Opportunities and Challenges of a High Altitude Multipurpose Observatory

Lawrence W. Jones*
University of Michigan

At earlier cosmic ray conferences I have discussed the concept of developing a cosmic ray laboratory/observatory at a very high elevation; one figure used was an elevation of 6500 m, or a depth in the atmosphere of less than 450 g/cm^2. This was first discussed in the small occasional circular "Cosnews" in 1980[1], and subsequently presented at the Paris "17th International Cosmic Ray Conference" in 1981[2]. Later, at the Emulsion Chamber Symposium in LaPaz and Rio de Janeiro, 1982, I discussed the possible elaboration of the Chacaltaya cosmic ray station in Bolivia in this context[3]. In 1986 at the IV International Symposium on Very High Energy Cosmic Ray Interactions in Beijing, I reviewed the earlier discussions and explored the topic in the context of the then-current cosmic ray situation[4].

In view of the location of this conference in Lhasa, so close to the highest mountains on Earth, it seemed altogether timely to review the topic once again, and to explore the practicality, the need, and the science related to such a laboratory. As noted in my earlier discussions, there is only one area on the Earth's surface where such a laboratory could be located, and that is in the mountain arc of the Himalayas.

In my earlier presentations I argued the advantages of observation at the highest possible altitude. Balloons and satellites are limited to exposure areas of at most a few square meters, and exposure times typically of days, although some satellite payloads could be aloft a year. A mountain top installation, of course, can employ an area of perhaps a square kilometer; emulsion chambers typically employ areas of tens of square meters, and air shower arrays have areas of hundreds of square meters. While the atmospheric overburden certainly reduces this area advantage for the direct observation of primary interactions, emulsion chambers at mountain sites have proven capable of making interesting discoveries.

*Supported in part by the U.S. National Science Foundation

The controversial issues which motivated my suggestion in 1980-81 were: a) the primary cosmic ray composition near the "knee" (one to ten PeV), b) determination of the inclusive parameters of primary nucleon-nucleus interactions (such as scaling in the forward region, inelasticity, etc.), and c) the nature, source, and frequency of exotic phenomena such as Centauros, Chirons, etc. It is interesting to note that each one of these problems remains unresolved to this day, and from reports at this and other recent cosmic ray meetings, no really definitive solutions appear close at hand. Cancellation of the SSC together with delays in the LHC make the cosmic ray studies of the primary interactions above one PeV (approximately the energy of the Fermilab Tevatron Collider in equivalent C.M. energy) particularly relevant.

The flux of primary cosmic rays of 10^{16} eV (10 PeV) and above is about one per (m^2 sterad year) at the top of the atmosphere. At this energy the interaction mean free path of a proton in nitrogen is about 50 g/cm^2[5]. However the absorption length of nucleons is greater; from the zenith angle dependence of flux, Slavatinsky quotes λ (abs) = 68 $\pm$ 6 g/cm^2 [6]. Yuda notes that the attenuation length characteristic of gamma families is even greater; 100-110 g/cm^2 [7]. There is therefore great pressure for placing large-area detectors as high as physically possible, if one is to draw unambiguous conclusions concerning the nature of the primary interactions at energies much above a PeV.

Recently it has been emphasized that gamma ray astronomy also benefits from very high altitude observation. The Yangbajing surface scintillator array benefits from its 4300 meter elevation by being able to lower its primary gamma threshold to 8 TeV; a higher elevation site could explore to a lower energy still. Ahlen and Salamon have proposed the location of a very large air Cherenkov telescope at Yangbajing, also to study primary gamma rays, at a lower energy than the surface air shower arrays; D. Kieda reported on studies of this concept at this meeting[8]. The radiation from a primary gamma of a TeV or less occurs so high in the atmosphere that the location of an air Cherenkov telescope is optimized by a site with the cleanest, clearest air. The atmosphere is certainly more transparent at high mountain elevations, and these authors argued a significant improvement in performance of such a telescope for the study of 10 to 500 GeV gammas from a Yangbajing location relative to a 1000 - 1500 m elevation site, such as the Whipple telescope.

Other research areas would also profit from a very high altitude site. The air scintillation technique for studying primary cosmic ray composition over the energy interval between 0.1 PeV to 10 PeV is one example. The competition between air scintillation and air Cherenkov radiation favors scintillation at lower atmospheric densities, so that a study of the composition in the "knee" region with the Flys Eye technique would profit from such a location.

Atmospheric water vapor falls more rapidly with elevation than air pressure, and water vapor is the primary problem in surface-bound infra-red and microwave astronomical observations. Hence it is attractive to consider location of an infrared telescope at a new high-altitude site. Another installation might be a microwave detector system to map out in greater resolution than possible up to this time the primordial black body radiation temperature fluctuations.

And finally, an established laboratory at an elevation well above any permanent habitation will invite exploitation by human physiologists and by atmospheric scientists, among others.

For completeness, it should be noted that a very high elevation site offers no advantage for the study of the highest-energy cosmic rays (of energies of an EeV and above); the shower maximum in air at these energies is close to sea level (for vertical showers). Even vertically incident primaries of a PeV would induce showers with a maximum often at or below the elevation of this proposed installation.

In order to put these thoughts on a new high altitude station into proper perspective, let me emphasize that I enthusiastically welcome the development of Yangbajing and the continued exploitation of the Pamirs and Chacaltaya stations. I believe that the research capabilities of these sites are under-utilized. I, of course, welcomed the discussions at this meeting by Piazzoli[9] and Kieda relevant to expanded exploitation of the Yangbajing site. It may be useful to summarize the existing active mountain cosmic ray stations; as noted below.

In spite of my enthusiasm for more intensive exploitation of these sites, I remain convinced that a new station at least 100 g/cm^2 above the highest existing sites would have great usefulness in our study of primary cosmic rays in the PeV region. There are areas in the Himalayas at or above 6500 m where there are reasonably flat sites. As argured in my earlier reports, such a site would almost surely require supply and communication by air, would require special pressurized enclosures for habitation and instrumentation, and would probably require self-contained power; nuclear power or some kind of solar cell-battery systems. Personnel working in "the field" (outside the enclosures) would require both appropriate clothing and an oxygen system; a special helmet connected to an oxygen-tank back pack, for example.

Table I. Current Cosmic Ray Mountain Stations

Elevation Range, meters	Station
3000 - 4000	South Pole*#
	Tien Shan*
	Aragatz*
	Norikura*
4000 - 5000	Pamirs
	Fuji
	Yangbajing*
5000 - 6000	Chacaltaya*
	Kamba La

* Electric power available
# Elevation is barely 3000 m, but the equivalent atmospheric pressure is lower due to the very cold ambient temperature.

To be sure, this will be more expensive to establish and maintain than the stations listed in the table above. However the challenge of this frontier of human environmental experience will propel this concept to reality, I am convinced. Mankind reached the South Pole in the early years of this Century, and about mid-Century humans first ascended Mount Everest. A few years later men were placed into orbit around the earth and reached the moon. Now we have a permanently-staffed installation at the South Pole, and are planning a Space Station to be manned indefinitely. The high-mountain environment is surely next! And Cosmic Ray research has been at the forefront of each of these frontiers. Van Allen's sounding rockets were early harbingers of the Space Age, and the first massive satellite payloads were Grigorov's calorimeters. And at this conference we heard from Wang YuFang of a proposal by S.C.C. Ting for a serious cosmic ray instrument for the Space Station.[10] Meanwhile, at the South Pole, the AMANDA neutrino detector and the SPASE air shower array are significant cosmic ray research facilities justifying the investment in that station.

Against the perspective of this summary, I believe that a cosmic ray laboratory/observatory/station will surely be established at an elevation of over 6000 or 6500 meters. I do not know when this will happen; it may be far in the future. However I do know that, whenever it is built, it will not be far from Lhasa; there is no place else on Earth!

References

[1] L.W. Jones, "Thoughts on a High Altitude EAS Observatory", Cos. News 14, 3 (1980).

[2] L.W. Jones, "The Ultimate Air Shower Obsevatory" Proc. XVII ICRC, Paris 6, 314 (1981).

[3] L.W. Jones, "Remarks Concerning Cosmic Ray Physics in Latin America", Workshops on Cosmic Ray Interactions and High Energy Results, La Paz and Rio de Janeiro, C.M.G. Lattes, ed., 422 (1982).

[4] L.W. Jones, "Further Considerations Concerning a Very High Altitude Air Shower Obsevatory", Proc. of Intrl. Symp. on Cosmic Ray Superhigh Energy Interactions, Beijing, p. 1-97 (1986).

[5] M. Nagano *et al.*, 22nd Intrl. Cosmic Ray Conference, Dublin, 4, 189 (1991).

[6] S. Slavatinsky, 8^{th} Intrl. Symp. on Very High Energy Cosmic Ray Interactions, Tokyo (1994) *(to be published)*.

[7] T. Yuda, "Studies of High Energy Cosmic Rays at High Altitude" *presented at this conference.*

[8] D. Kieda, "Monte Carlo Performance of a Large Atmospheric Cherenkov Mirror..." *presented at this conference.*

[9] B.D'E. Piazzoli, "Detection of Small Size Air Shower at High Altitude..." *presented at this conference.*

[10] Wang Yufang, "An Antimatter Spectrometer in Space", *presented at this conference.*