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Aragats Multidirectional Muon Monitor

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Aragats Multidirectional Muon Monitor (AMMM) has been used to measure the flux of cosmic-ray muons with threshold energy 5 GeV, arriving from different directions. The detector setup allows registration of the muon flux in zenith angels $\vartheta = 5^o \div 60^o$ and azimuth angels $\varphi = 45^o \div 360^o$. The angular accuracy depends on the direction and changed from 3^o to 5^o for ϑ and from 10^o to 15^o for φ. In this work we present detailed calculation of the expected muon flux from the different directions taking into account the detector response and make comparisons with the measured muon flux.

Multidirectional Muon Monitor h.a./st. Aragats (3200 m)

Energy threshold oh muon $E_\mu = 5 \times Sec\Theta\, (GeV)$.

The intensity of muon flow with the threshold - $E_{\mu} = 5\ (GeV)$:

$I(\Theta) = 20 \times Cos^2\, \Theta\, (м^{-2} c^{-1} cp^{-1})$.

The Monitor is divided to 9 blocks, in eights scintillator every block. Every block can be linked to the circuit of coincidence with 3 scintillators, located in houses on the roof of the calorimeter (look picture 1). The registration of the muon flows is fulfilled in the range of the zenith angles **Θ – 5÷60°** and azimuth angles **φ – 0÷360°** depending on the connection to the circuit of coincidence of the scintillator's blocks, located in the houses 1,2,3,4,6,7 on the roof of the calorimeter. At present time 8 blocks of the Monitor works in the underground hall and 5 blocks of 3 scintillators works on the calorimeter (D-1, D-2, D-3, D-4, D-7).

In the course of work was carried out detailed calculation of the muon flows for different directions taking into account the real configuration of the allocation of the scintillation detectors (S_i=1m^2) in the muon underground hall (to within 12% on the supposition of isotropic distribution of CR muons).

In the tables listed below – **I_{cc} (min^{-1})** corresponds with the flow of muons in the solid angle (ΔΘ, Δφ) per minute; **Σ_{cc+ac}(1÷8)** - calculated and experimental value of coincidence in consideration of the accidental coincidence for 5 minutes for compound muon flow throughout the complex of the muon hodoscope.

Table 1

1. D-1 (Northward (Θ – 7÷30°; φ – 45°÷145°))

Block	**ΔΘ**	**Δφ**	**I_{cc} (min^{-1})** **[calculation]**	**I_{cc+ac} (5 min^{-1})** **[calculation]**	**I_{cc} (5 min^{-1})** **[exp]**
1	22°-28°	83°-100°	44	510	836
2	14°-22°	70°-100°	51	545	735
3	7°-15°	45°-90°	56	570	730
4	20°-28°	70°-100°	45	516	623
5	13°-20°	100°-125°	52	550	735
6	**5°-13°**	**90°-137°**	**58**	**575**	**523**
7	22°-30°	122°-134°	43	507	900
8	15°-24°	125°-145°	50	540	1170

2. D-2 (Eastward (Θ – 32÷48°; $φ_1$ = 157°; $φ_2$ = 192°))

Block	**ΔΘ**	**Δφ**	**I_{cc} (min^{-1})** **[calculation]**	**I_{cc+ac} (5 min^{-1})** **[calculation]**	**I_{cc} (5 min^{-1})** **[exp]**
1	38°-41°	157°-167°	27	426	810
2	34°-39°	167°-177°	31	445	622
3	32°-37°	178°-192°	33	456	610
4	41°-45°	163°-171°	23	405	524
5	38°-43°	172°-182°	26	421	590
6	**37°-42°**	**182°-191°**	**26**	**420**	**418**
7	46°-48°	166°-175°	19	387	795
8	44°-46°	175°-183°	21	395	872

3. D-3 (Southward (Θ – 13÷37°; φ_1 = 244°; φ_2 = 321°))

Block	**ΔΘ**	**Δφ**	**I_{cc} (min^{-1})** **[calculation]**	**I_{cc+ac} (5 min^{-1})** **[calculation]**	**I_{cc} (5 min^{-1})** **[exp]**
1	16°-23°	298°-321°	50	541	910
2	23°-29°	296°-311°	43	506	722
3	32°-37°	294°-305°	35	465	644
4	13°-21°	270°-295°	52	550	797
5	24°-28°	275°-294°	42	500	726
6	**30°-34°**	**279°-290°**	**36**	**468**	**451**
7	18°-23°	244°-270°	49	536	945
8	24°-29°	258°-274°	42	500	1050

4. D-4 (North-eastward (Θ – 32÷48°; φ_1 = 18°; φ_2 = 60°))

Block	**ΔΘ**	**Δφ**	**I_{cc} (min^{-1})** [calculation]	**I_{cc+ac} (5 min^{-1})** **[calculation]**	**I_{cc} (5 min^{-1})** **[exp]**
1	43°-48°	39°- 48°	20	390	850
2	42°-46°	30°- 40°	22	400	651
3	41°-45°	18°- 30°	23.6	408	600
4	40°-44°	42°- 52°	24.8	414	572
5	38°-42°	32°- 42°	27	425	657
6	**36°-40°**	**22°- 34°**	**29**	**437**	**455**
7	35°-40°	42°- 60°	29.5	438	936
8	32°-37°	36°- 49°	33	456	1958

5. D-7 (Westward (Θ – 32÷50°; φ_1 = 330°; φ_2 = 360°))

Block	**ΔΘ**	**Δφ**	**I_{cc} (min^{-1})** **[calculation]**	**I_{cc+ac} (5 min^{-1})** **[calculation]**	**I_{cc} (5 min^{-1})** **[exp]**
1	42°-46°	352°-359°	22	400	703
2	44°-48°	345°-352°	20	391	542
3	46°-50°	336°-345°	18	382	505
4	38°-42°	347°-357°	27	425	456
5	41°-44°	340°-347°	24	411	564
6	**43°-47°**	**332°-340°**	**21**	**395**	**386**
7	32°-37°	341°-353°	33	456	664
8	36°-40°	330°-342°	29	435	866

Table 2

Direction	**Σ_{cc+ac}(1÷8)** [calculation]	**Σ_{cc+ac}(1÷8)** [exp.]	Difference
D - 1 (North)	4315	5600	1.3
D - 2 (East)	3350	3790	1.13
D - 3 (South)	4065	5480	1.35
D - 4 (North-East)	3365	4980	1.48
D - 7 (West)	3290	4283	1.3

The analysis of the calculated and experimental data shows that the experimental calculation of coincidence is overstated because of the large share of accidental coincidence. Owing to the symmetry of the plant the calculating for the oppositely oriented houses must be approximately equal and it may be observed with small difference both in the computation and on the experiment. The computation of the influence of the accidental coincidences on the functioning of certain channels was carried out under the supposition that the duration of the impulses of coincidence ~ 1 mcs. The following formula was used in the calculation:

$$\mathbf{N = (\tau_1 + \tau_2)\, n_1 n_2 = 2 \times 10^{-6} \times 420 \times 50 \approx 4.2 \times 10^{-2}\ s\ .}$$

The difference in the calculated and experimental values is related with the fact that the duration of impulses for different channels have some spread relative to the taken value ~ 1 mcs.

It is necessary to take into account the fact that the share of accidental coincidences depends on the zenith angle and with the increasing of the zenith angle grows the accidental coincidences' share.