Horizontal Beam Size as Determined by a Beam Scan

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A horizontal beam scan was performed on day 6 during the MERIT experiment. The beam was swept horizontally over a distance greater than the inside width $D = 1.375'' = 34.9$ mm of the primary containment vessel.[1]

In this note I suppose that the number of secondary particles produced by the beam interaction with the walls of the primary containment vessel is proportional to the overlap of the proton beam with the walls. That is, I suppose that tertiary particle production scales with secondary particle production.

Then, if the proton beam has a Gaussian profile with standard deviation $\sigma_x \ll D$ along the transverse, horizontal axis x, the number of secondary particles produced for a beam centered on $x > 0$ is

$$\begin{aligned} N(x) &= \frac{N_0}{\sqrt{2\pi}\sigma_x} \int_{D/2}^{\infty} e^{-(x'-x)^2/2\sigma_x^2}\, dx' = \frac{N_0}{\sqrt{\pi}} \int_{(D/2-x)/\sqrt{2}\sigma_x}^{\infty} e^{-z^2}\, dz = \frac{N_0}{2}\left[1 - \mathrm{erf}\left(\frac{D/2 - x}{\sqrt{2}\sigma_x}\right)\right] \\ &\approx N_0 \left(\frac{1}{2} + \frac{x - D/2}{\sqrt{2\pi}\sigma_x}\right), \end{aligned} \tag{1}$$

where the approximation holds for $x \approx D/2$. Thus, we can estimate the standard deviation σ_x from the slope of the observed rate $N(x)$ near the wall:

$$\sigma_x \approx \frac{N_0}{\sqrt{2\pi}\frac{dN(D/2)}{dx}}\,. \tag{2}$$

Harold Kirk has located a figure made by Marcus Palm during a horizontal beam scan, probably day 6 of the MERIT run (see next page). We don't know the details of how he assigned the horizontal x coordinates, nor how the diamond detector data was normalized from shot to shot during the scan. I believe the beam energy was 14 GeV.

Taking the plots at face value, I estimate that

$$\frac{1}{N_0}\frac{dN(D/2)}{dx} \approx \frac{1}{8\text{ mm}}\,. \tag{3}$$

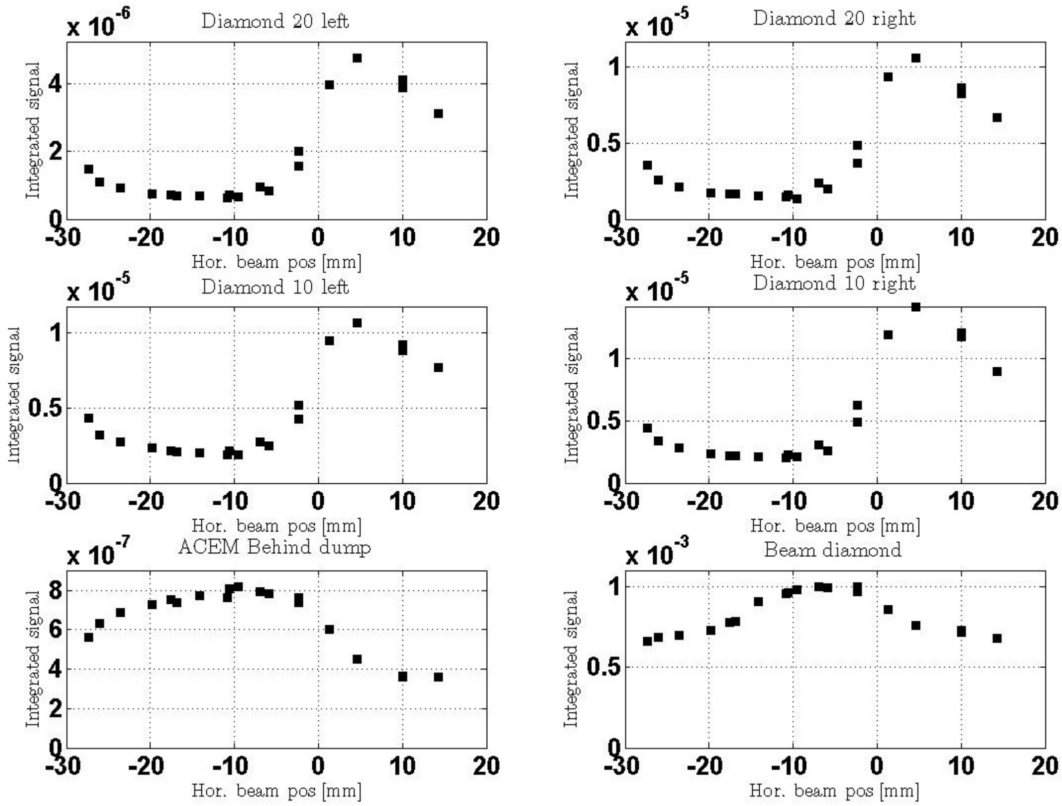
Then,

$$\sigma_x \approx \frac{8\text{ mm}}{\sqrt{2\pi}} = 3.2\text{ mm}. \tag{4}$$

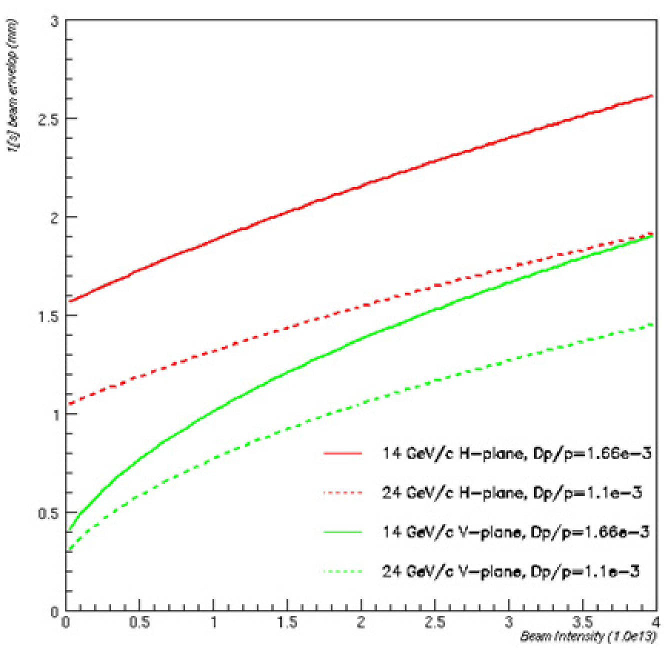
We can also estimate a correction to the horizontal scale by noting that the apparent distance from the low point of the scan ($x = -15$ mm) to the half height ($x = -1$ mm) is 14 mm, which corresponds to distance $D/2 = 15.5$ mm. Then, the horizontal scale in Marcus' plots should be scaled up by a factor $17.5/14 = 1.25$, so the revised estimate is

$$\sigma_x \approx 1.25 \times 3.2 = 4\text{ mm}. \tag{5}$$

[1] http://www.hep.princeton.edu/~mcdonald/mumu/target/graves/203-HJT-0610_R1.pdf

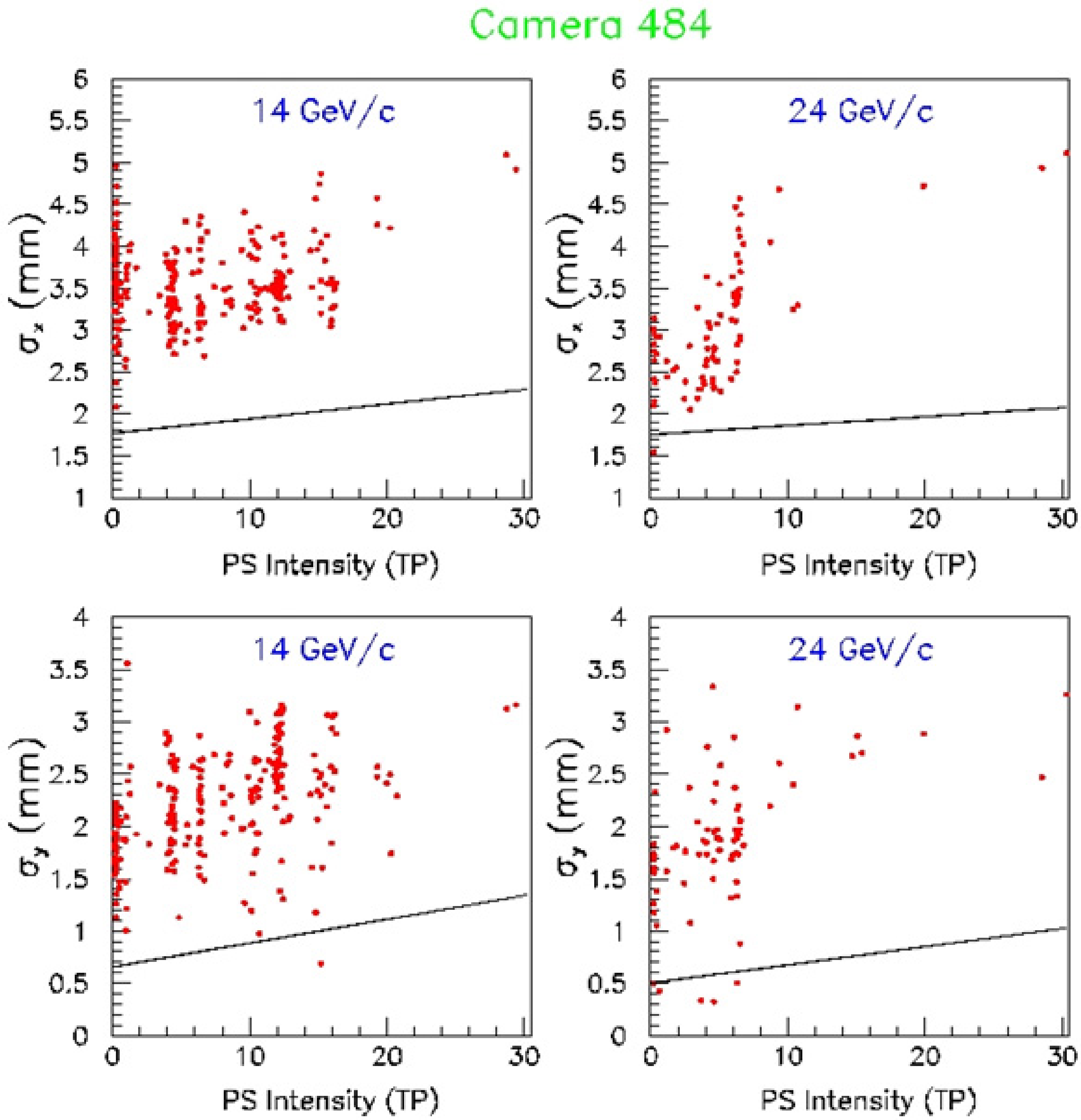


This result is considerably larger than that indicated by Ilias Efthymiopoulos,[2] as shown in the figure below, but is similar to that found by Goron Skoro from an analysis of the photographs of the upstream beam flags,[3] shown on the next page.



[2] http://www.hep.princeton.edu/~mcdonald/mumu/target/Ilias/ie-MERITAnalysisAll.pdf

[3] http://www.hep.princeton.edu/~mcdonald/mumu/target/Skoro/Saturation_profiles.pdf


Camera 484
14 GeV/c
24 GeV/c
σx (mm)
σy (mm)
PS Intensity (TP)