First TWIST Results

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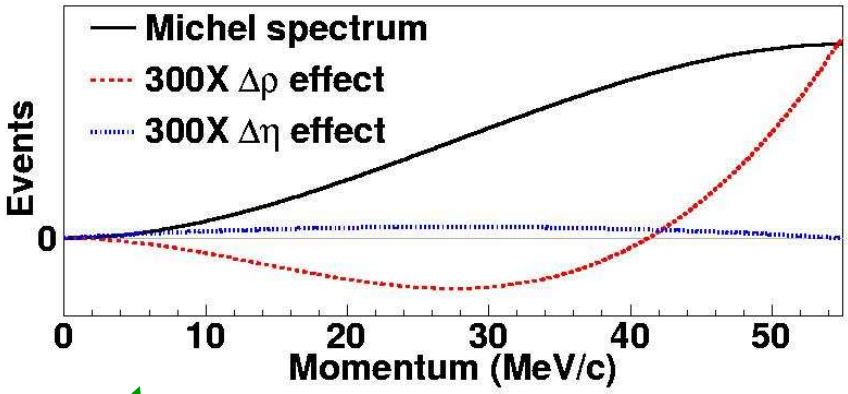
Michel Parameters

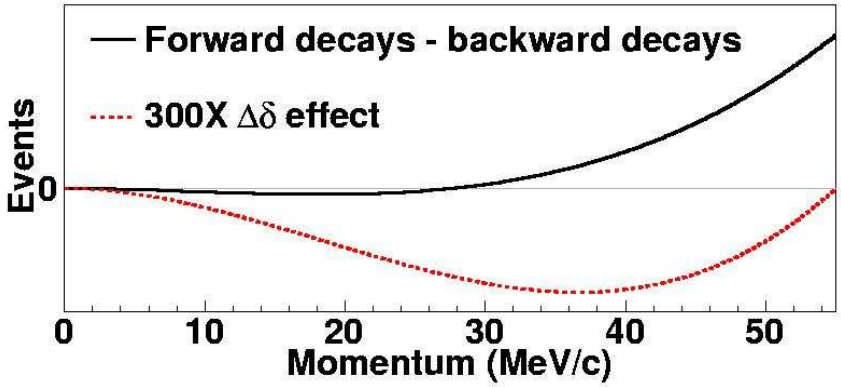


ρ and η: Describe un-polarized momentum distribution

Standard Model:
$\rho = \frac{3}{4}$, $\eta = 0$

δ: Describes momentum dependence of asymmetry

Standard Model:
$\delta = \frac{3}{4}$



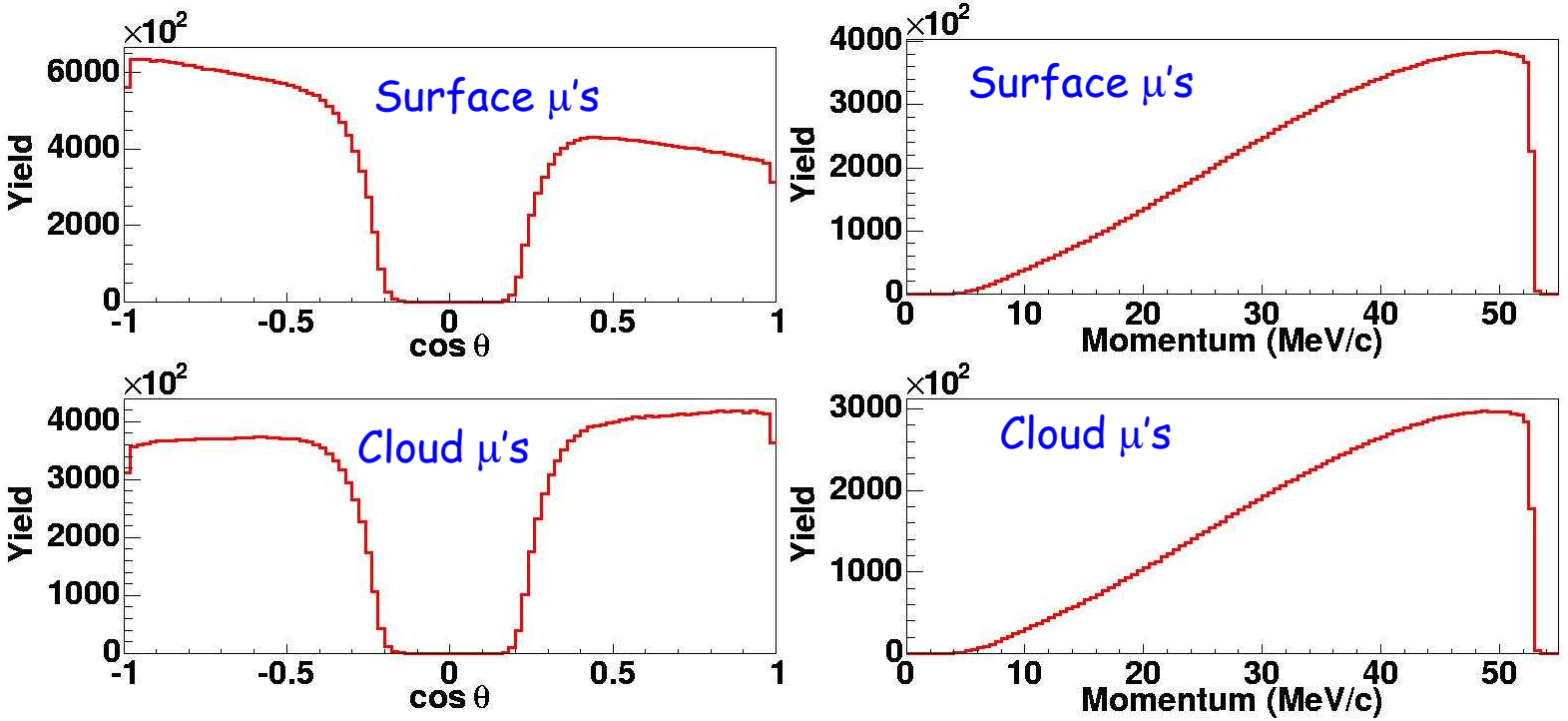
300X effects from differences at PDG uncertainties

Data Sets

1. Nominal A - surface muon set with 2T field
2. Nominal B - surface muon set with 2T field
3. Low Field - surface muon set with 1.96T field
4. High Field - surface muon set with 2.04T field
5. Cloud - cloud muon set with 2T field (only for ρ)

- Surface sets
  - High muon polarization (P_μ~-0.93)
  - Taken in 2 days
- Cloud sets
  - Low muon polarization (P_μ~0.22)
  - Taken in a few weeks
- Each set has ~3×10^8 events
- Corresponding Monte Carlo generated for each set

Surface and Cloud Muons



Polarization effects asymmetry but not momentum

Evaluation of Systematics

Definition: Any effect that is missing from or inaccurately reproduced by the simulation resulting in an error in the decay parameter fits

Methodology:

1. Exaggerate a condition that is a possible source of error
2. Measure the effect on the decay parameters
3. Measure or estimate the variance of the condition in data
4. Scale the effect according to the ratio of the variance to the exaggeration factor

Systematics List

Positron interactions
- Energy smearing
- Multiple scattering
- Hard interactions
- Stopping target thickness
- Material outside detector

Spectrometer alignment
- Translations
- Rotations
- z
- B field to detector axis

Momentum calibration
- Endpoint fits
- Magnetic field reproduction

Chamber response
- DC efficiency
- PC efficiency
- Dead zone
- Long drift time simulation
- HV variations
- Temperature and pressure
- Foil bulges
- Crosstalk
- t_o variations

Muon beam stability
- Stopping location
- Beam intensity
- Channel magnets

Material in Detector

Issue: The 2002 data run used a graphite coated target. The uncertainty on the graphite layer is 10μm.

Evaluation:

1. Generate Monte Carlo with default 10μm graphite layer on each side
2. Generate second Monte Carlo with 30μm layer
3. Fit result of modified Monte Carlo to default result

Systematic effect on ρ: 0.49×10^{-3}
Systematic effect on δ: 0.37×10^{-3}

Drift Chamber Rotational Alignment

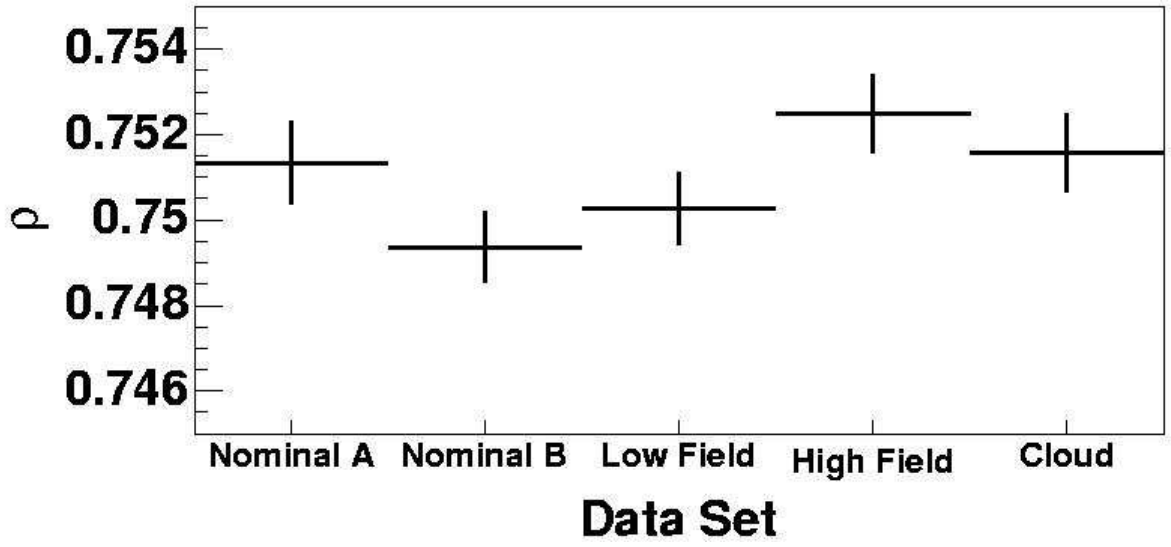
1. Rotational alignment corrections +/- σ are calculated for each plane
2. Data is analyzed with corrections
3. Second set of corrections generated with random values $\langle \Delta angle/\sigma \rangle \sim 80$
4. Data is reanalyzed with random corrections
5. One analysis result is fit to the other

Systematic effect on δ: 0.43×10^{-3}

Systematic Effect	Uncertainty on ρ (10^{-5})	Uncertainty on δ (10^{-5})
Chamber response	51	56
Stopping target thickness	49	37
Positron interactions	46	55
Spectrometer alignment	22	61
Momentum calibration	20	29
Radiative corrections (theory)	20	10
Track selection algorithm	11	non-issue
Muon beam stability	04	10
Upstream/Downstream efficiencies	non-issue	04

Data Set Fits for ρ

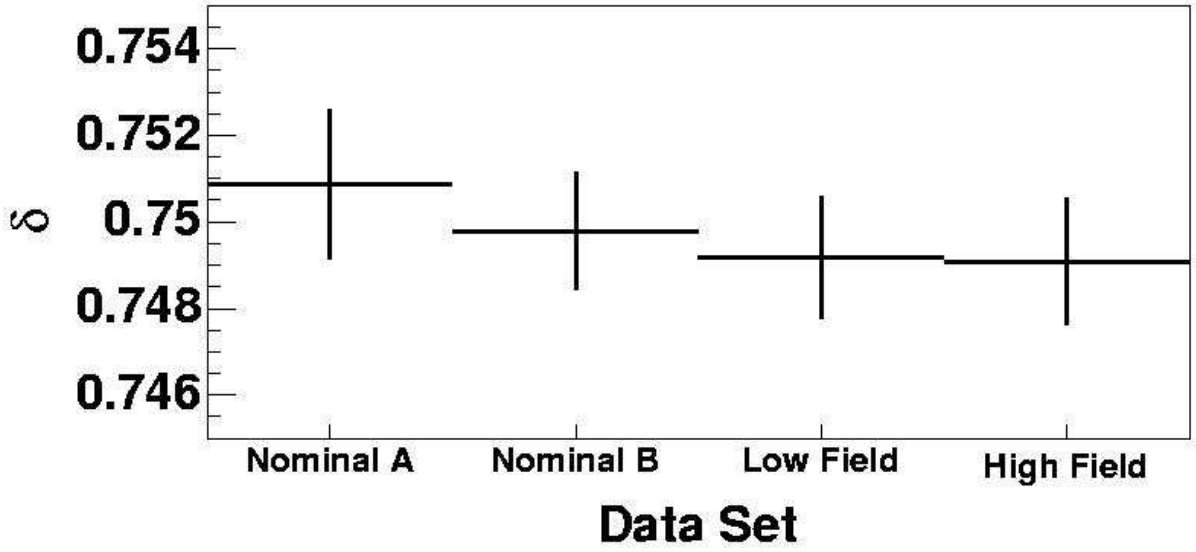
Data set	ρ	χ^2
Set A	0.75134 +/- 0.00083 +/- 0.00053	1814
Set B	0.74937 +/- 0.00066 +/- 0.00053	1965
1.96T	0.75027 +/- 0.00065 +/- 0.00055	1951
2.04T	0.75248 +/- 0.00070 +/- 0.00060	1804
Cloud	0.75157 +/- 0.00076 +/- 0.00053	1993



(1887 degrees of freedom)

Data Set Fits for δ

Data set	δ	χ^2
Set A	0.75087 +/- 0.00156 +/- 0.00073	1924
Set B	0.74979 +/- 0.00124 +/- 0.00055	1880
1.96T	0.74918 +/- 0.00124 +/- 0.00069	1987
2.04T	0.74908 +/- 0.00132 +/- 0.00065	1947



(1887 degrees of freedom)

TWIST Results

$$\rho = 0.75080 \pm 0.00032(stat.) \pm 0.00093(syst.) \pm 0.00023^{*}$$

(*Uncertainty due to uncertainty in η)

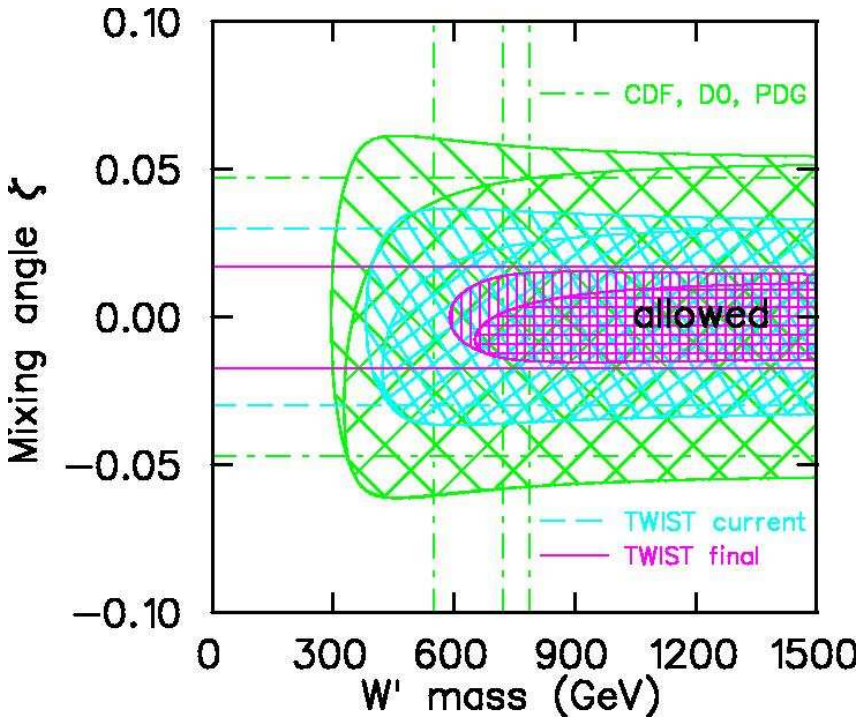
$$\delta = 0.74964 \pm 0.00066(stat.) \pm 0.00112(syst.)$$

Parameter	ρ	δ
TWIST	0.7508 +/- 0.0010	0.7496 +/- 0.0013
PDG	0.7518 +/- 0.0026	0.7486 +/- 0.0038
Standard Model	0.7500	0.7500

Left-right Symmetric Model Limits

ζ: W_R – W_L mixing angle

$$\zeta = \sqrt{\frac{1}{2} - \frac{2}{3}\rho}$$



90% confidence limits:

ζ:

$|\zeta| < 0.030$

M_R, mass of W_R:

$M_R > 420 GeV/c^2$ assumption of pseudomanifest left-right symmetry

$M_R g_L/g_R > 380 GeV/c^2$ non-manifest left-right models

General Right-handed interactions

The relative probability for a right-handed muon to decay into an electron

$$Q_R^\mu = \frac{1}{4}\left|g_{LR}^S\right|^2 + \frac{1}{4}\left|g_{RR}^S\right|^2 + \left|g_{LR}^V\right|^2 + \left|g_{RR}^V\right|^2 + 3\left|g_{LR}^T\right|^2$$

in terms of Michel parameters

$$Q_R^\mu = \frac{1}{2}\left[1 + \frac{1}{3}\xi - \frac{16}{9}\xi\delta\right]$$

(90% confidence limits)

$Q^\mu_R < 0.00184$

and

$|g^S_{LR}| < 0.086$

$|g^V_{LR}| < 0.043$

$|g^T_{LR}| < 0.025$

TWIST


TRIUMF
Canada's National Meson Facility
operated by
Centre National Canadien
pour les Mésons
géré par

Extra Slides

The following are slides from recent talks that I will have with me.

TWIST

TRIUMF
Ryan Bayes*†
Yuri Davydov
Jaap Doornbos
Wayne Faszer
Makoto Fujiwara
David Gill
Robert Henderson
Jingliang Hu
John A. Macdonald§
Glen Marshall
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Previous collaborators:

Peter Green, Arkadi Khruchinsky, Michael Kroupa, Farhana Sobratee, Sun-Chong Wang, Dennis Wright.

Professional and technical support:

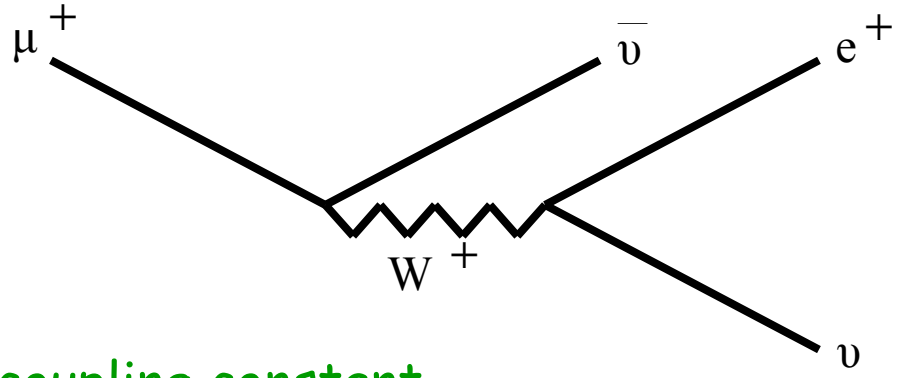
Daniel Allen, Pierre Amaudruz, Willy Andersson, Curtis Ballard, Michael Barnes, Brian Evans, Marielle Goyette, Peter Gumplinger, Doug Maas, Jan Soukup, Len Wampler, and many undergraduate student research assistants.

* graduate student
§ deceased
† also UVic
‡ also UNBC
‡‡ also Saskatchewan

General Description of Muon Decay

$$\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$$

$$\frac{4G_F}{\sqrt{2}} \sum_{\varepsilon,\mu}^{\gamma} g^{\gamma}_{\varepsilon\mu} \left\langle \bar{e}_e \left| \Gamma^\gamma \right| (\nu_e) \right\rangle \left\langle (\bar{\nu}_\mu)_\mu \left| \Gamma_\gamma \right| \mu_\mu \right\rangle$$



$g^{\gamma}_{\varepsilon\mu}$ – coupling constant

γ – Interaction, Γ^S(scalar), Γ^V(vector, Γ^T(tensor)

ε,μ – Positron handedness (L,R)

Michel Parameters

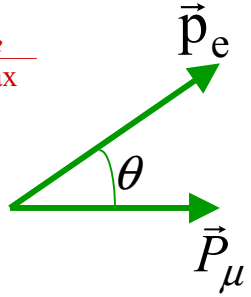
$$\frac{d^2\Gamma}{dx\,d\cos\theta} \propto \sqrt{x^2 - x_o^2}\left[F_{IS}(x,\rho,\eta) + \cos\theta P_\mu F_{AS}(x,\xi,\delta)\right] + R.C.$$

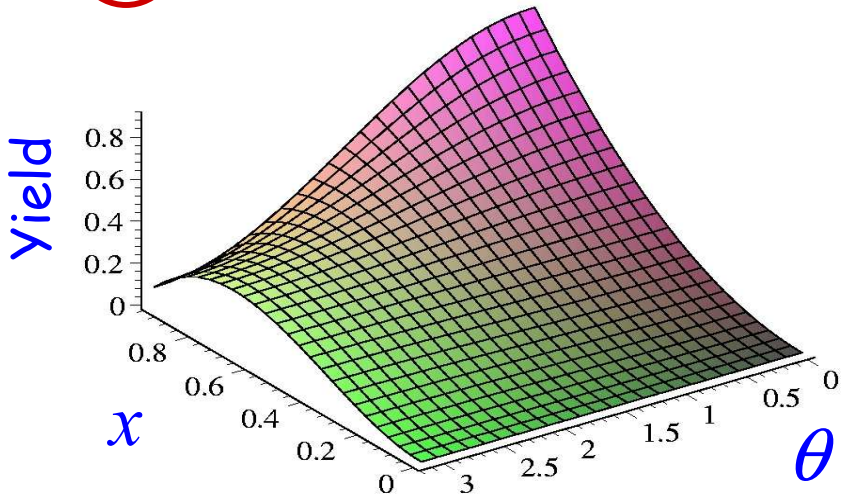
$$F_{IS} = \left(x - x^2\right) + \frac{2}{9}\rho\left(4x^2 - 3x - x_o^2\right) + \eta x_o (1 - x)$$

$$P_\mu F_{AS} = \frac{1}{3}\sqrt{x^2 - x_o^2}\left[P_\mu\xi(1-x) + \frac{2}{3}P_\mu\xi\delta\left(4x - 4 + \sqrt{1-x_o^2}\right)\right]$$

$$x = \frac{E_e}{E_e^{\max}}$$

$$x_o = \frac{m_e}{E_e^{\max}}$$





Long Drift Times

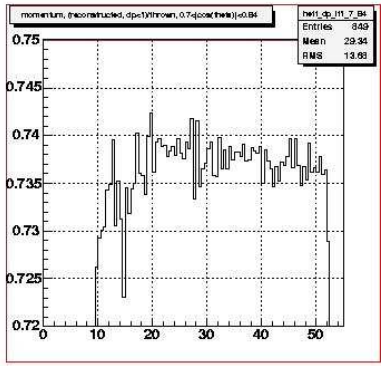
Issue: Inaccuracies in the simulation of efficiencies and drift times in corners of cells

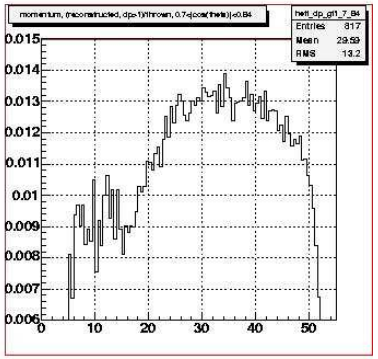
Evaluation:

1. Remove long drift time hits from both data and Monte Carlo
2. Fit data to Monte Carlo to determine decay parameters
3. Observe shift in parameters from standard fit

Systematic effect on ρ: 0.48×10^{-3}

Intermediate and Hard Interactions



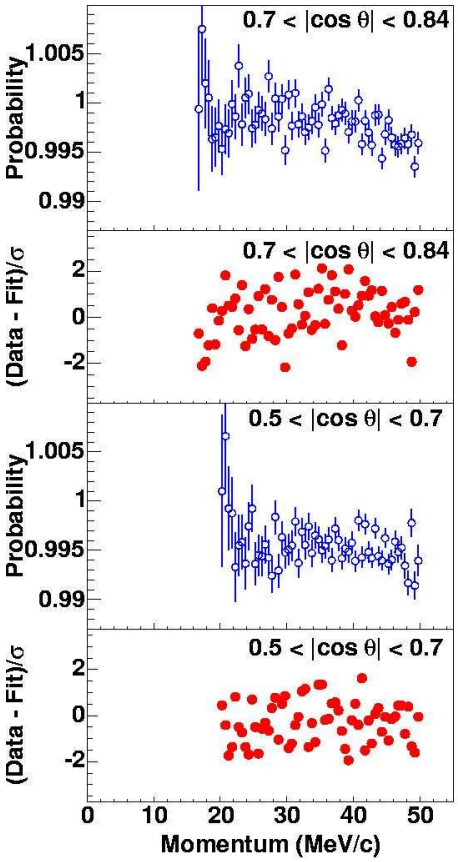


$$\frac{\text{Reconstructed}}{\text{Thrown}} \text{ vs. } |\vec{p}| \text{ for d}p < 1MeV/c \text{ and} > 1MeV/c$$

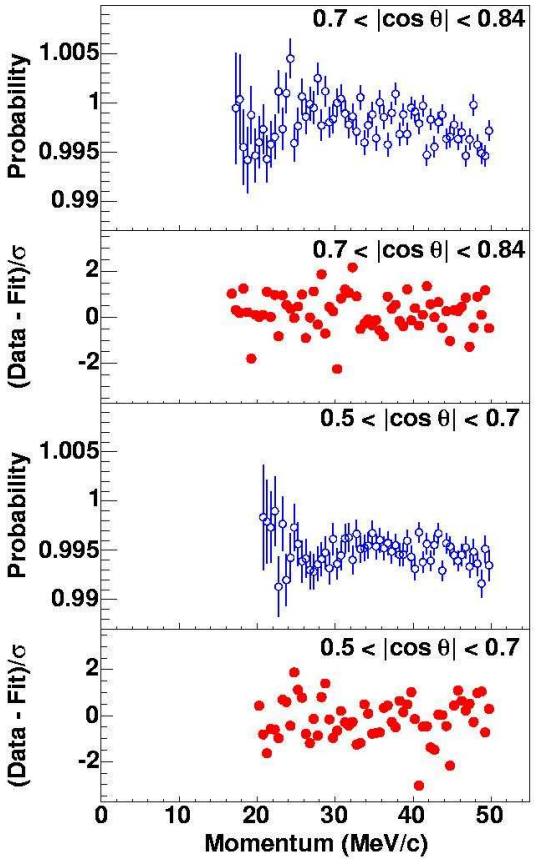
Intermediate interactions => 0.30% change in yield over fiducial
Hard interactions => 0.37% change in yield over fiducial
Change in yield due to $\Delta\rho$ => $\Delta\rho$ factor is 0.68
Scaling from validation of GEANT3 simulation:
Intermediate interactions validated to 5%
Hard interactions validated to 14%
Systematic effect on ρ: 0.45×10^{-3}

Detector Response and Fit Residuals

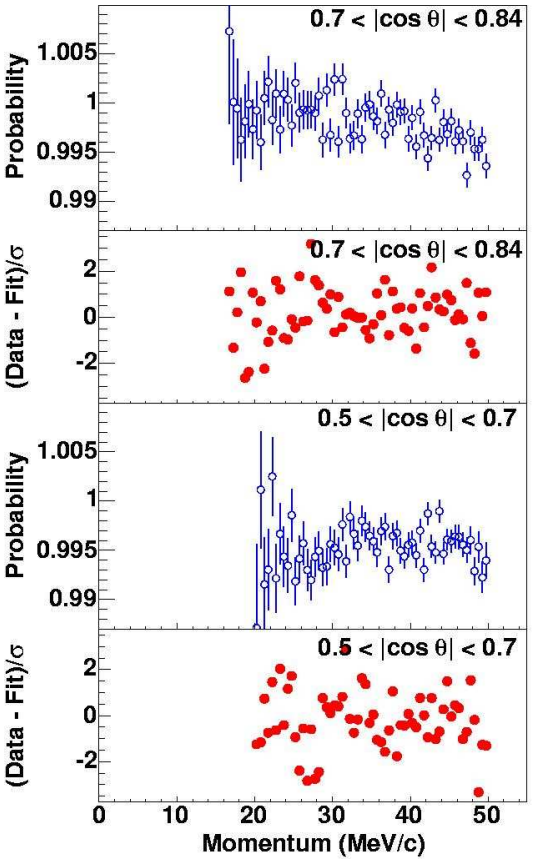
Surface μ's B=2T



Surface μ's B=2.04T



Cloud μ's



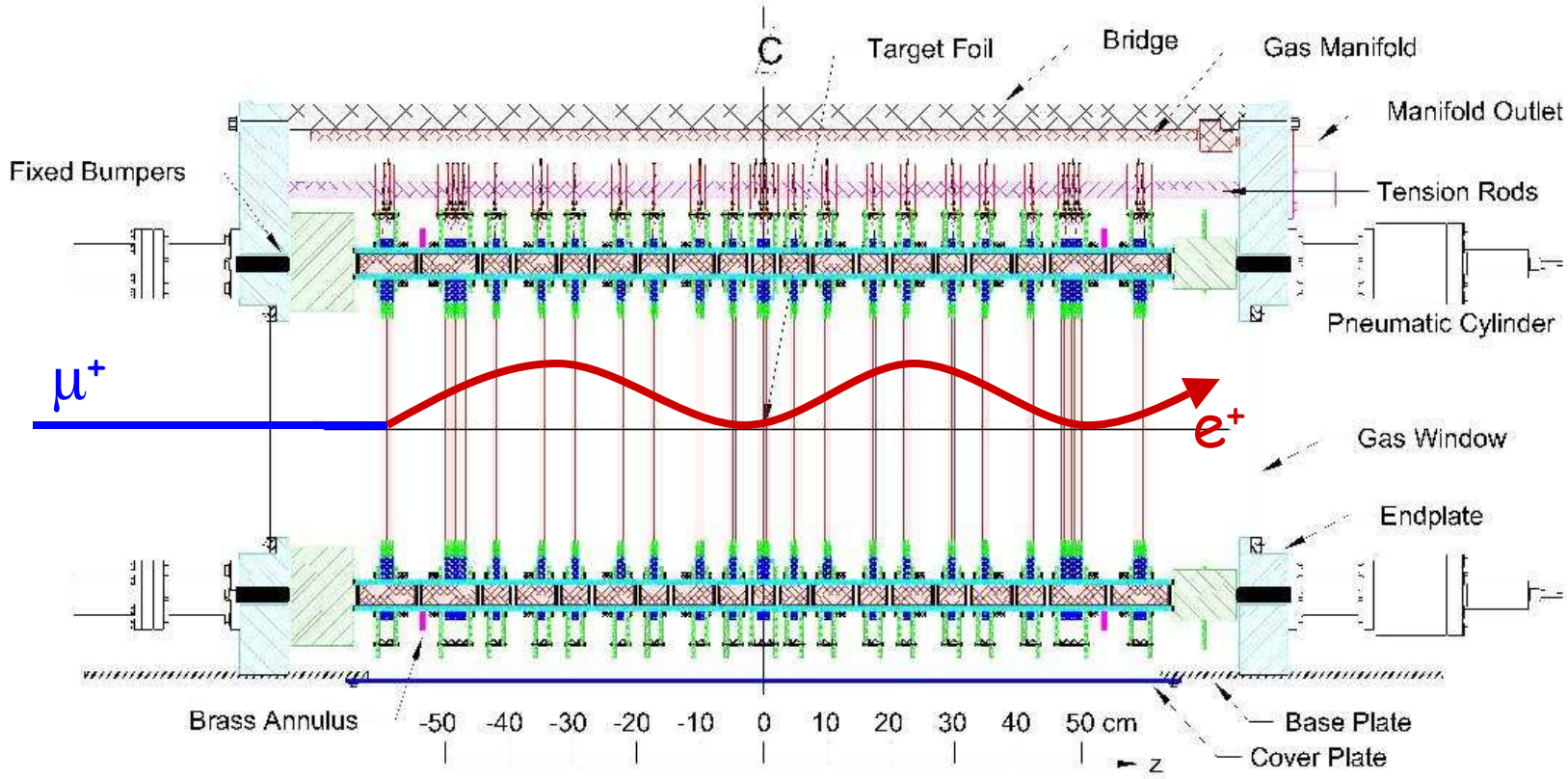
Monte Carlo (GEANT3) Verification

1. Take data under special conditions
2. Generate Monte Carlo under same conditions
3. Analyze with same software
4. Verify that effects are the same

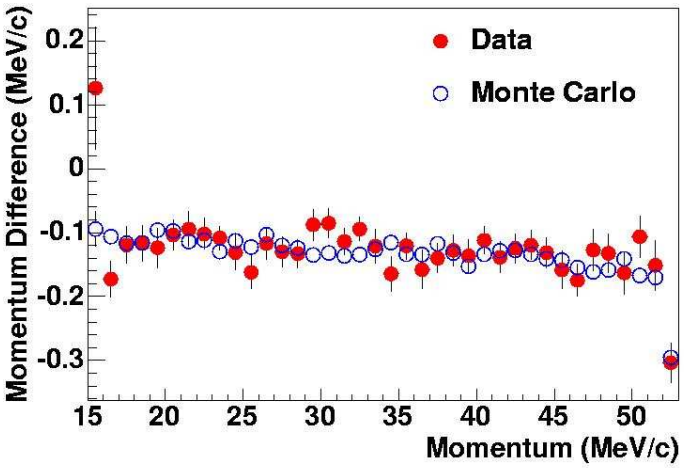
Verification studies

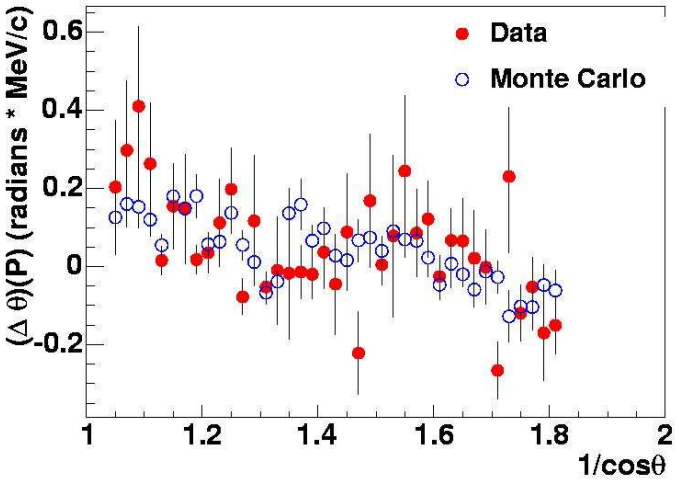
- Material outside detector
- Hits per plane
- Muon stopping position
- Cross-section for secondary particle production
- Energy loss
- Multiple scattering

Far Upstream Stops



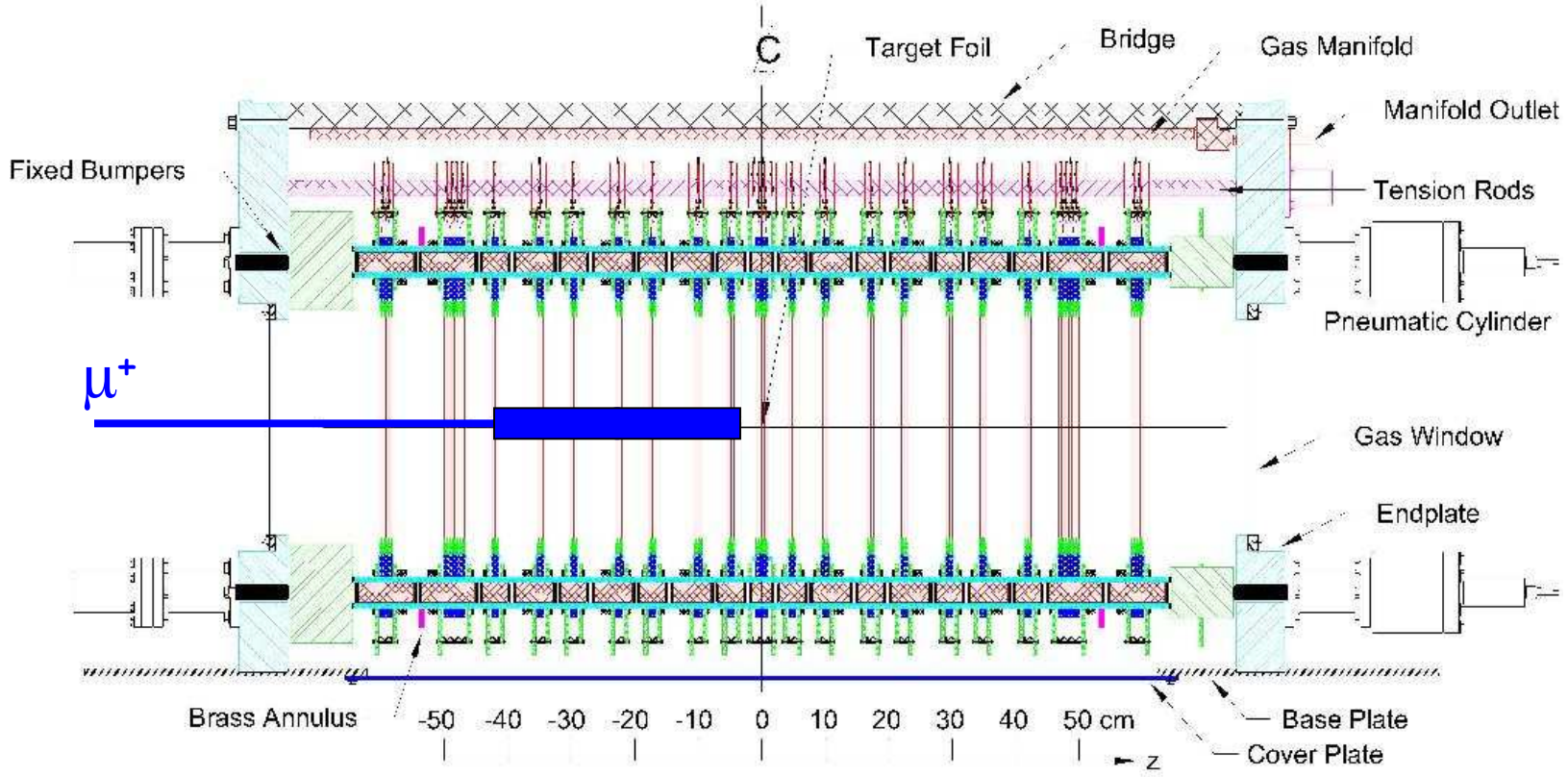
Energy Loss and Multiple Scattering





1. Decay positrons from far upstream stops traverse entire detector
2. Decays are fit upstream and downstream separately
3. Energy loss and scattering are derived from the differences

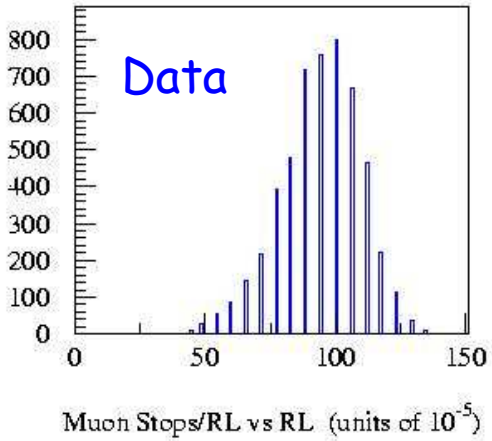
Upstream Sparse Stack Stops

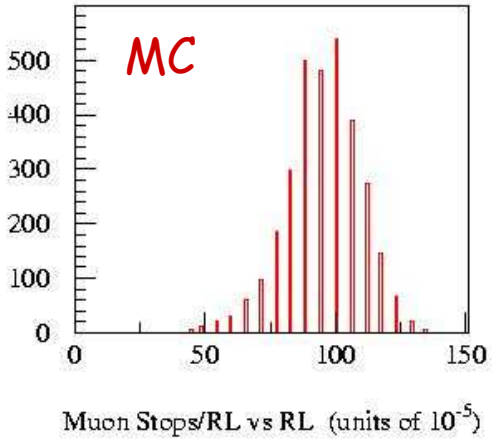


Stopping distribution spread over several DC's rather than concentrated in dense target

Muon Stopping Distribution

1. Muons are stopped upstream of the target in data and Monte Carlo
2. Distribution is spread over several thin DC's
3. Shapes are compared





TWIST Future

- Data has been taken for $P_\mu\xi$ with statistical precision of a part in 10^3
- Data has been taken for ρ with statistical precision of parts in 10^4

Ultimate TWIST goals

- Measurement of ρ, δ and $P_\mu\xi$ with a precision of a few parts in 10^4