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SDC
SOLENOIDAL DETECTOR NOTES

ELECTROMAGNETIC BACKGROUND IN THE MUON BARREL CHAMBERS

February 24, 1992

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In this note we have estimated the electromagnetic background in the barrel muon chambers MUC2-MUC4 due to bremsstrahlung and e^+e^- pair production by high energy muons originated from the beam crossing point and passing through the muon system. This question is rather important for optimization of the muon chamber design and for solving the problem of pattern recognition in muon system and developing the code of the muon track finding program.

For calculation of such a background the program SDC-GEANT has been used with updated apparatus geometry in it, according to the parameters from 12/11/1991. In our notation the muon chamber MUC2 (or BW1) is located just before the muon toriod and after the toroid are muon chambers MUC3 (BW2) and MUC4 (BW3). Before entering the MUC2 muon is travelling through the solenoid coils and calorimeter (about 2 m of Fe/Pb/Sc). Then to reach MUC3 chamber muon must go through the muon toroid (1.5 m of steel). The layer structure of the muon chambers has been implemented with aluminum walls (1mm thickness) and the following wire configuration in barrel chamber layers : MUC2 (4θ,4ϕ), MUC3 (4θ) and MUC4 (4θ,4ϕ,2 stereo). All muons have been generated in the ϕ range 0-360 degrees, θ range 40-140 degrees and with the four different momentum : 50,100,250 and 500 GeV/c. The samples generated contain from 5K to 10K single muons crossing the muon chambers. The energy cut for the electrons and gammas in GEANT (CUTGAM,CUTELE) has been equal to 2 MeV.

To analyze the effects of the multiple hits, produced by electrons and positrons associated with incoming muon, we define the following variables : $P_b(N)$,$P_{bz}(N)$, $R_b(N)$,$R_{bz}(N)$,$N_b(N)$ and $N_{bz}(N)$, where

- $P_b(N)$ is the probability to have extra hits (in addition to the muon one) in N layers of the given muon chamber simultaneously if in this chamber there are extra hits from the muon;

- $P_{bz}(N)$ is the same as $P_b(N)$, but only for extra hits, which suppose to be in the same sell with the muon hit (the sell size is 8 cm);

- $R_b(N)$ is the ratio of the number of muons with at least one extra hit in given layer N to the total number of muons;

- $R_{bz}(N)$ is the same as $R_b(N)$, but here we consider only extra hits in the sell where there is a muon hit also;

- $N_b(N)$ is the ratio of the number of extra hits in given layer N to the number of muons, which produce at least one extra hit in the same layer;

- $N_{bz}(N)$ is the same as $N_b(N)$, but here we count only extra hits in the same sell with the muon one.

RESULTS

In Fig.1a-4a the values of $P_b(N)$ are shown for different muon chambers and different muon momenta. The corresponding values of $P_{bz}(N)$ are shown in Fig.1b-4b. One can see, that the effect to have all layers in given chamber with extra hits is rather large and it is growing with the muon energy. On the other hand if we consider only extra hits in the muon sell (P_{bz}), this effect will be important for MUC3 only (about 32% for 50 Gev and 47% for 500 GeV). The values of $R_b(N)$ and $R_{bz}(N)$ are presented in Fig.1c-4c. Inside any given chamber there is no layer dependence seen and the average values of R_b and R_{bz} for all three muon chambers as a function of muon energy are shown in Fig.5a and Fig.5b (and in Table 1,2), respectively.

Table 1 : R_b (%) versus muon energy (GeV)

chamber	50	100	250	500
MUC2	13.4±0.4	15.9±0.5	20.0±0.8	25.4±1.0
MUC3	14.0±0.4	16.1±0.5	21.2±0.8	26.3±1.0
MUC4	14.0±0.4	15.7±0.5	20.0±0.8	24.1±1.0

Table 2 : R_{bz} (%) versus muon energy (GeV)

chamber	50	100	250	500
MUC2	4.3±0.3	5.1±0.3	7.4±0.6	8.9±0.5
MUC3	6.8±0.4	8.0±0.3	11.5±0.6	15.1±0.5
MUC4	5.1±0.3	5.4±0.3	7.6±0.6	10.1±0.7

The average numbers of extra hits $N_b(N)$ and $N_{bz}(N)$ are presented in Fig.1d-4d. And again inside any given chamber there is significant layer dependence and values of R_b and R_{bz} for all three muon chambers as a function of muon energy are shown in Fig.6a and Fig.6b (and in Table 3,4 also).

Table 3 : N_b versus muon energy (GeV)

chamber	50	100	250	500
MUC2	1.93±0.06	2.24±0.07	3.41±0.15	4.17±0.17
MUC3	2.11±0.10	2.22±0.07	3.55±0.14	4.97±0.20
MUC4	1.62±0.05	1.73±0.05	2.71±0.11	3.66±0.15

Table 4 : N_{br} versus muon energy (GeV)

chamber	50	100	250	500
MUC2	1.23±0.08	1.47±0.10	1.78±0.16	2.18±0.15
MUC3	1.63±0.08	1.65±0.08	2.54±0.13	3.50±0.18
MUC4	1.18±0.10	1.24±0.09	1.91±0.16	2.56±0.18

The average electron(positron) momentum as a function of the muon energy is shown in Fig.7 and it is of the order of 40-50 MeV/c. The average angle between electron(positron) and muon as a function of the muon energy is shown in Fig.8 and it is of the order of 0.35 radians.

The all presented here results were based on the wall thickness of 1 mm and GEANT parameters CUTELE,CUTGAM equal to 2 MeV. Now the design of the barrel muon chambers is known (University of Washington/SSC) and their tubes have a wall thickness of 1.6 mm of Al. Therefore we made another calculations of the electromagnetic background for the muon energy 100 GeV to see how the wall thickness effects on the results. Also in these calculations the cut-off parameters CUTGAM,CUTELE in GEANT were reduced to the value 0.9 MeV, since the range of electrons with 0.9 MeV in aluminum is less then 1.6 mm and such a cut is quite compartible with the new wall thickness. The old and new results are compared in Fig.9 and Fig 10. One can see that $R_b(N)$ and $N_b(N)$ from new calculations are slightly larger, then old ones. But the difference is not very big and it is of the order of 10-20%.

Figure 1a

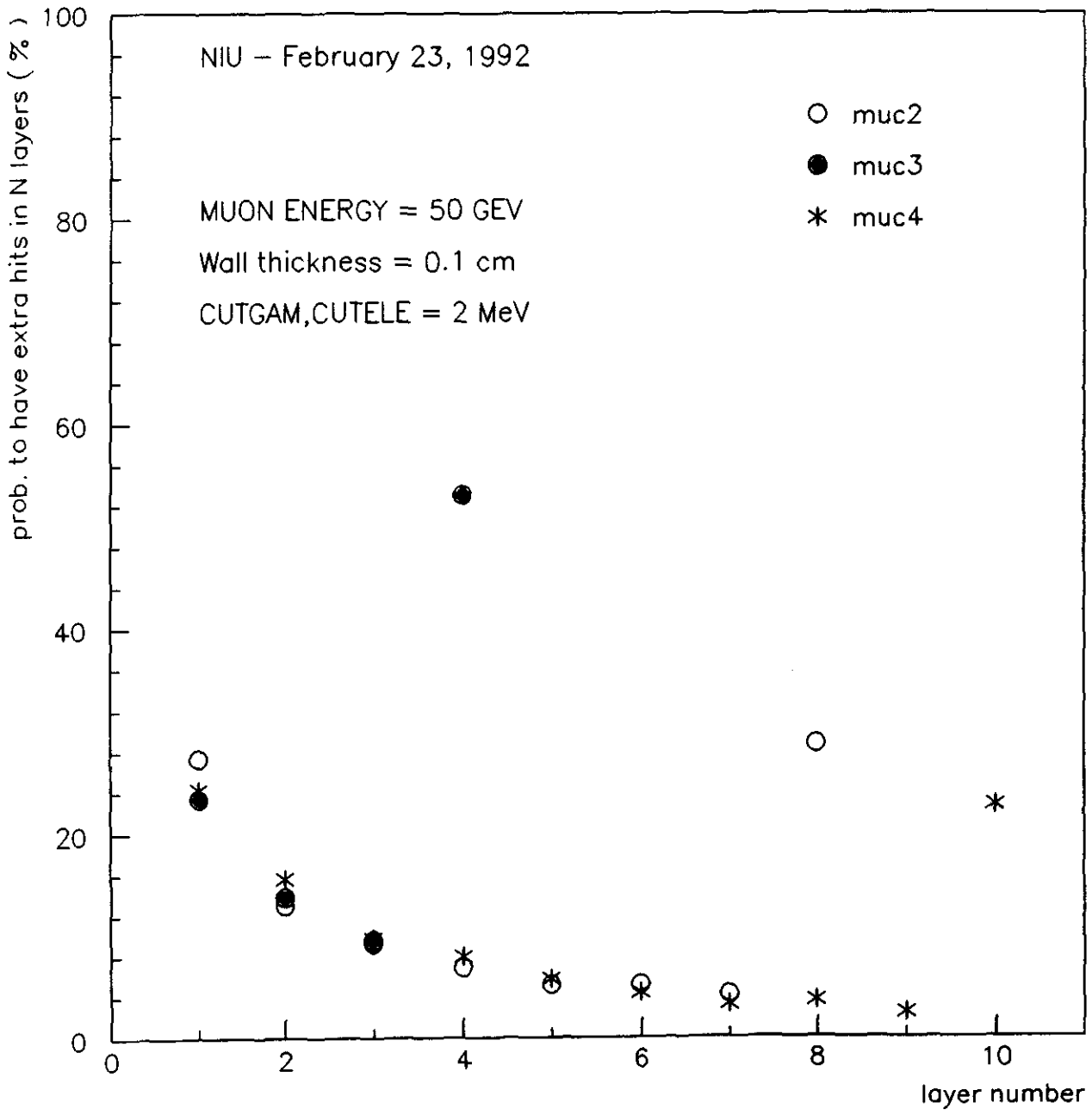

NIU – February 23, 1992
MUON ENERGY = 50 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
muc2
muc3
muc4
prob. to have extra hits in N layers (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 1b

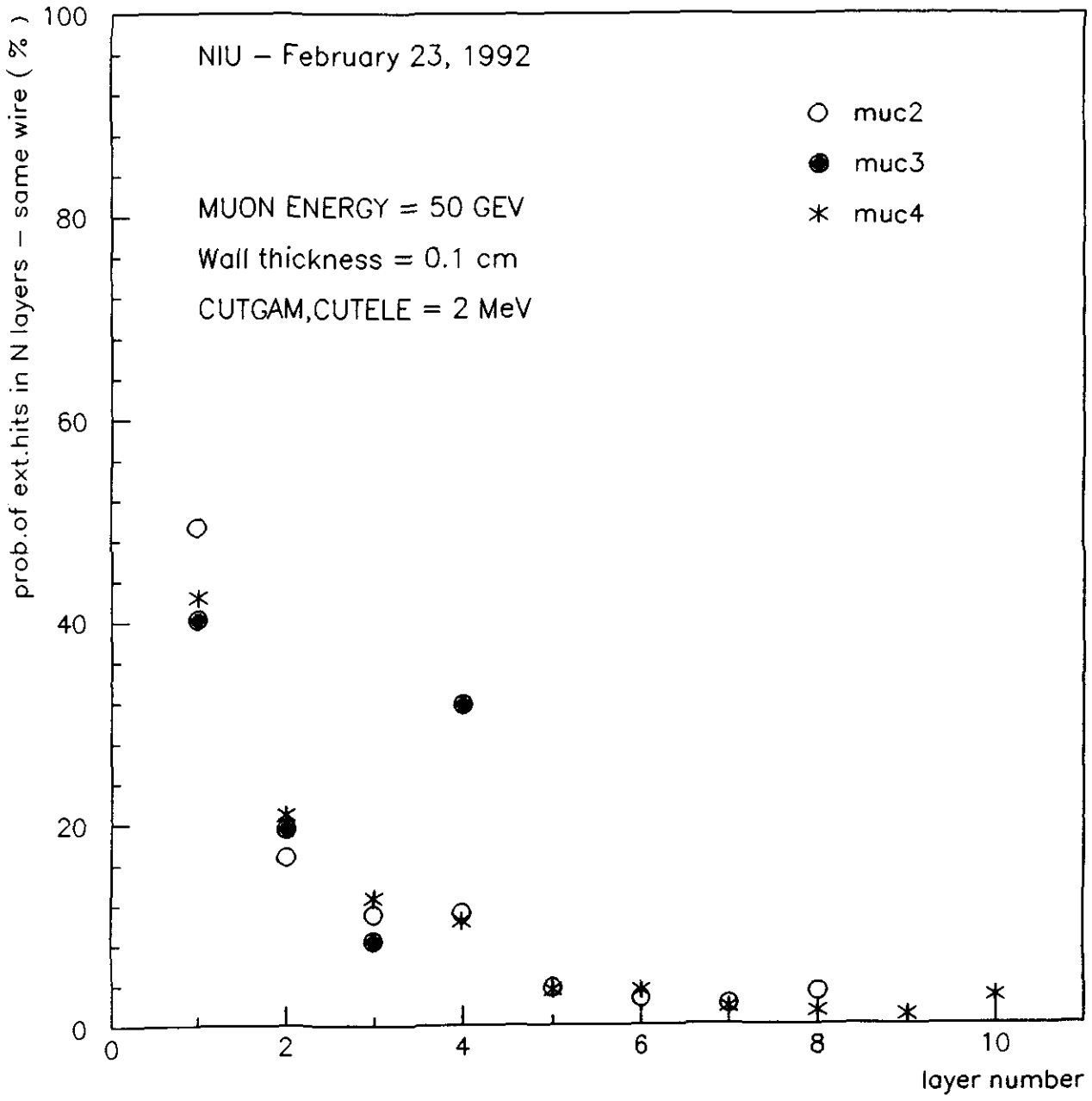

NIU – February 23, 1992
muc2
muc3
muc4
MUON ENERGY = 50 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
prob.of ext.hits in N layers – same wire (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 1c

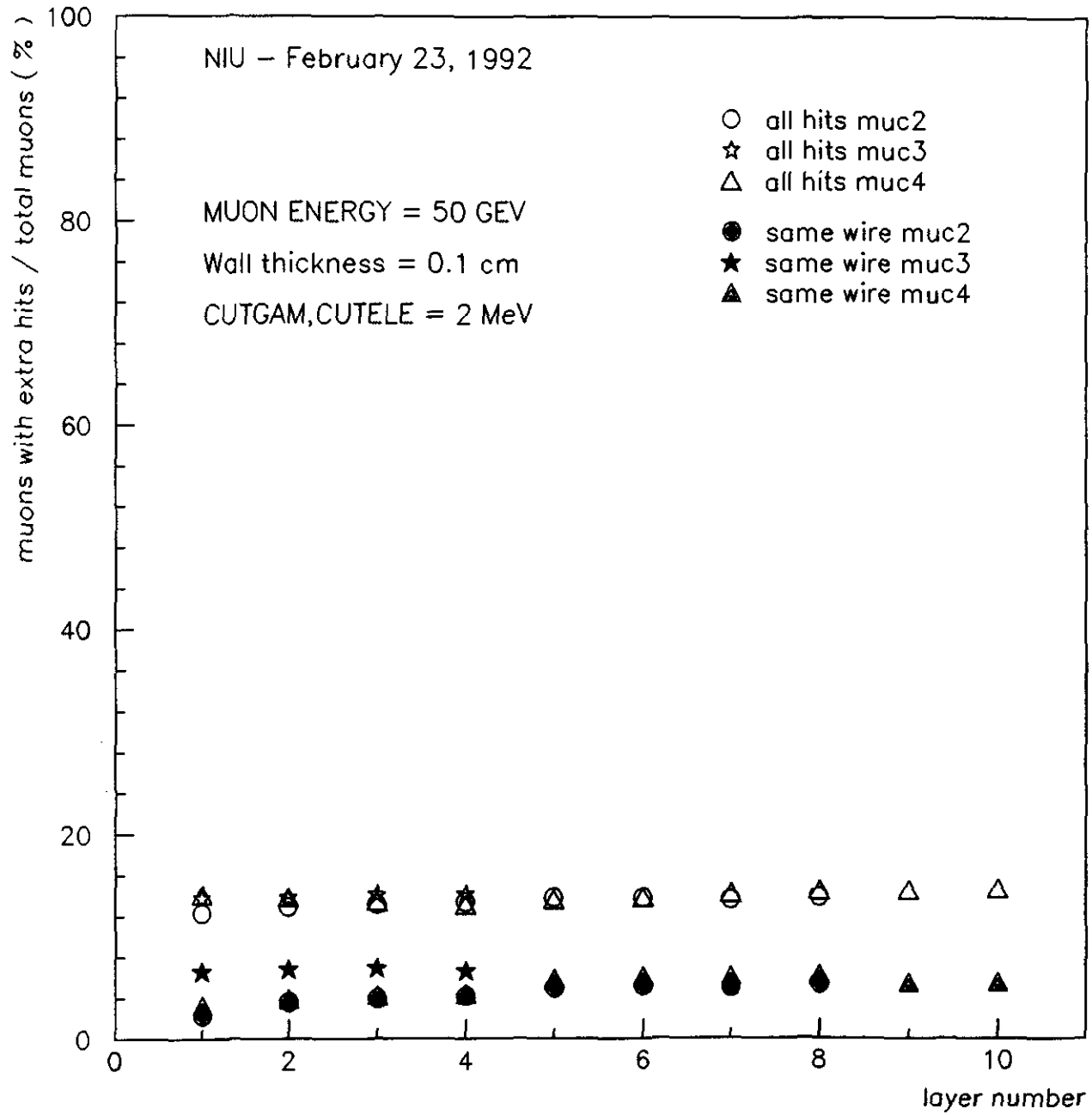

NIU – February 23, 1992
MUON ENERGY = 50 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
all hits muc2
all hits muc3
all hits muc4
same wire muc2
same wire muc3
same wire muc4
muons with extra hits / total muons (%)
layer number
0
20
40
60
80
100
0
2
4
6
8
10

Figure 1d

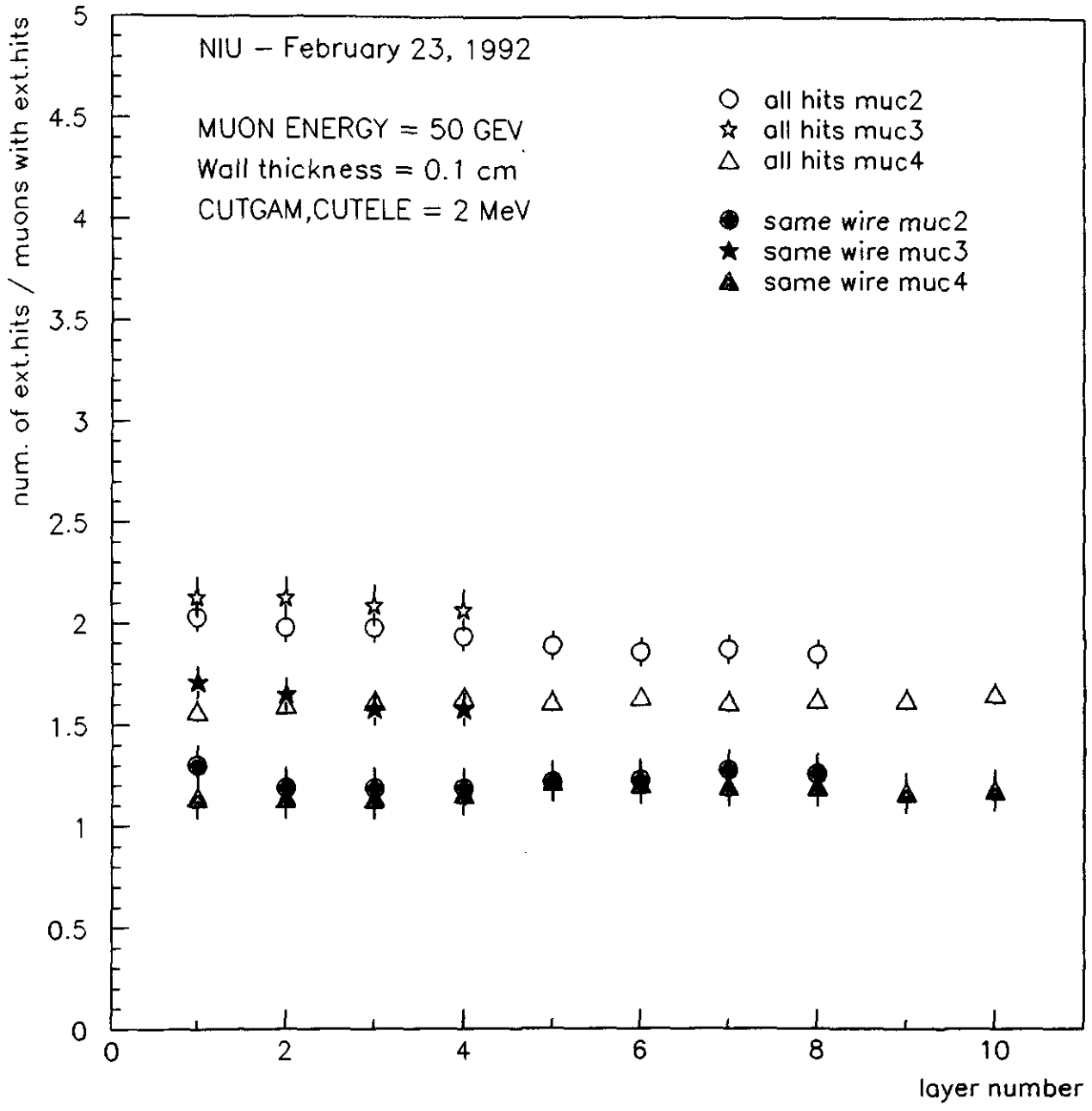

NIU – February 23, 1992
MUON ENERGY = 50 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
all hits muc2
all hits muc3
all hits muc4
same wire muc2
same wire muc3
same wire muc4
num. of ext.hits / muons with ext.hits
layer number
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
2
4
6
8
10

Figure 2a

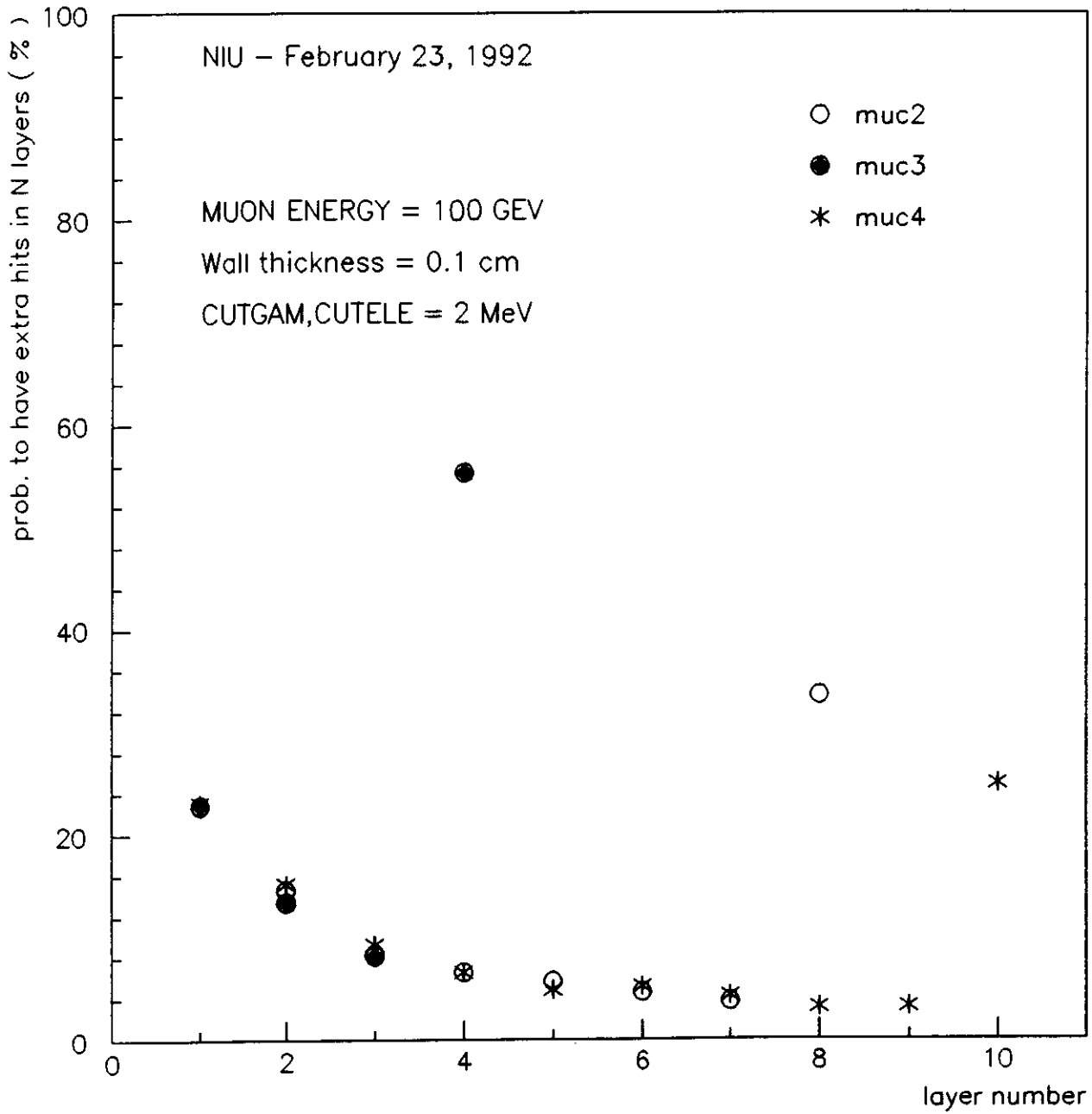

NIU – February 23, 1992
MUON ENERGY = 100 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
muc2
muc3
muc4
prob. to have extra hits in N layers (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 2b

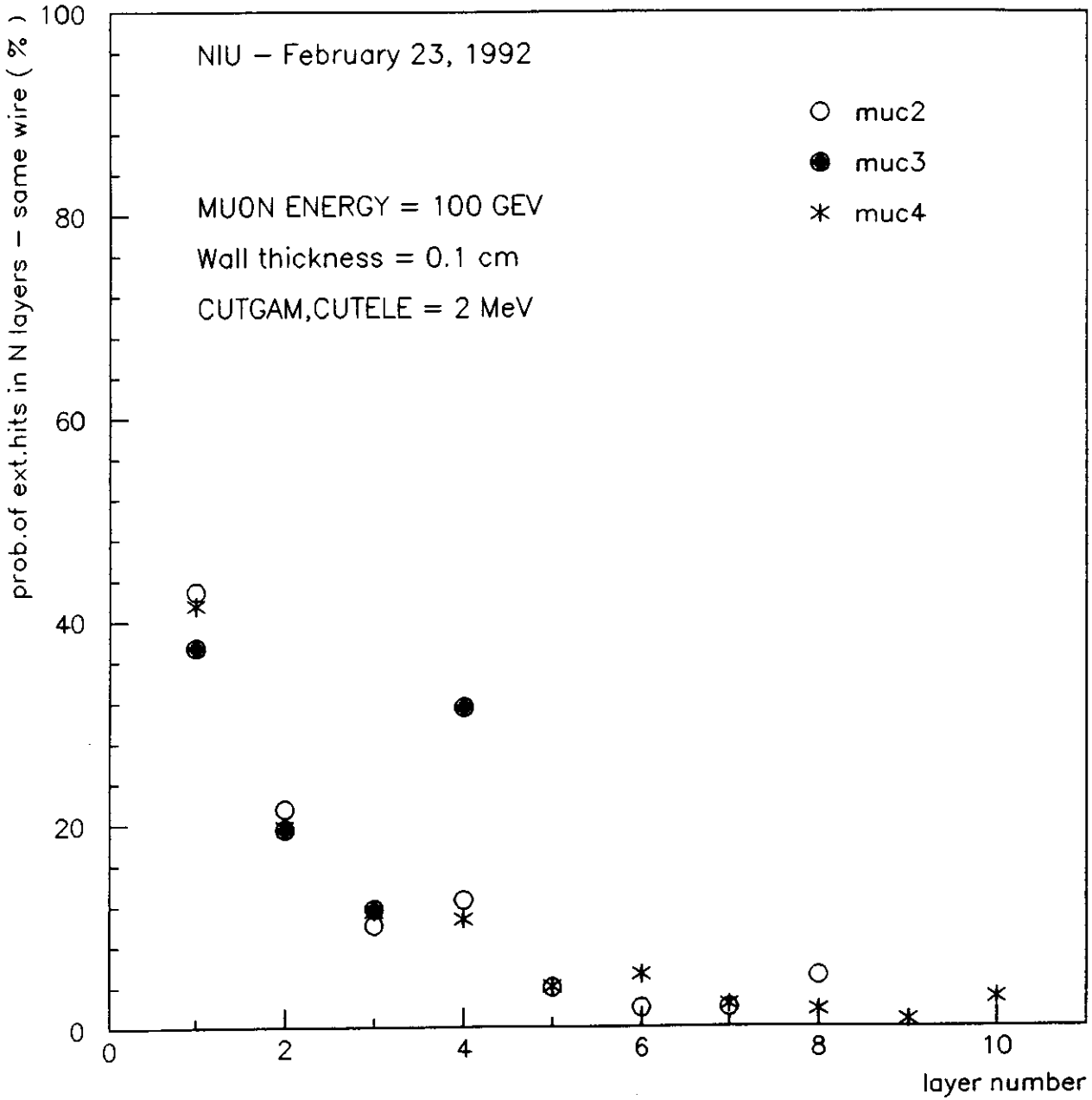

NIU – February 23, 1992
muc2
muc3
muc4
MUON ENERGY = 100 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
prob.of ext.hits in N layers – same wire (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 2c

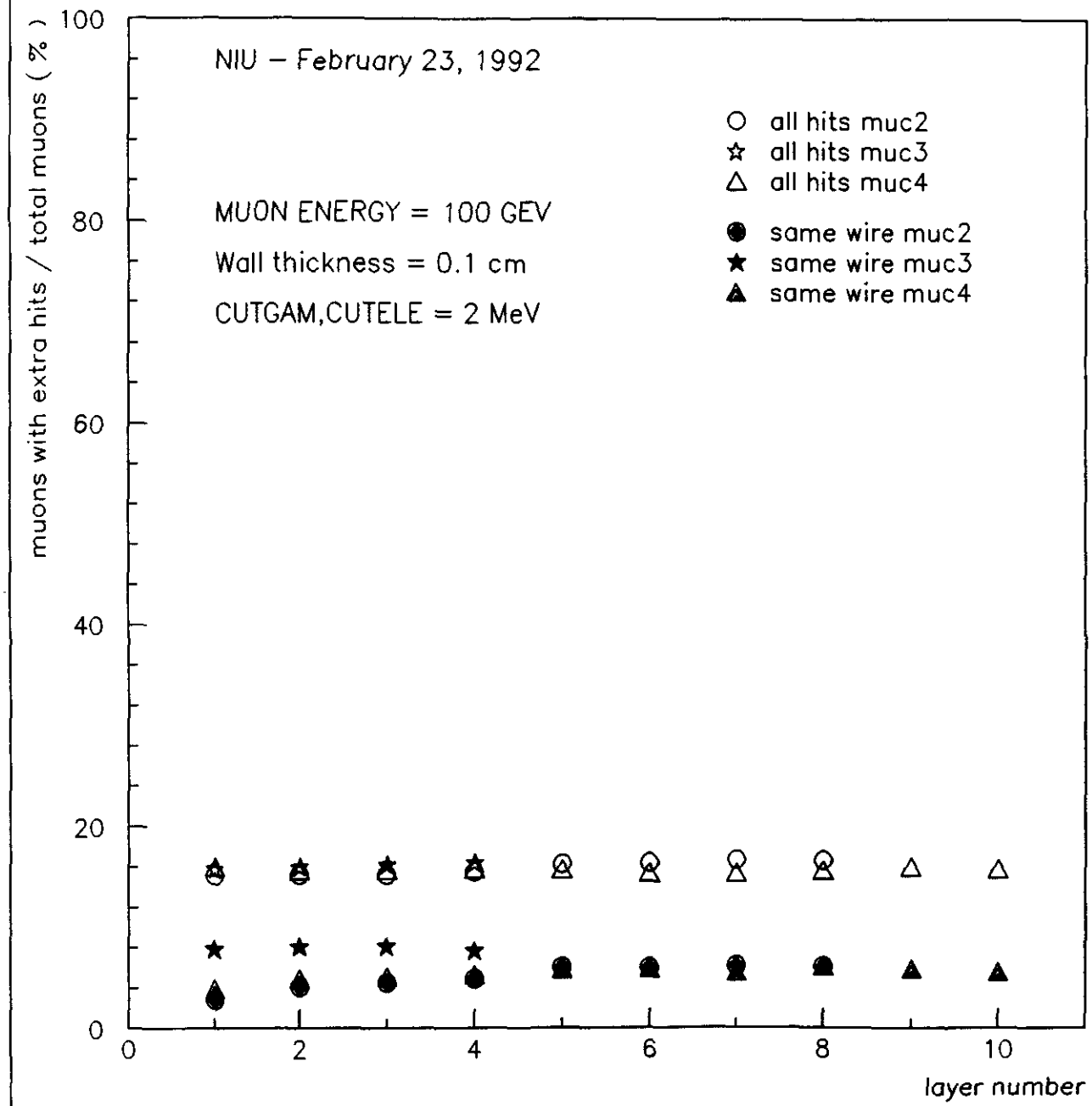

NIU – February 23, 1992
MUON ENERGY = 100 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
all hits muc2
all hits muc3
all hits muc4
same wire muc2
same wire muc3
same wire muc4
muons with extra hits / total muons (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 2d

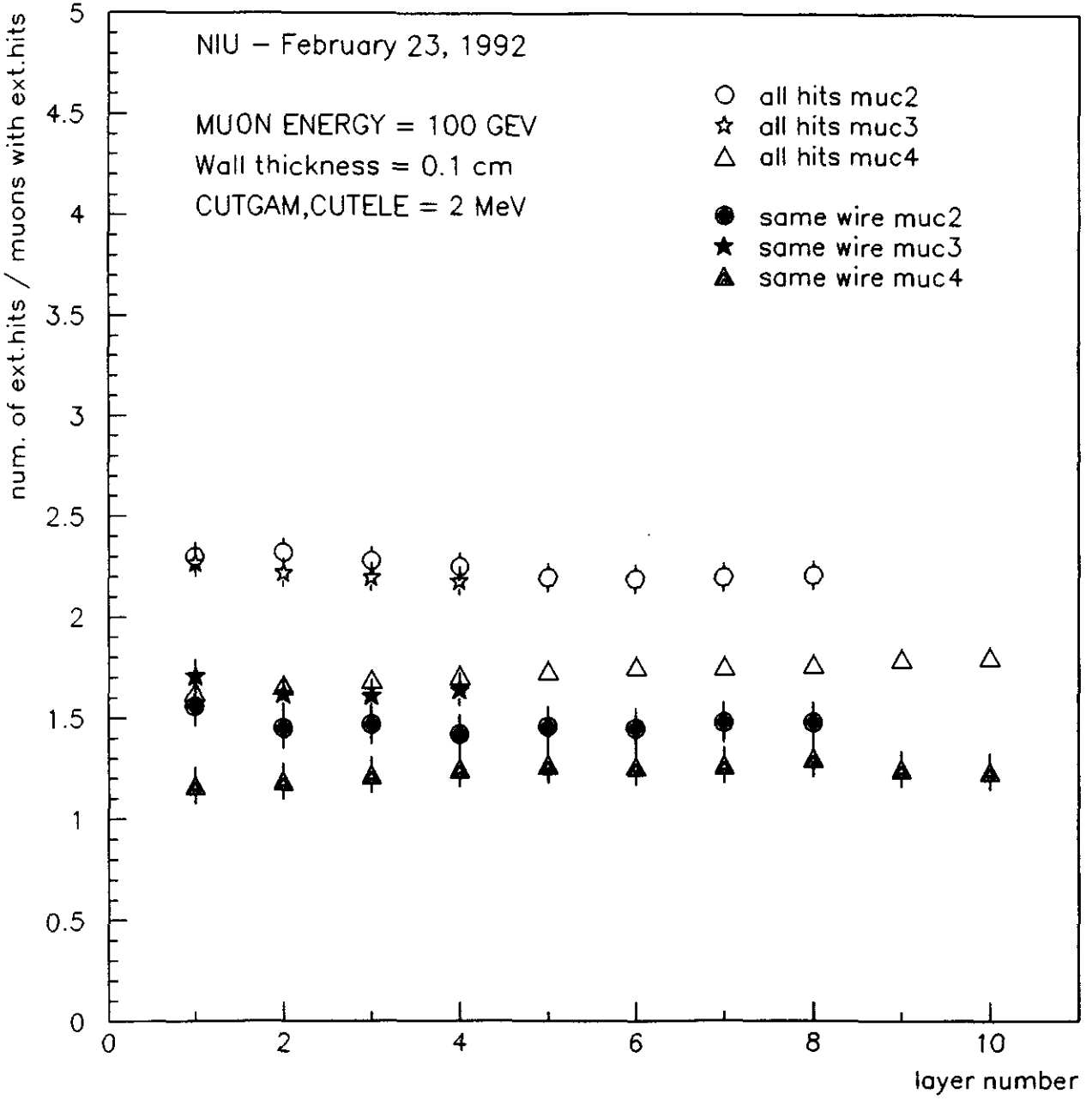

NIU – February 23, 1992
MUON ENERGY = 100 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
all hits muc2
all hits muc3
all hits muc4
same wire muc2
same wire muc3
same wire muc4
num. of ext.hits / muons with ext.hits
layer number
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
2
4
6
8
10

Figure 3a

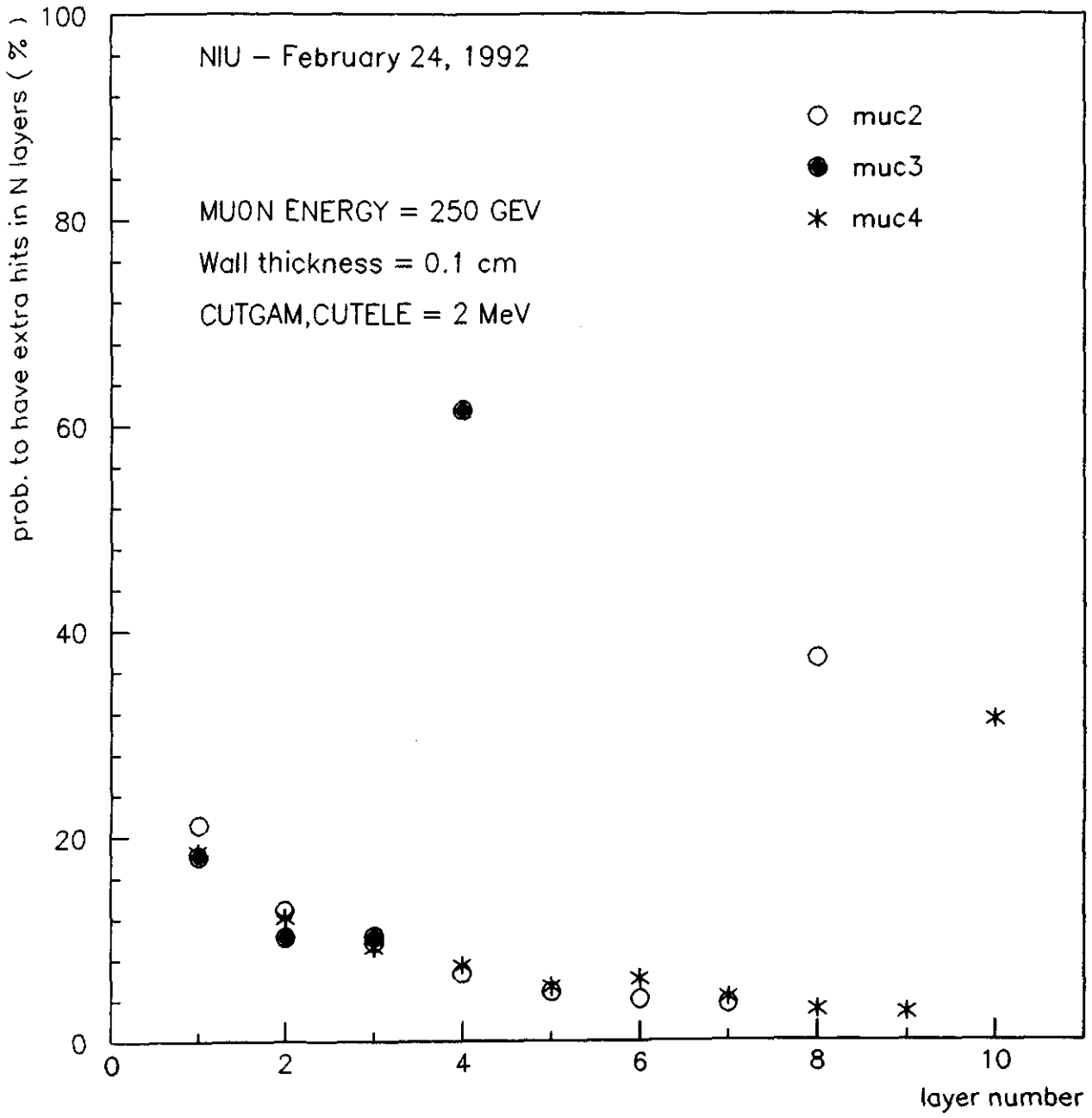

NIU – February 24, 1992
muc2
muc3
muc4
MUON ENERGY = 250 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
prob. to have extra hits in N layers (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 3b

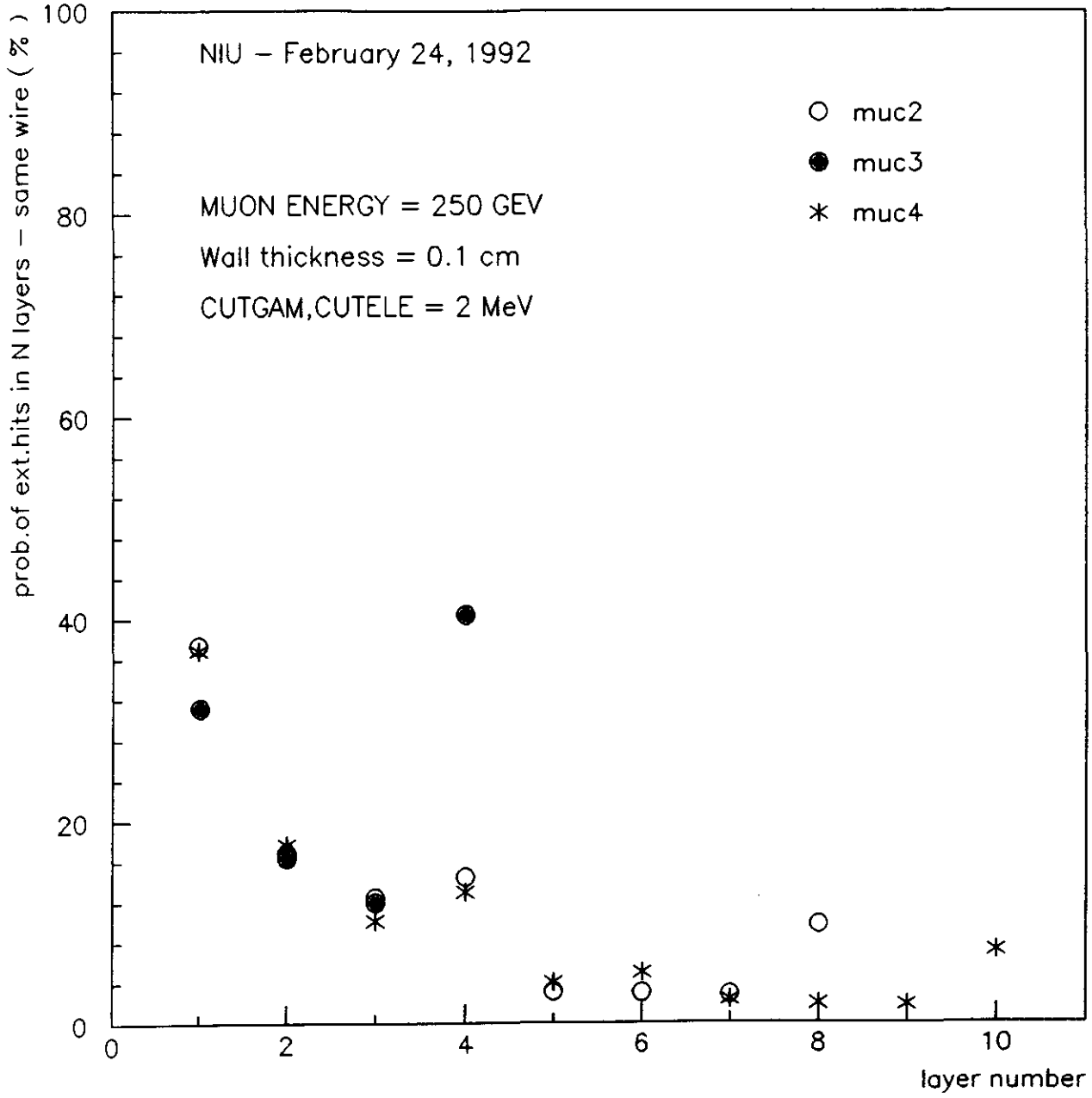

NIU – February 24, 1992
muc2
muc3
muc4
MUON ENERGY = 250 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
prob.of ext.hits in N layers – same wire (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 3c

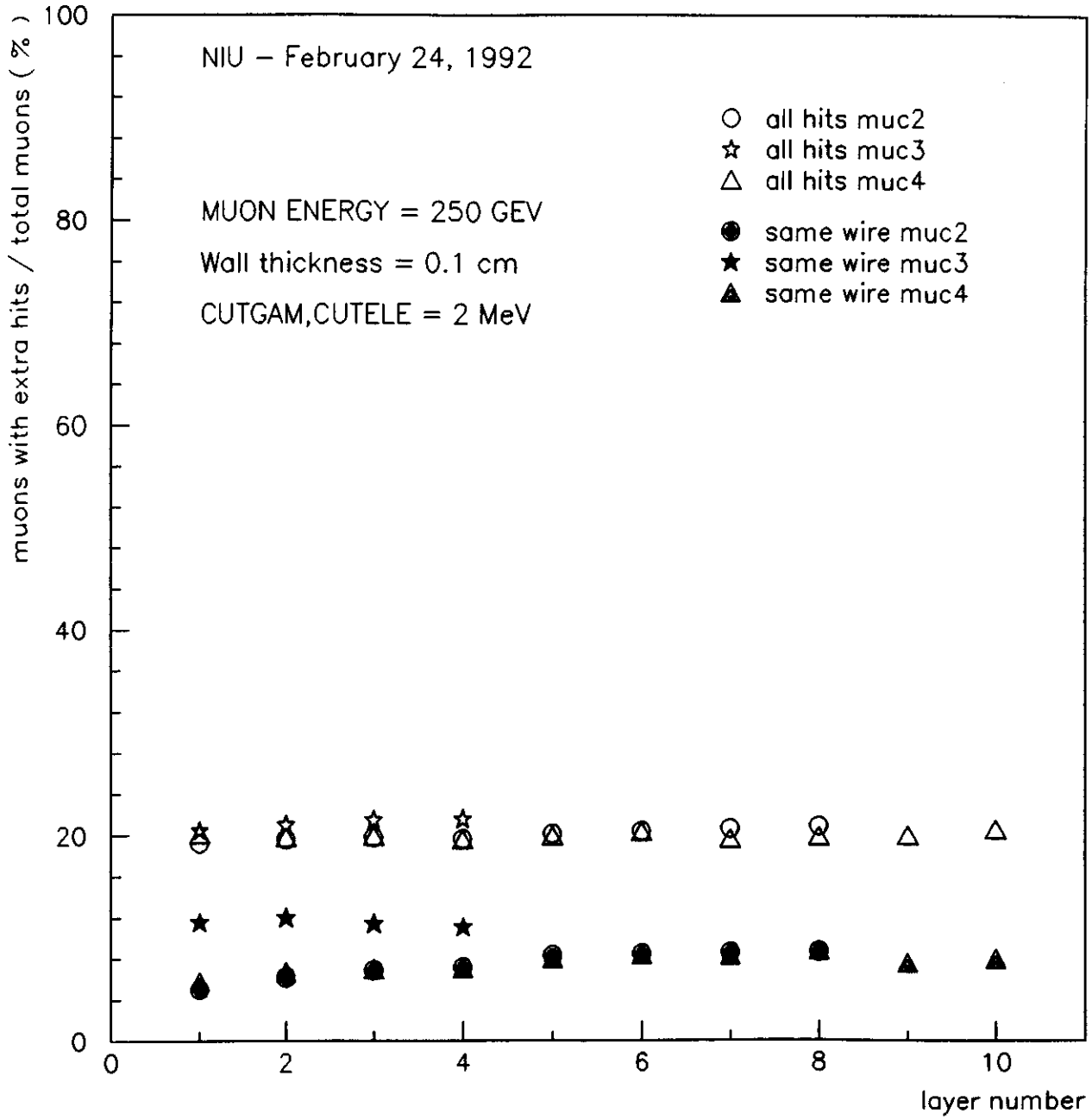

NIU – February 24, 1992
MUON ENERGY = 250 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
all hits muc2
all hits muc3
all hits muc4
same wire muc2
same wire muc3
same wire muc4
muons with extra hits / total muons (%)
layer number
0
20
40
60
80
100
0
2
4
6
8
10

Figure 3d

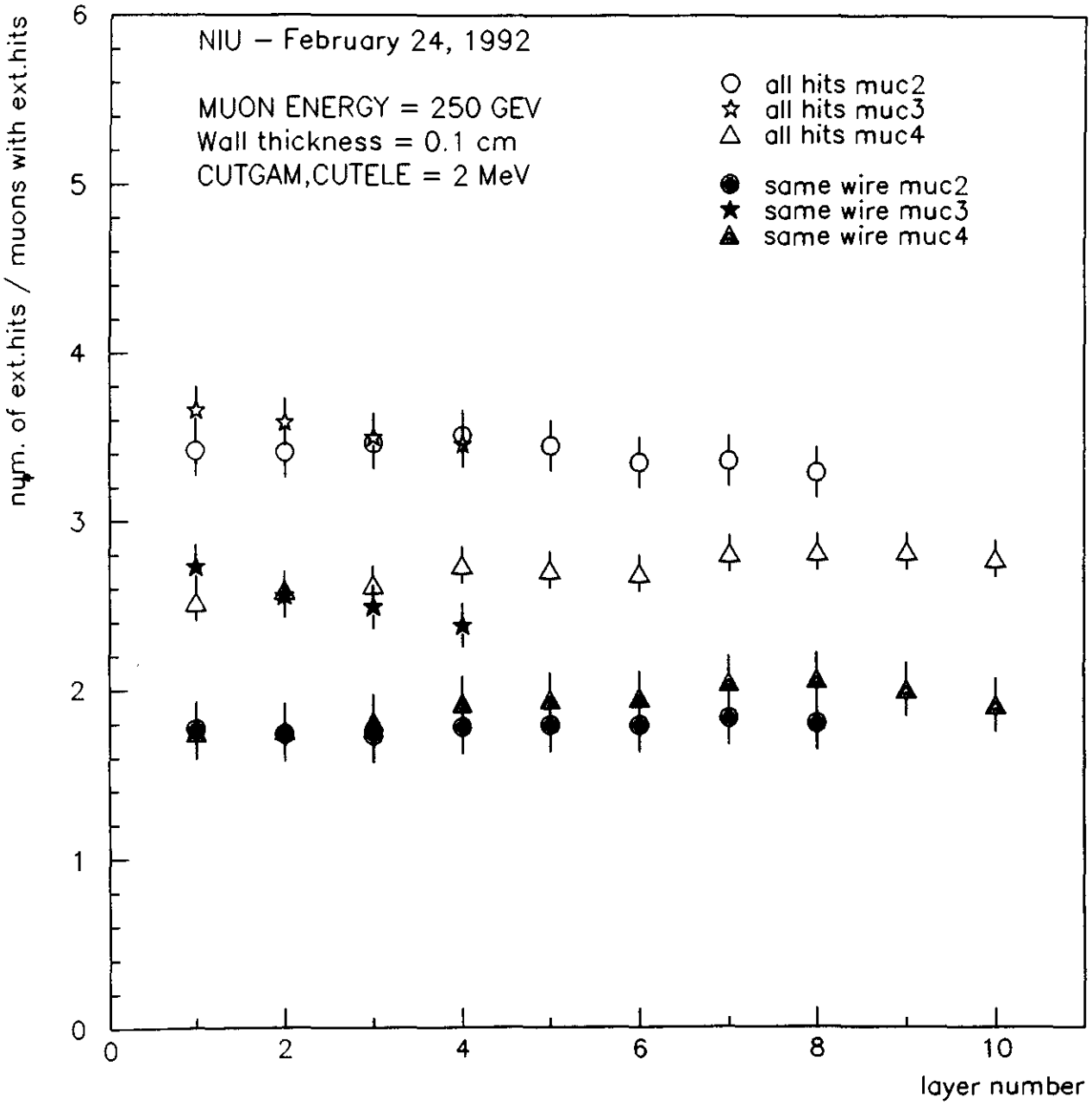

NIU – February 24, 1992
MUON ENERGY = 250 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
all hits muc2
all hits muc3
all hits muc4
same wire muc2
same wire muc3
same wire muc4
num. of ext.hits / muons with ext.hits
layer number
0
1
2
3
4
5
6
0
2
4
6
8
10

Figure 4a

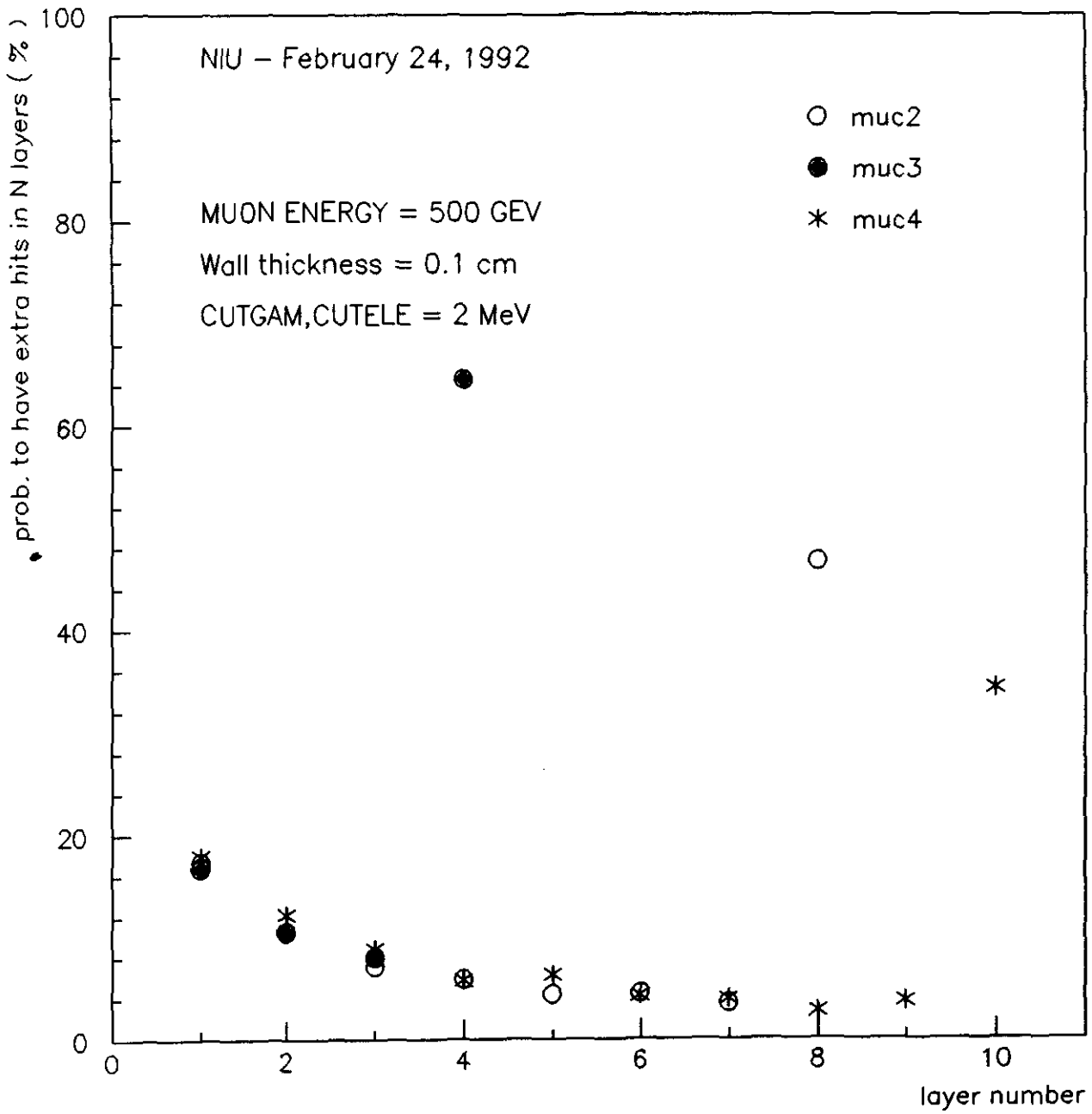

NIU – February 24, 1992
muc2
muc3
muc4
MUON ENERGY = 500 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
prob. to have extra hits in N layers (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 4b

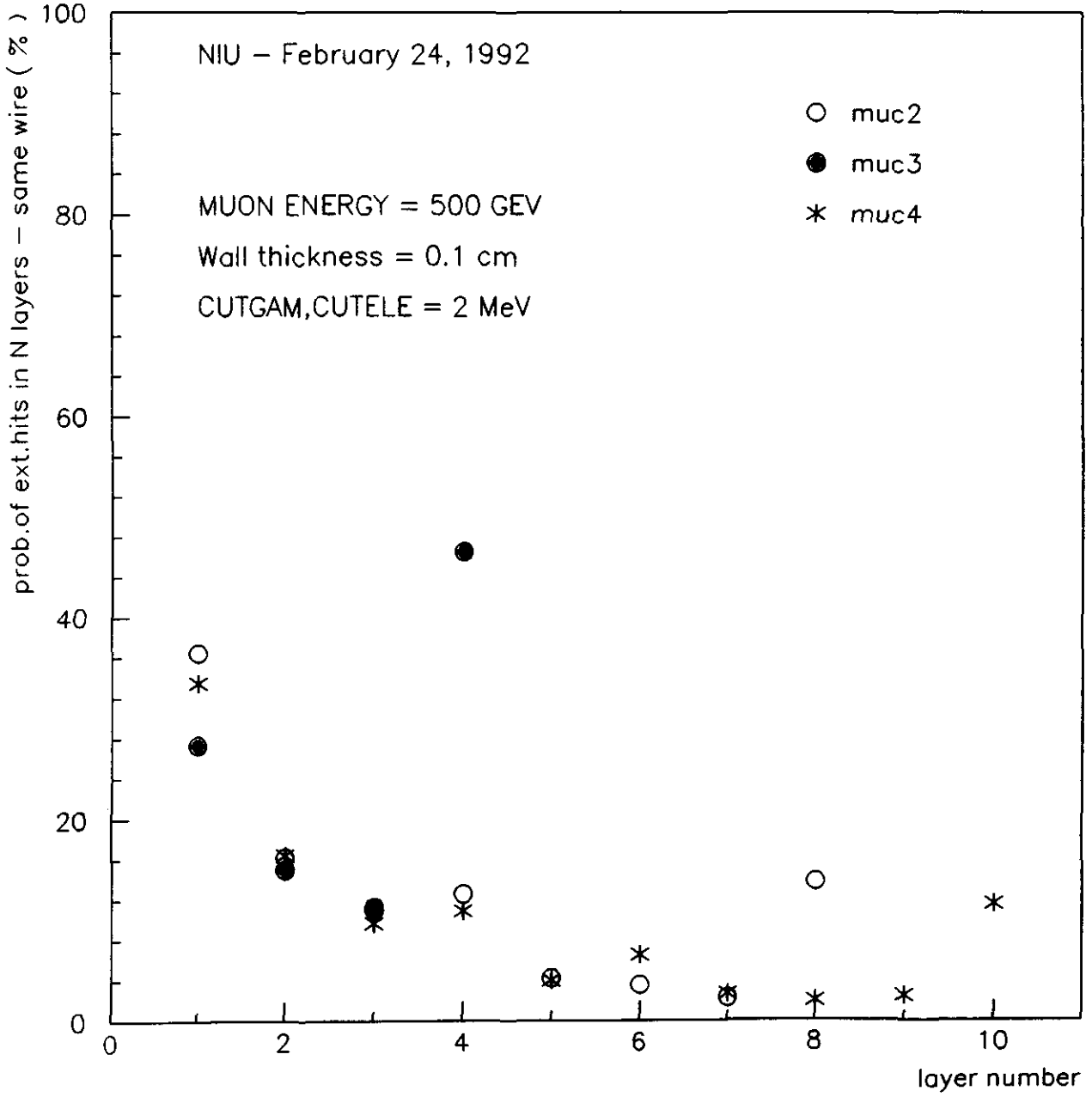

NIU – February 24, 1992
muc2
muc3
muc4
MUON ENERGY = 500 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
prob.of ext.hits in N layers – same wire (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 4c

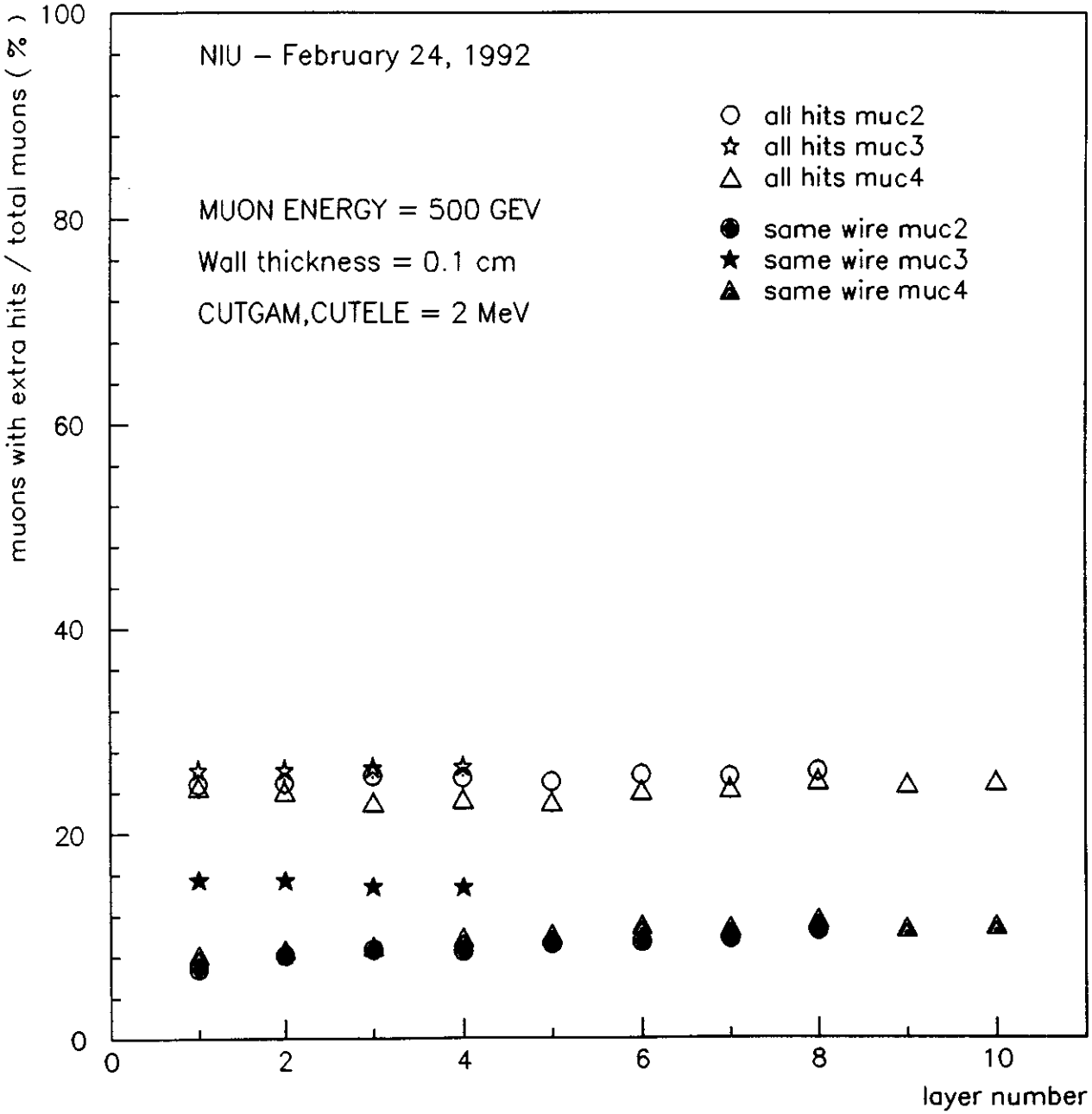

NIU – February 24, 1992
MUON ENERGY = 500 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
all hits muc2
all hits muc3
all hits muc4
same wire muc2
same wire muc3
same wire muc4
muons with extra hits / total muons (%)
layer number
0
20
40
60
80
100
0
2
4
6
8
10

Figure 4d

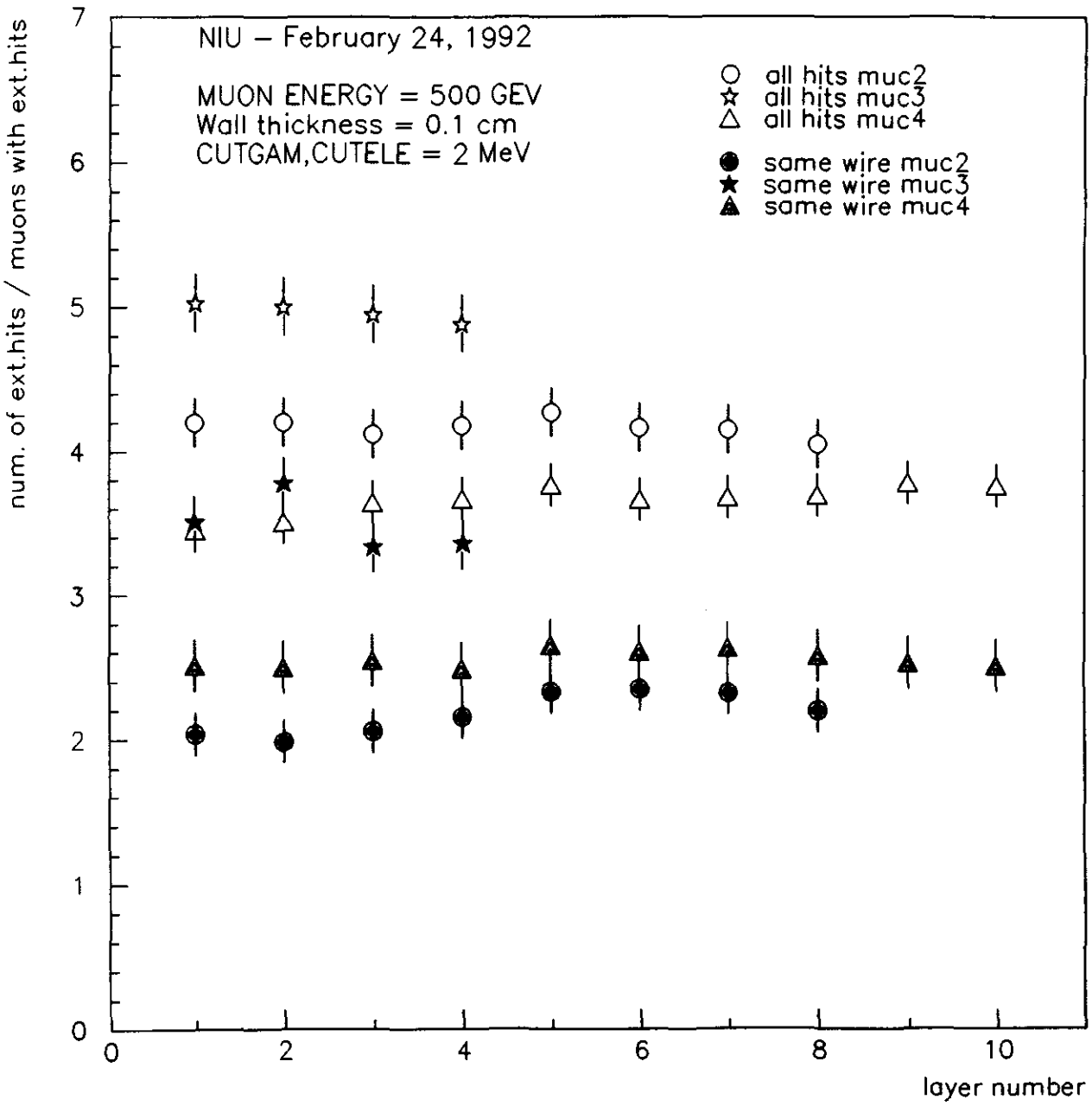

NIU – February 24, 1992
MUON ENERGY = 500 GEV
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
all hits muc2
all hits muc3
all hits muc4
same wire muc2
same wire muc3
same wire muc4
num. of ext.hits / muons with ext.hits
layer number
0
1
2
3
4
5
6
7
0
2
4
6
8
10

Figure 5a

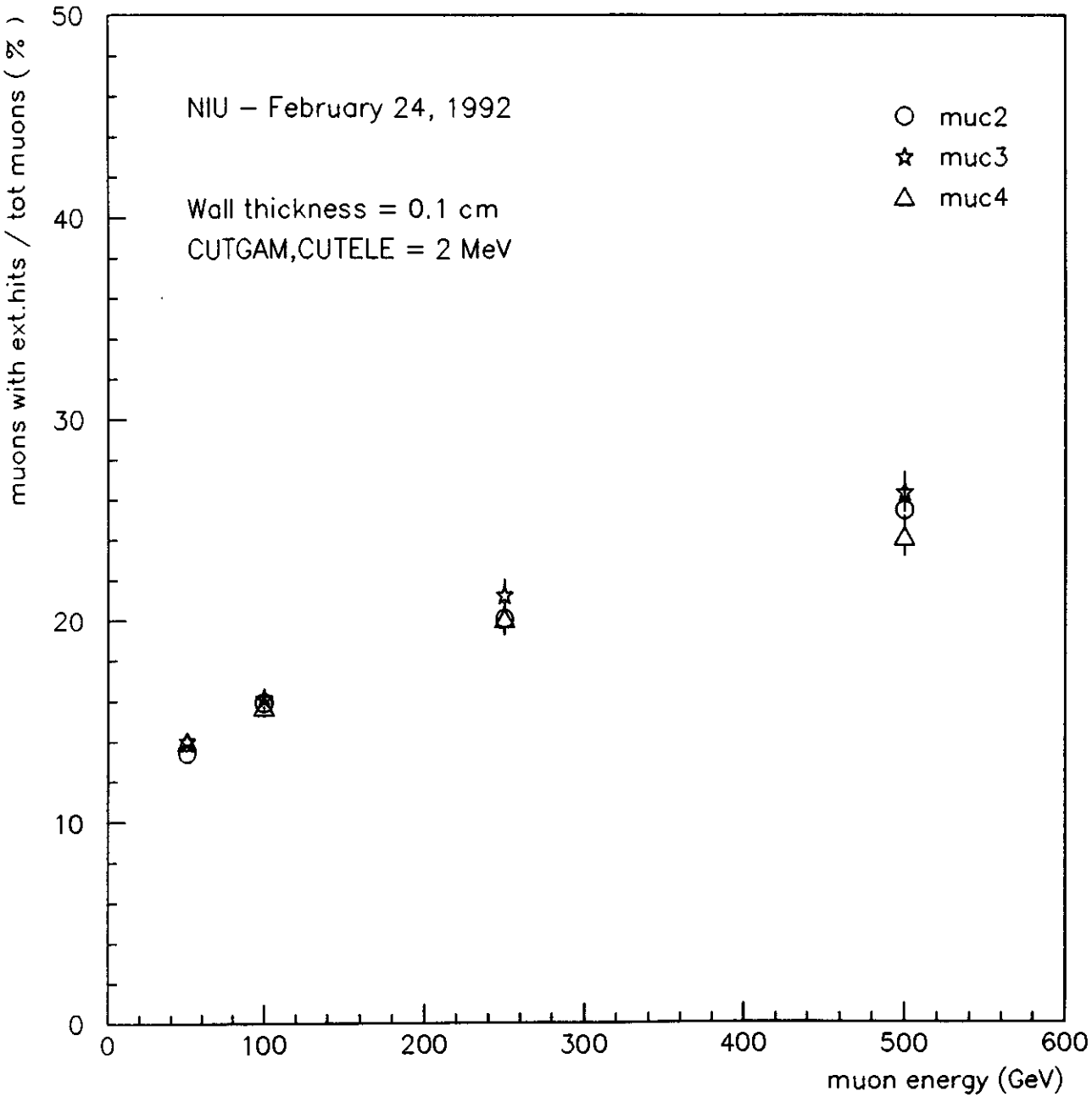

NIU – February 24, 1992
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
muc2
muc3
muc4
muons with ext.hits / tot muons (%)
muon energy (GeV)
0
10
20
30
40
50
0
100
200
300
400
500
600

Figure 5b

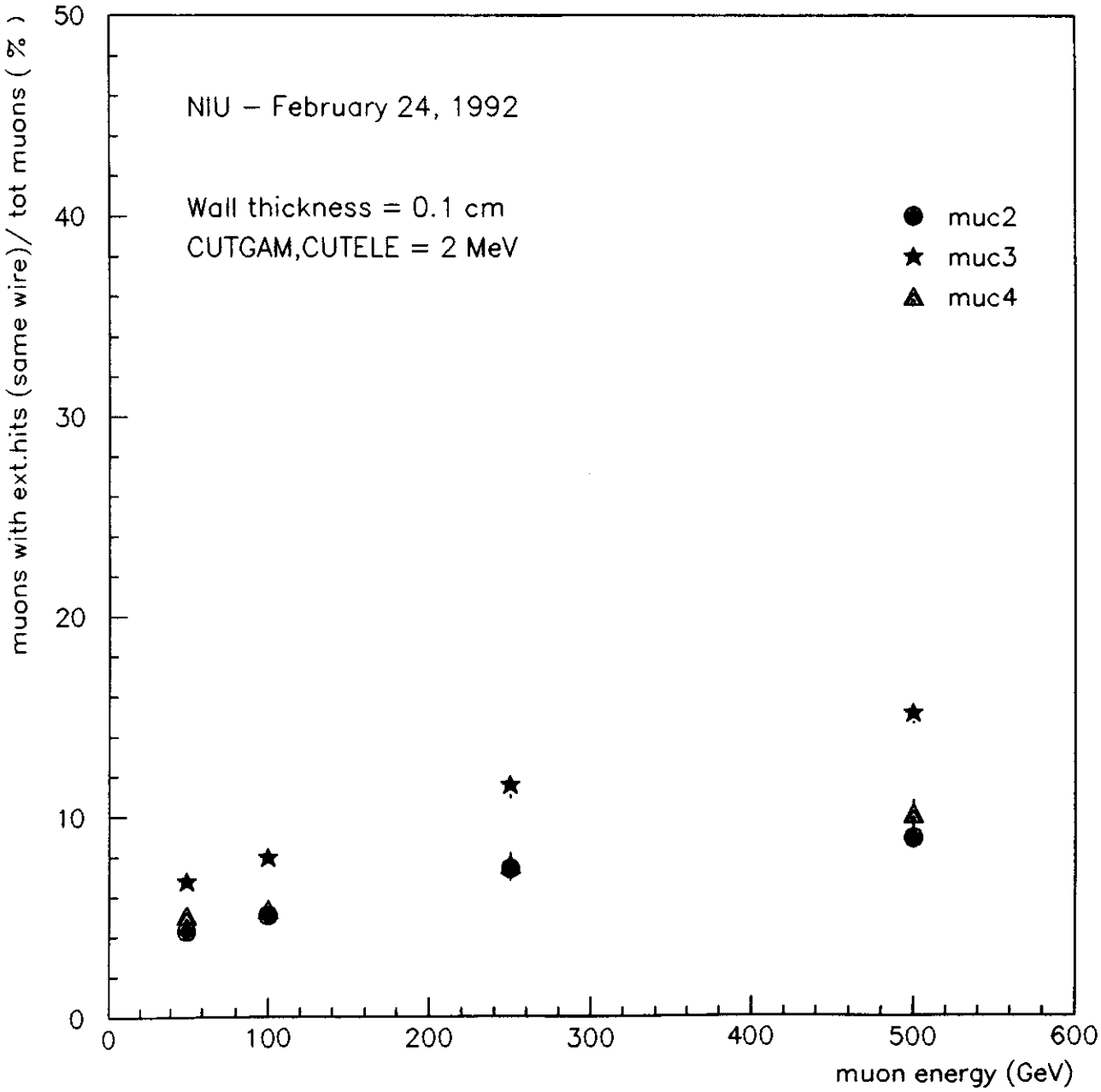

NIU – February 24, 1992
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
muc2
muc3
muc4
muons with ext.hits (same wire)/ tot muons (%)
muon energy (GeV)
0
10
20
30
40
50
0
100
200
300
400
500
600

Figure 6a

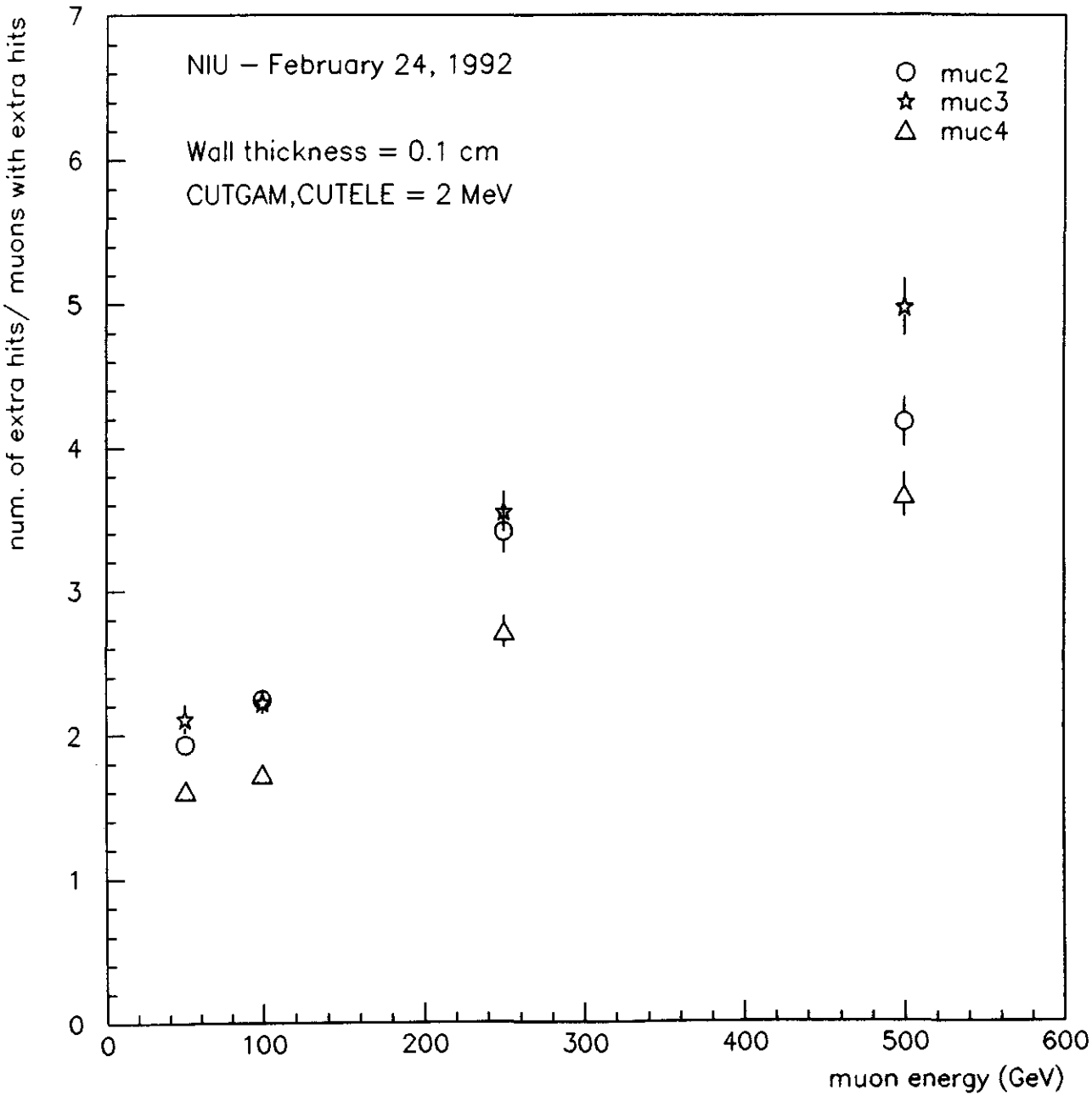

NIU – February 24, 1992
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
muc2
muc3
muc4
num. of extra hits/ muons with extra hits
muon energy (GeV)
0
1
2
3
4
5
6
7
0
100
200
300
400
500
600

Figure 6b

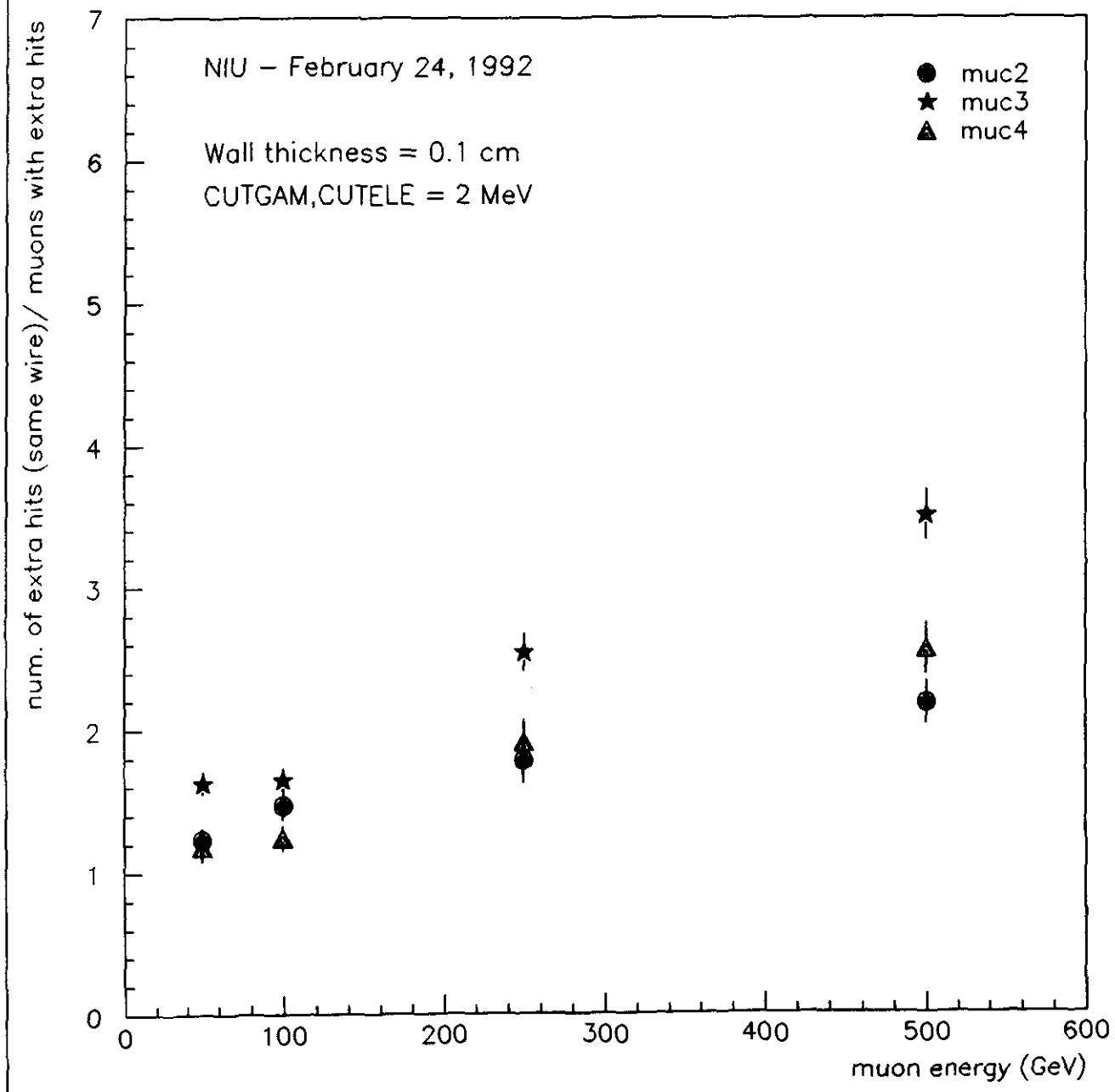

NIU – February 24, 1992
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
muc2
muc3
muc4
num. of extra hits (same wire)/ muons with extra hits
muon energy (GeV)
0
1
2
3
4
5
6
7
0
100
200
300
400
500
600

Figure 7

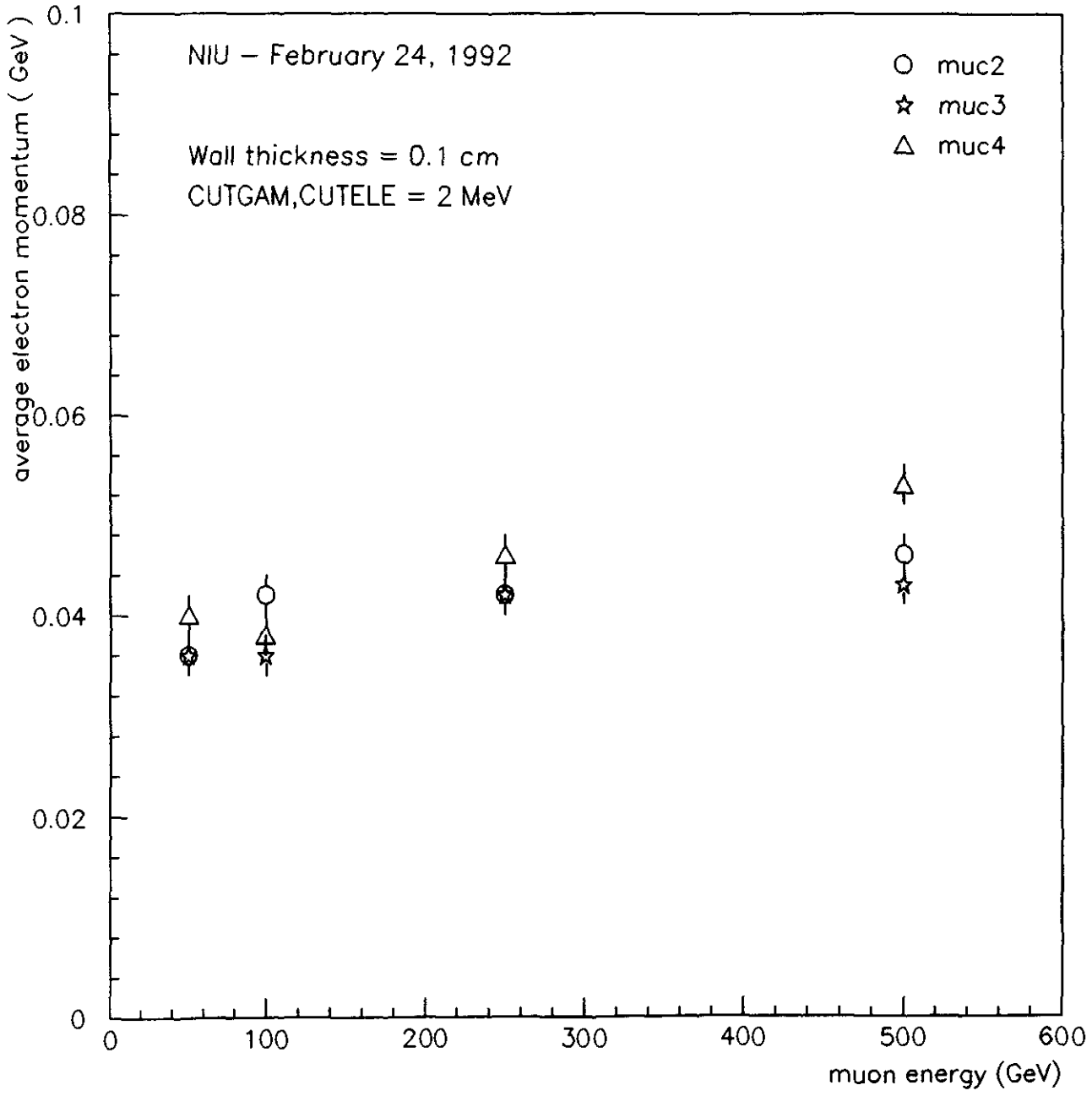

NIU – February 24, 1992
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
muc2
muc3
muc4
average electron momentum (GeV)
0.1
0.08
0.06
0.04
0.02
0
0
100
200
300
400
500
600
muon energy (GeV)

Figure 8

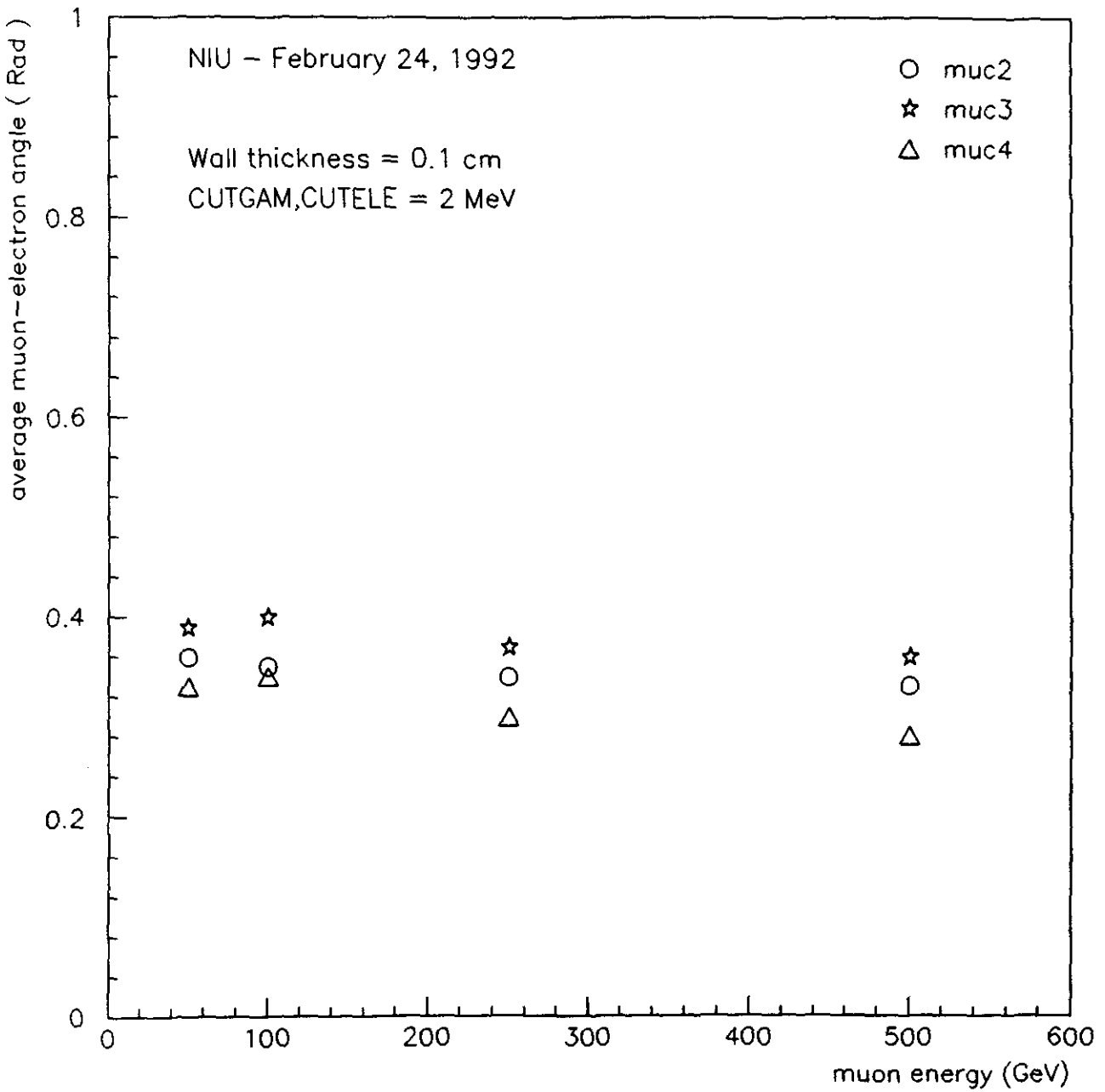

NIU – February 24, 1992
Wall thickness = 0.1 cm
CUTGAM,CUTELE = 2 MeV
muc2
muc3
muc4
average muon–electron angle (Rad)
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
muon energy (GeV)

Figure 9

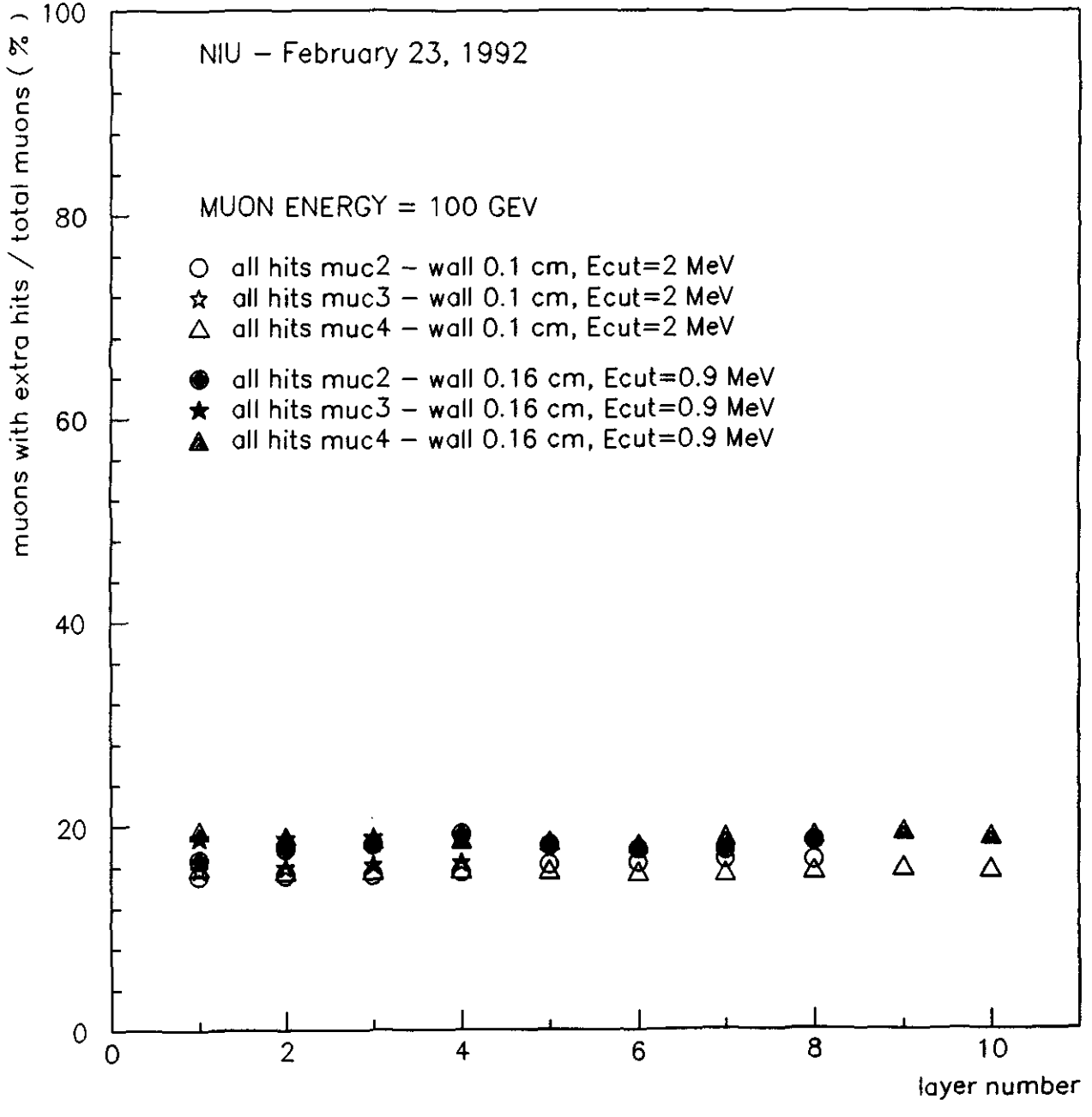
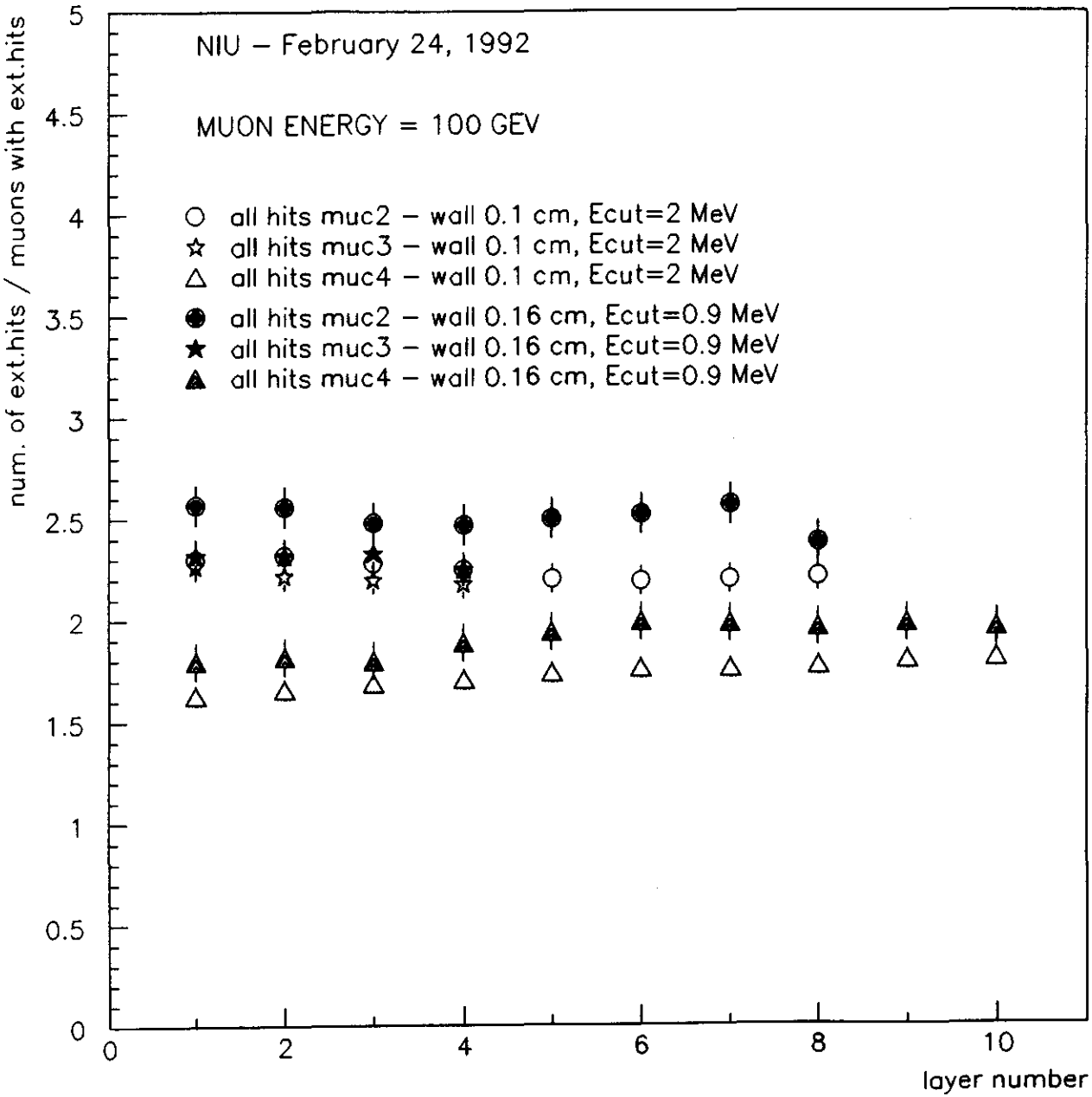

NIU – February 23, 1992
MUON ENERGY = 100 GEV
all hits muc2 – wall 0.1 cm, Ecut=2 MeV
all hits muc3 – wall 0.1 cm, Ecut=2 MeV
all hits muc4 – wall 0.1 cm, Ecut=2 MeV
all hits muc2 – wall 0.16 cm, Ecut=0.9 MeV
all hits muc3 – wall 0.16 cm, Ecut=0.9 MeV
all hits muc4 – wall 0.16 cm, Ecut=0.9 MeV
muons with extra hits / total muons (%)
100
80
60
40
20
0
0
2
4
6
8
10
layer number

Figure 10


NIU – February 24, 1992
MUON ENERGY = 100 GEV
all hits muc2 – wall 0.1 cm, Ecut=2 MeV
all hits muc3 – wall 0.1 cm, Ecut=2 MeV
all hits muc4 – wall 0.1 cm, Ecut=2 MeV
all hits muc2 – wall 0.16 cm, Ecut=0.9 MeV
all hits muc3 – wall 0.16 cm, Ecut=0.9 MeV
all hits muc4 – wall 0.16 cm, Ecut=0.9 MeV
num. of ext.hits / muons with ext.hits
layer number
0
0.5
1
1.5
2
2.5
3
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