Maximum Detectable Momentum in the MINOS FD

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Maximum Detectable Momentum in the MINOS FD

Definition of MDM

Why is it important?

How to measure MDM

How to calculate MDM

FD Values of MDM

Effect of Multiple Coulomb Scattering

Conclusions

(For more details, see MINOS Note 1511 ,   Feb 7, 2006)

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Definition

For a given track location and direction, the MDM is the momentum for which the measured curvature would be expected to be one standard deviation from zero.

This means that for actual track momentum larger than the MDM, neither the track momentum nor the sign of its charge can be measured with useful accuracy.

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Importance of MDM

Most cosmic muons have a momentum larger than the MDM,
Hence we should expect challenges in measuring their
charge ratio and their momentum spectrum.

Even for neutrino beam events, we wish to avoid hard
acceptance cuts, yet we need reliable momentum and
charge sign information.

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How to Measure the MDM

Turn off the magnetic field, then measure the (apparent) curvature of high energy muon tracks.

Not so easy to get zero field data in MINOS FD.
Partial alternative is to combine forward and reverse field curvature data.

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How to Calculate the MDM

The geometry of the scintillator strips determines (absolutely) the error in the sagitta. The MDM will be proportional to $B_{perp} * L^{2.5}$

The 2.0 comes from sagitta ~ L^2.
The 0.5 comes from the increased number of hits for long tracks.

A minor complication arises because many tracks traverse regions of both signs of field, and are thus S -shaped.

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Track enters detector at A and leaves at C.
The drawing is a projection perpendicular to z axis.
b is the impact parameter of the track.

θ_z is polar angle between track direction and z direction.

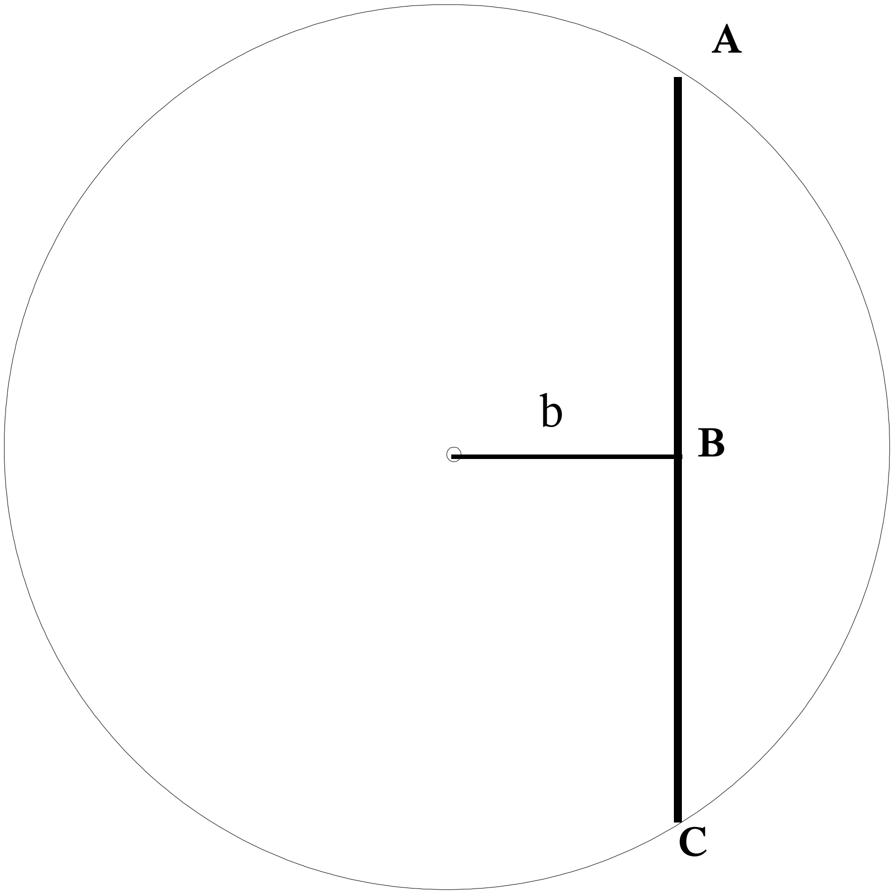

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Table 1 MDM and Length for side-to-side Tracks in MINOS FD

MDM in GeV/c

ϑ_z (degrees)=	Impact Parameter b (meters) 0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
10	471	470	469	468	467	466	465	464
20	471	469	465	460	455	451	447	246
30	471	467	458	447	391	298	197	92
40	344	333	304	262	213	159	103	47
50	235	226	203	171	135	98	62	28
60	232	223	197	162	124	87	52	22
70	231	221	193	156	115	77	44	17
80	270	257	223	177	128	82	43	15

Full Track Length in Meters

maxL=14.5 m=length of supermodule

ϑ_z (degrees)=	Impact Parameter b (meters) 0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
10	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
20	14.5	14.5	14.5	14.5	14.5	14.5	14.5	11.3
30	14.5	14.5	14.5	14.5	13.9	12.5	10.6	7.7
40	12.4	12.3	12.1	11.5	10.8	9.7	8.2	6.0
50	10.4	10.4	10.1	9.7	9.0	8.2	6.9	5.1
60	9.2	9.2	8.9	8.6	8.0	7.2	6.1	4.5
70	8.5	8.4	8.2	7.9	7.4	6.6	5.6	4.1
80	8.1	8.1	7.9	7.5	7.0	6.3	5.4	3.9

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Bperp/B

Impact Parameter b (meters)

ϑ_z (degrees)=	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
10	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99
20	1.00	1.00	0.99	0.98	0.97	0.96	0.95	0.94
30	1.00	0.99	0.97	0.95	0.93	0.91	0.89	0.88
40	1.00	0.99	0.96	0.91	0.87	0.84	0.81	0.79
50	1.00	0.98	0.94	0.88	0.82	0.76	0.71	0.67
60	1.00	0.98	0.92	0.84	0.76	0.68	0.61	0.55
70	1.00	0.97	0.90	0.81	0.70	0.60	0.51	0.42
80	1.00	0.97	0.89	0.79	0.67	0.55	0.43	0.31

The true B_{perp} falloff (and MDM falloff!) at large impact parameters is even more severe than shown, since these calculations assume B is constant versus radius.

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Multiple Coulomb Scattering

$$\theta_{MCS} / \theta_{Bend} = \frac{0.232}{[B_{PERP} * \sqrt{L}]}$$

B in Tesla, average along track
L in meters
Note that momentum does not appear.

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Table 3 - Multiple Coulomb Scattering – for half length tracks

$Theta_{proj}$(MCS)/Theta(bend)

Impact Parameter b (meters)

ϑ_z (degrees)=	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
10	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15
20	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.17
30	0.14	0.14	0.15	0.15	0.16	0.17	0.19	0.22
40	0.15	0.16	0.16	0.18	0.19	0.21	0.24	0.28
50	0.17	0.17	0.18	0.20	0.22	0.25	0.29	0.36
60	0.18	0.18	0.20	0.22	0.26	0.30	0.36	0.47
70	0.19	0.19	0.21	0.24	0.29	0.35	0.45	0.64
80	0.19	0.20	0.22	0.25	0.31	0.39	0.54	0.88

MCS Track Length in Meters

Impact Parameter b (meters)

ϑ_z (degrees)=	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
10	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
20	7.3	7.3	7.3	7.3	7.3	7.3	7.3	5.7
30	7.3	7.3	7.3	7.3	6.9	6.2	5.3	3.9
40	6.2	6.2	6.0	5.8	5.4	4.9	4.1	3.0
50	5.2	5.2	5.1	4.8	4.5	4.1	3.5	2.5
60	4.6	4.6	4.5	4.3	4.0	3.6	3.1	2.2
70	4.3	4.2	4.1	3.9	3.7	3.3	2.8	2.1
80	4.1	4.0	3.9	3.8	3.5	3.2	2.7	2.0

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Conclusions:

- Both MDM and MCS become very dicey at large impact parameter for tracks nearly perpendicular to z axis (e.g. cosmic muons).

- Tracks nearly horizontal behave well in both MDM and MCS.

- For full track length > 8 meters, MDM and MCS are favorable.

- Most cosmic muon tracks with p(true)>100 GeV will not be well-measured.