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The CERN disposal of the FELIX project proposal: Some comments on and justification for it

S. BHATTACHARYYA and DHIMAN ROY (*)
Physics an Applied Mathematics Unit, Physics and Earth Science Division
Indian Statistical Institute - Calcutta 700 035, India

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Summary. — The authors seriously questioned and still continue to question the overemphasised "prospects" in the past of the so-called FELIX project in the domain of ultrahigh-energy astroparticle physics and the optimism that was nourtured around it. This was and is somewhat irrational because there is so far no dearth in the accumulated data for the testing of the models for particle production. But that up to now we failed to build up a really and concretely standard theory of particle production is due to our poverty in outllook and philosophy. The authors picked up and pointed out the very basic down-to-earth observables which even in the available energy range would really suffice to judge the merits and successes of any of the models. That the spirit of FELIX-like proposals might resurrect with just some other name even after the present (and temporary?) setback of the FELIX project remains the point of concern to the authors.

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In the very recent past the LHC Committee had reportedly shelved, at least for the present, the Forward Elastic and Inelastic Experiments (FELIX) project at CERN. We believe it to be a right decision and the astro-particle physicsts' community should support it on the grounds, *inter alia*, further on given by the present authors in this work below. It was desired to be conducted by the construction of a Full Acceptance Detector (FAD) with the commissioning of the Large Hadron Collider (LHC) at CERN. It is probable that the negative CERN decision stemmed from some other reasons as well involving the operational aspects of the proposed project. However, we will try to make our own case for its justified fate from some purely theoretical considerations. Let us first present the scopes and objectives [1] of the FELIX project as stated and claimed by its enthusiastic proponents:

(*) Self-financed registered pre-doctoral student researcher.

i) Particle production could be studied in detail at energies up to $S^{1/2} = 14$ TeV corresponding in the laboratory system to $E_0 = 10^{17}$ eV, well above the knee.

ii) The detector was thought to have the capacity to measure very precisely the energy and particle flow in PP collision over the entire kinematics range up to pseudorapidity $\eta = 10$, covering the region in phase space where most of the cosmic-ray information comes from.

iii) Interactions were proposed to be carried out on either PP or P-ion (P-A) or ion-ion (A-A) regimes, which bring in the essential feature of P-air and nucleus-air interactions in the atmosphere.

iv) Unlike conventional central detectors, FELIX [2] could reportedly search for a variety of "unusual phenomena" associated with the production of very forward particles in cosmic-ray interactions and with collision energy in excess of $\sim 10^3$ TeV, *i.e.* $S^{1/2}$ larger than 1 TeV.

But the distinction between "usual" and "unusual" phenomena is an artifact in the sense that one cannot concretely distinguish between them without taking recourse to some model bias and model basis. Frichter, Gaisser and Stanev [3] rightly maintained that a major and so far almost insurmountable problem is the modeling of hadronic interactions not only beyond the knee region for the following reasons.

Though this region (near the "knee" area) is approximately equivalent to the c.m. energy of the Tevatron collider at Fermilab, there are two reasons for which the uncertainties persist even at this relatively lower energy:

i) One is that interactions in the atmosphere invariably involve nuclear targets and, in some cases, nuclear projectiles as well.

ii) The second is the fact that the forward fragmentation region of the collision is not the centre of attention of the measurements by the accelerator or collider groups of experimentalists whereas the cosmic-ray physics phenomena and the rate of energy deposition that generates the core of the astrophysics cascades depend very strongly on the forward fragmentation region. And it is very difficult to maintain the idea that the nature produces particles with separate rubber stamps of "central" and "forward fragmentation" in a discriminatory fashion. Particle production, that is, production of secondaries, should at the root, have a unique and singular nature. Nature does not differentiate between "soft" and "hard". Neither does it make so for the "central" or "forward fragmentation" of the particles. The intrinsic process or the methods of detection render the transverse-momentum factor low or high and the x-values small or large.

It is not the dearth of the data that hindered so far the development of the basic theory of any standard theory but the root of the problem lies in the lack of an appropriate philosophy, outlook and attempts at making a development on a step-by-step methodology. One has to decide the priorities in the theory constructions and experimentations.

FELIX or no FELIX, can we really solve the problem of having simultaneously two really and clearly unknown factors [4] which are: i) the composition of the primaries in the ultrahigh-energy cosmic rays and ii) the dynamics of particle interations from a single measurement? Regarding the first point, FELIX could hardly help in singling out the most acceptable composition-set beyond all controversies. This uncertainty, *inter alia*, is one of the stumbling blocks for ascertaining clearly the composition and spectrum of cosmic rays both below and beyond the "knee" or "ankle" region. Regarding the dynamics of particle production, the reality is: the high-energy or

TABLE I. – *Model-dependent natures of the Inelasticity parameter for* PP *collisions and for* P-*air interactions for two types of models*: A = *string-type models and* B = *statistical-type models. The headings for proton-air correspond to different assumed values of* $l_\nu > 1$.

Energy (GeV)	PP A	I_1 B	I_1	P-air (A)			P-air (B)		
				0.14	0.18	$I(E)$	0.14	0.18	I_1
10^3	0.50	0.50	0.55	0.56	0.63	0.53	0.55	0.56	0.63
10^7	0.55	0.26	0.62	0.64	0.74	0.58	0.38	0.40	0.45
10^9	0.57	0.19	0.66	0.66	0.79	0.60	0.35	0.39	0.40
10^{11}	0.58	0.15	0.68	0.70	0.81	0.61	0.35	0.39	0.36

cosmic-ray physicists could, so far, not derive even an expression for the average multiplicity of the secondaries from the first principles [5], let alone the same for other complicated measured (or proposed) "observables". The FELIX proponents laid much emphasis on the measurements of the inelasticity factor in the ultrahigh-energy region. But table I depicts the degree of model dependence and assumption dependence of even this factor. And, in fact, these assumptions and models also draw the line of demarcation between the "usual" and "unusual" or "exotic" phenomena in ultrahigh-energy physics.

In conclusion, we observe and maintain that FELIX, had it really come into operation, might supply some important data sets at higher energies and at the much-sought-after forward region. And, once again, we reiterate that this would provide no Open Sesame to any new or novel understanding of the inner dynamics of the particle interactions or disentangle either of interwined puzzles unless there is a radical departure and positive reversal of the outlook of the particle-physics community. We must remember that our consternations are not due to insufficiency in accumulating data, but to the lack of sincere and honest efforts of probing the deeper questions at the very fundamental level without any *a priori* bias or without holding any blind faith in any version of the so-called theories—standard or non-standard. And any self-consistent theory or any theory claimant to be what one may call a "complete" theory should, at least, have the seeds of deducing from the first principles the following physical observables for the bulk of "soft" particle, production which constitutes more than 90 per cent of the particle produced in high-energy collisions.

i) The average multiplicity of the variety of particles;

ii) the expression(s) for inclusive cross-section(s) separately for the various types of secondaries;

iii) the total cross-section(s) (for any specific interaction) comprising of two separate components, *viz*. elastic and inelastic, both of which provide good model-testing grounds;

iv) the parameter related to the leading-particle effect;

v) the inelasticity factor;

vi) the average transverse momentum of each type of the secondary particles;

vii) the cumulative factorial moments of the particles.

To our knowledge, no "theory" so far does really satisfy these very basic criteria which seem to provide the bedrock or the touchstone of any really successful and/or "complete" theory.

Note added

The authors are very grateful to receive a crucial piece of information from the learned and anonymous referee (of this paper) that FELIX has, for the present, really been abandoned by the LHC Commitee. But the basic points which we wanted to make here very emphatically still remain strongly valid and relevant. And unfortunately, the physics community, in this field of specialization, by and large, maintain a stoic indifference to and reticence on these very pertinent questions for reasons not altogether inexplicable or intangible.

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