SMC BEAM POLARIZATION MEASUREMENT

SMC Collaboration

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The μ of the SMC beam are obtained by decay of π (& K) produced by extracted protons from CERN SPS in a beryllium target.

When a phase space along the π flight line is selected the μ are longitudinally polarized (Parity non-conservation in weak decay).

- Selected along the line: $P_\mu = -100$ % $\Leftarrow$
- Selected opposit to the line: $P_\mu = +100$ %
- Real life: in between

Three methods to know the beam polarization:

- Monte-Carlo beam simulation
- $\vec{\mu}$ decay spectrum
- $\vec{\mu}-\vec{e}$ elastic scattering

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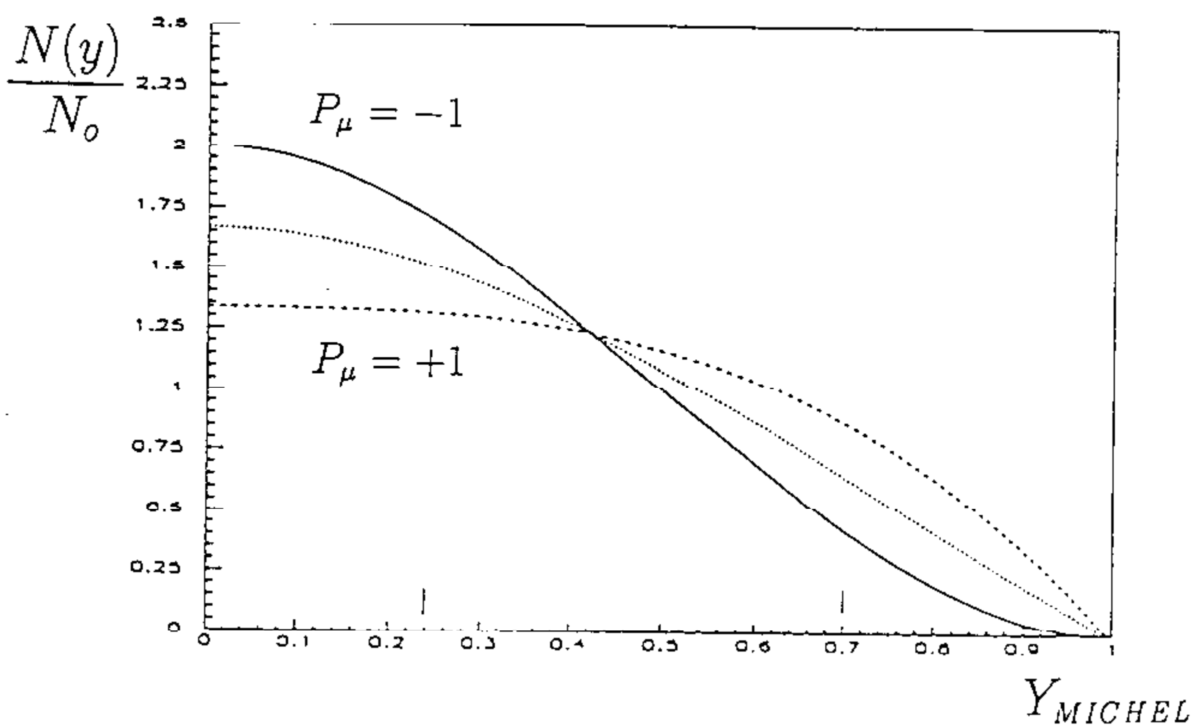
"μ DECAY" ANALYSIS

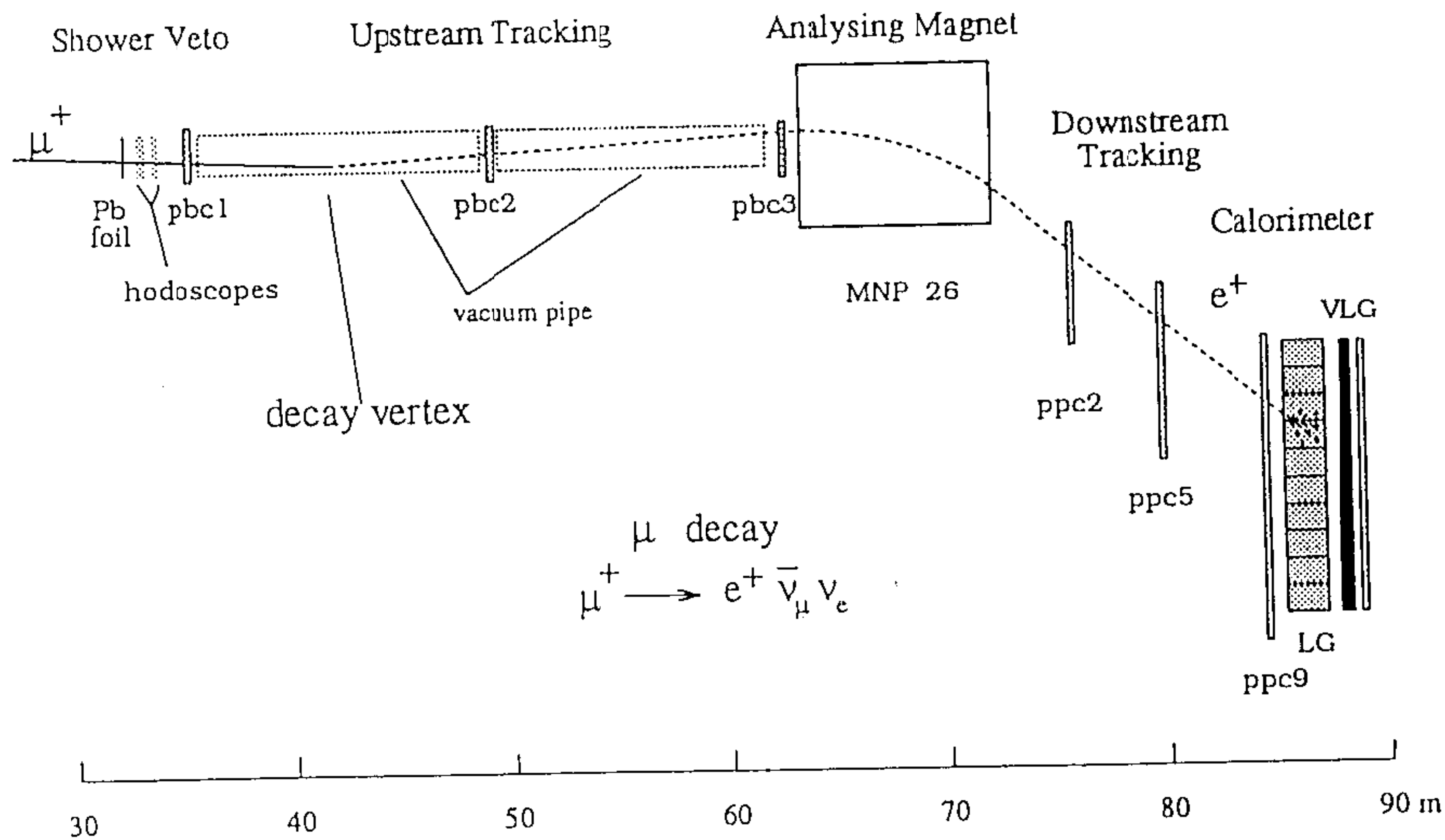
The decay spectrum of polarized μ:

$$N(y) = N_o\left[\frac{5}{3} - 3y^2 + \frac{4}{3}y^3 - P_\mu\left(\frac{1}{3} - 3y^2 + \frac{8}{3}y^3\right)\right]$$

$$P_\mu = \textit{Polarization of the Beam}$$

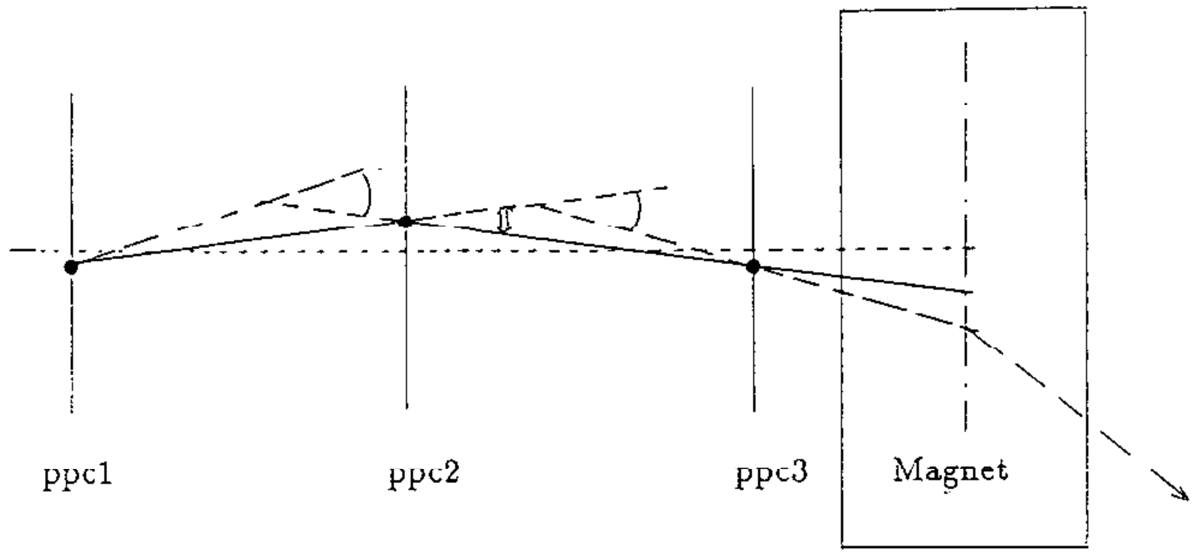
$$y = Y_{MICHEL} = \frac{E'_e}{E_\mu}$$




Shower Veto
Upstream Tracking
Analysing Magnet
μ+
Pb
foil
pbc1
hodoscopes
pbc2
vacuum pipe
pbc3
decay vertex
MNP 26
Downstream
Tracking
Calorimeter
e+
VLG
ppc2
ppc5
LG
ppc9
μ decay
μ+ → e+ ν̄μ νe
30
40
50
60
70
80
90 m

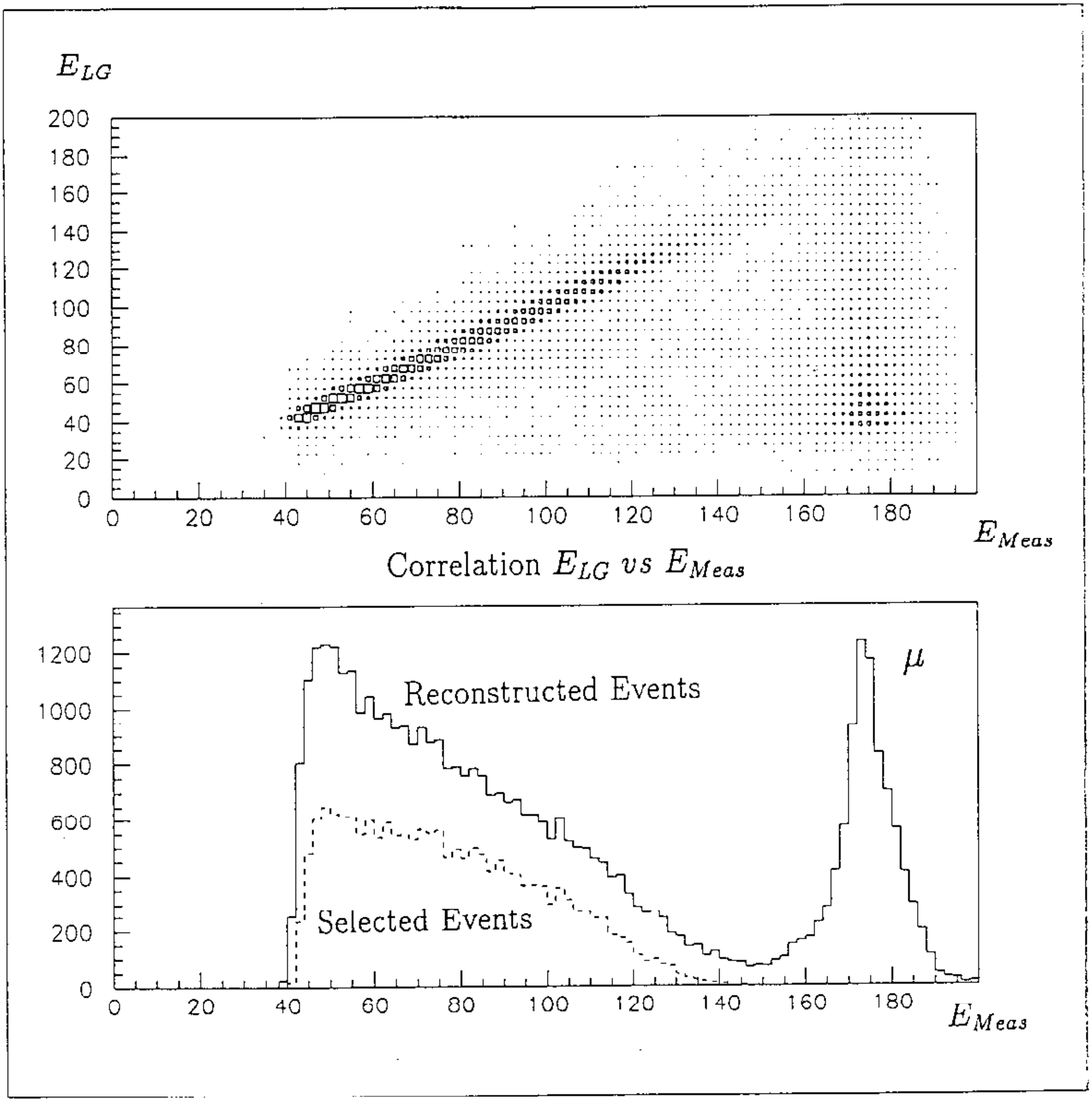
RECONSTRUCTION: $\mu^+ \longrightarrow e^+ \bar{\nu_\mu} \nu_e$

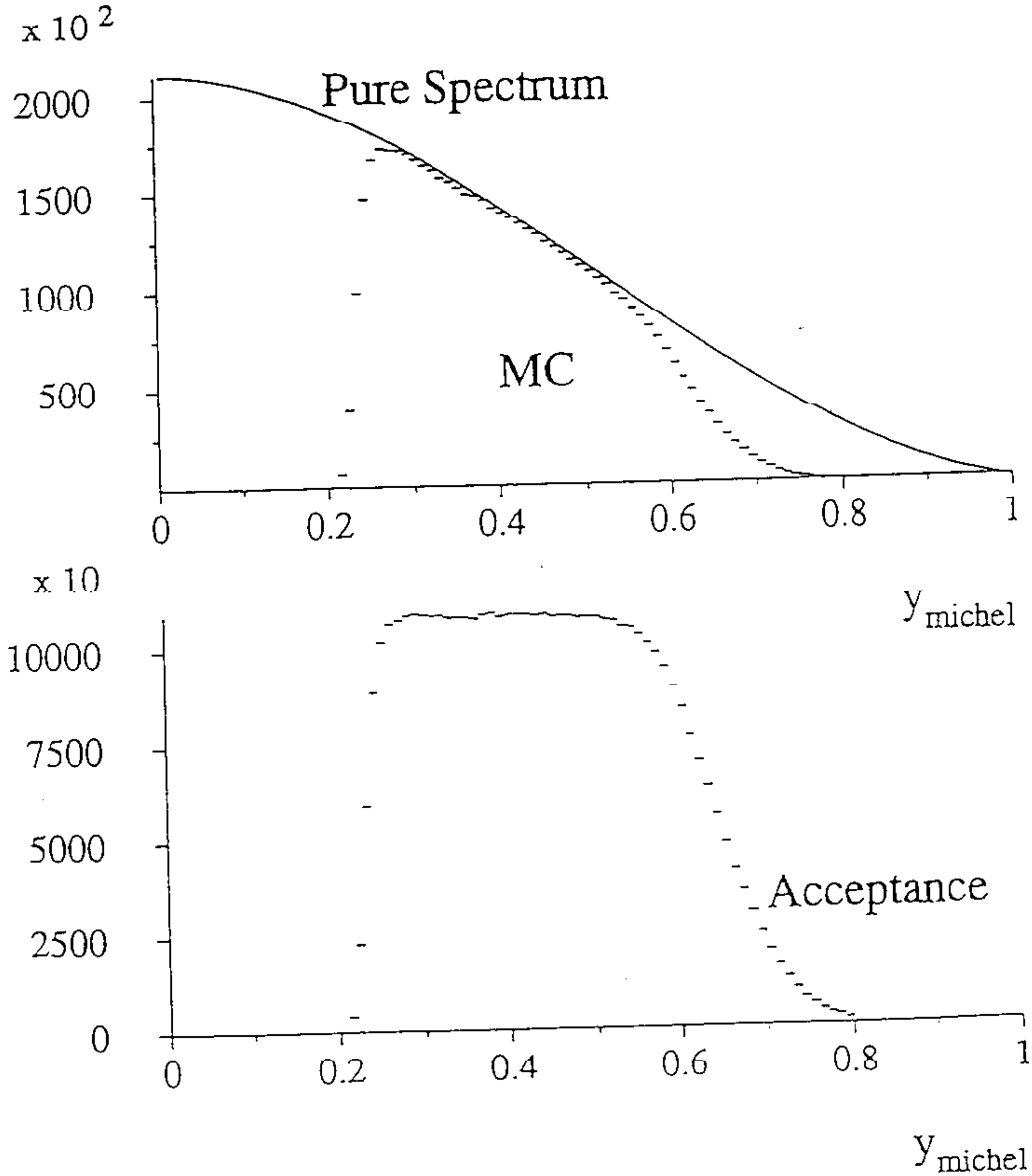
- The broken Line:



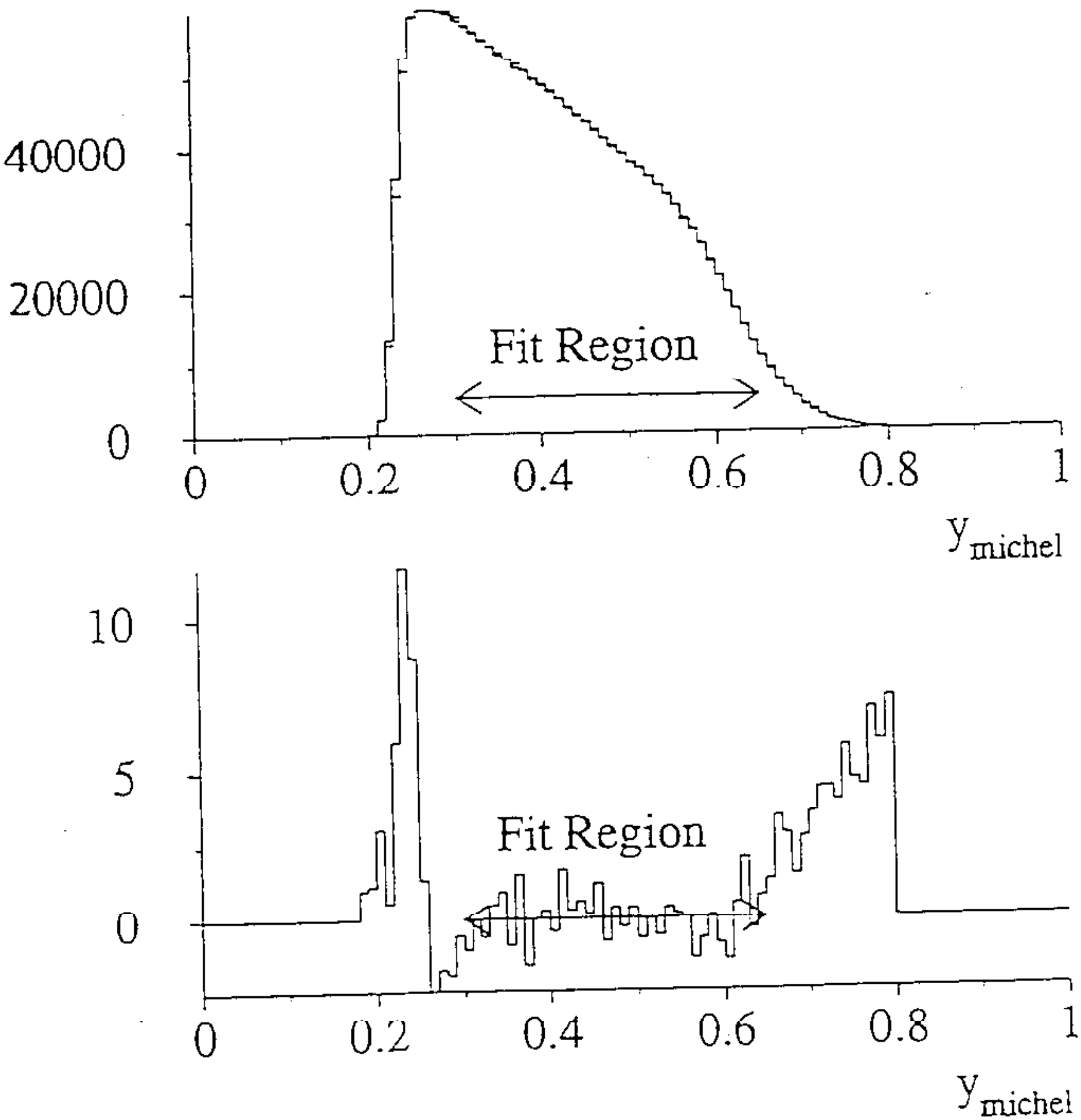
- The "physical" Cuts
  1. Matching UP-DOWNstream Track in the Magnet
  2. Matching $E_{LG} - E_{meas}$ (PID)

- Monte-Carlo (Geant):
  1. Acceptance +Chambers Efficiencies
  2. Radiative Corrections (effect $\sim 10\,\%$)
  3. Real photo-production not included

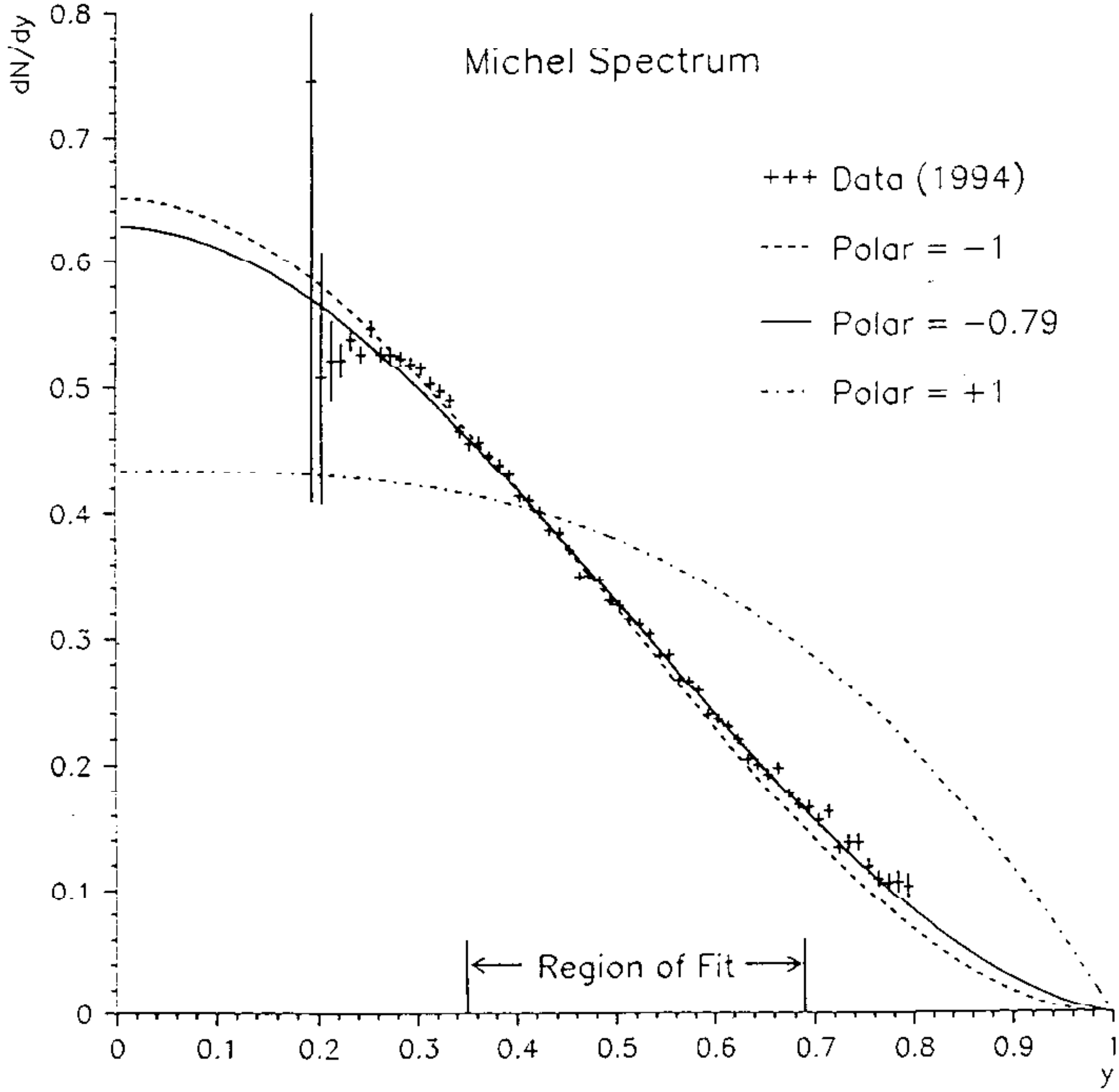

E_{LG}
E_{Meas}
Correlation E_{LG} vs E_{Meas}
Reconstructed Events
Selected Events
μ
E_{Meas}

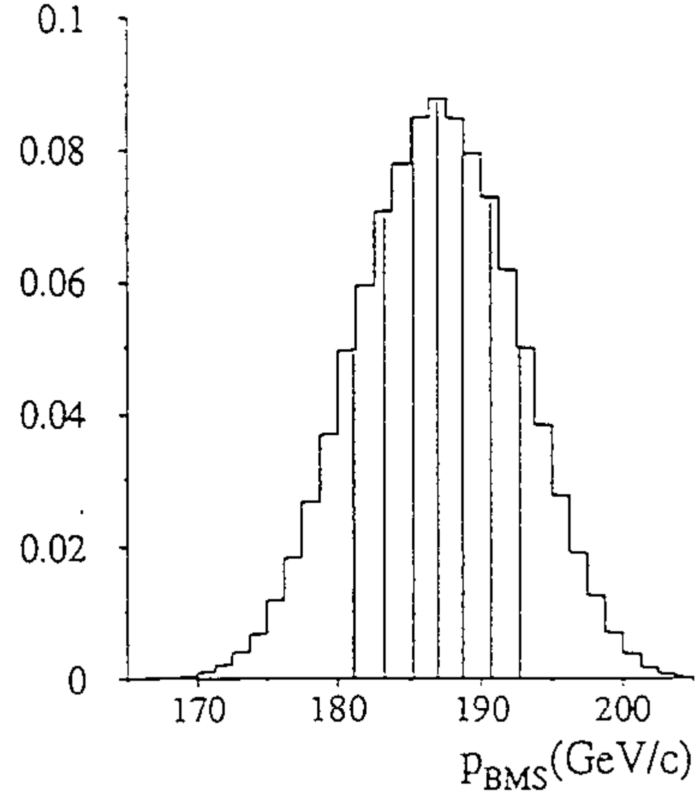


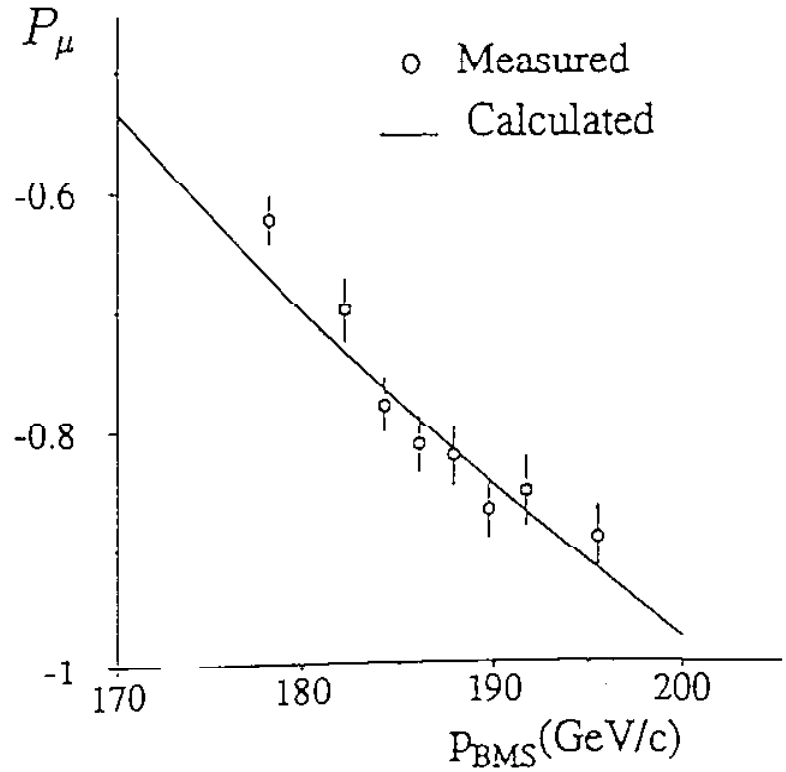
x 10 2
2000
1500
1000
500
Pure Spectrum
MC
0
0.2
0.4
0.6
0.8
1
y_{michel}
x 10
10000
7500
5000
2500
0
Acceptance
0
0.2
0.4
0.6
0.8
1
y_{michel}



40000
20000
0
0
0.2
0.4
0.6
0.8
1
Fit Region
y_{michel}
10
5
0
0
0.2
0.4
0.6
0.8
1
Fit Region
y_{michel}


Michel Spectrum
dN/dy
y
+++ Data (1994)
Polar = −1
Polar = −0.79
Polar = +1
Region of Fit
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1





Polarisation vs. Beam Energy (Measured and calculated, Assuming pure π primary Beam of 206.5 GeV)

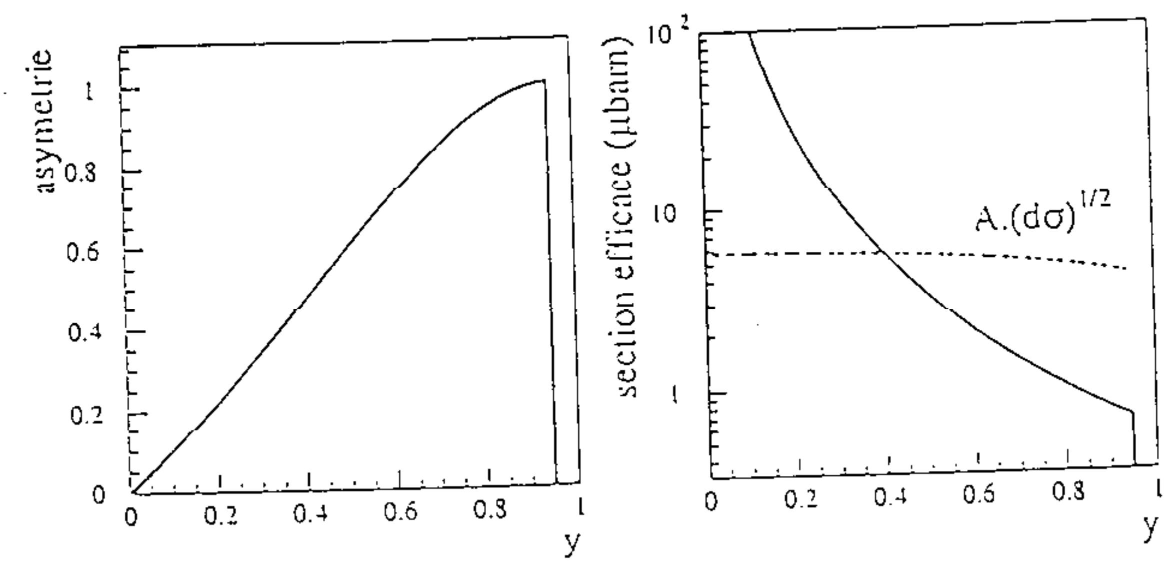
"$\mu - e$" ANALYSIS

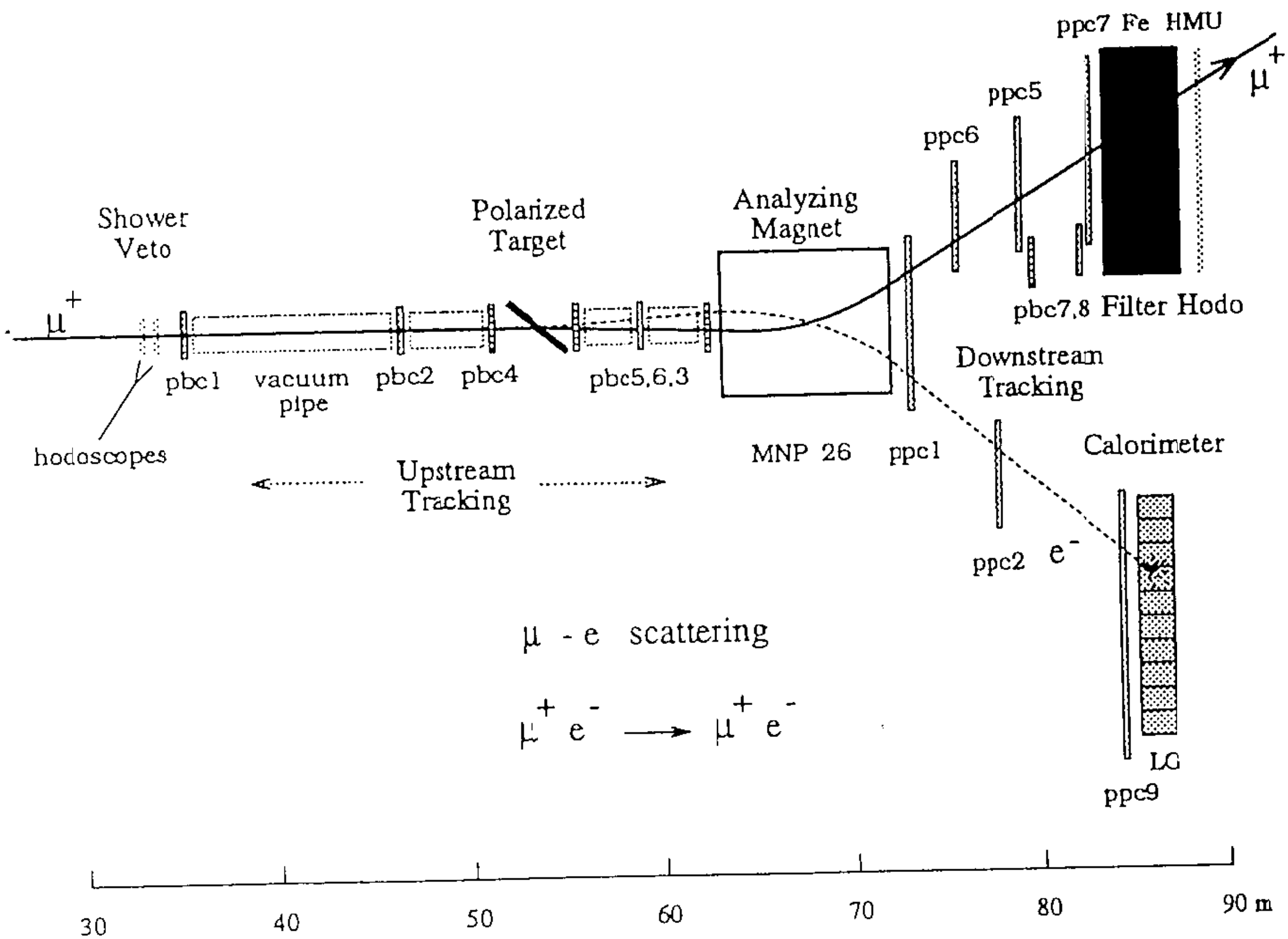
The scattering of longitudinally polarized μ by longitudinally polarized electrons (Born cross-section) is:

$$\frac{d\sigma^{Born}}{dy} = \frac{2\pi r_e^2 m}{E_\mu}\left[\frac{1}{y^2} - \frac{1}{yY} + \frac{1}{2} + P_e P_\mu\left(\frac{1}{Y} - \frac{1}{y} - \frac{1}{2}\right)\right]$$

$$\begin{aligned} P_e\,(,P_\mu) &= \textit{Polarization of electrons}\ (,\textit{beam}) \\ y &= E'_e/E_\mu = 1 - E'_\mu/E_\mu \quad (\sim Y_{MICHEL}) \\ Y &= y_{maximum} = (1 + M^2/2mE_\mu)^{-1} = 0.945 \end{aligned}$$

$$A_{\mu e} = \frac{d\sigma^{\uparrow\downarrow} - d\sigma^{\uparrow\uparrow}}{d\sigma^{\uparrow\downarrow} + d\sigma^{\uparrow\uparrow}} = P_e P_\mu \frac{y - y^2 Y + y^2/2}{1 - y/Y + y^2/2}$$

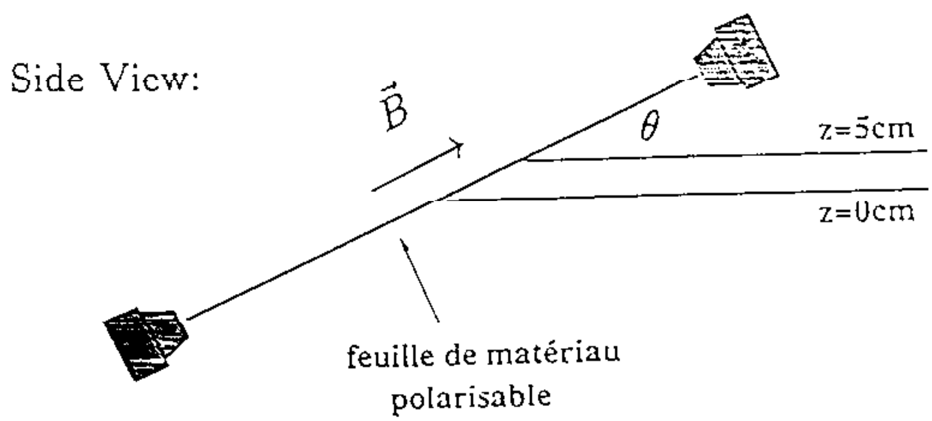


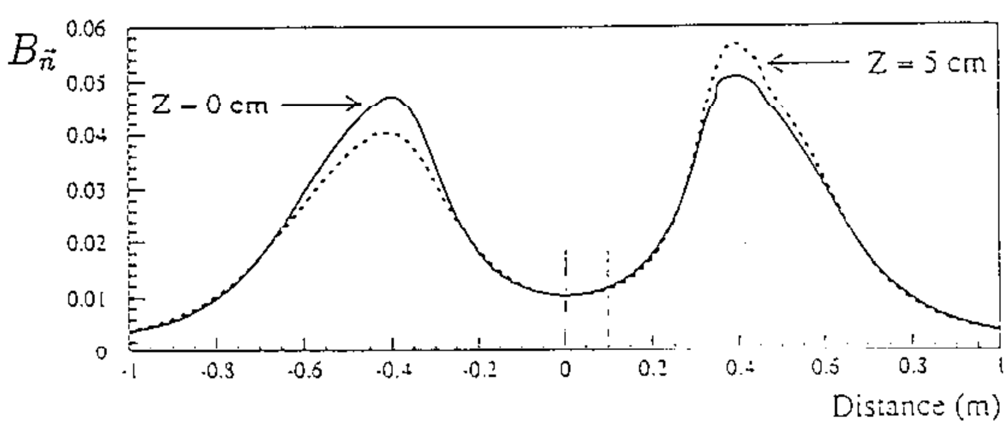


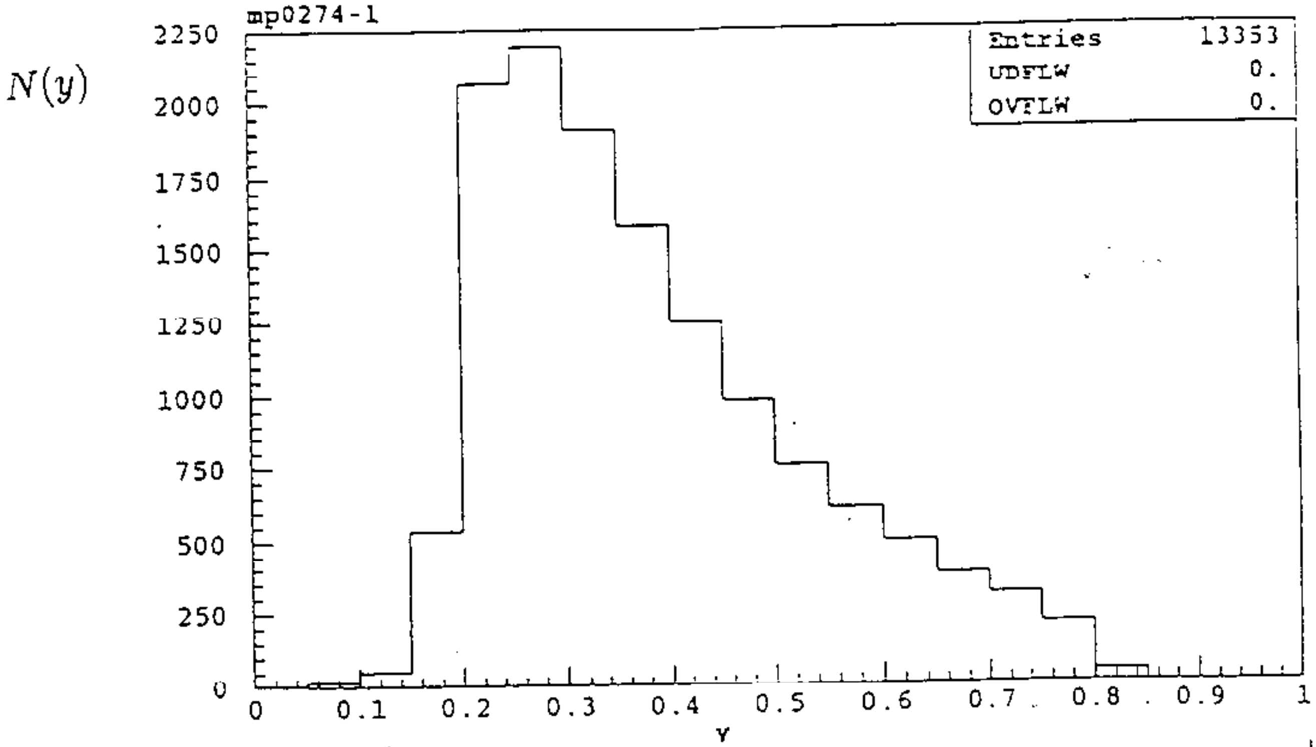
Shower
Veto
Polarized
Target
Analyzing
Magnet
ppc7 Fe HMU
μ+
ppc6
ppc5
pbc7,8 Filter Hodo
pbc1
vacuum
pipe
pbc2
pbc4
pbc5,6,3
Downstream
Tracking
hodoscopes
MNP 26
ppc1
Calorimeter
Upstream
Tracking
ppc2
e-
LG
ppc9
μ - e scattering
μ+ e- → μ+ e-
30
40
50
60
70
80
90 m

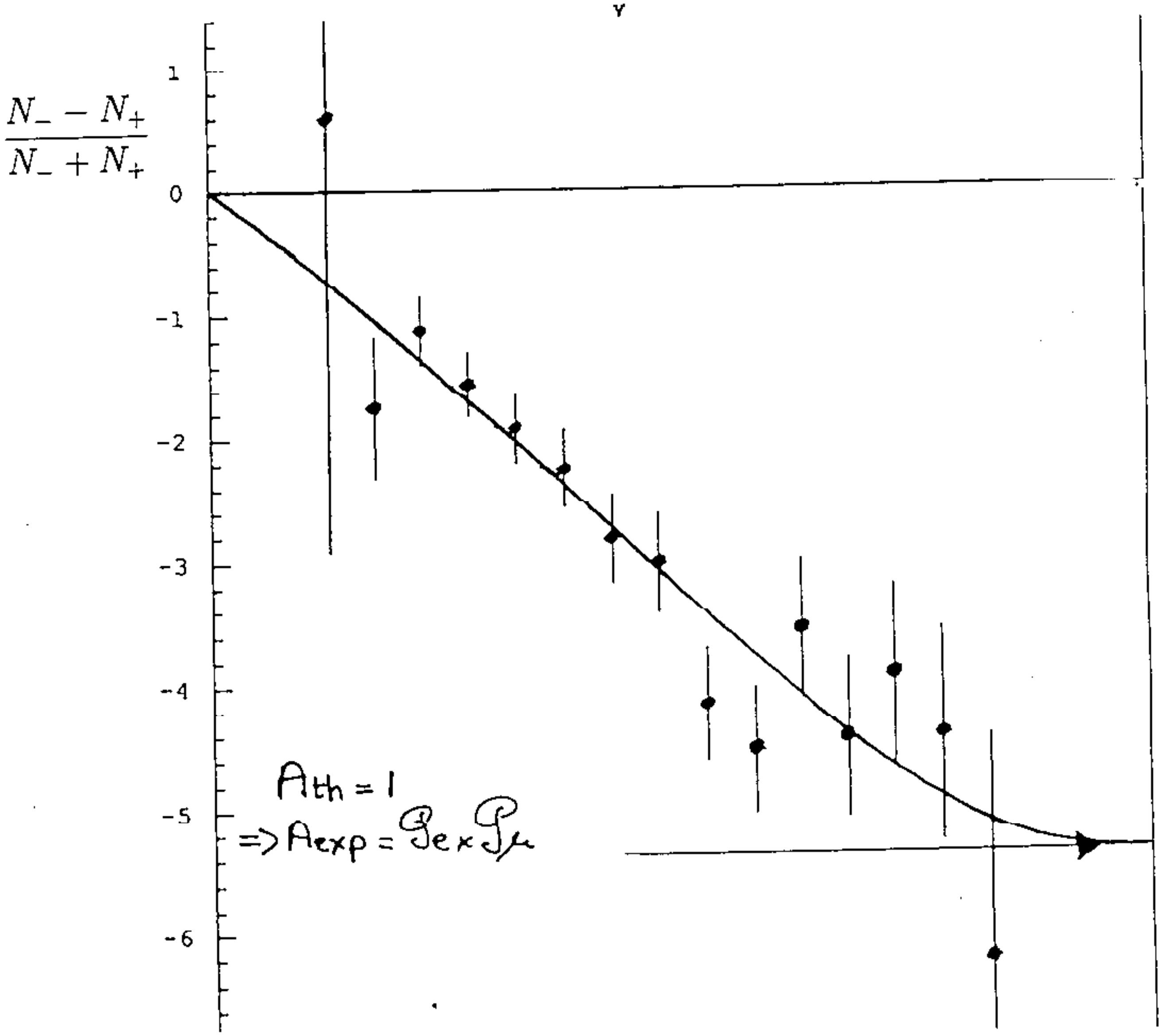
TARGET for $\mu - e$ Scattering

- Compositeness: Fe (49.3 %), Co (48.7 %), V (2.0 %)
- Polarization : $P_e^L = ([8.34 \pm 0.10]\ \%) \times \cos\theta$
- Thickness : $(2 \times 1.32\,mm)/\sin 25^o$ *in* 1993
  : $(4 \times 1.32\,mm)/\sin 18^o$ *in* 1994
- Total Field : $B_{\vec{n}}\,dL \simeq 0.050\ Tm$ (seen by particles)
  (The analysing magnet Field is $11.70\ Tm$).

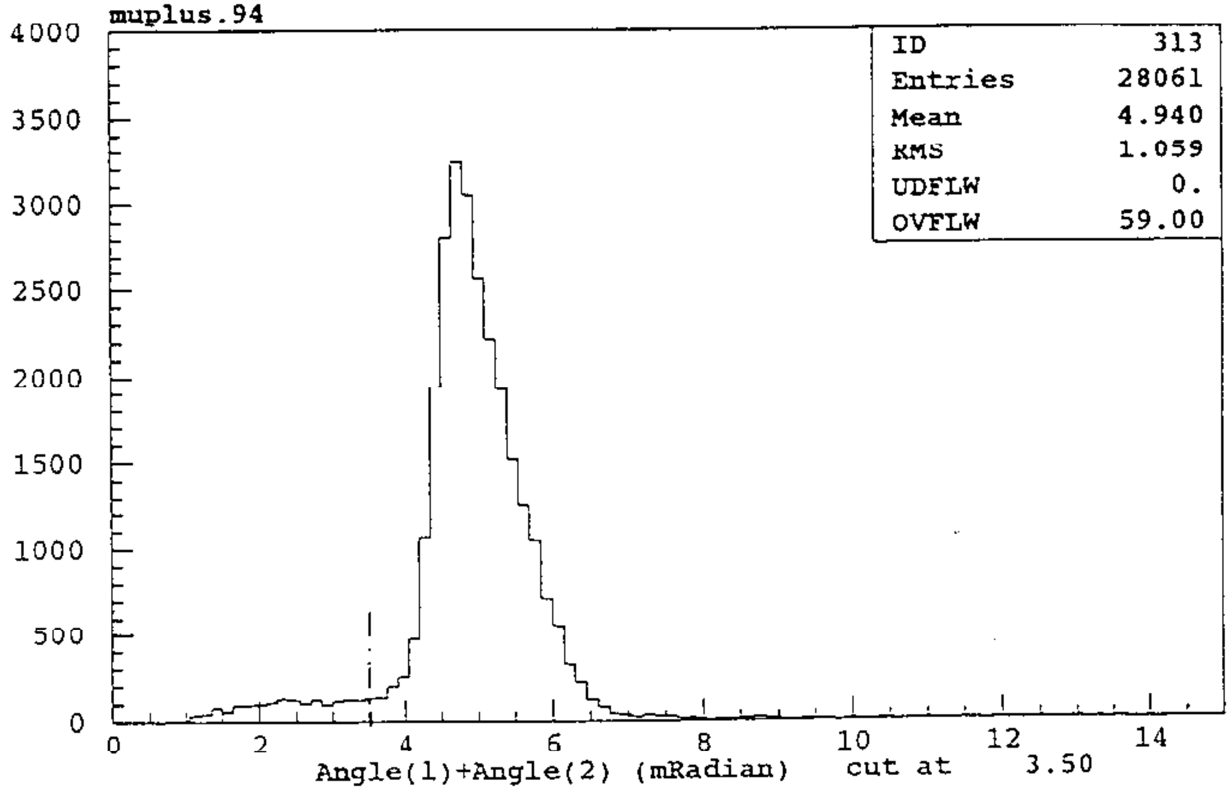


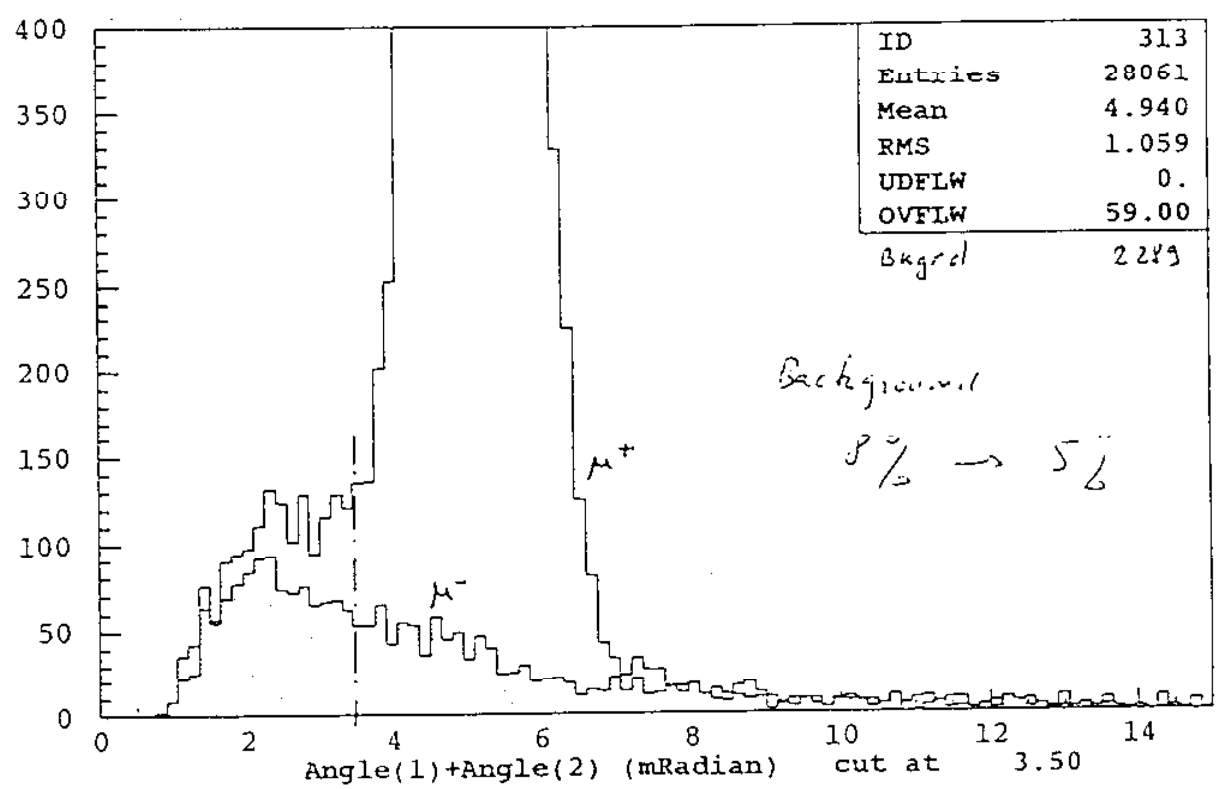


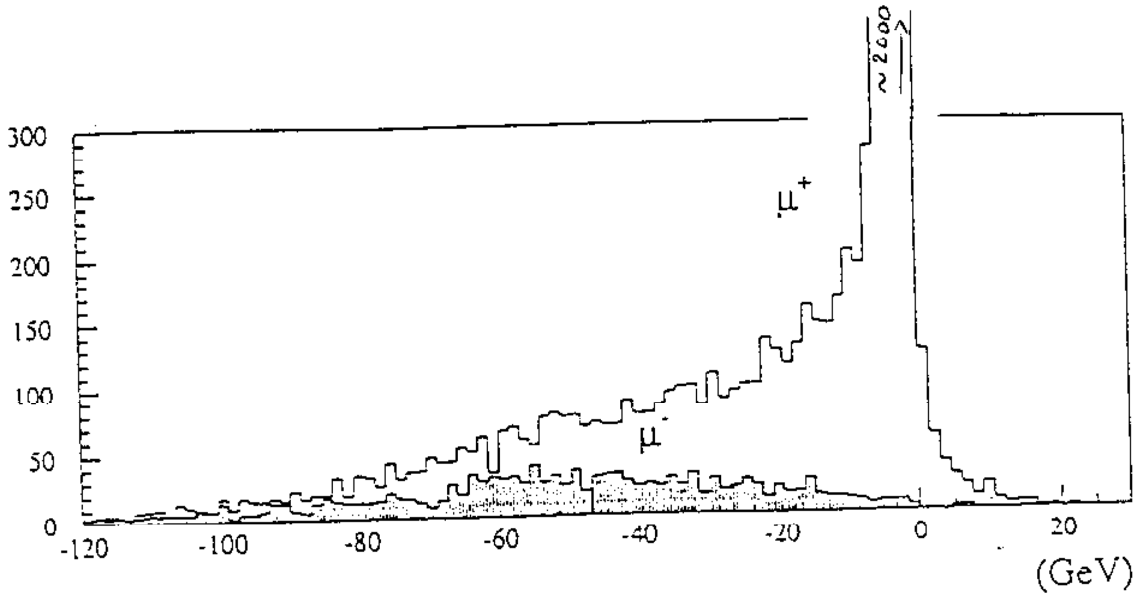

mp0274-1
N(y)
Entries 13353
UDFLW 0.
OVFLW 0.
2250
2000
1750
1500
1250
1000
750
500
250
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Y


$\frac{N_- - N_+}{N_- + N_+}$
1
0
-1
-2
-3
-4
-5
-6
Ath = 1
=> Aexp = Pe × Pμ

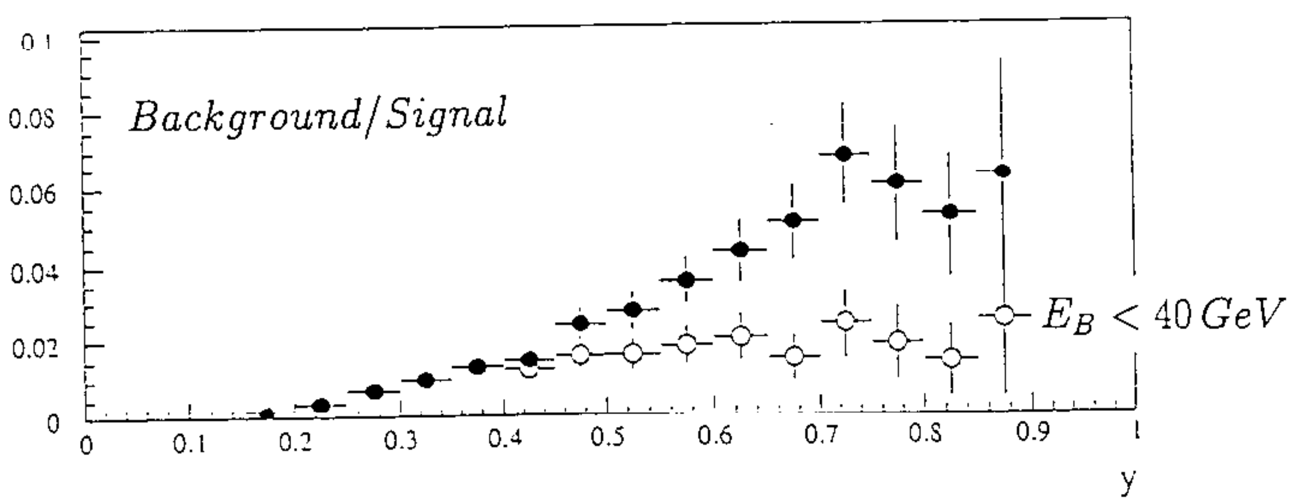
94/11/08 17.10 MU-E SCATTERING 1994 (preliminary)

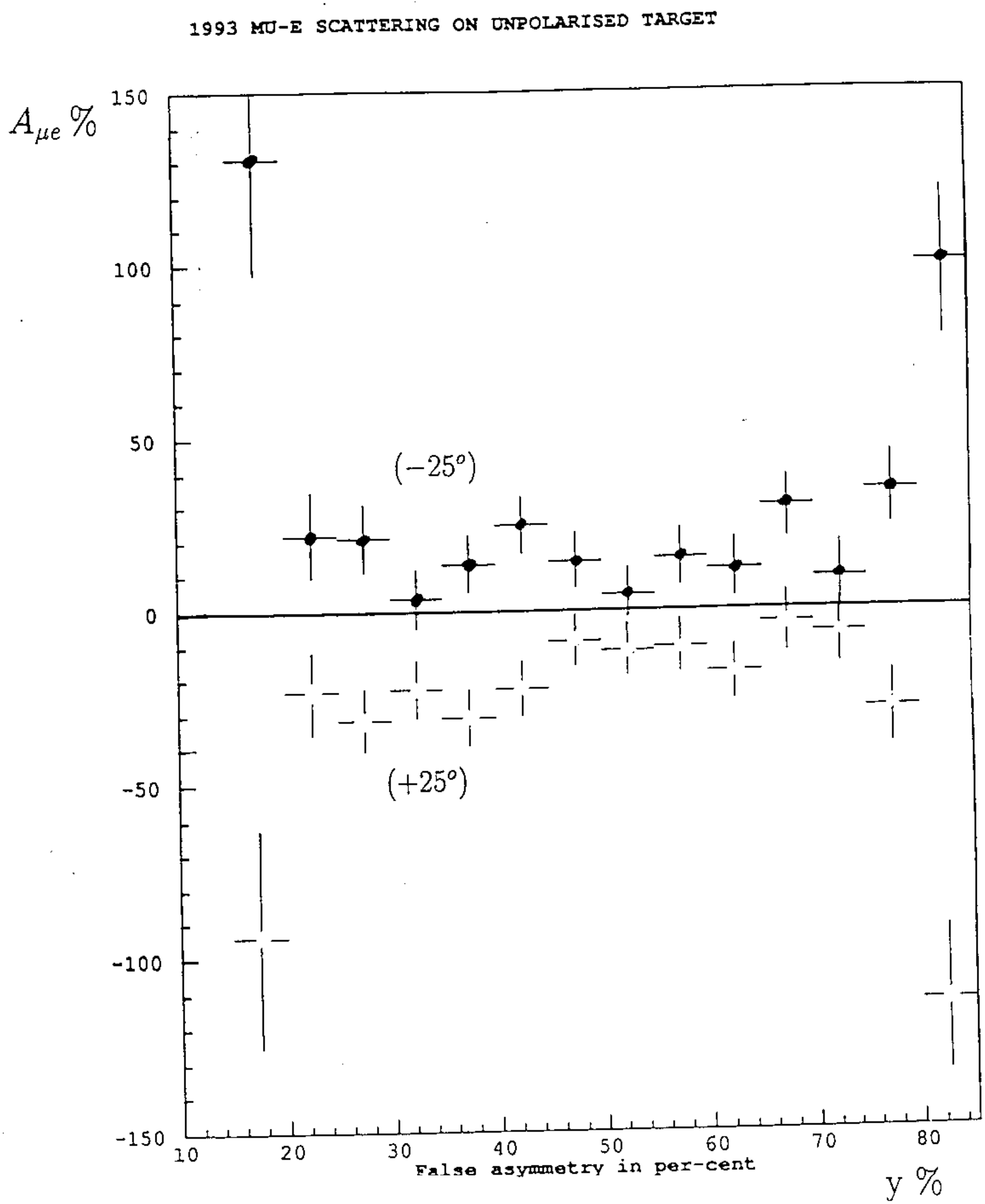






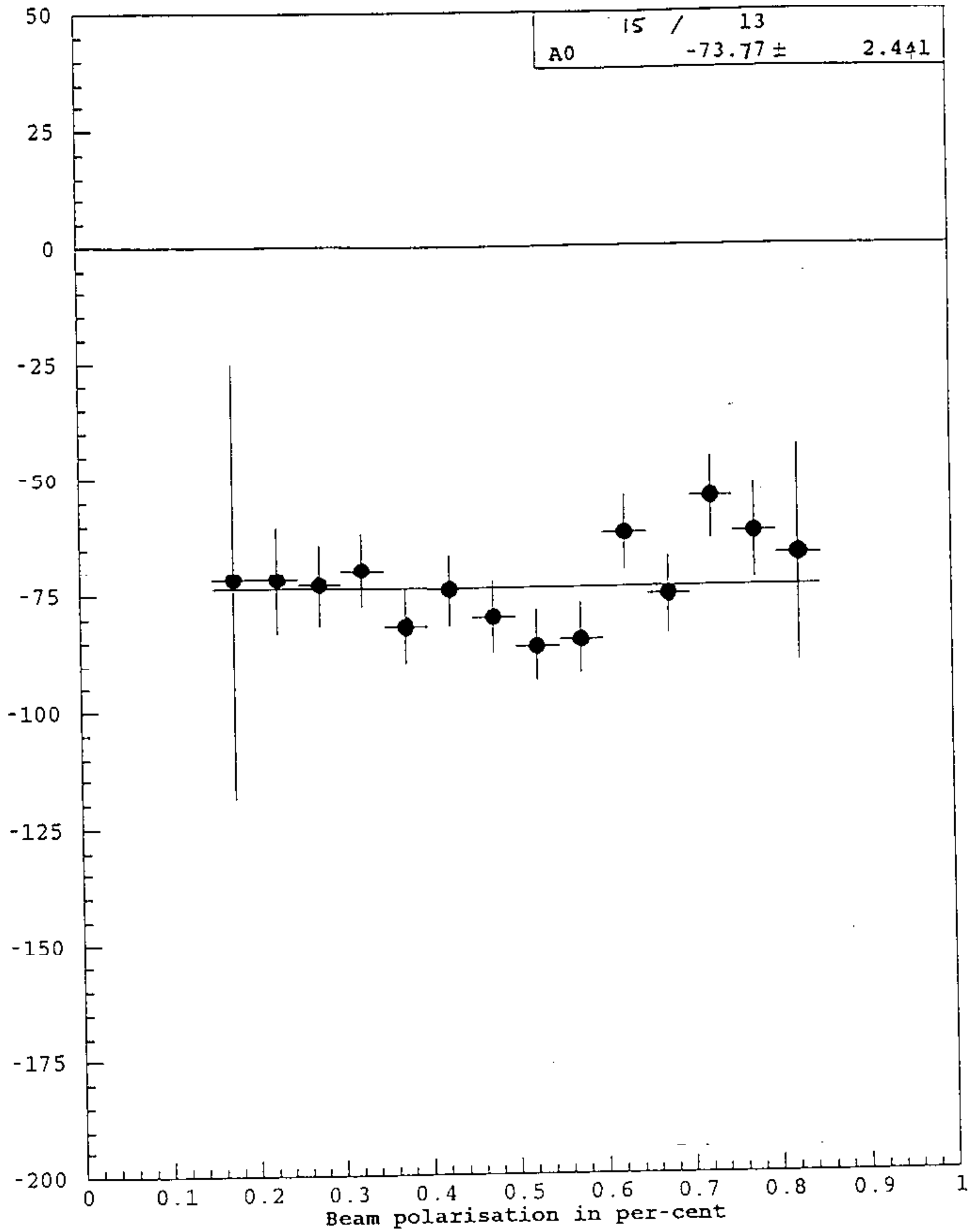
Energy balance: $E_B = E_\mu - E'_\mu - E'_e$





1993 MU-E SCATTERING ON UNPOLARISED TARGET
$A_{\mu e}$ %
150
100
50
0
-50
-100
-150
(−25°)
(+25°)
10
20
30
40
50
60
70
80
False asymmetry in per-cent
y %

MU-E SCATTERING 1993 190 GeV (all stat.)



RESULTS (Only part of the total statistic):

Simulation	-0.78	$\pm\, 0.05$	
μ decay (*published*)	-0.803	$\pm\, 0.029$	$\pm\, 0.020^{*}$
(*expected* $\rightarrow$		$\pm\, 0.009$)	
$\mu - e$ scattering	-0.774	$\pm\, 0.026$	$\pm\, 0.017$
(*expected* $\rightarrow$		$\pm\, 0.014$)	

SYSTEMATIC ERRORS FOR BOTH METHODS

	μ decay	$\mu - e$ scatt.
Normalisation (Stat.)	—	0.013
Target Polarization	—	0.009
Y_{MICHEL} Calibration	0.012	—
Monte-Carlo (Effic.)	0.012	—
Alignment	0.010	0.004
Radiative Corrections	0.010	0.002
Bremstrahlung	0.003	0.004
Cuts, fit Range,...	0.011	0.003
TOTAL	0.025	0.017

CONCLUSIONS

The (*SMC*) $\vec{\mu}$ beam Polarimetry:

- In μ decay Method:
  1. Large statistic (1 week of *good* data: $\rightarrow \pm 0.010$)
  2. Very sensitive to beam momentum calibration
  3. Difficulty to do an exact simulation
  4. Beam phase space study, time evolution ...

- In $\mu - e$ scattering Method:
  1. Smaller statistic (1 month of *good* data: $\rightarrow \pm 0.017$)
  2. Systematic errors under control
  3. Absolute beam polarization measurement

- Final Results expected before the end of this year