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AN ASYMMETRIC COLLIDER WITH THE TRISTAN MAIN RING

KOTARO SATOH, YOSHIHIRO FUNAKOSHI, HARUYO KOISO,
EIJI KIKUTANI and ASAO SATO
National Laboratory for High Energy Physics
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305 Japan

ABSTRACT The paper describes two preliminary designs of the asymmetric collider, 2GeV × 14GeV and 3.5GeV × 8GeV, with the TRISTAN main ring. The design goal of luminosity is $1 \times 10^{33} cm^{-2} s^{-1}$. While the total current is supposed to be limited by beam instabilities and accelerator hardware, it has not been examined whether the required total current can be stored.

INTRODUCTION

Asymmetric colliders have been proposed for B-meson factories in laboratories having large electron-positron storage rings, such as PETRA and PEP[1,2]. It is also reported that symmetric double-ring colliders proposed in PSI and Novosibirsk can be operated as asymmetric colliders[3,4]. In KEK a design study is going on for proving the feasibility of the asymmetric collider as a future project. One of the two rings is the TRISTAN main ring(MR) and the other is a new small ring(SR).

This paper includes two preliminary designs of the asymmetric collider in the KEK site. The design goal of luminosity is $1 \times 10^{33} cm^{-2} s^{-1}$ in both cases. The total current will be limited by coupled bunch instabilities, heat-up problems of the vacuum chamber, short beam life due to the vacuum pressure rise and RF input power through couplers. The current limitation, however, has not been examined in both designs. Neither the synchrotron radiation produced in the separation bend has been taken into account. We need the collaboration with physics groups to finalize the design.

In the first design the small ring is housed in one of the existing experimental halls in TRISTAN with least engineering work on the existing concrete wall. The energy of SR is 2GeV while MR is to be operated at 14GeV. One of the big problems of this design is the electron injection into MR with the 8GeV TRISTAN accumulation ring(AR). In the end of each operation cycle of MR the stored current will be damped before the deceleration to injection energy. It is foreseen that the filling time of MR would be too long with the result of low integrated luminosity. In order to obtain high integrated luminosity this proposal requires a new 14GeV booster ring in the

TRISTAN tunnel.

In the second design the energy of MR is chosen to be 8GeV, the maximum energy of AR. Then MR is always staying at the colliding energy. In the end of the operation cycle only the decrement of the stored current is refilled by AR. The energy of the small ring would be 3.5GeV. It is not necessary to construct a new booster injector. By the improvement of klystrons the linac would be able to inject positron beams directly into SR at 3.5GeV. In this case, however, the small ring is no longer fitted into the experimental hall.

2GeV × 14GeV COLLIDER

The size of SR is restricted by the area of the experimental hall(Fuji) and the RF harmonic number of MR. The circumference of SR is chosen as 1/32 of MR's. The geometry of SR and injection lines are drawn in Fig.1. Table I shows the machine parameters of the two rings. We adopt the flat-beam collision scheme instead of the round-beam collision. We choose a relatively small emittance ratio of 0.02. Suppose that the stored current in MR is 2mA per bunch, 640mA in total, and that the minimum β^*_{yMR} is 5cm. If the maximum tune shift is 0.03 in both rings, the luminosity is expected to be $1.2 \times 10^{33} cm^{-2}s^{-1}$ with the collision frequency of 32MHz.

TABLE I Ring Parameters (2GeV × 14GeV Design)
$\mathcal{L} = 1.2 \times 10^{33} cm^{-2}s^{-1}$

	MR	SR
Energy	14Gev	2GeV
Circumference	3018.1m	94.3m
Harmonic number	5120	160
Number of bunches	320	10
Current per bunch	2mA	224mA
Total current	640mA	2240mA
Emittance	2.4×10^{-7}m	4.8×10^{-7}m
Emittance ratio	0.02	0.02
β^*_x	2.5m	1.25m
β^*_y	0.05m	0.025m
Beam-beam $\Delta\nu$	0.03	0.03
Energy spread	7.7×10^{-4}	7.3×10^{-4}
Bunch length	2.0cm	2.0cm
Energy loss	13.8MeV	0.254MeV
f_{RF}	508.58MHz	508.58MHz
RF voltage	32MV	2MV
Synchrotron frequency	9.3kHz	143kHz
Cavity Type	APS 9-cell	Single-cell
Number of cavities	10	4
Shunt impedance	675MΩ	32MΩ
Beam loss	8.8MW	0.57MW
Cavity loss	1.5MW	0.125MW
Total power	10.3MW	0.7MW

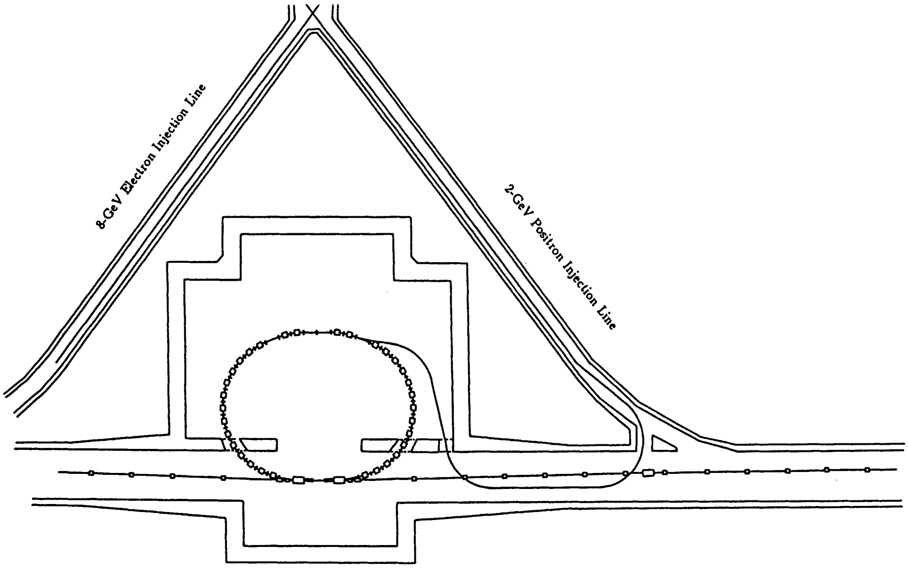


Fig 1. Geometry of the 2GeV × 14GeV collider.

The insertion layout is found in Fig.2. The free space in the colliding section is 2m long. The nearest two pairs of quadrupoles are composed of sectors of permanent magnet. The separation bend has a relatively high field of 0.6T. It produces synchrotron radiation with the 14GeV beam, which is to be a major noise source to physics detectors. The effect of the radiation on the experimental detector, or the method masking the radiation is not considered in the design.

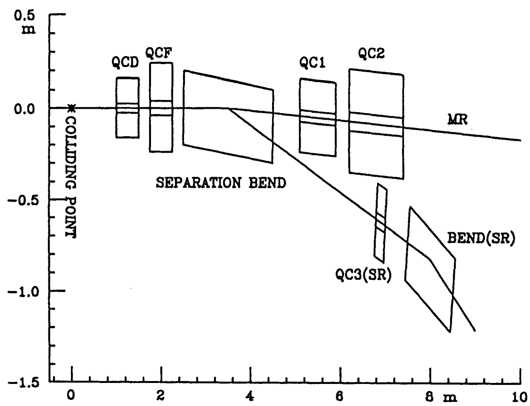


Fig 2. Insertion layout of the 2GeV × 14GeV collider.

The optimum emittance of MR is rather large compared with that in the original optics. In the example design the emittance is controlled by decreasing the phase advance of the normal cell from the nominal value of 60 degrees to 30 degrees. The present configuration of sextupole families is optimized for the nominal phase advance. Computer simulations using with tracking programs are necessary to analyze the sextupole correction in the high-emittance optics together with the chromatic effect produced by the strong quadrupoles in the colliding insertion.

In the present design conventional cavities are assumed in both MR and SR. In MR 10 nine-cell APS cavities, which are the same type as used in TRISTAN, are employed. In SR we adopt 4 single-cell cavities with the same acceleration frequency of MR. The parameters of the cavity are referred to the re-entrant cavity in KEK PF. It is believed that the total current is limited by coupled-bunch instabilities excited by higher-order modes in RF cavities. We have not examined the stability of the required stored current both in the two rings. If the estimated total current is much less than the required we would change the present RF design. In order to store so many bunches with large current it is definitely required to control or suppress the coupled bunch instability. Practical methods are the development of efficient feedback systems to damp the coherent motion of bunches, and the development of cavities with least higher-order mode resonances, such as a single-mode cavity.

One of the big problems is the electron injection into MR with the 8GeV AR. Keeping the stored current during the deceleration from 14GeV to 8GeV is supposed to be hardly practical. The stored current would be damped after each operation cycle. Then the electron filling time would be too long with the result of low integrated luminosity. Installation of a new 14GeV synchrotron in the TRISTAN tunnel would solve the problem. MR would have no need to change energy, staying at 14GeV, and only the decrement in the stored current is filled by the injection. It is also expected that coupled-bunch instabilities are less effective on the 14GeV beam than on the present 8GeV injected beam.

3.5GeV × 8GeV COLLIDER

The design of the 3.5GeV × 8.0GeV option has been done on the basis of that of the 2GeV × 14GeV option. The candidates of the circumference of SR are 1/20 and 1/16 of MR's considering the beam energy and the RF harmonic number. Of these candidates, 1/16 MR's is chosen to reserve enough space for RF cavities.

The geometrical view of SR is shown in Figure 3. Table II shows the machine parameters for the collider. Some assumed parameters are chosen as the same values as those in the first option; the emittance ratio as 0.02, the attainable current in MR as 2mA per bunch, 640mA in total and the maximum tune shift as 0.03. A smaller β^*_{yMR} of 3cm is obtained because the smaller energy asymmetry enables the final focusing Q magnets to be stronger than those of the first option. The design luminosity is $1.1 \times 10^{33} cm^{-2} s^{-1}$ with the collision frequency of 32MHz.

TABLE II Ring Parameters (3.5GeV × 8GeV Design)
$\mathcal{L} = 1.1 \times 10^{33} cm^{-2}s^{-1}$

	MR	SR
Energy	8Gev	3.5GeV
Circumference	3018.1m	188.6m
Harmonic number	5120	320
Number of bunches	320	20
Current per bunch	2mA	61mA
Total current	640mA	1220mA
Emittance	2.3×10^{-7}m	2.7×10^{-7}m
Emittance ratio	0.02	0.02
β_x^*	1.5m	1.25m
β_y^*	0.03m	0.025m
Beam-beam $\Delta\nu$	0.03	0.03
Energy spread	1.2×10^{-3}	9.4×10^{-4}
Bunch length	2.2cm	1.6cm
Energy loss	5.4MeV	1.3MeV
f_{RF}	508.58MHz	508.58MHz
RF voltage	14.2MV	5MV
Beam loss	3.5MW	1.6MW

The layout of the colliding insertion is found in Figure 4. The free space in the colliding section is 1.9m long. The separation bend is 2m long and has a considerably higher field(1.4T) compared with that of the former option. The critical energy of the synchrotron radiation emitted by the 8GeV beam in the bend is 59.6keV and is 20% lower than that by the 14GeV beam in the first option. The radiation power from the 8GeV beam in the bend is, however, 80% higher than that from the 14GeV beam.

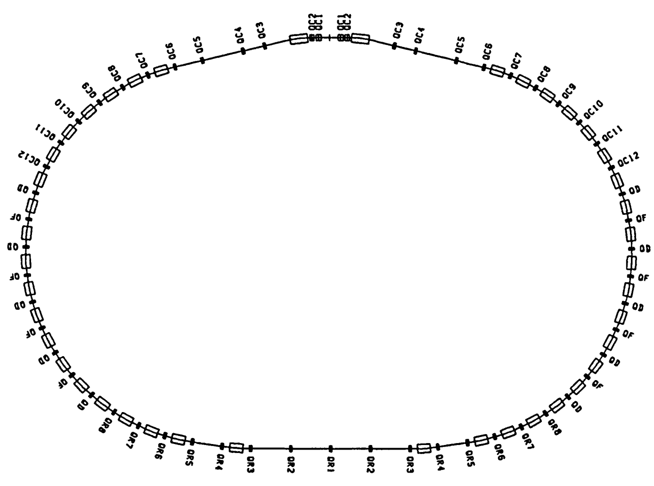
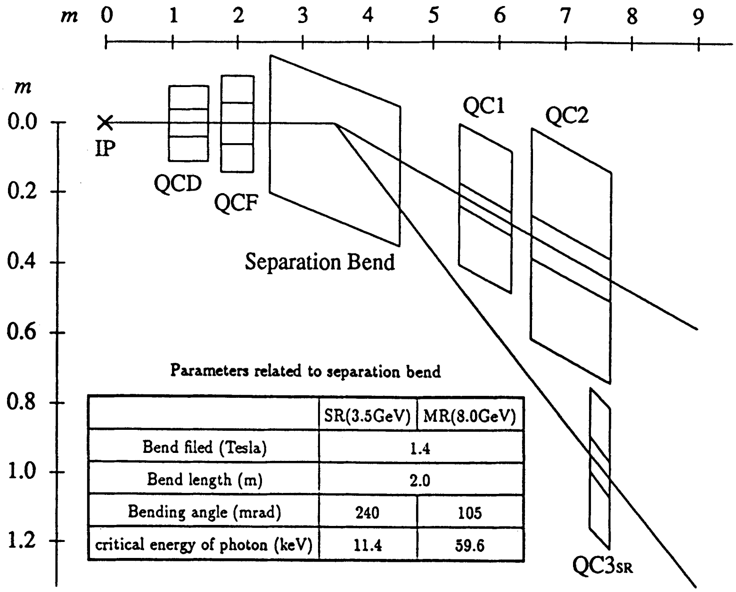


Fig 3. Geometry of the 3.5GeV ring.



Parameters related to separation bend

	SR(3.5GeV)	MR(8.0GeV)
Bend filed (Tesla)	1.4	
Bend length (m)	2.0	
Bending angle (mrad)	240	105
critical energy of photon (keV)	11.4	59.6

Fig 4. Insertion layout of the 3.5GeV × 8GeV collider.

The optimum emittance of MR is 2.3 $\times 10^{-7}$m and almost the same as that of the 2GeV × 14GeV design. To realize this rather large value, the phase advance of the normal cell is changed from the nominal value of 60 to 50 degrees, in addition to the use of 1.4T wiggler magnets installed in the symmetry region of the ring. Furthermore, the number of the bending magnets is halved in such a way that every other bending magnet is removed from the lattice used in the present MR. It is expected that the sextupole field becomes lower with wider dynamic aperture, since the dispersion in the sextupole magnets becomes larger. Any tracking study, however, has not been performed to examine the dynamic aperture in this scheme. The removal of the bends is also helpful to make additional space for vacuum pumps, which are necessary for the sufficiently low vacuum pressure to guarantee an enough beam life.

In this design, the bunch current and the number of bunches in MR are assumed to be the same as those in the 2GeV × 14GeV design. The coupled bunch instability is still the main difficulty for the attainment of the design luminosity.

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