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Booster Gold Beam Injection Efficiency and Beam Loss

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Study Period: January 13, 1997

Participants: C. Gardner, Tandem & MCR Staff

Reported by: S.Y. Zhang, & L. A. Ahrens

Machine: Booster

Beam: Au^{32+}

Tools: Booster Injection Transformer, TTB Transfer Line

Aim: To study the effect of Gold beam intensity upon the injection efficiency at the Booster

I. Summary

1. We suggest that the Booster injection efficiency of the Au^{32+} beam decreases in proportional to the beam loss in the ring.

2. The difference between this statement and the more conventional assumption that efficiency decreases with either the input beam intensity, or the circulating beam intensity in Booster, is subtle, but important.

II. Booster Injection Study

Following the observation of C. Carlson, C. Gardner repeated a study of the gold beam Booster injection in January 13, 1997, which is shown in Fig.1. The Tandem beam intensity was set by using 3 $\mu g/cm^2$ and 2 $\mu g/cm^2$ terminal foils. For the latter, the intensity was further adjusted by inserting multiwires and reducing the rotary aperture. These cases are denoted by A, B, C, and D in this report.

The reproduced Tandem beam current and the Booster beam intensity are shown in Fig.2, where the stacking is started at about 0.1 ms, and ended at 0.8 ms in all four cases.

Fig.3 reproduces the Booster intensity vs. time, now in unit of ions, but displays the Tandem input also in ions - the integral of the inputting current.

The Booster injection efficiency in Fig.4 is calculated for each time using the Booster beam intensity and the integral of the Tandem beam current from Fig.3. The Booster stacking was not linear with respect to the Tandem beam current. For some reason, the instantaneous stacking efficiency was the lowest at 0.2 to 0.4 ms, it increases at 0.5 to 0.6 ms, and decreases again at 0.7 to 0.8 ms.

III. Efficiency vs. Beam Loss

An examination of Fig.4 shows that the case B, with the highest Tandem intensity, has the lowest efficiency. The case A, on other hand, has the lowest intensity and the highest efficiency. Because of the complication of the Booster injection process, the information learned directly from Figs.3 and 4 is limited. The factors that have influence on the Booster injection efficiency are numerous. These can be:

1. Tandem beam profile, including transverse emittances, the momentum spread, etc.

2. The associated TTB transfer line tuning.

3. Booster injection section, including the inflector, the injection kickers, the Booster equilibrium orbit at the inflector, etc.

4. Booster injection tuning, including the Booster tune, $x - y$ coupling, etc.

In addition, the large difference of the loss mechanism between the stacking and capturing also made the observation difficult.

It can be assumed, however, that these factors had not been altered significantly during the study. For the most part, the machine is in the normal optimized configuration. Taking the Tandem beam intensity as the sole variable, its influence upon the injection efficiency can be singled out by the approach of comparison between the cases. To be specific, the efficiency ratio and the difference of the beam loss are used for examination.

The comparison of the efficiency ratio and the difference of the beam loss is shown in Fig.5 for all cases. The single line represents the difference of the beam loss, and the line with small circles represents the efficiency ratio. For convenience of examination, the efficiency ratio is inverted in Fig.5.

We have two observations,

1. In all cases, the efficiency ratio starts virtually from one at the low beam loss, it decreases in proportional to the increase of the difference of the beam losses.

2. By using this approach of comparison, the transition of the beam loss mechanism from the stacking to the capturing, at 0.8 ms, becomes very smooth.

The first observation suggests that the beam loss directly contributes to the Booster injection efficiency. This happened not only between the cases, but also with the entire injection process of each case, both at stacking and capturing.

The second observation shows further that the beam loss effect upon the Booster injection efficiency has indeed been singled out, despite the variation and transition of the beam loss mechanism during the injection period.

IV. Discussion

1. In an ideal injection, the beam loss would be zero, and the efficiency would be unity. The approach we used, i.e. the difference of beam loss and the efficiency ratio, compared with this situation, then becomes simply the beam loss vs. efficiency.

2. Due to some chronic beam loss mechanism at the stacking and capturing, the higher the Booster input intensity, the larger the beam loss, and hence, the lower injection efficiency. This is illustrated by the Booster gold beam injection morning numbers of 1994, 1995, 1996-97, and studies, shown in Fig.6. One may notice that at the Booster input around 50 to 60 $\times 10^8$ ions (which is defined as the total ions presented at the end of the TTB transfer line), the Booster early yields less than the injection with lower input intensity.

3. The difference of beam loss vs. the efficiency ratio of the cases B, C, and D compared with A are shown in Fig.7. It is interesting to notice that the data in whole injection process, including the stacking and capturing, fit in lines.

4. At some point, it was thought that the Booster injection efficiency is related with the Booster input intensity, or the circulating beam current in Booster. The difference between this and that the injection efficiency is indeed related with the beam loss is subtle, but nontrivial.

   - With the beam loss in mind, every effort to reduce beam loss in first place is relevant.
   - With the beam loss in mind, one focuses on what happened as the gold ions get lost, in order to improve the injection efficiency.

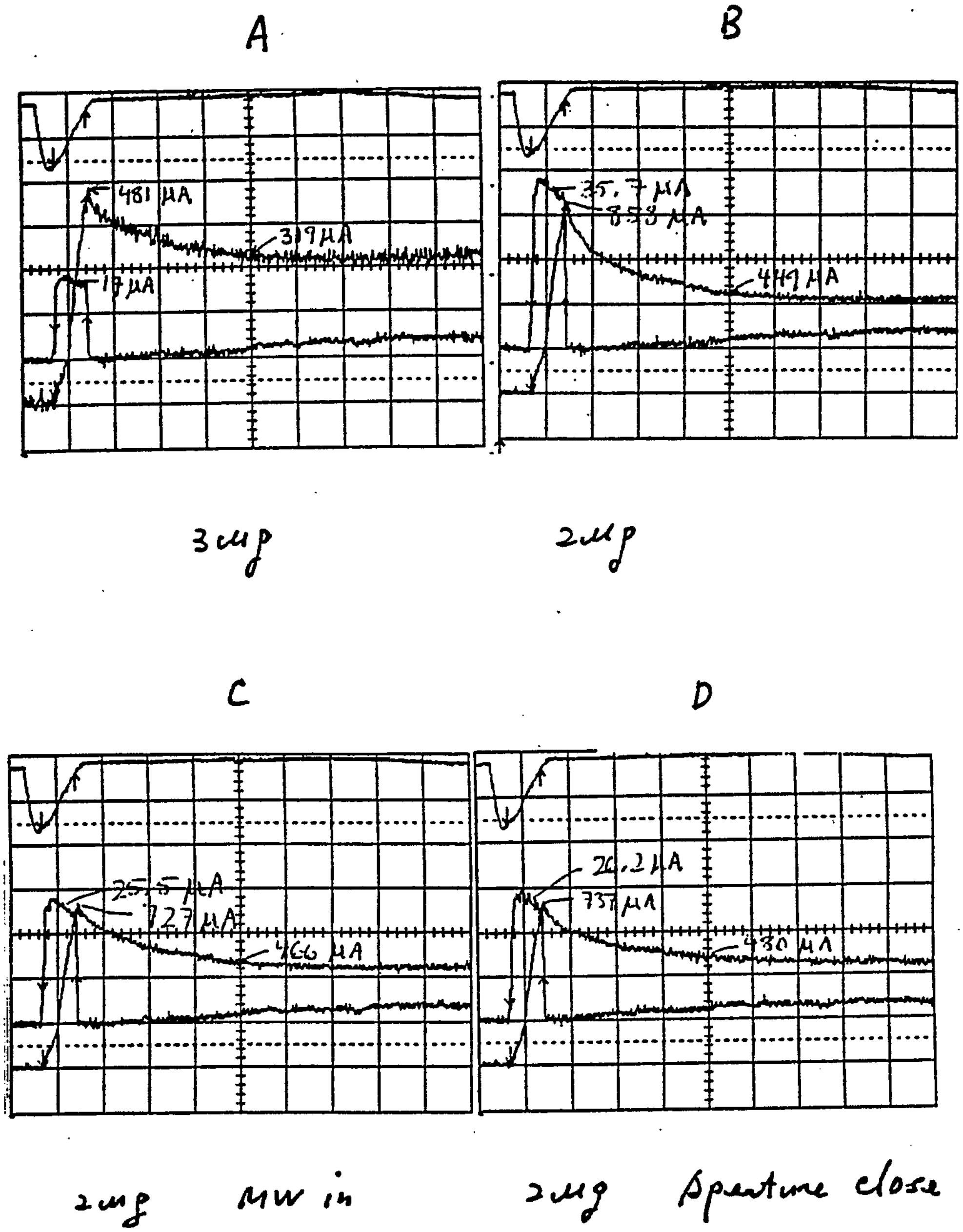

Fig.1. Booster Gold Beam Injection

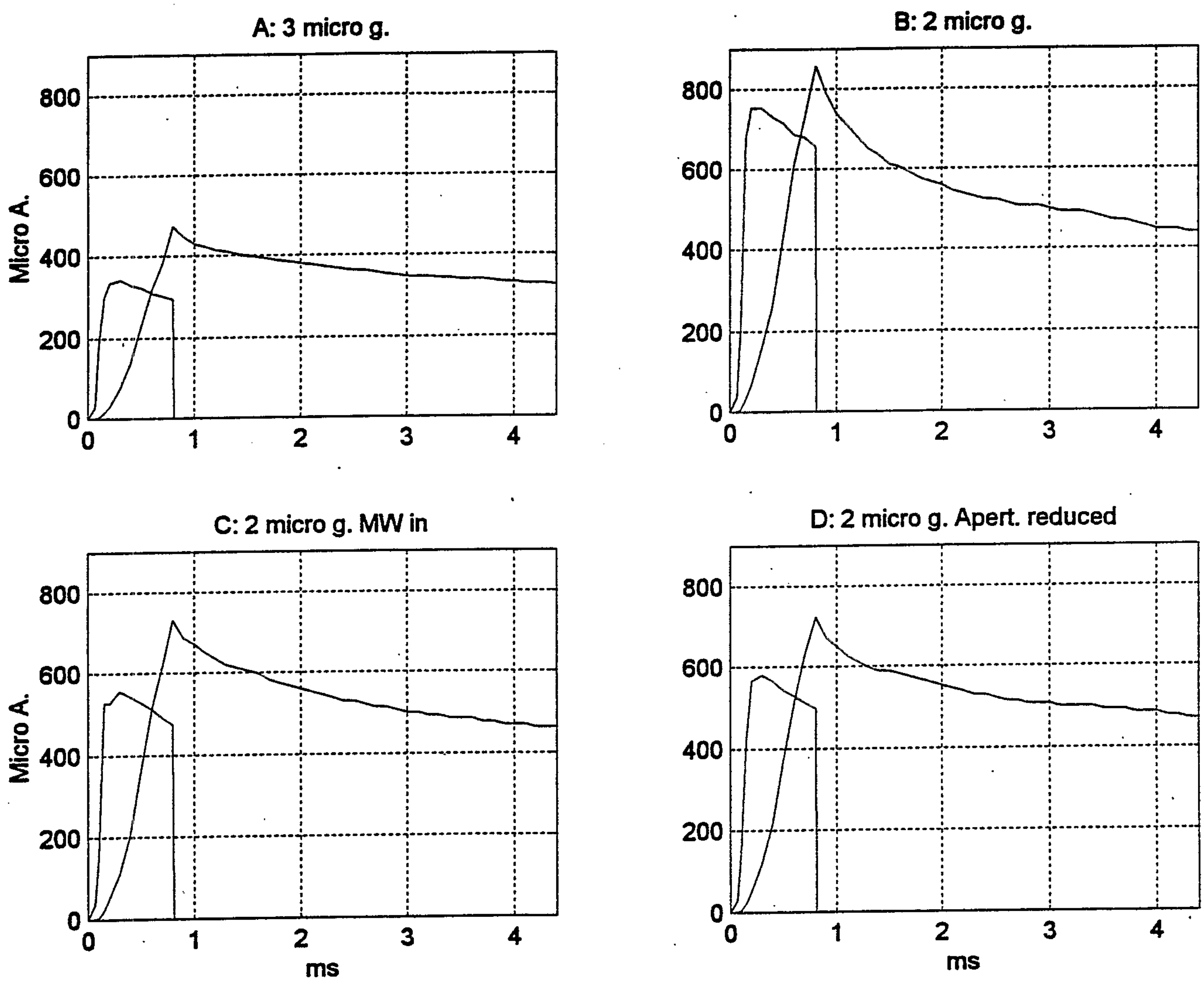

Fig.2. Reproduced Tandem and Booster Beam current

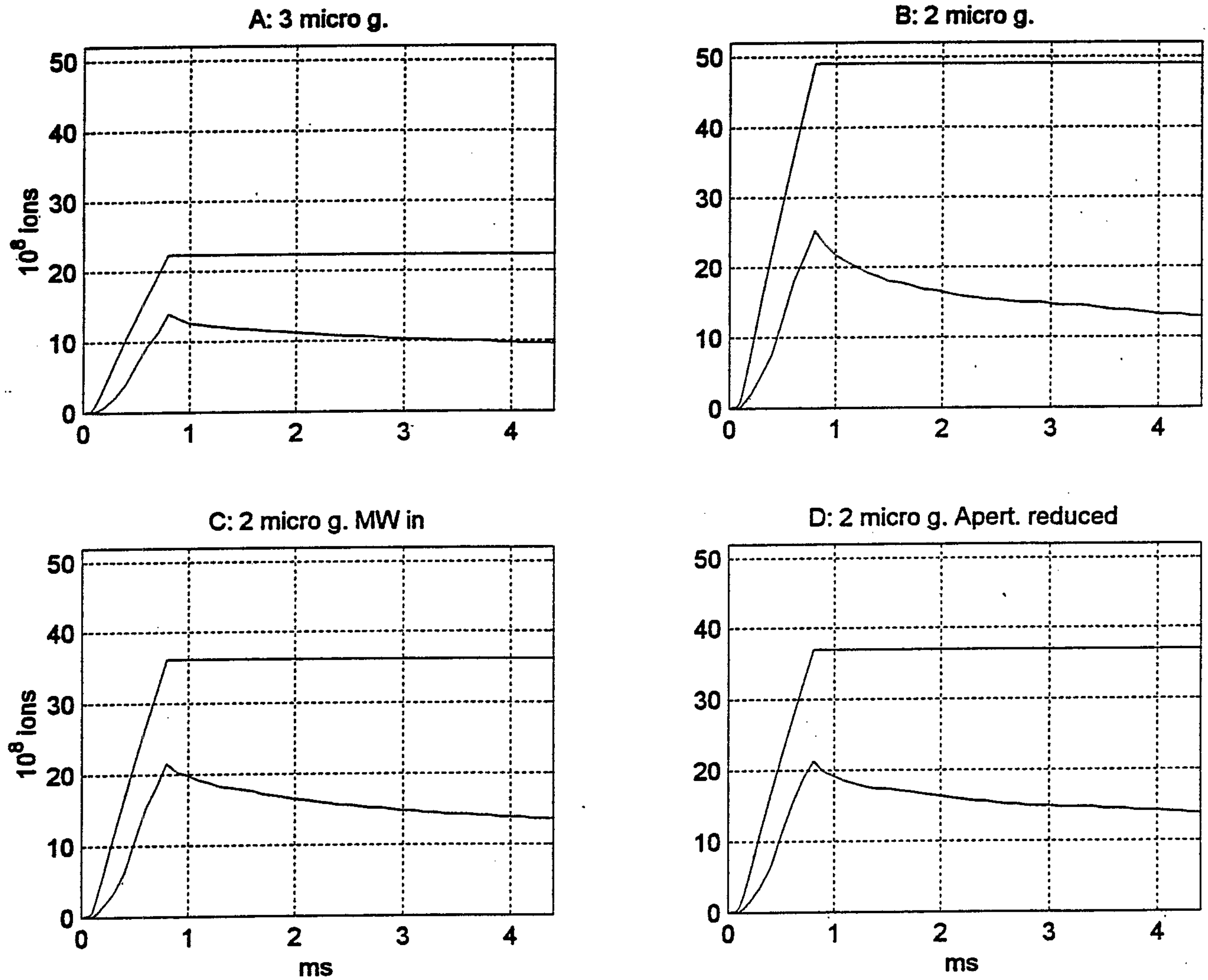

Fig.3. Booster Beam Current vs. Integral of Tandem Beam

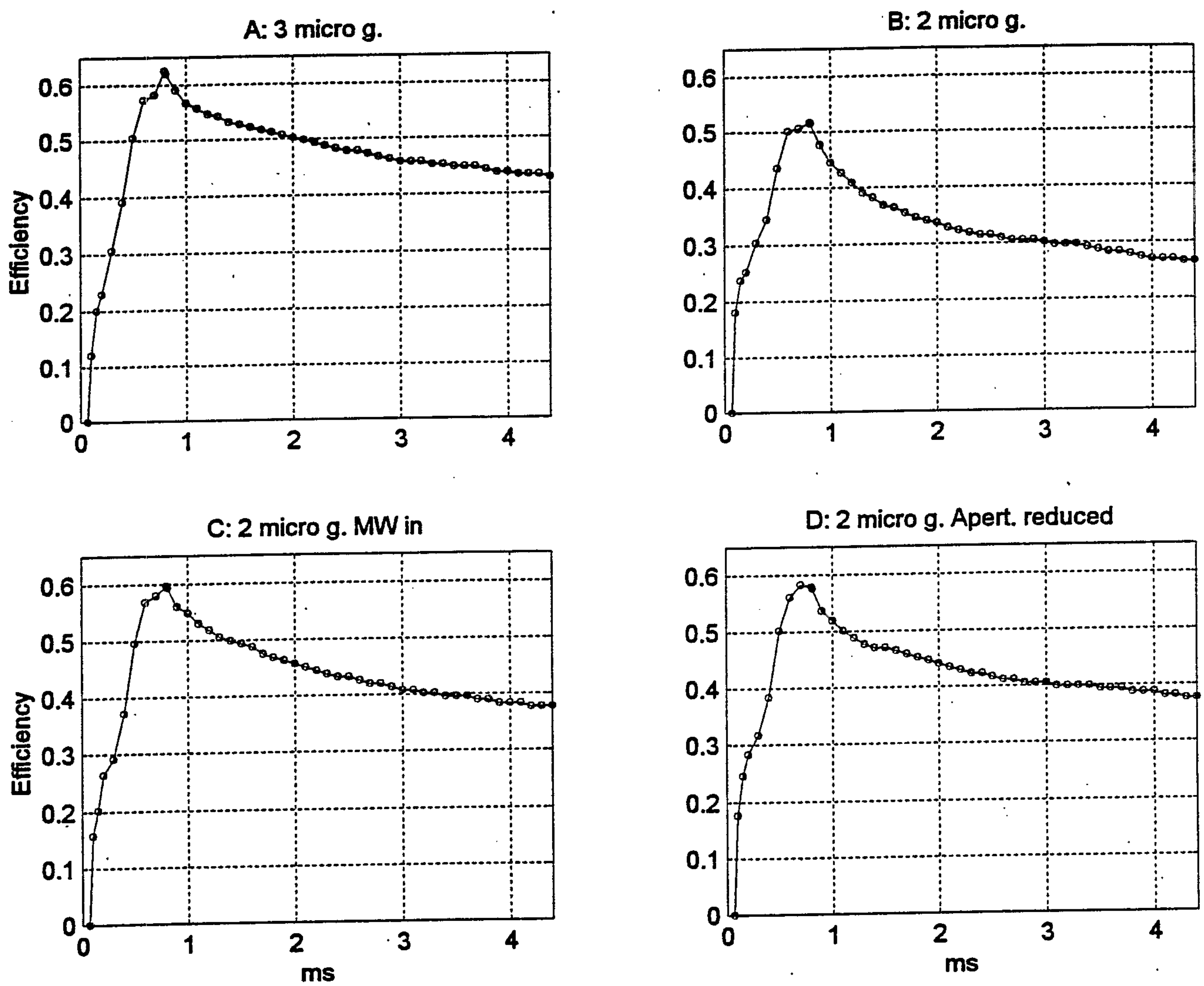

Fig.4. Booster Injection Efficiency

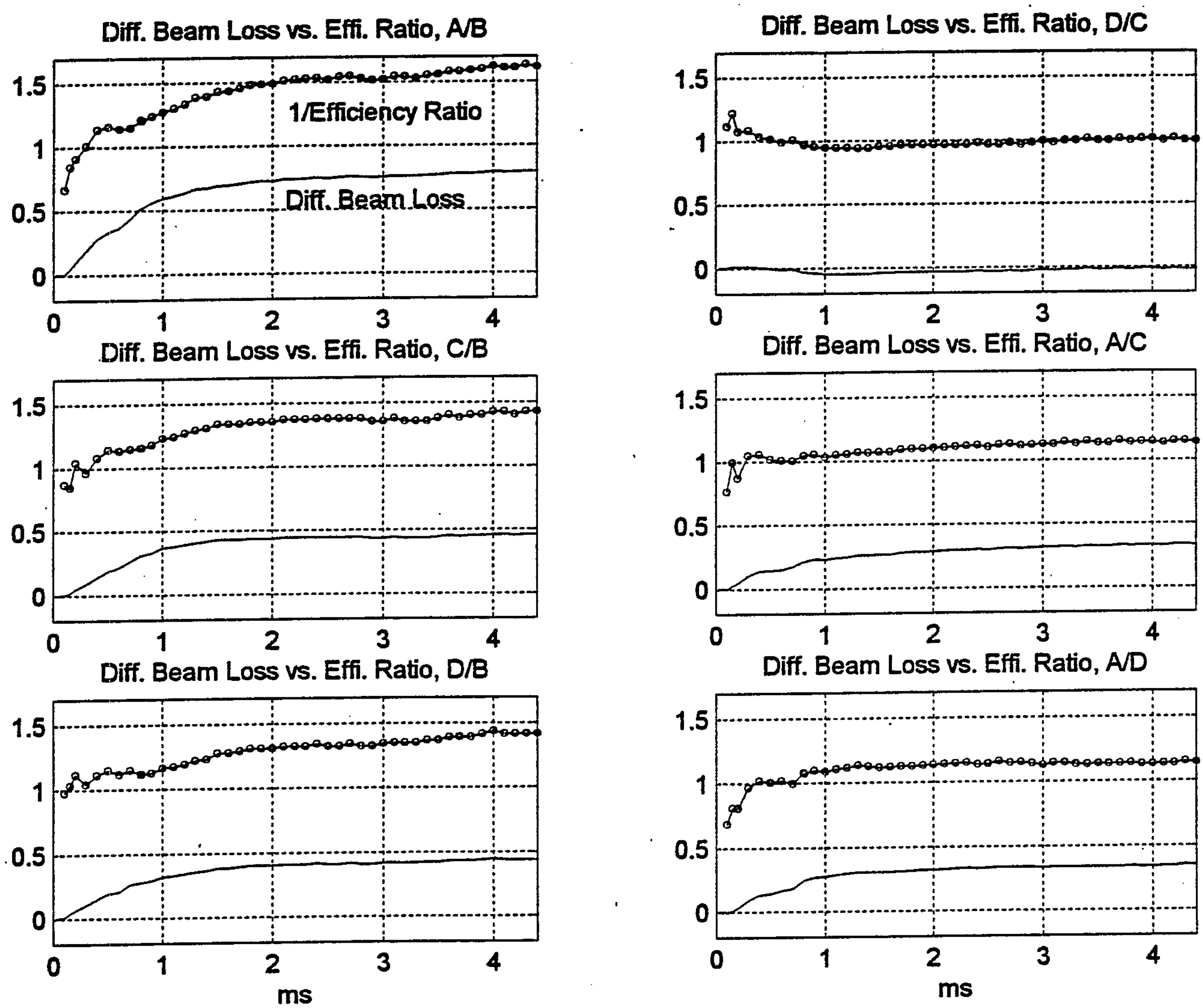

Fig.5. Difference of Beam Loss vs. Reversed Efficiency Ratio

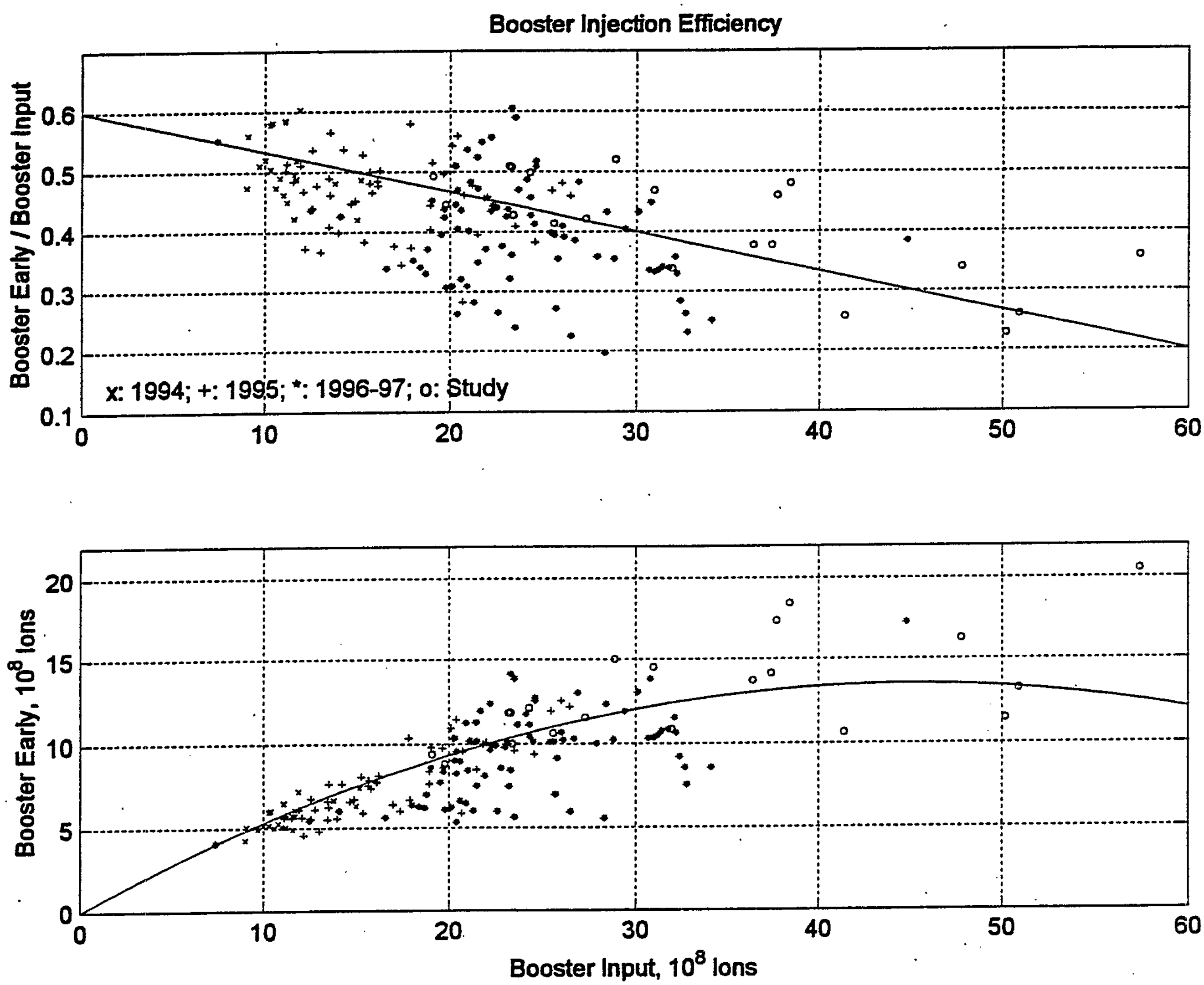

Fig.6. 1994, 1995, 1997-97 Morning Numbers

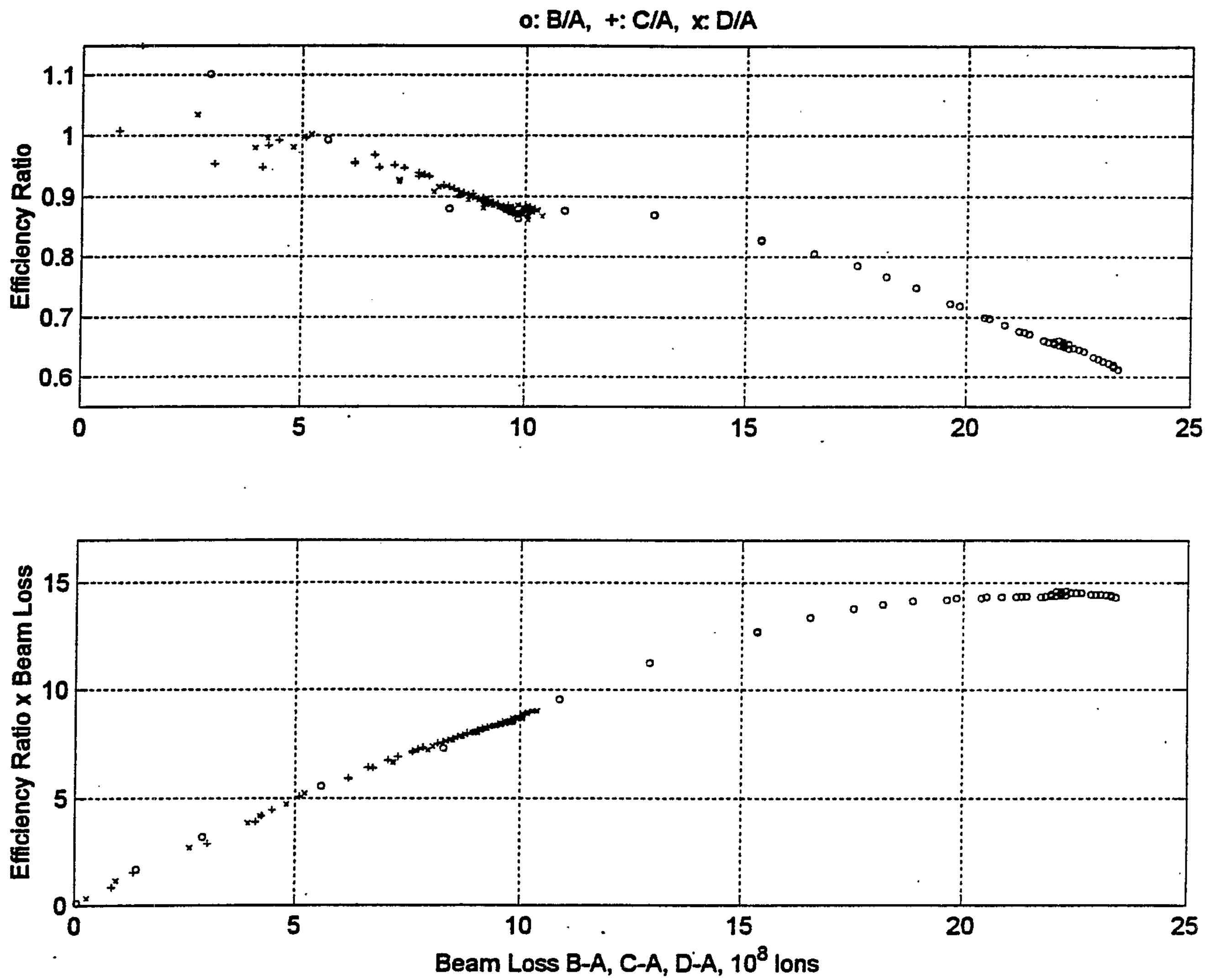

Fig.7. Beam Loss vs. Efficiency Ratio