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# POLARIZED PROTON PREACCELERATOR PROGRAM

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## Summary

The second 750 kV Cockcroft preaccelerator is being built for polarized $H^-$ ions. The accelerating column is similar to the present one. The accelerated ions will be transported by a 40 m beam line. At the beginning of the line, the spin is rotated from parallel to the beam to vertical. An ordinary $H^-$ ion source is also developed and 20 mA is achieved.

## Introduction

In the design study of the KEK proton synchrotron, acceleration of polarized protons was examined. However, a strong depolarization was supposed to occur in the 500 MeV booster synchrotron,[1] so that no effort had been done further. Recently, it was found that the polarization is substantially kept by spin flip in the booster.[2] A pulsed high current Lamb-shift ion source had been studied for $H^-$ injection into the synchrotron. Although more than 1 μA was achieved, more current was sought. Nowadays higher current of the polarized beam is hoped to be delivered by ion sources of the 2-nd generation. Thus a three year project of the polarized $H^-$ preaccelerator started in 1980.

## Layout of the Second Preaccelerator

In July of 1974, the present Cockcroft preaccelerator delivered its first 750 keV proton beam. Since then, it has supplied protons to the 20 MeV injector linac. As there is no enough space between the preaccelerator building and the control room, it is impossible to make a new building for the second open Cockcroft generator between them. Thus, the new building is decided to be built behind the present one as shown in Fig. 1, and the accelerated ions will be transported by a 40 m beam line. The floor of the new Cockcroft generator room is 1.4 m higher than that of the present one, because the new beam line must avade the power line cable tunnel which was already installed.

## Ion Sources

The booster was designed for five-turn injection of the 20 MeV proton beam. It is estimated that an effective 100 turn injection is possible for charge-exchange injection of 20 MeV $H^-$ ions.[3] It means that the equal circulating current is obtained either by a 10 μA $H^-$ beam or a 200 μA proton beam. Although it is very difficult to get a 10 μA polarized $H^-$ beam by the Lamb-shift source, such a high current beam will be extracted from a new polarized $H^-$ ion source, in which hydrogen atoms are polarized by charge-exchange reaction between fast protons and electron-spin oriented sodium atoms. The electron-spin oriented atoms were produced by a sextupole magnet and a polarized $H^-$ beam of 3 μA was obtained. Then, a high power dye laser was introduced to yield these atoms. So far, the beam

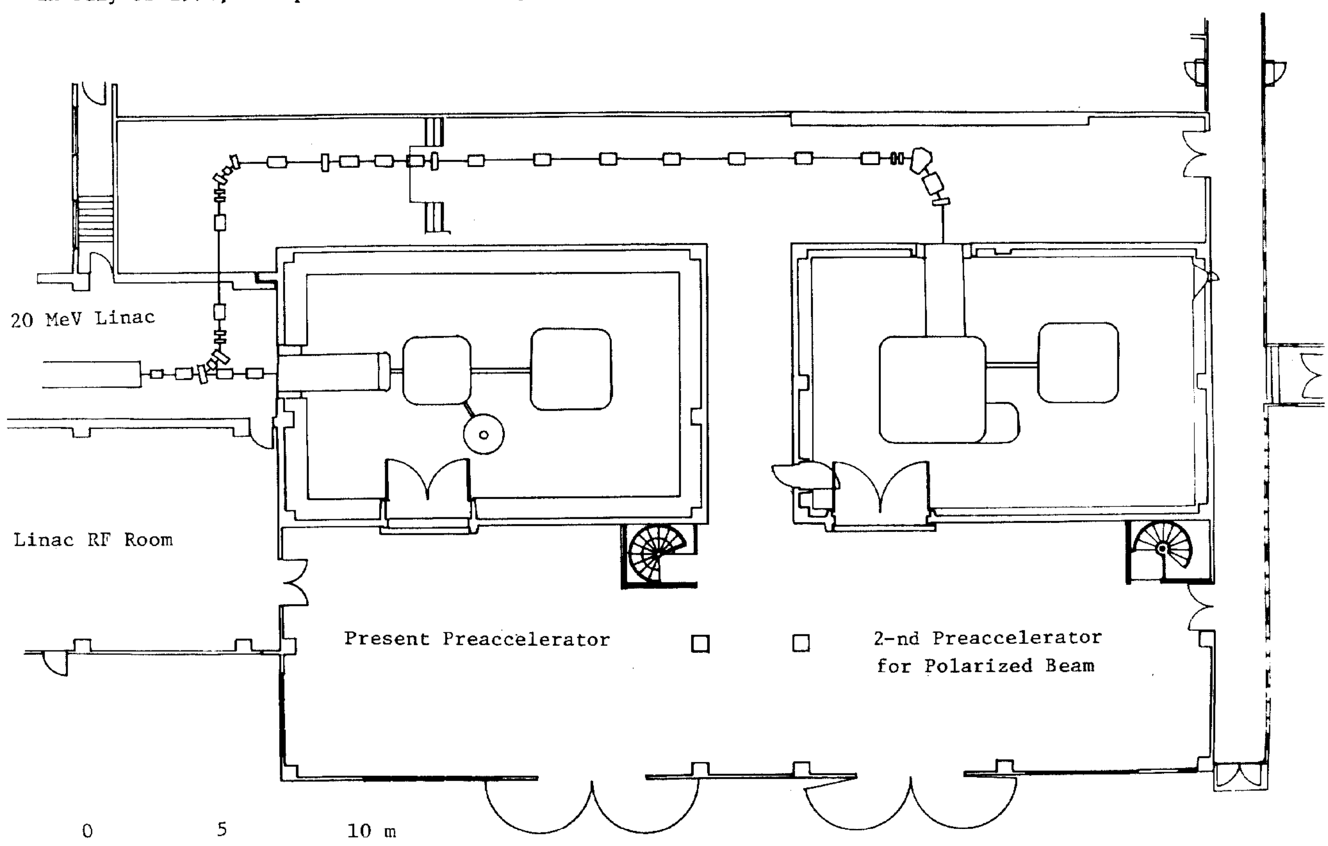


Fig. 1 Layout of KEK 12 GeV PS preaccelerators.

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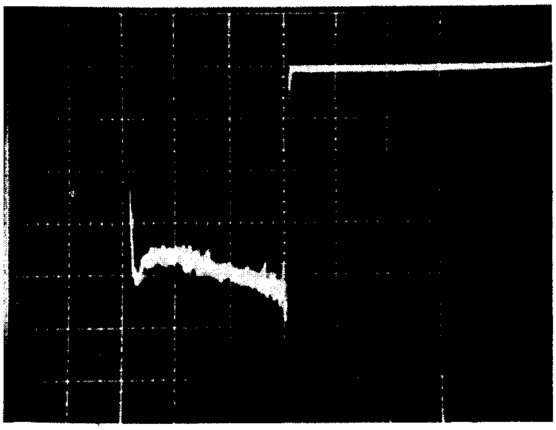
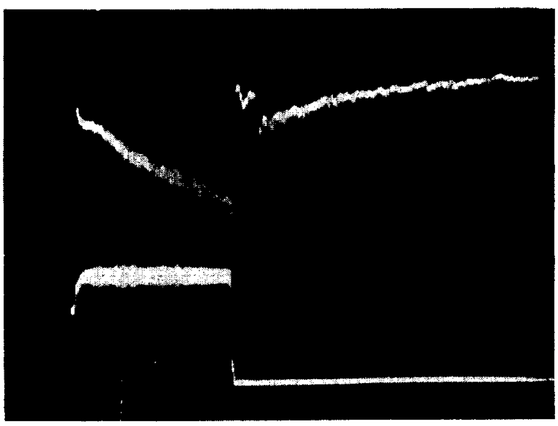


(a)



(b)

Fig. 2 (a) $H^-$ ion beam current of surface-plasma ion source. X: 50 μS/div, Y: 5 mA/div
(b) upper: Extracted current, 100 mA/div
lower: Arc current, 50 A/div

Operating parameters are:

| | | |
|---|---|---|
| repetition | : | 20 Hz |
| arc current | : | 100 A |
| arc voltage | : | ∿ 140 V |
| arc duration | : | 150 μsec |
| source mag. field | : | 920 Gauss |
| bend. mag. field | : | 1470 Gauss |
| extraction slit | : | 2 × 15 $mm^2$ |
| extraction gap | : | 2.5 mm |
| extraction volt. | : | 16 kV |
| acceleration volt. | : | 50 kV |
| cathode temp. | : | ∿ 460 °C |
| Cs feed tube temp. | : | ∿ 450 °C |
| Cs oven temp. | : | ∿ 180 °C |
| $H_2$ gas flow rate | : | ∿ 2 atm·cc/min. |

current increases to 5 μA and the new source seems promissing.[4]

When the charge-exchange injection system is installed in the booster, the present proton preaccelerator should be changed to a $H^-$ system. For this conversion, a magnetron type surface-plasma source[5] has been developed. A current of 20 mA was achieved in the cesium mode as shown in Fig.2 with operating parameters.

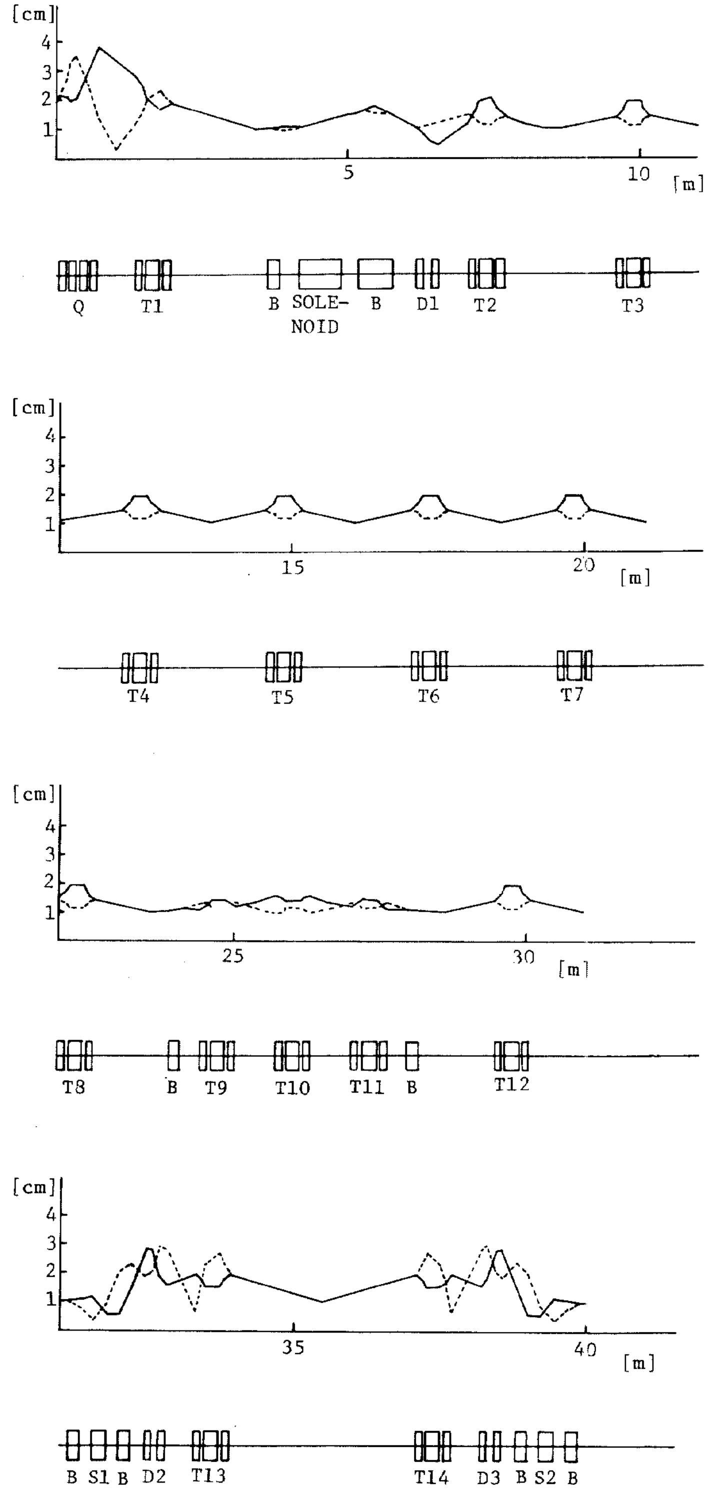



Fig. 3 Beam envelopes along LEPBT.

## High Voltage Aparatus

The accelerating voltage is supplied by an open Cockcroft-Walton generator. Its voltage is stabilized within 0.1 %. The high voltage terminal must be large enough to contain the polarized source and its auxiliary equipments. So its dome is 4 m long, 4 m wide and 3 m high. An electric power of 50 kW is supplied in it by a generator driven with a FRP shaft. The accelerating column consists of two big porcelain tubes.[6] Its inside diameter is about 1 m, thus it ensures a large conductance for the ion source gas load.

## Low Energy Polarized Beam Transporting System

In this beam line, not only $H^-$ ions but also their spin should be transported properly. When the $H^-$ ions are extracted from the polarized source, the spin is parallel to the beam direction. After acceleration of 750 kV, it is rotated by a 23.7° bending magnet and becomes perpendicular to the beam in the horizontal plane. Then the ions pass through a 0.0704 T-m solenoid and their spin is rotated around the axis by 90°. The beam line is shown in Fig. 1. Assuming emitances $\varepsilon_x = \varepsilon_y = 100$ πmm·mrad, beam envelopes were calculated by the computor programs MAGIC and TRANSPORT. They are shown in Fig. 3. Poles of the quadrupole magnets are hyperbolic as shown in Fig. 4. Deviation of dB/dr is less than 0.2 % within 80 % of the bore radius. Parameters of the quadrupole magnets are listed in Table 1.

The charge-exchange reaction of the 750 keV $H^-$ ions with residual gas atoms has a cross section of about $10^{-16}$ $cm^2$. Thus the pressure should be kept lower than $1 \times 10^{-7}$ Torr for a beam loss of less than 1 % in the 40 m LEPBT. Beam current and profile monitors are being developed for a very low current of several μA.

For tuning of the long LEPBT and the charge-exchange injection system, two cases are being examined, one is installation of the surface-plasma $H^-$ ion source and the other is extraction of unpolarized $H^-$ ions from the polarized source. If a sufficient current is extracted, the latter is more convenient.

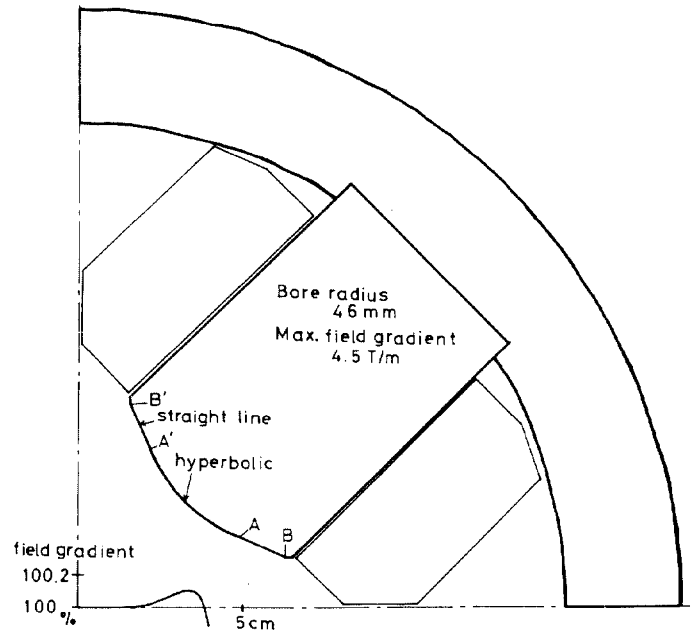



Fig. 4 Pole shape and calculated field gradient of quadrupole magnet.

Table 1 Parameters of LEPBT magnets.

| NAME | | L(m) | dB/dr (T/m) |
|---|---|---|---|
| Quartet | Q1 | 0.125 | 2.400 |
| | Q2 | 0.125 | -3.400 |
| | Q3 | 0.125 | -1.508 |
| | Q4 | 0.125 | 2.529 |
| Triplet (1) | Q5 | 0.12 | 1.490 |
| | Q6 | 0.24 | -2.081 |
| | Q7 | 0.12 | 1.490 |
| Doublet (1) | Q8 | 0.12 | 1.433 |
| | Q9 | 0.12 | -0.295 |
| Triplet (2) | Q10 | 0.12 | -2.433 |
| | Q11 | 0.24 | 2.350 |
| | Q12 | 0.12 | -2.433 |
| Triplet (3) | Q13 | 0.12 | -2.293 |
| | Q14 | 0.24 | 2.045 |
| | Q15 | 0.12 | -2.293 |
| Triplet (4) | * | | |
| Triplet (5) | * | | |
| Triplet (6) | * | | |
| Triplet (7) | * | | |
| Triplet (8) | * | | |
| Triplet (9) | Q31 | 0.12 | -2.055 |
| | Q32 | 0.24 | 1.650 |
| | Q33 | 0.12 | -2.055 |
| Triplet (10) | Q34 | 0.12 | 1.750 |
| | Q35 | 0.24 | -1.465 |
| | Q36 | 0.12 | 1.750 |
| Triplet (11) | ** | | |
| Triplet (12) | * | | |

| NAME | | L(m) | dB/dr (T/m) |
|---|---|---|---|
| Singlet (1) | Q43 | 0.24 | 3.166 |
| Doublet (2) | Q44 | 0.12 | 4.070 |
| | Q45 | 0.12 | -4.335 |
| Triplet (13) | Q46 | 0.12 | 2.678 |
| | Q47 | 0.24 | -2.989 |
| | Q48 | 0.12 | 2.678 |
| Triplet (14) | *** | | |
| Doublet (3) | **** | | |
| Singlet (2) | ***** | | |

*Triplet (3),(4),(5),(6),(7),(8) and (12) have the same quadrupole magnets.

**Triplet (9) and (11) have the same quadrupole magnets.

***Triplet (13) and (14) have the same quadrupole magnets.

****Doublet (2) and (3) have the same quadrupole magnets.

*****Singlet (1) and (2) have the same quadrupole magnets.

## References

1) H. Sasaki, Proc. US-Japan Seminar on High Energy Accelerator Science, 247, 1973.

2) S. Suwa, Proc AIP Conf., "High Energy Physics with Polarized Beams and Polarized Targets", 325, 1978.

3) T. Kawakubo et al., Proc. 3rd Symposium on Accelerator Science and Technology, Osaka, 31, 1980.

4) Y. Mori et al., paper submitted to this conference.

5) C.W. Schmidt et al., IEEE Trans. Nucl. Sci., NS-26, 4120, 1979.

6) S. Fukumoto et al., Proc. 1976 Proton Linac Conf., 189, 1976.