COUF - 8906234
CONF-8906234--1
DE90 006008

JACEE Long Duration Balloon Flights

The JACEE Collaboration:

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ABSTRACT: JACEE balloon-borne emulsion chamber detectors are used to observe the spectra and interactions of cosmic ray protons and nuclei in the energy range 1-100A TeV. Experience with long duration mid-latitude balloon flights and characteristics of the detector system that make it ideal for planned Antarctic balloon flights are discussed.

I. INTRODUCTION

Experience with JACEE[1] clearly shows that passive, large-acceptance emulsion chambers represent a detector system that can reliably achieve large exposure factors via balloon flight. The key to the success of this project has been the simplicity and self-contained nature of the detectors, allowing experimenters to take advantage of flight opportunities denied to heavier, more complex, or more costly detector systems. In particular, the relatively low pre-analysis investment in the detectors allows us to take flight success risks unacceptable to other groups.

Recent improvements in long duration flight capability as evidenced by several successful transcontinental flights greatly increase the collecting power available to balloon experiments. For example, the JACEE-7 balloon flight from Australia to Paraguay in January, 1987 logged over 140 hours at float altitude, and this performance was repeated the following year with a successful 120-hour flight from Australia to Brazil. Altitude profiles for these flights are shown in Figure 1. Following the successful long-duration flight and recovery of the GRAD experiment[2], planning is underway for expeditions to Antarctica where flight durations of 10-20 days will be possible[3].

II. EXPERIMENTAL TECHNIQUES

A typical emulsion chamber (EC), shown in Figure 2, consists of double-coated nuclear emulsion plates, X-ray films, and Pb sheets 0.5-2.5 mm thick. Each chamber unit, measuring approximately 40x50x20 cm and with mass ~100 kg, is sealed in an airtight, waterproof bag, to eliminate plate motion

Presented by R. J. Wilkes at Workshop on Astrophysics in Antarctica, Bartol Research Institute, June 9, 1989. To be published by AIP.

during pressure changes and for environmental protection following landing. Four such units can be accomodated on a gondola of total weight 1500 lbs, well within the scientific payload limit for a standard 28 MCF balloon[3].

The EC satisfies several basic requirements: (1) large geometrical factor, (2) accurate charge determination, with charge resolution essentially independent of energy, (3) reliable energy measurement, with energy resolution independent of (and to some extent, improving with) energy, and (4) simplicity and reliability. The latter factor has been especially important in allowing long cumulative exposure times via balloon flight. Since the emulsion chamber is primarily used as a vertex detector (although external atmospheric interactions can also be observed), the initiating particle is identified.

The detectors were assembled in flight-ready condition in the US, and then shipped by commercial air freight to Alice Springs, Australia, where they were interfaced to the NSBF flight equipment. Local liaison, logistics, and communications in Alice Springs were quite satisfactory. Although preflight preparation facilities were inadequately air conditioned (with outside ambient temperatures approaching 40°C), we encountered no significant problems.

All JACEE data were recorded onboard, including temperature and pressure altitude readings, using a data recorder employing high-density memory chips. An aneroid control system was used to shift a topside film layer out of registration with the main emulsion chambers when pressure altitude dropped below a preset level; shifter status was included in the data transmitted to NSBF by the ARGOS satellite tracking system. On these flights, 28 MCF balloons of the same type proposed for planned Antarctic flights were used. Total ballast carried was approximately equal to the 600 kg scientific payload, in order to maintain altitude above approximately 6 mbar for 5-6 nights. Due to weight and cost limitations, it was not possible to provide adequately for sea recovery in case of balloon failure. In the case of JACEE-7, unanticipated sudden altitude loss resulted in automatic flight termination over northern Paraguay. Despite logistical and diplomatic difficulties, the payload was returned to the US after several weeks' storage at local ambient temperatures. Although background fog levels in the emulsions and x-ray films were higher than usual, the payload is fully analyzable, and data reduction is well under way. For the JACEE-8 flight, termination and recovery proceeded as planned in southern Brazil. Despite advance preparation and energetic local liaison, the return of the apparatus was delayed several weeks due to bureaucratic delays, although in this case the emulsion chambers were stored in a controlled environment with no tangible degradation of data.

The Southern hemisphere balloon flight expeditions of 1987-88 approximately doubled the statistical weight of the JACEE data on primary composition, and we have reached the point where additonal factors of 2~10 in exposure will provide significant information on composition and spectra in the critical 10^{16} ev knee region[4].

III. SUITABILITY FOR ANTARCTIC FLIGHTS

JACEE detectors are in many ways very well matched to the requirements for Antarctic flights. Antarctica presents no population hazard to limit flight paths and durations, as is the case for northern hemisphere routes. Since Antarctica is an international zone, there are no national boundaries to cross, and the equipment remains under the control of US agencies throughout flight and recovery. While some diurnal variation of altitude will occur, ballasting requirements are greatly reduced by the absence of sunset, and the weight available for scientific payload is correspondingly increased.

The flight path is overland at all times, and it is in principle possible to recover the package from a much larger fraction of the underlying terrain than in the case of mid-latitude flights, where the package is over open ocean most of the time. JACEE payloads are modular, with a basic unit of dimensions roughly 40x50x20 cm and mass 100 kg. Thus the gondola can be broken down into components that are easily handled by a recovery crew working at the high altitudes which characterize the East Antarctic plateau, and essential components of limited weight can be removed if it is necessary to abandon the main gondola. In case of delayed recovery, the ambient environment in Antarctica (characterized by extremely low temperature and humidity) is much less hostile to photographic media than in Australia or South America, where high temperatures promote latent image fading and background fog. Although southern mid-latitude flights have the advantage of relatively high geomagnetic cutoff (hence reduced soft background in the emulsion and reduced fog level in the x-ray films), emulsion chamber detectors are inherently self-shielding, and to the extent that background levels will be higher than previous flights, they will provide us with an opportunity to confirm our ability to analyze plates with enhanced background in preparation for planned Space Station exposures[5].

Recovery is essential for emulsion chamber flights, but this also means that the package has negligible telemetry requirements, reducing the burden on flight operations facilities. For example, the typical JACEE detector is an ideal "guinea pig" for flight systems tests, because it is self contained and passive, can be prepared on relatively short notice, and loss of a given package can be tolerated since the main investment of effort by experimenters occurs following successful recovery.

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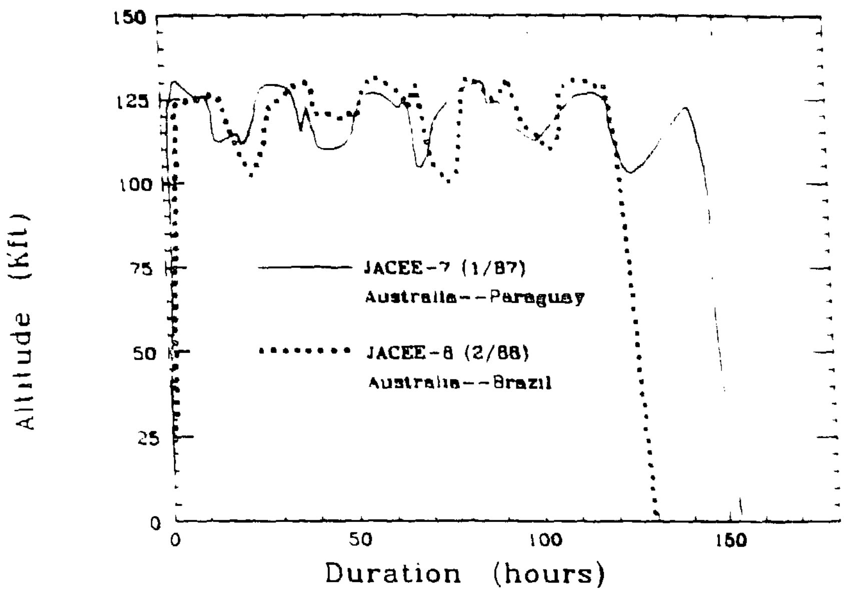
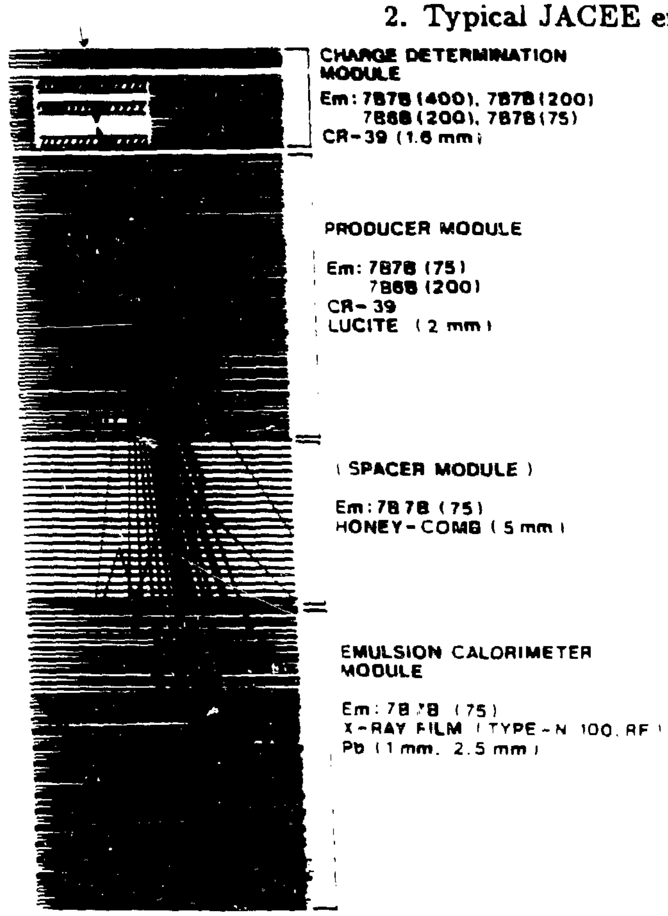
Fig. 1. Altitude profiles for JACEE-7 and -8, from ARGOS satellite data.



2. Typical JACEE emulsion chamber design.



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