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A study of Primary Mass Composition by XREC method at the energies 10-100 PeV

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It is presented the results of Primary Cosmic Ray (PCR) Mass Composition analysis performed on the basis of Pamir Collaboration X-Ray Emulsion Chambers (XREC) data. A number of selection criteria of gamma – families imitated by primary protons and nucleus are considered. Obtained results are in agreement with "normal" PCR composition slowly enriched by heavy nucleus above 10 PeV.

1. Introduction

The determination of the Primary Mass Composition (PMC) is very important problem to the reliable interpretation of the XREC experiment data about hadron – nucleus strong interaction characteristics.
According to some data obtained by XREC ~85% gamma-families with visible energies ΣE_γ>100 TeV originated from primary pA interaction. However, it is necessary to note, that registration efficiency of A-families produced by primary AA-interaction considerably lower than for P-families originating from PA-collisions because energy dissipation in AA-interactions is more higher. At the primary energies E_0 < 10 PeV a fraction of the A-families is rather small (20%<), but this value rapidly increase at the E_0 ~ 100 PeV.
Tashkent group has proposed the different selection criteria of gamma-families initiated by primary pA and AA interaction in XREC [1].

2. Method

For the PMC determination it was proposed method of comparison the energy dependence of the registered events fraction, satisfied to the definite selection criteria, with models, simulated on the different suppositions about PCR composition. As a result, it was shown that Pamir experimental data are in agreement with supposition about "normal" PCR mass compositions slowly enriched by heavy nucleus at the energies above 10^{16} eV.
To select of gamma-families mainly initiated by primary PA-interactions the following family characteristics were used:
$E_{in} = \Sigma E_\gamma / n_{in}$, $d = n_\gamma / n_{in}$, R_{1E}, $\chi_R = \Sigma E_\gamma / R_t$,
where $\overline{E_{in}}$ – average energy of family, n_γ, n_{in} number of of observed and initial quanta, $R_t = \Sigma R_{in}$, R_{in} and R_{1E} – a distance of the initial quanta and quanta with the highest energy particle E_{1E} on family center.
The families were subjected to the electromagnetic "decascading" procedure. Pair family particles satisfied the condition $Z_{ik}<Z_0$=10 TeV mm, (where $Z_{ik}=R_{ik}(1/E_i+1/E_k)^{-1}$, R_{ik} is a distance between the particles, E_i, E_k- their energies), were united into initial quantum. Thus the observable γ-families are transformed in the initial families. After that, initial families were further subjected to "rejuvenation" procedure: the quanta satisfied the condition: $f' = E_{\gamma i} / \Sigma E_{\gamma i} \geq f'_{min} = 0.04$, i.e. particles with energy $E_\gamma^{min} \geq 0.04\ \Sigma E$, were included in the family with n'_{in} initial, rejuvenated particles.

Estimated primary energy E_{est} was founded by using correlation relation:
$\lg E_{est} = A+B \lg(n_{in}, C)$,
where the coefficients A and B were derived from comparison with MCO model, $C= n_{in}/n'_{in}$;

3. Experimental results

Pamir experimental data consisted of $N_0 = 807$ families with observed energies $\Sigma E_\gamma = 100$-2000 TeV, number of particles $n_\gamma \geq 4$ and minimal energies $E_\gamma^{min} \geq 4$ Tev, $n_{in} = 6$-70 selected within a circle of radius $R_0=20$ sm are analyzed.
Experimental data are compared with MCO Quark-Gluon String model that gives a good description as accelerator data as Cosmic Ray results in energy region $E_0<10$ PeV [2]. The MCO - model was simulated at the suppositions about "normal" (PCR) composition (28% P, 18% α, 27% Fe) enriched by heavy nucleus with energy increasing at the energies above 10^{16} eV.
In XREC experiment it is registered $N = N_P + N_A$ number of events, consisting from N_P (proton P) and N_A (nucleus A) families. After using above mentioned selecting criteria number of selected events will be equal: $N^{cr} = N^{cr}_P + N^{cr}_A$, where N^{cr}_P and N^{cr}_A – number of P and A selected families. The value of fraction P – families, registered by XREC at the Pamir mountain level, is obtained from correlation:
$\Delta_p = \Delta^{cr}(1-\Pi_A)/\eta_p$,
where $\Delta^{cr} = N^{cr} / N$, $\eta_p = N^{cr}_P / N$ – selected P – family fraction (criterion "efficiency"), $\Pi_A = N^{cr}_A / (N^{cr}_P + N^{cr}_A)$ background A – families fraction between total selected events ("admixture"). The criterion parameters η_p and Π_A is derived from MCO – model. According to [1] weak dependence of these parameters on a wide set of models are obtained.
Fig.1. presents the experimental dependence of the registered P – family fraction Δ_p on the primary energy E_{est} by means of using selection criteria: $\boldsymbol{d \rangle 0{,}8 \bar{d}}$ and $\boldsymbol{\chi_R} > 0{,}4\, \boldsymbol{\bar{\chi}_R}$
(Fig.1a) black and white points)and $R_{1E}<0{,}9\, \boldsymbol{\bar{R}_{1E}}$ and $\boldsymbol{E_{in}} > 0{,}7\, \boldsymbol{\langle \bar{E}_{in} \rangle}$
(Fig.1b)crosses and triangles). As can see from fig.1 at the energies $E_{est} = 10$-20 PeV the experimental values $\boldsymbol{\Delta_p^{exp}} \sim 70\%$. At the same time these values obtained at the energy $E_{est} \sim 70$ PeV is essentially less and consist of 30-40 %. At that P- family fraction derived from MCO – model $\Delta_p^{mod} = 50$ % at the same energy.

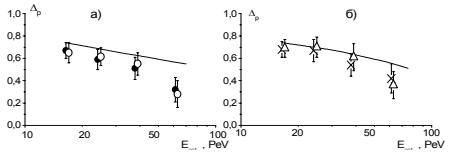

Figure.1 The dependence of event fraction ΔN ($\chi_R<0{,}45\ \boldsymbol{\bar{\chi}_R}$)/N satisfying to criterion $\chi_R<0{,}45\ \boldsymbol{\bar{\chi}_R}$ on value of $n_{in}C$ and family energy ΣE_γ . ●-exp., - - - Primary nucleus A, ——- Primary protons P, - x - -normal, -•- - heavy Mass Composition (HMCO-model).

Thus, the fraction of registered by XREC gamma – families, originating from primary PA – interaction, consist of ~ 70 – 80 % at the energies ~10 PeV and essentially decrease up to value $\Delta_p^{exp} = 30$-40 % at the energy $E_{est} \sim 70$ PeV.

References.

[1]Yuldashbaev T.S. et al, Nucl. Phys., B (Proc. Suppl.), 1999, 75 A, p.153.
[2]Muchamedshin R. Proc. 24th ICRC, Roma, Vol. 1, 1995, p. 347.