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Literatur

Demoulin, M. H., G. R. Burbidge: Astrophys. J. **154**, 3, 1968
Oke, J. B., W. L. W. Sargent: Astrophys. J. **151**, 807, 1968
Williams, R. E.: Astrophys. J. **147**, 556, 1967
R. J. Weymann: Astron. J. **73**, 895, 1968

Tabelle

Relative Emissionslinienintensitäten in NGC 4151

Übergang		beob.1)	theor.2)	theor.3)
[N II]	6584	25	4.2	39
Hα	6562	336	289	250
[N II]	6548	5	—	13
[O III]	5007	214	1710	2460
[O III]	4959	70	—	824
Hβ	4861	100	100	100
He II	4686	25	23	35
[O III]	4363	7	—	481
Hγ	4340	33	—	50
Hδ	4102	12	—	28
[Ne III]	3869	29	241	47
[O II]	3727	51	22	50
[Ne V]	3426	33	284	8722

1) Oke und Sargent 1968
2) Williams und Weymann 1968
3) Modell 3 für log $(D/N) = -17.50$

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Measurement of the Primary Cosmic Ray Proton and Alpha-Particle Spectra above 10 GeV/Nucl*.

Abstract

Several successful balloon flights have been carried out in 1967 to study high energy cosmic ray particles. Results reported here have been obtained from two flights launched from Texas, in which altitudes of 5.7 g/cm^2 and 11.4 g/cm^2 were reached and events were registered for about 22 hours. The equipment consisted of spark chambers, different target materials, and an ionization spectrometer for energy determination of incoming particles. After the balloon flights the equipment was calibrated with 10, 20.5, and 28 GeV/c protons from the Brookhaven AGS. These measurements and the balloon data allowed the calculation of the primary cosmi ray proton and alpha-particle spectra.

Apparatus consisting of an ionization spectrometer and spark chambers ha been exposed to primary cosmic radiation in two balloon flights which allowed dat collection for 14.3 and 8 hours at residual atmosphere of 5.7 g/cm^2 and 11.4 g/cm respectively. These flights were carried out during 1967. The purpose of this exper ment was to study flux, composition, possible time variations, and nuclear interactio properties of cosmic rays at energies above 10 GeV. Here the results pertaining the spectra of protons and alpha-particles are reported.

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A brief description of the apparatus has been given previously[1] [2]. It mainly consisted of two spark chambers of 4 and 12 gaps, respectively, and an iron absorber 330 g/cm^2 deep. As was stated in Ref. 1, the apparatus was triggered whenever a cascade had developed sufficiently well so that in two consecutive scintillation counters ionization equivalent to at least 13 minimum ionizing particles was registered. In addition, one minimum ionizing particle had to be registered in two beam defining counters; one between the spark chambers another one and above the upper spark chamber. During one flight two particles were also required to traverse the last scintillation counter at the bottom of the spectrometer in order to assure that the cascade traversed the whole depth of the absorber.

After the balloon flights the equipment was exposed to protons from the Alternating Gradient Synchrotron at Brookhaven National Laboratory in order to calibrate the spectrometer at least at the low energy end of measuring range. Some of the results were reported in Ref. 1. As was stated there, the measured parameter that exhibited the smallest fluctuations was the sum of the three pulse heights of the measuring photomultipliers. This sum was called ΣNi, meaning the sum of the three signals, each expressed in units of "minimum ionizing particles".

In order to measure the spectrum of primary protons by means of such a relatively shallow spectrometer one needs to know the mean of the measured signals $\overline{\Sigma Ni}$ as a function of primary energy E_0 and also the distribution of this measured signal around its mean. The relationship of $\overline{\Sigma Ni}$ with E_0 has been determined from Monte Carlo calculations. (Some of the results of these calculations were reported at the Budapest Conference on Cosmic Ray[3].) The calculations were first fitted to the results of the AGS measurements with the same apparatus and took into account its finite dimensions. Calculations were then carried out for higher energies. From these calculations, a calibration of the apparatus, i. e. the dependence of $\overline{\Sigma Ni}$ on E_0, was found to be well approximated by an $E_0^{0.985}$ power law.

The distributions of ΣNi around $\overline{\Sigma Ni}$ are also needed. Fig. 1 shows the distributions found from the calibration measurements at the AGS. Indicated are three distributions normalized to their mean. The standard deviations of these distributions

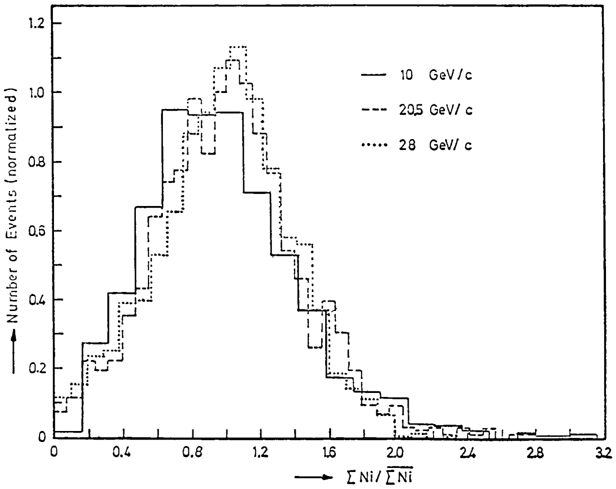

Fig. 1: Shown are the distributions of measured values of the parameter ΣNi for incident protons of the indicated energies

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are given in Fig. 3 (experimental points (b)) of Ref. 1. One can see that the distributions change little between 10 GeV and 20.5 GeV and exhibit almost no change between 20.5 GeV and 28 GeV. Since the major contributions to the width of these distributions are most likely the poisson distribution of interactions in the absorber and the inelasticity distribution of inelastic interactions, both of which from present knowledge change little if at all with increasing energy, these distributions are expected to remain constant in shape for at least one more order of primary energy. This expectation was verified by the Monte Carlo calculations.

Having established an energy calibration and the distribution function of measured values of ΣNi for a given incident energy, one can calculate what should be measured if the primary spectrum were a power law. Under the suppositions made the measured spectrum should be a power law with the exponent $\frac{1-\gamma}{0.985} - 1$ if the primary spectrum has the exponent $-\gamma$. At low energies the triggering efficiency of the apparatus was less than one. However, up to 28 GeV this could be determined from the AGS exposure. The corrections to be applied for deficiency of detection are a function of ΣNi and $\frac{1-\gamma}{0.985}$, the exponent of the integral spectrum. However, the change of such corrections with changing exponent is so slow that taking the exponent of the spectrum from a visual fit to the data is sufficient to enable one to carry out these corrections and then find the exponent more accurately from a maximum likelihood fit to the data.

Figure 2 shows the total number of events collected in two balloon flights as functions of ΣNi, where the proton spectrum has been corrected for triggering deficiency. A maximum likelihood fit of a power law to these data yields an exponent of 2.78 ± 0.02. This corresponds to an exponent of the primary spectrum of 2.75 ± 0.04 after the calibration is taken into account, where an error of ± 0.01 in the exponent of the calibration has been considered.

In order to find a meaningful calibration for alpha particles, such events were simulated from the AGS events in the following way: From the work of several authors – cf. Ref. 4 – it is known that, on average, two of the four nucleons participate in an interaction of an alpha particle. Thus four of the AGS proton events were added together as a group with the selection rule that two of the protons in each group interacted in a specified depth of the absorber and the other two interacted later. The distributions of the measured ΣNi around the mean $\overline{\Sigma Ni}$ for these groups should be narrower than those for single protons. However, events where only one, three, or all four of the nucleons constituing the alpha particle participate in the first interaction tend to widen the distribution again. Since the influence of the distributions of Fig. 1 on the measured spectrum – in case of triggering efficiency equal to one – is only a factor of about 1.06, the same was assumed for the alpha particle spectrum. Also the extrapolation of the calibration was done in the same way as described for protons. If $\overline{\Sigma Ni}_p$ is the average measured value for protons, and $\overline{\Sigma Ni}_\alpha$ the same for alpha particles, then, keeping in mind that these are "alpha particles" simulated in the manner described above, it is found that $\overline{\Sigma Ni}_p = 0.29\ \overline{\Sigma Ni}_\alpha$ at the same energy per nucleon. No correction is needed for triggering efficiency, since this efficiency was equal to one at least down to 20.5 GeV/nucl. and dropped only to about 90% at 10 GeV/nucl.

Although the alpha particle spectrum of Fig. 2 may not justify a power law fit, such a law was fitted to the spectrum by a maximum likelihood method in the same

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way as for protons. This fit yields an exponent of 2.79 ± 0.05, which corresponds to an exponent of the primary spectrum of 2.76 ± 0.07.

The spectra found in this way are for protons

$$N_p = (2.09 \pm 0.25)\, E_0{}^{-2.75 \mp 0.04}\ \mathrm{GeV^{-1}\,cm^{-2}\,sec^{-1}\,sr^{-1}}$$

and for alpha particles

$$N_\alpha = (1.1 \pm 0.4) \cdot 10^{-1}\, (E_0/\mathrm{nucl})^{-2.76 \mp 0.07}\ \mathrm{GeV^{-1}\,cm^{-2}\,sec^{-1}\,sr^{-1}}\,.$$

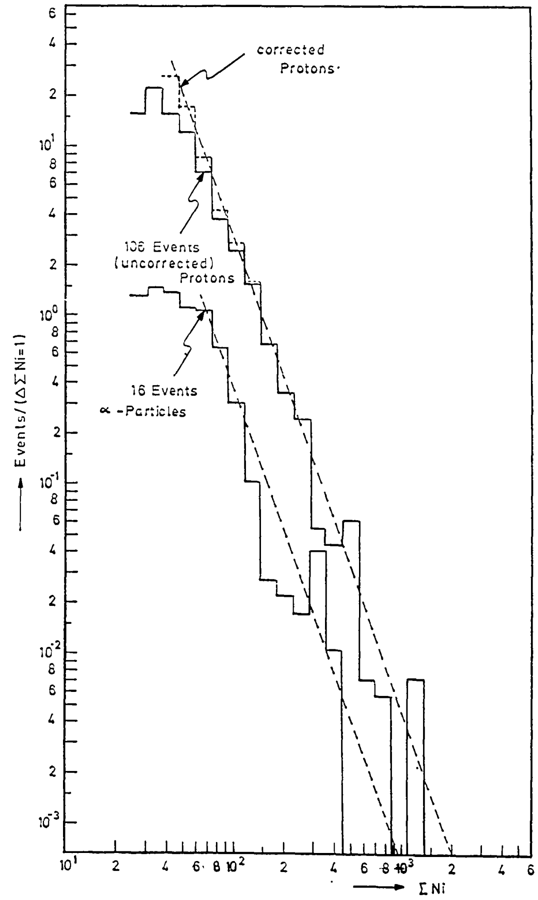

Fig. 2: Shown are all events of charge one and charge two detected during two balloon flights. The proton spectrum is corrected for threshold inefficiency of the apparatus. The dashed lines show power law spectra fitted by a maximum likelihood method

Both spectra were corrected for overlying matter within the apparatus by using the interaction length for protons and alpha particles, respectively. The interaction lengths were calculated for protons by using for the interaction cross section $\sigma = \pi \cdot r_T{}^2$ and for alpha particles by using $\sigma = \pi (r_T + r_\alpha)^2$ where r_T and r_α are the radii of the target nucleus and the alpha particle, respectively. r for a nucleus with mass number A was taken to be $r(A) = 1.2 \cdot 10^{-13} \cdot A^{1/3}$. For residual atmosphere an attenuation length of (120 g/cm²)^5) was used for protons and 52 g/cm² was used for alpha particles (WEBBER & ORMES, quoted with Ref. 6).

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In Fig. 3 the spectra are shown together with some results of other authors. The proton spectrum appears to be consistent with soms of the other results[7][8][9]. It also appears to be consistent with the cited spectrum of all particles[12] since this contains all nucleons, those in heavy nuclei included. The only direct measurements which have been performed in the same energy range as reported here are those from the Proton I and Proton II satellite experiments of Grigorov et al.[13]. The spectrum reported here disagrees with the satellite data by about a factor of two. The authors feel that for several reasons the spectrum of Grigorov et al. could be erroneous:

(a) Over the energy range considered here, their spectrum of "all particles" and of "protons" coincide. However, a sizable fraction of multiply charged particles at these total energies have been observed in this and other experiments.

(b) Their "event definition" and definition of the aperture of their equipment was based on scintillation counter and ionization chamber evidence only and not on any visual devices such as spark chambers.

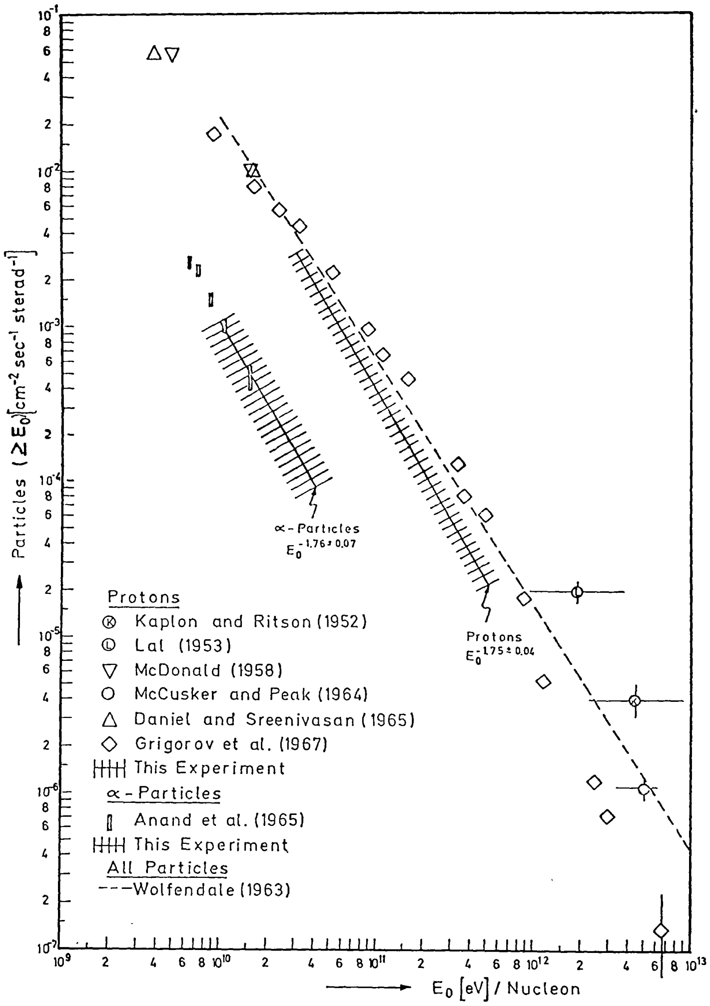

Fig. 3: Integral spectra reported here and some data of other authors. The shaded areas indicate the limitis of errors for the data reported here

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