STATUS OF THE AMSTERDAM PULSE STRETCHER PROJECT (AmPS).

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Abstract

The National Institute for Nuclear Physics and High Energy Physics' project to enhance the main specifications of its present e⁻ accelerator facility MEA with a 1 % duty factor and 550 MeV to a facility with a d.f. of >90 % and an energy of 0.9 GeV entered its construction phase. The actual status of the project is presented in this paper.

Introduction

To obtain electron beams with a high duty factor the beam from the existing linac will be injected into a new ring with a 211.6 m circumference, see fig.1. The ring will operate either in pulse stretcher mode or in storage mode. An extracted beam will be available in stretcher mode while the storage mode will be used for internal target physics.
The increase of the maximum energy of the electrons will be achieved by an upgrade of the linac modulators. In order to maintain an acceptable extracted current on target the maximum peak current of the linac has to be increased as well.
A comparison of the present and future modes is made in Table 1. Full details on the basic design and the choice of parameters were published in the proceedings of an earlier conference [1].
A large part of the hardware design has been completed and several prototypes have been tested. Recently a major milestone was achieved with the completion of the ring tunnel.

Table 1. Comparison of main beam parameters on target (present mode and future modes)

		Present	Stretcher	Storage
E_{max} @ i=0	[MeV]	580	910	910
Beamloading	[MeV/mA]	2.8	2.6	2.6
Linac pulse length	[μsec]	40	2.1	2.1
Rep. rate	[Hz]	300	400	-
Beam d.f.	[%]	1.2	> 90	100
i_{peak} linac	[mA]	10	80	10
$I_{average}$ on target	[μA]	100	67	200. [mA]

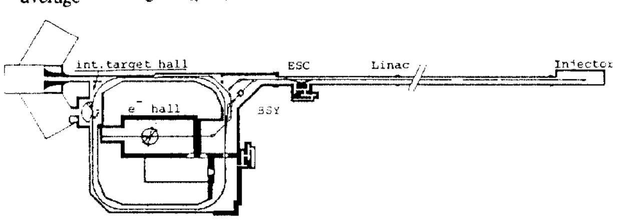

Fig. 1. Layout of the AmPS facility. The pulse stretcher and storage ring is nested around the existing buildings.

Linac modifications

Injector

The peak current from the linac has to be increased from 10 mA to 80 mA while maintaining the present low emittance of 0.15 mm mrad (x x'). Furthermore the injector current has to be very stable to avoid a deterioration of the energy spectrum of the linac beam. To this purpose the optical components of the injector have been repositioned and partially modified. At the end of 1990 a larger cathode will be implemented, the extractor voltage increased and the d.c. accelerating voltage stability improved. First tests with the fully upgraded injector are foreseen in 1991.

Modulators

The energy upgrade from 550 MeV to 900 MeV requires the 12 modulators to provide an RF output peak power of 130 MW [2]. This will be realised by replacing 11 of the present 5 MW klystrons by a new type (Thompson) able to deliver 10 to 20 MW rf power. With minor modifications the present power electronics of the modulators is suited to drive the new klystrons to an output level of 10 MW. To that purpose the pulse forming network (PFN) has to be adapted to produce shorter pulse lengths. A prototype klystron has successfully been tested up to 10 MW together with a modified modulator at NIKHEF and up to 20 MW at the factory.
The required flatness of the shortened pulse (1° rf phase shift at the output of the klystron) was achieved as well.
A first batch of 6 modulators will be modified late 1991, the remainder during 1992/93.

Energy Spectrum Compressor (ESC)

An ESC is foreseen to reduce the energy spectrum from the expected 1 % at high peak currents to the 0.1 % energy spectrum required for the injection into the ring.
The magneto-optical design has already been published [3]. The major systems of the ESC are the magnetic chicane and the rf accelerating waveguide. The contractual delivery of the magnets was scheduled in June 1989. This would allow their installation during a long shutdown period required for the construction of the ring tunnel. Until now, June 1990, they haven't been delivered. Although the magnets at last have been assembled they are not complying to the magnetic specifications because of a serious mechanical error. A new delivery schedule is still being discussed with the manufacturer.
The rf section (HRC) was delivered 1 month before the agreed delivery. It has been installed and tested with a 9 MW rf pulse with a length of 5 μsec. The calculated gain in energy, 8 MeV, could be measured.

Beam Switch Yard (BSY)

The existing BSY consisted of 2 doubly achromatic sections and was able to handle beams up to 600 MeV. Because of the energy increase to 900 MeV a modification was required. The basic optical design philosophy could be maintained but all dipoles had to be renewed. As almost every component had to be relocated it was decided to dismantle the whole BSY with the exception of the energy slit system and to reinstall all beamlines from scratch. The operation took place during the long shutdown period mentioned earlier.
Apart from a 7 month delay in the delivery of the magnets the modification was rather successful. The first beam was brought on target within 2 hours but further tests are required to tune the system.

Injection and Extraction Lines

The injection line consists of an achromatic 90° bending section, a phase telescope and the injection septum. A large number of beam position and profile monitors are implemented in the line to allow emittance and phase measurements and to steer the beam through the narrow injection septum channel. The hardware design is ready , the magnets have been ordered and the fabrication of the mechanical components has started. The line should be tested with beam early Spring 1991.
The extraction line consists of an electrostatic and a magnetic septum followed by a phase telescope and a 90° bending section. From there the beam is injected into the second achromatic bending section of the BSY. The optical design is almost finalised and the main magnets have been ordered.

The AmPS Ring

Optics

A detailed status report on the optical design is presented at this conference [4].

Civil engineering

The circumference of the ring is 211.6 m. About 50 % of the ring will be accommodated within the existing BSY vault. The remaining part will be located in a new tunnel with a length of about 100 m. An additional experimental hall for the internal target physics and an extension of the control building have been realised as well. Through some 130 piles, each with a length of 8 m, the buildings rest on a stable sand-layer 13.5 m below the surface.
Both the tunnel and the experimental hall are made of fibre-loaded concrete. The fibre prevents cracking of the concrete during its curing. As the buildings are located below the ground water level several other techniques were prescribed to ensure a watertight construction.
A cross section of the tunnel is shown in fig. 2, together with some foundation and geological details.
The buildings have been completed and are now covered with 2 m of dirt to provide the calculated additional shielding against radiation. Services are being installed and will be completed Summer 1990.

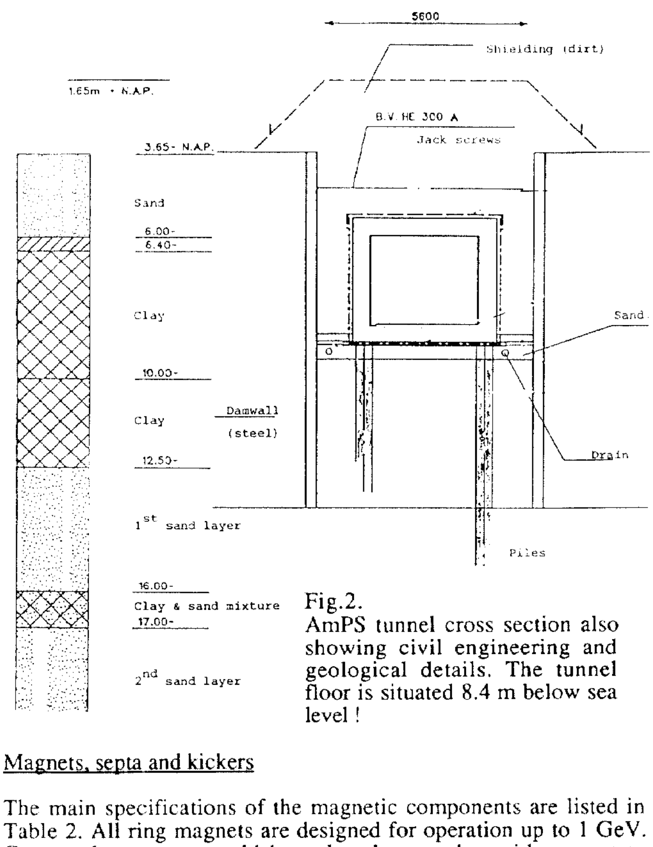

Fig.2.
AmPS tunnel cross section also showing civil engineering and geological details. The tunnel floor is situated 8.4 m below sea level !

Magnets, septa and kickers

The main specifications of the magnetic components are listed in Table 2. All ring magnets are designed for operation up to 1 GeV. Gaps and apertures could be reduced somewhat with respect to former ideas due to a careful analysis of the required minimum beam stay-clear. The magnets have been designed and optimised with help of the Poisson code. The availability of detailed designs together with field maps both from Cern (SPS) and Berkeley (ALS) were of great help. All dipoles, quadrupoles and sextupoles have been ordered. Prototypes of each kind should be available late Summer 1990. End shims will be specified on the basis of magnetic measurements of the prototypes. The serial magnets will be delivered in several "mixed" badges during the first half of 1991. The magnetic field of all magnets will be measured prior to installation. An accurate computer controlled XYZ measurement table has been realised at NIKHEF. Measurements on quadrupoles and sextupoles will be performed elsewhere with help of a rotating coil set-up.

The final choice on the type of steering magnets has not been made yet. A low sextupole content of these magnets is essential in stretcher mode operation. The magnets should also combine horizontal and vertical steering in one unit and furthermore each unit should be splittable for installation purposes as well.
Magnets will be connected in series as much as possible to reduce the costs of power supplies. Nevertheless some 95 power supplies are required for the ring. Budget estimates were obtained from several companies. Orders will be placed Mid 1990 for delivery in 1991.
Several prototypes of the injection septum have been made. The major problems, a low leak field and adequate cooling have been solved. Direct water cooling of the septum conductor could be avoided by achieving a good thermal contact with help of a thin enamel layer between the conductor and the yoke. The design is shown in fig. 3.

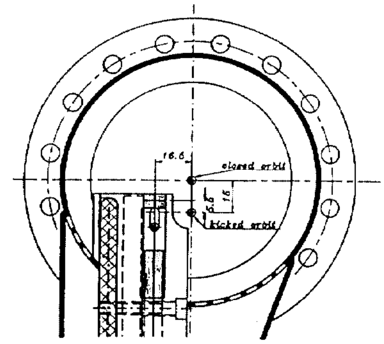

Fig.3. Cross section of the beam pipe showing the injection septum: the septum winding is shaded in grey; the cooling loop is hatched.The injected beam and both the central and kicked orbit are also shown.

The electrostatic extraction septum still has to be designed in full detail. Probably thin (50 μm) foils will be used instead of wires because of the electric field distribution. The magnetic extraction septum is similar to the injection septum.
Two very fast (80 nsec) electrostatic kickers are required to displace the closed orbit during injection. A prototype kicker has been made to investigate its mechanical stability and its rf behaviour. The prototype behaved satisfactorily; a Z/n of 0.2 Ω was measured. The construction of a prototype power supply based on a charging and a discharging circuit with thyratrons started recently.

Table 2. Specifications of ring magnets and septa.

D : dipole, Q_c : quadrupole curved section
Q_s : quadrupole straight section,S : sextupole

Magnet type		D	Q_c	Q_s	S
Quantity		32	36	32	32
Field @ 1 GeV	[T]	1	0.3	0.24	0.042
Gap/aperture	[mm]	45	71	95	80
Homogeneity	[.01 %]	1.5	-.	-.	-
Harmonic content	[%]	-.	0.1	0.1	1
Yoke length	[mm]	600	180	250	120

Extraction sextupoles: 4
Steering magnets: 32 H & 32 V; 1 mrad max. deflection
Kickers: electrostatic, length 1.6 m, 2.75 mrad deflect., flat pulse during 2.1 μsec, fall time < 80 nsec, deflection voltage @ 1 GeV : + & - 35 kV
Septa:
Injection septum: magnetic, d.c., septum thickness 3 mm, gap 10 mm, length 400 mm, 16 mrad deflection, field @ 1 GeV 0.135 T, current @ 1 GeV 1140 A, power @ 1 GeV 390 W
Extraction septum A: electrostatic d.c. foil septum, foil thickness 50 μm, gap 20 mm, length 0.9 m, 4 mrad deflection, voltage @ 0.9 GeV 80 kV.
Extraction septum B: magnetic, d.c., septum thickness 9 mm, gap 10 mm, 65 mrad deflection, field @ 0.9 GeV 0.283 T, current @ 0.9 GeV 2250 A, power @ 0.9 GeV 1.3 kW

Vacuum and mechanical constructions [5]

Because of its non-magnetic properties and its mechanical strength unto high temperatures (bake-out) stainless steel 316 LN will be used for the vacuum chambers and beam pipes in the curved sections and also for the beam pipes inside of the magnetic elements of the straight sections.
In stretcher mode 50 kW beampower will be injected continuously. Even with a few % loss the induced residual radioactivity in beampipes and components will be considerable. The amount of Co determines to a large extend the level of residual radioactivity. In the metallurgical process of 316 LN manufacturing the Co content is not important and therefore it is rarely specified. NIKHEF fortunately was able to obtain 316 LN material with a very low Co content.
During the first year the ring will mainly operate in stretcher mode. It is expected that this mode of operation will provide quite some "beam cleaning" and therefore it was decided that vacuum firing and in situ bake out of the vacuum envelopes will be omitted. The required final pressure is determined by the quantum lifetime in the storage mode for internal target physics. With a quantum lifetime of 1 hour the pressure with beam should be 10^{-6} Pa.
The required pump capacity in stretcher mode is about 3000 litre/sec; the storage mode (without the gasload from the target) requires an additional 1800 litre/sec. A decision on the pump type hasn't been made yet. In stretcher mode ion getter pumps would be adequate, but with internal targets using helium gasjets this choice is no longer obvious.
Most vacuum components have been designed and several, prototypes have been made to test their rf compatibility. A simple rf mesh shield that will be fitted in bellows, pump outs, etc. performed well.
The beamline components of the 4 curved sections, including the magnets, will be preinstalled and prealigned on 16 girders. A separate clean area will be used for this preassembly. The final installation of the girders in the tunnel should only require the alignment of the girders and not of the individual components.

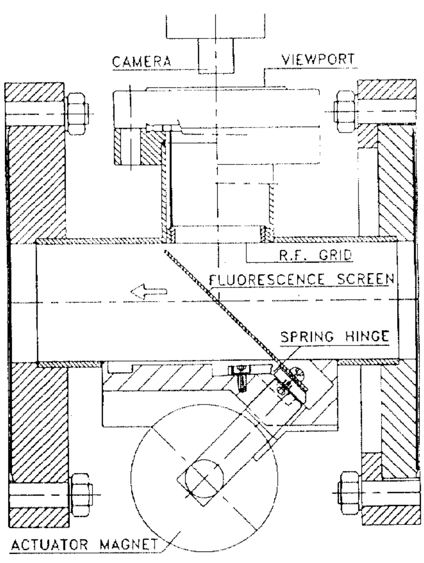

Fig.4. Design of a beam viewer for the AmPS ring. With retracted screen the monitor has a low rf impedance.

Diagnostics

Information on the position of the beam will be provided by 32 stripline monitors. Several prototypes have been made in order to minimise the Z/n of these devices. Fall 1990 a prototype will be tested with beam.
For the initial commissioning of the stretcher ring 16 beam viewers with retractable fluorescence screens will be available. A low rf impedance design has been made and is shown in fig.4; a prototype performed well.
To measure the d.c. current in the ring a parametric current transformer has been acquired (Bergoz).

RF

In order to minimise capture loss of the linac bunches the ring cavity in stretcher mode will operate at the linac accelerating frequency of 2.856 GHz. To allow fast phase and amplitude modulation during the injection process a slow wave cavity structure with a fill time of about 20 nsec will be implemented.
In storage mode the height of the rf bucket should be larger than approximately 6 times (b=6) the equilibrium energy spread of the beam to ensure an acceptable quantum life time. The required overvoltage is proportional to the cavity frequency. Calculations show that the effective duty factor of the beam as seen by the experimental set-up lowers considerably at frequencies below 500 MHz. The required overvoltage for 900 MeV and b=7 at 500 MHz is 150 kV and at 2.856 GHz it is 710 kV.
At present it is being investigated whether a hybrid system could be designed that would behave as a slow wave structure in stretcher mode and with some type of rf power feedback as a standing wave structure in storage mode. Such a system could allow operation in storage mode at 2.856 GHz up to energies of 750-800 MeV with the planned rf power source of 50 kW.
The rf power generator together with the amplitude and phase modulation has been designed. The construction will start late 1990.
Due to the high frequency used for acceleration in the ring the beam centre line components and the transitions between these components have to be extremely smooth in order to minimise bunch induced wake fields. Although calculation of the rf impedances nowadays provides good design guidelines impedance measurements of each type of component are an absolute necessity. To this purpose a 20 GHz network-analyser (HP 8720 B) has been bought; a Cern expert (Dr. F. Caspers) trained several NIKHEF engineers on the subject.

Controls

The existing MEA control system will be extended to allow control of the ring hardware. Local networks will consist of VME and Bitbus systems. The local stations will be linked to the Ethernet back-bone network. The detailed design will be available end of 1990.

Timeschedule

The project is scheduled according to the following scheme.

1990	physics in "low d.f. mode", design & construction of components, prototype tests
1991	no physics, construction of components, installation, test of injector, ESC & injection line, hardware system tests
1992	start commissioning in stretcher mode first physics in stretcher mode
1993	commissioning in storage mode first physics with internal targets

Acknowledgements

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