ON THE ENERGY SPECTRA PUBLISHED BY THE GAMMA GROUP IN 2001 AND 2002 AND PRESENTED IN 2004 on YerPhI seminar

Ashot Chilingarian,

June 14, 2004

What we are measuring – All Particle Spectra

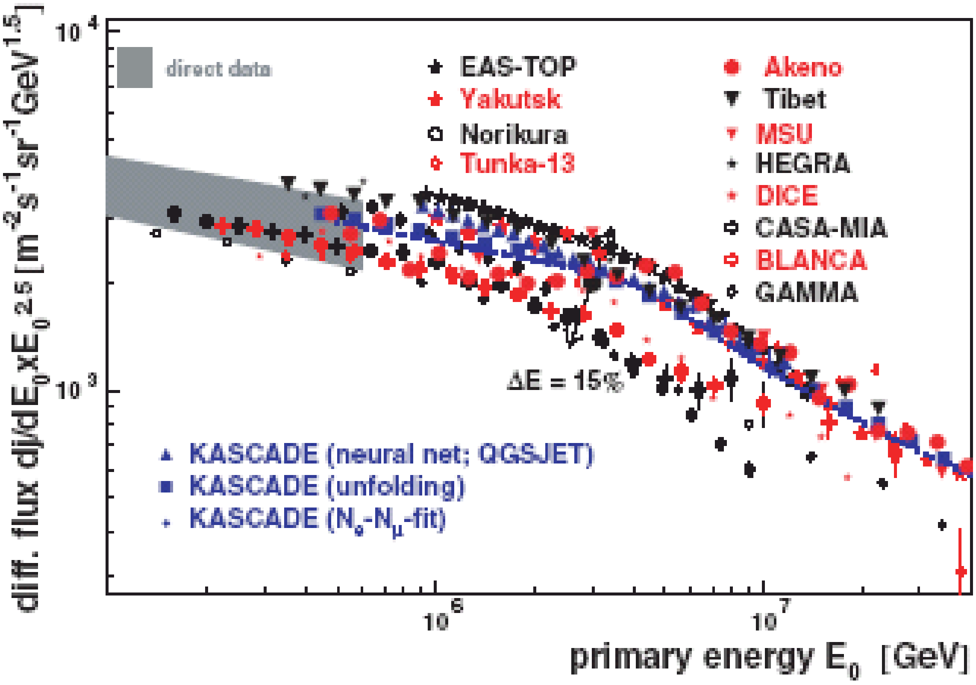

Figure 1 Compilation of different experimental results on the cosmic ray all-particle energyspectrum around the knee (from Haungs et. al, 2003). The effect of a 15% uncertainty inenergy reconstruction is indicated by 2-sided arrow.

Proceedings of ICRC 2001: 273 c Copernicus Gesellschaft 2001

New way for determination of the primary cosmic ray energy spectrum around the knee with the GAMMA array at Mt Aragats

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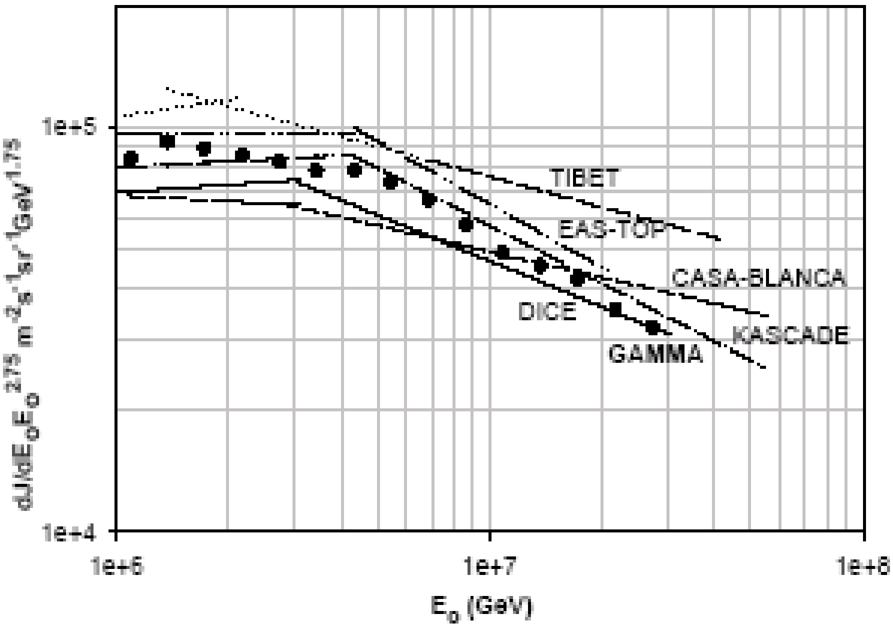

Fig. 3. Primary energy spectrum

Figure 2 GAMMA energy spectra from 2001

The primary energy E_0 is obtained using the experimental values of $\alpha_{exp}(70)$ and coefficient K=5.18 10^3. The errors of E_0 are the sum of errors of the method itself and of the experimental errors on the $\alpha_e(70)$ and S determinations. The correctness of E_0 strongly depends on $\sigma(S)/S$, which decreases with Ne. The accuracy of the E0 is ~25% around the knee. Figure 2 presents primary energy spectra obtained with GAMMA array in comparison with schematic approximations of results from some other experiments. Before the knee our spectrum is steeper then others and its slope is in agreement with the most of them after with **$\gamma \sim 3.20 \pm 0.1$** It can be seen that our spectrum after the knee is very close to the data of the KASCADE experiment.

5 Conclusion

In this way using the GAMMA array experimental data we have shown the applicability of a new primary energy estimator $\alpha(70)$ for the determination of the primary energy spectrum in the range 10^{15}-3 10^{16} eV. Obtained by this manner, the primary energy spectrum **doesn't contradict results from other experiments**. The showers selected by _(70) criterion have isotropic angular distribution. The presented energy spectrum is the spectrum of all kind of primary particles (nucleus) and obtained without any hypothesis about the primary mass composition, but on the assumption of deficiency of the strong hadron-nuclei interaction sharp changes. As a next step we plan to estimate mass composition of the primary cosmic radiation in this energy region using the multi-parameter analysis of EAS components.

A.P.Garyaka, R.M.Martirosov et.al., The Cosmic Ray Energy Spectrum Around the Knee Measured with
the GAMMA Array at Mt. Aragats,
J.Phys.G:Nucl.Part.Phys. 28(2002), pp.2317-2328.

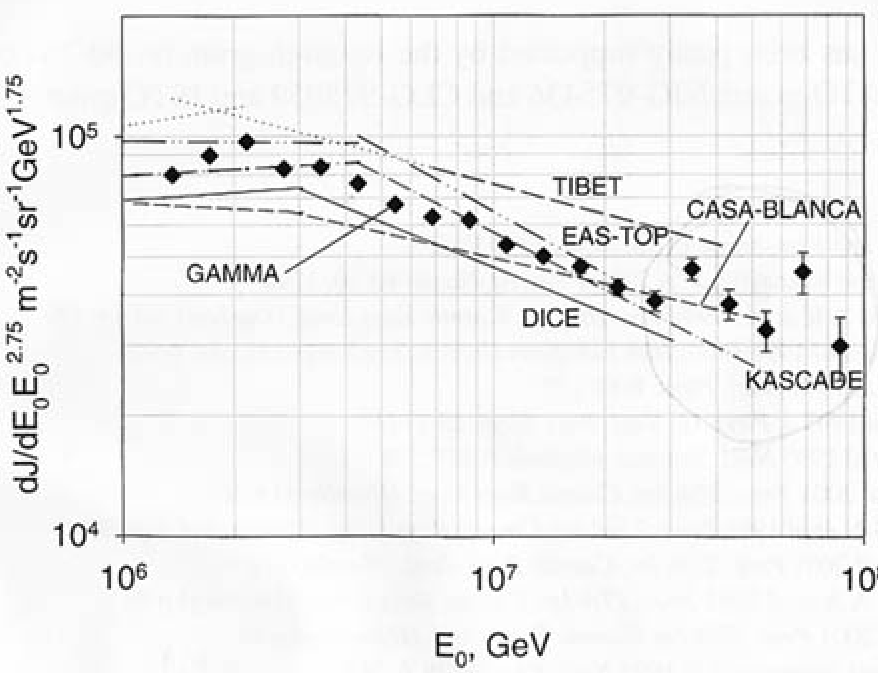

Figure 10. The primary energy spectrum in comparison with results from other experiments. The lines are fitting data of different experiments (see compilation in [22]). The bars are the statistical errors.

Figure 3 GAMMA energy spectra from 2002

Figure 10 presents the primary energy spectrum obtained with the GAMMA array in comparison with schematic approximation of results from some other experiments. **We would like to underline that the bumps observed at 3 x 10^7 GeV are not connected to any methodical effects.** Before the knee our spectrum is steeper than others. However, because the number of points are few, any definitive conclusion would be meaningless. After the knee its slope is in agreement with most of them with $\boldsymbol{\gamma \sim 3.10 \pm 0.1}$. It can be seen that our spectrum after the knee is very close to the data of KASCADE experiment.

5. Conclusions

Using the GAMMA array experimental data, **we show the applicability of the new primary energy estimator for determination of the primary energy spectrum**. **Obtained in this manner, the primary energy spectrum does not contradict the results from other experiments**.

The primary energy spectrum as obtained with extended statistics at the GAMMA array on Mt. Aragats*

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The energy spectrum

More than 1.000.000 showers with $N_e > 10^5$ within $\theta<30^0$, registered by GAMMA array during ~ 15.000 hours of operation, was used for analysis to obtain the primary energy spectrum at 10^{14}-10^{17} eV

In figure 3 the all-particle energy spectrum is presented. At the same figure schematic images of energy spectra obtained with several other installations are also shown.

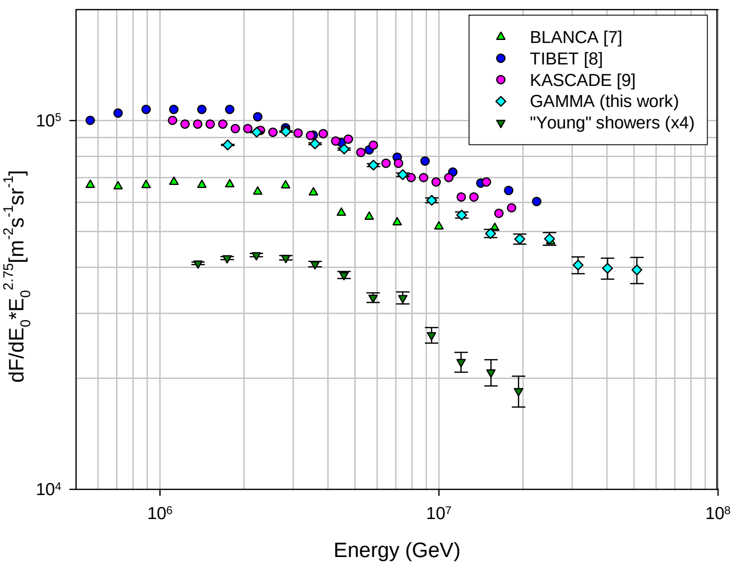

Figure 4 GAMMA energy spectra from 2004

One can see that our results are in a good agreement with data of KASCADE experiment. The spectral index after the knee is –3.1. At energy more than 30 PeV the spectrum becomes more flat. Such tendency is resided to all periods of data set.

The reason of the knee origin is associated with energy spectra of different type of the primaries. Using dependence $S_{NKG}^P = f(E_0)$ for proton obtained from CORSIKA simulation the

* http://crdlx5.yerphi.am/news/seminars/Energy_spectra.pdf

showers with $S_{NKG} < \langle S_{NKG}^{P} \rangle - \sigma S_{NKG}$ have been selected. Naturally the concentration rate by protons will increase with σS_{NKG} increasing. We used $\sigma S_{NKG}=0.07$. At that the portion of selected showers at knee region made up 12%. The spectrum of the selected by this way showers (multiplied by 4) is shown also in fig. 3. The break of spectrum is at the same energy as for the all-particle spectrum but spectral index **is –3.3**. Such behavior of spectrum is typical for predictions in the knee models with smooth change of the primary mass composition.

5. Conclusion

With help of the α-parameter using the extended simulated and experimental data the all-particle energy spectrum as well spectrum for "young" showers in the knee region were obtained. **Our data don't contradict to the spectra of other experimental results**. Energy spectrum for "young" showers generated for the most part by protons is also obtained. The behavior of this spectrum is in accord with predictions of smooth change of the primary mass composition.

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Only physical inference from GAMMA group spectra published in 2001-2002 and presented to the YerPhI seminar in 2004 is - **Our data don't contradict to the spectra of other experimental results-.**

But as we can see from the figures 1 and 2 GAMMA spectra2001 is much steeper comparing with world data;

GAMMA spectra2002 is less steeper, but contained bumps in high energy region, climbed to be of non-methodical nature;

GAMMA spectra2004 didn't contain any bumps and is very hard at high energies.

So, which of GAMMA spectra don't contradict to the other experiment data.

And, how GAMMA group can compare their data with other experiments if they didn't publish in these 3 works the spectral slope before knee and the knee region itself.

Possible explanation of mentioned contradictions lies in not correct account for all complicated method errors arise in the EAS experimentation. Without detailed investigation of the systematic uncertainties arising from the EAS parameter reconstruction procedures it is very difficult to find the source of discrepancy. We can point also on another result from GAMMA experiment (Daryan et.al., 2001) on energy spectra differing significantly from world data at high energies, from (Haungs, et.al., 2003). Therefore, we recommend to perform full cycle of the checks of reconstruction procedures, as we start for the MAKET experiment (Hovsepyan, Melkumyan et.al., 2003). Below we outline some necessary steps should be done before estimating the energy spectra from the EAS experiments. We highly recommend to GAMMA group include in simulation the response function of the GAMMA detector, investigate the size spectra and its angular dependence, and only then estimate energy spectra.

Methods of the Energy Estimation

Perform simulation experiments and calculate detector response function

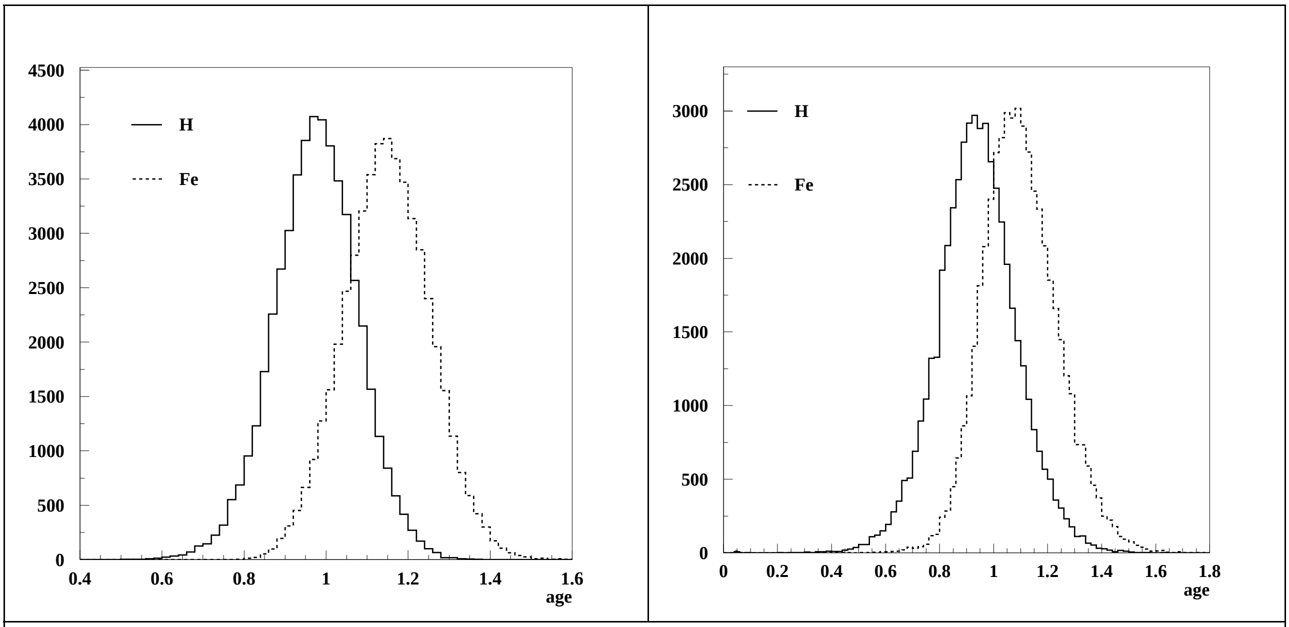

Figure 2 Shower Age distribution for simulated light and heavy primaries with (right) and without (left) incorporating of detector response.

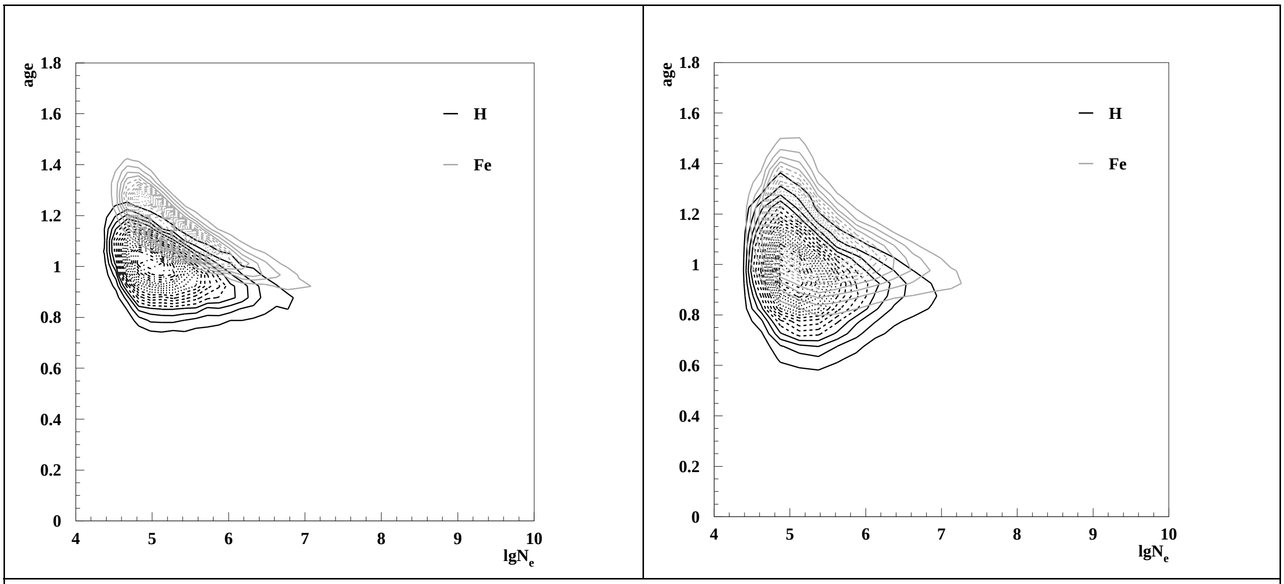

Figure 3 Scatter plot Shower Age versus Shower Size for simulated light and heavy primaries with (right) and without (left) incorporating of detector response.

Investigate from simulations which EAS parameters are correlated with primary energy

	lnE_0	lnN_e	S
lnE_0	1.00	0.99	-0.22
lnN_e	0.99	1.00	-0.31
S	-0.22	-0.31	1.00

	lnE_0	lnN_e	lnN_μ^{tr}	S
lnE_0	1.00	0.96	-0.98	-0.06
lnN_e	0.96	1.00	-0.97	-0.20
lnN_μ^{tr}	0.98	0.97	1.00	-0.11
S	-0.06	-0.20	-0.11	1.00

Calculation of RMS deviation of different Energy estimators

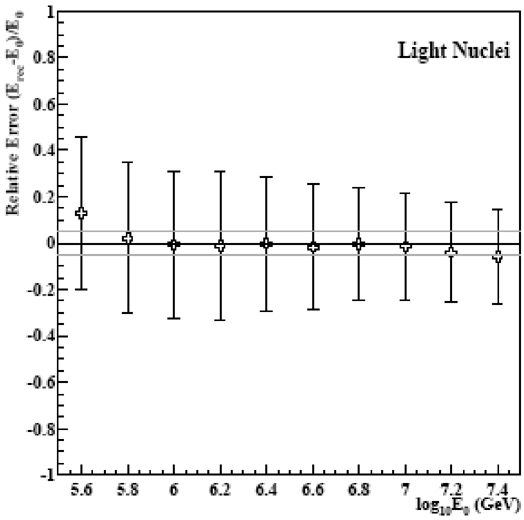

Figure 3: *Primary energy estimation of light nuclei (H,He) (MAKET)*

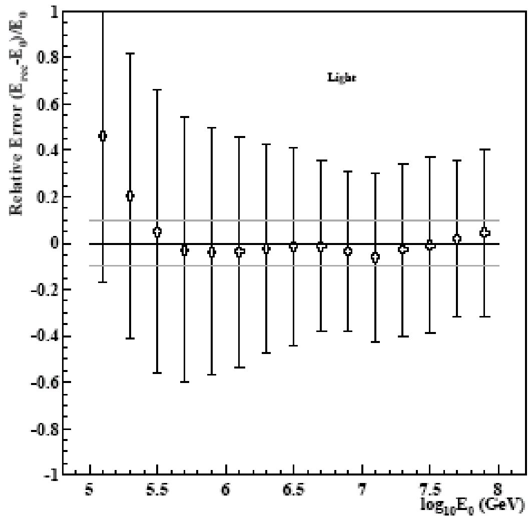

Figure 4: *Primary energy estimation of light nuclei (H,He) (KASCADE)*

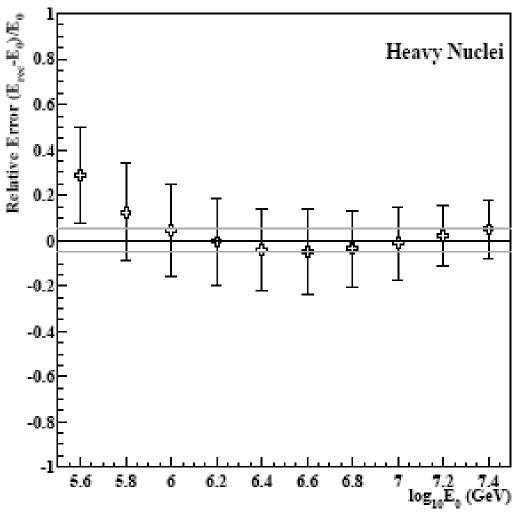

Figure 5: *Primary energy estimation of heavy nuclei (Si,Fe) (MAKET)*

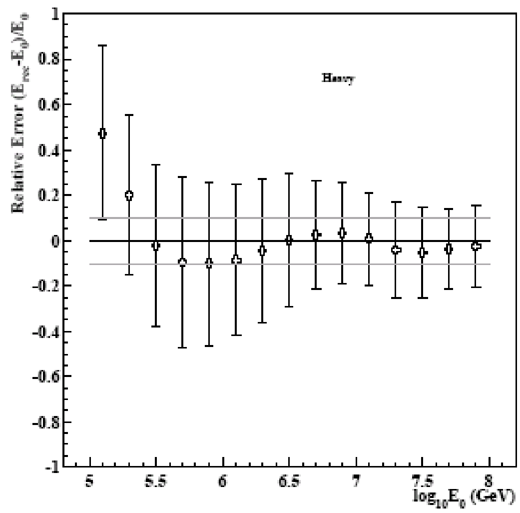

Figure 6: *Primary energy estimation of heavy nuclei (Si,Fe) (KASCADE)*

Comparison of the size spectra with world experiments

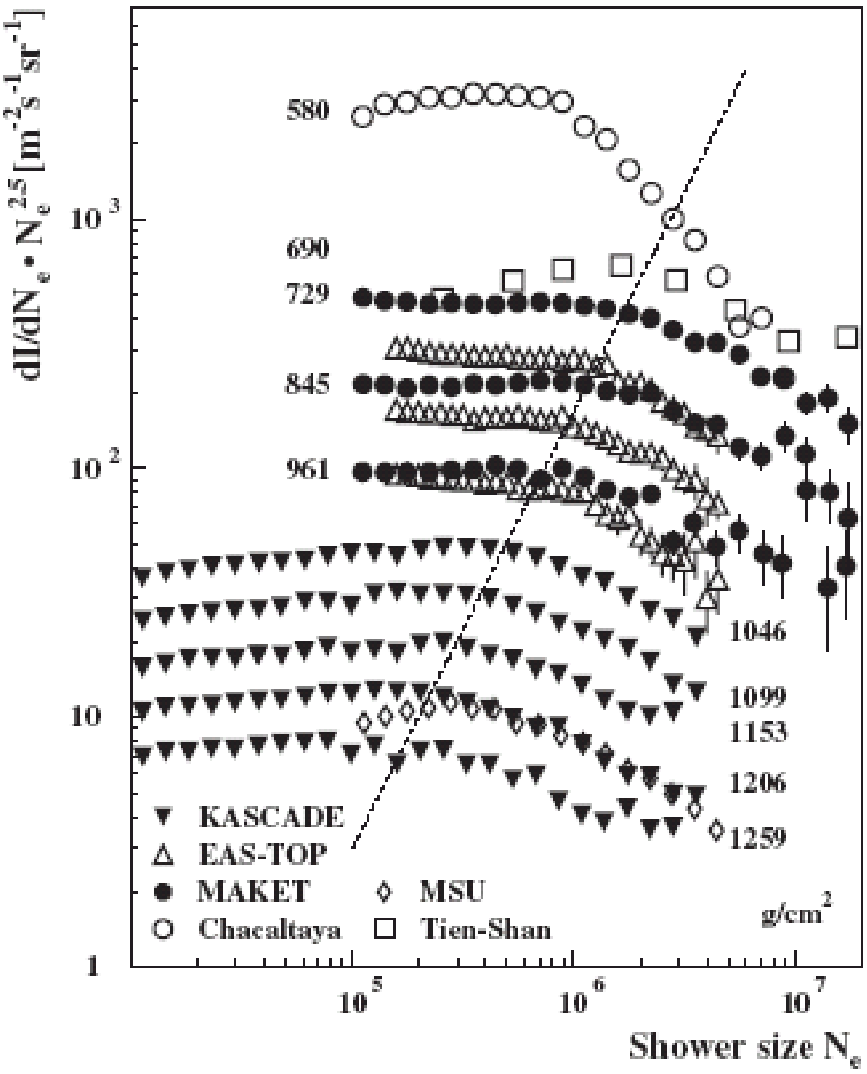

Figure 7. Shower size spectra observed in various experiments located at different altitudes and with different angles-of-incidence (indicated by the atmospheric grammage). The line is guiding the eyes to the knee positions in the spectra (KASCADE [66], EAS-TOP [67], MAKET [68], Chacaltaya [69], MSU [28], Tien-Shan [70]).

Recent comparisons of the size spectra measured by different detectors are performed by G.Schatz (Schatz, 2003) and we can also refer the rapporteur talk of Todor Stanev at SLC Cosmic Ray Conference (Stanev, 2001).

In all mentioned papers very good agreement of MAKET-ANI and KASCADE experiments were emphasized, as firm basis for the further physical inference on the energy spectra of primary CR.

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