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Neutrino Telescope'99

Upward-going muons with Baksan detector (an update, progress report)

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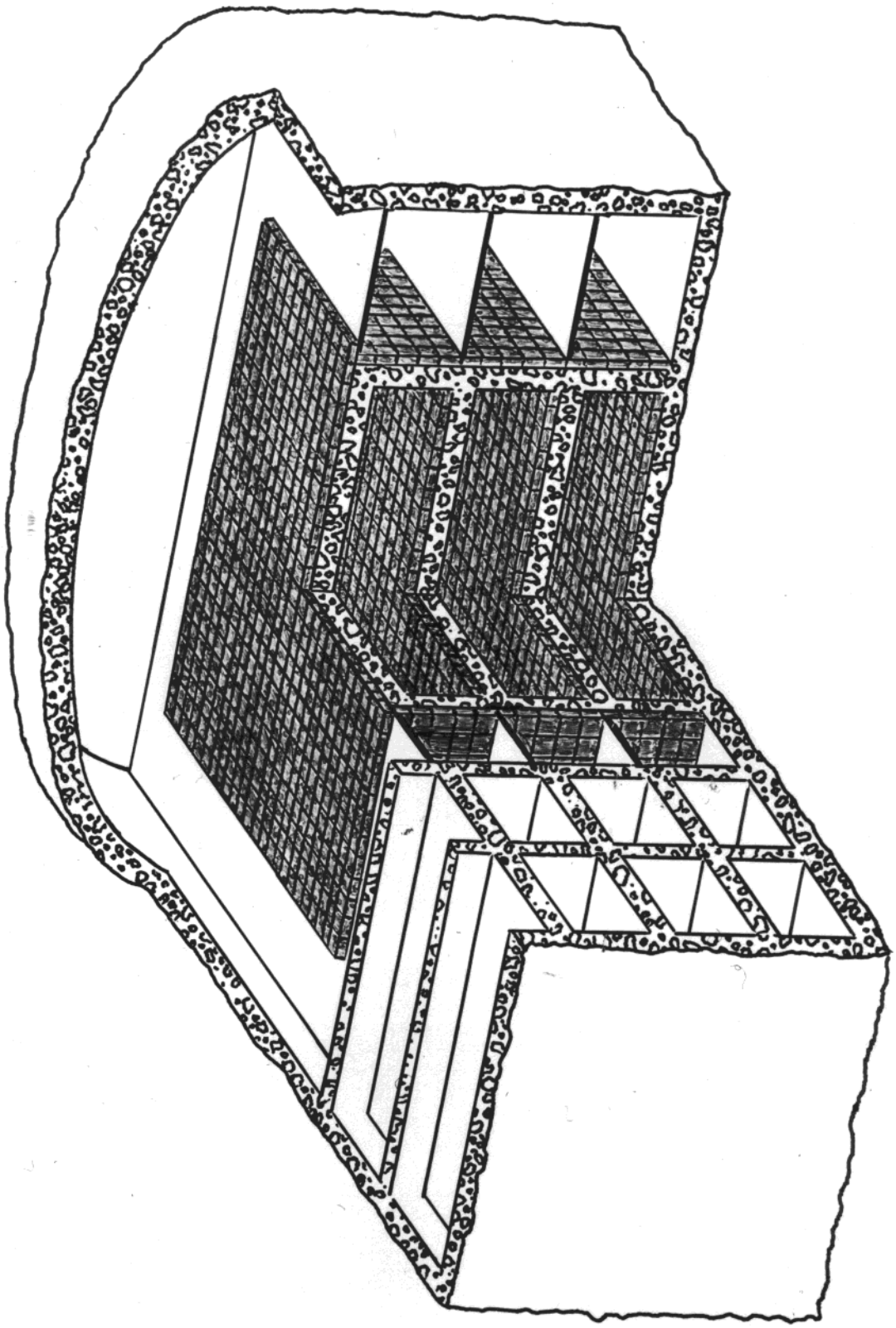
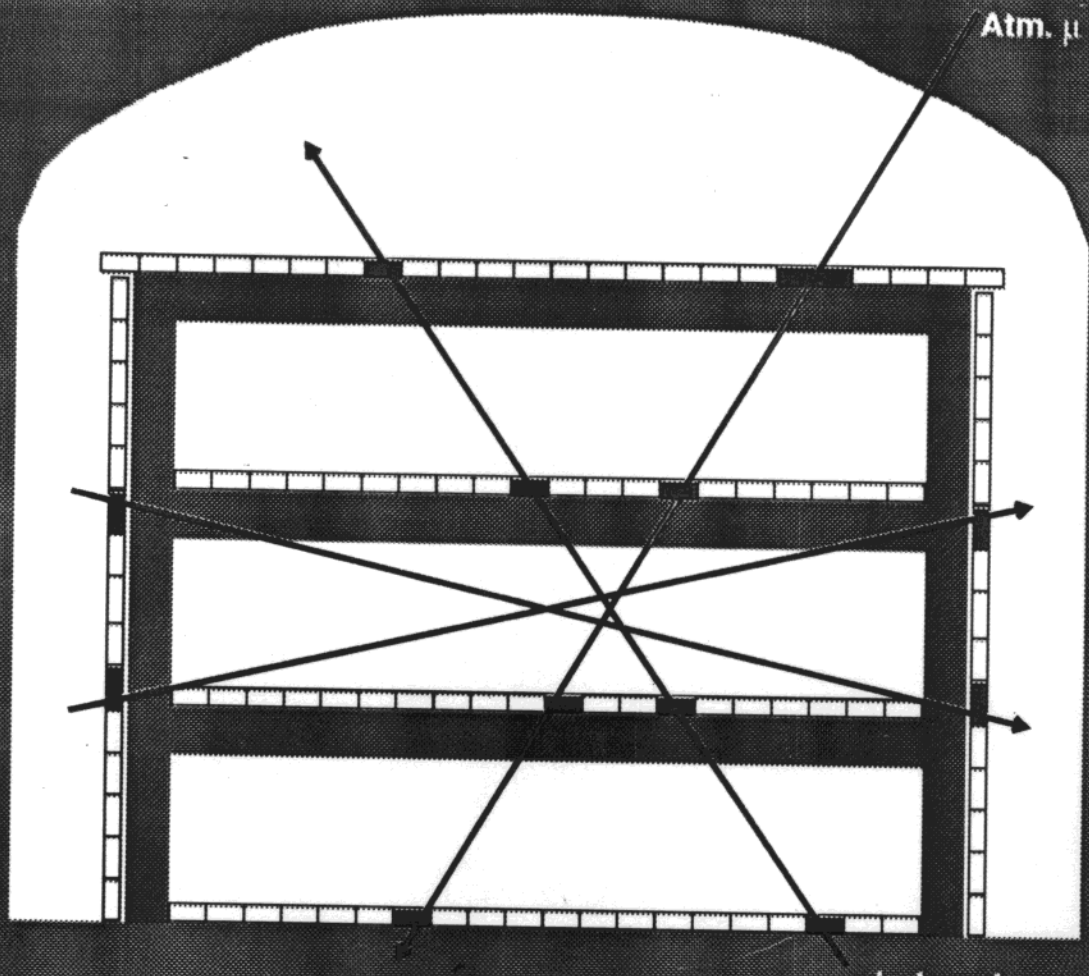


Baksan Underground Scintillator Telescope



Depth: 850hg/cm^2
Size: 17m×17m×11m

Tank size: 70cm×70cm×30cm
Number of tanks 3150

Angular resolution 2°
Time resolution 5ns

General trigger: ≥10MeV in any plane
Rate: 17Hz

Hardware Triggers

$$\frac{\text{Neutrino induced muons}}{\text{Atmospheric muons}} \approx 10^{-7}$$

TRIGGER I:

1. ≥ 3 scintillator planes
2. ≥ 2 negative Δt
3. ≤ 3 external scintillator planes

Efficiency 0.99

(Tested with down-going muons)

TRIGGER II:

1. = 2 vertical scintillator planes
2. = 0 horizontal scintillator plane
3. $\Delta t \geq 30$ns (pathlength ≥ 10m)

Trigger rate ≈ 0.02 Hz

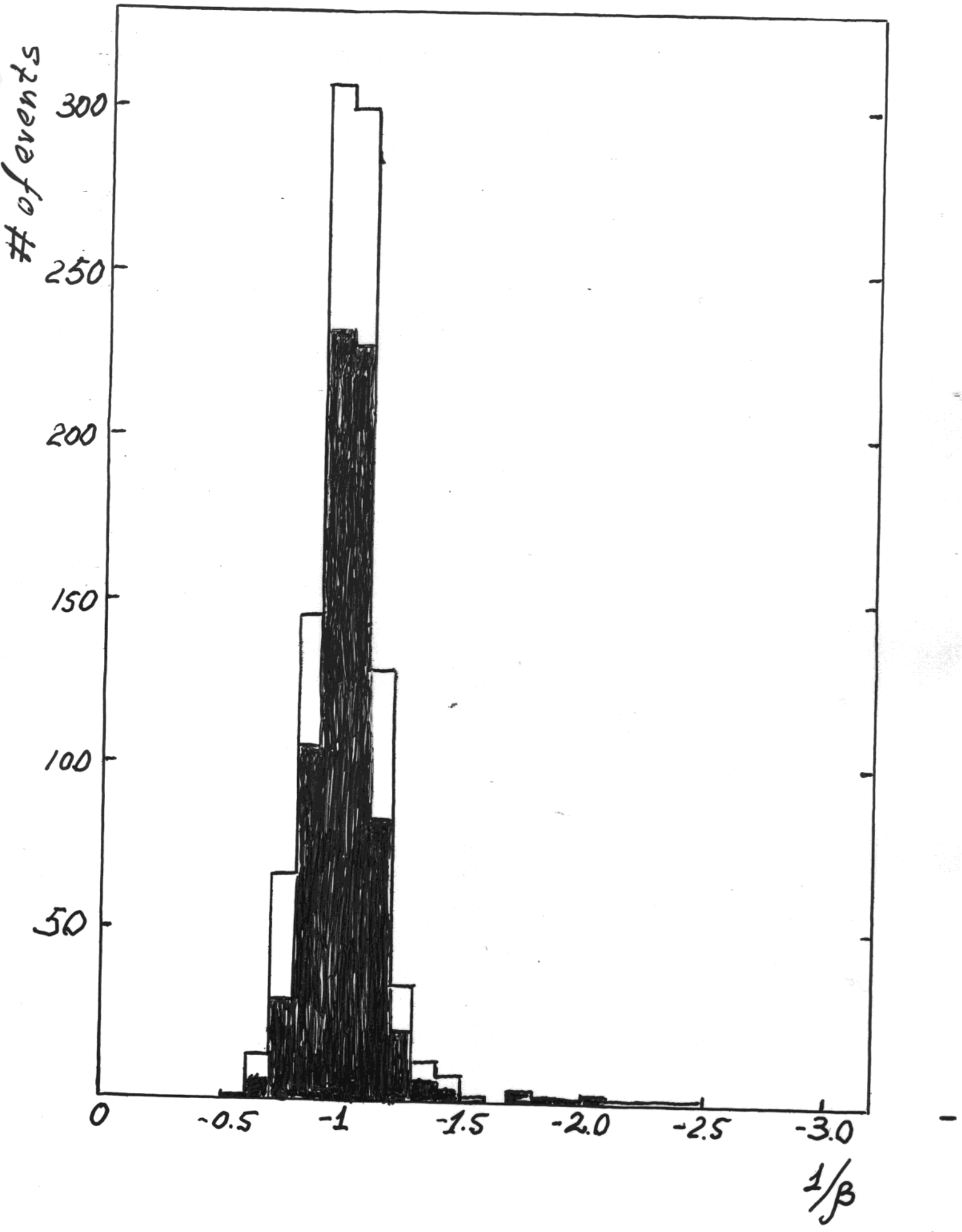
($\approx 10^{-3}$ of total rate)

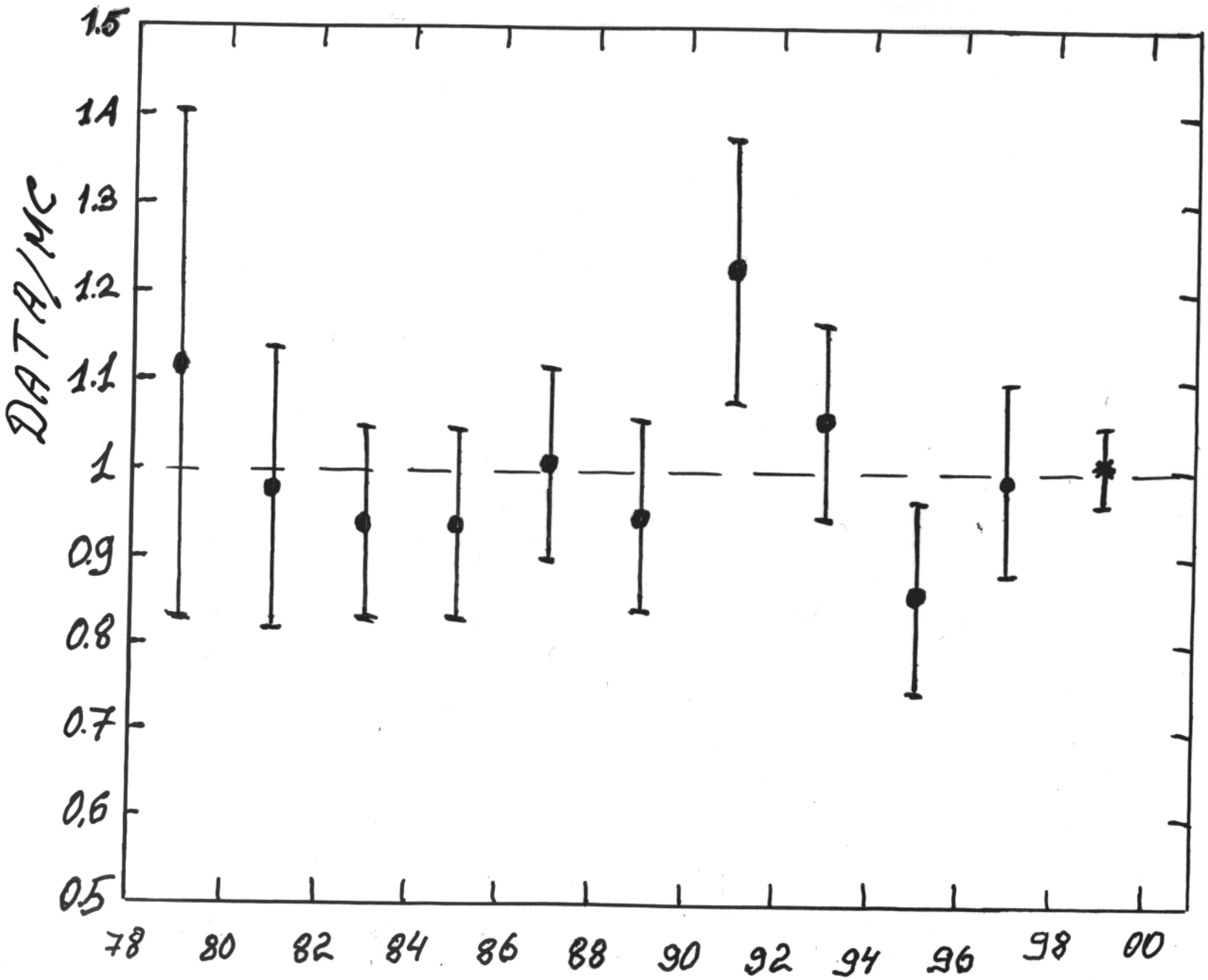
DATA ANALYSIS

12/1978 ÷ 11/1998

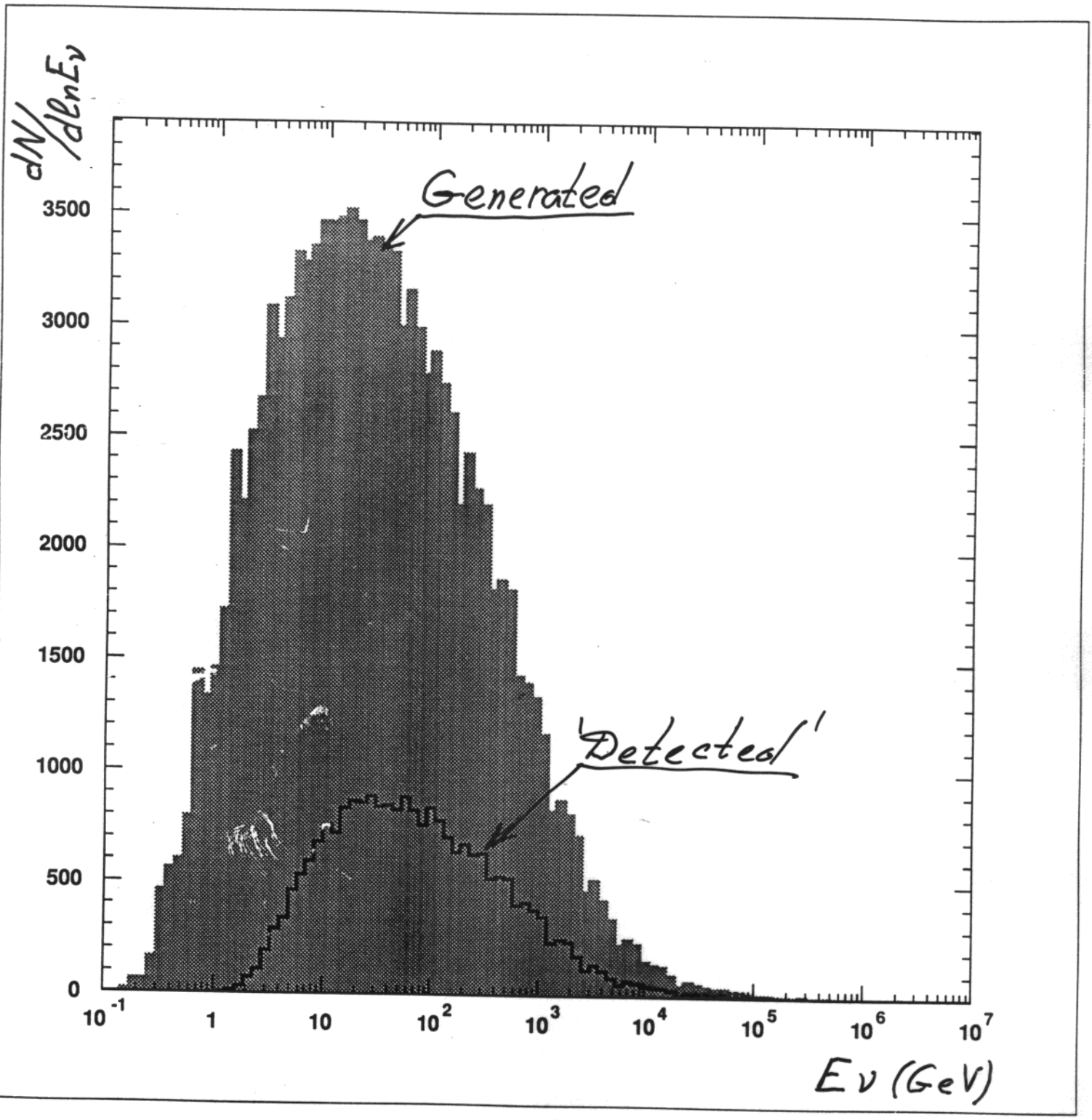
Live time: 14.8

	DATA	MC/1 year (30c year)
	17 sec^{-1}	229.55
Trigger	0.02 sec^{-1}	66.21
Reconstructed track	0.014 sec^{-1}	66.21
$1/\beta < 0$ ($\Theta > 90°$)	1076 ev.	63.96
Geometrical cuts Tr II	930	59.86
≥ 2 external planes	854	49.75
Visible muon range > 500 g/cm^2	713	49.81
$-1.3 < 1/\beta < -0.7$	685	49.21
		675.52

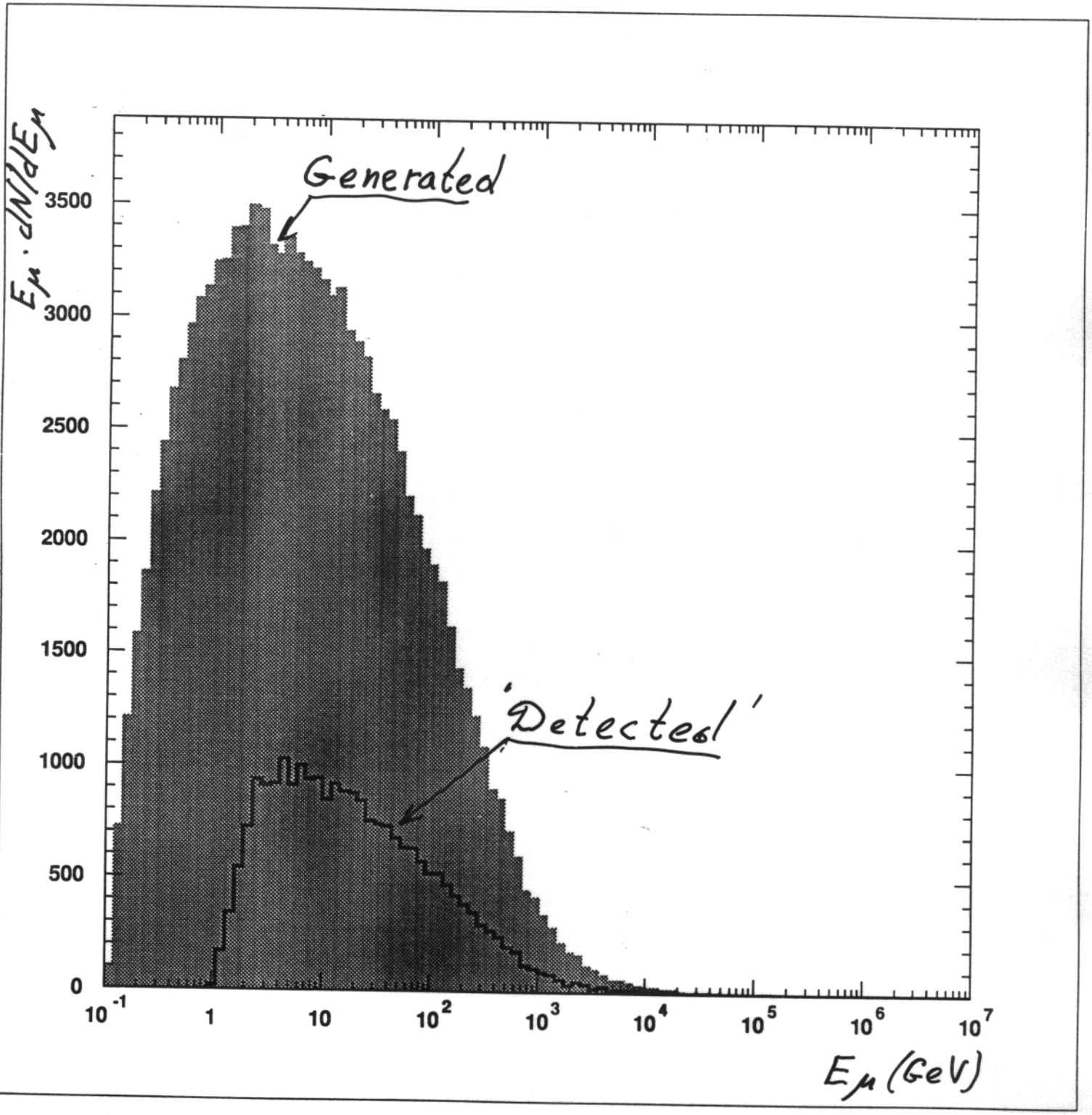

# of events
300
250
200
150
100
50
0
-0.5
-1
-1.5
-2.0
-2.5
-3.0
1/β

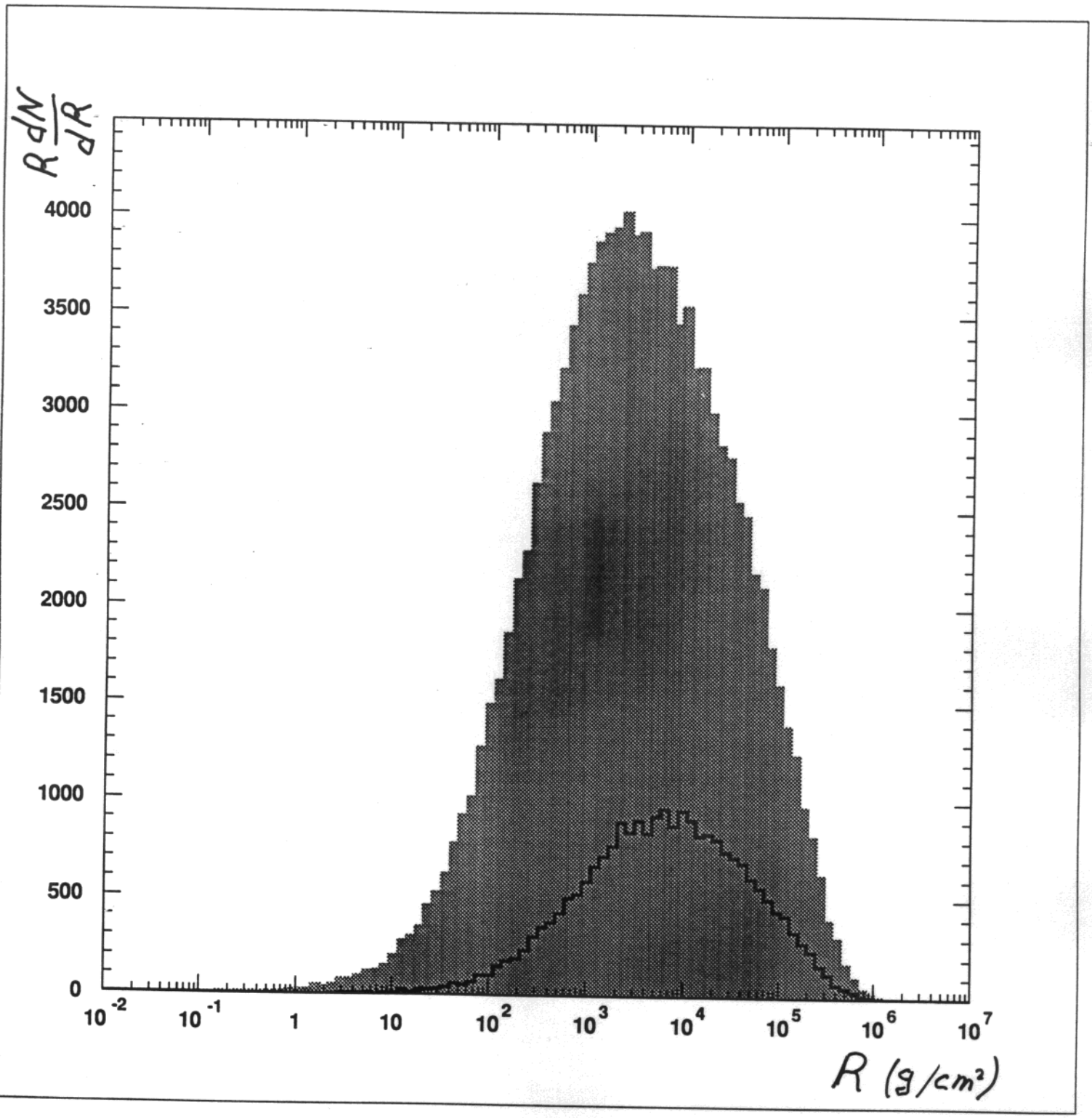

DATA/MC
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
78
80
82
84
86
88
90
92
94
96
98
00

Baksan-MC

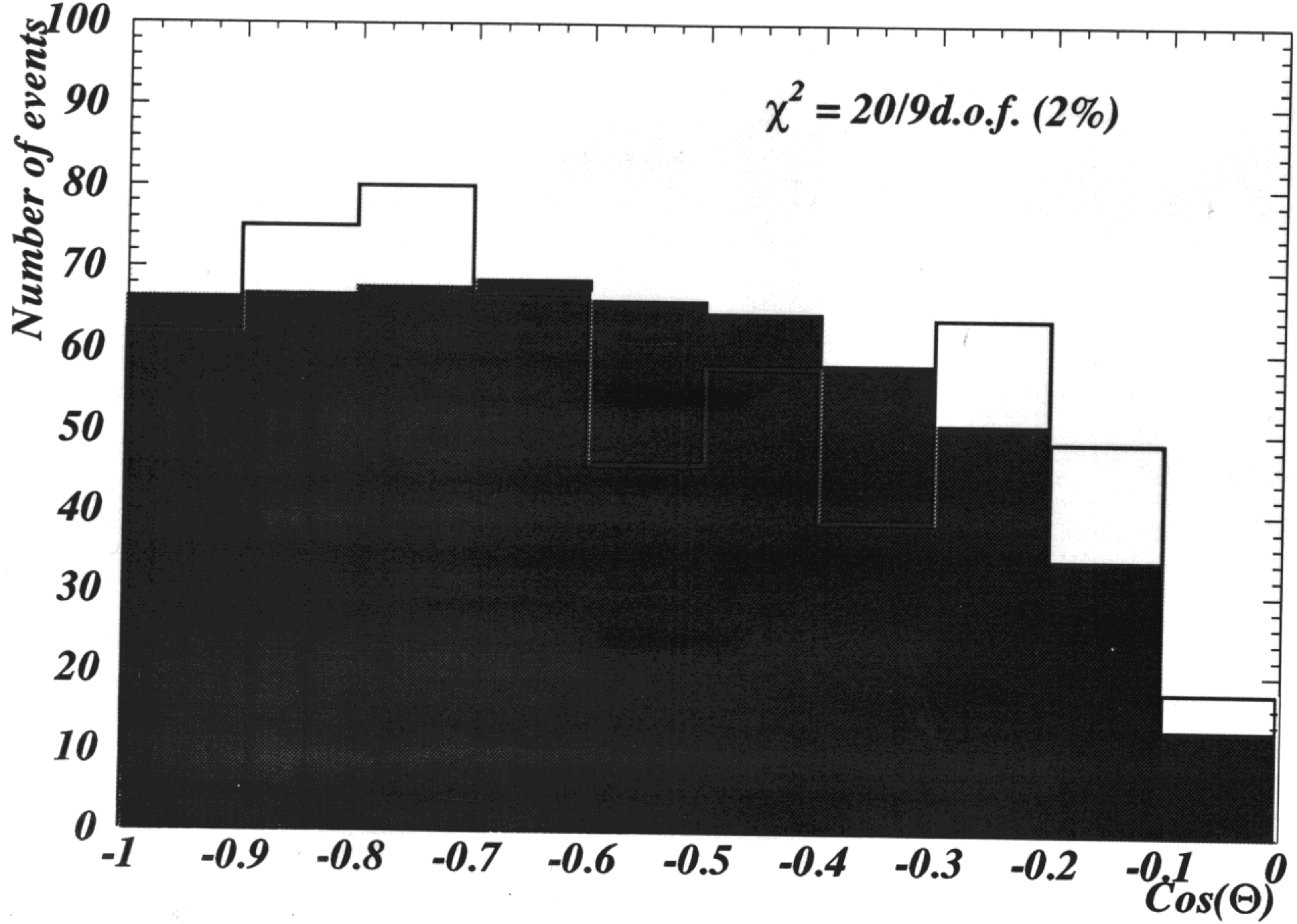

dN/dlnEν
Generated
'Detected'
3500
3000
2500
2000
1500
1000
500
0
10^-1
1
10
10^2
10^3
10^4
10^5
10^6
10^7
Eν (GeV)

Baksan-MC


$E_\mu \cdot dN/dE_\mu$
Generated
'Detected'
3500
3000
2500
2000
1500
1000
500
0
10^{-1}
1
10
10^2
10^3
10^4
10^5
10^6
10^7
E_μ (GeV)

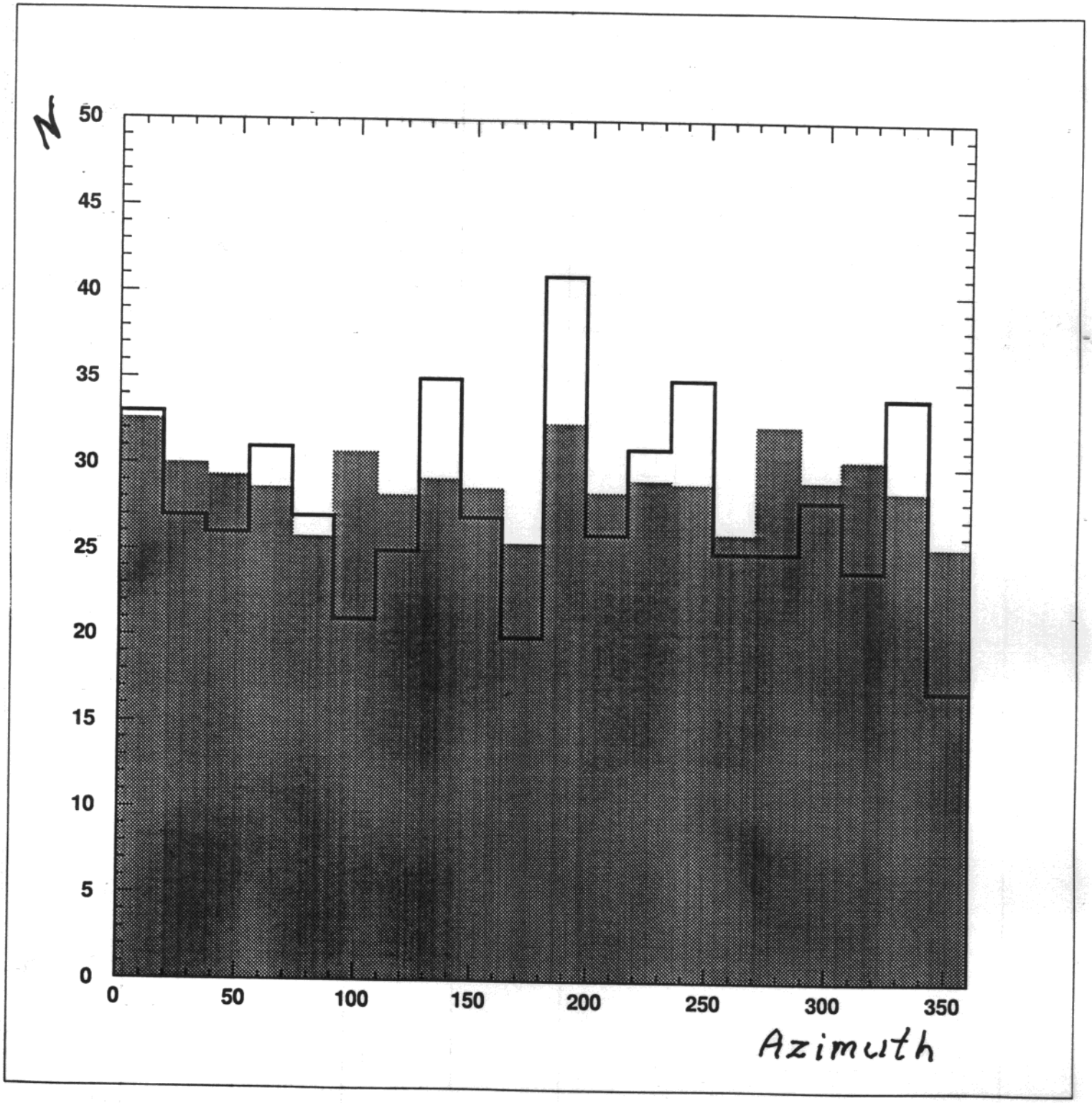

R dN/dR
4000
3500
3000
2500
2000
1500
1000
500
0
10^-2
10^-1
1
10
10^2
10^3
10^4
10^5
10^6
10^7
R (g/cm²)

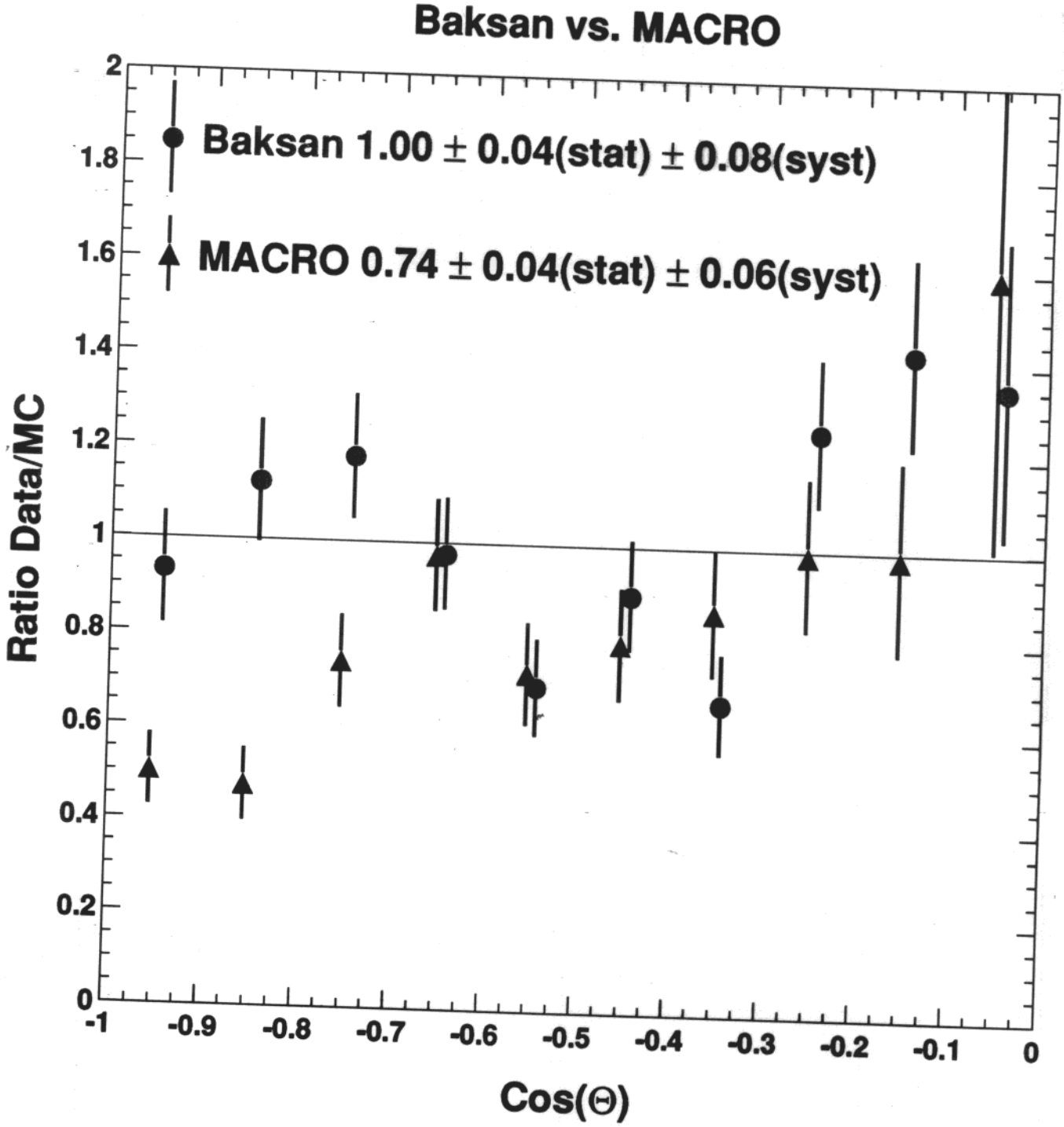
Baksan



Number of events
100
90
80
70
60
50
40
30
20
10
0
-1
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
Cos(Θ)
χ^2 = 20/9d.o.f. (2%)

(7)


N
50
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Azimuth


Baksan vs. MACRO
Baksan 1.00 ± 0.04(stat) ± 0.08(syst)
MACRO 0.74 ± 0.04(stat) ± 0.06(syst)
Ratio Data/MC
Cos(Θ)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-1
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0

Pion production at large angle

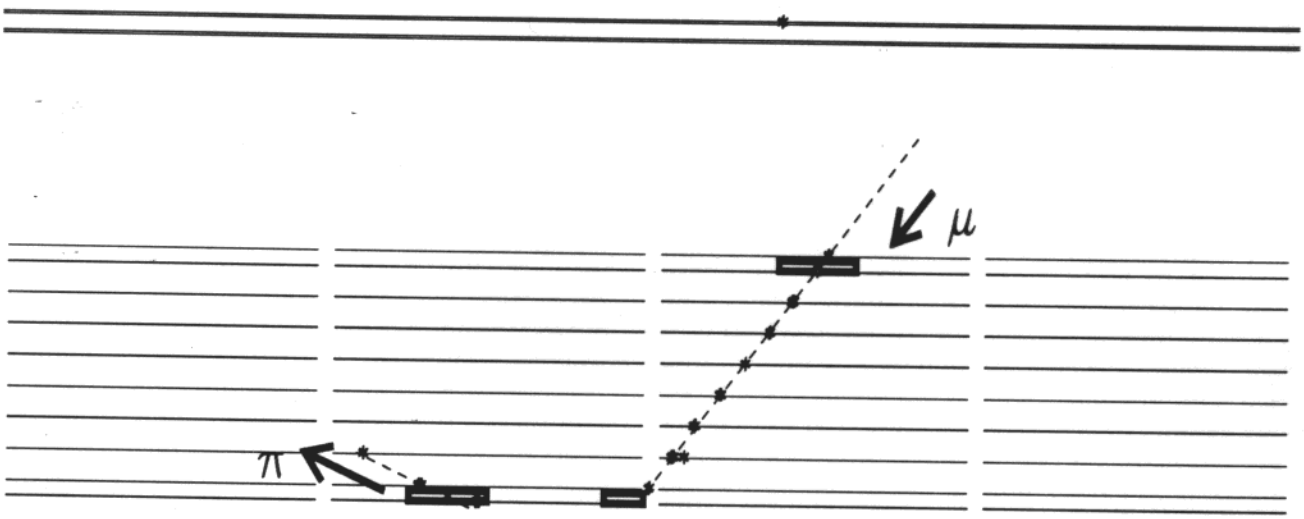


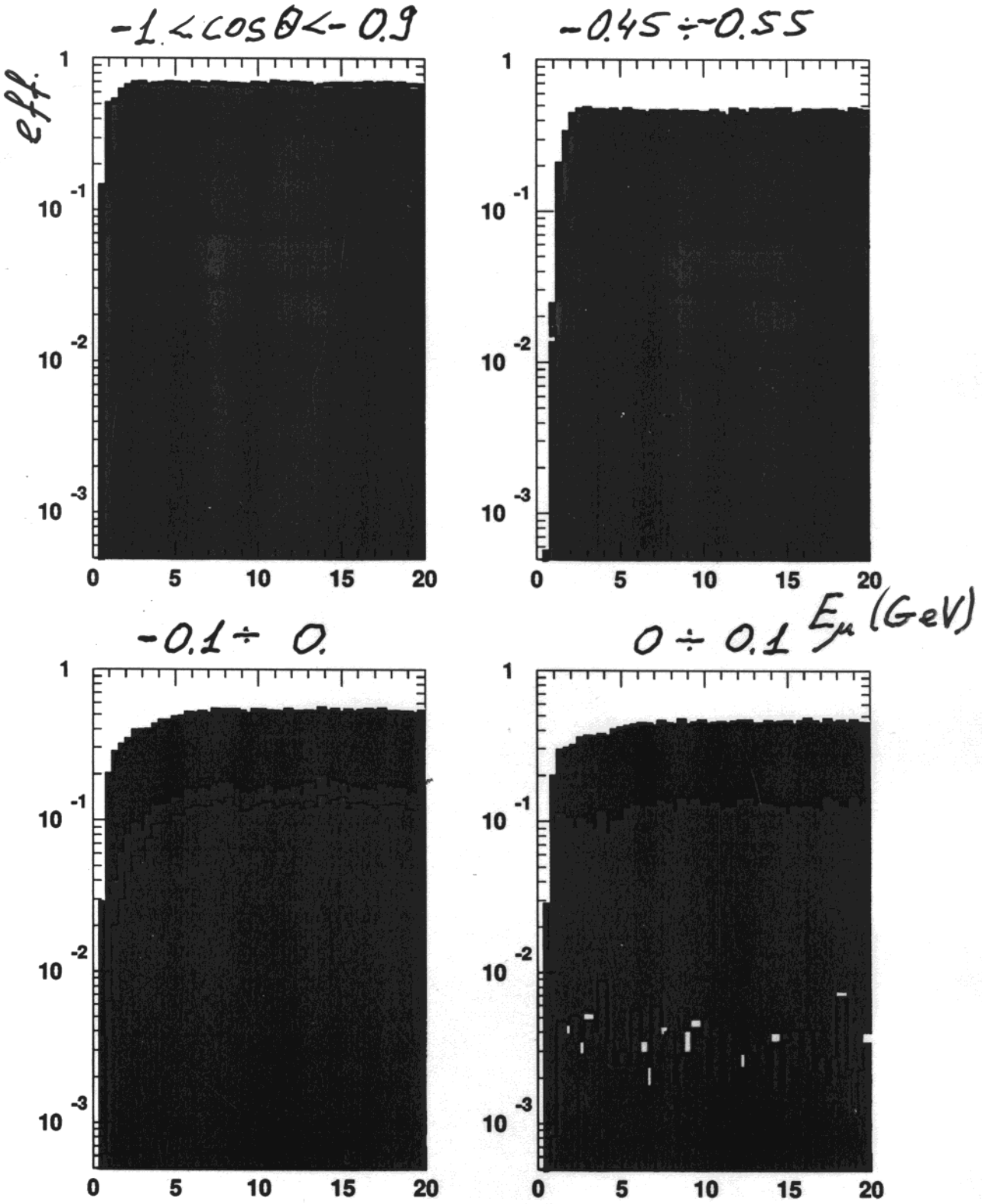
Figure 7: An upgoing particle in coincidence with a downgoing μ.

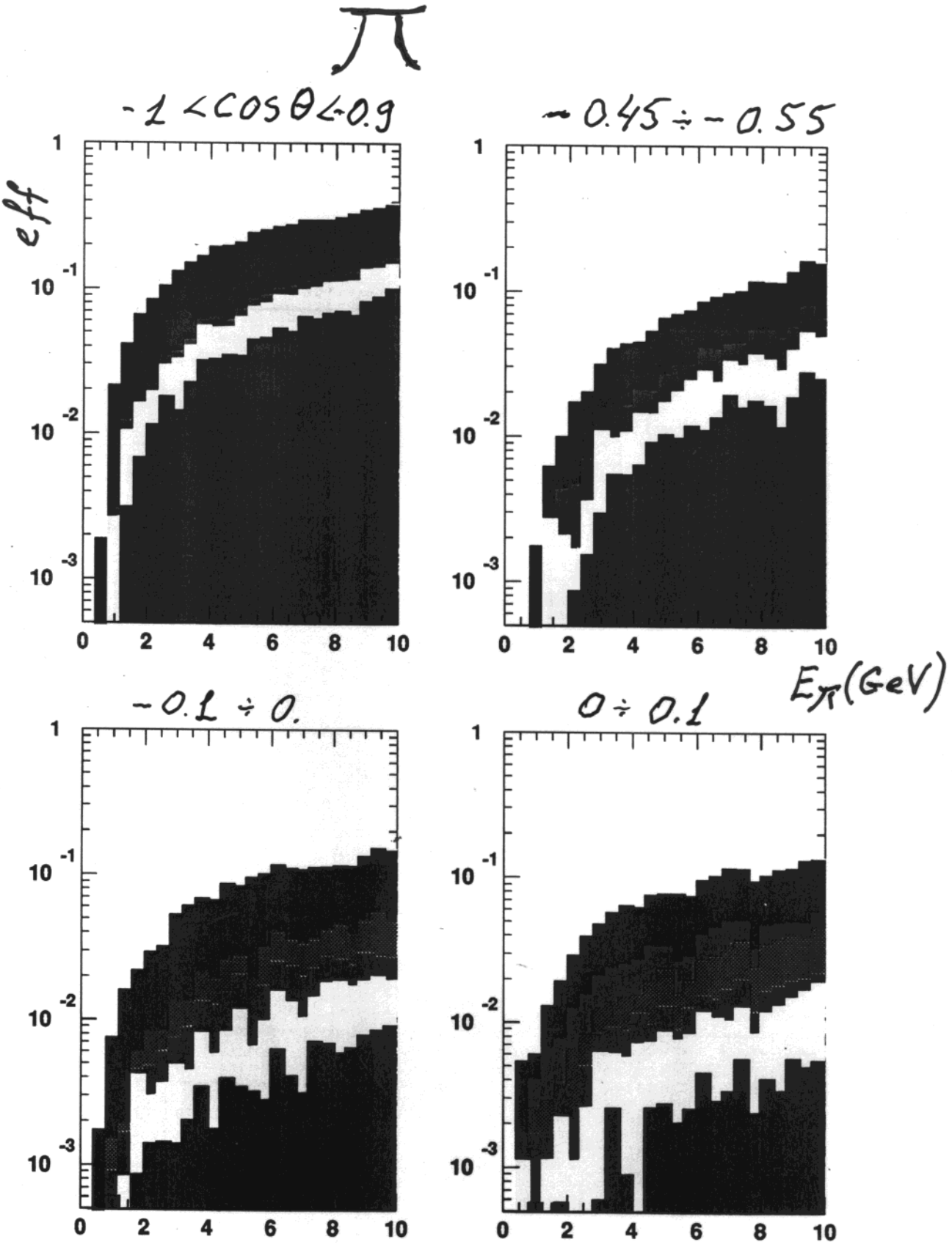
243 upgoing particles in coincidence with a downgoing μ in 1.55 yr between 12.2 million single muons.
Mainly pions produced at large angle in muon interactions in the rock around the detector ($\mu + N \rightarrow \mu + \pi^{\pm} + X$)
Monte Carlo from data and FLUKA agree: $N_{\pi/\mu} \sim 10^{-4}$
Possible background in MACRO:

- $\sim 10\%$ in stopping muon sample;
- $\sim 2\%$ in throughgoing $\mu \uparrow$ sample if $L_{lower\ MACRO} \geq 2m$ (≥ 200 g/cm^2)

but if 3700 m.w.e. $\Longrightarrow$ 1000 m.w.e. (i.e. Baksan) > 2 orders

μ




π
-1 < cosθ < 0.9
-0.45 ÷ -0.55
-0.1 ÷ 0.
0 ÷ 0.1
eff
E_π(GeV)
1
10^{-1}
10^{-2}
10^{-3}
0
2
4
6
8
10

$1/\beta$ CUT

$-1.3 < 1/\beta < -0.7$

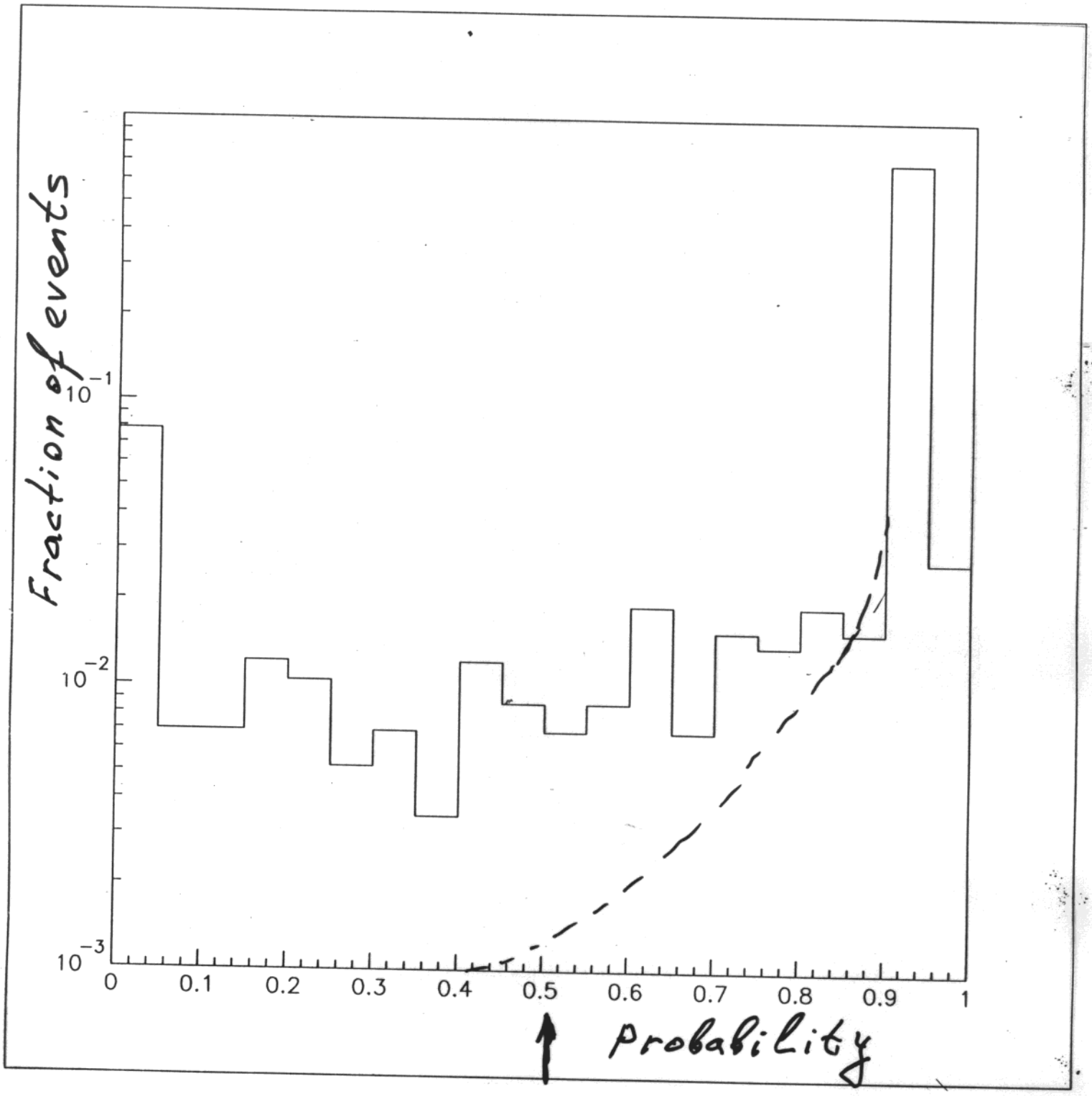
MC μ 1%

MC π 50%

DATA 2%

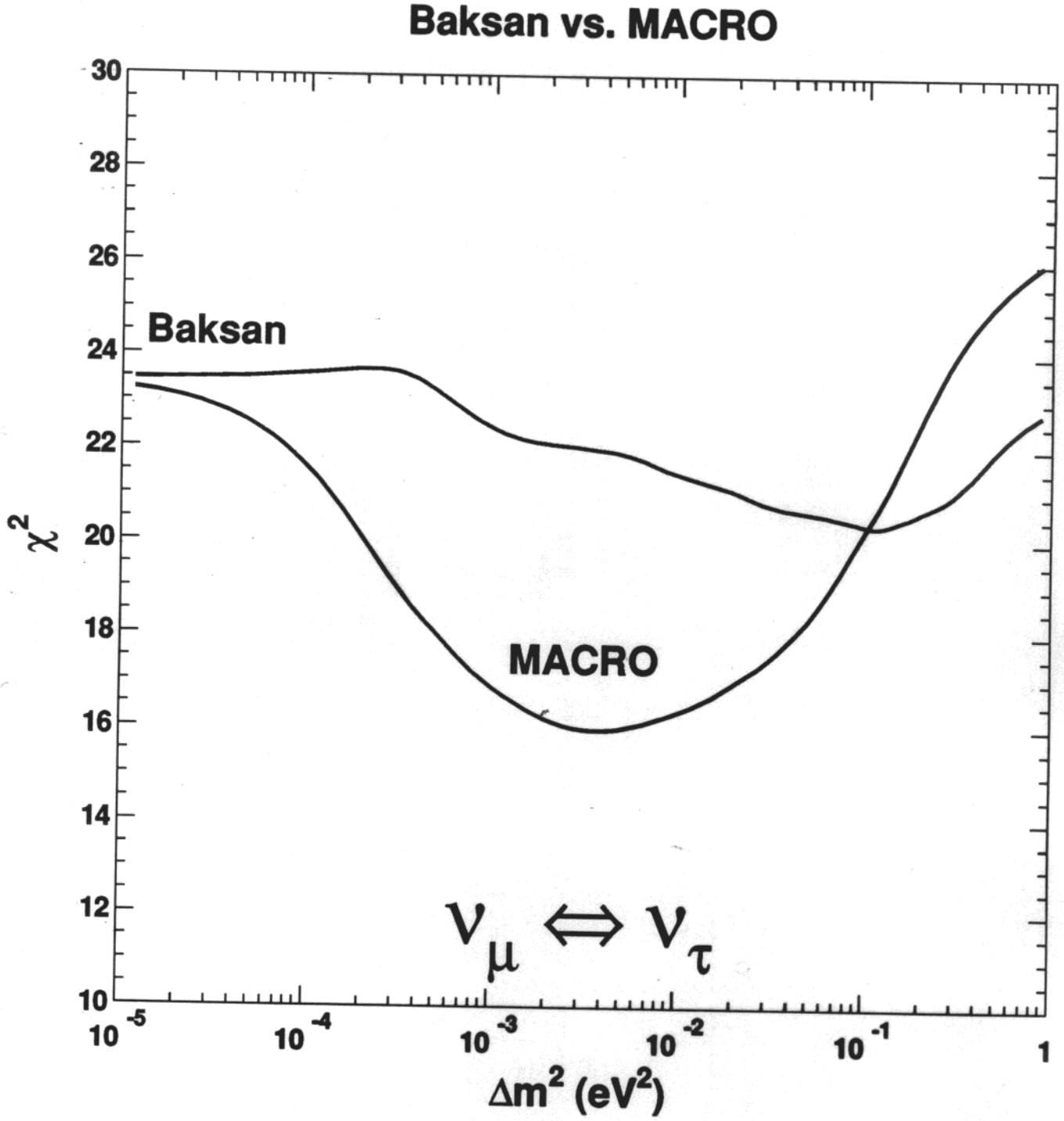
$\pi < 2\%$

~ 12 events


Fraction of events
10^{-1}
10^{-2}
10^{-3}
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Probability

Conclusion

1. 20 years of operation = 685 $\mu\uparrow$
2. $N_{\mu\uparrow}$ - is stable
3. $DATA/MC = 1.01 \pm 0.04_{stat} \pm 0.08_{sys}$
4. Shape of angular distribution is bad. $\chi^2 = 20/3$ dof (< 2%)
5. There is no indication for background from "backscattering"
6. There is some excess of events with additional hitted tanks ~ 10% data
   ~ 5% MC


Baksan vs. MACRO
Baksan
MACRO
$\nu_\mu \Leftrightarrow \nu_\tau$
χ^2
Δm^2 (eV^2)
30
28
26
24
22
20
18
16
14
12
10
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1