TWIST analysis strategy

* A primary strength of TWIST is its ability to make multiple measurements of the parameters under differing conditions. This results in consistency checks that build confidence in the final result.
Consistency Checks

* Since we obtain nearly the full angular distribution, we can determine \( \rho, \eta, \delta, \) and \( \xi \) from a single data set
* A statistically independent sample can be used to take the (forward+backward) distribution. This distribution is sensitive only to \( \rho \) and \( \eta \)
* The (forward-backward) distribution is sensitive only to \( \delta \)
  * Sensitivity of the data to \( \delta \) goes as \( P_\mu \xi \sqrt{N} \)
* A muon beam with polarization \( P_\mu = 0 \pm 0.05 \) can be used to make an additional measurement of \( \rho \)
Spectral Sensitivity

The global fit, applied to $10^9$ events, results in the following statistical uncertainties given the TWIST acceptance:

- $\Delta \rho = 0.4 \times 10^{-4}$
- $\Delta \eta = 16 \times 10^{-4}$
- $\Delta \delta = 0.6 \times 10^{-4}$
- $\Delta \xi = 0.7 \times 10^{-4}$
Fitting deviations in the Michel Parameters

In the context of the Michel parameters, the data can be viewed as an expansion in deviations from the Standard Model distribution

\[
\frac{d\Gamma}{dx d\cos(\theta)} \bigg|_{\text{Data}} = \frac{d\Gamma}{dx d\cos(\theta)} \bigg|_{\text{Std Model}} + \frac{\partial}{\partial \rho} \frac{d\Gamma}{dx d\cos(\theta)} \bigg|_{\text{Std Model}} \Delta \rho + \frac{\partial}{\partial \eta} \frac{d\Gamma}{dx d\cos(\theta)} \bigg|_{\text{Std Model}} \Delta \eta + \frac{\partial}{\partial \delta} \frac{d\Gamma}{dx d\cos(\theta)} \bigg|_{\text{Std Model}} \Delta \delta + \frac{\partial}{\partial \xi} \frac{d\Gamma}{dx d\cos(\theta)} \bigg|_{\text{Std Model}} \Delta \xi
\]

The data is fit to a series of Monte Carlo distributions which incorporate our best knowledge of the response function, and which incorporate the same tracking code used in the primary analysis.

The “Std Model” distributions allow for a blind analysis.
Sensitivity of the decay spectrum to the Michel parameters. Simulations based on $10^7$ events.

Differential in $\rho$

$\cos(\theta)$

$\times$ (reduced energy)

Differential in $\eta$

$\cos(\theta)$

$\times$ (reduced energy)

Differential in $\delta$

$\cos(\theta)$

$\times$ (reduced energy)

Differential in $\xi$

$\cos(\theta)$

$\times$ (reduced energy)
Correlations between the parameters can be reduced by combining data

$$\text{forward + backward} \sim 2x^2 \left[ 3 - 3x + \frac{2}{3} \rho (4x - 3) + 3\eta x_0 \frac{1-x}{x} \right]$$

The forward+backward distribution is independent of $\delta$ and $\xi$.

A separate data set used for a forward+backward analysis provides a valuable consistency check on the full spectrum.
The forward-backward distribution is independent of $\rho$ and $\eta$

A separate data set used for a forward-backward analysis provides a valuable consistency check on the full spectrum.
Data obtained with small polarization

An RF cut can be applied to select a muon beam with a mixture of cloud and surface muons.

We can tune this cut for $P_\mu \sim 0.00 + 0.05$ with a flux of $\sim 70$ Hz

A measurement made of $\rho$ with this beam will be used to test for instrumental asymmetries. The precise value of the polarization is not important.

The figures show the surface muon and cloud muon flux (top), and the net beam polarization (bottom), as a function of channel momentum. An RF cut has been applied to select the cloud muon timing.
Consistency check of the energy scale

\[
M = \frac{\frac{d}{dx} (dN(x = 0.5)/dx)}{dN(x = 0.75)/dx} = \frac{16}{9}
\]

For \(10^7\) toy Monte Carlo events

\[
M = \frac{2986 \pm 38}{1680 \pm 3} = 1.77 \pm 0.02
\]

\[
\frac{\Delta M}{\Delta \text{Shift in Energy Scale}} = 0.03 / 50\text{keV}
\]

With a sensitivity to the energy scale of \(30\ \text{keV} / \sigma_M\)

Looks promising, but requires validation with tracked Monte Carlo