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Wire Scanner Assessment of Transverse Beam Size in the Fermilab Side-Coupled Linac

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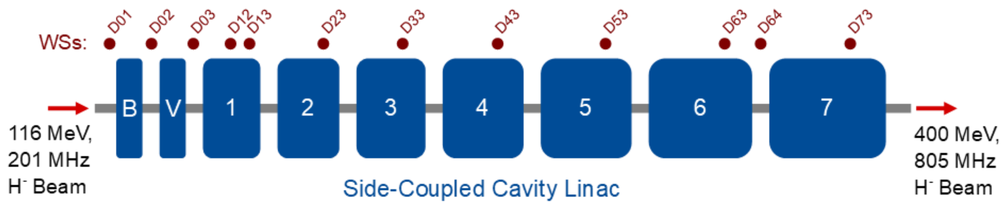
Overview of the Fermilab Side-Coupled Linac

The Fermilab Side-Coupled Linac (SCL) contains 12 wire scanners (WSs) to assess transverse beam characteristics.

Ongoing initiatives seek a more physics-based approach to day-to-day operation of the Fermilab Linac. This goal will be realized with support from data gathered from the WSs, prompting our presented investigation into the state and capabilities of the WSs & their data.



Schematic of the Fermilab Side-Coupled Linac [1], composed of seven 805 MHz modules (Modules 1-7) and a transition section (Module 0, containing the buncher (B) and Vernier (V) cavities) which accelerate 116 MeV beam to 400 MeV. The red dots represent the locations of the wire scanners (WSs).

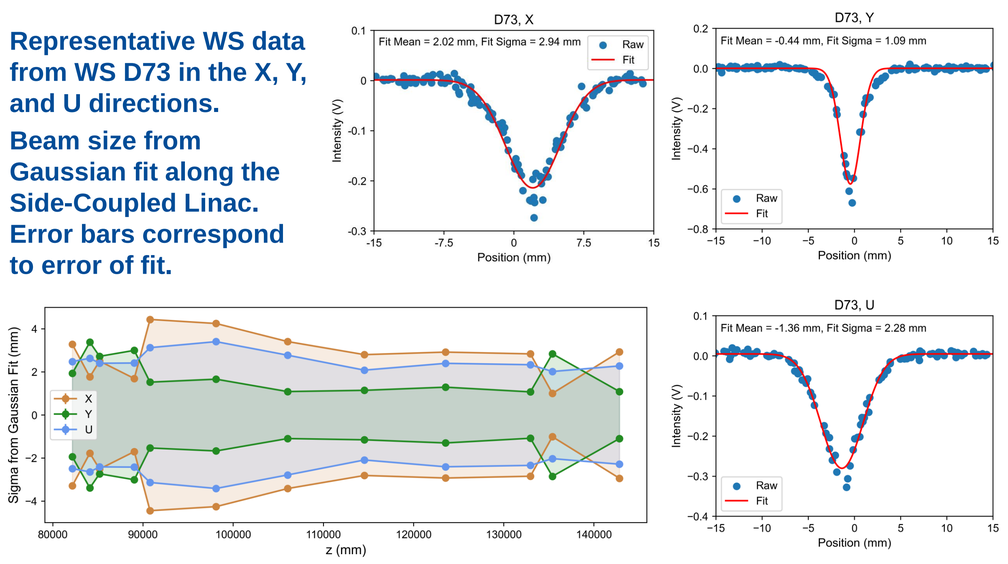
X-Y Coupling Analysis & Wire Scanner Data

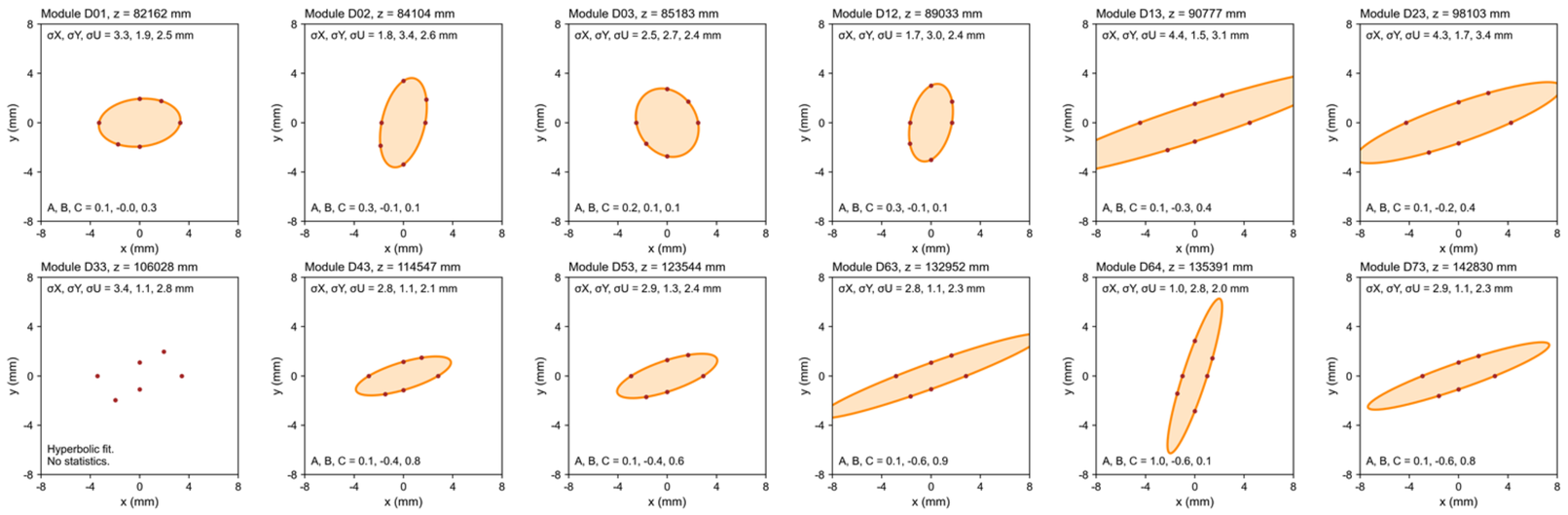
Wire scanner data consists of intensity in the wire vs. calibrated position of the wire. A Gaussian fit extracts σ, beam size.

The “U” wire assesses X-Y coupling. X, Y, and U data are fit to a rotatable ellipse. Results of this analysis show unexpected levels of coupling & non-physical beam sizes.

Representative WS data from WS D73 in the X, Y, and U directions.

Beam size from Gaussian fit along the Side-Coupled Linac. Error bars correspond to error of fit.



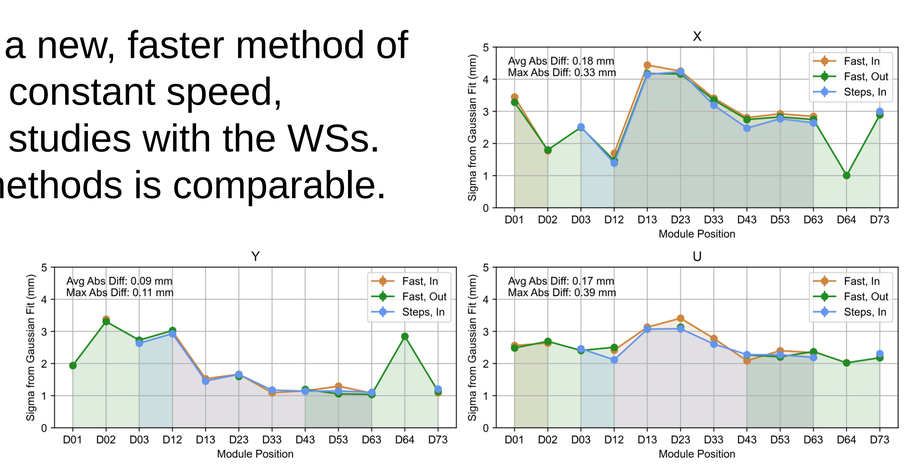


Beam size data from Gaussian fit in the transverse plane for each wire scanner. Data are from the constant speed program. Ellipses were calculated from $Ax^2 + Bxy + Cy^2 = 1$ where $B^2 - 4AC < 0$. Unfit data correspond to a hyperbolic system.

Wire Speed & Data Quality

In 2024, we introduced a new, faster method of collecting WS data at a constant speed, facilitate more complex studies with the WSs. Data quality between methods is comparable.

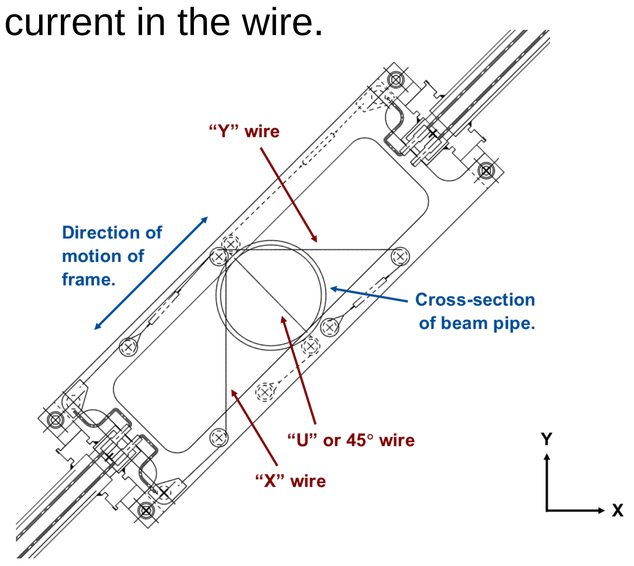
Scan time decreased from 10-15 min (“steps”) to 1.25 min (“fast”) at 5 Hz.



Comparison of beam size from Gaussian fit from three methods: wires moving “in” via constant speed, wires moving “out” via constant speed, and wire moving “in” via steps. Standard deviation of σ between replicate datasets in steps are ±0.3 mm.

Wire Scanner Layout

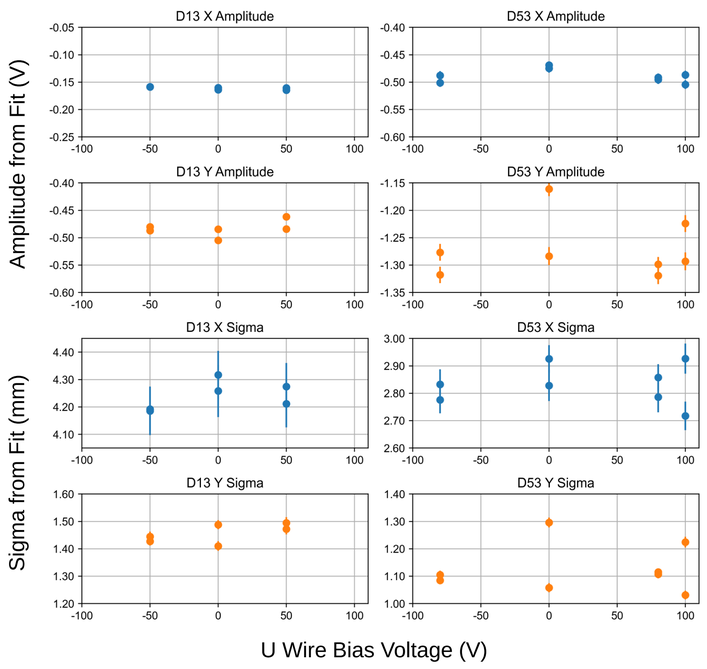
The wire scanners contain three electrically-isolated wires, mounted at different angles to assess the “X”, “Y”, and 45° (called “U”) directions [2]. The wires share a frame which is moved transversely across beam to record current in the wire.



Drawing of three-wire layout for the Fermilab Linac wire scanners.

Wire Biasing Study

To investigate whether secondary electron emissions from the wire are the cause of the X-Y coupling, we biased the “U” wire between -80 and 100 V and recorded the current in the “X” and “Y” wires. No significant changes are observed in response to bias voltage.



Beam intensity and size results from biasing in WSs D13 and D53. Two datasets were taken at each tested voltage.

If secondary electron emissions were the cause of the coupling, we would predict a more negative voltage would lead to a larger beam size and larger (more negative) amplitude in the X and Y wires.

References

[1] Noble, Robert. “The Fermilab Linac Upgrade.” *15th International Linear Accelerator Conference* (1991). FERMILAB-LU-172.

[2] McCrory, Elliott *et al*. “Beam Diagnostics for the 400 MeV Fermilab Linac.” *Conf. Proc. C.* Volume 910506 1249-1251 (1991).

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