Organization of the first week of the 8th Hellenic Summer Study by the European Research and Training Network, Probe for New Physics: main objectives and outcomes

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Abstract. The first week of the 8th Hellenic School on Elementary Particle Physics was organized according to the experimental scientific objectives of the European Training Network ‘Probe for New Physics’ guided by the Physics topics traditionally covered at the Corfu School. The main topics covered at the School are described and their educational impact assessed.

1. Introduction

The Corfu Summer Institute on Elementary Particle Physics normally focuses on Theoretical Particle Physics with a limited amount of lectures on some of the experimental aspects of this field. The European Research Training Network (RTN) ‘Probe for New Physics’ concentrates on the experimental aspects of this research field. The aim of the organizers was to fit the scientific objectives of this RTN with the Physics topics traditionally covered at the Corfu Elementary Particle Physics School and at the same time to open new fields of interest. Indeed by using the third generation as a probe for new physics, this RTN tackles most of the important topics in High Energy Physics especially as it handles them in a complementary way between the different machines and the main experiments presently ongoing or forthcoming. In the end this RTN covers a rather large scope of Particle Physics and it allowed the organizers to set up a fairly large overview of this field in all the three aspects i.e. theoretical, experimental and also technological. All these features are emphasized in the programme of this network as well.

Therefore the programme of the School in CORFU2005 during the week from September 4 to 11 was organized as a cruise in the Ionian Sea around the fanciest and most important topics in High Energy Physics presently and at the future experiments. The programme combined lectures given
by experts in the field and was completed by presentations of young researchers who explained special aspects they were working on for these different parts of the programme. This gave an interesting mixture of generation and expertise which after all is the basis also of our research field and especially one of the assets of our network. Confronting experiments with theory is another important ingredient of this first week of the school we organized, as described in more detail in the following.

2. Main Topics

After an introduction to the Electroweak Theory, the journey started with the main challenge ahead of us, the LHC; in a kind of natural continuation it was followed by a session on High Pt and Top Physics, then escaping to Neutrino Physics and jumping back to B Physics. The need for new means and tools to confront the future issues of our field was tackled from several ways. It started with the presentation of the next machine, namely the electron positron linear collider (International Linear Collider, ILC). Another crucial issue was also addressed, i.e. the huge amount of data that will be provided by these new machines such as LHC and ILC. The data handling and processing demand developing new computing framework such as the GRID network and the data analyses request further developments of statistical modern tools, such as the neural networks procedures. These new means are needed for entering in the beyond standard model which was the last part of this journey. This topic that will drive our whole field was introduced by first comprehending all what we know from the QCD world and then going to beyond standard theories and the experimental results obtained so far.

2.1 LHC: the experimental challenges and the confrontation with the Standard Model and Beyond Standard Model issues.

The opening session was devoted to a theoretical introduction on the Electroweak Theory, which is in some sense the foundation on which our present experimental world is working and beyond which the ongoing experiments and the forthcoming ones have to go. This introductory talk was given by Wolfgang Hollick. As an example, Jose Enrique Garcia Navarro explained the state of the art in this domain, as currently achieved with the measurement of W properties at CDF at the Tevatron.

The next 10 to 20 years in Particle Physics will be dominated by the Physics outcomes of the experiments at the LHC. We are at the crucial time when the machine is going to start to run and experiments are achieving their construction phase after many years of important R&D work on novel and highly performing detecting tools. Daniel Treille gave a complete review of the impressive challenges to be faced both by the LHC machine and by the various detectors that are being built and will operate in about one year from now at this new collider.

He didn’t forget to address the new tool that is needed for being able to handle, to process and to analyze the high rate and incredibly large amount of information in those very large worldwide collaborations namely: the GRID based network computing system. This will be described later on in details together with other newly developed tools; but it was already introduced as part of the experimental challenges for the new large scale HEP experiments.

Following this experimental talk, two lectures covered the LHC versus Standard and Beyond Standard Model challenges given by Giacomo Polesello and Frank Paige. It was interesting to see how the up to now simulated LHC world is preparing for the physics searches when the machine will be producing data. The interesting question of the commissioning period that was already introduced in the previous lectures on experimental challenges was pursued for discussion in these two lectures especially in the one of G. Polesello. He showed how some of the standard Physics processes will serve to commission the overall detector as well as the analysis tools.

As explained in these lectures, triggering is mandatory, in order to be able to extract interesting Physics processes from the huge amount of data produced in proton proton collisions especially at such high energy in the center of mass and such high luminosity. Two presentations by young researchers explained some aspects of this crucial issue at the LHC, namely a talk by Theodota Lagouri showed the main aspects on the B Physics triggering at ATLAS using the dimuon triggers and
Serge Sushkov presented how the ATLAS trigger is designed to cover broad physics range on beyond the standard model.

2.2 High Pt and top Physics Today

In order to explore the main Physics topics at the LHC, it is important to learn from the present ongoing analyses and searches using data coming from a similar experimental environment although if at lower energy in the center of mass and at a lower luminosity as this is the case at the Tevatron proton antiproton collider at FNAL. This machine is presently among the only ones running and indeed it is producing a remarkable amount of results that are very precious for improving our understanding of the Standard Model and also for starting to explore the beyond the standard model world. In some sense the Run II at the Tevatron has taken over from the work done at LEP and it is pursuing it further and will make certainly important advances and even breakthroughs before the start of the LHC. The third generation objects, i.e. the top, the bottom quarks and the \( \tau \) lepton are proving to be very strong probes in this experimental studies and searches, as can be seen from the already obtained results.

An introductory lecture on this topic was given by Tommaso Dorigo with a review of the main ingredients of the high Pt Physics which of course is essentially based on Jet Physics and therefore Jet tagging and characteristics measurements including also the important aspect of the jet energy scale which is the dominant factor in any measurement that includes jets and primarily in the accurate top mass measurement. Kuni Kondo described an interesting statistical method that he pioneered in the early searches for top quark at Run I and that demonstrated to be especially fruitful when dealing with all hadronic jet signatures of the top quark. This method, the Dynamical Likelihood Method, is used here for the determination of the top mass. Gervasio Gomez gave a review of the present status of the Top Physics at the Tevatron, emphasizing the various searches and methods to study the top events, with the top pair production and also the search for single top production at this machine. The latest results on the top mass measurement which is a crucial parameter of the electroweak theory and of the top production cross-section were presented. This review talk was followed by several talks on top searches focused on well defined decay processes: Giorgio Cortiana presented the results on the study of the all hadronic and \( \tau \) or multijets top cross sections that look for the decays of the top that are more difficult to identify especially in proton proton collisions, namely those where one of the W, produced from the top decays, decays into two quarks and the other one into a \( \tau \) lepton and its corresponding neutrino, the \( \tau \) decaying itself hadronically therefore producing another jet or the case where both W’s decay into quarks. These multijet signatures are particularly challenging ones. Stéphane Tourneur completed this topic by describing the ongoing analysis on the top decaying into \( \tau \) dileptons, producing signatures with one electron and one muon and a \( \tau \) lepton that decays hadronically therefore producing a jet with characteristics that permits to tag it as a \( \tau \) jet. Among the interesting feature of this analysis is the fact that if one finds that the ratio of the amount of top decaying into \( \tau \) leptons is different from one as compared to the amount of top decaying into electron or muons that means that the top might not decay 100\% into W b as predicted by the Model Standard and thus this would be an indication of beyond standard model. Jérôme Coss summarized the studies on the top charge determination that could also be a confirmation or not of the Standard Model.

2.3 The Neutrino Physics

A whole session was dedicated to Neutrino Physics which is among the most important topics both from the theoretical and experimental points of view.

This session started with a lecture from Alexei Smirnov who covered all the aspects of this theoretical field from the point of view of the standard and beyond. It included the most up to date developments in the field such as the discovery of neutrino oscillations, the resolution of the solar neutrino problem and the measurement of the neutrino parameters.

It was followed by two lectures on the experimental aspects of this Physics domain. Enrique Fernandez discussed the experimental Neutrino Physics using accelerators emphasizing that further
progress in understanding fully the neutrino masses and mixing will require a variety of experiments at different energies and baselines. David Wark described the experimental aspects of this Physics without accelerators with emphasis on the construction and the findings of the SNO experiment.

This session was concluded by a lecture by Jack Steinberger on the propagation of neutrinos in the Sun - oscillations and coherence as he understands it.

2.4 B Physics
B Physics is a key tool for exploring the flavored world. A lot of results are obtained these days in this Physics field that also proves how the third generation and especially in this case the b-quark is a remarkable tool to explore the beyond standard model.

The session was started by two theoretical lectures. Ahmed Ali presented the rare decays and CP violations in B Physics that are two items where B Physics can lead to indication of beyond standard model whereas Antonio Masiero discussed the beyond standard model flavours describing the various theoretical scenarios that are presently developed mainly in the mainframe of Supersymmetry.

The theoretical lectures were followed by two experimental talks that described the present state of the art in the B Physics especially at the Tevatron, from the point of view of the standard model by Donatella Lucchesi or the beyond standard model as described by Stefano Giagu both showed that although in many aspects the standard model is rather precisely confirmed there are some room for non standard model explanations. Jonatan Piedra described the Bs mixing analysis that has just led to the worldwide premiere measurement by the CDF collaboration of the oscillation frequency of the Bs-anti B, system. Simone Donati gave the perspectives on B Physics for the next coming years at the Tevatron with emphasis on the various detector improvements especially from the point of view of triggering on B’s based on central tracking and the vertex detectors especially challenging with the expected increase still at the Tevatron by a factor two to three. He also summarized how these searches will be pursued at the LHC especially with the LHCb experiment.

Two talks in this session demonstrated the powerfulness of the neural net tools for tagging objects such as B’s or optimizing event selections. Michal Kreps presented the optimization of the Bs candidate selection for the Bs mixing measurement and Michael Milnich emphasized the use of neural nets for opposite flavor tagging.

This session was concluded by a theoretical talk by Andrea Soddu, that focused on studying the difference in B+ and B° Direct CP asymmetry with a sequential fourth generation Physics Beyond Standard Model.

2.5 New Tools
The search for New Physics is demanding new tools and means among which a new machine in many sense complementary to the LHC namely a new e+e- collider successor of the LEP. Indeed there is a worldwide consensus that the next step in high energy physics implies the construction of an international linear collider (ILC) that will run at 500 GeV in the centre of mass to start with, and with the possibility to upgrade its energy to the TeV or beyond. Ties Behnke gave a lecture that explained first why and how to build such a machine, and the main R&D issues on both the detectors and the machines. He also presented some examples about the complementary aspects in terms of Physics of the ILC and the LHC. Both machines are expected to run with some overlap in time.

Modern algorithms which take into account the correlations between the different variables used to select an interesting event or to tag a particular property of the event are the artificial neural networks. They are now widely used to improve greatly the selection and tagging aspects in many analyses. It exist various neural nets techniques and a lot of progress is developed in this field that has also many interesting different applications in the real day to day world. Michael Feindt gave a tutorial on this tool and its applications.

Last but not least among these new and more and more used tools there is the GRID based network for computing. In his presentation of a “GRIDed world”, Jesus Marco described the impressive network that will be the global framework that will cope with the data handling and processing of the
LHC experiments. The capacity in terms of speed, large data flow, very high rates and worldwide distribution and easy access were discussed. An example of such a system already operating well in an existing experiment, CDF was presented by Francesco Delli Paoli, who was able then to show how such a network is able to handle the already impressive data processing from the ongoing CDF experiment. It also serves as training camp for the next step at LHC.

2.6 Quantum Chromodynamics

Before entering in the beyond standard model world, it is mandatory to pass by the Quantum Chromodynamics (QCD) world and this was achieved in two ways first with a lecture on the theoretical fundamentals of QCD Theory as reviewed by Carlo Ewerz. It was then addressed from the experimental point of view, insisting especially on how two different machines can be instrumental to make advances in this field. The first experimental talk by Hans Christian Schultz-Coulon emphasized the way this topic has been studied at the HERA electron - positron collider in DESY; what were the peculiar aspects that could be tackled by such a machine. Mario Martinez then summarized the impressive work that is being achieved by CDF at the proton-proton collider, the Tevatron at FNAL. He emphasized the use of the Kt algorithm to define jets. This jet algorithm was first introduced by the theoreticians and then applied to experiments as pioneered at the HERA experiments. Olga Norniella gave an example of the strength of this algorithm when used to determine the inclusive jet cross section in the CDF experiment. From both talks it was also important to note how the knowledge acquired in one machine (HERA) was fruitfully transmitted to another one, the Tevatron, allowing the whole field to progress a lot. The main message for the forthcoming LHC experiments is that the way to describe jets and their characteristics is becoming more and more unified between theory and experiments. This permits more direct crosschecks between these two aspects of the study. In some sense this was pioneered by HERA, QCD events that are copiously produced in hadronic colliders are an interesting source of important Physics; these events are studied in great details by the CDF collaboration and will be certainly a major topic especially when the LHC experiments start to run. Apart from their own Physics interest, they represent major sources of Physics backgrounds for most of the searches for New Physics, as they produce all kinds of event signatures that are mimicking quite well those that would be provided by various beyond standard model scenarios.

2.7 Entering in the beyond standard model world

We then arrived to the last place of this all-week cruise, namely the entrance in the beyond standard model bastion. To start with in this place, we were welcomed by two theoretical talks, the first one was given by Fabio Zwirner that described where do we are from the standpoint of Supersymmetry. This is still, up to now, the first theoretical frame offered to the experimenters to be checked carefully with the available (presently the Tevatron in particular) and the forthcoming data (those that will be delivered soon by the LHC, see Frank Paige’s and Giacomo Polesello’s lectures). This introduction to Supersymmetry was then extended to another theoretical lecture devoted to the Extra dimensional Worlds as reviewed by Antonio Delgado. He described in a very concise way the main aspects of this theoretical framework which may include or not Supersymmetry.

These two theoretical lectures were then followed by the “real life facts”, namely a complete overview of all the searches for the beyond standard model achieved so far at the Tevatron, by Mario Paolo Giordani and the first topic to look for that, namely the existence or not of a so called “standard” Higgs. The present status of this search for this new particle at the CDF experiment at the Tevatron was presented by Luca Scodellaro.

This journey was then completed and the hope at this stage was that people enjoyed it!

3. Conclusion

This school was organized in a very short time scale. Despite that, the attendance was quite large and it was believed to be a very positive first attempt to merge experimentalists with theoreticians, to
merge different generations of physicists and all this in such a wonderful place as Corfu. The focus was on reviewing a certainly very special and exciting time in our research field, when machines, such as the Tevatron, are indeed starting to produce important results and when new more powerful machines, such as the LHC, are going to be running soon, or are planned as the future next step, as the ILC. All these places are or will be unique in their way to allow us to enter in a new energy range, namely the TeV energy range!

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