30TH INTERNATIONAL COSMIC RAY CONFERENCE

Partial reanimation of experimental complex ANI at Mt. Aragats (proposal).

SHAULOV S.B.[1], MARTIROSOV R.M.[2], MAMIDJANIAN E.A.[1,2], JONES L.W.[3], SAAVEDRA O.[4], TAMADA M.[5]
[1] *P.N.Lebedev Physical Institute,Moscow, Russia*
[2] *Yerevan Physics Institute, Yerevan, Armenia*
[3] *University of Michigan, Michigan, USA*
[4] *Torino University,Torino, Italy*
[5] *Kinki University,Higashi-Osaka, Japan*
shaul@sci.lebedev.ru

Abstract: We present the proposal for reanimation of the half-built experimental complex ANI at Mt. Aragats (Armenia, 3200 m a.s.l.). It is proposed as a first stage to complete the functioning GAMMA installation by big X-ray emulsion chamber for detailed study of extensive air shower cores at energies $1-100$ PeV. Preliminary data obtained in this filed by the Tien-Shan HADRON installation are presented. This proposal is an EFT and requests creation of an international cooperation.

Introduction.

A most conspicuous feature of the cosmic ray (CR) primary energy spectrum is a distinct change of the spectral index of the power law fall off around 10^{15} eV, called the knee. This feature has been discovered about 50 years ago [1] is still of particular interest. All models and conjectures towards an explanation not only predict the shape of the spectrum and the position of the knee. They imply also specific variations of the elemental composition of the primary cosmic rays, sometimes in a very detailed manner, like in a recent hypothesis of a single near positioned supernova, whose production spectra is considered to be superimposed on the overall galactic contribution. The CR composition and fine structure of the CR energy spectrum are the most important sources of information about the CR origin in this region. It is also undoubtedly that part of the CR with energy more than several PeV must flow out of Galaxy taking into account the value of existing magnetic fields and their inhomogeneity. This process must form the smooth knee in the CR spectrum. At the same time the experimental spectrum has a sharp knee and some fine structure around the knee.

Up to now there are no any model explaining all features of the experimental spectrum. The main disagreements are for the spectra of the different nuclear groups. These data are model dependent. Besides the methods of nuclear composition determination are various for different experiments. Therefore indirect experimental data are admitted the existence of mutually exclusive variants of the spectra form and break position for nuclear groups.

One of the methods for estimation of the primary spectrum (proton spectrum) is an investigation and analysis the extensive air shower (EAS) core at mountain levels using X-ray emulsion chambers (EC). It is confirmed by many calculations that EAS with primary energy $0.1-10$ PeV and with gamma-families at the core are mainly generated by protons because the heavy nuclei decay to its constituent nucleons at the upper layers of the atmosphere. At the same time it is not still clear what is the value of the magnetic rigidity for the knee region (0.1 PV or 3 PV). From this point of view an estimation of position of the knee for the proton energy spectrum will shed light on the mass composition at the knee.

The project ANI [2] was aimed to attack this problem.

The anomalous experimental data at the knee region.

There are a several anomalous experimental results observed at the knee region. Three of them we are discussing below.

1. The first is the Centauro events in EC [3] which were explained by the stable or metastable particles of strange quark matter in primary cosmic rays (PCR) [4].

2. The EAS core investigations using the deep led ionization calorimeter at Tien-Shan leads for detecting long flying component (LFC) among the hadron cascades [5]. This effect was confirmed by the EC data of the Pamir collaboration [6] and by the analysis of the absorption curves for gamma-quanta and gamma-families in the atmosphere [7].

3. The anomalous large number of muons was detected in the EAS with gamma-families [8] in the later investigations of the EAS cores with the EC (162 m^2) exposed together with the Tien-Shan EAS array. Above the knee (at energy > 3 PeV) the average number of muons $< N_\mu >$ for EAS with gamma-families exceeds for 1.5 times $< N_\mu >$ for all EAS, whereas the traditional models predict an opposite effect. This difficulty is dramatized by the increase of gamma-quanta energy at the same region (Fig. 3). The contradiction can not be resolved in the frame of traditional CR composition and interactions.

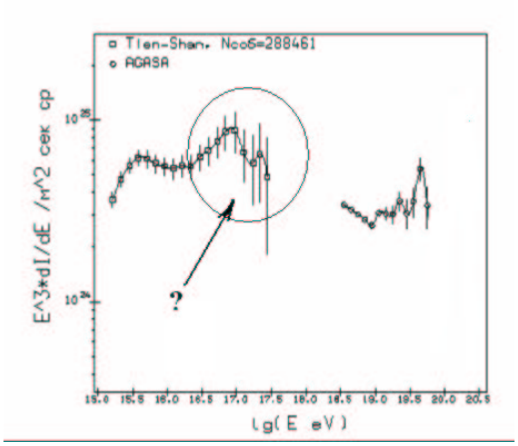

Figure 1: The Tien-Shan and Agasa E_0 spectra.

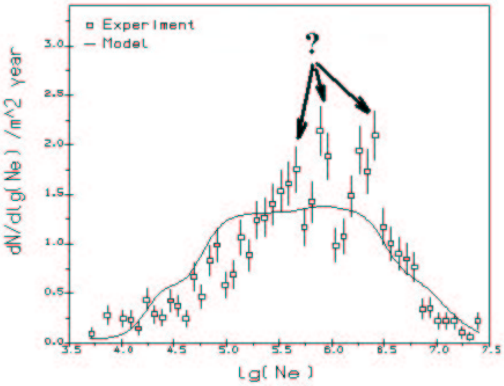

Figure 2: The fine structure of the N_e spectrum for EAS with γ-families.

Of cause it is attractive to interpret above-state data by the SQM hypothesis, but there are a few questions:

- Why this component don't visible at small CR energies? The local energetic spectrum can be received from the model of the near single source of CR [9] ;
- Why only one (or two !?) sources gives the contribution to anomalous CR flux? The absence of many sources contribution could be explained by relatively small life time for SQM (T$\sim$ 10^6 years) [10] in comparison with PCR life time ($T = 10^7 - 10^8$ years).
- Why we don't observe the SQM particles in CR? According to results of [11] using the CR39 the upper limit for the SQM flux was estimated as $I < 2.1 \cdot 10^{-15}$cm^{-2}sr^{-1}sec^{-1}=$6.6 \cdot 10^{-4}$m^{-2}sr^{-1}year^{-1} . This limit is much lower than a possible intensity of the exotic events. Is it mean that the SQM hypothesis is wrong? The main signature of SQM, which was used in [11], is a large electric charge for a single particle of the EAS particle deeply in the atmosphere. But the SQM particle could also be neutral. In this case existence of the SQM particles could be checked searching of the local source.

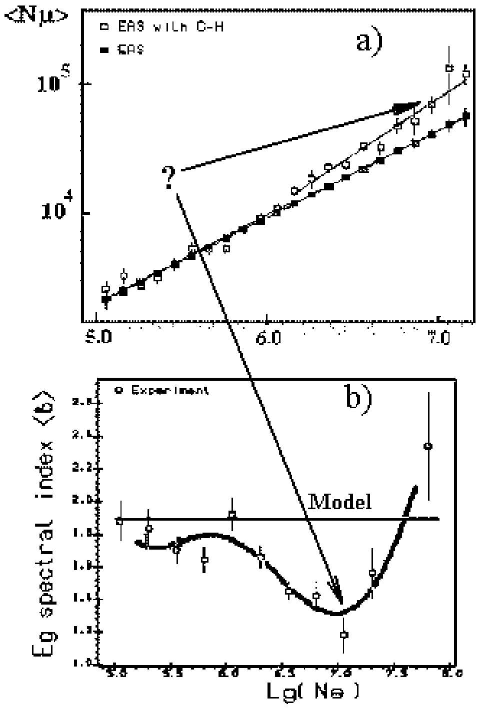

Figure 3: a) The N_e dependence of $< N_\mu >$ for all EAS (solid) and EAS with γ-hadron families (open). b)The N_e dependence of spectral indexes of E_γ spectra in EC .

The aims of the proposal.

Let's formulate some of experimental problems around the knee.

1) The first one is the inverse break in all particle spectrum at energies > 10 PeV (Fig. 1). This inverse break or bump, in a way, could be connected with very young EAS in this energy region [12].

2) The sharp form of the knee and fine structure around knee. The spectrum of EAS with gamma-families has a number of peaks [13], some of them are shown at Fig. 2. The analysis of the fine structure in different EAS experiments can be find in [14].

3) Existing of experimental contradiction between N_e dependencies for $< N_\mu >$ and E_γ spectral indexes b above the knee in EAS+γ data (Fig.3).

The method.

Three factors increase the method sensitivity:

- The installation should be placed in the atmosphere as high as possible;
- To be able for detecting the most energetic particles of EAS core;
- The complex investigation of the all main EAS components.

The EC is unique device with very high spatial resolution ~ 0.1 mm. This EC property allows to measure individual energies of the most energetic particles in the EAS core and to get their spectrum. The slope of such spectrum for iron nuclei (b~ 2) is two times larger of the proton spectrum. This fact allows to develop a new method for study of mass composition independently on muon component.

The nearest plans of the project development.

During a few first years to prepare the EC exposition (90 m^2) in combination with EAS installation and increase this square up to 600 m^2 later.

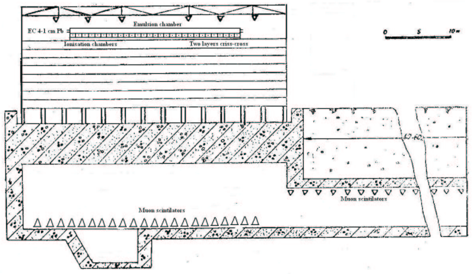

Figure 4: Plan of ARAGATS installation.

The layout of the complex installation is shown at Fig.4 [2]. It consists of EAS installation GAMMA [15, 16, 17] (see photo on Fig. 5) and EC at the top of the half-built concrete calorimeter.

Even the simplest variant of such installation has be an unique for CR investigation at energies 0.1-

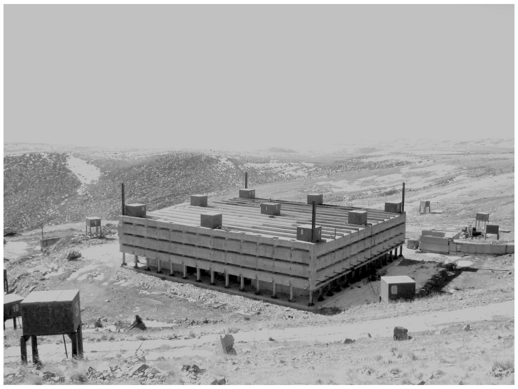

Figure 5: The surface part of GAMMA-installation at Mt.Aragats.

100 PeV because of large underground muon detector.

It is supposed that data of the high-mountain complex installations (Chackaltaya-5200 m.a.s.l., Than-Shan-3300 m.a.s.l.) with a big EC will be also analyzed in frame of this project [18].

References

[1] Kulikov G.V., Khristiansen G.B., JETF, **35, 3(9)**(1958) 635

[2] T.V.Danilova et al., Izv. AN Arm.SSR, physics, 1982, v.17, vip 3-4, p. 129-232

[3] C.M.G. Lattes, Y. Fujimoto and S. Hasegawa, Phys. Rep., **65** (1980) 151

[4] Bjorken J.D., McLerran L.D., Phys. Rev. D, 1979, V. 20, P. 2353.

[5] Yakovlev V.I., Int. Symp. on VHE CRI. Ann Arbor. USA. 1992. P. 154.

[6] Mihailova I.A., Rakobolskaya I.V., Sveshnikova L.G., Strogova O.P., Preprint NIIYF MGU - 88-014/33, Moscow 1988

[7] Shaulov S.B. et al., Preprint FIAN, N10, 1999, p. 1-30

[8] S.B. Shaulov, Heavy Ion Physics **4** (1996) 403-422.

[9] A.D. Erlykin, A.W. Wolfendale, Astroparticle Physics 7 (1997)1-13, 203-211

[10] E. Keith, E. Ma, Heavy Ion Physics **4** (1996) 381-386

[11] Saavedra O., Int. Simp. VHE CRI, China, Weyhay, 2006

[12] Shaulov S.B., Preprint FIAN, N7, 1999, 1-15

[13] Krutikova N.P., Shaulov S.B., Izv RAN, ser. phys., 1999, v. 63, N3, p. 477-480

[14] A.D. Erlykin, A.W. Wolfendale, J. Phys. G: Nucl. Part. Phys. **23**(1997)979-989

[15] S.V. Ter-Antonyan et al., 29th ICRC, Pune, HE1.2 6 (2005) 105

[16] Y.A. Gallant, A.P. Garyaka, L.W. Jones et al., Proc. 20th ECRS, Lisbon (2006) (in press)

[17] A.P. Garyaka, R.M. Martirosov, S.V.Ter-Antonyan et al., Accepted in Astrpart.Phys. (2007), (arXiv:0704.3200v1(astro))

[18] M. Tamada, Int. Symp. VHE CRI, Tokyo, 18 - 12 October,(1991) 263