DESIGN AND STATUS OF DCI

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Summary

The main characteristics of DCI are first briefly reminded. The present status is then presented, as well as the schedule for the completion of Ring 1 and Ring 2. The expected performances are given for Ring 1 operating with e^+e^- beams and for Ring 1 and Ring 2 operating in the e^+e^+ and $e^\pm e^\pm$ mode of functionning. Typical aspects of these are emphasized concerning the use of DCI for high energy physics and synchrotron light research.

1. Description of the machine

DCI is a machine for intermediate energies, E_{max} = 1.8 GeV, aiming at a luminosity for e^+e^- annihilation in the range of 10^{32} cm^{-2} s^{-1}. It consists of two superposed rings with two circulating beams in each one. The space charge compensation scheme[1] should allow to reach the design luminosity with conventional β function in the meter range and stored currents below 1 A (see fig. 1).

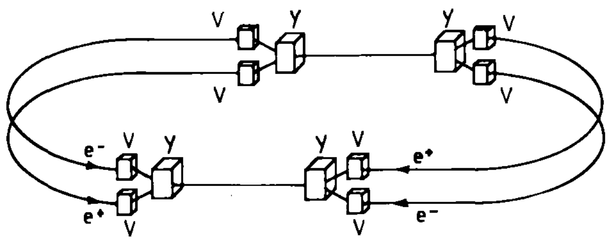

Fig. 1 : The four-beam charge compensation scheme.

Each ring has 4 half periods containing 3 horizontal 30° bending magnets (H), 2 vertical 10° bending magnets (V and Y) and 7 quadrupoles arranged in doublets except for the last one. Two straight sections 6 meter long, common to both rings, are used one for injection, the other for experimentation. The 4 beams will cross at the center of each of these. In practice, this limits the machine to the one-bunch mode operation.

Due to the lack of available space and to the maximum energy chosen for the machine, it has not been possible to incorporate in the design a matched insertion section. However the number of independant quadrupoles allows one to use different operating points with transition energies between 1.3 and 1.65 GeV for an RF power of 125 kW per beam.

The accelerating cavities work on the 8^{th} harmonic of the revolution frequency. Injection of both beams will take place at the energy of 1.2 GeV. When filling one bunch only, the injection speed should be of the order of 6 A/h. For experiments which require one beam in each ring the filling of the 8 bunches should be made at the speed of 20 A/h.

2. Status

The general lay-out of the machine is given in fig. 2.

2.1 Injector

In order to produce a positron beam of energy 1.2 GeV, the Linac has been modified to a large extent. A positron converter is now installed at the end of the first 1 GeV part of the Linac. From recent tests carried out after only 4 accelerating sections one expects to reach on the target a peak current of 0.6 A with a pulse duration of 20 ns. The converter immersed in a focussing lens is followed by 6 accelerating sections surrounded by a 0.2 T solenoid. The positron beam is refocussed by doublets and triplets of quadrupoles over 1.2 GeV. A peak current of 1.6 mA is expected at the end of the Linac. Switching from a positron beam to an electron beam should be done in a few minutes. This part of the program is nearing completion.

2.2 Transport system

Two beam transport lines will be used for injection in both ways. They match the emittance of the positron beam from the Linac to the acceptance of the machine. The optical magnification is about 1/5. The magnetic fields of the two transport lines can be reversed within a few minutes to switch from a positron beam to an electron beam. The North transport line should be completed at the end of 1974 and the South line 3 months later.

2.3 Magnets and quadrupoles

All the elements for both rings have been ordered. The bending magnets for Ring 1 are installed on their supports and connected. The last 9 magnets for Ring 2 which are not yet delivered are in a well advanced stage in the factory. 33 out of 48 quadrupoles are on the site and the rest is nearing completion. 8 special quadrupoles for the vertical arms of the 2 rings will arrive rather late in October or November this year. The machining of the bending magnets and of the quadrupoles is well within the tolerances (in fact 3 10^{-2} mm for the magnet gaps and 2 or 3 10^{-2} mm for the quadrupole aperture.

Besides the main coils, the quadrupoles are equipped with secondary quadrupolar coils for the separation of the wave numbers of the 2 rings. Furthermore 16 quadrupoles in each ring will have sextupolar windings.

2.4 Pulsed magnets

The pulse magnet system, which will work at the repetition frequency of 25 Hz, is made of 2 inflectors and 4 kickers. The inflectors are conventional iron cored septum magnet, 15 × 15 mm^2 useful aperture,

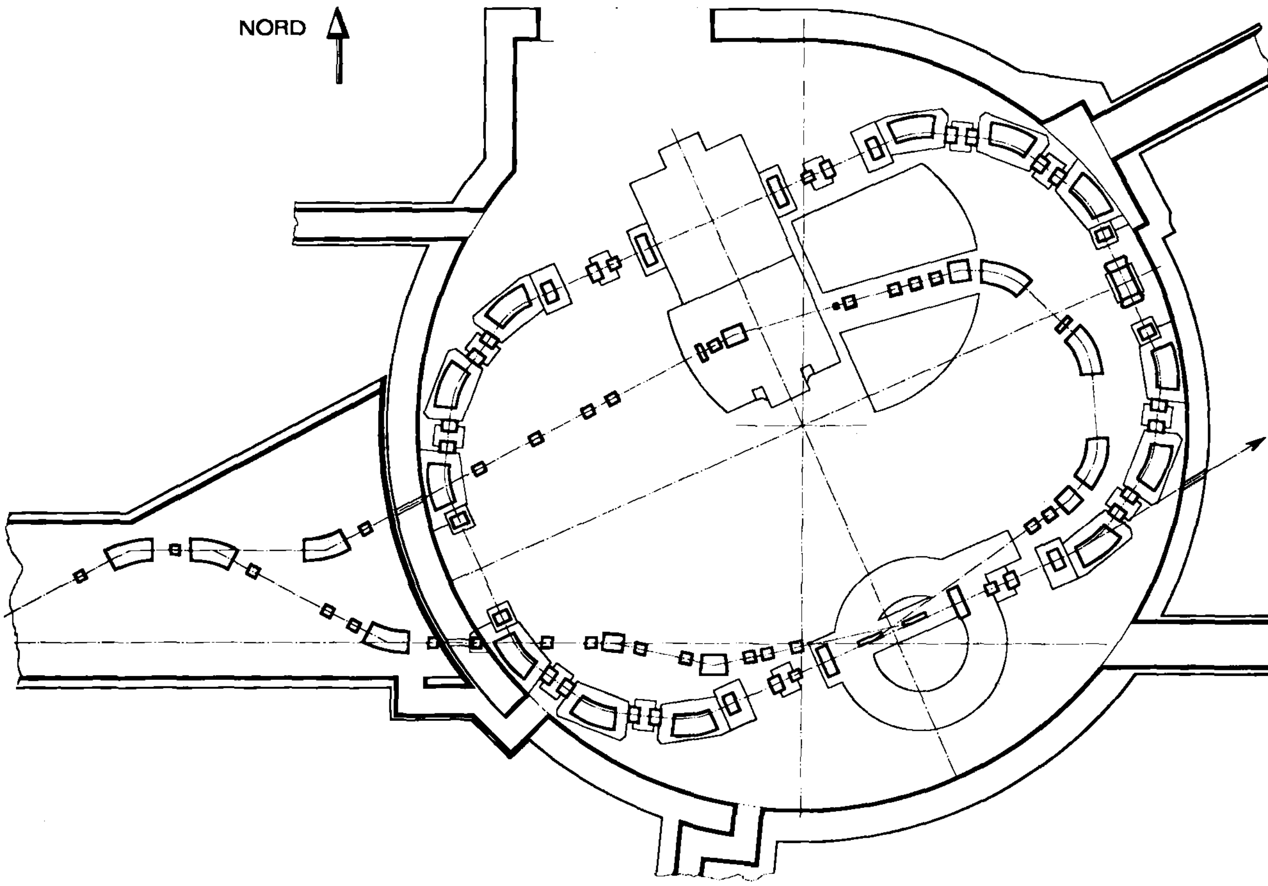

Fig. 2 : General lay-out of DCI

placed outside the vacuum chamber. The pulsed power supplies are completed and will soon be installed for tests.

The 2 kickers of each ring are separated by one half betatron wave length. They are of the full aperture type with an open ferrite circuit and will use CX 1192 thyratron switches. All the elements of the pulsed power supplies have been delivered except for the impedance transformer.

The whole system for Ring 1 should be ready in place at the end of the year.

2.5 RF

A 110 kW RF transmitter has been built in the laboratory and was tested at full power on a dummy load. An RF cavity has also been built and was tested at a power of 40 kW, corresponding to an accelerating voltage of 400 kV. The cavity is of a simple coaxial shape capacitively loaded by plates. It is made of pure aluminium and operates at 37° C. The cavity is completely evacuated. Power tests have shown that a good vacuum can be obtained after a reasonably short processing without baking out. Both the cavity and the RF transmitter are now installed in place. They will be connected by a 50 m long, 200 mm in diameter, coaxial line. The line has a characteristic impedance of 50 Ω and is matched at both ends by equivalent ideal transformers which also compensate for the loop impedance. The length of the line is $n\lambda/2$. It will be air cooled at full power.

The cavity for Ring 2 is being ordered just now. In the final stage each cavity will be driven by a 350 kW transmitter able to deliver 250 kW to the beams of each ring.

2.6 Vacuum chamber

Most of the elements of the vacuum chamber are made of stainless steel and have internal water cooled synchrotron light absorbers. The geometry of these absorbers is particularly complicated in the region between the horizontal and vertical magnets and has led there, to use copper chamber elements cooled from outside.

The total pumping speed for ring is 80 000 ℓ/s. At injection and during the process of rising the energy, high voltage electrodes are needed to separate electron and positron orbits. At 1.8 GeV, 50 kV would be needed. Until now a safe operation has been reached up to 40 kV.

At the moment 40 % of the vacuum chamber elements have been tested in the laboratory at the pressure of 1×10^{-10} Torr. The vacuum chamber for Ring 1 should be ready by the end of 1974.

2.7 Computer control and beam observation

The computer control system of DCI consists basically of a PDP 11/40 with a 48 k memory, associated with a one million word disk, a card reader and a magnetic tape unit. Two PDP 11/05 will manage for routine operation of the power supplies.

A real time monitor RSX 11 D will allow multiprogramming. Development of new programs will then be possible during normal machine operation. The interfacing of the computer system uses Camac modules.

The computer will do 4 essential jobs :

- Control of the power supplies, namely the main power supplies for the ring, correcting coils, sextupolar windings and part of the transport system power supplies. This includes the coupled variation of several element according to a predefined schedule.
- Control of the pulsed magnets : tuning, amplitude and commutation.
- Handling of the beam positron monitoring and display of the results.
- Interfacing with the operator through CRT screens allowing display of tables and curves and the selection of programs.

Two terminals consisting of an alphanumeric keyboard and two CRT screens will be provided.

Besides computer control, a manual operation of all the elements will be possible.

The computers have been already delivered. All the extra regulated power supplies and the Camac system should be delivered by September 1974. The software is expected to be operational next spring.

The beam control system includes the usual elements : beam positron monitor, measurement of beam profile and beam intensity. The power amplifier for beam excitation (wave number measurement, beam enlargement, feedback) delivers over 1 kV on a 10 pF electrode. A special system is designed to detect the beam positron in the interaction region with a reproducibility of a few 10^{-2} mm.

3. Expected performances

There will be 2 stages for DCI depending on the availability of Ring 1 and Ring 2.

- 1st Stage : Ring 1, e^+e^- beams

The luminosity curve and the current needed in each beam are given in fig. 3, for an available RF power of 35 kW/beam. The maximum luminosity is in the range of a few 10^{30} cm^{-2} s^{-1} at a transition energy variable between 1.4 and 1.7 GeV. During a long period of time the detectors for physics experiments on DCI will be somewhat shorter than the straight section. Two quadrupoles could therefore be installed in this section, as well as in the injection section, so as to reduce the β_s^*' by a factor 2, in the hope of increasing the luminosity.

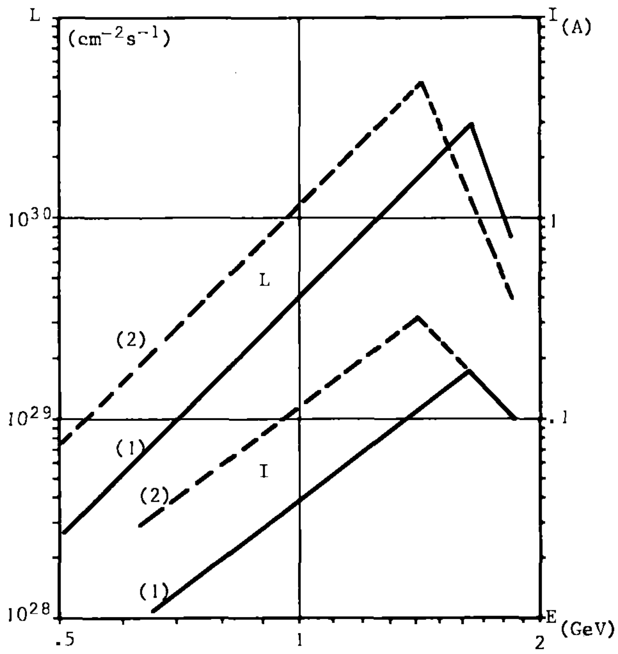

Fig. 3 : DCI - One Ring e^+e^-

$\beta_x^* = \beta_z^* = 2$ m — One bunch per beam

$\Delta\nu_o = .05$ — $P_{RF} = 35$ kW per beam

Curves (1) $\nu_x = 4.155$, $\nu_z = 2.155$ — Curves (2) $\nu_x = 3.845$, $\nu_z = 2.845$

- 2nd Stage : Ring 1 and Ring 2, e^+e^+ beams

The luminosity curve and the current needed in each beam are given in fig. 4, for an available RF power of 250 kW/ring. Each beam will have 8 bunches. The luminosity is in the range of 10^{31} cm^{-2} s^{-1}. This mode of functionning is envisaged for the use of DCI for two-photon experiments. Unwanted e^+e^- annihilation events are then suppressed. A rather good luminosity as well as a good duty cycle is obtained. Further, tagging systems can be used with maximum efficiency behind the Y magnets adjacent to the experimental section. In these three respects DCI is probably the best machine, if any, to carry out such experiments.

Ring 1 and Ring 2, $e^{\pm}e^{\mp}$ collisions

Fig. 5 give the ultimate performances of the machine with an available power of 125 kW/beam. The luminosity is in the range of 10^{32} cm^{-2} s^{-1}. One feels at Orsay that even a factor 10 below these figures would still make DCI, a very attractive machine in its energy range.

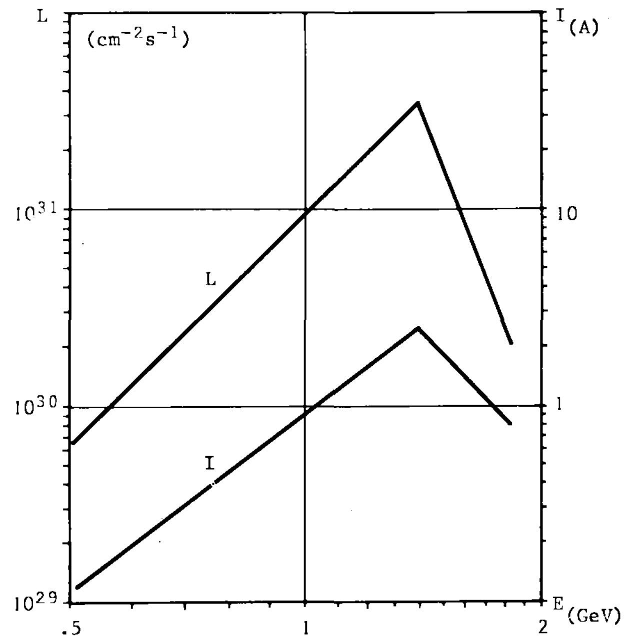

Fig. 4 : DCI – Two Rings e^+e^+

$\beta_x^* = \beta_z^* = 2$ m

$\Delta\nu_o = .05$

8 bunches per beam

$P_{RF} = 250$ kW per beam

$\nu_x = 3.845$

$\nu_z = 2.845$

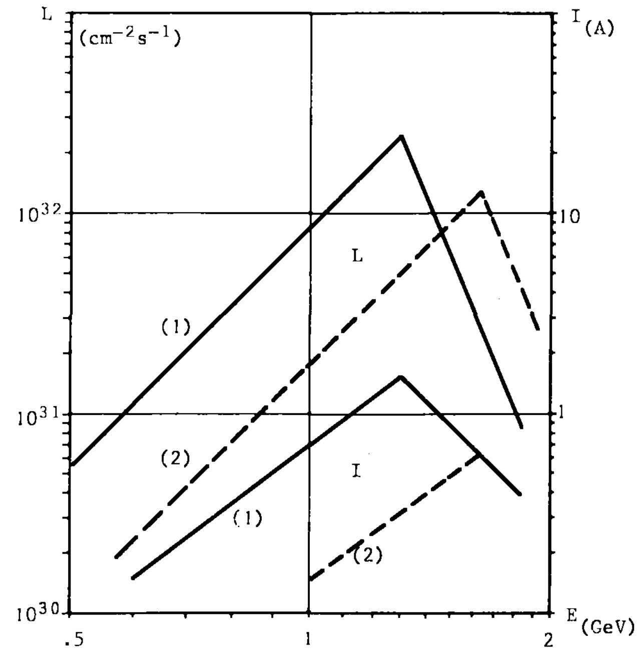

Fig. 5 : DCI – Two Rings $e^{\pm}e^{\mp}$

$\beta_x^* = \beta_z^* = 2$ m

$K\Delta\nu_o = .3$

One bunch per beam

$P_{RF} = 125$ kW per beam

Curves (1) $\nu_x = 3.845$, $\nu_z = 2.845$

Curves (2) $\nu_x = 4.845$, $\nu_z = 2.845$

4. Schedule and physics program

It is expected that the basic components for Ring 1 and the North transport line should be ready by the end of 1974 or the very beginning of next year and the South transport line, 3 months later. Ring 2 would then need another year to be completed.

One therefore hopes to start doing physics with one ring in September 1975 and with 2 rings in September 1976.

A physics program is being laid down now. It will probably involve the use of a detector for charged and neutral particles and then a magnetic detector (actually in installation on ACO). Two-photon experiments are also proposed which would use, besides tagging systems, one of these two detectors. The building up of a large, weak field many purpose magnetic detector is also widely supported by Orsay physicists.

5. Synchrotron light research at Orsay

A large effort is developping in France towards using synchrotron radiation from ACO and DCI. A beam line has been opened at the beginning of 1973 on ACO, which allows at the maximum energy of this machine (540 MeV), the use of synchrotron light down to 6 Å (max. at 20 Å). From 1976 on, this machine will be entirely devoted to this type of research and several others beams could be opened.

A similar effort is being made on DCI with the opening next year of a first beam line which will extend the use of very intense beams down to 0.65 Å (max. at 1.8 Å). The construction of a hall for experimentation in the close vicinity of DCI will start this year together with the major components of the beam line. A national institution under the name of LURE* has been created for this purpose.

*Laboratoire d'Utilisation du Rayonnement Electromagnétique (C.N.R.S. et Université Paris-Sud).

Reference

1. J.E. Augustin et al., Proceedings of the VIIth International Conference on High Energy Accelerators, Erevan (1969), vol. 2, p. 113.