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Informal Report

THOUGHTS ON STORAGE RING BY-PASS

L.C. Teng

August 21, 1972

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INTERSECTING STORAGE ACCELERATOR NOTES

THOUGHTS ON STORAGE RING BY-PASS

L.C. Teng
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Abstract

The statement was made that by-passes in a storage ring, namely putting interaction straight sections in parallel instead of in series, will improve the flexibility, thereby increase the experimental output. We will attempt to examine this thesis more in detail here.

A) Professor Gregory's Conclusions:

1. It is essential that in an interaction region one has the capability of going to the maximum luminosity of $10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$, otherwise the interaction region is "second class". Therefore, an interaction region must have the capability of low- β , zero- X_p , etc., etc. and, hence must have a minimum length of $\sim 200 \text{ m}$ (based on the designs in the Grey Book).

2. For a given fixed budget, it is most profitable to construct as many "first class" interaction straight sections as possible, even to the extent of leaving some interaction regions "bare" to be equipped for experimental use in the future.

3. All the interaction regions should be in series. The discipline required of the experimentalists to get their equipment ready for installation and installed on rigid schedule which is necessary for the all series mode of running can be obtained although with pain.

B) Analysis

We assume a total of N interaction regions and compare the following two arrangements.

All series arrangement (S):

All N interaction regions in series.

Series parallel arrangement (P):

M parallel by-passes with $\frac{N}{M}$ in series in each by-pass or, equivalently M interaction regions in parallel with $\frac{N}{M}$ of these parallel bundles in series.

1. Scheduling Troubles

This is certainly worse for (S) than for (P), but according to Prof. Gregory's experience the required discipline can be enforced.

2. Average Number of Simultaneous Experiments

Define $F = \frac{\text{running time}}{\text{running time} + \text{set-up time}}$ for an average experiment. Then the average number of experiments running simultaneously is

NF for (S)

$\frac{N}{M}$ for (P) .

Hence if $F > \frac{1}{M}$ (S) comes out ahead. The experience at ISR is that $F > \frac{1}{2}$. Even for $F = \frac{1}{2}$ (P) will lose out if $M > 2$.

3. Compatibility Among Series Experiments

These include energies of the beams, intensities of the beams, etc. The degrees of incompatibility for these two arrangements are roughly proportional to

$(N-1)^n$ for (S)

$M(\frac{N}{M}-1)^n$ for (P)

where n is a number larger than unit. It is difficult to evaluate the ultimate damage this incompatibility does to the experimental program, but it is clear that this consideration favors arrangement (P).

4. Cost

The extra cost for (P) compared to (S) is that for the magnets (including dewar, refrigeration, and power supply) and tunnels needed to form the by-passes. Depending on the specific design this may be 1/8 to 1/4 of that for the basic ring for each by-pass. This is roughly enough to provide for one or two additional "bare" interaction regions. This means that if we had four interaction regions I and II in parallel, III and IV in parallel, and I, II and III, IV in series we could put them all in series and have enough excess funds to add two

to four "bare" interaction regions in series for future development.

5. Machine Downtime For Maintenance and Repair

This is usually a fixed fraction of the time when the machine is running. Therefore it affects (S) and (P) equally. Arrangement (S), however, has the advantage that major machine modifications or additions can be scheduled to coincide with the (1-F) period for setting up experiments. For arrangement (P) since the machine is running all the time, major machine modifications or additions will have to be done at the expense of experiment running time.

6. Future Additions

By-pass branches can always be added later, but series interaction regions must be designed in and constructed at the very beginning. Hence with a fixed initial budget, one should install as many series interaction regions as possible leaving the addition of parallel branches for future improvements. In addition for (S) all interaction regions are accessible from both sides whereas in (P) the spaces between parallel interaction regions are generally too small for accessibility. This is true, for example, when one considers the addition of an electron-positron ring for e-p experiments.

7. Beam Switching

Beam switching between parallel by-pass lines together with safety beam plugs so that when beam is running in one line people can safely work on all other parallel lines (even in the event of an accident) is not a simple matter and will likely lead to different beam optics and dispersion characteristics in different parallel lines (which can presumably be taken into account in the interaction region design). The design and operation of the machine with (P) is certainly more complex, hence less reliable than that with (S).

It is difficult, if not impossible, to assign proper weight-factors to these considerations and compute a truly quantitative comparison. My personal prejudice is to attach more weights to considerations (2), (3), (4), and (6); and to conclude that this analysis does, indeed, substantiate Prof. Gregory's conclusions (2) and (3). Based on this, therefore, we have:

C. Conclusion For ISA

We should not contemplate by-passes for the ISA. If more than two "first class" interaction straight sections are considered necessary for the experimental

program (which seems to be the conclusion of discussions during the past weeks) we should lengthen the four short straight sections to, say, 300 m and change the ring to a six-fold symmetry which, incidentally, will also reduce the number of dangerous structure resonances. To reduce the cost for the initial construction, we could leave some of these long interaction regions "bare" for future development.

D. By-Pass Geometry

If after all the analysis one still wants to see some possible by-pass geometries some of them are shown in the accompanying drawing.

1. The by-pass shown on the left side contains two interaction regions in series each having a length of l_2 which depends on the angle θ and the length L of the main branch interaction region. The added magnet and tunnel length for forming the by-pass is $2\rho\theta$. As shown in the drawing we have:

$$\begin{array}{lll} \theta = 22.5^\circ & L = 350 \text{ m} & l_2 = 190 \text{ m} \\ \rho = 220 \text{ m} & 2\rho\theta = \rho \times 45^\circ = \frac{1}{8} \text{ of ring} & \end{array}$$

The length $l_2 = 190 \text{ m}$ may be too short especially since the separation from the main branch is rather small at one end. This can be lengthened by lengthening L to, say, 400 m. Increasing θ will also lengthen l_2 and increase the separation of l_2 from the main branch, but this means increasing the added magnet and tunnel length $2\rho\theta$ for forming the by-pass.

2. The by-pass shown on the right side contains one interaction region of length l_1 which depends on θ , L and the separation S . As shown,

$$\begin{array}{lll} \theta = 22.5^\circ & L = 350 \text{ m} & l_1 = 215 \text{ m} \\ \rho = 220 \text{ m} & 2\rho\theta = \rho \times 45^\circ = \frac{1}{8} \text{ of ring} & \\ S = 30 \text{ m} & & \end{array}$$

again, increasing L or θ will increase l_1 .

3. Also shown on the lower part is half of an $e^\pm$ ring for e - p collision in the main branch interaction regions. Although not shown, presumably there will be by-passes on the $e^\pm$ ring and e - p interaction is between the by-pass of the $e^\pm$ ring and the main branch of the p - p ring. Note first that the addition of by-passes on the $e^\pm$ ring is for an entirely different purpose, and secondly this geometry for e - p interaction is independent of whether there is by-pass on the p - p ring.