STATUS REPORT ON THE PSI-ACCELERATOR FACILITY

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ABSTRACT

The main activity at the PSI-590 MeV accelerator facility is the preparation of an extended upgrade program. The main ring cyclotron will be equipped with new power amplifiers delivering more than 500 kW of RF-power per cavity. Injection-, extraction- and diagnostic elements will have to be renewed. The main target station and the beam dump will be completely exchanged and a connection to the spallation neutron source (SINQ) will be prepared.

On Injector I major progress has been achieved in the improvement of the source for polarized particles. In the future polarized proton beams of 10 μA at 590 MeV will be available.

PSI proposes to build an electron-positron collider (B-meson factory) for particle physics with τ-leptons and b- and c-quarks. The design luminosity is 10^{33} cm^{-2}s^{-1} at a center of mass energy of about 10 GeV.

1. INTRODUCTION

The Paul Scherrer Institute (PSI), a national laboratory of Switzerland, is the successor of the former SIN and its neighbouring reactor institute. The PSI is an annex institution of the Federal Institute of Technology (ETH).

The accelerator facility at PSI consists of the ring cyclotron for 590 MeV protons and two 72 MeV injector cyclotrons for alternative use. The ring feeds two pion production targets E and M (see Fig. 1). In the future the proton beam will be recollected after target E and guided further to the spallation neutron source (SINQ). At two positions fractions of the beam are split away from the main beam a) at the 72 MeV beamline for the production of isotopes and b) at 590 MeV for nuclear physics experiments, for the medical program and for the investigation of proton induced radiation damages in materials (PIREX). The concepts of the main ring and Injector I and II are described in detail in refs. 1-3).

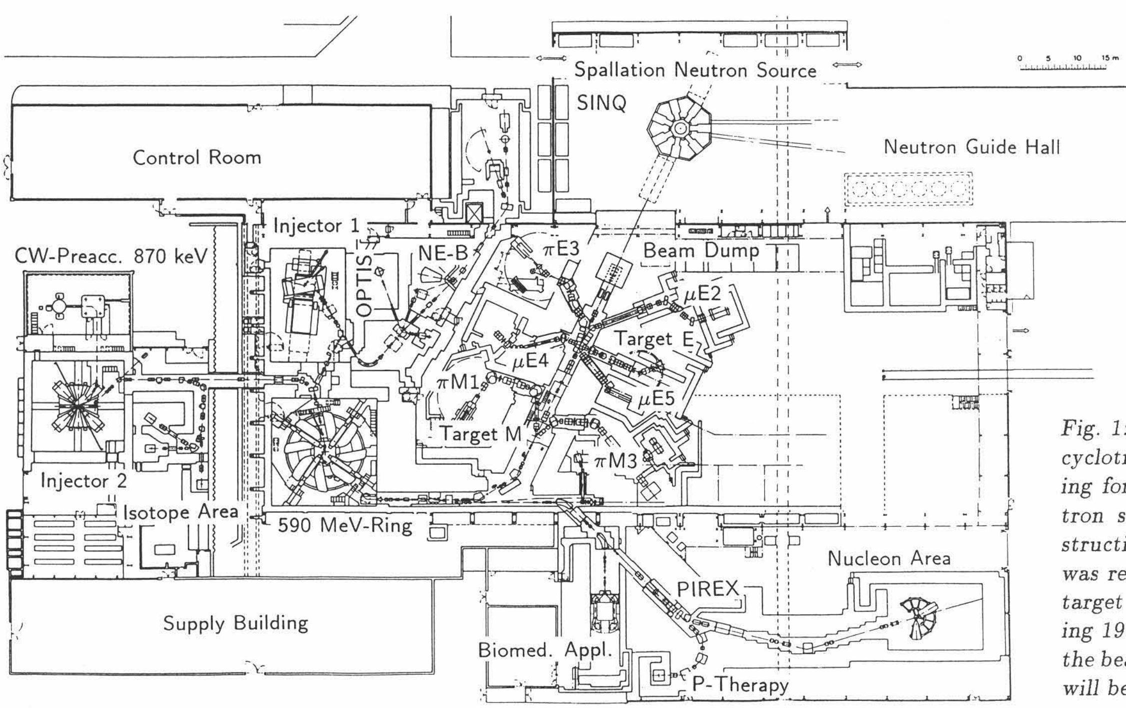

Fig. 1: Layout of the 590 MeV cyclotron facility. The building for the spallation neutron source is under construction. While target M was reconstructed in 1985, target E will be renewed during 1990. At that occasion the beam channel to the SINQ will be prepared.

The Injector I-Cyclotron and the main ring came into operation in 1974. The Injector I, manufactured by Philips Company (NL), is a variable energy machine equipped with an internal ion source and a polarized ion source with axial injection. This cyclotron is able to produce reliably proton currents close to 200 μA on target. The 590 MeV-ring can handle much higher beam currents. With an appropriate upgrade of the RF-systems the current limit may be pushed up to 1-2 mA. The Injector II was designed and built to make use of the current capabilities of the main ring. The maximum current extracted so far from Injector II is 1.15 mA.

2. UPGRADING PROGRAM FOR THE 590 MeV-FACILITY

2.1 Injector II and 590 MeV-Ring

The main motivation for the upgrade comes from the spallation neutron source (SINQ) which is under construction. The SINQ will be installed behind target E using the waste proton beam. In order to reach the envisaged beam current of 1 mA and higher it is not only necessary to increase the available RF-power of the 590 MeV-ring, but also injection and extraction channels must be improved. In addition, target E and beam dump need to be adapted to the new situation. It is planned to replace target E and beam dump in a one year shutdown in 1990. At that occasion the channel connecting the SINQ with the target station will be prepared.

The problems involved in the upgrade of the main ring and Injector II have been described at the previous conference[4].

In Injector II all the turns are well separated due to the use of the flattop principle[5]. The extraction losses are completely negligible for currents up to approximately 500 μA. However, at currents near 1 mA beamtails develop and lead to a drastic increase of extraction losses. It was established that the beam width at extraction increases linearly with beam current and it is assumed that this is the result of an increased energy spread caused by the longitudinal space charge effects in the beam bunches[6,7].

In order to reduce the effect of the space charge forces the following measures have been (or will be) taken:

a) An additional flattop-resonator, known as the 'miniflattop', was installed in the central region, providing a flattop voltage over the first few revolutions which are not in the reach of the existing flattop cavities.
Beam experiments with the miniflattop showed some improvement of the energy spread at extraction, however, in order to benefit fully from this additional flattoping, it will be necessary to install a second miniflattop resonator in a symmetric location.

b) During acceleration the space charge forces in the bunches lead to an S-shaped deformation in radius and phase. While the linear part of this deformation can be compensated with the phase of the third harmonic flattop voltage (producing a 'tilted top'), higher harmonic voltages are needed to minimize the energy spread including the tails. For this purpose an RF-cavity operating at 500 MHz is under construction and will be installed in 1991.

The most expensive part of the upgrading program of the main ring is the increase of RF-power of the 50 MHz-accelerating systems and of the 150 MHz-flattop systems. The importance of these improvements can easily be seen from the following considerations. At a beam current of 1.5 mA the beam power reaches a level of 900 kW whereof 780 kW will be delivered by the main ring. This calls for an increase of the available RF power from 200 kW (in 1989) to at least 500 kW for each of the four cavities. The power balance will then be as follows:

- 220 kW (or 44%) per cavity will be delivered to the beam. This includes an extra 24 kW that will be coupled into the flattop cavity by the beam.
- 280 kW (or 56%) are needed to generate the peak accelerating voltage of 650 kV in the cavity. This power is dissipated in the cavity walls.

The envisaged increase of RF peak voltage from todays 450 kV to 650 kV in the future will enhance the turn separation, enabling the acceptance of higher energy spread and also reducing the extraction losses. Also the effect of the longitudinal space charge forces will be reduced.

The above mentioned transfer of RF-power from the four accelerating cavities into the flattop cavity creates additional problems (see ref. 4)). The 150 MHz flattop system has to cope with a beam load varying over a very wide range. Without beam the 150 MHz amplifier will be loaded by the cavity absorbing $\sim$ 90 kW. At a current of 1.5 mA the beam deposits 96 kW in the cavity, which means that in the extreme case the power amplifier has to absorb power from it. This drastic variation in load makes it necessary that amplifier and transmission lines are immune against reflected power from the cavity. Control loops for phase and amplitude have to be designed to maintain the stability of the cavity voltage also under conditions of zero and negative power output of the amplifier.

An alternative method to handle the large load varia-

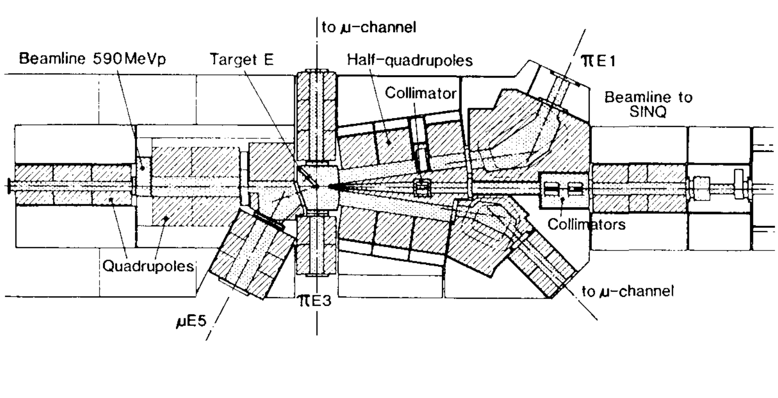

Fig. 2: The new target station E, designed for beam currents up to 2 mA. The target is a rotating graphite wheel cooled by radiation. The beam enters the target from the left side. The two foreward pion channels use half quadrupoles in combination with mirror plates. The μE5-channel collects surface muons from the target. Behind the target station a vertical bending magnet either deflects the beam downward into the SINQ-beam line or steers it into a high power beam dump.

tions foresees a variable load acting on the flattop cavity and keeping the power output from the amplifier constant. Such a beam power absorber is proposed and described by P. Sigg[8].

The existing chain of amplifiers for the 50 MHz system is assembled from units of 1, 10 and 200 kW, all of them in the grounded cathode configuration. In the future a grounded grid amplifier with a nominal output power of 800 kW will be added to the chain[9]. The driving power will be in the order of 80 kW, which will allow to operate the existing amplifier chain under more relaxed conditions.

For the time being the 200 kW power amplifiers are installed near the cyclotron. The new power stages will be installed outside the cyclotron vault and connected to the cavities via new and rather long 50 Ω coaxial lines with an outer diameter of 24 cm. This rather expensive solution was chosen in view of the future maintenance of the amplifiers, because we expect the average neutron dose rate in the cyclotron vault to increase by typically a factor of 30.

A prototype of the 800 kW-amplifier, using a Siemens tetrode RS 2074 will be tested toward the end of 1989 at full power. During the shutdown 1990 one cavity will be equipped with the new amplifier whereas the other systems will be modified during 1991 and 1992.

2.2 Reconstruction of Target E and Beam Dump

The pion production targets originally designed for proton-currents around 200 μA are routinely operated at 250 μA. Occasionally 350 μA where accelerated for a short period of time. The current limit is dictated by a weak point at the target vacuum chamber where a leak might develop due to thermal effects. Another limitation is given by the lifetime of an O-ring seal near the beam dump. This O-ring has to be exchanged after 250 000 μAh or every third month.

The concept of the new target station is shown in Fig. 2. The target is a rotating and radiation cooled graphite wheel, absorbing 25 MeV from the beam. The pions are collected by two

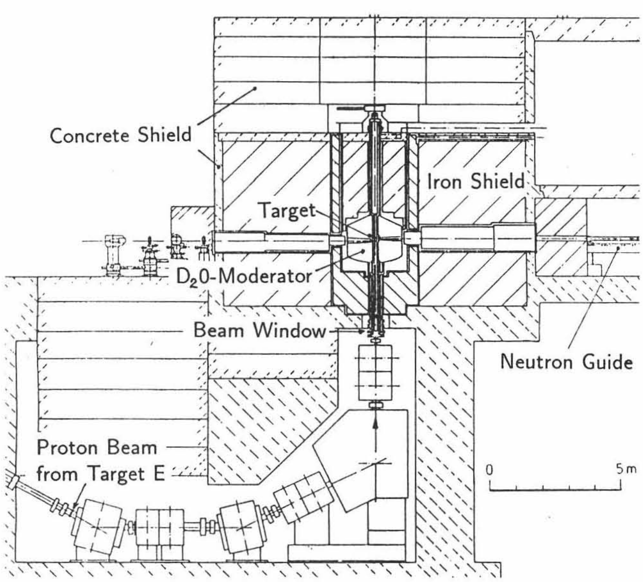

Fig. 3: The spallation neutron source SINQ. The proton beam is injected vertically from below into a liquid metal target. The fast neutrons from the target are thermalized in the D_2O-moderator. Two cold sources are included in the moderator tank.

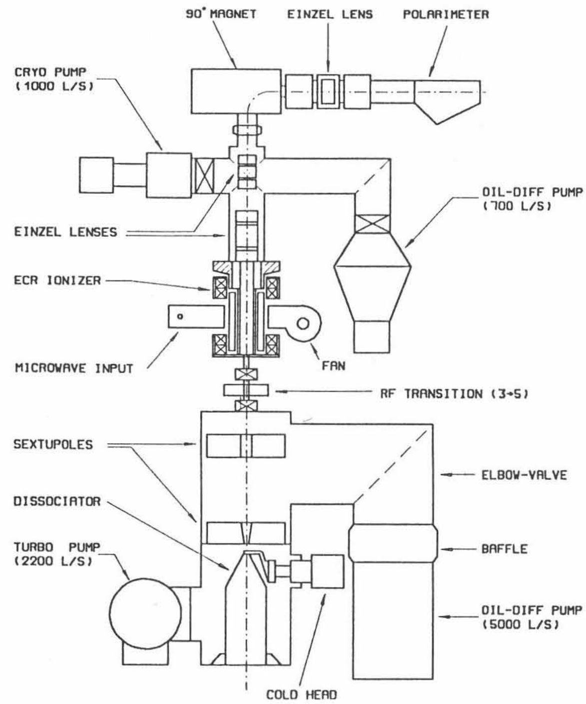

Fig. 4: Schematic diagram of the test bench for the source for polarized protons and deuterons, using an ECR-ionizer.

channels in foreward direction, two channels under 90° to the beam axis and a channel collecting the surface muons emitted in the backward direction. The two foreward oriented channels use triplets made from half quadrupoles in combination with mirrorplates. Collimators are foreseen to clean the beam from halos after the target. About 30% of the beam current will be dumped in the collimators!

The spallation neutron source (SINQ) [10] is schematically presented in Fig. 3. The proton beam is injected vertically into a liquid metal target from below through a triple window. The target material is an eutectic mixture of lead and bismuth with a melting point of 125°C. The heat transfer from the beam region to a water cooled heat exchanger is made by natural convection. The fast neutrons from the target are thermalized in a large D_2O-moderator. The D_2O moderator-tank includes two cold sources, one of 22 l of liquid D_2 to provide long wavelength neutrons for a guide system and the other one of 0.5 l volume filled with liquid H_2. The peak thermal flux in the D_2O moderator will be $10^{14} n/cm^2 s$ at a beam current of 1 mA.

The construction work for the SINQ-buildings started in 1988. The installation of the source is planned for 1992 with comissioning at the end of 1993.

3. ACTIVITIES AT THE INJECTOR I-CYCLOTRON

At Injector I very lively scientific activities are continuing. During 1988 2 900 hours were devoted for nuclear physics experiments, 370 h for the medical therapy program OPTIS [11] and 390 h for isotope production. During 5 days every 4 weeks the Injector I takes the burden of feeding the main ring for high energy production, while Injector II is used for beam development experiments. However, during the past years three short circuits developed between the concentric trimcoils and ground. The cause for these failures, which for the moment do not really restrict the use of the cyclotron, are presumably due to radiation damages in the insulation of the coils and a major shutdown in the near future seems inevitable.

During the past few years experiments with polarized particles became more and more an important part in the research program at low energies mainly, but also at medium energies. Frequently polarized protons are used to produce beams of polarized neutrons through spin transfer reactions on carbon. This trend certainly stimulated the continuous improvement of the source of polarized protons[12]. The first step on this line was to cool down the nozzle of the dissociator about 30°K. The second step will be the installation of an ECR-ionizer during 1989 (see Fig. 4). We expect an increase in beam current by a factor 2 to 3. The ECR ionizer was built and tested in a collaboration between PSI and KfK Karlsruhe[13]. Proof of principle experiments demonstrated the following properties:

- no depolarization occurs through the hyperfine state mixing in the ECR source.
- the beam emittance is excellent and the energy spread is a few 10 eV only
- extracted currents up to 1 mA from the source have been observed.

Based on these results the construction of a new nucleon area (NA1) was decided. We expect a primary polarized proton beam (at 590 MeV) of at least 10 μA. This will produce a flux of polarized neutrons of $5x10^6/cm^2s$ (12 m behind the target) with a polarization of 40%.

4. PLANS FOR A B-FACTORY AT PSI

The PSI plans the construction of a B-meson factory, an electron-positron collider of high luminosity. Such a facility would enable important experiments with heavy quarks and leptons[14]. B-mesons consist of a heavy b-quark and a light antiquark $\bar{u}$, $\bar{d}$ or $\bar{s}$. B-mesons have a mass of 5.3 GeV and a lifetime of $\sim$ 1 ps. A centre of mass energy of at least 2x5.3 GeV is thus needed for their production in pairs. The B-meson factory consists of two identical storage rings for energies up to 7 GeV for e^+ and e^- arranged on top of each other in the same tunnel. Two collision zones are foreseen. The double ring concept allows a maximum number of bunches per ring and offers the possibility for an asymmetric mode of operation. In this mode the centre-of-mass of the colliding electrons and positrons is moving and 'flying B's' are produced.

The B-meson factory is scetched in Fig. 5. The storage rings are fed by a 400 MeV linac, an accumulator and a booster synchrotron. The positrons are produced with an intense electron beam from a 200 MeV linac.

The possible use of the B-factory as a synchrotron radiation facility has also been investigated.

The main parameters of the double ring collider are the following:

Max. luminosity, optimized for (2x5.3 GeV)	$4x10^{33}$ $cm^{-2}s^{-1}$
Circumference	648 m
Beam current e^+, e^-	0.5-1 A
Beam energy: symm. mode	1+1 up to 7+7 GeV
asymm. mode	mainly 7+4 GeV

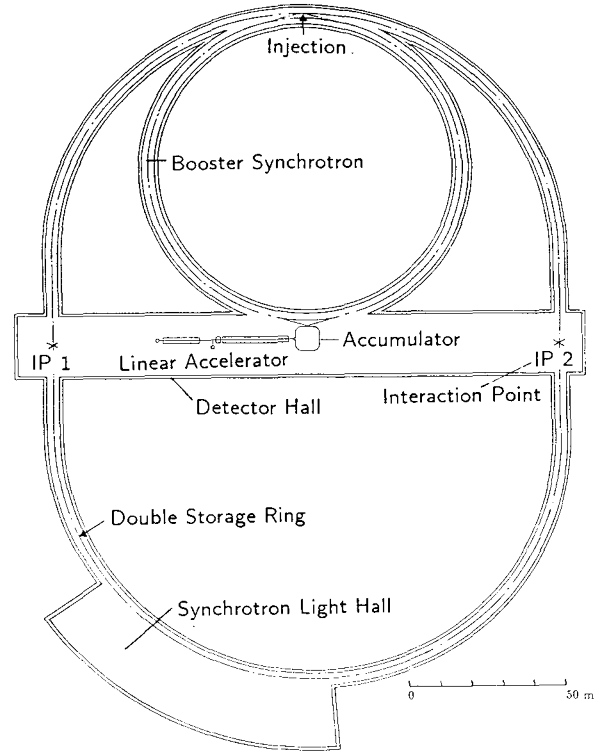

Fig. 5: The proposed B-meson factory at PSI, a high luminosity collider with two identical storage rings for e^+ and e^-. The maximum beam energy is 7 GeV.

The B-meson factory budget is 130 MSFr. including buildings plus 50 MSFr. for the detectors. The synchrotron light facility and manpower are not included. Provided that the project will be approved by the Swiss Parliament by the end of 1990 commissioning could start at the end of 1994.

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