Extraction of the Michel parameter, ρ, of normal muon decay

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Reconstruction code output

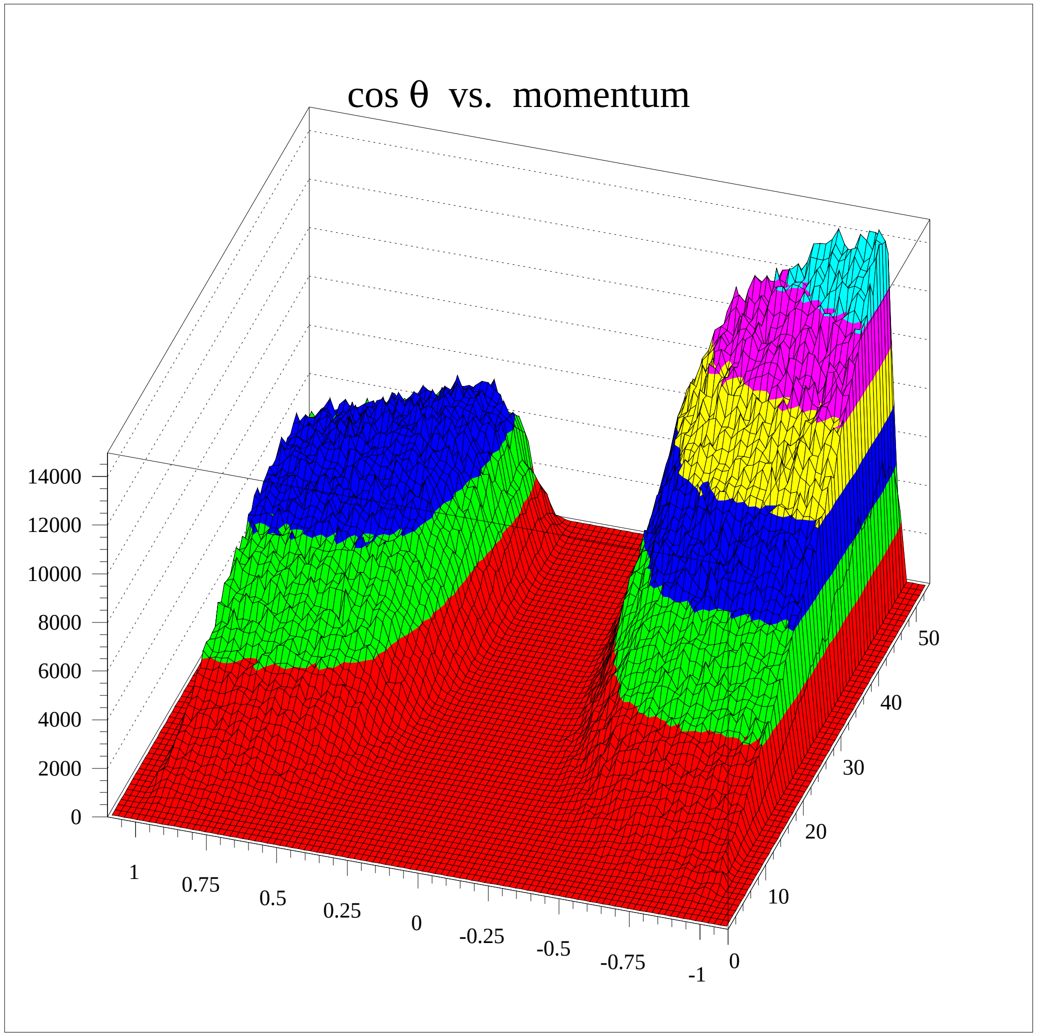
Physics variables

- Decay e^+ momentum, $|\vec{p}|$
- Decay e^+ $\cos\theta$

Variables for cuts

- Particle time of flight
- μ^+ stopping location
- Fitter results

Histogram in bins of $|\vec{p}|$ and $\cos\theta$



17% of standard data set

Fitting ρ

The energy and angular distribution of the Michel positron is given by:

$$\frac{d^2\Gamma}{dx\,d(\cos\theta)} \propto F_{IS}(x,\rho,\eta) + P_\mu \cos\theta F_{AS}(x,\xi,\delta)$$

Where

$$F_{IS} = x^2(1-x) + \frac{2}{9}\rho x^2(4x-3) + \eta\frac{m_e}{E_e^{max}}x(1-x)$$

$$F_{AS} = \frac{1}{3}\xi x[1-x+\frac{2}{3}\delta(4x-3)]$$

Fitting ρ

Integrating over $\cos\theta$ or computing Forward + Backward yields:

$$\frac{d\Gamma}{dx} \propto F_{IS}(x,\rho,\eta) + \epsilon P_\mu F_{AS}(x,\xi,\delta)$$

Where ϵ represents an unknown reconstruction asymmetry.

Note that the effect of $F_{AS}(x,\xi,\delta)$ can be reduced by minimizing ϵ and/or P_μ.

Fitting $\Delta\rho$ and $\Delta\eta$

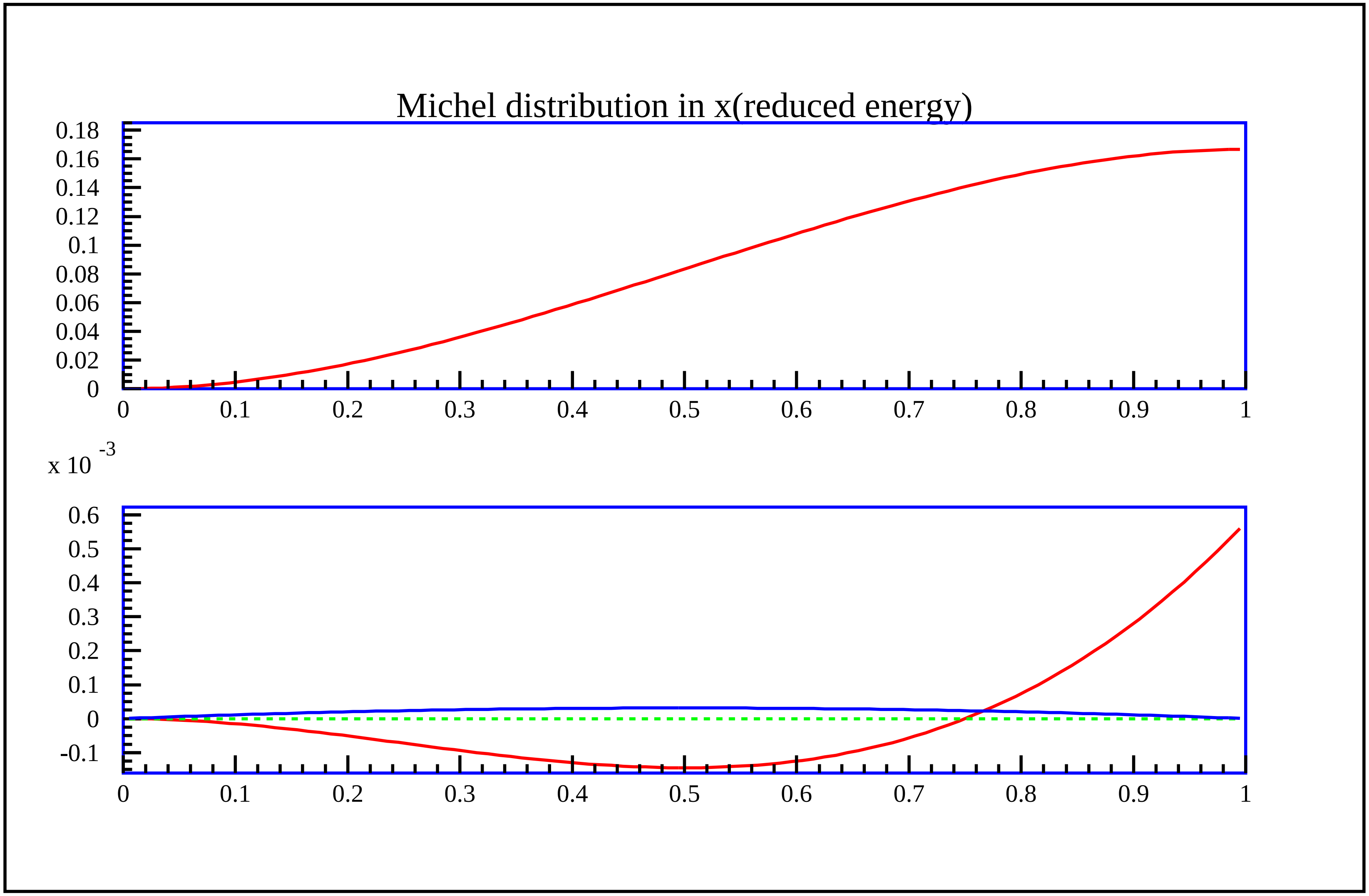
$$\left[\frac{d\Gamma}{dx}\right]_{Data} = \left[\frac{d\Gamma}{dx}\right]_{Std}$$

$$+\frac{\partial}{\partial\rho}\left[\frac{d\Gamma}{dx}\right]_{Std}\Delta\rho + \frac{\partial}{\partial\eta}\left[\frac{d\Gamma}{dx}\right]_{Std}\Delta\eta + \frac{\partial}{\partial\xi}\left[\frac{d\Gamma}{dx}\right]_{Std}\Delta\xi + \frac{\partial}{\partial\delta}\left[\frac{d\Gamma}{dx}\right]_{Std}\Delta\delta$$

Where

$$\frac{\partial}{\partial\rho}\left[\frac{d\Gamma}{dx}\right]_{Std} = k\frac{\partial}{\partial\rho}\Big[F_{IS}(x,\rho,\eta)\Big]_{Std} \qquad \frac{\partial}{\partial\eta}\left[\frac{d\Gamma}{dx}\right]_{Std} = k\frac{\partial}{\partial\eta}\Big[F_{IS}(x,\rho,\eta)\Big]_{Std}$$

$$\frac{\partial}{\partial\xi}\left[\frac{d\Gamma}{dx}\right]_{Std} = \epsilon P_{\mu} k\frac{\partial}{\partial\xi}\Big[F_{AS}(x,\xi,\delta)\Big]_{Std} \qquad \frac{\partial}{\partial\delta}\left[\frac{d\Gamma}{dx}\right]_{Std} = \epsilon P_{\mu} k\frac{\partial}{\partial\delta}\Big[F_{AS}(x,\xi,\delta)\Big]_{Std}$$



Standard Model(top), $\Delta\rho$ (bottom, red), $\Delta\eta$(bottom, blue)

Fitting ρ with a blind analysis

(Ignoring $\cos\theta$ term)

Consider

$$\rho = \rho_{Std} + \Delta\rho \quad \rightarrow \quad \rho = \rho_o + \Delta\rho'$$

$$\eta = \eta_{Std} + \Delta\eta \quad \rightarrow \quad \eta = \eta_o + \Delta\eta'$$

Fitting $\Delta\rho'$ and $\Delta\eta'$

$$\left[\frac{d\Gamma}{dx}\right]_{Data} = \left[\frac{d\Gamma}{dx}\right]_{\rho_o,\eta_o} + \frac{\partial}{\partial\rho}\left[\frac{d\Gamma}{dx}\right]_{\rho_o,\eta_o}\Delta\rho' + \frac{\partial}{\partial\eta}\left[\frac{d\Gamma}{dx}\right]_{\rho_o,\eta_o}\Delta\eta'$$

Where

$$\frac{\partial}{\partial\rho}\left[\frac{d\Gamma}{dx}\right]_{\rho_o,\eta_o} = k\frac{\partial}{\partial\rho}\Big[F_{IS}(x,\rho,\eta)\Big]_{\rho_o,\eta_o} \qquad \frac{\partial}{\partial\eta}\left[\frac{d\Gamma}{dx}\right]_{\rho_o,\eta_o} = k\frac{\partial}{\partial\eta}\Big[F_{IS}(x,\rho,\eta)\Big]_{\rho_o,\eta_o}$$

Systematic errors

Reconstruction efficiency as a function of $\cos\theta$, $|\vec{p}|$ and . . .

DC HV (track fitting)

PC HV (pattern recognition)

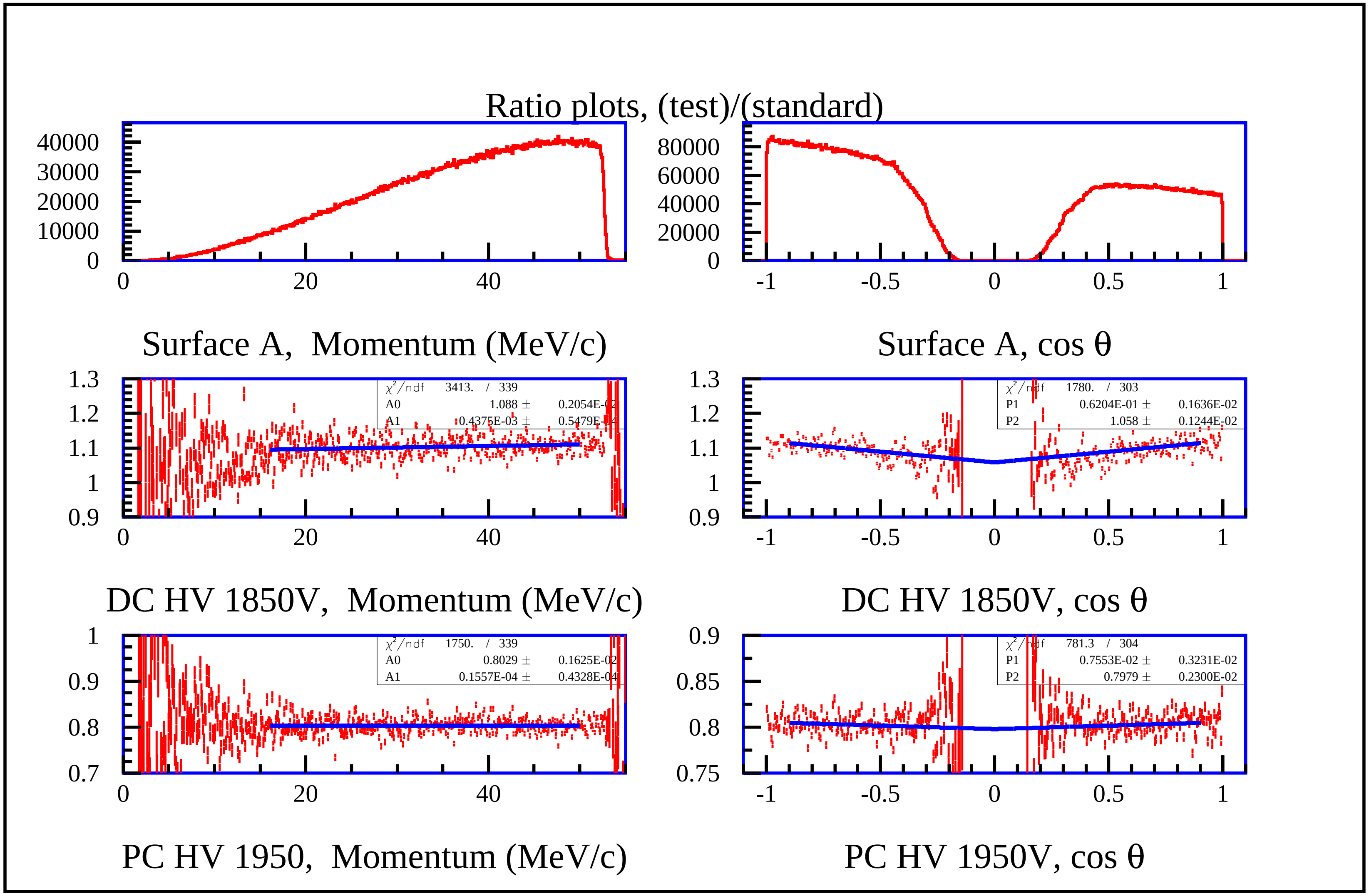
Chamber gas density

μ^+ rate

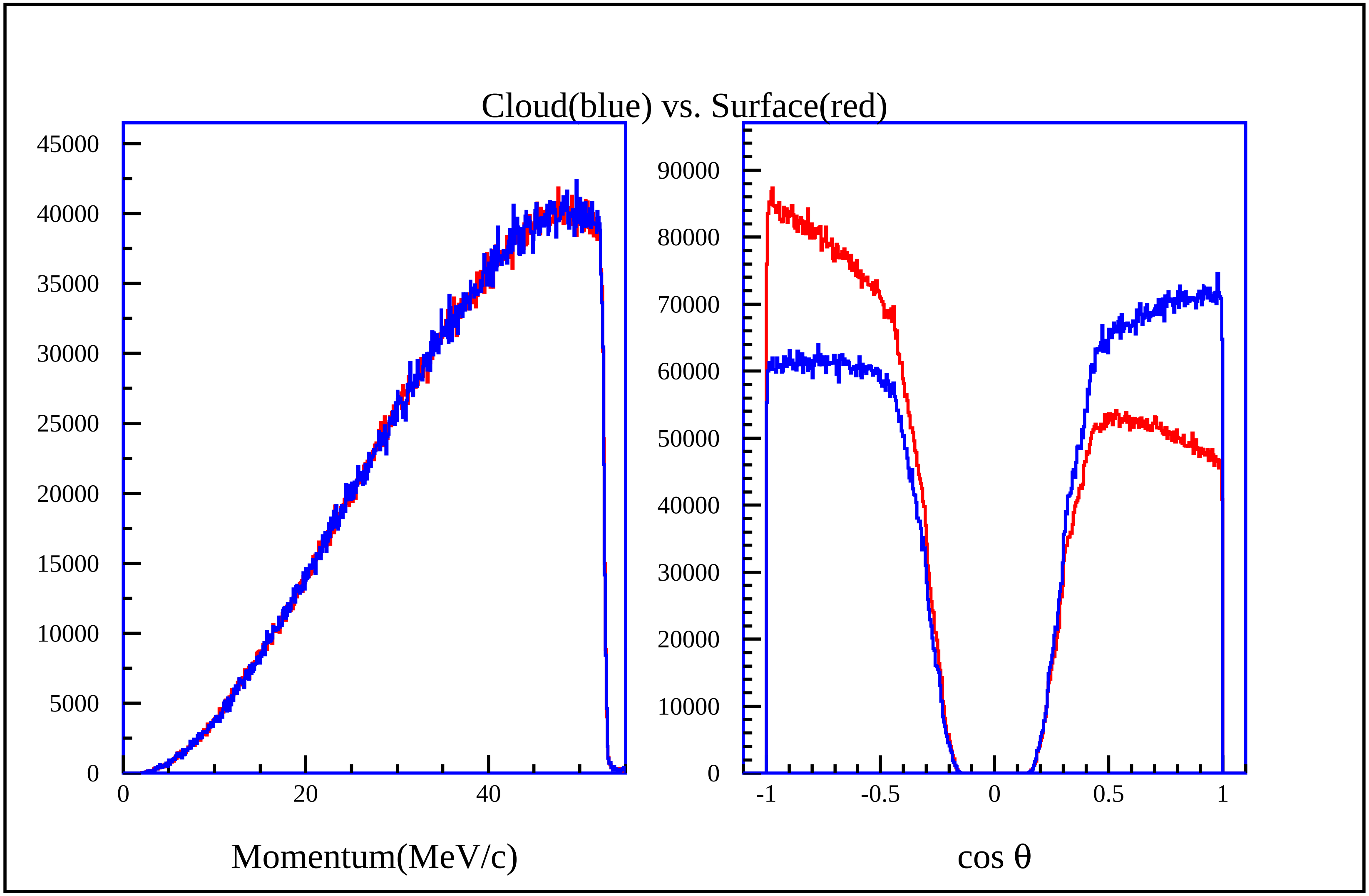
Beam e^+ rate

Upstream/downstream asymmetry*

Philosophy: exaggerate a possible source of error to put limits on its effect.



Surface(17% of standard data set), DC HV 1850V(19%), PC HV 1950V(14%)



Surface(17% of standard data set), Cloud(6%)

Summary

Data has been taken for a measurement of ρ with a statistical precision of a part in 10^3.

Data with comparable statistics has been taken to study a variety of possible systematic effects.

$\mathcal{TWIST}$ is setting limits on systematic effects by using data to data comparisons

$\mathcal{TWIST}$ is employing an effective blind analysis technique