Fermi National Accelerator Laboratory

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Feasibility Study on the Installation of a Flying Wire System in the Collision Region

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The possibility has arisen that we may have the opportunity to install a Flying Wire system in the collision region just before the roll-in of the Collider Detectors in Run II. This capability would allow us to measure the ratio of beam size at the current Flying Wire Locations (E11 and E17) to the collision region.

The question arises of where to actually place the test system in the collision region. The beta function in a drift region can be parameterized by two quantities, β*, and it's longitudinal position s_o via the formula

$$\beta(s) = \beta * + \frac{(s - s_0)^2}{\beta *}.$$

If we can measure these two parameters using bpm's and trim dipole magnets (and/or a trim quadrupole placed near s_o and using the tune change), the Flying Wire position could be placed anywhere in the collision region and we could extrapolate the beam size to s_o . The reason one desires this flexibility is that the actual beam size at the collision point is very small, typically 40 microns (rms). This is calculated from measured beam sizes (0.6 mm) at E11 by the formula $\sigma_{\beta*} = (\beta*/\beta_{E11})^{1/2} * \sigma_{E11}$. Systematic errors in the Flying Wires may dominate and spoil the attempt to measure the tiny beam size at β* itself. This TM is an attempt to determine what if any known aspects of the Flying Wire system would limit our ability to make this measurement.

<u>Wire Size</u>

The Fermilab Flying wire system uses a 30 micron diameter carbon filament to measure the beam profile. This size wire has an effective rms of 7.5 microns (= d/4). Therefore in principle at least, it should not be a problem to extract beam sizes from the measurement when

the beam rms size is reasonably larger than 7.5 μm. Using a Gaussian approximation for the wire,

$$\sigma_{beam} = ((\sigma_{measured})^2 - (7.5\ \mu m)^2)^{1/2}.$$

Just to check this simple estimate, Gaussian beam profiles with σ = 10, 20, and 30 microns were numerically convoluted with a circular wire of diameter 30 μm. This function was then fit with a simple Gaussian function - the actual function used in the wire analysis. A plot of the three trials overlaid with the fit function is shown in the figure below.

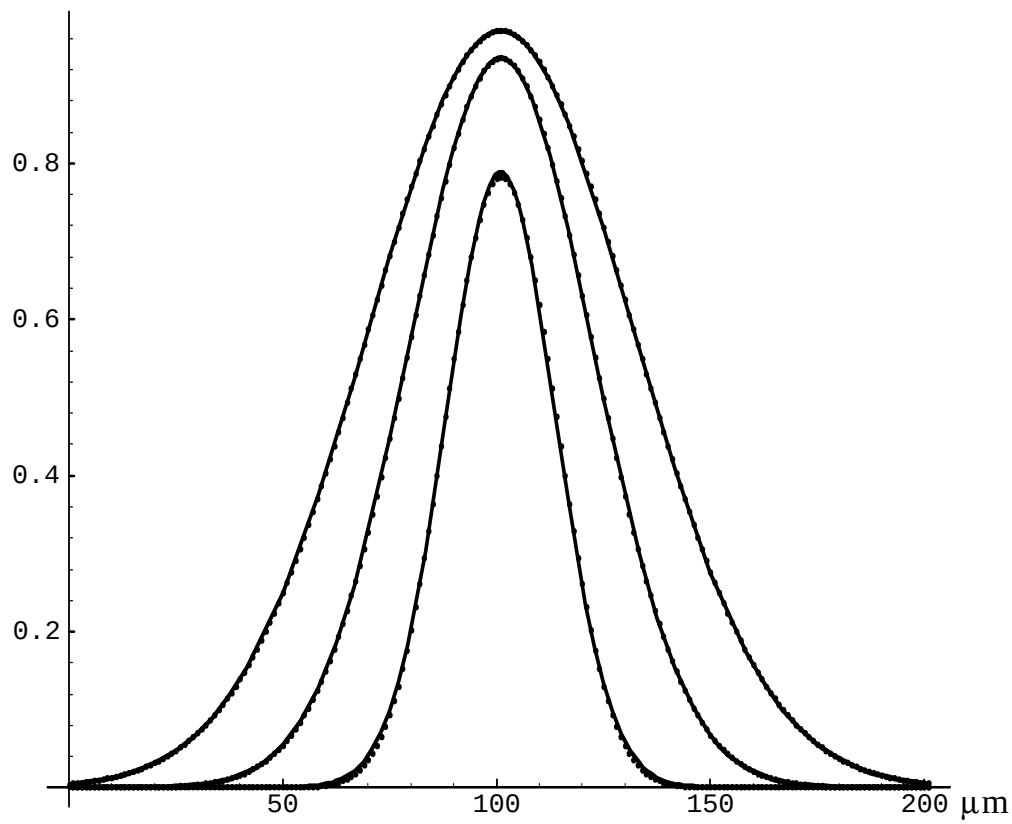

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Figure 1: Resulting Profiles from Convolution of 30 μm diameter wire with 10, 20, 30 μm Gaussian beams. The data points (easiest seen in the 10 μm case, as the other cases are hidden by the curves) are from the convolution. The curves are from a Gaussian fit to the profile. All raw peaks had amplitudes of 1.0 before the convolution.

As one can see, only the 10 μm σ profile gives any real evidence of a slight deviation in the Gaussian profiles. The calculated σ_{beam} values, using the simple formula above gives 10.31, 20.04, and 30.01 μm for the three cases. Therefore I conclude that the wire diameter is not a limiting parameter in measuring beam sizes on the scale of 30 μm.

Finally it might be noted for a measurement of this type, there is no reason to try and keep the beam emittance small. All that is necessary is a measurement of the beam at E11 and in the collision region. Thus one could blow up the emittance to reduce any systematics in the wire measurement itself.

Wire Heating

Another potential problem may be that for such small beam sizes, the wire might conceivable be destroyed. At our current Flying Wire locations, the beams are roughly 0.6 mm in diameter in both planes. Thus the heating of the wire by the beam is spread over a relatively long piece of carbon filament. Just scaling the peak heating density at the E11 to β^* gives a ratio proportional to β^*/β_{E11} or factor of 200. Reducing the beam intensity (factor 10?), decreasing the number of bunches from 6->1, and blowing up the emittance would lower the instantaneous heating factor. If one were really worried, the wires could be placed some meters up or downstream of the actual IP which would effectively increase the beam spot size. However, as the current wires survive flying though fixed target beam which has been already several times more intense than the best collider intensities (6 x 300 10^9), it is probably not necessary to take any drastic steps. The current fix target run (1996->?) will provide even more data. Therefore I feel that the wires either are or can be made survivable at the IP by some of the simple expedients listed above.

Wire Motion

The Flying Wire typically moves with a velocity of 5 m/s. For each revolution of the beam, the wire moves an arc distance of 5 m/s * 21 μs =105 μm. Ignoring the projection of the wire motion to the transverse plane for the moment, it is clear that this effective step size is much too large. To measure small beams, the step size or sampling should be small compared to the rms value. If we choose (arbitrarily at this stage) 10 μm as the step size, then we should slow

the wire speed to 0.5 m/s. This coupled with the angle the wire path cuts through the beam alleviates the step size problem.

Another uncertainty lies in the smoothness of the motion itself. It is possible to study the actual wire motion in a lab setup by using a fast-gated video camera from Sync Lite. If the motion is not smooth enough on this small distance scale, one can envision the addition of a large inertia flywheel (10x current value of inertia) to the flying wire fork assembly which would mechanically smooth out the motion. This is possible even with the current drive motor since we only require a wire velocity of 0.5 m/s, and so the initial wire acceleration can be lowered a factor of 10.

Pickup Non-Linearity

We have data now which suggest that the Flying Wire Scintillator phototubes were showing signs of saturation during the Run 1b Collider Run. The early evidence suggests the effect was on the order of 5-10% in σ (the true widths were actually narrower than reported to ACNET). This issue is being studied and by the time one would expect this test run to occur, hopefully solved. The issue will be addressed in a future TM.

Conclusion

A Flying Wire system (one horizontal and one vertical) could be setup in the collision region between the low beta quads. Depending upon future explorations of the smoothness of the wire motion, the actual location can range from the IP to just next to the low beta quads. In the first case, we could directly derive the ratio of β^* to β(E11), whereas in the latter case, we would require other measurements of the collision point region to fix the parameters of the lattice in this region. These other measurements are desirable in their own right, and so we would expect to undertake them in any case.