BNL-104239-2014-TECH

AGS.SN367;BNL-104239-2014-IR

Scanning the New TTB Slits

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October 1997

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U.S. Department of Energy

USDOE Office of Science (SC)

AGS Complex Machine Studies

(AGS Studies Report No.367)

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Study Period: 25 October 1997, 1900 - 2100

Participants: L. Ahrens, S.Y. Zhang, J. Benjamin

Reported by: L. Ahrens

Machine: TtB and Booster

Beam: Iron 10+

Tools: TtB Slits and Window Frame, TtB Multiwires, and Booster Current Transformer

Aim: To understand the effect of intentional TtB (Tandem-to-Booster transfer line) beam scraping on downstream multiwire profiles and on Booster intensity.

Booster/AGS Study Note   Scanning the New TtB Slits

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Prior to the October 1997 Iron physics run, a complete set of adjustable slits and a plungable "window frame" aperture were installed by the Tandem group in downstream TtB. The slits are located just down stream of "27MW154", the multiwire at the end of section 27. The window frame is just downstream of the next multiwire "28MW132". Two more multiwires exist between the window frame and the Booster injection point, "29MW090" and "29MW141". There were several motivations for installing these new devices. The slits (or really the current flowing from the slits) will provide a signal sensitive to subtle beam motion in the downstream line. This may ultimately result in more stable machine performance. In addition, if halo on the injecting beam is responsible for Booster vacuum degradation, judicious use of the apertures may improve Booster performance. The underlying relevant situation is Gold injection for RHIC. That was not an option for exploration this fall but Iron was.

What is reported here is primarily a verification of the basic function of the slits as inferred from beam information. We are interested that they cleanly cut away the incoming beam and that the slits and the other new aperture, the "window frame" cut different parts of the halo. The slit positions are adjusted manually – in the tunnel. This can nevertheless be done quite efficiently at least in the context of a study. The effect of the slits can be seen on downstream multiwires – hopefully always as an intensity reduction and sometimes in the appearance of edges - for multiwires at appropriate phase advances from the slits.

Each slit (left, right, top, bottom) was independently stepped into the beam, in mm steps, until more than half of the beam was being removed. At each step the multiwires and Booster current transformers were recorded. The intensity in TtB downstream of the slits is measured by each multiwire (i.e. six measurements) and by a current transformer in TtB – presented in MCR as the "Booster Input" number. Comparison of these data showed the expected linear agreement. The Booster Input number, because it had undergone an absolute calibration in terms of ions is used here. However, it is modified by adding an offset correction (the reported intensity is increased by 60 counts – about 3% of the highest intensity) on the basis of the relative intensity measured on the last multiwire in the line. The profiles for this multiwire indicate that their reported sum would if anything underestimate the true intensity, but by a relatively small amount. The resulting input number provides the denominator for some of the efficiencies reported later on.

Figure 1 gives one aspect of this study – the intensity in the transfer line downstream of the slit vs slit position. What is seen is a reasonable intensity reduction as each slit goes in. The change in position of a particular slit is well measured. Its absolute position relative to the beam is derived from the data, namely the position where the intensity is reduced to half (interpolated from the closest points) is defined to be the zero (for each slit) on the figure 1 abscissa and in the subsequent figures. The lines simply connect the points and are misleading for the steps out on the tails. That both the horizontal and vertical slopes are respectively about equal at the 50% point implies that the beam is symmetric up/down and in/out. The steeper vertical slope implies the beam is narrower in the vertical than horizontal at this point in TtB. (A dump of 27MW154 would have confirmed these things; we didn't do this during the study though earlier scans are consistent with this.

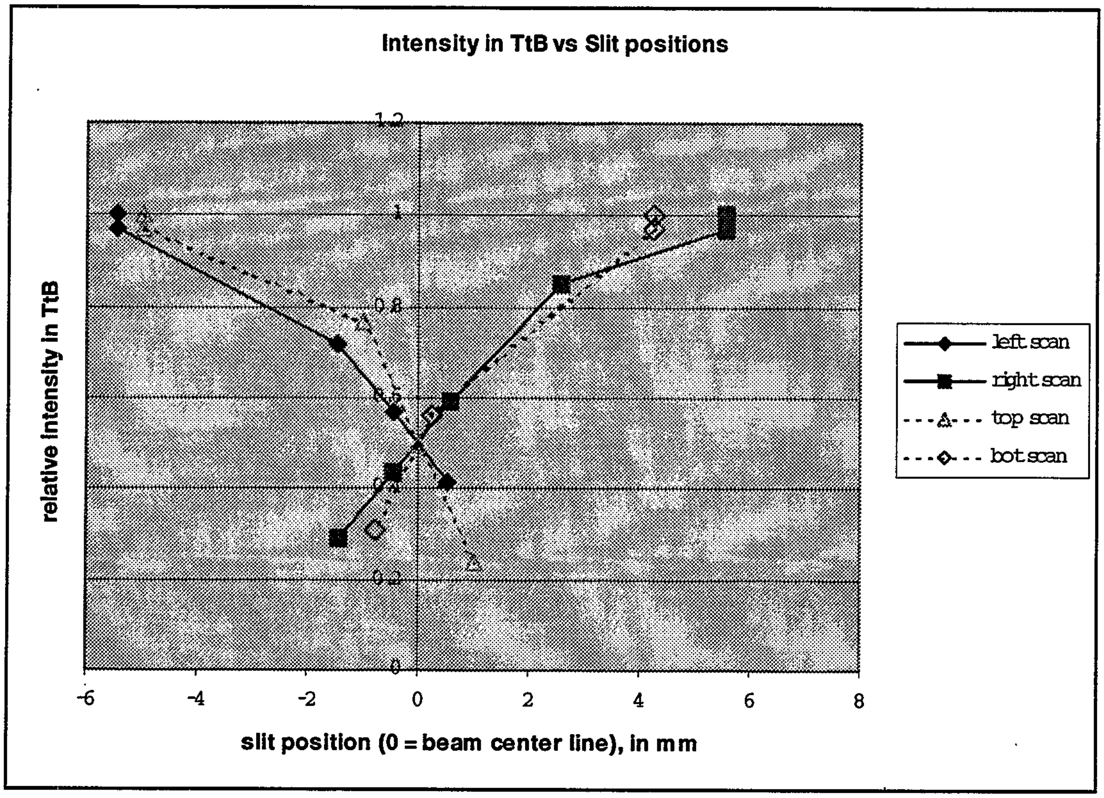

Figure 1 TtB Intensity vs Position of the New Slits

The next step is to look at the correlated beam intensity seen in the Booster. This is shown in figures 2 (for the horizontal slit scans) and 3 (for the vertical slit scans). These figures are a bit confusing. First note that the horizontal scales are identical to that of figure 1. In figure 2, just consider the two groups of points denoted by the solid and open boxes. These give the Booster injection and stacking efficiency vs horizontal slit position. This efficiency is defined as (surviving beam intensity measured just after the fast - few turn - injection losses are taken) / (the Booster Input number discussed above). Intensity in the Booster is taken from the injection current transformer, which was saved for each situation, converted into number of ions. The solid boxes represent the scan of the slit moving in from beam left, the open boxes represent the right scan. The extreme outward points at about +/- 6mm are in fact the same data – the starting "retracted slits" position. The solid boxes then show that the injection efficiency decreases as the left slit moves in. When half the beam is scraped away, the efficiency has dropped from about 32% to about 15%. The open boxes give the same data for the insertion of the right slit. Now the efficiency rises, reaching about 45% when half the beam is gone – as it must if the two halves are to equal the whole (which efficiency is just the retracted number of about 30%). This general asymmetric behavior is physically possible, but was not the expected behavior. Shaving away the tails of the injecting beam was expected in all cases to have either a neutral or positive effect on the efficiency, with a return to the average value by the time half the beam is gone.

So much for the injection efficiency data for now. Next move to the points represented by solid and open diamonds. These give the acceleration efficiency defined as (beam intensity late enough that subsequent losses in the cycle are unimportant) / (The beam intensity after injection-stacking losses as used above), which for the saved current transformer files is implemented as (beam intensity at 8 ms / beam intensity at 3.2 ms). Injection begins at about 2 ms in the time reference frame used here. The trends are quite similar to those for the spiral efficiency. Here the acceleration efficiency may be being affected by the intensity of the beam in the machine. At some point the rf will have trouble with signals needed by the loops and created by the beam.

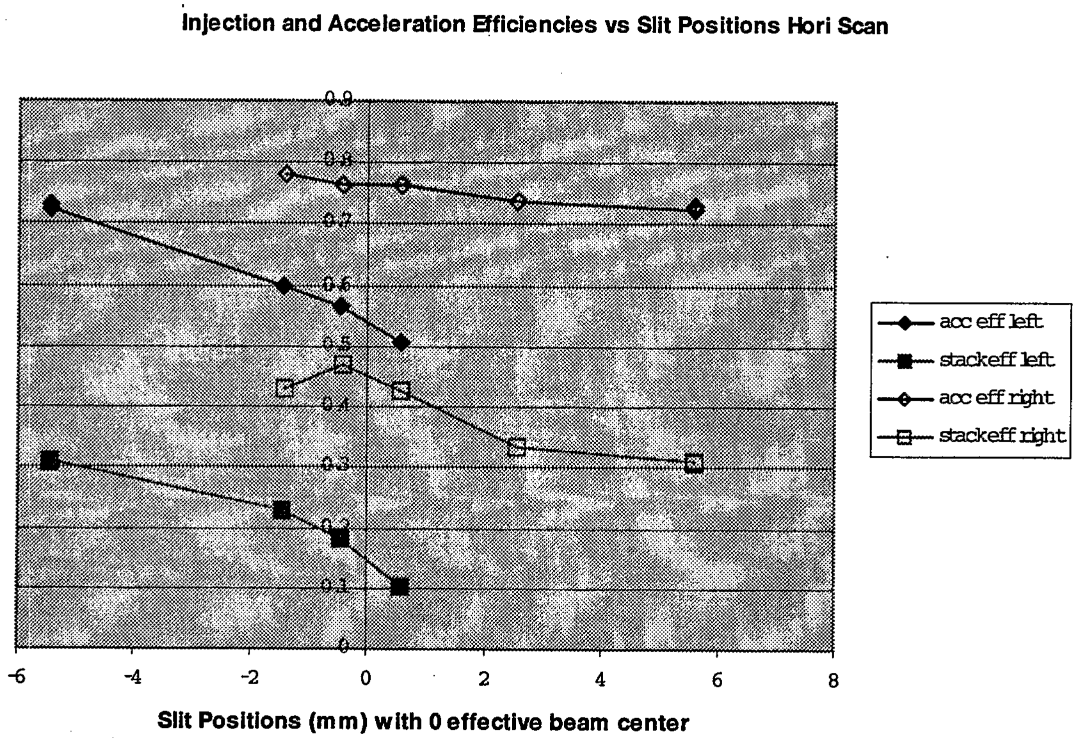

Figure 2 Injection and Acceleration Efficiencies vs Horizontal Slit Positions

Injection and Acceleration Efficiencies vs Slit Positions Vertical Scan

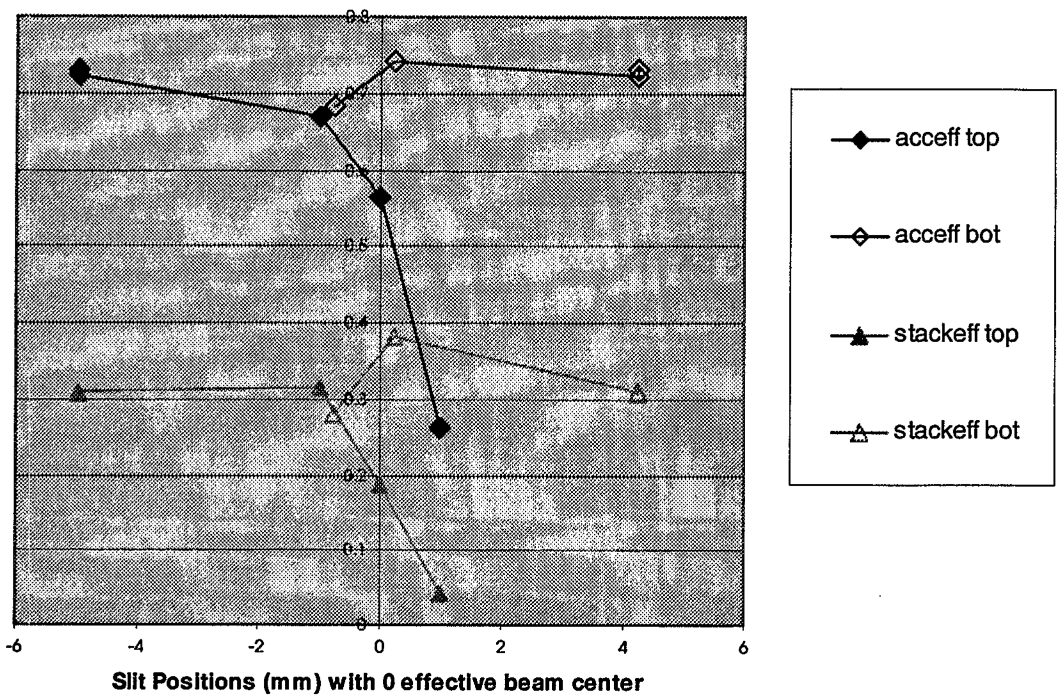

Figure 3 Injection and Acceleration Efficiencies vs Vertical Slit Positions

Figure 3 gives the same type of information, and the same presentation, for the scans done with the vertical slits. The qualitative result is much the same. The beam is not so well explored in part because it is narrower in the vertical and we did not reduce our step size accordingly. There appears again to be a very asymmetric response for efficiency vs scan direction.

We turn now to an analysis of the response of the multiwires downstream of the slits in terms of the beam shapes as the slits are adjusted. If we expect to use the slits and the window frame to remove independent parts of the edges from the beam, it is important that the window frame not be an image of the slits. We don't want to see edges of the slits at 28MW132, which is just upstream of the aperture location. Quantitatively in addition to "sums" which we have used above and which behaved consistently, the program generates a width and a mean for each profile along with the profile itself. If the slit (all angles one x) were imaged on the multiwire a sharp edge would appear and the profile width and average would move systematically. If the optics rotate that edge to be spread across all x at the multiwire, then the only effect of inserting the slit is a reduction in the sum. This statement is experimentally weakened since as the intensity at the multiwire goes down the signal-to-noise for the channels decreases and structures can appear (which are probably background) which change the reported width and average numbers.

Figure 4 shows how the "normalized" multiwire width and average move for a situation where an edge is very evident qualitatively, namely for the vertical slit imaged at 29MW090. The width and average are divided by the initial width. The average has the initial (normalized) position subtracted. As usual half the beam is cut away by the time the slit has reached zero. The initial (normalized) average is then 0 and the initial width is 1. A perfect multiwire located at the slit would show a reduction in width (full width at half-maximum value) to .5 when half the beam is gone. For a Gaussian initial distribution, the normalized average would move slightly less than .3 units. For 29MW090, which looks like a slit, we see (figure 4) the width decrease to .6 (expected .5) and the average move by .3 .

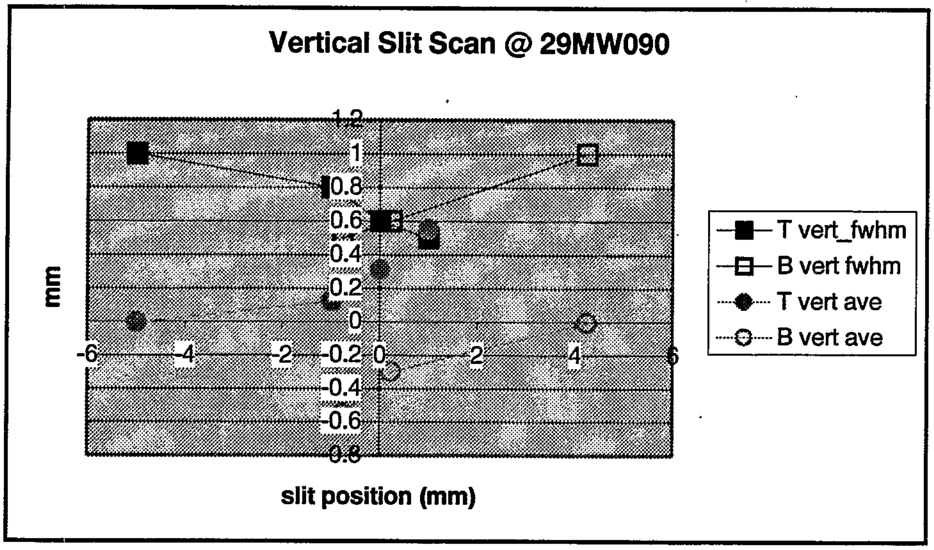

Figure 4 Effect of the Vertical Slit Scan at 29MW090

Now for 29MW141, which we claim shows little action qualitatively, our quantitative measures are given in figures 5a and b. One reason we are interested in 29MW141 is that from other studies we know the window frame aperture does qualitatively change the profile widths in both planes.

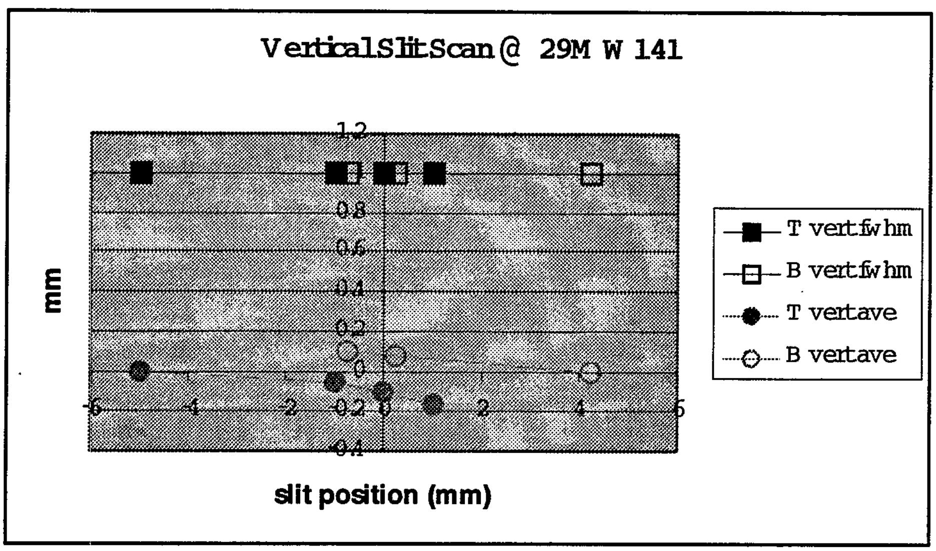

Figure 5a Effect of the Vertical Slit Scan at 29MW141

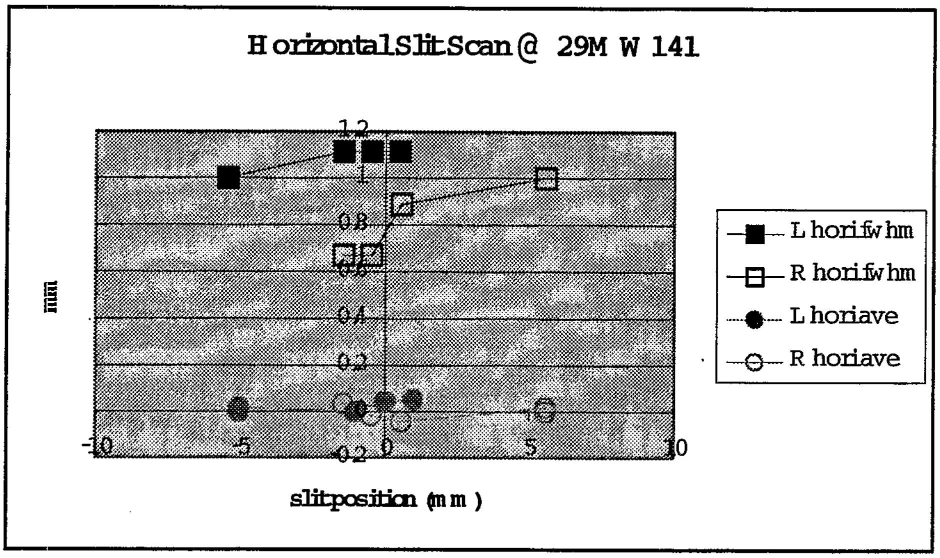

Figure 5b Effect of the Horizontal Slit Scan at 29MW141

Here in the vertical we see no change in the width, and motion of the average of less than .1 unit. In the horizontal there is little motion but our measure of the width is damaged by the narrowness of the profile and our coarse extraction of the width. Now what happened in these measures at 28MW132?

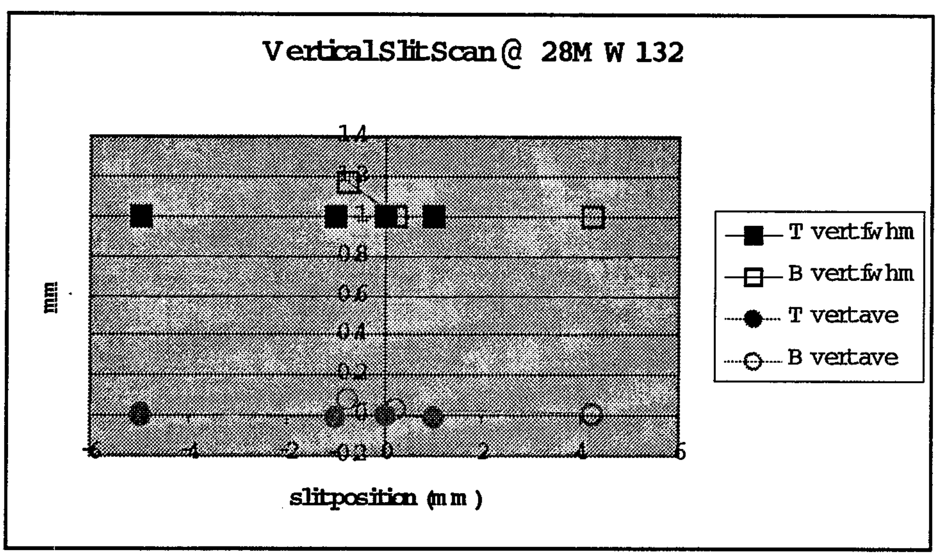

Figure 6a Effect of the Vertical Slit Scan @ 28MW132

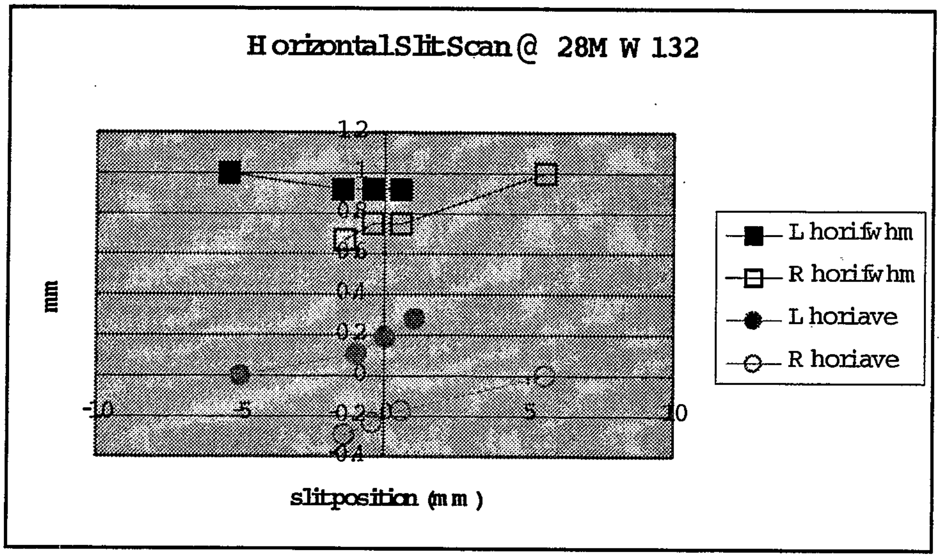

Figure 6b Effect of the Horizontal Slit Scan @ 28MW132

Here the vertical shows little change as the beam is cut away. The Horizontal certainly does show some motion so here presumably we will be somewhat less effective in trimming orthogonal parts of the beam, if the optics are left in this state.

Conclusions:

What was most startling in this study was the behavior of the efficiency, which in each plane improved with cutting from one side and deteriorated with cutting from the other. Apparently the hottest part of the beam in TtB is not aimed at the center of the aperture in the Booster. The right half injects with 12% efficiency while the left half with 36%. The effect is there in the vertical, though the data is not so clean. This would be interesting to revisit under conditions thought to be optimal.

Another implication from this is some caution about the effect of the window frame aperture. For this aperture there is no independent adjusting of the aperture sides or even of the average position, it is either in or out. So if there were an "efficient beam side" at the window frame it might hit the aperture or it might not. The beam itself would have to be scanned, which is more difficult in that the scan itself can affect Booster injection than the moving of a slit. Indeed, the first studies done with the slits this year assumed that it was fair to cut the beam symmetrically simultaneously. The results were very curious presumably because the beam has this noncentered maximum, (and in addition the beam center was not exactly the a priori defined center of the scan). So this experiment stands as a warning that unexpected beam setups could yield incorrect conclusions.

As some more work suggested by the study, it would be useful to see if some likely aperture, for example the electrostatic inflector at C3 is "inphase" with the slits. Such a connection would most easily explain the curious efficiency measurement.