Why the knee at 100 PeV could not be seen?

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Astrophysical approach

The astrophysical origin of the "knee" in primary cosmic ray spectrum in PeV region is very popular and is widely exploited in practice for a long time of about 50 years. A lot of models try to explain the "knee" by the existence of different CR sources.

But, experimental data accumulated up to now in cosmic ray physics seed some doubt to the "knee" existence in primary cosmic ray spectrum (see Yu.Stenkin, 29ICRC, 2005).

1. What gave us recent experiments?

- Tibet AS vs KASCADE (KASCADE-GRANDE)

Both gave many interesting results.

But, their data contradict each other!

The problem of the "knee" is still open!

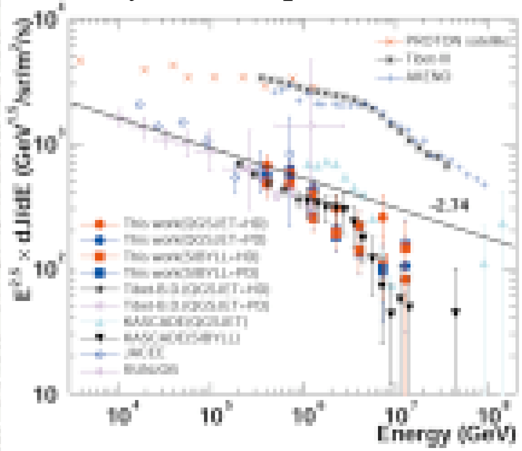
Moreover, it become even more unclear….

(see G. Schatz. Proc. 28th ICRC, Tsukuba, (2003), 97;
Yu. Stenkin. Proc. 29th ICRC, Pune (2005), v.6, 621;
M.Amenomori et al. Astrophys. J, (2008), v.678, 1165)

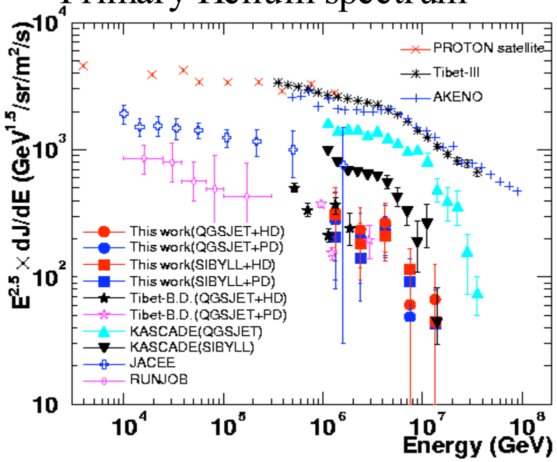
P, He by Tibet hybrid Experiment

(Phys. Lett. B, 632, 58 (2006))

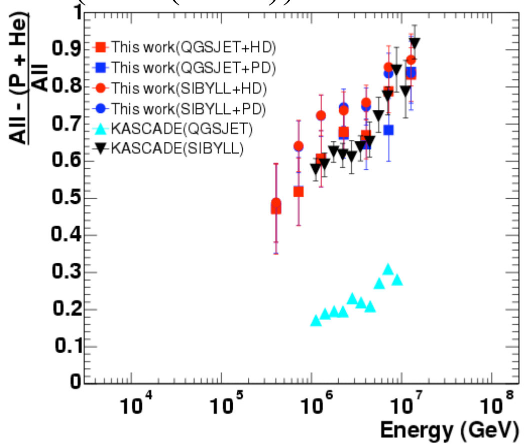
Primary Proton spectrum



Primary Helium spectrum



(All - (P+He)) /All



Conclusion: 1)Our results show that the main component responsible fo knee structure of the all particle s is heavier than helium nuclei.

Tibet ASγ used hybrid method and that is why it can really select ligth primaries. We do believe their result.

But, KASCADE associate the knee with proton primaries...

Investigating the 2^{nd} knee: The KASCADE-Grande experiment

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Abstract. Recent results from the multi-detector set-up KASCADE on measurements of cosmic rays in the energy range of the so called "first" knee (at $\approx 3\,\mathrm{PeV}$) indicate a distinct knee in the energy spectra of light primary cosmic rays and an increasing dominance of heavy ones towards higher energies. This leads to the expectation of knee-like features of the heavy primaries at around 100 PeV. To investigate this energy region KASCADE has recently been extended by a factor 10 in area to the new experiment KASCADE-Grande. Main results of KASCADE as well as set-up, capabilities, and status of KASCADE-Grande are presented.

Cosmic Rays from the Knee to the Highest Energies

Johannes Blumer, Ralph Engel, and Jorg R. Horandel

arXiv:0904.0725v1 [astro-ph.HE] 4 Apr 2009

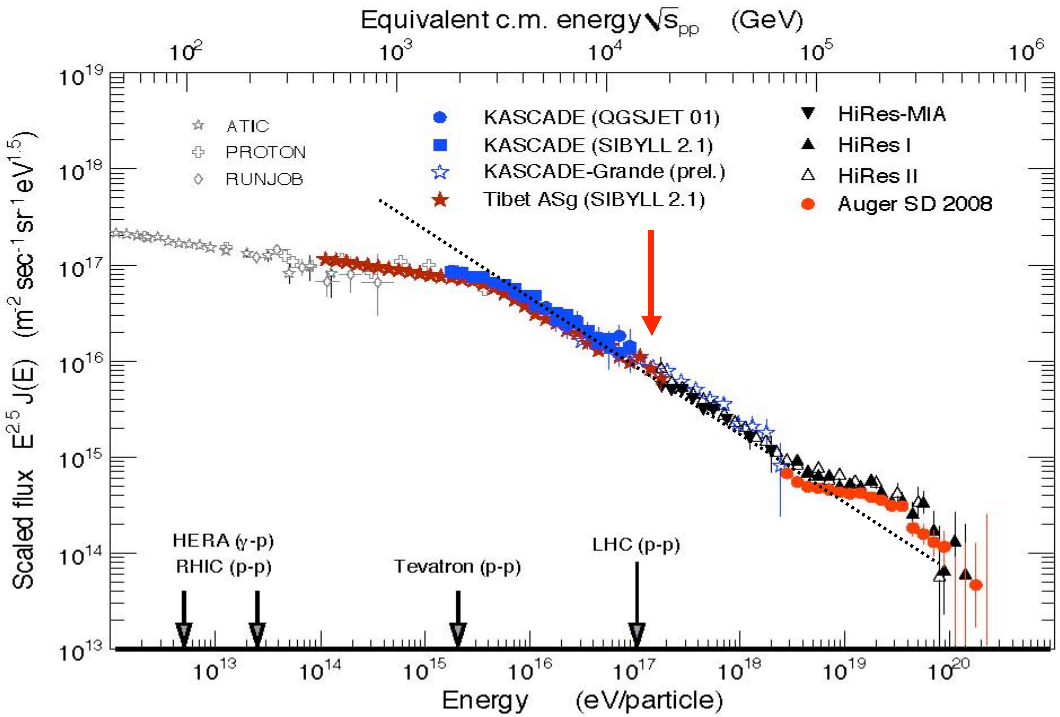

Figure 7: All-particle cosmic-ray energy spectrum as obtained by direct measurements above the atmosphere by the ATIC [280, 281], PROTON [282], and RUNJOB [284] as well as results from air shower experiments. Shown are Tibet ASγ results obtained with SIBYLL 2.1 [285], KASCADE data (interpreted with two hadronic interaction models) [286], preliminary KASCADE-Grande results [287], and Akeno data [288, 42]. The measurements at high energy are represented by HiRes-MIA [289, 290], HiRes I and II [291], and Auger [221].

But, where could one see the «knee» in a case if visible one is connected with iron primaries (if Tibet AS is correct)?

Sure, it could be seen to the left from PeV rigion!

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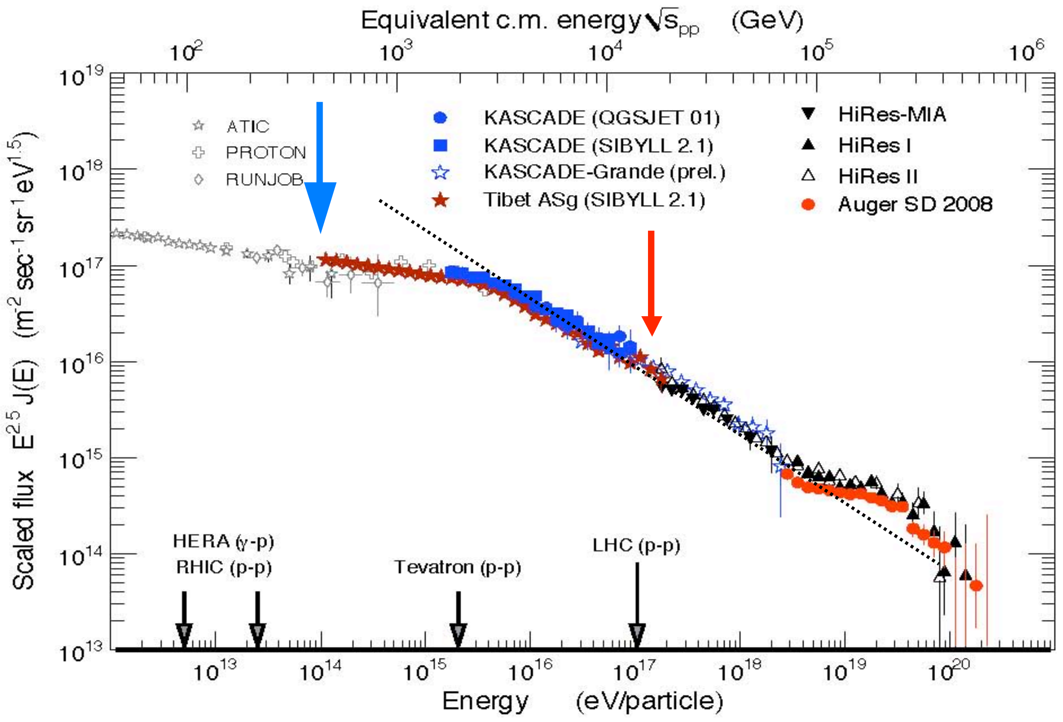

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A. Haungs, J.Kempa et al.(KASCADE) Report FZKA6105 (1998).

6 Spectral Variations of Shower Samples of Different Mass Classifications

This is their old but correct paper on my opinion

$\Delta\beta \approx 0.4$

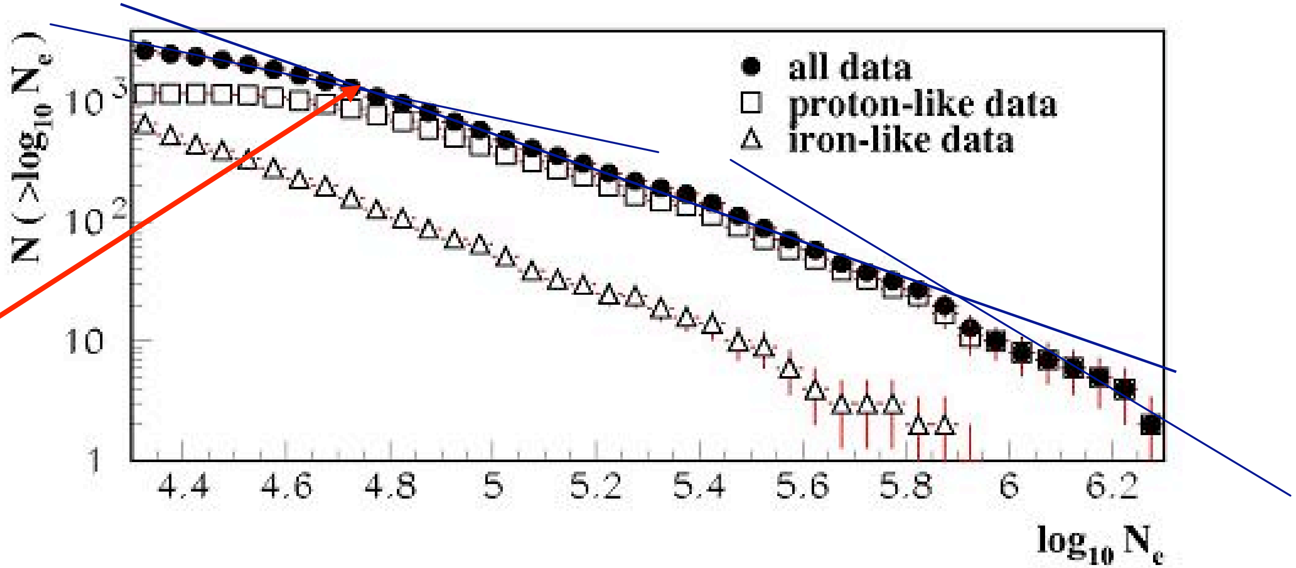


Figure 13: *Integral spectra of the shower size N_e for all, for proton-like and for iron-like measured showers.*

F.Arqueros , J.A.Barrio   et al. (HEGRA-Collaboration).
Astron. Astroph. 359, 682-694 (2000)

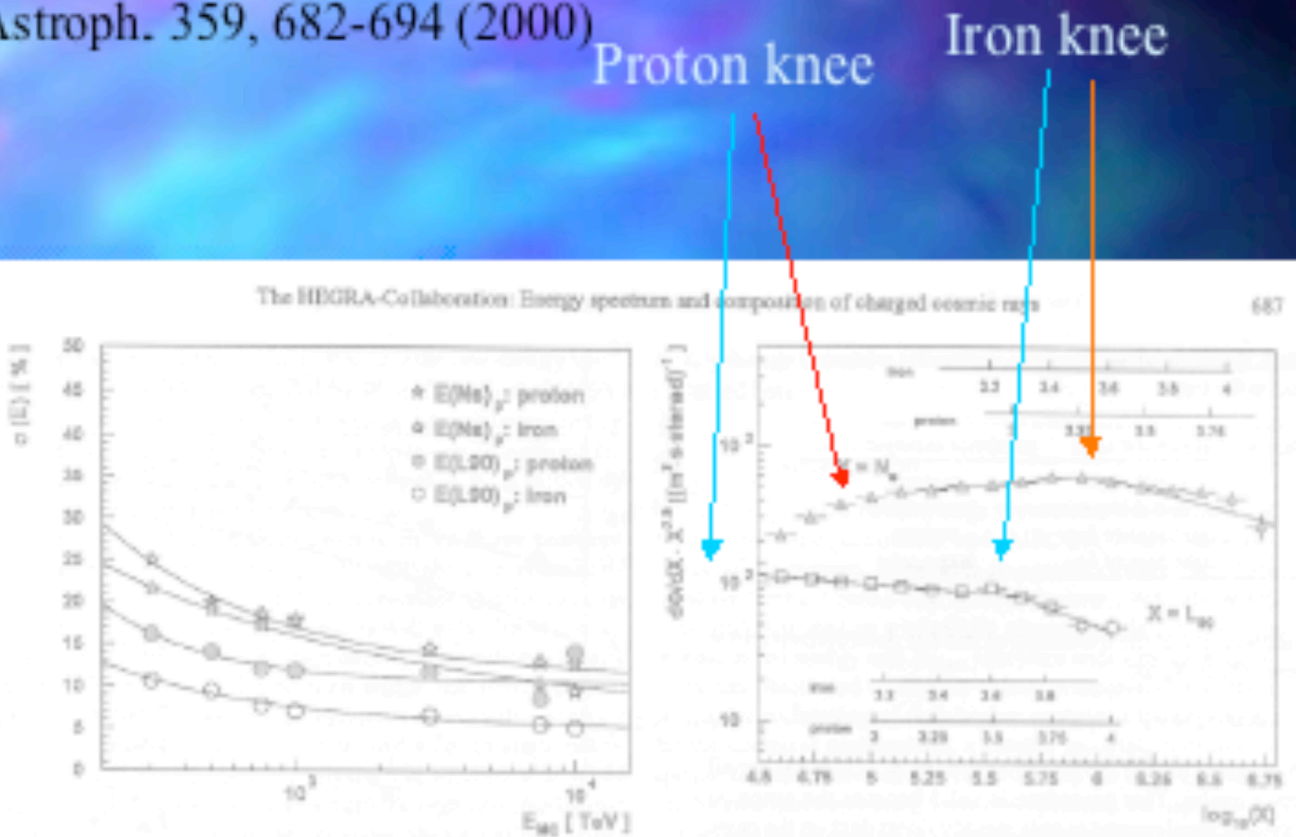


Fig. 4. The energy resolution obtained for different primary nuclei as a function of the generated MC energy. N_e in brackets denotes an energy reconstruction that combines the measured shower size at detector level and slope, L_{90} denotes the results obtained from the Cherenkov light density alone. The energy reconstruction was always performed assuming that the primaries are protons (referred to as methods 1 (stars in the figure) and 3 (dots in the figure) in the text; this fact is symbolised by the subscript "p" on the energy). The "proton" (filled symbols) "iron" (open symbols) after the colon indicate the primary for which the energy resolution was determined. The lines show fits used for convolution procedures to determine the final results (see text).

Fig. 5. The differential shower-size spectrum and "light-density at 90 m core distance (L_{90})" spectrum. The values used for the construction of these spectra, were employed for the energy reconstruction. The full lines indicate the best fit in the range 5.3–6.8 and 4.5–6.1 for N_e and L_{90} respectively. Two power laws which meet in a single flux value ("the knee") were assumed. The best-fit power law indices are (-2.35/-2.92) and (-2.61/-3.13) (before/after) the knee at a position of $\log_{10}(N_e)/\log_{10}(L_{90}) = 5.99/5.64$ for the shower size/light density respectively. The energy scales were derived under the assumption that the primaries are all protons, resp. iron nuclei for shower size (upper scales) and light density (lower scales).

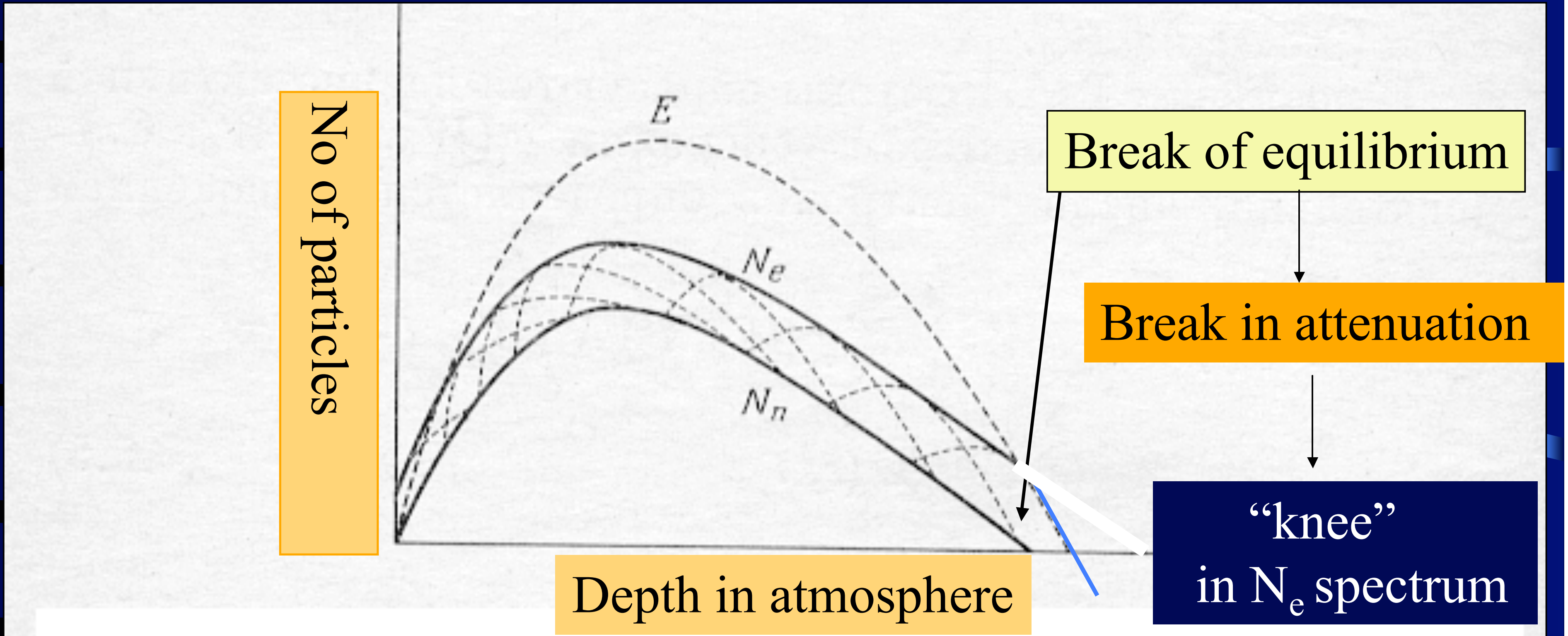
Phenomenological approach

Proposed in: Yu. Stenkin. Mod. Phys. Lett. A, **18**, 1225 (2003)

The idea is:

Primary spectrum follows pure power law $\sim E^{-\gamma}$. The «knee» visible in the EAS e-m component ($\sim N_e^{-\gamma/\alpha}$) is caused by a break of equilibrium between the main hadronic and secondary e-m components in a point where the number of cascading hadrons becomes close to 1 and then to 0 results in a break of α in a function $N_e(E_0) \sim E_0^{\alpha}$.

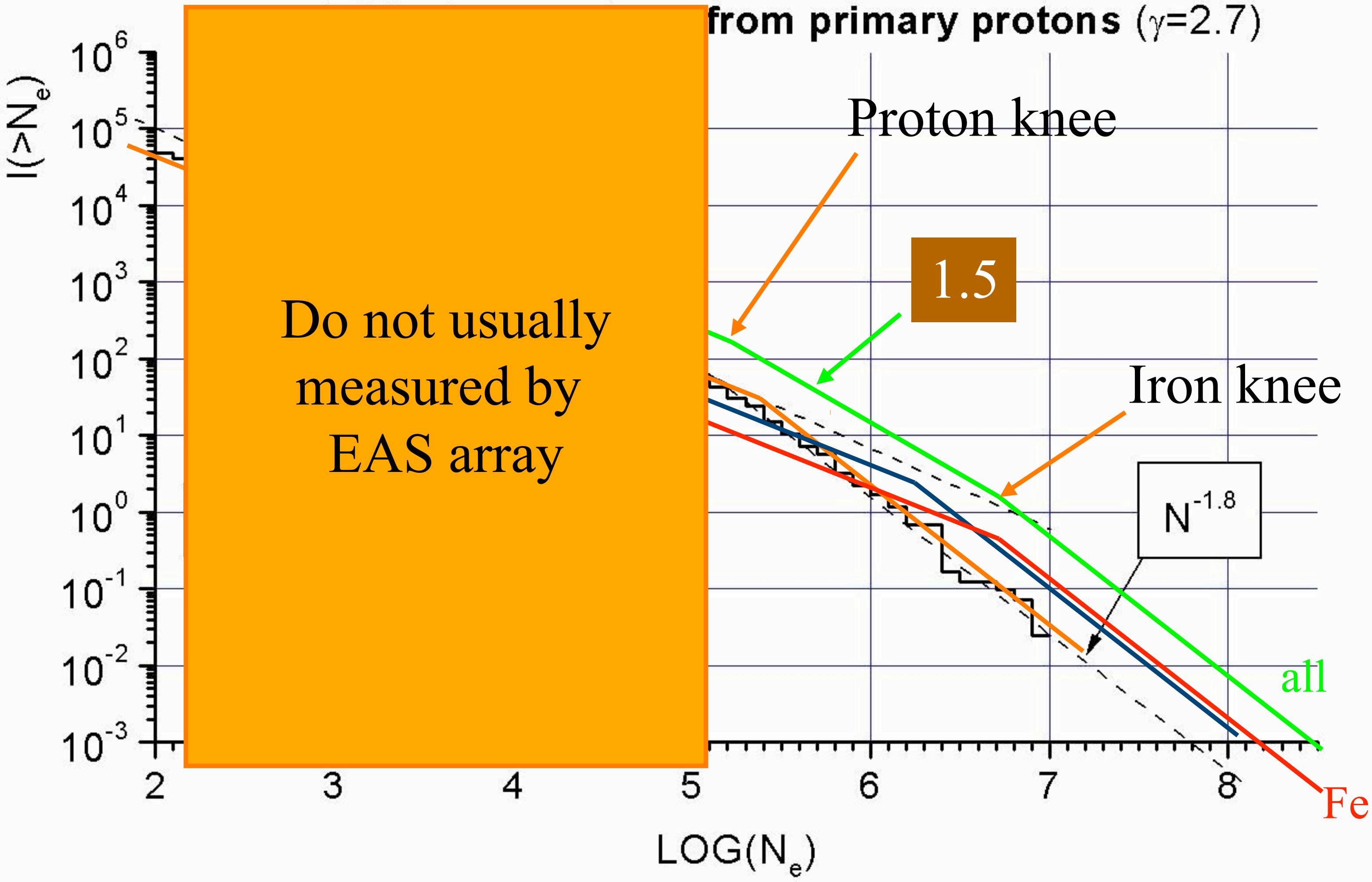
EAS components equilibrium



From Hayakawa manual on cosmic ray physics

Because primary c.r. masses are spread between 1 and 56 and effect depends on Eo/nucleus, then:

Monte-Carlo simulations with CORSIKA program (v.6012), X=1.7Km



Predictions of the phenomenological model

<u>This model predicts:</u>

- the knee should occur at almost equal N_e
- first “knee” should be $\Delta\beta \sim 0.35$ at $N_e \sim 10^{4.8}$
- second “knee” should be $\Delta\beta \sim 0.4$ at $N_e \sim 10^{6.3}$

Therefore, it predicts the position and absolute value of the knee!

The only way to clearify the stuation on my opinion is:

To costruct a novel type of EAS array based on new principals

Such as:

PRISMA

(PRImary Spectrum Measurement Array)

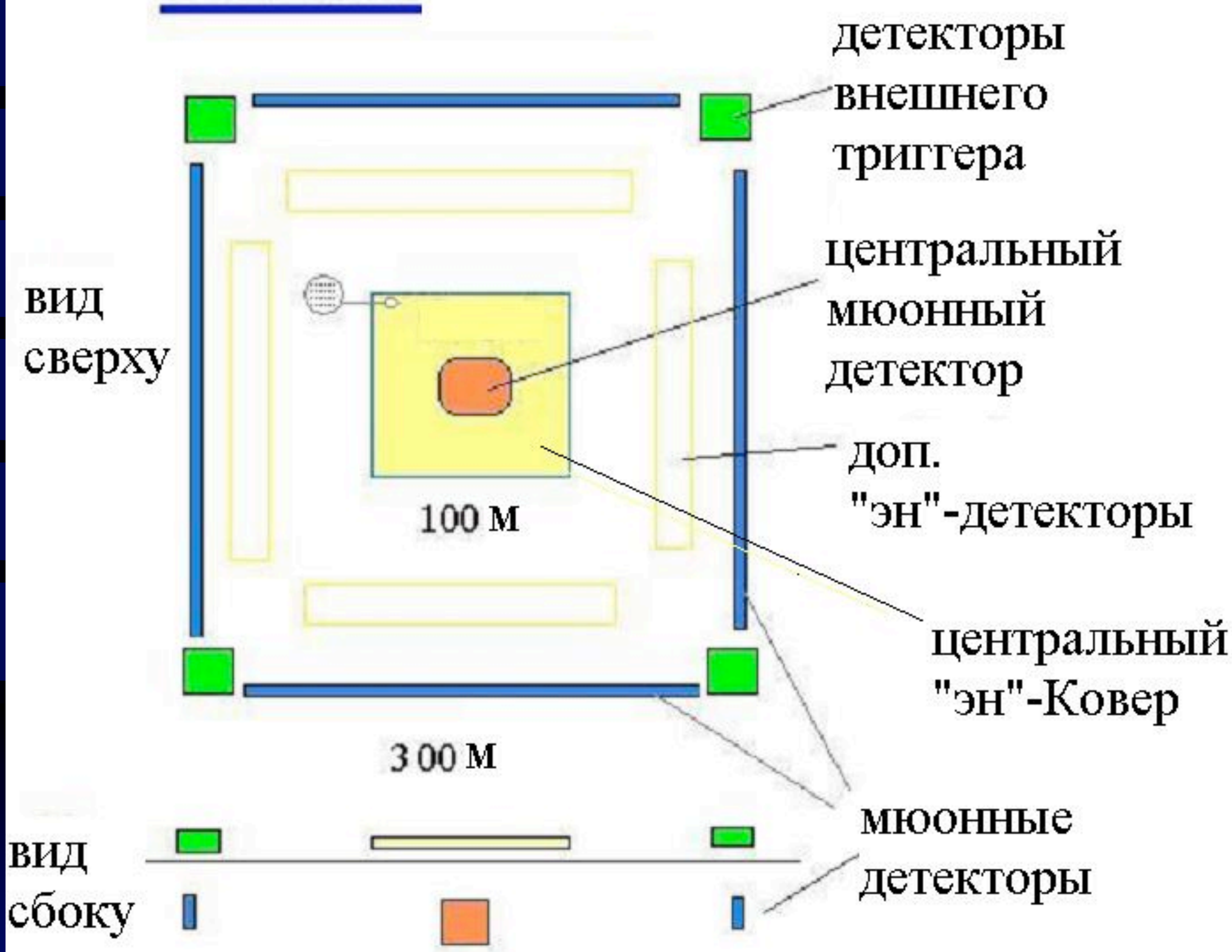
The project based on new principals. Hadrons will be the main recording component. Hadronic sensitive detectors will cover an area more than 10^4 m^2.

It will measure primary spectrum from 10 TeV through 30 PeV.

(see Yu. Stenkin. On the PRISMA project. ArXiv: 0902.0138v1 [Astro-ph.IM])

Thank you!

PRISMA



Yu.V. Stenkin. On the PRISMA project. // Nucl. Phys. B (Proc. Suppl.), v. 196, 2009, p. 293-296.