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dE/dx of Cosmic Muons in ECAL

Introduction

Analysis of the cosmic ray data taken in the ECAL petal 3 at RAL is described together with a Monte Carlo simulation used to understand the data . We show that the relativistic rise of dE/dx with P can be seen when it is looked for . However it is not strong enough to explain the rise of dE/dx with angle reported in the Saclay tests at the Royal Holloway meeting in January 88 .

1. dE/dx vs. Angle

Figure 1 shows the momentum spectrum of cosmic rays measured at 0 , 30 and 45 degrees to the vertical [refs 1 and 2]. The spectrum is harder at high angles so we expect the mean value of dE/dx to increase with angle due to the relativistic rise. We have generated events with these momentum distributions and calculated dE/dx for each event then found the mean value of dE/dx at each of the three angles. The results depend on where one puts the minimum momentum cut off Pmin . The maximum momentum Pmax has very little effect as long as it is fairly large , we used Pmax = 25 GeV/c .

Angle	< dE/dx > (relative to minimum ionising)			
	Pmin=0.4	Pmin=0.5	Pmin=1.0	Pmin=2.0
0	1.200+-.002	1.208	1.241	1.287
30	1.217	1.222	1.249	1.295
45	1.235	1.241	1.267	1.305

These results show that < dE/dx > rises by about 2.5 % between zero and 45 degrees . This is compared with the petal and barrel cosmic ray data in figure 2 . It can be seen that stacks 1 and 3 are in reasonable agreement with the Monte Carlo but stack 2 shows a significant decrease of dE/dx with angle. The Saclay curve shows a much stronger increase of dE/dx than is predicted by the Monte Carlo. In conclusion , we do not understand the reason for these variations of dE/dx with angle but we do not believe that they can be explained by the relativistic rise.

2. Use of multiple scattering

We have looked at the possibility that the amount of multiple scattering of a cosmic muon in the petal may be used as a rough measure of its momentum. We generated vertical muons and simulated their scattering (Fig. 3) including the correlation between Theta_A and Theta_S [Ref 4]. The error on Theta_A and Theta_S due to wire chamber resolution was also simulated. Only the measurements in the X-Z plane were used because those in the Y-Z plane were too inaccurate in the apparatus at RAL . A function was used [5] to calculate an estimated

momentum (Pest) from the amount of multiple scattering .
The mean of dE/dx in three bins of Pest is given in the table below and plotted in figure 5 . Figure 4 shows the momentum spectrum of each bin estimated by the Monte Carlo.

Momentum	dE/dx			
	Stack 1	Stack 2	Stack 3	Monte Carlo
Pest < 1.0 <P> = 1.9 GeV	80.4	183.0	94.3	1.116
1 < Pest < 3 <P> = 3.7 GeV	85.7	197.0	101.9	1.215
3 < Pest <P> = 5.3 GeV	89.1	205.0	107.2	1.271

This shows that we can see the rise of dE/dx with momentum in the RAL petal data , it is consistent with that predicted by the Monte Carlo .

References

[1] Wolfendale et al. Cosmic rays at ground level . ISBN 0 85498 025 3
[2] Crookes and Rastin . Nucl. Phys. B58 (1973) 93.
[3] Allison and Cobb . Oxford University preprint 13/80 .
[4] Rossi . High Energy Particles .
[5] The function used was;

Pest = 0.2059 / SQRT((S+A)**2 + 17.65 * (S-A)**2)
where S = sqrt(3) * Theta_S , A = Theta_A

This function is designed to optimise the correlation between P and Pest in the case when there is no error in measuring A and S.

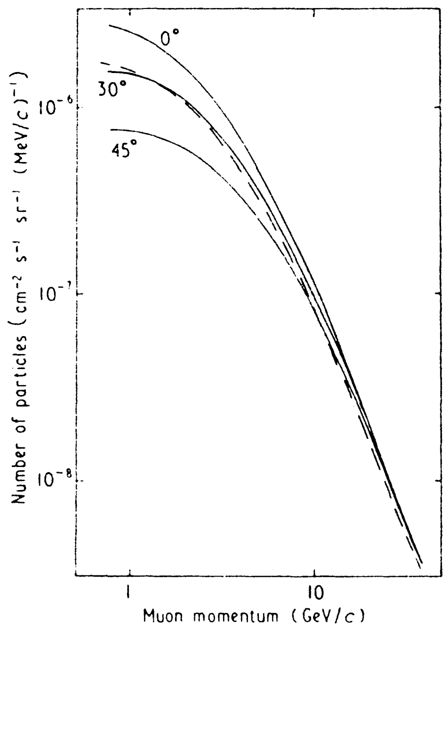
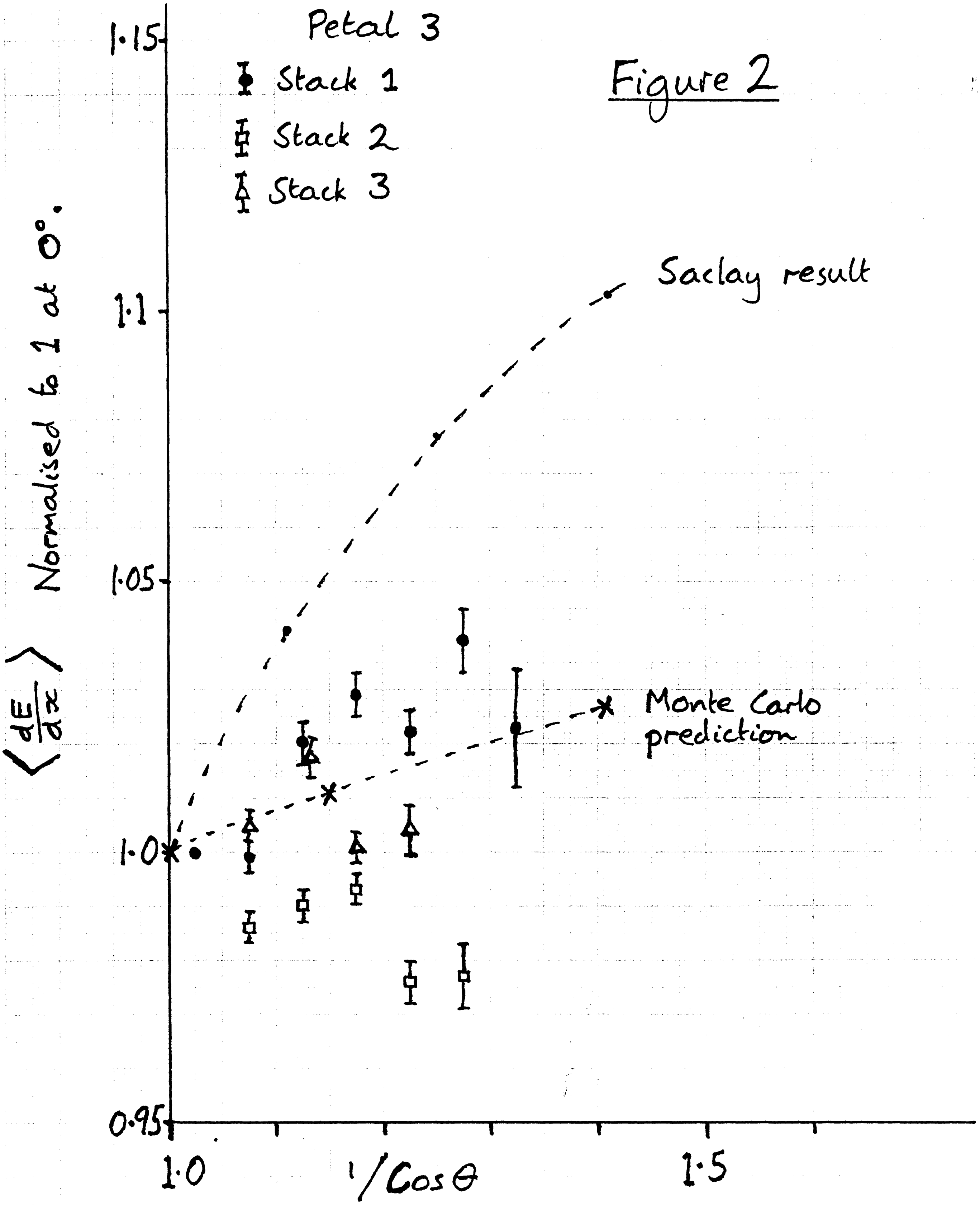


Figure 1

[redacted]. The best fit spectra of Coates and Nash (1962) at 0°, 30° and 45° to the zenith compared with the spectrum of Moroney and Parry (1954)—broken curve, at 30°.


Petal 3
Stack 1
Stack 2
Stack 3
Figure 2
Saclay result
Monte Carlo prediction
⟨dE/dx⟩ Normalised to 1 at 0°.
1·15
1·1
1·05
1·0
0·95
1·0
1/Cos θ
1·5

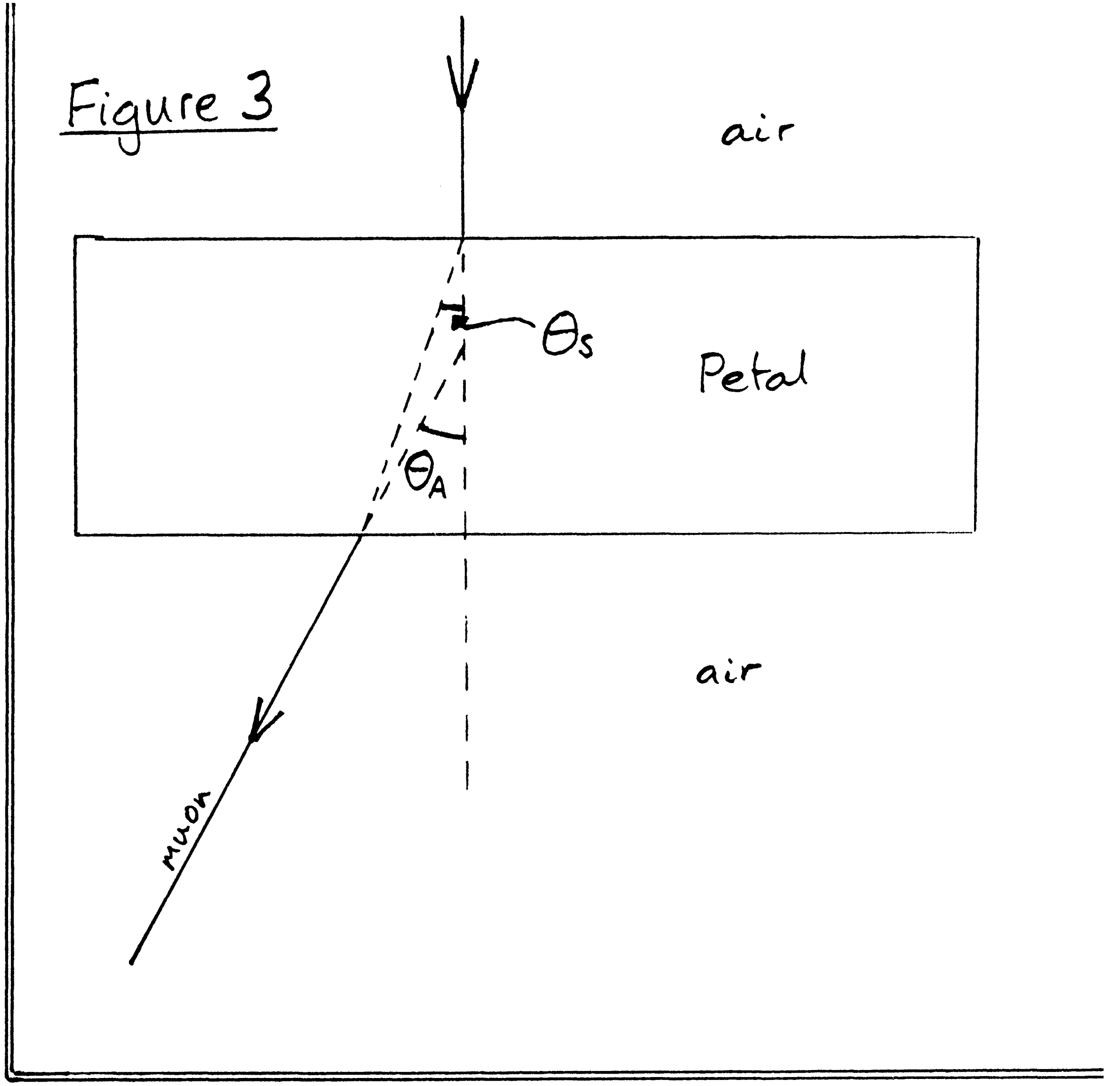


Figure 3

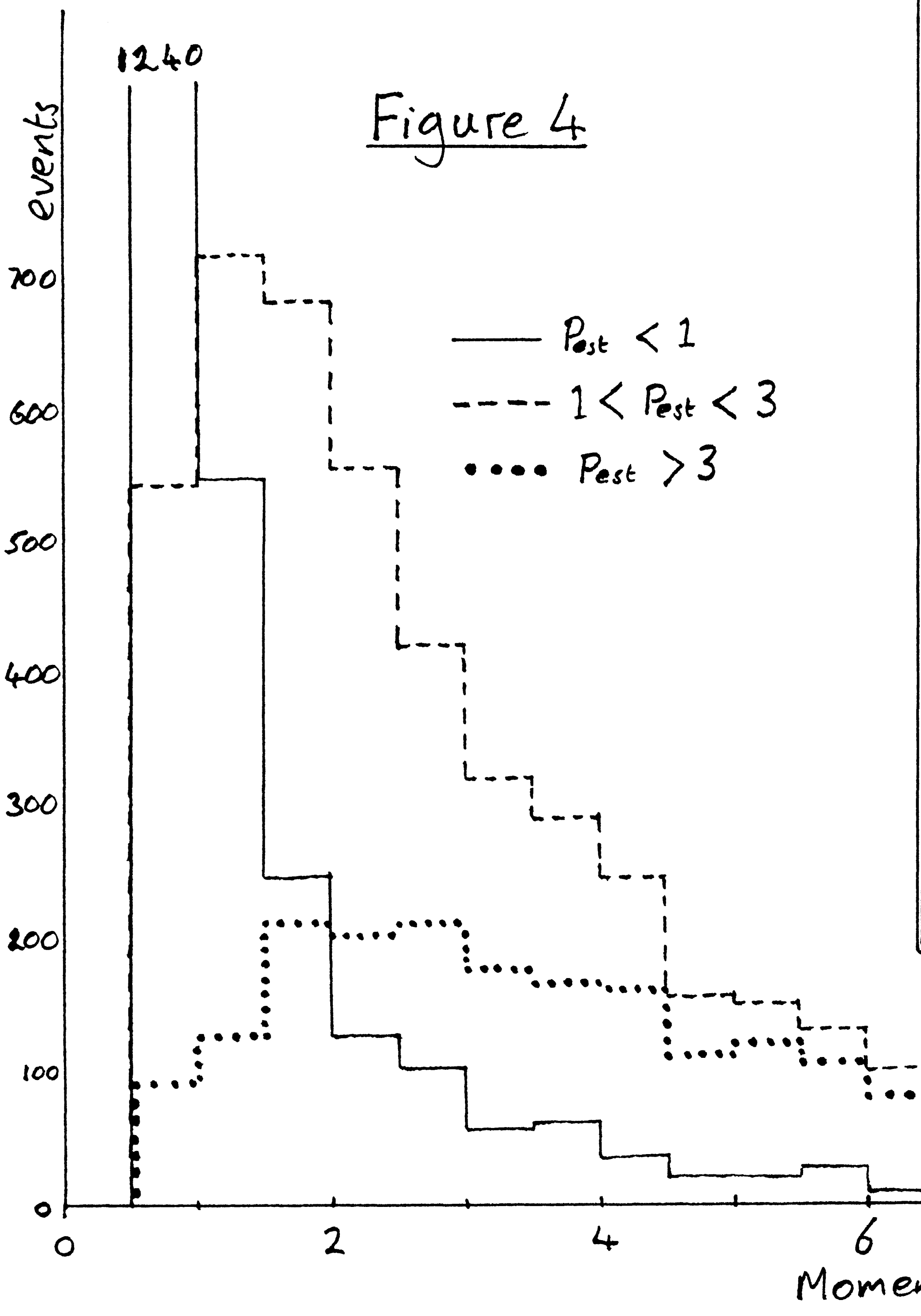


Figure 4

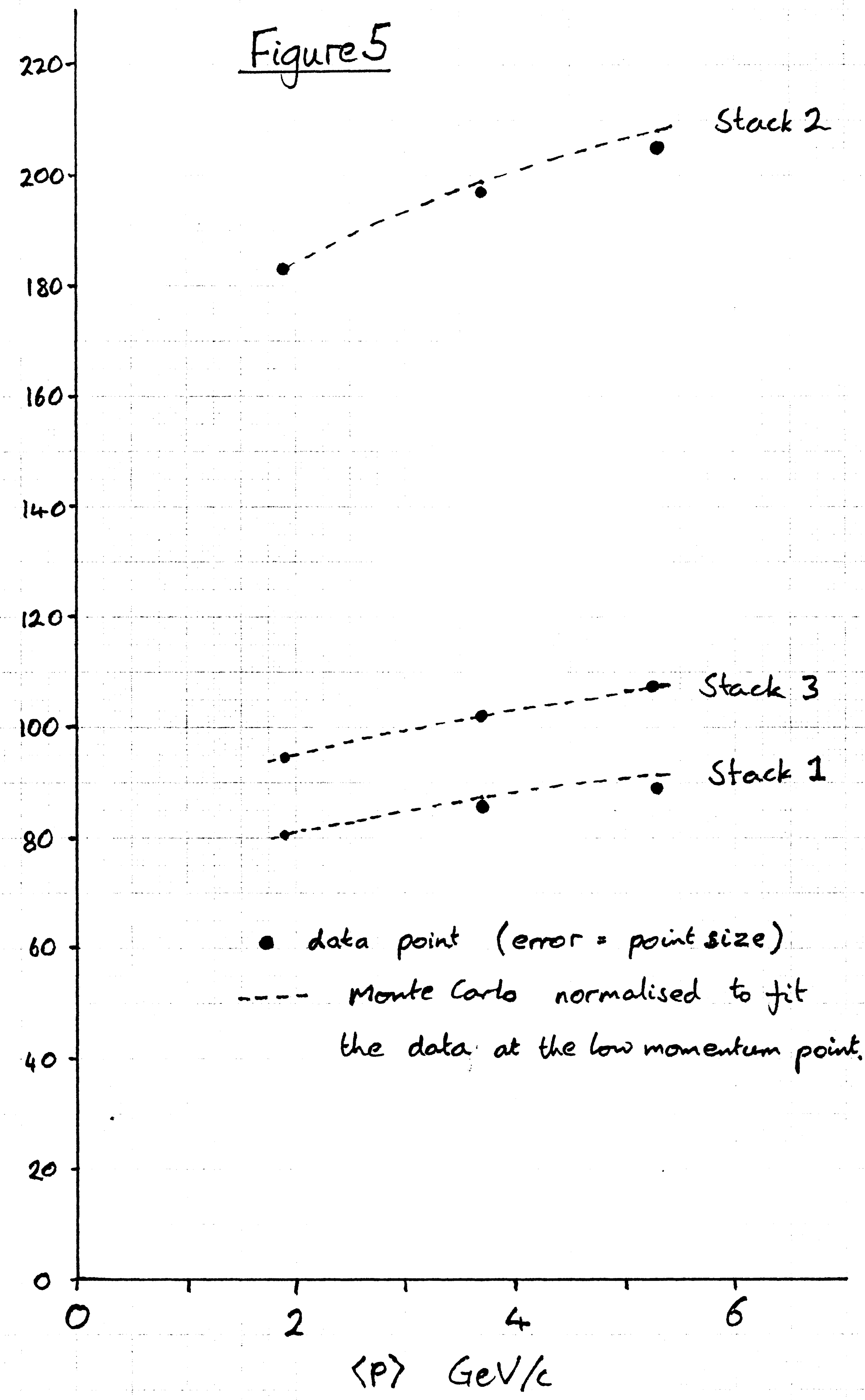


Figure 5
220
200
180
160
140
120
100
80
60
40
20
0
Stack 2
Stack 3
Stack 1
data point (error = point size)
Monte Carlo normalised to fit the data at the low momentum point.
0
2
4
6
⟨P⟩ GeV/c