of the ring, connected with welded stainless steel bellows which in turn are welded to the aluminium chambers. In-situ Argon-glow-discharge is the principal cleaning method for obtaining ultra high vacuum, though provisions for thermal bake-out have also been made.
A vacuum better than 10^{-8} Torr is expected in the presence of the beams, ensuring beam life times of 4 to 10 hours.

Injection

The injection scheme, making use of DESY as the principal 7 GeV injector and DORIS as a 2.2 GeV intermediate storage ring for positron accumulation has been described in (1), (2). All components for the fast ejection of single bunches out of DORIS back into DESY and out of DESY into PETRA have been installed in January of 1977. It is expected that by late spring of 1977 the positron ejection channel and the first octant in PETRA (from hall SE to hall E) will be completely assembled so that testing of the whole ejection sequence - injection of 30 bunches of positrons from Linac II into DESY, acceleration to 2.2 GeV in DESY and transfer to DORIS, accumulation of 30 positron bunches in DORIS and ejection of single bunches back to DESY, acceleration of these single bunches up to 7 GeV in DESY and ejection to PETRA, injection into PETRA and taking these single bunches through the PETRA system to hall E - can commence. This early start of injection tests is considered essential in order to have enough time to test this somewhat involved injection scheme and the control and monitoring systems in PETRA.

Controls

Three North-Data-10 computers located in the main control room will be used to control all PETRA components and monitors via a serial data acquisition system SEDAC (14). Extensive use will be made of the software developed for this computer for the CERN SPS project. SEDAC sub-controls are located in all experimental halls and rf-buildings. Three independent parallel systems allow data transmission to and from individual components via SEDAC sub-controls. Each of the three systems include one coaxial cable for transmission of analog signals. Beam monitors include 112 electrostatic pick-up systems, 2 total current monitors, 6 synchrotron light observation stations and 16 screen monitors for adjustment of the first turn. Most prototypes of the SEDAC control units have been developed, and series production of the components has started. A temporary control hut in hall E with two of the three control computers has been set up for the injection tests scheduled to start in May 1977.

Structures, Site Work and Geodetic Survey

The PETRA physical plant is described in more detail in another paper at this conference (15). Construction of the 2304 m long ring tunnel, the 6 experimental halls, 4 radiofrequency halls and the injection channels was started in February 1976 and is now essentially complete. Overall ring survey is done by distance measurements using a modulated xenon light source (Mecometer) and the help of an auxiliary surveying grid consisting of 14 surveying monuments. The magnet survey is accomplished by distance and angle measurement directly between ring magnets. Short distance accuracies (over typical distances of a betatron wave-length) are .2 mm in the horizontal and .1 mm in the vertical plane.

The Experimental Program

A PETRA-Research Committee PRC with physicists from many European countries has been formed to make recommendations on the experimental program. Experimental proposals were submitted in August 1976, and 5 major experimental facilities were recommended for approval in October 1976. Groups from 26 different institutes in 8 countries including Japan, the US and Israel form the 5 collaborations which support these experiments. Specifically, the recommended facilities are:

CELLO

(a DESY-Karlsruhe-München-Orsay-Paris-Saclay collaboration) is a detector using a thin superconducting solenoid (1.6 m Ø, 3.5 m long) particularly suited for lepton physics. Special features are cylindrical drift and proportional chambers, a large solid angle Argon calorimeter and a foreward spectrometer to analyze recoil electrons from 2-γ processes. The small diameter of the coil together with the high field strength (15 kG) provides for good muon discrimination against pion decay in flight.

JADE

(a Daresbury-DESY-Hamburg-Heidelberg-Lancaster-Manchester-Tokyo-collaboration) is a detector using a conventional solenoid (3.5 m long, 1.9 m Ø, 5 kG). This solenoid surrounds cylindrical high pressure drift chambers which make dE/dx-measurements possible. 3048 lead glass shower counters measure e.m. showers. Large shielding blocks of loaded concrete (total weight 2000 t) discriminate muons against hadrons. T.o.f.-measurements provide for a certain degree of particle identification.

Mark J

(a DESY-MIT-collaboration) is a detector especially designed to look for small asymmetries in muon-production from interference effects from weak interaction forces. Muons are analyzed by following the tracks through magnetized iron slabs with interspersed proportional chambers. The cubical arrangement covers 95 % of solid angle. In order to eliminate asymmetries of the apparatus, easy rotation in ϕ- and Ξ-directions is provided.

TASSO

(an Aachen-Bonn-Hamburg-Imperial College London-Mainz-Oxford-Rutherford Laboratory and Weizmann Institute collaboration) is a large solenoid detector (2.7 m Ø, 4 m long) with special emphasis on hadron identification. For this, 25 % of the solid angle is covered by Aerogel and Cerencov counters. Drift and proportional chambers inside of the solenoid, liquid Argon chambers and muon detectors outside and a foreward detector for γ-γ processes compliment the instrumentation. The large diameter of the detector improves time of flight measurements and the resolution of jets.

PLUTO

(a DESY-Wuppertal-Siegen-Hamburg-Aachen and Frascati collaboration) is one of the already successfully operatring detectors on DORIS, which will be moved to PETRA, after some improvements with end cap shower counters and dE/dx chambers have been put into effect and tested.

A policy decision was made that all detectors will have to be movable such that removing them from the interaction regions and reinstalling them in operating condition shall not take longer than a week each. In order to accommodate two of the mentioned large experiments in one experimental hall, experimental hall NE will be extended sideways to + 30, - 25 m from the interaction point.

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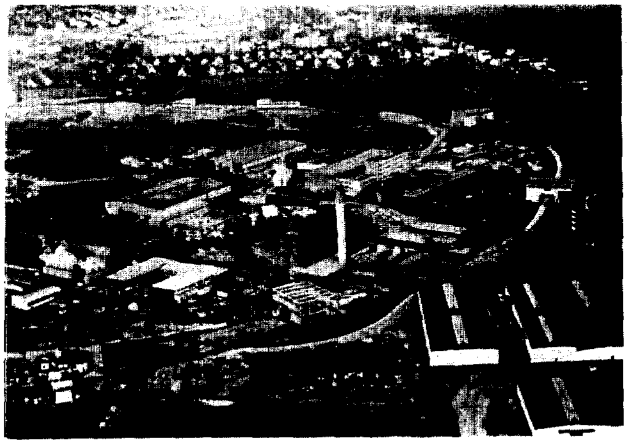

Fig. 4 PETRA with experimental halls SE, E, NE and two rf-halls N (Dec. 76)