Andrzej Bialas and High Energy Hadronic Collisions (Especially with Nuclei).

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October 13, 2006

Abstract

I discuss the work that Andrzej as been done on the study of high energy hadronic collisions.

1 Physics I Learned from Andrzej

I believe the first time I met Andrzej Bialas was the meeting on Quark Matter Formation and Heavy Ion Collisions organized by Helmut Satz in Bielefeld, Germany, in 1982. Andrzej gave a talk about particle formation in high energy hadron nucleus collisions.[1]

I was already familiar with his work then. I had been trying to estimate the energy deposition in ultrarelativistic heavy ion collisions, and Andrzej's work on formation time was a crucial ingredient in this study. His work told one where the matter was formed. But to determine the energy density, I needed to understand the wounded nucleon model, as this provided a phenomenological viable theory of particle production. A consequence of the wounded nucleon model is limiting fragmentation, and I have spent a large amount of my career trying to understand this phenomena; the effort forms the underpinnings of my research over the past ten years.

Later, Andrzej and Robie Peschanski proposed a theory of fluctuations in particle production, intermittancy, decribing well many features of the distribution of particles produced in hadronic collisions. I am still trying to understand these observations and their deeper significance.

My friendship with Andrzej has drawn me and many others to attend and profit from the meetings he organized at Zakopane, and through those annual schools I met many good friends and have learned many new concepts. The work I have been involved with for the last ten years, understanding the high energy limit of QCD, was stimulated by a Zakopane meeting where I heard the early results from the Hera data on the rise of the gluon distribution function. This was in a meeting where heavy ion collisions were also discussed. The combination of the two sets of phenomena, and their implications, kept me awake late at night for many months afterwards.

2 Limiting Fragmentation and the Wounded Nucleon Model

Limiting fragmentation is the statement that as a function of x, the ratio of the energy of a produced particle to that of the projectile, distributions are independent of the energy of the projectile at high energies for $x \sim 1$, that is ,in the fragmentation region of the projectile.

This is perhaps understood at very high energies: The projectile scatters from the wee x constituents of the target, which is black up to some scale Q^2. The scale Q^2 depends on energy, but without too rapid a dependence. Therefore all the partons of the projectile are stripped from the projectile up to this scale. Since parton distributions are very weakly dependent upon Q^2 in the fragmentation region, the resulting distribution of produced hadrons has only a very weak dependence upon energy.

Limiting fragmentation was understood within the wounded nucleon model.[2]-[3] The projectile nucleon when it goes through a target becomes excited. There is only one type of excited nucleon which is triggered by an inelastic collision, so its decay products are universal. This is a very naive version of the idea of Bialas and collaborators. What they suggest is the simplest, and in my opinion most successful explanation of limiting fragmentation.

The wounded nucleon model successfully predicts the multiplicity of produced particles in pA and AA collisions. It gives the proper correlation between struck nucleons and associated central region multiplicity. It has been tested in ultrarelativistic nuclear collisions and is one of the standard tools that we use when understanding such collisions.

3 Formation Time

In the wounded nucleon model, if a particle is excited during a collision, it takes time for it to decay. If it is moving very fast, then the time scale become Lorentz time dilated. This means that the fragments of the projectile are produced far away from the place where the collision took place.

This concept was generalized by Bialas and collaborators to decay products with a range of momenta between projectile and target[4] This observation was crucial in making a description for the space-time points where energy is deposited in hadronic collisions. As such, it is absolutely necessary to understand how much energy density is locally produced in heavy ion collisions. When combined with information from the wounded nucleon model and some insight from Bjorken,[5] it allows the energy densities in such collisions to be be estimated. Together with Ramesh Anishetty and Peter Koehler, I combined these elements to make the first realistic estimates of energy deposition in ultrarelativistic heavy ion collisions. [6]

4 Intermittancy

Intermittancy reflects the observation that there is a spectrum of fluctuations extending to all scales.[7] This occurs in turbulence, where the scale of instabilities has a power law Kolmogorov spectrum as a function of scale size. Perhaps intermittancy might arise as a result of plasma like instabilities recently described by Mroczynski.[8]

In this picture, quantum fluctuations in the initial state are amplified by chaotic instabilities in the matter produced in such collisions. These chaotic instabilities might be responsible for the early thermalization seen in RHIC experiments.

5 Thanks

Thanks, Andrzej, for the physics you have done that shaped my thinking and my career. Thanks for the Crakow School of Physics, where I learned much that changed the direction in which I developed as a scientist, and where I have met so many good friends, and where I enjoyed the beautiful mountains. I must say, Zakopane was also essential for my political science education, but that is another story.

Most of all, thank you for your friendship and sense of irony mixed with warmth, since this taught me that you cannot do good physics without skepticism, enthusiasm, and a sense of humor.

I end this presentations pictures of Zakopane (taken from the web):

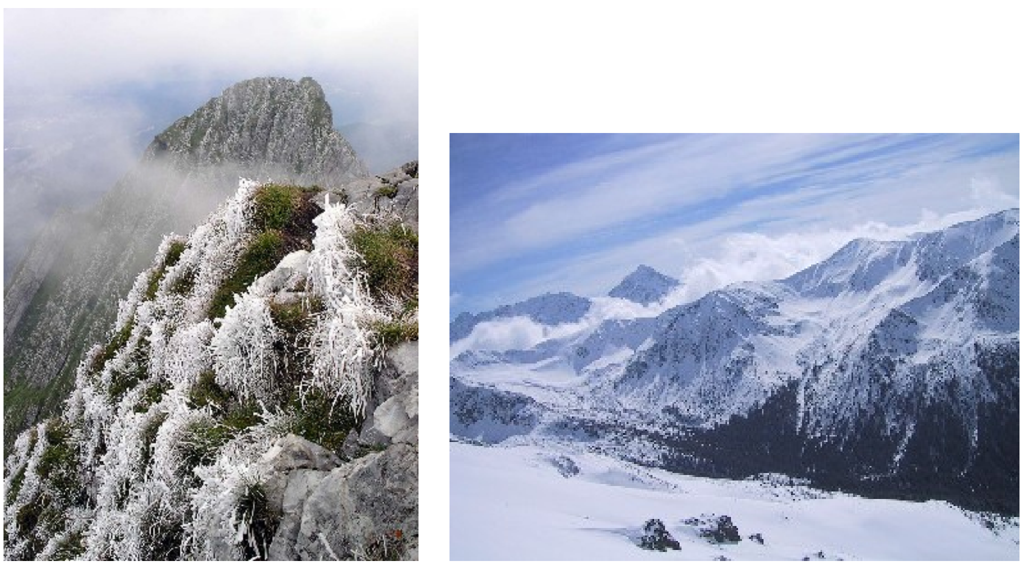

Figure 1: (a)The Gievont after a dusting of fresh snow. (b) The Tatras near Zakopane after snow.

Perhaps these images will encourage some young person to experience the Crakow School of Physics, and enjoy as I have the physics and friendships that it offers every summer.

Figure 2: (a)A poster advertising Zakopane. (b) Downtown Zakopane.

6 Acknowledgements

This talk was given to celebrate the 70'th birthday of Andrzej Bialas at the XLVI'th Crakow School of Theoretical Physics, Zakopane, Poland, May 27 - June 5, 2006

I gratefully acknowledge Michal Praszalowicz, who organized this Zakopane meeting, and invited me to give this talk.

This manuscript has been authorized under Contract No. DE-AC02-98H10886 with the U. S. Department of Energy.

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