Fermilab

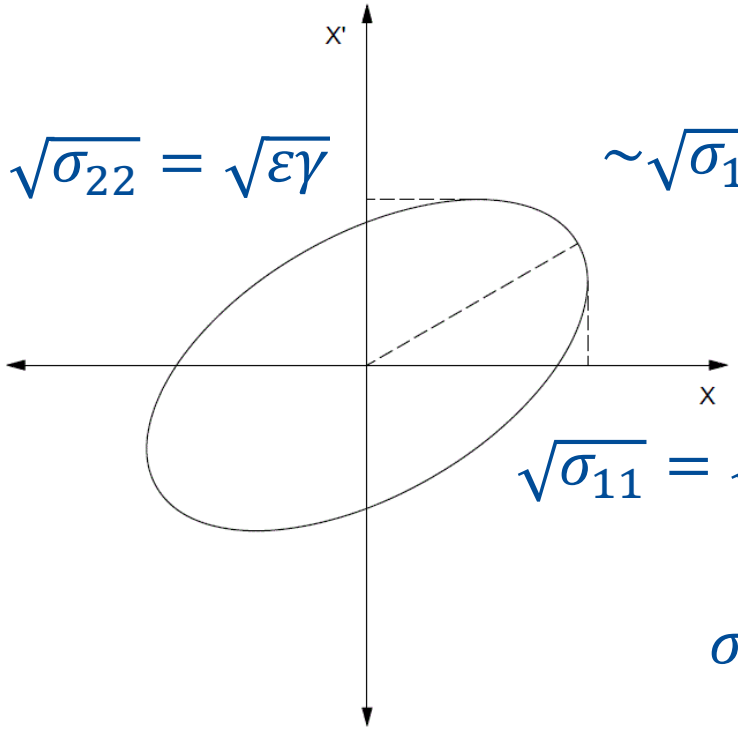
Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Momentum Error in the Booster Neutrino Beamline

T. Kobilarcik
MicroBooNE Beams Group
24 February 2016

Spot Size

An idealized beam can be characterized in phase space by it's size and orientation. Two common characterizations:



$$\sqrt{\sigma_{22}} = \sqrt{\varepsilon\gamma} \qquad \sim\sqrt{\sigma_{12}} = \sqrt{\varepsilon\alpha}$$

$$\sqrt{\sigma_{11}} = \sqrt{\varepsilon\beta}$$

$$\sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{bmatrix} = \varepsilon \begin{bmatrix} \beta & -\alpha \\ -\alpha & \gamma \end{bmatrix}$$

Transformation

Sending the beam through a drift, bend, or quadrupole can be represented as a linear transformation:

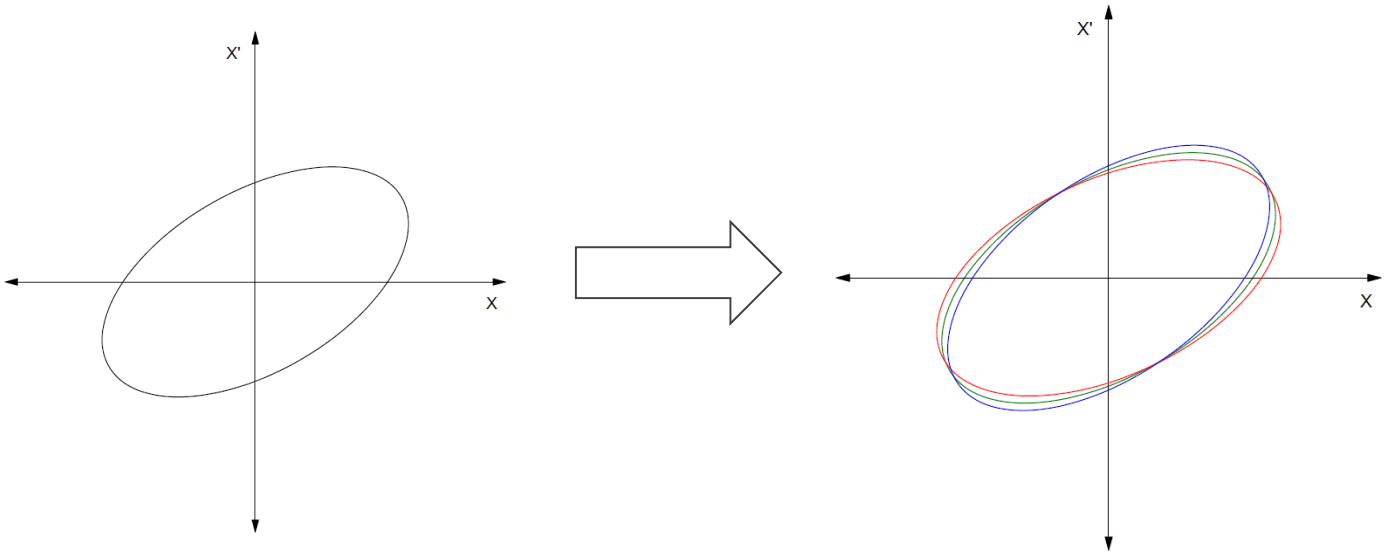
$$\sigma_f = M\sigma_i M^T$$

For example, a drift is:

$$\begin{bmatrix} 1 & L \\ 0 & 1 \end{bmatrix}$$

Momentum Spread

Beam is not mono-energetic – there is a momentum spread. So if you send if through a bending magnet, this happens:



Momentum Spread

We can handle this by adding a third term to the matrices

$$\sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{16} \\ \sigma_{21} & \sigma_{22} & \sigma_{26} \\ \sigma_{61} & \sigma_{62} & \sigma_{66} \end{bmatrix} \quad M = \begin{bmatrix} m_{11} & m_{12} & m_{16} \\ m_{21} & m_{22} & m_{26} \\ 0 & 0 & 1 \end{bmatrix}$$

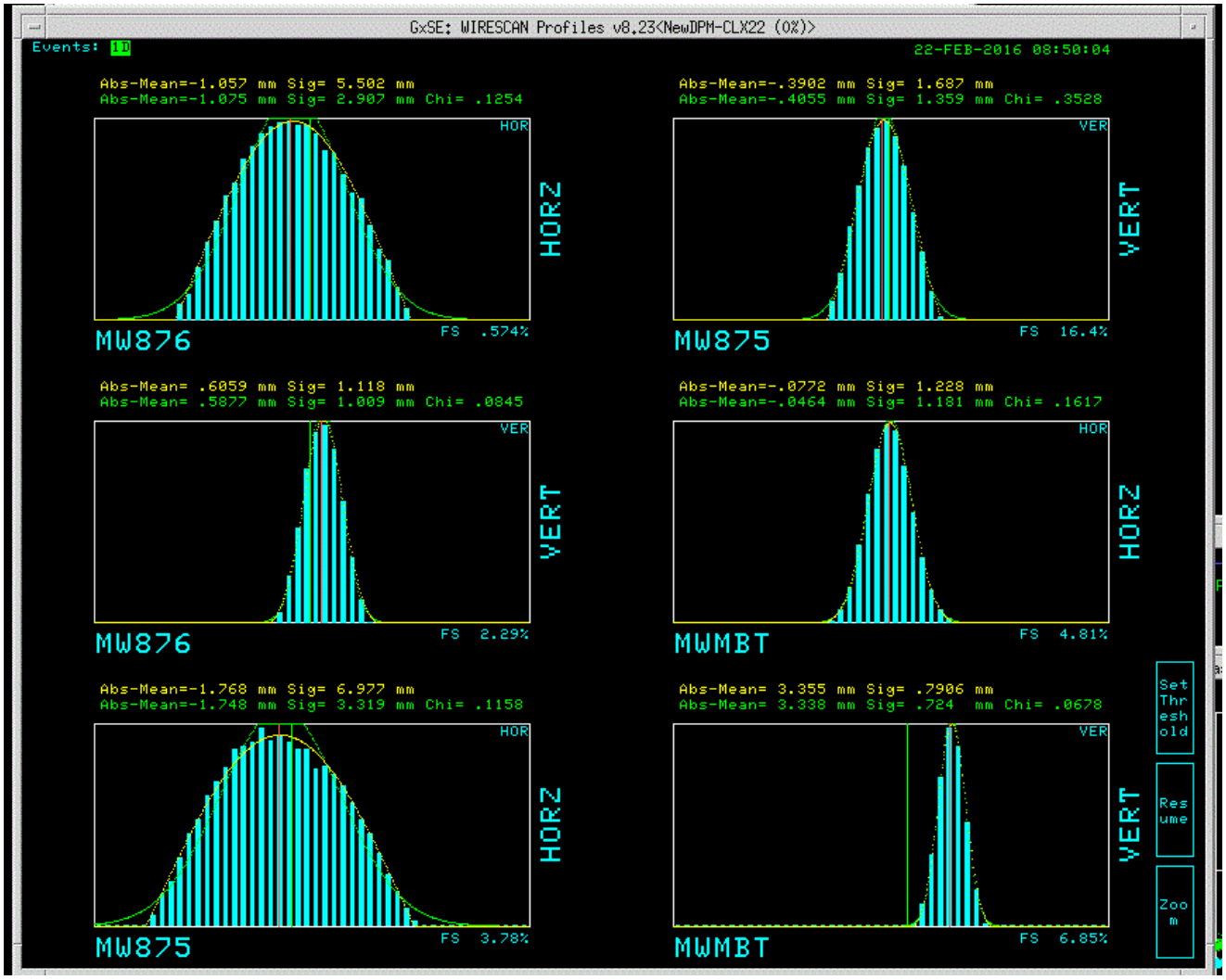
$$\sigma_{66} = \left(\frac{\Delta p}{p}\right)^2$$

Some Numbers

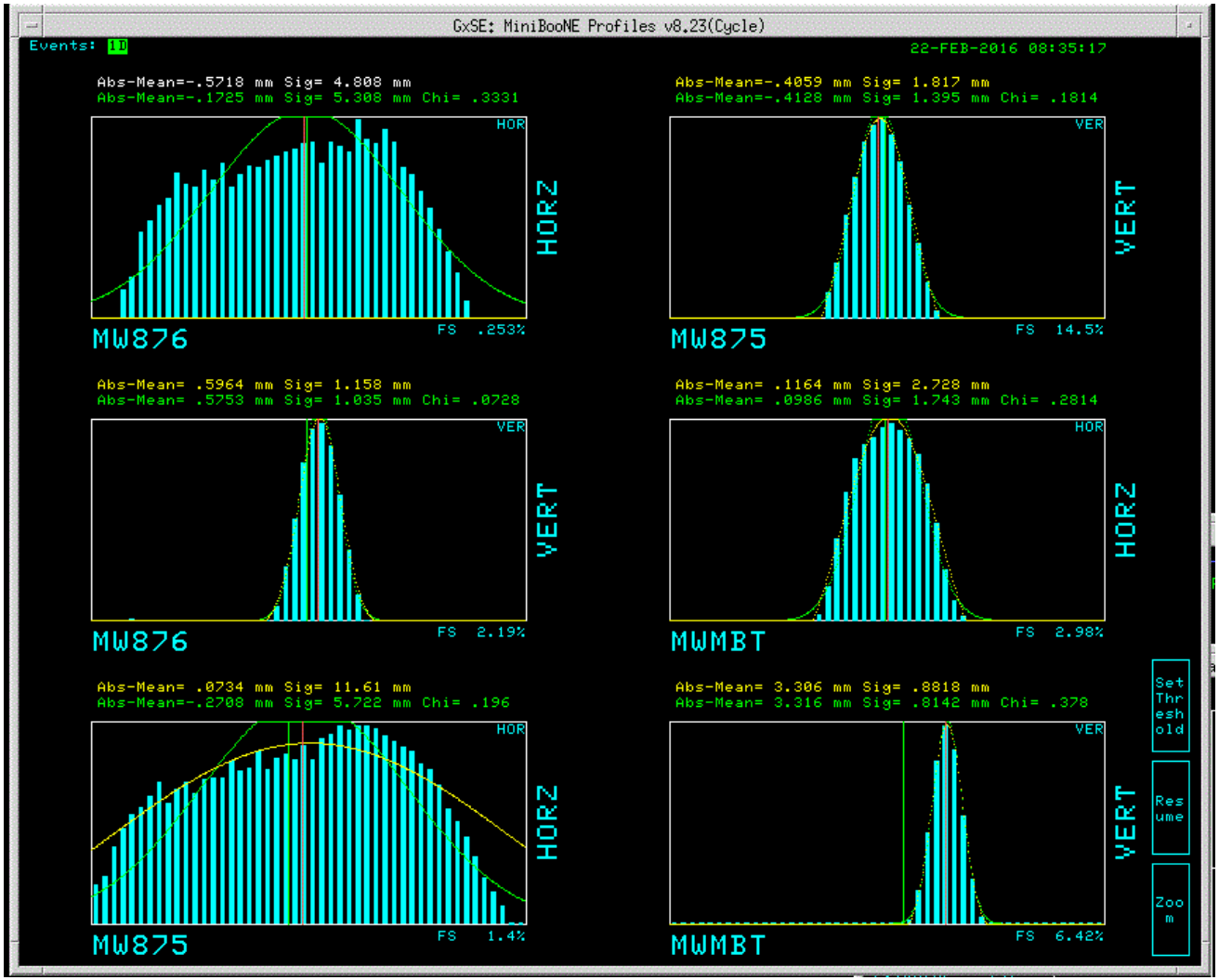
- For our beam, $\frac{\Delta p}{p} = 6.4 \times 10^{-4}$.
- Dispersion at MW875 is ~7 m; at target center, ~0.14 m.
- For a 0.658 mm spot at target center, if one doubles the momentum spread the resulting spot is 0.663 mm (TRANSPORT calculation).

- Can we get some idea of how much momentum changes when the dampers are not working? Yes.

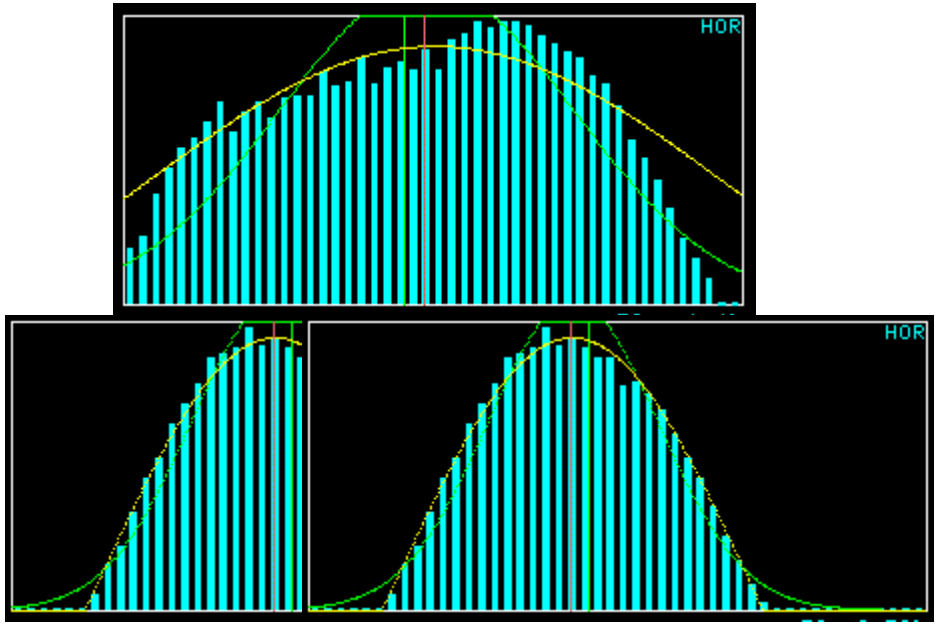
Nominal Beam



Dampers Not Tuned



Measuring Momentum Offset



Let's assume the broad profile is do to two nominal profiles of different central momentum. If we know the dispersion and position change, we can calculate the difference in momentum.

Peaks differ by about 23 wires, which is 11.5 mm. This gives a momentum difference of 1.64×10^{-3}, or the central momentum $\pm 0.82 \times 10^{-3}$.

Running the Numbers

- Run TRANSPORT again, increasing momentum bite to 6.4×10^{-4}+8.2×10^{-4} = 14.2×10^{-4}.
- Beam width, at center of target increases from 0.658 mm to 0.664 mm.
- Beam at upstream face of target is 1.029 mm X 0.595 mm; beam at downstream face of target is 0.888 mm X 0.979 mm. (Target is 9.5 mm diameter.)
- It would be interesting to look at this with the RWM data.

Conclusions

- Knowledge of the beamline's dispersion at the multiwires can be used to measure the momentum error of the beam.
- The beam is highly focused at the target center; the beamline's dispersion is small at the target center.
- Even with the relatively large momentum error, the beam is fully contained within the target.