RELATION BETWEEN GAMMA-RAY FAMILY AND EAS CORE
- MONTE-CARLO SIMULATION OF EAS CORE -

Tomotake YANAGITA
Takakura-cho 5-4-301, Nishinomiya, 662 JAPAN

ABSTRACT

Preliminary results of Monte-Carlo simulation on EAS($Ne=10^5$) core is reported. As the first collision at the top of atmosphere, high multiplicity (high rapidity density) and large Pt (1.5GeV average) model is assumed. The most of the simulated cores show complicated structur.

1. Introduction. Several simulation studies on the EAS core structure were performed previously(Ref.1). Although various models or assumptions (fire ball, CKP, heavy primary or energy dependent Pt etc.) were tested in these works, the prominent frequency of the multi- or complicated core structure has not been simulated.

Recently, in the direct and pseudo-direct observation of nuclear interaction by EC (JACEE and CONCORDE, Ref.2, 3), very high multiplicity (high rapidity density) and comparatively large transverse momenta events were detected. The feature of these events gives us a motive for another EAS core simulation. We performed the core simulation taking these interaction feature in the simple model.

2. Simulation. The final output of the simulation calculation is the electron density map. We postulate 16*10 of packed array consist of 50*50 cm^2 density detectors, then area is 40 m^2 which is similar to the Norikura Spark Chamber Array(Ref.4).

The first collision depth (hereafter it is abreviated as Zo) is not sampled randomly, but is fixed to 10, 50 and 100 g/cm^2. The nuclear cascade is traced to observation depth($750 g/cm^2$) and the gamma-rays produced through neutral pion decay are filed (x,y,z-coordinate, directional cosine and the energy). From the gamma-ray file the core density map is generated superposing each electromagnetic cascade. As the electron lateral distribution function of the electromagnetic cascade, the NKG-formula is used.

Tracing the nuclear cascade, only the forward region in the rapidity space is concerned but the central and backward regions are neglected in each interaction.

Model and Postulate for the first interaction :
- survival particles are not in concern
- total energy of produced particles is fixed to 600TeV.
- multiplicity of charged hadrons is fixed to 20.
- multiplicity of neutral pion is fixed to 10.
- production energy spectrum is exponential type.
- transverse momentum distribution is exp(-Pt/Po), Po = 1.5 GeV/c

Other Interaction :
- collision mean free path is 90 g/cm^2.

(a)

11	12	13	14	15	17	19	20	19	17	16	15	14	13	12	11
12	12	14	15	17	23	30	35	23	22	19	17	15	14	12	12
12	13	15	16	21	28	36	42	36	31	21	19	17	15	13	12
13	16	18	18	23	41	71	71	71	40	26	22	19	16	14	13
14	25	24	19	24	34	55	67	83	59	33	30	23	19	16	13
14	17	21	21	25	34	44	62	72	59	36	25	23	22	17	13
13	16	25	20	26	34	36	48	58	49	35	23	20	18	16	13
12	14	17	19	22	26	29	29	35	47	32	20	17	15	14	12
11	13	15	16	19	21	25	23	26	28	25	18	16	14	13	12
11	12	13	15	16	18	19	19	18	18	17	16	14	13	12	11

(b)

11	12	13	15	16	17	17	19	20	18	18	19	18	16	15	14
11	12	13	16	20	20	20	23	22	21	21	26	19	18	18	16
12	13	14	17	20	23	24	25	25	24	30	24	22	20	18	17
12	13	15	16	19	23	35	41	39	31	30	35	27	30	23	19
12	13	15	17	21	26	49	74	63	58	36	38	31	41	27	21
12	13	15	18	27	27	44	83	174	73	44	39	34	29	26	23
12	13	15	17	21	26	37	94	113	75	47	44	38	32	31	33
12	13	14	16	20	29	31	52	67	61	47	44	62	53	44	48
12	13	14	16	18	21	24	30	41	61	51	52	51	88	37	27
12	12	13	15	16	18	21	24	29	33	33	32	33	33	26	19

(c)

17	21	24	23	23	25	30	35	37	32	28	27	25	21	19	17
18	23	36	26	25	29	33	37	40	43	39	31	26	23	22	19
18	22	25	28	30	34	45	52	78	59	48	37	30	24	23	26
19	21	26	33	40	39	47	68	89	80	61	51	38	25	23	21
19	22	28	44	42	46	60	103	140	147	95	57	34	25	21	19
20	24	31	37	37	48	96	85	160	303	253	56	33	25	21	19
20	26	38	33	33	41	51	66	84	97	87	47	31	24	20	18
20	26	42	41	38	37	45	55	51	48	41	33	26	22	19	17
20	23	39	74	55	54	46	41	39	36	32	27	23	20	18	16
20	22	33	47	101	96	46	34	31	33	28	25	21	19	17	15

(d)

11	14	20	15	15	22	16	17	19	17	16	16	13	12	11	11
14	17	17	16	17	20	18	18	20	20	21	18	15	14	14	13
15	26	18	17	17	18	19	19	19	20	23	20	16	16	17	15
15	19	23	22	20	21	22	22	21	21	23	30	19	17	16	14
14	21	45	28	27	30	40	39	33	24	26	29	22	16	14	12
15	23	33	29	30	48	48	55	39	29	33	34	29	18	14	12
16	30	32	27	29	32	38	37	35	39	47	36	23	17	14	12
16	20	22	23	23	23	26	24	25	40	81	45	21	16	13	12
15	28	20	18	18	19	25	21	21	29	34	29	20	15	13	11
17	17	17	15	16	17	18	17	17	18	19	18	16	14	12	11

Fig.1-a,b,c,d. Core density maps for $Zo=10g/cm^2$. One of the most simple example is in (a). Typical complicated examples are in (b), (c) and (d).

(a)	(b)
(c)	(d)

22	22	25	28	32	33	35	38	39	38	35	32	29	28	23	21
23	24	26	31	38	39	43	51	63	58	49	38	32	28	25	22
23	25	29	33	38	46	60	80	112	72	54	43	34	30	26	23
24	29	34	36	42	59	102	150	175	105	67	51	39	34	30	25
27	34	41	44	53	76	126	209	240	141	83	76	45	40	41	26
32	33	41	51	64	68	95	158	206	130	126	66	48	47	36	26
26	30	37	41	51	72	78	121	124	140	110	59	45	50	34	25
23	25	29	33	42	63	87	72	69	70	60	47	39	35	30	24
22	24	26	30	35	45	52	54	45	43	41	48	36	29	26	23
20	22	24	27	30	34	37	37	36	35	34	35	31	26	24	21

20	22	25	29	31	33	40	44	42	36	35	32	29	26	24	21
21	26	30	33	35	40	52	81	58	46	42	41	33	27	24	23
22	29	43	37	40	46	66	91	100	59	53	43	34	29	25	23
23	29	35	38	43	53	97	191	129	78	68	54	39	30	26	23
23	28	31	35	47	67	130	286	187	86	65	61	45	33	28	23
23	27	31	36	50	85	135	175	177	91	71	66	49	41	30	24
22	26	31	38	48	63	86	93	102	123	86	53	67	39	35	30
21	24	30	47	40	51	54	68	62	76	54	42	40	35	28	23
20	22	27	31	36	38	47	43	43	42	41	34	31	28	25	21
19	21	23	26	28	31	33	35	35	34	37	30	27	24	22	20

22	24	26	29	33	36	38	43	47	47	40	33	29	27	24	21
24	31	29	32	38	46	50	54	56	51	45	36	31	28	25	22
25	28	32	34	40	56	106	75	69	62	48	38	33	31	26	23
25	27	31	36	44	64	105	120	116	90	53	41	35	31	27	24
26	28	32	38	47	64	138	309	245	104	58	43	36	33	30	25
24	28	33	39	47	60	134	323	213	106	56	42	37	34	33	25
24	28	34	38	51	55	101	139	117	71	50	39	34	31	29	25
23	26	30	34	40	47	55	59	57	52	42	36	33	29	26	23
22	24	28	31	35	39	46	49	46	42	37	33	33	28	24	22
22	24	27	31	33	35	39	43	41	38	33	31	28	25	22	21

22	24	27	33	34	36	40	43	46	45	45	38	35	31	26	24
23	26	30	36	44	45	50	55	59	65	52	47	51	36	29	25
24	27	31	40	69	56	68	90	80	84	81	63	47	44	31	27
25	29	33	41	57	72	96	118	115	122	161	74	49	38	32	27
26	36	34	41	51	76	169	218	210	135	95	88	53	38	32	28
26	30	34	41	52	77	167	351	281	121	91	66	50	38	32	28
25	29	34	40	49	73	115	168	171	102	67	55	52	38	31	27
24	28	32	42	45	52	60	77	99	72	65	48	41	35	29	26
24	26	30	35	39	43	48	56	61	56	48	42	35	31	28	25
22	25	28	31	34	38	40	43	59	44	42	39	34	29	26	23

Fig.1-e,f. Core density maps for $Z_o=50g/cm^2$.
Fig.1-g,h. Core density maps for $Z_o=100g/cm^2$.

(e)	(f)
(g)	(h)

inelasticity is uniform distribution of 0-1.
multiplicity is fixed to 9 and 1/3 of these are pi-zero.
production energy spectrum is exponential type.
transverse momentum distribution is exp(-Pt/Pm),
Pm = 0.4 GeV/c.

Decay of hadrons were not concerned except neutral pion. Atmosphere is isothermal and the scale height is 7.0 km.

3. Results. In the case of Zo=10g/cm^2, almost 50 percent of the cores have multi- and/or complicated structure. On the other hand, scarce cores (10 or less percents) have complicated structure, when Zo=50 and 100g/cm^2.

In Fig.1, typical examples of the core map are presented. The contour lines in the maps are drawn at the densities of (average density of the 16*10 detectors)*2^n, where n=0, 1, and so on. Small sub-peaks are marked by the broken line.

Even in the most simple structured cores, we can find some small scale sub-peaks in the case of Zo=10g/cm^2. There is no examples having well separated multi-core, when Zo=50 and 100g/cm^2.

4. Discussion and Concluding Remarks. Multi-cored EAS was observed at the prominent rate at a mountain altitude (Ref.4). And, the baloon and airplane born EC detected gamma-ray families with large multiplicity, high rapidity density and large transverse momentum. And in the JACEE events the projectiles are identified to He and heavier nuclei.

Our simulation results indicate that these phenomena are closely connected. It can be said that the interaction feature like the gamma-ray families mentiond above and the sufficiently high first interaction point can produce multi-cored EAS at the prominent rate, but steep and simple structured cores scarcely.

References:
1. Ogita, N. et al. Canad. J. Phys., Vol.46, (1968)S164.
   Thielheim,K.O. et al. Acta Physica 29, Supl.3(1970)519.
   Dake, S. et al. Contribution to Workshop on Cosmic Ray and High Energy Gamma Ray Experiments for the Space Station Era, Baton Rouge (1984), and ICR-Report=121-85-2, University of Tokyo, (1985).
2. Burnett, T.H. et al.
3. Iwai, J. et al. Nuovo Cimento A, Vol.69, (1982)295.
4. Kino, S. et al. Rpoc. ICCR, Vol.8, EA(1977)79.
   Sasaki, H. et al. Proc. ICCR, Vol.8 EA(1979)190.
5. Nakatsuka, T. et al. proc.ICCR, Vol.11, (1981)326.