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A BALLOON FLIGHT FROM AN ANTARCTIC BASE TO GET THE BEST CONDITIONS IN THE SEARCH FOR COSMIC ANTIPROTONS

A Balloon Flight from an Antarctic Base to Get the Best Conditions in the Search for Cosmic Antiprotons.

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Summary. — Searching for cosmic antiprotons, balloon-borne experiments were performed in the last years, but without a clear answer on the $\bar{p}$ rate and origin. Here we present the project of an antarctic flight of a balloon-borne apparatus that in principle could be greatly helpful in clarifying the situation before that experiments on space station or satellites provide the high statistics for a more complete scenario.

PACS 29.90 – Other topics in high-energy and nuclear experimental methods and instrumentation.
PACS 94.80 – Aerospace facilities and techniques; space research.

1. – Physical motivation for $\bar{p}$ search.

The main question on cosmic antiprotons is: are the antiprotons all secondary products of cosmic-ray interactions with the medium (essentially $p + p \rightarrow$ $\rightarrow \bar{p} + p + p + p + anything$ [1]) or is there a significant fraction that comes out from other processes, or should they be considered as primary?

In order to answer to this question and to fit the data (which in several cases are contradictory), many models have been proposed, models that can be divided in two classes:

1) models, based on secondary production, which try to explain the data with modification of the mechanism of acceleration or of the amount of traversed matter;

2) exotic models which take into account different origins for the antiprotons.

In fig. 1a) and b) the predictions of these two classes of models are presented, respectively, as well as the experimental data [2]. To explain the apparent experimental overabundance of $\bar{p}$, that cannot be justified by the standard model, there are several hypotheses of high scientific interest from the extreme case of presence of antigalaxies [3] to the simplest model of a large amount of traversed matter, including elementary-particle speculations (e.g., the existence and annihilation of photinos [4] as dark-matter candidates), or cosmological ideas (e.g. evaporating small back holes [5]).

[1] T. K. GAISSER and R. H. MAURER: Phys. Rev. Lett., **30**, 1264 (1973).

[2] R. L. GOLDEN, S. HORAN, B. G. MAUGER, G. D. BADHWAR, J. L. LACY, S. A. STEPHENS, R. R. DANIEL and J. E. ZIPSE: Phys. Rev. Lett., **43**, 1196 (1979); E. A. BOGOLOMOV, G. Y. VASILYEV, S. YU. KRUT'KOV, N. D. LUBYANAYA, V. A. ROMANOV, S. V. STEPANOV and M. S. SHULAKOVA: Proceedings of the XX International Cosmic Ray Conference, Vol. 2 (Moscow, 1987), p. 72; A. BUFFINGTON, S. M. SCHINDLER and C. R. PENNYPACKER: Astrophys. J., **248**, 1179 (1981); R. L. GOLDEN, B. G. MAUGER, S. NUNN and S. HORAN: Astrophys. Lett., **24**, 75 (1984); S. AHLEN, S. BARWICK, J. J. BEATTY, C. R. BOWER, G. G. GERBIER, R. M. HEINZ, D. LOWDER, S. McKEE, S. MUFSON, J. A. MUSSER, P. B. PRICE, M. H. SALAMON, G. TARLÉ, A. TOMASCH and B. ZHOU: Phys. Rev. Lett., **61**, 145 (1988). Other data have been presented by R. L. Golden at the 6th Course of the International School of Cosmic Ray Astrophysics at Erice, Italy, in April 1988 and are in course of publication.

[3] F. W. STECKER, R. J. PROTHEROE and D. KAZANAS: Astrophys. Space Sci., **96**, 171 (1983); S. A. STEPHENS: Proceedings of the XVIII International Cosmic Ray Conference, Vol. 9 (Bangalore, 1983), p. 167.

[4] J. SILK and M. SREDNICKI: Phys. Rev. Lett., **53**, 624 (1984); F. W. STECKER, S. RUDAZ and T. F. WALSH: Phys. Rev. Lett., **55**, 2622 (1985).

[5] P. KIRALY, C. SZABELSKI, J. WDOWCZYK and A. W. WOLFENDALE: Nature, **293**, 120 (1981); M. S. TURNER: Nature, **297**, 379 (1982).
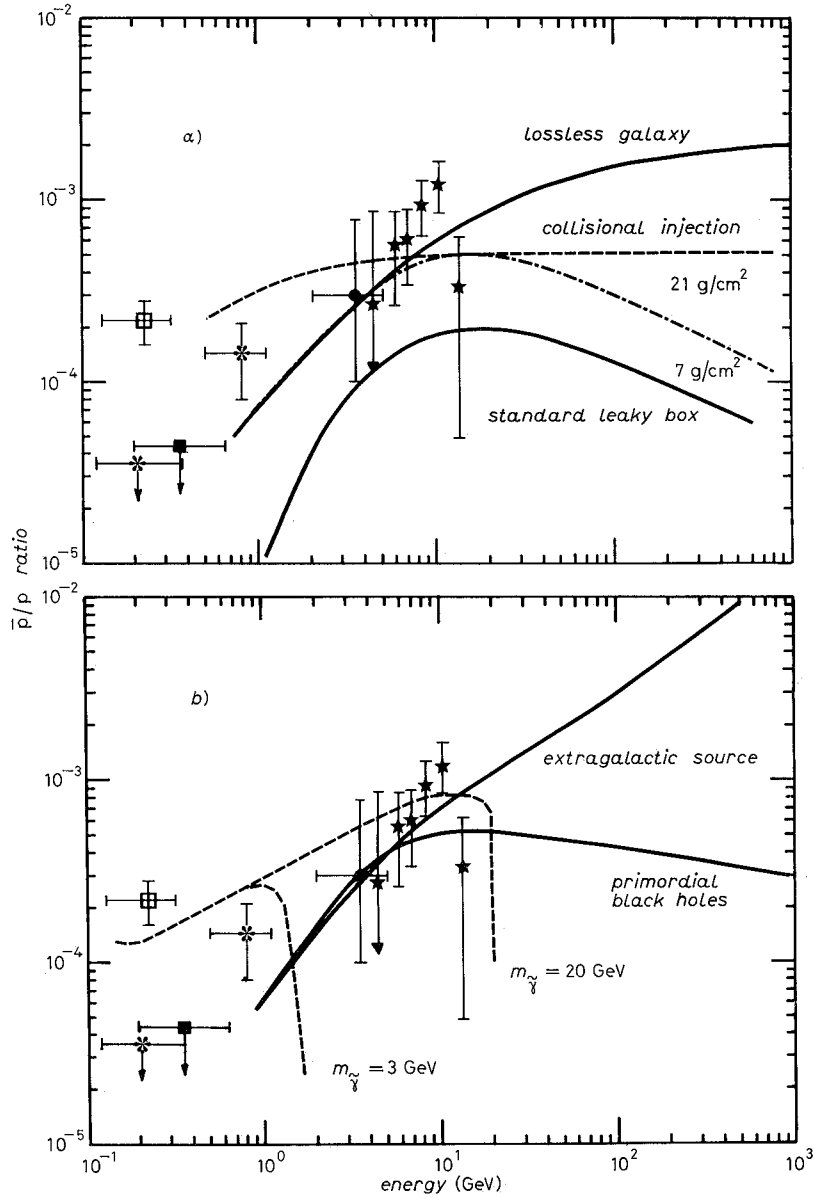
Fig. 1. – The various hypotheses coming from the calculations of the theorists (ranging from photino and antiphotino annihilation to the idea of evaporating small black holes) provide several different predictions: a) cosmic-ray models, b) therefore, getting a higher statistics can lead to discriminate among different models following the shape of the antiproton spectrum. □ Buffington et al. ([2]); ● Bogolomov et al. ([2]); ★ Golden et al. ([2]); ■ Ahlen et al. ([2]); * Golden et al. ([2]).

It is not in the purposes of this paper to go deep into the description of the models (for this, see [6]); what one must stress here is the fact that the present impossibility to choose among them comes from the existence of very few experimental data (up to now, adding all the experiments, only 51 $\bar{p}$ were collected for all the energies).

2. – Difficulties in $\bar{p}$ detection. The necessity of a polar flight.

The present low statistics in $\bar{p}$ collection is explained by the difficulties of their detection. In fact, in addition to the necessity of flying outside the atmosphere to detect $\bar{p}$, there are three major problems to overcome: the terrestrial magnetic field, the solar wind and the night-and-day thermal excursion.

In the terrestrial magnetic field, low-energy charged particles are trapped and their trajectory distorted, so that low-energy antiprotons (up to some GeV depending on the parallel) cannot reach the detector. But, the terrestrial magnetic field being closed at the two poles, a balloon-borne apparatus, which flies in proximity of one of the magnetic poles, greatly reduces the geomagnetic cut-off (fig. 2a)).

The solar-wind effect, due to the electrical charged particles coming from the Sun, and producing with their motion a magnetic feld, is able to cause distortions on the trajectory of the cosmic particles crossing the solar wind itself (fig. 2b)) [7]; therefore, in order to partially overcome this effect, the $\bar{p}$ measurements should be made during the minimum (or periods close to the minimum) of the cycle of solar activity.

The thermal excursion effect plays a big role in reducing the duration of the balloon flight especially for the heavy payloads that cannot carry a lot of ballast. In fact, when a changement in the temperature occurs, one must throw away some amount of ballast to mantain the altitude; when the payloads are heavy (like for antiproton search in which both magnet and full containement calorimeter are very useful) the total amount of carriable ballast is small, thus reducing the duration of the flight because the ballast itself is soon finished.

Due to the fact that the present technology does not allow to build balloons able to carry more than about three tons, the only way to increase the duration of the balloon flight is to choose an area with the smallest thermal excursion.

[6] G. BASINI, A. MORSELLI and M. RICCI: Matter and Antimatter in the Same Universe?, to appear in Riv. Nuovo Cimento.

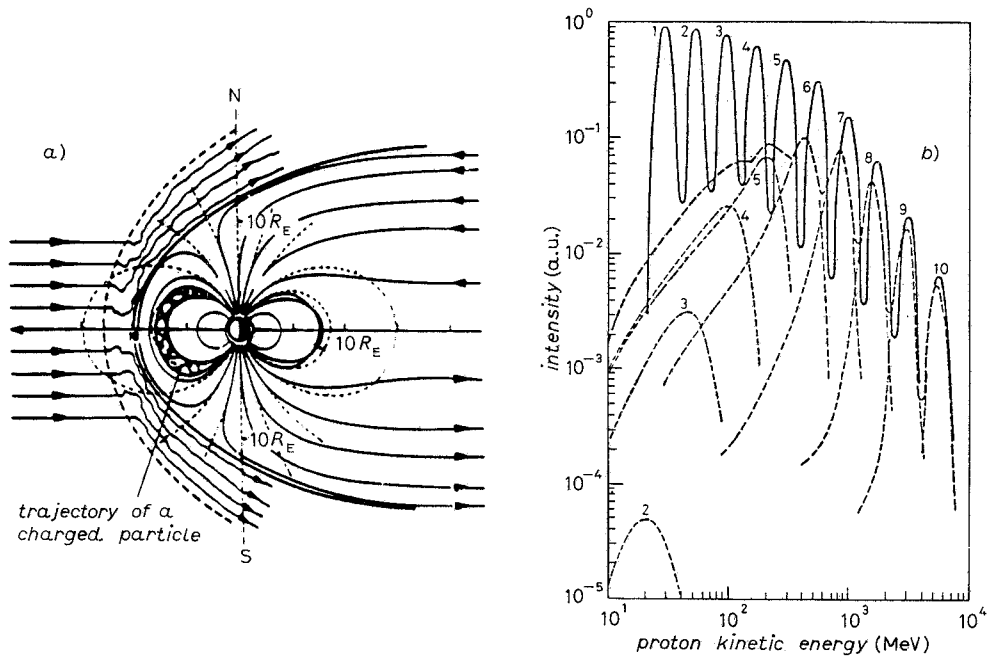[7] M. L. GOLDSTEIN, L. A. FISK and R. RAMATY: Phys. Rev. Lett., 25, 832 (1970).

Fig. 2. – a) The geomagnetic field. b) A series of essentially monoenergetic proton spectra in interstellar space (solid) and their resultant modulated spectra at 1 AU (dashed).

3. – The Italian Antarctic Base: a possible choice.

Located in the antarctic area in front of the Sea of Ross at 74°41' latitude S and 164°07' longitude E, the Italian Antarctic Base (fig. 3), built under the supervision of the ENEA (Ente Nazionale per l'Energia Nucleare e Alternative) and of the CNR (Consiglio Nazionale delle Ricerche), is roughly half-way from the geographic South Pole and the magnetic South Pole, so in a zone enough close to the magnetic pole to reduce drastically the geomagnetic cut-off and enough close to the geographic pole to profit from the practical absence of the 24 h thermal excursion (especially at 45 km, which is the typical altitude for a balloon flight).

Under the assumption that it could be possible to overcome the technical difficulties typical of such an area and maybe with the support of bases of other nations equipped with an airport (an airplane is necessary to follow the balloon flight and to localize the landing point of the payload), the Italian Antarctic Base would be an exceptionally good place to launch a balloon for antiproton search.
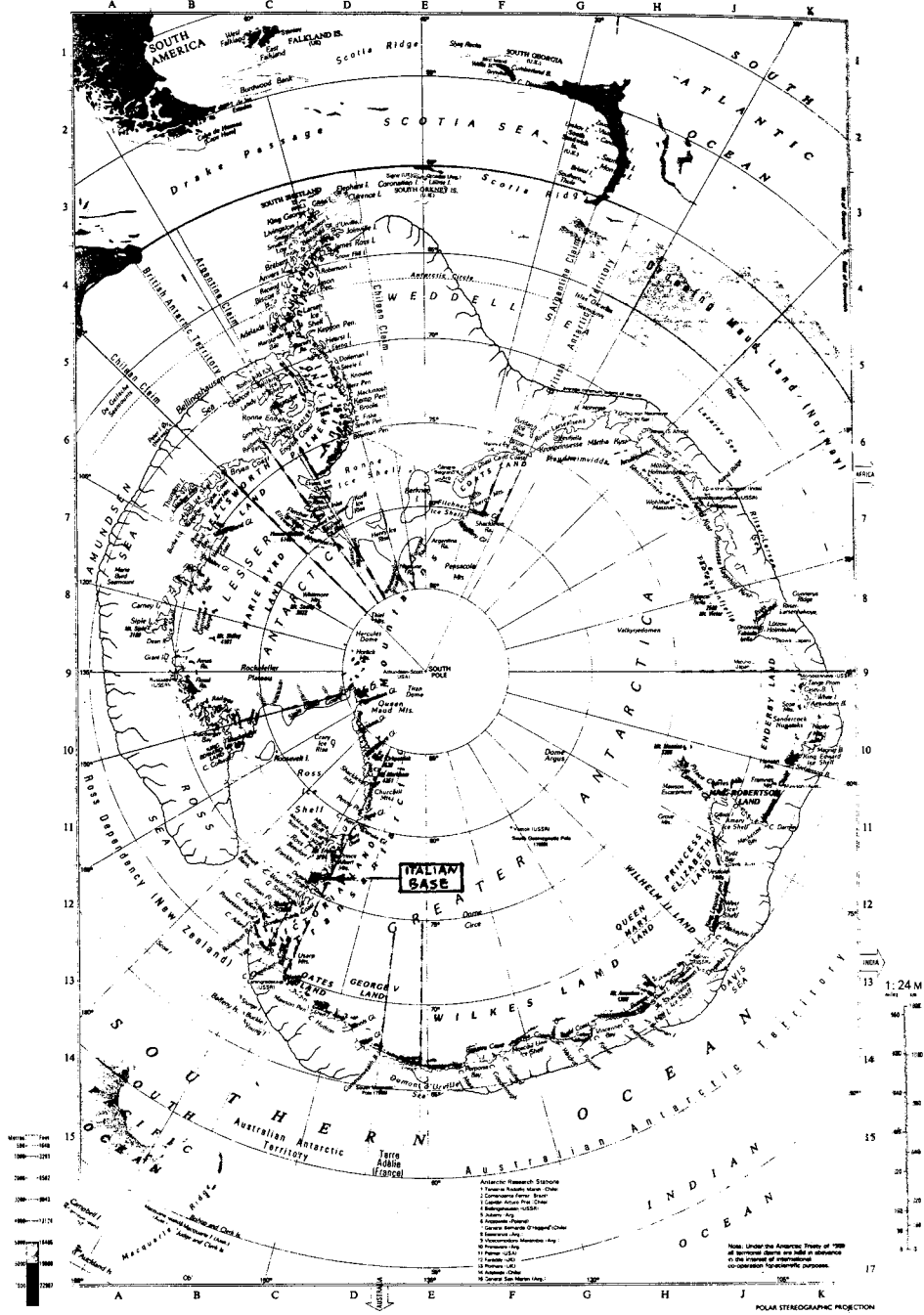
ANTARCTICA

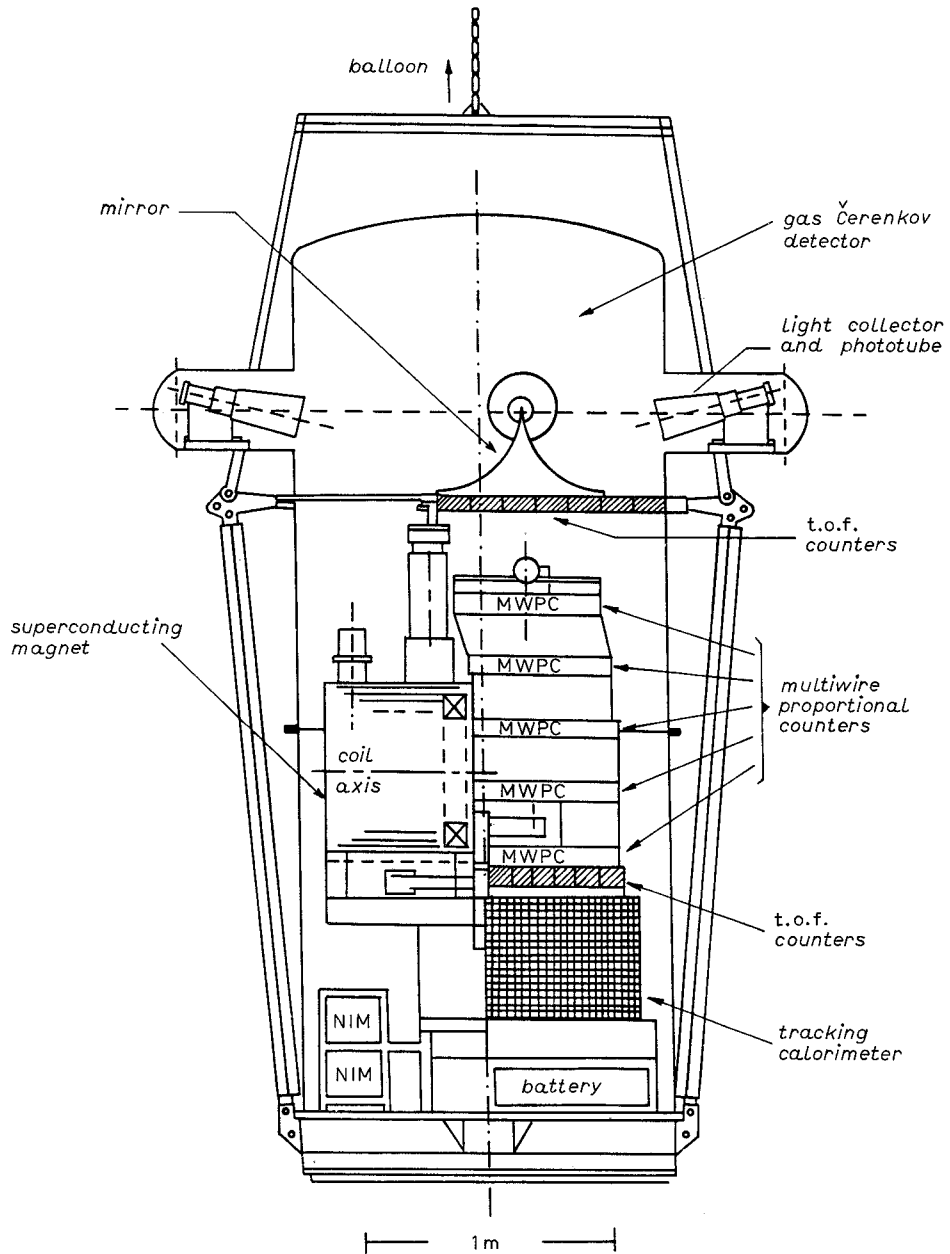Fig. 3. – Location of the Italian Antarctic Base.

Fig. 4. – The MASS apparatus.

4. – Two possible options for the apparatus: MASS or Silicon MASS.

Destined to be flown from Canada in August 1989, the MASS apparatus (Matter-Antimatter Space Spectrometer) (fig. 4)[8] is composed of a super-conducting magnet, multiwire proportional chambers (MWPCs), time-of-flight counters, a Čerenkov counter and a tracking calorimeter made of limited streamer brass tubes.

Combining the momentum measurement (magnet + MWPCs) with the measurement of the energy released (calorimeter), the time of flight of the incoming particle and the Čerenkov signal, it is possible to get a clear information on the nature of the particles arriving into the geometrical acceptance. Moreover, the calorimeter (fig. 5a), b)) is a tracking one, so that it can provide a reconstruction of the topology of an event showing the vertex of the interaction and, in case of an antiproton, the characteristical figure of annihilation (the annihilation star) with several prongs outcoming from that vertex. In conclusion, the MASS experiment shows itself as an apparatus in principle perfectly able to get the hoped for goals and it seems reasonable to foresee an antarctic flight in 1990-1991 after the 1989 Canadian launch.

Yet using the MASS spectrometer, there is an alternative possibility: to put a silicon tracking calorimeter in place of the streamer tube calorimeter (fig. 5a), c)). Under development for the Space Station[9] experiment WIZARD[10], the silicon calorimeter can be an useful device for balloon-borne apparatus too[11].

The silicon detectors (SDs) have been used in nuclear physics for a long time. The application of SDs is the measurement of the energy loss (dE/dx) and of the total energy E of highly ionizing particles. In elementary-particle physics SDs are used for short-lifetime measurements and for precision-tracking ($\Delta x \approx 5\,\mu$m) determination.

Below some features are listed that make SDs attractive for use in balloon-borne experiments or generally in space.

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[8] R. L. GOLDEN, G. D. BADHWAR, J. L. LACY and J. E. ZIPSE: Nucl. Instrum. Methods, 148, 179 (1978); G. BASINI, S. BARTALUCCI, F. BONGIORNO, A. CODINO, M. MENICHELLI, A. MORSELLI, M. OCCHIGROSSI, P. PICOZZA, M. RICCI and P. SPILLANTINI: Nuovo Cim. C, 11, 339 (1988).

[9] The Particle Astrophysics Magnet Facility, Report of the ASTROMAG Definition Team, edited by J. F. ORMES, M. ISRAEL, M. WIEDENBECK and R. MEWALDT (May 1988).

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[11] G. BARBIELLINI, A. VACCHI, G. BASINI, A. MORSELLI, M. OCCHIGROSSI, M. RICCI, F. BONGIORNO, P. SPILLANTINI, R. BERNABEI, M. DE PASCALE, P. PICOZZA, A. CODINO and M. MENICHELLI: Nuovo Cimento B, 102, 661 (1988).
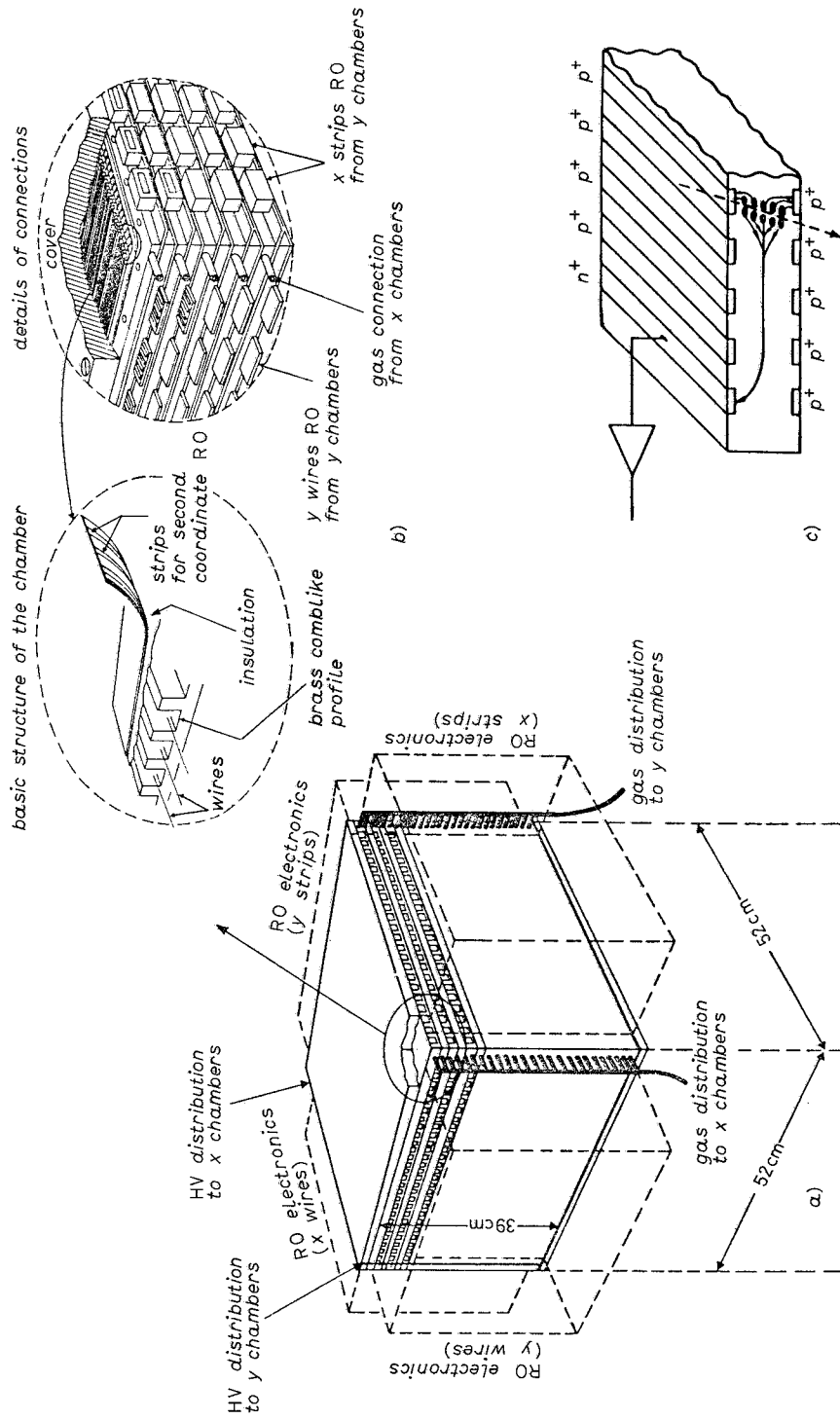
Fig. 5. – The tracking calorimeter. In a) one can see the general distribution of planes, that, even if visualized for the streamer tube case, can be considered valid also for silicon; in b) some details of the assembling of streamer tubes are shown; in c) a particular is shown in the case of silicon detectors with the voltage distribution applied to the electrodes to obtain the drift field.

i) The energy required for the separation of the charges in the detector is quite small: a minimum ionizing particle (MIP) produces 80 electron-hole pairs while crossing 1 μm of detector.

ii) The production of the charge is a linear process avoiding the typical instability of the high-gain charge amplification.

iii) Because of i) the longitudinal dimension of the SD can be small and the calorimeter can be very compact.

iv) The detectors are very uniform and do not suffer from saturation or the nonlinearity effect.

v) The low-voltage supply and the low dark current assure a small power consumption.

5. – Conclusions.

In conclusion, a polar balloon flight from an antarctic base seems to be a logical continuation of the trail of balloon flights in the search for antiprotons operated up to now around the world, mainly if performed using a very complete apparatus like the MASS detector.

A strong indication of the necessity of such a mission will obviously come from the results of the planned MASS flight from Canada.

● RIASSUNTO

La ricerca di antiprotoni cosmici è stata intrapresa negli anni passati con esperimenti installati su palloni, ma ancora non si è ottenuta una chiara risposta sulla «rate» di antiprotoni né sulla loro origine. Viene qui presentato il progetto di lancio dall'Antartide di un apparato installato su pallone che, in linea di principio, potrebbe essere di grande aiuto nel chiarire la situazione prima che futuri esperimenti sulla stazione spaziale o su satelliti possano fornire una statistica piú elevata per uno scenario piú completo.

Полет воздушного шара из антарктической базы для получения наилучших условий для поиска космических антипротонов.

Резюме (*). — В течение последних нескольких лет были проведены эксперименты на воздушных шарах с целью поиска космических антипротонов, однако не было получено ясного ответа об интенсивности и происхождении антипротонов. В этой работе предлагается проект антарктического полета воздушного шара с аппаратурой, который, в принципе, позволит прояснить ситуацию до проведения экспериментов на космической станции или спутнике с обеспечением высокой статистики для более полной программы исследований.

(*) *Переведено редакцией.*

NOTE BREVI

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